

4STAR: Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research

Development and Results from First Test-flights



A collaboration involving:

- ▶ **PNNL:** C. Flynn, E Kassianov, C. Kluzek, B. Schmid
- ▶ **NASA Ames:** S. Dunagan, R. Johnson, M Kacenenelbogen J. Redemann, P. Russell, M Segal Rozenhaimer, Y Shinozuka, R Srikanthan
- ▶ **NASA GSFC:** B. Holben, S. Sinyuk

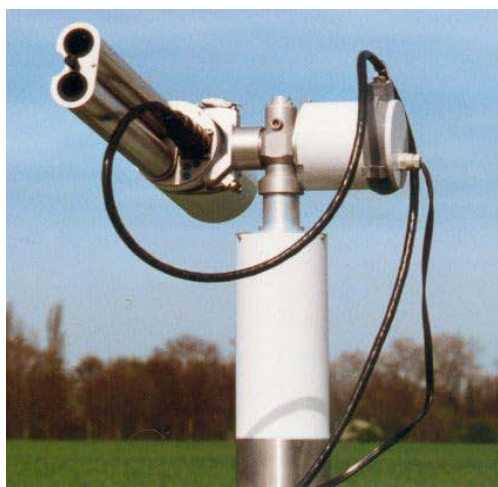


4STAR: Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research

AERONET-like capability

Ground-based direct beam + sky scanning yields column-integrated properties:

- AOD
- Size distributions
- Single-scattering albedo
- Asymmetry parameter
- Sphericity
- Cloud OD

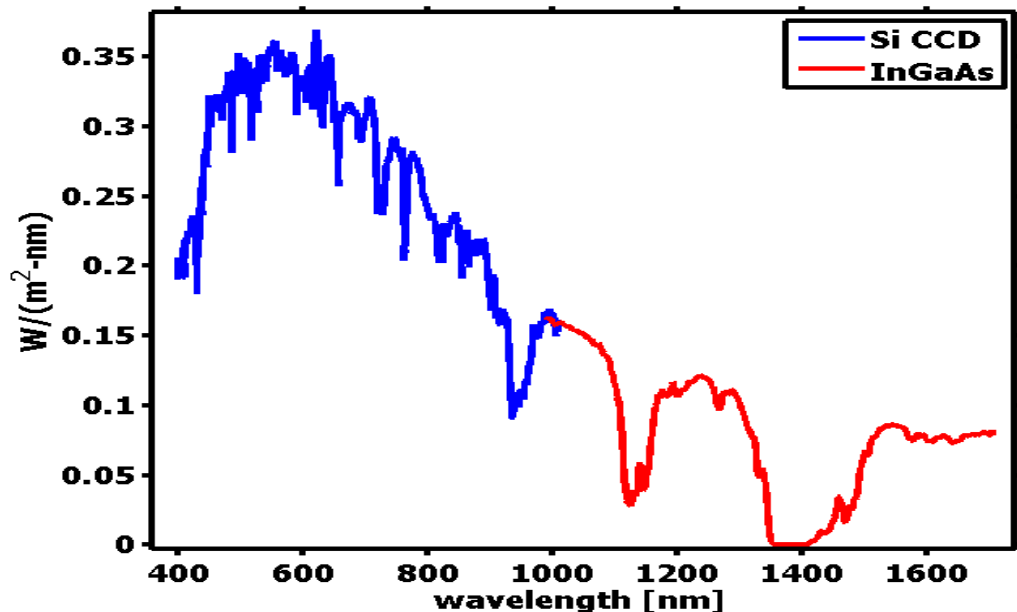


AATS-like capability:

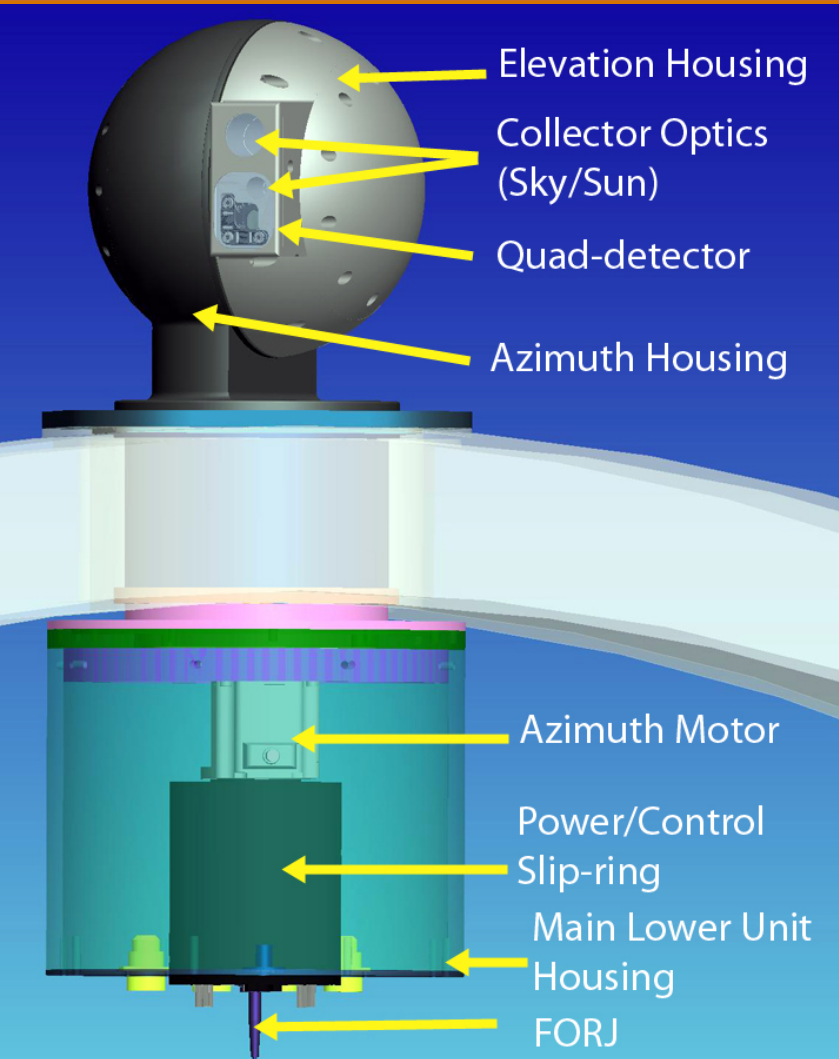
AOD at 13 wavelengths
 H_2O

horizontally and vertically resolved

Direct Solar Irradiance



4STAR Integration and test flights on PNNL/Battelle G-1, Aug-Sep 2010



Anticipated 4STAR data products:

▶ Solar Direct Beam

- Atmospheric Transmittance
- Aerosol Optical Depth and Ångstrom exponent
- Aerosol Extinction (via aircraft vertical profiling)
- Gases: H₂O, O₃, NO₂, CO₂ (column and in profile)

▶ Angularly-resolved sky radiance inversions

- Scattering phase function, asymmetry parameter
- Aerosol size distributions, fine/coarse mode fraction
- Aerosol absorption
- Aerosol sphericity

▶ Zenith radiance cloud retrievals

- Cloudy/clear transition zone (Marshak, Chiu)
- Cloud Optical Depth, Droplet effective Radius (with auxiliary measurements, Barker et al.)
- Water vapor, liquid water, ice water fractionation (Daniels et al.)

4STAR and its Use...

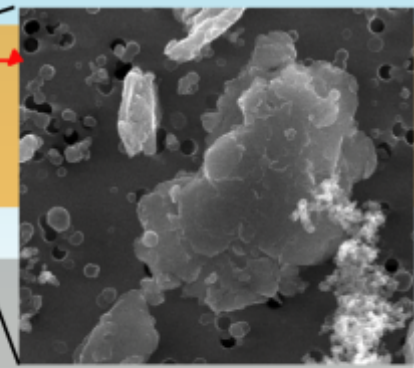
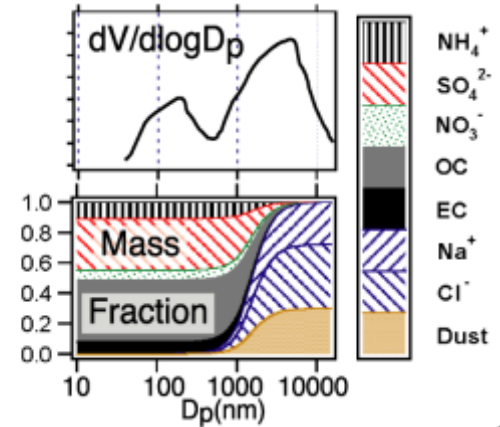
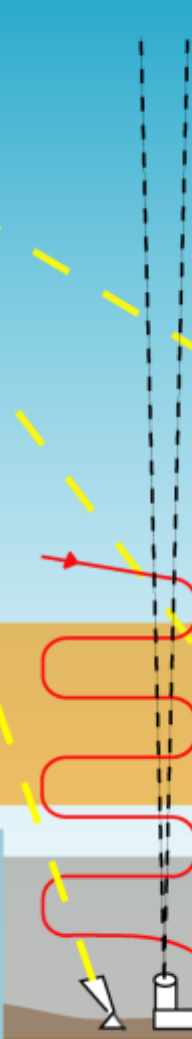
Advantage :

Exact match in layers sampled by airborne sunphotometer & in situ instruments

- Tightens closure
- Key link

Satell. ↔ in situ

- Helps explain discrepancies

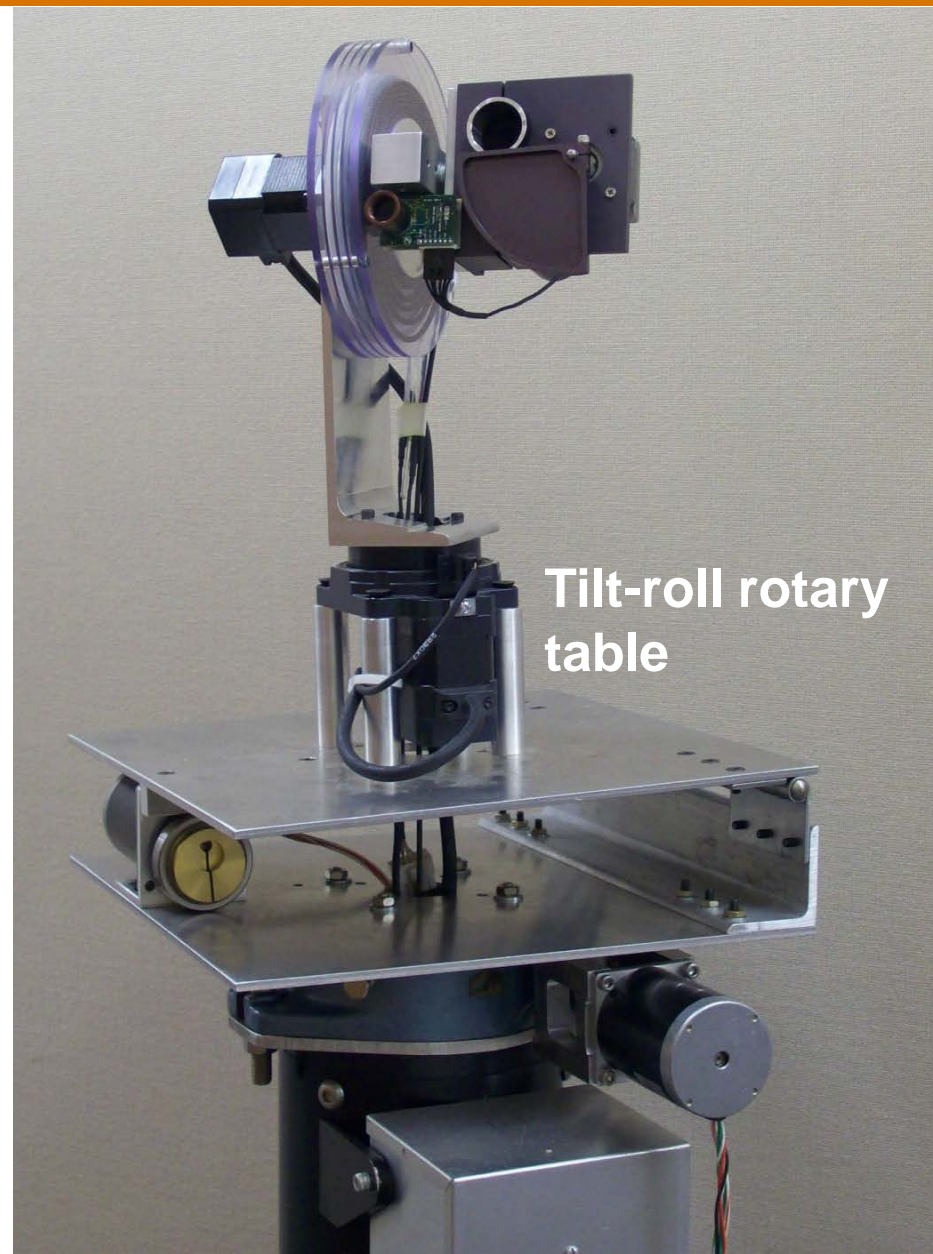
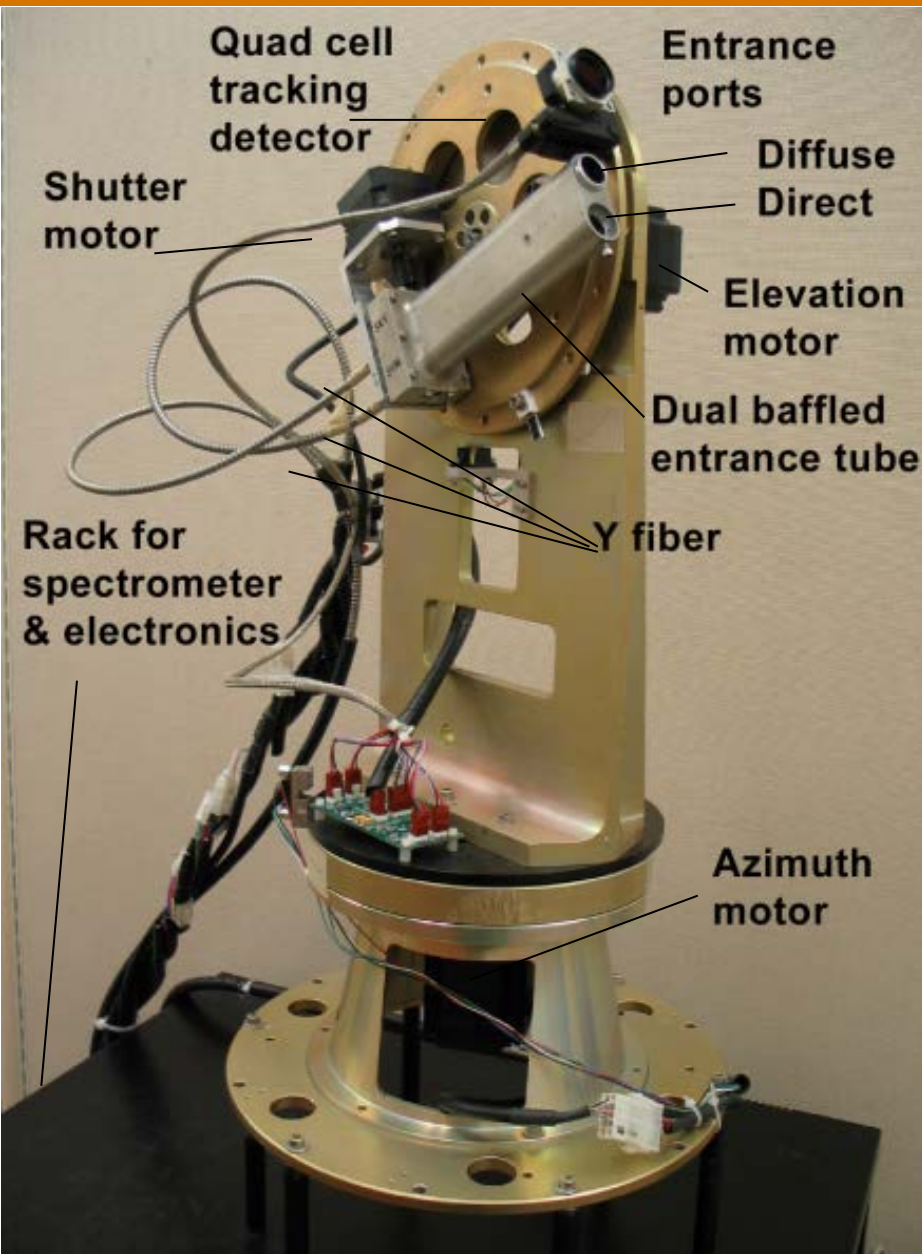


Key Technological Hurdles

- ▶ Sun tracking across pressure differential
- ▶ Fiber optic couplings with $<1\%$ calibration stability (Connections/Rotation)
- ▶ Irradiance calibration to 1% over a period of months.
- ▶ Radiance calibration to a few percent.
- ▶ Stray light rejection: measure skylight down to within 3° of sun
- ▶ Entrance window contamination
- ▶ Sky scan within 100 seconds (10 km in flight)
- ▶ Stray light inside spectrometers



Ground Prototypes (4STAR-G)



Aircraft Integration and Flight Testing of 4STAR – supported by ARM AAF

FY 2010: Aircraft integration, safety flight, pressure seal.

Sept 28: 2010: Moffet Field, sun tracking tests, profiling

- Condensation → dry air purge

Apr 14, 2011: Pasco, Sun & Sky

- Real-time NAV data and ephemeris for tracking recovery
- Elevation home switch → adjust tolerances
- Light budget issues → Improve optics train

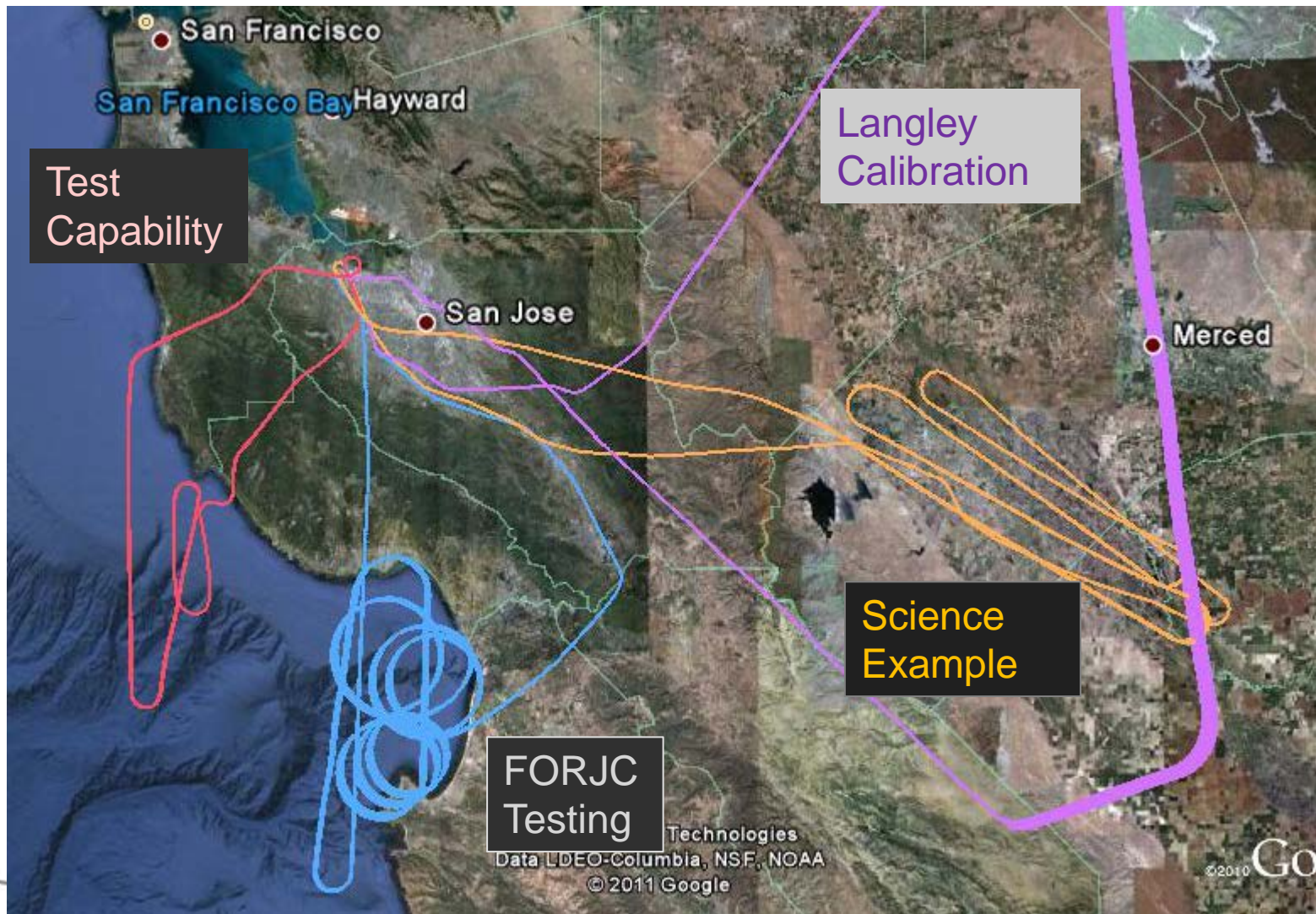
July 11, Ground intensive at Moffett Field

- Rotational corrections interdependent with FOV and tracking
- FOV needs to be flat spatially AND spectrally

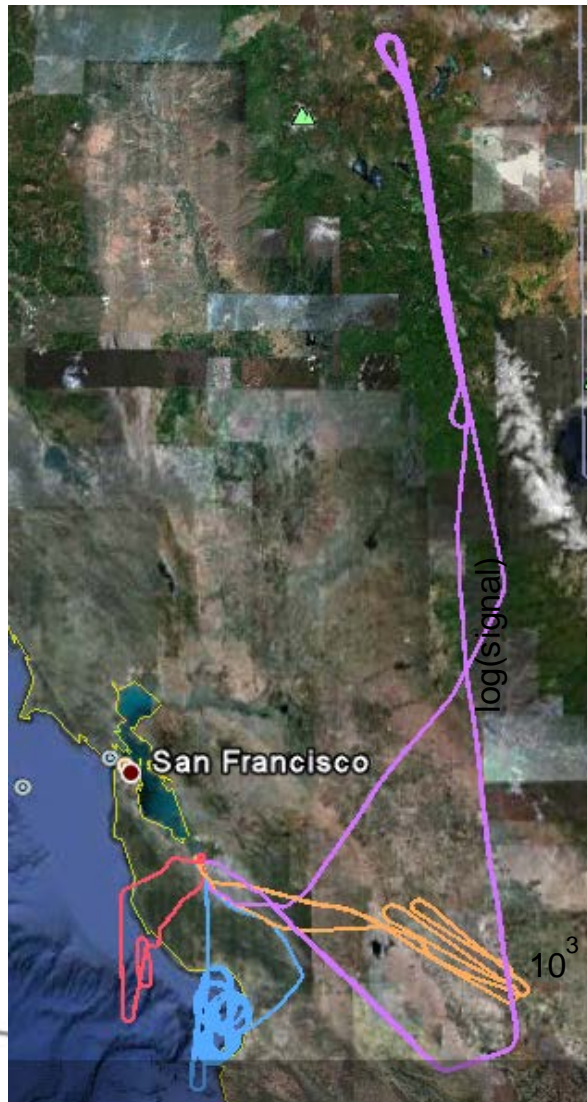
Aug 29-31: Moffet Field, test all measurement modes

- Orbit / spiral tests
- Langley “calibration” flight demonstrates sensitivity
- Sun tracking and sky scanning, profiling

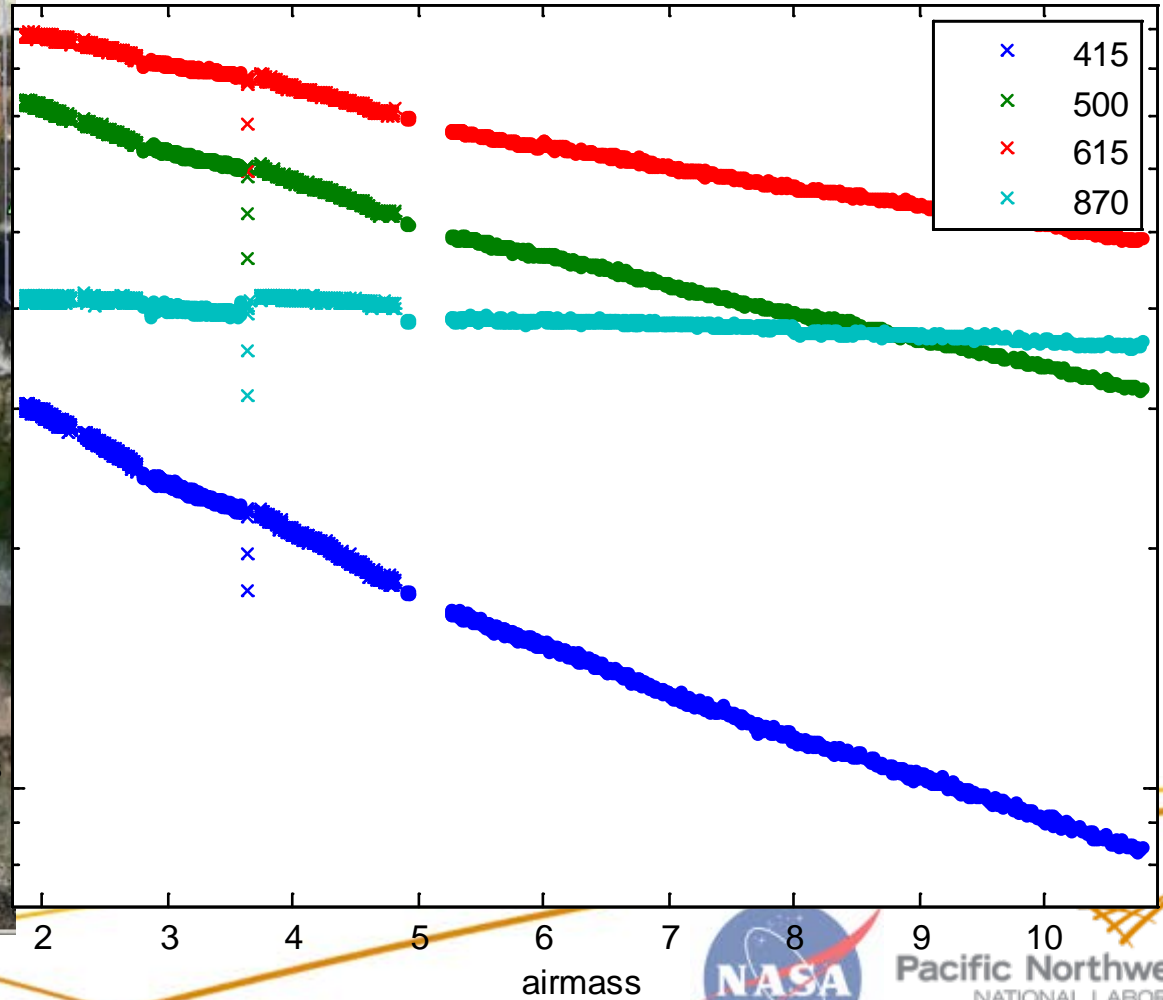
Final flight series Late Aug 2011



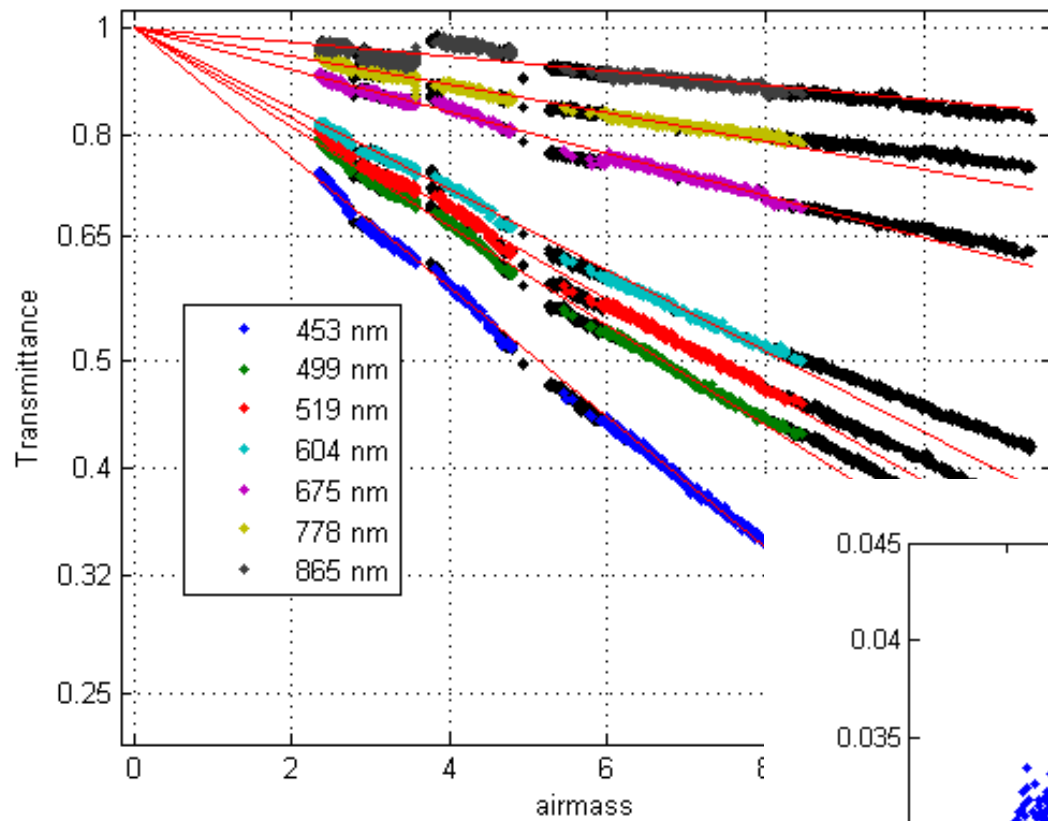
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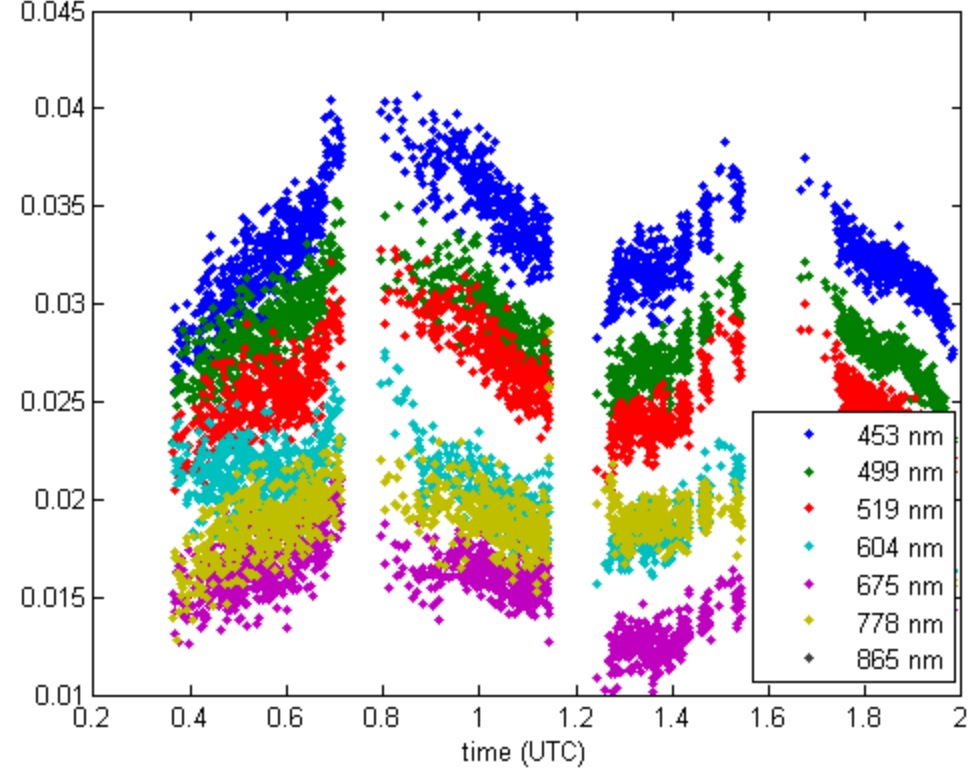
Raw langley - shows promise



Air-Langley



column OD - Rayleigh OD - Ozone(270 DU)

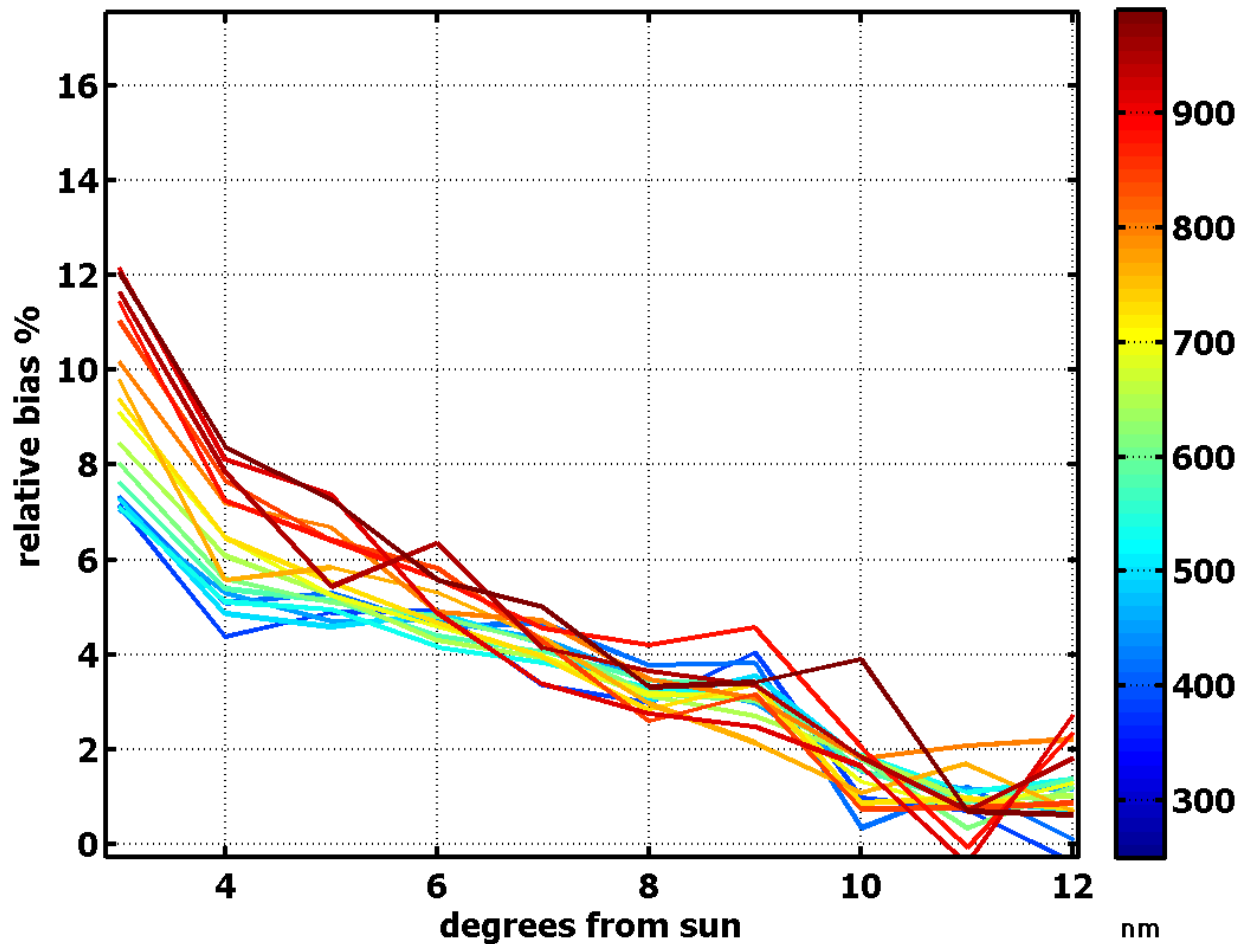


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Unshaded - Shaded signal bias
20120305_034_VIS_MANUAL.dat



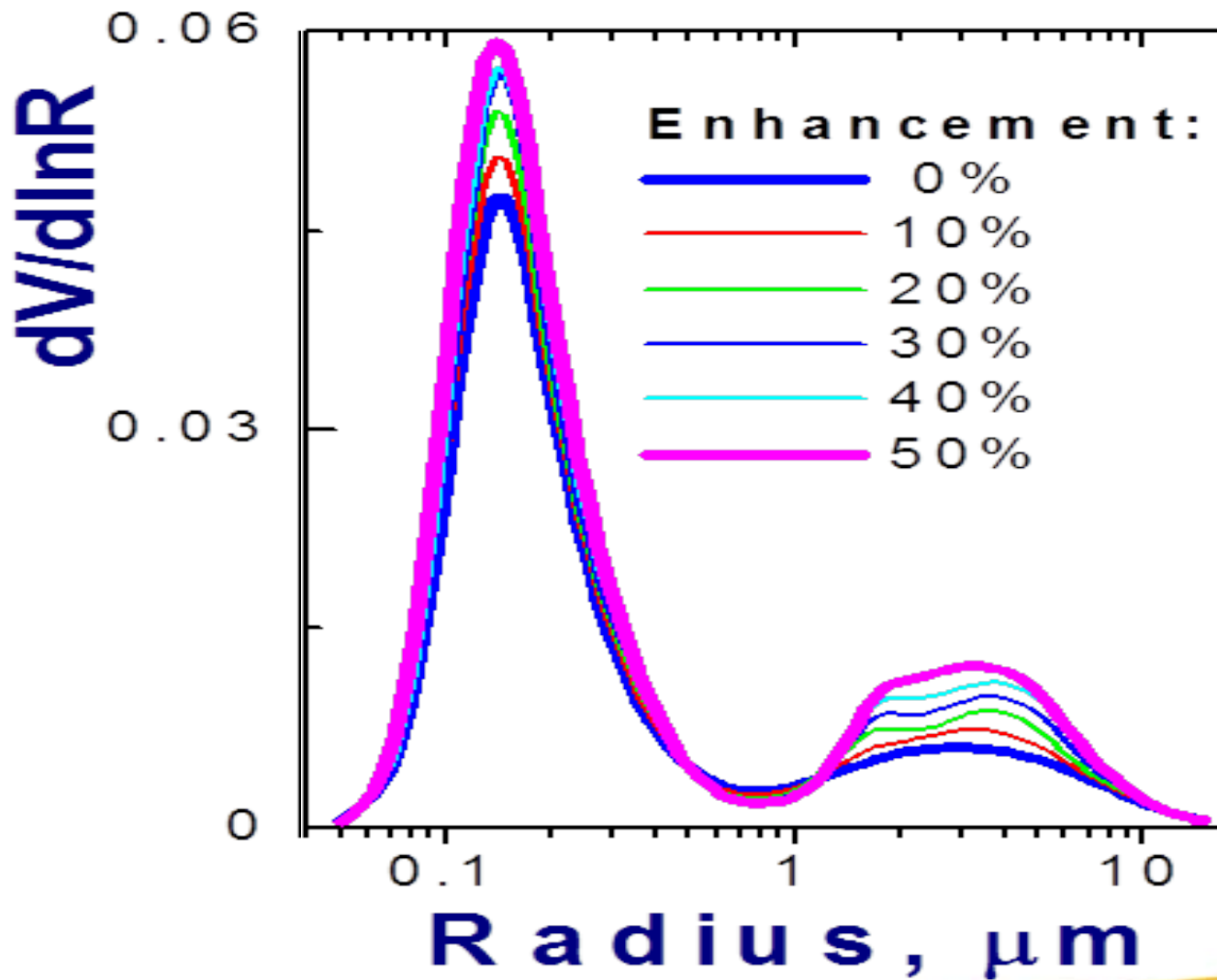
Aerosol Retrievals from 4STAR Observations in Support of TCAP: Sensitivity Tests

▶ *Evgueni Kassianov, et al*

Modeled impact of sky radiance “enhancement” and “offset” on retrievals of aerosol intensive properties via the Aeronet retrieval code.

Poster session *MUST SEE!*

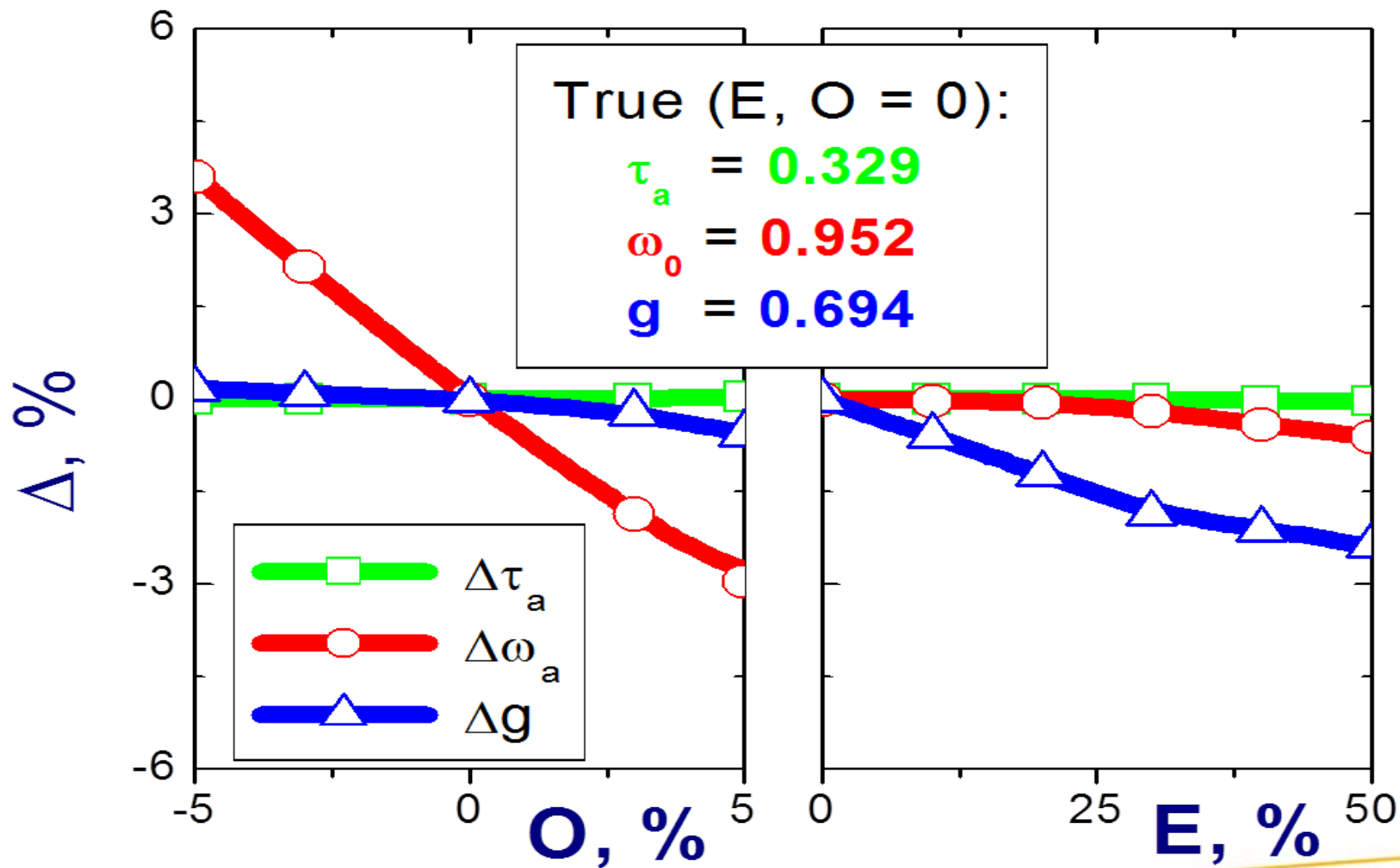




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Absolute calibration of both sun barrel and sky barrel is IMPORTANT.

- ▶ Continue rotational (FORJC) assessment.
- ▶ Solidly assess linearity with integration time.
- ▶ Fully characterize spectrometer internal artifacts.
- ▶ Radiance cals of 4STAR and Prede at NASA Ames.
- ▶ Irradiance cals of 4STAR, Prede, ARM Cimel at MLO.
 - Also provides independent radiance comparison.
- ▶ Ground-based comparison of 4STAR, Prede, Cimel at airport before and after flights during TCAP to track relative calibrations in irradiance and radiance.



Meanwhile... retrieval work is in progress.

- ▶ Adapt AATS code for direct beam to 4STAR.
- ▶ Incorporate real-time AOD and PWV retrievals to instrument display.
- ▶ Continue work to adapt the ground-based AERONET retrieval code to flight mode.
- ▶ Refine gas phase retrievals. E.g., multi-component linear regression of NO_2 , O_3 , O_4 , H_2O courtesy of Michal Segal Rosenheimer.



Retrieval results from the 440-490 nm spectral range

