Simulating specific clouds: Evaluating CAM6 Microphysics using in situ aircraft observations

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Thanks to: H. Morrison (NCAR), J. Kay, J. English (NCAR, U. CO)

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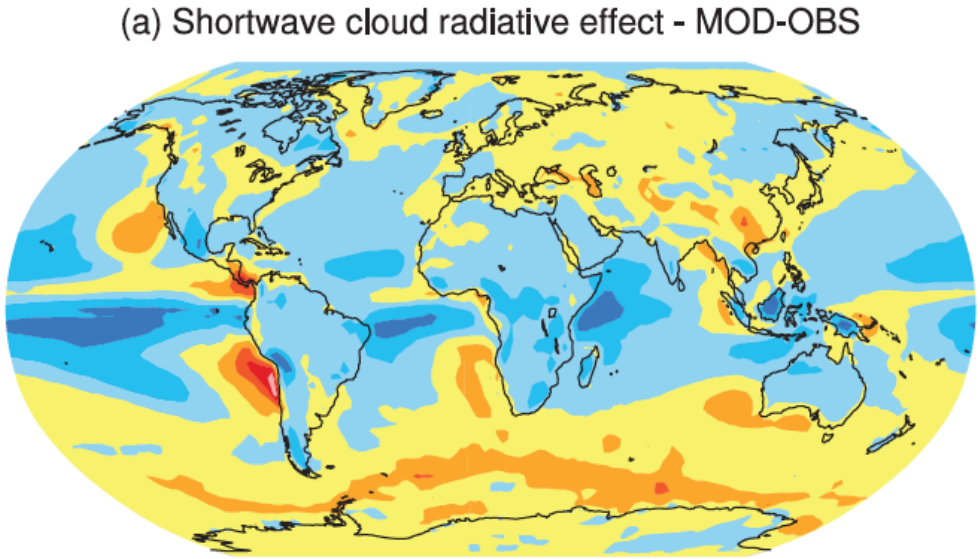
Outline

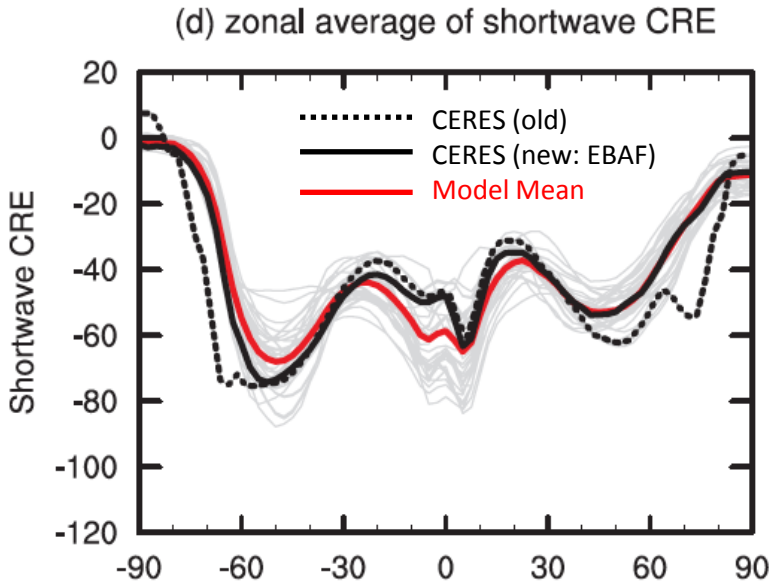
- Motivation:
  - S. Ocean Climate Model Biases
  - Greenland surface energy balance
- Key processes: super-cooled liquid
- Observations and comparisons:
  - Satellites, Aircraft, in-situ Data
- Perturbation Experiments
- Summary/Future directions

Note: work is ‘in process’, working towards a paper

S. Ocean Cloud Biases: CMIP5

Multi-Model

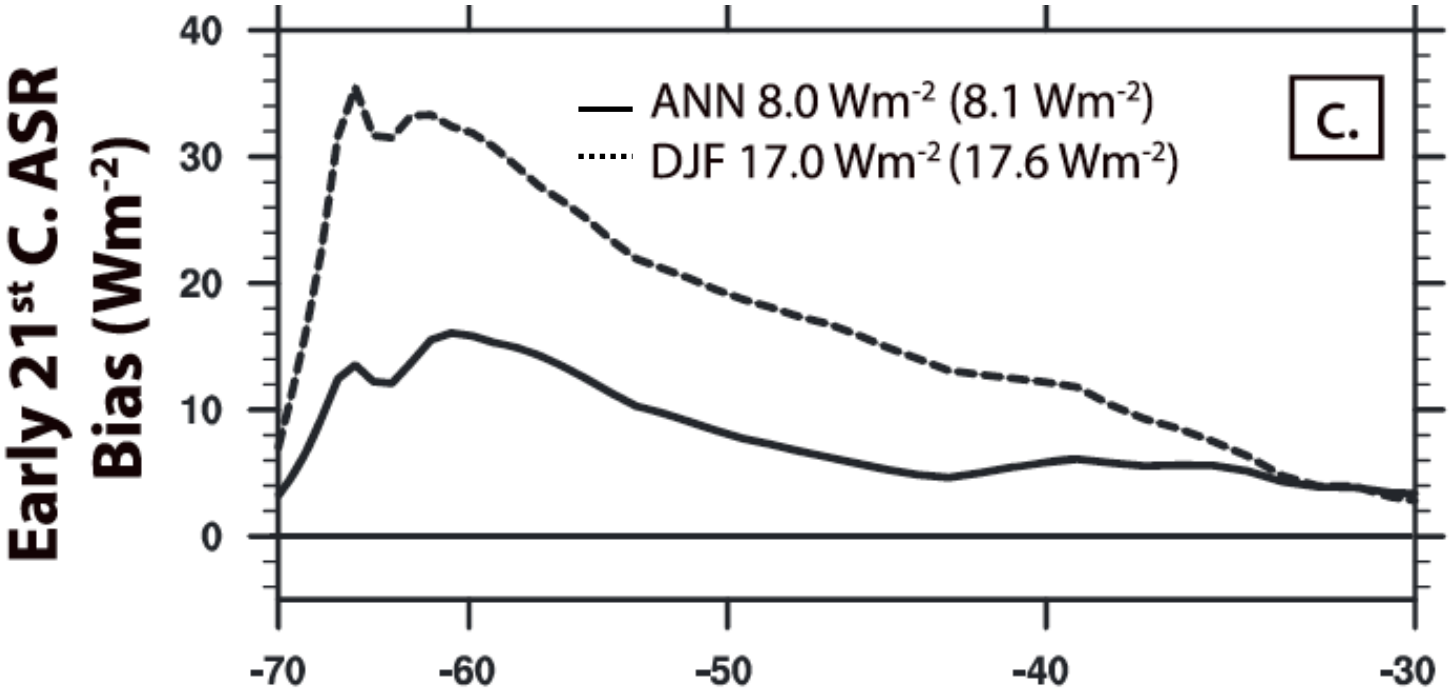




IPCC AR5, 2013: Fig 9.5

S. Ocean Cloud Biases: CESM

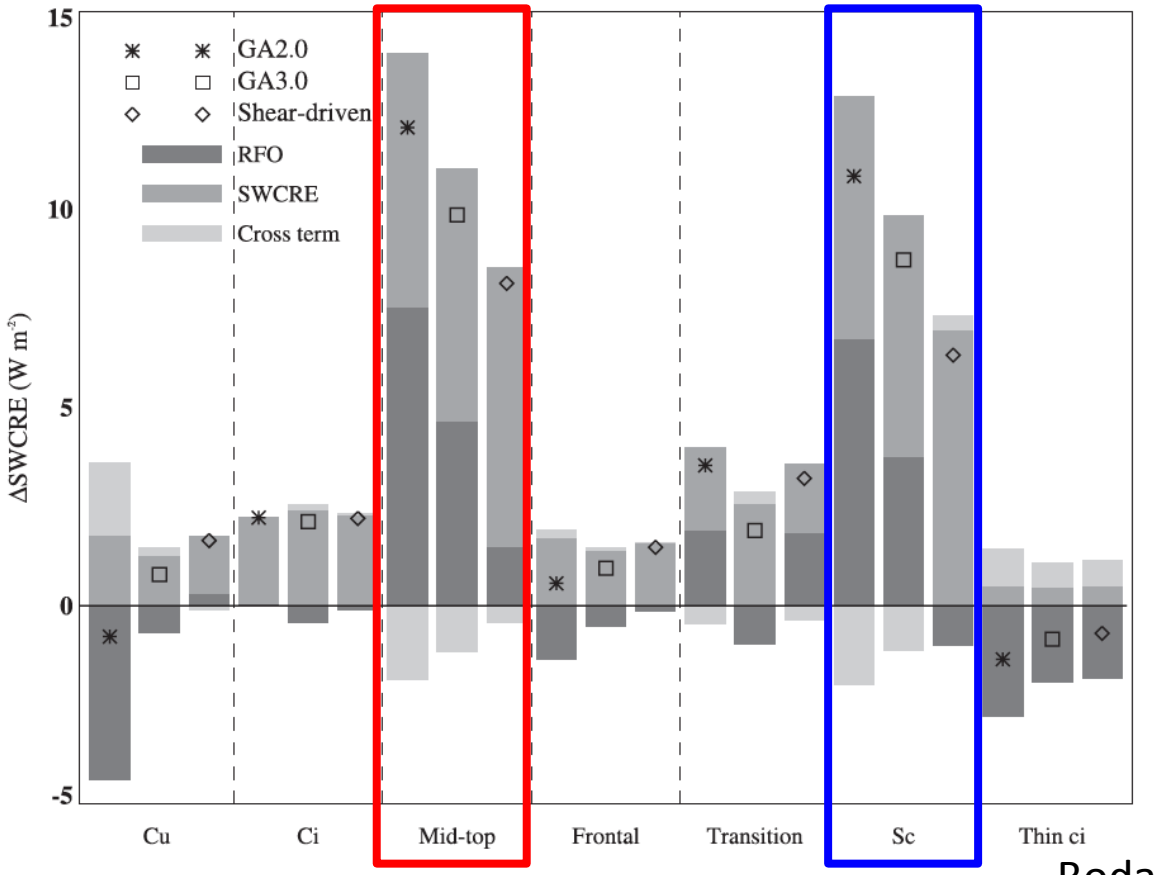
CESM has the same problem



Kay et al., 2014

Where does Cloud Bias come from?

Met Office Model: Mid level and Strato-Cumulus
Clouds are ‘mixed phase’



Bodas-Salcedo et al 2012

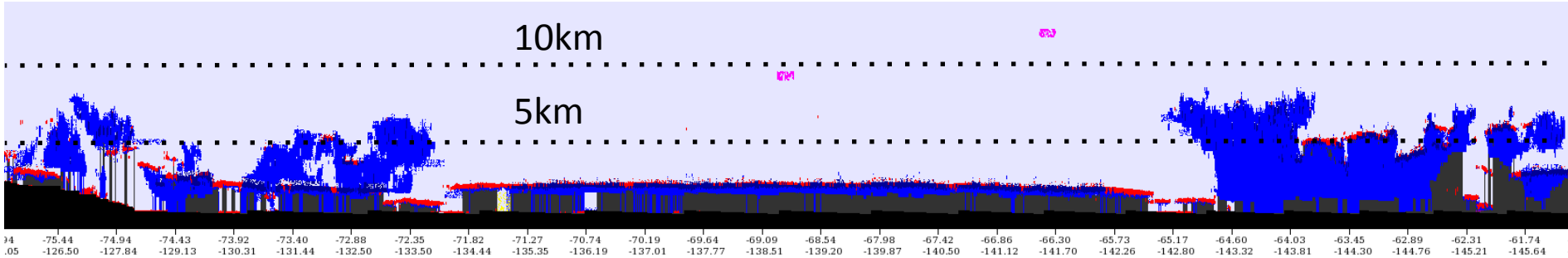
Satellite Super-cooled Liquid

Most thin layers of super-cooled liquid over ice

Radar & Lidar (CloudSat + Calipso) product DARDAR

Delanoë and Hogan 2010, Huang et al 2012

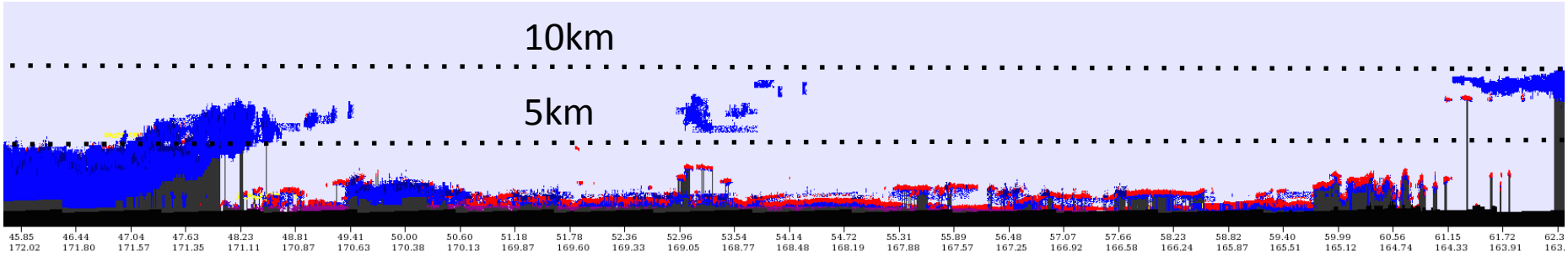
2013-01-01 S. Ocean (S. Of Pacific)



70S 61S

Liquid Ice Supercooled

2014-02-07 N. Pacific

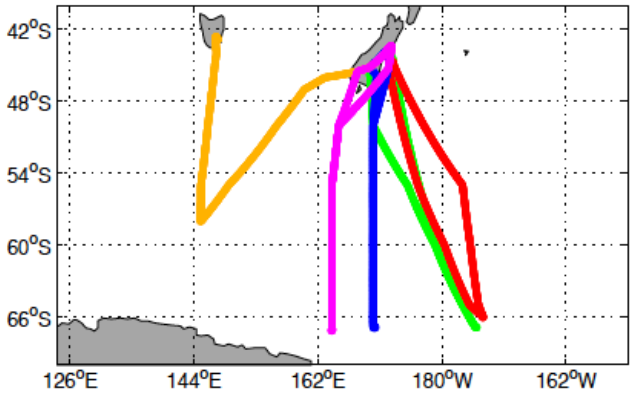


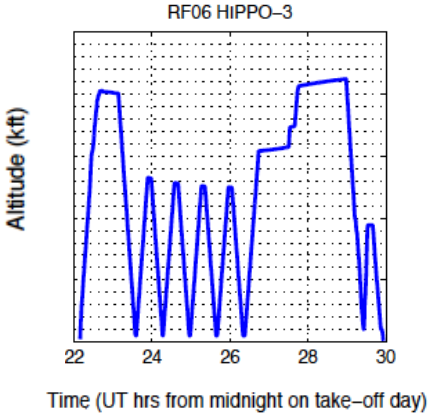
45N 60N

NSF G-V HIPPO Experiment

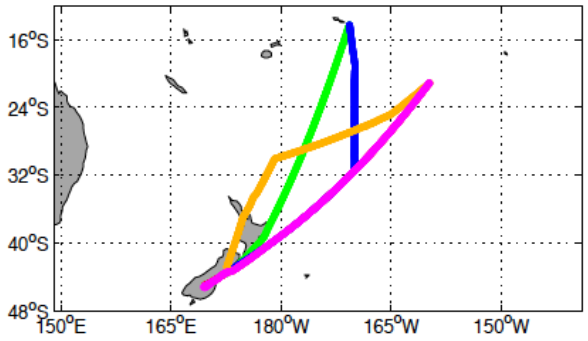
'HIAPER Pole to Pole Observations': multiple deployments (different seasons)

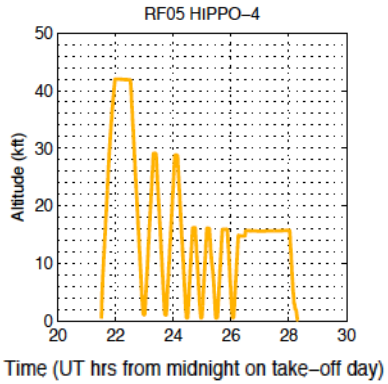
- Mostly a carbon cycle experiment.
- Some deployments had cloud microphysical probes
- Measured mass of liquid & ice and particle number concentrations





Selected 2 flights with microphysics data in S. Ocean or S. Pacific

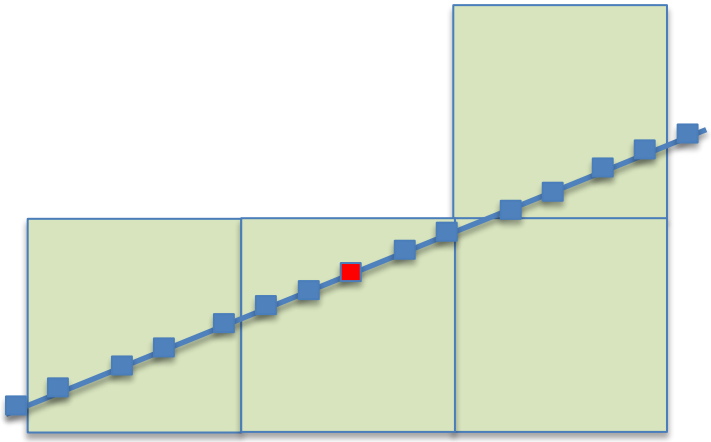




Now: simulate these cases with CESM

CESM Co-location Strategy

- Specified Dynamics simulation: 2008-2011
- CESM1.2: 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)



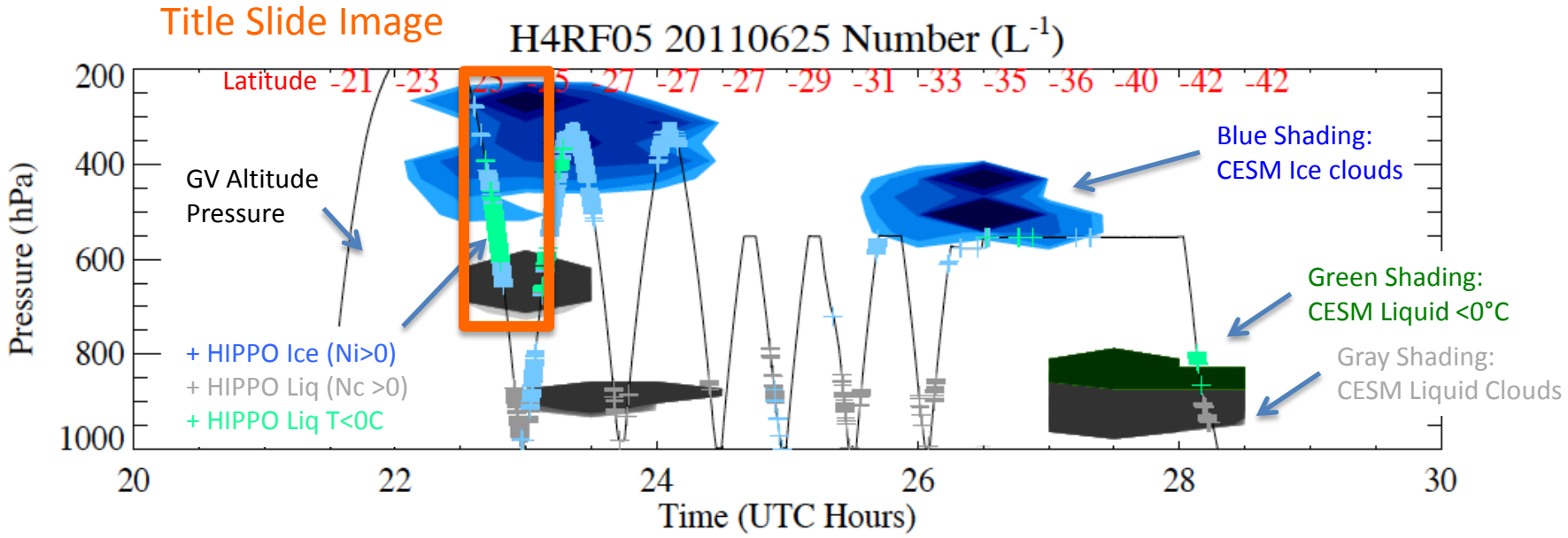
Hippo flight track with 10s obs (■)

HIPPO Observation (10s=3km, 360s~100km)

CESM Grid Box (100km @ 60N)

Section along H4RF05 (Jun) Flight Track

Title Slide Image



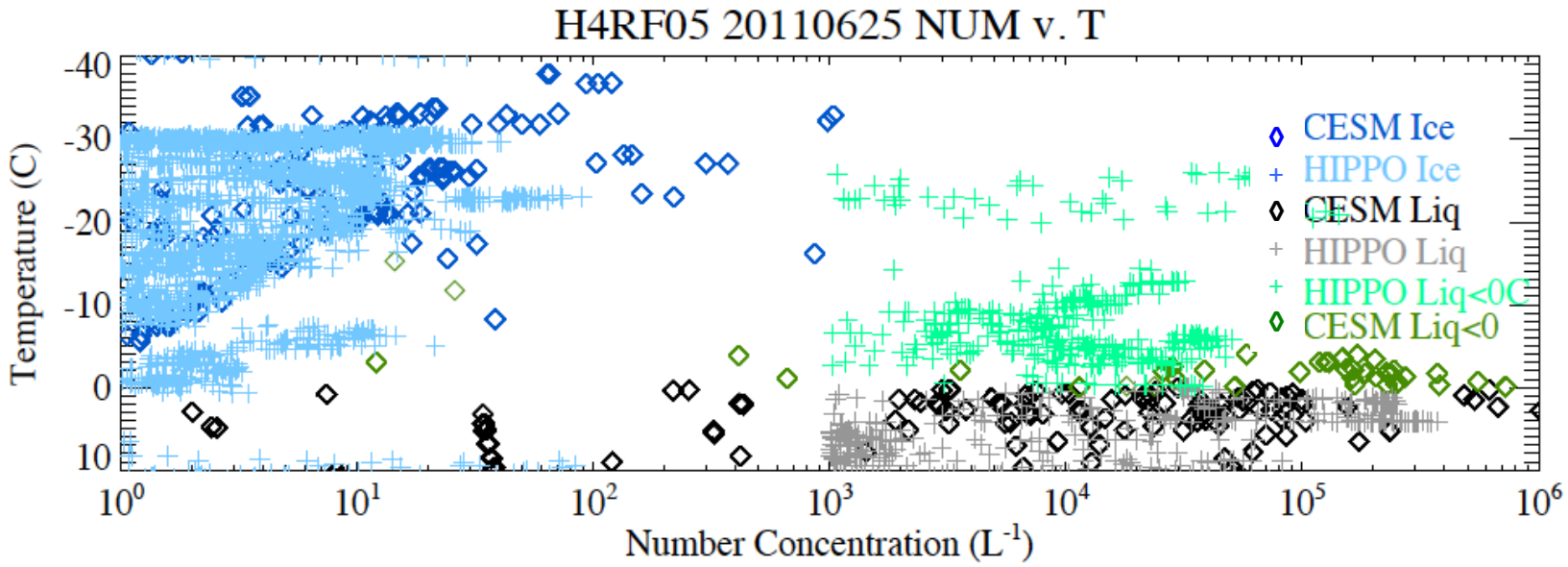


Image of selected clouds

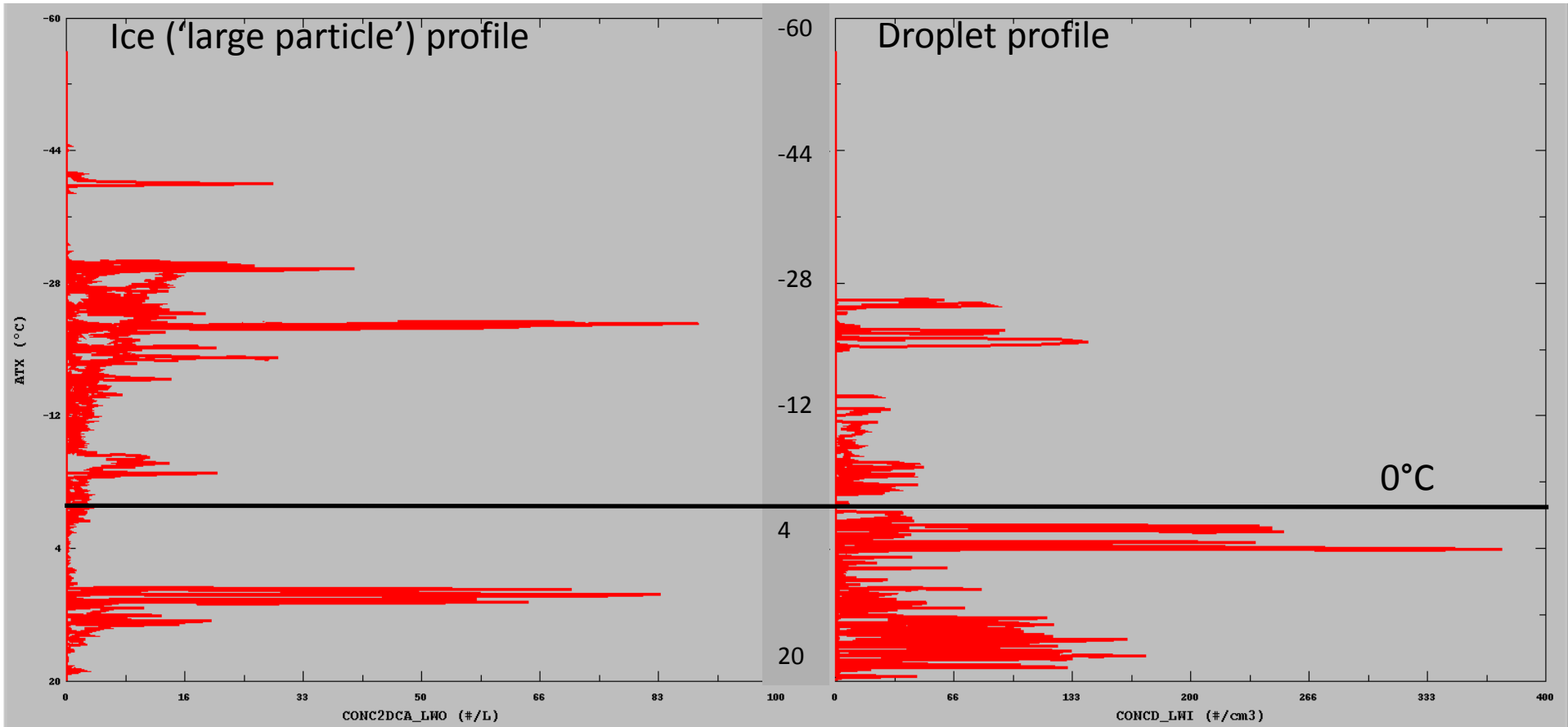
rf05
06/25/2011

Date	2011-06-25
Start_UTC	22:39:04
GGALT	8884.333984
GGLAT	-25.450125
GGLON	-166.541122
ATX	-29.393610
DPXC	-32.631737
PSXC	331.821869
RHUM	73.464317
TASX	237.843719
THDG	251.549698
PITCH	0.668893
ROLL	0.278141
WSC	33.624100
WDC	280.748627
DP_VXL	-32.631737
VMR_VXL	1193.928711

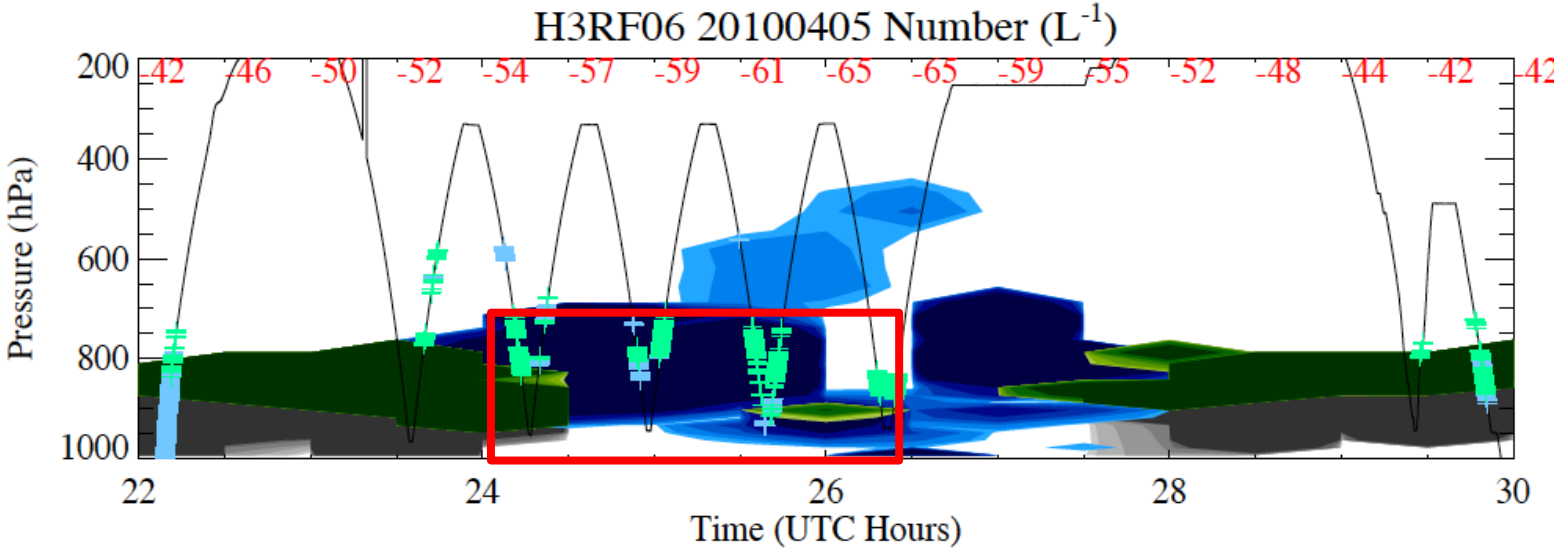
25°S, -30°C, 300hPa, Winter

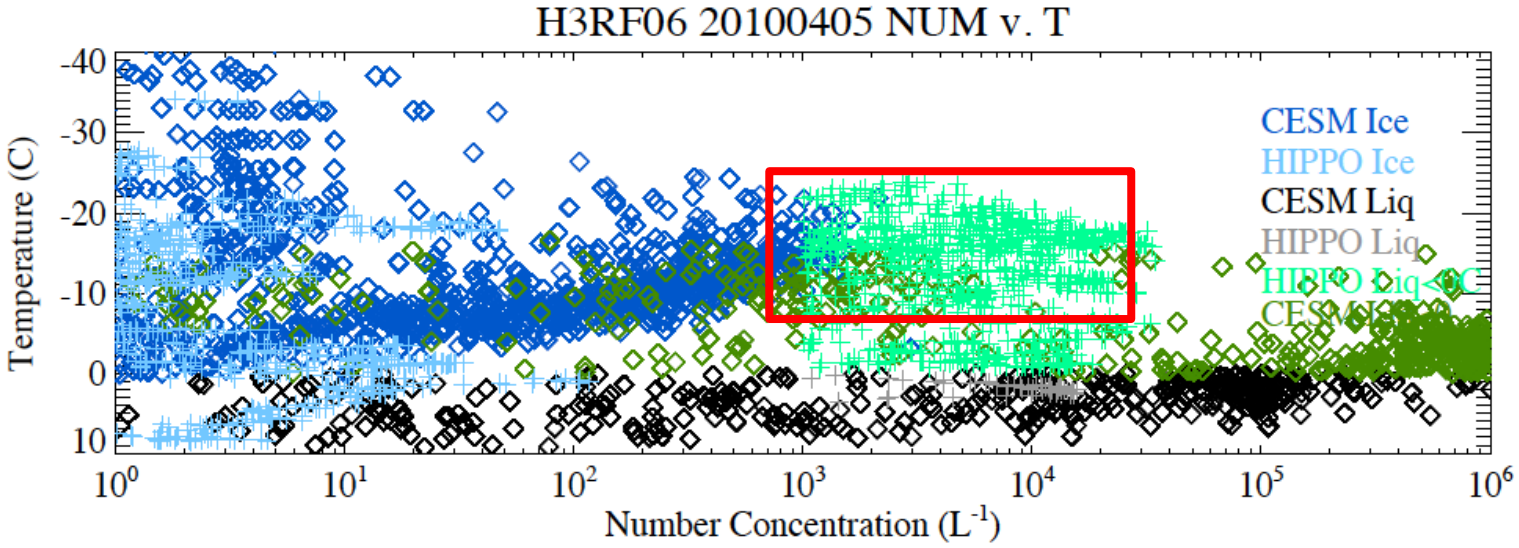
Cloud Number Concentrations

- Super-cooled liquid missed in CESM between 7.7 km (-22°C) & 4 km (0°C)
- Relatively high ice concentrations also evidence for active rime-splintering process at lower levels.



Across S. Ocean (H3RF06) April





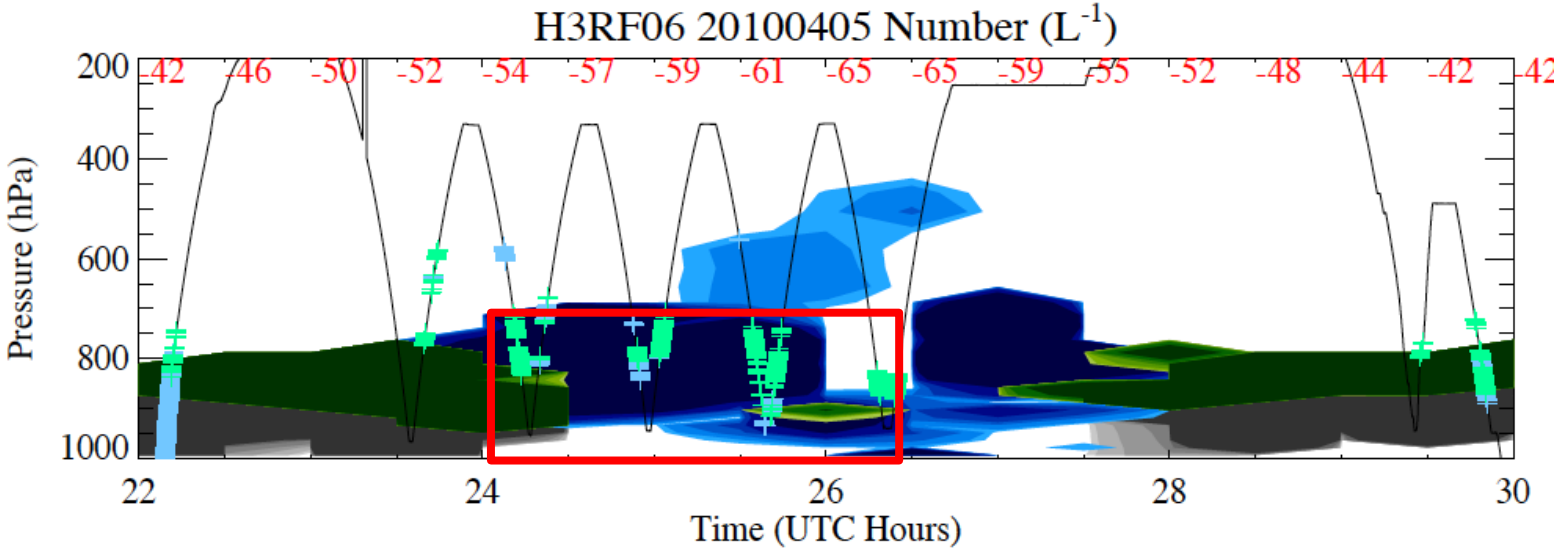
Obs=Liquid
Model = Ice

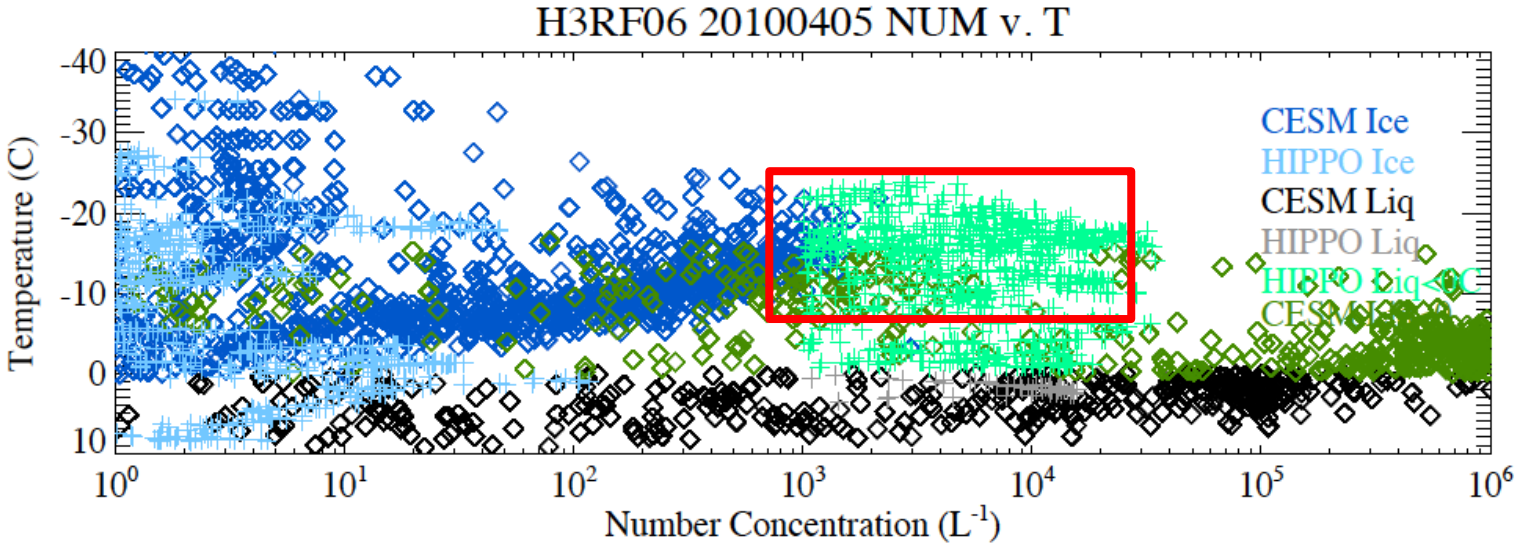
Summary

- Can simulate particular events (down to cloud system level) with a coarse resolution global model
- Compare cloud microphysics
- CESM missing super-cooled liquid (25°S-60°S)
  - Down to -25°C

CESM1.2

Across S. Ocean (H3RF06) April





Obs=Liquid
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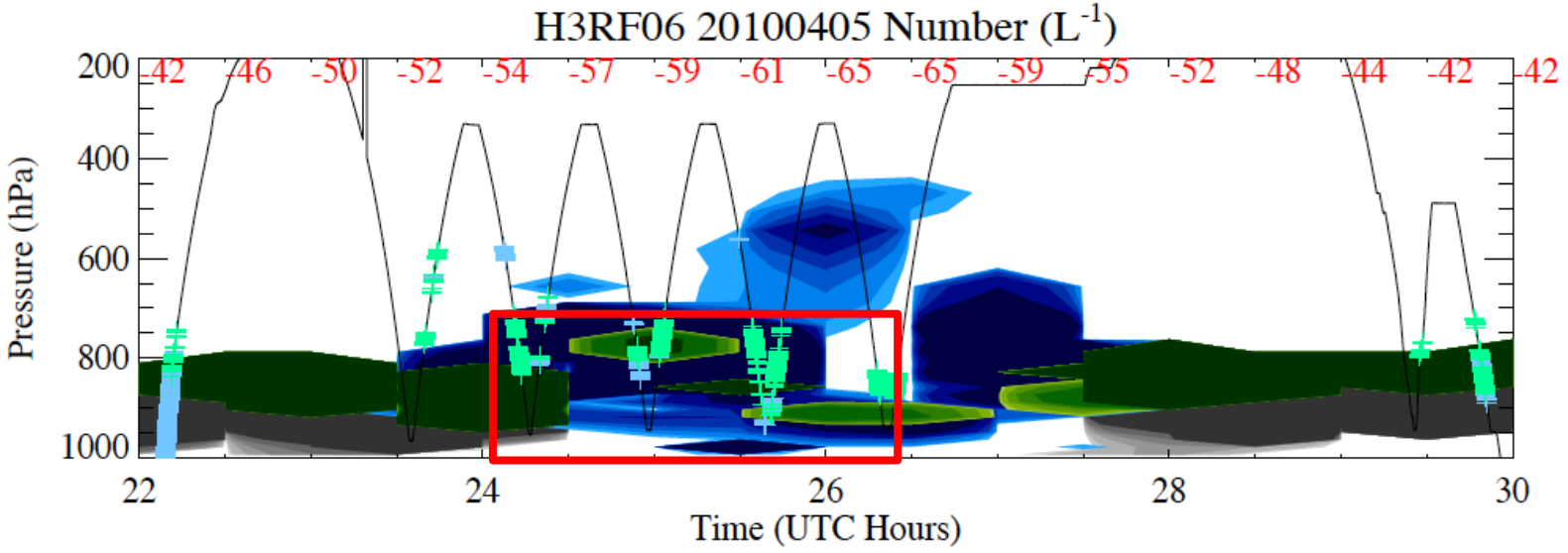
CESM1.2+ New Mixed Phase Ice Nucleation (Hoose et al. 2010)

Across S. Ocean (H3RF06) April



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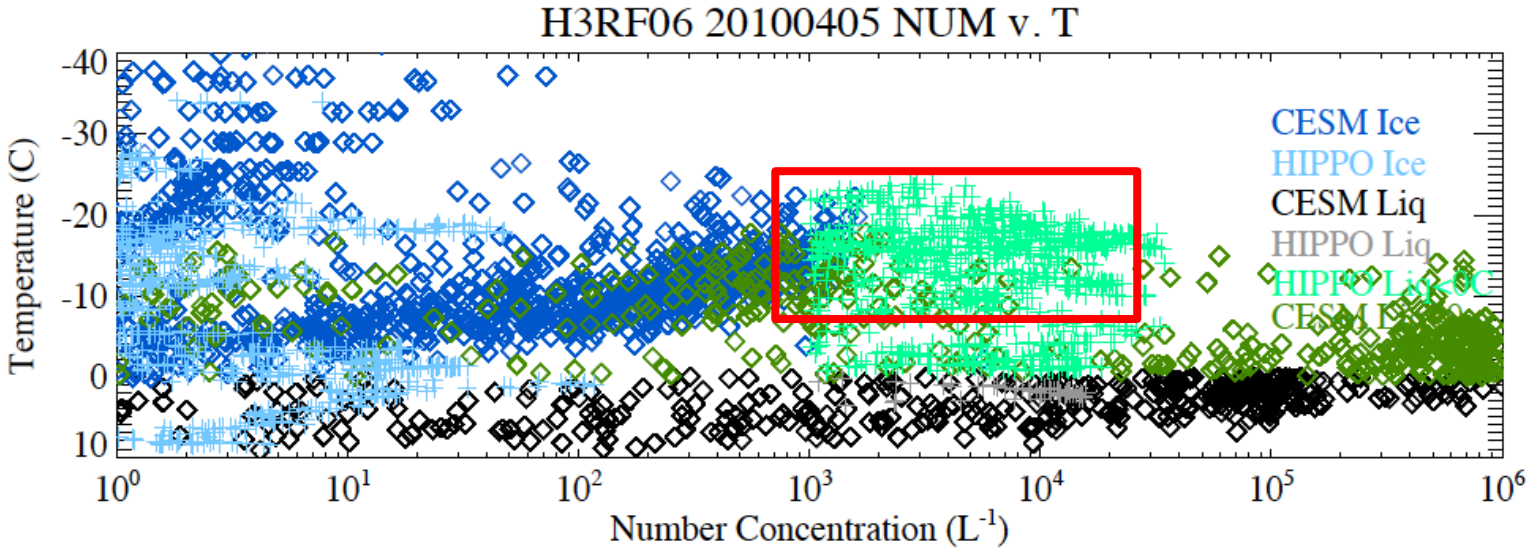
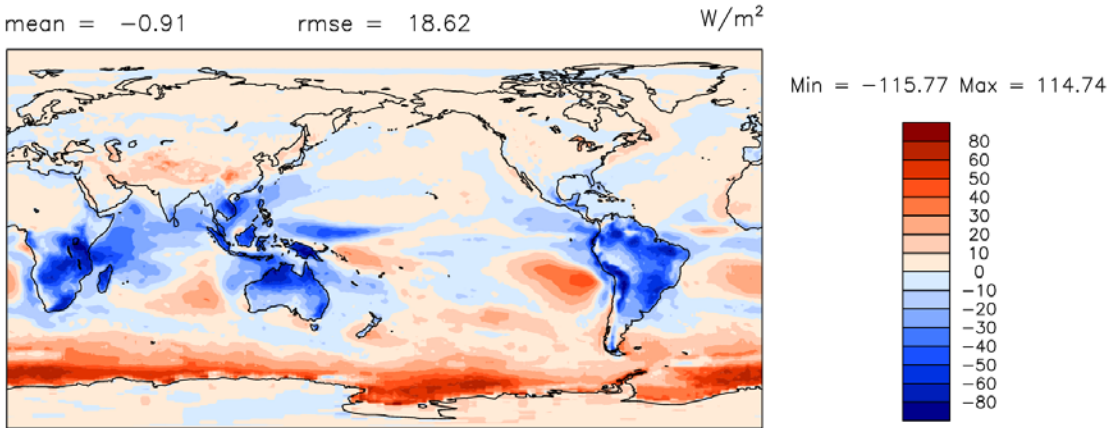


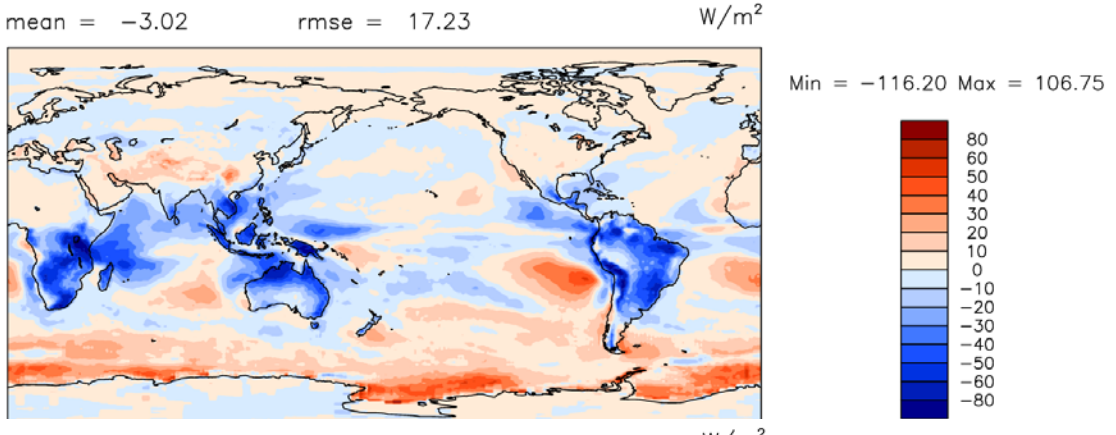
CESM2 development

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

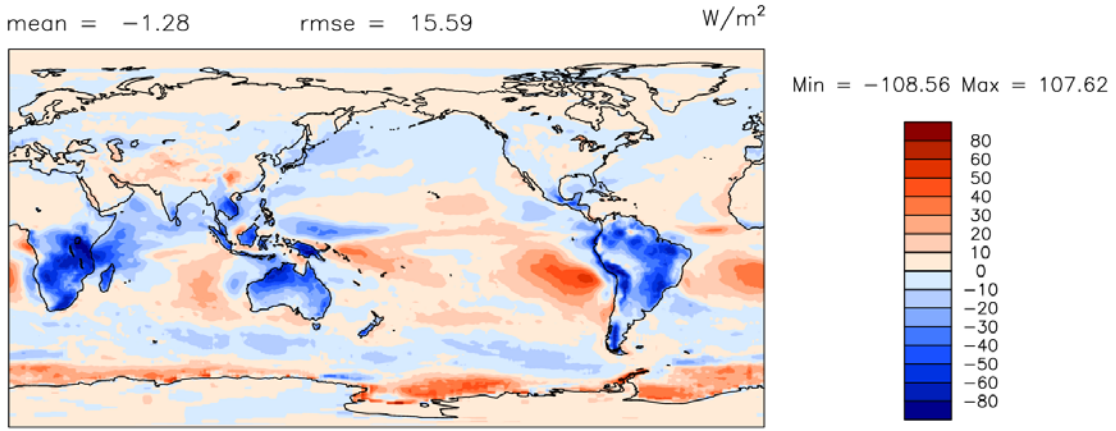
Current (CESM1.2)



CESM1.2+New Ice Nucleation

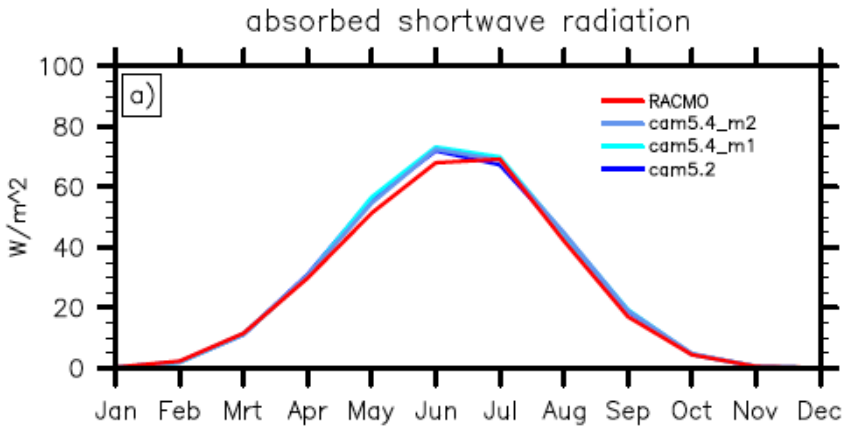


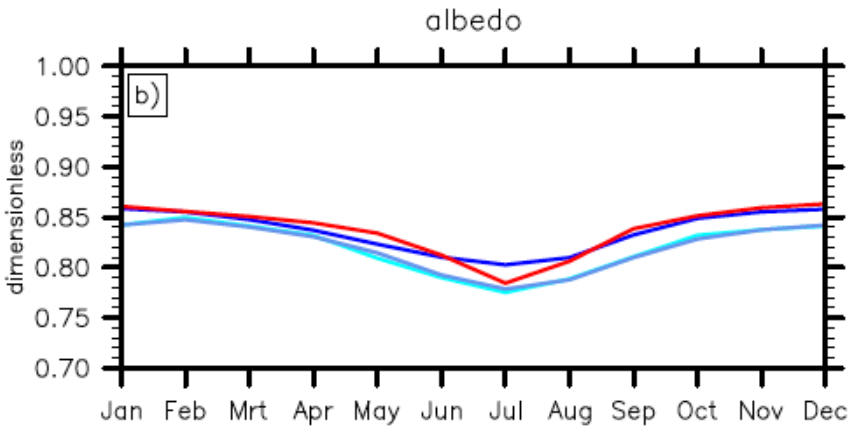
CESM1.2 + New Microphysics

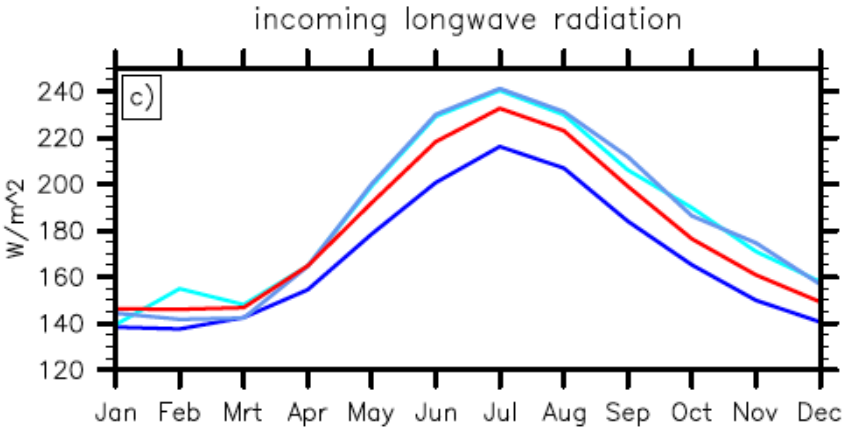


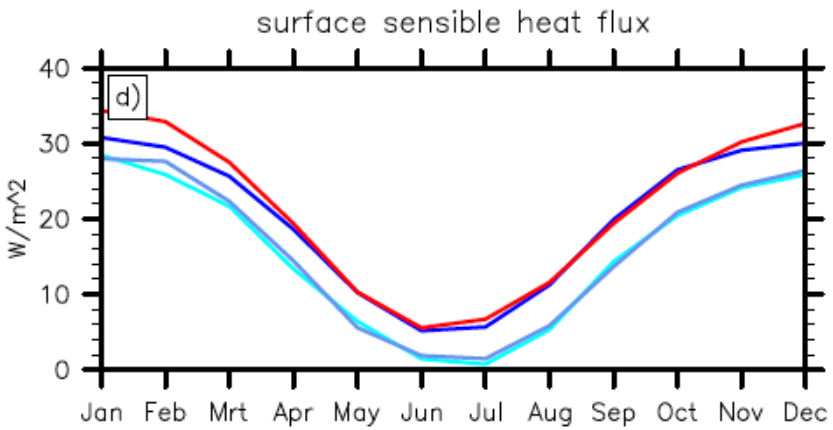
mean surface energy balance

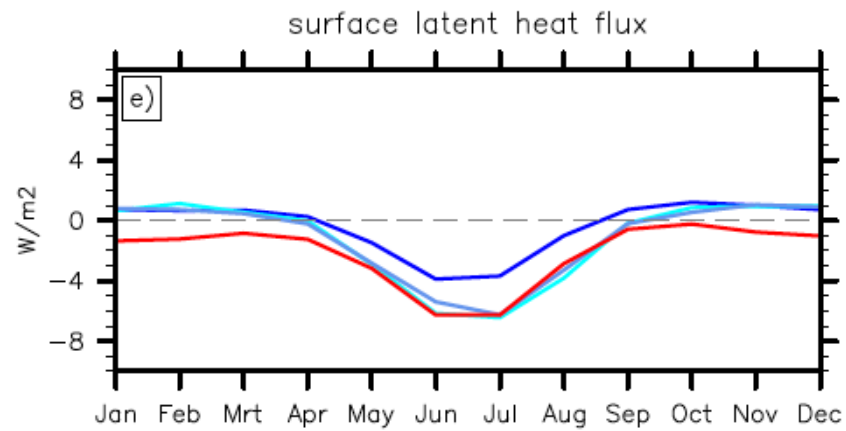
J. Lenaerts, Personal Communication

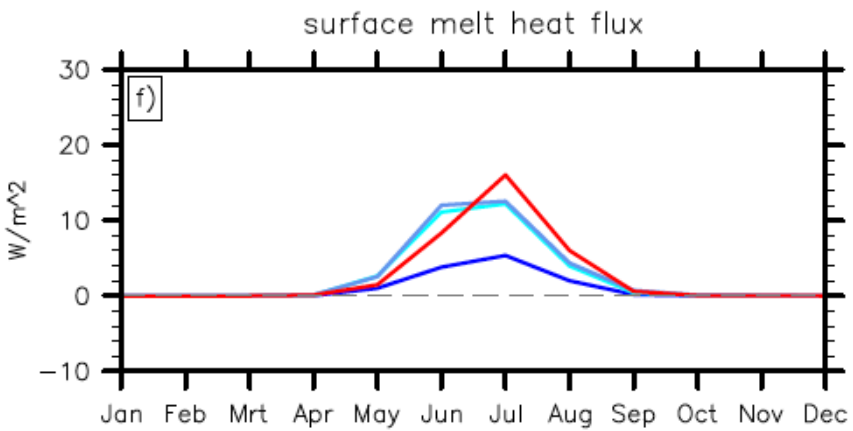












Conclusions

- New ways of setting up climate models to get closer to observations (in-situ, aircraft) can reproduce observations
  - Can go from obs→climate
  - These tools are part of public CESM releases
- 'Mixed phase' clouds with super-cooled liquid are important
- Critical: mixed phase ice nucleation, new microphysics
  - Reduces SH ASR bias significantly, also
- Working also on vapor deposition
- Next Steps:
  - detailed case studies with perturbed physics
  - Comparison of super-cooled liquid with satellites

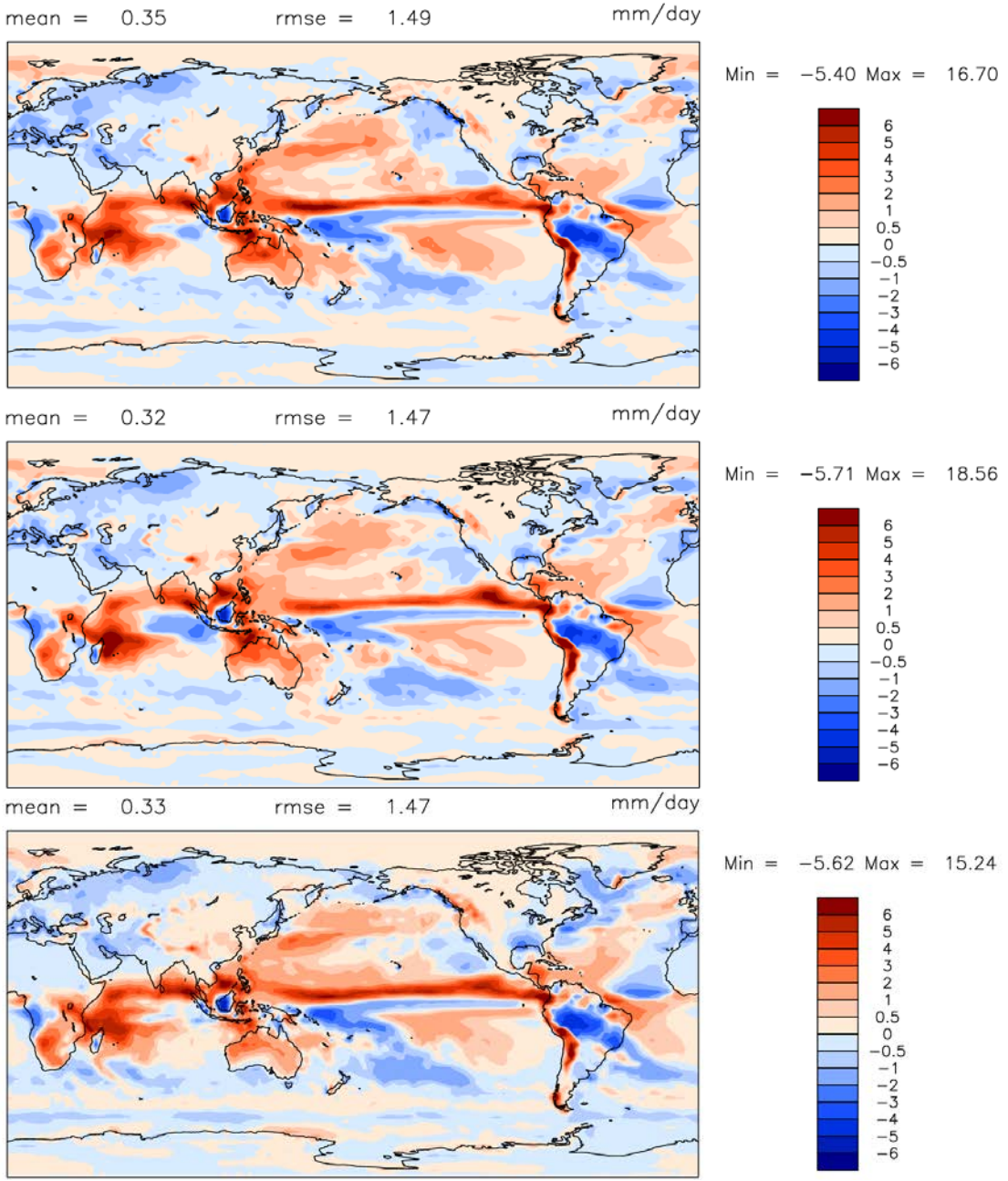
ITCZ Shift?

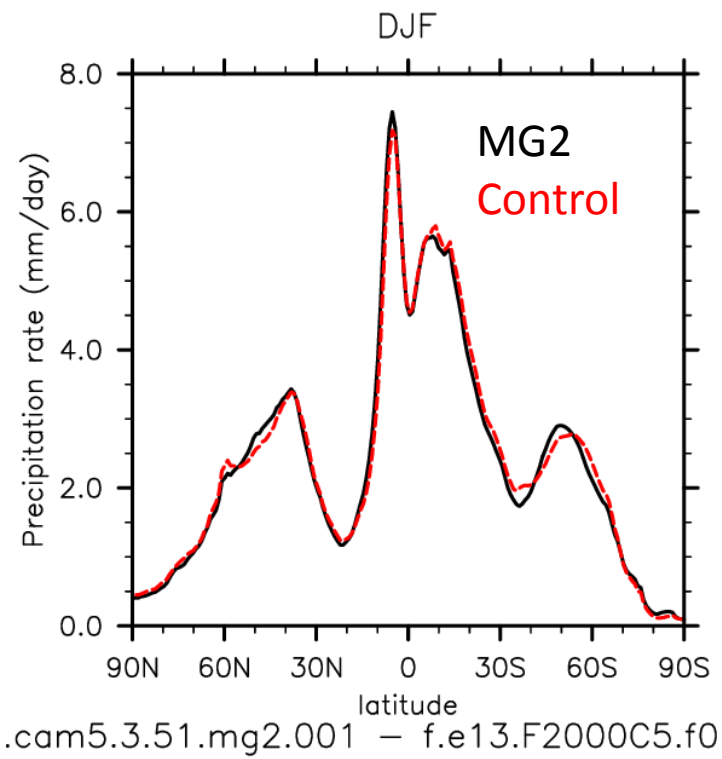
DJF precip bias from GPCP

Current (CESM1.2)

+New Ice Nucleation

+ New Microphysics





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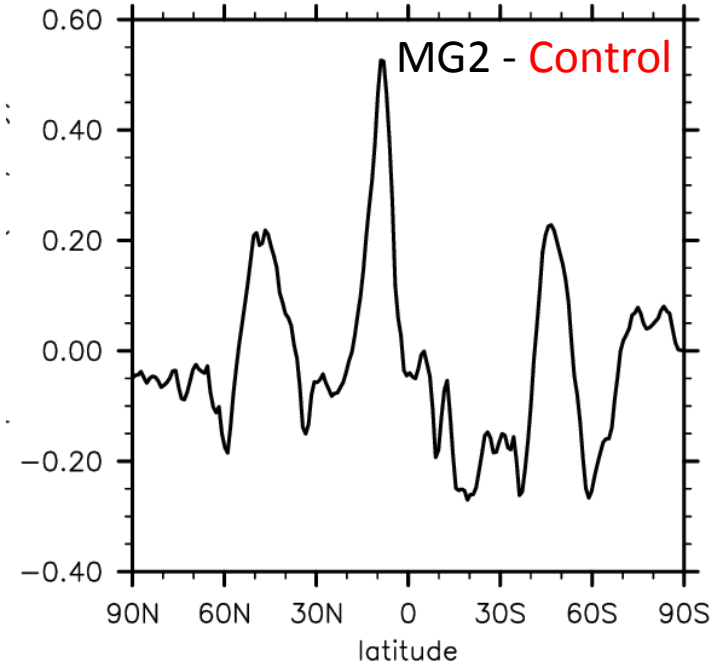

Small S. Shift when ASR bias reduced