Using remote sensing data to assess the association between seasonal influenza and meteorological parameters

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[**Subject/statement of problem**] The burden of seasonal influenza continues to be a serious economic and public health concern. Each year, influenza infects approximately 5-15% of the world's population and causes up to 500,000 deaths (WHO, 2014). The economic burden of seasonal influenza in the United States has been estimated to be US$71-167 billion per year (Molinari et al., 2007).

[**Background**] Because the timing of influenza epidemics varies across latitude, weather and environments may play a role in providing the necessary conditions for influenza transmission. This is especially true in the temperate regions, where influenza epidemic peaks during winter time; the dry and cold conditions (low temperature and humidity) have been demonstrated to promote influenza transmission and prolong virus survival (Lowen et al., 2007; Polozov et al., 2008; Shaman and Kohn, 2009). In the tropics, however, the seasonality and pattern of influenza epidemic are less well defined; they range from year-round high influenza activity, peaks that coincide with rainy seasons, to multiple peaks in a year (Viboud et al., 2006). Year round ~~H~~high temperatures in the tropics ~~, despite being associated with the observed increase in influenza transmission (with small variability),~~ may not be suitable for effective influenza transmission (Lowen et al., 2008). Instead, influenza in the tropics is more often associated with rainfall. It is postulated that rainfall promotes indoor crowding that, in turn, increases the chances for contact transmission.

[**Objective(s)**] Identification of meteorological parameters associated with influenza transmission, combined with the use of satellite-derived remote sensing data, could enable influenza transmission forecast that can help in developing strategies for prevention and control efforts.

[**Previous work**] Studies of the role of weather conditions on influenza transmission have primarily involved temperate locations, and only a few used satellite-derived data (Charland et al. 2009; Soebiyanto et al. 2010; Shaman et al. 2010)~~. [add refs of previous work]~~. In order to address this gap, we have investigated the role of meteorological parameters – temperature, specific humidity, rainfall, and solar radiation – on influenza transmission in both temperate and tropical locations, using satellite-derived data (Soebiyanto et al., 2010; Soebiyanto and Kiang, 2012; Soebiyanto et al., 2014; Acker et al., 2014; Soebiyanto et al., 2015a).

[**What was done**] In our studies, we used the 3B42 precipitation data from the Tropical Rainfall Measuring Mission (TRMM) via NASA's Giovanni system (Acker and Leptoukh, 2007), which has daily temporal resolution and 0.25° (~ 25 km) spatial resolution. Daily data were~~as~~ used because the epidemiological data were~~as~~ at weekly resolution. ~~[why daily and not 3-hourly?]~~ Near surface temperature and specific humidity were obtained from the Global Land Data Assimilation System (GLDAS) (Rodell et al., 2004). Resolutions for these data are 3-hourly and 0.25°. Note that 3-hourly data were~~as~~ used, because this was the only temporal resolution available that was higher than that of the epidemiological data. ~~[if 3B42 was daily, were GLDAS data upscaled to daily?]~~ Where available, air temperature data were obtained from ground stations (National Climatic Data Center, 2012). All of the meteorological data were~~as~~ aggregated into weekly resolution in order to match the epidemiological data. Figure **1** shows examples of these meteorological parameters, along with influenza data, for different climatic regions (World Health Organization, 2013).

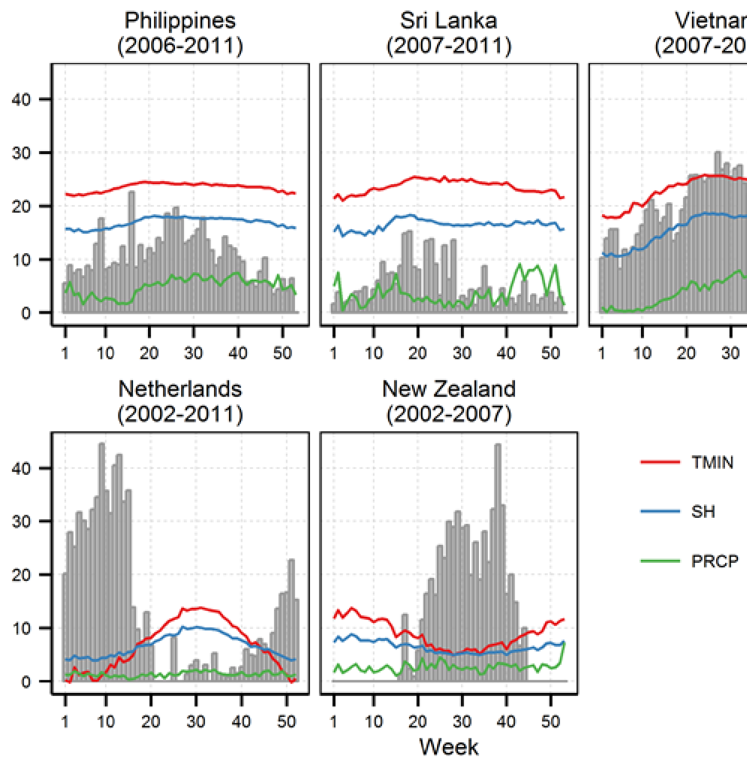

Figure 1. Weekly influenza activity (grey bar) as represented by the weekly influenza positive (%) and corresponding meteorological parameters. All data were averaged across the indicated years. TMIN is minimum temperature (°C), SH is specific humidity (g/kg), and PRCP is precipitation (.1 cm). Image source: Acker et al. (2014)

In order to assess the relationship between meteorological conditions and influenza transmission, we used regression models~~, including~~ which included logistic regression (Soebiyanto et al., 2014; Acker et al., 2014; Soebiyanto et al., 2015a), time series regression (Soebiyanto et al., 2010), as well as a generalized additive model which allowed nonlinear relationship with the predictors (Soebiyanto et al., 2015b). ~~[is generalized additive model #3 in the list of regression models? That's the way that I read it.]~~ We have also used a neural network to capture the nonlinear relationship between meteorological conditions and influenza transmission (Soebiyanto and Kiang, 2014).

[**What was found**] Our models indicated a bimodal relationship between specific humidity and influenza activity in temperate locations, sub-tropics, and tropics. In temperate and selected sub-tropical locations, specific humidity was inversely associated with influenza activity (Soebiyanto et al., 2015b). In the tropics, on the other hand, specific humidity was positively associated with influenza activity. There was one exception for Guatemala, where the climate resembles that of temperate locations, and, similarly, an inverse relationship between specific humidity and influenza activity was found (Soebiyanto et al., 2015a). The relationships between influenza activity and precipitation and temperature were found to be location-dependent. Where a precipitation- or temperature-influenza relationship existed, it typically did not have as much an effect on the models as did specific humidity.

Once the relationship between meteorological parameters and influenza activity was determined, we used the identified parameters and calibrated models to estimate influenza activity for data that were not used in training the model. In most of the study locations, the models could reasonably estimate the major influenza peaks (Fig. 2). However, the models could not do as well in estimating the low-level influenza activity, possibly indicating that low-level influenza activity was not strongly associated with meteorological conditions.

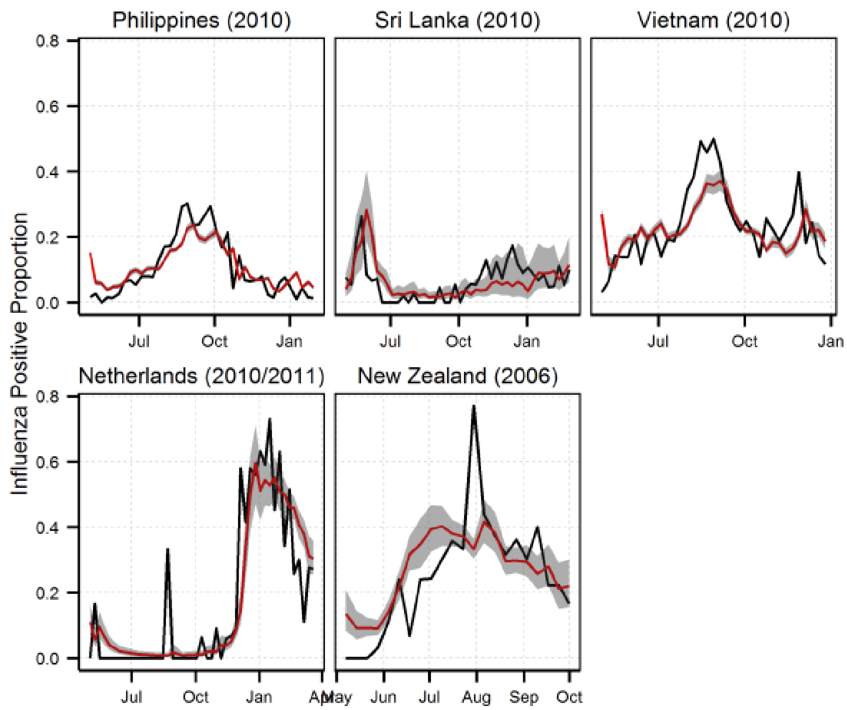

Figure 2. Regression model prediction of influenza activity using meteorological parameters. Black line is observed data (validation data set, not used in training the models). Red line is model prediction, with grey shades indicating the 95% confidence interval. Image source: Acker et al. (2014).

[**Conclusion(s)**] Our influenza prediction work has demonstrated the feasibility of such prediction using satellite-derived meteorological data. With the current data and models used in our study, we were able to predict influenza activity one to two weeks ahead. In future studies, short term weather forecasts could be used to potentially estimate influenza activity ~~in the~~ up~~coming~~ to three to four weeks ahead. Such ~~a~~ forecast capability could be useful for public health decision makers.

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