Ocean Spinup in CESM.
Current issues and discussion.

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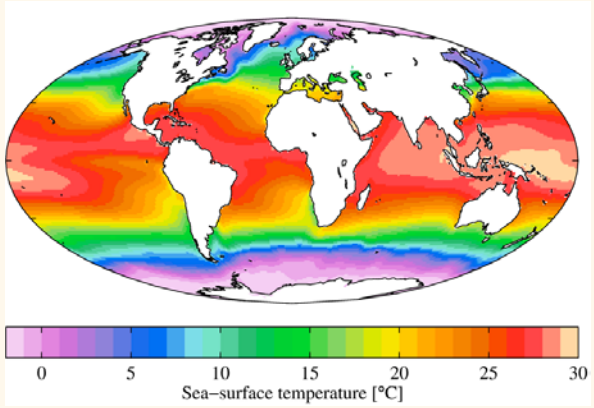
Outline

- **Methods to initialize CESM**
- **Spin up issues with the Spectral Element dynamical core**
- **What controls the SSTs ?**
- **Take home message and discussion**

Ways to initialize the ocean in CESM

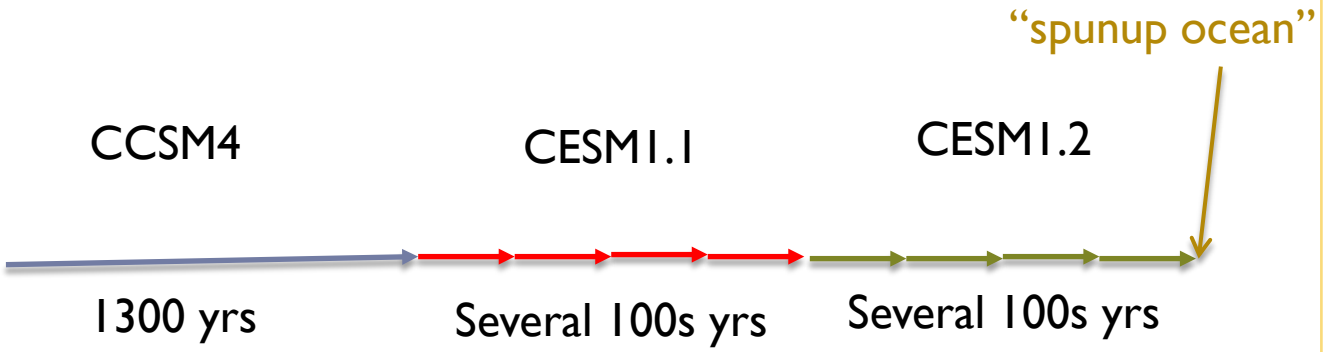
Levitus

Start from Levitus climatology based on observations

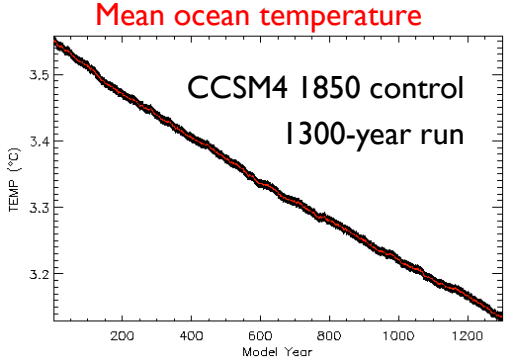


Long spunup ocean

Start from a long previous run (or succession of runs)



Pros and Cons of each initialization

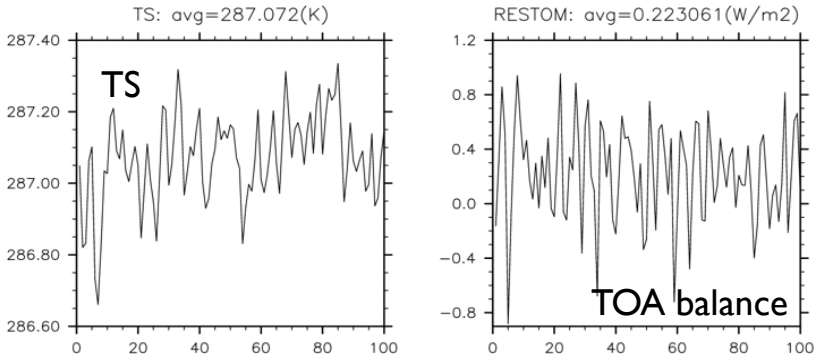
	Pros	Cons
Levitus	"Clean" way to initialize	Each run requires long spin-up. - At each experiment we will repeat this long spunup - More challenging to tune (*). Levitus is present day ocean. Is it best to initialize 1850 ?
Long spunup ocean	Fast to adjust Easier to tune	The model has drifted far away from reality. Mean ocean temperature  Difficult to reproduce.

* tune = adjust parameters ("tuning parameters") to achieve TOA radiative balance ~ 0 W/m^2

What happens in the first 100 years of the run?

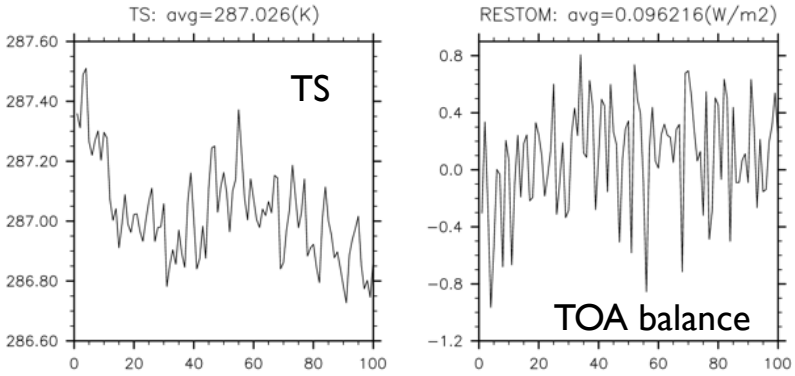
CESM1.1: Finite volume (FV)

Spunup ocean



When starting from spunup ocean, model quickly adjusts (20 years)

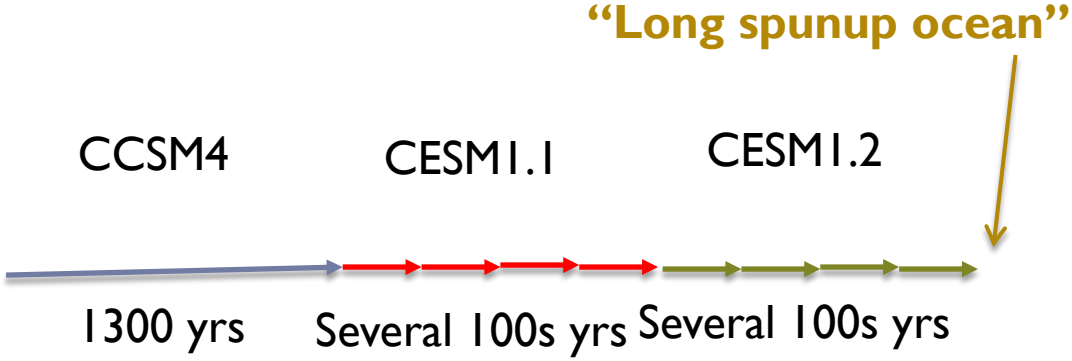
Levitus



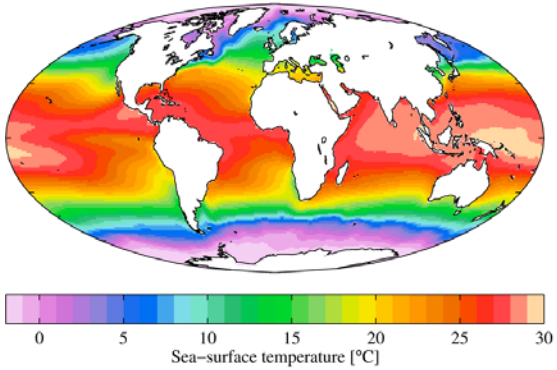
When starting from Levitus, model spinups longer (100 years).

Proposed strategy to tune the model

(1) Use "long spunup" initialization,
to obtain tuning parameters
to adjust TOA balance ~ 0 W/m2



(2) Use tuning parameters obtained in (1)
and restart the run from Levitus

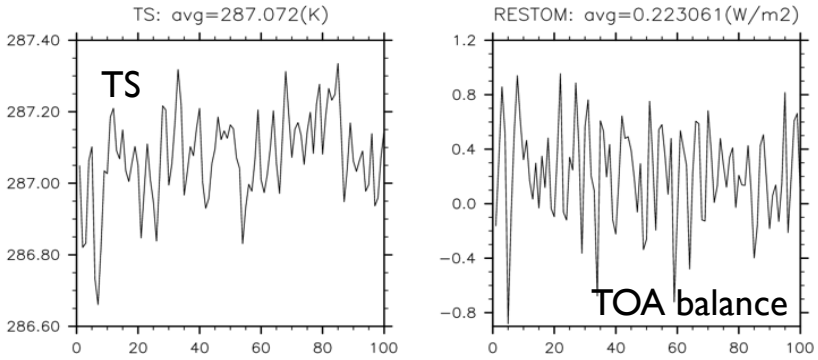


(3) Retune "along the way" if needed to maintain TOA balance ~ 0 W/m2

What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

Spunup ocean



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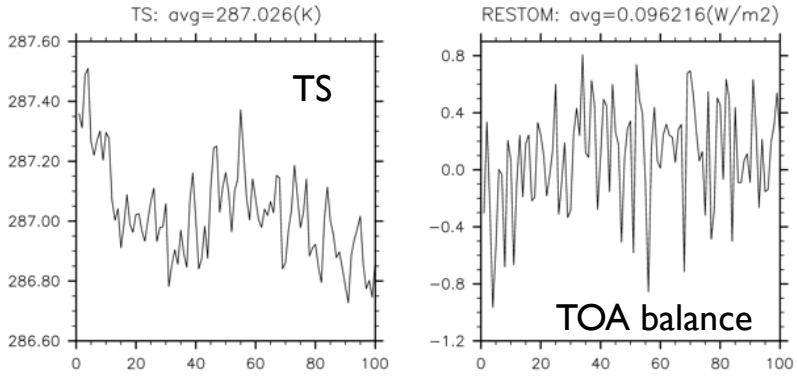


When starting from Levitus, model spinups longer (100 years).

Proposed strategy was quite successful in CESM1.1.

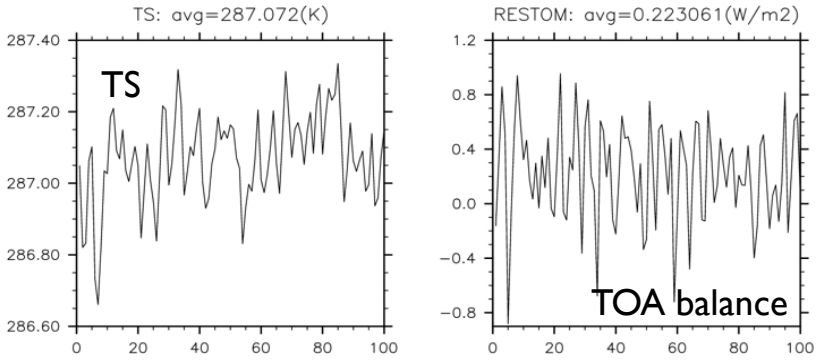
Used for "large-ensemble"

What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

CESM1.2: Spectral element (SE)

Spunup ocean



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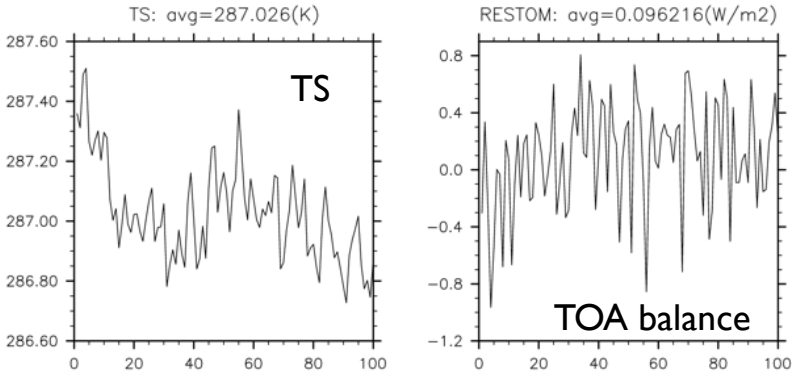


When starting from Levitus, model spinups longer (100 years).

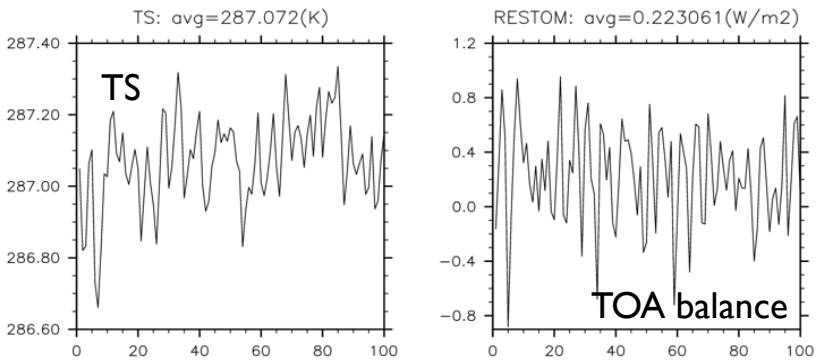
Then comes CESM1.2 and its new dynamical core

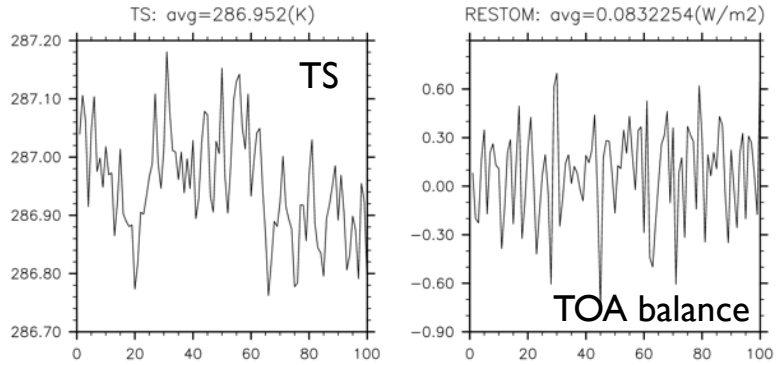
What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

CESM1.2: Spectral element (SE)

Spunup ocean





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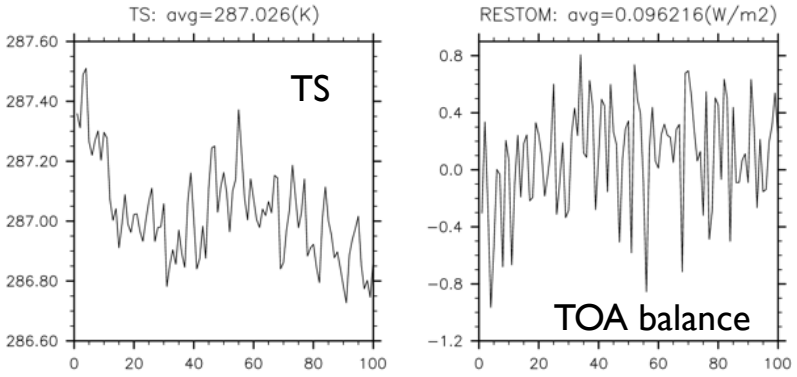
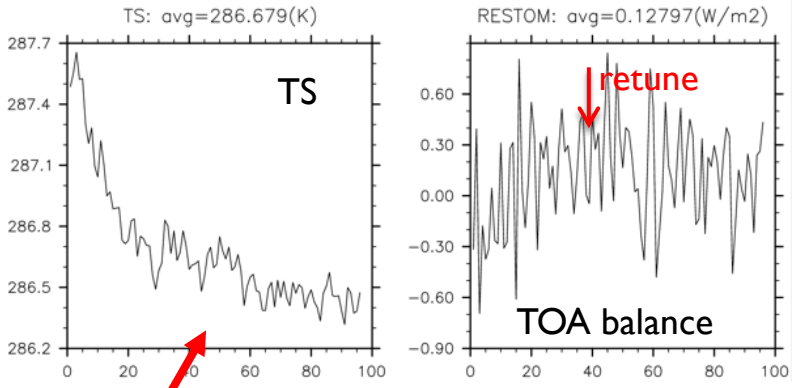




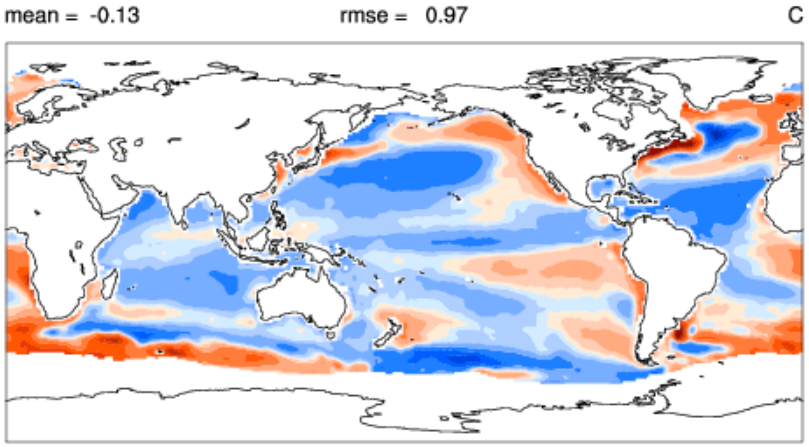
When starting from Levitus, model spinups longer (100 years).

"Houston, we have problem"

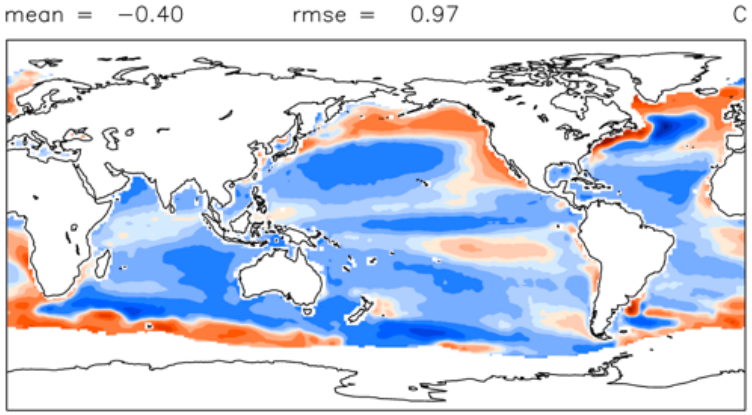
SST biases

Compared to HadISST/OI.v2 (pre-industrial)

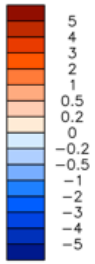
Finite Volume: Spunup ocean



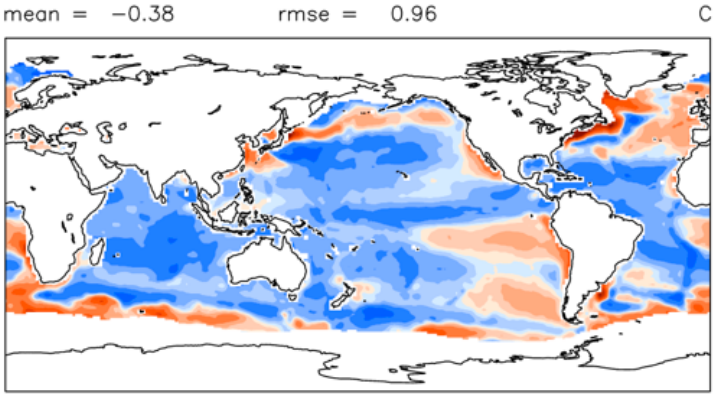
Spectral Element: Spunup ocean



Similar bias that FV except SE Pacific.



Finite Volume: Levitus



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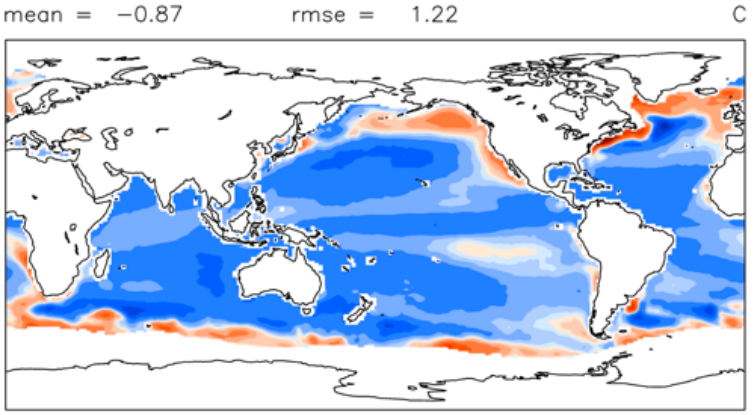
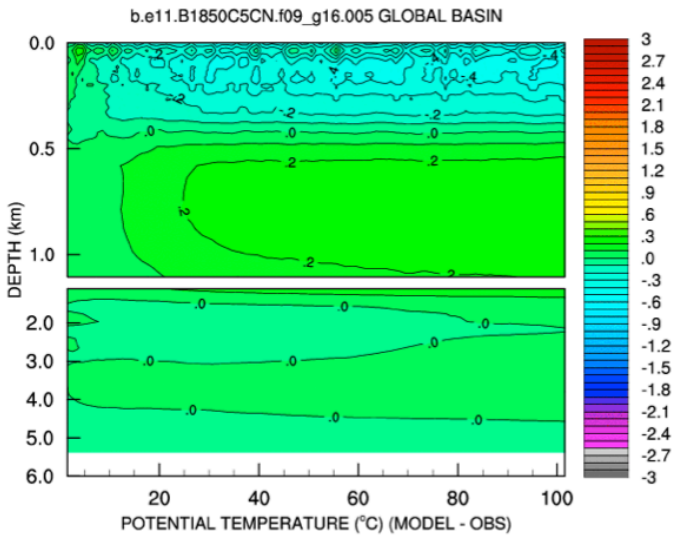


SSTs stabilize but too cold compared to obs
SST: 0.5K colder than FV

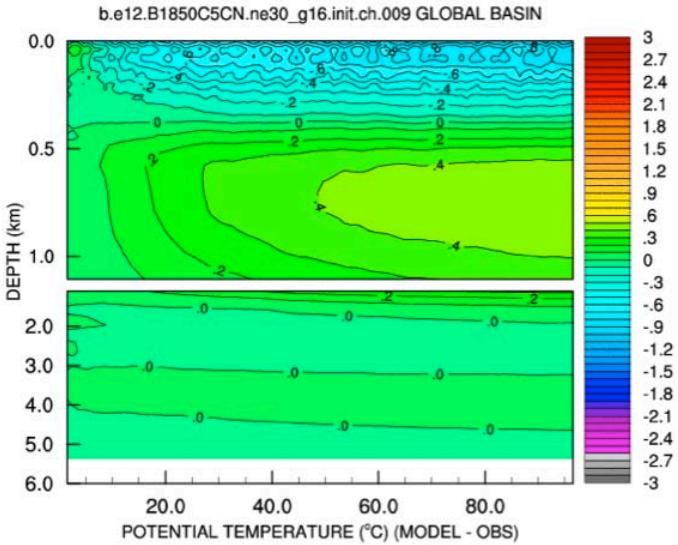
Ocean temperature bias

T bias = Tocn - Levitus

Finite Volume: Levitus



Spectral Element : Levitus

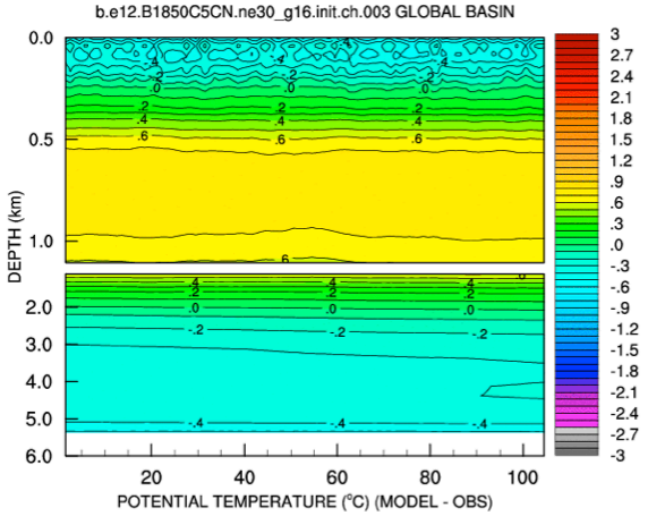


When starting from Levitus:
- cools near the surface
- warms around 750 meter
- exacerbated in SE

When starting from long spunup ocean:
- the 750-meter warm layer is present at initialization

750-meter warm layer is a signature of Spectral Element (present in every run)

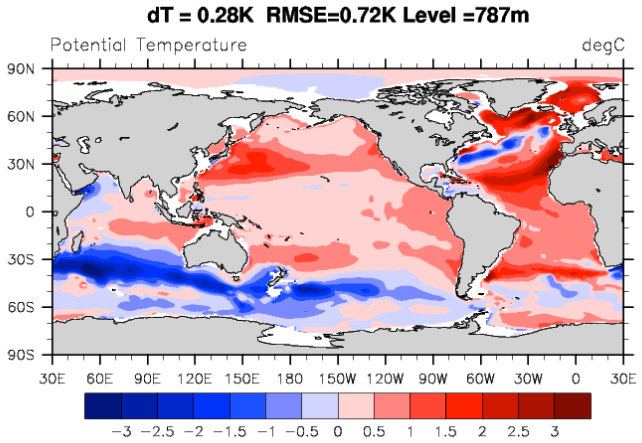
Spectral Element: Spunup ocean



Is 750-meter warming uniform over ocean ?

Bias at 750m = T 750-m - Levitus

Finite Volume (yrs 70-89)



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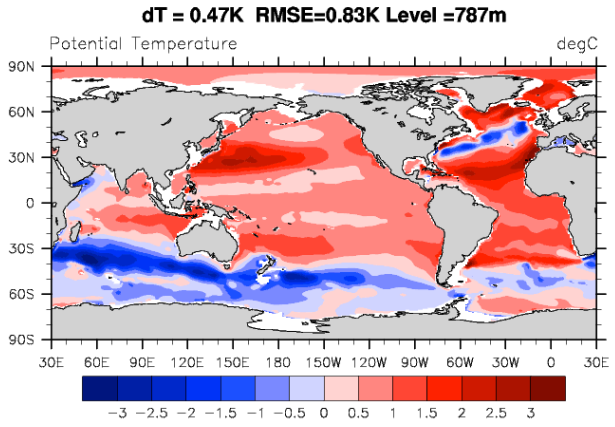


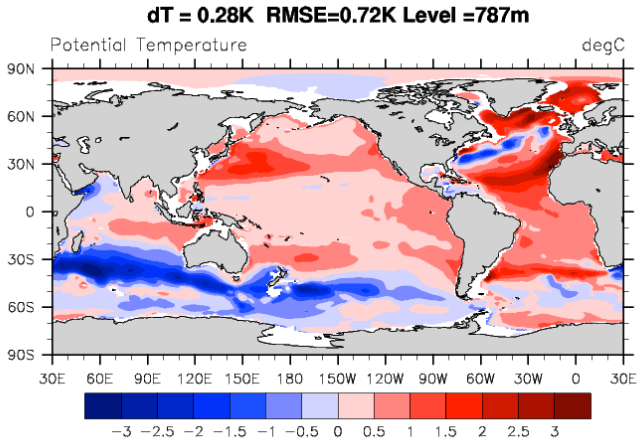
Warming is not uniform: areas of warming and cooling

Warming also exists in Finite Volume but cooling compensates warming globally.

Is 750-m warming correlated to SSTs cooling?

Bias at 750m = T 750-m - Levitus

Finite Volume (yrs 70-89)



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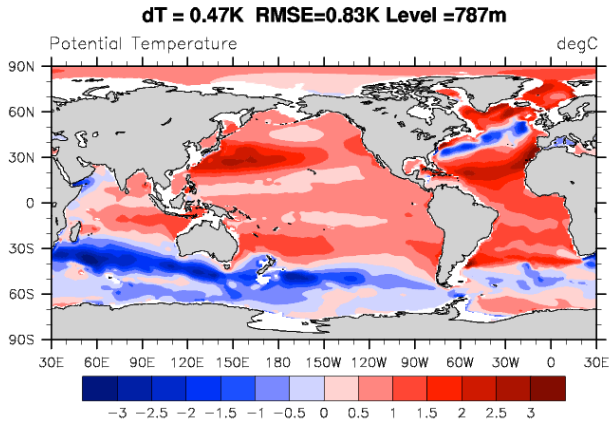
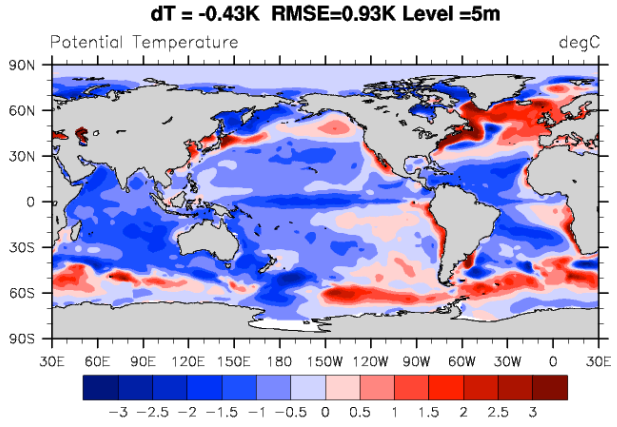


SST bias = SST - Levitus

Finite Volume (yrs 70-89)



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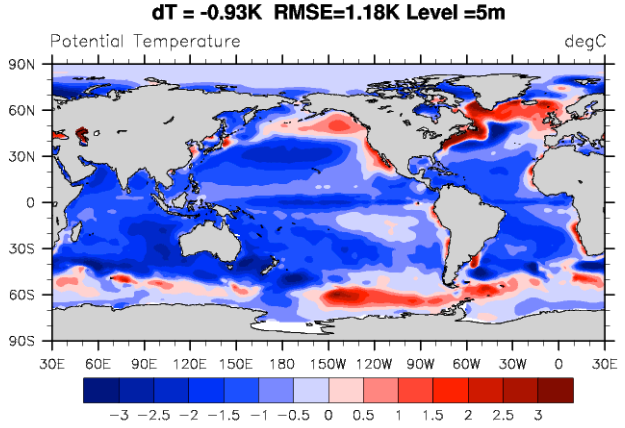
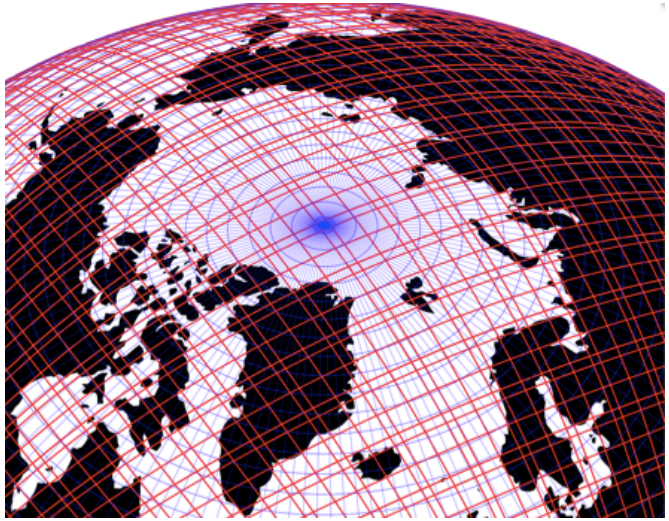


What is different (Finite Volume⇔Spectral Element) ?

Tuning parameters

	FV	SE
rhminl	0.8925	0.884
rpen	10	5
dust_emis	0.35	0.55

Grid differences at high latitudes



Red: CAM-SE grid
Blue: CAM-FV grid
(at about 2 degree)

Courtesy:
Peter Lauritzen

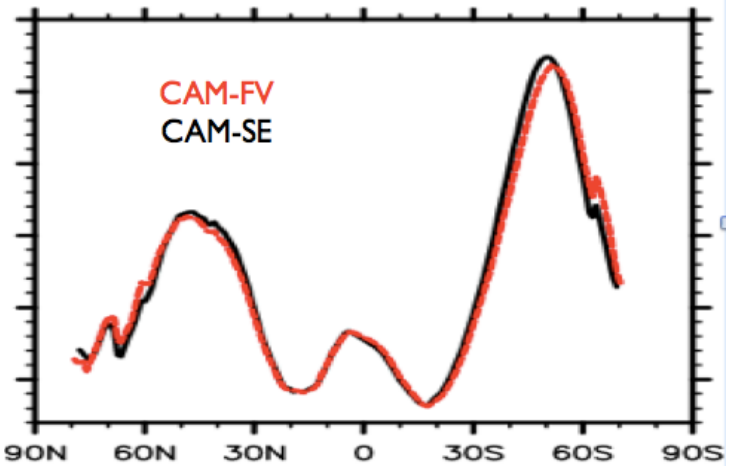
What's the impact on physics and remapping?

Topography

New software to generate topography (accommodate unstructured grids and enforce more physical consistency)

Climate

SST colder in SE than FV
Atmosphere is drier in SE that FV
Surface stress in Southern Ocean

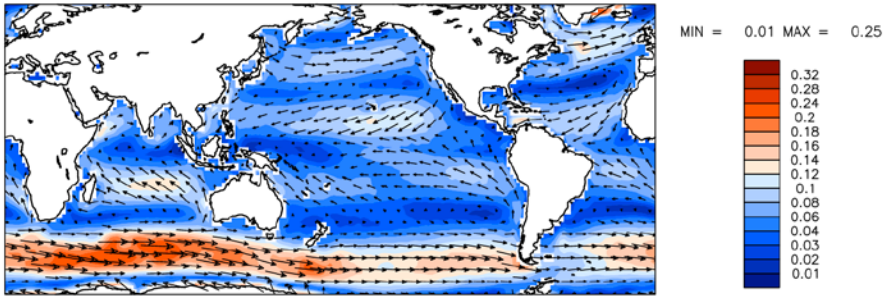


TAUX in CAM-SE:
- Location: maximum moves north
- Amplitude increases

Surface stress

Observed surface stress

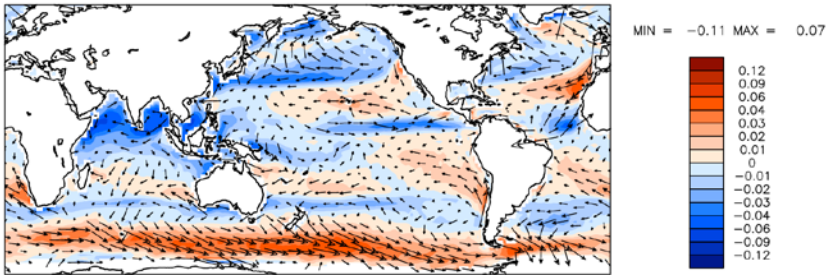
Large-Yeager (2009)



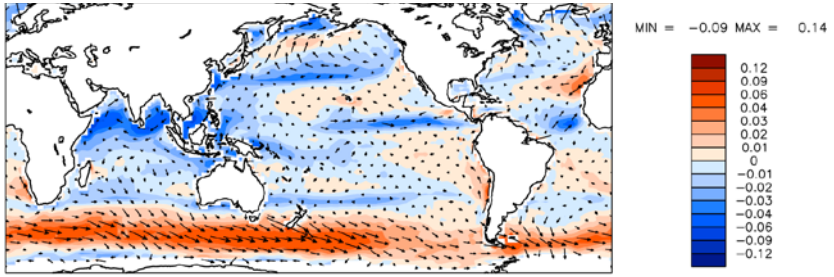
Significant differences in surface stress
- **Southern oceans**
- **Close to Greenland**

Surface stress errors

CAM-FV - Obs

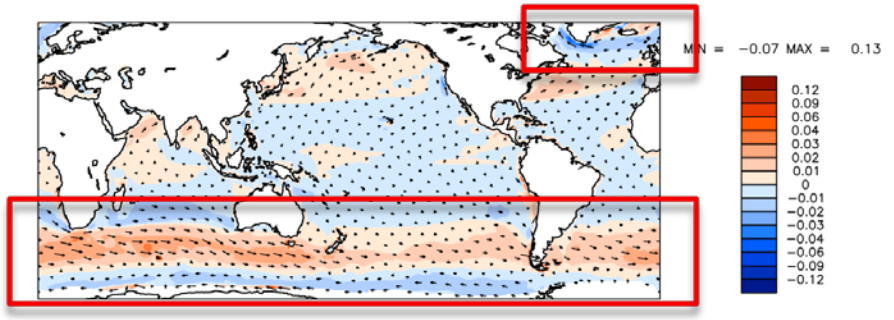


CAM-SE - Obs



Surface stress differences

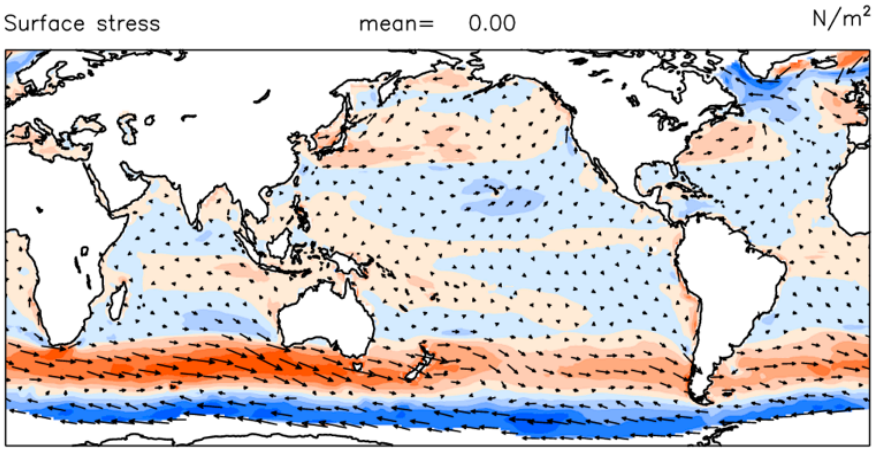
CAM-SE – CAM-FV



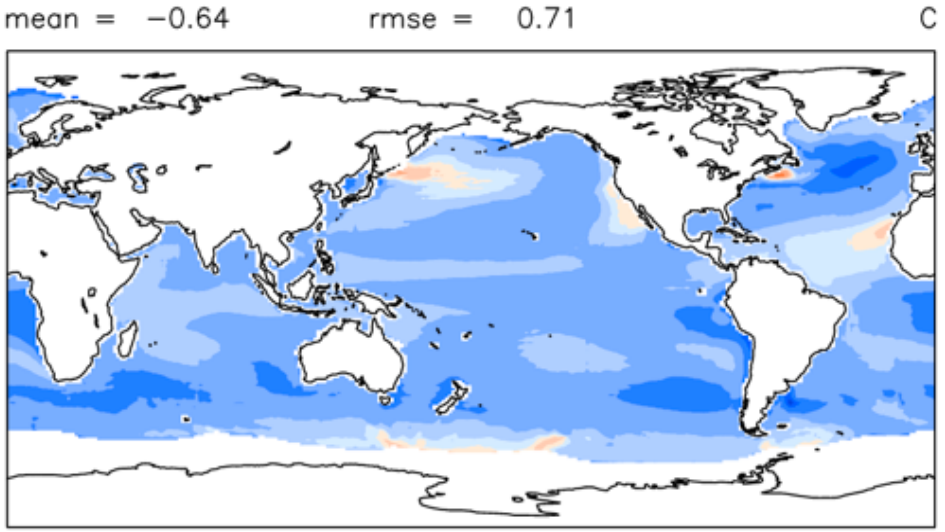
Surface stress and SSTs

Difference between CAM-SE and CAM-FV

Surface stress: SE-FV



SSTs: SE-FV

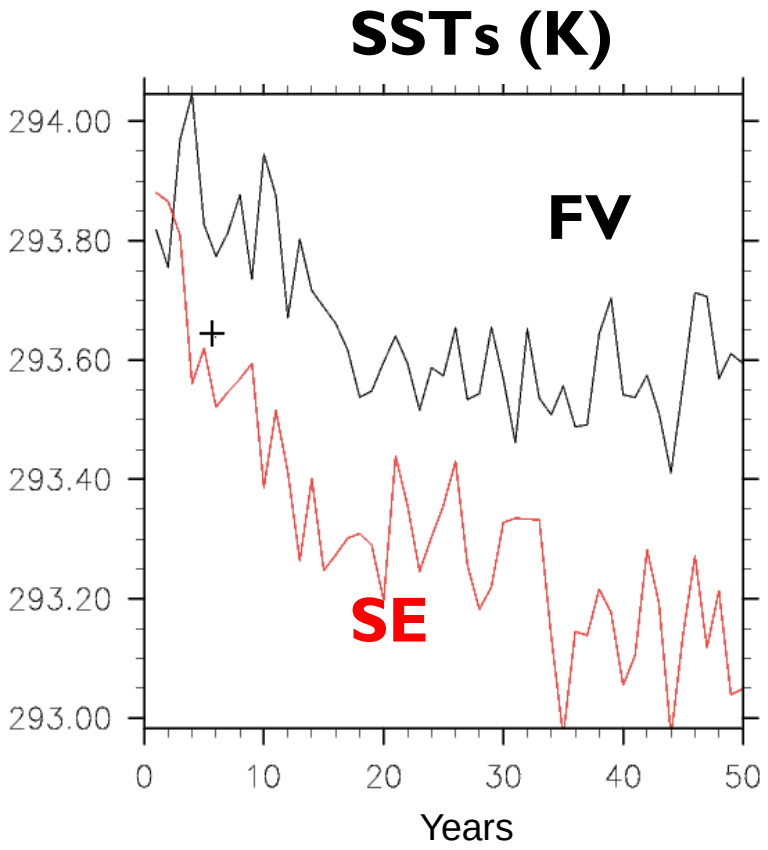


Correlation between SST and surface stress differences

What controls SST cooling in SE ?

Inventory of differences (SE ⇔ FV)

- Tuning parameters
  - Dust emission factor
  - Cloud tuning (rhminl, rpen)
- Topography
- Remapping (ocn ⇔ atm)
- Surface stresses



Can we identify differences responsible of the SSTs cooling in SE ?

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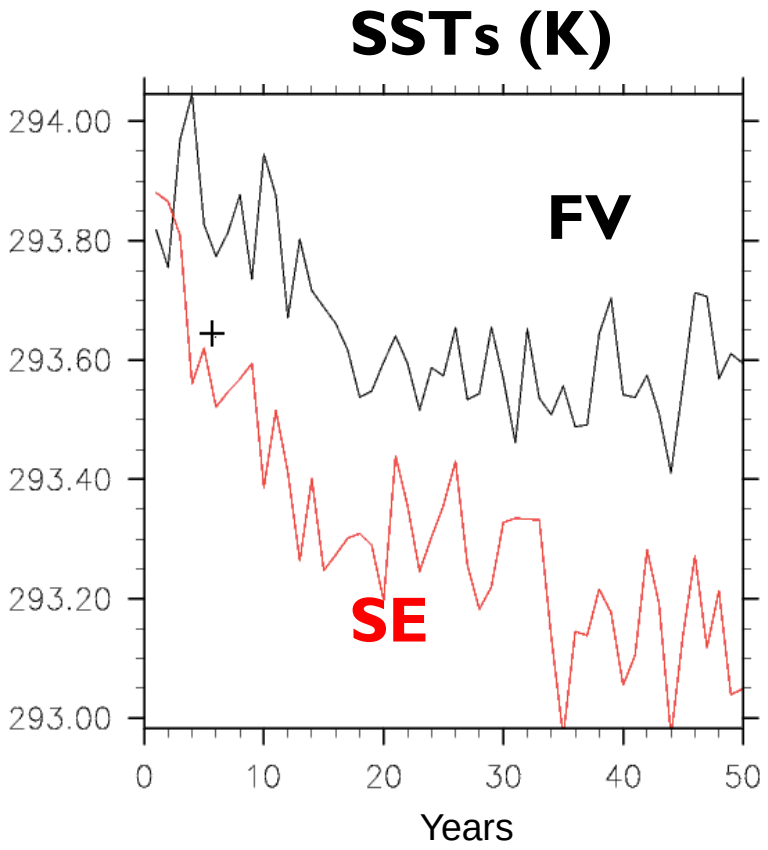
  - Turn off turbulent mountain stress
  - Increase turbulent mountain stress
  - Change gravity wave



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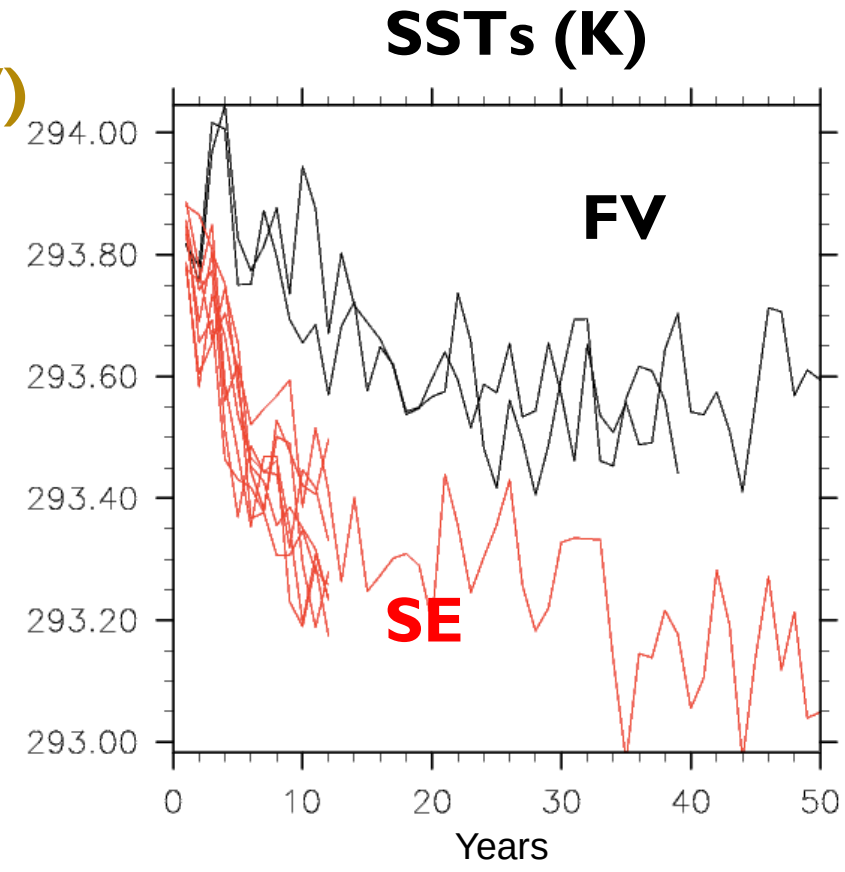

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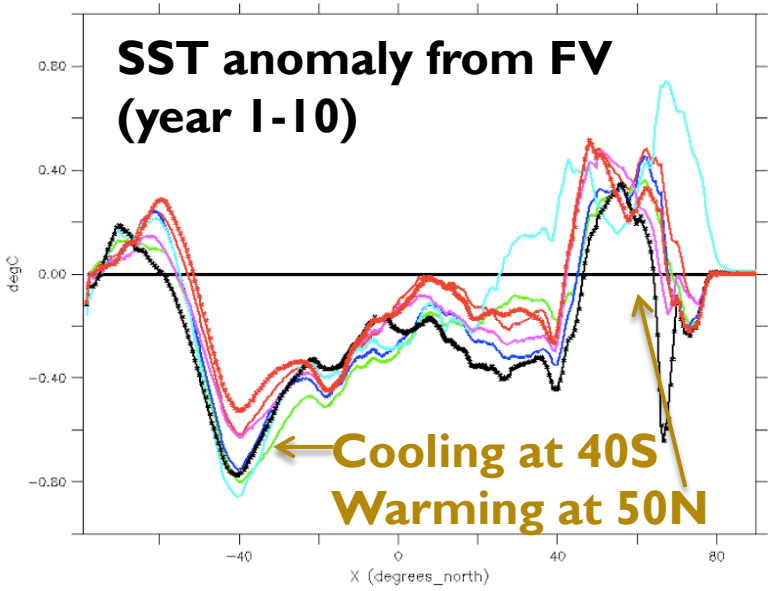
Mechanism responsible of SST cooling in SE



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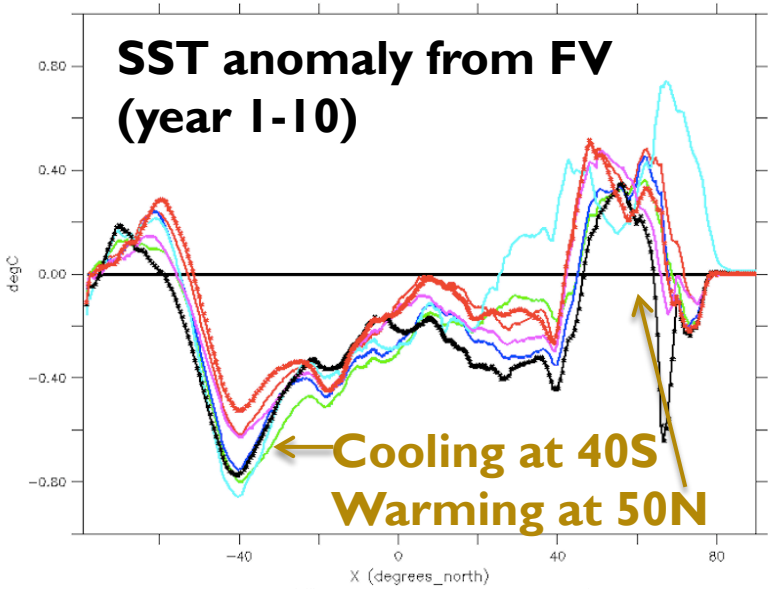

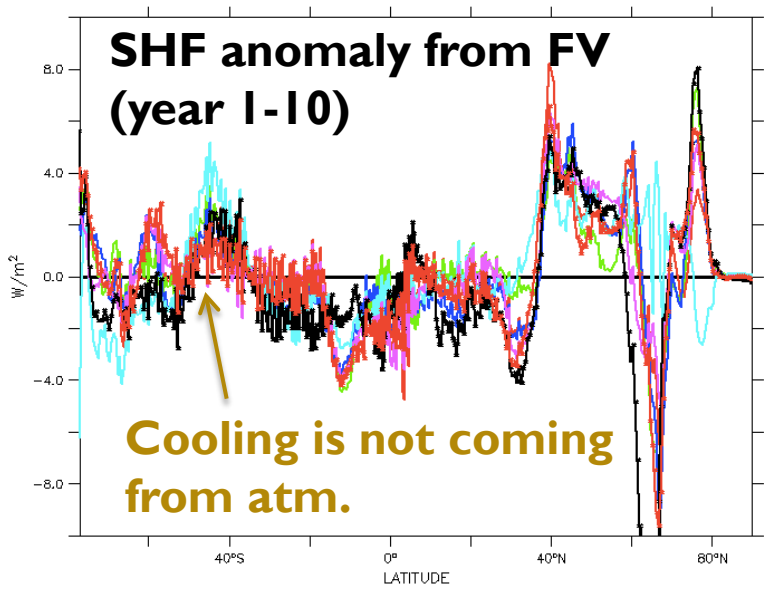

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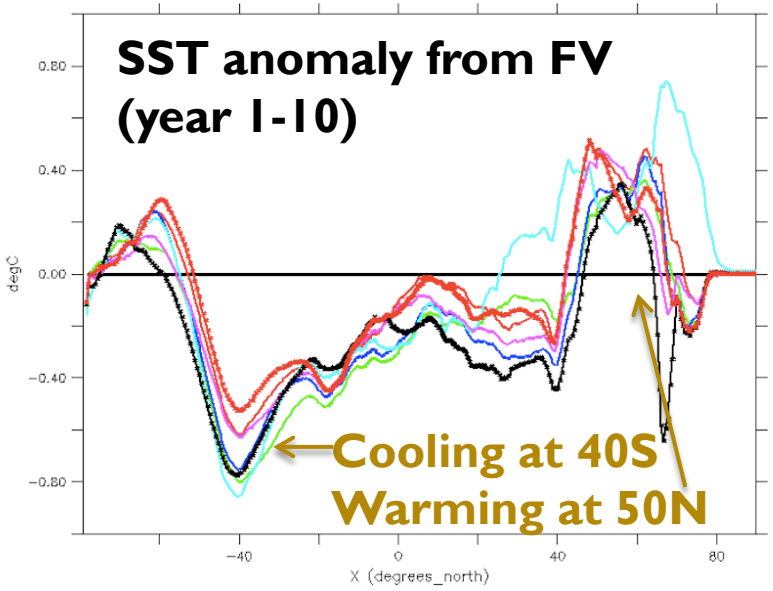

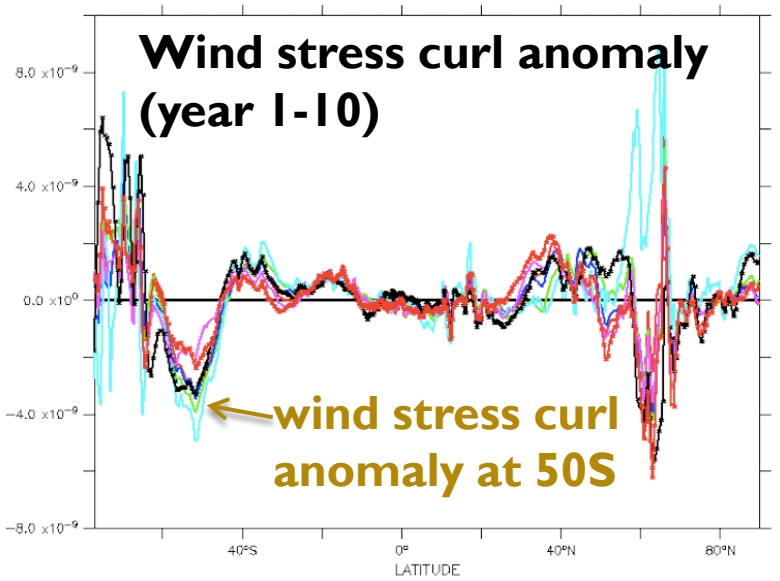

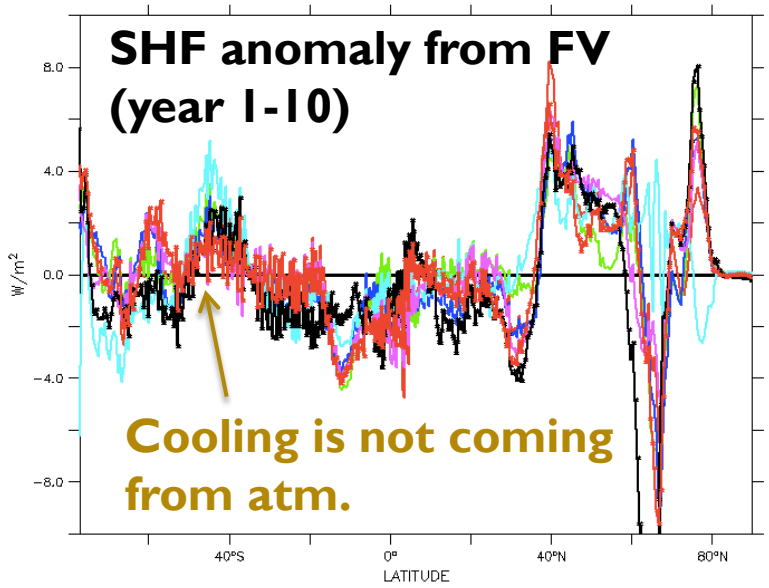

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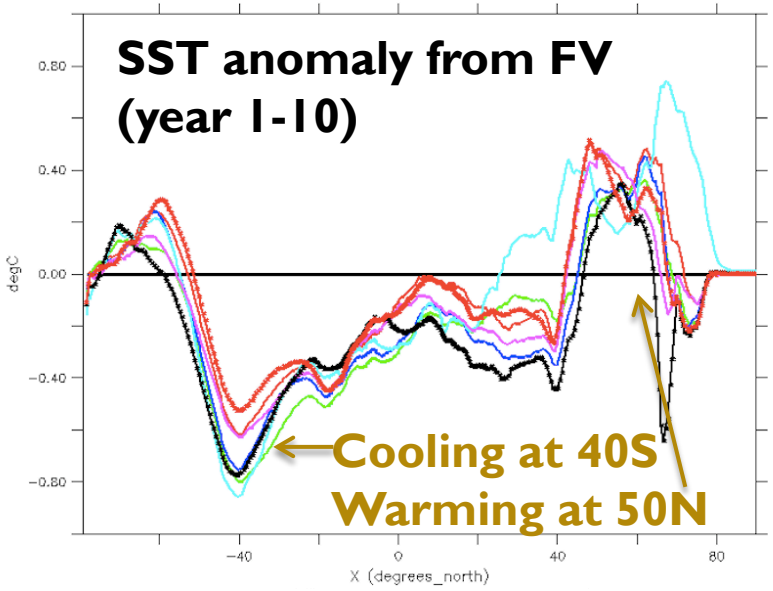
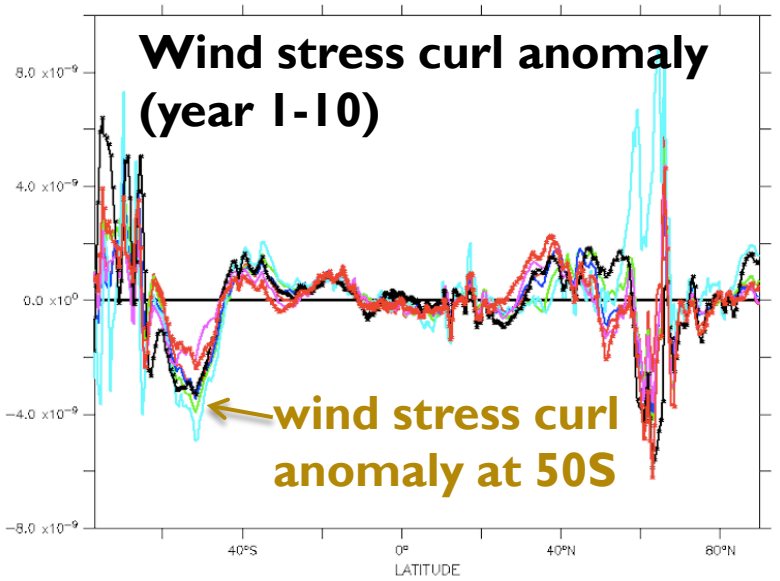
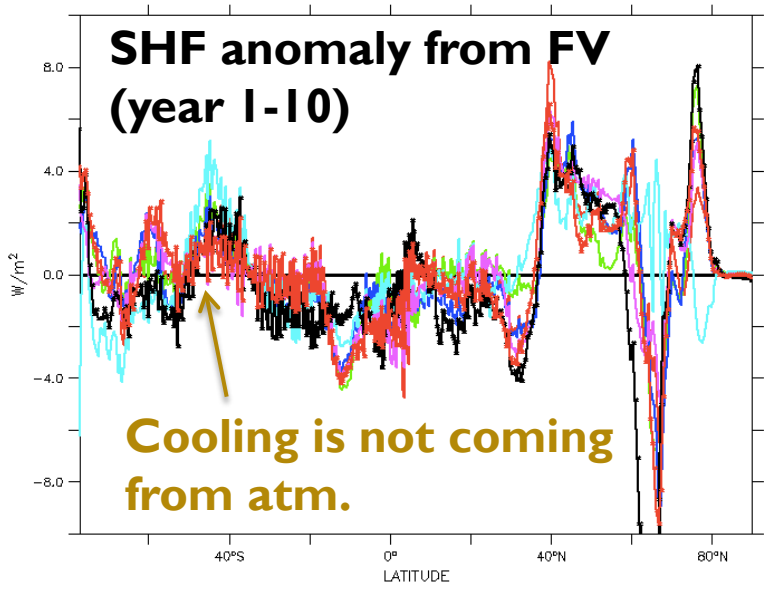
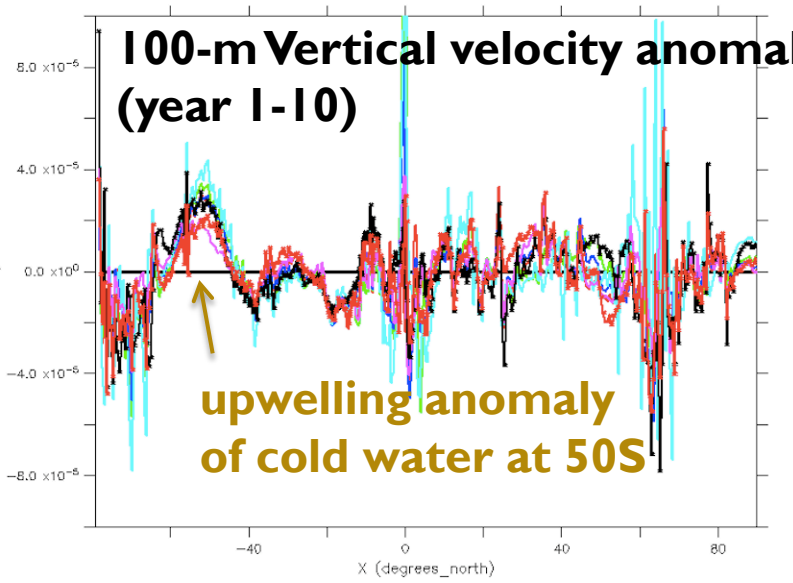








Take home message

Spinup issue with the Spectral Element dycore

When starting from Levitus

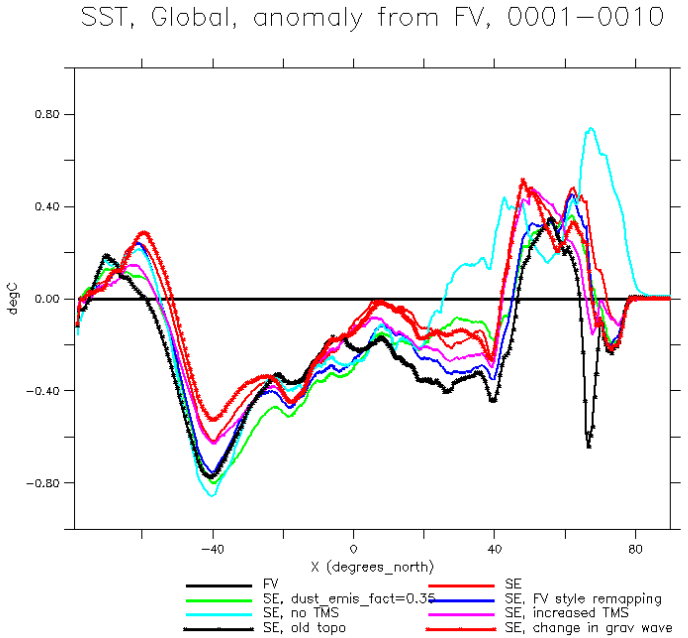
- **SSTs are cooling too much**
- **Formation of 750m warm layer**

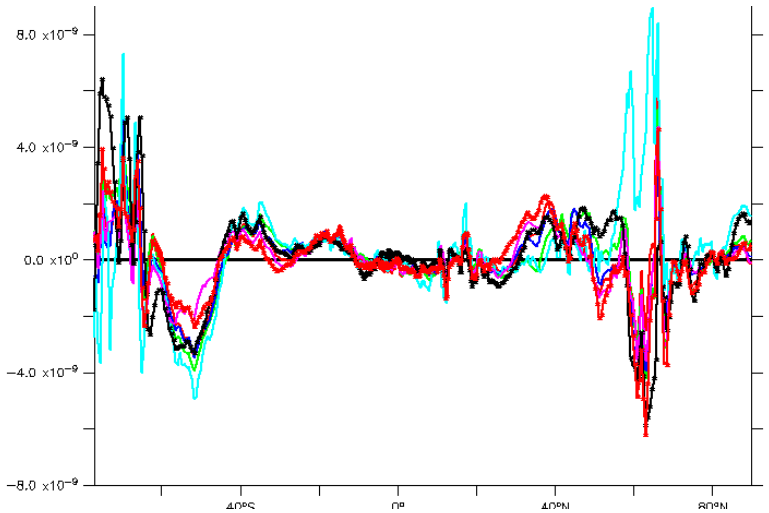
Wind stress curl anomaly (from FV) responsible of upwelling anomaly at 50S. This leads to SSTs cooling anomaly in Southern ocean.

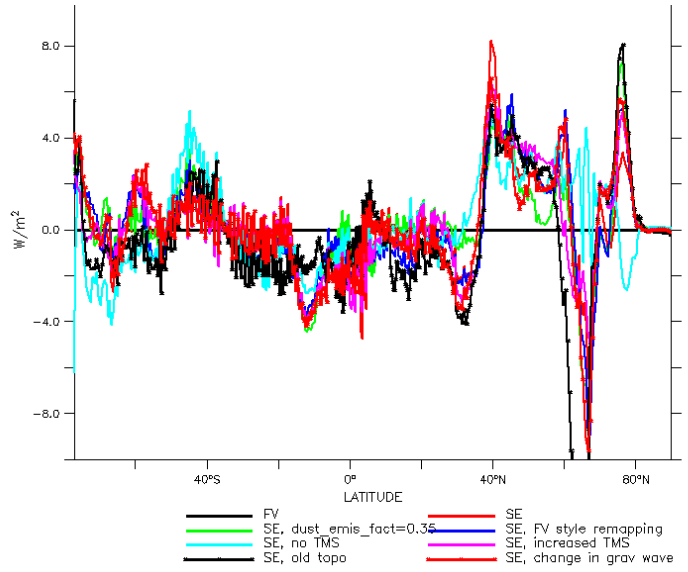
Next step: compare with CORE

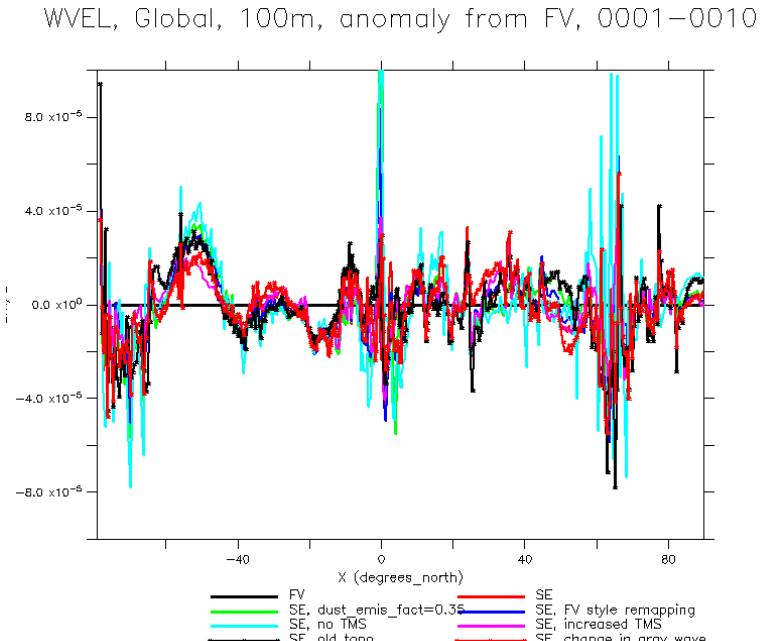
- **Extra slides**

Mechanism responsible of SST cooling in SE



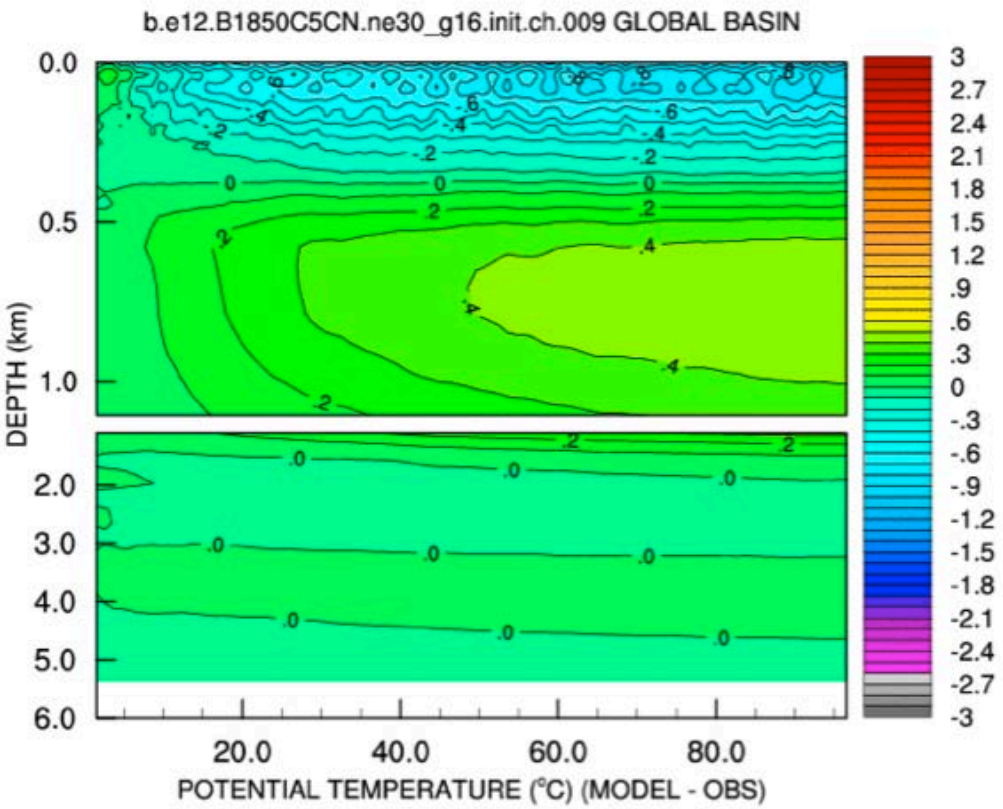




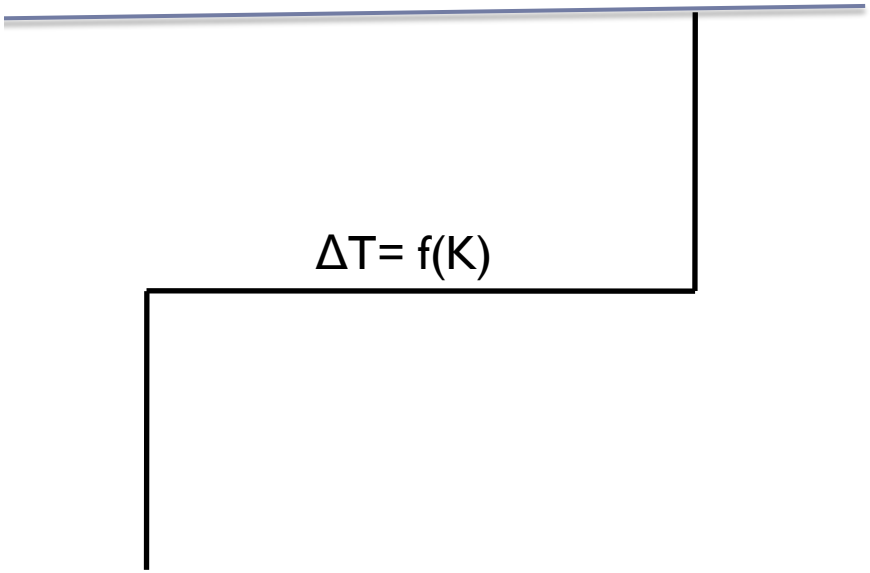


Can we adjust ocean vertical mixing ?

Ocean Temperature Bias

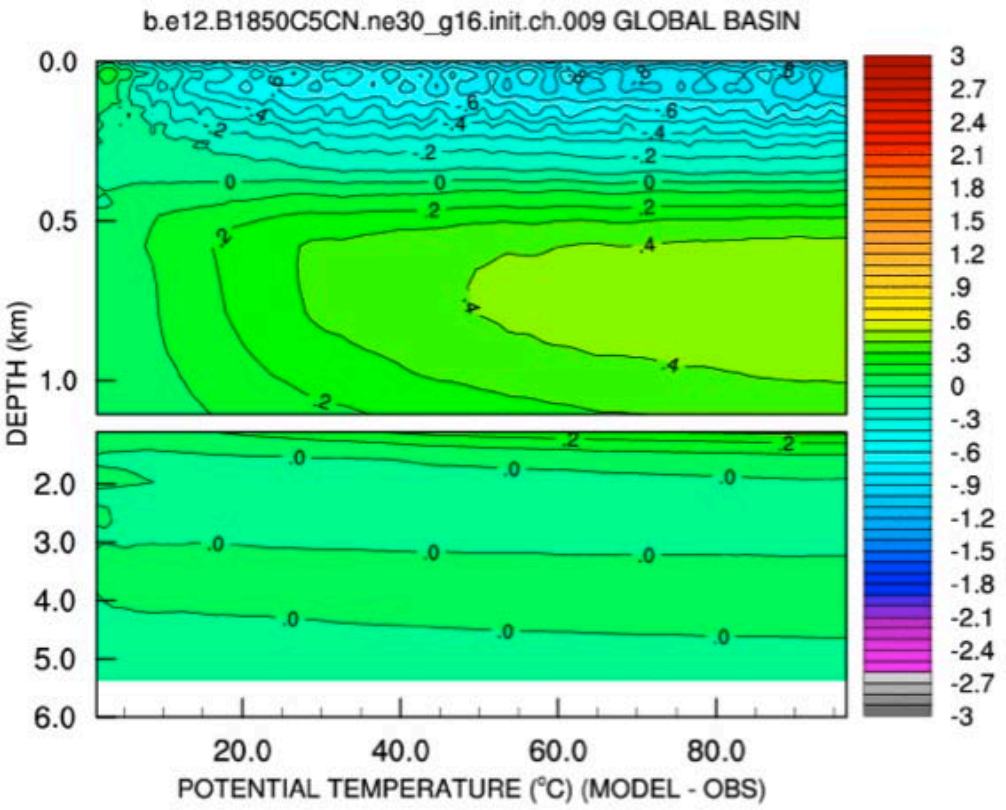


Temperature profile in the ocean



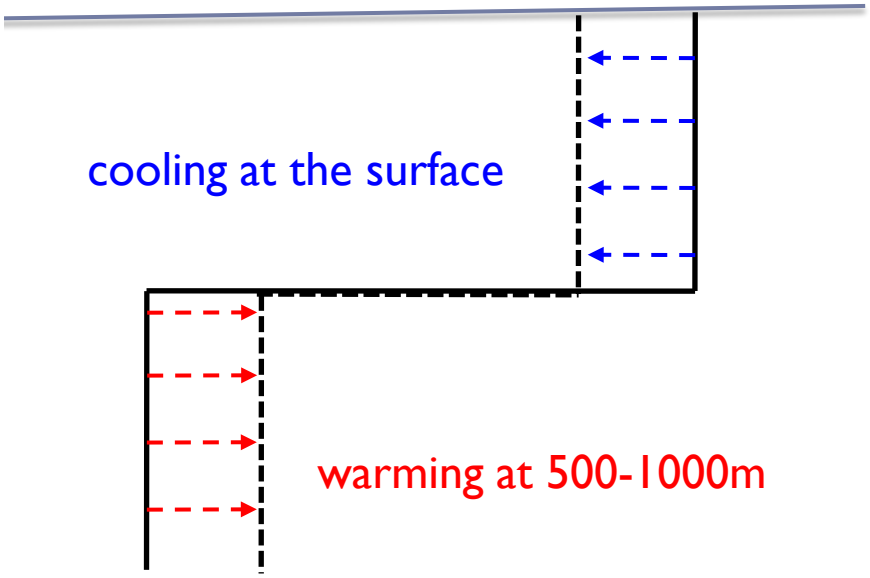
Can we adjust ocean vertical mixing ?

Ocean Temperature Bias



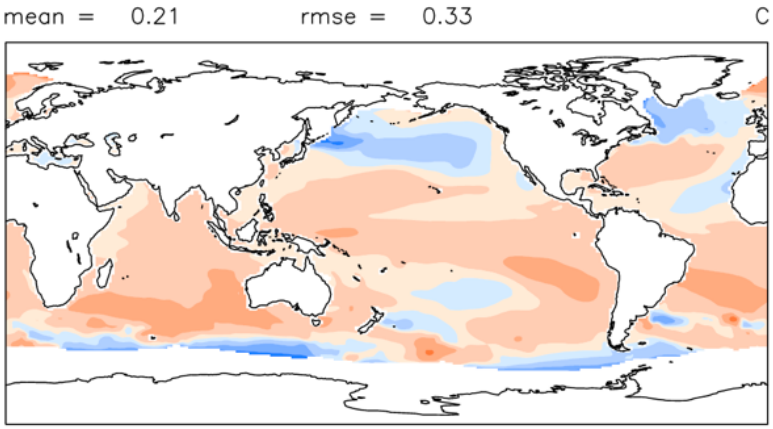
Temperature profile in the ocean

If there is too much mixing

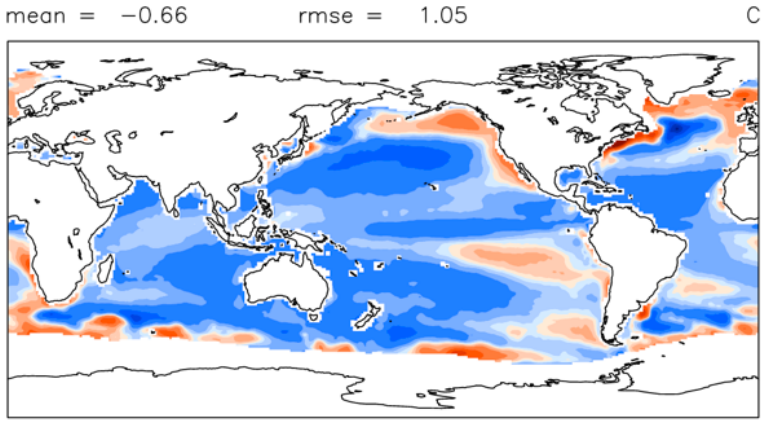


Wind stress seen by the ocean is reduced by 30% south of 35S.

Change in SSTs when wind stress reduced



SST bias: model - HadISST/OI.v2



Changing the maximum amplitude reduces the SST cooling but the SSTs are still much colder than in FV