EOSC 595: Directed study, Arctic Climate change
An updated review on Arctic warming and it's implications on the hydrological cycle

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1 Introduction

In recent years many papers have been written on the state of knowledge of Arctic warming and amplification [Davy et al., 2018, Previdi et al., 2021, Vihma et al., 2016, Serreze and Barry, 2011] as well as the changing hydrological cycle. As we better understand concepts such as cloud microphysics [Pithan et al., 2014] and water vapour transport [Gimeno et al., 2019], our understanding of the changing weather of the region too changes. Recent updates such as the Arctic Report Card 2022 [Druckenmiller et al., 2022] give updated changes to the region, which influence our overall understanding.

This review will focus specifically on how the climate of the Arctic region is causing changes to the atmospheric hydrological cycle

define all of the variables which are seeing change and combine them together on one figure

2 Regions of the Arcitc

2.1 How we define the Arcitc

Number of papers which define the Arctic as x degrees etc

2.2 Local geography

The changes in sea ice extent and thickness, transport of moisture and heat, humidity and precipitation all rely heavily on local geography and weather, therefore this will be considered when writing the review. Therefore in this review we split changes occuring in the Arctic into local and remote.

3 Defining Arctic Change

define arctic warming, amplification, polar amplification and antropogenic forcing

3.1 Arctic Warming

3.2 Polar Amplification

Polar amplification is the phenomenon in which any change in net radiation balance on Earth produces larger temperature changes in the poles than on the rest of the planet. The changes in the Arctic occur more severely and intensely, in a process known as Arctic amplification [England et al., 2021].

3.2.1 Arctic Amplification

Arctic amplification is stronger during the winter months, with winter warming being almost four times stronger than summer warming [Bintanja and Van der Linden, 2013].

4 An introduction to the atmospheric hydrological cycle of the Arctic

Include the sketch of the hydrological cycle explaining the basic mechanisms

Introduce the mechanisms which will be talked about - do not repeat from introduction

5 Characterizing change

Arctic climate change is mainly characterized by a warmer and wetter atmosphere. This is due to the overall global increase in temperature, in addition to poleward energy transport, snow and ice albedo feedbacks, loss of sea ice and snow, the confining of warming to the near-surface in the polar atmosphere, moisture transport and water-vapor radiative feedback which all contribute to amplification [Serreze and Barry, 2011]. These are combined effects which differ between the hemispheres.

how do these changes matter and how do they differ?

6 Local changes

The amount of moisture in the Arctic is determined by the rates of local evaporation and moisture transport from lower latitudes.

6.1 Local temperature change

mean change - more humidity

6.2 Local humidity change

Increasing temperature leading to how much increased humidity etc Temperature trend due to CC relation

The increase in Arctic annual mean surface temperature (land and ocean) between 1971 and 2019 was three times higher than the increase in the global average during the same period [AMAP, 2021]. Newer studies estimate that this change is 4 times the amount [Rantanen et al., 2022]. These temperature increases are driving ice losses and changes in moisture transport.

show a table showing which paper, what methods, for what amount of temperature change

Moist energy balance models and general circulation models show 1.8 times more warming than dry models, due to the warming effect of latent heat transport [Feldl and Merlis, 2021], showing that humidity is an important factor when characterizing amplification.

6.2.1 Sea ice & Ocean interactions

In recent years the effects of changing humidity have been explored, with the cause for overall warming being attributed to increases in humidity and precipitation [McCrystall et al., 2021] as well as sea ice losses. Humidity changes can occur both due to sea ice losses and the transport of moisture from other regions.

how is sea ice changing humidity? more open water for evaporation how do we quantify this?

how are sea ice changes affecting humidity?

increased snow changing sea ice trends

Previous work investigating Arctic amplification focused on sea ice losses [Serreze et al., 2009]. With warming temperatures, ice has less time to form which makes it thinner and causes it to melt earlier. This allows for stronger heat transfer from the ocean to the atmosphere. There has been a considerable loss in sea ice extent since 1979, with a yearly decrease in sea ice expected to continue with the increase in CO2 in the atmosphere [Dai et al., 2019].

Some work has shown that in aquaplanet models, with no sea ice, Arctic amplification still occurs [Russotto and Biasutti, 2020], showing that while sea ice loss is an important mechanism, other factors are just as important to research when investigating what is contributing to amplification.

As mentioned above, winter warming in the Arctic is more severe than that in the summer, with this change being attributed to sea ice changes. Sea ice changes are mainly being forced by changes in the summer climate.

Ice, leads and polynas Due to a large amount of evaporation from leads and polynyas, the near-surface air humidity over Arctic sea ice is generally close to saturation concerning the ice phase and therefore sublimation is weak [Andreas et al., 2002]. Leads are large fractures within an expanse of sea ice, where a linear area of open water is present, and often used for transport. They can vary in width from meters to hundreds of meters. Polynyas are areas of open water surrounded by sea ice.

6.3 Local precipitation changes

Changes are being seen in how these sources of precipitation are changing both over time and between regions, with end-of-century humidity recycling projected to account for 60-64% of precipitation [Ford and Frauenfeld, 2022].

overall more humidity - therefore rain instead of snow

have this as a different paragraph??

number of events

Changing precipitation patterns

6.4 The influence of land interactions

Evapotranspriation changes melting glaciers

Vegetation

melting permafrost

7 Remote changes

7.1 Moisture transport and intrusions

7.1.1 Transported moisture

meridional changes - differ in the summer/winter months not much agreement here

Other sources of atmospheric moisture in the Arctic are transported from lower latitudes, driven by the north-south gradient in air-specific humidity and are affected by large-scale circulation patterns such as planetary waves, subtropical jet stream, the Polar front jet stream and storm tracks [Gimeno et al., 2019]. These phenomena are split up into mean meridional circulation, stationary eddies and transient eddies.

There has been an overall increase in atmospheric and ocean heat transport to the poles due to changes in the transport of latent energy (moisture) and dry static energy (the sum of sensible and potential energy) by atmospheric circulations [McGraw et al., 2020]. Particularly there are large increases seen over the Atlantic sector of the Arctic [Dufour et al., 2016], with little analysis of moisture transport over the Western Canadian Arctic.

7.2 Storm tracks and blocking

7.3 Aerosols

see figure 1 [Vihma et al., 2016]

8 Knowledge gaps

9 Conclusion

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