ATMOSPHERIC SCIENCES
THE UNIVERSITY OF UTAH

Relationships Between Ice Cloud Properties and Radiative Effects from A-Train Observations and Global Climate Models

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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

Cloud Identification

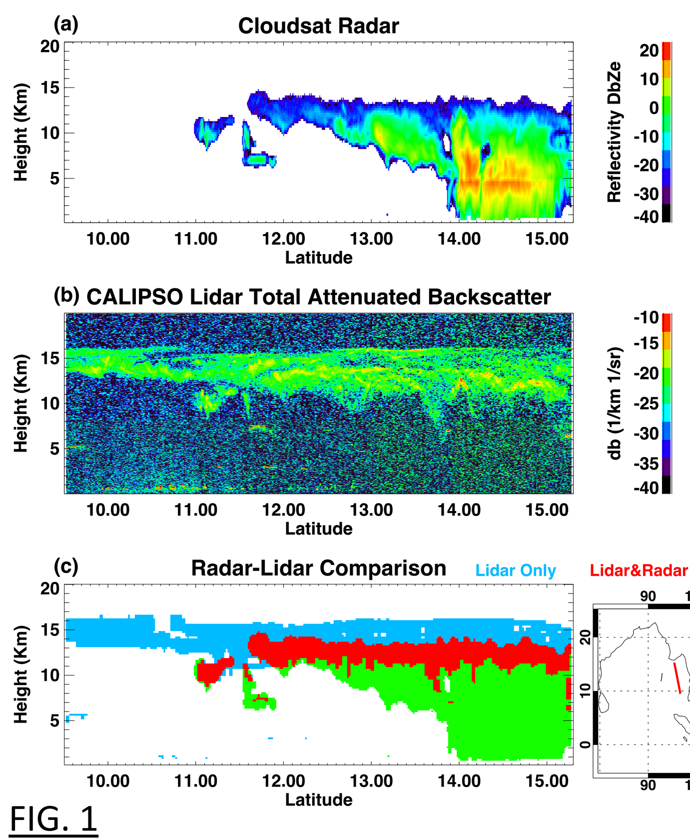

FIG. 1

- 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)

FIG. 1 A typical cloud scene in the Southeast Asia analysis region. (a) CloudSat radar reflectivity, (b) CALIPSO lidar backscatter and (c) combined radar-lidar cloud mask. The red line on the map shows the location of this cloud scene.

Data and Methods

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)

FIG. 2 Microphysical retrieval for a thick cirrus cloud (a) CloudSat radar reflectivity [DbZ = -32 indicates cloud observed by lidar only] (b) retrieved total water content, and (c) retrieved effective radius

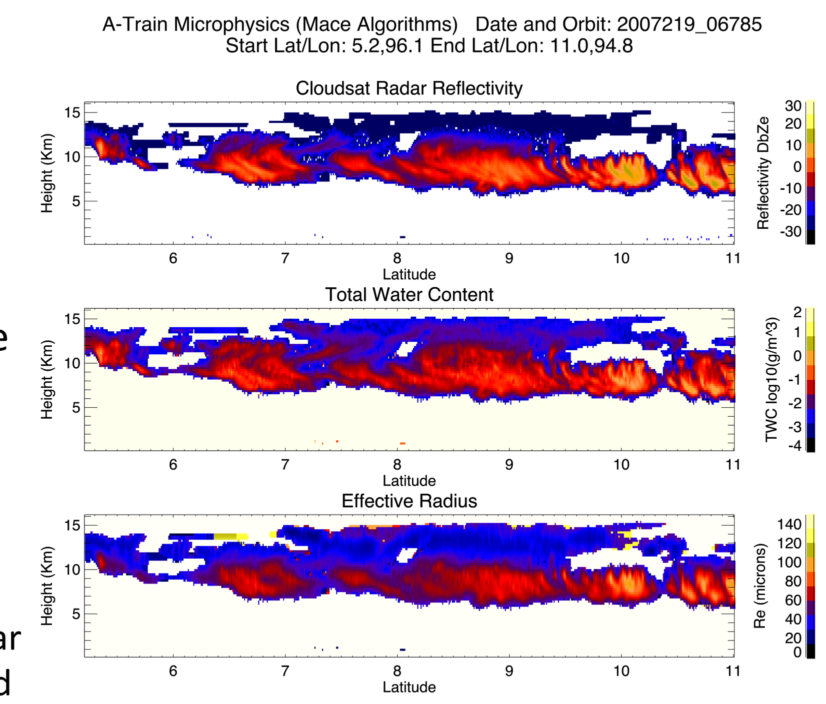

FIG. 2

Radiative properties are calculated using existing parameterizations.

Rapid Radiative Transfer Model (RRTM; Mlawer et al., 1997)

Outputs: profiles of shortwave and longwave fluxes

FIG. 3 The retrieved radiative fluxes and microphysics for the thick cirrus case shown in FIG 2. (a) Reflected solar at TOA, (b) outgoing longwave at TOA, (c) total water path, (d) optical depth. Our retrieved values (in black) are compared to other retrievals (in red).

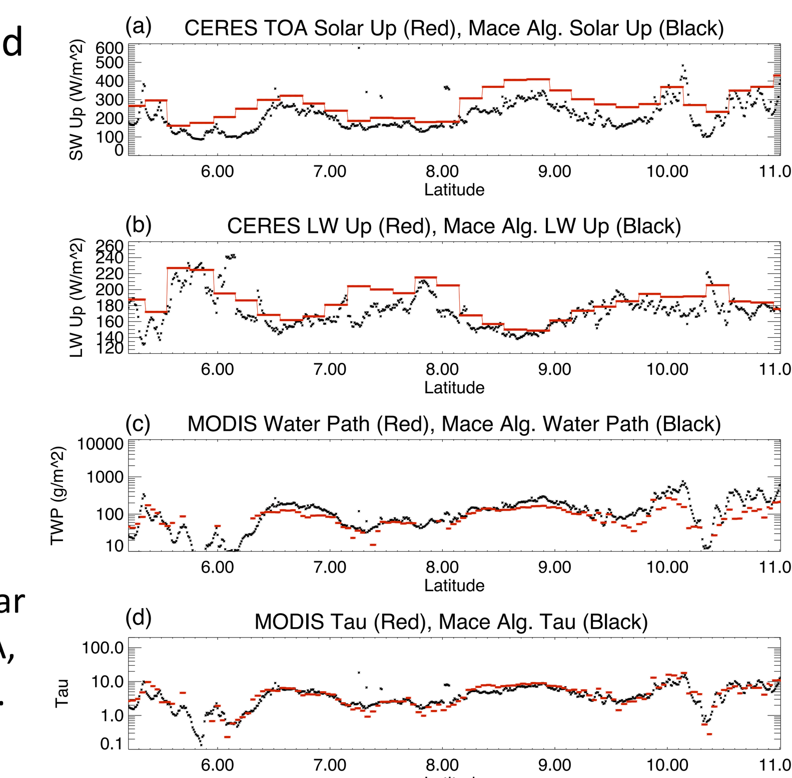

FIG. 3

Results: A-Train observations of ice clouds in Southeast Asia

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

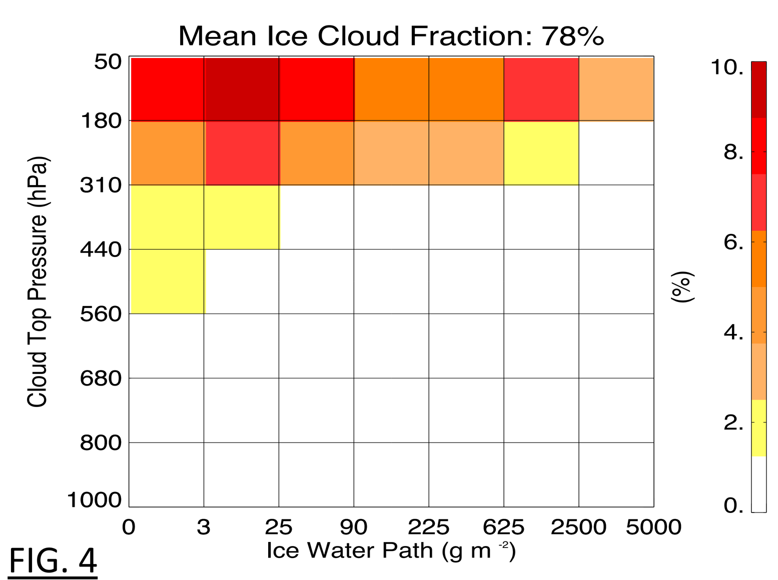

FIG. 4

FIG. 4 *Cloud fraction (C)* as functions of CTP and IWP

- **Mean IWP = 440 g m^{-2} Median IWP = 24 g m^{-2}**
- Cloud fraction decreases with increasing IWP bins
- 87% of hydrometeor 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

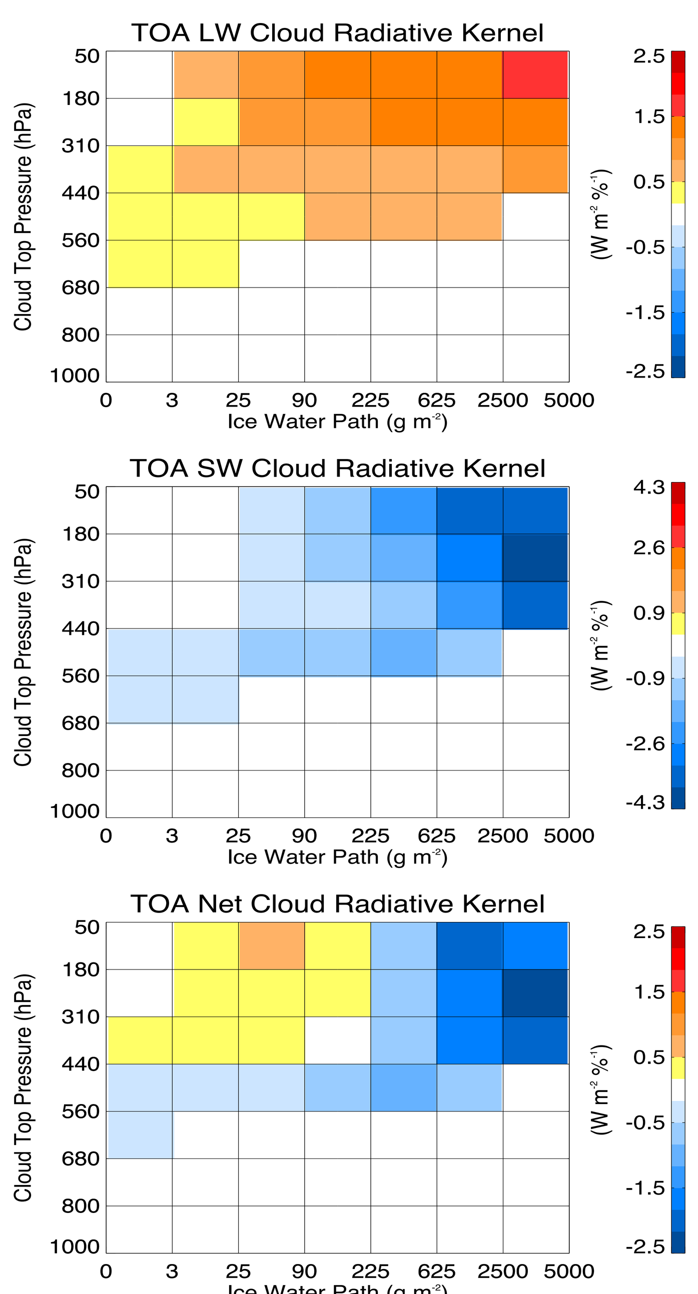

FIG. 5

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

FIG. 5 *Cloud Radiative Kernel (K)*: gives the sensitivity of TOA fluxes to perturbations in cloud fraction as functions of CTP and IWP

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

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

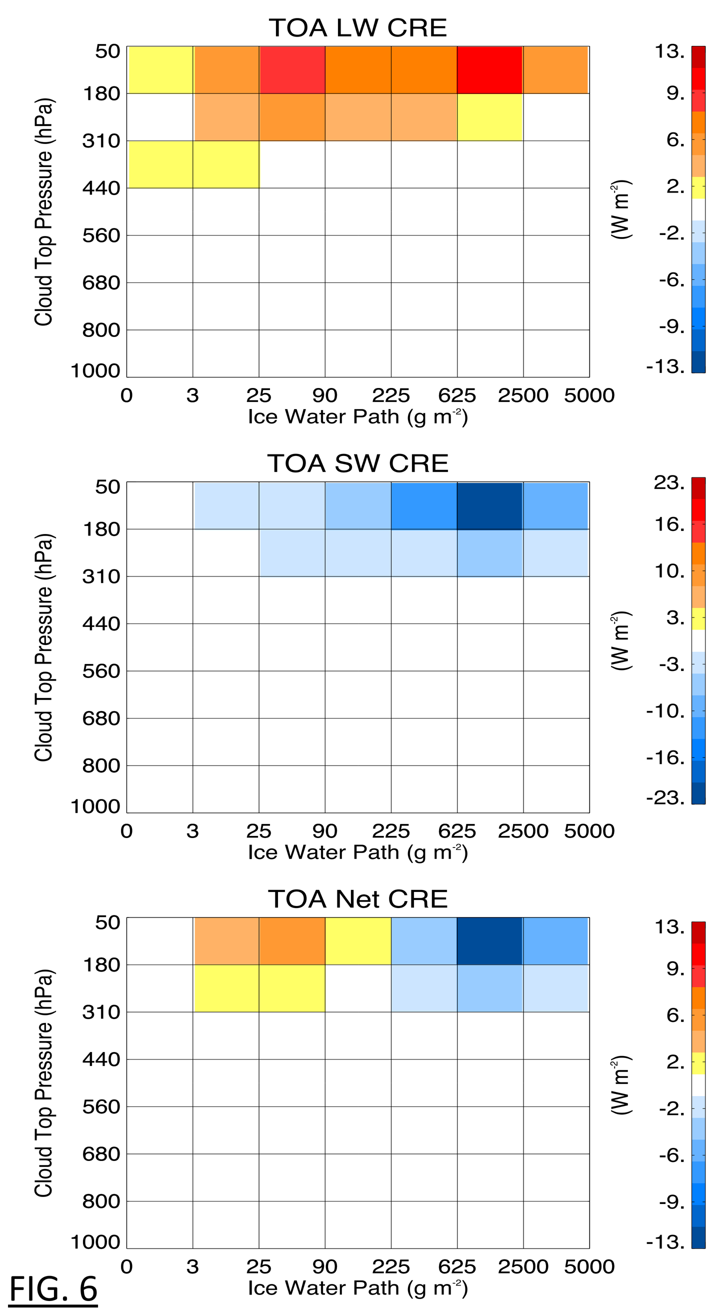

FIG. 6

FIG. 6 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 5 - 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

Do models show a similar distribution of cloud ice and radiative effect?

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)

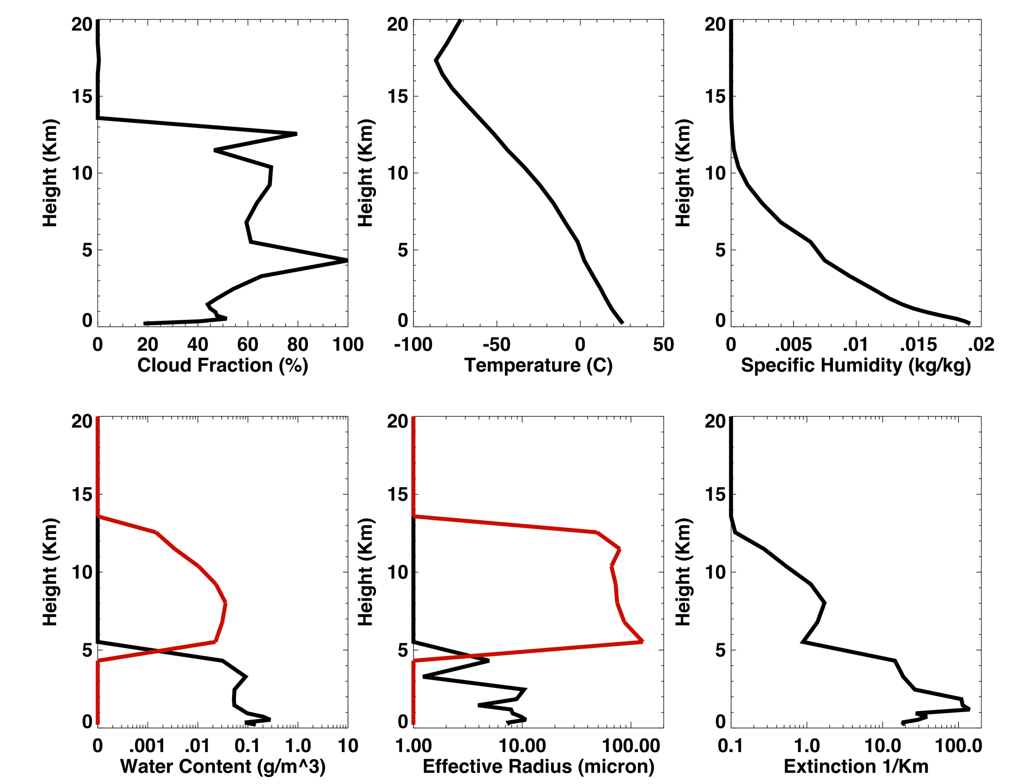

FIG. 7 Thermodynamic and cloud microphysical variables from a CAM5 grid box [latitude: 12.32°, longitude: 102.5°] in our study domain at 12Z on August 1, 2007.

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.

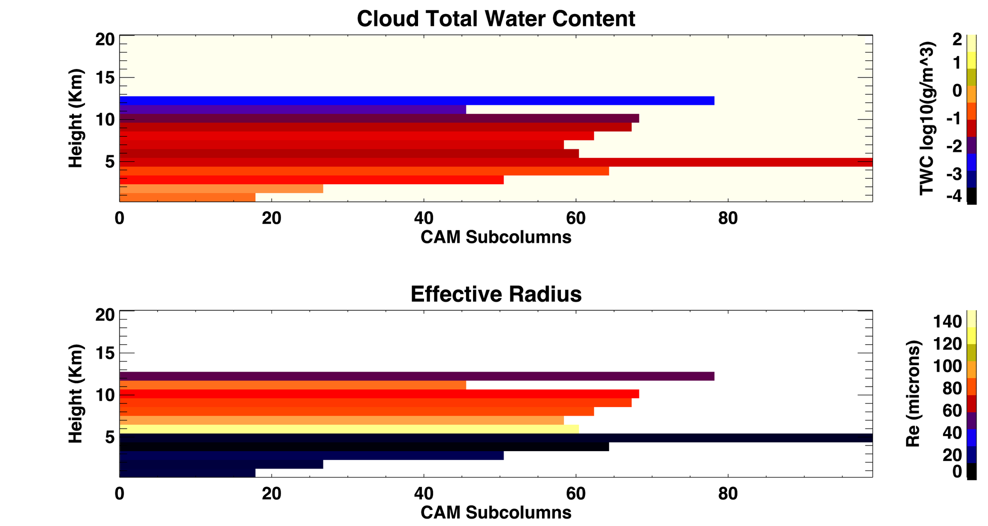

FIG. 8 Generated sub columns of cloud microphysical properties for the grid box data shown in Fig. 7.

Future Work

- Calculate the radiative properties and run the radiative transfer model for the model sub columns in Southeast Asia
- Perform cloud radiative kernel analysis with CAM5
- How do modeled ice clouds differ from observed clouds?
- 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. Mace (2014), Cloud properties and radiative effects of the Asian summer monsoon derived from A-Train data. *J. Geophys. Res. Atmos., 119*, 9492-9508.