Research Scanning Polarimeter (RSP)

Retrievals from PODEX and SEAC4RS

Brian Cairns, Bastiaan van Diedenhoven, Mikhail Alexandrov, Jacek Chowdhary, Andrzej Wasilewski, Michael Mishchenko

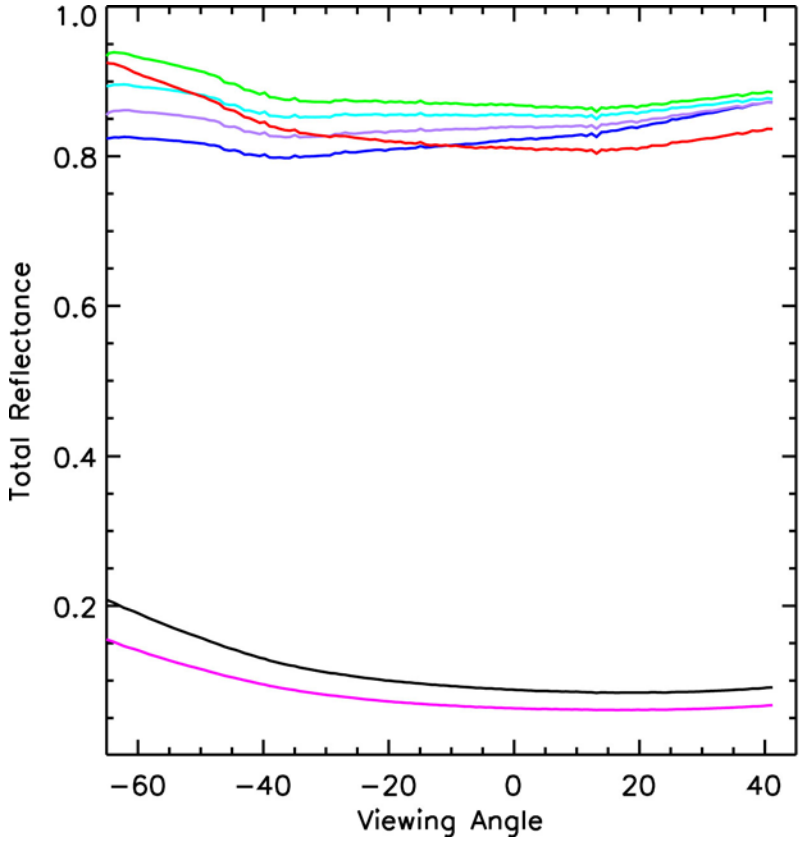
June 10th, 2014

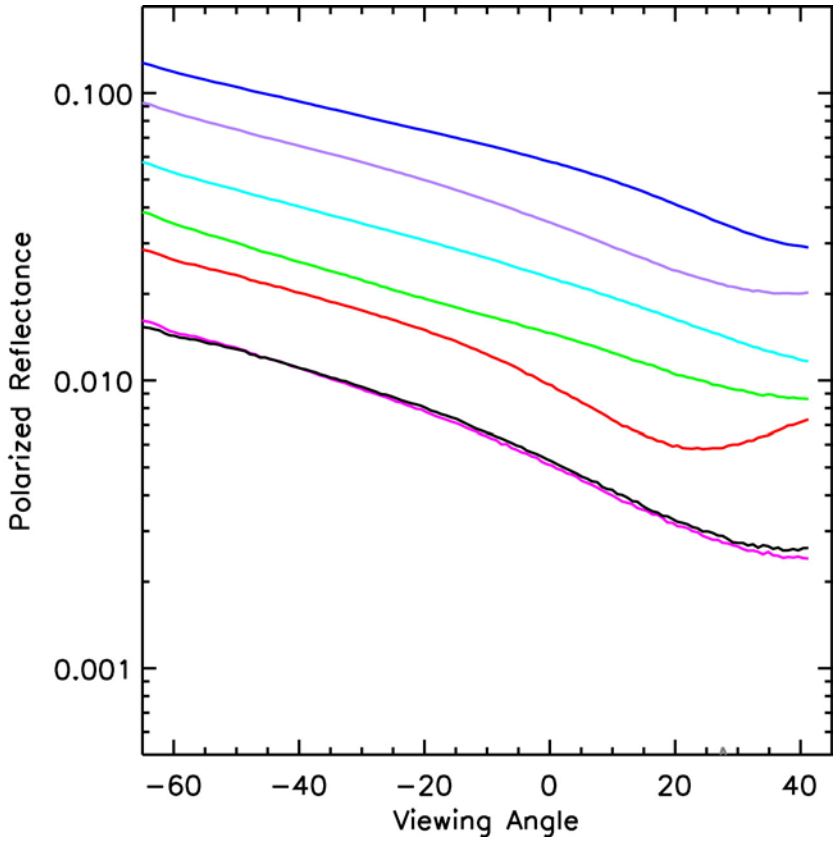
Research Scanning Polarimeter

- Brian Cairns (PI-GISS), Jacek Chowdhary, Matteo Ottaviani, Bastiaan van Diedenhoven, Mikhail Alexandrov, Andrzej Wasilewski
- Prototype for APS sensor on Glory
- 152 viewing angles/scene+dark reference and calibrator on every scan
- 410, 470, 555, 670, 864, 960, 1593, 1880, 2263 nm aerosols/clouds; 960 nm water vapor; 1880 nm cirris
- No swath, ±60 deg from nadir
- All RSP L1B PODEX data available at http://data.giss.nasa.gov/pub/rsp/ along with spreadsheets that indicate aircraft coincidences
- Obtained data over a wide variety of scenes and targets during the PODEX flights
- New retrieval capabilities tested using PODEX data
  - New procedure to screen for water clouds above snow
  - Aerosol retrievals above snow
  - Aerosols below cirrus
  - Aerosol above fog over land

Research Scanning Polarimeter

- **Snow is grey in polarized reflectance, just like many other surface types.**
  - Aerosol retrievals over snow at 3000 m show that there is not much aerosol there





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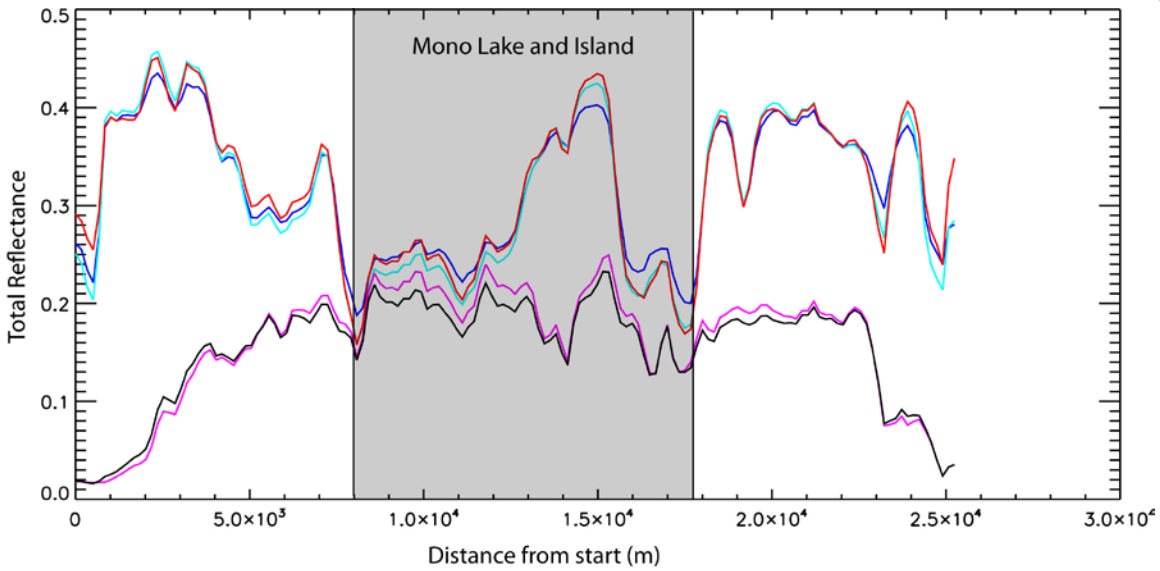

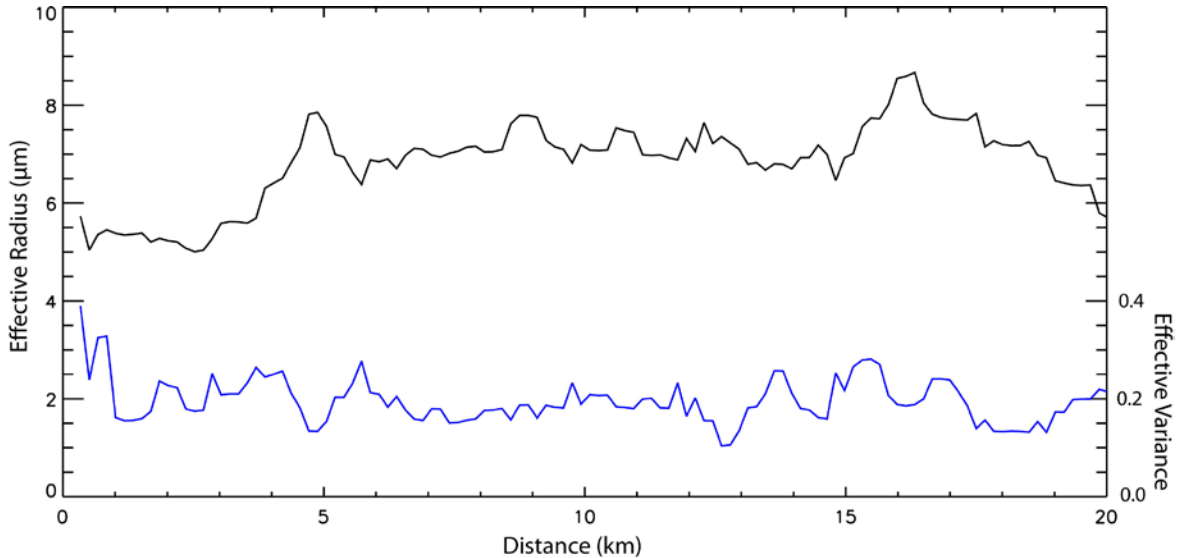

- Screening for fog above snow using radiances is problematic. Using the cloud bow is an effective method for low lying fog above snow covered surfaces

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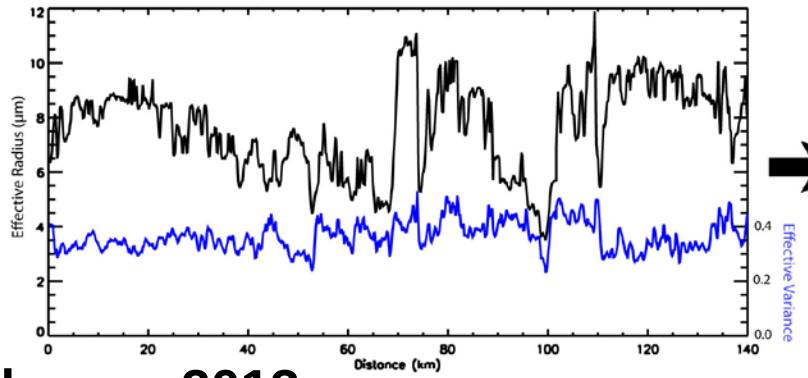
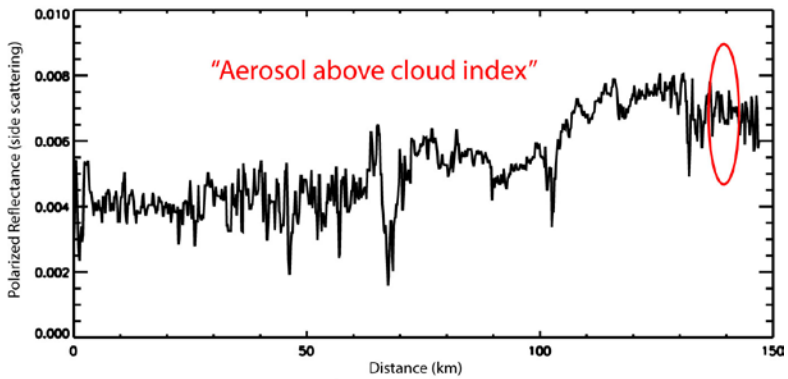
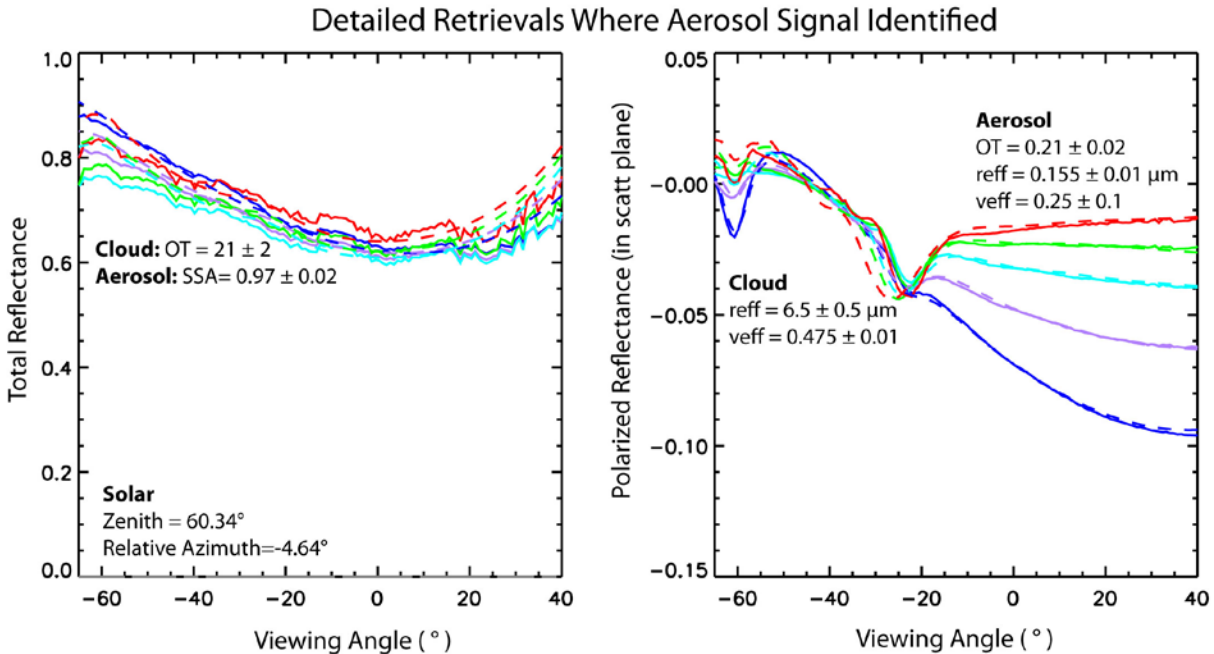




- **6th February 2013**
  - **Aerosols above fog over land**
    - Estimate cloud size distribution and use to calculate "aerosol above cloud index"
    - Where index indicates presence of aerosols to complete retrieval of cloud optical depth and aerosols optical depth and microphysical model
    - SSA sensitivity comes from brightness of cloud which is apparent in total radiance **AND** DoLP



Research Scanning Polarimeter

Liquid Water Cloud Products

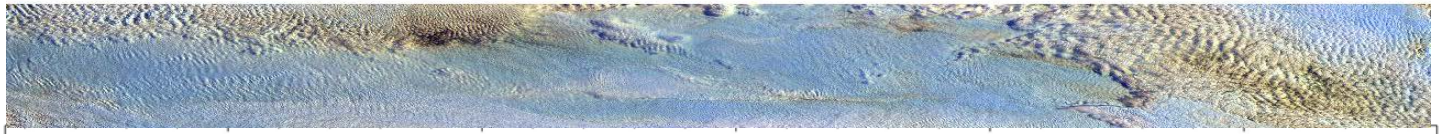
- Droplet size distribution (DSD)
  - Parametric approach (mono-modal gamma): R_{eff}, V_{eff}
  - Rainbow Fourier Transform (RFT): DSD shape, mode decomposition
- Cloud Optical Thickness (COT)
- Droplet number concentration (preliminary)

Data are available from

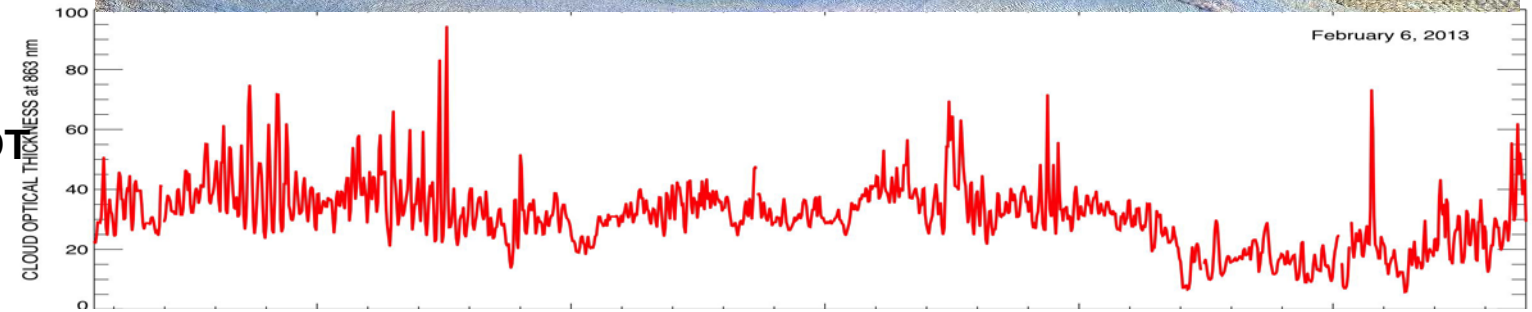
http://data.giss.nasa.gov/pub/rsp/PODEXB/Water_Clouds/

Data example: Fog in CA Central Valley on Feb. 6

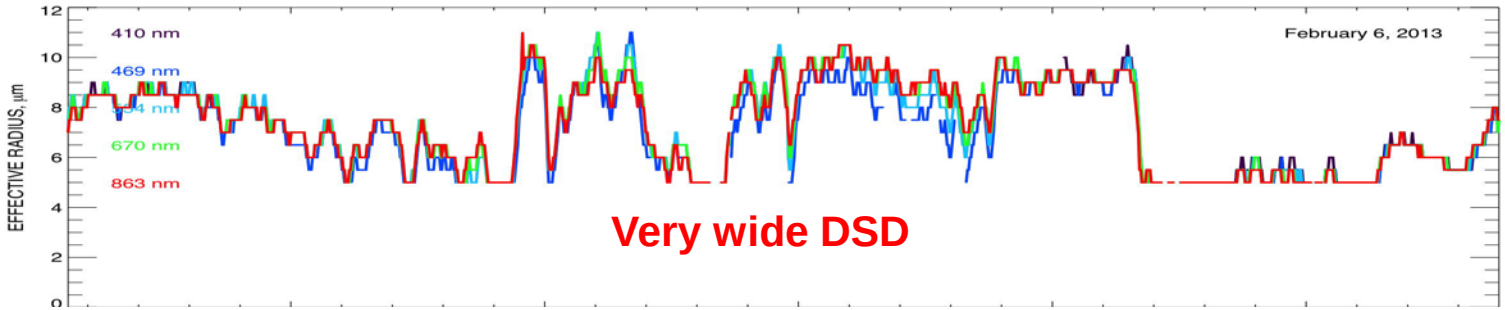
AMS RGB



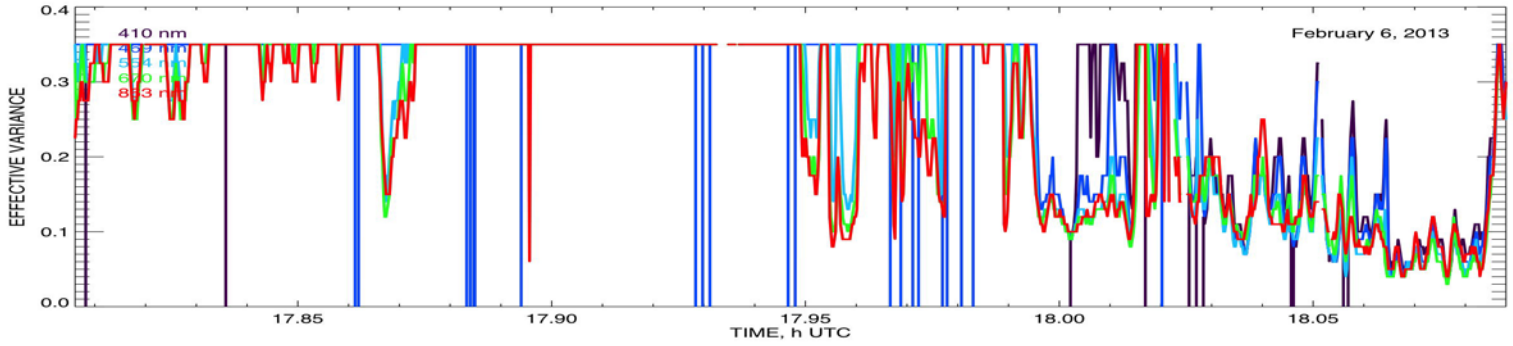
RSP COT



RSP R_{eff}

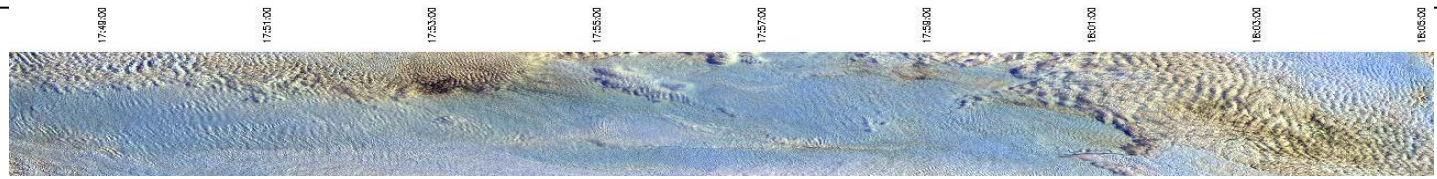


RSP V_{eff}

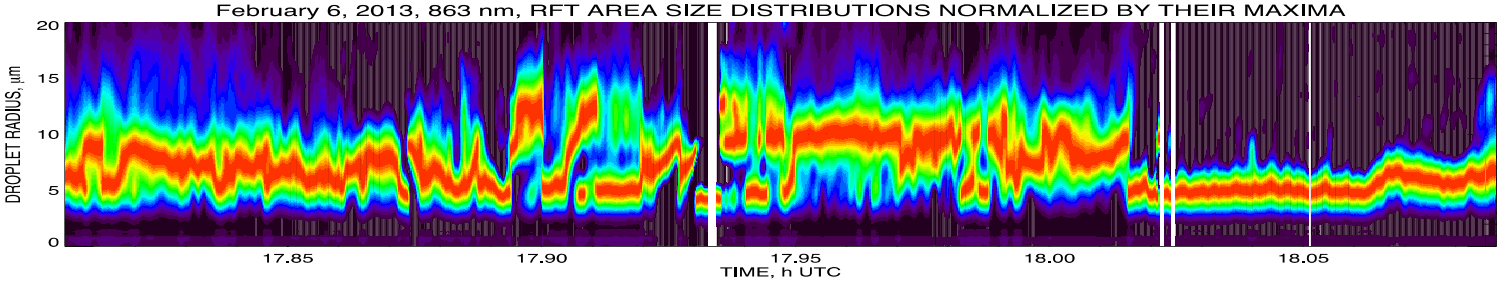


Data example: Fog in CA Central Valley on Feb. 6

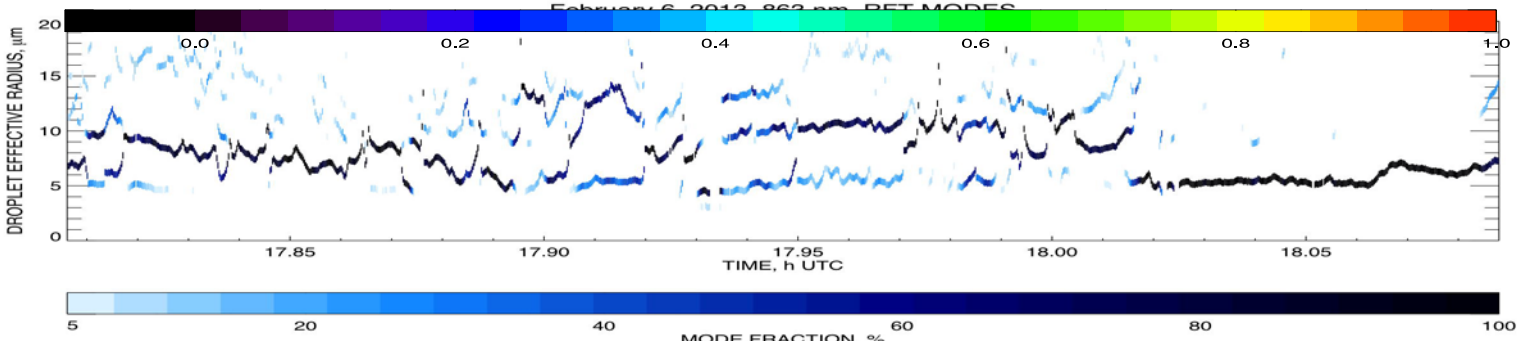
AMS RGB



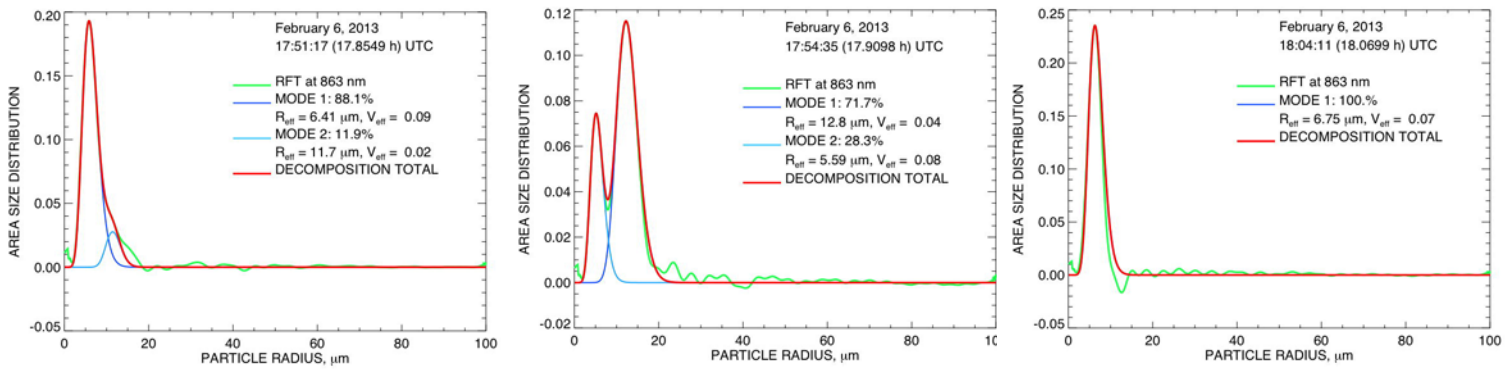
RSP RFT



R_{eff}, W for each mode



RFT mode decomp.

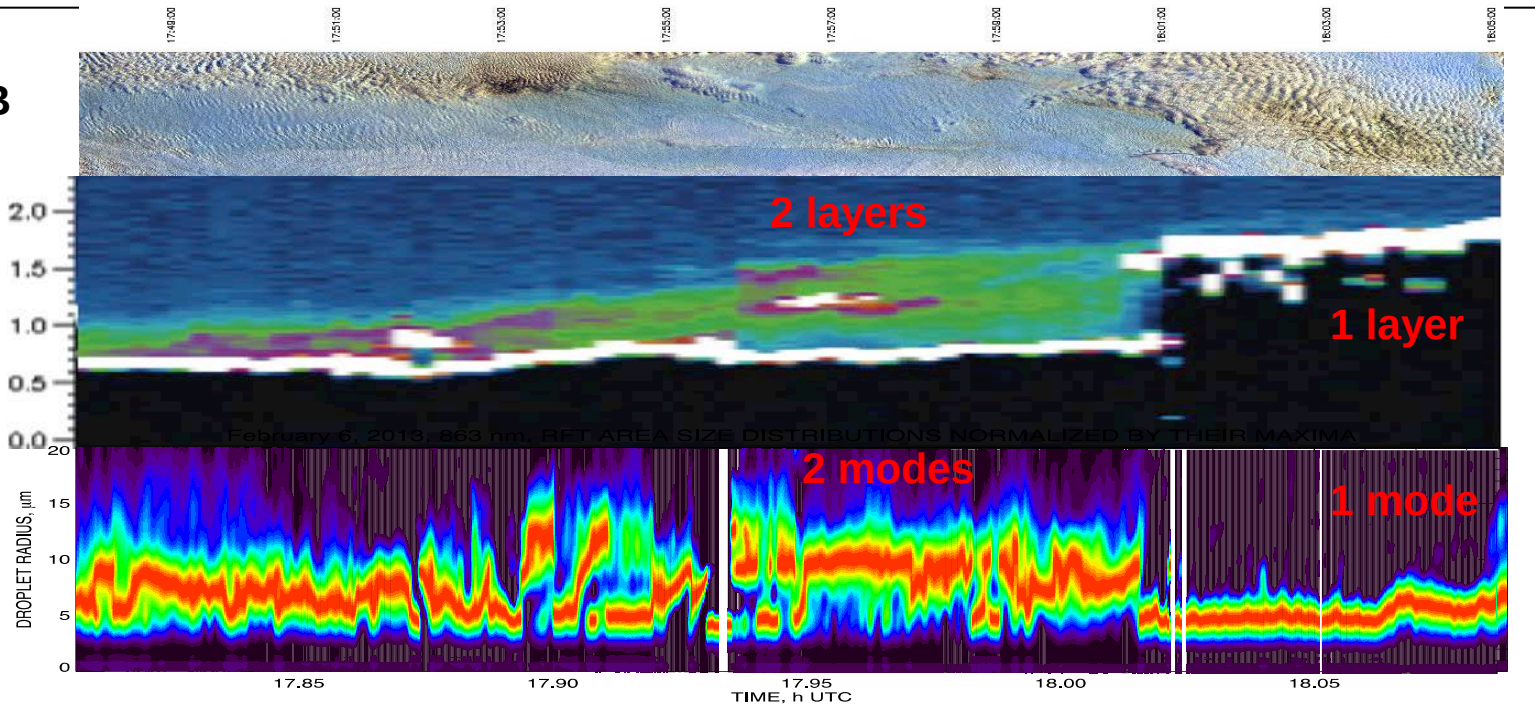


Data example: Fog in CA Central Valley on Feb. 6

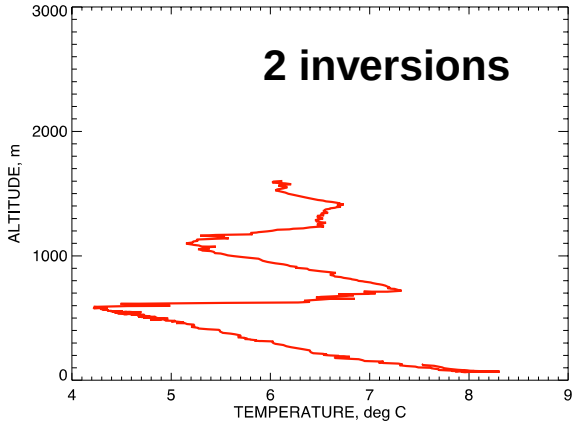
AMS RGB

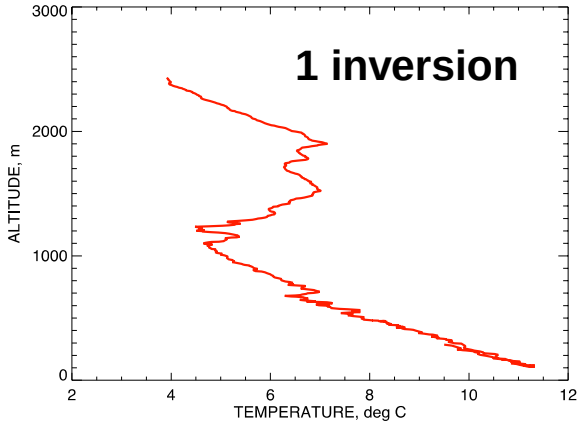
CPL Bcsctr

RSP DSD



DISCOVERAQ Temp. profiles





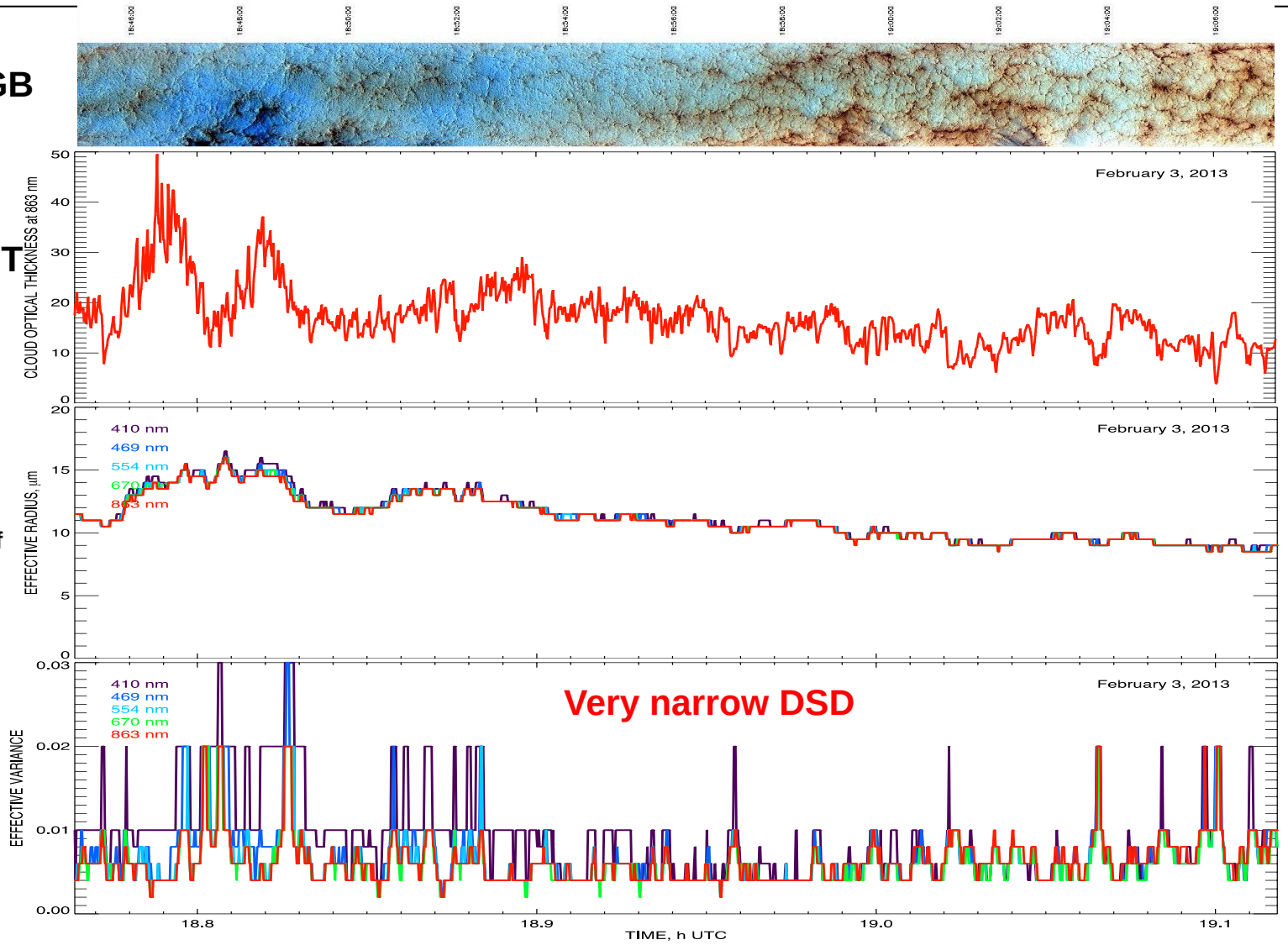
Data example: marine stratocumulous on Feb. 3

AMS RGB

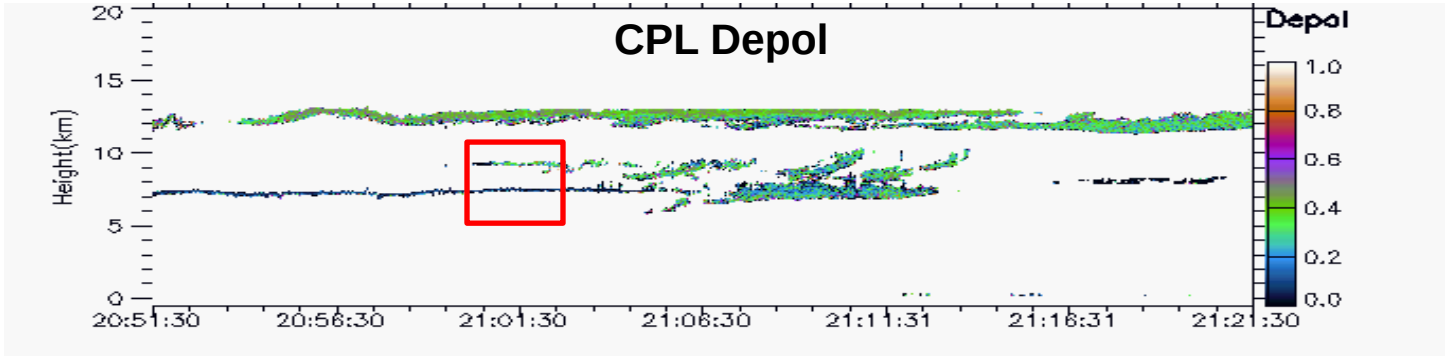
RSP COT

RSP R_{eff}

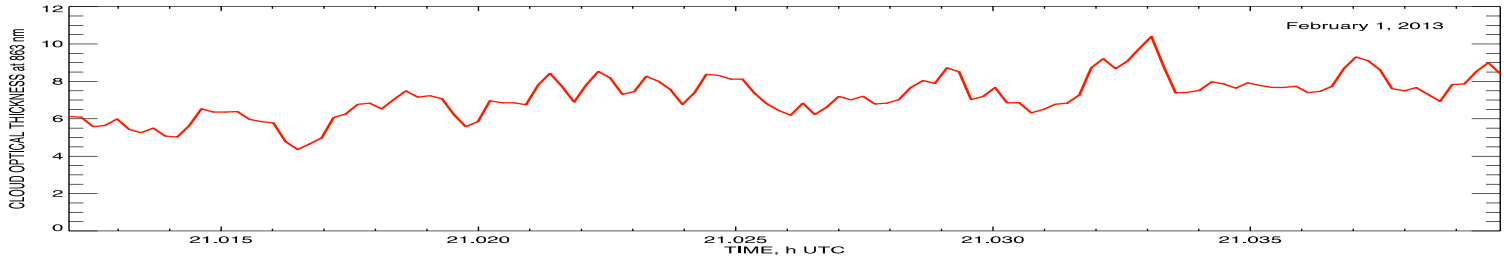
RSP V_{eff}



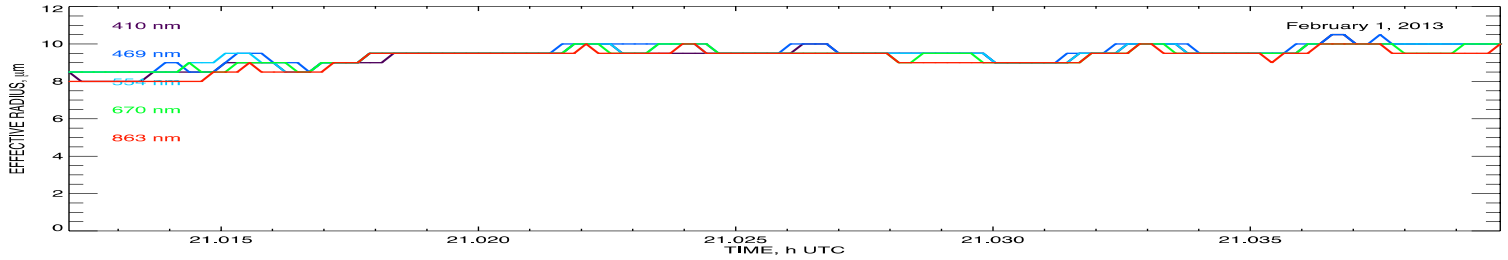
Data example: super-cooled water cloud on Feb. 1



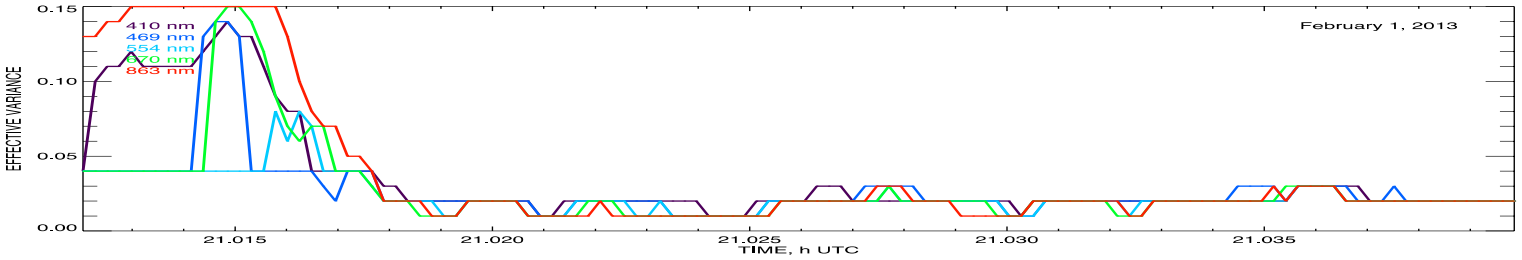
RSP COT



RSP R_{eff}

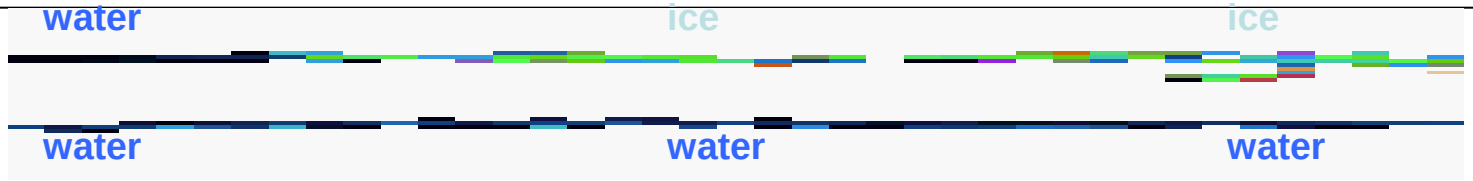


RSP V_{eff}

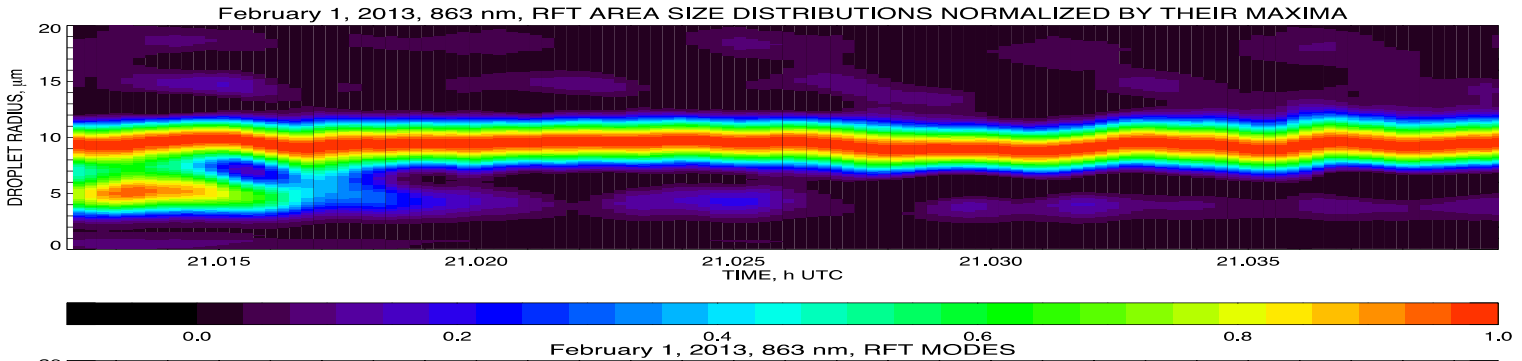


Data example: super-cooled water cloud on Feb. 1

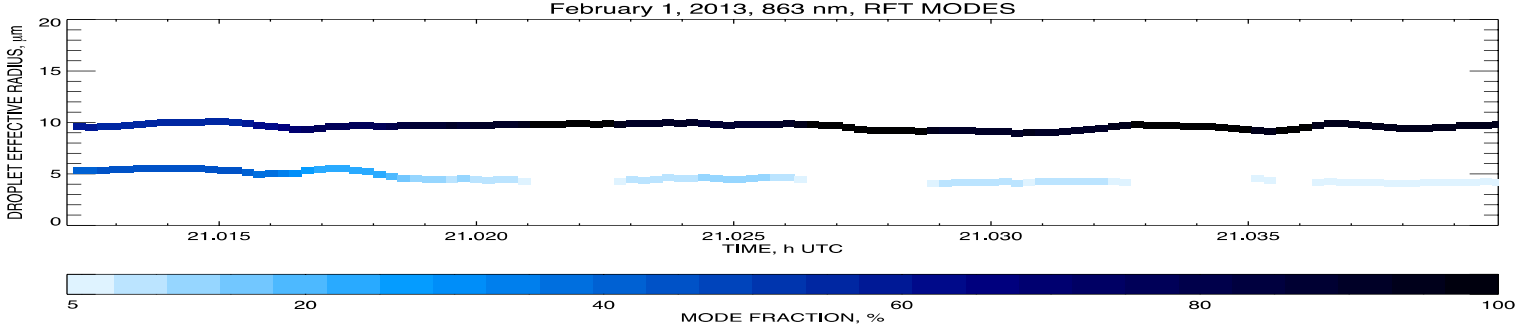
CPL Depol



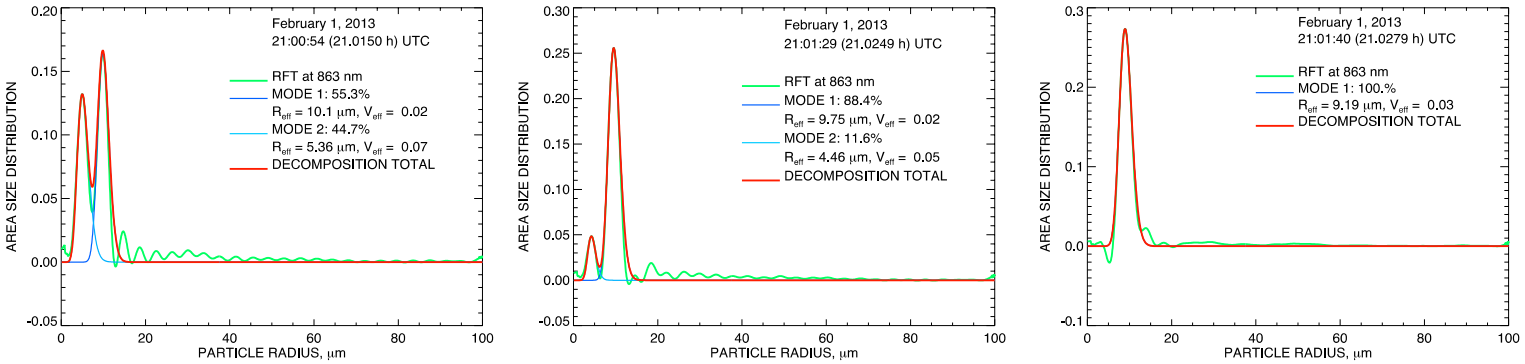
RSP DSD

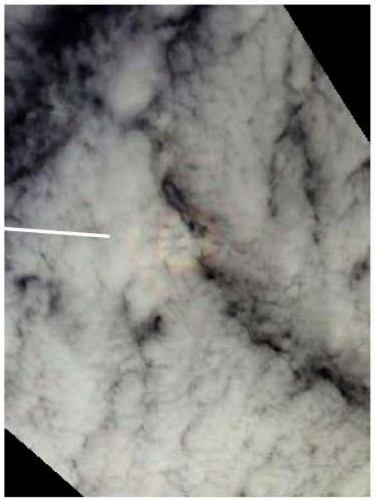


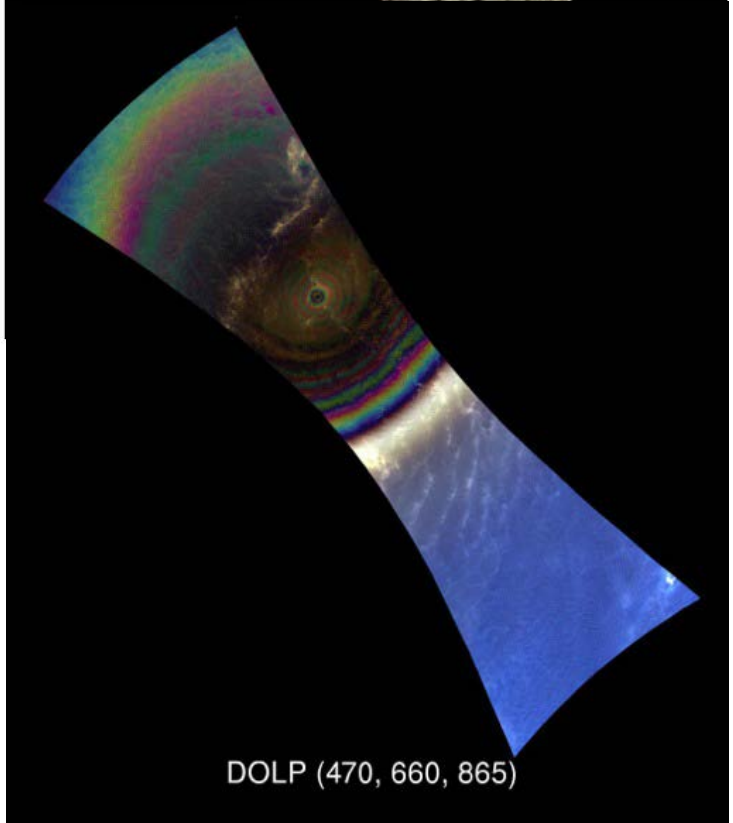
R_{eff}, W for each mode



RFT mode decomp.

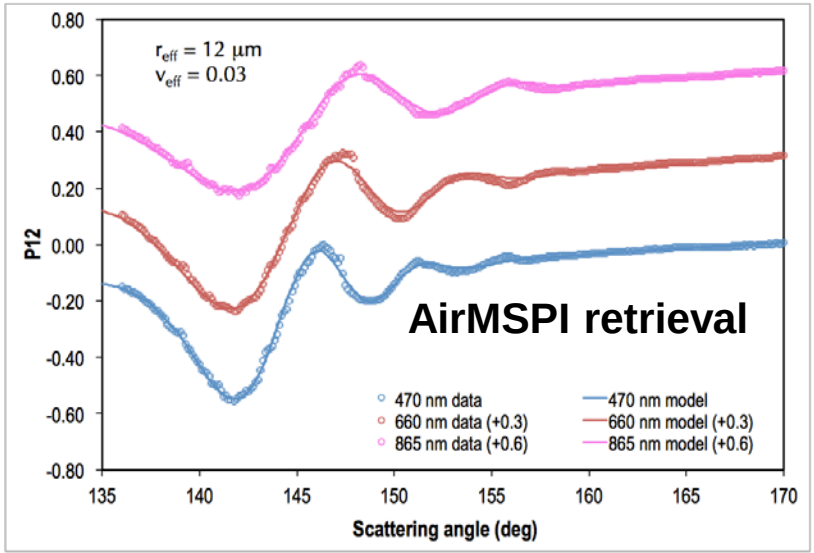




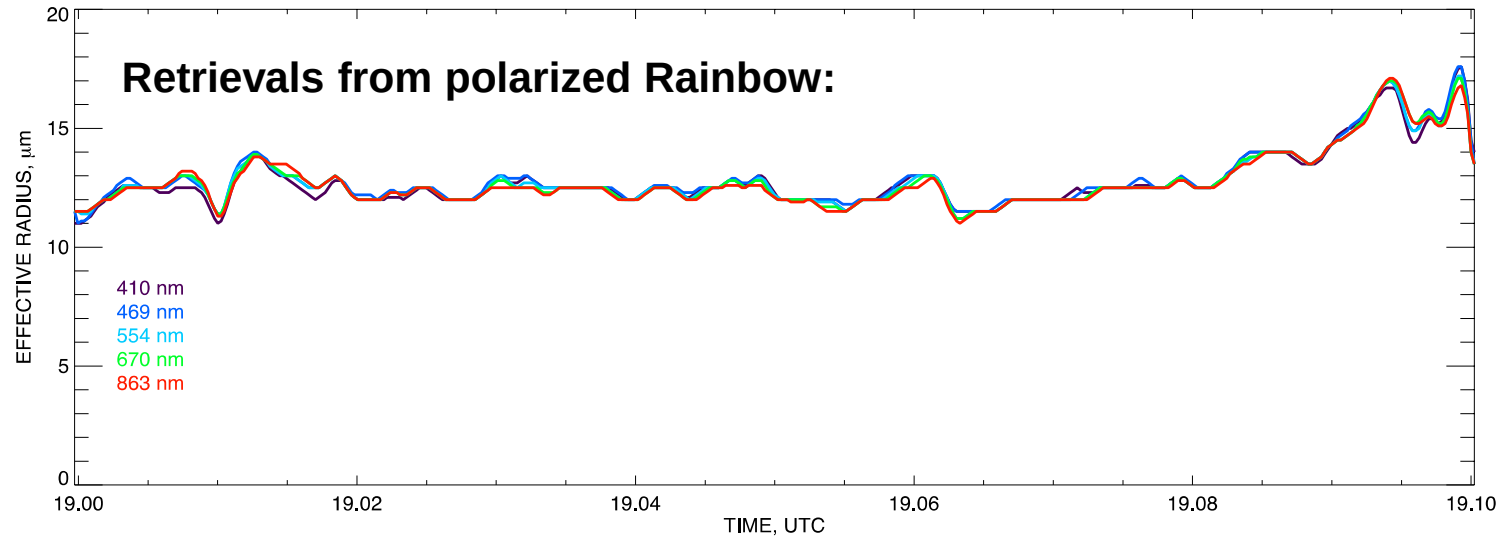


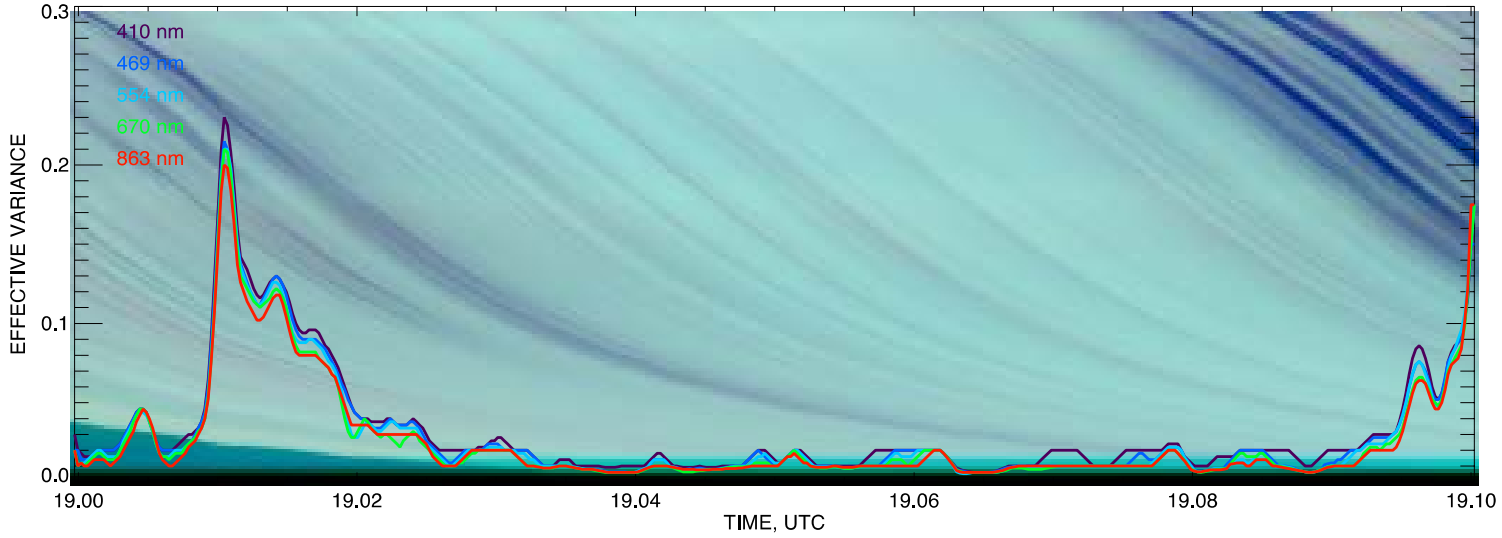
glory at 180° scattering angle

12 μm droplets with wider droplet size dispersion fits well



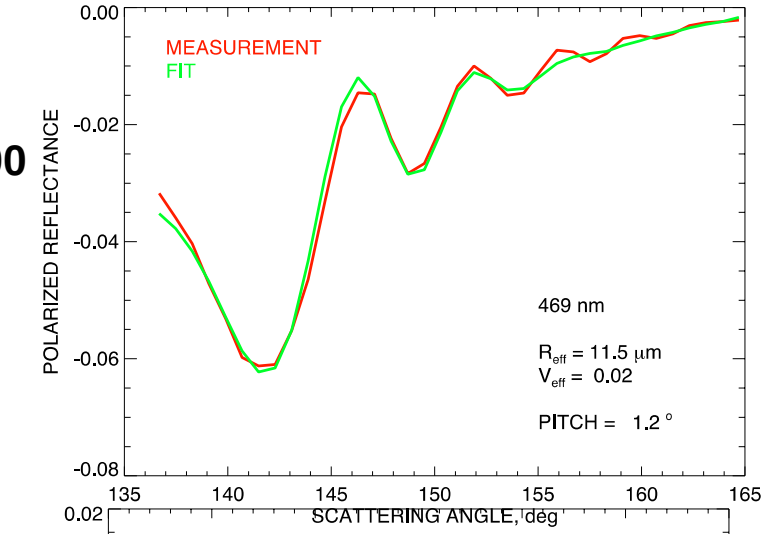
August 6, 2013: marine Sc off Oregon coast: RSP 19:00 - 19:10 UTC

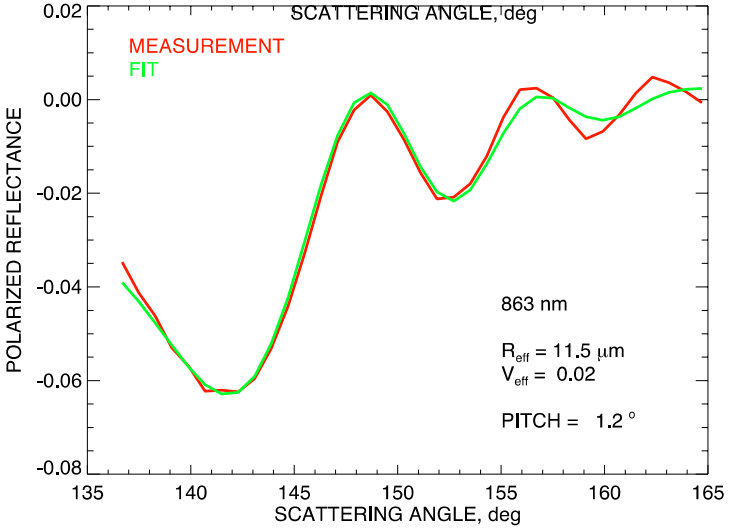




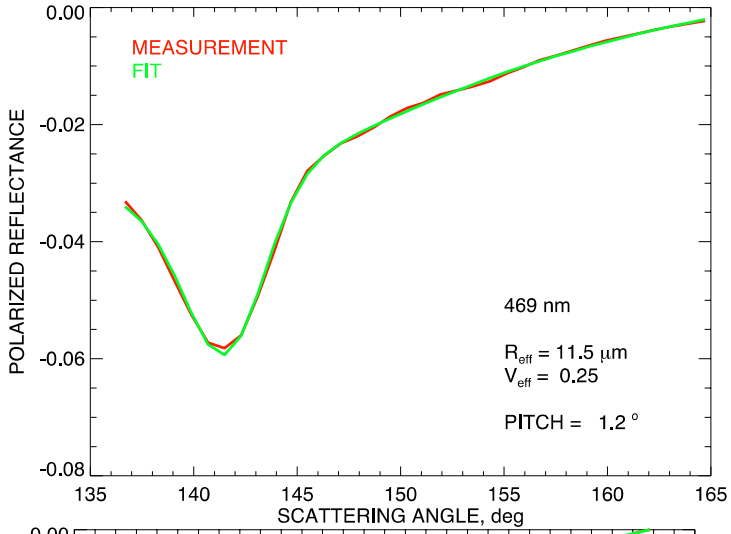
August 6, 2013: marine Sc off Oregon coast: RSP 19:00 - 19:10 UTC

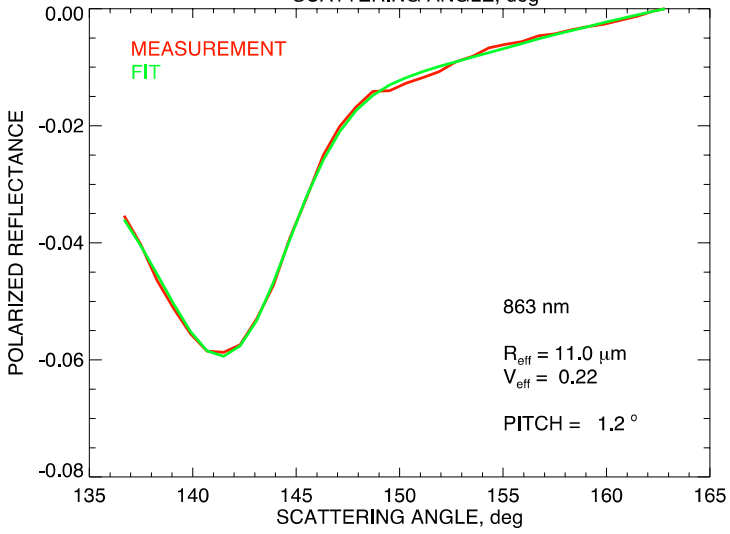
19:00



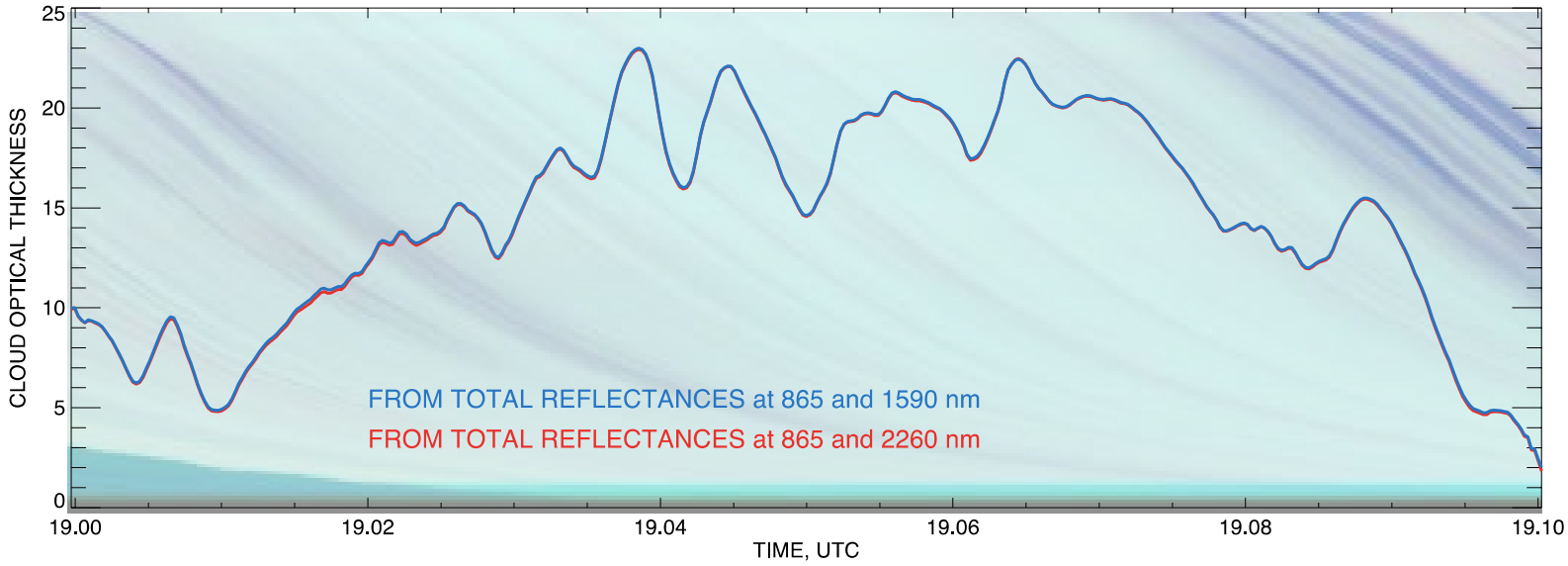


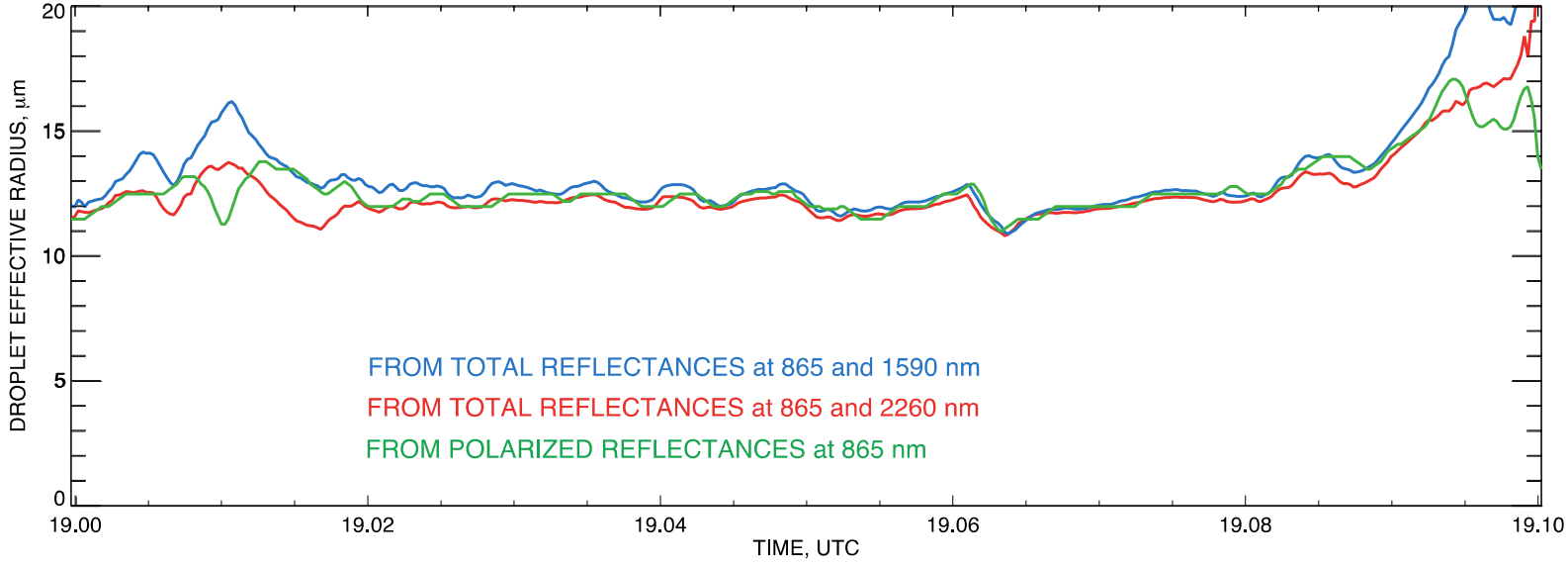
19:06





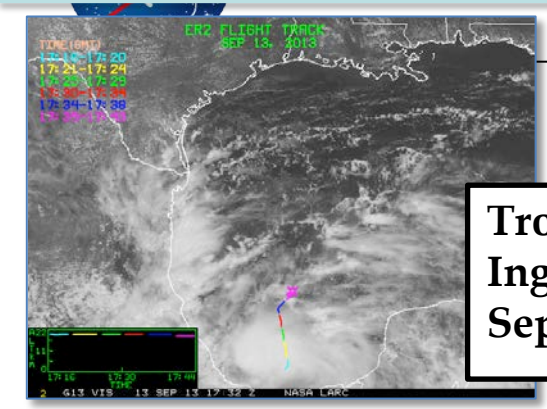
Retrievals from total reflectances (Nakajima & King):





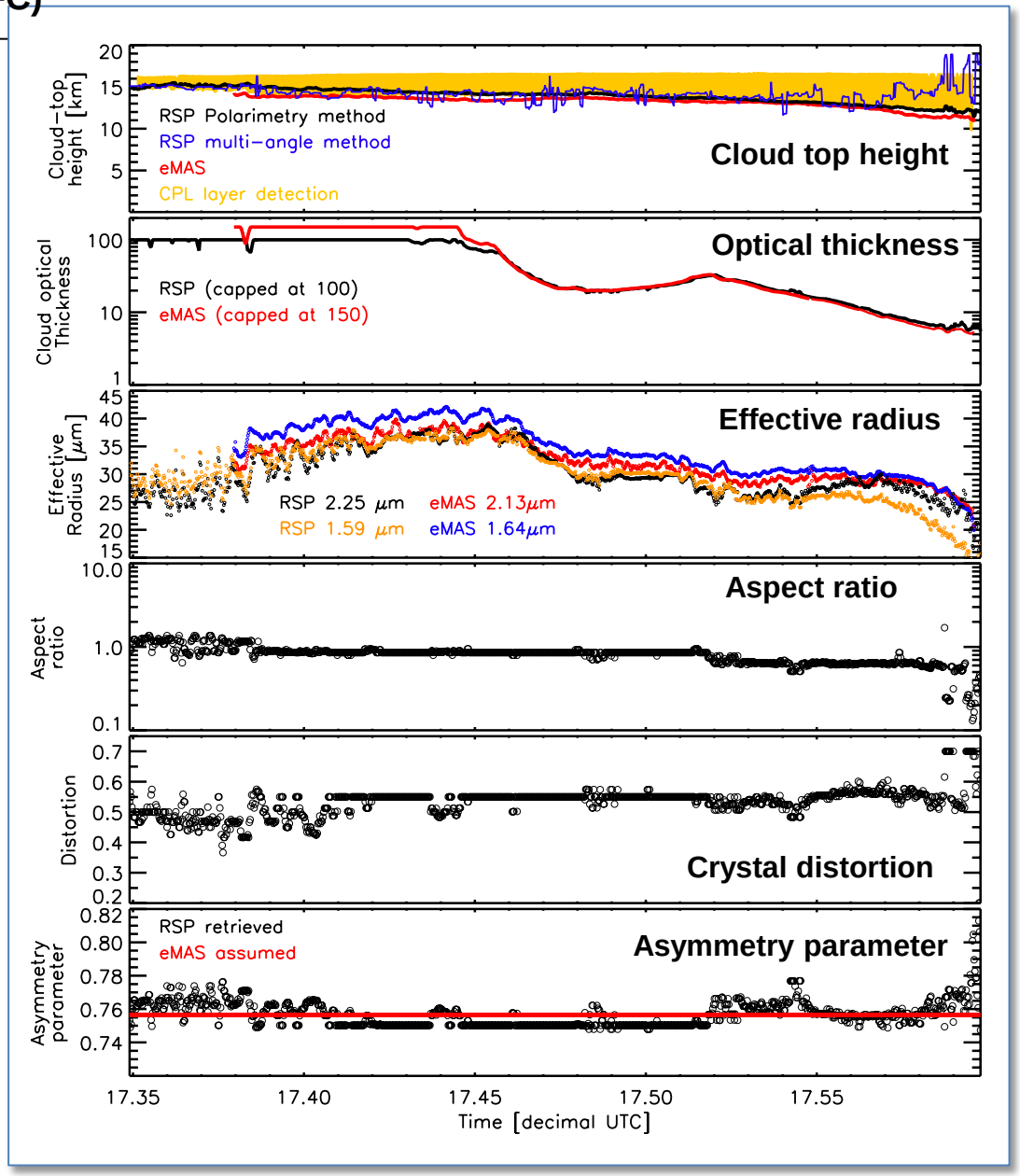
SEAC⁴RS ice cloud retrievals –RSP & eMAS

Bastiaan van Diedenhoven, Brian Cairns (GISS); Steven Platnick, Tom Arnold (GSFC)



Tropical storm Ingrid, 13 September

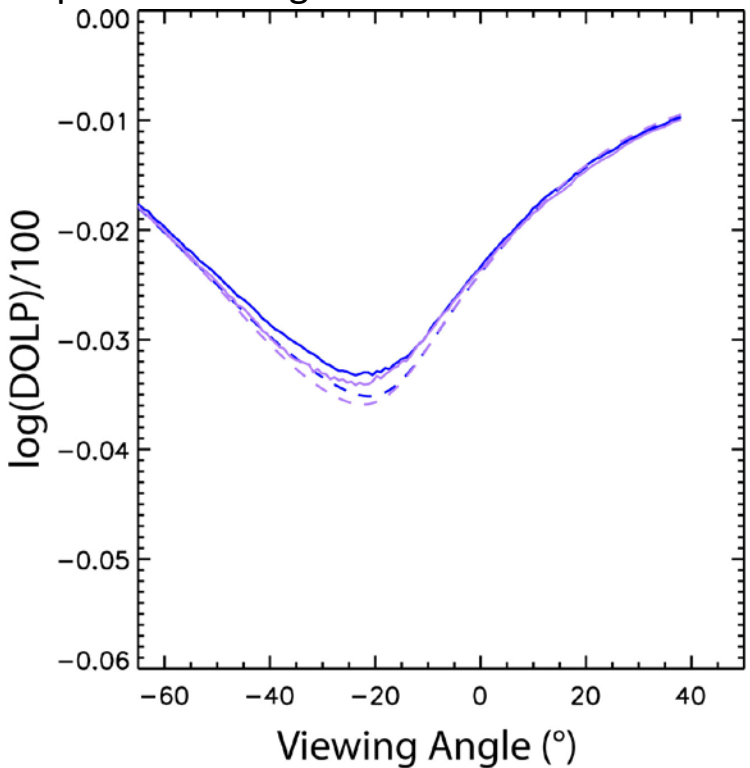
- Particle aspect ratio, distortion and asymmetry parameter from RSP multi-directional polarimetry
- RSP, eMAS and CPL lidar heights compare well
- RSP vs AMS cloud optical thickness and effective radius compare generally well
- eMAS assumed asymmetry parameter consistent with value retrieved by RSP
- Compact distorted ice crystals
- Larger particles at cold, thick core of storm

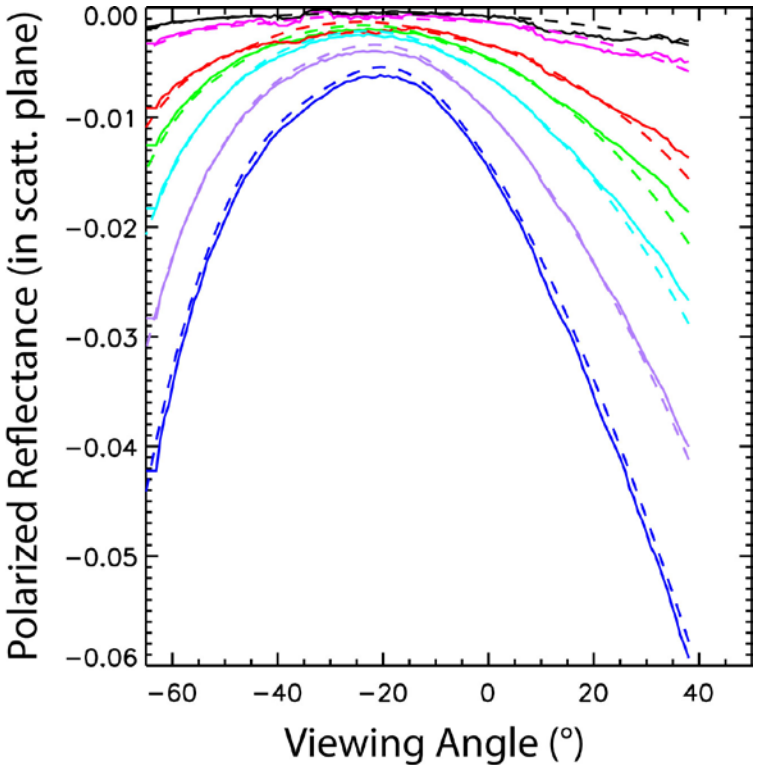


Research Scanning Polarimeter

Broken Clouds Revisited

- The retrieval uses a non-linear least squares iterative search for an aerosol model that best fits the polarized reflectance at 410, 469, 555, 670, 863, 1590 and 2260 nm and the Degree of Linear Polarization (DoLP) at 410 and 470 nm.
- Only these two bands are used with DoLP when doing retrievals in broken cloud, because they are dark (surface albedo ~ 0.04). For the other bands, since the aggregation is to cloud top, lots of different surface pixels are seen and constructing a surface model in such a case is sufficiently complex that using these bands for aerosol retrievals has limited value.

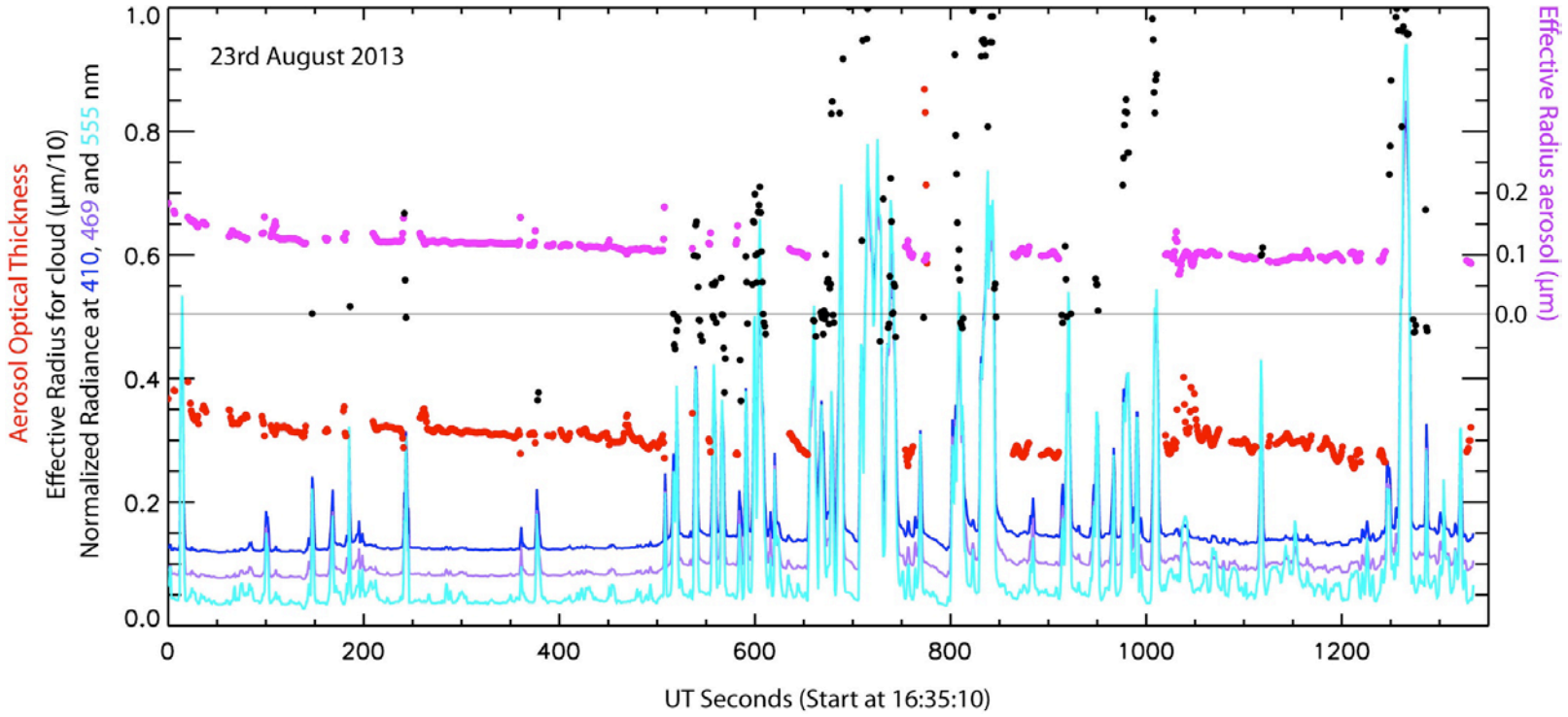




Research Scanning Polarimeter

Broken Clouds Revisited

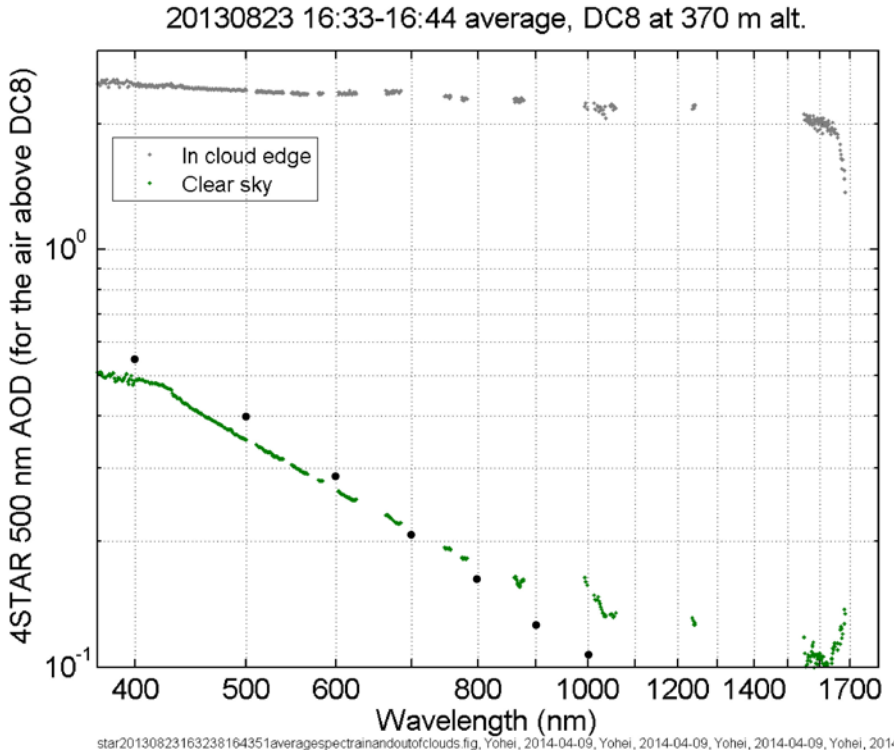
- In retrievals from 08/23/2013 there are no obvious issues with the retrievals between the clouds and no apparent aerosol growth. In this case, where the aerosol burden has a substantial contribution from smoke above the clouds, this is not surprising.
- The clouds show much larger variations in particle size than the aerosols with the droplet size being strongly correlated with cloud top height and cloud optical thickness and anti-correlated with the effective variance of the size distribution. This is again not surprising given the expected growth and narrowing of droplet size distributions in convective plumes.

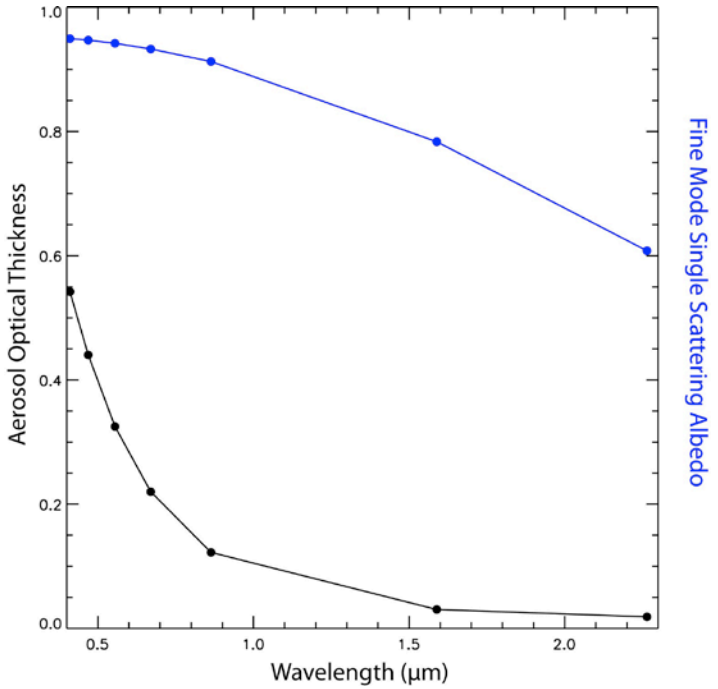


Research Scanning Polarimeter

Broken Clouds Revisited

- The single-scattering albedo at 555 nm of 0.942 is typical of smoke from boreal forest fires.
- While it is possible to perform aerosol retrievals above cloud for these broken cloud fields using the polarized reflectance, it is not possible in these cases to make any use of the total intensity observations, because 3D effects (leakage from cloud side, shadowing etc.) are substantial and cannot effectively be incorporated into a plane parallel radiative model – hence the need for Will Martin to get a postdoc doing 3D retrievals.

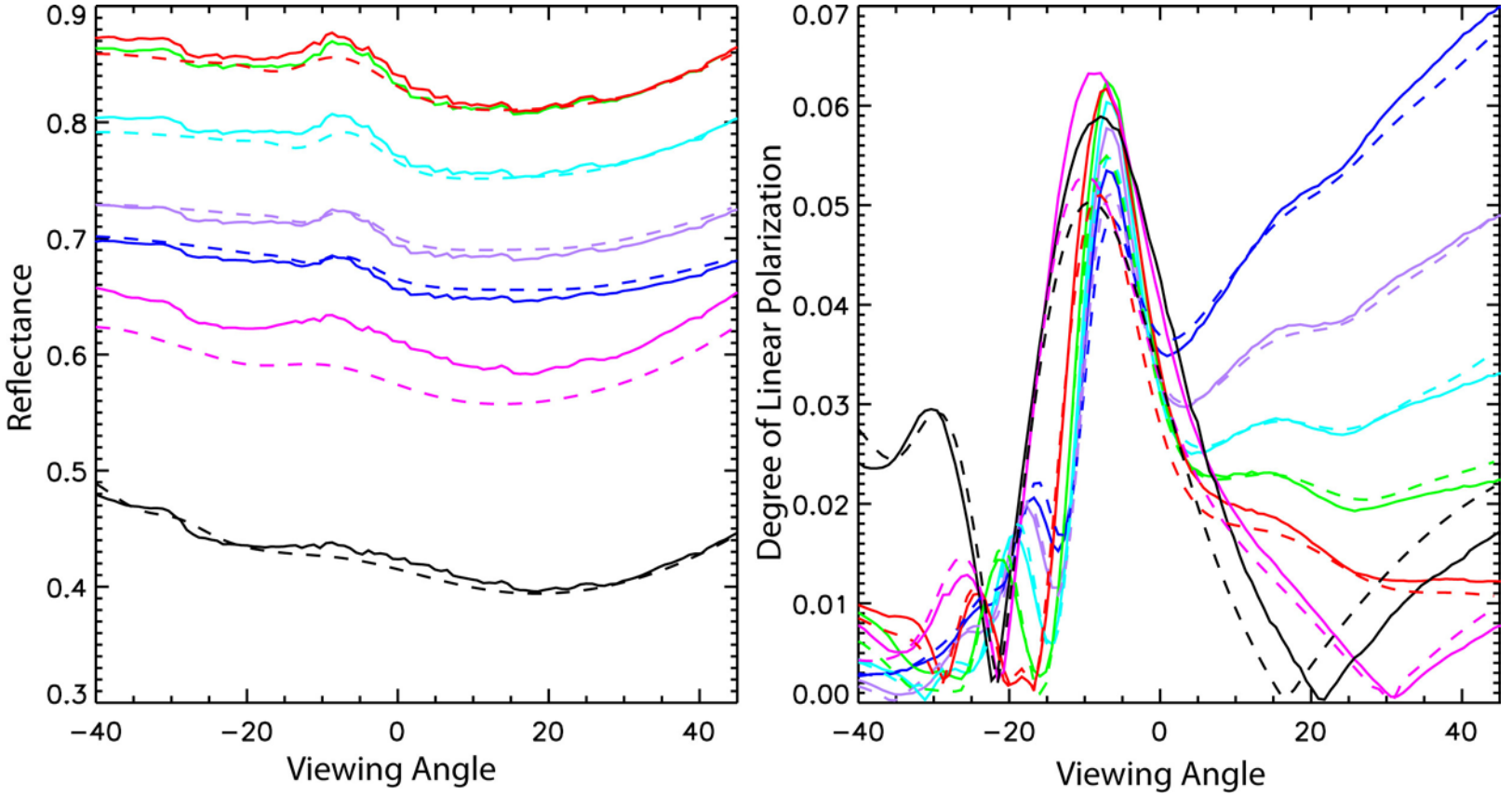




Research Scanning Polarimeter

Aerosol Above Clouds

- Aerosol absorption is strongly constrained by reflectance and DoLP above bright cloud
- Uncertainties in optical depth and imaginary index reduced to 10% by using reflectance and DoLP



Research Scanning Polarimeter

- **Brian Cairns (PI-GISS), Jacek Chowdhary, Bastiaan van Diedenhoven, Mikhail Alexandrov, Andrzej Wasilewski, Michael Mishchenko**
- **Make RT program publically available**
  - **Clean, streamline, and document the RT program code**
  - **Comply with Standard Fortran programming language**
  - **Publish summary of method, validation, and benchmark results**
  - **Develop user-friendly website for RT results, applications, and updates**
- **Incorporate RT results for ocean color into GRASP**
  - **GRASP: Generalized Retrieval of Aerosol and Surface Properties (Dubovik *et al*)**
    - **Note: ignores polarimetric and bidirectional properties of water-leaving radiance**
  - **Calculate and incorporate reflection matrices for water-leaving radiance**
    - **Include variations with wavelength and Chlorophyll a concentrations**
    - **Variations with ocean surface wind properties are negligibly small**
- **Comparing in house iterative retrieval with GRASP**
  - **Developing neural net scheme for fast and accurate first guess**
    - **Iterative retrieval schemes are required to improve aerosol retrievals, but are slow. Better first guess means fewer iterations.**
  - **Include aerosol above cloud and cirrus above aerosol in iterative scheme**
    - **Add ice and water clouds to database of single scattering properties. Water clouds are in many respects a better lower boundary condition than either ocean, or land, because they are bright and aerosol absorption provides a large signal.**
    - **GRASP can be used for aerosol above cloud retrievals, but not with existing SOS code. Evaluating using vector doubling/adding within GRASP.**