Atmospheric Rivers and Their Effects on Arctic Sea Ice

Levi Newell
Linghan Li and Forest Cannon

Motivation/Background:

Other studies have looked at atmospheric rivers (ARs) and how they can open large holes in sea ice in the antarctic[1]. However little to no research has been published regarding the effects of ARs in the Arctic. As the Arctic warms due to climate change, we are expecting to see less and less sea ice extent in the summer as well as in the winter. This could have major implications for the defence and shipping interests in many of the arctic countries so this area of research is an important avenue to proceed down. Particularly of interest is how ARs have been changing over the past 40 years and to what degree they can affect the landscape of sea ice in the Arctic.

Methodology:

First we began by looking at several AR events identified in 2007 in the ECMWF Reanalysis Version 5 (ERA5)[2] dataset. We choose 2007 due to its being one of the lowest sea ice extent summers on record. Once we had completed that we moved on to more broad analysis of the Arctic, to do this we computed climatological averages for variables including sea ice concentration, integrated water vapor transport(IVT), longwave radiation, shortwave radiation, latent heat, and sensible heat. Each of these were calculated for 4 decadal averages from 1981-2020 as well as bidecadal periods of 1981-2000 and 2001-2020. We then began to use the AR catalog created by Guan and Waliser (2015)[3], this catalog identifies AR events based on different qualifiers including IVT, size, shape, and duration. This is all computed from the Modern-Era Retrospective Analysis for Research and Applications Version 2 (MERRA2)[4]. From this we re-gridded the catalog to the gridspace of the ERA5 to make future work easier and more streamlined. From this catalog AR frequencies were computed and analyzed against other variables.

Results:

A total of 5 case studies were analyzed in 2007, however for the sake of brevity the most important one is analyzed here. This event occurred in the very beginning of December, a typical time for sea ice to be building up, however we see that in this case an AR event has caused a large area off the coast of Russia to experience sea ice loss. This enhanced area is then further analyzed by plotting a time series of the surface fluxes for the defined area of sea ice loss, this can be seen in **Figure 1**. The AR passage is seen with the increase in sensible heat flux, this also corresponds to the sea ice concentration loss. This case study is pivotal in showing that ARs can have a monumental impact on sea ice, even in the winter time.

We then computed the frequency of ARs for the two bidecadal periods which were talked about above. To better visualize the trends we are seeing, a difference plot was made between the two which is seen in **Figure 2**. As we can see, the majority of the Arctic is seeing an increased average number of ARs per year between the two periods. Some of the highest increases are in important shipping areas such as the Bering Strait and the Baffin Bay. Also plotted is the average minimum sea ice extent for the two periods, showing the rapid decrease in sea ice extent that has opened this area up in the summers.

Conclusions:

From this analysis and others not shown, we can conclude that Arctic Sea ice has been declining in the past few decades, this also corresponds to an increase in the number of AR events happening in the Arctic. This begs the question of their linkage and if one may be affecting the other. There are strong background signals that interfere with a direct relationship; however in future work, this background signal can be removed and we can see what effect ARs have on melting sea ice both annually and how this effect may have changed over time.

Figures:

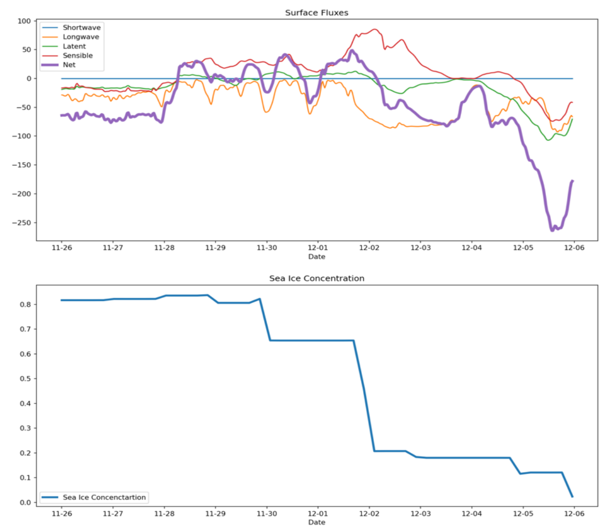

Figure 1: A time series of surface fluxes and sea ice concentration of a region in the Arctic that experienced the passage of an AR event in the winter

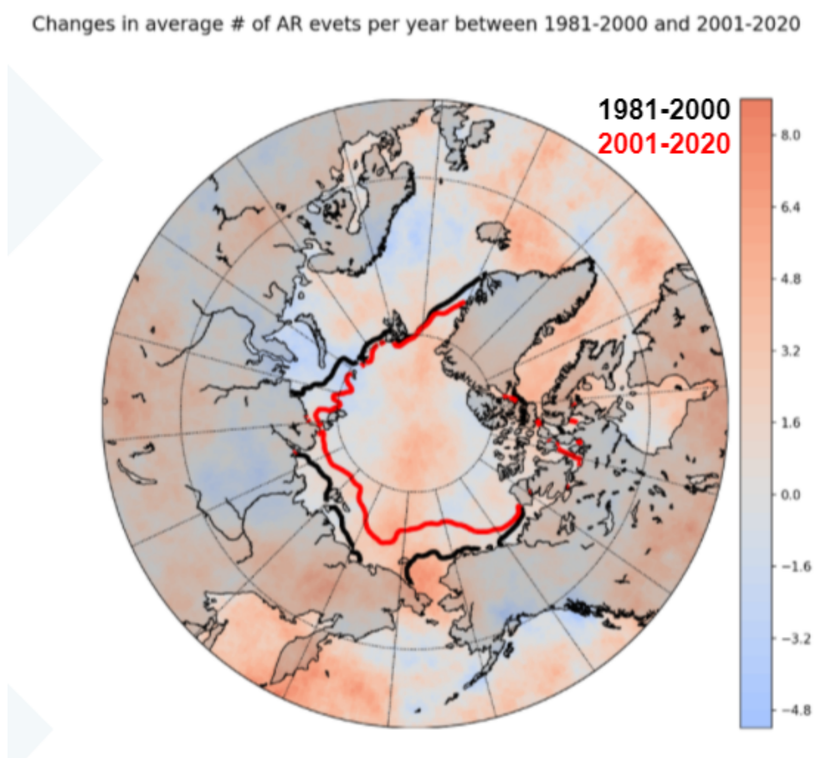

Figure 2: A difference plot in the average number of ARs that occurred annually in the two time periods 1981-2000 and 2001-2020, also plotted is average sea ice minimums that occurred in those two periods

References:

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3. Guan, B., & Waliser, D. E. (2019). Tracking Atmospheric Rivers Globally: Spatial Distributions and Temporal Evolution of Life Cycle Characteristics. Journal of Geophysical Research: Atmospheres, 124, 12523– 12552. https://doi.org/10.1029/2019JD031205

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