Model Intercomparison of Aerosol Effects on Liquid and Mixed-phase clouds

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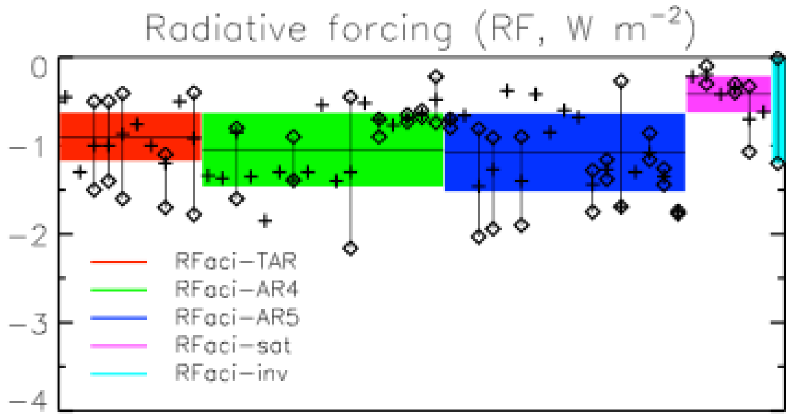
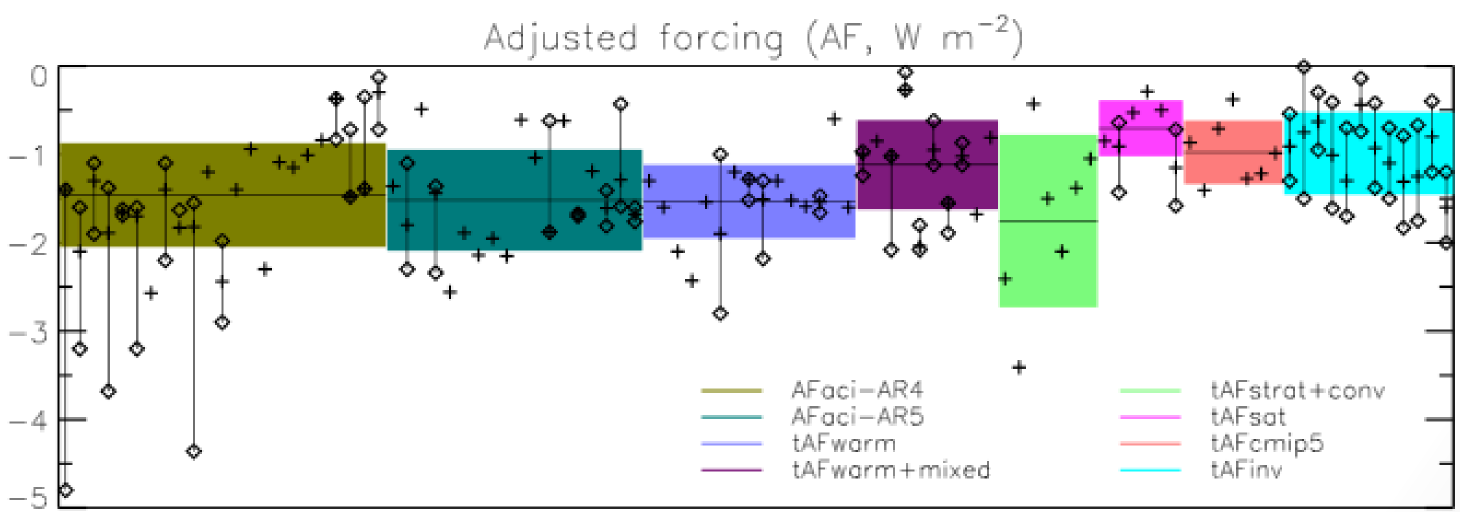
Aerosol-cloud interactions, AR5





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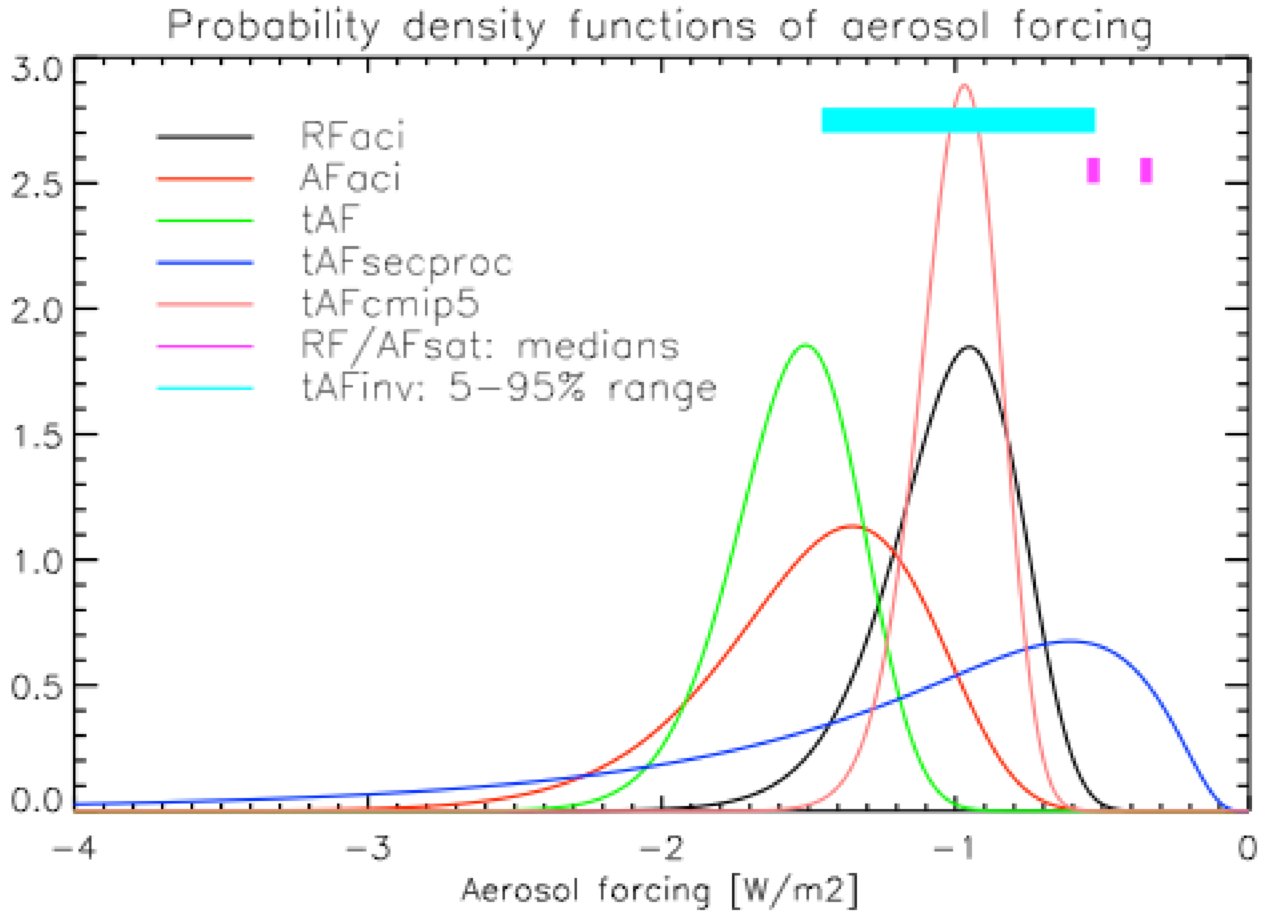
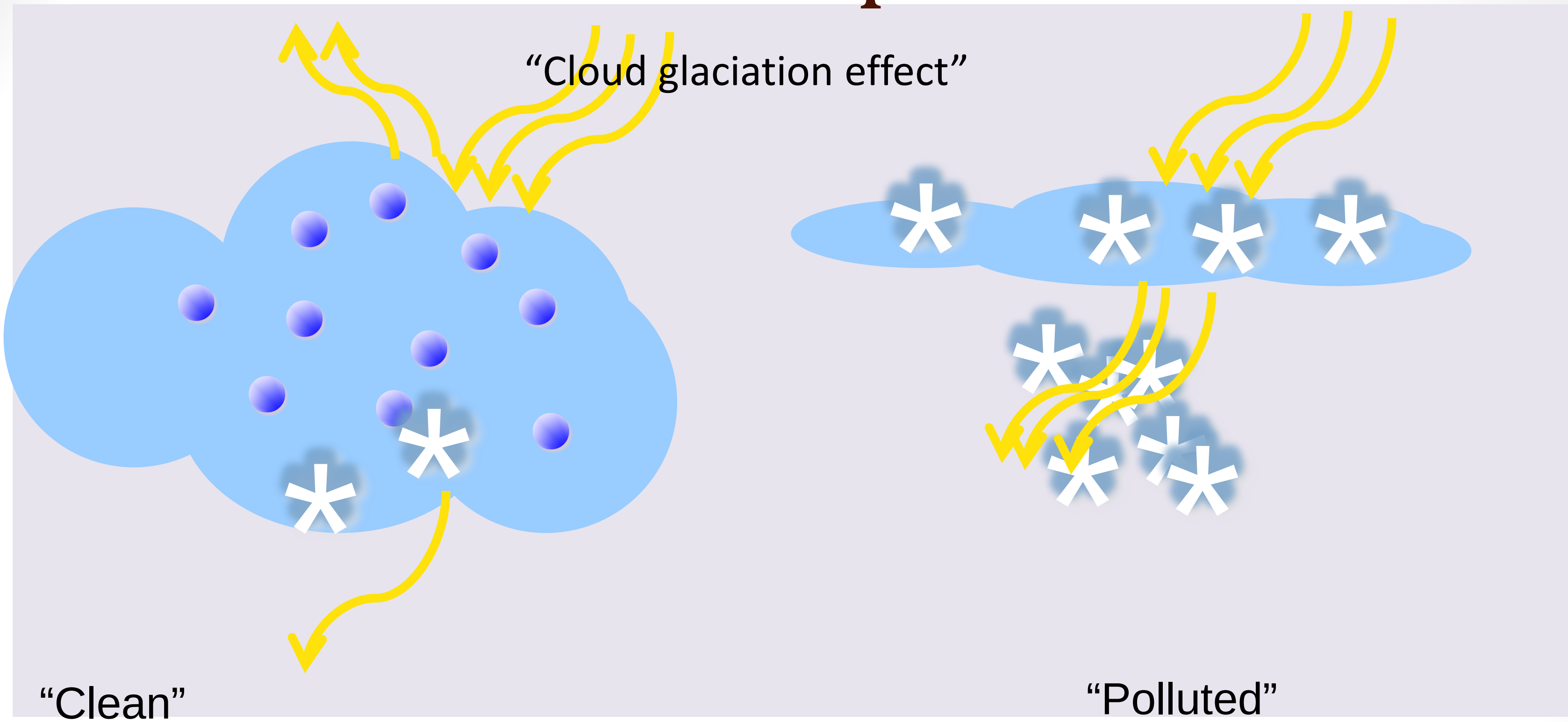


Aerosol and mixed-phase clouds



Anthropogenic emissions ?	More IN	Cloud glaciation via Bergeron-Findeisen process	More precipitation	Reduced cloud thickness/lifetime → WARMING

Ways that mixed-phase clouds could influence the total aerosol effect

1) Glaciation effect: Anthropogenic emissions = more IN (reversed lifetime effect)
2) De-activation effect: Coating of soluble material can "de-activate" IN = fewer IN
3) By limiting effects on liquid clouds: many liquid clouds, stronger effect

Model Intercomparison on aerosol effects on liquid and mixed-phase cloud: Key questions

- Will a subset of models that explicitly represent mixed-phase cloud microphysics yield a lower aerosol adjusted forcing?
- How sensitive is the aerosol indirect effect to the choice of heterogeneous ice nucleation parameterization?
- How does the aerosol forcing change when IN concentrations are kept the same in PD and PI simulations?
- How do the simulated liquid cloud fractions compare to satellite observations

Experimental set-up

- Experiment 1: Simulations using the DeMott et al. (PNAS, 2010) ice nuclei (IN) parameterization, in which the number concentration of IN active at cloud temperature T_k (in Kelvin) is given by:

$$n_{IN,T_k} = a(273.16 - T_k)^b (n_{aer,0.5})^{(c(273.16-T_k)-d)}$$

where *a, b, c* and *d* are constants and $n_{aer,0.5}$ is the concentration of insoluble aerosol particles larger than 0.5μm. $n_{aer,0.5}$ was prescribed and identical in PD and PI simulations.

- Experiment 2: Simulations using the DeMott et al. parameterization, but this time each model simulated it's own concentration of insoluble particles larger than 0.5μm.
- Experiment 3: Simulations in which the models all used their own internal treatment of heterogeneous freezing
- Each experiment was run twice: once with PD, and once with PI Emissions. Emissions were taken from Dentener et al. (Atm. Chem. Phys., 2006). Both direct and indirect effects were included.

Model intercomparison

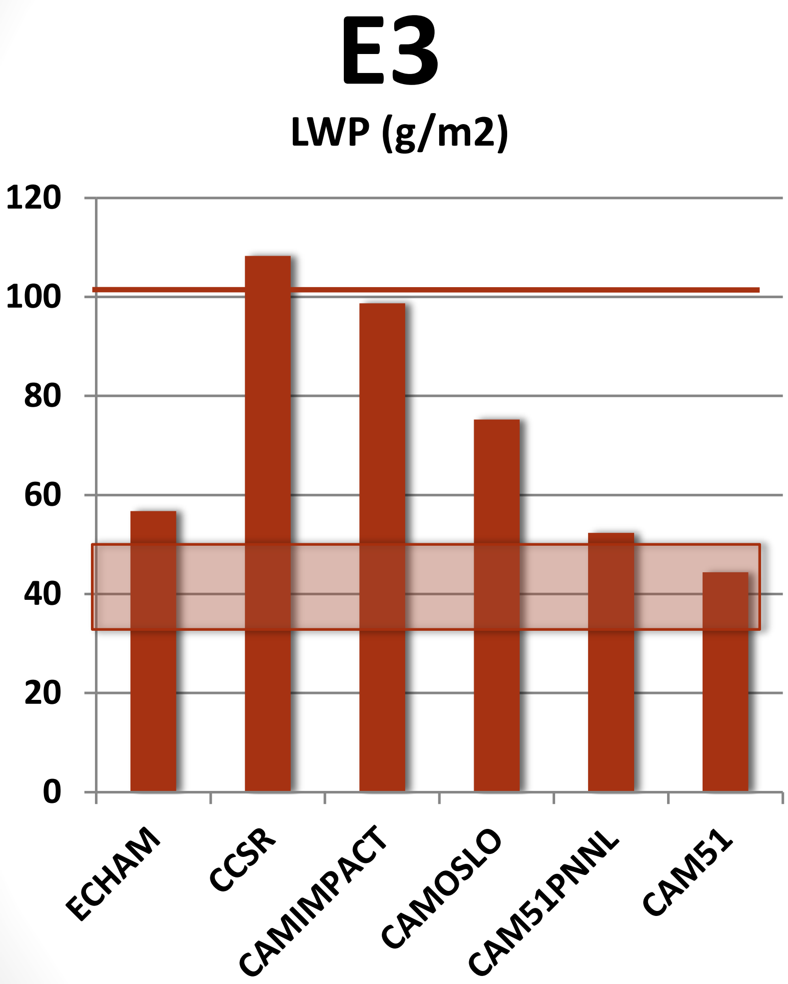
- **Participating models:ECHAM5-HAM, CAM-Oslo, CAM-Impact, MIROC-SPRINTARS (CCSR), CAM5.1, CAM5.1-PNNL**
- **Requested output**

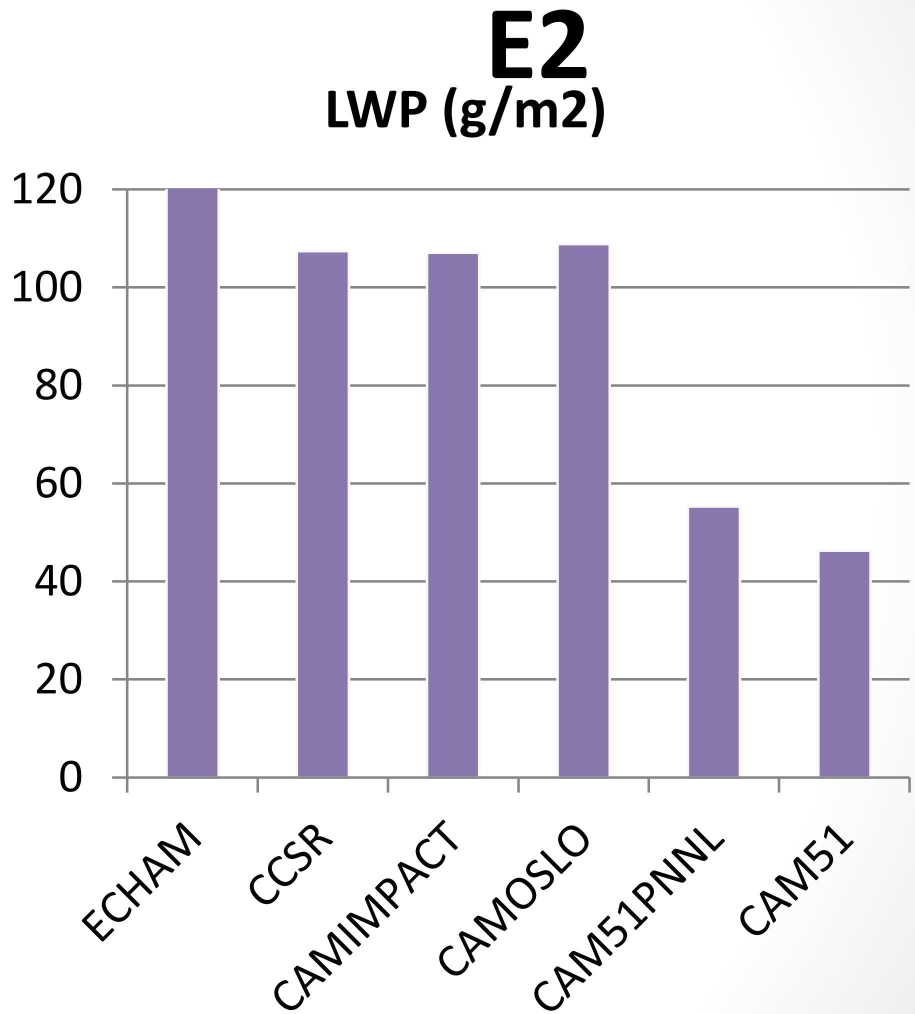
  - 2D fields: LWP, IWP, SWCF, LWCF, Net SW & LW radiation, (TOA and surface), column cloud droplet and ice crystal number concentrations, Cloud cover

  - 3D fields: Ice and water mixing ratios, Ice crystal and cloud droplet number concentrations, Ice crystal and cloud droplet effective radii, Cloud cover, Concentration of particles larger than 0.5um (only for exp. 2), Number concentration of insoluble particles that are potential IN (only for Exp. 3), Total particle number concentration.

  - Additional output: Additional output on isotherms (-5°C, -10°C, -15°C, -20°C, -25°C, -30°C, -35°C) for comparisons with CALIOP (calculated only in grid-boxes in which: i) the temperature is that of the isotherm +/- 1°C ii) total (liquid & ice) water content exceeds 1.e-10 kg/kg and iii) there is no grid-box above that has an optical depth larger than 3).

Liquid Water Path (LWP)

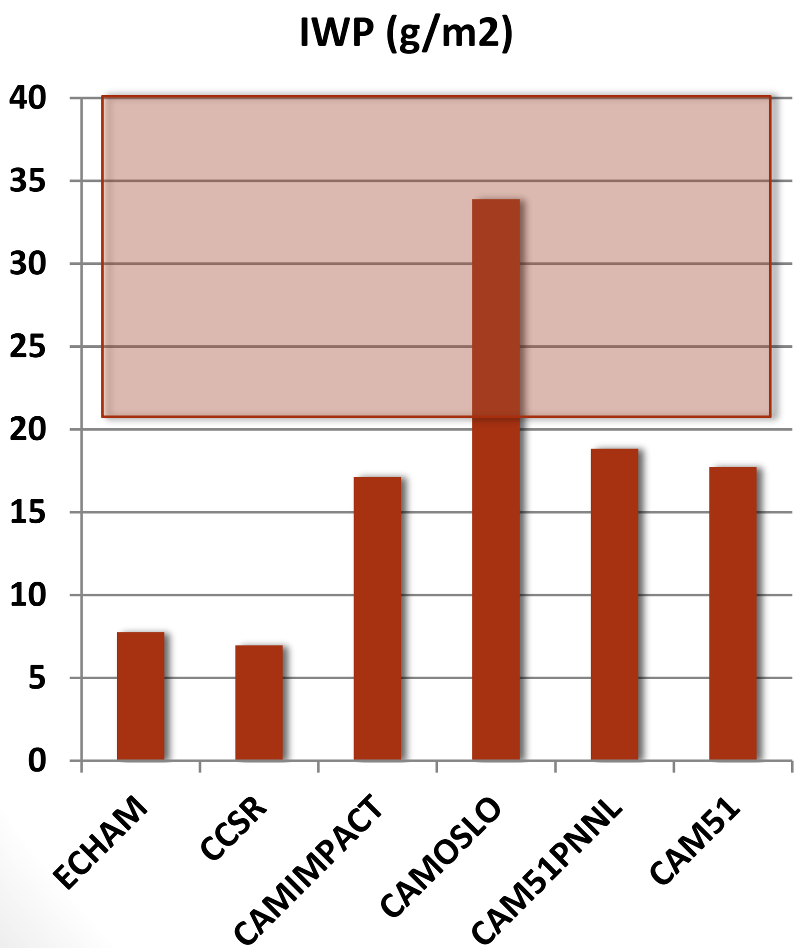




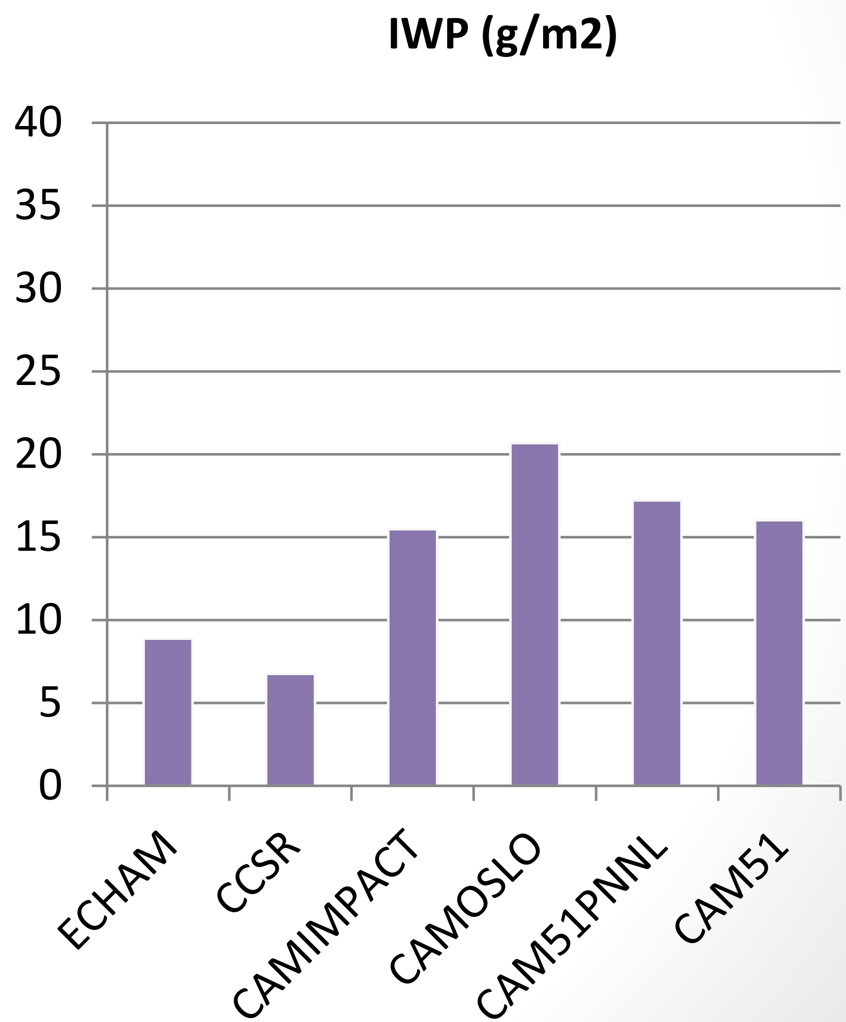
A-train observations taken from Jiang et al. (2012)

Ice Water Path (IWP)

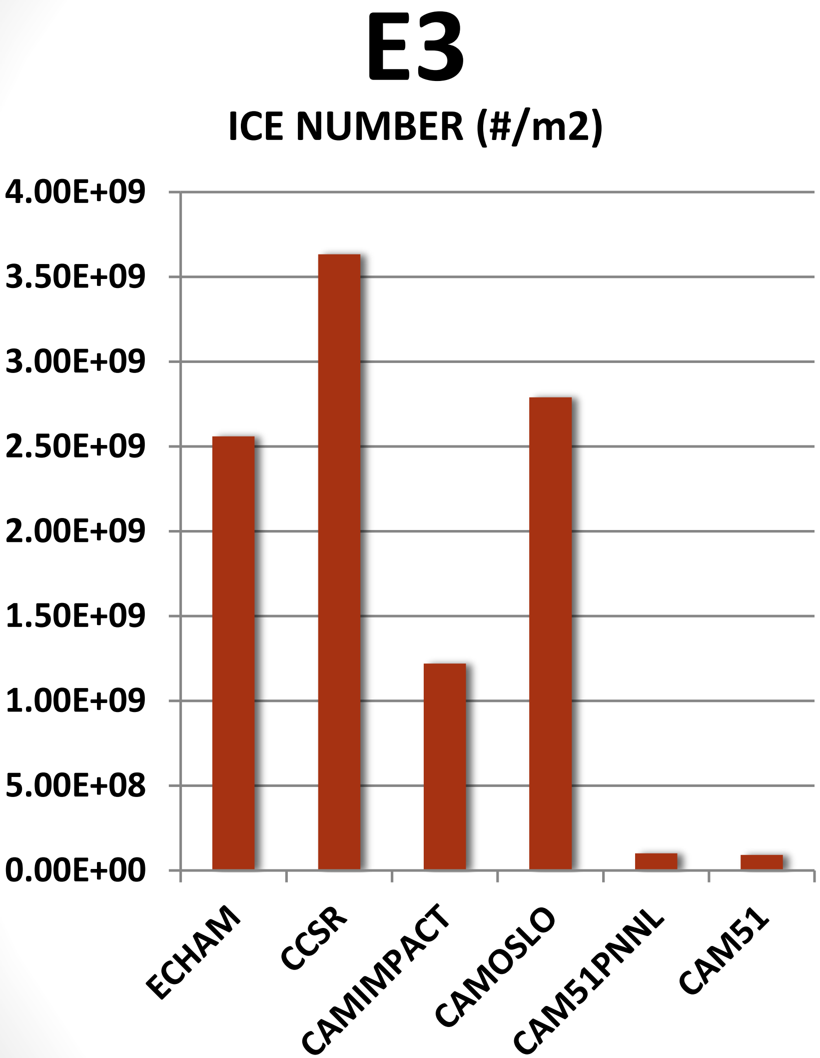
E3

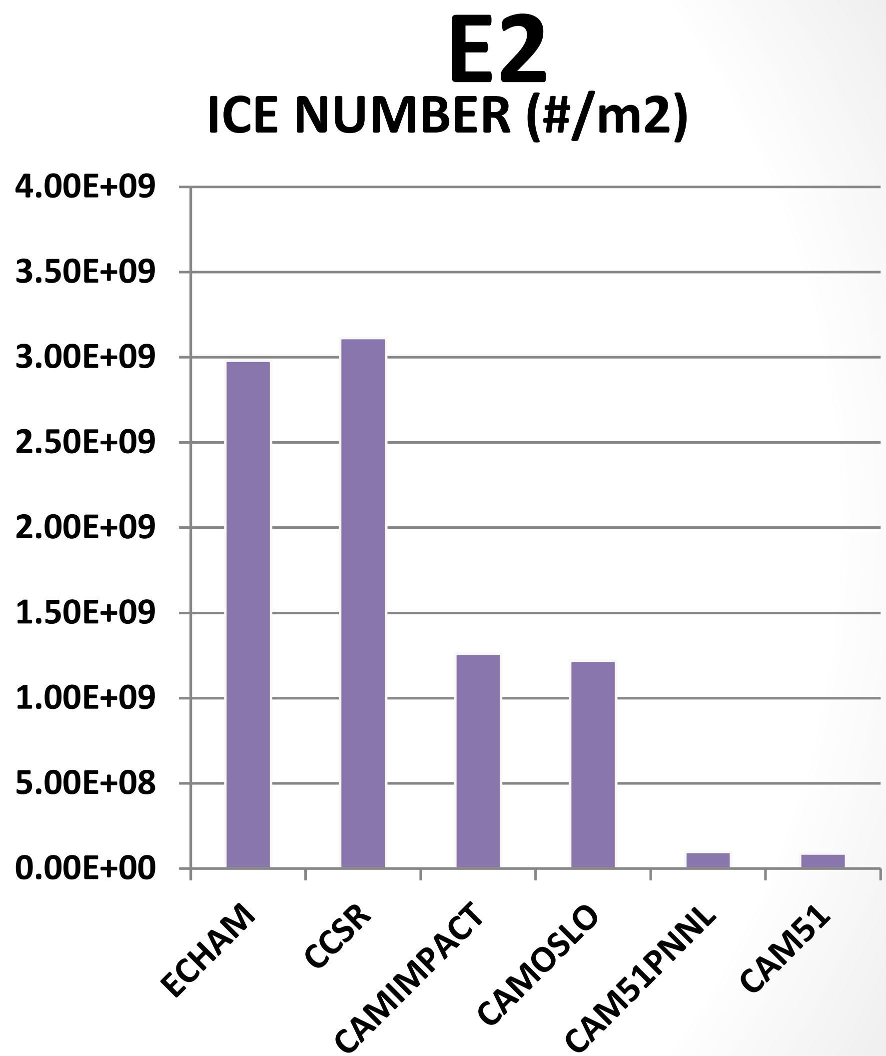


E2

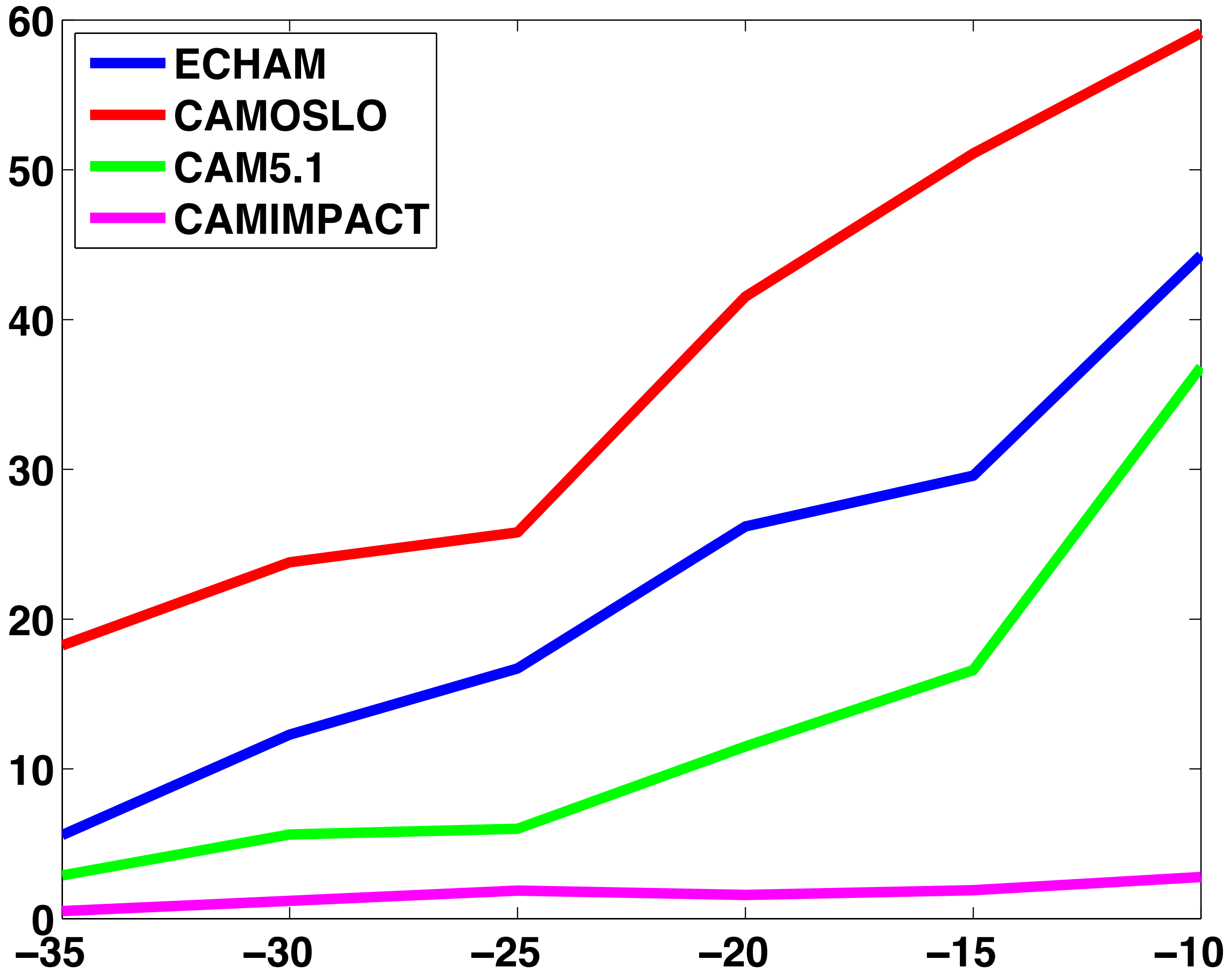


Column ice crystal number

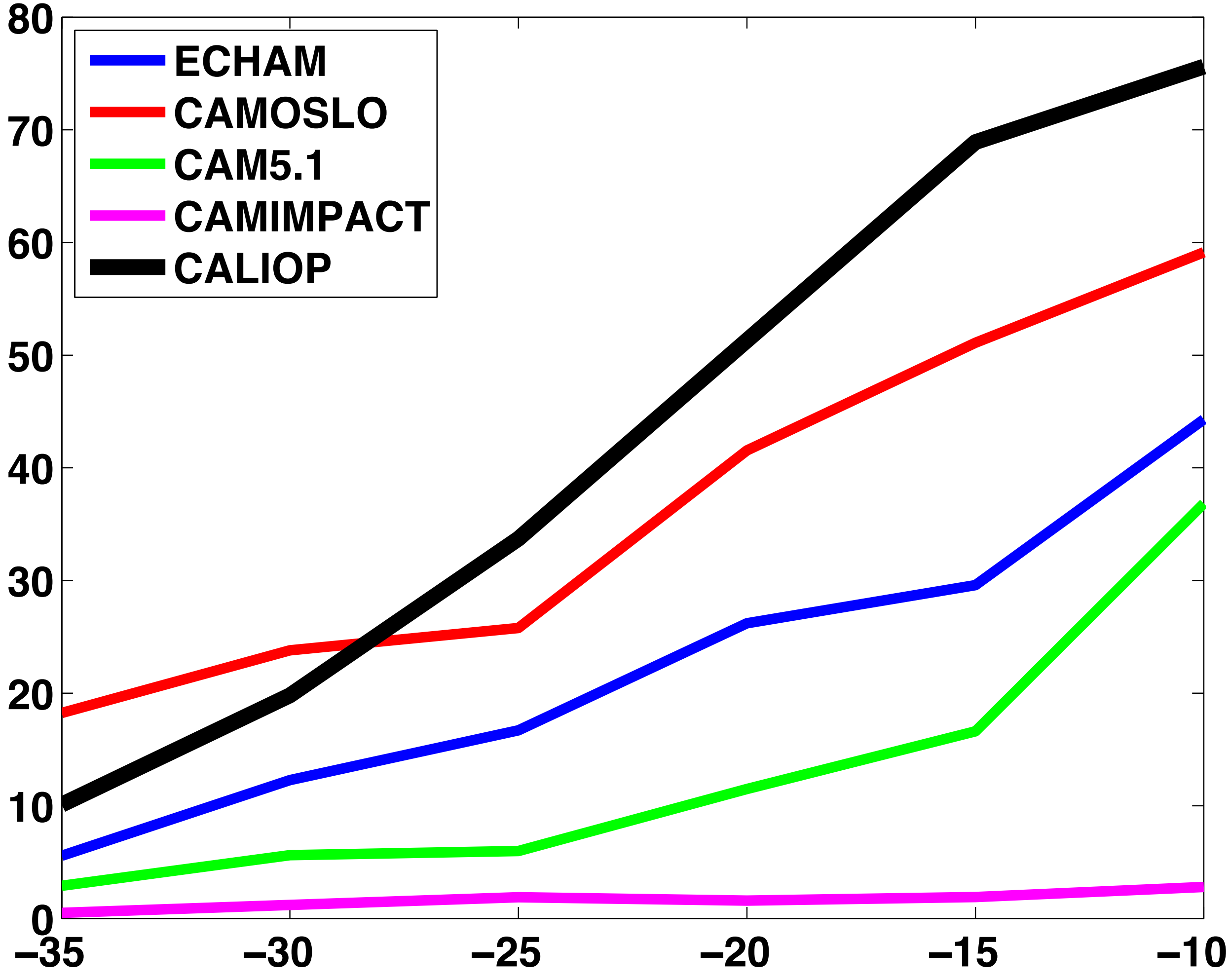




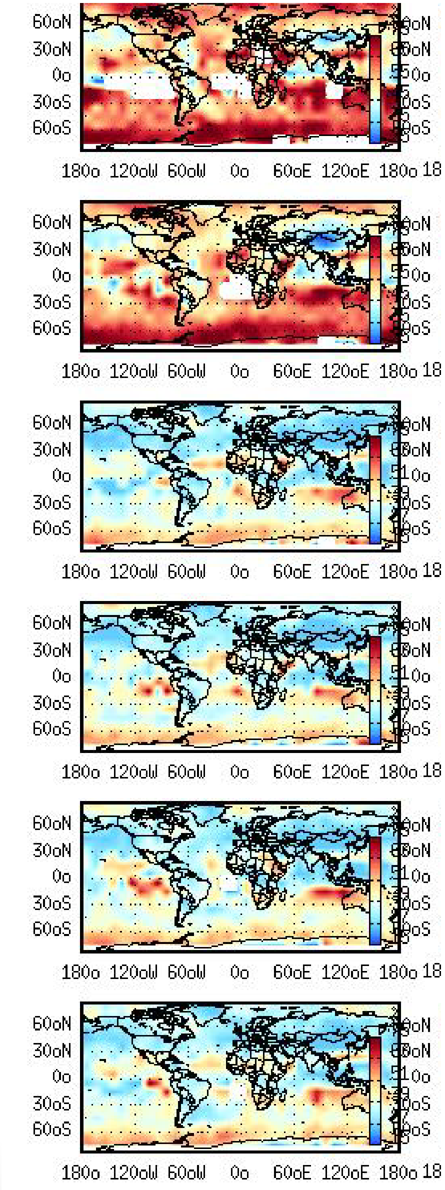
Global Annual Mean Liquid Fraction



Global Annual Mean Liquid Fraction



Validating with CALIOP



2006

2007

2008

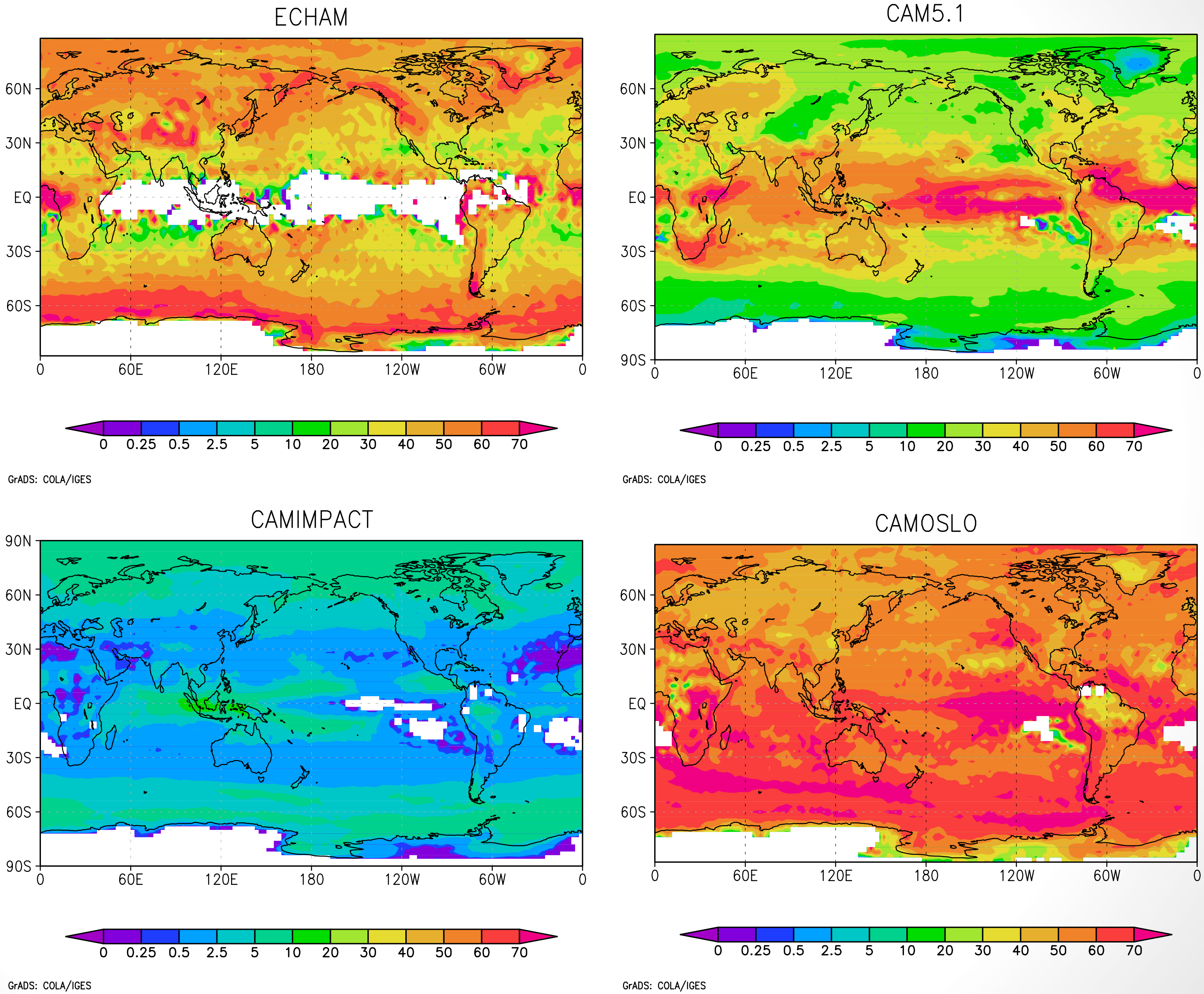
2009

2010

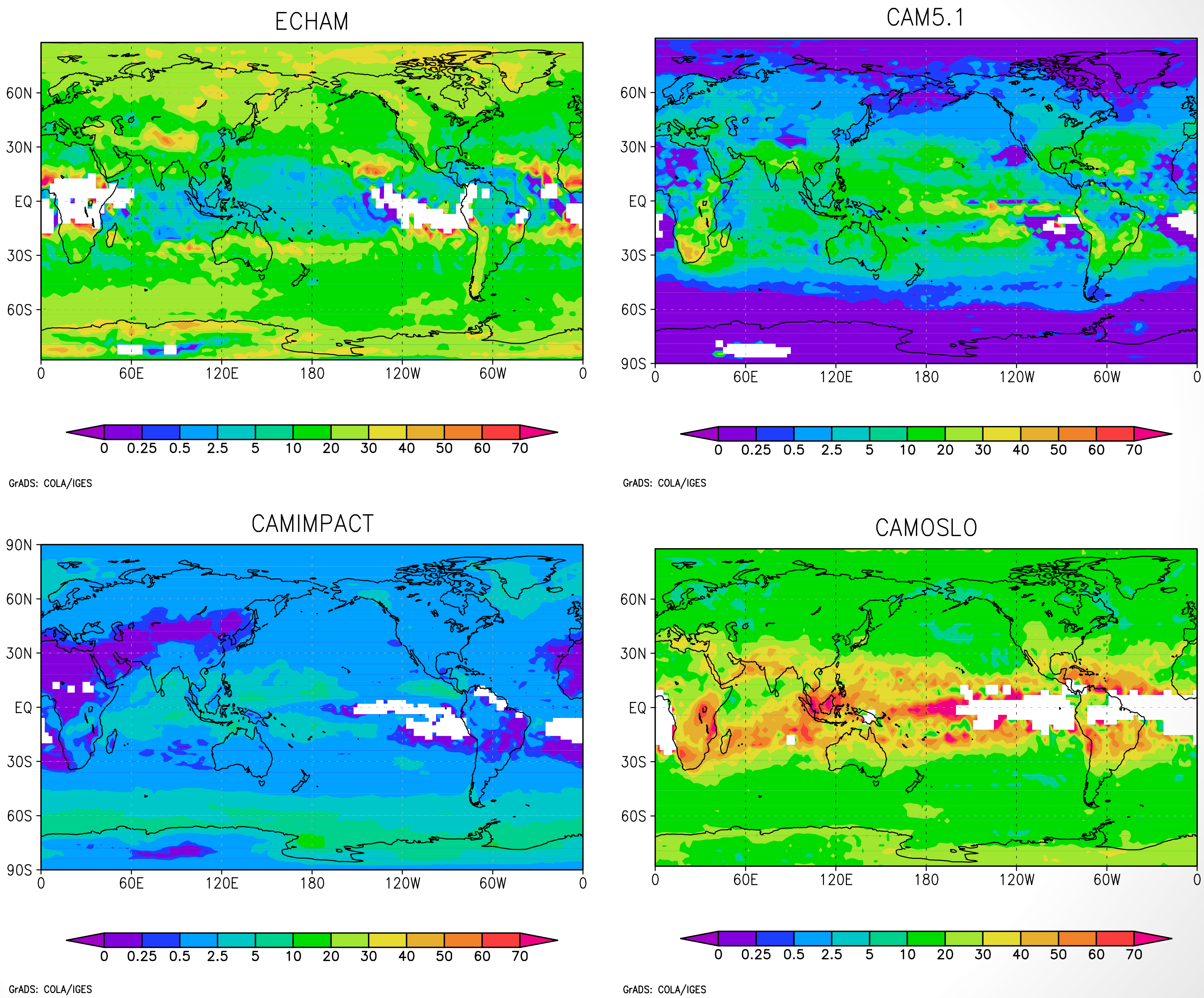
2011

- Dramatic change in supercooled liquid fraction (here shown for the -20°C isotherm) after off-nadir tilt in November 2007.
- For the purpose of the intercomparison, only 2008-2012 data should be used.

Simulated supercooled liquid fractions at -10°C

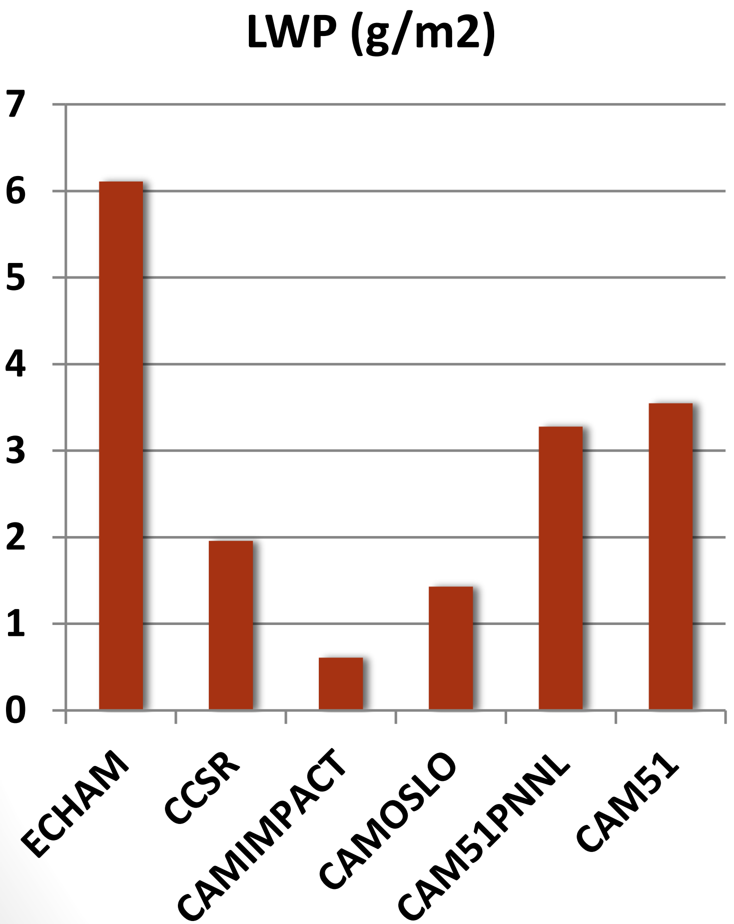


Simulated supercooled liquid fractions at -25°C

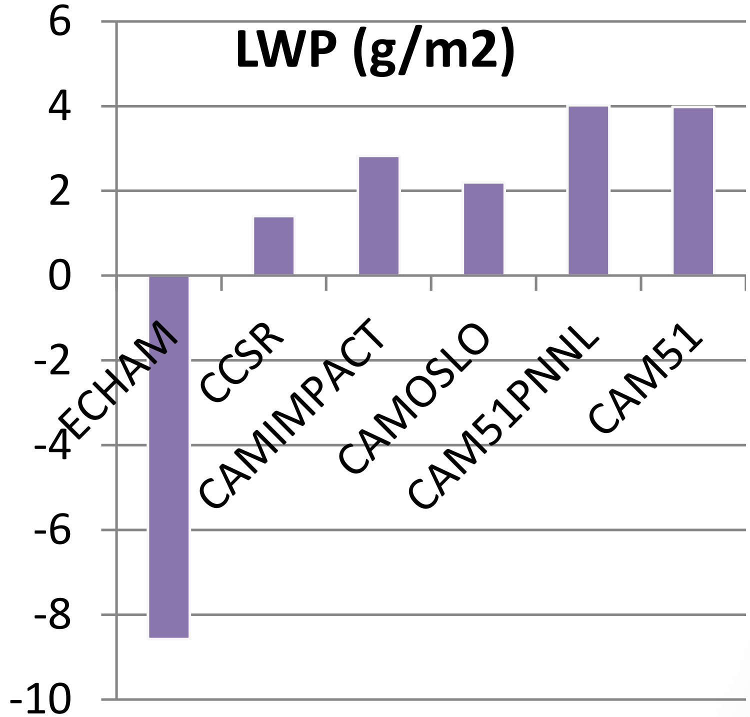


Change (PD-PI) in LWP

E3

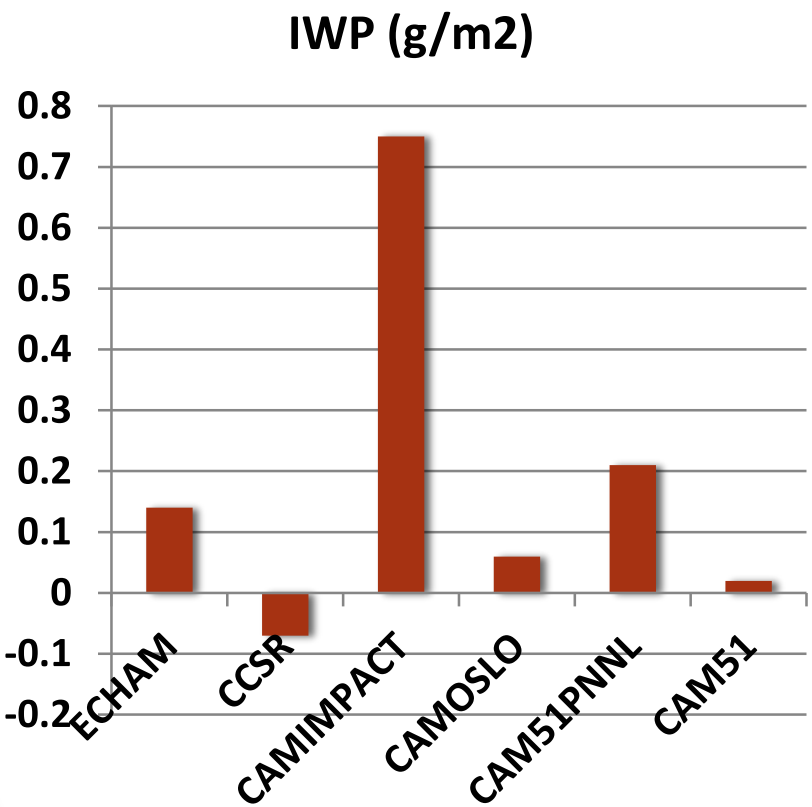


E2

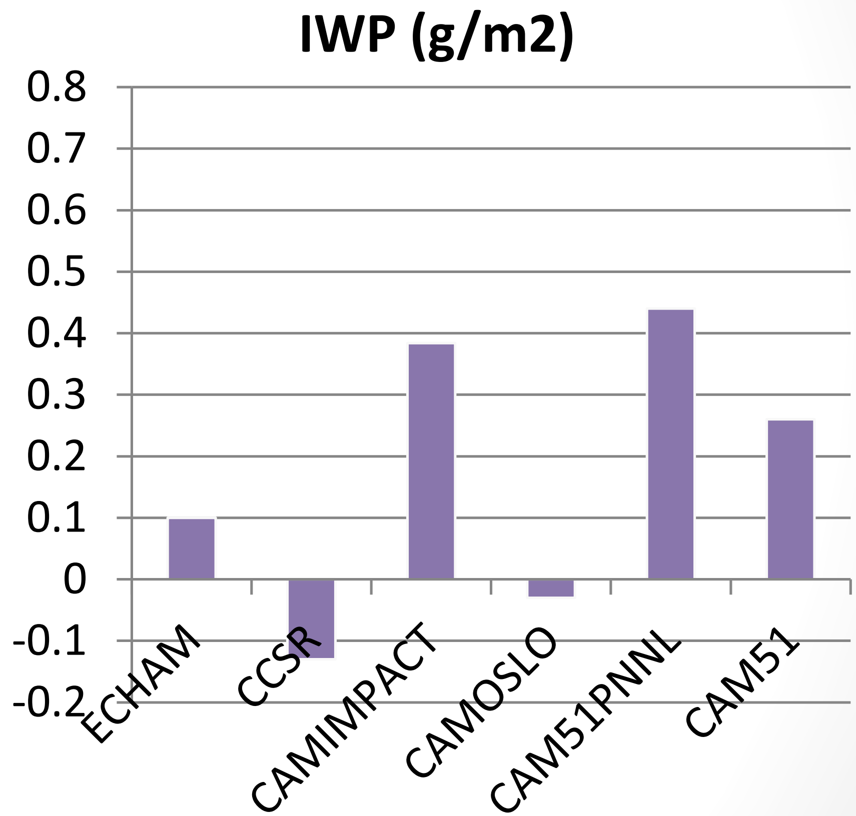


Change (PD-PI) in Ice Water Path

E3

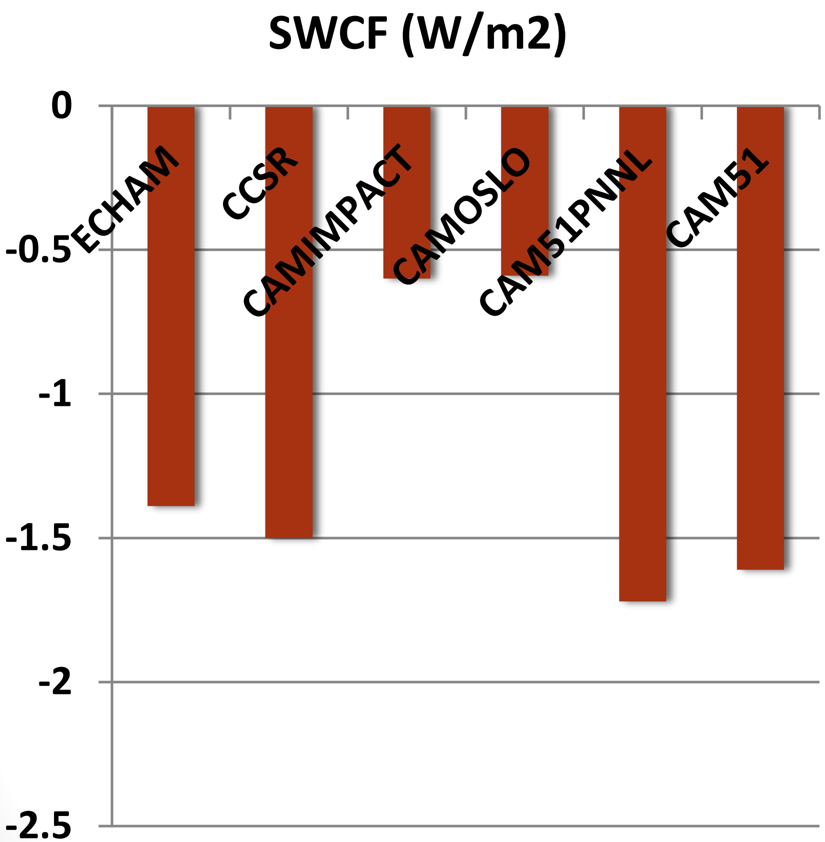


E2

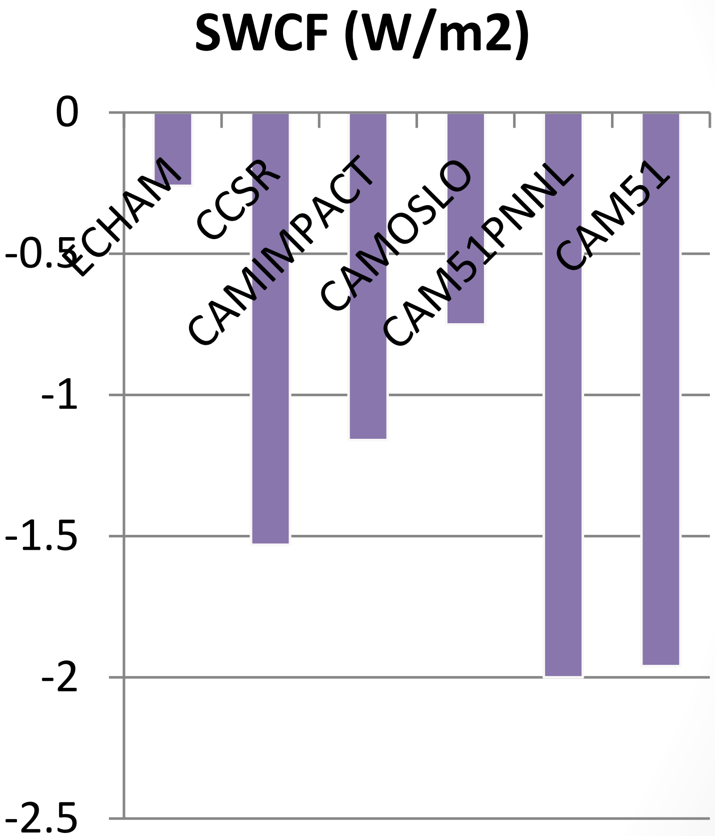


Change (PD-PI) in SW cloud forcing

E3

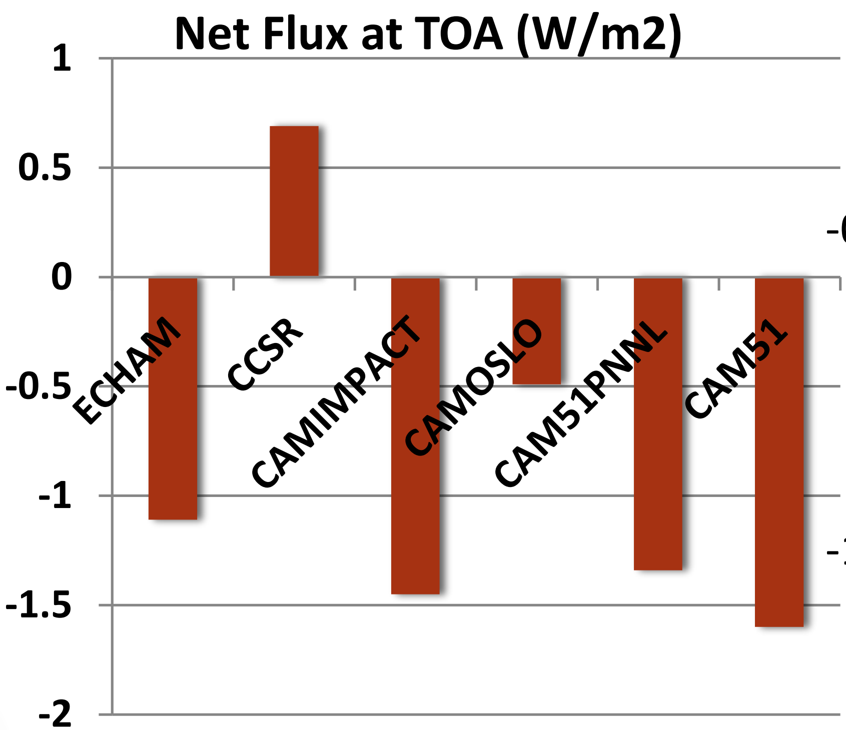


E2



Change (PD-PI) in net flux, TOA

E3



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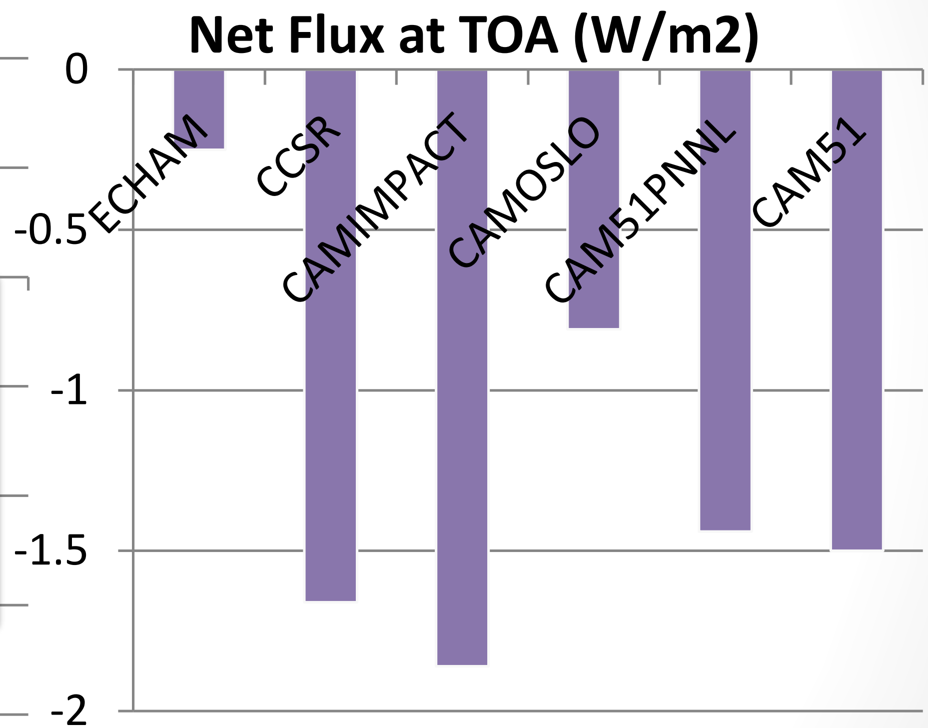

Preliminary intercomparison results

- Models show a wide spread in simulated IWP, LWP, ice crystals concentrations and supercooled liquid fractions.
- Comparison with satellite data suggests models liquid fractions are on the low side, but CALIOPs sensitivity to off-nadir tilt is a reminder that satellite retrievals have their own challenges.
- Simulated aerosol adjusted fluxes seem to be sensitive to the choice of ice nucleation parameterization (some more than others).
- The simulated total aerosol adjusted flux is lower in the 6 participating models than in the mean of estimates in the literature (compiled for AR5).