Cirrus cloud ice water content in the uppermost troposphere:

Six years of observations from the Cloud and Aerosol Lidar with Orthogonal Polarization

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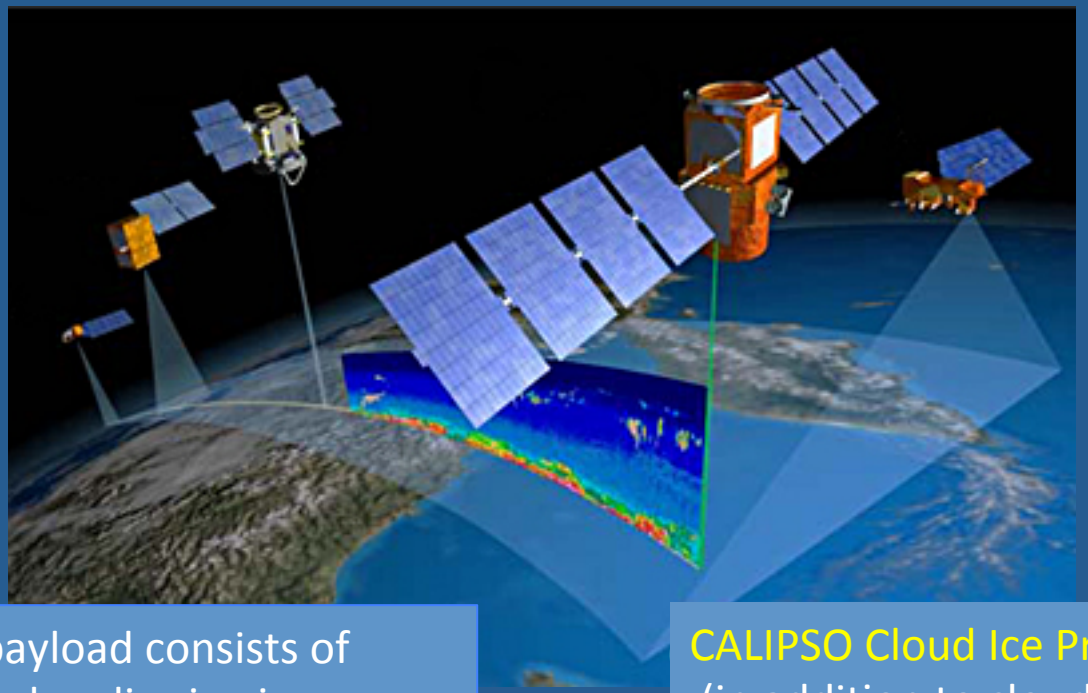
CALIOP on CALIPSO



The CALIPSO payload consists of three co-aligned nadir-viewing instruments:

- Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)
- Imaging Infrared Radiometer (IIR)
- Wide Field Camera (WFC)

Operational since June, 2006

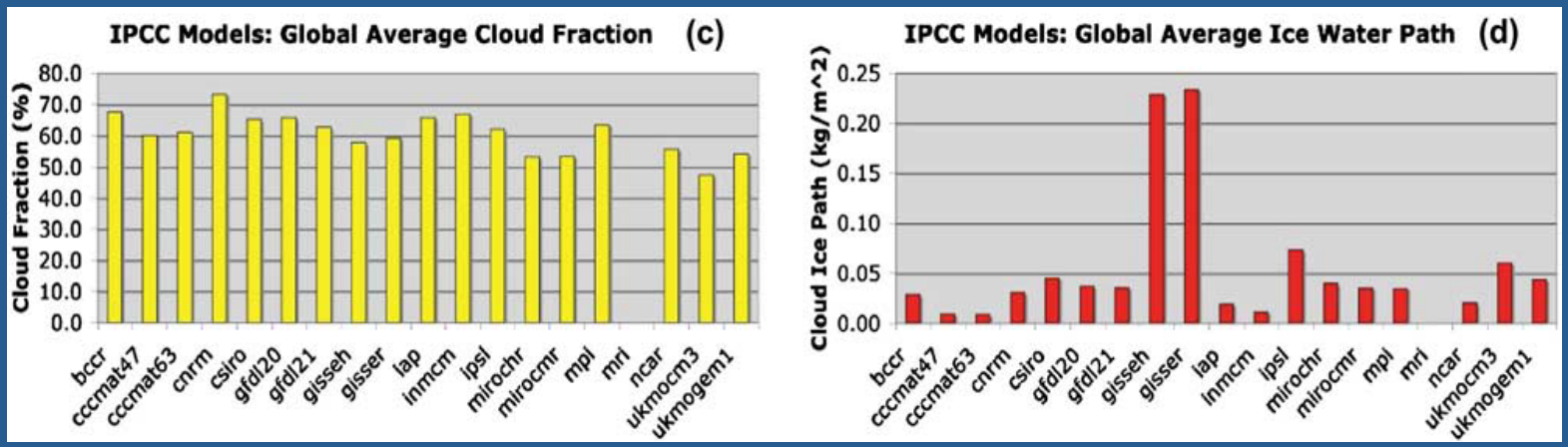
CALIPSO Cloud Ice Products:
(in addition to cloud top height and cloud fraction…)

- CALIOP Ice Water Content (IWC)
- CALIOP Ice Water Path (IWP)
- CALIOP Extinction
- CALIOP Optical Depth (OD)
- IIR Ice Water Path (IWP)
- IIR Optical Depth (OD)
- IIR Effective Diameter
- IIR Microphysical Parameter

Why Measure Cloud Ice Water Content from Satellite Instruments?

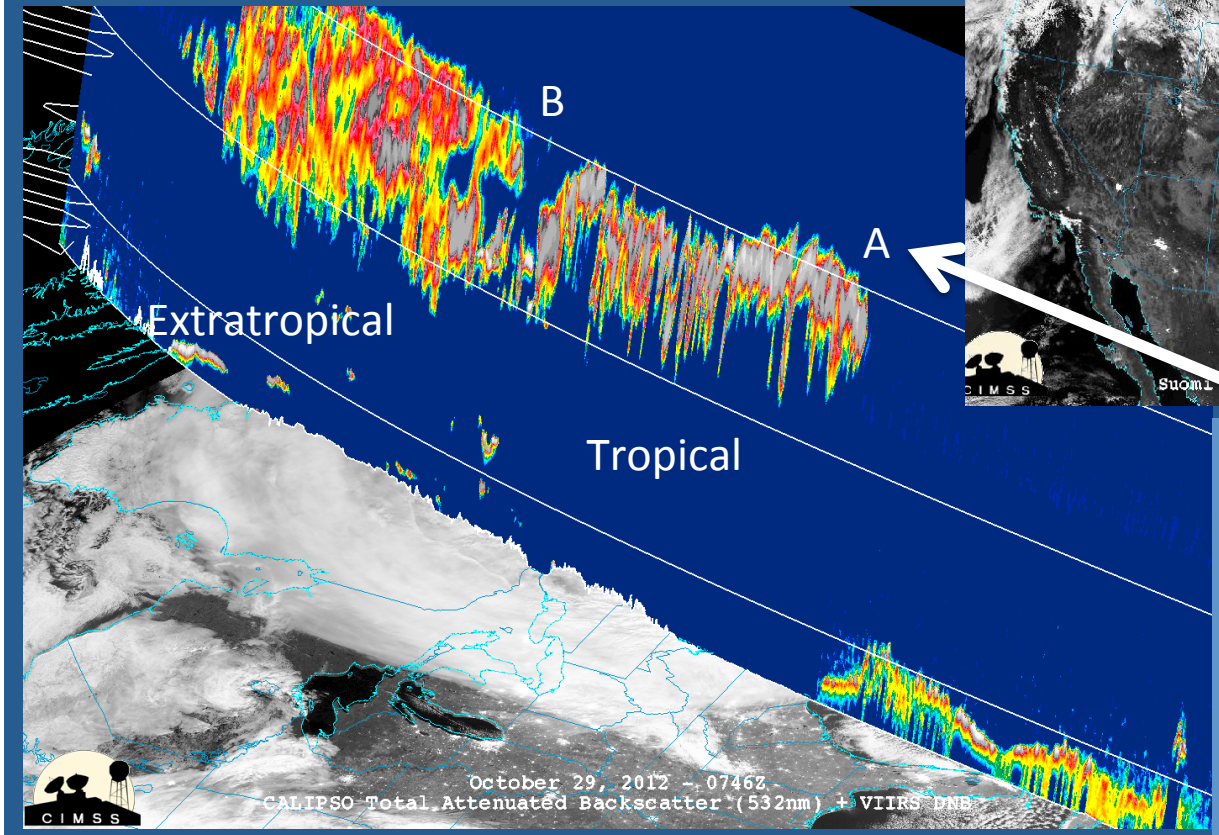
Clouds are currently the largest source of uncertainty in climate models

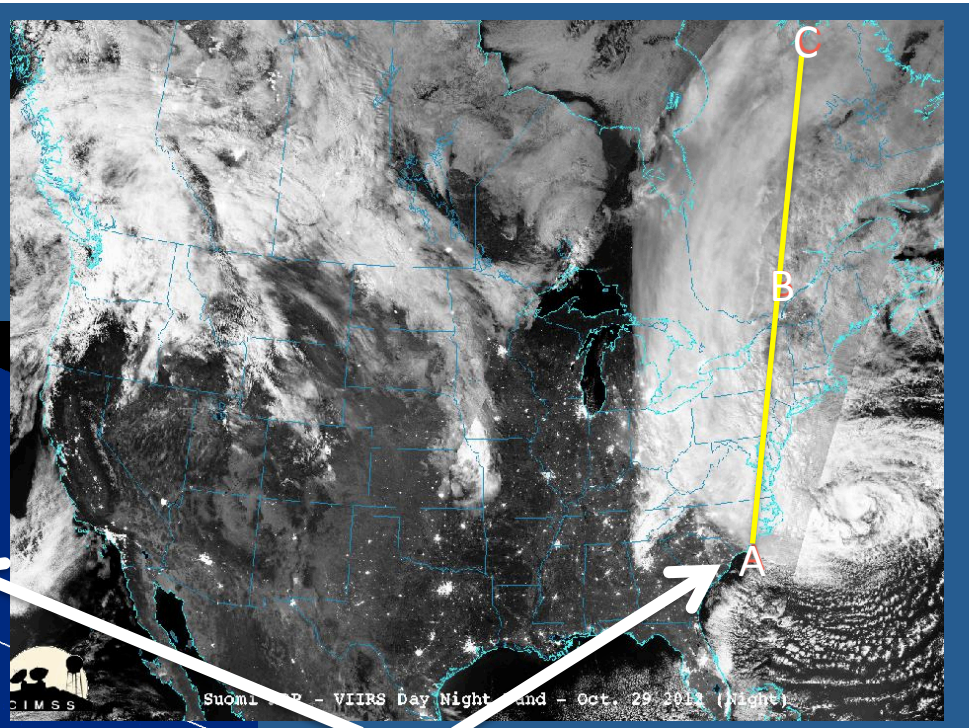
- Ice clouds affect the net amount of both latent & radiative heating
- Limited high-altitude aircraft-based measurements
- Climate model differences in IWC are largest in the upper troposphere
- Models range between ~ .03 - 15 x MLS IWC (Jiang, 2012)



IPCC model comparison from Waliser, 2009

Hurricane Sandy Nighttime Overpass Oct. 29, 2012





Images credit: William Straka III, U. Wisconsin, CIMSS

VIIRS Day Night Band and CALIPSO Lidar images of Sandy

- VIIRS image shows the massive extent of the storm.
- CALIOP attenuated backscatter shows the tropical vs extra-tropical cloud morphology.

CALIOP near real time Expedited data is now available with a 12 hour latency.
Browse images at: http://www-calipso.larc.nasa.gov/products/lidar/browse_images/
Expedited data files are released to the public, as of January, 2013

Building CALIOP Ice Water Content

1 – Retrieve extinction coefficients from measured attenuated backscatter coefficients.

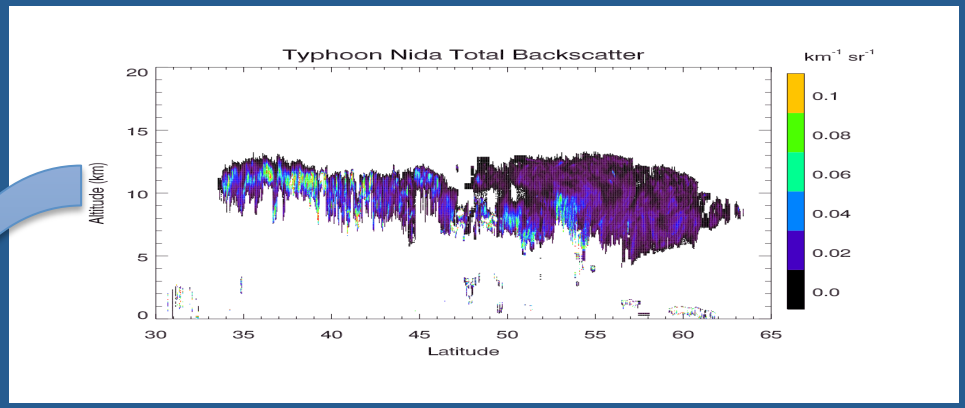
Young and Vaughan (2009); *J. Atmos. Oceanic Tech., 26*, 1105-1119, doi: 10.1175/2008JTechA1221.1

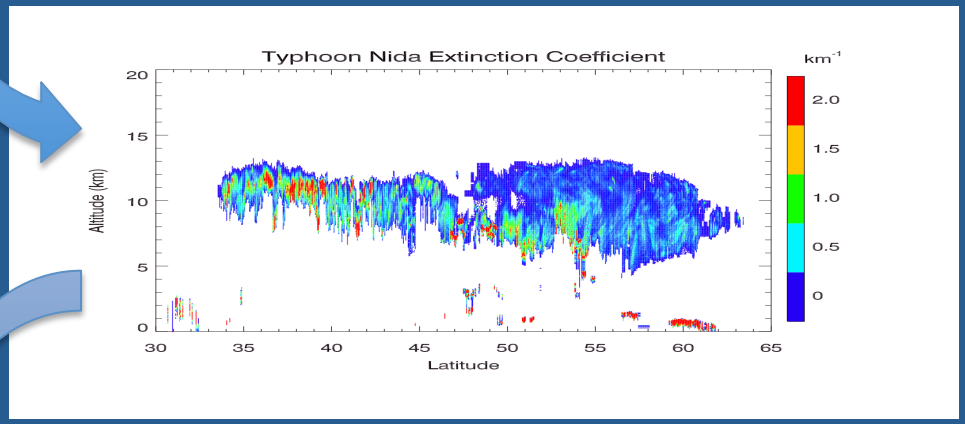
2 – Parameterize ice water content using *in situ* IWC relationship with extinction.

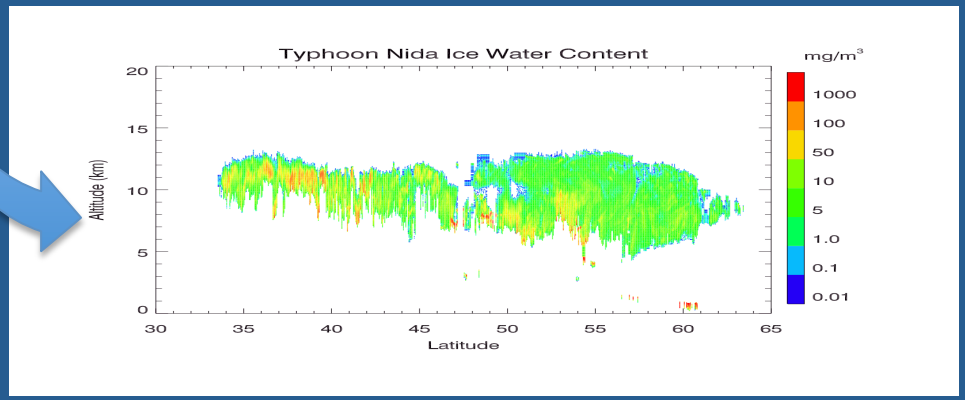
Heymsfield, Winker and van Zadelhoff (2005) *Geophys. Res. Lett., 32*, L10807, doi:10.1029/2205GL022742.

Version 3: $IWC = a\sigma^b$, a=119, b=1.22

Version 4 will include temperature-dependent coefficients a and b





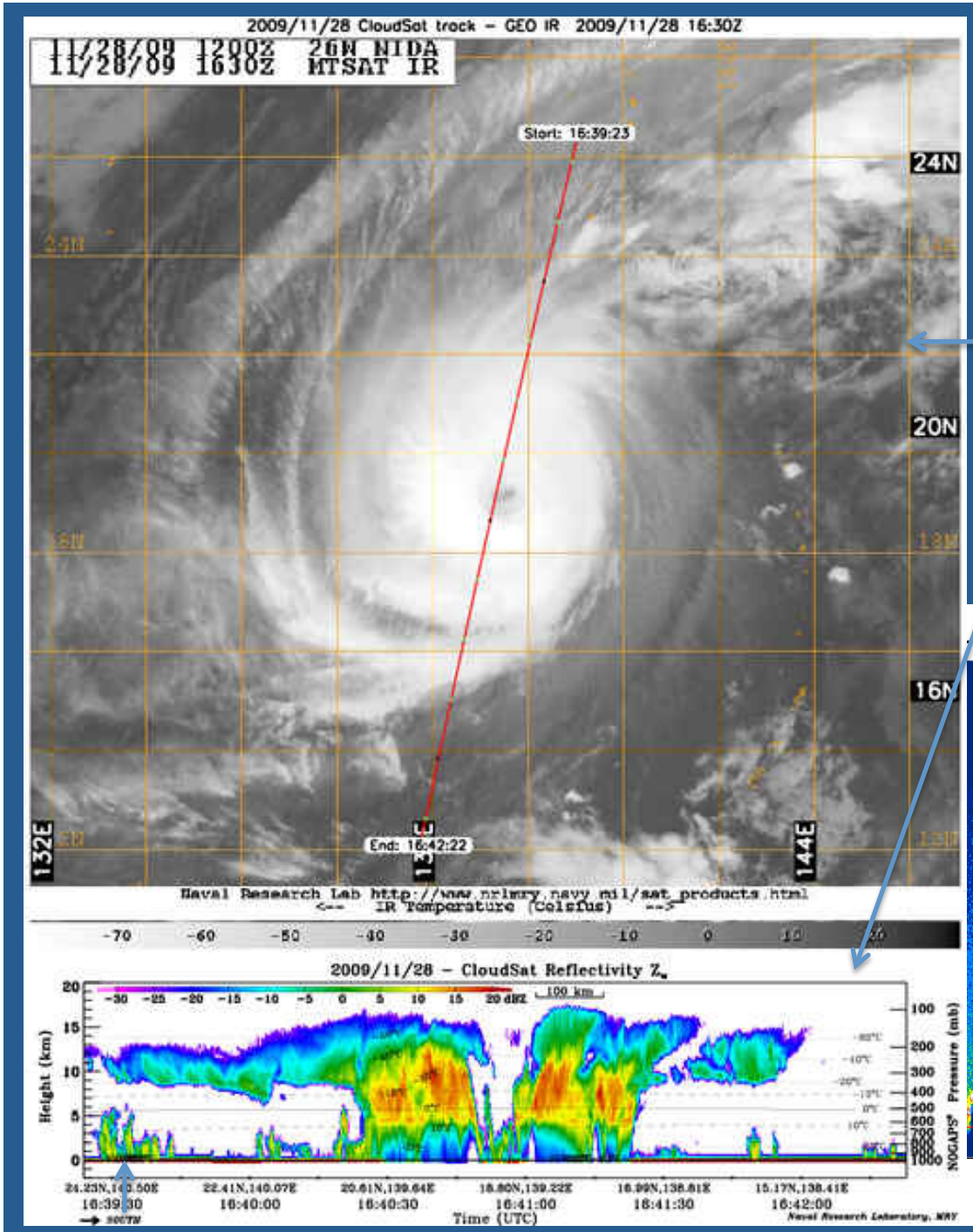


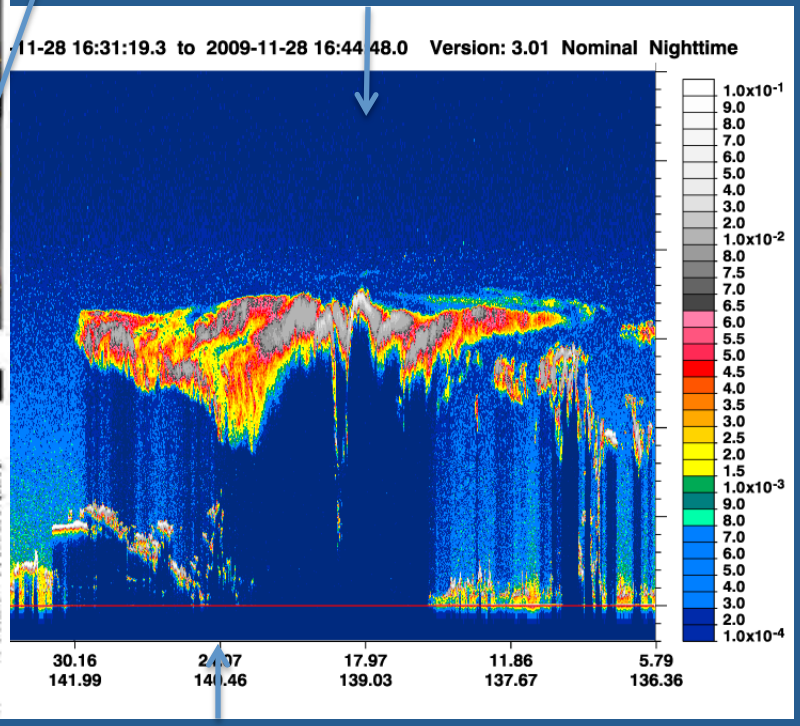
Three Views of Typhoon Nida November 28, 2009

MODIS IR

CPR Reflectivity

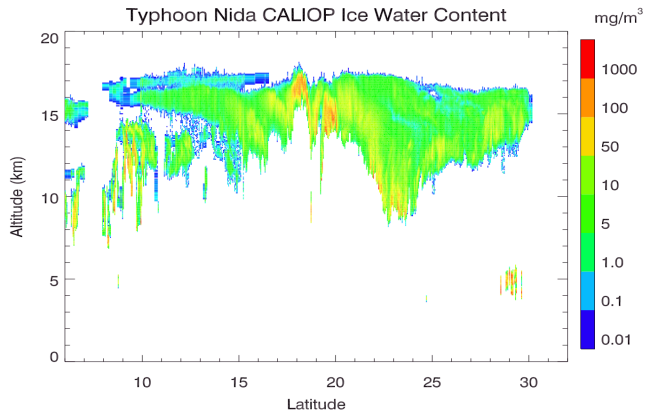
CALIOP Attenuated Backscatter



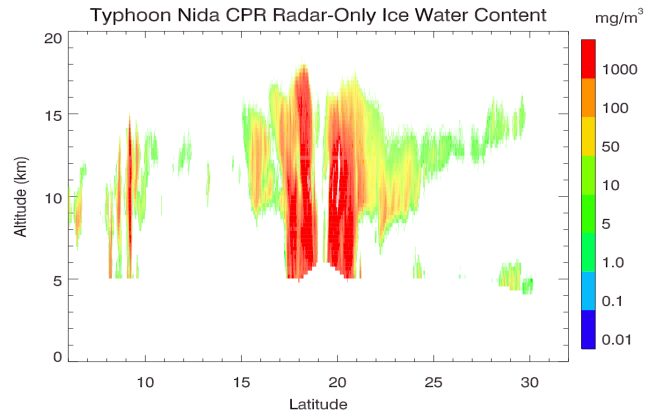


Typhoon Nida Active Sensor Ice Water Content Comparison

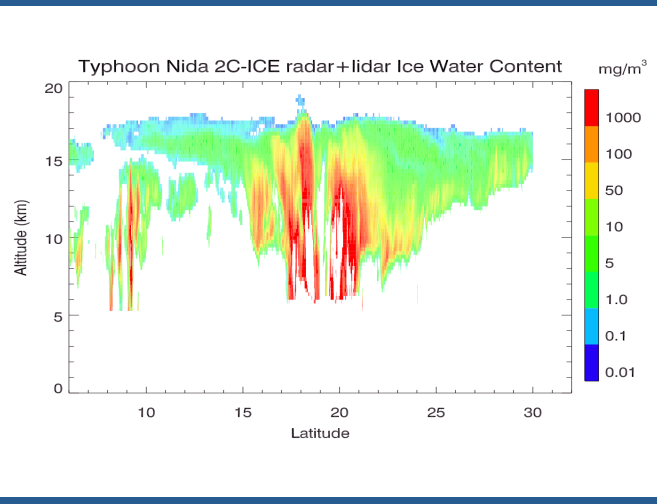
CALIOP – Lidar Only



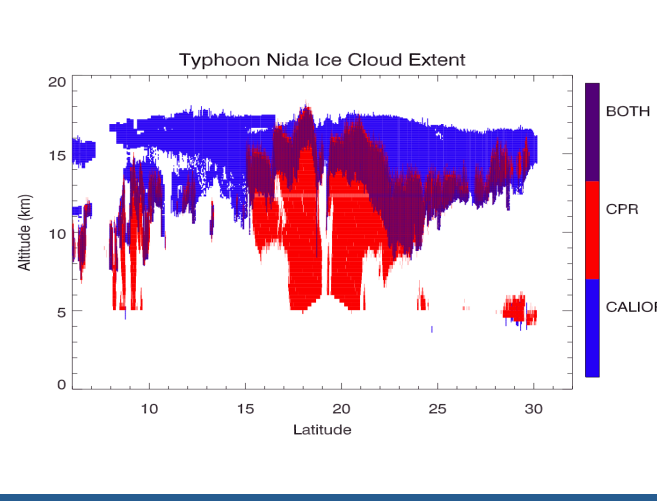
CPR – Radar Only



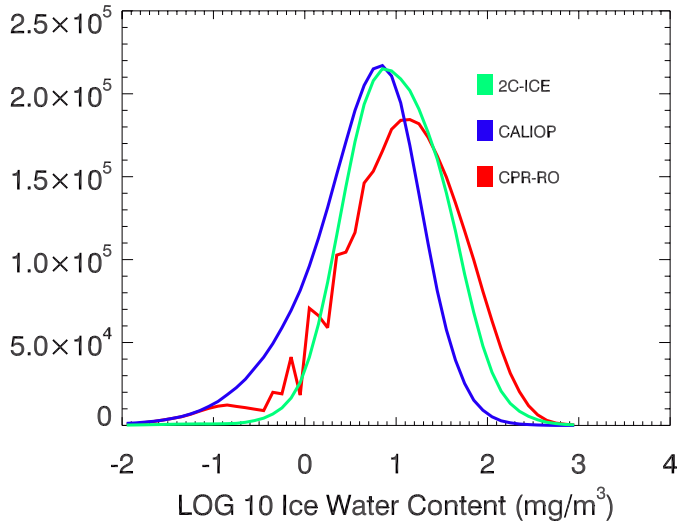
2C-ICE – Lidar + Radar

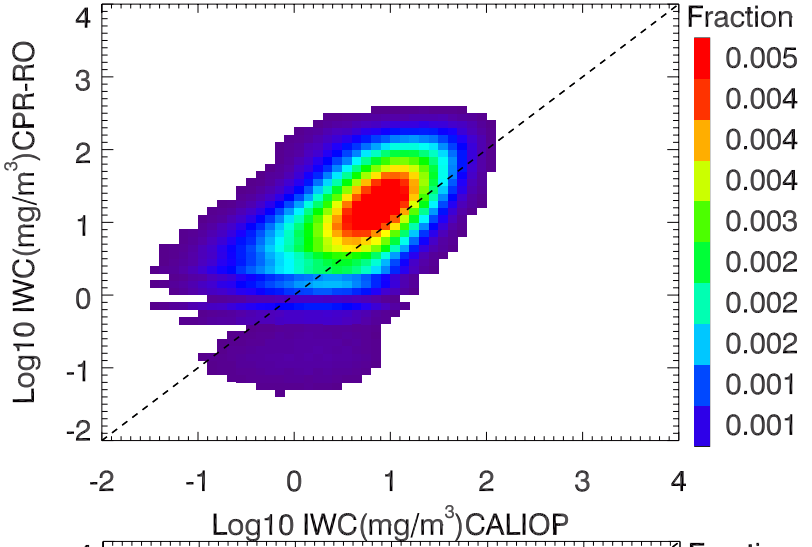


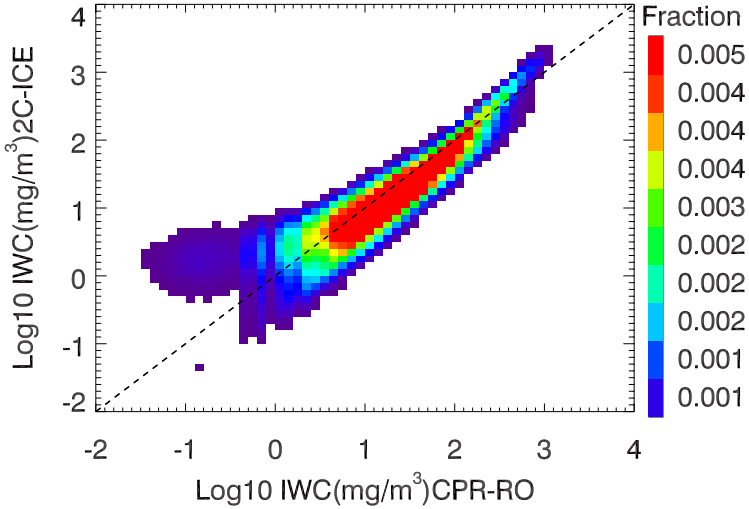
Cloud-top Height Comparison

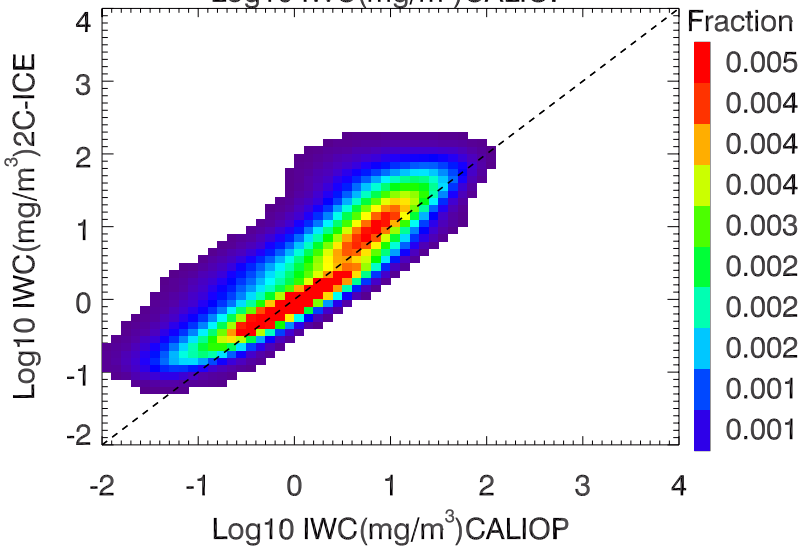


Three-Way Comparison of CALIOP, CPR and 2C-ICE (combined) IWC, January, 2008

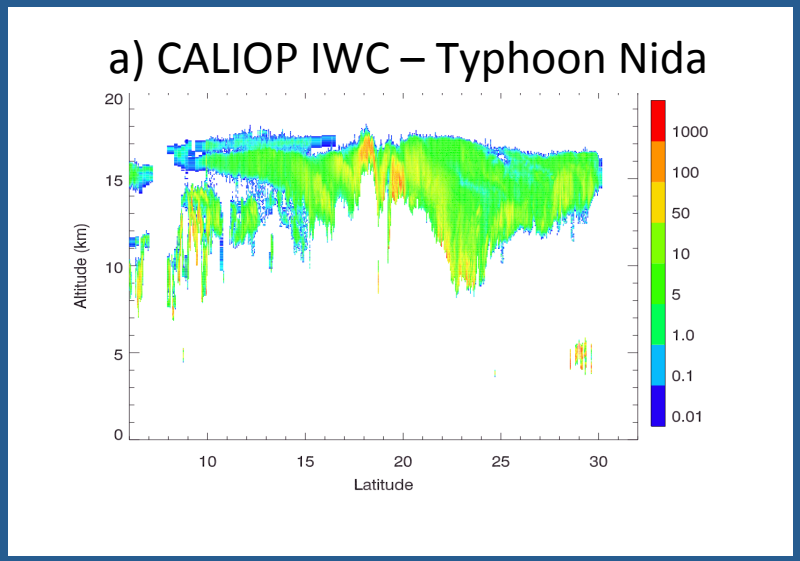


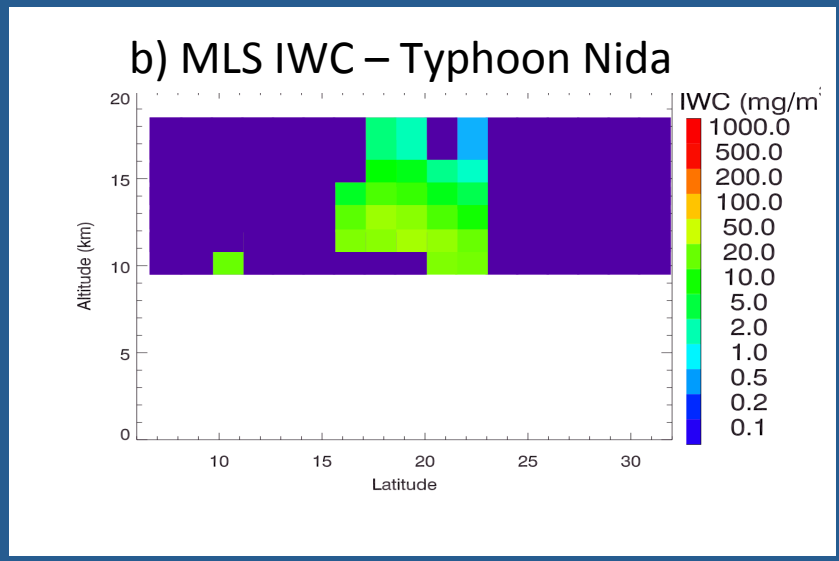


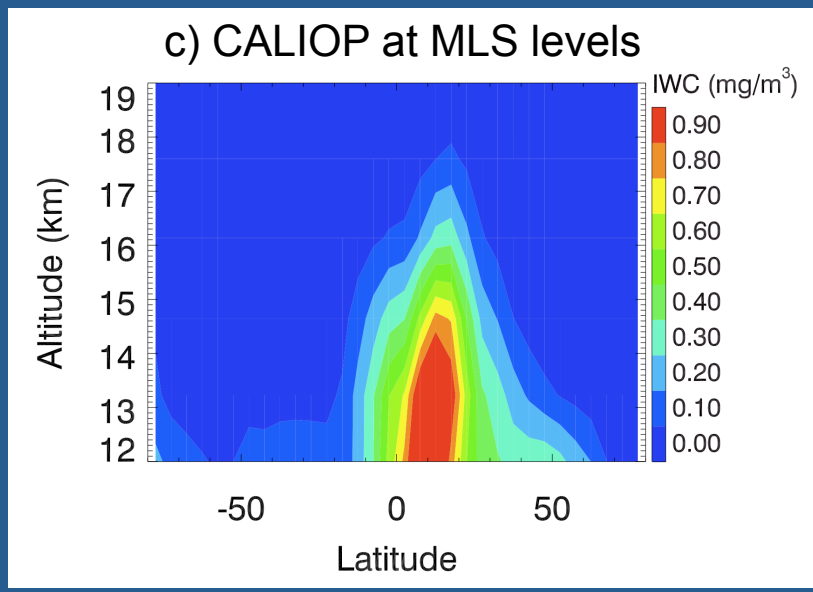


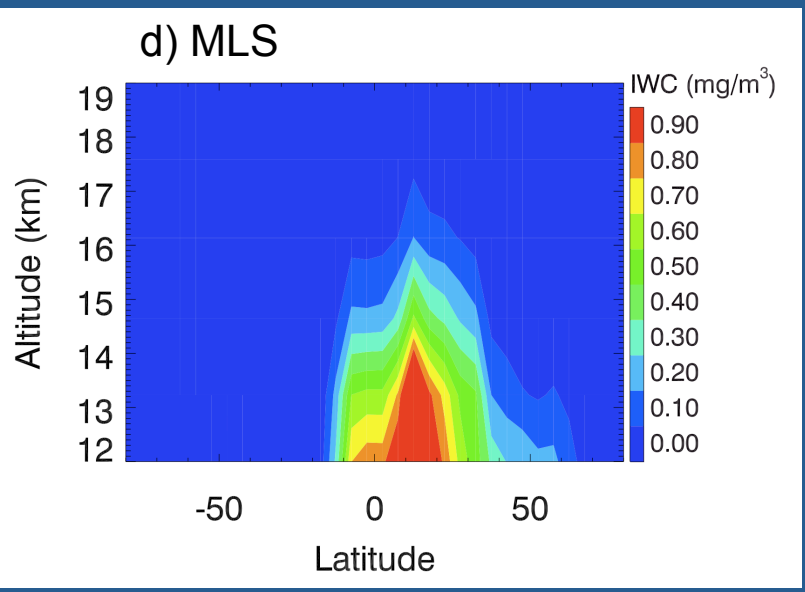


CALIOP and Microwave Limb Sounder Ice Water Content Comparisons

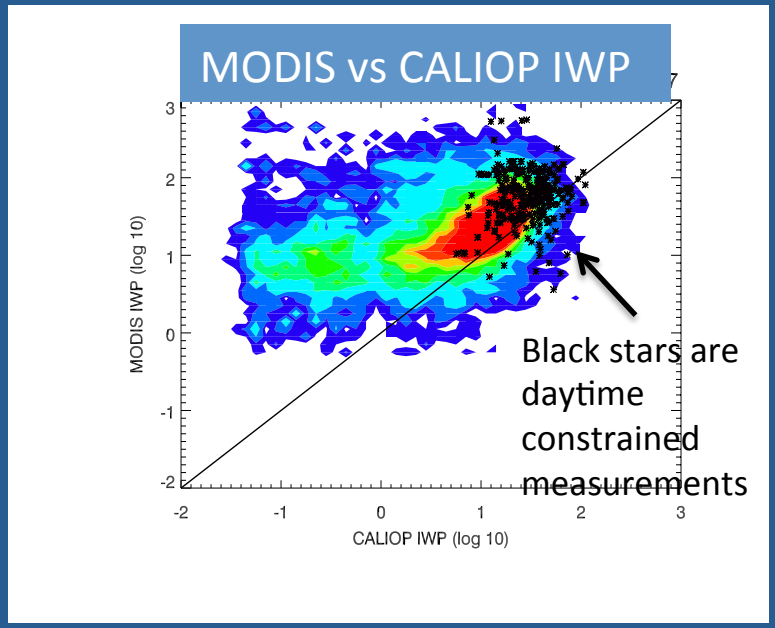






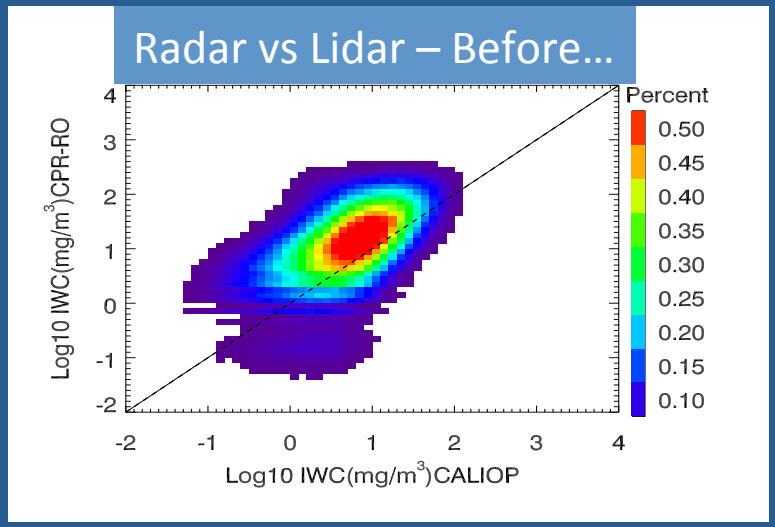


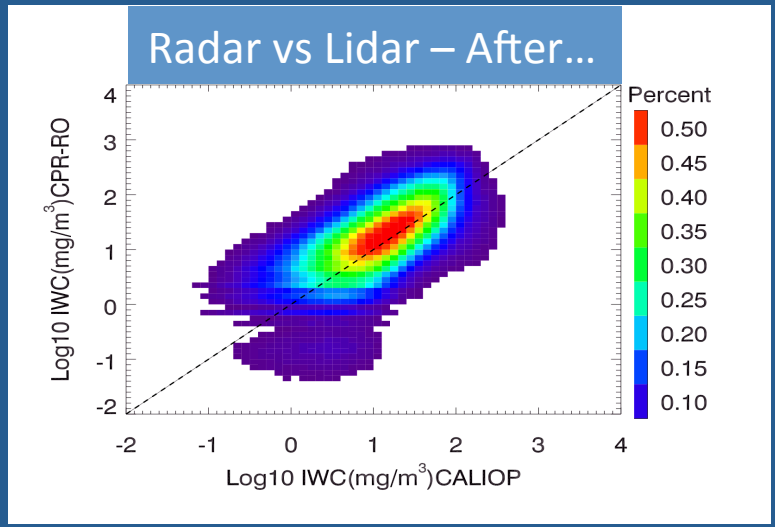
Preliminary Comparison with MODIS (Collection 5) IWP



Another success story from the A-Train:

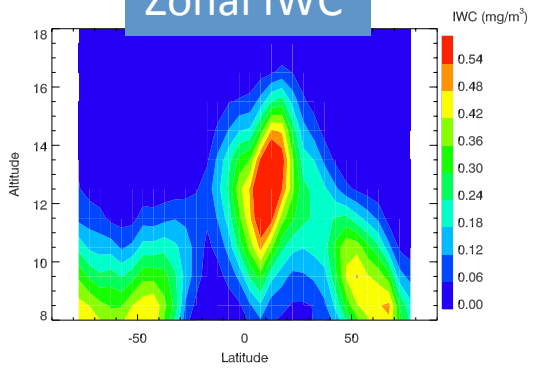
Comparison of MODIS Collection 5 and CALIOP cloud optical depths using the CALIPSO IIR as a transfer standard motivates a better MODIS retrieval and improved CALIOP OD and IWC.





CALIOP IWC Distribution and Uncertainties:

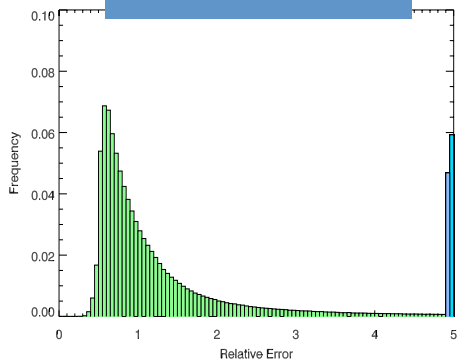
Zonal IWC



CALIOP IWC Sensitivity:

- Daytime 0.1 mg/m^3
- Nighttime 0.02 mg/m^3

Relative Error



CALIOP IWC Uncertainty:

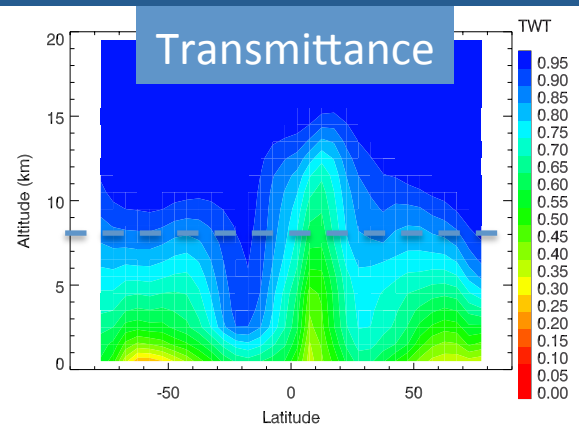
- Extinction retrieval ~ 20-70%

(Young, Vaughan, Kuehn and Winker (2012); J. Atmos. Oceanic Technol., doi: 10.1175/JTECH-D-12-00064.1.)

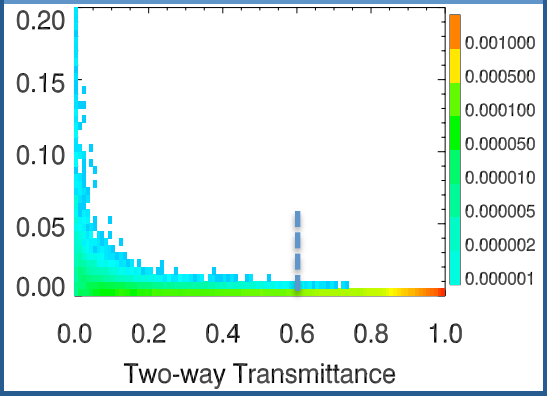
- IWC parameterization ~ 30-80%

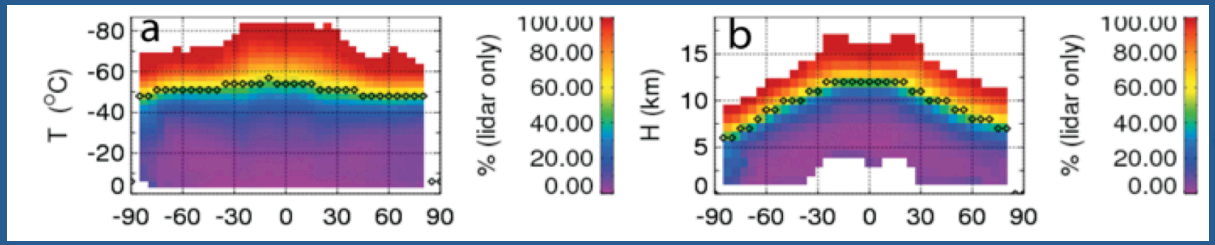
based on *in situ* observations (*particle shattering adds a bias)*

Transmittance



IWC Uncertainty fcn TWT



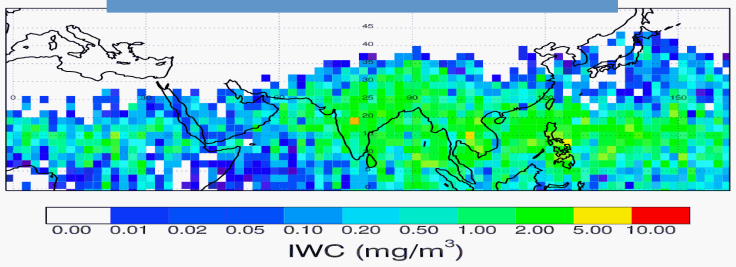


Fraction of lidar-only measurements in a combined lidar-radar cloud ice retrieval

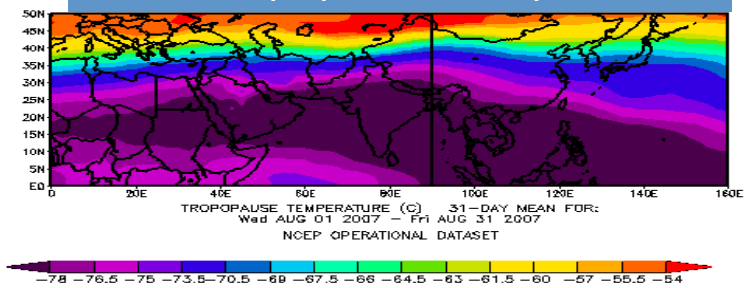
Image to be published in Heymsfield et. al., in preparation

CALIOP Observations of the Asian Monsoon Cycle

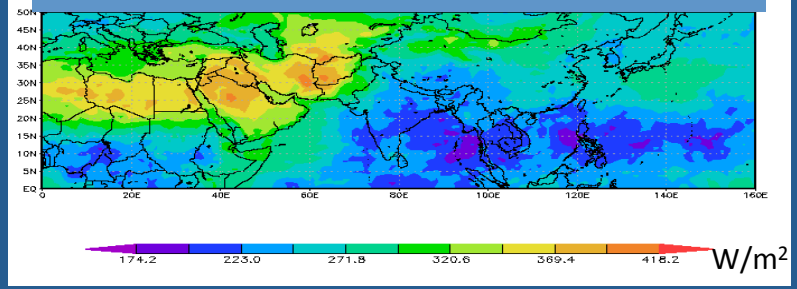
08/2007 CALIOP 15 km



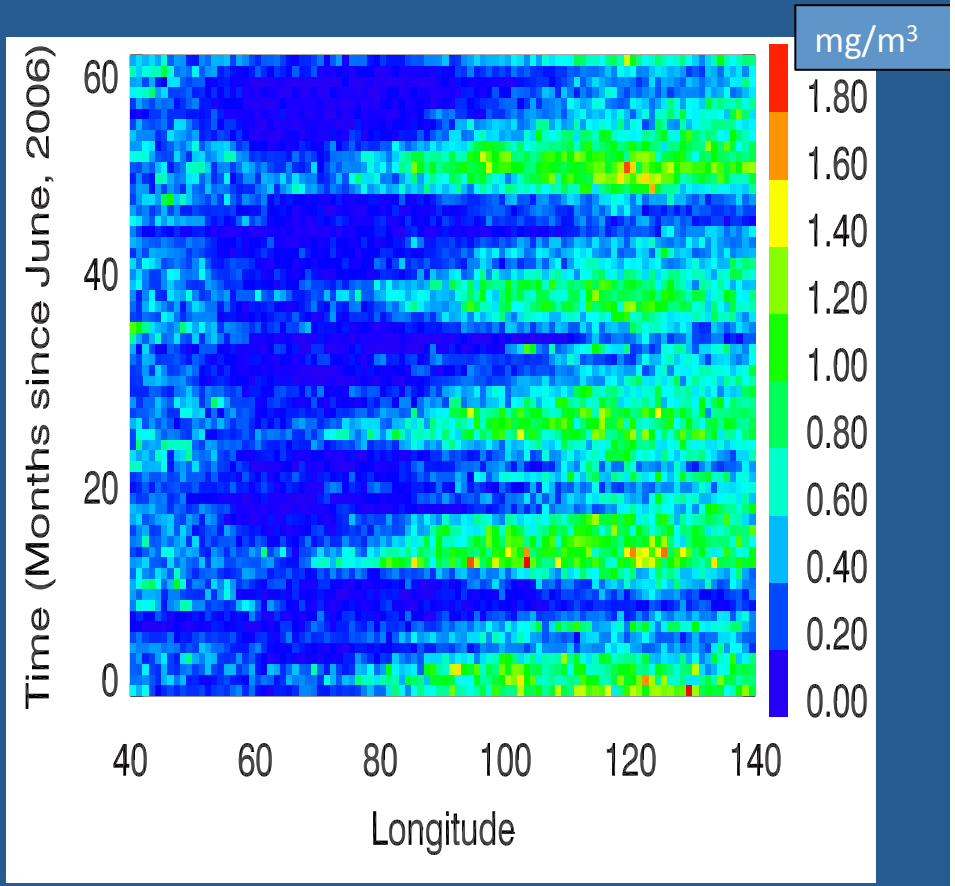
NCEP Tropopause Temperature



AIRS Outgoing Longwave Radiation



Upper Tropospheric Ice Water Content: Asian Monsoon Cycle



Summary

- CALIOP (CALIPSO lidar) provides a unique 3-D global view of mid and high-altitude tropical cloud ice. (And at lower altitudes in the subtropics & poles.)
- CALIOP data is now available as an "expedited" data set in near-real time.
- Ice water content is a reliable product. We are working hard to validate our cloud data products by comparison with *in situ* and other satellite data sets.
- Cloud ice water content measurement accuracy is likely limited by natural variability in cloud microphysical properties.
- Creation of Version 4 of CALIOP data products is underway. This includes:
  - More accurate calibration of attenuated backscatter measurements
  - Improved cloud optical depth retrievals
  - More accurate cloud ice water content parameterization

Many thanks to our sponsors at NASA and CNES