

# **Airborne Sunphotometry and Integrated Analyses of Dust, Other Aerosols, and Water Vapor in the Puerto Rico Dust Experiment (PRIDE)**

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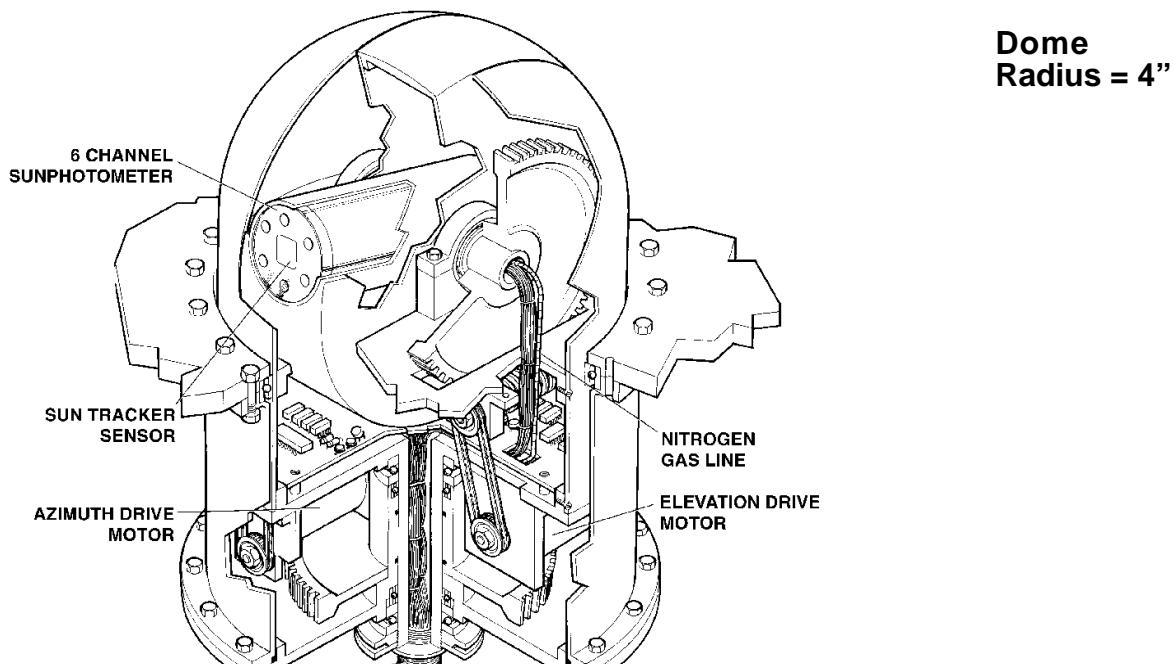
A proposed investigation presented at

PRIDE Videocon  
NASA Goddard and Ames  
24 January 2000

## **What we want to do & How we plan to do it**

# Task 1. Install AATS-6 on the SPAWAR Navajo

AIRBORNE SUNPHOTOMETER



**AATS = Ames Airborne Tracking Sunphotometer**

# How AATS-14 flew in TARFOX and ACE-2

Sunphotometer  
Dome radius = 4"



Pelican Optionally Piloted Aircraft (OPA)

Next Tasks: Address Yoram's Lists

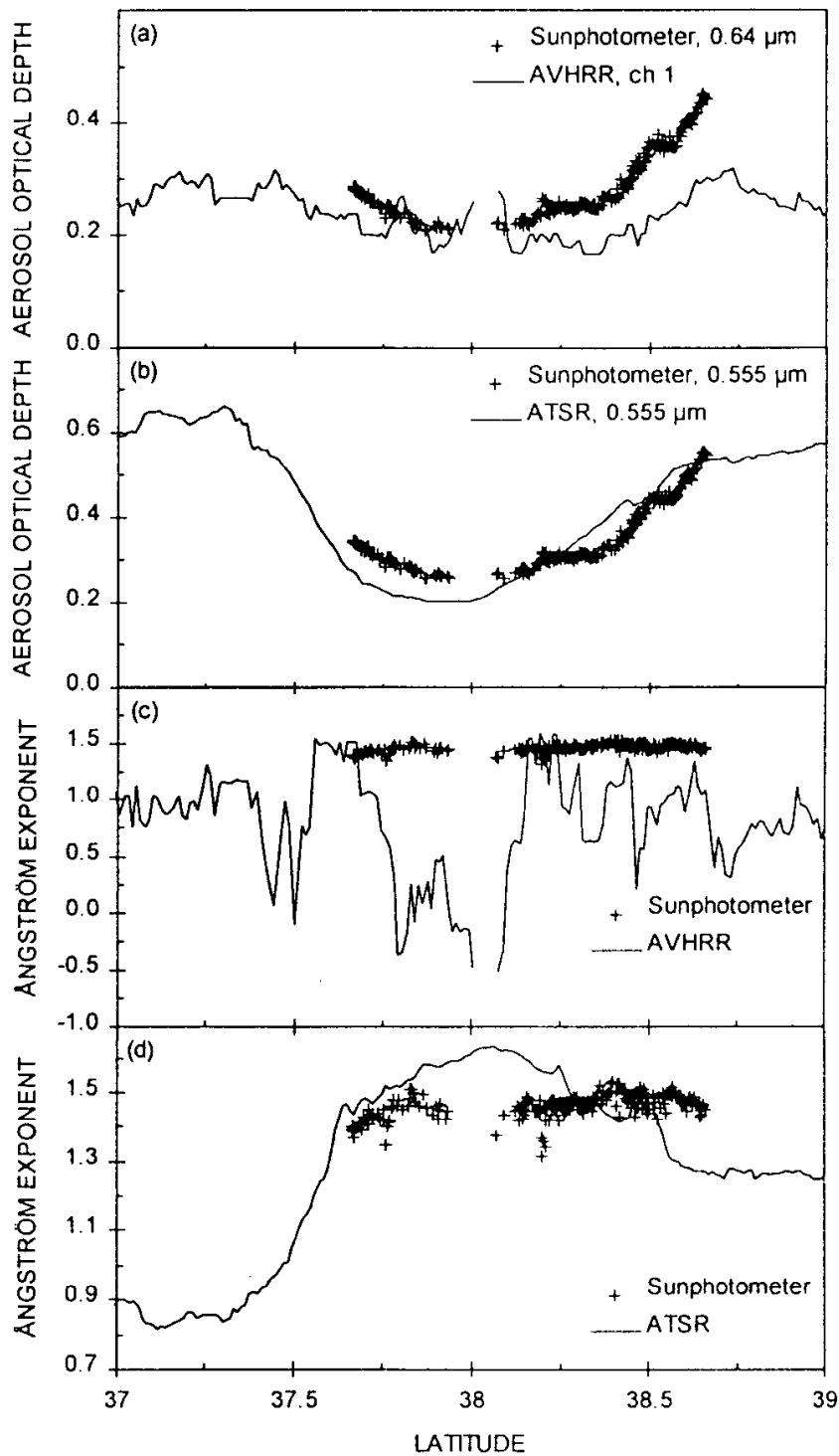
# **Yoram's Lists\***

## **What to measure in PRIDE:**

- Spectral optical thickness under Terra over glint free and glint regions
- Ground based measurements of dust absorption, scattering and iron concentration during a given period of time
- Vertical profiles of whatever we can measure
- Ocean spectral properties
  - Why:
    - Dust is most abundant aerosol, yet its properties least known. What can we measure?
    - Dust fertilizes the ocean. What is the relationship between the dust optical thickness, absorption and iron concentration ? How variable is it?
    - Need to know how badly dust (aspherical, inhomogeneous) degrades MODIS and other retrievals (which assume spherical homogeneous particles).
  - In coastal regions, need to know how badly underwater reflection degrades MODIS retrievals.
  - The best dust measurements are from ground based instrumentation. How representative are they of the vertical column?

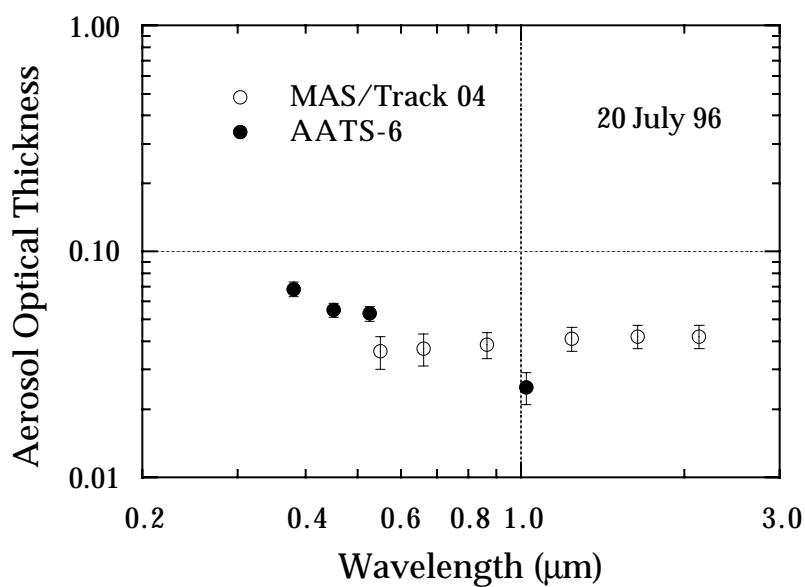
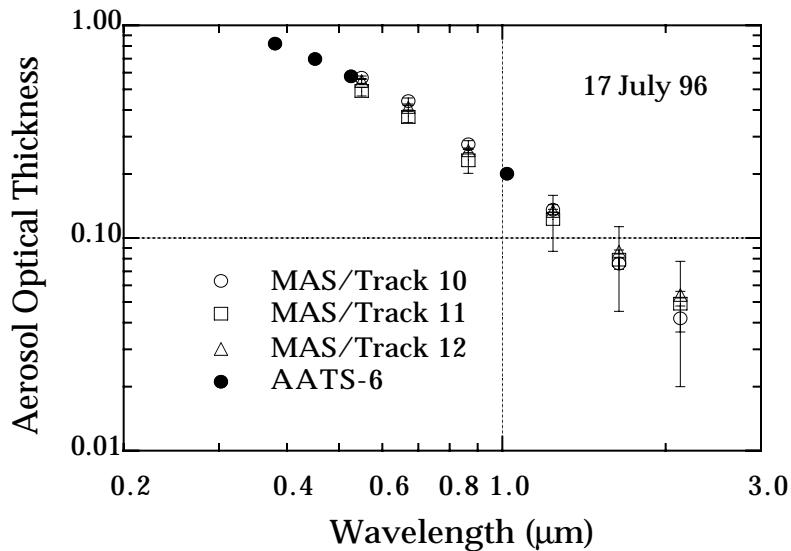
\*Yoram Kaufman's email of 1/17/00

**Example:  
AATS-6 continuous transect of multi- $\lambda$  AOD  
demonstrates quantitatively how ATSR-2  
retrieval accuracy exceeds AVHRR**



Veefkind et al., JGR, 1999

**Example:  
AATS-6 underflights of MODIS Airborne Simulator  
(MAS) quantify how MAS retrieval accuracy  
depends on AOT magnitude**



Tanre et al., JGR, 1999

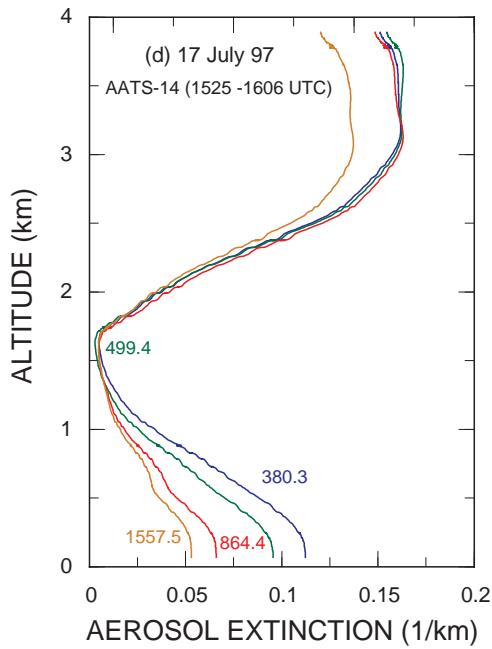
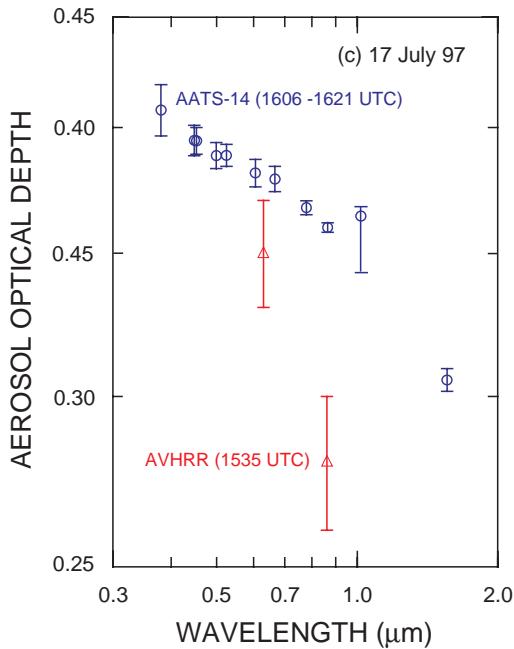
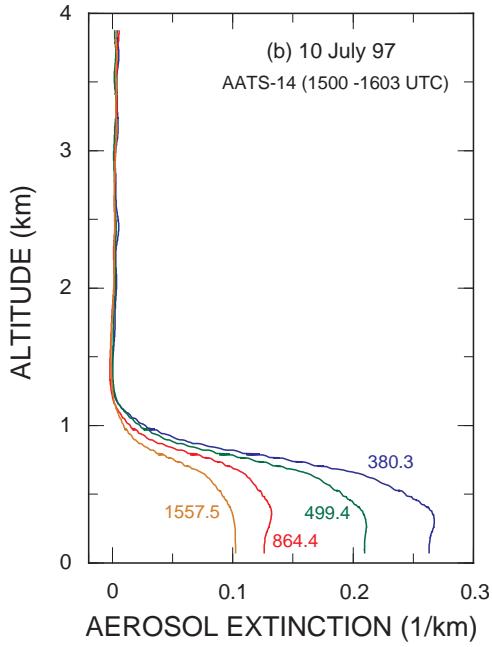
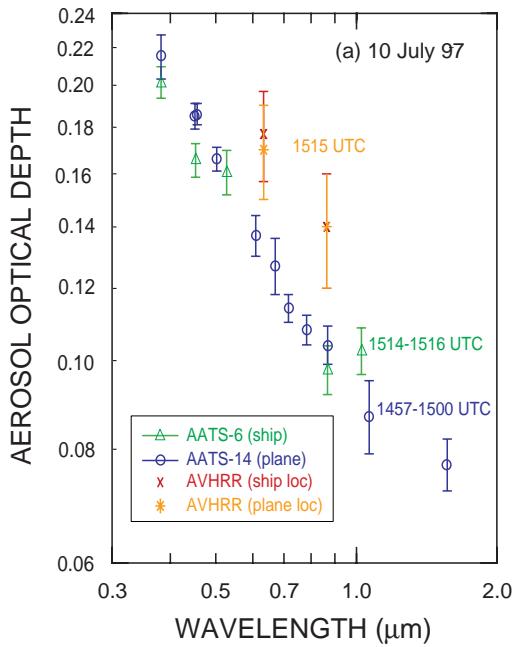
# **Yoram's Lists\***

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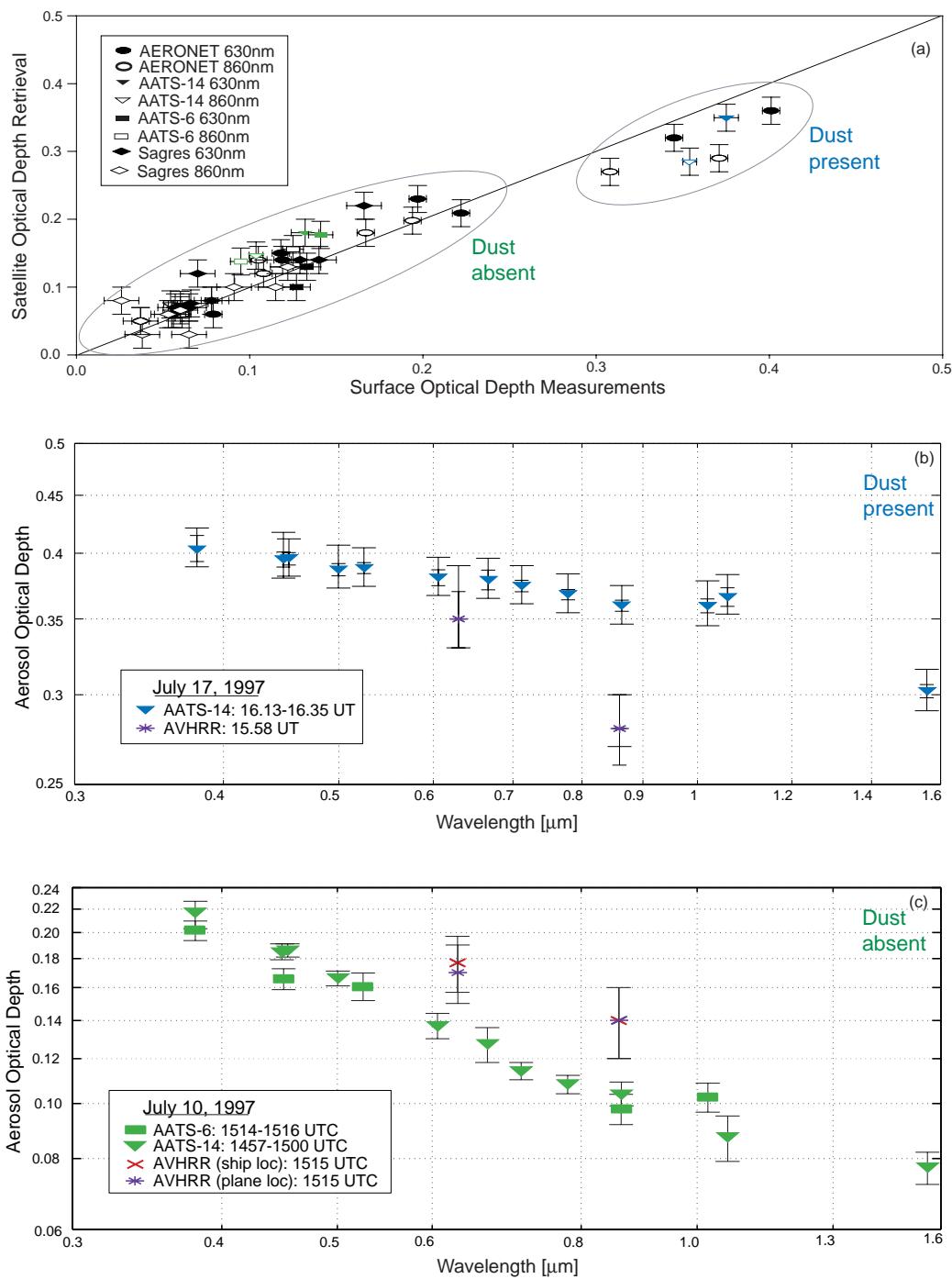
\*Kaufman email, 1/17/00

# Example: AATS-6 and -14 AOD spectra and continuous vertical profiles quantify how dust changes bias of AVHRR retrievals



Livingston et al., *Tellus*, 2000; Schmid et al., *Tellus*, 2000

# We need many comparisons to see if the dust/no-dust difference is statistically stable



Durkee et al., *Tellus*, 2000  
 Livingston et al., *Tellus*, 2000; Schmid et al., *Tellus*, 2000

# The cardinal rule of satellite validation

Whenever possible, use validation instruments and methods that have a proven track record:

- Error bars based on a comprehensive error analysis
- History of successful intercomparisons to other accepted techniques



Documented  
in the peer-  
reviewed  
literature

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## Rule 2:

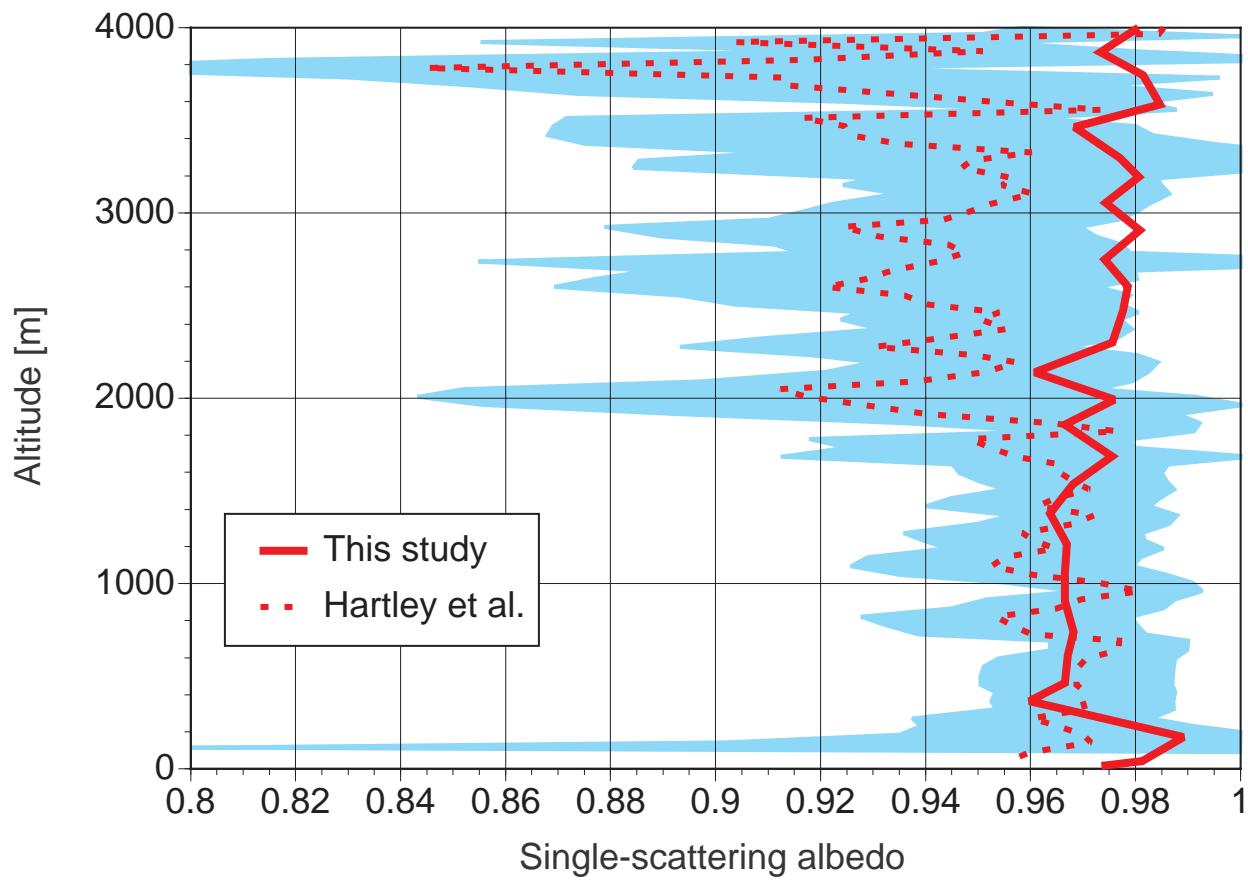
Demand spatiotemporal coincidence between satellite data and validation data.

(We live in a very inhomogeneous, changing world.)

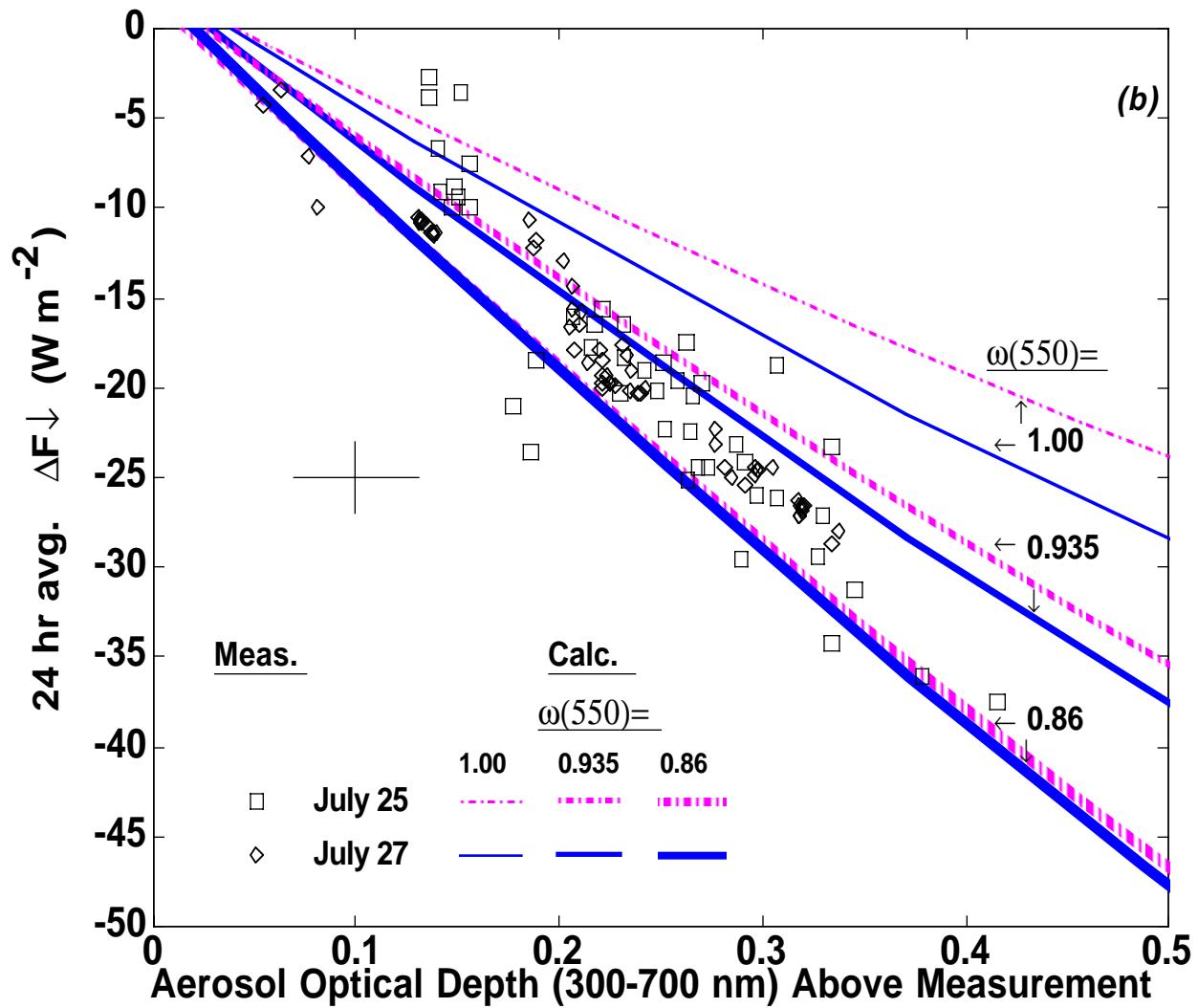
- Mobility & spatiotemporal continuity of validation measurements really help to achieve this coincidence

# We've demonstrated lots of other measurements and collaborative analyses that would be useful in PRIDE

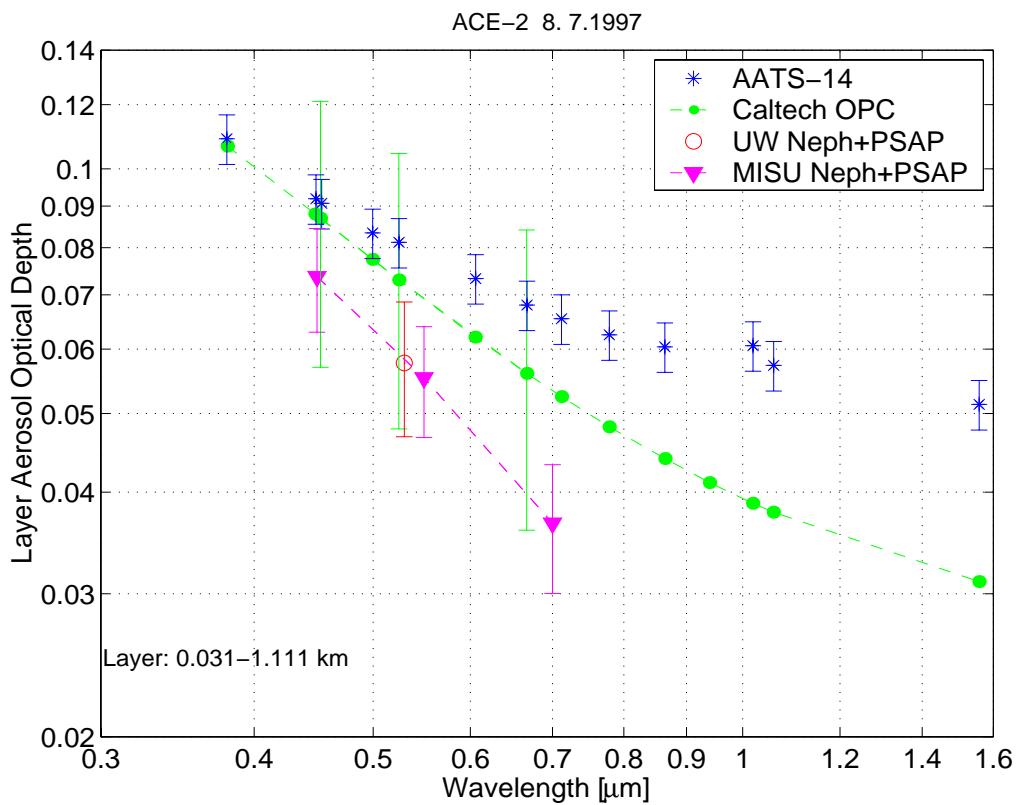
- Ways to get absorption (see Yoram's list) of the ambient, unperturbed aerosol:
  - AATS vertical profiles in the MicroPulse Lidar (MPL) beam, to get  $B/E(z)$ ; hence  $\omega(z)$  (Redemann et al., 2000; Schmid et al., 2000; Welton et al., 2000)
  - Combine SSFR Flux( $z, \lambda$ ) with AATS AOD( $z, \lambda$ ) to get diffuse/direct Flux( $z, \lambda$ ); hence  $\omega(\lambda)$  (Russell et al., 1999b)
- Many comparisons to airborne in situ measurements, to test closure:
  - AOD( $\lambda$ ) from AATS, nephelometer, PSAP, size spectrometers, chemistry(r) (Schmid et al., 2000; Collins et al., 2000; Livingston et al., 2000)
  - $n(r)$  from AATS vs size spectrometers (corrected for inlet losses, evaporation, calibration, etc.) (Schmid et al., 2000)
- Water vapor column from AATS (Livingston et al., 2000):
  - Compare to satellite retrievals; test correlation with AOD retrieval errors
  - Study effect on aerosol size, composition



Aerosol single-scattering albedo profiles determined for TARFOX flight 1728 (July 17, 1996) by two techniques. Solid line: derived by Redemann et al. (2000b) using *in situ* particle size distributions and aerosol layer complex refractive index estimates from Redemann et al. (2000a) that produce best agreement among profiles of lidar backscatter, sunphotometer extinction, and relative size distribution. Values were used in the first band of the Fu-Liou radiative transfer model ( $0.2 \mu\text{m} < \lambda < 0.7 \mu\text{m}$ ). Dashed line: derived by Hartley et al. (2000) at 450 nm by combining *in situ* scattering, absorption, and size distribution measurements. The gray-shaded area represents their uncertainty estimates based on one standard deviation plus instrumental error.

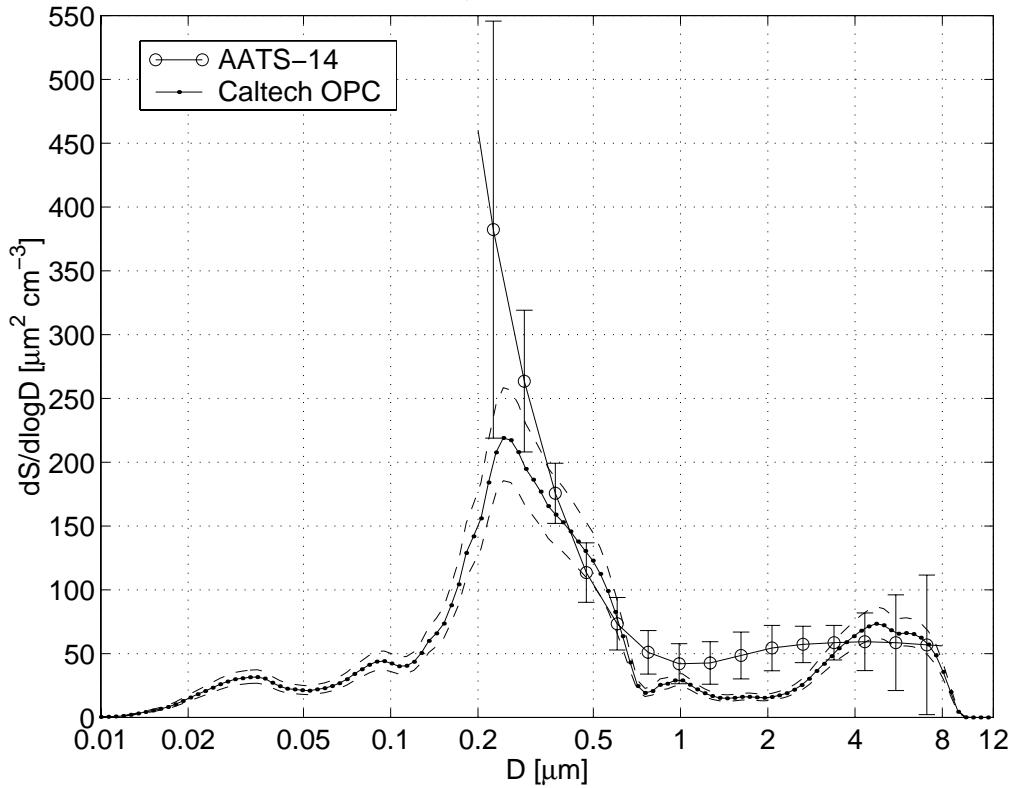


Comparison between aerosol-induced change in downwelling solar flux derived from C-130 pyranometer measurements (data points) and calculated (curves) for size distributions retrieved from sunphotometer optical depth spectra using an aqueous sulfate real refractive index and a range of imaginary indexes to give the  $\omega$  (550) values shown. The error bar (cross) shows the uncertainty in flux change and broadband visible optical depth determined from the C-130 pyranometer measurements (Russell, et al., 1999b).

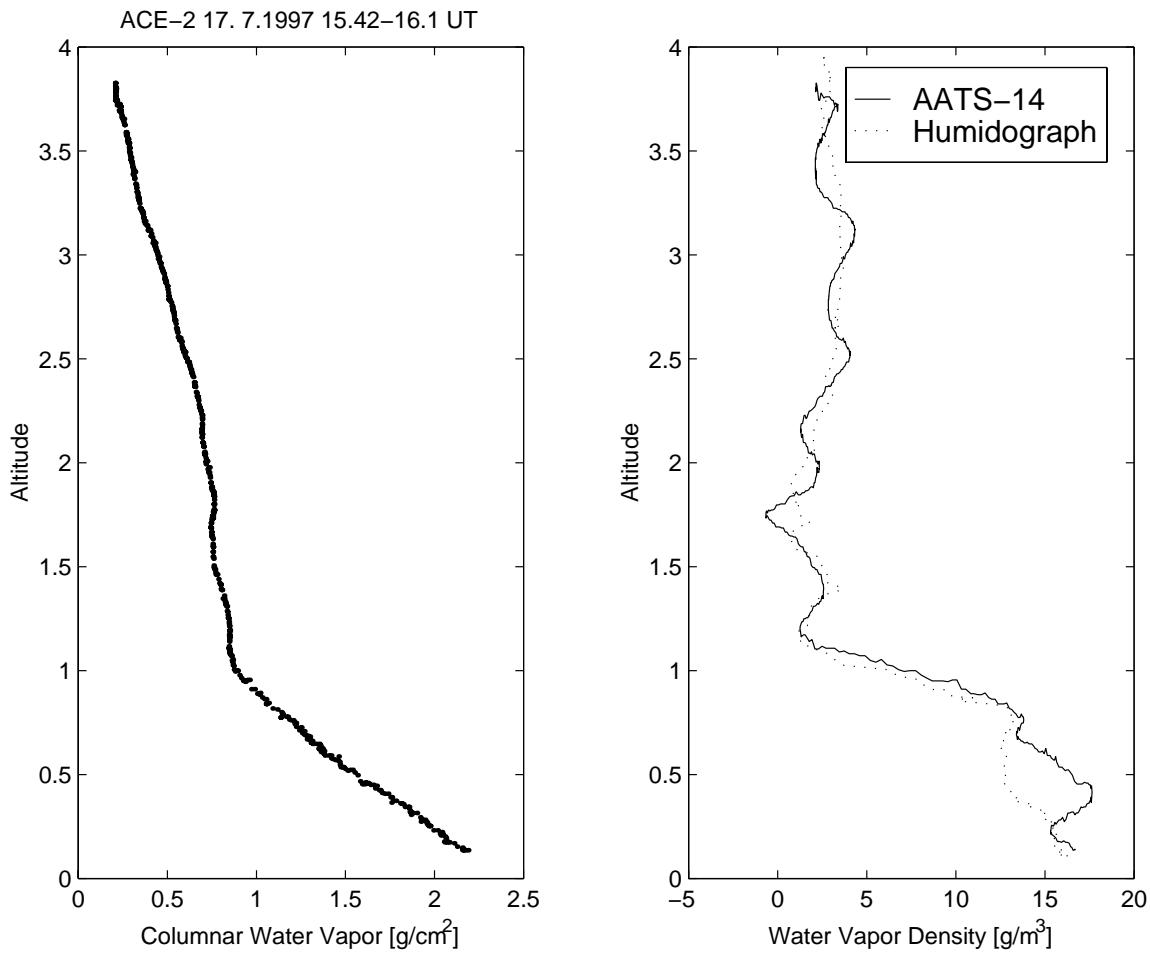


Comparison of aerosol optical depth spectra for the marine boundary layer (31–1111 m) during Pelican flight tf20 in ACE 2 on July 8, 1997 (Schmid et al., 2000).

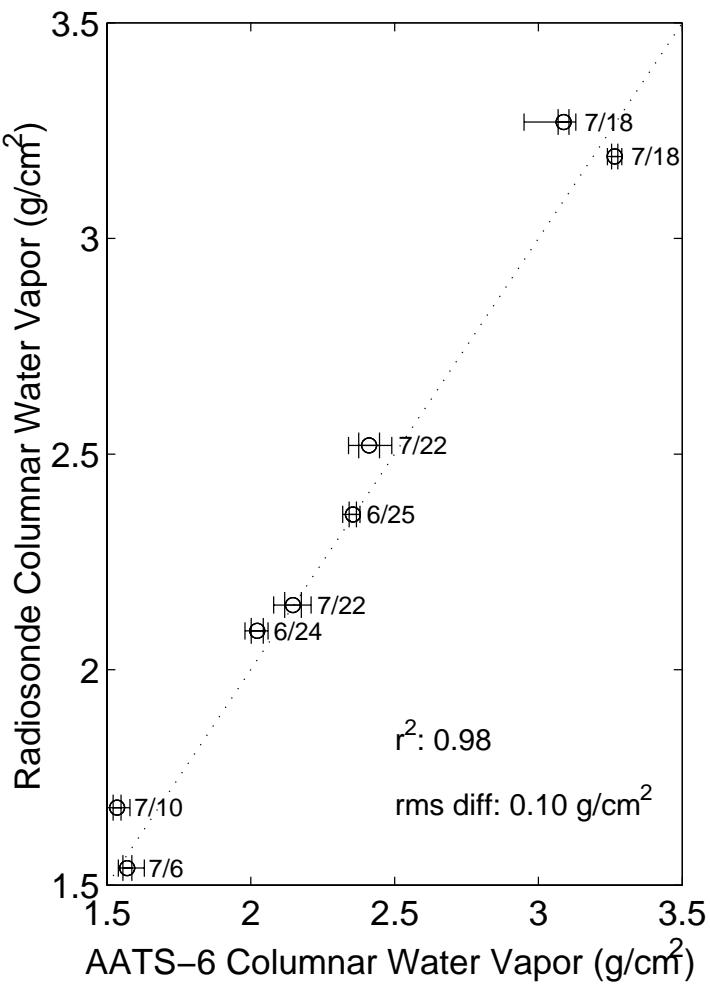
17 July 97, MBL 203–882m



Comparison of marine boundary layer aerosol size distributions from in situ measurements and inverted from AATS-14 extinction spectra measured on Pelican flight tf15 in ACE 2 on July 17, 1997. Dashed lines indicate uncertainty of the in situ results (Schmid et al., 2000).

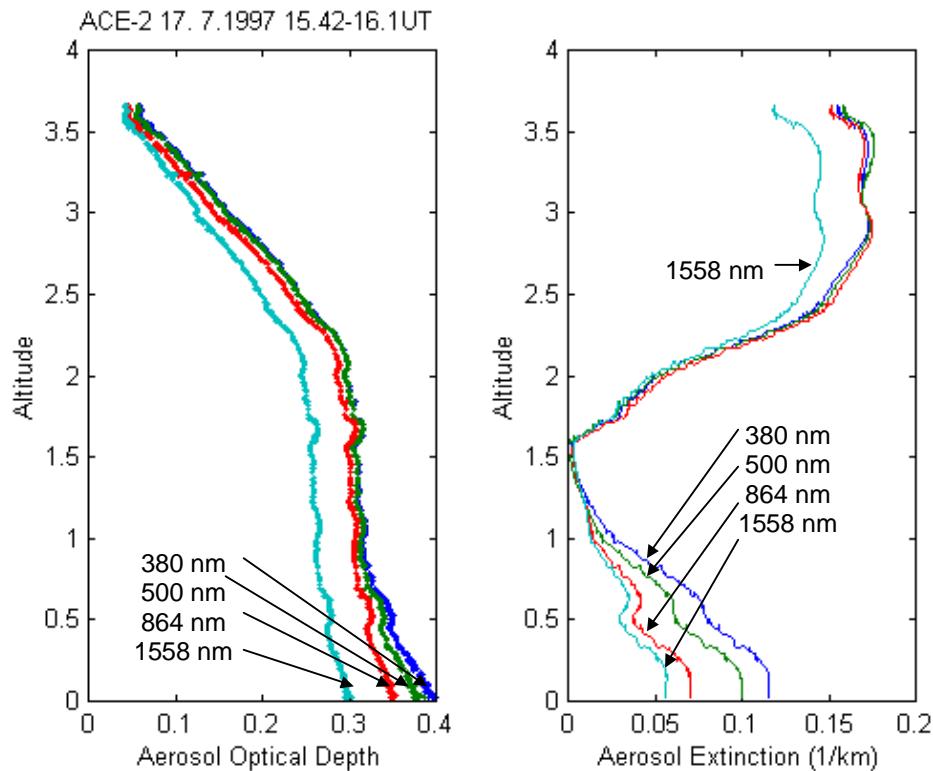


Left panel: Profile of the columnar water vapor above the Pelican aircraft measured in ACE-2 south of the coast of Tenerife. Right panel: Water vapor density derived by differentiating the profile in the left panel. Also shown for comparison is the profile obtained by combining readings of a humidograph and outside temperature on Pelican (humidograph data courtesy of S. Gasso, University of Washington). (Schmid et al., 2000)



Scatter diagram of columnar water vapor calculated from radiosonde measurements and from AATS-6 measurements during ACE-2. Each AATS-6 data point represents the mean calculated over the time period spanned by the radiosonde measurements; horizontal bars show the corresponding standard deviation (wide ticks) and the range (narrow ticks) for that time period (Livingston et al., 2000).

# Vertical profiles of aerosol extinction are obtained by vertically differentiating AATS continuous vertical profiles of AOD



Left panel: Profiles of aerosol optical depth at four selected AATS-14 wavelengths (380, 500, 864 and 1558 nm) measured in ACE-2 south of the coast of Tenerife. Right panel: Aerosol extinction profiles derived by differentiating the profiles in the left panel. (Schmid et al., 2000b)

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**Investigation Title: Airborne Sunphotometry and Integrated Analyses of Dust, Other Aerosols, and Water Vapor in the Puerto Rico Dust Experiment (PRIDE)**

Principal Investigator and team  PI: Philip B. Russell  Co-Is: Beat Schmid Jens Redemann John M. Livingston Peter Pilewskie	Philip B. Russell Atmospheric Chemistry and Dynamics Branch NASA Ames Research Center MS 245-5 Moffett Field, CA 94035-1000 prussell@mail.arc.nasa.gov Phone: 650-604-5404. Fax: 650-604-6779  Beat Schmid, Bay Area Environmental Research Institute, 650-604-5933 Jens Redemann, Bay Area Environmental Research Institute, 650-604-6259 John M. Livingston, SRI International, 650-859-4174 Peter Pilewskie, NASA Ames Research Center, 650-604-0746
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**Investigation objectives:**

- (1) Improve understanding of dust, other aerosol, and water vapor effects on radiative transfer, radiation budgets and climate in the Caribbean region
- (2) Test and improve the ability of satellite remote sensors (such as MODIS, MISR, CERES, TOMS, AVHRR) to measure these constituents and their radiative effects.

**Tasks:**

(a) Integrate an Ames Airborne Tracking Sunphotometer on a PRIDE aircraft (e.g., AATS-6 on the SPAWAR Navajo, or AATS-14 on the CIRPAS Twin Otter). (b) Calibrate AATS before and after PRIDE. (c) Provide continuous realtime measurements of aerosol and thin cloud optical depth spectra and water vapor column contents during PRIDE flights. (d) Use these data in flight direction and planning. (e) Compare results to those of the satellite sensors listed above; in cases of disagreement, investigate causes and retrieval algorithm improvements. (f) For aircraft profiles derive profiles of aerosol extinction spectra and water vapor density. (g) Combine these data with those from the Pilewskie SSFR and conduct new analyses of aerosol radiative forcing sensitivity, single scattering albedo, and the solar spectral radiative energy budget. (h) Derive aerosol size distributions from optical depth and extinction spectra. (i) Combine data with in situ measurements of chemical composition, size distribution, hygroscopic growth, and single-scattering albedo to provide tests of closure and integrated assessments of aerosol and trace gas radiative effects.

**Outputs (what and when):**

- Aerosol and thin cloud optical depth spectra (380 to 1020 or 1558 nm) and water vapor column contents, in real time color displays. Produced continuously throughout A/C flight when sunphotometer's view of sun is not blocked by thick clouds ( $\tau > \sim 3$ ) or A/C obstructions (e.g., tail, antennas).
- For A/C profiles, haze extinction spectra profiles (380 to 1020 or 1558 nm) and water vapor concentration profiles. Produced after flight from smoothed profiles of data resulting from #1. Requires reasonable horizontal/temporal homogeneity.

Integrated analyses (see above) and publications produced several months to years after measurements, depending in part on availability of others' data and analyses, plus funding levels.

**Activity timetable:**

2000:

- Jan-Feb: Funding Decision
- Feb-Apr: A/C Integration Planning, Fit Checks
- May: Pre-Campaign Sunphotometer Aerosol/Water Vapor Calibration, Mauna Loa Observatory
- 1-21 Jun: A/C Integration and Test Flights
- 26 Jun-21 Jul: PRIDE Deployment, Roosevelt Roads, PR
- Aug-Oct: Post-Campaign Sunphotometer Aerosol/ Water Vapor Calibration, Mauna Loa Observatory