Using A-Train Observations to Evaluate Ice Water Path and Ice Cloud Radiative Effects in the Community Atmosphere Model

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Motivation

- Large differences exist between modeled cloud ice and observations (Li et al., 2012)
- Yet models show consensus for a positive high cloud feedback (Vecchi and Soden, 2011)
- Examine cloud radiative effects as a function of *Ice Water Path (IWP)*
- Which type of cirrus contribute most to heating the upper troposphere?
- Use A-Train satellite data to evaluate ice clouds in a global climate model

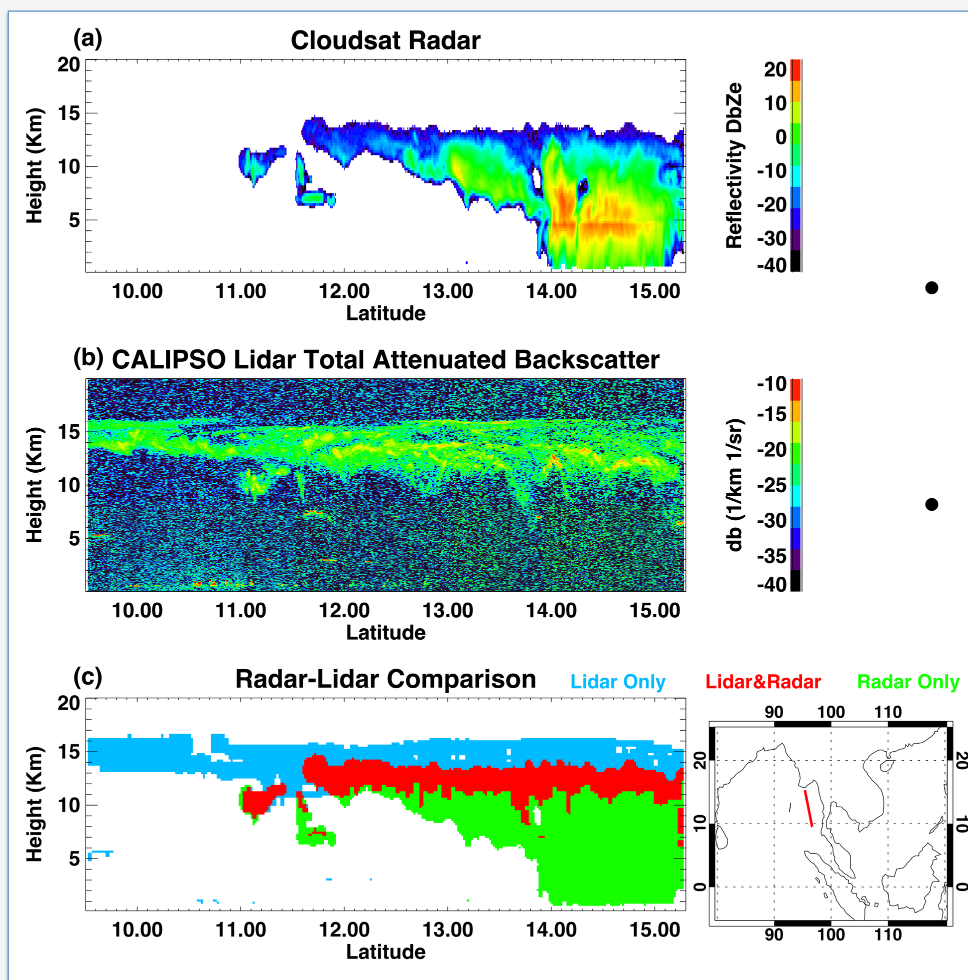

FIG. 1 A typical cloud scene in the analysis region

Data and Methods

- Focus on region of Southeast Asia during monsoon season (August + September 2007-2008)
- Geometric cloud layers identified by combined radar-lidar mask (Mace et al, 2009)
- Multiplatform algorithm suite (CloudSat, MODIS, AMSRE) to derive the liquid cloud microphysical properties (Mace, 2010)
- Ice microphysical properties from the CloudSat/CALIPSO 2C-ICE dataset (Deng et al., 2010)
- Radiative properties are calculated using existing parameterizations.
- Rapid Radiative Transfer Model (RRTM; Mlawer et al., 1997)
- Outputs: profiles of shortwave and longwave fluxes

A-Train Results

Use idea of cloud radiative kernels (Zelinka et al., 2012a) to examine the radiative impact of ice clouds at the *Top Of Atmosphere (TOA)*

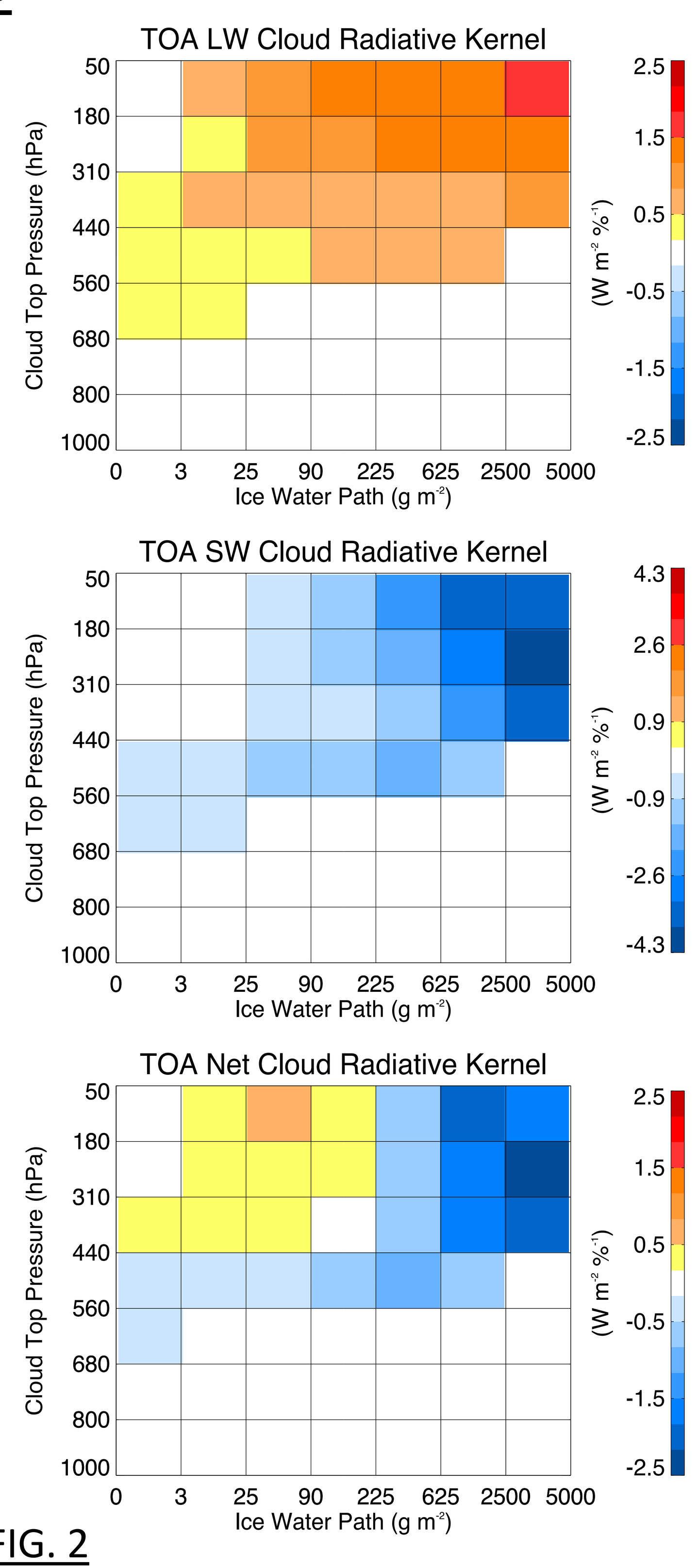

FIG. 2

FIG. 2 Sensitivity of TOA fluxes to perturbations in cloud fraction (K)

Clouds with the highest cloud top and moderate IWP (25-90 gm^{-2}) produce the strongest warming effect at TOA

For cirrus clouds with IWP > 225 g m^{-2}, solar effects begin to dominate over the IR effects and clouds produce net cooling

Cloud Type	Top Height	Thickness	Occurrence	Mean IWP
T.T.L. Cirrus	> 14Km	< 3 Km	11%	6 gm^{-2}
Thin Cirrus	10-14Km	< 3Km	13%	13 gm^{-2}
Thick Cirrus	> 10Km	3-6 Km	23%	64 gm^{-2}
Deep Layers	> 10Km	> 6Km	34%	744 gm^{-2}

Table 1. Characteristics of the most common cloud layers

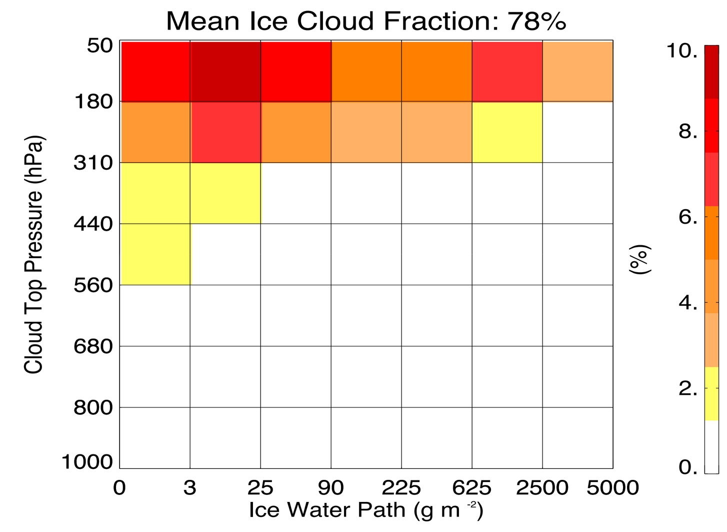

FIG. 3 *Cloud fraction (C)* as a function of CTP and IWP

Cloud fraction decreases with increasing IWP bins

Mean IWP = 440 g m^{-2} **Median IWP = 24 g m^{-2}**

- 87% of profiles are not precipitating/convective
  - median IWP = 16 g m^{-2}
  - "cloud mode" represents 34% of total ice mass
- 13% of profiles are precipitating/convective
  - median IWP = 1394 g m^{-2}
  - "precip mode" represents 66% of total ice mass

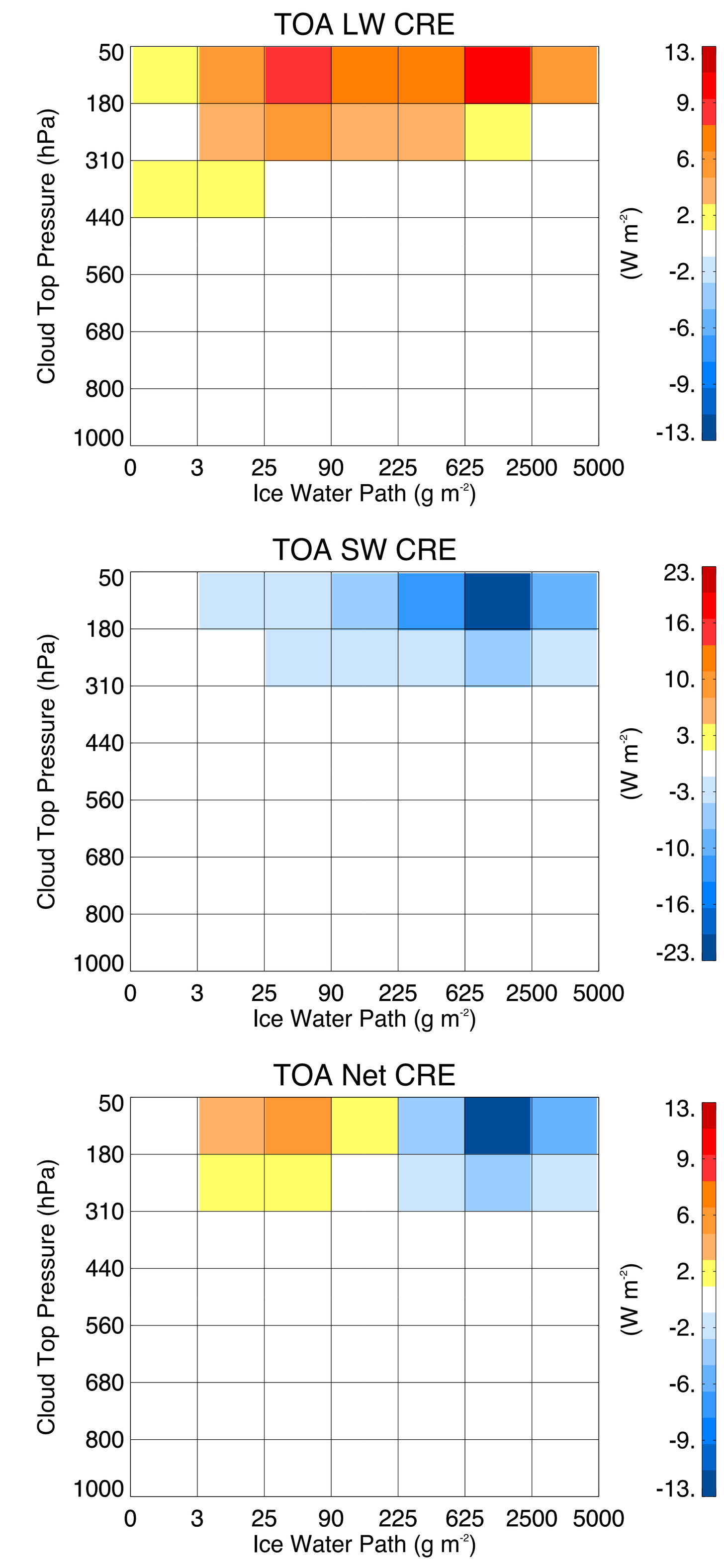

FIG. 4

FIG. 4 Contribution of each cloud type to TOA radiation (R), where R = K*C

TOA Net *Cloud Radiative Effect (CRE)* from cirrus = 17 W m^{-2}

Cirrus with IWP between 3 - 90 g m^{-2} contribute most to heating given their frequency

Sum of TOA net CRE (-11 W m^{-2}) indicates a near balance between commonly occurring cirrus that warm the atmosphere and less frequent deep layers that produce strong cooling at the surface.

Due to skewed IWP distribution, the median IWP is a better diagnostic of the radiative impact for cirrus clouds than the mean IWP

Preliminary Model Analysis

Examine ice clouds in *Community Atmosphere Model Version 5 (CAM5)*

- Output from 2005-2008 global run with 30 vertical levels and a 96x144 horizontal grid (~ 1.9° latitude x 2.5° longitude)
- 2-moment bulk stratiform cloud microphysics scheme (Morrison et al. 2005) with four hydrometeor species
- Process-based treatment of ice supersaturation and ice nucleation (Gettelman et al., 2010)

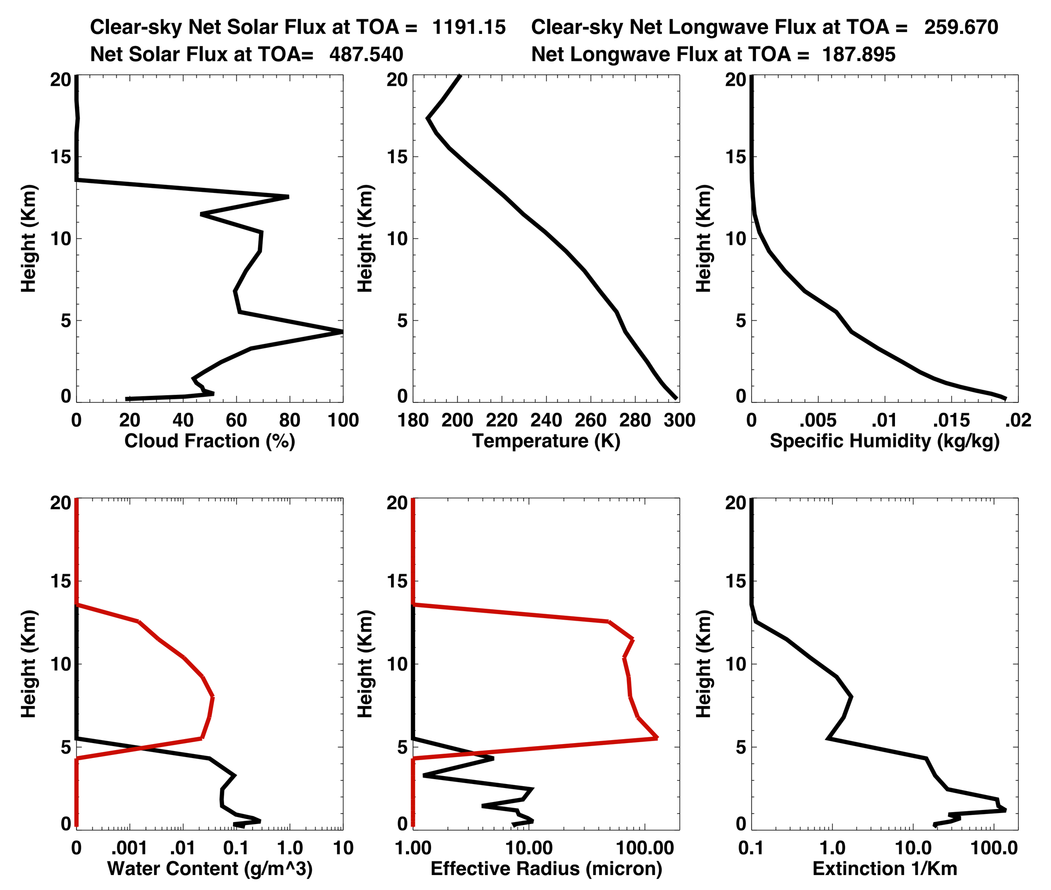

FIG. 5 Thermodynamic and cloud microphysical variables from a CAM5 grid box [latitude: 12.32°, longitude: 102.5°] in our study domain at 12Z on August 1, 2007.

- Grid box quantities won't produce the same variability found in statistics from satellite data (grid box >> CloudSat footprint)
- Using a maximum-random cloud overlap assumption (Jakob and Klein 1999) we divide the grid box data into 100 sub columns

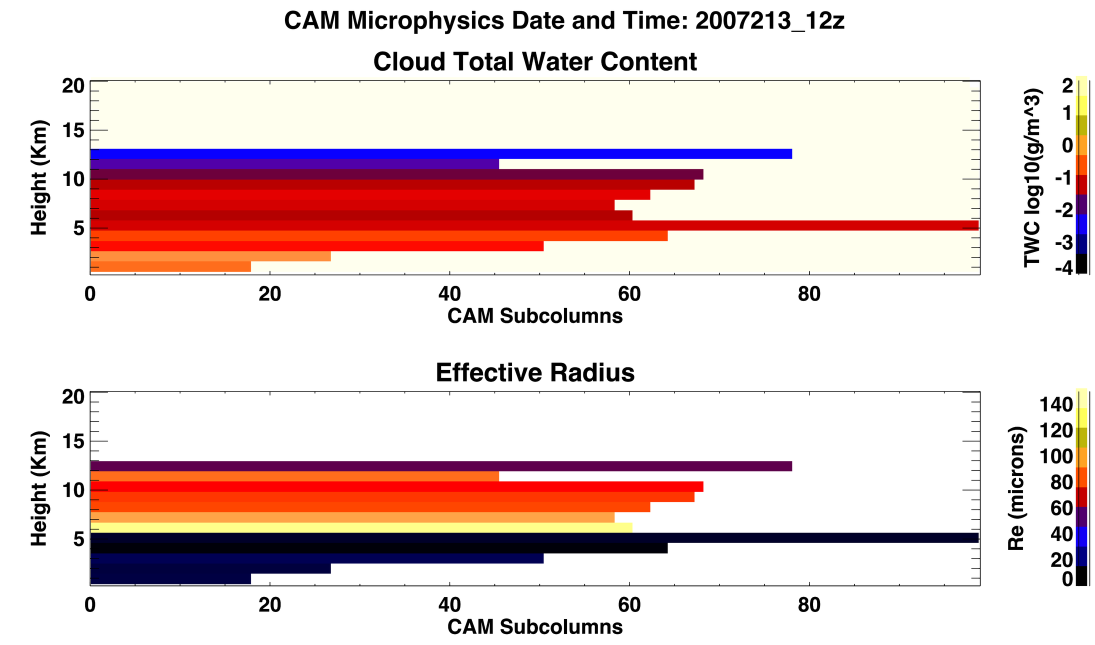

FIG. 6 Generated sub columns of cloud microphysical properties for the grid box data shown in Fig. 7.

Future Work

- Calculate the radiative properties and run the radiative transfer for the model sub-columns in Southeast Asia
- Perform cloud radiative kernel analysis with CAM5
- How do modeled ice clouds differ from observed clouds?
- **Do climate models show a similar distribution of cloud ice and radiative effect**?
- Use output from CAM5, run in weather forecast mode (Xie et al., 2012), to see how quickly ice cloud biases develop

Berry, E., and G. G. and Mace (2014), Cloud properties and radiative effects of the Asian summer monsoon derived from A-Train data. *J. Geophys. Res. Atmos., 119*, 9492-9508.