Distribution of Cirrus Cloud Ice in the TTL as Observed During ATTREX 2014

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Talk Roadmap

Focus on the Space-Based Lidar Data CALIOP:
Cloud and Aerosol Lidar with Orthogonal Polarization

- Is it sensitive?
- Is it representative?
- What are we looking at?

↓

What can we learn with it?

1. Basic lidar info
2. ATTREX 2014 – Aircraft data comparisons
3. ATTREX Regional Overview
4. Regional Characteristics and Time Series

Lidar Signal Interpretation is a Multiple Step Process:

Range-Resolved, Normalized Signal

Calibrated Attenuated Backscatter Profiles; 532 P, 532 S, 1064

Atmospheric "Features" located dH = 333m, 1km, 5km, 20km, 80km

Atmospheric Features Identified Layer-Integrated properties: Attenuated Backscatter, 532 nm Depolarization, 1064/532 nm ratio

Extinction, Particulate Backscatter Coefficients Retrieved

IWC parameterized from Extinction Aircraft Data

Calibration

L1 → Volume backscatter coefficients, integrated attenuated backscatter, volume depolarization, volume CR

Feature Detection

Vaughan, 2009

Feature Identification

Liu, 2009; Hu, 2009 (cloud phase)
Omar, 2009 (aerosol type)

L2 → Profiles at 1km, 5km, 60m vertical resolution in the UT/LS; Layer-Integrated quantities, stats

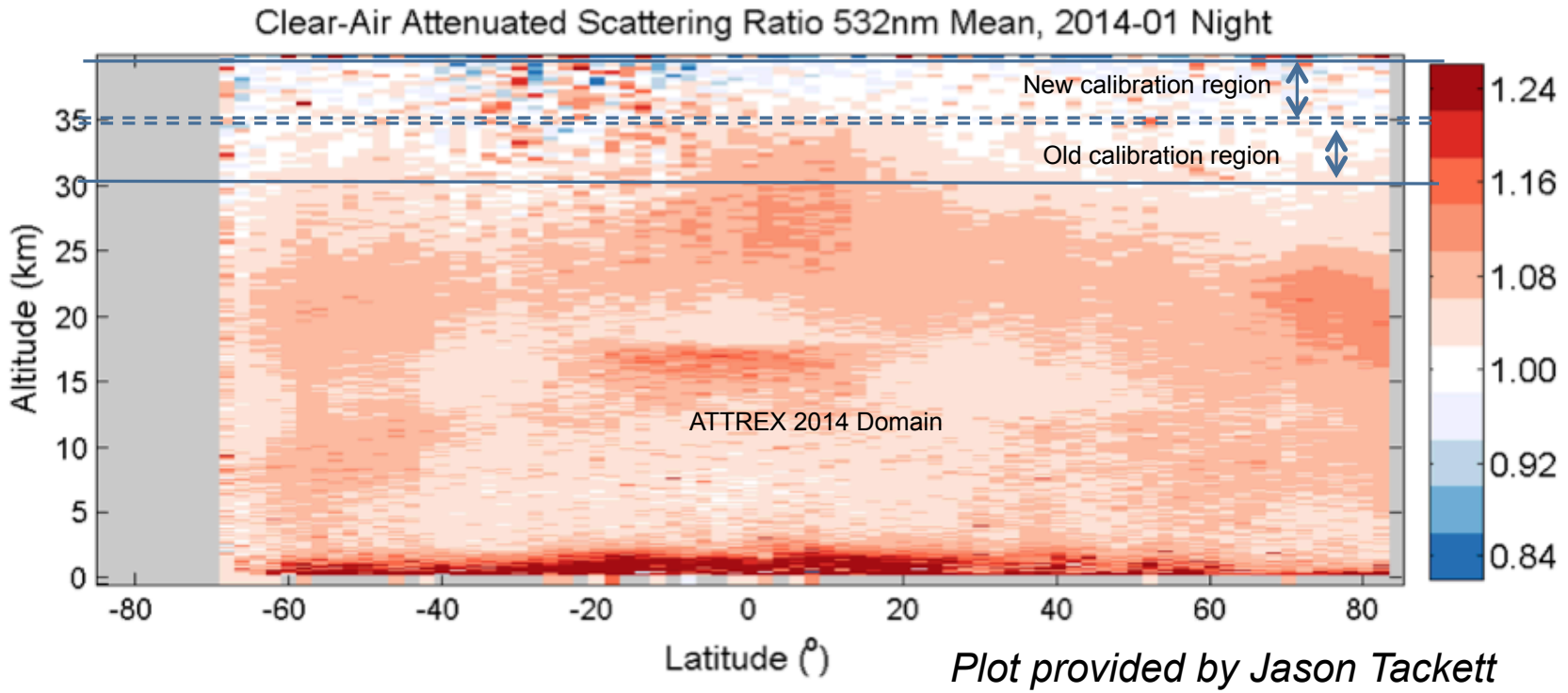
Young and Vaughan 2009, Young, 2012

TTL cirrus IWC

Heymsfield, 2014

CALIOP Version 4 – Much Improved Calibration

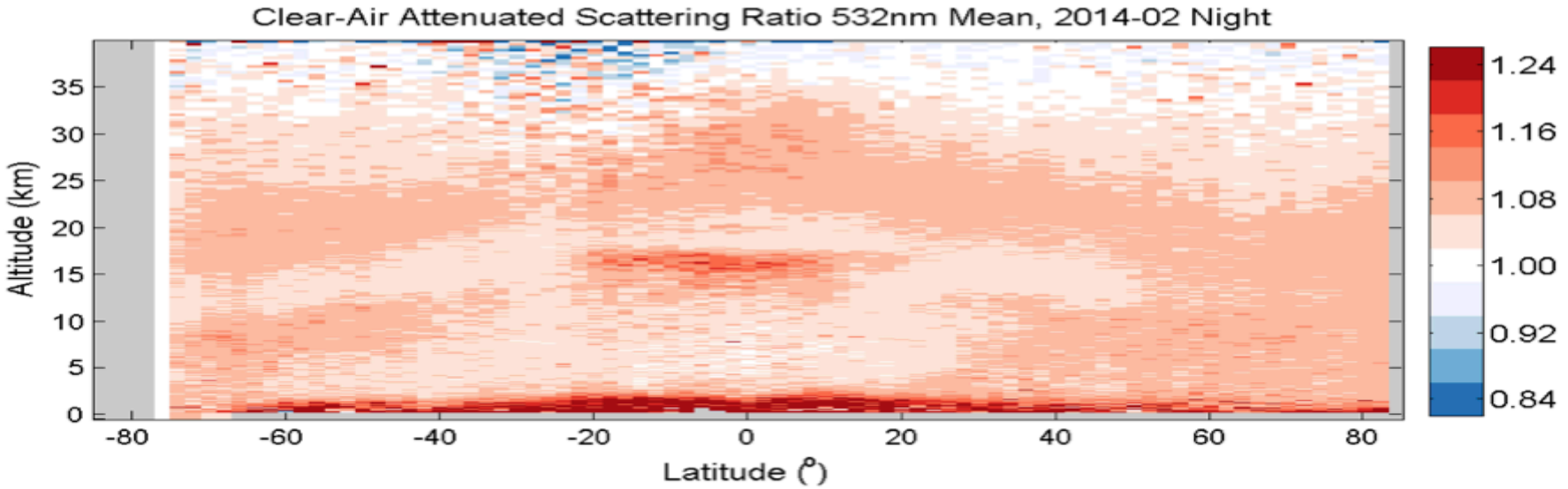
New Version 4 Level1 improves 532 nm night, day/night agreement and 1064 calibrations.



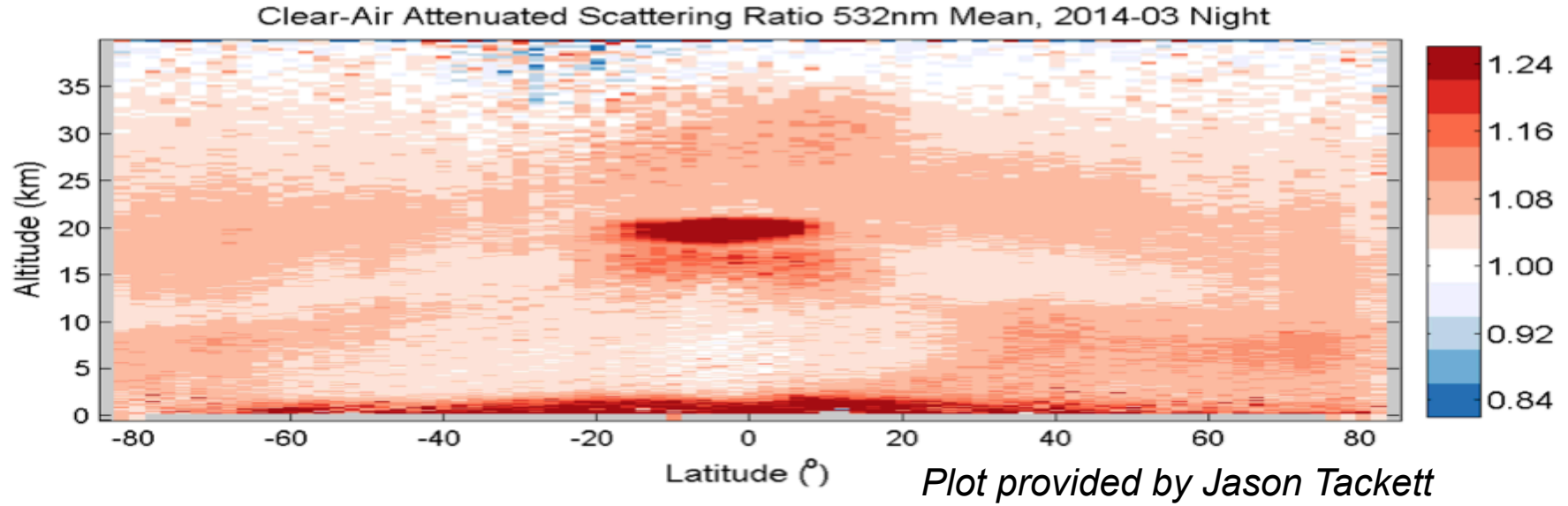
Plot provided by Jason Tackett

CALIOP 532 nm Nighttime channel clear air scattering ratios show that in the Tropics, CALIOP sees volcanic aerosols and ice particles with particle concentrations too small to detect as layers.

Clear Air Scattering Ratio – Before and After Kelud Eruption



Plot provided by Jason Tackett



Plot provided by Jason Tackett

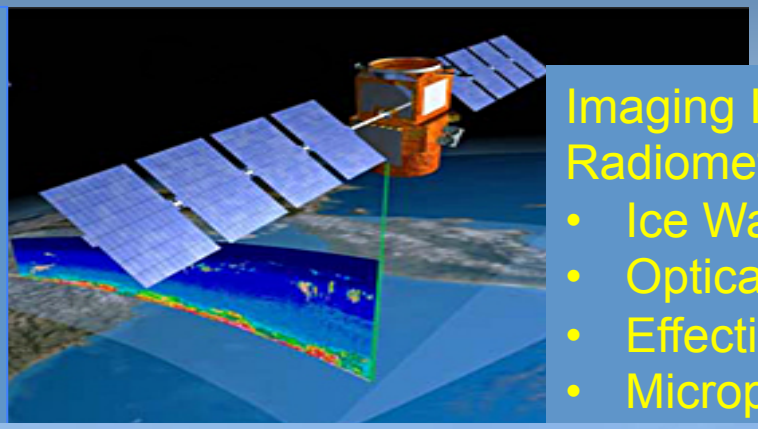
ATTREX – Guam

February, March 2014

Comparisons with Aircraft Observations

ATTREX 2014 Instruments and Measurements

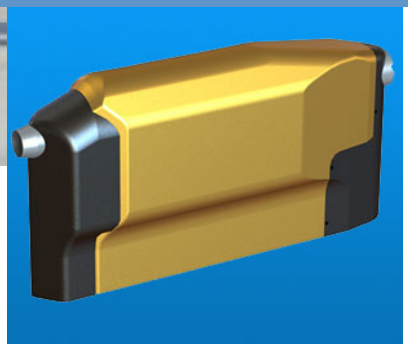
Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)
- Ice Water Content (IWC)
- Extinction (Ext)
- 532 nm Depolarization
- 1064/532 BS Ratio



Imaging Infrared Radiometer (IIR)
- Ice Water Path (IWP)
- Optical Depth (OD)
- Effective Particle Size
- Microphysical Param.

NOAA Water
- Water vapor
- Cloud IWC

SPEC, Inc. Hawkeye
- 2D-S (PSD, Ext, IWC)
- CPI images
- FCDP (PSD, Ext, IWC)



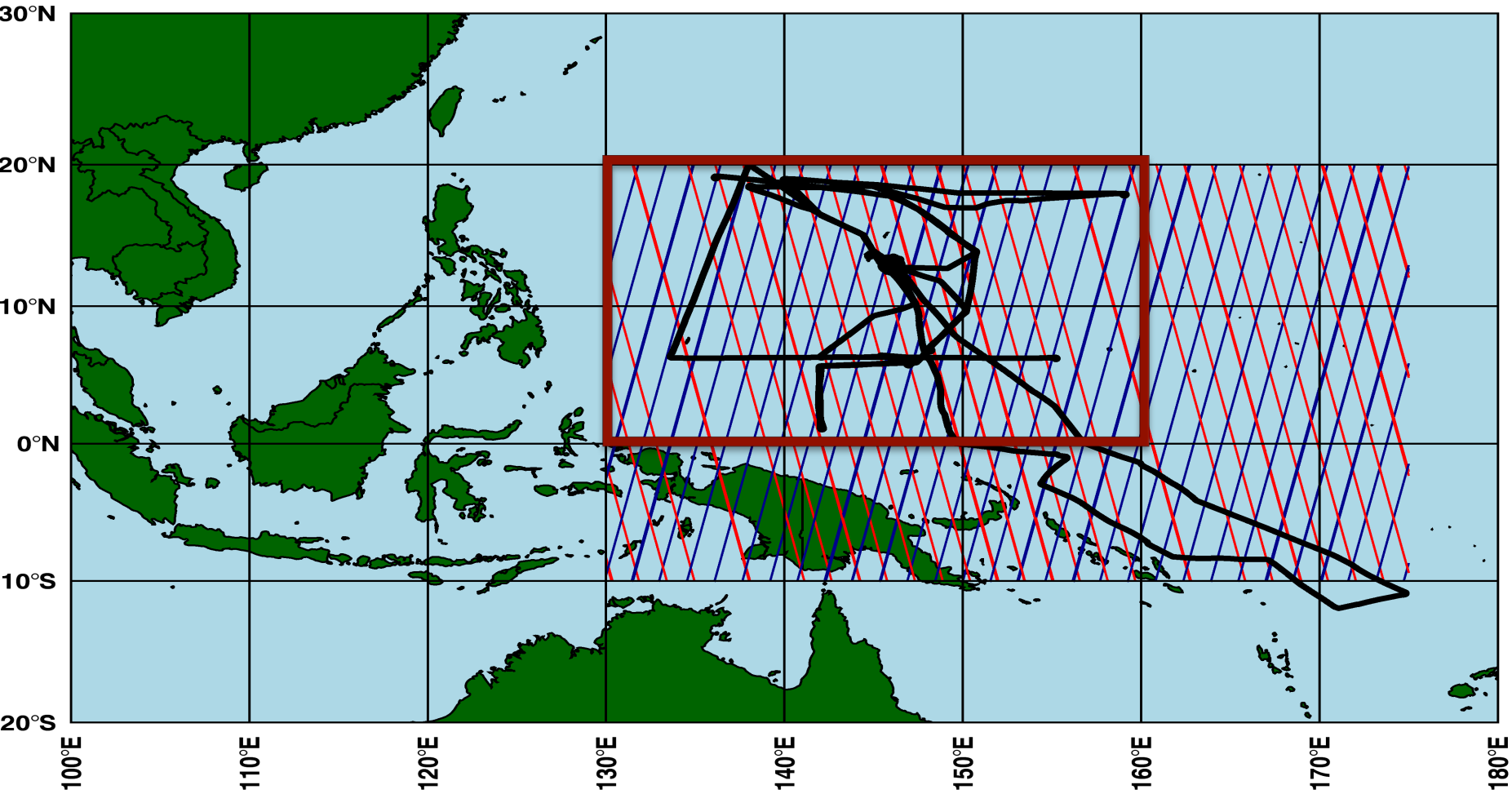
The ER-2 Cloud Physics Lidar
NASA's PREMIERE HIGH-ALTITUDE LIDAR SYSTEM

Cloud Physics Lidar (CPL)
- 3 wavelengths
- Extinction
- 1064 nm Depolarization
- BS Ratios

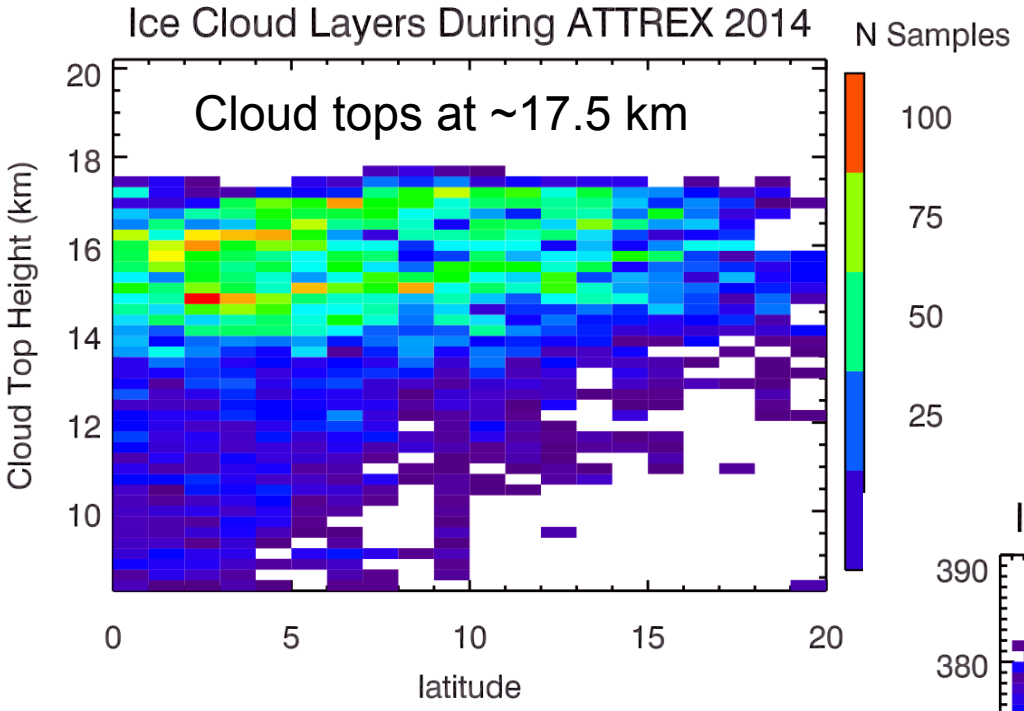
Data Coverage during ATTREX 2014

February 10 – March 14, 2014

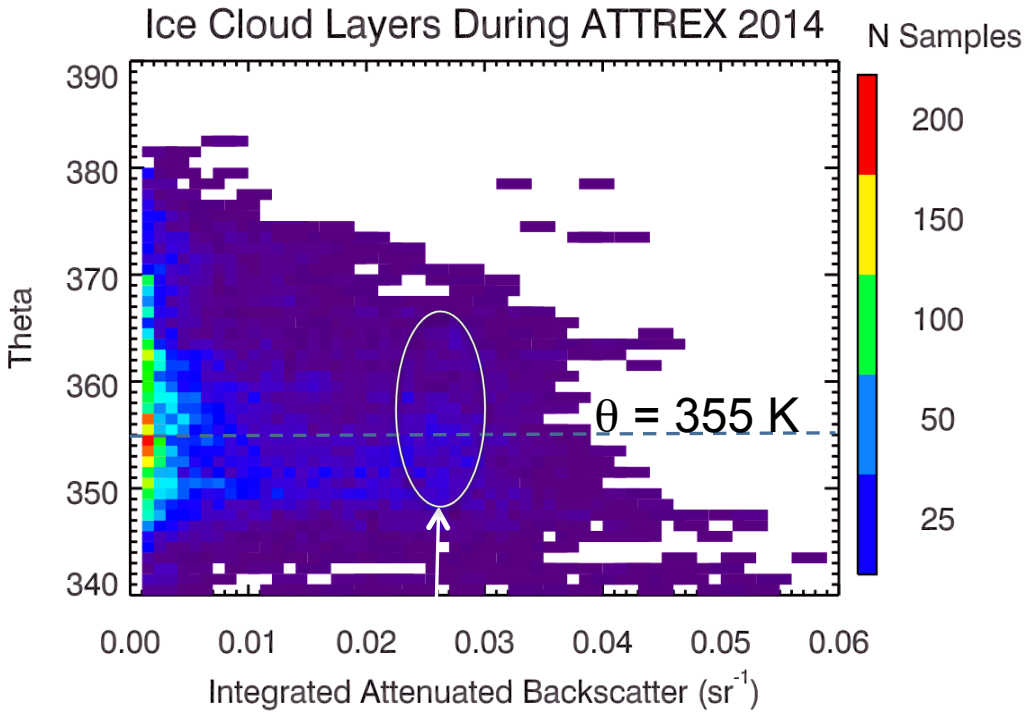
8.2 – 20.2 km (mainly above θ = 355 K), Cold ice clouds (cloud base < -40)



CALIOP Overview: Feb 10 – Mar 14, 2014

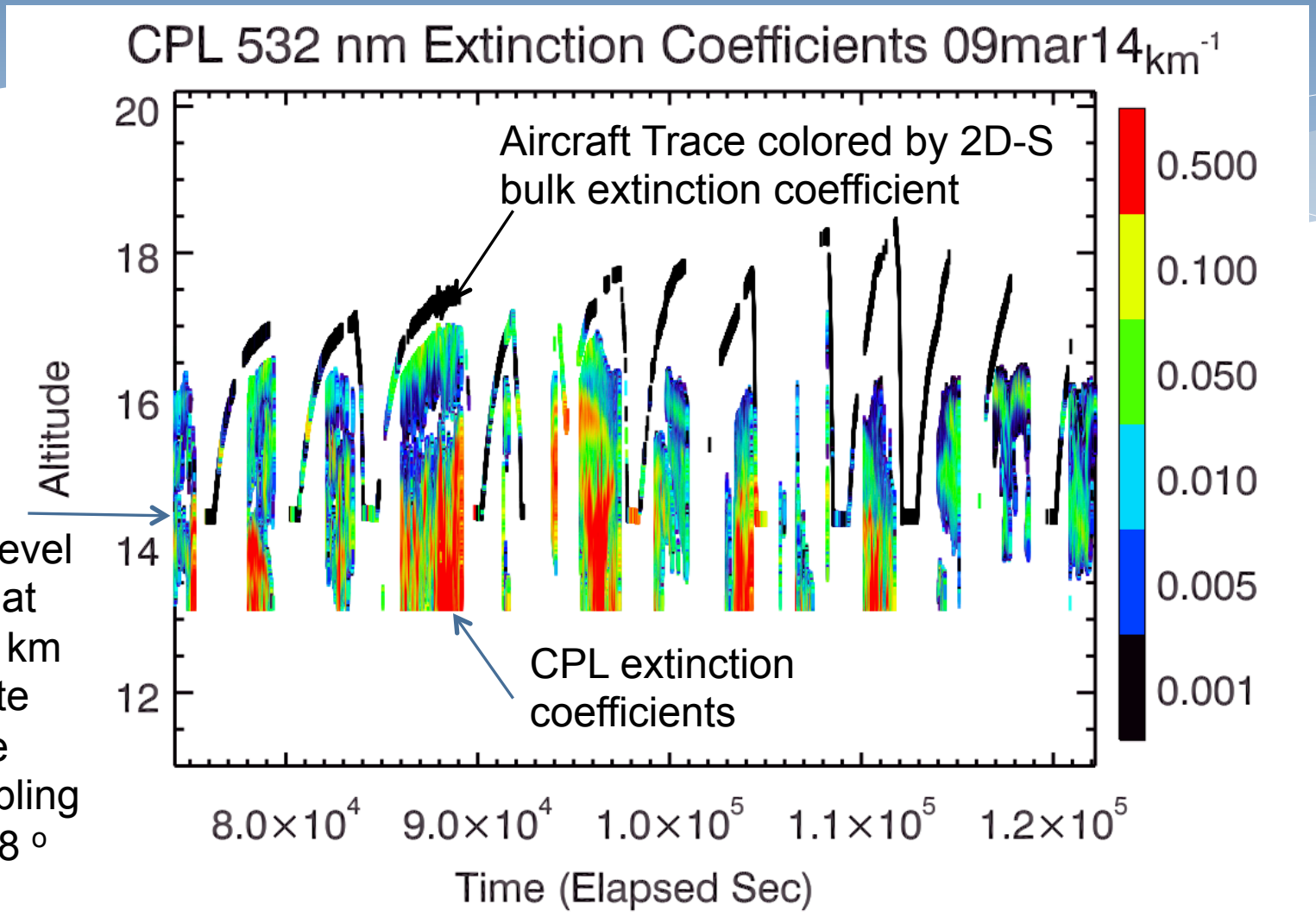


CALIOP measures cloud tops directly. Most cloud layers with bases > 8.2 km have cloud tops between 14 – 17.5 km.



Integrated attenuated backscatter (IAB) shows two modes of cloud optical thickness.
IAB of ~ 0.028 sr^{-1} are opaque to CALIOP with OD > ~ 3 and are likely to be associated with convection. Many transparent layers have IAB < 0.005 sr^{-1}

2D-S and CPL Extinctions

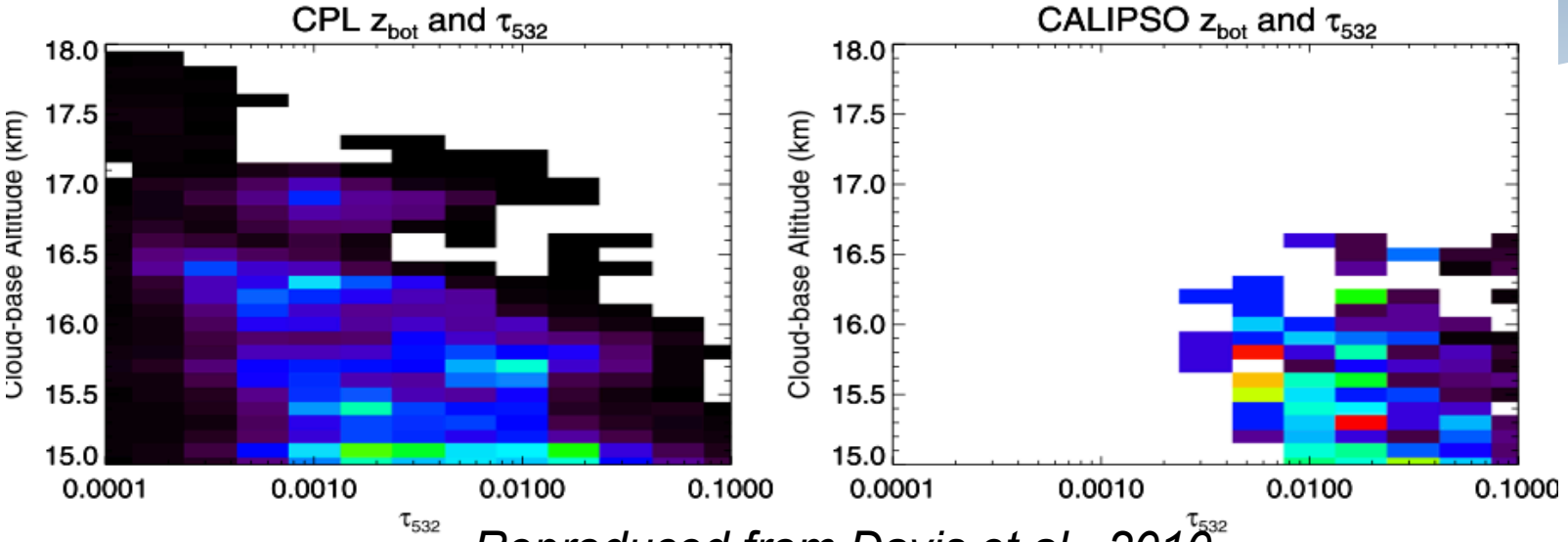


GH level legs at 14.5 km create more sampling at -68 °

Example Flight on March 9

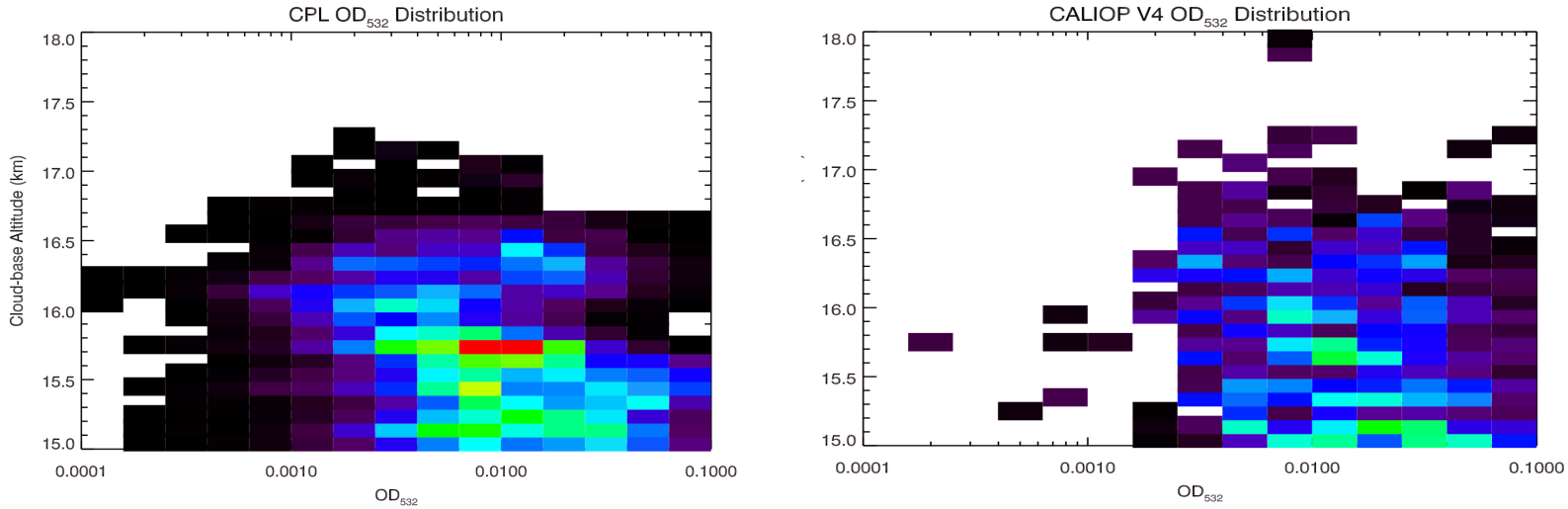
TC4 vs ATTREX, CPL and CALIOP Optical Depth

TC^4 CPL and CALIOP OD Comparison, Cloud Bases 15-18 km

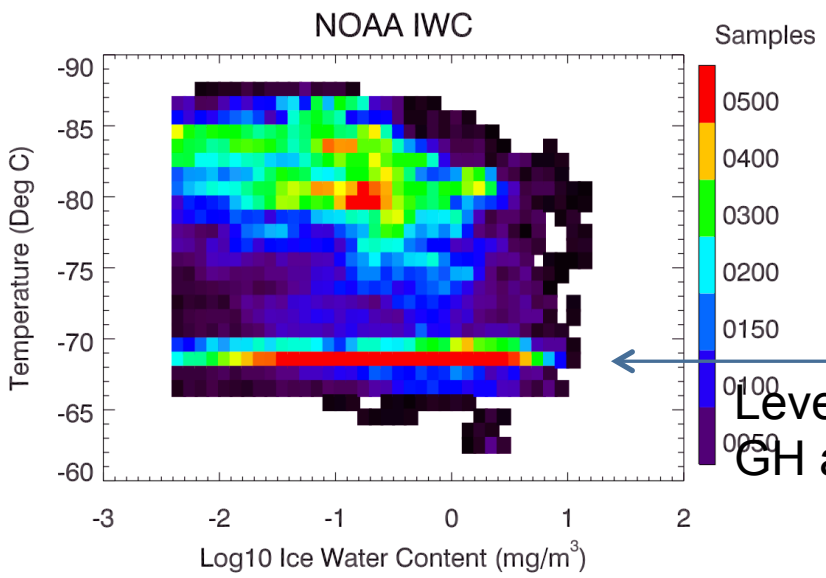


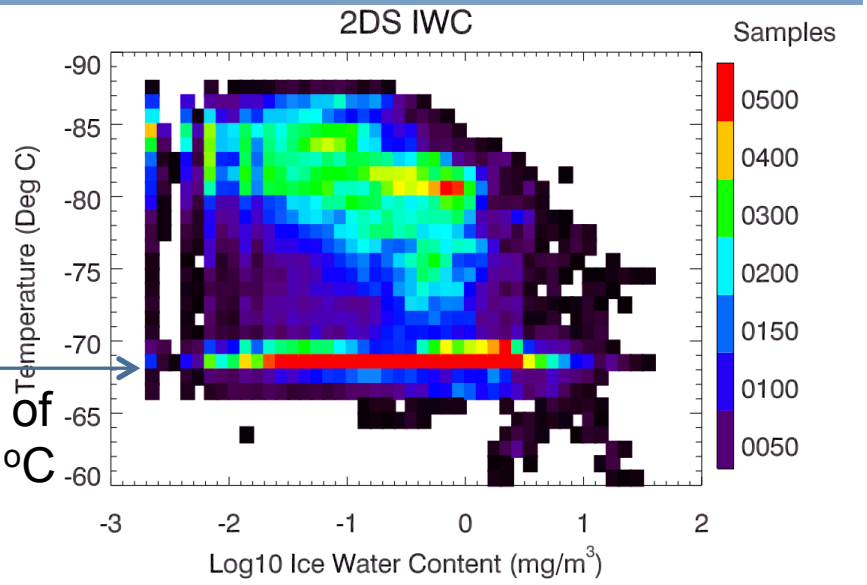
Reproduced from Davis et al., 2010

ATTREX – 2014, Guam OD Comparison, Cloud Bases 15-18 km

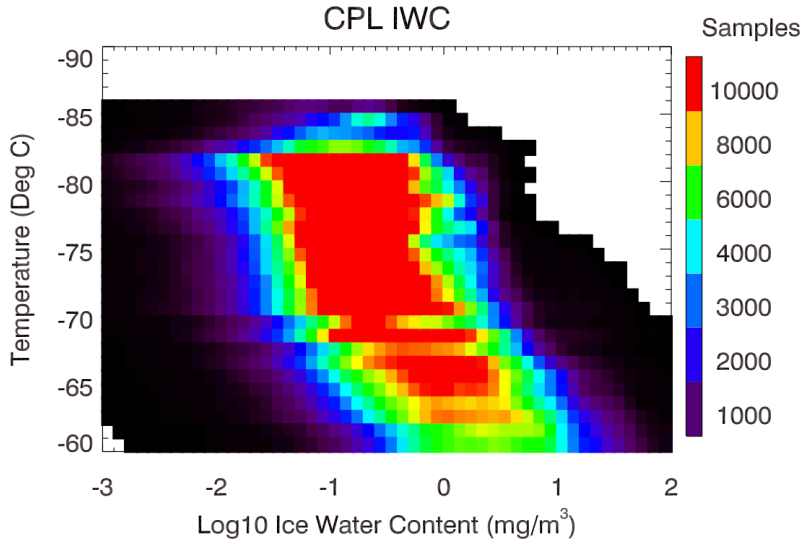


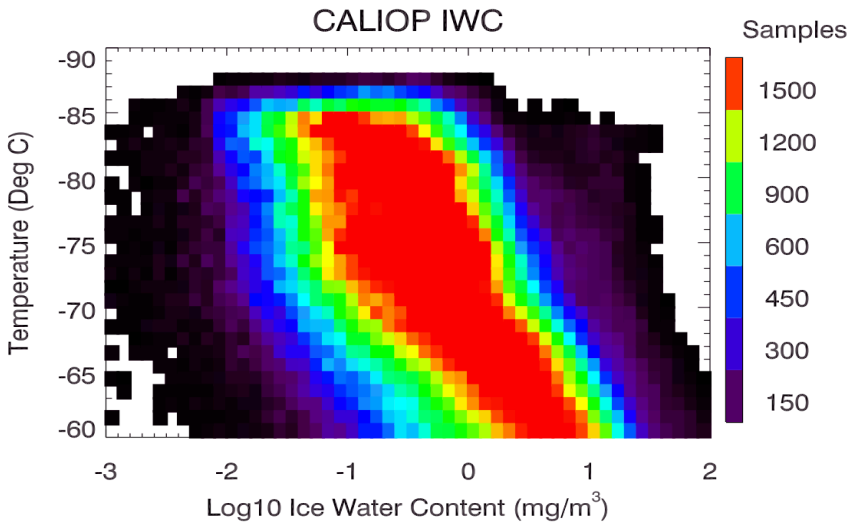
IWC Distribution Comparison



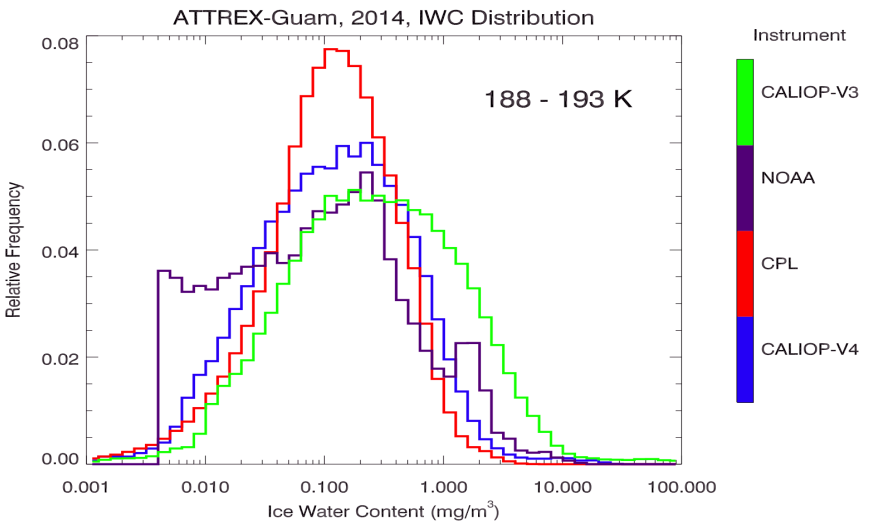


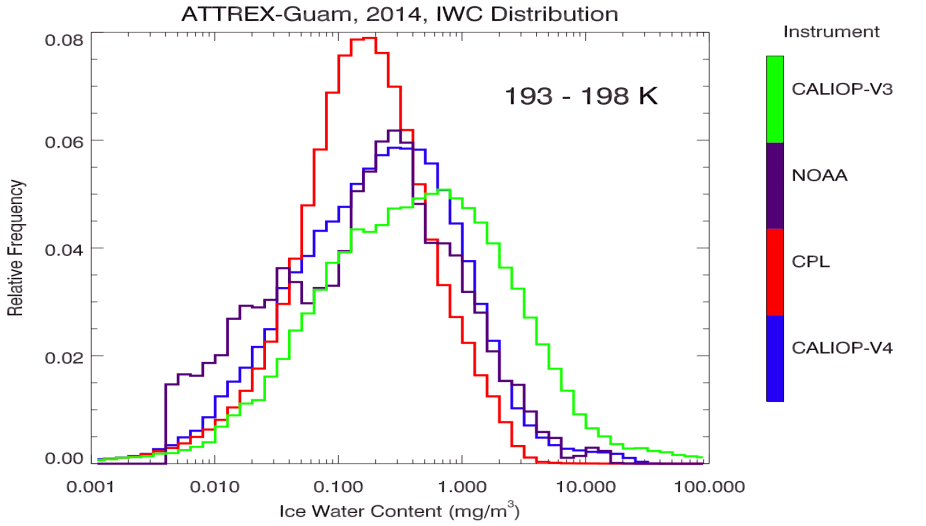
Level legs of GH at -68 °C

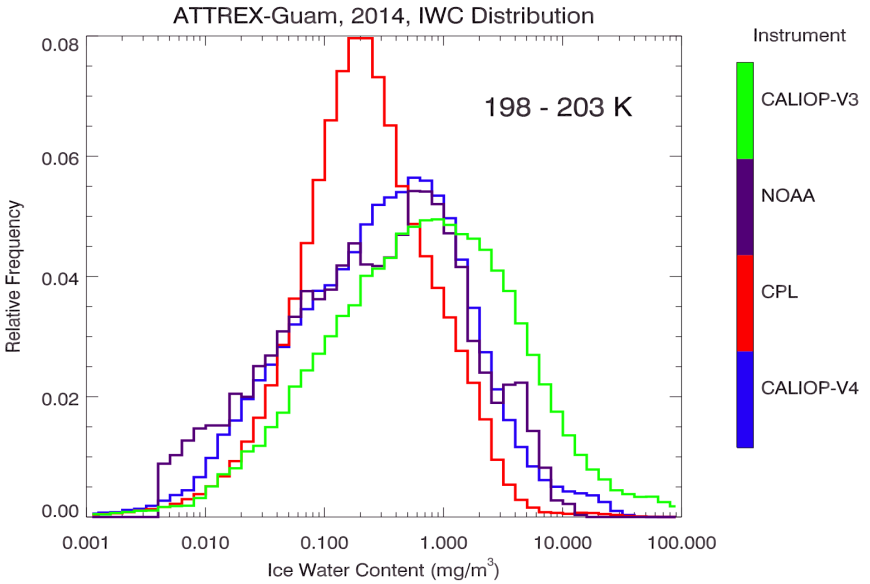


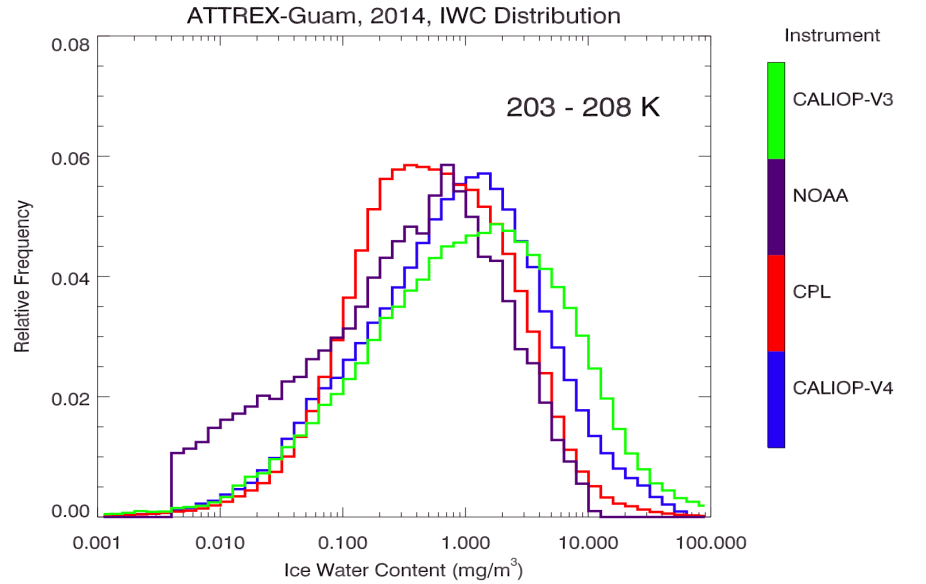


ATTREX-2014 IWC Comparison

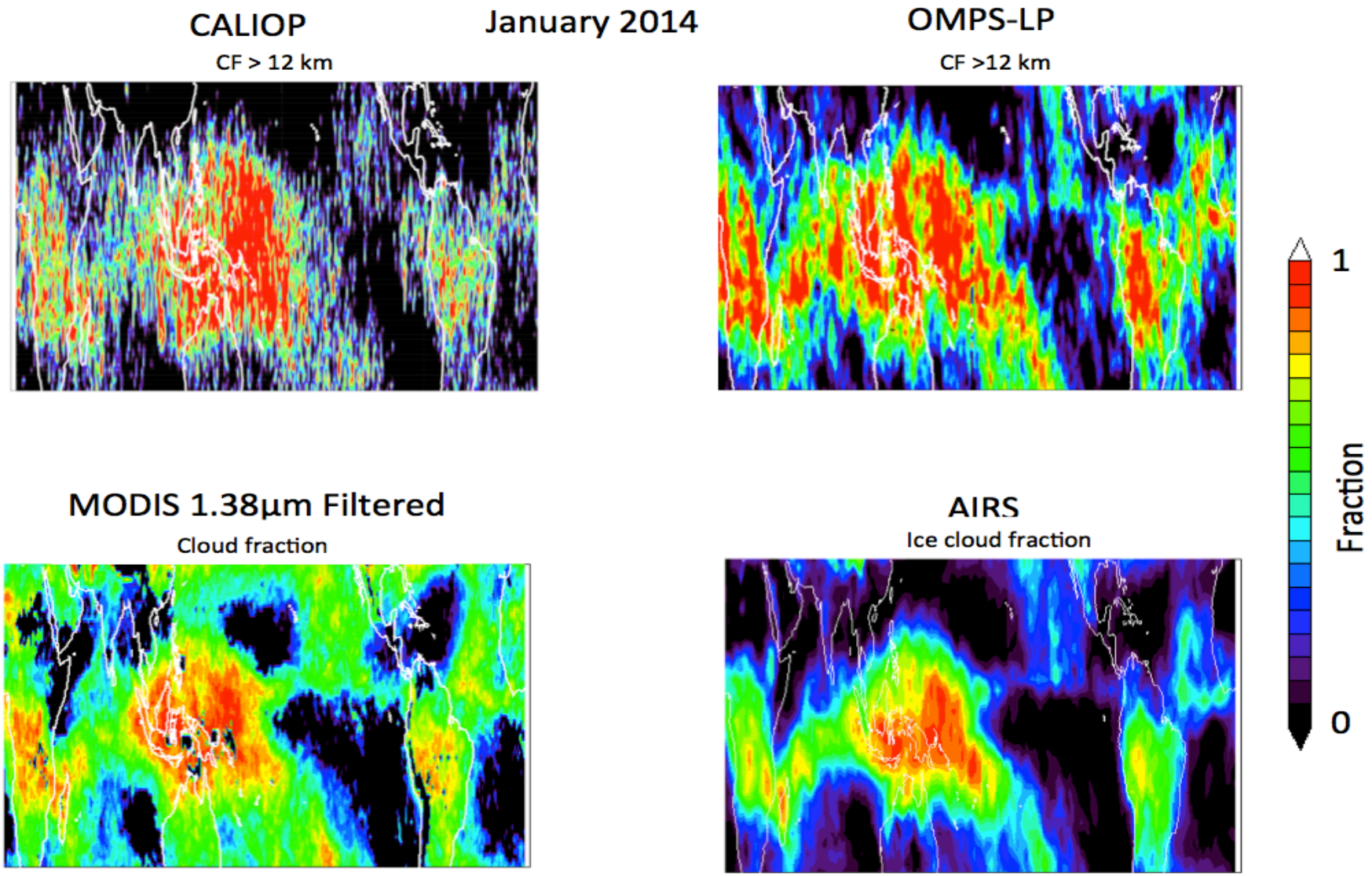








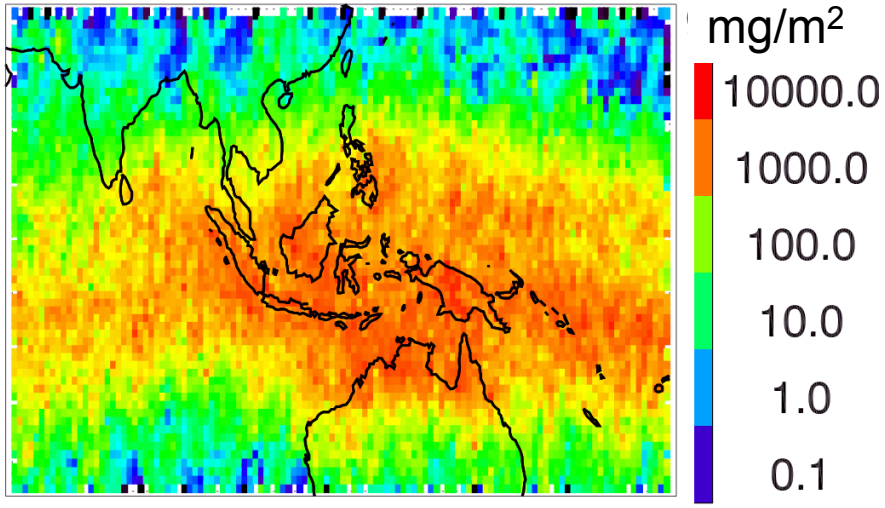
Jan. 2014 Tropical Cloud Frequency Comparison (z > 12 km)



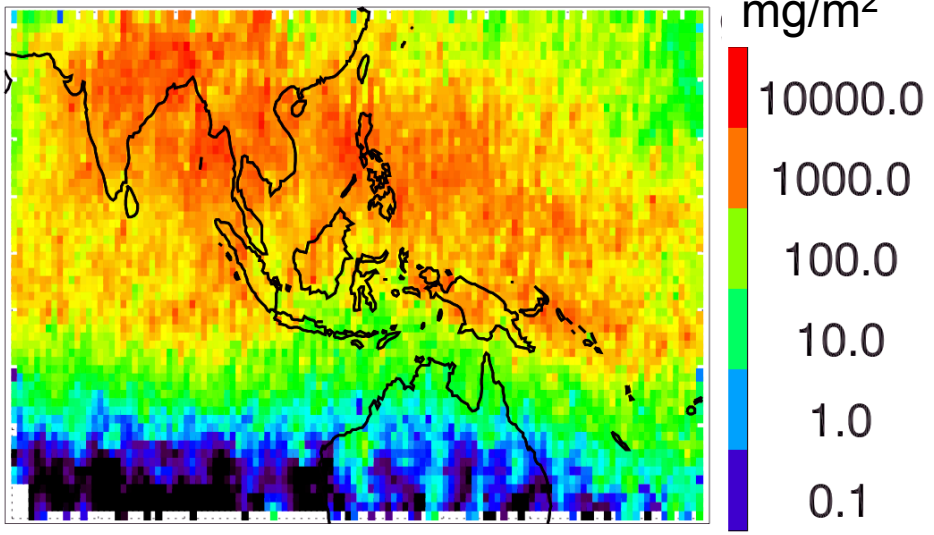
Plot provided by Mark Schoeberl

Regional Climatology from CALIOP

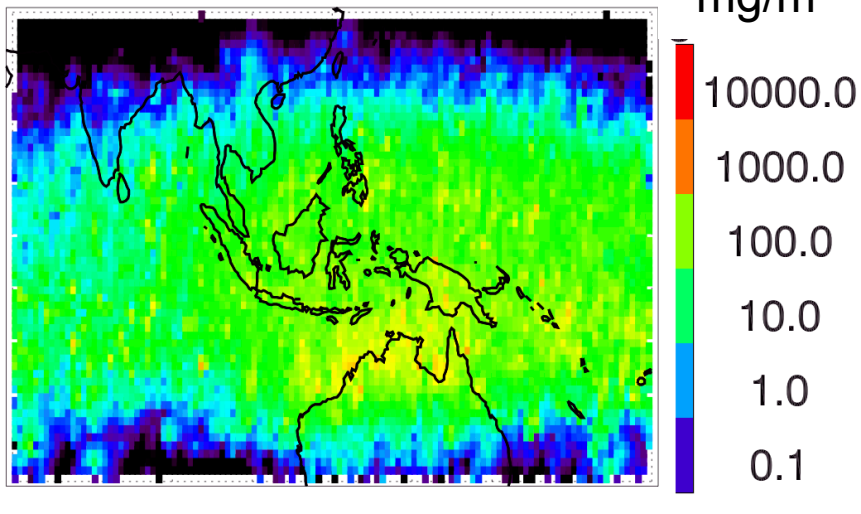
DJF, Mean UT Ice Mass, Z > 12 km



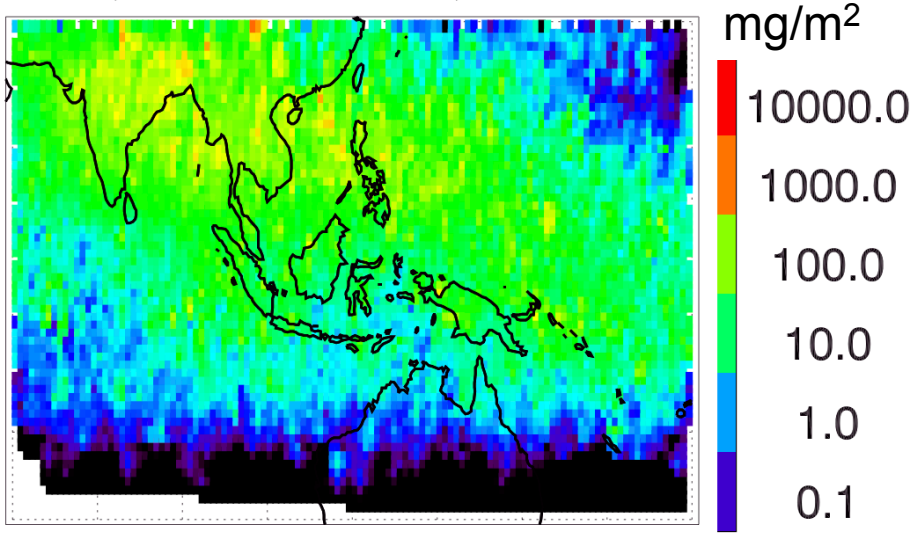
JJA, Mean UT Ice Mass, Z > 12 km

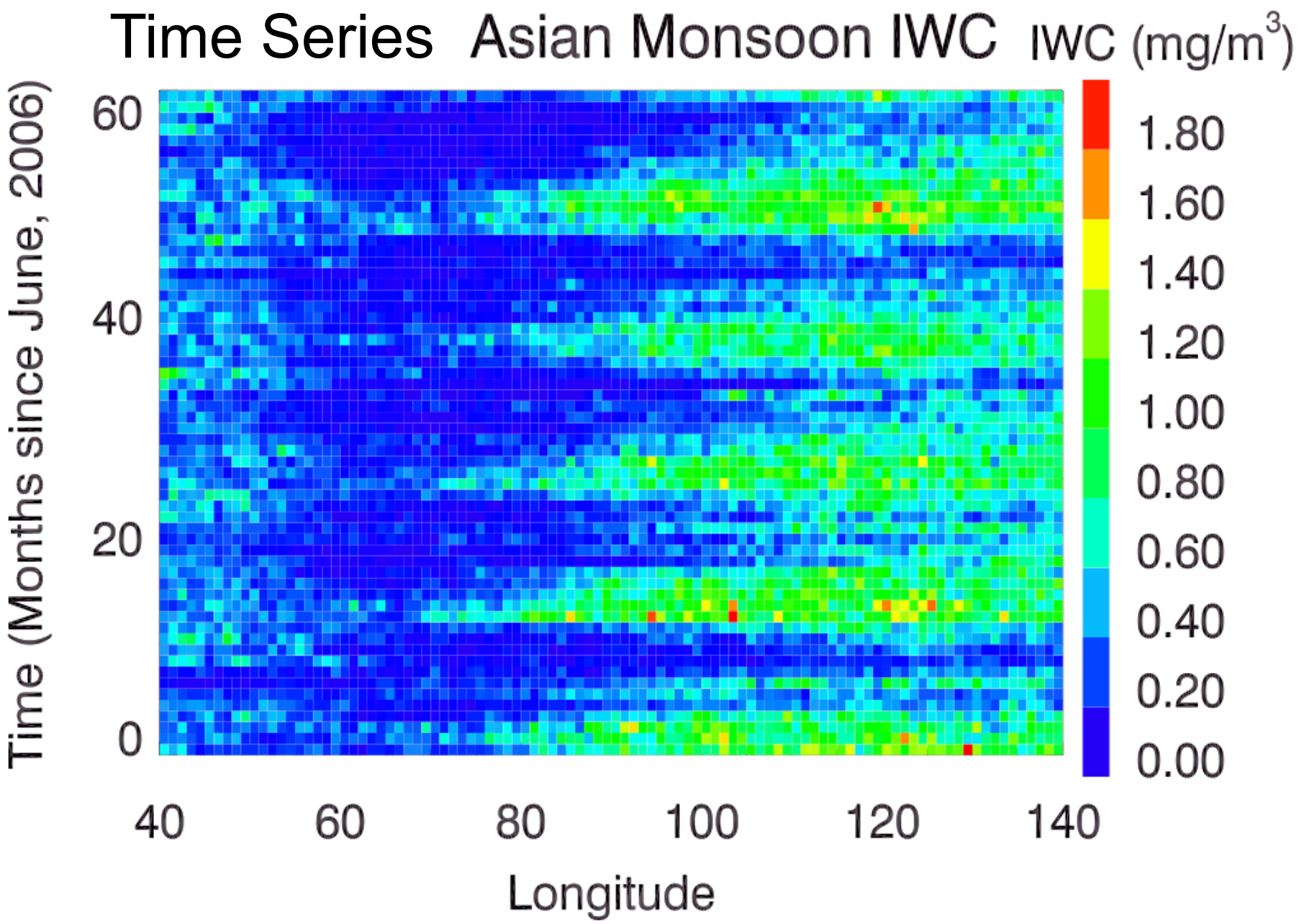


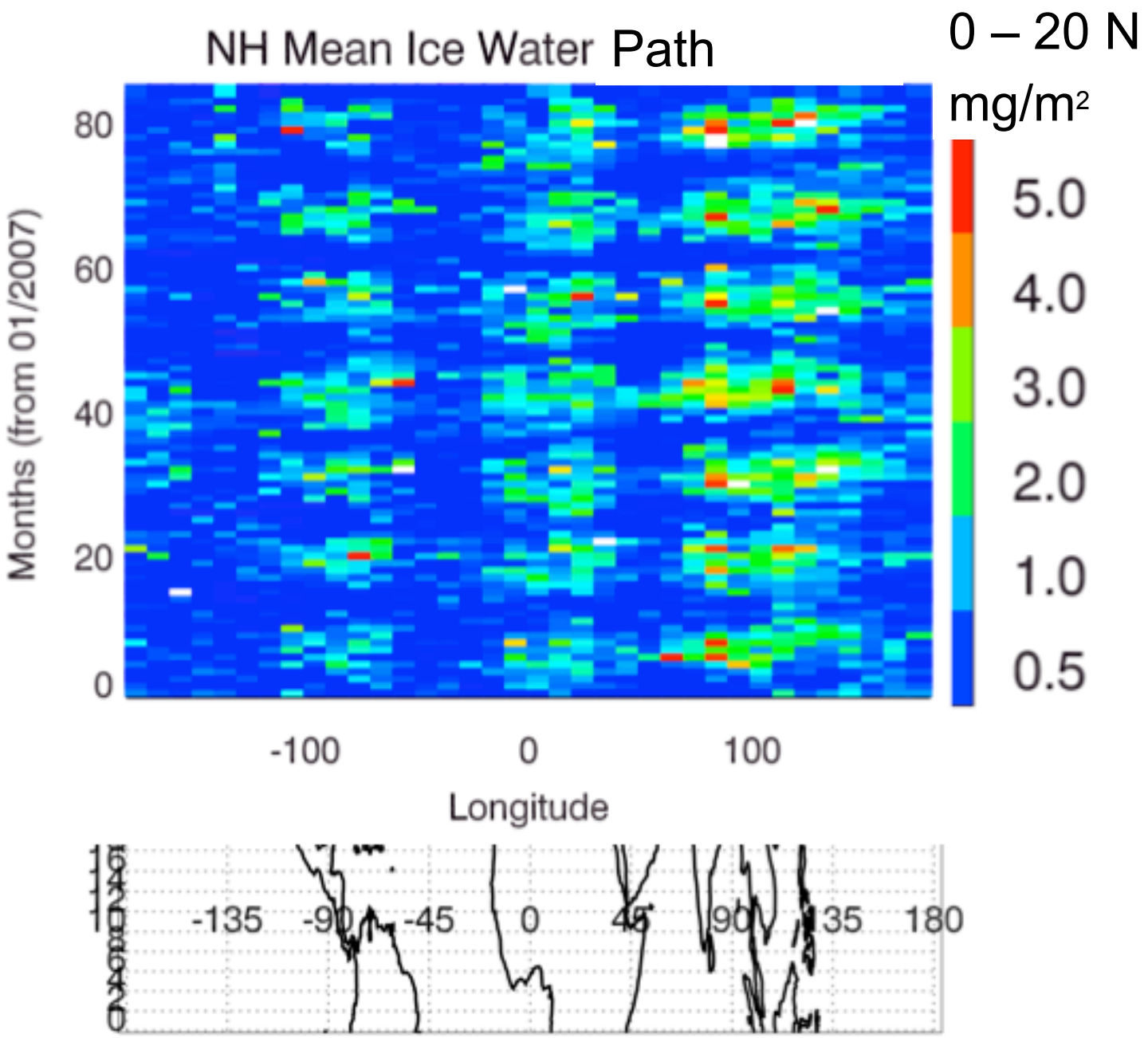
DJF, Mean UT Ice Mass, Z > 15 km

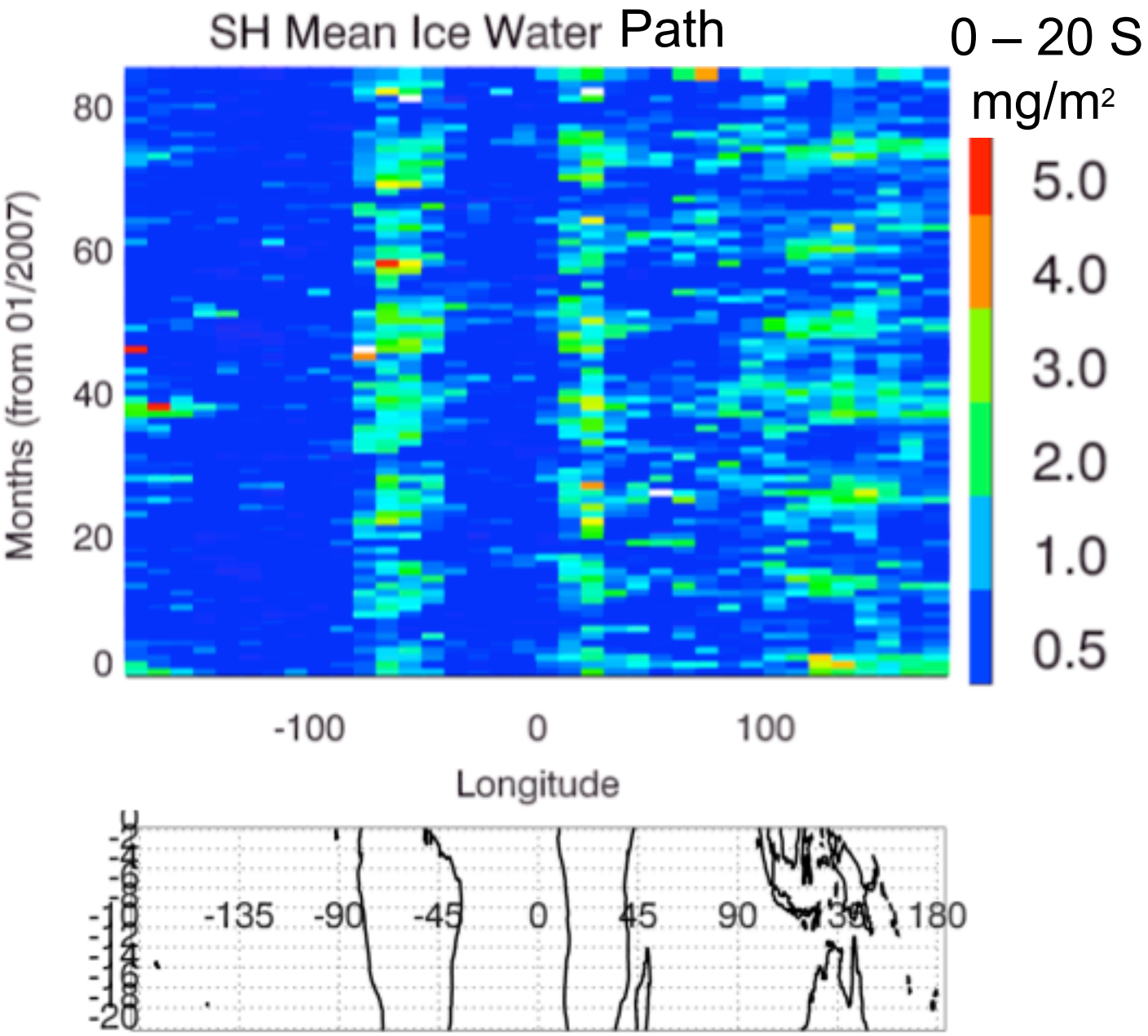


JJA, Mean UT Ice Mass, Z > 15 km




Time Series Asian Monsoon IWC
IWC (mg/m3)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Time (Months since June, 2006)
60
40
20
0
40
60
80
100
120
140
Longitude


NH Mean Ice Water Path
0 – 20 N
mg/m2
5.0
4.0
3.0
2.0
1.0
0.5
Months (from 01/2007)
80
60
40
20
0
-100
0
100
Longitude
-135
-90
-45
0
45
90
135
180


SH Mean Ice Water Path
0 – 20 S
mg/m2
5.0
4.0
3.0
2.0
1.0
0.5
Months (from 01/2007)
80
60
40
20
0
-100
0
100
Longitude
-135
-90
-45
0
45
90
180

Summary

- CALIOP Version 4 calibration is helpful for better TTL observations
- Lidar sensitivity down to ~0.003 OD in the TTL
- Layers provide convenient information, but miss some features because of orientation
- Scattering ratios averaged over enough time may provide more information (with caution because depolarization has a relatively low signal to noise ratio)
- For extinction retrievals, we need to know the extinction to backscatter ratio.
- Working on extinction comparison from ATTREX (σ=2A).
- Particle area to mass power law derived by NOAA group (Troy Thornberry, poster yesterday).
- Error estimate in the TTL is a work in progress, due to extra challenges in the TTL.