Workshop Multi-annual to Decadal Climate Predictability in the North Atlantic-Arctic
(20-22 September 2021)

Multi-year Predictability of the Atmospheric Blocking Stemming from the North Atlantic Ocean

Young-Oh Kwon[1], Panos Athanasiadis[2], Hyodae Seo[1], Caroline Ummenhofer[1], Terry Joyce[1], Steve Yeager[3], Alessio Bellucci[2], David Smith[4], and Stefano Tibaldi[2]

(1: WHOI, USA; 2: CMCC, Italy; 3: NCAR, USA; 4: Northeastern Univ, USA)

WOODS HOLE OCEANOGRAPHIC INSTITUTION

BLUE ACTION

Two parts of today's talk

Part I. Does the AMV influence the low-frequency variability of the blocking?

Kwon, Y.-O., H. Seo, C.C. Ummenhofer, and T.M. Joyce, 2020: Impact of Multidecadal Variability in Atlantic SST on Winter Atmospheric Blocking. *J. Climate*, **33**, 867-892, https://doi.org/10.1175/JCLI-D-19-0324.1.

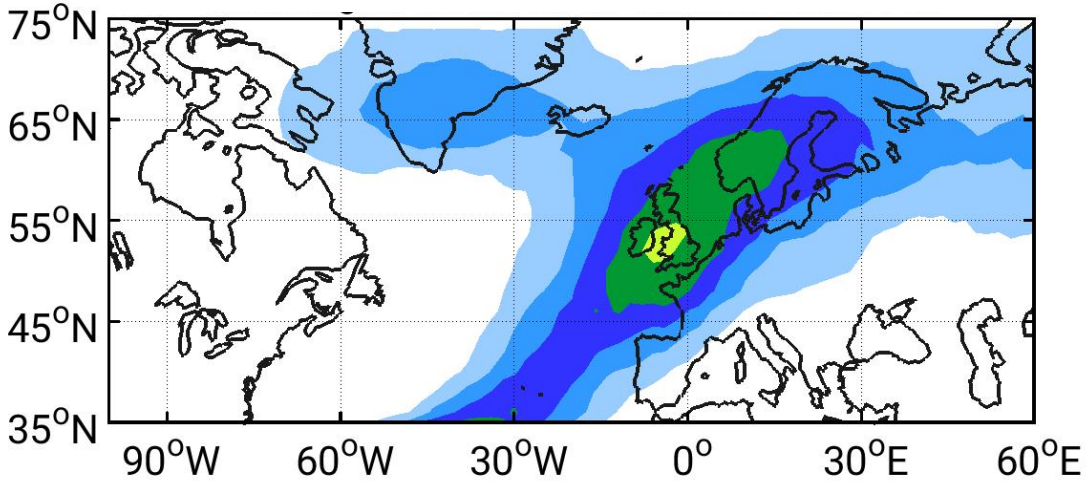
Part II. Can the impact from the AMV render multi-year predictability of the blocking?

Athanasiadis, P., S. Yeager, Y.-O. Kwon, A. Bellucci, D.W. Smith, and S. Tibaldi, 2020: Decadal predictability of North Atlantic blocking and the NAO. *npj Climate and Atmospheric Science*, **3**, https://doi.org/10.1038/s41612-020-0120-6.

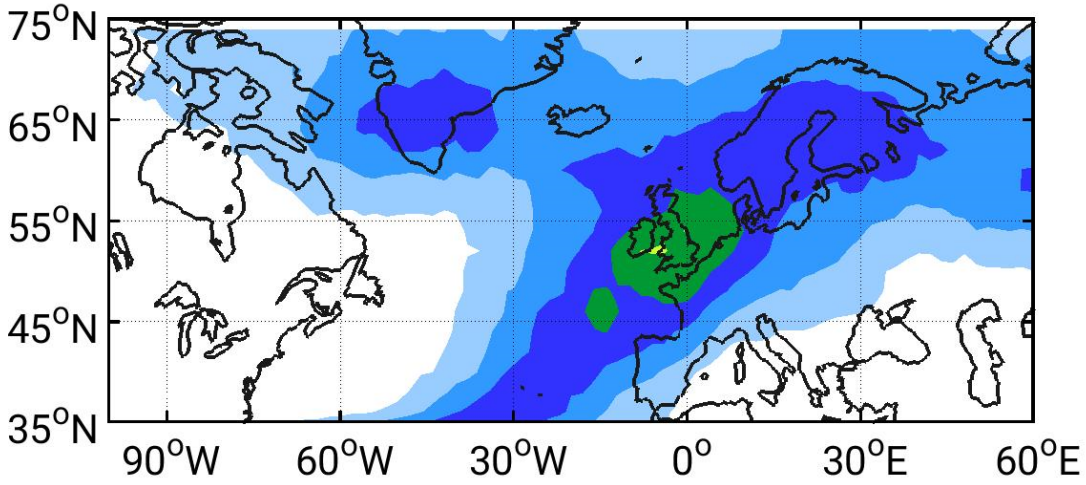
Winter (DJFM) number of blocking days

1901-2010 from the NOAA 20th Century Reanalysis
based on Scherrer et al. (2006)'s 2-D blocking definition applied to daily Z500

Climatological mean



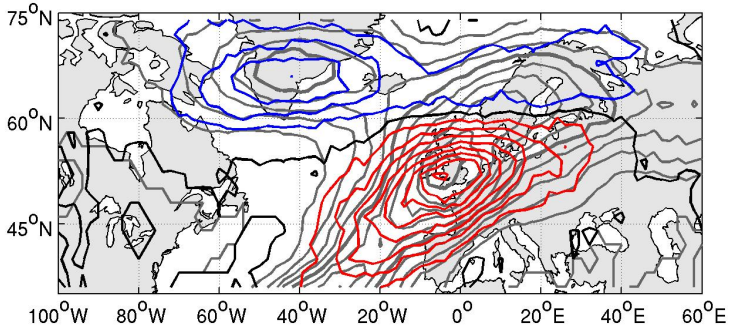
Interannual standard deviation

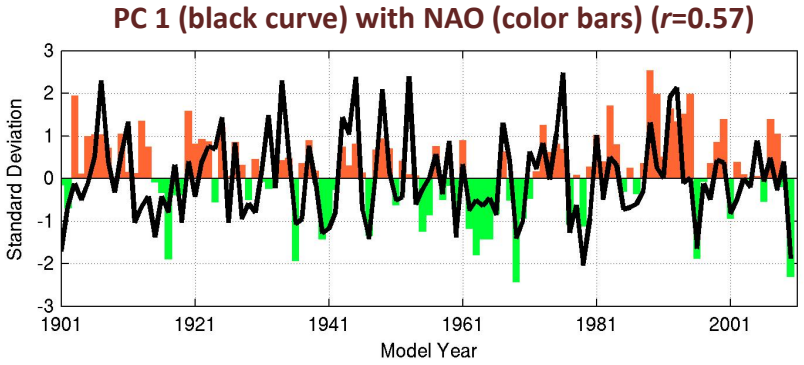


EOFs of the DJFM number of blocking days

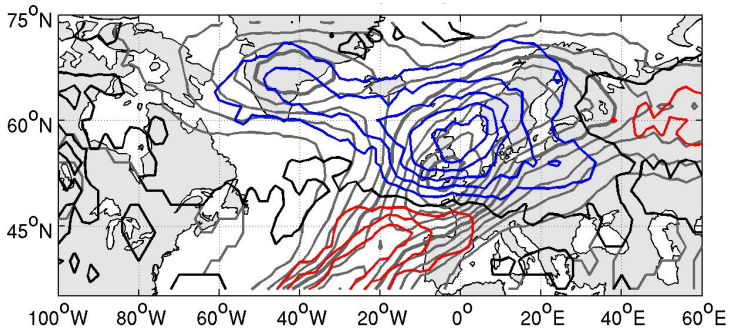
(1901-2010 from the 20CR ensemble mean field)

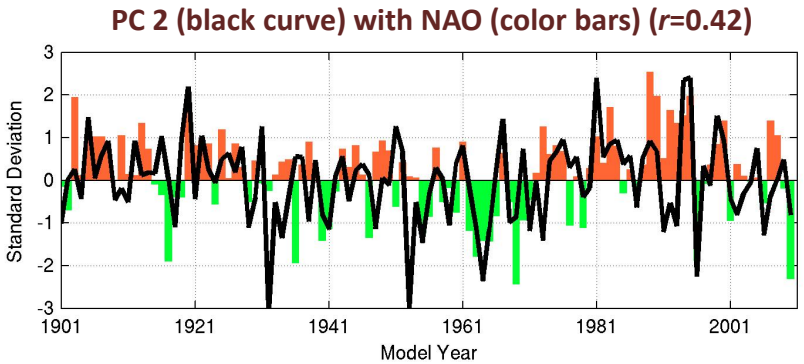
EOF 1
(19.1%)



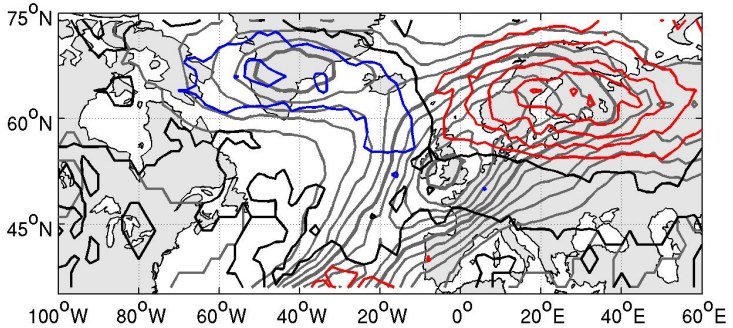


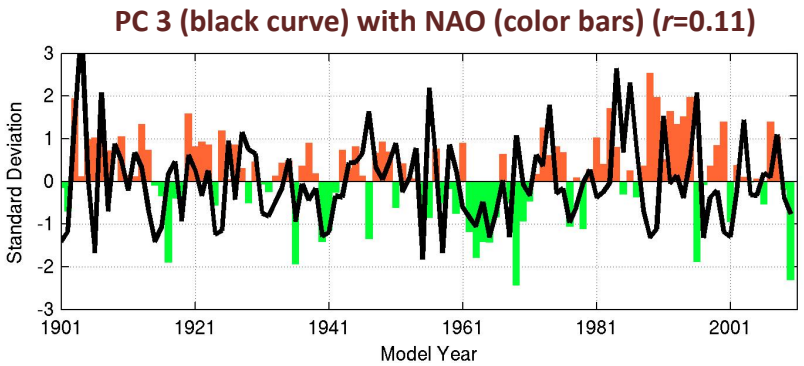
EOF 2
(10.7%)





EOF 3
(7.6%)



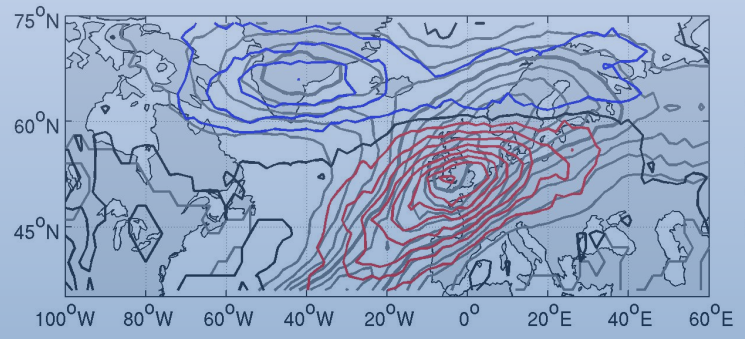


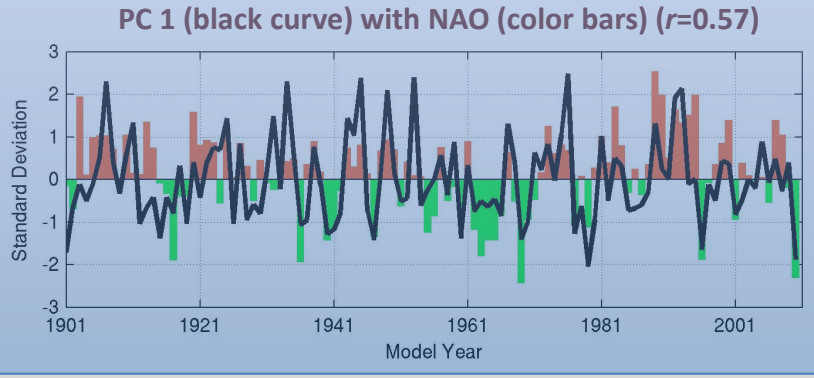
Linearly detrended / Contour Interval: 1 day / Blue (red): negative (positive) anomalies / Gray: mean

EOF2 is best correlated with the AMV time series

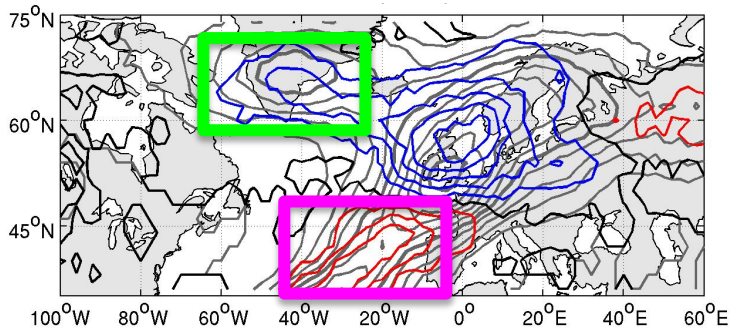
EOFs of the DJFM number of blocking days (1901-2010 20CR ensemble mean field)

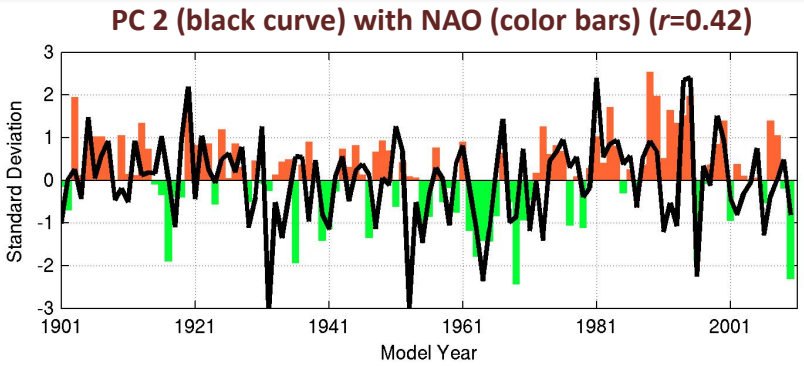
EOF 1
(19.1%)



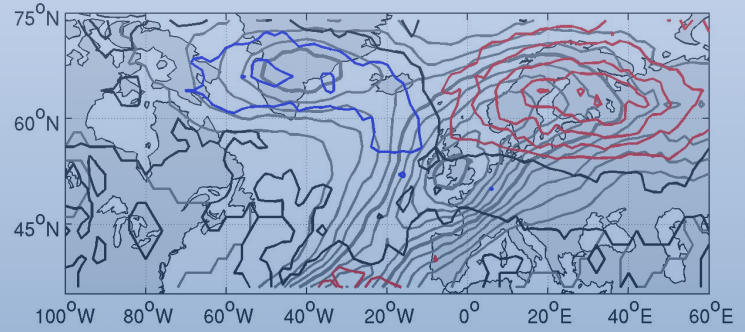


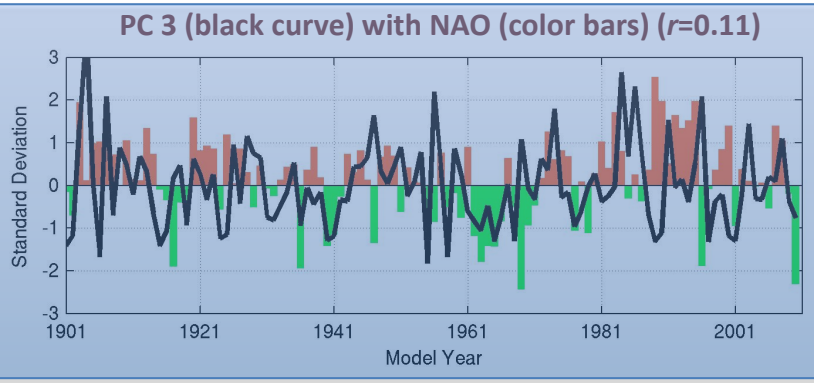
EOF 2
(10.7%)





EOF 3
(7.6%)

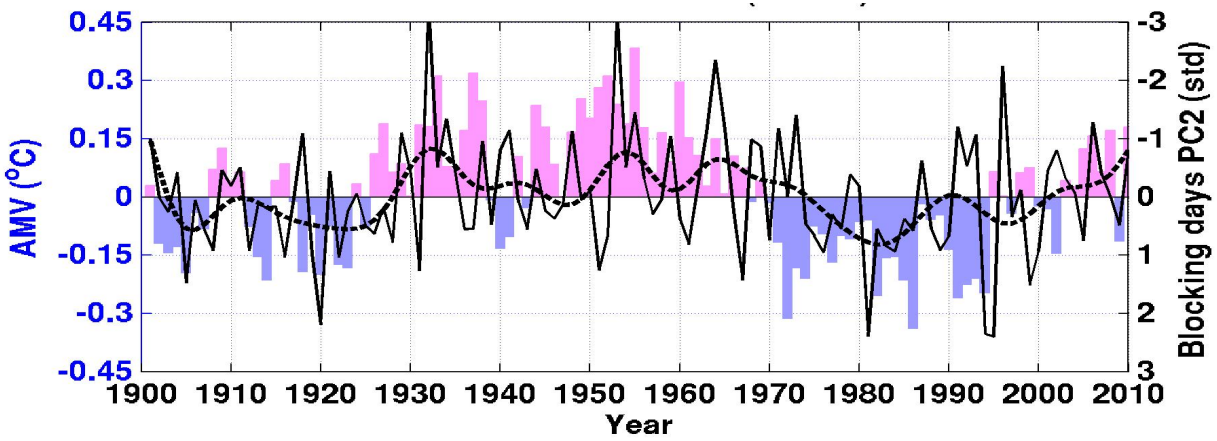




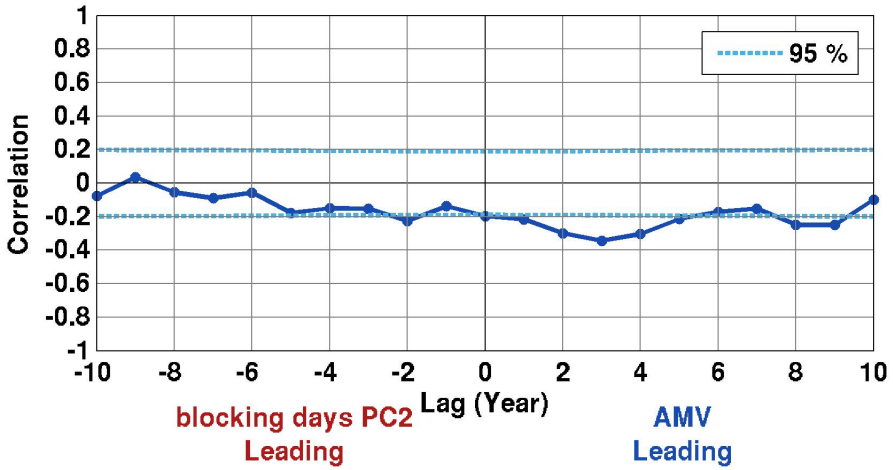
Linearly detrended / Contour Interval: 1 day / Blue (red): negative (positive) anomalies / Gray: mean

AMV leads the blocking days EOF2 by 3-4 years

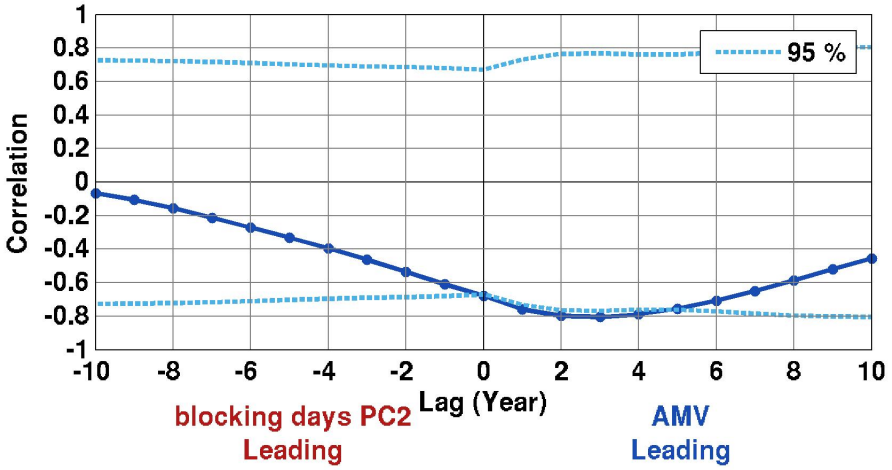
DJFM number of blocking days **PC2** (black lines; dashed for 10-yr low-pass)
vs. annual mean **AMV** (color bars)



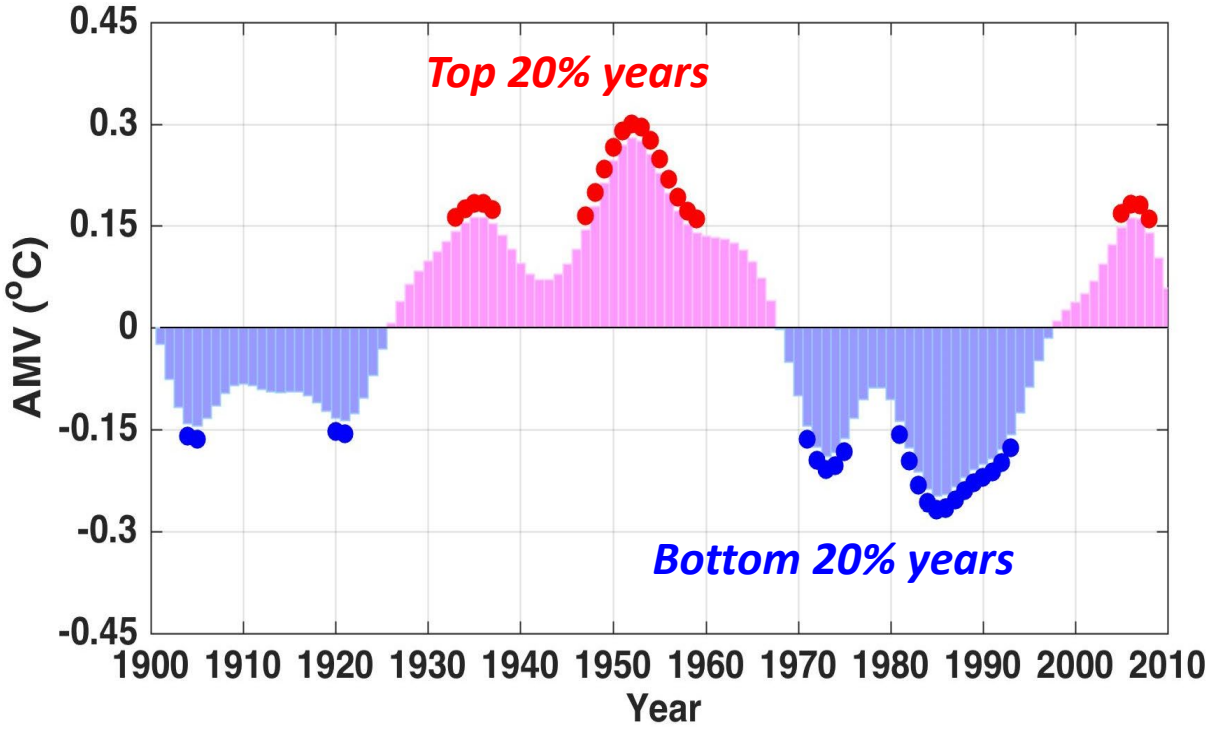
Unfiltered lag-correlation



10-yr low-pass filtered lag-correlation



Composite analysis for the *top 20%* and *bottom 20%* years of the 10-yr low-pass filtered AMV index is used to examine the detail (1901-2010)



AMV index is calculated and detrended following Ting et al. (2009) / Häkkinen et al. (2011)

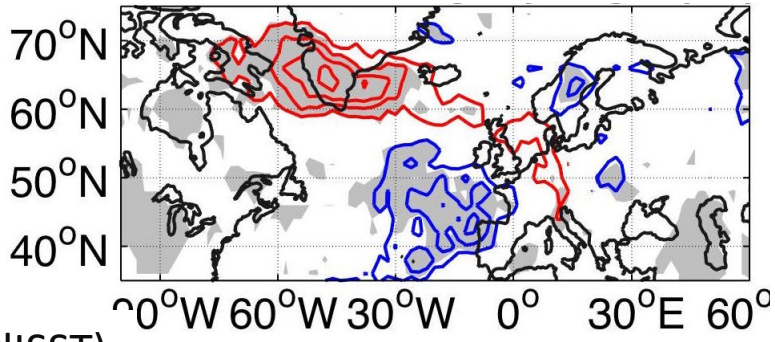
For the composite,

- tropical Indo-Pacific influence is removed based on linear regressions *only when* AMV is leading
- the atmospheric variables are 1-2-1 smoothed and linearly detrended, but not low-pass filtered.
- Statistical significance is based on 10,000 random permutations in 2-yr blocks

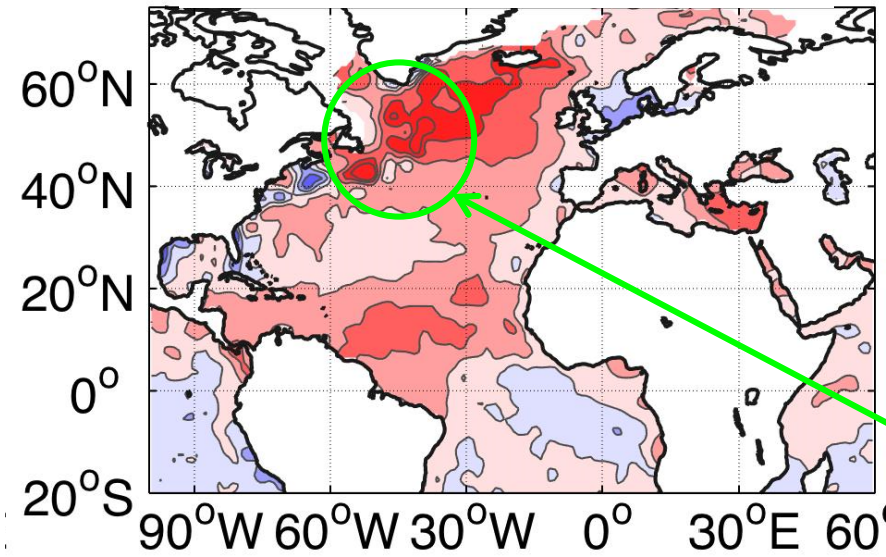
Warm SST and ocean-to-atmosphere heat flux in w. subpolar gyre is associated with the blocking anomalies.

Lag-composite patterns when *warm AMV leads by 4 yrs* (1901-2010)

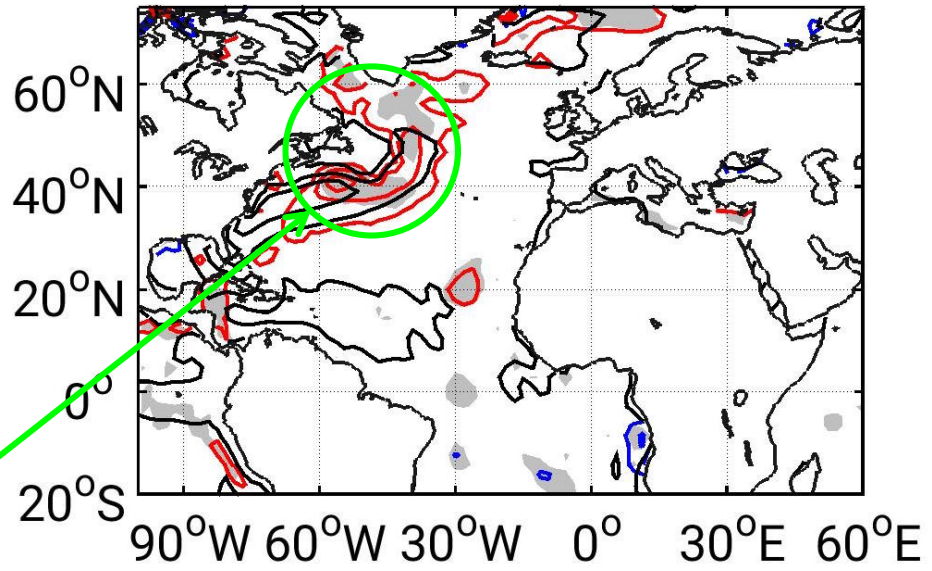
DJFM Blocking Days (C.I.: 1 day)



DJFM SST (C.I.: 0.1°C; HadISST)



DJFM Turbulent heat flux (C.I.: 5 W/m^2; 20CR)
Positive = ocean to atmosphere



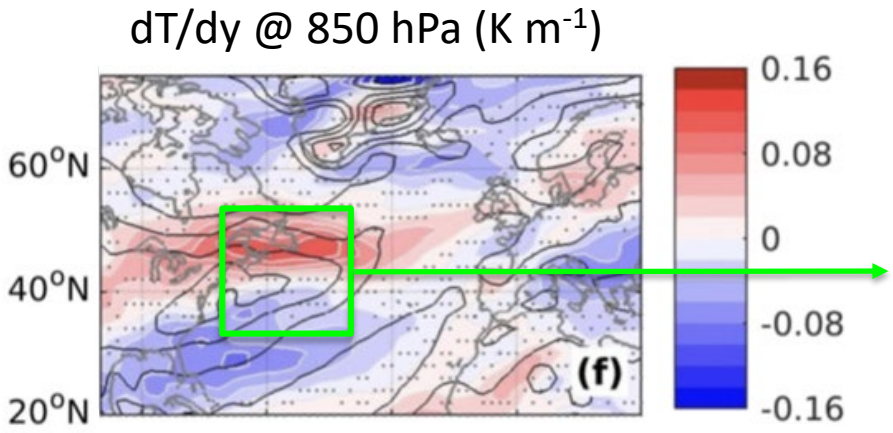
Damping SST' by heat flux in western subpolar gyre & North Atlantic Current

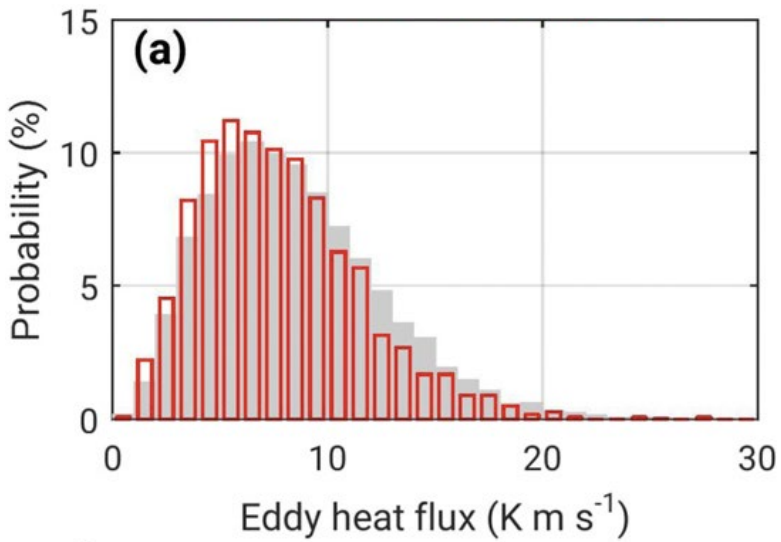
Blue (red): negative (positive) anomalies

Black: Climatological mean (C.I.= 100W/m^2)

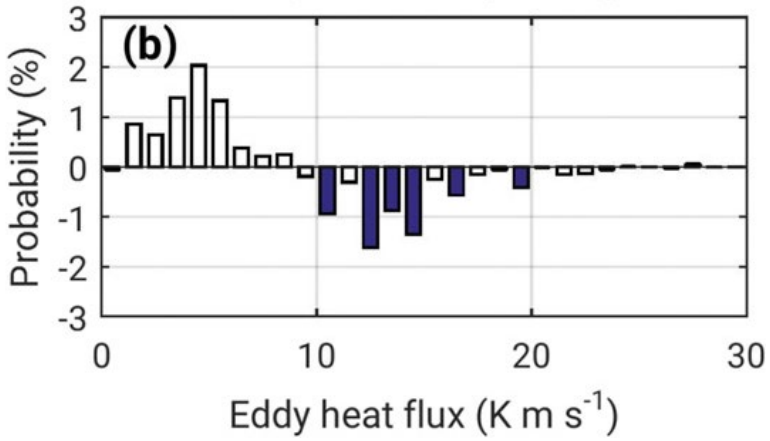
AMV+ SST forcing weakens the low-level dT/dy and $\overline{v'T'}$.

Warm AMV leads by 7 yrs





Daily histogram of $\overline{v'T'}$
@ 850hPa, 30°-50°N, 40°-70°W
(red: yrs following AMV, gray: all yrs)

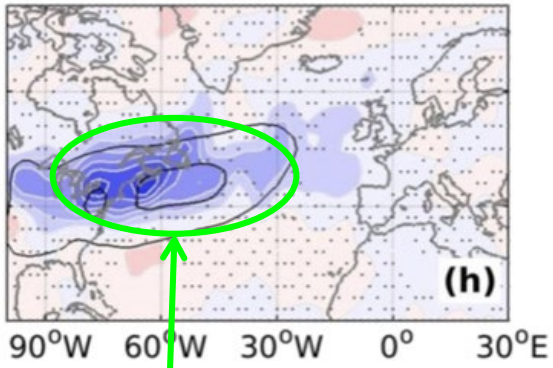


Difference daily histogram of $\overline{v'T'}$
(red minus gray)

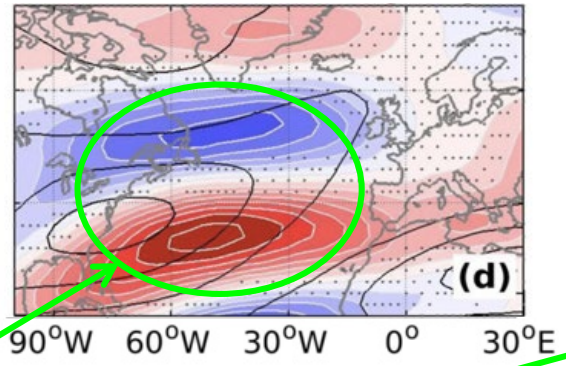
Weaker storm-track activity leads to southward shift of the eddy-driven jet.

Lag-composite patterns when *warm AMV leads by 7 yrs*

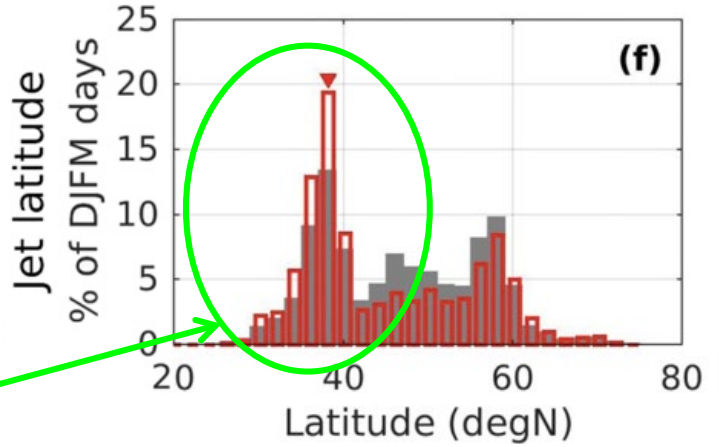
850hPa $\overline{v'T'}$
(C.I.: 0.2 K m/s)



U850
(C.I.: 0.5 m/s)



Daily Jet latitude
(75°W -15 ° E)



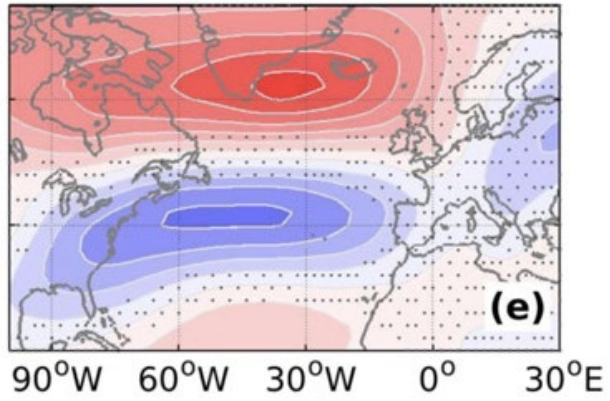
Blue (red): negative (positive) anomalies
Black: Climatological mean

Grey: all years; Red: 7 yrs lagging AMV+
Triangles: significant peak at 95%

Storm track weakens and Jet shift southward

Favors the Rossby wave breaking over Greenland, thus more blocking.

Z500 (C.I.: 5m)



AMV ⇨ **Storm-track activity** ⇨ **Eddy-driven jet latitude** ⇔ **Rossby wave breaking** ⇨ **Blocking**

Part II. Can the impact from the AMV render multi-year predictability of the blocking?

Athanasiadis, P., S. Yeager, Y.-O. Kwon, A. Bellucci, D.W. Smith, and S. Tibaldi, 2020: Decadal predictability of North Atlantic blocking and the NAO. *npj Climate and Atmospheric Science*, **3**, https://doi.org/10.1038/s41612-020-0120-6.

Community Earth System Model-Decadal Prediction-Large Ensemble (CESM-DP-LE; Yeager et al. 2018, BAMS)

- Retrospective multi-year prediction experiment using a fully coupled climate model.
- Initialized on each Nov. 1st for 1954-2015, thus 62 start dates.
- 40 ensemble members (round-off perturbation of atmospheric initial conditions)
- 122 month simulation for each start date and each ensemble member

→ (retrospective) predictions with lead years 1 – 10 for each start dates

→ 40 x year-1 prediction time series for 1955-2016
40 x year-2 prediction time series for 1956-2017
…
40 x year-10 prediction time series for 1964-2025

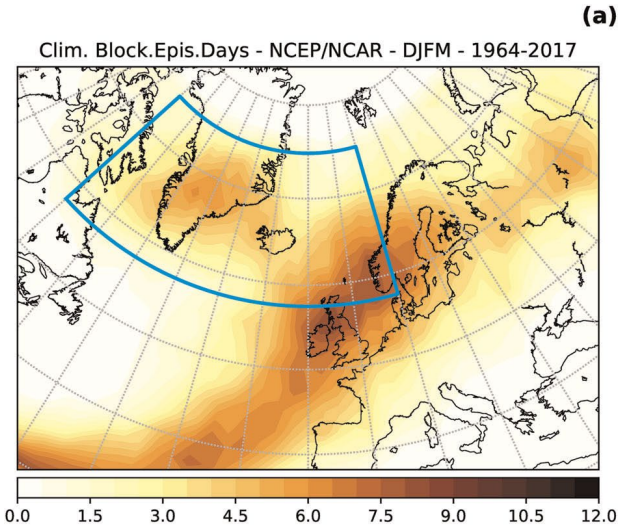
* There is a parallel 40 member uninitialized CESM-LE hindcast (1920-2005)+RCP8.5 projection (2006-2100).

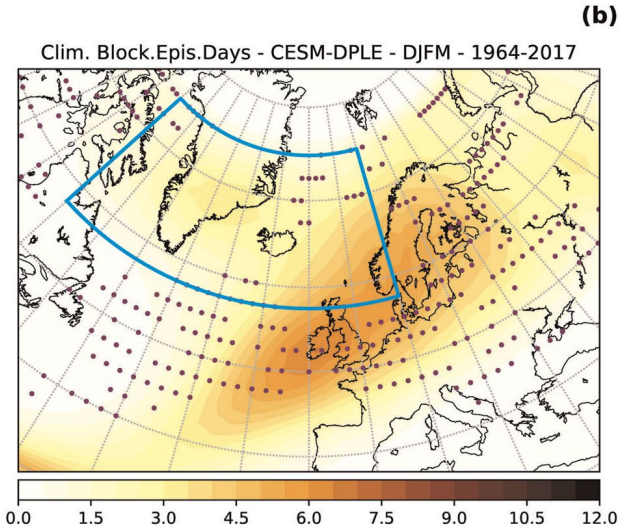
DJFM number of blocking days (1964-2016)

NCEP-NCAR R1

CESM-DP-LE

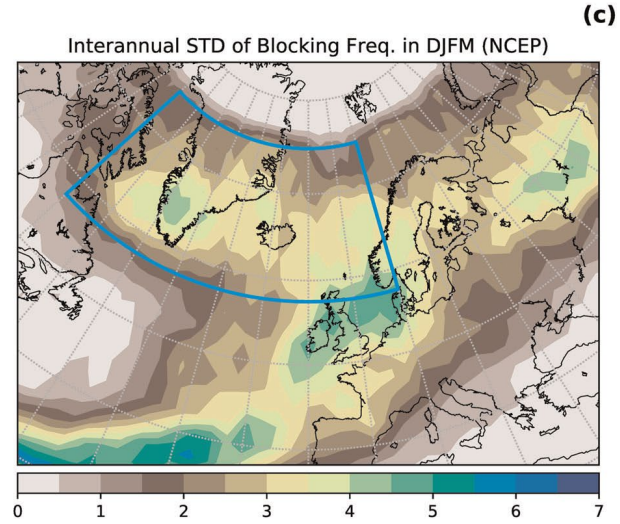
Climatological Mean

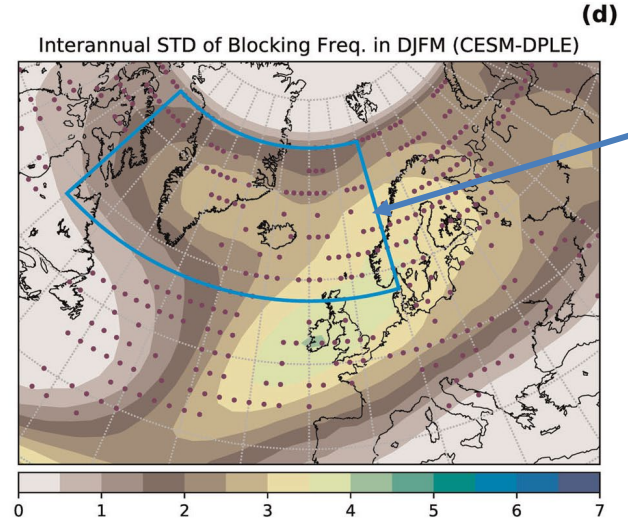




2-D blocking definition following Scherrer et al. (2006) using daily Z500

Interannual Standard Deviation





High Latitude Blocking

Maximum prediction skill (ACC=~0.65) is found for lead years 2-8 years.

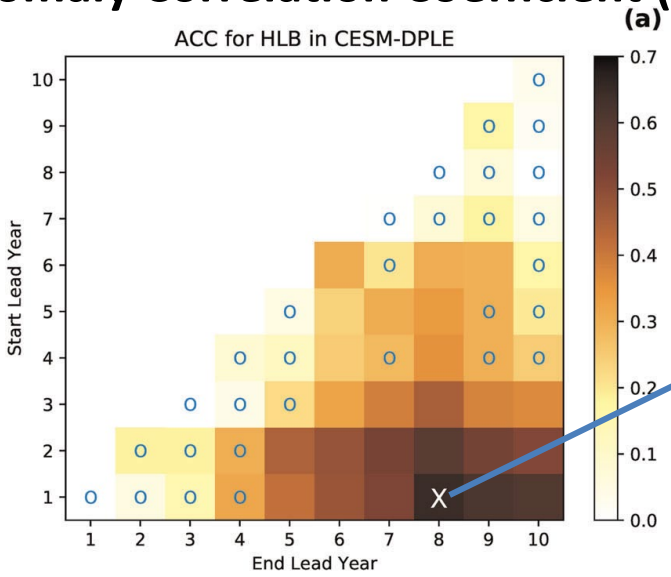
Anomaly Correlation Coefficient (ACC)

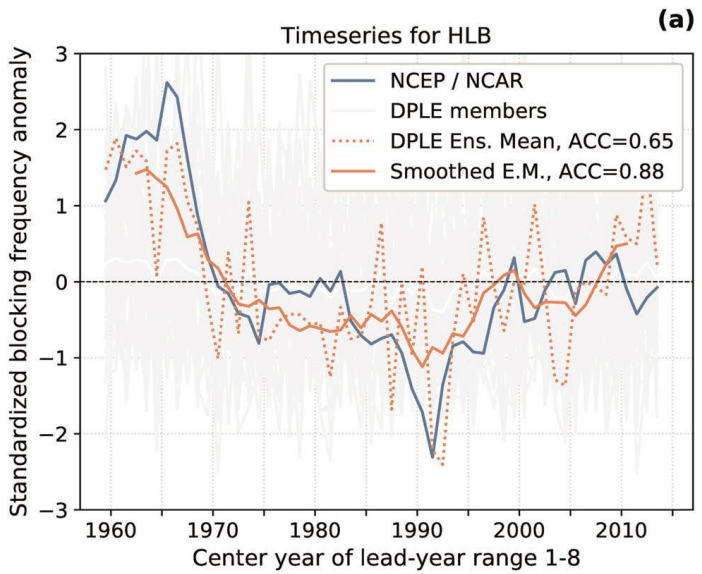
Time Series

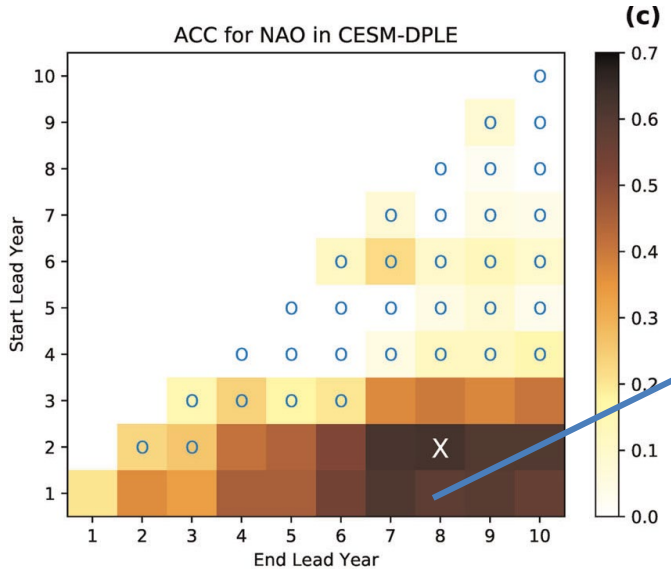
High Latitude Blocking

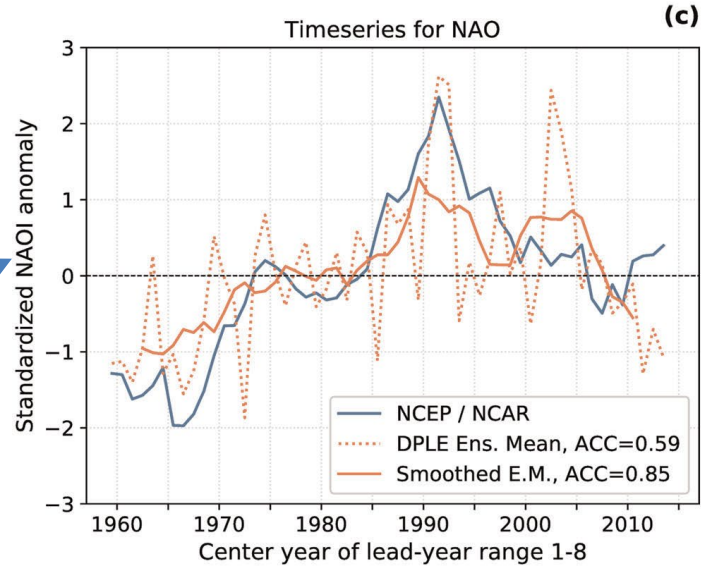
Blue circles: insignificant at 5%

NAO







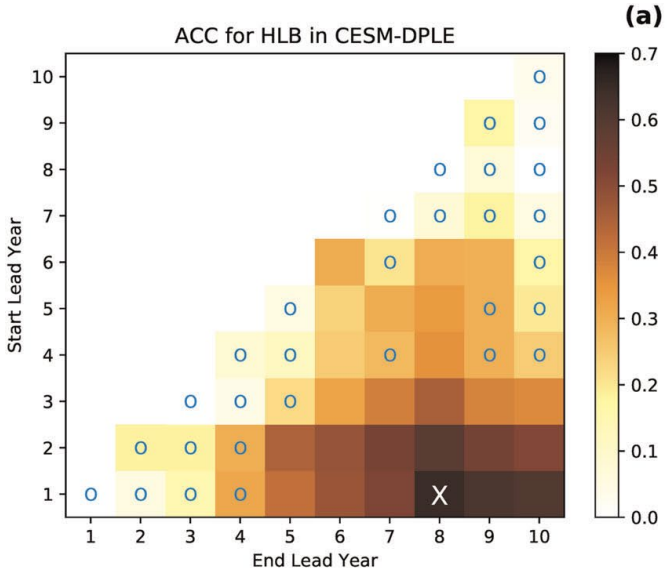


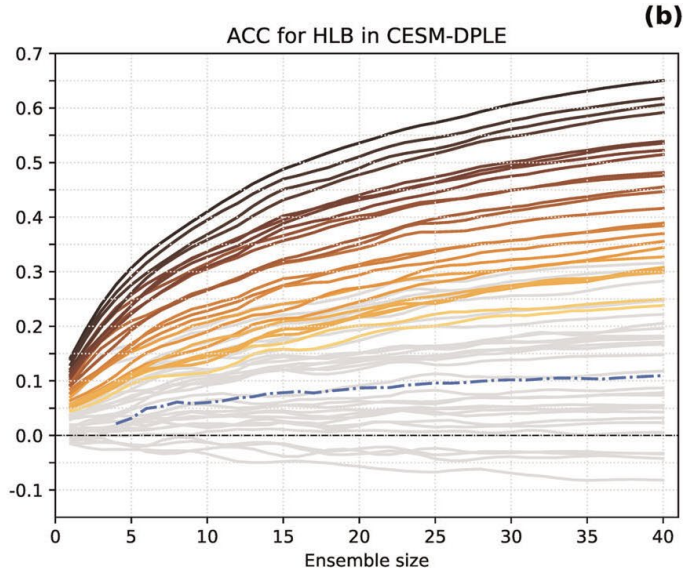
Prediction skill increases with the ensemble size.

ACC

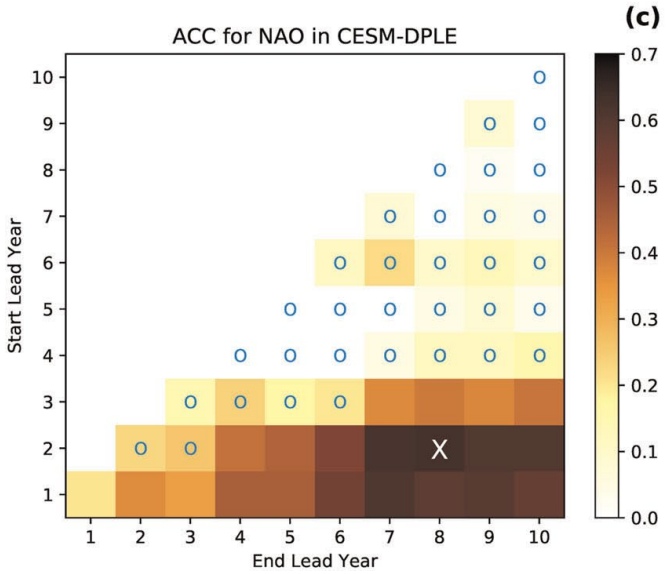
ACC vs. ensemble size

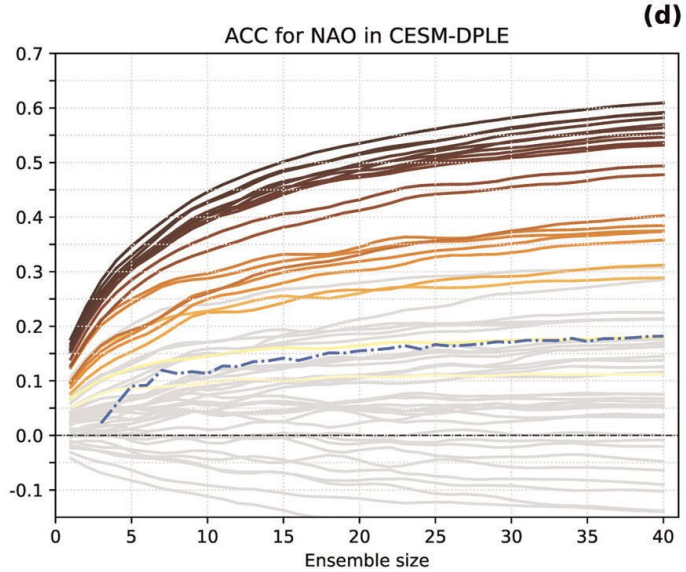
High Latitude Blocking





NAO

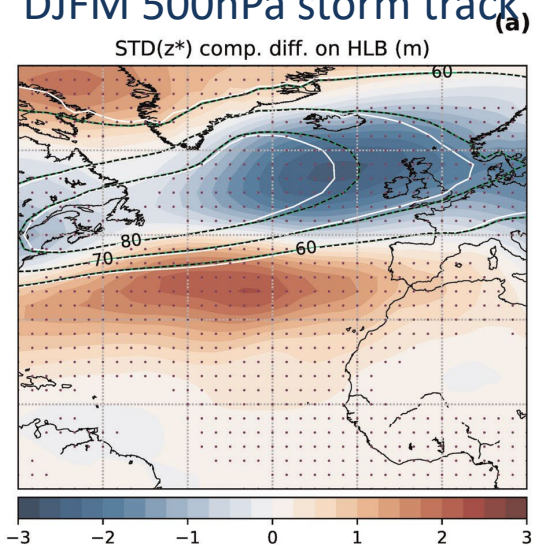




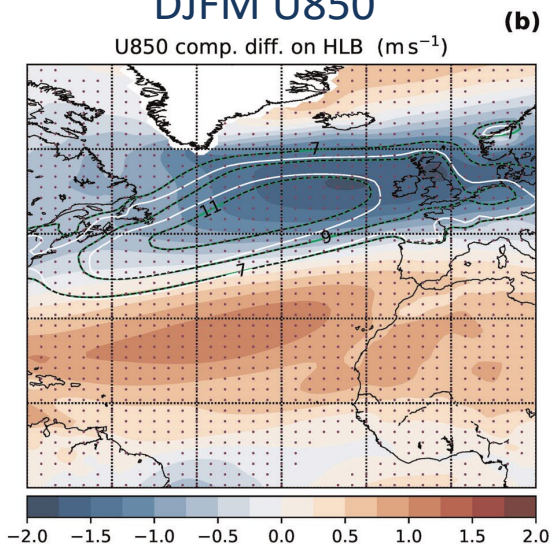
AMV ocean anomalies are the primary source of the predictability.

Composite differences based on years with high (top 10%) and low (bottom 10%) ensemble-mean high-latitude blocking

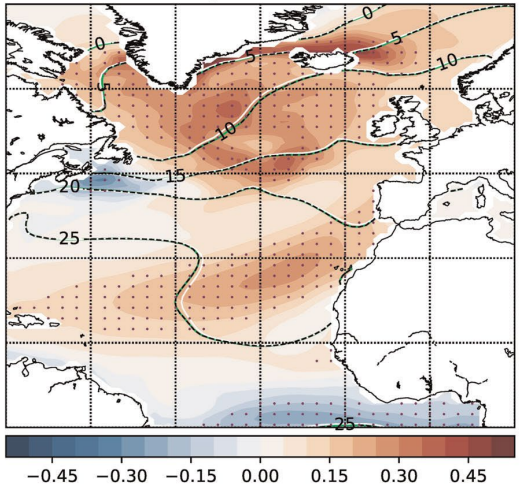
DJFM 500hPa storm track



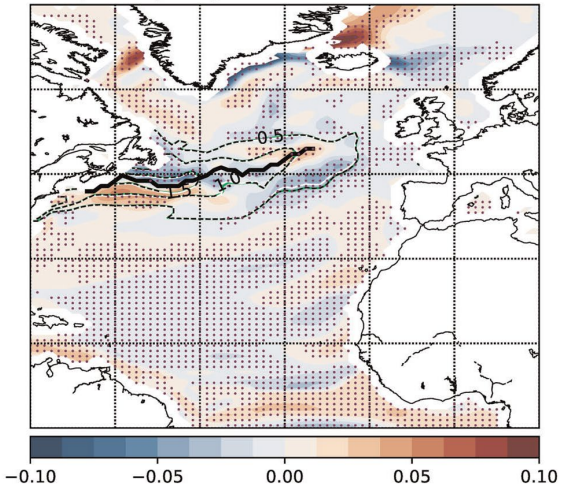
DJFM U850



SON SST



SON SST gradient



Summary: Part I+II

- Observational/reanalysis data suggest AMV positive (negative) phase drives more (less) blocking over the Greenland and less (more) over the Azores, which also results in the NAO negative (positive) phase.

- Observational/reanalysis data further suggest the evolutions of the SST anomalies and the associated blocking/NAO responses are different between AMV positive and negative phases.

- CESM-DP-LE exhibits unprecedented high multi-year prediction skill for the high-latitude North Atlantic blocking and NAO, based on the AMV impact on the atmospheric circulation.

Thank you!