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Variations in climate and global spread of COVID-19: Implications for control in tropical and warmer climates

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Abstract

Health and climatic changes have been linked for centuries. Viruses, bacteria, fungi and parasites are sensitive to environmental conditions including ambient temperature, humidity, smog, and other climatic factors like exposure to sunlight. Viral respiratory tract infections such as seasonal influenza are known to become epidemic primarily during cold weather conditions influenced also by population density and travel patterns.(1) The winter months in China are from November to March. The SARS-CoV-1 outbreak commenced in Guangdong Province, in November 2002 and the SARS-CoV-2 outbreak in Wuhan in early December 2019. Understanding how the emergence and spread of COVID-19 could be affected by climatic conditions may be an important aspect for disease control. As of August 4th 2020, 18 142 718 confirmed cases and 691 013 deaths have been reported to the WHO from all continents.(2) As the pandemic continues apace around the world, the great hope is that in addition to the effects of social distancing and mass quarantine measures, transmission may slow down as the weather warms over summer periods, bringing down the current exponential growth.

Introduction

The basic reproduction number (R^0) or rate of human-to-human transmission during an outbreak depends on three closely linked factors: the innate physical and genetic characteristics of the pathogen itself, the conduciveness of the environment through which it transmits, and the human host. R^0 is defined as the average number of people who will contract a disease from one contagious person and current estimates of the contagiousness of SARS-CoV-2, have typically been estimated to range from 1.5 to 3.(3,4) Here, we postulate how an intervention to alter the conduciveness of the environment to SARS-CoV-2 through changes in the ambient temperature and humidity and their potential effects on human behaviour may be able to reduce the R^0 in a wide range of warmer, more humid settings.

The underlying rationale for this has a sound historical basis - cold and influenza viruses display seasonality and tend to dissipate in warmer weather. They also tend to cause smaller, less sustained outbreaks in more tropical climates.(5)

Why do we see this seasonal outbreak pattern though? This may in part be a result of factors related to the weather itself during winter (including lower ambient temperature, lower humidity, less circulating air indoors and increased wind speeds outside, less sunlight) (1) and environment-induced changes in the human host (e.g. changes to the physical barriers limiting infection such as of the mucosal lining of the upper respiratory tract and less sunlight and vitamin D reducing the effectiveness of the immune system (6,7,8). Behavioural effects may also play a role such as the relatively greater indoor densities of human populations observed during the winter months and tropical rainy seasons as individuals and families huddle together to keep warm.(1)

Seasonality of coronaviruses

SARS-CoV-2 belongs to the beta coronavirus genus. While endemic beta coronaviruses like HCoV-OC43 and HCoV-HKU1 also show this seasonal pattern, this is by no means established yet for SARS-CoV-2 or for past epidemic emergencies like SARS-CoV-1 and MERS-CoV. HCoV-OC43 and HCoV-HKU1 for their part, are considered the second most common cause of the common cold and cause annual wintertime outbreaks of respiratory illness in temperate regions.(1) Some initial analyses of the COVID-19 pandemic does however suggest that transmission is occurring more rapidly in colder climates and an association with weather at this stage is therefore not unreasonable.(9) Initial pre-print linear regression analysis from 100 cities in China prior to the national lockdown which radically changed human host conditions for propagation of the virus - indicates that higher temperatures and humidity significantly reduce transmission of COVID-19 after controlling for population density and GDP per capita of the cities.(10) This early finding has been subsequently affirmed by a number of peer-reviewed environmental studiesimilarly finding slower transmission in higher temperature and higher relative humidity settings across China.(11-13)

On the other side of the world, Sajadi and colleagues (14) found that SARS-CoV-2 has established significant community spread globally in cities and regions along a narrow east-west distribution, roughly along the $30\text{-}50^{o}$ N' temperate corridor. The community spread happened at consistently similar weather patterns consisting of average temperatures of $5\text{-}11^{o}$ C, combined with low specific (3-6 g/kg) and absolute humidity (4-7 g/m^3). These findings are consistent with the behaviour of a seasonal respiratory virus and suggest those temperate zones in neon green below and in the blue northern zones (as they warm) are most at risk (see figure 1).(14,15) In Africa, countries experiencing their winter/rainy seasons should perhaps be most worried as the rest of the inhabited world warms.
FIGURE 1
Early on in the outbreak, positive findings from pre-print analysis on seasonality has spurred more definitive peer-reviewed publications. Bukhari and Jameel (16) in a pre-print published in late March analysed patterns in local weather of all global regions affected by SARS-CoV-2 from January 10^{th} to March 22^{nd} 2020. Their analysis indicated the maximum number of new cases developed in regions with mean temperatures between 4 to 17^0C and absolute humidity between 3 and 9 g/m^3 and that the number of cases for regions with temperature > 17^0C and absolute humidity > 9 g/m^3 was relatively lower.(16) Similarly, researchers from Chicago and California (17), presented analysis of data from a global sample comprising of 166,686 confirmed new COVID-19 cases from 134 countries from January 22, 2020 to March 15, 2020. Their study found statistically significant evidence that a 1°C increase in local temperature reduces COVID-19 transmission by 13% [-21%, -4%, 95%CI].(17) More recent peer-reviewed studies, are now also reaching similar conclusions and building in temperature and humidity linked transmission dynamics into their predictive modelling.(18)
As such, the growing body of evidence does broadly point to a strengthening association between sunnier, warmer and more humid climates and a slowing of SARS-CoV-2 transmission. The logic of the argument now appears to have become compelling enough to inform action. Already, national authorities around the world have put in place mass quarantine and social distancing mitigation measures to slow the exponential increase in new cases, and hopefully shift the epidemic curve into the warmer months when seasonal viral infections and perhaps COVID-19 will start to wane and reduce the pressure on secondary and intensive healthcare services. Recent modelling work published by Kissler and colleagues (19), adopted potential seasonal reductions in R^0 of up to 40% (from 2.2 to 1.3) for SARS-CoV-2 based on analysis of the past five seasons of beta corona viruses HCoV-OC43 and HCoV-HKU1. The likelihood of seasonal variation has also been built into other models being developed that attempt to predict the likelihood and size of subsequent peaks in the coming winter season (2020/2021) particularly as they relate to more temperate regions.(20)

A possible intervention in tropical and warmer climates

Thus, can more be done on the basis of these associations to further reduce the R^0 of the virus? In climatic zones with already warm or rapidly warming environments, national governments should urgently investigate the potential role of ambient temperature and absolute humidity on virus transmission and consider restrictions on the use of air-conditioning. Results published by the US Department of Homeland Security's National Biodefence Analysis and Countermeasures Center (NBACC) in mid-April after extensive laboratory studies, have found that SARS-CoV-2 decays progressively faster indoors at a relative humidity above 40% and is increasingly less stable at higher ambient temperatures.(21) Sunlight exposure has also been found to rapidly increase viral decay.(22) On the basis of their results, the NBACC studies offer operational advice "if a location has a COVID-19 positive individual and is going to be vacated for cleaning, turn up indoor heat and humidity".(21) Across sub-tropical and tropical regions from the Southern United States and Latin America, to Lagos in West Africa, Nairobi in East Africa, and the major travel hubs of Dubai, Doha, Singapore, Bangkok and Kuala Lumpur, all regions seeing sustained local outbreaks to varying degrees of COVID-19, setting the air conditioning system to a relatively high temperature or switching it off in major public spaces (e.g. airports, hospitals, malls and office blocks, mass transit systems including buses and trains etc.) as well as in private homes, apartment blocks, elderly care homes and private taxis, while

balancing the need to prevent overheating and minimise the risk of heat stroke in excessively hot and humid settings, may well have the effect of slowing transmission. Average air conditioning temperatures for airports, apartment blocks and hospitals with centralised AC systems, are usually set at 18-21^{O}C, with a relative humidity of 40% - mimicking climate conditions in more temperate zones of the world - while the ambient daily average temperatures in highly air-conditioned cities like Singapore (where 75% of households are estimated to be air-conditioned) and Kuala Lumpur for the month of March and April have been 32-33^{o} C with on average 79-80% humidity.
Furthermore, in middle and lower income households in many of these settings, families often converge into single air-conditioned rooms to lower electricity bills.(23-25) The added benefit of a temporary restriction on air conditioner use during this emergency pandemic response phase, would thus be a reduced incentive to densely huddle within households as the external temperatures continue rising – supporting further the primary goal of interrupting transmission through social distancing. This would be particularly important for intergenerational households where vulnerable adults mix with children. Additionally, air-conditioning has already been identified as a possible factor in driving transmission with a cluster of cases in China.(26) Positive externalities of 'a nationwide AC shut down' for the duration of the social distancing and mass quarantine period would include a positive effect on greenhouse gas emissions and the monetary savings from lower utility bills that would accrue for public institutions, businesses and households already struggling from the financial fallout of the pandemic. Within the built environment these shutdowns should be coupled with measures to improve indoor ventilation and encourage greater outside air fractions and higher air exchange rates in buildings which may help to dilute the indoor contaminants, including viral particles, from air that is breathed within the building.(27) Some personal discomfort will be a small price to pay to help slow transmission.

Further research and policy action

If, as anticipated, COVID-19 does display some seasonality as other flu and cold viruses normally do, the potential benefits of a 'mass AC shutdown' for already warm global regions are significant. Further research is urgently warranted to not only definitively establish the seasonality of COVID-19 but also to be able to accurately inform quantitative models seeking to predict the impact of varying amounts of sunlight, heat and humidity on virus transmission (R^0). Even if modest reductions in the R^0 of the virus are achieved through this intervention, it will result in tens of thousands fewer infections across these regions over the short-term when pressures on health services are greatest. Any negative consequences of such an intervention are minimal and given the world is already throwing the proverbial kitchen sink at trying to reduce the attack rate of the virus, this is one intervention that warmer regions should put in place immediately to complement their existing pandemic response strategies.

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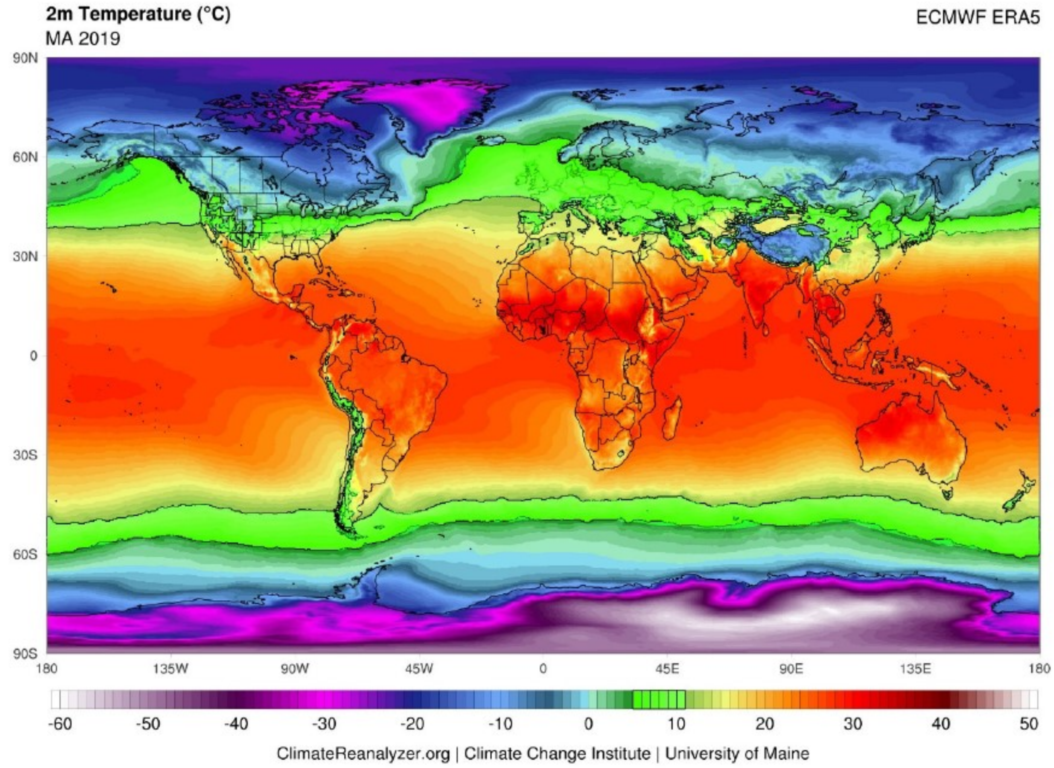

Figure 1: World 2 metre average temperature map March 2019-April 2019 predicting at risk zone for March-April 2020. Colour gradient indicates average 2 metre temperatures in degrees Celsius, except neon green band which shows a zone with both 5-11oC and specific humidity between 3-6 g/kg. Tentative zone at risk for significant community spread in the near-term include land areas within the neon green bands.
Adapted from Sajadi et al.[14]