AEROCOM Intercomparison

Aerosol Effects on Cirrus Clouds (IND-ICE)

- CAM5
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- CAM5-Michigan
  - C. Zhou, J. Penner (U. of Michigan)
- ECHAM6-HAM2
  - D. Neubauer, U. Lohmann (ETH, Zurich)
- GEOS-5
  - D. Barahona (NASA GSFC)

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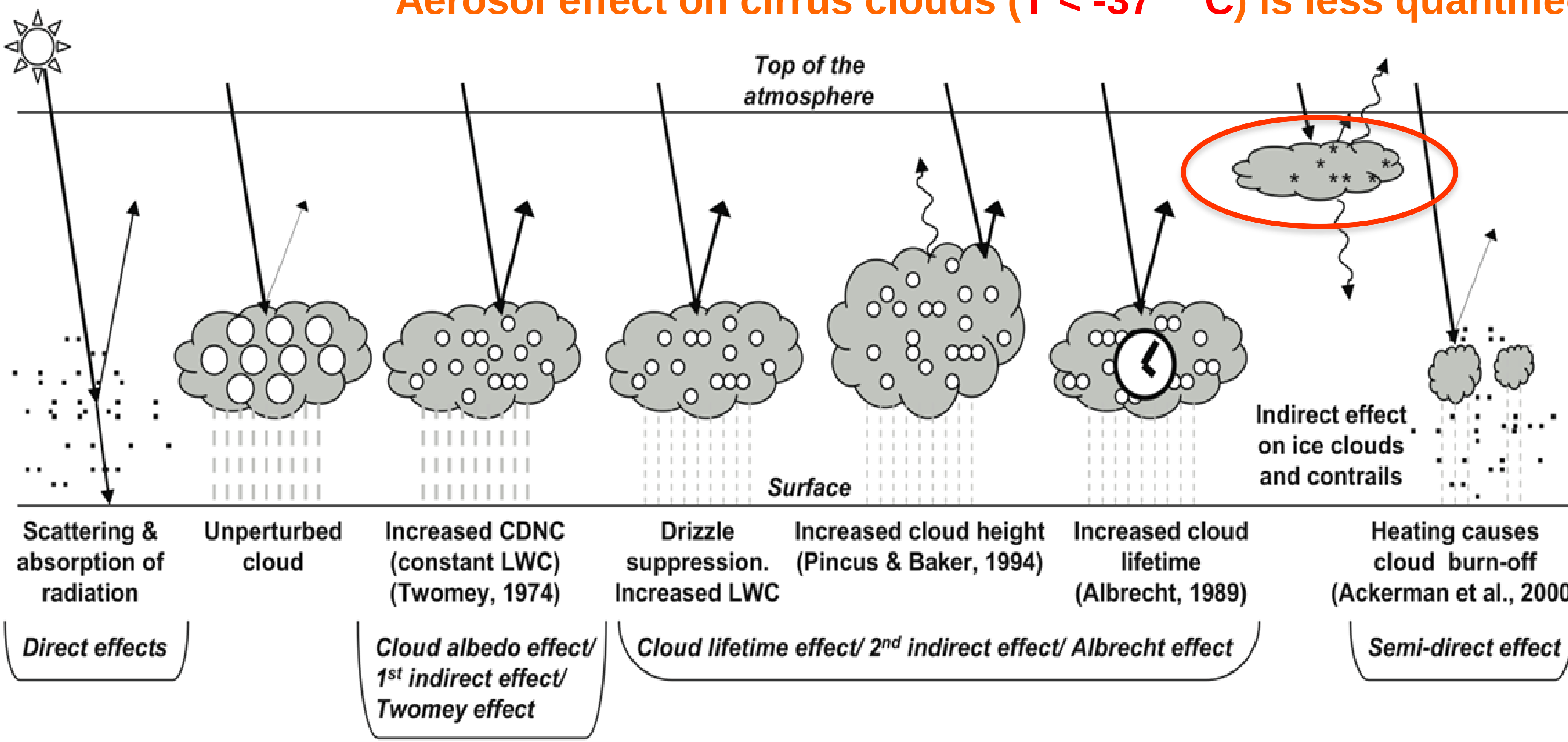
September 29-October 2, 2014

Climatic effects of atmospheric aerosols

Aerosols strongly impact the Earth's energy budget through modifying the properties of clouds

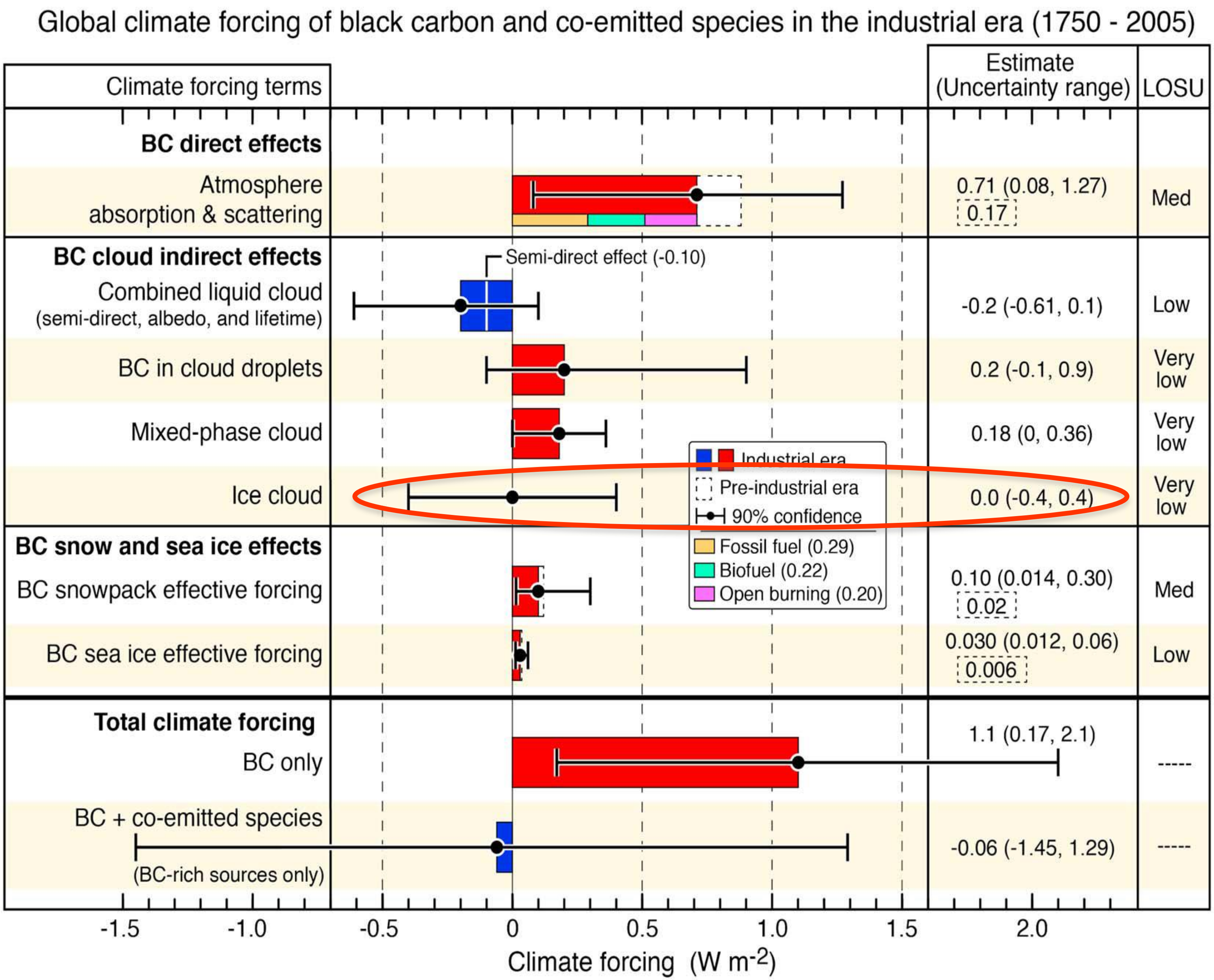
Aerosol effect on cirrus clouds (T < -37 ° C) is less quantified



IPCC AR4 2007

Global Mean Black Carbon Radiative Forcing from 1750 to 2005

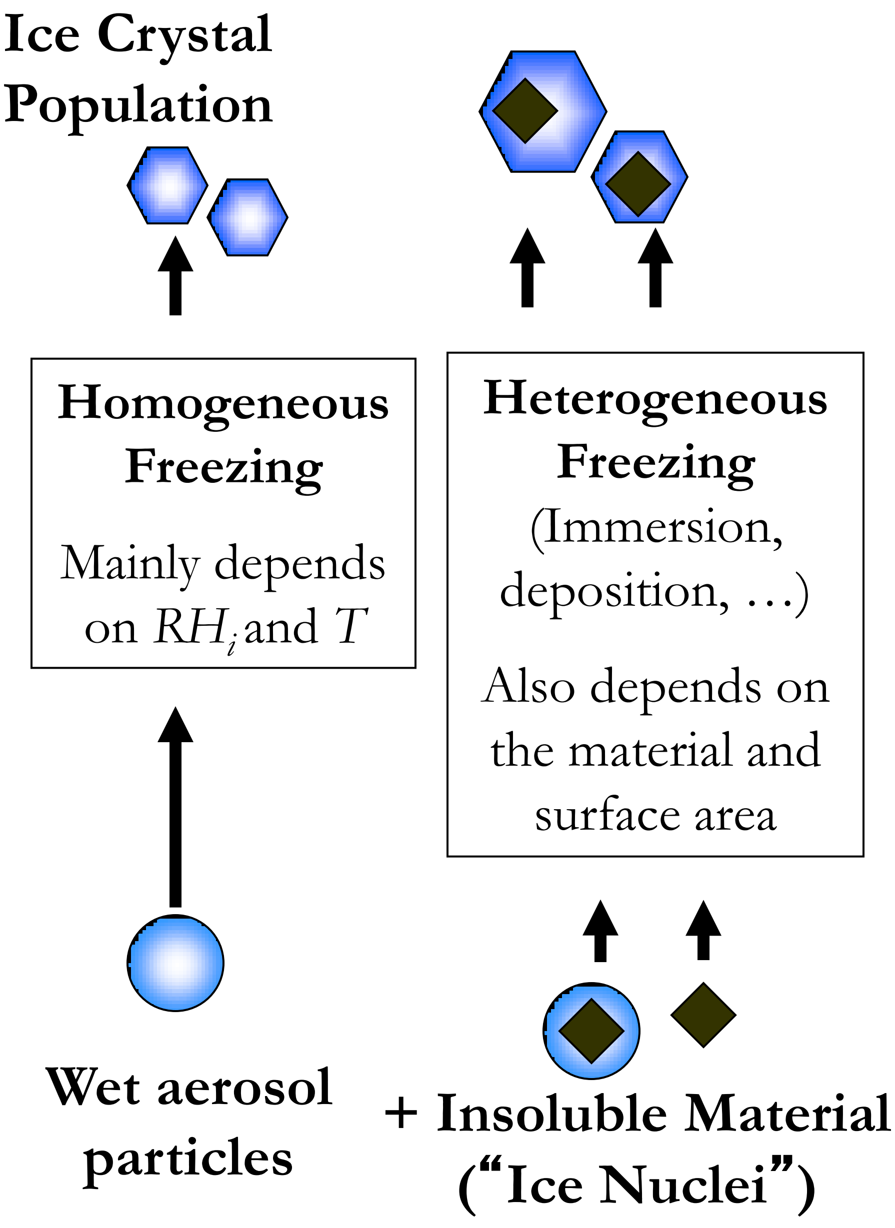
Bond et al. (2013)



Motivation

- Global climate models have started to include the treatment of ice nucleation linked to aerosols
  - Homogeneous nucleation on sulfate aerosol
  - Heterogeneous nucleation on dust and/or black carbon (BC)
  - Competition between homogeneous vs. heterogeneous
- The goal of this AeroCom intercomparison (IND3-ICE) is to more systematically assess the impact of aerosols on cirrus clouds and to estimate associated anthropogenic aerosol forcing.

Ice Nucleation in Cirrus 101



Multiple mechanisms for ice formation can be active.

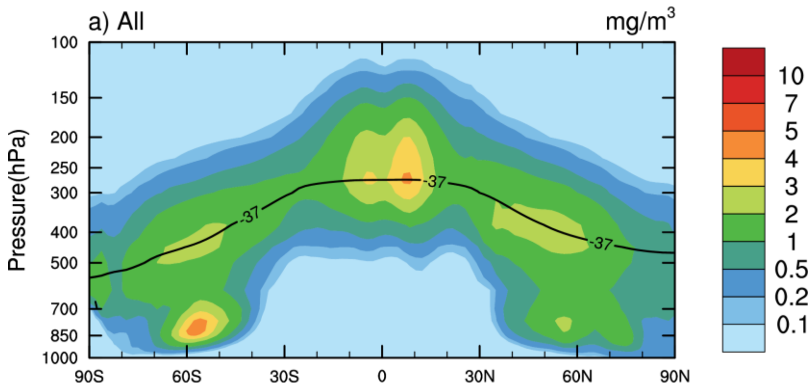
AEROCOM Intercomparison (IND3-ICE)

- GCM simulations with configuration:
  - Prescribed SST
  - Nudged with reanslysis data (wind)
  - IPCC AR5 emissions
- Three sets of simulations (**PD** & **PI**)
  - **CTL:** Homogeneous and heterogeneous combined
    - Reference model
  - **FIX:** Fixed ice nucleation in cirrus clouds (Gettelman et al. 2012)
    - Fixed ice nucleation for T<-37 C° using a constant ice number of 383.6 /L, based on Cooper (1986) for T= -37C°
  - **HOM:** Homogeneous nucleation only
    - No heterogeneous ice nucleation in cirrus clouds when T<-37 C°

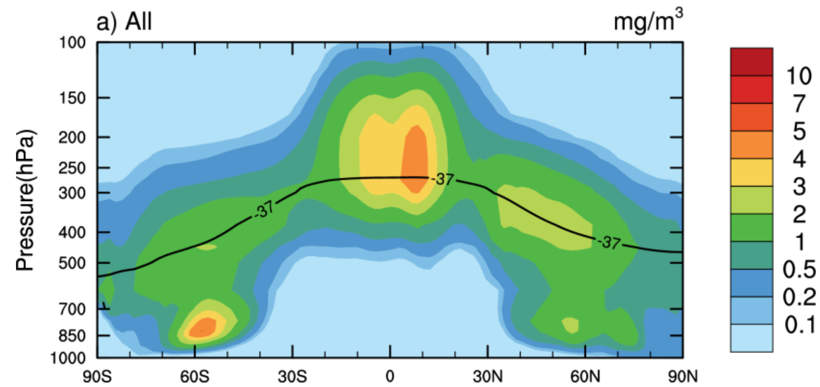
Ice Water Content

CTL

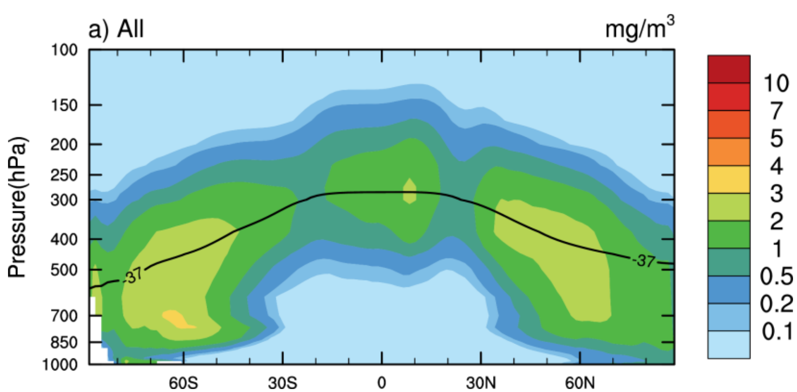
CAM5



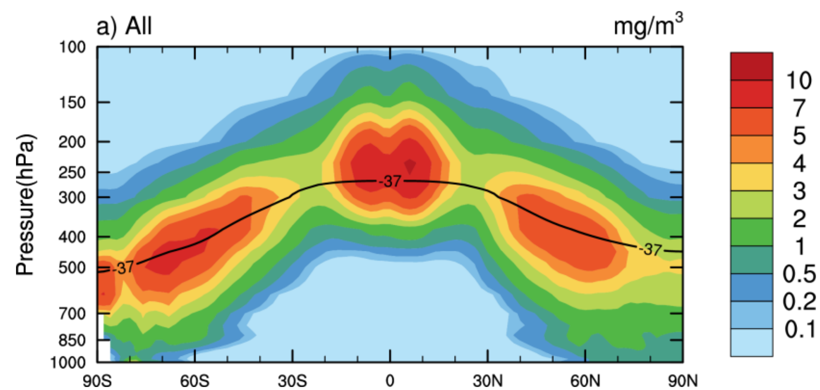
CAM5-Michigan



ECHAM6



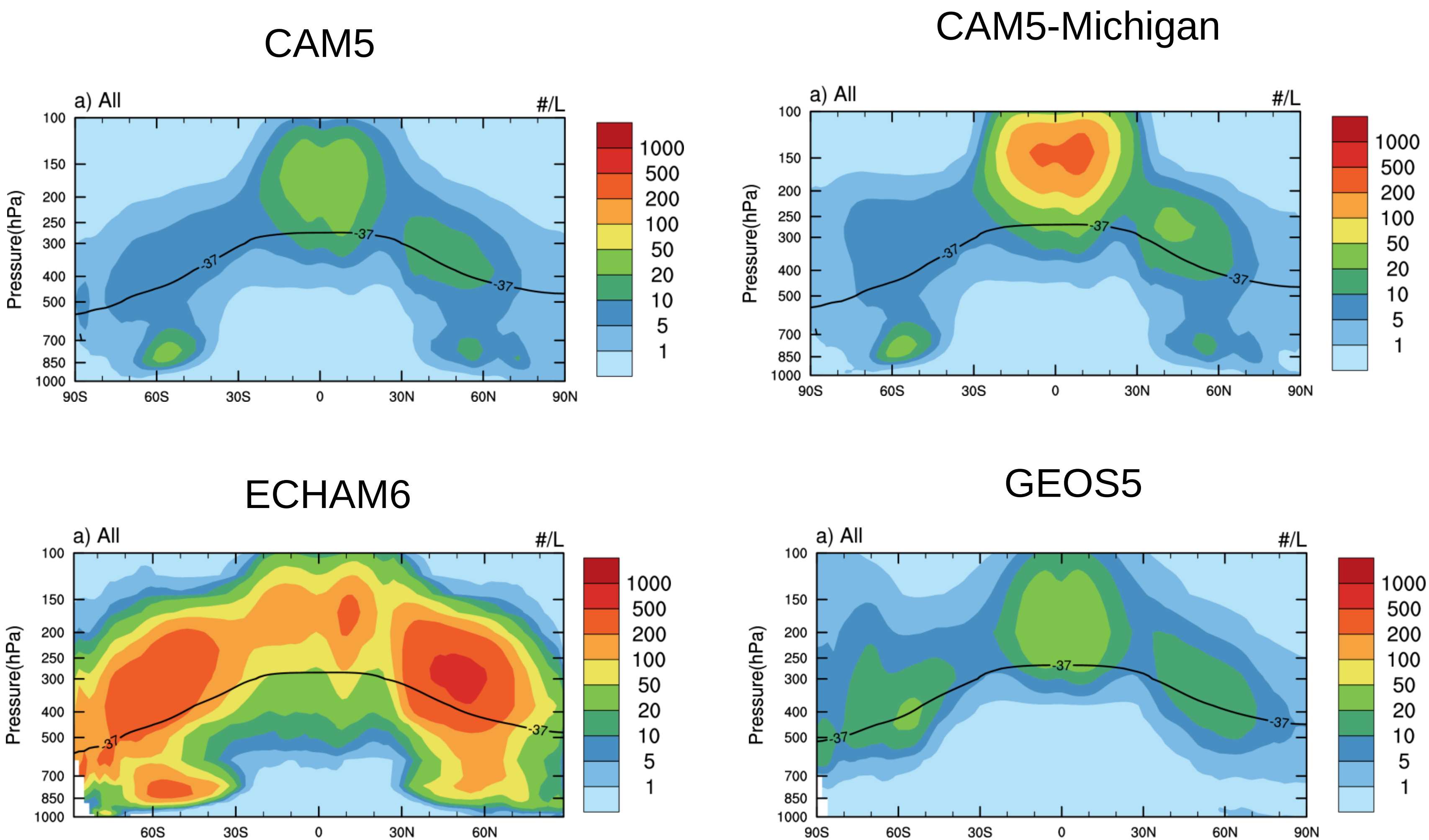
GEOS5



IWP = 17.3 g/m2 (CAM5), 18.9 (CAM5-Michigan), 10.2 g/m2 (ECHAM6), 26.9 (GEOS5)

Ice Crystal Number Concentration

CTL

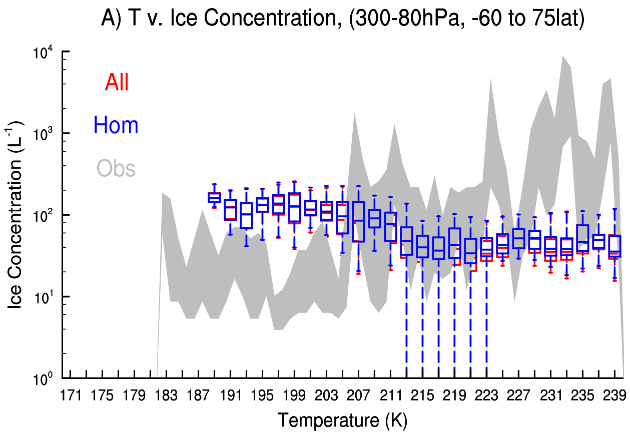


ICENUM = 0.96 /m2 (CAM5), 3.2 (CAM5-Michigan), 14.5 /m2 (ECHAM6), 3.3x10[4] (GEOS5)

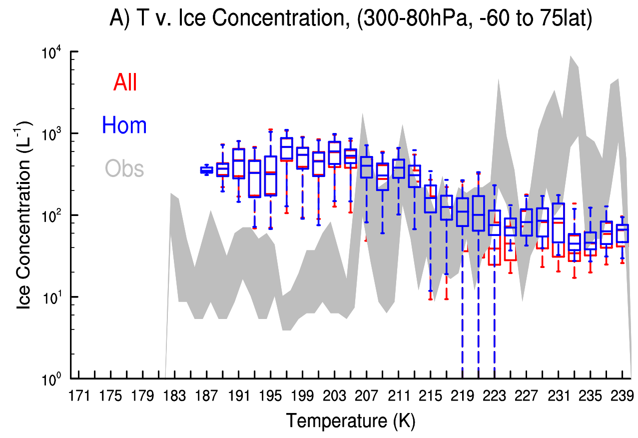
Ice Number vs. Krämer Data

CTL
& HOM

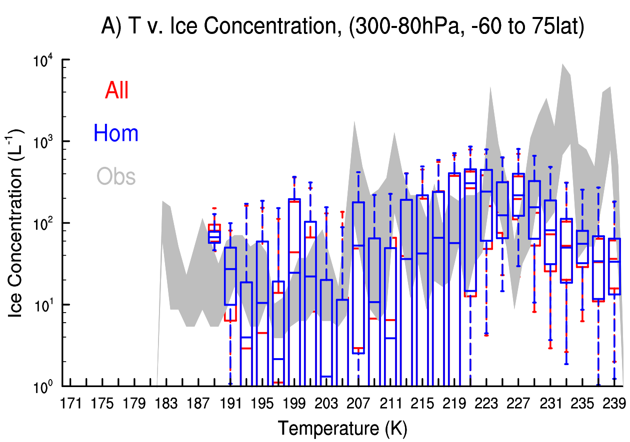
CAM5



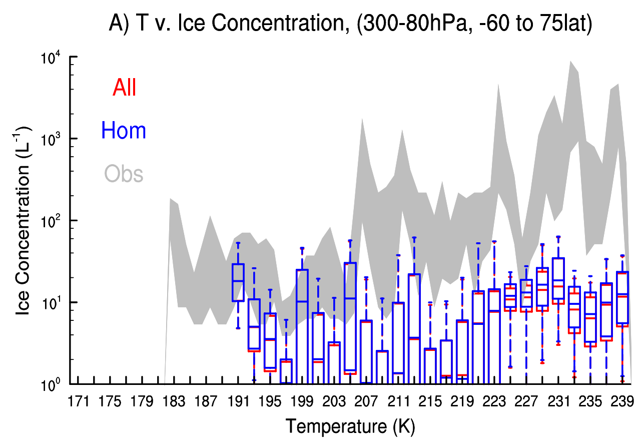
CAM5-Michigan



ECHAM6



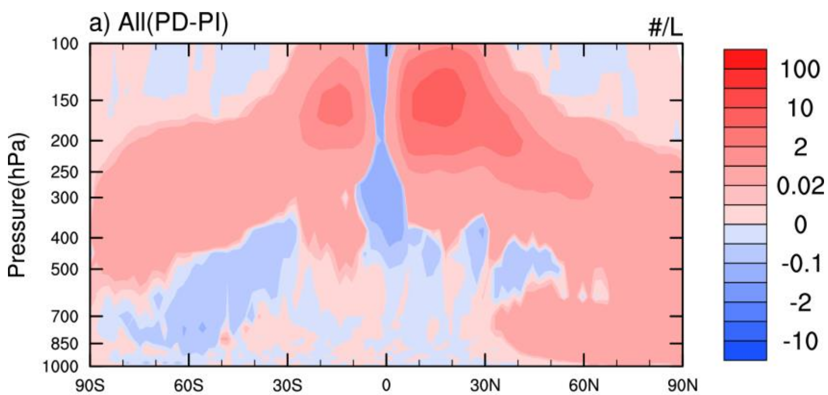
GEOS5



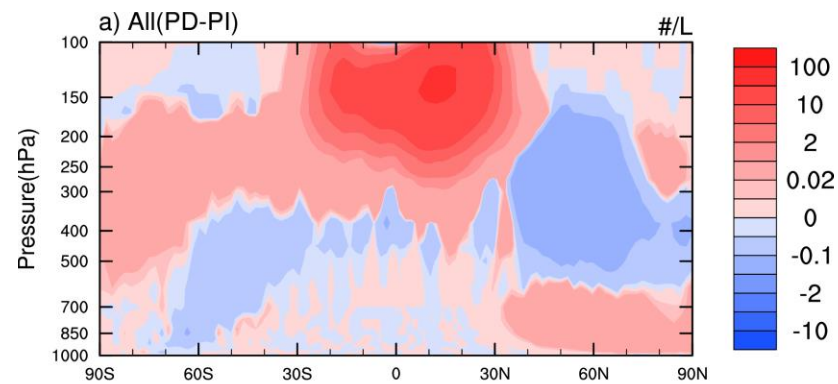
Ice Number Change (PD-PI)

CTL

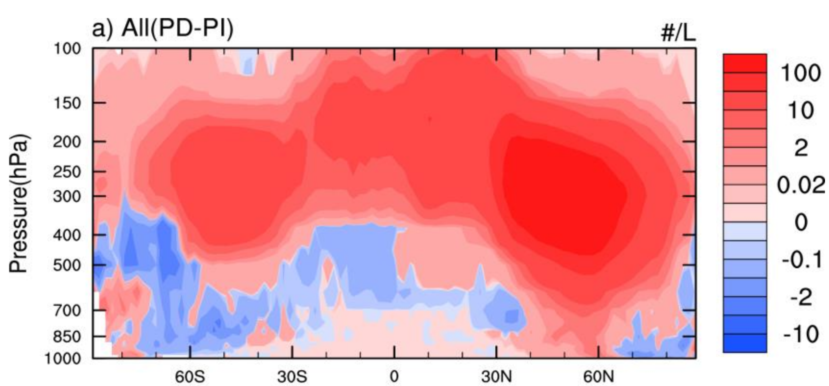
CAM5



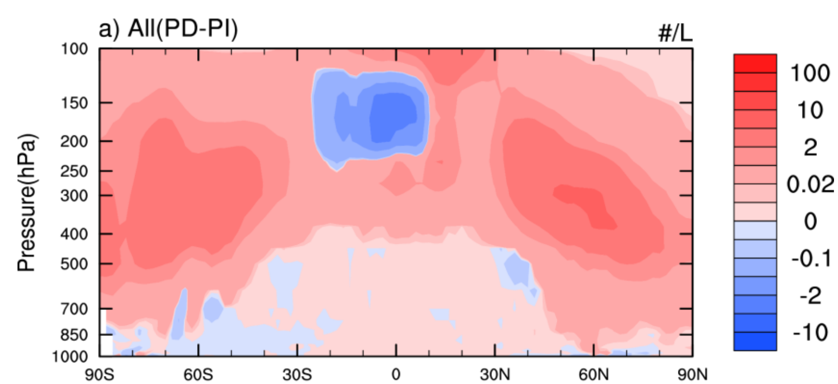
CAM5-Michigan



ECHAM6



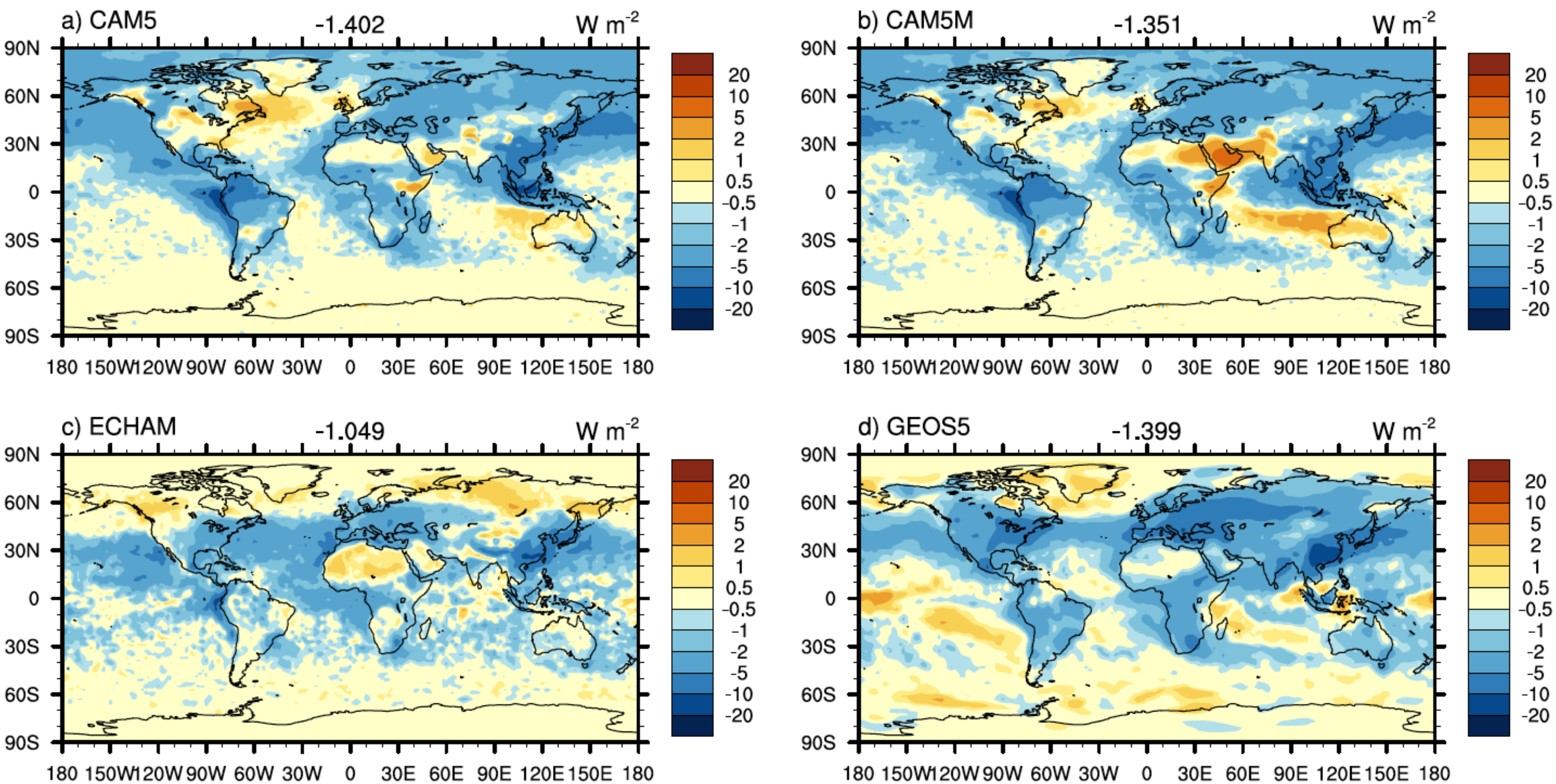
GEOS5



TOA Net Flux Change (PD-PI)

CTL

CAM5 | CAM5-Michigan



ECHAM6 | GEOS5

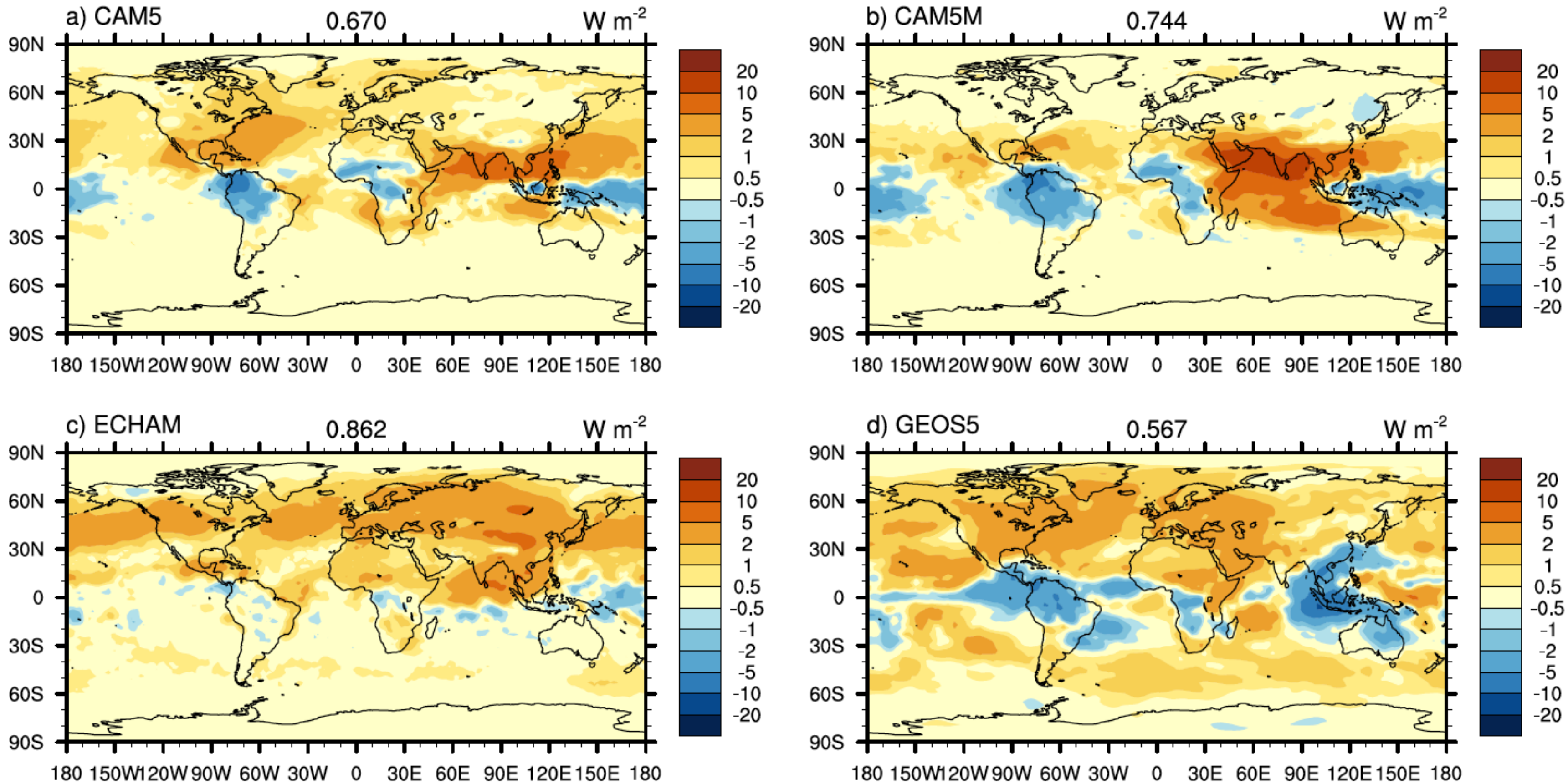
Δnet (SW+LW) = -1.4 (CAM5), -1.35 (CAM5-M), -1.0 (ECHAM6), -1.4 W/m2 (GEOS5)

TOA Net LW Flux Change (PD-PI)

CTL

CAM5

CAM5-Michigan



ECHAM6

GEOS5

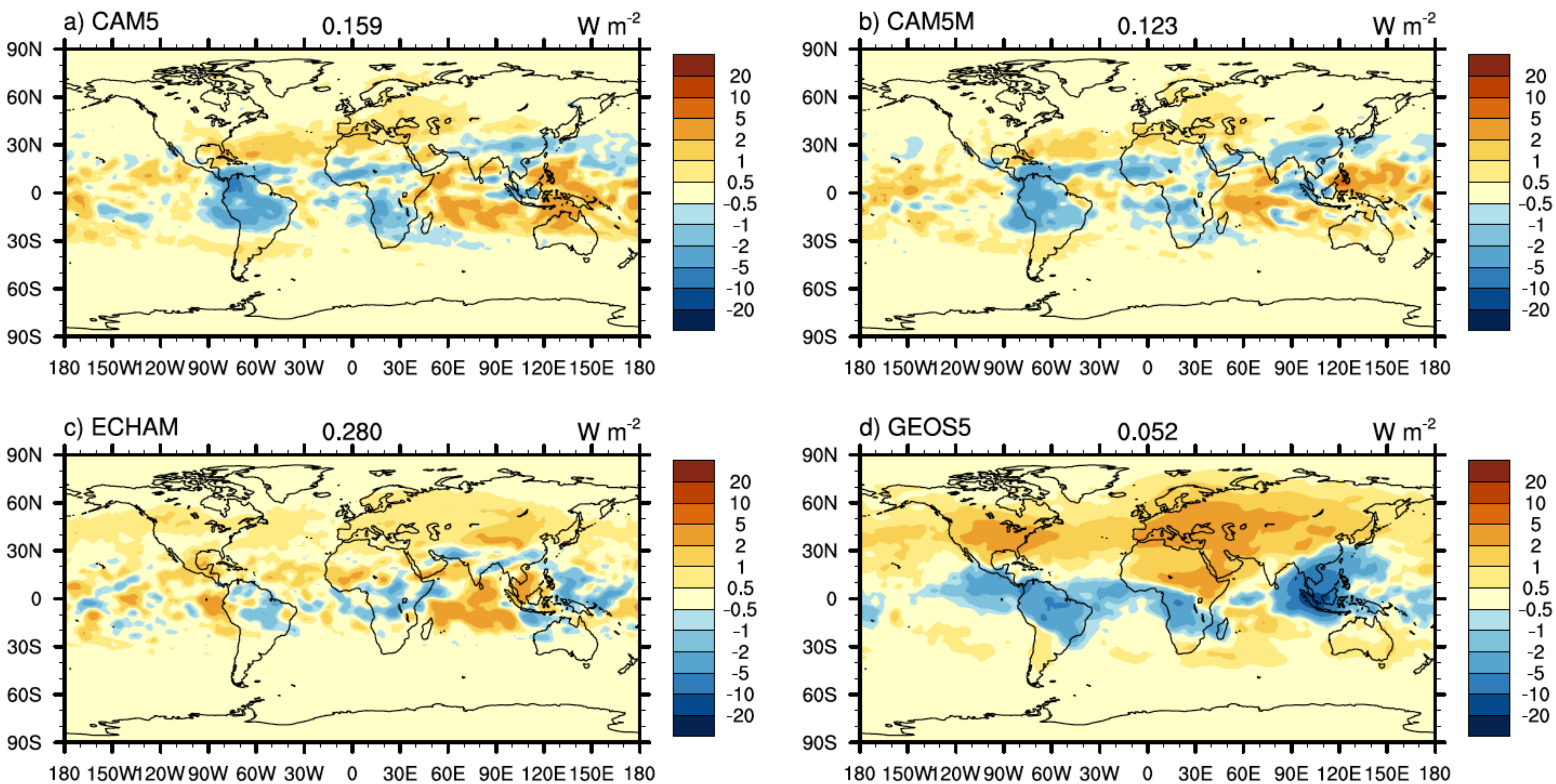
ΔLW = 0.67 (CAM5), 0.74 (CAM5-M), 0.86 (ECHAM6), 0.57 W/m2 (GEOS5)

TOA Net LW Flux Change (PD-PI)

FIX

CAM5

CAM5-Michigan



ECHAM6

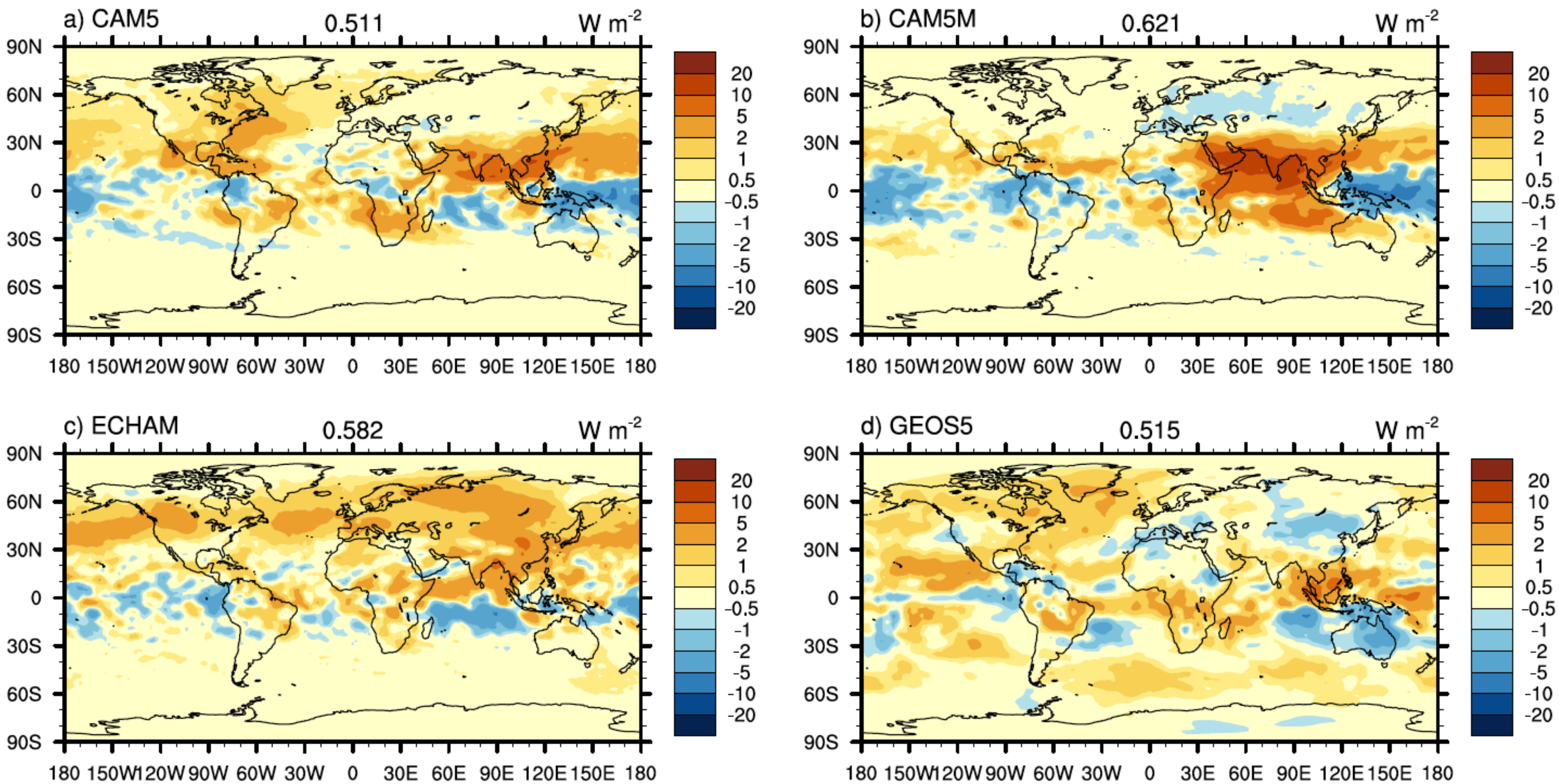
GEOS5

TOA Net LW Flux Change (PD-PI)

CTL – FIX = AIE-cirrus

CAM5

CAM5-Michigan



ECHAM6

GEOS5

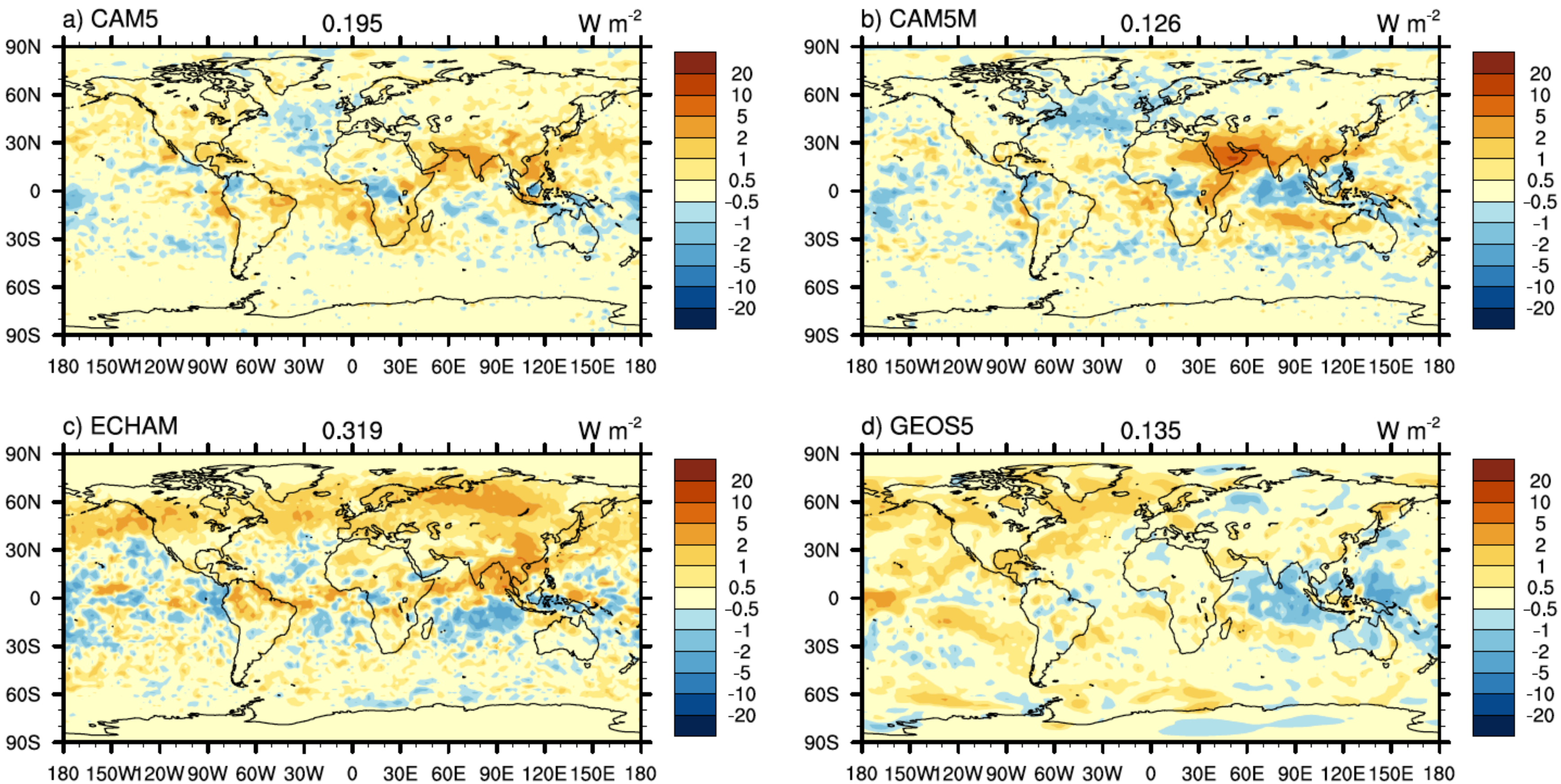
ΔLW (cirrus) = 0.51 (CAM5), 0.62 (CAM5-M), 0.58 (ECHAM), 0.52 W/m2 (GEOS5)

TOA Net Flux Change (PD-PI)

CTL – FIX = AIE-cirrus

CAM5

CAM5-Michigan



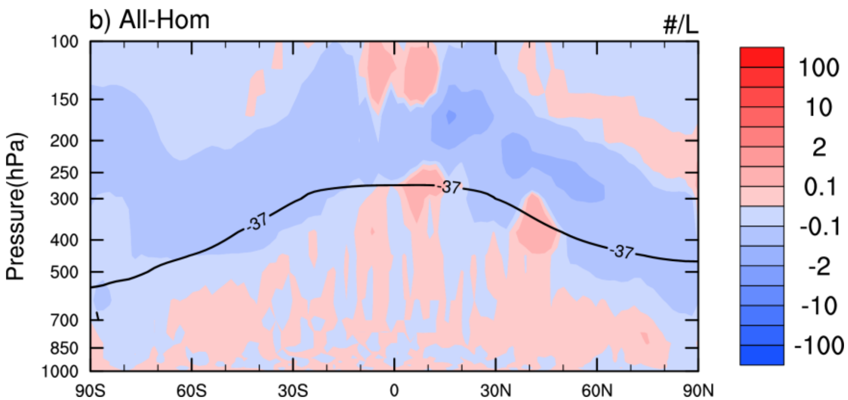
ECHAM6

GEOS5

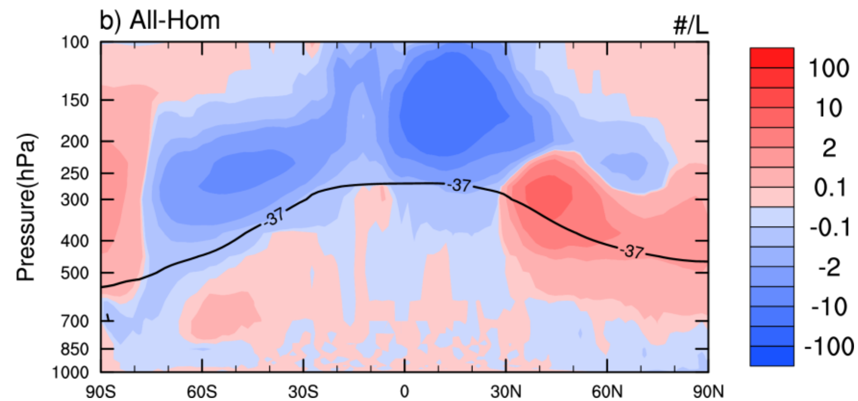
ΔSW+LW (cirrus) = 0.20 (CAM5), 0.13 (CAM5-M), 0.32 (ECHAM), 0.14 W/m2 (GEOS5)

Ice Number Change (CTL – HOM)

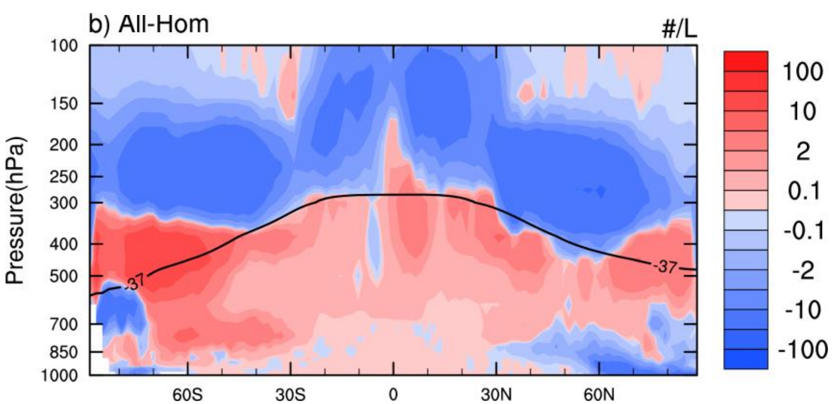
CAM5



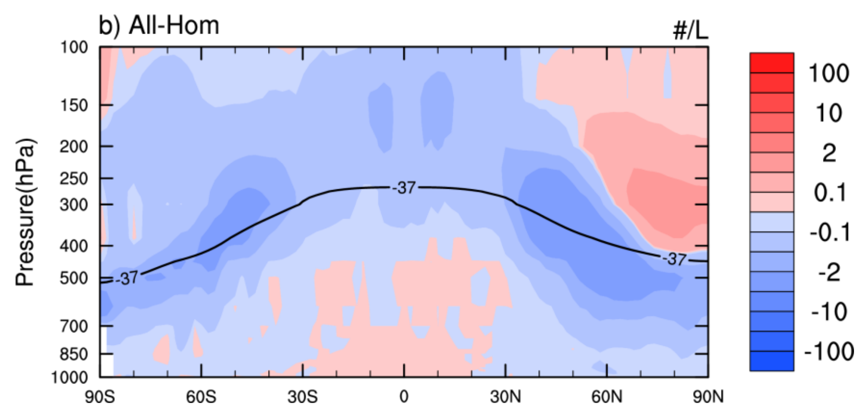
CAM5-Michigan



ECHAM6

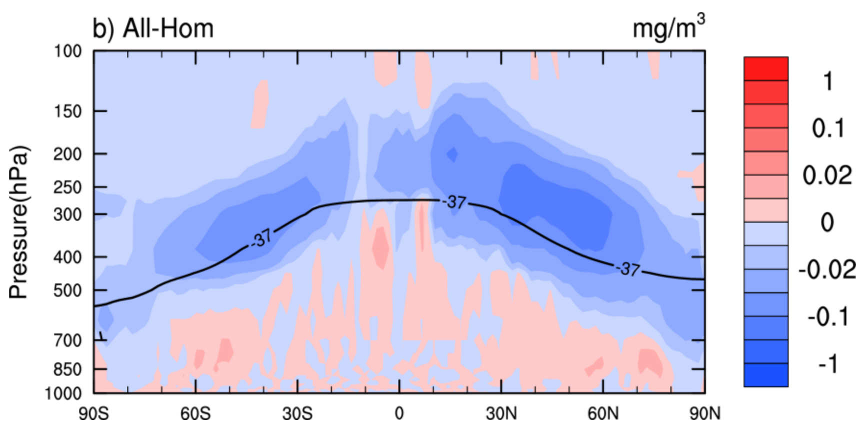


GEOS5

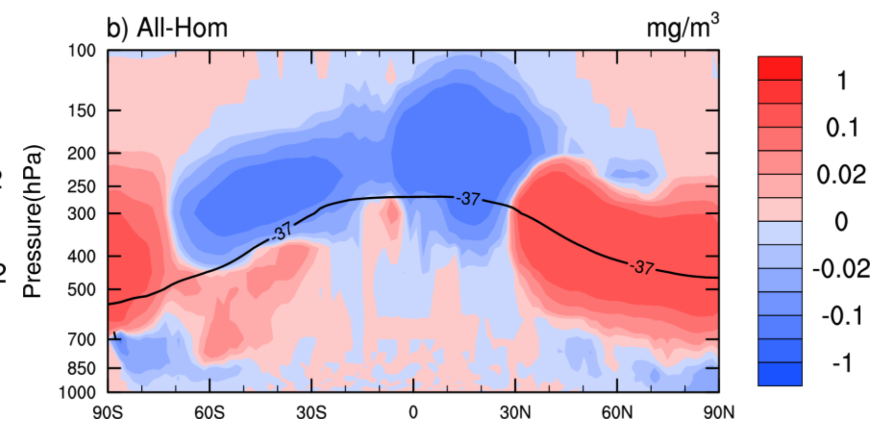


Ice Water Content Change (CTL – HOM)

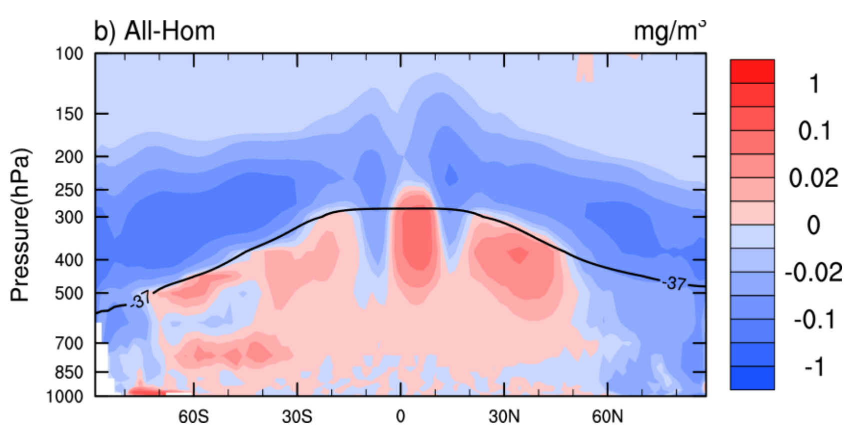
CAM5



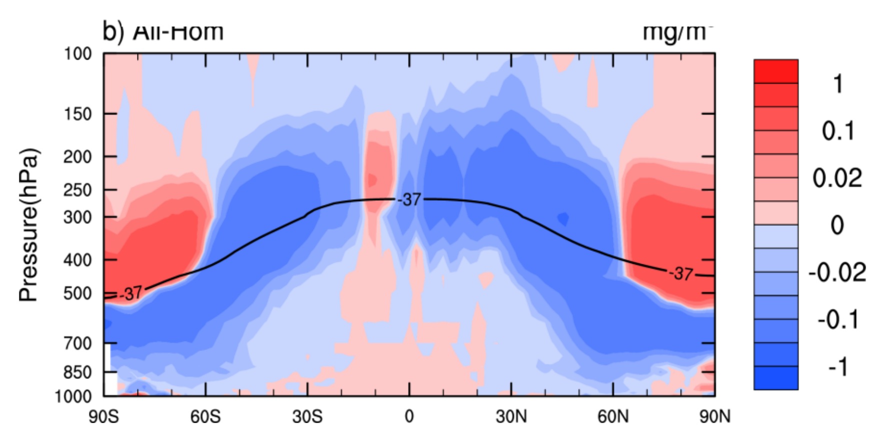
CAM5-Michigan



ECHAM6

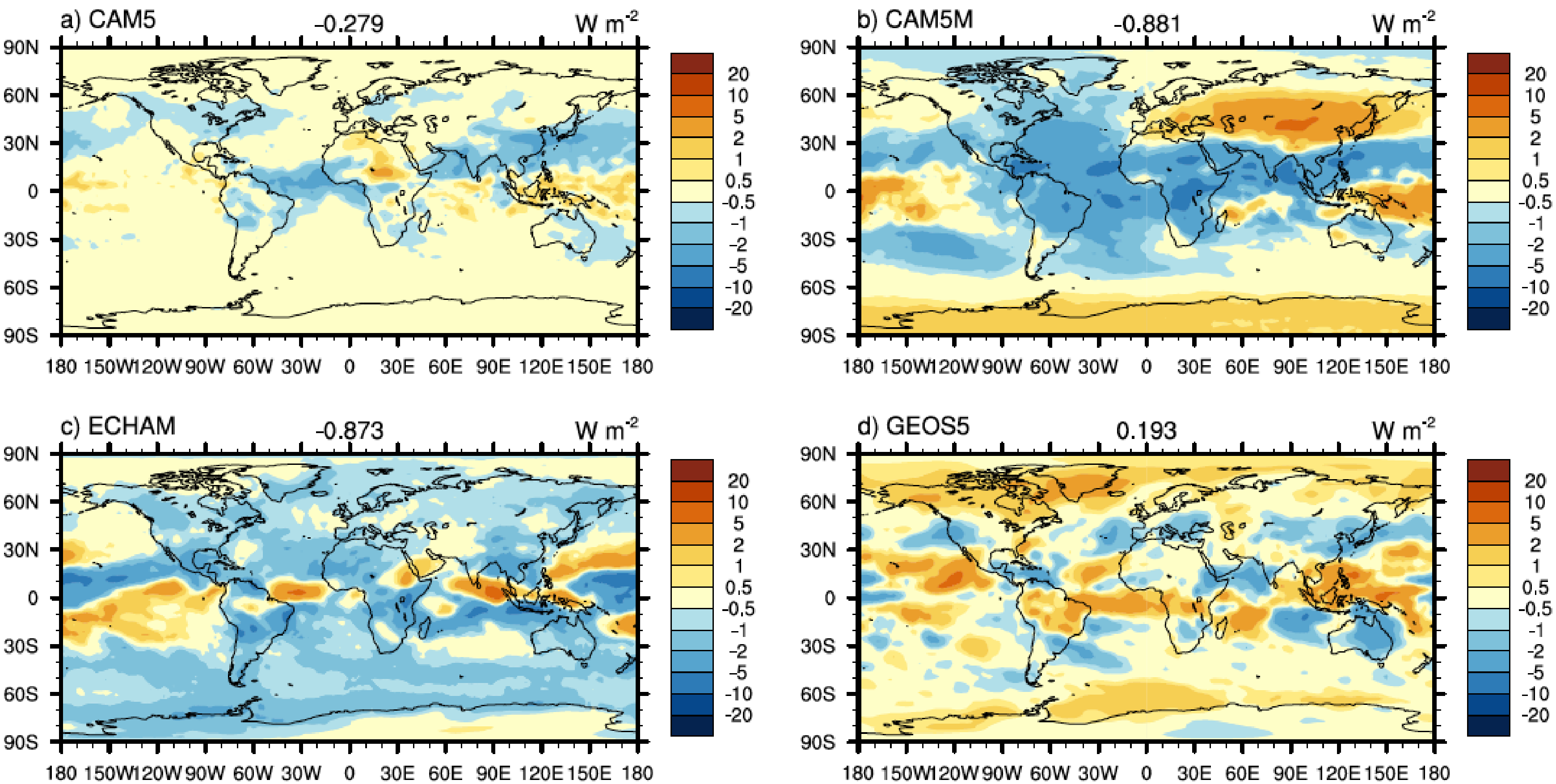


GEOS5



TOA Net LW Flux Change (CTL - HOM)

CAM5 CAM5-Michigan



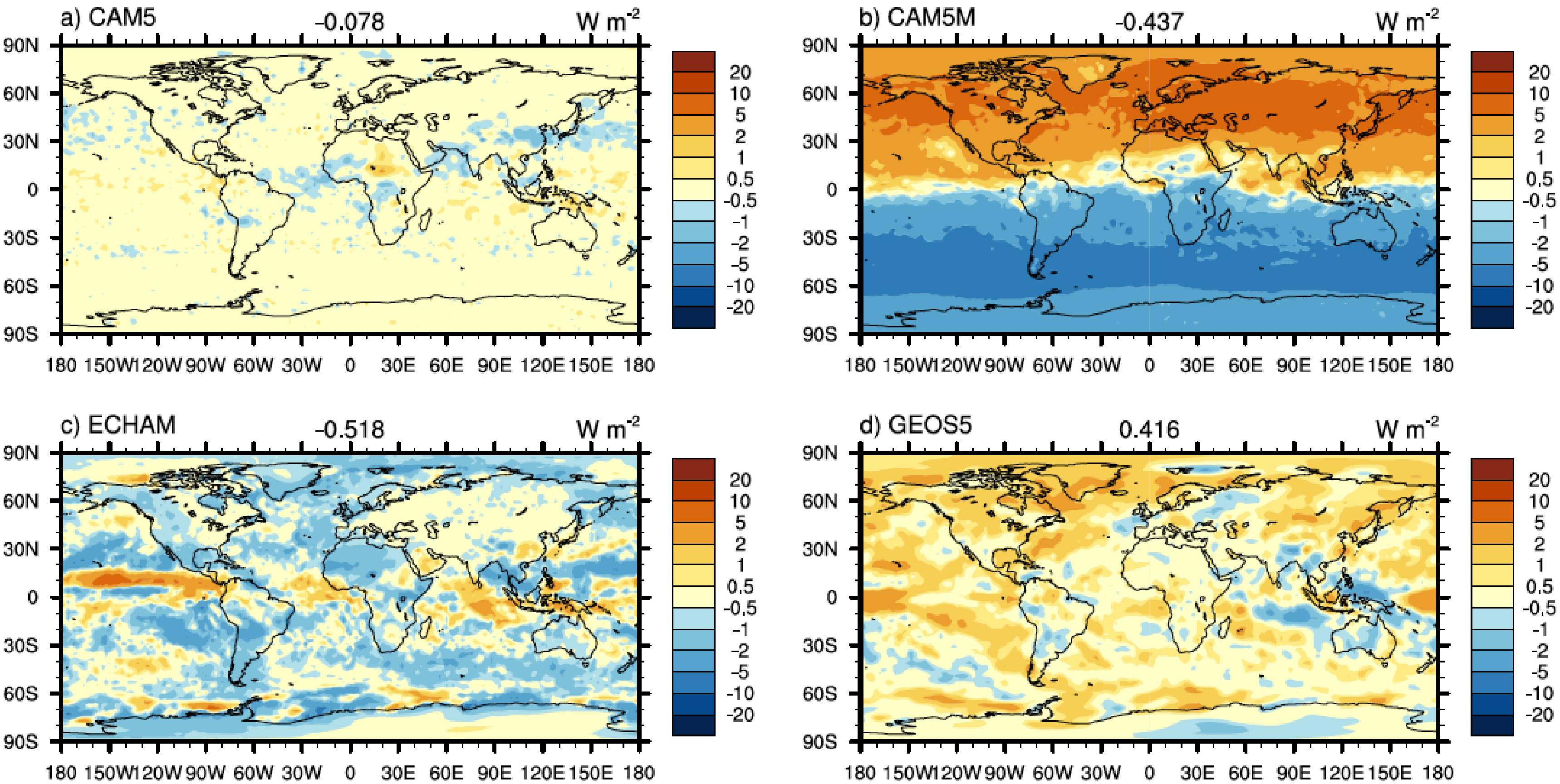
ECHAM6 GEOS5

ΔLW (cirrus thinning) = -0.28 (CAM5), -0.88 (CAM5-M), -0.87 (ECHAM), 0.19 W/m2 (GEOS5)

TOA Net Flux Change (CTL - HOM)

CAM5

CAM5-Michigan



ECHAM6

GEOS5

ΔSW+LW (cirrus thinning)= -0.1 (CAM5), -0.44 (CAM5-M), -0.52 (ECHAM), 0.42 W/m2 (GEOS5)

Summary

- The global mean IWC differ by a factor of 2, and the difference in ice number concentration is larger (by ~ one order of magnitude) between CAM5, CAM5-Mich, ECHAM6 and GEOS5;
- Anthropogenic aerosol increases ice number concentration in cirrus clouds in most of global regions from pre-industrial to present-day time, with a longwave forcing of **0.5-0.6** W/m2, and net forcing of **0.1-0.3** W/m2 between CAM5, CAM5-Mich, ECHAM6 and GEOS5 (regional differences are larger)
- Cirrus thinning experiment (CTL – HOM) reduces ice number concentration in cirrus clouds in most of global regions, with a net flux change of -0.1 (CAM5), -0.4 (CAM5-Mich), -0.5 (ECHAM6), and +0.4 W/m2 (GEOS5).

Future Plan

- Compare high frequency model output (3 hourly) with observation data;
- Write the results for publications.

Relative Contribution of Ni from HOM and HET, HET/(HOM+HET)

CTL