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)

- **CCSM4**
  - 1300 yrs
- **CESM1.1**
  - Several 100s yrs
- **CESM1.2**
  - Several 100s yrs
## Pros and Cons of each initialization

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td><strong>Levitus</strong></td>
<td>“Clean” way to initialize</td>
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<tr>
<td>Levitus is present day ocean. Is it best to initialize 1850?</td>
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<tr>
<td><strong>Long spunup ocean</strong></td>
<td>Fast to adjust</td>
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<tr>
<td></td>
<td>Easier to tune</td>
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* tune = adjust parameters (“tuning parameters”) to achieve TOA radiative balance $\sim 0 \text{ W/m}^2$
What happens in the first 100 years of the run?

**CESM1.1: Finite volume (FV)**

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

When starting from Levitus, model spins up longer (100 years).
Proposed strategy to tune the model

(1) Use “long spunup” initialization, to obtain tuning parameters to adjust TOA balance \( \sim 0 \, \text{W/m}^2 \)

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

(3) Retune “along the way” if needed to maintain TOA balance \( \sim 0 \, \text{W/m}^2 \)
What happens in the first 100 year of the run?

CESM1.1: Finite volume (FV)

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

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)

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

TS: $\text{avg}=287.072(K)$

TOA balance

LEVITUS

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

CESM1.2: Spectral element (SE)

Then comes CESM1.2 and its new dynamical core
When starting from spunup ocean, model quickly adjusts (20 years).

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
mean = -0.13  rmse = 0.97

Spectral Element: Spunup ocean
mean = -0.40  rmse = 0.97

Finite Volume: Levitus
mean = -0.38  rmse = 0.96

Spectral Element: Levitus
mean = -0.87  rmse = 1.22

Similar bias that FV except SE Pacific.

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

Finite Volume: Levitus

Spectral Element: Levitus

$T\text{ bias} = T_{ocn} - \text{Levitus}$

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

Spectral Element: Spunup ocean

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)
Is 750-meter warming uniform over ocean?

Bias at 750m = T 750-m - Levitus

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)

Spectral Element (yrs 70-89)

SST bias = SST - Levitus

Finite Volume (yrs 70-89)

Spectral Element (yrs 70-89)
What is different (Finite Volume ↔ Spectral Element)?

### Tuning Parameters

<table>
<thead>
<tr>
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<th>FV</th>
<th>SE</th>
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<tbody>
<tr>
<td>rhminl</td>
<td>0.8925</td>
<td>0.884</td>
</tr>
<tr>
<td>rpen</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>dust_emis</td>
<td>0.35</td>
<td>0.55</td>
</tr>
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### Grid Differences at High Latitudes

- Red: CAM-SE grid
- Blue: CAM-FV grid

(at about 2 degree)

### 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 than FV
- Surface stress in Southern Ocean

What's the impact on physics and remapping?

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

Courtesy: Peter Lauritzen
Surface stress

Observed surface stress
Large-Yeager (2009)

Significant differences in surface stress
- Southern oceans
- Close to Greenland
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?
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
  - Turn off turbulent mountain stress
  - Increase turbulent mountain stress
  - Change gravity wave

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

Inventory of differences (SE ↔ FV)

- Tuning parameters
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Can we identify differences responsible of the SSTs cooling in SE?
Mechanism responsible of SST cooling in SE

SST anomaly from FV (year 1-10)

Cooling at 40S
Warming at 50N
Mechanism responsible of SST cooling in SE

SST anomaly from FV (year 1-10)

Cooling at 40S  Warming at 50N

SHF anomaly from FV (year 1-10)

Cooling is not coming from atm.
Mechanism responsible of SST cooling in SE

**SST anomaly from FV (year 1-10)**

*Cooling at 40S  Warming at 50N*

**Wind stress curl anomaly (year 1-10)**

*wind stress curl anomaly at 50S*

**SHF anomaly from FV (year 1-10)**

*Cooling is not coming from atm.*
Mechanism responsible of SST cooling in SE

**SST anomaly from FV (year 1-10)**

- Cooling at 40S
- Warming at 50N

**Wind stress curl anomaly (year 1-10)**

- Wind stress curl anomaly at 50S

**SHF anomaly from FV (year 1-10)**

- Cooling is not coming from atm.

**100-m Vertical velocity anomaly (year 1-10)**

- Upwelling anomaly of cold water at 50S
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

SST, Global, anomaly from FV, 0001–0010

WVEL, Global, 100m, anomaly from FV, 0001–0010
Can we adjust ocean vertical mixing?

\[ \Delta T = f(K) \]

Ocean Temperature Bias

Temperature profile in the ocean

\[ \Delta T = f(K) \]
Can we adjust ocean vertical mixing?

ΔT = f(K and wind)

Temperature profile in the ocean

If there is too much mixing

cooling at the surface

warming at 500-1000m
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.