

Hypothesis on a possible role of El Niño in the occurrence of influenza pandemics

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Abstract The El Niño phenomenon is the Earth's strongest climatic fluctuation on an interannual timescale and has a quasi-global impact, although originating in the tropical Pacific Ocean. A very strong El Niño is recognized to cause extreme dryness and wetness in different parts of the world. We show that all the eight well-documented influenza pandemics, starting from the first certain one documented in AD 1580, originated in China and in Russia, a few years after the occurrence of a very strong or after a prolonged strong/moderate El Niño event. At present, the next El Niño will probably occur at the beginning of 2013 (Mazzarella et al. *Theor Appl Climatol* 100:23–27, 2010), and this forecast may suggest to be well prepared to take appropriate precautionary epidemiological measures.

1 Introduction

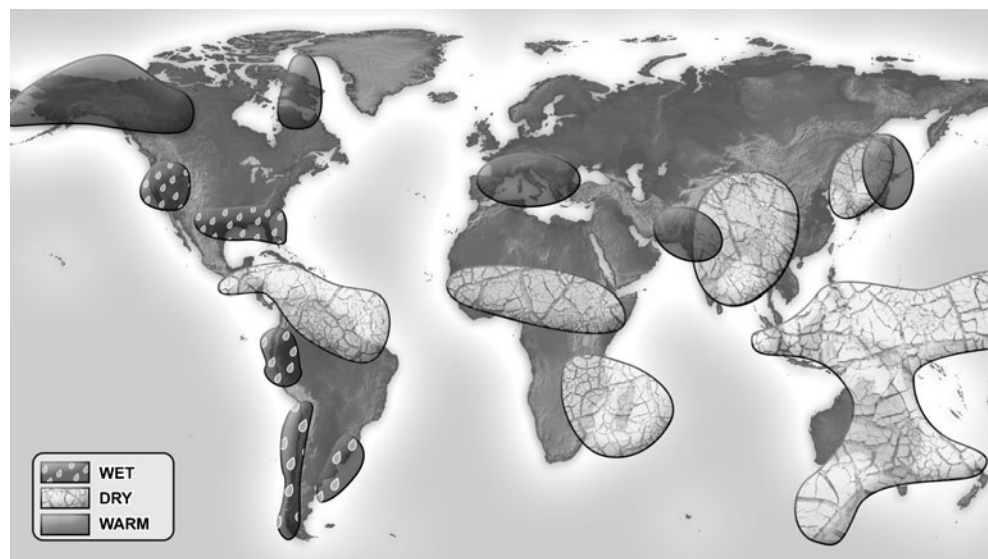
Influenza outbreaks have been described throughout recorded history (Ghendon 1994; Kilbourne 1987). There may be several circulating virus strains causing regional outbreaks or epidemics. An important characteristic of the influenza virus is that it is complex and continuously mutating. This drift yields slightly different virus strains every year (Kilbourne 2006; Health Protection Agency 2009). These mutations make it possible for people to become re-infected during subsequent years. Vaccines are yearly produced for new influenza strains so as to effectively protect individuals. Abrupt changes in the influenza A virus result in a new virus subtype and, thus, in an antigenic shift that leaves entire populations without any antibody protection. When this occurs, worldwide epidemics or pandemics may result. The 1918 so-called Spanish flu was a cataclysmic outbreak of infection wherein over 50 million people died worldwide within 18 months (Oxford et al. 2005). The Asian flu, originating in the Far East in 1957, and the Hong Kong flu of 1968, were less severe because of earlier vaccine inoculation and improved medical care. The most recent swine flu occurred in 2009, and although it did not entail the initially feared effects, there is a concern that the virus will mutate again, causing a new pandemic wave that could have a devastating effect on the worldwide population's health and well-being. Moreover, widespread illness will increase the likelihood of a sudden and potentially significant shortage of personnel who provides essential community services. There have been substantial differences among the three pandemics of the last century and between them and the swine flu. Therefore, there is considerable uncertainty about both the timing of the next pandemic and its precise impact. The unknown factors are sickness severity, spreading rapidity,

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Fig. 1 Areas most consistently affected by El Niño

and most susceptible populations. The actual impact of a pandemic depends not just on the virus type but also on other factors, as well as seasonal epidemics. Although seasonality is one of the most familiar features of influenza, it is one of the least understood. Indoor crowding at cold weather conditions, seasonal fluctuations in host immune responses, and environmental factors, such as relative humidity, air temperature, and UV radiation, have all been suggested to account for this phenomenon, but none of these hypotheses has been directly tested yet. In this paper, we investigate the possible role of El

Niño events in the occurrence of influenza pandemics. El Niño is a complex atmospheric and oceanographic phenomenon (Ropelewski and Halpert 1987) characterized by a sudden and large warming of surface waters in the tropical eastern Pacific Ocean. El Niño's variability in the equatorial Pacific changes the position of the major heat sources that drive the atmospheric circulation and the atmosphere adjusts itself, changing the weather patterns around the globe (teleconnection; Moron and Ward 1998; Mason and Goddard 2001; Feng and Hu 2004; Fig. 1).

Table 1 List of influenza pandemics and El Niño occurrences

Influenza pandemic occurrence (years) and region of origin	El Niño occurrence (years)	El Niño strength index (confidence index)	Lag (in years) between El Niño and influenza pandemic
1580 (China)	1578–1579	6 (5); 6 (5)	2
	1720	6 (5)	
1729–1733 (Russia)	1728	6 (5)	1
1781–1782 (China)	1776–1777–1778–1782	4 (3); 4 (3); 4 (3); 4 (3)	5
	1791	6 (5)	
1830–1833 (China)	1828–1830–1832	6 (5); 2 (2); 3 (5)	2
	1877–1878	6 (5); 6 (5)	
1889–1892 (Russia)	1887–1888–1889–1891	3 (4); 3 (4); 3 (4); 6 (5)	2
1918–1920 (China)	1917–1918–1919	3 (5); 6 (5); 5 (5)	1
	1925–1926	6 (5); 6 (5)	
1957–1958 (China)	1957–1958	4 (5); 4 (5)	0
1968–1969 (Hong Kong–China)	1969	1 (3)	1
	1982–1983	6 (5); 6 (5)	
	1987	6 (5)	
	1992–1993	6 (5); 5 (5)	
	1997–1998	6 (5); 6 (5)	
?	2013?	6 (?)	

Strength index: 1=near-moderate; 2=moderate; 3=moderate+; 4=strong; 5=strong+; 6=very strong. Confidence index: min=2; max=5

Table 2 Year of volcanic eruption together with the relative VEI

Year	Volcano	Region	VEI
1964	Agung	Indonesia	5
1965	Taal	Philippines	4
1966	Kelut	Indonesia	4
1966	Awu	Indonesia	4
1968	Fernandina	Ecuador	4

VEI is a simple 0–8 index of logarithmically increasing explosivity, each interval representing an increase by a factor of around 10

VEI volcanic explosivity index

2 Data collection

We have analyzed: (a) the influenza pandemics catalogue (Potter 2001; Jeung 2006) derived from a detailed analysis of different independent comprehensive reviews, most of which were published as books. Authored event lists were not accepted without valid and referenced information sources. The investigative process has allowed the identification of eight non-ambiguous pandemics (Table 1), starting from the first well-documented influenza pandemic that occurred in AD 1580. (b) The El Niño events catalogue (time interval: 1520–1987; Quinn et al. 1987) that accurately reviewed preceding publications to obtain information by atmospheric and oceanic evidences observed on the west coast region of Northern South America and its adjacent Pacific Ocean waters on the basis of wind and current effects on the travel times of ancient sailing ships, physical damage degree or destruction, rainfall amounts and flooding, mass mortality of endemic marine organisms and guano birds, extent of invasion by tropical nekton, rise in sea temperature and sea level, and effects on coastal fishery. All the identified events were classified according to a strength index (SI) ranging from 1 to 6 (SI=

1: near-moderate; SI=2: moderate; SI=3: moderate+; SI=4: strong; SI=5: strong+; SI=6: very strong) and to a confidence index ranging from 2 to 5 (Quinn et al. 1987). Here, the 1918–1919 El Niño event has been considered much stronger (Giese et al. 2010) than previously evaluated, for which the 1918–1919 El Niño SI has been here increased from 2 to 6. The El Niño events catalogue has been updated according to the Multivariate ENSO Index which is operative since 1950 and combines six variables observed over the tropical Pacific: sea level pressure, zonal and meridional components of the surface wind, sea surface water temperature, ground air temperature, and cloudiness (Wolter and Timlin 1993, 1998).

3 Results

Table 1 lists eight certain influenza pandemics, starting from the first well-documented one that occurred in AD 1580, together with the nearest El Niño episode. All the eight investigated pandemics originated in China and in Russia and occurred after a very strong (SI=6) El Niño or after a prolonged moderate or strong (SI=3–4) El Niño. Only the 1968–1969 influenza pandemic is found to occur in correspondence of a just near-moderate (SI=1) El Niño and with a confidence level barely equal to 3. This is probably due to the five energetic volcanic eruptions that characterized the years immediately before 1968 and that occurred in tropical regions where the El Niño data are usually measured (Table 2). Such eruptions could have biased atmospheric pressure, surface wind, sea/air temperatures, and cloudiness data from which the strength of an El Niño event is estimated, considerably weakening it and perhaps shifting its peak. It is worth noting that some very strong El Niños occurred in 1720, 1791, 1877–1878, 1925–1926, 1982–1983, 1987, 1992–1993, and 1997–1998 without being followed by an influenza pandemic. To test the time randomness of the eight influenza pandemics which occurred during the last 400 years, we used the Cantor dust method that computes the logarithm of the percentage R of time intervals of length t including at least one event as a function of $\log(t)$ (Mazzarella 1998). The results reported in Fig. 2 show that the angular coefficient between $\log(R)$ and $\log(t)$ takes values equal to 1, for intervals shorter than 64 years, and equal to 0, for intervals longer than 64 years, and not intermediate values between 0 and 1. This behavior is typical of a random distribution of eight yearly events within 400 years. Recently, a robust statistical analysis has been applied to the Multivariate ENSO Index (MEI) whose highest values represent El Niño events (Mazzarella et al. 2010). The plot of MEI index (Fig. 3) shows low values during 2009, to indicate the failure to forecast a strong El Niño that would occur in

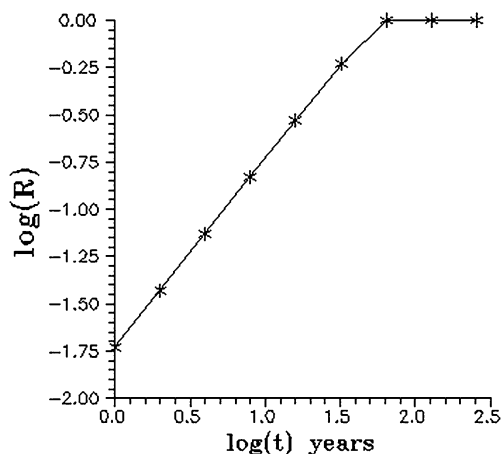
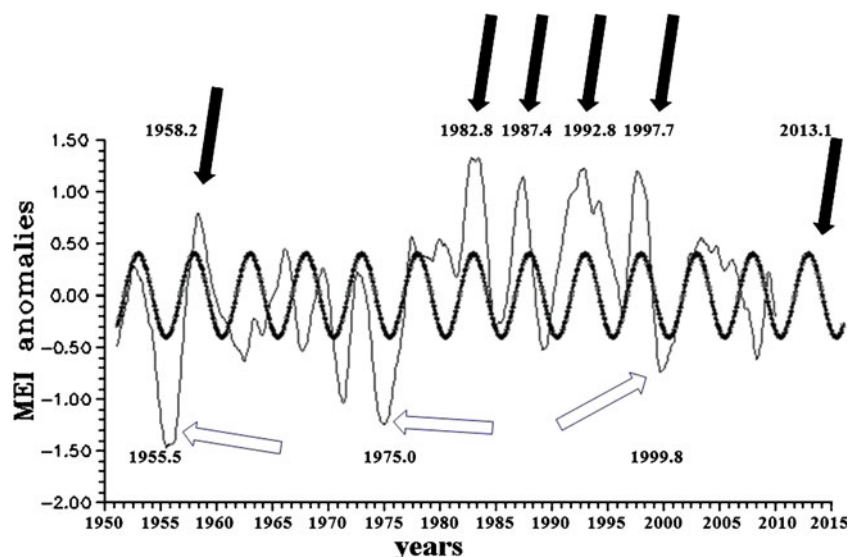


Fig. 2 Logarithm of the percentage R of time intervals of length t (in years), including at least a pandemic event, as a function of $\log(t)$

Fig. 3 Time series plot of the 25-month running mean of the Multivariate ENSO Index (MEI) from January 1951 to December 2009; *solid line* represents the 60-month cycle extrapolated to 2015. The *black arrows* are relative to El Niño time occurrences, while the *white arrows* are relative to La Niña time occurrences (figure taken from Mazzarella et al. 2010, updated to 2010)



2009, and a 60-month cycle that provides an estimate for the coming El Niño occurrence at the beginning of 2013.

4 Discussion

The analysis of different comprehensive reviews has allowed the identification of eight well-documented influenza pandemics (Potter 2001; Jeung 2006; Table 1) that are found to occur after a very strong or prolonged strong/moderate El Niño event. Table 1 shows that the influenza pandemics follow El Niño events with a time lag variable from 0 to 5 years that might be related to the time of diffusion of the virus. Table 1 shows that only 8 of the 16 available El Niños have been followed by influenza pandemics, and this indicates that the probability of a strong El Niño episode being responsible for an influenza pandemic is only 50%. The El Niño phenomenon causes a decrease in the strength of trade winds and of the monsoon regime (Feng and Hu 2004; Young-Kwon and Kwang-Yul 2007). A deficiency in rainfall might cause a large-scale severe drought and famine, particularly in China (Fig. 1) where almost all influenza pandemics originated and where one quarter of the earth population lives and where ducks, pigs, and humans live in closest proximity and at highest density. The influenza virus subtypes do not arise by endogene mutation from existing strains, but as reassortants of human, avian, and pig virus strains. The Asiatic population would become more prone to infective diseases and to the development of epidemic events that often spread throughout the world as pandemic events. Although the last four very strong El Niño events have not been closely followed by an influence pandemic, the avian and swine influenza still represent a considerable risk that may suggest not underestimating our expectations of the next El

Niño event by the beginning of the year 2013. Such a forecasting may be of great help to epidemiologists to take appropriate precautionary measures. If an El Niño event should really be associated with an influenza pandemic, its forecasting would be an inexpensive and easy method to make an epidemiological risk assessment.

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