Tropical-Extratropical teleconnections in climate models (EC-Earth ensemble simulations)

Susanna Corti

Contributions from

Irene Mavilia[1], Paolo Davini[2,1],Chinxue Yang and Jost von Hardenberg

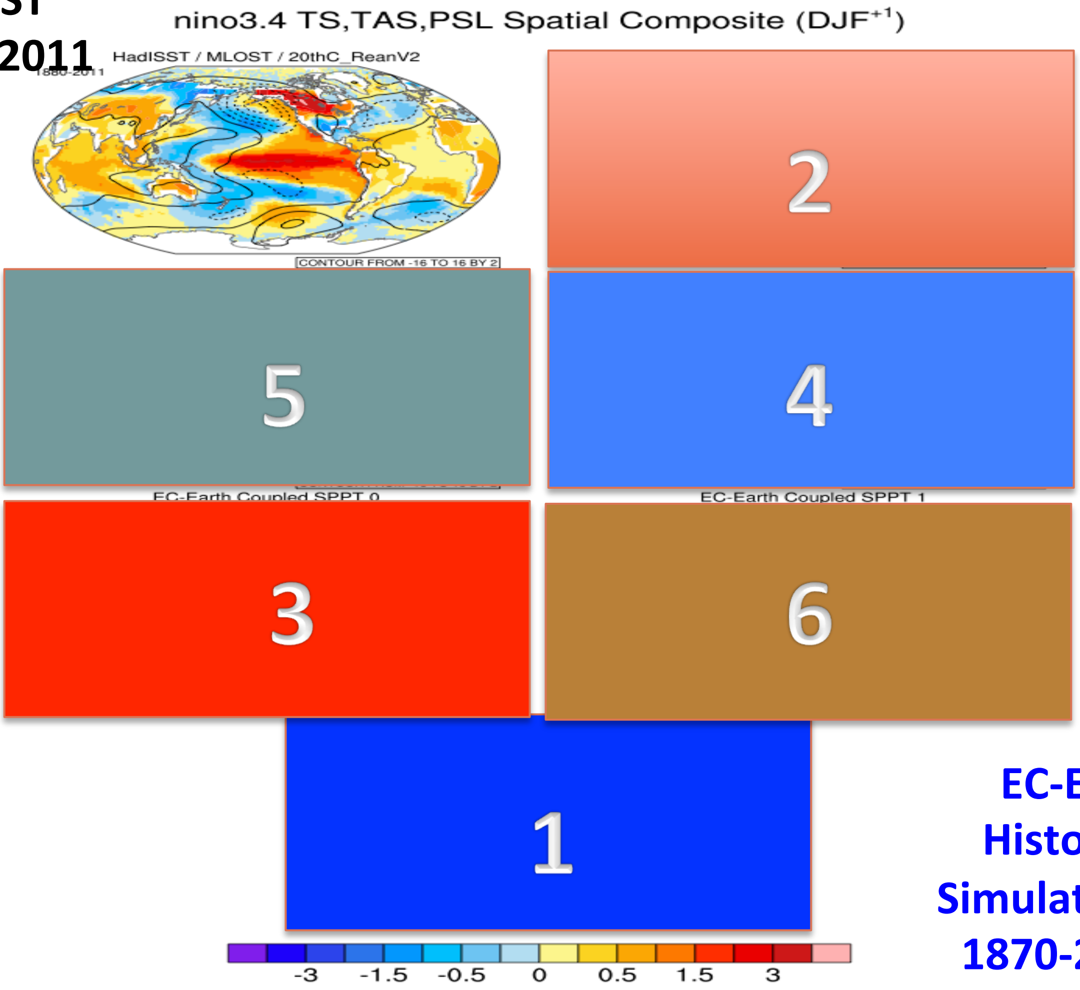
[1]Istituto di Scienze dell'Atmosfera e del Clima,
Coniglio Nazionale delle Ricerche, Bologna, Torino, Italy
[2]Laboratoire de Météorologie Dynamique,
École Normale Supérieure, Paris

ICTP Workshop on
Teleconnections in the Present and Future Climate
24 -28 October 2016, Trieste

ISAC
Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

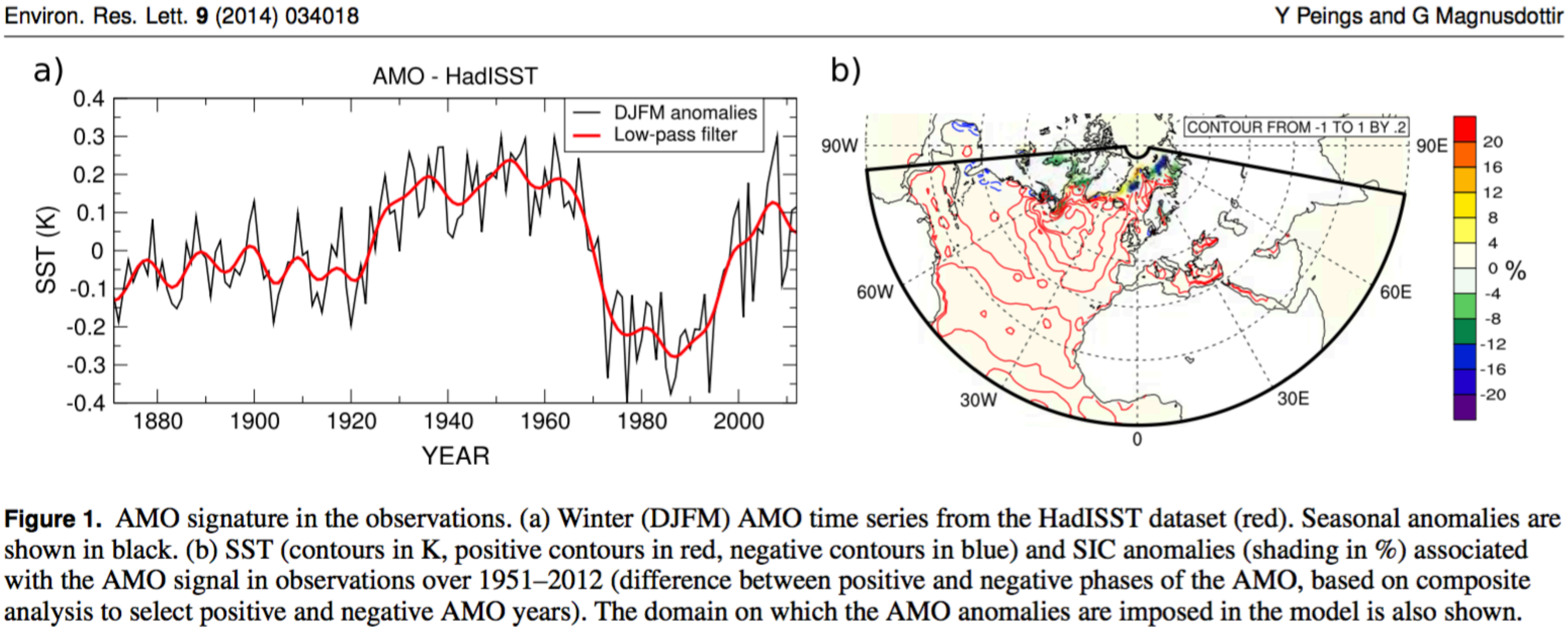
Teleconnections: The “Old Queen” : El Niño-PNA (or PNA-like)

HadISST
1880-2011



EC-Earth
Historical
Simulations
1870-2011

AMV(or AMO)



Environ. Res. Lett. **9** (2014) 034018 Y Peings and G Magnusdottir

Figure 1. AMO signature in the observations. (a) Winter (DJFM) AMO time series from the HadISST dataset (red). Seasonal anomalies are shown in black. (b) SST (contours in K, positive contours in red, negative contours in blue) and SIC anomalies (shading in %) associated with the AMO signal in observations over 1951–2012 (difference between positive and negative phases of the AMO, based on composite analysis to select positive and negative AMO years). The domain on which the AMO anomalies are imposed in the model is also shown.

AMV index: yearly anomalies of the North Atlantic SSTs between 75° W–5° W and 0° –70° N minus 10-year running mean of the global SSTs (area-averaged between 60° S and 60° N) (Trenberth and Shea 2006).

AMO(or AMV) & The Euro-Atlantic Flow Regimes Frequencies

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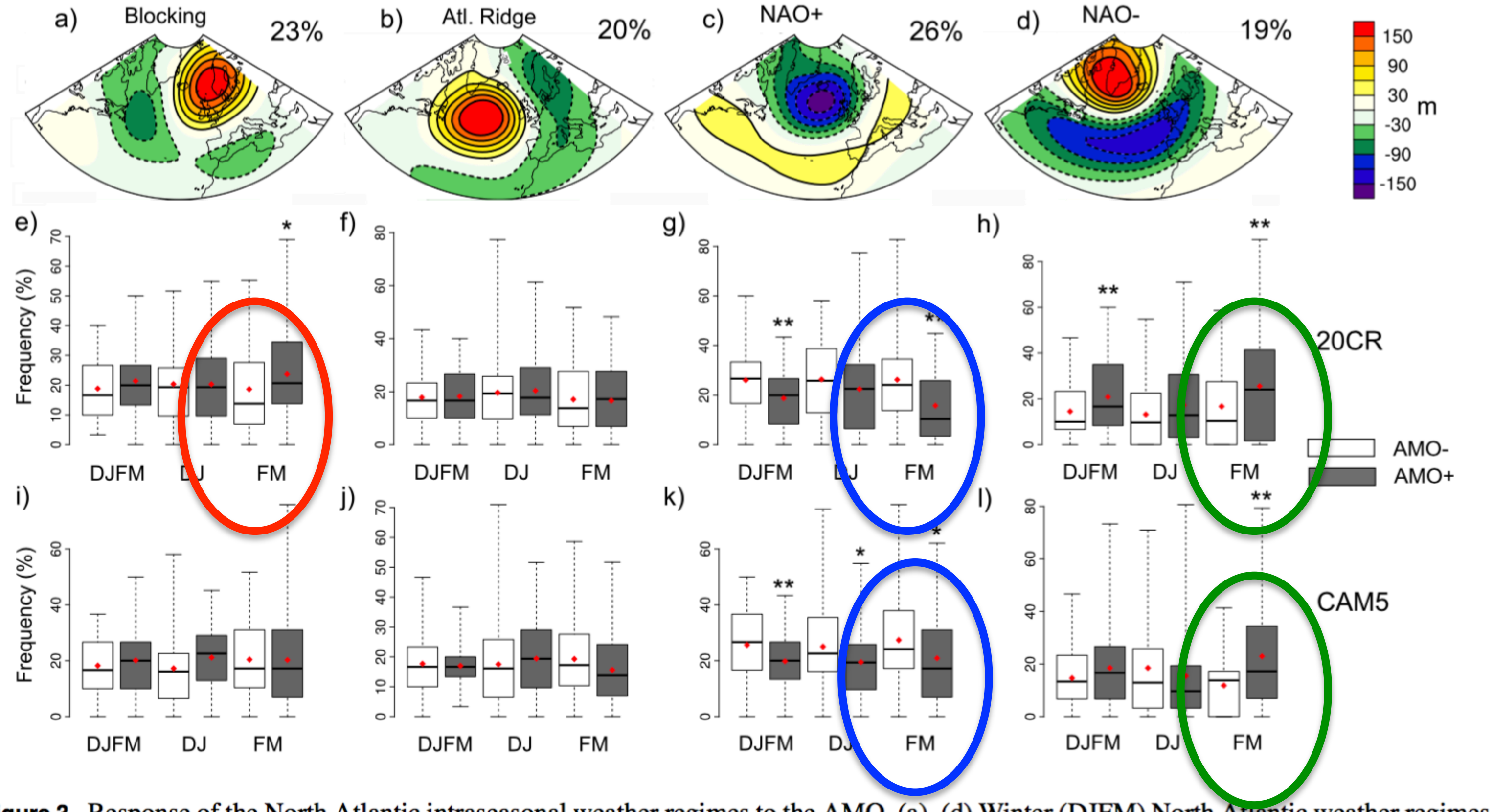
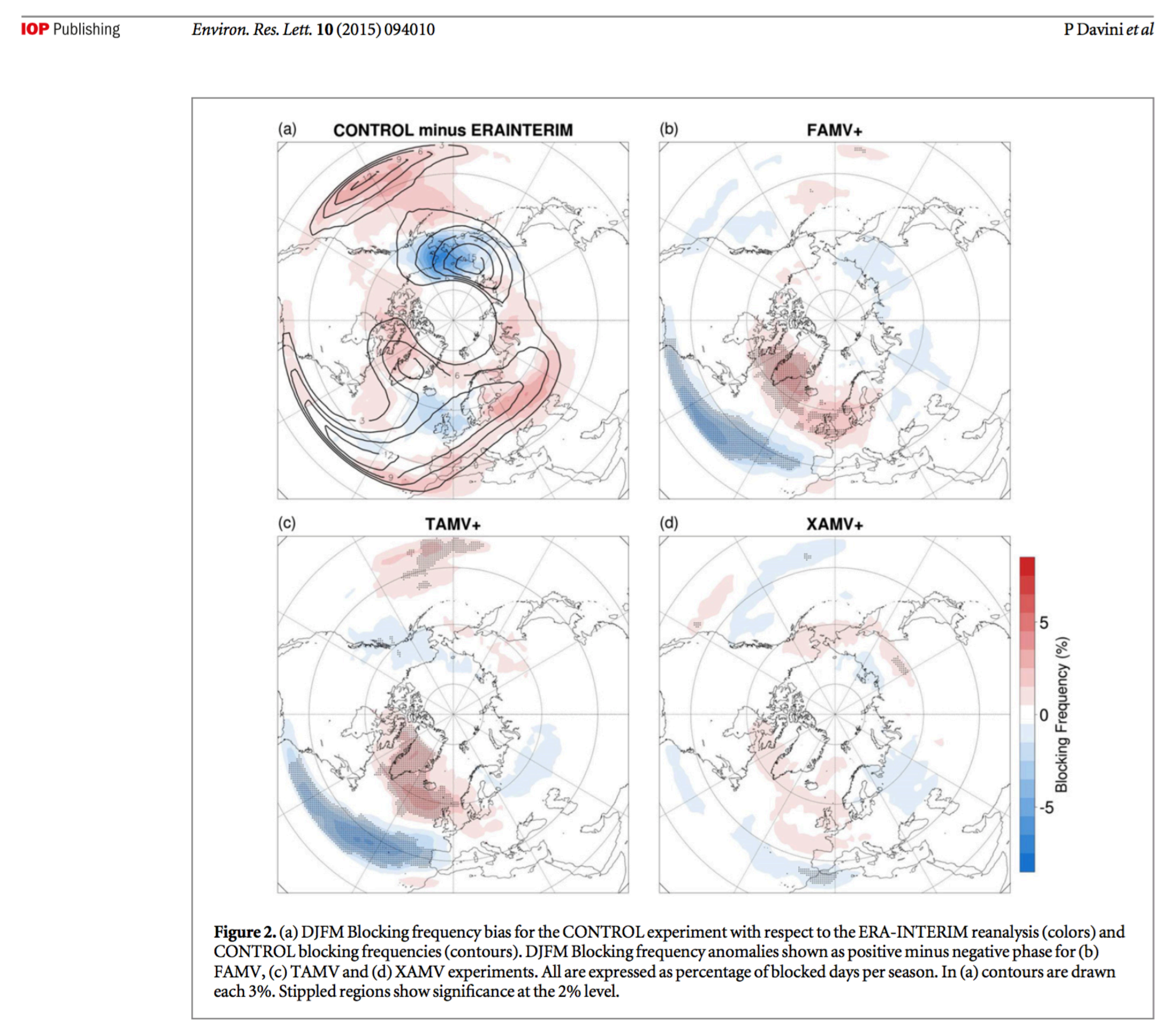


Figure 3. Response of the North Atlantic intraseasonal weather regimes to the AMO. (a)–(d) Winter (DJFM) North Atlantic weather regimes computed over 1901–2010 from the Z500 anomalies (in m) of 20CR. Frequencies of occurrence over the 1901–2010 wintertime days are indicated in %. (e)–(h) Distribution of seasonal regime frequencies in 20CR over 1901–2010, during AMO− (53 years, white boxplots) and AMO+ (57 years, gray boxplots) for winter (DJFM), early (DJ) and late (FM) winter. (i)–(l) same as (e)–(h) except for CAM5 (AMOn in white and AMOp in gray, 50 years for each experiment). Boxplots indicate the maximum, upper-quartile, median, lower-quartile and minimum of the distribution (horizontal bars). The mean of the distribution is shown by red diamonds, and asterisks indicate the significance level of the difference of the mean between AMO− and AMO+ (AMOn and AMOp for the simulations): *: $p < 0.1$; **: $p < 0.05$ (t-test).

AMO(or AMV) & The Euro-Atlantic Blocking



IOP Publishing *Environ. Res. Lett.* **10** (2015) 094010 P Davini *et al*

Figure 2. (a) DJFM Blocking frequency bias for the CONTROL experiment with respect to the ERA-INTERIM reanalysis (colors) and CONTROL blocking frequencies (contours). DJFM Blocking frequency anomalies shown as positive minus negative phase for (b) FAMV, (c) TAMV and (d) XAMV experiments. All are expressed as percentage of blocked days per season. In (a) contours are drawn each 3%. Stippled regions show significance at the 2% level.

Questions

- How well are the teleconnection patterns “reproduced” in climate models?
- What is the degree of “reproducibility” of these teleconnection patterns in a set of climatological sister simulations?
- What are the factors that might weaken or strengthen a teleconnection pattern (or the regime sensitivity to “decadal oscillations”)?

CLIMATE SPHINX

EC EARTH3

PRACE

ISAC Consiglio Nazionale delle Ricerche
Istituto di Scienze dell'Atmosfera e del Clima

UNIVERSITY OF OXFORD

Climate SPHINX *(Stochastic Physics High Resolution Experiments)* ***is a PRACE EU project which aims at investigating the sensitivity of climate simulations to model resolution and stochastic parameterizations****, and to determine if very high resolution is truly necessary to facilitate the simulation of the main features of climate variability.*

SPHINX is a project by **ISAC-CNR**, lead by Jost von Hardenberg, in collaboration with Oxford University (Tim Palmer and Antje Weisheimer group).

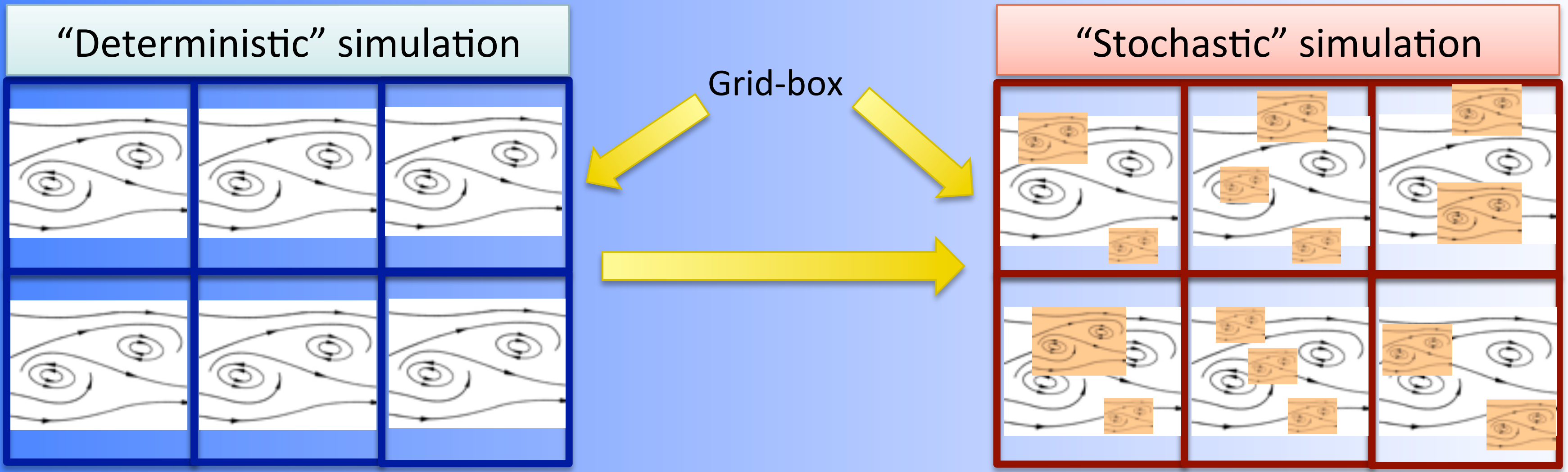
20 millions of core hours have been run on **Supermuc** @ LRZ Computing Center, Garching, Germany for a single-year PRACE project ended in **March 2016.**

EC-Earth Earth System Model **version 3.1** has been used.
Website and data access: (http://sansone.to.isac.cnr.it/sphinx/)

WHAT IS STOCHASTIC PHYSICS?

Instead of explicitly resolving small-scale processes by increasing the resolution of climate models, a **computationally cheaper** alternative is to **use stochastic parameterization schemes** (Palmer 2012).

A stochastic scheme includes a **statistical representation of the small scales**, and hence is able to represent the impact of such small-scale processes on the resolved scale.



"Deterministic" simulation

Grid-box

"Stochastic" simulation

Practically, **Gaussian perturbations are applied on the 3D field tendencies**.

There is mounting evidence that stochastic parameterizations are beneficial for climate variability in GCM simulations (e.g. Weisheimer, Corti, Palmer and Vitart, Phil. Trans. 2014).

Stochastic physics schemes

Stochastically perturbed physical tendencies (SPPT):

Perturbations to the sum of all parameterised tendencies of physical processes with multiplicative **noise** $X_p = (1+\mu r)\, X_c$ *for* $X=\{u,v,T,q\}$;

r is a uni-variate random number described through a spectral pattern generator which is smooth in space and time ;

μ is a function that tapers the perturbation to zero in the boundary layer and stratosphere;

Spectral coefficients of r are described with an AR(1) process Gaussian distribution, truncated at ±2σ ;

Three components with different correlation scales

Stochastically perturbed backscatter scheme (SPBS):

A fraction of the dissipated kinetic energy is backscattered upscale acts as a streamfunction forcing for the resolved-scale flow;

Total dissipation rate is sum of numerical, orographic gravity wave drag and convective dissipation

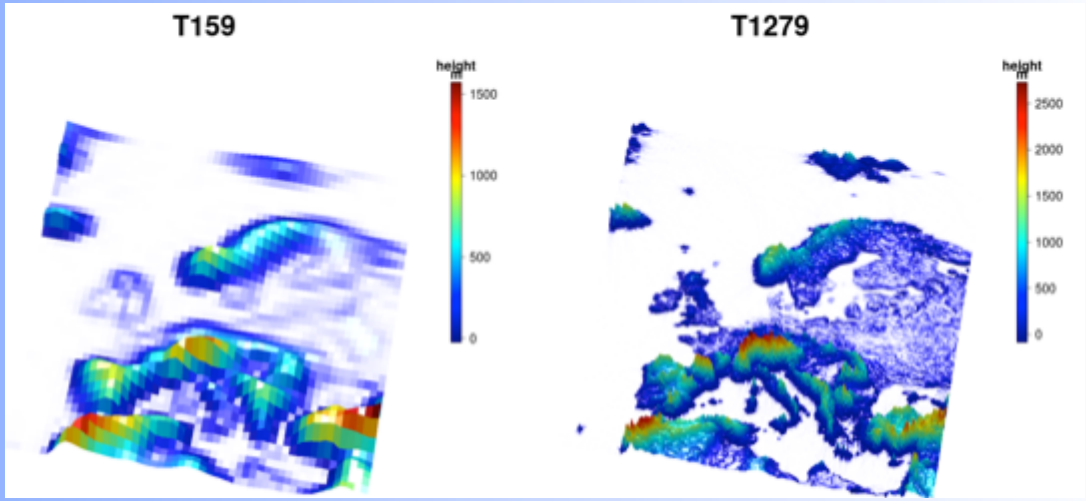
EXPERIMENTS & RESOLUTIONS

Atmospheric-only:
5 horizontal resolutions

Present day
1979-2008

Future Scenario
2039-2068 RCP85

Coupled: T255L91
1850-2100, historical + RCP8.5



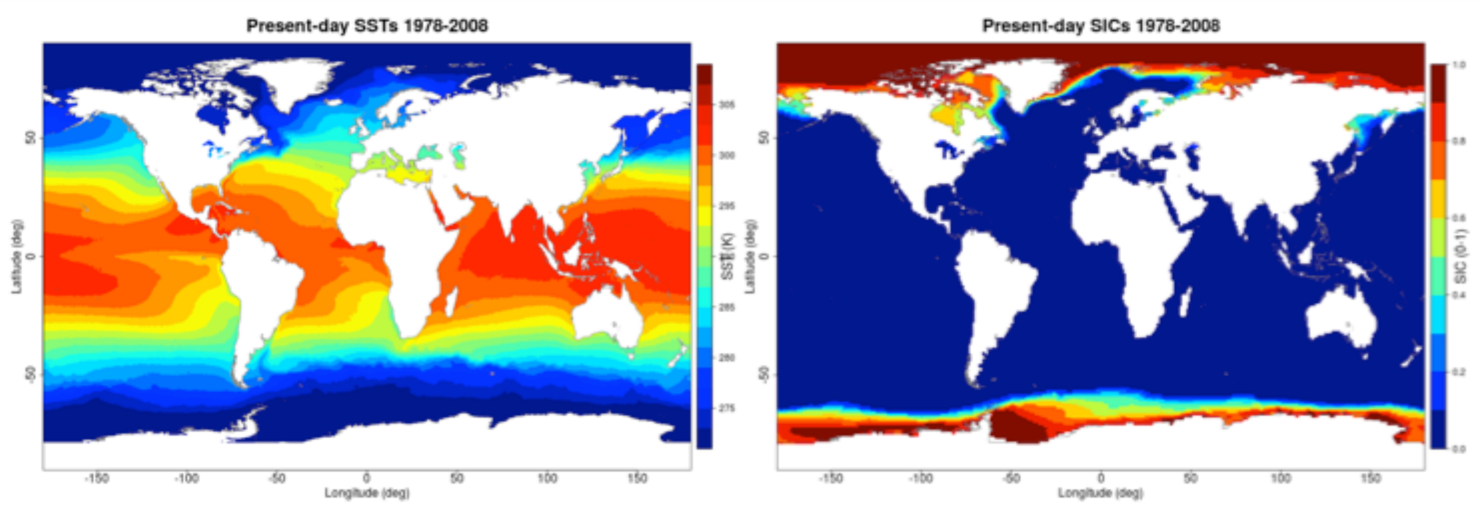
Tuning has been performed once only for T255L91 with no stochastic physics!

More than 110 simulations available!

T159L91 (125km): 10+10 ensemble members
T255L91 (80km): 10+10
T511L91 (40km): 6+6
T799L91 (25km): 3+3
T1279L91 (16km): 1+1

THE FORCING: PRESENT DAY

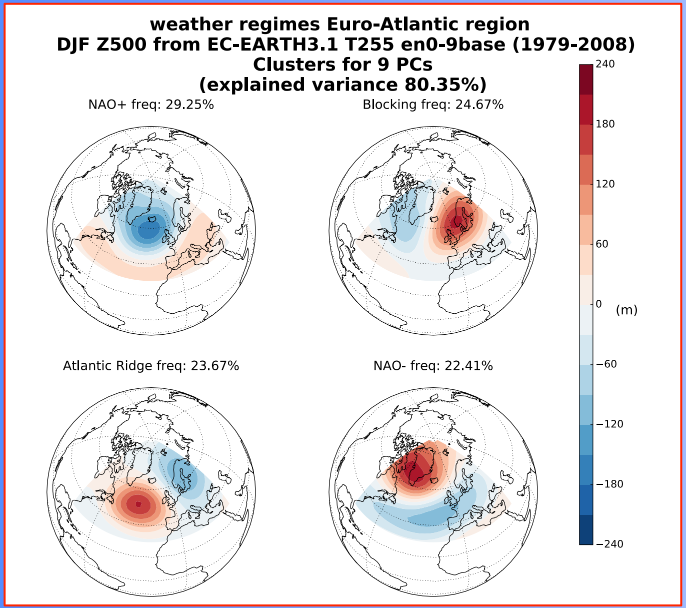
- New oceanic dataset: **HadISST 2.1.1** (Titchner et al., 2014; Kennedy et al, 2016)
- **Pentad-based daily 0.25x0.25 dataset for SST and and 1x1 for SIC.**
- ICs from ERAINTERIM 1979-01-01.
- 1979-2008: **Historical CMIP5 forcing for GHG.**
- Lake (not defined inland points): **ERAINTERIM 1-month lagged seasonal cycle** (Hersbach et al., 2015), ice when below zero. Coastal points (land-sea mask mismatch) are extrapolated.

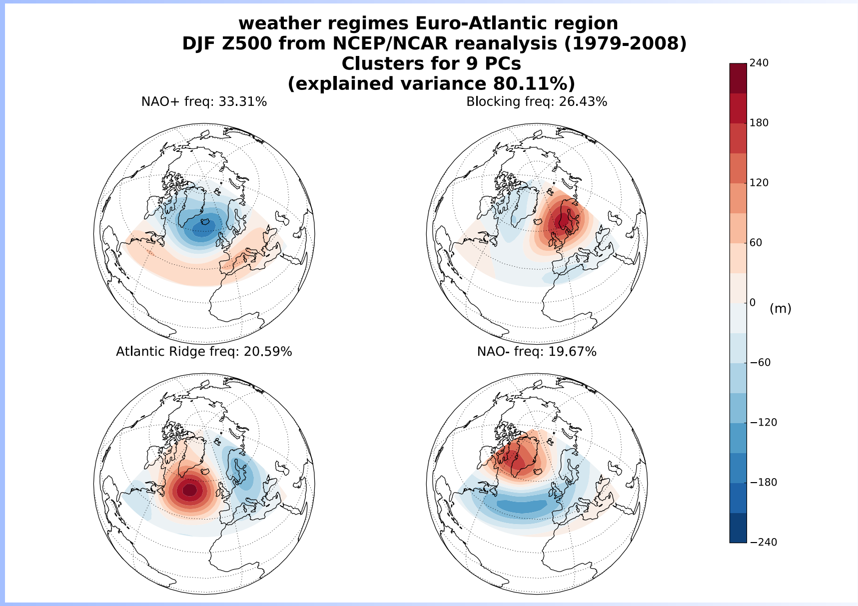


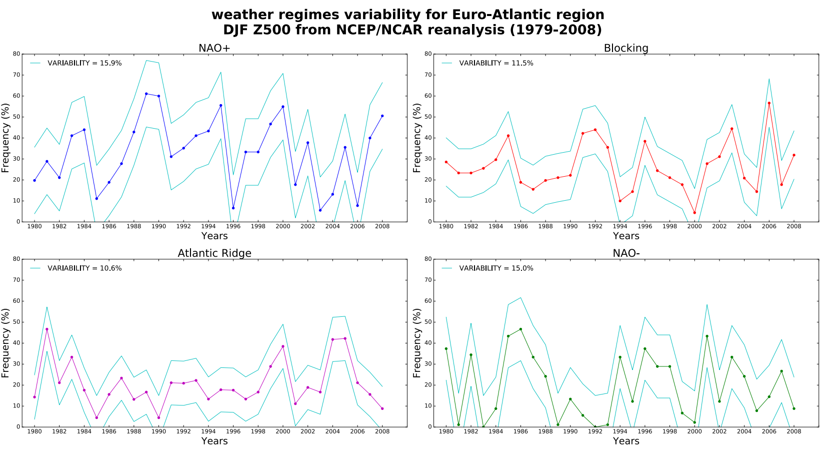
Euro-Atlantic Weather regimes
AMIP T255 [10 ensemble members]

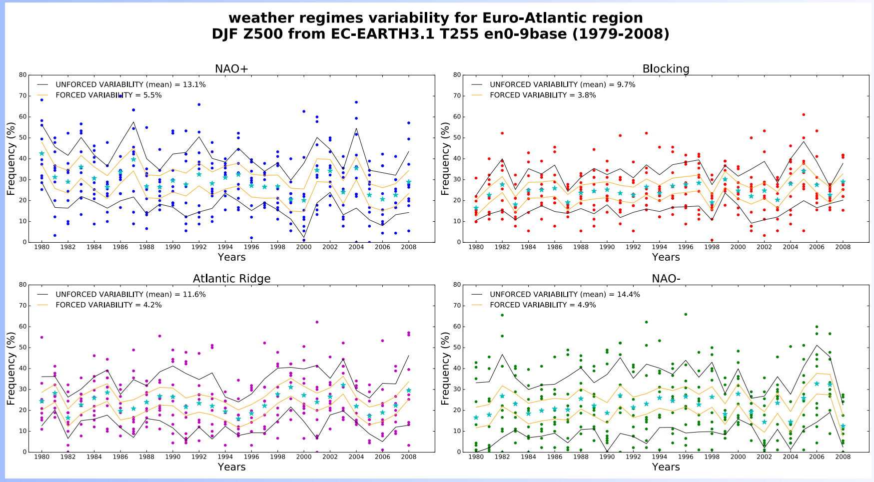
EC-Earth

NCEP



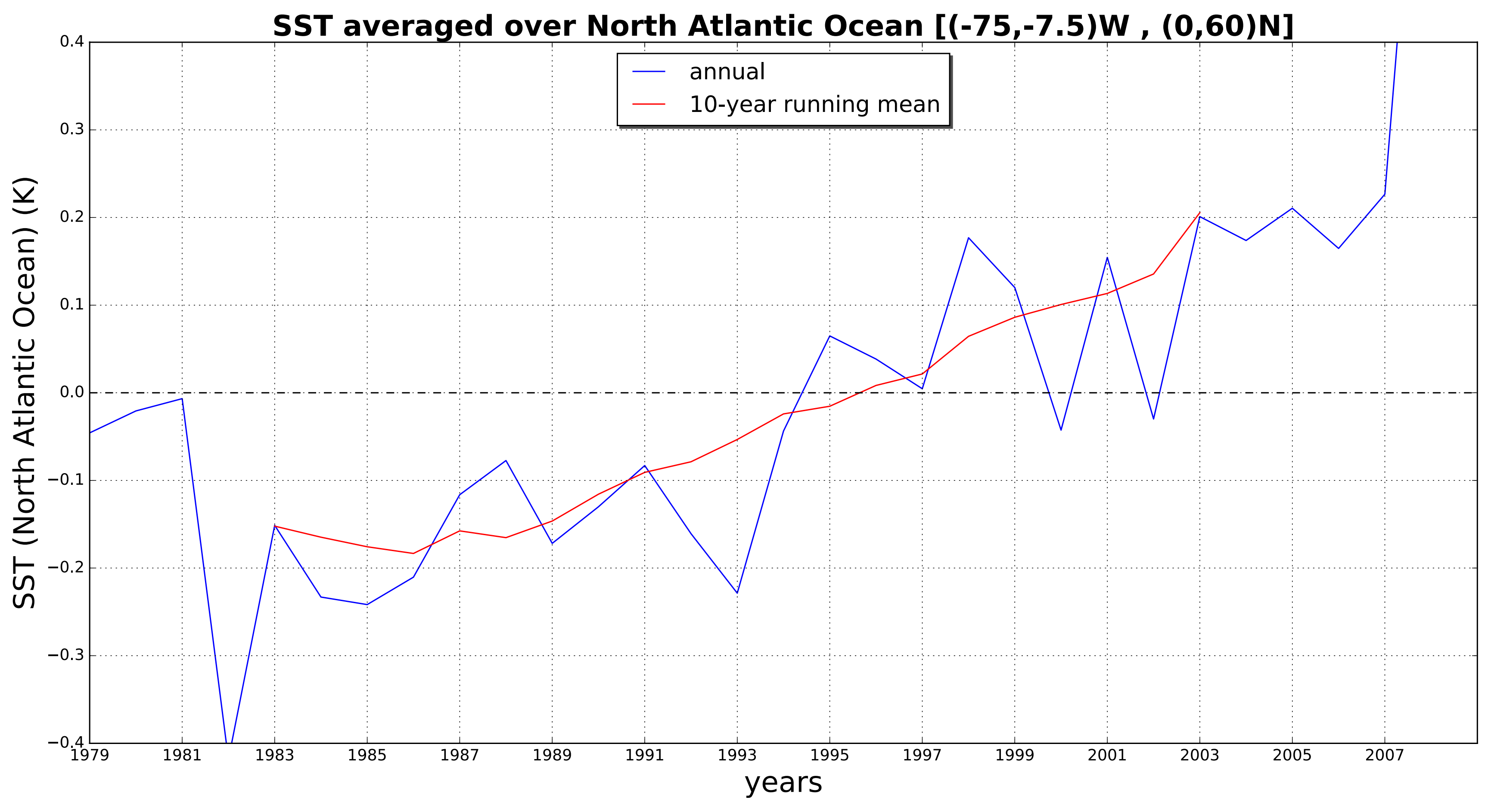




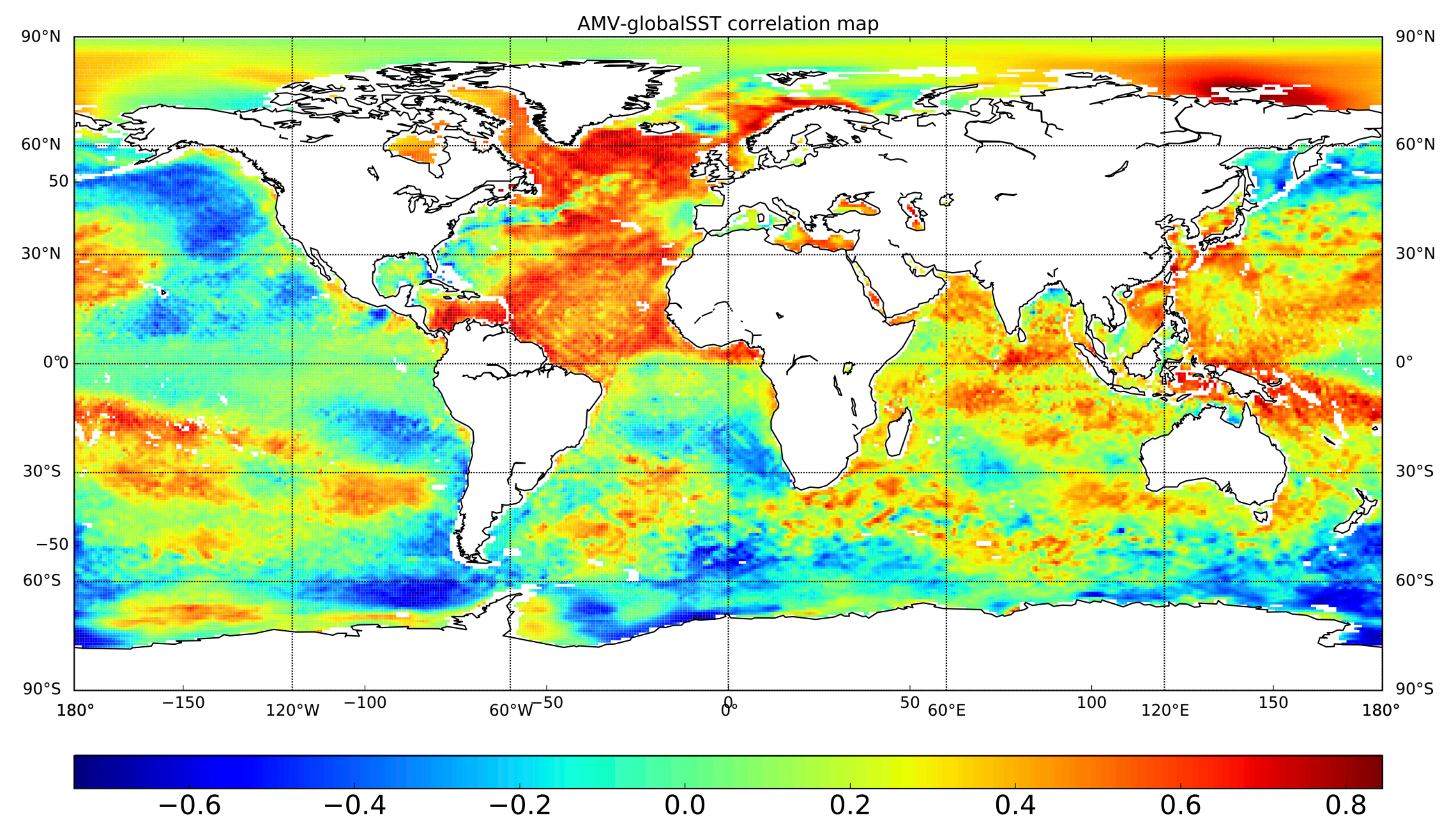


Atlantic Multidecadal Variability (AMV)

AMV- (1979-1995) AMV+ (1996-2008)



AMV & global SSTs



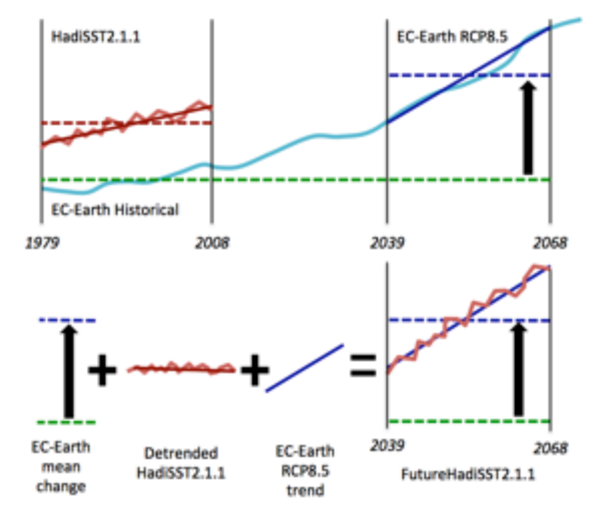
THE FORCING: FUTURE SCENARIO

- Future SSTs: **the new dataset has the same variability of HadISST2.1.1 and the mean field and values of EC-Earth ensemble mean.**

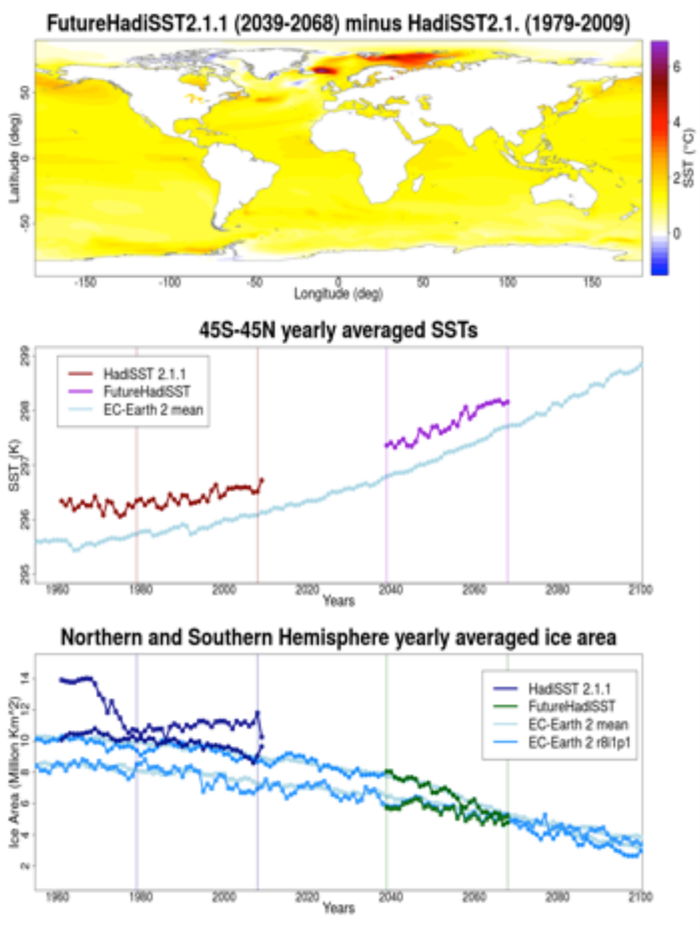
- EC-Earth 2 **CMIP5 ensemble mean for mean values and trend of SST**, and **daily variability is taken from HadiSST 2.1.1**.

- **2039-2068**: **RCP8.5 CMIP5.**

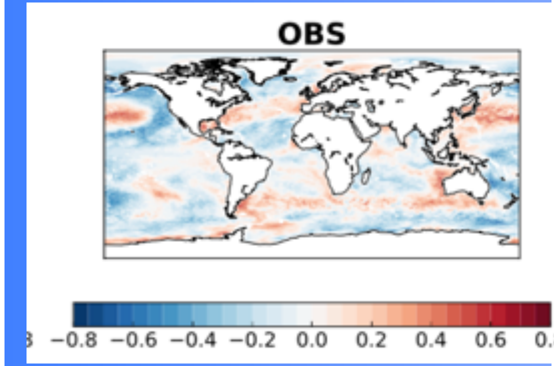
- For SICs, we pick one ensemble member of EC-Earth CMIP5 representative of the dataset (i.e. closer to ensemble mean).

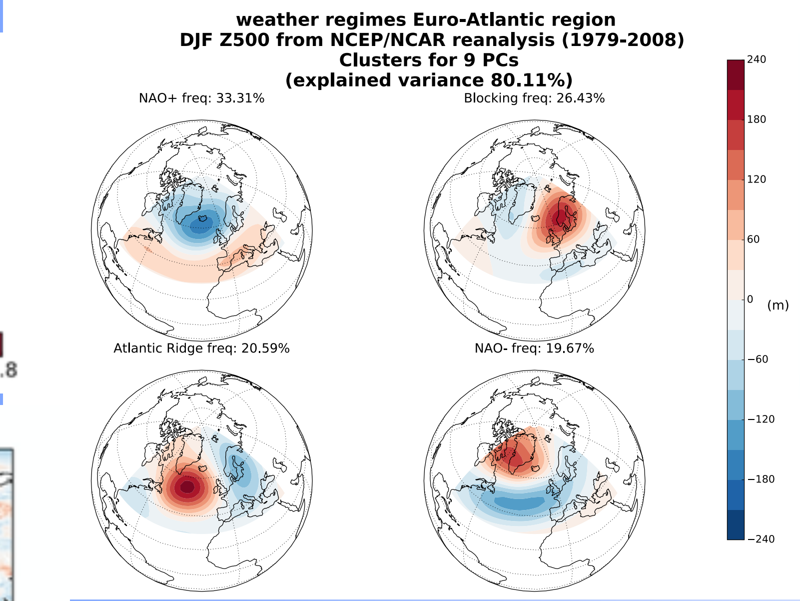


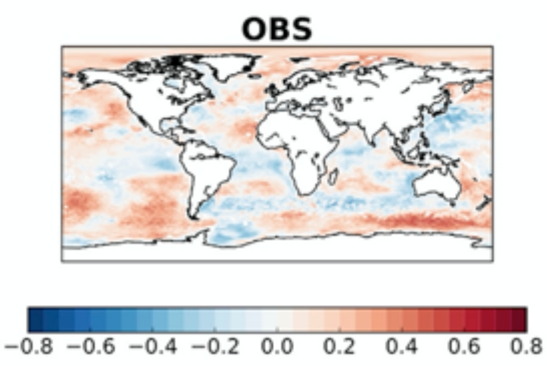
- **Bare-points due to retreat of sea-ice:** specific filling combining a linear interpolation and HadISST 2.1.1 variability.

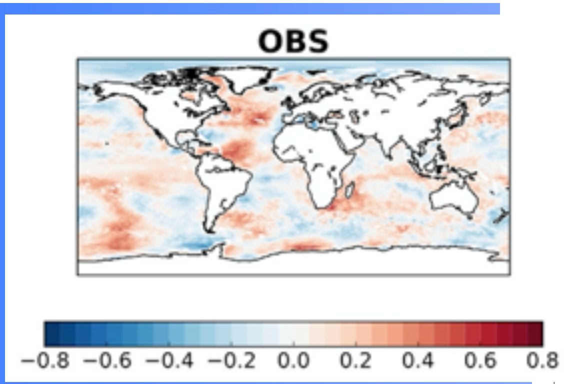


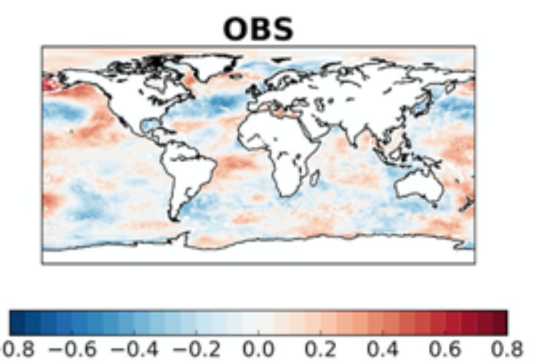
Euro-Atlantic Weather regimes NCEP

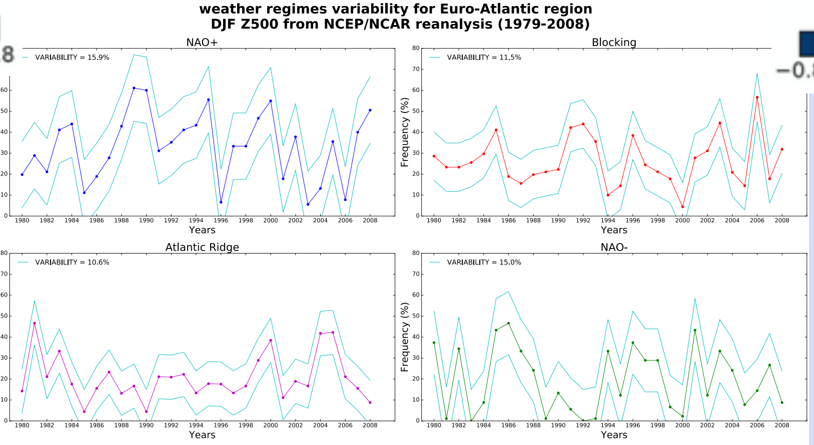



weather regimes Euro-Atlantic region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)
Clusters for 9 PCs
(explained variance 80.11%)

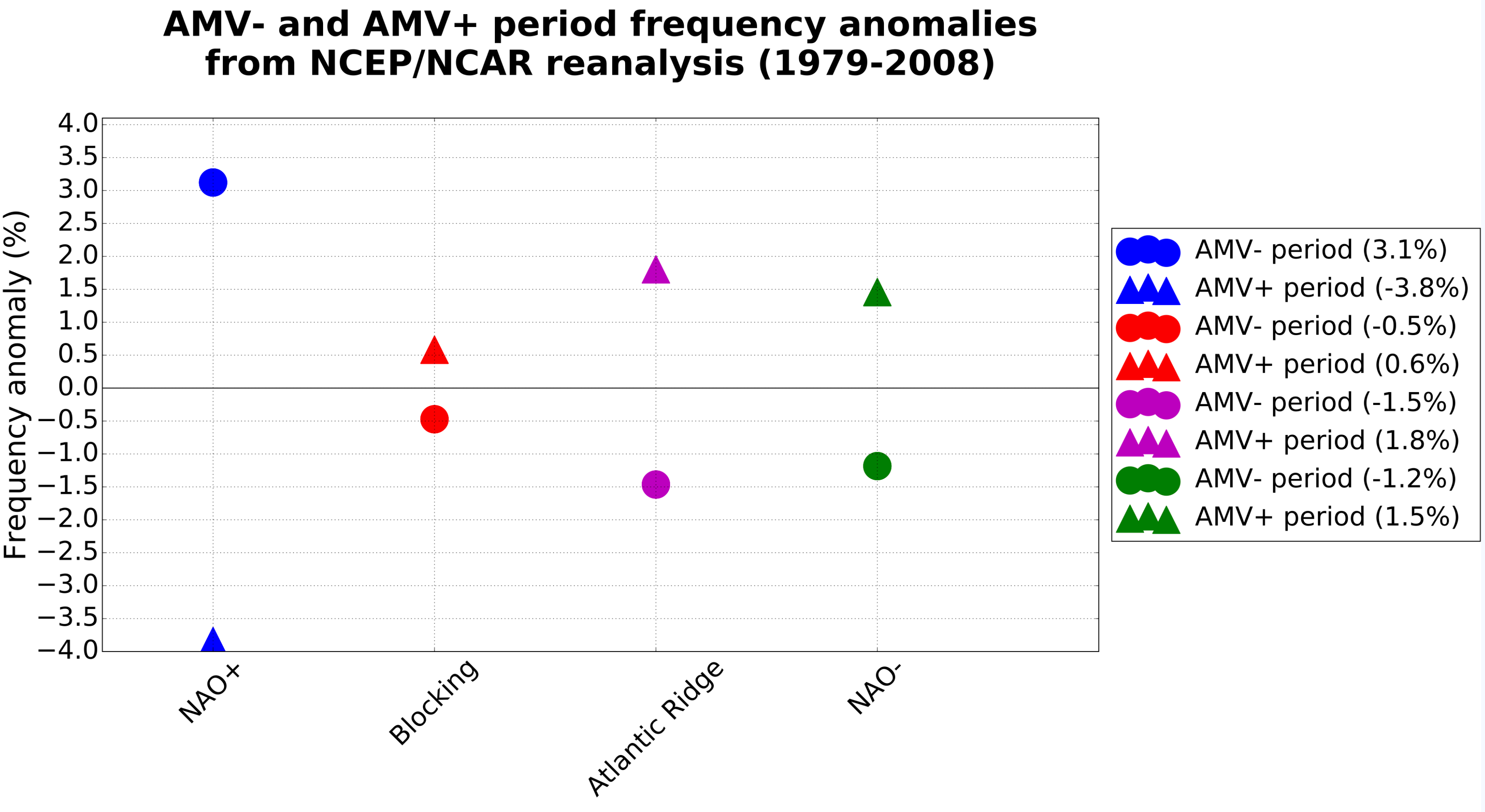







weather regimes variability for Euro-Atlantic region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)

Sensitivity of Euro-Atlantic Weather regimes Frequency to AMV (NCEP)



Sensitivity of Euro-Atlantic Weather regimes Frequency to AMV (EC-Earth-AMIP)

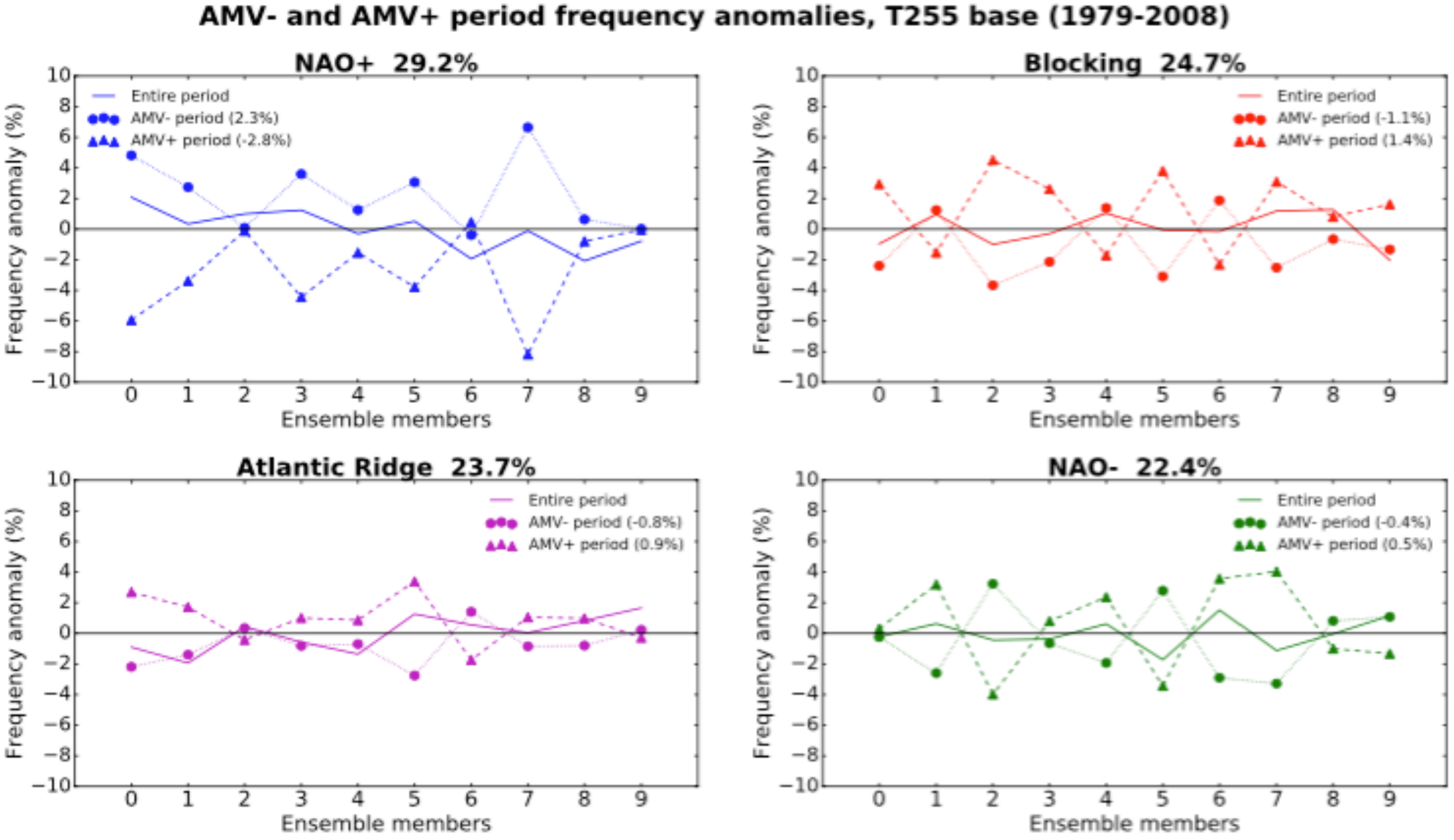
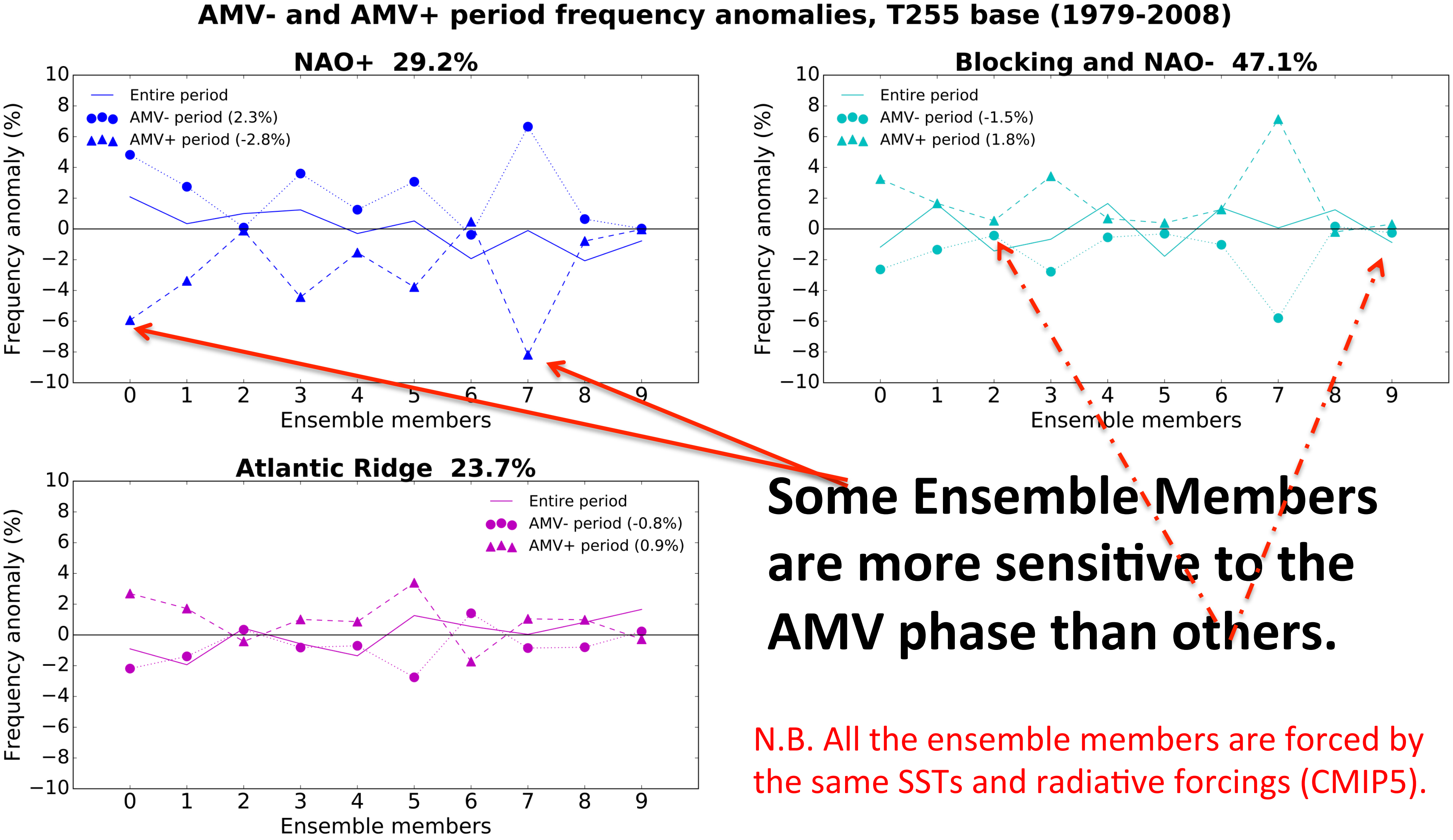


Figure 2: Regime frequencies anomalies with respect to the entire period (1979-2008) shown in solid line; during AMV- (1979-1995) in circles and during AMV- (1996-2008) in triangles.

Sensitivity of Euro-Atlantic Weather regimes Frequency to AMV (EC-Earth-AMIP)

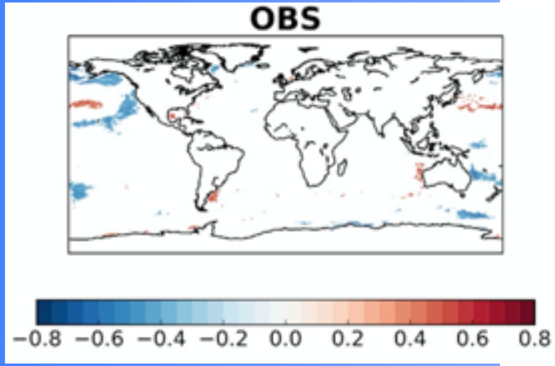


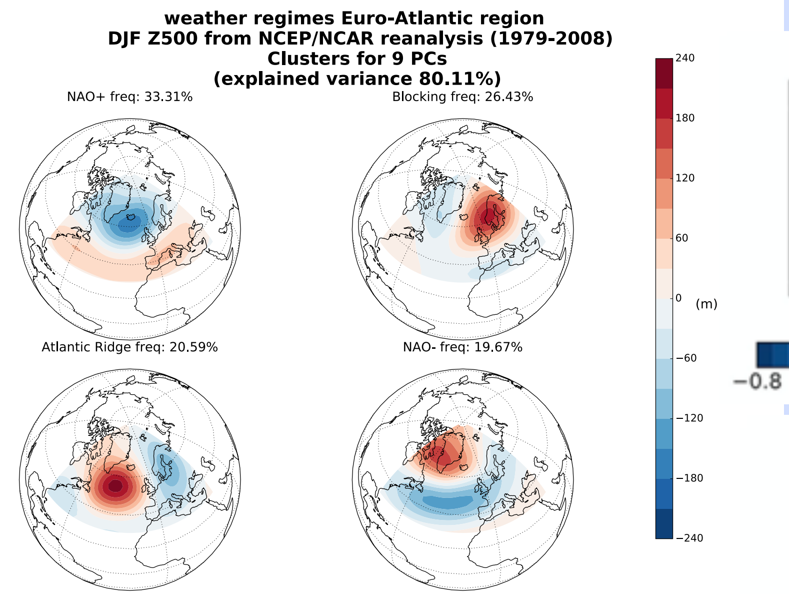
AMV- and AMV+ period frequency anomalies, T255 base (1979-2008)

Some Ensemble Members are more sensitive to the AMV phase than others.

N.B. All the ensemble members are forced by the same SSTs and radiative forcings (CMIP5).

Euro-Atlantic Weather regimes NCEP

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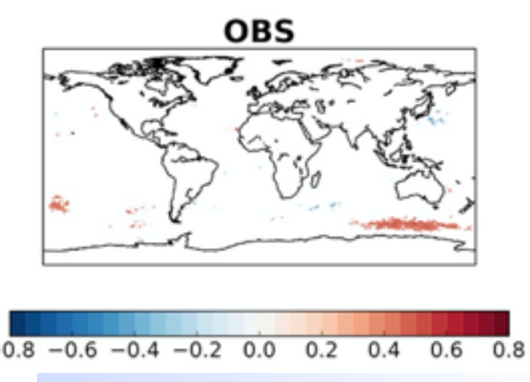
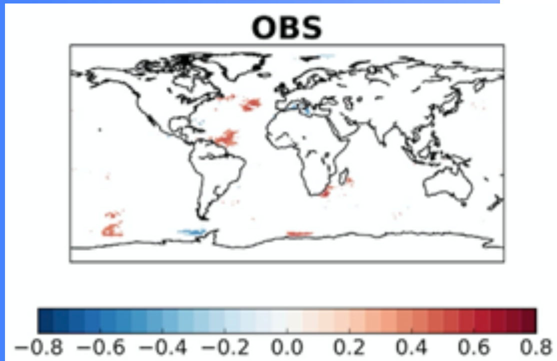
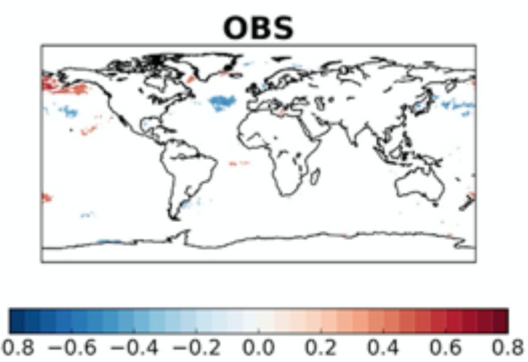
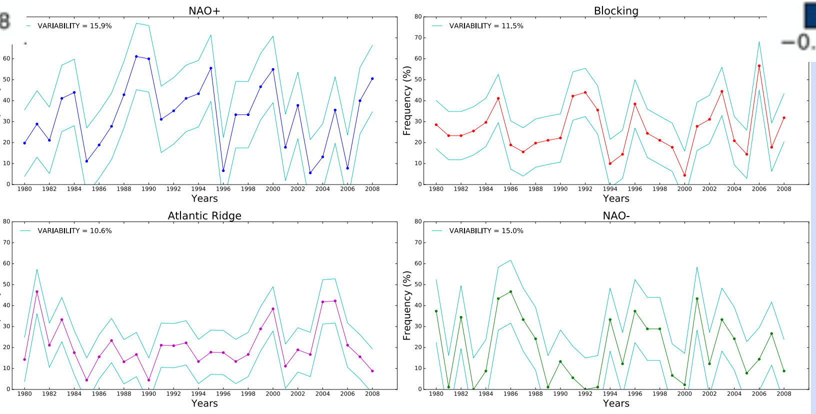


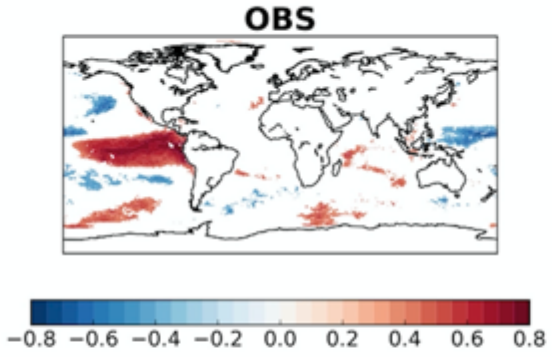


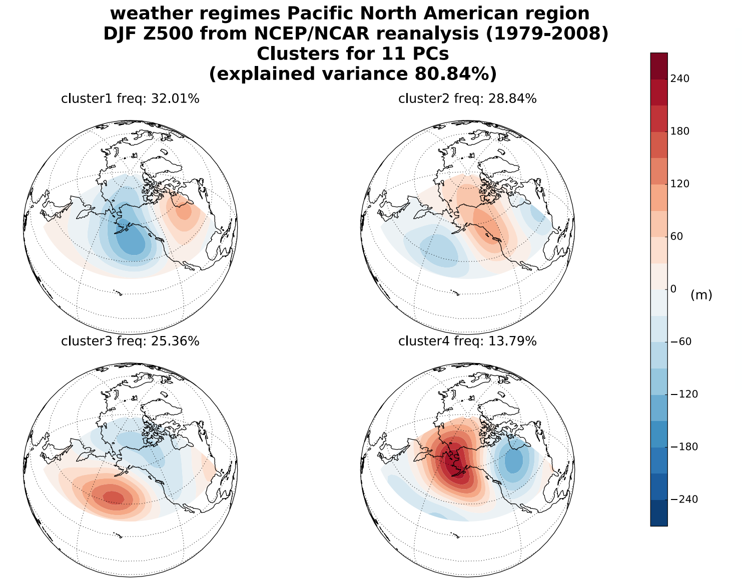


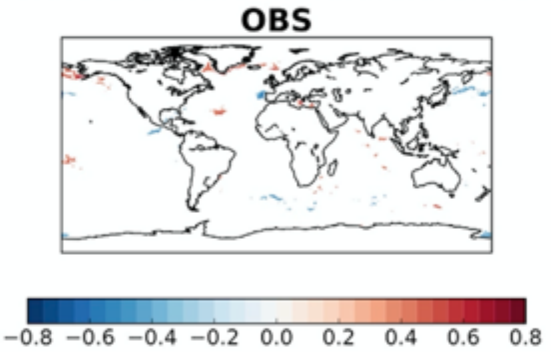
weather regimes variability for Euro-Atlantic region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)

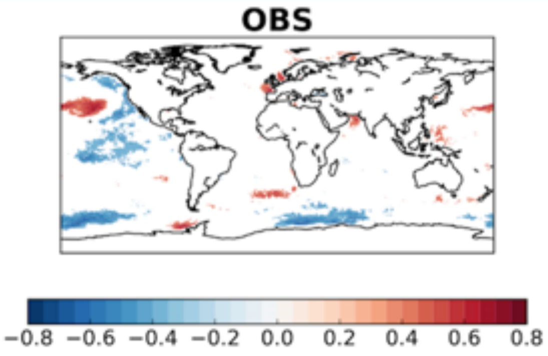


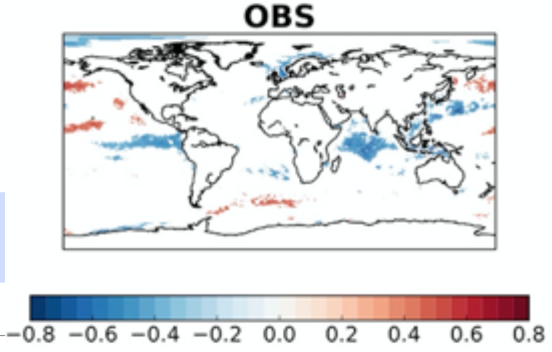
Pacific-North America Weather regimes NCEP




weather regimes Pacific North American region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)
Clusters for 11 PCs
(explained variance 80.84%)







weather regimes variability for Pacific North American region
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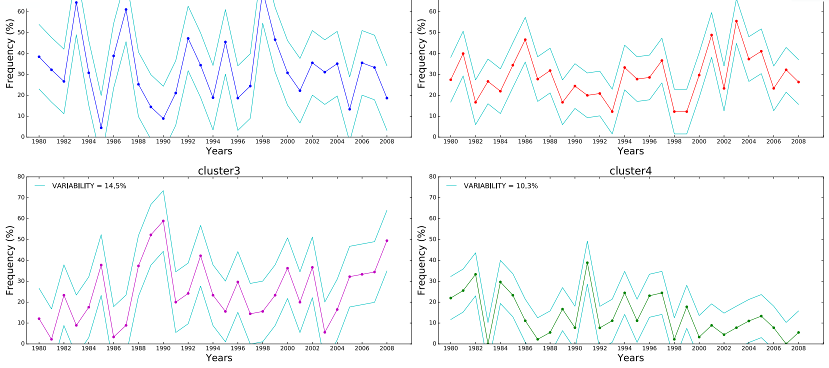


Sensitive and Insensitive ensemble members

What are the factors that might amplify (or inhibit) the regime sensitivity to AMV in an "AMIP-world"?

Possible candidates: Eurasian Snow anomalies and/or Stratospheric Warming events in (or not in) phase with the AMV

Positive anomaly of Eurasian Snow Depth in Autumn/Winter → NAO-

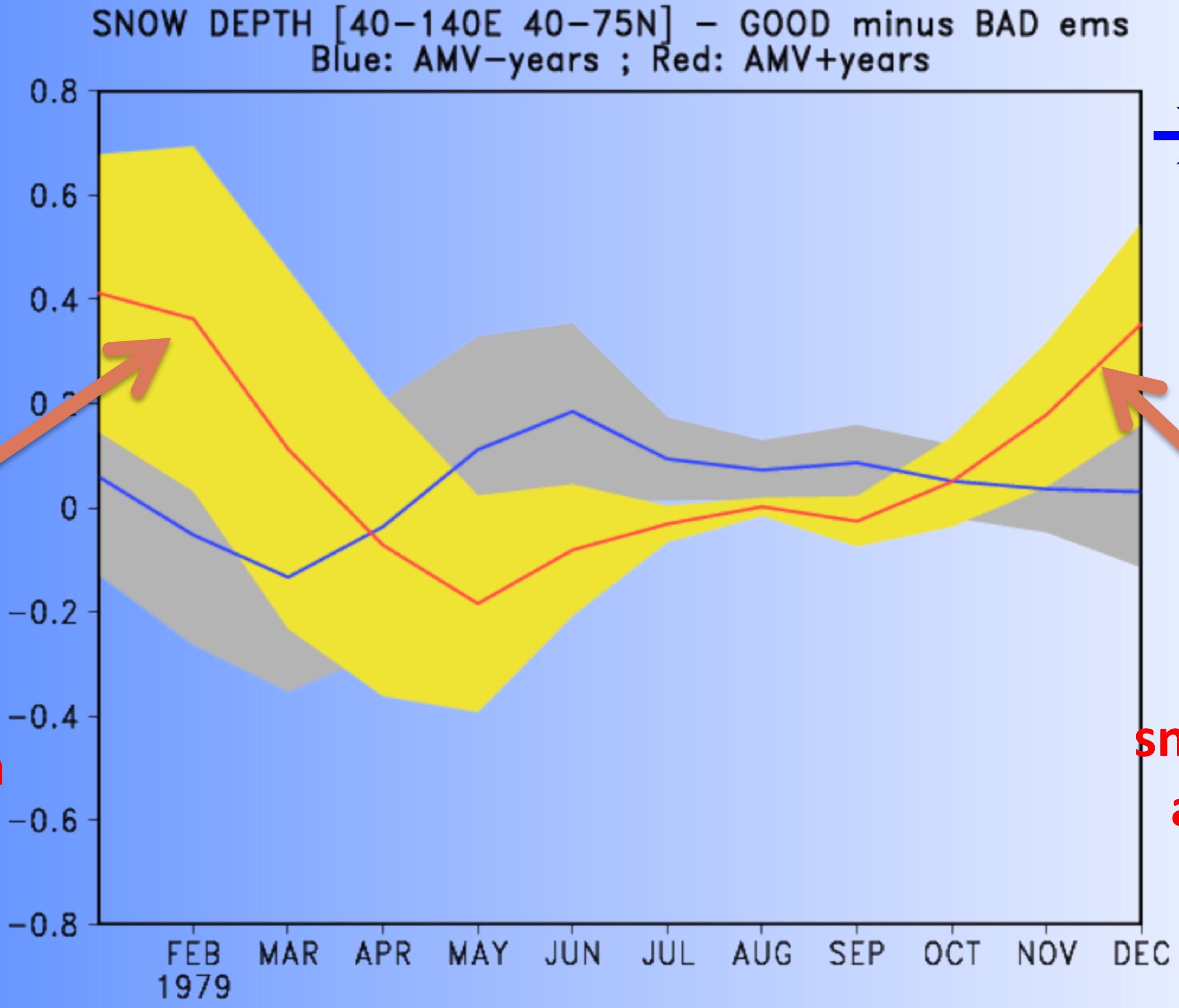
Stratospheric Warming events → NAO-

Strategy: Split the ensemble in 5 good (i.e. most AMV sensitive) and 5 bad (i.e. least AMV sensitive) ensemble members and look at the differences in snow depth and T50hPa climatology for AMV+ and AMV- years.

Eurasian Snow Depth
Good minus BAD

RED
AMV+
years
→NAO-

BLUE
AMV-
years
→NAO+



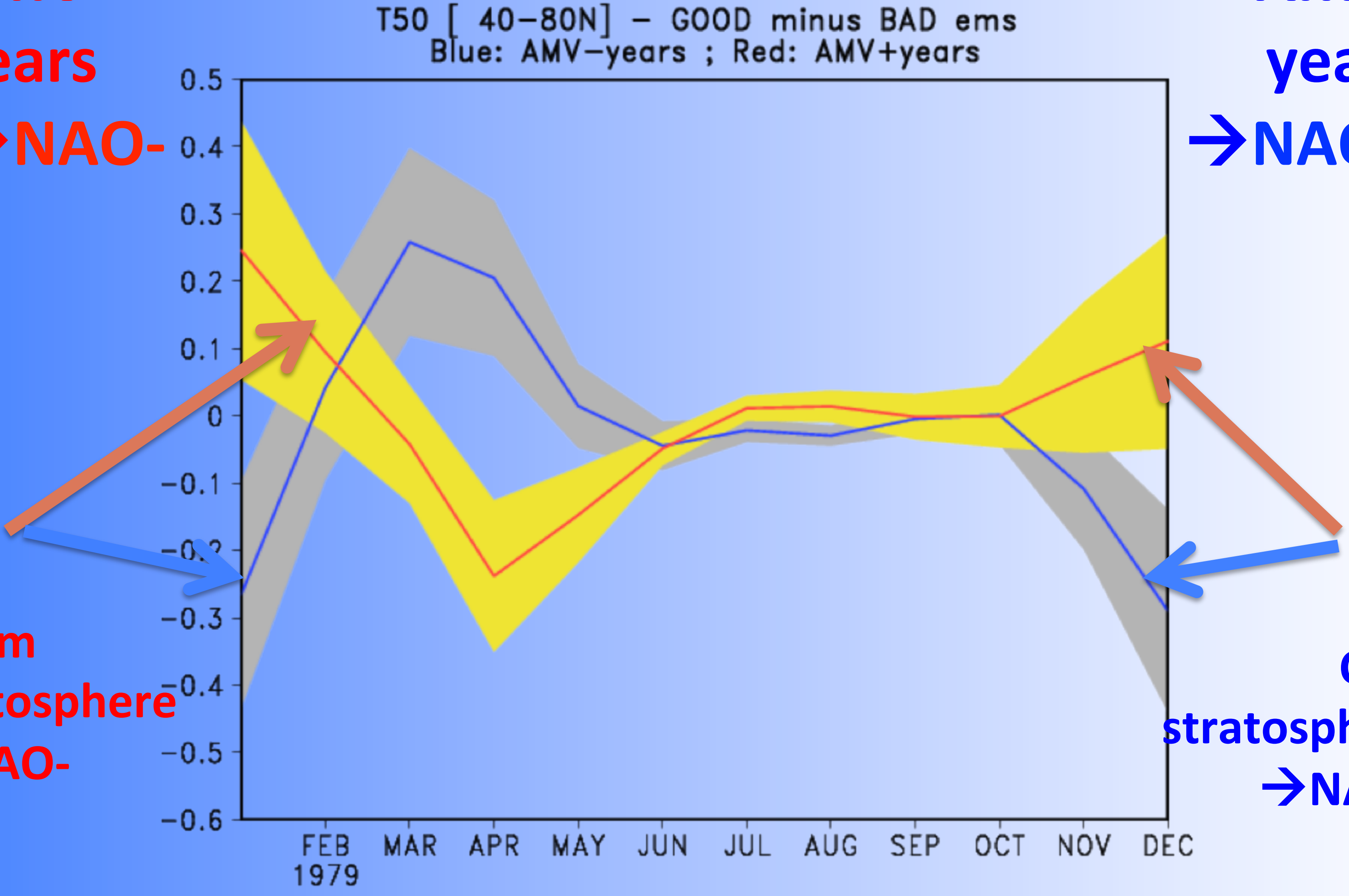
Positive snow depth anomalies →NAO-

Positive snow depth anomalies →NAO-

Temperature at 50hPa [40-80N] Good minus BAD

RED
AMV+
years
→NAO-

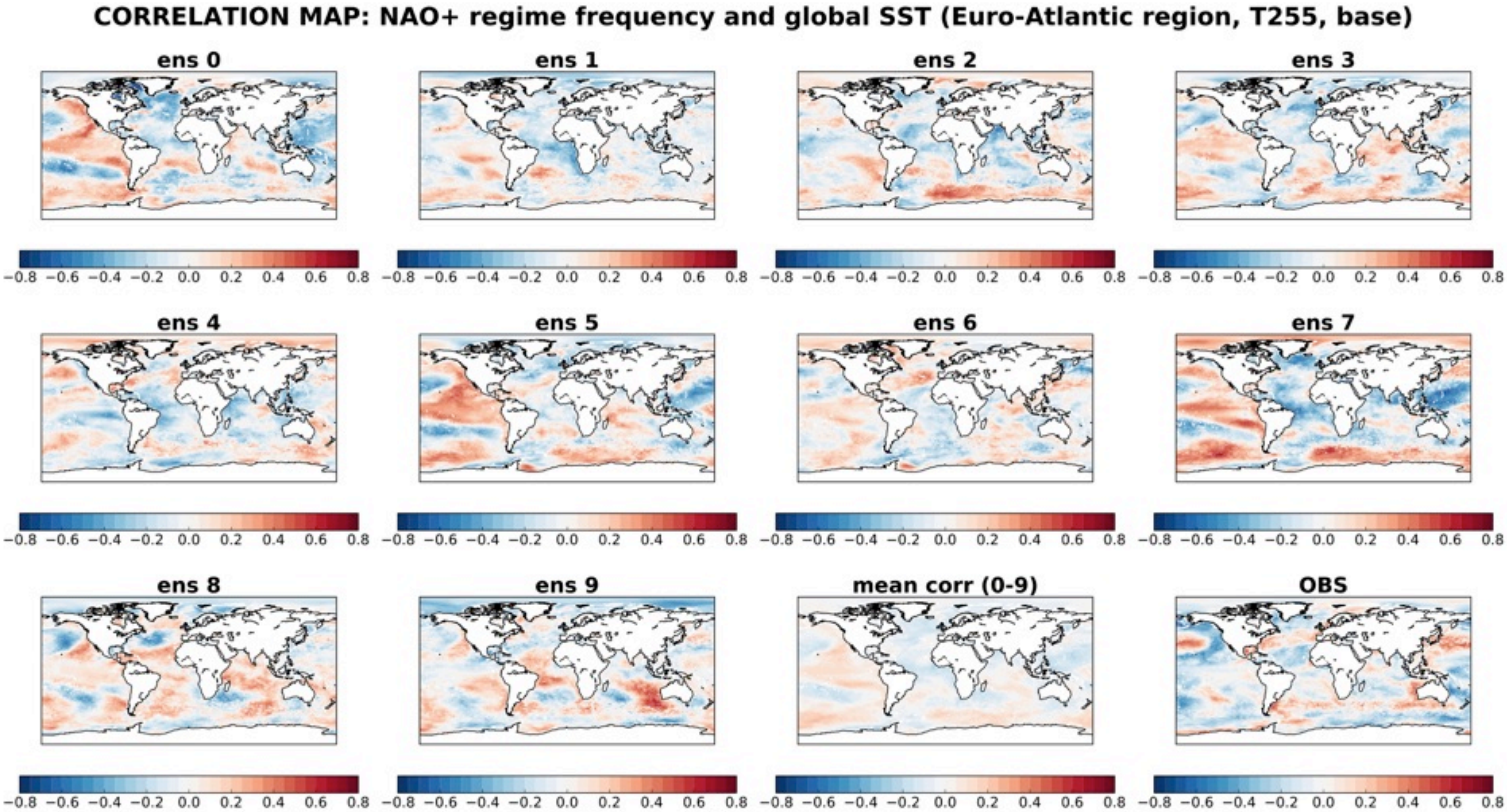
BLUE
AMV-
years
→NAO+



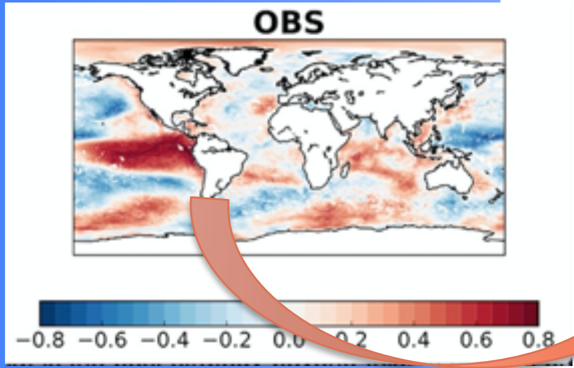
Warm stratosphere →NAO-

Cold stratosphere →NAO+

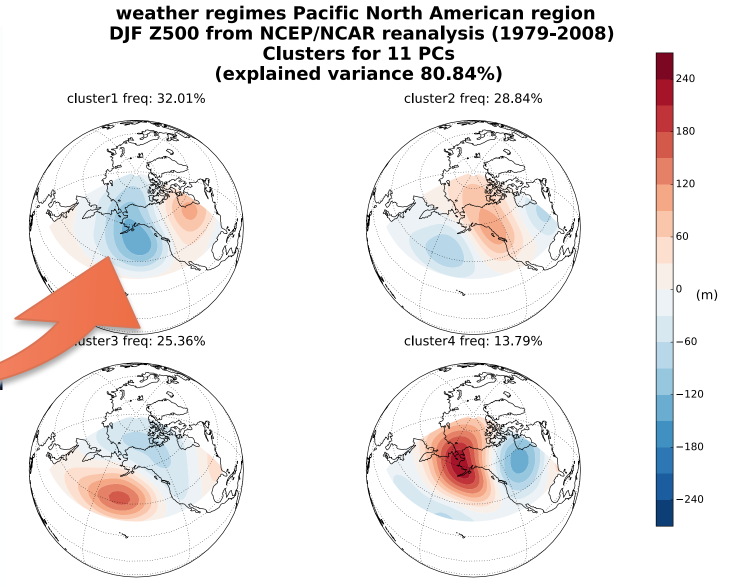
NAO+ Frequency & Global SST T255

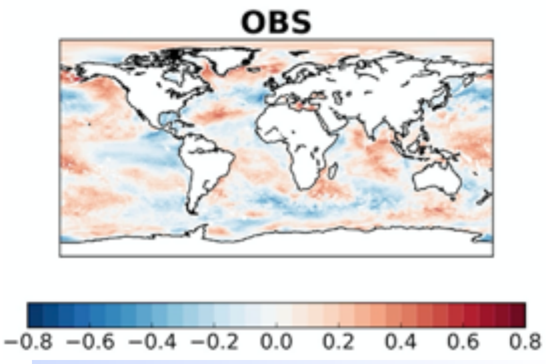


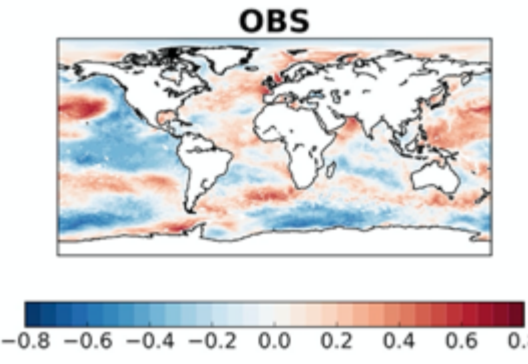
Pacific-North America Weather regimes NCEP

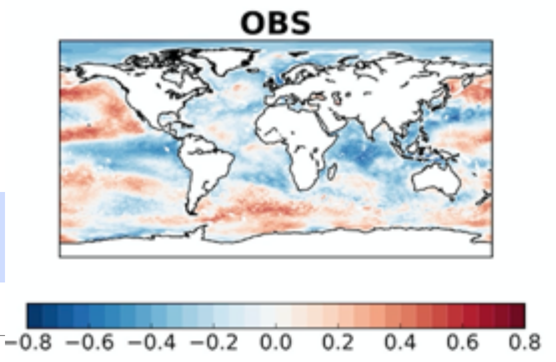


weather regimes Pacific North American region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)
Clusters for 11 PCs
(explained variance 80.84%)

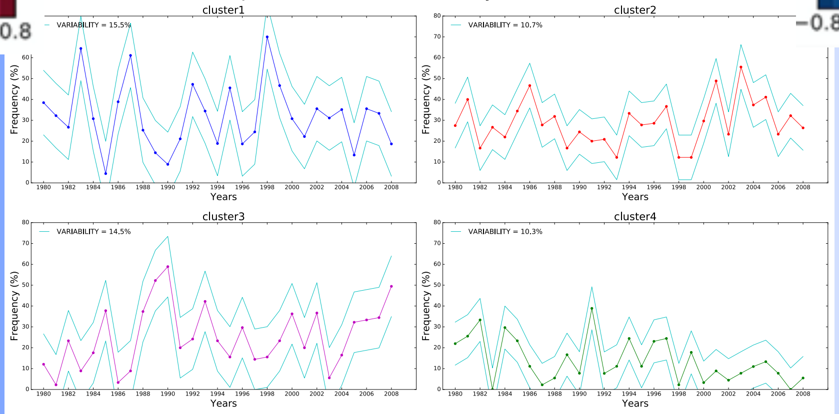




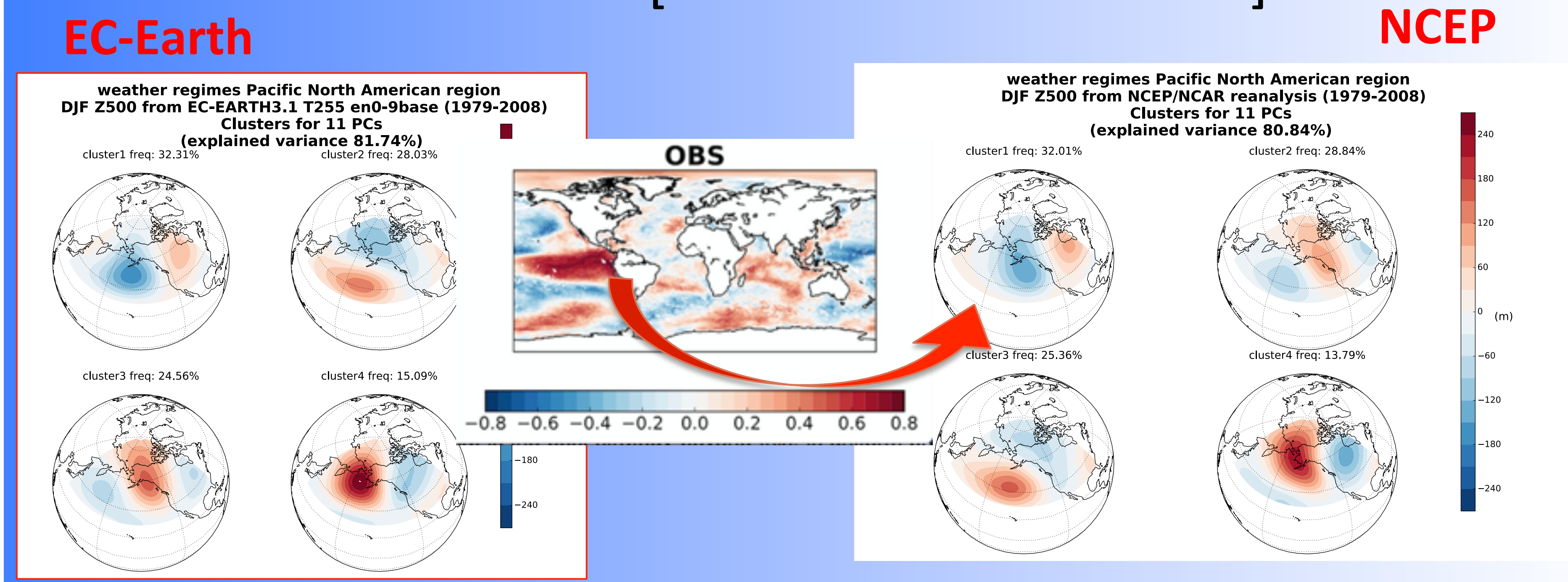




weather regimes variability for Pacific North American region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)



Pacific-North America Weather regimes
AMIP T255 [10 ensemble members]

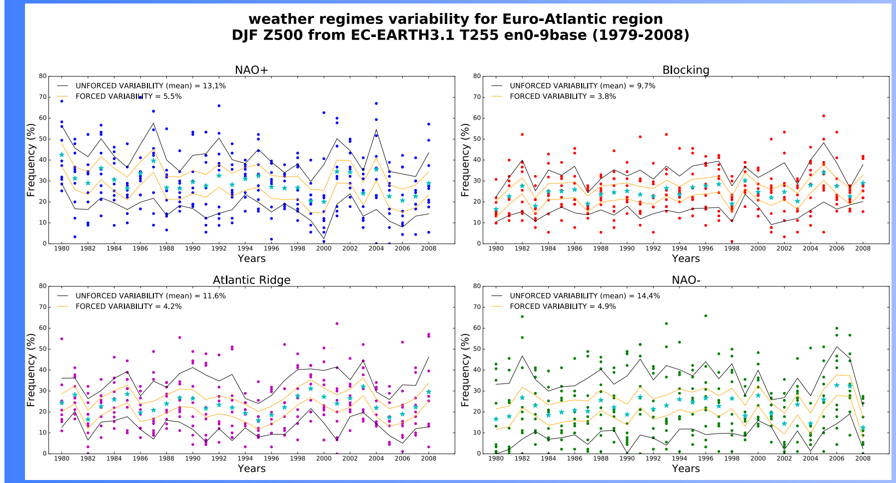


weather regimes Pacific North American region
DJF Z500 from EC-EARTH3.1 T255 en0-9base (1979-2008)
Clusters for 11 PCs
(explained variance 81.74%)

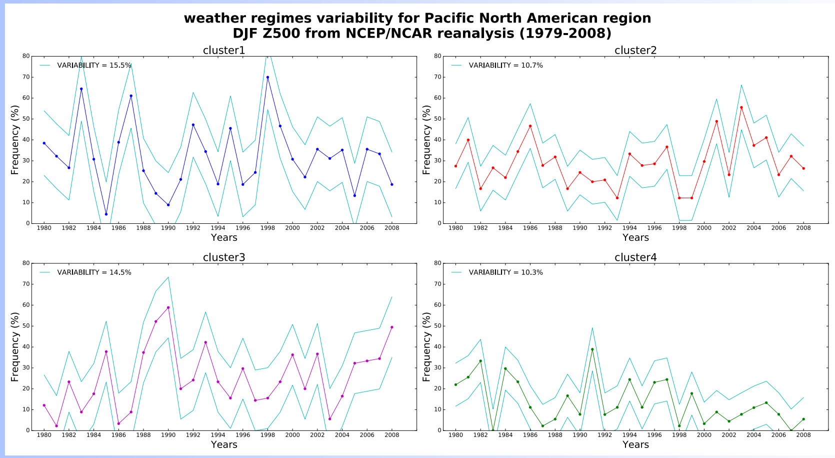
cluster1 freq: 32.31%
cluster2 freq: 28.03%
cluster3 freq: 24.56%
cluster4 freq: 15.09%

weather regimes Pacific North American region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)
Clusters for 11 PCs
(explained variance 80.84%)

cluster1 freq: 32.01%
cluster2 freq: 28.84%
cluster3 freq: 25.36%
cluster4 freq: 13.79%

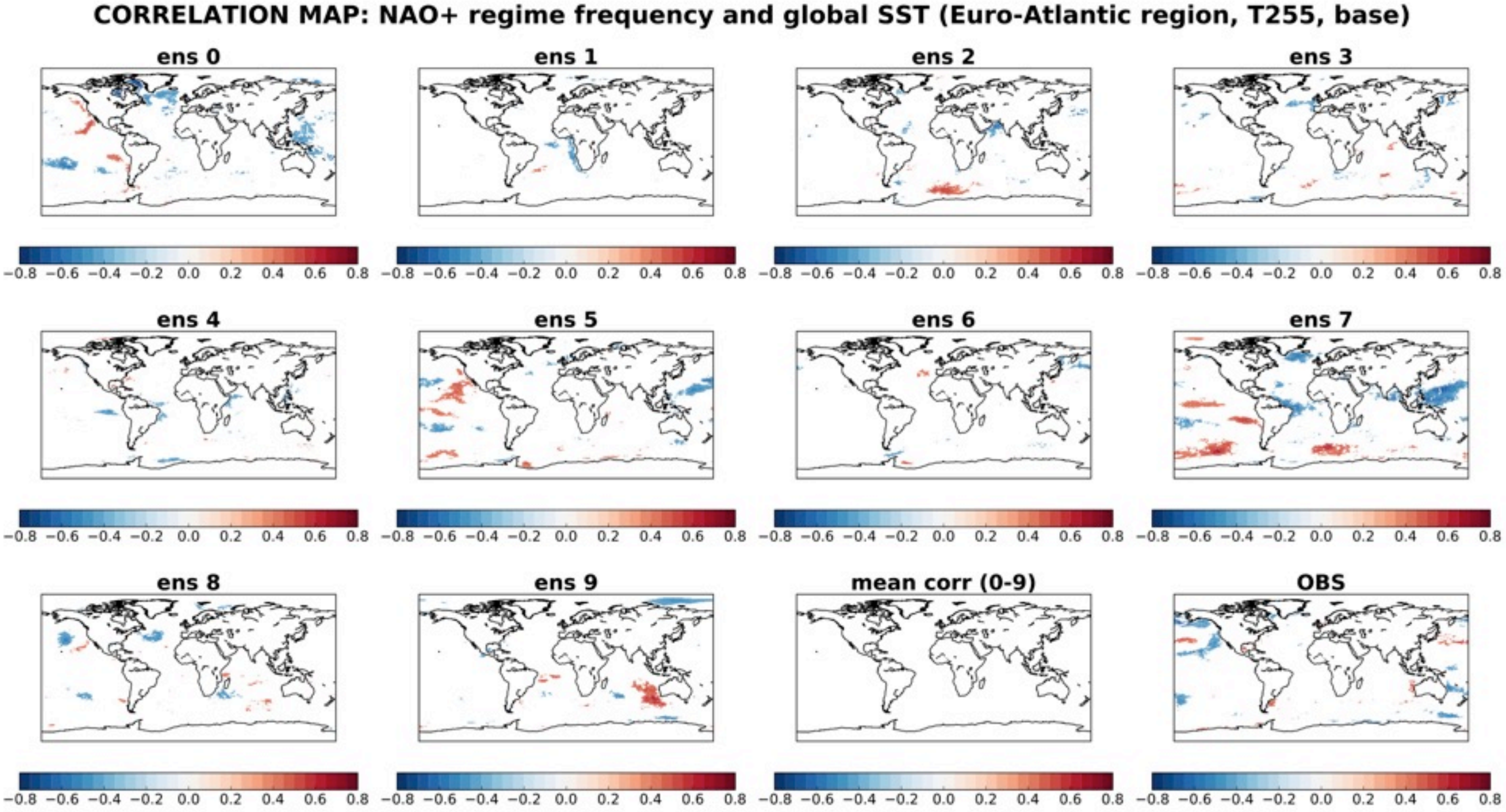


weather regimes variability for Euro-Atlantic region
DJF Z500 from EC-EARTH3.1 T255 en0-9base (1979-2008)

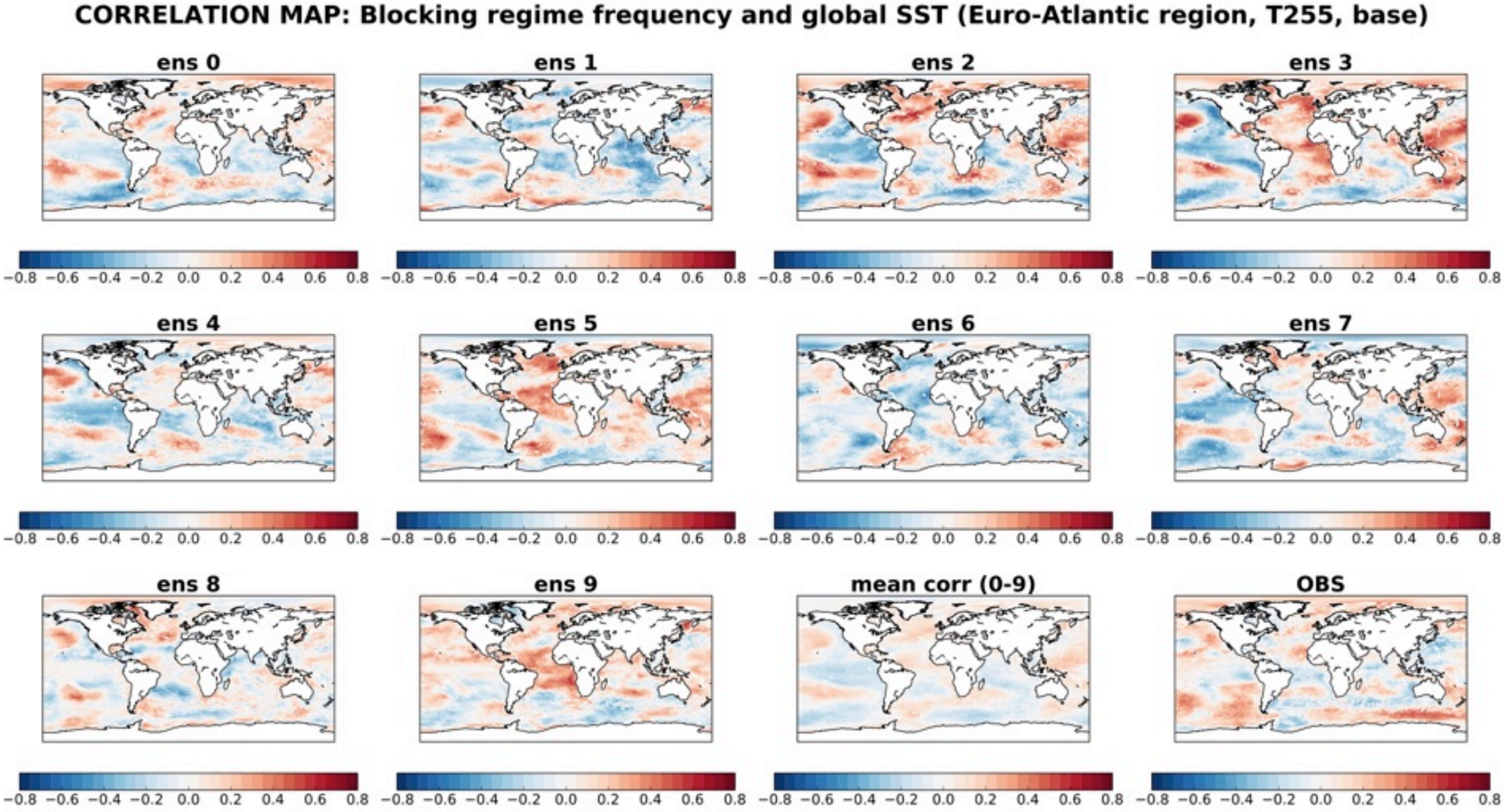


weather regimes variability for Pacific North American region
DJF Z500 from NCEP/NCAR reanalysis (1979-2008)

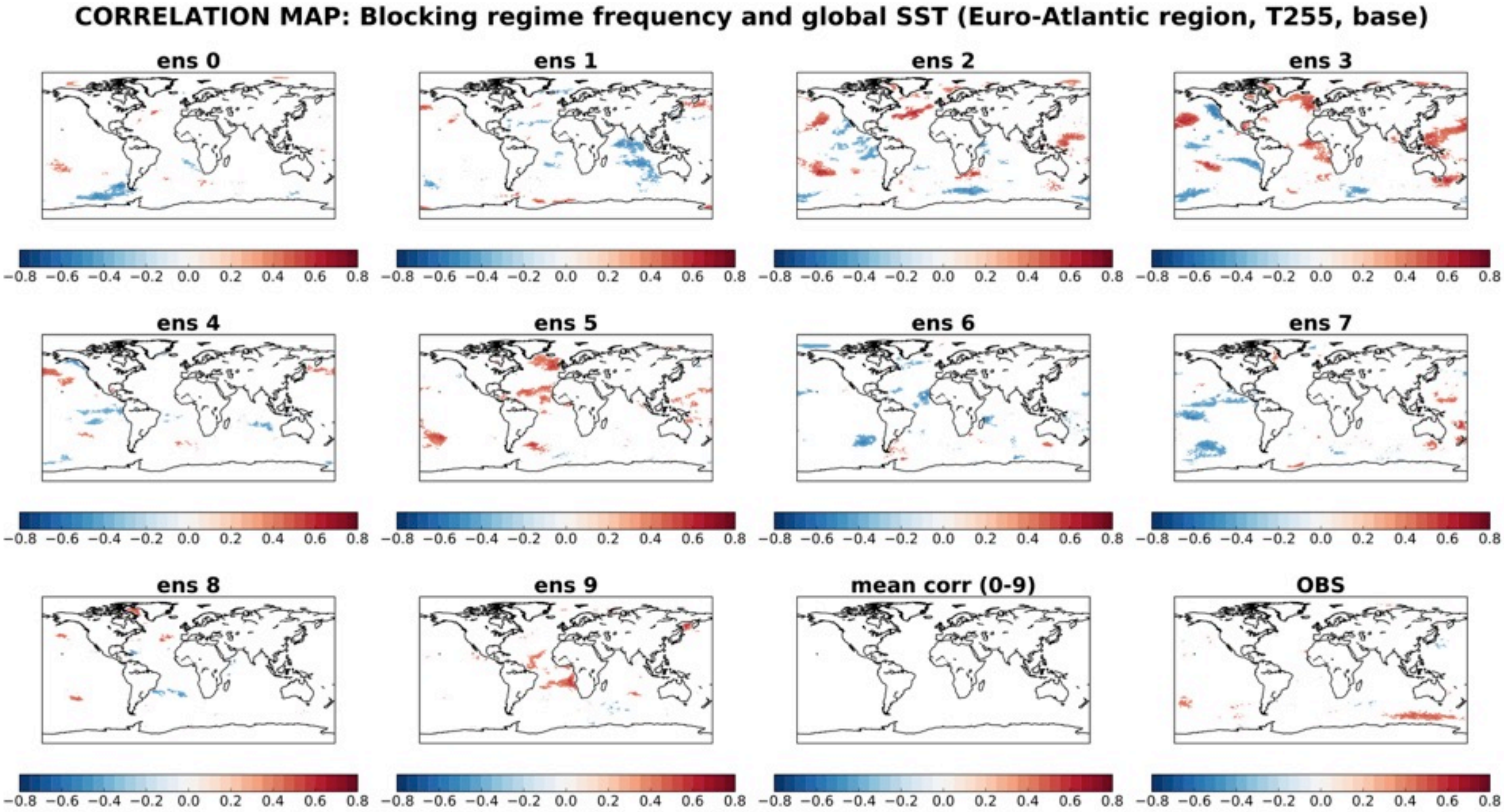
NAO+ Frequency & Global SST T255



Blocking Frequency & Global SST T255

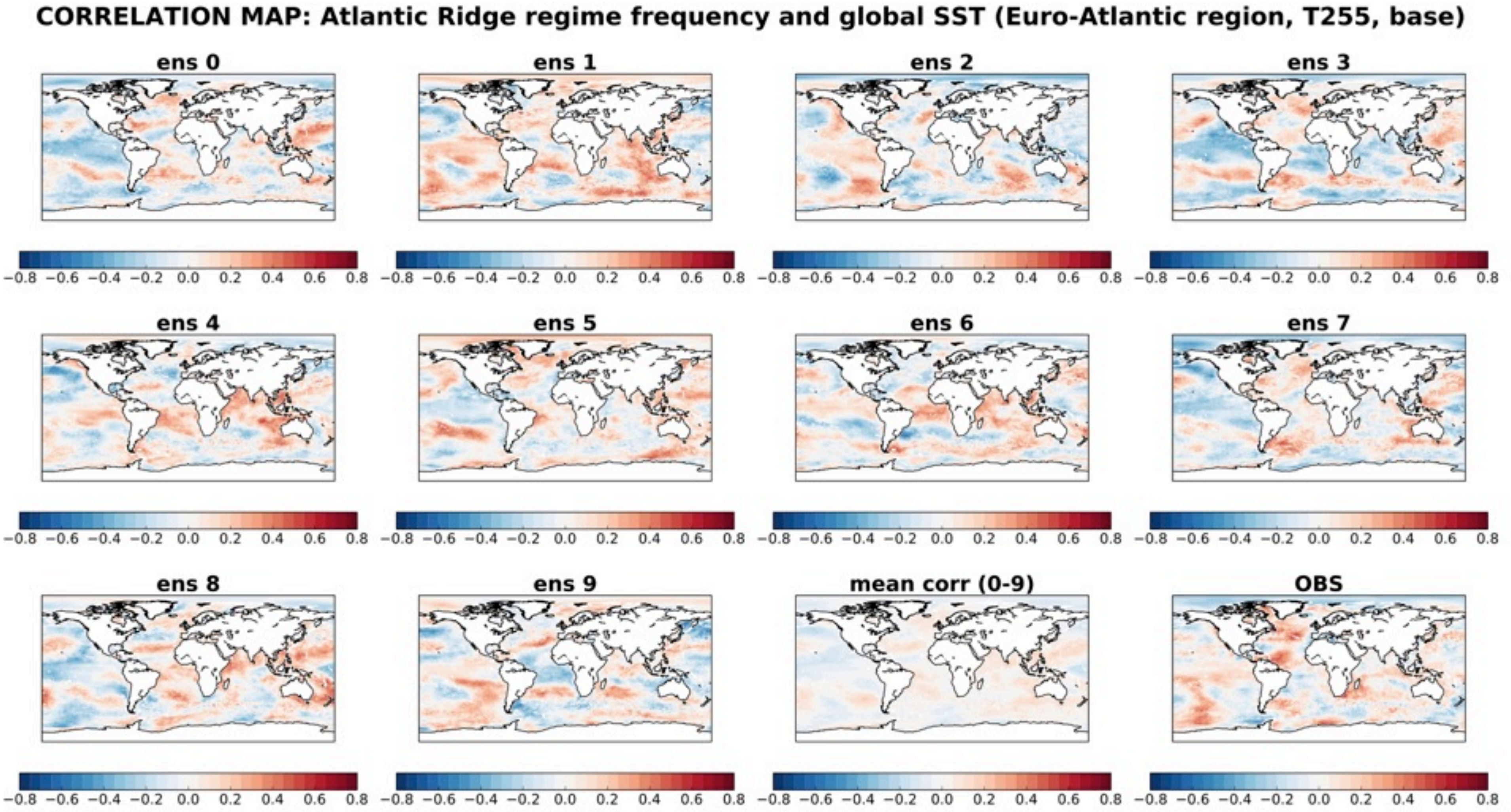

CORRELATION MAP: Blocking regime frequency and global SST (Euro-Atlantic region, T255, base)

Blocking Frequency & Global SST T255

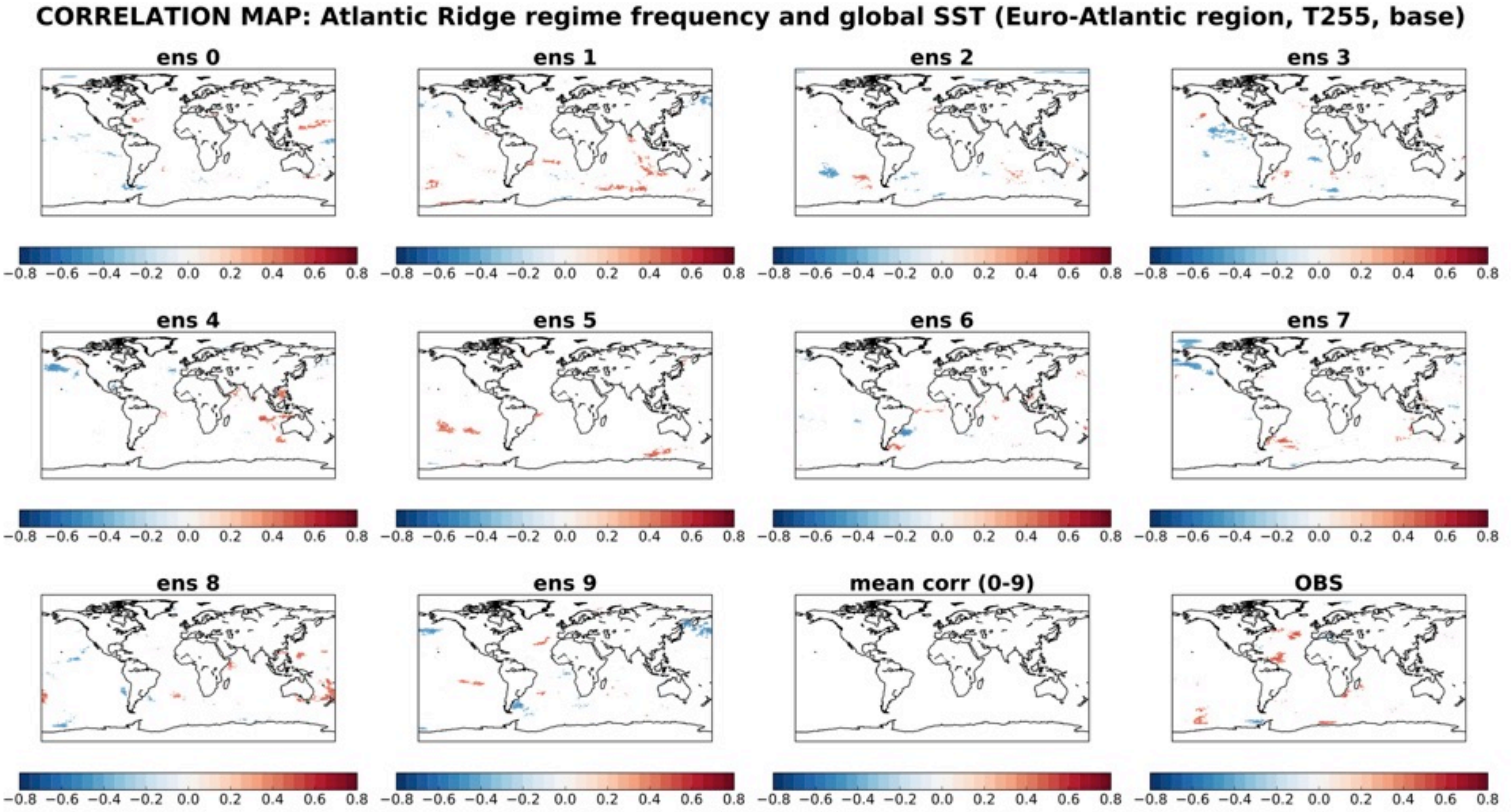


CORRELATION MAP: Blocking regime frequency and global SST (Euro-Atlantic region, T255, base)

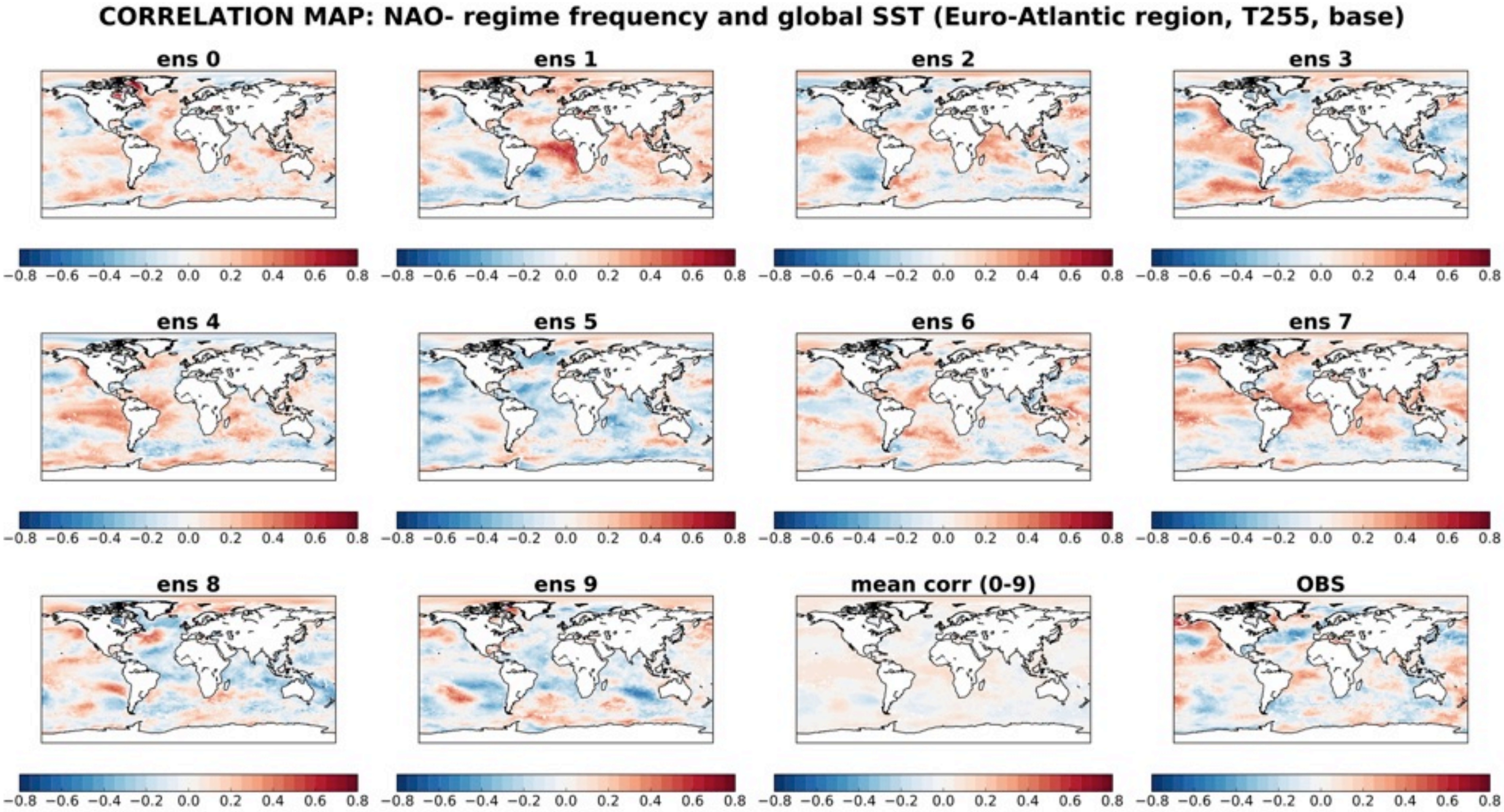
Atlantic Ridge Frequency & Global SST T255



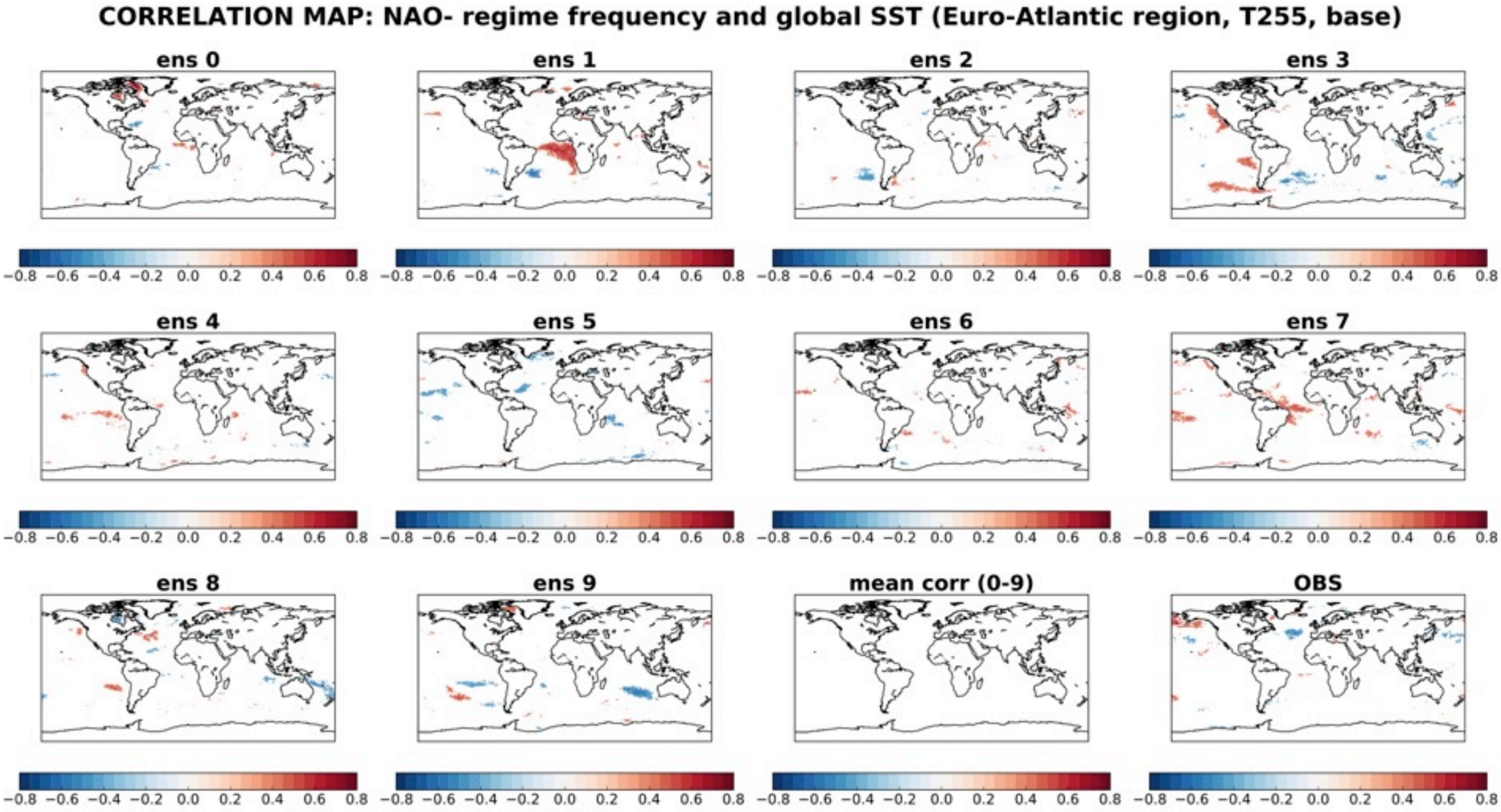
Atlantic Ridge Frequency & Global SST T255



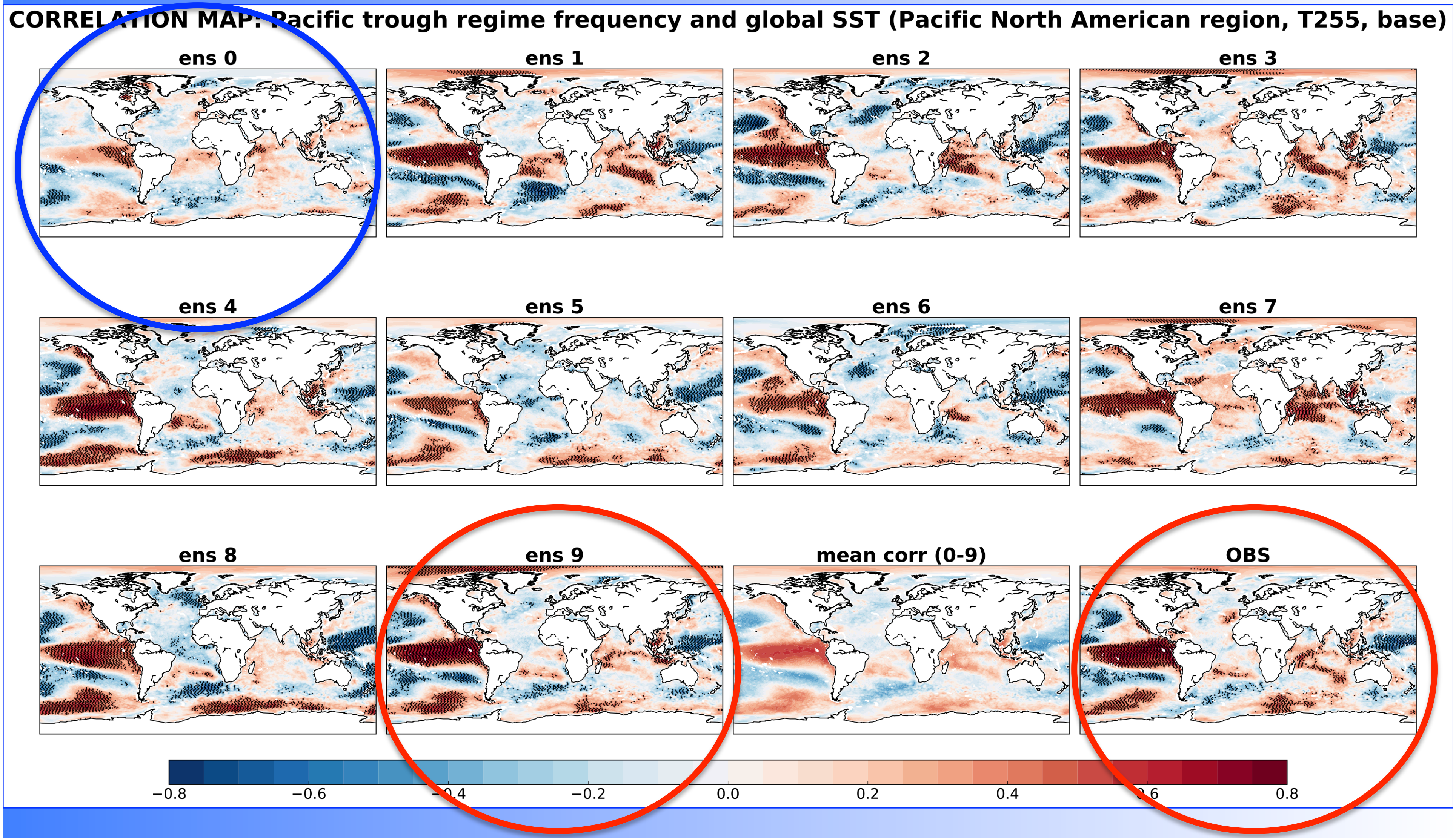
NAO- Frequency & Global SST T255



NAO- Frequency & Global SST T255



Pacific Trough Frequency & Global SST T255 DJF



Possible influence of the stratosphere

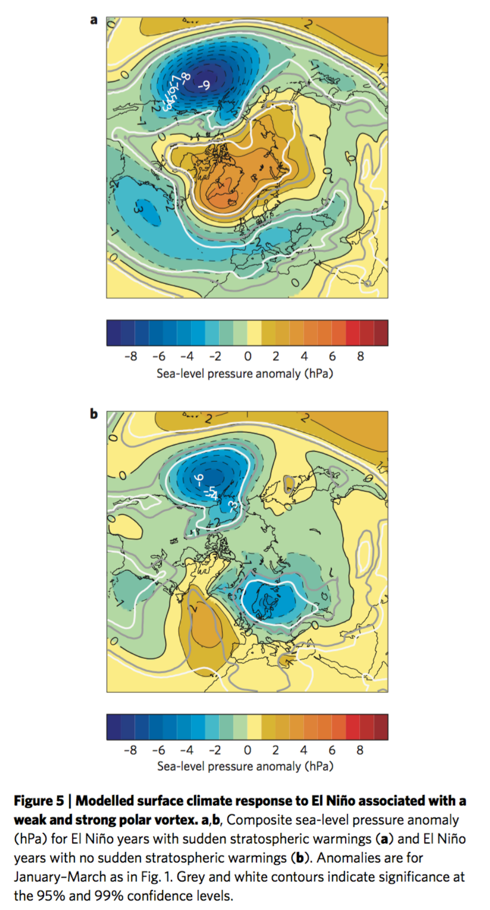
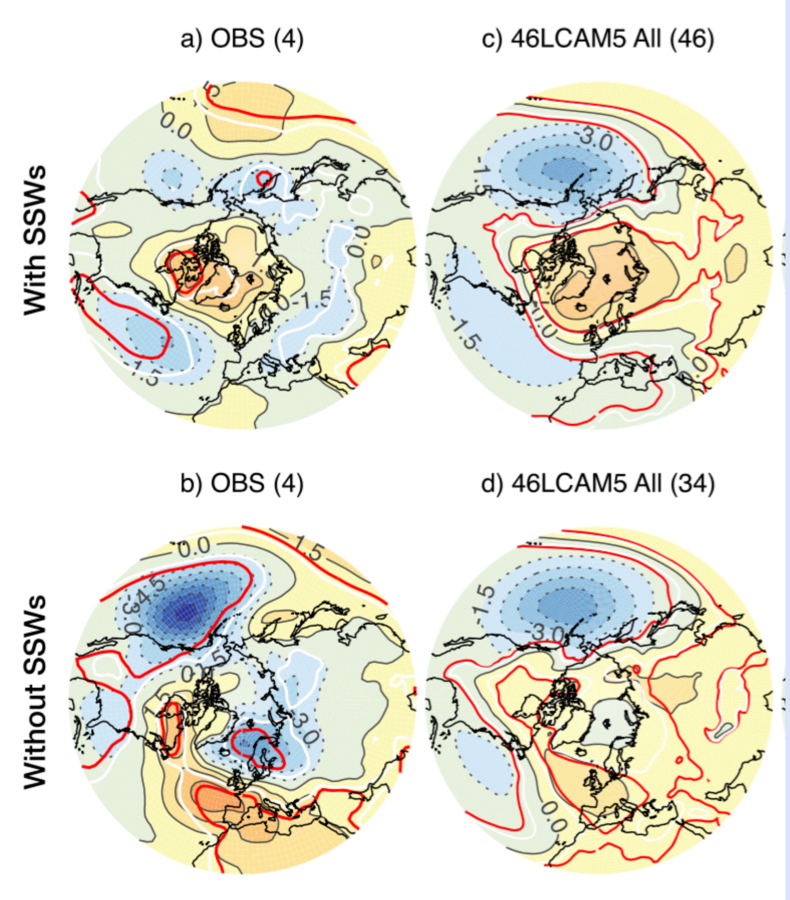


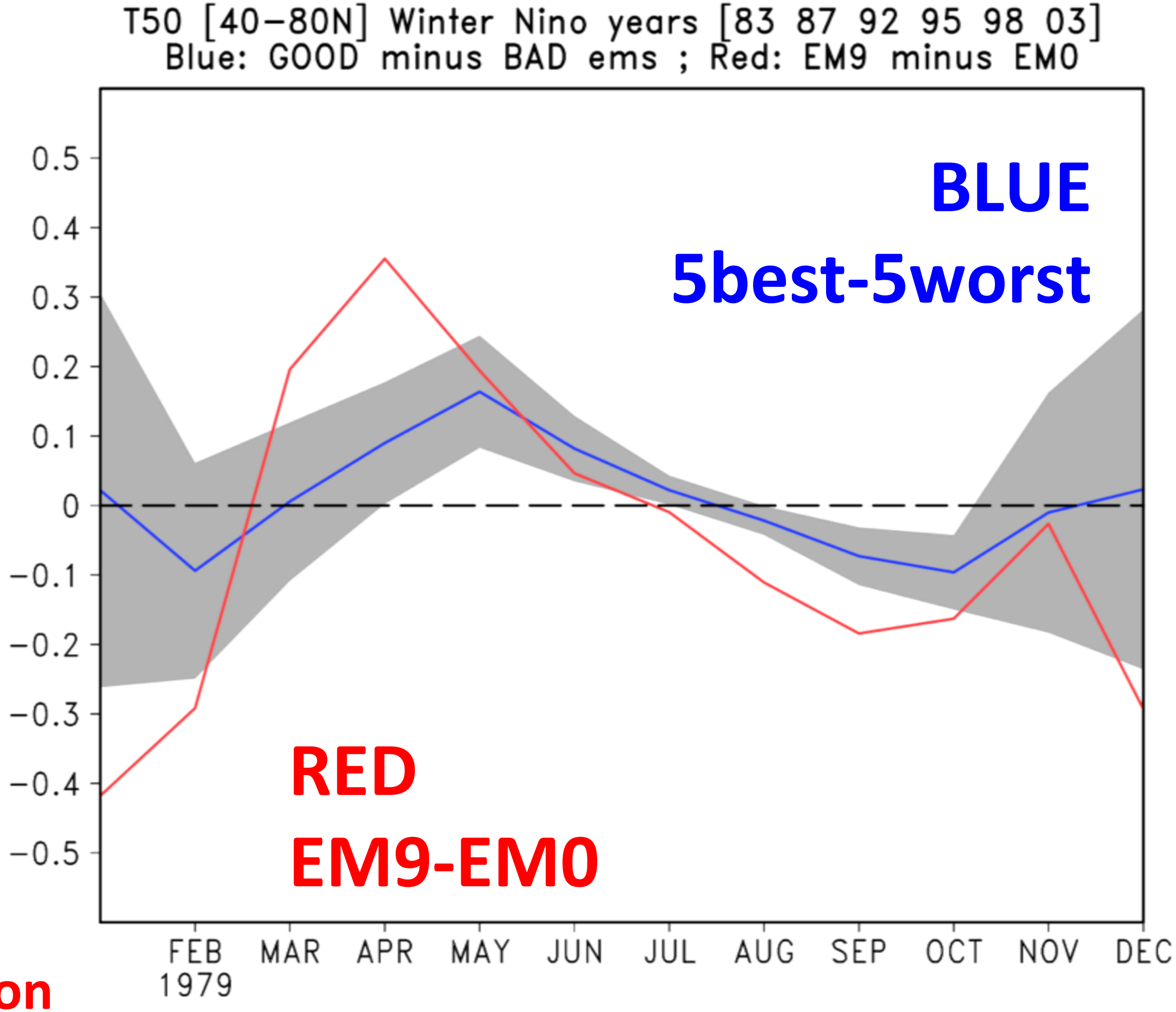
Figure 5 | Modelled surface climate response to El Niño associated with a weak and strong polar vortex. a,b, Composite sea-level pressure anomaly (hPa) for El Niño years with sudden stratospheric warmings (**a**) and El Niño years with no sudden stratospheric warmings (**b**). Anomalies are for January–March as in Fig. 1. Grey and white contours indicate significance at the 95% and 99% confidence levels.



Ineson and Scaife 2009
Nature GeoScience

Richter et al. 2015 ERL

Temperature at 50hPa [40-80N]
Good minus BAD – NIÑO WINTERS


T50 [40–80N] Winter Nino years [83 87 92 95 98 03]
Blue: GOOD minus BAD ems ; Red: EM9 minus EM0

BLUE

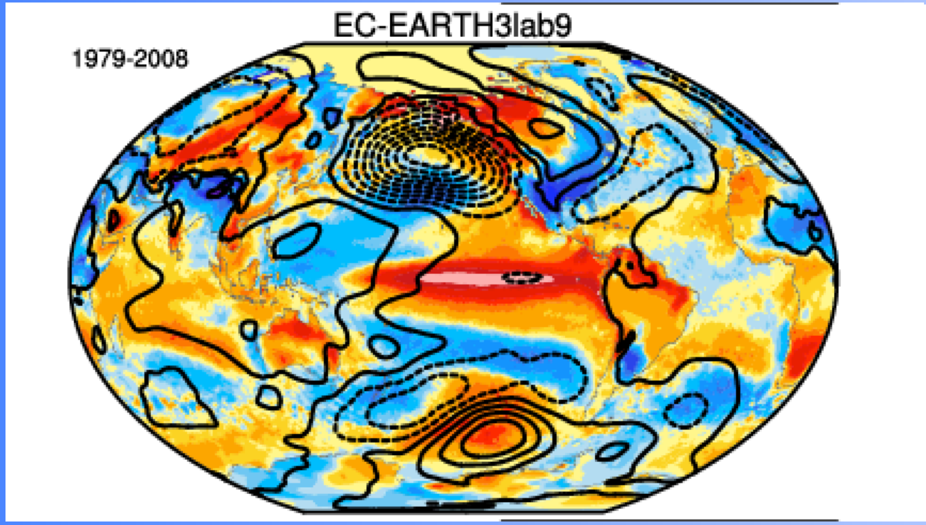
5best-5worst

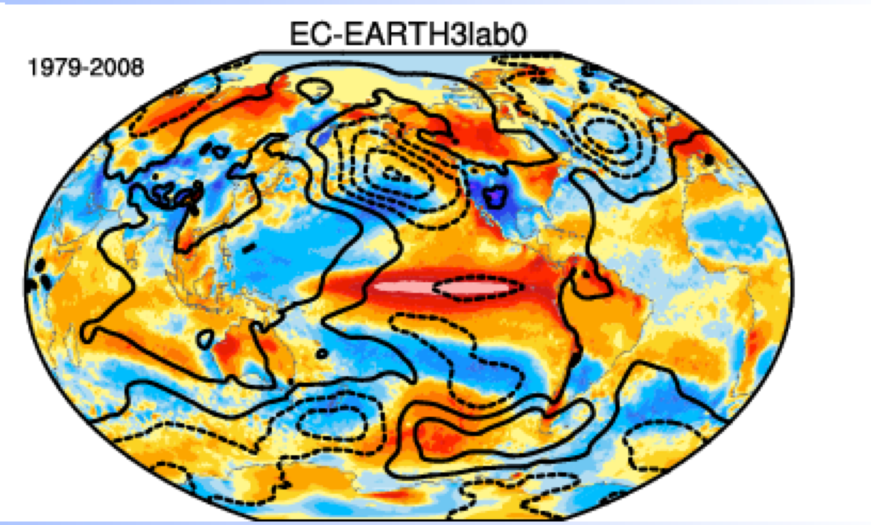
RED

EM9-EM0

Warm stratosphere →Week teleconnection

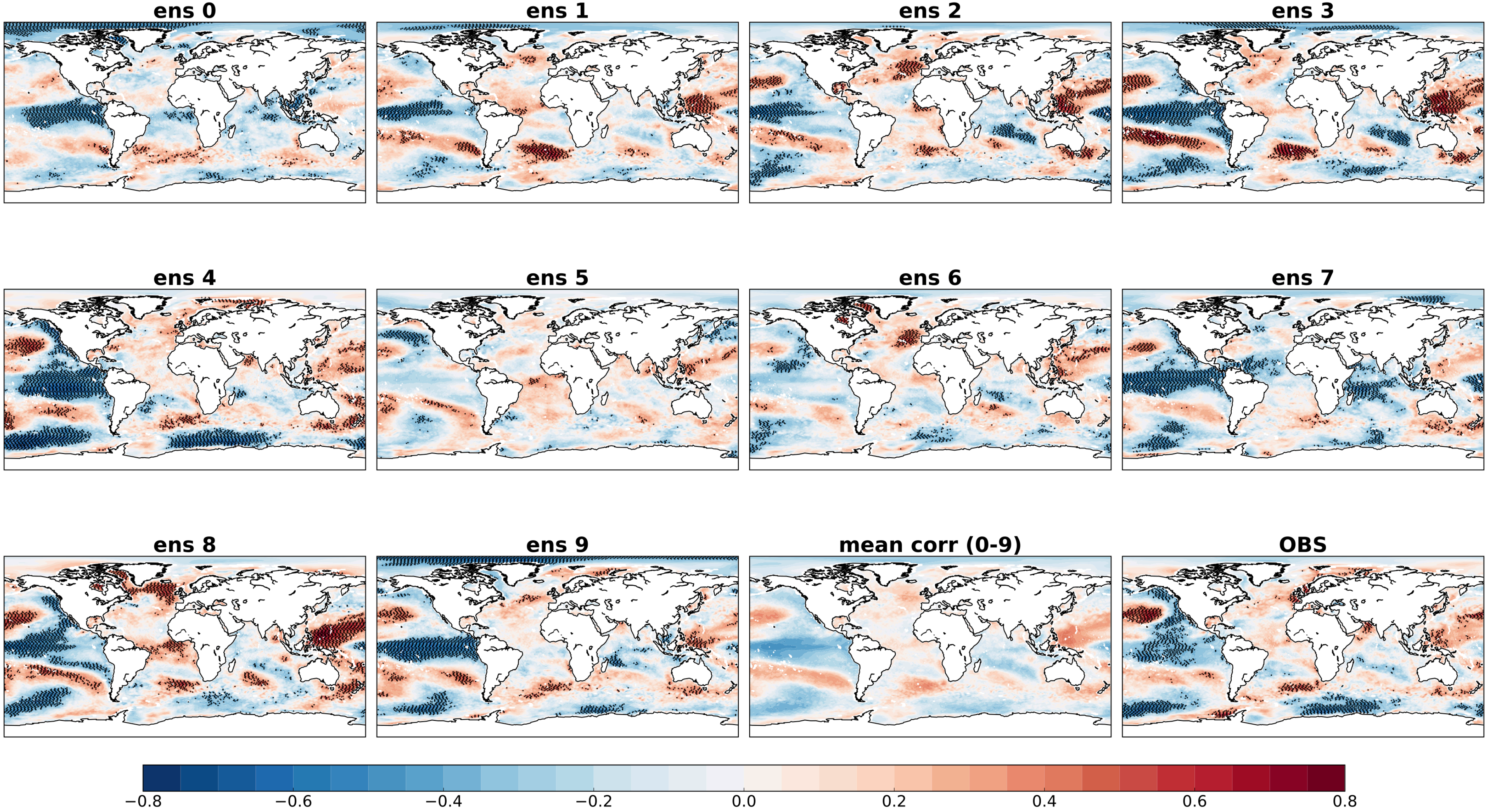
Nino3.4 Teleconnection in ens9 and ens0



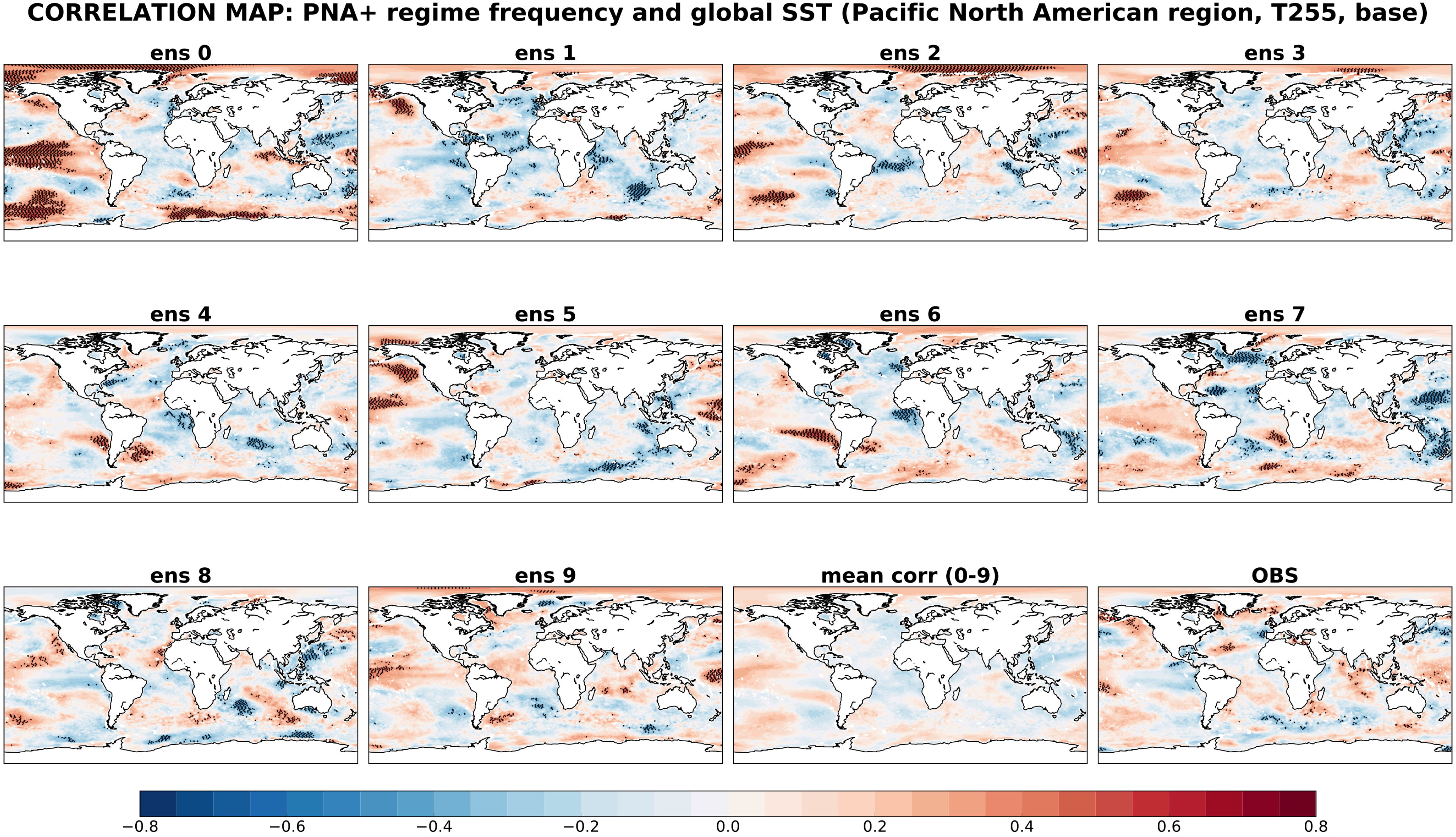


PNA- Frequency & Global SST T255

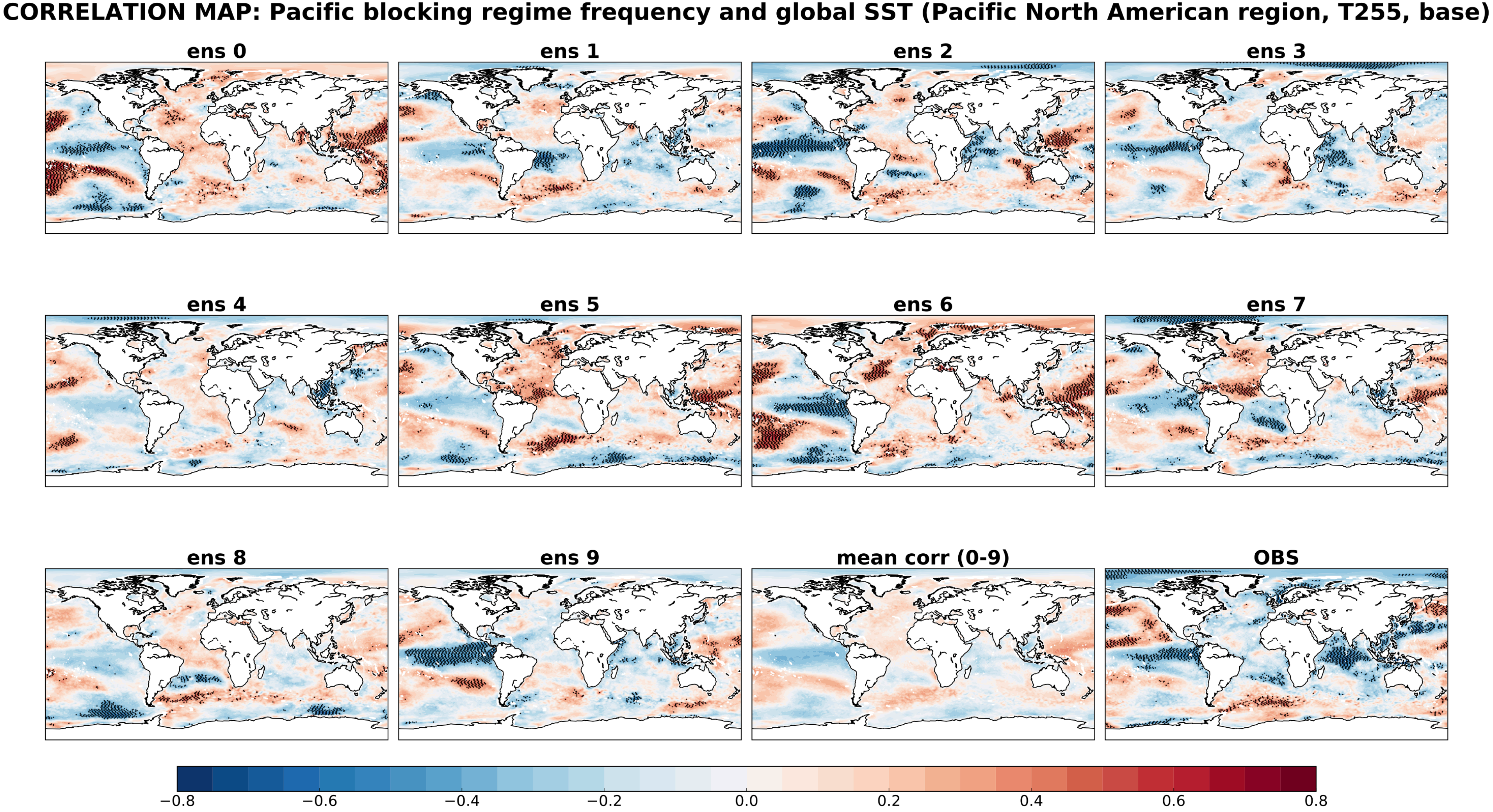
CORRELATION MAP: PNA- regime frequency and global SST (Pacific North American region, T255, base)



PNA+ Frequency & Global SST T255



Alaskan Ridge Frequency & Global SST T255



CORRELATION MAP: Pacific blocking regime frequency and global SST (Pacific North American region, T255, base)

ens 0

ens 1

ens 2

ens 3

ens 4

ens 5

ens 6

ens 7

ens 8

ens 9

mean corr (0-9)

OBS

Concluding remarks

- Euro-Atlantic and Pacific-American Regime patterns are well simulated.
- As in Peings and Magnusdottir [2014] and Davini et al. [2015], the observations show an increased blocking and NAO- frequency during AMV + period and a decreased NAO+ frequency during AMV-: there is an opposite sign relationship between the polarities of the AMV and the NAO.
- In AMIP simulations, the sensitivity to the AMV phase changes largely according to the ensemble member. The most sensitive ensemble members are those with positive anomalies in Eurasian Snow Depth and Temperature in the Stratosphere in DJF
- The DJF PNA-Niño teleconnection exhibits a non-negligible inter-ensemble variability as well.
- The stratosphere might play a role in amplifying or inhibiting the teleconnection. During El Niño winters the best ensemble member has a colder stratosphere than the worst. However the signal is only partially coherent among ensemble members and winters and further investigation is needed to drive conclusions.