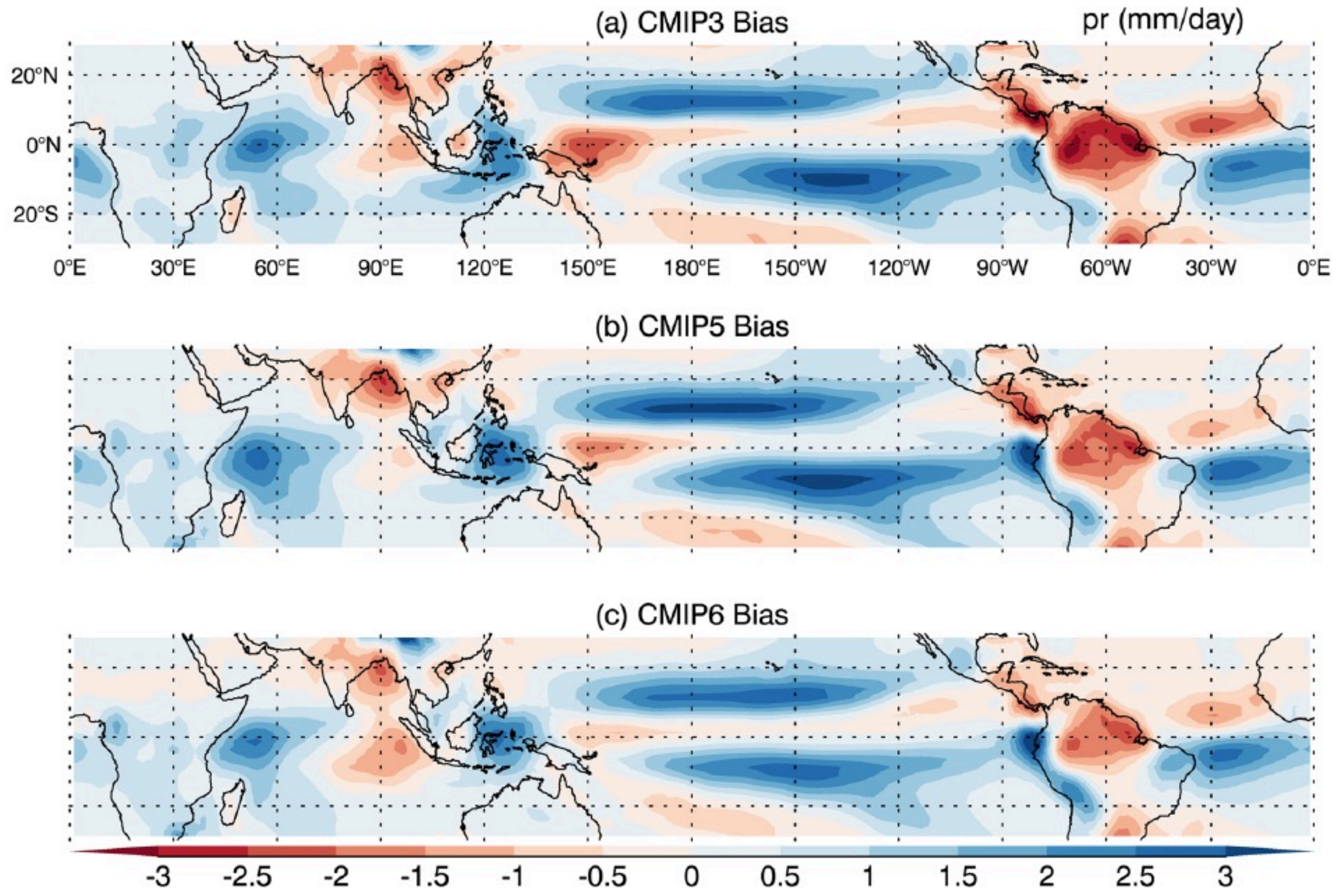
Recent development of a supermodel - an interactive multi-model ensemble

Shuo Wang[1], *François Counillon*[1,2], *Shunya Koseki*[1], *Noel Keenlyside*[1,2], *Alok Kumar Gupta*[3], *Maolin Shen*[1]

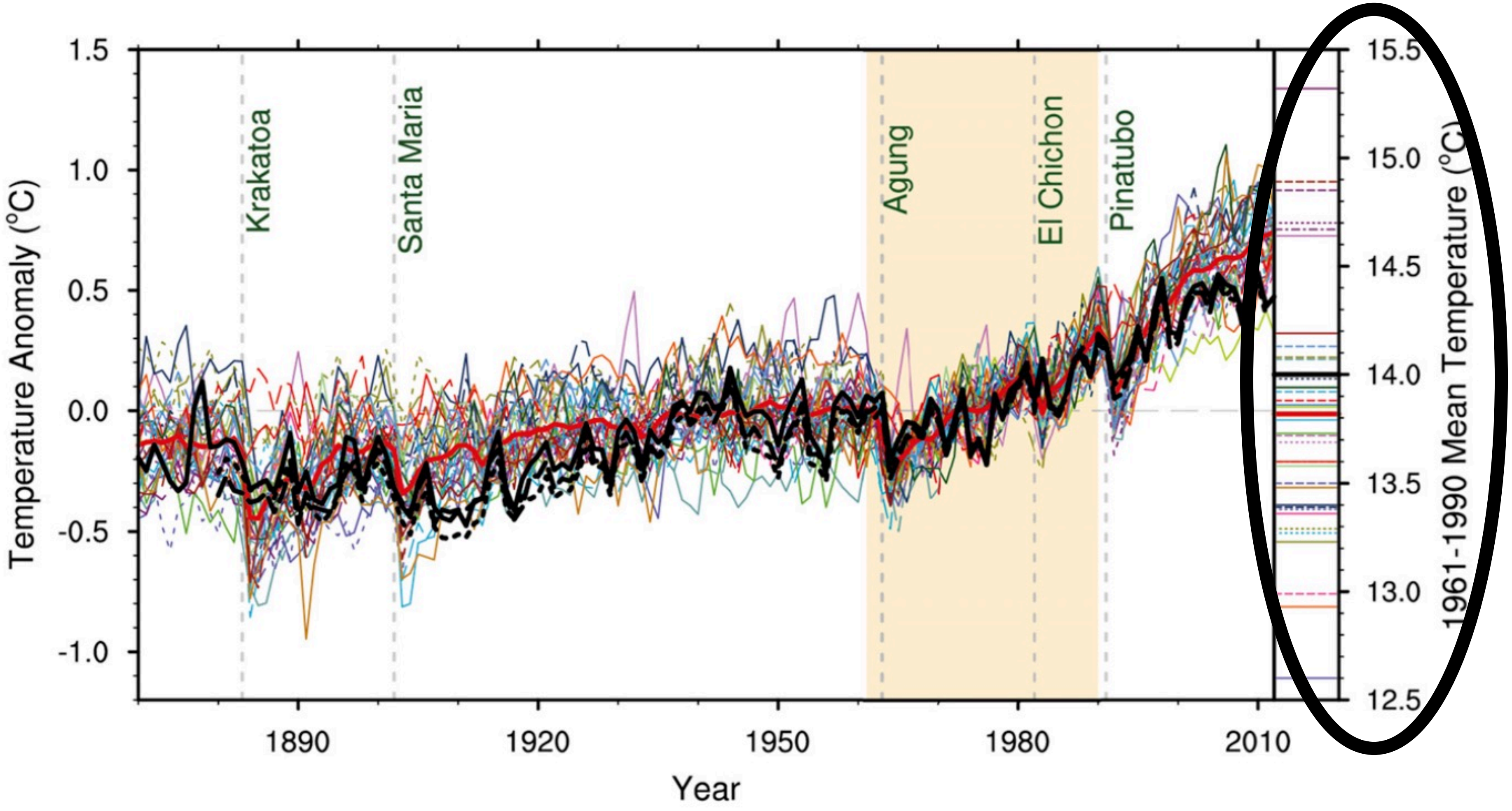
1. Geophysical Institute, University of Bergen and Bjerknes Centre for Climate Research, Bergen, Norway
2. Nansen Environmental and Remote Sensing Centre and Bjerknes Centre for Climate Research, Bergen, Norway
3. NORCE Norwegian Research Centre AS and Bjerknes Centre for Climate Research, Bergen, Norway

Persistent model biases along model development



Tian and Dong 2020

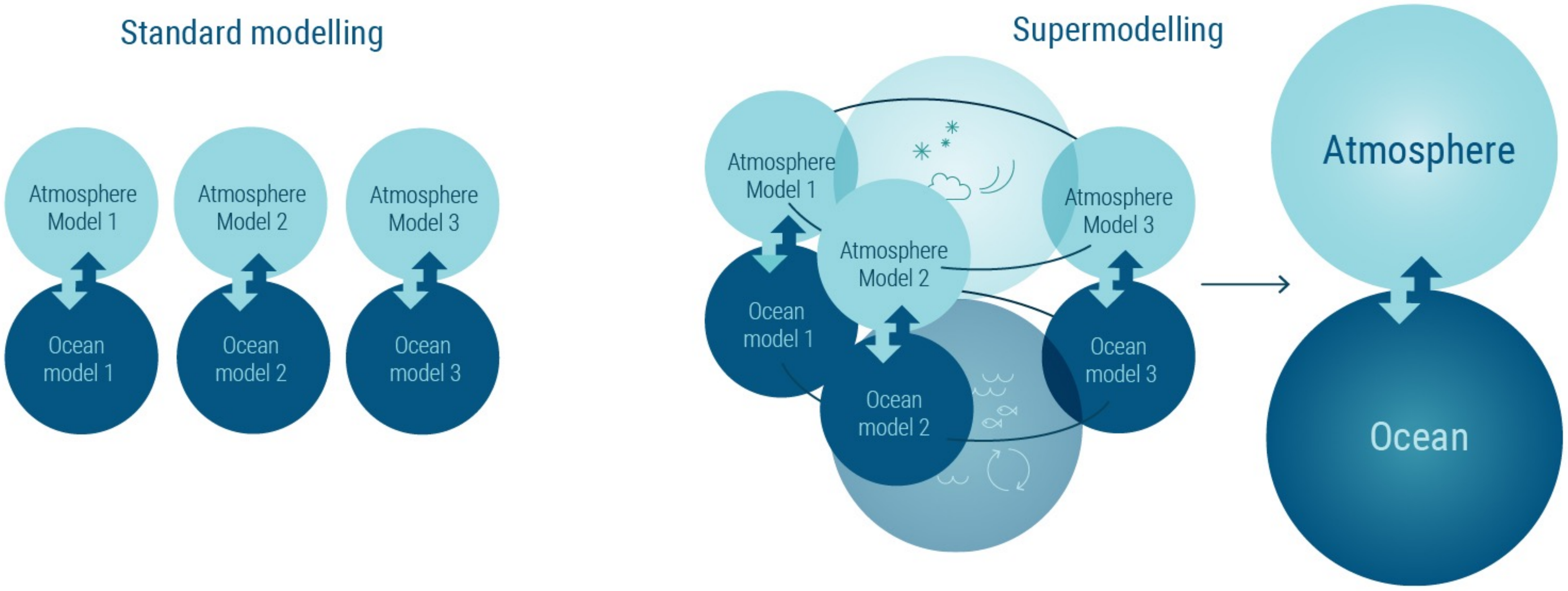
Bias is often larger than the signal we analyze or predict



Palmer and Stevens, PNAS, 2019

Can we learn from model diversity to train a better climate model?

Standard modelling VS Supermodelling



A supermodel is an optimal dynamical combination of models that is superior to its individual constituent models

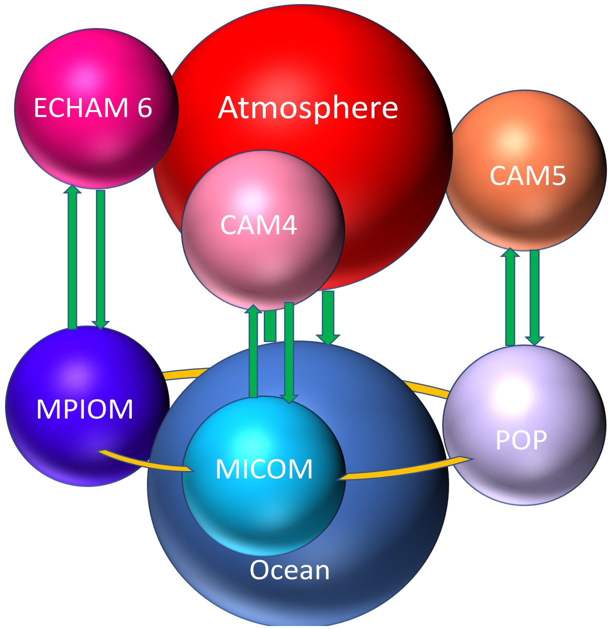
Supermodel improved the predictions skill

- Extensively tested with toy models, e.g. Lorenz 63 system (*van den Berge et al., 11, Mirchev et al. 12*) and AGCMs (*Wiegerinck et al., 17*; *Schevenhoven et al. 17)*
- Can remove structural error such as double ITCZ with two AGCMs coupled to an OGCM (Shen et al. 16,17)
- Improves short term weather forecasts with the intermediate complexity climate model SPEEDO (*Schevenhoven et al., 19*)

Our work focuses on fully coupled Earth system models

An ocean connected super-ESM

	Ocean	Atmosphere
MPIESM	MPIOM (z-coordinate, 1.5°)	ECHAM 6 (2°)
CESM	POP (z-coordinate, 1°)	CAM5 (1°)
NorESM	MICOM (isopycnal, 1°)	CAM4 (2°)



<u>Recursive approach:</u>

1. The three models are propagated for 1 month
2. Generate pseudo-observations (here SST only) from the three individual CMIP5 ESMs (weighted mean)
3. Assimilate the pseudo-observations back into each models (correct the full ocean state) with the Ensemble Optimal Interpolation (*Counillon et al. 2009)*

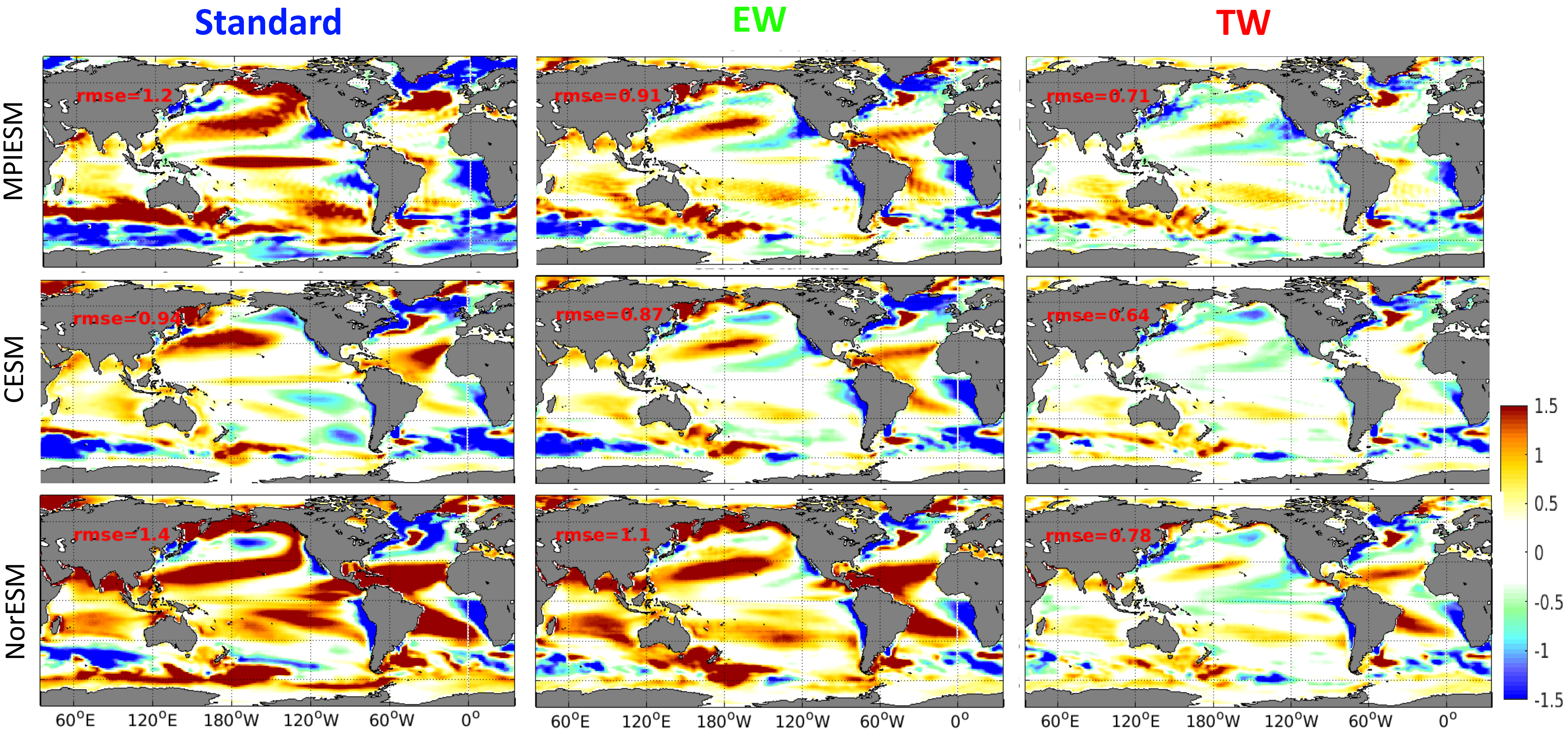
11 nodes 1408 CPU, ~10 model-year per day

Experimental set-up

We compare the performance of different approaches for 1980 to 2006:

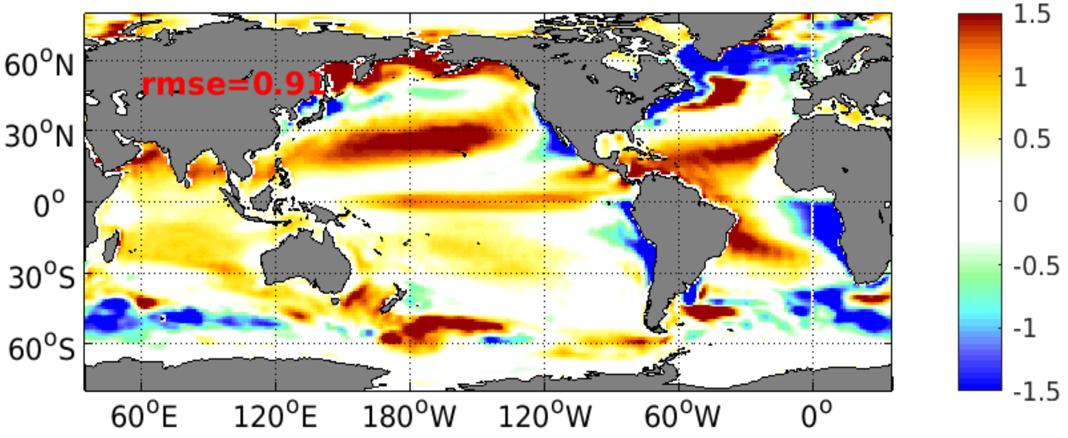
1. A posteriori averaging of the individual models (**Standard**)
2. Supermodel with equal weight (**EW**)
3. Supermodel with spatially and monthly varying trained weight (**TW**).
    - Weights estimated offline from the performance of the individual model reanalyses with assimilation of real SST
    - Weights estimated as in Particle Filter (*Van Leeuwen 2009*); weights are positive and normalised

SST bias against OISST for 1980 - 2006

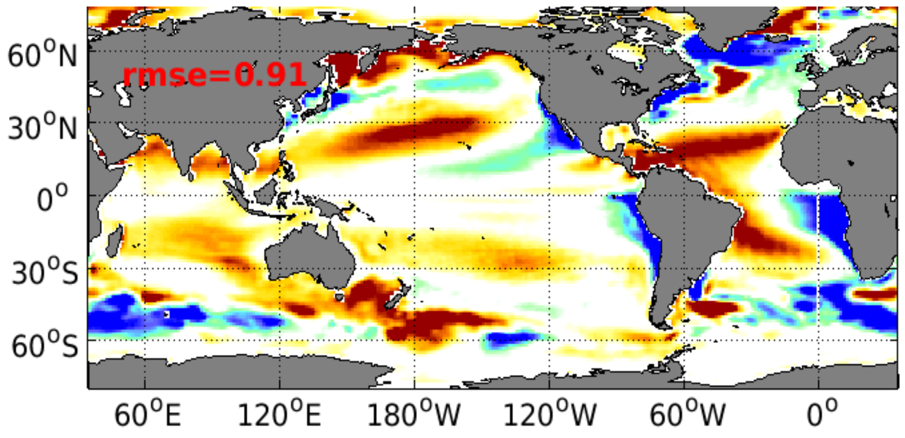


Multi-model mean SST bias

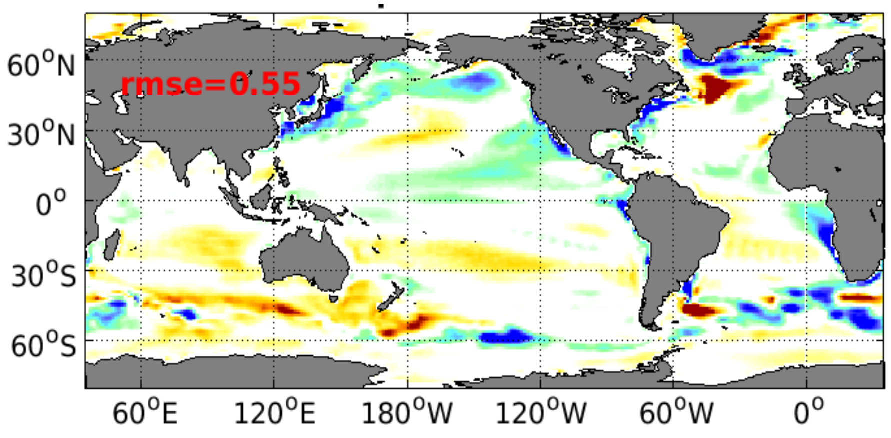
Standard



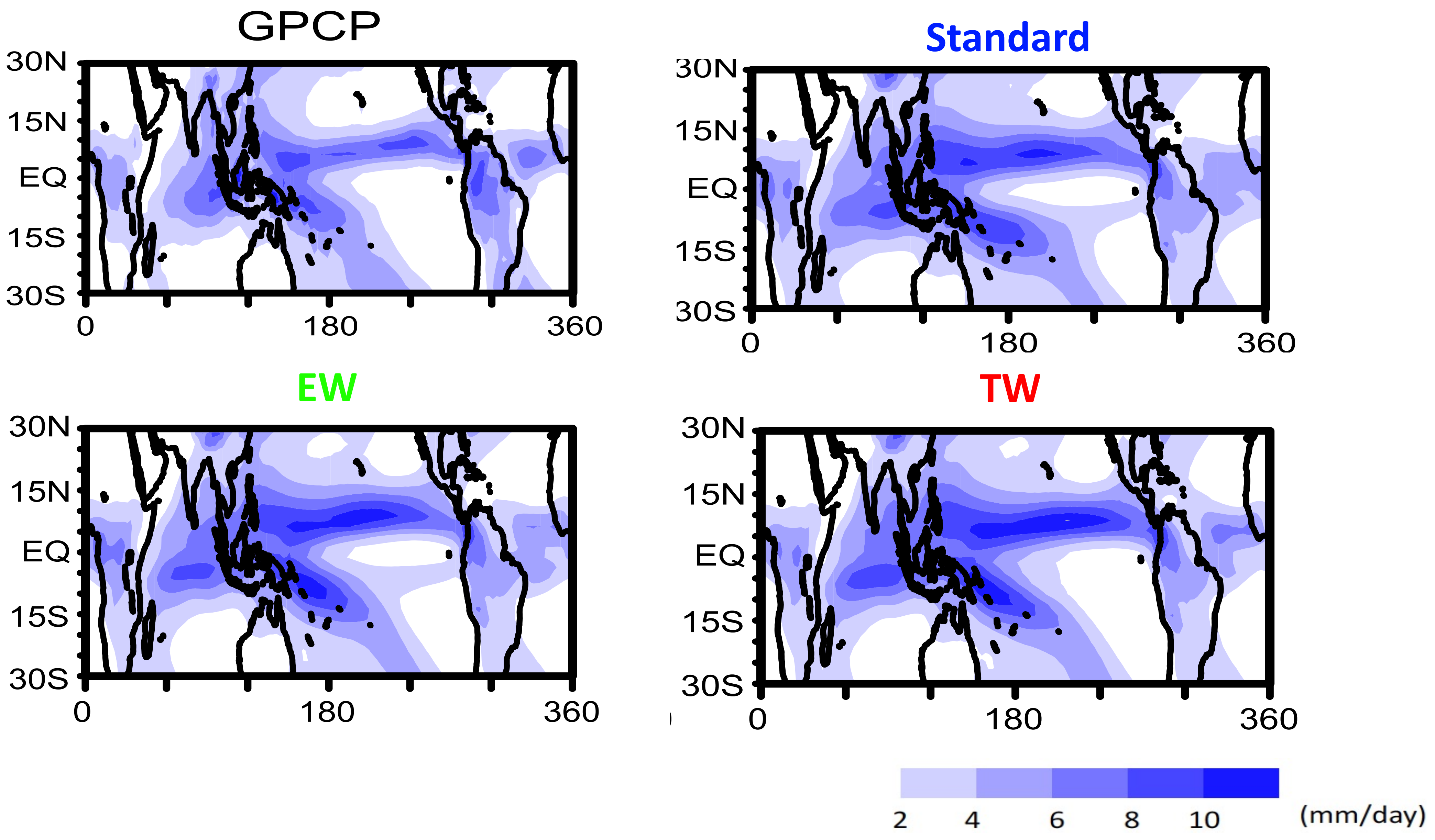
EW



TW

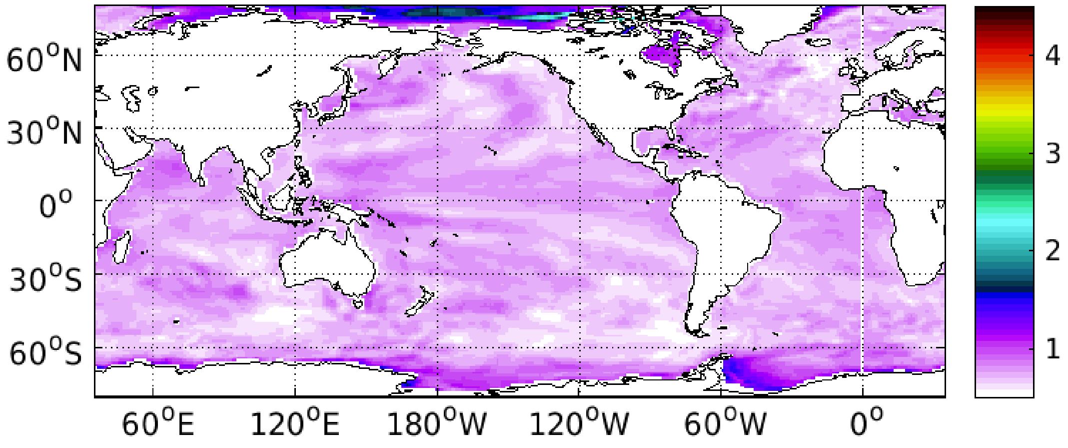


Annual-mean precipitation climatology in the tropical Pacific



Synchronisation of SST

Standard

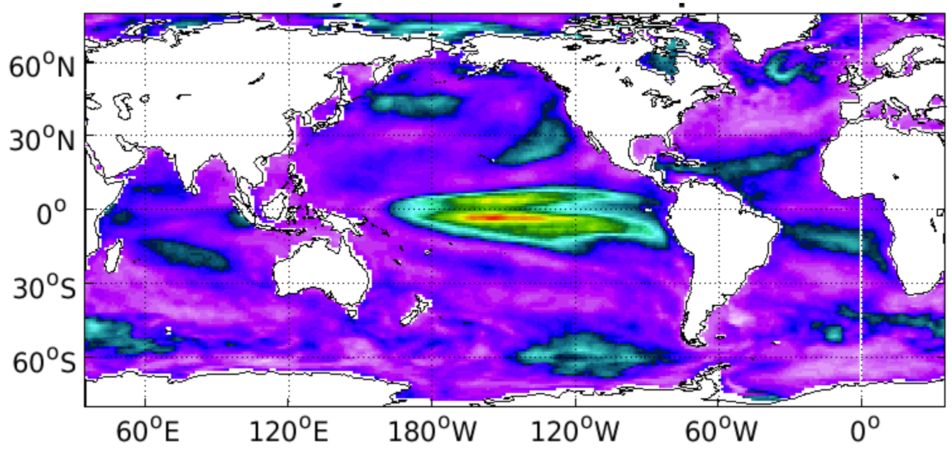


Synchronisation metric:

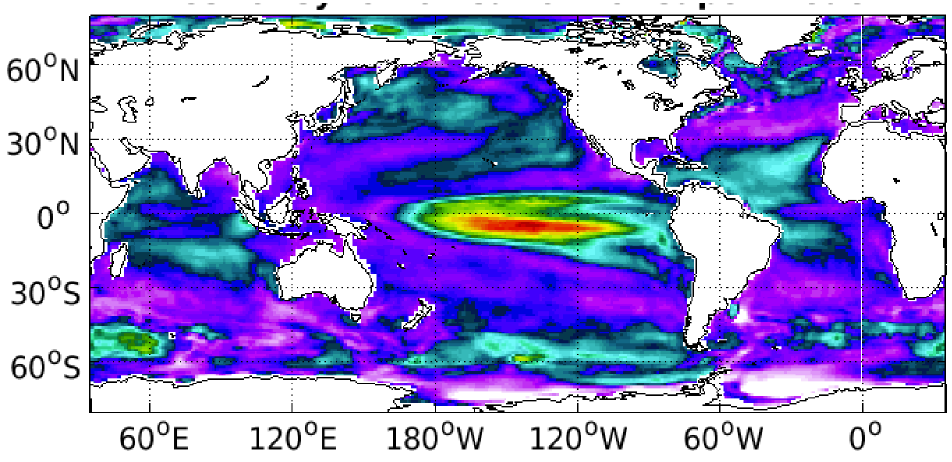
time-std(multimodel_mean)/time_avg(std(multimodel))

- =1 ; i.e. inter models std = climatological variability
- <1; i.e. inter models std < climatological variability
- >1; i.e. inter models std > climatological variability

EW

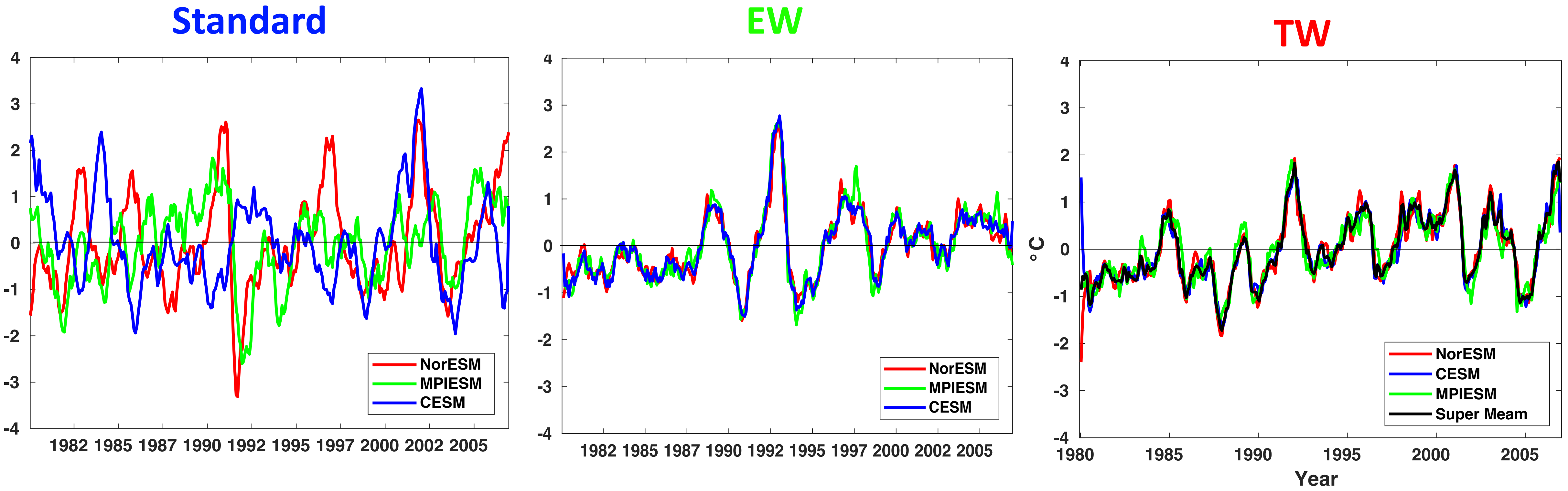


TW



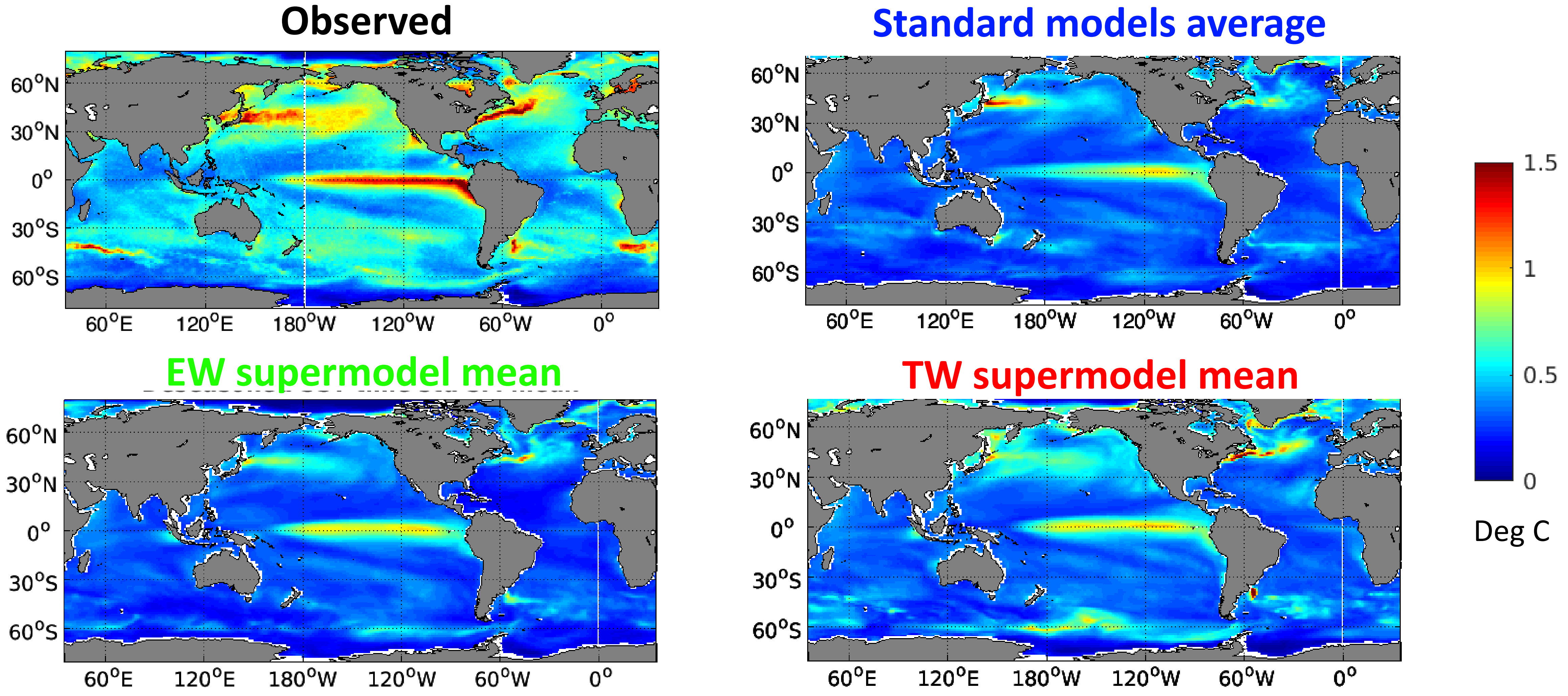
With monthly SST synchronization, the tropical Pacific is somewhat connected

Time SST variability: NINO 3.4



- Internal variability in tropical Pacific is partially synchronised
- The variability is little damped, but less than the standard ensemble mean.

Standard deviation of SST anomalies



Supermodel mean simulates reduced SST variability (less than standard models mean), with some indications of improved pattern

Summary

- A supermodel based on 3 ESMs are connected by ocean assimilation
- It reduces mean biases of SST and precipitation
- Improvements greater than the standard ensemble mean, because of non-linear properties of the climate system
- Synchronisation is achieved in some regions with connection of monthly SST
- Internal variability is dampens because averaging of unsynchronised variability in the pseudo observation causes a spurious deflation during assimilation
- We working towards improving the system:
    - improving connectivity (connection of ocean & atmosphere; more frequent)
    - Isolate the part of variability that can be synchronised
    - Training the weights online

We aim to perform climate prediction and climate change experiments