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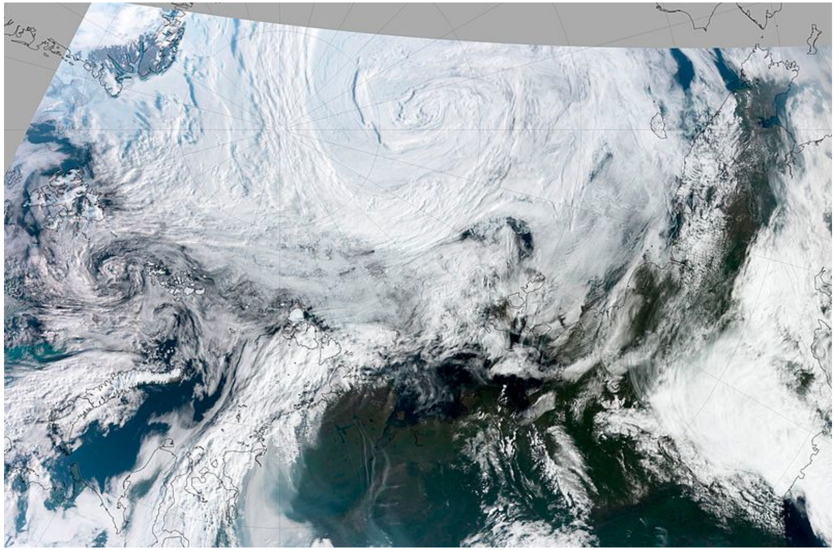
Understanding cyclone variability in the Barents Sea



Cyclone over the Arctic August 2012
NASA Earth Observatory
https://eoimages.gsfc.nasa.gov/images/imagerecords/78000/78808/arctic_vir_2012220_lrg.jpg

EGU2020-10690 | Displays | CL4.15/AS4.5/OS1.31

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the Nansen LEGACY

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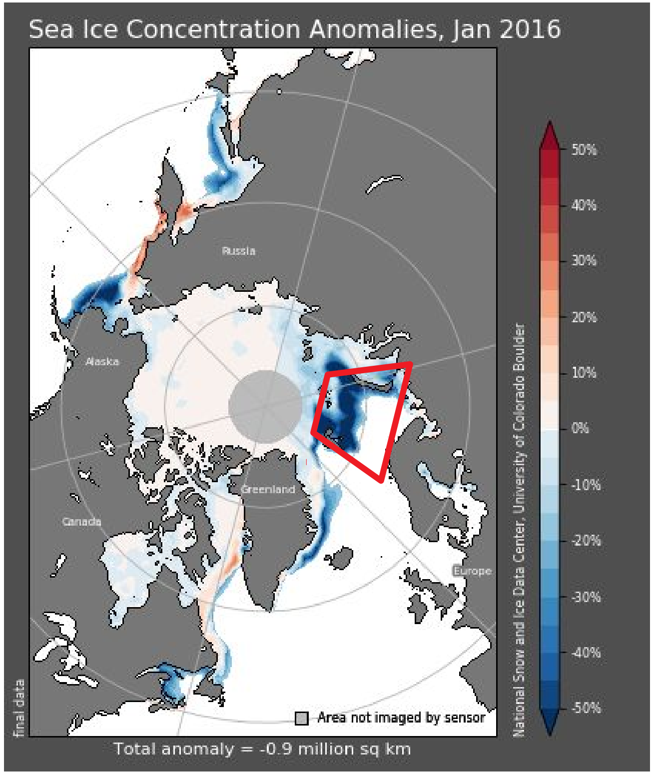
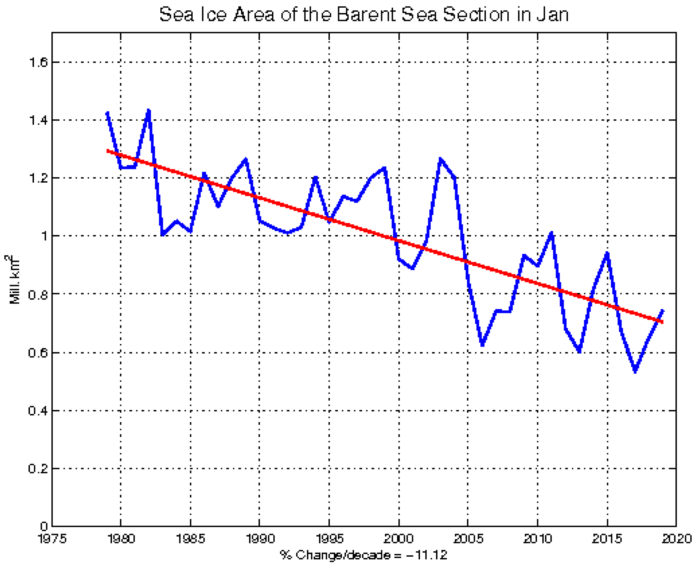
Motivation: why the Barents Sea?



Sea ice concentration anomalies for January 2016
https://nsidc.org/data/seaice_index/

Negative trend in Barents Sea sea ice area, but **large interannual variability**.



Sea Ice area trend for the Barents Sea in January. From https://arctic-roos.org/node/94

The Barents Sea (**BS, 70-80°N, 20-70°E**) is the region with the most drastic wintertime sea ice decrease.

It is also located at the end of the North Atlantic storm track and is a gateway for cyclones entering the high Arctic.

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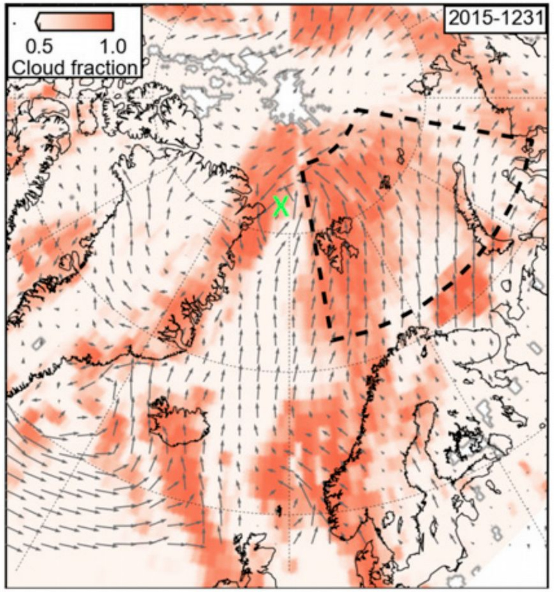
Cyclones can impact the sea ice

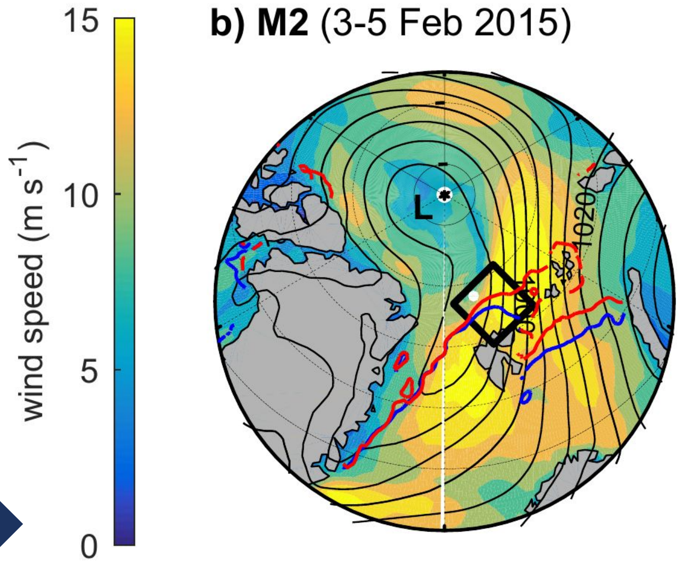


MERRA-2 winds (vectors) and AIRS cloud fraction for 31 December 2015, during the passage of a moist cyclones, marked by the green cross. From Boisvert et al. 2016, MWR

Impact the surface energy budget (IR effect, moisture intrusion)

Influence the sea ice drift (strong winds effect)

see also:
Woods and Caballero 2016
Moore et al. 2016
Binder et al. 2017
Kim et al. 2017



Wind speed and SLP averaged over the period of a major winter storm (3-5 February 2015) and 85% sea ice concentration before (blue) and after (red) the passage of the cyclone. From Graham et al. 2019, Sci. Rep.

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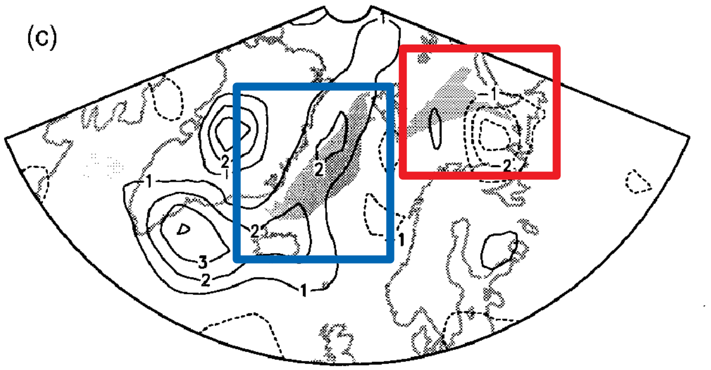
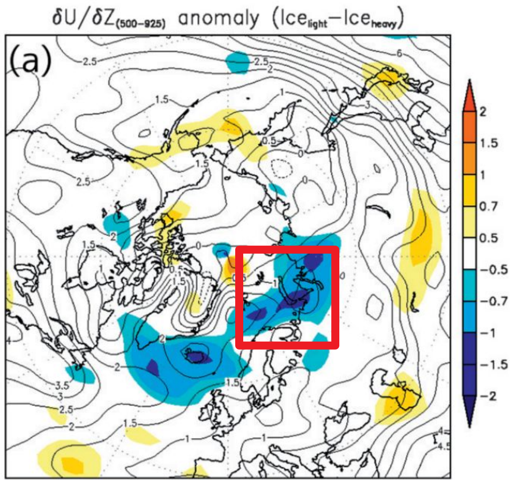
But can the sea ice decline impact cyclones?

Previous studies suggested that there is a local response of the atmospheric circulation to the changing sea ice cover.



Low-minus-high composite differences of winter cyclone (contours) based sea ice (shading). Years with less ice show more cyclones in the Labrador sea, less in the Barents Sea
From Deser et al. 2000, J. Climate

Some studies link the decrease in cyclones in the Barents Sea to the decline in sea ice (e.g. Inoue 2012)



Difference in baroclinicity based on 5 DJF with low – 5 DJF with high sea ice.
From Inoue et al. 2012, J. Climate

Proposed mechanism:
years with low sea ice have a weak gradient in sea surface temperature. This reduces the low level baroclinicity over the Barents Sea, which in turn prevents cyclones from traveling eastward and reaching the Barents Sea. As a result cyclones shift poleward.

Research questions:

1) Does the drastic sea ice decline in the Barents Sea have an impact on cyclone frequency?

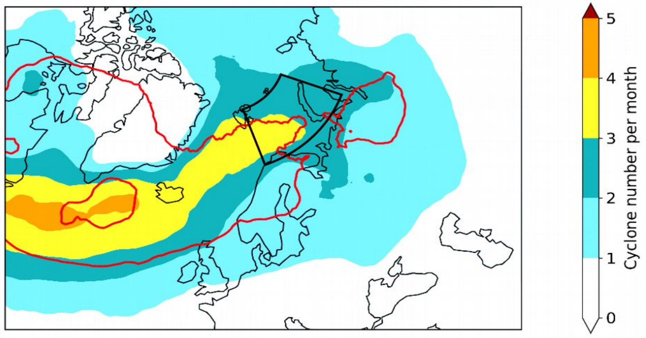
2) What controls the variability of cyclones at high latitudes?

3) Do the surface impacts of cyclones depend on their origin and path?

Approach: increase the sample size and analyze the link between cyclone frequency, baroclinicity and the large-scale flow

- Data: ERA-Interim, DJF 1979-2017
- Cyclone track based on SLP (Murray et al. 1991)
- Keep only tracks longer than 2 days
- Select 1/3 of the months with **many/few** cyclone tracks in the Barents Sea (BS, 70-80°N, 20-70°E, black box)
- Baroclinicity measured by the Eady Growth Rate (EGR)
- Blocking detected using the method of Schwierz et al. 2004 (persistent negative PV anomalies)

Climatology of cyclone tracks (shading) and monthly blocking frequency (contours, 5% intervals)



$$EGR = 0.31\frac{f}{N}\left\|\frac{d\mathbf{u}}{dZ}\right\|$$

stability

Vertical wind shear

Madonna et al. submitted

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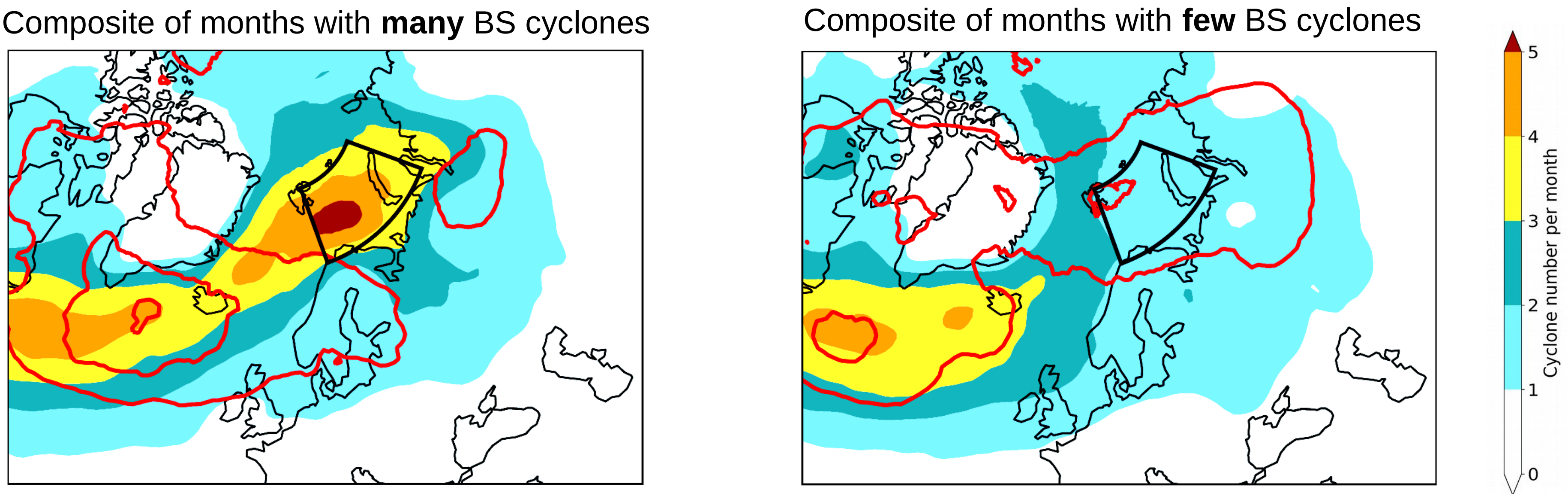
Barents Sea cyclones are linked to blocking



Contour: monthly blocking frequency [5%,intervals]

During months with many cyclones (left), no blocking are located over the Barents Sea. Months with few cyclones (right) show enhanced blocking over the Barents Sea and more cyclones entering the Arctic through the Fram Strait. The positive SLP anomaly over the BS discussed in several papers is not just the absence of cyclones!

Madonna et al. (in review)

Differences in baroclinicity linked to the upper-level wind (jet)

Composite of months with **many** BS cyclones

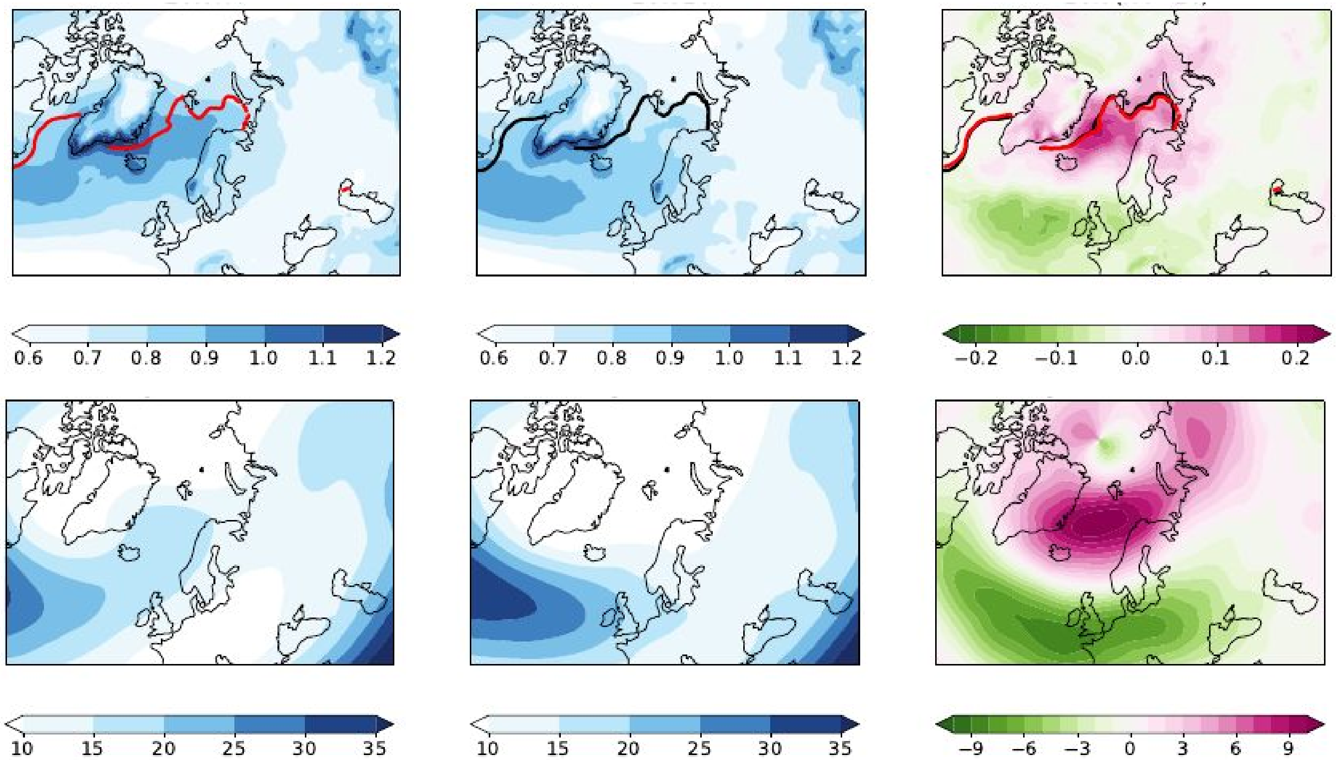
Composite of months with **few** BS cyclones

Composites difference (many -few)

Eady Growth Rate (EGR) [shading, in 1/d]

sea ice extent [15% contour]

Zonal wind at 300 hPa [shading, in m/s]



Composites difference shows a dipole structure in EGR, not localized over the BS

For both composites the sea ice edge is at a similar location

The dipole structure in baroclinicity arises from changes in the vertical wind shear and reflects differences in the upper-level wind (i.e. the jet)

Madonna et al. (submitted)

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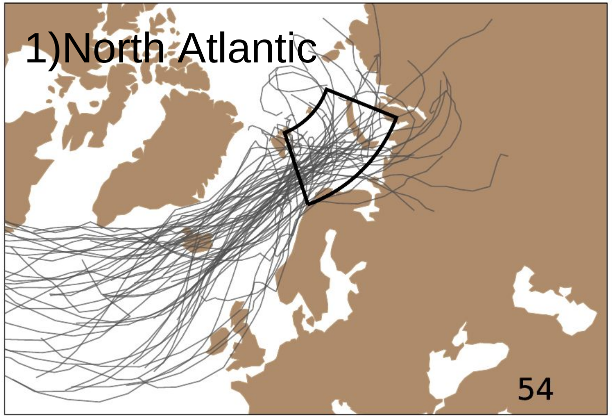
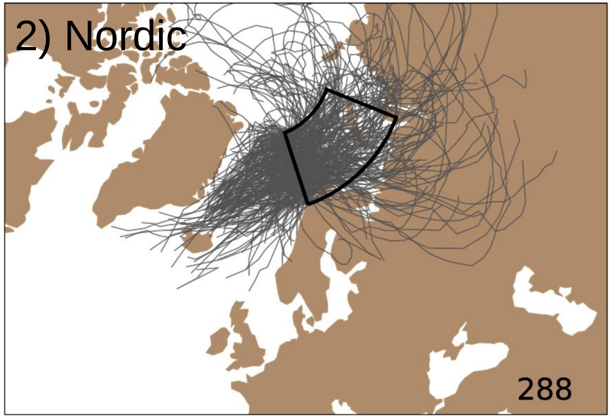
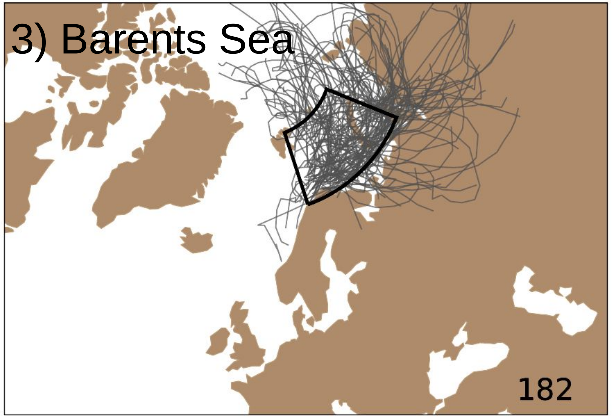
But not all cyclones are equal







Most of the cyclones (75%) reaching the Barents Sea are coming from the West (1+2) or born there (3).

We separate cyclones based on their origin into 3 categories:

1) North Atlantic: genesis south of 60°N
2) Nordic: genesis north of 60°N
3) Cyclone with genesis in the Barents Sea

and look at their surface effect in term of temperature anomalies.

Madonna et al. (submitted)

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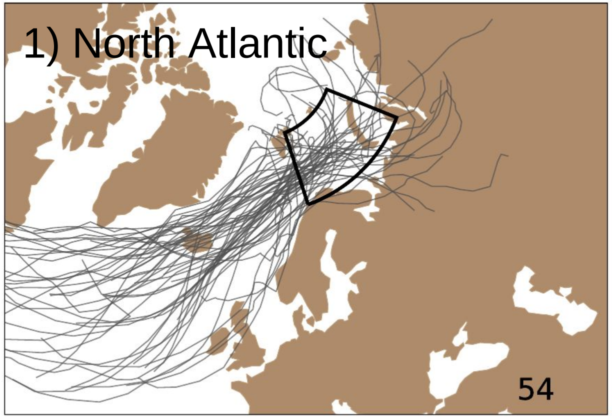
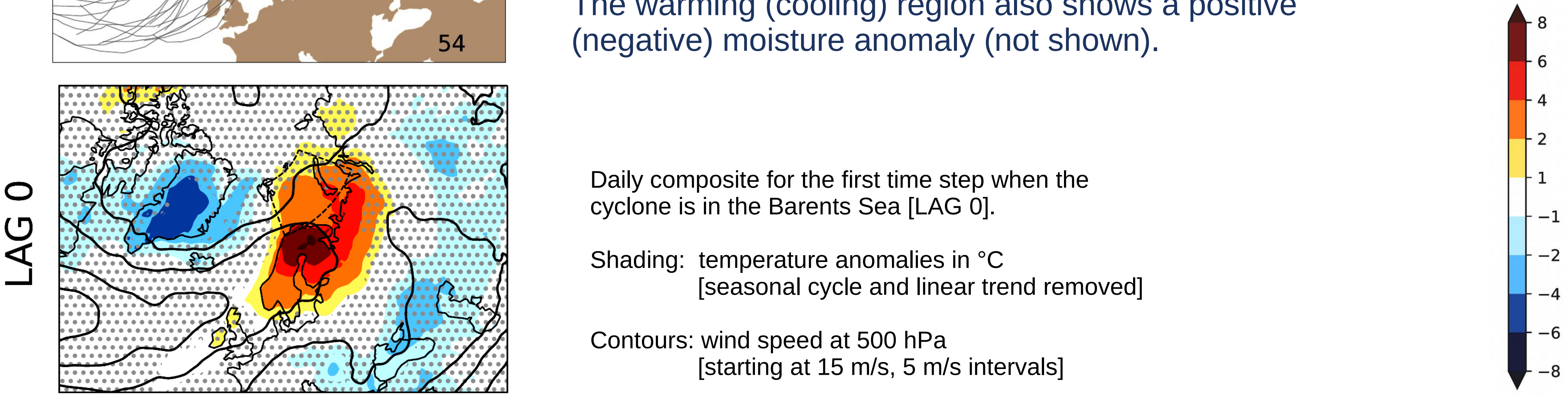
North Atlantic cyclones warm the Barents Sea



The composite shows:

- a southwest-northeast tilted jet stream
- strong surface warming (cyclone warm front)
- cooling over Greenland (circulation at the cyclone's rear)

The warming (cooling) region also shows a positive (negative) moisture anomaly (not shown).



Daily composite for the first time step when the cyclone is in the Barents Sea [LAG 0].

Shading: temperature anomalies in °C [seasonal cycle and linear trend removed]

Contours: wind speed at 500 hPa [starting at 15 m/s, 5 m/s intervals]

Madonna et al. (submitted)

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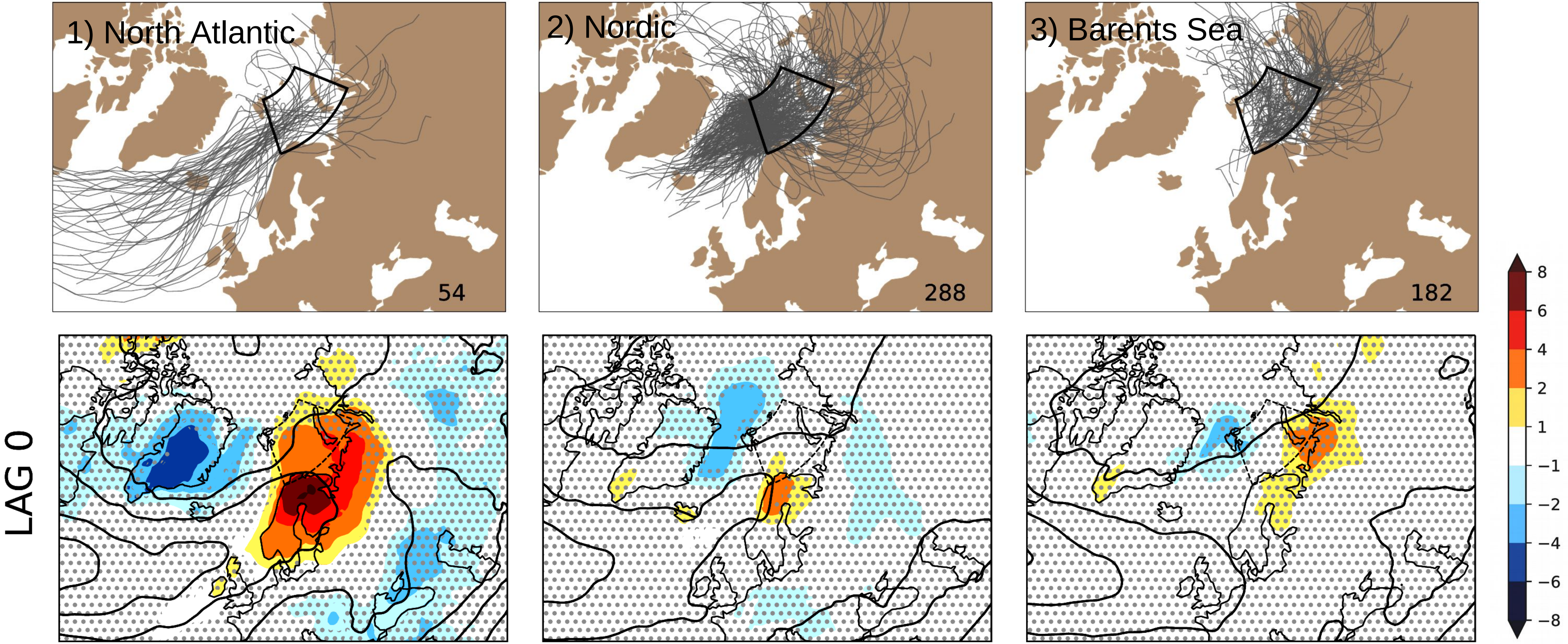
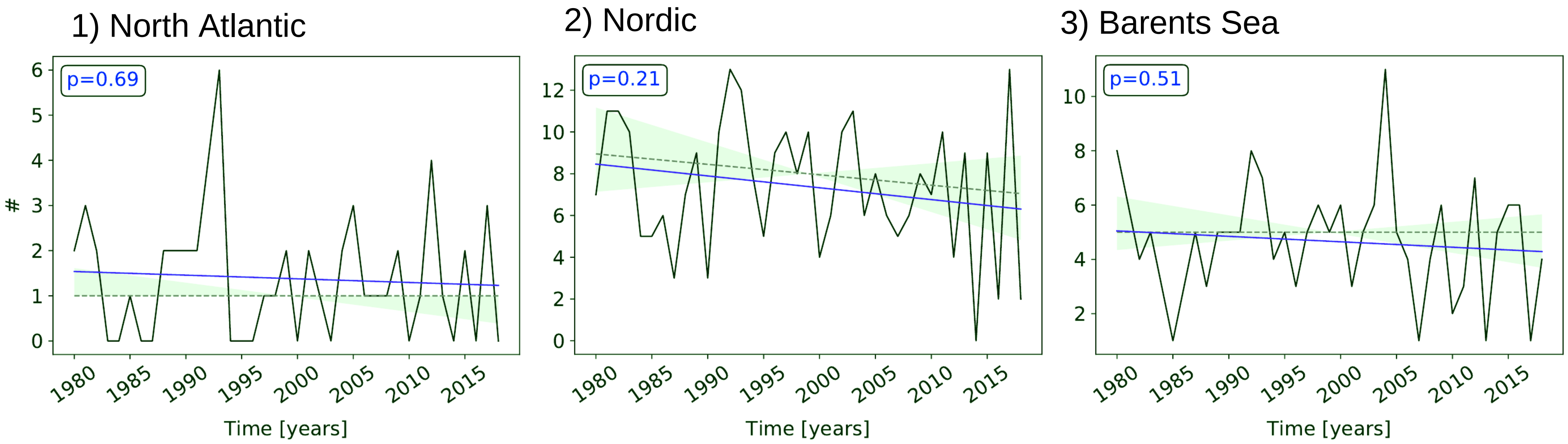
Temperature signal depends on cyclones' origin



Madonna et al. (submitted)

Is there any trend in any of the categories?



Time series of the number of cyclone tracks for the different cyclone categories during DJF winter. Linear regression slopes (p-value in the top left corner) are shown in blue. Theil-Sen median slope and 95% confidence interval are shown in green.

- Large year-to-year variability
- None of the trends are robust (also not the trend considering all categories together)

Madonna et al. (submitted)

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Conclusions

1) Does the drastic sea ice decline in the Barents Sea have an impact on cyclone frequency?

→ **Barents Sea cyclone frequency exhibits large interannual variability and non-robust trends**

2) What controls the variability of cyclones at high latitudes?

→ **Large-scale flow conditions (jet stream and blocking) influence the development and path of cyclones at high latitudes**

3) Do the surface impacts of cyclones depend on their origin and path?

→ **Cyclones born south of 60°N produce the strongest surface warming when reaching the Barents Sea**

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Comments?

Questions?

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