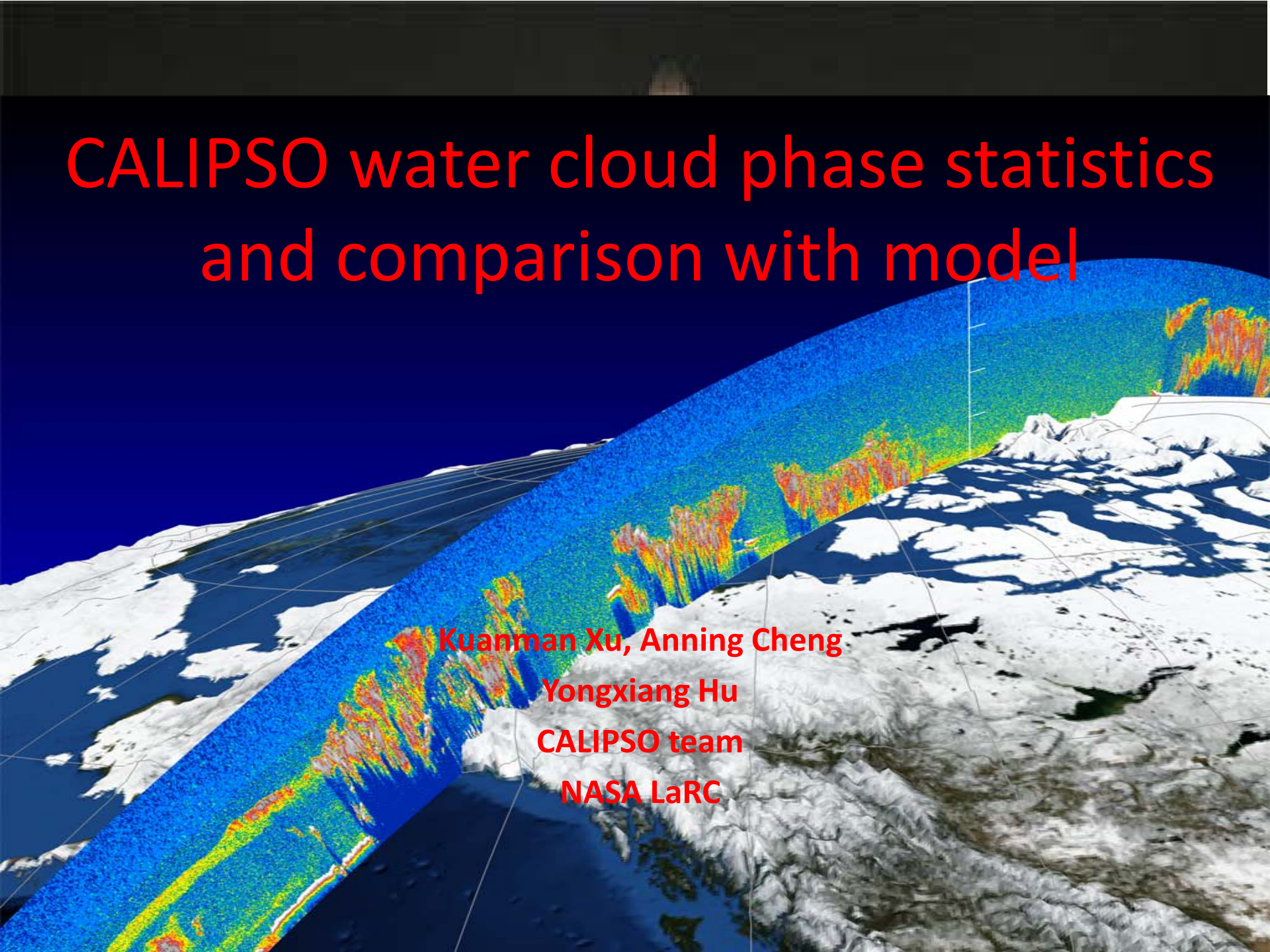
CALIPSO water cloud phase statistics and comparison with model



Kuanman Xu, Anning Cheng

Yongxiang Hu

CALIPSO team

NASA LaRC

CALIPSO Payload
Three Near Nadir Viewing Instruments

Lidar

CALIOP

Cloud-Aerosol Lidar with Orthogonal Polarization

Vertical profiles of atmosphere

2 wavelength polarization sensitive lidar:

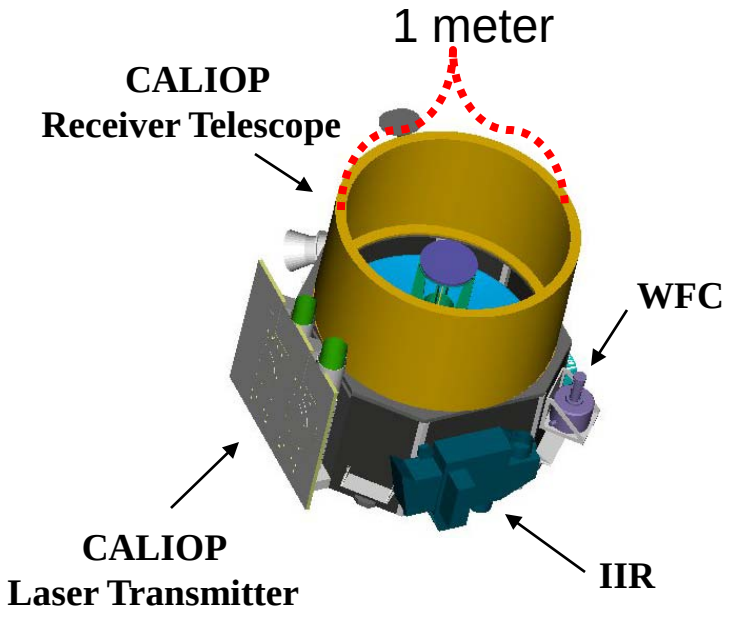
1064 nm, 532 nm (parallel and perpendicular)

Imaging Infrared Radiometer (IIR)

High-resolution image (swath product)

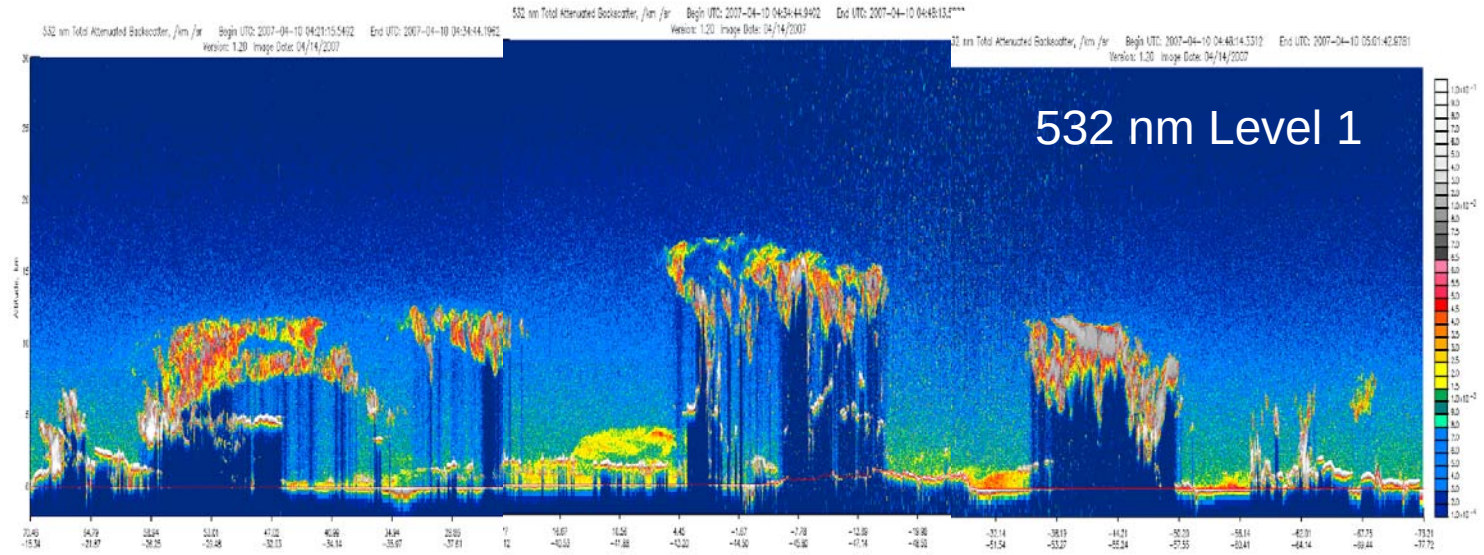
Wide Field Camera (WFC)

High-resolution image (125m resolution)



CALIPSO Payload

CALIPSO unambiguously discriminates water and ice phase at cloud top



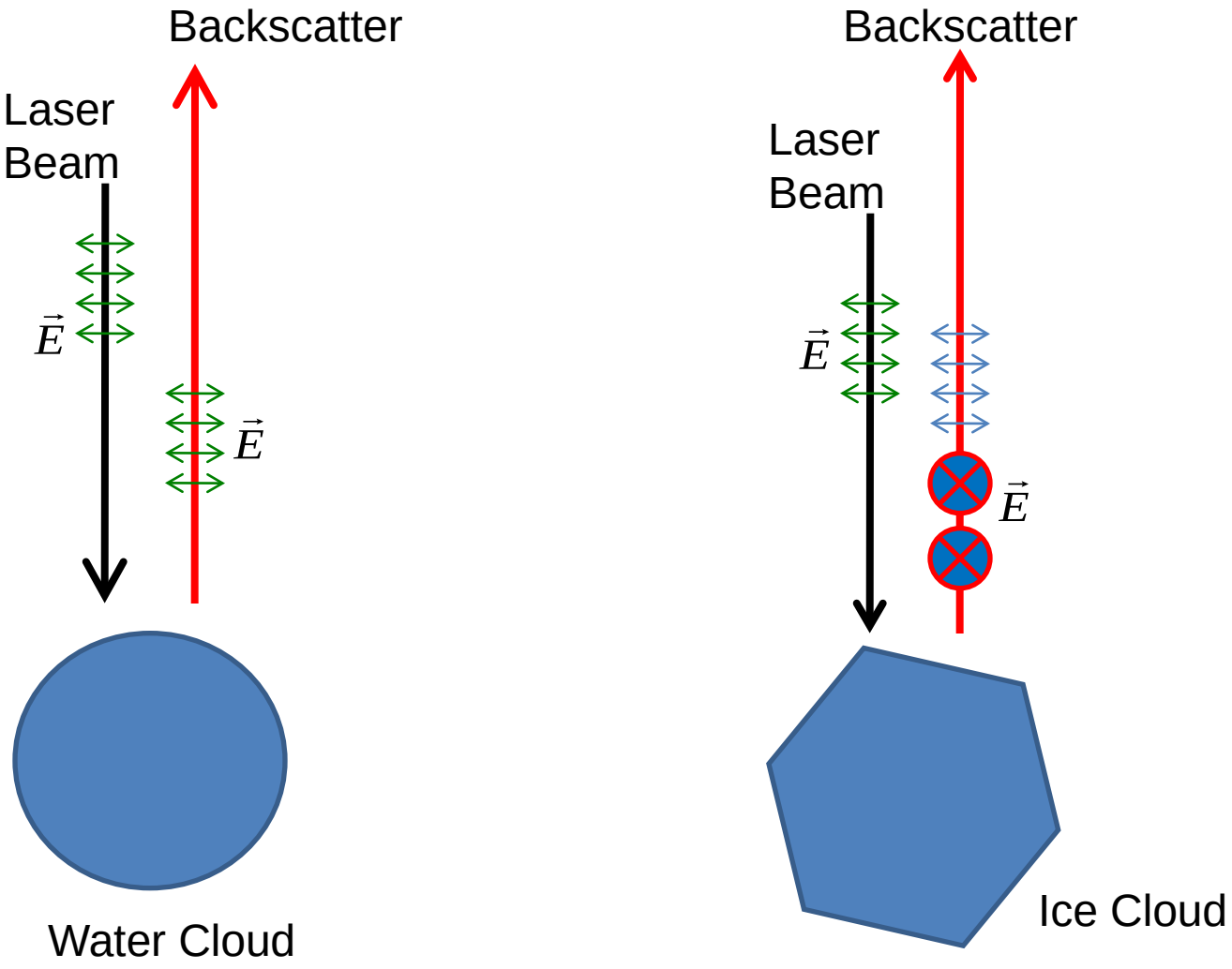
Technique in discriminating liquid and ice phase

- **MODIS**: absorption of solar infrared radiation (ice absorbs slightly more than liquid for each scattering event)
- **Parasol**: linear polarization of reflected sunlight at rainbow angles (liquid: highly polarized)
- **CALIPSO**: polarization change of backscattered laser light (ice: yes; water: no); lidar backscatter intensity (water > 0.04 sr^{-1}; ice< 0.035 sr^{-1}) *more straight forward; less assumptions; works for multi-layered clouds*

These technique only valid at cloud top

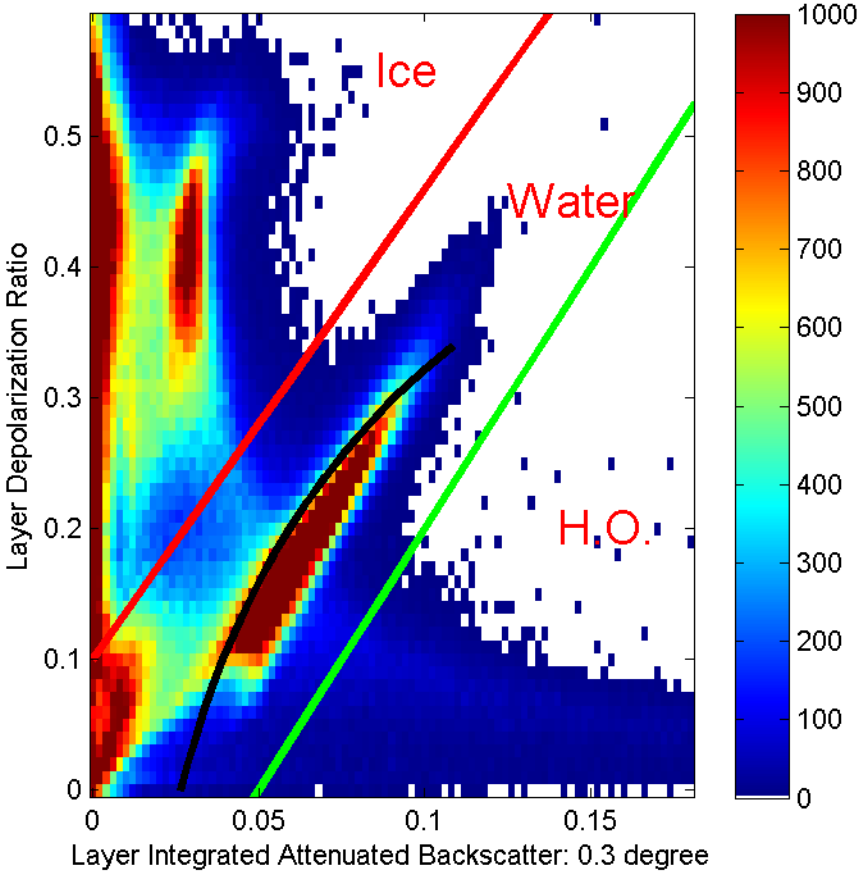
Cloud Phase discrimination from Lidar Depolarization:

$\delta_{sphere} = 0 - 0.3$; $\delta_{nonsphere\text{-}R} = 0.3 - 0.55$

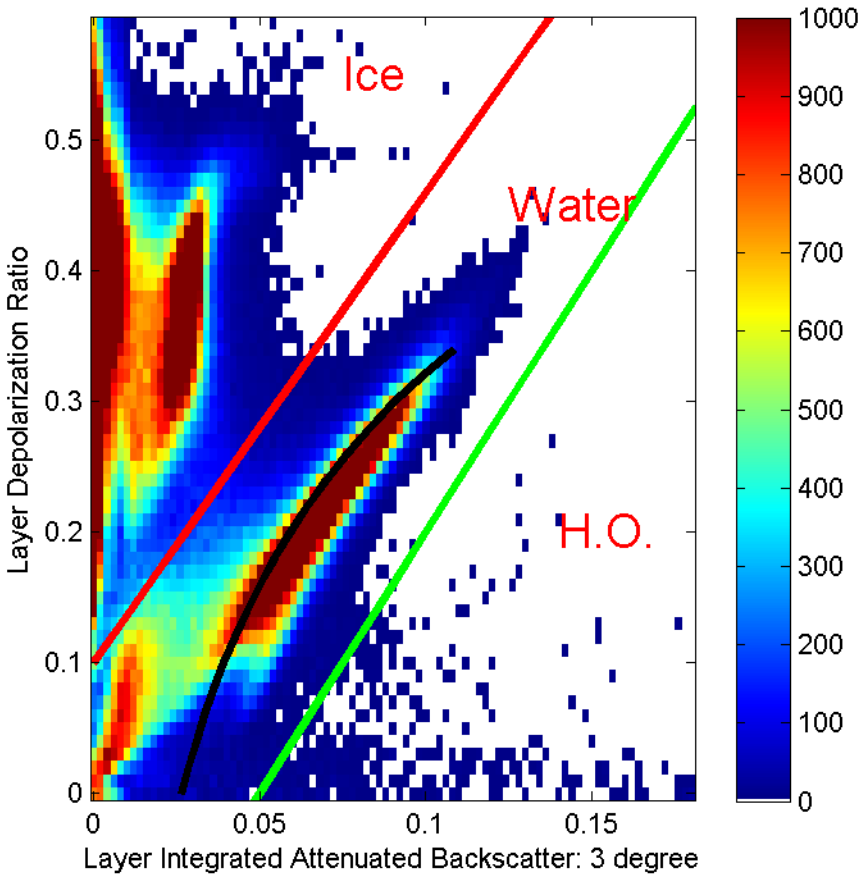


Impact of Multiple Scattering and Particle Orientation on CALIPSO's Cloud Phase from Depolarization

Jun 2006 – Dec 2007: 0.3 off-nadir

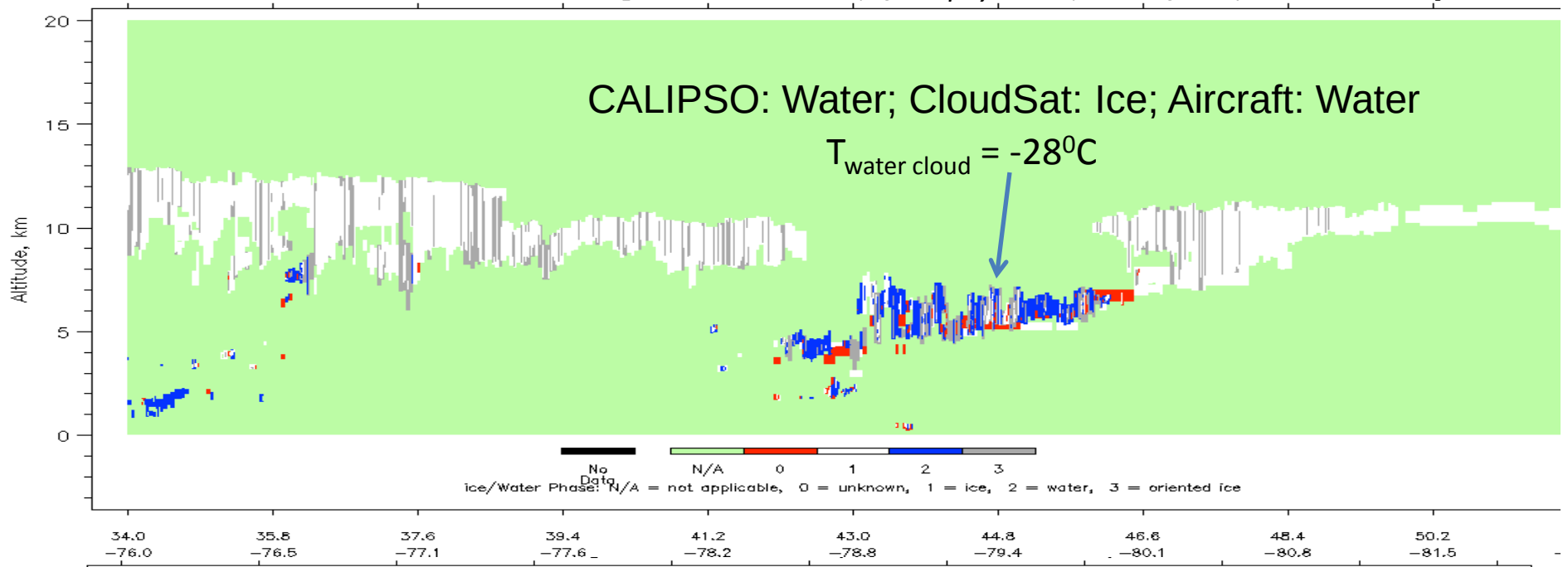


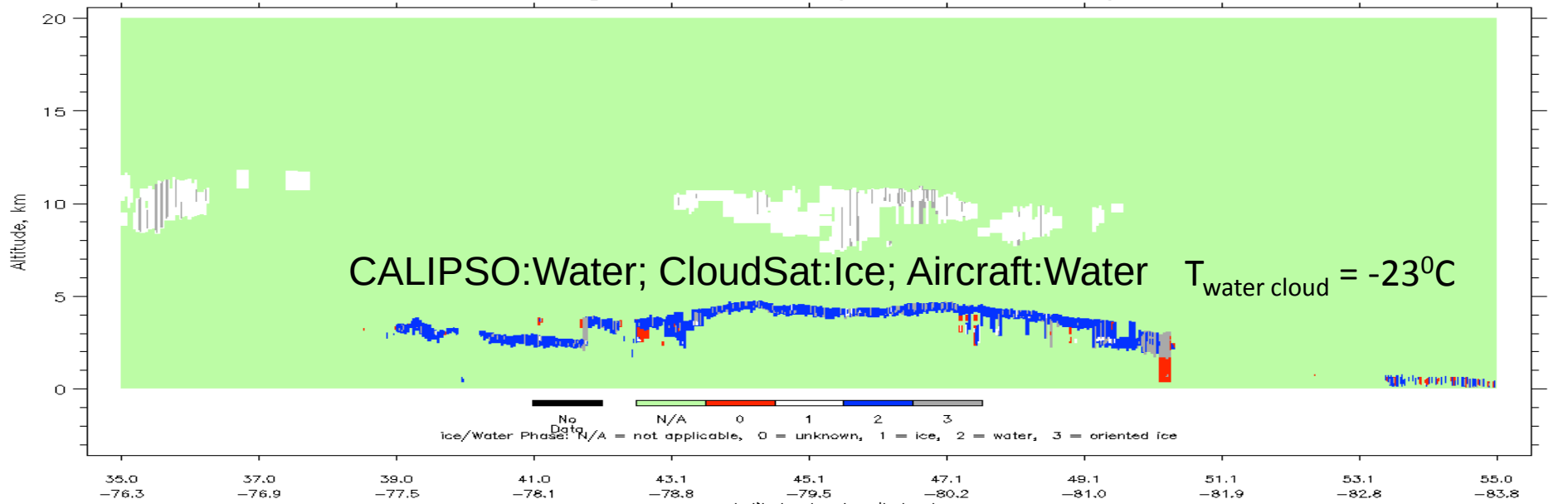
Dec 2007 – end of CALIPSO: 3 degree



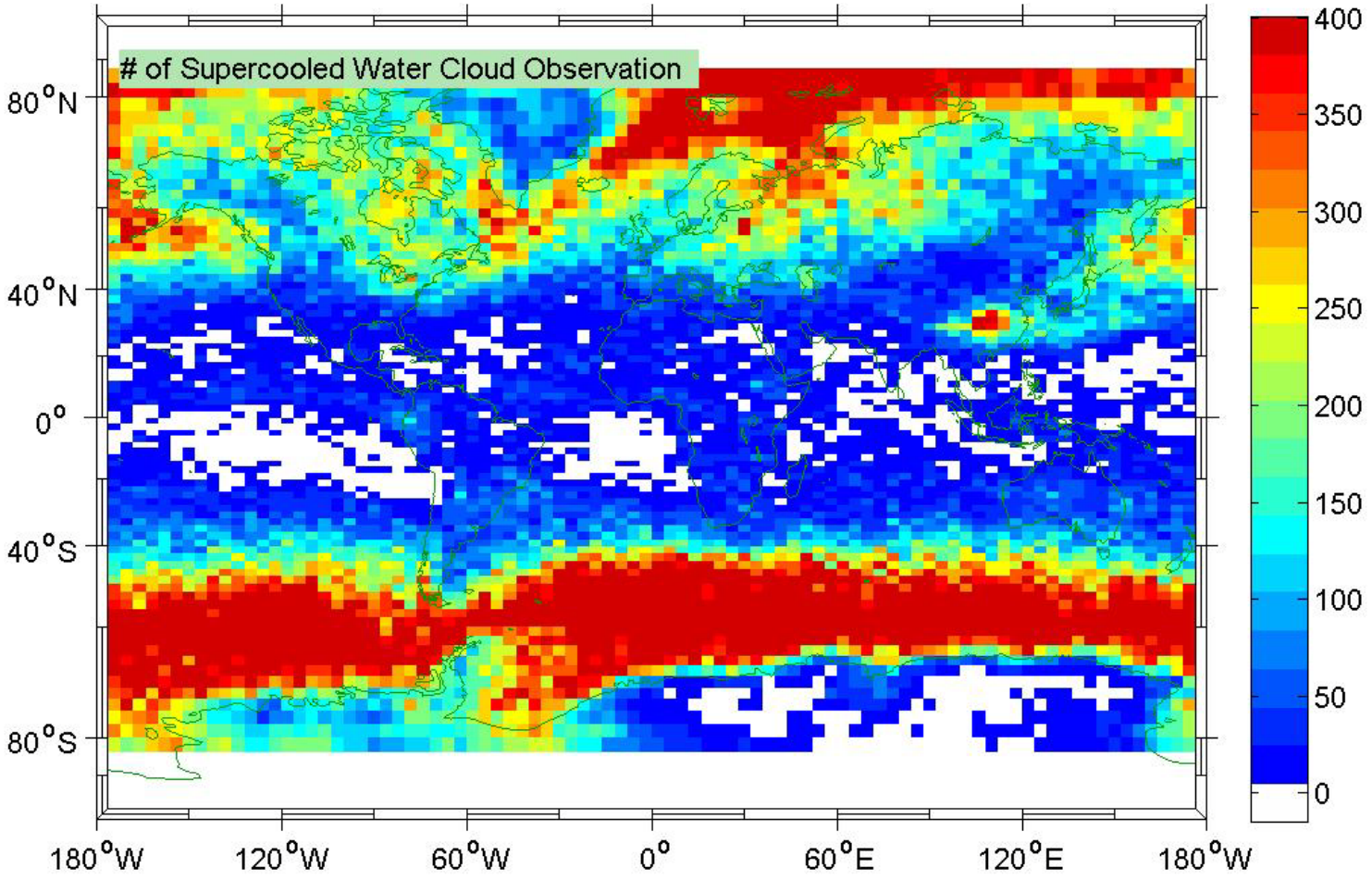
Aircraft measurements confirms CALIPSO phase

[Noh, Y.-J., C. Seaman, T. H. Vonder Haar, D. R. Hudak, and P. Rodriguez (2011), Comparisons And Analyses Of Aircraft And Satellite Observations For Wintertime Mixed-Phase Clouds, *J. Geophys. Res.*, doi:10.1029/2010JD015420]





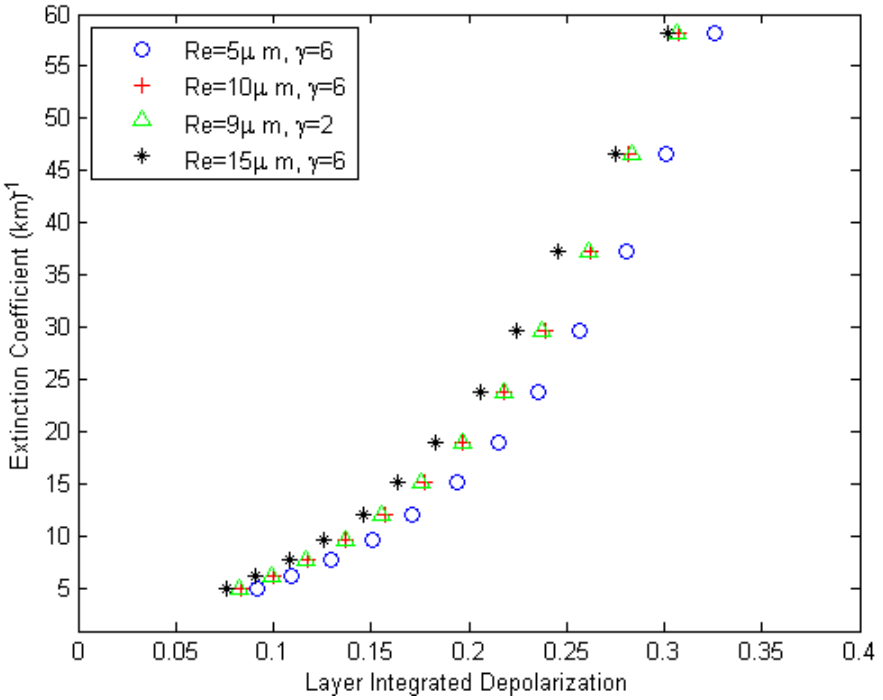
Occurrence of the supercooled water clouds

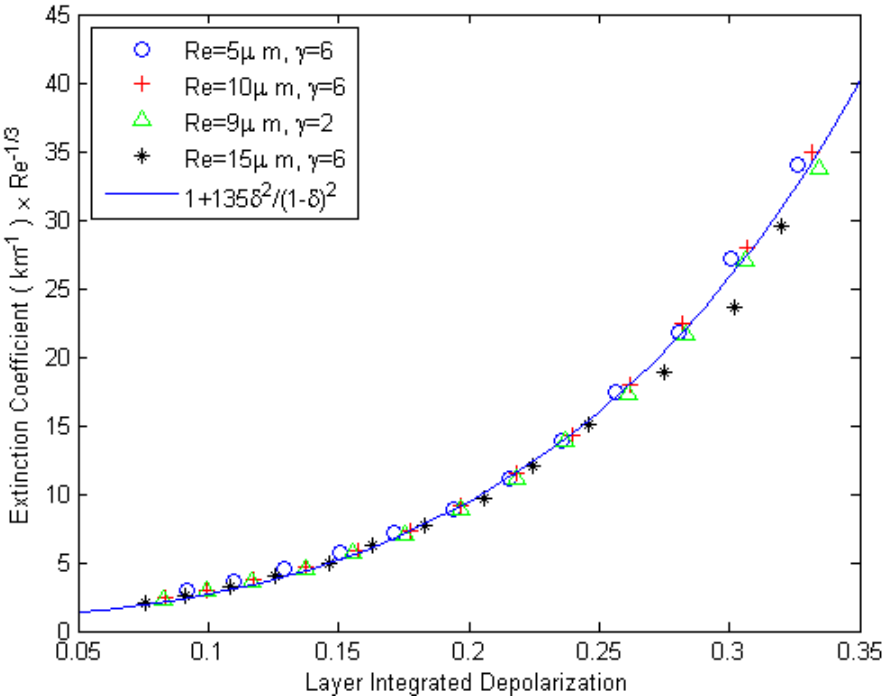


CALIPSO provides cloud top liquid water content and droplet concentration

Using a simple physics relation for deriving water cloud droplet number concentration from CALIPSO depolarization measurement (Hu et al., ACP, 2007):

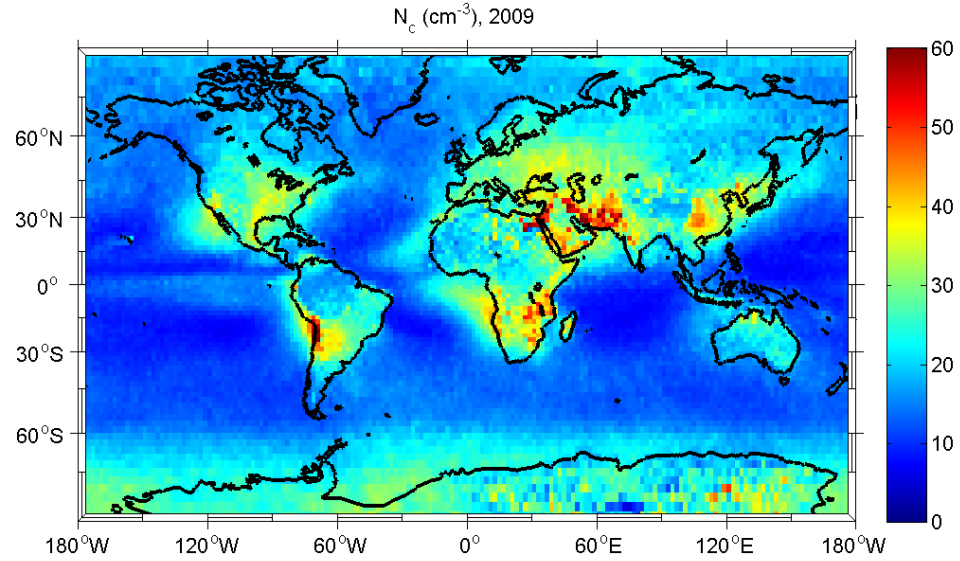
Lidar depolarization ratio of water clouds → multiple scattering → extinction coefficient → add MODIS droplet size → water cloud droplet concentration

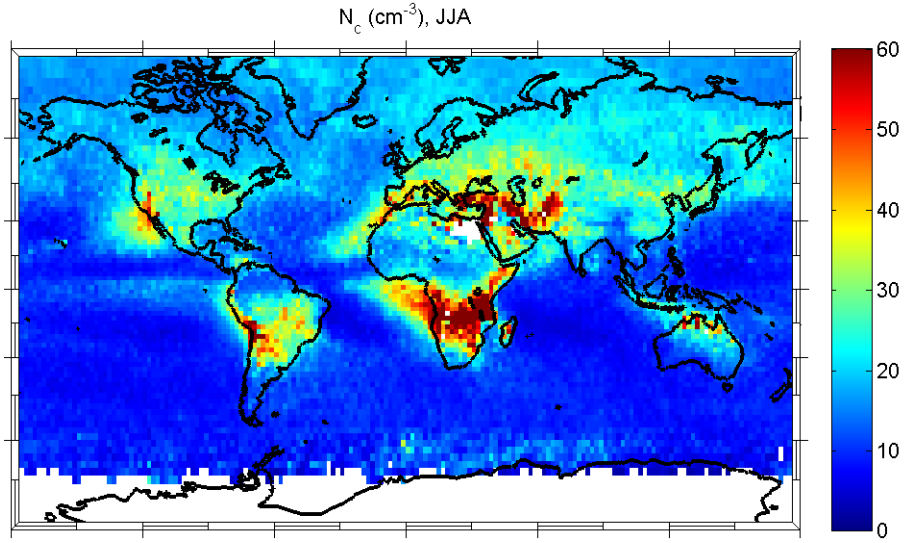


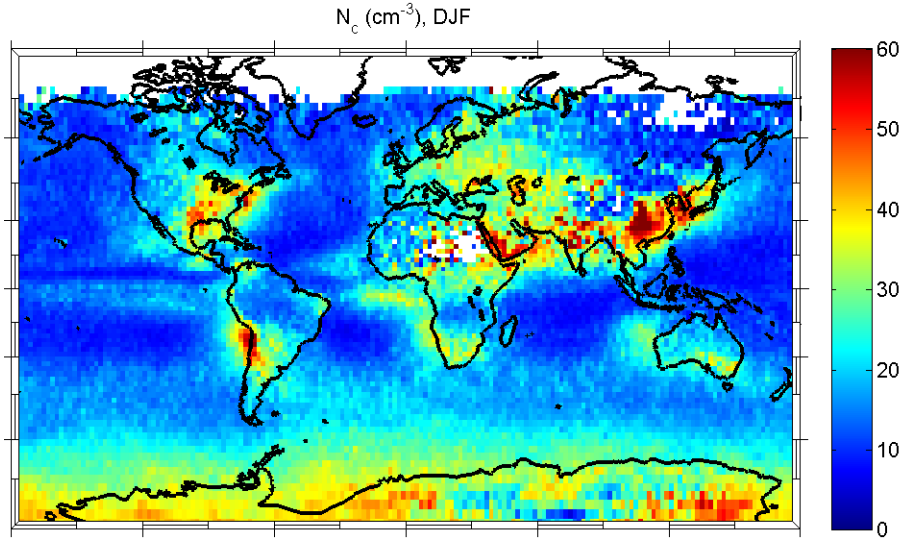


Cloud top water droplet number concentration (N) statistics from CALIPSO

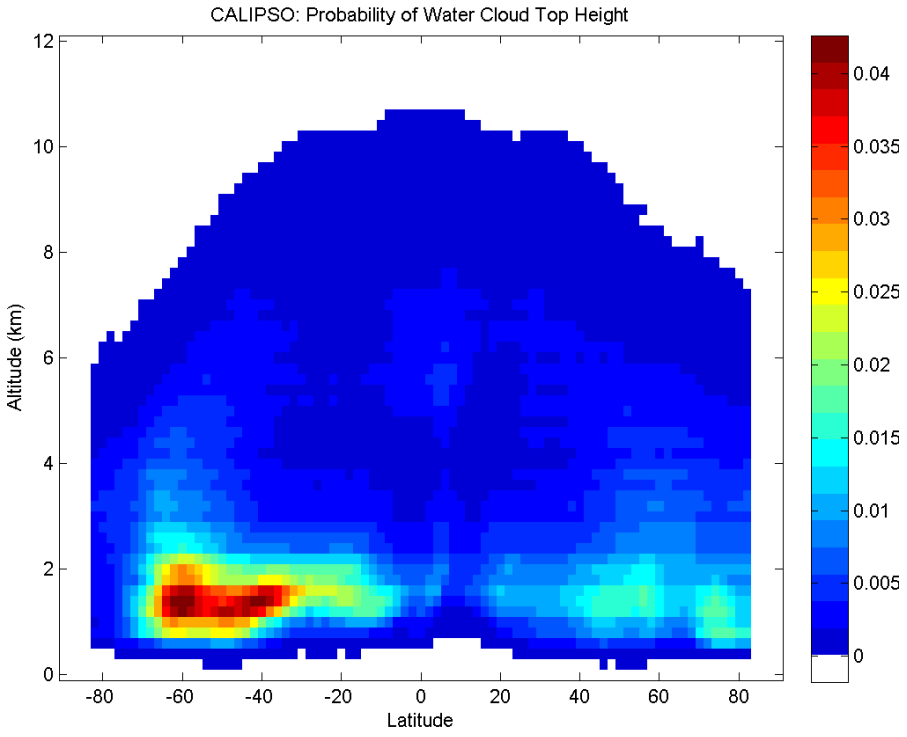
N for winter-time clouds over ocean very small

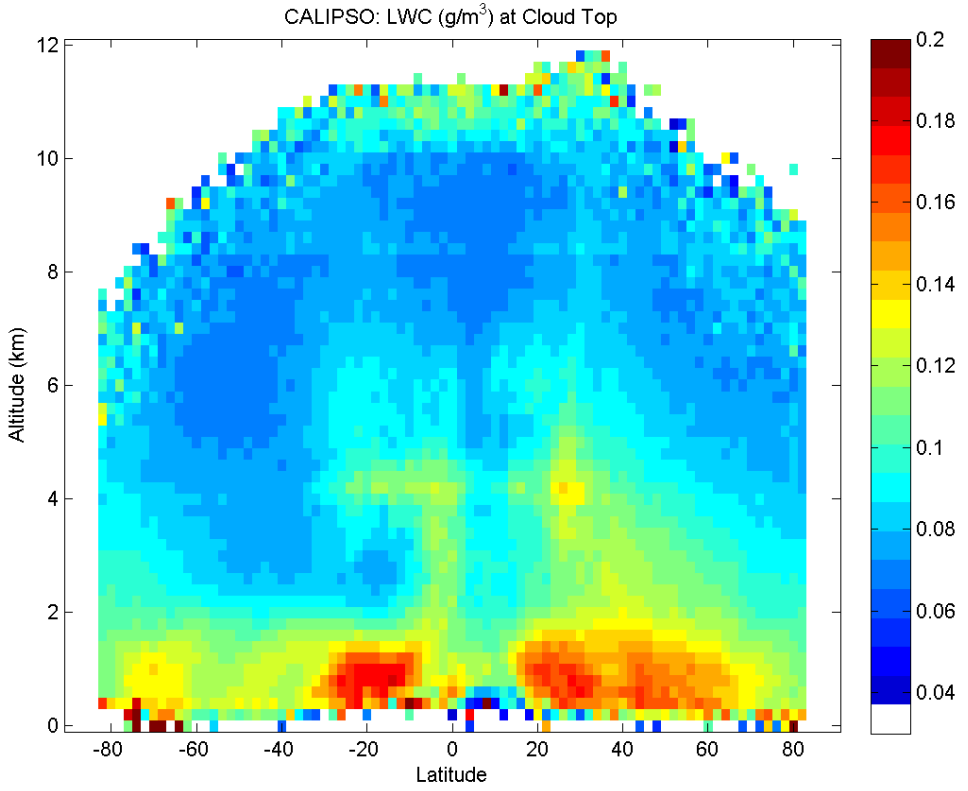




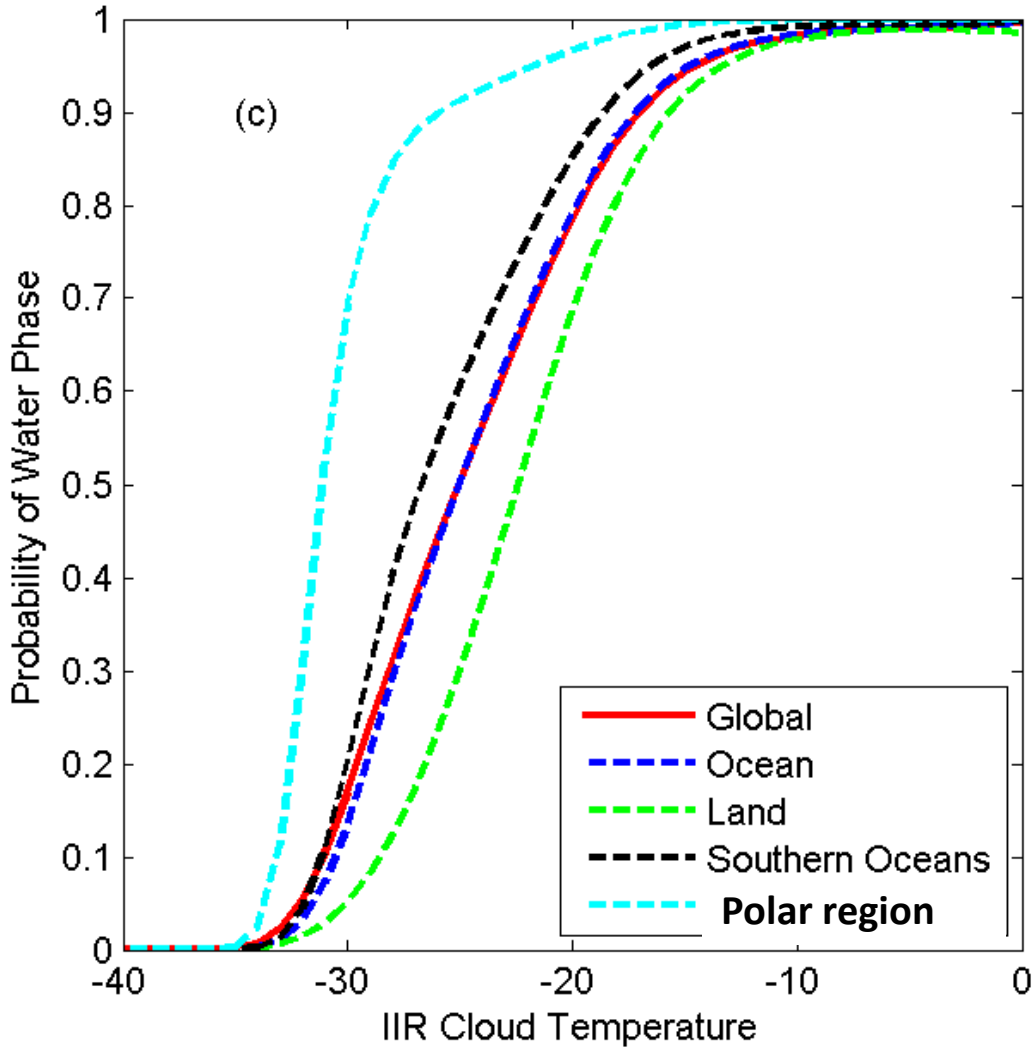


Water cloud top height and cloud top LWC from CALIPSO

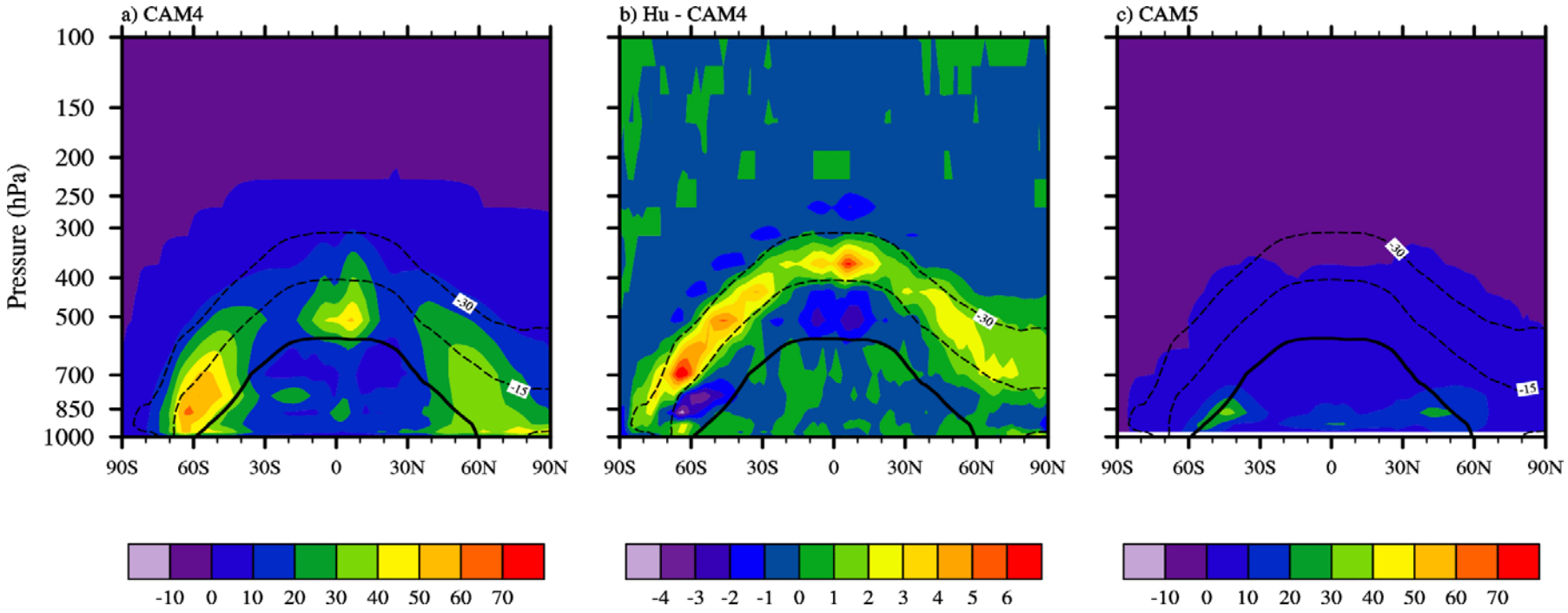


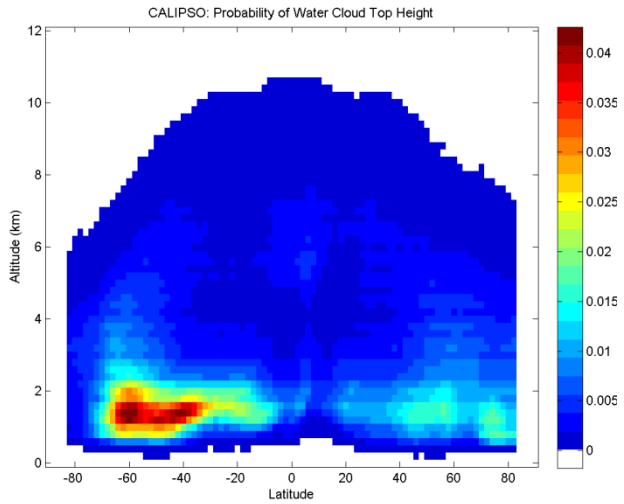


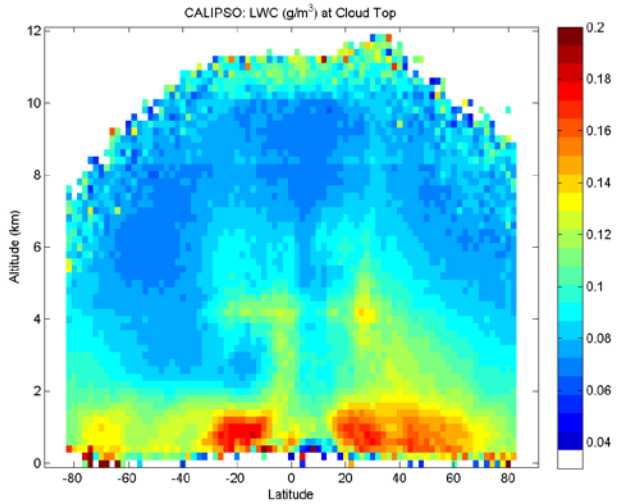
Spatial distribution of supercooled water clouds



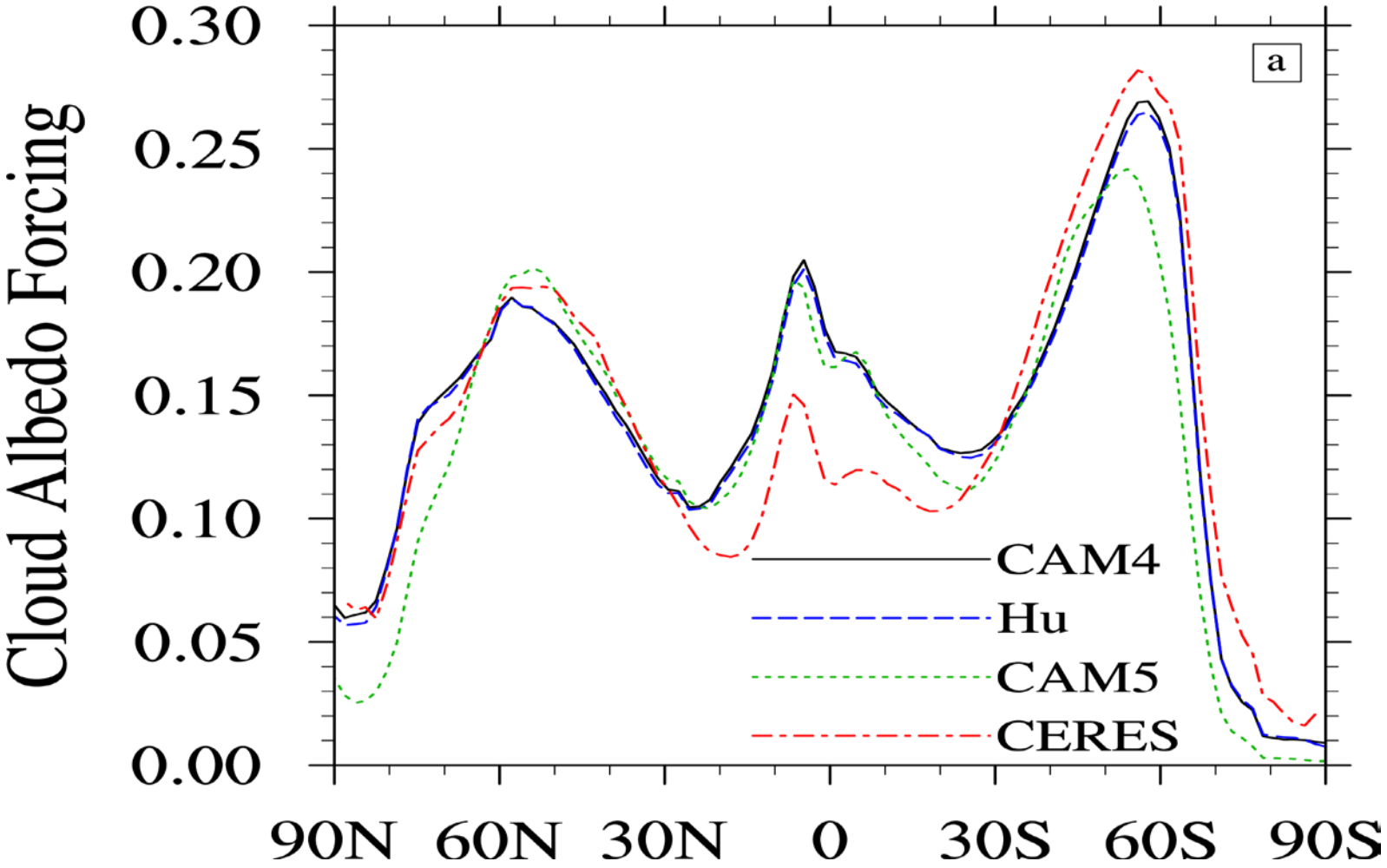
Comparisons of cloud liquid water content







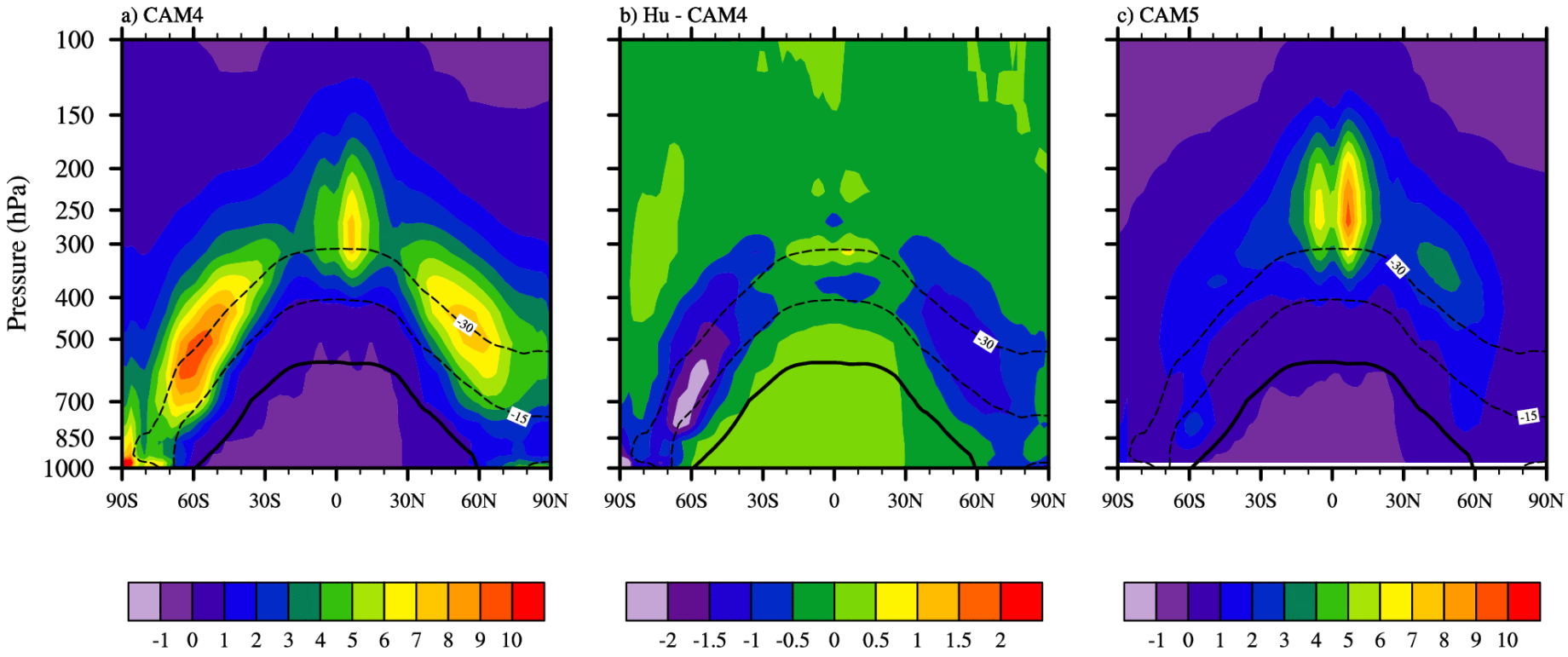
Comparisons of albedo



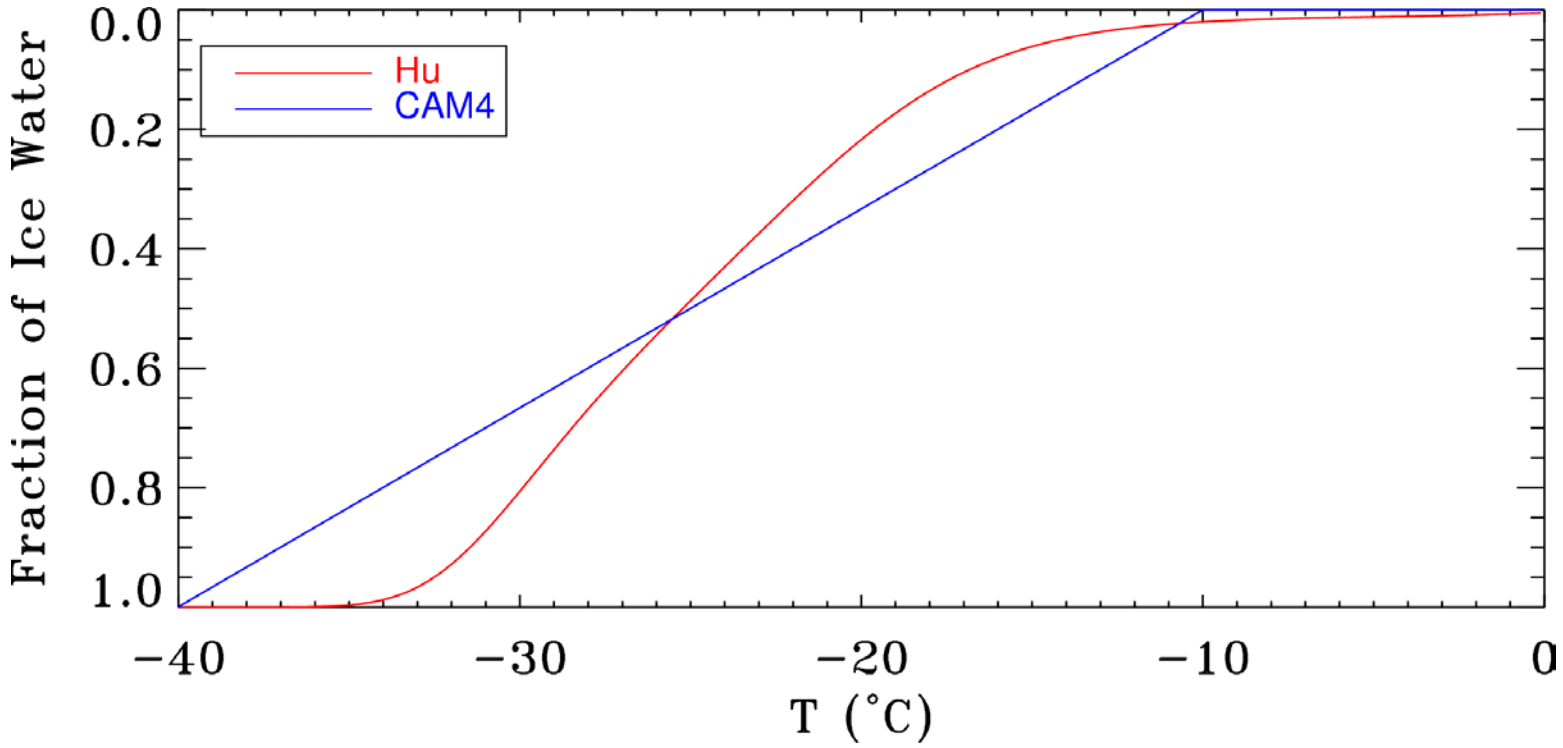
Summary

- CALIPSO provides unambiguous information about cloud thermodynamic phase, liquid water content and water droplet number concentration at CLOUD TOP
- CALIPSO data suggests that there are a lot more supercooled liquid water clouds over ocean and at high latitude
- Water cloud droplet number concentration at cloud top derived from CALIPSO are considerably low. The lowest number concentrations are around 10 per cc (most water clouds over ocean during winter-time)
- Liquid water content at cloud top, derived from CALIPSO, reduces slowly with cloud top height
- Applying the cloud phase – temperature relation from CALIPSO, CAM4 produces slightly more liquid water between -15^0C and -30^0C

Comparisons of cloud ice water content

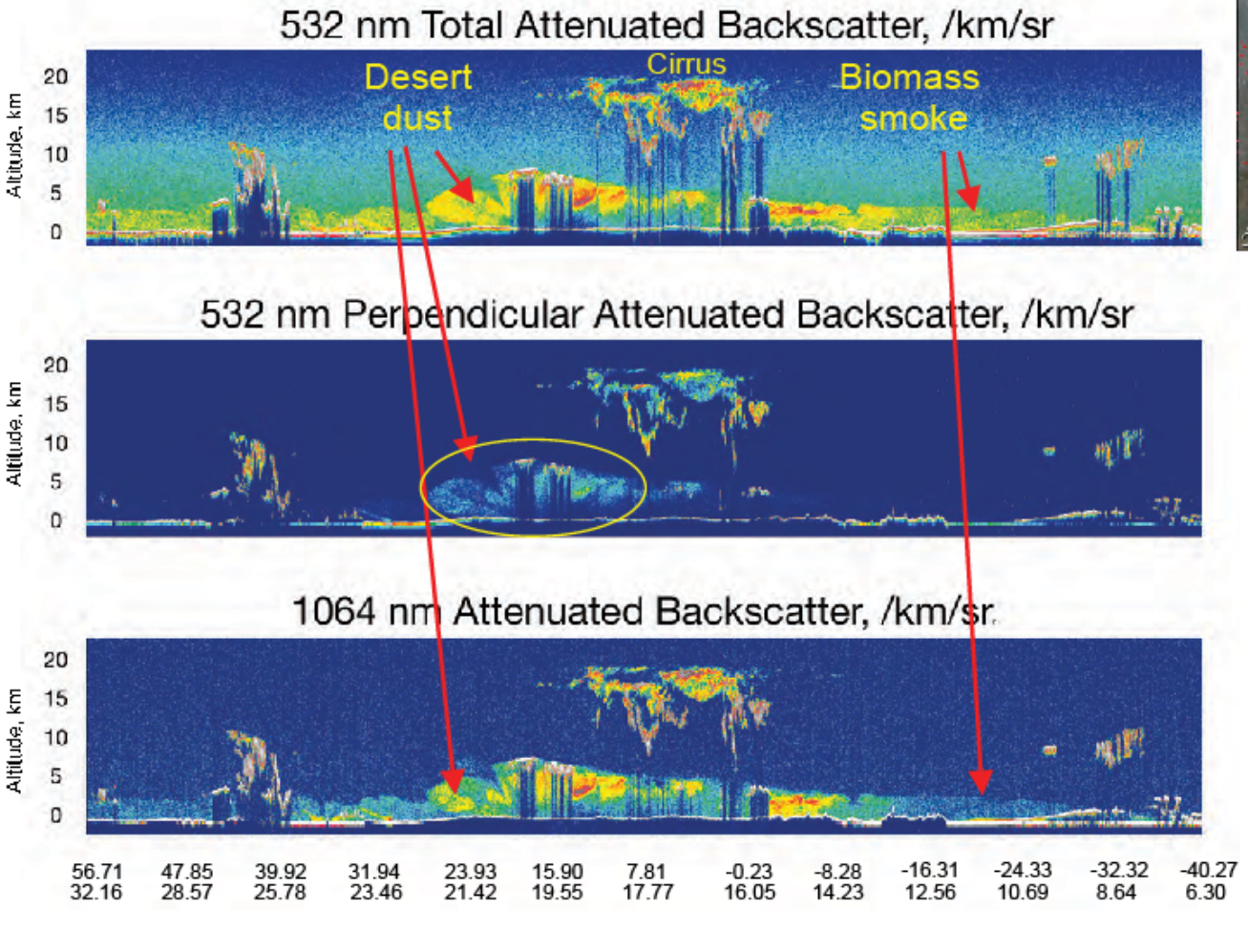


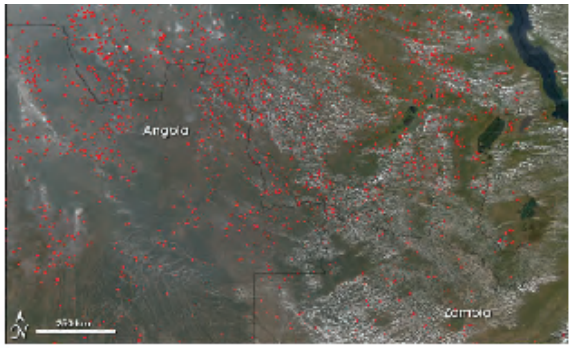
???


Hu
CAM4
Fraction of Ice Water
0.0
0.2
0.4
0.6
0.8
1.0
−40
−30
−20
−10
0
T (°C)

CALIPSO identifies cloud layers and aerosol layers accurately

June 9, 2006





Fire locations in southern Africa from MODIS, 6/10/06