

CALIPSO and Mixed-phase Clouds

Dave Winker¹, Xia Cai², and Anne Garnier²

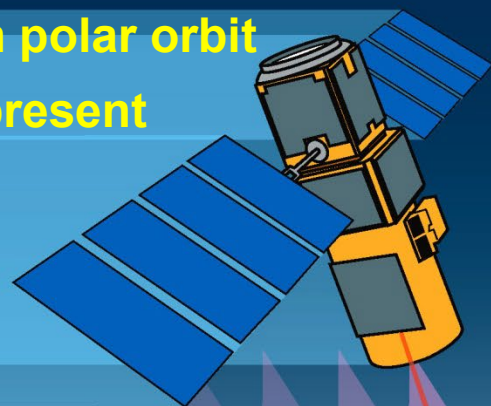
1) NASA Langley Research Center, Hampton, VA

2) SSAI, Hampton, VA

CALIPSO mission:

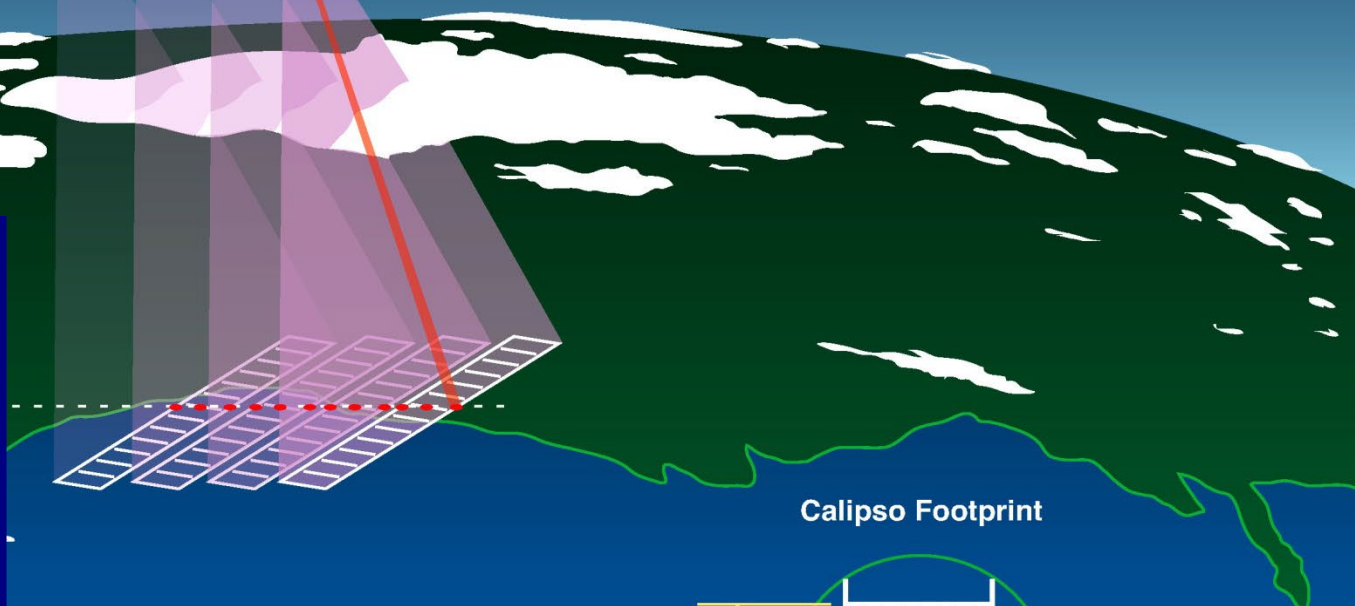
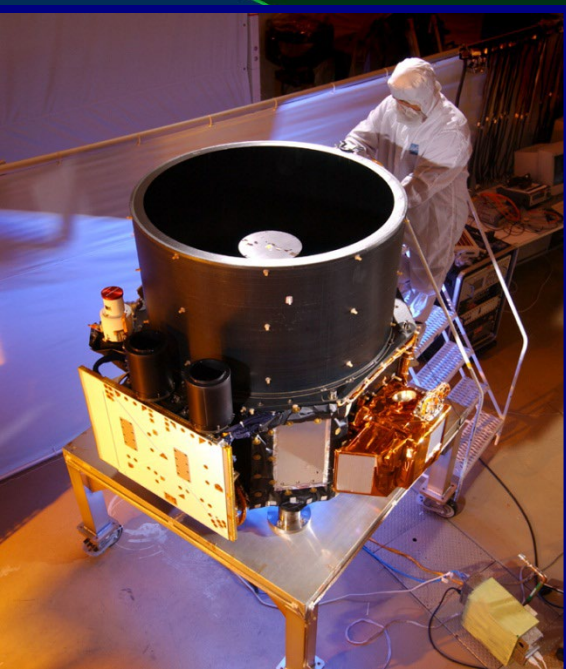
1:30 pm polar orbit

2006 - present

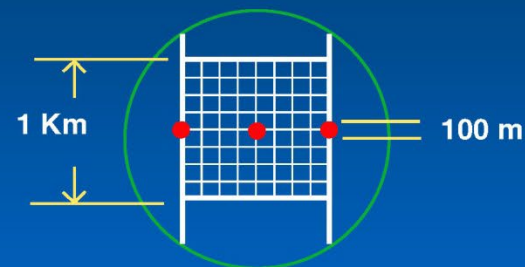


Three co-aligned instruments:

- ❑ CALIOP: polarization lidar
 - 70-meter footprint
 - 1/3 km footprint spacing
- ❑ IIR: Imaging IR radiometer
 - 8.6, 10.5, 12.0 μm
 - 1 km footprint, 60 km swath
- ❑ WFC: Wide-Field Camera

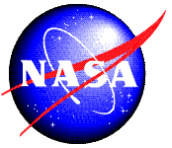


Calipso Footprint





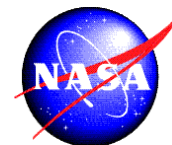
Motivation



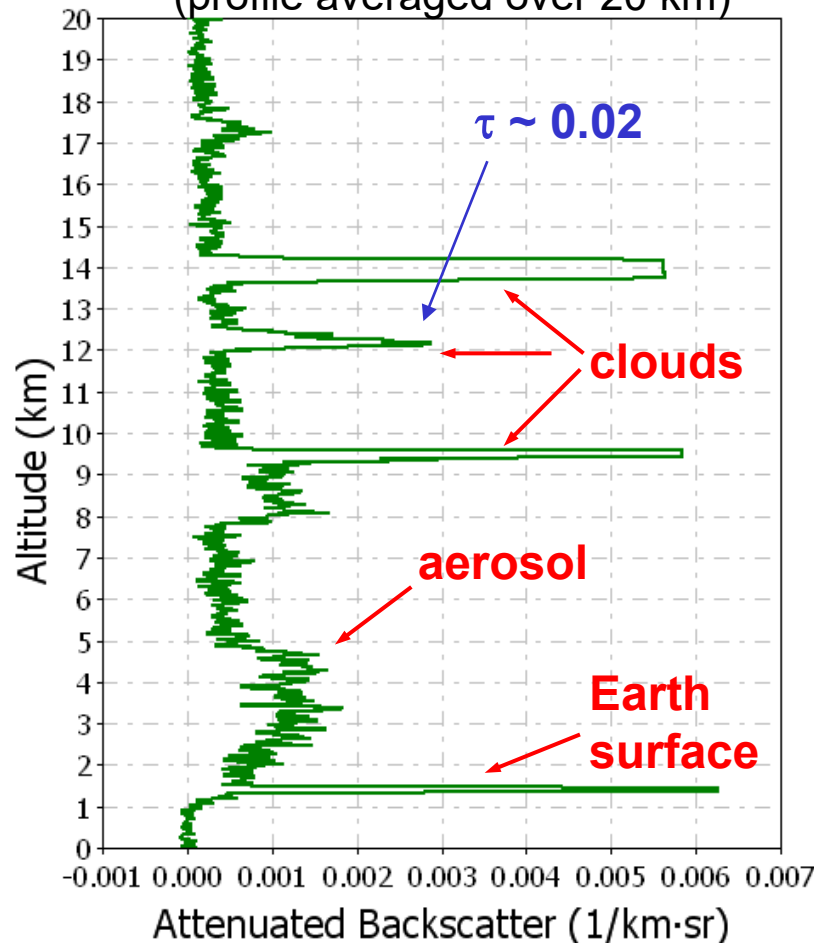
- ❑ Supercooled and mixed phase clouds play an important role in high latitude radiation budgets
- ❑ Models have difficulty simulating the observed persistence of mixed phase clouds
- ❑ But observations of high latitude mixed phase clouds are limited to a handful of field campaigns and a handful of ground-based sites
- ❑ CALIOP algorithms classify the ice/water phase of vertically resolved cloud layers, but has no mixed-phase cloud type



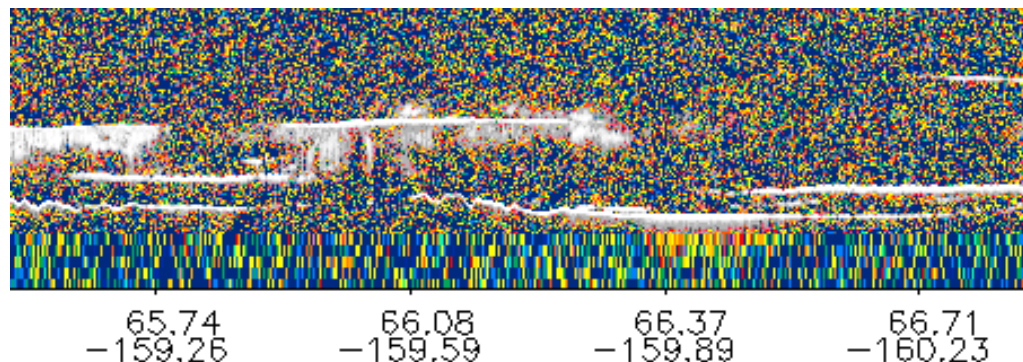
CALIPOP Signals



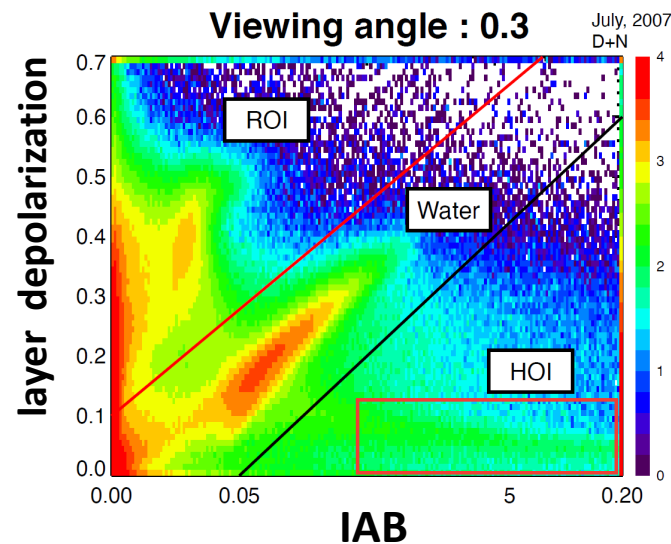
(profile averaged over 20 km)



Cloud heights measured from pulse time-of-flight



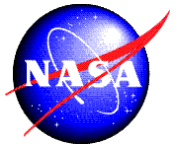
Cloud ice-water phase is determined from integrated backscatter signal and depolarization



IAB= integrated cloud signal

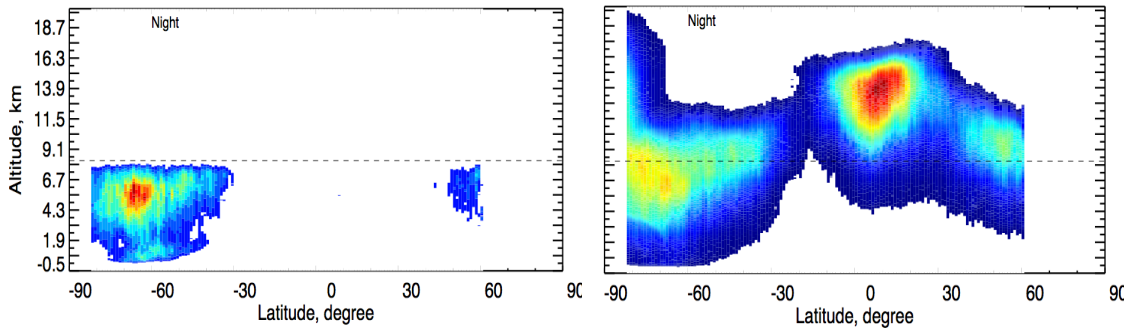


Mixed-phase clouds occur mostly at high latitudes

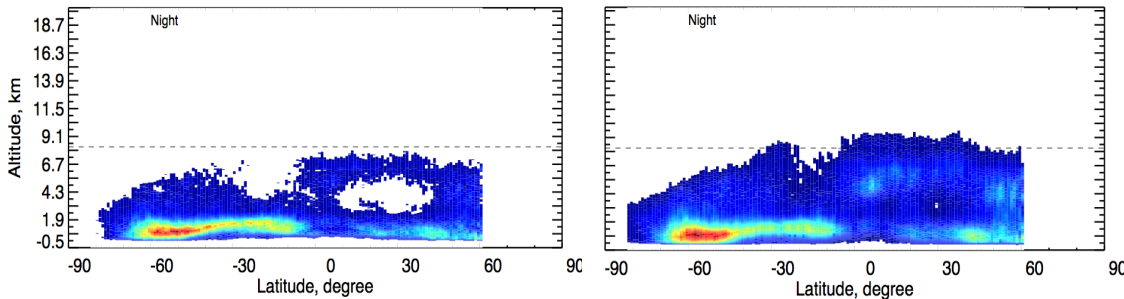


- CALIOP algorithms identify cloud layers as ice or water
- Most water clouds found in the lowest 4 km
- Standard products report clouds at 1/3 km or 5 km horizontal resolution

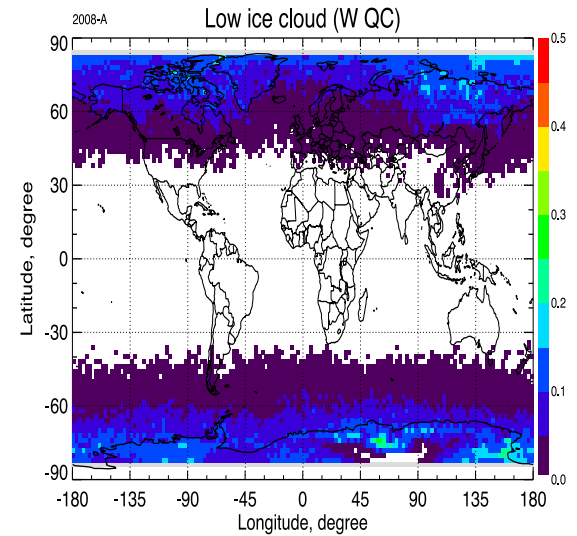
1/3 km Ice clouds 5 km



1/3 km Water clouds 5 km



Occurrence of ice clouds in the lowest 4 km



1/3 km profiles are only available below 8.2 km

Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL087554

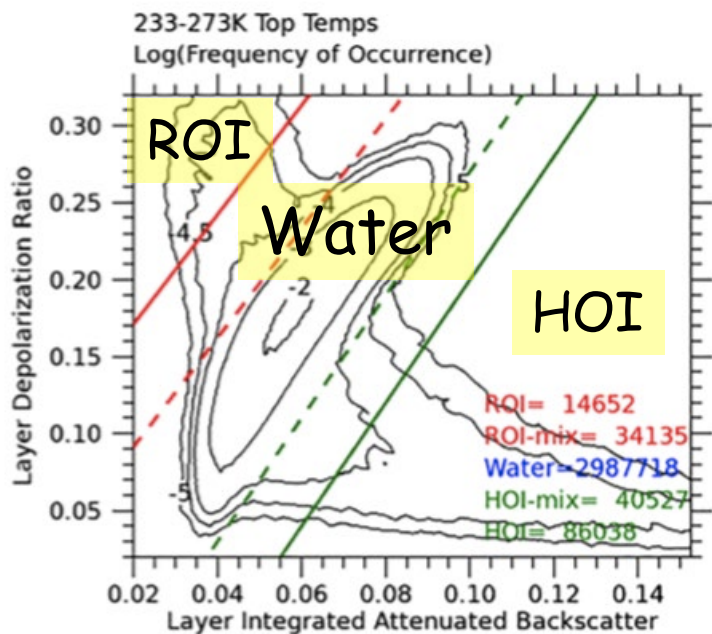
Special Section:
Southern Ocean clouds, aerosols, precipitation and radiation

Key Points:

On the Frequency of Occurrence of the Ice Phase in Supercooled Southern Ocean Low Clouds Derived From CALIPSO and CloudSat

Gerald G. Mace¹, Sally Benson¹, and Yongxiang Hu²

¹Department of Atmospheric Science, University of Utah, Salt Lake City, UT, USA, ²NASA Langley Research Center, Hampton, VA, USA



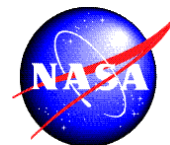
Mace et al. Figure 3a

Based on CALIOP data over Southern Ocean:
2006-2007
Opaque 5-km layers with tops 0°C to -40°C

- Find that liquid clouds are confined more tightly in Depol-IAB space than thresholds used in the CALIOP phase algorithm
- Define two new regions, suggesting they contain mixed-phase clouds

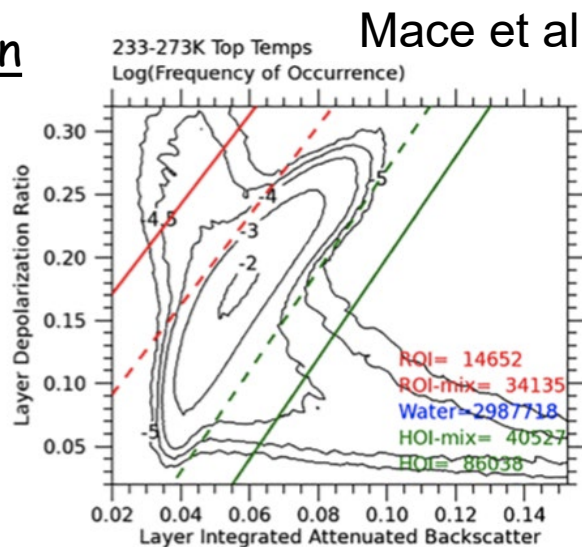


Our test of the Mace results

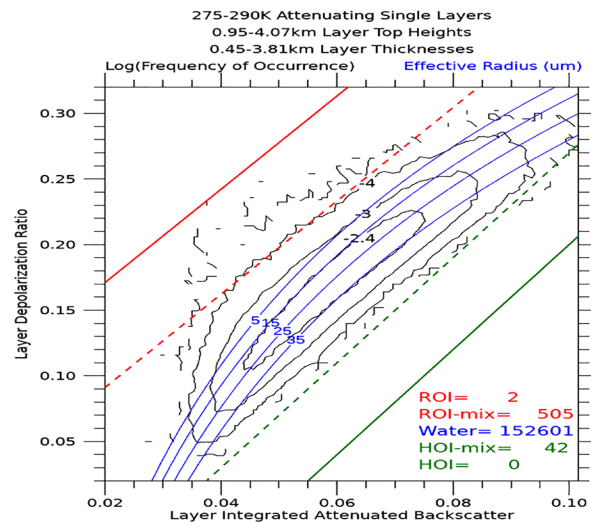


Southern Ocean

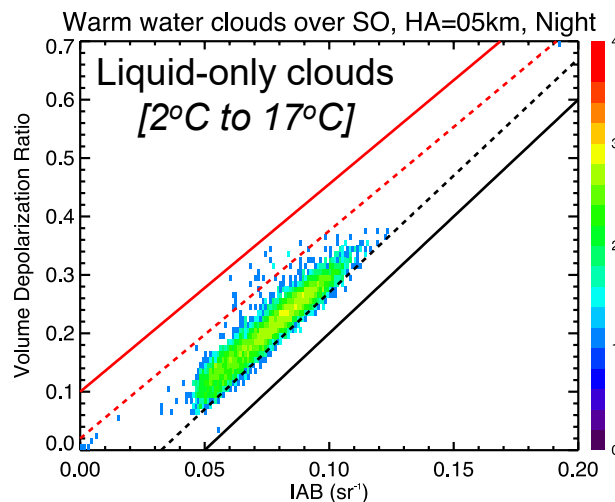
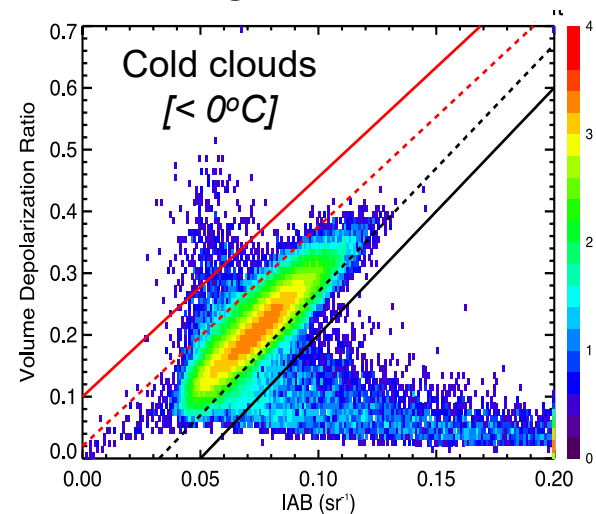
Cloud tops:
233-273K



Cloud tops:
275-295 K

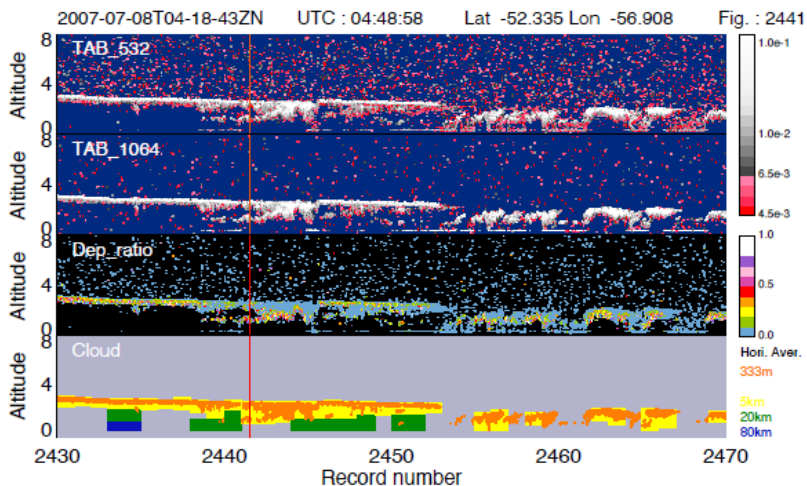
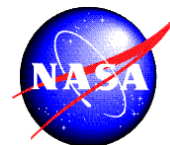


Our results

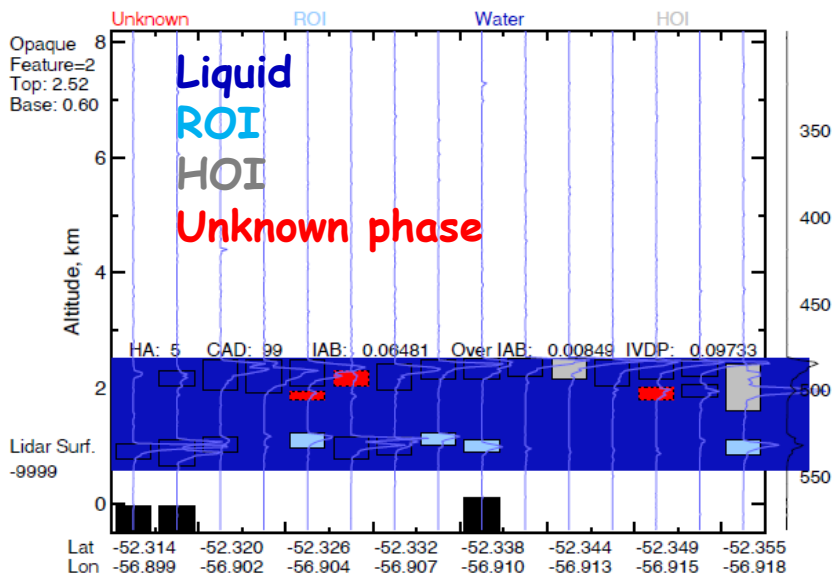




Another view of 'mixed phase'



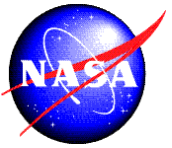
We investigate the homogeneity of phase within 5-km layers by looking at phase of single-shot layers detected within the 5-km layer



We ignore phase classification of the 5-km layer and instead look at the phase of the embedded 1/3 km layers



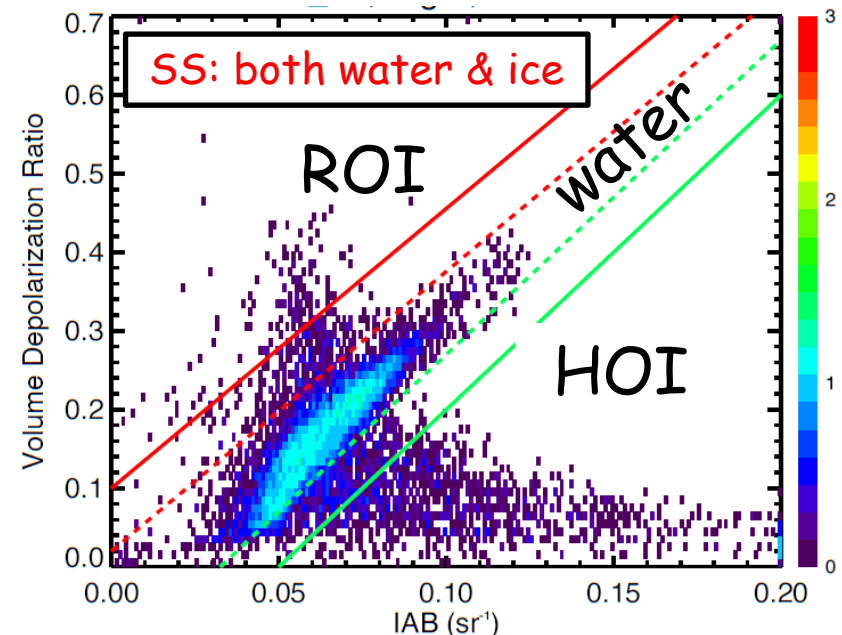
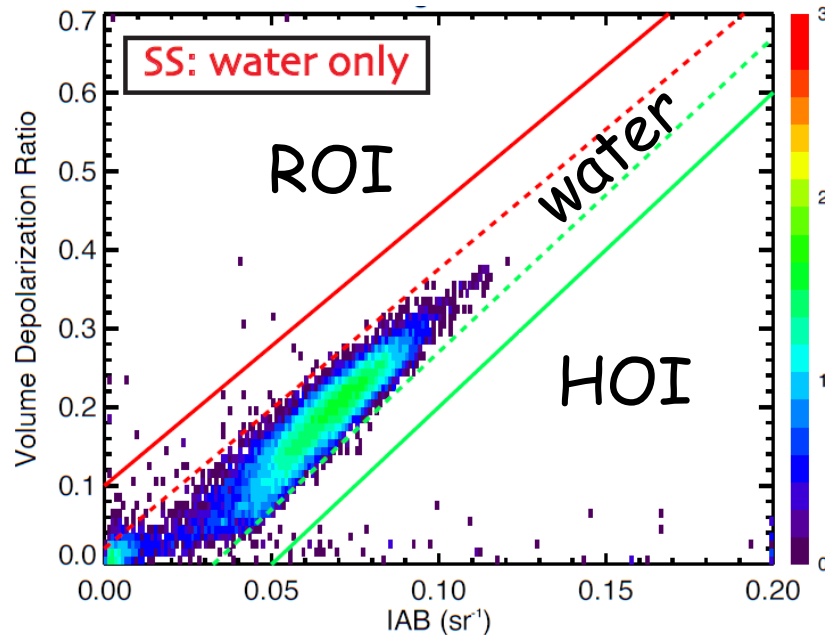
Partitioning cloud layers by phase of single shots



Based on the phase of single shot layers within 5-km layers:

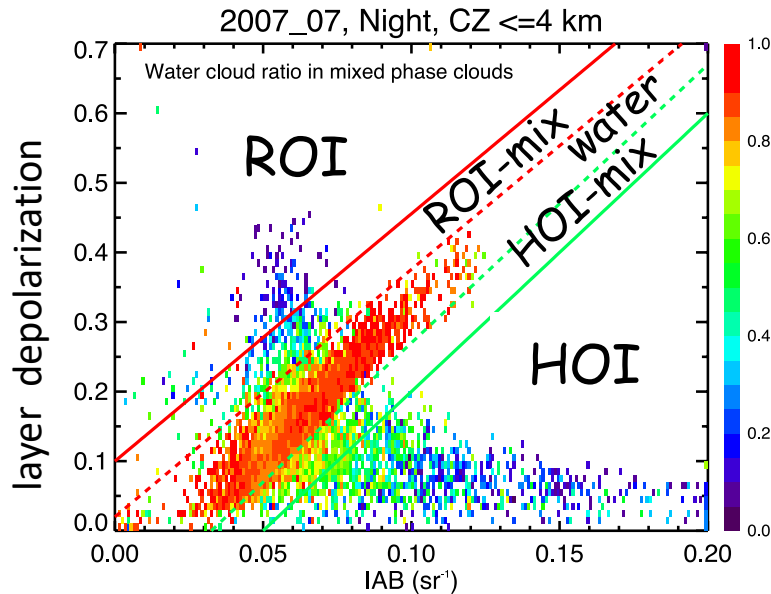
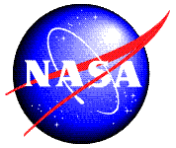
- ❑ Liquid clouds fall within the tighter Mace et al boundaries (left)
- ❑ But clouds containing both liquid and ice also fall within the Mace et al boundaries (right)
- ❑ Some mixed phase clouds also found in ROI and HOI sectors

2007, night, cloud top < 4 km





Liquid Fraction



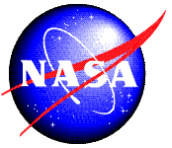
Color coding indicates fraction of the 1/3 km layers within each 5km layer which are liquid

Inspecting the fraction of single-shot liquid vs ice layers:

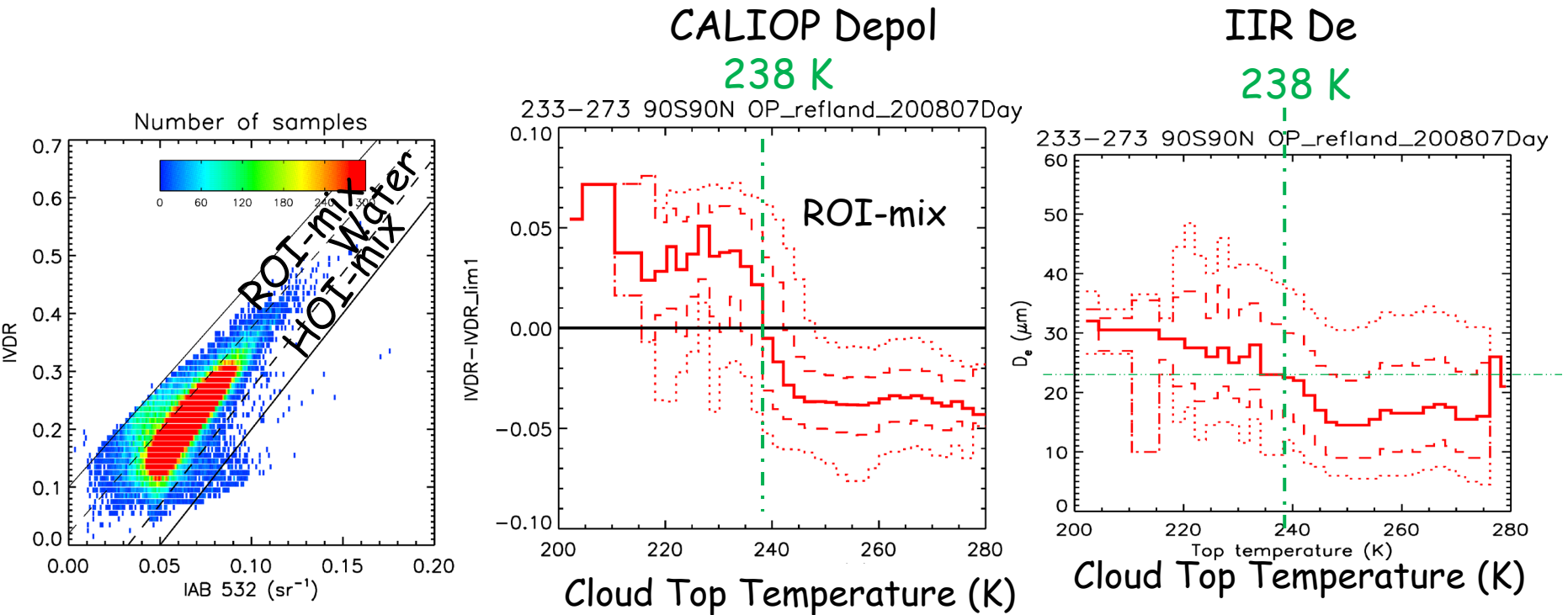
- ❑ The Mace 'liquid' sector is mostly, but not entirely liquid
- ❑ The ROI and HOI sectors are mostly, but not entirely ice
- ❑ The 'mix' regions have intermediate mixtures of liquid and ice



Lidar vs Infrared Observations



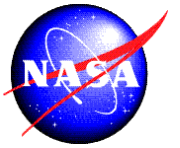
CALIOP classification of ROI/Liquid is consistent with particle size from IIR



CALIOP and IIR observations both indicate increased occurrence of ice below 238 K

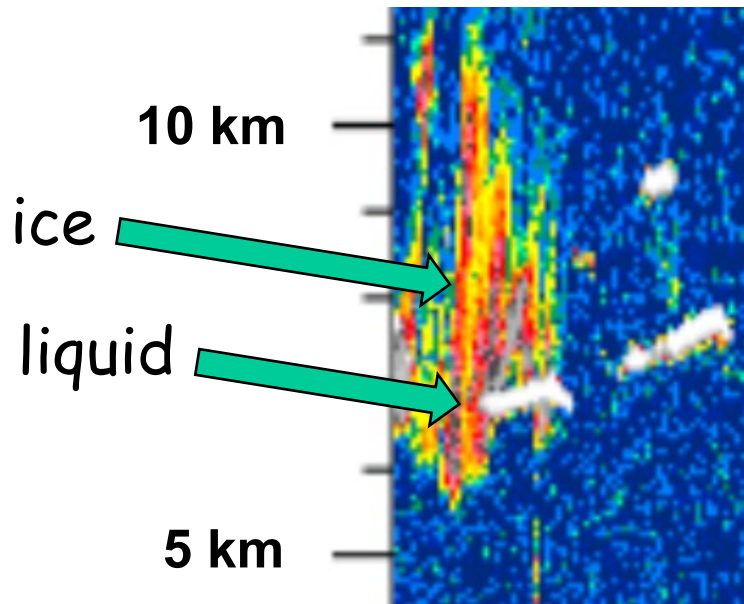


Lidar vs Radar

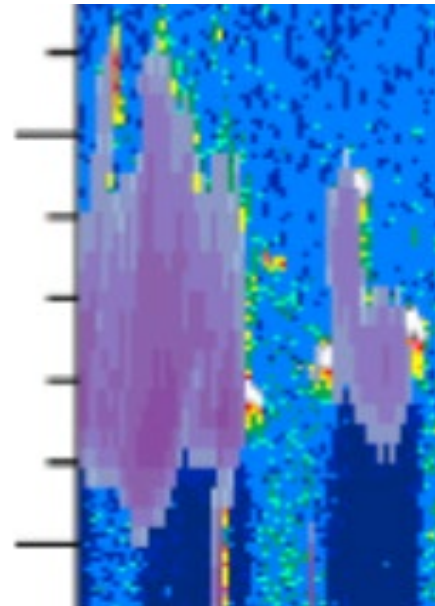


- Supercooled liquid often invisible to CloudSat W-band radar
- CloudSat can see ice within supercooled liquid and below liquid clouds opaque to CALIOP

CALIOP

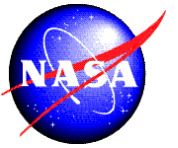


CloudSat reflectivity overlaid on CALIOP





Summary



- ❑ Mixed phase clouds can be identified in CALIOP data from the distribution of ice and water within cloud layers detected at standard 5-km horizontal resolution
- ❑ Mixed phase clouds appear most frequently near the boundaries of the Ice and Water sectors of the cloud phase diagram
- ❑ Small IIR D_e corresponds to CALIOP liquid mixing ratios larger than 50 %
- ❑ There are further synergies to be explored between co-located A-train lidar, infrared, and W-band radar observations

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