Tropical-Extratropical teleconnections in present and future climate: sensitivity to model resolution and stochastic parameterizations.

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EMS Annual Meeting 2016,
Towards better understanding mid-latitude atmospheric teleconnections
13th of September 2016, Trieste

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

Outline

- Climate SPHINX experiment setup [present day and future AMIP integrations with EC-Earth 3.1. Different resolutions and inclusion (or not) of stochastic physics]
- Wintertime (DJF) Weather regimes in the Euro-Atlantic and Pacific American regions in the NCEP reanalysis and teleconnections with global SSTs
- Weather regimes simulation in AMIP integrations (patterns – frequency – teleconnections) for present day and future: sensitivity to resolution and stochastic physics.

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).

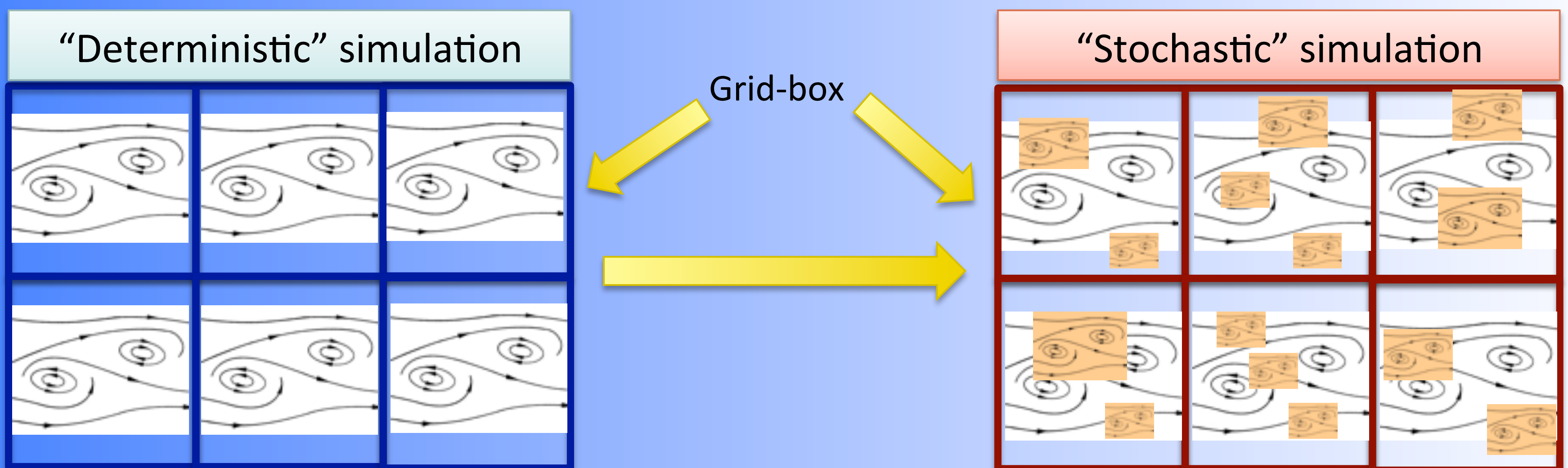
20 millions of core hours have been run on **Supermuc** @ LRZ Computing Center, Garching, Germany for a single-year PRACE project ended in **March 2016.**

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.



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 $\pm 2\sigma$;

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

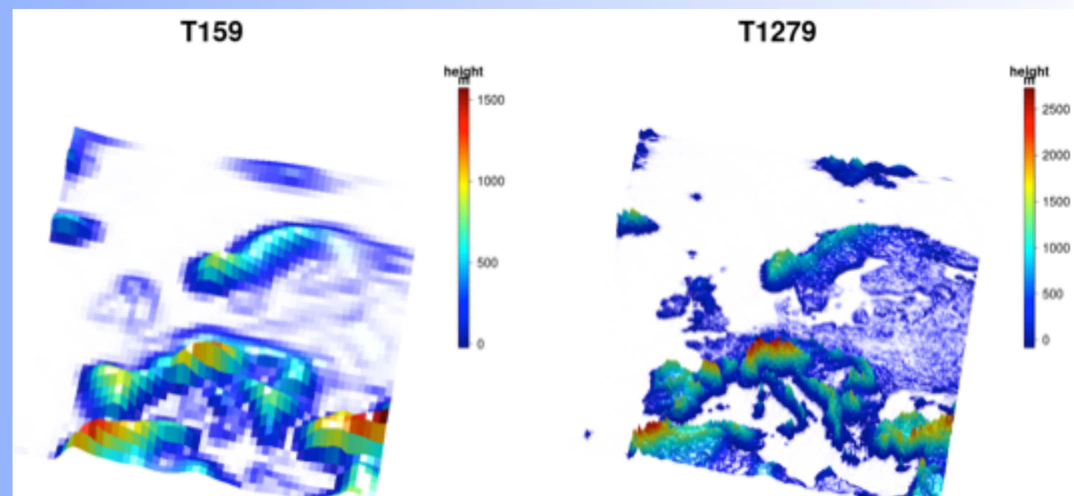
EXPERIMENTS & RESOLUTIONS

Atmospheric-only:
5 horizontal resolutions

Present day
1979-2008

Future Scenario
2039-2068 RCP85

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



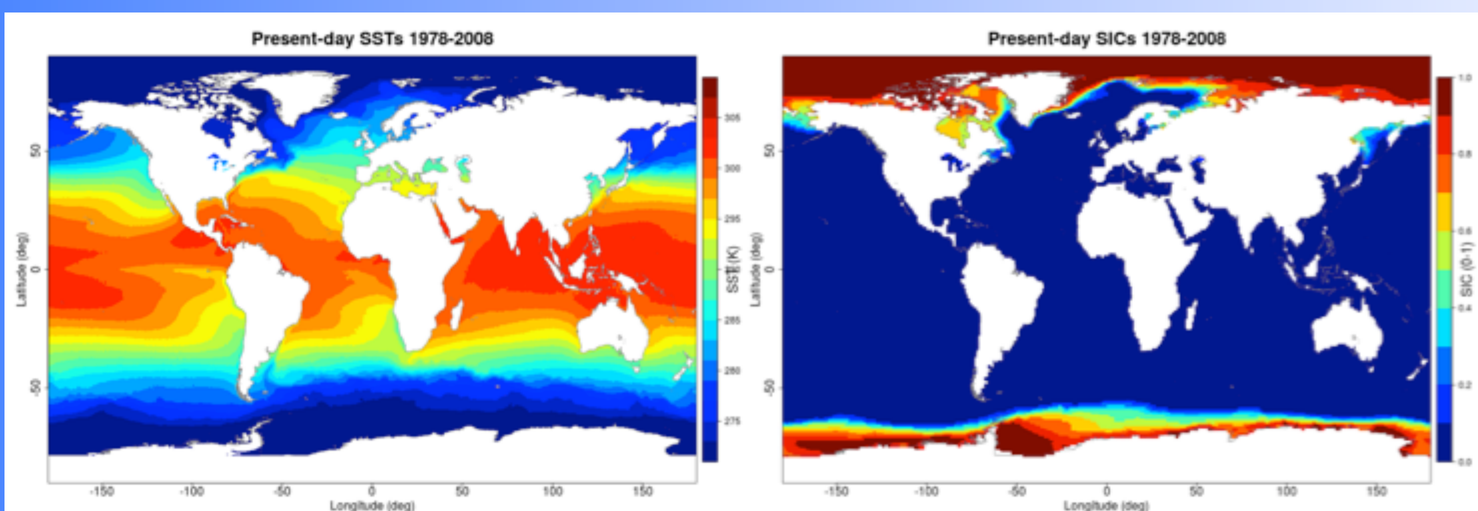
Tuning has been performed once only for T255L91 with no stochastic physics!

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.



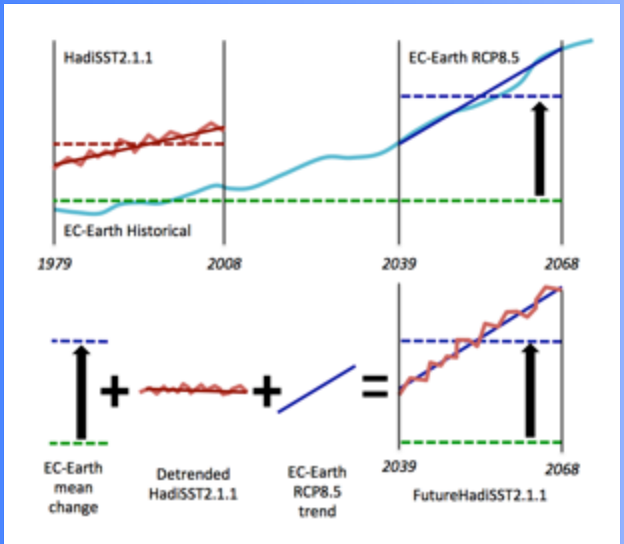
THE FORCING: FUTURE SCENARIO

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

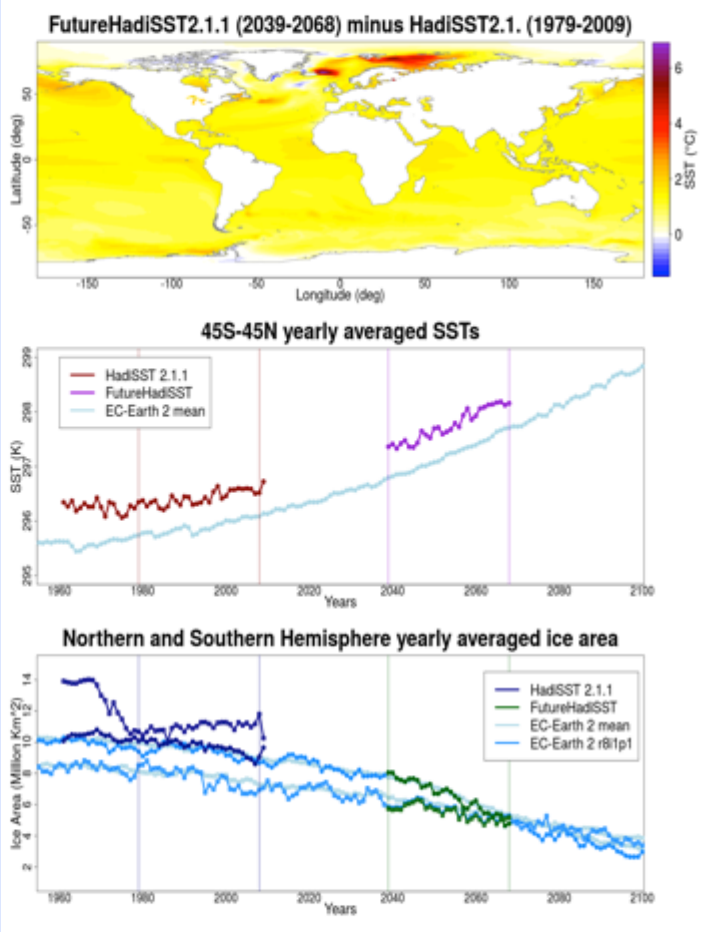
- EC-Earth 2 **CMIP5 ensemble mean for mean values and trend of SST**, and **daily variability is taken from HadiSST 2.1.1**.

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

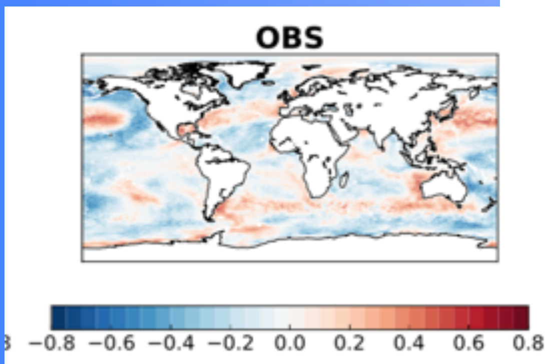
- For SICs, we pick one ensemble member of EC-Earth CMIP5 representative of the dataset (i.e. closer to ensemble mean).

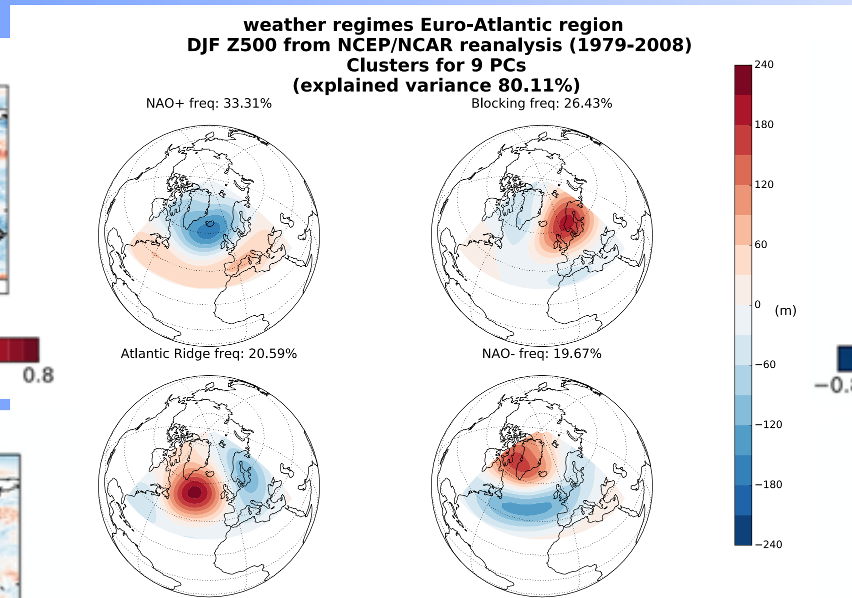


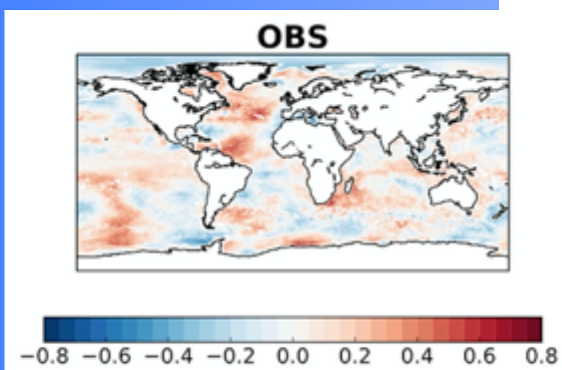
- **Bare-points due to retreat of sea-ice:** specific filling combining a linear interpolation and HadISST 2.1.1 variability.

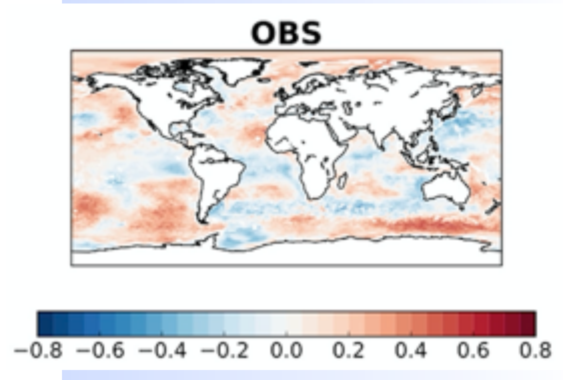


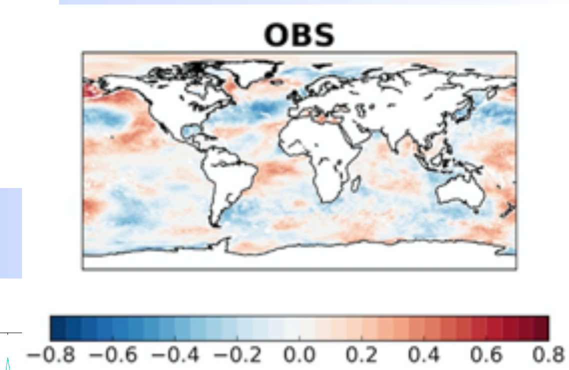
Euro-Atlantic Weather regimes NCEP

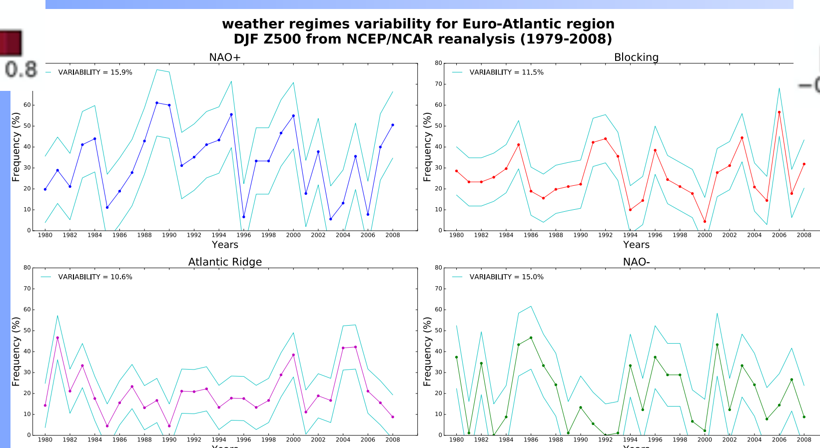












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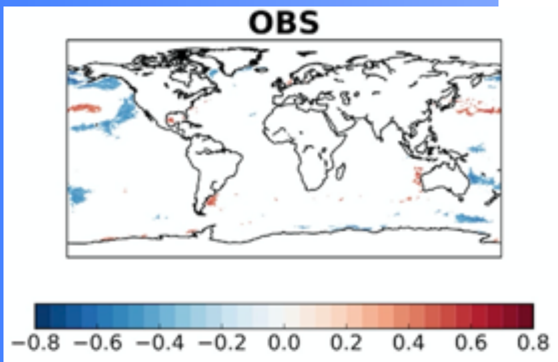
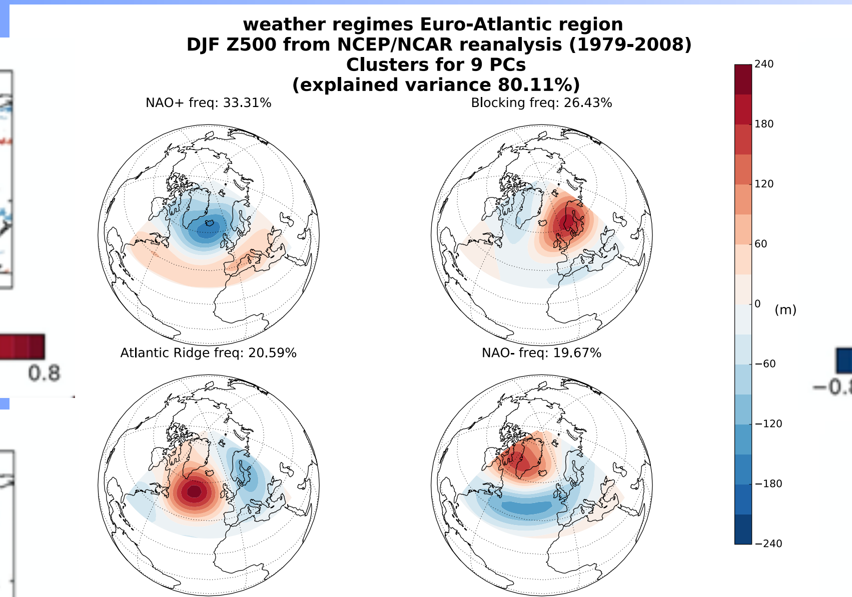
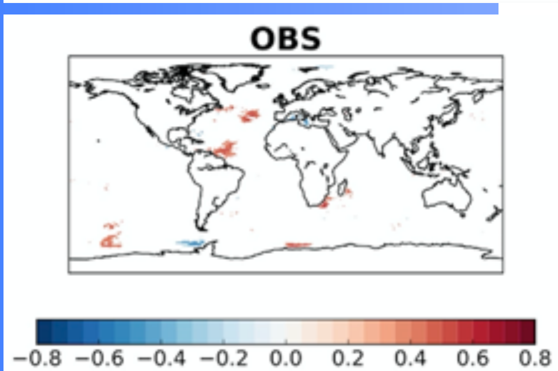
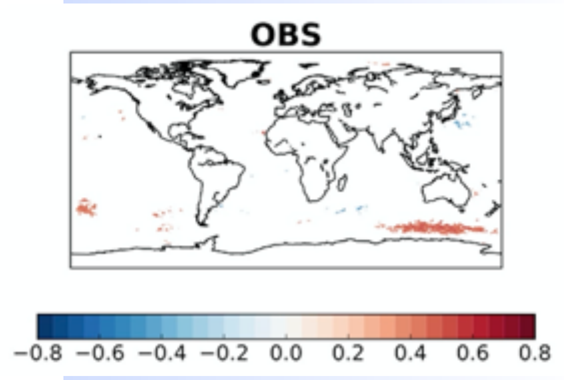
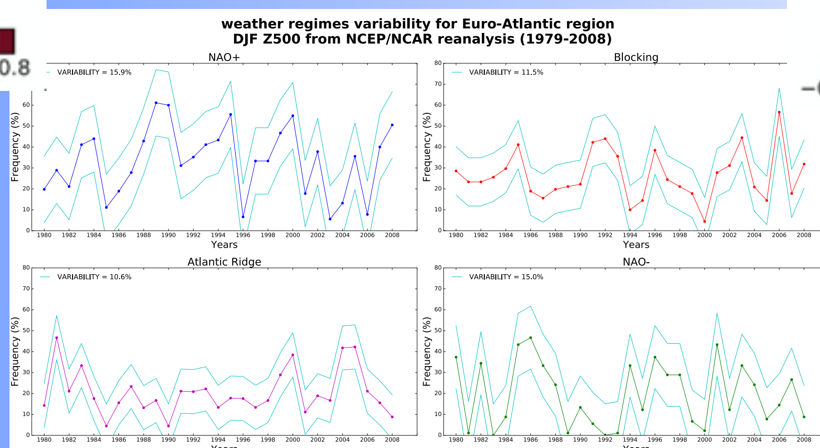
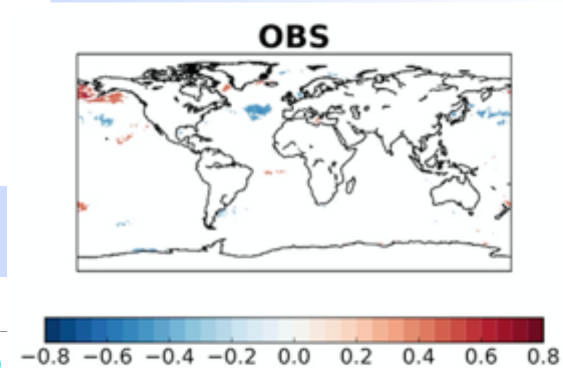




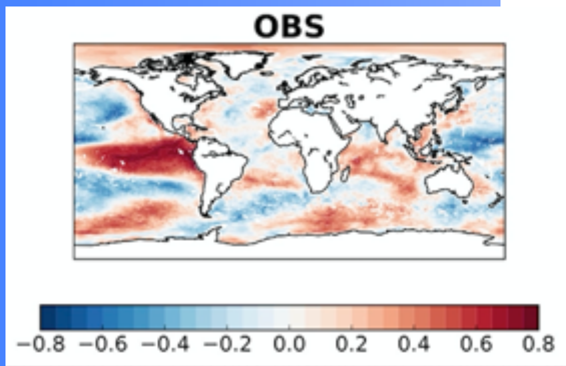


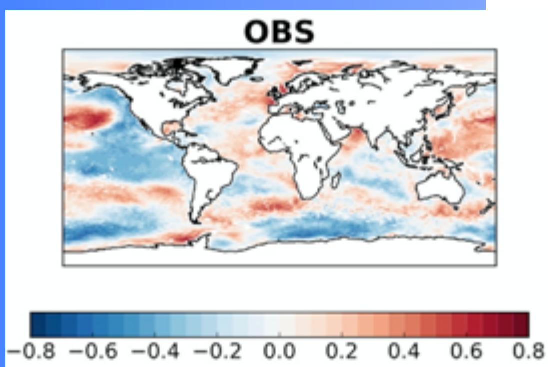


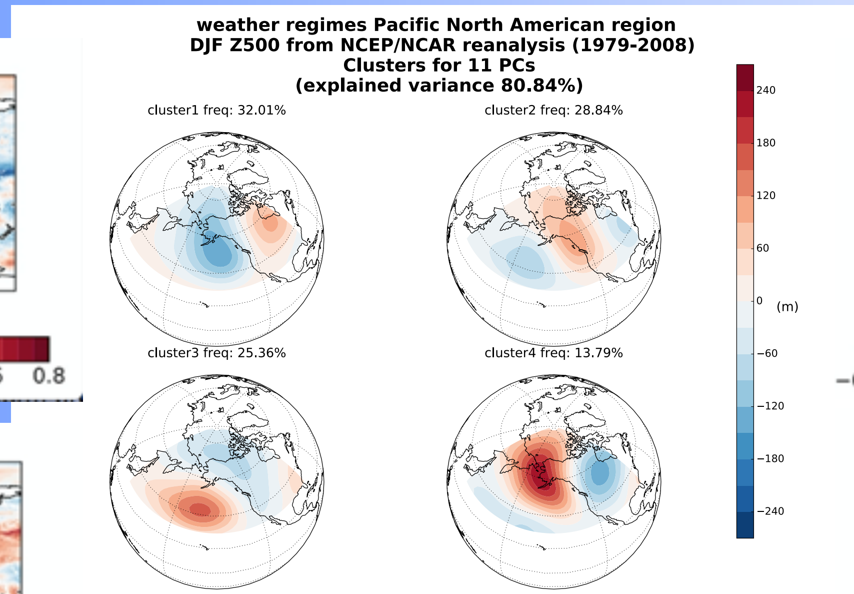


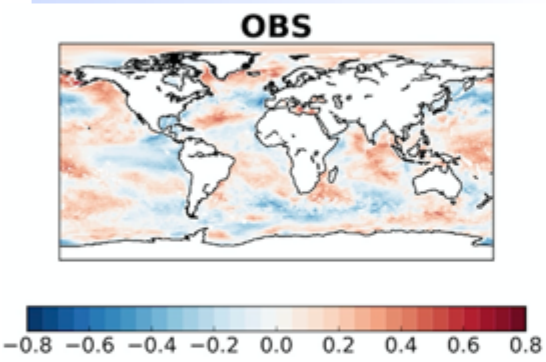


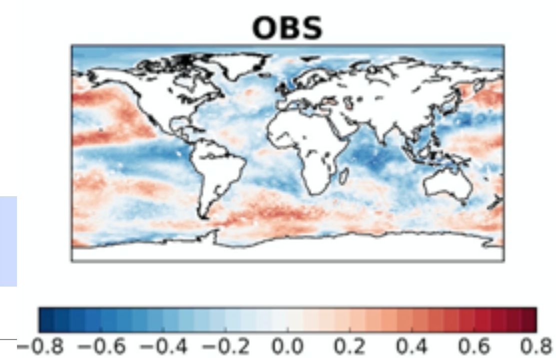
Pacific-North America Weather regimes NCEP

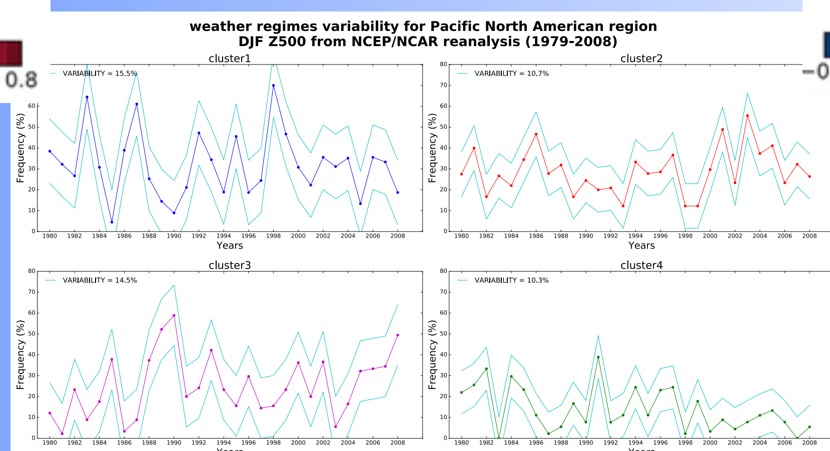




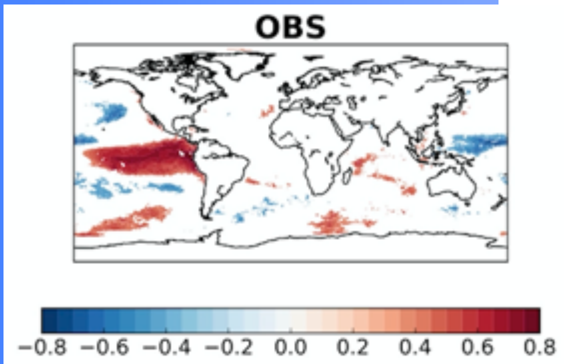


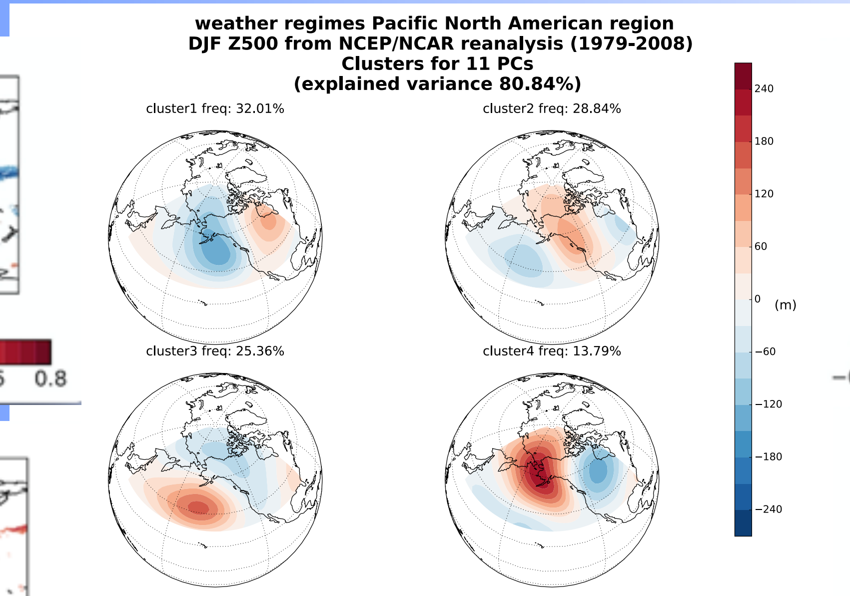


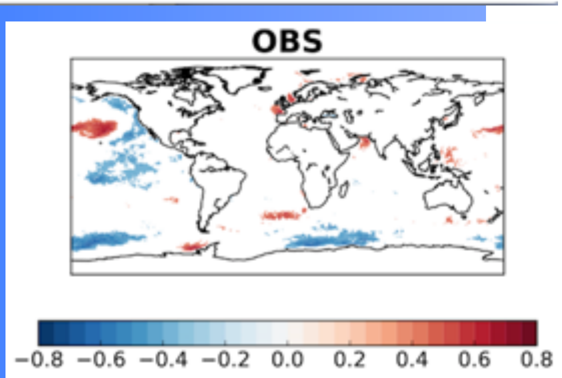


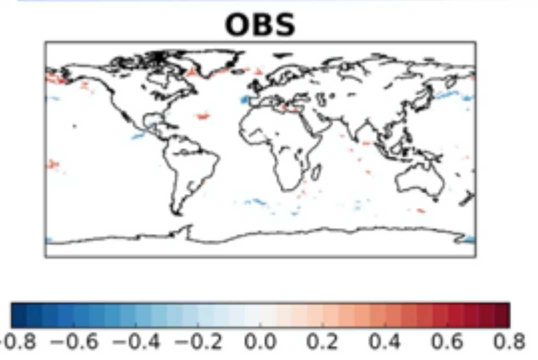


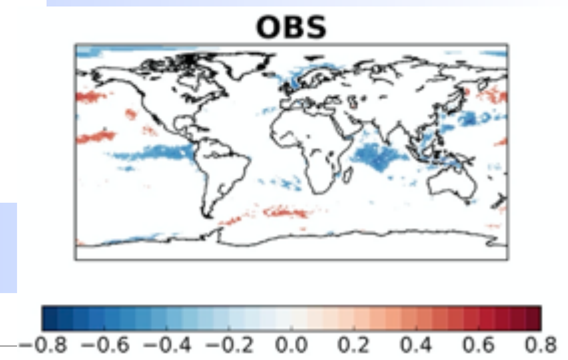
Pacific-North America Weather regimes NCEP

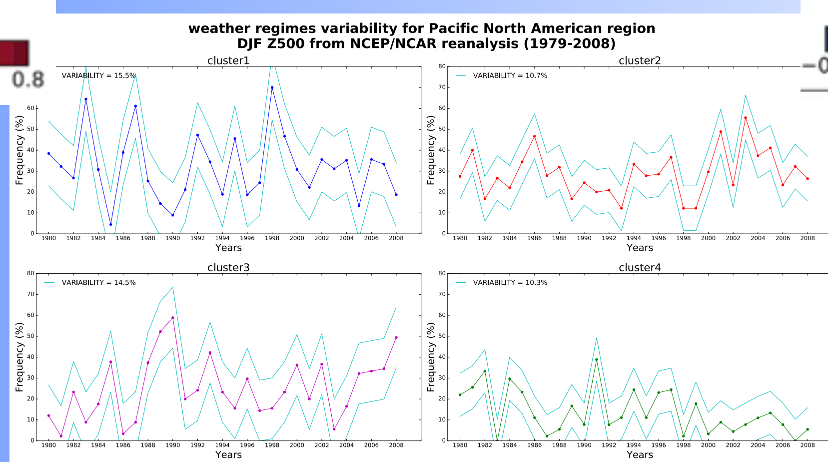






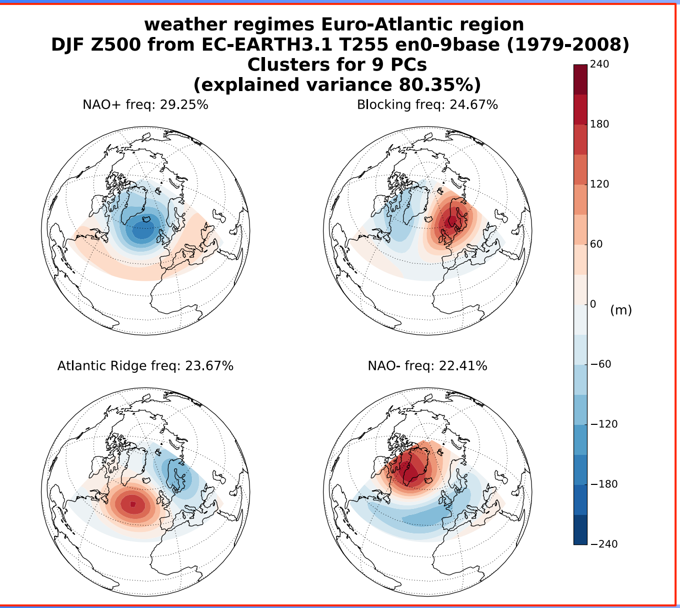


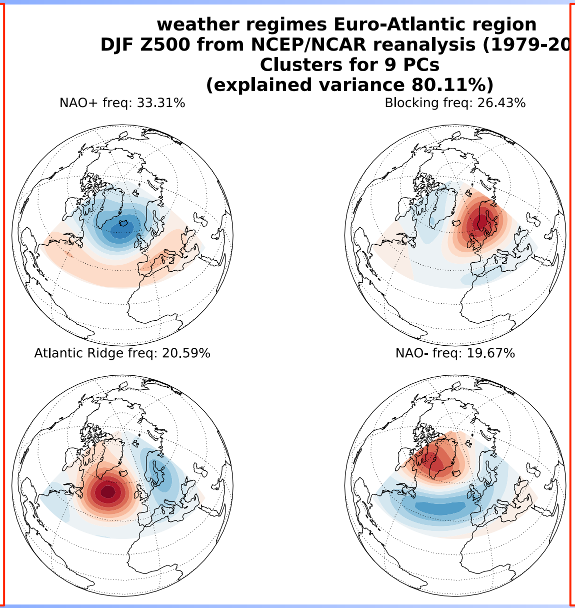


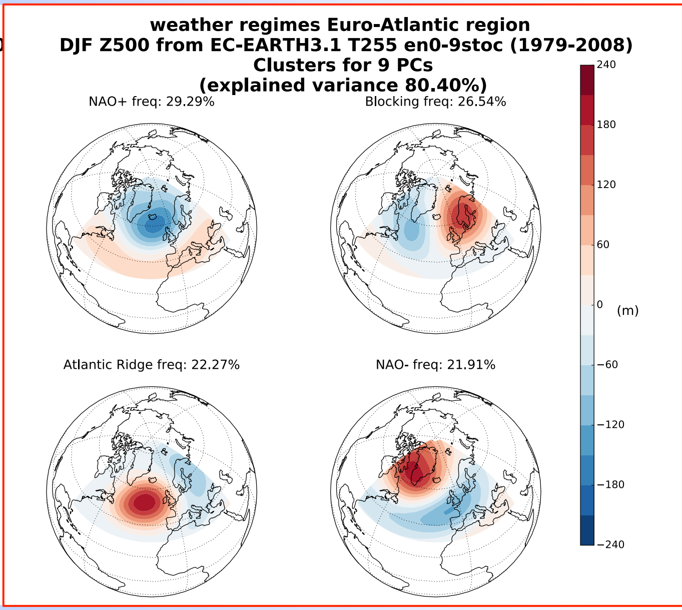


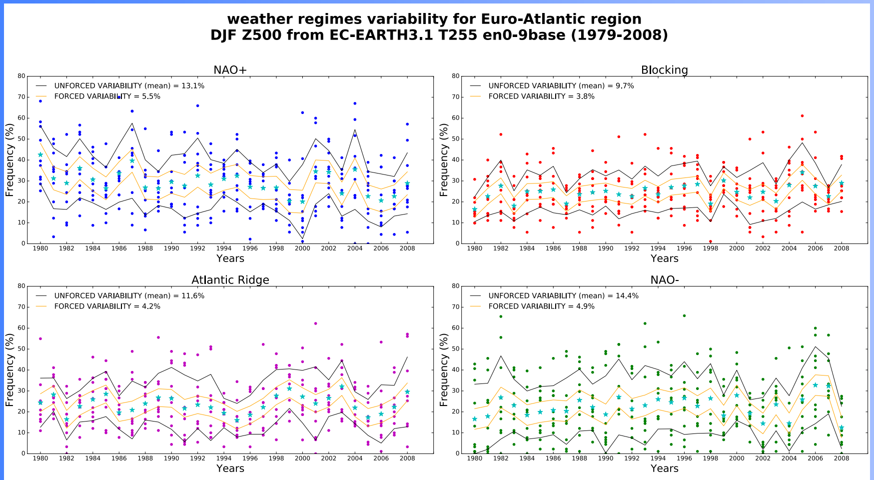
Euro-Atlantic Weather regimes
AMIP T255 [10 ensemble members]

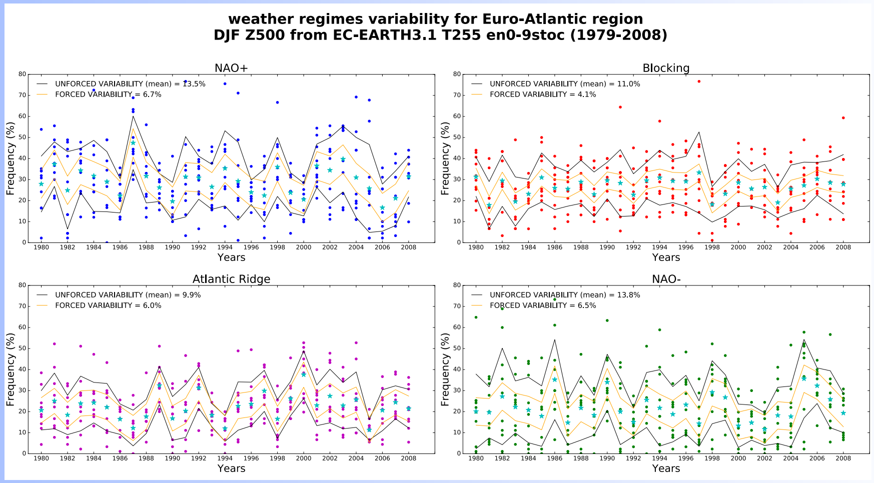
BASE **NCEP** **SP**





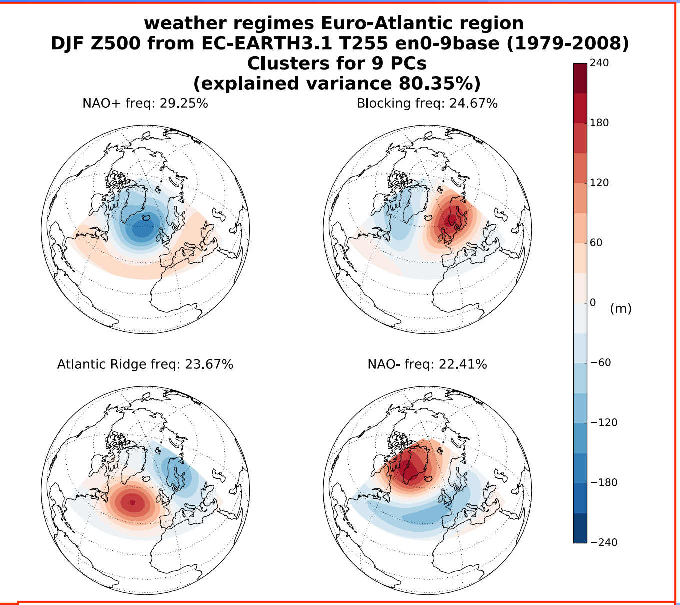




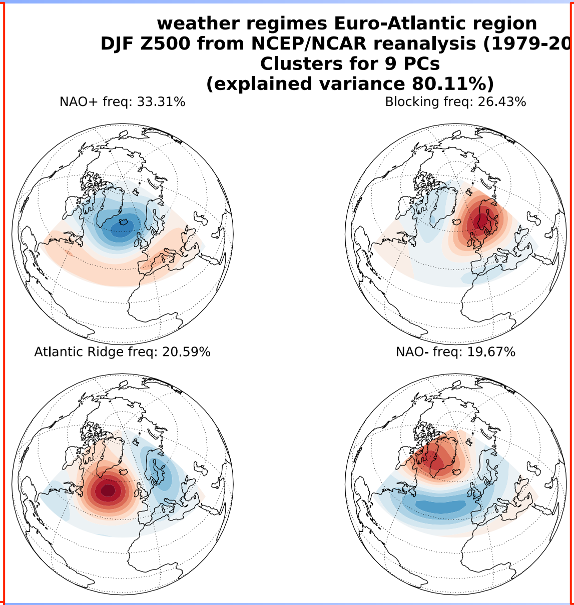


Euro-Atlantic Weather regimes
AMIP T255 [10 ensemble members]

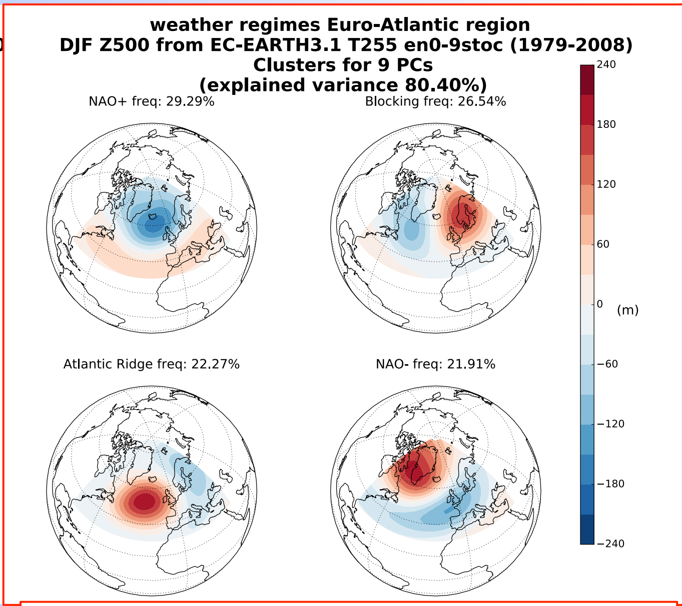
BASE

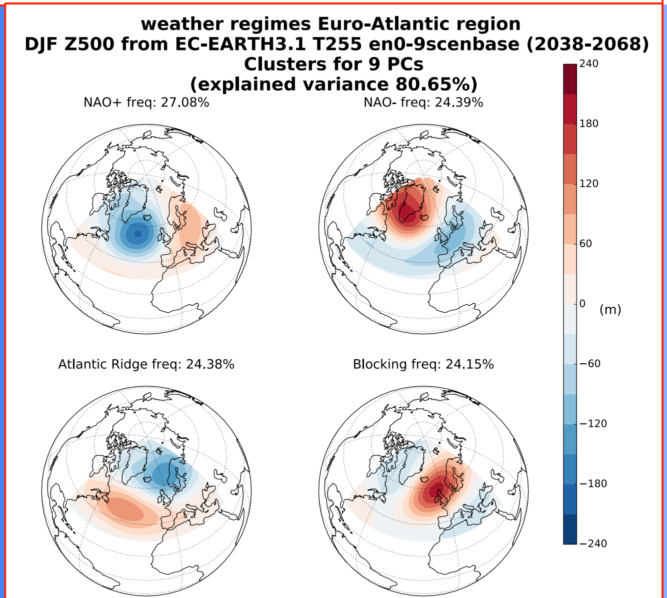


NCEP

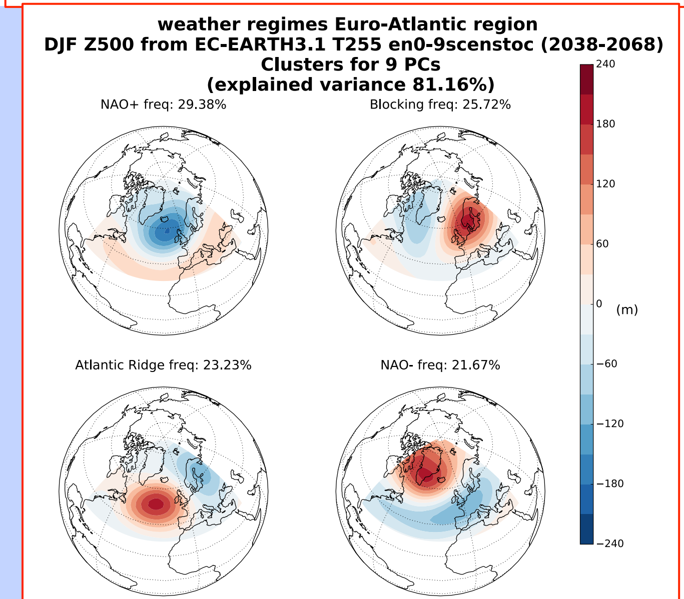


SP





Future Scenario



Euro-Atlantic Weather regimes
AMIP T511 [6 ensemble members]

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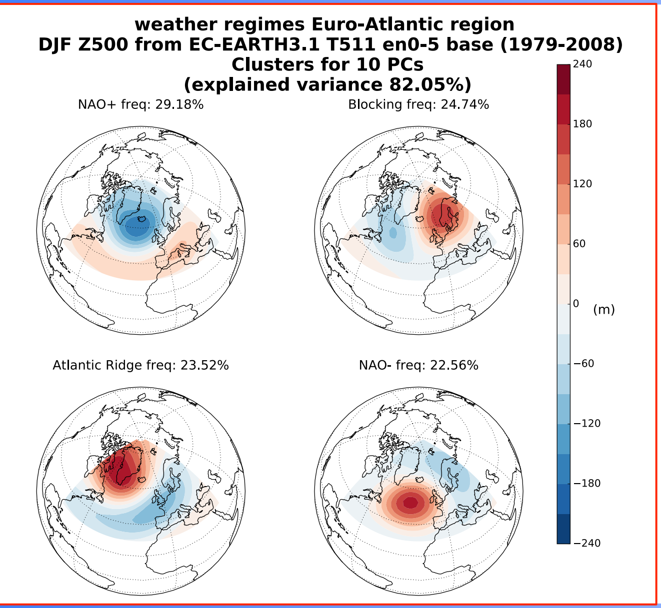
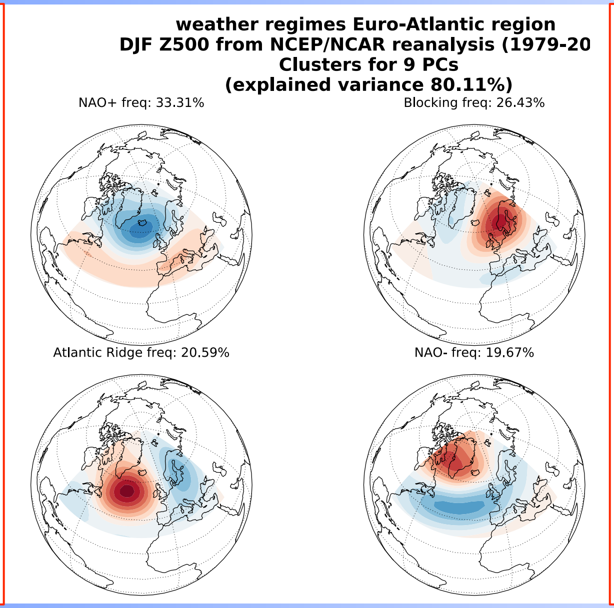
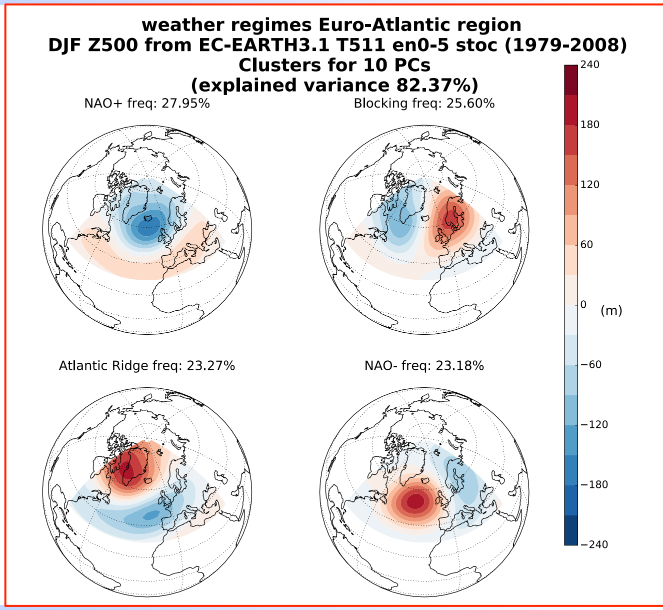
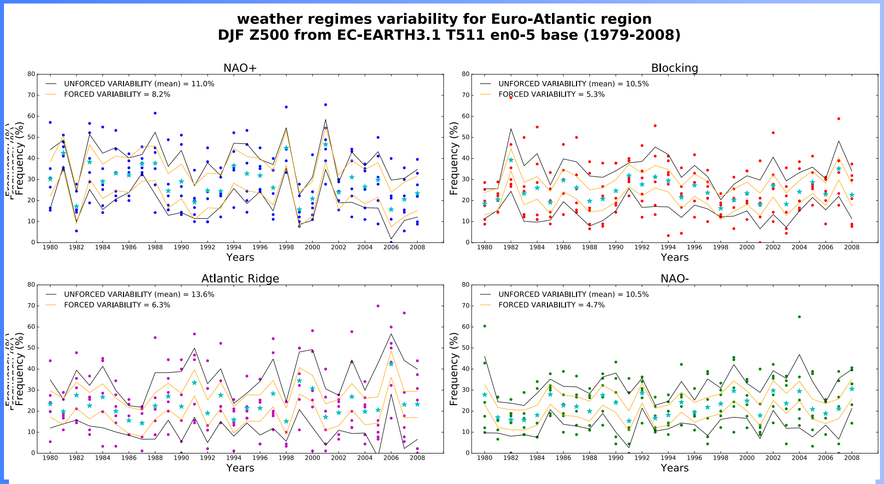
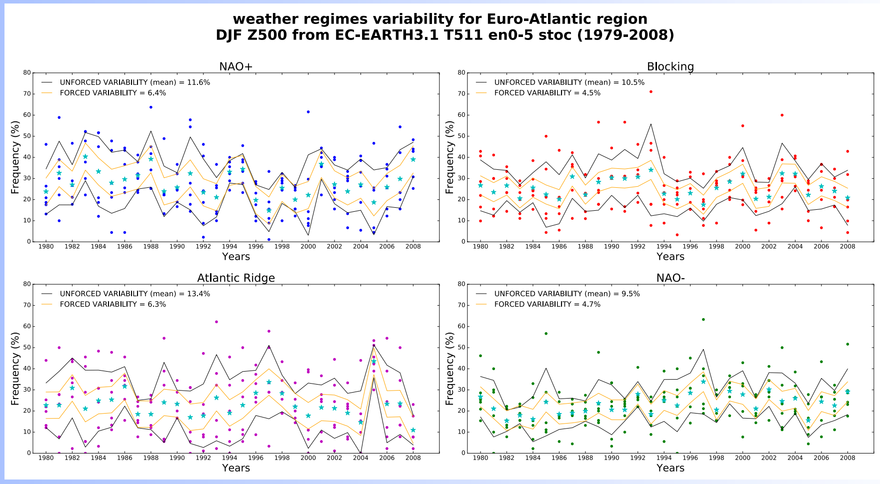




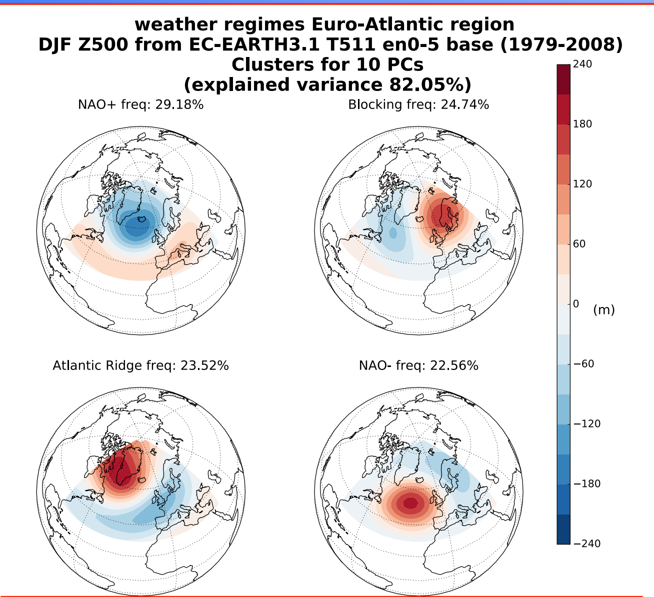


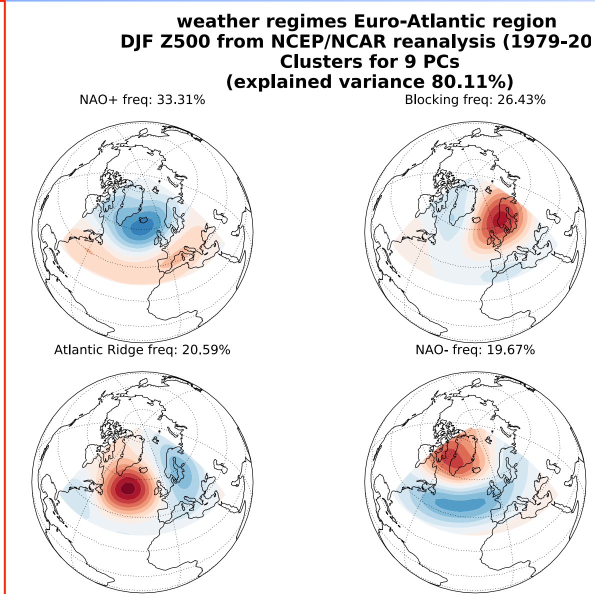


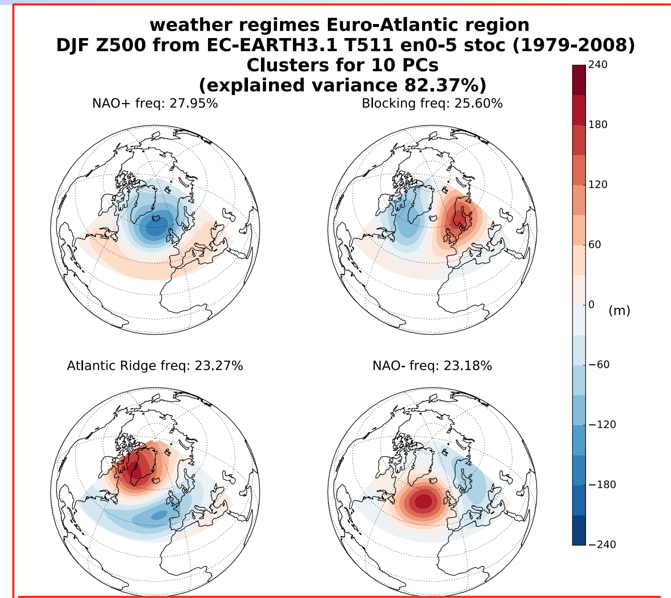


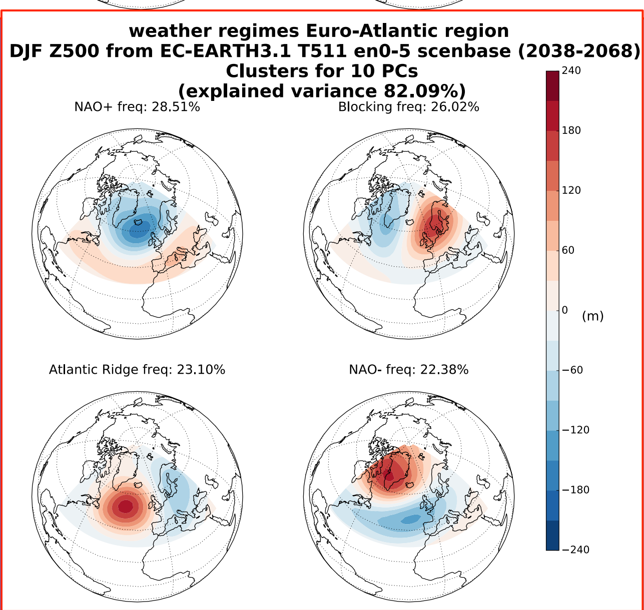
Euro-Atlantic Weather regimes
AMIP T511 [6 ensemble members]

BASE **NCEP** **SP**

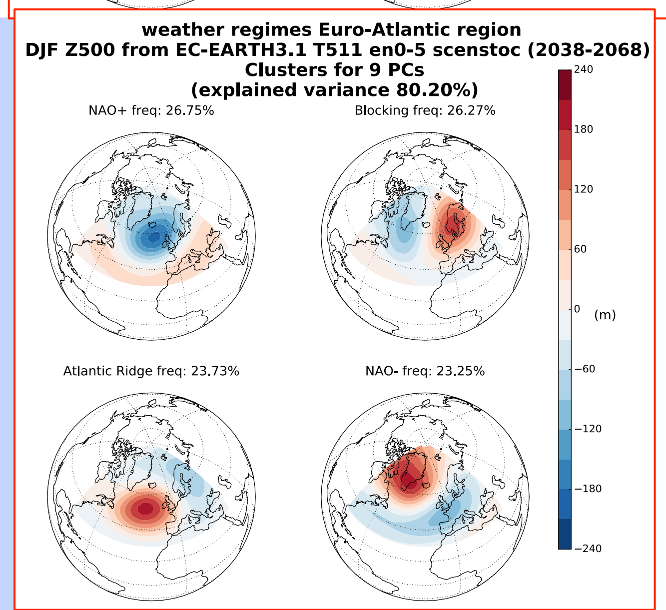






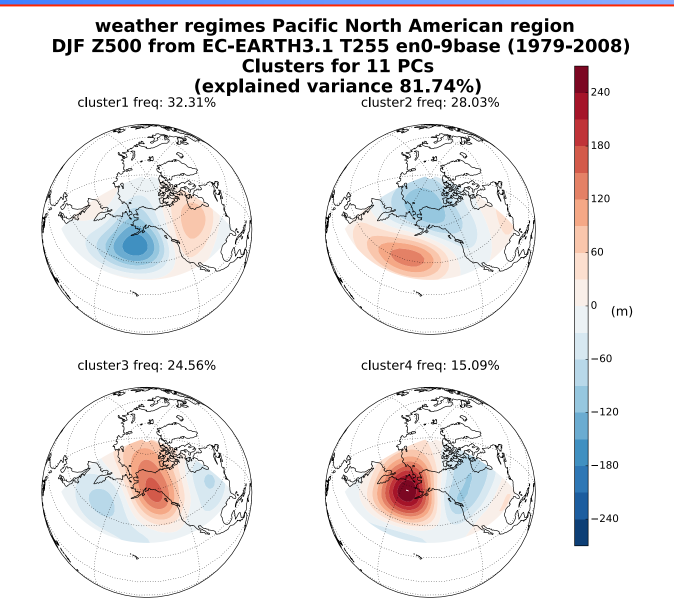


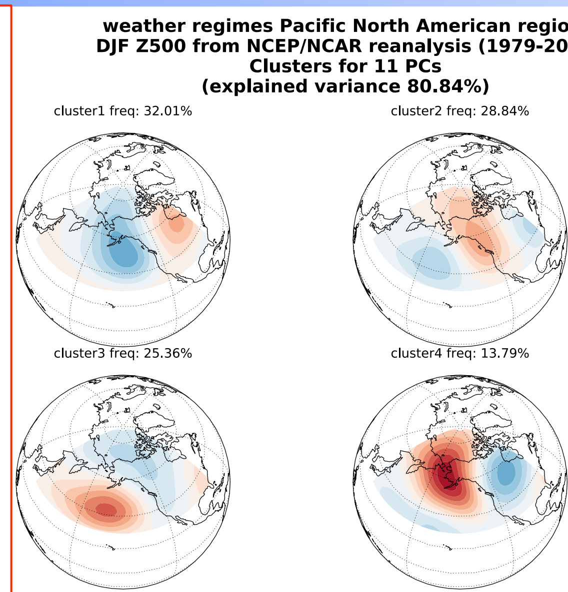
Future Scenario

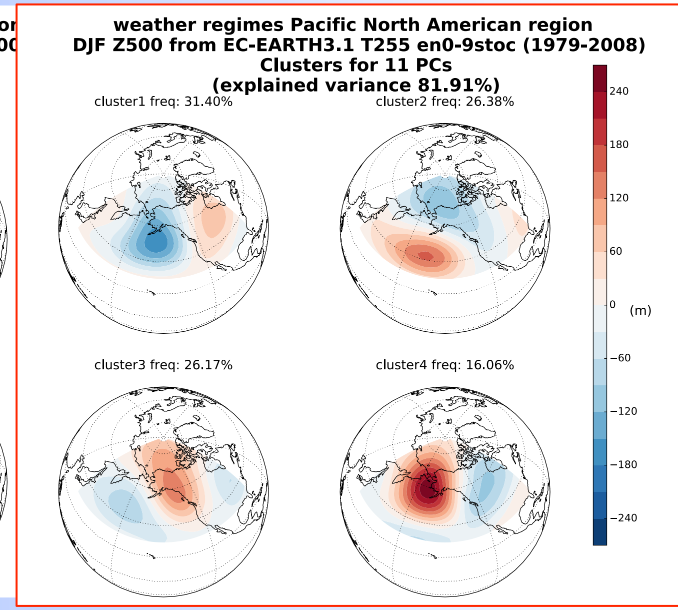


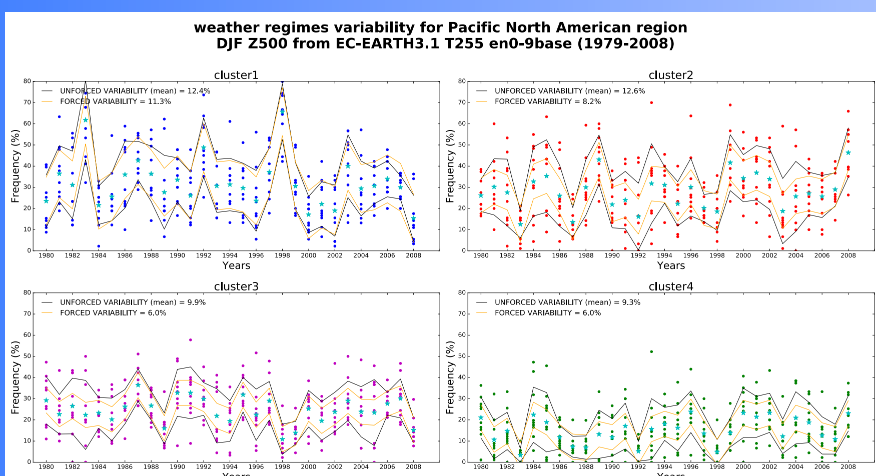
Pacific-North America Weather regimes
AMIP T255 [10 ensemble members]

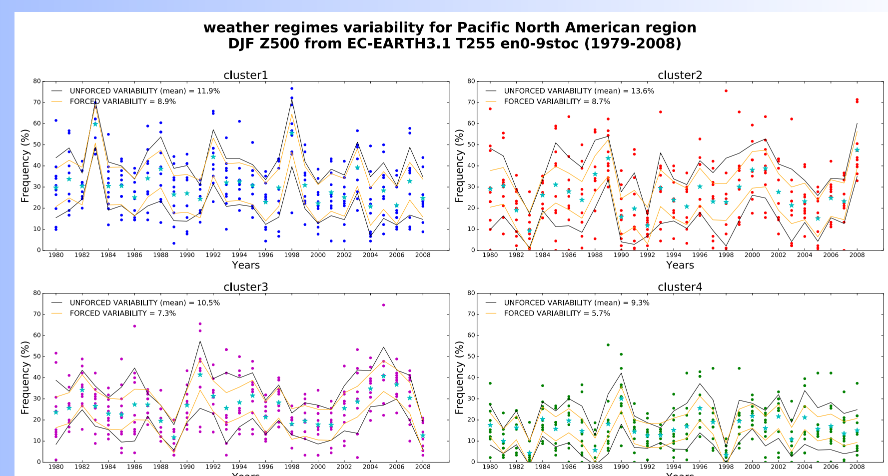
BASE **NCEP** **SP**





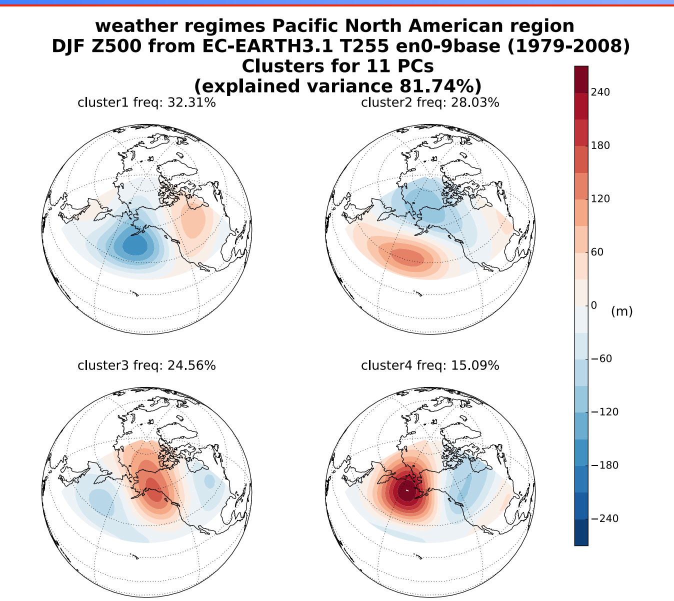




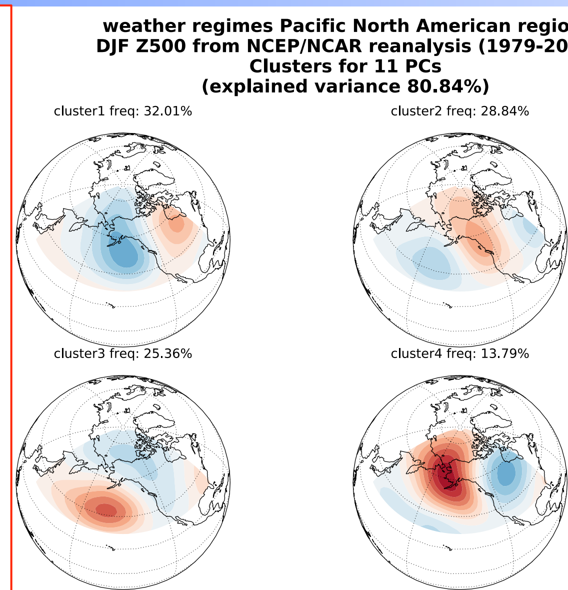


Pacific-North America Weather regimes
AMIP T255 [10 ensemble members]

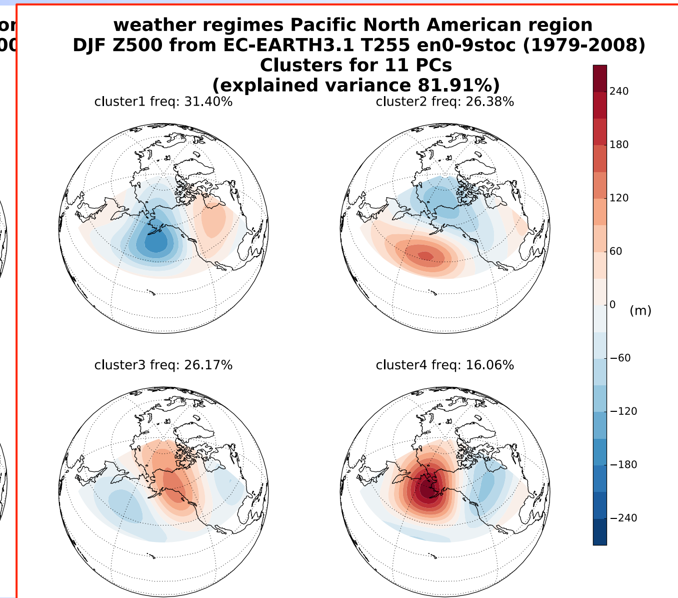
BASE

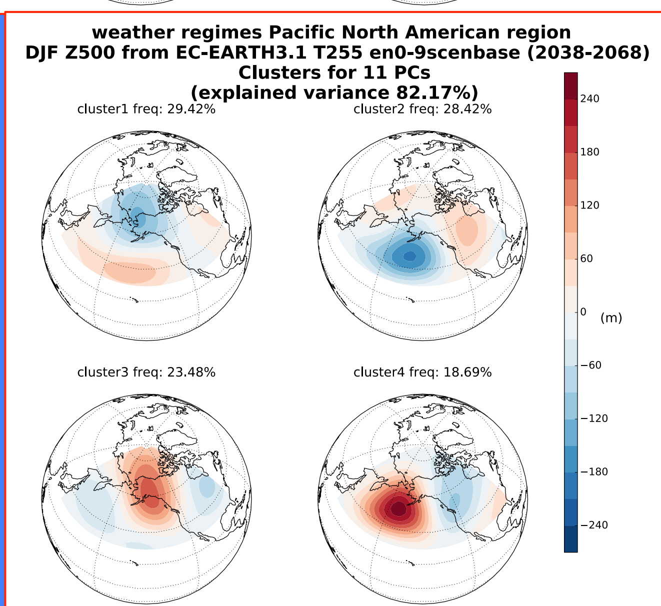


NCEP



SP





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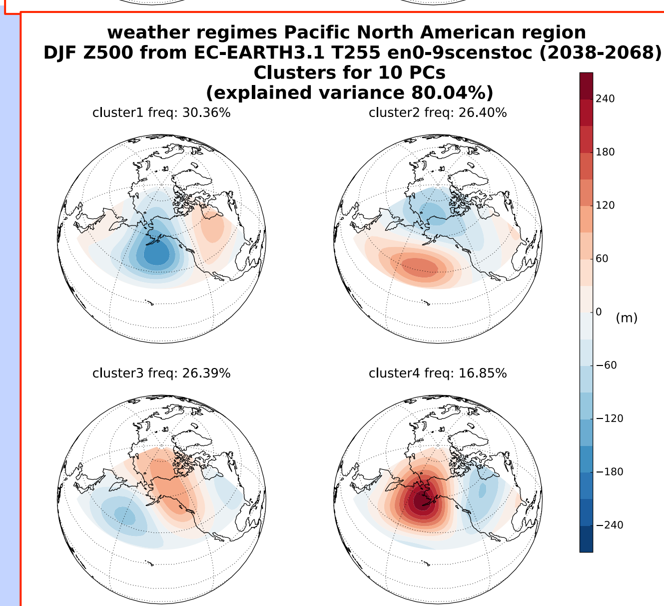
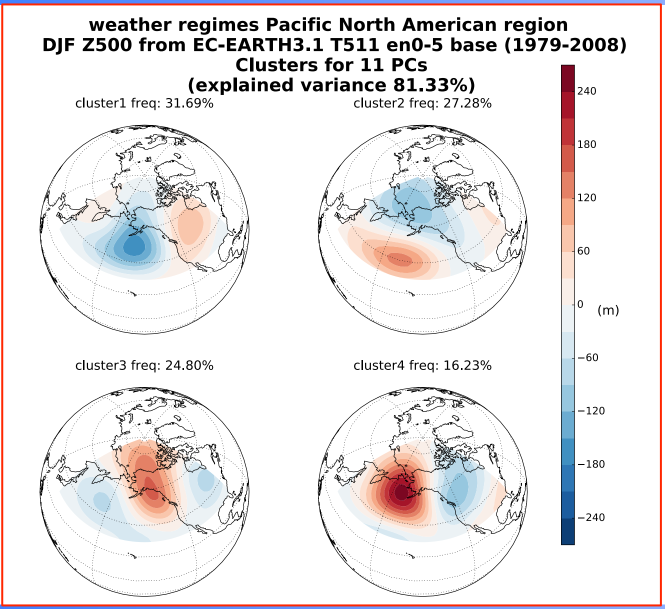


Pacific-North America Weather regimes
AMIP T511 [6 ensemble members]

BASE



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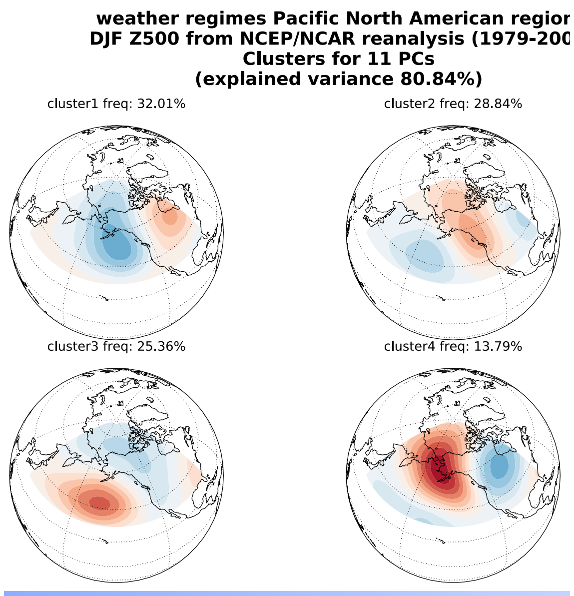

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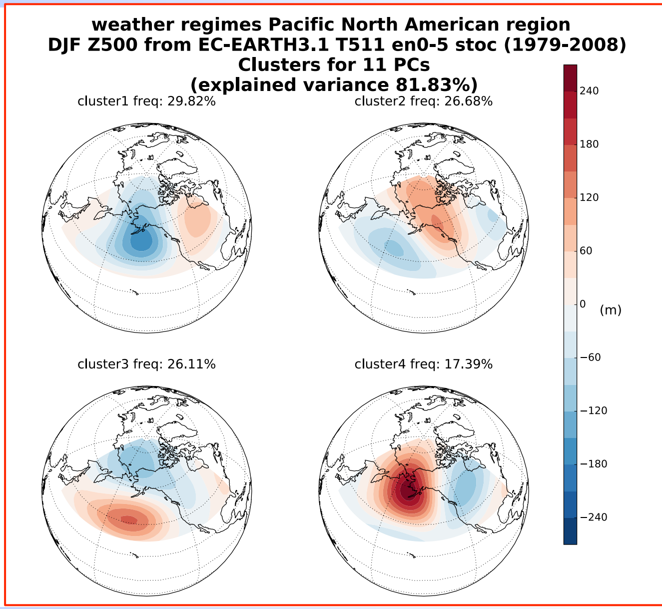
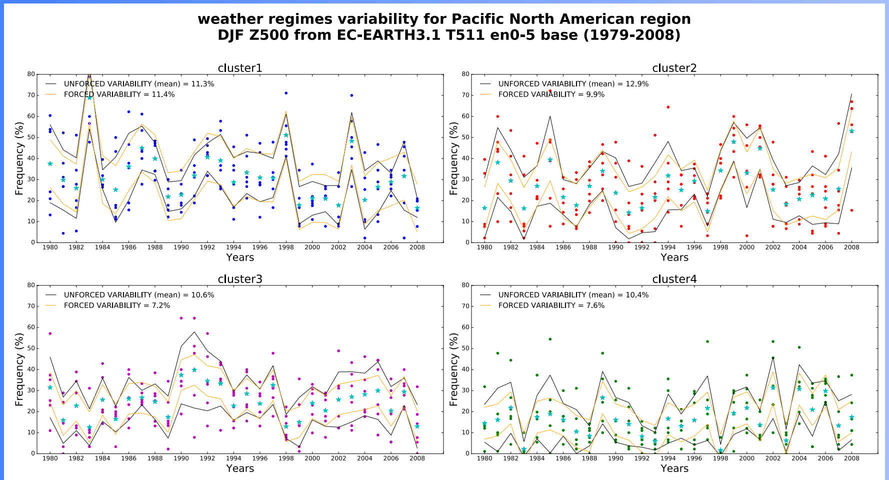
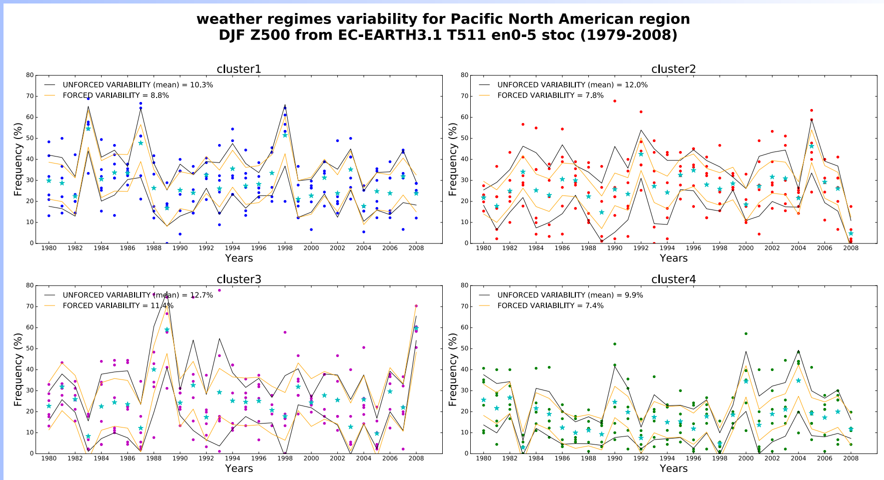
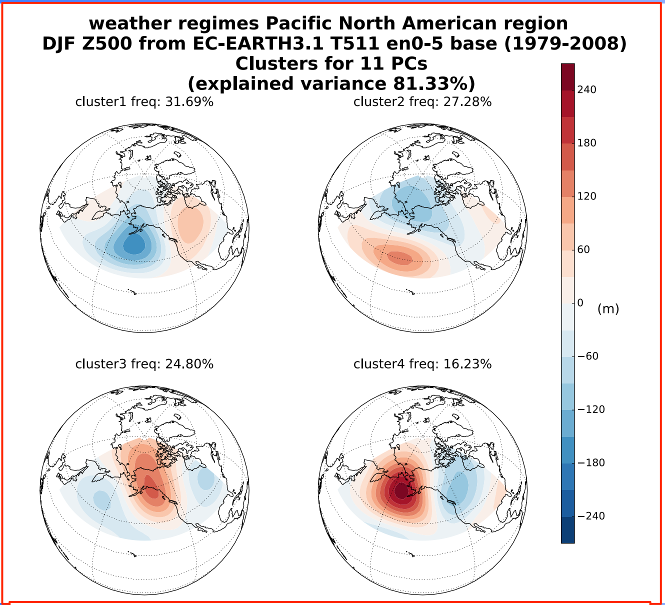


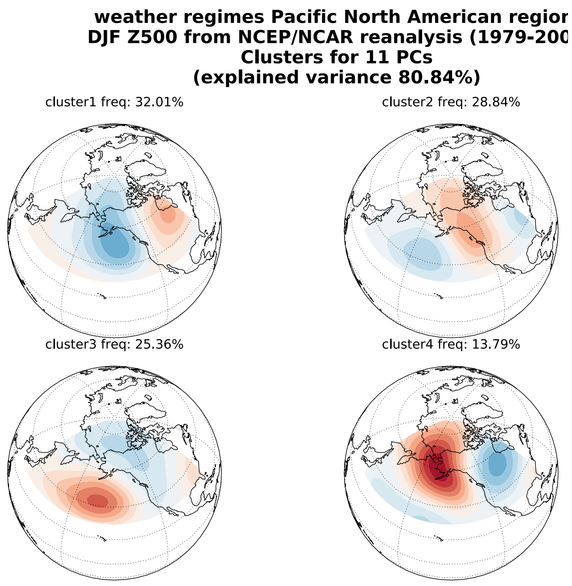


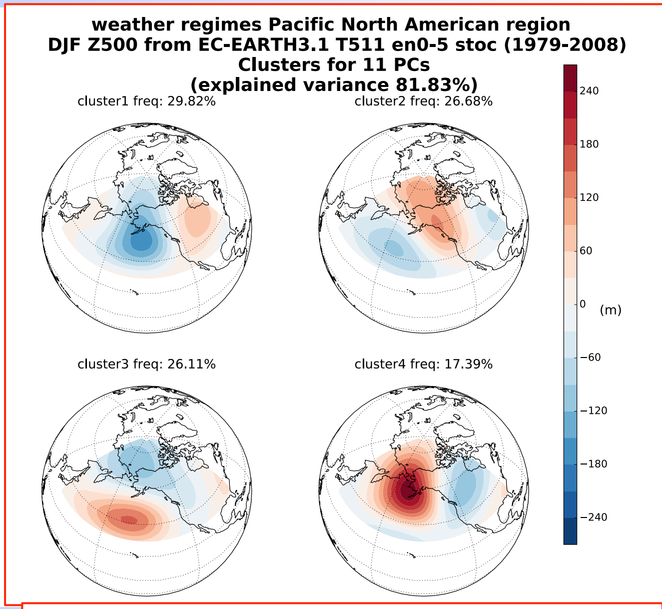


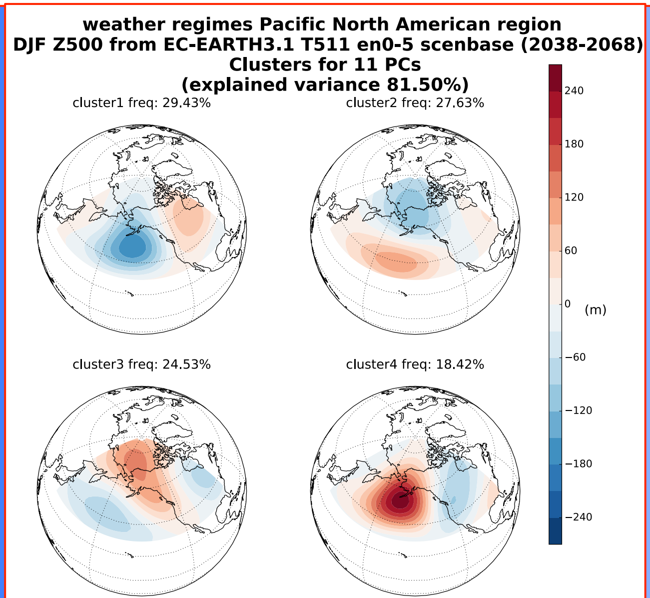
Pacific-North America Weather regimes
AMIP T511 [6 ensemble members]

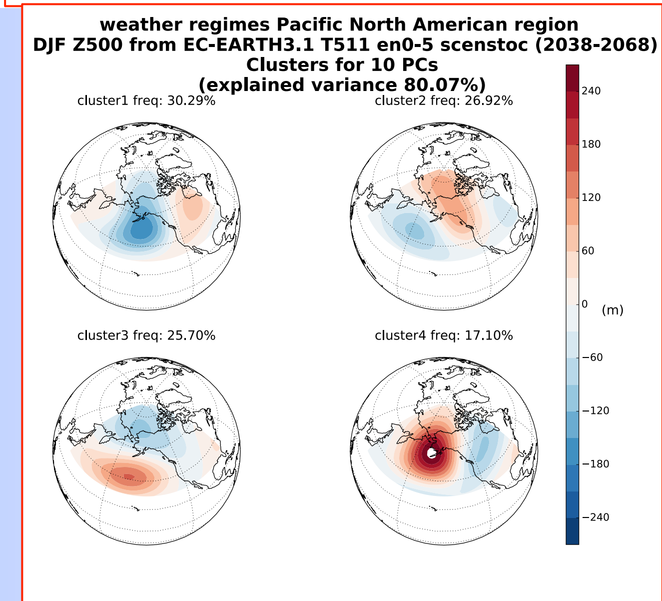
BASE **NCEP** **SP**



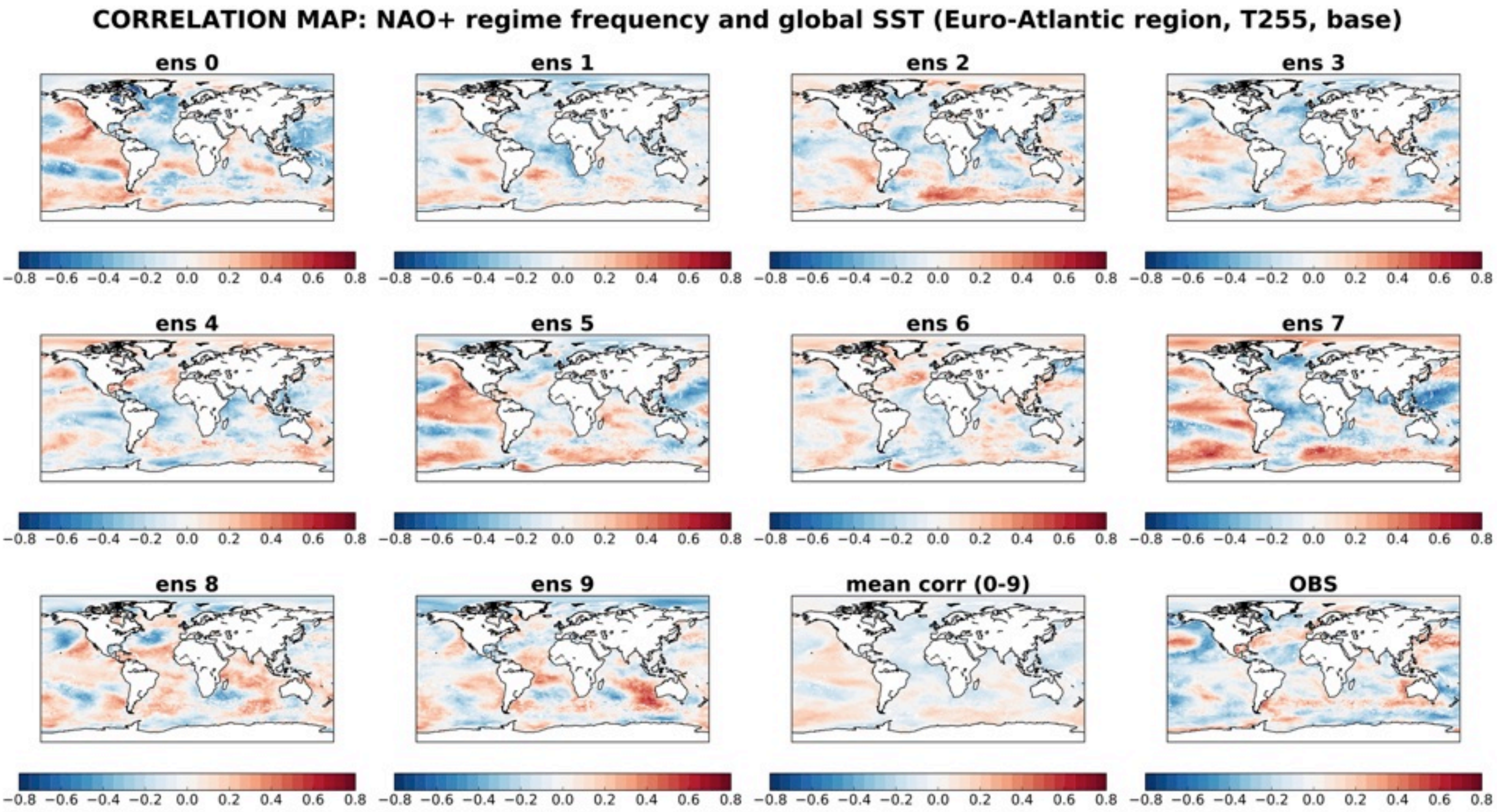








NAO+ Frequency & Global SST T255



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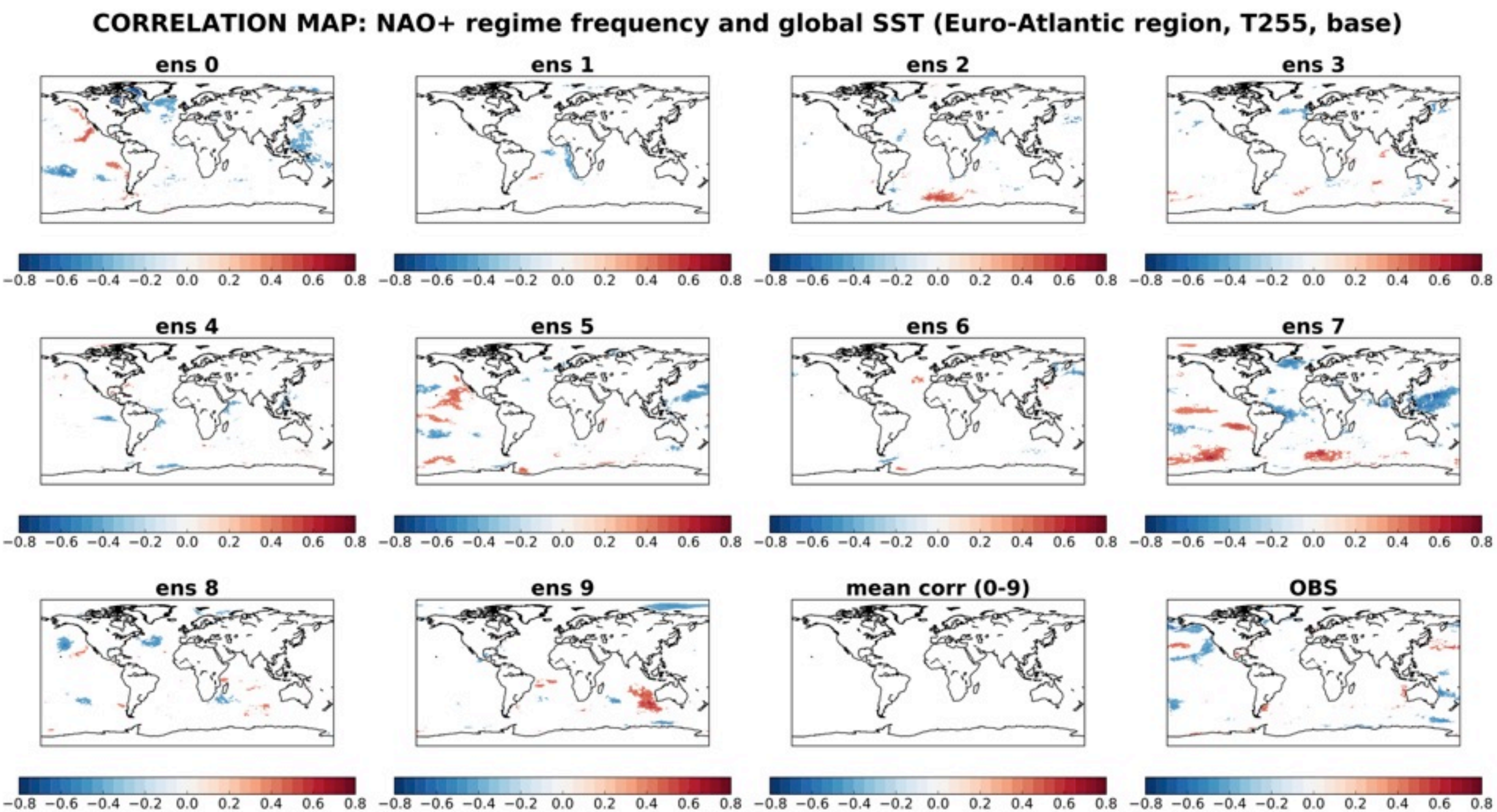
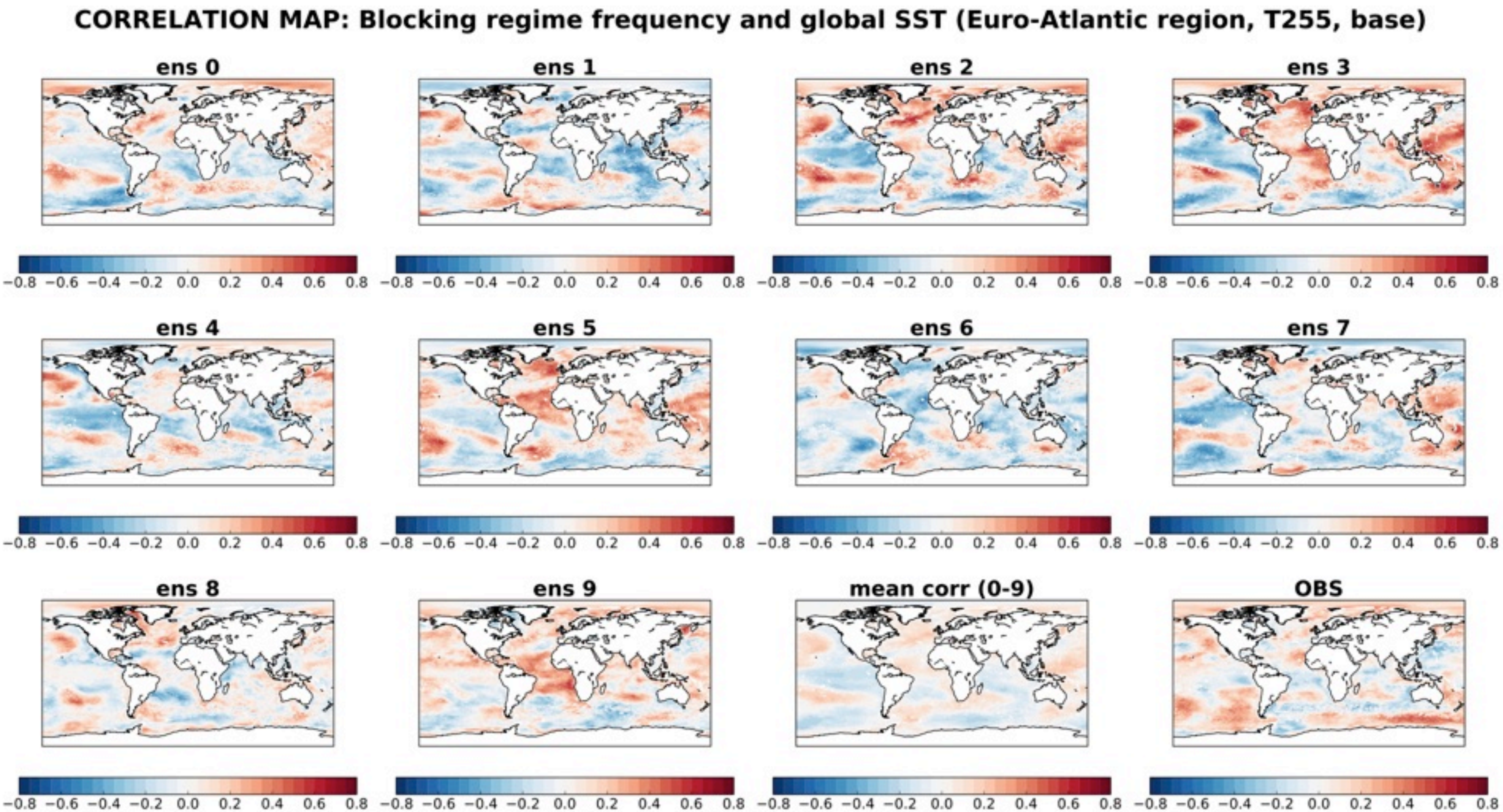
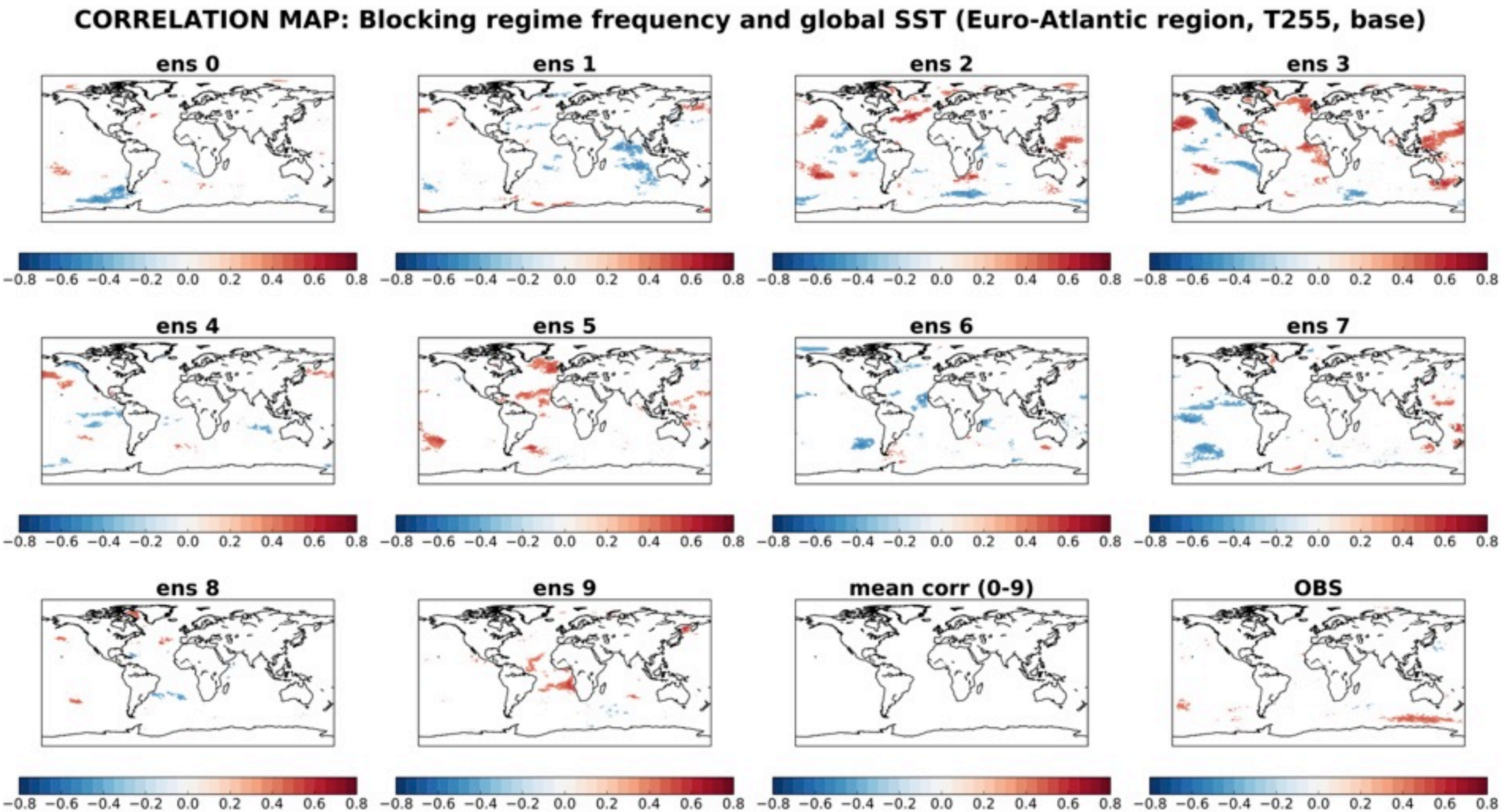


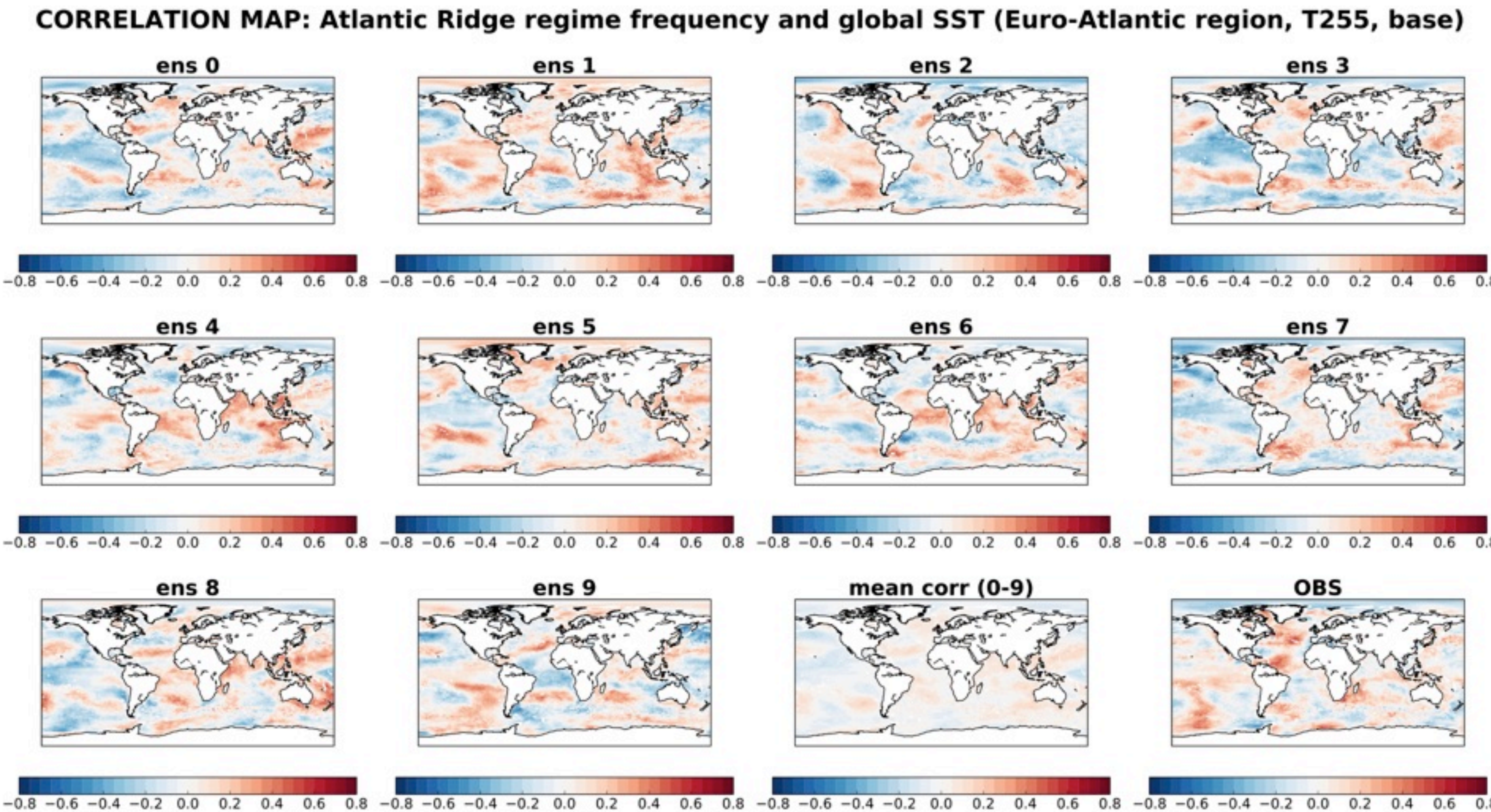
Blocking Frequency & Global SST T255



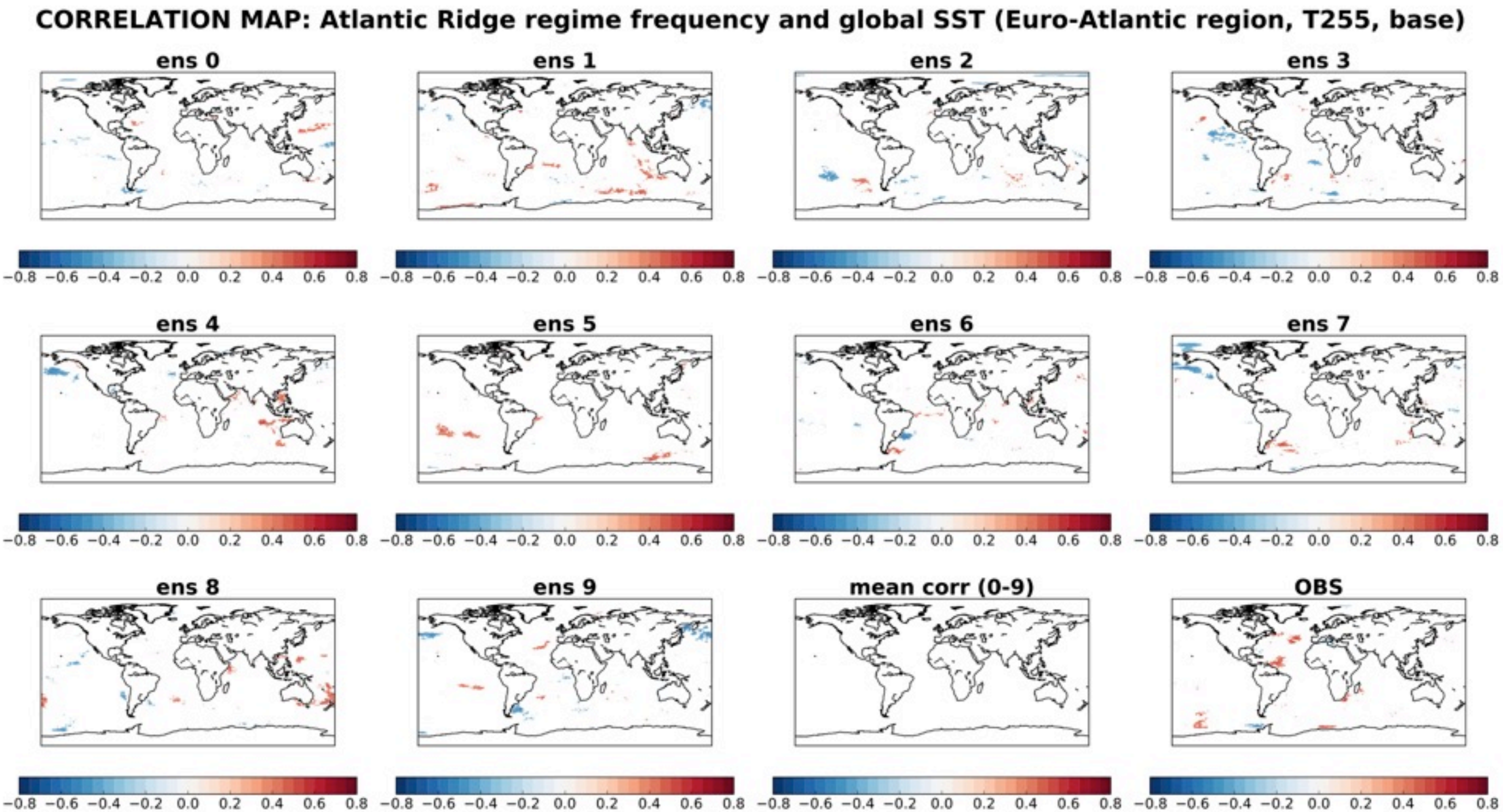
Blocking Frequency & Global SST T255



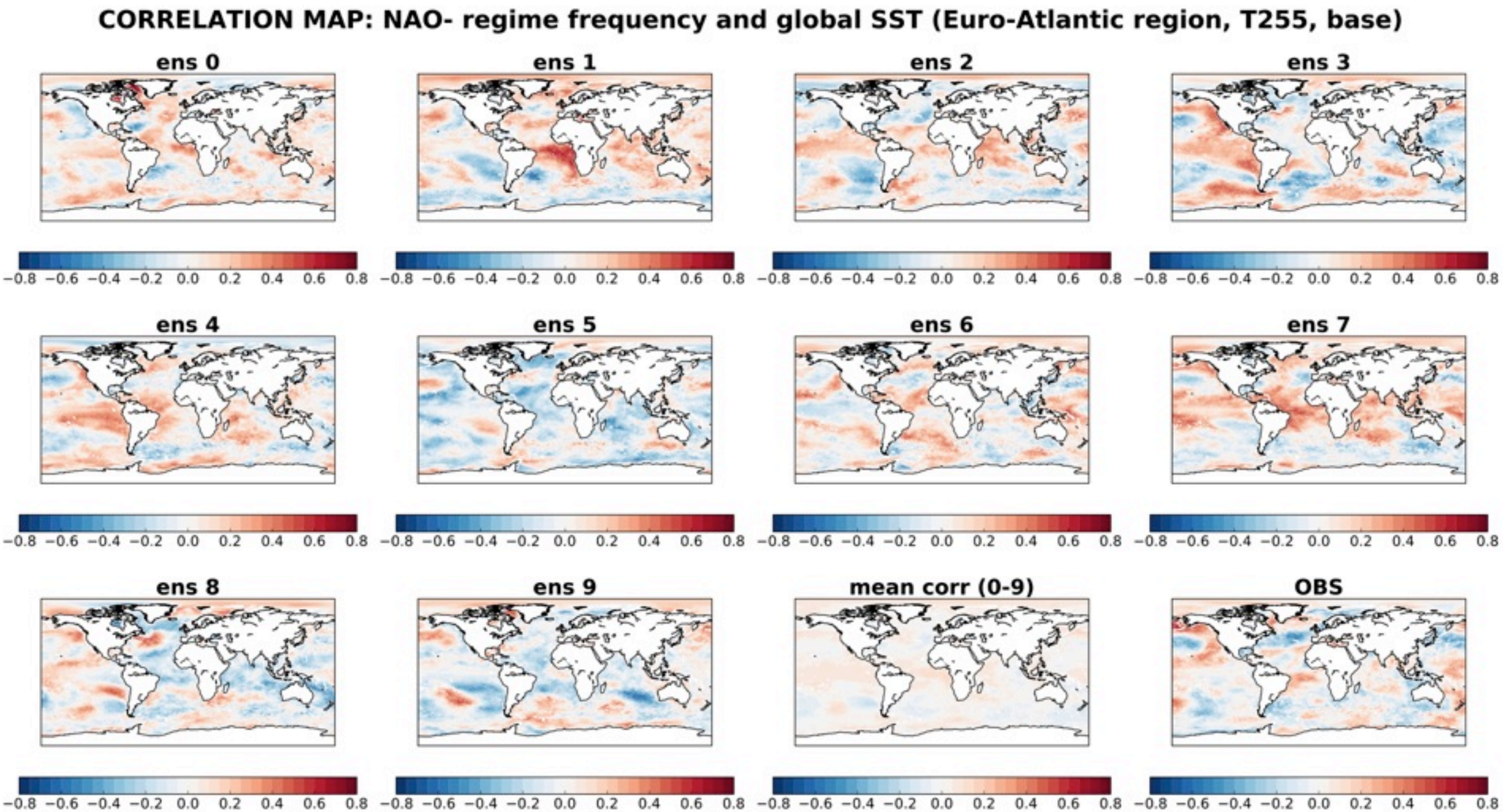
Atlantic Ridge Frequency & Global SST T255



Atlantic Ridge Frequency & Global SST T255



NAO- Frequency & Global SST T255



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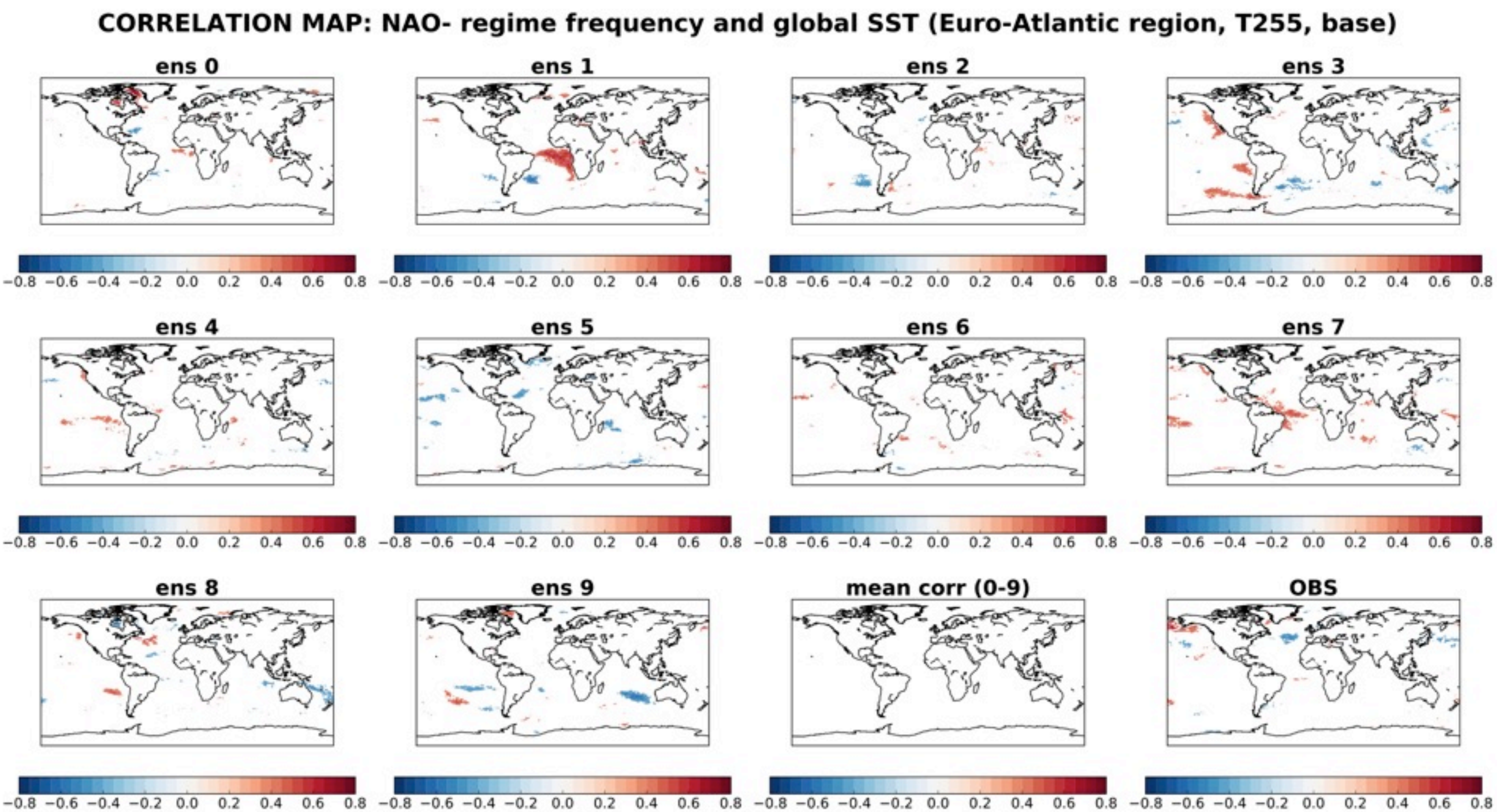
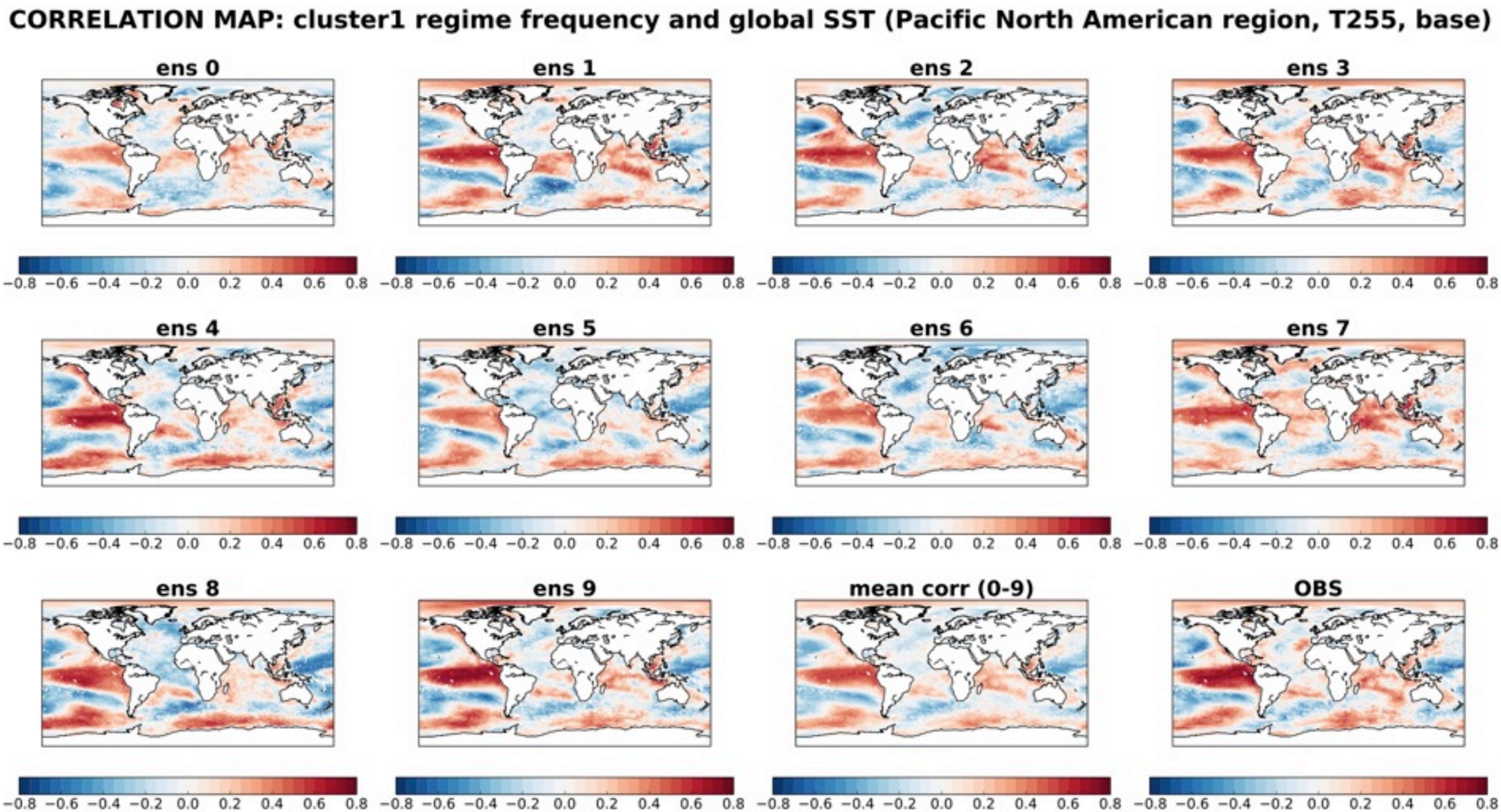
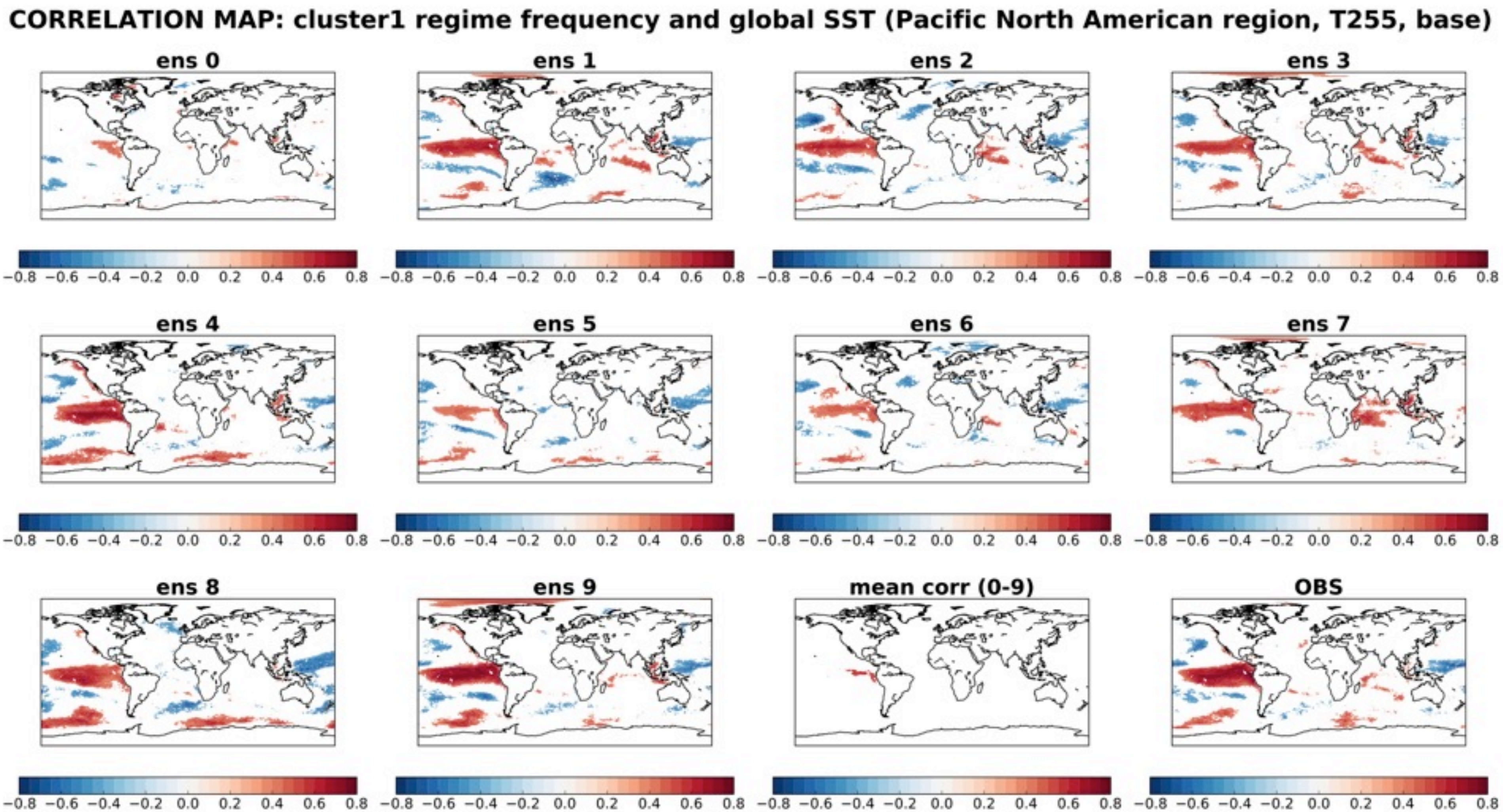


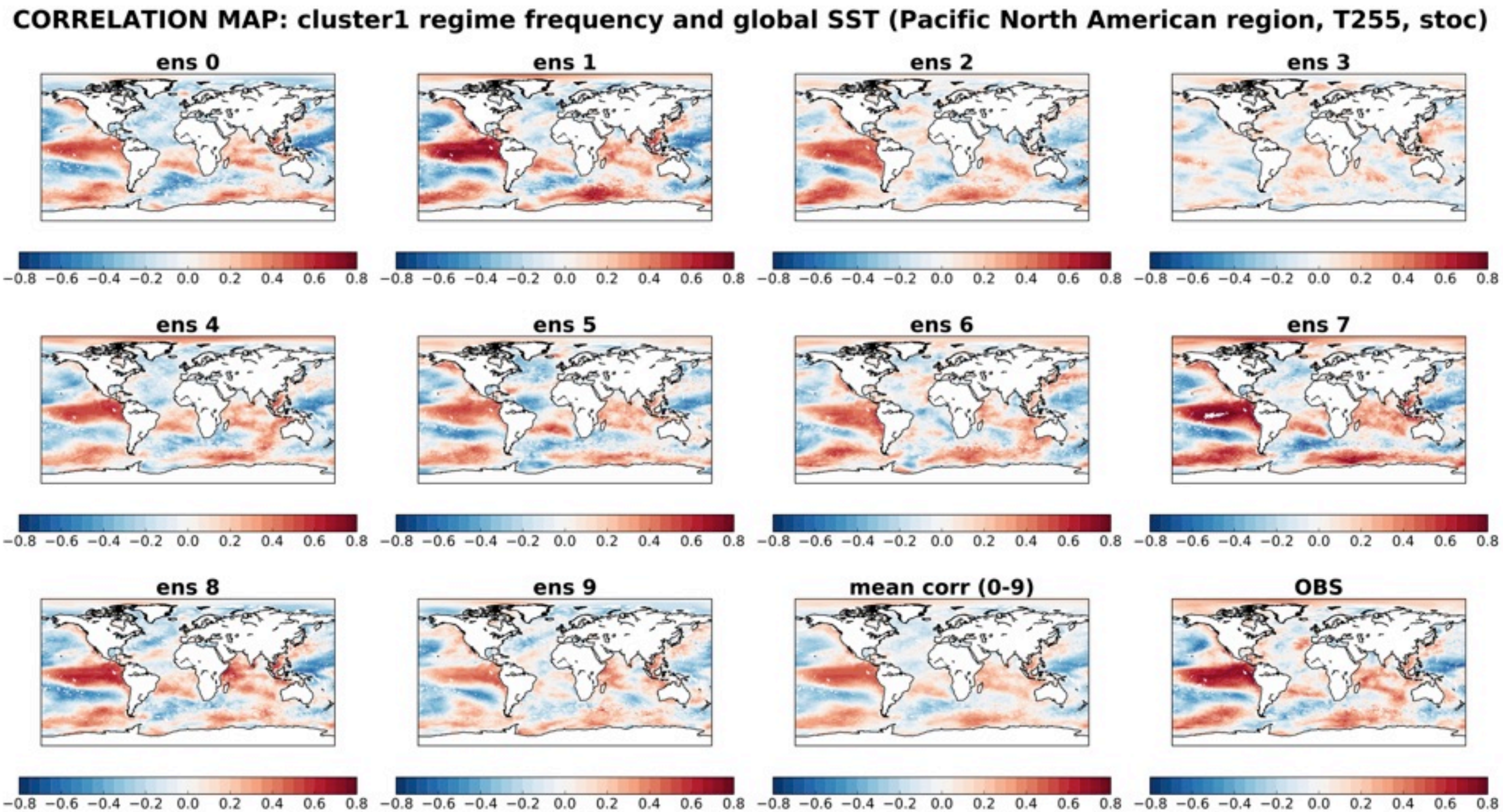
Pacific Trough Frequency & Global SST T255



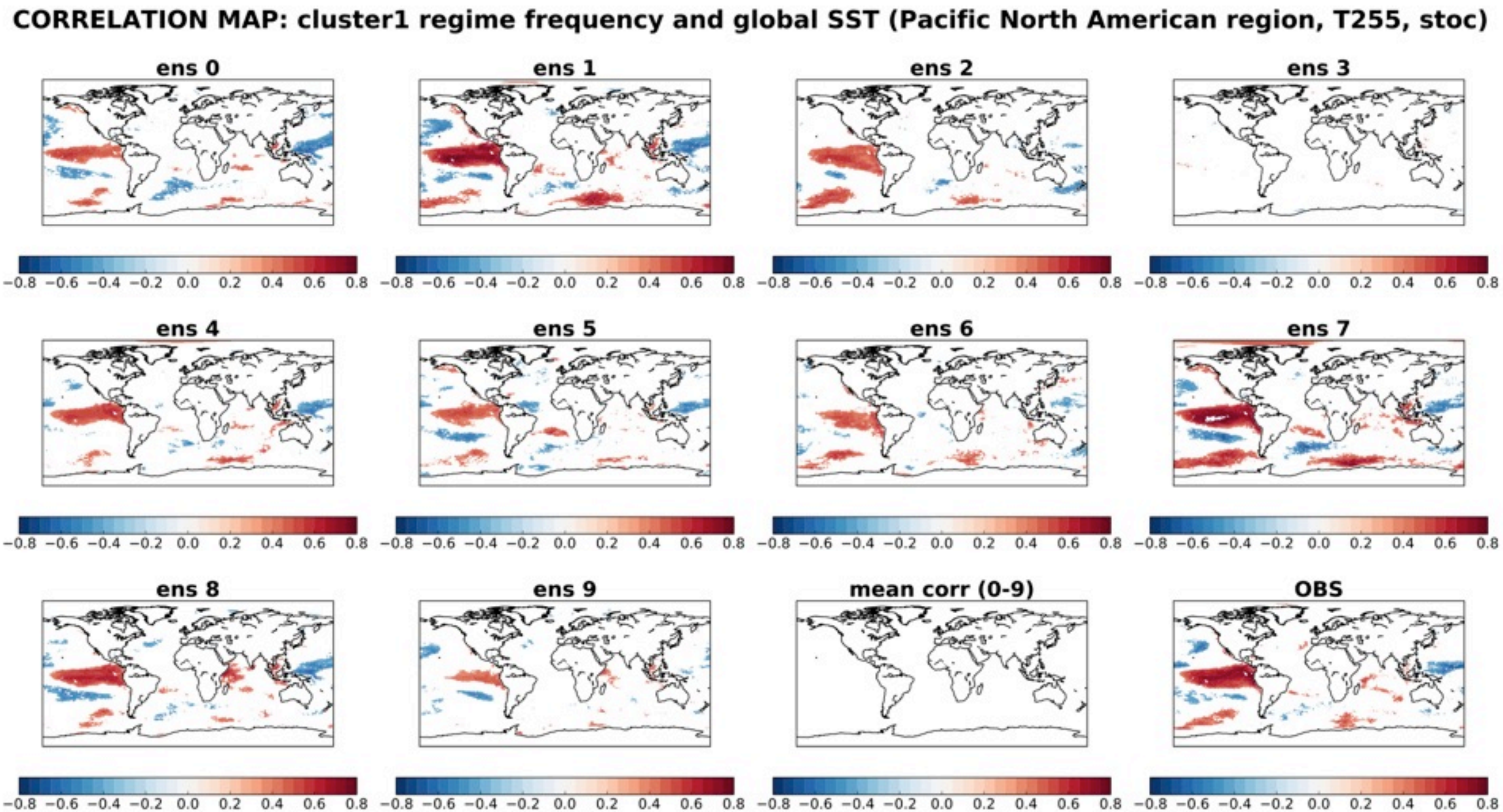
Pacific Trough Frequency & Global SST T255



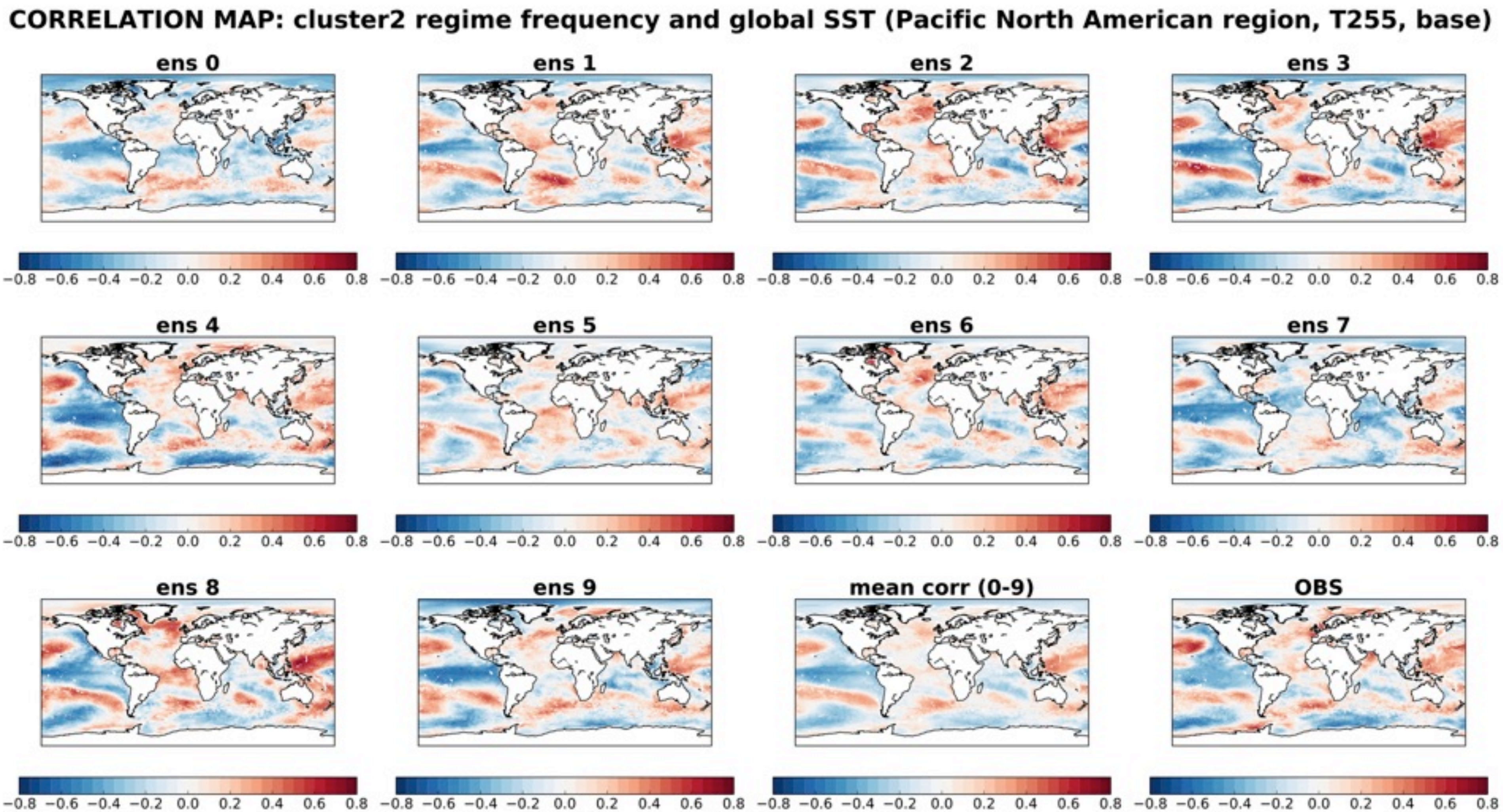
Pacific Trough Frequency & Global SST T255-SP



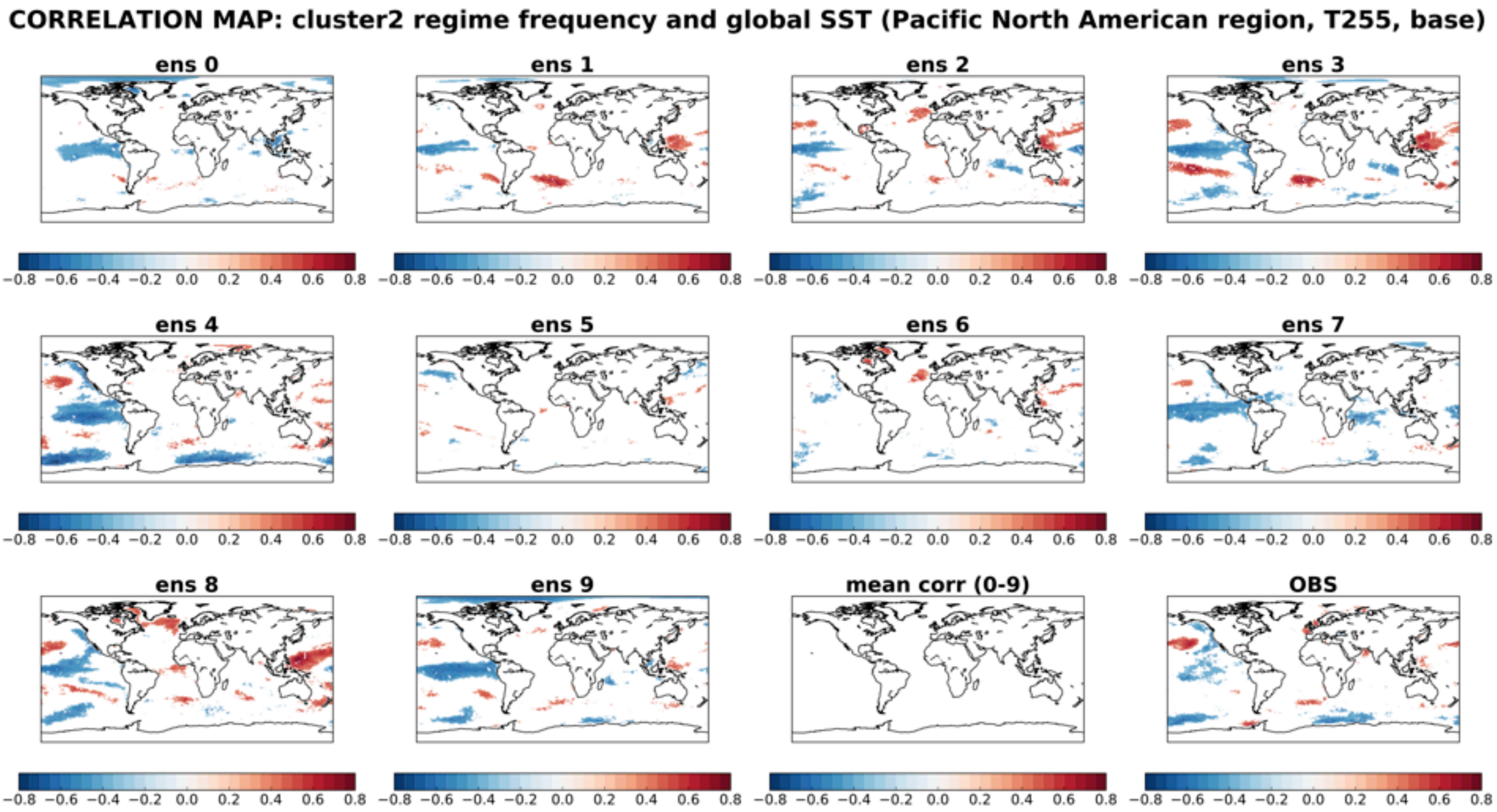
Pacific Trough Frequency & Global SST T255-SP



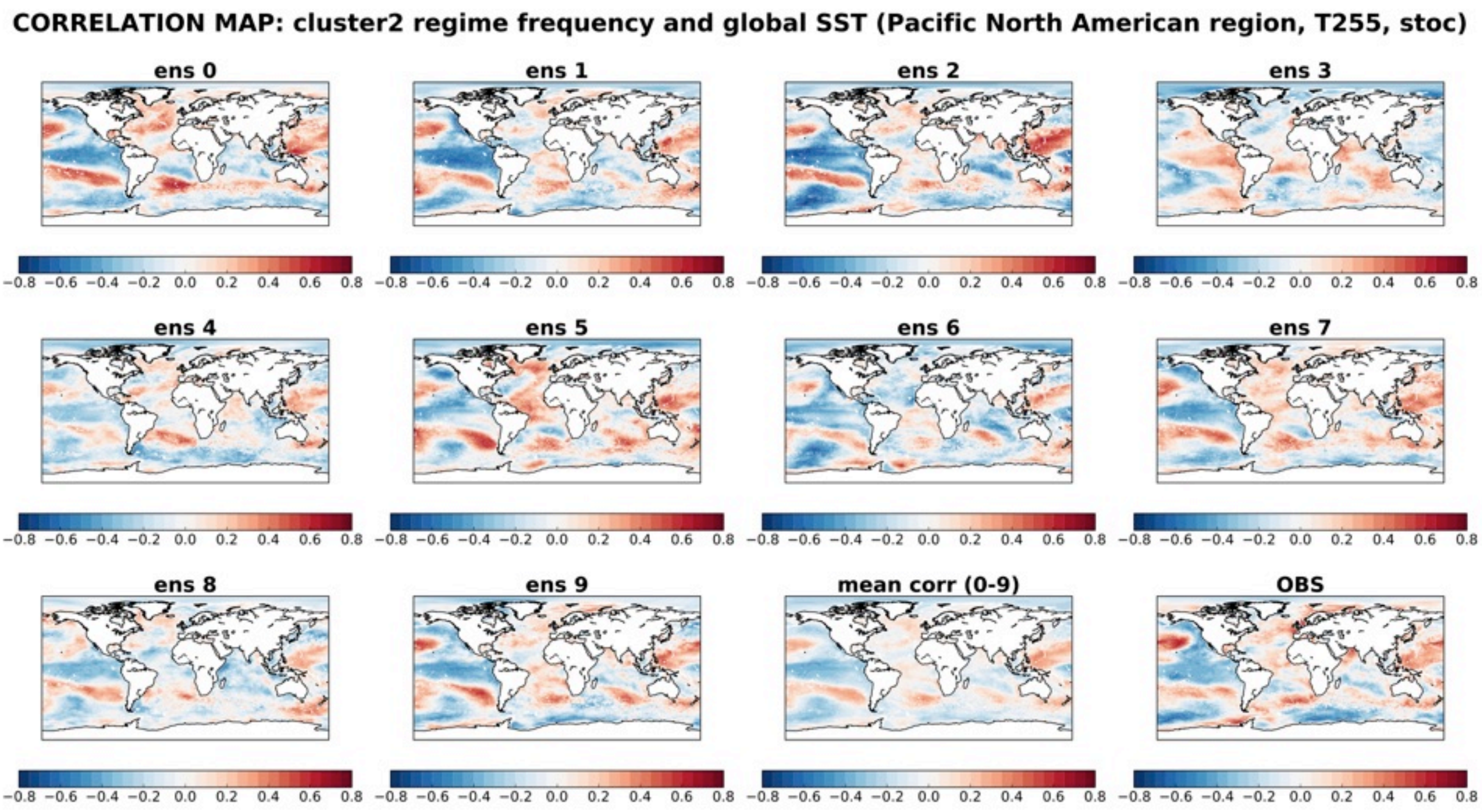
PNA- Frequency & Global SST T255



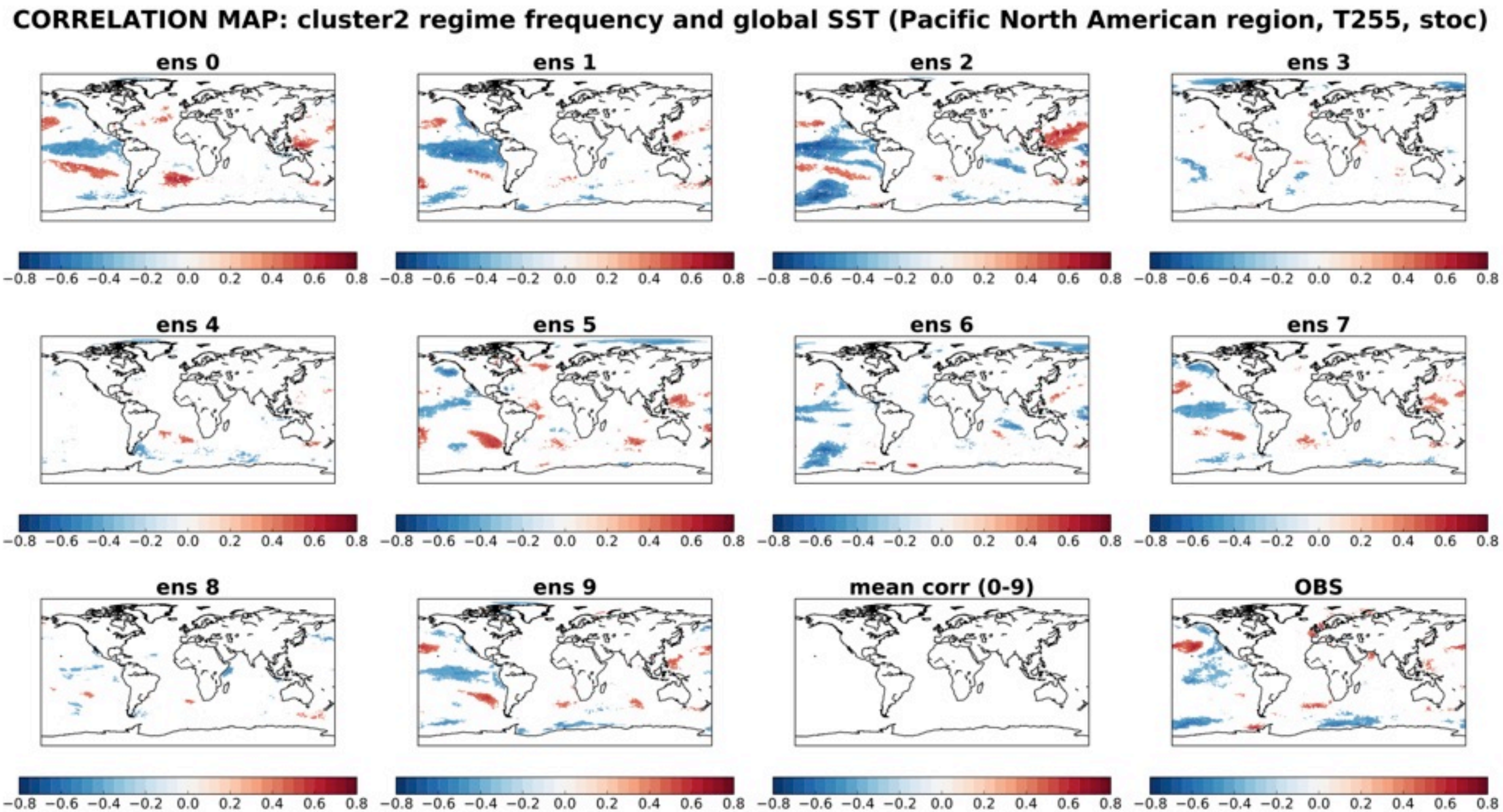
PNA- Frequency & Global SST T255



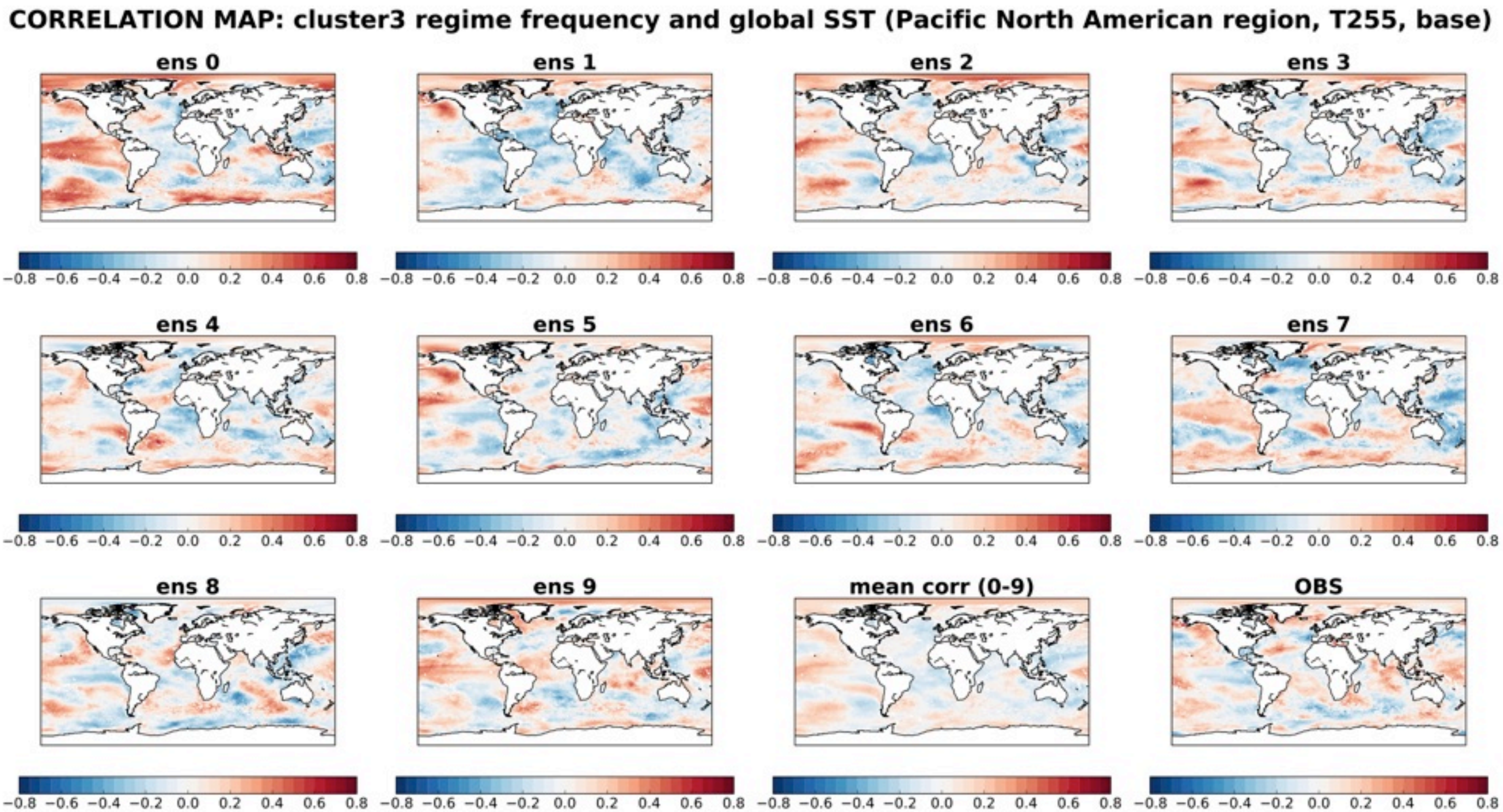
PNA- Frequency & Global SST T255-SP



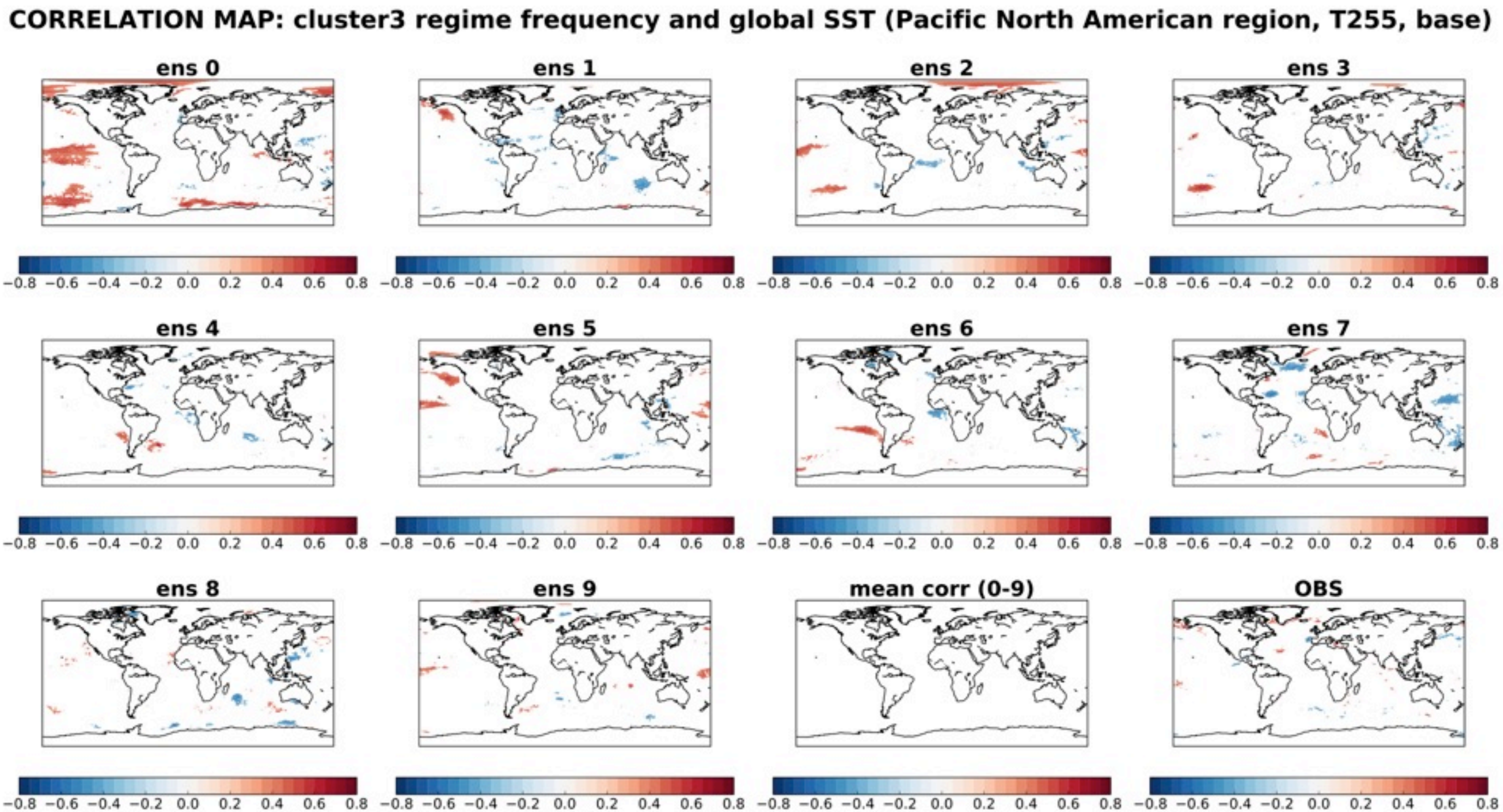
PNA- Frequency & Global SST T255-SP



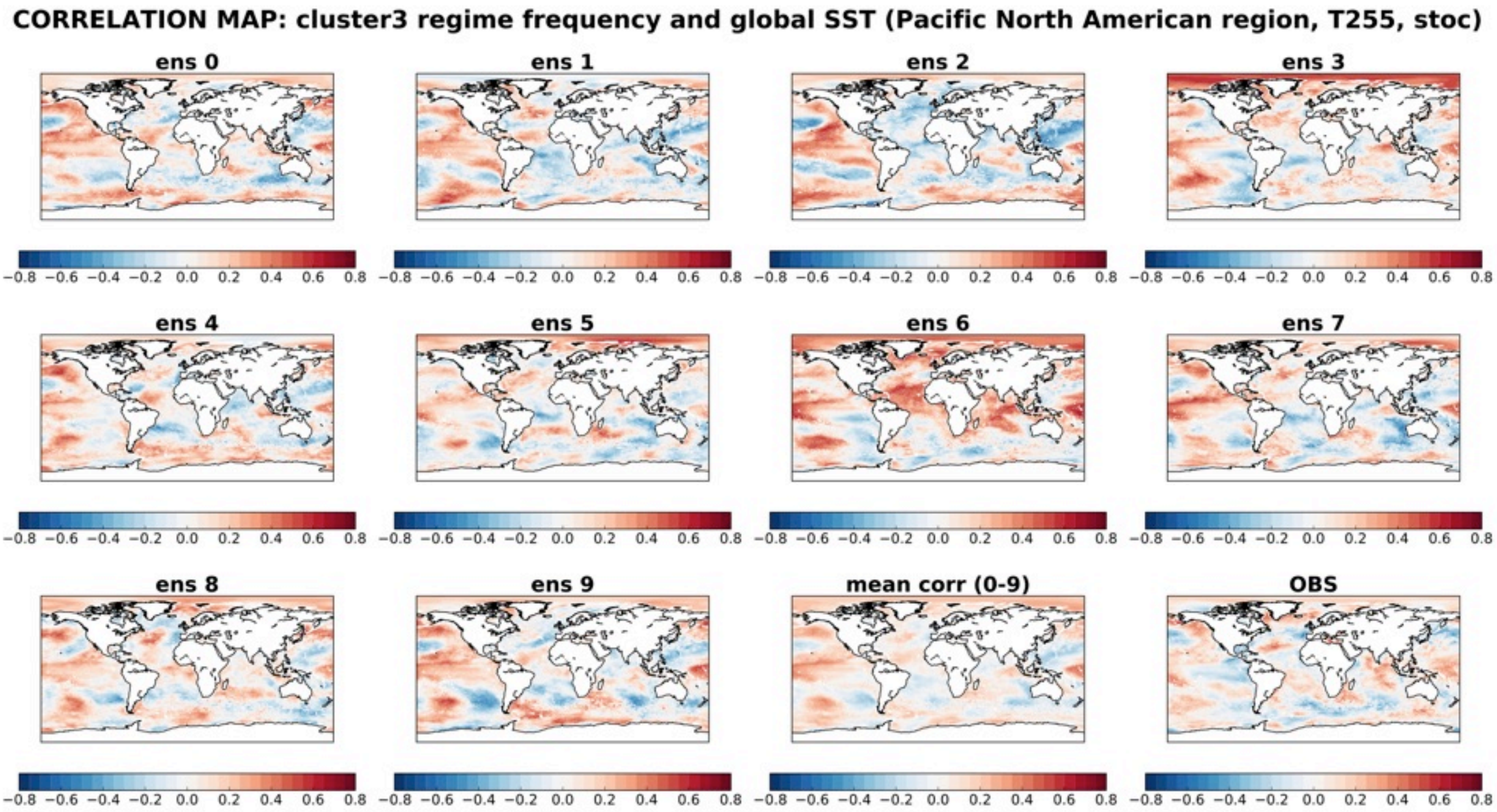
PNA+ Frequency & Global SST T255



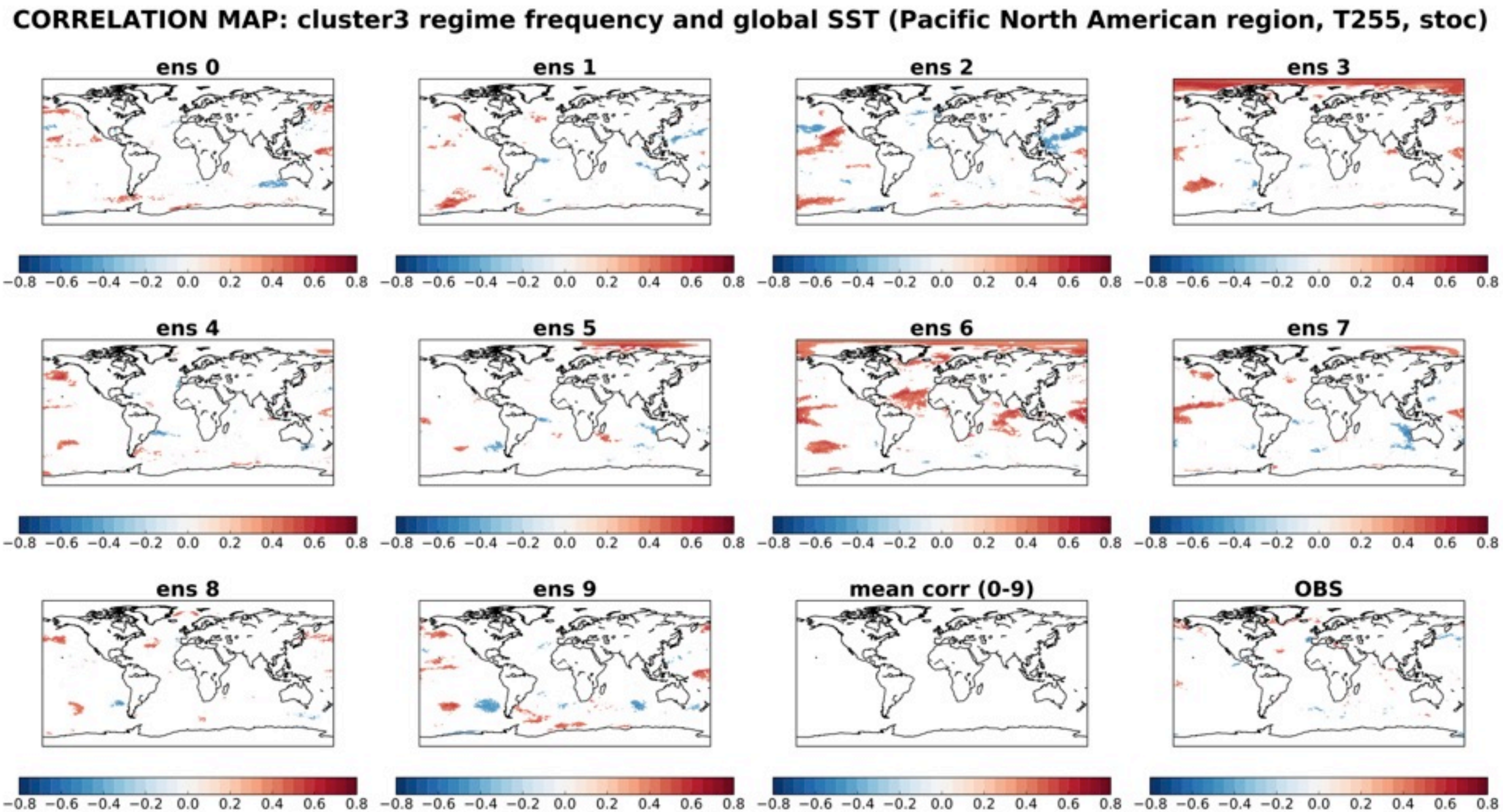
PNA+ Frequency & Global SST T255



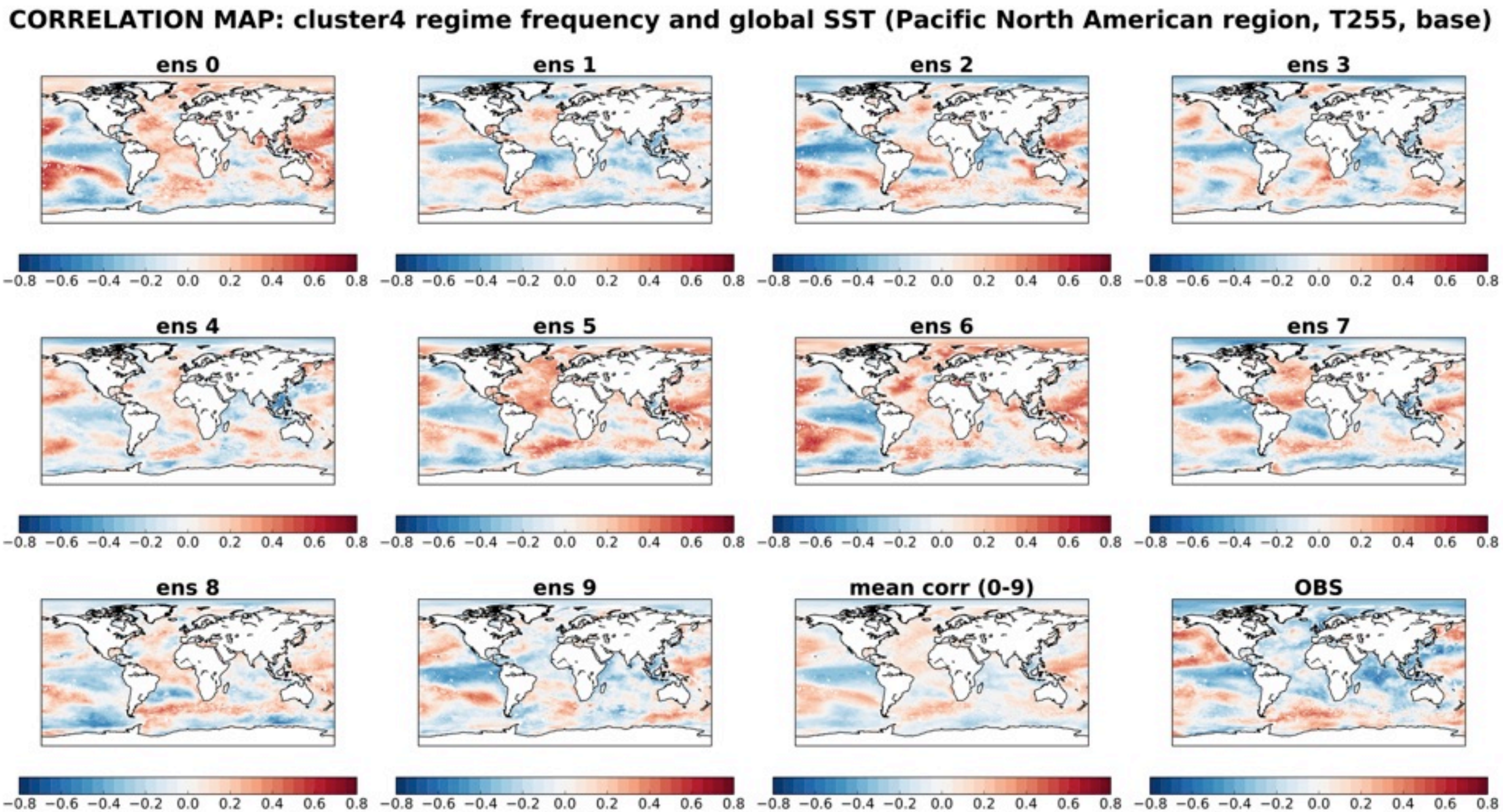
PNA+ Frequency & Global SST T255-SP



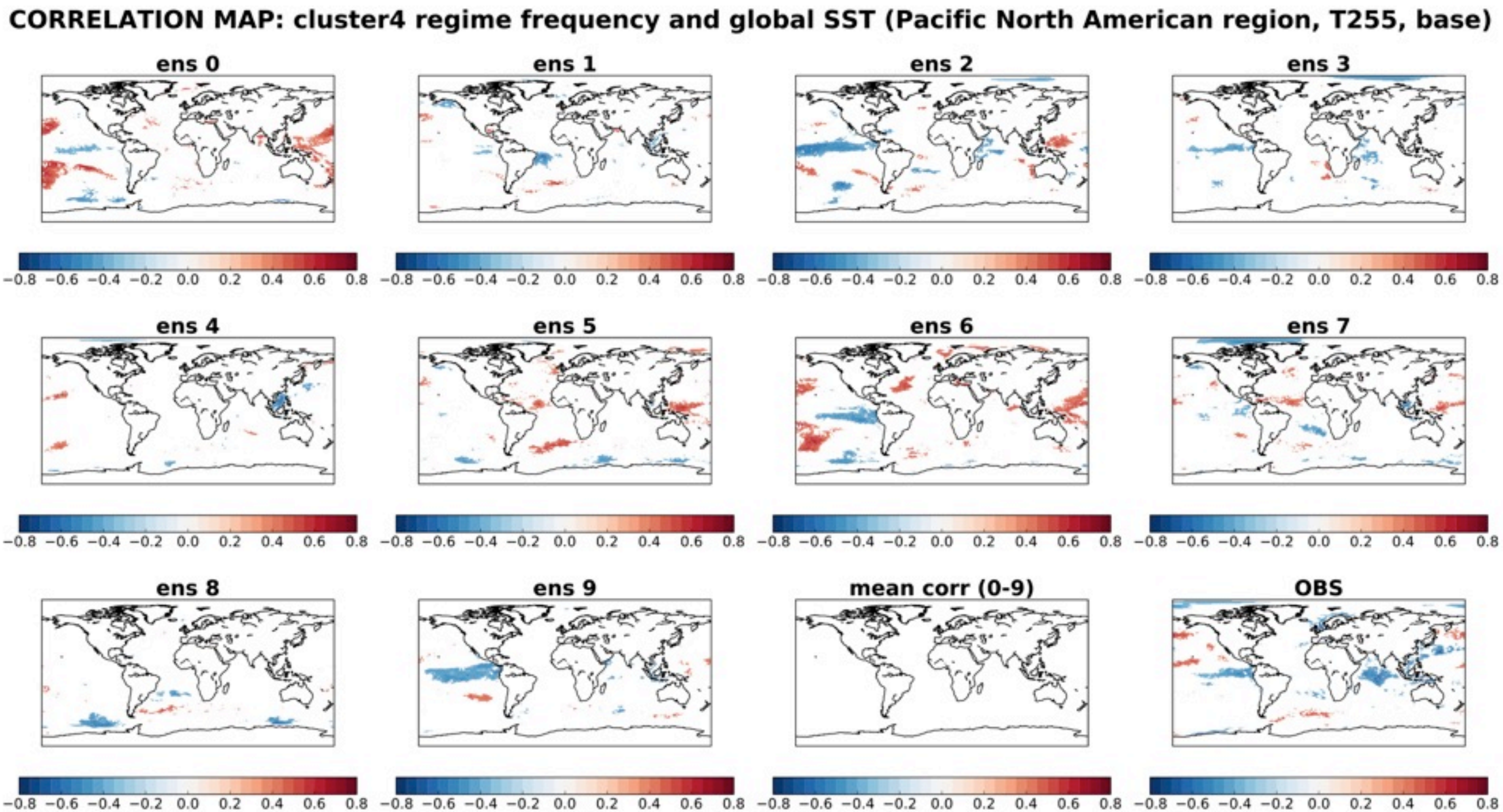
PNA+ Frequency & Global SST T255-SP



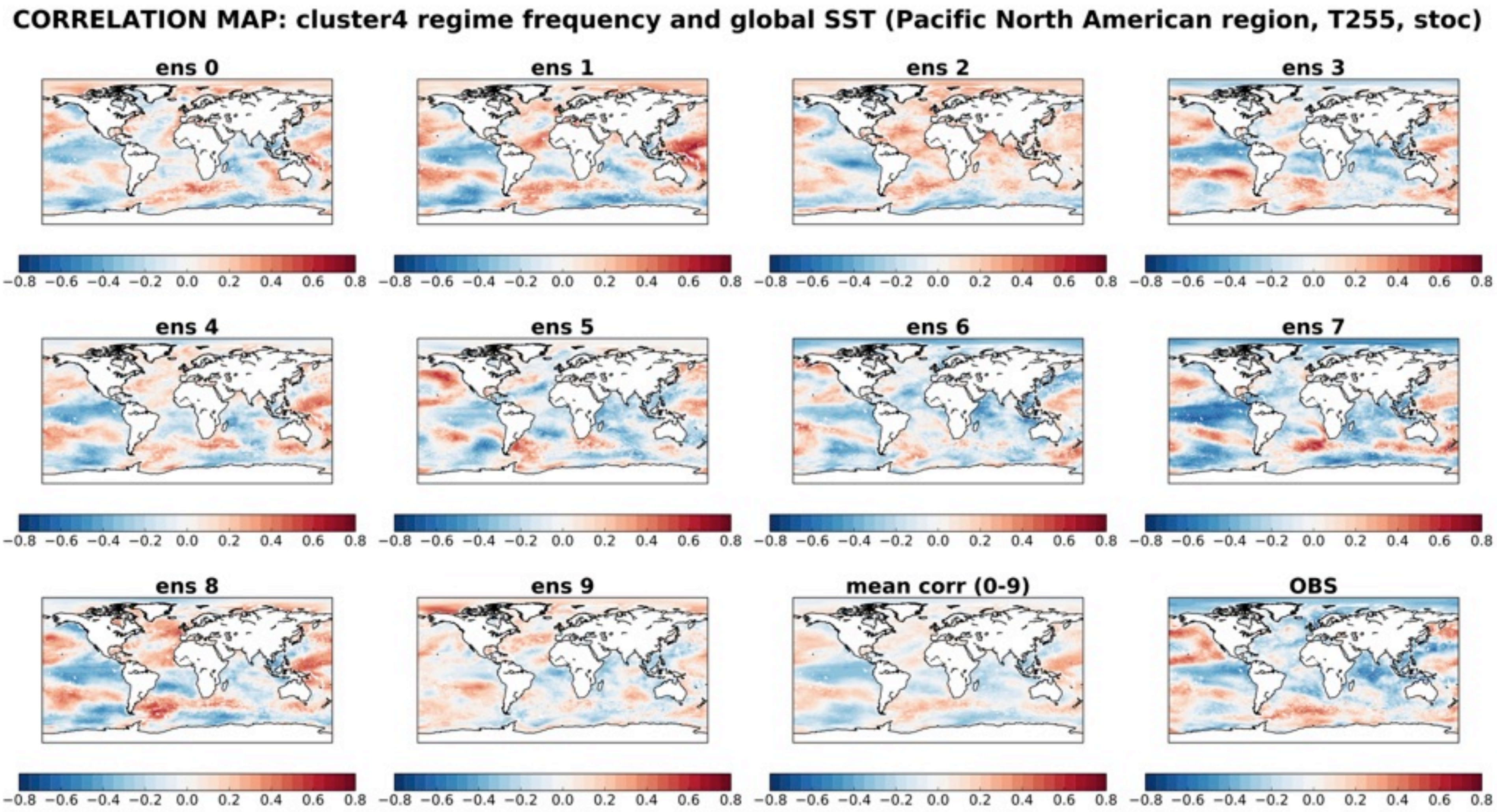
Alaskan Ridge Frequency & Global SST T255



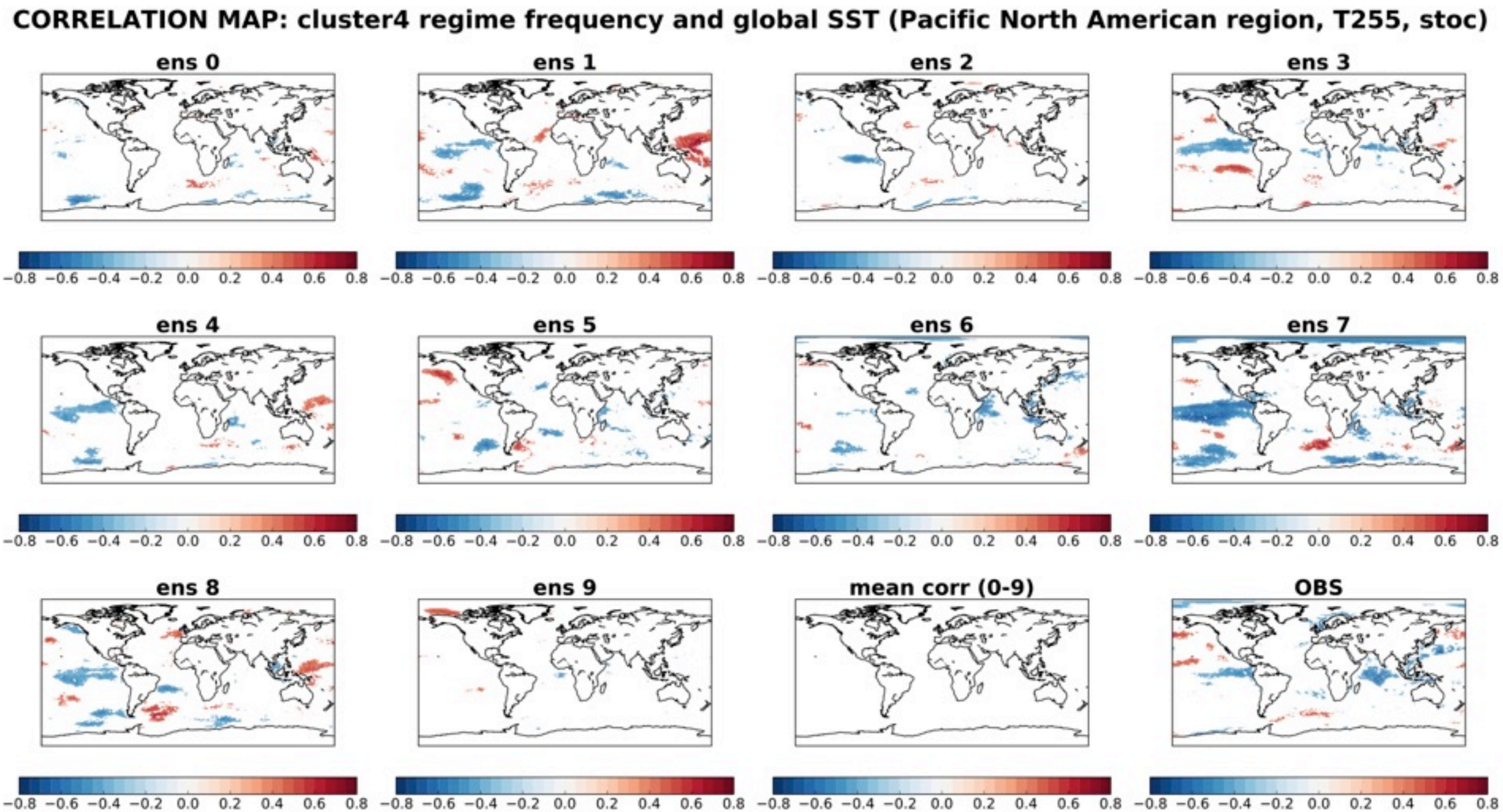
Alaskan Ridge Frequency & Global SST T255



Alaskan Ridge Frequency & Global SST T255-SP



Alaskan Ridge Frequency & Global SST T255-SP



Concluding remarks (Present day)

- North-Atlantic and Pacific-American Regimes patterns well simulated at both resolution and including (or not) stochastic physics
- Frequency: underestimation of Scandinavian blocking frequency; improvement with stochastic physics, no improvement with resolution
- Pacific-American region: With the application of stochastic physics there is an increase in the frequency of the PNA+ regime, more in agreement with observations.
- Teleconnections: huge variability in the Atlantic Region among the different ensemble members (somehow expected). Non negligible variability for the Pacific Region as well (less expected).