Approaches to reduce model biases to improve in climate prediction

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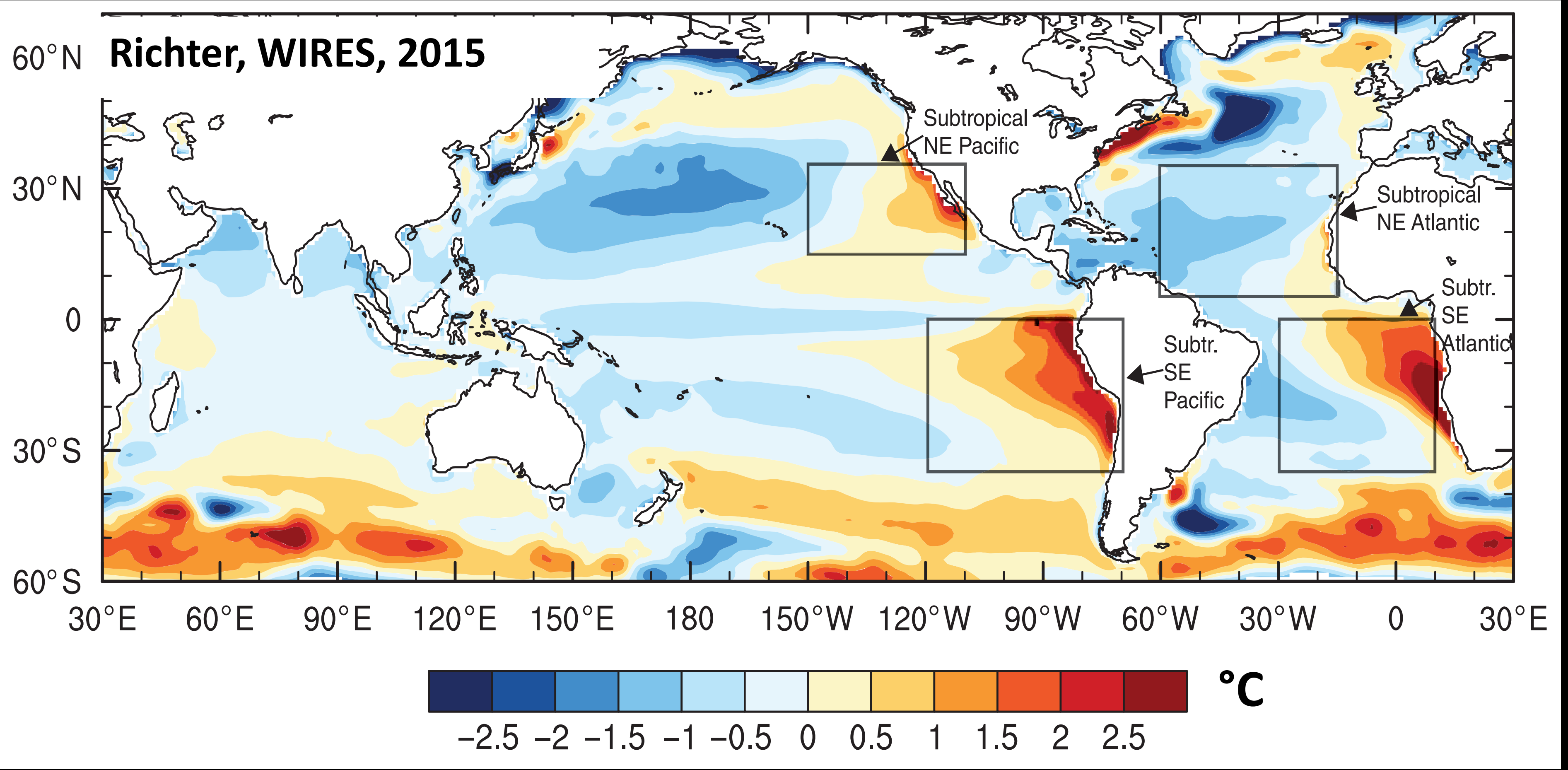
Persistent model biases – dramatic improvement unlikely soon

CMIP5 multi-model mean sea surface temperature error



Two alternative approaches

1. Anomaly coupling -> Improved seasonal prediction in the Tropical Atlantic

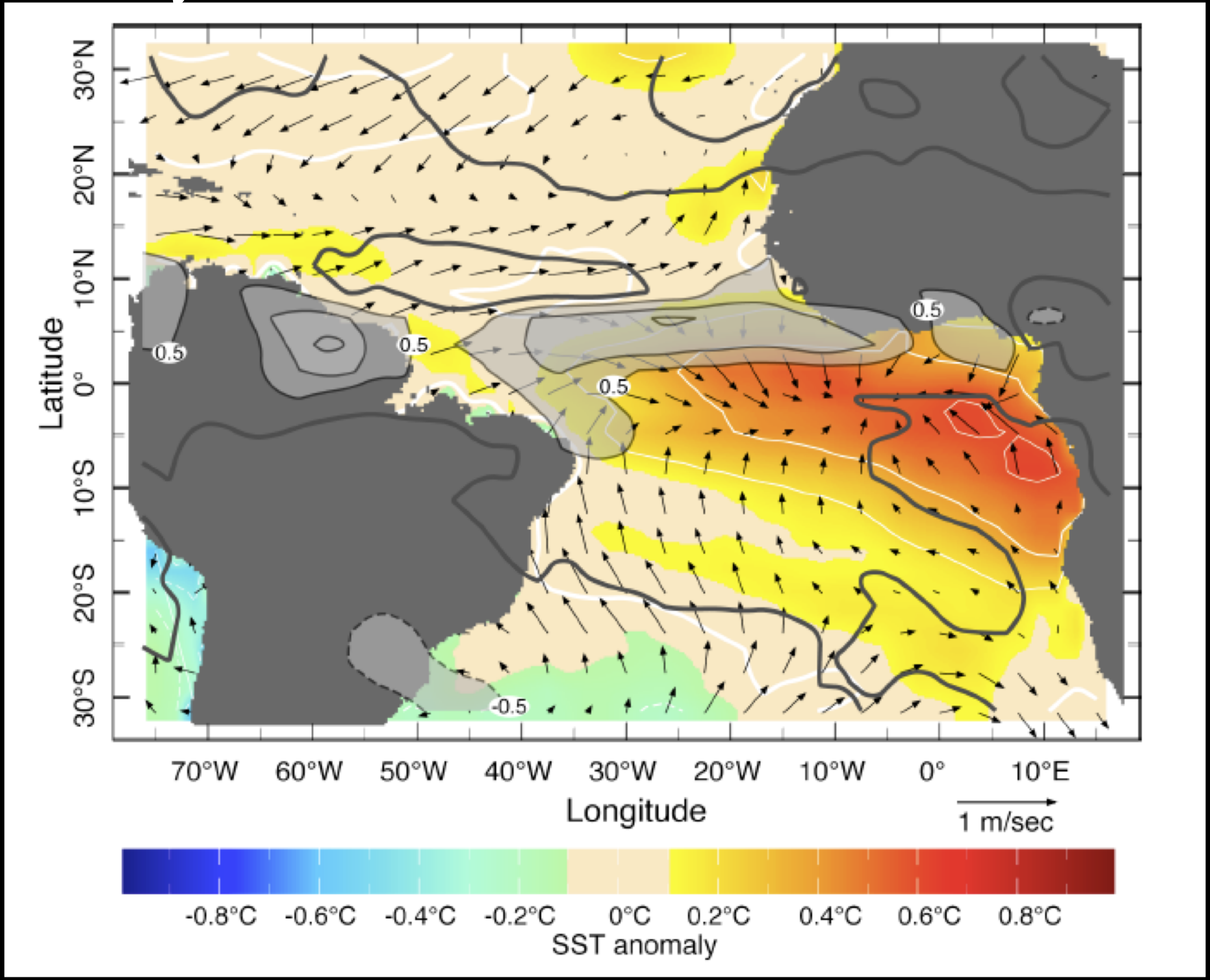
   (Counillon et al. to be submitted)

2. Supermodelling -> Reduces the Pacific double Inter-tropical Convergence Zone bias

   (Shen et al. 2016, 2017)

The Atlantic Niño

First EOF of June-August precipitation
Linearly related SST and surface wind vectors



Chang et al. 2006

The Atlantic Niño

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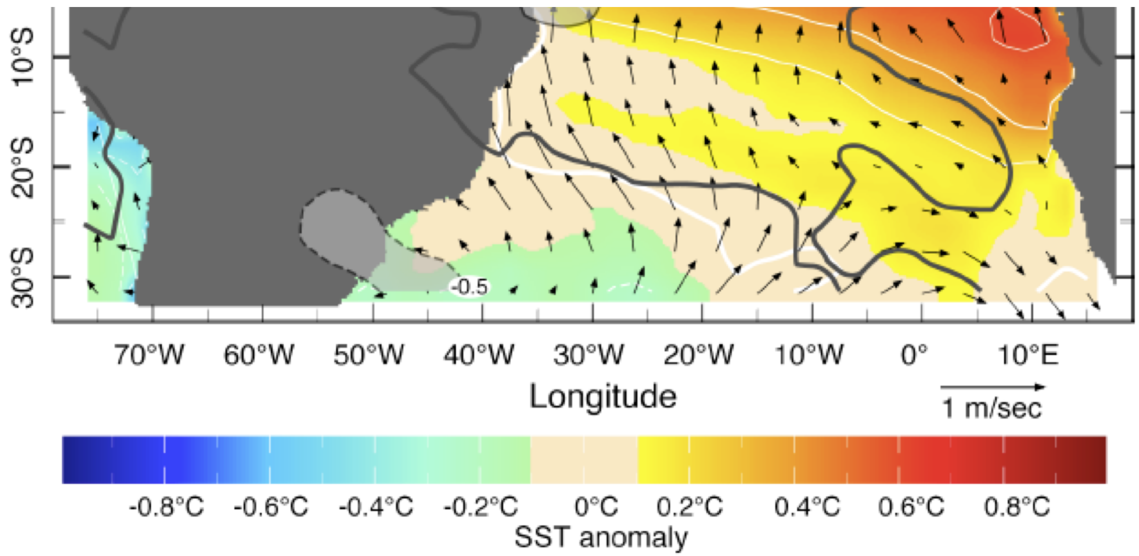
The Bjerknes Positive feedback and delayed negative feedbacks underlie the Atlantic Niño
[e.g., Zebiak 1993, Keenlyside & Latif, 2007, Ding et al. 2010]



Chang et al. 2006

The Atlantic Niño

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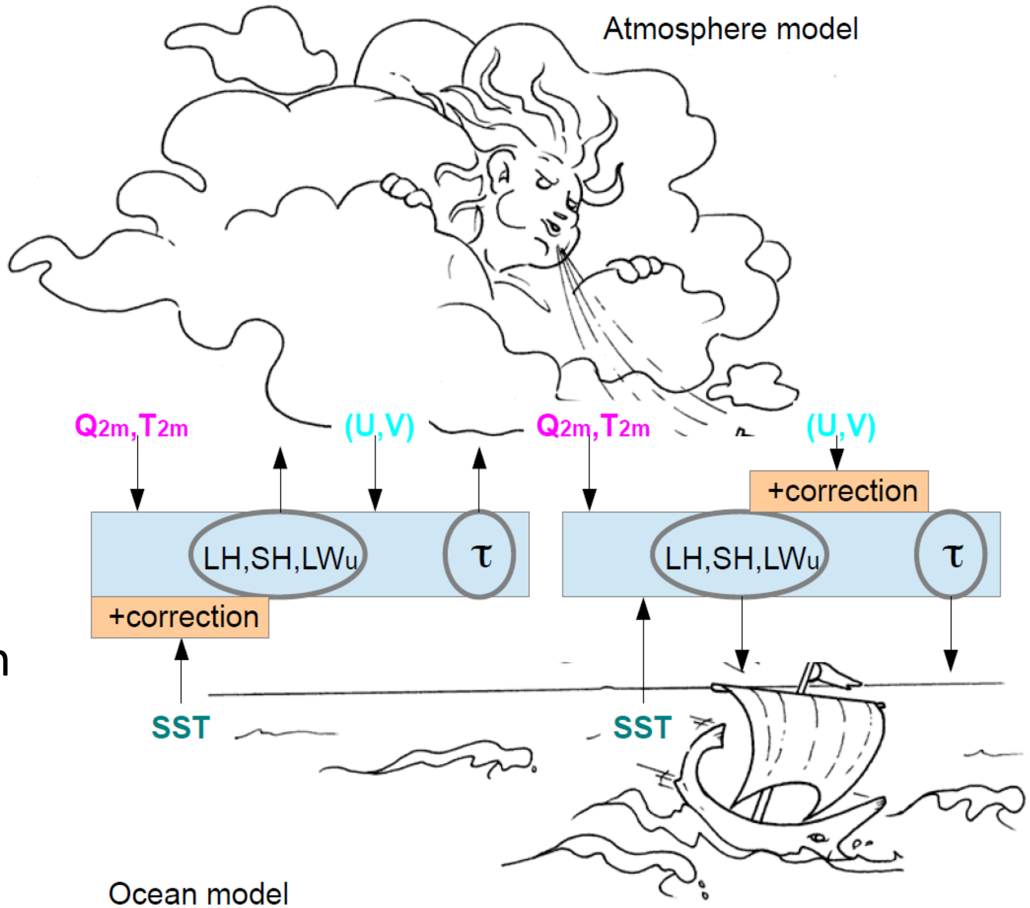
Consistently with the warm bias, coupled models underestimate the thermocline feedback
[e.g., Nnamchi et al. 2015, Deppenmeier et al. 2015, Ding et al. 2015a,b]

Chang et al. 2006

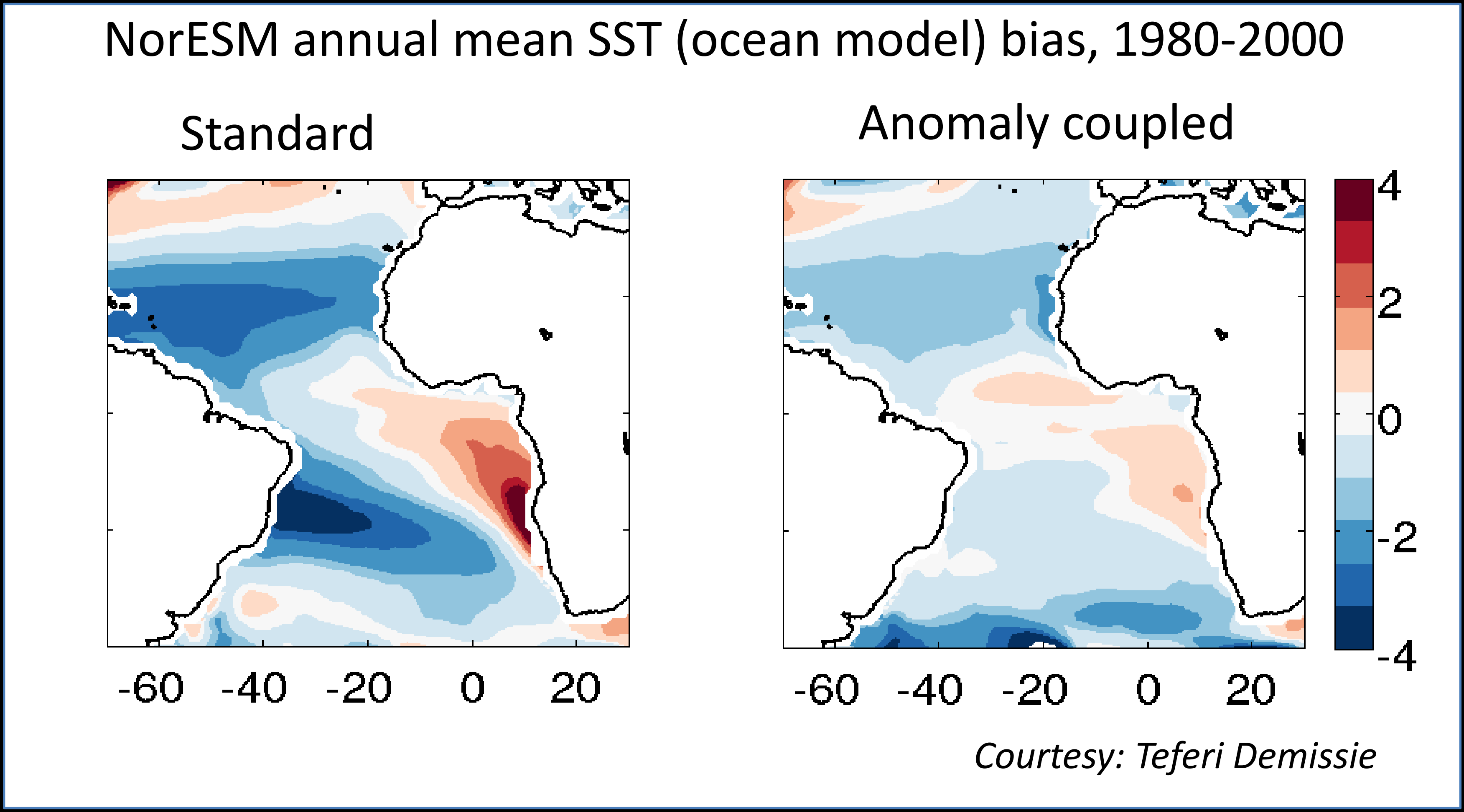
A methodology to correct mean state biases: Anomaly coupled model



Correction added to quantities exchanged between atmosphere and ocean

Courtesy: Thomas Toniazzo

Anomaly coupling captures Atlantic cold tongue



Seasonal predictions – With and without mean state bias

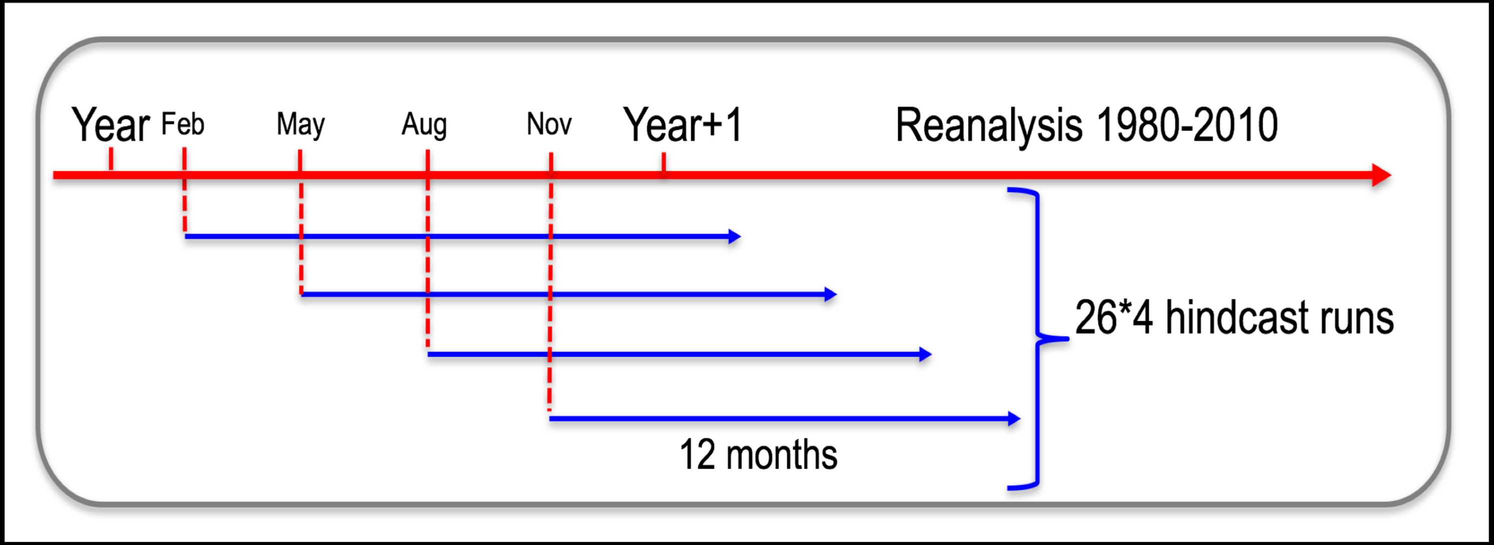
Norwegian Earths System Model with and without anomaly coupling (Toniazzo & Kosseki 2018)

Reanalysis

- 30 member ensemble
- Assimilation of anomaly SST, and T,S profiles , 1980-2010

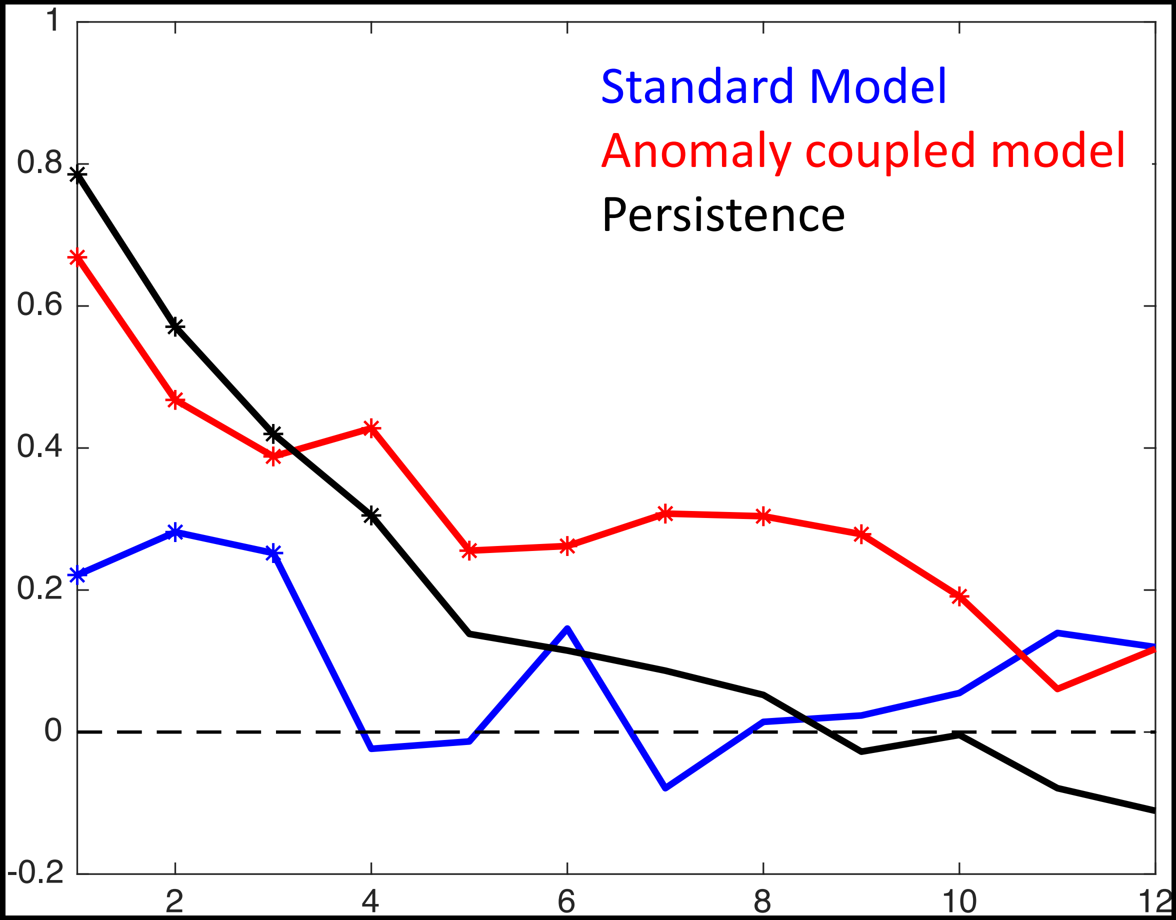
Retrospective forecasts

- 1985 to 2010 with 9 members and 4 start date per year



Reduced biases enhances seasonal prediction skill for the Atlantic Niño

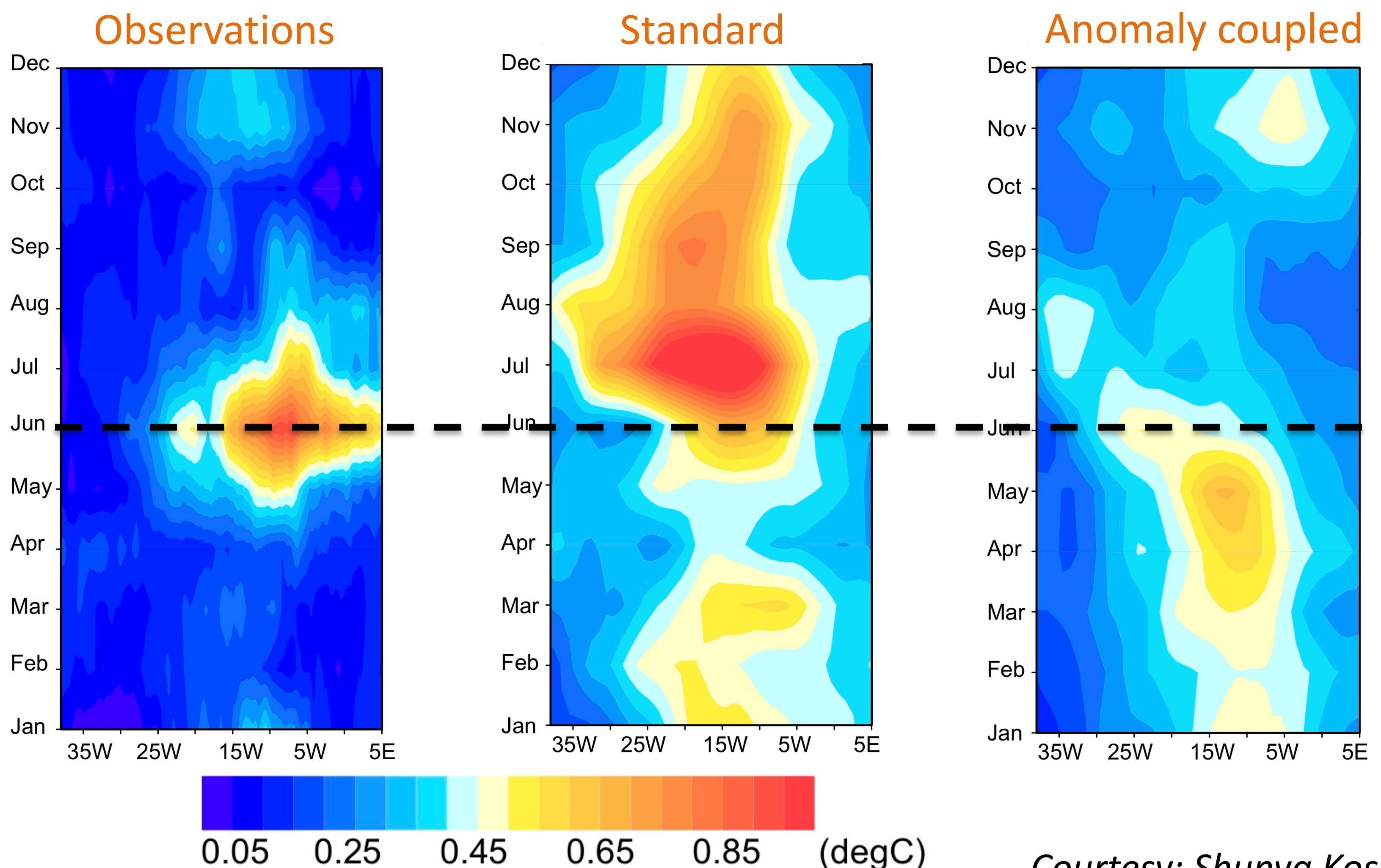
Norwegian Climate prediction Model, Correlation skill for ATL3 region
1985-2010, 4 starts per year (Feb. May, Aug. Nov.), 9 ensemble members



Courtesy: Francois Counillon

Reduced bias -> better equatorial variability

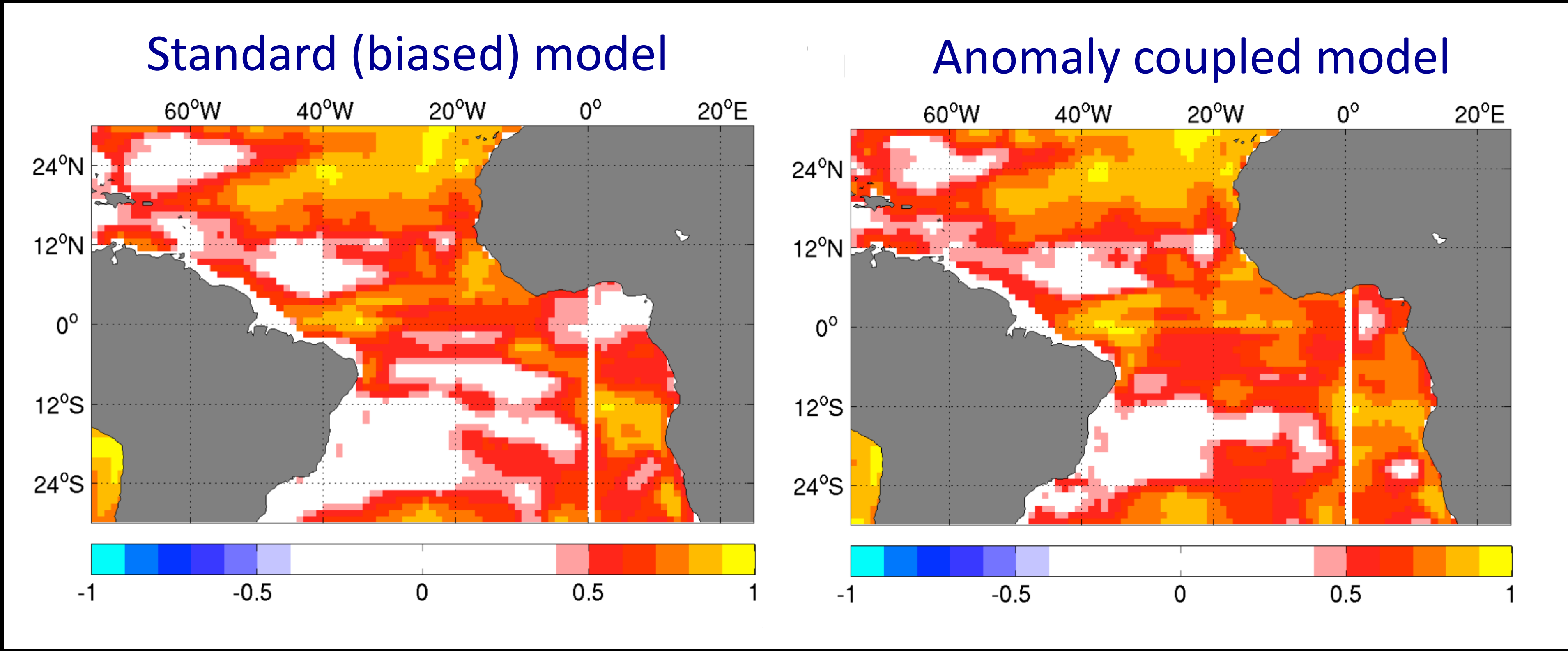
Standard deviation of SST along the equator, January - December



Courtesy: Shunya Koseki

Reduced bias enhances ocean analysis

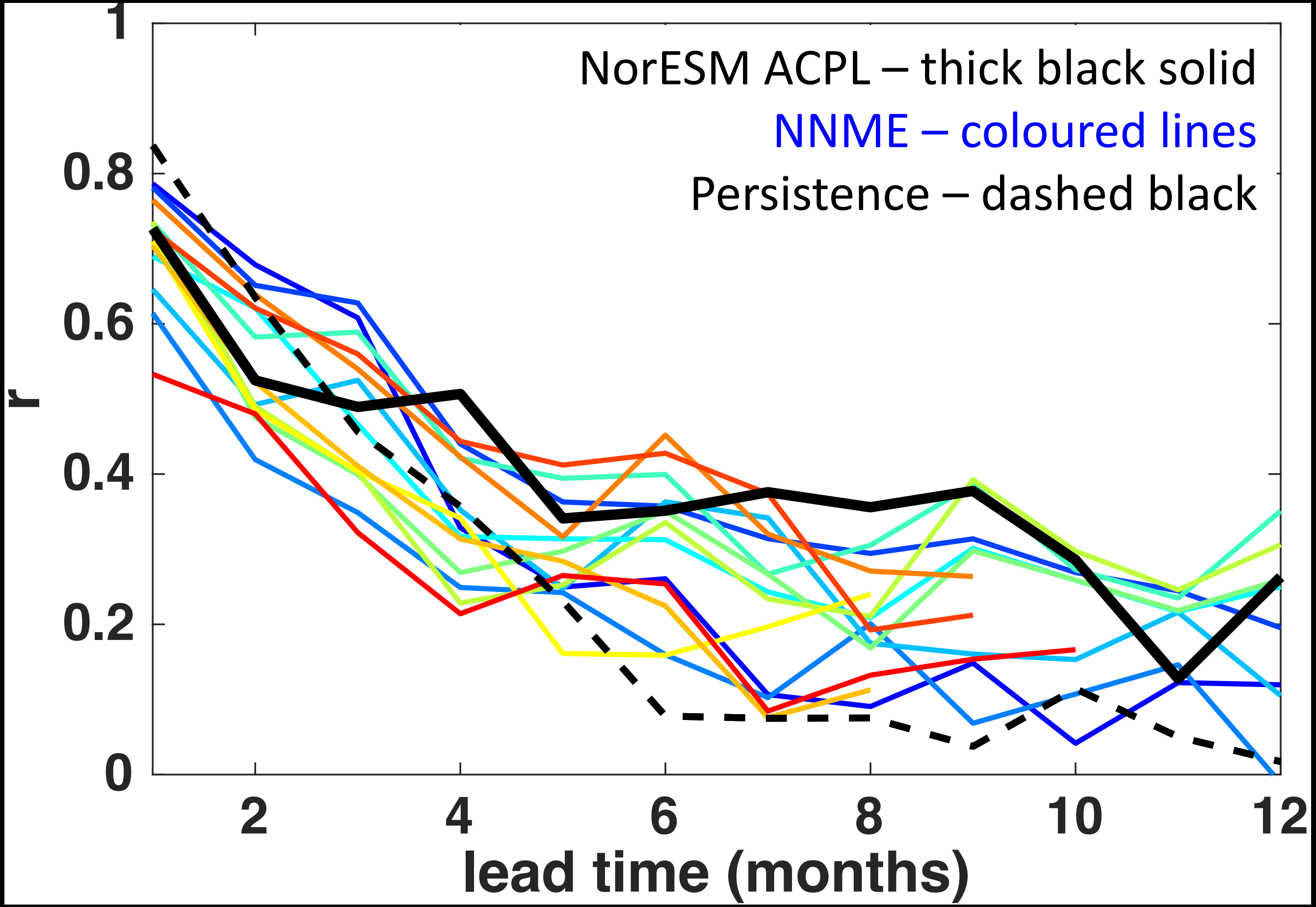
Correlation (1980-2010), 200m heat content
EN4 objective analysis with
Norwegian Climate Prediction Model ocean reanalysis



Courtesy: Francois Counillon

… but skill remains poor, and not better than other models

Correlation skill for ATL3 region, NorCPM anomaly coupled
and North American Multi-Model Ensemble
1985-2010, 4 starts per year (Feb. May, Aug. Nov.), 9 ensemble members

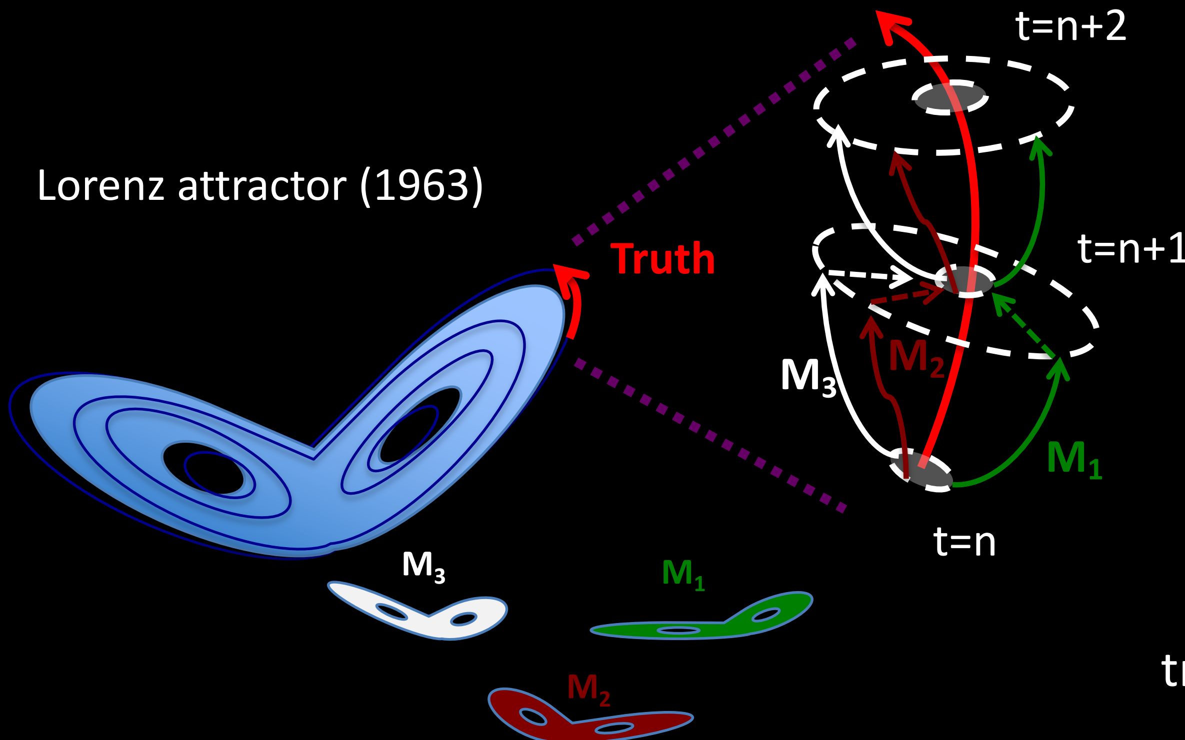


Courtesy: Francois Counillon

Supermodelling reduces the Pacific double Inter-tropical Convergence Zone bias

(Shen et al. 2016, 2017)

Synchronising complex systems to compensate systematic errors



$M^*_1 = M_1 + \vec{a}_{12} M_2 +$

$M^*_2 = \cdots\cdot$

$M^*_3 = \cdots\cdot$

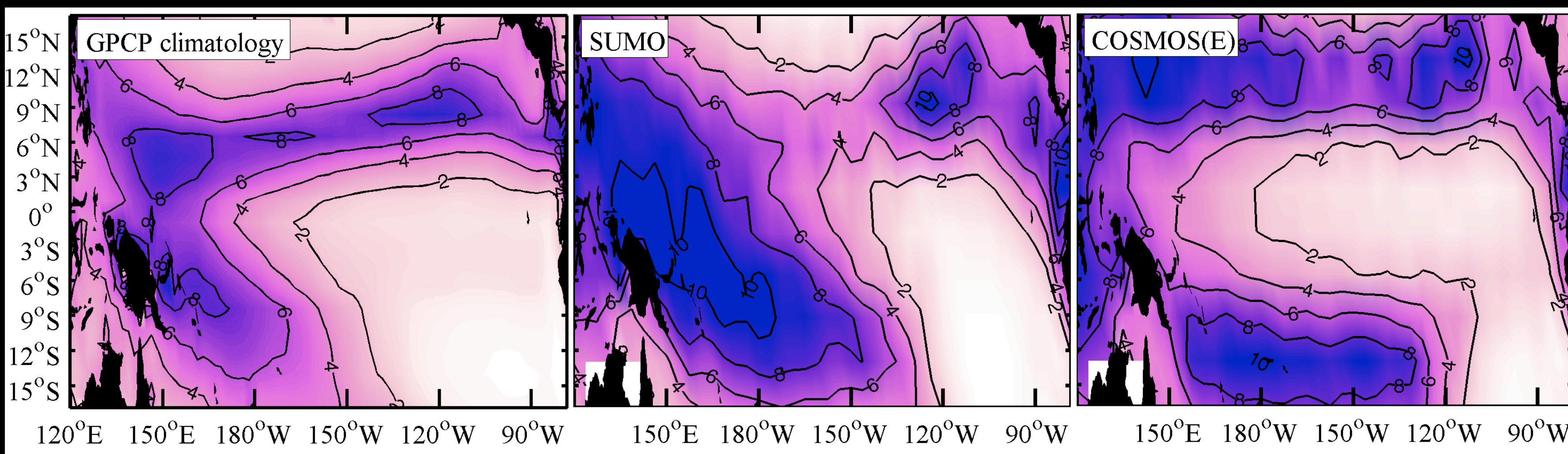
Constants a_{12} and a_{13} trained to reproduce truth

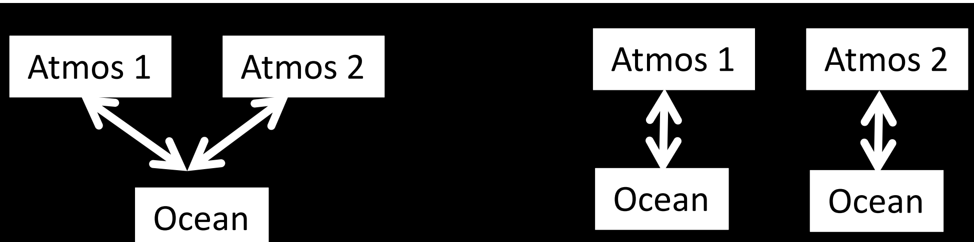
Approach successfully applied to simple models (e.g., Van den Berge et al. 2011) and to quasi-geostrophic models (e.g., Selten et al. 2017)

Super model versus standard approach

Results from simplified ECHAM5/MPIOM super model

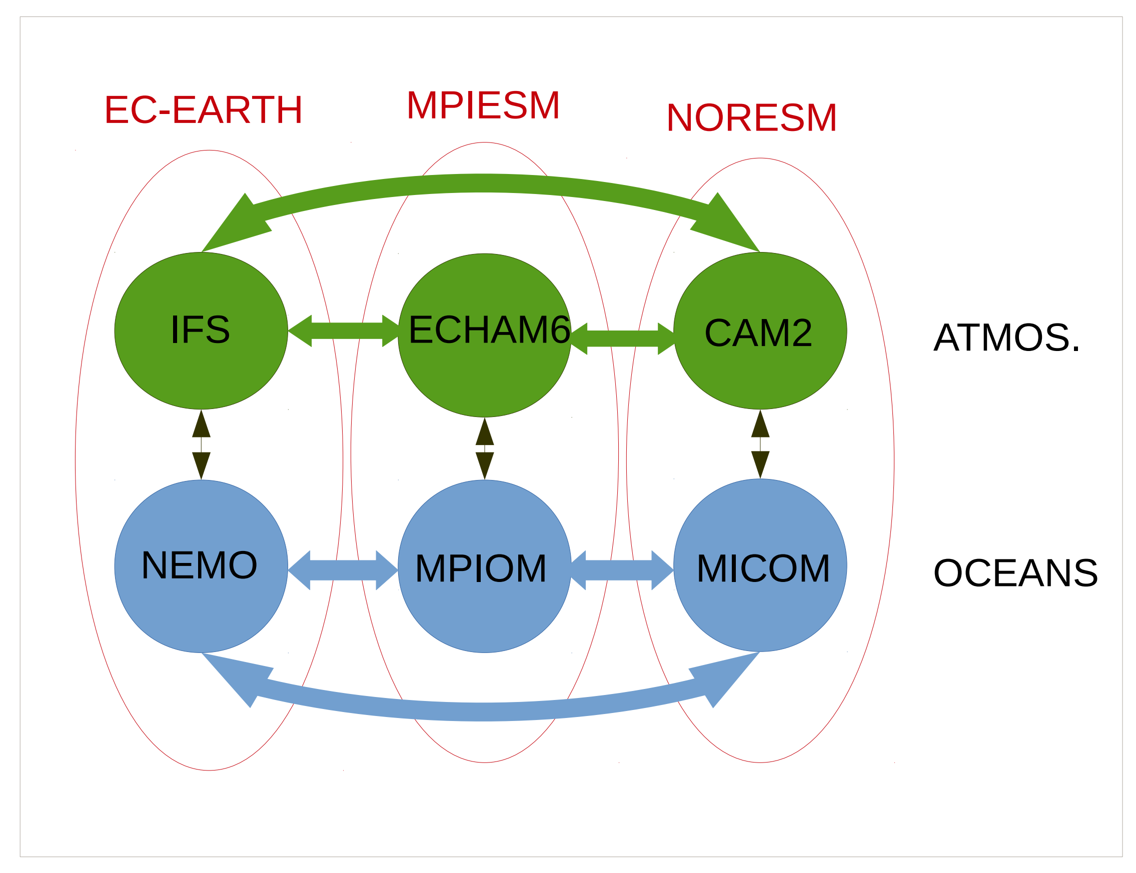
Climatological Precipitation in Tropical Pacific





(Shen et al. 2016, 2017)

Three synchronized Earth System Models

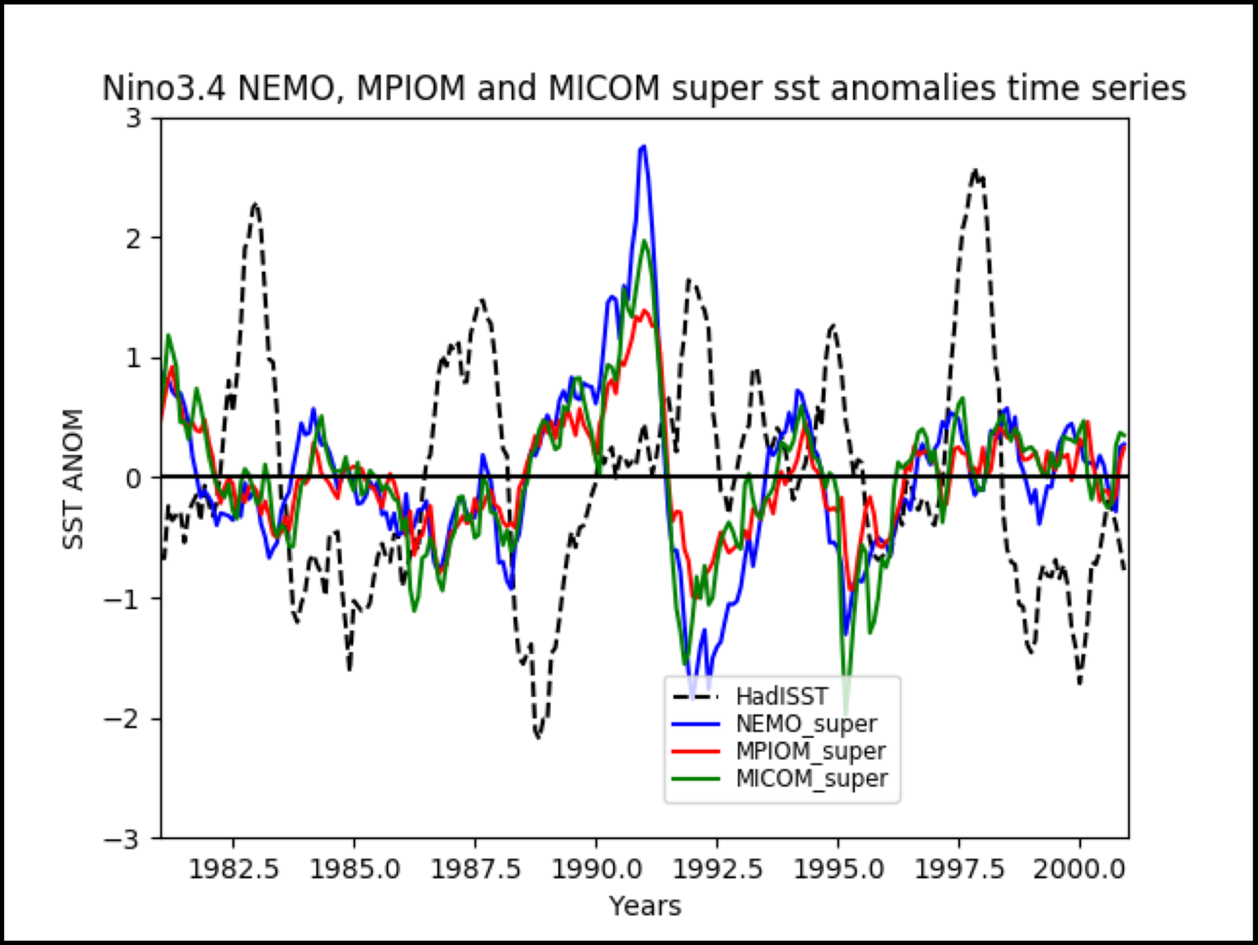


Current stage: Ocean models coupled by assimilating SST

$$SST_{SuperModel} = \frac{1}{3} SST_{EcEarth} + \frac{1}{3} SST_{MpiEsm} + \frac{1}{3} SST_{NorEsm}$$ Ocean connection

F. Counillon, M. Devilliers

Three synchronized Earth System Models



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Two alternative approaches

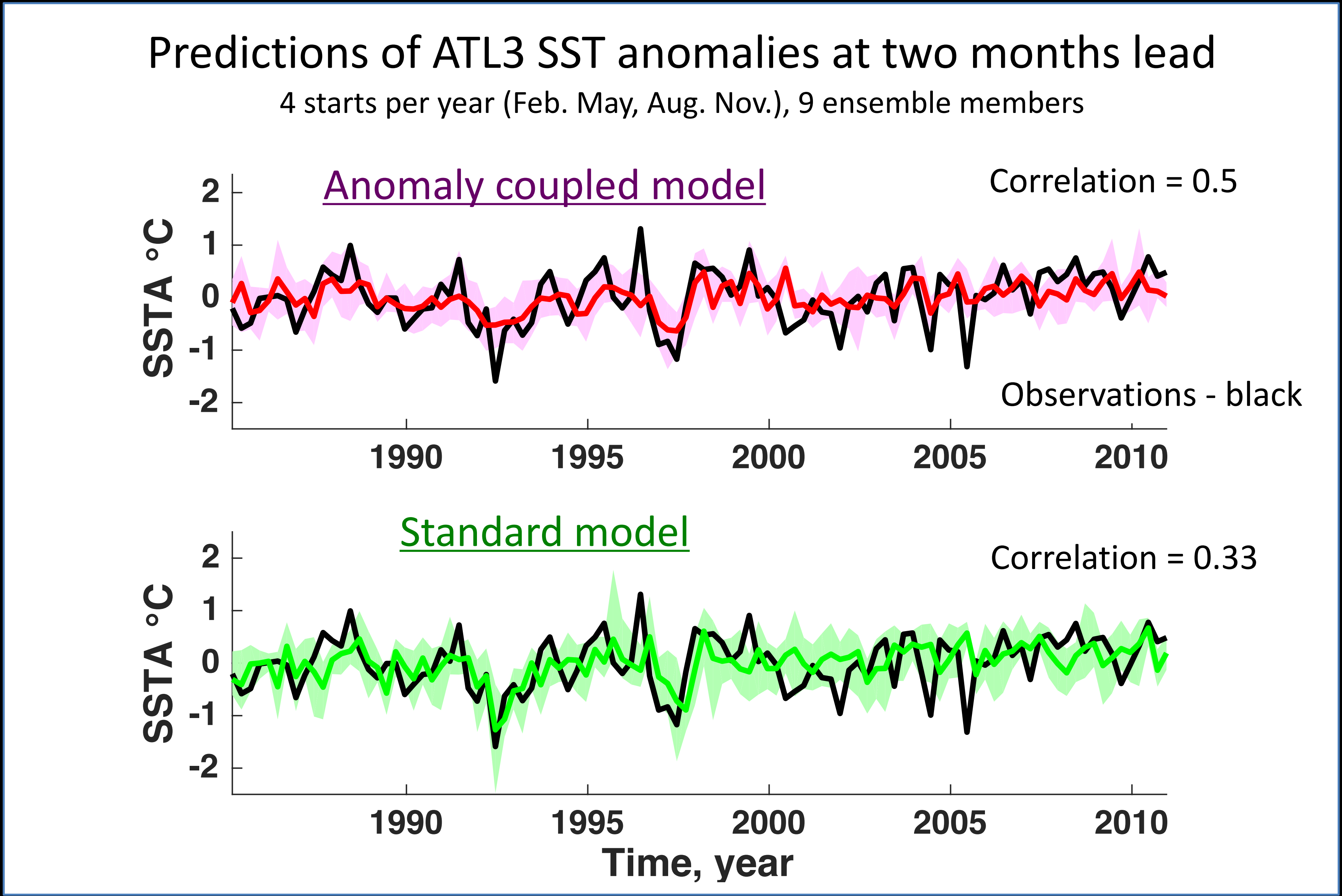
1. Anomaly coupling -> Improved seasonal prediction in the Tropical Atlantic
   - Improved simulation of ocean-atmosphere interaction
   - Better initial conditions

   (Counillon et al. to be submitted)

2. Supermodelling -> Reduces the Pacific double Inter-tropical Convergence Zone bias
   - Synchronized models can achieve greater bias reduction, because of non-linearity in the climate system
   - First steps towards 3D coupled Earth System Models

   (Shen et al. 2016, 2017)

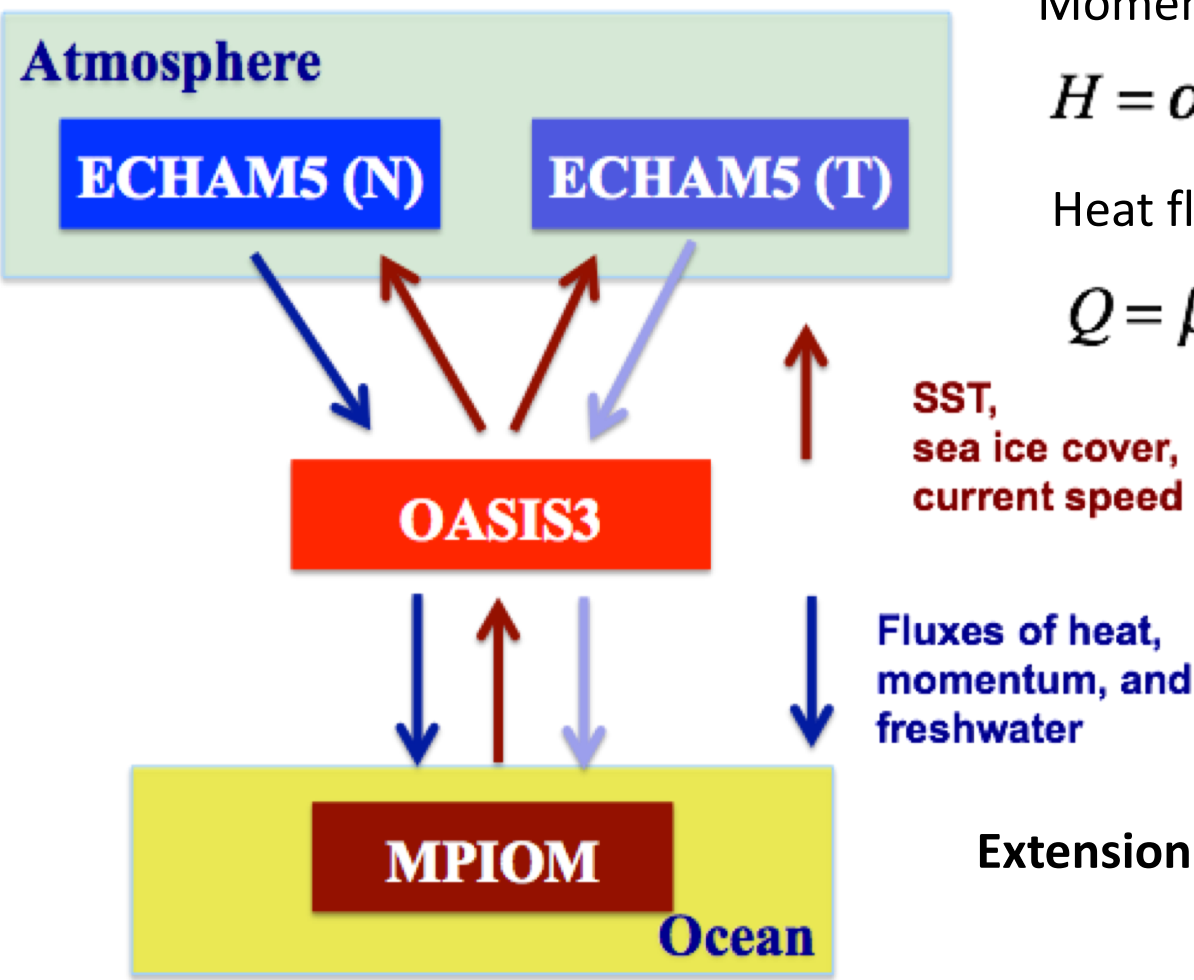
Reducing biases enhances Atlantic Niño prediction



Courtesy: Francois Counillon

Super model strategy – Interactive Ensemble

Coarse resolution model: T31L19 atmosphere, 3 degree ocean,
Differing in the atmospheric convection scheme



Momentum flux:

$$H = \alpha H_{Nordeng} + (1-\alpha) H_{Tiedtke}$$

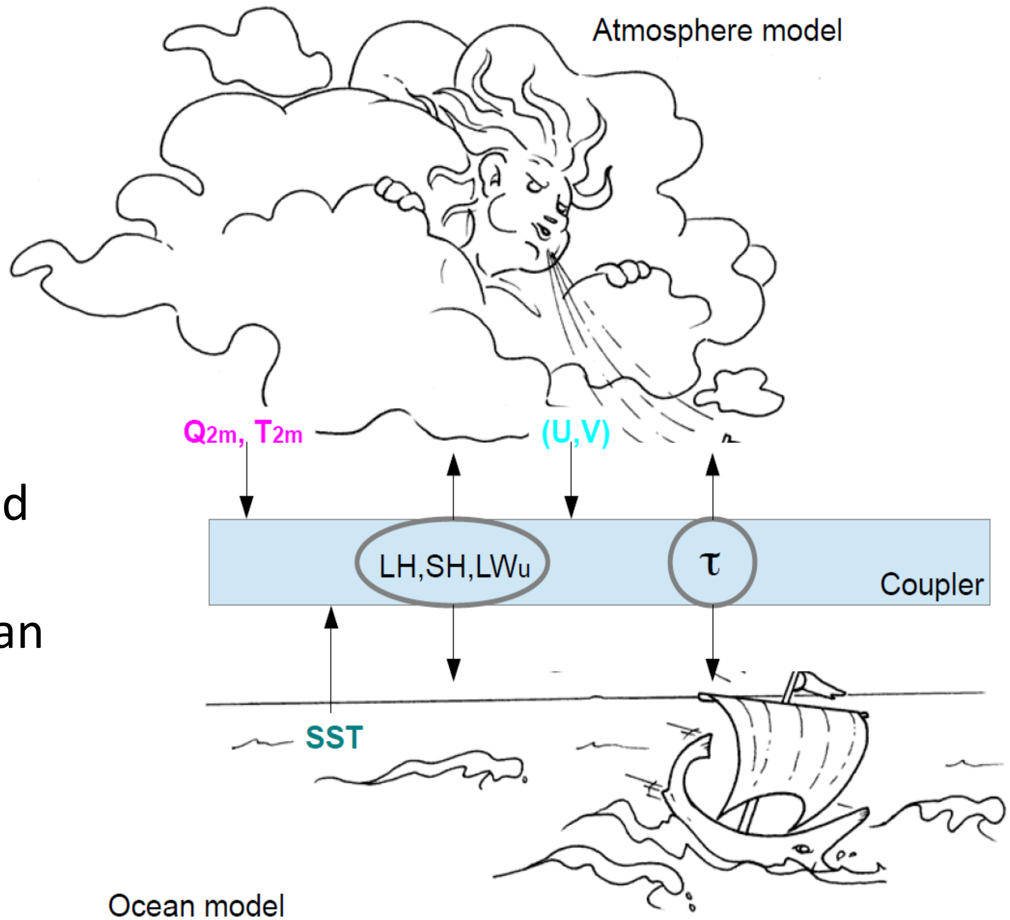
Heat flux:

$$Q = \beta Q_{Nordeng} + (1-\beta) Q_{Tiedtke}$$

Extension of Kirtman et al., 2003.

Standard coupled model

Quantities exchanged between atmosphere and ocean



Courtesy: Thomas Toniazzo