Temperature and latitude analysis to predict potential spread and seasonality for COVID-19

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Abstract

A significant number of infectious diseases display seasonal patterns in their incidence, including human coronaviruses. We hypothesize that SARS-CoV-2 does as well. To date, Coronavirus Disease 2019 (COVID-19), caused by SARS-CoV-2, has established significant community spread in cities and regions only along a narrow east west distribution roughly along the 30-50 N" corridor at consistently similar weather patterns (5-11^{O}C and 47-79% humidity). There has been a lack of significant community establishment in expected locations that are based only on population proximity and extensive population interaction through travel. We have proposed a simplified model that shows a zone at increased risk for COVID-19 spread. Using weather modeling, it may be possible to predict the regions most likely to be at higher risk of significant community spread of COVID-19 in the upcoming weeks, allowing for concentration of public health efforts on surveillance and containment.

Many infectious diseases show a seasonal pattern in their incidence. An onerous burden for health care systems around the globe, influenza is the characteristic example.[1] The influenza virus shows significant seasonal fluctuation in temperate regions of the world but nevertheless displays less seasonality in tropical areas.[2-4] Despite the multitude of possible mechanisms proposed to explain this variation, our current understanding of this phenomenon is still superficial.[5]

Coronavirus Disease 2019 (COVID-19), caused by SARS-CoV-2, initially came to attention in a series of patients with pneumonia of unknown etiology in the Hubei province of China, and subsequently spread to many other regions in the world through global travel.[6] Because of geographical proximity and significant travel connections, epidemiological modeling of the epicenter predicted that regions in Southeast Asia, and specifically Bangkok would follow Wuhan, and China in the epidemic.[7] However, the establishment of community transmission has occurred in a consistent east and west pattern. The new epicenters of virus were all roughly along the 30-50^{o} N" zone; to South Korea, Japan, Iran, and Northern Italy (Figure 1).[8] After the unexpected emergence of a large outbreak in Iran, we first made this map in late February. Since then new areas with significant community transmission include the Northwestern United States and France (Figure 1). Notably, during the same time, COVID-19 failed to spread significantly to countries immediately south of China. The number of patients and reported deaths in Southeast Asia is much less when compared to more temperate regions noted above.[8]

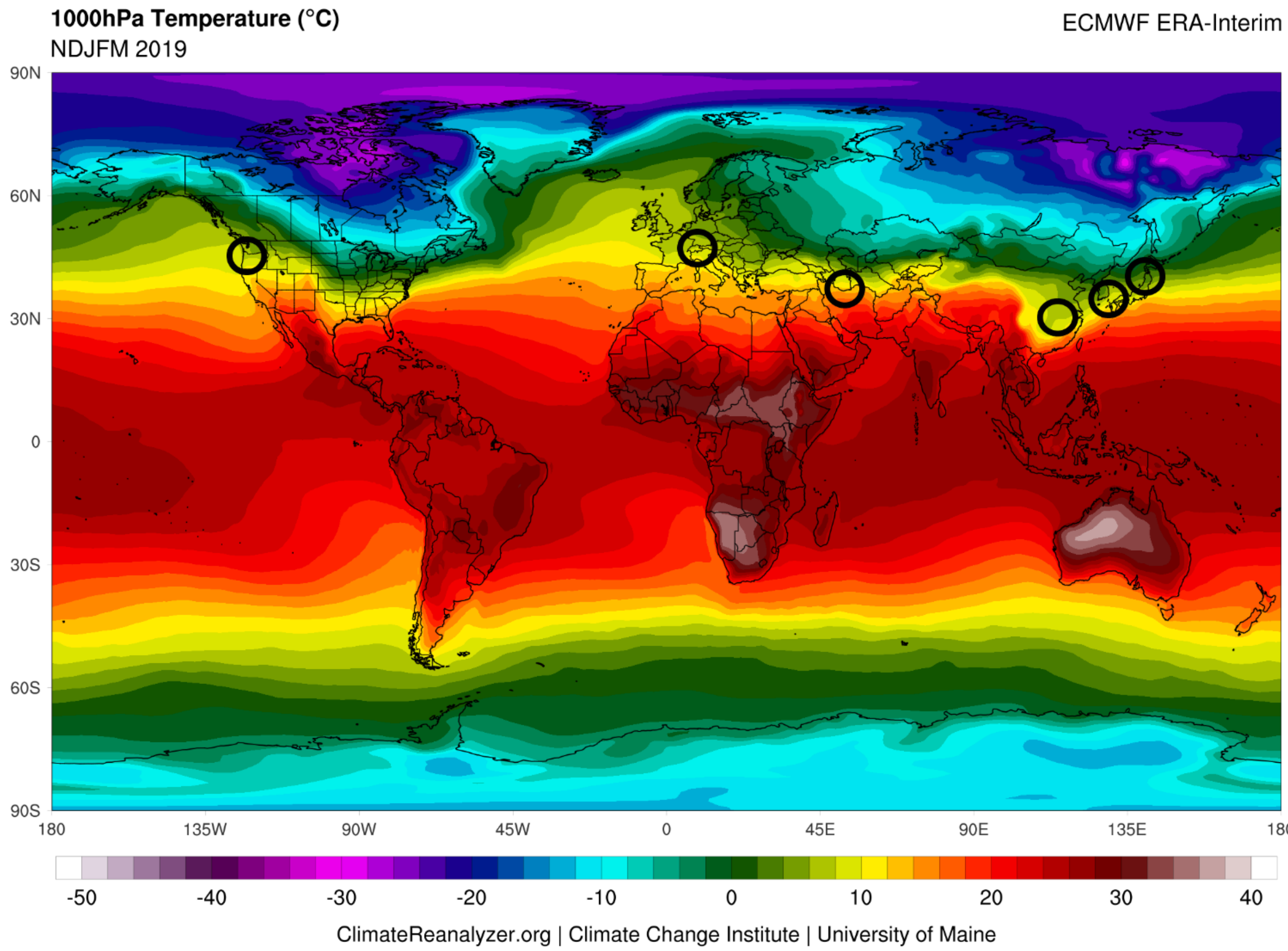

Figure 1. World temperature map November 2018-March 2019. Color gradient indicates 1000hPa temperatures in degrees Celsius. Black circles represent countries with significant community transmission (> 6 deaths as of 3/5/3019). Image from Climate Reanalyzer (https://ClimateReanalyzer.org), Climate Change Institute, University of Maine, USA.

Further analysis using 2-meter (2m) temperatures from 2020 rather than hPa temperatures yields similar results (Figure 2). In the months of January 2020 in Wuhan and February 2020 in the other affected, there is a striking similarity in the measures of average temperature (5-11ºC) and relative humidity (RH, 47-79%) (Table 1). In addition to having similar average temperature, humidity, and latitude profiles, these locations also exhibit a commonality in that the timing of the outbreak coincides with a nadir in the yearly temperature cycle, and thus with relatively stable temperatures over a more than a one month period of time (Supplementary Figure 1). In addition, none of the affected cities have minimum temperatures going below 0 ºC (Supplementary Figure 1).

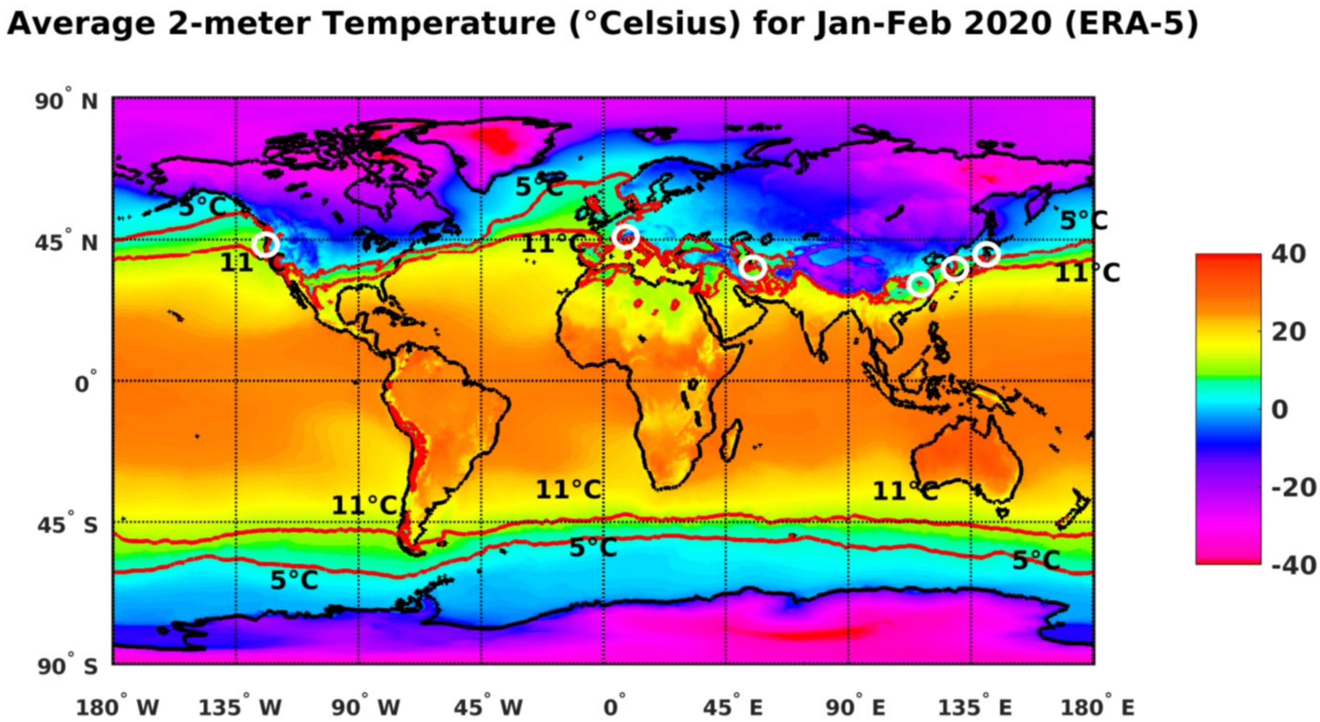

Figure 2. World temperature map January 2020-February 2020. Color gradient indicates 2-meter temperatures in degrees Celsius based on data from the ECMWF ERA-5 reanalysis. White circles represent countries with significant community transmission (> 6 deaths as of 3/5/3019), and red isolines areas with temperature between 5-11ºC. Generated using Copernicus Climate Change Service Information 2020.

City	Nov 2019	Dec 2019	Jan 2020	Feb 2020
Cities with community spreading of COVID-19				
Wuhan	18ºC/44%	12 ºC/56%	7 ºC/74%	13 ºC/66%
Tokyo	17 ºC/53%	11 ºC/52%	9 ºC/54%	10 ºC/47%
Qom	12 ºC/52%	10 ºC/58%	7 ºC/59%	10 ºC/47%
Milan	11 ºC/77%	8 ºC/74%	7 ºC/69%	11 ºC/58%
Daegu	11 ºC/64%	5 ºC/62%	4 ºC/68%	5 ºC/62%
Seattle	9 ºC/76%	6 ºC/84%	6 ºC/84%	7 ºC/79%
Mulhouse	7 ºC/84%	6 ºC/82%	6 ºC/80%	8 ºC/74%
Large cities tentatively predicted to be at risk in the coming weeks				
London	8 ºC/78%	8 ºC/80%	8 ºC/80%	8 ºC/70%
Manchester	7 ºC/82%	6 ºC/83%	7 ºC/83%	6 ºC/73%
Berlin	8 ºC/81%	5 ºC/80%	5 ºC/81%	6 ºC/75%
Prague	7 ºC/81%	4 ºC/78%	3 ºC/79%	6 ºC/71%
Hamburg	6 ºC/89%	5 ºC/86%	6 ºC/88%	6 ºC/83%
Vancouver	8 ºC/75%	6 ºC/84%	5 ºC/84%	5 ºC/78%
New York	8 ºC/55%	4 ºC/72%	4 ºC/61%	5 ºC/62%
Warsaw	8 ºC/76%	4 ºC/78%	3 ºC/78%	5 ºC/72%
Glasgow	5ºC/87%	5 ºC/89%	6ºC/86%	4 ºC/84%
Kiev	6 ºC/74%	4 ºC/83%	1 ºC/85%	3 ºC/76%
St. Louis	6 ºC/71%	5 ºC/78%	3 ºC/77%	3 ºC/73%
Beijing	9ºC/33%	2 ºC/43%	2 ºC/41%	5 ºC/45%
Previously predicted city where COVID-19 failed to take hold				
Bangkok	31 ºC/52%	30 ºC/45%	32 ºC/50%	32 ºC/51%

Table 1. November 2019 to February 2020 average temperature (°C) and humidity (%) data from cities with community spreading of COVID-19 and those at potentially at risk. Temperature and humidity data obtained from www.worldweatheronline.com

The association between temperature in the cities affected with COVID-19 deserves special attention. There is a similarity in the measures of average temperature (5-11ºC) and RH (47-79%) in the affected cities and known laboratory conditions that are conducive to coronavirus survival (4ºC and 20-80% RH).[9] Temperature and humidity are also known factors in SARS-CoV, MERS-CoV and influenza survival.[10] Furthermore, new outbreaks occurred during periods of prolonged time at these temperatures, perhaps pointing to increased risk of outbreaks with prolonged conditions in this range. Finally, the temperatures in these cities did not dip below 0ºC, pointing to a potential minimum range, which could be due to avoidance of freeze-thaw cycles that could affect virus viability or other factors (at least one human coronaviruses tested is freeze-thaw resistant).[11] All of these point to a potential direct relation between temperature and SARS-CoV-2 environmental survival and spreading. This hypothesis can be tested in experimental conditions similar to work that has been done before,[9] and with environmental sampling and testing from areas of ongoing infection.

Given the temporal spread among areas with similar temperature and latitude, some predictions can tentatively be made about the potential community spread of COVID-19 in the coming weeks. Using 2019 temperature data for March and April, risk of community spread could be predicted to affect areas just north of the current areas at risk (Figure 3). These could include (from East to West) Manchuria, Central Asia, the Caucuses, Eastern Europe, Central Europe, the British Isles, the Northeastern and Midwestern United States, and British Columbia. However, this simplified analysis does not take into account the effect of warming temperatures. The marked drop in cases in Wuhan could well be linked to corresponding recent rising temperatures there (Table 1).

In the coming 2 months, temperatures will rise dramatically across many areas in the Northern Hemisphere. However, areas to the north which develop temperature profiles that may now overlap the current areas at risk only transiently as they rapidly warm (with possible exception of areas such as the Northwest United States and British Columbia, which can show prolonged cyclical nadirs) (Supplementary Figure 1). Furthermore, as the virus moves further north it will encounter sequentially less human population densities. The above factors, climate variables not considered or analyzed (cloud cover, maximum temperature, etc.), human factors not considered or analyzed (impact of epidemiologic interventions, concentrated outbreaks like cruise ships, travel, etc.), viral factors not considered or analyzed (mutation rate, pathogenesis, etc.), mean that although the current correlations with latitude and temperature seem strong, a direct causation has not been proven and predictions in the near term are speculative and have to be considered with extreme caution.

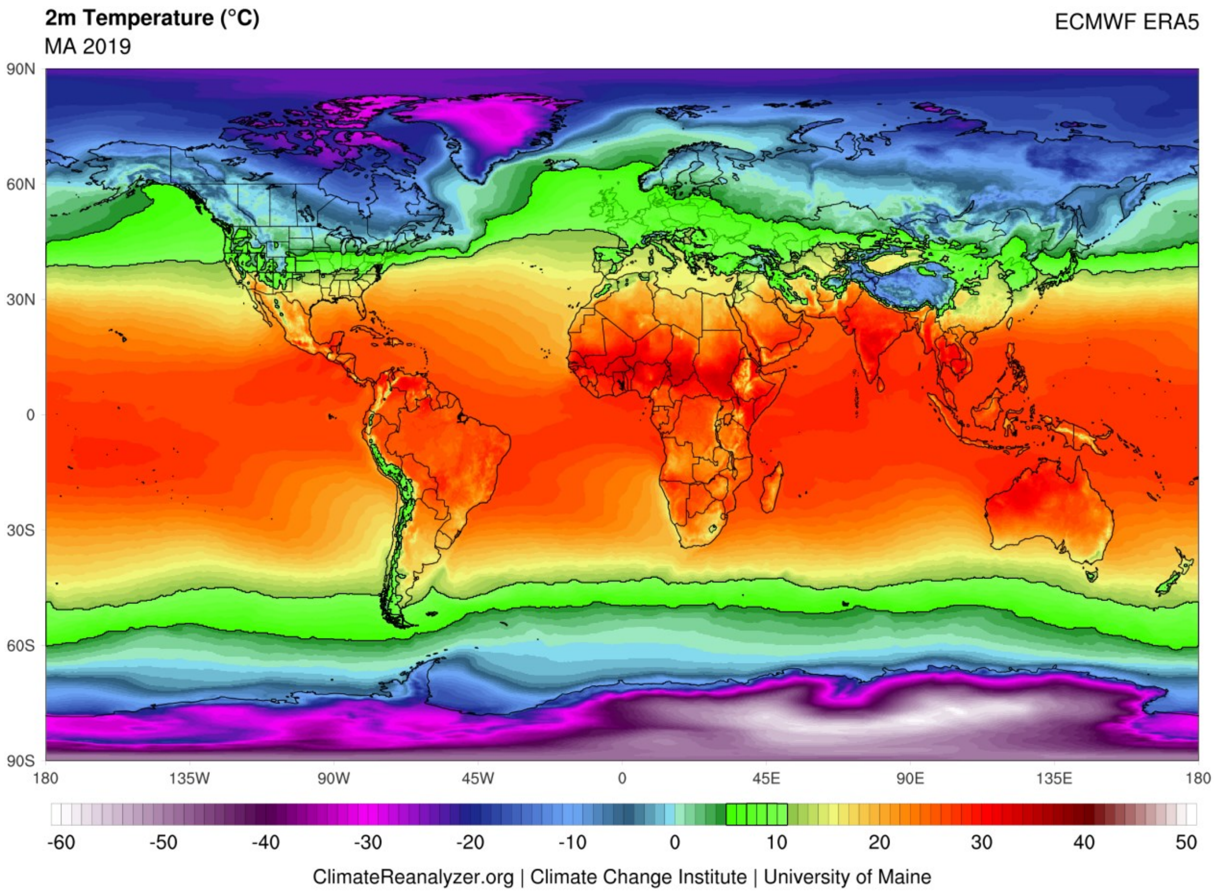

Figure 3. World 2M temperature map March 2019-April 2019 showing at risk zone. Color gradient indicates 2M temperatures in degrees Celsius. Tentative zone at risk for significant community spread in the near-term include land areas within the green bands, outlined in dark black (showing 5-11°C zone based on 2019 data), and will change based on actual average temperatures during this time period. Image from Climate Reanalyzer (https://ClimateReanalyzer.org), Climate Change Institute, University of Maine, USA.

Human coronaviruses (HCoV-229E, HCoV-HKU1, HCoV-NL63, and HCoV-OC43), which usually cause common cold symptoms, have been shown to display strong winter seasonality between December and April, and are undetectable in summer months in temperate regions.[12] Although it would be even more difficult to make a long-term prediction at this stage, it is tempting to expect COVID-19 to diminish considerably in affected areas (above the 30° N") in the coming months. It could perhaps prevail at low levels in tropical regions similar to influenza and begin to rise again in late fall and winter in temperate regions in the upcoming year. One other possibility is that it will not be able to sustain itself in the summer in the tropics and Southern Hemisphere and disappear. Surveillance efforts in the tropics, as well as New Zealand, Australia, South Africa, Argentina, and Chile between the months of June through September may be of value in determining establishment in the human population.

Along these lines, an avenue for further research involves the use of integrated or coupled epidemiological-earth-human systems models, which can incorporate climate and weather processes and variables (e.g., dynamics of temperature, humidity) and their spatiotemporal changes, as well as simulate scenarios of human interactions (e.g., travel, transmission due to population density). Such models can assimilate data currently being collected to accelerate the improvements of model predictions on short time scales (i.e., daily to seasonal). This type of predictive approach would allow to explore questions such as what are population centers most at risk and for how long; where to intensify large scale surveillance and tighten control measures to prevent spreading; better understanding of limiting factors for virus spreading in the southern hemisphere; and making predictions for a 2021-2022 virus season. A better understanding of the cause of seasonality for coronaviruses and other respiratory viruses would undoubtedly aid in better treatments and/or prevention, and be useful in determining which areas need heightened surveillance.

Conflict of interest: None to declare.

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Acknowledgements: Image manipulation of Figure 3 courtesy of Cameron Gutierrez and Glenn Jameson

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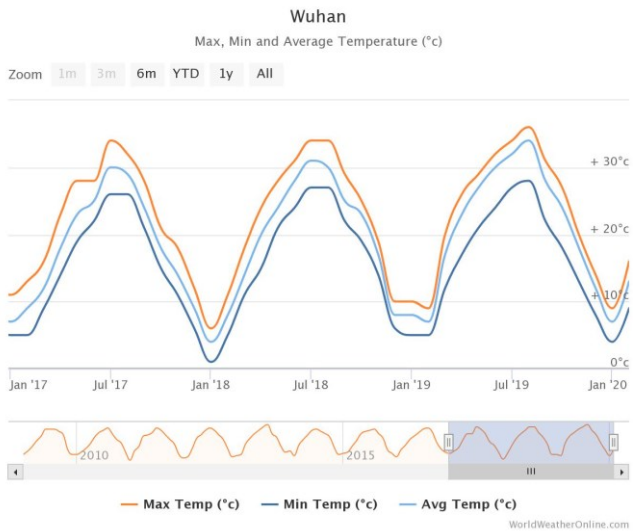

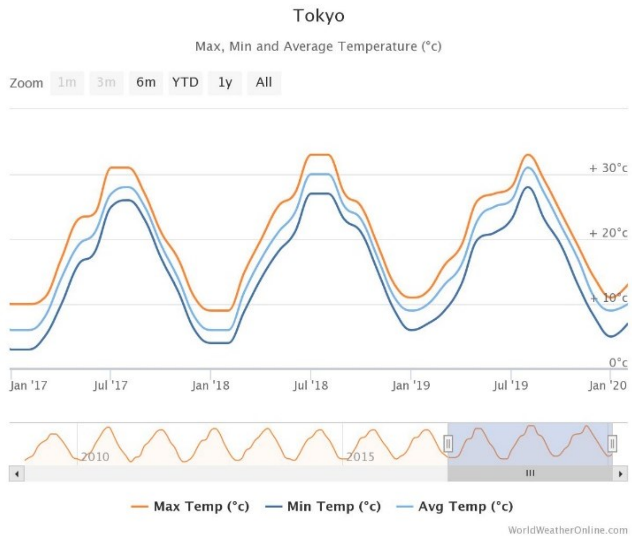

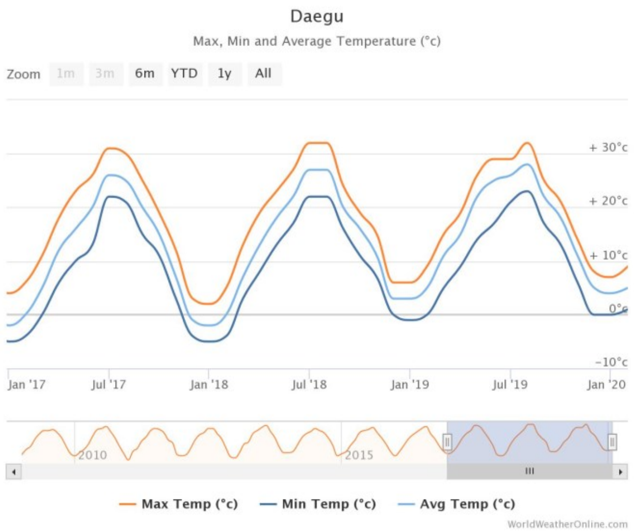

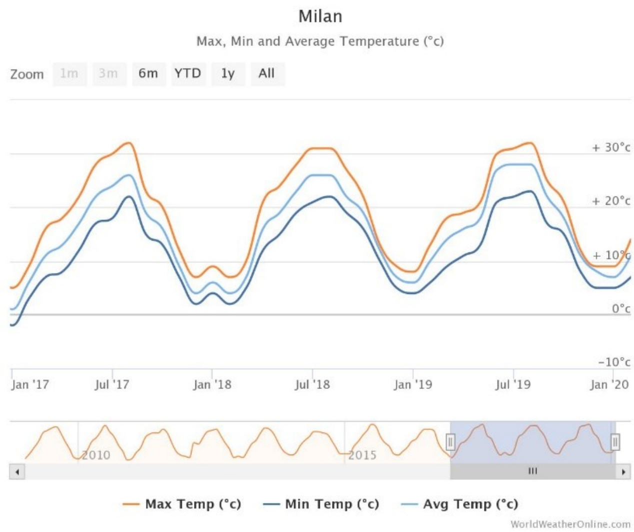

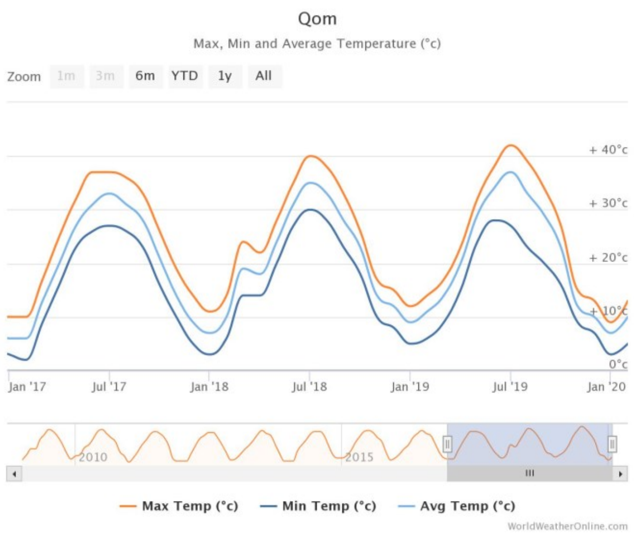

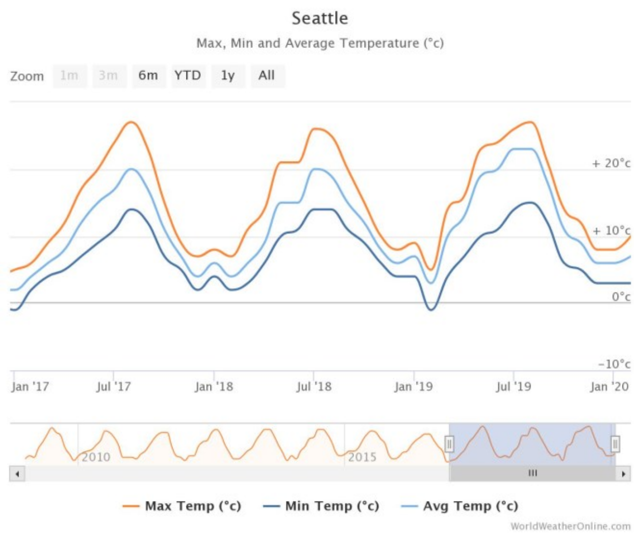

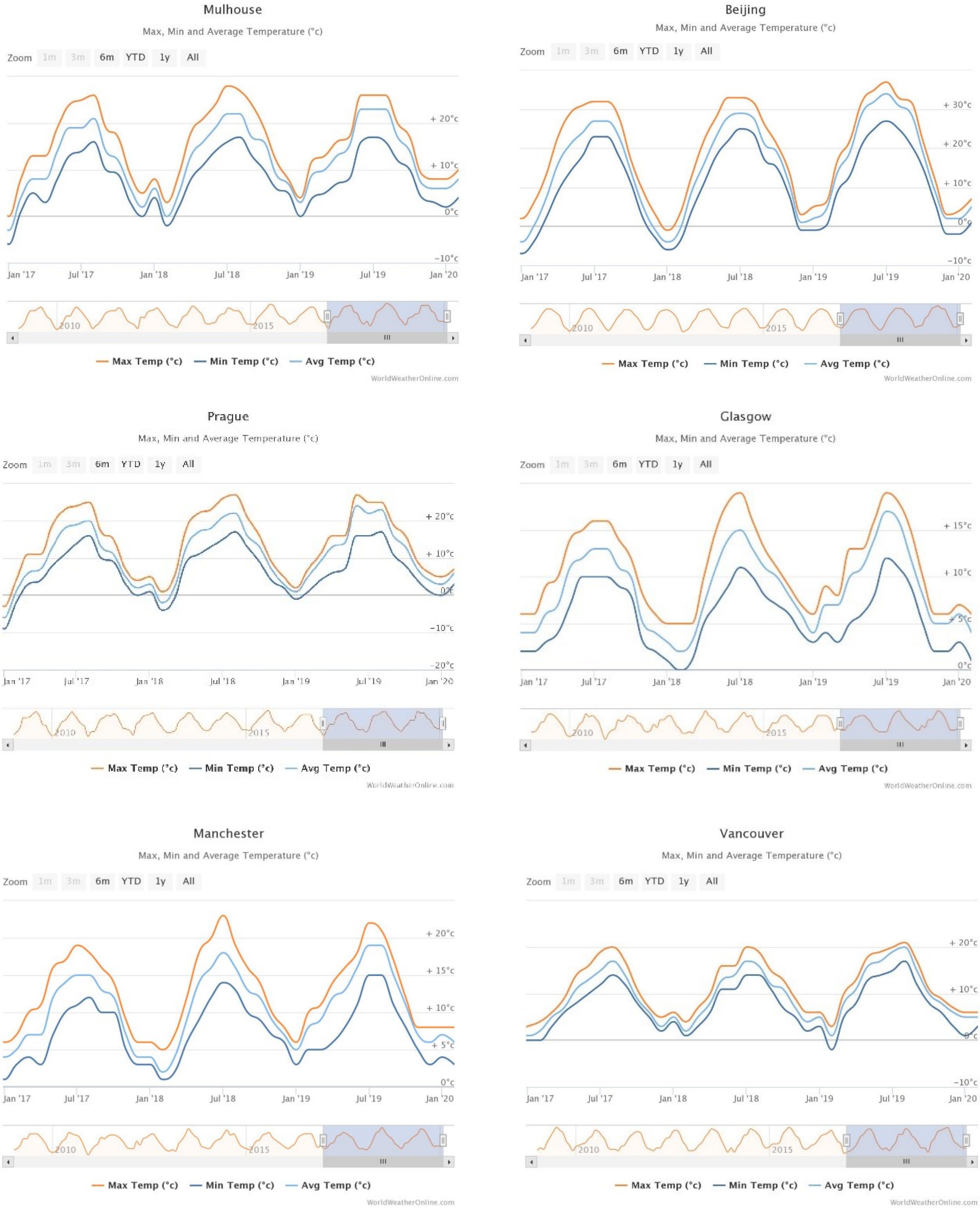

Supplementary Figure 1. Three and ten year temperature data (through February 2020) from seven cities currently affected and five at potential risk of epidemic spread. In the months that cities had outbreaks of COVID-19, minimum and average temperature was > 0ºC, and outbreaks occurred during prolonged temperature nadirs that typically lasted > 1 month. Temperature graphs for five cities potentially at risk also provided (Beijing, Prague, Glasgow, Manchester, and Vancouver,).