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Perspective

Future Arctic Polar Vortex is Driven by Tropical Pacific Warming

Lars Bertram*

Department of Marine and Environmental Sciences, University of Cadiz, Cadiz, Andalusia, Spain

ABOUT THE STUDY

The wintertime Arctic stratospheric polar vortex is characterized by a circumpolar westerly jet, confining the coldest temperatures over the Arctic. The future stratosphere is globally dominated by a strong radiative cooling due to the increase in greenhouse gases, enhancing the Arctic cooling. However, we find that over North America, the Arctic stratospheric cooling is suppressed or rather warming occurs, whereas over Eurasia stratospheric cooling is most pronounced, leading to an asymmetric polar vortex, based on 21st century climate model simulations. There are many causes that drive polar vortex variability, such as Arctic sea ice loss, and midltitude and tropical Pacific warming, which make future projections highly uncertain [1,2]. Our model simulations demonstrate that tropical warming induces the asymmetric polar vortex. The eastern equatorial Pacific warming causes eastward-shifted tele-connection, which strengthens the polar vortex over Eurasia and weakens over North America by enhancing the vertical wave propagation into the stratosphere. The asymmetric polar vortex is projected to markedly develop in the 2030, and so could also affect winter surface climate over mid- to high-latitudes of Eurasia in the near future.

To explore what induces the asymmetric polar vortex response, we make use of existing simulations with an atmospheric general circulation model. Although there are many causes that drive polar vortex variability, our simulations enable to quantify the atmospheric response derived from global SST warming and sea ice loss, Arctic sea-ice loss, midlatitude SST warming, and tropical SST warming, respectively. To validate the asymmetric polar vortex response to the eastern equatorial Pacific warming, we diagnose anomalous planetary waves using a linear baroclinic model [3].

The stratospheric variations can have a strong impact on surface weather and climate through the stratosphere troposphere coupling. In the late 21st century, subseasonal surface temperature variability is projected to significantly decrease over the mid- to high-latitude NH due to Arctic amplification. However, the cold extremes are likely to increase during a few decades from the 2030. Despite recent debate on the impact of Arctic sea ice loss, in a few decades, the asymmetric polar vortex could act to increase the cold extreme events, such as recent cold-airoutbreak over Eurasia. Indeed, composite analysis based on AGCM simulations shows that surface cooling is enhanced over Eurasia associated with a polar vortex shift towards Eurasia, basically consistent with the impact of recent shift towards Eurasia on surface temperature [4-6].

As stratospheric variability is easily dependent on a model's lid height, we confirmed the reproducibility of the polar vortex, although it is suggested that there is no clear link between a model's lid height and the response in inter-model differences. The climatological zonal that in JRA55 reanalysis, but its distribution is well reproduced. Despite the fact that many low-top models have much little stratospheric variability compared with reanalysis data, our ensemble-member jet variability has a comparable magnitude with JRA55 reanalysis [7]. The horizontal distribution and variability of the polar vortex are also well captured in this model. These results confirm that our low-top model is suitable for understanding changes in the polar vortex.

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Correspondence to: Lars Bertram, Department of Marine and Environmental Sciences, University of Cadiz, Cadiz, Andalusia, Spain, E-mail: bertramlars@uca.es

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