Ocean Predict

SYMPOSIUM OP'24

In partnership with unesco Intergovernmental Oceanographic Commission

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Supermodelling towards improved climate prediction

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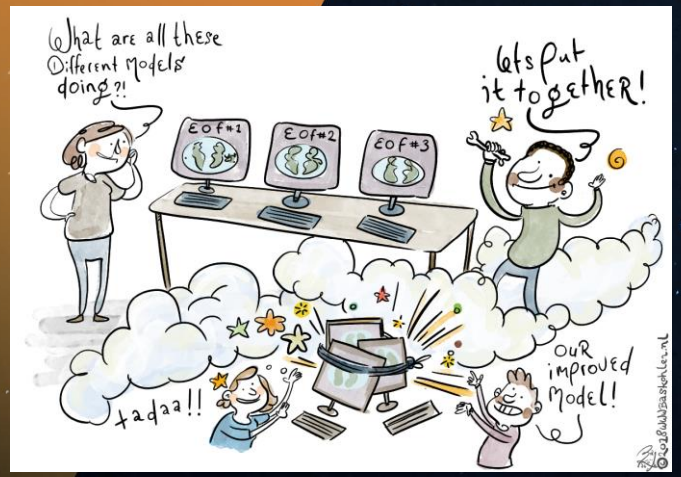
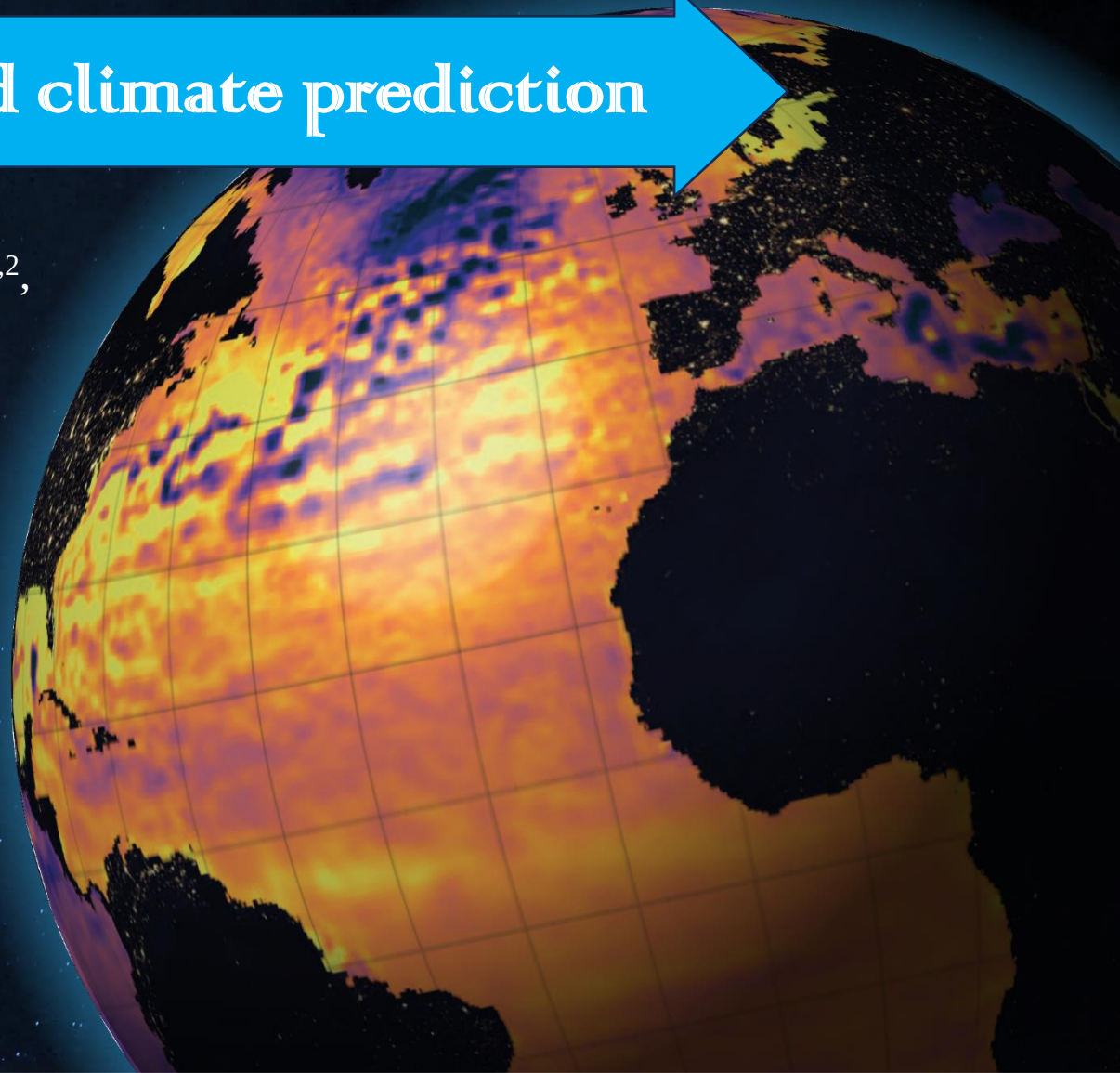
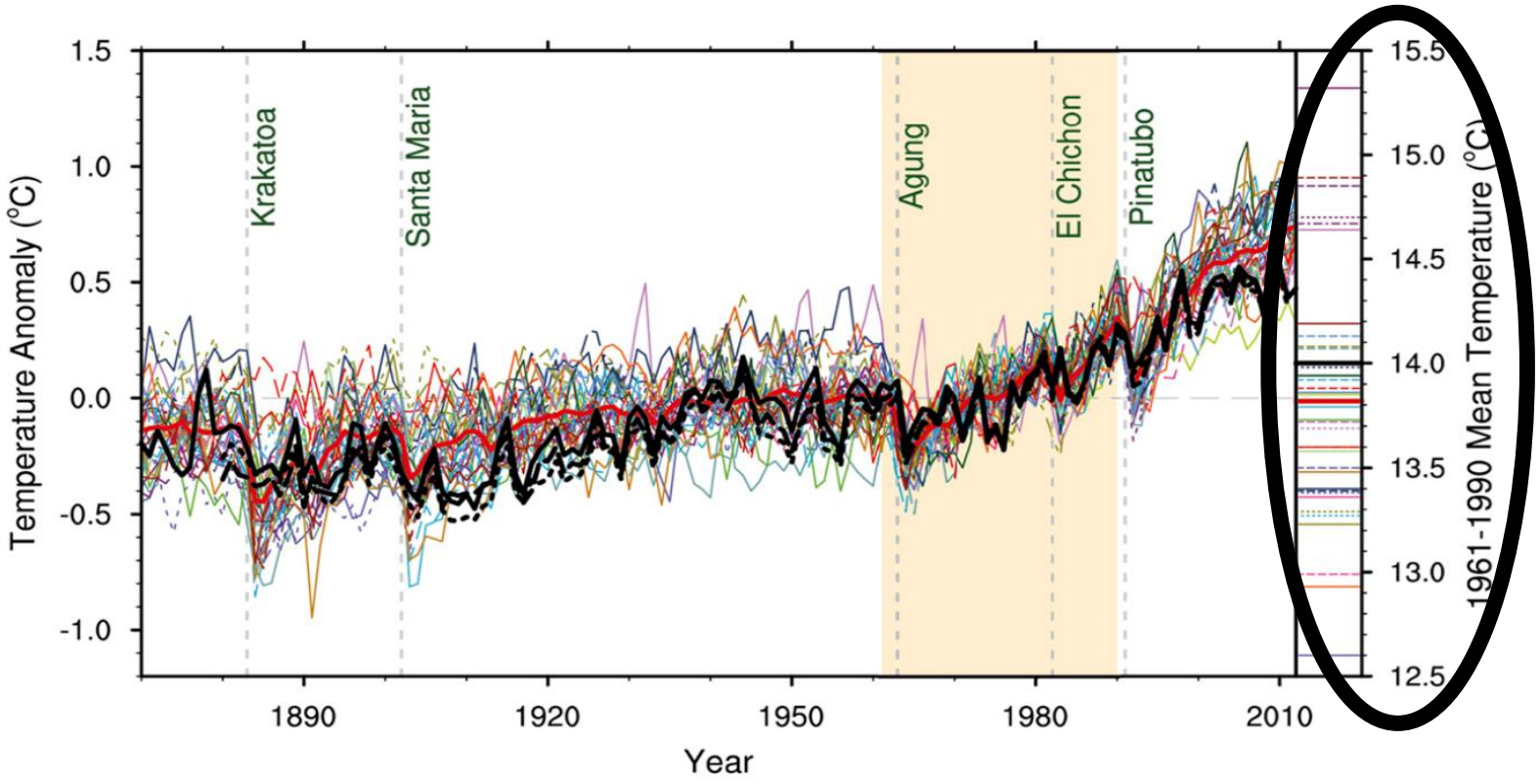


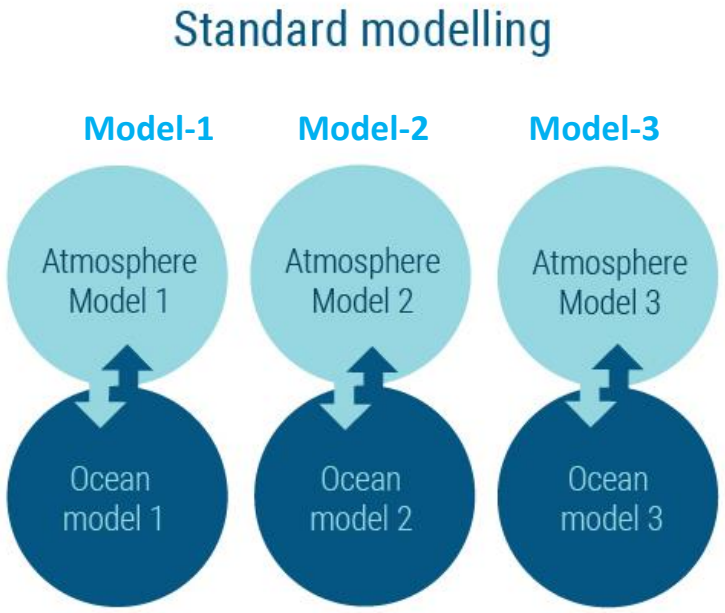


Bias is often larger than the signal we analyze or predict



Palmer and Stevens, PNAS, 2019

Standard modelling



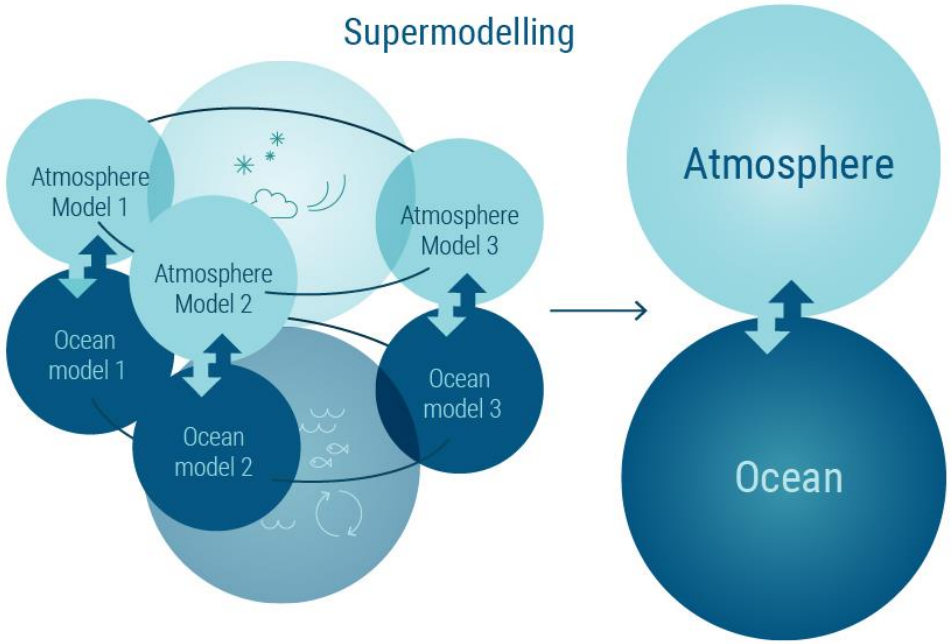
Non-interactive models (**NI**)

A standard approach to handle such bias is to take the multi-model ensemble mean (MME) as a post-processing step but

- It does not correct non-linear responses (e.g., climate sensitivity)
- Challenging to assess internal variability
- It cannot remove common biases such as the double ITCZ

Supermodelling

Supermodel: An interactive ensemble of models, models are ***dynamically combined*.**

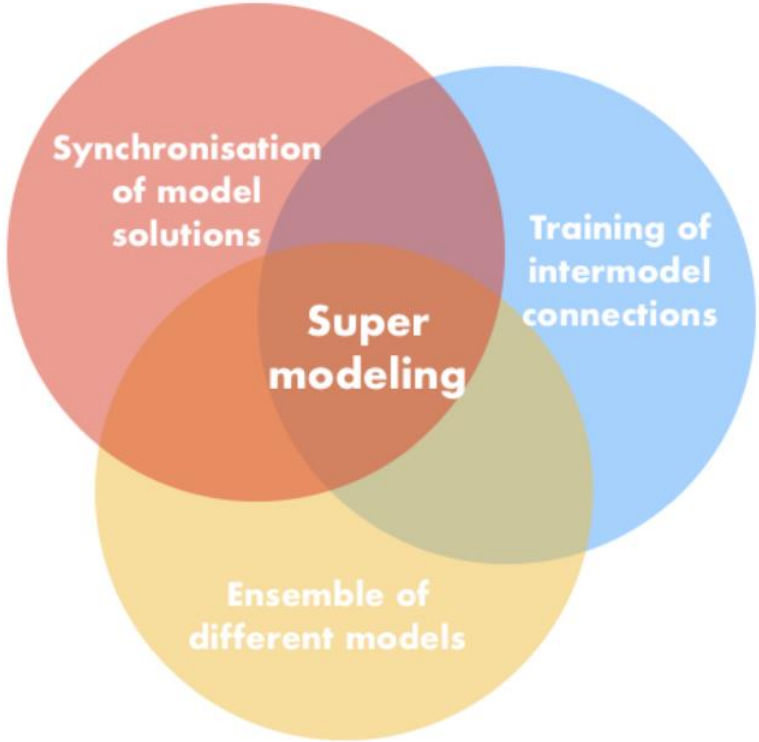


Frequent interaction between the models.

- ✓ Errors can be corrected at an early stage before they develop into large-scale climate model biases.
- ✓ Supermodel is a new dynamical system.

Key ingredients of supermodelling

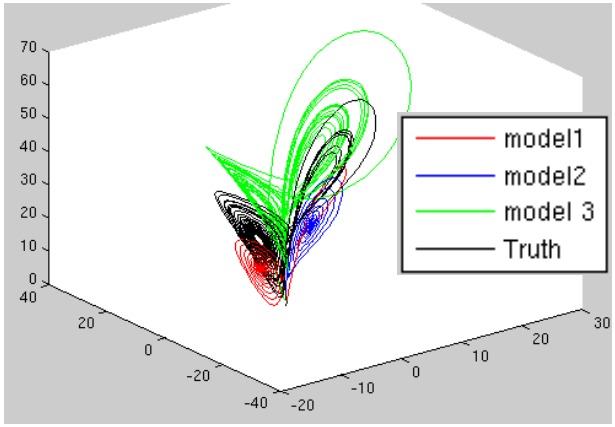
- ✓ The models synchronisation is important to ***maintain internal variability***.
- ✓ Optimal strength of connections between models based on ***training on the basis of historical observations***.
- ✓ Models in the ***ensemble*** need to be different enough to compensate for each other's shortcomings.



An example of a Lorenz 63 supermodel

$$\dot{x} = \sigma(y - x)$$
$$\dot{y} = x(\rho\text{-}z)\text{-}y$$
$$\dot{z} = xy\text{-}\beta z$$

	σ	ρ	β
Truth	10	28	8/3
Model 1	13.25	19	3.5
Model 2	7	18	3.7
Model 3	6.5	38	1.7



A supermodel add connections to the other imperfect models
Example:

$$\dot{x}_1 = \sigma_1(y_1 - x_1) + C_{12}^{x}(x_2 - x_1) + C_{13}^{x}(x_3 - x_1)$$

Nudging to other models

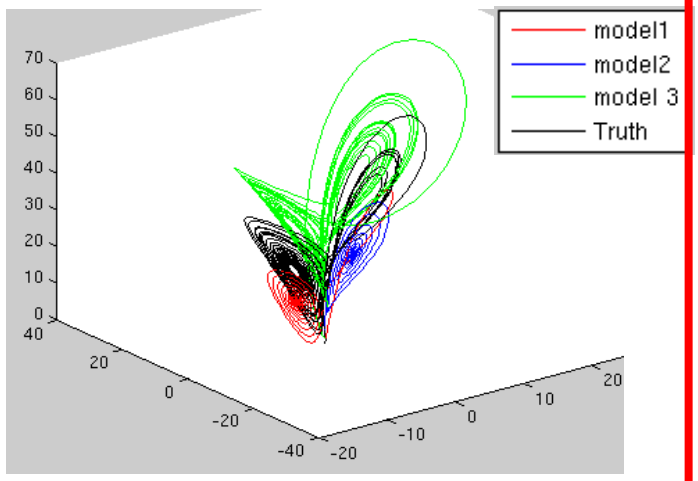
Van den Berge et al. 2011

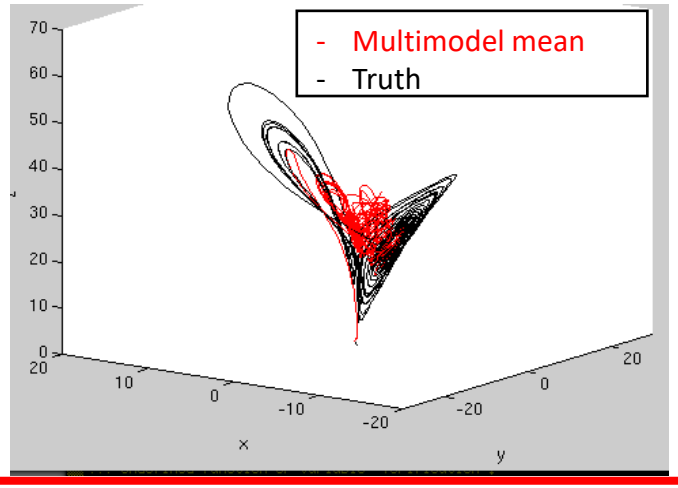
In **training phase**: use observations to estimate the nudging coefficients (and constrain the state during)

In **verification phase**: coefficients are frozen and the system can be used as a new dynamical system

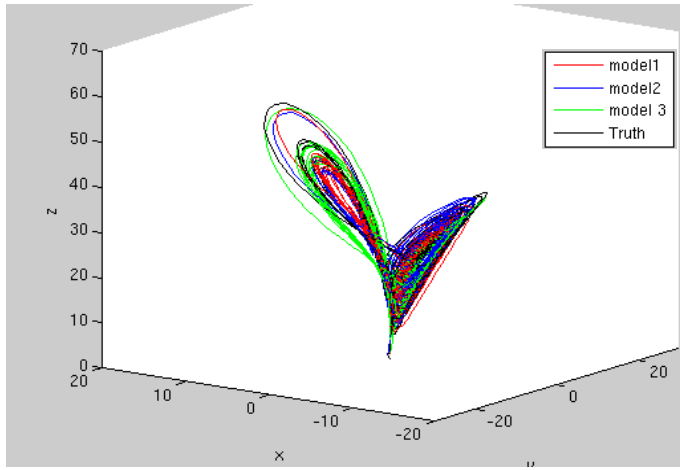
Supermodel verification

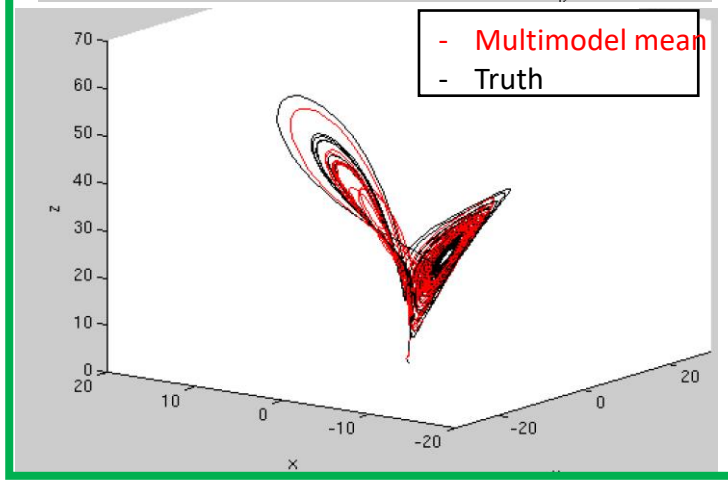
Unconnected mean





Supermodel





- All models have corrected the bias
- Internal variability is in line with the truth

Van den Berge et al. 2011

Supermodelling with state-of-art climate Models

Supermodels are demonstrated with idealised models, but their application to climate models is challenging because they **do not share the same state space, grid and resolution**

Can data assimilation provide a framework to handle this challenge?

JAMES | Journal of Advances in Modeling Earth Systems

Research Article | Open Access

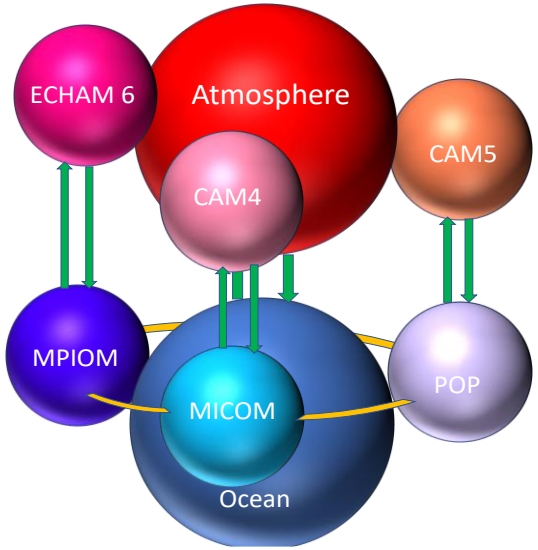
Framework for an Ocean-Connected Supermodel of the Earth System

François Counillon, Noel Keenlyside, Shuo Wang, Marion Devilliers, Alok Gupta, Shunya Koseki, Mao-Lin Shen

First published: 09 March 2023 | https://doi.org/10.1029/2022MS003310 | Citations: 3

An ocean connected super-ESM with DA

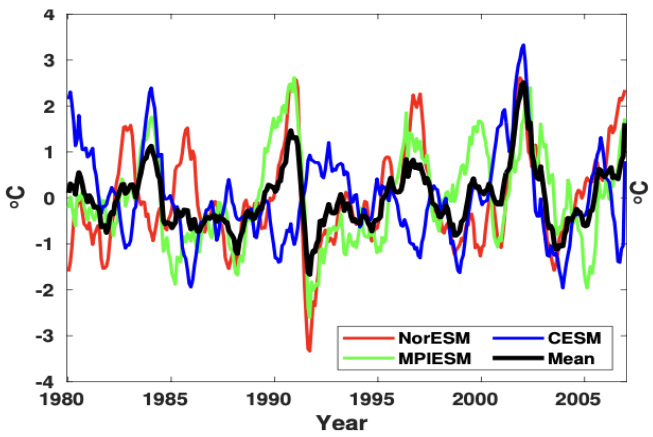
(Counillon, et al. 2023)



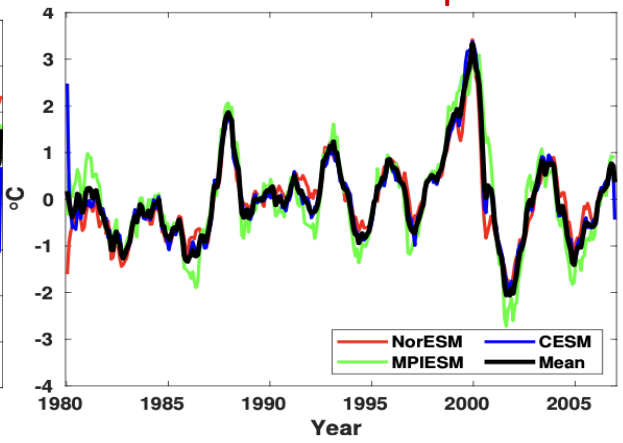
1. Propagate models for 1 month
2. Generate pseudo-observations (from models SST; *i.e.*, weighted mean, weight is trained based on observations)
3. Assimilate the pseudo-observations back into each model (correct the full ocean state)

ENSO variability (NINO 3.4)

Non-interactive models



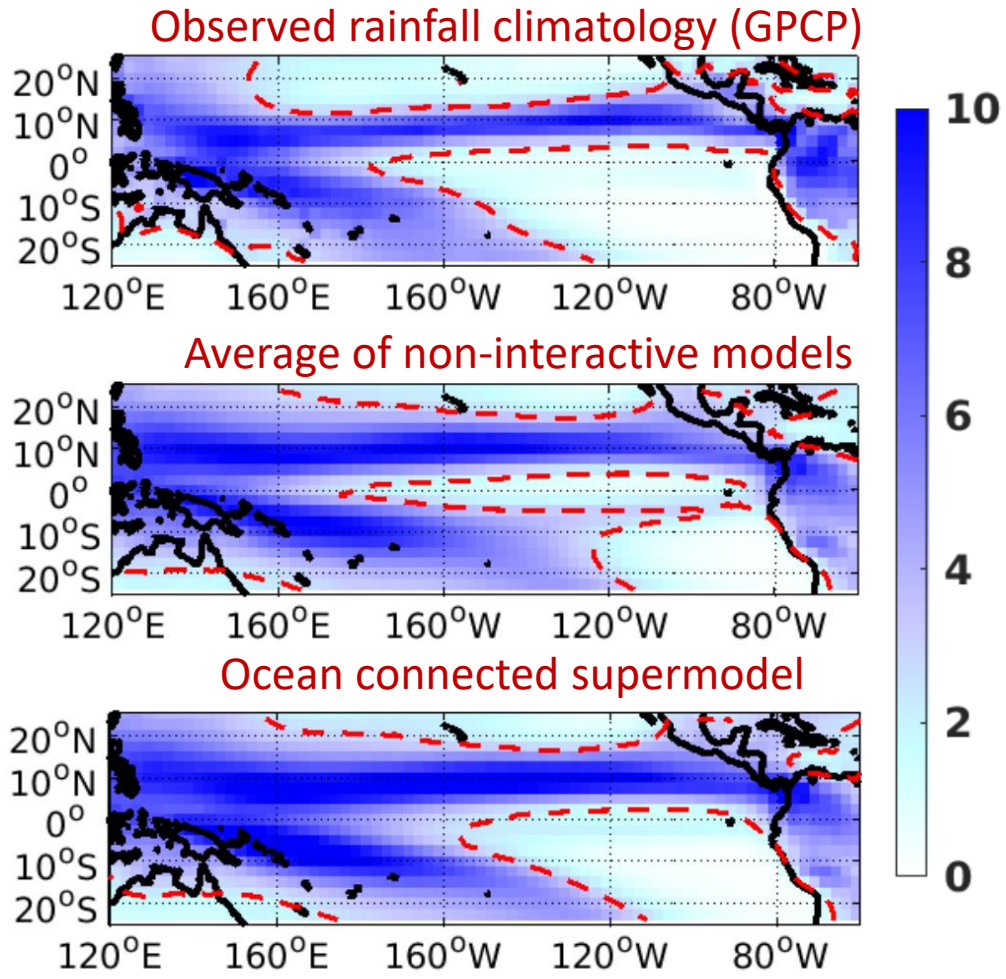
Ocean connected supermodel



Internal variability in the Nino 3.4 seems well synchronised in the supermodel.

An ocean connected super-ESM with DA

Rainfall climatology in the tropical Pacific (2006-2021)



Supermodel mitigates the double ITCZ problem !

Schevenhoven et al. 2023

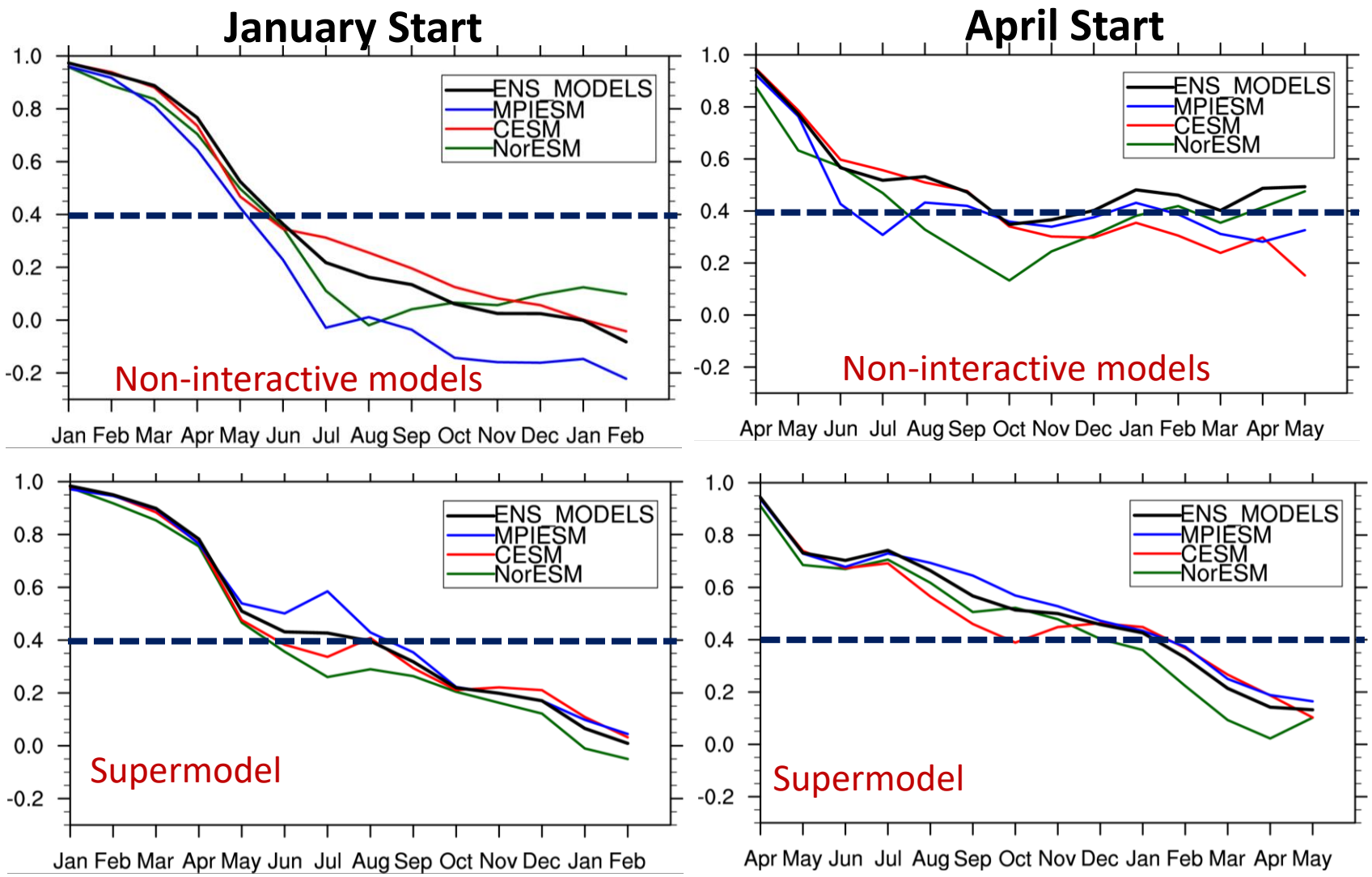
First seasonal prediction results with a supermodel

- Initial conditions produced by assimilating NOAA SST observations.
- Seasonal predictions, single member, 4 per year, 1991-2020

Supermodel demonstrates some skill in crossing the spring predictability barrier.

(Singh et al., in prep)

Prediction of Niño3.4, Anomaly Correlation Skill, 1991-2020



Summary

- A successful ocean-connected supermodel framework for Earth system models combining MPIESM-NorESM-CESM
- Supermodel reduces long-standing climate biases (SST and precipitation), and preliminary results demonstrate some skill in crossing the spring predictability barrier.
- Now, there is also an atmospheric-connected supermodel using the CESM ensemble.

Implementation and validation of a supermodelling framework into CESM version 2.1.5

William E. Chapman [1], Francine Schevenhoven [2], Judith Berner [1], Noel Keenlyside [2], Ingo Bethke [2], Ping-Gin Chiu [2], Alok Gupta [3], and Jesse Nusbaumer [1]

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[2]Geophysical Institute and Bjerknes Centre for Climate Research, University of Bergen, Bergen, Norway
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Work underway

- More investigation on the seasonal prediction skills
- Adding EC-Earth3 to the supermodel

IMPETUS 4CHANGE

Future Steps

- Use supermodel for downscaling (synchronisation between outer and inner model) SEACLIM
- A supermodel with both atmosphere and ocean connected?

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