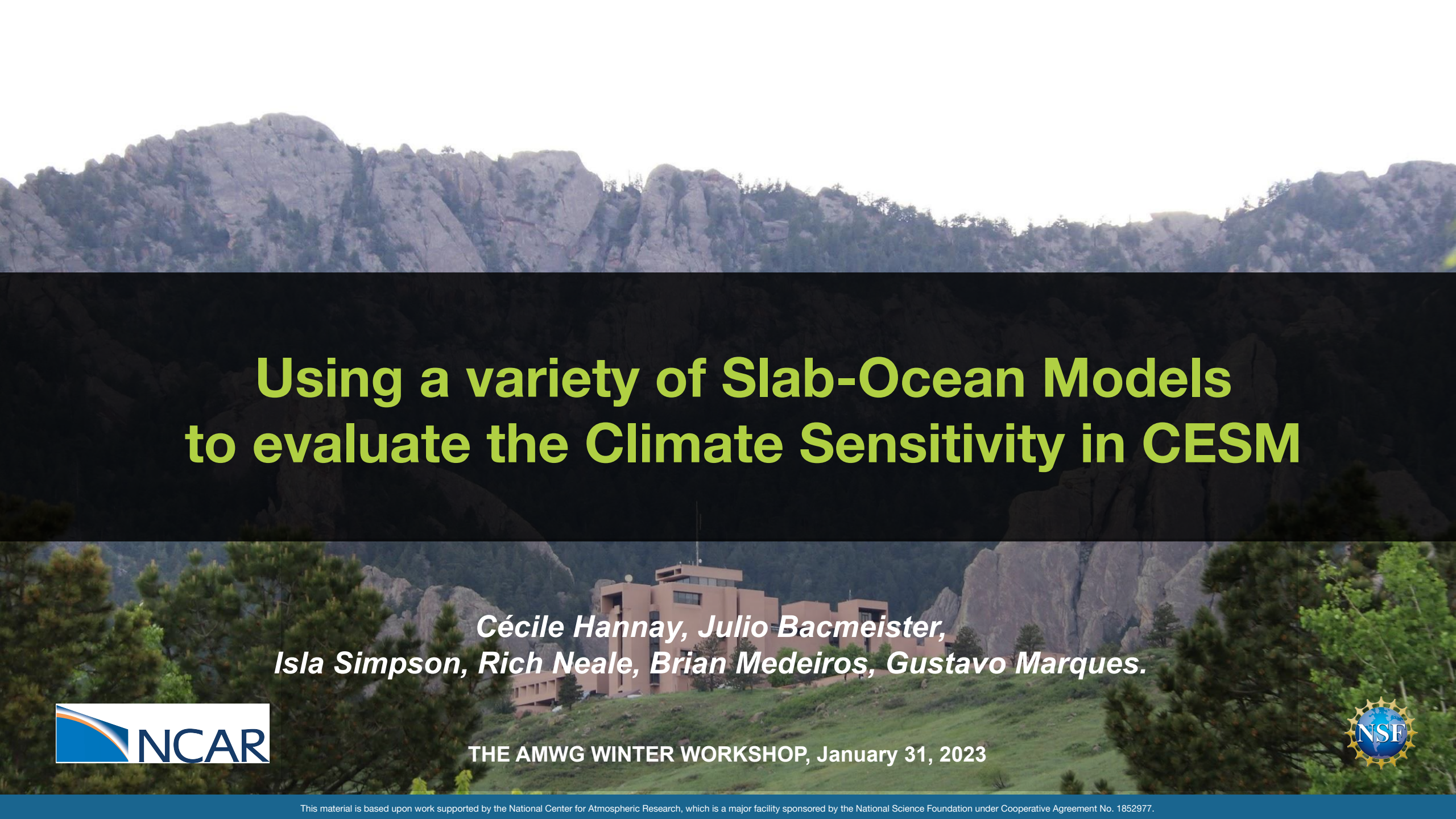

Using a variety of Slab-Ocean Models to evaluate the Climate Sensitivity in CESM

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NCAR

THE AMWG WINTER WORKSHOP, January 31, 2023

NSF

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Motivation

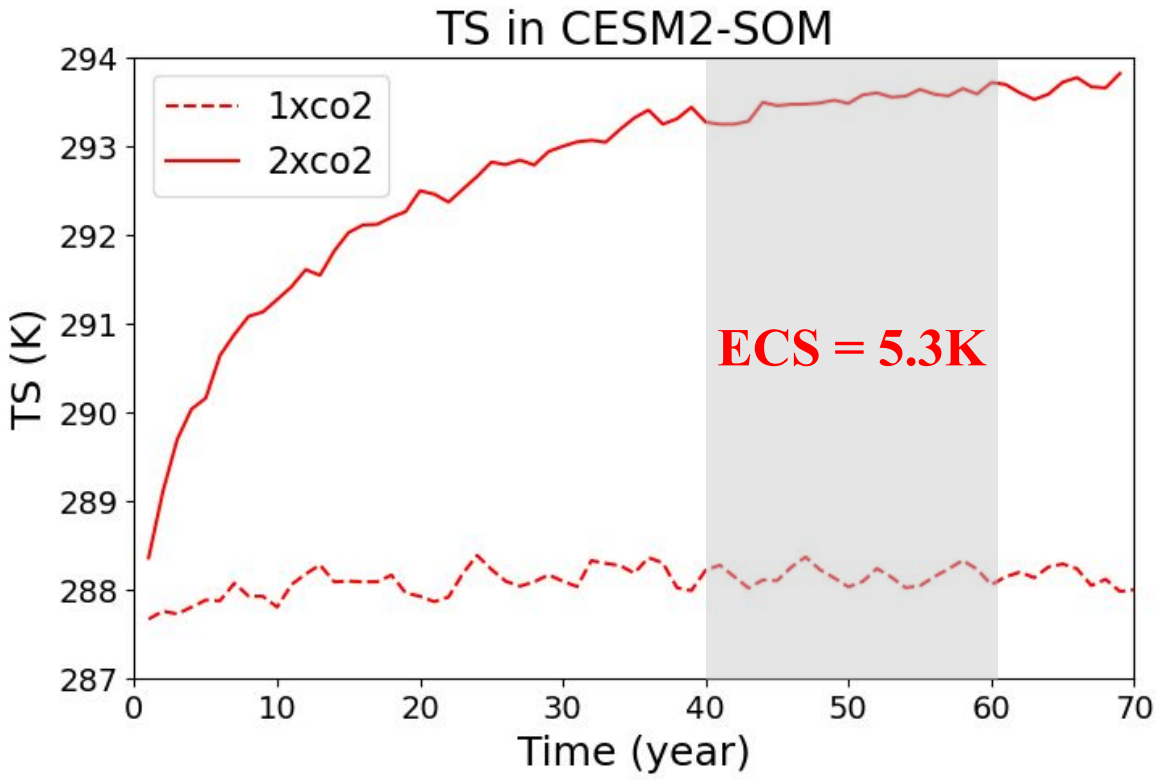
Equilibrium Climate Sensitivity (ECS) = globally averaged equilibrium surface temperature response to a doubling of CO_2

The current procedure to estimate the ECS in CESM is fairly involved.

Could we simplify the procedure ?

Estimating Equilibrium Climate Sensitivity (ECS) in CESM

- Estimates of the ECS are typically obtained using a Slab Ocean Model (SOM)
- SOM = mixed layer ocean model with prescribed ocean heat fluxes ("qflux")
- Why SOM? Equilibrium after 10s years (SOM)⇔ 1000s years (coupled model).



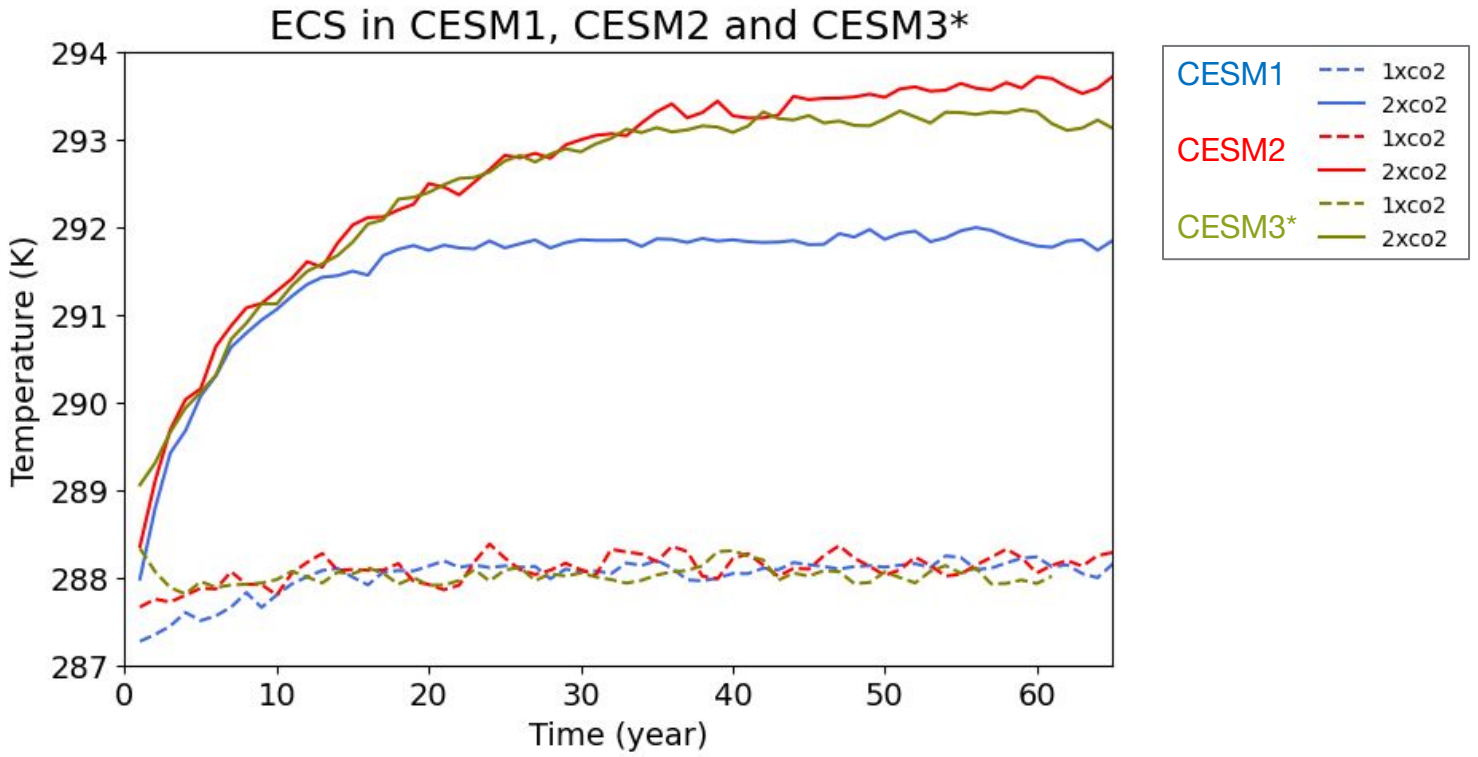
Typical SOM experiment with CESM

- 1xCO2 and 2xCO2 runs
- 1xCO2: no drift in global annual TS.
- 2xCO2: quasi-equilibrium after 40^{ish} years
- ECS is obtained from years 40-60 (*)

(*) other methods exist (Gregory plot, radiative kernels...). Not covered here.

ECS in CESM1, CESM2 and CESM3*

- Different versions of CESM have a different climate sensitivities
- CESM1 => CESM2: ECS increases by 1K (due to cloud feedback)
- CESM2 => CESM3*: ECS is similar in initial estimates



Climate sensitivity

CESM1: 3.8K

CESM2: 5.3K

CESM3*: 5.2K

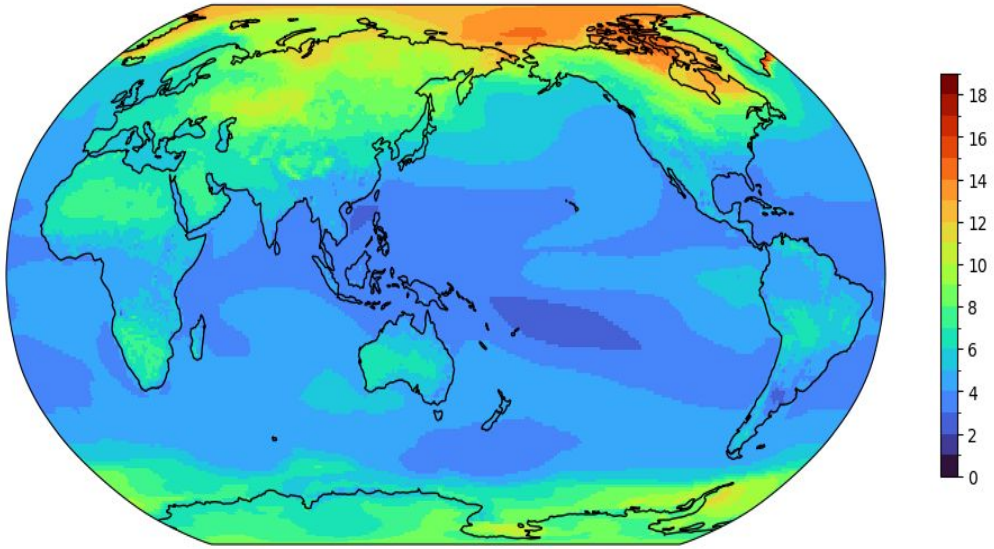
CESM3* = our development version of "CAM-SE-L58 + MOM6"

ECS is not the whole story => Regional differences

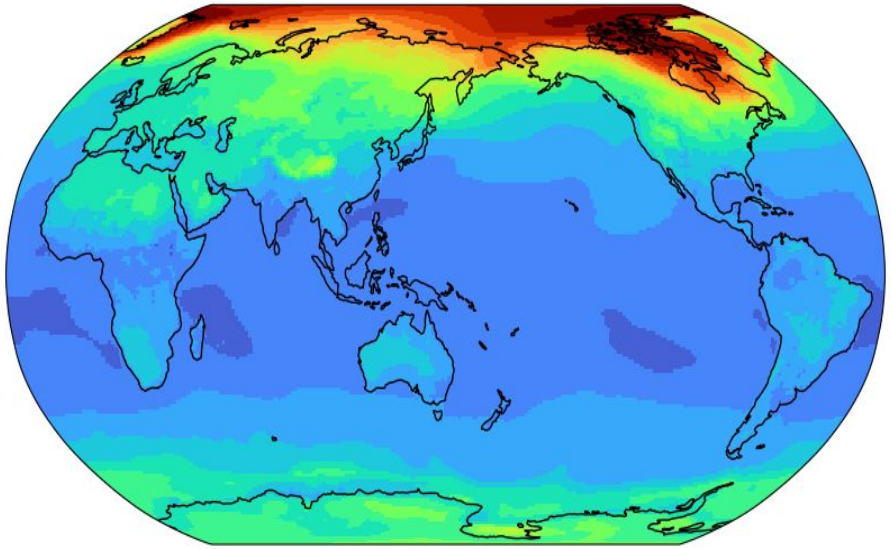
- **ECS is only one measure of the climate sensitivity.**
- **Models that agree in terms of the ECS can have very different regional response to increased greenhouse gases (i.e CESM2 and CESM3*)**

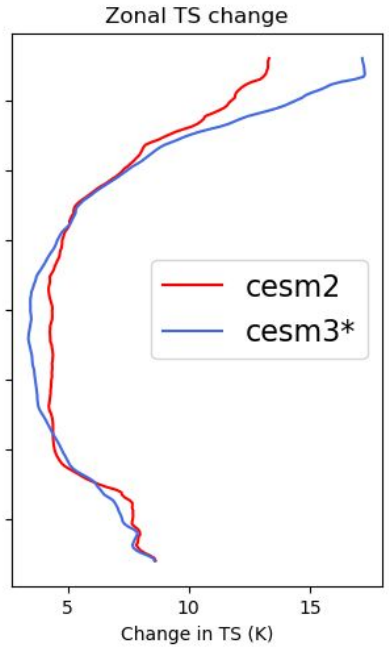
Annual TS change when doubling 2xco2 (years 40-60)

CESM2 (ECS = 5.3K)



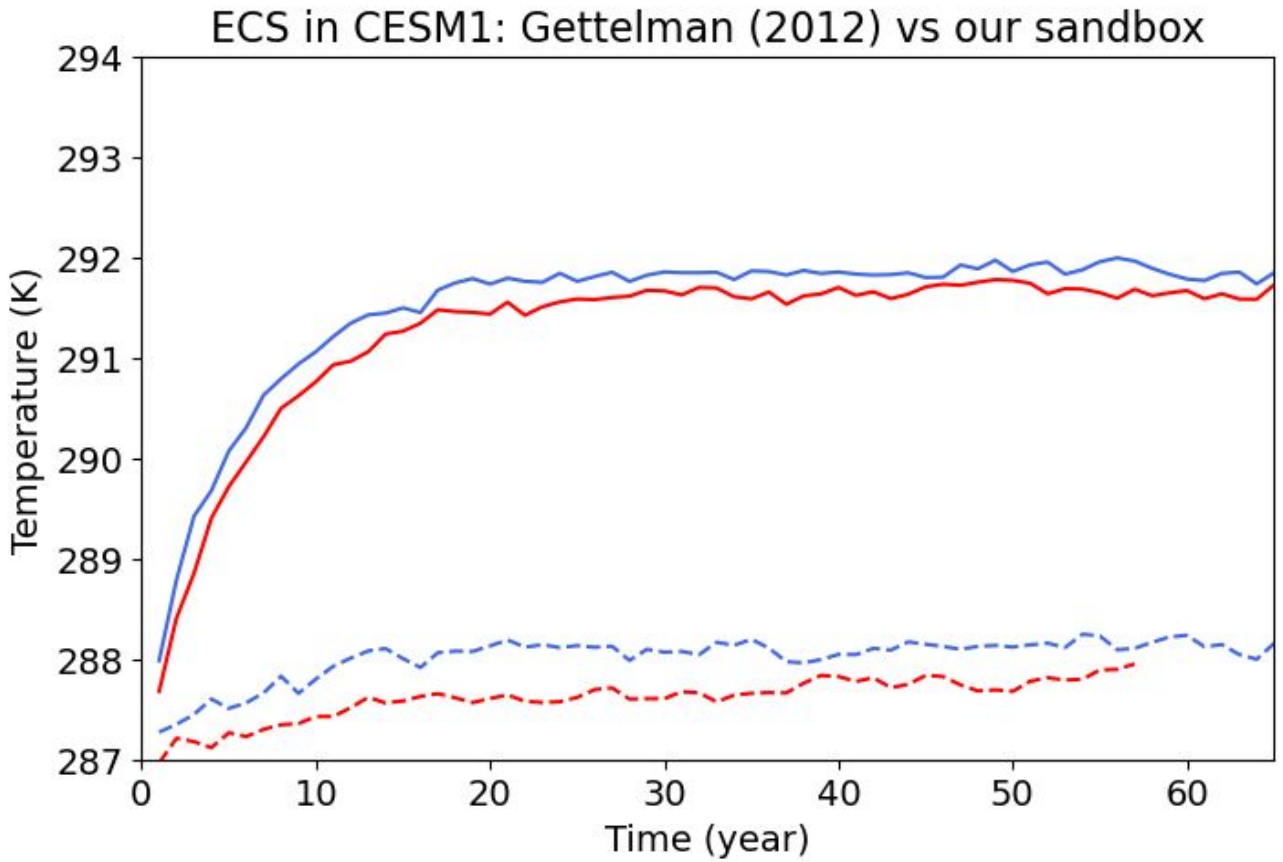
CESM3* (ECS = 5.2K)





A quick word about the CESM1 climate sensitivity

We are aware CESM1 ECS in our SOM experiments is slightly different from Gettelman et al (2012)



CESM1 climate sensitivity

Gettelman et al: ECS = 4.0K

Our sandbox: ECS = 3.8K

Procedure to estimate the "qflux" in CESM

- Requires 50-year well balanced coupled run (in same "configuration")
- qflux are computed from the coupled run using the equation:

$$\rho_o \, c_p \, h_{mix} \frac{\partial SST}{\partial t} = F_{net} + \; q_{flux}$$

where:

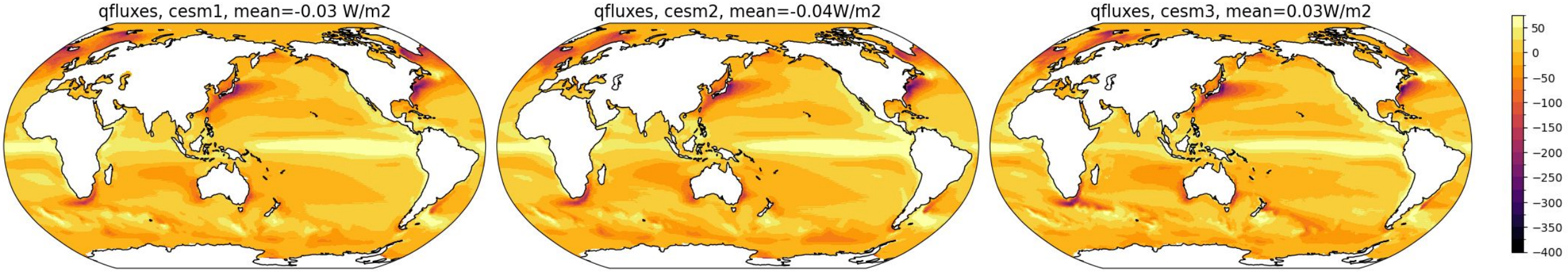
SST = Sea Surface Temperatures
ρ_o = density of seawater
c_p = ocean heat capacity
h_{mix} = mix layer depth
F_{net} = net heat fluxes into the ocean (from atm and sea-ice)
q_{flux} = deep ocean heat fluxes

q_{flux} are periodical (12 month) and normalized to have a global annual mean of zero

- This is fairly involved. Can we get away with a simplified method ?

Can we simplify the procedure to estimate the qfluxes?

How much do the details of the qflux matter in the assessment of the ECS?

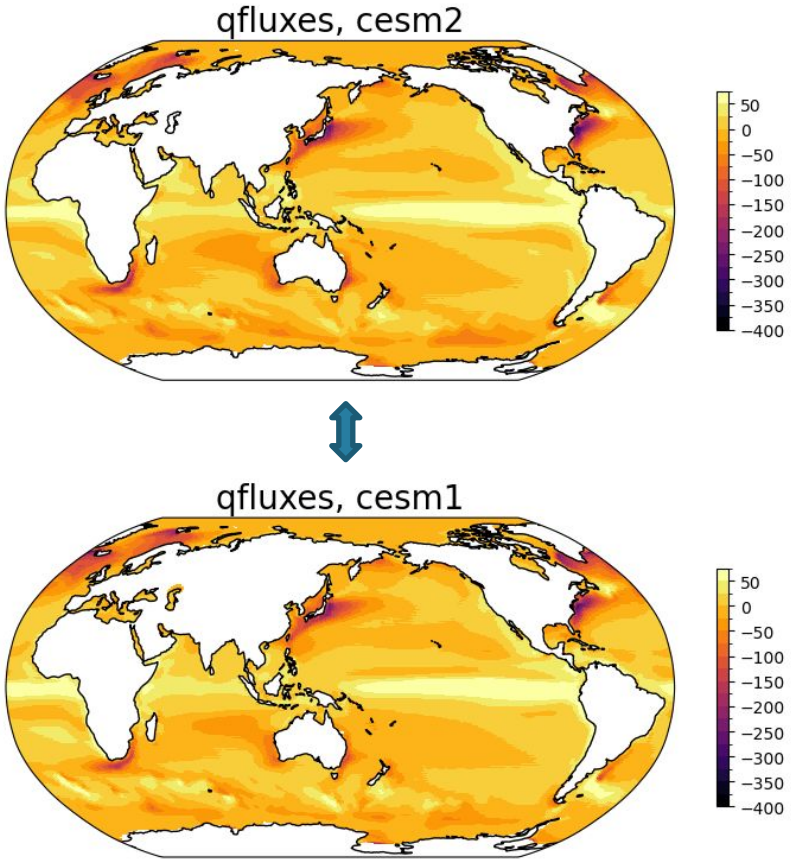


Two questions:

- Do we really need to compute qflux for every model version?
- Can we use an idealized qflux?

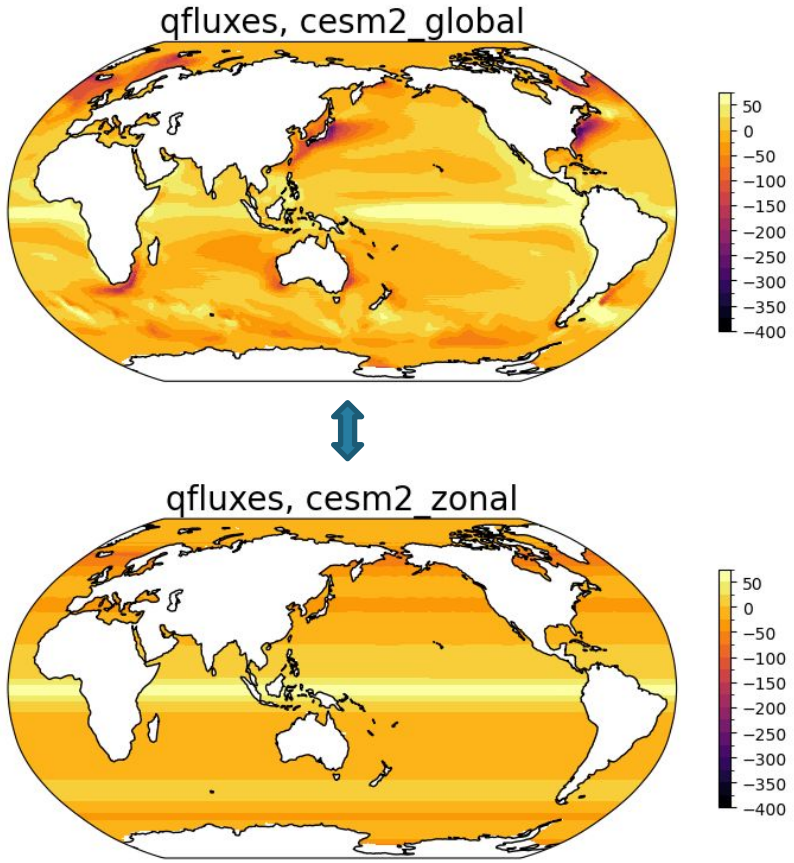
Swapping qflux in CESM2-SOM experiments

Q1: Do we really need to compute qflux for every model version?



Swapping cesm2 ⇔ cesm1 qflux

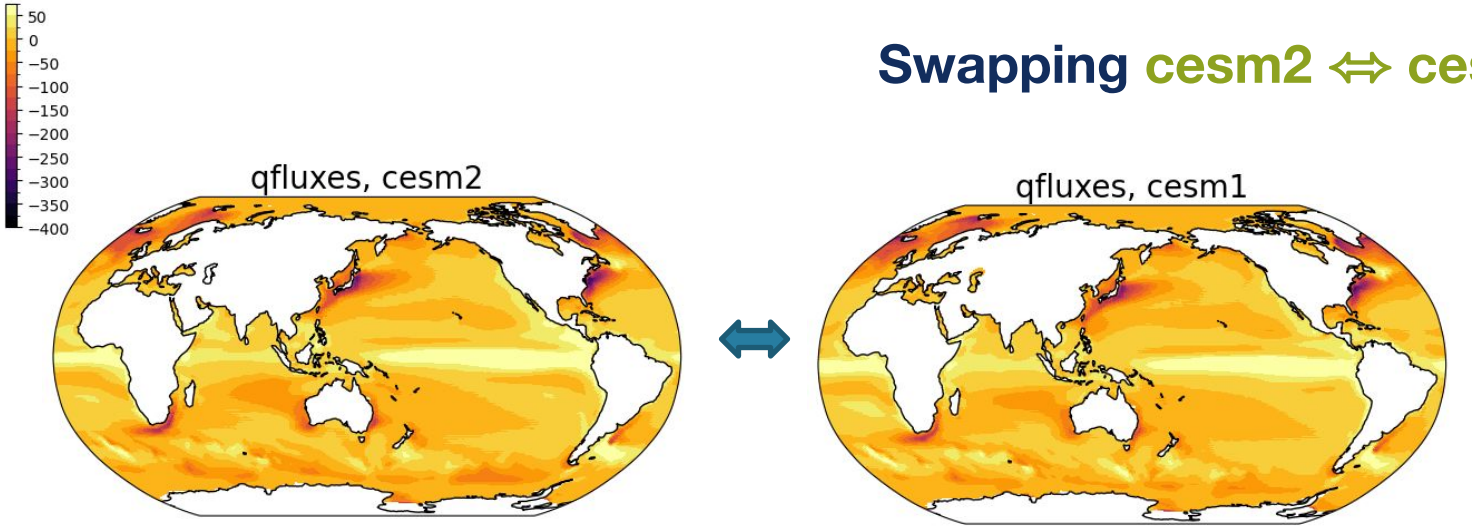
Q2: Can we use an idealized qflux?

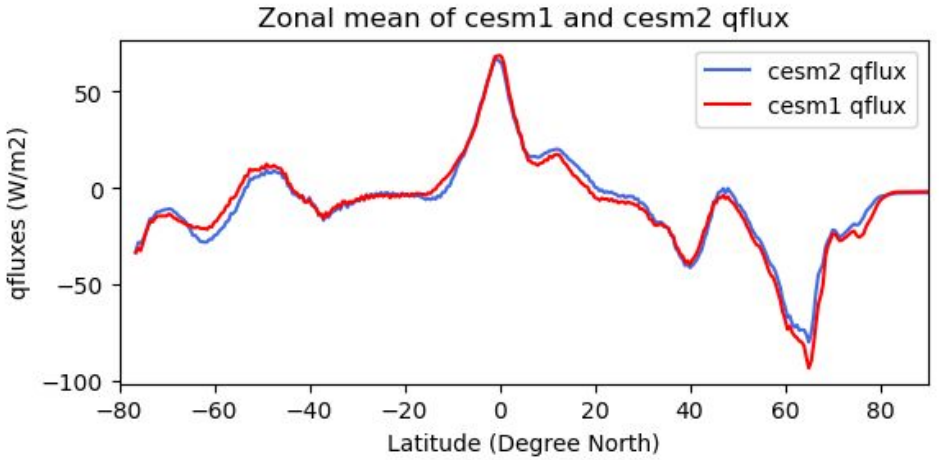


Swapping cesm2 ⇔ cesm2 zonal qflux

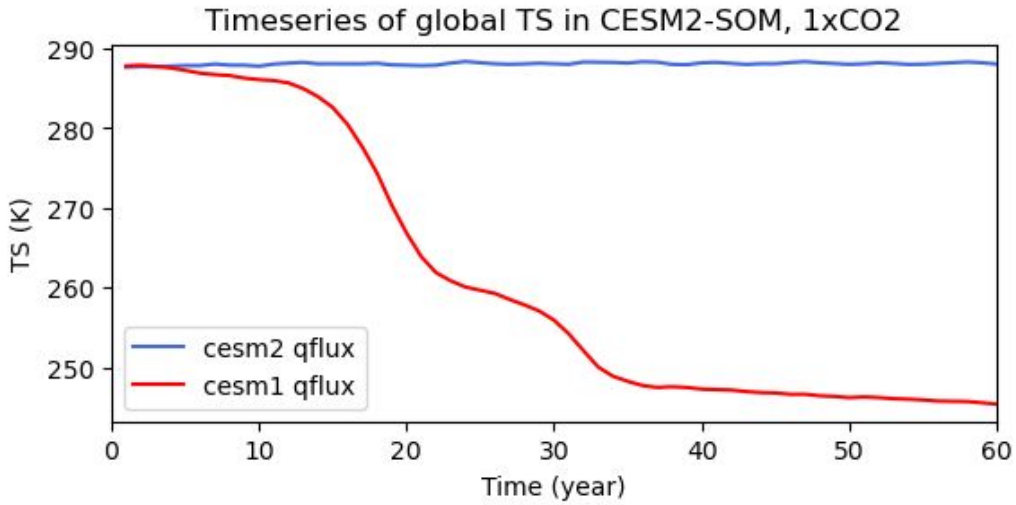
Running CESM2-SOM with CESM1 qflux

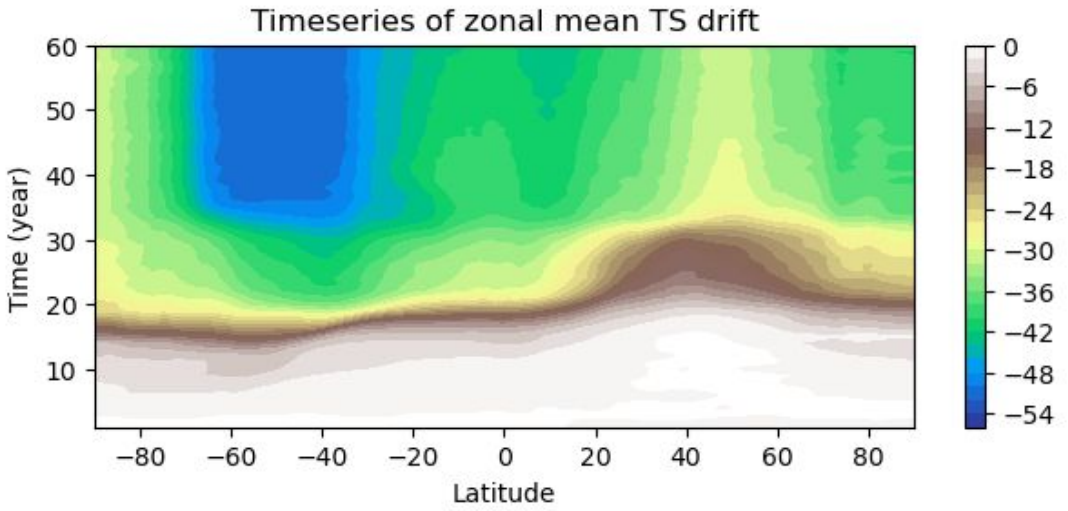
Swapping cesm2 ⇔ cesm1 qflux





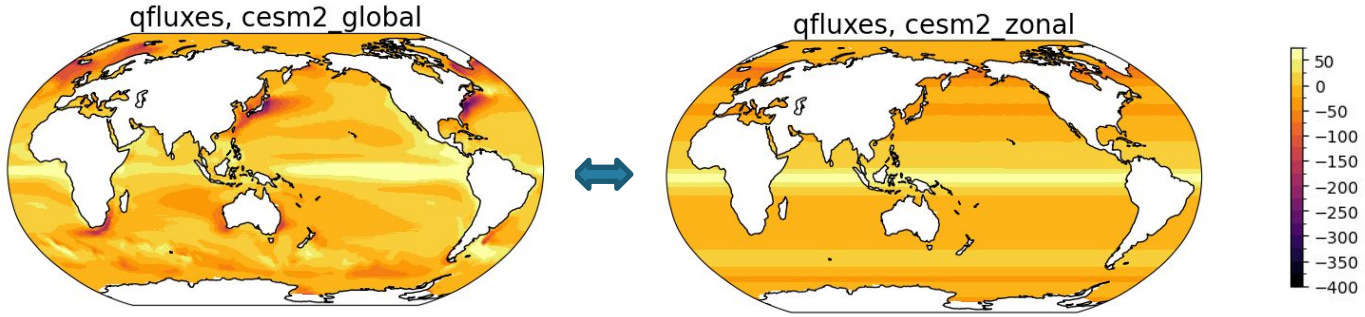
leads to catastrophic TS cooling (initially originating in the Southern Ocean)



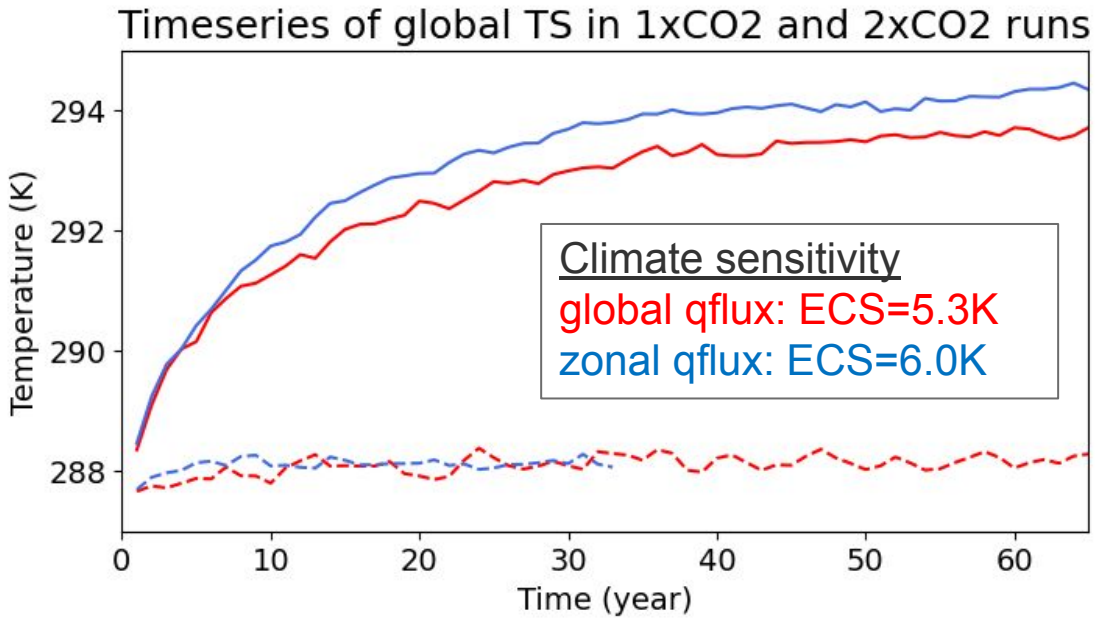


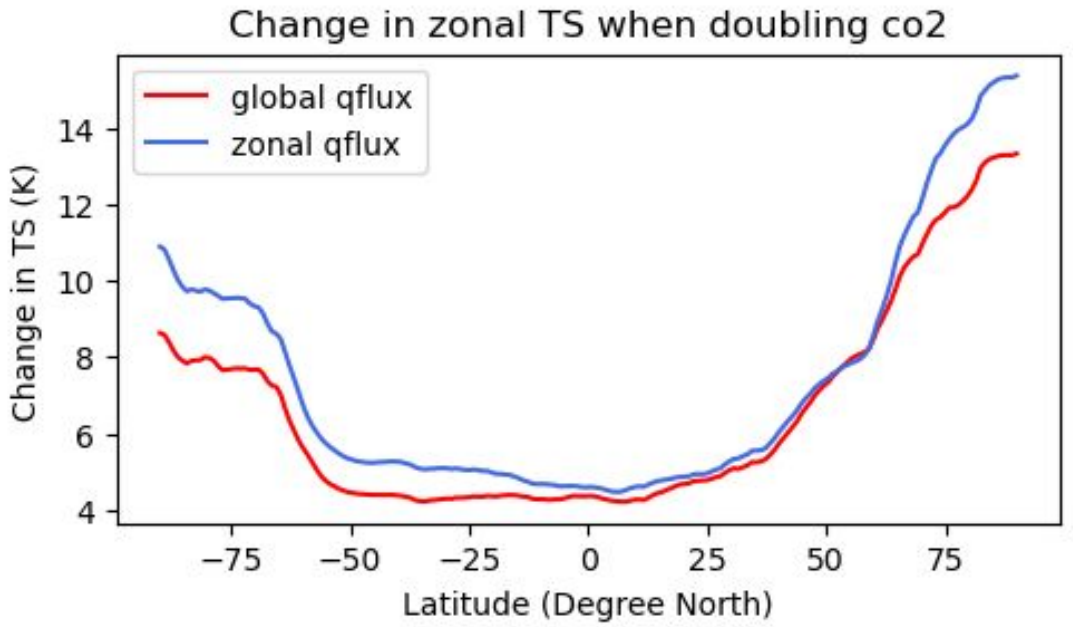
Running CESM2-SOM with an idealized qflux

Swapping cesm2 global⇔ cesm2 zonal qflux



increases the ECS (dominated by the SH and polar regions)





Conclusions

- The current procedure to estimate the ECS in CESM is fairly involved:
  It requires a 50-year well balanced coupled run.
  - How much do the details of the qflux matter in the assessment of the ECS?
  - Do we really need to compute qflux for every model version?
  - Can we use an idealized qflux?

- The details of the qflux between model versions matter
  - Swapping cesm1 qflux ⇔ cesm2 qflux => catastrophic cooling of TS
  - Southern Hemisphere (especially Southern ocean) matters the most
  - More work is needed to understand when a new qflux (between versions) is required
  - Potential role of sea-ice

- Exploring idealized qflux
  - Swapping cesm2 global qflux ⇔ cesm2 zonal qflux => promising results
  - Are there options to build an idealized qflux ?

Questions ?