New Cirrus Retrieval Algorithms and Results from eMAS (enhanced MODIS Airborne Simulator) during SEAC4RS

R. Holz[1], S. Platnick[2], K. Meyer[2,3], C. Wang[2,4], G. Wind[2,5], G. T. Arnold[2,5],
N. Amarasinghe[2,5], M. D. King[6], A. Heidinger[7], S. A. Ackerman[8],
J. Yorks[2,5], M. McGill[2,] B. Van Diedenhoven[9]

[1]U. Wisconsin, [2]GSFC, [3]USRA/GESTAR, [4]ESSIC, [5]SSAI, [6]CU, [7]NESDIS, [8] UW/CIMSS, [9]Columbia U.

eMAS Instrument Team

J. Meyers, R. Dominquez, E. Hildum, H. Su, P. Grant, T. Ellis

Ames Airborne Sensor Facility/UC Santa Cruz

Science Team
Meeting 2015

eMAS Instrument

- NASA ESD facility imager at NASA Ames Airborne Sensor Facility
  - 38 spectral channels (VNIR-LWIR), 50 m nadir spatial resolution and 37 km swath from 20 km altitude (ER-2). Onboard 2-point blackbody IR cal.
  - Recently upgraded with a new Stirling-cooled infrared spectrometer
  - Further information: http://mas.arc.nasa.gov
- Spectral Radiometric Correction Studies
  - IR channels

    Algorithm to filter noise from Stirling cooler (60 Hz + harmonics). Mainly affects ends of detector array (H_2O, CO_2 channels).

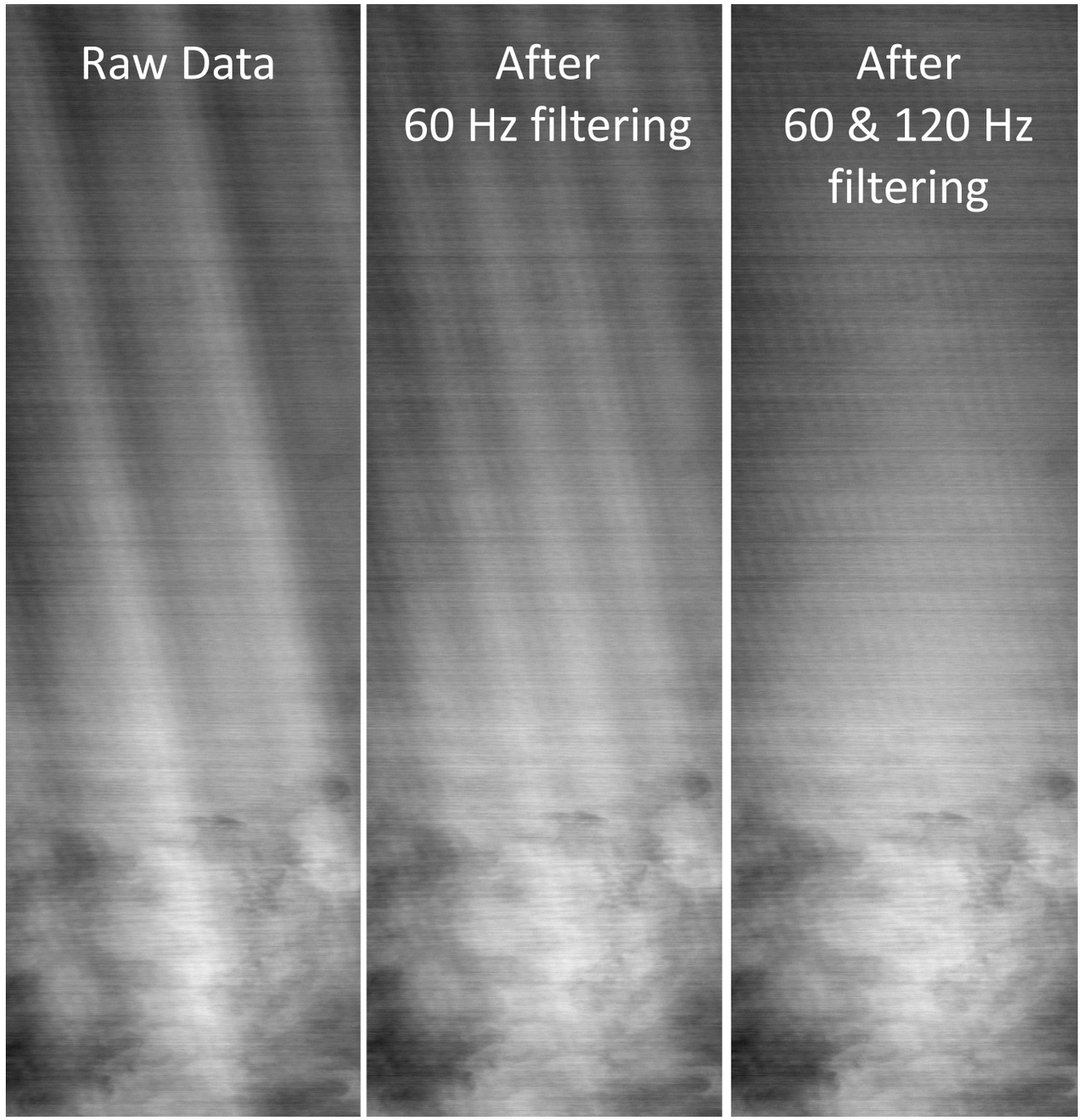
    Intercomparison with MODIS
  - Solar reflectance channels

    Radiometric intercomparison with MODIS and vicarious calibration (Ivanpah Playa – JPL, UC Davis), etc.

eMAS IR 60 Hz Coherent Noise Reduction Update

T. Hildum, R. Dominguez

- Coherent noise most significant at ends of LWIR detector array (water vapor and CO_2 channels)
- Less significant in middle of array (window channels)
- Radiometric accuracy vs. Terra MODIS LWIR w/Stirling cooler turned off: < 0.5K bias in eMAS window channels [C. Moeller]



eMAS channel 30 (6.7 µm), 13 Sept. 2013, 18:32 UTC

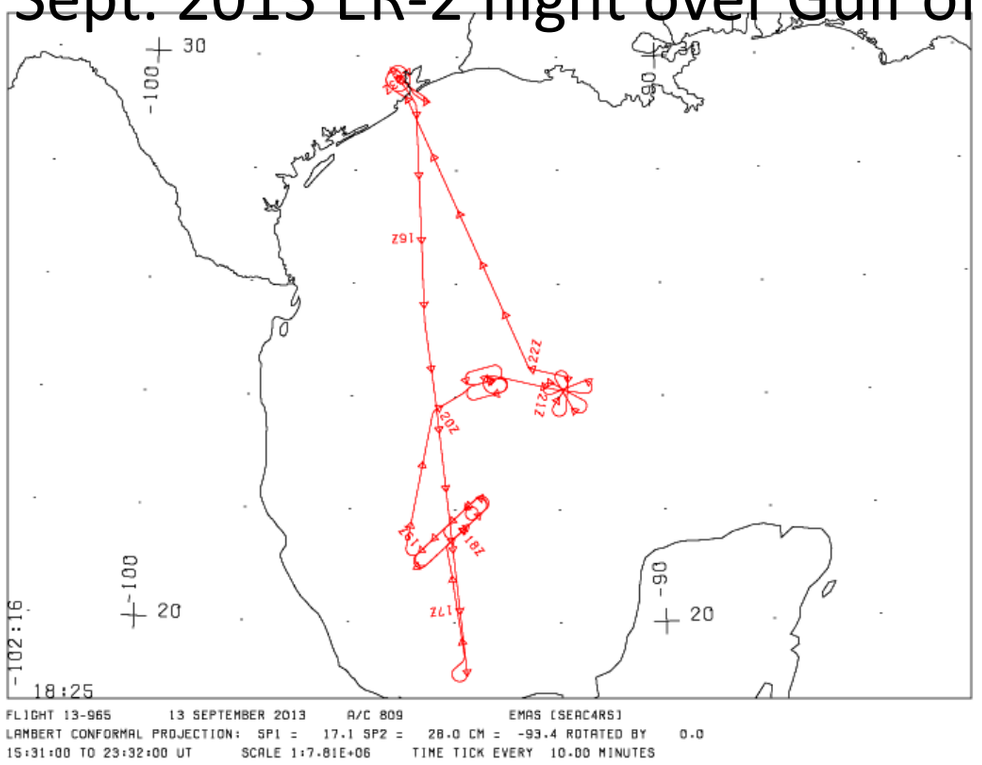
Collocated ER2 Data products

- Physical collocation software developed to facilitate quantitative inter-comparisons between the remote sensing observations on the ER2.
- The software currently supports eMAS, CPL, and RSP
- Using the collocation software merged data files are created containing the L1 and L2 products for each instrument averaged to a consistent resolution

eMAS Cirrus Retrieval Examples

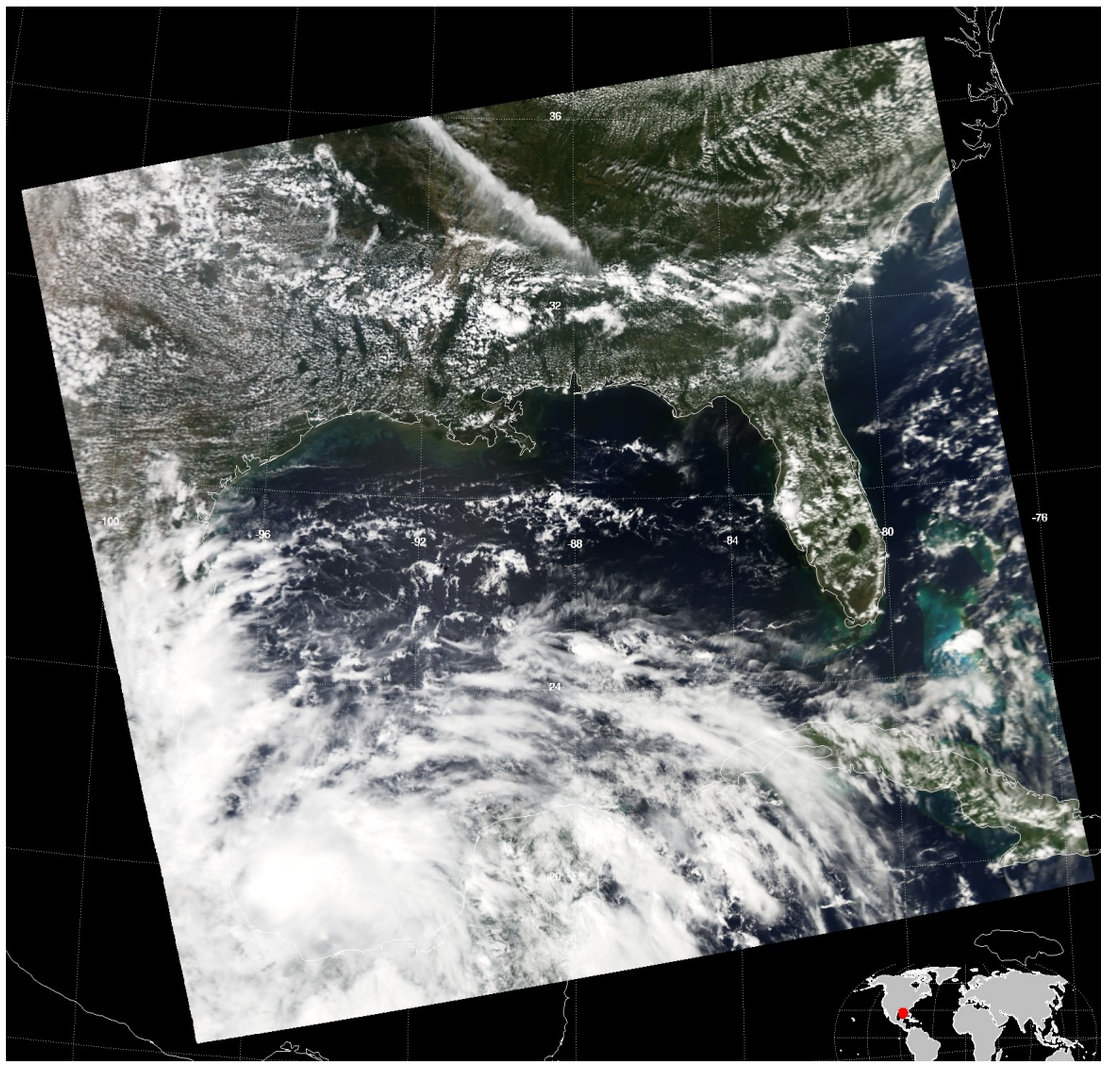
- Algorithms
  - VNIR/SWIR/MWIR method using MOD06/VIIRS-like code (0.6, 1.6, and 2.1 um)
  - 1.83 & 1.93 water vapor channels [K. Meyer et al.]
  - IR Optimal Estimation (all LWIR channels except O_3) [C. Wang et al.]
  - IR + CPL heights OE [R. Holz et al.]
  - CPL cirrus optical thickness [J. Yorks, M. McGill]
  - RSP [see van Diedenhoven et al]

- Examples from 13 Sept. 2013 ER-2 flight over Gulf of Mexico (T.S. Ingrid)

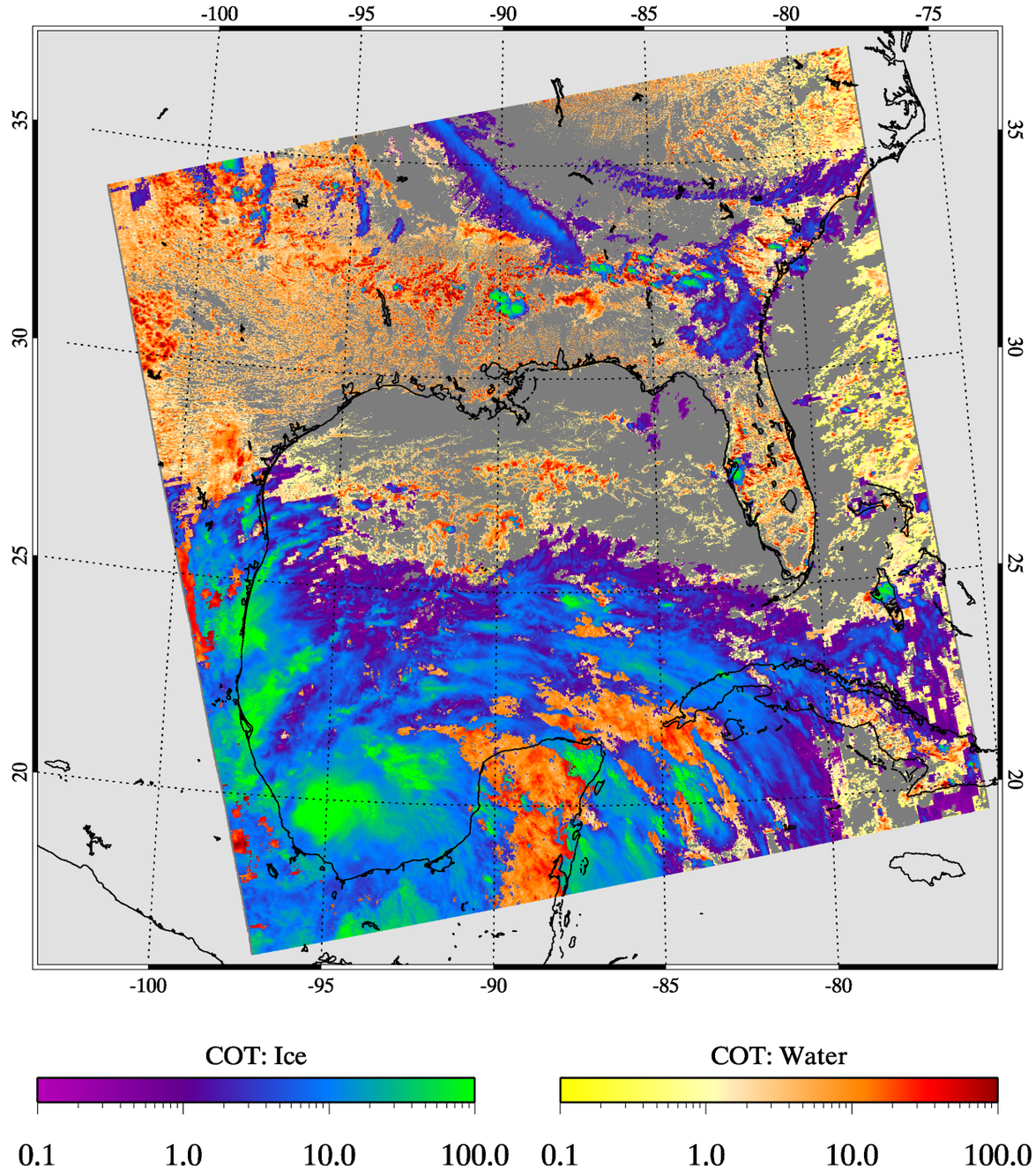


MODIS Aqua, 1910 UTC, 13 Sept. 2013

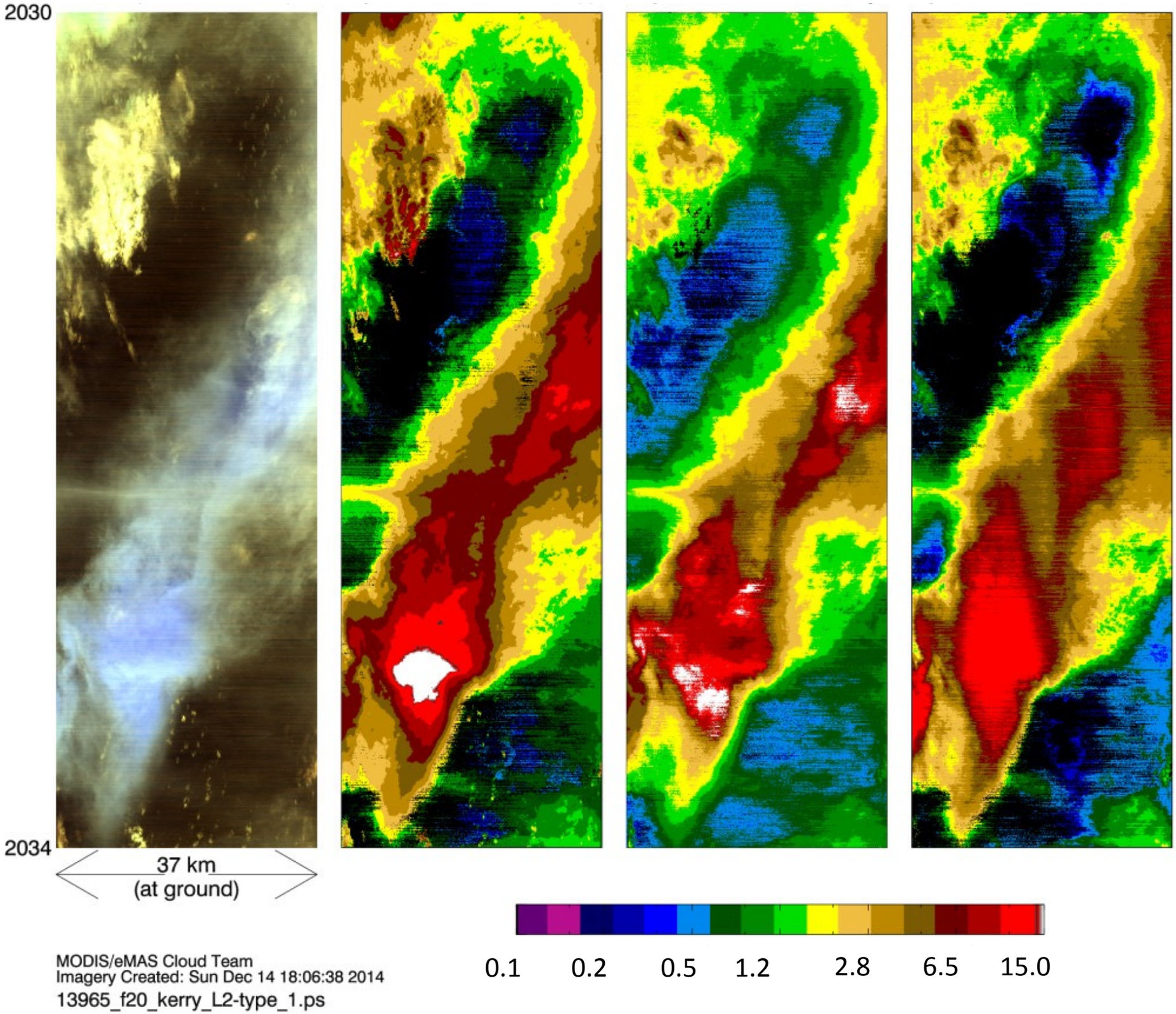
true color



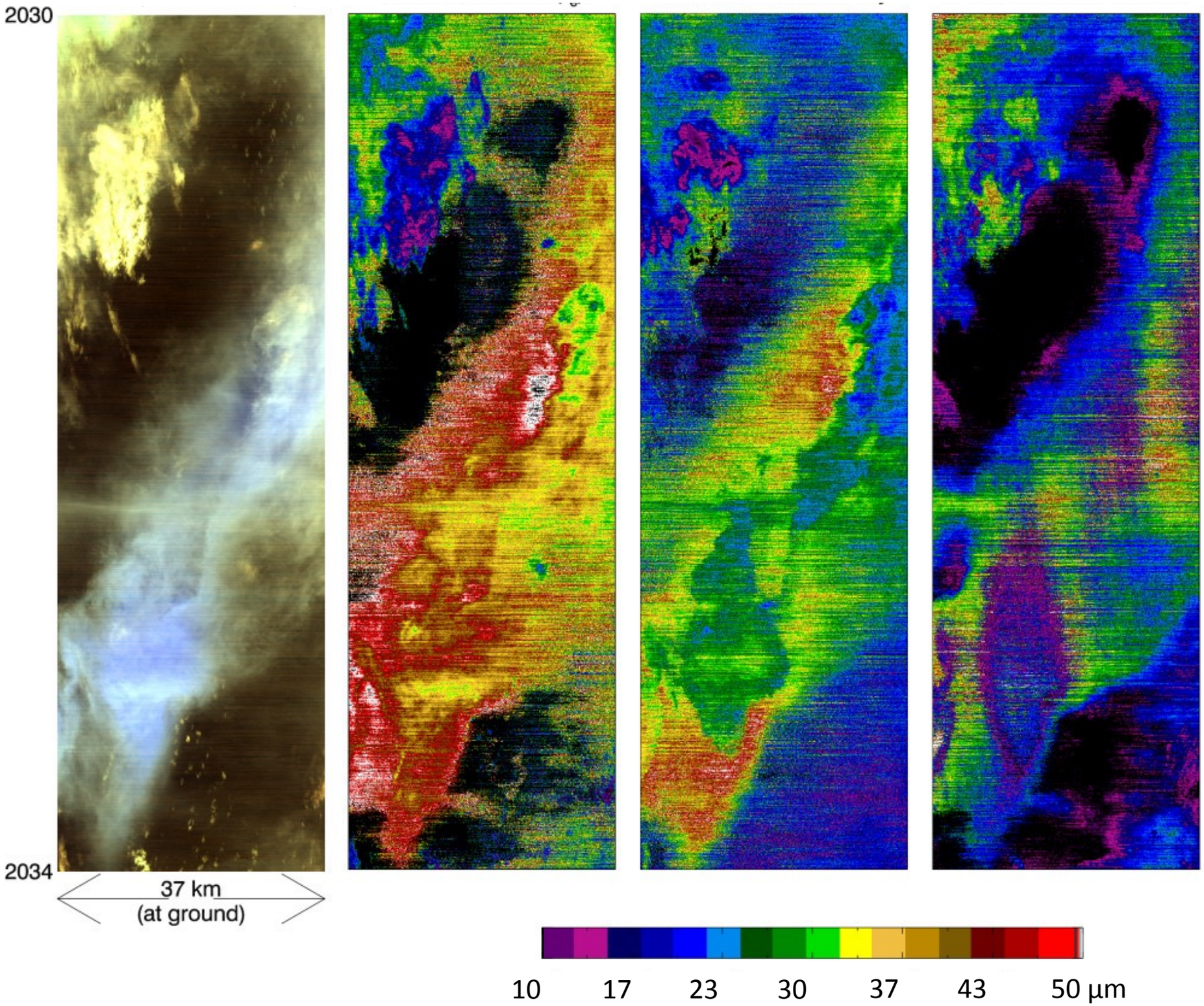
MOD06 Liquid & Ice Cloud Optical Thickness



eMAS Flight Track #20, 13 Sept. 2013 **Cloud Optical Thickness**



eMAS Flight Track #20, 13 Sept. 2013 **Cloud Effective Radius (µm)**

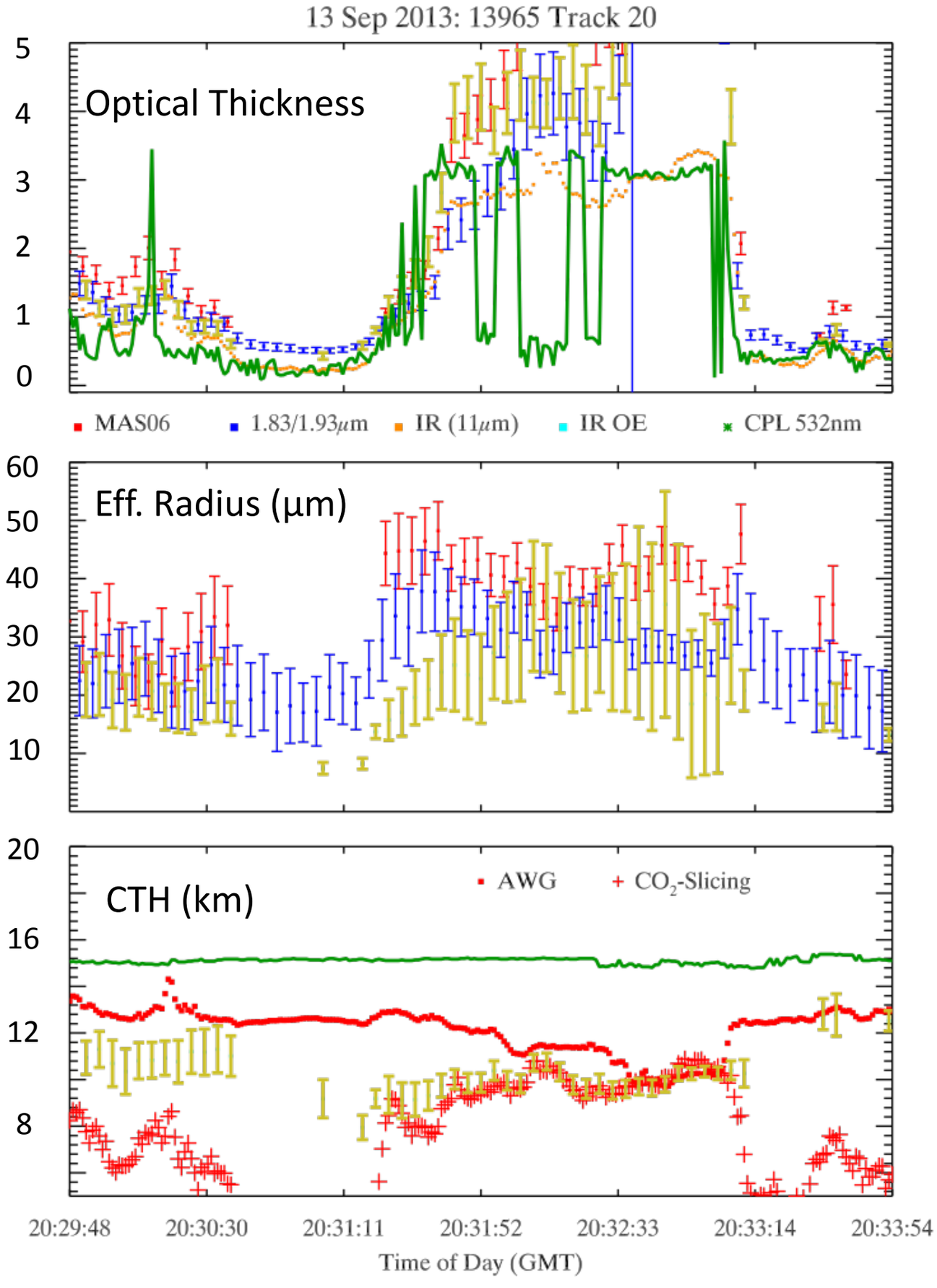


Ice Cloud Retrievals along Nadir Track

eMAS Track #20, 13 Sep 2013
(128 pixel regions for CPL matchup)

KEY

- – **CPL**
- • **IR (11µm) + CPL**
- • **MOD06/AWG**
- + **MOD06 CO2 slicing**
- • **1.88 µm dual channel**
- • **IR OE**



Summary

- **eMAS Cirrus Retrievals**
  - Three new retrievals have been developed (dual 1.88 µm water vapor channels, IR OE (EMAS only), and CPL+eMAS OE) and compared with Collection MOD06-like and CPL retrievals.
  - Optical thickness retrievals in very good agreement (typically within expected uncertainties).
  - Effective radius retrievals often within uncertainties for moderately thick cirrus, but some substantial differences.
  - IR OE cirrus heights generally between CO2 slicing and retrievals using the team's VIIRS AWG algorithm (A. Heidinger). The cirrus retrievals are being performed on a track-by-track basis
- **eMAS SEAC4RS Archive**
  - All L1B and L2 cloud retrievals be archived in MODIS distribution system LAADS: ladsweb.nascom.nasa.gov/data/ftp_site.html
  - Solar reflectance calibration corrections have been finalized
  - IR coherent noise filtering completed. Revisiting a subset of flight tracks.
- **Aerosol Retrievals**
  - Contact R. Levy (GSFC)

Improving CALIPSO/MODIS Ice Cloud Optical Thickness and Effective Radius Retrievals Using SEAC4RS Aircraft Observations

Robert Holz, Paolo Veglio, Anne Garnier, Melody Avery, Bastian, John Yorks, and Steve Platnick

The Challenge of Using Aircraft Observations for Satellite Validation

- Satellite match-ups (sampling statistics)
- Collocation (FOV size)
- The vertical dimension
- Sensitivity differences between observations

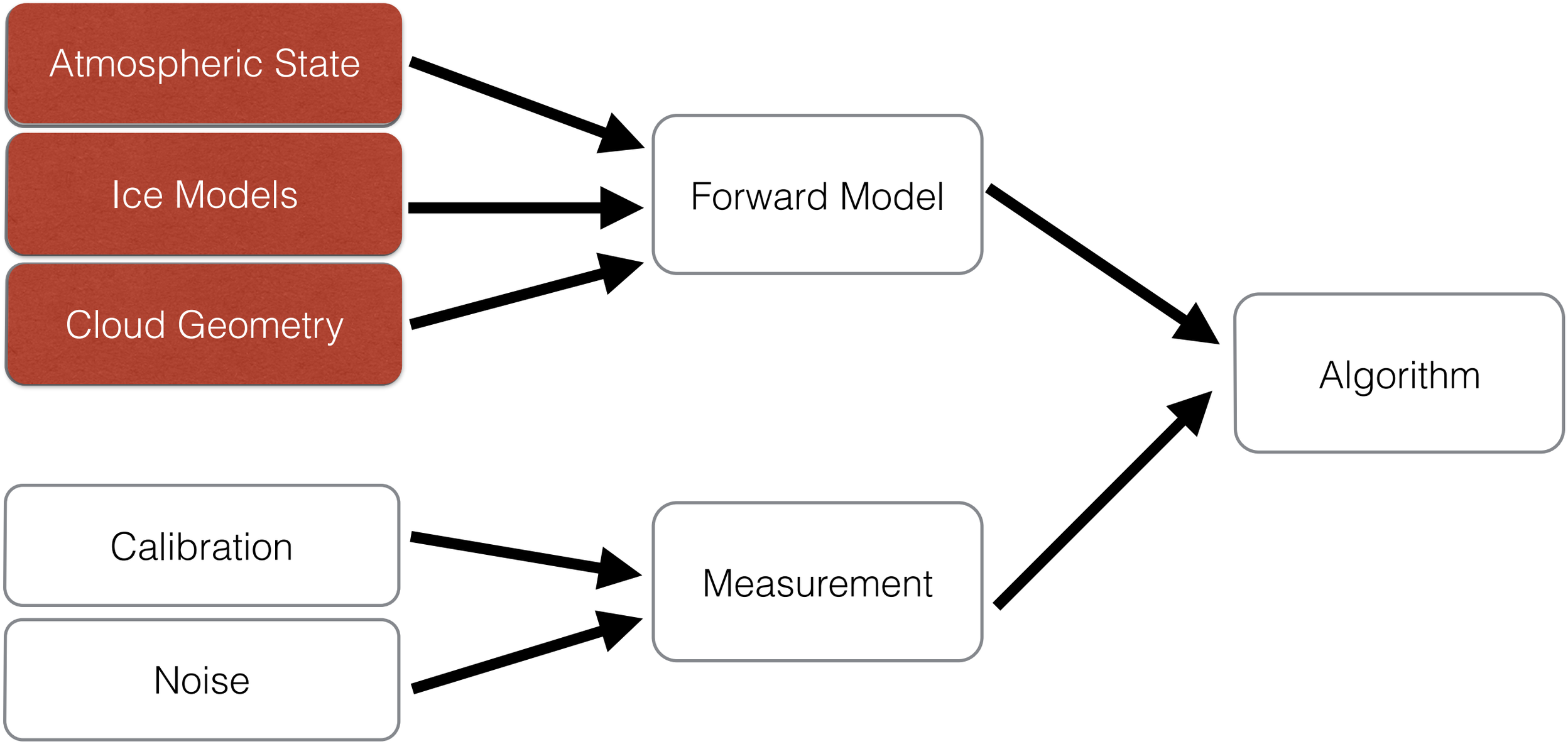
Methodology

- Use the aircraft remote sensing platform (ER2) as as a satellite simulator. This requires developing retrievals for the aircraft observations that are designed to reproduce the satellite sensitivities

- Leverage the active remote sensing (CPL) capabilities to retrieve the vertical distribution of cloud extinction to relate the in-situ observations to passive retrievals

- Using these capabilities assemble a large data set of “coincident” in-situ and remote sensing observations using both SEAC4RS and past experiments

Sources of Uncertainty for Passive Observations

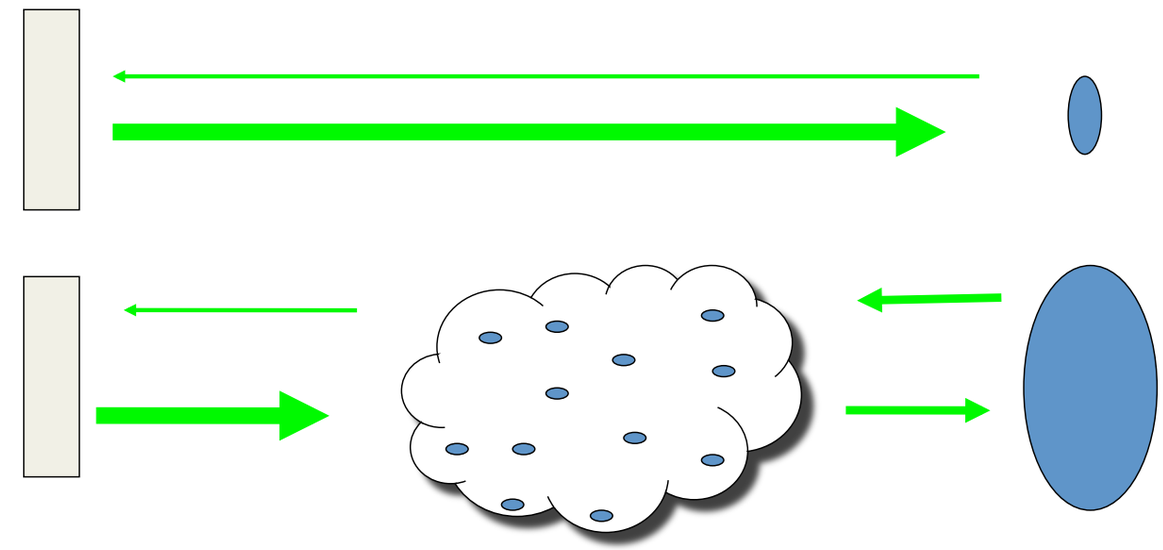


CALIPSO Uncertainty Sources

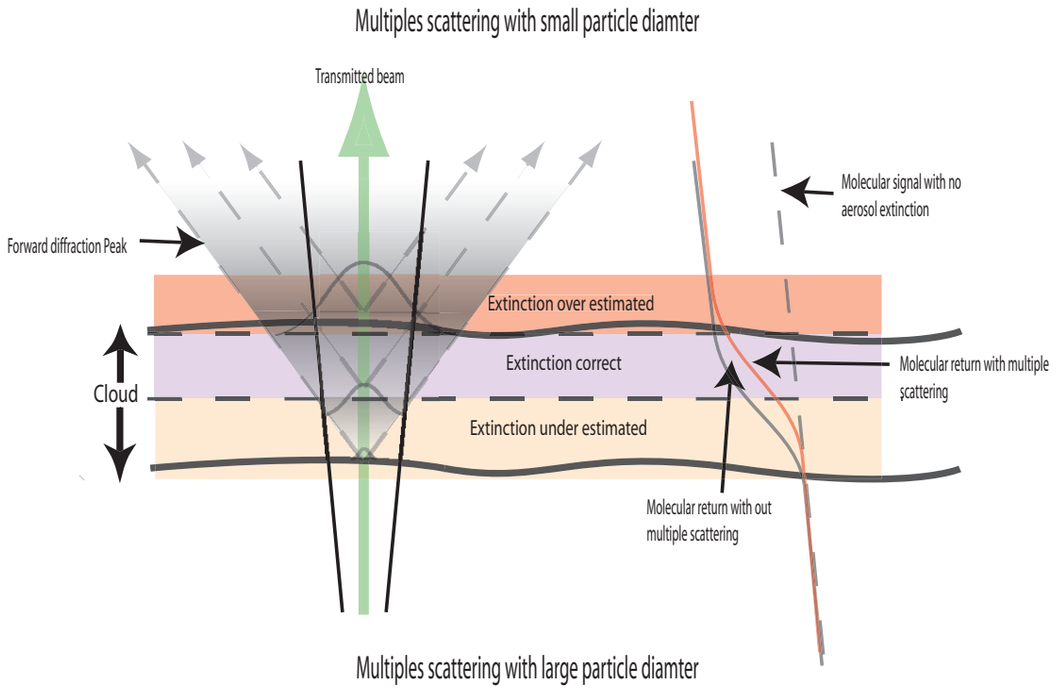
Lidar Ratio

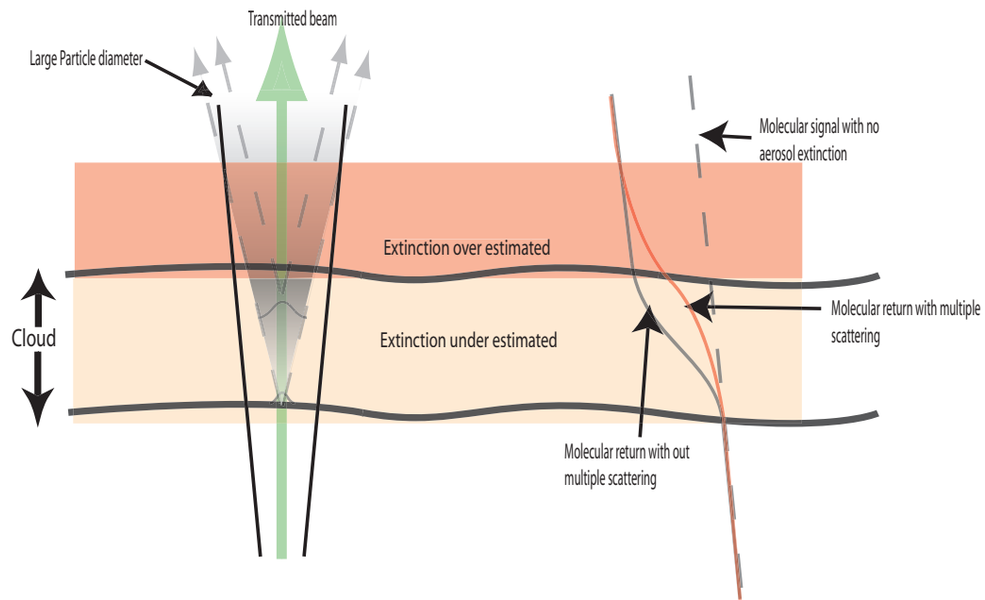
Single Channel lidar

$$N(r) = N_o \frac{cA_r}{2r^2}\left(\beta_a(r)\frac{\mathrm{P_a}(\pi,r)}{4\pi} + \beta_m(r)\frac{3}{8\pi}\right)\exp\left(\int_0^r \beta_e(r')dr'\right)$$

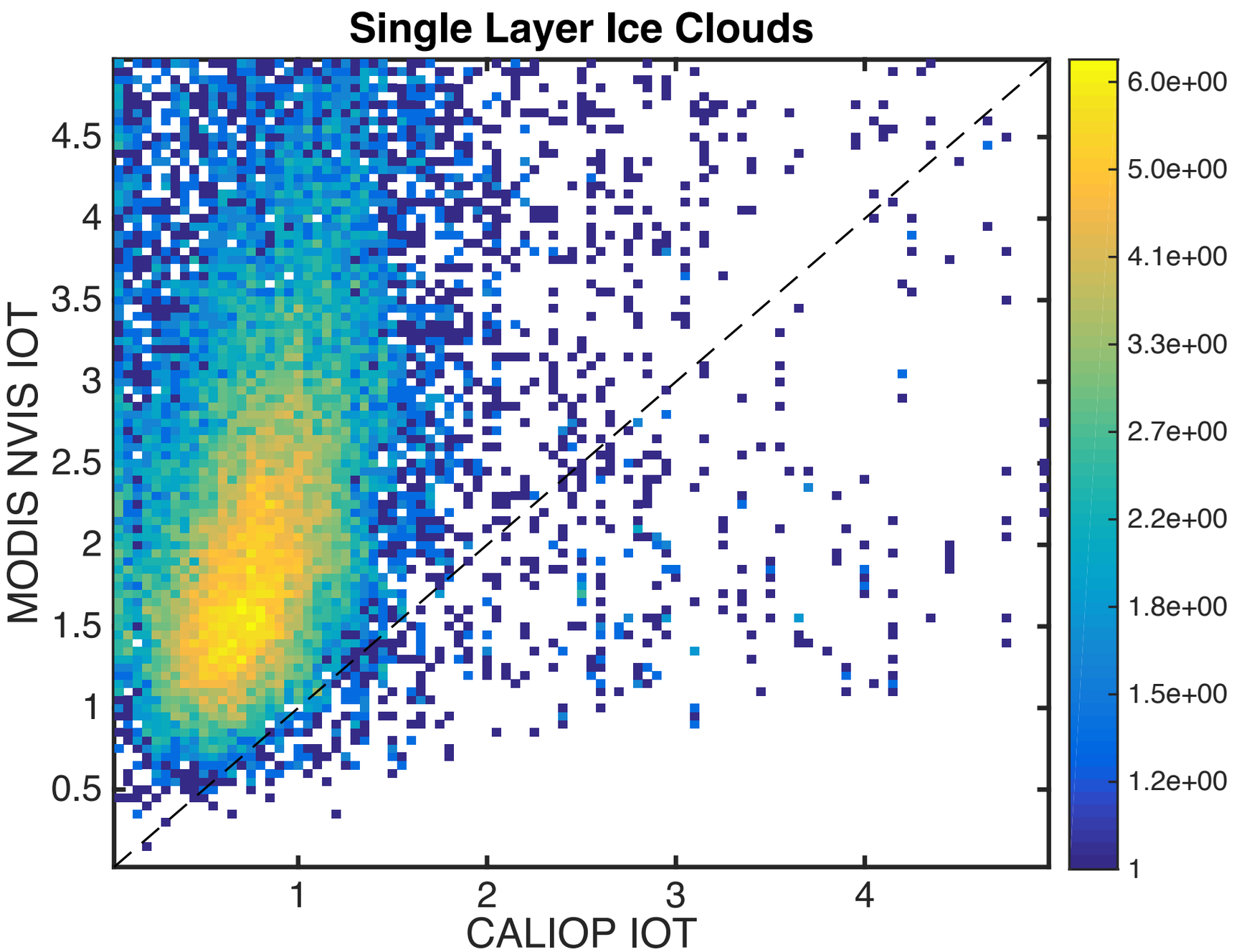


Multiple Scattering

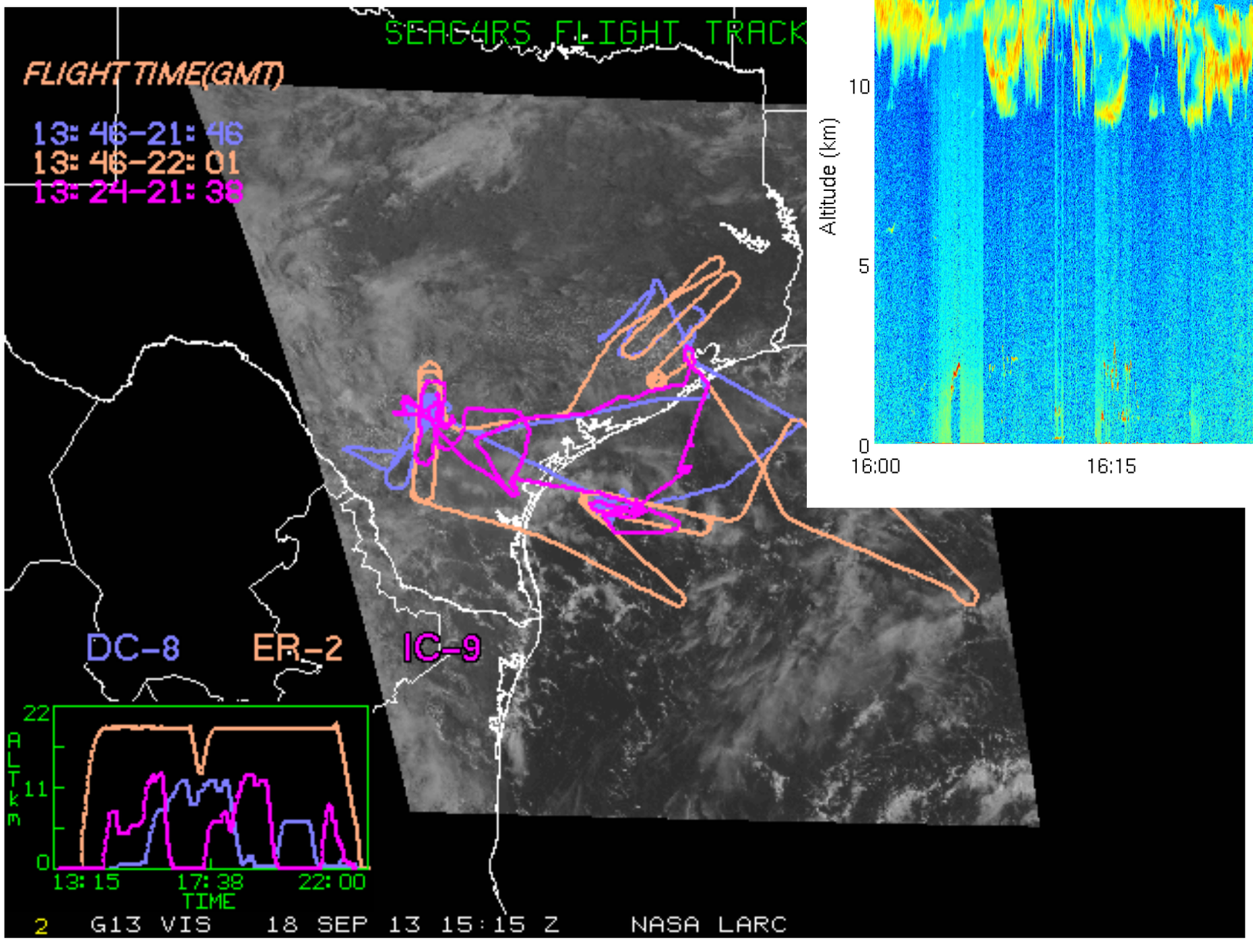


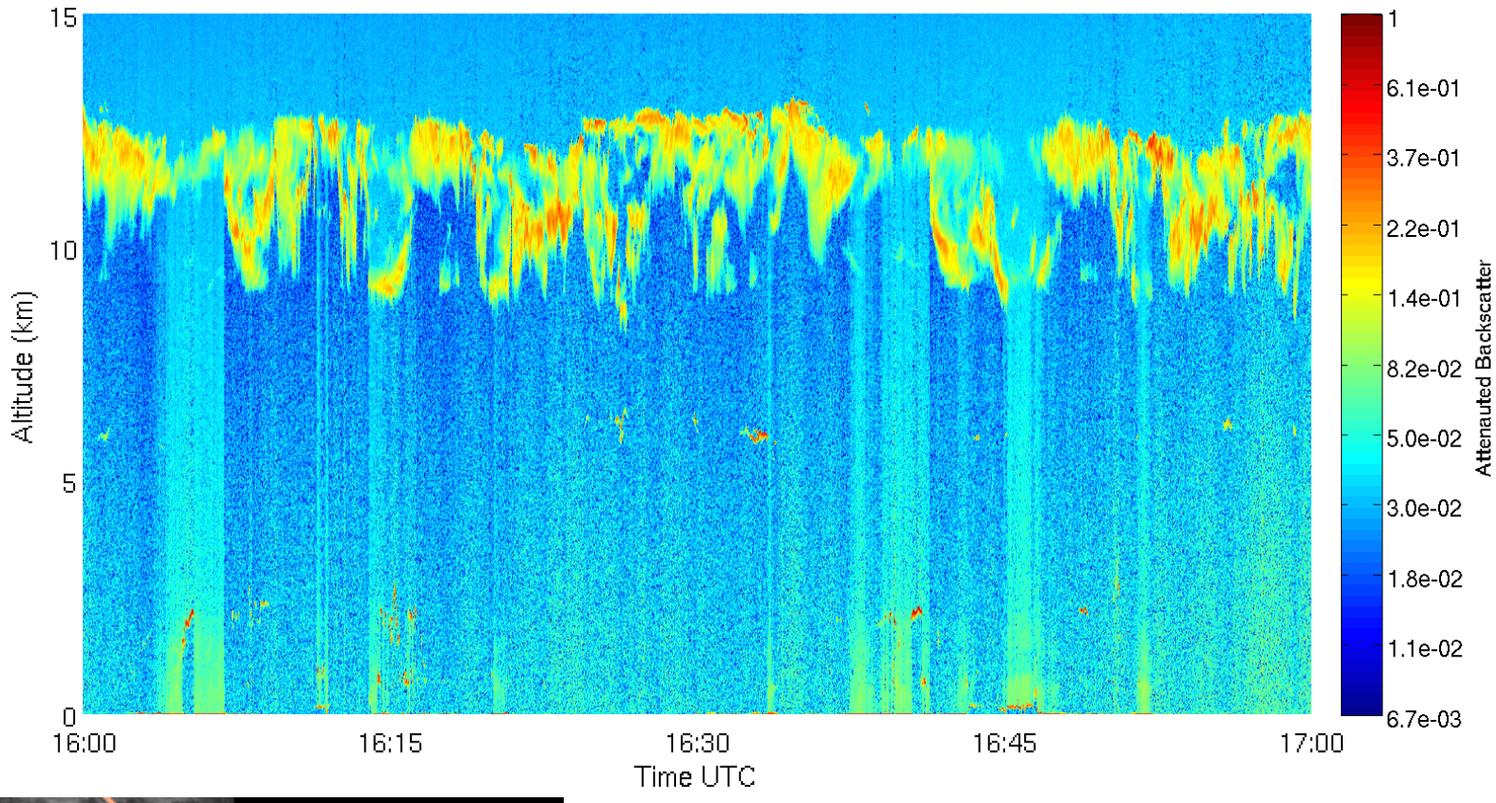


Cirrus OD Biase

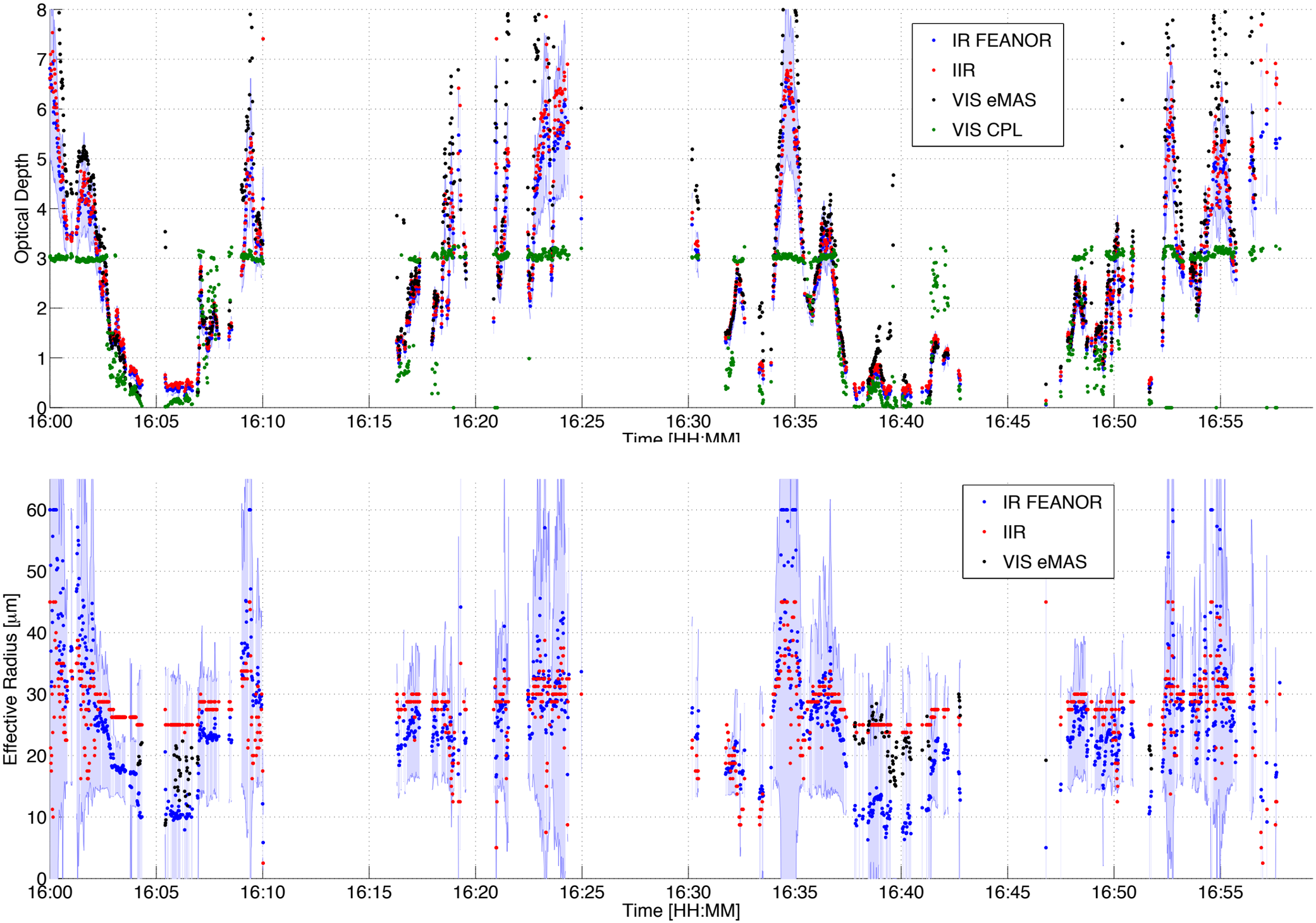


September 18th Case Study

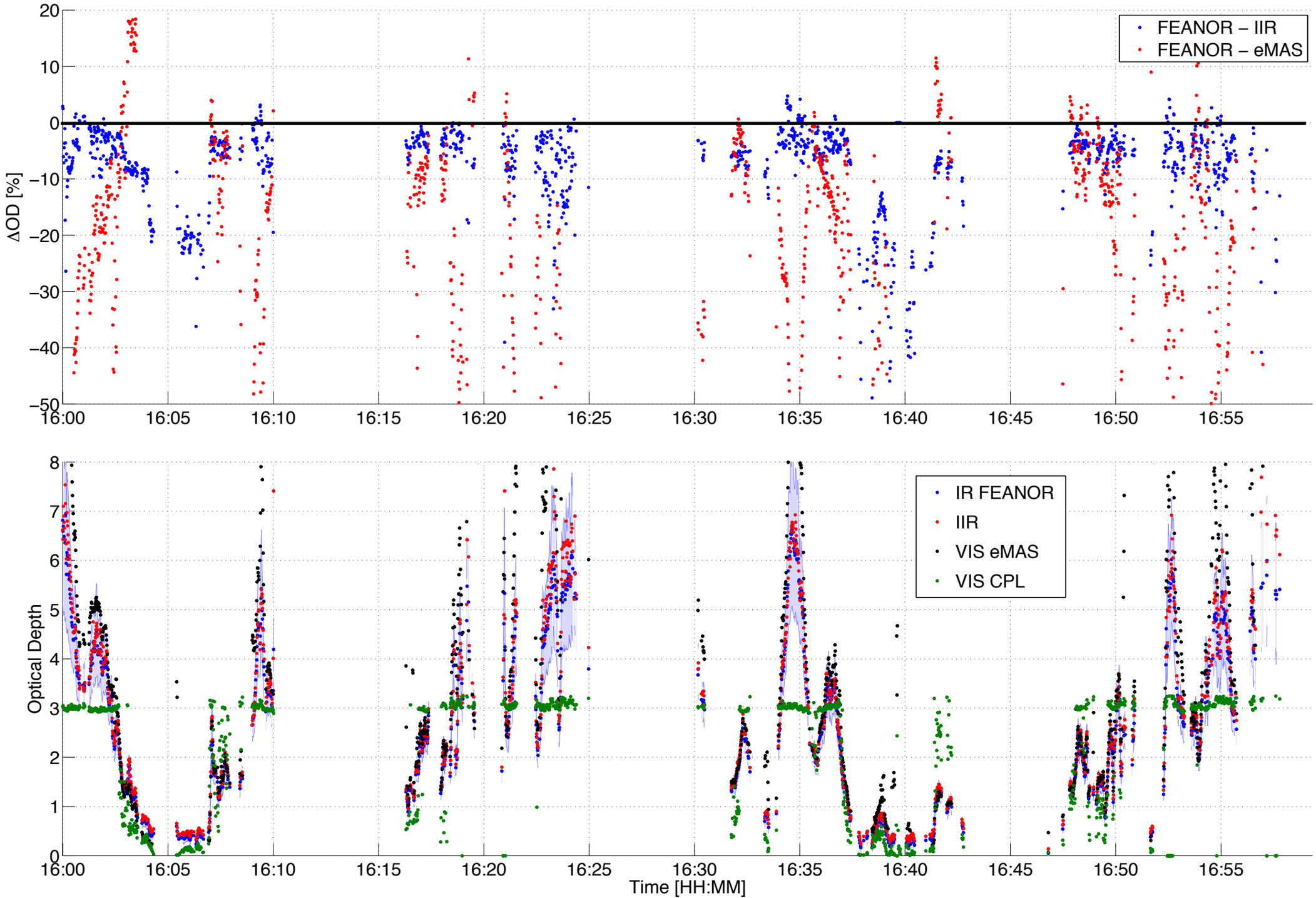




Collocated Cirrus Retrievals

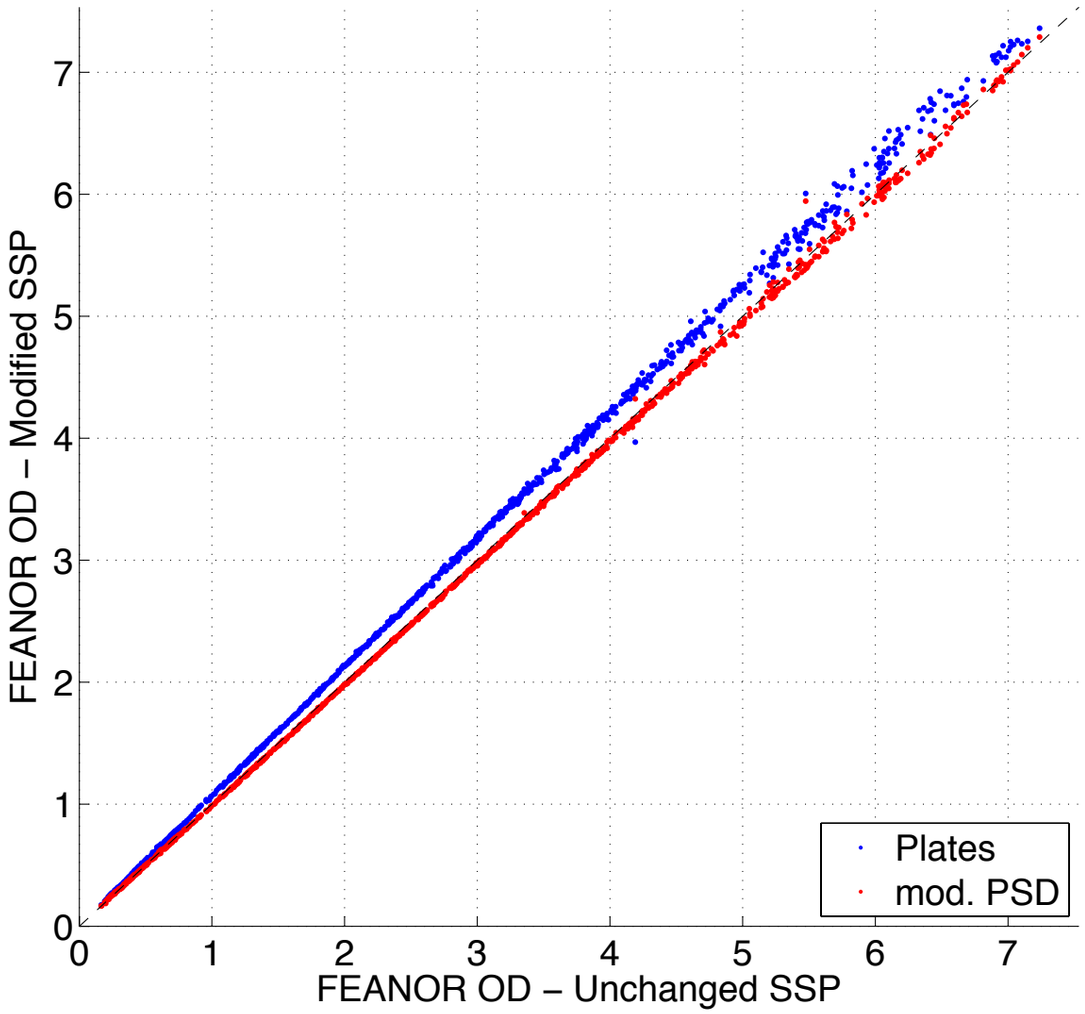


IR Retrievals

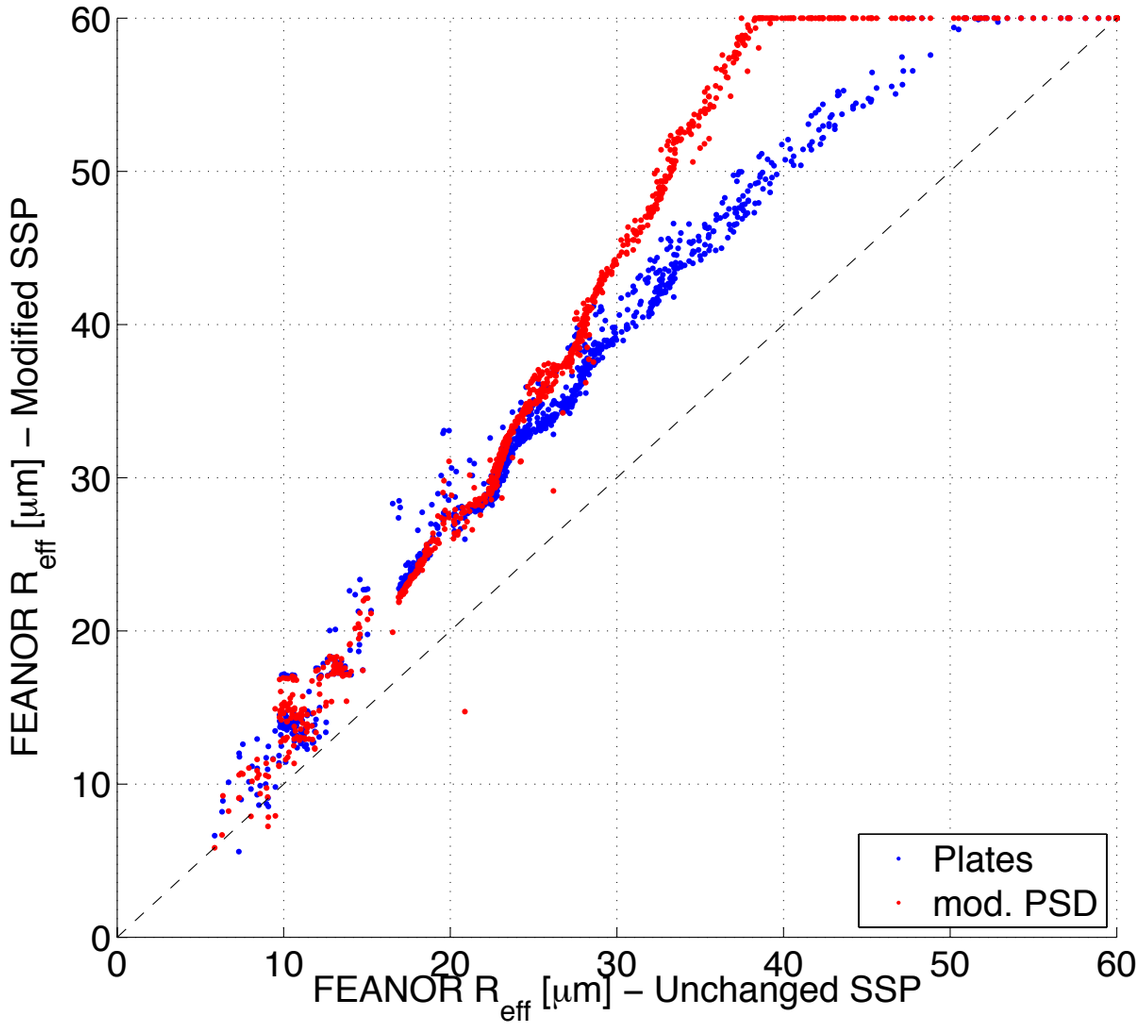


IR sensitivity to particle size distribution and habit

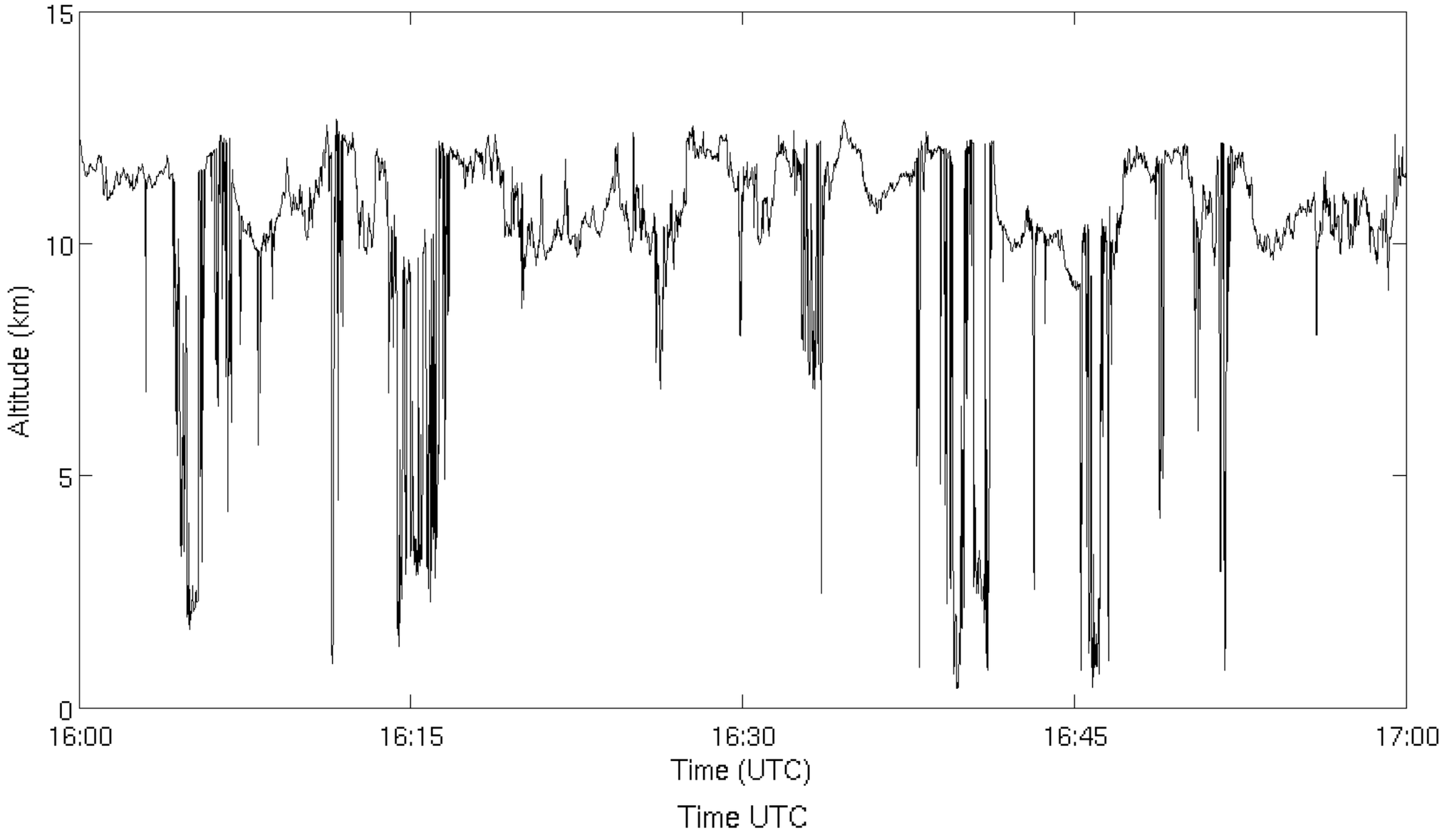
Optical Depth



Effective Radius



CPL Derived IR Vertical Weighting



Summary

- Inter comparison between aircraft and satellite observations is challenging due to the very limited coincidence and different viewing geometries between the satellite and aircraft observations

- Satellite retrieval algorithms for both MODIS and CALIPSO have been modified to work with the aircraft observations providing a satellite “simulator” for the remote sensing observations on the ER2

- New retrieval approaches (OE) that better propagate retrieval uncertainties are being developed for the aircraft observations

- Using the CPL, methods to quantify the vertical sensitivity of the passive observations have been developed providing a means to vertical average the active and in-situ observations

- We plan to apply these new techniques to both SEAC4RS and past field campaigns to build a statistical meaningful dataset

- Using these new capabilities we plan to experiment with modifications to the assumed ice scattering properties constrained by the in-situ observations