

Cloud Phase and Climate

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Thanks to: Stith, Morrison (NCAR)

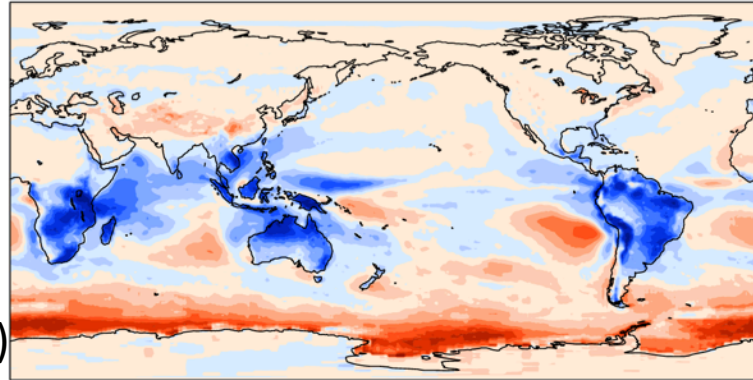


Conclusions: CESM2 development

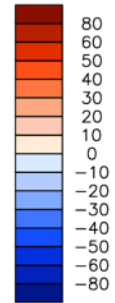
DJF SW Cloud Radiative Effect
Bias v. Satellite (CERES)
Bias = too much Absorbed Solar (ASR)
Free running (Fixed SST) simulations

Current (CESM1.2-CAM5.3)

mean = -0.91 rmse = 18.62 W/m²

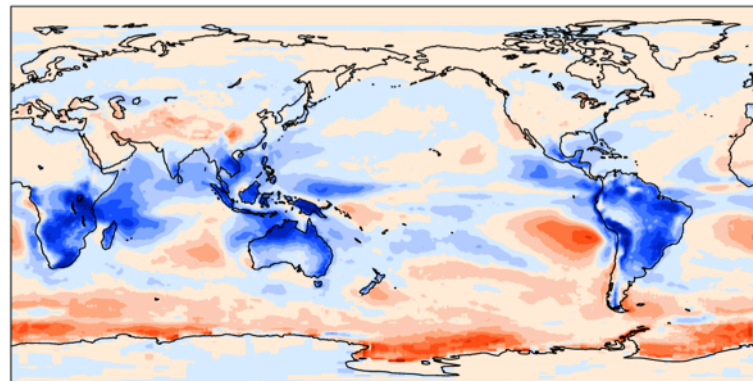


Min = -115.77 Max = 114.74

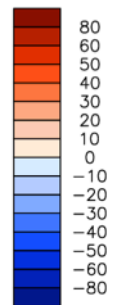


CAM5.4 (new ice nucleation)

mean = -3.02 rmse = 17.23 W/m²



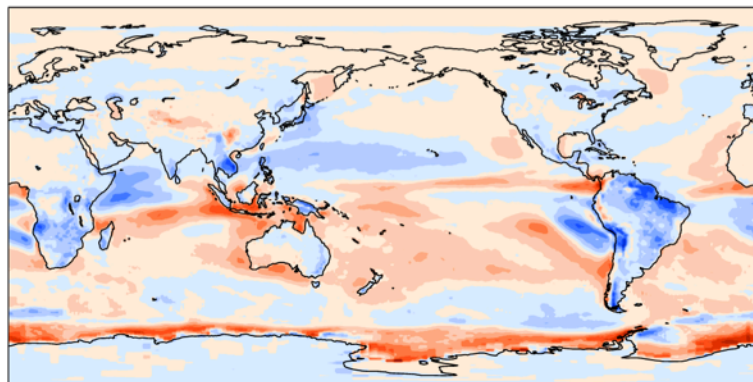
Min = -116.20 Max = 106.75



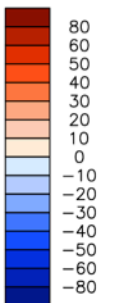
Remaining S. Ocean 'bias'
may be data issues around
sea ice edge.

CESM2 α

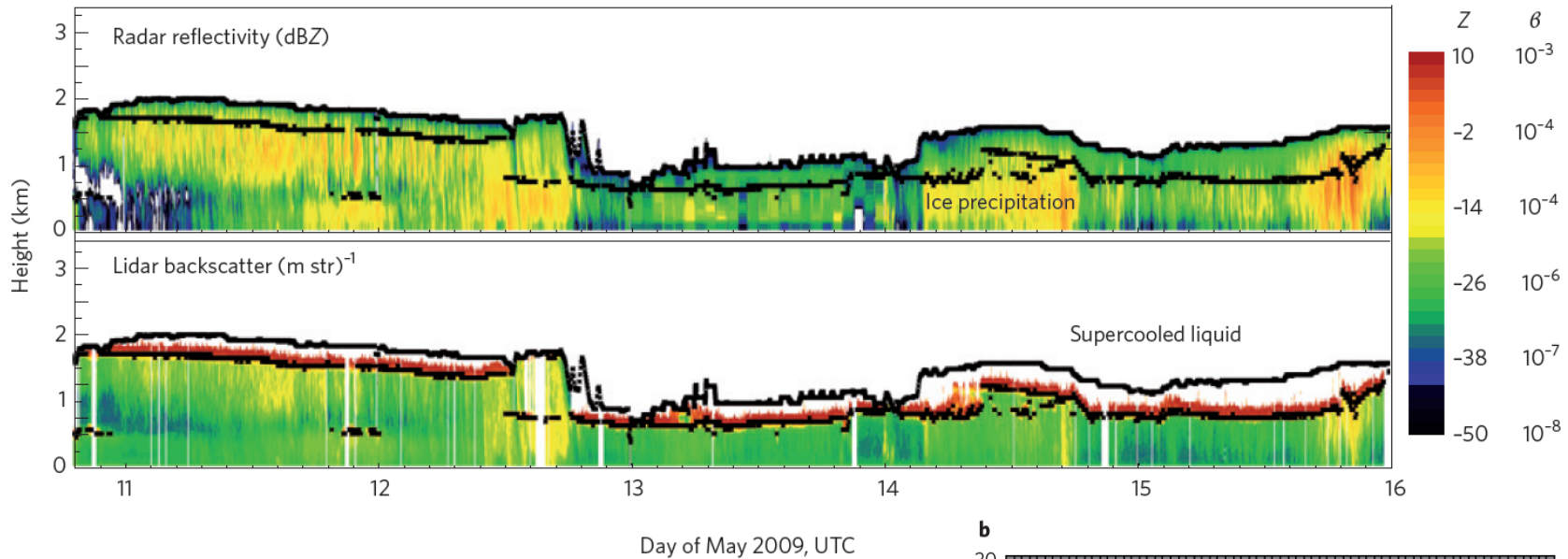
mean = 2.35 rmse = 12.58 W/m²



Min = -72.89 Max = 98.74



Mixed Phase: Arctic Surface Fluxes

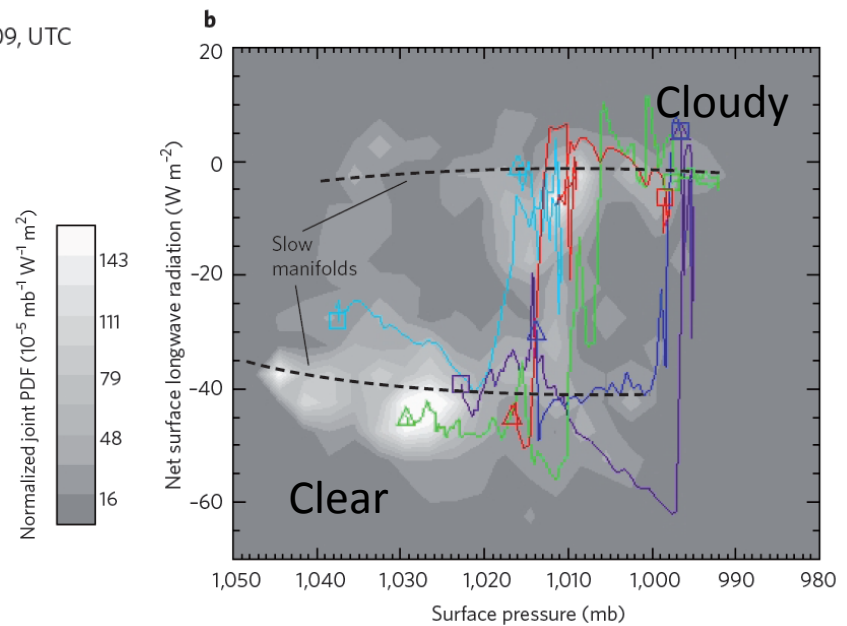


Arctic: Supercooled liquid precipitates Ice. Nucleation is critical: affects lifetime

Two radiative states:

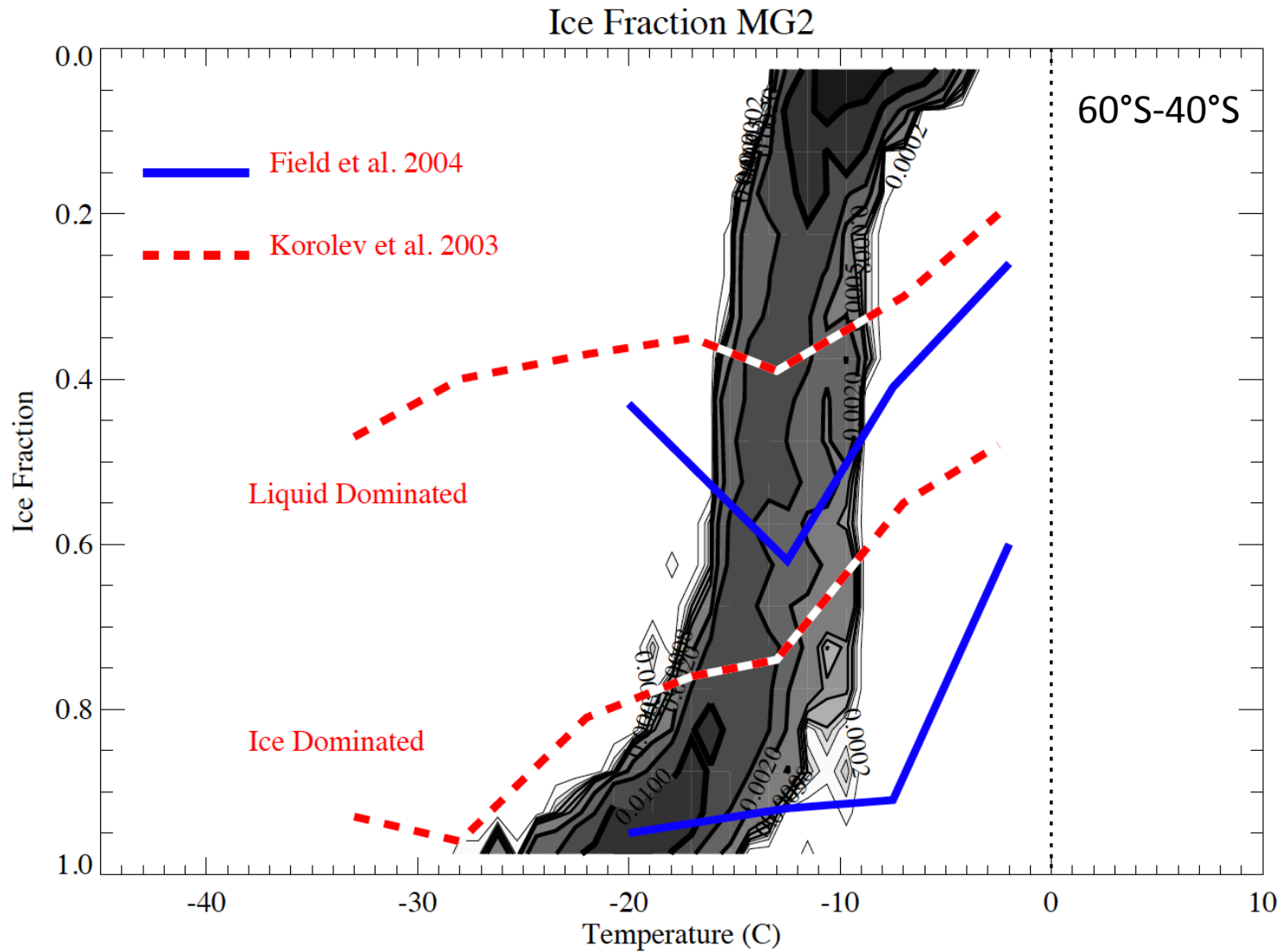
Clear (Neg net LW, High Ps)

Cloudy (Zero net LW, Low Ps)



Morrison et al., 2011: Nat. Geosci.

CESM: Not enough supercooled liquid



Observations

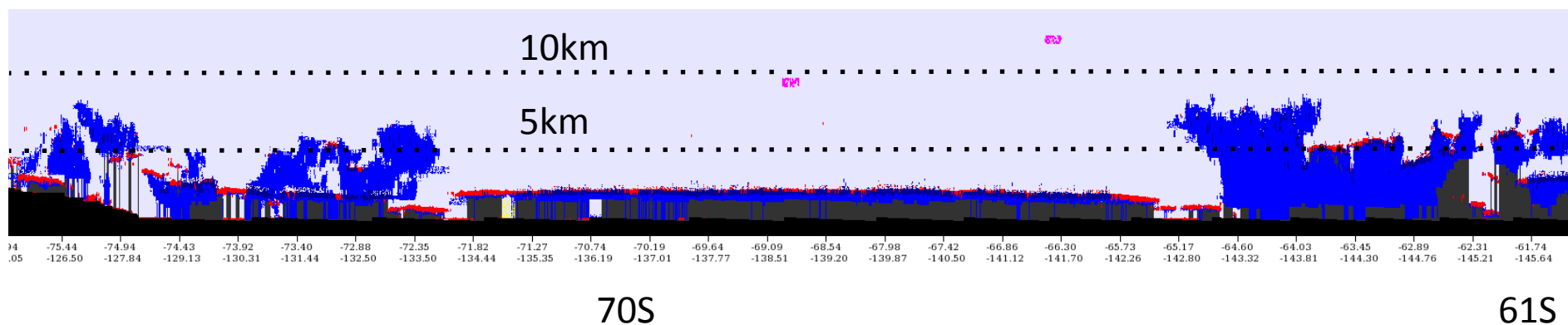
- Satellites: CALIPSO, CloudSat
- Aircraft: NSF G-V HIPPO Flights

Satellite Super-cooled Liquid

Some are thin layers. Some are All super-cooled.
Radar & Lidar (CloudSat + Calipso) product

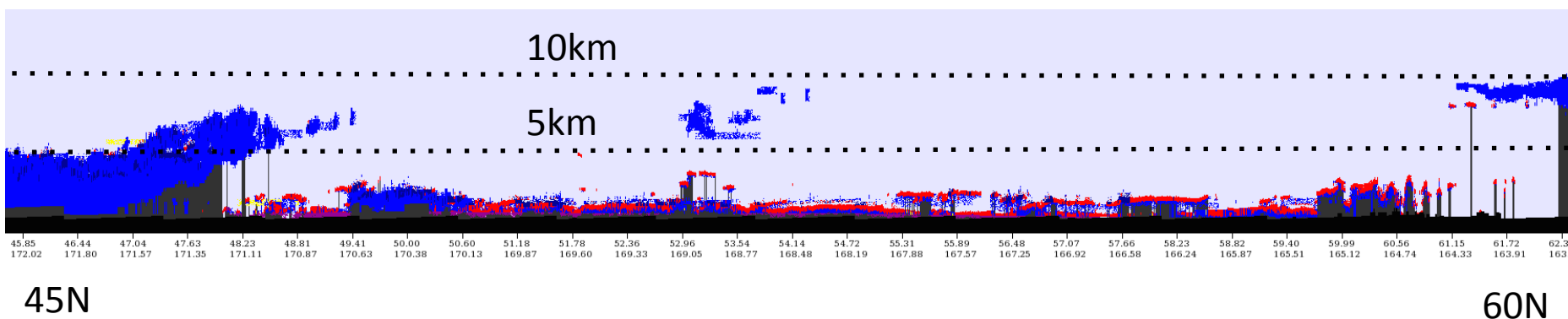
2013-01-01

S. Ocean (S. Of Pacific)



Liquid Ice Supercooled

2014-02-07 N. Pacific



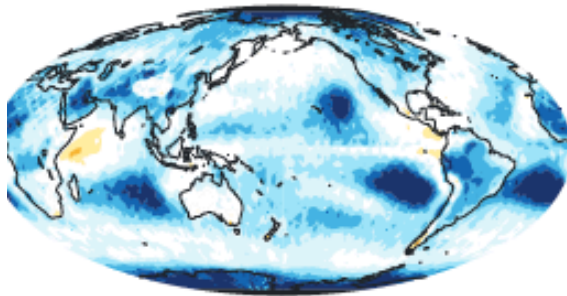
Satellite Derived Ice Clouds

Bias relative to CALIPSO

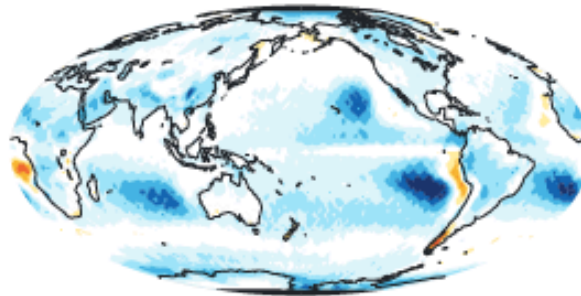
Using Cloud Phase Diagnostics in COSP (Cesana & Chepfer 2013)

CAM5

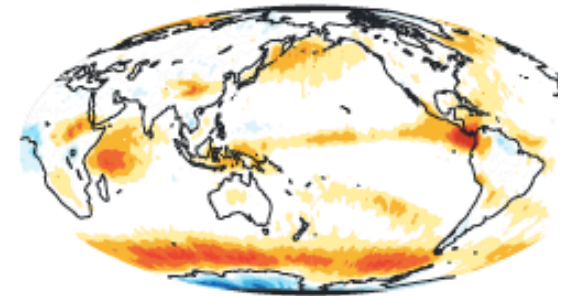
a) CAM5 Total (-11.0%)



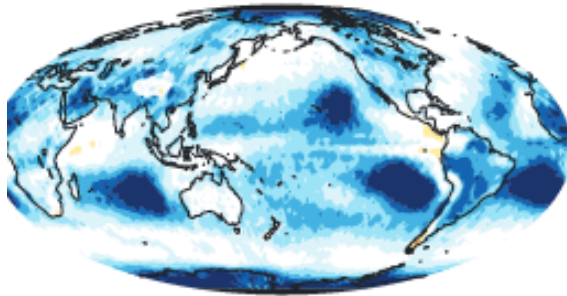
b) CAM5 Liquid (-7.4%)



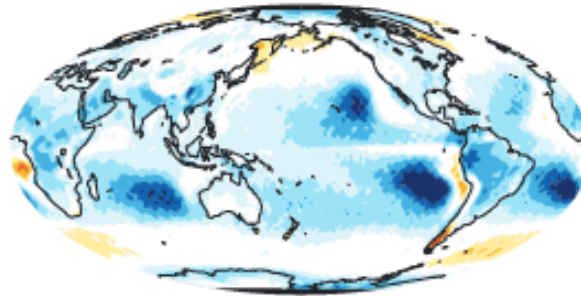
c) CAM5 Ice (+3.2%)



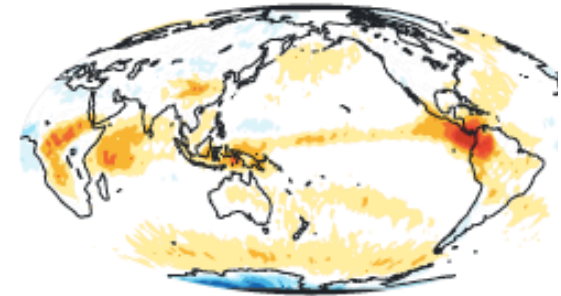
d) CAM5* Total (-12.4%)



e) CAM5* Liquid (-6.6%)

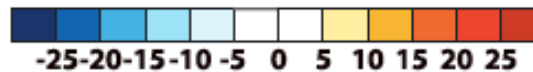


f) CAM5* Ice (+2.2%)



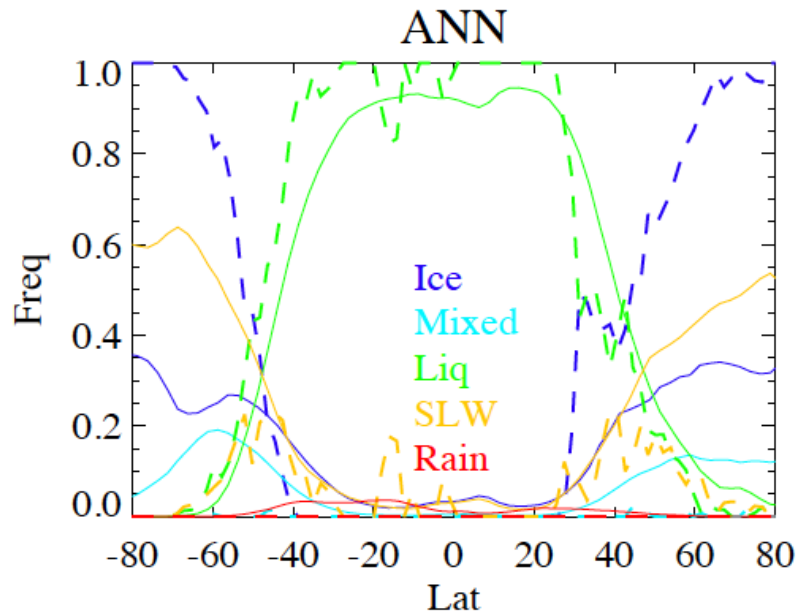
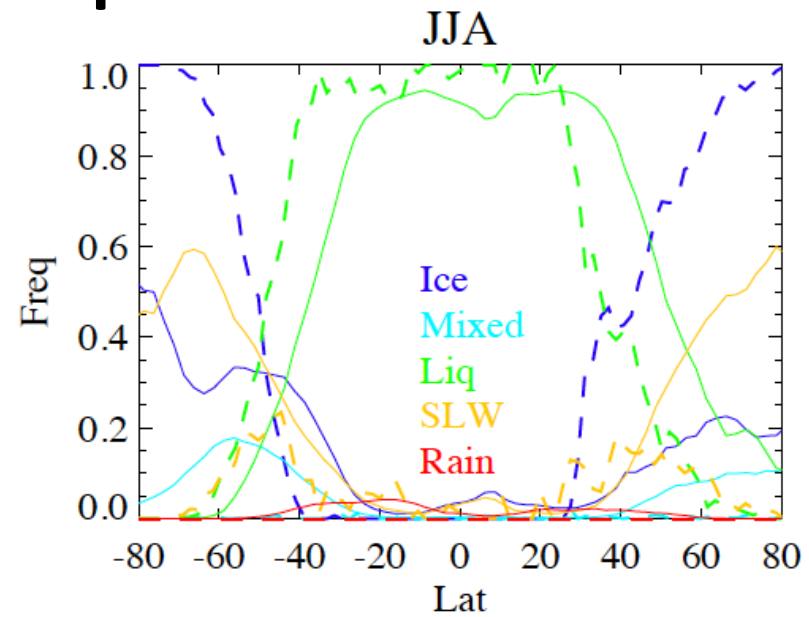
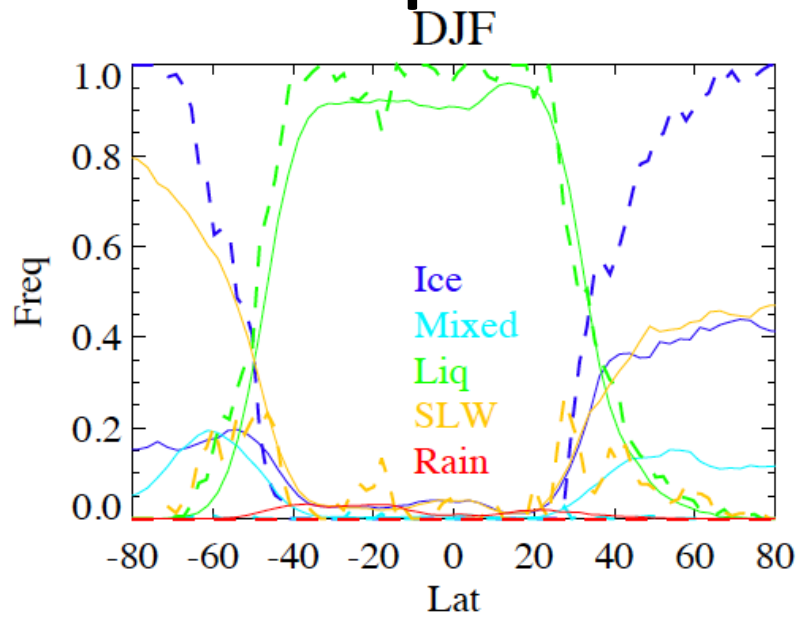
Modified CAM5 (Shallow Cu)

CALIPSO Cloud Cover Bias



Kay et al 2016, JGR, Fig. 11

Supercooled liquid in CESM



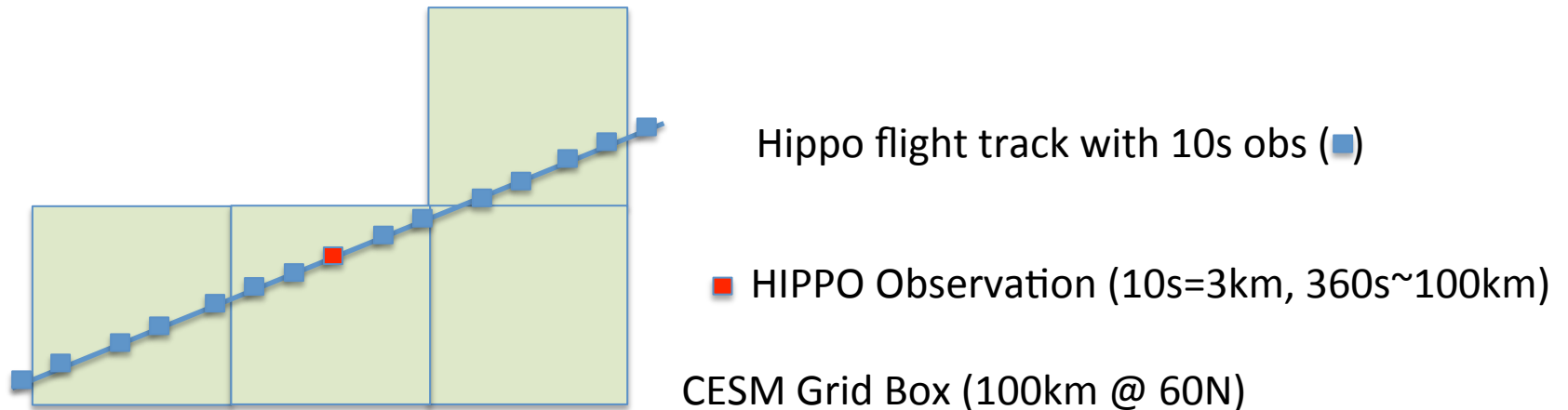
Frequency of occurrence of different hydrometeors at cloud top.
Solid = Satellite observations. (DARDAR)
Dashed = CAM5.4

Getting some **super-cooled liquid water (SLW)**, not quite enough
Liquid looks good (too much **Ice**)

Global Model Forecasts

Use a climate model like a weather model. Simulate individual cases.

- Specified Dynamics simulation: 2008-2011
- CESM1.2 (CAM5.3): GEOS-5 Meteorology, 200km resolution (equator)
 - Winds and Temps forced
 - Water species (q, clouds, aerosols) model calculated
 - Climate is reasonably in balance (-1.6 Wm^{-2} TOA)
- Output columns along (and around) HIPPO flight tracks
- Sample CESM box containing point & adjacent grid boxes
- Do every 10s. Model timestep is 1800s (oversample model)

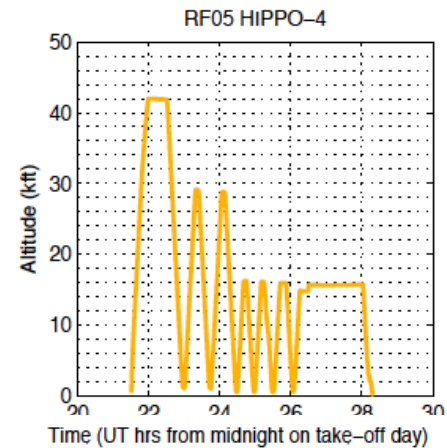
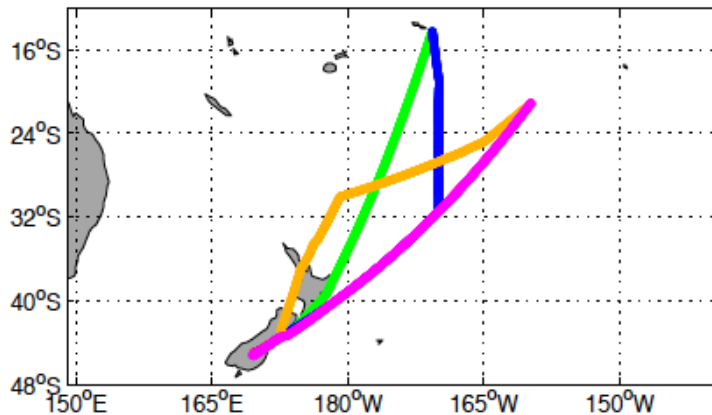


NSF G-V HIPPO Experiment

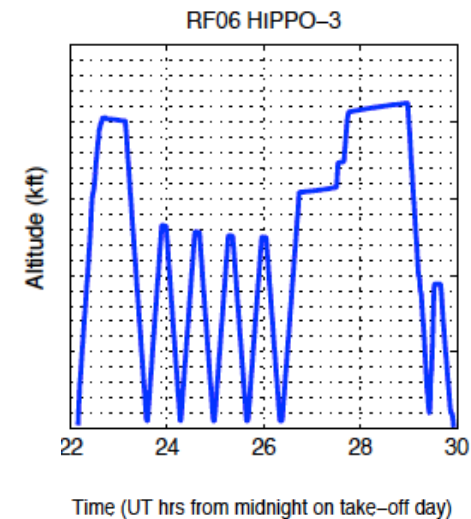
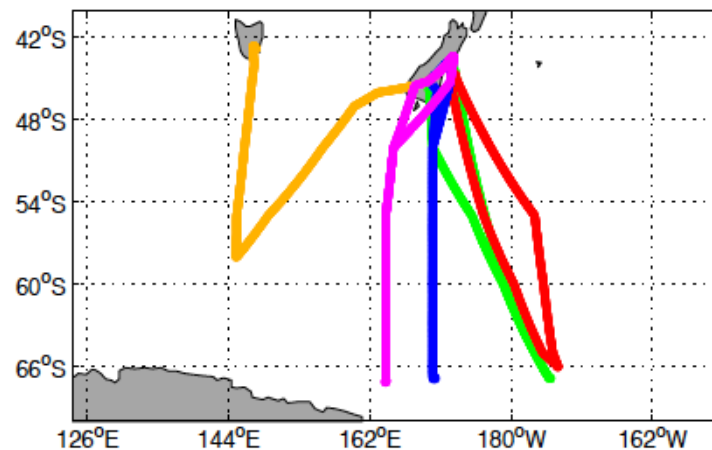
‘HIAPER Pole to Pole Observations’: multiple deployments (different seasons)

- Measured mass of liquid & ice and particle number concentrations
- Selected 2 flights with microphysics data in S. Ocean or S. Pacific

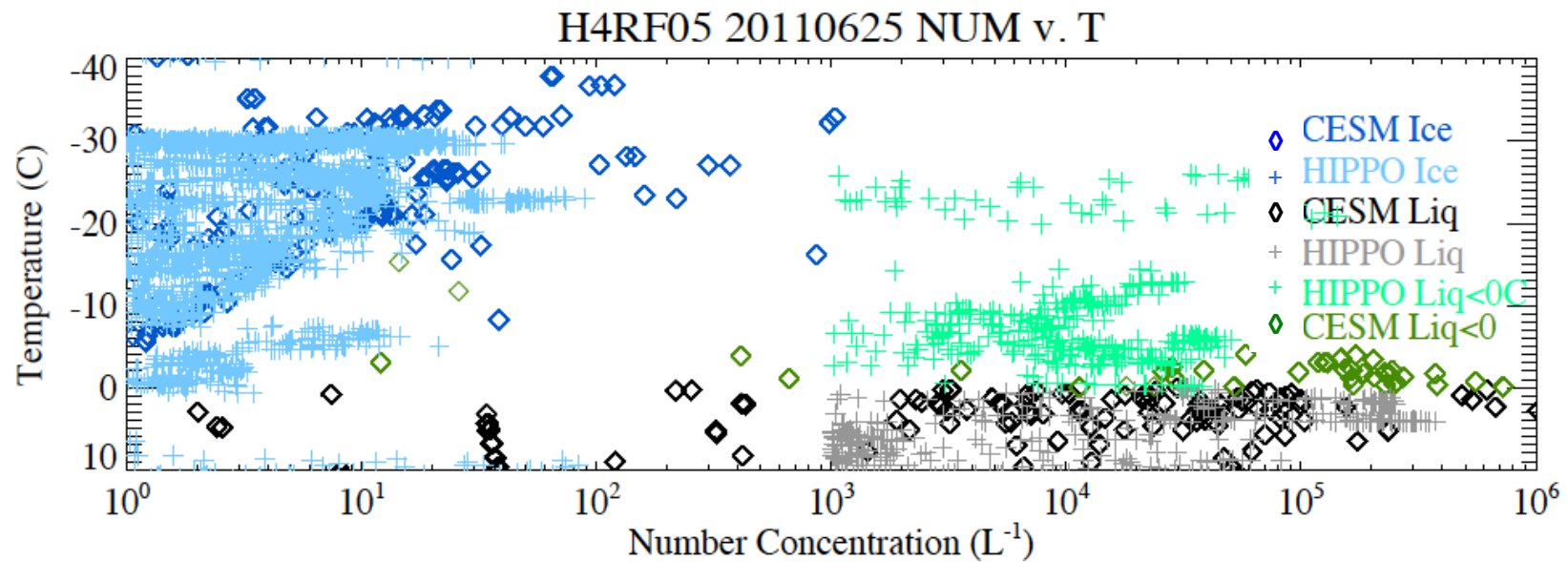
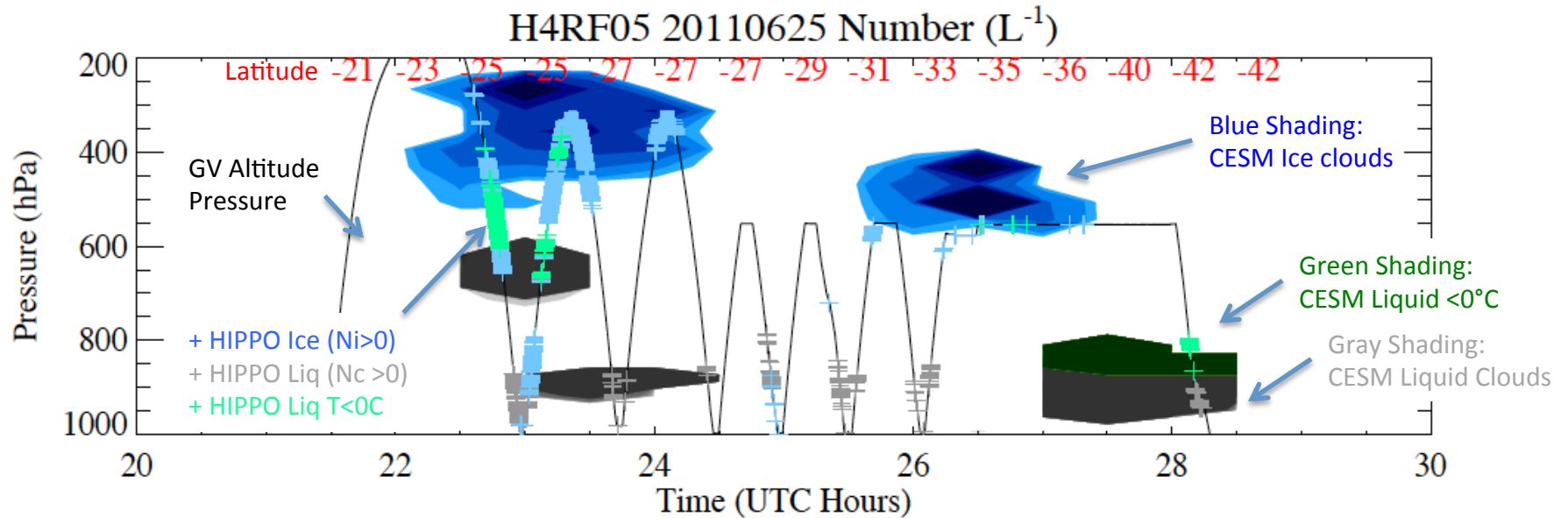
Subtropical
Winter



S. Ocean
Fall

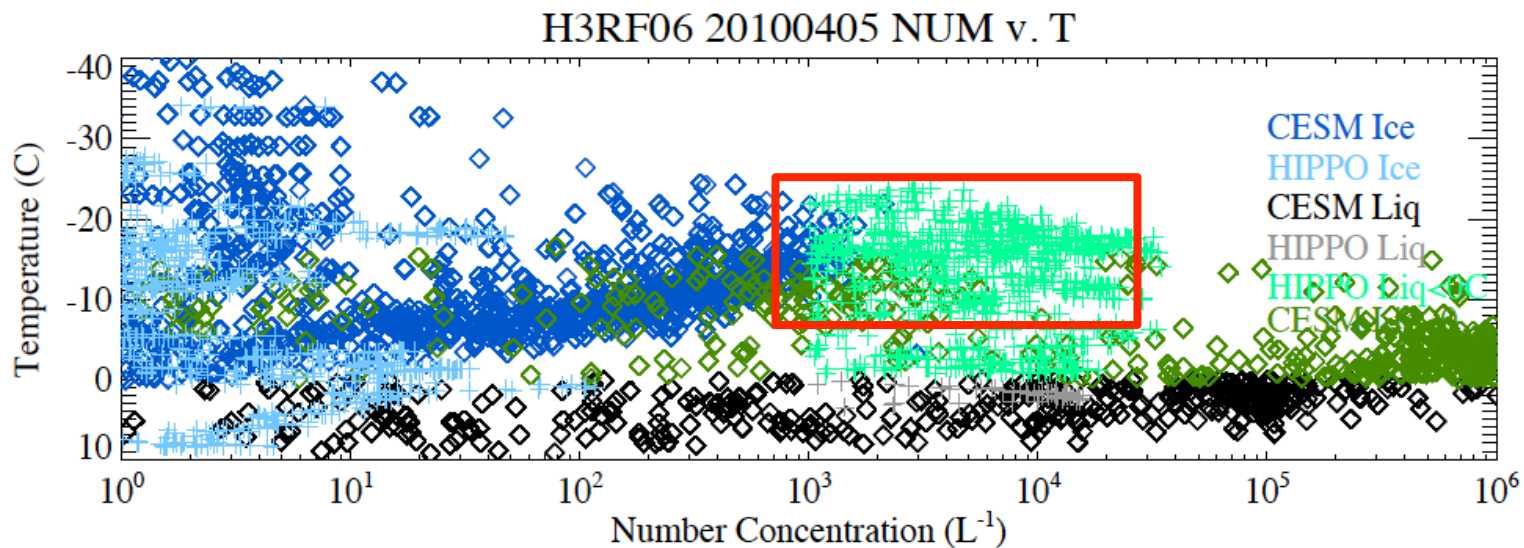
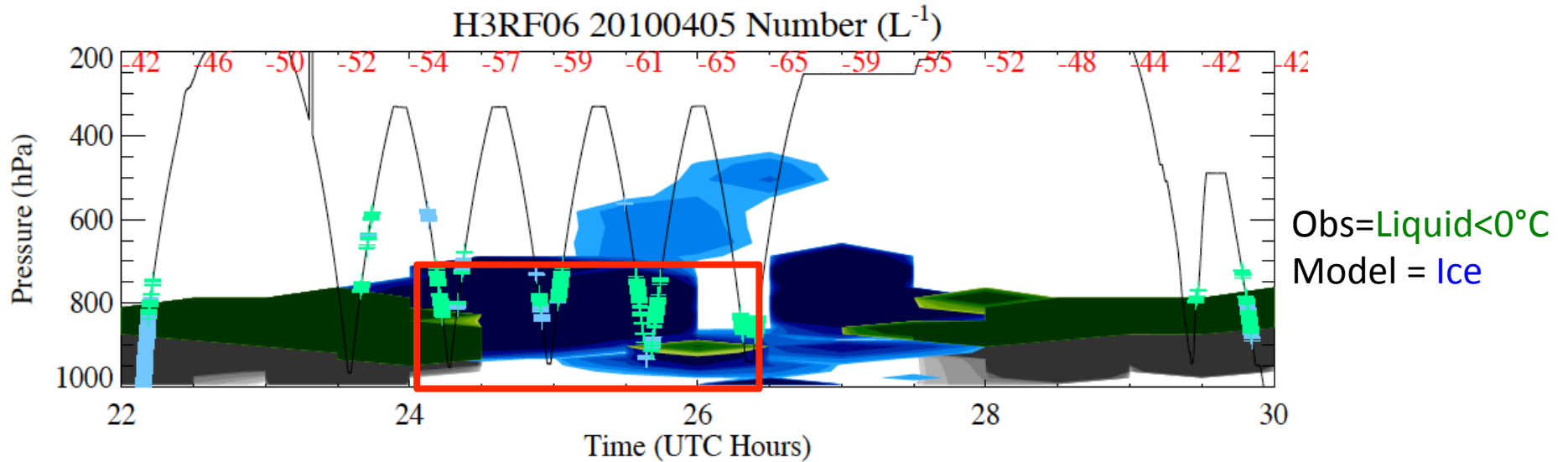


Section along H4RF05 (Jun) Flight Track

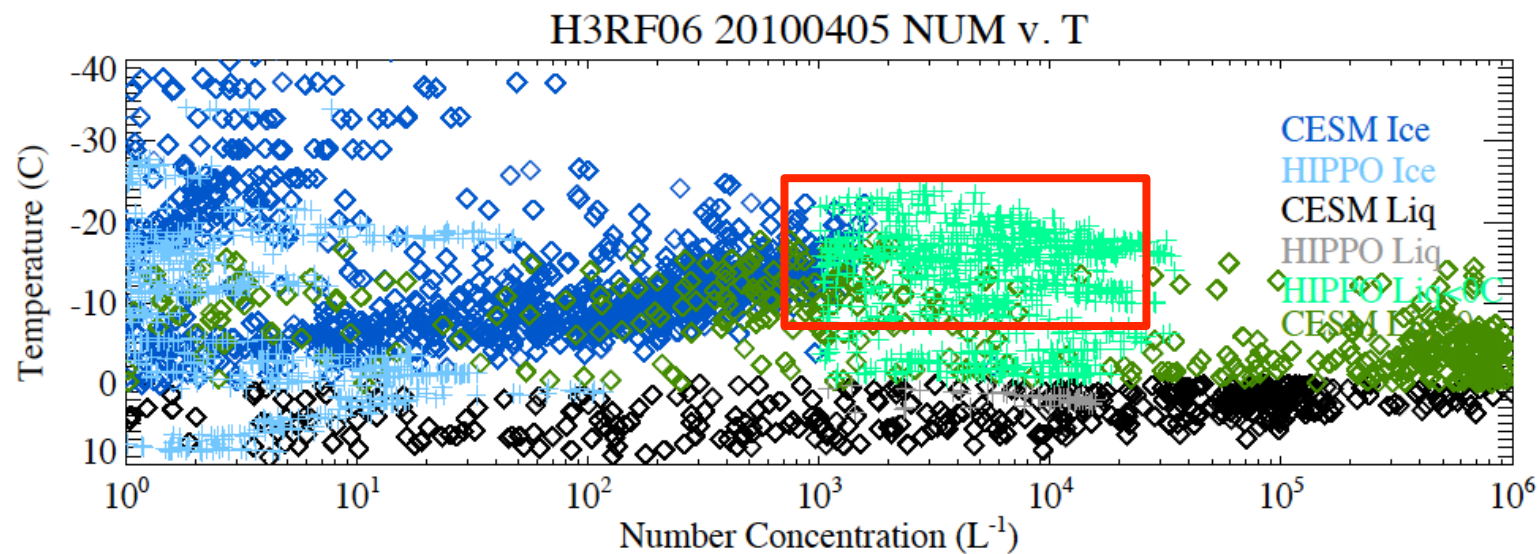
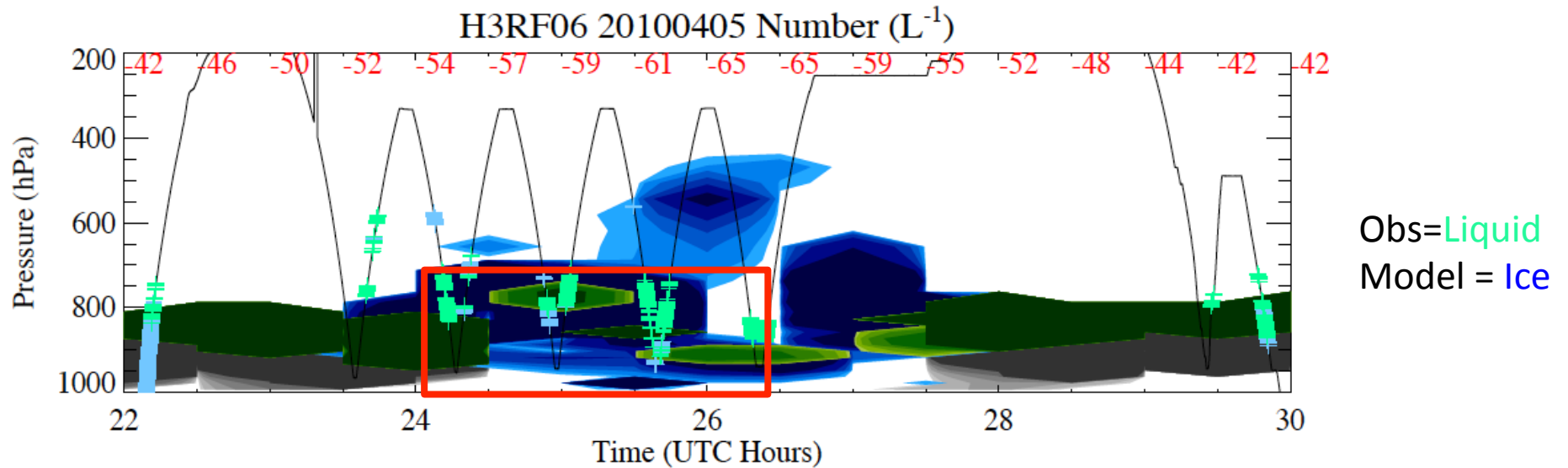


CAM5.3

Across S. Ocean (H3RF06) April



CAM5.4 (+ New Mixed Phase Ice Nucleation [Hoose et al. 2010]) Across S. Ocean (H3RF06) April



Summary

- S. Ocean Clouds Critical for Climate
- Mixed phase regime is important
- CESM misses super-cooled liquid seen by Aircraft (HIPPO) and satellites (Radar-Lidar)
- Sensitivity tests show large changes in cloud radiative effects with supercooled liquid
 - Affects Arctic as well. Critical for Greenland
- Need more observations to physically constrain parameterizations
- Note: **HOWEVER**. It does not change climate sensitivity in CESM (\neq Tan et al 2016).
 - Need to remove compensating biases first.