Identify Opaque and Non-opaque Tropical Upper-Tropospheric Ice Clouds from the MODIS Measurements at 8.5, 11, and 12 μm

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Opaque/Non-opaque Ice Clouds

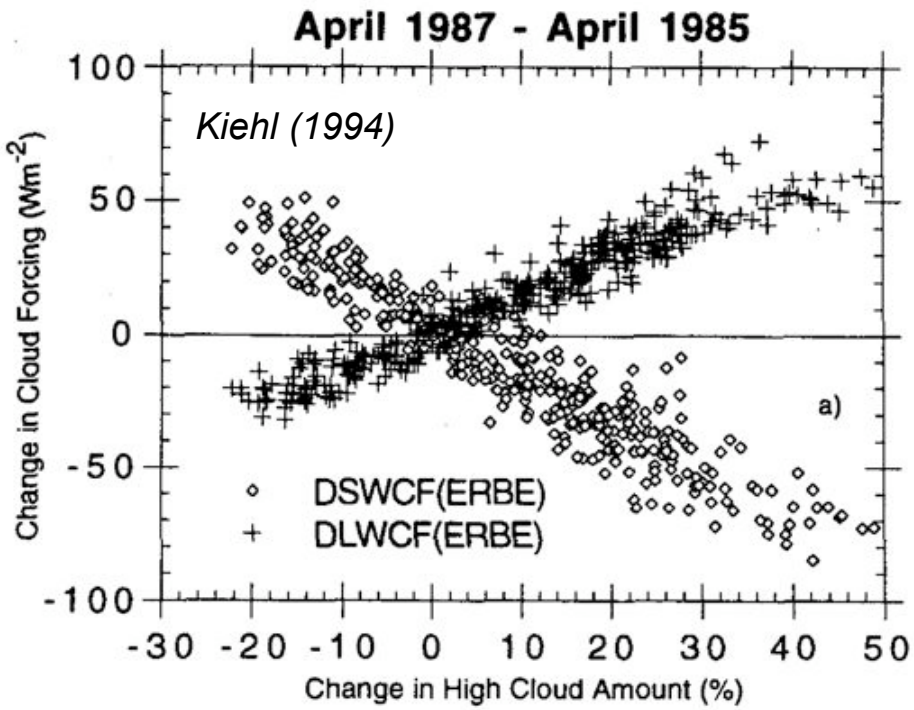
Pavolonis et al. (2005):

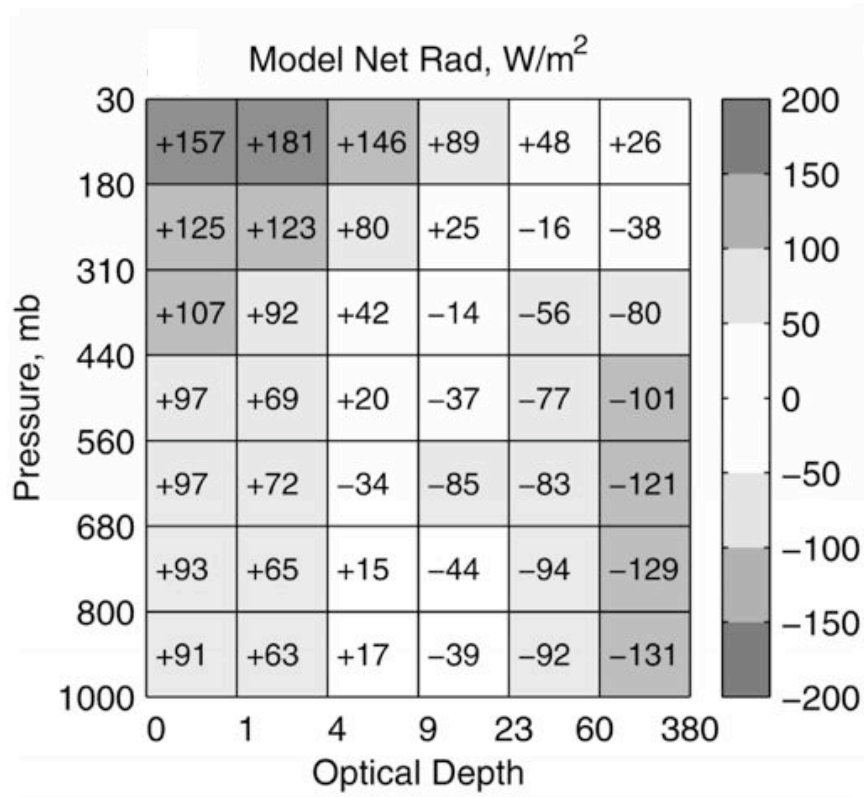
Non-opaque ice cloud: Transmissive ice clouds (visible optical thickness $\tau_{vis} < 5$)
Opaque ice cloud: Nontransmissive ice clouds ($\tau_{vis} > 5$)

Wylie and Menzel (1999); Stubenrauch et al. (2006); Menzel et al. (2008):

Non-opaque ice cloud: Effective emissitiy $N\varepsilon < 0.95$, corresponding to $\tau_{vis} < 6$
Opaque ice cloud: $N\varepsilon > 0.95$, corresponding to $\tau_{vis} > 6$

Ice Cloud Radiative Forcing

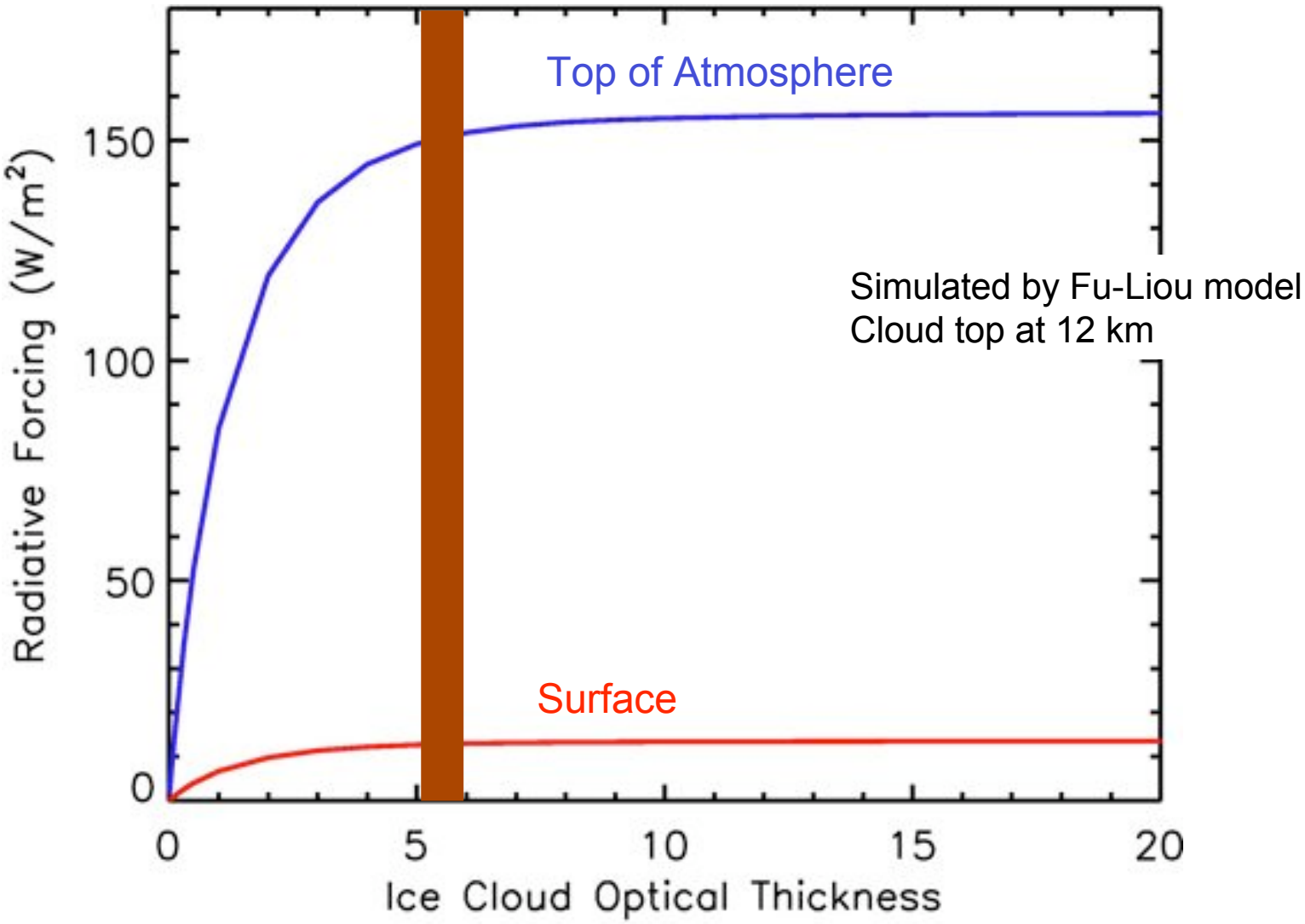




Near cancellation over thick ice clouds: Longwave and Shortwave Radiationve Forcing

Cancellation is a property of the ensemble of clouds associated with thick ice clouds (Hartmann et al. 2001)

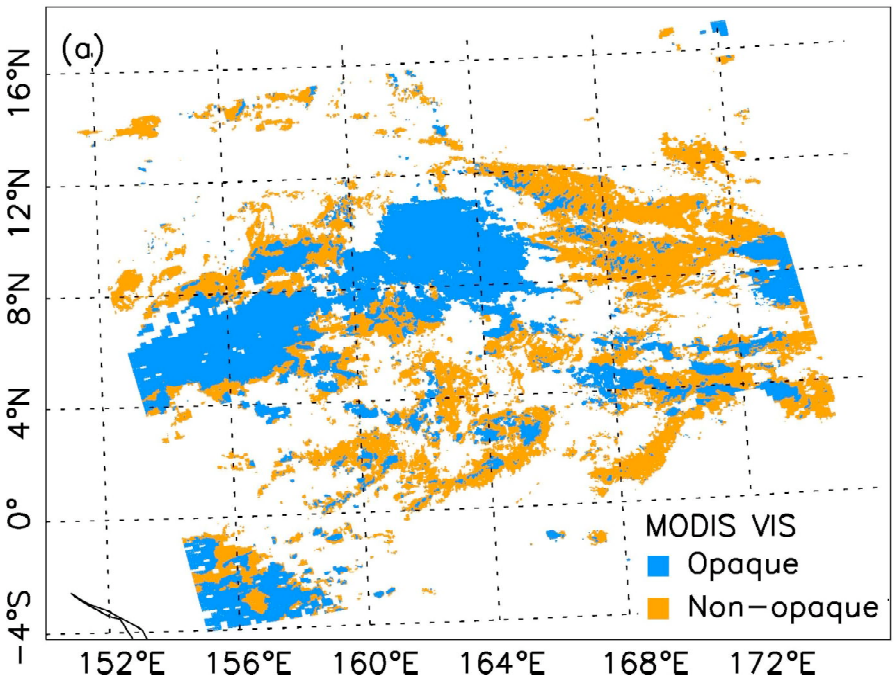
Infrared Radiative Forcing of Ice Clouds



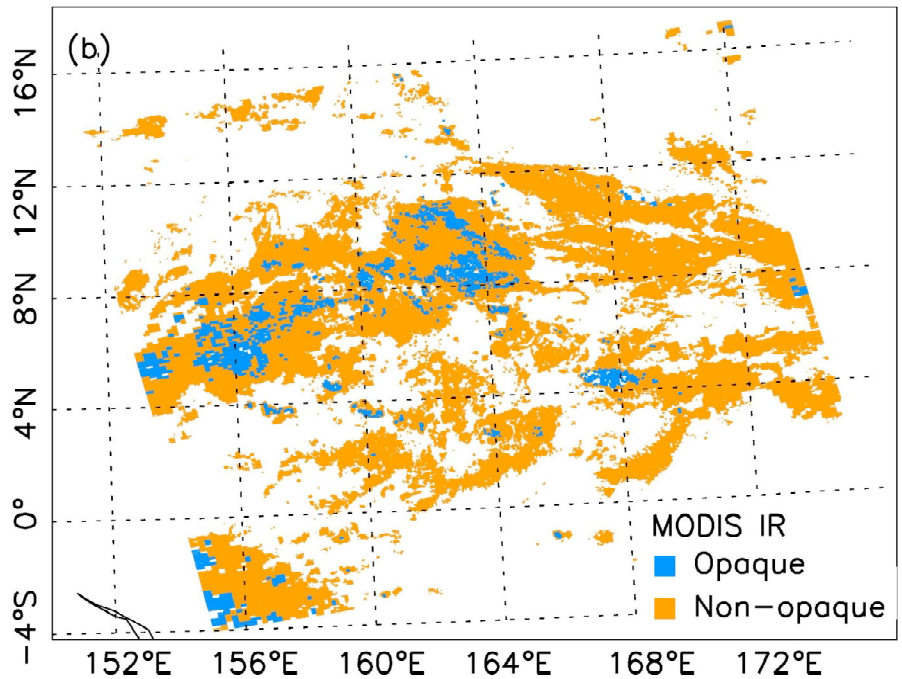
Identifying Opaque/Non-opaque Ice Clouds

Passive visible measurements: τ_{vis}, only available at daytime

Passive infrared measurements: on the basis of effective emissivity, both daytime and nighttime



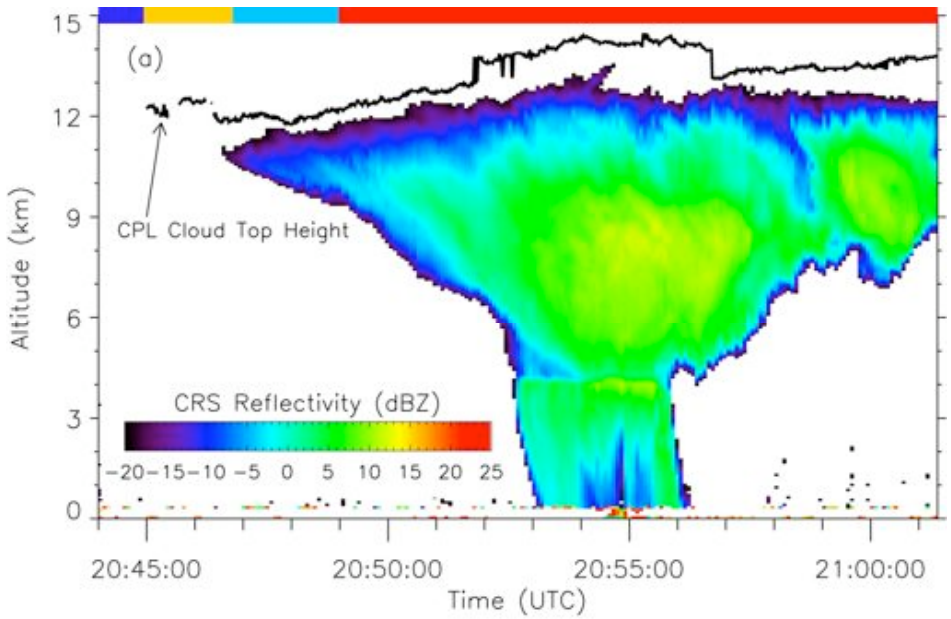
Opaque τ_{vis}> 6, Non-opaque τ_{vis}< 6



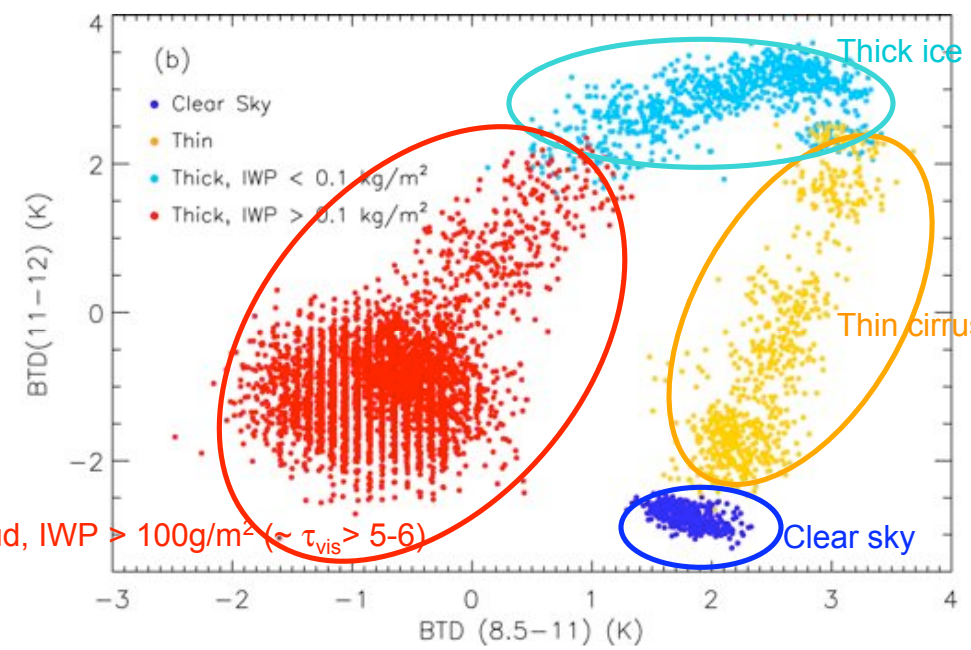
Opaque $N\varepsilon$ > 0.95, Non-opaque $N\varepsilon$ < 0.95

Objective: Developing a IR method (8.5, 11, and 12 μm) to identify opaque/non-opaque ice clouds that are consistent with results identified by MODIS visible retrieved $\tau_{vis.}$

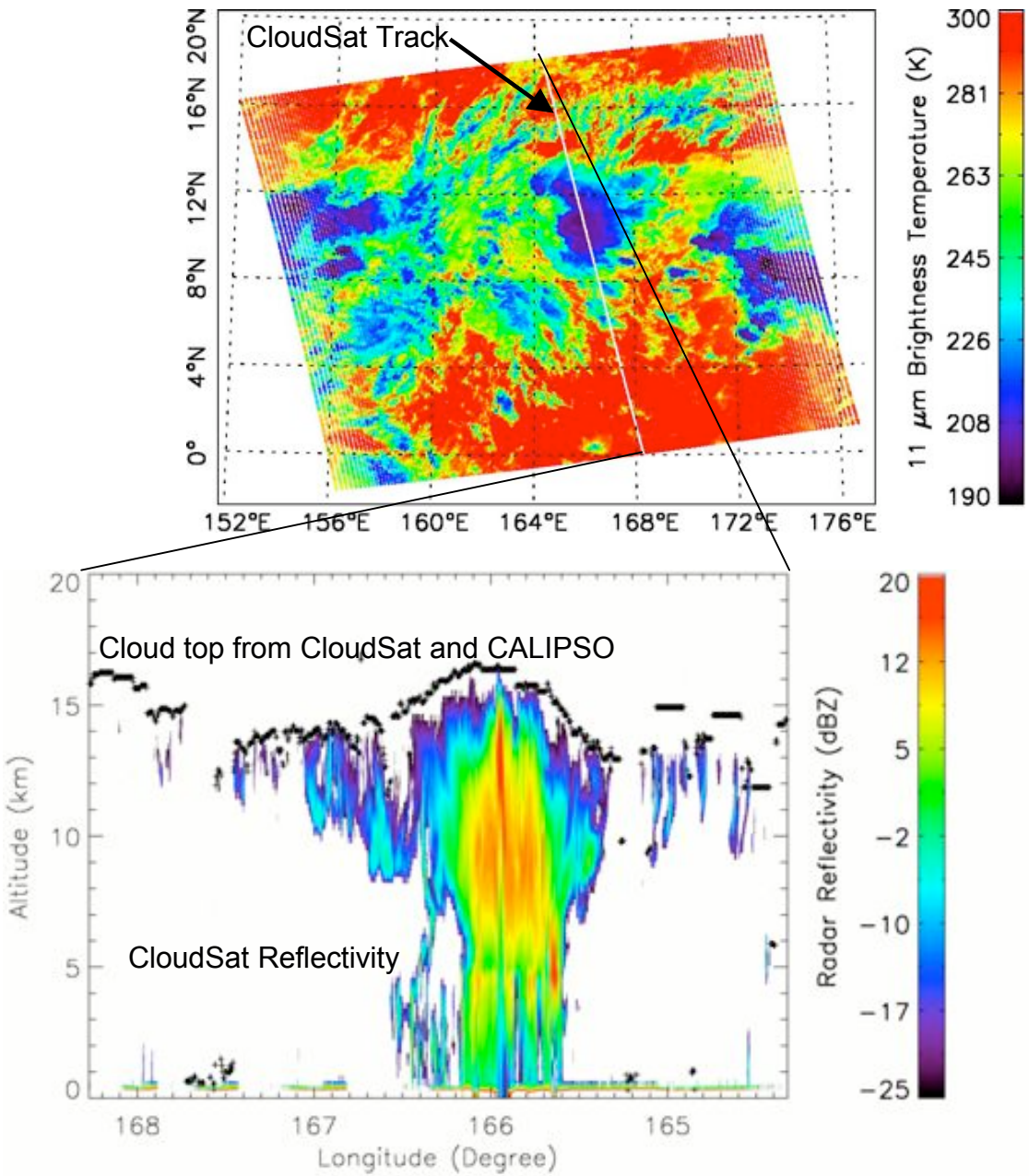
A Case from CRYSTAL-FACE



CPL: Cloud Physics Lidar
CRS: Cloud Radar System
MAS: MODIS Airborne Simulator



A-Train: Multiple Sensors and Platforms



MODIS cloud τ_{vis}
CALIPSO/CloudSat cloud top

↓

Opaque/non-opaque upper tropospheric ice clouds

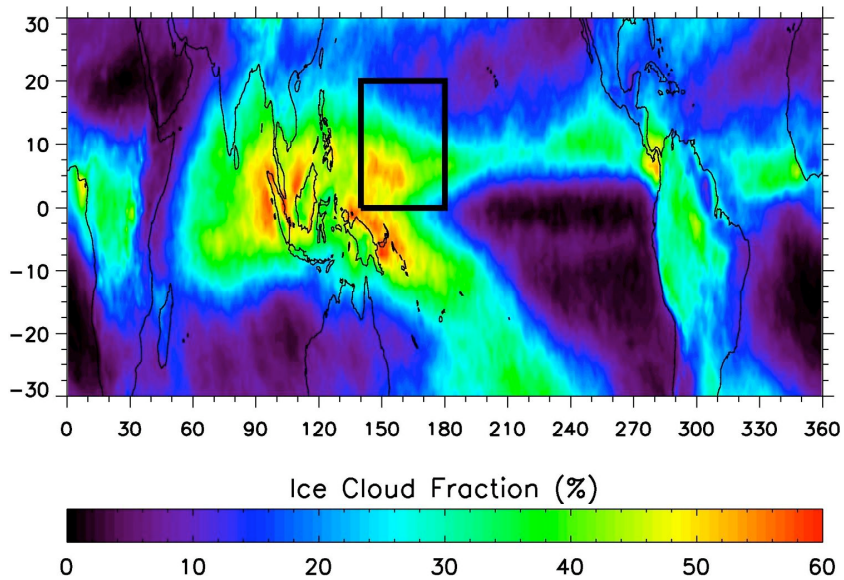
↕

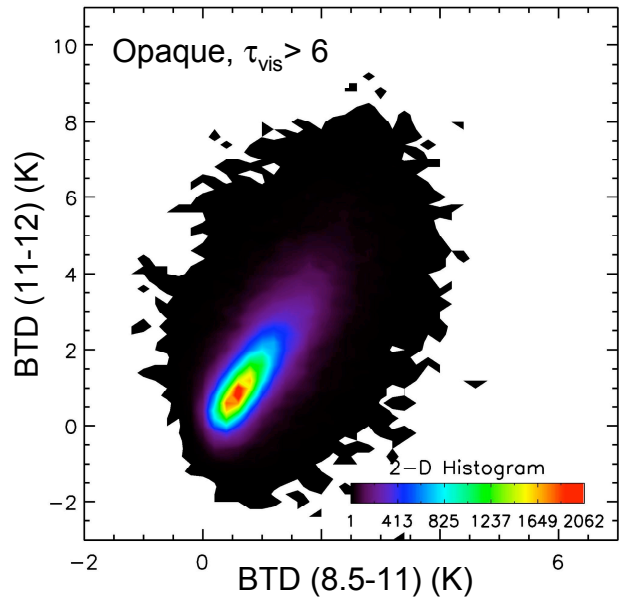
MODIS IR BTs at 8.5, 11, and 12 μm

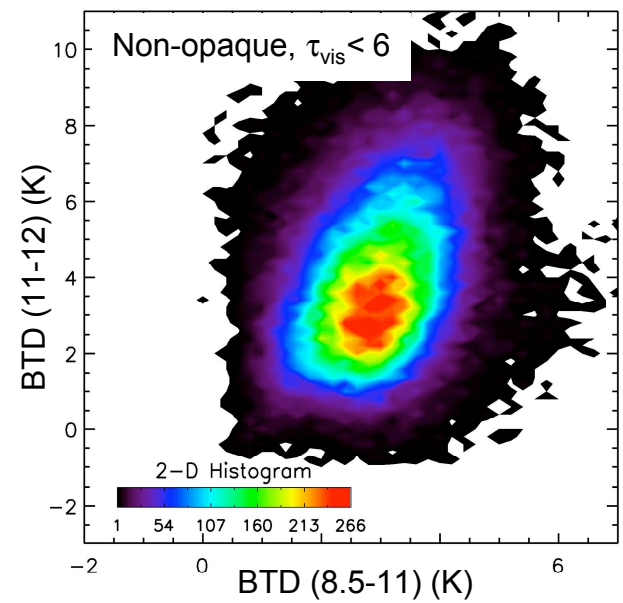
↑

MODIS retrieved cloud top

A Tri-spectral Method to Identify Opaque/Non-opaque Ice Clouds

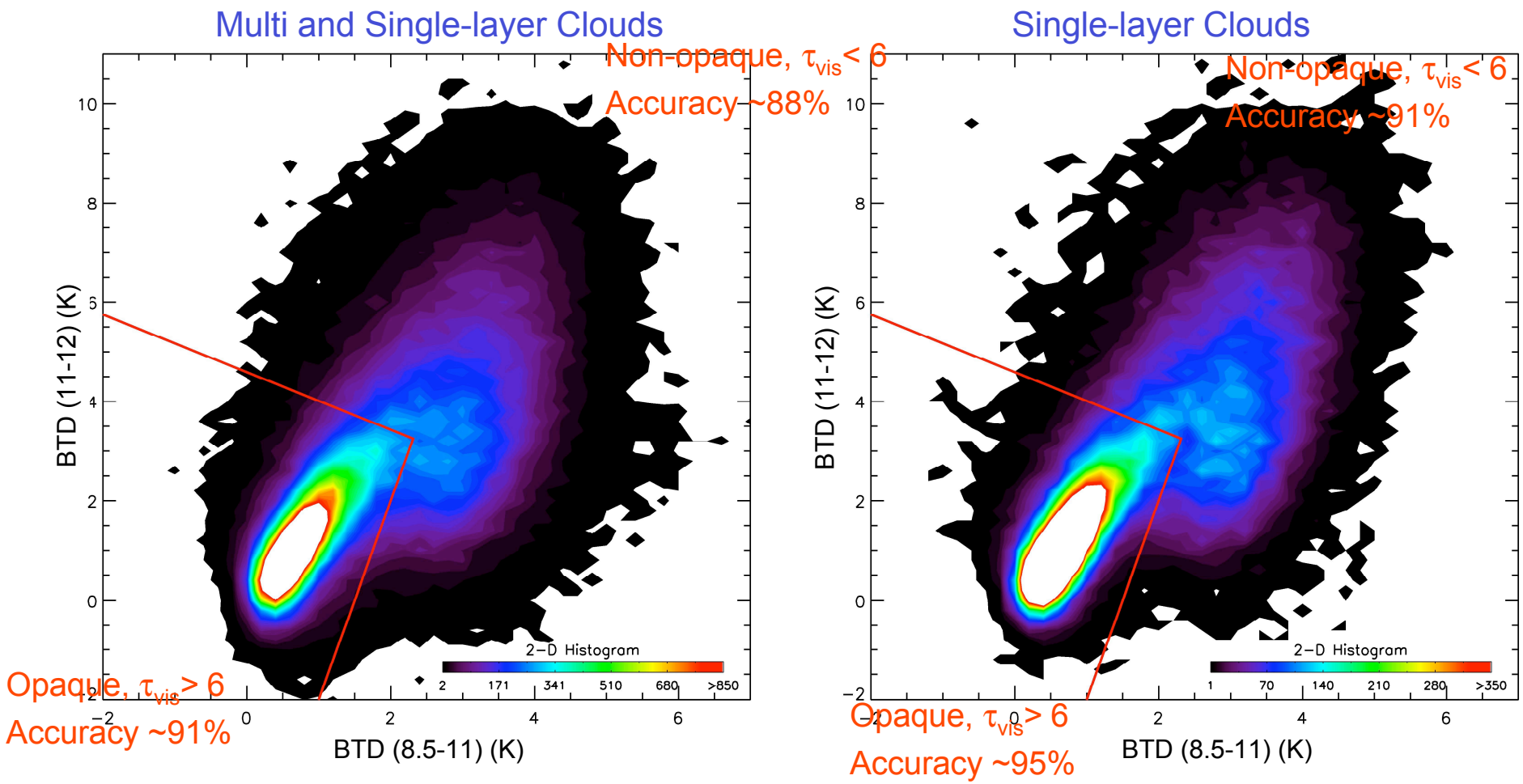




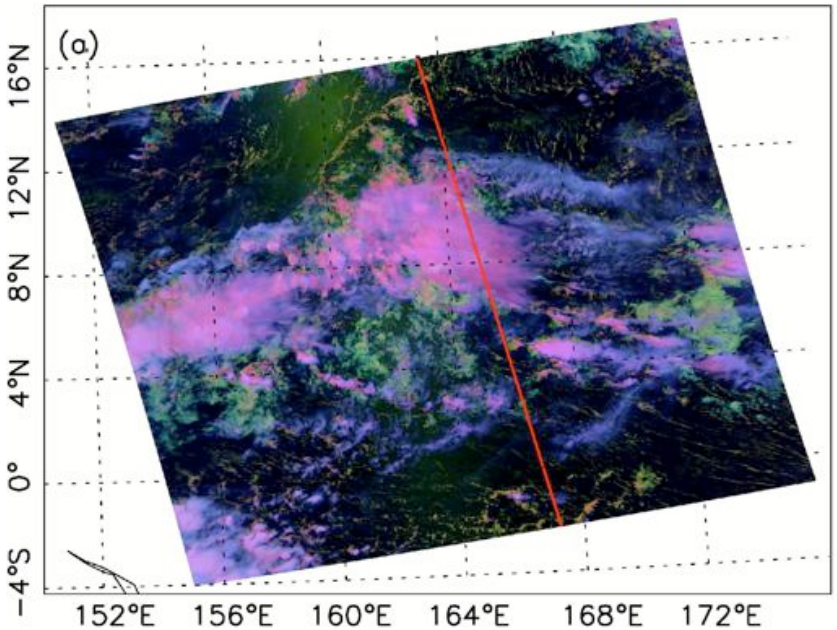


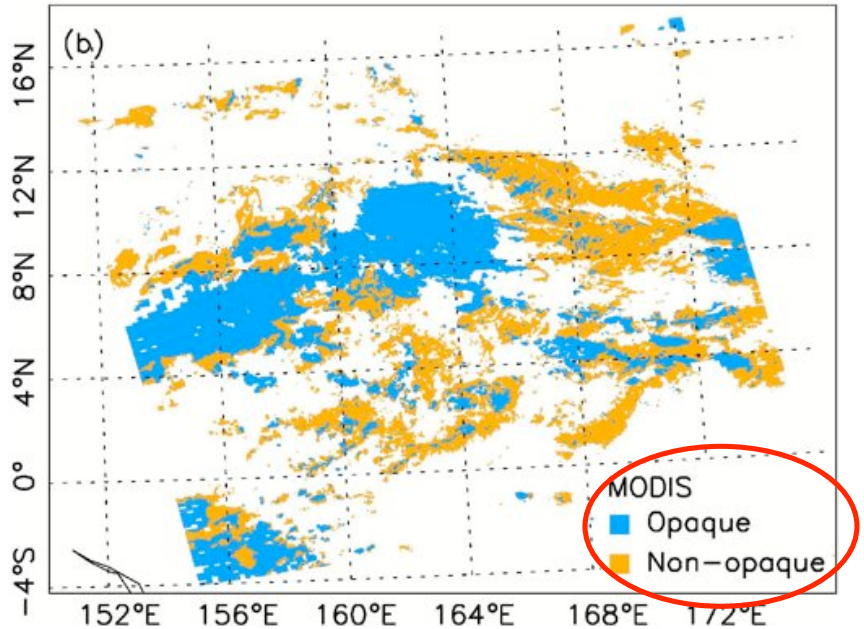
2-D historgrams of BTD (8.5-11) and BTD (11-12) for opaque and non-opaque upper tropospheric ice clouds in 2007.

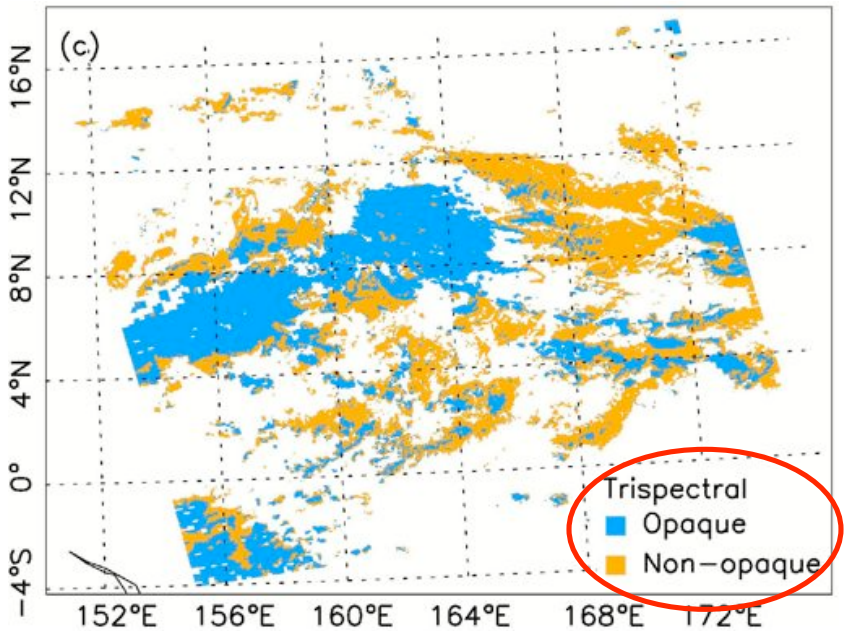
A Tri-spectral Method to Identify Opaque/Non-opaque Ice Clouds



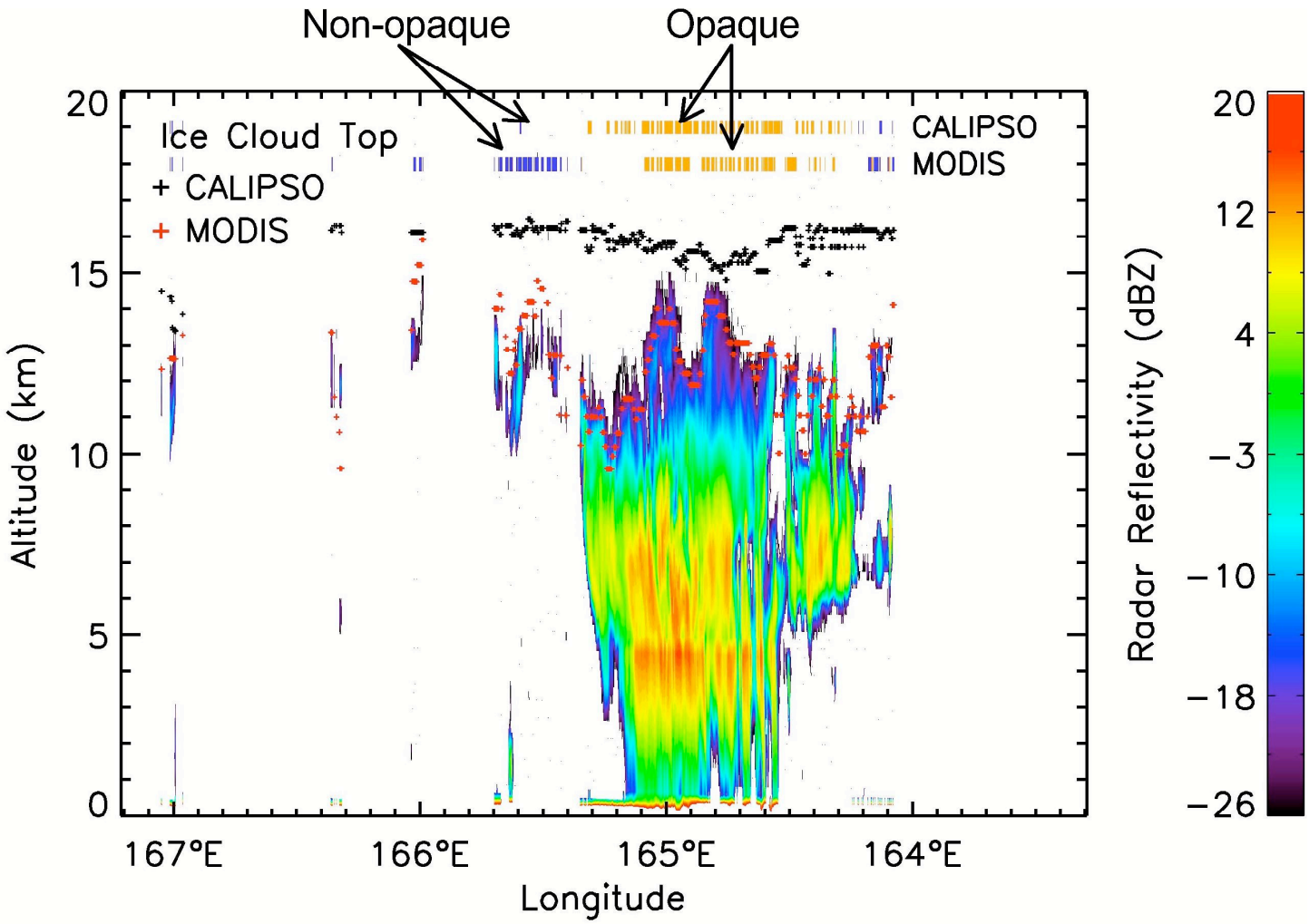
A Tri-spectral Method to Identify Opaque/Non-opaque Ice Clouds







Effect of Cloud Tops on Identifications



Cloud tops from CALIPSO and CloudSat are generally 2.3±1.8 km higher than MODIS

Within a cloud top difference in 4 km, accuracies of identifications for opaque and non-opaque ice clouds are about 90%.

Summary

- Identification of opaque and non-opaque upper tropospheric ice clouds is important for understanding their IR radiative forcing.
- Opaque and non-opaque ice clouds detected from visible measurements and IR effective emissivity show distinct differences.
- A tri-spectral technique (8.5, 11, and 12 μm) for identifying opaque and non-opaque upper tropospheric ice clouds is developed on the basis of the near simultaneous MODIS visible and IR, CALIPSO, and CloudSat measurements from the A-Train.
- Results from the tri-spectral technique are consistent with MODIS visible measurements.