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

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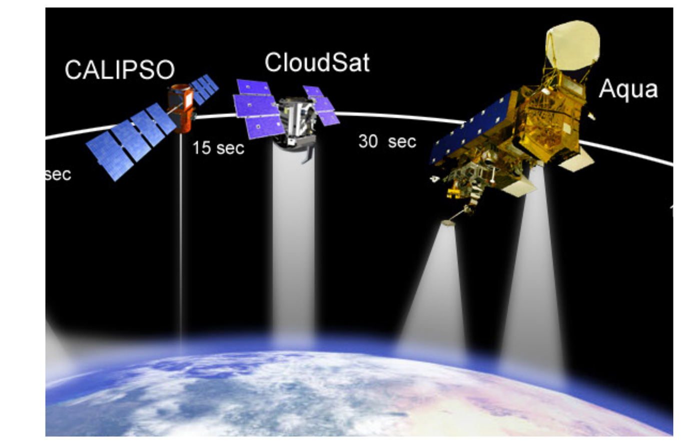
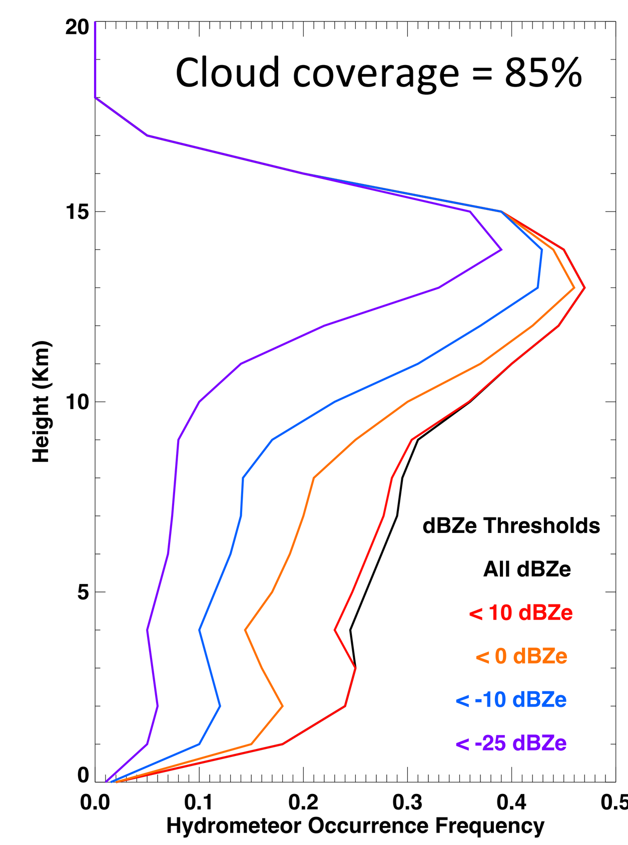


Motivation

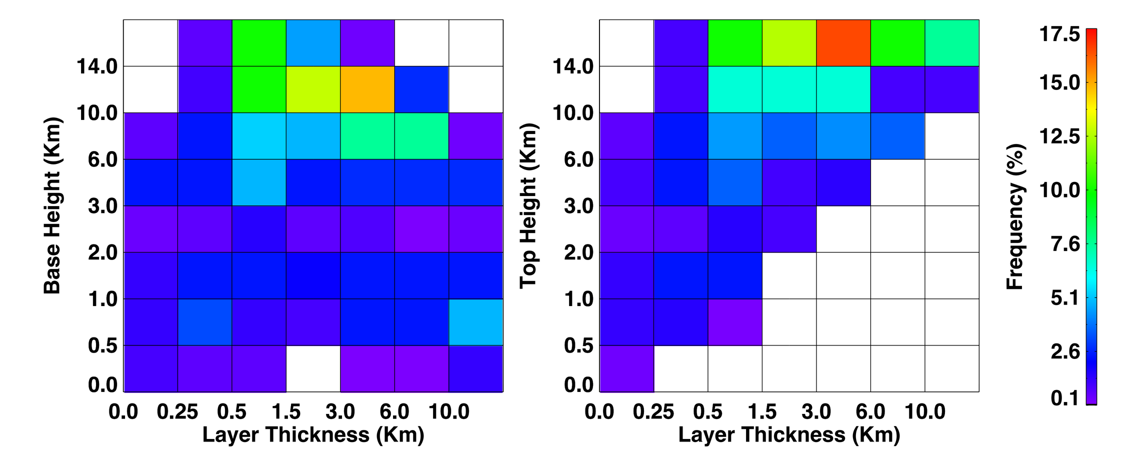
- Large differences exist between modeled cloud ice and observations (Li et al., 2012)
- Yet models show consensus for a positive high cloud feedback (Vecchi and Soden, 2011)
- Examine cloud radiative effects as a function of ice water path
- Which type of cirrus contribute most to heating the upper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

Cloud Characteristics

- Focus on Southeast Asia during monsoon season (Aug. & Sep. 2007-2008)
- High clouds dominate vertical distribution
- DbZ thresholds reveal more small ice at higher heights
- Large fraction of midlevel clouds are precipitating
- CloudSat misses clouds below ~ 1km due to multiple scattering effects

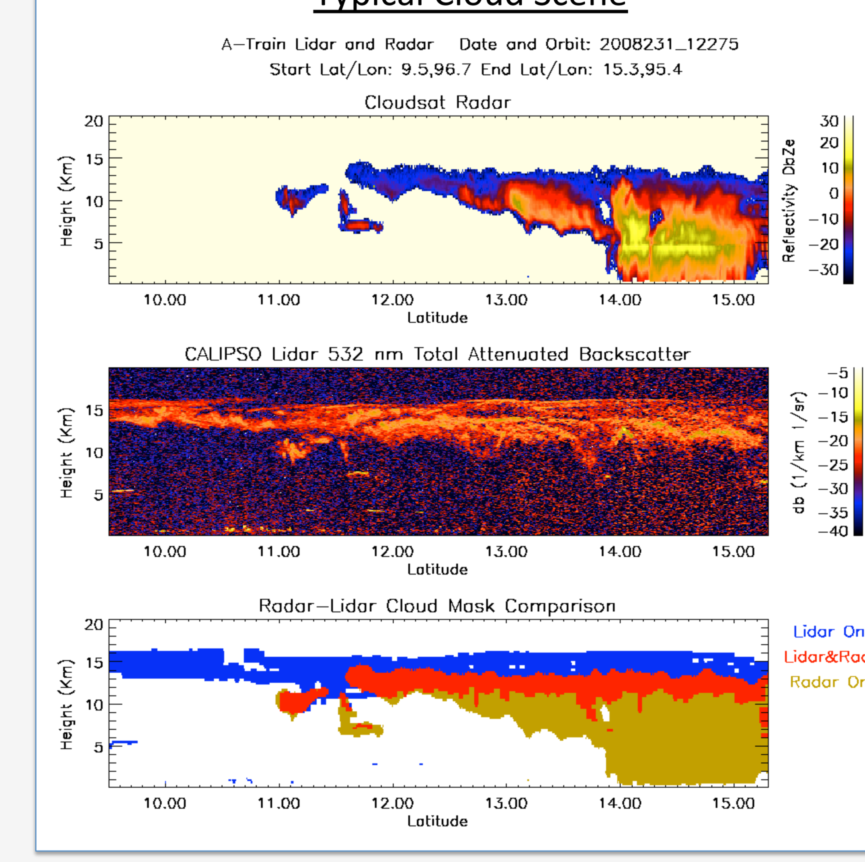


Geometric cloud layers



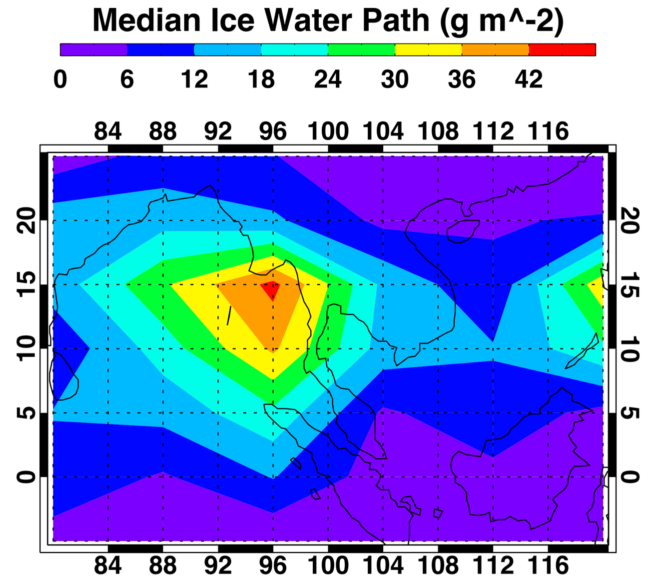
Cloud type	Top Ht.	Thickness	Occurrence
TTL cirrus	>14km	<3km	11%
Thin cirrus	>10km	<3km	13%
Thick cirrus	>10km	3-6km	23%
Deep layers	>10km	>6km	34%

Typical Cloud Scene



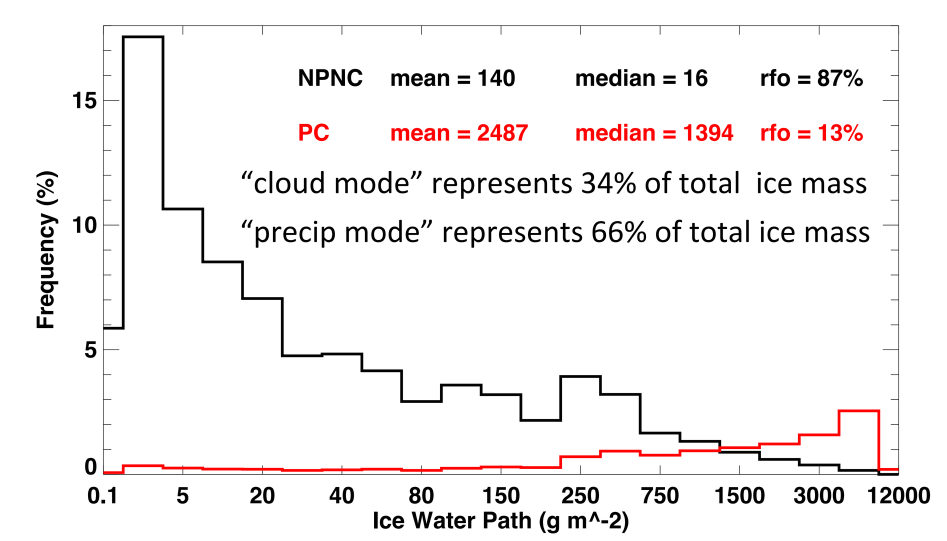
Ice Water Path (IWP) Statistics

- Ice microphysical properties from the CloudSat/ CALIPSO 2C-ICE dataset (Deng et al., 2010)
- Precipitating/Convective profiles identified with 2B-CLDCLASS-LIDAR dataset (Waliser et al., 2009)
- Mean IWP= 440 g m^{-2}, Median IWP= 24 g m^{-2}
- Due to skewed distribution, mean IWP is a poor diagnostic of radiative impact for cirrus clouds

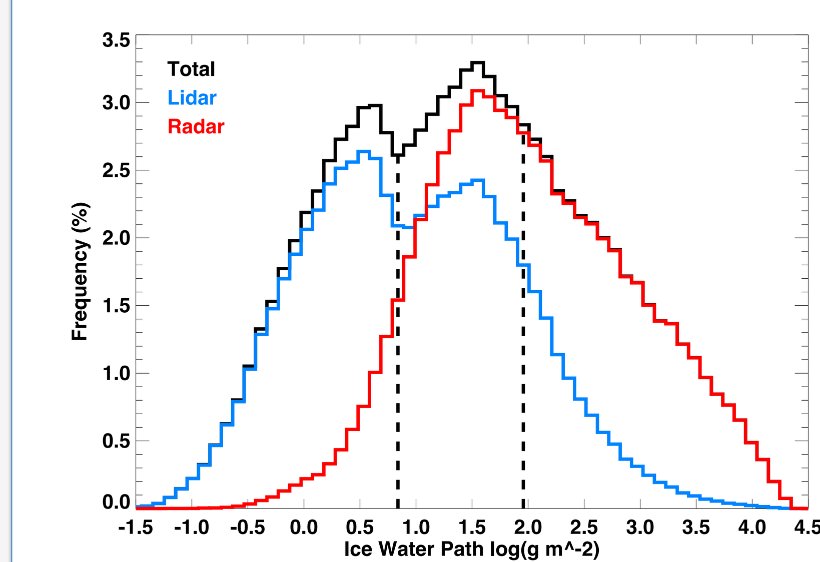


Geographical distribution

Distribution of IWP for nonprecipitating and nonconvective profiles (black) and precipitation or convective profiles (red)



How much ice is observed by CloudSat radar vs. CALIPSO lidar?



- Radar and lidar are important for describing the entire PDF of IWP
- Greatest synergy near IWP 5-10 g m^{-2}
- Lidar observes small IWP with small CRE, but their frequency makes them significant
- Lower tercile: 33% IWP < 6 gm^{-2}
- Upper tercile: 33% IWP > 80 gm^{-2}

Cloud Radiative Effect (CRE)

$$CRE = (F\downarrow - F\uparrow)_{All} - (F\downarrow - F\uparrow)_{Clear}$$

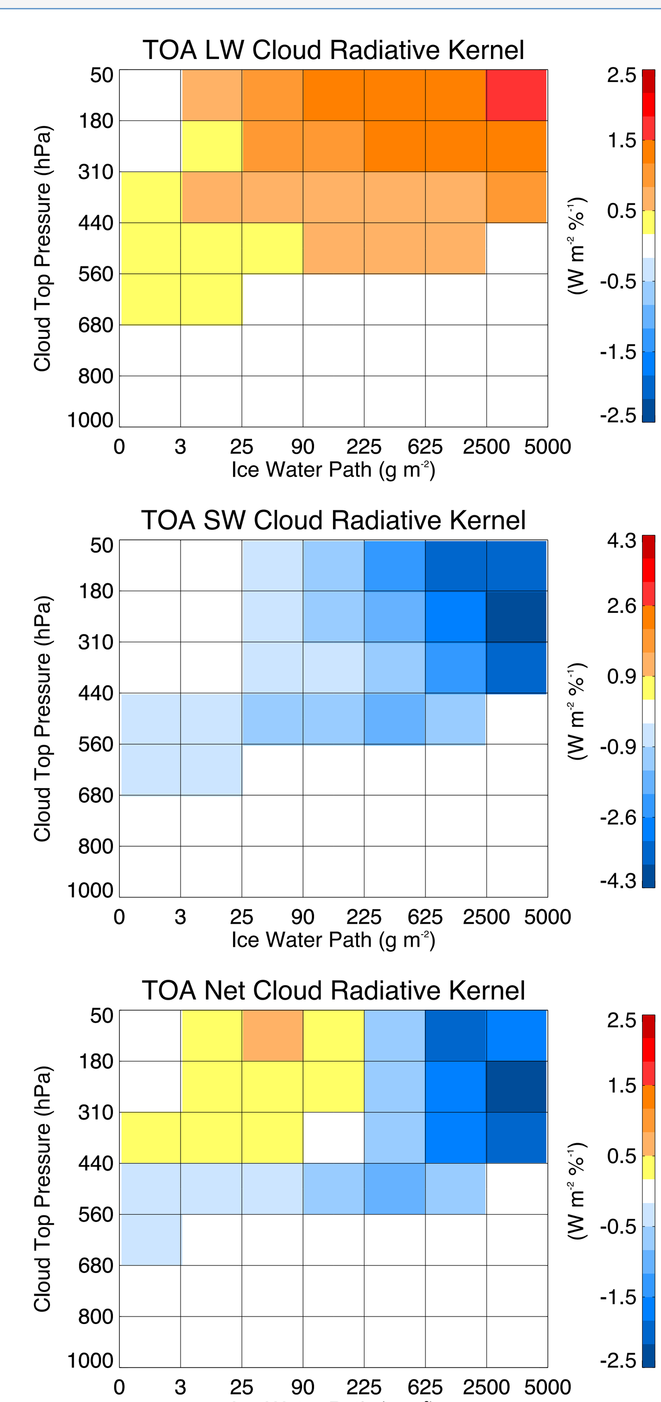
Methodology

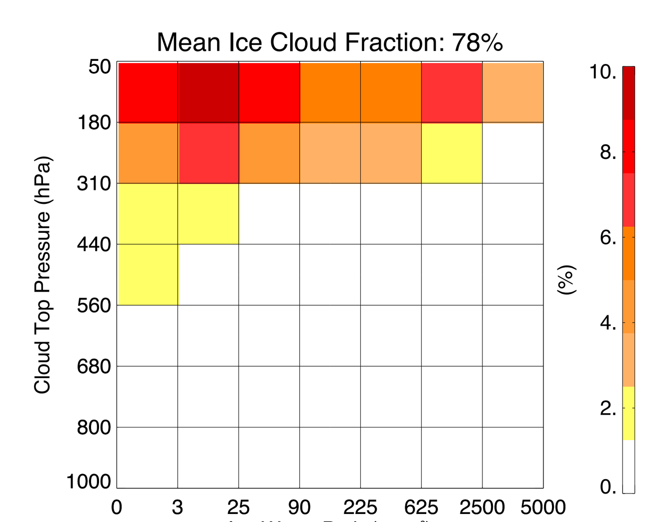
- Multiplatform algorithm suite (CloudSat, CALIPSO, MODIS optical depth) to derive the cloud microphysical and radiative properties (Mace, 2010)
- A two-steam radiative transfer model is used to obtain the radiative fluxes (Toon et al., 1989)
- Use cloud radiative kernels (Zelinka et al., 2012a) to investigate radiative impact of ice clouds: R = K*C.

R is contribution of each cloud type to top of atmosphere (TOA) radiation

Cloud radiative kernel (K): gives the sensitivity of TOA fluxes to perturbations in cloud fraction as a function of cloud top pressure (CTP) and IWP

C is the cloud fraction histogram



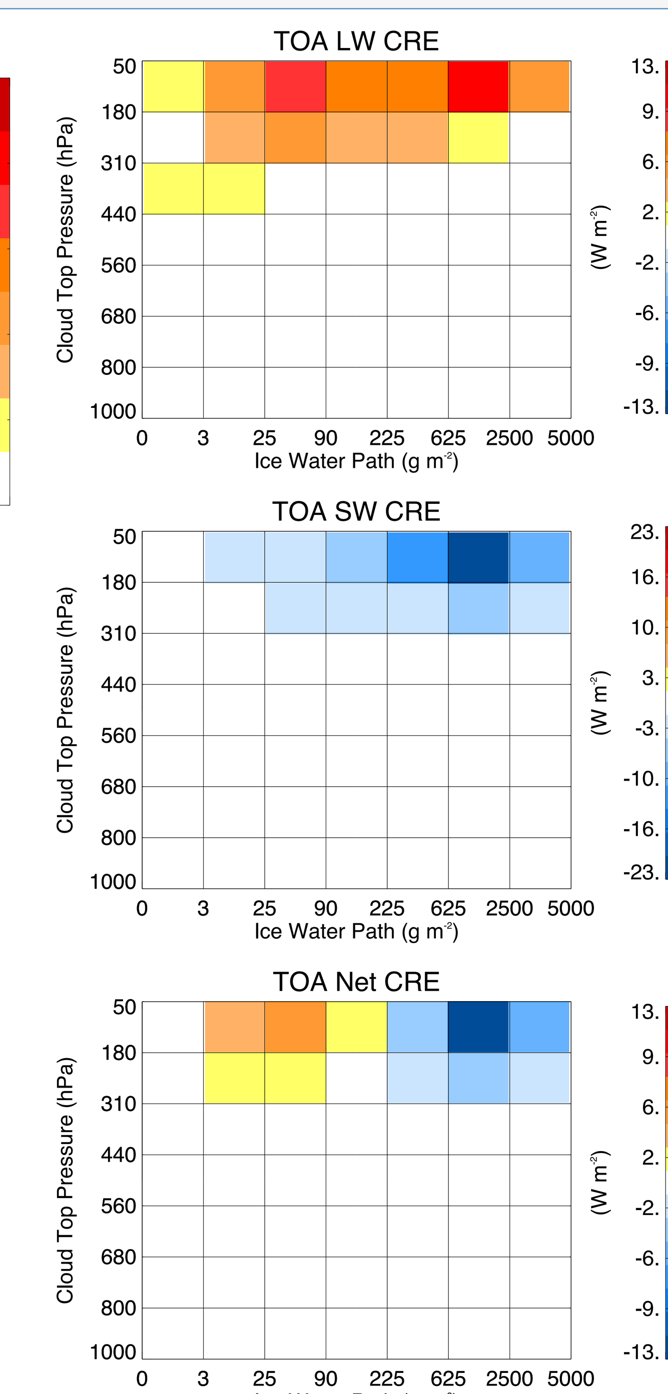


Above: Cloud Fraction (C) generally decreases with increasing IWP bins

Left: Radiative Kernel (K)

Clouds with the smallest cloud top pressure and a moderate IWP produce the strongest warming effect at the TOA

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



Left: TOA Radiation (R)

Due to frequency of occurrence, ice clouds with CTP < 180 hPa contribute most to the TOA radiation

Net CRE for cirrus = 17 W m^{-2}

Cirrus with IWP between 25-90 g m^{-2} contribute most to heating given their frequency

Sum of net CRE (-11W 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.

Future Work

- Do climate models show a similar distribution of cloud ice and radiative effect?
- Perform cloud radiative kernel analysis with Community Atmosphere Model version 5 (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.* (submitted)