Absolute Humidity Drives the Epidemiology of Influenza-like Illness in Vietnam

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INTRODUCTION

Understanding the transmission of influenza viruses is of prime importance for both vaccine design and vaccination policies. A number of factors have been explored as potential drivers of human seasonal influenza including human behaviour, dynamics of immunity driven by viral evolution (Smith *et al*. 2004), and climatic factors. Climatic factors have, in particular, retained attention from researchers because of the modes of influenza transmission that impose the virus to spend a substantial amount of time in the air. Thus, climatic variables have been hypothesised to influence host susceptibility and viral survival and dispersal in the air. Because viral particles are carried in droplets in the air, humidity has long been considered as a perfect candidate to explain influenza transmission, without much success to prove it, until recently. In 2009, the re-examination of experimental data conducted on Guinea pigs (Lowen *et al*. 2007) showed a strong negative correlation between humidity and influenza transmission if absolute humidity (the quantity of water in the air) was considered instead of the more common measure of relative humidity (Shaman and Kohn 2009). This result was confirmed two years later with epidemiological data from the USA, showing that, every year, influenza epidemics were triggered by a drop in absolute humidity (Shaman *et al*. 2010). These results provided a reasonable understanding of the drivers of the influenza epidemiology, at least in temperate countries where the epidemiology was highly seasonal. However, when looking at other countries in the world, it appeared that the intensity of seasonality faded out the closer we got to the equator (Viboud *et al*. 2006).

Some recent studies have attempted to explain the observed variability in influenza seasonality that was observed around the world. Alonso *et al*. (2007) characterised a latitudinal gradient of influenza seasonality in Brazil but the authors did not explain it in terms of climatic variables. Yu *et al*. (2013) developed a similar approach in China and used temperature and the number of hours of sunshine to explain the influenza epidemiology. However, the authors did not test for absolute humidity. A complementary approach was developed by Bloom-Feshbach *et al*. (2013) and Tamerius *et al*. (2013) who compared the epidemiology of influenza in 72 cities all around the world. These studies showed that the epidemic started in cold and dry conditions in the temperate regions and in humid and rainy conditions in the tropical regions. The authors however, did not try to explain the variability of seasonality in these different cities. The purpose of the present study is to explain the variability of seasonality in terms of climatic variables.

MATERIALS AND METHODS

This study was based in Vietnam, a country of reasonably small size (330,000 km2), highly populated (90,000 inhabitants) and exhibiting a particularly high diversity of climates due to its orthogonal latitudinal (8-21 degrees) and altitudinal (from sea level in the east to more than 3,000 m in the west) gradients. We used influenza-like illness (ILI)

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data from the national routine surveillance system of Vietnam, aggregated by month and province (52) from 1991 to 2010. Monthly climatic variables were retrieved from the meteorological bureau and included minimal, average and maximal temperatures, relative and absolute humidities, rainfall and hours of sunshine.

Seasonalities of epidemiological and climatic time series were quantified from the global wavelet spectra, using the value of the power for a period of one year, as a quantified measure of the intensity of seasonality. The seven climatic time series were characterised by 534 summary statistics that included, in addition to the seasonality, minimal, average and maximal values, amplitude, and the duration spent above a given threshold varying from the minimal to the maximal values. These 534 summary statistics were entered in a tree regression in order to identify the key factors explaining the seasonality of ILI.

Once our model was calibrated with the Vietnamese data, we used the climatic data simulated from the NCEP/NCAR project to validate the global data.

RESULTS

The intensity of the ILI seasonality in Vietnam was best explained by the intensity of the AH seasonality. The findings were that ILI seasonality was weak in provinces experiencing weak seasonal fluctuations in AH (annual power <17.6), whereas ILI seasonality was strongest in provinces with pronounced AH seasonality (power >17.6). The relationship between the seasonality of AH and ILI was highly non-linear, the value of 17.6 being almost a threshold value. Using the model fitted to Vietnamese data and the time series of the absolute humidities generated from the NCEP/NCAR project, we could predict the epidemiological regimen (seasonal vs non-seasonal) in all the 2.5 x 2.5 degrees pixels on the surface of the globe. We compared these predictions with the data from the Tamerius *et al*. (2013) study that classified the epidemiology in 72 cities around the world as having one or two peaks a year. By interpreting the two peaks per year epidemics as less seasonal as the one peak per year, we could compare data fro, Tamerius *et al*. (2013) with our model predictions, which produced a sensitivity of 85%.

DISCUSSION

Our results identified a role for AH in driving the epidemiology of ILI in a tropical setting. However, in contrast to temperate regions, a high rather than low AH was associated with increased ILI activity. Fluctuations in AH may be the climatic factor that underlies and unifies the seasonality of ILI in both temperate and tropical regions.

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REFERENCES

Alonso, W. J., C. Viboud, L. Simonsen, E. W. Hirano, L. Z. Daufenbach, and M. A. Miller. 2007. Seasonality of Influenza in Brazil: A Traveling Wave from the Amazon to the Subtropics. American Journal of Epidemiology 165:1434–1442.

Bloom-Feshbach, K., W. J. Alonso, V. Charu, J. Tamerius, L. Simonsen, M. A. Miller, and C. Viboud. 2013. Latitudinal variations in seasonal activity of influenza and respiratory syncytial virus (RSV): a global comparative review. PLoS ONE 8:e54445.

Lowen, A. C., S. Mubareka, J. Steel, and P. Palese. 2007. Influenza virus transmission is dependent on relative humidity and temperature. PLoS Pathogens 3:1470–1476.

Shaman, J., and M. Kohn. 2009. Absolute humidity modulates influenza survival, transmission, and seasonality. Proc Natl Acad Sci U S A 106:3243–3248.

Shaman, J., V. E. Pitzer, C. Viboud, B. T. Grenfell, and M. Lipsitch. 2010. Absolute humidity and the seasonal onset of influenza in the continental United States. PLoS Biology 8:e1000316.

Tamerius, J. D., J. Shaman, W. J. Alonso, K. Bloom-Feshbach, C. K. Uejio, A. Comrie, and C. Viboud. 2013. Environmental Predictors of Seasonal Influenza Epidemics across Temperate and Tropical Climates. PLoS Pathogens 9:e1003194.

Viboud, C., W. J. Alonso, and L. Simonsen. 2006. Influenza in tropical regions. PLoS Medicine 3:e89.

Yu, H., W. J. Alonso, L. Feng, Y. Tan, Y. Shu, W. Yang, and C. Viboud. 2013. Characterization of regional influenza seasonality patterns in China and implications for vaccination strategies: spatio-temporal modeling of surveillance data. PLoS Medicine 10:e1001552.