Coupled Simulations with CAM5.3.

Ocean Spinup in CESM: Is it dycore dependent ?

Cécile Hannay, Rich Neale and Joe Tribbia
Atmospheric Modeling and Predictability (CGD/NCAR)

Keith Lindsay and Gokhan Danabasoglu
Oceanography Section (CGD/NCAR)

Thanks to gazillions of people including: Mariana Vertenstein, Julio Bacmeister, Patrick Callaghan, Andy Mai, and many others…

Background/Flashback

This is where we were at Breckenridge (June 2013):

Summary from Breckenridge

CAM5.3 was released in June 2013 (as the atm. component of CESM1.2.0)

Finite Volume (CAM-FV) and Spectral Element (CAM-SE) dycores

In standalone mode: CAM-SE is definitely ready

AMIP run: CAM-SE is competitive with CAM-FV (better Taylor score)

CAM-SE is not scientifically validated yet in coupled mode.

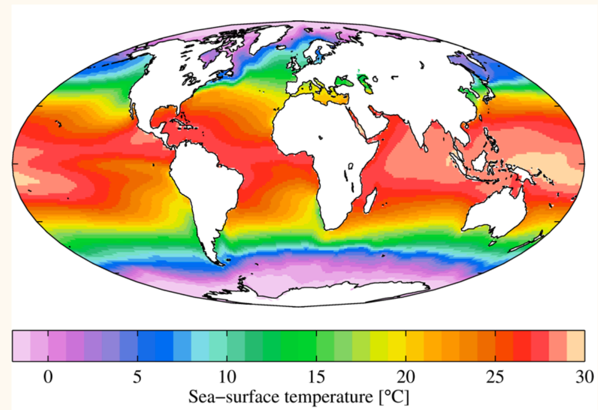
Ocean spin-up issues with CAM-SE

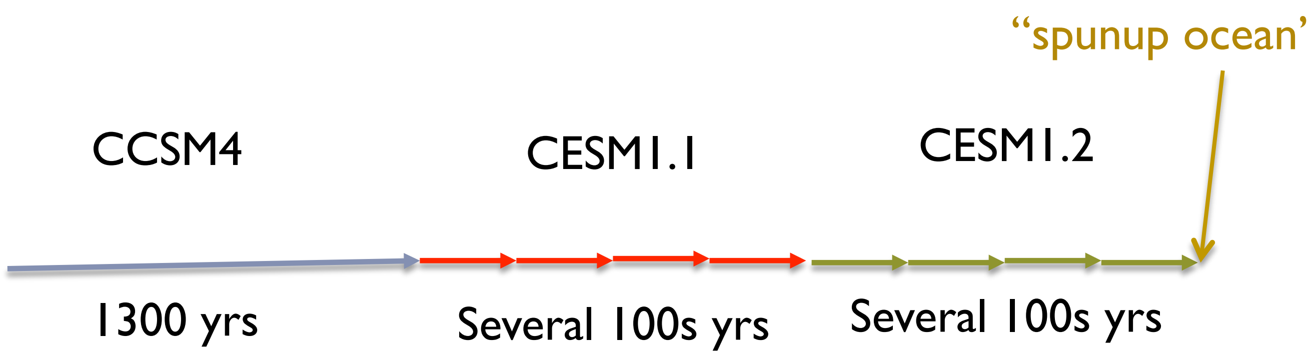
Today's topics

Outline

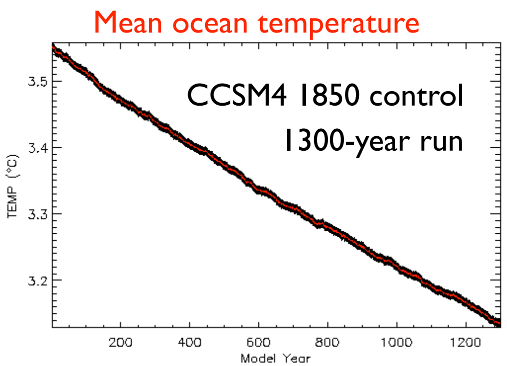
- **Ways to initialize the ocean in CESM**
- **Spin up issues with the Spectral Element dynamical core**
- **What controls the SSTs ?**
- **Take home message**

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

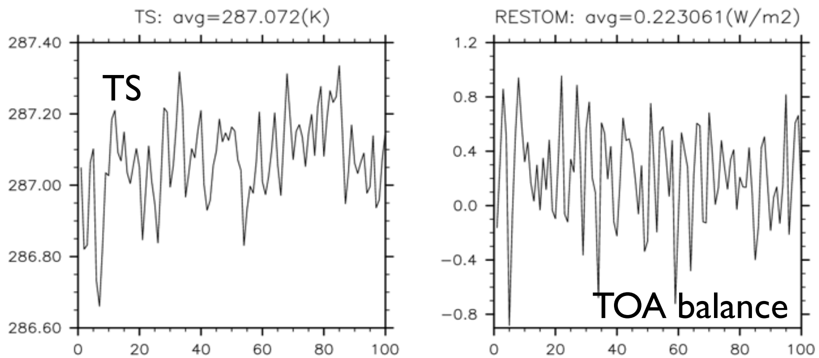
	Pros	Cons
Levitus	"Clean" way to initialize	Each run requires long spin-up. - At each experiment we will repeat this long spunup - More challenging to tune (*). Levitus is present day ocean. Is it best to initialize 1850 ?
Long spunup ocean	Fast to adjust Easier to tune	The model has drifted far away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

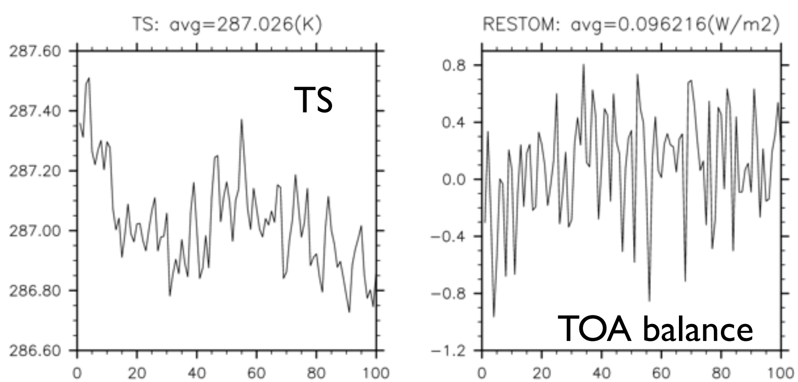
CESM1.1: Finite volume (FV)

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

Use best of both worlds !

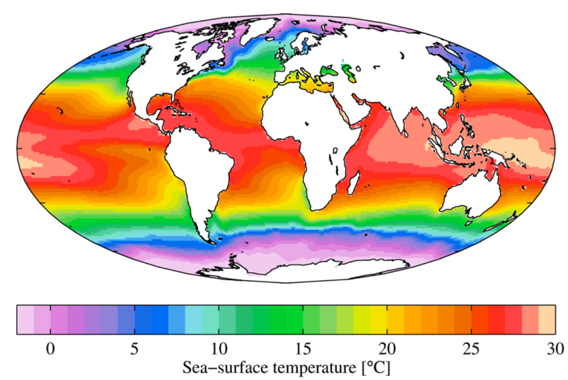
"Long spunup ocean"

CCSM4 — CESM1.1 — CESM1.2

1300 yrs — Several 100s yrs — Several 100s yrs

(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

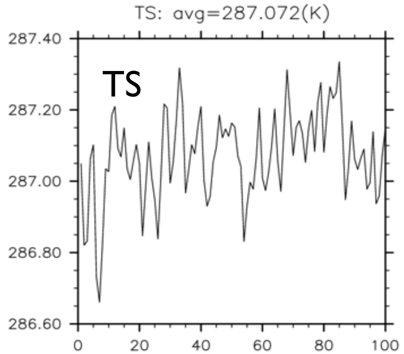


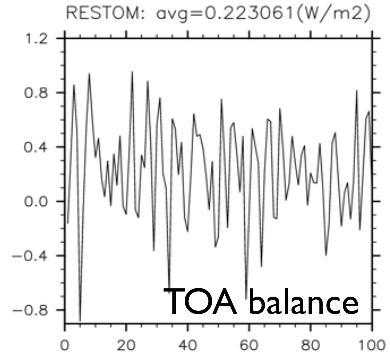
(3) Retune "along the way" if needed to maintain TOA balance ~ 0 W/m2

What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

Spunup ocean





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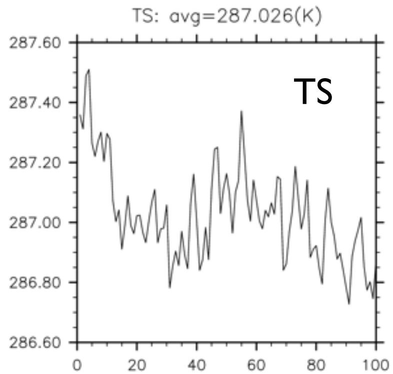
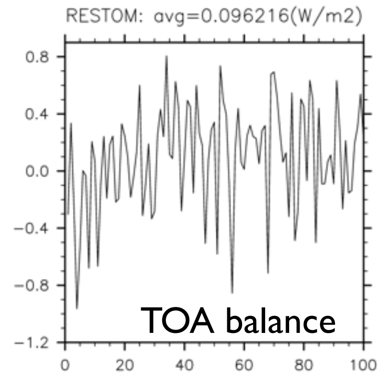
Levitus





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

Proposed strategy was quite successful in CESM1.1.

Used for "large-ensemble"

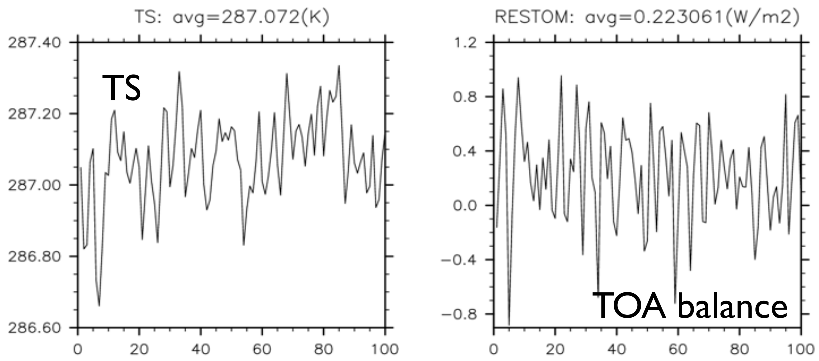
What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

CESM1.2: Spectral element (SE)

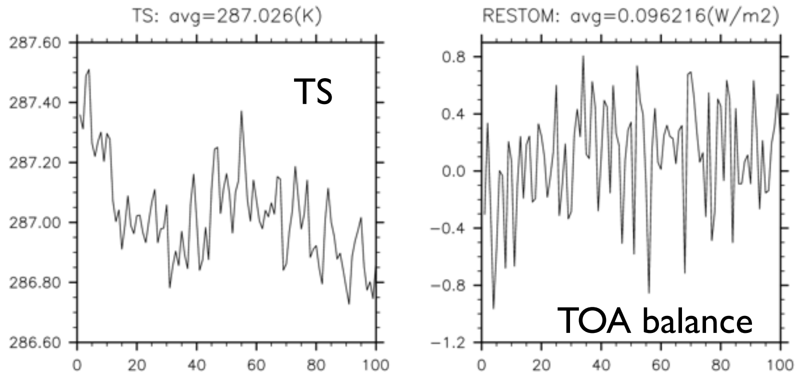
Then comes CESM1.2 and its new dynamical core

Spunup ocean



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

Levitus

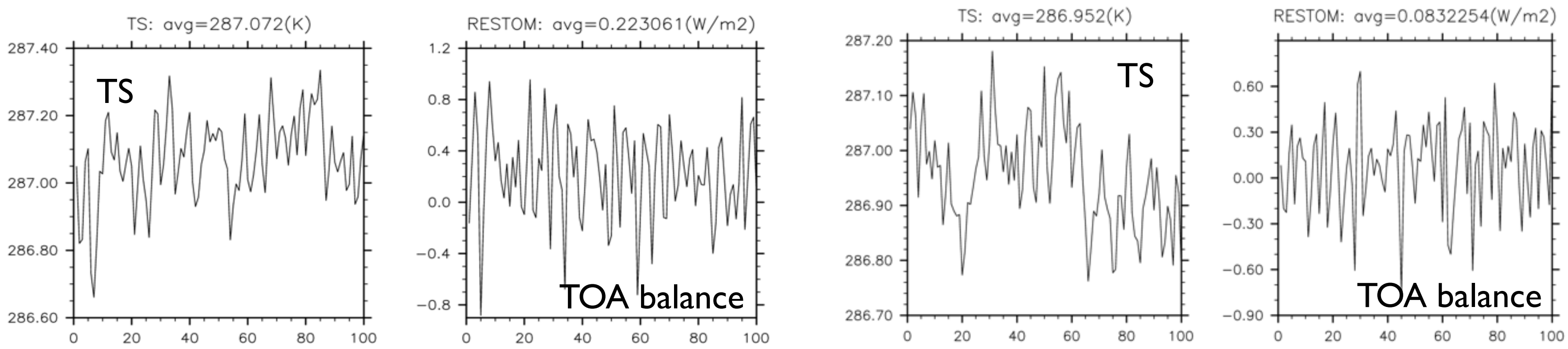


When starting from Levitus, model spinups longer (100 years).

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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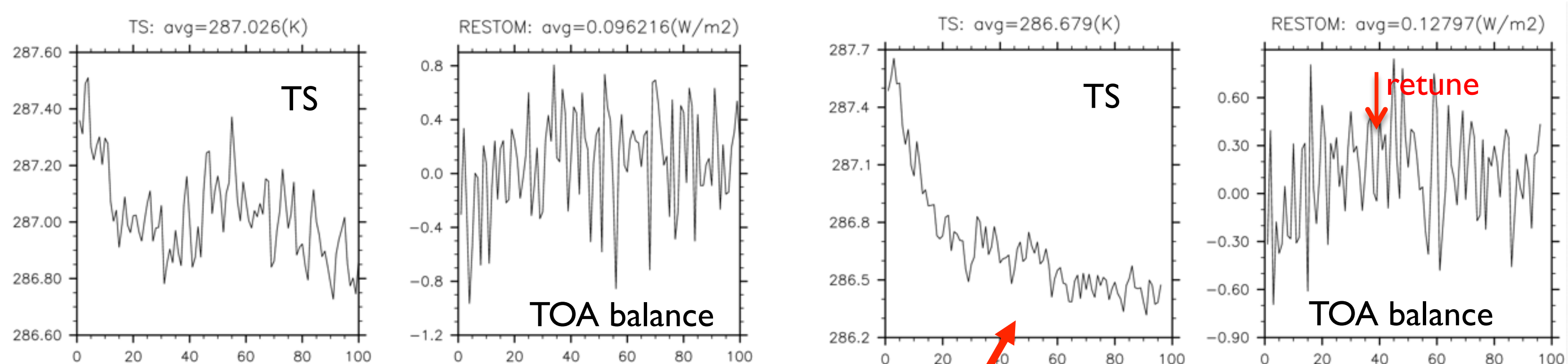
Levitus



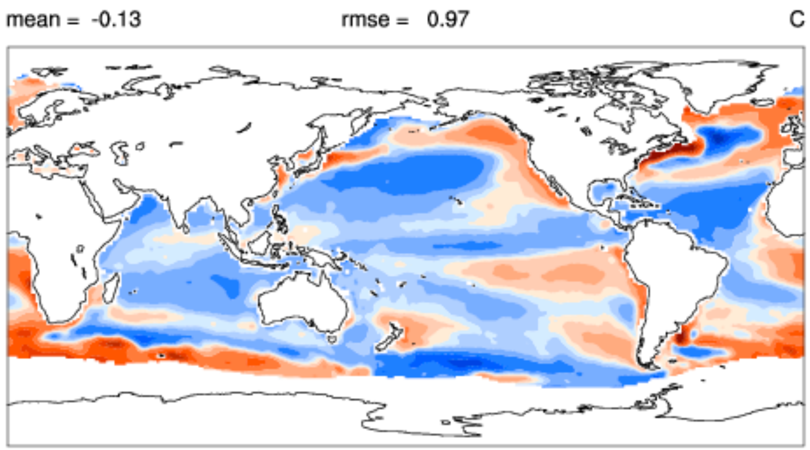
When starting from Levitus,
model spinups longer (100 years).

"Houston, we have problem"

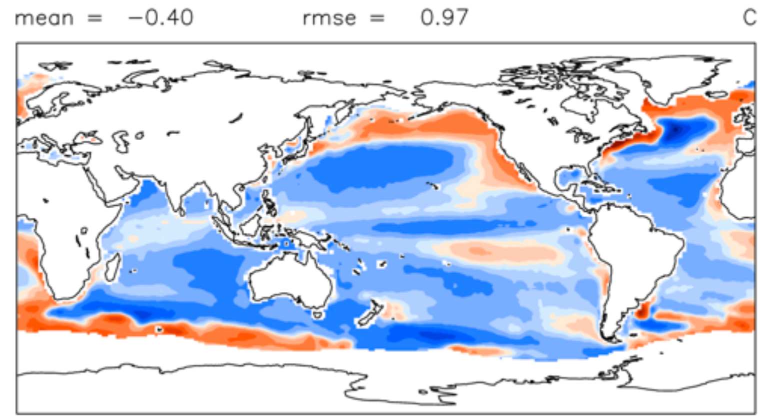
SST biases

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

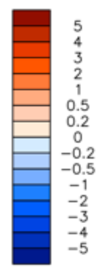
Finite Volume: Spunup ocean



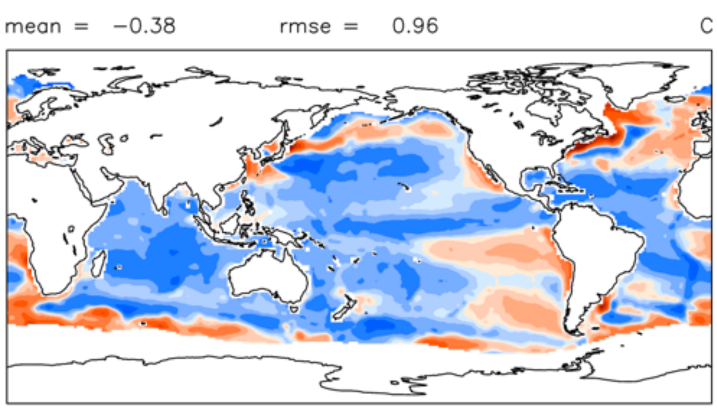
Spectral Element: Spunup ocean



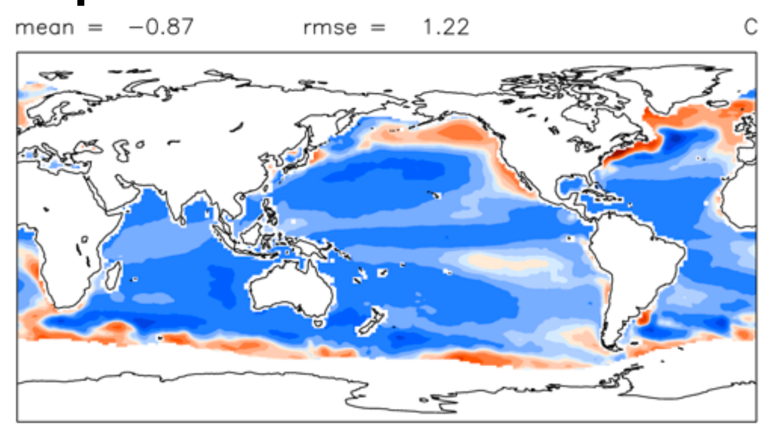
SST Bias similar to FV except SE Pacific.



Finite Volume: Levitus



Spectral Element: Levitus

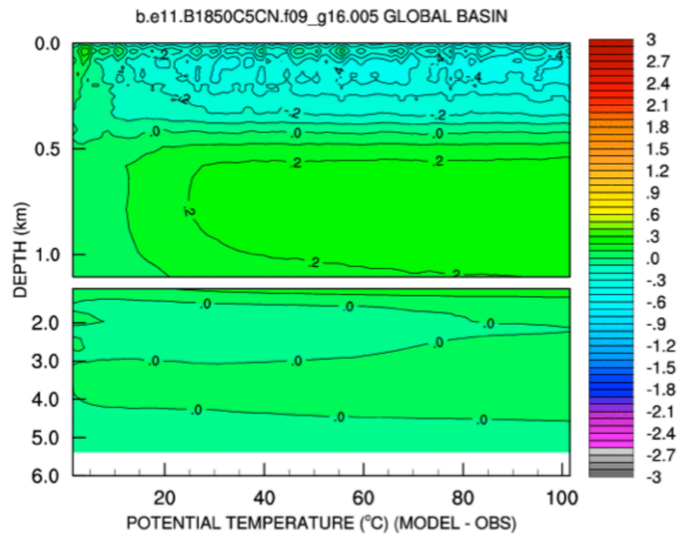


SSTs stabilize but too cold compared to obs
SST: 0.5K colder than FV

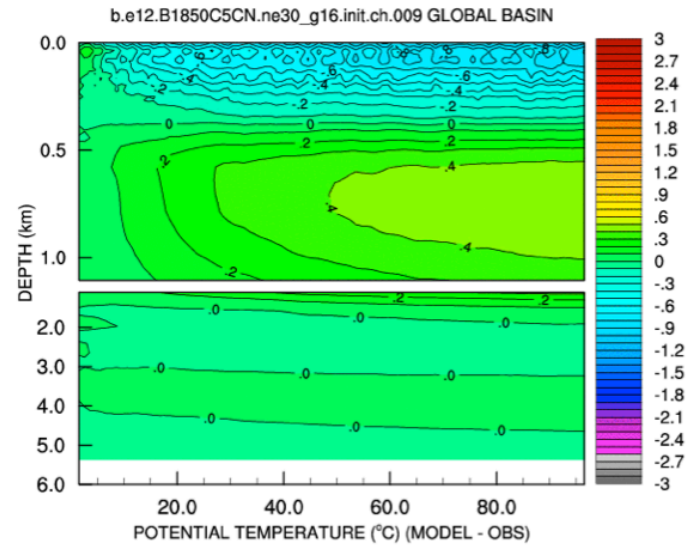
Ocean temperature bias

T bias = Tocn - Levitus

Finite Volume: Levitus



Spectral Element : Levitus



When starting from Levitus:

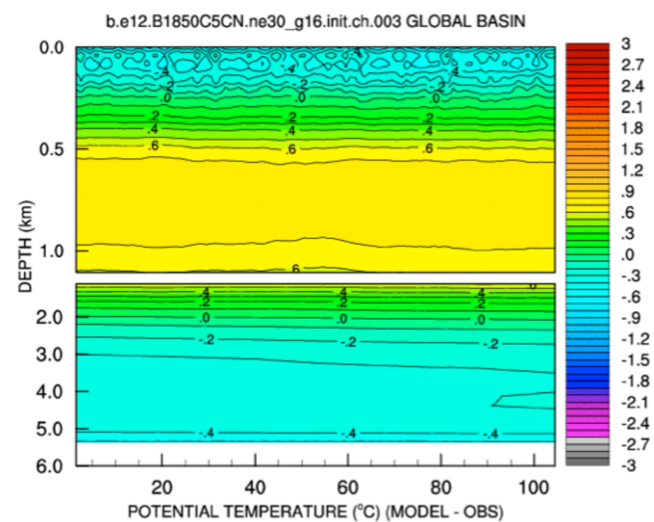
- cools near the surface
- warms around 750 meter
- exacerbated in SE

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)

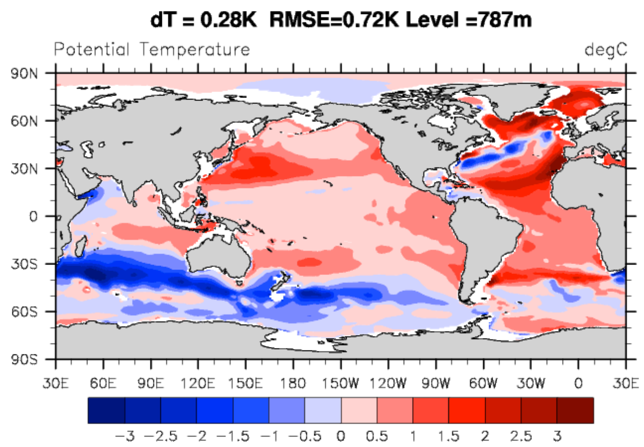
Spectral Element: Spunup ocean



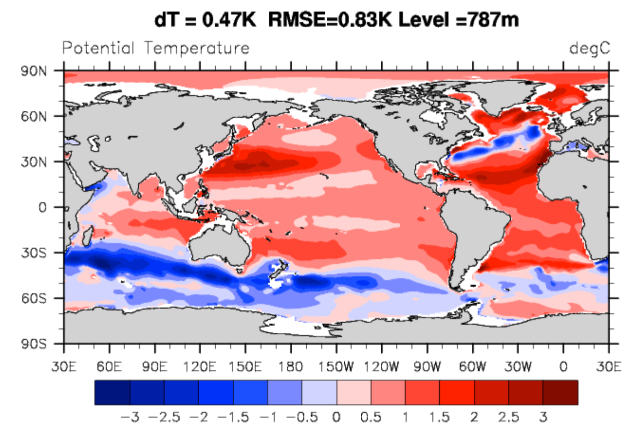
Is 750-meter warming uniform over ocean ?

Bias at 750m = T 750-m - Levitus

Finite Volume (yrs 70-89)



Spectral Element (yrs 70-89)



Warming is not uniform: areas of warming and cooling

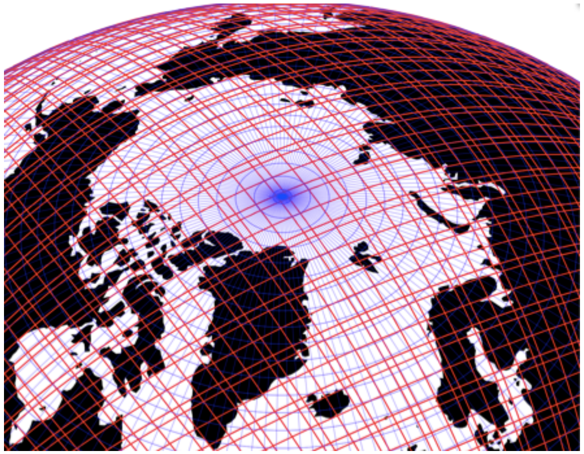
Warming also exists in Finite Volume but cooling compensates warming globally.

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

Topography

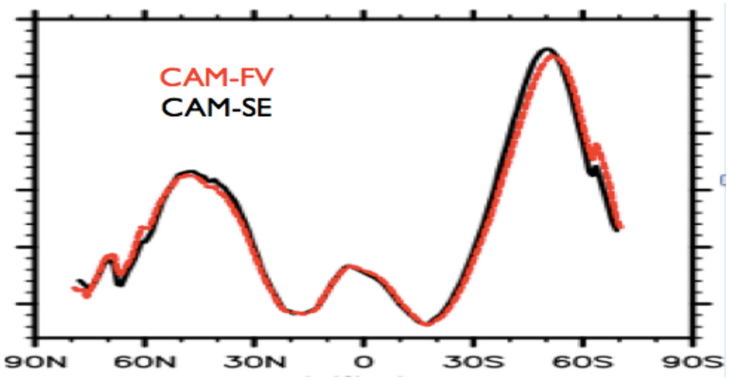
New software to generate topography (accommodate unstructured grids and enforce more physical consistency)

Remapping differences (ocn ⇔ atm)

State variables: FV uses "bilinear" and SE "native"

Climate

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



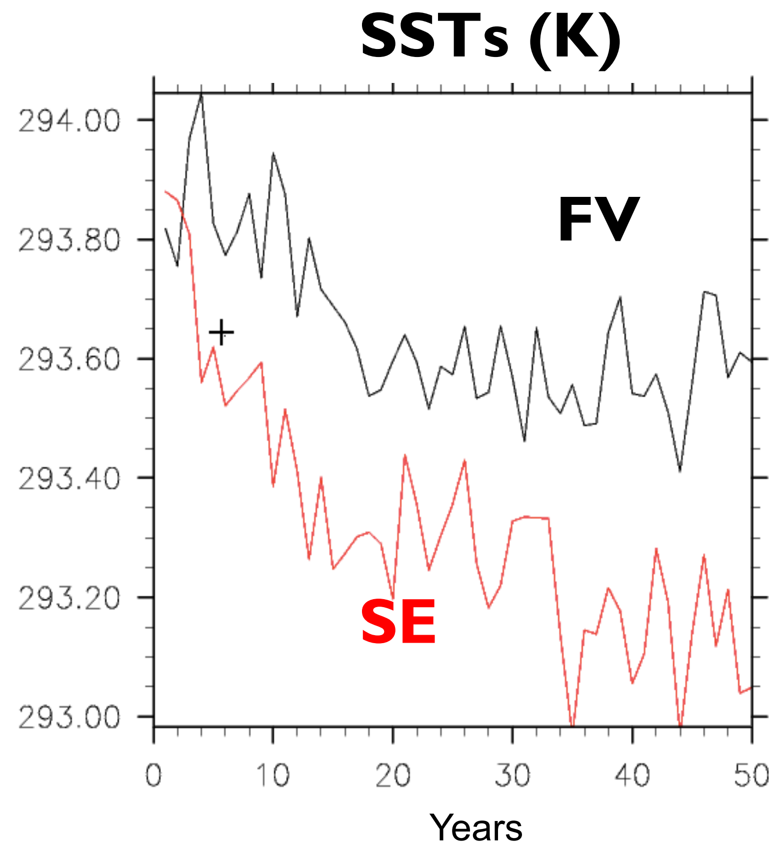
TAUX in CAM-SE:

- Location: maximum moves north
- Amplitude increases

What controls SST cooling in SE ?

Inventory of differences (SE ⇔ FV)

- Tuning parameters
  - Use FV tuning for dust, rhminl, rpen
- Topography
  - Use smoother topography
- Remapping (ocn ⇔ atm)
  - Use bilinear for state variables
- Grid differences at high latitude
  - Use refined poles grid
- Surface stresses
  - Turn off turbulent mountain stress
  - Increase turbulent mountain stress
  - Change gravity wave
  - Nudging to Finite Volume winds



Can you guess ?

What controls SST cooling in SE ?

Inventory of differences (SE ⇔ FV)

- Tuning parameters
  - Use FV tuning for dust, rhminl, rpen
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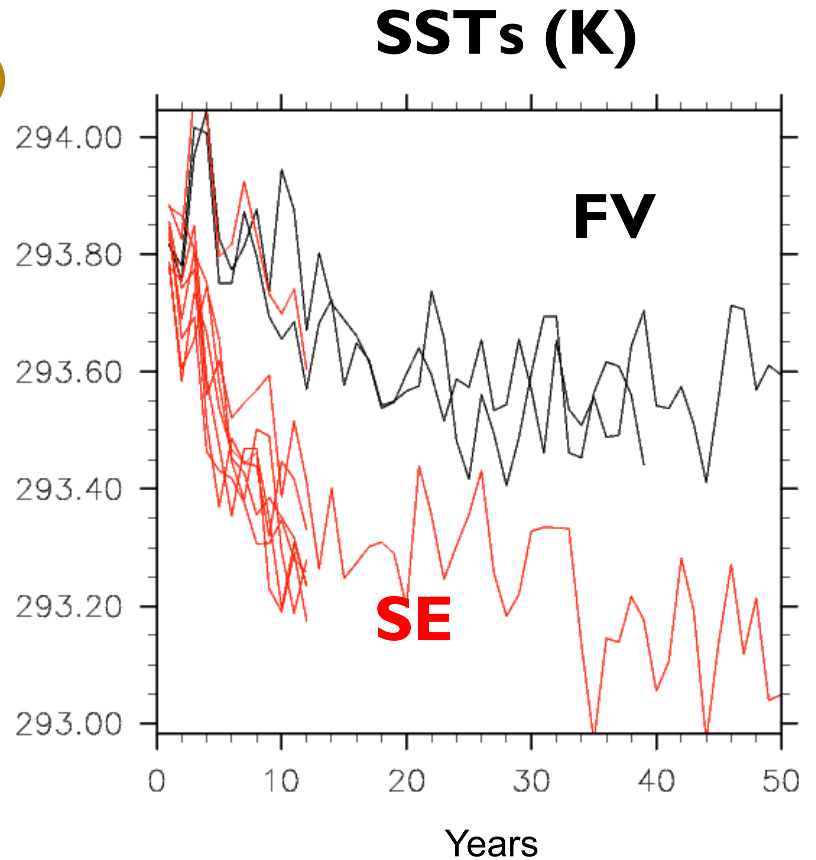
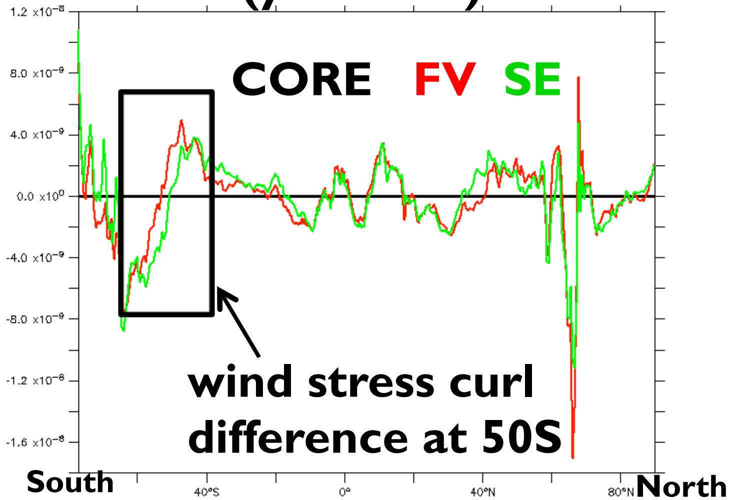


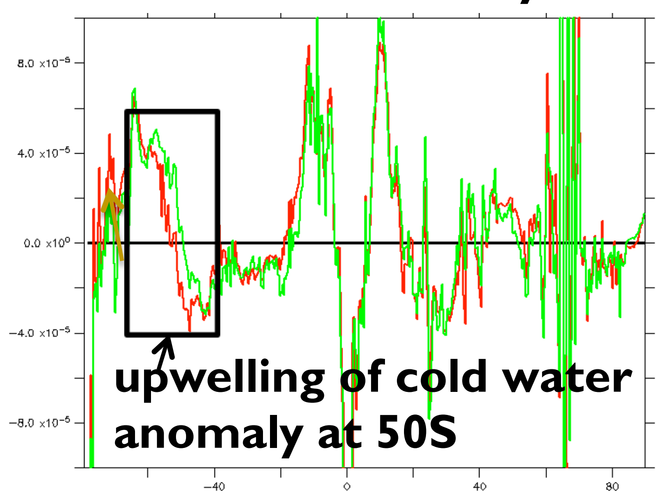
Nugging to FV winds yields to "FV-like SSTs"

Mechanism responsible of SST cooling in SE

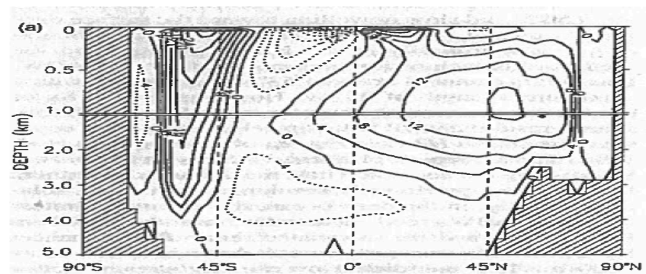
Wind stress curl anomaly (year 1-10)



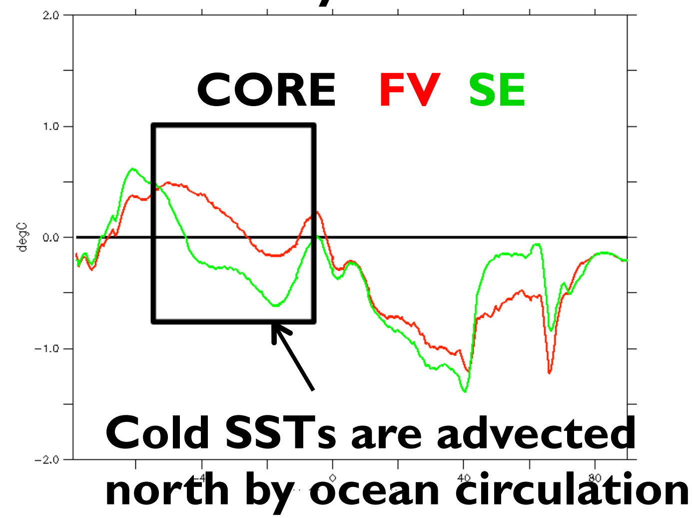
100-m vertical velocity anomaly



Ocean circulation

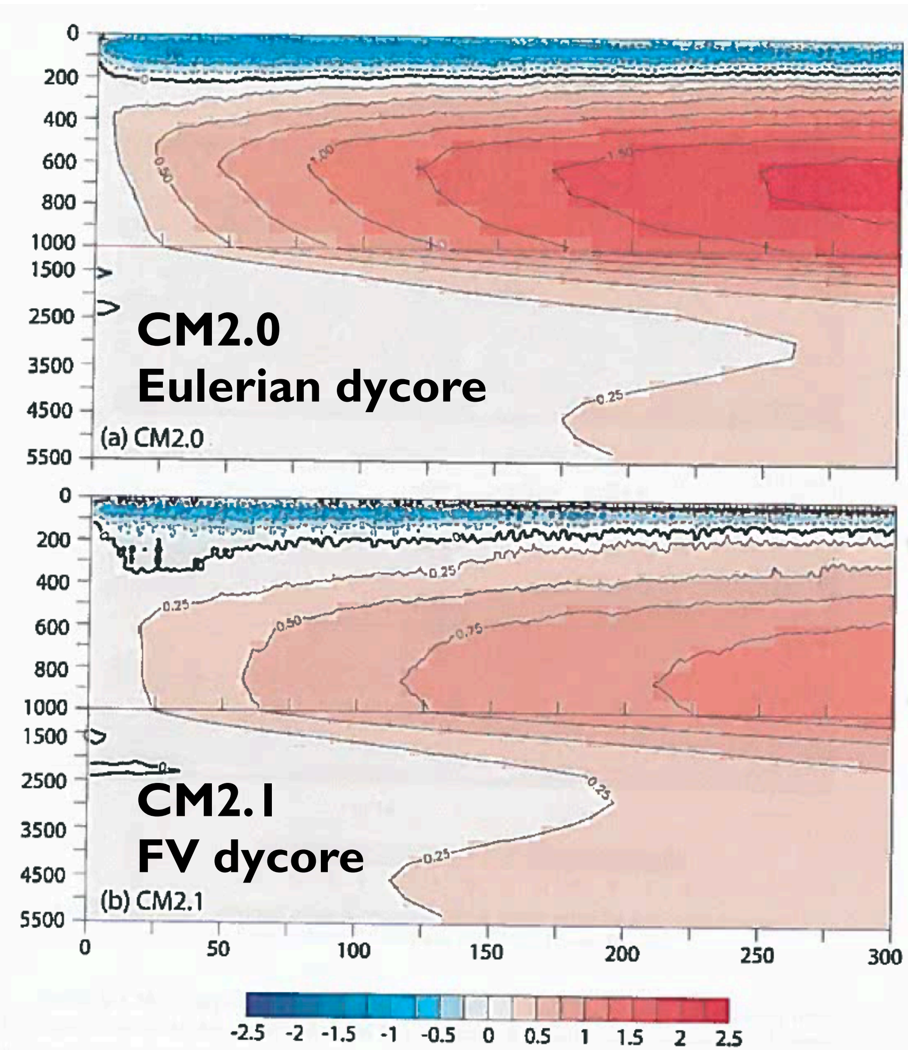


SST anomaly from CORE



Changes in location of upwelling zones associated with ocean circulation is responsible of the SST cooling

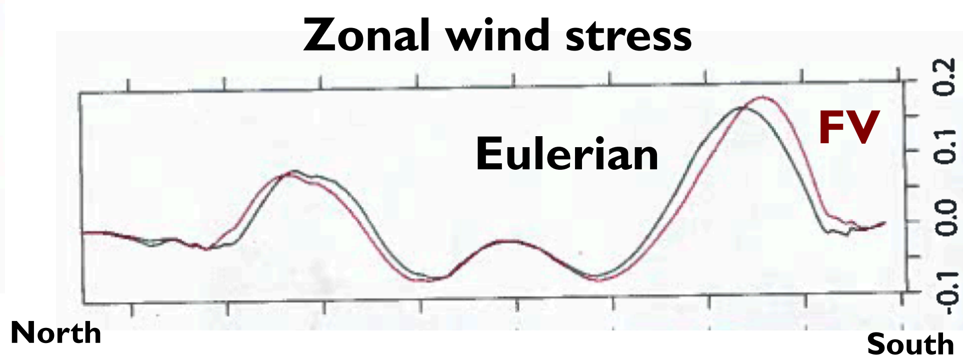
Similar behavior in GFDL model



SST cooling

warm layer at 750m

Reduced biases in FV



Take home message

Spinup issue with the Spectral Element dycore

When starting from Levitus

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

Changes in location of cold water upwelling zones associated with ocean subtropical circulation is responsible of SST cooling and likely of 750-m warming