Looking Back: Lessons Learned from CALIPSO Validation

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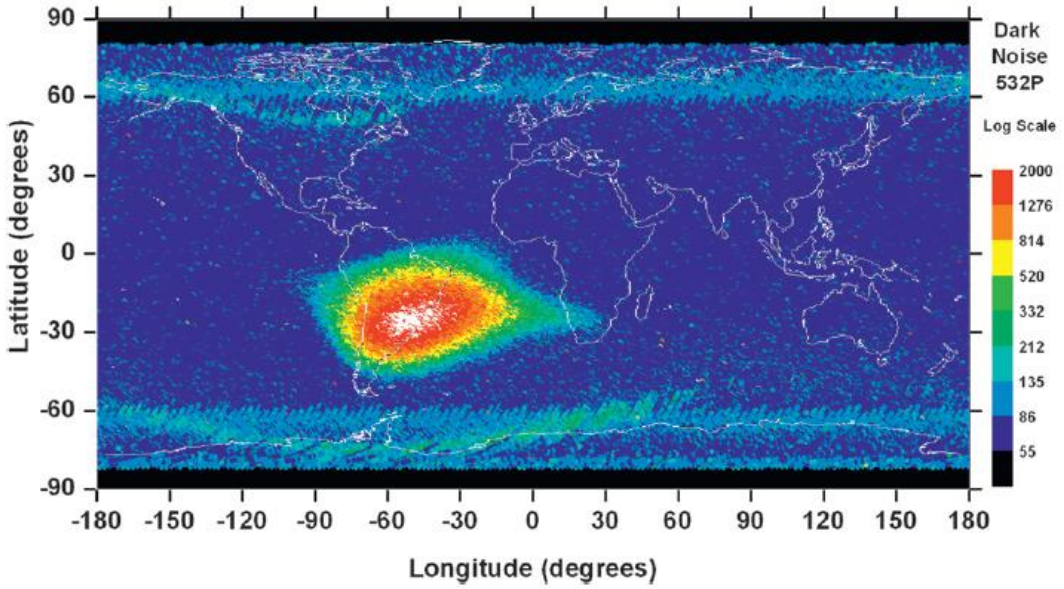
Validation Objectives

- Verify instrument performance
  - calibration, SNR, linearity, transient recovery
- Verify geolocation
  - pointing, altitude registration
- Quantify the accuracy and precision of Level 2 science data products
  - identify sources of random errors and biases
- Examine underlying assumptions in retrieval algorithms
  - S_a, S_c, spectral independence of cirrus backscatter
- Supports quality assurance, algorithm improvement activities

Lessons Learned from On-orbit Checkout
(pre-validation)

- **Discovered ranging error**
  - **Speed of light ≠ 3.00E+8 m/s**
  - **Required a change to payload software (~ 1 week)**
- **Intra-orbit drifts in 1064 channel calibration**
  - **Finally fixed in 2014**
- **Discovered excess PMT noise in South Atlantic Anomaly**
  - **Not seen during LITE (260 km orbit altitude)**
  - **Required modification of 532 nm calibration algorithm**



532n m dark noise

Validation Resources

– **Ground-based networks**
  - **Aeronet**
  - **Earlinet, ADnet**

– **Satellite comparisons**
  - **MODIS, MLS, AIRS**
  - **SAGE-III**

– **Targeted, aircraft campaigns**

• LaRC HSRL (King Air)	Jun 2006 - 20012
• NOAA ESRL (Cessna)	Jul-Aug 2006-2009
• NASA ER-2	Aug 2006, ORACLES

– **Large field campaigns**

• NASA AMMA (Cape Verde)	Aug 2006
• SAMUM	2006, 2008
• CIRCLE-2	May 2007
• NASA TC^4 (Costa Rica)	Jul-Aug 2007
• ASTAR/PAM-ARCMIP	April 2007/09/11/12
• ARCTAS/PolarCat	April, July 2008
• SEAC4RS	Aug-Sep 2012
• etc	

Initial Level 1 Validation

- Early validation of Level 1 profiles was critical
- Targeted airborne campaign in Aug 2006 (CC-VEX)
- Payload on NASA ER-2:
  - Goddard Cloud Profiling Lidar (CPL)
  - JPL W-band radar (CRS)
  - MODIS Airborne Simulator (MAS)
- Initial CALIOP Level 1 validation objectives:
  - Sanity check on Level 1 lidar profiles
    - Do they 'look right'? Unexpected artifacts?
  - Verify predicted detection sensitivity
  - Radiometric calibration
  - Relative calibration of perpendicular channel (PGR)
    - Performed using on-board pseudo-depolarizer

Airborne validation of spatial properties measured by the CALIPSO lidar

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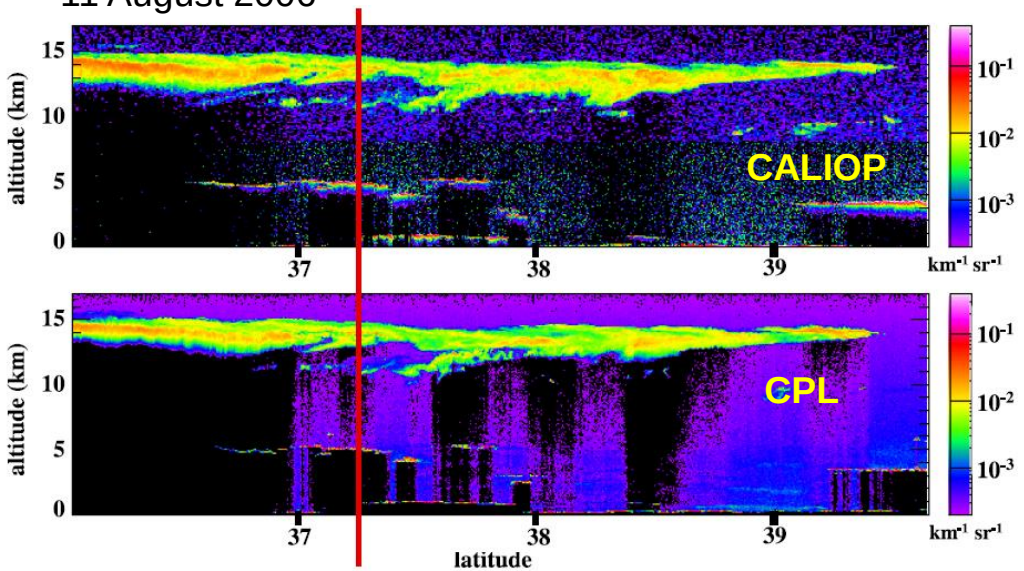
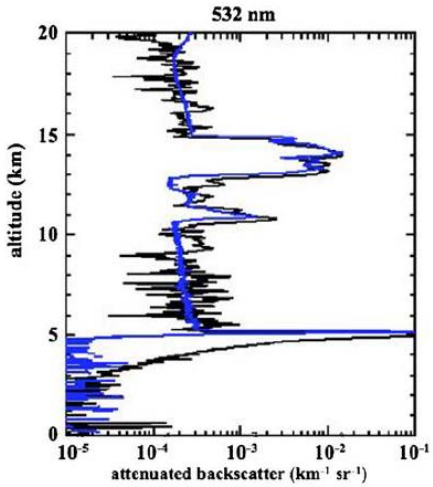
11 August 2006

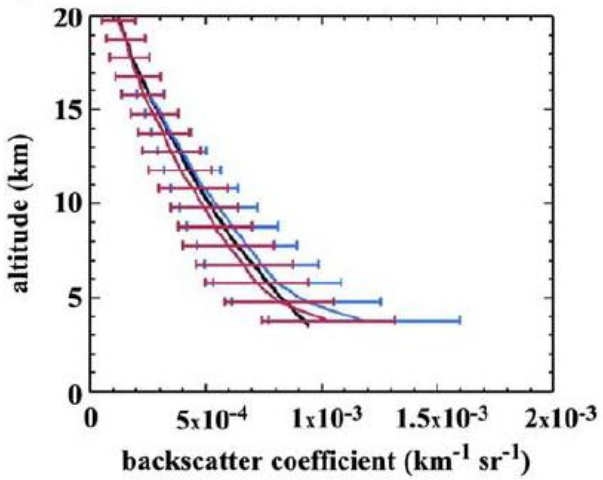




CALIOP (black)
CPL (blue)

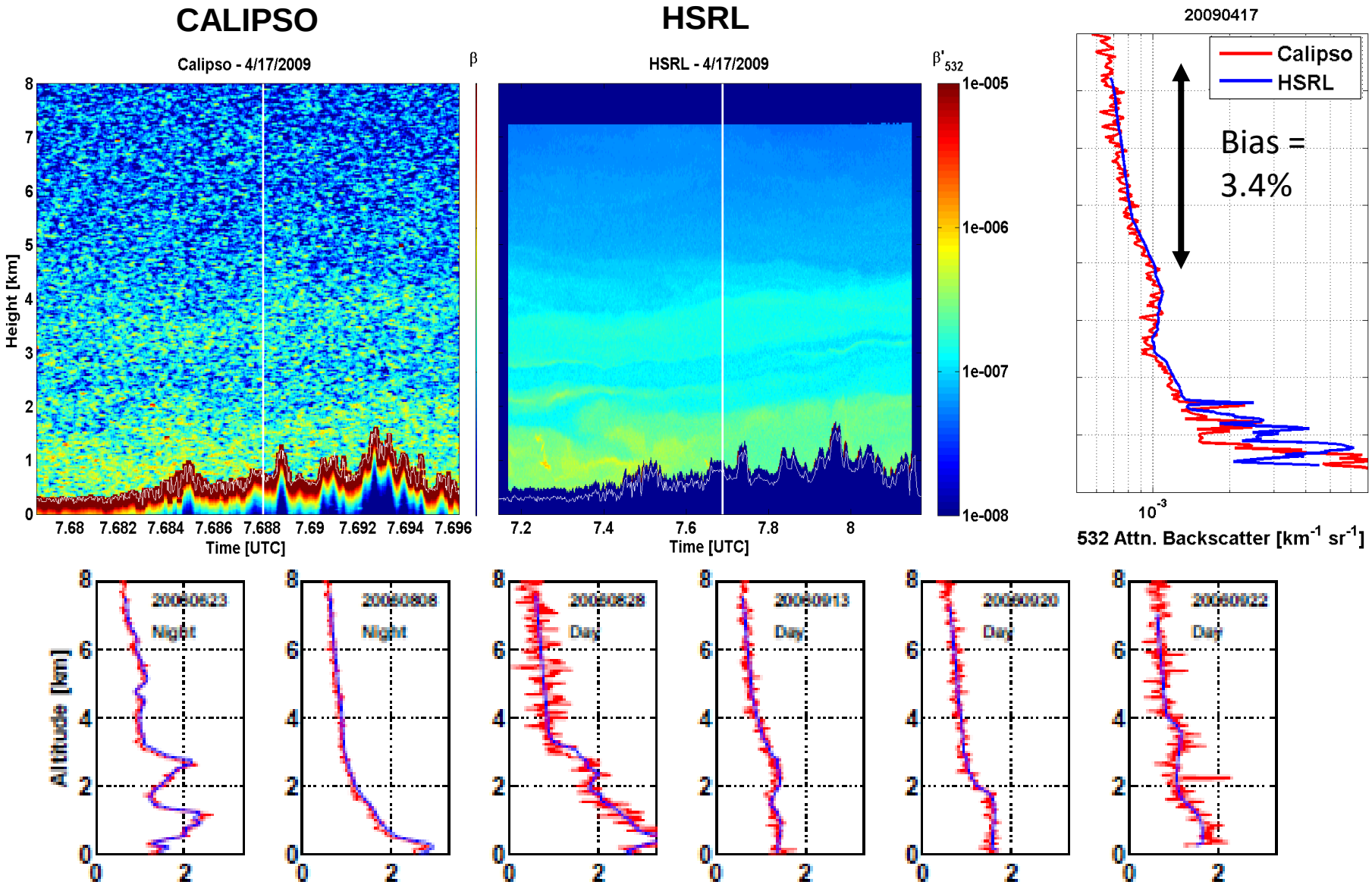
Rayleigh backscatter profiles:

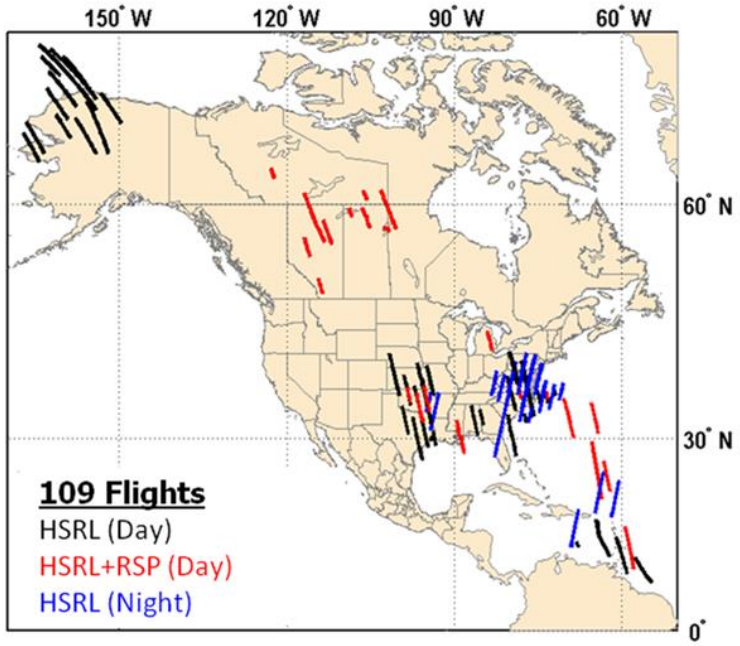
CALIOP – red
CPL – blue
rawinsonde - black



532 nm Backscatter Calibration Assessment

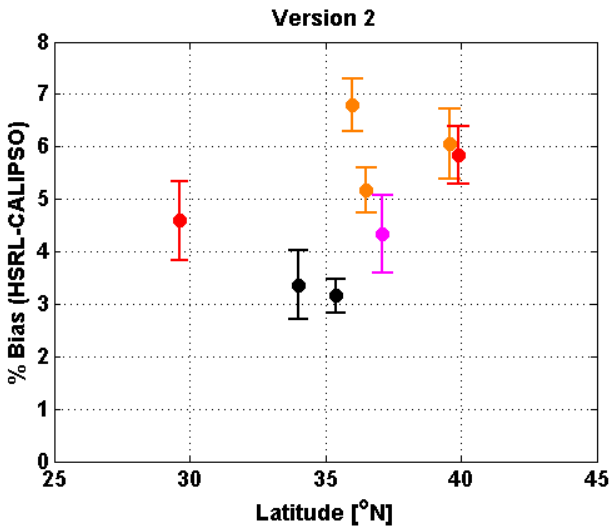
4/17/2009

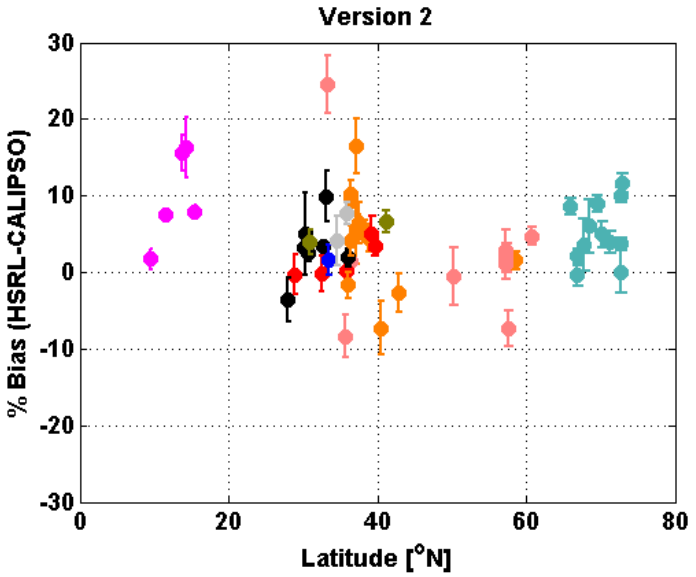




HSRL used as independent check on CALIOP calibration

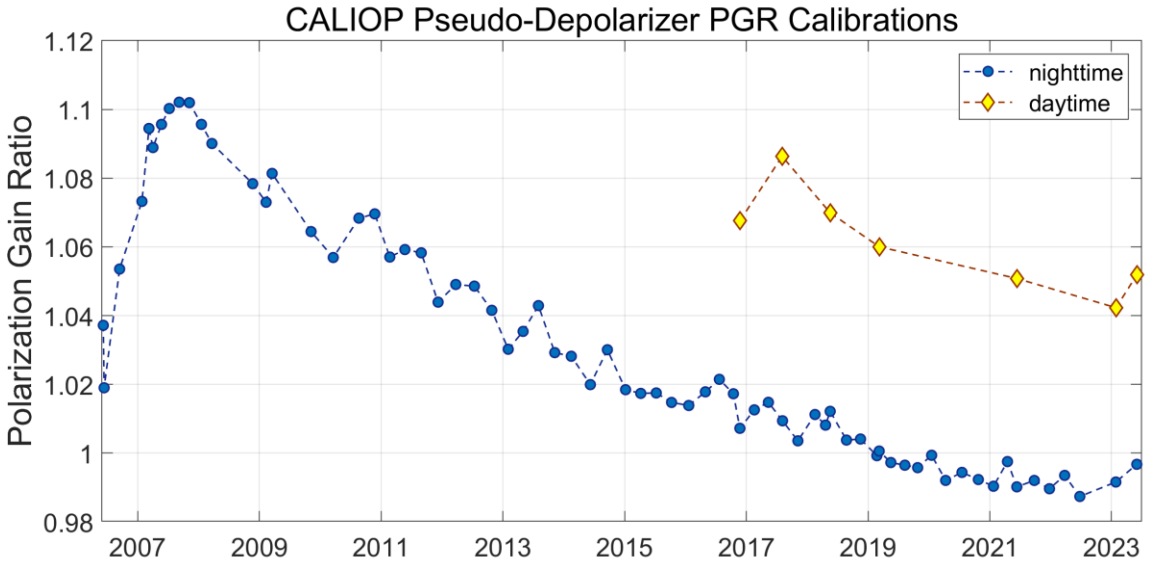
Over 140 underflights since 2006:
a mix of field campaigns
and dedicated flights





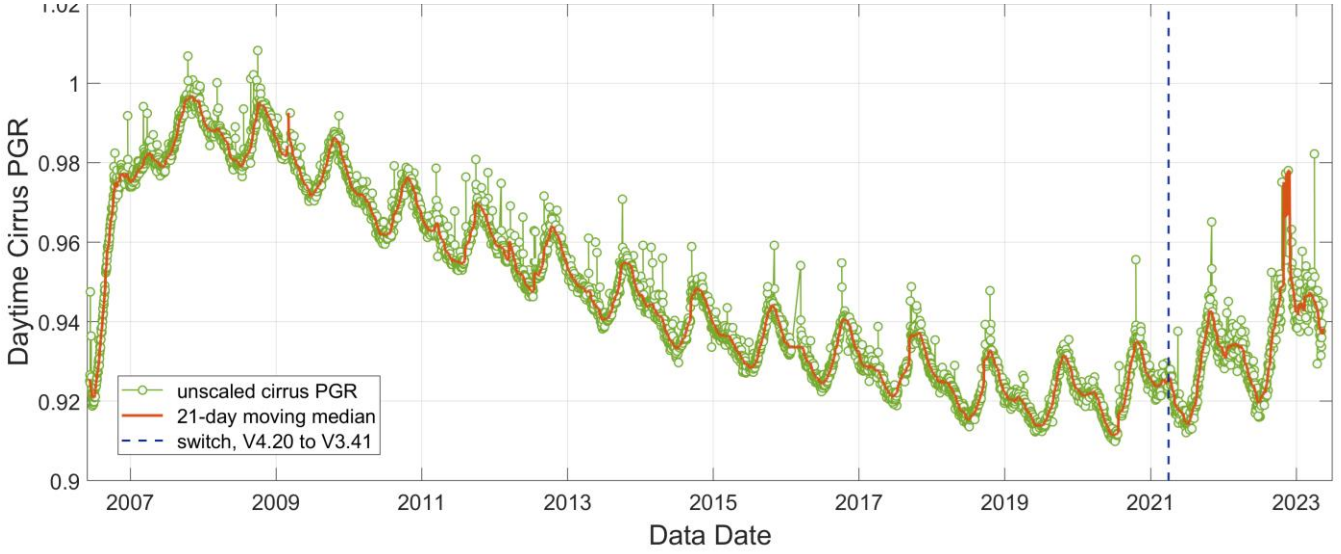
Biases and uncertainties in method estimated at 4.5%±3.2%
(Rogers et al, ACP, 2011)

PGR Calibration: OBH vs Cirrus Solar BG



Polarization Gain Ratio Trends
using on-board calibration hardware

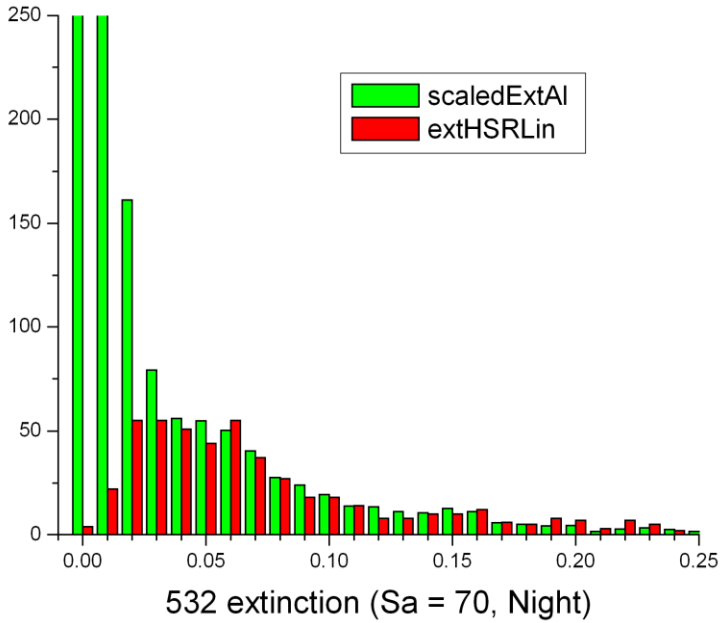
unscaled daytime PGR using in CALIOP V4.51 data products



Validation of Level 2 aerosol from HSRL

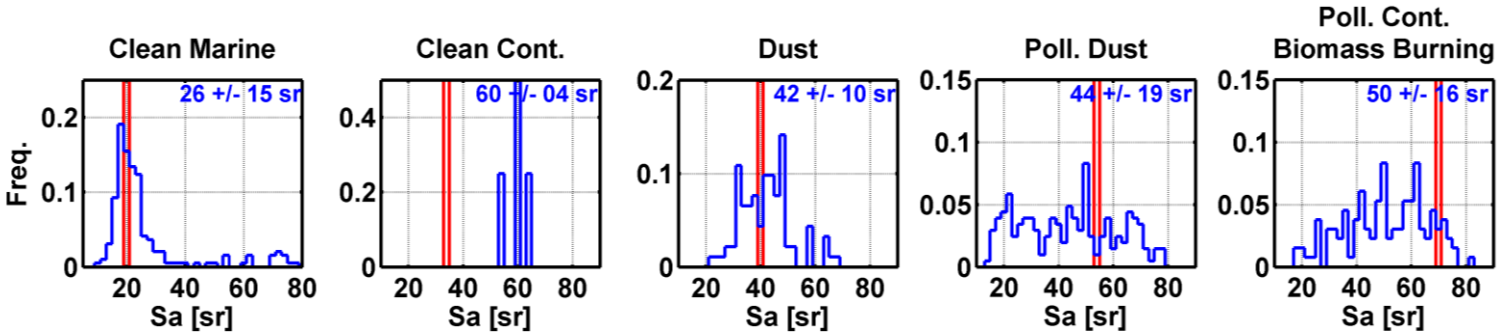
Direct characterization of extinction sensitivity:

- **histogram of HSRL aerosol inside layers detected by CALIOP vs. histogram of all HSRL aerosol**



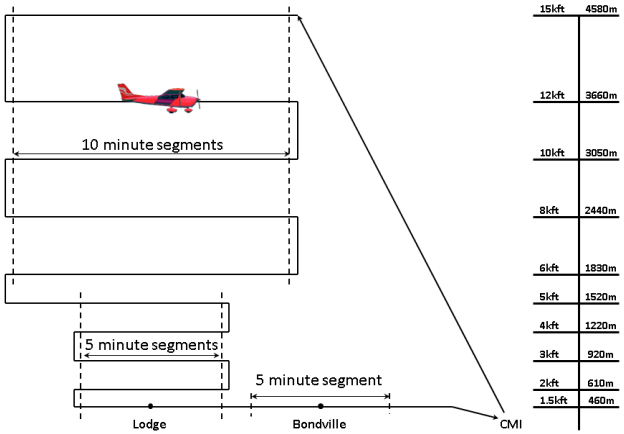
Validation of CALIOP aerosol typing:

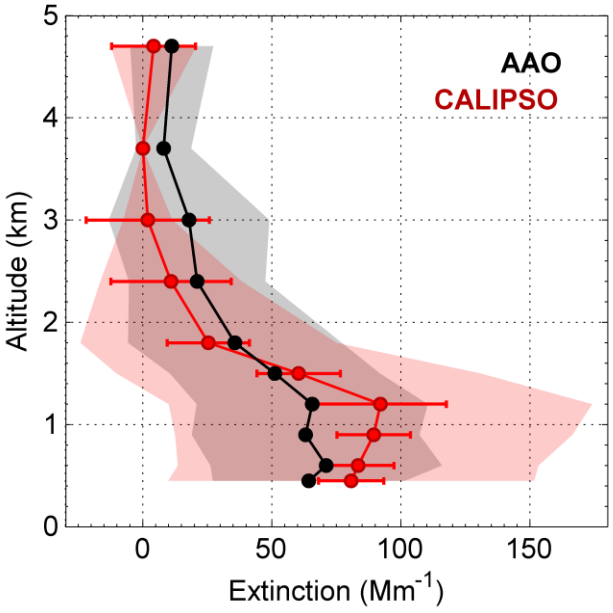
HSRL measured lidar ratio vs. CALIOP aerosol type (daytime)



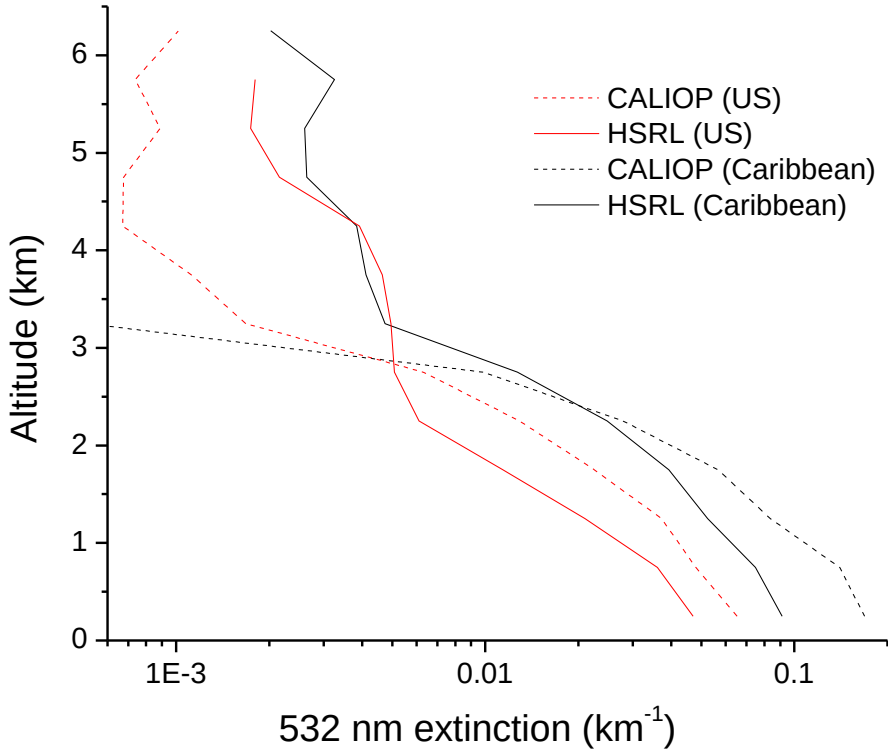
(Rogers et al, 2012)

NOAA/ESRL Cessna T206 campaign
28 cases from 63 underflights, 2006-2009





Mean extinction profiles from nighttime HSRL underflights (mostly in eastern US)

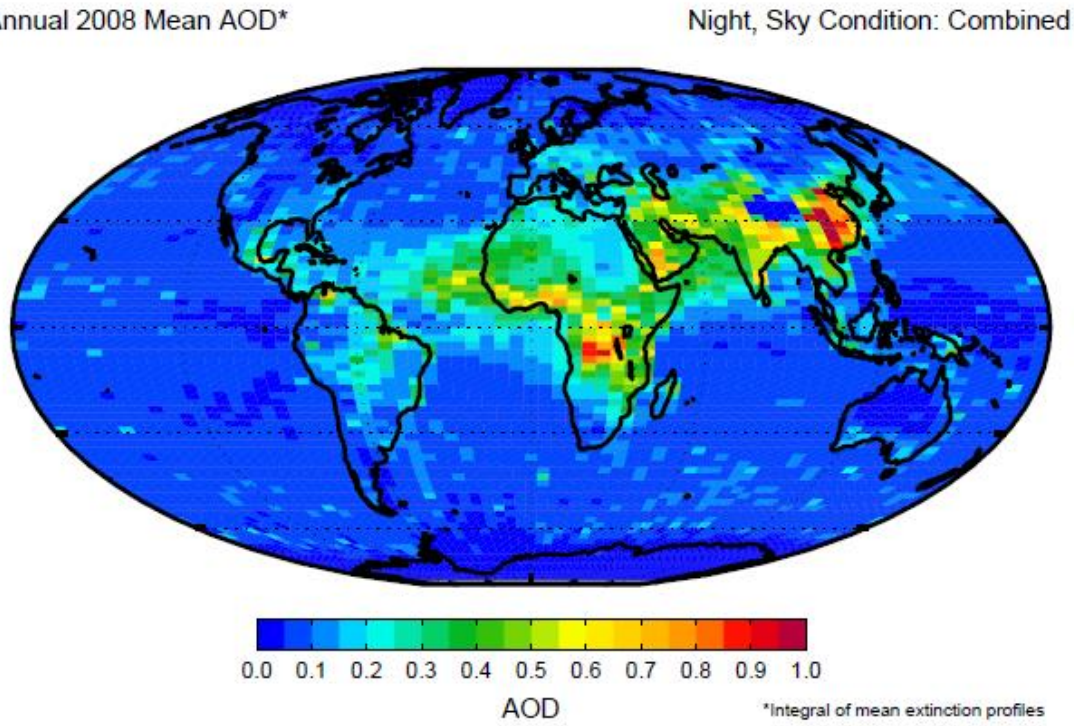


Mean extinction profiles for 28 collocated *in situ* airborne measurements in Illinois

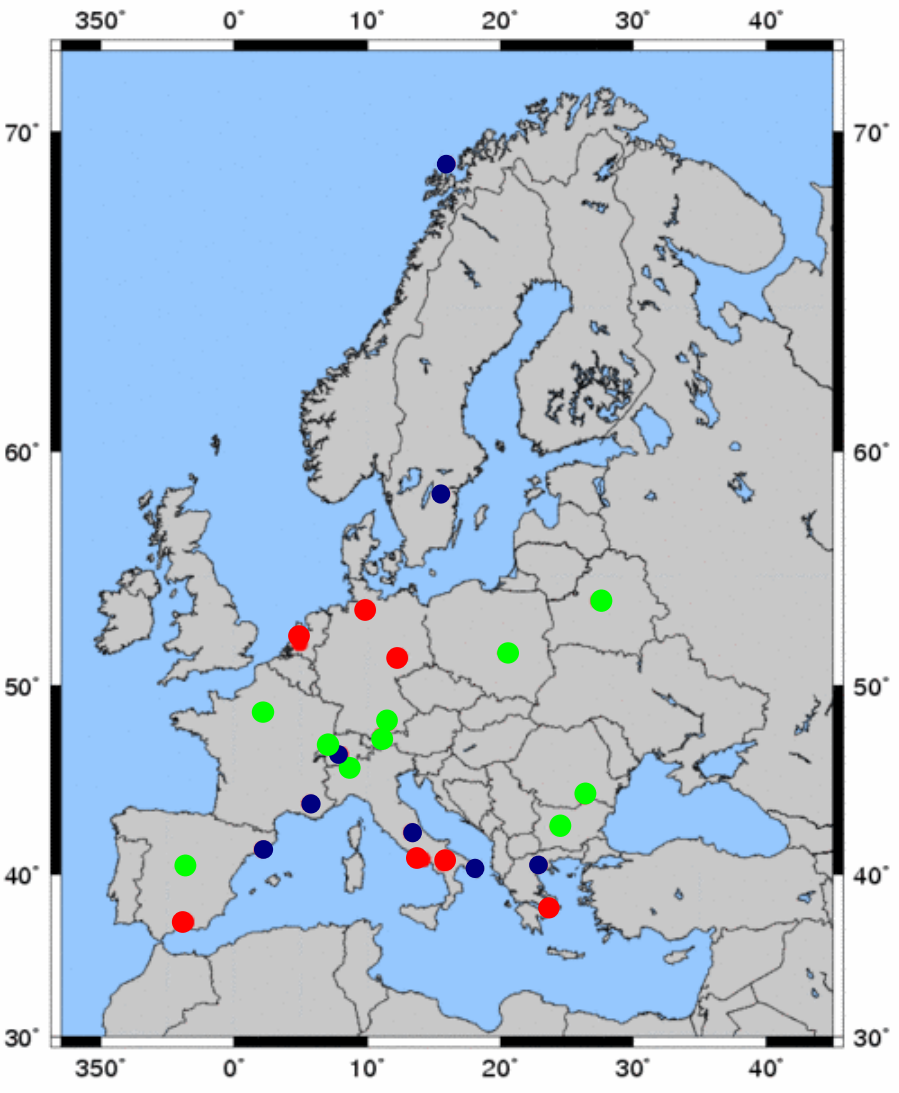
(Sheridan et al, 2012)

‘Validation’ is not always possible

- Consistency checks (does it 'look right’)
  - Not exactly “validation” but useful, especially in the early days
  - sometimes nothing better
- Satellite comparisons
  - Depending on parameter and sensor, varies from true validation to 'sanity check'



Ground Networks: Earlinet

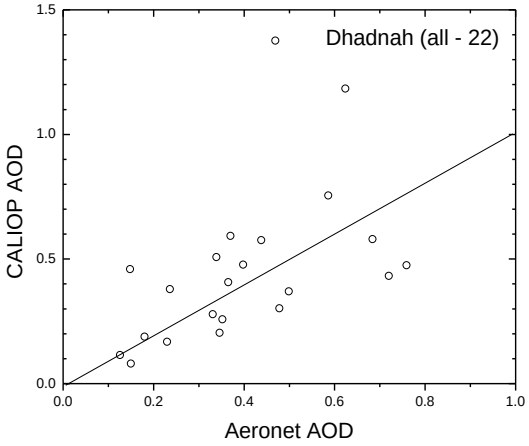


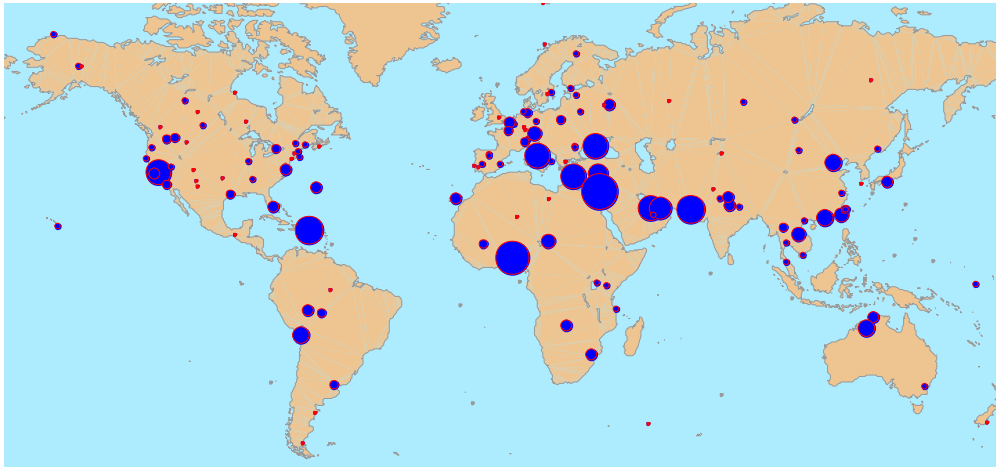
- One of several networks
- > 20 stations
- Many 355 nm Raman lidars
- A few 532 nm Raman lidars
- Routine observations over years
- Issues:
  - Spatial mismatch
  - Raman mostly night only
  - Perrone et al (2011) describes comparison methodology
  - Comprehensive L2 analysis not yet carried out

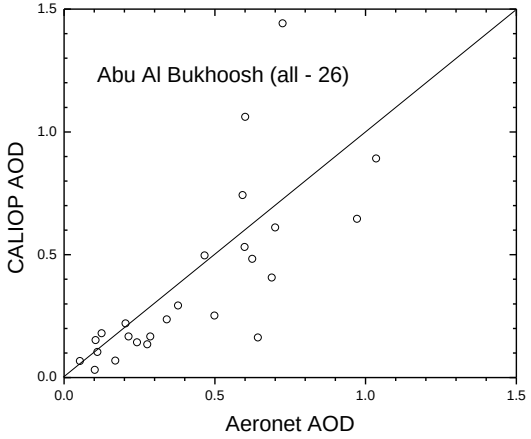
    (c. 2012, still true?)

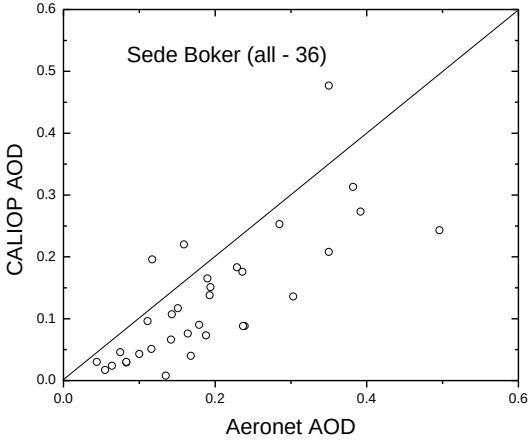
Ground Networks: Aeronet

- **Useful, but need to accumulate samples over several years**
  - **Typically find one or two usable samples/station/year**
  - **Only provide column properties**









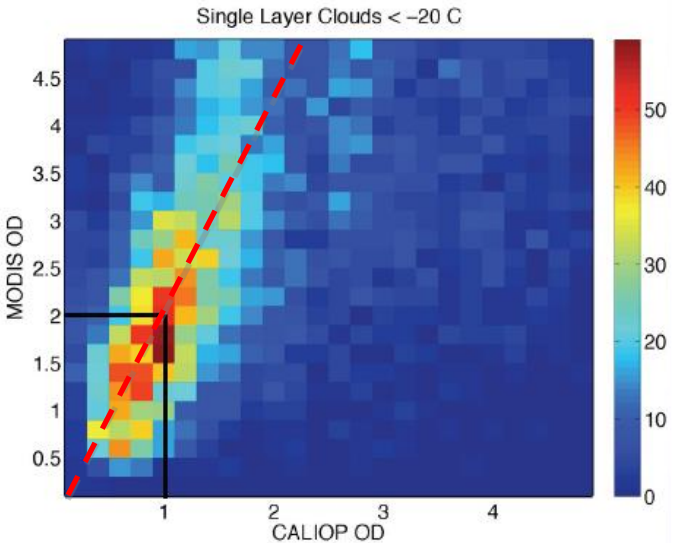
Omar et al, 2012: 1081 samples over 4 years (600 cloud-free)
Identified problems due to:
- **Spatial mismatch**
- **Topography**
- **Aeronet cloud contamination**

in addition to CALIOP retrieval errors

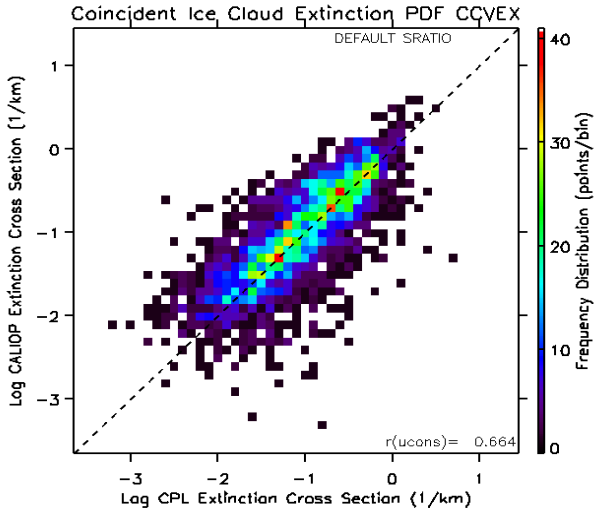
MODIS: Cirrus Optical Depth

- Initial CALIOP-MODIS comparison indicated significant discrepancy
  - Daytime only
  - Mostly unconstrained retrievals
- Whereas initial CALIOP-CPL comparison indicated good agreement
  - But CALIOP and CPL retrievals not completely independent
- MODIS team concerns (Collection 6) led to informal working group (NASA, NOAA, NCAR, LMD, LOA)
- Have made progress using 12 um optical depth from IIR

CALIOP vs. MODIS



CALIOP vs. CPL

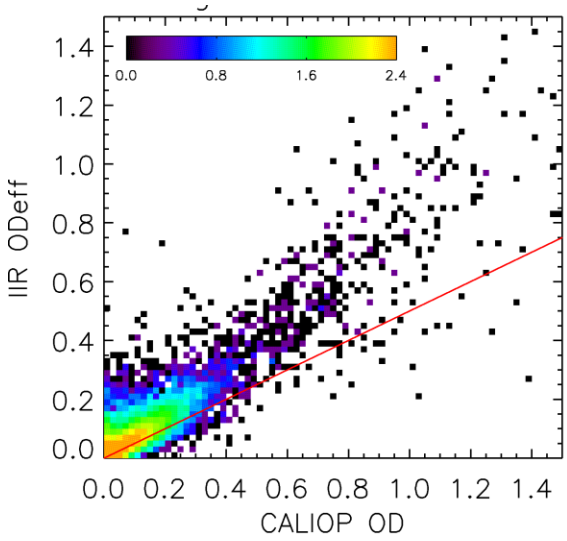


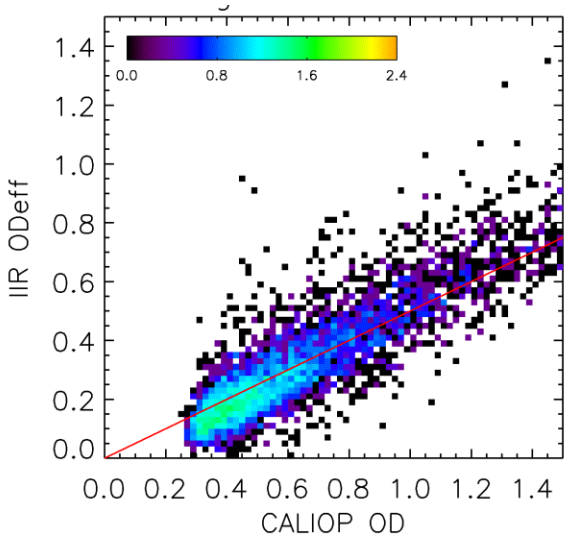
CALIPSO IIR: Cirrus Optical Depth

Unconstrained

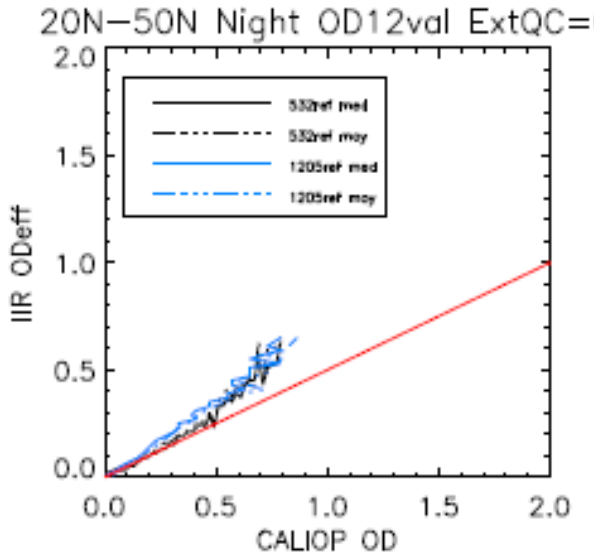
Constrained

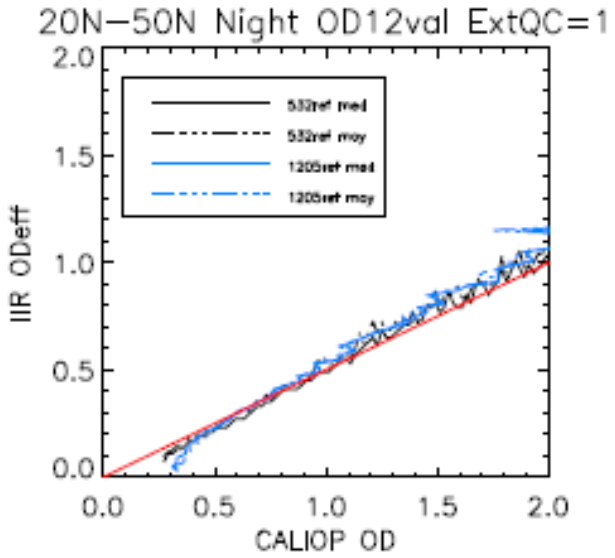
(nighttime)





means and medians:





Final Thoughts

- “Truth” is elusive
- Validation is never finished
  - It is only approached asymptotically
- Validation of products globally is challenging
- Ground-based measurements have co-location issues
- Large field campaigns useful, but:
  - Validation tends to be one objective of many
- Not exactly “validation” but critically important
  - Consistency checks (does it 'look right’)
  - Intercomparison of multiple retrieval algorithms based on independent assumptions
- Depending on parameter, “validation” can vary from ‘sanity check’ to true validation