Climate and the distribution of vector-borne diseases: what's in store?

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Surveillance of endemic/epidemic diseases, including early-warning systems, is of prime public health importance. Geographical information systems (GIS), with visualization, modelling and statistical analysis as basic components, display epidemiological data in a way that facilitates perception of the spatio-temporal development of disease distribution patterns. Approaches building on the landscape epidemiology concept (Pavlovsky, 1966) derived from GIS and remotely sensed data from Earth-observing satellites have become an integral part of national control programmes. This methodology is well suited for modelling through its ability to present the ecological niche as a basal geographical layer merged with climate information available from sources such as the WorldClim database (Hijmans *et al.*, 2005). These 19 biologically significant climate variables and annual trends (Bioclim) facilitate delimitation of endemic areas and the discovery of hotspots. Those interested in the initial development of Bioclim and its relevance to current ecological studies and modelling of species distribution will find further information in the well-researched review by Booth *et al.* (2012).

In addition to environmental variables, the concept of *growing degree days* (GDD), a measure of heat accumulation originally used to predict the harvest time for cereals, is also useful for the study of parasitic infections (Malone *et al*., 1998). Two landmark papers on schistosomiasis endemicity used the GDD concept to assess the transmission dynamics of this infection in China retrospectively and prospectively using a biology-driven GDD model. Covering the period 1972-2002, Yang *et al*. (2006) found distinct, seasonal trends but only marginal, spatial variations, while Zhou *et al*. (2008) demonstrated a considerable expansion potential in the North: 662,373 km^2 by 2030 and 783,883 km^2 by 2050. The work is based on the fact that the intermediate snail host cannot reproduce at temperatures below 5.8ºC, while 15.4ºC is the limit for transmission to humans and other definitive hosts as parasite growth inside the snail ceases if the temperature falls below this figure. The estimated spatial increase of schistosomiasis endemicity in China by 2050 corresponds to more than 8% of the present area, which goes to show that small variations can have huge effects and that the effect of temperature change is crucial.

The average temperature of Earth, regularly recorded since 1880, shows a rising trend which has now reached 0.9°C above the mean for the entire period of recorded observations (https://www.climate.gov/). The rate is also increasing, which introduces an element of urgency as regards the already observed spread of various tropical diseases into currently temperate zones (Yang *et al*., 2006; Zhou *et al*., 2008) changing endemic areas within tropical areas (Khormi and Kumar, 2016; Leedale *et al*., 2016) or expansion of potential ranges of infections within temperate zones, *e.g*., tick-borne diseases (Genchi *et al*., 2011; Asghar *et al*., 2016).

The correlation between temperature and carbon dioxide shown in ice cores dating over the last 400,000 years (Petit *et al*., 1999), together with the fact that the atmospheric concentration of this greenhouse gas has escalated in step with industrial development, makes a strong case for attempting to curb further increase. Indeed, the carbon dioxide level has recently surpassed 400 ppm, which is well above that estimated for the whole quaternary geological period (http://www.biocab.org/Climate_Geologic_Timescale.html). Although sustained emissions may result in continued warming in the near-term, celestial influences dim the long-term picture. For example, even the minute annual change of the degree of tilt of the Earth's axis makes the Tropics of Cancer and Capricorn, as well as the Arctic and Antarctic Circles, move at a rate of 14-15 m per year, altering the influx balance of solar energy near them, while the sun-earth distance variation can activate glacial periods. The latter effect, however, can only be discerned over periods of 100,000 years and longer whereas changes in solar activity have an effect here and now.

Henrik Svensmark, a physicist at the Danish National Space Center, has advanced the theory that solar activity, as indicated by sunspot fluctuations, is associated with the intensity of cosmic radiation reaching Earth resulting in periodic warming and cooling of the planet. He suggests that large numbers of sunspots lead to reduced cloud covers and higher temperatures due to their association with a stronger solar magnetic field, which shields Earth by reducing the influx of cosmic rays. On the other hand, the fewer the number of spots, the weaker the solar magnetic field allowing a higher atmospheric penetration rate. According to Svensmark (2007), this cosmic radiation ionizes the air and produces dense clouds reflecting much of the solar energy leading to a cooler planet, processes that can explain the temperature variations during the last few centuries as well as the current period of global warming. If this hypothesis is verified, which more recent research (Svensmark *et al*., 2013) indicates, the weakening trend of the latest sunspot cycles should introduce a strong cooling

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effect, begging the question of whether we are on our way towards another *little ice age*, similar to that endured between 1650 and 1710, rather than approaching runaway warming. Of course it is possible that neither scenario might occur as the two effects could cancel each other out. The overall effect is, however, difficult to estimate as noted by Bond *et al*. (2001), who have demonstrated that even very minor changes in the Sun energy output have led to comparatively strong climate variations on Earth over the last 11,700 years.

Sunspots vary in 11-year cycles of different strengths, the phenomenon that has been known since Galileo first observed them in the beginning of the 17th century, which provides a 400-year record. It is recognized that sunspot minima coincided with three major cold periods peaking around 1680, 1810 and 1900, the first of which was of unusual intensity (Maunder, 1904). However, these three strong climate swings are unpredictable and a clear direction might only be assumed after a run of ever diminishing or increasing solar cycles. Without going into details here, suffice it to say that carbon^{14}-based dendroclimatology data indicate that the increased level of solar activity initiated in the 1940s was the strongest for 9000 years (Solanki *et al*., 2004), and that we are currently at the tail end (approaching a minimum) of sunspot cycle 24, which is the lowest cycle since accurate records started in 1750 (http://www.swpc.noaa.gov/products/solar-cycle-progression).

Temperature is the most easily measured climate variable but it does not change in isolation, *e.g*., surface hydrographic changes affect deep-water circulation amplifying the input results of solar energy and conveying changes globally (Bond *et al*., 2001). This hydrological cycle effects atmospheric moisture, clouds, precipitation and winds creating droughts in some areas and floods in others, as illustrated by the change between El Niño and La Niña in the El Niño Southern Oscillation (ENSO) in the Pacific (https://www.climate.gov/news-features/blogs/enso/what-el-ni%C3%B1o%E2% 80%93southern-oscillation-enso-nutshell). In addition, there are also more long-term changes in soil moisture and evaporation that have resulted in drought conditions in large parts of the world, the Sahel region of Africa in particular (Dai and Zhao, 2016).

Climate-change models can predict which factors might challenge disease control activities but forecasting suffers from ambiguity even in time-frames as short as the next 30-50 years. Worryingly, future climate changes might be precipitous rather than gradual, and therefore strongly resistant to mitigation demanding a rapid pre-emptive response earlier rather than later. It would therefore seem prudent to consider several different potential distribution scenarios when attempting to construct predictive ecology models. In order to do this, models using a sliding scale of estimated future biological variables ought to be developed. The moving Tropics and the northern limit of schistosomiasis in China alluded to above should encourage us to constantly monitor areas for changes in the endemicity of vector-dependent parasites. However, instead of adhering strictly to a global warming trend, forecasting should rather be seen as a project considering various scenarios with different possible endpoints. Models would need to be continuously updated as new information becomes available and we should be ready to rapidly modify present strategies in order to mitigate the risk due to climate-sensitive diseases. At the moment, the most important risks appear to be atmospheric carbon dioxide levels on the one hand and solar activity on the other. Will there be a warm welcome or a chilling embrace?

References

Asghar N, Petersson M, Johansson M, Dinnetz P, 2016. Local landscape effects on population dynamics of Ixodes ricinus. Geospat Health 11:487.

Bond G, Kromer B, Beer J, Muscheler R, Evans MN, Showers W, Hoffmann S, Lotti-Bond R, Hajdas I, Bonani G, 2001. Persistent solar influence on North Atlantic climate during the Holocene. Science 294:2130-6.

Booth TH, Nix HA, Busby JR, Michael F, Hutchinson MA, 2012. BIOCLIM: the first species distribution modelling package, its early applications and relevance to most current MAXENT studies. Diversity Distrib 20:1-9.

Dai A, Zhao T, 2016. Uncertainties in historical changes and future projections of drought. Part I: estimates of historical drought changes. Climatic Change 2016:1-15.

Genchi C, Mortarino M, Rinaldi L, Cringoli G, Traldi G, Genchi M, 2011. Changing climate and changing vector-borne disease distribution: the example of Dirofilaria in Europe. Vet Parasitol 176:295-9.

Hijmans RJ, Susan E, Cameron SE, Parra JL, Jones PG, Jarvis A, 2005. Very high resolution interpolated climate surfaces for global land areas. Int J Climatol 25:1965-78.

Khormi HM, Kumar L, 2016. Future malaria spatial pattern based on the potential global warming impact in South and Southeast Asia. Geospat Health 11:416.

Leedale J, Tompkins AM, Caminade C, Jones AE, Nikulin G, Morse AP, 2016. Projecting malaria hazard from climate change in eastern Africa using large ensembles to estimate uncertainty. Geospat Health 11(Suppl.1):393.

Malone JB, Gommes R, Hansen J, Yilma JM, Slingenberg J, Snijders F, Nachtergaele F, Ataman E, 1998. A geographic information system on the potential distribution and abundance of Fasciola hepatica and F. gigantica in east Africa based on Food and Agriculture Organization databases. Vet Parasitol 78:87-101.

Maunder EW, 1904. Note on the distribution of sun-spots in heliographic latitude, 1874-1902. Mon Not R Astron Soc 64:747-61.

Pavlovsky EN, 1966. Natural nidality of transmissible diseases (with special reference to the landscape epidemiology of zooanthroponses). (Translated from the Russian edition 1964). University of Illinois Press, IL, USA.

Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola J-M, Basile I, Benders M, Chappellaz J, Davis M, Delayque G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Pépin L, Ritz C, Saltzman E, Stievenard M, 1999. Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399:429-36.

Solanki SK, Usoskin IG, Kromer B, Schüssler M, Beer J, 2004. Unusual activity of the Sun during recent decades compared to the previous 11,000 years. Nature 431:1084-7.

Svensmark H, 2007. Cosmoclimatology: a new theory emerges. Astron Geophys 48:1-19.

Svensmark H, Enghoff MB, Pedersen JOP, 2013. Response of cloud condensation nuclei (>50 nm) to changes in ion-nucleation. Phys Lett A 377:2343-7.

Yang GJ, Gemperli A, Vounatsou P, Tanner M, Zhou XN, Utzinger J, 2006. A growing degree-days based time-series analysis for prediction of *Schistosoma japonicum* transmission in Jiangsu province, China. Am J Trop Med Hyg 75:549-55.

Zhou XN, Yang GJ, Yang K, Wang XH, Hong QB, Sun LP, Malone JB, Kristensen TK, Bergquist NR, Utzinger J, 2008. Potential impact of climate change on schistosomiasis transmission in China. Am J Trop Med Hyg 78:188-94.