Impact of Atlantic water inflow on winter cyclone activity in the Barents Sea: Insights from coupled regional climate model simulations

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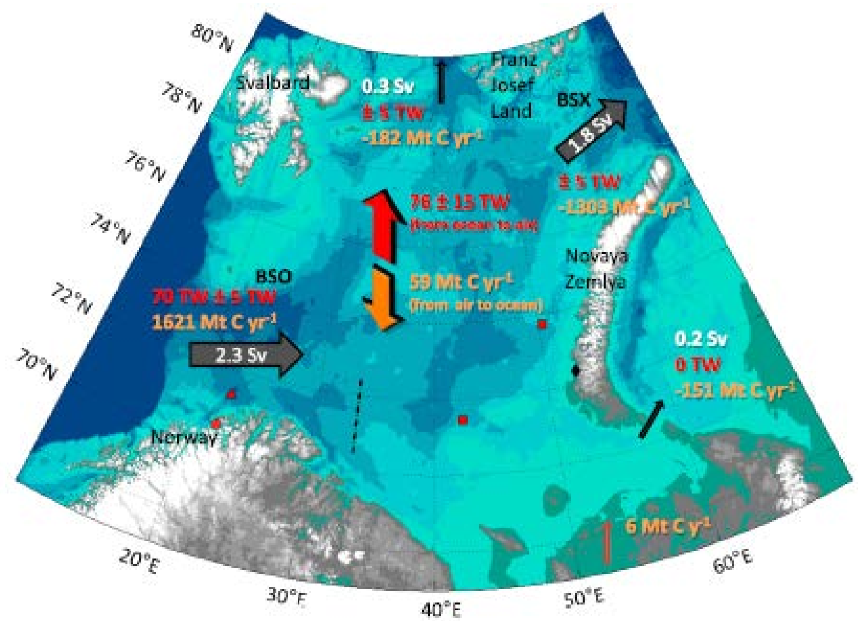
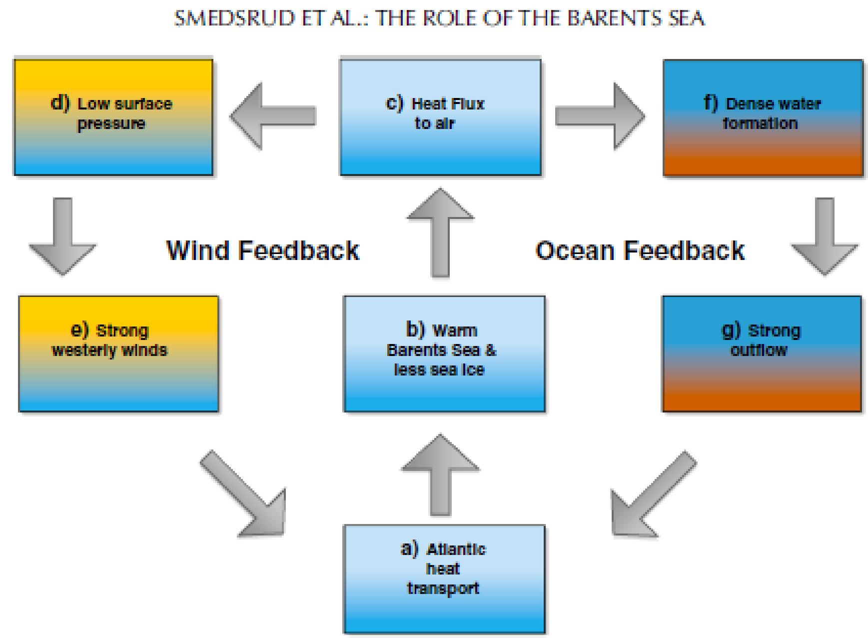
Motivation



The mean oceans transport to the Barents Sea (Smedsrud et al., 2013)



The two hypothesized positive feedback loops for the Barents Sea (Smedsrud et al., 2013)

Aim of this work:

- examine the role of Atlantic water volume (AW) inflow into the Barents Sea in changes of regional winter cyclone activity, based on ensemble simulations with a coupled regional climate model (RCM) HIRHAM-NAOSIM.

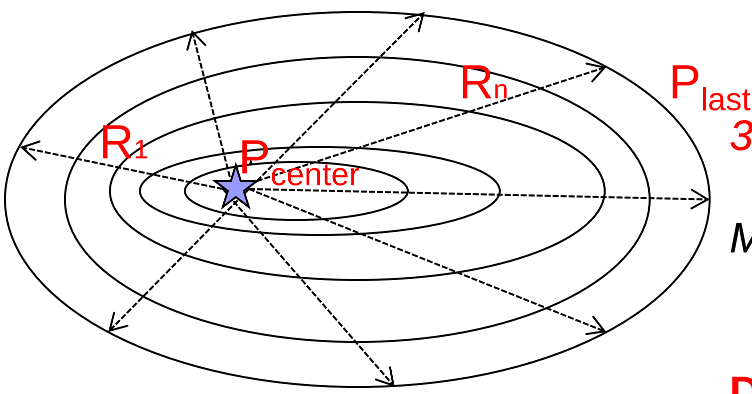
Data and methods

- 6-hourly mean sea level pressure data (**MSLP**), monthly data for sea-ice concentration (**SIC**), sea surface temperature (**SST**), surface sensible and latent heat fluxes (**LHF, SHF**), near-surface air temperature (**SAT**), temperature at 500 hPa (**T500**), ocean temperature (**T**), and zonal current (**U**) from **an ensemble of 10 (with different initial sea ice and ocean conditions) hindcast simulations** with RCM HIRHAM-NAOSIM for the **Barents Sea** (65-85^{0}N, 20^0-60^{0}E).
- Analysis period–**1979-2016** and season–**DJF**.
- Cyclone identification method (based on MSLP) – (Bardin and Polonsky, 2005; Akperov et al., 2015).

Cyclone’s identification method

1. Identification of cyclones using 6-hourly MSLP data (Bardin and Polonsky, 2005; Akperov et al., 2007):

- Cyclones are determined as domains that contain the single local minimum of the *MSLP* (*hPa*) enclosed within the maximum closed contour.



1. Cyclone frequency(fr.) = total number/years; [cyclones per month]

2. *ΔP (cyclone depth)* = $|P_{center}-P_{last}|$, where Pcenter– central pressure, Plast– pressure on outermost closed isobar; [hPa]

*3. R(cyclone radius)=1/n*sum(R_i), where i=1,n; [km]*

Measure of cyclone intensity $E_k \sim (\delta p)^2$ (e.g. Golitsyn et al., 2007; Simmonds and Keay, 2009)

Deep (intense) cyclones – 95% percentile of fr. (*ΔP*), 20 hPa

Non-deep (not instense) cyclones < 20hPa

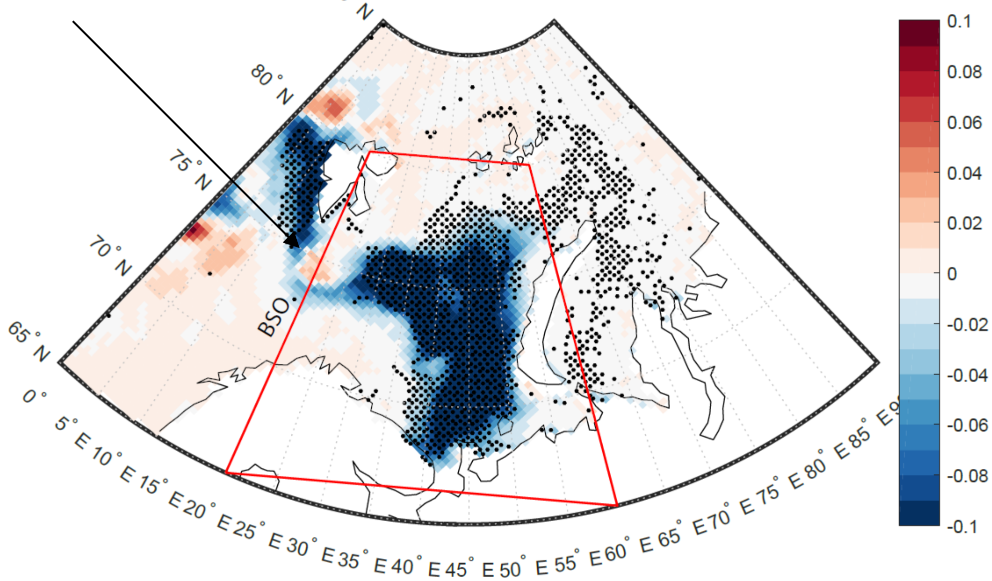
2. Cyclone’s tracking:

- nearest neighbour analysis

Max distance between two consequent 6-hour steps ≤ 600 km;

Calculation of the Atlantic water inflow and heat transport

Barents Sea Opening (BSO)

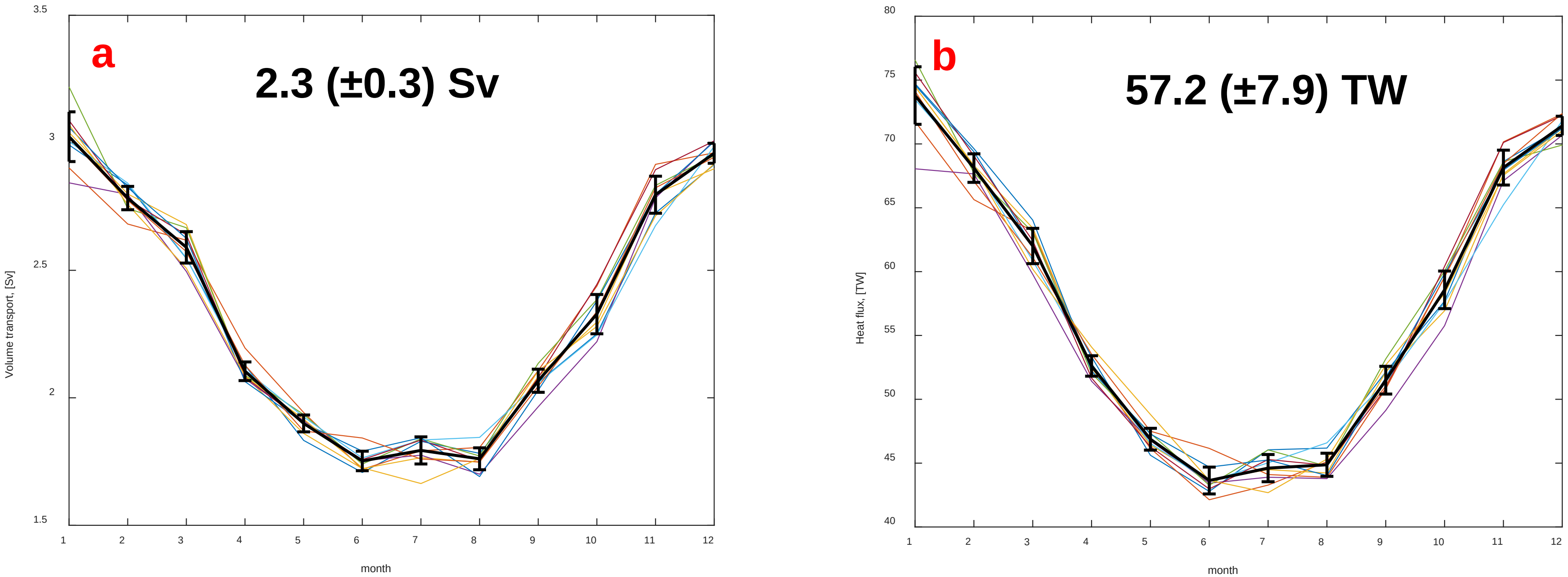


$$\iint_A v\,dA$$ - AW volume inflow (Sv = 10^6 m^3/s)

$$\iint_A (T - T_0)\,v\,dA$$ - ocean heat transport (TW = 10^{12} W)

where ν - zonal ocean current, **T** – ocean temperature, $\mathbf{T_0}$ – reference temperature (0^0C), A represents the BSO (area between Svalbard and Norway) (calculation performed for water column till 337 m)

Calculation of the Atlantic water inflow and heat transport

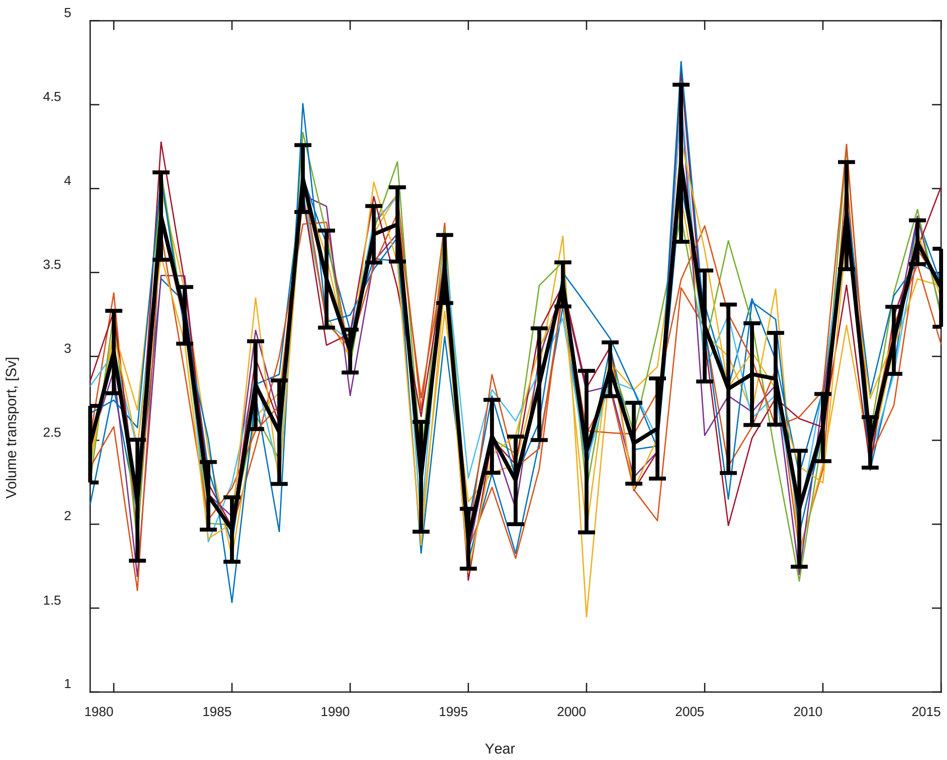


Annual cycle of (a) water volume (Sv) and (b) heat transport (TW) through the Barents Sea from simulations.

Observations:

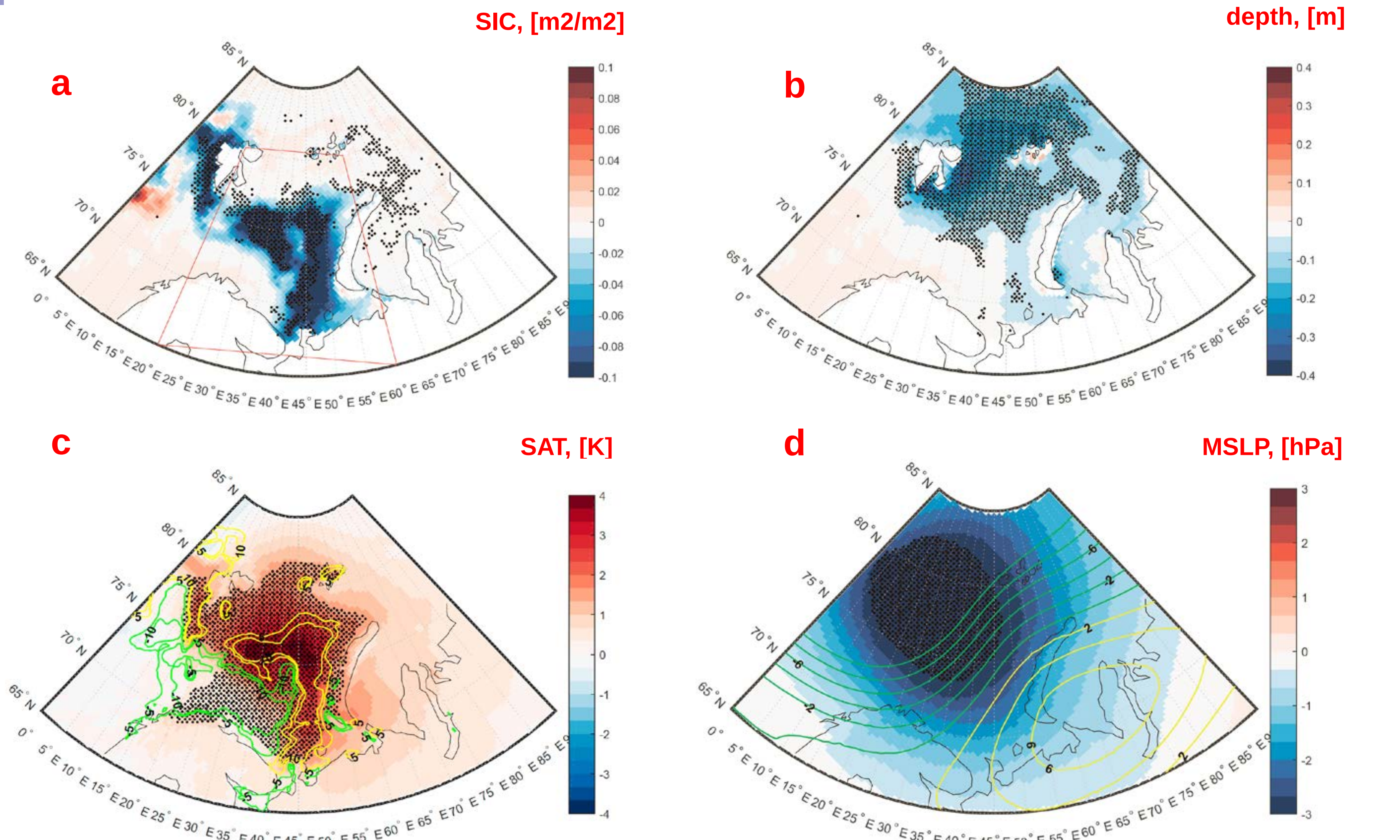
2.3 Sv, 70 TW (Smedrud et al., 2013) and **55 TW** (Tsobouchi et al., 2018).

Compositing of Atlantic water inflow for DJF

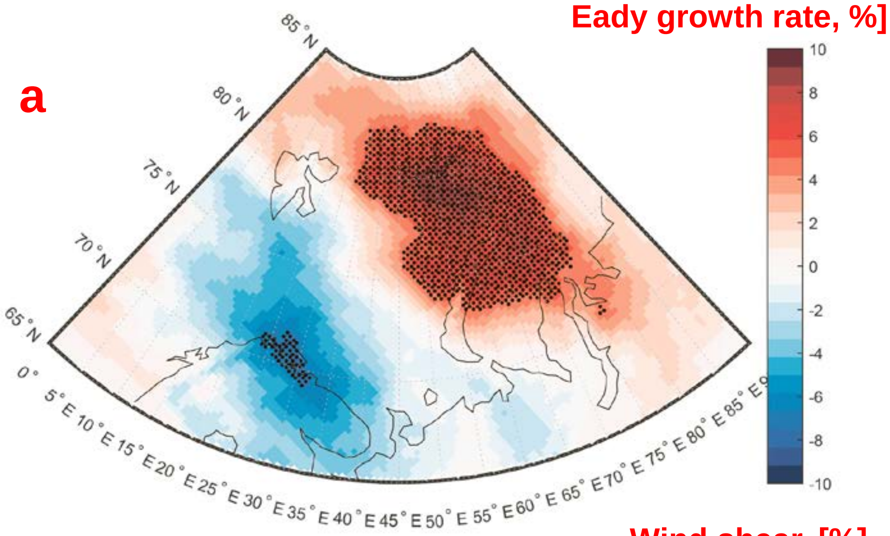


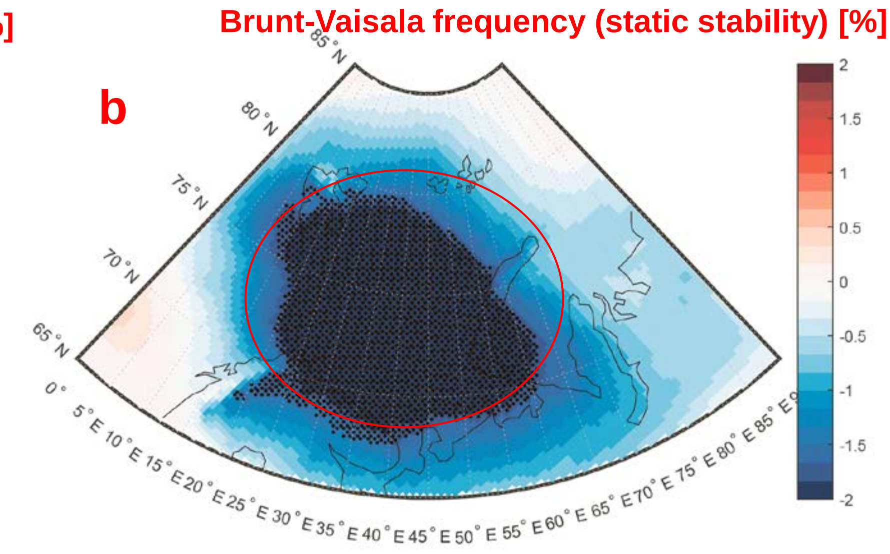
Low and high AW inflow cases were selected when the deviation of the AW inflow from the ensemble mean was larger than one standard deviation.

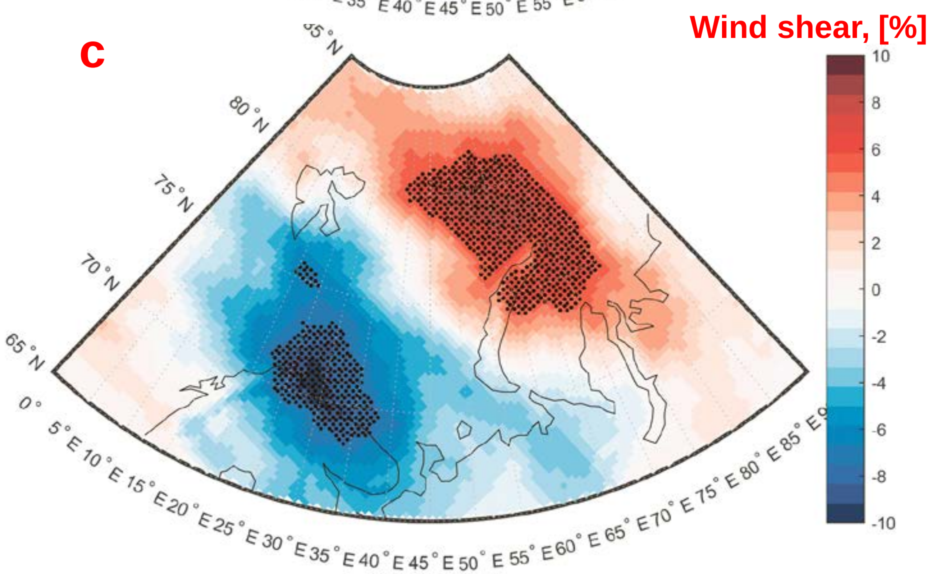
Interannual variability of AW volume through the Barents Sea in winter (DJF) from an ensemble simulations.



Composite difference "High minus low AW inflow in winter for (a) sea ice concentration, (b) sea ice thickness (m), (c) surface air temperature (K; color shading) and total (latent+sensible) surface turbulent heat flux (W/m^2; isolines), (d) sea level pressure (hPa; color shading) and geopotential height at 250 hPa (gpm; isolines) for winter (DJF).





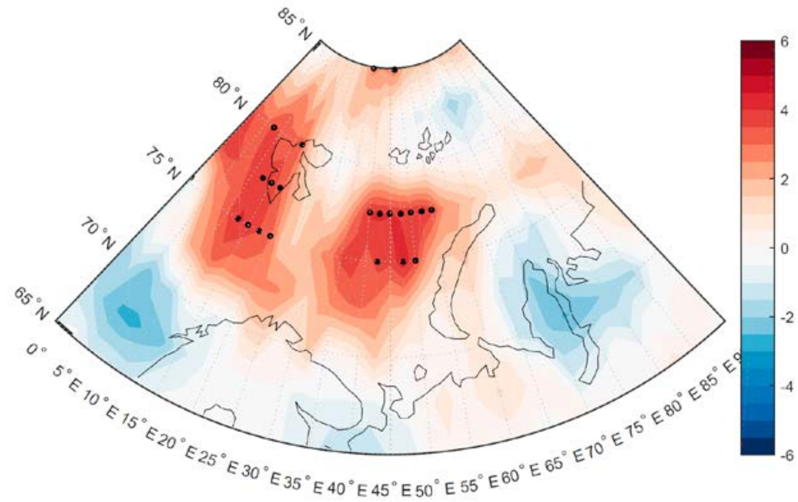


$$EGR = 0.31 f \left| \frac{\partial V}{\partial z} \right| N^{-1}$$ **- Eady growth rate, 1/day**

$$N = \left(\frac{g}{\theta} \frac{d\theta}{dz} \right)^{1/2}$$ **- Brunt-Vaisala frequency, 1/day**

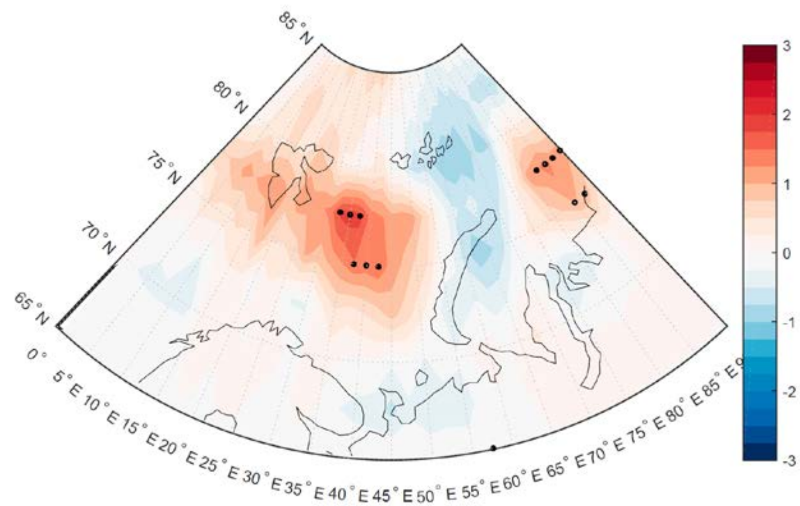
where *f* is the Coriolis parameter, *V* is the horizontal wind speed, *z* is the height.

a



Non-intense cyclone frequency [per season]

b



intense cyclone frequency [per season]

Composite difference “High minus low AW inflow in winter” for frequency of occurrence of (a) non-intense cyclones (depth<20 hPa), (b) intense cyclones (depth ≥ 20 hPa) and (c) cyclone size histogram for the Barents Sea cyclones. for **DJF**.

Conclusions

- The model quite well reproduces the connection between AW inflow and climate variability in the Barents Sea
- Increased AW inflow into the Barents Sea leads to increased baroclinicity in the lower troposphere and thus favorable conditions for cyclone activity
- An increased frequency of cyclones, particularly of intense cyclones, appears over the Barents Sea in years with high AW inflow, accompanied by an increase of cyclone depth (intensity) and size

Akperov, M., V.A. Semenov, I.I. Mokhov, W. Dorn, and A. Rinke (2019): Impact of Atlantic water inflow on winter cyclone activity in the Barents Sea: Insights from coupled regional climate model simulations, Environmental Research Letters, https://doi.org/10.1088/1748-9326/ab6399