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 1: "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

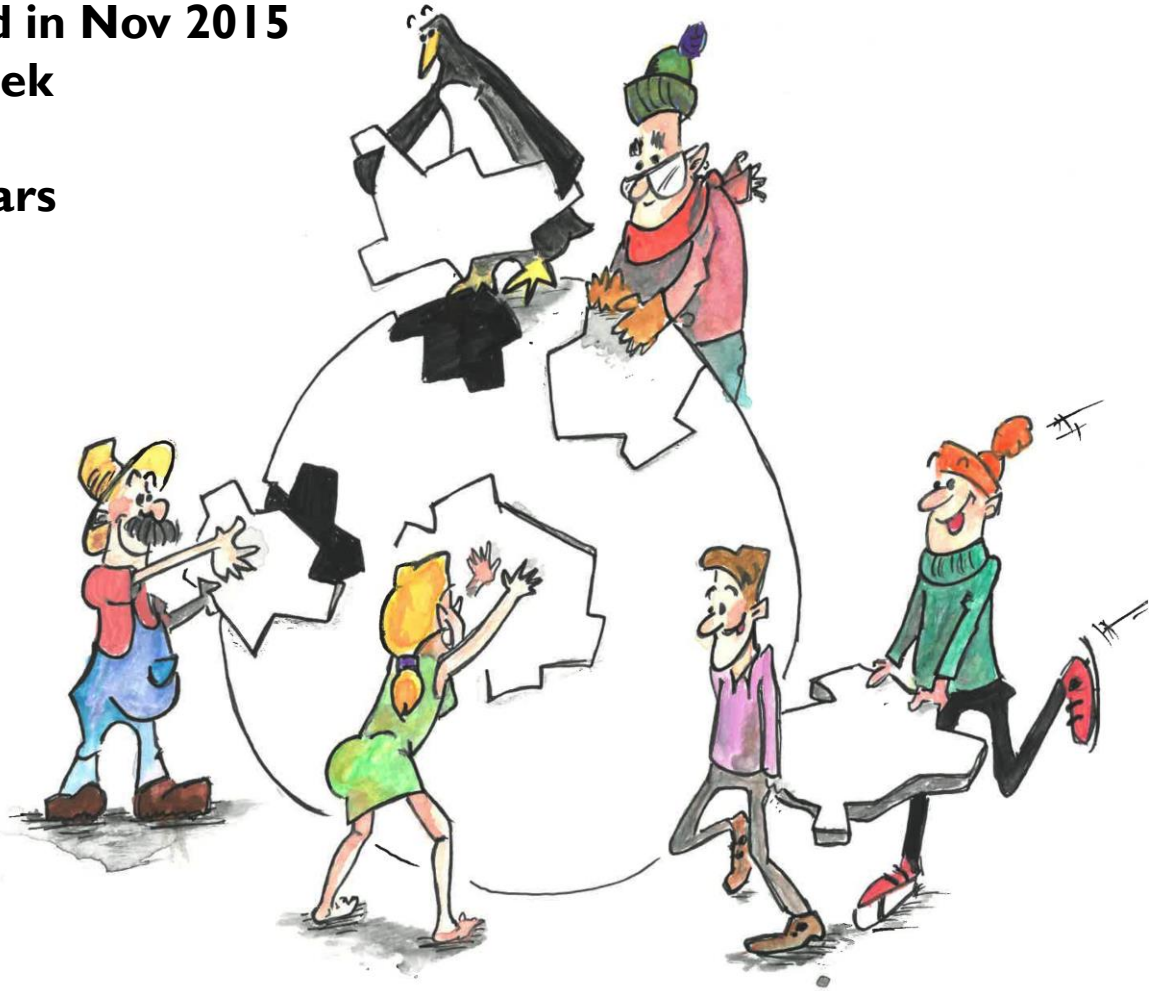
Phase 2: "Let's put it together"

- **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

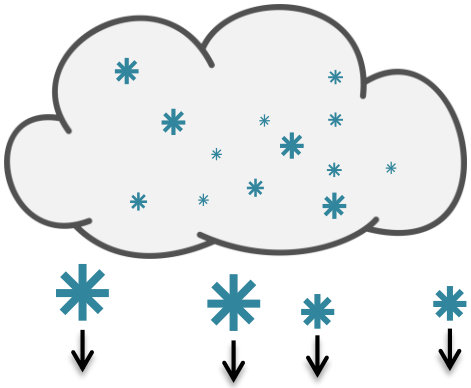
Model tuning

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

Tuning knobs = parameters weakly constrained by observations

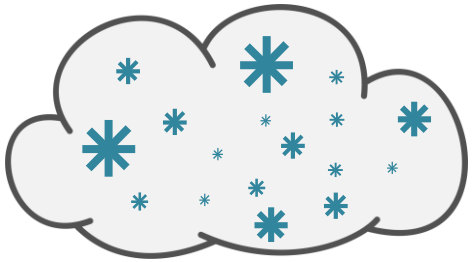
Dcs = Threshold diameter to convert cloud ice particles to snow

Smaller Dcs



Less ice cloud
Less LWCF

Larger Dcs



More ice cloud
More LWCF

Model tuning

Tuning = adjusting parameters ("tuning knobs")
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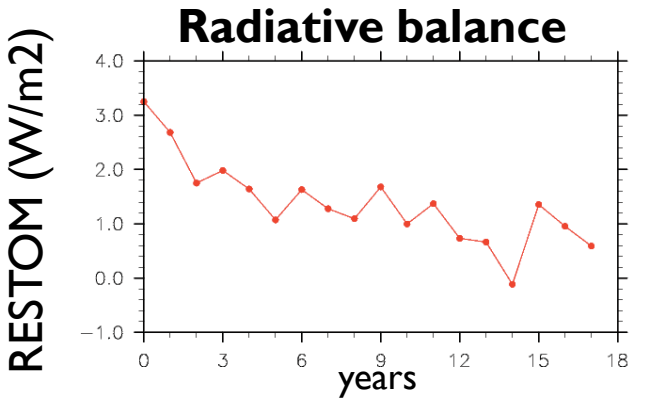
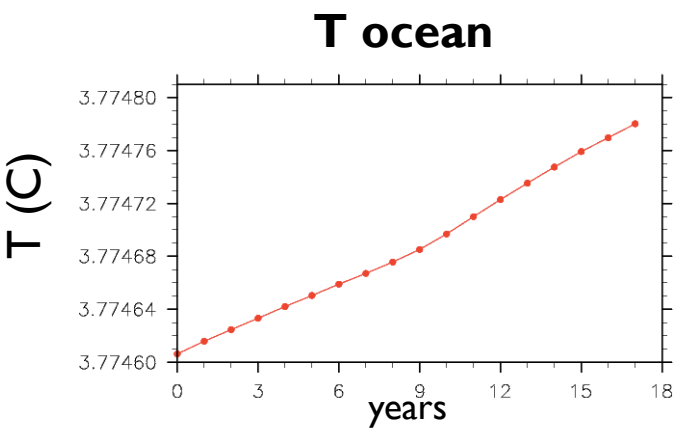
Top of atmosphere radiative balance should be near zero





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

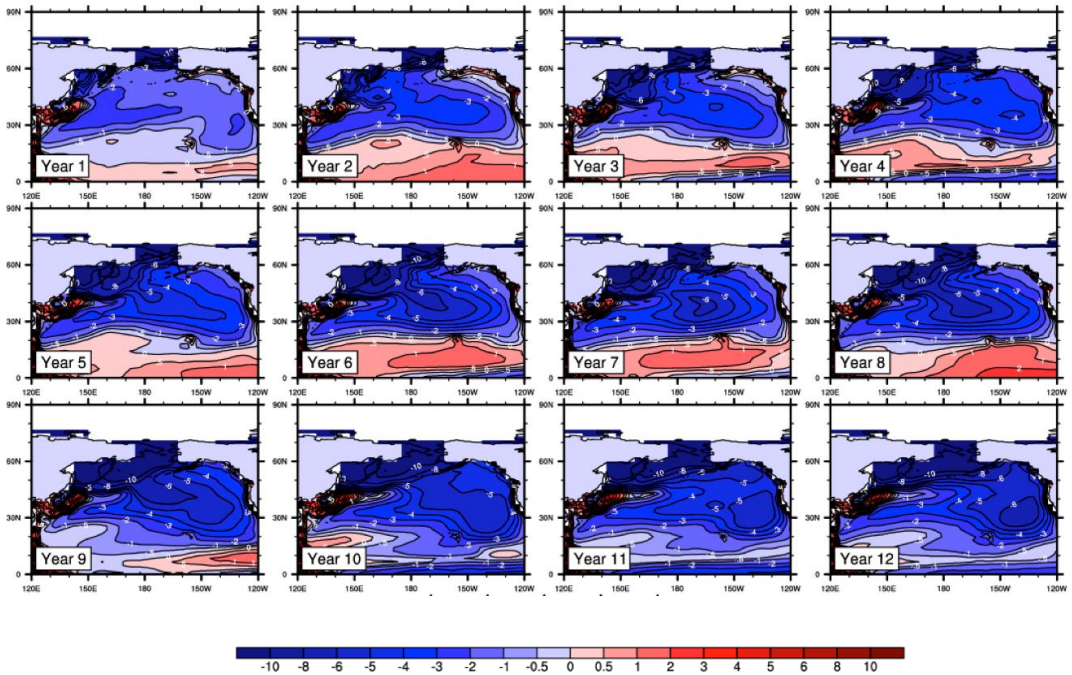
- **Fully active ocean**
- **Coupled bias and feedback**

Example of unleashing the beast (1)

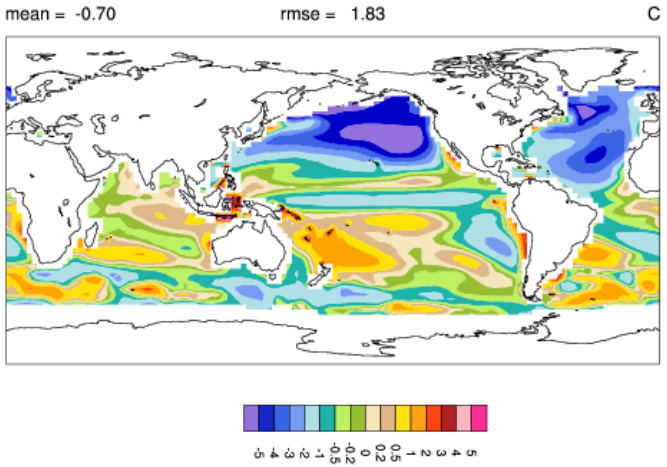
Tuning CAM5 (CESM1 development, 2009)

- **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

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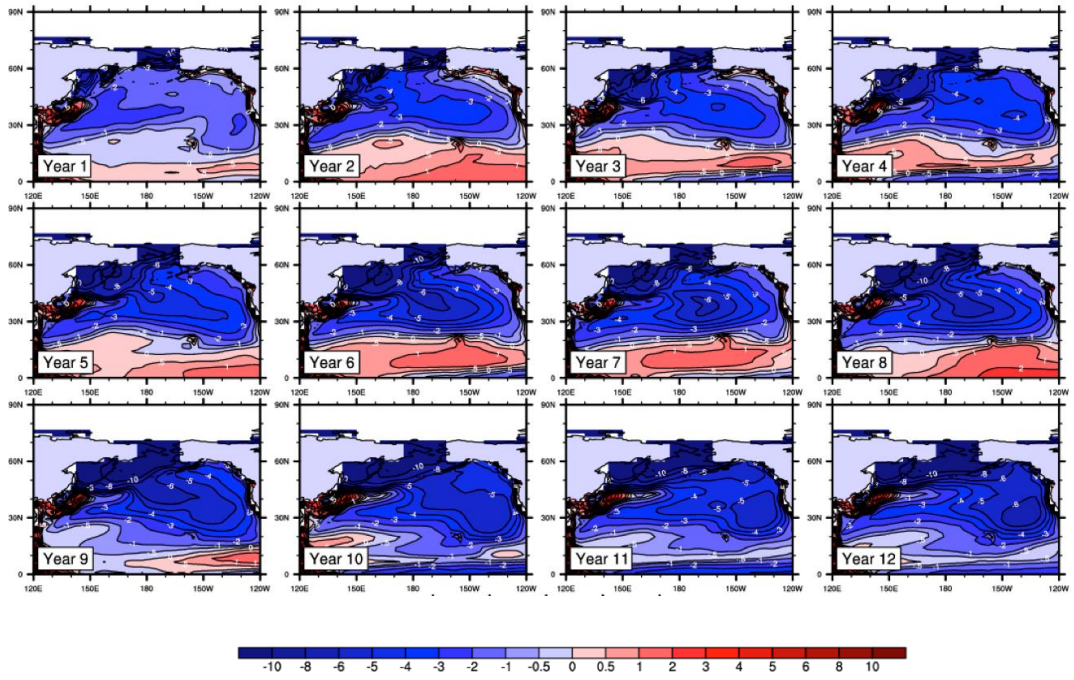

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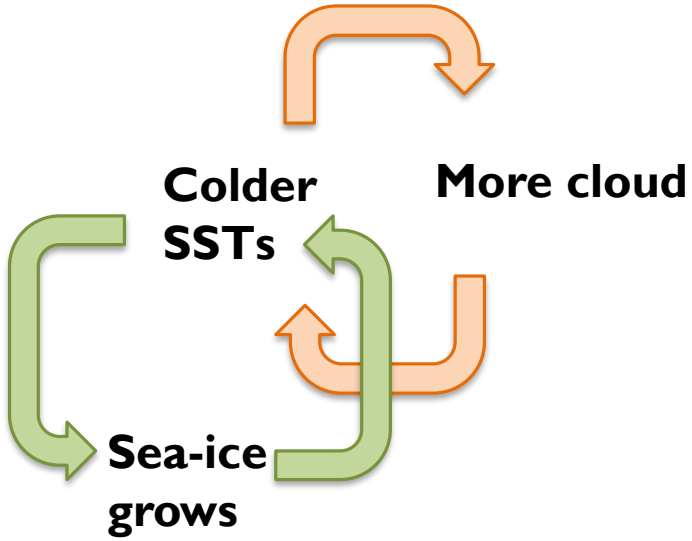
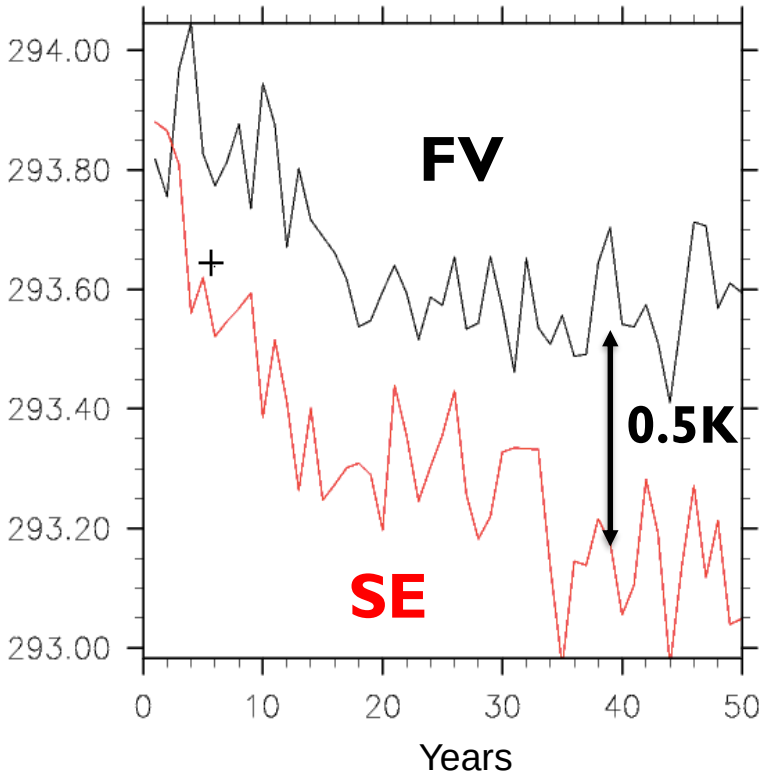


Example of unleashing the beast (2)

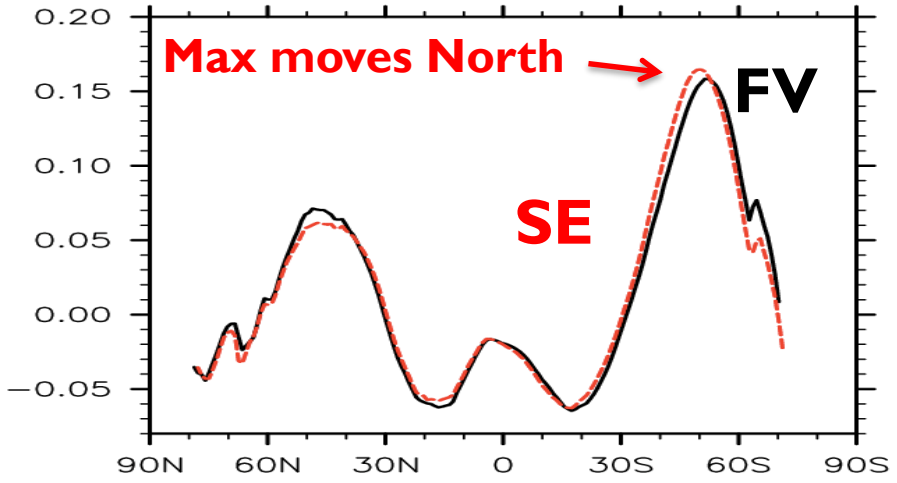
Spectral Element dycore development (CESM1.2, 2013)

- **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)



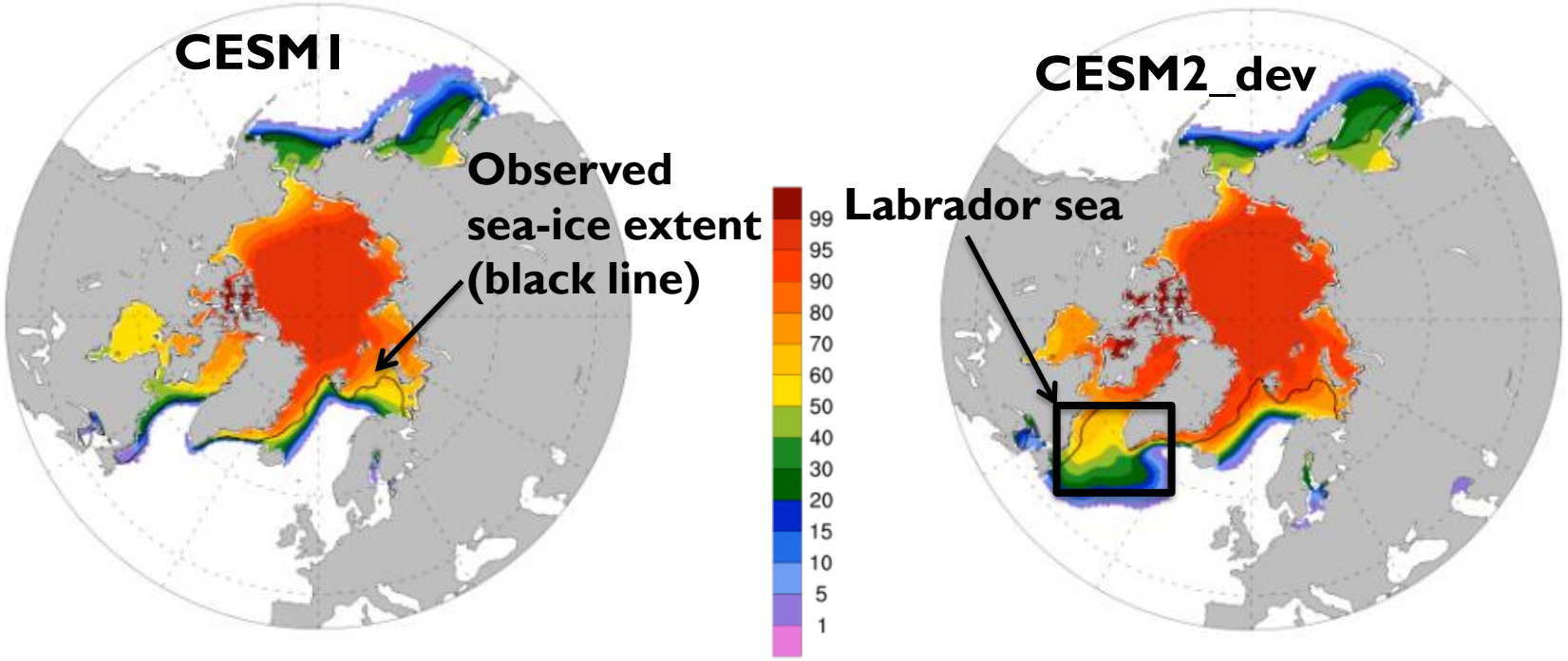
Changes in location of upwelling zones associated with ocean circulation is responsible of the SST cooling

Example of unleashing the beast (3)

The Labrador Sea issue (CESM2 development, 2016)

- **The Labrador Sea was freezing in CESM2_dev.**

Sea-ice extent



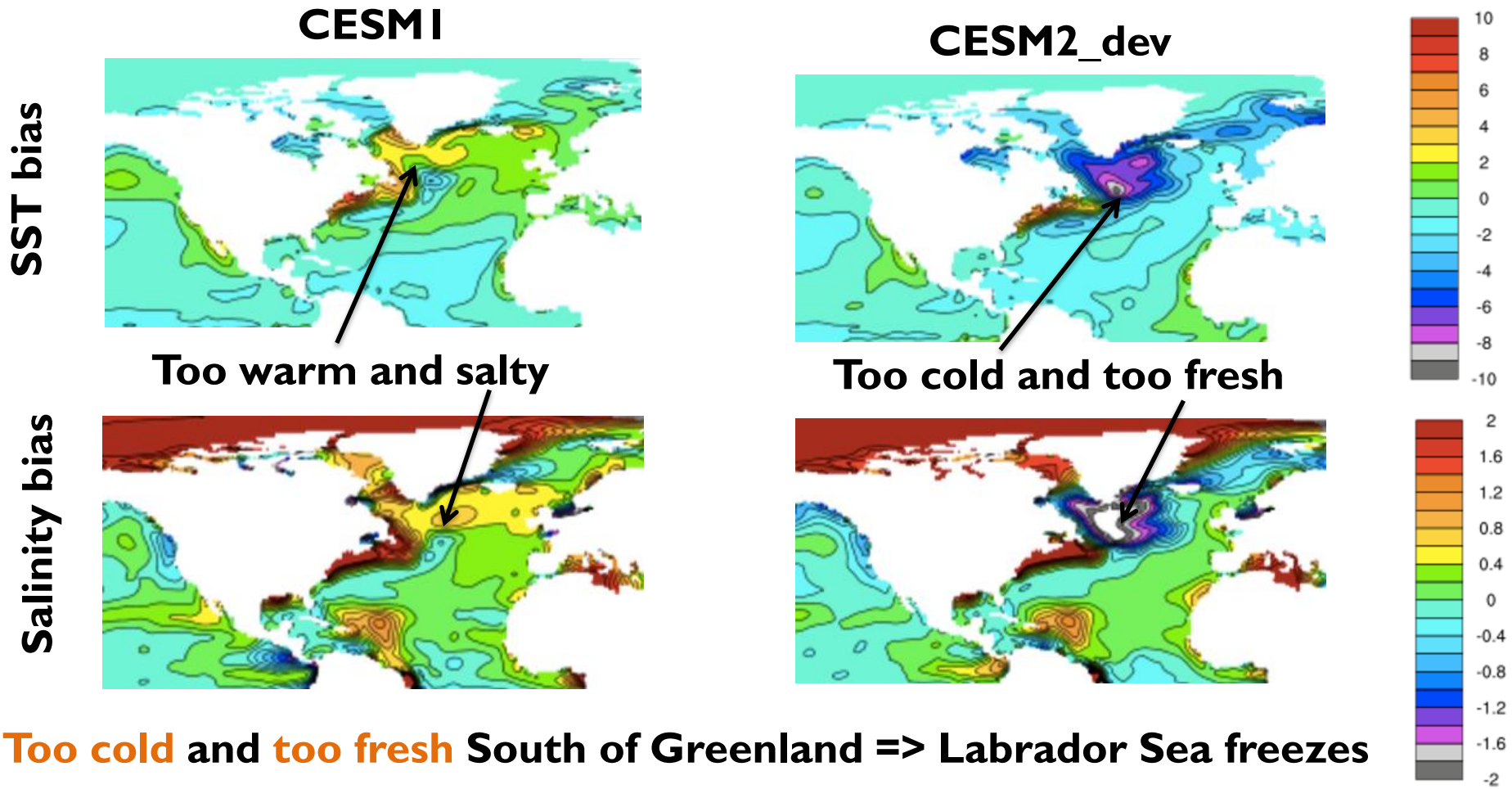
Sea-ice extent is close to obs.
Labrador sea is ice free

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 ?**



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**