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Arctic climate response to extreme events in synoptic and planetary scale atmospheric energy transport

Johanne H. Rydsaa, Rune G. Graversen, Patrick Stoll

INTRODUCTION

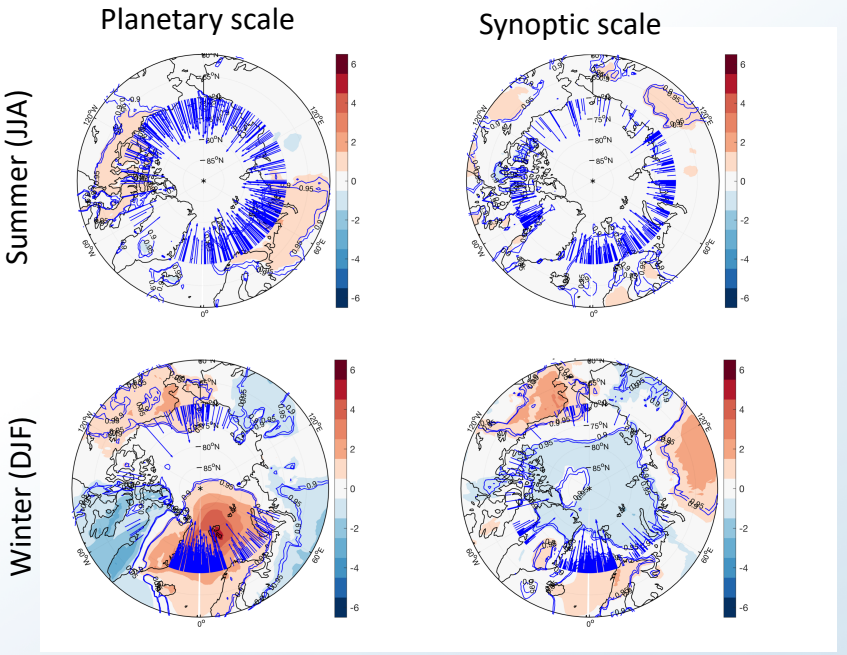
Atmospheric energy transport into the Arctic has been shown to play an important role in the Arctic weather and climate. Particularly latent energy impact on temperatures through cloud formation and increased LW towards the surface.

Here, we investigate how extreme transport events on planetary and synoptic scales affect the Arctic (>70°N) temperatures differently. We particularly focus on the effect of latent energy transport in different seasons, and how the transport on separate scales has changed over the past 40 years.

METHOD

Here, we use the recently released ERA5 dataset and separate the total transport of latent energy into large planetary scale transport, and smaller synoptic scale transport. To achieve this, we apply a Fourier decomposition of the northward latent energy transport with respect to zonal wavenumbers, an approach presented by Graversen and Burtu, (2016,) and evaluated by Heiskanen et al., (2020).
Here we define planetary scale systems as comprised of wavenumbers 1-3 and synoptic scale systems as wavenumbers 4-20 at 70°N.

SEASONAL TEMPERATURE EFFECTS



Mean temperature anomalies as composites of days with strong latent energy transport anomalies (> 90th percentile per season) across 70°N, show that large temperature anomalies are seen in winter, and not in summer. Blue arrows along 70°N indicate the point of maximum transport anomaly for each extreme day. They are grouped over relatively warm ocean areas in winter, and evenly distributed in summer. The length of the arrows is scaled only for illustrative purposes, and does not reflect the extent to which the transport reaches into the Arctic area. Blue lines surround areas with statistically significant results, according to a Monte Carlo type test for significance with 5000 simulations.

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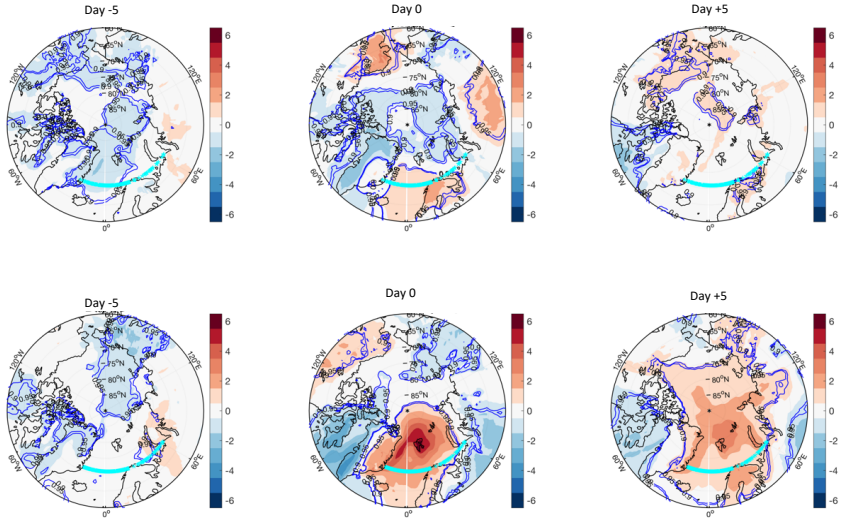
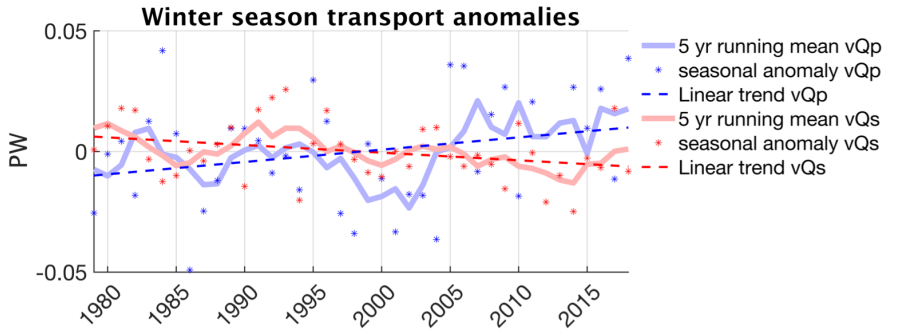
/ RESULTS

/ WINTER SEASON TEMPERATURE EFFECTS; ATLANTIC SECTOR

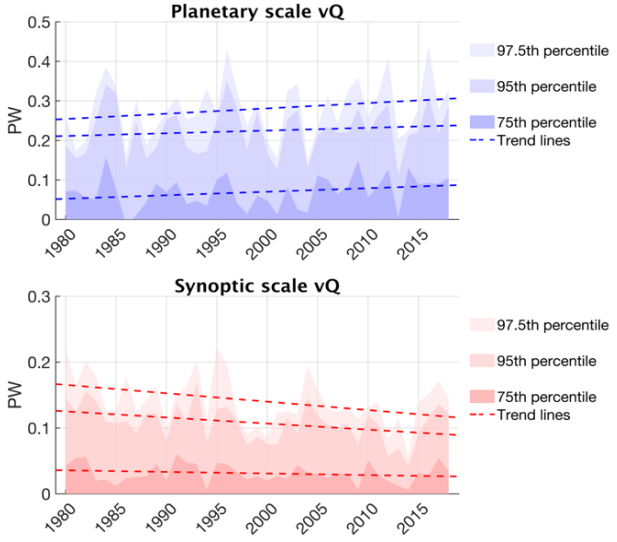


Temperature anomalies surrounding strong transport events (above the 90th percentile) entering the Arctic in the Atlantic sector (cyan dots) show that the synoptic events on average act to dissolve cold anomalies inside the Arctic region, while planetary scale events are associated with a warming anomaly spreading across the Arctic and lasting for several days. Five days ahead of strong events (left column) on day of event (middle column) and five days after events (right column) for synoptic scale (upper row) and planetary scale events (lower row). Blue lines surround areas with statistically significant anomalies.

/ SEASONAL TRENDS (1979-2018)



Winter season anomalies in latent energy transport (dots) for planetary scale transport (blue) and synoptic scale transport (red) show that planetary scale transport has increased, and synoptic scale transport has decreased over the past 40 years. Wintertime planetary events are more associated with warming in the Arctic.



Seasonal mean winter (DJF) anomalies in latent energy transport across 70°N show that the upper percentiles have changed the most, i.e. the planetary scale strong transport events have increased (blue colors) and synoptic scale strong events have decreased (red colors) over the time period 1979-2018.

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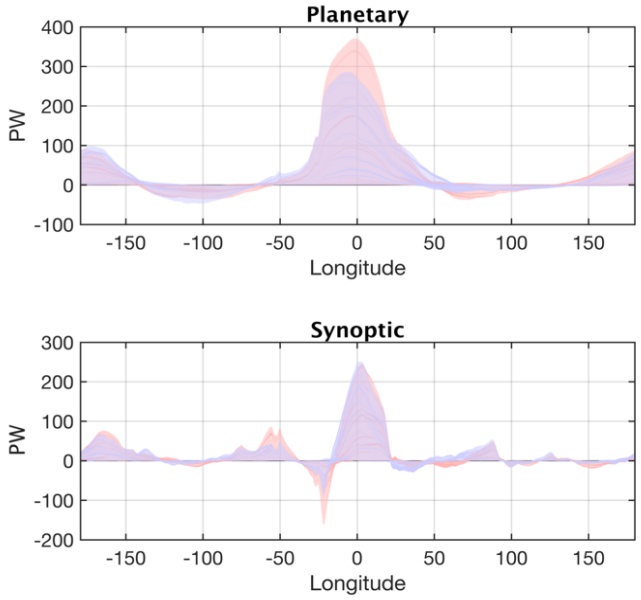
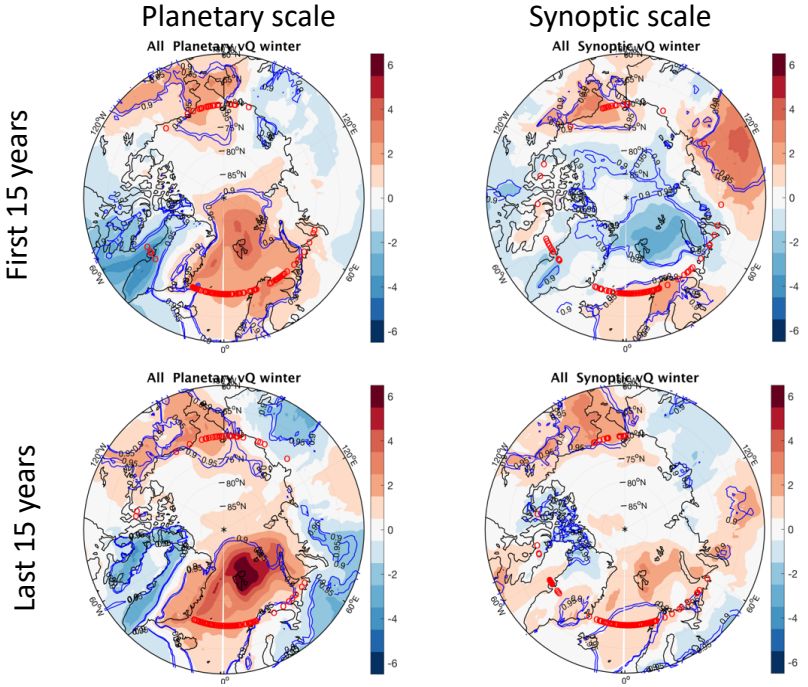
/ RESULTS

/ THEN AND NOW: COMPARING THE LAST 15 YEARS TO THE FIRST 15 YEARS



Distribution (stacked) of latent energy transport along 70°N show that over the last 15 years there has been an increase in strong planetary events in the Atlantic sector (around 0°E), as compared to the first 15 years, shown as stacked curves of daily mean energy (PW) for days with strong transport events (exceeding the 90th percentile each season). Blue shades show contributions over the early 15 winter seasons (1979-1993), while pink shades show contributions as accumulated over the late 15 winter seasons (2004-2018). Note that scales differ among panels.



Composites of temperature anomalies of strong transport events in the first 15 years as compared to the last 15 years, show that in the later 15 years, planetary scale transport is more associated with warming, and a weaker temperature gradient in the Atlantic sector during synoptic events. Red circles indicate the location of the peak of the daily mean transport for each strong transport day.

/ REFERENCES

Graversen, R. G. and M. Burtu (2016). "Arctic amplification enhanced by latent energy transport of atmospheric planetary waves." Quarterly Journal of the Royal Meteorological Society 142(698): 2046-2054.

Heiskanen, T. I. H., et al. (2020). "Comparing wavelet and Fourier perspectives on the decomposition of meridional energy transport into synoptic and planetary components». Accepted for publication in Quarterly Journal of the Royal Meteorological Society.