Improving the Simulation of Mixed-Phase Cloud Partitioning in CAM

Xiaohong Liu, Y. Wang, M. Zhang, D. Zhang, Z. Wang

University of Wyoming

C. Hoose

Karlsruhe Institute of Technology

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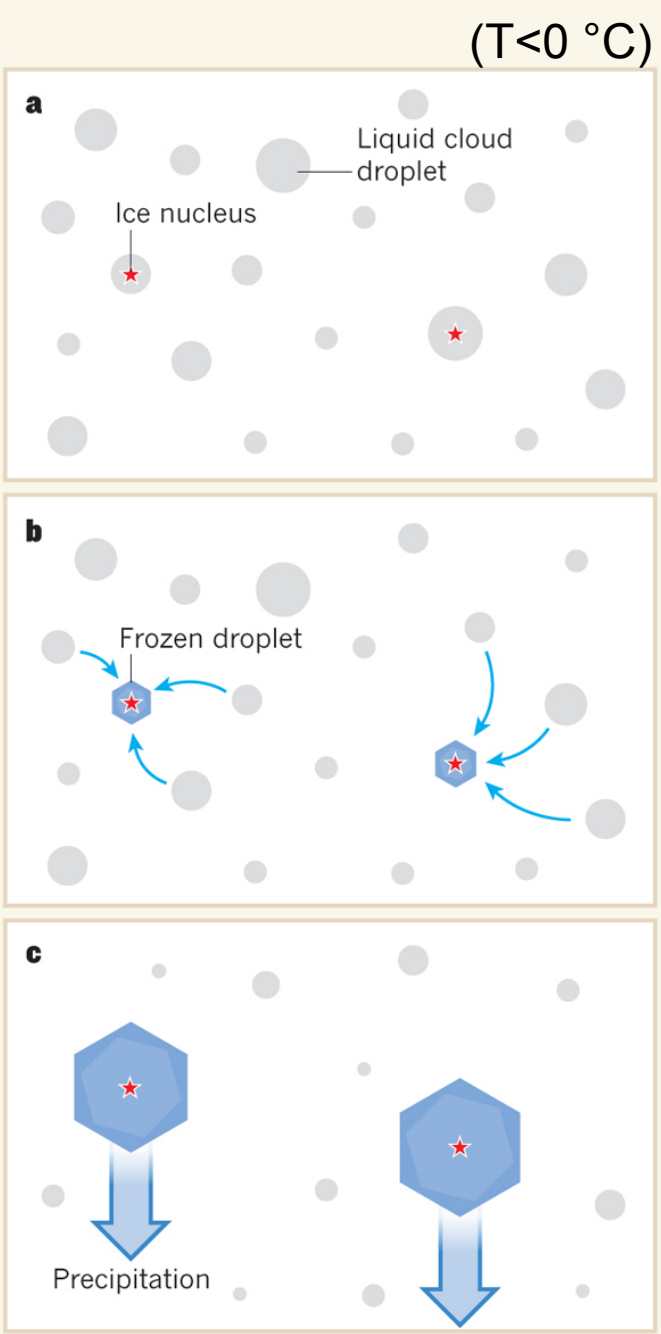
Cloud microphysics important for radiation and precipitation formation in mixed-phase clouds

Ice Nucleation

Bergeron-F. Process

Precipitation Initiation



Koop, Nature (2013)

Community Atmospheric Model (CAM5)

- Two-moment stratiform microphysics (*Morrison & Gettelman 2008; Gettelman et al. 2010*)
- Modal Aerosol Module (MAM, *Liu et al. 2012)*
  - Predicting aerosol mass, number and size distribution
- Cloud liquid droplet activation (*Abdul-Razzak & Ghan 2000*)
- Cloud ice crystal nucleation (*Liu et al. 2007*)
  - *Mixed-phase clouds*:

  Meyers et al. (1992) for deposition/immersion/condensation freezing of cloud droplets; *no link to aerosol*

  Young (1974) for contact freezing of cloud droplets by dust
- Wegener-Bergeron-Findeisen (WBF) process treated assuming homogeneous mixing of liquid and ice water in mixed-phase clouds

Model Experiments

- CAM5.1 with FV dynamic core, 1.9° x 2.5°, 30 levels
- 6-yr climatological runs with prescribed SST and sea ice (AMIP II type of run)

- CTL : Meyers et al. (1992) for deposition/condensation/ immersion in mixed-phase clouds, with no link to aerosol
- ICE : Classical nucleation theory (CNT) with PDF-contact angle (Wang and Liu 2014), with link to aerosol
- DSC : threshold T_{ice} over which all convection detrained condensate is liquid changed from -5 ^{o}C to -20 ^{o}C (Kay et al. 2016)
- NUG : model (u,v,T) nudged towards ERA-Interim (2005-2008)

Data Sets and Methodology

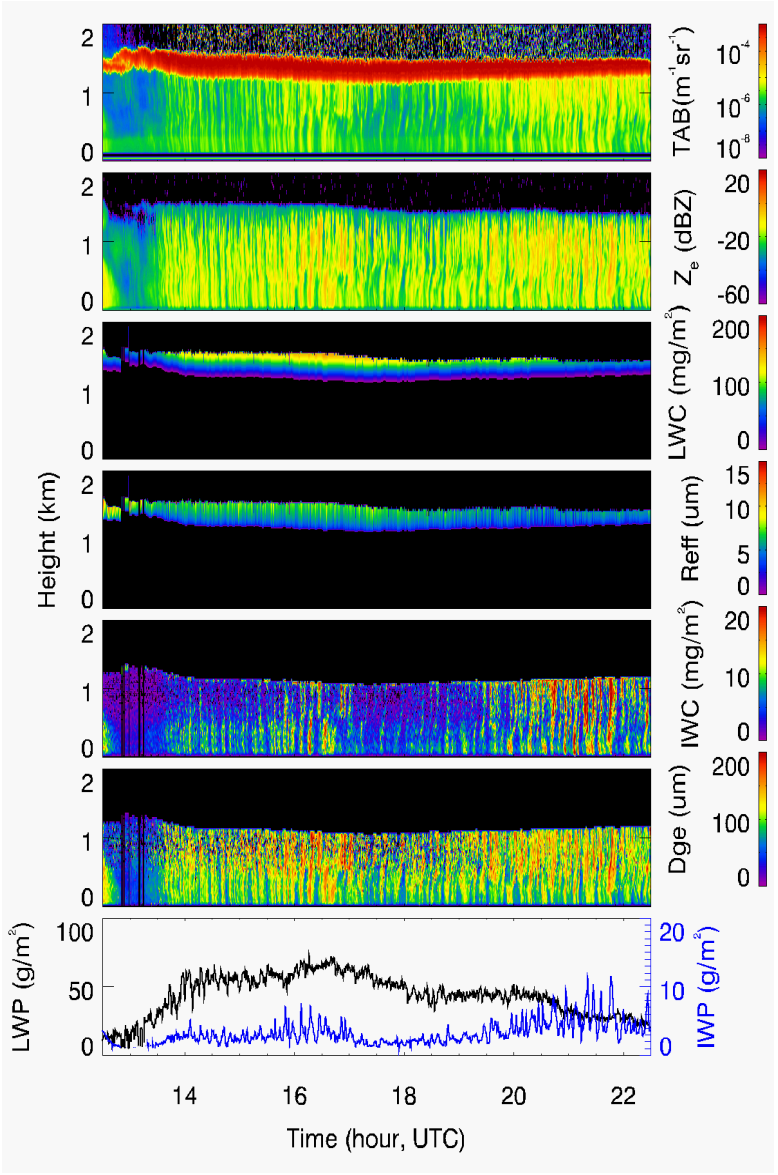
- Targets: Clouds with cloud top temperature between -40 and 0 ^{o}C.
- Cloud Phase Partition: CloudSat 2B-CLDCLASS-LIDAR product (Wang 2013).
- LWP: MODIS (MOD06) cloud product (King et al. 2003). Only for water and mixed-phase clouds.
- IWP: Integration of IWC (using temperature-depended Z_e-LWC relationship (Hogan et al. 2006)) from CPR radar detected cloud base to top. Only for mixed-phase and ice clouds.
- SLF (supercooled liquid fraction) calculation:

$$SLF = \frac{LWP}{LWP + IWP}$$

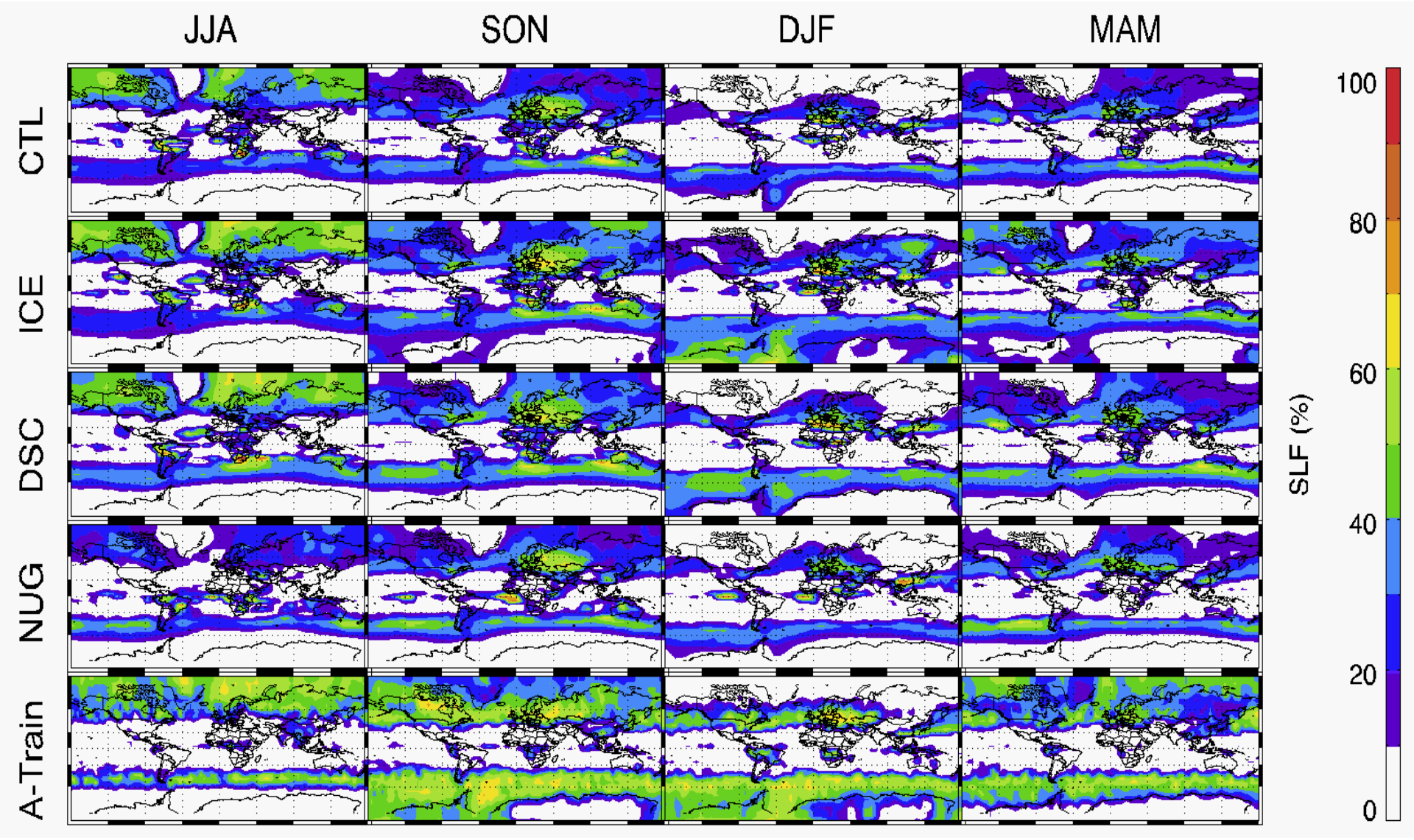
Multi-sensor Retrieval of Stratiform Mixed-phase Clouds Microphysical Properties

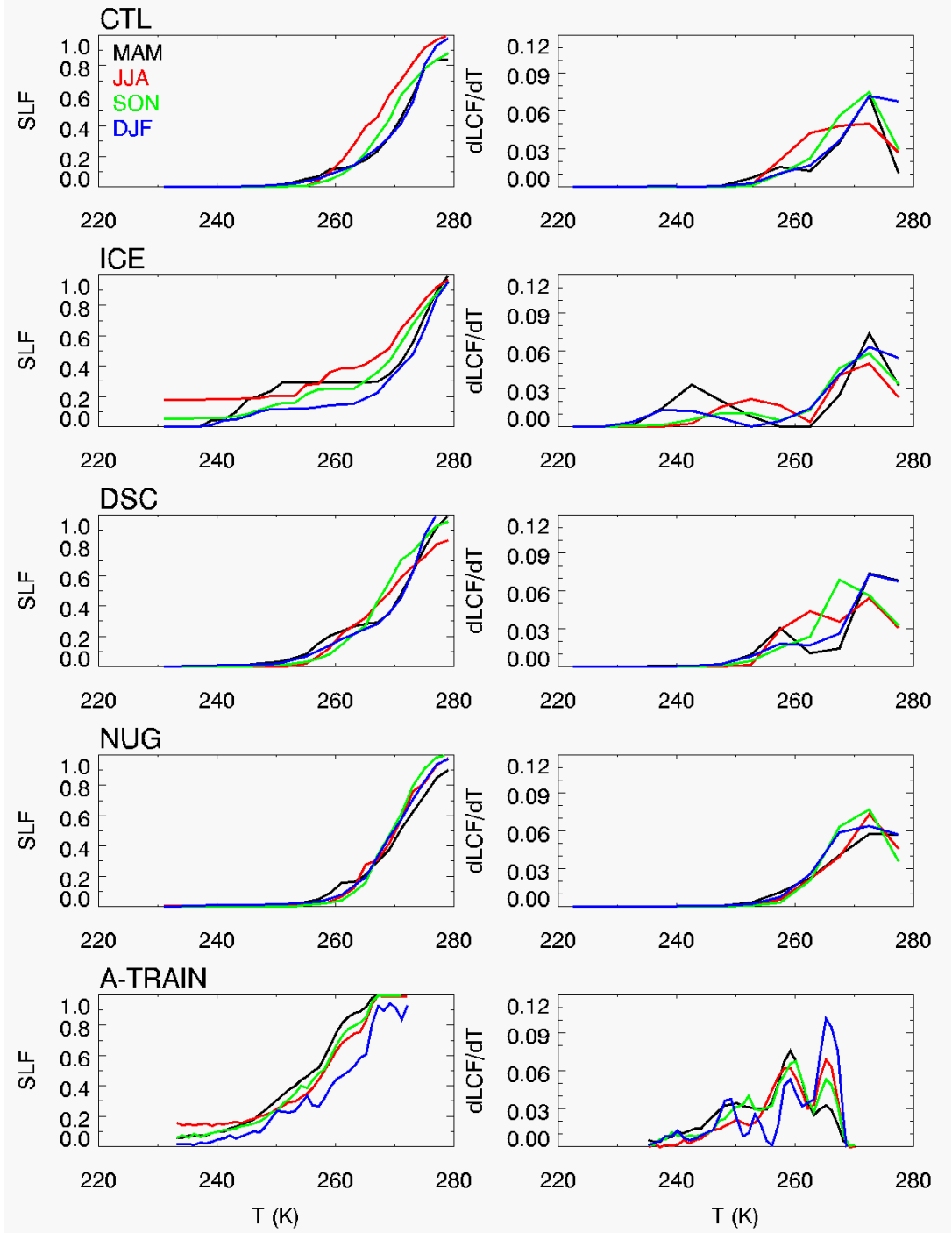
Multi-sensor retrieval algorithms

- **Input:** cloud radar, MWR, lidar, temperature profile.
- **Output:**
  - **Ice phase:** IWC, IWP, and general effective radius, N_{ice}.
  - **Liquid phase:** LWC, LWP, effective radius, and droplet concentration.

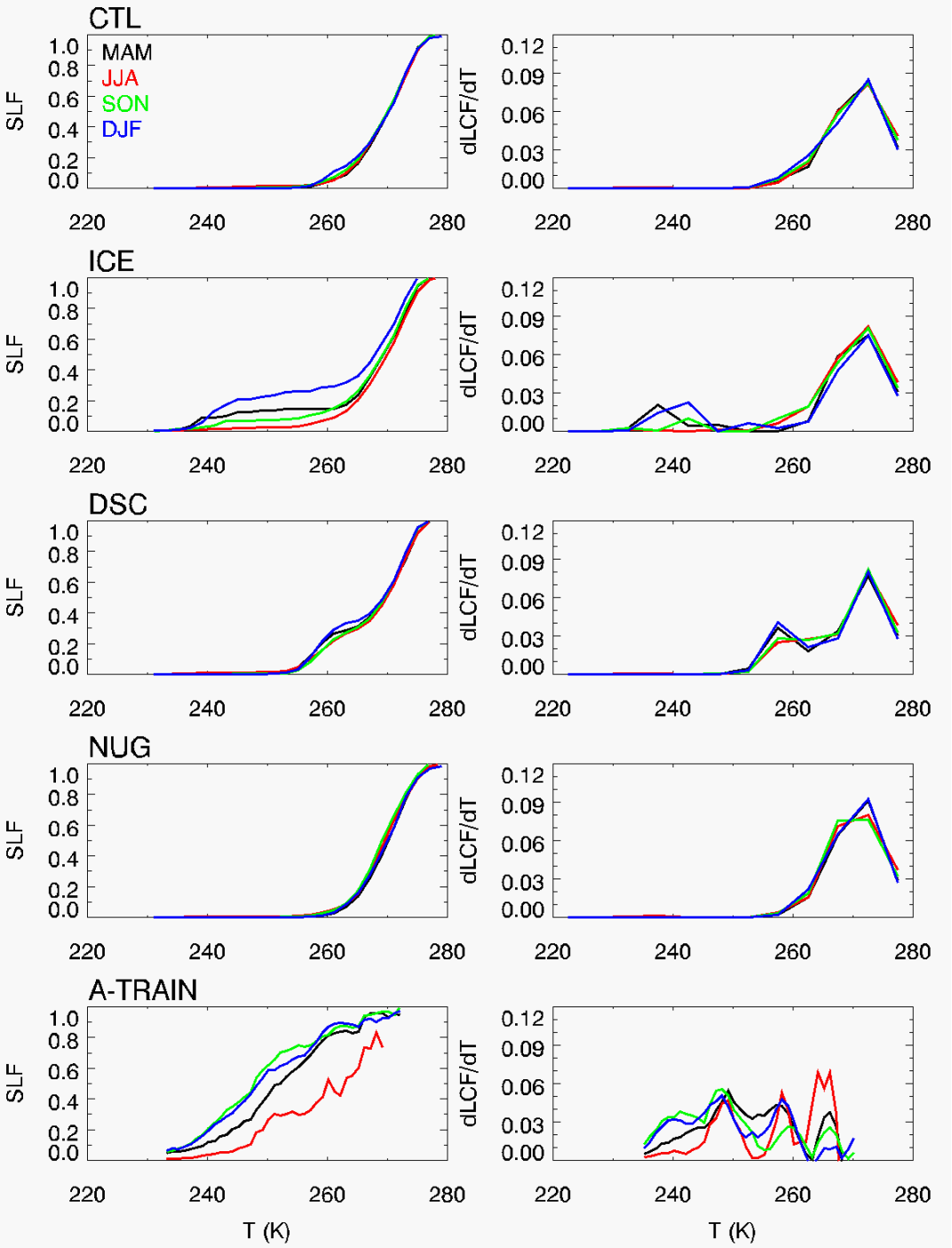


Global Distributions of SLF



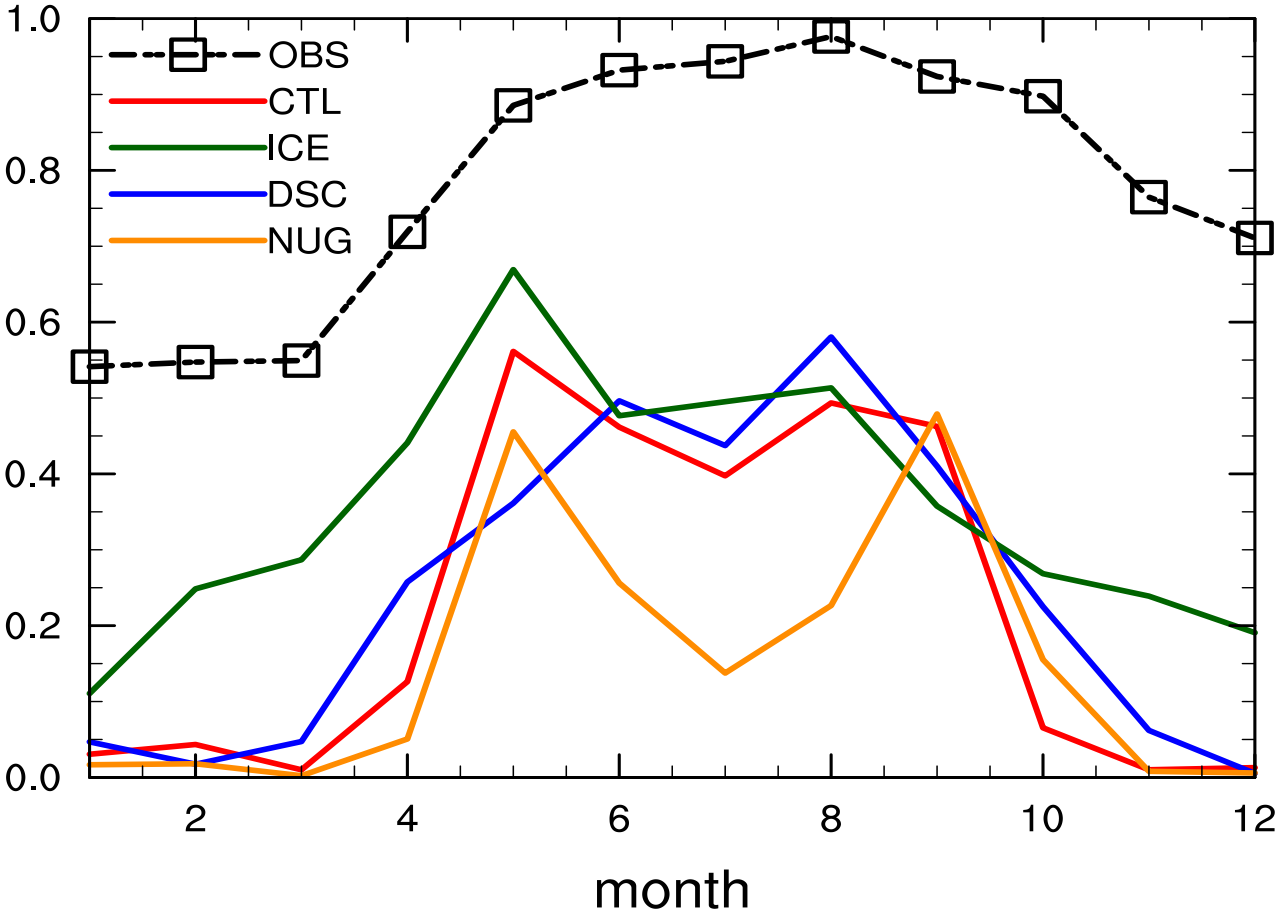


(Left) The diagnosed mixed-phase partitioning in four simulations to compare with the A-Train observations in the **60°N-90°N** latitude band for four seasons. (Right) The slope of the SLF at each temperature in each simulation.



SLF in **60°S-90°S** latitude band.

Supercooled Liquid Fraction at NSA



Summary

- Compared to Meyers et al. (default), new ice nucleation parameterization linking to aerosols significantly increases modeled mixed-phase supercooled liquid fraction at temperatures colder than -20°C
  - Improved comparison with A-Train observations in many regions
- Changing transition temperature for convection detrained cloud water mainly improves SLF low bias over Southern Ocean.
- Nudging meteorology (U,V,T) slightly improves SLF low bias in Southern Ocean, but degrades simulation in N. Hemisphere. Nudging Q?
- With the above modifications, low biases persist in many regions (e.g., Greenland). Improve the WBF process. Improve aerosol processes for high latitudes?