Contents

ASM Sc. J.
Volume 3(2), 2009

RESEARCH ARTICLES

Continued on the inside of the back cover.

ISSN 1823-6782
9 771823 678004

MOSTI

AKADEMI SAINS MALAYSIA

ASM Science Journal 3(2) 2009

ASM Science JOURNAL

In Pursuit of Excellence in Science

Vol. 3, No. 2, December 2009 • ISSN: 1823-6782

Price (2 Issues)

Malaysia: RM100 (*Individual*)
RM200 (*Institution*)

Other Countries: USD50 (*Individual*)
USD100 (*Institution*)

ASM Science Journal

Editorial

First I would like to thank the Editorial Board of the *ASM Sc. J.* for inviting me to be their Guest Editor for this *special issue* of the Journal devoted to polar sciences. As the Director of the Malaysian Antarctic Research Programme (MARP) it is a pleasure to see how the Programme has grown. When the idea of establishing the Programme was undertaken by the Task Force on Antarctic Research under the Academy in 1998, one of the main worries of the members was the sustainability of the Programme. This sustainability is supported on two pillars: one is the continued funding of research by the Ministry of Science, Technology and Innovation (MOSTI); and the other is the support of the researchers participating in the programme from all the universities and research institutions in Malaysia. MARP's success is very much dependent on these two pillars and to date I have to commend MOSTI and the researchers for the support that they have given.

In trying to develop polar research, one of the major constraints that Malaysian scientists face is the lack of local logistics support. Malaysia has no base to embark on its own scientific programme in Antarctic or the Arctic. As such, we are very much dependent on the goodwill of our international partners. I would like to take this opportunity to thank our international partners, namely Antarctica New Zealand, Australian Antarctic Division, British Antarctic Survey, Japanese National Institute of Polar Research, Korean Polar Research Institute, Instituto Antartico Argetino, Instituto Antarctico Chile, Instituto Antarctico Equador, South Africa National Antarctic Program and National Centre for Antarctic and Ocean Research of India. We are also thankful to the Scientific Committee of Antarctic Research and Asian Forum on Polar Sciences for all the support and co-operation given to enable our scientists to embark on polar research.

It is with pride that I note that our scientists and their post-graduate students have embraced our polar research initiatives with so much enthusiasm. Some spent more than two months away from their loved ones in order to undertake field work in the extreme environment of Antarctic. They had to assimilate different cultures and food, and for some post-graduate students the field trip was their first trip overseas. However, most of them would love to be given a second and maybe a third chance to go back to Antarctic for their field work. MARP is lucky to have such an enthusiastic group of scientists and young researchers.

However, in pursuing their love of science some have paid a higher price than others. I would like to record our condolences to the family of the late Omar Pozan who died while undergoing training (diving) in Tasmania for a scientific expedition.

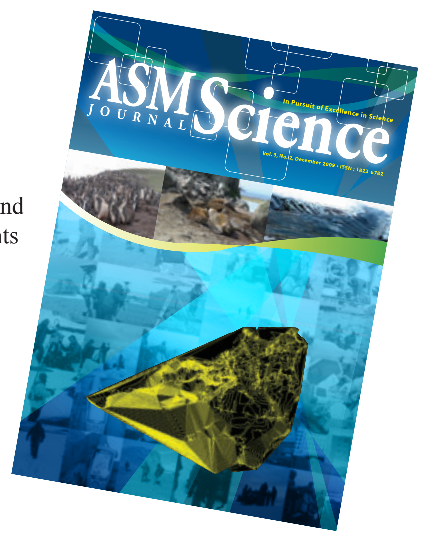
As in any scientific venture, the proof of success is in the scientific output i.e. publications and post-graduate training. In this area, MARP has been able to produce three refereed conference proceedings and a number of papers in refereed international journals such as *Polar Biology* and *Journal of Geophysical Research*. We have trained three PhD students and there are now more than fifty post-graduates pursuing research under MARP. A testimony to this active research is that the Academy of Sciences Malaysia has kindly undertaken to produce this special issue of their Journal devoted to polar research undertaken under the MARP and our international collaborators. This issue is a demonstration of how far polar sciences in Malaysia has advanced and can be used as a milestone of our progress. It is my hope that R&D in Malaysian polar sciences will be further expanded and deepened so that Malaysia will be considered as a leader in certain niche areas such as microbiology, biodiversity and tropical-polar interactions in the ocean and atmosphere. Already some of our researchers are active in helping polar research developments in the field of microbiology for some of our Latin American partners. We are now an active member of SCAR committee on capacity building, education and training, and helping the developing countries in the SCAR community. I am sure this issue will not only be of interest to the Malaysian but also the international community of polar scientists. Finally, I would like to thank again the Academy of Sciences for undertaking this special issue on Malaysian polar sciences in their prestigious Journal; acknowledge the 22 reviewers for their evaluation of the 13 articles, and Kanesan Solomalai for editing and finalizing the editorial processing of this issue.

Azizan Abu Samah (Director of MARP)
and
Siti Aisyah Alias (Deputy Director of MARP)
(Guest Editors)

Cover:

Background photos show the survey activities related to the GIS and GPS studies; the figure below is the contour generated from GPS points of the project area
(Article on pp. 163–169).

The photographs in the upper section depicts the sampling sites of a biodiversity study of Antarctic microfungi from ornithogenic soils in the Beaufort and Barrientos Islands
(Article on pp. 187–197).



The Academy of Sciences Malaysia (ASM)

The Academy of Sciences Malaysia (ASM) was established, under the *Academy of Sciences Act 1994* which came into force on 1 February 1995, with the ultimate aim to pursue excellence in science. Thus the mission enshrined is to pursue, encourage and enhance excellence in the field of science, engineering and technology for the development of the nation and the benefit of mankind.

The functions of the Academy are as follows:

- To promote and foster the development of science, engineering and technology
- To provide a forum for the interchange of ideas among scientists, engineers and technologists
- To promote national awareness, understanding and appreciation of the role of science, engineering and technology in human progress
- To promote creativity among scientists, engineers and technologists
- To promote national self-reliance in the field of science, engineering and technology
- To act as a forum for maintaining awareness on the part of the Government of the significance of the role of science, engineering and technology in the development process of the nation and for bringing national development needs to the attention of the scientists, engineers and technologists
- To analyse particular national problems and identify where science, engineering and technology can contribute to their solution and accordingly to make recommendations to the Government
- To keep in touch with developments in science, engineering and technology and identify those developments which are relevant to national needs to bring such developments to the attention of the Government
- To prepare reports, papers or other documents relating to the national science, engineering and technology policy and make the necessary recommendations to the Government
- To initiate and sponsor multi-disciplinary studies related to and necessary for the better understanding of the social and economic implications of science, engineering and technology
- To encourage research and development and education and training of the appropriate scientific, engineering and technical man power
- To establish and maintain relations between the Academy and overseas bodies having the same or almost similar objectives in science, engineering and technology as the Academy
- To advise on matters related to science, engineering and technology as may be requested by the Government from time to time; and
- To carry out such other actions that are consistent with the *1994 Academy of Sciences Act* as may be required in order to facilitate the advancement of science, engineering and technology in Malaysia, and the well being and status of the Academy.

The Academy is governed by a Council. Various Working Committees and Task Forces are charged with developing strategies, plans and programmes in line with the Academy's objectives and functions.

The functions of the Council are:

- To formulate policy relating to the functions of the Academy
- To administer the affairs of the Academy
- To appoint such officers or servants of the Academy as are necessary for the due administration of the Academy
- To supervise and control its officers and servants
- To administer the Fund; and
- To convene general meetings of the Academy to decide on matters which under this Act are required to be decided by the Academy.

The Academy has Fellows and Honorary Fellows. The Fellows comprise Foundation Fellows and Elected Fellows. The Academy Fellows are selected from the ranks of eminent Malaysian scientists, engineers and technocrats in the fields of medical sciences, engineering sciences, biological sciences, mathematical and physical sciences, chemical sciences, information technology and science and technology development and industry.

The Future

Creativity and innovation are recognised the world over as the key measure of the competitiveness of a nation. Within the context of K-Economy and the framework of National Innovation System (NIS), ASM will continue to spearhead efforts that will take innovation and creativity to new heights in the fields of sciences, engineering and technology and work towards making Malaysia an intellectual force to be reckoned with.

Published by the Academy of Sciences Malaysia

Contents

ASM Sc. J.
Volume 3(2), 2009

RESEARCH ARTICLES

RESEARCH ARTICLES

SCIENCE FORUM

ANNOUNCEMENTS

ASM Sci. J., **3(2)**, 107–112

Antarctic Bacteria Inhibit the Growth of Pathogens

C.M.V.L. Wong[1*], H.H. Chung[1], S. Aisyah[2], S. Omar[2], Y.K. Cheah[3], L.G. Maria de[4] and H.A. Moreano[5]

There are relatively little data on bacteria with antimicrobial activities from Antarctic, especially from the South Shetland Islands when compared to the other parts of the world. Hence, this project was set to isolate and characterize bacteria that produce anti-microbial compounds from Greenwich Island (one of the South Shetland Islands), Antarctica. A total of 356 strains of bacteria were isolated from Greenwich Island. They were screened for antimicrobial activities against 13 Gram-negative and one Gram-positive indicator food-borne pathogens. Two out of the 356 Antarctic bacterial strains exhibited an antagonistic effect on the indicator strains, *Escherichia coli*, *Salmonella spp., Klebsiella pneumoniae, Enterobacter cloacae, Vibrio parahaemolyticus* and *Bacillus cereus*. The two Antarctic bacterial strains were designated as SS157 and SR13. Biochemical and 16S rDNA analysis indicated that the strain SS157 was closely related to *Pseudomonas congelans* while the strain SR13 was closely related to *Pseudomonas tremae*. The anti-microbial compounds produced by the two Antarctic bacteria were not sensitive to temperature and were not degraded by trypsin or pronase indicating that they were likely to be chemical compounds or antibiotics. Antimicrobial compounds from strains SS157 and SR13 were broad spectrum, and targeted both Gram-positive and negative pathogens.

Key words: Antarctica; anti-microbial compounds; food-borne pathogens; 16S rDNA sequence; South Shetland Islands; Greenwich Island; SS157; SR13; isolation; screening; identification

Antarctica is the fifth largest continent on Earth with a surface area of 14 million km^2. This continent consists mostly of rocky regions and 99.7% is covered by permanent ice and snow (Convey *et al.* 2008). The temperature in Antarctica usually remains below 0ºC throughout the year except during the summer months where the soils are subjected to thawing. Due to the harsh conditions, micro-organisms living in the continent and the islands around have unique adaptation strategies for survival in the critical environment. In order to gain competitive advantage, some micro-organisms produce extracellular antimicrobial compounds to inhibit the growth of their competitors (O'Brien *et al.* 2004), and some of these compounds may have medical importance such as antibiotics.

Antibiotic is a low molecular weight natural substance produced by micro-organisms to inhibit the growth of or kill other micro-organisms. Antibiotics from microbes have been used to develop drugs to treat various diseases caused by pathogens. Over the years many of the pathogens have acquired resistance to the existing classes of antibiotics (Radu *et al*. 2001; Radu *et al*. 2002). Hence there is a need to discover new classes of antibiotics to kill the multiple resistance strains of pathogens.

Studies conducted on bacteria isolated from the terrestrial (Moncheva *et al*. 2002; Nediakova & Naidenova 2004; O'Brien *et al.* 2004; Stackebrandt *et al*. 2004) and marine samples (Lo Giudice *et al.* 2007) from various locations in Antarctica have revealed that there are many novel species of micro-organisms that produce a wide variety of anti-microbial compounds such as antibiotics (O'Brien *et al*. 2004; Stackebrandt *et al.* 2004). Nevertheless, the information pertaining to bioactive compounds of bacteria from the maritime Antarctic such as the South Shetland Islands is sparse. Hence, the aims of this study were: (i) to isolate, screen and identify Antarctic bacteria with anti-microbial activity against pathogens from Greenwich Island, (ii) to partially characterize the anti-microbial compounds produced.

MATERIALS AND METHODS

Isolation of Antarctic Bacteria

Soil samples were collected from Greenwich Island, one of the South Shetland Islands during the scientific expedition organized by the Instituto Antartico Ecuatoriano (INAE) in 2007. The samples were collected using a sterilized

[1]Biotechnology Research Institute, Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia
[2]Institute of Biological Sciences, Faculty of Sciences, University of Malaya, Lembah Pantai, 50603 Kuala Lumpur
[3]Department of Biomedical Science, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia
[4]Universidad San Francisco de Quito, via Cumbaya, Ecuador
[5]Instituto Antartico Ecuatoriano, 9 de Octubre 416 y Chile, Guayaquil, Ecuador
[*]Corresponding author (e-mail: michaelw@ums.edu.my)

spatula and stored in sterilized containers at –80ºC until used. Isolation of the Antarctic bacteria was performed in Malaysia using several growth media namely, Tryptic soy agar (Difco) (TSA), Luria-Bertani agar (LBA), nutrient agar, R2A agar (Difco), Antarctic bacterial medium (ABM) and lactobacillus (MRS) agar. Approximately 1 g of the soil sample was inoculated into 10 ml of sterile distilled water, serially diluted 100 times and plated on various media. The agar plates were incubated at 20ºC between two to ten days for recovery of the Antarctic bacteria. Recovered bacteria were tested for their ability to grow on media at different temperatures, salt concentration and pH.

Detection of Antimicrobial Agents' Production

Antimicrobial compound production was determined using a modified deferred antagonism procedure of Kekessy and Piguet (1970). Antarctic bacteria were spot-inoculated onto an appropriate agar medium, and overlaid with 10 ml of molten nutrient agar (1.3% nutrient broth and 0.7% agar) containing one of the indicator bacteria after five days of incubation. Gram-negative bacteria, *Escherichia coli* 0157:H7, *E. coli* V517, *E. coli* 0125, *Salmonella typhimurium* (S. Tm 13), *S. typhimurium* (S. Ty 10), *S. biafra, S. braenderup, Klebsiella pneumonia* 14x, *Enterobacter cloacae* 22x *Vibrio parahaemolyticus* 1808, *V. parahaemolyticus* 1896, *V. parahaemolyticus* 2053, *V. parahaemolyticus* 2341 and Gram-positive Bacillus cereus K3 were used as the indicator bacteria. These food-borne pathogens were provided by Prof. Son Radu from Universiti Putra Malaysia, Malaysia. The assay for antimicrobial activities was conducted at 20ºC. In order to test the sensitivity of the antimicrobial compounds to temperatures, assays were also conducted at 4ºC, 30ºC and 37ºC.

Sequencing of the 16S rDNA Analysis

Chromosomal DNA extraction was carried out as described by Vaquero et al. (2004). PCR amplification of the 16S rDNA was carried out using primers, 5'-AGAGTTTGATCCTGGCTCAG-3' and 5'-AAGGAGGTGATCCAGCCGCA-3'. The amplified 16S rDNA were sequenced and the resulting sequences were analyzed for homology using the basic local alignment search tool (BLAST) (http://www. ncbi.nlm.nih.gov/blast). Alignment analyses and phylogenetic trees constructions were conducted based on Neighbor-Joining method (Saitou & Nei 1987) using the MEGA4.0 software.

Biochemical Analyses

The biochemical profiles were determined using the API 20NE and API 20E strips (bioMerieux, Marcy-l'Etoile, France) according to the instructions from the manufacturer. The carbon assimilation was tested by using the API 50CH strips (bioMerieux, Marcy-l'Etoile, France) while the ability to produce enzymes was tested by using the API ZYM strips (bioMerieux, Marcy-l'Etoile, France). The result's biochemical tests were analyzed using the Apiweb software provided by the manufacturer.

Partial Characterization of the Anti-microbial Compounds

The properties of the antimicrobial compounds were determined by using the deferred antagonism assays described by O'Brien *et al*. (2004). The antimicrobial compound was exposed to a series of enzymes namely, protease (EC 3.4.24.31) (Sigma), catalase (EC 1.11.1.6) (Sigma), lipase (EC 3.1.1.3) (Sigma), α-amylase (EC 3.2.1.1) (Sigma) to determine whether the compound was degraded by these enzymes. All the enzymes (25 mg/ml) used were prepared in accordance with the manufacturer's instructions. The assay was conducted at 20ºC overnight.

RESULTS AND DISCUSSION

In this study, it was found that R2A agar medium supported the growth of substantially higher numbers of bacterial species when compared to the other agar media tested. The bacteria on the R2A medium produced colonies with orange, yellow, beige and purple coloured pigment indicating that this medium supported the growth of many different species. This may be due to the combinations of low concentration of nutrients in the R2A medium which allowed a wide spectrum of bacteria to grow without the fast-growing bacteria suppressing the slow-growing species (Reasoner & Geldreich 1985). It was reported that nutritionally rich media usually support the growth of fast-growing bacteria, and this may suppress the slow growing or stressed bacteria (Lillis & Bissonnette 2000).

Frequency of Detection

A total of 356 bacteria were isolated in this study. Two isolates were found to inhibit the growth of food pathogens (Figure 1). Hence, the frequency of isolation of inhibitor producers in this study was 0.56% (2/356 colonies) which was higher than those of 0.29% (13/4496 colonies) reported by Lo Giudice *et al*. (2007) from Antarctic marine samples. However, the numbers were lower than those reported by O'Brien *et al*. (2004) of 3.8% (22 bacteria out of 580 colonies) from the east Antarctic terrestrial samples. Nevertheless, Lo Giudice *et al*. (2007) indicated that the detection rate depended on the isolation and screening procedures, for instance whether selective or rich media was used and the sources of micro-organism. In cases whereby isolation was carried out using selective medium targeting at the Antarctic actinomycetes, the frequency of inhibitor producers isolated may be as high as 40% (Moncheva *et al*. 2002; Nediakova & Naidenova 2004).

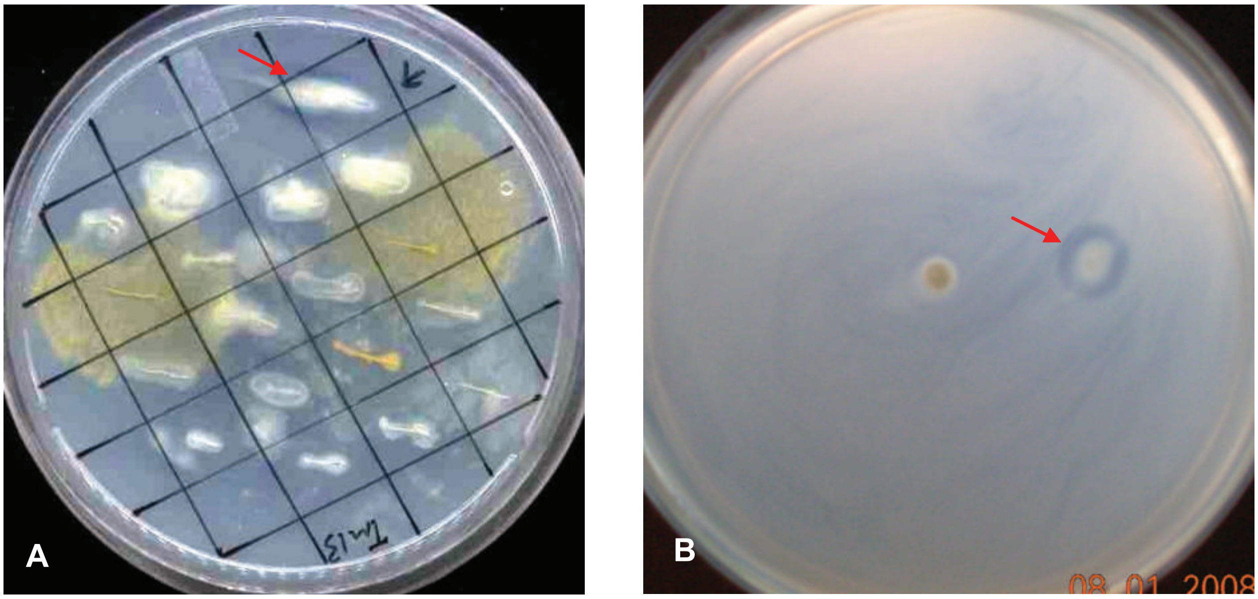


Figure 1. Representative plates indicating the inhibitory zone of the pathogen (red arrow) by the Antarctic bacteria.

Spectrum of Inhibition

The two isolates were designated as strains, SS157 and SR13. They were found to exhibit inhibition or antimicrobial activity against *E. coli* 0157:H7, *S. typhimurium* (S. Tm 13), *S. typhimurium* (S. Ty 10), *K. pneumonia* 14x, *V. parahaemolyticus* 1808, *V. parahaemolyticus* 1896, *V. parahaemolyticus* 2053, *V. parahaemolyticus* 2341 and *B. cereus* K3 (Table 1). However, they did not inhibit the growth of *E. coli* V517, *E. coli* 0125, *S. biafra, S. braenderup*, and *E. cloacae* 22x (Table 1). The ability to inhibit the growth of Gram-negative and Gram-positive pathogens from five different genus showed that the antimicrobial compounds have very broad spectrum targets. The similar inhibitory profiles of the strains, SS157 and SR13 indicated that they were closely related and possibly from the same species or genus.

Characteristics and Identification of the Antarctic Bacteria

Characterization of the two strains indicated that their optimal growth temperature was 20ºC, salt tolerance up to 3% (w/v) and had optimal growth at pH 7. They failed to grow at the incubation temperatures of 30ºC and 37ºC, and grew very slowly at 4ºC indicating that they were psychrotolerant bacteria. Both strains were Gram-negative cocci. The biochemical analyses indicated that both SR13 and SS157 had very similar profiles except that strain SR13 did not exhibit any urease activity (Table 2). The analysis conducted using the Apiweb software found that the nearest significant taxa for both SR13 and SS157 were *P. fluorescens* with the percentage of identity at 99.9%. The biochemical profiles confirmed their genus but were unable to differentiate the two bacterial strains at species level (Table 2). Hence, they were further differentiated based on their 16S rDNA sequences. BLASTn search results revealed that SS157 was closely related to *P. congelans* DSM 14939T (99% similarity) while SR13 was closely related to *P. tremae* CFBP 6111T (98% similarity) (Table 3). The two bacteria were from the γ-Proteobacteria phylum. A phylogenetic analysis confirmed that strain SS157 was a *P. congelans* while strain SR13 was a *P. tremae* since they were clustered more closely to the *P. congelans* and *P. tremae*, respectively than to the *P. fluorescens* (Figure 2). Strains SS157 and SR13 were distantly related to the other *Pseudomonas* spp. and the control *M. luteus* (Figure 2).

Partial Analyses of the Antimicrobial Compounds

The properties of the antimicrobial compounds of the two bacterial strains were partially resolved by testing the sensitivities of the compounds produced by the two bacterial strains towards several enzymes. The results from the enzyme sensitivity tests indicated that the active moieties of the antimicrobial compounds of strains SSR157 and SR13 were not sensitive to catalase, lipase and α-amylase, and therefore did not contain any hydrogen peroxide, lipid or glycan. The antimicrobial compounds remained active after the treatment with enzymes. They were also not sensitive to the treatment of protease thus indicating they did not have a protein structure. In contrast, O'Brien *et al.* (2004) found that three inhibitors (antimicrobial compounds) produced by the Antarctic bacteria that they have isolated were

Table 1. Inhibition profiles of the bacterial strains SS157 and SR13 against the 13 food-borne pathogens, *E. coli* O157:H7, E. coli V517, *E. coli* 0125, *S. typhimurium* (S. Tm 13), *S. typhimurium* (S. Ty 10), *S. biafra* (S. Bi 8), *S. braenderup* (S. Br D), *K. pneumonia* 14x, E. cloacae 22x, *V. parahaemolyticus* 1808, *V. parahaemolyticus* 1896, *V. parahaemolyticus* 2053, *V. parahaemolyticus* 2341, *B. cereus* K3. (–) = no inhibition and (+) = with inhibition.

Isolates	Inhibition of tester pathogens													
	O157: H7	V517	0125	S. Tm 13	S. Ty 10	S. Bi 8	S. Br D	14X	22X	1808	1896	2053	2341	K3
SS157	+	–	–	+	+	–	–	+	–	+	+	+	+	+
SR13	+	–	–	+	+	–	–	+	–	+	+	+	+	+

Table 2. Results of the biochemical tests using the API20NE and the API 20E test strips on the bacterial strains, SS157 and SR13.

Characteristics	SS157	SR13
Reduction of nitrate	–	–
Indole production	–	–
Fermentation of glucose	–	–
Enzyme tests		
Arginine dihydrolase	+	+
Urease	+	–
β-glucosidase (Esculin)	–	–
Protease (Gelatin)	+	+
β-galactosidase (ONPG)	–	–
Tryptophane deaminase	–	–
β-galactosidase (PNPG)	–	–
Ornithine decarboxylase	–	–
Carbon sources		
D-Glucose	+	+
L-Arabinose	+	+
D-Mannose	+	+
D-Mannitol	+	+
N-acetyl-glucosamine	+	+
D-Maltose	–	–
Potassium gluconate	+	+
Capric acid	+	+
Adipic acid	–	–
Malic acid	+	+
Trisodium citrate	–	–
Phenylacetic acid	–	–

(+) = Positive reaction; (–) = negative reaction).

sensitive to trypsin and pronase, and two were sensitive to pronase. They concluded that the inhibitors from those bacteria which were sensitive to trypsin and pronase had proteinaceous structures.

The antimicrobial compounds of bacterial strains SSR157 and SR13 were not sensitive to temperatures 4ºC, 30ºC and 37ºC, and remained active. Hence, they were not likely to be bacteriocins. Bacteriocin is a peptide that possesses antimicrobial properties and is proteinaceous in nature. A bacteriocin is only active at an optimal temperature and its activity is inhibited at other temperatures (Leroy & De Vuyst 1999; Keren *et al.* 2004). The antimicrobial compounds produced by the bacterial strains, SSR157 and SR13 were not sensitive to (i) protein degrading enzymes such as trypsin and pronase and (ii) elevated temperatures which indicated that their anti-microbial compounds were not bacteriocin. Hence, there were possibilities that the anti-microbial compounds produced by the bacterial strains, SSR157 and SR13 were chemical compounds such as antibiotics which were not sensitive to temperatures. These findings and the fact that the antimicrobial compounds of bacterial strains, SSR157 and SR13 had a wide spectrum of targets were interesting and require more in-depth studies on them. This work showed that the maritime Antarctica had a relatively good source of bacteria with bioactive compounds when compared to other parts of Antarctica, and warranted more concerted effort to isolate and study them.

Table 3. The 16S rDNA gene sequence affiliation of the bacterial strains, SS157 and SR13 to their closest neighbours

Phylum	Isolate	Nearest taxonomic neighbour / Assession number	Similarity
γ-Proteobacteria	SS157	*Pseudomonas congelans* /DSM 14939T	1516/1531 (99%)
γ-Proteobacteria	SR13	*Pseudomonas tremae* /CFBP 6111T	1512/1538 (98%)

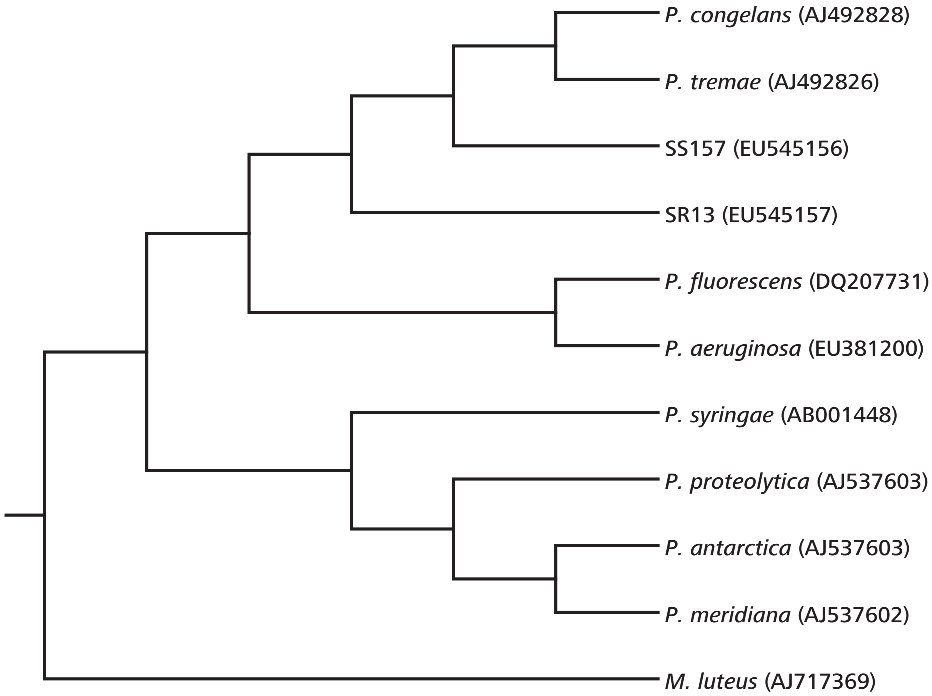


Figure 2. Phylogenetic tree constructed using the neighbour-joining method based on 16S rDNA sequence showing the relationship of the bacterial strains, SS157 and SR13 and their closely related species.

ACKNOWLEDGEMENTS

We would like to thank the Academy of Science Malaysia for funding this project, and the Instituto Antartico Ecuatorian (INAE), Ecuador for the logistic support. We would also like to thank Prof Son Radu for providing the indicator food-borne pathogens for this work.

Date of submission: October 2008
Date of acceptance: June 2009

REFERENCES

Convey, P, Gibson, JAE, Hillenbrand, CD, Hodgson, DA, Pugh, PJA, Smellie, JL & Steven, MI 2008, 'Antarctic terrestrial life — challenging the history of the frozen continent?', *Bio. Rev*., vol. 83, pp. 103–107.

Kekessy, AM & Piguet, DB 1970, 'New method for detecting bacteriocin production', *Appl. Microbiol*., vol. 20, pp. 282–283.

Keren, TM, Yarmus, GH & Shapira, R 2004, 'Immunodetection of the bacteriocin lacticin RM: analysis of the influence of temperature and Tween 80 on its expression and activity', *Appl. Environ. Microbiol.*, vol. 4, pp. 2098–2104.

Leroy, F & De Vuyst, L 1999, 'Temperature and pH conditions that prevail during fermentation of sausages are optimal for production of the antilisterial bacteriocin sakacin K', *Appl. Environ. Microbiol*., vol. 65, pp. 974–981.

Lillis, TO & Bissonnette, GK 2000, 'Detection and characterization of filterable heterotrophic bacteria from rural groundwater supplies', *Lett. Appl. Microbiol*., vol. 32, pp. 268–272.

Lo Giudice, A, Brilli, M, Bruni, V, De Domenico, M, Fani, R & Michaud, L 2007, 'Bacterium-bacterium inhibitory interactions among psychrotrophic bacteria isolated from Antarctic seawater (Terra Nova Bay, Ross Sea)', *FEMS Microbiol. Ecology*, vol. 3, pp. 383–396.

Moncheva, P, Tishkov, S, Dimitrova, N, Chipeva, V, Antonova-Nikolova, S & Bogatzevska, N 2002, 'Characteristics of soil actinomycetes from Antarctica', *J. Culture Collec*., vol. 3, pp. 3–14.

Nedialkova, D & Naidenova, M 2004, 'Screening the antimicrobial activity of actinomycetes strains isolated from Antarctica', *J. Culture Collec*., vol. 4, pp. 29–35.

O'Brien, A, Sharp, R, Russell, NJ & Roller, S 2004, 'Antarctic bacteria inhibit growth of food-borne microorganisms at low temperatures', *FEMS Microbiol. Ecology*, vol. 48, pp.157–167.

Radu, S, Ooi, WL, Rusul, G. Karim, MIA & Nishibuchi, M 2001, 'Detection of *Escherichia coli* O157:H7 by multiplex PCR and their characterization by plasmid profiling, antimicrobial resistance, RAPD and PFGE analyses', *J. Microbiol. Methods*, vol. 46, pp. 131–139.

Radu, S, Vincent, M, Apun, K, Rahim, RA, Benjamin, PG, Yuherman & Rusul, G 2002, 'Molecular characterization of Vibrio cholerae O1 outbreak strains in Miri, Sarawak (Malaysia)', *Acta Tropica,* vol. 83, pp.169–176.

Reasoner, DJ & Geldreich, EE 1985, 'A new medium for the enumeration and subculture of bacteria from potable water', *Appl. Environ. Microbiol*., Vol. 49, pp. 1–7.

Saitou, N & Nei, M 1987, 'The neighbor-joining method: A new method for reconstructing phylogenetic trees', *Mol. Biol. Evol*., vol. 4, pp. 406–425.

Stackebrandt, E, Brambilla, E, Cousin, S, Dirks, W & Pukall, R 2004, 'Culture-independent analysis of bacterial species from an anaerobic mat from Lake Fryxell, Antarctica: prokaryotic diversity revisited', *Cell Mol. Biol*., vol.5, pp. 517–24.

Vaquero, I, Marcobal, A & Munoz, R 2004, 'Tannase activity by lactic acid bacteria isolated from grape must and wine', *Int. J. Food Microbiol.*, vol. 96, pp. 199–204.

ASM Sci. J., **3(2)**, 113–120

Isolation and Rapid Identification of *Streptomonospora*, a Strictly Halophilic Filamentous Actinomycetes from Antarctic Soil (Barrientos Island, Antarctic)

Y.K. Cheah[1*], L.H. Lee[1], S. Radu[2], M.C.V.L. Wong[3], H.M. Andrade[4]

The genus *Streptomonospora* is a group of extremely halophilic filamentous actinomycetes that form a distinct branch in the 16S rRNA gene phylogenetic tree adjacent to the genera *Nocardiopsis* and *Thermobifida*, family *Norcadiopsaceae*. To date, genus *Streptomonospora* only contain two validly described species which are *Streptomonospora* salina and *Streptomonospora* alba. During a biodiversity study on halophilic filamentous actinomycetes from 18 co-ordinates in Barrientos Island, Antarctic, numerous actinomycetes strains were isolated. To identify whether these isolates were members of the genus *Streptomonospora*, a genus specific primer that allow the rapid detection of the genus *Streptomonospora* by means of PCR amplification was used. Furthermore molecular cloning was performed to make identical and multiple copies of the target gene. In addition, morphological characteristic identification was performed to validate isolates with positive amplification during PCR.

Key words: antarctic soil; actinomycetes; *Streptomonospora*; genus-specific primers; isolation; identification; morphological characteristics; PCR amplification; SEM; 16S rRNA

Barrientos Island (Aitcho Islands), 62º 24’ S, 59º 47’ is located at the north entrance to the English Strait between Robert and Greenwich Islands. This 1.5 km island’s north coast is dominated by steep cliffs which gently slope down to the south coast. The eastern and western ends of the island are black sand and cobbled beaches. The confirmed breeders in this island includes Gentoo penguin (*Pygoscelis papua*), Chinstrap penguin (*Pygoscelis antarctica*), southern giant petrel (*Macronectes giganteus*), kelp gull (*Larus dominicanus*), and skuas (*Catharacta* spp.). According to the Antarctic treaty visitor’s site guide, the other suspected breeders in this island comprises Blue-eyed shag (*Phalacrocorax atriceps*) and Wilson’s storm-petrel (*Oceanites oceanicus*). The regularly haul out animals are Weddell seals (*Leptonychotes weddellii*), southern elephant seals (*Mirounga leonine*), and from late December Antarctic fur seals (*Arctocephalus gazella*) will be observed.

Soil is a complex environment colonized by diversity of micro-organisms such as bacteria, virus, fungi and protozoa. Bacteria like actinomycetes have been identified as one of the major groups of the soil population (Küster *et al*. 1964) which may vary with soil type. Actinomycetes are gram-positive bacteria having high G+C (>55%) content in their DNA and now recognized as prokaryotic organisms. It is well known that soil actinomycetes have great potential in producing useful bioactive compounds. Historically, natural product screening projects have focused on the genus *Streptomyces* for the production of different medically important compounds (Sanglier *et al*. 1993).

Lately, *Streptomyces* isolated from different environments have produced the same compound due to frequent genetic exchange between species (Bredholt *et al*. 2008). Hence, this results in reduced chances of finding genuinely new biologically active molecules from *Streptomyces* (Baltz 2006; Busti *et al.* 2006). Therefore halophiles like *Streptomonospora* occur as a new important resource similarly to potential producers of novel bioactive compounds (Zhi *et al*. 2006). *Streptomonospora* can grow at a high concentration of salt, and are not capable of growing

[1] Department of Biomedical Science, Faculty of Medicine and Health Sciences, University Putra Malaysia, 43400 UPM Serdang, Selangor D.E.
[2]Department of Food Science, Faculty of Food Science and Technology, University Putra Malaysia, 43400 UPM Serdang, Selangor D.E.
[3]Biotechnology Research Institute, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia
[4]Instituto Antartico Ecuatoriano, Guayaquil, Ecuador
[*]Corresponding author (e-mail: ykcheah@medic.upm.edu.my)

in non-salt-contained medium. These characteristics enable them to be filamentous actinomycetes with extreme halophilic capacity that enable them to be one of the perfect material for ecological study (Zhi *et al*. 2007) and distribution of minerals.

Genus *Streptomonospora* form a distinct branch in the 16S rRNA gene phylogenetic tree adjacent to the genera *Nocardiopsis* and *Thermobifida*, family *Norcadiopsaceae*. The advancement in technology enabled the comparative analysis of nucleic acid based 16S rRNA gene sequences, that allow the development of novel and powerful tools that can be used for the study of micro-organisms (Ludwig & Schleifer 1994). Compared to the tedious conventional morphological and time-consuming chemical techniques, PCR-based detection using genus-specific primers has been proven to be useful for rapid identification of several actinomycetes genera (Laurent *et al.* 1999; Moron *et al*. 1999; Rintala *et al*. 2001; Salazar *et al*. 2002; Tan *et al*. 2006; Zhi *et al.* 2006).

In this study, 18 soil samples were collected from different locations throughout Barrientos Island, Antarctic to investigate the distribution of *Streptomonospora* using genus-specific primers. Furthermore, molecular cloning was performed to make identical and multiple copies of the target gene. In addition, morphological characteristics identification was performed to validate isolates which yielded positive PCR amplification.

The aim of this study was focused mainly on isolation and identification of *Streptomonospora* utilizing molecular methods and imaging by scanning electron microscope (SEM) as confirmation.

MATERIALS AND METHODS

All isolation and related experiments were conducted in Malaysia. Soil samples were transported in cold conditions and kept in a frozen state (–80ºC) until further use.

Culture Media

A synthetic medium, starch-casein agar (SCA), which is composed of soluble starch or glycerol, 10 g; casein, 0.3 g; KNO_3, 2 g; NaCl, 2g; K_2HPO_4, 2 g; $MgSO_4$. $7H_2O$, 0.05 g; $CaCO_3$, 0.02g; $FeSO_4$. $7H_2O$, 0.01 g; Bacto Agar, 18 g; distilled water, 1 litre; pH 7.2 was used for the isolation of actinomycetes.

Isolation of Actinomycetes from Soil

Soil from 18 different co-ordinates was air dried for 7 days at room temperature (~25ºC) under clean conditions. Next, the air-dried soil was suspended in sterile distilled water and incubated in an orbital shaking incubator at 28ºC for 30 min. Mixtures were allowed to settle and a serial dilution up to 10^{-1} was prepared. 0.1 ml from 10^{-1} dilution of all the suspensions were aseptically inoculated by spread-plate technique on to the starch-casein agar supplemented with cycloheximide (50 µg/ml) to suppress growth of unwanted fungi (Takizawa *et al*. 1993). Inoculated plates were then incubated at 28 ± 1 ºC for 2–4 weeks until growth was observed. Actinomycete colonies were recognized by their characteristic tough, leathery texture, branched vegetative mycelia and the presence of sporulating aerial mycelia (Jensen *et al.* 1991). Non-mucoid, smooth colonies with only vegetative mycelia were also presumptively identified as actinomycete. Individual colonies with characteristics of actinomycete morphology were isolated and pure cultures of the respective isolates were obtained by streaking on SCA plates. The pure isolates were transferred to SCA semisolid agar and preserved at 4ºC.

DNA Extraction

Total genomic DNA of all the pure isolates were extracted and purified using the method as described by Cui *et al*. (2001).

PCR Amplification

Genomic DNA extracted were used as the template for 16S rRNA genes amplification using primers A 8-27f (50-CCG TCG ACG AGCTCA GAG TTT GAT CCT GGC TCA G-30) and B1523–1504r (50-CCC GGG TAC CAA GCT TAA GGA GGT GAT CCA GCC GCA-30), according to the method described by Cui *et al*. (2001). The amplified 16S rRNA gene product was used as template for PCR reaction targeting specific gene fragment of *Streptomonospora*. PCR reaction with primers Stmp1 and Stmp2 were performed in a final volume of 20 µl containing 20 ng of genomic DNA, 2.0 µl 10x PCR buffer, 2.0 µl 2.5 mM dNTPs, 1 unit *Taq* polymerase (Intron, Korea) and 10 pmoles of each primer. The amplification were carried out in an Eppendorf Mastercycler (Eppendorf, Hamburg, Germany) with cycling parameters of 3 min at 94ºC for pre-denaturation, 30 cycles each of 1 min at 94ºC for denaturation, 45 s at 58ºC for annealing, 2 min at 72ºC for extension, and a final extension at 72ºC for 5 min. The post-PCR process included a lectrophoresis process using 1.5% agarose gel (Sigma, St Louis, MO, USA) to resolve amplified products, staining with ethidium bromide (0.5 µg ml^{-1}) and viewed by gel documentation system (Alpha Imager, Alpha Innotech, U.S.A).

Molecular Cloning

PCR product was purified using GeneAll Expin Gel SV purification kit (GeneAll, Seoul, Korea) and proceeded to molecular cloning using QIAGEN PCR cloning kit (Qiagen, Hilden, Germany) according to manufacturer's protocol. Through the blue-white selection, insert was verified by colony-PCR and colonies with transformations were preceded to plasmid DNA extraction (Eppendorf, Hamburg, Germany) according to manufactuer's protocol. Purified plasmid DNAs served as templates for PCR to confirm the insertion of the gene of interest.

Morphological Characteristic

Cultures grown on Actinomycetes Broth (Becton Dickinson, New Jersey, USA) at 28°C for 14 days to 28 days were observed with a JOEL-JSM 6400 scanning electron microscope (SEM). Cultures grown in broth were harvested by centrifugation at 2000 r.p.m. for 5 min. Each cell pellet was subjected to separate vials and fixed in fixative (4% glutataldehyde) for 4 h to 6 h at 4ºC. After fixation, the 4% glutataldehyde was discarded and followed by washing with 0.1 M sodium cocadylate buffer for three changes of 10 min each. After washing, the buffer was discarded and a post-fixation was performed in 1% osmium tetroxide for 2 h at 4ºC. After post-fixation, supernatant was discarded by washing steps with 0.1 M sodium cocadylate buffer for three changes of 10 min each and followed by a series of dehydrations with acetone at different concentrations (35%, 50%, 75%, 95% and 100%), 10 min for each concentration and three changes for 100% acetone. Next, the specimen was subjected to critical point drying by placing it into a critical dryer for 1.5 h. Subsequently, the mounting step was performed by sticking the specimen onto the stub using double-sided adhesive tape. The mounted specimen was then coated with gold using the sputter coater.

RESULTS AND DISCUSSION

Soil Sample

Barrientos Island is famous among Antarctic visitors. The entire centre of the island is covered by a very extensive moss carpet. A total of 18 different sites that were not covered by moss were obtained around Barrientos Island as indicated by the GPS locations in Table 1. The soil samples were taken from the abandoned rookeries, active rookeries, resting areas of Chistrap penguin (*Pygoscelis Antarctica*) and Gentoo penguin (*Pygoscelis papua*), and nests of southern giant petrel (*Macronectes giganteus*). Various types of soil texture were selected ranging from damp soil to rocky sand. *Streptomonospora* were successfully isolated from among 39% of the sample sites included in this study. The soil in which *Streptomonospora* were successfully recovered included the abandoned rookeries.

PCR Amplification

Specific identification of *Streptomonospora* utilizing Stmp1 and Stmp2 primers were successfully performed on the extracted DNA and were found to be specific as shown in Figure 1. Molecular identification is essentially useful in mass screening process. On the other hand, the targeted fragments were successfully cloned. The cloned colonies were successfully validated with colony PCR as shown in Figure 2. These clones can be useful in developing in-house probes and standards for the *Streptomonospora*. This molecular approach enabled the rapid screening process of this microbes and this would indirectly contribute to the biodiversity expansion and geographical soil conditions as this particular microbes survived well in high salinity soil. *Streptomonospora* could be a topologically important microbe besides contributing major novel bioactive compound search.

Morphologic Description

The aerial mycelium, at maturity, forms short chains of non-motile spores; spores in short chains are oval- to rod-shaped with wrinkled surfaces as indicated in Figure 3, Figure 4 and Figure 5 (A and B). According to Li *et al.* (2003), substrate mycelium is extensively branched with non-fragmenting hyphae which were in concordance with our SEM micrograph shown in Figure 4. Single, round to oval spores were borne on substrate mycelium as indicated in Figure 5 (A and B). The overall morphology observation from the SEM analysis was in agreement with the structure description reported by Li *et al.* (2003) in which two types of single spore, wrinkled surfaces, on aerial mycelium and substrate mycelium are as shown in Figure 5 (A) and Figure 5 (B).

CONCLUSION

This study demonstrated a valuable identification of *Streptomonospora*. Specific PCR identification allows rapid screening of the particular microbes and this would allow greater chances of new species identification in *Streptomonospora*. Besides that, the identification of this microbes in soil would indirectly allow us to predetermine soil salinity in certain area. Further analysis such physiological characteristics of the microbe need to be conducted for identification of new species.

ACKNOWLEDGEMENTS

The authors are grateful to Instituto Antartico Ecuatoriano, Ecuador for their partial support of the XI Ecuadorian Antarctic Expedition to Research Station 'Pedro Vicente Maldonado', Greenwich Island, South Shetlands Islands, Antarctic latitude 62º 26' 57.6" S longitude 59º 44' 32.1" W from 3 January 2007 to 10 February 2007. This project was supported by the Malaysian Antarctic Research Program under the Academy of Sciences Malaysia.

Date of submission: November 2008
Date of acceptance: June 2009

Table 1. Soil samples description with frequency of isolated Streptomonospora.

No	Sample	GPS Location		Soil description	Frequency of *Streptomonospora*
1	442	S 62° 24’ 23.2”	W 59° 44’ 29.6”	Active penguin rookery (chinstrap) on a hill, feather shedding season. Mixture of mud, guano and shedded feathers at the soil surface. Underneath the mud layer is hard, light brown.	0
2	443	S 62° 24’ 22.7”	W 59° 44’ 29.1”	Abandoned rookery. Rocky, hard soil, penguin guano on top layer and brownish alluvium underneath it.	1
3	444	S 62° 24’ 24.0”	W 59° 44’ 30.5”	Abandoned Gentoo penguin rookery. Rocky, hard and very little soil, shedded feathers on soil surface, dark soil matter and damp.	0
4	445	S 62° 24’ 24.0”	W 59° 44’ 25.8”	Abandoned Gentoo Penguin rookery. Soil surface covered by feathers, soil – very hard, rocky and damp, dark soil matter and less soil.	2
5	446	S 62° 24’ 20.7”	W 59° 44’ 20.5”	Active Chinstrap penguin rookery. Dark soil matter, soil surface covered with feathers, guano, soil is hard and damp, on top of a hill.	0
6	447	S 62° 24’ 21.3”	W 59° 44’ 16.7”	Active Chinstrap rookery on a hill. Soil surface – mixture of watery dark soil matter (mud-like) and shedded feathers. Underneath it – brownish red and hard soil and rocky.	0
7	448	S 62° 24’ 21.3”	W 59° 44’ 16.7”	Penguin gathering area on top of a hill, watery and mud-like soil on the surface – mixture of bron and black soil matter and shedded feathers.	0
8	449	S 62° 24’ 21.3”	W 59° 44’ 13.2”	Active Chinstrap rookery on a hill. Soil surface – mixture of watery dark soil matter (mud-like) and shedded feathers. Underneath it – dark brown and hard soil and rocky.	1
9	450	S 62° 24’ 24.4”	W 59° 44’ 44.2”	Abandoned penguin rookery. Soil surface covered with guano and rocks. Underneath it – dark brown soil matter and damp.	3
10	451	S 62° 24’ 25.2”	W 59° 44’ 45.9”	Gentoo penguin resting area. Moss cover around the area. Soil surface – mixture of moss and black soil matter and covered with shedded feathers.	0
11	452	S 62° 24’ 26.0”	W 59° 44’ 49.1”	Abandoned penguin rookery. Soil surface looks white (penguin guano), moss cover and soil – mixture of moss and dark brown soil matter.	1
12	453	S 62° 24’ 28.5”	W 59° 44’ 52.3”	Penguin resting area at a hill side with moss cover around the area. Soil surface has some shedded feathers, soil – mixture of moss, dark soil matter and partially damp.	0
13	454	S 62° 24’ 27.0”	W 59° 44’ 58.5”	Unidentified abandoned rookery. Thick moss cover around the area. Soil surface – greenish and damp. Soil underneath – mixture of moss and reddish soil matter and damp.	0
14	455	S 62° 24’ 19.2”	W 59° 45’ 00.8”	Active Gentoo penguin rookery. Soil surface covered with moss and shedded feathers. Soil underneath – dark brown soil matter, hard and damp.	1
15	456	S 62° 24’ 18.7”	W 59° 45’ 05.7”	Abandoned penguin rookery, on top of a hill. No vegetation around the area. Soil surface looks white. Top soil – black soil matter, underneath – dark brown soil matter.	0
16	457	S 62° 24’ 26.1”	W 59° 45’ 20.6”	West side. Gentoo penguin rookery at the hill side. Moss cover around the sampling area (but not at the sampling site). Rocky area, soil is of dark brown matter and partially damp.	0
17	458	S 62° 24’ 27.5”	W 59° 45’ 24.3”	Behind a big rock which looks like a seal. Very near to seal colony. Penguin feathers on top of the soil surface, thick moss layer underneath. Soil – black soil matter, rocky and damp.	1
18	460	S 62° 24’ 23.2”	W 59° 45’ 39.3”	Petrel nest, behind a big decaying rock, no vegetation around and rocky. Soil – black soil matter.	0

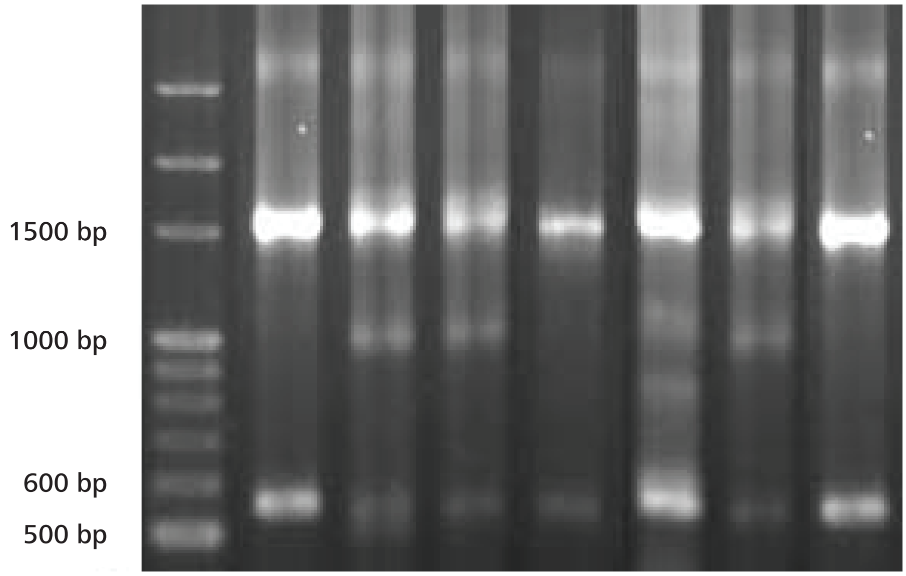


Figure 1. Representative gel electrophoresis of specific PCR amplification of Stmp1 and Stmp 2 with the product size of 565 bp fragment.

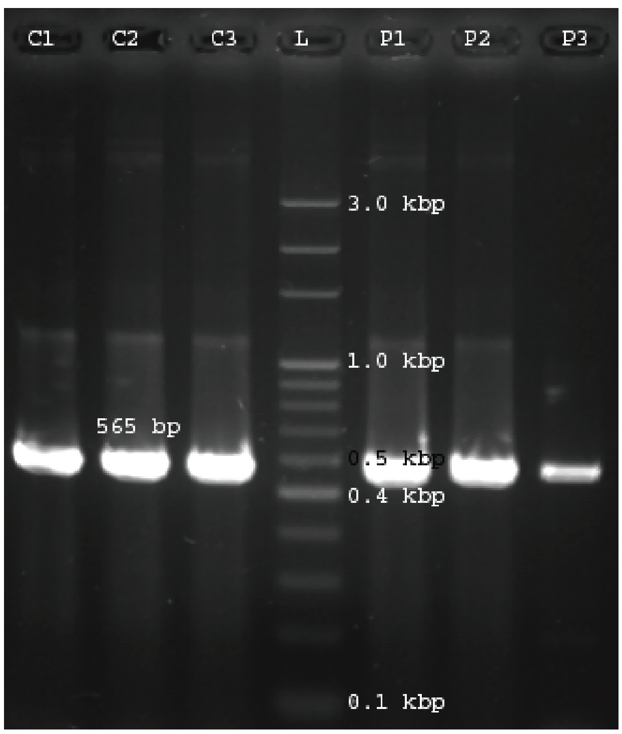


Figure 2. Representative gel electrophoresis of colony PCR amplification of clones with the product size of 565 bp fragment.

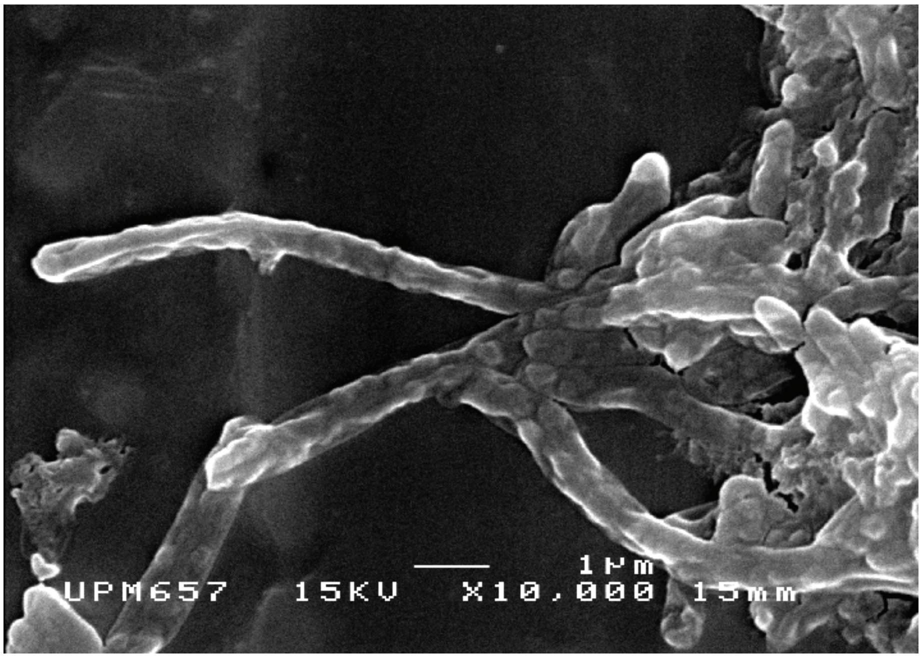


Figure 3. SEM micrograph of Streptomonospora long mycelium attached to medium.

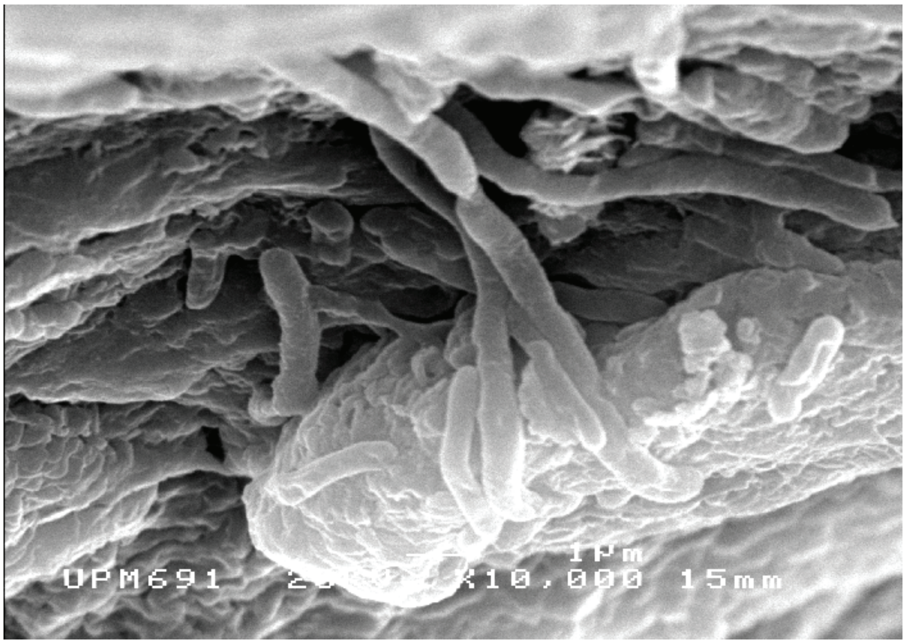


Figure 4. SEM micrograph of significant wrinkled surfaces of the Streptomonospora spores attached together.

A

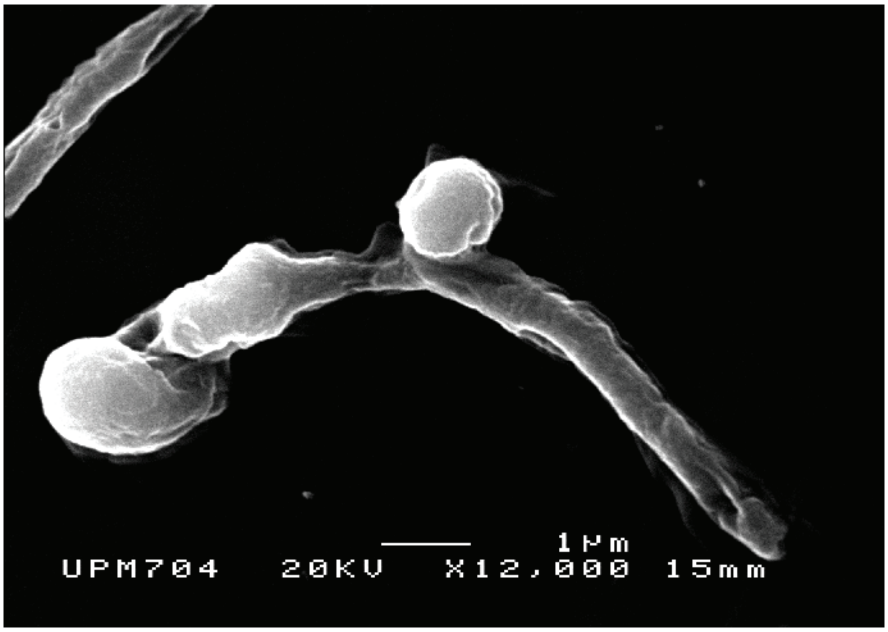


Figure 5A. SEM micrograph showing spores of streptomonospora:
Spores, round to oval shaped with wrinkled surfaces attach to aerial mycelium.

B

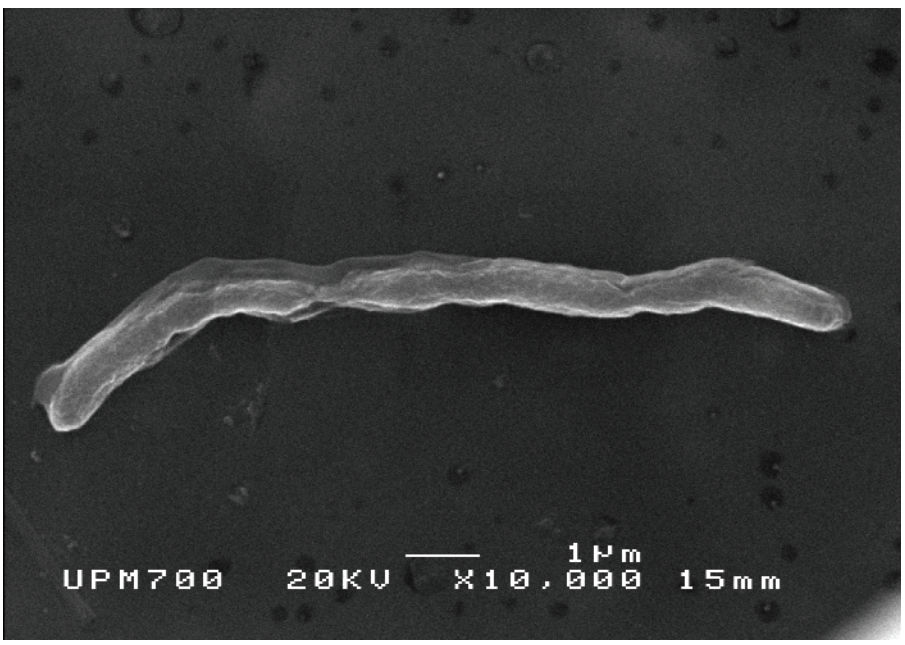


Figure 5B. SEM micrograph showing spores of streptomonospora:
Single spore in short chains wrinkled surfaces.

REFERENCES

Baltz, RH 2006, 'Marcel Faber Roundtable: is our antibiotic pipeline unproductive because of starvation, constipation or lack of inspiration?', *Journal of Industrial Microbiology and Biotechnology*, vol. 33, pp. 507–513.

Bredholt, H, Fjaervik, E, Johnsen, G & Zotchev, SB 2008, 'Actinomycetes from sediments in the Trondheim fjord, Norway: diversity and biological activity', *Marine Drugs*, vol. 6, no. 1, pp. 12–24.

Busti, E, Monciardini, P, Cavaletti, L, Bamonte, R, Lazzarini, A, Socio, M & Donadio, S 2006, 'Antibiotic-producing ability by representatives of a newly discovered lineage of actinomycetes', *Microbiology*, vol. 152, pp. 675–683.

Cui, XL, Mao, PH, Zheng, M, Li, WH, Zhang, LP, Xu, LH & Jiang, CL 2001, '*Streptimonospora salina* gen. nov., sp. nov., a new member of the family *Nocardiopsaceae', International Journal of Systematic and Evolutionary Microbiology*, vol. 51, pp. 357–363.

Jensen, PR, Dwight, R & Fenical, W 1991, 'Distribution of actinomycetes in near-shore tropical marine sediments', *Applied and Environmental Microbiology*, vol. 57, no. 4, pp. 1102–1108.

Küster, E & Williams, ST 1964, 'Selection of media for isolation of Streptomycetes', *Nature*, vol. 202, pp. 928–929.

Laurent, FJ, Provost, F & Boiron, P 1999, 'Rapid identification of clinically relevant Nocardia species to genus level by 16S rRNA gene PCR', *Journal of Clinical Microbiology*, vol. 37, no. 1, pp. 99–102.

Li, W-J, Xu, P, Zhang, L-P, Tang, S-K, Cui, X-L, Mao, P-H, Xu, L-H, Schumann, P, Stackebrandt, E & Jiang, C-L 2003, '*Streptomonospora alba* sp. nov., a novel halophilic actinomycete, and emended description of the genus *Streptomonospora* Cui et al. 2001', *International Journal of Systematic and Evolutionary Microbiology*, vol. 53, pp. 1421–1425.

Ludwig, S & Schleifer, KH 1994, 'Bacterial phylogeny based on 16S and 23S rRNA sequence analysis', *FEMS Microbiology Reviews*, vol.15, pp. 155–173.

Moron, R, Gonzalez, I & Genilloud, O 1999, 'New genus-specific primers for the PCR identification of members of the genera *Pseudonocardia* and *Saccharopolyspora*', *International Journal of Systemic and Evolutionary Bacteriology,* vol. 49, no. 11, pp. 149–162.

Rintala, H, Nevalainen, A, Ronka, E & Suutari, M 2001, 'PCR primers targeting the 16S rRNA gene for the specific detection of streptomycetes', *Molecular and Cellular Probes*, vol. 15, no. 6, pp. 337–347.

Salazar, O, Gonzalez, I & Genilloud, O 2002, 'New genus-specific primers for the PCR identification of novel isolates of the genera *Nocardiopsis* and *Saccharothrix*', *International Journal of Systemic and Evolutionary Microbiology*, vol. 52, no. 4, pp. 1411–1421.

Sanglier, JJ, Haag, H, Huck, TA & Fehr, T 1993, 'Novel bioactive compounds from actinomycetes: a short review (1988–1992)', Research in Microbiology, vol. 144, pp. 633–642.

Takizawa, M, Colwell, RR & Hill, RT 1993, 'Isolation and diversity of actinomycetes in the Chesapeake Bay', *Applied Environmental Microbiology*, vol. 59, pp. 997–1002.

Tan, GY, Ward, AC & Goodfellow, M 2006, 'Exploration of *Amycolatopsis* diversity in soil using genus-specific primers and novel selective media', *Systemic and Applied Microbiology*, vol. 29, pp. 557–569.

Zhi, XY, Tang, SK, Li, WJ, Xu, LH, & Jiang, CL 2006, 'New genus-specific primers for the PCR identification of novel isolates of the genus *Streptomonospora*', *FEMS Microbiology Letters*, vol. 263, pp. 48–53.

Zhi, XY, Yang, LL, Wu, JY, Tang, SK & Li, WJ 2007, 'Multiplex specific PCR for identification of the genera *Actinopolyspora* and *Streptomonospora*, two groups of strictly halophilic filamentous actinomycetes' *Extremophiles*, vol. 11, pp. 543–548.

ASM Sci. J., **3(2)**, 121–130

Observations of Travelling Ionospheric Disturbances During Storm Events Over Antarctica

M.A. Momani[1,2]*, B. Yatim[1], M.A.M. Ali[1,2] and M. Abdullah[1,2]

The paper examines the propagation direction and speed of large scale travelling ionospheric disturbances (LSTIDs) obtained from GPS observations of extreme geomagnetic storms during the 23rd solar cycle; these are the October 2003 and November 2003 geomagnetic storms. In the analysis, the time delay between total electron content (TEC) structures at Scott Base station (SBA) (Lat. –77.85º, Long. 166.76º), McMurdo (McM4), (Lat. –77.84º, Long. 166.95º), Davis (DAV1), (Lat. –68.58º, Long. 77.97º) and Casey station (CAS1) (Lat. –66.28º, Long. 110.52º) GPS stations as well as the distance between these stations were employed in the analysis. The measurements during the October 2003 storm showed obvious time delay between the TEC enhancement occurrences at SBA/MCM4, DAV1 and CAS1 stations. The time delay indicated a movement of the ionospheric structures from higher to lower latitudes in a velocity ranging between 0.8 km/s – 1.2 km/s. The first sudden TEC enhancement was observed at SBA/McM4 (Lat. –75.84º) followed by CAS1 station (Lat. –66.28º) and the final TEC enhancement was seen at DAV1 station (Lat. –68.58º) with TEC magnitude decreasing while moving from higher to lower latitudes. One important observation was that although the latitude of the CAS1 station was lower than the DAV1 station, the TEC enhancement was firstly seen at the CAS1 station due to the shorter distance between SBA and CAS1 compared with the distance between SBA and CAS1 of about 500 km. The TEC measurements during the November 2003 storm showed an opposite propagation direction (i.e. poleward direction from lower to higher latitudes) which was seen with a velocity ranging between 0.3 km/s – 0.4 km/s. As similar response was observed using vertical TEC measurements obtained from individual PRN satellites but with higher velocity ranges (1.2 km/s – 2.4 km/s during October and 0.5 km/s – 0.7 km/s during November). The equatorward or poleward expansion of LSTIDs during the October and November 2003 storms was probably caused by the disturbances in the neutral temperature which occurred close to the dayside convection throat or due to the neutral wind oscillation induced by atmospheric gravity waves launched from the aurora region.

Key words: antarctica; GPS; ionosphere; magnetic storm; disturbances; total electron content;

Significant interaction between solar wind and the earth's atmosphere takes place at high latitude regions (Jakowski *et al*. 1996). The ionosphere in this region is influenced by precipitating particles and the large-scale electric field of magnetospheric origin. The field-aligned currents couple the high-latitude ionosphere with the magnetosphere causing energetic particles to precipitate to the lower thermosphere and below. This process causes considerable heating of the ionized and neutral gases, increases the ionospheric ionization at higher latitudes, uneven expansion of the thermosphere and disturbed thermospheric circulation (Buonsanto 1999). A number of phenomena such as large-scale travelling ionospheric disturbances (LSTIDs) and radio scintillations are generated (Jakowski *et al.* 1996; Jakowski *et al.* 2002). The most dramatic changes take place very frequently in the auroral and polar ionosphere (Krankowski *et al*. 2005). In these regions, irregularities of different scales (large, medium- and small-scale fluctuations) are common which cause fluctuations in the total electron content (TEC) (Krankowski *et al*. 2005). The spatial and temporal extent of the irregularities can be much greater than at the lower latitude ionosphere although the intensity is less (Hargreaves 1992). A strong correlation between scintillation and TEC fluctuations can be also observed (Basu *et al*. 1999).

The LSTIDs are ionospheric disturbances having periods between 30 min to 3 h and scale size wavelengths exceeding 1000 km (Schaer 1999). These irregularities are believed to be ionospheric manifestations of the passage of the atmospheric gravity waves that are generated at high latitudes due to the energy input from the magnetosphere, where the energy input is considered to be injected coincidentally into both hemispheres (Tsugawa *et al*.

[1]Institute of Space Science, ANGKASA, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
*Corresponding author (e-mail: mhomom@yahoo.com; momani@ukm.my)

2006). Balthazor and Moffett (1997) showed that the thermospheric heating in the auroral regions may cause a production mechanism of LSTIDs. In their analysis, the coupled thermosphere-ionosphere-plasmasphere (CTIP) model was employed to explain the production mechanism of TIDs which originate at the conjugate auroral zones and propagate to lower latitudes. Based on the CITP model, the solar wind energy input to the upper atmosphere of the polar region during severe storm periods causes considerable heating and expansion of the neutral atmosphere. The generation mechanism of the LSTIDs in the polar region is explained as follows: the disturbances in the neutral temperature originate close to the dayside convection throat (latitude from 65º–75º) where impulsive joule heating and ion drag forces on the neutral atmosphere give rise to neutral winds. These winds in turn, can blow ions up or down the field lines and thus modulate the ionosphere and in turn the joule heats itself (Idenden 1998). The neutral winds are driven in both equatorward or poleward directions away from the pressure bulge. The equatorward winds transport the composition changes to lower latitudes, therefore, the composition disturbance of increased mean molecular mass reaches from high to middle latitudes (Prölss & Roemer 1987). The migration of ionospheric composition from higher to lower latitudes manifest themselves as large scale travelling ionospheric disturbances (Buonsanto 1999). The poleward neutral winds on the other hand are much larger in magnitude than the equatorward winds due to the Lorenz force produced and pressure gradient forces (Idenden 1998). The disturbances of neutral temperature variation which originate close to the dayside convection throat is one possible explanation of LSTID generation in the polar region. Another possible explanation is the AGW/TID relationship in the aurora region. Balthazor and Moffett (1997) stated that the TID is the signature in the ionosphere of the passage of the AGW, the ions being forced along the field lines by neutral air winds driven by pressure waves. The TID in the aurora region are commonly considered to be caused by neutral wind oscillation due to atmospheric gravity waves through neural-ion collision (Hunsucker 1982; Hocke & Schlegel 1996).

Previous studies on the equatorward and poleward expansions of LSTIDs have been examined using multiradar systems measurements (Prölss & Ocko 2000; Foster *et al*. 2005). The advent of global positioning system (GPS) provides a low cost solution for monitoring the ionosphere on a global basis where the TEC measurements obtained from GPS observables are used to determine the propagation direction and speed of LSTIDs (Buonsanto 1999; Yue-Jin *et al.* 2001; Tang *et al*. 2001; Jakowski *et al*. 2002; Baran *et al.* 2002; Yizengaw *et al.* 2004). However, most of these studies employed the delay time between the primary peak at high latitude and the secondary peak at lower latitude regions in determining the propagation direction and speed of LSTID. Most of the previous studies

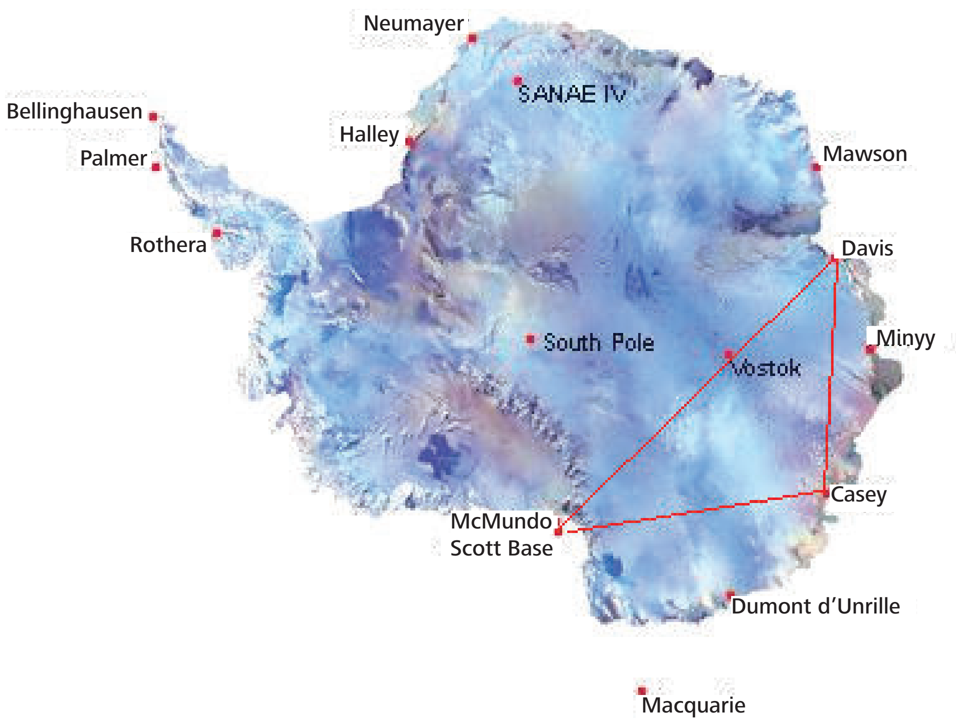


Figure 1. Geographic map of Antarctica showing the location of the Scott Base, McMurdo, Davis and Casey ionospheric stations.

on LSTIDs were made over the northern hemisphere; there is a lack of research done over the southern hemisphere. This paper examines the propagation direction and speed of LSTIDs obtained from GPS observations of severe storm events during the 23rd solar cycle, the October 2003 and November 2003 magnetic storms. In the analysis, the delay time between the primary and secondary TEC peaks at several GPS stations over Antarctica was employed in determining the propagation speed and direction of LSTID. Data from Scott Base station (SBA), (Lat. –77.85º, Long. 166.76º), McMurdo (McM4) (Lat: –77.84º, Long: 166.95º), Davis (DAV1), (Lat. –68.58º, Long. 77.97º) and Casey station (CAS1), (Lat. –66.28º, Long. 110.52º) GPS stations were employed in the analysis. Figure 1 presents the geographic location of the GPS stations. As shown in the figure, SBA and McM4 stations are near to each other (distance of 3 km from SBA to MCM4) and is about 2185 Km from CAS1 and 2713 km from DAV1, the distance between CAS1 and DAV1 is about 1400 km.

Data Processing

The absolute GPS TEC can be obtained from differential time delay (P1-P2) or from differential phase advance (L1-L2). The TEC obtained from differential time delay gives the level of absolute TEC but it is highly exposed to multipath effect, while the TEC attained from differential phase advance gives high precision TEC but the level is unknown due to the initial offset called the ambiguity. Therefore, the level of TEC is adjusted to the TEC derived from the corresponding code difference for each satellite-receiver pair (Otsuka *et al*. 2002). In this work, the time delay measurements were used to remove the ambiguity term, and by combining the phase and the code measurements for the same satellite receiver pair, the absolute TEC was obtained with high precision (Klobuchar 1996). The TEC values were corrected from the receiver and satellite biases by using the AIUB Data Center of Bern University in Switzerland (AIUB 2005). The equivalent absolute vertical TEC, percentage deviation of the GPS TEC and the rate of change of TEC (ROT) was calculated using the standered methods discussed in Warnant and Pottiaux (2000), Forster and Jakowski (2000), Abdul Rashid *et al.* (2006) and Momani *et al*. (2008).

RESULTS AND DISCUSSION

The LSTIDs propagation direction and speed was examined for pronounced storm enhanced density periods during the October 2003 and November 2003 geomagnetic storms. The experiment was conducted based on the latitudinal variations of absolute GPS VTEC measurements at SBA, McM4, DAV1 and CAS1 stations. In these analyses, the time delay between the TEC enhancements at different locations was employed in determining the LSTIDs propagation direction and speed.

Large-scale TID Measurements During the October 2003 Geomagnetic Storm

The period from 28 October to 1 November of 2003 was characterized by extreme solar activity that resulted in a series of intense geomagnetic storms. This period was considered as the greatest storms during the 23rd solar cycle and one of the fastest travelling solar storms in the last two decades (Spectrum 2003). Three distinct *Dst* minima were recorded during this storm: the first *Dst* minimum (–180 nT) around 12:00 UT on 29 October, the second *Dst* minimum at 01:00 UT (–363 nT) on 30 October 2003 and the third *Dst* minimum at 23:00 UT (–401 nT) on the same day. The sudden storm commencement (SSC) of the first storm episode took place around 06:00 UT on 29 October 2003, the second SSC event occurred around 12:00 UT of the same day, while the third SSC event took place around 17:00 UT on 30 October 2003. During this period, the 3 h *Kp* index reached its maximum value of 9 three times: at 09:00 and 21:00 UT on 29 October, and from 21:00 until 24:00 UT on 30 October. Figure 2 presents the diurnal variations of TEC measurements at SBA, McM4, DAV1 and CAS1 GPS stations as well as the planetary *Dst* and *Kp* magnetic indices during the October 2003 geomagnetic storm between 28 October and 1 November 2003. As shown in the figure, the TEC variations follow the geomagnetic field response where the maximum TEC activities were observed during maximum *Kp* and *Dst* indices. Similar TEC variations are observed at SBA and McM4 stations with the TEC enhancements-depletions periods occurring at about the same time. At both stations, quiet TEC activity was observed during the period between SSC at 06:00 UT until evening UT time on 29 October. A strong TEC enhancement period was observed between 21:00 UT on 29 October until 02:30 UT on 30 October 2003 followed by a TEC depletion response that persisted until the evening UT time on 30 October. During the evening UT on 30 October 2003, another severe TEC enhancement was observed between 19:00 UT and 23:00 UT on 30 October 2003. This strong activity was followed by TEC depletion signatures until the morning UT time on 1 November 2003 where TEC enhancement took place. At CAS1 and DAV1 GPS stations, the TEC signatures were close to each other with normal TEC activity observed between the SSC time on 29 October and the evening UT time on 30 October followed by TEC enhancement signature between 19:00 UT and 24:00 UT on 30 October 2003.The response during 31 October and 1 November at both GPS stations followed a similar response that was observed at SBA and McM4 stations.

Figure 3 zooms into the measurements of TEC and percentage deviation of the TEC (ΔTEC%) during the period between 12:00 UT on 30 October and 12:00 UT on 31 October 2003 at SBA, CAS1 and DAV1 GPS stations. The ΔTEC% is determined by the difference in the disturbed day TEC from quiet days when the *Kp* index during a day

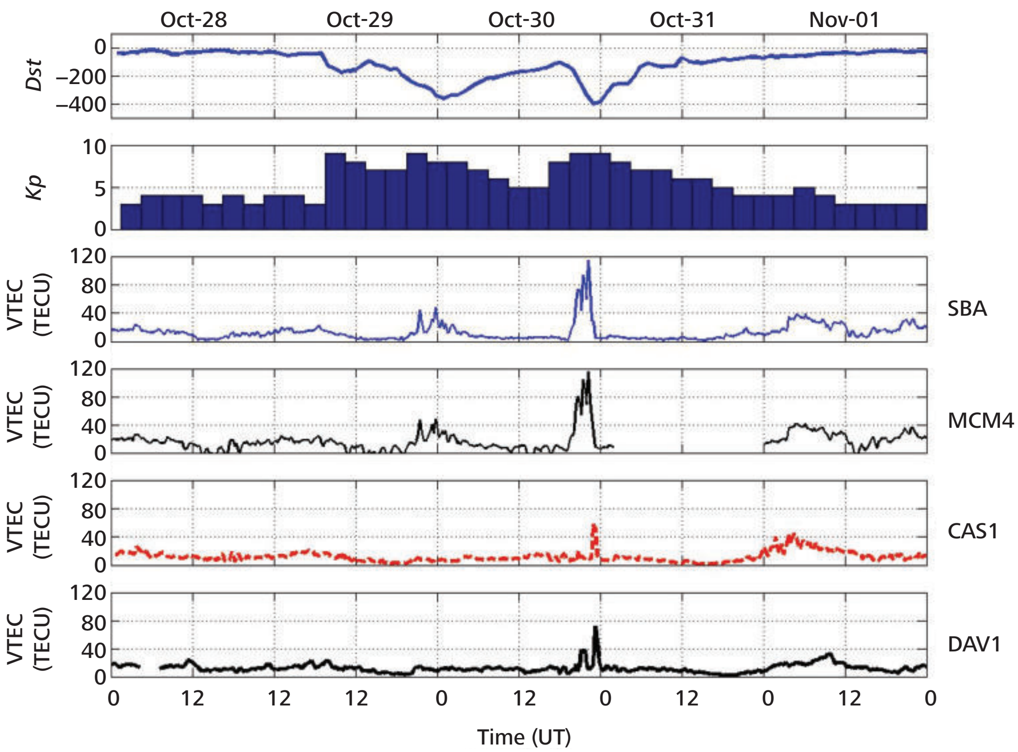


Figure 2. Temporal daily variations of the absolute VTEC measurements at SBA, MCM4, CAS1 and DAV1 GPS stations with daily *Dst* and *Kp* indices during the October 2003 magnetic storm.

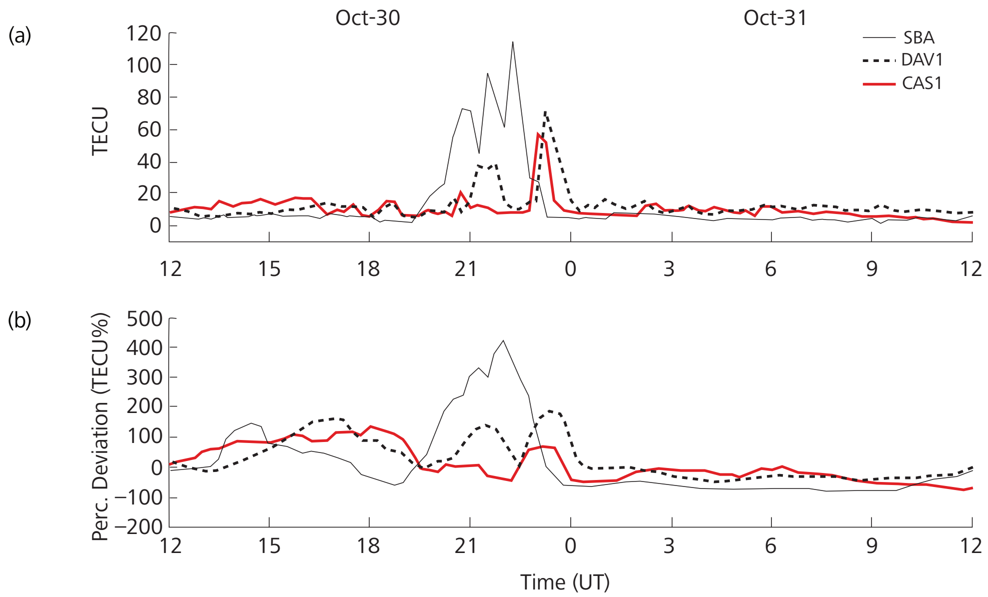


Figure 3. The TID observations at SBA, MCM4, DAV1 and CAS1 stations during the period between 12:00 UT on 30 October and 12:00 UT on 31 October 2003 (a) VTEC (b) ΔTEC%.

was ≤ 2 (days 9, 10 and 11 October were selected to find the quiet day TEC). As shown in the figure, an obvious time delay was observed between the TEC signatures at the four stations, the first sudden TEC enhancement was observed at SBA (Max. value at 22:10 UT) followed by CAS1 station (Max. value at 23:00 UT) and finally at DAV1 station (Max. value at 23:20 UT). This delay (i.e. 50 min and 20 min) indicated a movement of the ionospheric structures from the cusp region at SBA location to lower latitudes. Although the CAS1 station (Lat. 66.28ºS) was lower in latitude than DAV1 station (Lat. 68.58ºS), the TEC enhancement at CAS1 was seen there first, this was because the distance between SBA and CAS1 was shorter than the distance from SBA to CAS1 by about 500 km. It was also observed that the TEC magnitude was decreasing while moving from higher to lower latitudes with a TEC minimum seen at CAS1 station. Based on the time delay between the TEC peaks shown in Figure 3 and the great circular arc distance between the GPS stations (i.e. 2185 km between SBA and CAS1 stations and 1401 km from CAS1 to DAV1), the LSTIDs propagation speed was in the range between 0.8 km/s – 1.2 km/s in an equatorward direction.

The TEC measurements obtained from individual PRN satellites passes were also used to determine the propagation direction and speed of LSTIDs. The vertical TEC measurements obtained from PRN6 during the period between 22:00 UT and 24:00 UT on 30 October 2003 at SBA, CAS1 and DAV1 stations are shown in Figure 4. As shown in the figure, the first TEC peak was observed at SBA followed by the second TEC peak at CAS1 station and the last TEC peak was seen at DAV1 stations. The maximum TEC enhancement at SBA station occurred at 22:35 UT while at CAS1 and DAV1 stations it occurred at 22:55 UT and 23:10 UT, respectively. The delay time between the TEC peaks at the three stations as obtained from PRN6 (i.e. 20 min and 15 min) indicated a propagation speed of 1.5 km/s – 1.8 km/s in an equatorward direction.

Figure 5 presents the vertical TEC measurements obtained from PRN17 at the three GPS stations between 22:00 UT and 24:00 UT on 30 October 2003. As shown in the figure, the TEC enhancements were first seen at SBA followed by CAS1 then DAV1 stations. At SBA station, the TEC peak was seen at 22:30 UT (Max. value of 105 TECU). At CAS1 station, the TEC peak was seen at 22:45 UT (Max. value of 50 TECU) and at DAV1 station it was seen at 23:05 UT (Max. value of 85 TECU). The delay time between the three TEC peaks obtained from PRN17 (i.e. 15 min and 20 min) indicated a velocity of 1.2 km/s – 2.4 km/s in an equatorward direction. The LSTID propagation direction and speed was also verified using the rate of TEC measurements from the same PRNS at different locations. The ROT measurements were used to detect the high frequency changes in the TEC due to irregular ionospheric phenomena such as TIDs and scintillation effects (Pi *et al.* 1997; Warnant & Pottiaux (2000). ROT is directly measured from the geometry free combination of the GPS carrier phase measurements (Warnant & Pottiaux 2000).

The ROT measurements obtained from PRN21 during the period between 21:00 and 24:00 UT on 30 October 2003 storm at SBA, MCM4, CAS1 and DAV1 GPS stations are shown in Figure 6. As shown in the figure, the TEC irregularities at different stations were seen during different periods of time with a clear time delay observed. The measurements showed that the TEC irregularities were simultaneously seen at SBA and MCM4 stations with Max value at 22:35 UT (McM4 is 3 km far from SBA) followed by CAS1 station 22:55 UT and finally at DAV1 station between 23:05 UT. The time delay between the TEC activity at the four stations (i.e. 20 min and 10 min) indicated a movement of the storm from higher to lower latitude and from east to west (equatorward/westward) with a propagation velocity between 1.8 km/s – 2.3 km/s.

The observations of equatorward LSTIDs over the southern polar region during the October 2003 storm was probably due to the effect of impulsive joule heating and ion drag forces on the neutral atmosphere which gave rise to neutral winds as shown in Idenden (1998). The neutral winds were driven at both equatorward and poleward directions to either side of the dayside convection throat carrying the compositions away from the convection throat to either lower or higher latitudes forming the LSTIDs. The TID in the polar region are commonly considered to be caused by neutral wind oscillation due to atmospheric gravity waves (AGW) through neural-ion collision (Hunsucker 1982). Tang et al. (2001) showed that most LSTIDs that originated in the polar region propagate in an equatorward direction, while a few LSTIDs events propagate in a poleward direction mainly during summer seasons which are strongly pertinent to solar activity. An example of poleward propagation of LSTIDS was observed during the November 2003 magnetic storm which is discussed below.

LSTIDs Measurements during the November 2003 Magnetic Storm

The November 2003 magnetic storm occurred on 20 November with SSC at around 10:00 UT. The maximum magnetic *Dst*, *Kp* and *Ap* indices during this event were –465 nT, 9 and 117, respectively. The solar and magnetic activities as well as the X-ray solar flare activity were strong during the days 20 and 21 November but decreased during the following days (IPS 2003). The *Dst*, *Kp* indices obtained from world data center as well as the daily GPS TEC measurements at SBA, CAS1 and DAV1 GPS stations for the November 2003 magnetic storm are shown in Figure 7. As shown in this figure, the SSC of the storm at the three stations began at around 10:00 UT on 20 November 2003, coincident with strong TEC depletion observed at the

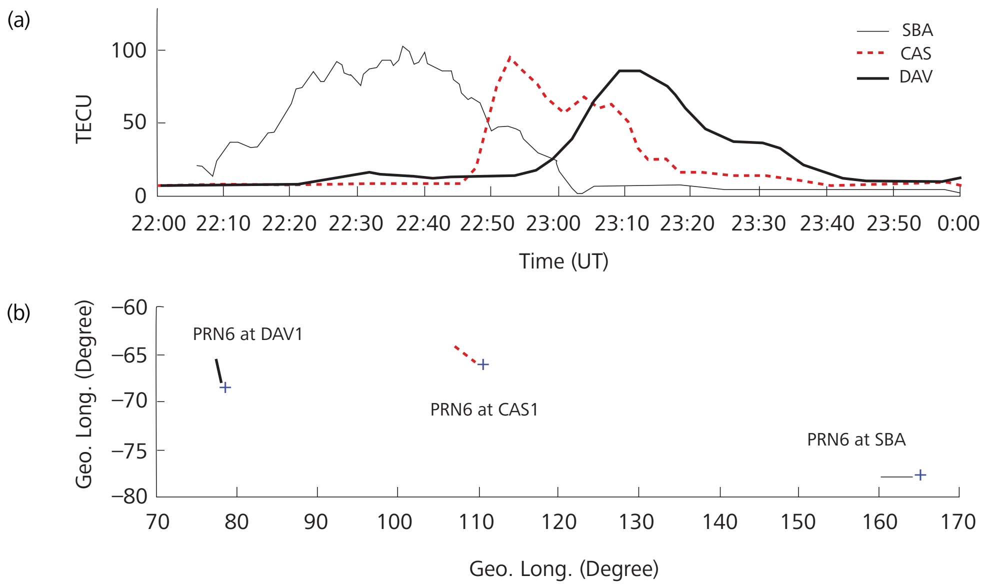


Figure 4. GPS TEC measurements obtained from PRN6 pass at SBA, CAS1 and DAV1 stations between 22:00 and 24:00 UT on 30 October (a) TEC measurements (b) PRN6 pass at SBA, CAS1 and DAV1 stations.

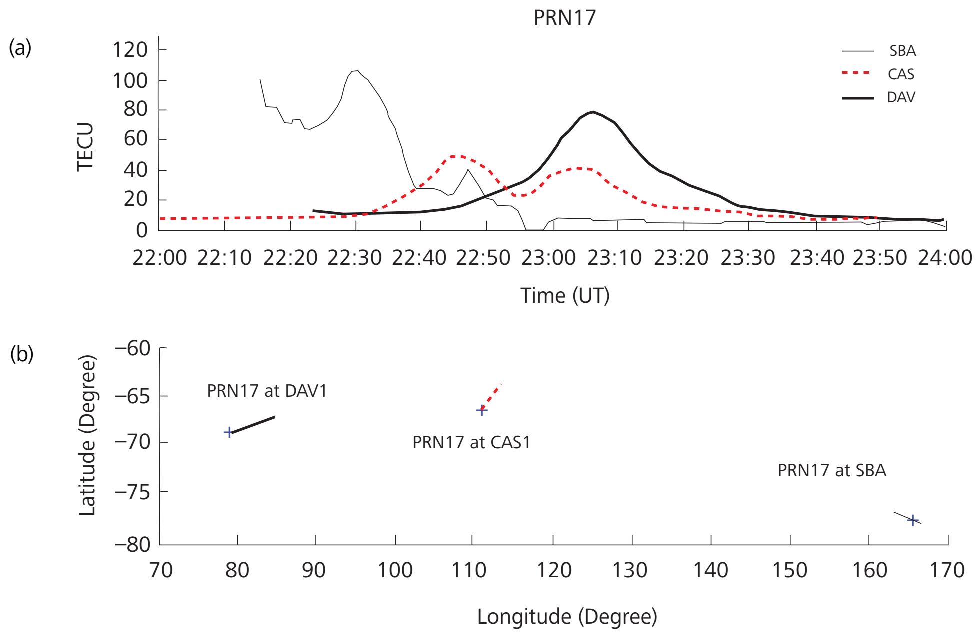


Figure 5. The TEC measurements from PRN17 during 22:00 to 24:00 UT on 30 October 2003 at SBA, CAS1 and DAV1 stations (a) TEC measurements (b) Satellite PRN17 pass at SBA, CAS1 and DAV1 stations.

three stations. The durations of TEC depletion that were observed post-SSC varied from one station to another. The TEC depletion at SBA station was observed between 11:00 UT and 19:30 UT (8.5 h), between 11:00 UT and 15:30 UT (4.5 h) at CAS1 station and between 11:00 UT and 17:00 UT (6 h) at DAV1 station. The TEC depletion period at the three stations was followed by strong TEC enhancement signature of Tongue of Ionization (TIO). The duration of TIO was about 2 h at CAS1, 1.5 h at DAV1 and 1 h at SBA. The pronounced enhancement period was followed by significant TEC depletion between 17:00 UT on 20 November and 16:00 UT on 21 November at CAS1, from 19:00 UT on 20 November until 18:00 UT at DAV1 and from 20:00 UT on 20 November until 16:00 UT on 21 November. Following this time, the storm entered the recovery phase during which the TEC started to recover to normal levels, with TEC values between 30 TECU and 35 TECU. The recovery phase persisted until the evening UT of the day 22 November 2003.

The TEC measurements during the period between 12:00 and 24:00 UT on 20 November 2003 at SBA, CAS1 and

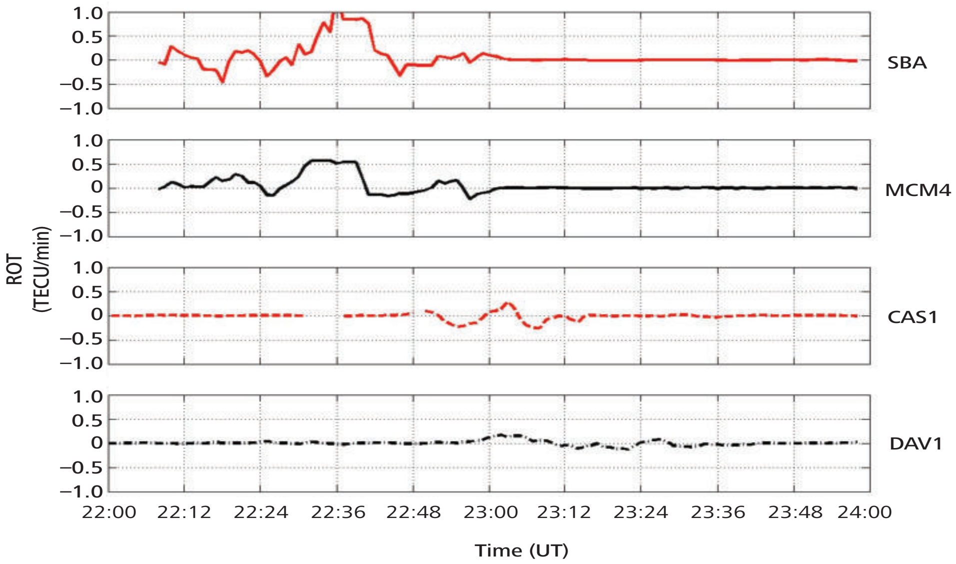


Figure 6. ROT measurements obtained from PRN21 at SBA, MCM4, CAS1 and DAV1 GPS stations during the period between 21:00 and 24:00 UT on 30 October 2003

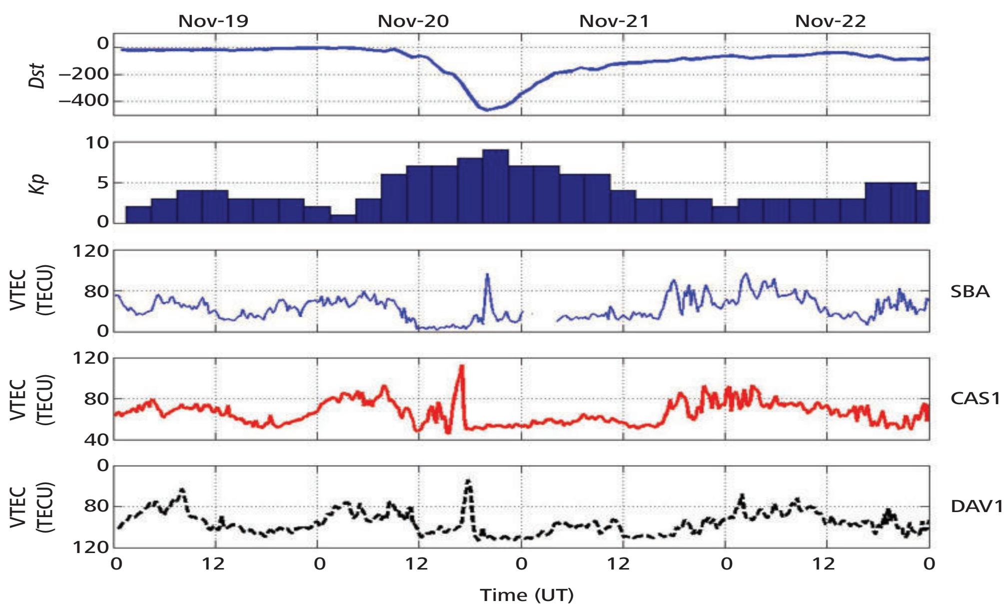


Figure 7. The *Dst*, *kp* indices and the daily TEC measurements obtained from SBA, CAS1 and DAV1 GPS stations during the November 2003 storm.

DAV1 GPS stations are shown in Figure 8. As shown in the figure, the TEC enhancement at the three GPS stations was observed at different periods with obvious delay between the TEC peaks. The first TEC peak was observed at CAS1 station (Lat. –66.28º, Max. value at 16:30 UT) followed by second TEC peak at DAV1 station (Lat. –68.58º, Max. value at 17:50 UT) at around 18:00 UT and the third TEC peak at 20:00 UT (Lat. –79.85º, Max value at around 20:00 UT). Obvious decrease in the magnitude of the TEC peak was also observed between at the three stations with maximum values of 45 TECU at CAS1, 40 TECU at DAV1 and 35 TECU at SBA. The delay time between the similar TIO structures at the three stations (i.e. 65 min between CAS1 and DAV1 and 130 min between DAV1 and SBA) during the main phase of the storm implied a propagation velocity of LSTIDs with a range between 300 m/s – 400 m/s in a direction from lower to higher latitudes and from west to east (poleward/eastward propagation).

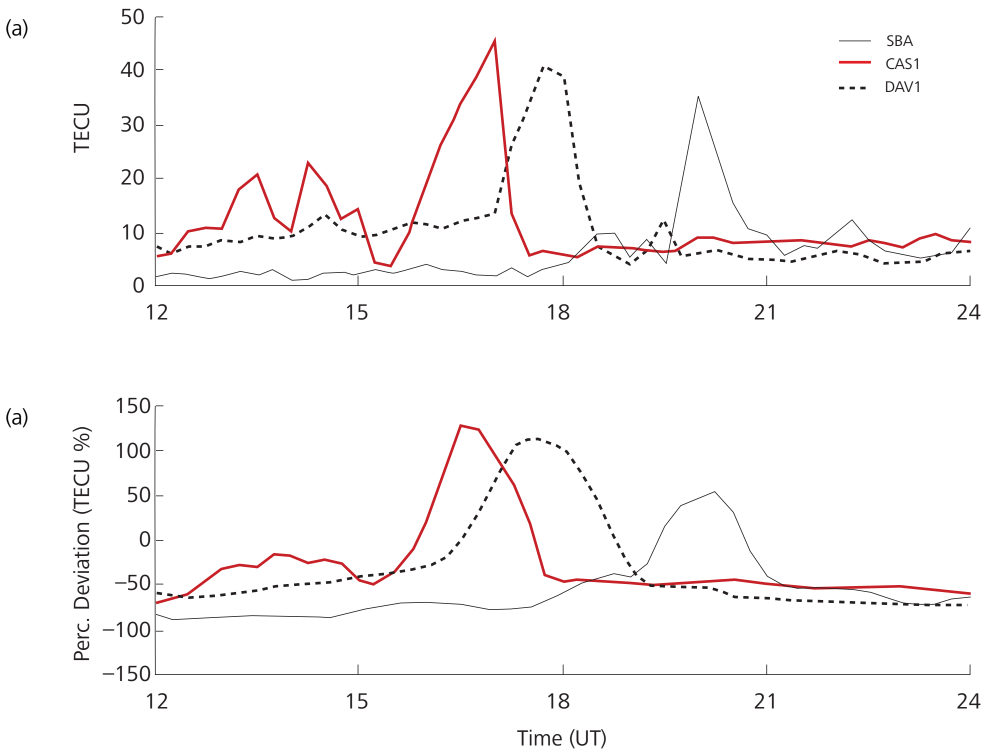


Figure 8. TEC and ΔTEC% measurements at CAS1, DAV1 and SBA GPS stations during the period between 12:00 UT and 24:00 UT on 20 November 2003 storm (a) VTEC measurements (b) ΔTEC%.

The TEC measurements obtained from satellite PRN5 between 16:30 UT and 20:00 UT were employed to determine the propagation direction and speed of LSTIDs during the November 2003 storm as in Figure 9. As shown in the figure, the obvious time delay between the three TEC peaks at three stations was obviously seen. The first TEC peak was seen at CAS1 station at around 17:00 UT (Max value of 37 TECU) followed by second TEC peak at DAV1 station at 17:40 UT (Max value of 46 TECU) then by SBA station at around 18:30 UT (Max value of 14 TECU). The maximum TEC enhancement at CAS1 station was observed at around 17:10 UT with a value of 37 TECU. At DAV1 station, the TEC activity began at 17:15 UT with a maximum value of 43 TECU at 17:35 UT and at SBA station it began at 18:10 UT with a maximum value of 14 TECU observed at 18:30 UT. The delay time between the three TEC peaks (i.e. 40 and 50 min) indicated a propagation direction from low to high latitudes in a poleward direction 0.5 km/s – 0.7 km/s.

Previous measurements for storm time expansion during the November 2003 superstorm were carried out by Foster *et al*. (2005) using a multi-radar system over the northern polar region. Foster *et al.* (2005) observed poleward movement of the LSTIDs and concluded that the dayside source of the polar TIO is the plume of SED transported from low latitudes in the post-noon sector by the sub-auroral disturbances electric field. The convection carries this material through the dayside cusp and across the polar cap to the nightside (Foster *et al.* 2005). The poleward expansion of LSTIDs during this storm was probably caused by disturbances in the neutral temperature which occurred close to the dayside convection throat and gave rise to TIDs which propagated poleward from the convection throat. Another explanation is that the LSTIDs are induced by neutral wind oscillation due to atmospheric gravity waves through neural-ion collision. The propagation direction and speed for the LSTIDs during the enhanced storm density periods of October 2003, November 2003 and July 2004 over the southern polar region are summarized in Table 1.

CONCLUSION

The paper investigates the propagation direction and velocity of LSTIDs obtained from GPS TEC measurements during the storm events of October 2003 and November 2003. The diurnal TEC and the percentage deviation of the TEC measurements as well as the TEC obtained from individual satellites PRNs at SBA, McM4, DAV1 and CAS1 GPS stations were employed in the analysis. The propagation direction and velocity of LSTIDs were determined based on the delay time between similar TEC structures observed at different stations and the distance between these locations. The observations during the October 2003 storm showed obvious time delay between the TEC

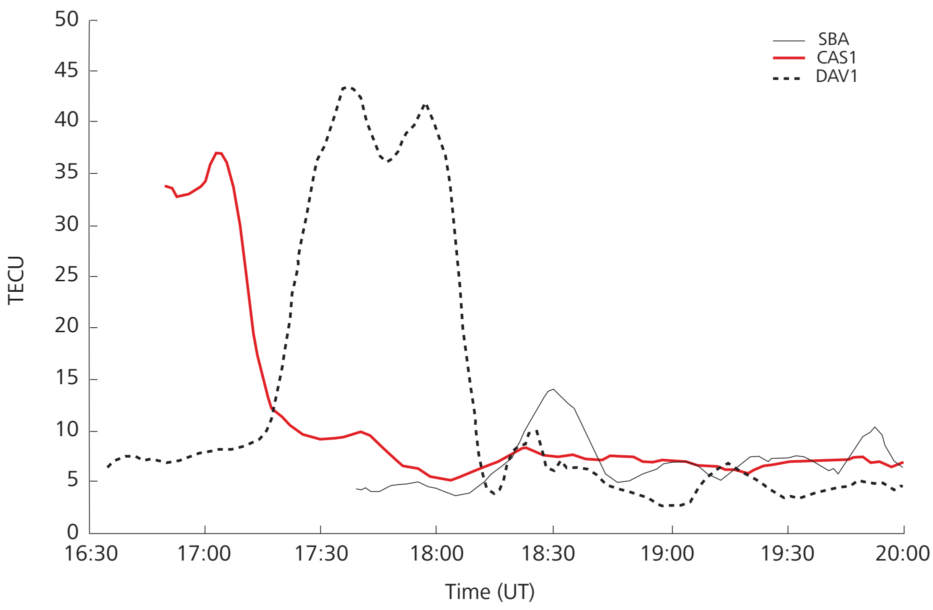


Figure 9. The VTEC measurements obtained from PRN 5 at SBA, CAS1 and DAV1 stations between 16:30 UT and 20:00 UT on 20 November 2003.

Table 1. Propagation direction and speed of LSTIDs obtained from latitudinal variations of the TEC measurements.

Magnetic Storm	Propagation direction	Propagation speed (km/s)	
		From diurnal TEC	From single PRNs
October 2003	Equatorward	0.8 km/s – 1.2 km/s	1.2 km/s – 2.4 km/s
November 2003	Poleward	0.3 km/s – 0.4 km/s	0.5 km/s – 0.7 km/s

structures at SBA/MCM4, DAV1 and CAS1 stations with a propagation direction from the cusp region at SBA location to lower latitudes. The first sudden TEC enhancement was observed at SBA/McM4 location (Lat. –77.84º) followed by CAS1 station (Lat. –66.28º) and then at DAV1 station (Lat. –68.58°). It was observed that although the CAS1 station is lower in latitude than the DAV1 station, the TEC enhancement at the CAS1 station was seen earlier due to the shorter distance between SBA and CAS1 than the distance from SBA to CAS1 by about 500 km. This time delay showed a movement of the ionospheric structures from higher to lower latitudes in a velocity which ranged between 800 m/s – 1200 m/s. Obvious decrease in the TEC magnitude during this event was clearly seen while moving from higher to lower latitudes. The diurnal TEC measurements during the November 2003 storm showed an opposite propagation direction to that observed during October 2003 with velocity that ranged between 0.3 km/s – 0.4 km/s. A similar response was observed using the vertical TEC measurements obtained from individual PRN satellites but with higher velocity ranges (i.e. 1.2 km/s – 2.4 km/s during October and 0.5 km/s – 0.7 km/s during November). The equatorward or poleward expansion during the October and November 2003 storms were most probably caused by the disturbances in the neutral temperature which occurred close to the dayside convection throat and gave rise to TIDs which propagated poleward from the convection throat. Another explanation for the production of LSTIDs in the polar region is that the LSTIDs was commonly considered to be caused by neutral wind oscillation due to atmospheric gravity waves (AGW) launched from the aurora region through the neural-ion collision.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Academy of Sciences Malaysia (ASM) and the Ministry of Science, Technology and Innovation, Malaysia (MOSTI) for sponsoring this research, and for Antarctica, New Zealand for providing the data and logistical support.

Date of submission: November 2008
Date of acceptance: June 2009

REFERENCES

Abdul, RZA *et al.* 2006 'GPS ionospheric TEC measurement during the 23 November 2003 total solar eclipse at Scott Base Antarctica', Journal of Atmospheric and Solar Terrestrial Physics, vol. 68, pp.1219–1236.

Astronomisches Institut Universität Bern 2005, *Differential GPS code biases (DCBs)*, <http://www.aiub.unibe.ch/download/CODE>.

Balthazor, RL & Moffett, RJ 1997, 'A Study of atmospheric gravity waves and travelling ionospheric disturbances at equatorial latitudes', *Annales Geophysicae*. vol. 15, pp. 1048–1056.

Baran, LW *et al.* 2002, *The response of polar ionosphere to a magnetic storm obtained from GPS observations*, SCAR Report 21.

Basu, S *et al.* 1999, 'A comparison of TEC fluctuations and scintillations at Ascension Island', *Journal of Atmospheric and Terrestrial Physics*, vol. 61, pp. 1219–1226.

Buonsanto MJ 1999, 'Ionospheric storms – a review', *Space Science Review*, vol. 88, pp. 563–601.

Forster, M & Jakowski, N 2000, 'Geomagnetic storm effects on the topside ionosphere and plasmasphere: a compact tutorial and new results', *Surveys in Geophysics*, vol. 21, pp. 47–87.

Foster, JC *et al.* 2005, 'Multiradar observations of the polar tongue of ionization', Journal of Geophysical Research, vol. 110, A09S31, doi:10.1029/2004JA010928.

Hargreaves, JK 1992, *The solar terrestrial environment*, Cambridge University Press, Cambridge.

Hocke, K, & Schlegel, K 1996, 'A review of atmospheric gravity waves and travelling ionospheric disturbances: 1982–1995', Annales Geophysicae, vol. 14, pp. 917–940.

Hunsucker, RD 1982, 'Atmospheric gravity waves generated in the high latitude ionosphere: a review', *Reviews of Geophysics and Space Physics*, vol. 20, pp. 293–315.

Idenden, D 1998, '*The thermospheric effects of a rapid polar cap expansion', Annales Geophysicae*, vol. 16, pp. 1380–1391.

Ionospheric Prediction Services 2003, *IPS daily solar and geophysical reports*. <http://www.ips.gov.au>.

Jakowski, N *et al.* 1996, '*Relationships between GPS signal propagation errors and EISCAT observations', Annales Geophysicae*, vol. 14, pp. 1429–1436.

Jakowski, N *et al.* 2002, 'GPS/GLONASS-based TEC measurements as contributor for space weather forecast, *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 64, pp. 729–735.

Klobuchar, JA 1996, '*Ionospheric effects on GPS, in global positioning system: theory and applications*, vol 1, eds. BW Parkinson & JJ Spilker, American Institute of Aeronautics and Astronautics, Washington D.C.

Krankowski, A *et al.* 2005, 'Study of TEC fluctuations in Antarctic ionosphere during storm using GPS observations', *Acta Geophysica Polonica*, vol. 53, no. 2, pp. 205–218.

Momani, MA *et al*. 2008, 'GPS observations at quasi-conjugate points under disturbed conditions', *Acta Geophysica,* vol. 56, no. 4, pp. 1179-1201.

Otsuka, Y *et al*. 2002, 'A new technique for mapping of total electron content using GPS network in Japan', *Earth Planets and Space*, vol. 54, pp. 63–70.

Pi, X *et al.* 1997, 'Monitoring of global ionospheric irregularities using the worldwide GPS network', *Geophysical Research Letters*, vol. 24, pp. 2283.

Prölss, GW & Roemer, M 1987, 'Thermospheric storms', *Advances in Space Research*, vol. 7, no. 10, pp. 223–235.

Prölss, GW & Ocko, M 2000, 'Propagating of upper atmospheric storm effects towards lower latitude'. *Advances in Space Research*, vol. 20, no. 1, pp.131–135.

Schaer, S 1999, 'Mapping and predicting the earth's ionosphere using the global positioning system', PhD thesis, University of Bern.

Spectrum 2003, *IEEE spectrum newsletter, October 2003 storm*, <http://www.spectrum.ieee.org/WEBONLY/newslog/news10-30-03.html>.

Tang, Q *et al.* 2001, 'Properties of large-scale TIDs observed in central China', *Science in China*, vol. 31, no. A, pp.133–136.

Tsugawa, T *et al.* 2006, 'Geomagnetic conjugate observations of large-scale traveling ionospheric disturbances using GPS networks in Japan and Australia', *Journal Geophysical Research*, vol. 111, A02302, dio: 10.1029/2005JA011300.

Yizengaw, E *et al.* 2004, 'The southern hemisphere and equatorial region ionization response for 22 September 1999 severe magnetic storm', *Annales Geophysicae*, vol. 22, no. 8, pp. 2765–2773.

Yue-jin, W, Wilkinson, P & Caruana J 2001, 'Using GPS to monitor ionospheric irregularities in the southern high latitude region', *IPS Radio and Space Services*, Australia.

Warnant, R & Pottiaux, E 2000, 'The increase of the ionospheric activity as measured by GPS', *Earth, Planets Space*, vol. 52, pp. 1055–1060.

ASM Sci. J., **3(2)**, 131–142

Model Development of Microwave Remote Sensing of Sea Ice

Y.J. Lee[1], H.J. Yap[1], W.K. Lim[1], H.T. Ewe[2*] and H.T. Chuah[2]

Three techniques to retrieve information on sea ice thickness from both active and passive radar backscatter data are presented. The first inversion model is a combination of the radiative transfer theory with dense medium phase and amplitude correction theory (DMPACT), and the Levenberg-Marquardt optimization algorithm. The radiative transfer theory was applied as the forward model to generate radar backscatter data, while the DMPACT was included to account for the close spacing effect among the scatterers within the medium. The Levenberg-Marquardt optimization algorithm was then applied to reduce the error between the model generated radar backscatter data and the measured radar backscatter data from satellite images so that the sea ice thickness could be estimated. The second method presented was the neural network inversion method which utilizes a chain of neurons with variable weights. Once the network was fully operational it would be possible to predict the sea ice thickness, provided sufficient training data are given. The last method was the genetic algorithm which is a search technique used in order to predict the approximate sea ice thickness from the measured data. Data from ground truth measurements carried out in Ross Island, Antarctica, together with radar backscatter data extracted from purchased satellite images were used as input to verify the models. All three models were tested and successfully predicted sea ice thickness from actual terrain using the ground truth measurement data, with several constraints and assumptions placed to avoid problems during the retrieval process. While the models still have their own limitations, the potential use of the models for actual sea ice thickness retrieval was confirmed.

Key words: radar backscatter data; inversion model ; radiative transfer theory; DMPACT; Levenberg-Marquardt optimization algorithm; neural network inversion method; genetic algorithm; Ross Island; Antarctica; satellite images; sea ice thickness

The study of the polar region has grown more thorough in recent years as it is driven by a variety of reasons, including the increase in awareness of global climate change. The fact that the polar regions which cover up to 25% of the earth's surface play a critical role in balancing the world climate, has led many researchers to venture into studies of the extent of sea ice and the heat exchange between the ocean and the atmosphere (Haykin *et al*. 1994). This research can prove to be both costly and dangerous due to the extremeness of the polar region's climate and its hostile environment (Veysoglu 1994). As such, remote sensing offers a practical means to monitor and study this harsh continent. Remote sensing is currently the only practical means to assess and map the ice thickness for large regions such as these.

In active microwave remote sensing, the scattering mechanism between the microwave emissions and the medium is first studied to understand the interaction between the two. In this paper, a forward model based on the radiative transfer theory will first be presented. The model considers the sea ice as electrically dense random discrete media (Albert *et al*. 2005). Yet, the traditional model treats the scatterers in the medium as independent of each other which is inaccurate for the snow and sea ice are both considered as dense medium. As a solution to this, the dense medium phase and amplitude correction theory (DMPACT) are included in the phase matrix of the scatterers to take into account the close spacing effect among the scatterers (Chuah *et al.* 1996).

Ground truth measurements have been carried out in Ross Island, Antarctica since 2001, to obtain the actual parameters to verify the developed multi-layer model. The field team usually makes stops along the route from Scott Base to Cape Royds. On average, about four stops occurred for every 15 km travelled. In the year 2006, measurements were done at one point for every stop during the field trip. For the year 2007, the measurement procedure changed, measurements were done at three points for each stop and

[1] Faculty of Engineering, Multimedia University, Malaysia, Jalan Multimedia, 63100 Cyberjaya, Selangor, Malaysia
[2] Faculty of Information and Communication Technology, Universiti Tunku Abdul Rahman, 46200 Petaling Jaya, Selangor, Malaysia
*Corresponding author (e-mail: eweht@mail.utar.edu.my)

the average value taken as the final data for that area. These points were about 10 m away from each other. In this paper, a brief description of the work done in Antarctica as well as some of the measurement results for the year 2006 is presented.

From various reports in literature, it is known that sea ice thickness plays an important factor in understanding the dynamics of sea ice cover, as well as air-ocean heat exchange. Several methods using inverse scattering algorithms for the recovery of sea ice thickness have been explored and reported (Golden *et al.* 1998a). Four approaches to recover sea ice thickness were presented: radiative transfer-thermodynamic model for thickness retrieval from time-series scattering data, neural network inversion for sea ice thickness, reflectivity inversion for sea ice thickness and proxy indicators for sea ice thickness. Based on some of these approaches, three new algorithms were developed to retrieve sea ice thickness from actual conditions.

The first inversion algorithm proposed was loosely based on the radiative transfer-thermodynamic model for thickness retrieval from time-series scattering data (Shih *et al*. 1996). The proposed new model is a combination of the radiative transfer-DMPACT model and an optimization method. The forward model applied the algorithm to calculate the expected backscatter data from a set of sea ice parameters. The Levenberg Marquardt optimization algorithm was then applied to reduce the error between the result from the forward model and the radar backscatter data extracted from satellite images, and then improve the estimate. Finally, a comparison was made between the estimated sea ice thickness with data obtained from ground truth measurements.

The second inversion method for sea ice thickness involved the use of neural network (NN). At first, the brightness temperatures (vertically and horizontally polarized) were calculated by the radiative transfer-DMPACT model. A back-propagation NN with Levenberg-Marquardt algorithm was then constructed to accept the input-output data pairs from the radiative transfer-DMPACT model for the training purpose. When the NN was fully calibrated, it would be able to predict the sea ice thickness speedily, when provided with the brightness temperatures of the sea ice.

The third method was based on the genetic algorithm (GA). The GA based method was designed to search for a suitable sea ice thickness value that would fit into the characteristics of sea ice based on the prediction from the radiative transfer-DMPACT model. In the search process, the candidate solutions from the randomly generated population would undergo evolution processes in order to obtain the best solution that would become dominant. This was done by evaluating the fitness function for the entire population. Suitable sea ice thickness value could be found that matched the brightness temperatures profile obtained from the satellite data.

FORWARD MODEL

One of the main objectives of sea ice remote sensing is to utilize information on the electromagnetic fields that are scattered or emitted by the sea ice to deduce its physical properties (Golden *et al*. 1998b). It is for such purposes that research had been done on the forward modeling of electromagnetic scattering properties of the sea ice to understand the scattering mechanisms of the sea ice. The results from the development of the forward model had a direct application on the advancement in microwave remote sensing of the sea ice. In addition, such forward models formed the basis of the development of inverse algorithms to reconstruct the physical properties of sea ice from the radar backscatter data. Many forward models have been developed, based on the distorted Born approximation and the radiative transfer theory. In this section, a forward model based on the radiative transfer theory would be presented.

RT-DMPACT Model

The forward model developed utilized the radiative transfer theory combined with DMPACT. The DMPACT was applied as the sea ice layer was treated as electrically dense random discrete media. The RT-DMPACT Model was a single forward layer model which treated the sea ice terrain as consisting of only one sea ice layer.

Model configuration. The model configuration for the RT-DMPACT model is shown in Figure 1. The sea ice layer was modeled as a layer with bubbles or brine inclusions as scatterers embedded inside the host medium which consisted of ice. In the first year sea ice, it could be assumed that the majority of the scatterers consisted of brine. On the other hand, multi-year sea ice scatterers were generally a combination of air bubbles and brine inclusions.

Model formulation. The classical formulation of the radiative transfer equation can be found in Chandrasekhar (1960). In the radiative transfer equation, the propagation and scattering of a microwave of a specific intensity in a particular medium could be written in the form of Equation 1, where I, K_e, P, $d\Omega$ and z are the Stokes vector, extinction matrix, phase matrix of the medium, solid angle and vertical direction, respectively. The scattering and absorption losses of the Stokes vector along the propagation direction had been taken into account by the extinction matrix, K_e.

$$\cos\theta \frac{d\bar{I}}{dz} = -\bar{\bar{\kappa}}_e \bar{I} + \int \bar{\bar{P}}\bar{I}\, d\Omega \qquad \ldots 1$$

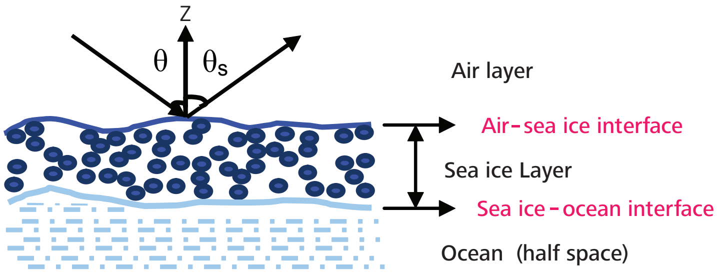


Figure 1. Cross section of sea ice terrain.

The phase matrix, P used in Equation 1 had the expression as shown in Equation 2, where $\langle|\psi|^2\rangle_n$ was the dense medium phase correction factor (Chuah *et al*. 1996) and S the Stokes' matrix for Mie scatterers with the close spacing amplitude correction (Fung & Eom 1985):

$$\overline{\overline{P}}(\theta,\phi;\theta',\phi') = \langle|\psi|^2\rangle_n \cdot \overline{\overline{S}} = \begin{bmatrix} P_{vv} & P_{vh} \\ P_{hv} & P_{hh} \end{bmatrix} \quad (2)$$

The dense medium phase and amplitude correction factor took into account the coherent effects of the scattering between closely spaced scatterers. From the above equation, $\langle|\psi|^2\rangle_n$ it could be further expressed as the following:

$$\langle|\Psi|^2\rangle_n = \frac{1-e^{-k_{si}^2\sigma^2}}{d^3} + \frac{e^{-k_{si}^2\sigma^2}}{d^3}\sum_{q=1}^{\infty}\frac{(k_{si}^2\sigma^2)^q}{q!}\cdot$$
$$\left[\left(\sqrt{\frac{\pi}{q}}\left(\frac{l}{d}\right)\right)^3 \exp\left(\frac{-k_{si}^2 l^2}{4q}\right) - a(k_x)a(k_y)a(k_z)\right] \quad (3)$$

where, $a(k_r) =$

$$\sqrt{\frac{\pi}{q}}\left(\frac{l}{d}\right)\exp\left(\frac{-k_r^2 l^2}{4q}\right)\operatorname{Re}\left\{erf\left(\frac{(qd/l)+jk_r l}{2\sqrt{q}}\right)\right\}$$

In Equation 3, d is the average distance between the scatterers, d^3 is the volume of the medium under consideration, k_{si} represents the difference between the propagation vectors in the scattering and incident directions, σ^2 represents the variance of the positions of the scatterers, a is the radius of the scatterer, l is the correlation length and finally *erf* (.) represents the error function.

The radiative transfer equation was first converted from the differential radiative transfer equation into an integral radiative transfer equation. This equation was then solved iteratively by including the boundary conditions when the surface scattering was studied through the integral equation method (IEM) (Fung *et al.* 1992). The resulting solution consisted of both coherent and incoherent components including surface scattering, volume scattering and surface-volume scattering for different polarizations. The basic approach for obtaining the solutions for the equation can be found in Ulaby *et al.* (1986) and Fung (1994).

The total backscatter obtained from the RT-DMPACT model was the sum of the terms derived for the surface, volume-surface and volume scattering of the medium and its boundaries, as shown in Equation 4 (Ewe *et al*. 1998):

$$\sigma_{total} = \sigma_{surface} + \sigma_{volume} + \sigma_{surface-volume} \quad (4)$$

A detailed derivation of the various terms can also be found in same paper.

INVERSE MODEL

As mentioned earlier in the Forward Model, the purpose of operational sea ice remote sensing was to record the physical parameters of sea ice through the use of radar backscatter data. In order to do so, there was a need to develop inverse scattering algorithms for the reconstruction of the physical parameters of sea ice from the scattered electromagnetic field data. The development of such algorithms paved the way towards the retrieval of sea ice properties, such as sea ice thickness, which is a parameter of geophysical and climatological importance (Golden *et al*. 1998a).

In this section, three methods of using inverse algorithms to recover sea ice thickness are presented. The first method is the radiative transfer-dense medium phase and amplitude correction theory (RT-DMPACT) inverse model for sea ice thickness retrieval from active microwave remote sensing data. The second method is the NN inversion for sea ice thickness using passive microwave remote sensing data. The last method is the genetic algorithm inversion for sea ice thickness using passive microwave remote sensing data.

Radiative Transfer-dense Medium Phase and RT-DMPACT Inverse Model for Sea Ice Thickness Retrieval from Active Microwave Remote Sensing

This algorithm was loosely based on the radiative transfer-thermodynamic inverse model for sea ice thickness from time-series scattering data, which was reported in Golden *et al.* (1998a). The original model utilized the radiative transfer theory to explain the relationship between the expected backscatter measurements from the radar parameters and the sea ice characteristics. A growth model for saline ice was also applied to predict more accurately the evolution of the sea ice through the use of time-series measured data. The Levenberg Marquardt optimization method was then used to adjust the parameters and estimate the sea ice thickness. This method has been successful in the reconstruction of estimated sea ice thickness from time series electromagnetic measurements of laboratory grown saline ice (Shih *et al.* 1998).

However, while the algorithm was successful towards the reconstruction of estimated laboratory grown sea ice, it had yet to be tested on actual conditions in the polar region although the results showed that there was potential in using the algorithm in the future. In addition, the collection of time series measurements using active microwave remote sensing could be tedious and costly, even with the use of the Canadian RADARSAT or the European remote sensing satellite (ERS). The newly developed algorithm was a variation of the above model and was aimed to explore the possibility of infering sea ice thickness through the use of the radiative transfer theory without the need for time series measurements.

RT-DMPACT model. For this algorithm, the RT-DMPACT Model was used as the forward model to simulate the expected backscatter data from a set of sea ice parameters. The purpose for the use of the forward model in this inversion algorithm was to establish a relationship between the sea ice parameters and the radar backscatter data. The output from the forward model was defined as the expected backscatter data, which would then be used to compare with the actual radar backscatter data extracted from synthetic aperture radar (SAR) measurements using satellites, like the RADARSAT. The configuration and formulation for the RT-DMPACT model had been explained earlier in the RT-DMPACT model.

Optimization technique. The inversion algorithm utilized the Levenberg Marquardt optimization method for the optimization of the inversed results (Marquardt 1963). The Levenberg Marquardt method was used for both the multi-dimension problem, where multi polarization radar backscatter data (σ_{VV}, σ_{VH}, σ_{HV}, σ_{HH}) was used to retrieve the sea ice thickness, and for the single-dimension problem, where sea ice thickness was estimated through the use of single polarization radar backscatter data (σ_{HH}). As an alternative to the Levenberg Marquardt algorithm, the possibility of applying Newton's method for sea ice thickness retrieval using single polarization data was also explored.

Flow chart of the inverse scattering model. The following flow chart in Figure 2 describes how the new inverse model which used the RT-DMPACT model as its foundation, together with the optimization techniques, retrieved sea ice thickness from radar backscatter data. The following subsection explains this block diagram in detail.

Method. In the retrieval process, a set of sea ice parameters was first input into the RT-DMPACT Model. Among those parameters, one of them was the sea ice

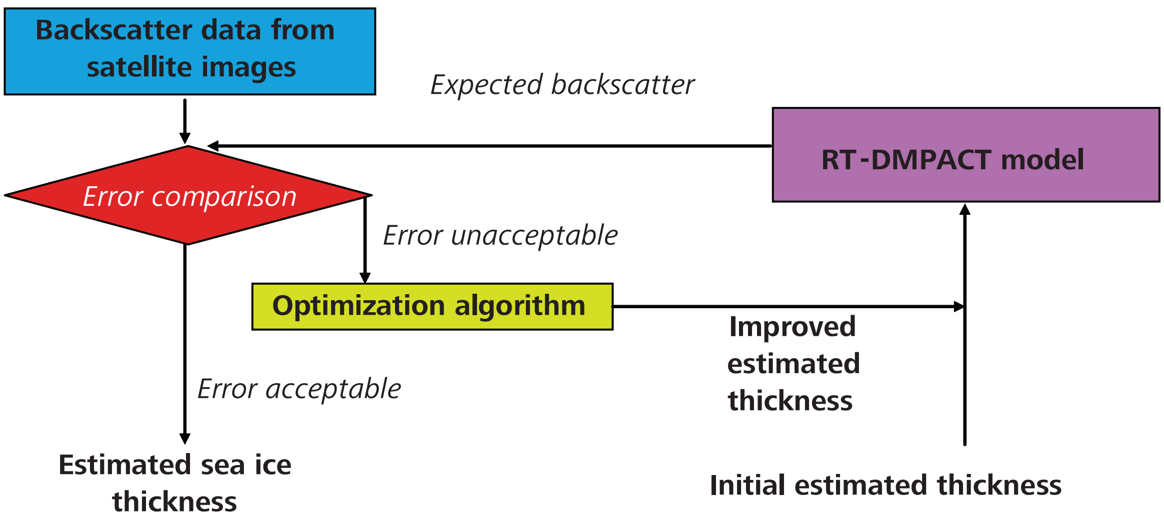


Figure 2. Flow chart of inversion algorithm using RT-DMPACT.

thickness. Initially, the sea ice thickness was estimated. The other parameters, such as scatterer permittivity, sea ice permittivity and scatterer radius were treated as known parameters and were input accordingly from data obtained from ground truth measurements or from the analysis of these data. The RT-DMPACT model would then calculate the backscatter coefficient based on the input parameters. This set of data was treated as the expected backscatter coefficient.

On the other hand, another set of backscatter coefficient was extracted from satellite images purchased from the Canadian RADARSAT and ENVISAT. This set of backscatter coefficient was treated as the actual measured data. A comparison was then made between the simulated data with the actual measured data. The difference between the two sets of data was then defined as the error. In the inversion process, the simulated backscatter coefficient from the forward model had to match as closely as possible to the actual measured data from the satellite, in order for the sea ice thickness estimation to be accurate. Therefore, the error had to fall within an acceptable range to ensure that the difference was close to negligible.

In the event that the error was too big, an adjustment to the estimate of the sea ice thickness was required. The inversion model would do this by utilizing the Levenberg Marquardt optimization algorithm, to improve on the sea ice thickness estimate. The improved estimate of the sea ice thickness would then be input once again into the RT-DMPACT model together with the other parameters, which were treated as constants for the simulation, to recalculate the expected backscatter coefficient. The whole process was then repeated until the error was found to be within the acceptable range, where the final estimated sea ice thickness was considered the estimated sea ice thickness from the model. Finally, the estimated sea ice thickness was then compared with the sea ice thickness recorded during the ground truth measurement to verify its accuracy.

Constraints and assumptions. Several conditions had to be applied to the model during the retrieval process to avoid multiple solutions or being trapped in the local scenario. Firstly, the model was restricted to the thickness retrieval of only the first year's sea ice. The forward model in the algorithm only catered for a single layer. Ground truth measurements also proved that for that time of the year, the snow had almost melted completely on the first year's sea ice surface.

Next, the thickness of the first year's sea ice was usually between 0.3 m – 2.0 m. During the retrieval process, the model was set to narrow down on the possible sea ice thickness solutions within this range. This helped to eliminate multiple solutions and aided the model to filter out wrong solutions.

In addition, during the retrieval, only the sea ice thickness was considered as an unknown parameter. The other parameters input into the model were treated as known constants based on multi-year data observations. It had been found that several measurement parameters like the ocean salinity and temperature, sea ice salinity and temperature, snow salinity and temperature and air temperature yielded consistent values. The dielectric properties of the mediums involved that were calculated using these parameters also therefore showed little variation. An average value using data of the other parameters collected over the years was assigned as the other input into the model.

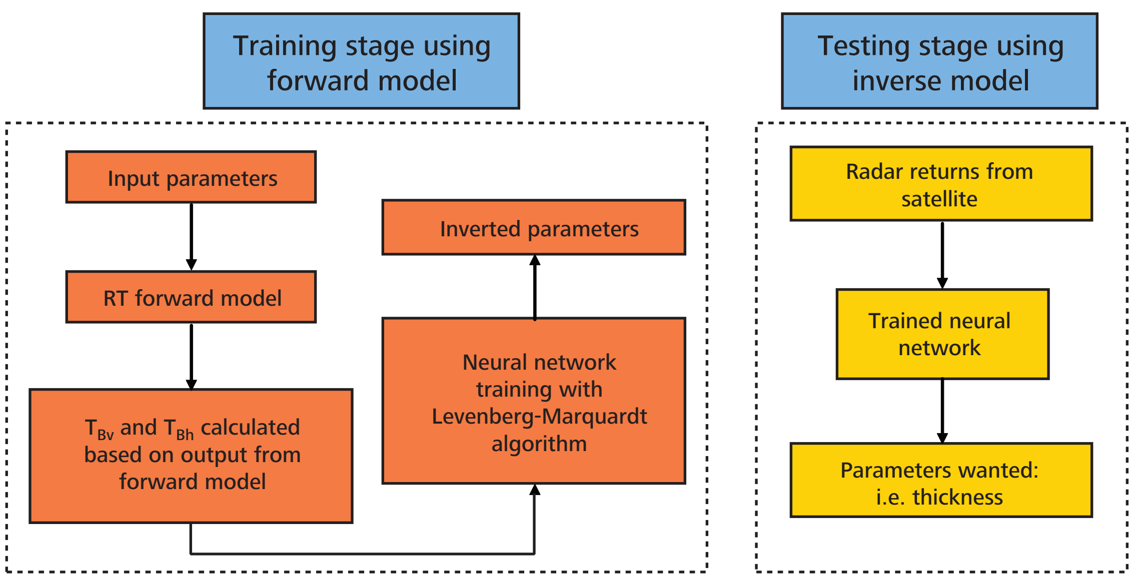


Figure 3: The training stage and the testing stage involving the neural network for the sea ice thickness inversion process.

Data Training and Sea Ice Thickness Inversion by Neural Network from Passive Microwave Remote Sensing

The RT-DMPACT Model mentioned above was used to calculate the passive microwave returns in terms of brightness temperature of vertically (T_{Bv}) and horizontally (T_{Bh}) polarized waves. The NN constructed consisted of an input layer, two hidden layers and an output layer. Each layer employed several neurons which were connected to other neurons in the adjacent layer with different weights. The signals propagated from the input layer, through hidden layers and to the output. The network was configured by the input-output data generated from the RT-DMPACT Model. The process was carried out by changing the values of the inter-connecting weights of the neurons in the layers using the Levenberg-Marquardt algorithm (Martin & Mohammad 1994), according to the error generated. The weights in the NN were then changed in each iteration to reduce the error to an acceptable margin. The error was set so that it was no more than one tenth of the desired result. There were four layers of neurons, with three neurons in the input layer, five neurons in each of the two hidden layers and one neuron in the output layer. In the cases where local conditions were encountered, new sets of weights would be generated to rerun the simulations until the desired results were obtained.

The inversion process by NN was divided into two parts as illustrated in Figure 3. At the training stage, the NN was characterized by the training data provided by the forward model. At the testing stage, the NN was ready to do the inversion when it was fully trained, using the data from the Special Scanning Microwave Imager (SSM/I) on a Defense Meteorological Satellite Program (DMSP) satellite.

Sea Ice Thickness Inversion by Genetic Algorithm from Passive Microwave Remote Sensing

The GA is a random search technique that provides an optimal solution to a problem. The GA encoded the candidate solutions from the existing population into a sequence of numbers that were called chromosomes. These chromosomes underwent a process like natural selection, where the fitter chromosomes were more likely to survive and pass their traits to the next generation by a reproduction process called crossover. Crossover happened between two chromosomes to create new off-springs by genes being switched at a random point in the chromosomes. Mutations caused small random changes in a chromosome and introduced diversity into the population at a small probability of P_m. The chromosomes were evaluated with an objective function to determine their fitness. The process was repeated until a solution had been found. The process flow of the GA is shown in Figure 4.

Again, the SSM/I on a DMSP satellite was utilized for validation of the inversion result.

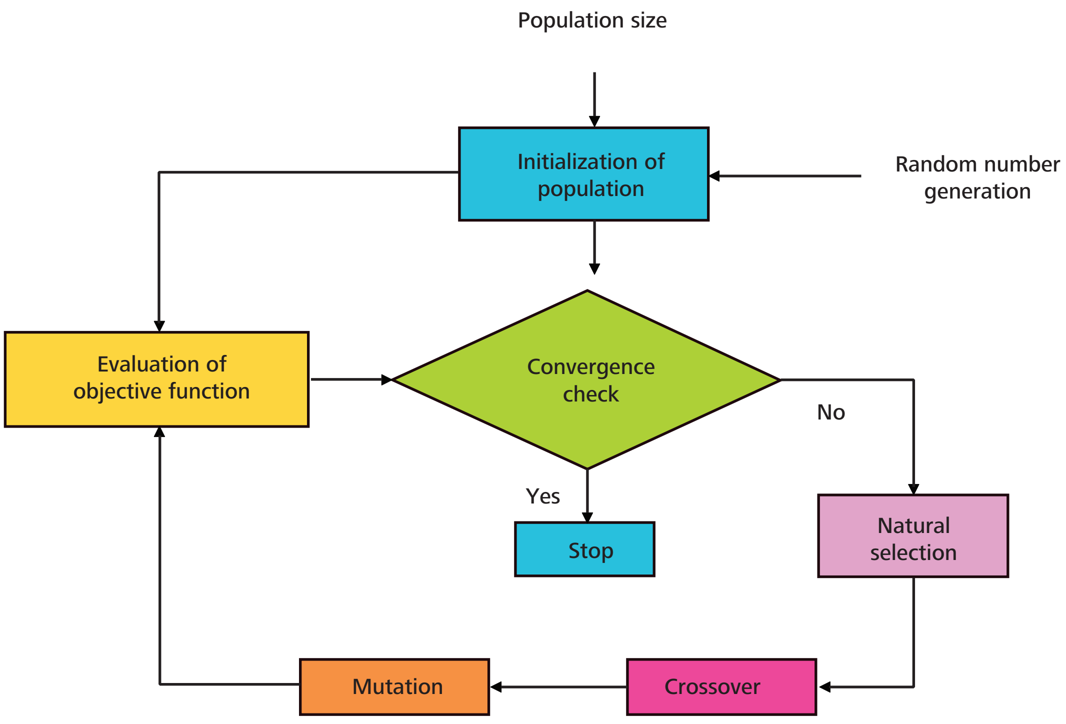


Figure 4. The process flow of the genetic algorithm.

GROUND TRUTH MEASUREMENT

As a key part of the validation process of the inversion result, the carrying out of the ground truth measurements were essential to collect data on the sea ice parameters that would serve as both the input parameters into the sea ice model as well as serve as to compare with the simulation results. The measurements were carried out every year to understand the electrical properties of the sea ice medium as well as its structure over the years and to see whether such changes would affect the radar backscatter data as well as its impact on the simulation results.

The ground truth measurements were conducted around Ross Island, Antarctica. The areas visited included the front of Scott Base, William's Field and Cape Evans. The measurements included the sea ice and snow surface roughness; sea ice and snow cover thickness; sea ice snow and ocean salinity; air, sea ice, snow and ocean temperature; snow and sea ice density; sea ice brine volume and size. All these parameters served as important input for the development of the sea ice scattering model that would in turn determine the inversion result.

Tables 1 and 2 show examples of some of the data collected during the ground truth measurements in 2005.

RESULTS AND DISCUSSION

RT-DMPACT Inverse Model for Sea Ice Thickness Retrieval from Active Microwave Remote Sensing

The RT-DMPACT inverse model was tested using ground truth measurement data from the years 2006 and 2007. The data used were from measurements done in first or fast ice areas in Ross Island. The reason that the model was not tested on multi-year sea ice was because during the time of the ground truth measurement, the snow layer for first year ice had already melted thus leaving only the sea ice layer. As mentioned earlier, the inverse model utilized the RT-DMPACT model as its forward model. As such, the terrain of the first year ice matched the model configuration of the forward model.

The graph in Figure 5 shows the retrieval result using parameters from ground truth measurements in the year 2006 from single polarization backscatter data (σ_{HH}). The measured single polarization backscatter data was obtained from the purchased RADARSAT satellite image. Thus far, the sea ice thickness from four sites had been successfully retrieved and the estimated sea ice thickness was quite close to that measured during the ground truth measurement.

Table 1. Data from ground truth measurements in 2005.

Site	Co-ordinates Longitude	Latitude	Snow thickness (cm)	Snow temperature (°C)	Air temperature (°C)	Ocean temperature (°C)	Ocean salinity (p.p.t.)
S1	166º43.40'E	77º51.677'S	–	–15.3	–14.3	–1.8	33.1
S2	166º42.502'E	77º51.804'S	111.0	–15.2	–13.1	–1.7	32.7
S3	166º33.709'E	77º48.924'S	24.0	–18.3	–10.9	–1.8	33.8
S4	166º33.181'E	77º48.083'S	37.0	–19.9	–13.3	–1.8	31.0
S5	166º31.018'E	77º46.841'S	35.0	–15.8	–7.4	–1.7	26.6
S6	166º27.354'E	77º43.969'S	13.0	–14.3	–9.4	–1.7	21.9
S7	166º21.409'E	77º37.797'S	3.0	–12.0	–10.9	–1.8	34.1
S8	166º14.824'E	77º35.378'S	6.5	–10.9	–5.9	–1.8	34.1
S9	166º11.491'E	77º33.622'S	–	–	–6.4	–1.8	34.1

Table 2. Data from ground truth measurement in 2005.

Site	Sea ice thickness (cm)	Sea ice temperature (ºC)
S1	300	–11.9
S2	220	–8.8
S3	460	–15.2
S4	510	–13.3
S5	525	–16.0
S6	400	–14.3
S7	189	–11.4
S8	187	–9.4
S9	200	–8.9

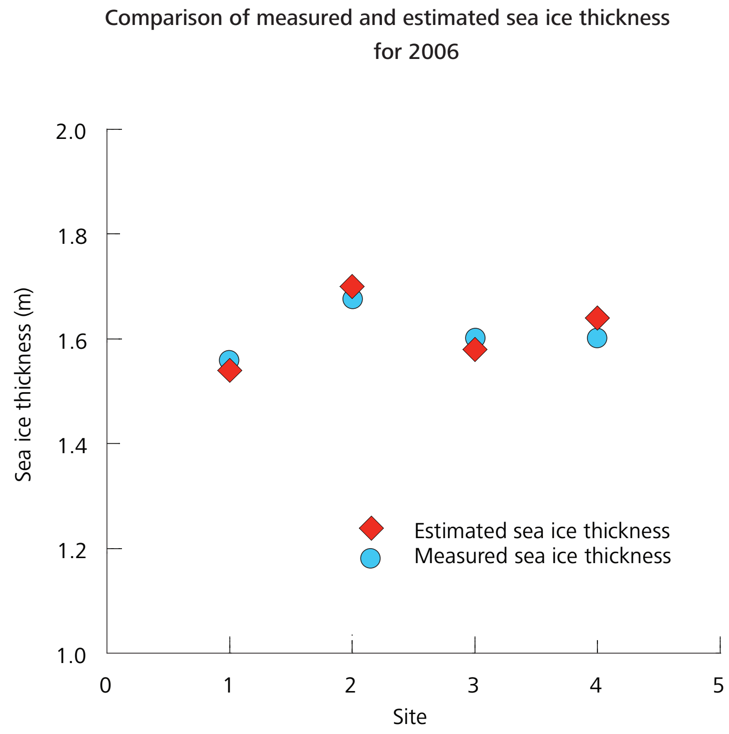


Figure 5. Sea ice thickness retrieval for 2006.

The graph in Figure 6 shows the retrieval result using parameters from the ground truth measurement in the year 2007 from single polarization backscatter data (σ_{HH}). Only one site was shown in this graph because that year, the measurement plan of sea ice had been changed compared to that of the previous year. That year, for one site, three measurements were done in close proximity and the average results of those three measurements are considered the final data for that particular site. In addition, the weather was bad during the ground truth measurement that year, limiting the time to conduct measurements due to safety reasons. As such, only one first year ice site was visited for 2007.

The results from both years showed promising results in using the developed inverse model to retrieve the sea ice thickness from actual conditions in the polar region using single polarization backscatter data (σHH). In this case study, the area researched was around Ross Island in Antarctica. Several restrictions, such as assuming that there was no snow layer on the sea ice and considering only first year sea ice, had been placed on the model during the retrieval testing, as stated above.

Currently, there are plans to record the sea ice thickness using data measured during the ground truth measurement in 2005. The work was currently still in progress. Also, the capability of using the inverse model to retrieve sea ice thickness from multi-polarization backscatter data (σ_{VV}, σ_{VH}, σ_{HV}, σ_{HH}) would also be explored. In addition to that, it was also planned that the testing would include the data gathered for the ground truth measurement which would be conducted in October 2008.

Sea Ice Thickness Inversion by NN and GA from Passive Microwave Remote Sensing

Simulation was first carried out by using the RT-DMPACT model at a frequency of 19 GHz, to calculate the various brightness temperature data sets for different sea ice parameters as shown in Table 3, by varying the sea ice thickness.

These data sets were then provided to the NN for training purposes before the inversion process could be made. The inversion result (thickness) was compared to that of the training data sets for validation, as shown in Figure 7. For GA, a search routine was set up to look for suitable sea ice thicknesses with the corresponding brightness temperatures profile. The inversion result from GA is shown in Figure 8.

Figures 7 and 8 show the comparison of the inversion results from NN and GA to that of the theoretical result from the forward scattering model. Figure 7 checks the validity of the theoretical result from the inversion model, and how it would perform at a higher thickness level, where-else in real data verification we generally look at cases with thicknesses less than 3 m and at lower frequencies.

The general trend was that both approaches yielded similar results in terms of sea ice thickness in meters. To further test them in real sea ice cases, we decided to pick the test sites located to the North West of Beaufort Sea, in the Arctic Ocean around the longitude of 152.641487W – 155.436310W and the latitude of 80.591475N – 80.648062N.

Figure 9 shows inversion results for both NN and GA compared to the forward model results by using the brightness temperature profile from the SSM/I on a DMSP satellite dated 19 September 1997. The Arctic sea ice thickness data was collected from the submarine upward looking sonar measurement data. The measurement data can be found in the SCICEX-97 data on National Snow and Ice Data Center website http://nsidc.org/data/g01360.html. We could see that the inversion results from NN and GA were quite close to that of the thickness measurement data.

CONCLUSION

In this paper, a RT-DMPACT forward model was first presented. Three inversion algorithms which were developed are also presented. The first model, based on the RT-DMPACT Forward Model and Levenberg-Marquardt optimization showed promising results towards the retrieval of sea ice thickness using single polarization active microwave remote sensing data. The two other models developed which were used to retrieve sea ice thickness

Table 3. Estimated input parameters to the RT forward model.

Volume fraction	5% – 10%
Scatterer radius	0.25 mm – 0.50 mm
Effective dielectric constant of top layer (air)	1.0 + j0.00
Scatterer dielectric constant (brine)	18.4 – j28.2
Background dielectric constant (asea ice)	3.17 – j0.06
Effective dielectric constant of bottom layer (lower half space)	18.4 – j30.2

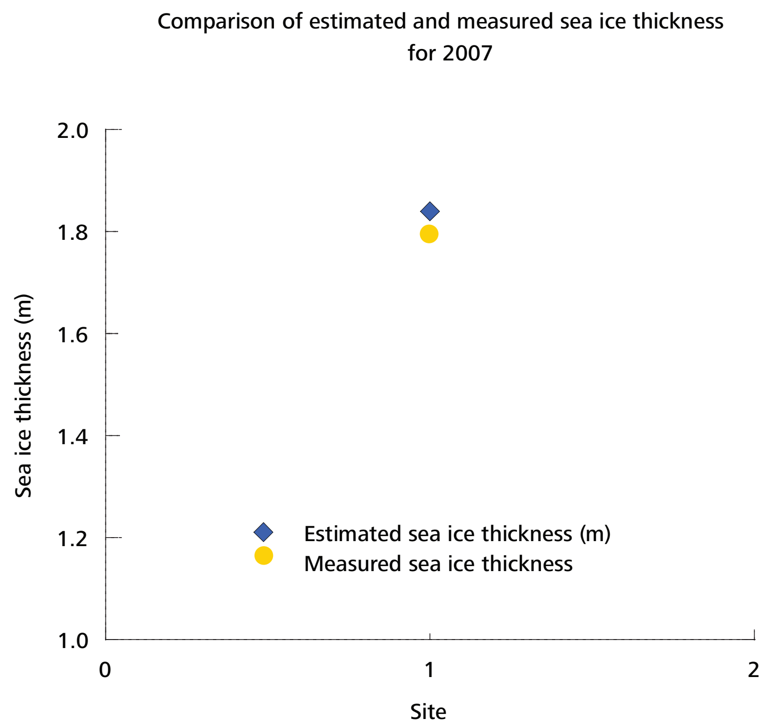


Figure 6. Sea ice thickness retrieval for 2007.

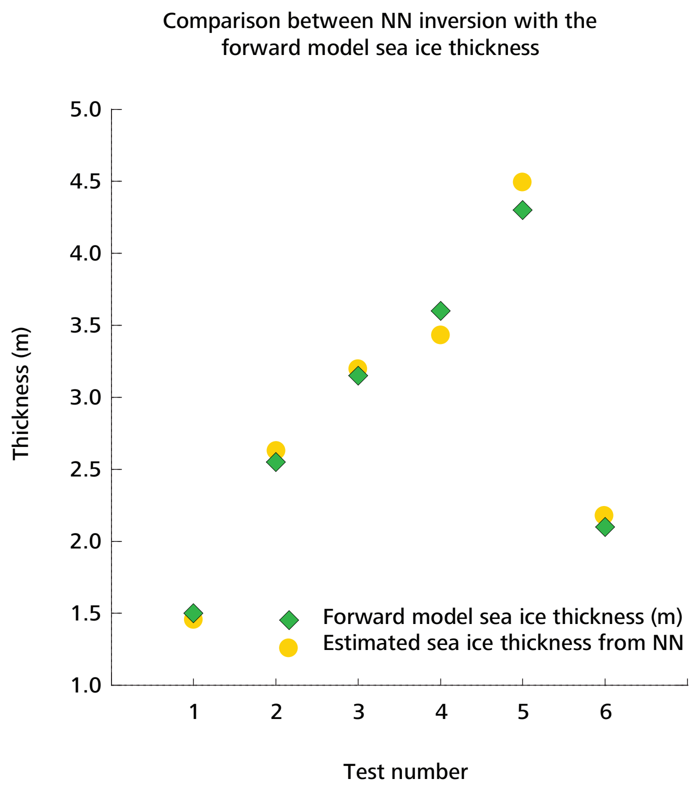


Figure 7. Inversion result from NN compared to that of the forward model.

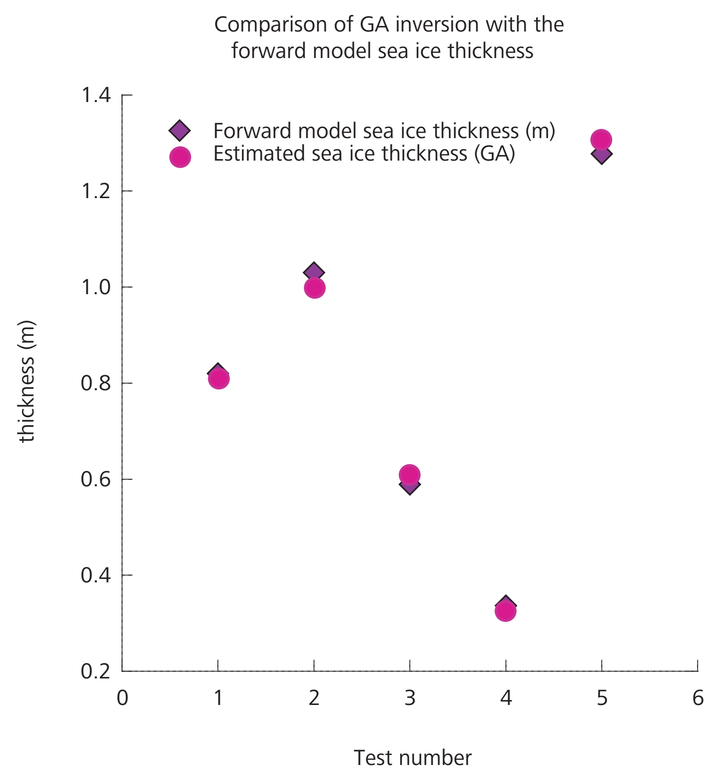


Figure 8. Inversion result from GA compared to that of the forward model.

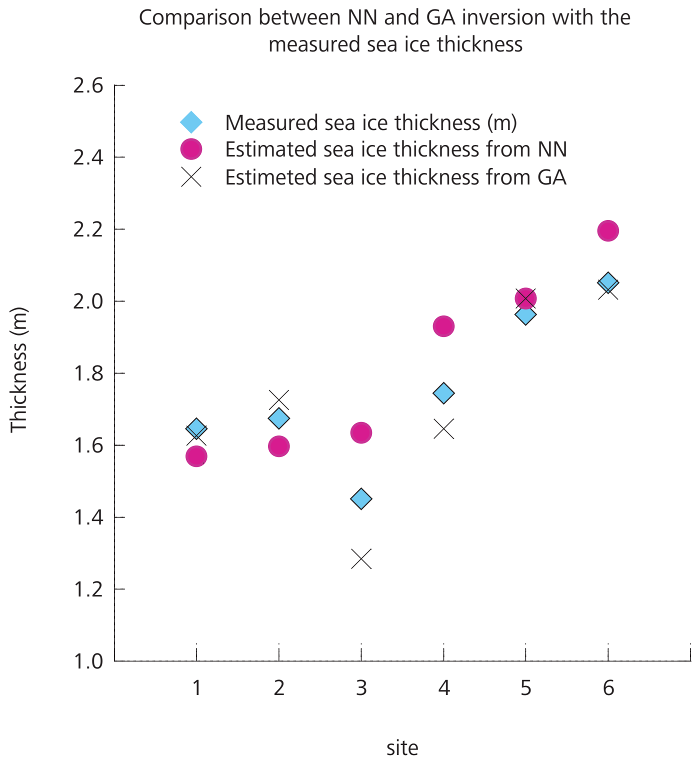


Figure 9. Inversion results from NN and GA compared to the forward model result.

from passive microwave remote sensing were the NN and GA. The applicability for both models had also been studied. The results showed that sea ice thickness retrieval using passive microwave remote sensing was possible.

ACKNOWLEDGEMENT

We would like to express our gratitude to the following parties who supported us in this study: Academy of Sciences Malaysia; Antarctica New Zealand and Multimedia University.

Date of submission: October 2008
Date of acceptance: June 2009

REFERENCES

Albert, MD, Tan, TE, Ewe, HT & Chuah, HT 2005, 'A theoretical and measurement study of sea ice and ice shelf in antarctica as electrically dense media', *Journal of Electromagnetic Waves & Applications*, vol. 19, no.14, pp. 1973–1981.

Arthur, KJ & Murat, EV 1994, 'Electromagnetic remote sensing of sea ice', *Inverse Problems*, vol. 10, pp. 1041–1058.

Chandrasekhar, S 1960, *Radiative transfer*, Dover, New York.

Chuah, HT, Tjuatja, S, Fung, AK & Bredow, JW 1996, 'A phase matrix for a dense discrete random medium: evaluation of volume scattering coefficient', *IEEE Transactions on Geoscience and Remote Sensing*, vol. 34, no.5, pp. 1137–1143.

Dawson, MS, Olvera, J, Fung, AK, Manry, MT 1992, 'Inversion of surface parameters using fast learning neural networks', in *Geoscience and Remote Sensing Symposium*, 1992, *IGARSS '92*, pp. 910–912.

Ewe, HT, Chuah, HT & Fung, AK 1998, 'A Backscatter Model for a dense discrete medium: analysis and numerical results', *Remote Sensing of Environment*, vol. 65, no.2, pp.195–203.

Fung, AK 1994, *Microwave scattering and emission models and their applications*, Artech House Norwood, MA.

Fung, AK & Eom, HJ 1985, 'A study of backscattering and emission from closely packed inhomogeneous media', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 23, no.5, pp. 761–767.

Fung, AK, Li, Z & Chen, KS 1992, 'Backscattering from a randomly rough dielectric surface', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 30, pp. 356–369.

Golden, KM *et al.* 1998, 'Inverse electromagnetic scattering models for sea ice', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, no.5, pp. 1675–1704.

Golden, KM *et al.* 1998, 'Forward electromagnetic scattering models for sea ice', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, no.5, pp. 1655–1674.

Haykin, S, Lewis, EO, Raney, RK & Rossiter, JR 1994, *Remote Sensing of Sea Ice and Iceberg*, John Wiley & Sons, Inc.

Kamal, S & Eric, SL 1997, 'Characterization of optimum polarization for multiple target discrimination using genetic algorithms', in *IEEE Transactions on Antenna and Propagation*, vol. 45, no. 12, pp 1810–1817.

Leung, T *et al.* 1992, 'Inversion of snow parameters from passive microwave remote sensing measurements by a neural network trained with a multiple scattering model', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 30, no. 5, pp. 1015–1024.

Marquardt, DW 1963, 'An algorithm for least-squares estimation of non-linear parameters', in *SIAM Journal on Applied Mathematics*, vol. 11, pp. 431–441.

Martin, TH & Mohammad, BM 1994, 'Training feedforward networks with the Marquardt algorithm', in *IEEE Transactions on Neural Network*, vol. 5, no 6, pp. 989–993.

Randy, LH 1995, 'An introduction to genetic algorithm for electromagnetics', in *IEEE Antenna and Propagation Magazine*, vol. 37, no.2, pp. 7–15.

Shih, SE *et al.* 1996, Thickness retrieval using time series electromagnetic measurements of laboratory grown saline ice, in *Proceedings IEEE IGARSS'96 Symposium*, pp. 1208–1210.

Shih, SE *et al.* 1998, 'Saline ice thickness retrieval using time series c-band polarimetric radar measurements', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, no.5, pp. 1589–1598.

Ulaby, FT, Moore, RK, Fung, AK 1986, '*Microwave remote sensing — active and passive, vol. III: from theory to application*', Artech House Inc.

Veysoglu, ME *et al.* 1994, 'Inversion algorithms for remote sensing of sea ice', in *Geoscience and Remote Sensing Symposium 1994, IGARSS '94, 'Surface and Atmospheric Remote Sensing: Technologies, Data Analysis and Interpretation', August 1994*, International vol. 1, pp. 626–628.

Yi-Cheng, L & Kamal, S 1999, 'Retrieval of forest parameters using a fractal-based coherent scattering model and a genetic algorithm', in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 37, no. 3, pp. 1415–1424.

ASM Sci. J., **3(2)**, 143–151

Surface Coverage and Some Soil Chemicals Properties at Punta Fort William, Greenwich Island, Antarctica

Y.S. Hii[1]*, S.A. Alias, A. Hussin[2], M.P. Zakaria[3], H. Moreano[4], M. Riofrio[4], W. Cárdenas[5], and N. Ordóñez[5]

Surface coverage and some properties soil chemicals were assessed at the Punta Fort William, Greenwich Island during the summer from 1–11 February 2008. Twenty sampling points were established along two strip transects covering a total area of 160 m^2. Punta Fort William was basically barren. Rocks, stones and pebbles covered 89.4% of the Punta Fort William. The diversity of vegetation in Punta Fort William was relatively low as compared to other South Shetland Islands. Mosses predominated the area and covered 9.1% of the total surface. *Colobantus quitensis* was the only vascular plant found at the Punta Fort William. It covered 0.5% of the total surface area. Lichens contributed 0.2% of the surface coverage. Although lichen coverage was low, its frequency of occurrence was among the highest. Total organic carbon (TOC) and total nitrogen (TN) in the study area ranged from 1 g to 39 g C kg^{-1} and 12 µg to 3892 µg N kg^{-1}, respectively. The level of TOC and TN were comparable to those reported in other maritime locations in Antarctic. Higher levels of TOC and TN were detected in the areas with intensive biological activities. Hydrocarbon concentration was very low in this area and the sources of hydrocarbons were both natural and anthropogenic. The natural hydrocarbons source was mostly biogenic while the petrogenic hydrocarbons input was anthropogenic.

Key words: vegetation; surface coverage; total organic carbon; total nitrogen; hydrocarbons; Colobantus quitensis; anthropogenic; biogenic; quantitative survey

Antarctica is a unique continent where 96% of the surface area is covered by ice and snow throughout the year (NGDC 2006). The extreme coolness causes Antarctica to be relatively lower in its biodiversity and the ecosystem is relatively simple as compared to other biospheres. The fauna and flora actively proliferate during the short summer in the Antarctic, which merely lasts about three months (Convey 2001). Nutrient cycles and the rate of mobility are interesting subjects in this short time-span ecosystem. What is the key mechanism that supports the nutrient demands during the summer? Does the Antarctic soil serve as a source or a sink in the dynamic environment? The survey of surface coverage is an extremely important baseline activity which can give an insight into the productivity, soil fertility, biodiversity, and species component structure and its abundance in an ecosystem.

Punta Fort William of Greenwich Island provided an ideal environment for the study of soil chemistry and flora coverage since most of the areas were free from ice and snow during the summer. Greenwich Island is one of the South Shetland Islands situated at 62º south. The South Shetland Islands have a cold oceanic climate with frequent summer rains and moderate annual thermal amplitude. The reported annual precipitation ranged from 470 mm to 700 mm in the area. The average annual temperature is about −3ºC and the annual thermal amplitude ranges between 8ºC and 10ºC. The ice-free zones are located in areas where the average annual temperature exceeds −2ºC (Schwerdtfeger 1970; Bello *et al.* 1996). Generally, the temperature in these areas was above 0ºC during summer. It results in snowmelt and the formation of an active layer in the topsoil during the short summer (Simonov 1977; Rakusa-Susczewski 1993). The effect of the cold ocean tends to keep the summer temperature low and the winter temperatures from falling as low as they do inland to the south. There are intensive biological activities on the maritime Antarctic during the short summer (Battaglia *et al*. 1997). Valverde and Arcos (1990) have prepared a checklist on the vegetation in the study area. However, there are neither quantitative survey nor soil nutrient reports of Greenwich Island.

There are two major islands situated nearby the Punta Fort William of the Greenwich Island, Dee Island and

[1] Faculty of Agrotechnology and Food Science, University Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia
[2] Institute of Oceanography and Earth Science, University Malaya, 50603 Kuala Lumpur, Malaysia
[3] Faculty of Environmental Studies, University Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia
[4] Instituto Antartico Ecuatoriano, 9 de Octubre , 416 y Chile, Edifico Citibank 4o Piso, P.O. Box 09-01-7658, Ecuador.
[5] Escuela Superior Politécnica del Litoral, Guayaquil, Ecuador
*Corresponding author (e-mail: hii@umt.edu.my)

Barrientos Island. Dee Island had the least biological activities as compared with the Punta Fort William and the Barrientos Island. The penguin rockery on the Barrientos Island and whale watching in the Chile bay (*Discoveries Channel*) near the island are famous tourist spots in the Antarctica. Small-scale tourism expeditions have existed since 1957 and are currently self-regulated by the International Association of Antarctica Tour Operators (IAATO). In 2006–2007 alone, 37 506 tourists visited Barrientos Island. The number is predicted to increase to over 80 000 by the year 2010 (Huber 2007). It is important to note that not all vessels are associated with the IAATO. The ship and cruise ferry tourists through the Chile Bay which is an interesting environment, to study the lateral and vertical transport of the pyrogenic and petrogenic hydrocarbons in the study area. This is the first quantitative survey on the hydrocarbons, surface coverage and the soil chemical properties of the areas.

MATERIALS AND METHODS

Expedition and Study Area

Data presented in this report were based on the survey and soil samples collected during the XII Institute of Antarctica, Ecuadorian (INAE) Expedition. The expedition was conducted during the summer from 31 January 2008 to 17 February 2008. The analysis of the surface coverage and nutrient profile was focused on Punta Fort William. Twenty sampling points were established along two transectional lines (Figure 1) and covered a total area of 160 m^2 in Punta Fort William headland. The sampling points for the surface coverage and soil nutrients are listed in Table 1. Five soil samples were collected from each sampling point. The soil samples were pooled and mixed thoroughly before being transferred into soil sampling bags (Whirlpack). The samples were labeled and stored at

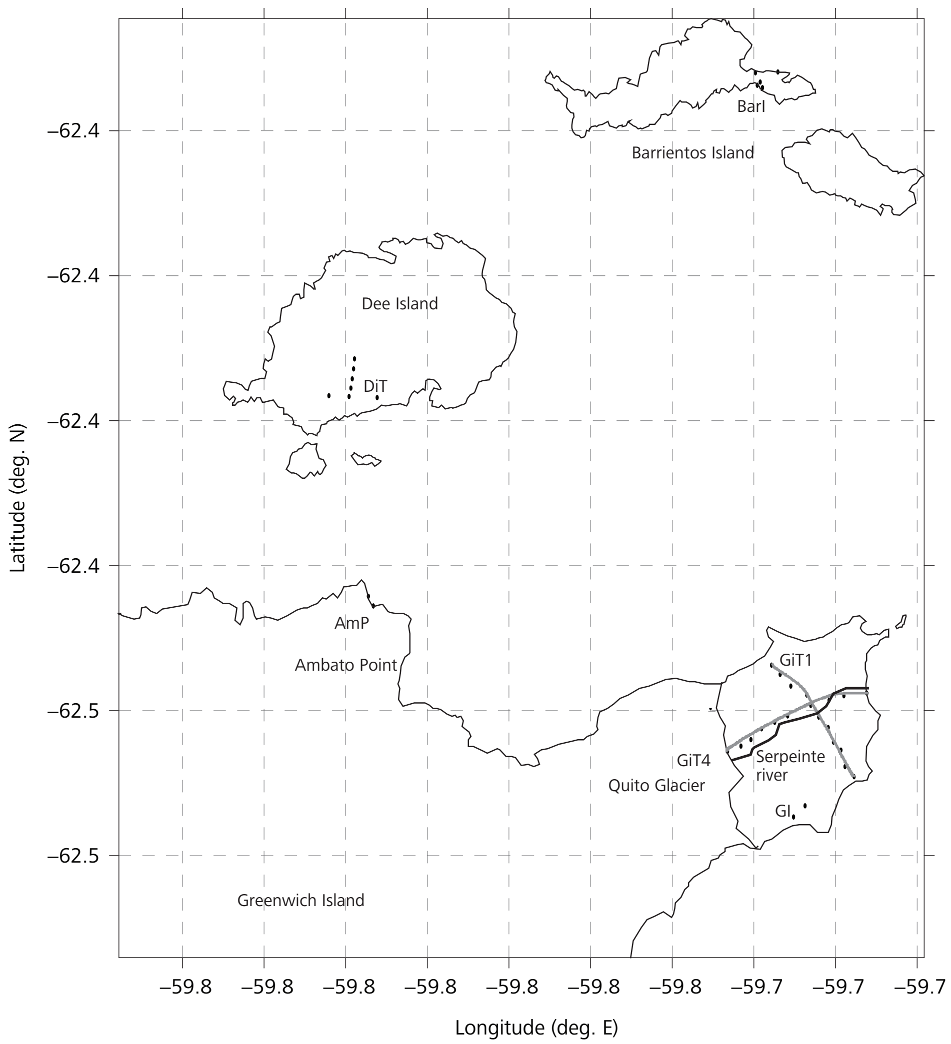


Figure 1. Position of the sampling points and transectional lines used in the study. Transectional lines are indicated by black dotted lines. ▲ Indicates sampling points.

Table 1. Position and description of the sampling points on Greenwich Island.

Station	Longitude (m)	Latitude (m)	Description
Transect 1			
GiT1_0	359344	3072856	Beach
GiT1_105	359202	3072829	Nearby a lake
GiT1_205	359110	3072790	Covered by moss
GiT1_500	358853	3072659	Covered by moss
GiT1_800	358629	3072467	Moist and covered by moss
GiT1_910	358568	3072414	Barren land
GiT1_972.5	358485	3072371	The edge of glacier
GiT1–600	358774	3072606	Soil saturated with water
GiT1–700	358693	3072553	Soil saturated with water
Transect 2			
GiT4_0	358735	3073044	Sandy, barren land
GiT4_100	358793	3072976	Sandy, barren land
GiT4_200	358864	3072889	Sandy, barren land
GiT4_300	358967	3072825	Moist, nearby a lake
GiT4_400	358996	3072746	Near to ice
GiT4_500	359050	3072658	Water saturated
GiT4_600	359114	3072580	Near to ice, hill slope
GiT4_700	359151	3072470	Hill, intensive bird nests
GiT4_800	359201	3072410	Barren land, rocky
GiT4_900	359232	3072285	Hill, intensive bird nests
GiT4_1K	359293	3072210	Seaside

0ºC before being shipped to the laboratory. The soil samples were stored at –20ºC in the laboratory until further analysis. All the analyses were performed within one month after the sampling.

For hydrocarbon study, a broader sampling area which covered the Dee Island and Barrientos Island was necessary for studying the sources of hydrocarbon in the area. The sampling points for hydrocarbon analysis are listed in Table 2. The collection and storage of samples were similar to that of the soil nutrient analysis.

Surface Coverage

The surface coverage in the study area was surveyed along the transects (Table 1). The survey was targeted at three dominant flora in the study area: vascular plants, mosses and lichens. The percentage of the flora coverage were surveyed at every 100 meters along the transectional lines by using a 1 m^2 quadrate. The percentage of coverage at each sampling point was recorded in a logbook and a digital image was captured by using a 8.0 mega pixel digital camera (Canon, Ixus 860i) for reference. The position and elevation of each sampling point was obtained by using a differential-global positioning system (D-GPS) (Trimble). UHTSC Image tool software ver. 1.1 was used to measure the percentage of coverage and frequency of occurrence. Activities of fauna (seabirds, penguin and seals) in the area were observed but not quantitatively determined.

Determination of Total Organic Carbon

Total organic carbon (TOC) was analyzed as based on Simas *et al.* (2007) method. The soil sample was mixed and sieved (<500 µm) to obtain a homogeneous sample. TOC in soil was determined by using a solid sample module (SSM) incorporated into a TOC machine (Shimadzu TC5000). The total organic matter in the soil was determined by the dry-ash method described by Burkins *et al.* (2000). A standard curve was established between area and organic carbon obtained from TOC-SSM 5000A. Sodium bicarbonate and potassium hydrogen phythalate were used as inorganic carbon (IC) and total carbon (TC) standards, respectively. Strong correlations of $y = 0.4907\ x;\ r^2 = 1$ and $y = 0.4619\ x;\ r^2 = 1$ were obtained for TC and IC, respectively. Each sample was conducted in triplicate. TOC was obtained by the net difference between TC and IC.

Determination of Soil Nitrogen

Total nitrogen in soil was determined by the Kjedahl method (McGill & Figueiredo 1993). In order to measure total nitrogen in soil, 1 gram of sieved (500 µm) air-dried soil was weighed and added into a 50 ml Kjedahl flask. 0.5 g of Hibbart's salt mixture (K_2SO_4 : $FeSO_4$: $CuSO_4$; 10: 1: 5) was added into the flask. The soil was moistened with some distilled water. 5 ml of concentrated 98% H_2SO_4 was then added into the sample. The mixture was digested in a Markham Apparatus for about 2 h. 30 ml of distilled water was added upon cooling. The digest

Table 2. Position and description of sampling stations for hydrocarbons analysis.

Station	Longitude (m)	Latitude (m)	Location	Description
DIT2-75	355985	3075055	Dee Island	Dried water channel; Surface covered with algae
DIT2-30	355987	3075102	Dee Island	Dried water channel
DIT2-20	359989	3075110	Dee Island	Hill side, far from melted glacier
DIT2-60	355987	3075070	Dee Island	Dried water channel with moss and fine rocks
DIT2-70	355985	3075060	Dee Island	Dried water channel. Surface covered with algae
DIT2-40	355986	3075090	Dee Island	Far from dried water channel
DIT2-80	355985	3075050	Dee Island	Near drying water channel, alluvial-moss scarce
BarI-4	358440	3077589	Barrientos Island	Beach—where penguins gather
BarI-6	358582	3077602	Barrientos Island	Active rookery-chinstrap
GI-007	358885	3072081	Greenwich Island	Soil, algae with water—edge of Quito glacier
GI-008	358926	3072033	Greenwich Island	Soil, water—edge of Quito glacier
AmP-4	356164	3073498	Ambato Point	Drying water channel at the beach
AmP-6	355955	3073412	Ambato Point	Soil and water-lake from melted glacier

was transferred to a 100 ml volumetric flask. The volume was made up to 100 ml. 10 ml of the digest was pipetted into the distillation apparatus. 10 ml of 40% NaOH was added and it was distilled and collected in 10 ml of boric acid-indicator solution. The distillate was titrated with 0.01N H_2SO_4 until the colour changed from green to purple. Each analysis was conducted in triplicate and a blank sample was used to correct the result. A recovery test was conducted on total nitrogen analysis of L-glutamic acid. A good recovery of 99.5% was obtained from the recovery test.

Determination of Hydrocarbons in Soil Sample

Authentic native standards for polycyclic aromatic hydrocarbons (PAHs) and alkanes (C16-C36) were purchased from Sigma Chemical Company (St. Louis, MO, The United States) and Chiron (Norway). All organic solvents used in the analysis were distilled in glass. Soil samples were defrosted under aluminum foil cover at room temperature and homogenized with a pre-cleaned spatula. Five grams of the samples (based on dry weight) were dried with baked anhydrous sodium sulfate and placed in pre-cleaned cellulose thimbles and soxhlet extracted for 11 h in distilled dichloromethane. The extracts were subjected to activated copper and left overnight to remove the elemental sulphur which might interfere with the analysis. Precisely, 200 µl of the surrogate internal standards mixture containing 10 p.p.m. each of components naphthalene-d8, anthracene-d10, benzo[a]anthracene-d12, and chrysene-d12 were spiked into the extracts. The solution was purified and fractionated by the method previously described by Zakaria *et al.* 2002. Briefly, the solution was transferred onto the top of a silica gel column (i.d. 0.9 cm, length 9 cm) which was deactivated with 5% distilled H_2O to remove polar components. PAHs ranging from 2 to 7 rings and Hopanes were eluted with 20 ml of 3:1 hexane/dichloromethane (v/v). The solution was then fractionated using a fully activated silica column (i.d. 0.47 cm, length 18 cm) to obtain hopane and PAHs fractions using 4 ml hexane and 14 ml 3:1 hexane/dichloromethane (v/v), respectively. PAHs and alkane fractions were individually evaporated to approximately 1 ml, transferred to 2 ml amber vials, and evaporated to dryness under a gentle stream of nitrogen. Polycyclic aromatic hydrocarbon fractions were re-dissolved into an appropriate volume (200 µl) of isooctane containing p-terphynyl-d14 as an internal injection standard (IIS).

PAHs and alkanes analyses were carried out by using a Hewlett Packard 5972A quadrupole mass spectrometer integrated with a HP5890 gas chromatograph equipped with a J&W Scientific Durabond HP-5MS, 30 m fused silica capillary column, 0.25 mm i.d. and 0.25 µm film thickness, using helium as the carrier gas on a constant pressure of 60 kg/cm^2. The GC-MS operating conditions had a 70 eV ionization potential with the source at 200ºC and electron multiplier voltage at 1200 eV. The injection port was maintained at 300ºC and the sample was injected in split mode followed by purge at 1 min after the injection. For PAHs' analysis, the column temperature was held at 70ºC for 2 min, then programmed to go at 30ºC/min to 150ºC, 4ºC/min to 310ºC and to hold for 10 min. A selected ion monitoring method was employed after a delay of 4 min. PAHs were monitored at m/z = 178 (phenanthrene, anthracene), m/z = 192 (methylphenanthrenes), m/z = 202 (fluaranthene, pyrene), m/z = 228 [benz(a)anthracene, chrysene], m/z = 252 [benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k) fluoranthene, benzo(e)pyrene, benzo(a)pyrene, perylene] and m/z = 276 {indeno[1,2,3-cd]pyrene, benzo(ghi) perylene}. Individual PAHs were quantified by comparing the integrated peak area of the selected ion with the peak area of the IIS. Acenaphthene-d8 and chrysene-d12 were used as IIS for the quantification of PAHs ranging from phenanthrene to 1-methylphenanthrene and for PAHs from fluoranthene to Dibenzo (a,h) antharacene, respectively. Corrections for relative response at the corresponding mass/charge ratio were made by analyzing a PAH standard (phenanthrene, anthracene, 1-methylphenanthrene, fluoranthene, pyrene, chrysene, benzo[b]fluoranthene, benzo[e]pyrene, benzo[a]pyrene, perylene, benzo[ghi] perylene) under the same instrumental conditions as the sample analyses. No 9 and 1-methylphenanthrene standards were available, therefore the estimated response factors for these compounds was based on a response for 9 and 1-methylphenanthrene. Similarly, benz[a] anthracene benzo[j]fluoranthene+benzo[k]fluoranthene and indeno[1,2,3-cd]pyrene concentrations were based on the chrysene/triphenylene, benzo[b]fluoranthene and benzo[ghi]perylene response, respectively. Since naphthalenes were difficult to quantify due to their high volatility, the present study focused on PAHs with three or more benzene-rings (i.e. phenanthrene–Dibenzo(a,h) antharacene). PAHs concentrations were recovery-corrected using the spiked surrogates and this procedure typically yielded recoveries of PAHs in the range of 77% to 108%. The precision of the method was determined through four replicated analyses of the heavy residual oil sample. The relative standard deviation (RSD; n = 4) of individual PAHs identified in sample extracts was <10%.

Statistical Analyses

Statistical analyses on general descriptive statistical and data distributions were conducted to verify the pattern of vegetation coverage. The content of nutrient and organic carbon in the biologically intensive areas and barren land were compared. The frequency-distribution of the data was tested with a normality test. Comparisons of the stations were conducted by using *t*-tests at a significant level, α = 0.05.

RESULTS

Surface Coverage

Table 3 reveals descriptive statistics for surface coverage in the study area. Most of the area was barren. Rock, pebbles and coarse sand covered 90.2% of the surface area. Mosses, lichen and *C. quitensis* covered 9.1%, 0.22% and 0.48%, respectively. The vegetation coverage in the area showed a strong patchy distribution as indicated by the high skewness and kurtosis values (Table 3). Seaweed fragments found in the area were more than 500 meters from the seaside. Figure 2 shows the surface coverage of the transects. *Transect 1* which lay along the Serpeinte river showed a higher percentage of vegetation coverage, predominantly mosses. There was only one vascular plant found in this area, *Colobanthus quitensis*. The other Antarctic vascular plant, Dechampsia antarctica was not found in the study area. The lowland area closer to the river was predominatly occupied by mosses. Lichen was found at the higher and drier areas. The Serpeinte river in the *Transect 1* saturated the soil with melt water from the Quito Glacier. The water-saturated soil boosted the growth of mosses in the area. *Transect 2* was relatively drier, the overall vegetative coverage was lower but more evenly distributed. Mosses obtained water from the melting ice and snow patches. The vascular plant, *Colobanthus quitensis* was mostly found on *Transect 2*.

Soil pH, Moisture, Total Nitrogen and Total Organic Carbon

Table 4 shows the soil chemical baseline of the study area. The soil pH in the study area was slightly acidic and poorly buffered. Average soil pH in the area was 5.98. TOC in the soil ranged from 0.8 to 39 mg C kg^{-1} and it was not homogeneously distributed. TOC varied from point to point

Table 3. Descriptive statistics for the major flora recorded in the study area.

	Moss	Vascular plants	Lichen
Mean	9.10	0.48	0.22
Standard Error	1.39	0.15	0.18
Median	0.3	0	0
Standard Deviation	17.53	1.95	2.26
Sample Variance	307.43	3.83	5.12
Kurtosis	9.06	49.50	118.70
Skewness	2.89	6.56	10.26
Range	98	18	27
Minimum	0	0	0
Maximum	98	18	27
Confidence Level (95.0%)	2.75	0.30	0.35

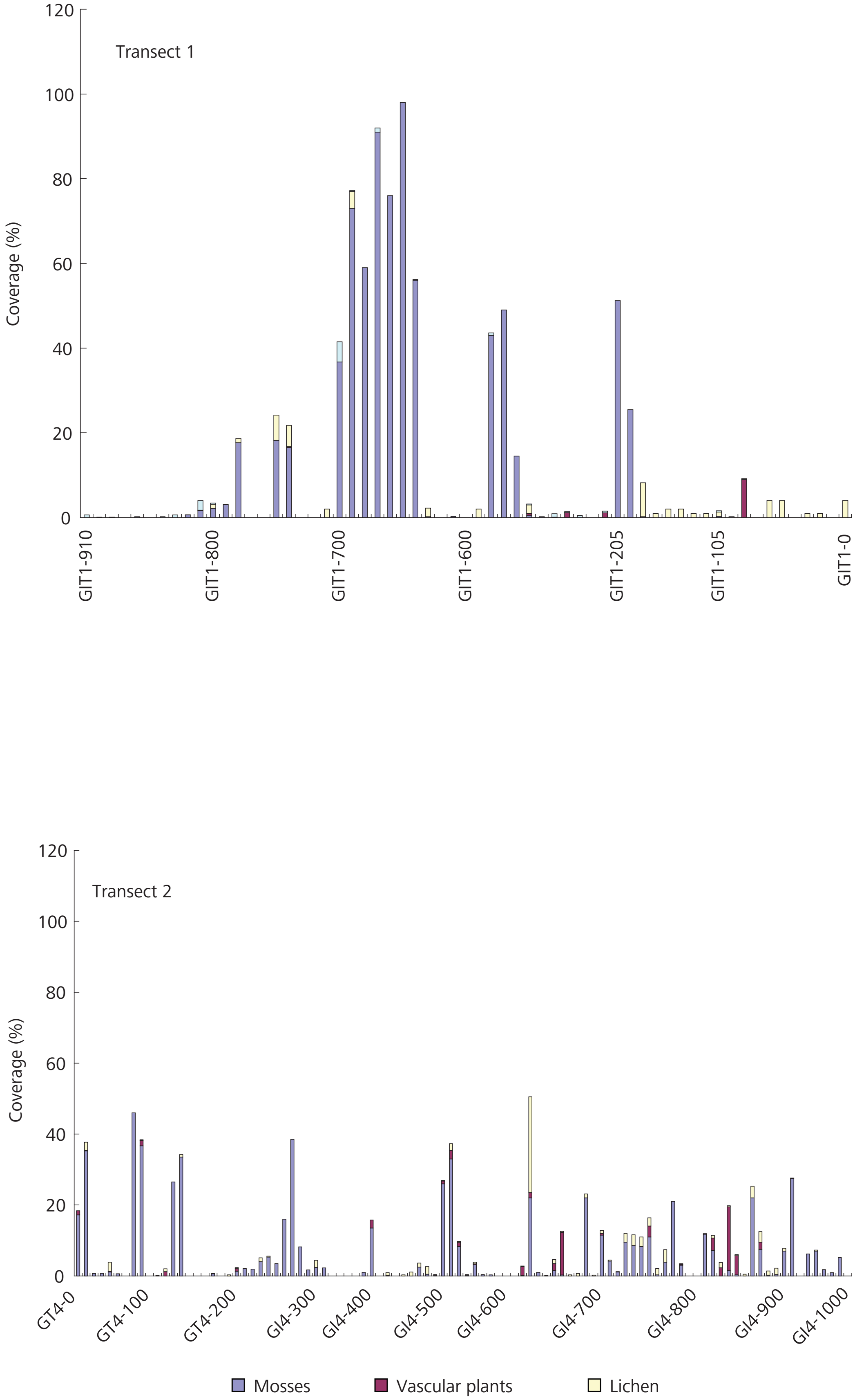


Figure 2. Vegetation coverage in the study areas.

Table 4. Some baseline chemistry of the soil samples in the study area.

Station	Temperature (ºC)	pH	Moisture contents (%)	Total organic carbon (mg C kg^{-1})	Total nitrogen (µg N kg^{-1})
GiT1_0	13.6	6.19	5.7	8.2	814
GiT1_105	8.2	5.74	19.8	3.8	336
GiT1_205	10.4	5.77	6.8	27	3315
GiT1_500	12.5	5.74	10.4	39	3892
GiT1_600	8.9	5.66	17.2	7.2	676.3
GiT1_700	5.7	7.12	15.1	8.0	572.1
GiT1_800	14.6	6.14	9.7	30	3671
GiT1_910	8.8	6.30	18.8	1.5	17.5
GiT1_972.5	6.2	6.55	19.2	1.7	28.3
GiT4_0	9.1	5.51	4.3	1.9	42.5
GiT4_100	6.2	5.71	5.3	3.2	23.1
GiT4_200	4.3	5.73	7.4	2.4	37.5
GiT4_300	7.3	6.66	22.2	4.3	427.0
GiT4_400	3.8	5.73	9.3	2.7	36.4
GiT4_500	7.3	5.47	4.4	5.0	365.4
GiT4_600	5.2	5.68	10.8	0.8	40.1
GiT4_700	4.1	5.66	15.1	24	1694
GiT4_800	4.5	5.89	12.2	3.4	12.1
GiT4_900	5.0	6.10	10.1	10.1	1733
GiT4_1000	5.3	6.19	5.7	7.2	638

Table 5. Hydrocarbons contained in the soil samples at different sampling points.

Station	Location	Total alkane (ng/g)	L/H	Total PAHs (ng/g)	MP/P
DIT2-75	Dee Island	191	0.1	4	0.6
DIT2-30	Dee Island	29	0.2	7	0.8
DIT2-20	Dee Island	21	0.1	2	0.2
DIT2-60	Dee Island	13	0.1	n.d	0.3
DIT2-70	Dee Island	70	0.3	5	0.7
DIT2-40	Dee Island	n.d	N.A	n.d	N.A
DIT2-80	Dee Island	n.d	N.A	n.d	N.A
BarI-4	Barrientos Island	21	0.2	4	0.5
BarI-6	Barrientos Island	85	0.1	9	0.3
GI-007	Greenwich Island	298	1.8	17	1.1
GI-008	Greenwich Island	131	1.7	11	1.3
AmP-4	Greenwich Island	n.d	N.A	n.d	N.A
AmP-6	Greenwich Island	n.d	N.A	n.d	N.A

- L/H is the ratio of lower molecular weight to high molecular weight C16-C36 alkanes, total PAHs is the sum of concentrations of phenanthrene + anthracene + 3-methylphenanthrene + 2-methylphenanthrene + 9-methylphenanthrene + 1-methylphenanthrene + fluoranthene + pyrene + benza[a]anthracene + chrysene + benzofluoranthene + benzo[e]pyrene + benzo[a]pyrene + indeno[1,2,3-cd]pyrene + benzo(ghi)perylene.
- MP/P ratio = a ratio of the sum of 3-methylphenanthrene + 2- metylphenantherene + 9-methylphenanthrene + 1-methylphenantherene relative to phenantherene,
- n.d = not detected, N.A = not applicable.

even within a very close distance (less than 100 meter). Total soil nitrogen in the study area ranged from 12.1 to 3892 µg N kg^{-1}. The total nitrogen in the soil samples also varied significantly from station to station ($p<0.05$).

Hydrocarbons

A trace amount of hydrocarbons was detected in the study area. Total alkane and total polycyclic aromatic hydrocarbons (PAHs), which ranged from a non-detectable level up to 298 ng g^{-1} and 17 ng g^{-1} were detected in the soil sample. Table 5 reveals hydrocarbons detected in the soil sample.

DISCUSSION

Rocks, stones and pebbles covered most of the surface area of Punta Fort William, Greenwich Island. The diversity of vegetation in the study area was relatively lower as compared to other islands in the South Shetland Island and other maritime Antarctic locations (Adams *et al.* 2006). Mosses were predominant in the area. Similar observations were reported by Convey (2001) on other maritime Antarctic localities. Mosses were extensive in low land where the soil moisture content was high. *C. quitensis* in this study was the only vascular plant found at higher elevations with lower soil moistures. Although lichen had relatively low coverage, the frequency of occurrence was among the highest. No vegetation was found by the seaside and areas with a relatively thinner layer of topsoil. The flora distribution in the study area showed a strong patchy pattern. There was a significant difference in the flora coverage in *Transect 1* and *Transect 2* ($p<0.05$). *Transect 1* showed a higher percentage of flora coverage. The mosses which grew along Serpeinte River extended from the Quito glacier down to the discovery channel. The coverage of vegetation in the study area was regulated by geo-morphological properties and availability of water. These factors contributed to the distinctive distribution of the vegetation. Habitats adjacent to water (lakes and ice melts) had significantly higher biological activities. The vegetation in the study area might be sensitive to the soil osmotic pressure.

TOC showed a distinctive pattern. In general, newly exposed soil from the melting glacier contained lower TOC (GiT1_910, GiT1_972.5). Open area with relatively less biotic activities were also found to be low in TOC in the soil (GiT4_0, GiT4_200). Higher TOC was detected in soil with active biotic activities. The TOC in the study area was comparable to that reported in Maritime Antarctica (Simas *et al.* 2007). Simas *et al*. (2007) reported that the penguin rookery was the most abundant TOC source in Antarctica. A similar distribution pattern was observed in the study area. A higher TOC was also detected in areas with active seabird nestings. Total nitrogen (TN) in the study area revealed a similar distribution pattern. The higher TN was associated with intensive biological activities in the study area. The range of total nitrogen detected in the study area was similar to those reported on Garwood Valley, the Ross Sea Region (Hopkins *et al*. 2006). A carbon: nitrogen (C/N) ratio, which ranged from 7 up to 328, was detected in the study area. The exposed barren land had a higher C/N ratio while areas with intensive biological activities tended to have lower C/N ratios. A lower C/N ratio was observed in the newly exposed ex-glacier soil (GiT1_910, GiT1_972.5). Gentoo penguins were occasionally spotted near the seaside, but there was no penguin rookery on the Greenwich Island.

Seabirds in maritime Antarctica particularly skuas, *Catharacta* sp. and giant petrel *Macronectes giganteus* play important roles as 'transporters' to convey nutrients from the sea to terrestrial domains (Vincent & Vincent 1982). The digestive systems of the seabirds convert organic matter back into their inorganic form for the utilization of terrestrial organisms during the short summer in the Antarctic. Hence, seabirds were speculated to play important roles in providing organic matter to the study areas. The digestive systems of seabirds convert their food into inorganic nutrients. When the ice melts during the summer, the melting water would transport the inorganic nutrients into the lowland areas. Soil microbes would further decompose the remaining organic matter into inorganic nutrients. As a result, these create an ideal environment for mosses and other cyanobacteria in the basin area. The seabird nestings were believed to be the 'source' for nutrients in the area. Higher soil nutrient contents were recorded in the areas with denser bird activities. We believe the nutrients derived from the birds could probably be more than those derived by soil microbes. Nutrient cycles in the Antarctic present another interesting scenario as compared to the tropics. Further investigation is necessary to compare the nutrient transportation models in both regions.

This study also surveyed hydrocarbons in the soil. A wider sampling area including Dee Island and Barrientos Island was covered in order to gain a better view of the distribution of airborne pyrogenic and petrogenic hydrocarbons. Hydrocarbons were detected in most of the sampling stations (Table 5). Based on the alkane signature, most of the hydrocarbons detected in the study area were of biogenic origin except for stations GI-007 and GI-008 on Greenwich Island. High L/H ratios ($L/H > 1.0$) and low MP/P in the respective stations showed that the hydrocarbons detected in the areas were of pyrogenic origin. The hydrocarbons may have been transported via soot particles as suggested by Prahl and Carpenter (1983). The hydrocarbon content in Dee Island and Barrientos Island were comparatively lower as compared to Punta Fort William. The Ambato Point was free from hydrocarbons but Punta Fort William showed the anthropogenic input signature of hydrocarbons. Localized input of petroleum hydrocarbons in the area was possible. The results were consistent with the MP/P ratios (>1), which indicate a mixture of petrogenic and pyrogenic input. A more detailed study is needed to further elaborate on the hydrocarbon source and distribution in the study area.

ACKNOWLEDGEMENTS

The Authors would like to acknowledge the Malaysian Antarctica Research Program and Instituto Antartico Ecuatoriano for sponsoring the survey.

Date of submission: October 2008
Date of acceptance: November 2009

REFERENCES

Adams, BJ *et al.* 2006, 'Diversity and distribution of Victoria Land biota', *Soil Biology* & *Biochemistry*, vol. 38, no. 10, pp. 3003–3018.

Battaglia, B, Valencia, J & Walton, DWH 1997, *Antarctic communities: species, structure and survival*, Cambridge University Press, United Kingdom.

Bello, S, Bidegain, M & Lobato, H 1996, *Características climatológicas de la Bahía Collins (Isla Rey Jorge, Antártida)*, Dirección General de Meteorología del Uruguay, Montevideo.

Burkins, MB, Virginia, RA, Chamberlain, CP & Wall, DH 2000, 'Origin and distribution of soil organic matter in Taylor Valley', *Antarctica Ecology*, vol. 81, pp. 2377–2391.

Convey, P 2001, 'Antarctic ecosystems', in *Encyclopedia of Biodiversity,* vol. 1, ed S Levin, Academic Press, San Diego, pp. 171–184.

Hopkins, DW *et al.* 2006, 'Carbon, nitrogen and temperature controls on microbial activity in soils from an Antarctic dry valley', *Soil Biology* & *Biochemistry*, vol. 38, pp. 3130–3140.

Huber, J 2007, *The Antarctica Treaty*, Antarctic Treaty Secretariat Newsletter, 30th Antarctic Treaty Consultative Meeting. Final Report.

McGill, WB & Figueiredo, CT 1993, 'Total nitrogen', in *Soil sampling and methods of analysis*, ed MR Carter, Lewis Publ., Boca Raton, FL, pp. 201–212.

National Geophysical Data Center (NGDC) 2006, National Satellite, Data, and Information Service. Retrieved on 9 June, 2006.

Prahl, FG & Carpenter, R 1983, 'Polycyclic aromatic hydrocarbon (PAH)-phase associations in Washington coastal sediment', *Geochimica et Cosmochimica Acta*, vol. 47, pp. 1013–1023.

Rakusa-Susczewski, S 1993, *The maritime antarctic coastal ecosystem of Admiralty Bay*, Department of Antarctic Biology, Polish Academy of Sciences, Warsaw.

Schwerdtfeger, W 1970, 'The climate of Antarctic', in *World Survey of Climatology*, ed HE, Landsberg, Orvig, S., Amsterdam, pp. 253–355.

Simas, FNB *et al.* 2007, 'Organic carbon stocks in permafrost-affected soils from Admiralty Bay, Antarctica', in *Antarctica: A Keystone in a Changing World — Online Proceedings of the 10th International Symposium on Antarctic Earth Sciences*, USGS Open-File Report 2007–1047, Short Research Paper 076.

Simonov, IM 1977, 'Physical geographic description of the Fildes Peninsula (South Shetland Islands)', *Polar Geogr.*, vol. 1, pp. 223–242.

Valverde, F & Arcos, F 1990, 'Estudios preliminares de la cobertura vegetal en Punta Fort Williams-Isla Greenwich, *Acta Antártica Ecuatoriana*, vol. 2, no. 1, pp. 47–55.

Vincent, WF & Vincent, CL 1982, 'Response to nutrient enrichment by the plankton of Antarctic coastal lakes and the inshore Ross Sea', Polar Biology, vol. 1, pp. 159–165.

Zakaria, MP et al. 2002, 'Distribution of polycyclic aromatic hydrocarbons (PAHs) in rivers and estuaries in malaysia: a widespread input of petrogenic PAHs', *Environ. Sci. Technol*., vol. 36, pp. 1907–1918.

ASM Sci. J., **3(2)**, 152–160

Impact of a Katabatic Wind Event on GPS PWV Measurements at Scott Base Station, Antarctica

W. Suparta[1]*, A.A. Samah[2] and A.R. Harper[3]

Katabatic winds dramatically affect the polar climate. Their activity depends on density of air and temperature in the source region. This paper presents for first time an analysis of the precipitable water vapour (PWV) variability and its relation to a katabatic event at Scott Base station, Antarctica. A significant effect in their characteristics toward calculation of a reliable user accuracy in GPS applications is addressed. Our investigations using the data between 21st and 30th of November 2002 showed that the PWV profile exhibited an irregular pattern with a maximum value of 7.38 mm (~ 6 mm on average), and was more strongly influenced by relative humidity than by wind speed activity. The dominant wind flow during this period was from the North-Northeast (blowing from the Ross Sea) with a median speed of 4.96 ms^{-1}. The PWV was high when the temperature was between –15ºC and –11ºC. During the dates identified as a katabatic event between 21:30 UT of 28th November and 18:40 UT on 29th November, the wind blew from the Southeast-South direction (from the Ross Ice Shelf) with a maximum speed of 10.92 ms^{-1}. The PWV increased ~1.4 mm (23%) from the mean value, indicating severe wind during this event which had pronounced effect on GPS observations.

Key words: meteorology; polar climate; characteristics; accuracy; relative humidity; wind speed

It is well known that water vapour is one of the most important components of Earth's atmosphere and a highly variable atmospheric constituent. It is fundamental to the transfer the energy in the atmosphere and in the formation and propagation of weather (Rocken *et al*. 1997). It is also the source of precipitation, and its latent heat is a critical ingredient in the dynamics of most major weather events (Ware *et al.* 1998). As a greenhouse gas, water vapour also plays a critical role in the global climate system. However, water vapour remains one of the most poorly characterized meteorological parameters. Improved knowledge of its distribution is needed for a variety of atmospheric research applications and for improved weather forecasting (Rocken *et al.* 1999). The understanding of the circulation mechanisms and its effects on atmospheric radiation is thus important in predicting long-term climate changes.

Modeling water vapour in the troposphere can give great insight into how weather forms and how it can be predicted. Unfortunately, water vapour is difficult to accurately model using current technology. Recent advances in GPS technology, especially ground-based GPS receivers (Rocken *et al.* 1995; Welsh 2000) and space-based GPS applications (Yuan *et al*. 1993), have enabled us to quantify the atmospheric precipitable water vapour (PWV). Considerable developments in GPS analysis has led to remarkable improvements in the accuracy of PWV estimation. Many comparisons of GPS PWV with radiosondes and water vapour radiometers have demonstrated that GPS-sensed PWV has achieved an accuracy of about 1 mm with a relative uncertainty of 5%–10% (Liou *et al*. 2000; Nakamura 2003). The high quality of GPS PWV allows it to be used for climate studies.

Recently, there was a huge interest by scientists to study the impact of global climate change through bipolar to equatorial regions, or vice versa. Therefore, the quality of GPS signals during severe weather conditions, particularly in sensible areas (i.e. Antarctica) where there was a demand to observe for improved global climate change models. Antarctica's location and its present stormy waters are pristine, majestic and unique in terms of weather and climate. This iciest, coldest, windiest and driest continent on Earth has a great influence on the world's climate and acts as a global barometer and a base for an international weather laboratory in collecting satellite data and meteorological information including the presence and effect of moisture, CO_2 and electrified particles on atmospheric circulation for the study of global climate change and development of a high resolution global numerical weather prediction (NWP) forecast system.

[1]Institute of Space Science, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]Department of Geography, Faculty of Art and Social Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia
[3]NIWA Instrument Systems, P.O. Box 8602, 10 Kyle St, Riccarton, Christchurch 8003, New Zealand
*Corresponding author (e-mail: wayan@ukm.my; w_suparta@yahoo.com)

Despite large regional differences and the unique location of Antarctica, severe wind events such as katabatics also plays an important role in the local climate, in particular winter climate in which strong katabatic winds are frequent at some sites and infrequent in others, creating large variations in mean annual temperatures owing to the warming effect of the winds (Nylen *et al*. 2004). It was observed that strong wind speed during quiet solar activity was shown to increase the PWV content in Antarctica (Suparta *et al*. 2008). However, one would notice that not all stronger winds at Antarctica are categorized as katabatic. Katabatic winds are most commonly found blowing out from the large and elevated ice sheets of Antarctica and Greenland. This wind originates from the cooling by intense radiation of air at the top of a plateau, a mountain, glacier, or even a hill (Turner & Pendlebury 2004). Since the density of air increases with lower temperature, the air will flow downwards, warming adiabatically as it descends. The temperature of the wind can become hot by the time it reaches sea level. In the case of Antarctica, the wind is extremely cold. These winds can cause sudden changes in the weather itself and in the area when the winds spill out. Severe weather and heavy precipitation related to the PWV dynamics in the boundary layer are a further great challenge in attempts to quantify their impact on the GPS signals.

This article measures the GPS related signals to determine the PWV. The temporal variation of PWV during a katabatic event at Scott Base station, Antarctica for a 10 day measurement and its correlation are also presented. Detecting the characteristics of a katabatic event using both ground-based GPS technique and meteorological observations were also made.

DATA AND METHODS OF ANALYSIS

The methods for determining the PWV from a GPS and ground-based meteorological observation, the measurement system and data processing techniques were elucidated. The analyses were based on the data gathered from 21st to 30th of November 2002 at Scott Base, Antarctica.

PWV Determination from GPS

The current GPS constellation consisted of 32 satellites in six orbital with an inclination of 55º. The GPS satellites transmitted in the radio range at L-band frequency and had two modulated frequencies of 1575.42 MHz as L_1 and 1227.6 MHz as L_2. For powerful civilian signals to used in the near future, the aeronautical navigation band of L5 frequency (1176.45 MHz) would be added on L1 and L2 (http://tycho.usno.navy.mil/gps.html). The orbit of each GPS satellite was approximately circular and semi-synchronized, and was placed at 20 183 km from the mean surface of the Earth with orbital radius of 26 600 km. The navigation parameters were based on the ECEF (Earth Centered Earth Fixed) WGS-84 worldwide common grid reference system. This constellation produced global coverage for 24 hours a day. Thus, any location on Earth would see roughly 8–12 satellites or 1/3 of the satellites at any given time. In the processing, by a 10 min interval (a reasonable timescale for large ionospheric and tropospheric dynamics), the GPS line-of-sight (LOS) respect to the ground receiver's field-of-view only moved three degrees in 20 separate measurements which were capable of temporal change. Based on these orbital characteristics, PWV measurements from ground receivers could easily detect temporal variation within the troposphere (often called the lower atmosphere).

When the GPS signal propagates through the Earth's atmosphere, it is affected by the variability of the refractive index of the ionosphere and troposphere. It causes an excess delay of the signal and the change in the refractive index with height causes bending of the signal. The total delay along the slant path is composed of two parts: ionospheric delay and tropospheric delay. The ionospheric delay is frequency dependent and it can be nearly corrected by observing both of the frequencies transmitted by the GPS satellites (L_1 and L_2) of a dual-band GPS receiver (Kunches & Klobuchar 2000). The remaining delay is the tropospheric delay or neutral delay, it is not frequency dependent but depends on the constituents of the atmosphere. As such, this delay along the path of the radio signals to a receiver on the ground is sensitive to the local surface pressure, temperature and water vapour variations. Additionally, by differencing the pseudorange at two different frequencies, the errors caused by clock biases between receiver and satellite or non-dispersive components in tropospheric delay calculation can be isolated. Therefore, the most straight forward measurement of the PWV comes from the pseudorange calculation. Based on this assumption, the atmospheric delay caused by the neutral atmosphere can be determined from the 'hydrostatic delay' associated with the 'dry' atmosphere and the 'wet' delay associated with the permanent dipole moment of water vapour. The total tropospheric delay or zenith tropospheric delay (ZTD) is the sum of the zenith hydrostatic delay (ZHD) and the zenith wet delay (ZWD). The ZHD is mainly caused by the dry part of the gaseous layer in the atmosphere which depends solely on local pressure and the position of GPS receiver, and the ZWD depends mainly on the total amount of water vapour along the paths of the radio signals to all satellites from a GPS receiver position. Figure 1 shows the basic measurement of GPS PWV adapted from Nakamura (2003). Details of ZTD and PWV determination can be found in Suparta *et al.* (2008).

Referring to the basic measurement of Figure 1, a GPS receiving system was installed at Scott Base Station, Antarctica (77.9ºS, 166.8ºE) at a height of 28.2 m at sea level. The system was up and running on the beginning

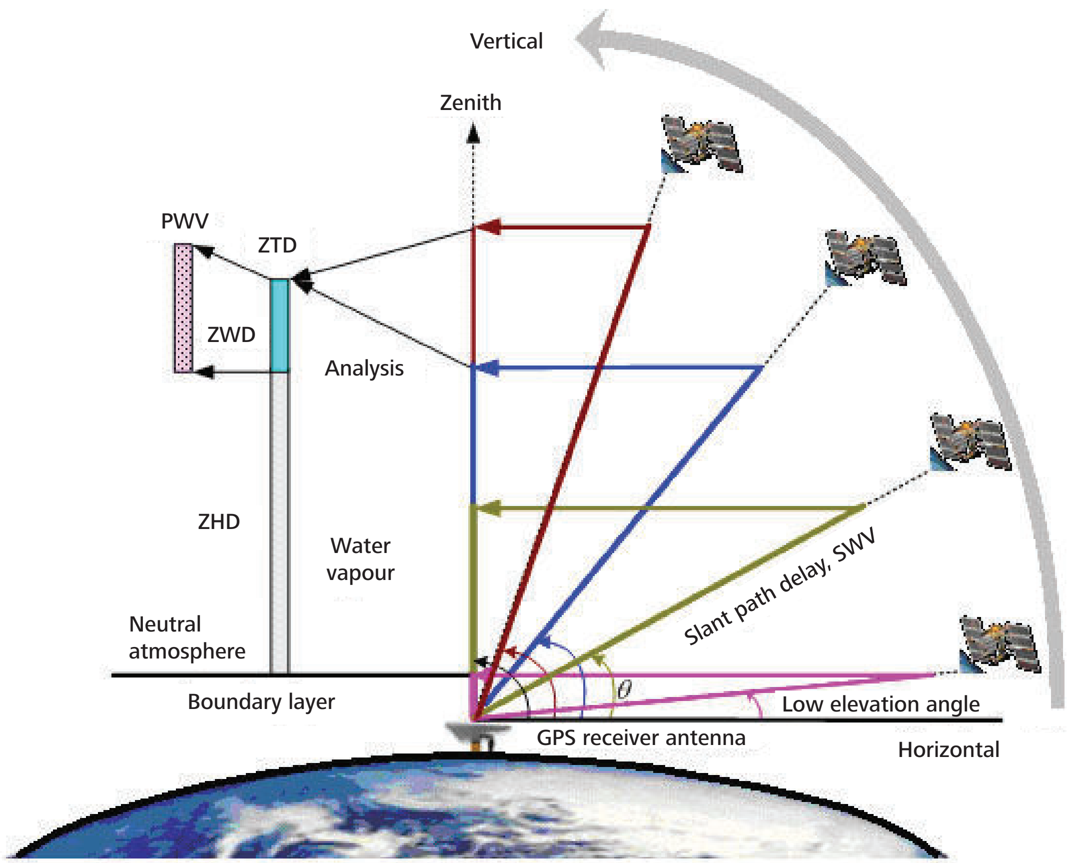


Figure 1. Basic concept of GPS PWV measurements.

of November 2002. The GPS system consisted of a Trimble TS5700 24-channel, high precision, dual-frequency GPS receiver with Trimble Zephyr Geodetic antenna and a notebook computer for data logging. The GPS system belonged to the Malaysian Antarctic Research Programme (MARP) and was maintained by Antarctica New Zealand (ANZ). The receiver was set to track GPS signals at a one-second sampling rate and the cutoff elevation angle was set to 13º to eliminate multipath effects on GPS data. The Trimble TS5700 receiver produced three sets of data in Trimble binary format (*.dat, *.ion, and *.eph). A Translate/Edit/Quality Check (TEQC) routine developed by UNAVCO (http://www.unavco.org) was then used to convert the Trimble.dat into RINEX files (*.*n and *.*o) and then rearrange them into separate individual data files (C1, L1, L2 and P2) for ease of processing. A 30 second data sampling was used in order to reduce the processing time. In this work, the GPS observables (ZTD, ZHD, ZWD and PWV) were computed every 10 minutes. A Matlab programme was developed by the first author to perform GPS PWV determination. The method and processing algorithm for PWV determination are presented in Figure 2.

Ground-based Meteorological Observations

As shown in Figure 2, PWV was determined from GPS signals and also from surface meteorological measurements. Therefore, the measurement system for this work consisted of a GPS receiving system and a ground meteorological system. The ground meteorological system was operated and managed by the National Institute of Water and Atmospheric Research Ltd., (NIWA), New Zealand and ANZ. The measurement system consisted of a Vaisala HMP45D for air temperature (*T*) in degrees Celsius and percentage relative humidity measurement (*H*), Vaisala PTB 100A analog Barometer for pressure measurement (*P*) in mbar, Munro Mk11 cup anemometer for determination of wind speed (*W*) in ms^{-1} and a W200P for determination of wind vector direction (*D*) in degrees. The relative humidity and air temperature probe was located inside a standard large wooden Stevenson's screen. The wind sensors were at the top of a 10 m mast. The pressure sensor was located in one of the SBA laboratories alongside the data logger. The sensors were all connected to a Campbell Scientific CR10X data logger. The sample

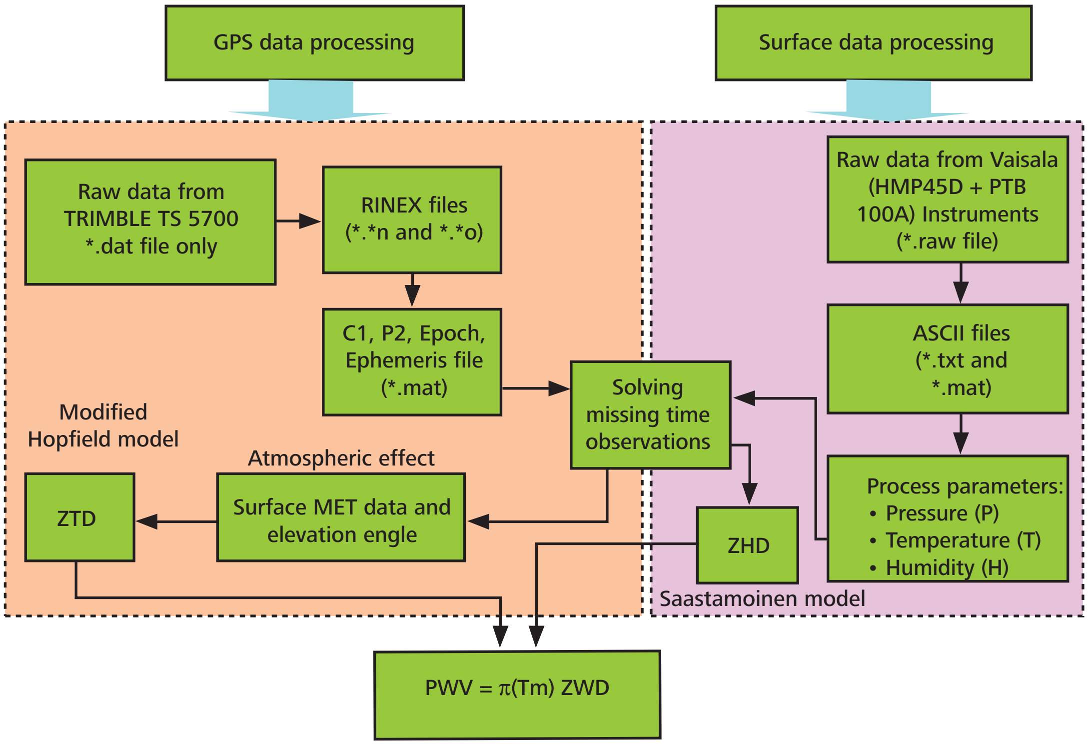


Figure 2. Data processing techniques for PWV determination using GPS and surface meteorological measurements.

rate was 3 seconds. Mean data were logged at 10-minute intervals. On the whole, both the ground-based GPS receiving system and meteorological observations were located at Scott Base station, (Figure 3). As displayed in the figure, Scott Base was at a distance of about 3 km from McMurdo station (US Base) and 1353 km from the South Pole with Mt. Erebus behind it, near the tip of Hut Point Peninsula on Ross Island. Within this station, the average minimum and maximum elevation looking towards the GPS satellites were about 39 and 61 degrees, respectively. The mean annual values for temperature and wind speed were about –19ºC and 6 ms^{-1}, respectively.

RESULTS AND DISCUSSIONS

The profiles of GPS observable results (ZHD, ZWD, ZTD and PWV) for a 10 day observation were plotted (Figure 4). The results were averaged at 10-minute intervals and the date marked on the figure represented noon UT. The temporal of ZTD variation closely followed the ZHD patterns, where the ZHD pattern followed the variation in surface pressure. The ZTD value varied from 2.23 m to 2.38 m and was dependent on the variation of the elevation angle or slant-path length of the GPS satellites. Depending on the geographical position, the typical value of ZTD in zenith direction was between 1.90 m to 2.50 m at sea level (Rocken *et al*. 1995) and it increased with decreasing satellite elevation angle. During the observation period, the temporal of PWV variation exhibited an irregular pattern closely following the ZWD patterns, however the PWV profile had some resemblances with variation of local temperature.

Figure 5 shows the local surface conditions at Scott Base station. Note that the period of observation was in November which is the last month of the spring season (late spring) of Antarctica. This usually causes the melting of the ice packs of the winter season. The temporal variation of surface pressure during the observation period exhibited a sinusoidal pattern which was a discrepancy compared to the local temperature and humidity profiles. The humidity profile during this period was a reversal compared to the surface temperature patterns. The wind was observed flowing in all direction with speeds varying between 0 and 10.92 ms^{-1}. The mean values of the humidity, temperature, surface pressure, wind speed and wind direction for this period were 70.67%, –13.18ºC, 983.50 mbar, 3.78 ms^{-1} and 83.04 degrees, respectively.

Based on the severe wind depiction from Parish (personal communication 2006) and Glickman (2000), katabatic winds are strong winds with a minimum speed of 4 ms^{-1} during which the pressure and humidity level rise while the temperature level falls. This wind originates in the cold upland areas of the Transantarctic mountains and cascades toward lower elevations to McMurdo Sound under the influence of gravity. Accordingly, to identify

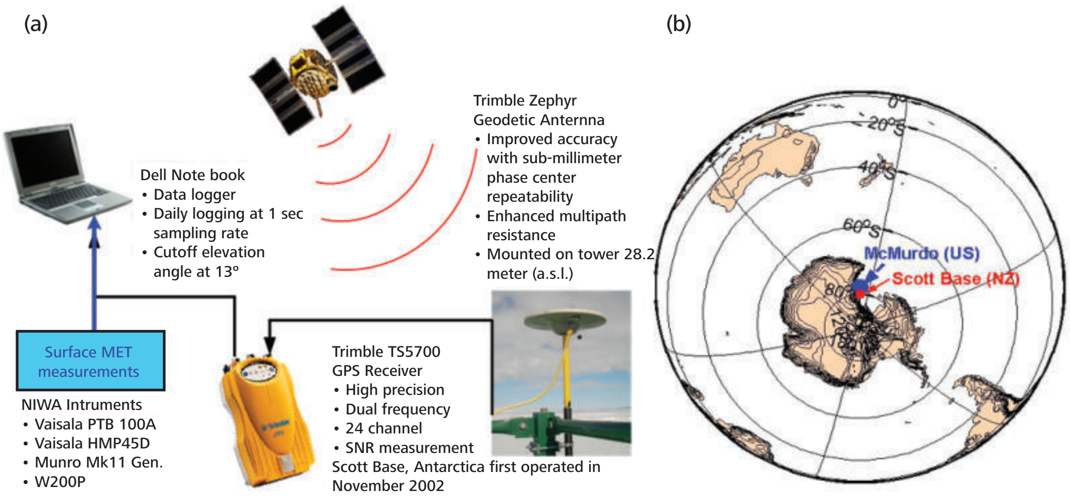


Figure 3. (a) Ground-based GPS PWV measurements; (b) Location of observation.

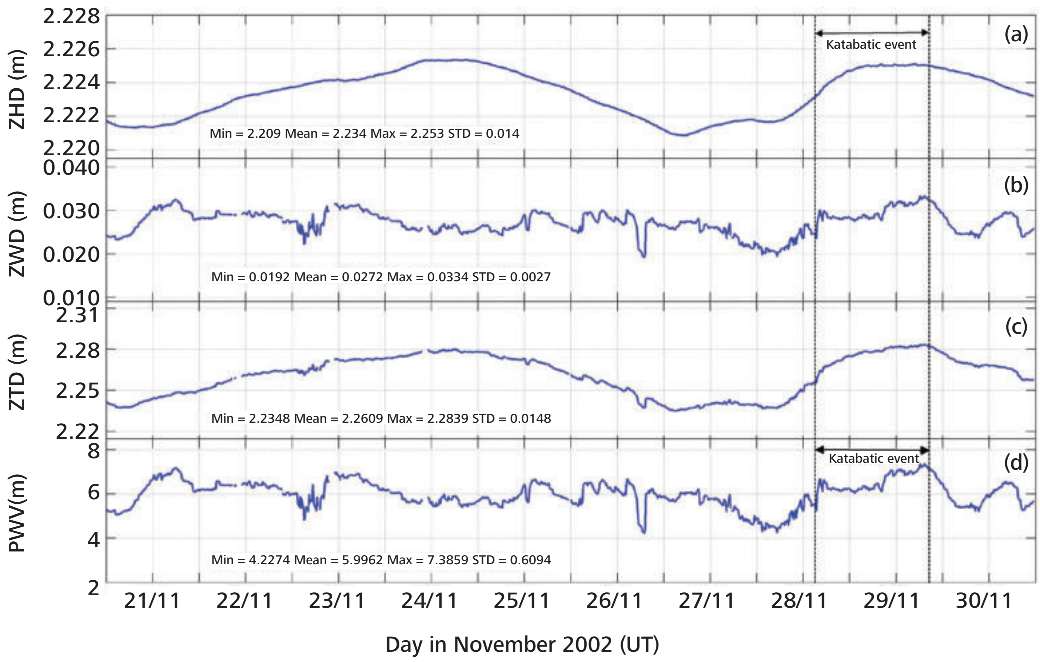


Figure 4. (a) Time series of ZHD; (b) ZWD; (c) ZTD and (d) PWV at Scott Base station Antarctica for the period from 21st to 30th of November 2002. Local Time at Scott Base was UT+12 h. Katabatic event detection can be noted in the figure between 28th and 29th of November 2002.

this katabatic winds, wind speed and wind direction in the surface meteorological records in Figures 5d and 5e are firstly compared. There were nine episodes of wind katabatic event which were identified based on the wind speed activities. These episodes are marked as A to I on the figure. Note in the figure: during episode *H*, strong winds between 21:30 UT on 28th November and 18:40 UT on 29th November are observed to flow from Southeast-South at a median speed of 8.05 ms^{-1}. For episodes *B, D, E* and *F*, there was moderate winds from the Northeast-Northwest into the land of the Ross Sea with a median speed of 4.92 ms^{-1}. These wind episodes were not of a katabatic wind type, they could be due to the storm activity originating from the sea. Low wind speed at episodes *A, C, D, G* and *I* were observed to flow from North-Northeast at a median speed of 2.97 ms^{-1}. These winds were not coming from the Ross Ice Shelf. However, in episode C, the wind seems to change directions frequently in all directions with a median speed of about 1.97 ms^{-1}. From the identification of wind episodes in Figure 5 and by comparing it with Figure 4, four

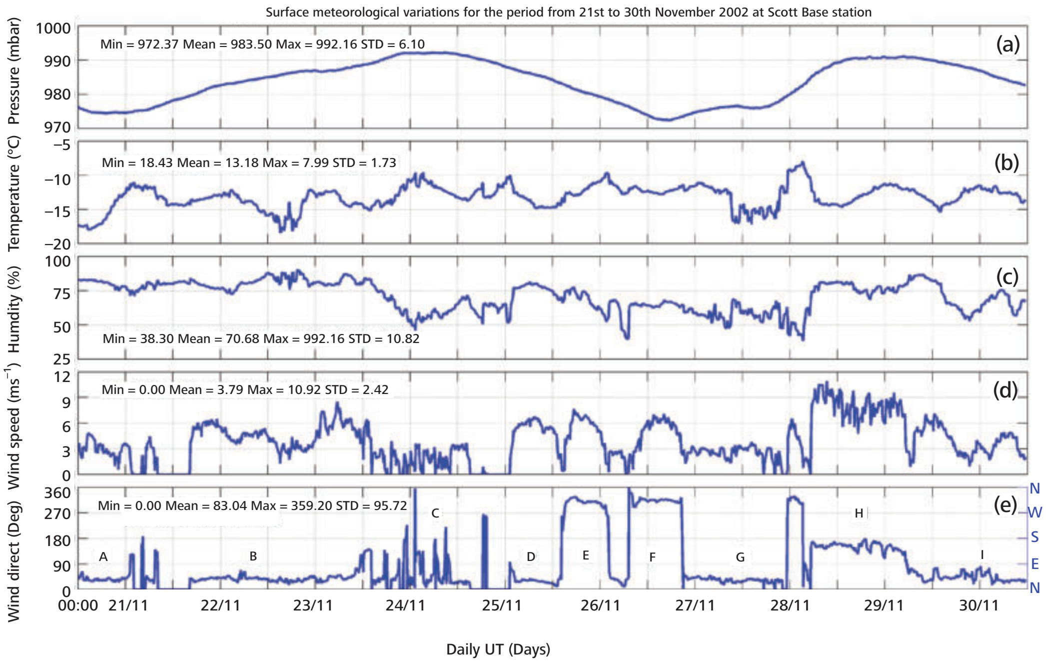


Figure 5. Time series of pressure, temperature, humidity, wind speed and wind direction measurements at Scott Base, Antarctica from 21st to 30th of November 2002.

episodes of katabatic winds could possibly be identified from ZHD (Figure 4). Ambient horizontal pressure gradients (Figure 5a) could have played a central role in shaping the katabatic winds that forced the PWV through ZHD variability. These are episodes *A, C, G* and *H*. Both wind episodes *A* and *G* had the same character with the average ZHD of 2.205 m, average PWV of 5.40 mm, and the wind was coming from North-Northeast with a maximum speed of about 4.96 ms^{-1}. The wind episodes *C* and *H* had the same average ZHD of about 2.254 m. However the wind episode *H*, had a higher PWV than that of wind episode C, with an average PWV of 6.525 mm and the difference in PWV between the two episodes was around 1.4 mm. Maximum wind speed recorded during wind episode *H* was about 10.92 ms^{-1}.

To make clear the detection of the characteristics of a katabatic event, wind speed versus wind direction, or wind in compass form was plotted (Figure 6a). As shown in Figure 6b, there were three katabatics event detected over the helm topographic control, NE, SE and NW. From Figure 6a, the dominant wind patterns were observed flowing from the North-Northeast (Ross Sea Island) direction, but their direction was not consistently coming from the Ross Ice Shelf (SE). By analyzing the characteristics of katabatic wind events in Figure 5 and comparing it with Figure 6b, the wind in episode *H* had a clear signature of katabatic wind. During this event, the wind pattern flowed from the SE, followed by surface pressure ascending up to 989.3 mbar and the temperature degraded abruptly down to –15ºC, while the humidity level increased abruptly up to about 80%, suggesting that during this condition, the ice surfaces were rapidly sublimating together (Nylen *et al.* 2004).

Figure 7 shows the impact of a katabatic event on GPS PWV variability. There are correlation coefficients for their relationships displayed in each figure. In Figures 7a and 7c, the PWV versus wind speed and humidity showed a linear relationship with correlation coefficients of 0.63 and 0.72, respectively. The relative humidity showed a stronger influence on the PWV than that of the wind speed. The PWV observed exhibited a nonlinear relationship with surface pressure and temperature (Figures 7b and 7d). The association between PWV and surface pressure was difficult to quantify. The relationship between PWV and temperature was not linear on any conditions, it was factually proper in exponential form when viewed at the long-term data (Suparta *et al.* 2009). The PWV maximum was between –15ºC and –11ºC. On the whole, the maximum PWV value obtained at Scott Base station for this period was 7.38 mm, which was in good agreement with the result obtained by Vey *et al.* (2003) with the calculated value of PWV which was below 10 mm at 6 stations in Antarctica (one of the stations was at McMurdo). Their satellite radiometric measurements were conducted for a five year period from 1997 to 2002. The low PWV content at Scott Base was due to the station which was situated at the coast which had very dry conditions. Table 1 shows the results from Scott Base Station for the period between 21st and 30th of November 2002 which was identified as a katabatic event.

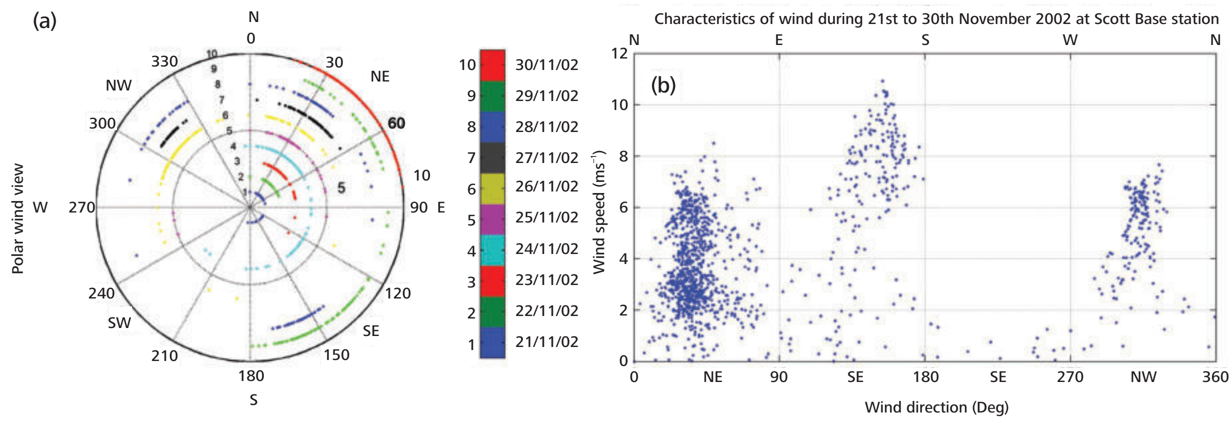


Figure 6. Profile of wind direction versus wind speed (wind compass) measured at Scott Base station, Antarctica from 21st to 30th of November 2002.

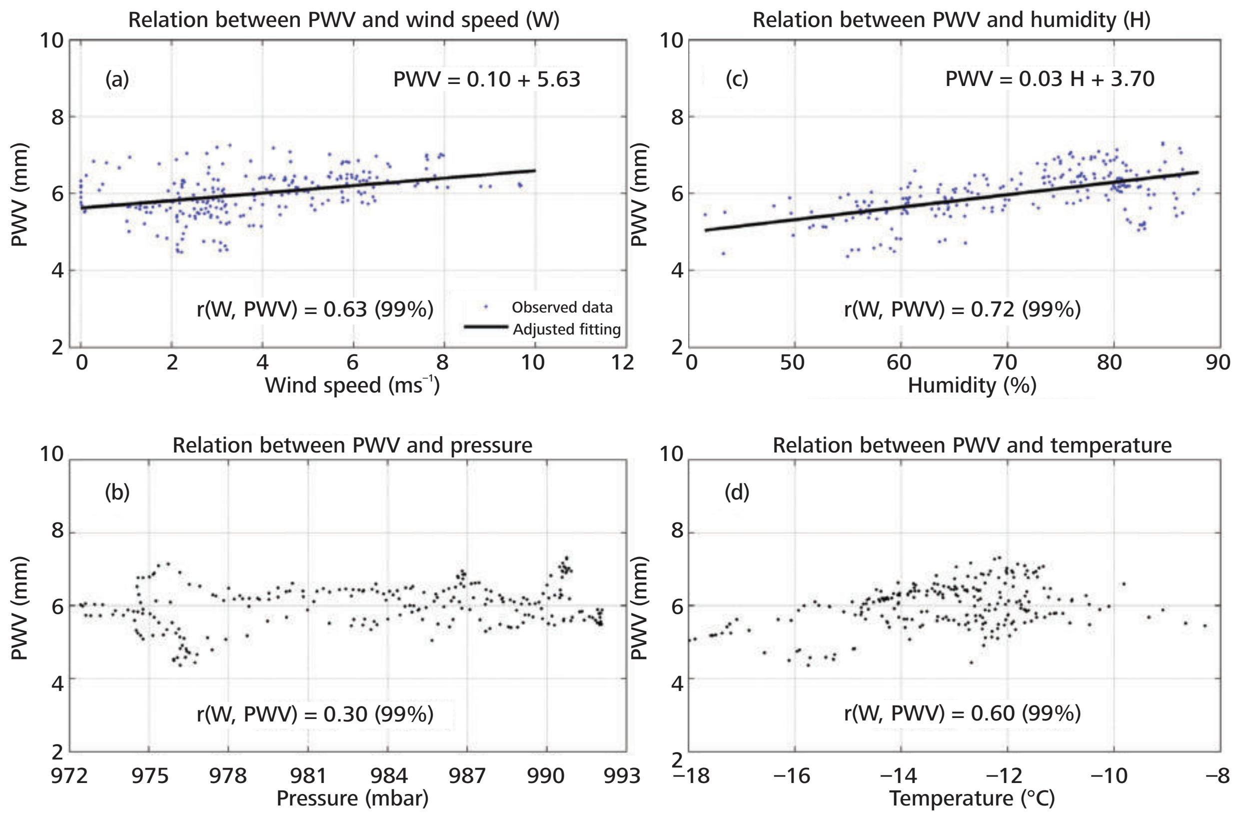


Figure 7. (a) The relation between PWV and wind speed; (b) PWV versus surface pressure; (c) PWV versus humidity and (d) PWV versus temperature measured at Scott Base station, Antarctica for the period from 21st to 30th of November 2002. All correlation coefficients (r) were significant at the 99% confidence level.

SUMMARY AND CONCLUSION

This study employed a ground-based GPS and surface meteorological measurements to quantify the PWV. Based on the relationship between GPS observables and surface meteorological data, analysis of severe winds to detect a katabatic event became feasible. Accordingly, to the authors' knowledge, the detection of a katabatic event at Scott Base, Antarctica for the period between 21st and 30th of November 2002 was done for the first time. Our investigations showed that during the observation period, the temporal of ZTD variation exhibited a periodic pattern which closely followed the ZHD and surface pressure patterns. PWV value at this period was more strongly influenced by humidity than by wind speed. The dominant wind flowed from the North-Northeast (blowing from the

Table 1. Summary of ground-based GPS and surface meteorological observations at Scott Base Station, Antarctica (77.9ºS, 166.8ºE) from 21st to 30th of November 2002.

Parameters	Statistical summary of observations				Remarks
	Minimum	Mean	Maximum	STD	
ZHD (m)	2.208	2.234	2.254	0.014	Depends on surface pressure and geographic location (~98% dry air)
ZWD (m)	0.009	0.017	0.023	0.014	Depends on the moisture and temperature conditions
ZTD (m)	2.564	2.817	3.047	0.095	Their patterns follows the ZHD and elevation angle variations
PWV (mm)	4.227	5.996	7.386	0.510	Increases at temperatures between –15ºC and –11ºC
Pressure (mbar)	972.37	983.50	992.16	6.100	Typically 1013.25 mbar, depends on location and greater number of air molecules above the site
Temperature (ºC)	–18.43	–13.18	–7.99	1.730	Coldness and warmth of region depends on atmospheric conditions and solar radiation at the surface
Humidity (%)	38.30	70.68	90.40	10.820	Depends on amount of water vapour in the air
Wind speed (ms^{-1})	0	3.79	10.92	2.420	Depends on the movement of air or other gases in the atmosphere and local conditions.
Katabatic wind (ms^{-1})	4.76	8.02	10.92	1.281	Occurred on 21:30 UT on 28th November to 18:40 UT on 29th November, the wind flowed from the Southeast-South direction
PWV (mm)	5.241	6.525	7.386	0.429	

Ross Sea) direction with a median speed of 4.96 ms^{-1}. A katabatic wind event was identified between 21:30 UT on 28th November and 18:40 UT on 29th November, which flowed from the Southeast-South (from the Sea Ice Shelf) direction at a median speed of 8.05 ms^{-1}. PWV was observed to increase during this event to a maximum value of 7.38 mm. The PWV content was high and was about 1.4 mm (~23%) from its mean value at temperatures between –15ºC and –11ºC.

For the first time, the association between PWV and katabatic wind was discussed (Results and Discussion). As indicated by Parish (personal communication 2006), the characteristics of an identified katabatic wind is described as follows. On the high Polar plateau, katabatic winds descend down the mountain slopes (the valleys of the Transantarctic mountains), and flow down the side of the continent into the ocean, or in the case where it affected Scott Base, mixed with the surface inversion and are generally much stronger than mountain breezes. They flow down the slopes driven by cooling at the slope surface during periods of light larger-scale winds; the nocturnal component of the along-slope wind systems. When this cold air (denser than warm air), moves to lower elevations, its speed accelerates, and becomes very fast winds. These winds can cause sudden changes in the weather in the area when the winds spill out. When the katabatic winds descend the mountains and mix with the surface inversion (an inversion is an area where temperature increases with height, instead of the usual case where temperature decreases with height), they actually become warmer than the surrounding air. At this junction, the temperature decreases at the onset of the katabatic event, and the moisture becomes more active and water vapour molecules increase. This event also increases the humidity which causes the katabatic event in the Antarctic coast to significantly affect precipitation (PWV). However, further investigations over many months are needed to accurately quantify these results or dependencies and to better describe their physical mechanisms. The impact of the katabatic event on the GPS signals was probably influenced by the local horizontal gradients of total tropospheric delay.

ACKNOWLEDGEMENTS

This work was supported by the Institute of Space Science, Universiti Kebangsaan Malaysia. The authors would like to express their gratitude to Malaysian Antarctic Research Programme co-ordinated by the Academy of Sciences Malaysia and Ministry of Science, Technology and Innovation Malaysia (MOSTI) for funding this research under PKT1/2003 grant. We are grateful to Antarctica New Zealand for the logistics support under the ANZ K141B event and the National Institute of Water and Atmospheric Research Ltd., New Zealand for the meteorological data.

Date of submission: October 2008
Date of acceptance: November 2009

REFERENCES

Duan, J *et al.* 1996, 'GPS meteorology: Direct estimation of the absolute value of precipitable water', *J. Appl. Meteorol.*, vol. 35, no. 6, pp. 830–838.

Glickman, TS 2000, *Glossary of meteorology*, American Meteorological Society (AMS), <http://amsglossary.allenpress.com/glossary/Katabatic_wind>.

Kunches, JM & Klobuchar, JA 2000, 'Eye on the ionosphere, some aspects of the variability of geomagnetic storms', *GPS Solutions*, vol. 4, no. 1, pp. 77–78.

Liou, YA, Huang, CY & Teng, YT 2000, 'Precipitable water observed by ground-based GPS receivers and microwave radiometry', *Earth Planets Space*, vol. 52, pp. 445–450.

Nakamura, H 2003, *International workshop on GPS Meteorology*, <http://dbx.cr.chiba-u.jp/Gps_Met/gpsmet/CD1_Proceedings_PDF/01_Head%5C01_08_WsSummary.pdf>.

Nylen, TH, Fountain, AG & Doran, PT 2004, 'Climatology of katabatic winds in the McMurdo dry valleys, Southern Victoria land, Antarctica', *J. Geophys. Res.*, 109(D03114), doi:10.1029/2003JD003937.

Rocken, C *et al.* 1995, 'GPS/STORM-GPS sensing of atmospheric water vapour for meteorology', *J. Atmos. Oceanic Technol*., vol. 12, pp. 468–478.

Rocken, C, Hove, TV & Ware, R 1997, 'Near real-time GPS sensing of atmospheric water vapour', *Geophys. Res. Lett*., vol. 24, no. 24, pp. 3221–3224.

Rocken, C *et al.* 1999, 'Water vapour tomography with low cost GPS receivers', GPS Research Group, UCAR, P.O. Box 3000, Boulder CO 80308, <http://www.gst.ucar.edu/gpsrg/arm98_paper.pdf>.

Suparta, W *et al.* 2008, 'Observations of precipitable water vapour and its responses to the solar activity at Antarctica based on GPS sensing', *J. Atmos. Sol-Terr. Phys*., vol. 70, pp. 1419–1447.

Suparta, W, Mohd Ali, MA & Yatim, B 2009, 'Characterization of water vapour variability based on GPS sensing', *The International Journal of Climate Change: Impacts and Responses*, vol. 1 , pp. 17–29.

Turner, J & Pendlebury, S (eds.) 2004, *The international Antarctic weather forecasting handbook*, British Antarctic Survey, Cambridge, UK.

Vey, S, Johnsen, KP, Miao, J & Heygster, G 2003, 'Cross validation of water vapour retrievals from ground based GPS and satellite radiometric measurements over Antarctica', in *International Workshop on GPS Meteorology*, Tsukuba, Japan.

Ware, R, Alber, C, Rocken, C & Solheim, F 1997, Sensing integrated water vapour along GPS ray paths, *Geophys. Res. Lett*., vol. 24, pp. 417–420.

Welsh, D 2000, 'Global positioning system for water vapour measurements', <http://www.etl.noaa.gov/technology/archive/gps/>.

Yuan, L *et al.* 1993, 'Sensing climate change using the Global Positioning System', *Geophys. Res., vol*. 98(D8), pp. 14925–14937.

ASM Sci. J., **3(2)**, 161–167

Geographic Information System Mapping in Pedro Vicente Maldonado Ecuadorian Scientific Station Antarctica Base (Greenwich Island) Antarctic Peninsular

R. Fauzi[1]*, D.M. Salazar[2], R.M. Kadzim[3], L. Burbano[4] and A. Hussin[5]

In this project, a Geographic Information System (GIS) was used to collect and compile various field data in the Pedro Vicente Maldonado Ecuadorian Scientific Station Antarctica Base area. The main source of data was obtained from a global positioning system (GPS) survey using kinematic GPS (GPS-RTK) which allowed continuous point mapping in the terrain. GPS units were utilized in the collection of spatial data for all field work. The co-ordinates obtained were used to produce a point map which was then exported into GIS software where the proximity of cartographic phenomena and boundaries were mapped. All the collected data were subsequently gathered to develop the GIS database which was then used to generate and compile different maps to test for spatial and temporal relationships. The output of the project comprises a GIS database, spatial maps and 3D terrain model of the area. The developed GIS database can be used with other ecological datasets to provide biogeographical information, potential range distribution and sampling adequacy. The database is also applicable to geographical management and multi-disciplinary research projects.

Key words: survey; GPS; collection; spatial data; GIS database; ecological datasets; biogeographical information; range distribution; sampling adequacy; 3D terrain model

In the past, detailed spatial mapping was a difficult, and sometimes, impossible task to carry out in areas without topographic information. Even in locations where good topographic maps are available, mapping of small or very irregular landforms can be difficult (Vieira *et al.* 2000). Today, Geographic Information Systems (GIS) are used significantly for detailed spatial surveying, mapping and developing spatial databases with accuracy at much faster rates. Moreover, this is more practical with a kinematic GPS (GPS-RTK) that allows mapping points or lines continuously in the terrain with an error of only a few centimetres.

Basically, the objectives of the GIS project in this expedition were to collect field data and subsequently compile other data obtained by different scientists which would be transferred into a GIS program. The geo-referenced data was then used to generate and compile different maps to test for spatial and temporal relationships. The project's tasks include developing a standard spatial data model, obtaining and integrating spatial data sets and providing an interface for the data. This was the basis for studying the relationship between geology, geomorphology, glacial retreat and their impact to the biology, environmental management and multi-disciplinary research projects.

MATERIALS AND METHODS

Detailed mapping was carried out around Pedro Vicente Maldonado Ecuadorian Scientific Station Antarctica Base at 62º 31'S, 59º 47' W. This provided a coherent geological and topographical picture of the surroundings. Mapping was carried out in the Fort William headland area, glacier sites, coastal areas and in the raised beach sites.

GIS Procedures

Firstly, GIS techniques were used for mapping and developing a spatial data base for the project. The main source of data was from a global positioning system (GPS) survey using a kinematic GPS (GPS-RTK) which allowed continuous point mapping of the terrain. Each point consisted of Northing (UTM), Easting (UTM) and altitude

[1] Geography Department, Faculty of Arts & Social Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2] Universidad Estatal Peninsula De Santa Elena, Via La Libertad, Santa Elena, Ecuador
[3] Department of Surveying Science & Geomatic, Faculty of Architecture, Planning and Surveying, MARA University of Technology, 40450 Shah Alam, Selangor, Malaysia
[4] Instituto Oceanográfico de la Armada, Ave.25 de Julio (Avenida de la Marina), via Puerto Base Naval Sur, 5940 Guayaquil, Ecuador
[5] Geology Department, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
*Corresponding author (e-mail: rosmadifauzi@um.edu.my)

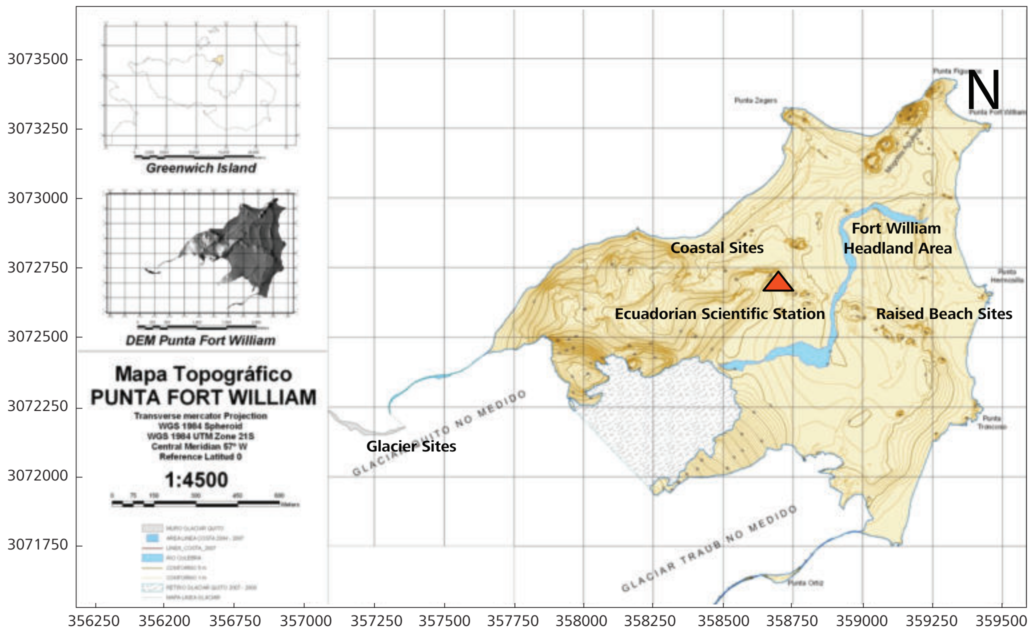


Figure 1. The Mapping areas.

readings in WGS 1984 (UTM), Universal Transverse Mercator Projection with UTM Zone 21º S Central Meridian 57º W. GPS units were utilized in the collection of spatial data for all field work. The co-ordinates obtained were used to produce a point map which was then exported into GIS software where the proximity of cartographic phenomena and boundaries were mapped. Other data gathered from field observations on topography, geology, landforms, flora and fauna were also used for mapping the station and its adjoining areas. All the collected data were subsequently compiled to develop the GIS database and generate different maps to test for spatial and temporal relationships. Photos related to the GIS and GPS survey are shown in Figure 2.

For the detailed GIS and GPS survey, the GPS-RTK system was programmed to record co-ordinates continuously at 1 m intervals as the operator was moving. The chosen paths were saved in its memory as sets of individual points representing latitude, longitude and altitude. The data collected in the field survey was exported into an ASCII table, with identification of the measurement point number, latitude (UTM), longitude (UTM) and altitude. This table was then imported into the GIS software Arc GIS 9.2. The co-ordinates were used to produce a point map that was exported to a drawing package as shown in Figure 3. The proximity between the points was large enough for drawing the lines that formed the cartographic phenomena. The final spatial map was constructed within the drawing package and included both the information collected with the GPS-RTK system and the classical field survey.

In this project, digital maps of Greenwich Island with a scale of 1:50 000 were used as the base maps for the thematic layers and listings of processed data in the field area. Spatial and non-spatial data were analyzed through various GIS technique functions, such as geo-processing, data analysis and overlaying, and GIS modelling. The results were then displayed as thematic layers in 2D and 3D GIS models as shown in Figure 4. The Arc Toolbox application in Arc GIS 9.2, which provides a powerful set of geo-processing functions, was used to import the GPS data surveys and map layers into the Arc Map application. Each of the different shoreline types and boundaries were imported as different layers. In the geographic data view, geographic layers representing the GPS survey types were compiled into GIS data sets (Seeber 1993). A table of contents interface organizes and controls the drawing properties of the GIS data layers in the data frame.

Designed for GIS mapping, Arc Map also enables the use of different in-built symbols to represent some important environmental resources. In the page layout view, the layout can be modified to improve the design and visual balance of the composition by adding new map elements and changing the properties of the existing map elements (Chang 2008).

Previously, the area was never mapped at such a detailed scale by other researchers. The maps constructed in this project not only benefited from the information of previous works but also contained new data, especially regarding

Figure 2. GIS and GPS Survey.

Figure 3. Points from GPS Survey.

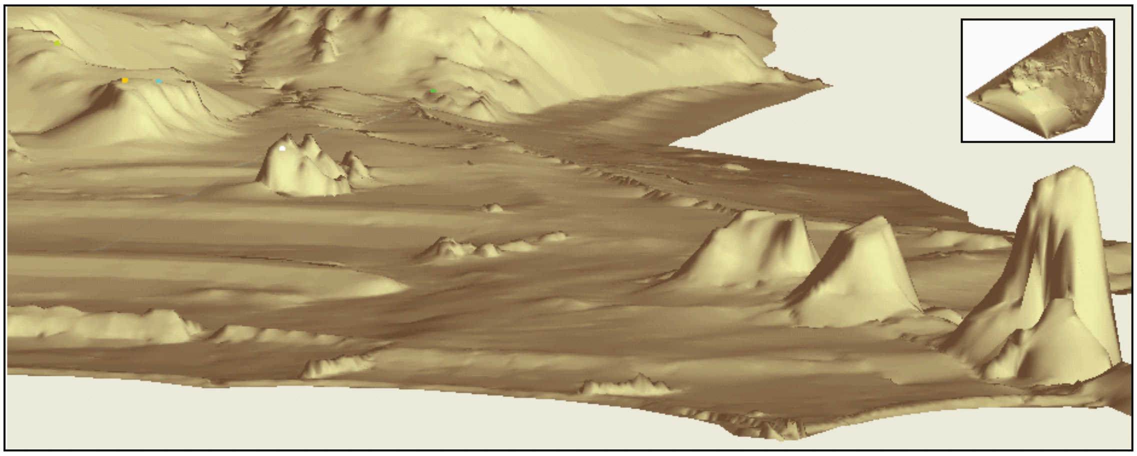


Figure 4. Results displayed as thematic layers in GIS model.

glacial forms and deposits. However, the maps were not completely GPS-RTK based due to the scarce amount of time available to use the system and the experimental nature of this approach. It is important to note that the kind of information generated during this survey was accurate and could be used in much more detailed scales than 1:5000. The independent georeferenced data allows a high flexibility for its future use, making its application possible in a variety of scales. Furthermore, the use of this kind of system allows very accurate and fast mapping as well as full integration with GIS (Klepikov 2001). These can be significant factors for its implementation despite its relatively high cost; the system has applications for a wide range of mapping purposes in the framework of earth, biological or environmental (Leick 1990). In areas where there are no existing topographic maps or with bad topographic maps, the GPS-RTK can also be used to generate contour or to correct the topographic background (Lambiel & Delaloye 2004). The contour of the areas generated from GPS points is shown in Figure 5.

RESULTS

The output from the GIS project consists of the GIS database, spatial model and the 3D terrain model. These are descriped below.

GIS Database

A GIS database for Pedro Vicente Maldonado Ecuadorian Scientific Station Antarctica Base and its surroundings was developed. The database could be utilized for presenting and distributing existing information on the base station area. The database contains topographical data as well as data on the geology, landforms, flora and fauna. The data representative of the attributes associated with the objects were placed in files accessible by GIS software which utilizes the data to form a GIS database from which GIS maps are formed as shown in Figure 6.

Spatial Maps

Among the maps produced from the mapping project were maps of location sites of flora and fauna, such as penguin habitats and birds' nests, and physical features such as rivers, lakes and the snowmelt boundary. The shoreline and bathymetry near the base area had also been mapped. The spatial maps significantly visualize the spatial patterns of the features surrounding the base area as shown in Figure 7. The maps provide spatial information that describe the physical features of the area and the biogeographical features of its surrounding. These maps are essential in the management of current research and future planning of the area.

3D Terrain Model

Figure 8 shows a 3D terrain model developed for the base area which include the four mapping area sites: the Fort William headland area, the Glacier sites, the coastal area and the raised beach site. The 3D model represents the ground surface topography of the areas.

The model was produced using GIS techniques which utilized the elevation data obtained from the direct GPS survey using kinematic methods and a laser range finder. Terrain analysis had been done to evaluate the watershed, vertical profiling and slope of the areas. The result of one such analysis is shown in Figure 9 below. The 3D model will be used by various researchers to study the relationship between terrain and other biogeographical elements.

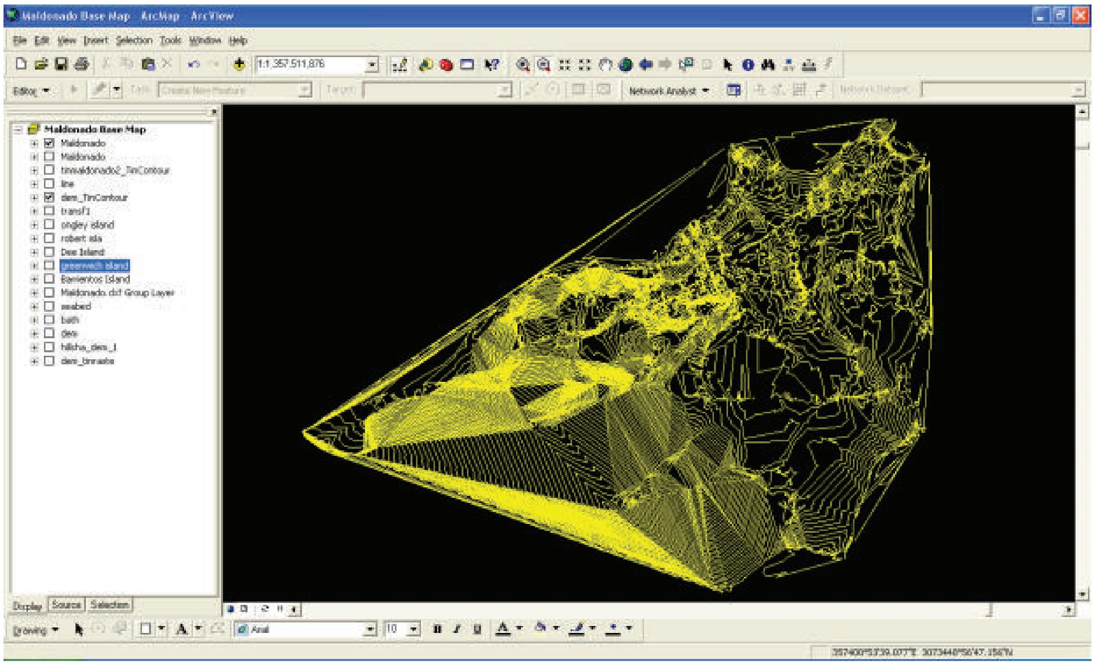


Figure 5. Contour Generated from GPS points.

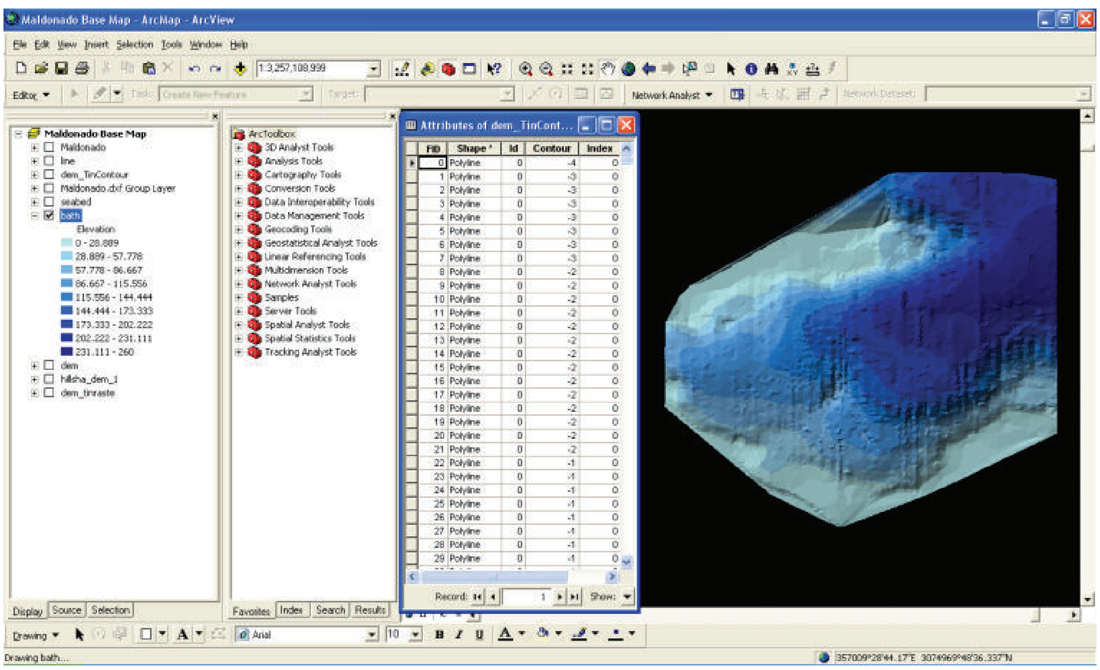


Figure 6. Developed GIS database.

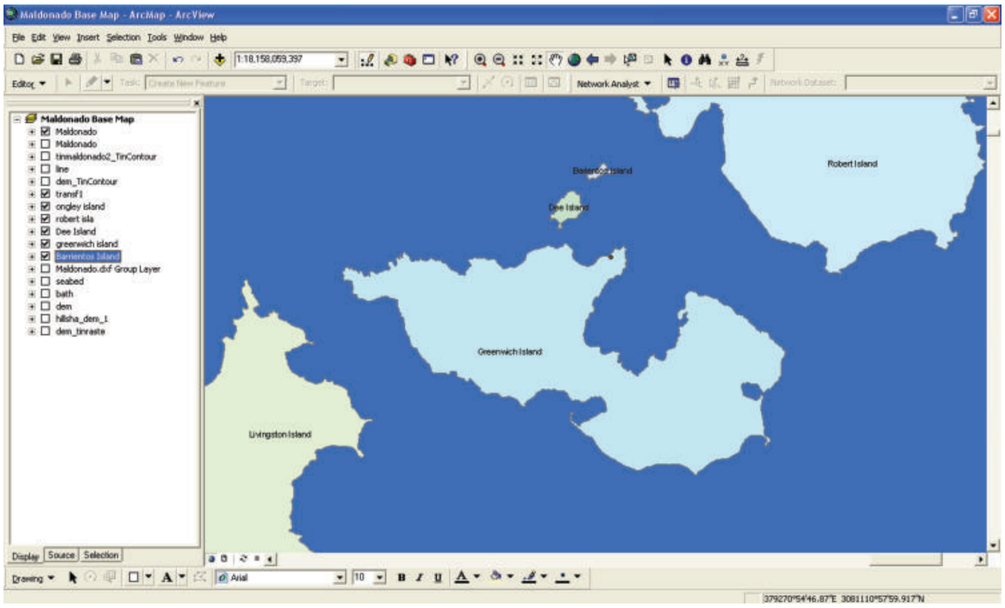


Figure 7. Spatial maps.

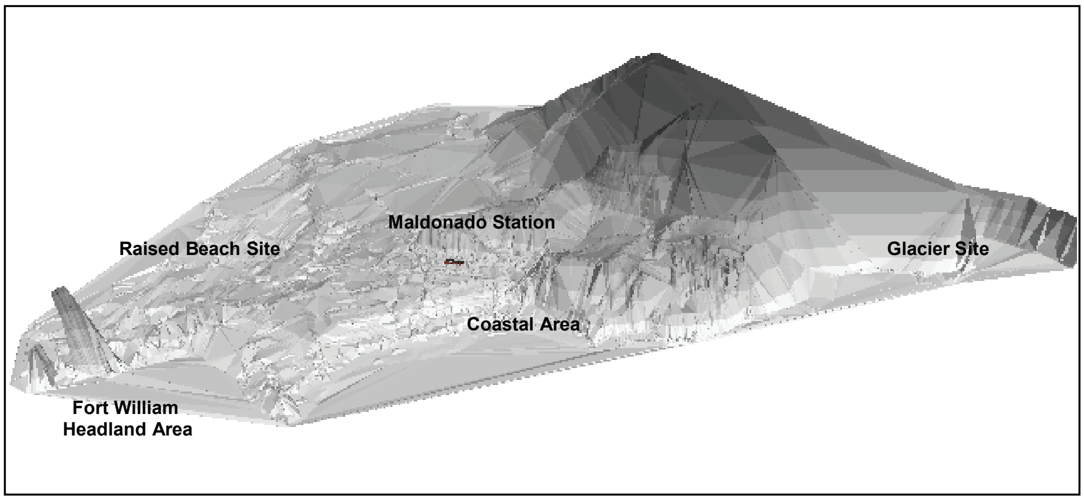


Figure 8. 3D Model derived from GIS.

CONCLUSION

It is worth noting that the availability of GIS influenced not only our procedures but our whole approach to the survey. The ability to easily capture and manipulate map data and its associated attributes encouraged us to take a flexible map-based approach. As a result, a greater use of existing resources (topographic maps and aerial photographs) was made and, geographic features and data within defined survey plots (requiring mapping and mathematical standardization) was recorded. This yielded more directly comparable data values which were lacking in the more conventional grid-based approach.

As the project progressed, the integrated database generated from differing fieldwork formed an integral part of the results of the project; allowing researchers to reassess results, compare them with other surveys, or carry out

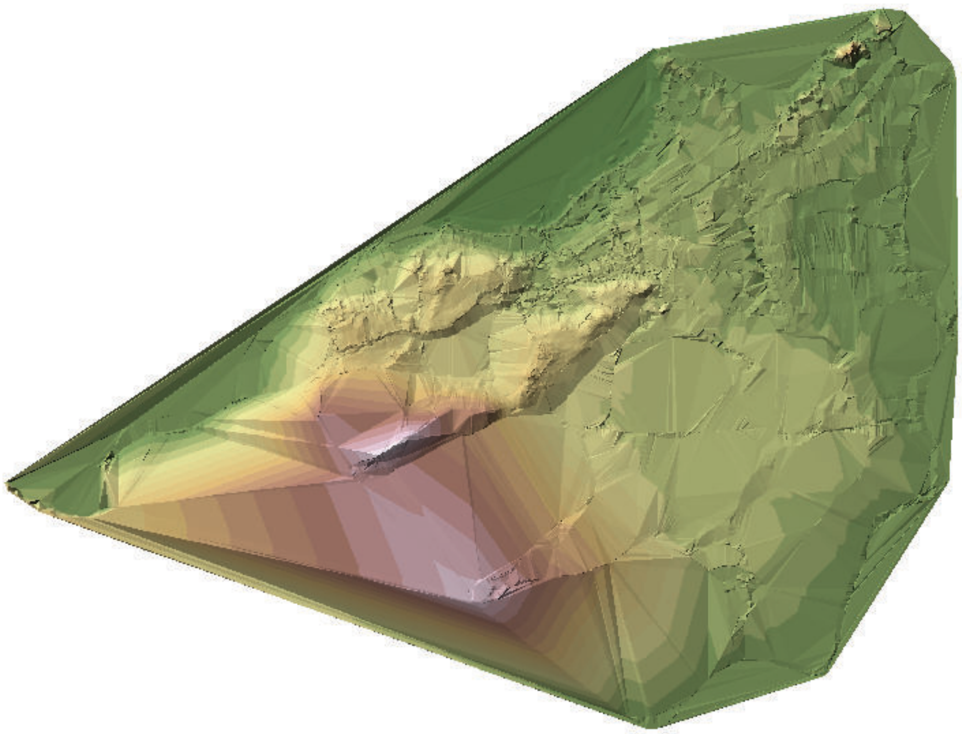


Figure 9. GIS Manipulated-TIN Surface.

further analyses. It is hoped that this project will become a model for detailed topographical landscape analysis through GIS. Perhaps a much larger field survey of the area could be carried out in future to complete more specialised aspects of the study and perfect the methodology.

ACKNOWLEDGEMENTS

This project is part of Instituto Antartico Ecuatoriano (INAE) and Malaysia Antarctic Research Programme research. The authors gratefully acknowledge the support for this scientific expedition given by the Geography Department University of Malaya, Universidad Estatal Peninsula De Santa Elena (UPSE) Ecuador, MARA University of Technology Malaysia, Instituto Oceanográfico de la Armada Ecuador, Academy of Sciences Malaysia and all the expedition team members.

Date of submission: October 2008
Date of acceptance: November 2009

REFERENCES

Chang, K 2008, *Introduction to geographic information systems*, Mc Graw Hill, New York.

Klepikov, A 2001, 'Outline of geographic information system of the antarctic environment developing in the arctic and antarctic research institute', in *Proceedings of the SCAR Antarctic Geodesy Symposium*, 2001, SCAR, St. Petersburg Russia.

Lambiel, C & Delaloye, R 2004, 'Contribution of real-time kinematic GPS in the study of creeping mountain permafrost: examples from the Western Swiss Alps', *Permafrost and Periglacial Process*, vol.15, pp. 229–241.

Leick, A 1990, *GPS satellite surveying*, John Wiley and Sons, New York.

Seeber, G 1993, *Satellite Geodesy: foundations, methods and applications*, Walter de Gruyter, New York.

Vieira, G, Ramos, M & Garate, J 2000, 'Detailed geomorphological mapping with kynematic GPS. Examples from Livingston Island, Antarctic', *Estudos do Quaternário*, vol. 4, pp. 35–42.

ASM Sci. J., **3(2)**, 168–177

Ionospheric GPS-TEC Characteristics during the 2003 Extreme Storm Events at Scott Base Antarctica

S. Sulaiman*, M.A.M. Ali, B. Yatim and M.A. Momani

The response of the ionosphere provides us with some indicators of the processes and geophysical changes of the Sun-Heliospheric system during an intense geomagnetic period. In this work, we investigated the characteristics of the 2003 extreme storm events, based on global positioning system (GPS) -total electron constant (TEC) measurement at Scott Base station Antarctica (GC: 77.85ºS, 166.76ºE; CGM: 79.94ºS, 327.23ºE). Our main emphasis was on the characteristics during extreme storms events and the mechanisms that triggered the events during the October and November 2003 storms. Analyses from the two storm events clearly indicated that the October 2003 storm had more of an impact on ionospheric response than the November 2003 storm. Our discussions would include the daily GPS-TEC and percentage of TEC deviation (Δ% TEC) at Scott Base Station compared with the solar X-ray flux from Geostationary Operation Environmental Satellite (GOES), interplanetary magnetic field (IMF) solar wind data from MFI/SWE instruments and plasma parameters (velocity, density and temperature) onboard the WIND and Ulysses spacecrafts. Comparisons were also made with the planetary magnetic and solar indices from WDC and NOAA SEC.

Key words: geomagnetic storm; GPS-TEC; ionosphere; solar wind; solar X-ray; GOES; MFI/SWE; plasma parameters; Ulysses spacecrafts; WDC Kyoto; NOAA SEC

The ionosphere is prone to significant disturbances which are considerably worse during periods of high solar activity, such as at solar maximum (Moore *et al.* 2001). From time to time, the ionosphere suffers major perturbations, called geomagnetic or thermospheric/ionospheric storms, which last from a few hours to a few days. Geomagnetic storms tend to occur during times of geophysical disturbances resulting from increases in solar activity communicated via the solar wind. The magnitude of the effects vary with latitudes, being greatest at middle and high latitudes where the maximum electron density may be depressed by as much as 30% in a strong storm (Hunsucker & Hargreaves 2003).

The ionospheric storm response most often studied has been the dramatic variation of plasma densities at the F2 region of the electron density peak. Those variations can at times exceed 100% from averages and involve enhancements (so-called positive storm phases) and depletions (negative storm phases). The knowledge of plasma density variations, i.e. the capability to give advance predictions for a reasonable time span even for disturbed conditions, has practical significance for such areas of human activity as radio communication, space technology, accurate surveying using global navigation satellite systems (GNSS), and other applications which constitute important goals of the recent space weather activities (Matthias & Norbert 2000).

The response of the ionosphere provides us with some indicators of the processes and geophysical changes of the Sun-Heliospheric system during intense geomagnetic periods. When the sun erupts, it can suddenly and violently release bubbles of gas and magnetic fields called the Coronal Mass Ejection (CME); solar events such as solar flares (the huge eruptions on the sun), coronal mass ejection, filament disappearance and eruptive prominences are able to initiate intense geomagnetic storms but it does not mean that each solar event will cause an intense geomagnetic storm (Siqing *et al.* 2004). A large number of observations have indicated that the primary causes of geomagnetic storms were the long-duration of southward IMF which play an important role in determining the amount of solar wind energy transferred into the magnetosphere, the south BZ usually occured within the interplanetary material associated with CME. The conditions and the mechanisms that lead to complex spatial and temporal structures in the ionospheric F region and above during geomagnetic storms have been studied by a large number of scientists worldwide and were summarized in some excellent reviews (Ljiljana & Spomenko 2005).

The magnetic storms on 29–31 October 2003 were among the most extreme disturbances that had resulted from the Earth's magnetosphere interaction with very fast streams of solar plasma. They were accompanied with strong magnetopause compression and auroral oval

Institut Sains Angkasa (ANGKASA), Engineering Building, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor
*Corresponding author (e-mail: sumazly@hotmail.com; sumazly@umt.edu.my)

expansion and were characterized by extremely large variations in magnetospheric parameters (Kalegaev *et al.* 2005). Although plasma density was not so high, these interplanetary shocks influenced two-hump magnetic storms with Dst up to –400 nT. The interplanetary magnetic field (IMF) B_Z component changed orientation several times. This magnetic storm had a very complicated structure. It consisted of three injections, of actually three different magnetic storms. The first one began after a small IMF B_Z negative excursion and continued under a strong positive B_Z IMF jump. The next two injections took place under stable negative IMF B_Z. In combination with strong solar wind dynamic pressure variations they produced significant Dst depressions. This storm was the greatest storm during the 23rd solar cycle and was one of the fastest traveling solar storms in the last two decades (internet link, Spectrum, October 2005). The event was preceded by high solar X-ray energy, which started to take place one week before the storm event. During that time, several solar active regions (SAR) were visible on the surface of the sun which produced substantial solar flare activity a week before, with a combination of a large M-Class followed by six X-Class flares and huge groups of sunspots on the visible solar disk were observed (Panasyuk *et al*. 2004); (Veselovsky *et al.* 2004). The maximum solar X-ray energy was recorded on 28th October at around 09:51 UT, when a series of X17.2/4B flares occurred, accompanied by bursts of radio emissions and ejections of solar mass were observed. The most intense storm activities occured on 29–30 October; during those days, two high-speed streams of solar wind which originated from the coronal hole produced a large series of magnetic storms.

A more strong magnetic storm developed in the magnetosphere with peak Dst approaching –465 nT on November 20–22, 2003. This storm was a 'classical' magnetic storm with a long period of negative B_Z IMF and significant substorm-related activity during the maximum period of magnetic storm. However, the November 20–22 storm had much weaker plasma density and a lower temperature than the 29–31 October storm, albeit it has a higher plasma velocity (> 650 km/s). SAR activity during 20–21 November was high. Region 501 produced an M9.6/2 b flare at 0747 UT. This flare also produced a CME with an estimated velocity of 700 km/s. Region 507 produced a C8.6 at 1929 UT. The geomagnetic field had been quiet at severe storm levels. A CME shock arrived at SOHO/MTOF and was observed at 0740 UT, and a geomagnetic sudden impulse was observed at 0805 UT. A very strong (55 nT) southward component of the IMF resulted in severe geomagnetic storms during the latter half of the day.

In this paper, we present the ionospheric TEC response during the 2003 major geomagnetic storm events based on GPS TEC measurement at Scott Base station Antarctica Geomagnetic Co-ordinate (GC): 77.85ºS, 166.76ºE; corrected geomagetic (CGM): 79.94ºS, 327.23ºE; local time (LT) = universal time (UT) + 12. Our main emphasis will be on the characteristics of ionospheric TEC and the physical mechanisms responsible for the generation of ionospheric storms, in particular with respect of the effect of solar wind-magnetosphere (SWM) origin. The measurement setup, data processing, and geomagnetic storm classification were discussed in detail in Rashid *et al.* (2005). Our discussion would include the daily GPS-TEC and percentage of TEC deviation (ΔTEC%) at Scott Base Station as compared with the solar X-ray flux from GOES, global IMF and the solar wind data from MFI/SWE instruments and plasma parameters (velocity, density and temperature) onboard the WIND and Ulysses spacecrafts. Comparisons were also made with the planetary magnetic and solar indices from WDC Kyoto and NOAA SEC.

2003 GEOMAGNETIC MAJOR STORM EVENTS

During the year 2003, a total of five significant geomagnetic storm days were identified based on WDC classifications. These five storm days are classified as extreme storm events during the summer period of 29–31 October 2003 and 20–2 November 2003. Table 1 summarizes the extreme geomagnetic storms events for the year 2003 along with their respective parameters and classifications.

During quiet geomagnetic conditions, peak Dst values were between –20 and 20 nT and reached below –100 nT during highly disturbed periods. In the case of severe storms, Dst values were below –250 nT, even below –300 nT in extreme cases.

CHARACTERISTICS OF TEC

Figures 1 and 2 show the temporal profile of geomagnetic indices (Dst, Kp, and Ap), solar indices ($F_{10.7}$ and SSN), the day-to-day variations of ionospheric vertical GPS-TEC (VTEC) and the percentage of TEC deviation (ΔTEC%) for the period from 28 October to 2 November 2003 (October Storm) and for the period from 19–22 November 2003 (November storm), respectively. The temporal profile of the day-to-day variations of ionospheric VTEC and percentage of TEC deviation were based on average data for 15 min. ΔTEC% was determined as based on the percentage of the ratio of the difference between TEC during disturbed conditions and the mean TEC during a quiet day (mean QD) to the mean TEC during a quiet day. For the October storm, the days 9, 10 and 11 of October 2003 were taken as the quiet days while for the November Storm, the days 27, 28 and 29 of November 2003 were taken as the quiet days.

As shown in Figure 1, during the period of 29 October to 31 October 2003, the geomagnetic activity was extremely severe with a minimum of three Dst. During this storm,

Table 1. Extreme geomagnetic storm events for year 2003

Month of storm	Day of storm	Dst peak (nT)	Kp (max)	∑Kp	Ap	$F_{10.7}$	SSN
Oct 2003							
	29/10/03	–345	9	55	189	279	330
	30/10/03	–401	9	57	162	271	293
	31/10/03	–320	8	47	93	249	266
Nov 2003							
	20/11/03	–465	9	48	117	175	118
	21/11/03	–312	7	34	39	177	131

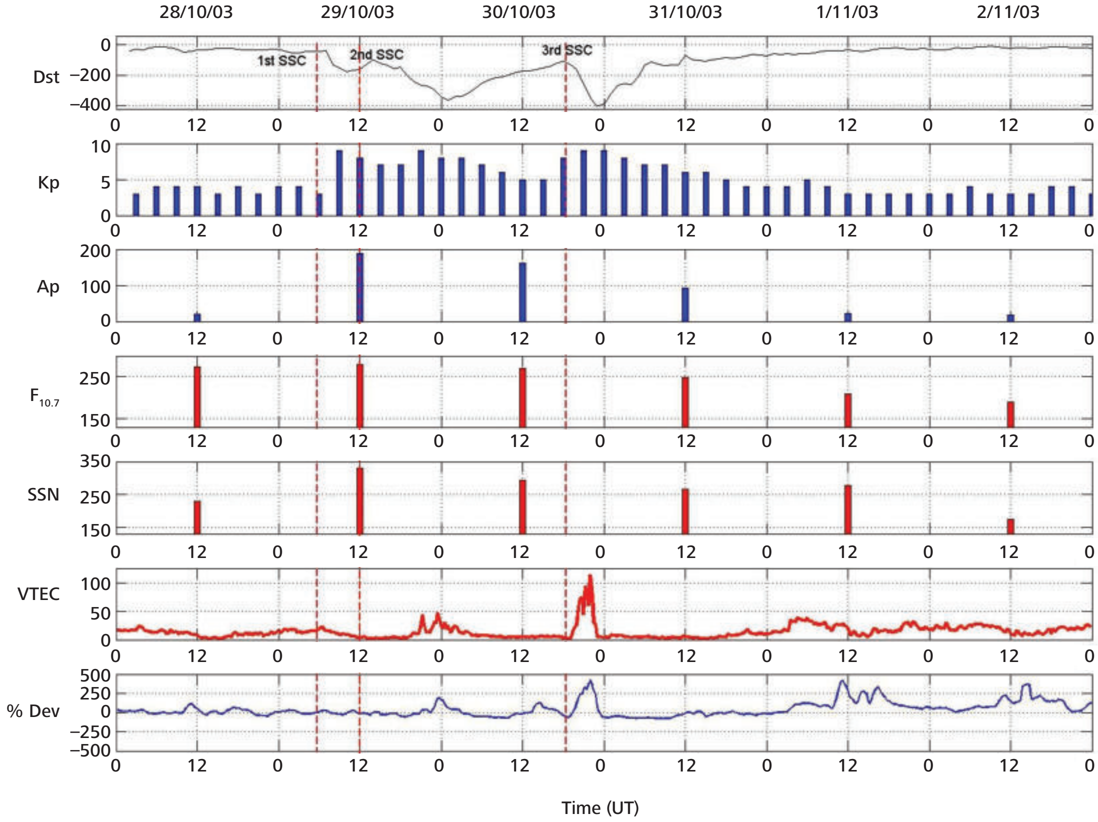


Figure 1. The magnetic and solar indices, GPS-TEC and ΔTEC% for the period from 28th October to 2nd November 2003. The vertical dash line represents the SSC.

planetary geomagnetic activity indices reached extreme values on 29 and 30 October with ∑Kp = 55 and ∑Kp = 57, respectively, and on 31 October ∑Kp = 47. The storm's first sudden storm commencement (SSC) impulse registered at 0600 UT on 29 October 2003, the second SSC impulse occured around 1200 UT of the same day and the third SSC impulse began at around 1700 UT on 30 October 2003 as shown in the figure. During the storm, the 3 h Kp index recording equaled 9 for four times at 0900 UT and at 2100 UT on 29 October, and at 2100 UT until 2400 UT on 30 October. Peak Dst occured at 1000 UT on 29 October, 2400 UT/0000 UT on 29/30 October and at 2300 UT on 30 October. During this event, Ap jumped abruptly from 20 on 28 October to 189 on 29 October and decreases dramatically to a value of 21 on 1 November when the storm subsided. For this storm, the recovery period started at 0 UT of 31 October 2003 till the end of the day. The solar index $F_{10.7}$ > 250 and SSN > 200 a few days before the storm event and maintained their high values during the whole storm event.

Referring to Figure 1, a series of VTEC enhancement-depletions were observed from the beginning of the storm until the end. During the first, second and third SSC, VTEC

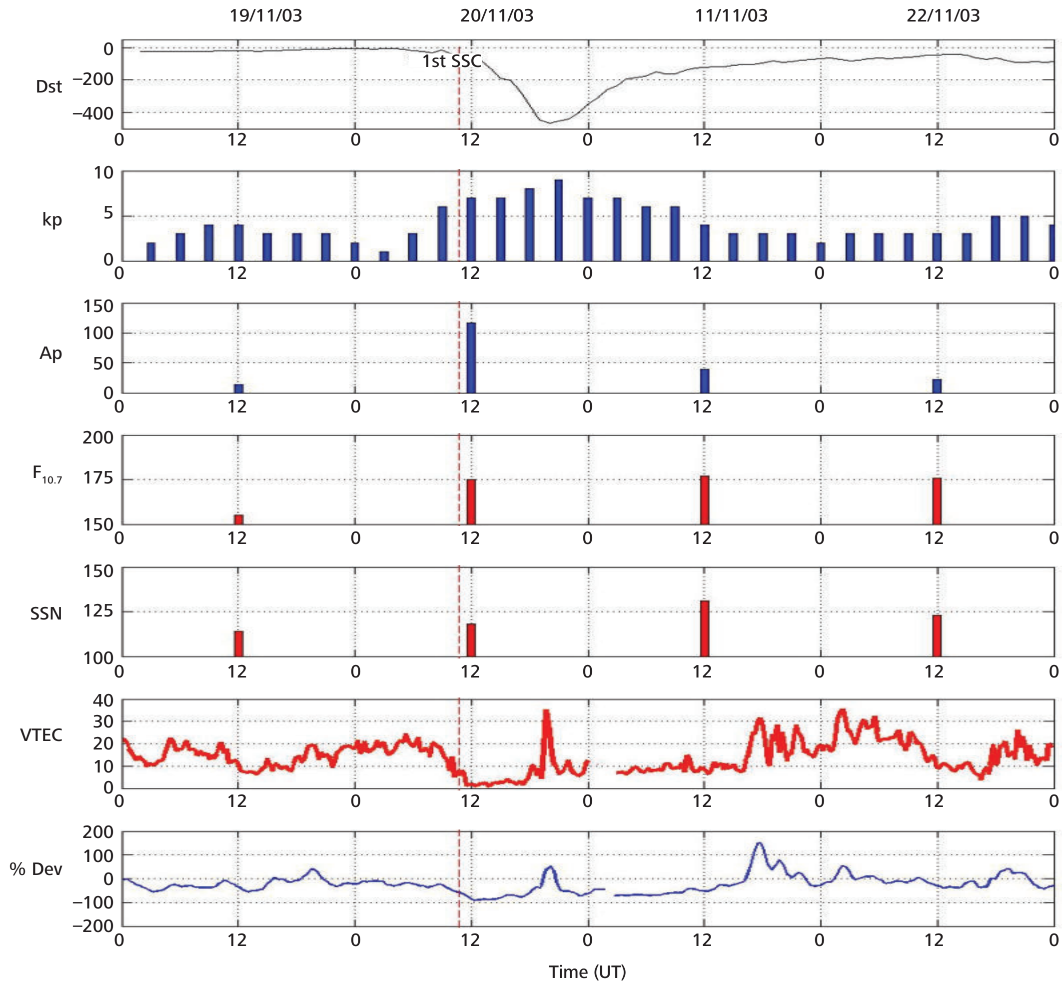


Figure 2. The magnetic and solar indices, GPS-TEC and ΔTEC% for the period from 19 to 22 November 2003. The vertical dash line represents the SSC.

reached values of 22 TECU at 0630 UT (on 29 October 2003), 5 TECU at 1230 UT (on 29 October 2003), and 10 TECU at 1730UT (on 30 October 2003), respectively. Prior to the storm's first SSC, during the UT afternoon of 28 October, ΔTEC% was observed to vary between 50% and 100%. A few hours before the onset of the storm's first SSC until about a few hours after the second SSC, ΔTEC% fluctuated about ± 30%. At around 2100 UT on 29 October until 0300 UT on 30 October, a positive storm phase (TEC enhancement) with maximum ΔTEC% (190% at 2350 UT, a few minutes earlier than the storm's second Dst minima) was observed, this is followed by a negative storm phase (depletion) of 50% for about 9 h before the ΔTEC% begin to increase again at 1400 UT. At the onset of the third SSC, ΔTEC% increased abruptly and reach a maximum value of 410% at 2200 UT. During this time, the VTEC peak reached a significantly high value of 114 TECU. Following this, at the beginning of UT day 31 October, TEC begin to deplete by about 50% for about 10 h, during that time the storm subsided. On 1 November, beginning from 0300 UT until the end of the UT day, a positive TEC enhancement was observed with maximum TEC and maximum ΔTEC% of 38 TECU and 400%, respectively. On 2 November, positive TEC enhancement was observed with maximum TECU and maximum ΔTEC% of 30 TECU and 350%, respectively. These non-storm ionization events would be discussed later. The total VTEC (∑VTEC) enhancement on 30 October 2003 with respect to the mean QD was about 31% and it increased by a factor of 1.3 with respect to 29 October (∑VTEC = 1.1 × 10^3 TECU and 1.43 × 10^3 TECU on 29 and 30 October 2003, respectively). During the recovery phase which was the whole day of 31 October 2003, ∑VTEC = 0.54 × 10^3 TECU. The ∑VTEC during the non-storm ionization events on 1 November and 2 November are 2.0 × 10^3 TECU and 1.77 × 10^3 TECU respectively.

As shown in Figure 2, the extreme storm event for November storm occured for two consecutive days, beginning from 20 until 21 November 2003. During this storm, planetary geomagnetic activity indices reached high values on 20 and 21 October with ∑Kp = 48 and ∑Kp =

34 respectively. The Kp recorded a value of 9 at 2100 UT on 20 November 2003. The storm SSC impulse began at 1100 UT on 20 November as shown in the figure. Peak Dst occured at 2000 UT on 20 November. During this event Ap jumped abruptly from 14 on 19 November to a maximum value of 117 on 2 November and decreases dramatically to a value of 39 on 21 November when the storm subsided. The solar index $F_{10.7}$ and SSN were quite low before the storm and maintained a reasonably high value of about 175 and 118, respectively during the storm and increased a bit after the storm. The storm entered a short recovery phase between 0100 UT and 0400 UT on 21 November and then followed a short main phase during the period between 0400 UT and 0800 UT on the same day, entering another short recovery phase before the storm subsided.

Referring to Figure 2, a series of VTEC depletion-enhancements were observed from the beginning until the end of the storm. Prior to the SSC, VTEC reached a minimum value of 2 TECU at 1130 UT. After the start of SSC on 20 November, Δ TEC% dipped below 0% to a minimum of 100%. At around 1730 UT to 1830 UT a short positive phase of TEC was observed with maximum Δ TEC% of 50% with VTEC reaching a maximum value of 35 TECU. This is followed by a long negative phase for about 20 h before the Δ TEC% began to increase again between 1630 UT –2230 UT on 21 November 2003 with a maximum Δ TEC% of 150% due to a minor storm. During this time VTEC reached a maximum value of 30 TECU. The ∑ VTEC enhancement on 21 November 2003 with respect to mean QD was about 15%. The ∑ VTEC for 21 November 2003 was 1.11 × 103 TECU and for 20 November 2003 it was 1.09×10^3 TECU.

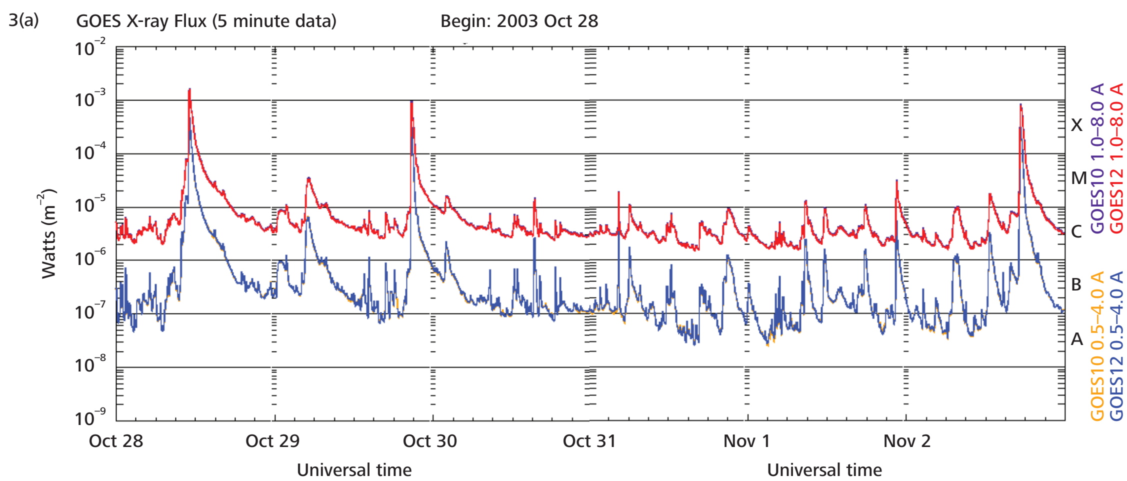
PHYSICAL MECHANISMS

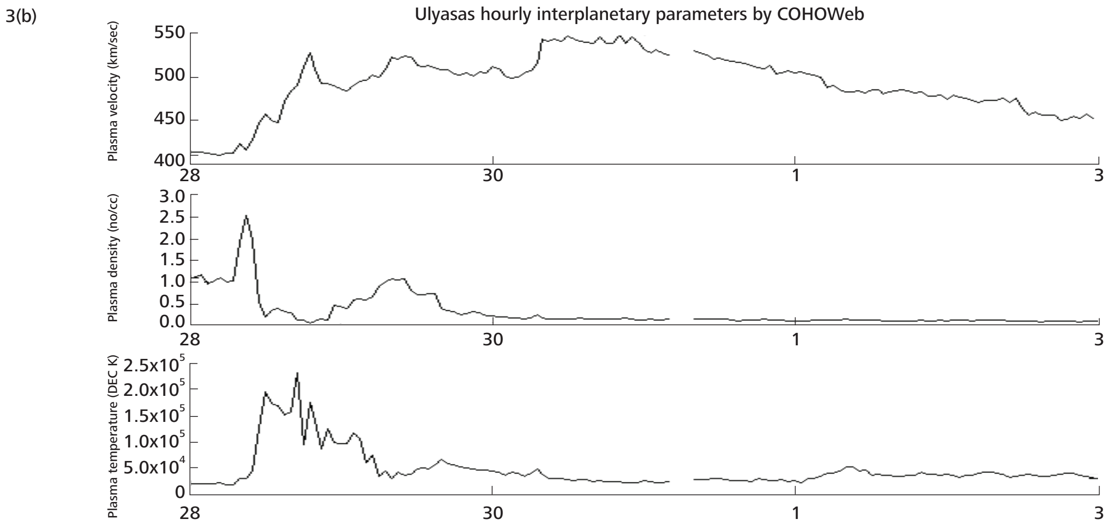
Figure 3 and 4 present the measurements of solar X-ray flux obtained from the GOES 12 spacecraft, the plasma parameters (velocity, density and temperature) obtained from the Ulysses spacecraft, and the solar wind IMF B_y and B_Z components obtained from WIND/MFI instrument onboard the WIND spacecraft during the period from 28 October to 2 November 2003 and from 19 to 22 November 2003, respectively.

Referring to Figure 3, solar and geomagnetic activities were high on 28 October with X17.2/4B observed at 1110 UT as shown in Figure 3 (a), positive storm phase was dominant during this day with a peak Δ TEC% of 130% at around 1100 UT. Quiet IMF activity prevailed during this period with IMF B_Z positive most of the time with values < 10 nT, while IMF B_y fluctuated between negative and positive values between < ± 10 nT. In Figure 3 (b) sudden increases in plasma velocity, density and temperature were observed around 0700 UT. Following this time, a sharp increase in plasma density with a wall-like figure of peak value of 2.5 no/cm^3 was observed at 0900 UT which was followed by a sudden decrease which continued until the end of the day. The plasma temperature exhibited a sudden increase a few minutes after 0700 UT and reached a peak value of 2.3×10^5 deg Kº at around 1700 UT before it gradually decreased until the early morning. The plasma velocity increased steadily and reached its peak value of 530 Km/s at 1900 UT and continues increasing until the end of the day. On that day, maximum Dst, Kp, Ap, $F_{10.7}$ and SSN indices were < –50 nT, 4, 20, 274 and 230, respectively.

Prior to the first SSC on 29 October, a M1 flare was observed at 0151 UT followed by another M3 flare at 0511 UT. At 0400 UT, significant plasma density enhancement started to increase and persisted during the first SSC, then decreased at 1100 UT. The first SSC occurred around 0600 UT on 29 October due to the arrival of CME, which reached the earth after 19 h of X17.2 event on the 28 October. During this time, the velocity boosted, and the temperature decreased with Dst first minima (–180 nT at 1000 UT). The Dst recovered at 1200 UT. At first SSC the IMF-B_Z component turned from a northward to a southward direction ($B_Z < 0$) with a sudden impulse or spike-like figure of –56.3 nT and the IMF B_y component suddenly changed westward with a maximum value of –54.3 nT, the period of the impulse continued for about 2 h. Following this until the second SSC time around 1200 UT, the IMF- B_Z exhibited strong fluctuations from negative and positive directions but mostly moved towards a northward direction. At the second SSC time, the maximum readings of B_Z and B_y were ± 15 nT. This response was followed by strong fluctuations between negative and positive directions until around 1830 UT then the direction of IMF B_Z turned southward which persisted until 0230 UT next day (8 h duration), during that time IMF B_y fluctuated between negative to positive but mostly was > 0. The maximum value of B_Z was –27.3 nT and B_y was ± 17 nT. At 2049 UT, a X10/2B flare followed by a very fast and large full halo CME was observed. The most intense TEC and Δ TEC% occurred between 2100 UT until 0230 UT next day with maximum values of 47 TECU and 190%. The maximum values of Kp, Ap, $F_{10.7}$ and SSN during that day were 9, 189, 279 and 330, respectively. A second Dst minima of –363 nT was observed at 0100 UT on 30 October.

On 30 October, high solar activity with only M and C class flares were observed, a sudden increase in plasma velocity occurred around 0500 UT with significant enhancement of plasma density and temperature observed between 0500 and 0800 UT. At the third SSC, around 1700 UT (CME arrived 20 h after the 29th flare), an abrupt decrease in the Dst index was observed which reached its minimum –401 nT at 2300 UT. The IMF B_Z totally turned southward between 1700 UT and 2300 UT (6 h duration) and a maximum value of –32.9 nT occurred around 2300 UT. Following this period, IMF B_Z turned in a northward





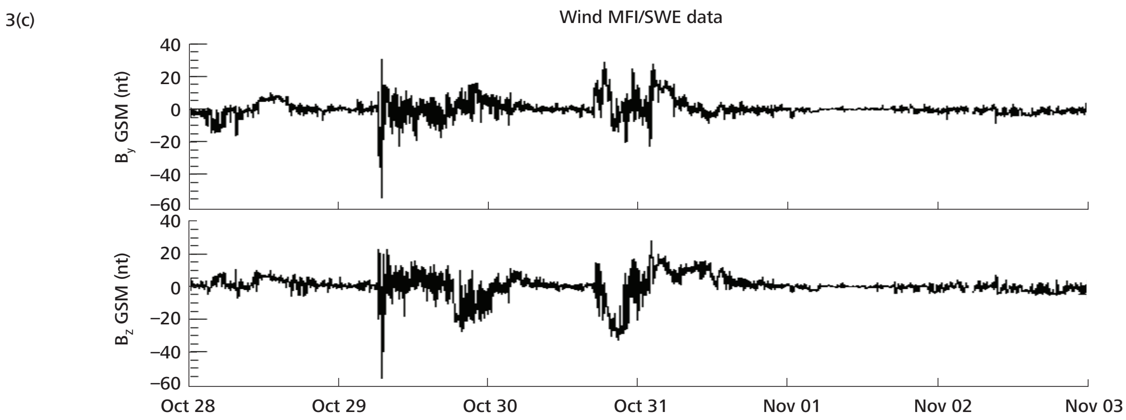


Figure 3 (a). The solar X-ray flux during 28 October–2 November 2003 for GOES; (b). The plasma velocity, plasma density and plasma temperature during 28 October–2 November 2003 from Ulysses spacecraft; (c). The solar wind IMF during 28 October–2 November 2003 for B_y and B_Z from MFI/SWE instruments.

direction which indicated the end of the main phase of the storm and entered the recovery phase of the storm. During that period, the IMF By fluctuated between negative and positive with values between –23 to 27 nT. The maximum Kp, Ap, $F_{10.7}$ and SSN during that day were 9, 162, 271, 293, respectively. The enhanced period on 29th October was followed by TEC depletion until the post midday time of 30 October with Δ TEC% of 70%, then there was a positive effect until the end of the day. The most TEC and Δ TEC% activity occurred between 1900 and 2300 UT with TEC and Δ TEC% values of 114.3 TECU and of 410%, respectively. Note that the TEC activity on 29/30 October lagged behind the IMF B_Z by about 3 h.

On 31 October and on the next day, solar activity remained at high levels with only M and C class flares observed, the plasma velocity remained high with significant decrease in the density and temperature observed. The enhanced period on 30 October was followed by a long duration depletion of 100% until midday followed by a period of TEC enhancement-depletion until the end of the day. During the whole of 1 November 2003, the positive storm phase was often seen with a maximum value of 400% which occurred at 1130 UT. The moderate flare activity during these days was followed by strong activity on 2 November when a X8.3 flare was observed around 1725 UT. The IMF B_Z and B_y directions during the period from 31 October to 2 November were positive with values near to zero. For this particular event, the timing of first SSC from the ground magnetometer show similar timing with the WIND/SWE measurement, with the storm time from both instruments at about 0600 UT.

Referring to Figure 4, on the day of 19 November, quiet solar and geomagnetic activities were observed with a M1/1N flare observed at 0401 UT, with Kp, Ap and Dst indices at 4, 14 and –25 respectively, and with the $F_{10.7}$ and SSN at 155 and 133, respectively. A negative storm phase was dominant during that day, with a maximum negative and positive Δ TEC of –60% TECU and 40%, respectively. The maximum TEC during that day was 21 TECU around 0400 UT. As shown in Figure 4 (b), significant enhancement in plasma density was observed with a sudden increase observed between 0200 to 0300 UT, plasma velocity during that day was between 690 and 730 Km/s which showed a gradual declination. The temperature was not significant with values less than 0.61 $\times 10^4$ deg Kº. The enhanced periods of plasma density were followed by a sharp declination in the density on 20 and 21 November and with a gradual declination in the velocity which continued until the evening of 22 November. Prior to the midnight of 19 November, a sudden increase in the temperature was observed with a maximum value observed around 0230 UT, the temperature kept decreasing until the midday of 21 November 2003. IMF showed low activity during 19th November, with values close to zero.

On 20 November, quiet to severe storms occurred around 1100 UT, when the Dst index started to decrease abruptly with maximum values of Dst, Kp and Ap at –465 nT, 9 and 117, respectively, $F_{10.7}$ and SSN were at 175 and 129, respectively. Prior to the SSC, SAR of 508, 507 and 501 were observed on the solar disk which produced M class flares of M1.4 observed around 0214 UT followed by a M9.6 flare at 0747 UT. A negative storm phase was observed with Δ TEC% –80% at SSC time. As shown in Figure 4 (c), the sudden changes in solar wind IMF B_Z and B_y components started to take place around 0830 UT followed by strong and rapid fluctuations for about two hours where at most times it was negative . At 1100 UT, IMF B_Z turned northward and at 1200 UT it turned completely southward with a maximum value of –53 nT at 1630 UT which continued until the early morning of the next day (duration of 14 h). This was followed by a positive B_Z of about 20 nT for about 2 h and then IMF B_Z fluctuated southward and northward during the rest of the period of the study with values ranging between ± 10 nT. A negative storm phase of –100% was seen post SSC until 1730UT, then a short period of positive phase with maximum TEC of 35 and Δ TEC% of 50% around 1800 UT. During evening around 2353 UT, another flare of M5.8 was observed.

On 21 November, the solar and magnetic activates persisted high with quiet to major storm levels; Dst, Kp and Ap indices were at –312, 7 and 39, respectively and $F_{10.7}$ and SSN at 177 and 131, respectively. Around midday, the plasma temperature exhibited an increase between 1000–1500 UT followed by a decrease until the evening of 22 November when strong plasma activity took place between 1900 and 2400 UT where only M flare activity was observed. During 21 and 22 November, no part or full CMEs were observed (internet link, dxlc, February 2005). Maximum values of TEC and Δ TEC% occurred around 1800 UT on 21 November at 30 TECU and 150%, respectively and on 22 November the maximum values were 35% and 50%, respectively. For this particular storm, the timing of SSC from the ground magnetometer showed a delay of about 2 h with respect to the WIND/MFI measurements.

DISCUSSION

We have observed the ionospheric TEC response using GPS TEC measurements during the October and November 2003 extreme geomagnetic storm events. The ionospheric characteristics and the solar-magnetospheric effect of the generation of ionospheric storms during the events have been presented. Supporting data from GOES, global IMF and solar wind data from MFI/SWE instruments and plasma parameters onboard the WIND and Ulysses spacecrafts were employed in the analyses. Comparisons were also made with the planetary magnetic and solar indices from WDC Kyoto and NOAA SEC.

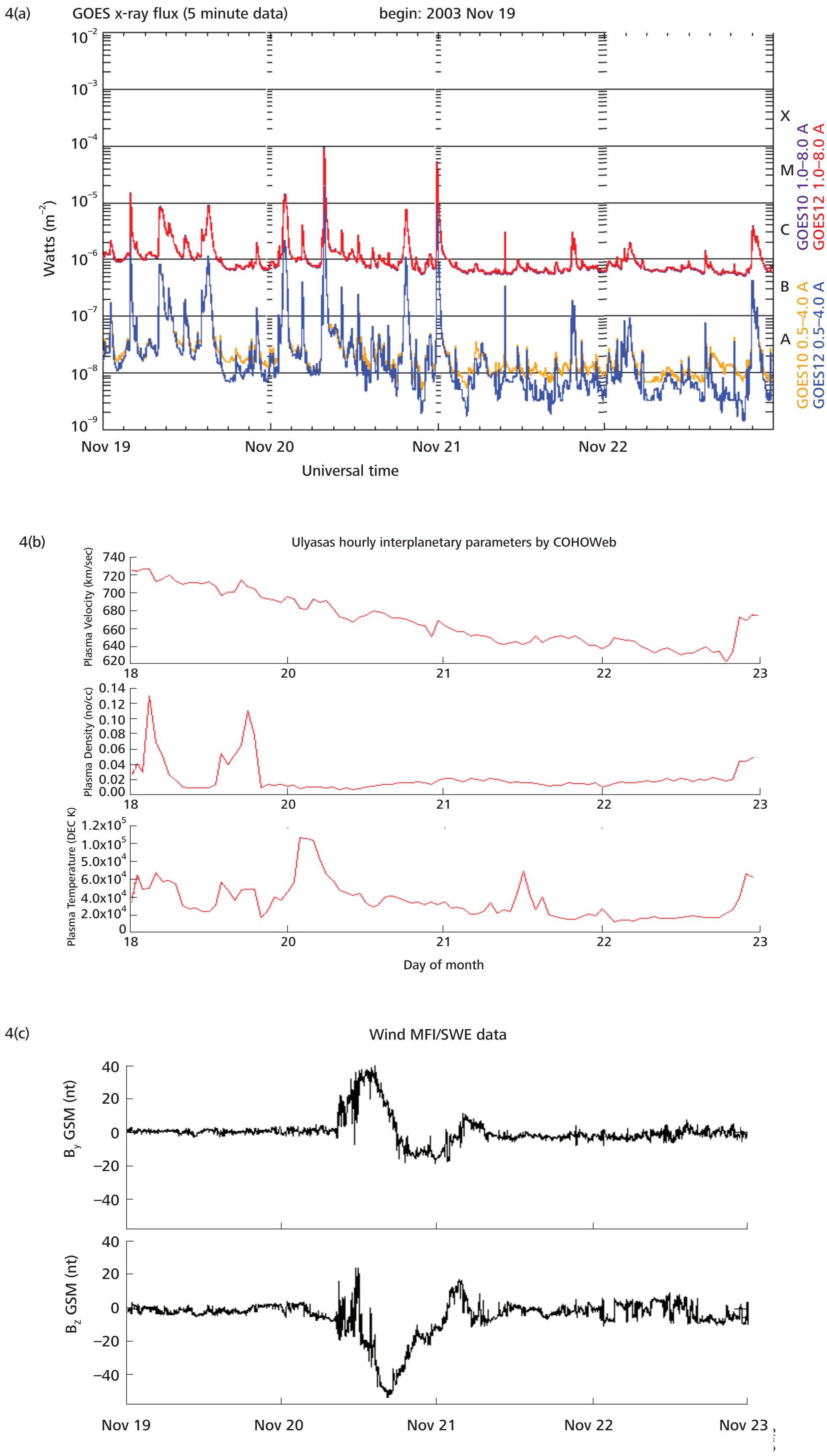


Figure 4 (a). The solar X-ray flux during 19 –22 November 2003 for GOES; (b). The plasma velocity, plasma density and plasma temperature during 19th–22nd November 2003 from Ulysses spacecraft; (c). The solar wind IMF during 19–22 November 2003 for B_y and B_Z from MFI/SWE instruments.

Analyses from the two storm events clearly indicate that the October 2003 storm produced more impact on ionospheric response than the November 2003 storm. The November 2003 storm had a more intense magnetic storm but only for 14 h while for the October 2003 storm there were three injections and a storm duration of about 60 h. For the October 2003 storm, the VTEC peak equalled 114 TECU with Δ TEC% of 410% and the duration of the positive storm phase and negative storm phase were 23h and 37 h, respectively. For the November 2003 storm, the VTEC peak equalled 35 TECU with Δ TEC% of 50% and the duration of the positive storm phase and negative storm phase were 2 h and 30 h, respectively. In the October 2003, the positive storm phase was lagging by about 3 h with respect to the onset of the southward IMF B_Z and for the November 2003 storm the short positive storm phase lagged about 9 h with respect to the onset of the southward IMF B_Z. A pronounced positive storm phase was observed during the October 2003 storm but for the November 2003 storm a negative storm phase was more dominant. For both storms, TEC enhancement occured during late morning to afternoon local time. Significant ionospheric responses were observed following the storm recovery phase with peak Δ TEC% of about 400% on October 2003 storm and about 150% for the November 2003 storm. It should be noted that the long TEC depletion and positively high response of TEC during the October 2003 storm at Scott Base station was in agreement with Yizengaw (Yizengaw *et al.* 2004) observation at the mid-and high-latitudes of the southern hemisphere and deMorais (deMorais *et al.* 2005), who observed a high peak of TEC (over 180 TECU) during the event at Palo Alto, USA (37ºN, 122 ºW).

The October and November 2003 storms had a distinct characteristic to each other. The October 2003 storm had a lower plasma speed but with increasing trend as opposed to the November 2003 storm, which had a higher plasma speed, but with decreasing trend. The plasma density and temperature for November 2003 was much lower than that for October 2003. The October 2003 storm had two X class of important flares but on November 2003 only two M class of important flares were observed. We noticed that the southward IMF B_Z was observed to coincide with the low value of plasma density and temperature for both of the storms.

The occurrence of the storm was indicated by the turning of the IMF B_Z towards the southward direction for both storms. However, for the October 2003 storm the southward turning of the IMF B_Z was observed to occur at about a day after the initiation of the flare, but this is not clearly seen on the November 2003 storm. During the first SSC and second SSC of the October 2003 storm, the TEC response was flat with Δ TEC% of about 0%. This could be due to the cancellation effect caused by the rapid fluctuations of the IMF B_Z contributed by the high density plasma carried by solar wind. The decreasing of Dst and the southward turning of the IMF B_Z for October storm occured at about the same time while for the November storm, the decrease in Dst was observed to lag by two hours.

The TEC enhancement was observed to lag behind the southward IMF B_Z by about 3 h for the October storm and by about 9 h for the November storm. The long duration of the positive storm phase observed during the October 2003 storm could be related to the mechanism of penetration of the solar wind energy disturbance to ionospheric heights other than by auroral precipitation, as was suggested by Danilov and Lastovicka (2001) and as cited by Yizengaw (Yizengaw *et al.* 2005). The long duration of negative storm phase, which was more pronounced during the November 2003 storm, could be contributed to Joule heating. Significant ionospheric responses which followed the storm recovery phase on both storms, were not generated by the coupling of the solar wind and the magnetosphere, but it could be due to Joule heating expansion in the neutral atmosphere inducing TID, which propagated towards the equator as suggested by Fuller Rowell (Fuller *et al.* 1994) for high latitude ionization enhancement. Based on our analysis for the 2003 extreme storm events, it is quite difficult to generalize the physical mechanisms of the origin of the F2 layer ionospheric storm and it's characteristics.

CONCLUSION

We have investigated the storm characteristics during extreme storm events for year 2003 at Scott Base Antarctica. The results of the October and November storm measurements have shown highly irregular TEC enhancements during the intense geomagnetic period.

ACKNOWLEDGEMENT

This work was initiated by the late Dr Zainol Abidin Abdul Rashid and supported by the Academy of Sciences Malaysia (ASM) under the ANZ K141Z Grant. The authors would like to express their gratitude to ASM and Ministry of Science, Technology and Innovation Malaysia for sponsoring this research and the staff of Antarctica New Zealand for their logistic support and hospitality at Scott Base.

Date of submission: October 2008
Date of acceptance: November 2009

REFERENCES

Yizengaw, E *et al*. 2004, 'The Southern Hemisphere ionosphere and plasmasphere response to the interplanetary shock event of 29–31 October 2003', *EOS Trans. AGU*, vol. 85, no. 47.

Yizengaw, E *et al*. 2005, 'Ionospheric dynamics over the Southern Hemisphere during the 31 March 2001 severe magnetic storm using multi-instrument measurement data', *Annales Geophysicae*, vol. 23, pp. 1–15.

Fuller, RTJ *et al*. 1994, 'Response of the thermosphere and ionosphere to geomagnetic storms', *J. Geophys. Res*., vol. 99, pp. 3893–3914.

<http://www.dxlc.com/solar/old_reports/2003/november/20031123.html>.

<http://www.spectrum.ieee.org/ WEBONLY/newslog/news10-30-03.html>.

Ljiljana, R *et al.* 2005, 'Ionospheric spatial and temporal variations during the 29–31 October 2003 storm', *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 67, pp. 1118–1128.

Forster, M & Jakowski, N 2000, 'Geomagnetic storm effects on the topside ionosphere and plasmasphere: a compact tutorial and new review', *Survey in Geophysical*, vol. 21, pp. 47–87.

Panasyuk, M, Kuznetsov, S & Yushkov, B 2004, 'Magnetic storms in October 2003', *Cosmic Research*, vol. 42, no. 5, pp. 489–534.

Hunsucker, RD & Hargreaves JK 2003, '*The high latitude ionosphere and its effect on radio propagation*', Cambridge University Press.

Siqing, L *et al.* 2004, 'Primary studying of relationship among coronal mass ejections, *Bs Events and Geomagnetic Storms*.

Moore, T, Dodson, A & Aquino, M 2001, 'Ionospheric scintillation monitoring in Northern Europe', in *ION GPS 2001 Conf.*, Salt Lake City, Utah, USA.

de Morais, TN *et al.* 2005, 'Global behaviour of the equatorial anomaly since 1999 and effects on GPS signals', *IEEE Aerospace and Electronics Systems Magazine*, March 2005.

Kalegaev, V *et al.* 2005, 'Magnetic field in the earth's magnetosphere during October-November 2003 Magnetic Storms', in *Proceedings of ISSS-7*, 26–31, March 2005.

Veselovsky, I, Panasyuk, M & Yanke, V 2004, 'Solar and heliospheric phenomena in October–November 2003: causes and effects', *Cosmic Research*, vol. 42, no. 5, pp. 453–508.

Rashid, ZAA *et al.* 2005, 'GPS ionospheric TEC measurement during the 2003 major storm events at scott base antarctica, in *IES 2005*, Virginia, USA.

ASM Sci. J., **3(2)**, 178–183

Influence of Nitrogen Source on the Growth and Biochemical Composition of an Antarctic *Chlorella*

W.L. Chu[1,2], S.M. Phang[2]*, S.L. Lim[2], M.L. Teoh[2] and C.Y. Wong[2]

Chlorella is one of the common microalgae found in a wide range of habitats, including Antarctica. *Chlorella* UMACC 234 is an interesting isolate in the collection of Antarctic microalgae in the University of Malaya algae culture collection (UMACC) as it grows well at temperatures much higher than the ambience. The alga was isolated from snow samples collected from Casey, Antarctica. This study investigates the influence of nitrogen source on the growth, biochemical composition and fatty acid profile of *Chlorella* UMACC 234. The cultures were grown in Bold's Basal Medium with 3.0 mM $NaNO_3$, NH_4Cl or urea. The cultures grown on $NaNO_3$ attained the highest specific growth rate (μ = 0.43 day^{-1}) while the specific growth rates of those grown on NH_4Cl and urea were not significantly different ($p > 0.05$). The urea-grown cells produced the highest amounts of lipids (25.7% dry weight) and proteins (52.5% dry weight) compared to those grown on other nitrogen sources. The cell numbers attained by the cultures grown at $NaNO_3$ levels between 0.3 and 3.0 mM were similar but decreased markedly at 9.0 mM $NaNO_3$. The fatty acids of *Chlorella* UMACC 234 were dominated by saturated fatty acids, especially 16:0 and 18:0. The percentage of polyunsaturated fatty acids was very low, especially in cells grown on urea (0.9% total fatty acids). Characterisation of the growth and biochemical composition of this Antarctic *Chlorella* is important to our studies on the relationship of *Chorella* isolates from tropical, temperate and polar regions, especially in terms of phylogeny and stress adaptation.

Key words: *Chlorella*; Antarctica; nitrogen source; biochemical composition; fatty acids; urea

Chlorella is one of the most widely distributed and most frequently encountered eukaryotic algae on earth. The alga has often been used as a model organism to examine basic physiological processes in plants, and is exploited for biotechnological applications. In the University of Malaya Algae Culture Collections (UMACC) there are many isolates of *Chlorella* and among these, *Chlorella vulgaris* UMACC 001 is one of the most well studied species. This species is able to grow under heterotrophic conditions and has been successfully used to treat rubber effluent and palm oil mill effluent (Phang & Chu 2004).

Chlorella is one of the common microalgae found in Antarctica, especially in terrestrial habitats and freshwater ponds. For instance, *Chlorella mirabilis* was observed in enrichment cultures established with mineral soils from Cierva Point, Antarctic Peninsula (Mataloni *et al.* 2000). Recently, an interesting psychrophilic *Chlorella* was isolated from a transitory pond near Bratina Island, Antarctica (Morgan-Kiss *et al.* 2008). The *Chlorella* isolate grows optimally at around 10ºC and is also able to grow heterotrophically in the dark.

In collaboration with the Australian Antarctic Division, Malaysian scientists have participated in four expeditions to Casey Station in the Windmill Islands region in Antarctica since 2001. A collection of polar microalgae has been established in the UMACC, which includes several isolates of *Chlorella* from snow and soil samples (Chu *et al.* 2002; Phang *et al*. 2007). The *Chlorella* isolates were chosen for our studies on the adaptation and response of Antarctic microalgae to UVR and temperature stress, in comparison with tropical and temperate species (Wong *et al.* 2007; Teoh *et al.* 2004). *Chlorella* UMACC 234 was originally isolated from snow samples from Casey, Antarctica. The alga grows well at temperatures ranging from 5ºC to 20ºC (Teoh *et al.* 2004).

The presence of nitrogenous compounds is an important factor that determines the distribution of microalgae in various habitats. In the Antarctic, high levels of nitrogen in habitats such as penguin rookeries and human impacted areas may promote the abundant growth of algae such as *Prasiola crispa* and *Phormidium autumnale* (Ohtani *et al.* 2000). Cyanobacteria were dominant in ornithogenic

[1]International Medical University, No. 126, Jalan 19/155B, Bukit Jalil, 57000 Kuala Lumpur, Malaysia
[2]Institute of Biological Sciences & Institute of Earth and Ocean Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
*Corresponding author (e-mail: phang@um.edu.my)

soils highly enriched with nitrogen and phosphorus while chlorophytes and diatoms were dominant in sites with lower amounts of these two nutrients in a study conducted at Cierve Point, Antarctic Peninsula (Mataloni & Tell 2002).

The objective of the present study was to investigate the influence of nitrogen source on the growth, biochemical composition and fatty acid profile of *Chlorella* UMACC 234. The study was important as enrichment of nitrogen could affect the adaptation and occurrence of algae in the harsh environment of Antarctica.

MATERIALS AND METHODS

Algal Cultures

The cultures of *Chlorella* UMACC 234 were maintained in Bold's Basal Medium (BBM) (Nichols 1973) and grown in a controlled-environment incubator set at 4ºC with irradiation of 42 µmol m^{-2} s^{-1} on a 12:12 h light-dark cycle.

Effect of Nitrogen Source

The inoculum from exponential phase cultures standardised at an optical density at 620 nm (OD_{620}) of 0.2 were used for all the experiments. Three nitrogen sources were used, namely $NaNO_3$, NH_4Cl and urea. A volume of 10 mL of culture was inoculated into 90 ml BBM containing 3 mM of $NaNO_3$, NH_4Cl or urea, buffered with 10 mM 4-(2-hydroxyethyl)-piperazine-1-ethane-sulphonic acid (HEPES). The concentration of nitrogen source used was equivalent to the $NaNO_3$ contained in BBM. The cells from the inoculum were pelleted by centrifugation (3000 r.p.m., 20 min) and resuspended in nitrogen-free medium before being added into BBM with the different nitrogen sources. After inoculation, growth was monitored by counting the cells daily for 10 days using a haemocytometer (Improved Neubauer).

The specific growth rate (µ, day^{-1}) was determined using the following formula: $\mu = (\ln N_1 - \ln N_2) / (t_2 - t_1)$ where N_1 and N_2 represent the cell number at times t_1 and t_2 respectively, within the exponential phase.

At the end of the experiment, the cells were harvested by filtration onto glass fibre filters (4.7 cm, 0.45 µm) for the extraction of lipids, carbohydrates, proteins and chlorophyll a. Lipids were extracted in $MeOH$-$CHCl_3$-H_2O (2:1:0.8) and determined by gravimetric method (Bligh & Dyer 1959). Proteins were extracted in 0.5 N NaOH (80ºC, 30 min) and the concentration determined by the dye-binding method (Bradford 1976). Carbohydrates were extracted in 2 N HCl (80ºC, 30 min) and the concentration determined by the phenol-sulphuric method (Kochert 1978). The lipids were transesterified in 1% H_2SO_4 in methanol and the fatty acid methyl esters were analysed by gas chromatography as described in Chu *et al*. (1994).

Effect of $NaNO_3$ Level

In this experiment, the cultures were grown in BBM containing 0, 0.3, 1.0, 3.0 and 9.0 mM $NaNO_3$ buffered with 10 mM HEPES. Growth was monitored based on cell number on day 4 and 8.

Statistical Analysis

The data were compared using one-way ANOVA followed by Duncan's multiple range test (Statistica v5.0). The difference between means was considered significant when $p < 0.05$.

RESULTS

Of the three nitrogen sources, $NaNO_3$ supported the best growth of *Chlorella* UMACC 234 based on specific growth rate (µ) and final cell number, biomass and chlorophyll a concentration attained (Table 1). The µ's of the cultures grown on NH_4Cl and urea did not differ significantly ($p > 0.05$). Further experiments were conducted to investigate the effect of $NaNO_3$ levels on the growth of *Chlorella* UMACC 234. The growth of *Chlorella* UMACC 234 was similar at $NaNO_3$ concentrations ranging from 0.3 mM to 3.0 mM (Figure 1). The cell number decreased markedly at 9.0 mM $NaNO_3$.

In terms of biochemical composition, cells grown on urea contained the highest amount ($p < 0.05$) of proteins (52.5% dry weight) (Figure 2). In comparison, cells grown on $NaNO_3$ contained the highest amount ($p < 0.05$) of carbohydrates (30.4% dry weight). The lipid content ranged from 12.3% to 25.6% dry weight and was highest in cells grown on urea.

The dominant group of fatty acids of *Chlorella* UMACC 234 was saturated fatty acids (SFA), ranging from 63.7% to 96.7% total fatty acids (Figure 3). The major SFA of *Chlorella* UMACC 234 were 16:0 and 18:0 (Table 2). The percentage of polyunsaturated fatty acids (PUFA) with the dominance of 18:3 was highest in cells grown on NH_4Cl. Cells grown on urea contained a very low percentage of PUFA.

DISCUSSION

The ability of *Chlorella* to utilise different nitrogen sources varies with species and strains. For instance, endosymbiotic *Chlorella* strains in *Paramecium bursaria* were not able to utilise ammonium nitrate as the sole nitrogen source, but were able to assimilate a wide range of amino acids (Kato

Table 1. Growth characteristics of *Chlorella* UMACC 234 cultured on different nitrogen sources.

Nitrogen source	Specific growth rate (μ, day^{-1})	Final cell number (x 10^8 mL^{-1})	Final biomass (mg dry weight L^{-1})	Final chlorophyll a concentration (mg L^{-1})
$NaNO_3$	0.43 ± 0.02[a*]	7.36 ± 0.30[a]	185.0 ± 10.0[a]	1.22 ± 0.06[a]
NH_4Cl	0.36 ± 0.01[b]	5.22 ± 0.15[b]	161.0 ± 3.0[a]	0.88 ± 0.05[b]
Urea	0.31 ± 0.05[b]	5.05 ± 0.64[b]	103.0 ± 22.0[b]	0.70 ± 0.10[b]

*Different alphabets within the same column denote significant differences at $p < 0.05$ (n=3)

Table 2. Fatty acid composition (% total fatty acids) of *Chlorella* UMACC 234 grown on different nitrogen sources. All values are expressed as mean ± standard deviation.

Fatty acid	Nitrogen source		
	$NaNO_3$	NH_4Cl	Urea
Saturated fatty acids (SFA)			
14:0	4.3 ± 0.5	–	2.7 ± 1.3
16:0	54.8 ± 6.1	45.8 ± 0.1	49.9 ± 5.2
18:0	24.0 ± 0.1	22.1 ± 5.4	44.1 ± 2.5
Monounsaturated fatty acids (MUFA)			
16:1	0.5 ± 0.1	–	–
18:1	3.5 ± 1.1	7.5 ± 0.6	2.9 ± 0.6
Polyunsaturated fatty acids (PUFA)			
16:4	2.6 ± 0.9	2.6 ± 0.6	–
18:2	0.7 ± 0.1	4.1 ± 5.9	–
18:3	9.2 ± 1.6	17.3 ± 5.9	0.9 ± 0.1
18:4	1.5 ± 0.1	1.4 ± 0.1	–

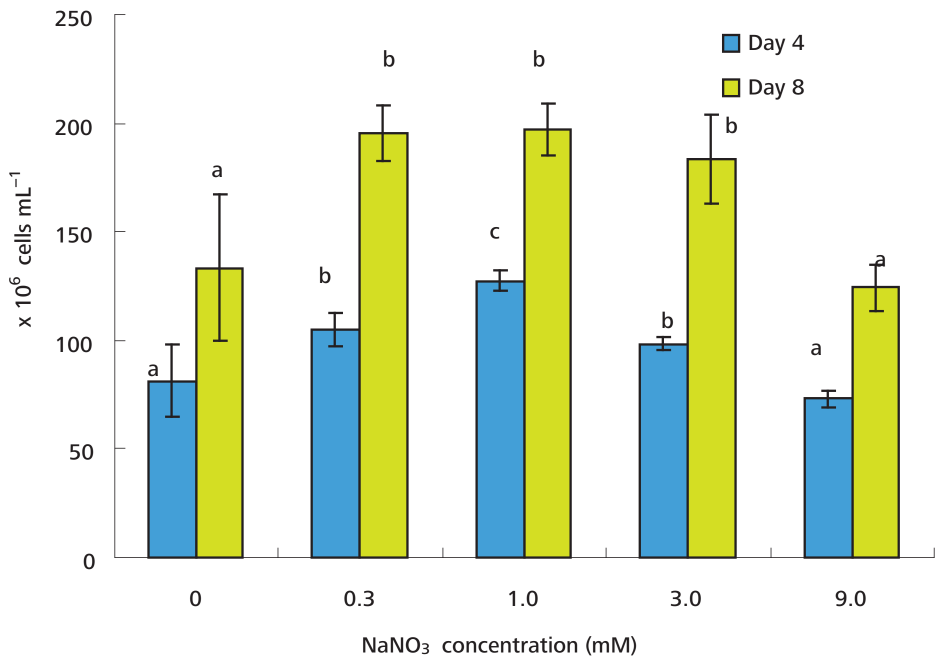


Figure 1. Growth based on cell number of *Chlorella* UMACC 234 cultured at different concentrations of $NaNO_3$. Different alphabets above the bar charts denote significant differences ($p < 0.05$, n = 3) in the cell numbers on day 4 and day 8, respectively.

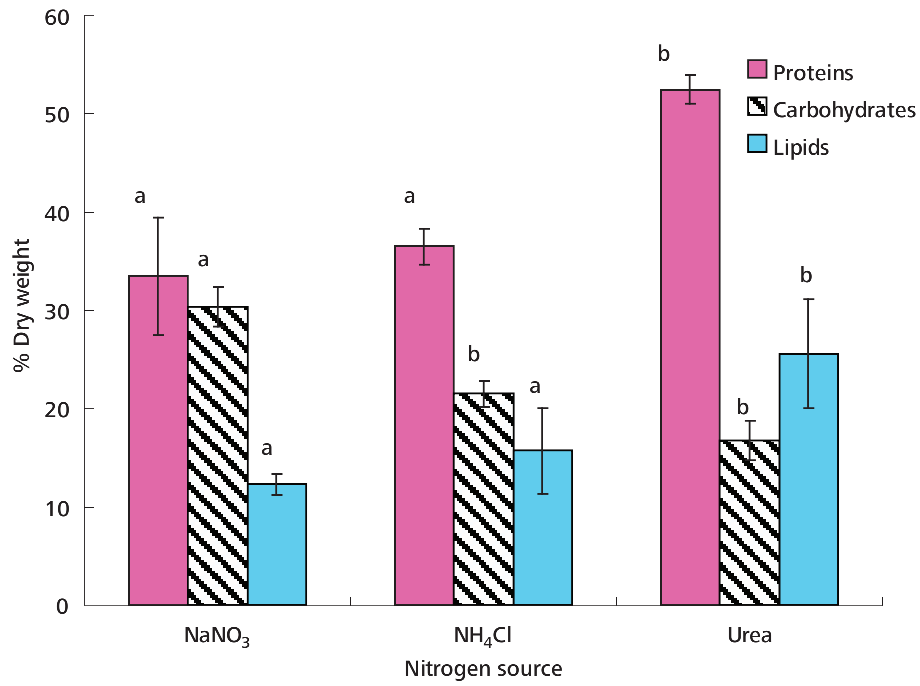


Figure 2. Biochemical composition of *Chlorella* UMACC 234 grown on different nitrogen sources. Vertical bars indicate standard deviations from three replicates. Different alphabets above the bar charts for each biochemical component denote significant differences at $p < 0.05$ (n = 3).

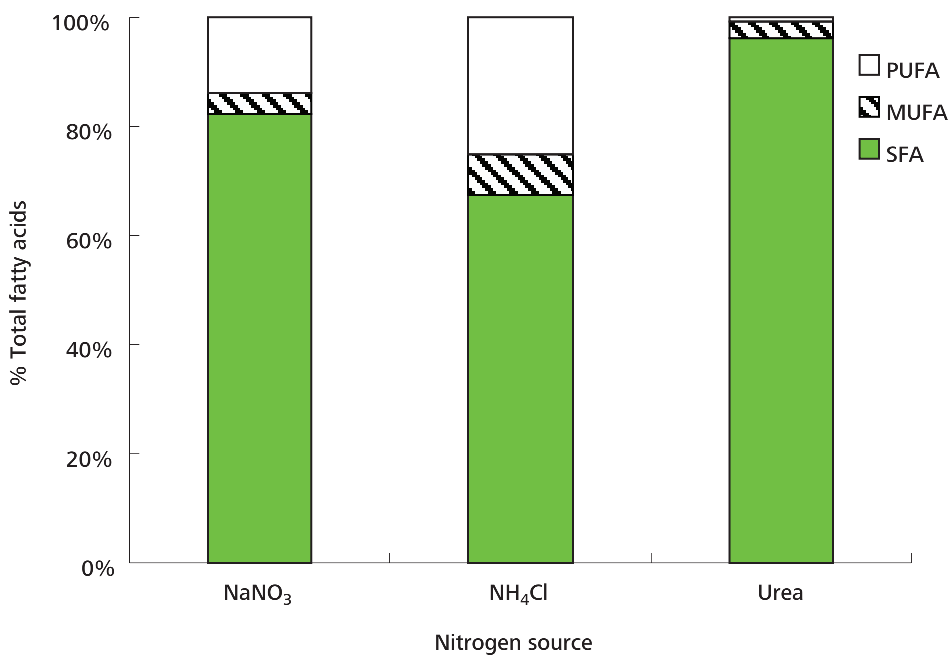


Figure 3. Distribution of saturated, monounsaturated and polyunsaturated fatty acids (SFA, MUFA and PUFA) of *Chlorella* UMACC 234 grown on different nitrogen sources.

et al. 2006). In comparison, *Chlorella prothecoides* grew better on NH_4^+ than on NO_3^- (Ahmad & Hellebust 1990). Some *Chlorella* strains might be highly tolerant to ammoniacal nitrogen. For instance, an isolate of *Chlorella pyrenoidosa* from leachate samples was able to grow, even at NH_4^+-N as high as 135 mg L^{-1} (Lin *et al*. 2007). Results showed that *Chlorella* UMACC 234 grew better on $NaNO_3$ than NH_4Cl or urea. This is in contrast with other *Chlorella* strains which grow well on urea. For instance, *C. protothecoides* produced higher biomass when grown on urea than on NO_3^- or NH_4^+ under heterotrophic condition (Shi *et al*. 2000).

The lower growth on ammonium and urea compared to nitrate could be due to the origin of this alga. *Chlorella* UMACC 234 was isolated from snow, which is known to contain very little ammonium or urea. Snow algae are known to be psychrophilic and they do not grow at temperatures above 10ºC (Hoham 1975). However, *Chlorella* UMACC 234 grows even at 30ºC (Teoh *et al.* 2004). Thus, it is most probably a soil rather than a snow alga. Soil algae are known to be brought onto the snow surface due to wind action, as reported for *Raphidonema nivale* (Stibal & Elster 2005). The soil below the snow at the collection site of *Chlorella* UMACC 234 was probably low in nitrogen. This was different from other soil habitats such as penguin rookeries which may contain high levels of ammonium and nitrate (Mataloni & Tell 2002; Ohtani *et al*. 2000). However, in those habitats, chlorophytes such as *Stichococcus bacillaris* and *Prasiola crispa* are commonly found but not *Chlorella*. In contrast, several species of *Chlorella* have been found to occur in mineral soils low in nitrogen at Victoria Land, Antarctica (Cavacini 2001) and Cierva Point, Antarctic Peninsula (Mataloni *et al*. 2000).

Chlorella UMACC 234 grew well at $NaNO_3$ concentrations ranging from 0.3 mM to 3.0 mM but its growth was markedly reduced at 9.0 mM. The Antarctic *Chlorella* isolate required a much lower concentration of $NaNO_3$ for growth compared to the tropical isolate *Chlorella vulgaris* UMACC 001, which grew well even at 18.75 mM $NaNO_3$ (Chu *et al.* 2007).

The major biochemical component of *Chlorella* UMACC 234 were proteins (33.5% – 52.5% dry weight) followed by carbohydrates (16.8% – 30.4% dry weight) and lipids (12.3% – 25.6% dry weight). *Chlorella* is known to contain high amounts of protein. For instance, *Chlorella sorokiniana*, an isolate from hot springs, contains 68.5% protein (Matsukawa *et al.* 2000).

The nitrogen source is an important factor that can influence the biochemical composition of algae; however, the effect varies with species. For instance, the marine eustigmatophyte *Ellipsoidion* sp. contains higher amounts of lipids when grown on NH_4Cl, than on $NaNO_3$ or urea (Xu *et al.* 2001). *Chlorella* UMACC 234 grown on urea produced higher amounts of lipids and carbohydrates at the expense of proteins compared to cells grown on $NaNO_3$ and NH_4Cl. However, the protein content of cells grown on $NaNO_3$ and NH_4Cl were not significantly different. This was in contrast with *C. protothecoides*, which contains more proteins in cells grown on NO_3^- than those on NH_4^+ (Ahmad & Hellebust 1990).

The fatty acid composition of *Chlorella* UMACC 234 was similar to that of other *Chlorella* strains, with the dominance of SFA, especially 16:0 and 18:0 (Teoh *et al*. 2004; Wong *et al.* 2007). In comparison, 18:0 was not found in three species of temperate *Chlorella* and a psychrophilic strain of *Chlorella* as reported by Petkov and Garcia (2007) and Morgan-Kiss *et al.* (2008), respectively. The high percentage of 18:0 detected in *Chlorella* UMACC 234 could be due to the use of non-aerated cultures. Aeration is known to affect the production of 18:0 in *Chlorella*. For instance, a high percentage of 18:0 was only produced in *C. sorokiniana* when the cultures are not aerated (Chen & John 1991). Urea also appeared to enhance the production of 18:0 at the expense of 18:3 in *Chlorella* UMACC 234. A high percentage of 18:0 was reported for *C. pyrenoidosa* grown in olive-mill wastewater rich in organic nitrogen source (Sanchez *et al*. 2001). There was a relatively low percentage of PUFA in this *Chlorella*, in agreement with the findings on other Antarctic *Chlorella* strains (Wong *et al*. 2007; Morgan-Kiss *et al.* 2008).

The characterisation of *Chlorella* UMACC 234 in terms of nitrogen requirement would contribute to our studies on the response of Antarctic *Chlorella* to stress, in comparison with temperate and tropical isolates. The findings would also contribute to our studies on phylogeography of *Chlorella* from different regions.

ACKNOWLEDGEMENTS

This study was supported by a research grant from the Ministry of Science, Technology and Innovation, Malaysia co-ordinated by the Academy of Sciences Malaysia. This research also forms part of a project under the Australian Antarctic Division (AAD #2694). The berths offered by the AAD and field assistance provided by the staff of Casey Station are gratefully acknowledged.

Date of submission: October 2008
Date of acceptance: November 2009

REFERENCES

Ahmad, I & Hellebust, JA 1990, 'Regulation of chloroplast development by nitrogen source and growth conditions in a *Chlorella prothecoides* strain', *Plant Physiology*, vol. 29, 294 – 300.

Bligh, EG & Dyer, WJ 1959, 'A rapid method of total lipid extraction and purification', *Canadian Journal of Biochemistry and Physiology*, vol. 37, pp. 911–917.

Bradford, MM 1976, 'A rapid and sensitive method for quantitation of microgram quantities of protein utilizing the principle of dye-binding', *Analytical Biochemistry*, vol. 72, pp. 248–254.

Cavacini, P 2001, 'Soil algae from northern Victoria Land (Antarctica)', *Polar Bioscience*, vol. 14, 45–60.

Chen, F & John, MR 1991, 'Effect of C/N ratio and aeration on the fatty acid composition of heterotrophic *Chlorella sorokiniana*', *Journal of Applied Phycology*, vol. 3, pp. 203–209.

Chu, WL, Phang, SM & Goh, SH 1994, 'Studies on the production of useful chemicals, especially fatty acids in the marine diatom *Nitzschia conspicua* Grunow', *Hydrobiologia*, vol. 285, pp. 33–40.

Chu, WL, Ramadhona, MS & Phang, SM 2007, 'Assessment of three tropical chlorophytes as bioassay organisms for nitrogen and phosphorus enrichment in freshwater ecosystems', *Malaysian Journal of Science*, vol. 26, no. 2, 15–25.

Chu, WL *et al.* 2002, 'Isolation and culture of microalgae from the Windmill Islands Region, Antarctica', in *Proceedings of the Malaysian International Seminar on Antarctica, 5–6 Aug 2002*, Kuala Lumpur, pp. 53–59.

Hoham, RM 1975, 'Optimum temperatures and temperature ranges for growth of snow algae', *Arctic Alpine Research*, vol. 7, pp. 13–24.

Kato, Y, Ueno, S & Imamura, N 2006, 'Studies on the nitrogen utilization of endosymbiotic algae isolated from Japanese *Paramecium bursaria*', *Plant Science*, vol. 170, no. 3, pp. 481–486.

Kochert, AG 1978, 'Carbohydrate determination by the phenol-sulfuric acid method', in *Handbook of phycological methods: physiological and biochemical methods*, eds JA Hellebust & JS Craig, Cambridge University Press, pp. 95–97.

Lin, L *et al.* 2007, 'Use of ammoniacal nitrogen tolerant microalgae in landfill leachate treatment', *Waste Management*, vol. 27, pp. 1376–1382.

Mataloni, G & Tell, G 2002, 'Microalgal communities from ornithogenic soils at Cierva Point, Antarctic Peninsula', *Polar Biology*, vol. 25, pp. 488–491.

Mataloni, G, Tell, G & Wynn-Williams, DD 2000, 'Structure and diversity of soil algal communities from Cierva Point (Antarctic Peninsula)', *Polar Biology*, vol. 23, pp. 205–211.

Matsukawa, R *et al.* 2000, 'Antioxidants from carbon dioxide fixing *Chlorella sorokiniana', Journal of Applied Phycology*, vol. 12, pp. 263–267.

Morgan-Kiss, RM *et al.* 2008, 'Identity and physiology of a new psychrophilic eukaryotic green alga, *Chlorella* sp., strain BI, isolated from a transitory pond near Bratina Island, Antarctica', *Extremophiles*, vol. 12, pp. 70 –711.

Nichols, HW 1973, 'Growth media – freshwater', in *Handbook of phycological methods: culture methods and growth measurements*, ed J Stein, Cambridge University Press, pp. 7–24.

Ohtani, S *et al.* 2000, 'Distribution of soil algae at the monitoring sites in the vicinity of Syowa Station between austral summers of 1992/1993 and 1997/1998', *Polar Bioscience*, vol. 13, pp. 113–132.

Petkov, G & Garcia, G 2007, 'Which are fatty acids of the green alga *Chlorella*?' *Biochemical Systematics and Ecology*, vol. 35, pp. 281–285.

Phang, SM & Chu, WL 2004, 'The University of Malaya Algae Culture Collection (UMAC) and potential applications of a unique *Chlorella* from the collection', *Japanese Journal of Phycology*, vol. 52, pp. 221–224.

Phang, SM *et al.* 2007, 'A checklist of microalgal isolates from Ny Alesund, Svalbard', in *8th Ny-Alesund Seminar*, 16 – 17 October 2007, Cambridge, UK, *The Journal of the CNR's Network of Polar Research*, pp. 11–14.

Sanchez, S *et al.* 2001, 'Mixotrophic culture of *Chlorella pyrenoidosa* with olive-mill wastewater as the nutrient medium', *Journal of Applied Phycology*, vol. 13, pp. 443–449.

Shi, X, Zhang, X & Chen, F 2000, 'Heterotrophic production of biomass and lutein by *Chlorella protothecoides* on various nitrogen sources', *Enzyme and Microbial Technology*, vol. 27, pp. 312–318.

Stibal, M & Elster, J 2005, 'Growth and morphology variation as a response to changing environmental factors in two Arctic species of *Raphidonema* (Trebouxiophyceae) from snow and soil', *Polar Biology*, vol. 28, pp. 558–567.

Strickland, JD & Parsons, TR 1968, *A practical handbook of seawater analysis*, Bulletin No 167, Fisheries Research Board Canada.

Teoh, ML *et al.* 2004, 'Influence of culture temperature on the growth, biochemical composition and fatty acid profiles of six Antarctic microalgae', *Journal of Applied Phycology*, vol. 16, pp. 421–430.

Wong, CY *et al.* 2007, 'Comparing the response of Antarctic, tropical and temperate microalgae to ultraviolet radiation (UVR) stress', *Journal of Applied Phycology*, vol. 19, pp. 689–699.

Xu, N *et al.* 2001, 'Effects of nitrogen source and concentration on growth rate and fatty acid composition of *Ellipsoidion* sp. (Eustigmatophyta)', *Journal of Applied Phycology*, vol. 13, pp. 463–469.

ASM Sci. J., **3(2)**, 184–194

Comparison of Diversity of Microfungi in Ornithogenic Soils from Beaufort Island, Continental Antarctica and Barrientos Island, Maritime Antarctica

S. Omar[1*], S.A. Alias[1*], J. Smykla[2], H. Moreano[3], M.L. Guerra[3] and C.Y. Ming[1]

Results of a biodiversity study of Antarctic microfungi from ornithogenic soils are presented in this paper. A wide range of soil habitats within and adjacent to active and abandoned penguin rookeries were sampled in order to examine relationships between environmental factors and the biodiversity of soil microfungi. Soil samples were collected from two contrasting Antarctic locations: (1) Beaufort Island (Ross Sea, Continental Antarctica), which is largely ice- and snow-covered, isolated, difficult to access and infrequently visited, and (2) Barrientos Island (maritime Antarctica) which is mostly ice-free during summer and is often visited by scientists and tourists. Soil sampling at Beaufort and Barrientos Islands was completed during the austral summer seasons of 2004/05 and 2006/07, respectively. Warcup's soil method was used for fungi cultivation. A total of 27 fungal taxa were isolated from the two study sites, consisting of 11 ascomycetes, 13 hyphomycetes and three yeasts. Only three taxa — *Geomyces* sp., a pink and a white yeast — occurred on both sites. The isolated fungi were classified according to their thermal characteristics in culture, with seven psychrophilic, 10 psychrotrophic and 10 mesophilic fungi being isolated. *Thelebolus* microspores, *Thelebolus* sp., *Geomyces* sp. and *Antarctomyces* sp., were the most frequently isolated fungi. A total of 10 taxa were isolated from the 20 soil samples from Beaufort Island, consisting of five psychrophilic, four psychrotrophic and one mesophilic fungi. *Thelebolus* microsporus, *Thelebolus* sp., Asco BI8 and *Phoma* sp. were the most frequently obtained fungi (20%–27% of isolates). A total of 22 fungal taxa were isolated from 23 soil samples from Barrientos Island, consisting of four psychrophilic, six psychrotrophic and 12 mesophilic fungi. *Geomyces* sp. and *Antarctomyces* sp. were the most frequently isolated taxa. Thus, the fungal diversity of Beaufort Island was dominated by Ascomycetes while that of Barrientos Island was dominated by hyphomycetes.

Key words: soil habitats; penguin rookeries; environmental factors; biodiversity; thermal characteristics; psychrophilic; psychrotrophic; mesophilic; soil samples; hyphomycetes

Antarctic Microfungal Diversity

Studies of the diversity of microfungi in the Antarctic has predominantly focused on the Continental Antarctic (Sugiyama *et al.* 1967; Wicklow 1968; Atlas *et al*. 1978; Friedmann 1982; Martin 1988; Del Frate & Carretta 1990; Onofri & Tosi 1992; Moller & Gams 1993; Smith 1994; Azmi & Seppelt 1998; Cheryl & Seppelt 1999; Selbmann *et al*. 2005) rather than maritime Antarctic (Dennis 1968; Gray *et al.* 1982; Pugh & Allsopp 1982; Weinstein *et al.* 1997). Studies of fungi in the barren soils of the Antarctic have included areas that are more easily accessible such as the Windmill Islands (Azmi & Seppelt 1990; Cheryl & Seppelt 1999), and more challenging areas such as the Victoria Land Dry Valleys (Friedmann *et al.* 1985; Cameron *et al.* 1971). The occurrence of fungi in areas of historic human activity — the 'historic huts' and associated habitats — have been studied extensively by Tubaki (1961), Martin (1988), Blanchette (2000), Blanchette *et al*. (2004) and Held *et al*. (2005).

Fungal studies have encompassed a range of habitats, including soil (Onofri 1990; Kerry 1990a,b; Finotti 1992; Azmi & Seppelt 1998; Hughes *et al*. 2003), ice and permafrost (Gilichinsky *et al*. 2005), lake sediments (Sugiyama *et al.* 1967) and also the air (Marshall 1997). Airborne transfer of spores of *Cladosporium* sp. between South America and the Maritime Antarctica have been proposed (Marshall 1997). A number of fungi reported in Antarctic studies do not appear to have growth characteristics in culture that suit them well to the Antarctic environment. For instance, Sugiyama *et al*. (1967) reported *Penicillium*

[1] Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
[2] Department of Biodiversity, Institute of Nature Conservation, Polish Academy of Sciences, Mickiewicza 33, PL-31-120 Krakow, Poland
[3] Instituto Antartico Ecuatoriano (INAE), Blvd. 9 de Octubre 416 y Chile, Edificio Citibank Cuatro Piso Officina 402, Guayaquil, Ecuador
*Corresponding author (e-mail: saa@um.edu.my; siti.alias@gmail.com)

sp. dominating the fungal flora of Lake Vanda sediments (Victoria Land). The isolated fungus however, can only survive at a temperature of 20ºC or above. Gilichinsky *et al.* (2005) reported that 40 fungal strains representing 12 different taxa were isolated from cryopegs of Don Juan Pond, including *Penicillium* spp. *Alternaria* sp., *Aureobasidium* sp. and *Verticillium* spp. but that their growth was reduced sharply at 10ºC. However, Tubaki (1968) suggested that, for survival under extreme conditions, the ability to maintain slow growth at low temperatures (near 0ºC) could be more important than that of rapid growth at optimum (20ºC) temperatures. Gilichinsky *et al*. (2005) also reported *Geomyces* sp. to be the most common fungus isolated from cryopegs.

Impact of Seabirds on Antarctic Soil

Antarctica's terrestrial ecosystems are fragile and easily affected by human or animal disturbance (Kerry 1990; Chown & Gaston 2000; Selmi & Boulinier 2001). Chown & Gaston (2000) stated that human activities, in the form of tourism and the establishment of permanent stations, threaten these vulnerable ecosystems. Colonial-breeding seabirds such as penguins impose specific types of disturbance. They feed at sea but reproduce and rest on land in high densities at specific locations. These results in the deposition of large quantities of guano and other sources of nutrient (e.g. feathers, carcasses), fertilizing the otherwise nutrient-poor terrestrial ecosystem (Allen *et al*. 1967; Smith 1985; Myrcha *et al.* 1985; Myrcha & Tatur 1991; Tatur 2002).

Tatur (2002) reported that about 30 000 – 50 000 pairs of penguins (*Pygoscelis* spp.) nest on the western shore of Admiralty Bay, King George Island (maritime Antarctica), where they deposit about 6.35 tonnes (dry mass) of guano on the land daily. The runoff from these penguin rookeries directly fertilizes surrounding grounds (Park *et al.* 2007), although this effect decreases with increasing distance from the rookeries (Rankin & Wolff 2000). Strong winds also transport and redistribute fine particles of guano and volatile ammonia to a wider area, on the scale of kilometres (Wodehouse & Parker 1981; Legrand *et al.* 1998). Vegetative development in surrounding areas can be generally categorised into several zones relating to the degree of rookery impact. The zone under the most immediate influence of penguin guano and trampling is usually devoid of visible vegetation except for small thalli of the foliose green alga *Prasiola crispa*. The adjacent zone is typically dominated by the nitrophilous cyanobacterium, *Phormidium attenuatum*. The Antarctic hair grass, *Deschampsia antarctica*, then enters the flora tolerant of the level of fertilisation and disturbance, followed by a zone dominated by mosses such as *Sanionia georgico-uncinata* and *Bryum pseudotriquetrum*. The zone least affected by penguin guano is dominated by lichens such as *Acarospora macrocyclos* and *Buellia falklandica* (Smykla *et al.* 2007), before the vegetative community becomes esssentially typical maritime Antarctica 'fellfield' — a mixed community dominated by bryophytes and lichens.

Penguin rookery soils are therefore enriched with nutrient (Tatur & Myrcha 1989; Tatur 1989). The surface layer of active rookeries contains fresh and leached guano, and is underlaid by aluminium-iron phosphatic clay (Tatur *et al*. 1997). The toxic levels of over manuring and trampling mean that this soil is entirely devoid of vegetation. However, and in contrast abandoned penguin rookeries can quickly become covered by a well-developed moss layer (Smykla *et al*. 2007). High levels of potassium and marine-derived salts are present in this ornithogenic soil due to the production of faeces, urine and nasal salt secretion (Rankin & Wolff 2000). Soil near penguin rookeries has also been found to contain high concentrations of low molecular weight sugars and polyols (in the form of mono-saccharides and disaccharides) (Roser *et al*. 1994).

Barientos and Beaufort Islands

Barrientos Island is a small island in the Maritime Antarctica, South Shetland Islands. It is one of the most frequently visited islands in the Aitcho Island group, where it is often the first landing site for many Antarctic tourists and can receive more than 400 tourists a day. The island is snow-free during summer and provides a variety of avian habitats. Numerically, penguin rookeries dominate the avifauna of the island, with a smaller number of other important species, such as nesting southern giant petrels. Elephant seals (*Mirounga leonina*) also haul out and moult on some of the beaches and fur seals (*Arctocephalus gazella*) are present later in the summer season. However, there has only been a little study of the island's smaller organisms, and in particular there are no published records of the mycobiota.

In contrast, Beaufort Island, located in the Ross Sea off the Victoria Land coast, is mostly ice and snow covered, although it still includes a variety of ice-free habitats that support a relatively diverse terrestrial biota for this region (Seppelt *et al*. 1996). Beaufort Island is isolated, difficult to access and is known to be visited only infrequently. The first scientific report relating to Beaufort Island was that of Stonehouse (1966), relating to local marine currents and the island's emperor penguin (*Aptenodytes*) colony. Further studies of the island's avifauna have been published by Woehler (1993) and Woehler and Croxall (1996) but these studies remain sporadic. Seppelt *et al*. (1996) studied the island's byoflora and its relationship with the vertebrate fauna. The island has not been comprehensively studied or documented, and remains largely undisturbed by any human activity. Hence, it has been exposed to fewer opportunities for anthropogenic colonization events than many other sites in the Ross Sea area, and may therefore be considered as a reference area for this region.

Figure 1 (a–d). Sampling sites in Beaufort Island (a–b) and Barrientos Island (c–d).

The island also hosts several relic penguin rookeries. Emslie *et al*. (2007) described these as being dominated by matted layers of pin feathers that are characteristic of moulting sites. Previously Seppelt *et al*. (1999) suggested the possible presence of a former breeding colony of Emperor or Adélie (*Pygoscelis adeliae*) penguins, with these now identified as those of Adélie penguins. Emslie *et al*. (2007) dated feathers and bone to an age of more than 44 000 years, and this remains the oldest such record of this species in Antarctica.

The main objectives of the current study were (1) to isolate and obtain axenic cultures of soil fungi from both islands, and (2) to compare the resulting diversity of cultures of microfungi from both islands. This comparison may highlight differences in the myco-community between the Maritime and Continental Antarctica regions.

MATERIALS AND METHODS

Sampling Sites

Beaufort Island. The study area was located in the northern part of Beaufort Island (76º57'S, 166º55'E). It has warm summer temperatures (Figure 1a and 1b) because of its northerly location and shelter from the cold southerly winds. The local microclimate, stability of substrate and supply of water from the nearby ice-cliffs and snow fields provided conditions favourable for supporting a relatively diverse terrestrial biota, and this site possessed the most extensive, continuous stand of mosses yet known in the McMurdo Sound region (Seppelt *et al.* 1996). Field collections were completed during the austral summer of 2004/05. Samples of the upper 10 cm of the soil were collected using sterile spatulas and placed in sterile polyethylene bags (Whirl-Pack) and then frozen by reducing temperatures over a 48 h period from 1ºC to –20ºC. Twenty three soil samples from 20 sites on Beaufort Island were collected.

Barrientos Island. Soil sampling was done in the central and western parts of Barrientos Island. These areas were mostly barren of visible vegetation, especially close to the beaches where penguins gather in rookeries (Figure 1c). The western side of the island also hosts seals, snow petrels (*Pagadroma nivea*) and Gentoo penguins (*Pygoscelis papua*) (Figure 1d). Studies at this location were completed during the austral summer of 2006/2007. Again, the upper 10 cm of the soil were collected using sterile spatulas, placed in sterile polyethylene bags (Whirl-Pack) and frozen at –20ºC. Twenty three soil samples were obtained.

Isolation of Fungi

Fungi were isolated from the frozen soil samples after their return to the University of Malaya, using a modification of Warcup's soil plate method (Warcup 1950). Approximately 0.1 g of soil was placed on the agar surface and distributed using 1 ml of sterile distilled water and rotating the plate. Five replicates of each soil sample were plated on isolation media obtained from OXOID (Potato dextrose agar — PDA) and incubated at 4ºC and 25ºC. PDA was chosen as the growth medium for its ability to encourage growth of many genera of fungi. All plates were examined daily to determine number of colonies and to avoid overgrowth of colonies. Fungal isolates were sub-cultured for identification of species. Filamentous fungi were identified, wherever possible. The percentage occurrence of fungal taxa within samples was determined by dividing the frequency of occurrence by the total number of replicates.

Isolated fungi were categorised in three different groups according to their frequency of occurrence. Fungi occurring in more than 10% of cultures were categorised as very common, those between 5% and 10% as common, and those less than 5% as infrequent. Isolated fungi were also categorised according to their thermal characteristics. Psychrophilic taxa were those which only occurred in culture at 4ºC, psychrotrophic those which occurred at both 4ºC and 25ºC, and mesophilic, those that only occurred at 25ºC.

RESULTS

Table 1 shows the frequency of occurrence of the fungi isolated at two different culture temperatures, 4ºC and 25ºC, respectively. Ten distinct taxa were isolated from Beaufort Island, while 23 were recorded from Barrientos Island. In total, 28 taxa were isolated from both islands: 11 of which were ascomycetes; 14 hyphomycetes and three yeasts. *Geomyces* sp., and white and pink yeasts were recorded from both islands. The majority of fungi isolated from Beaufort Island were ascomycetes (7 taxa), while hyphomycetes and yeasts contributed one and two taxa, respectively.

Geomyces sp. was the most frequently isolated fungus (16.3%) (Table 1). Other very common taxa included *Thelebolus microsporus*, *Antarctomyces* sp.1 and *Thelebolus* sp. (12.5%, 11.9% and 11.6%, respectively). Asco JBI8, *Phoma* sp. and unidentified fungus JBIsp5 were common (9.6%, 9.3% and 7.8%, respectively). The remaining 21 fungi isolated were infrequent.

T. microsporus, Thelebolus sp., Asco BI8 and Phoma sp. were very common on Beaufort Island, with occurrence of 20% and above, while unidentified sp. 5 and *Thelebolus globosus* were common (16.9% and 7.5%, respectively) (Table 2). The soil microfungal community on Beaufort Island was low in diversity and most taxa that were present occurred in high frequencies. In contrast, on Barrientos Island only two species occurred in more than 20% of cultures, these being *Geomyces* sp. and *Antarctomyces* sp.1 (25.0% and 21.3%, respectively). The remaining taxa occurred infrequently.

Therefore, four species of the taxa obtained from Beaufort Island were apparently psychrophilic, four were psychrotrophic, and only one was mesophilic (Figure 2). Of the taxa cultured from Barrientos Island, only four were psychrotrophic, six psychrophilic and 12 mesophilic (Figure 3). A total of seven psychrophilic, 11 psychrotrophic and ten mesophilic fungi were isolated from both islands, 25%, 39% and 36%, respectively, of the taxa cultured (Figure 4). Of the seven psychrophilic fungi, six were ascomycetes and one was a hyphomycete. Three ascomycetes, five hyphomycetes and three yeasts were psychrotrophic. Two ascomycetes and eight hyphomycetes were mesophilic (Figure 5).

Ten taxa were isolated from the relic penguin rookeries on Beaufort Island while 21 taxa were isolated from soil adjacent to penguin rookeries on Barrientos Island. However, no filamentous fungi were isolated from active penguin rookeries, excepting for a single brown yeast after nearly six weeks of incubation, isolated from two out of four rookeries.

DISCUSSION

Azmi & Seppelt (1998) reported only seven fungal taxa in isolates from penguin associated soils in the Windmill Islands, Continental Antarctica, recording a high occurrence of sterile mycelia and *Mortierella* sp. In the present study, the mycoflora of Beaufort Island was dominated by ascomycetes. *T. microsporus* was recorded in various sites in the Windmill Islands region (Azmi & Seppelt 1998), most frequently at sites with seabird influence. In soils of relic penguin colonies on Beaufort Island around 20%–27% of *T. microsporus*, *Thelebolus* sp., Asco BI8 and *Phoma* sp. occurred in an unusually high frequency of occurrence in studies of soil microfungal diversity. While this is an inevitable corollary of low overall diversity, it may indicate a founder effect, where these ascomycetes have been more successful in establishment in comparison with other fungal groups, and may also have survived subsequently since the period over 44 000 years ago when these rookeries were active (Emslie *et al.* 2007).

Table 1. Fungal taxa isolated from Beaufort Island and Barrientos Island, and their overall frequencies of occurrence.

Species	Frequency of occurrence (%)				Total frequency of occurrence (%)
	Beaufort Island		Barrientos Island		
	4˚C	25˚C	4˚C	25˚C	
Ascomycete					
Antarctomyces sp. 1	–	–	11.92	–	11.92
Antarctomyces sp. 2	–	–	2.91	–	2.91
Aureobasidium sp.	–	–	0.29	–	0.29
Geomyces sp. *	2.33	8.43	–	5.52	16.28
Penicillium sp.	–	–	–	4.07	4.07
Phoma sp.	8.43	0.87	–	–	9.30
Thelebolus microsporus	12.5	–	–	–	12.5
Thelebolus globosus	3.49	–	–	–	3.49
Thelebolus sp.	11.34	0.29	–	–	11.63
Asco sp. 5	1.74	–	–	–	1.74
Asco JBI8	–	9.59	–	–	9.59
Hyphomycetes					
EBIsp1	–	–	–	2.33	2.33
EBIsp2	–	–	1.45	0.58	2.03
EBIsp3	–	–	–	0.87	0.87
EBIsp6	–	–	0.29	1.45	1.74
EBIsp7	–	–	–	0.29	0.29
EBIsp9	–	–	–	0.29	0.29
EBIsp10	–	–	–	0.29	0.29
EBIsp11	–	–	–	0.29	0.29
EBIsp12	–	–	0.87	–	0.87
EBIsp17	–	–	–	0.87	0.87
EBIsp19	–	–	0.29	0.87	1.16
EBIsp21	–	–	0.29	0.58	0.87
EBIsp22	–	–	0.29	0.29	0.58
JBIsp5	2.91	4.94	–	–	7.85
Yeast					
Brown yeast	–	–	0.29	0.29	0.58
White yeast *	2.91	–	–	0.58	3.49
Pink yeast *	1.16	1.16	–	0.29	2.41

* Occurred at both study locations.

Hyphomycetes are also known to be able to colonise extreme environments, and utilise inorganic or toxic substances that are otherwise lethal to many fungi (Thomas & Hill 1976; Jongmans *et al.* 1997). Hyphomycetes are able to survive in xeric environments (Gunde-Cimerman *et al.* 2003), to degrade petroleum (Kirk & Gordon 1988), pathogenic to rotifers and tardigrades in Antarctic lakes (McInnes 2003) and to be nematophagous (Gray *et al.* 1982).

In the present study, the total numbers of taxa of psychrophilic and psychrotrophic fungi obtained from this continental Antarctic location were similar. However, psychrotrophic fungi occurred at a higher frequency compared to psychrophilic fungi. Robinson (2001) suggested that, although the majority of fungi isolated in Antarctic studies are able to grow around 0ºC, the substratrum microhabitat temperatures at certain times of the year can far exceed air temperatures (see also Möller & Dreyfuss (1996) for an example). Psychrotrophic fungi are able to withstand temperature fluctuations that are typical in many low-lying Antarctic terrestrial habitats, while psychrophilic fungi are less flexible and more stenothermic. Panikov *et al.* (2006) reported that the cold respiratory activity of soils sampled during winter reduced dramatically after mild warming incubation, illustrating the sensitivity of cold-acclimated organisms to warming. Mesophilic fungi were very poorly represented in our extractions of soils from Beaufort Island, consistent with their inability to withstand very low temperature despite the high nutrient availability in these soils.

In contrast, on Barrientos Island, hyphomycetes dominated the soil fungal flora. Of the 22 isolated taxa, 14 were hyphomycetes, five ascomycetes and three yeasts. Of these, four were psychrophilic, six psychrotrophic and 12

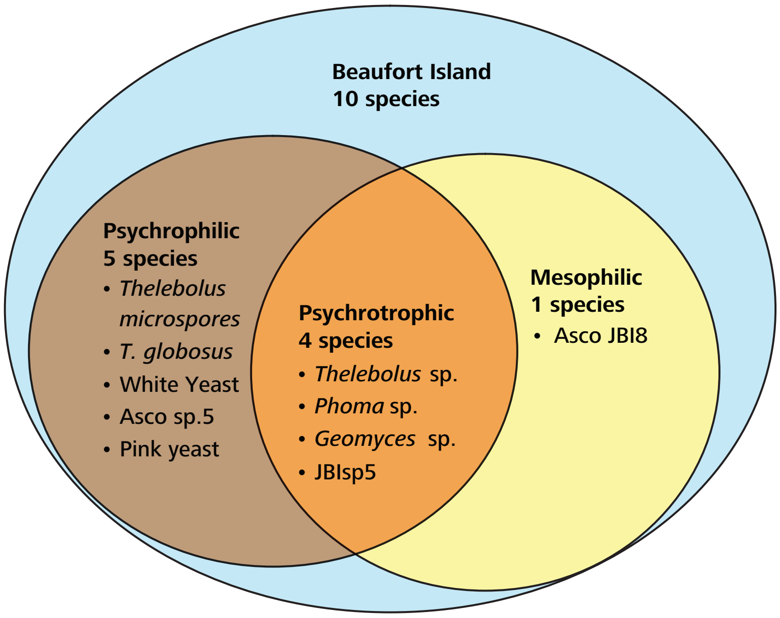


Figure 2. Diversity of microfungi in Beaufort Island classified in terms of thermal characteristics.

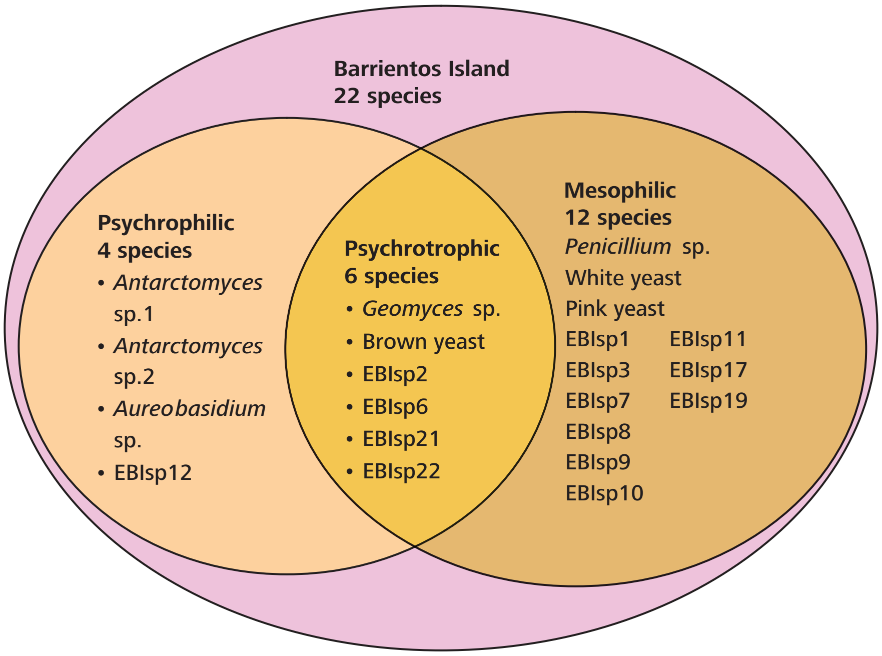


Figure 3. Diversity of microfungi in Barrientos Island classified in terms of thermal characteristics.

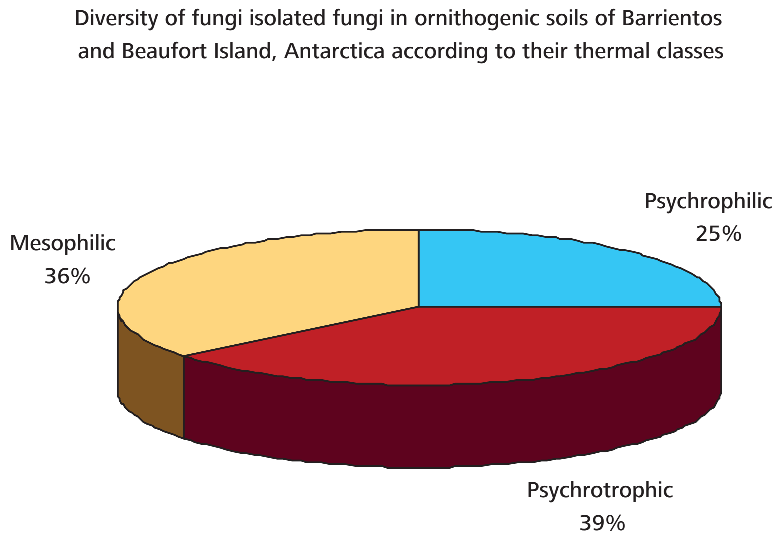


Figure 4. Percentage of isolated fungi according to their thermal classes.

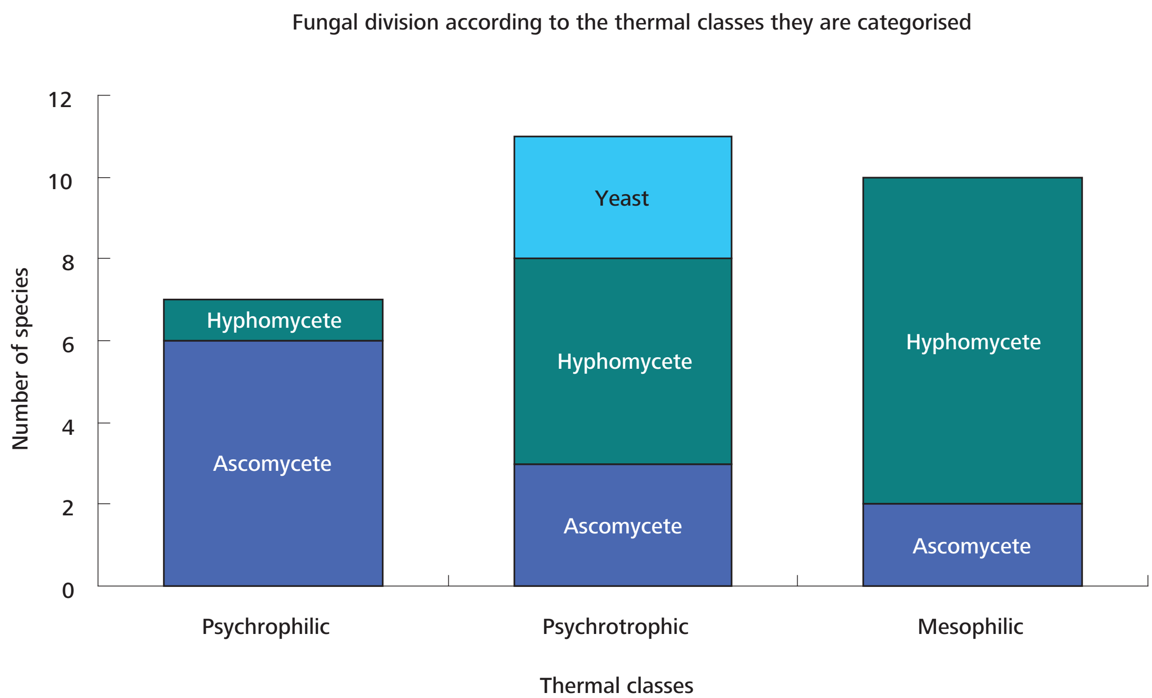


Figure 5. Division of isolated fungi for each thermal classes.

Table 2. Frequency of occurrence of very common and common fungal taxa on Beaufort and Barrientos Islands.

Beaufort Island	Barrientos Island
Thelebolus microsporus (26.88%)	*Geomyces* sp. (25.00%)
Thelebolus sp. (25.00%)	*Antarctomyces* sp.1 (21.35%)
Asco BI8 (20.63%)	*Penicillium* sp. (7.29%)
Phoma sp. (20.00%)	*Antarctomyces* sp.2 (5.21%)
JBIsp5 (16.88%)	
Thelebolus globosus (7.50%)	

Table 3. Fungal taxa cultured from relic and active penguin rookeries.

	Fungal occurrence	
Relic rookeries	Active penguin rookeries	Sites adjacent to penguin rookeries
Thelebolus microsporus	Brown yeast	*Antarctomyces* sp. 1
Thelebolus globosus		*Antarctomyces* sp. 2
Thelebolus sp.		*Geomyces* sp.
Geomyces sp.		*Penicillium* sp.
Asco sp. 5		*Aureobasidium* sp.
Asco JBI8		White yeast
Unidentified JBIsp.5		Pink Yeast
Phoma sp.		Unidentified EBIsp1
Pink Yeast		Unidentified EBIsp2
White yeast		Unidentified EBIsp3
		Unidentified EBIsp6
		Unidentified EBIsp7
		Unidentified EBIsp8
		Unidentified EBIsp9
		Unidentified EBIsp10
		Unidentified EBIsp11
		Unidentified EBIsp12
		Unidentified EBIsp17
		Unidentified EBIsp19
		Unidentified EBIsp21
		Unidentified EBIsp22

mesophilic. Three ascomycetes and only one hyphomycete were psychrophilic, while the psychrotrophic taxa included an ascomycete, a yeast and four hyphomycetes. The maritime Antarctica was generally warmer compared to continental Antarctica. During the study period on Barrientos Island, soil temperatures ranged from 5ºC to 8ºC, and they could rise up to 17ºC during summer (Convey *et al.* 2008). Thus, the soil microbiota of the maritime Antarctic were more adapted to exposure to higher temperatures. Hence, the number of psychrophilic fungi obtained was low compared to psychrotrophic and mesophilic classes, and mesophilic fungi dominated the fungal flora of this island.

Azmi & Seppelt (1998) observed that fungal diversity was low in ornithogenic soil in the centre of currently occupied penguin colonies. In the present study, no fungi other than a brown yeast were isolated from active penguin rookeries. This was likely to be due to poisonous ammonia concentrations from fresh guano (Legrand *et al*. 1998; Rankin & Wolff 2000), and also the presence of acrylic acid, a microbial antagonist that was also present in ornithogenic soils in active penguin rookeries (Fletcher *et al.* 1985; Roser *et al.* 1994). These soils also contained high concentrations of acetic and oxalic acids (Roser *et al*. 1994; Rankin & Wolff 2000), succinic acid (Roser *et al.* 1994), with high levels of sodium and potassium.

Geomyces spp. are widely distributed in Antarctica (Fletcher *et al.* 1985; Kerry 1990; Azmi & Seppelt 1998; Glichinsky *et al.* 2005) while tolerating various conditions (Kerry 1990). Although it is known to produce cellulase at 1ºC (Hurst *et al.* 1983) and is described as a psychrotroph, it is also a poor competitor (Ivarson 1974). Kerry (1990) described the occurrence of *Geomyces pannorum* in various sites, and noted its absence or low frequency of occurrence when other fungal species such as *Phoma herbarum* were present. In the present study, the frequency of occurrence of *Geomyces* sp. was low on Beaufort Island compared to Barrientos Island. In the former, the mycobiota was dominated by *Thelebolus* spp., *Phoma* sp. and Asco BI8, while on the latter, *Geomyces* sp. was the most common fungus in the absence of *Thelebolus* sp. and *Phoma* sp. These observations were consistent with those of Ivarson (1974) with fungi of this genus being effective primary colonisers.

CONCLUSION

Ornithogenic soils in active penguin rookeries on Barrientos Island (Maritime Antarctic) were dominated by hyphomycetes, while those of relic rookeries on Beaufort Island (continental Antarctica), were dominated by ascomycetes. Soil fungal diversity was strongly influenced by the availability of nutrients, the presence of toxic compounds derived from guano and environmental temperature. The fungi diversity within soils of relic penguin rookeries might indicate long-term presence over the millenia since the colonies were abandoned, and represent a form of the 'founder effect' .

ACKNOWLEDGEMENTS

We are grateful to the Ministry of Science, Technology and Innovation of Malaysia, the Polish Academy of Sciences and the Polish State Committee for Scientific Research (Grant no. 2P04F00127) for funding, and to the Institùto Antartico Ecuatoriano and US Antarctic Program for logistic support during the field surveys.

Date of submission: October 2008
Date of acceptance: December 2009

REFERENCES

Alias, SA, Abdul Wahab, A & Omar, S 2005, 'Occurrence of filamentous microfungi from Windmill Islands, in *Proceedings of Seminar: Antarctic Research in the University of Malaya*', Academy of Sciences Malaysia, pp. 99–103.

Allen, SE, Grimshaw, HM & Holdgate, MW 1967, 'Factors affecting the availability of plant nutrients on an Antarctic island', *Journal of Ecology*, no. 55, pp. 381–396.

Atlas, RM, di Menna, ME & Cameron, RE 1978, 'Ecological Investigation of yeasts', *Mycologia*, no. 61, pp. 748–774.

Azmi, OR & Seppelt, RD 1998, 'The broad scale distribution of microfungi in the Windmill Islands region, continental Antarctica', *Polar Biology*, no. 19, pp. 92–100.

Blanchette, RA 2000, 'A review of microbial deterioration found in archaeological wood from different environments', *International Biodeterioration and Biodegradation*, no. 46, pp. 189–204.

Blanchette, RA *et al.* 2004, 'Wood destroying soft-rot fungi in the historic expedition huts of Antarctica, *Applied and Environmental Microbiology*, no. 1, pp. 1328–1335.

Cameron, RE *et al.* 1971, 'Surface distribution of micro-organisms in Antarctic dry-valley soils: a Martian analog', *Antarctic Journal*, (Sept–Oct 1971), pp. 211–213.

Cheryl, FM & Seppelt, RD 1999, 'Filamentous fungi of the Windmill Islands, continental Antarctica', *Polar Biol*., no. 22, pp. 389–394.

Chown, SL & Gaston, KJ 2000, 'Island-hopping invaders hitch a ride with the tourists in South Georgia', *Nature*, no. 48, pp. 637.

Convey, P *et al.* 2008, 'Antarctic terrestrial life – challenging the history of the frozen continent', *Biological Reviews*, no. 83, pp. 103–117.

Del Frate, G & Caretta, G 1990, 'Fungi isolated from Antarctic material', *Polar Biology*, no. 11, pp. 1–7.

Dennis, RWG 1968, 'Fungi from South Georgia', *Kew Bulletin*, no. 22, pp. 445–448.

Easmus, D & Jennings, DH 1986, 'Water, turgor and osmotic potentials of fungi', in *Water, fungi and plants*, Cambridge University Press, Cambridge.

Finotti, E *et al.* 1993, 'Temperature effects and fatty acid patterns in Geomyces species isolated from Antarctic soil', *Polar Biology*, no. 13, pp. 127–130.

Fletcher, LD, Kerry, EJ & Weste, GM 1985, 'Microfungi of MacRobertson and Enderby Lands, Antarctica', *Polar Biol*, no. 4, pp. 81–88.

Friedmann, EI, McKay, CP & Nienow, JA 1985, 'The cryptoendolithic microbial environment in the Ross Desert of Antarctica', satellite-transmitted continuous nanoclimate data, 1984–1986', Polar Biology, no. 7, pp. 283–287.

Gilichinsky, D *et al.* 2005, 'Biodiversity of cryopegs in permafrost', *FEMS Microbiology Ecology*, no. 53, pp. 117–128.

Gray, NF, Wyborn, CHE & Smith, RIL 1982, 'Nematophagus fungi from the maritime Antarctic', *Oikos*, no. 38, pp. 194–201.

Gunde-Cimerman, N *et al.* 2003, 'Extremophilic fungi in arctic ice: a relationship between adaptation to low temperature and water activity', *Physics and Chemistry of the Earth*, no. 28, pp. 1273–1278.

Held, BW *et al.* 2005, 'Environmental factors influencing microbial growth inside the historic expedition huts of Ross Island, Antarctica', *International Bioterioration and Biodegradation*, no. 55, pp. 45–53.

Hughes, KA, Lawley, B & Newsham, KK 2003, 'Solar UV-B radiation inhibits the growth of Antarctic terrestrial fungi', *Applied and Environmental Microbiology*, no. 69, pp. 1488–1491.

Hurst, JL, Pugh, GJF & Walton, DWH 1983, 'Fungal succession and substrate utilization on leaves of three South Georgia phanerograms', *Br. Antarc. Surv. Bull*. no. 56, pp. 89–100.

Ivarson, KC 1974, 'Comparative survival and decomposing ability of four fungi isolated from leaf litter at low temperatures', *Can. J. Soil Sci.* no. 54, pp. 245–260.

Jongmans, AG *et al.* 2001, 'Rock-eating fungi', *Nature*, no. 389, pp. 682–683.

Kerry E 1990a, 'Microorganisms colonizing plants and soil subjected to different degree of human activity, including petroleum contamination in the Vestfold Hills and Mac. Robertson Land, Antarctica', *Polar Biol*, no. 10, pp. 423–430.

Kerry, E 1990b, 'Effects of temperature on growth rates of fungi from subantarctic Macquarie Island and Casey, Antarctica', *Polar Biology*, no. 10, pp. 293–299.

Kirk, PW & Gordon, AS 1988, 'hydrocarbon degradation by filamentous marine higher fungi', in *Adaptations to extreme environments, Mycologia*, no. 80, pp. 776–782.

Legand, M *et al*. 1998, 'Ammonium in coastal Antarctic aerosol and snow: role of the polar ocean and penguin emissions', *Journal of Geophysical Research*, no. 103 (D9), pp. 11043–11056.

Smith, RIL 1985, 'Nutrient cycling in relation to biological productivity in Antarctic adn sub-Antarctic terrestrial and freshwater ecosystems, in *Antarctic nutrient cycles and food webs*, eds WR Siegfried, PR Condy & RM Laus, Berlin, Heidelberg, New York, Springer-Verlag.

Lewis Smith, RI 1994, 'Species diversity and resource relationships of South Georgian fungi', *Antarctic Science*, no. 6, pp. 45–52.

Marshall, WA 1997, 'Seasonality of Antarctic fungal spores', *Applied and Environmental Microbiology*, June 1997, pp. 2240–2245

Martin, A 1988, 'Microbial flora of some soils of Mawson Base and the Vestfold Hills, Antarctica', *Polar Biology*, no. 8, pp. 421–427.

McInnes, S 2003, 'A predatory fungus (Hyphomycetes: Lecophagus) attacking Rotifera and Tardigrada in maritime Antarctic lakes', *Polar Biology*, no. 26, pp. 79–88.

Möller, C & Gams, W 1993, 'Two new hyphomycetes isolated from Antarctic lichens', *Mycotaxon*, no. 48, pp. 441–450.

Möller, C & Dreyfuss, MM 1996, 'Microfungi from Antarctic lichens, mosses and vascular plants', *Mycologia*, no. 88, pp. 922–933.

Myrcha, A, Pietr, SJ and Tatur, A 1985, 'The role of pygoscelid penguin rookeries in nutrient cycles at Admiralty Bay, King George Island, in *Antarctic nutrient cycle and food webs*. Berlin, Heidelberg, New York: Springer-Verlag, pp. 156–162.

Myrcha, A & Tatur, A 1991, 'Ecological role of current and abandoned penguin rookeries in the land environment of the Maritime Antarctic', *Polish Polar Research*, no. 12, pp. 3–24. In. Smykla, J., Wolek, J. and Barcikowski, A., 2007.

Park, J-H *et al.* 2007, 'Biogeochemical pools and fluxes of carbon and nitrogen in a maritime tundra near penguin colonies along the Antarctic Peninsula', *Polar Biology*, no. 30, pp. 199–207.

Pugh, GJF & Allsopp., D 1982, 'Microfungi on Signy Islands, South Orkney Islands', *Br. Antartc. Surv. Bull*. 57, pp. 55–67.

Rankin, AW & Wolff, EW 2000, 'Ammonium and potassium in snow around an emperor penguin colony', Antarctic Science vol. 12, no. 2, pp. 154–159.

Robinson, CH 2001, 'Cold adaptation in Arctic and Antarctic fungi', *New Phytologist*, no. 151, pp. 341–353.

Roser, DJ, Seppelt, RD & Nordstorm, O 1994, 'Soluble carbohydrate and organic content of soils and associated microbiota from the Windmill Islands, Budd Coast, Antarctica', *Antarctic Science*, vol. 6, no. 1, pp. 53–59.

Selbmann, L *et al.* 2005, 'Fungi at the edge of life: Cryptoendolithic black fungi from Antarctic desert', *Studies in Mycology*, no. 51, pp. 1–32.

Selmi, S & Boulinier, T 2001, 'Ecological biogeography of southern ocean islands: the importance of considering spatial issues', *Am. Nat*., no. 158, pp. 426–437.

Seppelt RD, Green TGA & Skotnicki M 1996, 'Notes on the Flora, Vertebrate Fauna and Biological Significance of Beaufort Island, Ross Sea, Antarctica', *Polarforschung*, no. 66(1/2), pp. 53–59, (printed 1999).

Smykla, J, Wolek, J & Barcikowski, A 2007, 'Zonation of vegetation related to penguin rookeries on King George Island, Maritime Antarctic', Arctic, *Antarctic and Alpine Research*, vol. 39, no.1, 2007, pp. 143–151.

Stonehouse B. 1966, 'Emperor penguin colony at Beaufort Island, Ross Sea, Antarctica', *Nature*, no. 210, pp. 925–926.

Sugiyama, J *et al.* 1967, 'Report of the Japanese Summer Parties in Dry Valleys, Victoria Land, 1963-1965. IV. Mycological Studies of the Antarctic Fungi. Part. 2. Mycoflora of Lake Vanda, an ice-free lake', *The Antarctic Record, Tokyo*. no. 28, pp. 23–32.

Tatur, A 1989, 'Ornithogenic soils of Maritime Antarctic', *Polish Polar Research*. no. 104, pp. 481–532.

Tatur, A 2002, 'Ornithogenic ecosystems in Maritime Antarctic – Formation, development and disintegration, in *Geoecology of Antarctic ice-free coastal landscapes*, eds L Beyer & M Bolter, *Ecological studies*, 156. Berlin: Springer, pp. 161–184.

Tatur, A & Myrcha, A 1984, 'Ornithogenic soils on King George Island (maritime Antarctic zone)', *Polish Polar Research*, no. 5, pp. 31–60.

Tatur, A & Myrcha, A 1989, 'Soils and vegetation in abandoned penguin rookeries (maritime Antarctic)', *Polar Biology,* no. 2, pp. 181–189.

Tatur, A, Myrcha, A & Niegodzisz, J 1997, 'Formation of abandoned penguin rookery ecosystems in maritime Antarctic', *Polar Biology*, no. 17, pp. 405–417.

Thomas, AR & Hill, EC 1976, 'Aspergillus fumigatus and supersonic aviation. I. Growth of A. fumigatus', *International Biodeterioration Bulletin*, no. 12, pp. 87–94.

Tubaki, K 1961, 'On some fungi isolated from the Antarctic materials', *Biol. Res*. JARE, no. 14, pp. 19.

Vidal, E, Jouventin, P & Frenot,Y 2003, 'Contribution of alien and indigenous species to plant-community assemblages near penguin rookeries at Crozet archipelago', *Polar Biology*, no. 26, pp. 432–437.

Warcup, JH 1950, 'The soil plate method for isolation of fungi from soil', *Nature*, no. 166, pp. 117–118.

Wicklow DT 1968, 'Aspergillus fumigatus Fresenius isolated from ornithogenic soil collected at Hallet Station, Antarctica', *Can. J. Microbiol.* no. 14, pp. 717–719.

Weinstein, RN *et al*. 1997, 'Ecological and physiological characterization of humicola marvinii, a new psychrophilic fungus from fellfield soils in the maritime Antarctic', *Mycologia*, no. 89, pp. 706–711.

Wodehouse, EB & Parker, BC 1981, 'Atmospheric ammonia nitrogen, a potential source of nitrogen eutrophication of freshwater Antarctic ecosystems', *Antarctic Research Series*, no. 30, pp. 155–167.

Woehler EJ 1993, *The distribution and abundance of Antarctic and Aubantarctic penguins*, SCAR, Cambridge, England.

Woehler EJ & Croxall JP 1996, *The status and trends of Antarctic and Subantarctic seabirds*, SC-CAMLR-XV/BG/ 29.

Antarctic Biology, the International Polar Year, and Beyond

P. Convey[1]

As we draw towards the end of the massive effort that has been the International Polar Year (IPY), it is opportune to consider what impact it has had on Antarctic biological research and its research community. Have we seen or are we going to see major advances in any particular areas of science? Has the hoped-for international integration of research communities been advanced, including those of the 'non-traditional' or 'less developed' polar nations? Have the 'global public' become more engaged with the polar regions?

To start with, this IPY was not created in the same historical and geopolitical context as its predecessors in the 1880s, 1930s and 1950s. The first 'polar year' had relatively little impact on the Antarctic, although it saw expeditions to the Southern Ocean and some sub-Antarctic islands. At that time, the 'heroic age' of exploration was still just around the corner and the main body of the Antarctic continent had yet to feel the impact of human footprints. On the other hand, the Southern Ocean and many of the sub-Antarctic islands had already seen substantial, and even now apparently irreversible, uncontrolled human exploitation of their vast biological resources, with this wholesale ecosystem destruction extending to the northern Antarctic Peninsula and Scotia arc archipelagos.

The 1930s saw unprecedented global economic depression, nevertheless with science hardly registering on the public and political radar.

Nevertheless, efforts such as the multi-year Discovery Investigations saw major advances in knowledge of the Southern Ocean and its ecosystem, some of which remain the benchmark studies to this day.

Of the previous IPYs, that with most significance to the Antarctic and its future place in human consciousness and research efforts was the polar component of the International Geophysical Year of 1958. This took place in a world climate deeply mired in Cold War fear, combined with post-World War II reconstruction, while tensions over the different national claims on segments of Antarctica were increasing. On the face of it, it was hardly a promising environment for the achievement of major financial and logistic investments, or of the lofty ideals of international co-operation. However, in the Antarctic context, the International Geophysical year (IGY) was in many ways a remarkable success, demonstrating that co-operation was possible even against the political tide of the time and providing the foundation for the next half century of peaceful scientific research and open access across the continent through its catalysis of the development of the Antarctic Treaty System (ATS). At national levels, the IGY was characterised by the construction of a network of year-round research stations in Antarctica — although inevitably with greater density in the more accessible northern Antarctic Peninsula region. These spanned the entire continent, with the then global superpowers being able to prove to each other that they had the strength and resources to build and support permanent stations in the previously inaccessible continental interior. Roughly a third of the stations first opened in the IGY remain functional today.

While the potentially thorny issue of territorial claims is in 'abeyance' under the terms of the Treaty, the case remains that research stations across the continent are constructed and run by separate nations (those of the 'claimant' nations are without exception within the boundaries of their historical claims), and funded within the national science budgets of each nation.

Since the original signing of the Treaty, many more nations have joined in, with the current number standing at 46 and representing about 70% of the global population. By joining the ATS, all these countries assent to the peaceful scientific use of the continent and their scientific presence is traditionally made credible by the construction of scientific research stations. To date, only one signatory country (the Netherlands) has not followed this model, choosing instead to demonstrate its scientific presence through negotiating access to space on the existing stations of other nationalities. The benefits of this approach appear self-evident, at least to the working scientists, providing a far greater return for a relatively smaller financial investment directly to the Netherlands' scientific community, as well as being far more in tune with the co-operative principles of the Antarctic Treaty itself. This would indicate to a pure scientist such as

[1] British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom.
(Co-Chairman, Scientific Committee on Antarctic Research 'Evolution and Biodiversity in the Antarctic' science research programme.)
Corresponding author (e-mail: pcon@bas.ac.uk)

myself that many countries have some way to go in terms of engaging with the principles of the Treaty. Countries new to the Treaty system, and those with increasing scientific involvement in the region that will hopefully join it in due course, stand to benefit considerably in following the example set by the Netherlands, with Malaysia being a particularly pertinent example at this time.

Even within this brief (and entirely personal) view of history, it is easy to understand how the ATS can be seen as a sort of 'club'. The vast costs of establishing stations and undertaking research away from the continental coast have recently driven some common-sense developments of international co-operation, as in the form of the joint French-Italian Concordia station on the continental plateau, the multinational efforts associated with the opening up of Dome A (albeit centred around a proposed new Chinese station) and in the Pine Island region of West Antarctica. The increasingly collaborative nature of leading international science, along with the recognition that addressing 'global' scientific issues requires a research footprint greater than that which can be achieved by a single researcher, group, or even national facility, further catalyse the integration of international effort, for example through organisations like the Scientific Committee on Antarctic Research (SCAR). Although the vast majority of Antarctic science completed 'on the ground' continues to be achieved by scientists of nations which are signatories to the Antarctic Treaty (inevitable, given the representation of the global population contributed by these nations), the increase of collaborative science has also led to an increase in numbers of scientists from non-signatory nations participating. Conversely, the inability of the ATS parties to control the siting of a proposed new Indian station in the Larsemann Hills, which immediately negates the area's proposed designation as an 'Antarctic Specially Managed Area' in the light of its environmental sensitivity and importance for research, highlights a fundamental weakness of the Treaty System as it stands, in that it contains no mechanism for rejection or enforcement, thus, possibly, weakening its credibility. In that the ATS is an evolving system, addressing such contradictions clearly presents it with urgent and important challenges.

With that preamble, what environment greeted the latest IPY? The tensions of the Cold War were hopefully, a part of history while, at least at its outset, global recession was not on the political radar. More than 40 nations had established research stations on the continent, although with vastly differing levels of financial commitment, scientific output and credibility. Antarctic research was an established and unquestioned concept across many of these nations and the Antarctic was increasingly seen as playing a central role in our understanding of the wider workings of the planet. Thus, this IPY did not appear to have a convenient geopolitical 'peg' on which to base itself.

Therefore it had set itself up, rather like the first and second IPYs of 1882–83 and 1932–33, to be based on the scientific priorities of the research communities already represented in the two polar regions. With hindsight, it is clearly easy to identify aspects of excessive micromanagement in a process that of itself offered no new hard money to fund science, with pre-proposal, reviewing and full proposal processes demanding time commitments akin to those of true research agencies. It also faced the difficult if not insoluble challenge of balancing the political requirement for 'inclusiveness', with the reviewing requirement for 'excellence', not to mention the different expectations and standards applied to researchers from different disciplines and countries. Countries also applied very different approaches towards funding of IPY research — covering a spectrum from some employing simple re-branding of existing research programmes, to others bringing forward significant new infrastructure (think of the Belgian Princess Elisabeth station for example), and in several cases real science funding amounting to $400 million in total (e.g. Canada, Norway, New Zealand). For the latter, continuation after the end of the IPY period (the 'IPY legacy') now provides a new challenge to the scientific community that has been engaged by the process and their funding agencies.

As demonstrated by the often-used IPY 'honeycomb' diagram illustrating the linkages in the approaching 200 programmes involved, this IPY has generated unprecedented involvement from the international science community, based on any measures of financial, personnel, international or disciplinary involvement employed. Particular features of the honeycomb linkages have been the number of cross-disciplinary and bipolar programmes involved and the prominence given to outreach and education activities. This is clearly a reflection of the diversity and energy that currently characterises the polar research communities. It is hard to find anything comparable in any other area of global science. Part of the process of evaluating expressions of interest has led to many smaller communities of scientists being invited to group themselves into larger entities to tackle bigger questions comprehensively — such as the Climate of Antarctica and the Southern Ocean (CASO) grouping, for instance. For acceptance by the IPY steering committee, projects had to demonstrate not only that their science was excellent but that they were committed to involve participants from less advantaged nations with non-traditional polar interests and that they had concrete plans for data, information management, exchange, education and outreach.

One of the desires of the IPY planners was to create a legacy not only in science and infrastructure but also in the encouragement of young scientists, and in the development of the observing systems needed as the basis for forecasting future change (this last being the primary interest of one the IPY's sponsors, the World Meteorological Organisation).

No proposals came forward in the Antarctic for any such observing system, so SCAR stepped in to invest time and effort in developing the design for a Southern Ocean Observing System (SOOS), addressing both the physics and the biology of this vast environment. The encouragement of young scientists has led to the development of the Association of Polar Early Career Scientists (APECS), which now has 1500 members worldwide. Data and information management, however, is still weaker than it needs to be — a challenge that SCAR is tackling to ensure that the IPY data legacy is worthwhile.

Where does biology, and particularly Antarctic biology, sit in all this? We have to start by recalling that biology was not a significant component of any of the previous IPYs, including the third — which became the IGY. So this IPY has been a plus in its emphasis on a comprehensive cross-disciplinary approach to polar science. At the outset it must be realised that the timescales within which Antarctic research is planned and delivered do not sit comfortably within a time-constrained event such as IPY, while the funding timescales and priorities existing within the different nations inevitably place further constraints. Within the framework of Antarctic science provided by SCAR, its five science programmes provide a form of co-ordinating structure for the use of planning and delivering international science. As with IPY programmes, these science programmes do not directly fund science, and are best seen as co-ordinating and facilitating activities – in other words by providing opportunities for new linkages, both IPY and SCAR provide 'added value' to researchers and programmes already funded through their national mechanisms.

Of these five SCAR programmes, only one — Evolution and Biodiversity in the Antarctic (EBA) (www.eba.aq) — lies in the field of biology, and it includes packages addressing Antarctic evolutionary history, adaptation, gene flow, diversity, and human impact, also expressly aiming to cross the traditional divide between marine and terrestrial ecosystems and biology in all of these. The Antarctic biological community is certainly more fragmented than is typical in some of the physical disciplines and it can be argued that it has to struggle sometimes as a consequence — there does not appear to be the unity of purpose or single over-riding question that would be required to justify the investment of vast research funds into a biological equivalent of a large hadron collider, international space station or, in a directly Antarctic context, a large single aim programme such as those addressing sub-glacial lakes or Dome A.

It is, however, naïve to consider that a 'one size fits all' model would be appropriate for such widely diverging disciplines. Biology, and in particular Antarctic biology, is fundamentally important if we are to to answer some of the 'big' questions facing us today — questions relating to the evolution and maintenance of life on Earth, to understanding the importance of diversity, and to understand how it (and we ourselves) may respond to the dramatic changes currently facing the planet.

It is in this context that the opportunities provided by IPY programmes on the shorter term, and SCAR science programmes on the longer term, can develop those already inherent in the more fragmented efforts of individual researchers, research groups and national programmes. I do not have the space to enumerate the contributions of all of the many IPY programmes with biological components, and it would be invidious even to try to do so, especially as many will not yet be at the stage of even initial reporting. I will rather focus on a small number of programmes or science areas that are close to my own biological sub-disciplines, and use these as examples as to how the impetus of IPY can 'add value' to the efforts of individuals and groups, or give pointers to how the broad directions of research should be developed in future, both under the auspices of SCAR, and within the practical constraints inherent in national funding streams.

In recent years, there has been broad realisation that both direct and indirect human activities (climate change/warming, pollution, exploitation, species invasion, ecosystem damage) have measurable and in some cases a fundamentally important impact on Antarctic ecosystems. In the Southern Ocean ecosystem, the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) is held up as a beacon or example for the development of fishery management practices globally. Yet it remains the case that remarkably little is known about diversity and ecosystem processes, even in the exploited pelagic realm of the Southern Ocean, with CCAMLR for obvious reasons focussing largely on potentially harvestable species and the Antarctic benthos remains one of the most poorly known marine ecosystems on the planet (with the exception of the generic recognition of its 'remarkable' diversity and biomass). The IPY programme 'Census of Antarctic Marine Life' (CAML), a subset of the global 'Census of Marine Life' (CoML), has already made major steps in improving the survey coverage of the Southern Ocean. The collections made will provide a probably unrepeatable research resource for many years and decades to come, much as the Discovery Investigations did under the leadership of George Deacon in the 1930s.

One direct human impact of acute concern at present lies in the recognition of the dangers associated with so-called 'alien' species arriving in Antarctica and the roles that human activity may play in this. In an era of unprecedented human contact with the Antarctic, both through the activities of national operators (including those stimulated by IPY itself) and of the tourism industry, it has been estimated that humans are responsible for two or more orders of magnitude more alien establishment events than would occur through natural dispersal and colonisation. This has rightly come to the attention of the Committee for Environmental Protection (CEP) of the ATS, as the Antarctic Treaty enshrines the requirement on its signatory parties to protect and conserve the Antarctic environment. However, while it has been easy to find knee-jerk scapegoats, baseline Antarctic data are virtually non-existent. Thus, in the complete historical absence of any form of monitoring programme, we cannot factually describe the magnitude of the problem (what are we actually bringing in, to Antarctica?), objectively rank the risks (which pathways, which imported organisms are at the greatest risk?) or, therefore propose effective mitigation that will minimise the 'real' risk. Thus, although the CEP is now charged with 'alien species' as a standing agenda item, it does not have the requisite tools at its disposal to address the issue. The IPY 'Aliens in Antarctica' programme was therefore conceived in order to provide objective data across all possible human-related import routes, in order to provide a set of continent-wide assessments of the objective risk associated with different activities, and thereby provide this missing advice. This work requires specialists across the international community including access to the international spectrum of national and tourist operators across the continent, and has clearly been facilitated through the IPY, while also providing a textbook example of developing the linkages between the science, policy and education communities within the ATS.

At the same time, biodiversity specialists within EBA have been charged with collating the baseline biodiversity information which is also fundamental to the identification of 'new' species arrivals. Within the longer term SCAR EBA research programme sits a daughter EBA-IPY programme. This focuses on using IPY as a catalyst to accelerate the wider aim of integrating the diffuse international biological research community within SCAR. This is particularly visible in the context of studies of biodiversity and adaptation, where it is increasingly clear that the spatial and temporal scales of study required across the Antarctic are far greater than can be achieved within the ambit of a single research group. This is the case, whether in the context of 'simple' survey work or complex analyses requiring the application of forefront molecular biological techniques — logistical realities dictate that only a few 'new' locations can be visited in a single season, particularly inland within the continent, while laboratory hardware cost and scarce personnel skills practically limit the availability of vital techniques. New international collaborations under the EBA umbrella are leading to fundamental changes in understanding the Antarctic diversity and biogeography on land and in the sea, in understanding of physiological and genomic adaptation, and to new interactions with the Antarctic geological, glaciological and climatological research communities.

While some elements of Antarctic biodiversity might be thought to be relatively well known, this is certainly not the case for the microbial world. 'Classical' microbial studies have leaned towards the description of relatively low diversity microbial communities in the Antarctic, largely made up of cosmopolitan species. However, most recent research, both within national programmes and through their interactions as seen in the IPY MERGE programme, is increasingly identifying that Antarctic microbial communities are both more diverse and more distinctive (i.e. endemic and evolved) than had been thought previously. This has been achieved through the application of expertise from the research communities in both 'traditional' and 'non-traditional' Antarctic nations and, within MERGE in particular, who have also addressed the question of bipolar influences, another feature of many IPY programmes, and even global polar-tropical gradients. This research obviously raises the possibility that, as we see in studies elsewhere on the planet, detailed examination of this diversity would reveal examples of novel functions and new potential (i.e. industrial/economic) applications. While such 'bioprospecting' raises uncomfortable and as yet unresolved issues, both within the ATS generally and within more specific national and international collaborative frameworks, it is an inevitable issue in the world of today and cannot be avoided.

The question of 'gradients' provides my final example of the need for and delivery of international collaborative research, encouraged both under the auspices of IPY and of SCAR EBA. The influence of gradients of various types (e.g. latitude, altitude, depth) has been almost axiomatic in the study of ecology for decades. In an Antarctic or polar context, gradients across wide spatial scales have long been proposed as proxies for environmental variation, and hence also for predictions of responses to environmental change. However, the requirements for observations or experiments that take place over wide spatial or temporal scales rapidly place such studies beyond the grasp of single research groups and short-term funding rounds, and even beyond the possibilities offered by many national programmes. Thus, the integration of long-term efforts across programmes is a prerequisite for research addressing fundamental questions relating, in particular, to responses to environmental change over space and time. Within the contexts of both IPY and SCAR EBA, prime examples of such integration are given by the Latitudinal Gradient Programme (LGP), Tarantella, and EBA itself.

Even drawing on this limited number of examples, several issues are highlighted that are fundamental in considering the future directions of Antarctic biological research, and in particular how they can be facilitated within models provided by current national funding agencies. Most of these examples share several common features. Key amongst these are: (1) the need for baseline survey and environmental description at large spatial scales, backed by (2) the existence of and access to key hardware with which to carry out linked cutting edge analyses (e.g. in barcoding, molecular phylogeography and genomics); (3) the need for a framework within which long-term field observation ('monitoring') and manipulation, in concert with laboratory parallels, can be achieved — it is axiomatic that change at the landscape and climate scale cannot be adequately studied within the single and short-term grant structure increasingly characteristic of funding regimes in most 'developed' countries; (4) the need for continued emphasis on and facilitation of longer-term bi- and multi-lateral international collaboration, and increased integration of logistic opportunities, within national systems that currently do not take account of different funding timescales and opportunities. While these are clearly not trivial challenges, especially in a time of global recession, they are equally not insurmountable. If we (i.e. individual scientists, research groups, collaborations, national operators, funding agencies, international bodies) can rise to this challenge then this IPY, together with the vibrant polar science research community, will indeed have generated a legacy of global importance.

ACKNOWLEDGEMENTS

I would like to thank the Editors for the opportunity to compose this article, and Colin Summerhayes and Robert Culshaw for helpful and constructive comments on an earlier version.

Date of submission: February 2009
Date of acceptance: December 2009

Antarctica: Bioprospecting, Access and Benefit-sharing of Genetic Resources

A.H. Zakri[1]

Recent studies by the United Nations University - Institute of Advanced Studies (UNU-IAS) demonstrate that bioprospecting is taking place in Antarctica and the Southern Ocean and that related commercial applications were being marketed. The bioprospectors' interest in Antarctica stems from two reasons. First, the lack of knowledge surrounding Antarctic biota provides opportunities to discover novel organisms of potential use to biotechnology. Second, Antarctica's environmental extremes, such as cold temperatures, extreme aridity and salinity present conditions in which biota have evolved unique characteristics for survival (UNU-IAS 2003). Thus bioprospecting opportunities include, *inter alia*, the discovery of novel bioactives in species found in cold and dry lithic habitat, novel pigments found in hyper-saline lakes and antifreezes in sea-lakes (Cheng & Cheng 1999).

Micro-organisms thriving in extreme conditions are called 'extremophiles'. They inhabit environments with high temperature, pressure, salt concentration, extreme pH conditions, nutrient concentration, or water availability. Such environments include arid deserts, hot springs, shallow submarine hydrothermal systems, alkaline soils, soda lakes, salterns, deep-sea sediments, and Alpine glaciers (UNU-IAS 2003). Some examples of extremophiles include the nitrate-reducing achaean, *Pyrolobus fumarii*, which can grow at temperatures of 113ºC. The green algae *Dunaliella acidophila* survives at pH 0, an acidity level that is close to that of ten per cent hydrochloric acid and stands in contrast to the pH level of seawater, pH 8 (Rothschild & Mancinelli 2001).

Amongst the many examples of commercially-useful applications discovered in Antarctica are antifreeze proteins sourced from fish and bacteria; a DNA extraction reagent developed from a micro-organism extracted from a volcanic vent; a bacteria able to degrade hydrocarbons and a frost-tolerant gene from Antarctic hairgrass with potential applications in agriculture (UNU-IAS 2008).

One interesting example of such applications is the use of anti-freeze proteins from a variety of bacteria, including *Marinomonas protea, Pseudomonas* sp. and *Moraxella* sp. in the frozen food industry, especially the ice cream industry. Marinomonin, an anti-freeze protein of a bacteria sourced from a hypersaline Antarctic lake could be added to ice cream to keep it creamy through the process of thawing and refreezing. The patent for this invention belongs to one of the biggest ice cream companies, Unilever (the owner of both Ben & Jerry's ice cream and Breyer's ice cream). With its 16% share of the USD59 billion global ice cream market, this invention, if successful, could bring considerable profit to Unilever (ATCM 2008).

Not all Antarctic discoveries however, involve micro-organisms. The Antarctic sponge *Kirkpatricka varialosa* is the source of a potential cancer drug, Variolin, which has been patented and is now being tested *in vivo* by the Spanish pharmaceutical company PharmaMar. The University of South Florida has shown that extracts from the tunicate *Synoicum adareanum* show selective toxicity against several different cancer cell lines, and may be useful in the treatment of cancers, particularly malignant melanomas, colon cancer, and renal cancer cell lines. The potential drug, Palmerolide A, is in preliminary experiments with laboratory mice at the United States National Cancer Institute. There experiments have shown that Palmerolide A maintains its test tube melanoma-killing properties in living tissue. Full testing on a mouse melanoma model should begin soon, but development of a human treatment using the compound will take years. If successful, these new cancer medications might generate similar annual sales to other successful cancer drugs such as Avastin (USD2.7 billion per year) or Herceptin (USD1.3 billion per year). However, it must be kept in mind that most of the experimental medicines do not lead to commercial drugs (ATCM 2008).

Research organizations and companies from a number of countries have undertaken research for commercial purposes in the Antarctic environment. These countries include Japan, USA, Spain, United Kingdom, Korea, Canada, Sweden, Russia, China, Chile, New Zealand, France, Belgium, India, Denmark, The Netherlands, Germany and Poland. Companies and organizations involved in commercially-oriented research and/or development of Antarctic genetic resources include A/F Protein Inc, Agriculture Victoria Serv Pty, Angulas Anguinaga, Antarctic Pharma AB, Aqua

[1] Centre for Global Sustainability Studies, Universiti Sains Malaysia, 11800 Penang, Malaysia
Corresponding author (e-mail: zakri@mosti.gov.my)

Bounty Technologies, Arunachal University, Benares Hindu University, Biozyme Systems Inc., Centre National de la Recherche Scientifique, Clarins, Council of Scientific and Industrial Research, Daicel Chem, Daiwa Kasei, DSM NV, Good Humor-Breyers Ice Cream, Green Blueprint International, Henkel, Institute of Advanced Industrial Science and Technology, Kang Jae Shin, Kao Corp, Kansai University, Katayama Tarou, Korea Food Research Institute, Korea Ocean Research and Development Institute, Landcare Research, Lipotec S.A., Ljakh Pavlovna, Loders-Croklaan BV, Lu Gao, Magellan BioScience, Molecular Plant Breeding CRC, Morski Inst Rybackis, Nagata Sangyo, Neptune Technologies & Bioress, New England Biolabs, New Mexico Tech Research Foundation, Nichiwa Sangyo, Nihon Nosan Kogyo, Nippon Paper Industries, Nippon Suisan Kaisha Ltd, Novo Nordisk, Nomura Nobuhiko, Novozymes A/S, Phairson Medical Inc., PharmaMar, Pharmanutrients, Puratos Naamloze Vennootschap, Regents of the University of California, Rigel Pharmaceuticals Inc, Shin Dong Bang Corporation, Symrise, Third Institute of Oceanography SOA, Tokuyama Corp, Tokyo University of Science, Transucrania, Unilever, Université de Liège, University of Chile, University of Shanghai, University of South Florida, Verenium and ZyGEM. This list is not exhaustive (UNU-IAS 2008).

According to the latest available information, there is continued and growing interest in conducting further research into commercially useful genetic resources and biochemical processes in Antarctica. This trend is evident in the number of patents that are being filed on innovations based on Antarctic genetic resources and the increasing amount of research being carried out on extremophiles. Global biotechnology market trends (Ernst & Young 2005) and technological innovations will also likely result in increased demand for novel biochemical compounds.

While the results of bioprospecting are generally considered to be beneficial to humankind, questions have been raised within the Antarctic Treaty Consultative Meetings about the need to manage or regulate this activity. At present, the Antarctic Treaty System (ATS) does not directly regulate biological prospecting activities. Nevertheless, provisions relevant to considering the issue are contained in the Antarctic Treaty, its Protocol on Environmental Protection (Madrid Protocol) and the Convention on the Conservation of Antarctic Marine Living Resources. It is still unclear whether those provisions are sufficient for the ATS to effectively regulate these complex activities that raise legal, political and environmental issues.

One issue that still remains to be addressed is the effects of patenting as well as other forms of legal protection (in particular trade secrets) on the free exchange of scientific information in Antarctica. The Antarctic Treaty requires scientific observations and results from Antarctica to be exchanged while feasible and practicable access be made freely available. At present while the results of scientific research are published in peer-reviewed journals and made widely available, the results of research funded by the private sector are generally kept confidential and are ordinarily not disclosed until after patent applications have been filed. It is, however, still unclear whether there is any evidence that bioprospecting has adversely affected the exchange of scientific information.

Another contentious issue has to do with access and benefit-sharing. The Parties to the Antarctic Treaty have raised the question of how access to Antarctic genetic resources should be conducted, for what purposes and under what conditions. Should a simple permit system be put in place, and if so, can this be done within the existing provisions of the Treaty? Additionally, there are complicated legal issues that may relate to the ownership and protection of these resources. It is also not clear whether the sharing of benefits from commercial products originating from Antarctic sources is possible, or even desired, and whether any regulation relating to access and benefit-sharing might in fact hinder scientific research. These issues will be further addressed by the Antarctic Treaty Parties in the future.

Some questions have also been raised about the potential environmental impact of bioprospecting. Generally, environmental impact of bioprospecting is thought to be relatively minimal at the early stages of collection, where the size of samples collected is small. If a given species has shown biotechnological potential, repeated collection may require larger quantities, raising the likelihood of environmental impact. However, synthetic manufacturing in a laboratory of the chemical of interest generally eliminates the need for repeated collection. Some products, such as krill oil, require continuous harvesting which could have an environmental impact. Environmental impact also remains a concern if the target organism is rare, has a restricted distribution, and/or the collection is focused on a particular population (Hunt & Vincent 2006). Anthropogenic pressures (such as helicopter landings, impact of camping or skidoos, etc.) can also have an impact on the pristine environment. Adding to the uncertainty of potential impact is the fact that the population and the characteristics of the life history of many Antarctic source organisms are not well known. Furthermore, the scale of the bioprospecting activity in terms of amount of samples collected, the exact location of collection, and the time period of sampling activity is often not disclosed (ATCM 2008).

It is important to clarify the rules and provisions of the ATS for managing and/or regulating bioprospecting in Antarctica. The absence of clear rules governing the use of genetic resources has already restricted the use of these resources and affected stakeholders in significant ways. For industry, the uncertainty about the use and ownership of samples inhibits their support for Antarctic research. For scientists, a lack of clear protocol for exchanging information arising from commercial activities inhibits their ability to work with companies and adapt to the changing nature of basic research around the world. For governments it has proven difficult to negotiate *de novo* how benefits of commercially orientated research are shared adequately (ATCM 2004).

ACKNOWLEDGEMENT

The author wishes to express his appreciation to Sam Johnston and Marjo Vierros of UNU-IAS for their inputs in the preparation of this manuscript.

Date of submission: January 2009
Date of acceptance: November 2009

REFERENCES

ATCM 2004, *Industry involvement in Antarctic bioprospecting*, Information paper 106 (IP-106-UNEP), Submitted to the XXVII Antarctic Treaty Consultative Meeting (ATCM) by UNEP.

ATCM 2008, *An update on biological prospecting in Antarctica, including the development of the Antarctic Biological Prospecting Database*, Working Paper 11 (WP-11) submitted to the XXXI Antarctic Treaty Consultative Meeting (ATCM) by the Government of Belgium

Cheng CC & Cheng L 1999, 'Evolution of an antifreeze glycoprotein' Nature, vol. 401 pp. 443–444. See also 'Antifreeze proteins – secrets for mankind?' at <http://www.nsf.gov/od/lpa/nsf50/nsfoutreach/htm/n50_z2/pages_z3/04_pg.htm>.

Ernst & Young 2005, '*Beyond borders global biotechnology report 2005*, <www.ey.com/beyonddborders>.

Hunt B & Vincent ACJ 2006, 'Scale and sustainability of marine bioprospecting for pharmaceuticals', *Ambio*, vol. 35, no. 2, pp. 57–64.

Rothschild LJ & Mancinelli RL 2001, 'Extremophilic organisms adapt to life in incredibly harsh environment' Nature, vol. 409 pp. 1092–1101.

UNU-IAS 2003, 'The international regime for bioprospecting – existing policies and emerging issues for Antarctica, UNU-IAS Report, <http://www.ias.unu.edu/binaries/UNUIAS_AntarcticaReport.pdf>.

UNU-IAS 2008, 'Antarctic bioprospecting database', <http://www.bioprospector.org/bioprospector/antarctica/home.action;jsessionid=6EE277A64F5AD5D62369AADCD7CA5549>.

Antarctic Research and the Ecuadorian Antarctic Institute, a Strategic Approach 2005–2008

H.R. Moreano[1]

Scientific research not only provides new knowledge, but is an instrument that supports university teaching in related life, physical and geosciences fields or disciplines. At the same time, it also supports the existence and expansion of human resources needed to develop a technological platform. Here academia, government and private organizations can join together to share all available resources to create an environment where a National Innovative System can be developed aimed to deliver products, services and ideas for the well-being of humanity.

In this context, the Ecuadorian Antarctic Institute was created in April 2004 as a new government entity to replace the former Ecuadorian Antarctic Programme which had worked under the Navy Oceanographic Institute umbrella since 1988. The task of the new Institute was that of a facilitator and co-ordinator of activities by the government, universities and private institutions, to achieve all five National Antarctic objectives, within the framework of policies related to each of them.

The aim of this paper is to describe the analysis of related and relevant facts with the choice of the right strategy to achieve the objectives. The analysis also addresses the way it was implemented in trying to keep the Institute as small as possible but nevertheless involving all relevant sectors to reflect a national identity.

Relevant Facts

Although the national interest for Antarctica was declared by the National Assembly in 1967, it took 20 years to organize the First Ecuadorian Scientific Antarctic Expedition under the responsibility of the Oceanographic Institute (EOI). The INOCAR is a prestigious entity of the Ecuadorian Navy with the responsibility of hydrographic surveying, oceanographic research and navigational aids along the coast line and insular region (Galapagos) of Ecuador. The expedition was made on board the *R/V ORION,* an oceanographic and hydrographic research vessel built in Japan in 1982. The expedition, to the southern oceans and the Antarctica Peninsula with logistic personal and researchers of the Institute, was focused on the oceanography of Drake Passage and Bransfield Strait, using up-to-date satellite positioning available in that time. Shallow and deep water echo soundings were carried out and some hydrographic surveyings were made. The conclusion was that most of the nautical charts available of the area were unsafe for use because of wrong depths and positioning.

The Second Ecuadorian Scientific Antarctic Expedition was made on board the same ship in early 1990, with the aim of building the first module of the Maldonado Research Station in a place already chosen during the first expedition: Fort William Point, Greenwich Island. At least 20 scientific projects were executed in the vicinity of the Station and in Discovery Bay, a wide water body just east of Fort William Point.

As the country was gaining experience in Antarctic matters and in order to make the activity sustainable an organizational structure was created with the Institute with the Ecuadorian Antarctic Programme as manager of Antarctic activities and the National Scientific Committee on Antarctic Research, created by the National Council for Science and Technology, as responsible for science; members were researchers from different fields and academic institutions. Both bodies started to work together from mid-1988, with this structure and with the expeditions already completed, the country acceded the Antarctic Treaty as a Consultative Member on 19 November 1990 and as a Full Member of SCAR in 15 June 1992.

Seven expeditions were carried out during the period 1991 – 2004, but only one of them was made on board the *R/V ORION* when the Maldonado Station was completed in 1998. All other six were made using ships and planes of countries like Chile, Uruguay and Brazil. Most of the research projects were focused on the in-shore area of Fort William using the support of the Station facilities. Unfortunately, the scientific structure was losing ground because of a weakened National Council and so most of the projects were under the charge of members of the Oceanographic Institute.

Antarctica is a complex continent and as such all national institutions should be involved in science and logistics.

[1] Instituto Antartico Ecuatoriano, 9 de Octubre 416 y Chile, Edifico Citibank, 4o Piso, P.O. Box 09-01-7658, Guayaquil, Ecuador.
Present address : Santa Elena State University, Centre for Integerated Environmental Studies. La Libertad, Santa Elena, Ecuador.
* Corresponding author (e-mail: hmoreano@gye.satnet.net; inae@gye.satnet.net)

The government then decided to change the status of the Antarctic Programme by creating the Ecuadorian Antarctic Institute (EAI) in April 2004, as an entity under the Ministry of Defense with its own Council.

The vision of EAI is to be recognized in the national and international context as the lead Institute in Antarctic matters in Ecuador. The mission is to foster and maintain the geopolitical projection and the continuous participation in Antarctic research activities within the framework of the Antarctic Treaty System. The financial support is from the State Annual General Budget.

National Policy and Objectives

The National Policy for Antarctic matters is sustained by the presence of Ecuador in Antarctica, participation and co-operation in scientific research, environmental protection and in the use of resources under the context of the Antarctic Treaty System.

The strategic vision of Antarctic matters has five strategic objectives:

- To promote active participation of Ecuador in Antarctica focused on scientific research for national interest.
- To contribute with the Consultative Parties for the protection of the Antarctic environment.
- To be present in all international fora related to Antarctic matters in co-ordination with other public or private national institutions.
- To promote the exchange of knowledge with similar institutions of the Consultative Parties; and
- To include the National Antarctic Policy into the National Plan on International Policy 2006 – 2020.

Strategy Build Up

The Institute started its work with only five staff, i.e. the Executive Director, the Scientific and Financial Officers, Cashier and an Accountant. A 200 square meter floor office was rented at downtown Guayaquil and all asset and legal issues were put in order before the end of 2005. At the same time the logistic party was organized with experts from the Navy to carry out urgent repair work at Maldonado Station during January and February 2006.

As the National Scientific Committee on Antarctic Research had been disbanded, the main task of EAI was to commence contacts with interested researchers with a post-graduate education in Antarctic science from national public and private universities and with those of the Oceanographic Institute, interested in Antarctica co-operation. Agreements were made by EAI with researchers through the various Faculty Deans or even the Chancellor or Director.

Although process was really slow, the process was successfully completed well before the end of 2006 and in time for the II Latin American Symposia on Antarctic Research organized by the Instituto Antarctico Chileno and the Universidad de Concepción, at Concepción, Chile in September 2006. Participants included scientists from Chile, Argentina, Brazil, Uruguay, Peru and Malaysia. The group was updated on Antarctic science, especially on those projects with regional and international interest and with the role of universities in Antarctic Research.

The National Secretariate for Science and Technology was appointed in 2005 as the operational branch of the National Council for Science and Technology with resources for funding scientific research. Thus, the strategy was to approach the Secretariate for possibilities of co-operation. Although the initiative was welcomed by the Secretary, general, support was not forthcoming due to budget constraints, but contact was made for future co-operation and funding of research projects.

A couple of relevant events occurred during the II Latin American Symposia. The first was the fact that after an exchange of views with the Malaysian Delegation on Antarctic science, it was interesting to note their work on microbiology in various places on the coastal zone around Antarctica. Considering that at Maldonado Station an area of 150 ha is free of ice and snow during the austral summer, it offered an excellent ground to make samplings. An invitation was made to the Academy of Science Malaysia (Antarctic Task Force) to carry out research at Maldonado Station during that coming summer with the participation of Ecuadorian counterparts.

The second issue was that at the first meeting of the regional group on the Census of Antarctic Marine Life (CAML), it was decided that an international project was to be carried out during the International Polar Year (IPY) 2007–2008 and convened by the OLA CAML whose co-ordinator was Lucia Campos, a Brazilian researcher with a post-graduate degree and a member of Rio de Janeiro Federal University. The group prepared a matrix of LA logistic resources and scientific projects carried out in Antarctica.

The national structure of Antarctic science was taking shape with a group of at least 15 post-graduate researchers and with links towards strengthening international co-operation.

Strategy Consolidation

Most of the research projects of the 2006–2007 and 2007–2008 seasons were made on the free ice area of Maldonado Station and they were related to geology, glaciology and landscape evolution, detailed GPS positioning to get a 3D map of the area and the generation of a GIS with all information available. A census of *Macronectes giganteus* was made and the data compared with those of 1991, 1992, 2001 and 2004. A report was presented to SCAR to assess the situation of birds around Antarctica and to the Agreement, particularly for the conservation of albatrosses and petrels (ACAP). This was an international effort to protect both species from the long-term fisheries threat.

The Antarctic Special Management Area of Admiralty Bay (ASMA No.1) was a measure approved by the XXIX Antartic Treaty Consultative Meeting in June 2006. Brazil led in co-ordinating the work in the area with the participation of Poland, Peru , Ecuador and the United States. These countries had Research Stations and refuges within the bay were part of the management plan to protect the ASMA No. 1. from the impact of human activities. Ecuador was then involved in an international and multidisciplinary project within the framework of the Madrid Protocol.

The Maldonado Station environmental management plan was updated by the group of environmental specialists with a total of twelve integrated plans with the aim of protecting the physical integrity of people, the station infrastructure and the environment that surrounded the Station. The First Aid manual for Polar Regions was also updated by the medical doctor.

The Malaysian Antarctic Task Force and their Ecuadorian counterpart developed and brought up new research projects in bacteria and fungi biodiversity, and nitrogen fixation by microbes. Samples were taken along two tracks, of about a thousand meters each, from the first pebble beach toward the glacier. Laboratory analysis showed some interesting results that were presented in workshops, symposia, conferences and published in different scientific journals.

Barrientos Island is one of the Aitchio Islands located northward of Maldonado Station and is one of the ten places most visited by tourists in the Antarctic Peninsula. As tourism is one activity that is rapidly increasing in Antarctica, a research project to evaluate the impact of visiting tourists in Barrientos was designed by a former Director of the Charles Darwin Research Station in the Galápagos was working for the San Francisco de Quito University. Furthermore as he was also working on tourism in protected areas as the Galapagos, some of the 'Good Practices' could be applied to Barrientos. The experience was shared during the Session, 'People and Resources at the Poles', in the SCAR/IASC IPY Open Science Conference, Saint Petersburg, Russia in July 2008.

The field work at Maldonado station sealed the strong friendship among researchers and logistic personnel, and everybody worked to achieve the objectives of each expedition and scientific project.

The co-operation was consolidated with the First Ecuadorian Symposia in Polar Science which was jointly organized by the Universidad Estatal Peninsula de Santa Elena and Instituto Antartico Ecuatoriano in 31July 2008. The scientific event was preceded by a series of talks with the coastal community and stakeholders and followed up by a workshop on fungi and bacteria in polar environments. The Symposium was a successful event with the participation of 1240 researchers, teachers, students and local residents.

Antarctica was included into the National Plan on International Policy (PLANEX 2007 – 2020) within Chapter IV Strategic Guidelines, paragraph 4.1.12

Achievement of Strategic Objectives

All five strategic objectives were achieved in a three-year time period despite the small structure of the Institute, but with its strength in both the scientific group of experts and the logistic party in charge of running the Station. Everyone worked together under the vision and mission of the Institute and with the objective of achieving national aspirations in Antarctica.

DISCUSSION

It is said and with good reason that organizations succeed or fail because of the quality of their ideas and the speed with which the best of them can be implemented. A good place to look for ideas and ways to implement them are in research universities where the most important assets are teachers, students and the knowledge they have. Universities are places where an intense exchange of ideas takes place and where the best work is performed within a decentralized environment full of initiative, creativity and innovation.

The EAI followed the similar strategy of the research university in its management and scientific approach with the inclusion of senior researchers and young students who performed their work with excellence, despite funding difficulties. The Institute managed to allocate some resources, especially for workshops and symposia participation where researchers had the opportunity to present their work, interact with colleagues and co-ordinate regional or international projects that would further strengthen the group.

The link between the government and the academia is already established, the next step should be to strengthen that with private and business organizations. This is the new challenge of the Institute in future.

Date of submission: July 2009
Date of acceptance: November 2009

MAHATHIR SCIENCE AWARD 2011

Invitation for Nominations

The Academy of Sciences Malaysia (ASM) is a body set up with a mission that encompasses pursuit, encouragement and enhancement of excellence in the fields of science, engineering and technology for the development of the nation and the benefit of mankind. The Academy has instituted the Mahathir Science Award (formerly known as ASM Award for Scientific Excellence in honour of Tun Dr Mahathir Mohamad) in recognition of scientists/institutions who have contributed to cutting-edge tropical research that have had an impact on society.

This Award is Malaysia's most prestigious Science Award for tropical research launched in honour of Tun Dr Mahathir Mohamad who promoted and pursued with great spirit and determination his convictions in science and scientific research in advancing the progress of mankind and nations. Tun Dr Mahathir was the major force and the man who put into place much of the enabling mechanisms for a scientific milieu in our country.

This Award will be given to researchers who have made internationally recognised breakthroughs in pioneering tropical research in the fields of Tropical Medicine, Tropical Agriculture, Tropical Architecture and Engineering, and Tropical Natural Resources.

One Award will be conferred in 2011 covering any of the above four fields. The Award carries a cash prize of RM100 000, a gold medal and a certificate.

NOMINATION CRITERIA

- Awards will be given to researchers who have made internationally recognised breakthroughs in pioneering tropical research that have brought greater positive impacts on the well-being of society.
- Nominations can be made by individuals or institutions.
- A recipient could be an individual or an institution.

Nomination forms may be downloaded from the Academy's website:
www.akademisains.gov.my

Closing date: 31 March 2011

For more information, please contact:
Academy of Sciences Malaysia
902-4, Jalan Tun Ismail, 50480 Kuala Lumpur
Tel : 603-2694 9898; Fax : 603-2694 5858
E-mail: seetha@akademisains.gov.my
admin@akademisains.gov.my

22nd Pacific Science Congress

Asia Pacific Science in the New Millenium: Meeting the Challenges of Climate Change and Globalisation

14 –18 June 2011, Kuala Lumpur, Malaysia

The Congress will provide an inter-disciplinary platform for scientists from the region to discuss and review common concerns and priorities; bring together scientists from remote states; and serve as a catalyst for scientific and scholarly collaboration and to announce and establish new research initiatives. The Pacific Science Association (PSA) focuses on countries bordering the Pacific Ocean and the islands of the Pacific basin. PSA is a regional, non-governmental, and a scholarly organization that seeks to advance S&T in support of sustainable development in the Asia Pacific.

Sub-themes will include topics on:

- A Changing Climate: Climate science; Physical impacts; Ecosystem responses; Mitigation and adaptation strategies, Climate policies, Vulnerable human populations
- Global Change & Ecosystems: Biodiversity, Landscape Systems, Ecosystem Services, Coupled Human-Natural Systems, Invasive Species, Museum collections and barcoding
- Oceans: Coral Reefs, Ocean Acidification, Large Marine Ecosystems, Marine Biotechnology; Fisheries, Marine Mammals
- Earth Systems & Risk Management: Earth Science and Geophysics, Meteorology, Natural Hazards, Integrated Disaster Risk Reduction
- Globalization: Human populations, Population movement, Urbanization, Megacities, Gender, Economics and trade, Governance issues, Challenges of small island states, Human security, Poverty alleviation
- Resource Constraints & Sustainability: Millennium Development Goals, Water, Agriculture, Food, Energy, Integrated Coastal Zone Management, Ecological economics
- Health Challenges: Persistent and emerging infectious diseases, HIV/AIDS, Chronic and lifestyle diseases, Microbiology, Medical tourism, Telemedicine
- Science for Policy and the Future: Science communication, Science education, Building science capacity, Science and the media, Traditional knowledge, Data access and management, Intellectual property, Universality of science, Frontiers of science (complexity science, materials science, biotechnology)

Schedule and Programme:

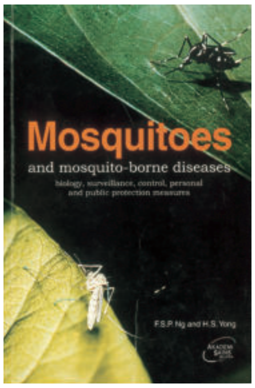
Both plenary and parallel sessions, invited lectures, poster sessions, with at least one session open to the public and an optional post-congress field excursion will be planned. Various symposia will also be organized around the sub-themes.

Enquiries:

Congress Secretariat
22nd Pacific Science Congress
c/o Academy of Sciences Malaysia
902-4, Jalan Tun Ismail
50480 Kuala Lumpur
Malaysia

Tel : (603) 2694 9898
Fax : (603) 2694 5858

e-mail: nasa@akademisains.gov.my; fardy@akademisains.gov.my
Website: www.akademisains.gov.my



Mosquitoes and Mosquito-borne Diseases: Biology, Surveillance, Control, Personal and Public Protection Measures

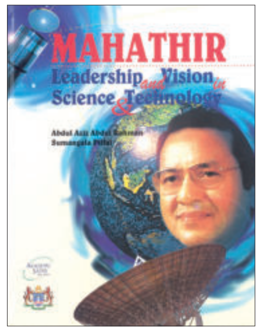
F.S.P. Ng and *H.S. Yong (Editors)*
(2000)

ISBN 983-9445-05-7
Price: RM60.00 / USD20.00

Mahathir: Leadership and Vision in Science and Technology

Abdul Aziz Abdul Rahman and *Sumangala Pillai*
(1996)

ISBN 983-9319-09-4
Price: RM100.00 / USD30.00



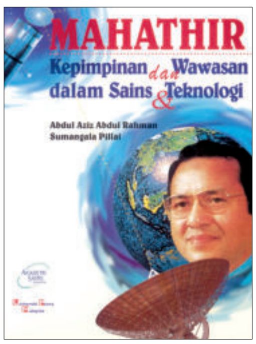
Budaya Kreativiti: Pameran Seratus Tahun Hadiah Nobel

Ulf Larsson (Editor)
(2004)

ISBN 983-9445-09-X
Price: RM50.00 / USD15.00

CD Kompilasi *estidotmy*

Edisi 1 – 94, 2002–2009
Price: RM40.00



Mahathir: Kepimpinan dan Wawasan dalam Sains dan Teknologi

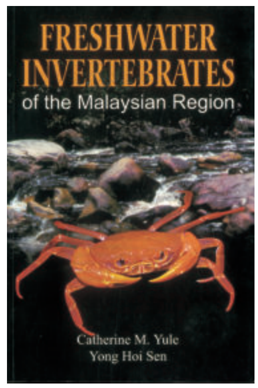
Abdul Aziz Abdul Rahman
dan *Sumangala Pillai*
(1996)

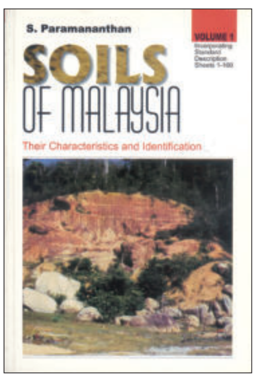
ISBN 983-9319-09-4
Price: RM100.00 / USD30.00

Freshwater Invertebrates of the Malaysian Region

Catherine M. Yule and *Yong Hoi Sen*
(2004)

ISBN 983-41936-0-2
Price: RM180.00 / USD52.00





Soils of Malaysia: Their Characteristics and Identification (Vol. 1)

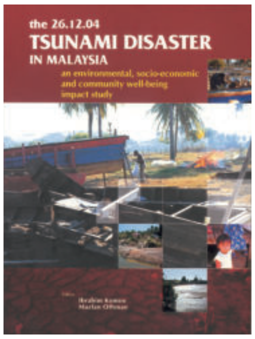
S. Paramananthan
(2000)

ISBN 983-9445-06-5
Price: RM100.00 / USD30.00

Bencana Tsunami 26.12.04 di Malaysia: Kajian Impak Alam Sekitar, Sosio-Ekonomi dan Kesejahteraan Masyarakat

Ibrahim Komoo (Editor)
(2005)

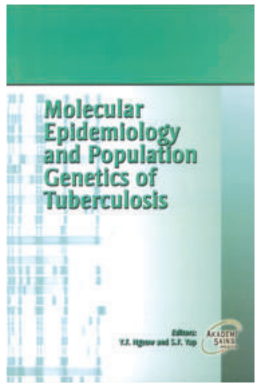
ISBN 983-9444-62-X
Price: RM100.00 / USD30.00



The 26.12.04 Tsunami Disaster in Malaysia: An Environmental, Socio-Economic and Community Well-being Impact Study

Ibrahim Komoo and *Mazlan Othman (Editors)*
(2006)

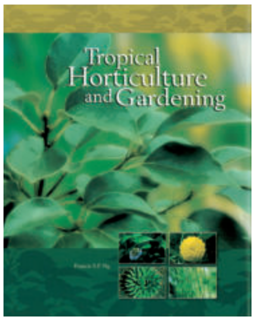
ISBN 983-9444-62-X
Price: RM100.00 / USD30.00



Molecular Epidemiology and Population Genetics of Tuberculosis

Y.F. Ngeow and *S.F. Yap (Editors)*
(2006)

ISBN 983-9445-14-6
Price: RM40.00 / USD12.00



Tropical Horticulture and Gardening

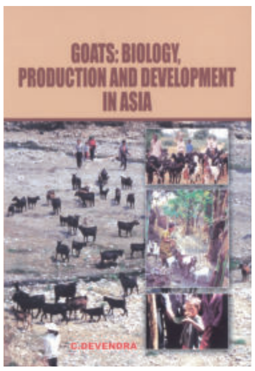
Francis S.P. Ng
(2006)

ISBN 983-9445-15-4
Price: RM260.00 / USD75.00

Kecemerlangan Sains dalam Tamadun Islam: Sains Islam Mendahului Zaman
Scientific Excellence in Islamic Civilization: Islamic Science Ahead of its Time

Fuat Sezgin
(2006)

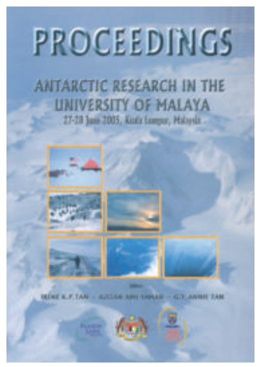
ISBN 983-9445-14-6
Price: RM40.00 / USD12.00



Goats: Biology, Production and Development in Asia

C. Devendra
(2007)

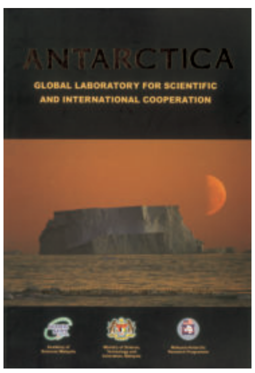
ISBN 978-983-9445-18-3
Price: RM180.00 / USD52.00



Proceedings: Seminar on Antarctic Research, 27–28 June 2005, University of Malaya, Kuala Lumpur, Malaysia

Irene K.P. Tan et al. *(Editors)*
(2006)

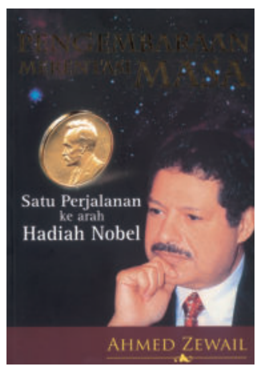
ISBN 978-983-9445-17-6
Price: RM40.00 / USD12.00



Antarctica: Global Laboratory for Scientific and International Cooperation

Aileen Tan Shau-Hwai et al. *(Editors)*
(2005)

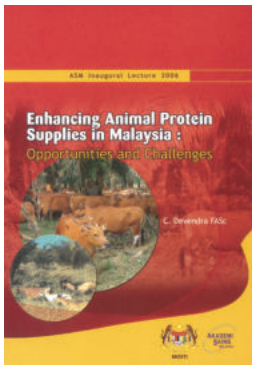
ISBN 983-9445-13-8
Price: RM40.00 / USD12.00



Pengembaraan Merentasi Masa: Satu Perjalanan ke Arah Hadiah Nobel

Ahmed Zewail
(2007)

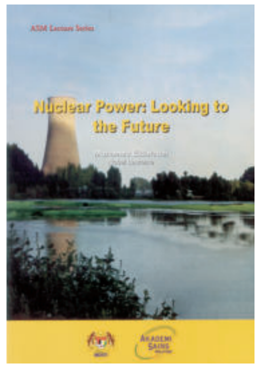
ISBN 978-9445-20-6
Price: RM40.00 / USD12.00



Enhancing Animal Protein Supplies in Malaysia: Opportunities and Challenges

C. Devendra
(2007)

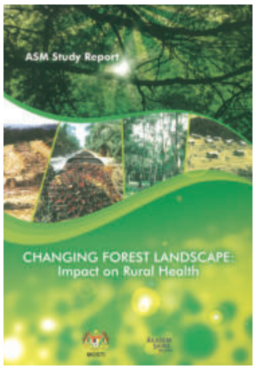
ISBN 983-9444-62-X



Nuclear Power: Looking to the Future

Mohamed ElBaradei
(2008)

ISBN 983-9445-14-6



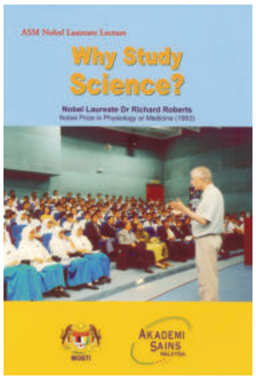
Changing Forest Landscape: Impact on Rural Health
(2007)

ISBN 983-9445-15-4

Dunia Sains
Vol. 5, No. 4, Oktober – Disember 2007
(2008)

A World of Science
Vol. 5, No. 4
October – December 2007

www. akademisains.gov.my/unesco/ dunia_sains/okt_dis_2007.pdf



Why Study Science?

Richard Roberts
(2008)

ISBN 978-983-9445-18-3

Dunia Sains
Vol. 6, No. 1, Januari – Mac 2008
(2008)

A World of Science
Vol. 6, No. 1
January – March 2008

ASM Science Journal
Vol. 1, No. 1, June 2007

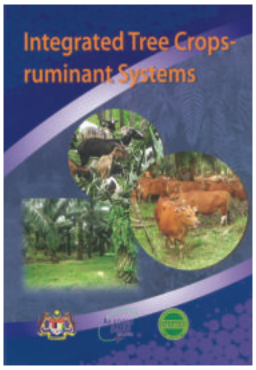
ISSN : 1823-6782

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)

ASM Science Journal
Vol. 1, No. 2, December 2007

ISSN : 1823-6782

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)



Integrated Tree Crops-ruminant Systems (Proceedings)

C. Devendra, S. Shanmugavelu and
Wong Hee Kum (Editors)
(2008)

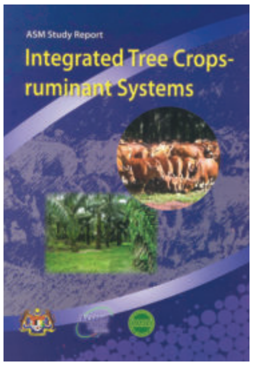
ISSN : 983-9445-24-3

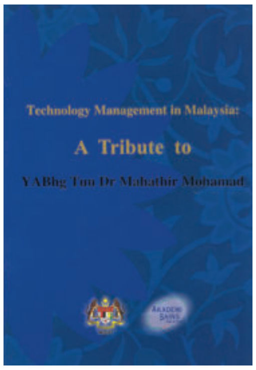
Price: RM40.00 / USD12.00

ASM Study Report:
Integrated Tree Crops-ruminant Systems
(2008)

ISSN : 983-9445-24-4

Price: RM30.00 / USD9.00



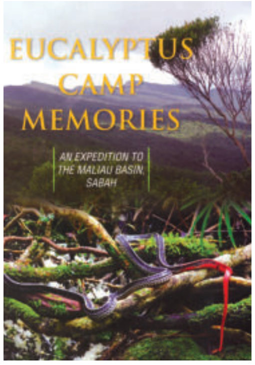


Technology Management in Malaysia:
A Tribute to YABhg Tun Dr Mahathir Mohamad
(2008)

Eucalyptus Camp Memories:
An Expedition to the Maliau Basin, Sabah
(2008)

ISSN : 978-983-9445-25-1

Price: RM220.00 / USD61.00 (Hard cover)
RM160.00 / USD42.00 (Soft cover)

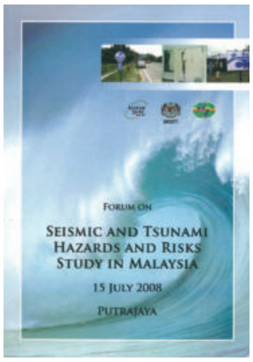


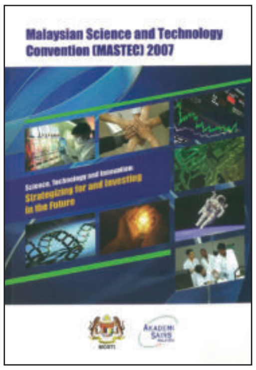
ASM Science Journal
Vol. 2, No. 1, December 2008

ISSN : 1823-6782

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)

Forum on:
Seismic and Tsunami Hazards and
Risks Study in Malaysia
15 July 2008





Science, Technology and Innovation:
Strategizing for and Investing in the Future
[Malaysian Science and Technology Convention
(MASTEC) 2007]
(2009)

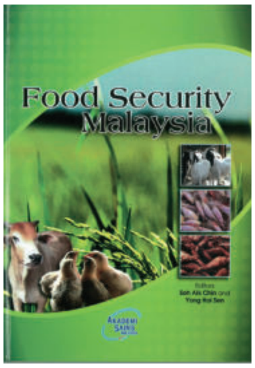
ISSN : 978-983-9445-27-5

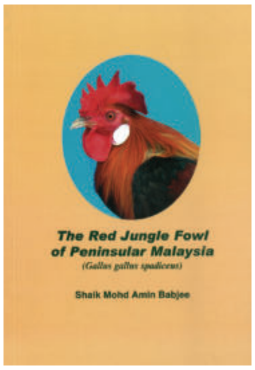
Price: RM51.00 / USD22.00

Food Security Malaysia (Proceedings)
Soh Aik Chin and Yong Hoi Sen (Editors)
(2009)

ISSN : 978-983-9445-28-2

Price: RM20.00 / USD6.00





The Red Jungle Fowl of Peninsular Malaysia

Shaik Mohd Amin Babjee
(2009)

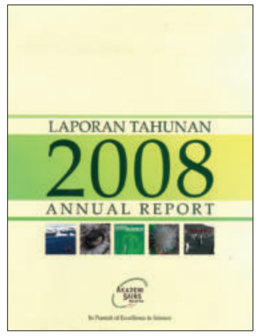
ISBN : 978-983-9445-29-9

Price: RM35.00 / USD12.00

Academy of Science Malaysia

Annual Report 2008

Price: RM50.00 / USD20.00



Journal of Science & Technology in the Tropics

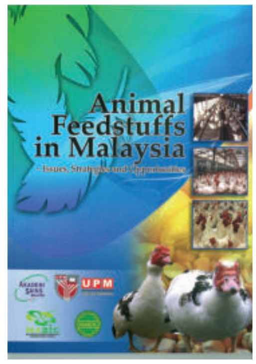
Vol. 4, No. 2, December 2008

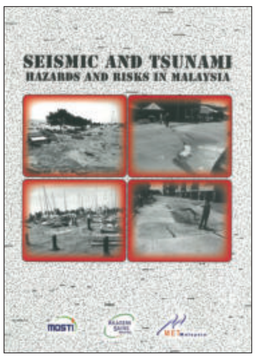
ISSN:1823-5034

Animal Feedstuffs in Malaysia – Issues, Strategies and Opportunities
(2009)

ISBN : 978-983-9445-30-5

Price: RM35.00 / USD12.00





Seismic and Tsunami Hazards and Risks in Malaysia
(2009)

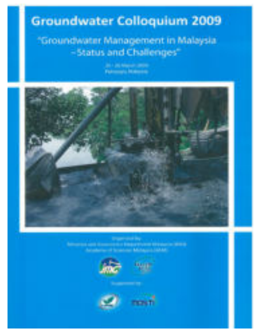
ISBN 978-983-9445-32-9

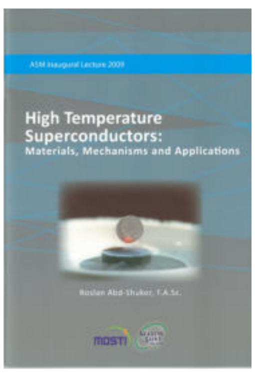
Price: RM45.00 / USD15.00

Groundwater Colloquium 2009 "Groundwater Management in Malaysia – Status and Challenges"

ISBN : 978-983-9445-30-5

Price: RM100.00 / USD75.00





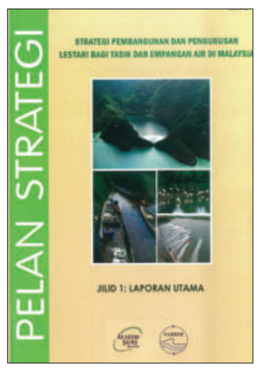
ASM Inaugural Lecture 2009
High Temperature Superconductors: Material, Mechanisms and Applications

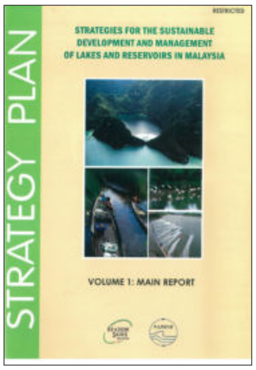
ISBN : 978-983-9445-30-5

Price: RM20.00 / USD8.00

Strategi Pembangunan dan Pengurusan Lestari bagi Tasik dan Empangan Air di Malaysia

Jilid 1: Laporan Utama



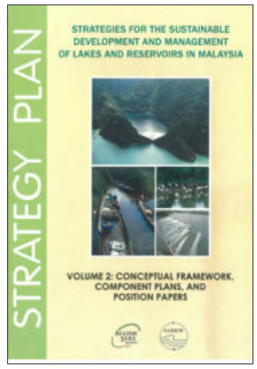


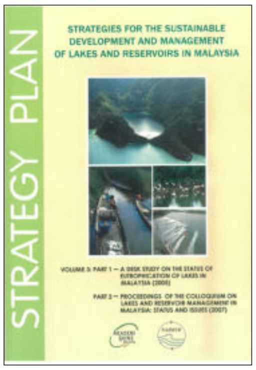
Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia

Volume 1: Main Report

Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia

Volume 2: Conceptual Framework, Component Plans, and Position Papers





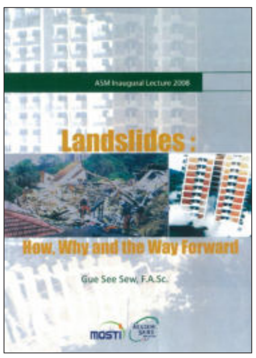
Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia

Volume 3: Part 1 & Part 2

ASM Science Journal
Vol. 2, No. 2, December 2008

ISSN : 1823-6782

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)



ASM Inaugural Lecture 2008 Landslides: How, Why and the Way Forward

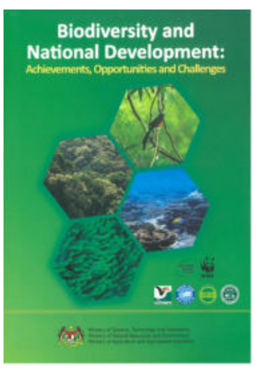
ISBN : 978-983-9445-30-5

Price: RM20.00 / USD8.00

Journal of Science & Technology in the Tropics

Vol. 5, No. 1, June 2009

ISSN:1823-5034



Biodiversity and National Development: Achievements, Opportunities and Challenges

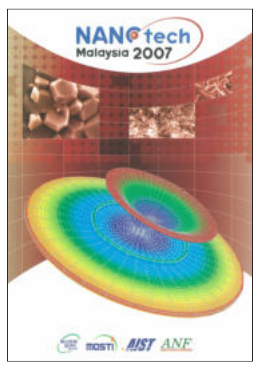
ISBN : 978-983-9445-30-5

Price: RM40.00 / USD15.00

Nanotech Malaysia 2007

ISBN : 978-983-9445-30-5

Price: RM55.00 / USD20.00



Proceedings for the 3rd Malaysian International Seminar on Antarctica (MISA3) "From the Tropics to the Poles" 2007

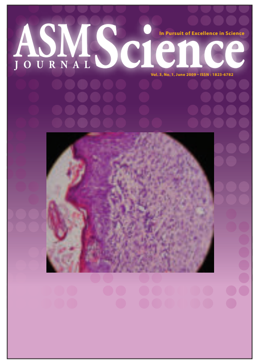
ISBN : 978-983-9445-30-5

Price: RM40.00 / USD15.00

ASM Science Journal
Vol. 3, No. 1, December 2009

ISSN : 1823-6782

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)



Journal of Science & Technology in the Tropics
Vol. 5, No. 2, December 2009

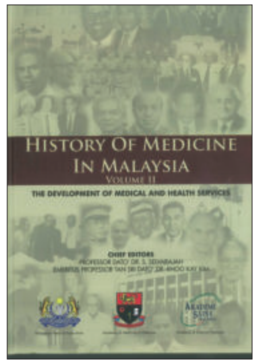
ISBN : 978-983-9445-30-5

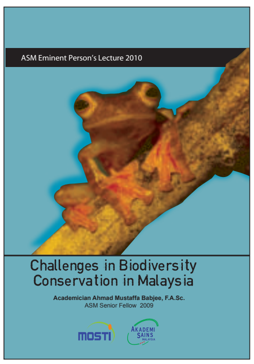
Price: RM40.00 / USD15.00

History of Medicine in Malaysia Volume II
The Development of Medical and Health Services

ISSN : 978-983-42545-1-3

Price: RM100.00 / USD50.00 (Individual)
RM200.00 / USD100.00 (Institution)





ASM Eminent Person's Lecture 2010

Challenges in Biodiversity Conservation in Malaysia

ISBN : 978-983-9445-39-8

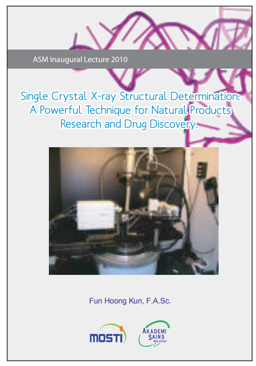
Price: RM20.00 / USD8.00

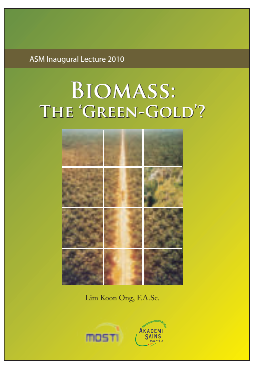
ASM Inaugural Lecture 2010

Single Crystal X-ray Structural Determination:
A Powerful Technique for Natural Products Research and Drug Discovery

ISBN : 978-983-9445-39-8

Price: RM30.00 / USD12.00





ASM Inaugural Lecture 2010

Biomass: The 'Green-gold'?

ISBN : 978-983-9445-38-1

Price: RM30.00 / USD12.00

For purchasing, please access:
http://www.akademisains.gov.my

About the Journal

Mission Statement

To serve as the forum for the dissemination of significant research, S&T and R&D policy analyses, and research perspectives.

Scope

The *ASM Science Journal* publishes advancements in the broad fields of medical, engineering, earth, mathematical, physical, chemical and agricultural sciences as well as ICT. Scientific articles published will be on the basis of originality, importance and significant contribution to science, scientific research and the public.

Scientific articles published will be on the basis of originality, importance and significant contribution to science, scientific research and the public. Scientists who subscribe to the fields listed above will be the source of papers to the journal. All articles will be reviewed by at least two experts in that particular field. The journal will be published twice in a year.

The following categories of articles will be considered for publication:

Research Articles

Each issue of the journal will contain no more than 10 research articles. These are papers reporting the results of original research in the broad fields of medical, engineering, earth, mathematical, physical, chemical and life sciences as well as ICT. The articles should be limited to 6000 words in length, with not more than 100 cited references.

Short Communications

These are articles that report significant new data within narrow well-defined limits or important findings that warrant publication before broader studies are completed. These articles should be limited to 2000 words and not more that 40 cited references. Five (5) Short Communications will be accepted for publication in each issue of the journal.

Research Perspectives

These are papers that analyse recent research in a particular field, giving views on achievements, research potential, strategic direction etc. A Research Perspective should not exceed 2000 words in length with not more than 40 cited references.

Reviews/Commentaries

Each issue of the journal will also feature Reviews/ Commentaries presenting overviews on aspects such as Scientific Publications and Citation Ranking, Education in Science and Technology, Human Resources for Science and Technology, R&D in Science and Technology, Innovation and International Comparisons or Competitiveness of Science and Technology etc. Reviews/Commentaries will encompass analytical views on funding, developments, issues and concerns in relation to these fields and not exceed 5000 words in length and 40 cited references.

Science Forum

Individuals who make the news with breakthrough research or those involved in outstanding scientific endeavours or those conferred with internationally recognised awards will be featured in this section. Policy promulgations, funding, science education developments, patents from research, commercial products from research, and significant scientific events will be disseminated through this section of the journal. The following will be the categories of news:

- Newsmakers
- Significant Science Events
- Patents from Research
- Commercial Products from Research
- Scientific Conferences/Workshops/Symposia
- Technology Upgrades
- Book Reviews.

Instructions to Authors

The *ASM Science Journal* will follow the Harvard author-date style of referencing examples of which are given below.

In the text, reference to a publication is by the author's name and date of publication and page number if a quote is included, e.g. (Yusoff 2006, p. 89) or Yusoff (2006, p. 89) 'conclude.......' as the case may be. They should be cited in full if less than two names (e.g. Siva & Yusoff 2005) and if more than two authors, the work should be cited with first author followed by *et al*. (e.g. Siva *et al*. 1999).

All works referred to or cited must be listed at the end of the text, providing full details and arranged alphabetically. Where more than one work by the same author is cited, they are arranged by date, starting with the earliest. Works by the same author published in the same year are ordered with the use of letters a, b, c, (e.g. Scutt, 2003a; 2003b) after the publication date to distinguish them in the citations in the text.

General Rules

Authors' names:

- Use only the initials of the authors' given names.
- No full stops and no spaces are used between initials.

Titles of works:

- Use minimal capitalisation for the titles of books, book chapters and journal articles.
- In the titles of journals, magazines and newspapers, capital letters should be used as they appear normally.
- Use italics for the titles of books, journals and newspapers.
- Enclose titles of book chapters and journal articles in single quotation marks.

Page numbering

- Books: page numbers are not usually needed in the reference list. If they are, include them as the final item of the citation, separated from the preceding one by a comma and followed by a full stop.
- Journal articles: page numbers appear as the final item in the citation, separated from the preceding one by a comma and followed by a full stop.

  Use the abbreviations p. for a single page, and pp. for a page range, e.g. pp. 11–12.

Whole citation

- The different details, or elements, of each citation are separated by commas.
- The whole citation finishes with a full stop.

Specific Rules

Definite rules for several categories of publications are provided below:

Journal

Kumar, P & Garde, RJ 1989, 'Potentials of water hyacinth for sewage treatment', *Research Journal of Water Pollution Control Federation*, vol. 30, no. 10, pp. 291–294.

Monograph

Hyem, T & Kvale, O (eds) 1977, *Physical, chemical and biological changes in food caused by thermal processing*, 2nd edn, Applied Science Publishers, London, UK.

Chapter in a monograph

Biale, JB 1975, 'Synthetic and degradative processes in fruit ripening', eds NF Hard & DK Salunkhe, in *Post-harvest biology and handling of fruits and vegetables*, AVI, Westport, CT, pp. 5–18.

Conference proceedings

Common, M 2001, 'The role of economics in natural heritage decision making', in *Heritage economics: challenges for heritage conservation and sustainable development in the 21st century: Proceedings of the International Society for Ecological Economics Conference, Canberra, 4th July 2000*, Australian Heritage Commission, Canberra.

Website reference

Thomas, S 1997, *Guide to personal efficiency*, Adelaide University, viewed 6 January 2004, <http://library.adelaide.edu.au/~sthomas/papers/perseff.html>.

Report

McColloch, LP, Cook, HT & Wright, WR 1968, *Market diseases of tomatoes, peppers and egg-plants*, Agriculture Handbook no. 28, United States Department of Agriculture, Washington, DC.

Thesis

Cairns, RB 1965, 'Infrared spectroscopic studies of solid oxygen', PhD thesis, University of California, Berkeley, CA.

Footnotes, spelling and measurement units

If footnotes are used, they should be numbered in the text, indicated by superscript numbers and kept as brief as possible. The journal follows the spelling and hyphenation of standard British English. SI units of measurement are to be used at all times.

Submission of Articles

General. Manuscripts should be submitted (electronically) in *MS Word* format. If submitted as hard copy, two copies of the manuscript are required, double-spaced throughout on one side only of A4 (21.0 × 29.5 cm) paper and conform to the style and format of the *ASM Science Journal*. Intending contributors will be given, on request, a copy of the journal specifications for submission of papers.

Title. The title should be concise and descriptive and preferably not exceed fifteen words. Unless absolutely necessary, scientific names and formulae should be excluded in the title.

Address. The author's name, academic or professional affiliation, e-mail address, and full address should be included on the first page. All correspondence will be only with the corresponding author (should be indicated), including any on editorial decisions.

Abstract. The abstract should precede the article and in approximately 150–200 words outline briefly the objectives and main conclusions of the paper.

Introduction. The introduction should describe briefly the area of study and may give an outline of previous studies with supporting references and indicate clearly the objectives of the paper.

Materials and Methods. The materials used, the procedures followed with special reference to experimental design and analysis of data should be included.

Results. Data of significant interest should be included.

Figures. If submitted as a hard copy, line drawings (including graphs) should be in black on white paper. Alternatively sharp photoprints may be provided. The lettering should be clear. Halftone illustrations may be included. They should be submitted as clear black and white prints on glossy paper. The figures should be individually identified lightly in pencil on the back. All legends should be brief and typed on a separate sheet.

Tables. These should have short descriptive titles, be self explanatory and typed on separate sheets. They should be as concise as possible and not larger than a Journal page. Values in tables should include as few digits as possible. In most cases, more than two digits after the decimal point are unnecessary. Units of measurements should be SI units. Unnecessary abbreviations should be avoided. Information given in tables should not be repeated in graphs and vice versa.

Discussion. The contribution of the work to the overall knowledge of the subject could be shown. Relevant conclusions should be drawn, and the potential for further work indicated where appropriate.

Acknowledgements. Appropriate acknowledgements may be included.

Reprints. Twenty copies of reprints will be given free to all the authors. Authors who require more reprints may obtain them at cost provided the Editorial Committee is informed at the time of submission of the manuscript.

Correspondence

All enquiries regarding the *ASM Science Journal*, submission of articles, including subscriptions to it should be addressed to:

The Editor-in-Chief
ASM Science Journal
Academy of Sciences Malaysia
902-4, Jalan Tun Ismail
50480 Kuala Lumpur, Malaysia.
Tel: 603-2694 9898; Fax: 603-2694 5858
E-mail: sciencejournal@akademisains.gov.my

ASM SCIENCE JOURNAL
(ASM Sc. J.)

ORDER FORM

Subscription (Two issues per year)	Malaysia	Other Countries
Individual	RM100	USD50
Institution	RM200	USD100

1. Complete form and return.

Name/Institution: ....
(Please print) ....
....

Street Address: ....
....
....

City, Region: ....

Country, Postal Code: ....

2. Payment method: Cheque/Bank Draft/Postal Order/
   Money Order No.: ....
   Payable to **"Akademi Sains Malaysia"**
   (Please include bank commission, if applicable)
   RM/USD: ....

Date: .... Signature: ....

Please send to:
Academy of Sciences Malaysia
902-4, Jalan Tun Ismail
50480 Kuala Lumpur, Malaysia
Tel: 03-2694 9898; Fax: 03-26945858
E-mail: sciencejournal@akademisains.gov.my

order form(diecut).pdf 12/3/2009 12:16:13 AM

C
M
Y
CM
MY
CY
CMY
K

ASM Science JOURNAL
In Pursuit of Excellence in Science

Affix
stamp
here

Academy of Sciences Malaysia
902-4, Jalan Tun Ismail
50480 Kuala Lumpur
Malaysia

RESEARCH ARTICLES

SCIENCE FORUM

ANNOUNCEMENTS