

# Four Blind Men Touching the Elephant: CALIOP, CloudSat, MLS and MODIS look at Ice Clouds in the Upper Troposphere



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Photo Credit: "Nowthatsnifty.com"

# About the Parable of the Blind Men and the Elephant:



Anekāntavāda (Devanagari: अनेकान्तवाद) is one of the most important and fundamental doctrines of Jainism. It refers to the principles of pluralism and multiplicity of viewpoints, the notion that truth and reality are perceived differently from diverse points of view, and that *no single point of view is the complete truth*.

Source: Wikipedia

# Why Measure Cloud Ice Water Content from Satellite Instruments?

*Clouds feedbacks are currently the largest source of uncertainty in climate models*

- Ice clouds effect the net amount of latent and radiative heating
- Limited high-altitude aircraft-based measurements
- Climate model differences in IWC are largest in the upper troposphere
- Models range between  $\sim 3\%$ - $15\times$  MLS IWC(Jiang, 2012)



# IWC Basics

$$IWC = \rho_{ice} V_p = \rho_{ice} \frac{4}{3} \pi \int r^3 N(r) dr$$

$$\sigma = 2A_p = 2\pi \int r^2 N(r) dr$$

$$r_{eff} = \frac{\int r^3 N(r) dr}{\int r^2 N(r) dr} = \frac{3 IWC}{2 \rho_{ice} \sigma}$$

CALIOP Empirical Relationship:

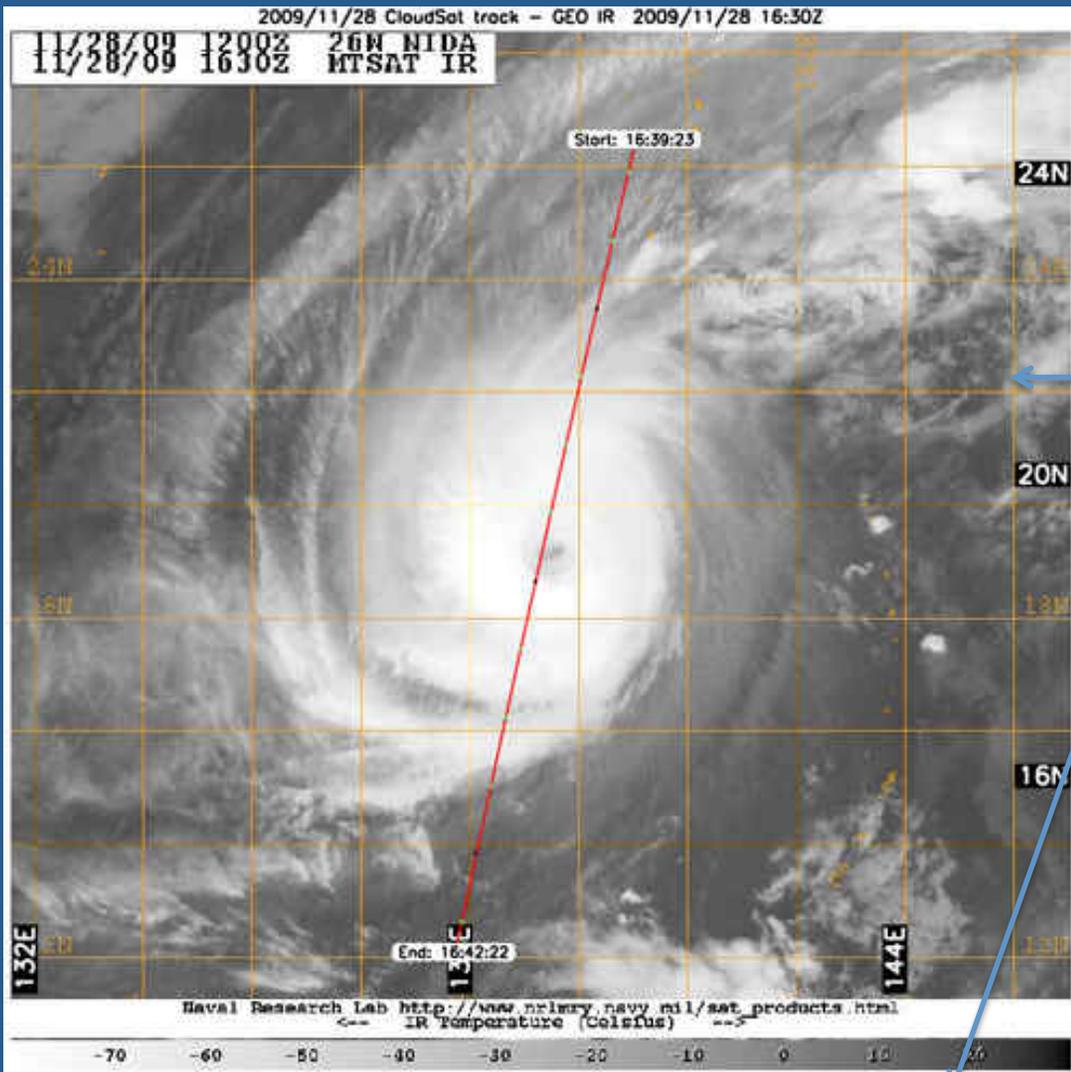
$$IWC = a\sigma^b, a=119, b=1.22$$



CALIOP IWC Uncertainties (OM):

- Attenuated backscatter coefficient measurement ~ 5%
- Estimated GEOS (number density) ~ 5%
- Cirrus extinction to backscatter coefficient ratio (AKA “lidar ratio”) ~ 30% (or higher for very thin Ci)
- Multiple scattering ~ 10%
- Attenuation (Overhead OD) ~ 0-200%, fcn(OHOD)
- IWC parameterization ~ 70-100%

Photo Credit: Preston Wells

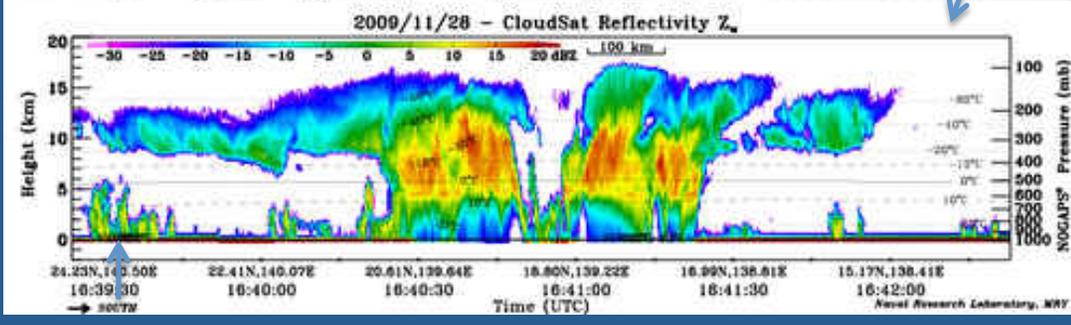
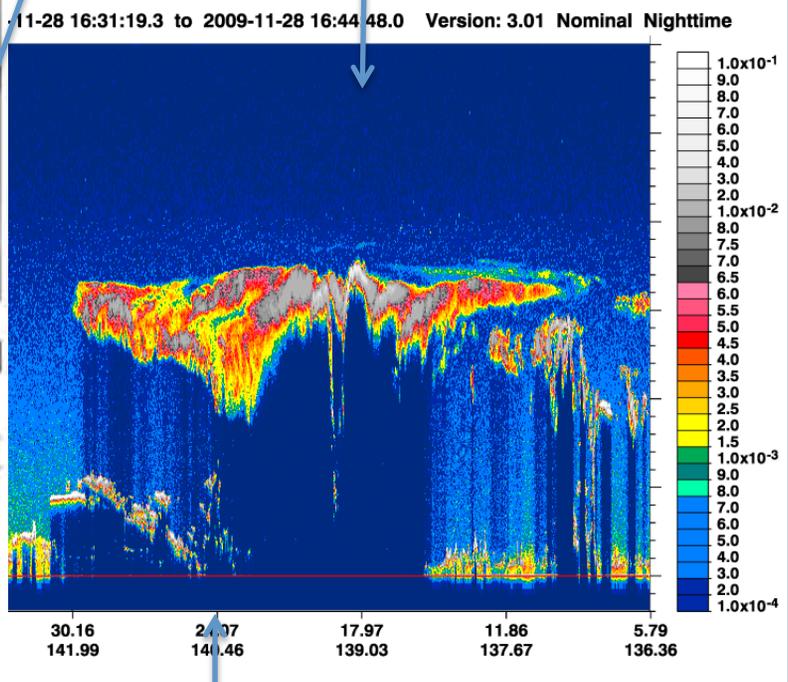


# Three Views of Typhoon Nida November 28, 2009

MODIS IR

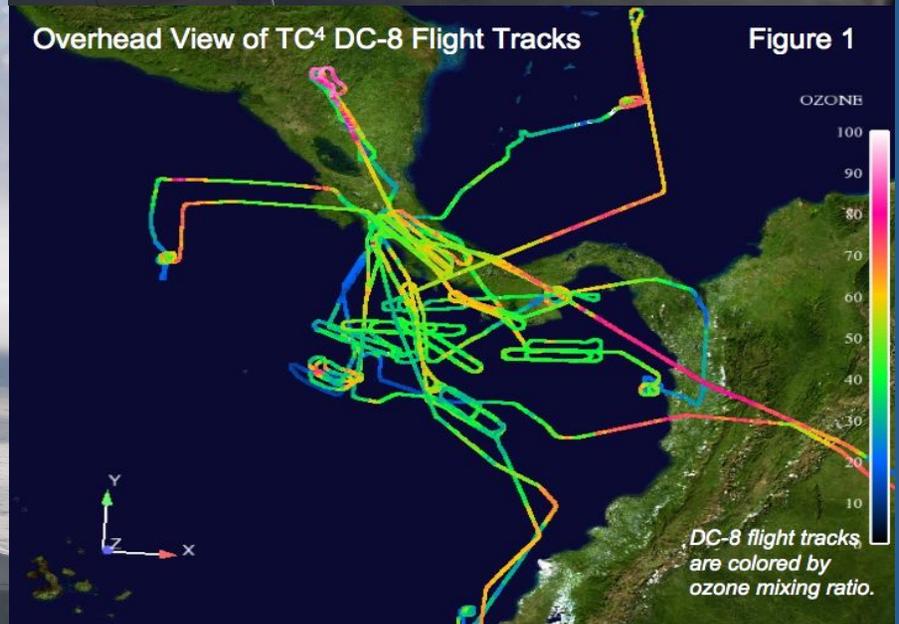
CPR Reflectivity

CALIOP Attenuated Backscatter





# Some Comparisons from TC<sup>4</sup>, July-August, 2007

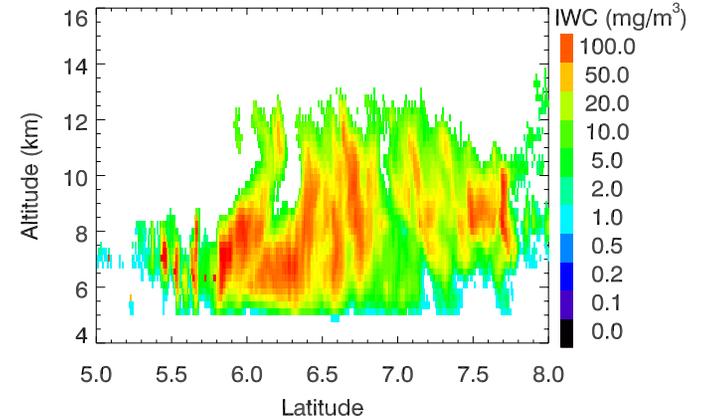
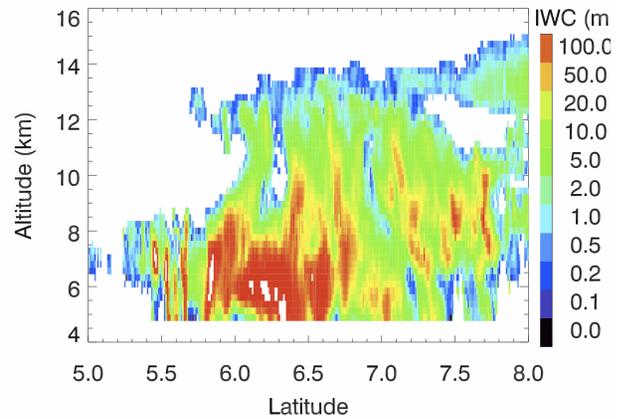
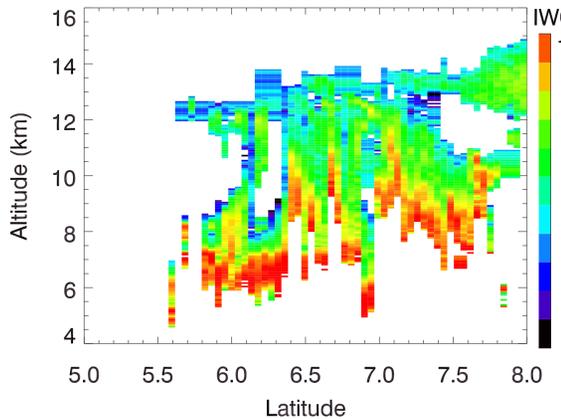


# CASE Study From TC<sup>4</sup>, August 5, 2007

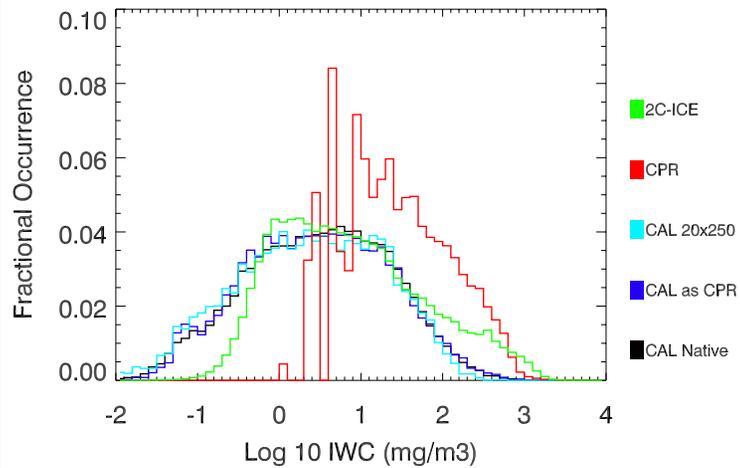
CALIOP

2C-ICE

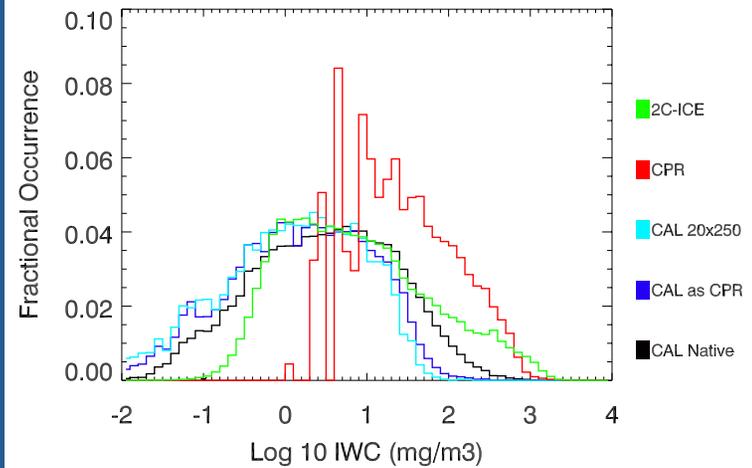
CPR



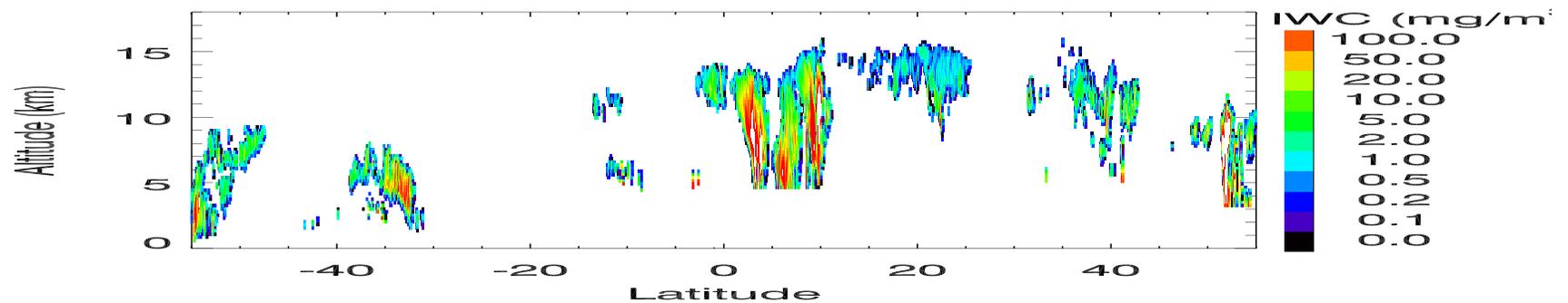
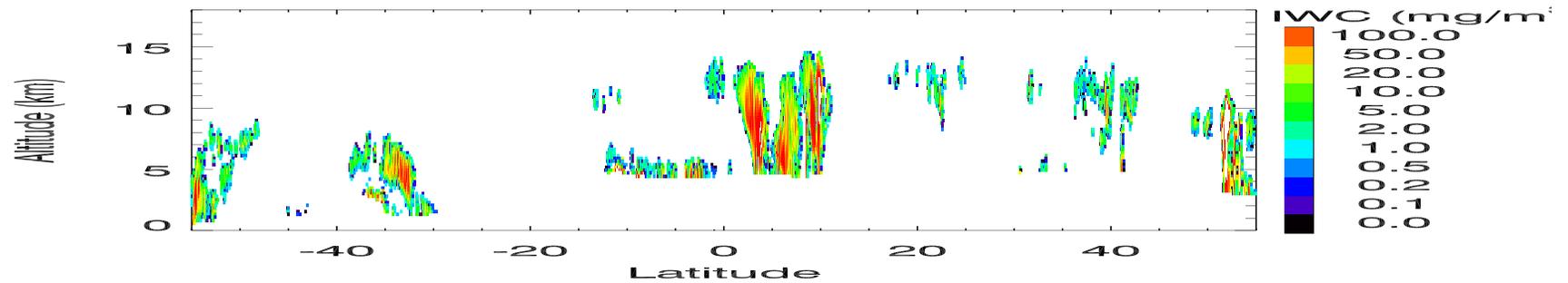
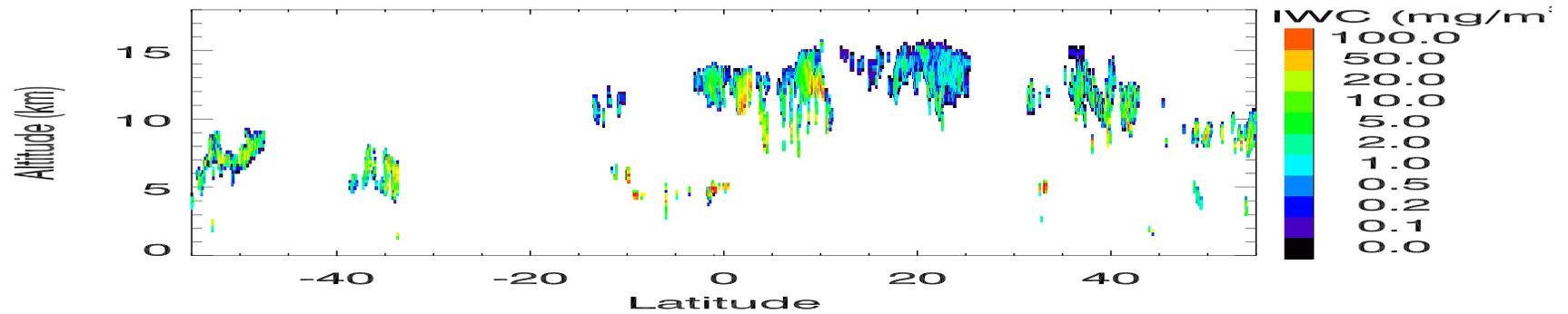
August 5, 2007, IWC pdf - Daytime 06763



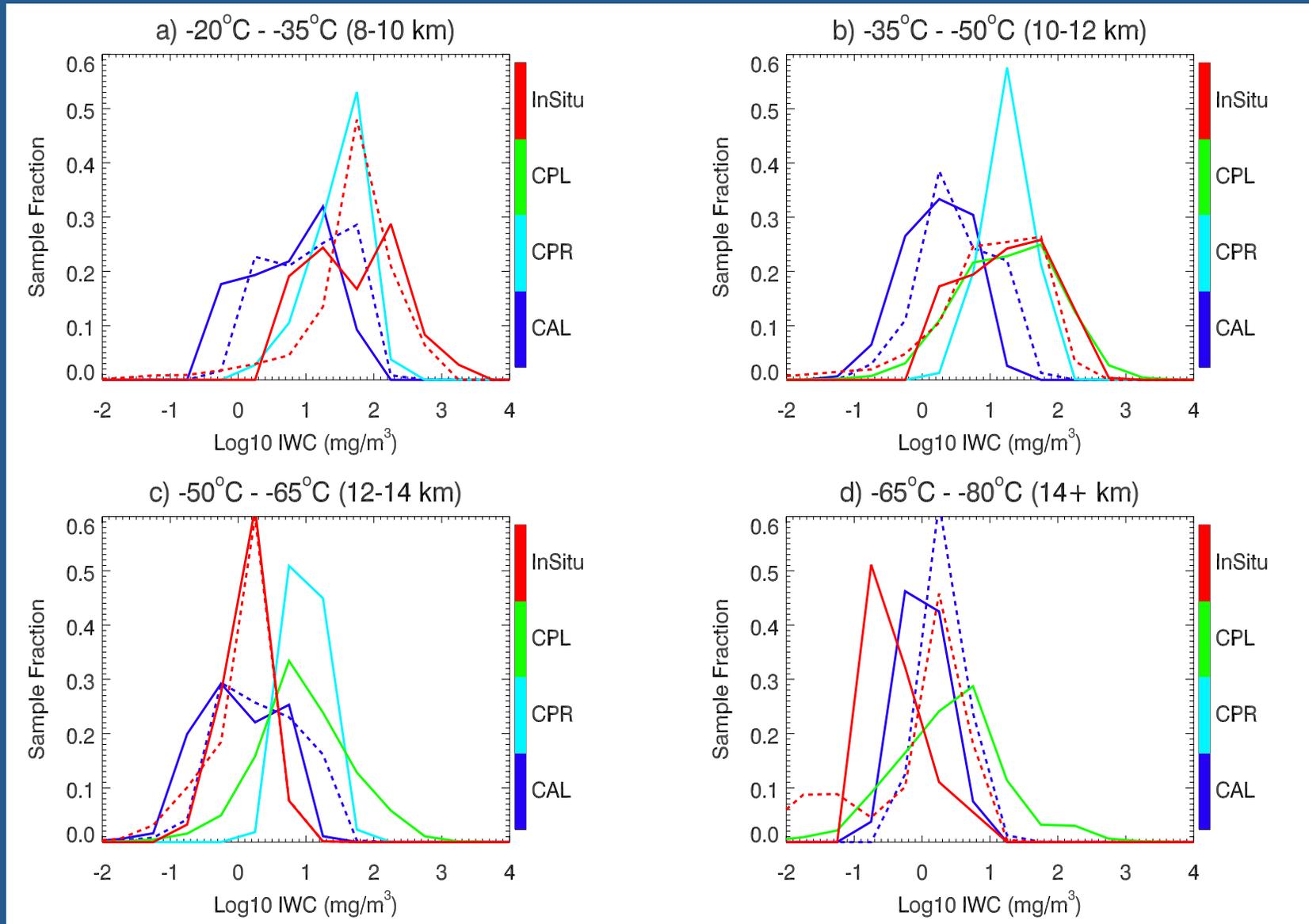
August 5, 2007, IWC pdf - Daytime 06763



# Three Ice Water Content Sections, August 5, 2007, 55S – 55N

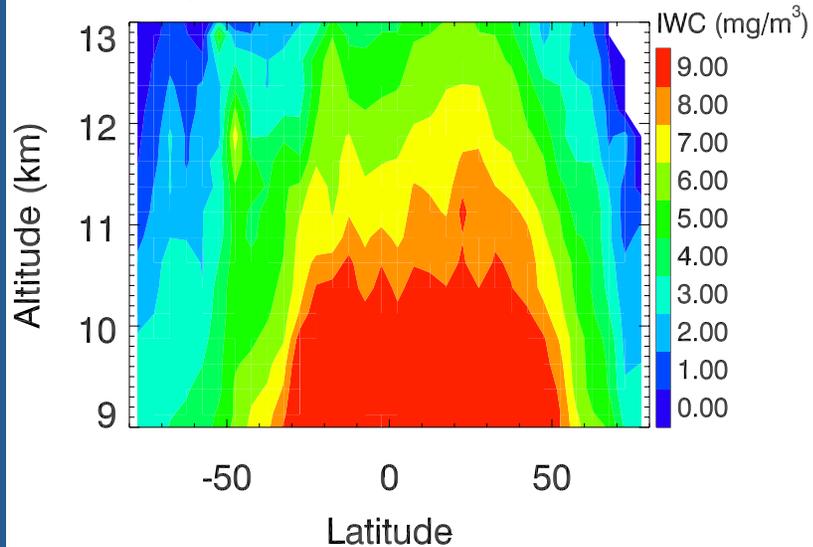


# TC<sup>4</sup> Measurement Histograms: *In situ*, CPR, CALIOP and CPL

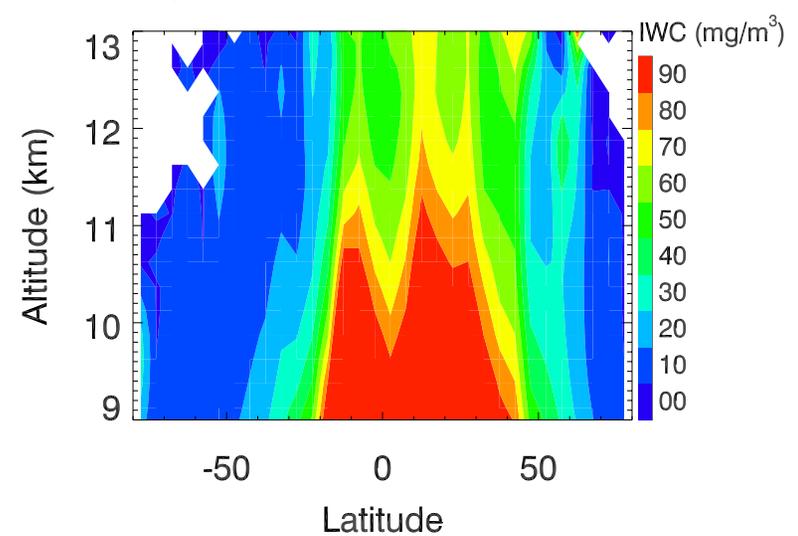


# Comparison of Zonal Averages (August, 2007)

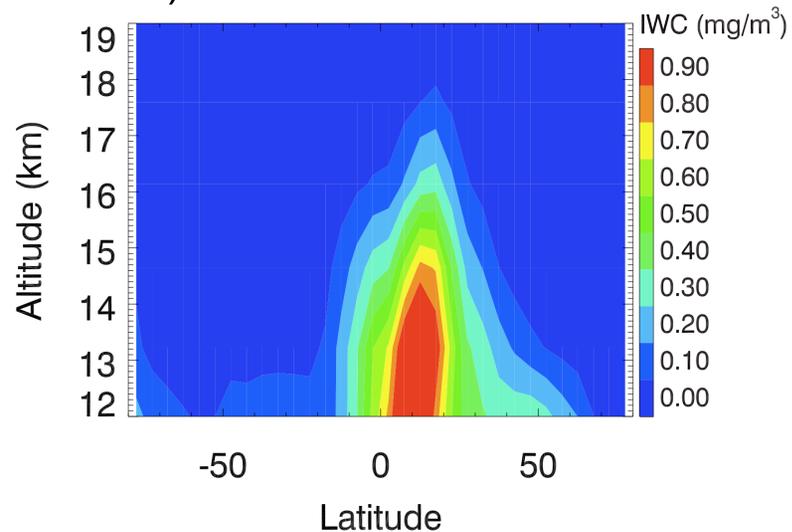
a) CALIOP



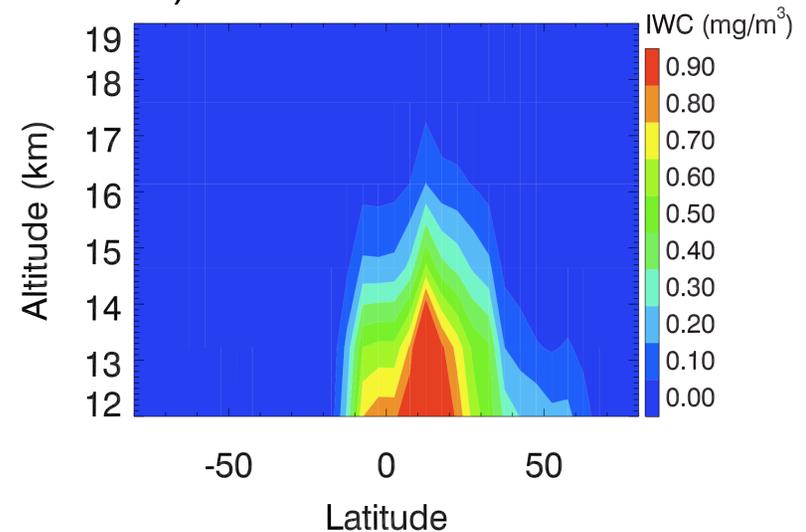
b) CloudSat



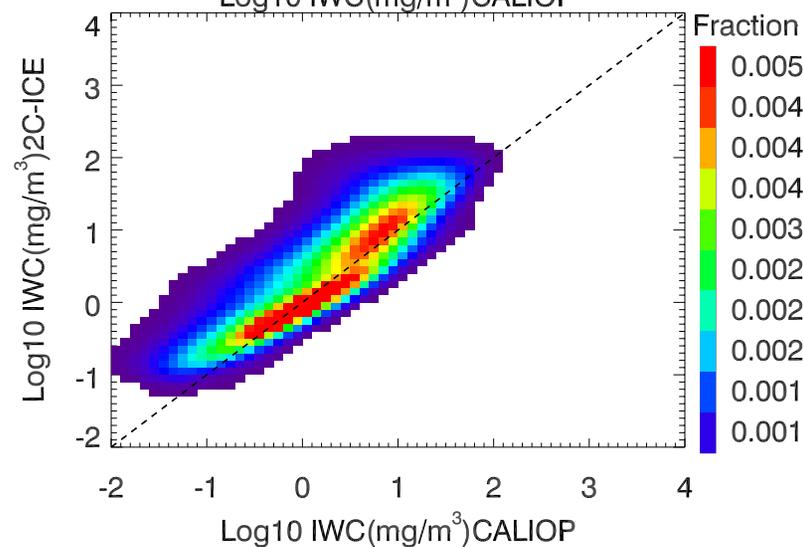
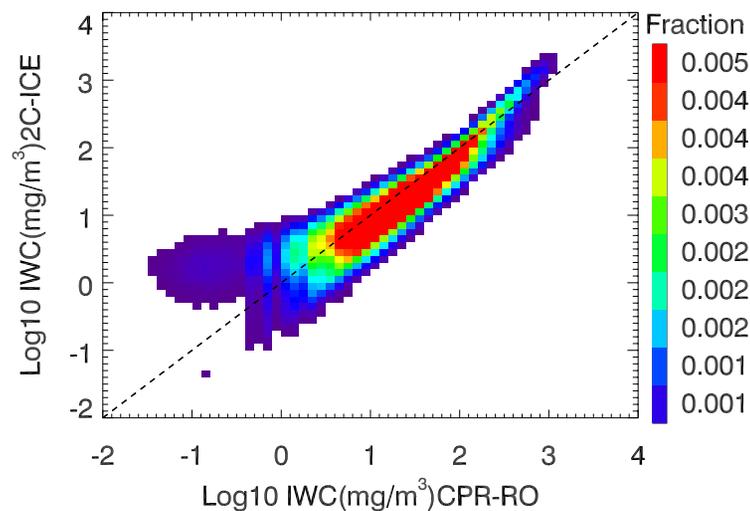
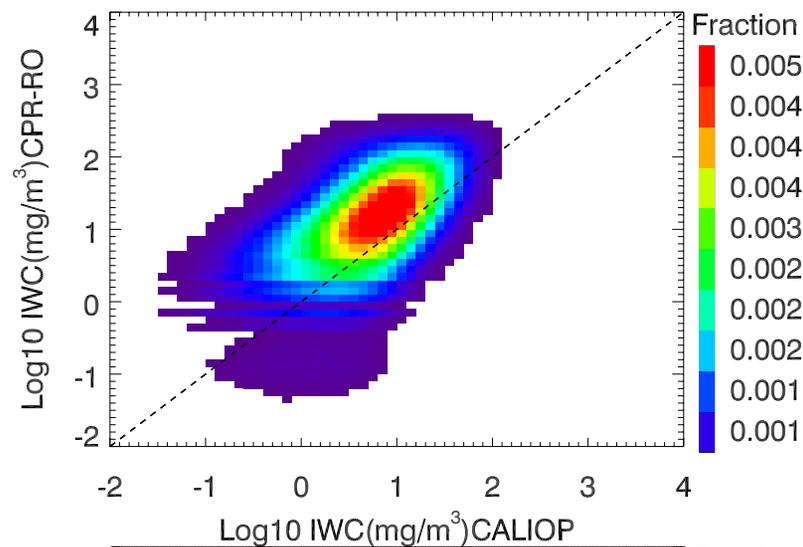
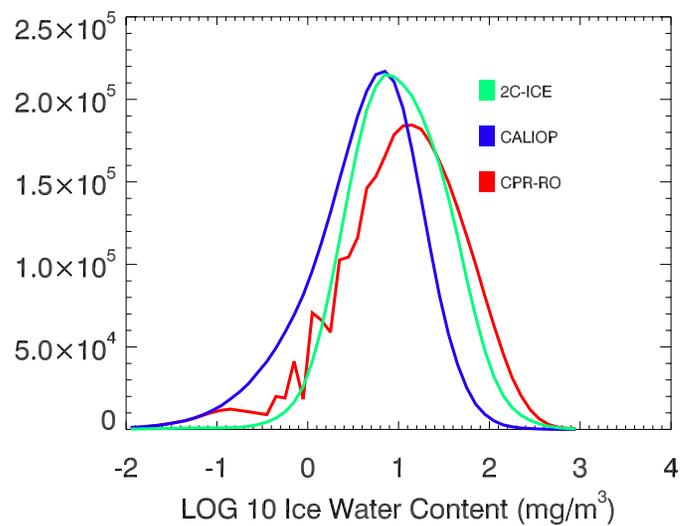
c) CALIOP at MLS levels



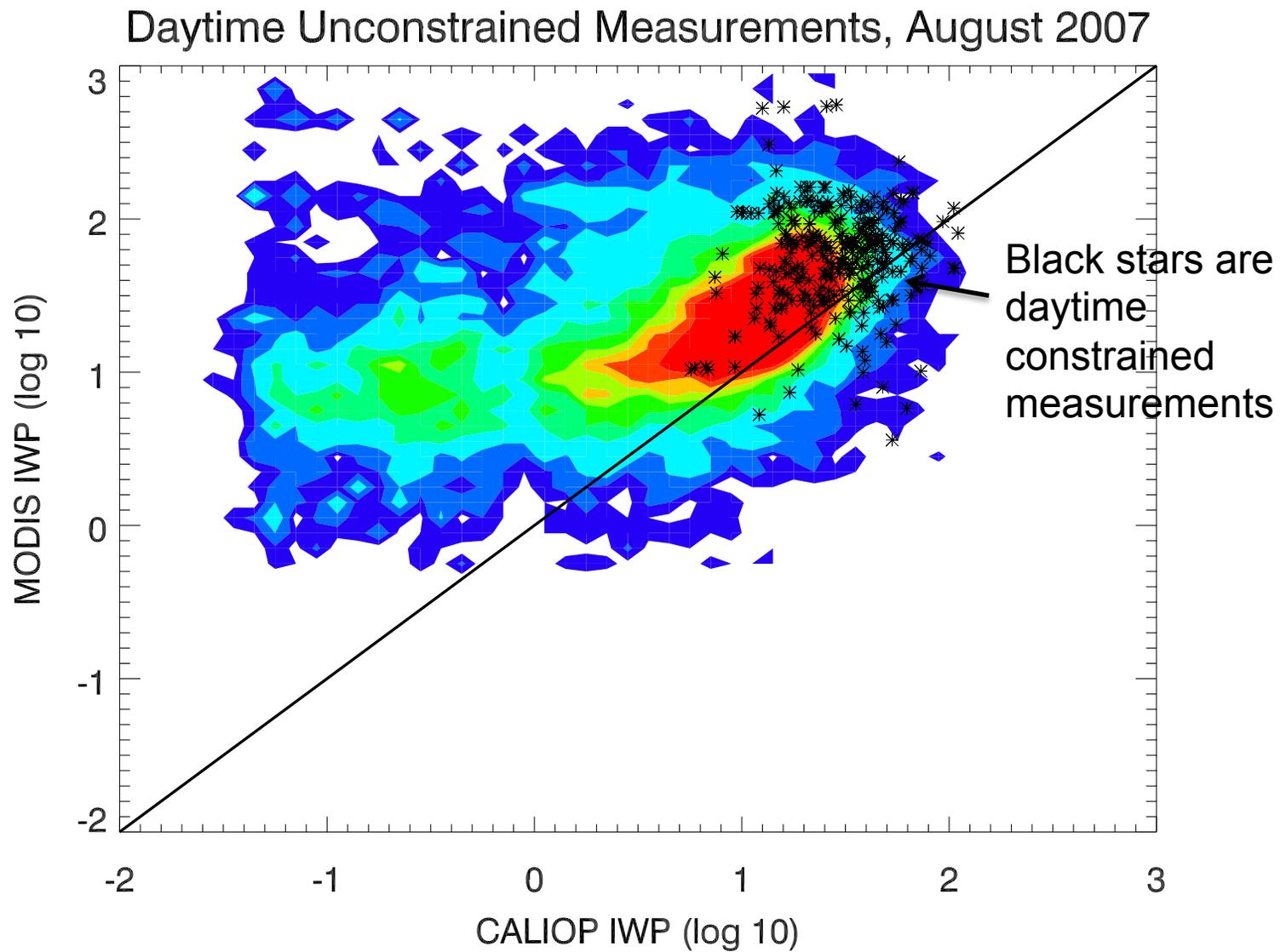
d) MLS



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



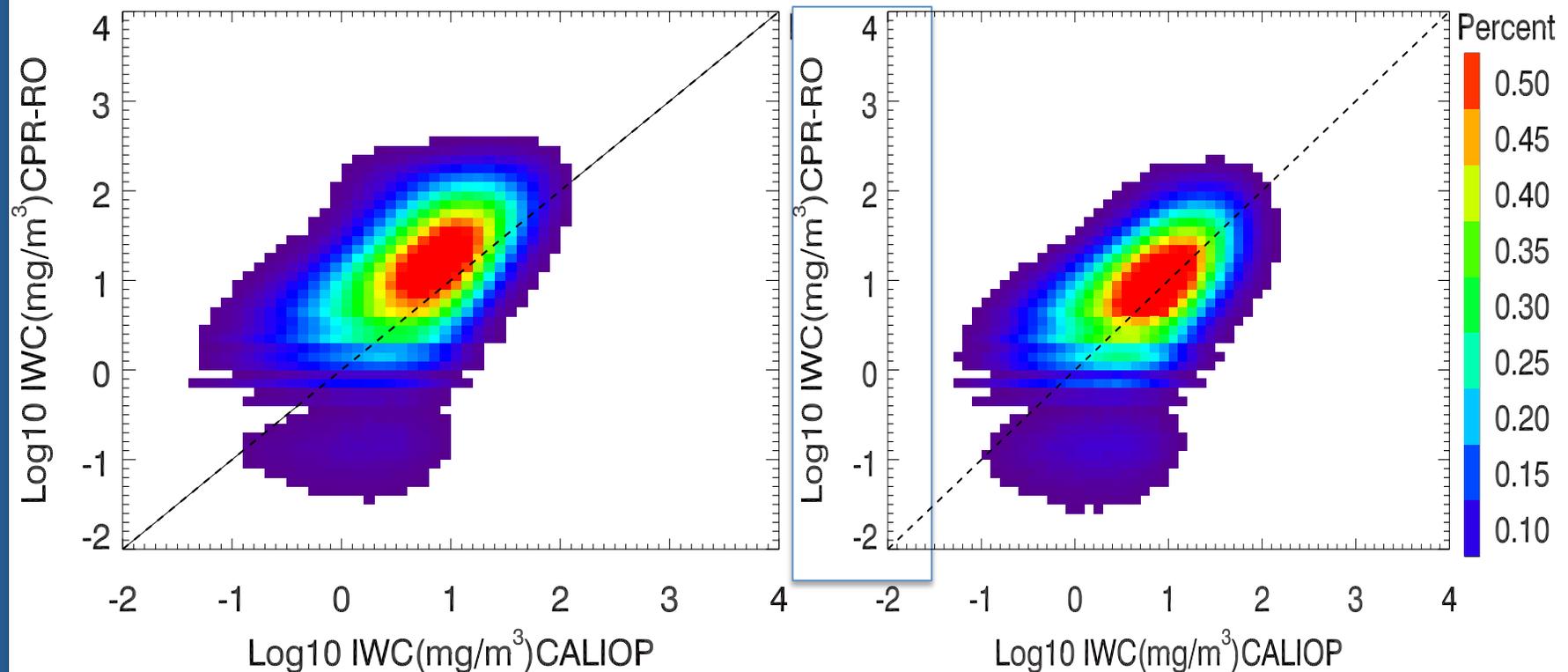
# Preliminary Comparison with MODIS (Collection 5) IWP



# Test CPR/CALIOP Comparison with New CALIOP Lidar Ratio

CALIOP V3.01,  
July 2010

CALIOP New LidarRatio, July  
2010



## CALIOP Version 4 IWC Planned\* Improvements:

- 532 nm calibration change – molecular normalization at higher altitude (36-39 km as opposed to 30-34 km):
  - Expected average 6% increase in attenuated scattering ratios, Tropics and Midlatitudes
- Tropopause will no longer be used to separate profiles into tropospheric clouds and stratospheric aerosols
  - Very high-altitude Tropical Ci will cease disappearing from cloud profiles
  - GEOS tropopause is not spatially well-matched to lidar
- Default lidar ratio for unconstrained retrievals will increase from 25 to about 32
  - Unconstrained extinction retrievals larger
  - Change based on SODA (Jossett,,2012) and MODIS/IIR/CALIOP COD comparison (Garnier, in preparation)
- New temperature-dependent IWC parameterization
  - 100k individual measurements from 10 field campaigns

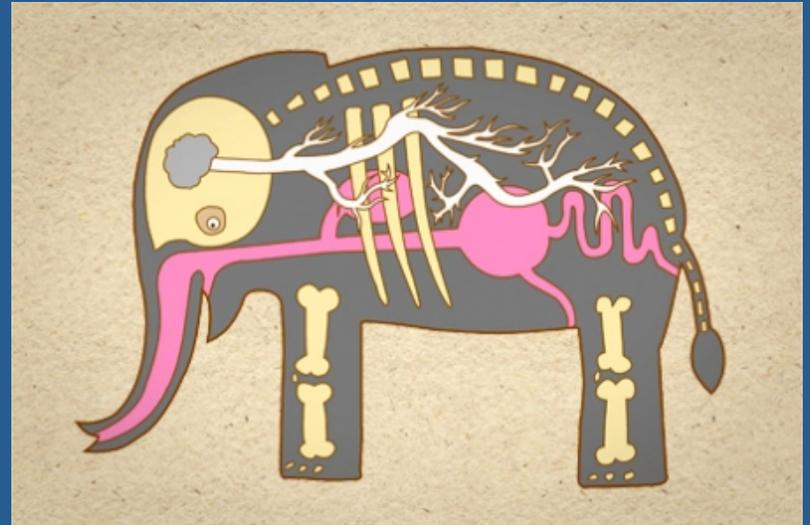
\* Version 4 Level 1 new calibration is definite, and production is imminent. Level 2 changes are *not yet finalized*, and are still being considered by the PI and algorithm development team – so the list shown here is tentative.

# Summary

- MLS and CALIOP have similar IWC ranges, but are difficult to compare directly due to spatial sampling differences.
- CPR and CALIOP are similar in spatial resolution, but sample different parts of the cloud.
- MODIS and CALIOP currently differ, but we are working together and improving both retrievals.
- *Each instrument has a version of the Cirrus cloud ice “truth”.*
- Given the natural variability in cloud ice microphysics, agreement to within a factor of two is pretty good.
- Working together, the measurement accuracy is improving.

# *Thanks to All My Colleagues and Friends*

*In situ* and Aircraft data: Andrew Heymsfield  
CALIOP: David Winker, Mark Vaughan,  
Anne Garnier, Yongxiang Hu  
MODIS: Robert Holz, Stephen Platnick  
MLS: Jonathan Jiang  
CPR/2C-ICE: Min Deng



*Coda...* Six blind elephants were discussing what men were like. After arguing they decided to find one and determine what it was like by direct experience. The first blind elephant felt the man and declared - "Men are flat."

After all the blind elephants felt the man, they agreed.

# Parable of the blind men and the elephant

*Which addresses the manifold nature of truth...*

A group of blind men heard that a strange animal, called an elephant, had been brought to the town, but none of them were aware of its shape and form. Out of curiosity, they said: "We must inspect and know it by touch, of which we are capable". So, they sought it out, and when they found it they groped about it. In the case of the first person, whose hand landed on the trunk, said "This being is like a drain pipe". For another one whose hand reached its ear, it seemed like a kind of fan. As for another person, whose hand was upon its leg, said, "I perceive the shape of the elephant to be like a pillar". And in the case of the one who placed his hand upon its back said, "Indeed, this elephant is like a throne". Now, each of these presented a true aspect when he related what he had gained from experiencing the elephant.

*None of them had strayed from the true description of the elephant.  
Yet they fell short of fathoming the true appearance of the elephant.*