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Impact of global warming on extreme hot and cold weather

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Abstract. After the industrial revolution, carbon dioxide emissions have continued to grow rapidly and global warming has become evident. Along with the warming, heat waves, cold waves, and protracted droughts are only a few examples of the extreme weather and climatic phenomena that additionally happened regularly, causing many casualties and property damages. In order to offer a foundation for future decision-making about the avoidance and reaction to severe hot and low temperature weather, we analyzed the reaction of future temperature to rising temperatures in the context of global heating in this study. This paper first analyzed the impact of global warming on extreme hot weather based on the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change(IPCC), in terms of the probability of occurrence of extreme hot weather when the average and temperature variance increase individually and together. Secondly, by examining the causes of the intensified polar vortex brought on by stratospheric warming as in setting of climate warming, the effects of global warming on extreme low degree weather were examined. The findings demonstrated that climate warming had an important impact on the occurrence of extreme high and low temperature weather. Warming on the one hand may make the average temperature and temperature variance change in some regions larger, and extreme high heat occurrences are more likely to occur as the temperature's average and variation both rise. Warming on the other hand will warm the stratosphere, which in turn will cause the asymmetric polar vortex to strengthen, making extreme low temperature events more likely to occur.

Keywords: global warming, extreme weather, temperature averages, temperature variance values, polar vortex.

1. Introduction

Global warming has become an important environmental issue in the twenty-first century, and according to IPCC's Sixth Assessment Report, the global surface temperature for the years 2001 to 2020 has risen by around 0.99 °C relative to the pre-industrial era [1]. The main cause of frequent global extreme weather is global warming caused by greenhouse gas emissions, and according to the climate assessment models of IPCC, the most recent World Meteorological Organization predictions for increases in surface temperature by the end of the period show that extreme weather will continue to increase in the future if global greenhouse gas emissions continue to remain high [2]. Because the average and variance of temperature across different parts of this world vary, some regions have a more significant warming effect, while others show cooling [3]. The effects of other factors need to be considered at this point, and these factors need to be further investigated. In addition, global warming

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increases the likelihood and probability of the event of a sudden increase in stratospheric temperature, which can make the polar vortex more unstable and cause severe cold temperatures to occur more frequently [4]. In this paper, based on the schematic diagram of the results of increasing temperature average and variance on extreme climate in the Fifth Assessment Report of IPCC, we analyze the mechanisms of the increase in mean temperature and variance and the combined increase of both on extreme temperature, and also by examining the strength and variations of the polar vortex in relation to global warming, it will be possible to more clearly identify how global warming is affecting severe high and low temperature weather in various places. In order to give a foundation for making decisions regarding the prevention and mitigation of disasters caused by extremely high or low temperatures under the setting of global warming.

2. Analysis

2.1. The effect of temperature averages on extreme high temperatures

Heat waves will become more powerful, longer, and more common as temperatures rise. extreme heat weather [5]. In terms of probability, if the temperature in a given area is normally distributed under multi-year average conditions, then weather conditions will occur most frequently at the average temperature, less frequently at the colder or hotter weather conditions, and even less frequently at the very cold or hotter weather. This rule also applies in the case of global warming(1 a), when the mean temperature in some regions may increase due to the effects of warming, when the probability of hot weather will increase significantly, and extreme hot weather, which was rare, may now occur frequently, and heat waves and other extreme weather occurrences will happen greater frequently. The probability of extreme heat events will change significantly even when the average temperature change caused by increasing CO_2 levels is small [6]. Using a coupled global climate model ensemble, the variability in mean temperature changes the temperature distribution over most regions above the current extreme temperature threshold, to which future heat waves on a global scale respond [7].

2.2. Effect of variance of temperature change on extreme high temperatures

In addition, global warming has the potential to increase the variance of temperature change in some regions(1 b). Many research have recently focused on the global surface temperature increase trend over the previous 160 years [8], the increase in temperature leads to a drying of the land surface, which dries out the evaporative cooling capacity of the land surface and thus warms more rapidly and heats the atmosphere through sensible heating. In the mid to low latitudes this localized heating may lead to the formation of atmospheric blocking high pressure, which further leads to the increase in temperature and drying of the land surface [9]. This warming-induced land surface-atmosphere interaction is the main reason for the formation of extreme heat disasters in Europe in recent years. With global warming, the land surface in these semi-arid regions will become drier, thus making the feedback mechanism of land surface-atmosphere interaction more likely to occur, increasing the variance of temperature and making extreme heat events more likely to occur.

2.3. Effects of temperature mean and variance of temperature change on extreme hot weather

When it comes to global warming, the rise in temperature average and variance typically happen at the same time(1 c). In this case, Europe, for example, is more prone to extreme heat events [10]. Studies have shown that there is a link between trends in mean and variance values of temperature and trends in temperature extremes, and that this relationship will continue in future climate change [11]. The joint alterations in the average and variance values of temperature may be to blame for the rise in the likelihood of severe high temperatures in the future on a global scale. When the climate system warms, the average and variance of temperature can change significantly. Changes in the dispersion of these two variables may alter the likelihood of occurrence and shape of the dispersion of severe temperatures.

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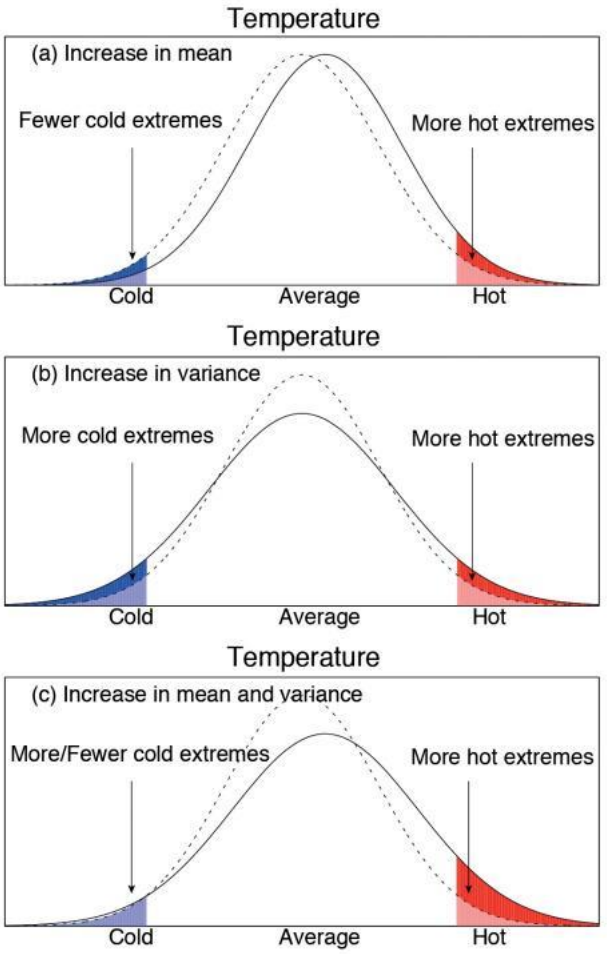

Figure 1. IPPC AR5 Graphic illustrations of the daily temperature's likelihood density function, which is typically roughly Gaussian. Solid lines indicate a new distribution, while dashed lines indicate an old distribution. The shaded sections represent the likelihood or frequency of the extremes. Changes in (a) the mean, (b) the variance or shape, and (c) both the mean and the variance have an impact on variations in the frequency of extremes in temperature [12].

2.4. Impact of climate warming on extreme cold weather

There is a high probability that extreme cold weather events will increase in the decades starting from 2030 [13]. In recent decades, global warming, the Arctic sea ice's shrinking and melting, and the absorption of large amounts of solar radiation by the poles have led to a faster temperature rise in the Arctic than in the middle and high regions, resulting in a smaller north-south temperature gradient and weaker westerlies in the middle and high regions, and this change in circulation has increased the frequency of blocking situations in the middle and high regions, which in turn has increased the frequency of cold air intrusion from the Arctic to the middle and high latitudes [14]. Global warming increases surface temperatures, more heat is transferred to the Arctic stratosphere, the Arctic stratosphere suddenly warms, and via stratosphere-troposphere interaction, changes in the stratosphere have a significant impact on terrestrial weather and climate [13]. As the Arctic polar vortices become extremely weak, they split into two or more circulations and begin to drift away from the pole. High pressure bands in the Earth's mid-latitudes advance toward the pole, replacing cold air, which causes the polar vortex to move even further south. Such events can make the polar vortex unstable, bringing cold air to the mid-latitudes causing frequent extreme cold weather.

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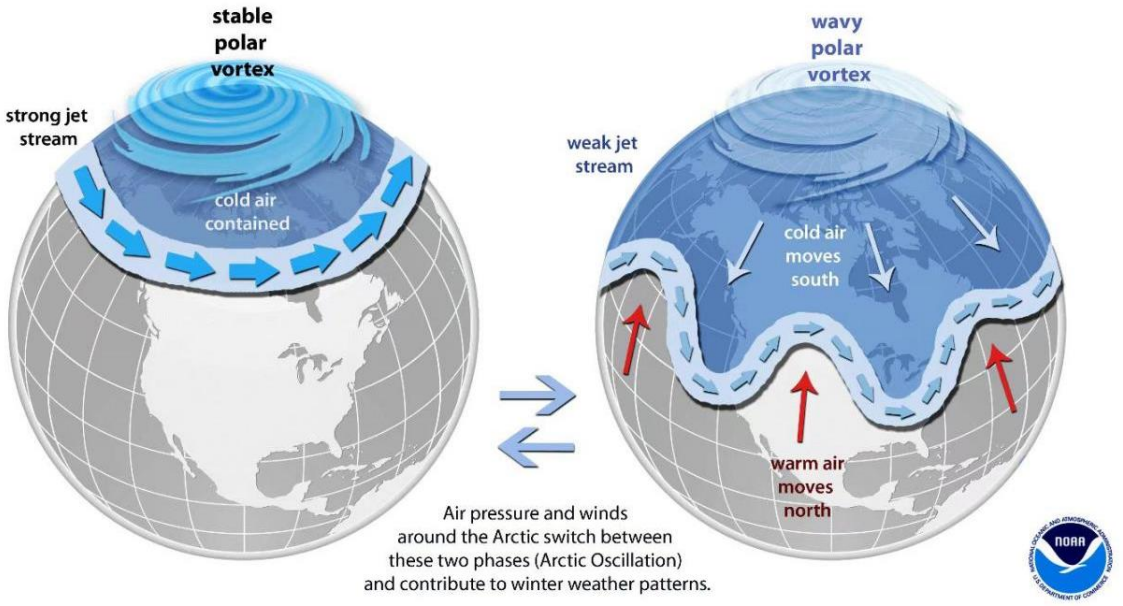

Figure 2. NOAA Mechanism of the formation of polar vortex [15].

3. Conclusion

When the mean temperature rises in some locations due to global warming, the overall normal distribution curve of average temperature and weather occurrence probability shifts in the direction of high temperature. Nowadays, as temperatures rise overall, the likelihood of experiencing extreme heat increases while the likelihood of experiencing extreme cold decreases. Similar to this, as global warming progresses, there is a greater likelihood that weather with moderately high and low temperatures will occur, as well as a greater likelihood that weather with extremely high and low temperatures will do so. In the case of global warming, the increase in the average and variance of temperature change usually occurs simultaneously. In this case, there is a significant increase in the probability of occurrence of hot weather and extreme hot weather, and little change in cold weather. In summary, global warming increases the probability of occurrence of extreme hot weather by affecting the mean temperature and the variance of temperature, and increases the frequency of occurrence of extreme cold weather by affecting the movement of the polar vortex to mid-latitudes.

There are limitations of this study. The mean values of temperature as well as the variance of the variance are not consistent across different regions of the globe. Some places are warming significantly, while some regions even show cooling. The non-uniform variation of ocean SST can affect the non-uniform variation of temperature mean and variance in different places. Such factors as the evolution of coupled sea-air modes such as El Niño-Southern Oscillation, internal noise in the atmospheric system, and the influence of soil moisture changes [16-17]. These variations cause variations in the incidence and severity of extremely elevated temperatures in various parts of the world. To be able to assess the effects of global warming more thoroughly in each region on the extreme high temperature weather in that region. Each region's dramatic temperature variations and unequal average temperature changes should be investigated, and specific analyses should be conducted for specific regions. Secondly, in the later part of the 21st century, extreme low temperatures are expected to decrease significantly due to the amplification of the Arctic, and the changes in extreme weather should be analyzed specifically for the degree of impact of climate warming at different times.

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