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Majid Afrouzeh, Abbas Mofidi, Azar Zarrin

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Spatiotemporal trend analysis of temperature in the northern hemisphere during the years 1982-2016

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اولین کنفرانس بین المللی توسعه پایدار در کشاورزی، محیط زیست، گردشگری و منابع طبیعی

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Spatiotemporal trend analysis of temperature in the northern hemisphere during the years 1982-2016

Majid Afrouzeh[1], **Abbas Mofidi**[2], **Azar Zarrin**[3]

[1]Department of Geography, Ferdowsi University of Mashhad, Mashhad, Iran; majidafrouzeh@gmail.com
[2]Department of Geography, Ferdowsi University of Mashhad, Mashhad, Iran; abbasmofidi@um.ac.ir
[3]Department of Geography, Ferdowsi University of Mashhad, Mashhad, Iran; zarrin@um.ac.ir

Abstract

In this study, long-term annual and seasonal trends in mean temperature are investigated over the northern hemisphere. The statistical significance of trends is assessed by the Mann-Kendall test. The results revealed that the temperature had experienced significant positive trends over Arctic region. The Arctic region has warmed more than twice as fast as the global average, a phenomenon known as Arctic amplification [1]. The probability of a link between Arctic change and mid-latitude weather has created research activities that reveal three potential dynamical pathways linking Arctic amplification to mid-latitude weather changes in storm tracks, the jet stream, and planetary waves and their associated energy propagation. However, because of incomplete knowledge of how high-latitude climate-change influences on mid-latitude weather, combined with sparse and short data records, and imperfect models, large uncertainties regarding the magnitude of such an influence remain. The results of studies show that we will need improved understanding, further Arctic observations, and modeling studies to discover the relationship between Arctic amplification and mid-latitude weather.

Keywords: Temperature, Arctic amplification, Northern hemisphere, Mann-Kendall, Anomaly.

Introduction

Climate change and global warming all over the world have recognized as the most important environmental problems that the world today is experiencing it [2]. Concern about climate change as one of the greatest environmental challenges of today's world have caused the international community; governmental and nongovernmental organizations forced to study the climate trends. Increase in anthropogenic greenhouse gases' concentrations in the atmosphere, mainly due to human activities and the conversions of the Earth's land to urban uses driven largely by the rapid growth of the Earth's human population are one of the causes of the warming climate system [3]. In the other words, many of the climate changes are the result of the industrial growth of humanity, which is climate change, as a reaction to nature against human activities [4].

The study of climate events as well as its features in hydrological studies, such as quantitative and qualitative water management, and the assessments of the impact of climate change on plant ecosystems, animals and aquaria are very important. According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8° Celsius (1.4° Fahrenheit) since 1880. This increase in the global temperature is not homogeneously distribute over the Earth's surface. It varies among regions and locations. A one-degree global change is significant because it takes a vast amount of heat to warm all the oceans, atmosphere, and land by that much. In the past, a one to two degree drop was all it took to plunge the Earth into the Little Ice Age. A five-degree drop was enough to bury a large part of North America under a towering mass of ice 20,000 years ago. The Arctic cryosphere is an integral part of Earth's climate system and has undergone unprecedented changes in the past few decades.

While the global-mean surface temperature has unequivocally risen over the instrumental record, spatial heterogeneity of this warming plays an important role in the resulting climate impacts [5]. Temperature change studies are one of the most important issues of interest to researchers because they directly affect human activities. In addition, temperature has a direct or an indirect relationship with other important climatic variables, such as atmospheric humidity, solar radiation, wind speed, precipitation, evaporation, and transpiration[6]. Nasri and Modarres (2009), Longobardi and Villani (2010), Safari (2012), Saboohi et al. (2012), Ahmad et al. (2015), Ahmadi et al. (2017), are some examples of the researchers who have investigated recent temperature trends In different areas. In this study, we focus on analyzing the recent trends in the annual and seasonal temperatures over the northern hemisphere. We find that the period from 1982 to 2016 contains climatic cycle and; therefore, the results could be a good indicator for recent climate interpretations.

Material and methods

To study the long-term annual and seasonal trends of temperature in the northern hemisphere and determine the linkage between Arctic amplification and mid latitude, daily mean air temperature data were obtained from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis archive[7]. All fields have a spatial resolution of 2.5° latitude × 2.5° longitude. A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures. Onoz and Bayazit (2003) showed that the parametric t -test has less power than the non-parametric Mann–Kendall test when the probability distribution is skewed, but that, in practical applications, they can be used interchangeably, with identical results in most cases.

Mann-Kendall test for trend

Mann-Kendall test is a statistical test widely used in analysis of trend in climatological time series. There are two advantages of using this test. First, it is a nonparametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis H_0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H_1, which assumes that there is a trend. Mann-Kendall test is a nonparametric test for identifying trends in time-series data. This test assumes that there exist only one data values for a time period. When multiple data points exist for a single time period, the median value will be used. The initial value of the Mann-Kendall statistic S is assumed zero. If the data asset value from a later time period is higher than a data value from an earlier time period, S is increased by 1. The net result of increments and decrements yields the final value of S. This method is more suitable for non-normally distributed and censored data and is less influenced by the presence of outliers in the data[8, 9]. As it is a rank-based procedure, it is robust to the influence of extremes and good test for skewed data.

The MK test statistic S is given by:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k)$$

Where n indicates the number of observations and x_j is the value of *j*th observations and sgn $(x_j - x_k)$ is the sign function, which can be defined as:

$$sgn(x_j - x_k) = \begin{cases} +1, & if\ (x_j - x_k) > 0, \\ 0, & if\ (x_j - x_k) = 0, \\ -1, & if\ (x_j - x_k) < 0, \end{cases}$$

The mean E(S) and variance V(S) of the S statistic are given by:

$$E(S) = 0$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18}.$$

Where t_i the number of ties for the *i*th value and m is the number of ties values. Therefore, the standardized Z statistic can be computed as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & if\ \ S > 0, \\ 0, & if\ \ S = 0, \\ \frac{S+1}{\sqrt{Var(S)}}, & if\ \ S < 0. \end{cases}$$

A positive Z indicates an increasing trend, whereas a negative Z indicates a decreasing trend. To test for either increasing or decreasing monotonic trend at p significance level, the null hypothesis is rejected if the absolute value of Z is greater than $Z_1 - p/2$, where $Z_1 - p/2$ is obtained from the standard normal cumulative distribution tables. In this work, the significance level of $p = 0.01$ and 0.05 are applied.

To see change of trend with time, used sequential values, $u(t)$ and $u'(t)$, from the progressive analysis of the Mann-Kendall test. Herein $u(t)$ is a standardized variable that has zero mean and unit SD. Therefore, its sequential behavior fluctuates around zero level. The following steps are applied to calculate $u(t)$ and $u'(t)$:

1. The values of x_j annual mean time series, (j=1,…, n) are compared with x_k, (k=1,…, j-1).

At each comparison, the number of cases $x_j > x_k$ is counted and denoted by n_j.

2. The test statistic t is then calculated by equation

$$t_j = \sum_{i=2}^{j} n_i$$

3. The mean and variance of the test statistic are

$$E(t_j) = \frac{j(j-1)}{4}$$

$$Var(t_j) = \frac{j(j-1)(2j+5)}{72}$$

4. The sequential values of the statistic $u(t)$ are then calculated as

$$U(t) = \frac{t_j - E(t_j)}{\sqrt{Var(t_j)}}$$

The values of $u'(t)$ are computed similarly backward, starting from the end of the series[10, 11]

Results and discussion

The current warming trend is of particular significance because most of it are extremely likely (greater than 95 percent probability) to be the result from human activity since the mid-20th century and proceeding at a rate that is unprecedented over decades to millennia[5]. In climate-change studies, temperature anomalies are more important than absolute temperature. A temperature anomaly is the difference from an average, or baseline, temperature. The baseline temperature is typically computed by averaging 30 or more years of temperature data. A positive anomaly indicates the observed temperature was warmer than the baseline, while a negative anomaly indicates the observed temperature was cooler than the baseline. When calculating an average of absolute temperatures, things like station location or elevation will have an effect on the data. However, when looking at anomalies, those factors are less critical[12]. Figure 1 shows the anomaly of annual mean temperature over the Northern Hemisphere during the year 2017 and 2 courses 1981-2016, 1951-1980; this observed phenomenon is termed polar or Arctic amplification.

Continuing the planet's long-term warming trend, globally averaged temperatures in 2017 were 1.62 degrees Fahrenheit (0.90 degrees Celsius) warmer than the 1951 to 1980 mean, according to scientists at NASA's Goddard Institute for Space Studies (GISS) in New York. That is second only to global temperatures in 2016. Last year was the third consecutive year in which temperatures were more than 1.8 degrees Fahrenheit (1 degree Celsius) above late nineteenth-century levels. As shown in Fig. 1 Earth's global surface temperatures in 2017 were the second warmest since modern record keeping began in 1880, according to an analysis by NASA.

Figure 2 illustrates the change in global surface temperature relative to 1951-1980 average temperatures sixteen of the 17 warmest years in the 136-year record all have occurred since 2001, except for 1998 (source: NASA/GISS).

Arctic temperature change is sensitive to variations in the poleward transport of heat and moisture into the Arctic from lower latitudes[14]. An explanation of the recent Arctic warming and associated sea ice loss has become one of the grand challenges of Arctic research[15]. Three factors have been identified as contributors to the polar amplification:

- The albedo-temperature feedback associated with a reduction of sea ice
- Increased atmospheric humidity and the associated increase of down welling longwave radiation
- Increased poleward transports by the ocean and atmosphere

Open water has a much lower albedo than ice; more sunlight is absorbed in the ocean surface, where sea ice has recently receded in the Arctic. More absorbed energy has resulted in 4–5 °C sea surface temperature anomalies in these newly ice-free regions[16]. Two mechanisms have recently been proposed for linking changes in the Arctic and middle latitudes via the atmospheric circulation. The first is based on the impact of Arctic warming on the pressure (geopotential height) fields in the Arctic and a role of these changes in the increased frequency of blocking in middle latitudes. The second is an Arctic mid-latitude connection via Eurasian snow cover. Both mechanisms are rooted in the atmospheric heating patterns that determine the three-dimensional pressure distribution, which in turn drives the atmospheric circulation.

The maps above shows the trend of temperature using Mann-Kendall test over the northern hemisphere during 1981-2016. As the maps show, global warming does not mean temperatures have risen everywhere at every time by the same. Temperatures in a given year or decade might rise 5 degrees in one region and drop 2 degrees in another. Exceptionally cold winters in one region might be followed by warm summers; alternatively, a cold winter in one area might be balanced by an extremely warm winter in another part of the globe. This hypothesis has been well publicized, to the extent that many nonscientists believe that future Arctic warming will have major effects on the weather, where we live[17].

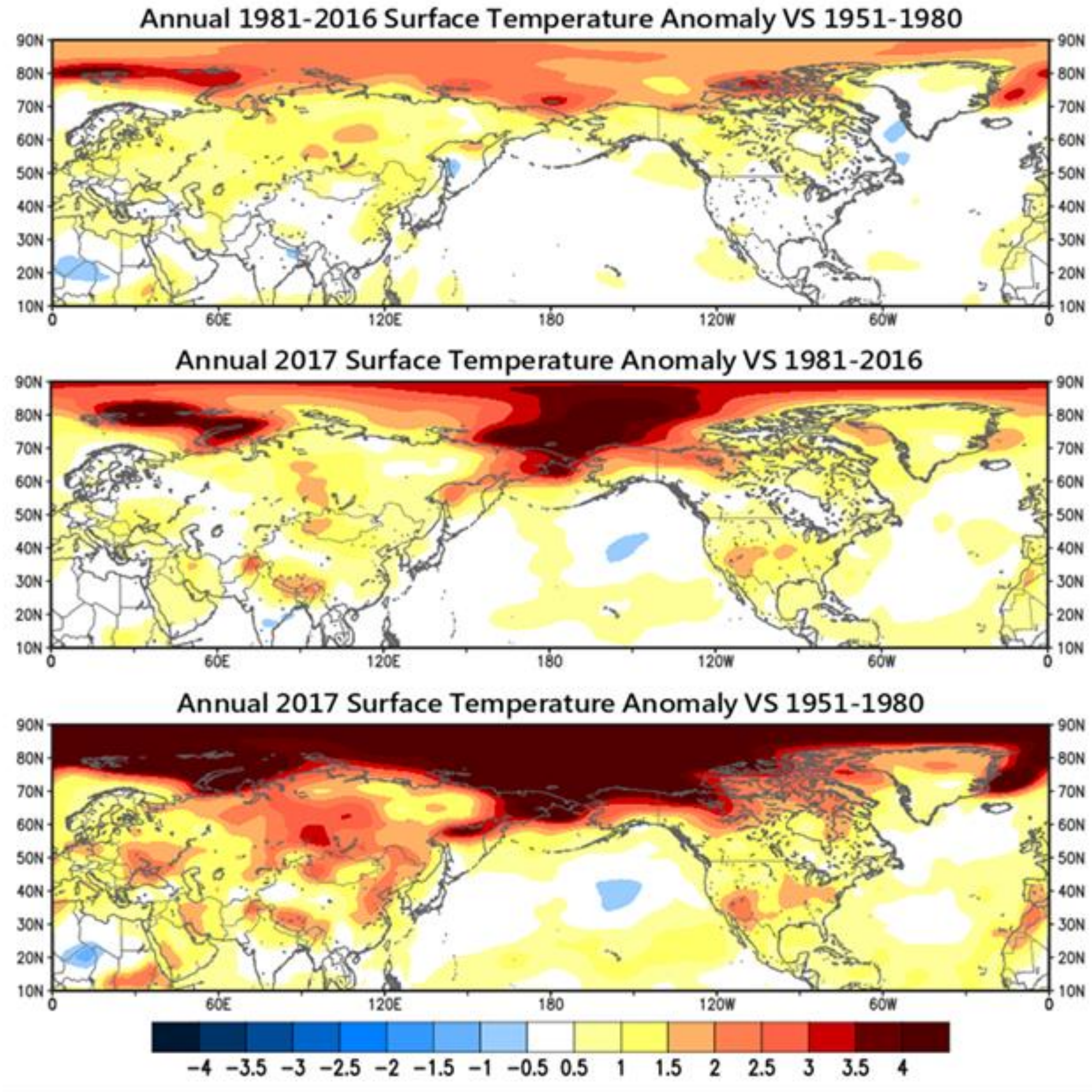

Figure 1. The anomaly of annual mean temperature over the Northern Hemisphere

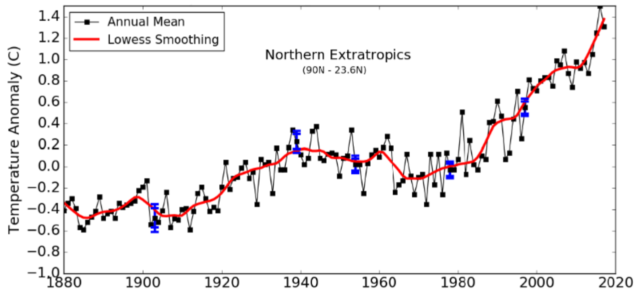

Figure 2. Annual and five-year smoothed temperature changes, with the base period 1951-1980. Uncertainty bars (95% confidence limits) for the annual and five-year smooth (inner) are based on a spatial sampling analysis. These estimates use land and ocean data (https://data.giss.nasa.gov/gistemp/graphs)-[13]

Conclusion

There is evidence that atmospheric water vapor, a greenhouse gas, has increased in the Arctic over the past several decades. As a result, the Arctic has warmed at about twice the global rate. Arctic warming can influence the jet (and therefore, surface weather) in mid-latitude regions. The slower jet stream may cause more amplified Rossby waves, increasing the frequency of atmospheric blocking and thus, persistent and extreme weather in mid-latitudes. Through changes in these keys atmospheric features, it is possible, for Sea, ice and snow cover jointly affect the jet stream and thereby influence mid-latitude weather patterns.

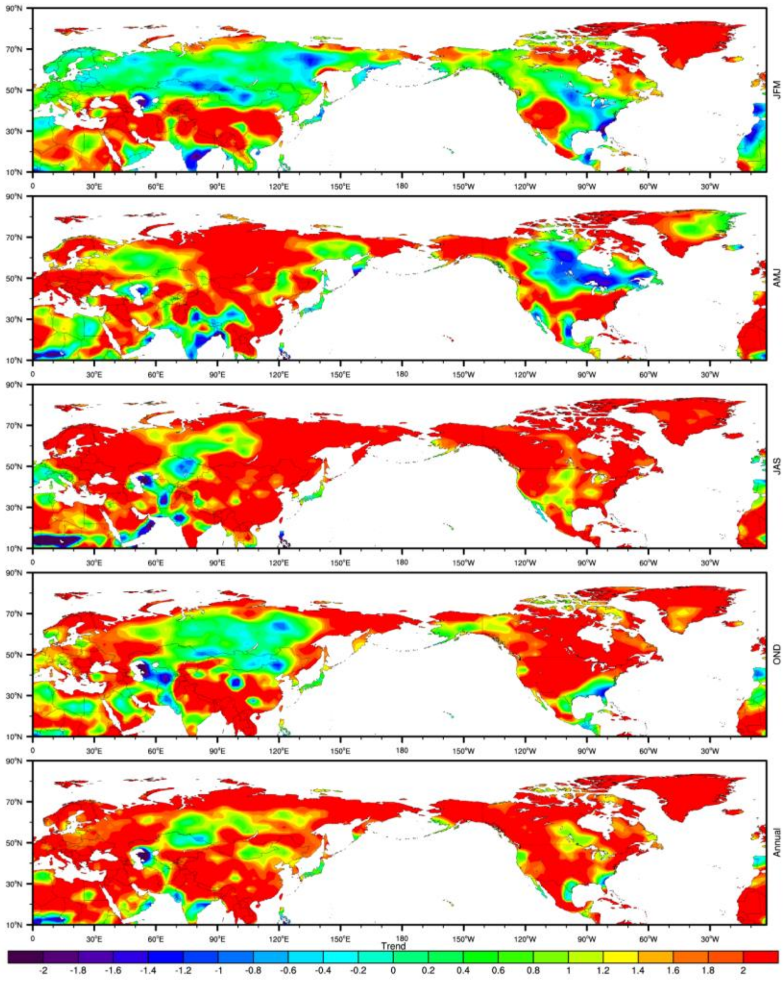

Figure 3. Trend analysis of temperature in the northern hemisphere during the years 1982-2016 using Mann-Kendall test

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