

The Art of Tuning and Coupling: A peek behind the scenes of CESM development



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CESM2: Development of the individual components

Phase I: “Let’s build it”

- Individual components were built within each working group
- Effort started around 2010

Land
CLM5



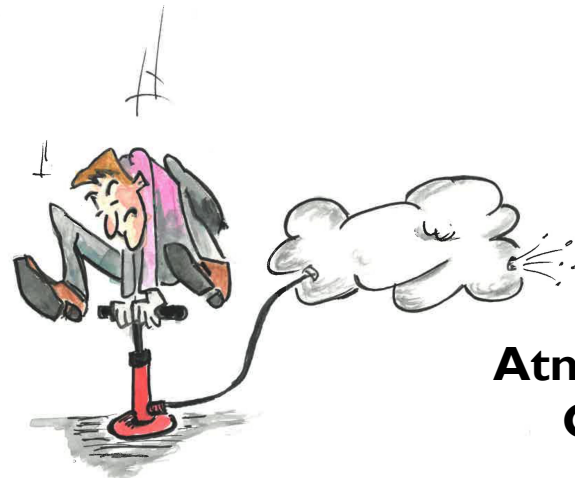
Sea-ice
CICE5



Ocean
POP2



Land Ice
CISM2



Atmosphere
CAM6

CESM2: Coupling of the individual components

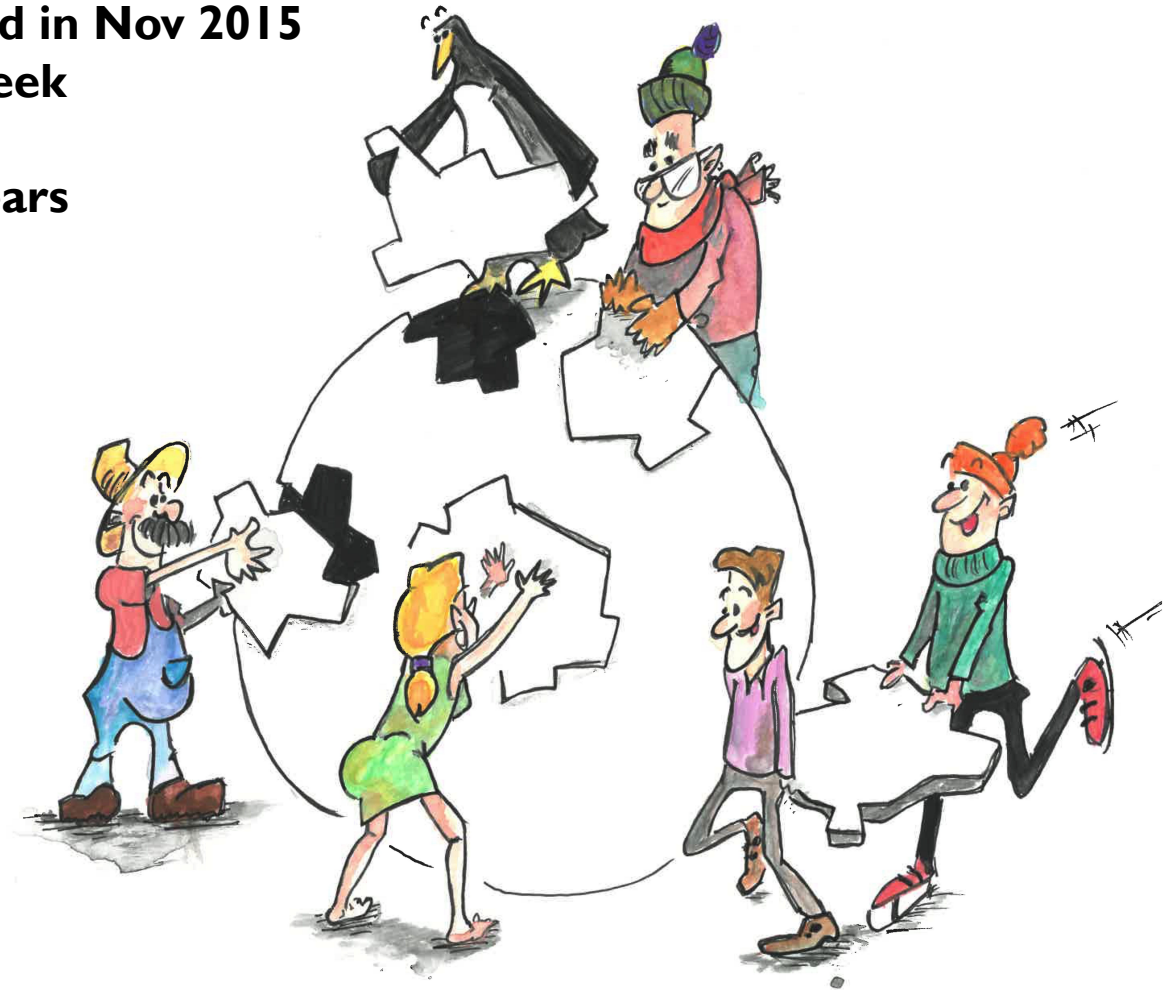
Phase 2: “Let’s put it together”

- Collaborative effort started in Nov 2015
- 2 co-chair meetings per week
- 300 cases
- Thousands of simulated years and diagnostics

CESM2 Release: June 2018

**Development requires:
Tuning and Coupling**

**In this talk, we’ll focus
on these aspects**



The Art of Tuning

Model tuning

Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.

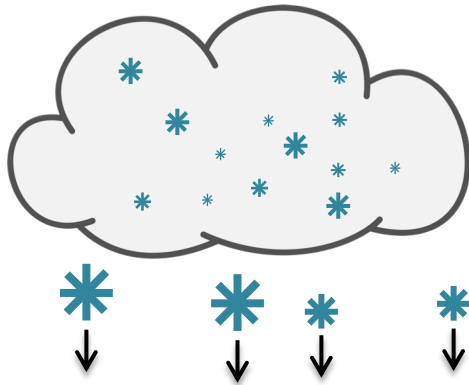
Model tuning

Tuning = **adjusting parameters** (“tuning knobs”) to achieve best agreement with observations.

Tuning knobs = parameters weakly constrained by observations

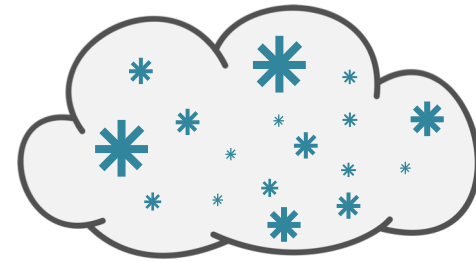
Dcs = Threshold diameter to convert cloud ice particles to snow

Smaller Dcs



Less ice cloud
Less LWCF

Larger Dcs

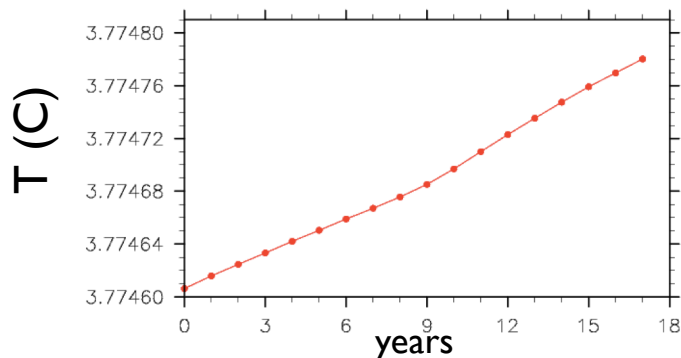
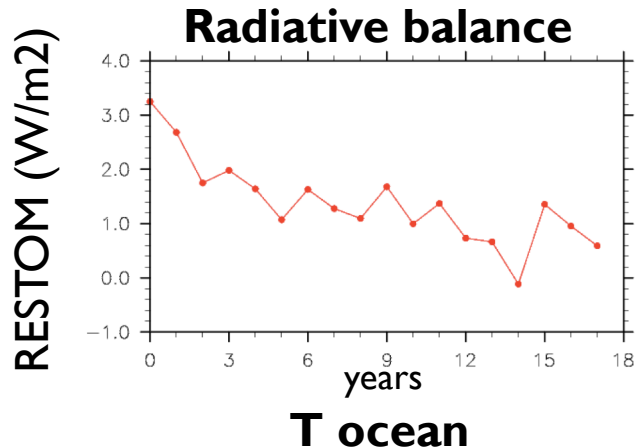


More ice cloud
More LWCF

Model tuning

Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.

Top of atmosphere radiative balance should be near zero



Other targets when tuning

- **Cloud forcing**
- **Precipitation**
- **ENSO amplitude**
- **AMOC**
- **Sea-ice thickness/extent**

Dilemmas while tuning

- **Subjectivity of tuning targets**

Tuning involves choices and compromises

Overall, tuning has limited effect on model skills

- **Tuning for pre-industrial ⇔ Tuning for present day**

Pre-industrial: Radiative equilibrium

Present day: Available observations

- **Tuning individual components ⇔ Tuning coupled model**

Tuning individual components is fast

But no guarantee that results transfer to coupled model

- **Tuning exercise is very educative**

We learn a lot about the model during the tuning phase.

The Art of Coupling

Coupling = Unleashing the Beast

AMIP run

- Prescribed SSTs
- No drift

Coupled run

- Fully active ocean
- Coupled bias and feedback

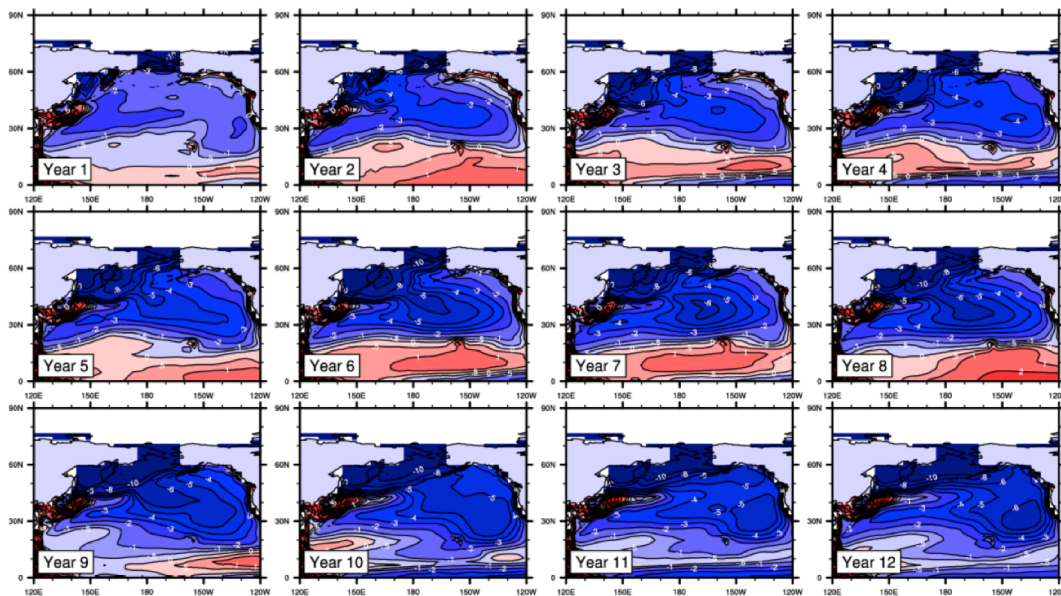


Example of unleashing the beast (I)

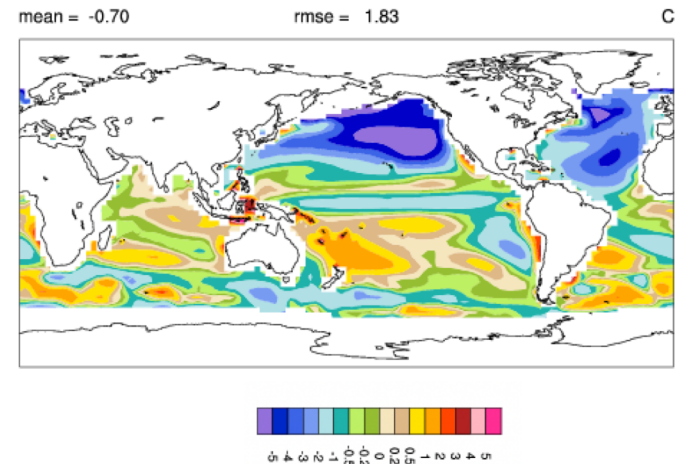
Tuning CAM5 (CESMI development, 2009)

- Tuning was done in **CAM**: looks like “perfect” simulation
- In coupled mode: strong **cooling of the North Pacific** (bias > 5K)

Evolution of the SST errors (K)



Mean SST errors (K)



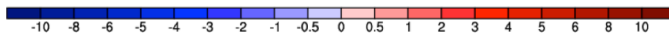
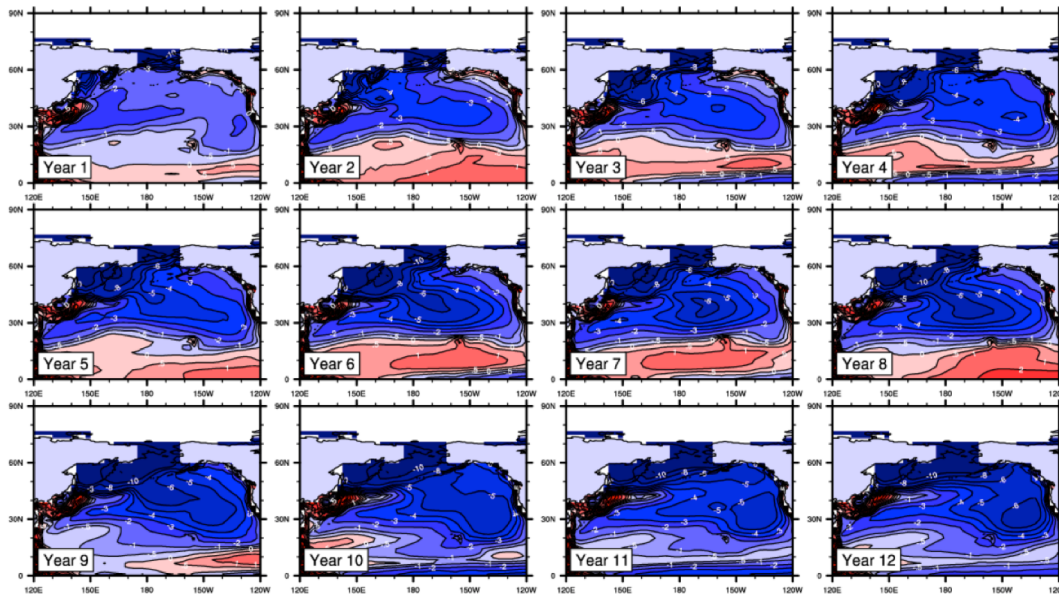
Courtesy Rich Neale

Example of unleashing the beast (I)

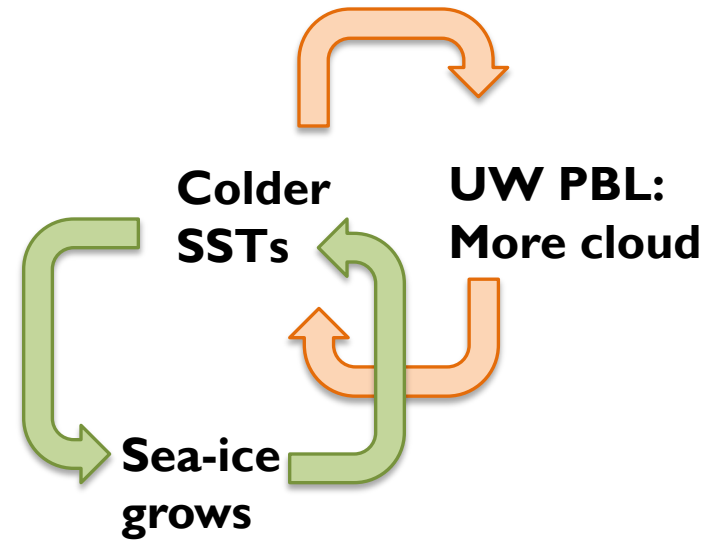
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Courtesy Rich Neale

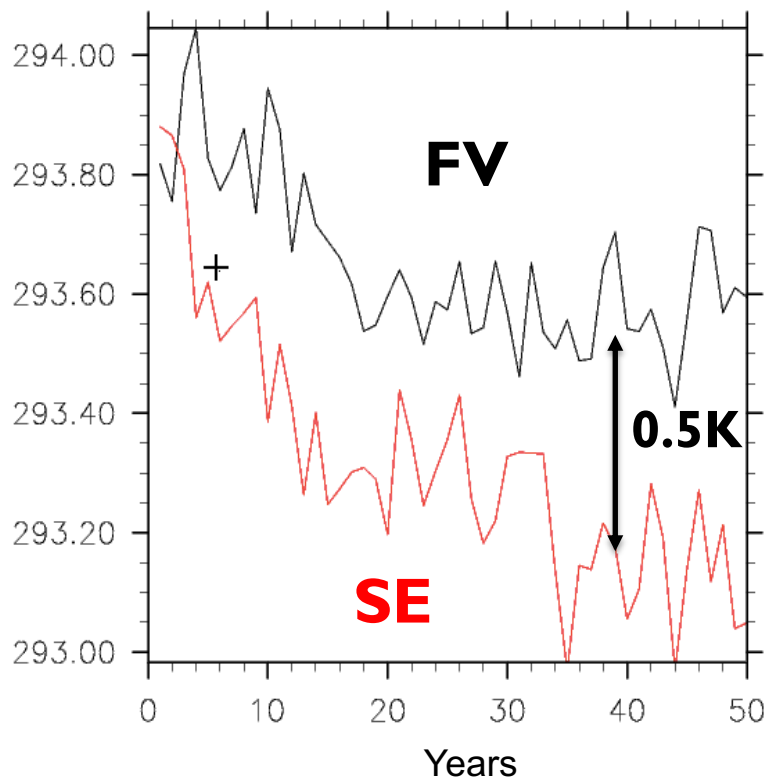


Example of unleashing the beast (2)

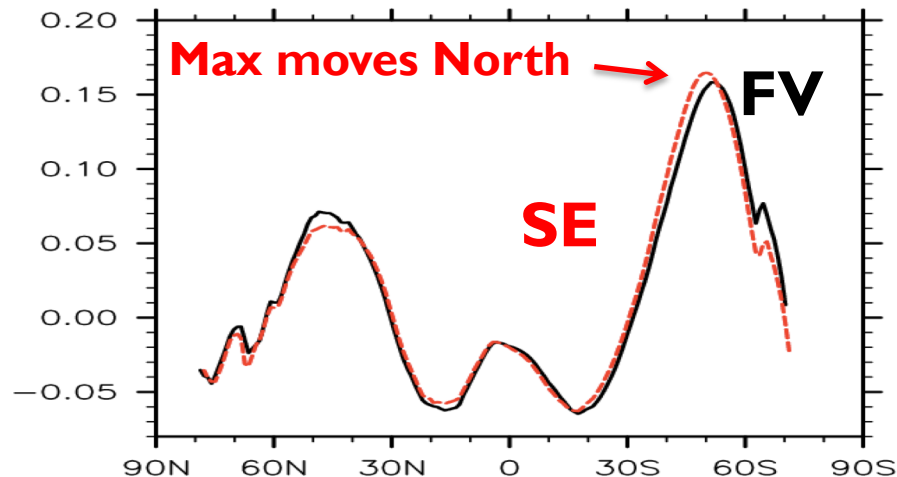
Spectral Element dycore development (CESMI.2, 2013)

- In CAM standalone: Finite Volume (FV) and Spectral Element (SE) dycores produces very similar simulations.
- In coupled mode: **SSTs stabilize 0.5K colder** with SE dycore

SSTs (K)



Zonal Surface Stress (N/m²)



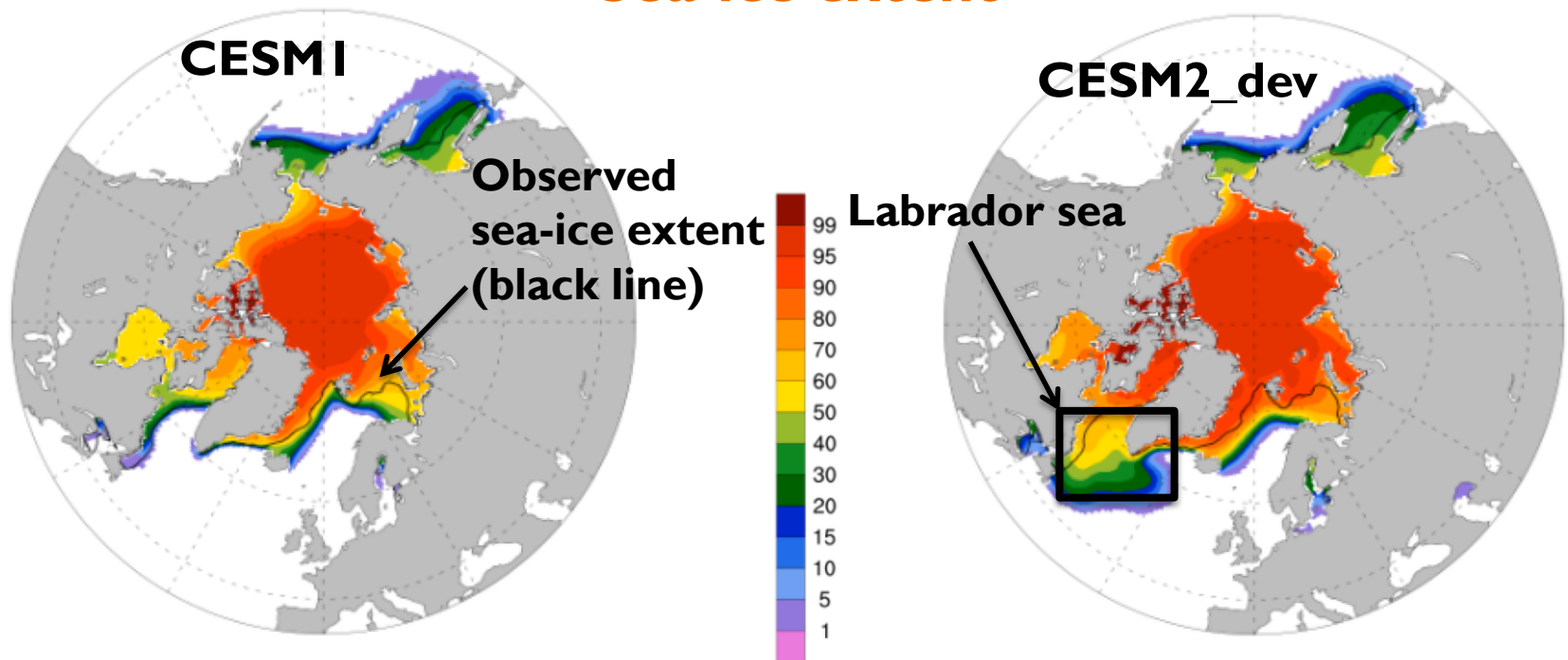
Changes in location of **upwelling zones** associated with **ocean circulation** is responsible of the **SST cooling**

Example of unleashing the beast (3)

The Labrador Sea issue (CESM2 development, 2016)

- The Labrador Sea was freezing in CESM2_dev.

Sea-ice extent



Sea-ice extent is close to obs.
Labrador sea is ice free

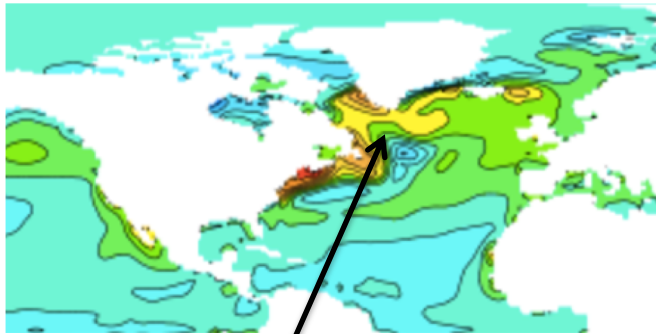
Labrador sea is ice-covered.
Can happen after 1 yr, 40 yr, 100+ yr

Example of unleashing the beast (3)

The Labrador Sea issue (CESM2 development, 2016)

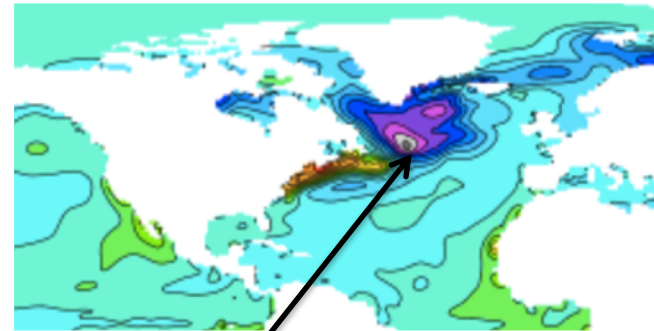
- Why was Labrador Sea freezing ?

CESM1



Too warm and salty

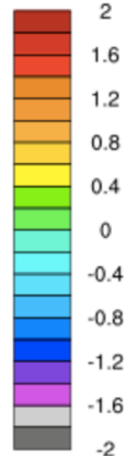
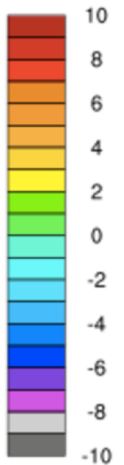
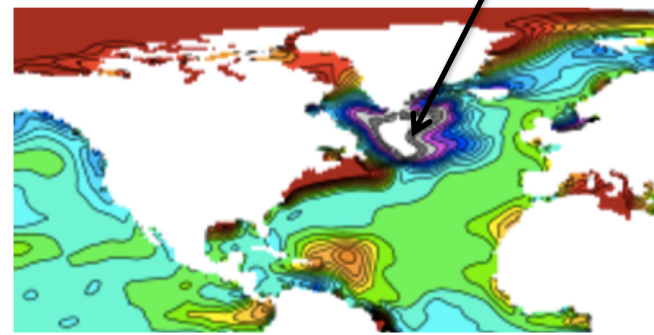
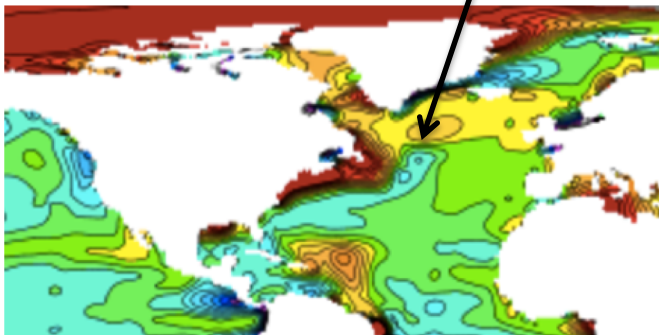
CESM2_dev



Too cold and too fresh

SST bias

Salinity bias



Too cold and too fresh South of Greenland => Labrador Sea freezes

Summary

The Art of Tuning

Tuning = adjusting parameters (“tuning knobs”) to achieve best agreement with observations.

- **Tuning involves choice and compromise**
- **We learn a lot about the model while tuning**

The Art of Coupling

Three examples of coupling challenge

- **CESM1: cold SST bias in North Pacific with CAM5**
- **CESM1.2: SSTs stabilize 0.5K colder with SE dycore**
- **CESM2: Labrador Sea is ice-covered**