Global Atmospheric Response to Arctic Amplification Using Pre-Industrial Climate Model Integrations

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Abstract

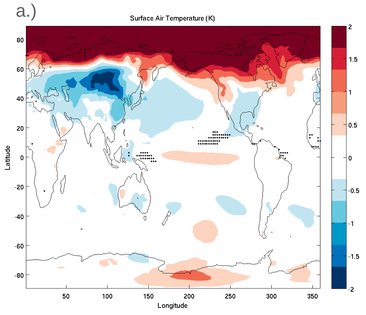
- Arctic Amplification (AA) states that the Arctic region is warming twice as fast as the global average. There could be potential effects that this mechanism has on our global climate, in particular, the mid-latitude general circulation. An increase of temperature and heavy rainfall has occurred since the 90's, however recently, extreme colds have taken over some mid-latitude regions, for example, the winter of 2014. Some recent studies attributed the increased frequency of extreme weather events to AA while others disagreed. Therefore, this study aims to better understand the Northern Hemisphere (NH) mid-latitude atmospheric response in association with AA. A 500-year CMIP5 GFDL pre-industrial model integration is used. With composites of anomalously warm and anomalously cold years over the Arctic region, surface air temperature, zonal wind, precipitation and sea ice concentration were examined globally.

Methods

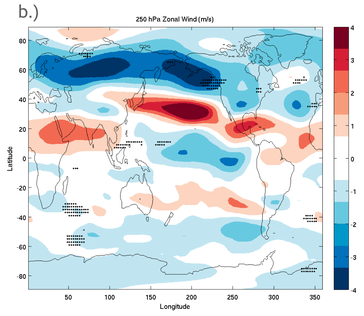
- In order to find the anomalously warm and anomalously cold years, a zonal and meridional average of the surface air temperature was taken from 67.5˚N to 90˚N, which defines the arctic region, for each year. These yearly averages were then averaged themselves, leaving us with one mean surface air temperature. Values one standard deviation higher and lower than the mean was calculated. The years outside this standard deviation signify the anomalously warm and anomalously cold years. Plots were then made of surface air temperature, zonal winds, precipitation, and sea ice concentration. Also, zonal mean profiles were constructed for air temperature and zonal wind.
  - Maximum temperature of 500 years: 251.05 K
  - Minimum temperature of 500 years: 242.57 K
  - Mean temperature of 500 years: 247.29 K
  - Standard deviation: 1.20 K
  - Anomalously warm years were signified by years greater than 248.48 K
    - 72 years
  - Anomalously cold years were signified by years less than 246.09 K
    - 82 years

Results / Discussion

a.)

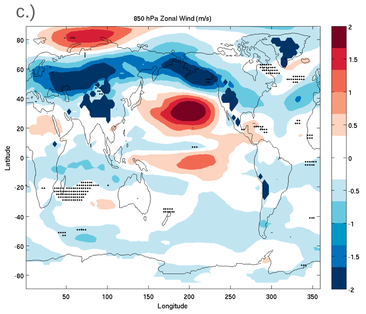


b.)



- Figure (a) is the surface air temperature. This plot shows wide spread warming of the Arctic region, while areas of Eurasia and North America experience a cooling effect. Figure (b) shows the 250 hPa zonal wind. There is an equatorward shift of the mid-latitude jet stream, meaning the jet is much slower over the mid-latitude region.

c.)



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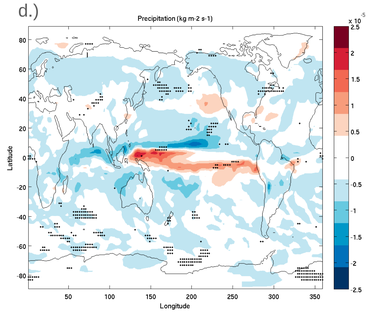
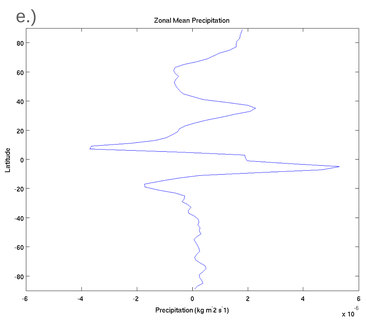


- Figure (c) is the 850 hPa zonal wind plot, which displays a decrease of the mid-latitude zonal wind. Figure (d) shows a plot of precipitation. This figure shows an equatorward shift of the ITCZ.

e.)



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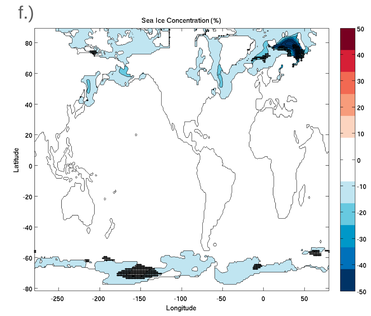
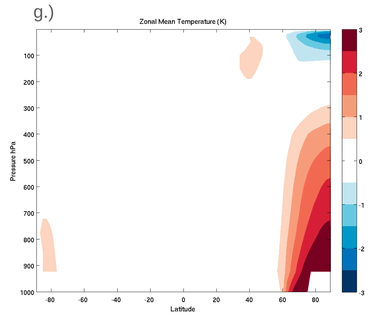
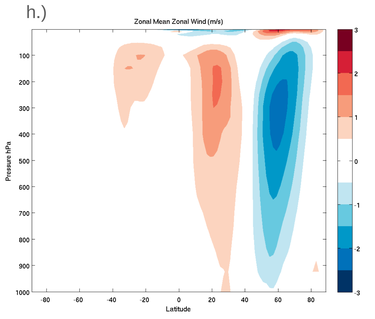


- Figure (e) is a plot of zonal mean precipitation, showing an increase of precipitation in the mid-latitude regions. Figure (f) shows an overall decrease in sea ice concentration over the Polar Regions, while major sea ice loss occurs over the Kara-Barents Sea region.

g.)



h.)



- Figures (g) and (h) show the zonal mean profiles for temperature and zonal wind, respectively. There is a warming from the surface to about 300 hPa over the Arctic region, while the stratospheric polar vortex experiences cooling. In (h), there is an equatorward shift of the mid-latitude jet stream, as well as an acceleration of the stratospheric polar vortex.

Conclusions

1. With the recent intense warming of the Arctic region, it is important to know the effects of this warming on our global circulation.
2. With the recent mid-latitude extreme cold winters, research has occurred to find a dynamical pathway between the warming Arctic and mid-latitude extreme weather. Possible pathways are changes in storm tracks, changes in the jet stream, and energy propagation of planetary waves.
3. We looked at a pre-industrial 500 year model integration that shows the basic effects that one could expect from our warming planet.
4. Since the global atmospheric response is examined during the same months of Arctic Amplification, the results may not directly imply causality (some features may possibly lead to Arctic Amplification).
5. We need to be cautious about the implications of this study to the future warming climate since Arctic Amplification is not the only consequence of global warming.