Testing Mixed-Phase Cloud Microphysics Parameterizations in GCMs During the ISDAC

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Goal: Improve Climate Model Parameterizations

- Tools: single column model version of CAM3 (SCAM3)
- Forcing data from ECMWF (Xie)
- Model-calculated surface heat fluxes (Ocean)
- High-resolution simulations: 60 vertical levels
- Evaluation data: ISDAC measurements

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CAM3 Microphysical Schemes

- **Standard microphysics (SCAM): Rasch & Kristjansson (1998)**
  - **single-moment, liq/ice partition determined by T**

    All ice when T < - 40C, all liq when T > -10C
- **Modified microphysics (SCAM-ICE) : Liu et al (2007)**
  - **Double-moment, liq/ice partition determined by microphysical processes (Bergeron-Findeisen, Rotstayns et al., 2000)**
- **Test mixed-phase cloud ice nucleation parameterizations in SCAM-ICE:**
  - **Meyers et al. (1992): N_{IN}~f(Si);**
  - **Phillips et al. (2008): N_{IN}~f(dust/BC/OC surface area) (based on CFDC)**

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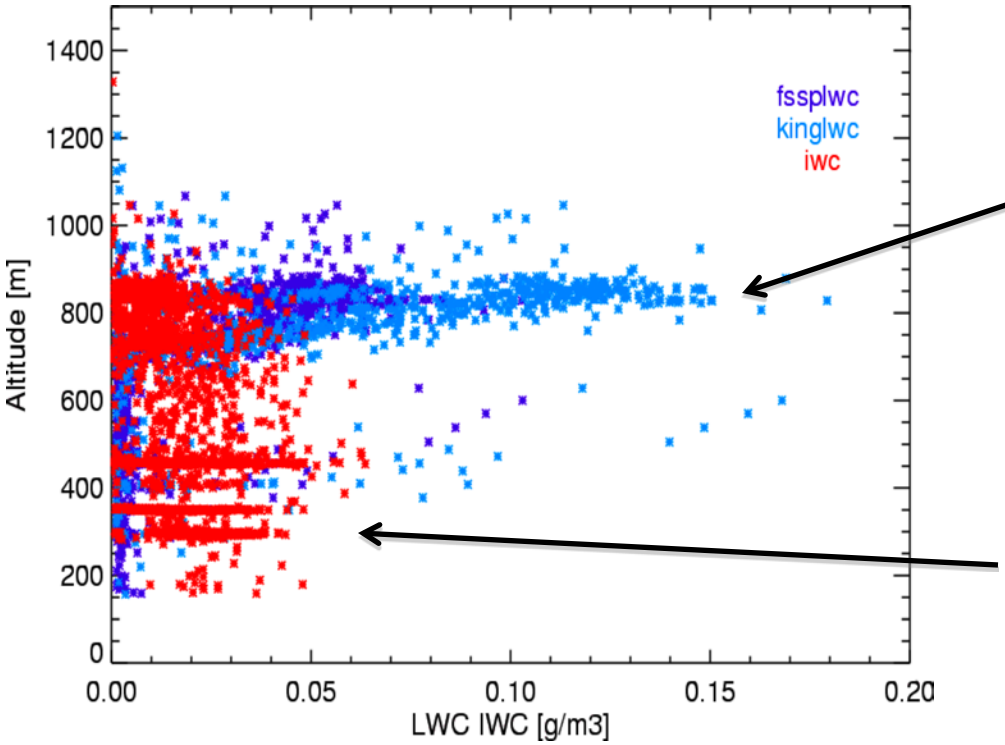
Aircraft Measured Cloud Water Content

Apr. 26, 2008



A strong liquid layer occurred near cloud top at 850m

Ice crystals in the liquid cloud layer and precipitating ice crystals beneath

(From A. Korolev)

For mixed-phase clouds, the range of cloud temp is from -12 C ~ -15 C (600-900 m)

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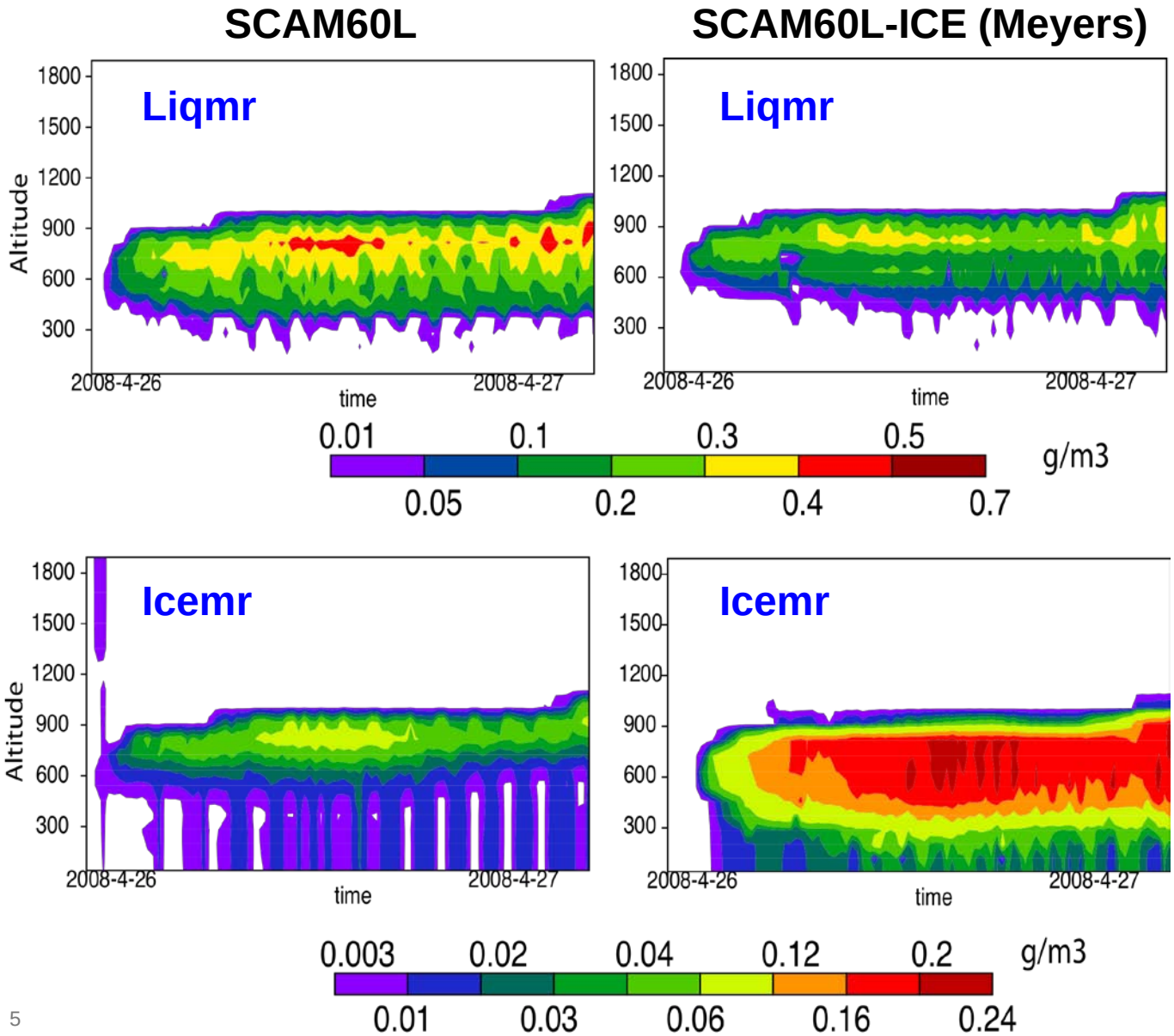
SCAM60L & SCAM60L-ICE of ISDAC (April 26)



- ***Obs:***
  H_{top}=850 m
  H_{base}=650 m
  LWC_{max}=0.1-0.15 g/m^3
  IWC=0.01-0.04 g/m^3

- ***IN number (CFDC, S. Brooks): 0.1-10/L, N_i = 0.5~1/L (size>100 um, A. Korolev)***

- ***SCAM60L-ICE separates LWC&IWC. However, too high in icemr.***

- ***SCAM60L-ICE (Meyers) gives IN=2-4/L***

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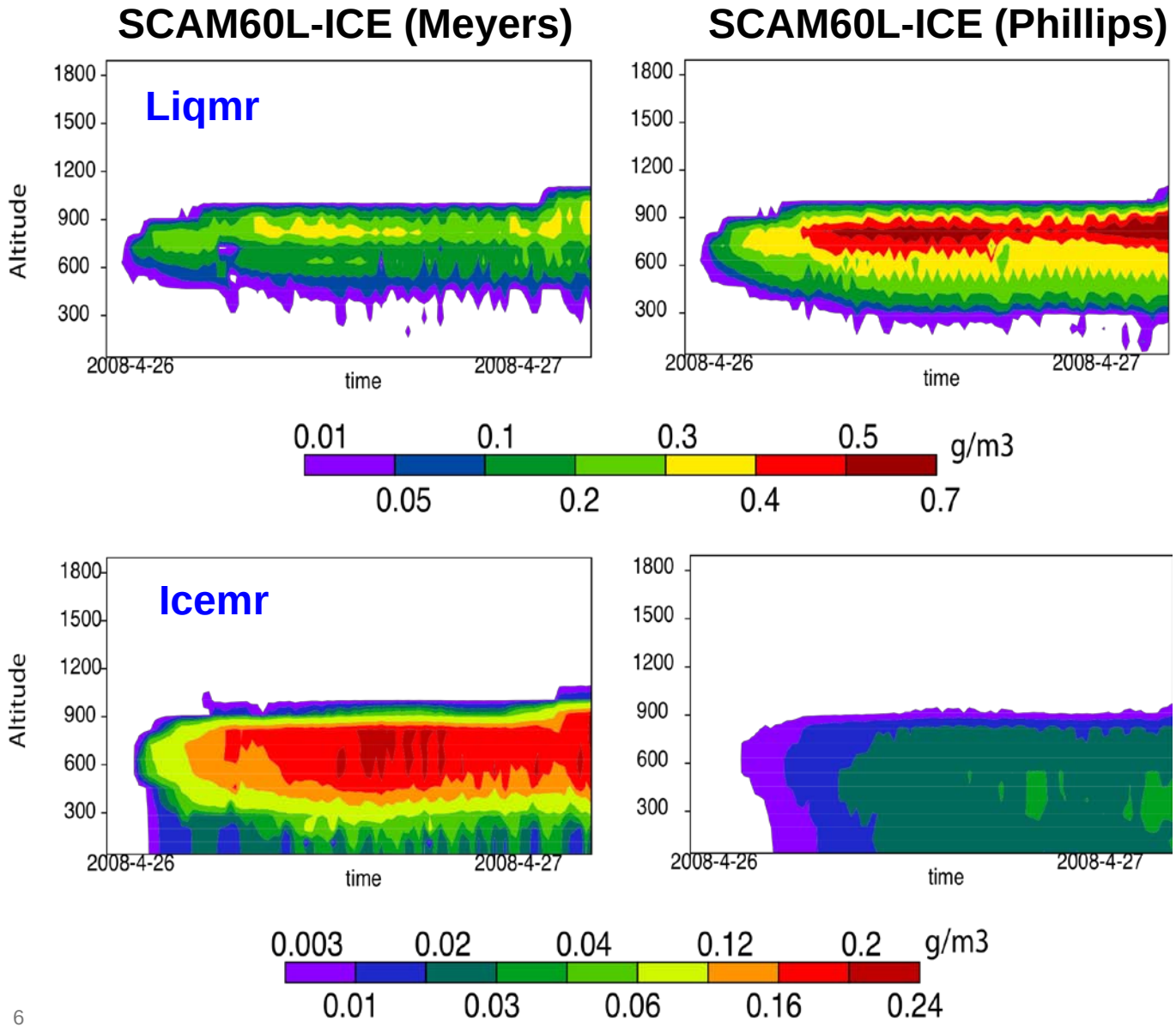
SCAM60L-ICE (Meyers vs Phillips) of ISDAC (April 26)



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- ***SCAM60L-ICE (Phillips) gives IN=0.1-0.2/L and IWC much lower (by 5-6 times)***

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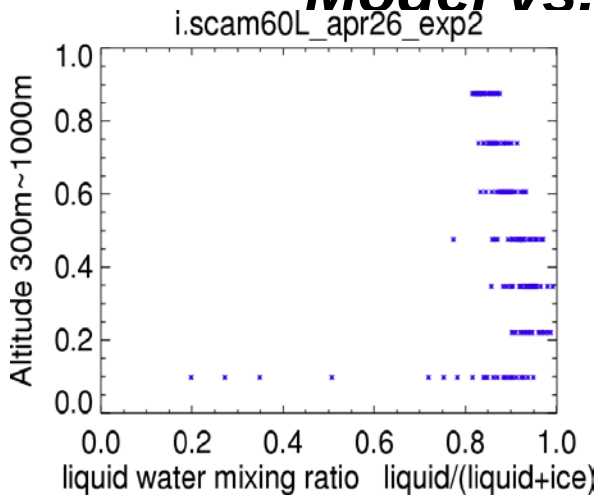
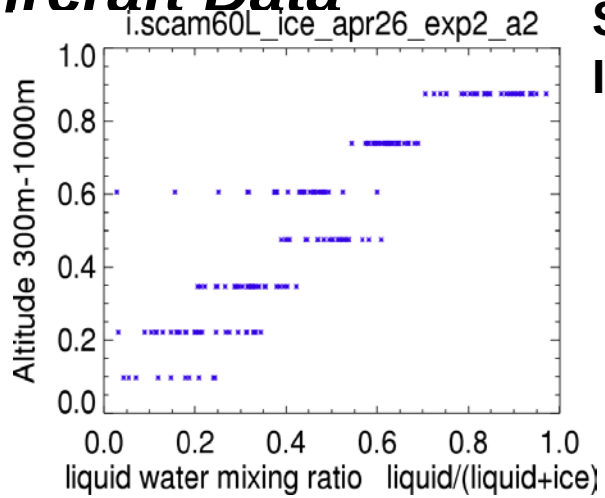
Boundary Layer Mixed-Phase clouds (April 26)

Model vs. Aircraft Data

SCAM60L



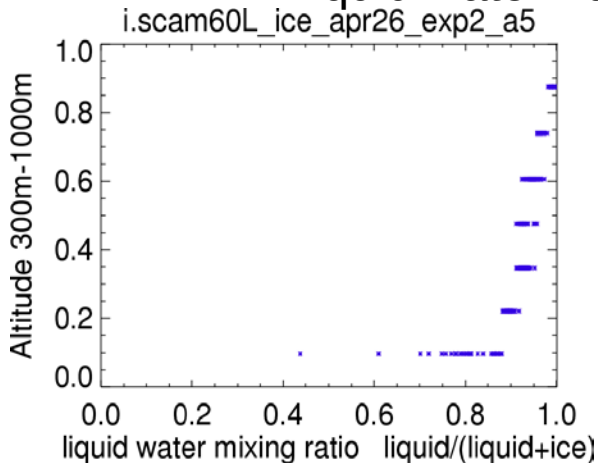
SCAM60L-ICE (Meyers)

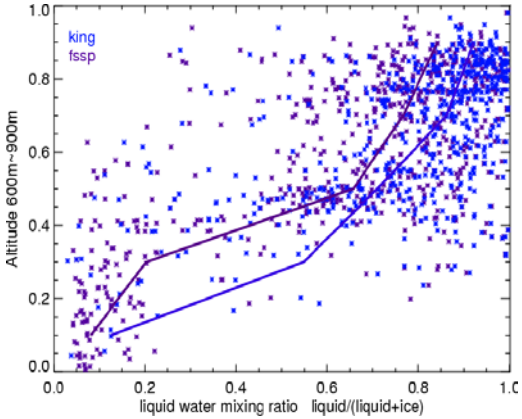


Normalized Height

Liquid water fraction, liq/(liq+ice)

SCAM60L-ICE (Phillips)





Obs

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Climate Effects of Ice Nucleation in Mixed-Phase Clouds

CAM Climate Simulations (camdev23_CAM3.6.28)

- Double-moment MG cloud microphysics
- PNNL modal aerosol module (MAM)
- UW PBL + shallow Cu + cloud macrophysics
- RRTMG shortwave and longwave radiative transfer

- 5 years at 1.9°x2.5° resolution

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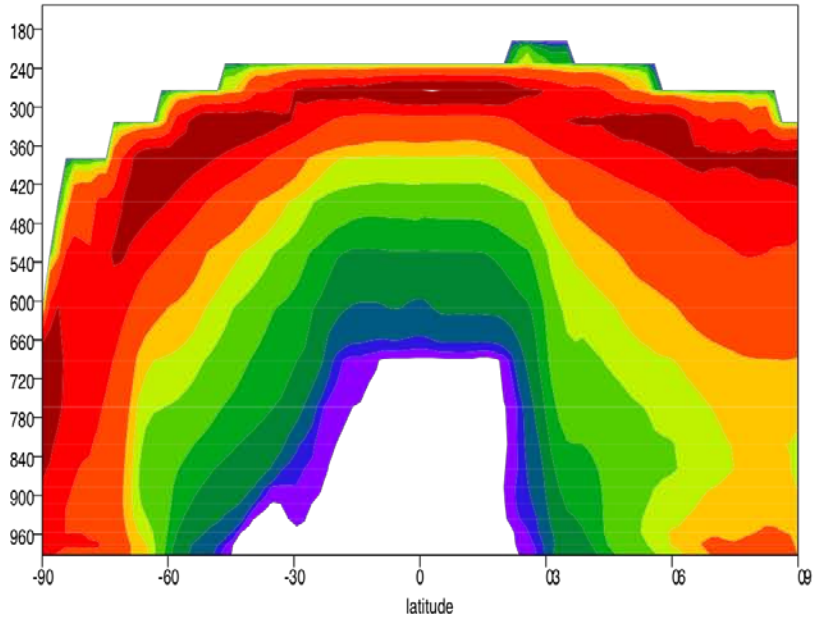
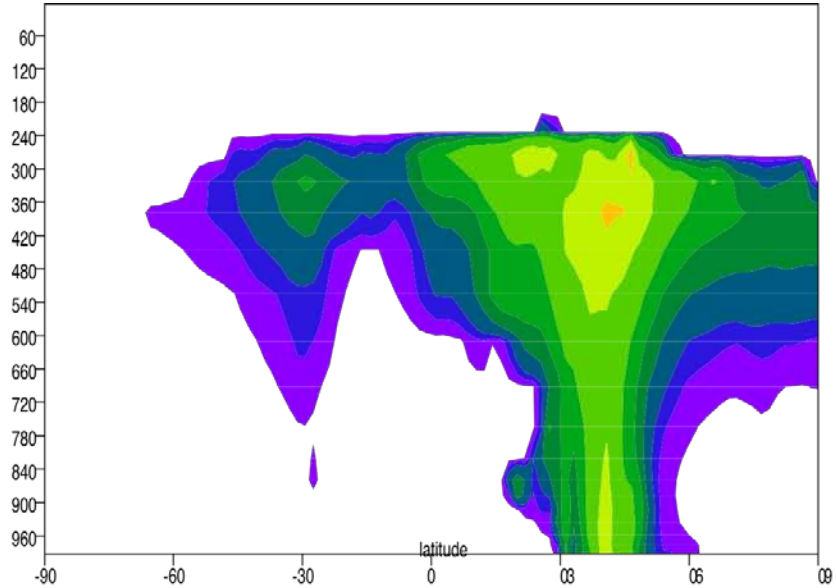
Ice Nuclei in Mixed-Phase Clouds from CAM

Meyers et al.



Phillips et al.



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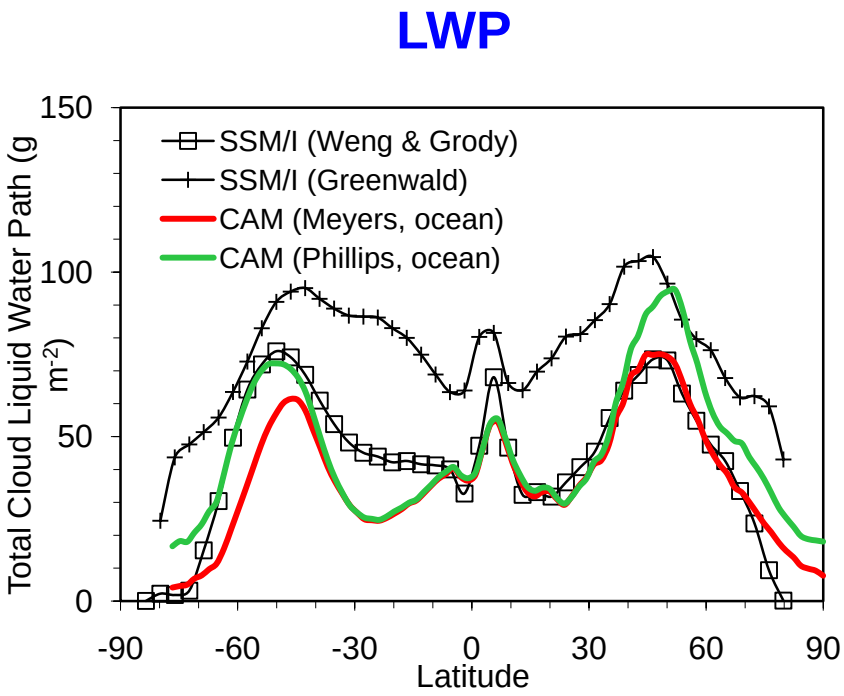
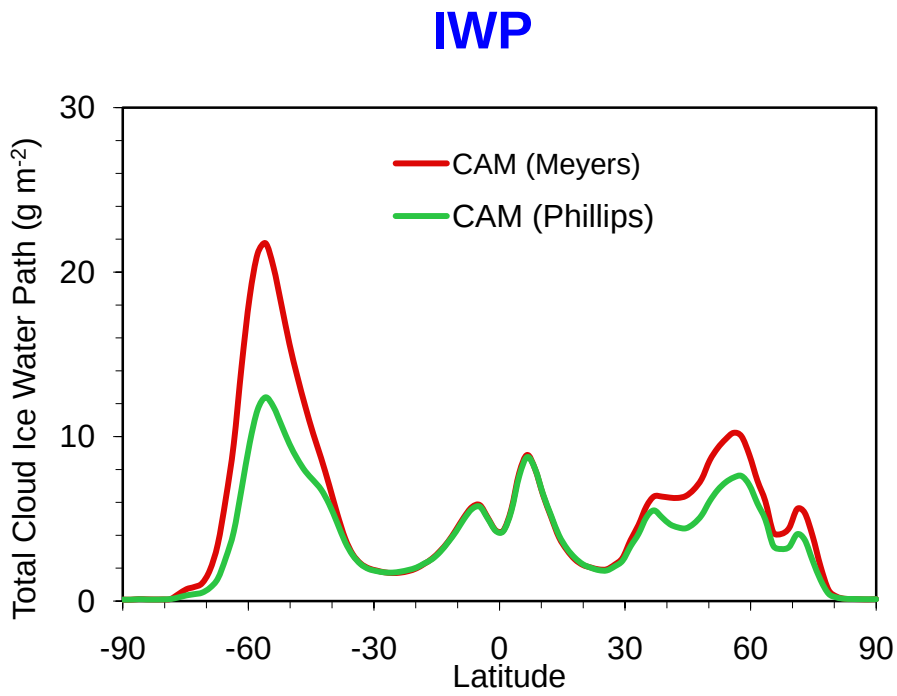
Climate Effects of IN parameterizations





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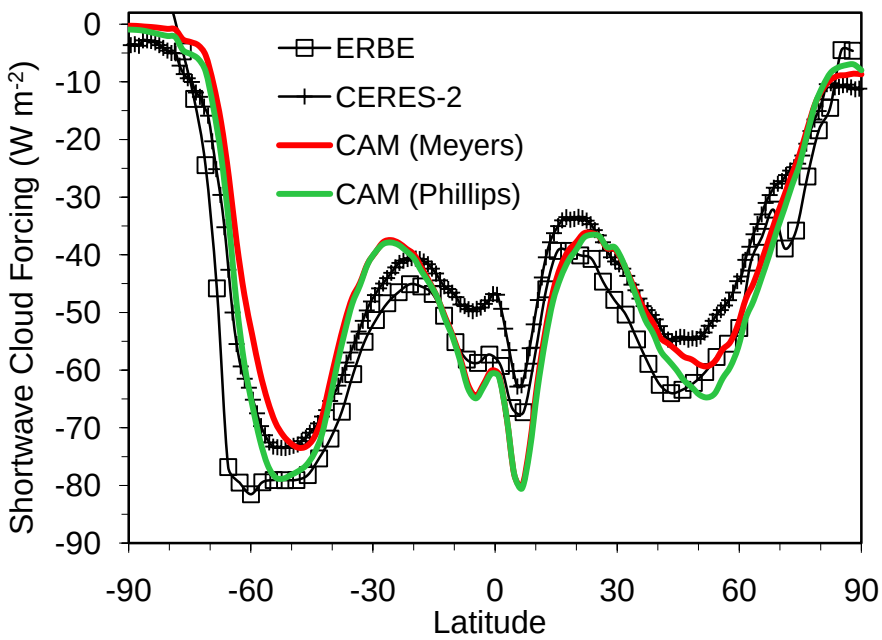
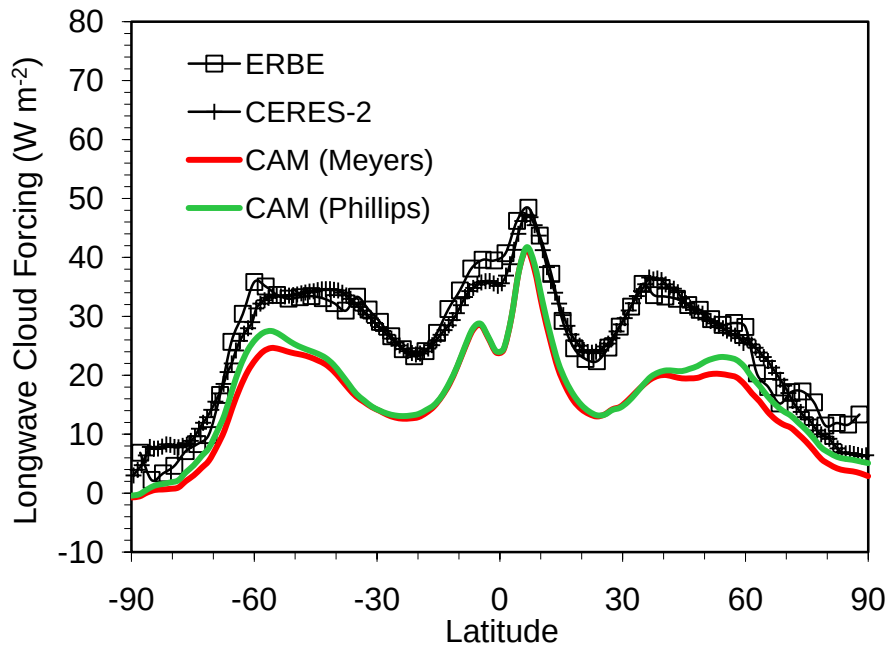
Climate Effects of IN parameterizations

SWCF



LWCF



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Global Annual Means

	Meyers	Phillips	OBS
LWP, g m^{-2}	40.5	45.6	48 (W&G, ocn) 79 (Greenwald, ocn)
IWP, g m^{-2}	5.6	4.5	
SWCF, W m^{-2}	-49.5	-51.6	-54.2 (ERBE) -47.1 (CERES2)
LWCF, W m^{-2}	19.2	20.1	30.4 (ERBE) 29.9 (CERES2)
FSDS, W m^{-2}	186.4	183.7	
CLDTOT, %	55.8	57.1	66.8 (ISCCP)

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Summary

- SCM testing for ISDAC shows that realistic treatment of mixed-phase cloud microphysics (ice nucleation and Bergeron-Findeisen process) is needed to reproduce cloud structure in Arctic mixed-phase clouds.

- Ice nucleation in mixed-phase cloud has important implication on global climate.

Future Work

- More detailed comparison with ISDAC data: sensitivity of cloud properties to aerosols

- Test ice nucleation parameterizations under DOE CAPT

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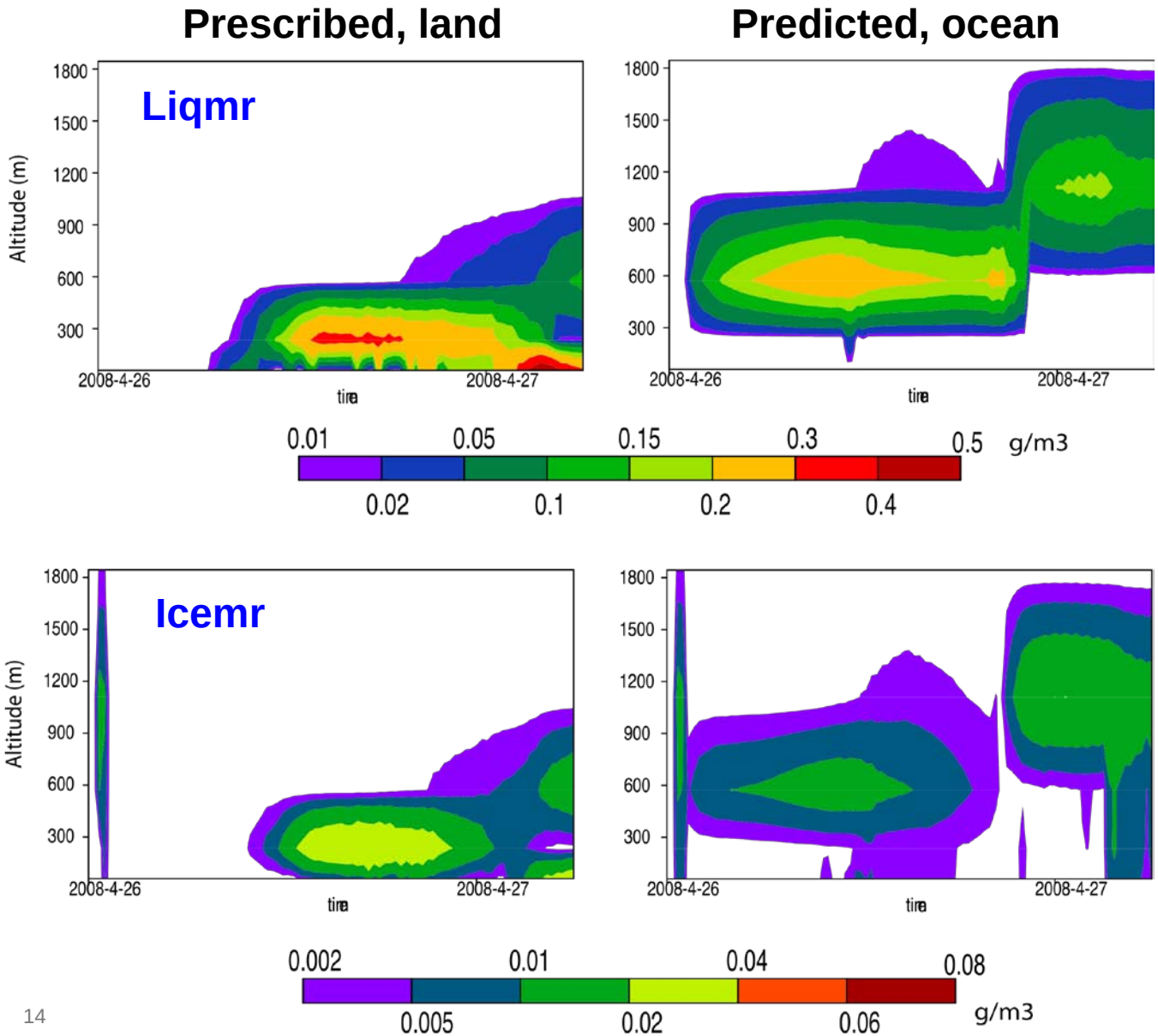
SCAM of ISDAC (April 26): Surface Heat Flux



- ***Obs:***
  H_{top}=850 m
  H_{base}=650 m
  LWC_{max}=0.1-0.15 g/m³
  IWC=0.01-0.04 g/m3

- ***Standard SCAM used***

- ***Prescribed surface flux predicts too low cloud levels, and too high liq & icemr***

- ***Predicted flux (ocean) gives better results (liq & icemr and macrophysics of cloud) for April 26 case; However, too deep clouds for April 8 case (not shown)***

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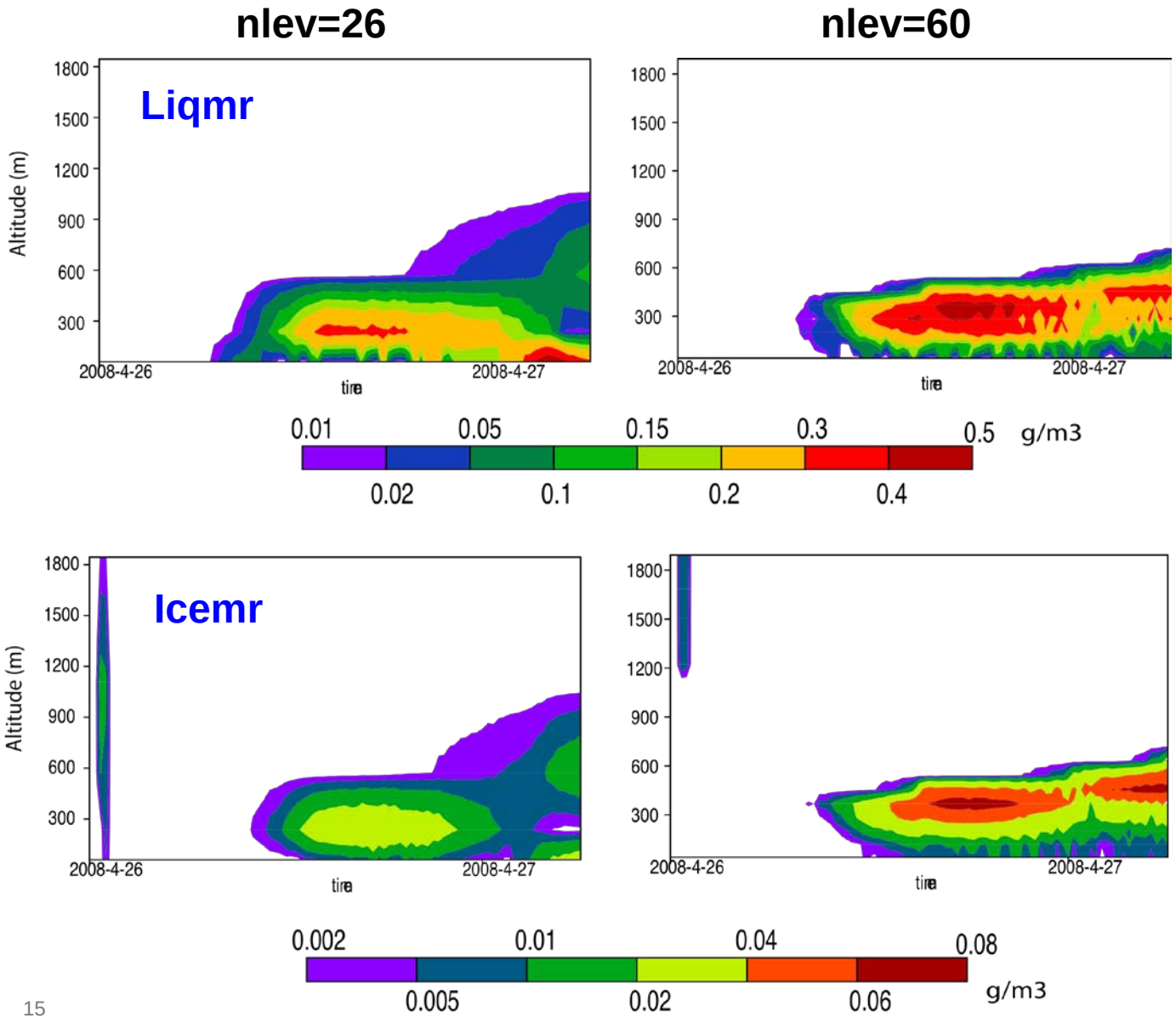
SCAM of ISDAC (April 26): Vertical Resolution



- ***Obs:***
  H_{top}=850 m
  H_{base}=650 m
  LWC_{max}=0.1-0.15 g/m^3
  IWC=0.01-0.04 g/m3
- ***Standard SCAM used***
- ***Prescribed surface flux (land) used***
- ***Higher resolution run increases cloud top height, still too low.***
- ***Higher resolution run predicts too high liq & icemr***

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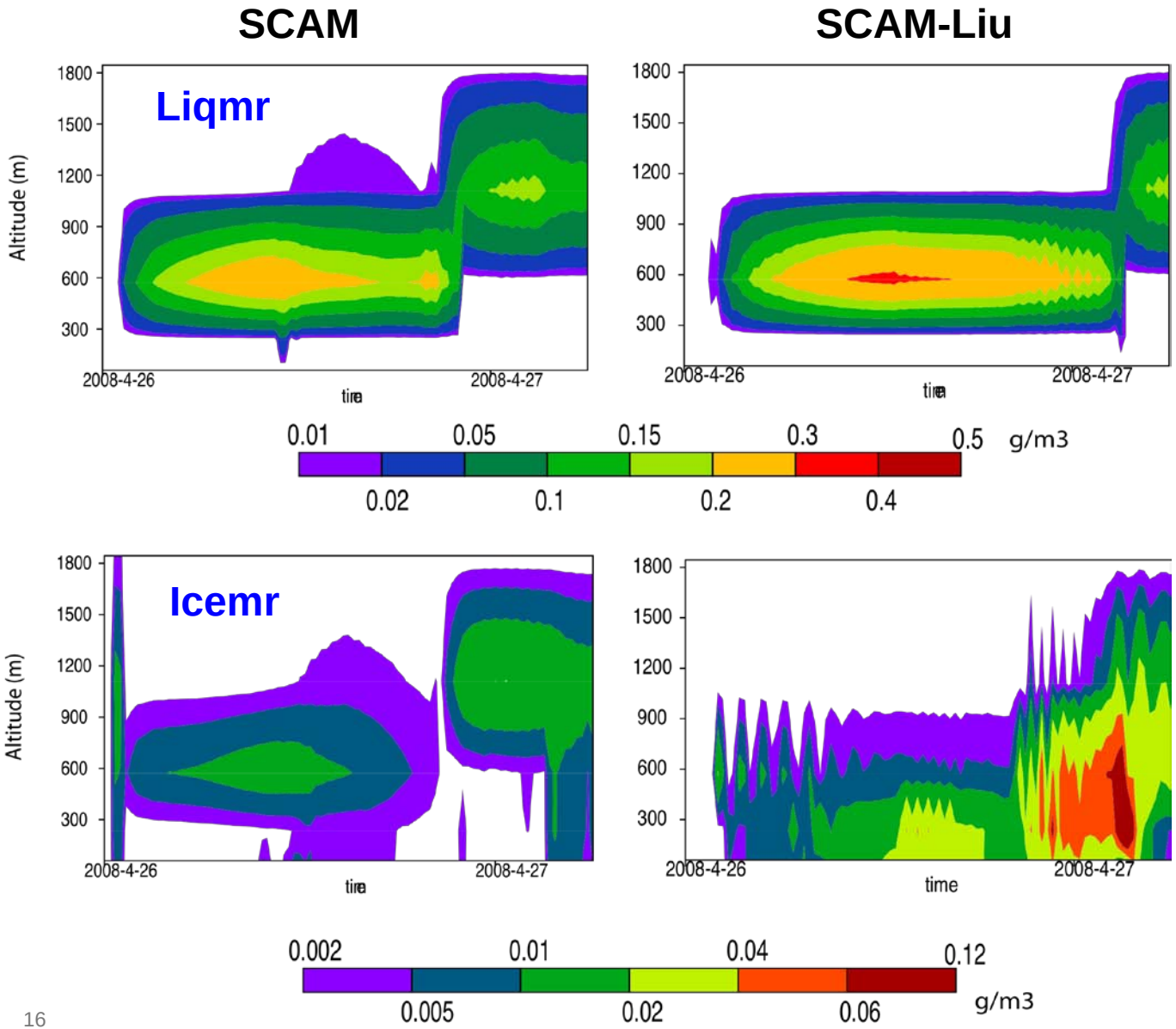
SCAM & SCAM-Liu for ISDAC (April 26)



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- ***Predicted surface flux (ocean) used and nlev=26***

- ***SCAM-Liu (Meyers) with IN=2/L***

- ***SCAM-Liu separates LWC&IWC. However, too high in IWC.***

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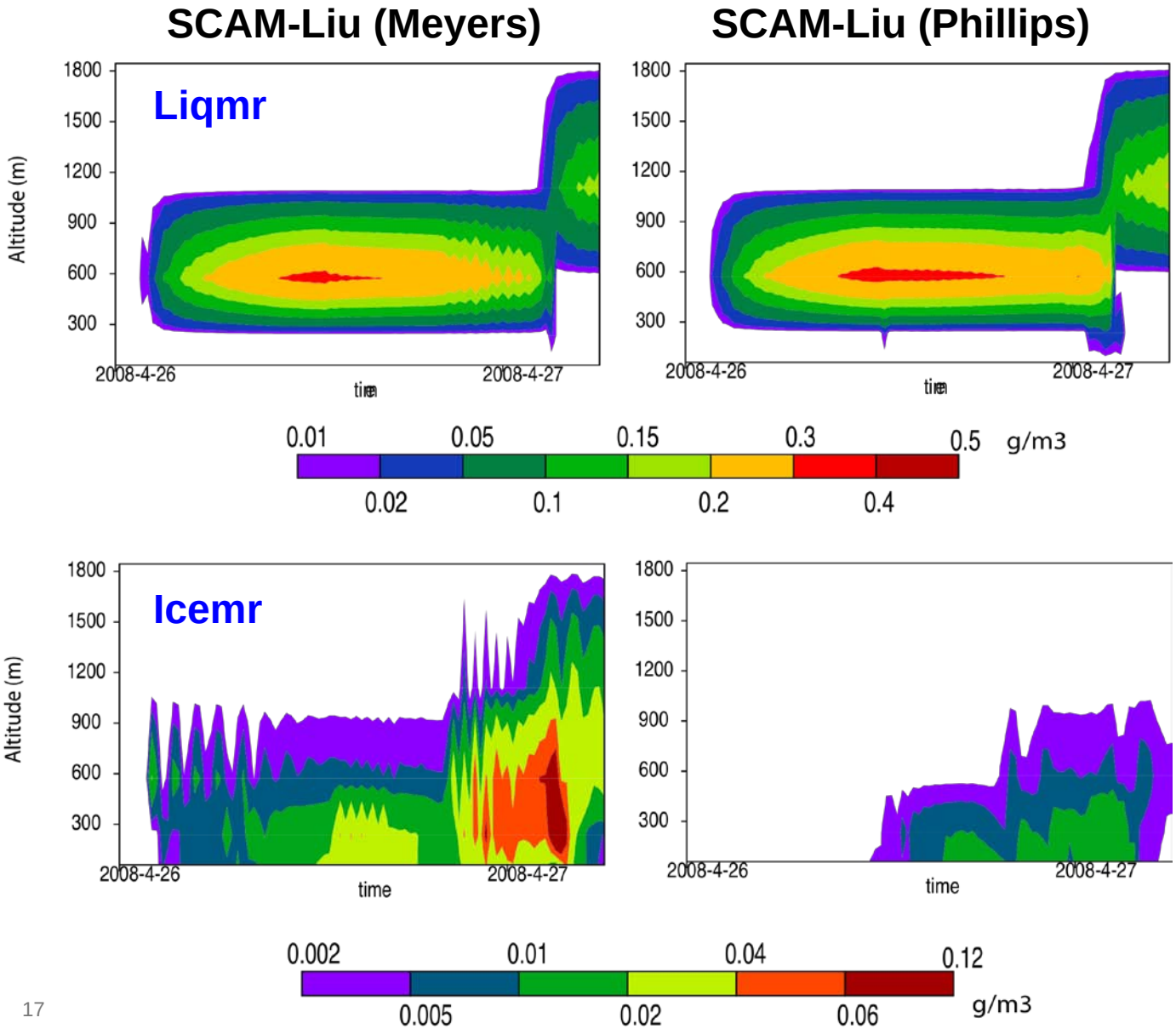
SCAM-Liu (Meyers vs Phillips) of ISDAC (April 26)



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- ***Predicted surface flux (ocean) used and nlev=26***

- ***SCAM-Liu (Meyers) IN=2/L***

- ***SCAM-Liu (Phillips) with IN=0.1/L predicts IWC much lower (by a few times)***

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