AEROCOM Intercomparison

Aerosol Effects on Cirrus Clouds (IND-ICE)

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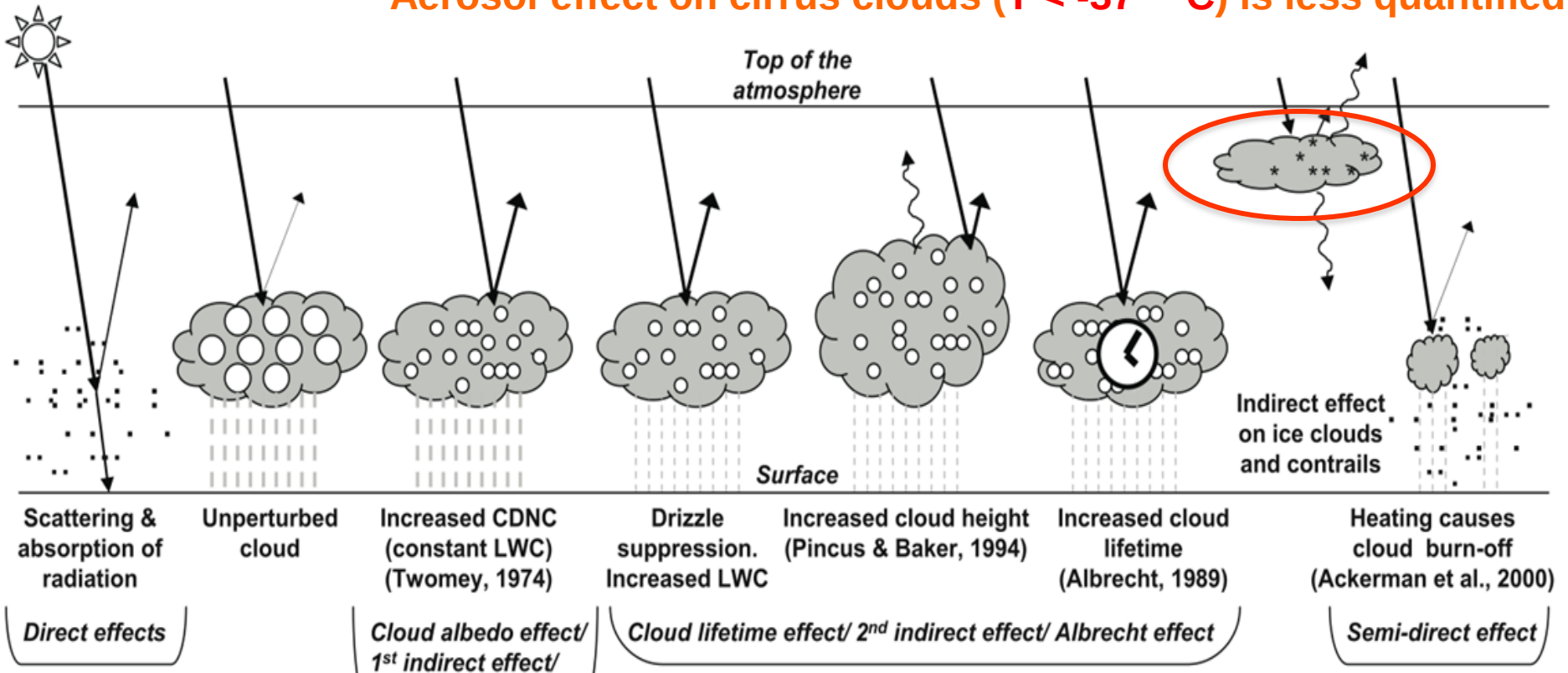
Climatic effects of atmospheric aerosols

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

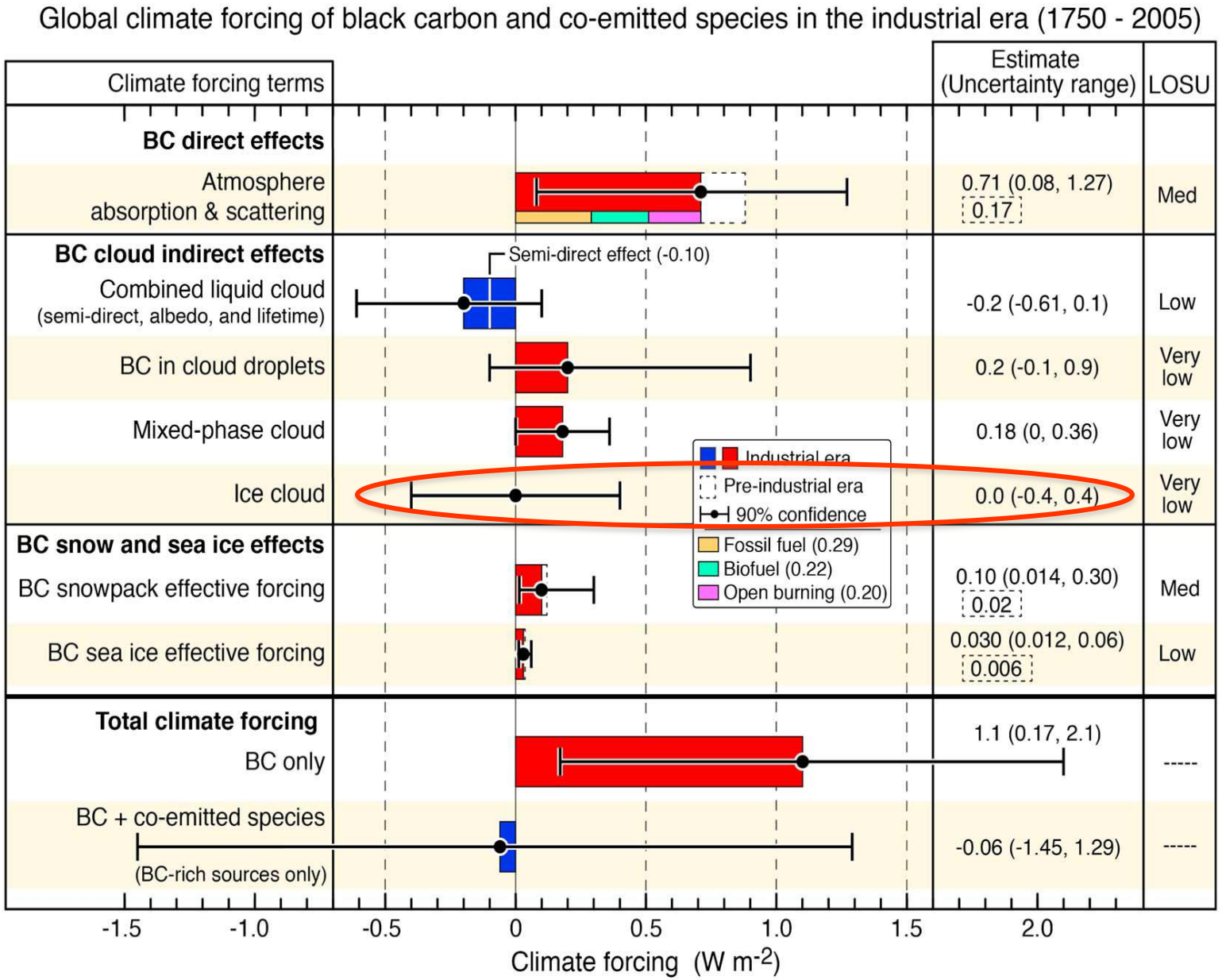
Aerosol effect on cirrus clouds (T < -37 ° C) is less quantified



IPCC 2007

Global Mean Black Carbon Radiative Forcing from 1750 to 2005

Bond et al. (2013)

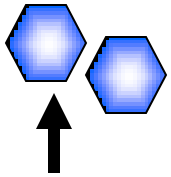


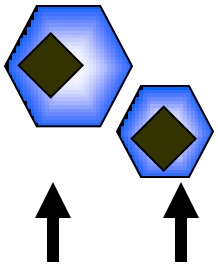
Motivation

- 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 (IND-ICE) is to more systematically assess the impact of aerosols on cirrus clouds and to estimate associated anthropogenic aerosol forcing.

Ice Nucleation in Cirrus (Ice)

Ice Crystal Population





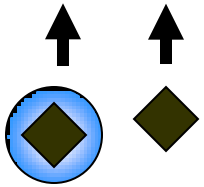
Homogeneous Freezing

Mainly depends on RH_i and T

Heterogeneous Freezing (Immersion, deposition, …)

Also depends on the material and surface area

Wet aerosol particles



+ Insoluble Material ("Ice Nuclei")

Multiple mechanisms for ice formation can be active.

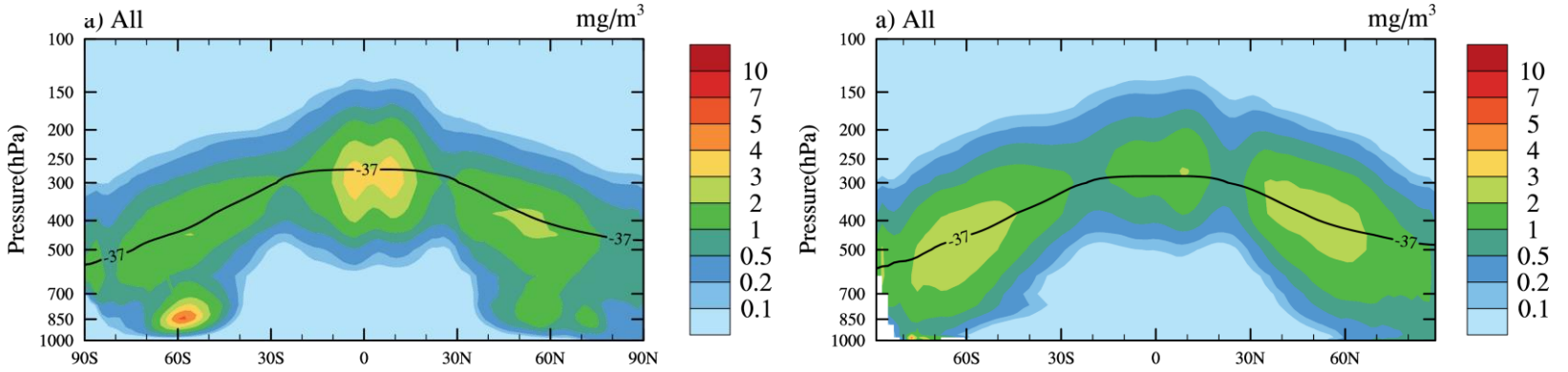
AEROCOM Intercomparison (IND-ICE)

- GCM simulations with configuration:
  - Prescribed SST
  - Nudged with reanslysis data (wind, T)
  - IPCC AR5 emissions
- Three sets of simulations (PD & PI) :
  - Homogeneous and heterogeneous combined (**ALL**)
  - Homogeneous nucleation only (**HOM**)
  - Fixed ice nucleation in cirrus clouds (**FIX**)
- Analysis of variables:
  - IWC, Ni, Rieff, clouds, Qv, TOA SW/LW flux, aerosols
- Participating models:
  - CAM5, ECHAM6-HAM2 (**submitted**)
  - CAM3-IMPACT, GEOS-5, CAM3-Oslo,…(expected)

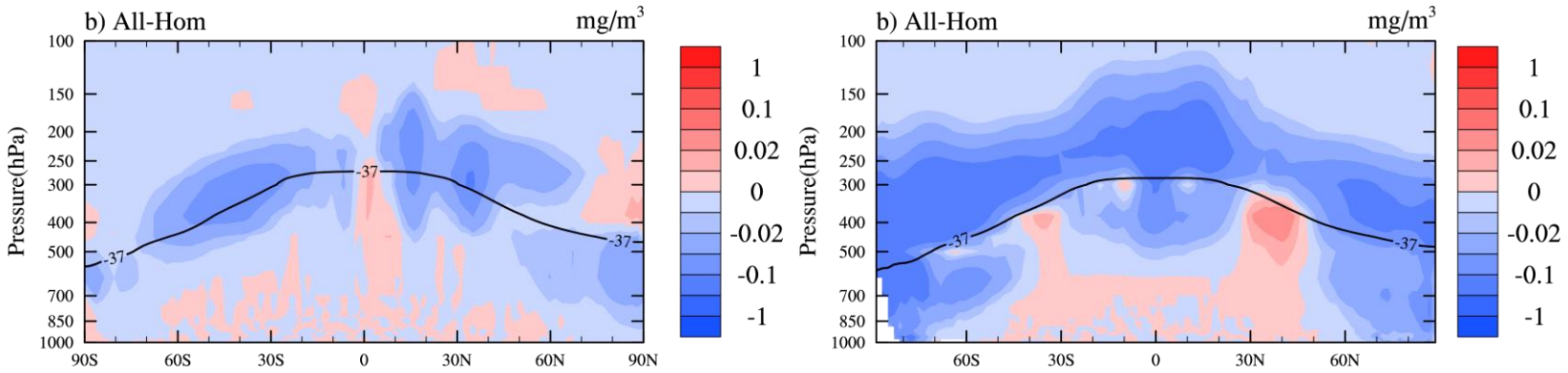
Ice Water Content

CAM5 **ECHAM6**

ALL



ALL - HOM



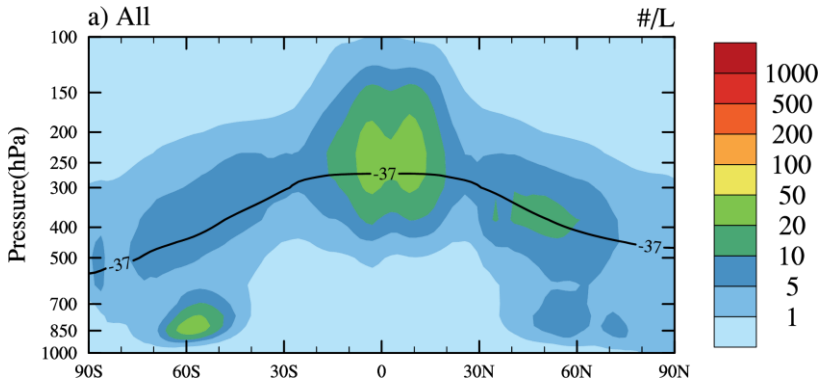
IWP = 15.8 g/m2 (CAM5), 8.8 g/m2 (ECHAM6)

Δ(IWP) = -0.16 g/m2 (CAM5), -0.54 g/m2 (ECHAM6)

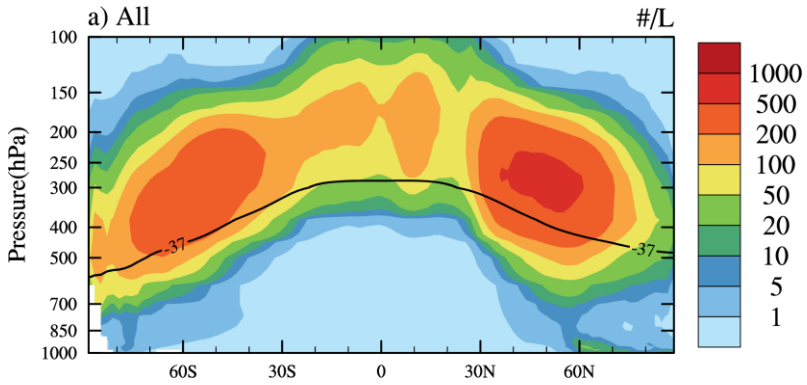
Ice Crystal Number Concentration

ALL

CAM5



ECHAM6



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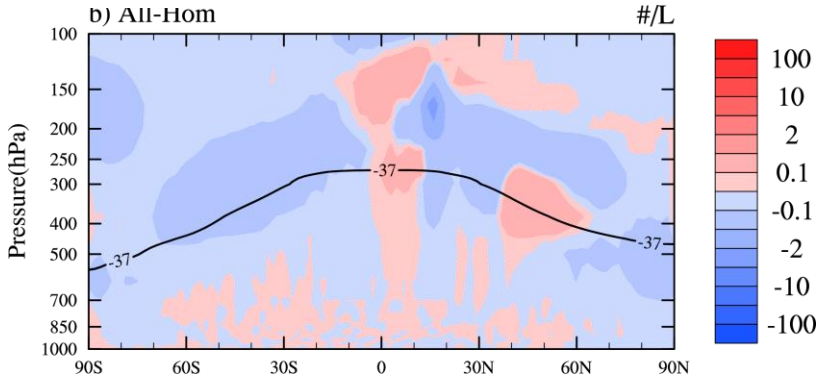
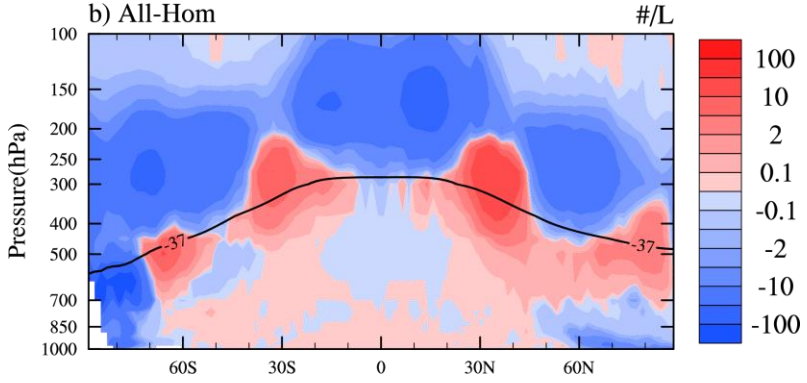




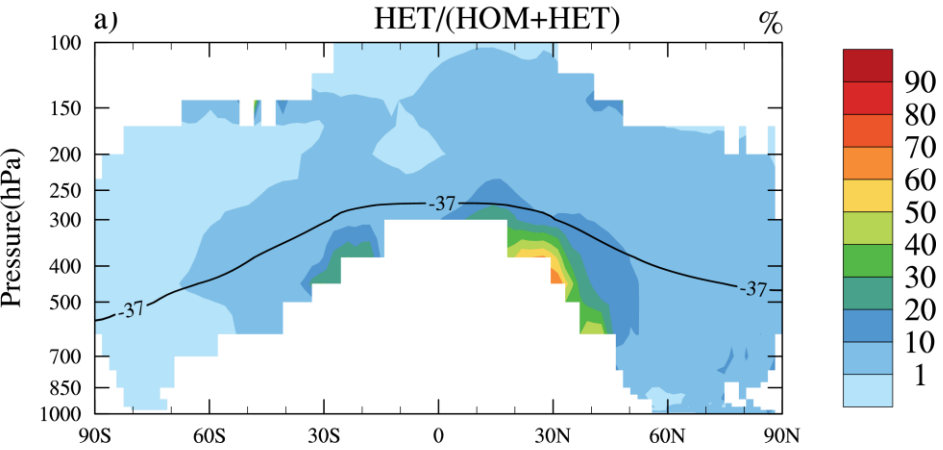
Coarse mode dust as heterogeneous IN in CAM5

Accumulation/coarse mode dust and BC as heterogeneous IN in ECHAM6

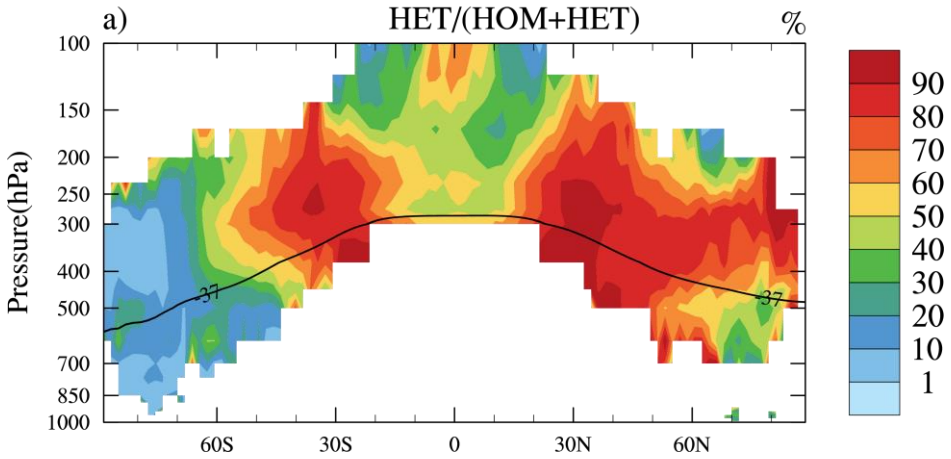
Relative Contribution of Ni from HOM and HET, HET/(HOM+HET)

CAM5

ALL



ECHAM6



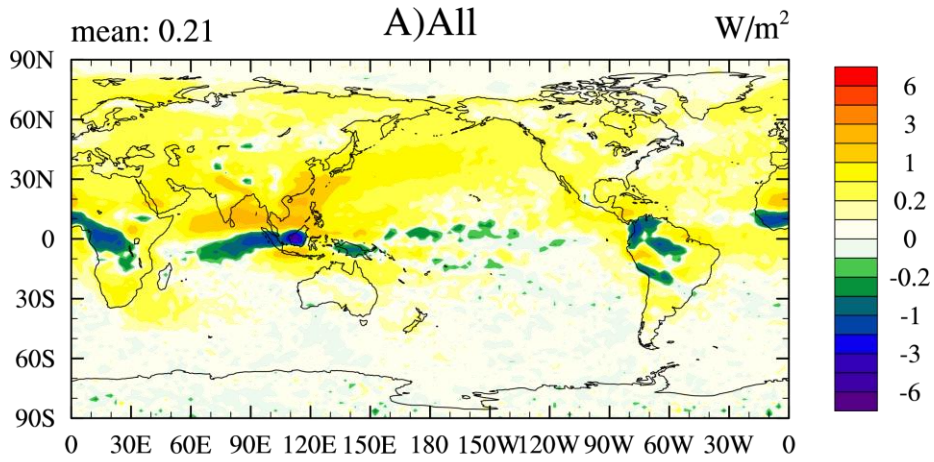
Coarse mode dust as heterogeneous IN in CAM5

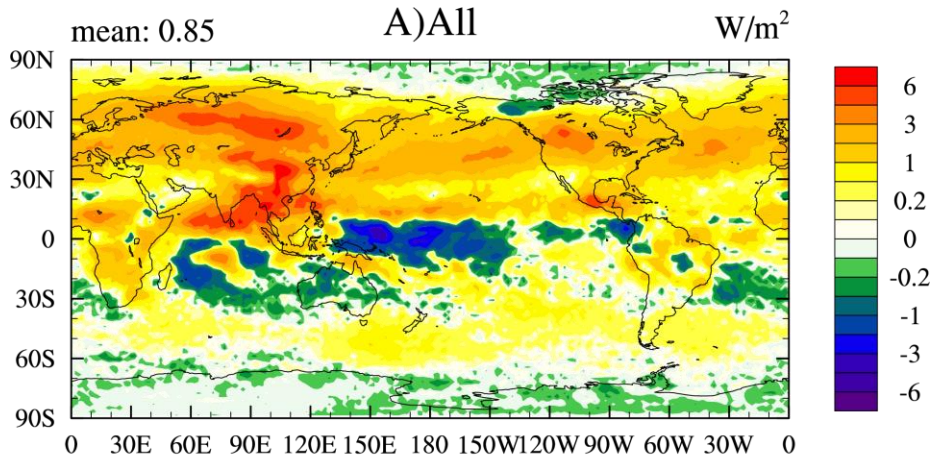
Accumulation/coarse mode dust and BC as heterogeneous IN in ECHAM6

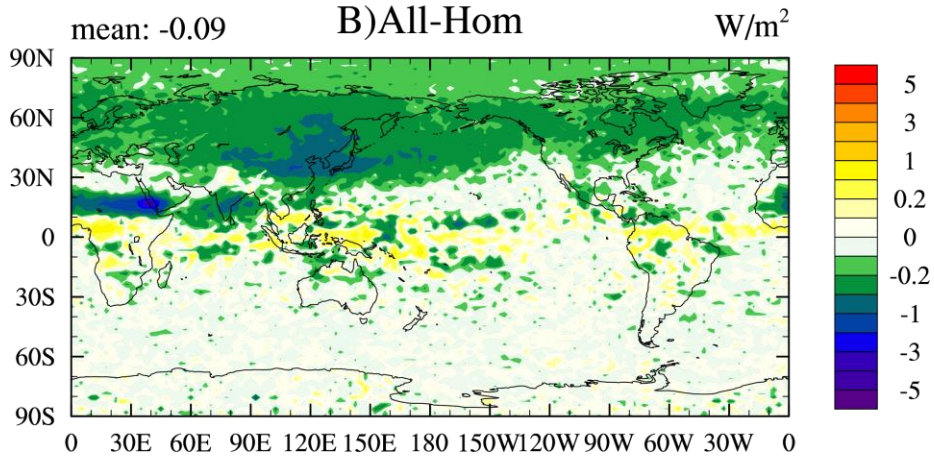
TOA Net LW Flux Change (PD-PI)

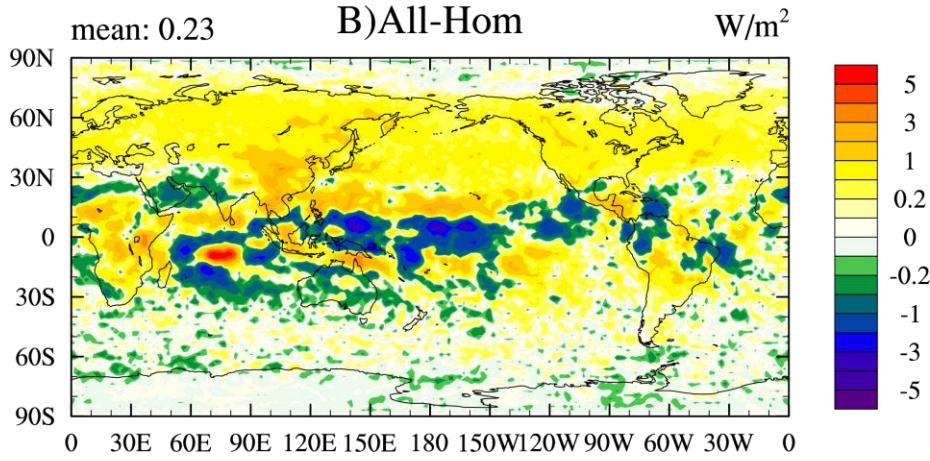
CAM5 **ECHAM6**

ALL









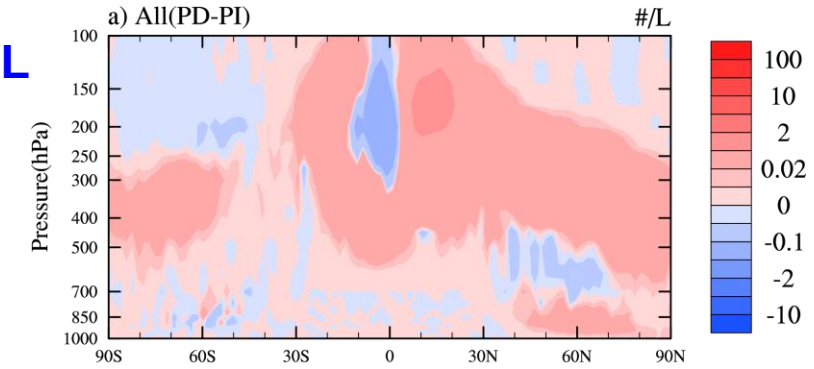
ALL - HOM

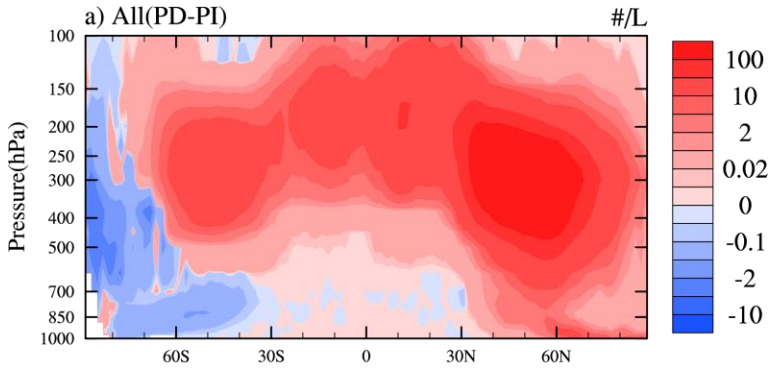
Ice Number Change (PD-PI)

CAM5

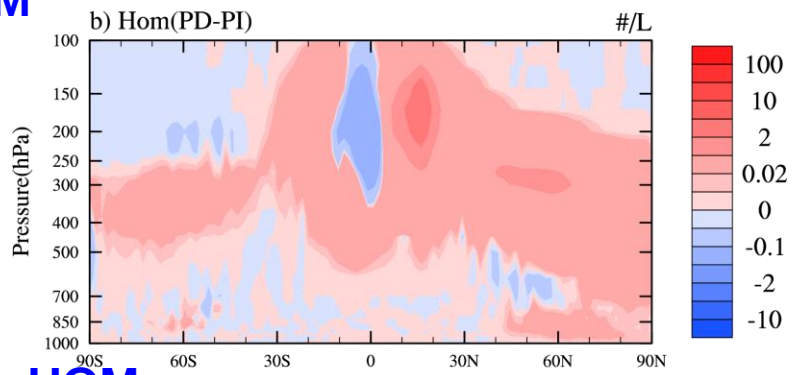
ECHAM6

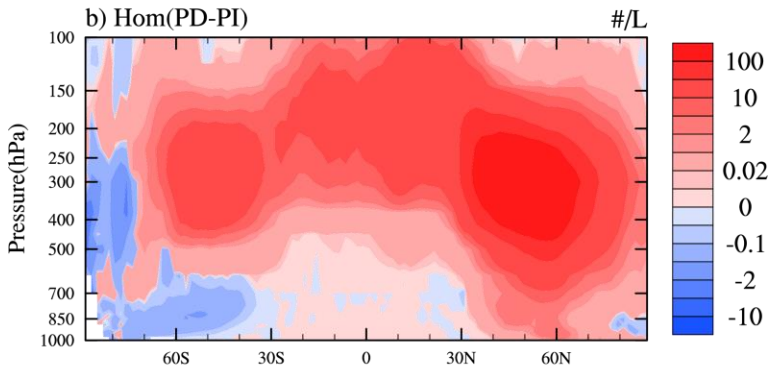
ALL



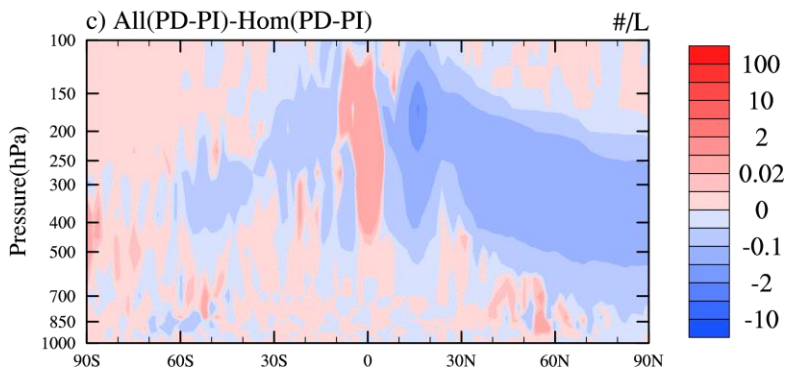


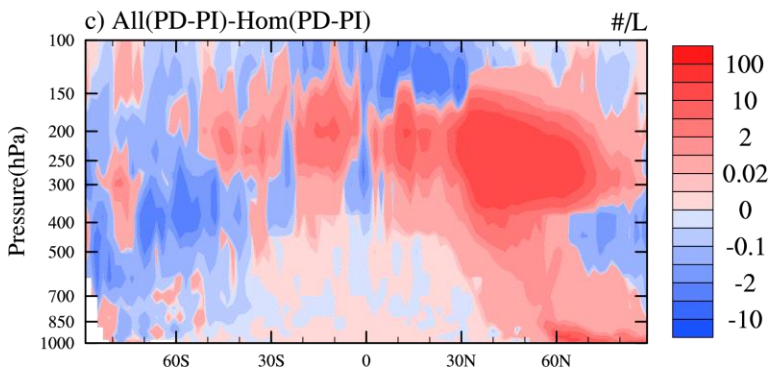
HOM





ALL-HOM

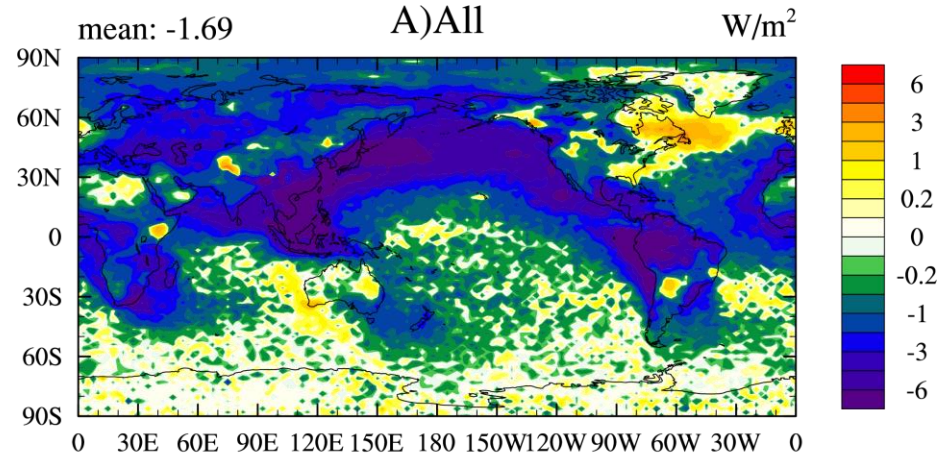


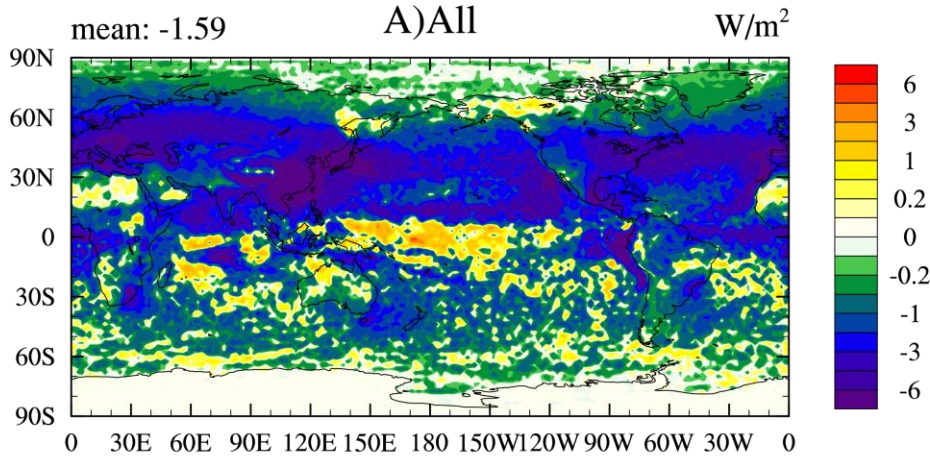


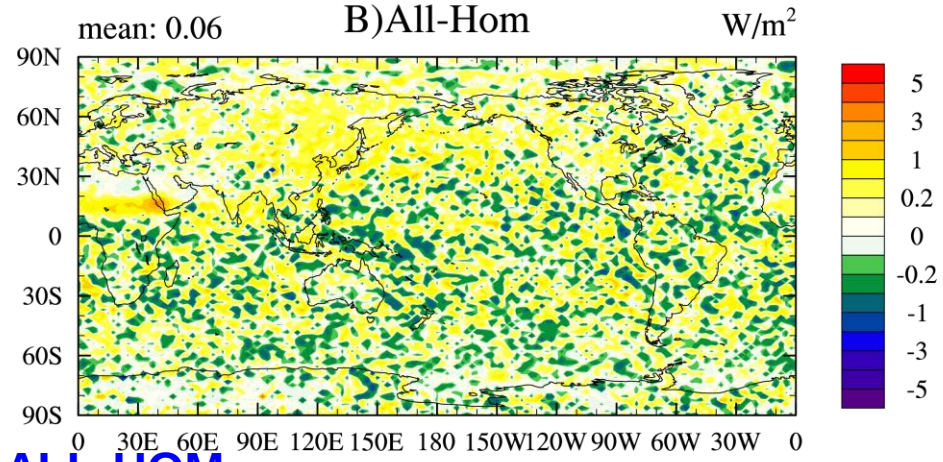
TOA Net SW Flux Change (PD-PI)

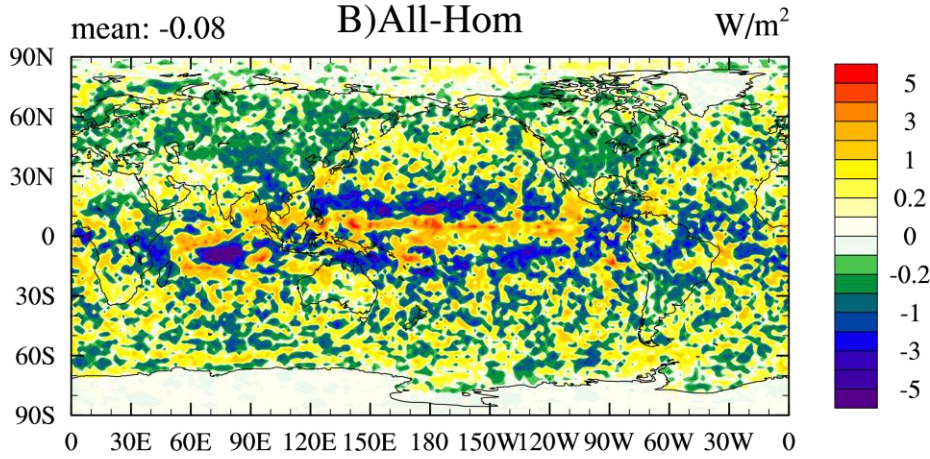
CAM5 **ECHAM6**

ALL







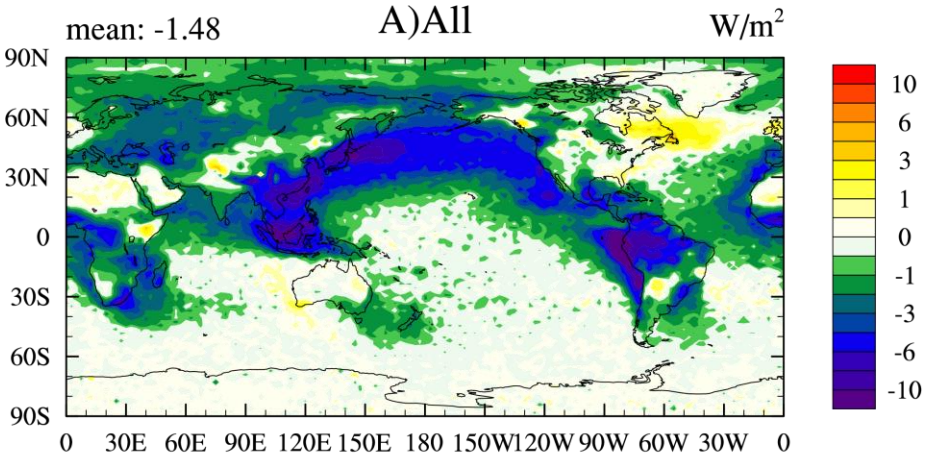


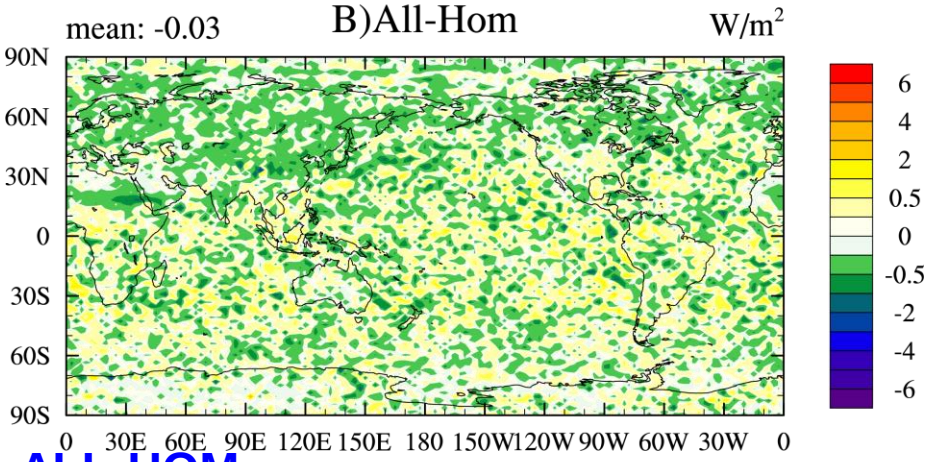
ALL-HOM

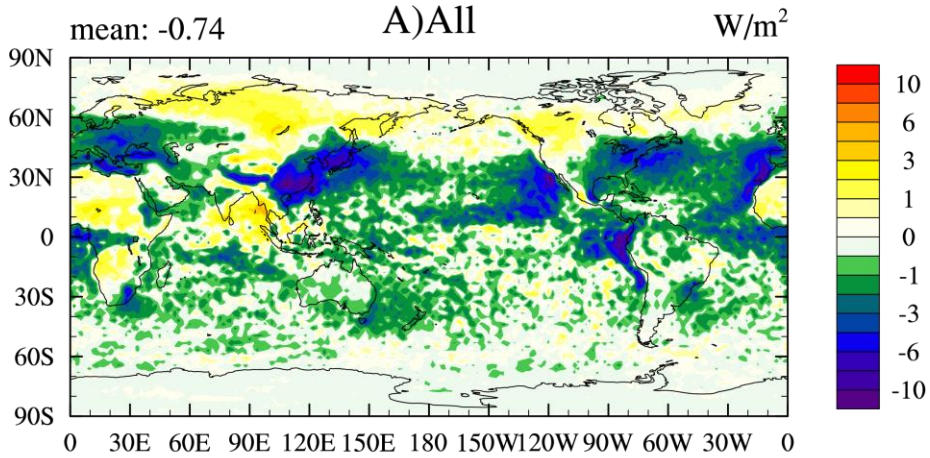
TOA Net Flux Change (PD-PI)

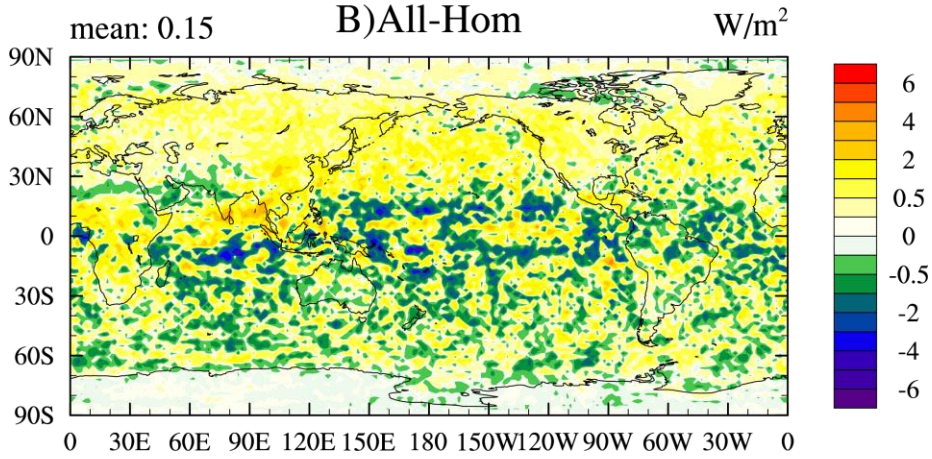
CAM5 **ECHAM6**

ALL





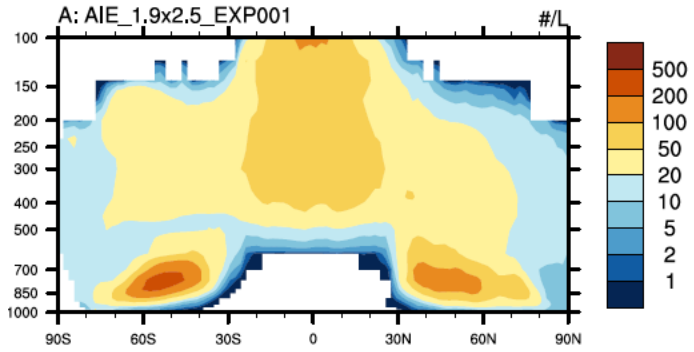




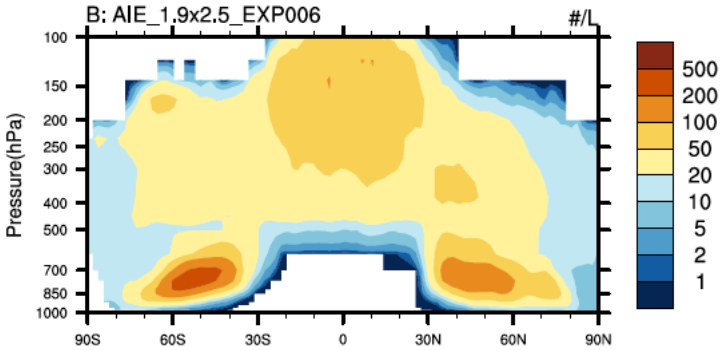
ALL-HOM

Impact of Nudging on Ice Number (CAM5)

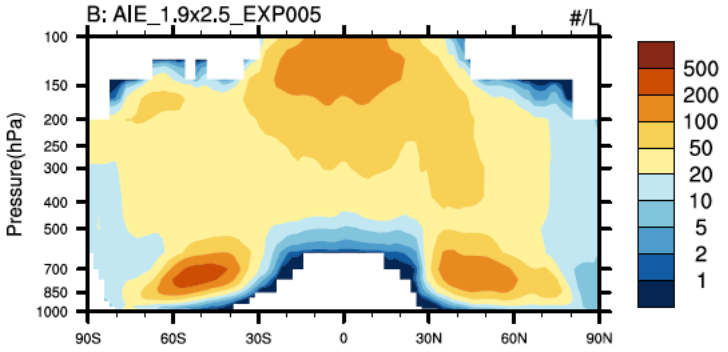
T 6H



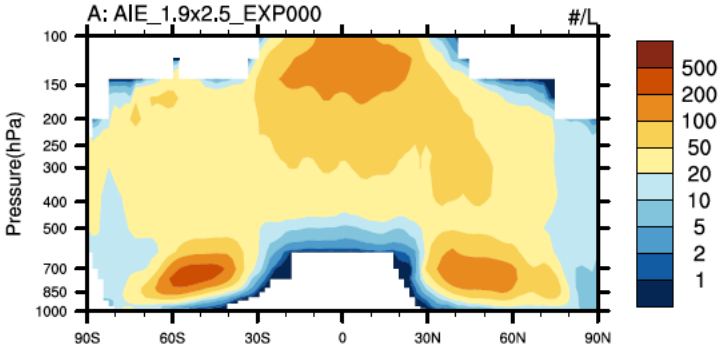
T 24H



T not nudged



Climatological run



Summary

- While the global mean IWC differ by a factor of 2, the difference in ice number concentration is much larger (by ~ one order of magnitude) between CAM5 and ECHAM6-HAM2;
- The one major source of differences in ice number concentration is related to heterogeneous ice nucleation, especially the role of BC;
- An unexpected result of nudging (of temperature) on upper troposperic water vapor and ice clouds (through detrainemnt of deep convection);
  - Only nudge to wind speed?

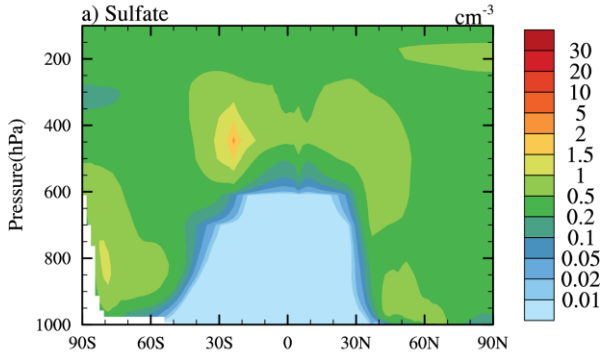
Future Work

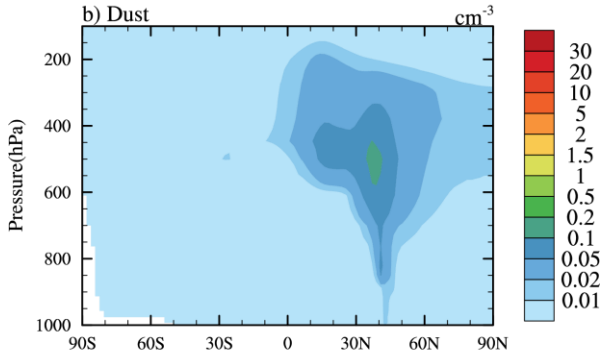
- Analyze the simulation of fixed ice nucleation (FIX), and estimate anthropogenic aerosol effect on cirrus clouds through *homogeneous and heterogeneous* nucleation: Δ(ALL – FIX)

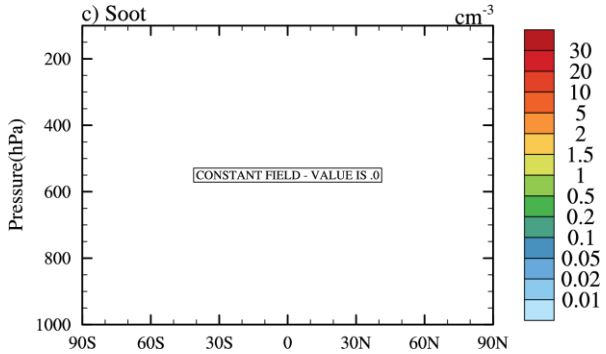
- Analyze results from more models;
- Compare models with more observation data.

Aerosols

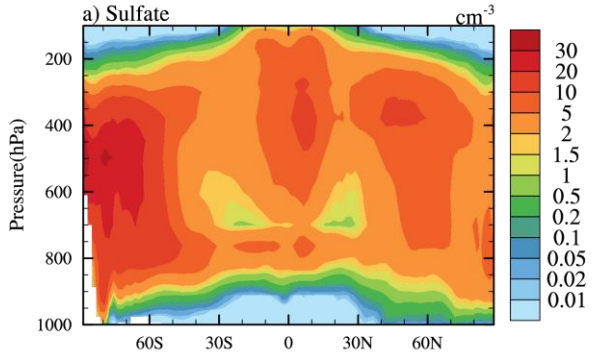
CAM6

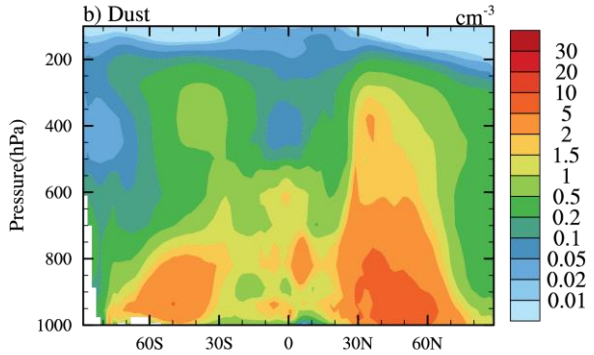


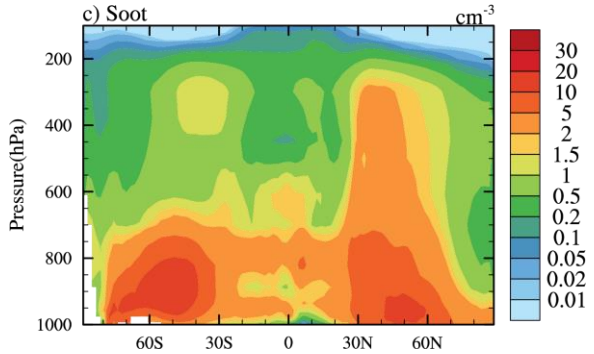




ECHAM6

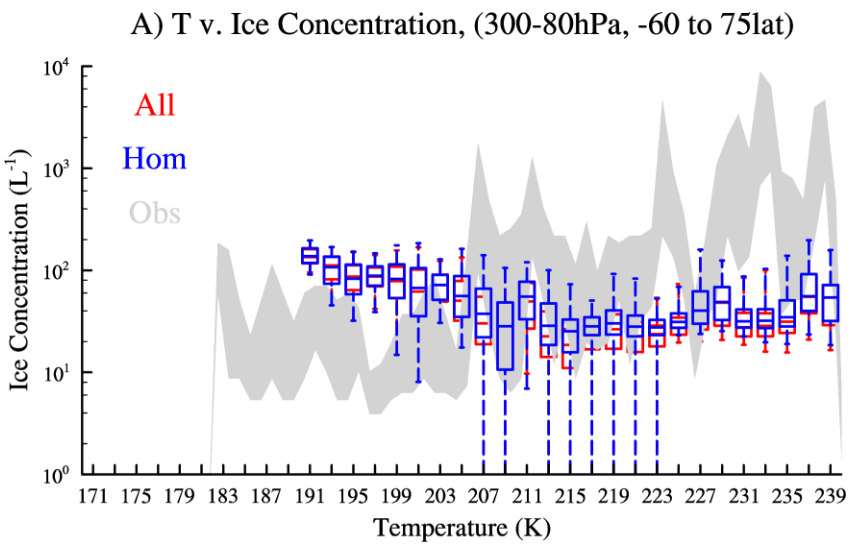




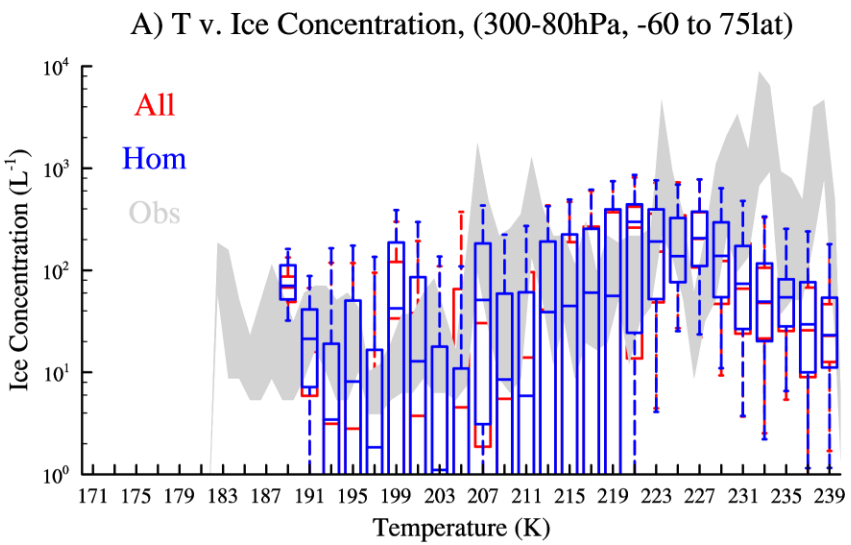


Ice Number vs. Krämer Data

CAM5



ECHAM6

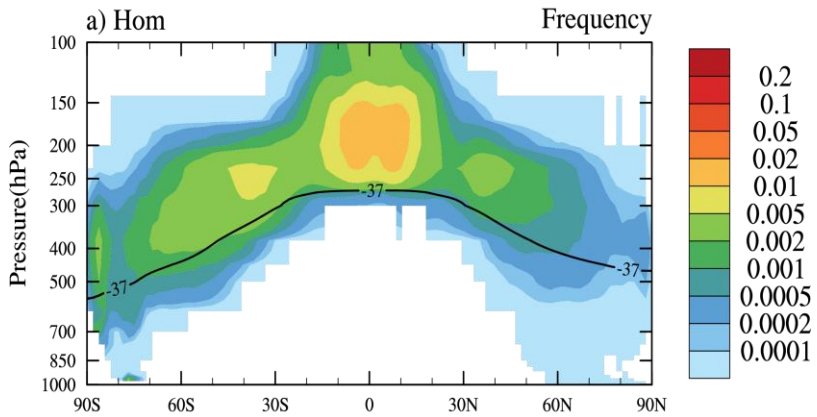


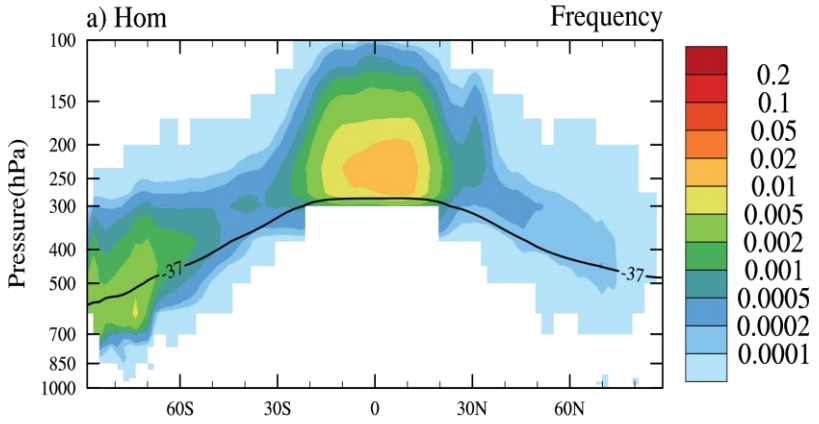
Frequency Occurrence of Nucleation Events

CAM5

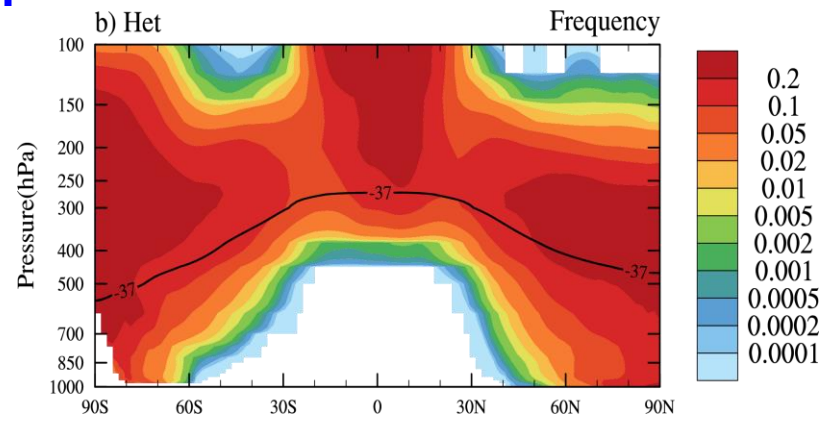
ECHAM

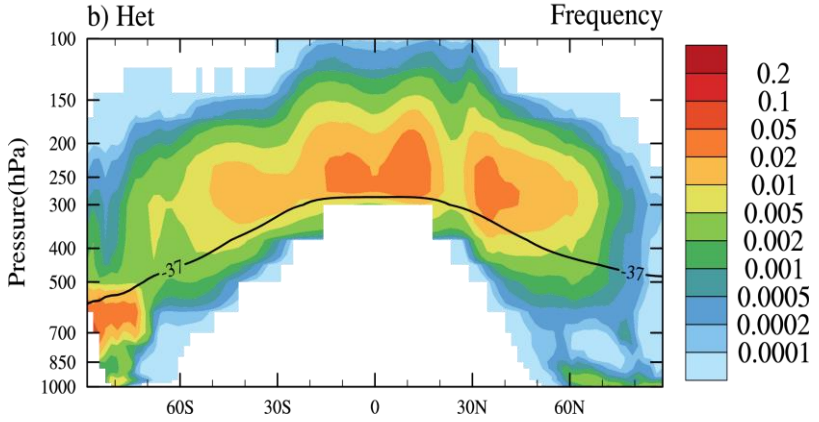
HOM





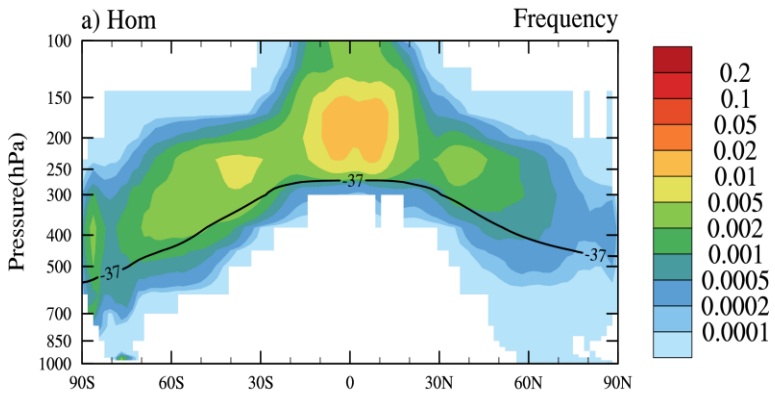
HET

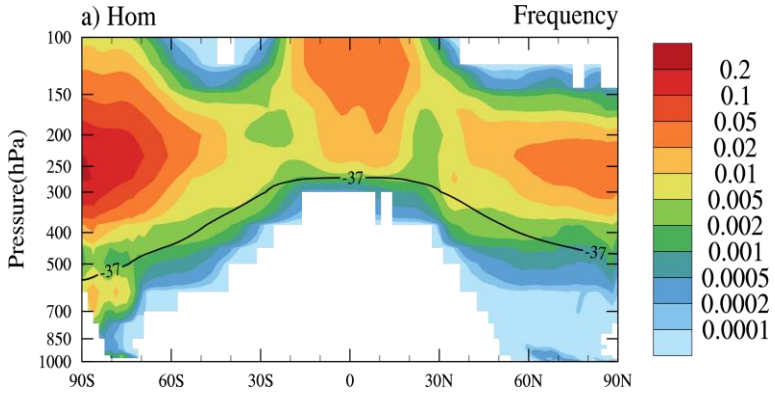




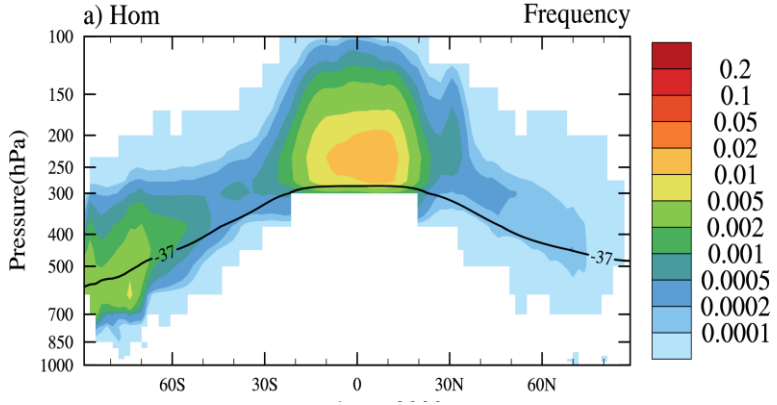
Frequency Occurrence

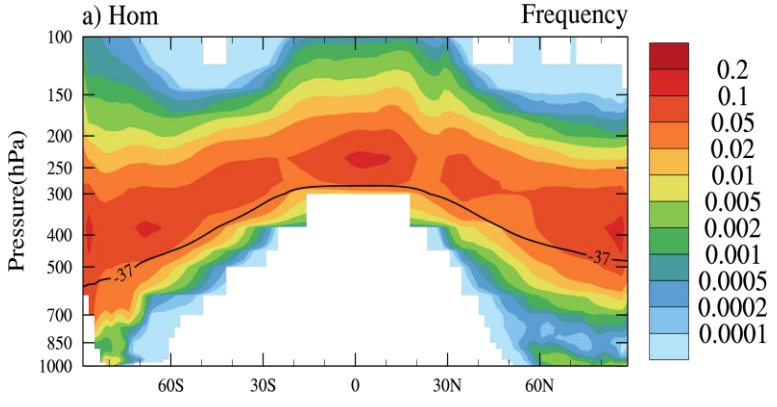
CAM





ECHAM



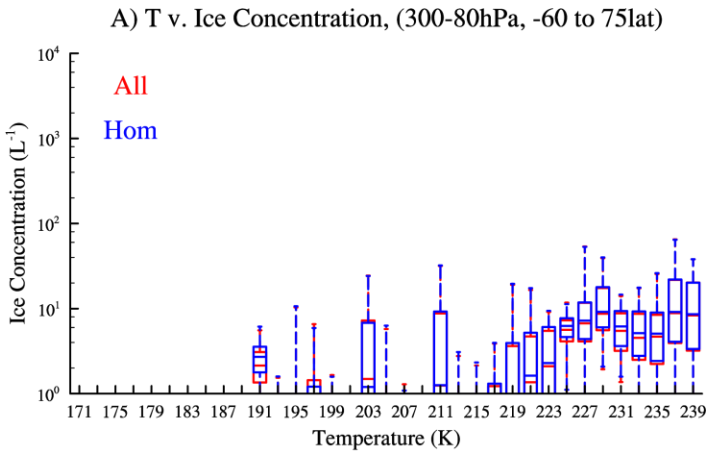


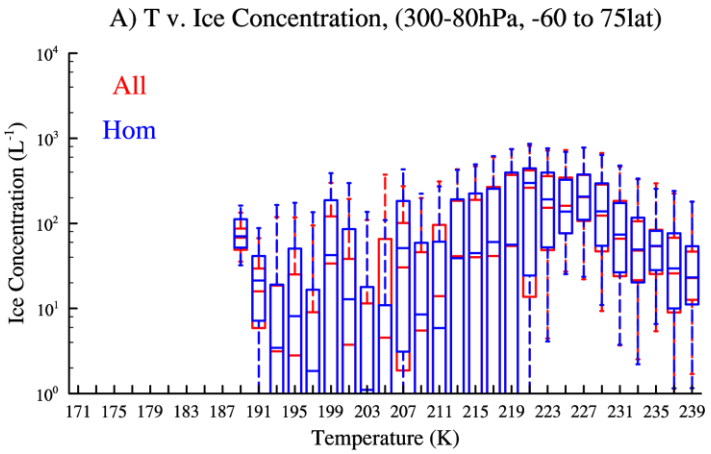
Ice Number and Size vs. Krämer Data

CAM5

ECHAM

Ni





Reff