RESEARCH ARTICLE

Climate variability and seasonal weather related to COVID-19

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Abstract: In view of the alarming situation related to coronavirus, of particular interest to the public, decision makers, health organizations, experts, professionals (epidemiologists, virologists, infectologists, psychologists, pulmonologists and others), it is also important to obtain seasonal weather outlook with general overview of the weather and climate conditions and how they would potentially affect the state of the COVID-19 transmission because a number of infectious diseases show seasonal features in their incidence. The analysis below represents an attempt to evaluate atmospheric processes that have a different spatiotemporal scale and depend on other modes of climate variability, and patterns of circulation and specific indices that affect seasonal variation and weather characteristics in a region. Based on seasonal outlook, the general impression is that sunny, warmer increase of (1.0 to 2.0°C) and frequently stormy weather conditions expected during May-June 2020 could likely give some optimistic scenario of slowing down the spreading of the virus further. This is confirmed with the further evaluation of the effective reproduction number, that is expected to decrease from 1.8 at middle of April to 1.2 at the end of June 2020. That is approximately 60-70% reduction during this warmer period. However, the conclusions are still general and should be taken with caution as the situation is changing from day to day and many other factors including climate conditions, population density and medical care quality also play role in virus transmission.

Keywords: climate variability, seasonal weather outlook, infection diseases, effective reproductive number, COVID-19 spread

1   Introduction

In view of the alarming situation related to coronavirus, of particular interest to the public, decision makers, health organizations, experts, professionals (epidemiologists, virologists, infectologists, psychologists, pulmonologists and others), it is also important to gain some knowledge about the seasonal weather outlook based on climate variability modes and coupled atmospheric-ocean models, and statistical model evaluation of the potential spread of COVID-19 over SEE. Many people wonder "What kind of spring awaits us?", "Will it be warmer or colder, wet or dry, stable or unstable?" This is a really useful question because a number of infectious diseases show seasonal features in their incidence. The analysis below represents

an attempt to evaluate atmospheric processes that have a different spatiotemporal scale and depend on other modes of climate variability, and patterns of circulation and specific indices that affect seasonal variation and weather characteristics in a region. To give a precise answer to the seasonal features of a few months in advance is not at all simple task, since atmospheric processes operate in different time scales from hours, days (time), months, years to decades (climate variability), through the ages (climate change). Seasonal weather outlook is a complex task, as different factors and processes influence the development and manifestation of weather over a given area. They are mainly related to solar radiation, heat balance, global atmospheric and oceanic circulation, planetary waves and physical processes in the atmosphere, sea surface temperatures. The above global processes affect the distribution of atmospheric systems, low and high air pressure centers, jet streams (currents) as drivers of these systems, temperature gradients, deviations of sea-surface temperature and other effects. A typical example is El Niño (South Oscillation, which includes surface temperatures of the equatorial Pacific and western tropical South America) that affects the climate of the entire planet. There are other modes of climate variability such as North Atlantic Oscillations (NAO), Arctic Oscillation (AO), low pres-

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sure polar center, sudden stratospheric warming and other indices.

2 Climate variability and health

Climate variability has significant social and health effects. The direct impact of climate change on ecosystems in combination with increased anthropogenic pressure across the environment, seriously affecting biodiversity and the transmission of infectious diseases (Figure 1). Disease transmission can be categorized as direct and indirect transmission. Direct transmission of the person basically involves transmission through physical contact, transmission of drops and infections. Indirect transmission of the human major occurs with the involvement of vectors or other pathogenic microorganisms. Vector infectious diseases fall into the category of communicable infectious diseases. These diseases that are caused by bacteria, viruses or parasites, which reach a large number of hosts, human or animals (birds or other living incubators), have been mentioned in vectors for some time. Vectoritis is a hematophagy insect (mosquitoes, ticks, waxes, fleas, flies, and other insect species). After a certain period of incubation (the time it takes the vector to become infected), the infected vector is often transmitted to the host with a sting. Since the vectors are organisms that do not have mechanisms for maintaining thermoregulation (body heat), which are directly dependent on the outside temperature and humidity in the surrounding environment, as a basic prerequisite for reproduction. Vector infectious diseases have a seasonal incidence because of the mode of transmission that depends on the activity of the vectors, such that in countries with temperate continental climates, vectors are most active mainly from spring to autumn. Many infectious diseases caused by vectors are endemic, which means that they are home to a specific area where the pathogen is maintained due to the presence of the corresponding infectious reservoirs and vectors. Several studies provide evidence for the association between occurrences of vectors and climate anomalies governed by the El Nino phenomenon.

Changing the temperature and return regime means changing the climate, so that some areas will be prone to drought and floods, as a prerequisite for the spread of infectious diseases through polluted water, air and food. Climate variability and the disruption of the balance of the natural environment definitely have important health consequences, and will, in turn, lead to disease and suffering for millions of people. Long-term climate change is condemned to exacerbate ongoing problems while undermining other health systems, infrastructure, social security systems, as well as the supply of food, water and
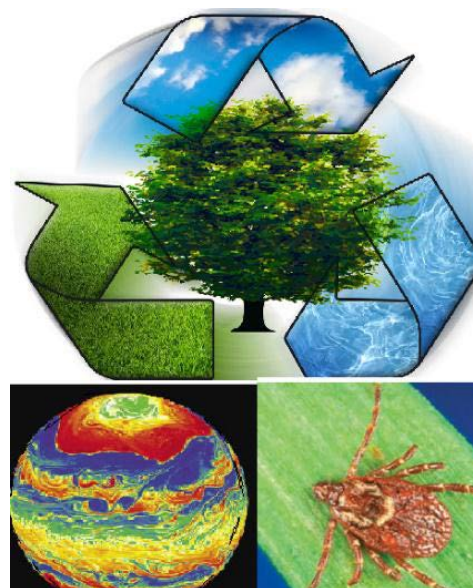

Figure 1. Climate change and vector borne diseases

other ecosystem products that are vital to the health of the individual. Therefore, a detailed study of the nature and biological cycle of the vectors is required, with a view to timely accessing the interventions in the environment and their spread. The negative impact of infectious diseases on health is significantly associated with increased stress or drivers such as poor sanitation, access to clean drinking water and food, quality of public health services and other factors. In order to prevent (or reduce) mortality associated with infectious diseases transmitted directly or via vectors, air, water or food, additional research is needed to clarify specific aspects related to this type of communicable disease.

3 Seasonal SEE outlook, Spring 2020

Based on both, the climate variability overview and initial scientific results about the correlation between meteorological parameters and spread of the coronavirus, we have accessed to detailed evaluation of the coming spring and summer season over SEE. Based on proposed methodology and available climate forecast data we came up with an objective assessment of the spread of the virus during this period. Spring is a transitional season when switching from winter to summer circulation. This means that oscillations are possible within the cycle itself, which is fundamentally more difficult to interpret than the available output data of the models. Looking closely at a particular mode of climate variability, and global climate models, the idea is to prepare a detailed analysis and find a logical link between individual climate indices (NAO, AO, ENSO), with the seasonal characteristics of the weather in the upcoming Spring-2020. The analysis
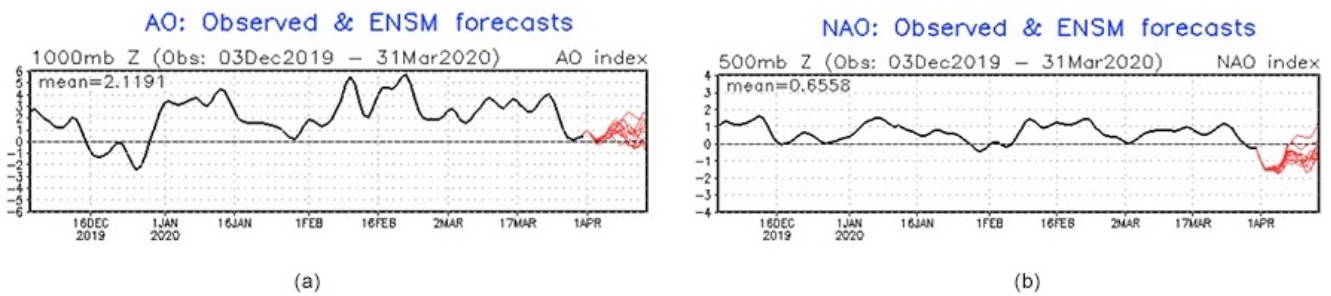
**Figure 2.** Current state of AO and NAO indices

additionally uses output data from several global climate models (ECMWF, DWD, GFS, MetOffice-UKMO, RCM-SEEVCCC) that show average anomalies (deviations) of air temperatures, precipitation, sea-level pressure, temperature at 850 hPa and the geopotential at 500 hPa. All of these forecasts represent an average seasonal framework over the spring months (March-April-May-June) and show the general prevailing weather. Our analysis begins with evaluation of an Artic Oscillation. According to the current situation and forecasts for the coming period Arctic Oscillation, AO as a climatic index of atmospheric circulation over the Arctic is in a positive phase with a tendency to gradually transition to neutral (Figure 2(a)). This means that at a positive AO index, and stable strongly expressed polar whirlpool (center with very low temperatures), cold air is forced to stay farther north, with less oscillation of the stream current. But the weakening of the positive phase and the gradual reduction of the polar whirlpool-wave polar whirlpool (especially in late March), will reduce the stability of the jet stream, and will cause its oscillation more frequently, with increased cold air penetration and increased cyclonic activity. Another, climate variability mode is the North Atlantic Oscillation (NAO). In the Northern Hemisphere, the position of the storms depends on the natural fluctuation known as the NAO. The NAO consists of two pressure centers in the North Atlantic: one center is a low-pressure area, usually located near Iceland, and the other center is under high pressure over the Azores (Figure 2(b)). The fluctuations in the strength of these features significantly alter the convection of the jet stream and ultimately affect the distribution of temperature and precipitation in this area. It is also important to note that AO and NAO are two separate indices that ultimately describe the same phenomenon of different pressure gradients in the northern latitudes and as a result of the effects on the temperature and the path of the volumes across the continent. Given the positive NAO index, there is a strengthening of the Icelandic low-pressure center and the Azores high-pressure anticyclone. This reinforcement results in an increased gradient of pressure over the North Atlantic, which results in an increase in western winds, which in turn suppresses cold

air in the North American continent rather than moving south. According to the European Centre for Medium-Range Weather Forecast (ECMWF), seasonal forecasts for a three-month period (April-May-June) shown on Figure 3, the positive temperature anomalies of about (1.0-2.0°C) are expected relative to the model climatological ensemble re-forecasts covering the 24 year period 1993-2016. Updated ECMWF seasonal forecasts with initialization (base time of April 2020), indicate a slight positive temperature anomaly, for South-Eastern Europe (SEE) of about (0.0-0.5°C) during May-June-July (MJJ) and (0.5-1.0°C) for (June-July-August) (JJA), respectively. Regarding the precipitation regime there is no signal for the period (MJJ), while slight deficit of about (0-50 mm) or relatively drier period is predicted for the summer months (JJA). The Mean Sea-Level Pressure (MSL) shows no oscillation, while slight positive deviations of the 500 hPa geopotential height of about 5-10 gpm is expected for (MJJ) and even higher during the summer cycle. The similar situation is found in respect to the air temperature at 850 hPa, where slight increase of about (0.2-0.5 K) is calculated for (MJJ) and (0.5-1.0 K) for (JJA), respectively.
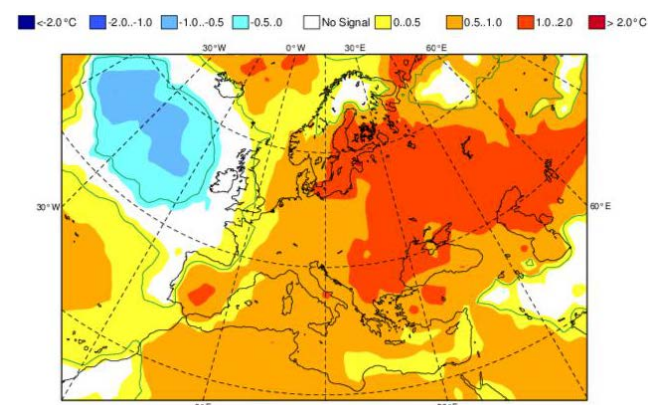
Figure 3. ECMWF seasonal forecast of mean 2 m temperature anomaly for (April-May-June), 2020

In addition to the seasonal outlook, it is necessary to analyze another important mode of climate variability such as the El Niño phenomenon, abnormal warming of the oceanic waters in the equatorial part of the Pacific (hot
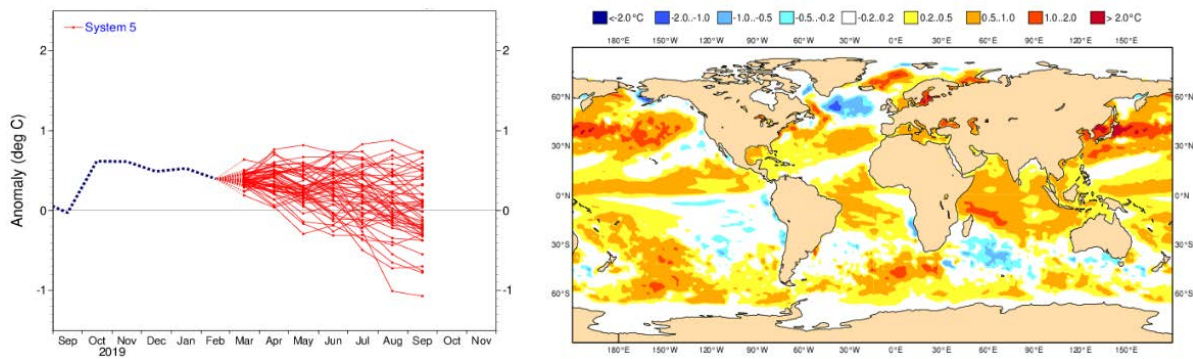
Figure 4. El Nino seasonal projection based on ECMWF ensemble atmospheric-ocean predictions

phase) and La Nina cooling (cold phase). This climate index is of great importance for the general oceanic atmospheric circulation, the interaction between the ocean and the atmosphere, and the global influence of time and climate on the entire planet. El Niño conditions exist in the tropical Pacific Ocean and are likely to continue in the coming months (Figure 4).

Based on the analyzed material, and according to monthly and seasonal forecasts from the global-climate models of multiple centers, using the statistical, numerical and analogy methods, a time evolution of air temperatures and weather phenomena in the upcoming spring period 2020 are derived. It is quite evident that estimates show a trend of gradual rise in air temperatures (both maximum and minimum temperatures). As part of this increase, there will also be periodic changes with changing weather conditions and lowering of temperatures when there is more humidity in the atmosphere and precipitation. The two cycles of late March and mid-April show cycles of rising temperatures, drier weather and more sunny days. Higher temperatures are expected in May, but increased frequency of unstable days with the development of thunderstorms (Figure 5).

4 Seasonal variations related to COVID-19

Although there is still insufficient detailed knowledge about the disease, many experts in the world say that seasonal changes in weather will contribute to improving the condition. Many of these viruses are transmitted by droplets or by direct contact. The combination of these two transmission mechanisms is a factor that determines portability in a given climate area. Air droplet transmission is more efficient in cold, humid climates. Preliminary studies just published show that coronavirus can survive in the external environment in aerosols as suspended micron floating particles in the air for up to three hours. Temperature can significantly change the transmission of COVID-19, the authors note. They also noted that "*the virus is very sensitive to high temperatures*". Although some infectious disease experts are not convinced enough, laboratory studies of a coronavirus (SARS-COV-2) copy that causes COVID-19 have shown that heat affects the virus and affects its behavior. The same opinion is shared by the top professor of pathology at the University of Hong Kong, Johnny Nichols. To his knowledge "In colder environments, there is a longer survival of the virus than in warm environments." For example, the Department of Epidemiology at Johann Hopkins University in Baltimore (agreed with many other scientists (epidemiologists)) believes that the upcoming warm season will be the primary driver of the seasonal decline in the spread of coronavirus. In addition, according to the latest guidelines for the diagnosis and treatment of coronavirus, the virus is not only sensitive to heat and dry conditions, but also to UV radiation and light, so that indoor ultraviolet radiation can effectively eliminate the virus. The COVID-19 is also sensitive to outside ultraviolet radiation and sunlight, so the infection is less likely to occur in sunny outdoors. Obviously, the sunny and warmer weather conditions will increase the length of the day and the exposure to sunlight, which inactivates the virus through UV light. Consequently, a dip in infections is expected as it is usually the case with the cold and flu in the spring and summer months. Viral and infectious diseases are very sensitive to climate conditions. A significant number of infectious diseases show seasonal patterns in their incidence, including human coronaviruses. According to the latest research from the Institute of Human Virology, University of Maryland School of Medicine, USA to date, the coronavirus (COVID-19) caused by SARS-CoV-2 shows a significant prevalence in the community in cities and regions east-west belt, approximately between 30-50 north latitude, with prolonged persistence of similar weather conditions (5-11°C) and relative air humidity of (47-79%) in busy cities. Similar results about the seasonability of COVID-19 are found in Sajadi *et al* (2020). They investigated the temperature and latitude
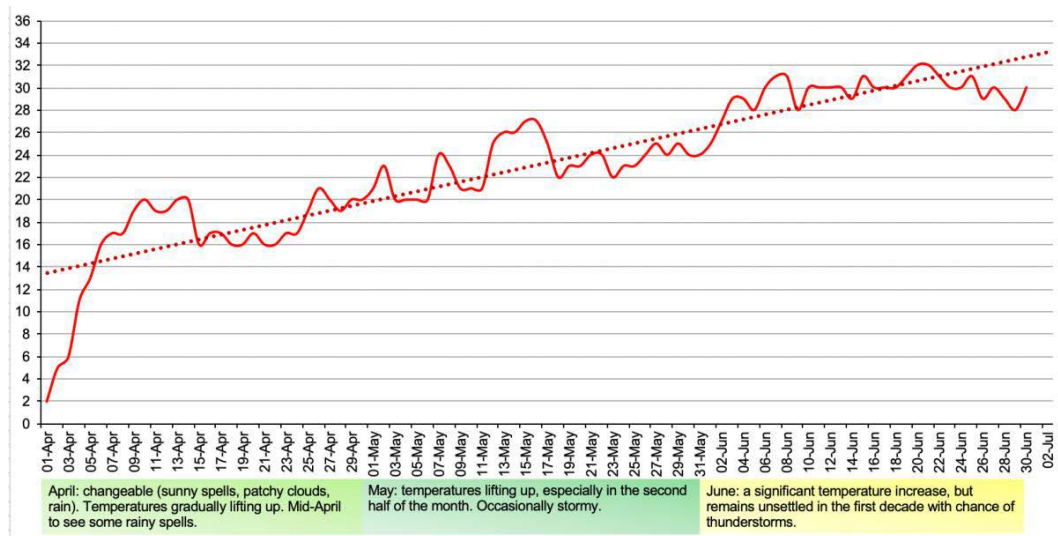
Figure 5. Time distribution of the maximum air temperature for Skopje, Macedonia during April-June, 2020
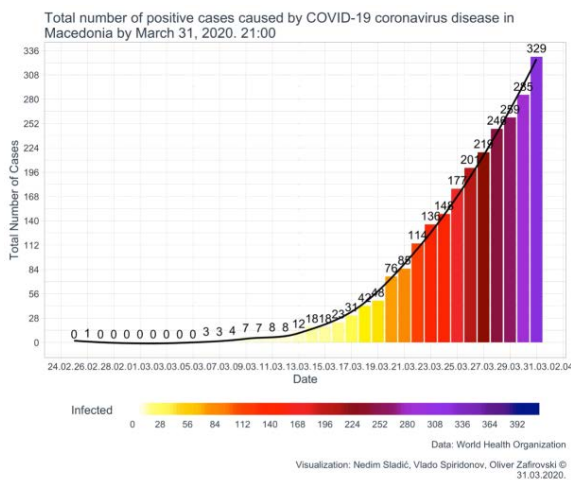
Figure 6. A total number of positive cases caused by COVID-19 in Macedonia by March 31, 2020. (Credit: Official site of the Ministry of Health (http://zdravstvo.gov.mk/korona-virus)

variations in potential virus transmission. They also suggested that using modelling, it may be possible in advance to predict regions likely to be at greater risk of significant COVID-19, which is quite useful in determining areas of risk, better measures, preparedness and treatment.

Based on the seasonal weather outlook and ERA-Interim reanalysis data we have performed the similar evaluation approach[1,2]. We calculate the effective reproductive number, R, a quantity which measures the intensity of infectiousness based on the weather and climate conditions[3]. The present evaluation is focused on Skopje (the capital city with largest number of population). The selected period corresponds with the onset of infection (Feb 26, 2020 to Jun 30, 2020). The general information about the virus spread in Macedonia is shown on Figure 6. Using the daily R values we find, under a
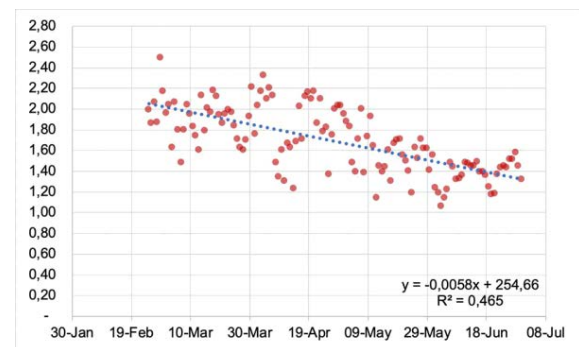
Figure 7. The daily effective reproductive number as function on temperature and relative humidity for Skopje from 25 Feb to 30 June, 2020

linear regression framework for Skopje shown on Figure 7, that relatively higher temperature and relative humidity expected especially during the second half of May will potentially reduce the transmission of COVID-19, respectively, The linear regression curve has indicate that R decreases linearly from baseline (2.0) at the beginning of the trans-mission (1.8) March-April, to (1.2) at the end of June for about 60-70 %. This is quite consistent result with those found in Wang *et al.* (2020)[4,5] and basically suggest that high temperatures have the effect of reducing the transmission of the virus during later spring and summer season.

5 Summary and conclusions

The human health depends on climate variability as many infections showed seasonal variation. Thus, our primarily objective is to provide an overview of the climate variability and human health with special emphasize on infective diseases with a direct and indirect way of trans-

mission (*e.g.* vector, air, water and food). Then we turn on examination of the seasonal weather conditions and various climate variability modes such as El Nino, AO, NAO, the state of the art atmospheric atmospheric-ocean and climate models, ECMWF long-range forecast data and ERA Interim reanalysis data to provide a seasonal weather outlook for the Spring 2020. Finally, we focused on evaluation of the potential dependence of some meteorological parameters as the air temperature and relative humidity and their influence on the spread of COVID-19. Based on seasonal outlook material, the general impression is the carriable initial spring with exchange of sunny and rainy days and warmer and stormy weather conditions expected during May-June 2020. Apparently, that the temperature anomaly for this period shows increase of (1.0 to 2.0°C) (outlined with a seasonal analysis), could likely give some optimistic scenario of slowing down the spreading of the virus further. This is confirmed with the further evaluation of the effective reproduction number, that I expected to decrease at about 60-70% during this warmer period. However, the conclusions are still general and should be taken with caution as many other factors including climate conditions, population density and medical care quality also play role in virus transmission.

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