Pacific Oceanic Front Amplifies the Impact of Atlantic Oceanic Front on North Atlantic Blocking

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Pacific oceanic front amplifies the impact of Atlantic oceanic front on North Atlantic blocking

First order impact of the Western boundary currents (Omrani et al. 2019)

SCIENTIFIC REPORTS
Corrected: Author Correction
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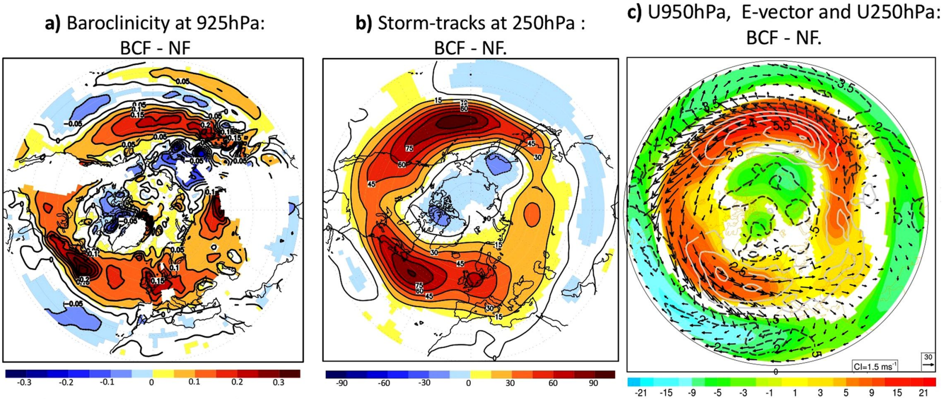
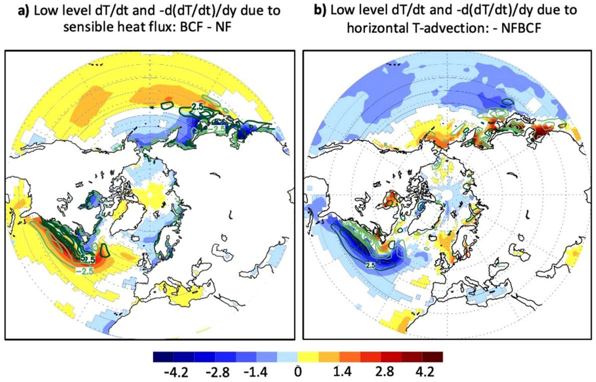
Key Role of the Ocean Western Boundary currents in shaping the Northern Hemisphere climate



The transient eddies, eddy-driven jet and storm tracks are very important ingredients for the blocking dynamics



SST-fronts maintain the eddy-driven jet and storm-track by maintaining low-level atmospheric baroclinicity (or temperature gradient), which is transferred from the ocean through turbulent heat fluxes.

Question: How the Atlantic and Pacific SST-fronts includin tropical SST-assymery impact the wintertime North Atlantic blocking frequency?

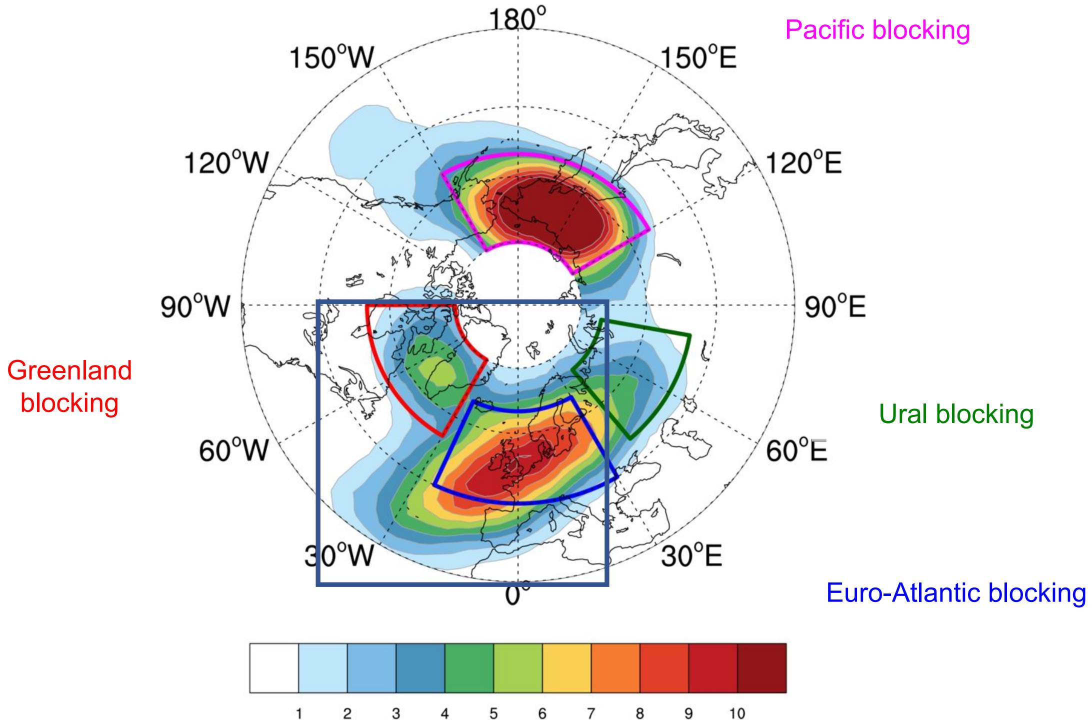
Blocking detection

-
  - Blocking refers to a warm-core anticyclone remaining quasi-stationary throughout the extratropical troposphere for minimum of 4-5 days
- Its frequently triggers extreme weather events, such as prolonged cold spells, heat waves, droughts and floods
- Computation

- $GHGN(\lambda, \varphi_0, t) = \frac{Z500(\lambda,\varphi_N,t) - Z500(\lambda,\varphi_0,t)}{\varphi_N - \varphi_0} < -10$ gpm
- $GHGS(\lambda, \varphi_0, t) = \frac{Z500(\lambda,\varphi_0,t) - Z500(\lambda,\varphi_S,t)}{\varphi_0 - \varphi_S} > 0$ gpm
- the gradients over 15 degrees of latitude, with $\varphi_N \epsilon [50,90]°N, \varphi_0 \epsilon [35,75]°N, \varphi_S \epsilon [20,60]°N$
- Blocking region should be larger than 1×10^6 km^2 and the event should persist at least 4 days

Blocking frequency in NCEP

DJF-mean blocking frequency
NCEP-NCAR reanalysis (1950-2009 climatology)



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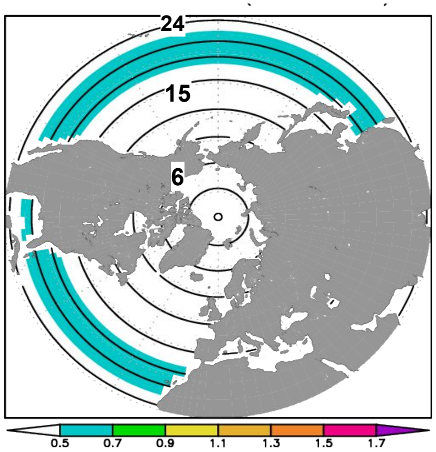
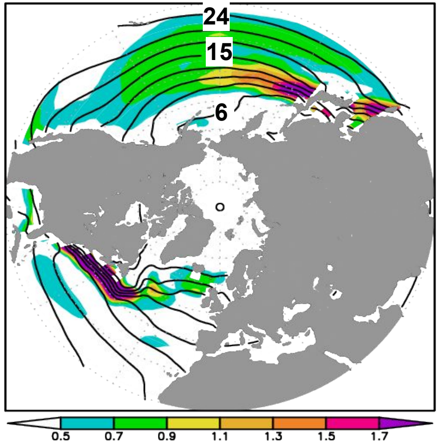
Experiments setup using MAECHAM5 model

a) SST and SST-gradient: NF-experiment (ZUNF)

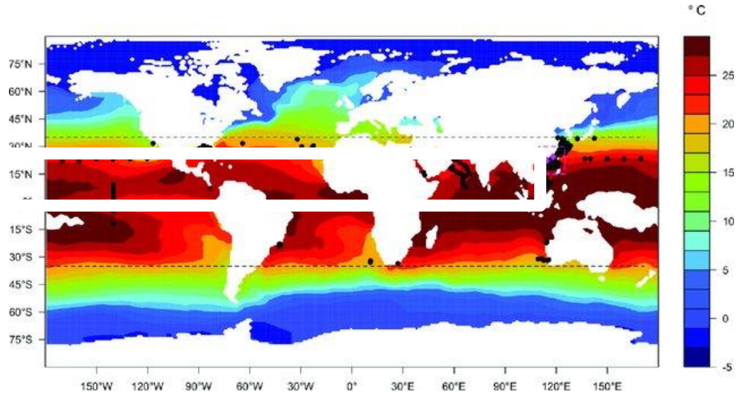


b) SST and SST-gradient: BCF-experiment (EXT_ALL)

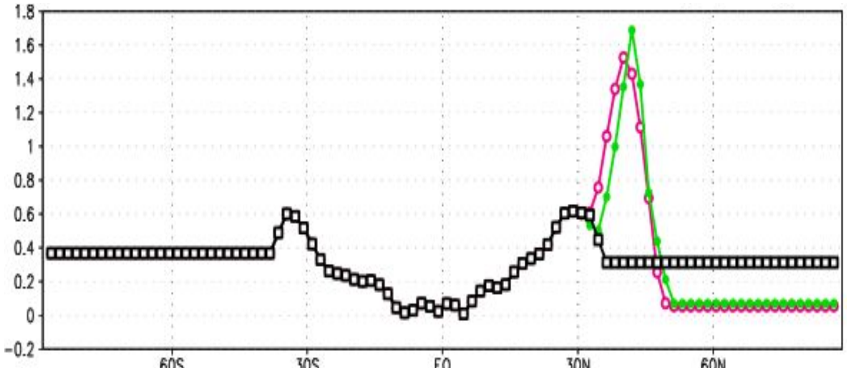


Omrani et. al 2019
Cheung et al. 2023

b) SST-gradient: and zonal tropical SST-asymmetry (FULL)



c) Zonally averaged SST-gradient in NF-, ASF- and PSF-experiments



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Experiments setup

Table 1. List of semi-idealised atmospheric-only experiments.

Experiment	Tropical SST	Extratropical Atlantic SST	Extratropical Pacific SST
Zonally uniform tropical SST/No front (ZUNF, NF).	Zonally Uniform	No front	No front
Realistic SST forcing in Northern Hemisphere and tropics (FULL)	Realistic	Realistic	Realistic
Realistic extratropical SST forcing (EXT_ALL)	Zonally Uniform	Realistic	Realistic
Realistic tropical SST forcing (TROP_ALL)	Realistic	No front	No front
Realistic extratropical Atlantic SST forcing (EXT_ATL)	Zonally Uniform	Realistic	No front
Realistic extratropical Pacific SST forcing (EXT_PAC)	Zonally Uniform	No front	Realistic

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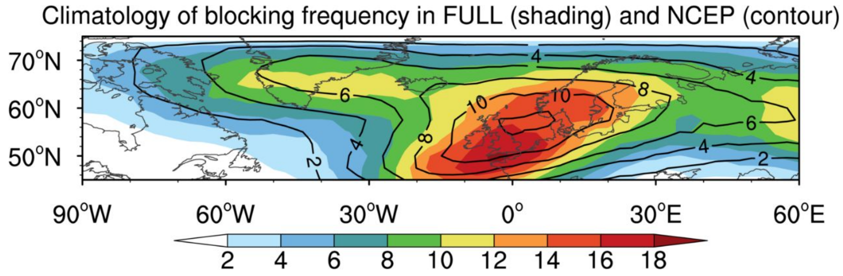
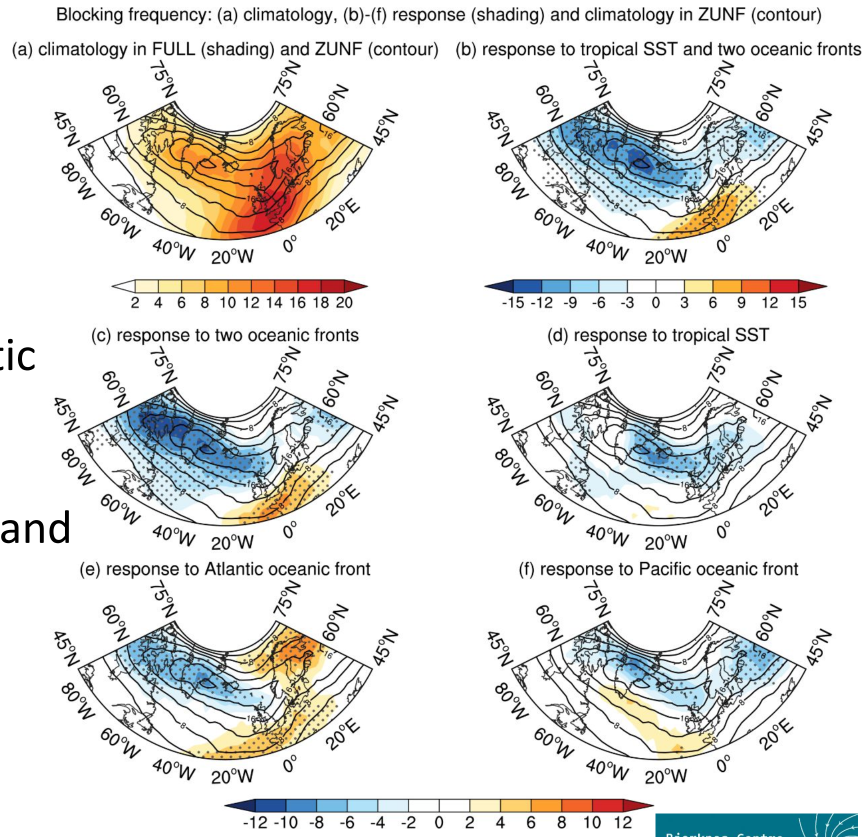
Impact of the extratropical SST-fronts and tropical zonal SST-asymmetry on North Atlantic blocking frequency (winter)





- Without the SST-front and tropical SST-asymmetry, the primary blocking center shifts from Euro Atlantic into Greenland
- Combined effect of the midlatitude North Atlantic and Pacific SST-fronts largely improve the blocking frequency. The tropical SST-asymmetry acts to improve the blocking frequency further.
- Both Atlantic and Pacific SST-fronts are required.

Midlatitude oceanic SST-front can influence the blocking frequency by affecting

(1) the dynamics of individual blocking events

(2) the background storm-track activity

(3) the overall atmospheric circulation.

Impact on the dynamics of individual blocking events

- $\frac{\partial Z_{500}}{\partial t} \approx -\frac{f}{g}\nabla^{-2}\left(\nabla_{\boldsymbol{H}} \cdot (\boldsymbol{V}\xi_a)\right)$

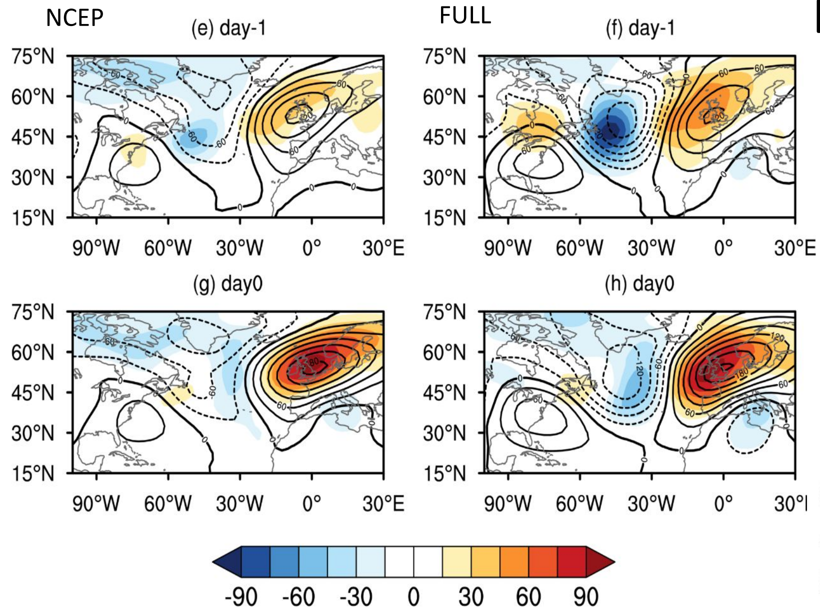
$$\nabla_H \cdot (\boldsymbol{V}\xi_a) = \underbrace{-\nabla_H \cdot \left(\overline{\boldsymbol{V}}\overline{\xi_a}\right)}_{(i)} \underbrace{-\nabla \cdot (\boldsymbol{V}'_{HP}\xi'_{\mathrm{HP}}) - \nabla_H \cdot \left(\overline{\boldsymbol{V}}\xi'_{HP} + \boldsymbol{V}'_{HP}\overline{\xi_a}\right)}_{(ii)}$$

- $\underbrace{-\nabla_H \cdot (\boldsymbol{V}'_{LP}\xi'_{LP}) - \nabla_H \cdot \left(\overline{\boldsymbol{V}}\xi'_{LP} + \boldsymbol{V}'_{LP}\overline{\xi_a}\right)}_{(iii)} \underbrace{-\nabla_H \cdot (\boldsymbol{V}'_{HP}\xi'_{LP} + \boldsymbol{V}'_{LP}\xi'_{HP})}_{(iv)}$

- Z500 tendency as function of the vorticity flux divergence, which can be decomposed into the contribution of the mean state (i) high-frequency (ii) and low-frequency (iii) transient eddies and cross frequency component (iv) reflecting the non-linear interaction between the low and the high frequency eddies

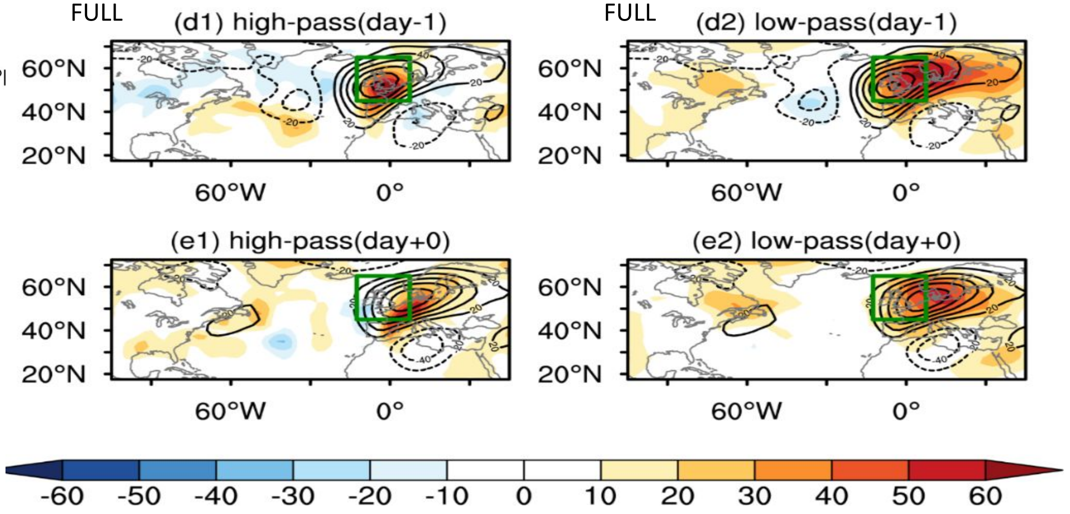
Dynamics of the individual Euro-Atlantic blocking events (Winter)

Euro-Atlantiic. Z500 (Contour) and Z500-tendency (shading)



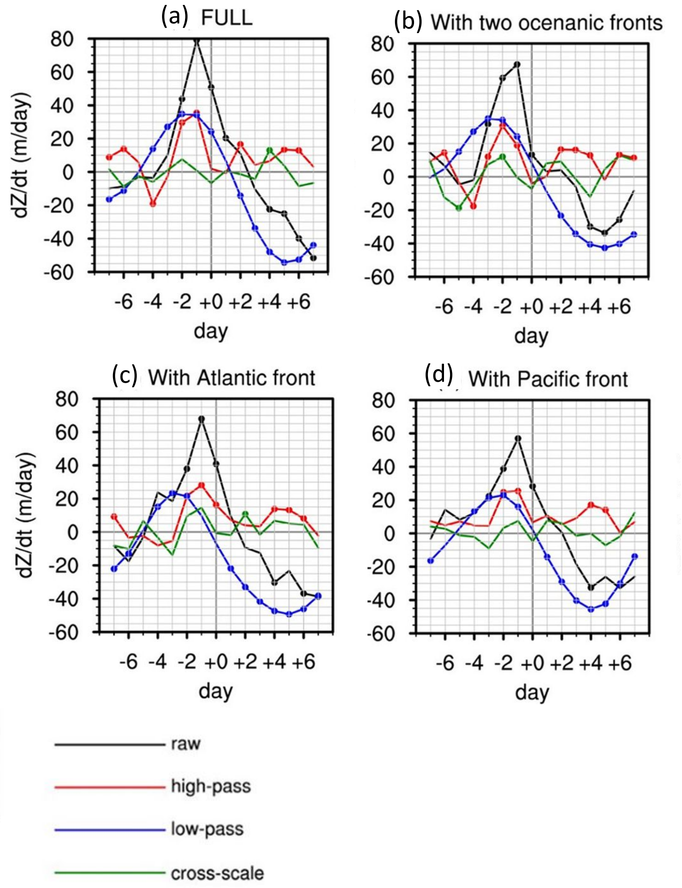
Euro-Atlantic Blocking:

- Pattern and tendency at lag -1 are similar to Scandinavian blocking regime with west east wave train showing pronounced trough in the North Atlantic and ridge in the North Euro-Atlantic region



- This trough ridge system is maintained by both high and low frequency eddies

Dynamics of the individual Euro-Atlantic blocking events (Winter)



- High- frequency eddy-forcing is mainly contributed by Atlantic oceanic fronts, whereas low-frequency eddy-forcing of Euro-Atlantic blocking is due to the joint effect of the Atlantic and Pacific oceanic fronts (not shown).

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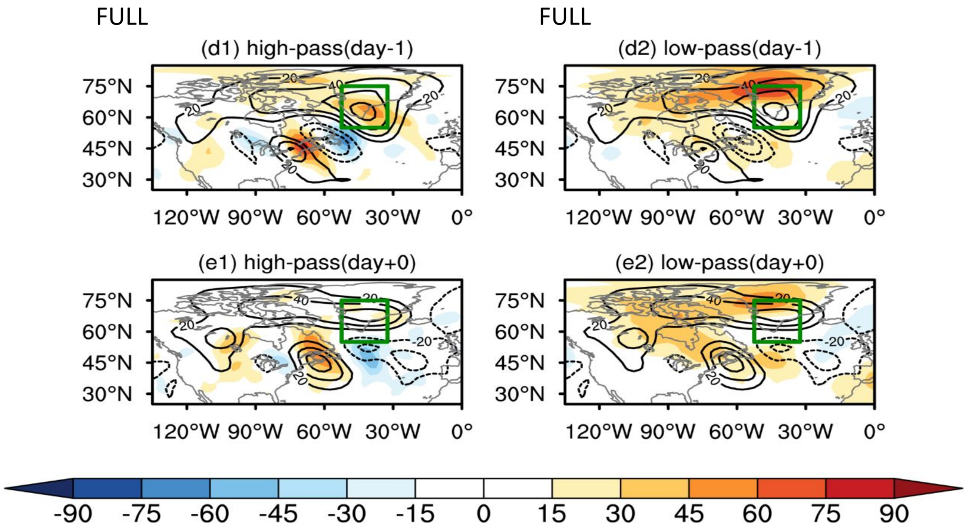
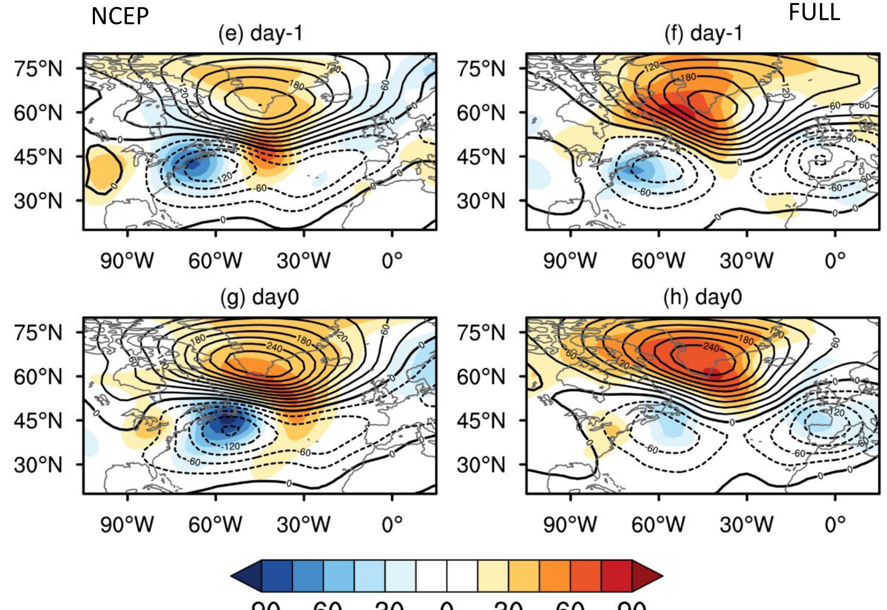
Dynamics of the individual Greenland blocking events (Winter)

- Pattern projects on negative NAO.
- Tendency show southwest-northeast shifted ridge-trough-ridge wave train system

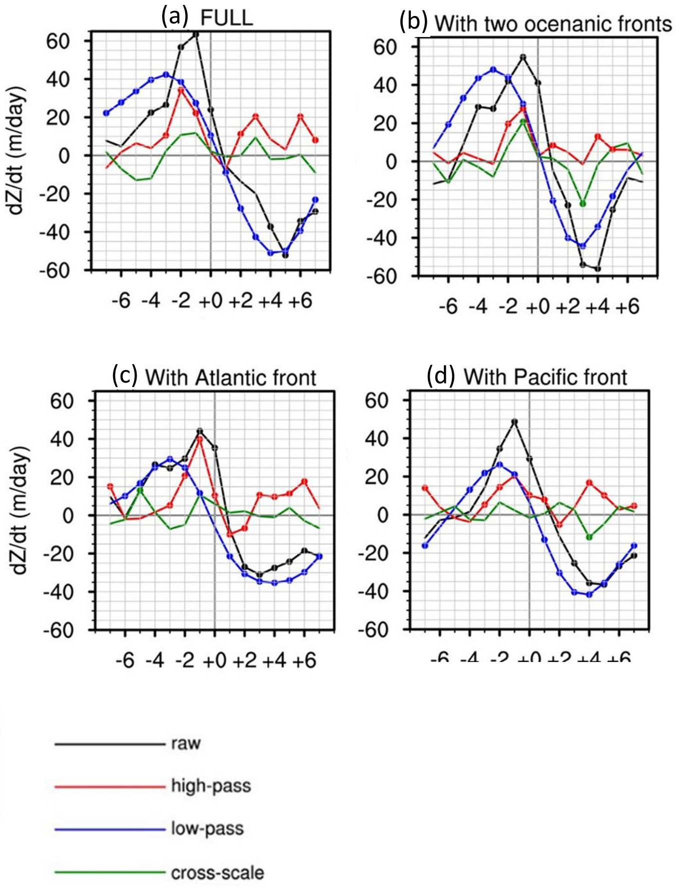


Greenland clocking. Z500 (Con.), its tendency (shad.)



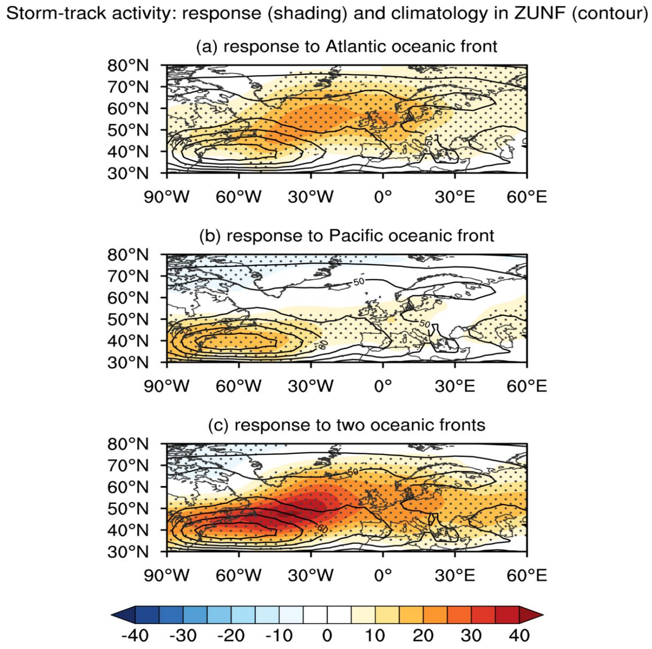
- Both low and high frequency eddies are important

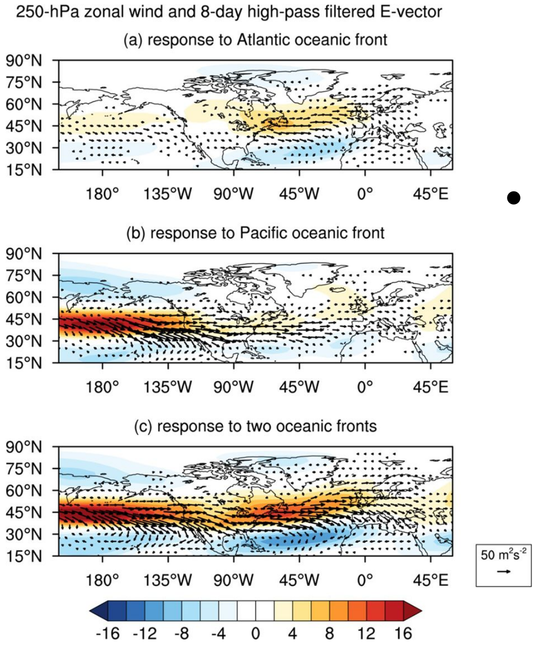
Dynamics of the individual Greenland blocking events (Winter)



- North Atlantic midlatitude oceanic fronts play a dominant role for the synoptic-scale forcing, whereas the low-frequency forcing is contributed by both Atlantic and Pacific SST-fronts (not shown).

SST-front impact (on Greenland blocking) via the storm track and eddy-driven jet (Winter)

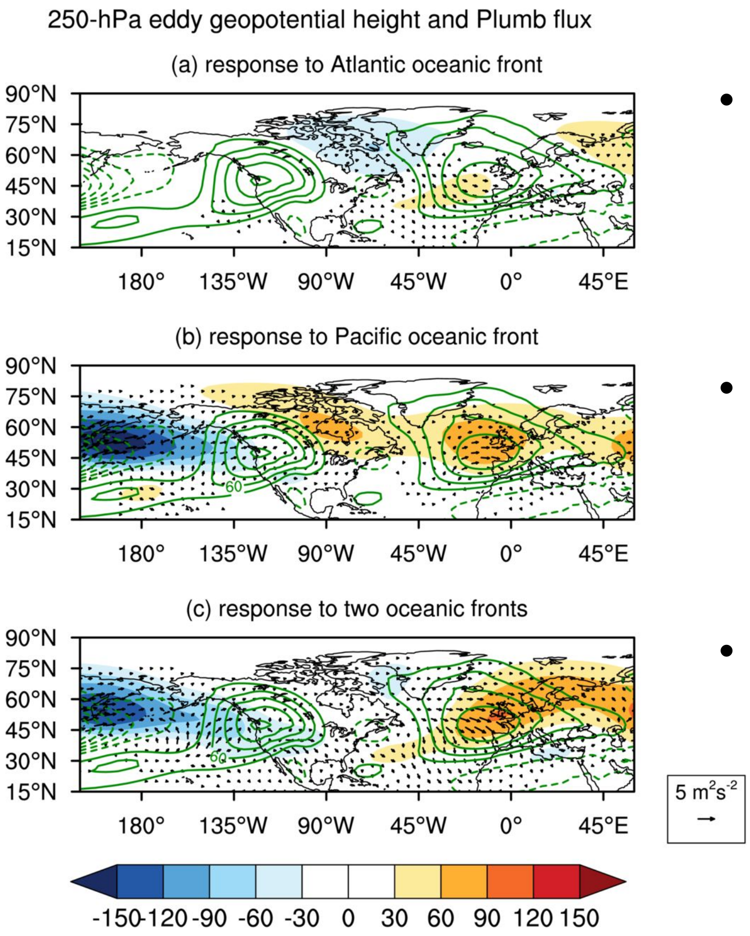




- Atlantic and Pacific SST-front maintain jointly the storm-track and eddy-driven jet

- The strengthening of the storm-track and eddy-driven jet are associated with low-pressure over Greenland that favorizes a reduced blocking frequency over Greenland

SST-front impact (on Euro-Atlantic blocking) via storm-track and ridge downstream (Winter)



- For the Euro-Atlantic blocking, we need not only migratory cyclone (storm tracks), but also quasi-stationary ridge downstream that act to block the downstream migration of storms into Europe.

- Atlantic and Pacific SST-front maintain jointly not only the storm-track activities but also the quasi-stationary ridge downstream, where the contribution of the Pacific SST-front is higher.

- The combined effect of the storm-track and ridge downstream favorize the development of Euro-Atlantic blocking.

Conclusions

Impact of SST-fronts on the wintertime North Atlantic Blocking:

- The SST-fronts and tropical SST-asymmetry improve the wintertime North Atlantic blocking frequency with the joint impact of the Atlantic and Pacific SST-front playing crucial role
- The Pacific SST-front reinforces the North Atlantic circulation storm track, eddy-driven jet and ridge in Europe, which favors the shift of primary blocking center from greenling into Euro Atlantic region making the blocking frequency realistic .
- The enhanced interaction between storm tacks and the European ridge in response to the join impact of Atlantic and Pacific SST-fronts favors the occurrence of Euro-Atlantic blocking.
- The strengthening of the Atlantic eddy-driven jet and storm tacks in response to join impact of Atlantic and Pacific SST-front reduces the Greenland blocking frequency (geostrophic balance).

- Omrani, N. E., Ogawa, F. & Nakamura, H. et al. Key role of the ocean western boundary currents in shaping the Northern Hemisphere climate. *Sci. Rep.* **9**, 3014 (2019).

- Cheung H N, Omrani N E, Ogawa F, Keenlyside N, Nakamura H, Zhou W. 2023. Pacific oceanic front amplifies the impact of Atlantic oceanic front on North Atlantic blocking. NPJ Clim Atmos Sci, 6: 61

Thank you!

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