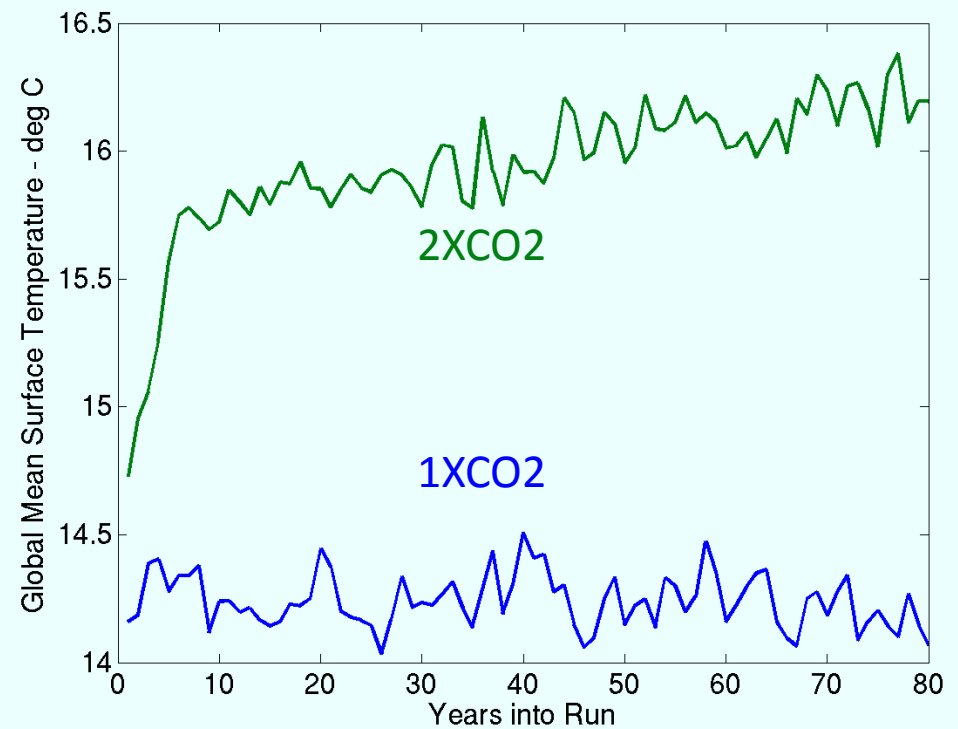
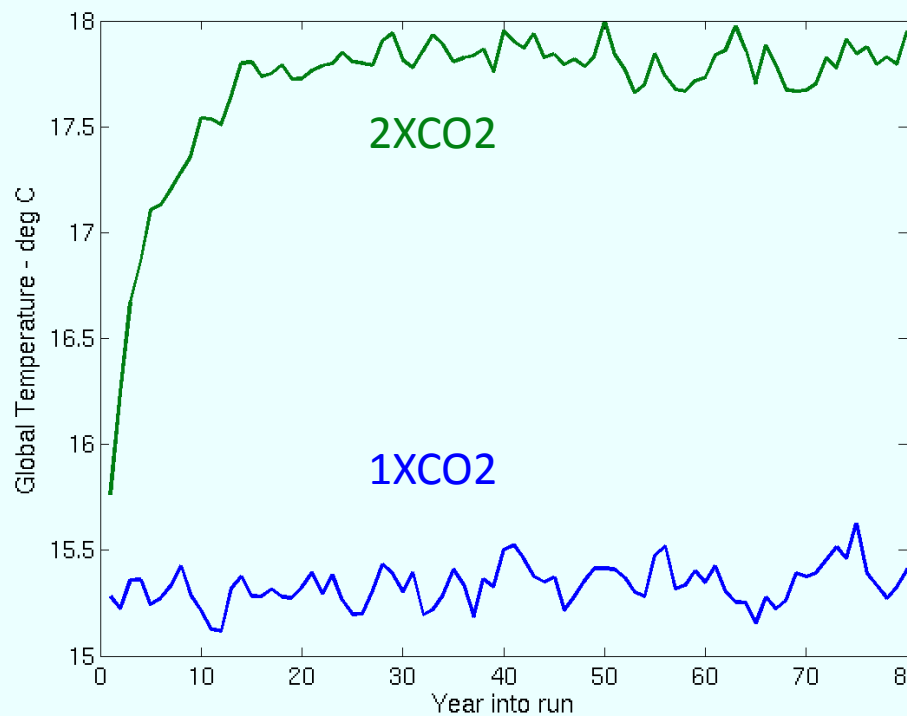


Global climate model simulations in exercise 6 are using Community Climate System Model Version 4 (**CCSM4**) – these are for IPCC AR5.

The runs in HW6 employ a Slab Ocean Model (**SOM**) rather than the full Ocean General Circulation Model (**OGCM**). The resolution is 2 deg in the atmosphere and land and 1 deg in the SOM and sea ice.

Which pair of curves are from CCSM4 with an OGCM/SOM?

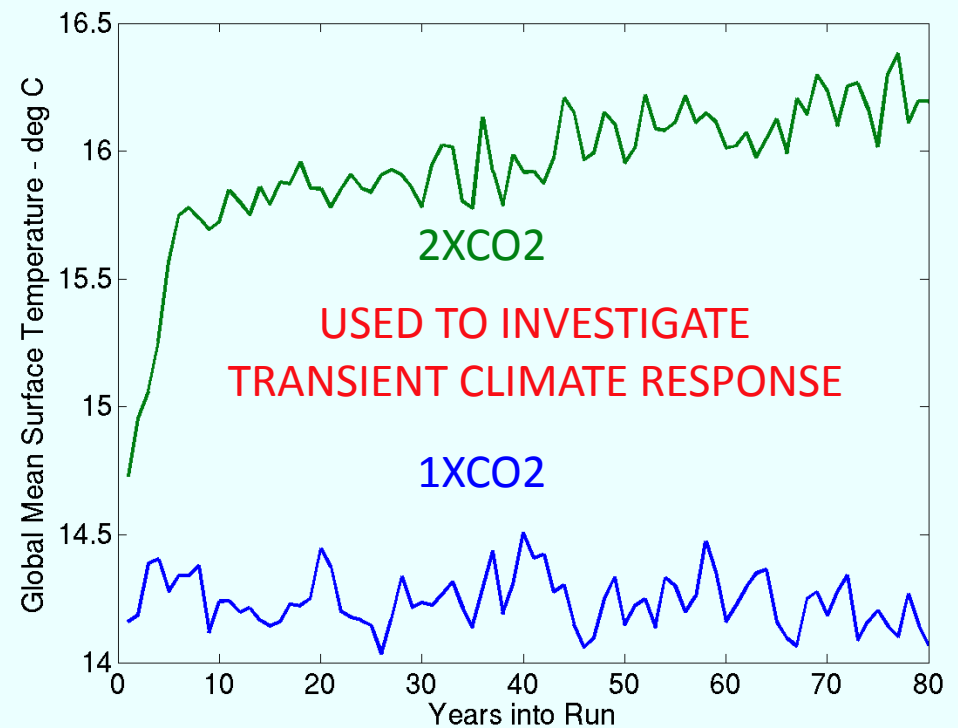
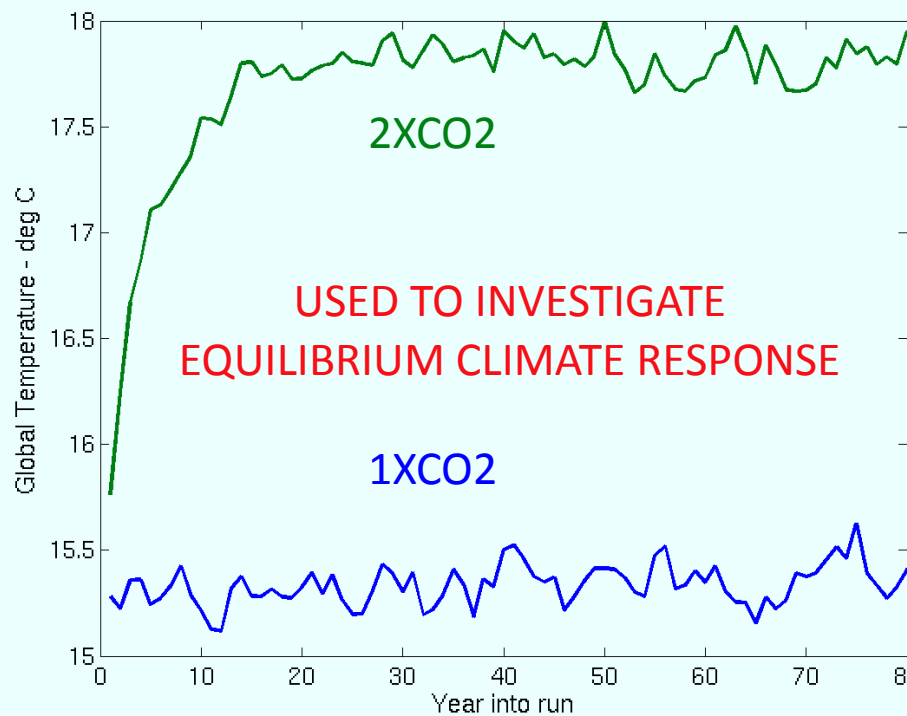
How can you tell?



In the 2XCO2 runs, CO2 is doubled instantly at the start

Which pair of curves are from CCSM4 with an OGCM/SOM?

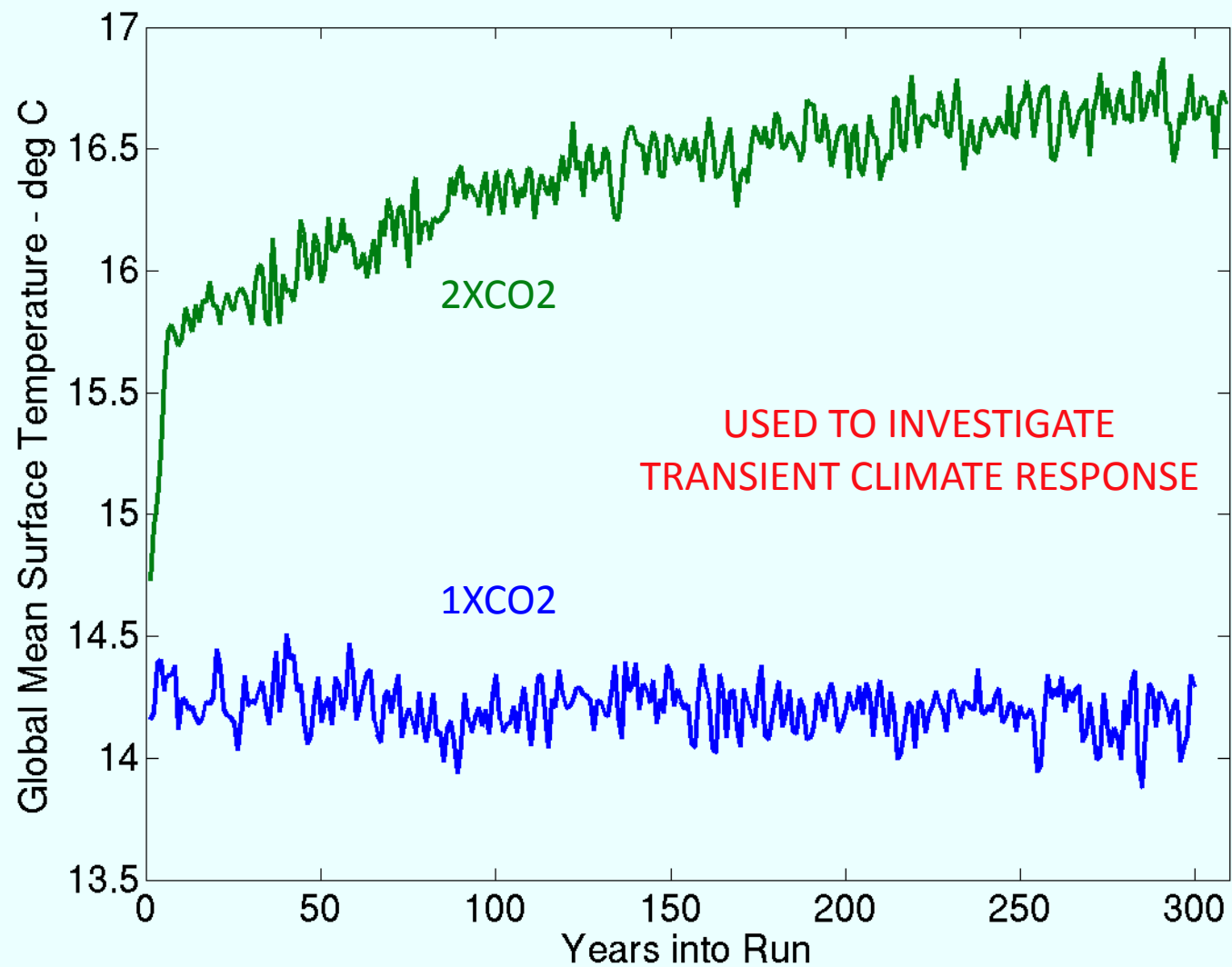
How can you tell?



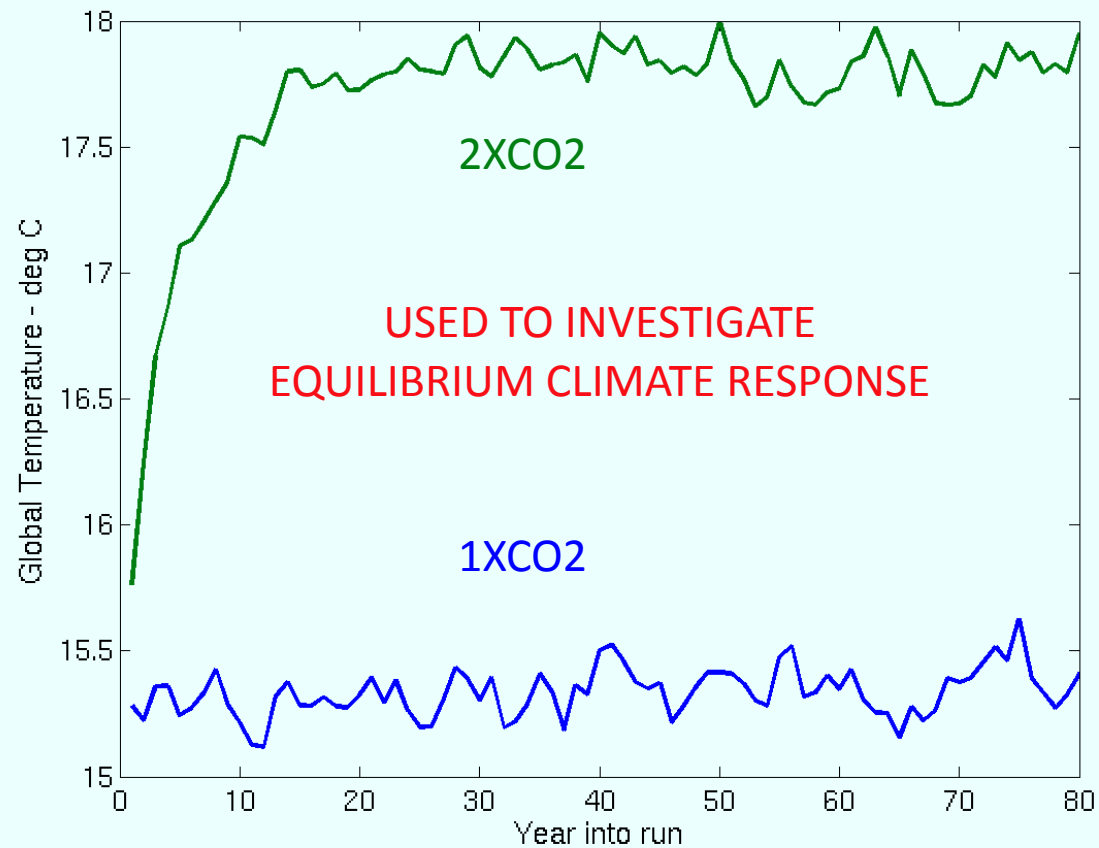
In the 2XCO2 runs, CO2 is doubled instantly at the start

In the OGCM Is the 2XCO2 run equilibrated yet?

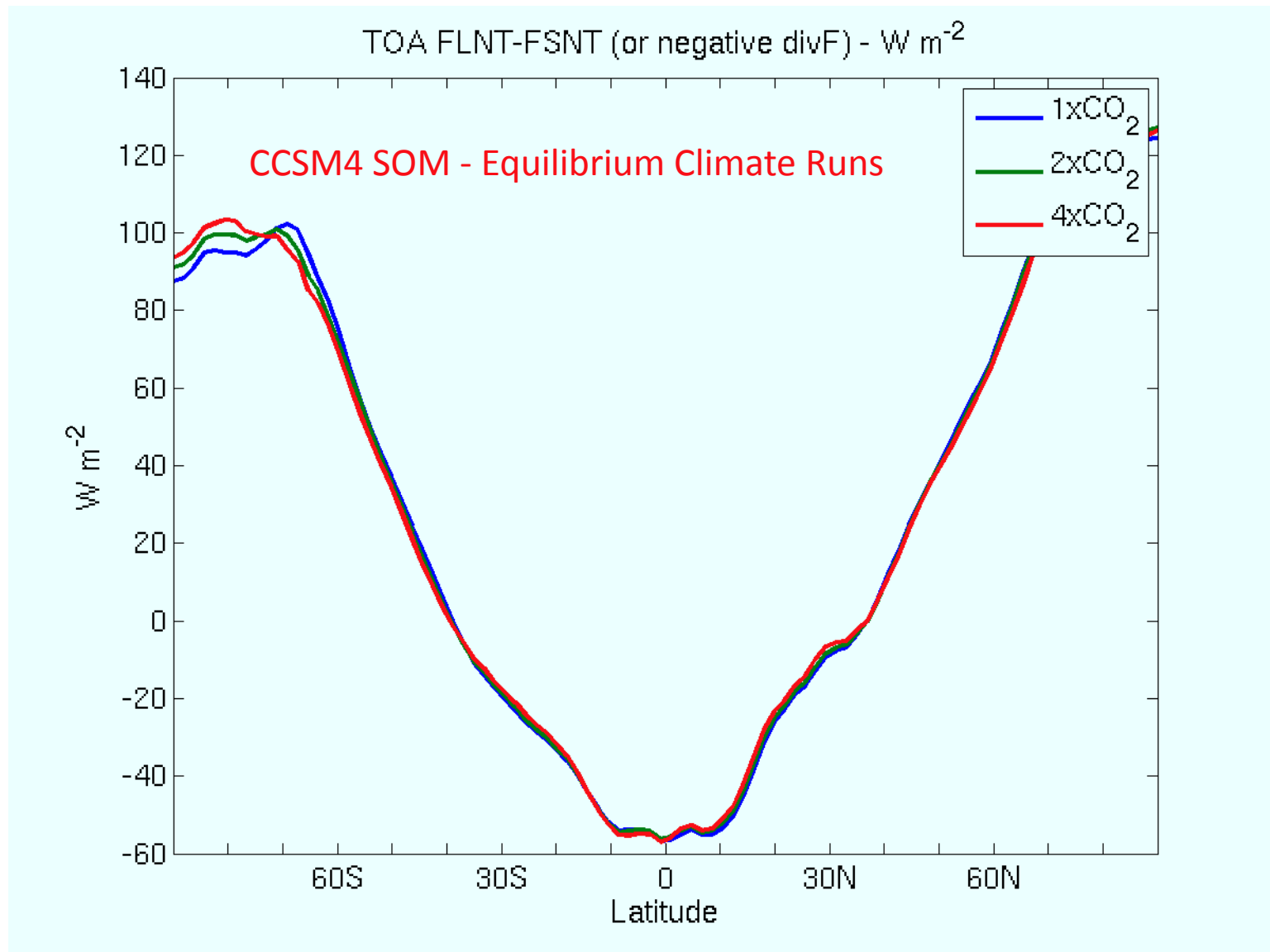
How can you tell?



What are the slowest timescales in the SOM version?

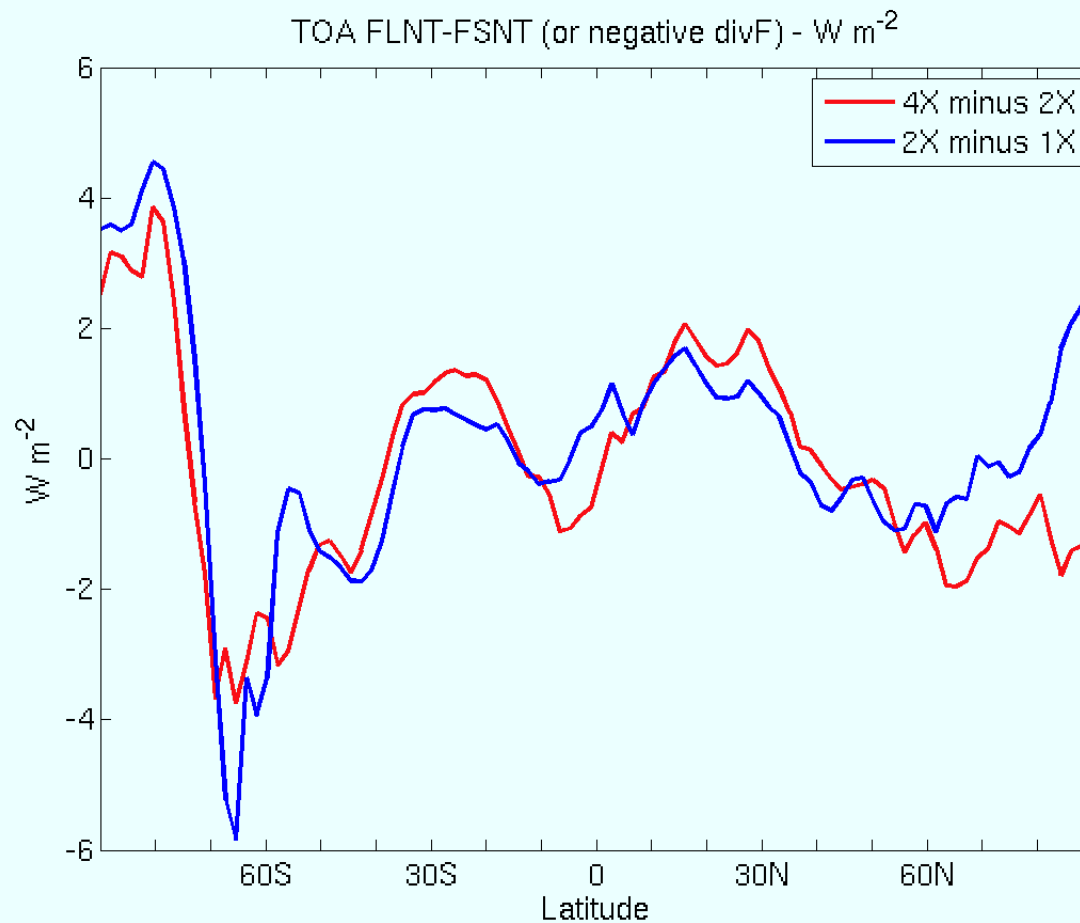


TOA F_{OUT} minus F_{IN} = Convergence of heat by horizontal transport



New Script analyze_ex6_b.m for you to use on Homework 6 (optional)

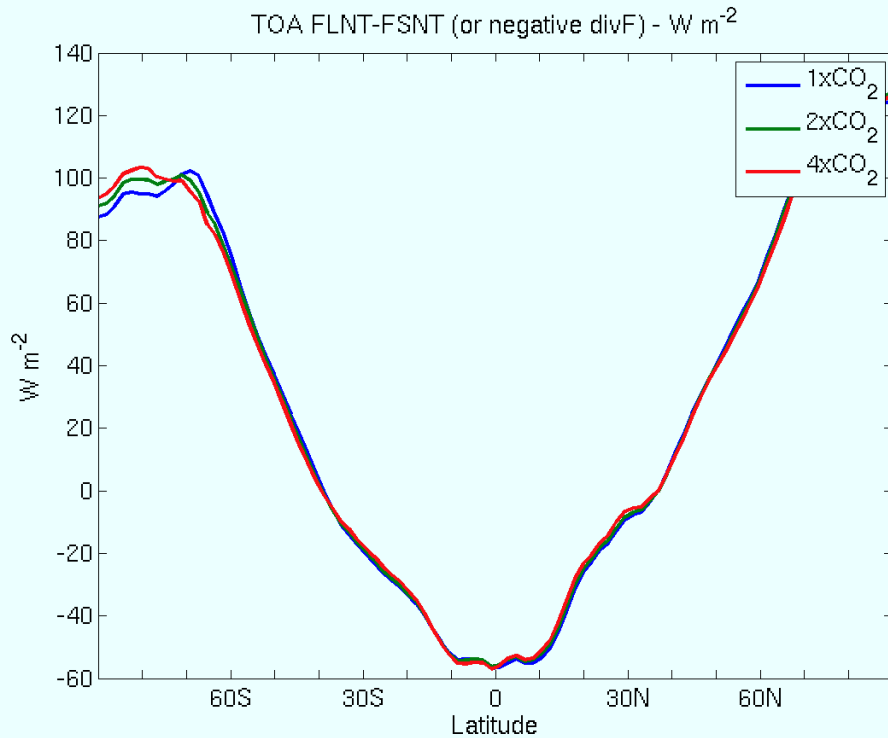
CCSM3 Equilibrium Climate Runs



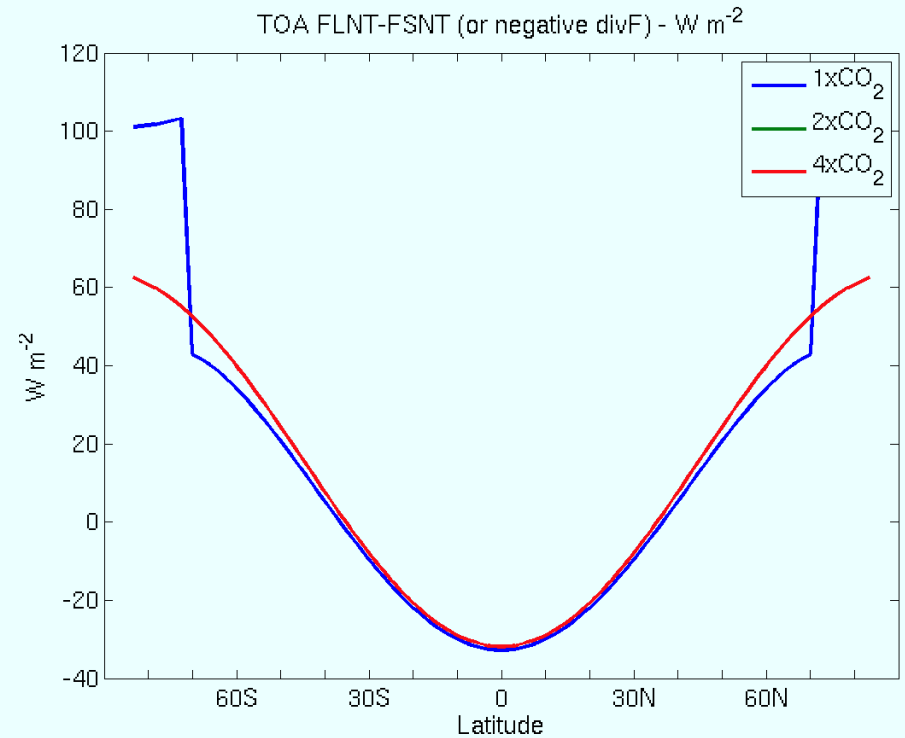
Generally less heat converging into the poles (except very close to South Pole) and less heat transported away from the tropics and midlatitudes in this model – classic view of polar amplification causing reduced pole-to-equator temperature gradient and weaker storms (not overcome by more moisture in this model).

TOA F_{OUT} minus F_{IN} = Convergence of heat by horizontal transport

CCSM4



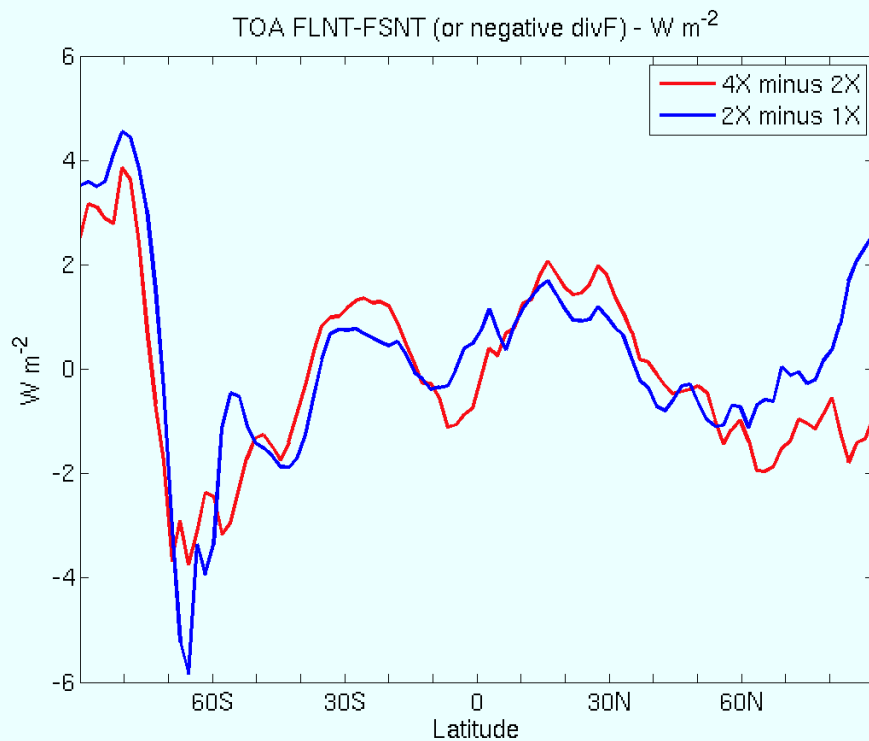
EBM



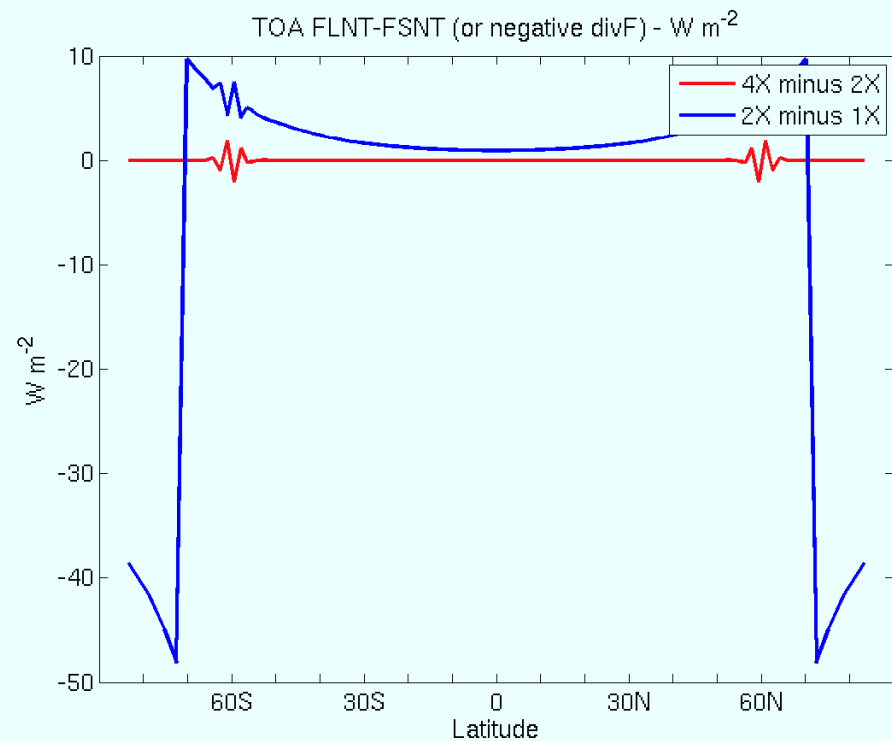
Warning divF in the EBM is off by -1 (Sorry!)
I fixed it in these plots

CCSM4 Equilibrium Climate Runs

CCSM4



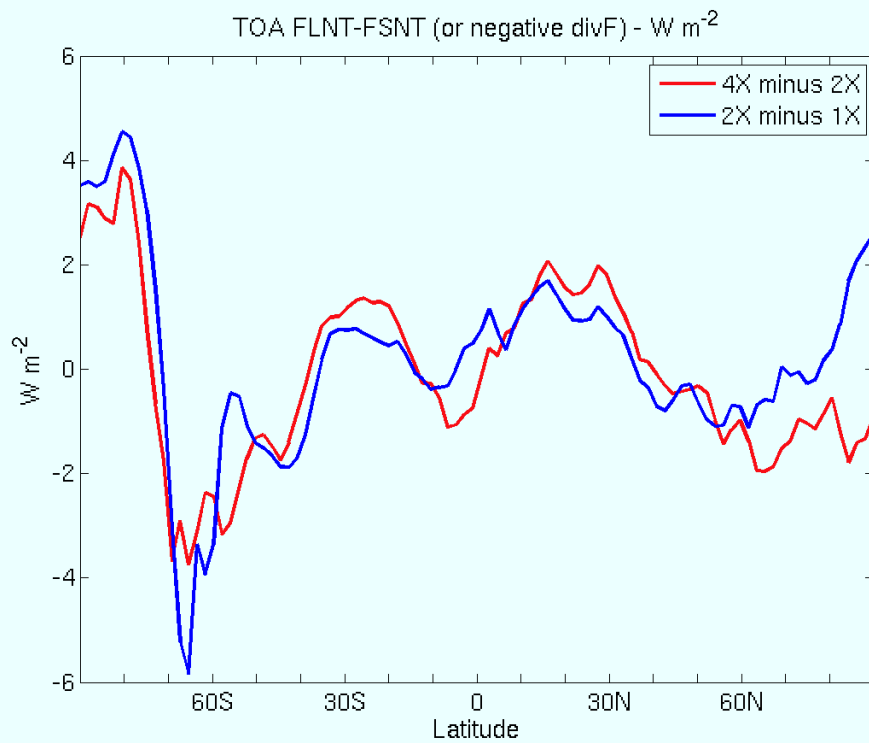
EBM



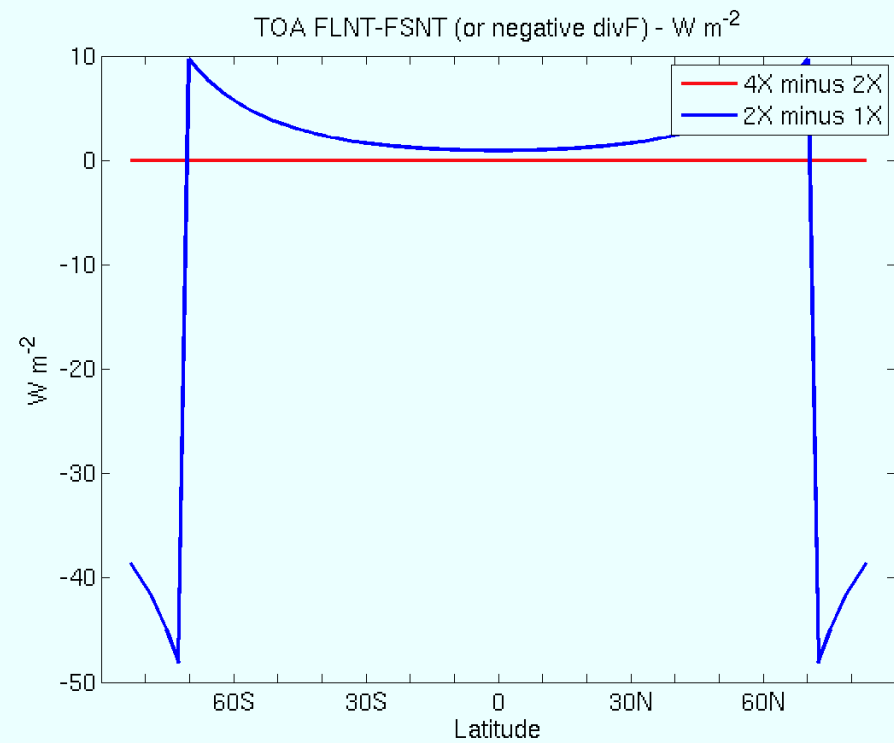
Strange wiggles in EBM are due to too large time step. The model has an implicit solution so it doesn't blow up, but it was nearly violating the Courant condition for the second order derivative that appears in the heat transport

CCSM4 Equilibrium Climate Runs

CCSM4

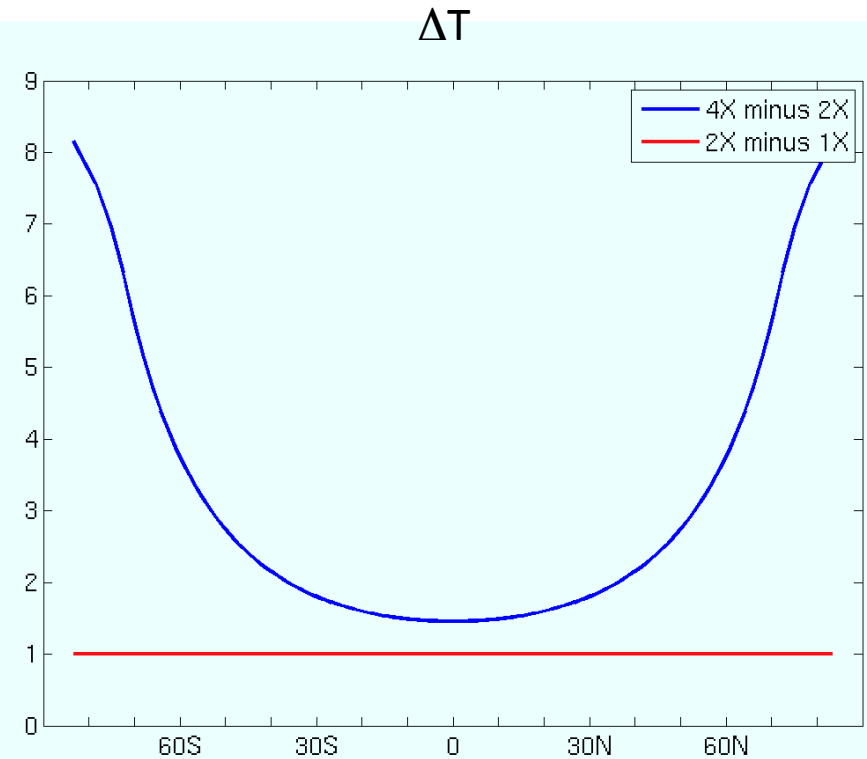
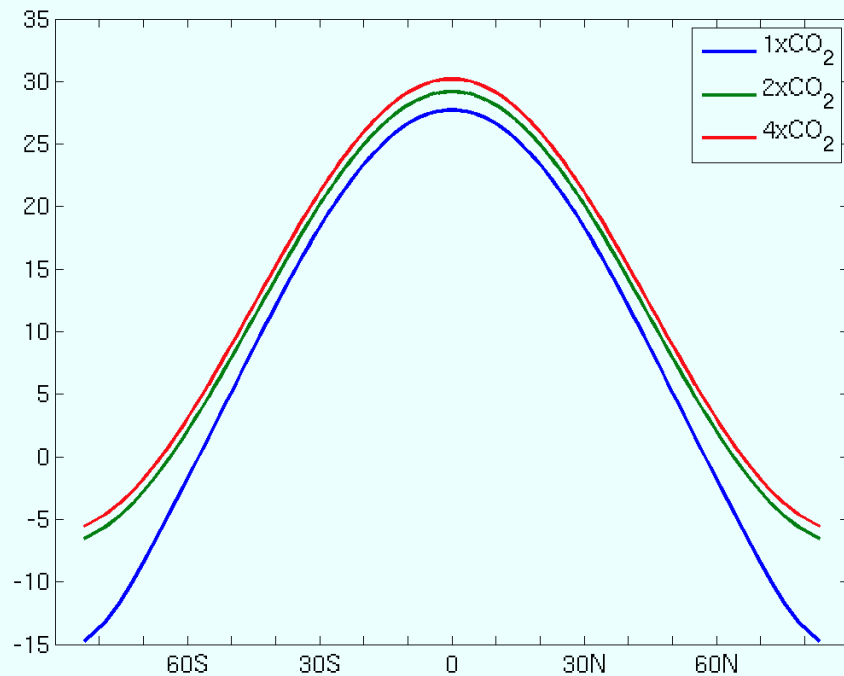


EBM



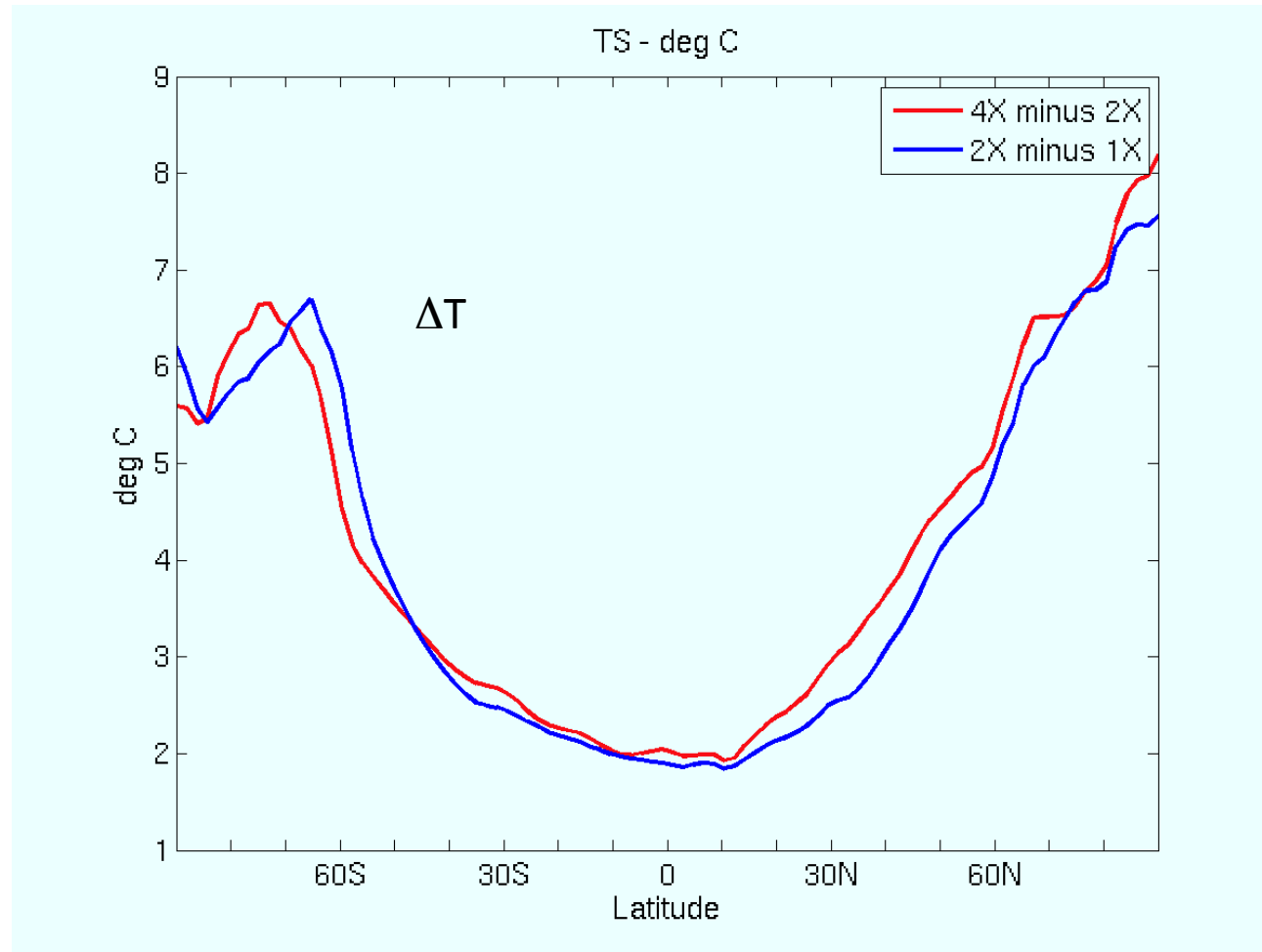
Reducing the EBM time step by 50% fixed it without changing the answer (whew!)

EBM Temperature as a function of CO₂ – through changes to variable A
in the Outgoing Longwave Radiation = $A + B T$



2X and 4X CO₂ runs have no ice! And hence have no polar amplification!
IN THIS MODEL!
(Temperature Change is VERY nonlinear in A)

CCSM4 Temperature Change as a function of CO2



All runs have sea ice and snow, though less and less with rising CO2
IN THIS MODEL!
(Temperature change is far more linear in this model)

Hey wait a minute!

The super simple model is far more non linear

Should I be surprised?

No

Imagine the CO2 Level Doubled Instantly

Less heat escapes, so

F_{OUT} decreases

“Radiative Forcing”

$$\Delta Q = F_{IN} - F_{OUT} = 3.7 \text{ W/m}^2$$

(estimated to within a few tenths)

Feedback Theory

$$\lambda \Delta T = \Delta Q$$

Note:

Δ : common symbol to refer to change in some quantity

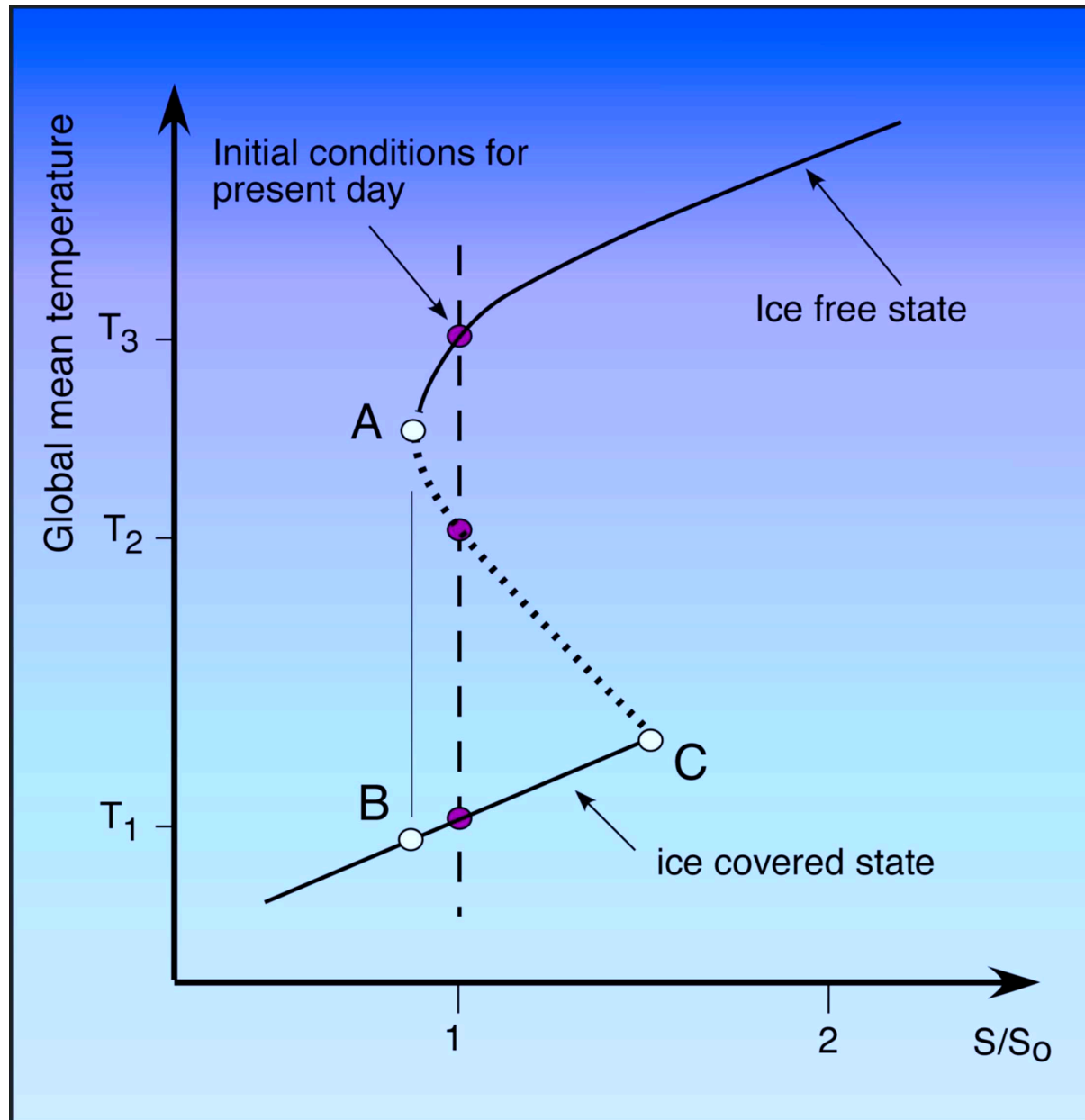
ΔQ : radiative forcing (or instantaneous change in energy balance)

ΔT : response (change in surface temperature)

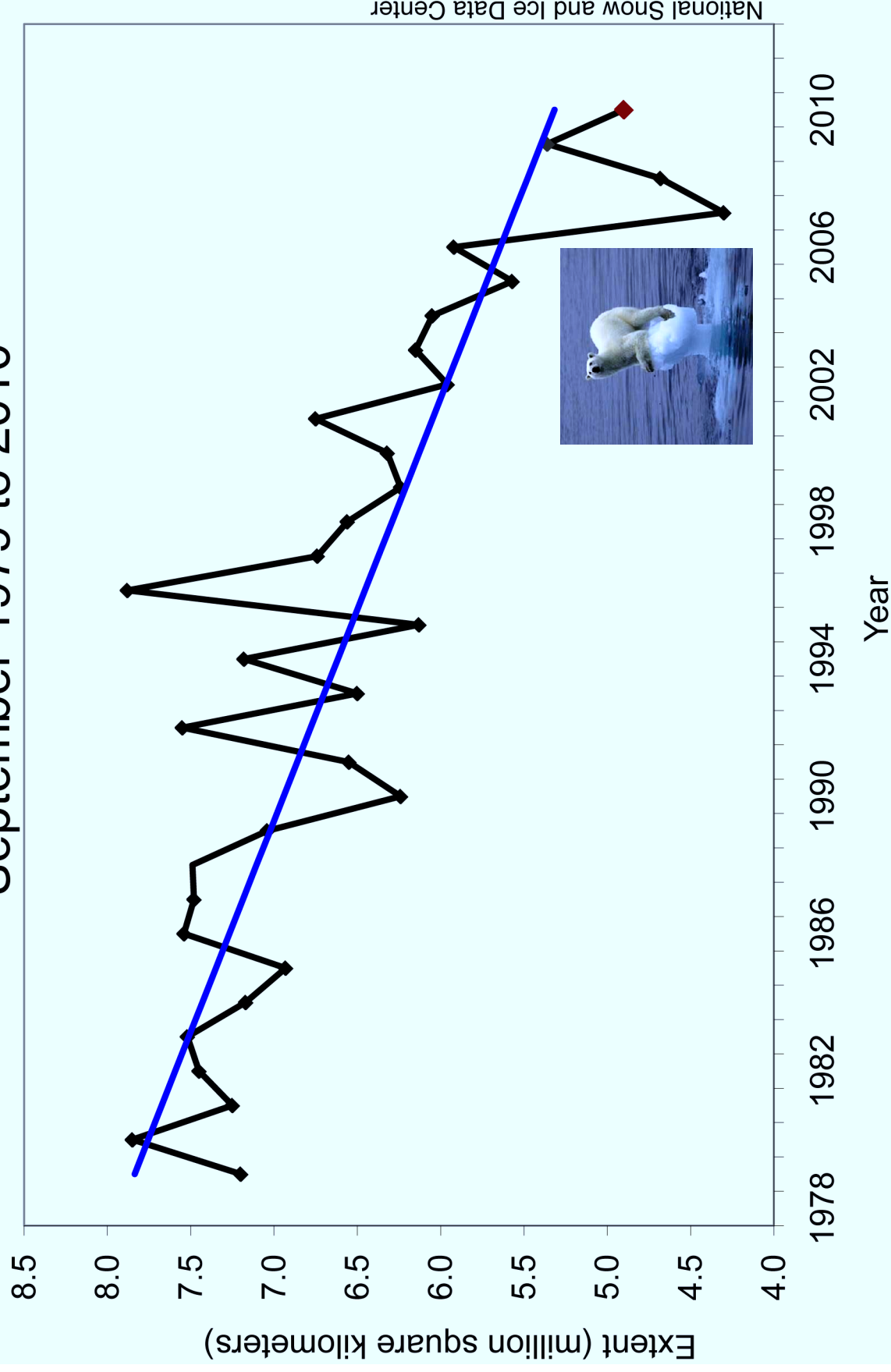
λ : total climate feedback (everything else)

λ : does not represent the wavelength of light here!

McGuffie and Henderson-Sellers Fig 3.4 on the stability of the EBM



Average Monthly Arctic Sea Ice Extent September 1979 to 2010



Commentary

Nature Reports Climate Change

Published online: 9 October 2008 | [Corrected online: 13 October 2008](#) |
doi:10.1038/climate.2008.108

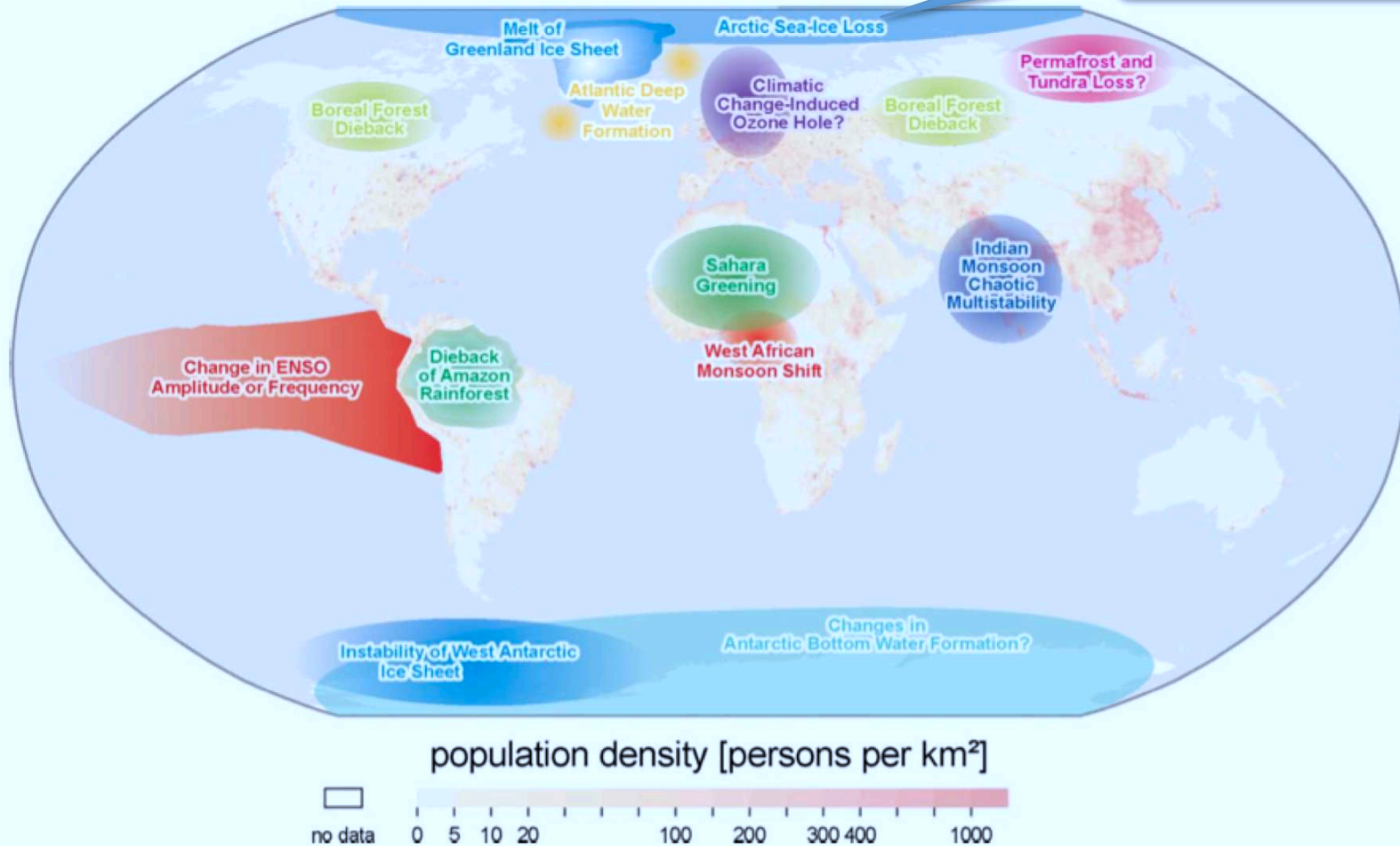
Standing on the brink

Mark C. Serreze & Julianne C. Stroeve

The emerging view is that if we're still waiting for the rapid slide towards this ice-free state, we won't be waiting much longer.

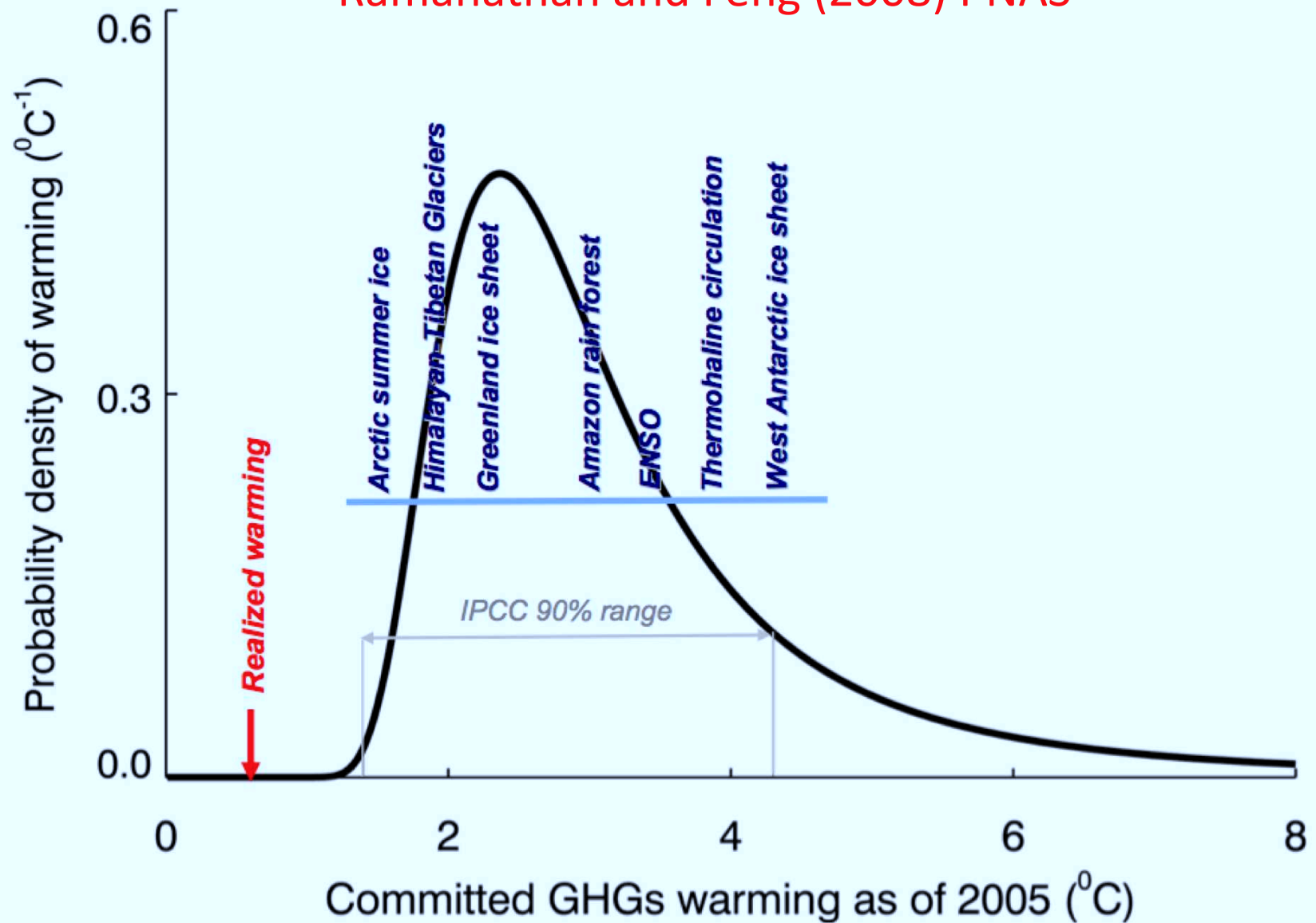
Lenton et al (2008) PNAS

Tips with 0.5-2C
warming since 1990

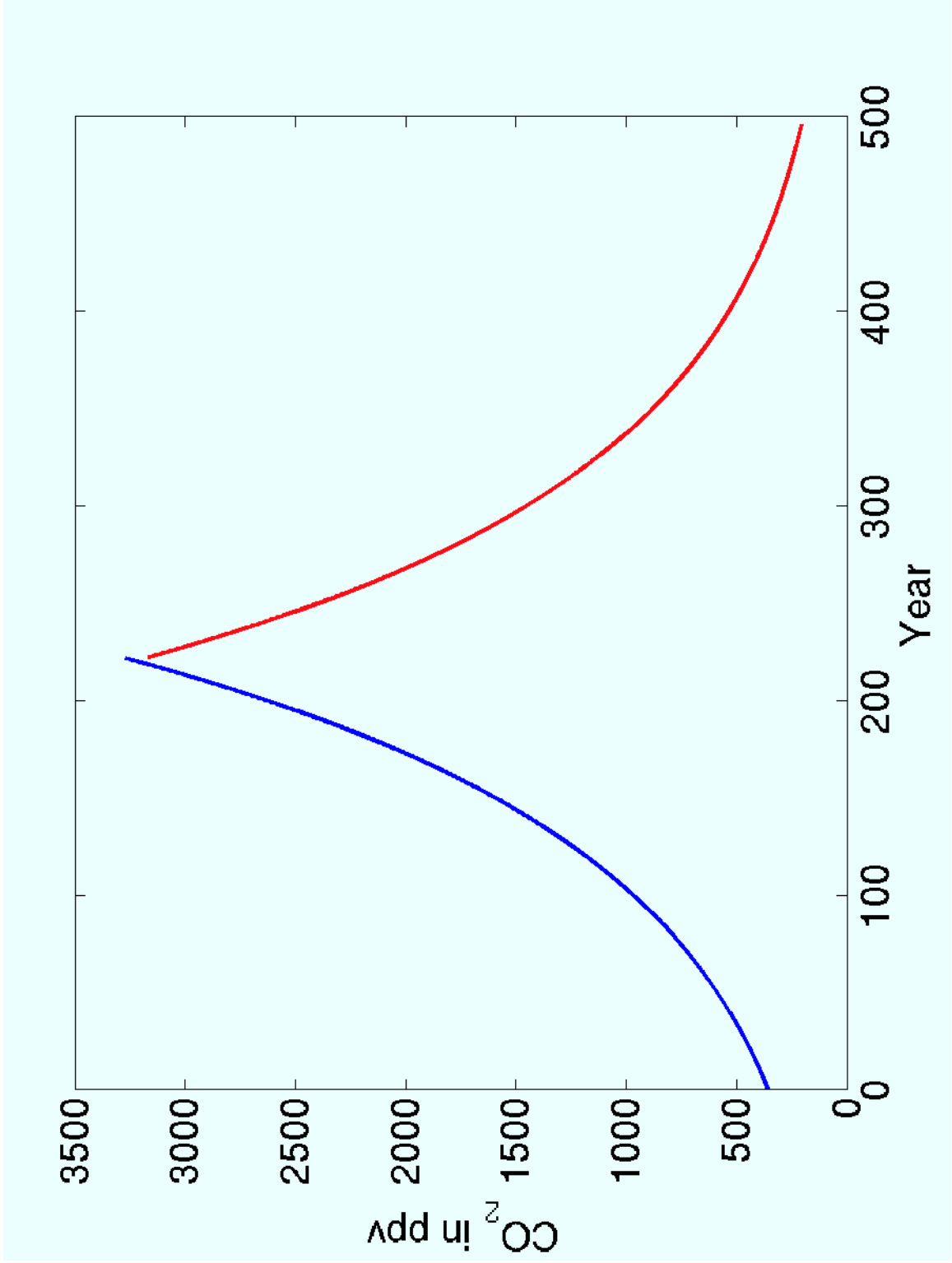


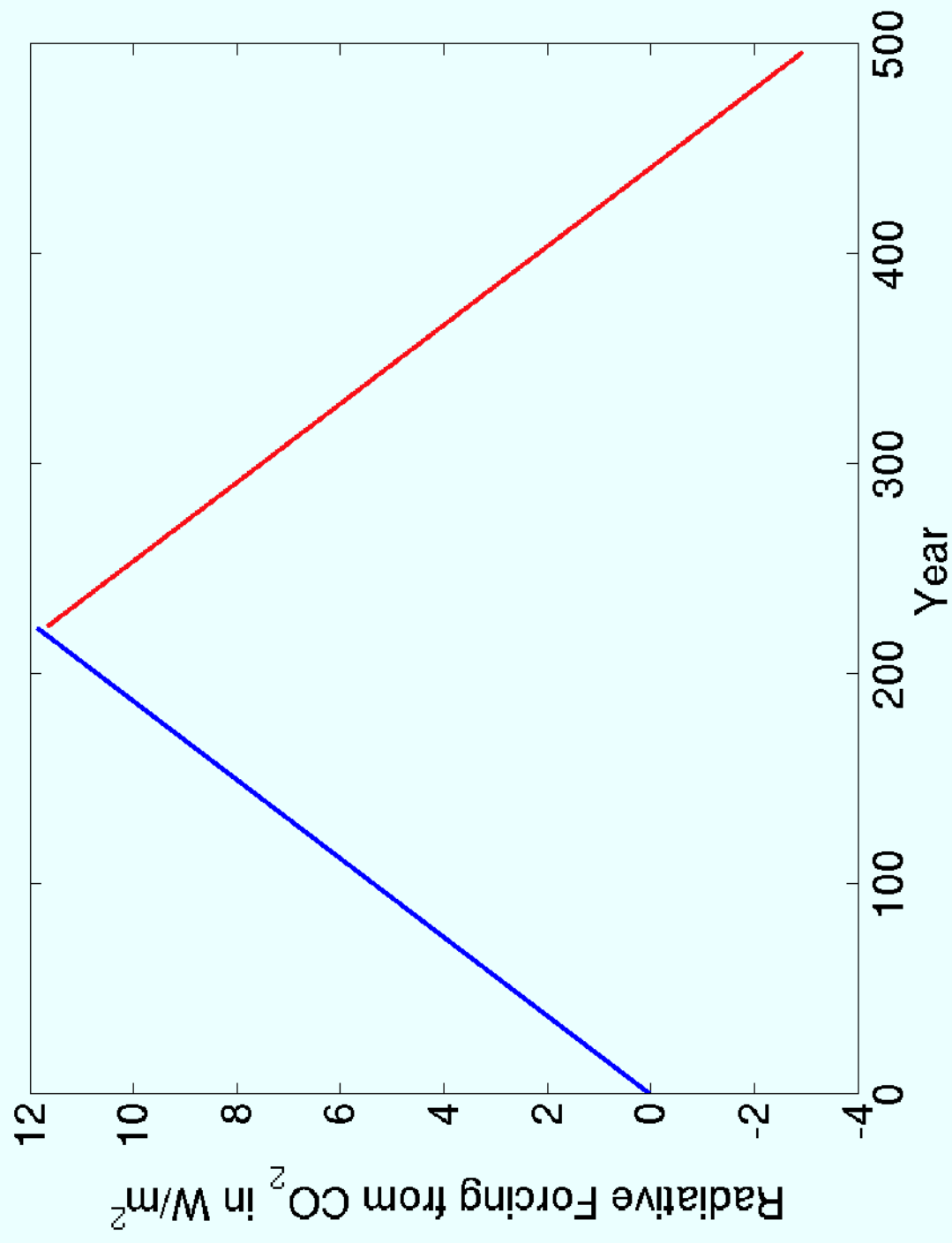
Potential policy-relevant tipping elements in the climate system this century. "...could exhibit threshold-type behaviors in response to anthropogenic climate forcing, where a small perturbation at a critical point qualitatively alters the future fate of the system."

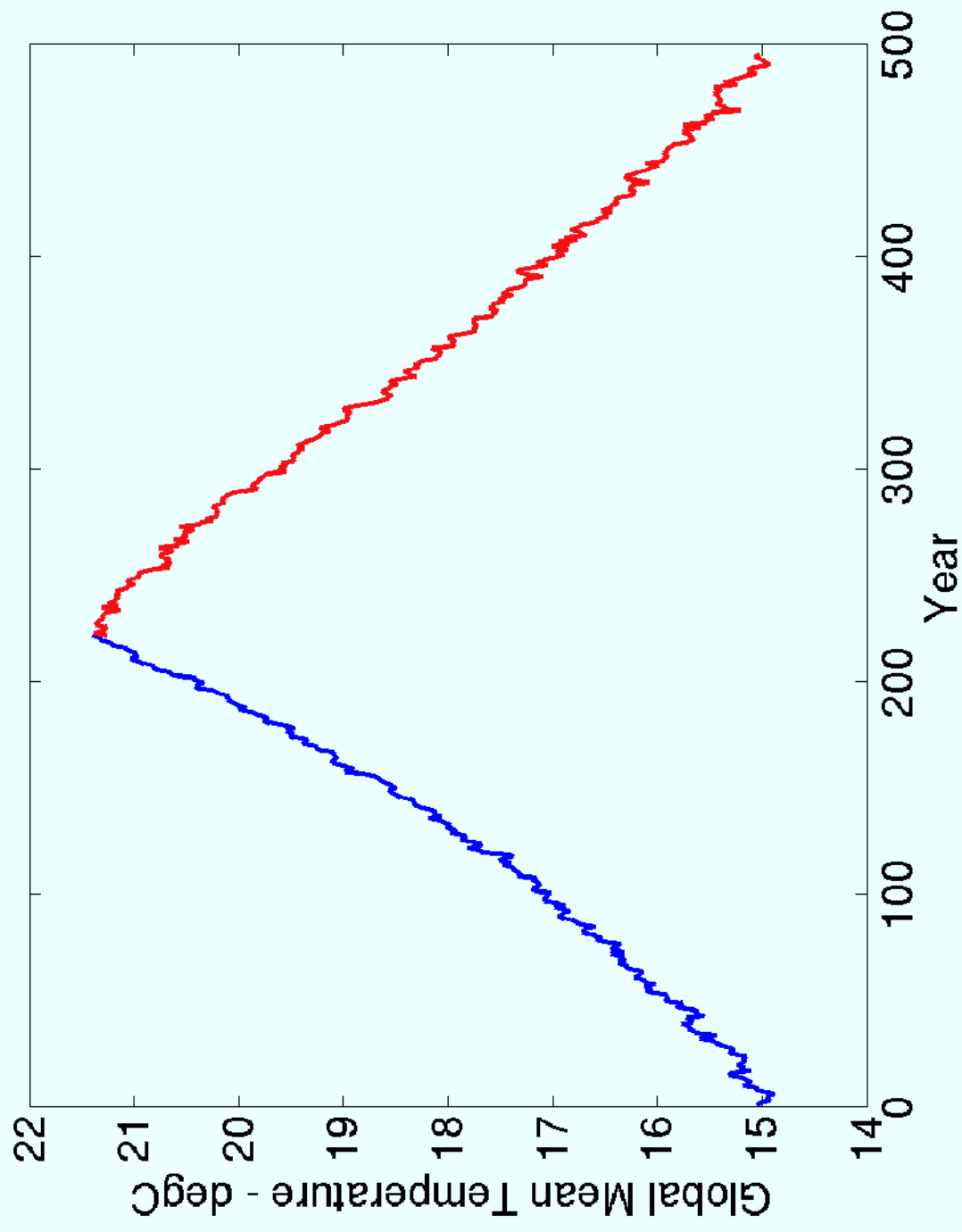
Ramanathan and Feng (2008) PNAS

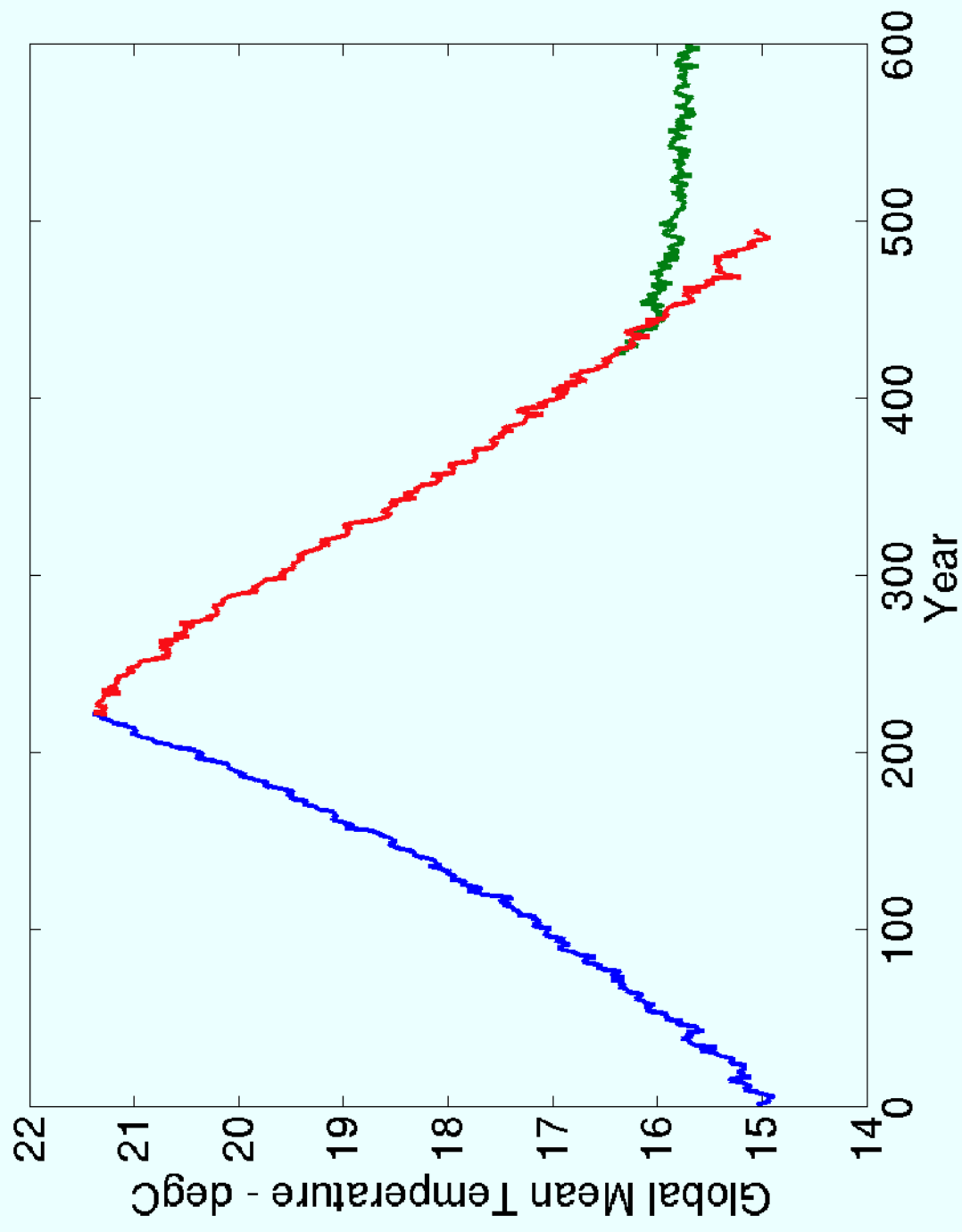


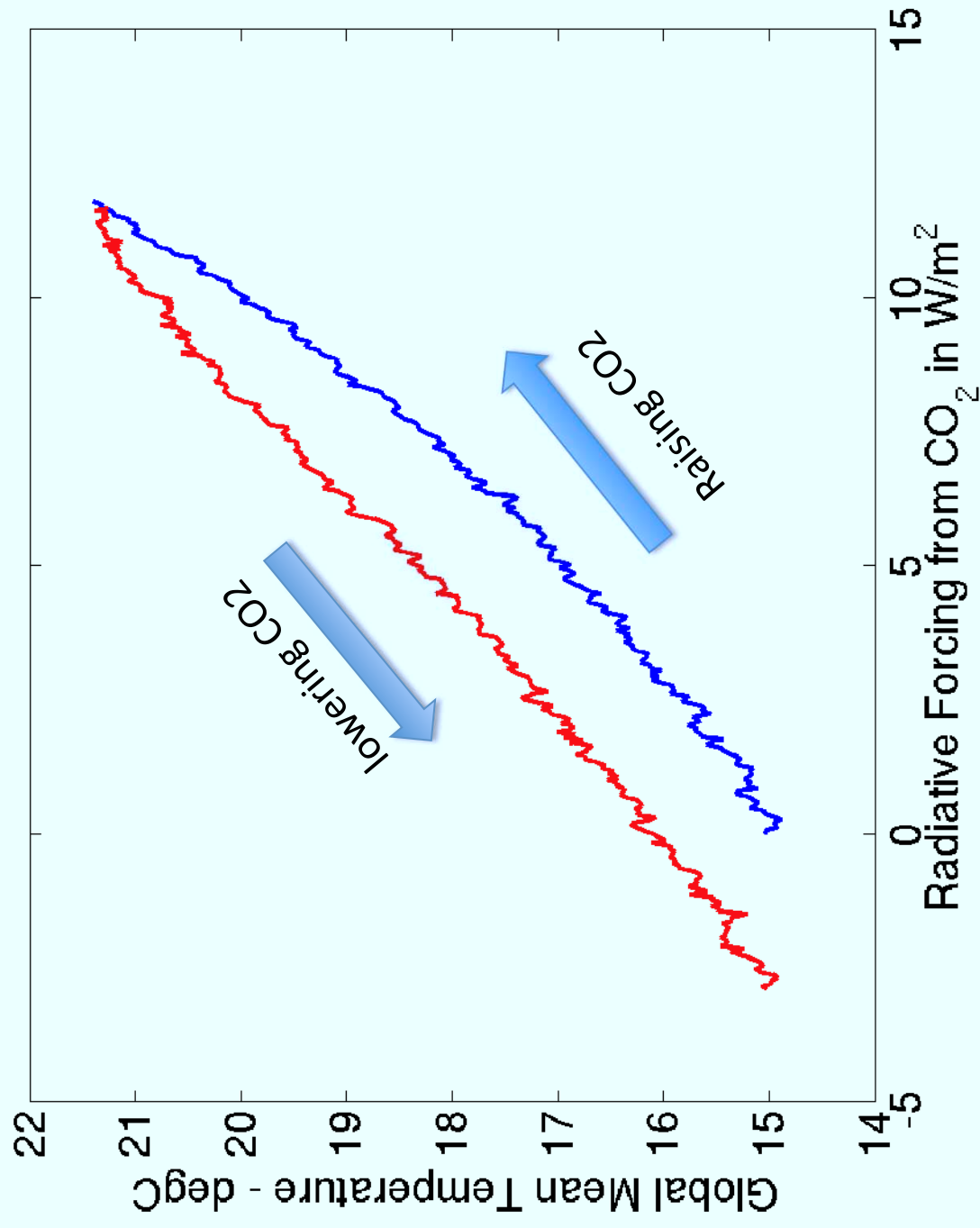
Includes warming from removing present day aerosols

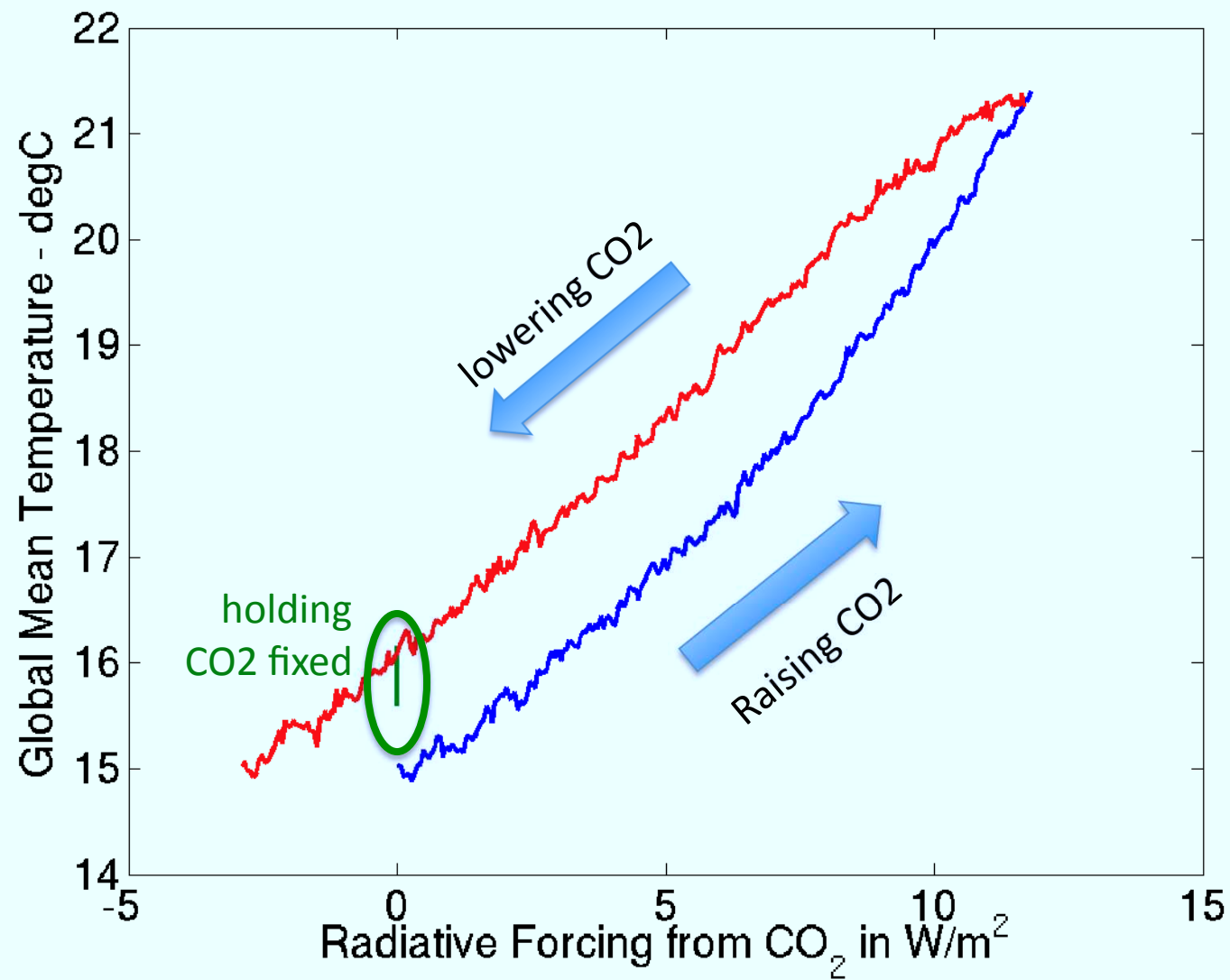


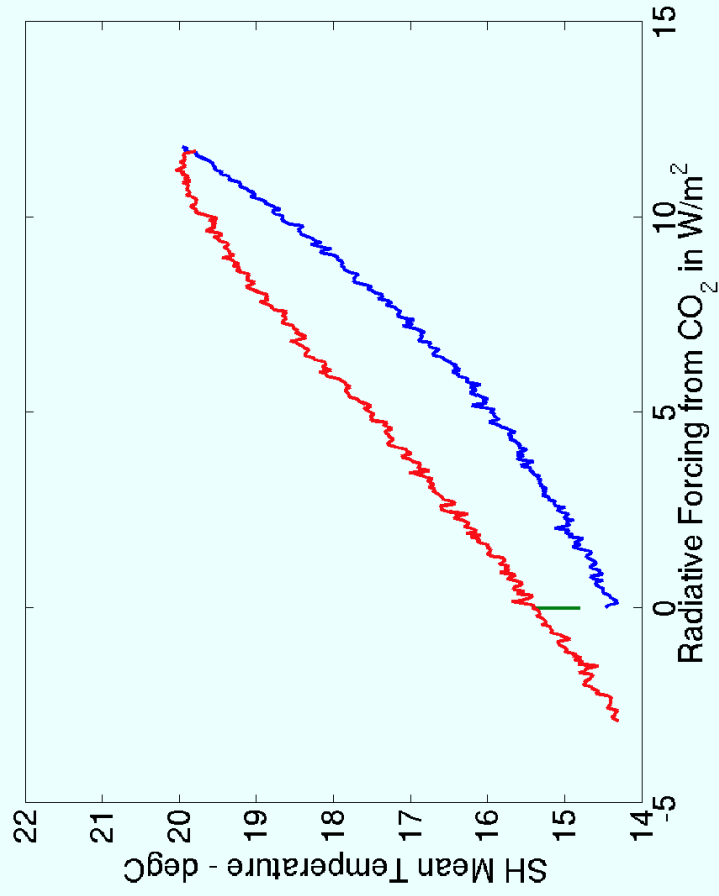
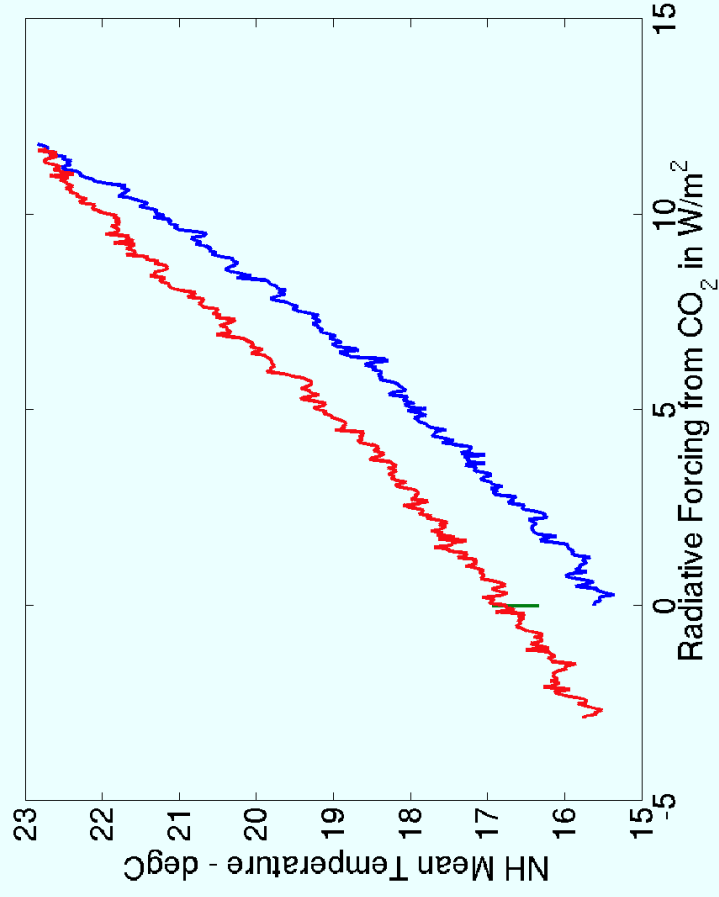


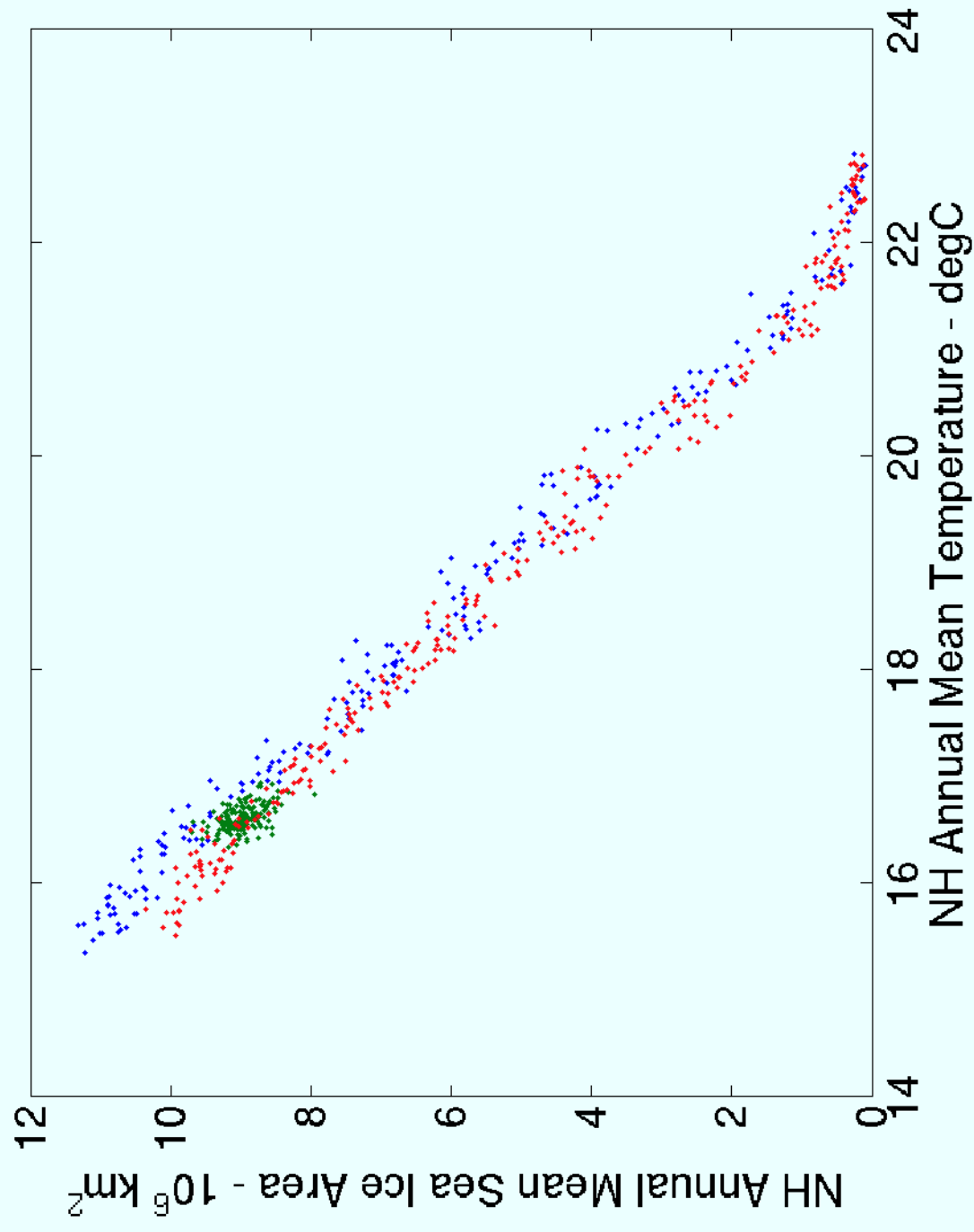


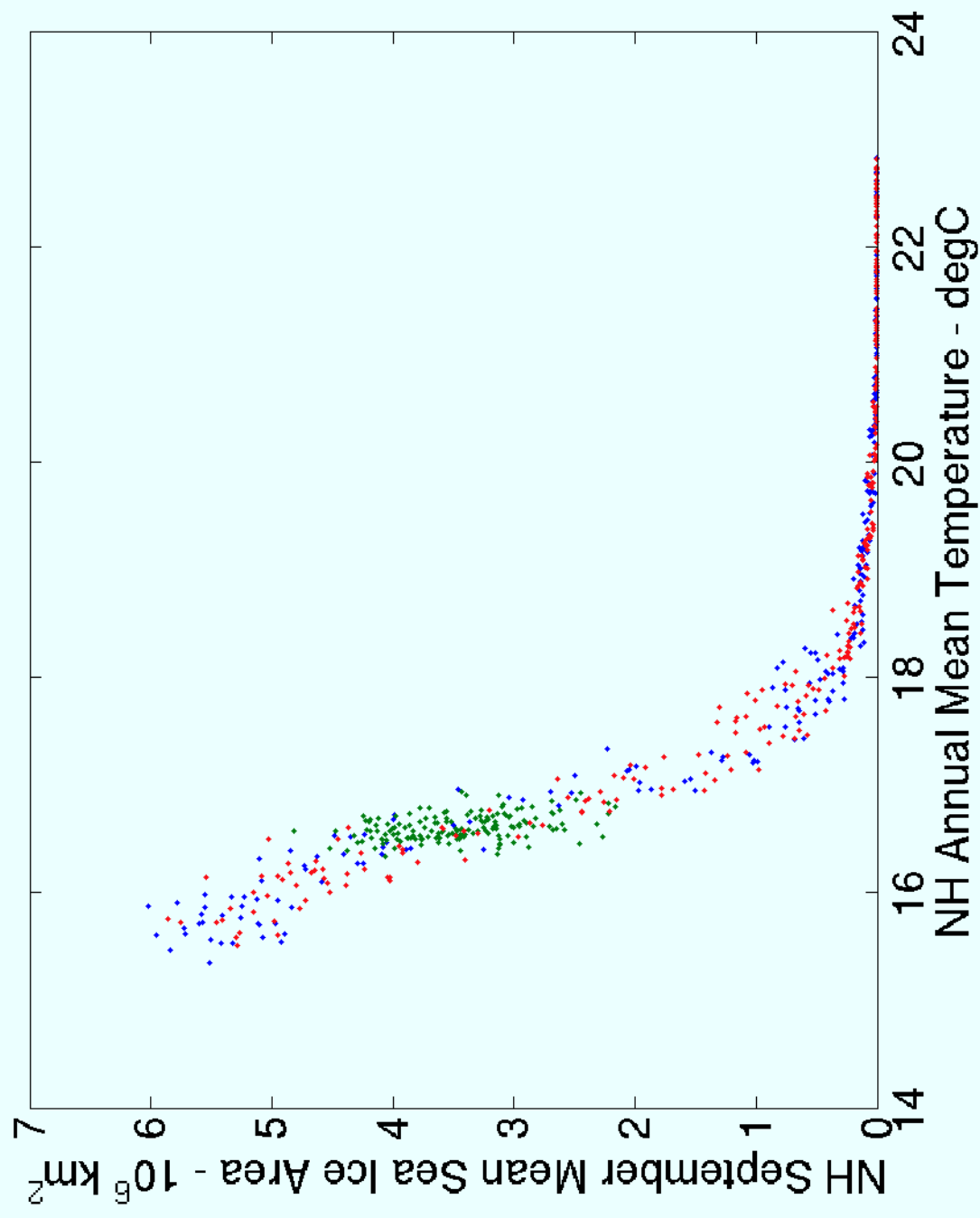


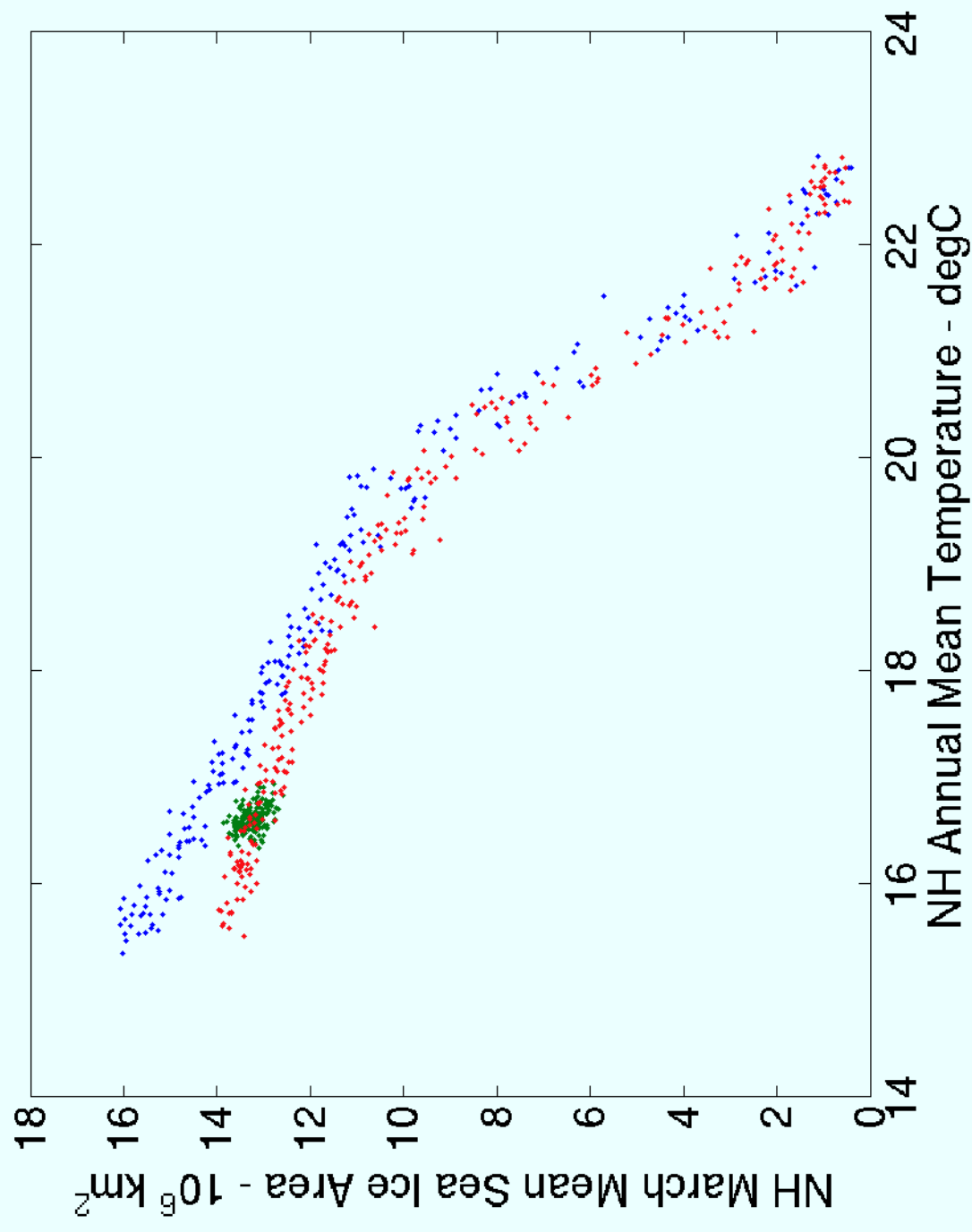


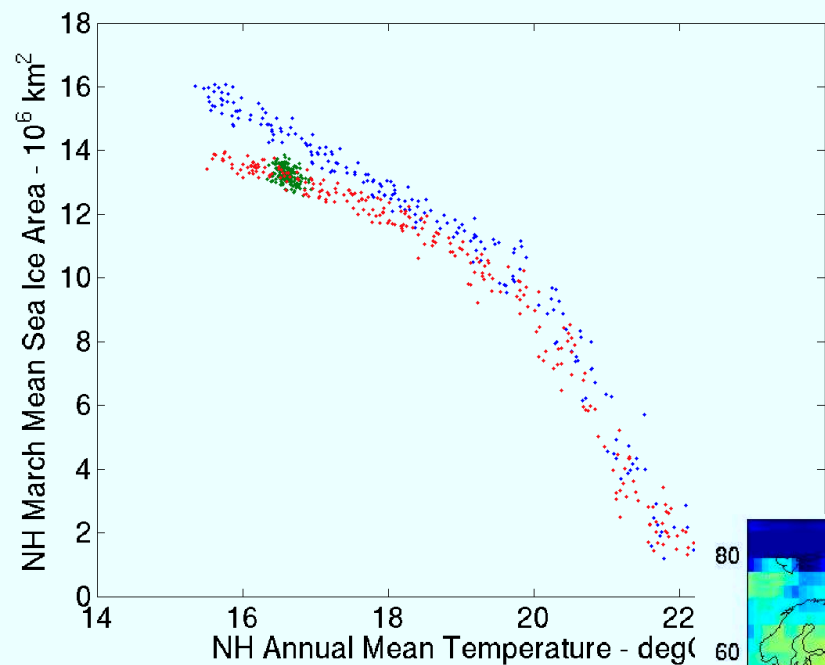












Map of Temperature Difference when NH mean is the same but March Sea Ice Area is very different showing cold ocean/warm land pattern

