California P-3B measurements during ARCTAS-CARB:

Flight patterns, example data, and potential analyses

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NASA Ames Research Center

With contributions from:

Yohei Shinozuka, Jens Redemann, John Livingston, Tony Clarke, Cam Mcnaughton, Steve Howell, John Hair, Sebastian Schmidt, Eike Bierwirth, Rich Ferrare, Ralph Kahn, Lorraine Remer, Jeff Reid, Betsy Reid, Anthony Bucholtz, Brent Holben, ...

ARCTAS California Workshop
30 June-1 July 2009
Davis, CA

3 California flights

of the P-3B in ARCTAS-Summer, 2008

P-3B in ARCTAS

Overall goal: Link variations in atmospheric radiation to microphysics and chemistry of haze & smoke aerosols + surfaces.

Needed for

--reliable interpretations of satellite inversions

--refining model products

--assessing climate forcing in terms of emissions and/or mitigation strategies.

P-3B in ARCTAS

Science objectives (long list) required:

- Measuring simultaneously
  - -- Aerosol chemical, physical & optical properties
  - -- Aerosol radiative effects
  - -- Trace gases (CO, O_3)
  - -- ++

Approach

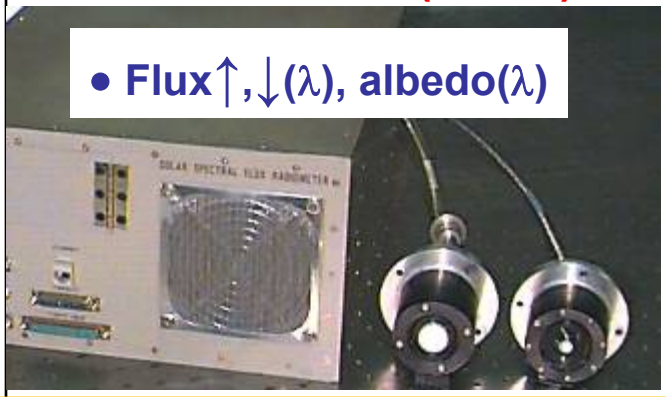
Fly a balanced suite of radiometric & in situ instruments on a single platform.

P-3B in ARCTAS: Payload

Ames Airborne Tracking Sunphotometer (AATS-

- AOD
- Ext
- H_2O vapor

Solar Spectral Flux Radiometer (SSFR)



- Flux↑,↓(λ), albedo(λ)

Broad-Band Radiometers (BBR)

LW SW

- Flux↑,↓, albedo

HiGEAR Aerosols & O_3

- OPC & DMA dry size dist, volatility
- Tandem Volatility DMA
- Neph scat + PSAP abs
- Humidified Neph f(RH)
- Ultrafine & CN
- Time of Flight Mass Spec size resolved chemistry
- SP2 black carbon mass

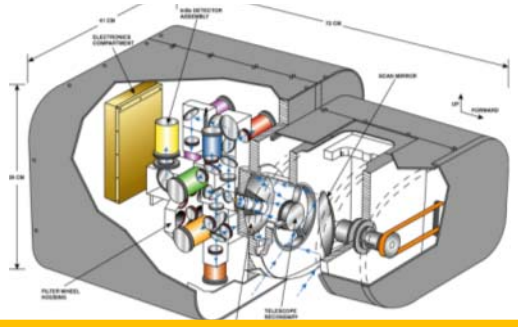
AERO3X

- Cavity Ringdown ext (2λ)
- Reciprocal Neph sca (2λ, RH)

- Nenes CCN
- PVM cloud drop r_{eff}, vol
- TECO O_3

Cloud Absorption Radiometer (CAR)

- Radiance, BRDF



COBALT: CO

P-3 Data System (PDS): Nav, Flight, Met (P, T, RH, …)

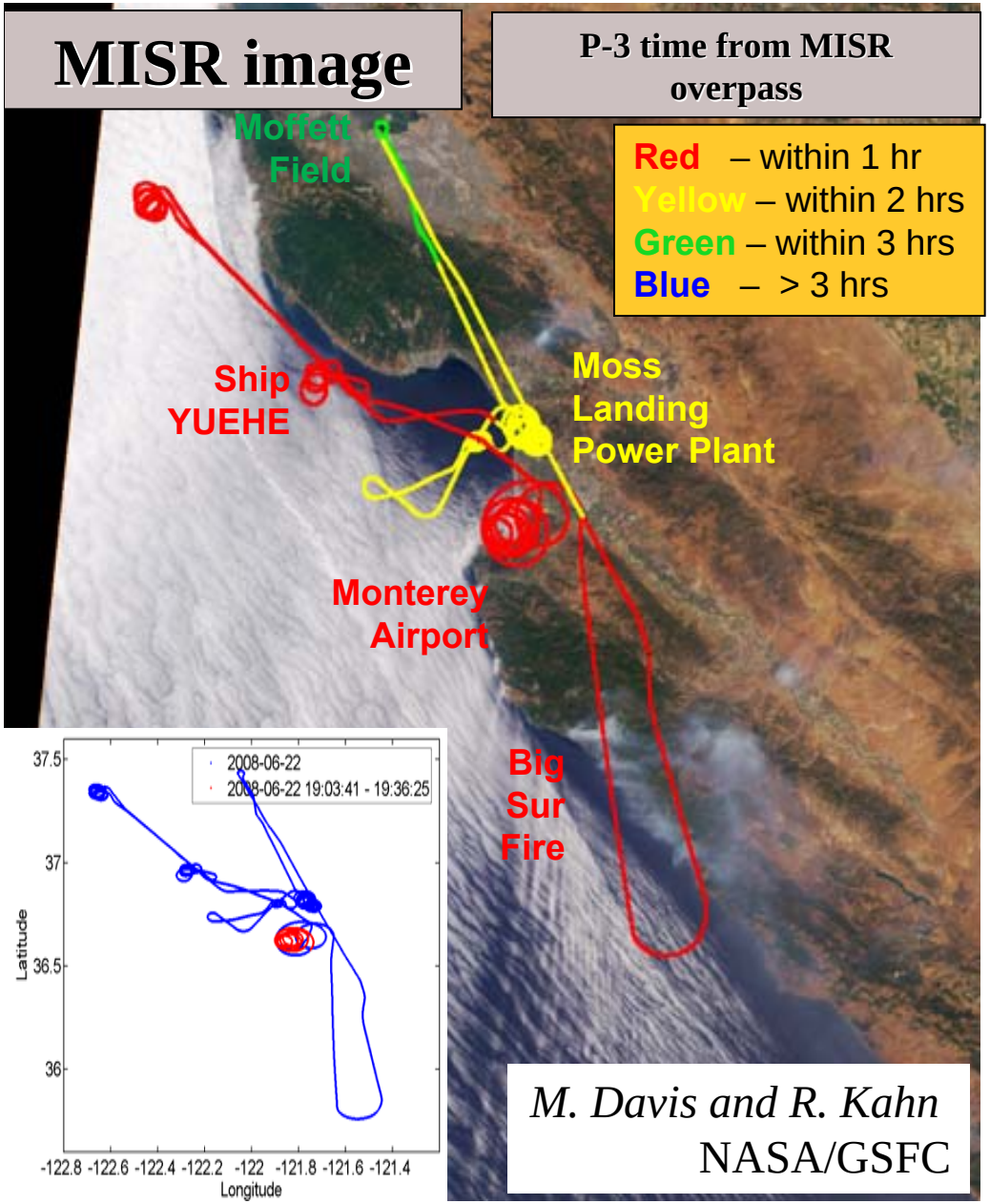
REVEAL & RTMM

P-3 California Flights
in ARCTAS Summer

Data Flt No.	Date, 2008	Track	Comments
11	22 Jun	Moffett-Monterey Bay-Big Sur-Moffett	Power plant plume, CAR circles, ship plume, AERONET, lidar, Terra, sonde, wildfire smoke.
12	24 Jun	Moffett-Los Angeles-Moffett	Plume crossings for 14 ships. Profiles under Terra & Aqua. Ocean BRDF (calm & 50-kt winds). Fire plumes & pollution plumes.
13 & 14	26 Jun	Moffett-Edmonton-Cold Lake	Lake Tahoe smoke radiation study in DC-8 lidar curtain & under Terra. Lake albedo & BRDF. Central Valley smoke gradient legs.

http://www.espo.nasa.gov/arctas/flightDocs.php

P-3B Data Flight #11, 22 Jun 2008:



Excerpts from flight report (http://www.espo.nasa.gov/arctas/docs/flight/2008-6-22_p3_report.pdf).

Moss Landing was clear on P-3 arrival, with power plant plume visible. P-3 circled plant several times & encountered CO & aerosol maxima (CO>500 ppb).
Nearby stratus clouds so brown they look like chocolate, because of Calif biomass fires.
Large smoke column sighted rising S of Monterey Peninsula (Big Sur fire).

1858 UT: MODIS Terra overpass.

1903: Low pass over Monterey Airport, next to NRL (with AERONET Cimel & MPL lidar). Monterey Airport is in hole in clouds. NRL released sonde near this time.

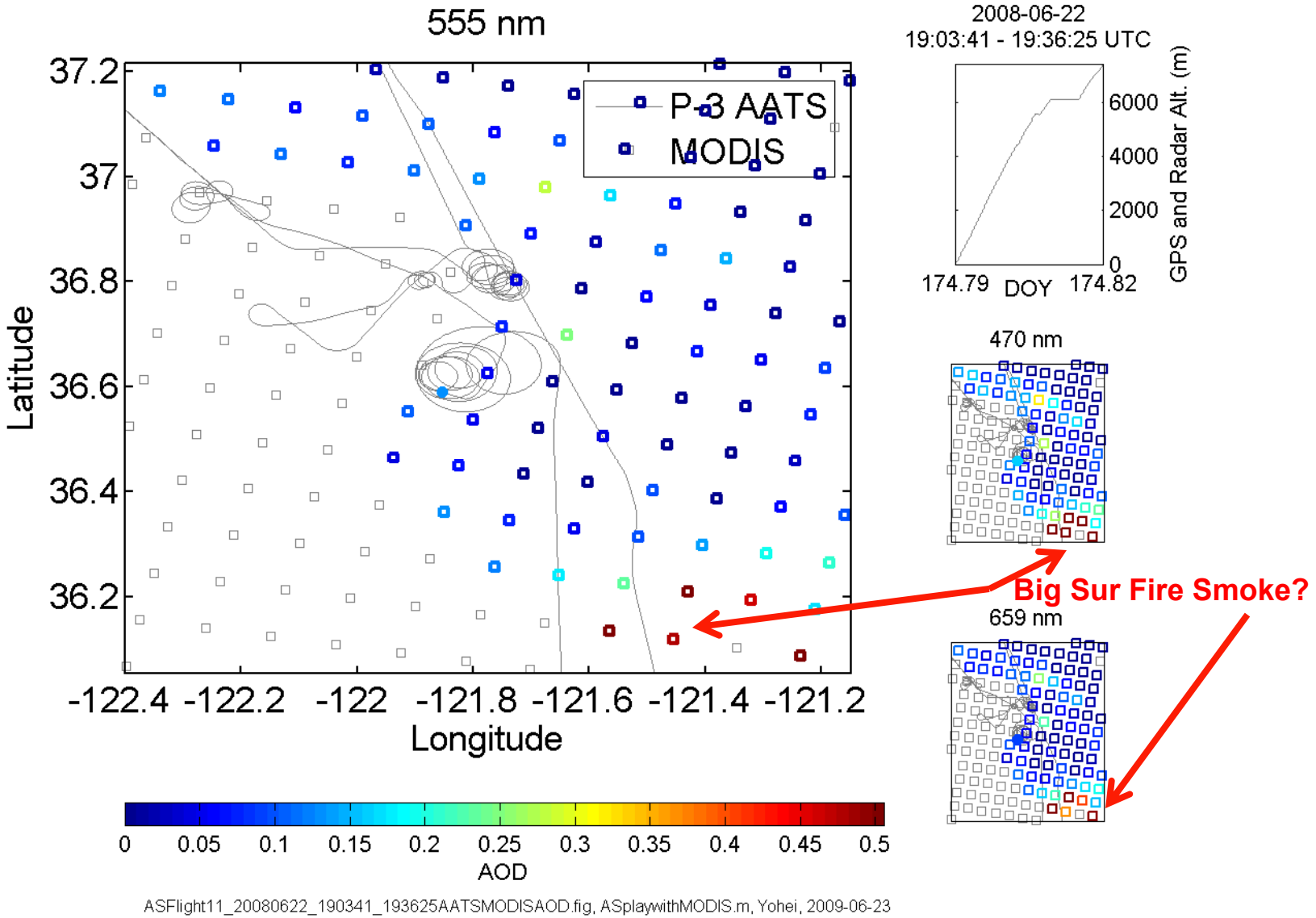
1905: Spiraling up over Airport. BB smoke column seen S of Monterey Peninsula. Brown clouds W of Monterey Peninsula.

1910: Elevated sulfate, GPS 8500 ft. Asian?

MODIS-Terra

Aerosol Optical Depth (AOD) Retrieval

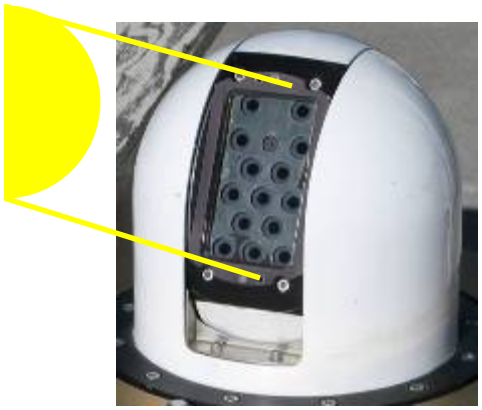
22 Jun 2008

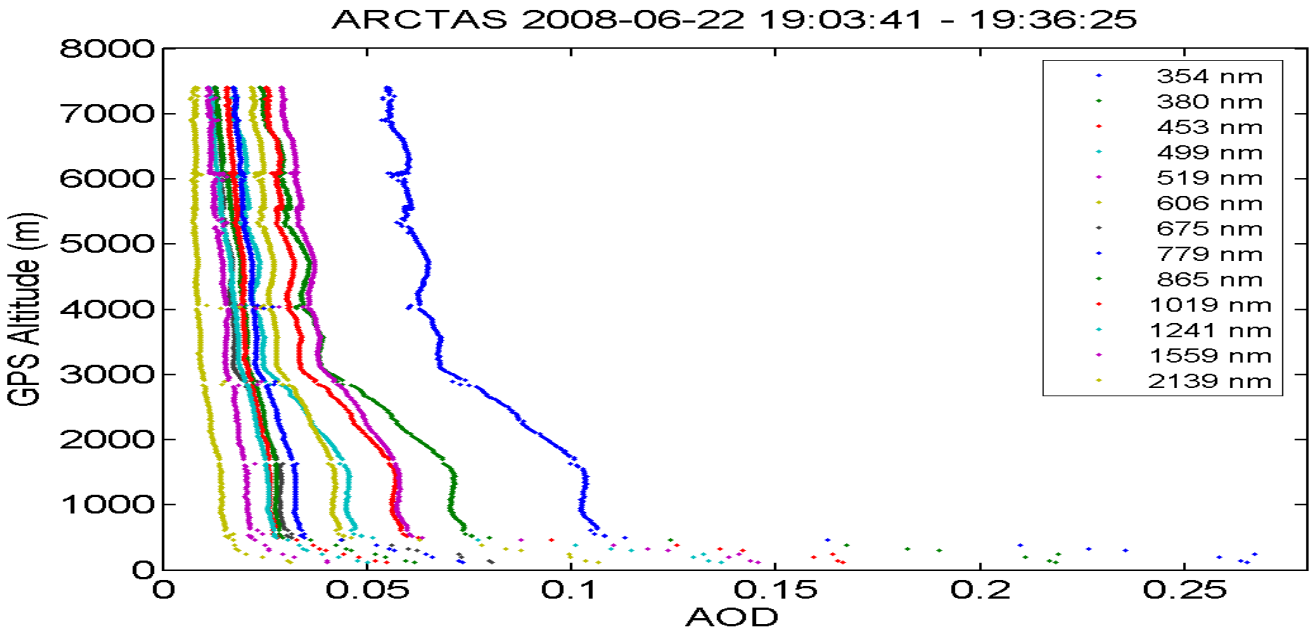


ASFlight11_20080622_190341_193625AATSMODISAOD.fig, ASplaywithMODIS.m, Yohei, 2009-06-23

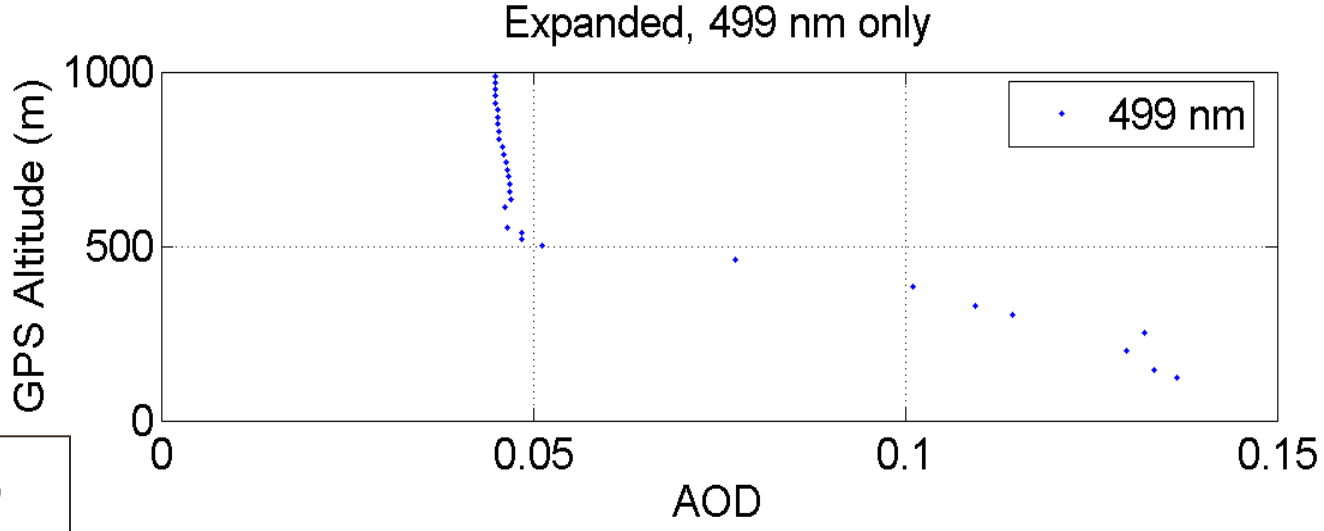
P-3B spiral up over Monterey Airport,

22 Jun 2008





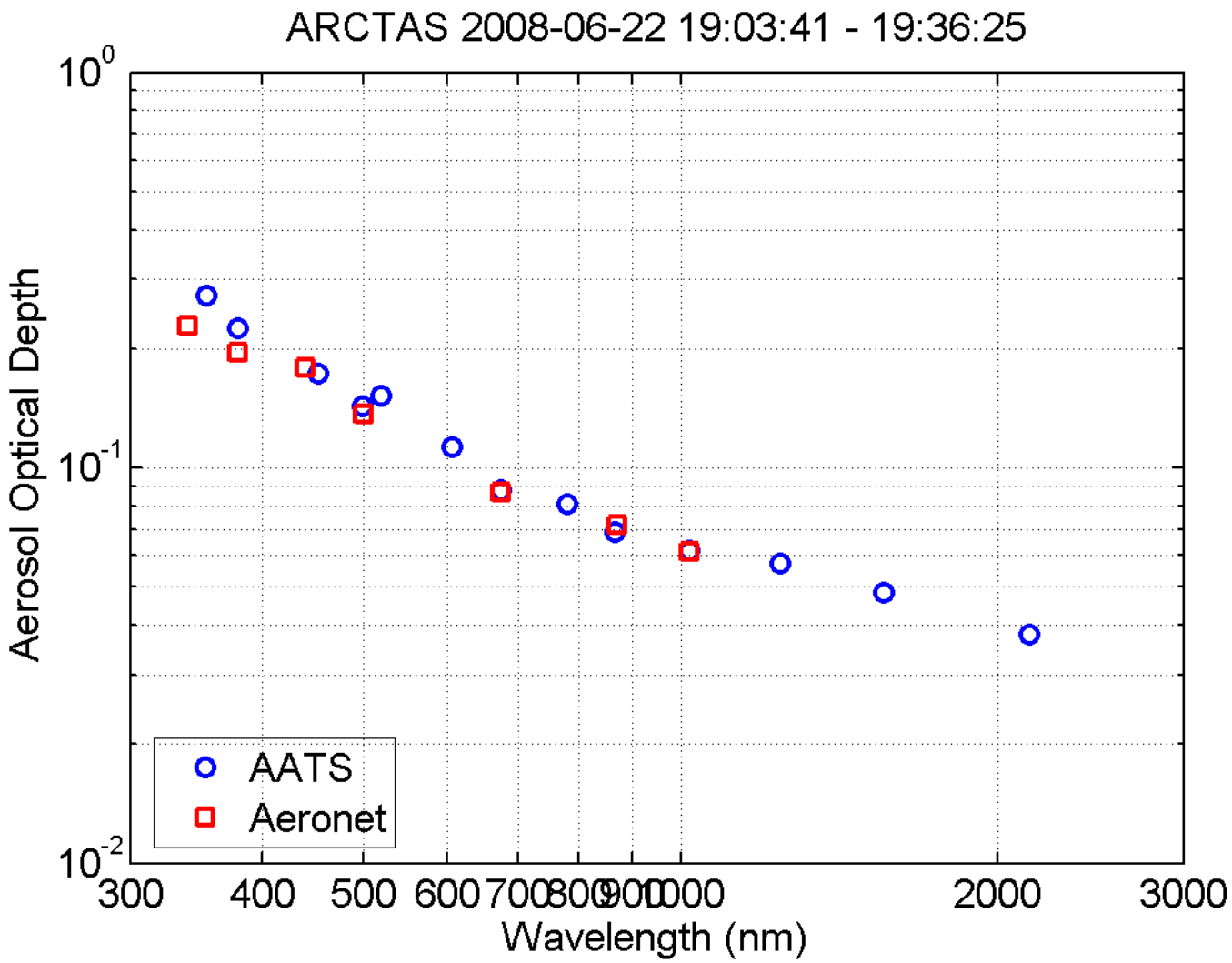
AOD from Ames Airborne Tracking Sunphotometer (AATS-14)



ASFlight11_20080622_190341_193625AeronetMontereyAATSprof.fig, ASEurekaPearlAeronetcomparison.m, Yohei, 2009-06-22

Redemann, Livingston, Shinozuka, …

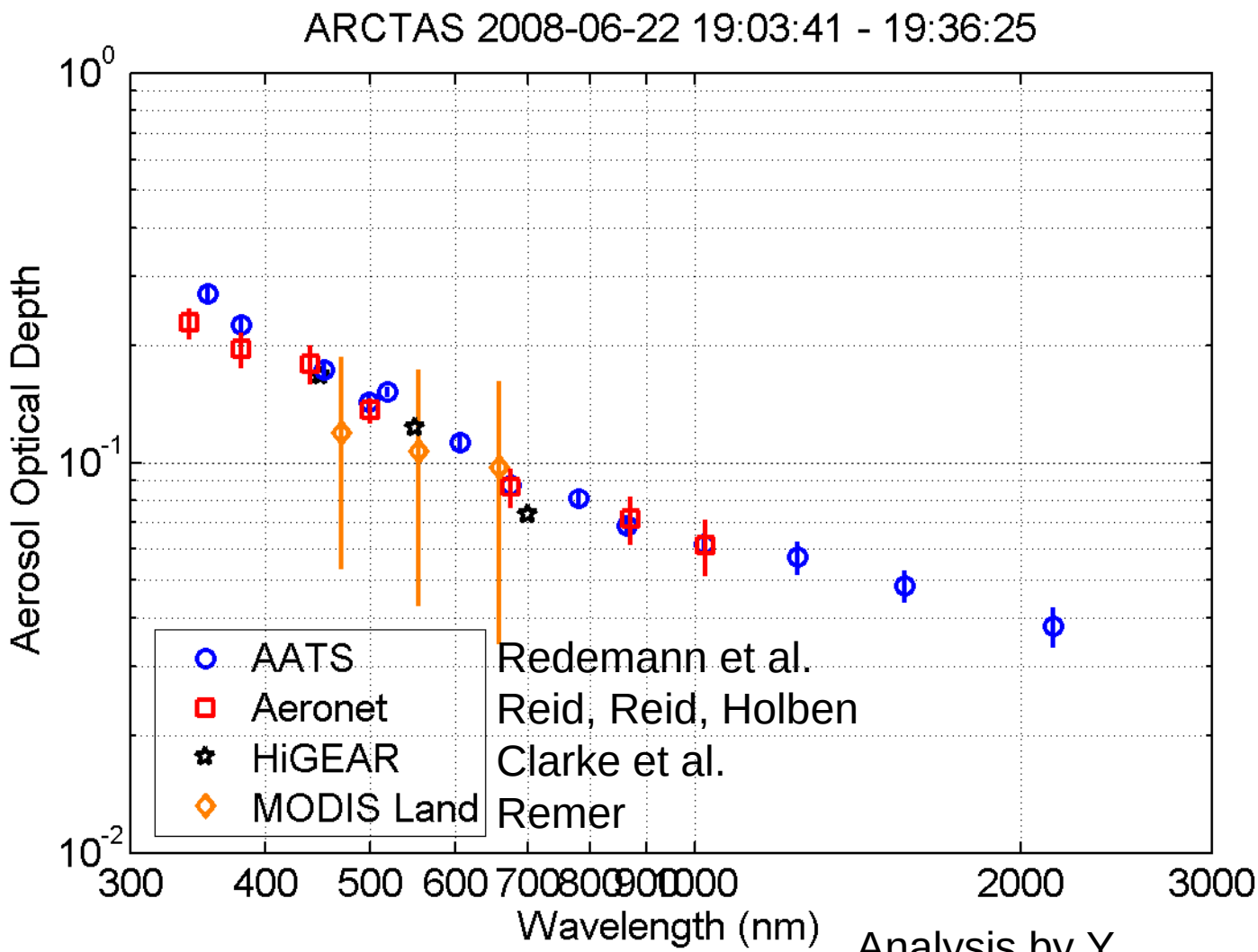
•AATS and AERONET agree within 10%+0.02. (good.)
•The 519 nm AATS AOD is higher than those at other wavelengths suggest. (this channel needs to be investigated.)



Redemann, Livingston, Shinozuka, Reid, Reid …

•AATS, HiGEAR and AERONET agree within 10%+0.02. (good.)
•The 519 nm AATS AOD is higher than those at other wavelengths suggest. (this channel needs to be investigated.)

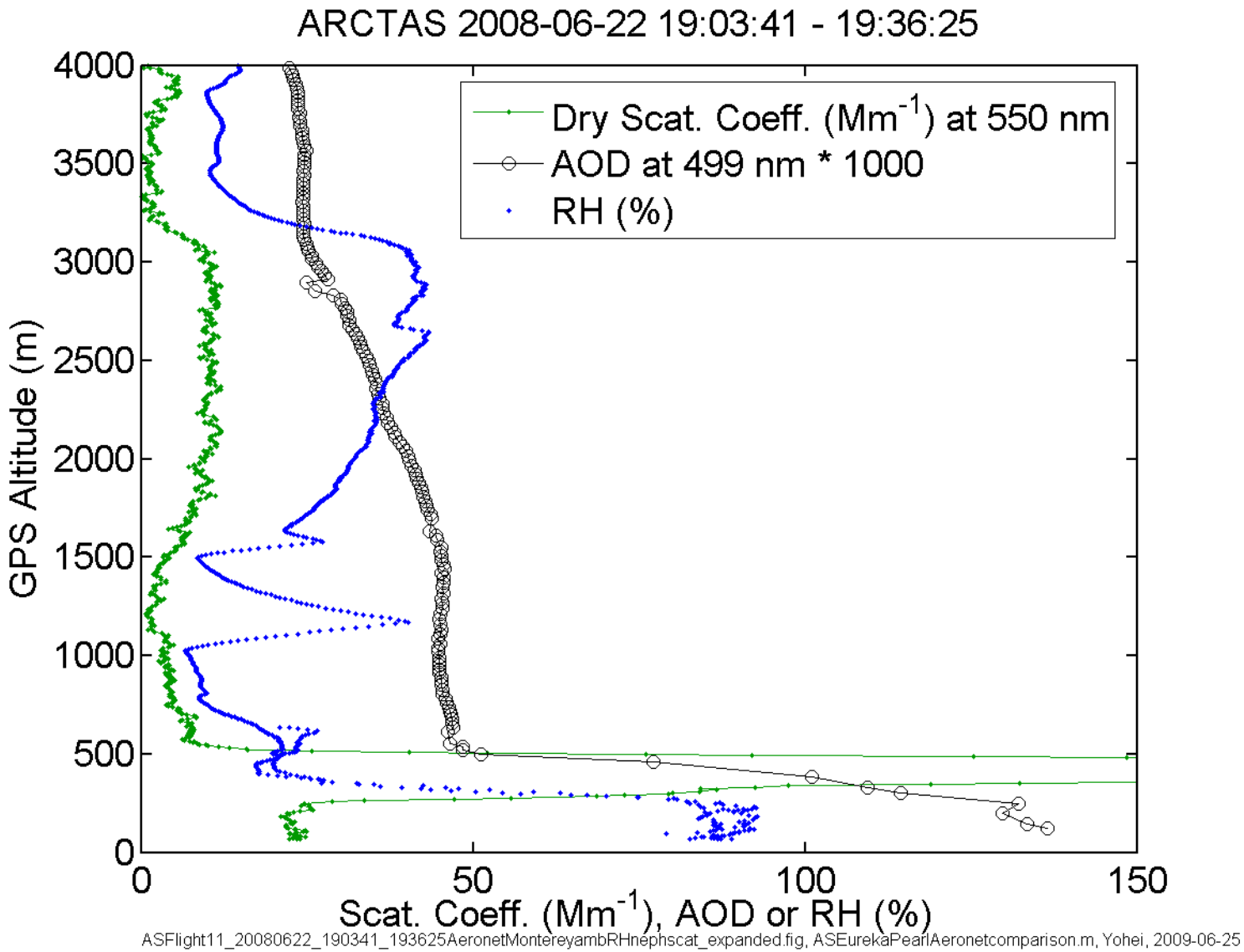
Minor notes:
•Almost perfect agreement at 675 nm makes the AATS marker invisible.
•MODIS uncertainty ±15%±0.05; AERONET unc 0.02 up to 440 nm, 0.01 for the longer wavelengths..



In an example of the complex nature of atmospheric constituents over California, the spiral saw three aerosol layers. They are assumed to be:

- **Asian? 1200 – 3210 m** (Flight note on elevated sulfate)
- **biomass burning plume 250 – 580 m** (Flight note, RH ~20%, Angstrom ~2.3 – fine particles),
- **marine aerosols up to 250 m** (RH ~90%, dry scattering Angstrom ~1.2 low value consistent with sea-salt),

AEROSOL TYPES TO BE VERIFIED.



P-3 California Flights

in ARCTAS Summer

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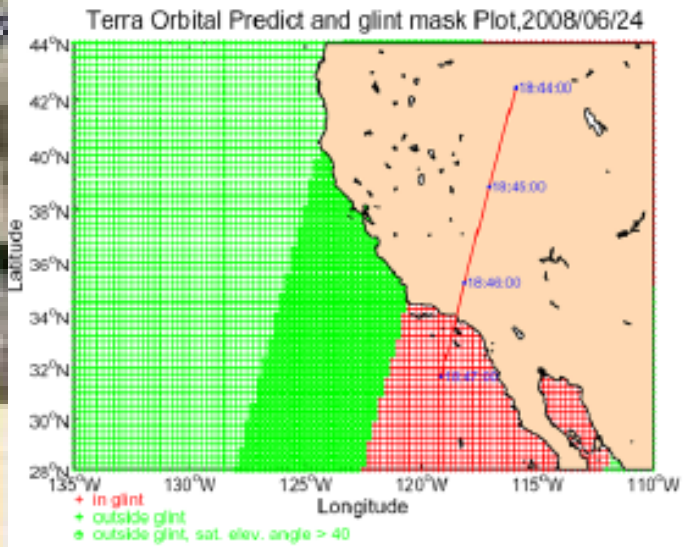
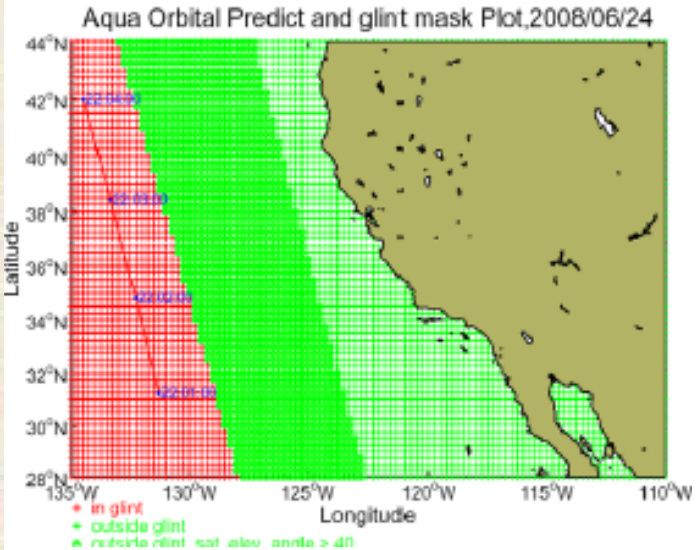
http://www.espo.nasa.gov/arctas/flightDocs.php

P-3B Data Flight #12, 24 Jun 2008

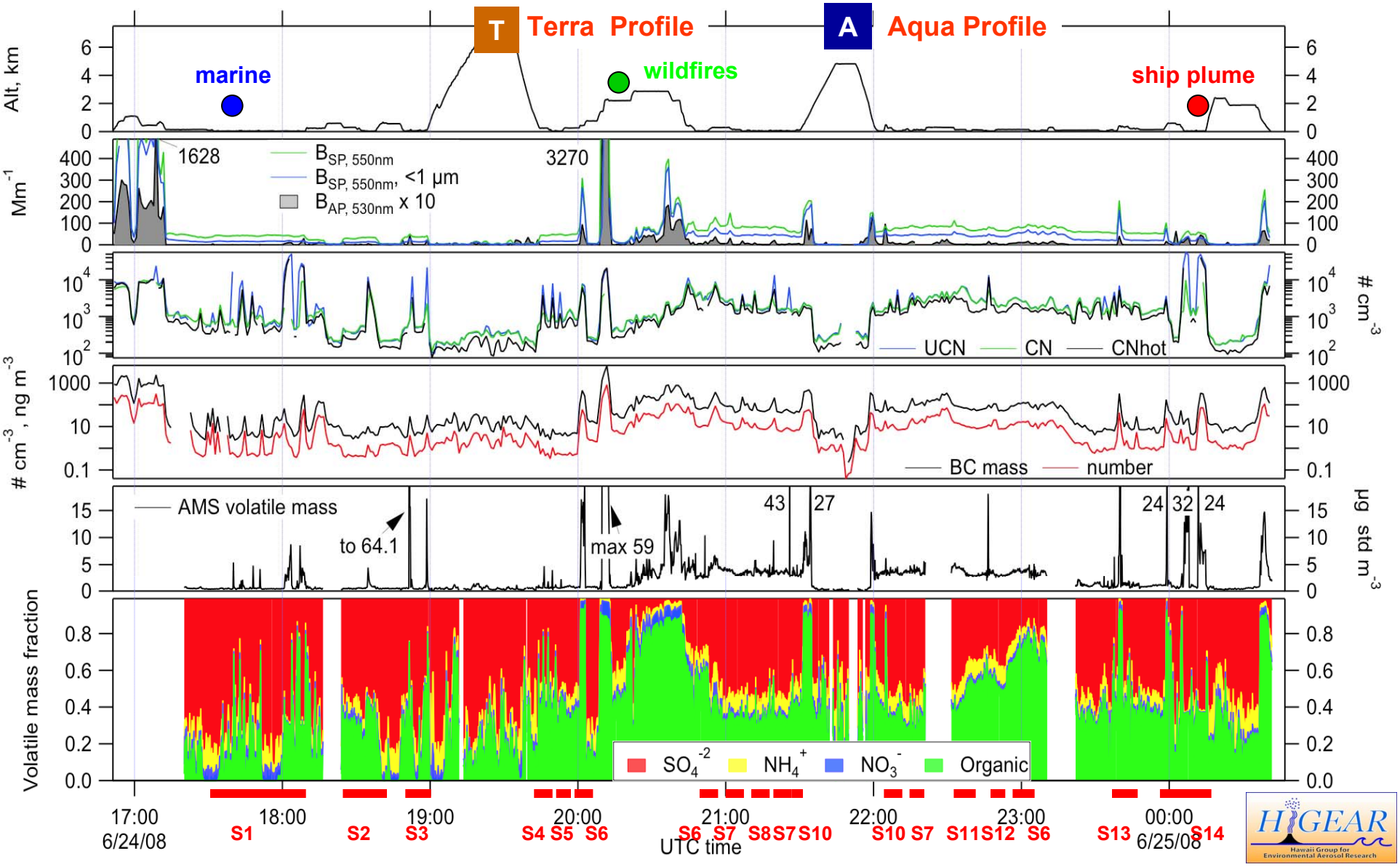




CARB P-3B Flight 12 – June 24th, 2008

See Clarke et al. Poster

Vertical profiles under TERRA and AQUA satellites. During the flight the HiGEAR system sampled three distinct plume types: **marine aerosol**, **California wildfires** and **ship plumes**. Each plume has unique combination of aerosol optical (scattering, absorption), microphysical (refractory:total CN) and chemical (SO_4:Org:BC) properties.



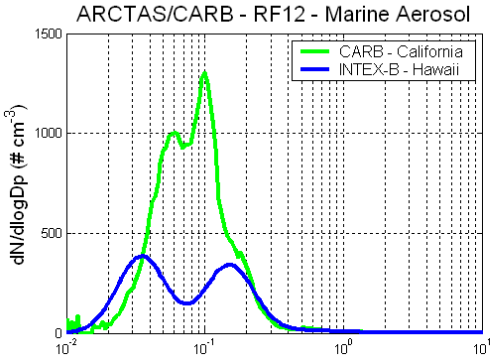
HIGEAR Hawaii Group for Environmental Aerosol Research

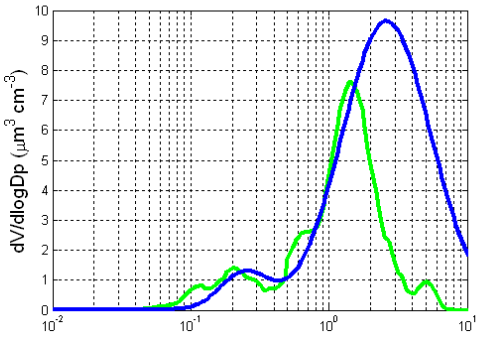
(Clarke, Howell, McNaughton, …)

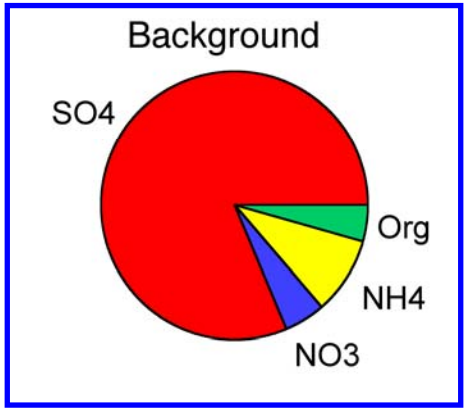
Aerosol Number

Aerosol Volume

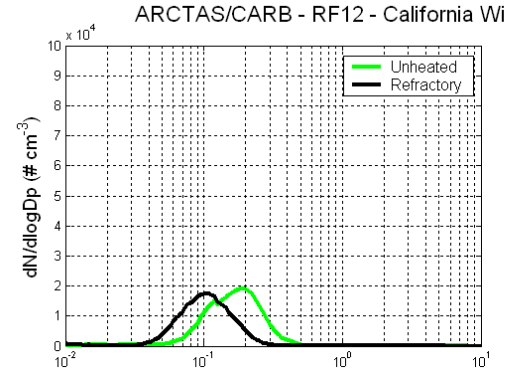
Composition

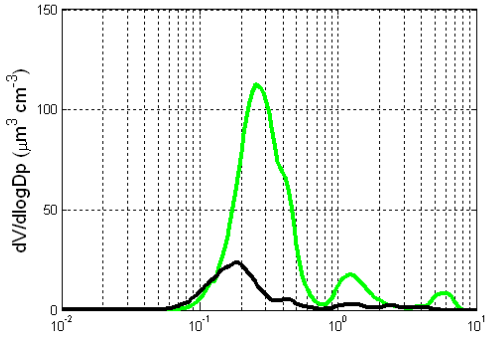


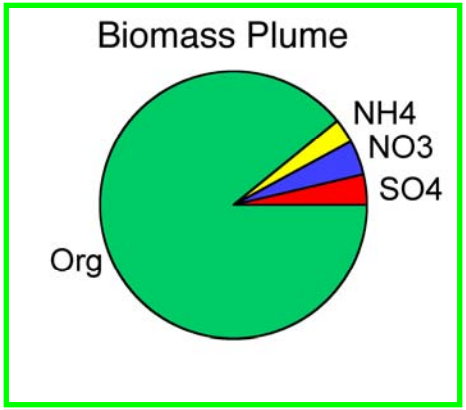




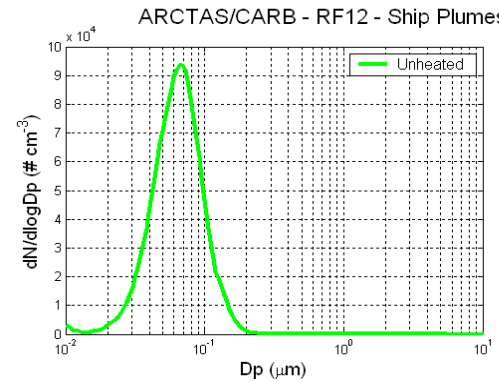
Clean marine aerosol dominated by supermicrometer seasalt and submicrometer sulfate.

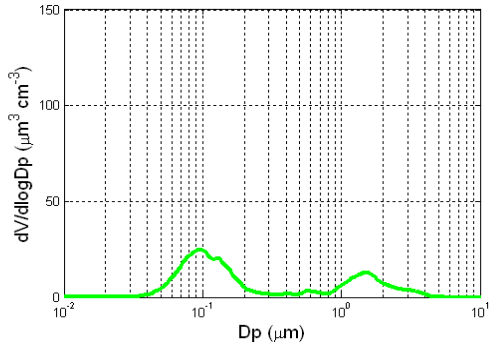


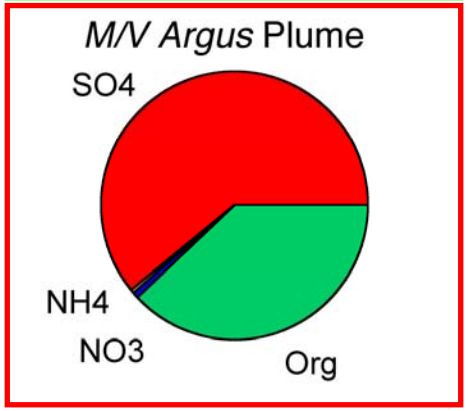




Emissions from the California wildfires are dominated by organic aerosol and have relatively large mean diameters.

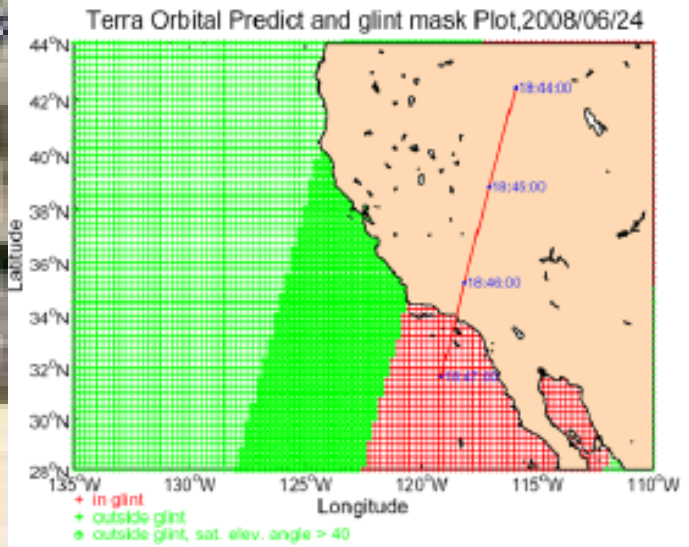


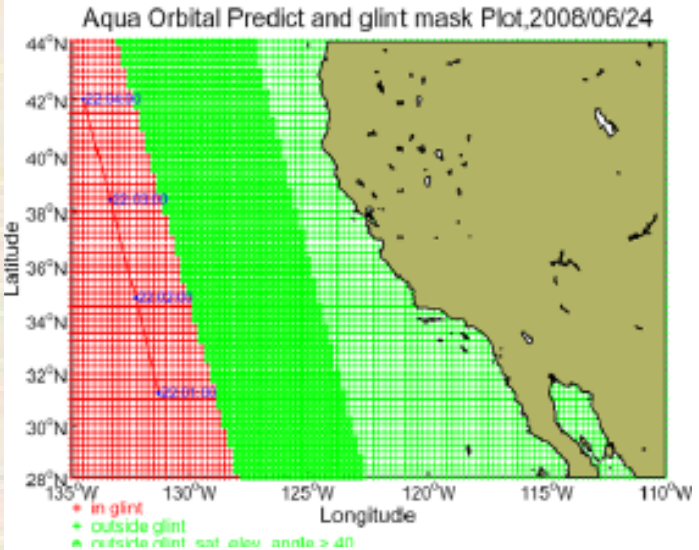




Fresh emissions from ships have high number ~10^5 cm^{-3}, but smaller mean diameters. Numbers tend to decrease, while diameter increases as the plumes age

P-3B Data Flight #12, 24 Jun 2008



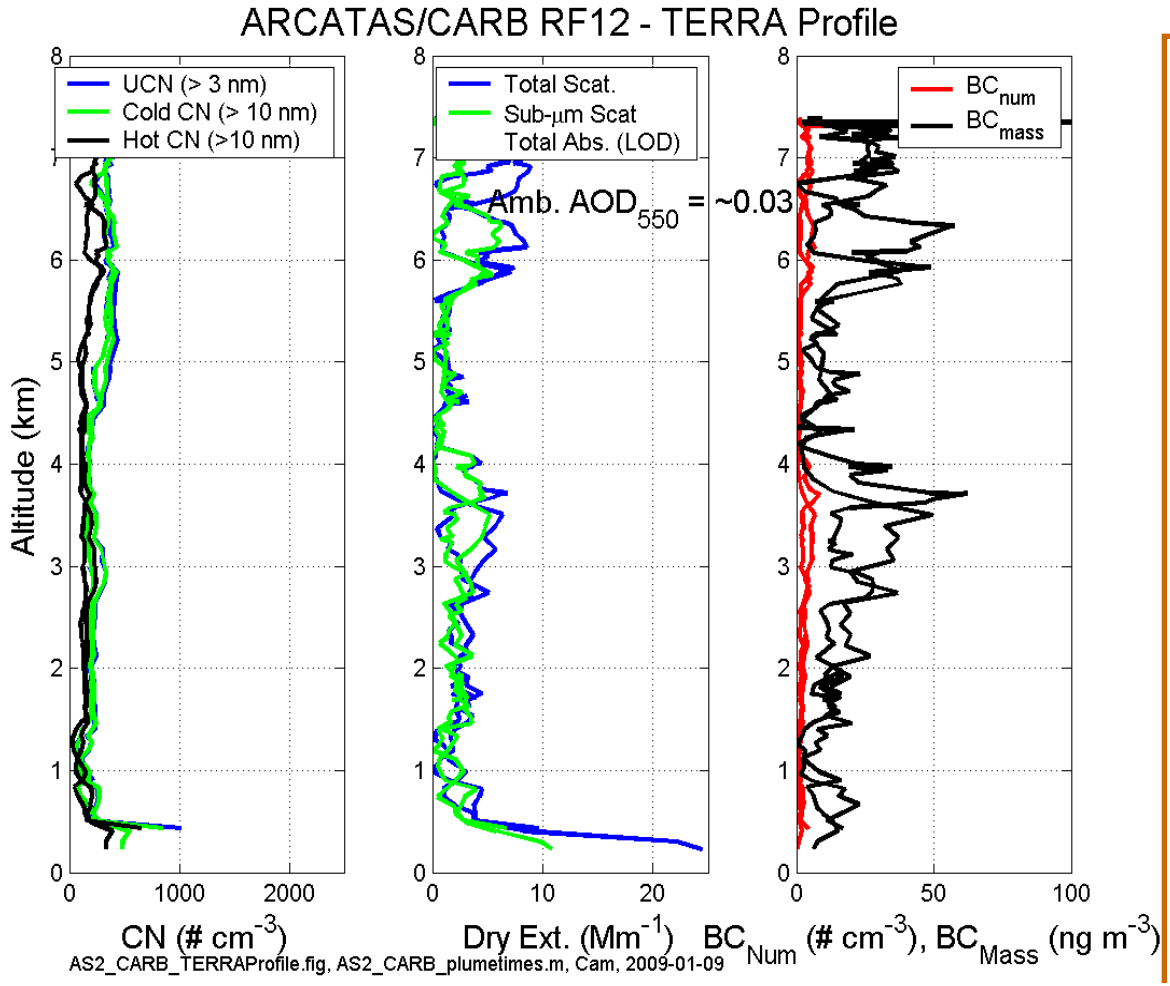


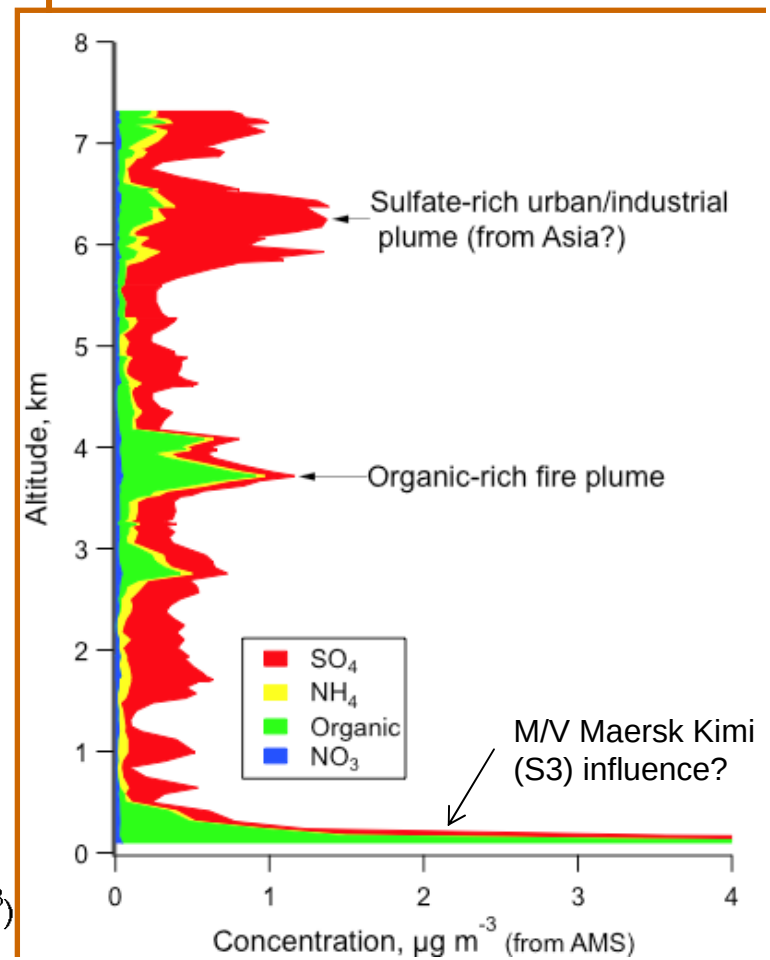
Terra was in clean offshore air with AOD aloft dominated by scattering. Absorption by BC indicates long range pollution transport. Enhanced sea-salt scattering is evident below 500m.

HiGEAR
Hawaii Group for Environmental Aerosol Research

Terra Profile AOD

HiGEAR AOD_550 = 0.03



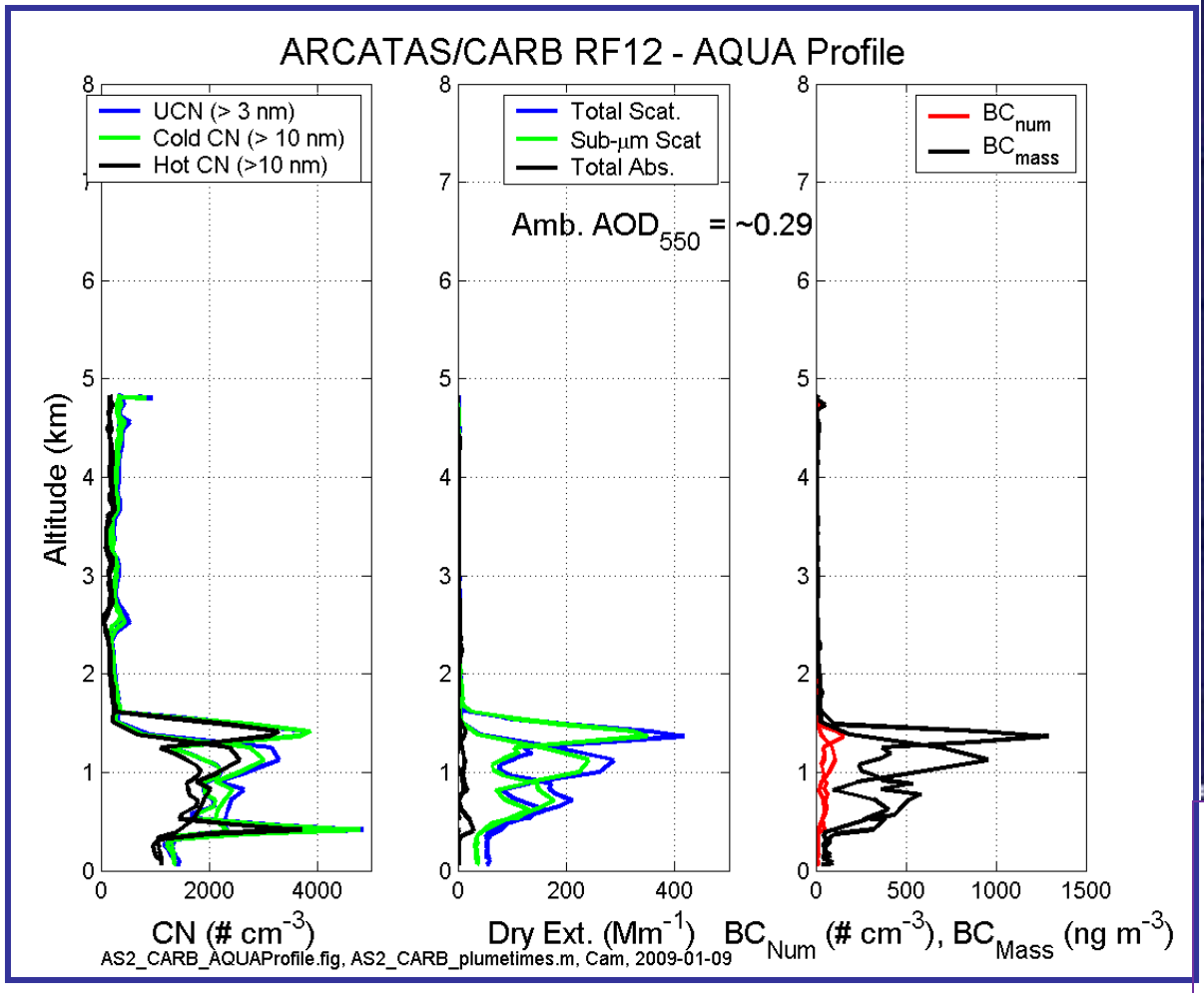


Aqua was at the southern end of flight with enhanced aerosol below 1.5km dominated by biomass burning from California wildfires. Note less pollution near surface.

AQUA differential AOD below 5km

HiGEAR AOD_550 = 0.29

AATS14 AOD_550 = 0.31*



*Redemann, Livingston, Shinozuka, …

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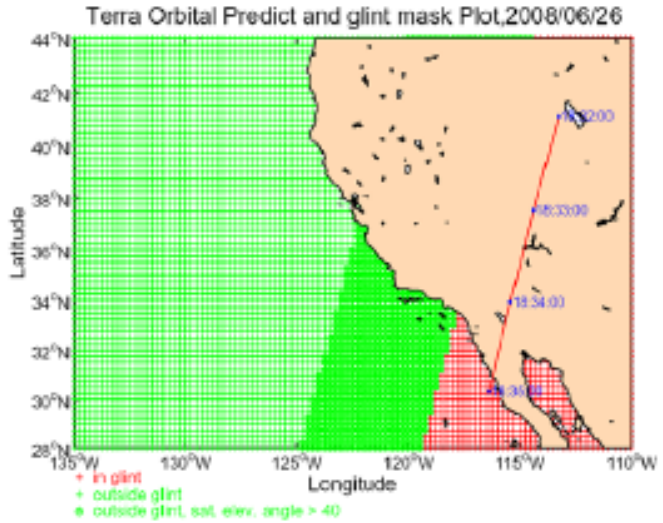
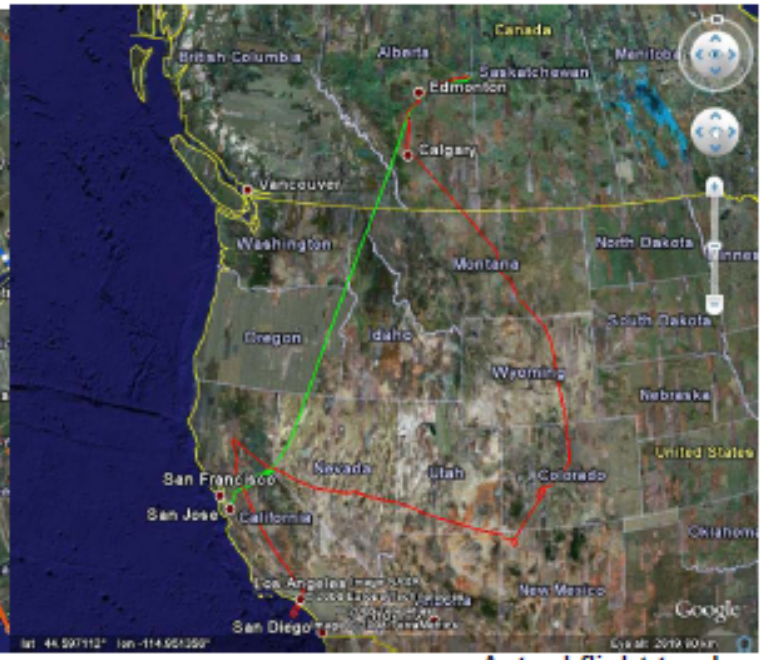
http://www.espo.nasa.gov/arctas/flightDocs.php

Flight Report
ARCTAS P-3B Data Flights 13 & 14, flown 26 Jun 2008 (Transit/Science)
Submitted by Phil Russell

Objectives
1) Transit Ames-Edmonton-Cold Lake
2) Lake Tahoe smoke radiation study in DC-8 lidar curtain
3) Central Valley smoke radiation gradient study
4) Lake Tahoe smoke radiation study under Terra overpass

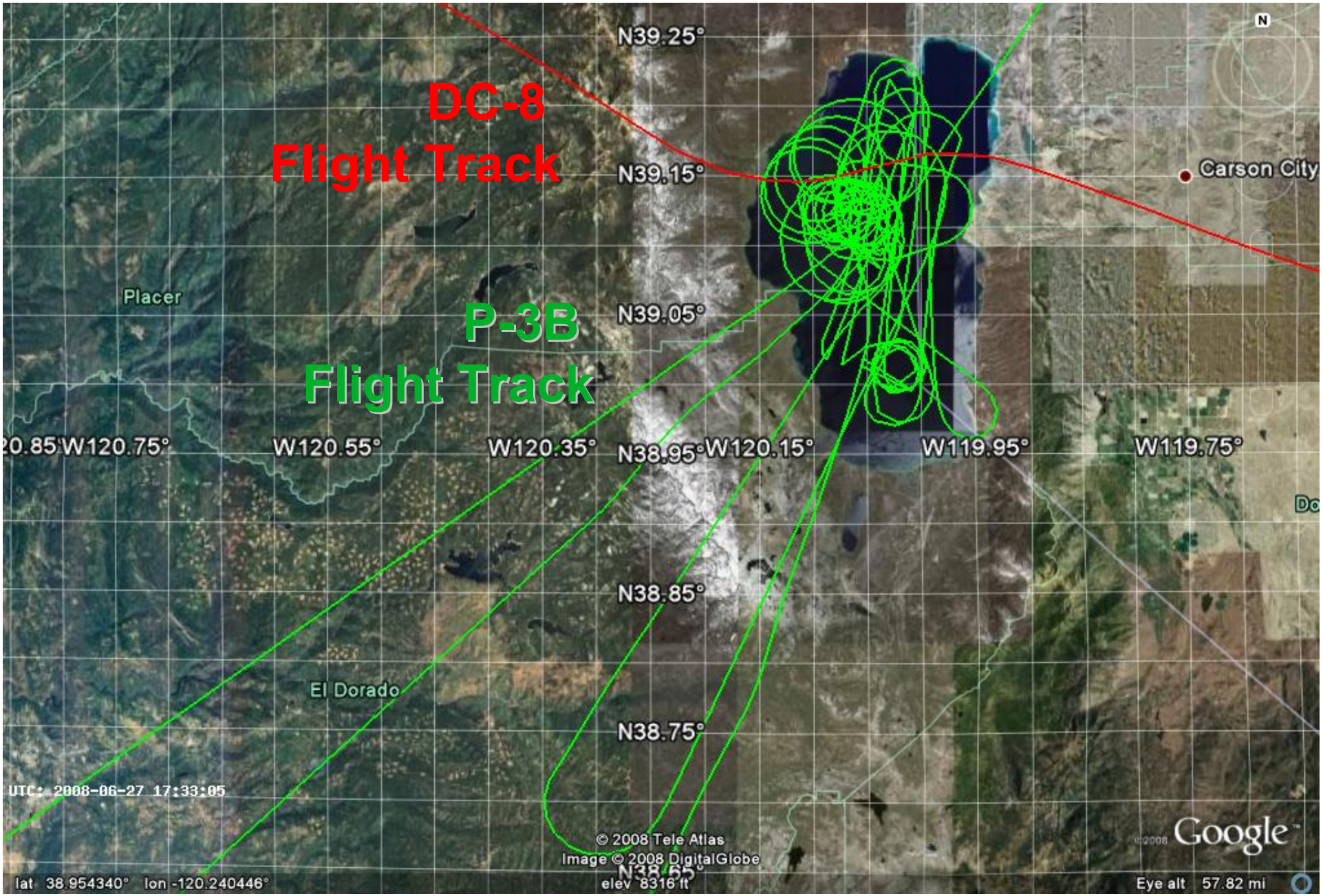


Planned flight track

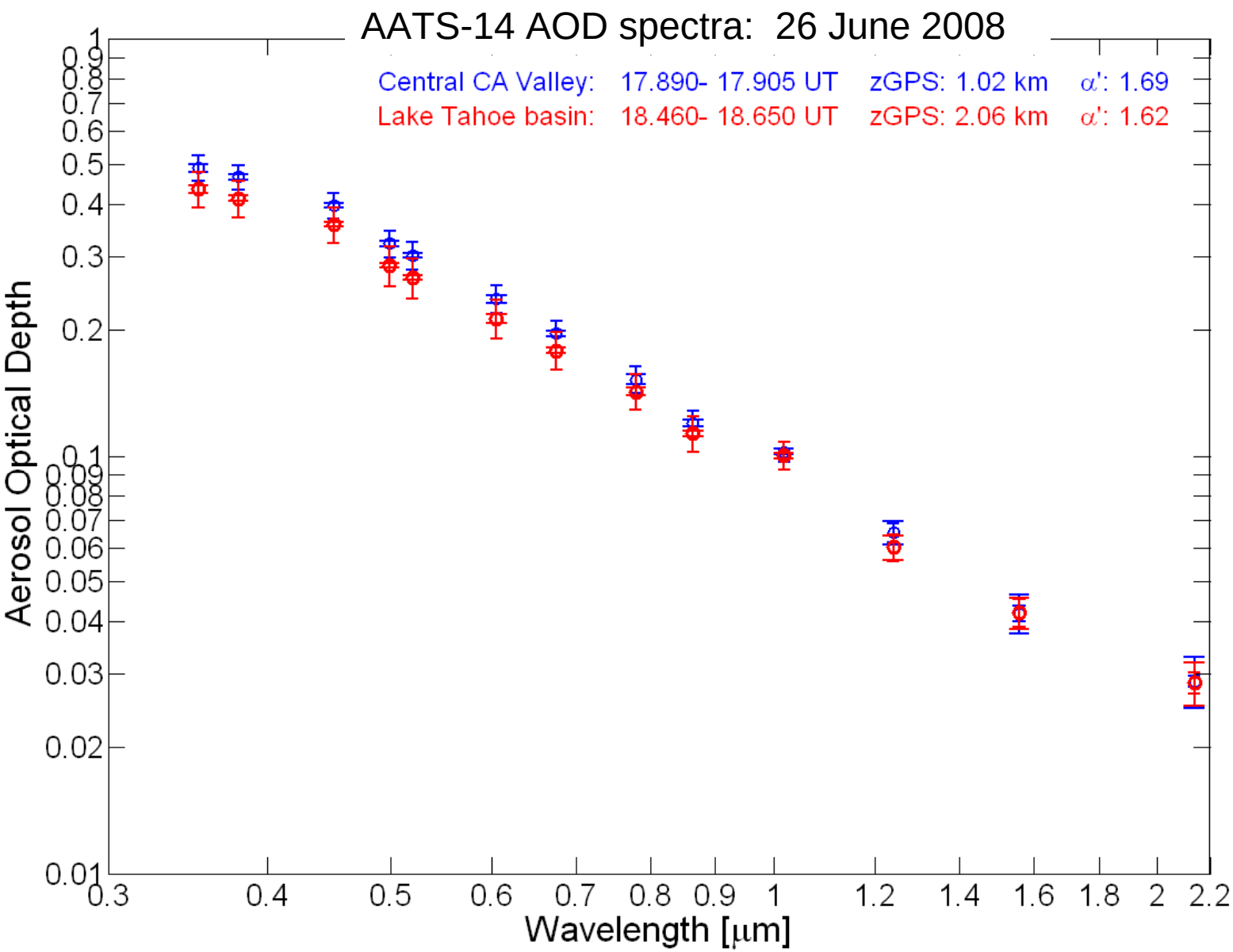


Actual flight track

P-3B Data Flight #13, 26 Jun 2008

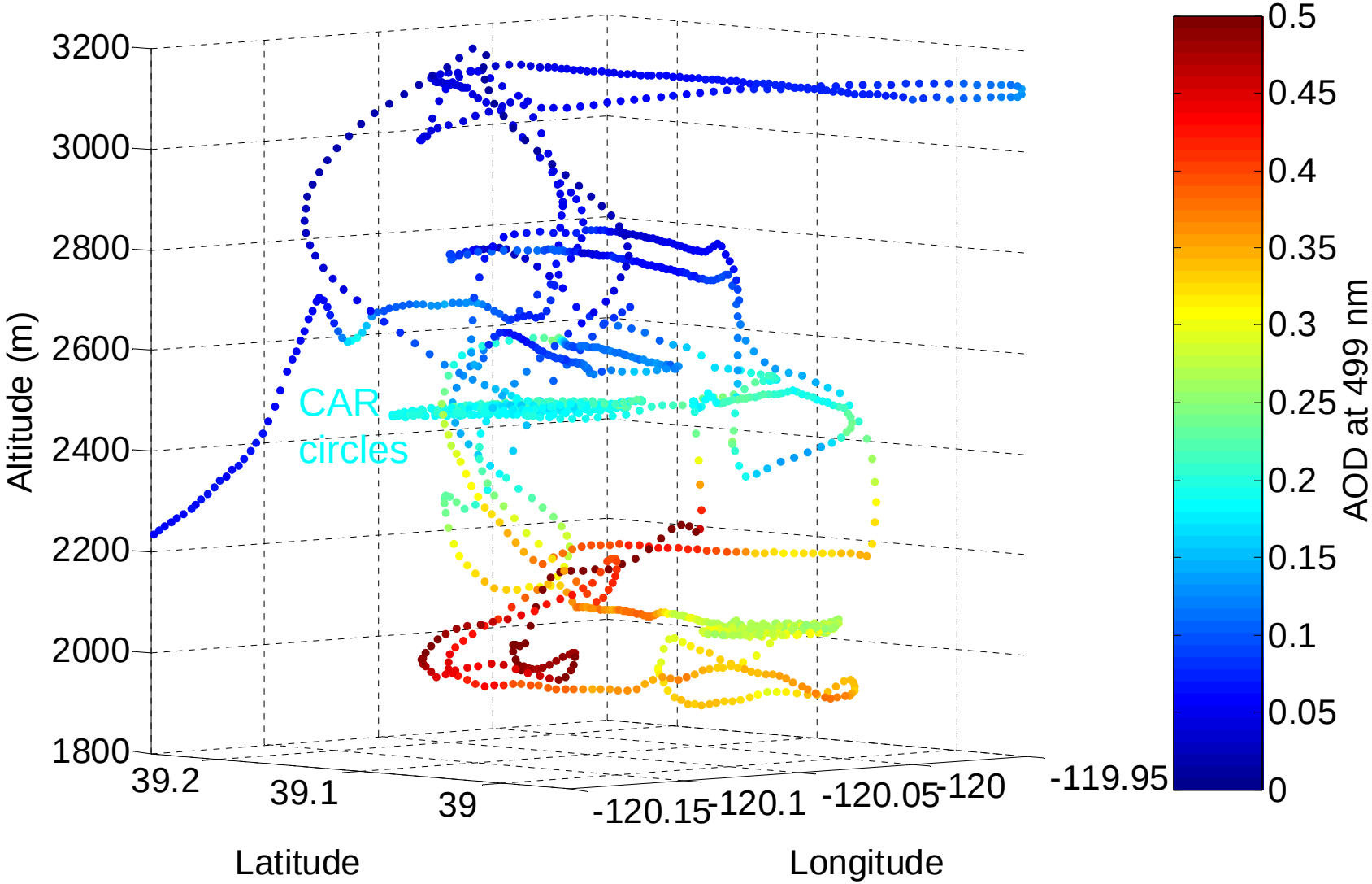


P-3B Data Flight #13, 26 Jun 2008



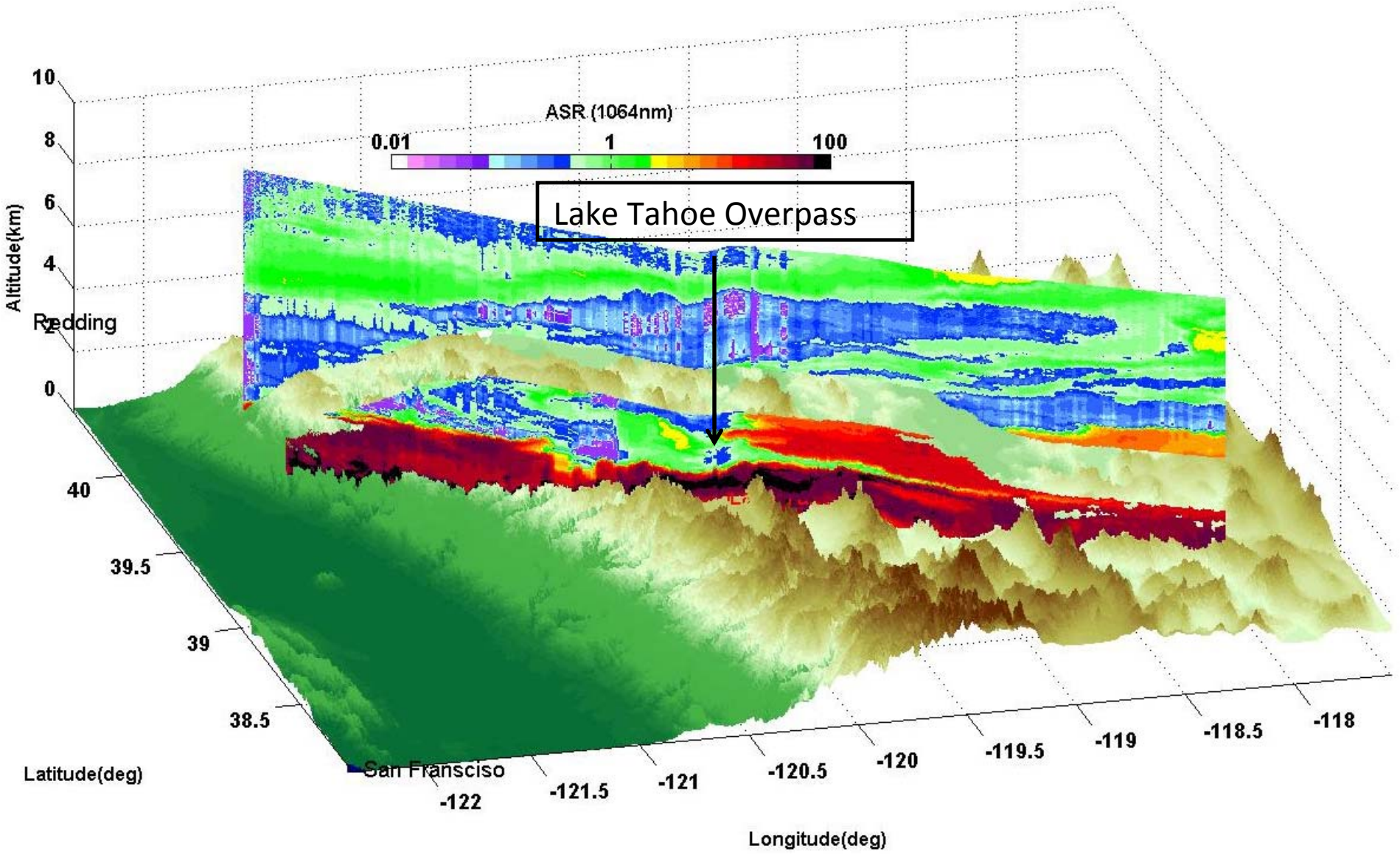
Redemann, Livingston, Shinozuka, …

AATS AOD above Lake Tahoe



Redemann, Livingston, Shinozuka, …

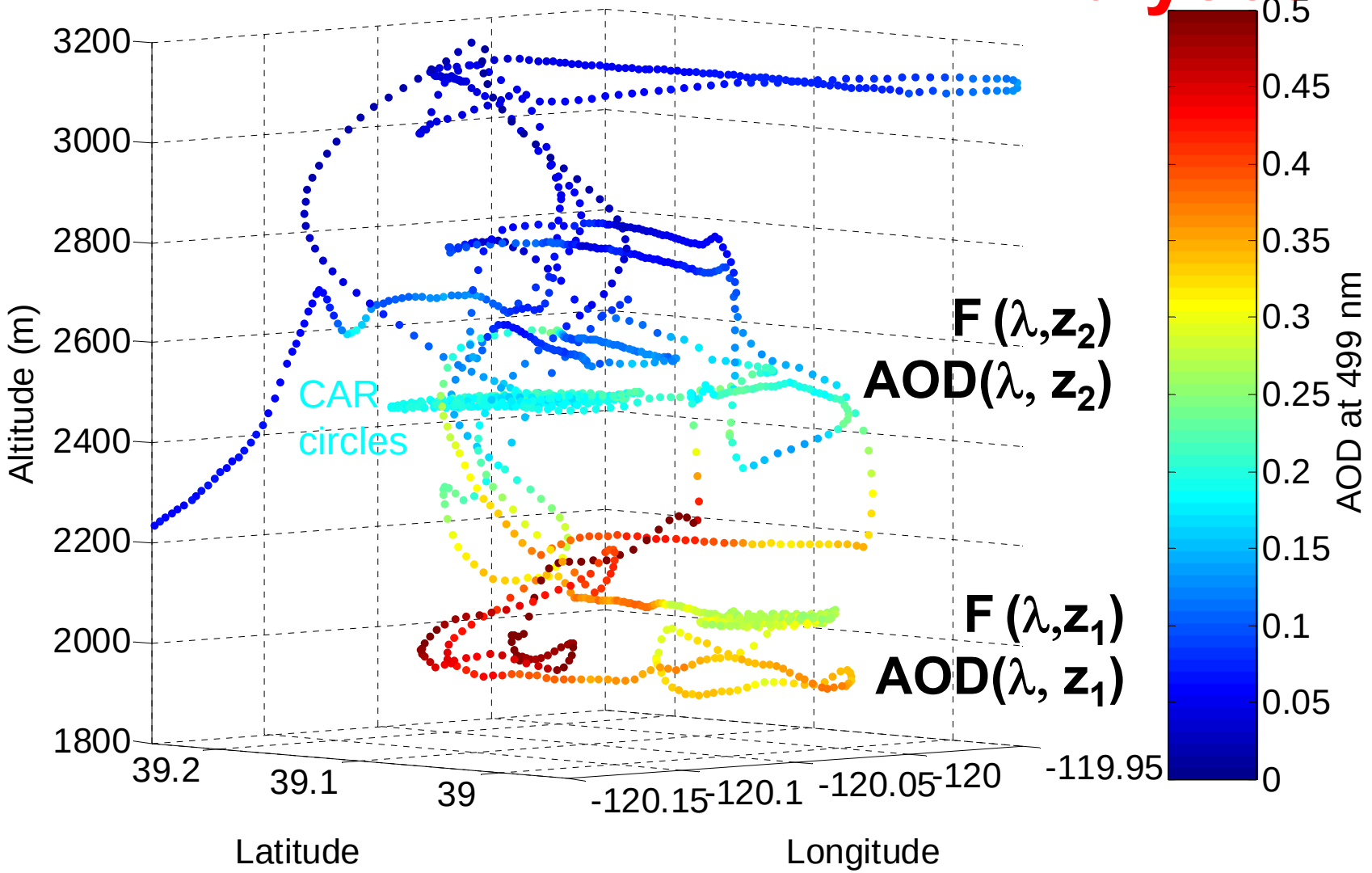
DC-8 Lidar curtain, 26 Jun 2008



[Hair et al.]

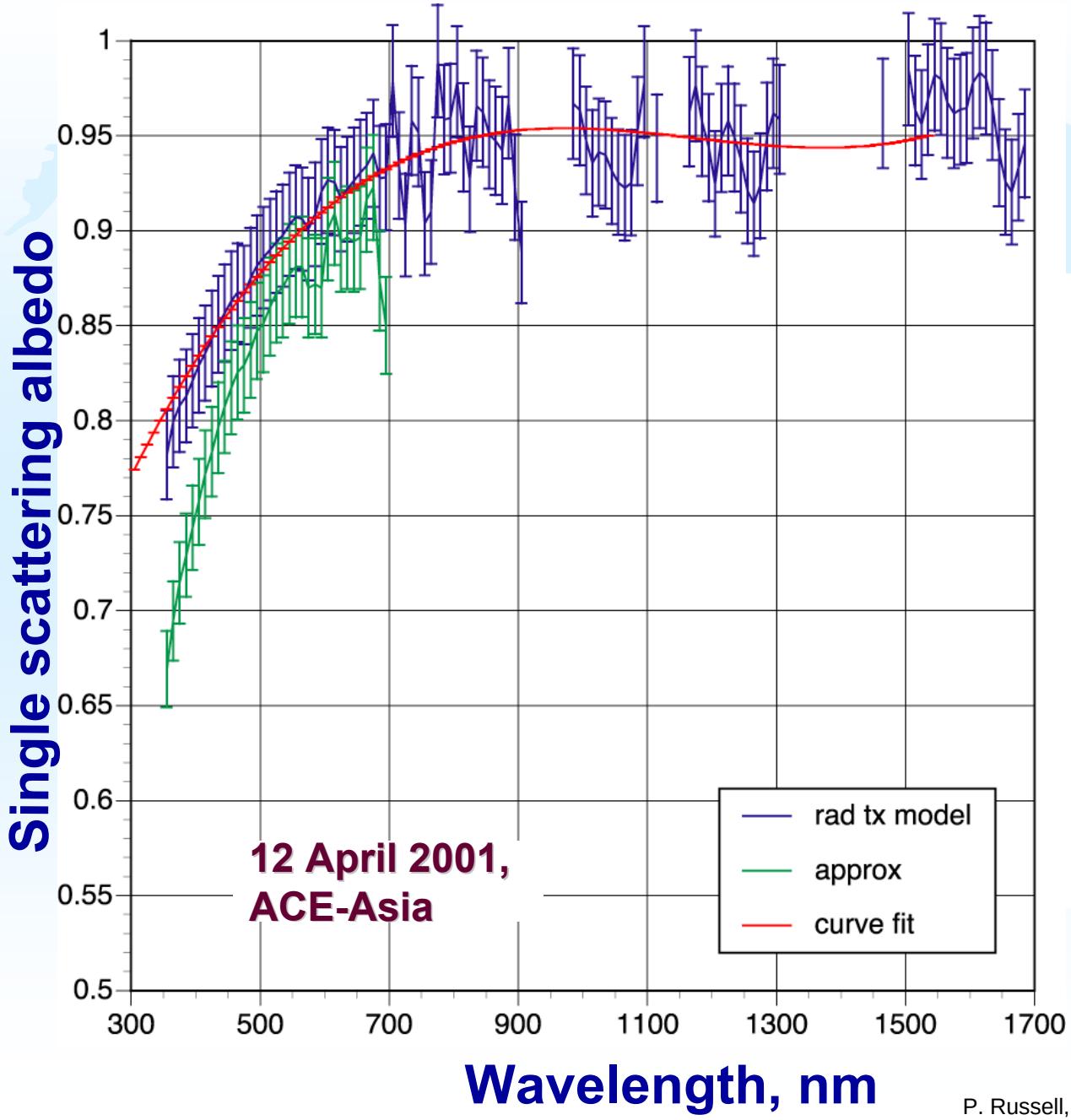
AATS AOD above Lake Tahoe

Potential Analyses…



Redemann, Livingston, Shinozuka, …

Aerosol Single Scattering Albedo Spectrum



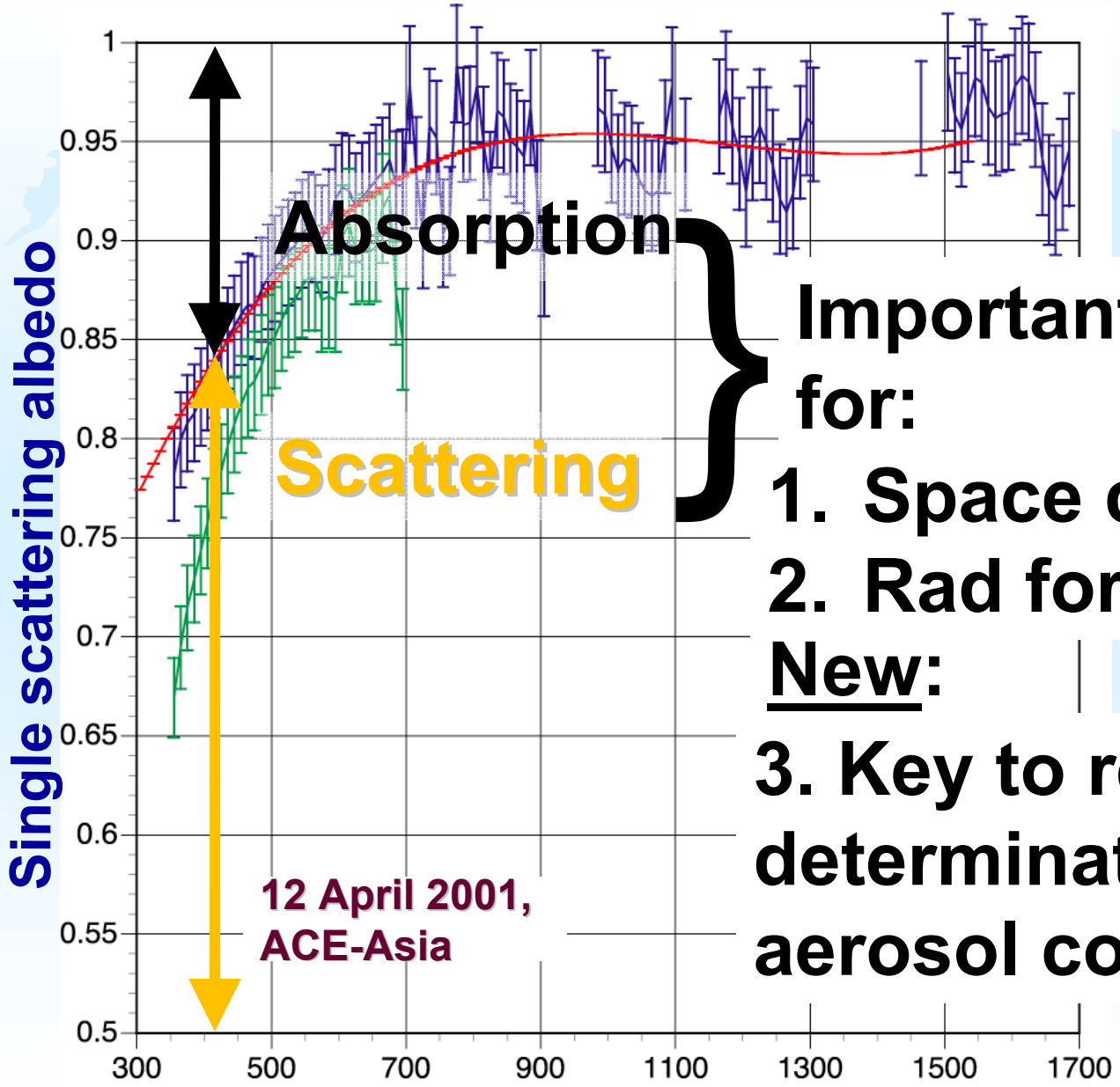
Derived from measured flux and AOD spectra.

Desirable features:

- **Describes aerosol in its ambient state (incl volatiles like water, organics, nitrates)**
- **Wide λ range: UV-Vis-SWIR**
- **Includes λ range of OMI-UV, OMI-MW, MISR, MODIS, CALIPSO, HSRL, Glory ASP, RSP, POLDER, …**
- **Coalbedo (1-SSA) varies by factor 4, λ = 350-900 nm**

[Bergstrom, Pilewskie, Schmid et al., *JGR* 2004]

Aerosol Single Scattering Albedo Spectrum



Derived from measured flux and AOD spectra.

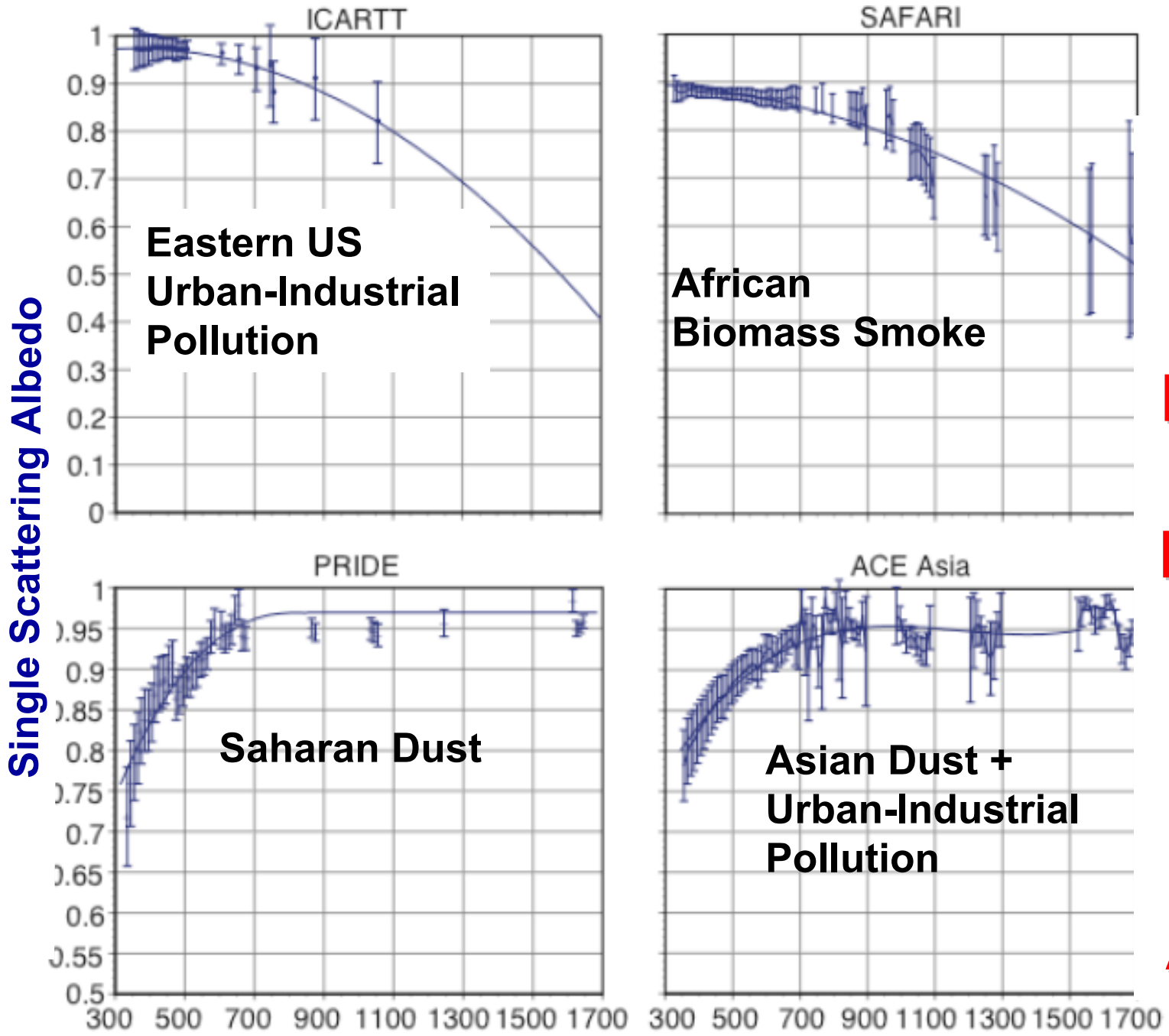
Important for:

1. Space determ of AOD
2. Rad forc of climate

<u>New</u>:

3. Key to remote determination of aerosol composition

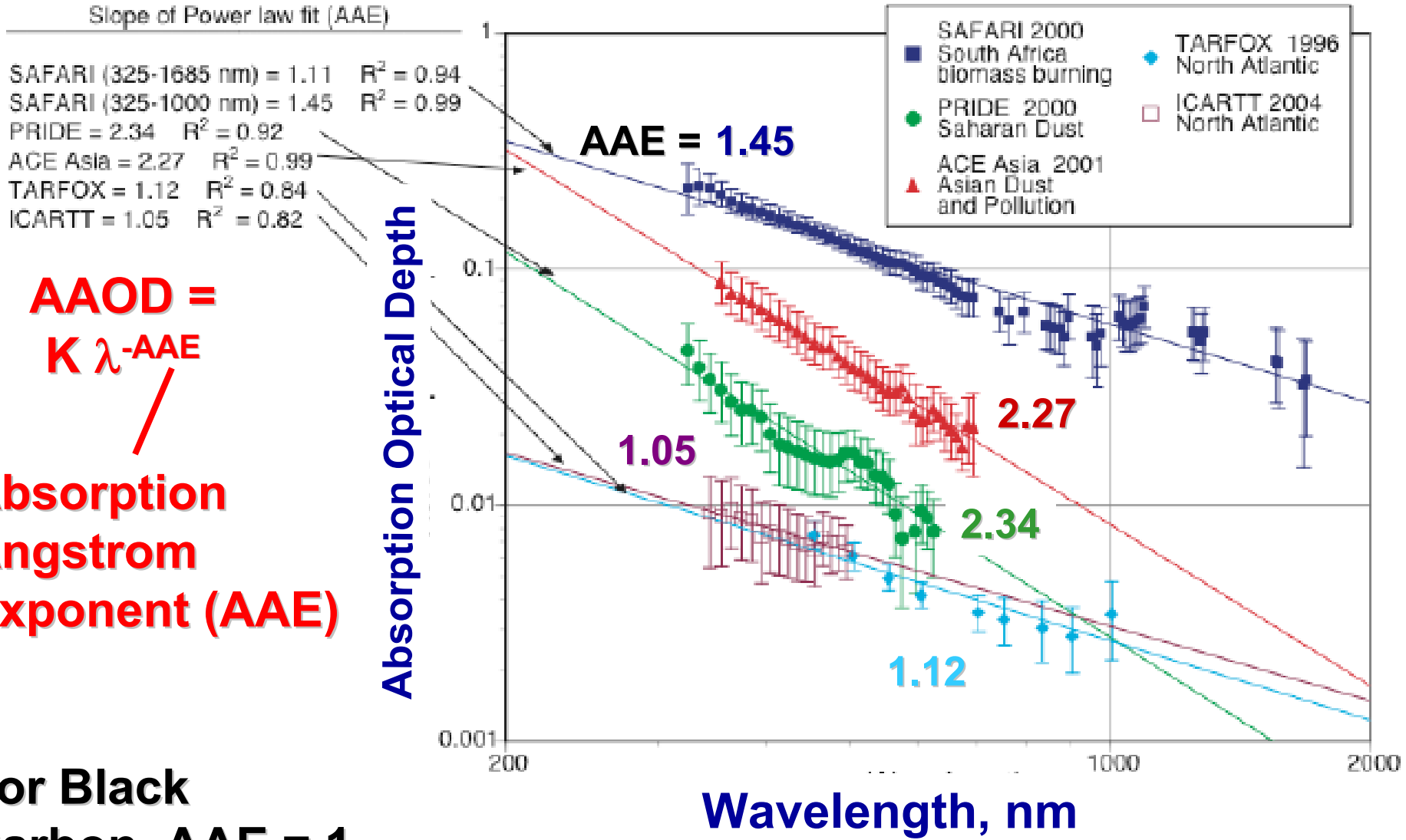
[Bergstrom, Pilewskie, Schmid et al., *JGR* 2004]



SSA Spectra from Expts in 4 Regions of the World Using F(λ) + AOD (λ)

Bergstrom et al., *ACP*, 2007

Aerosol Absorption Optical Depth (AAOD) Spectra from 5 Experiments

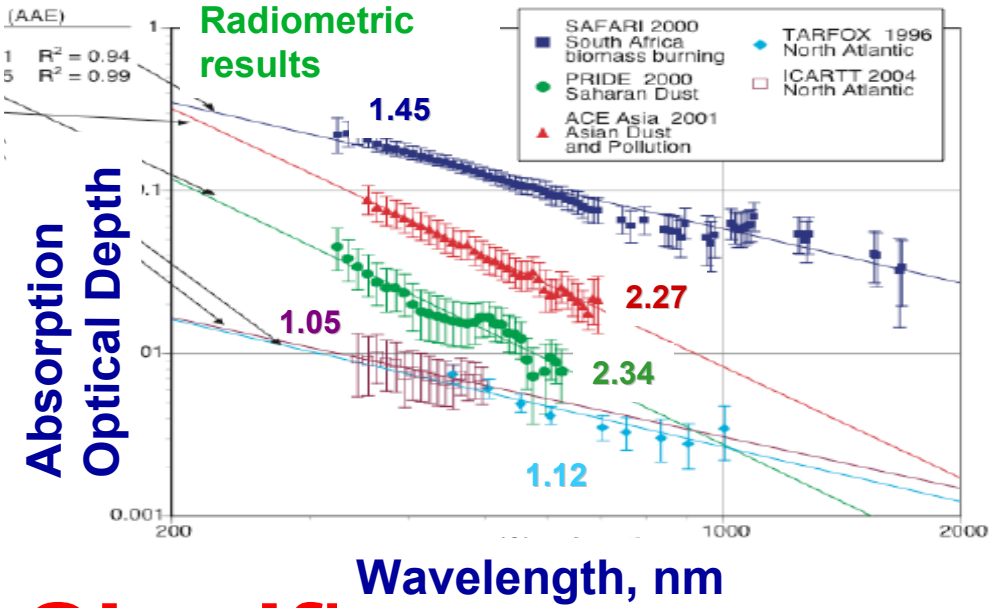


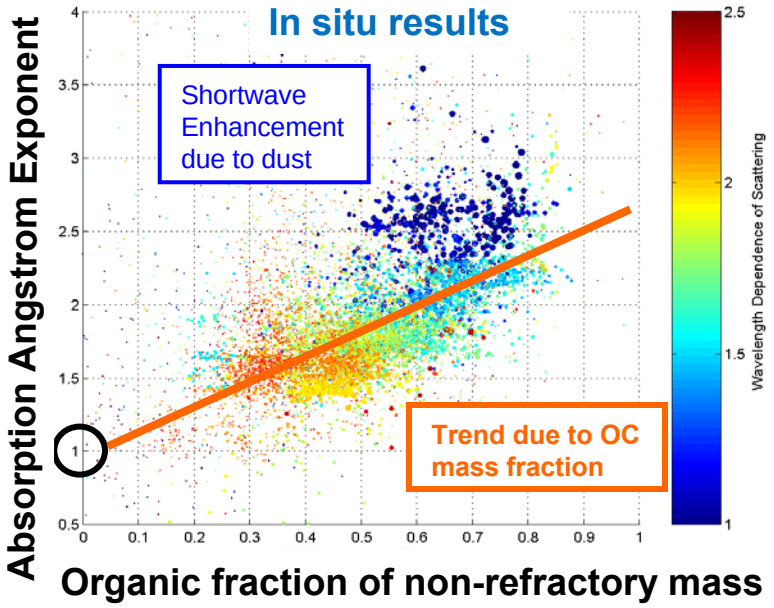
AAOD = K λ^{-AAE}

Absorption Angstrom Exponent (AAE)

For Black Carbon, AAE = 1

Bergstrom et al., *ACP*, 2007



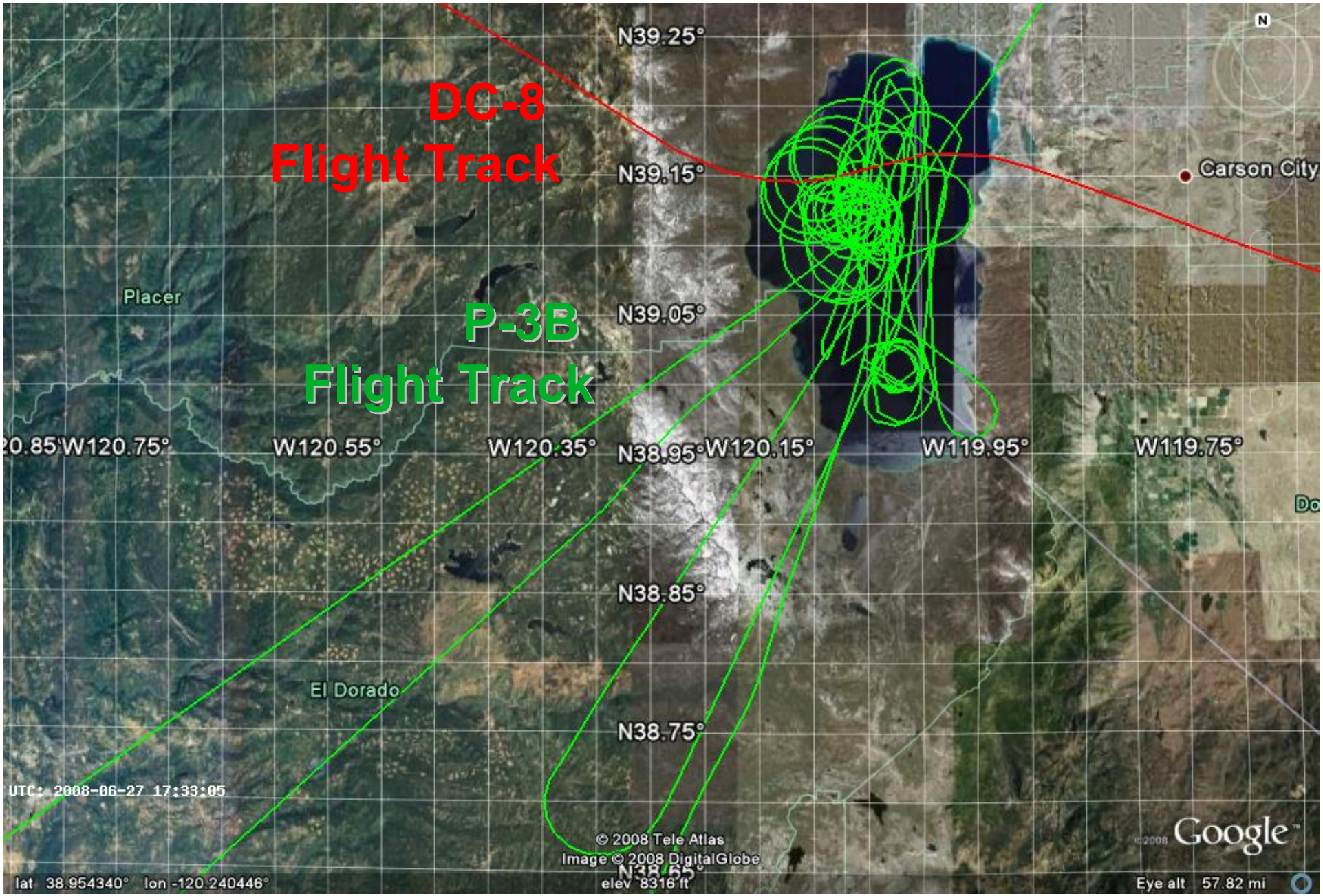


Significance: Both the radiometric and the in situ results indicate that knowledge of Absorption Angstrom Exponent, plus size (or Extinction or Scattering Angstrom Exponent) can be used to determine particle composition.

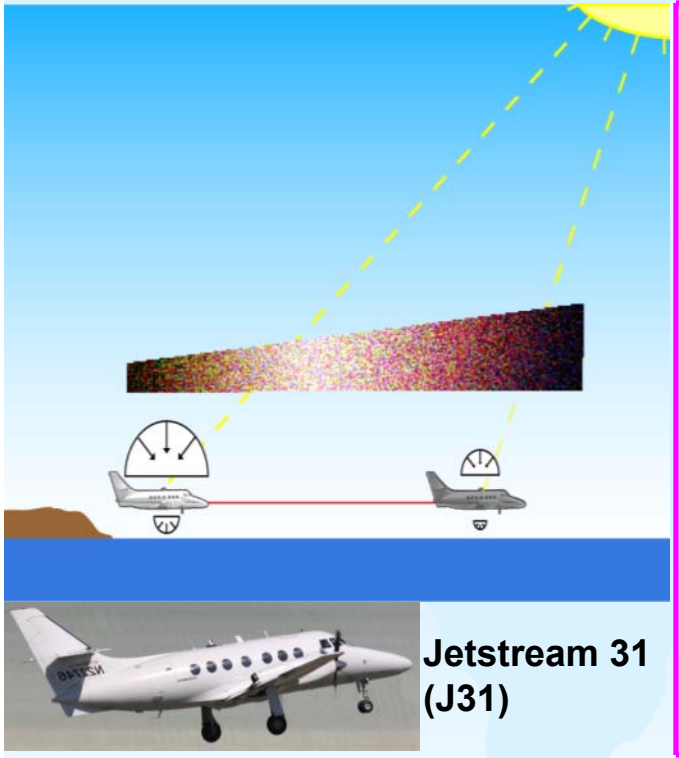
- This holds out the promise of determining aerosol composition from space, provided Absorption Angstrom Exponent can be determined from space.

- A future spacecraft, Glory, promises to do this.

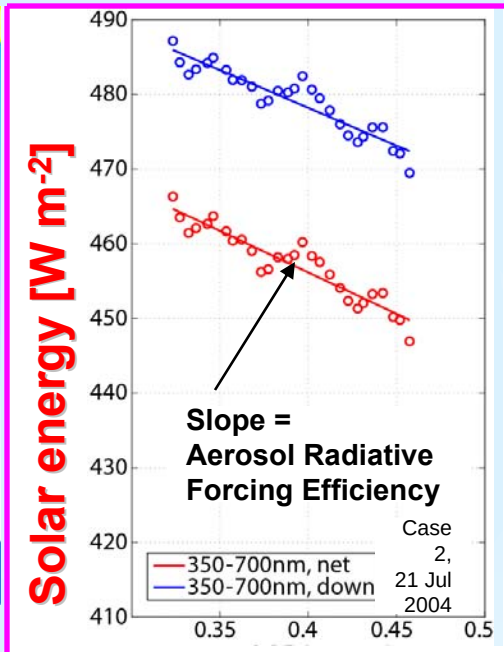
P-3B Data Flight #13, 26 Jun 2008



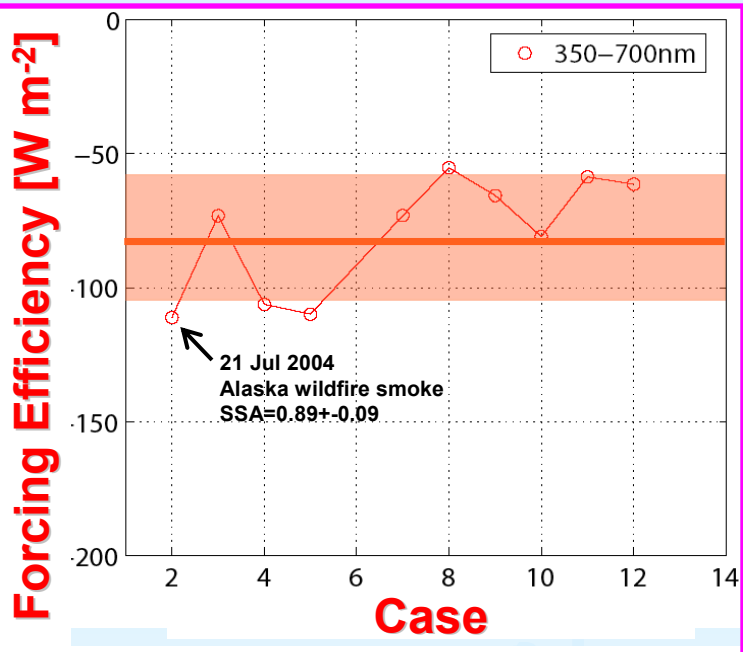
Another analysis example*: Determining aerosol radiative forcing efficiency from horizontal gradients (*from INTEX-A, 2004)



Jetstream 31 (J31)



Aerosol Amount, AOD(499 nm)



Redemann et al., *JGR*, 2006

Scientific Conclusions

1. The gradients (spatial variations) in AOD that occur frequently off the US East coast provide a natural laboratory for studying effects of aerosol particles on solar energy, and hence on climate.
2. For the average aerosol optical depth of ~0.5 in the 10 cases shown above, aerosols on average reduced the incident visible radiation (near midday) by the amount of energy it would take to power one 40 W light bulb for every square meter of ocean surface (0.5 x -80 W m^{-2} = -40 W m^{-2}; see right frame above).

J. Redemann, P. Pilewskie, P. Russell. NASA Ames & U. Colorado

P-3B California flights in ARCTAS-Summer 2008:

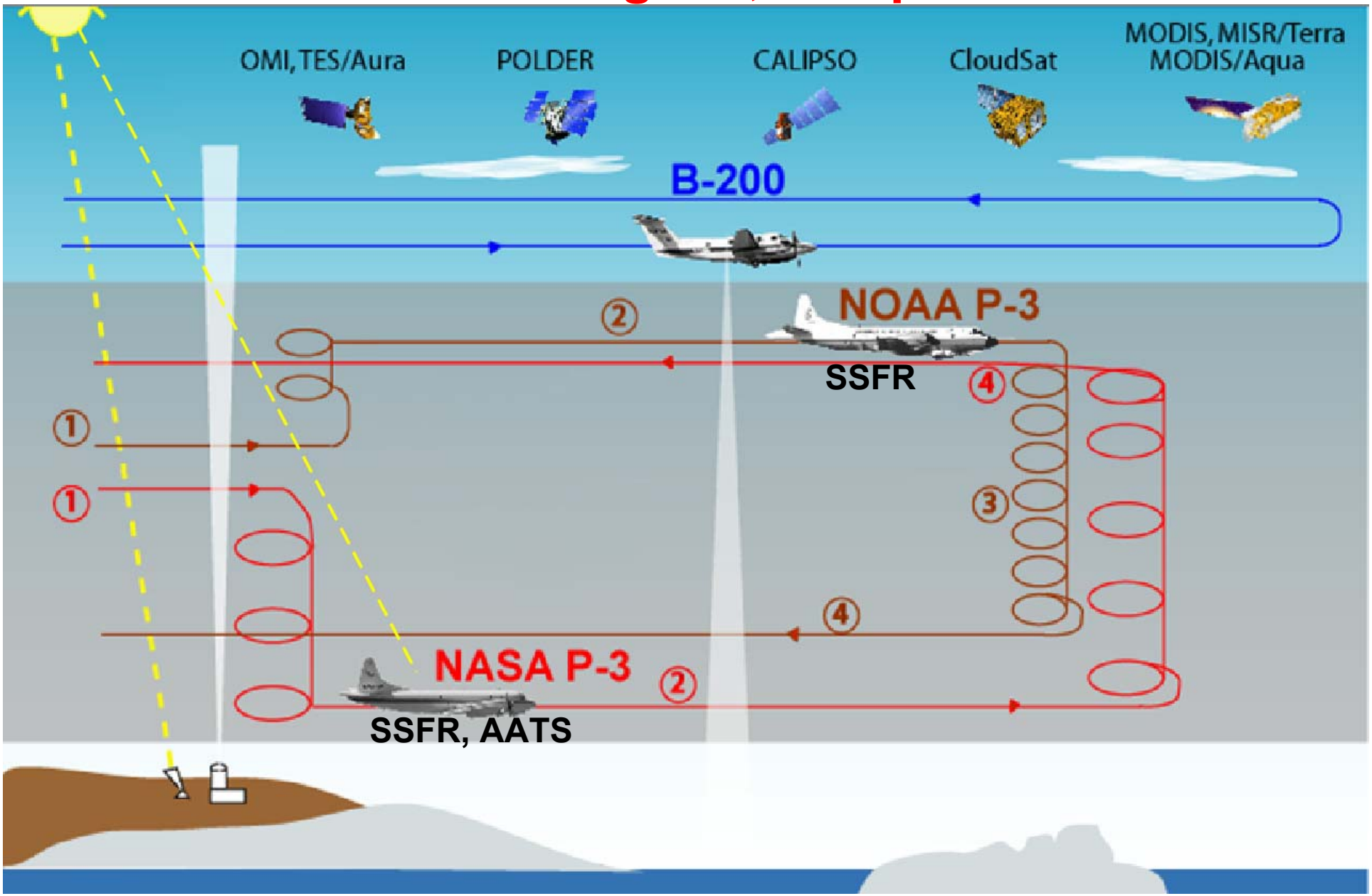
Summary & Conclusions

1. The 3 flights (22, 24, 26 Jun) produced a rich data set that links air, surface, & space measurements and addresses all goals
   - linking variations in atmospheric radiation to microphysics and chemistry of haze & smoke aerosols + surfaces.
   Needed for
   --reliable interpretations of satellite inversions
   --refining model products
   --assessing climate forcing in terms of emissions and/or mitigation strategies.
2. This data set has strong potential for scientific analyses of California aerosols (marine, ship, wildfire, power plant…).
- But ARCTAS analyses to date have focused on Arctic data.
- Reaping the full scientific benefit of the data set will require additional effort, which is currently unfunded.
3. See also Clarke et al. poster

End of Presentation

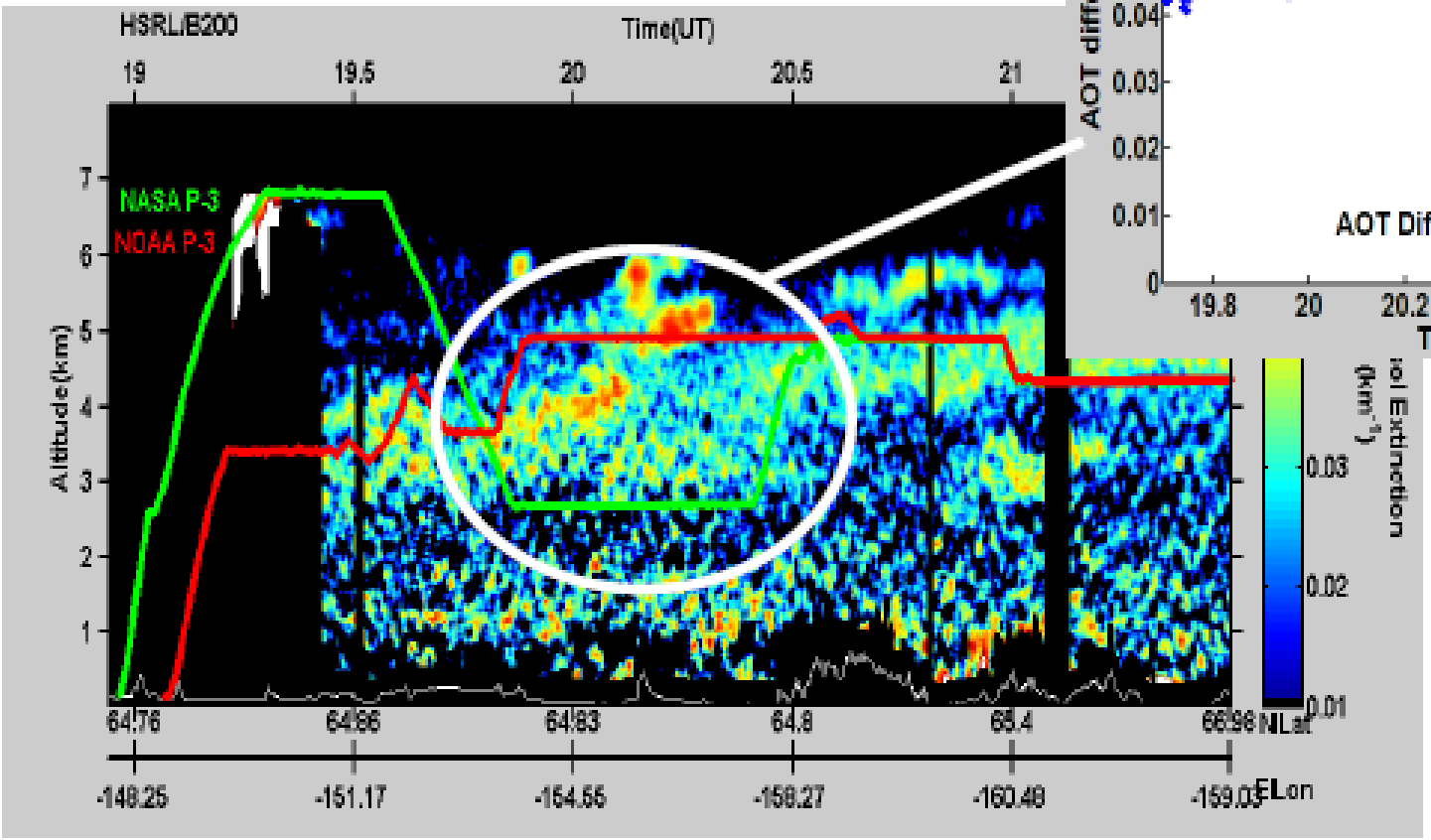
Remaining Slides are Backup

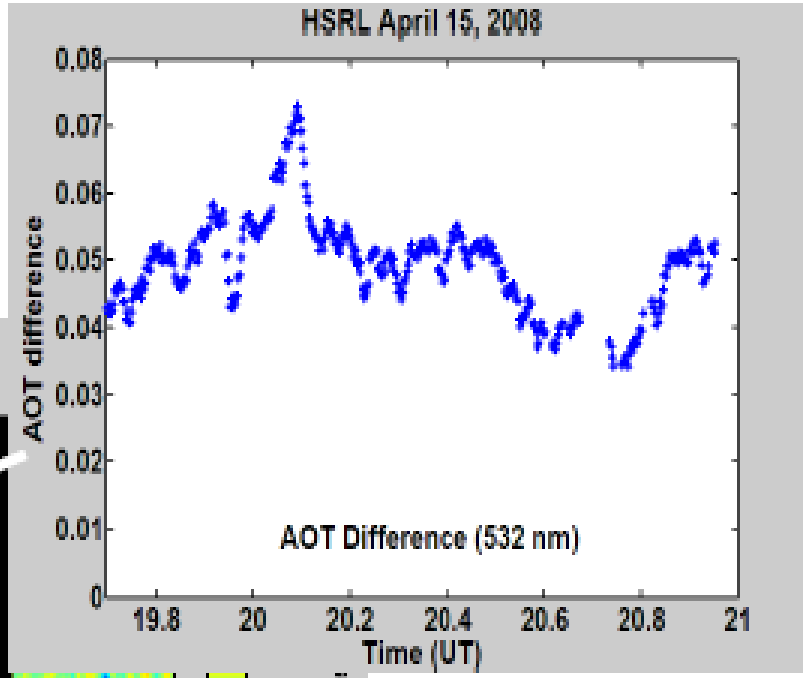
ARCTAS analysis example:
NASA P-3 Flight 9, 15 Apr 2008



20080415 – “Golden Day” (Spring)

Try to derive aerosol forcing efficiency from these radiation measurements...
Enough AOD between flight levels???

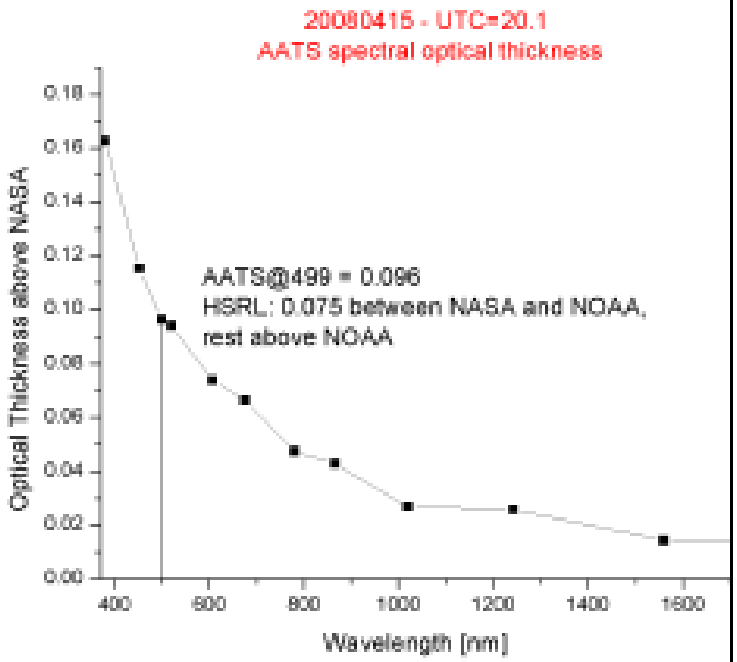




Plots:
Rich Ferrare

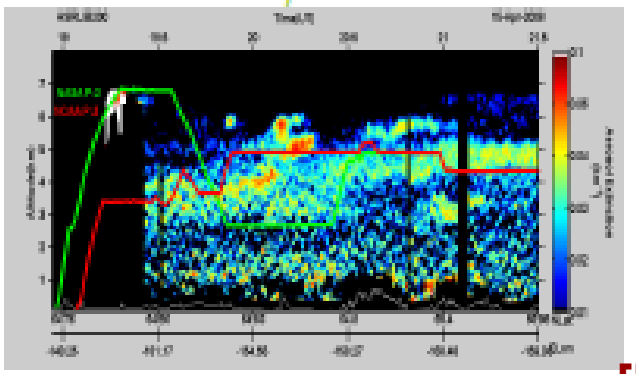
[Bierwirth, Schmidt, Ferrare et al., ARCTAS]

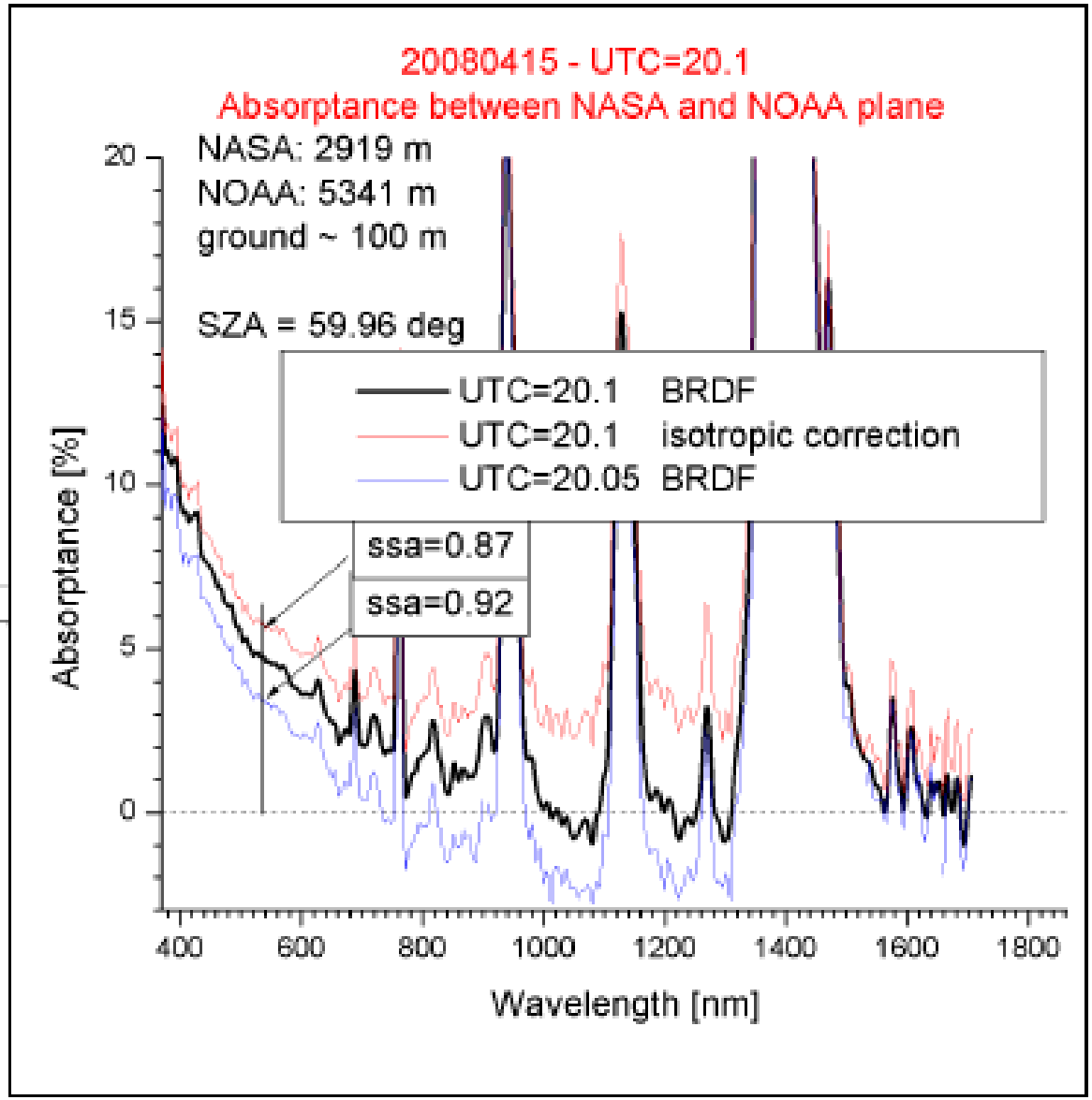
20080415 – “Golden Day” (Spring)



Jens Redemann, AATS-14

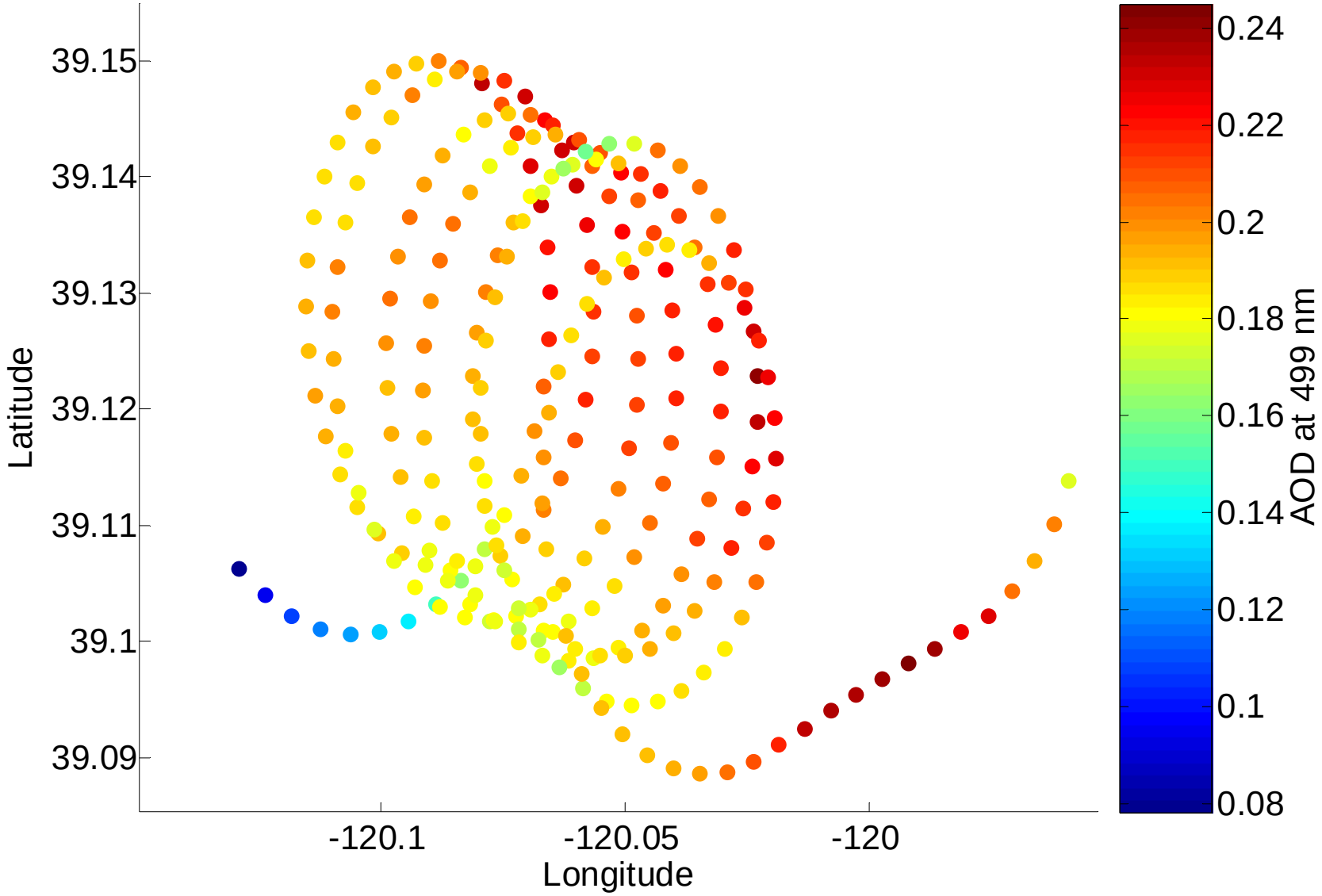
Rich Ferrare, HSRL





[Bierwirth, Schmidt, Redemann, Ferrare et al., ARCTAS]

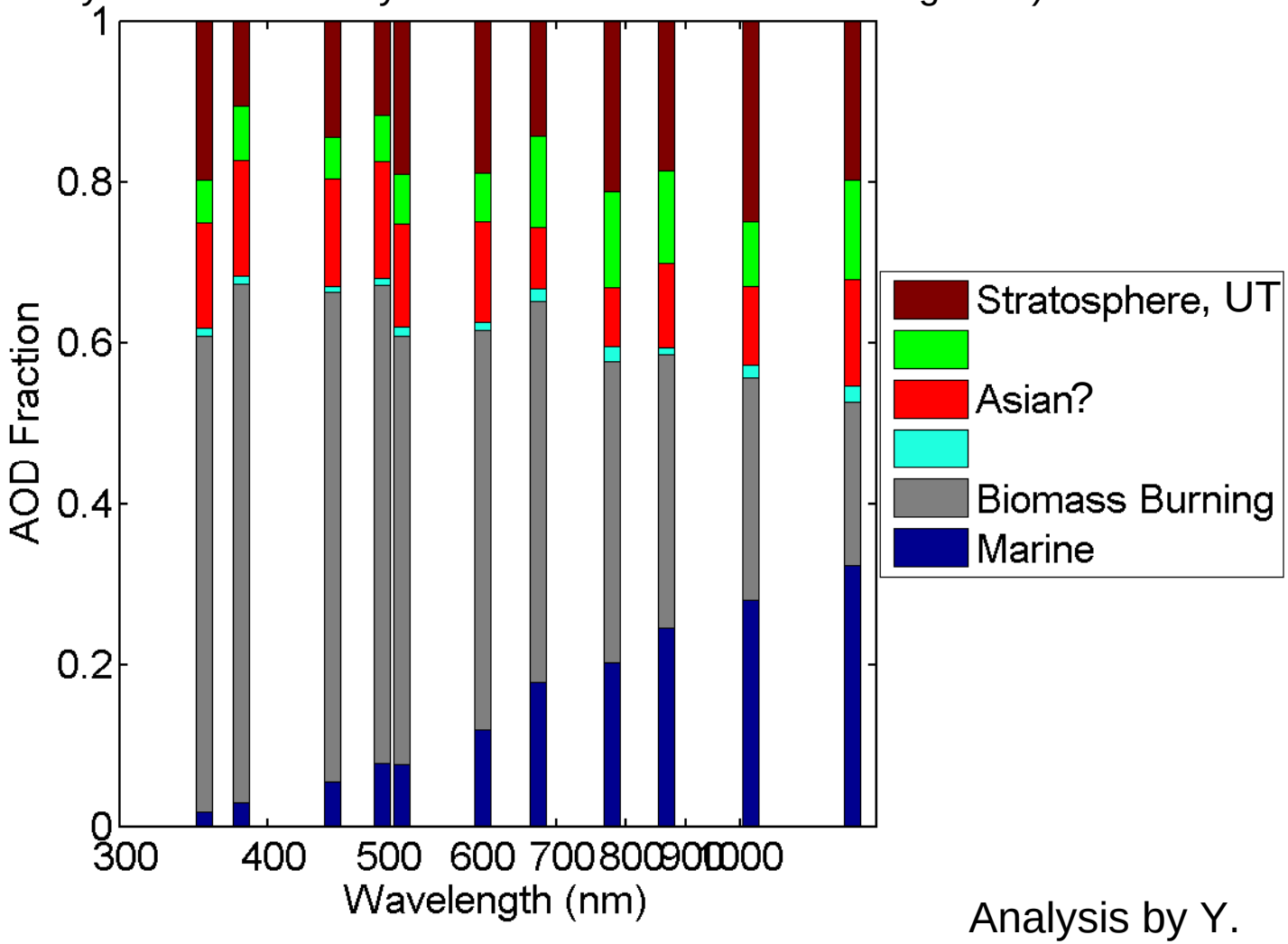
AOD during CAR circles ~600 m above Lake Tahoe



Redemann, Livingston, Shinozuka, …

Another presentation of the vertical structure, this time with AOD fraction. Biomass burning particles dominate shortwave AOD, but are comparable to marine aerosols near infrared.

(AATS-14's last 2 channels are omitted because the AODs at mid-troposphere are nearly constant as if layer AODs were zero or even negative.)

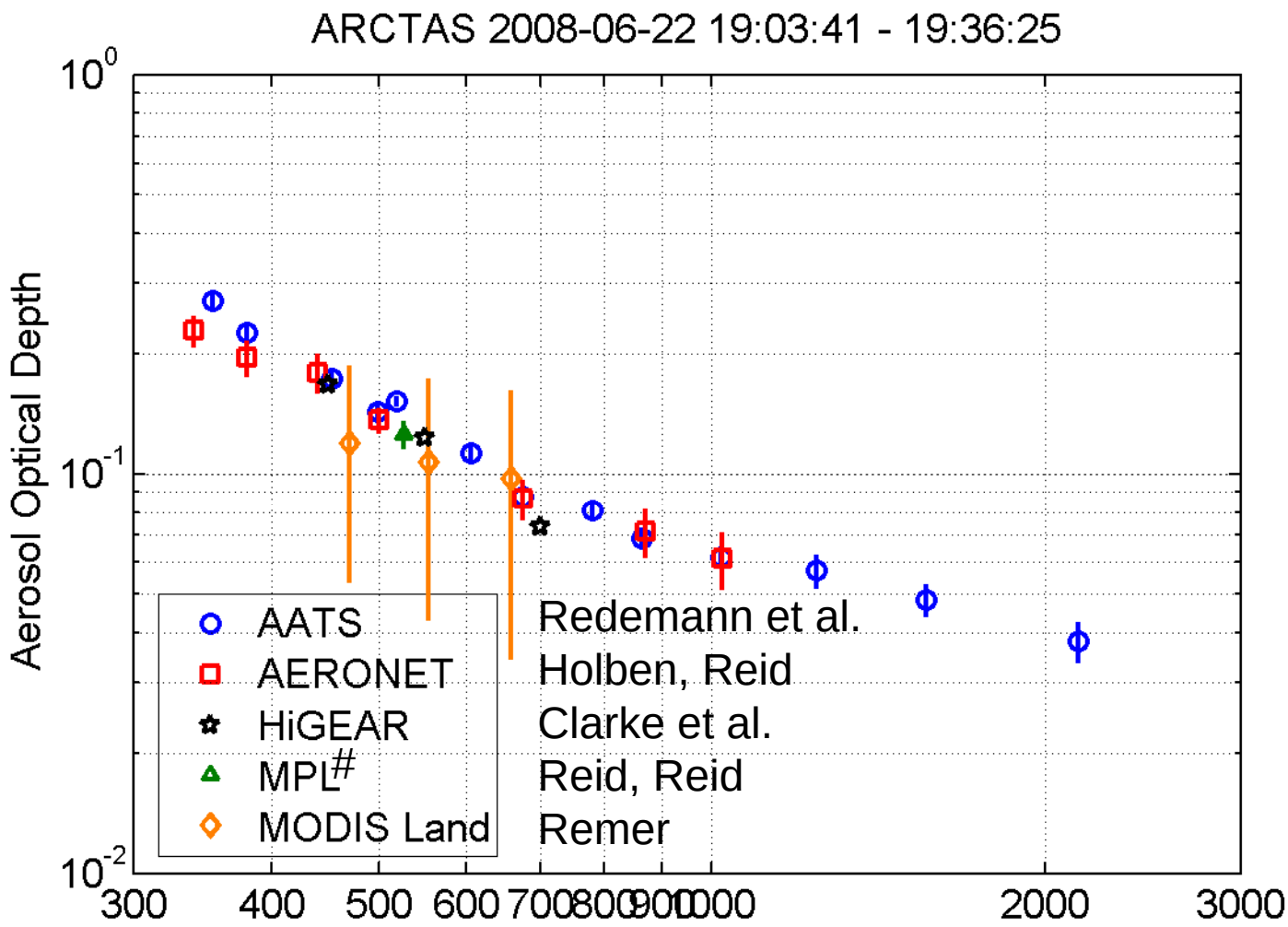


Analysis by Y. Shinozuka

ASFlight11_20080622_190403_193625AATSAODfraction2.fig, ASMontereyAeronetcomparison.m, Yohei, 2008-06-24

•AATS, HiGEAR and AERONET agree within 10%+0.02. (good.)
•The 519 nm AATS AOD is higher than those at other wavelengths suggest. (this channel needs to be investigated.)

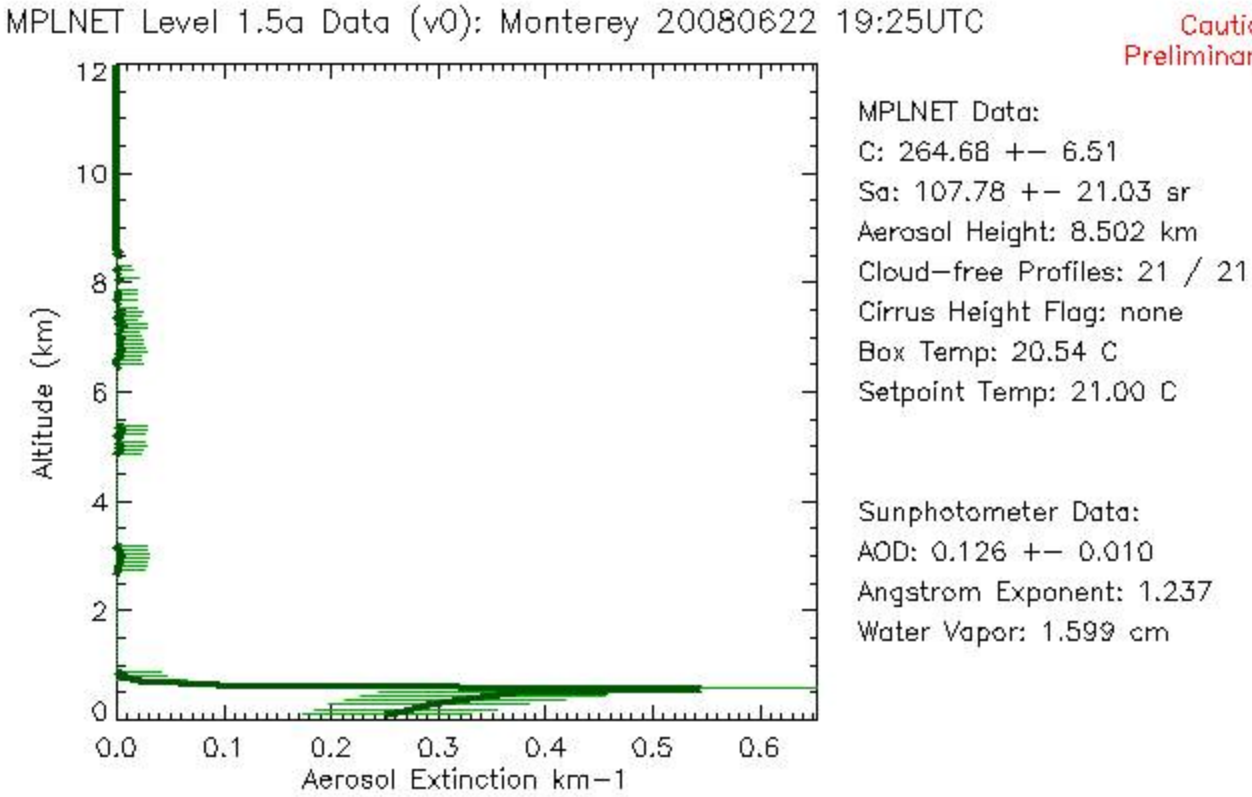
Minor notes:
•Almost perfect agreement at 675 nm makes the AATS marker invisible.
•MODIS uncertainty 15%+0.05; AERONET unc 0.02 up to 440 nm, 0.01 for the longer wavelengths..



#MPL Uses AERONET AOD in analysis

Analysis by Y. Shinozuka

ASFlight11_20080622_190341_193625AeronetMontereyAATSd.fig, ASEurekaPearlAeronetComparison.m, Yohei, 2009-06-25



MPLNET PI: **JeffReid**
jeffrey.reid@nrlmry.navy.mil

Site manager: Betsey Reid

http://aeronet.gsfc.nasa.gov/cgi-bin/bamgomas_interactive , click Backscatter and Extinction

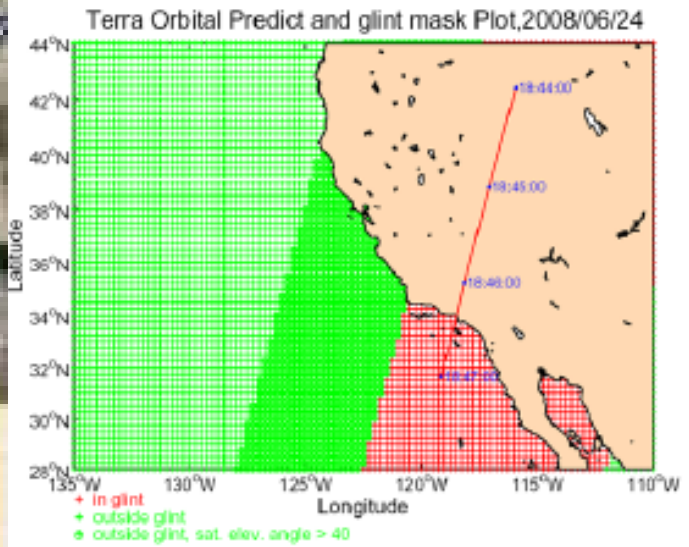
P-3 California Flights

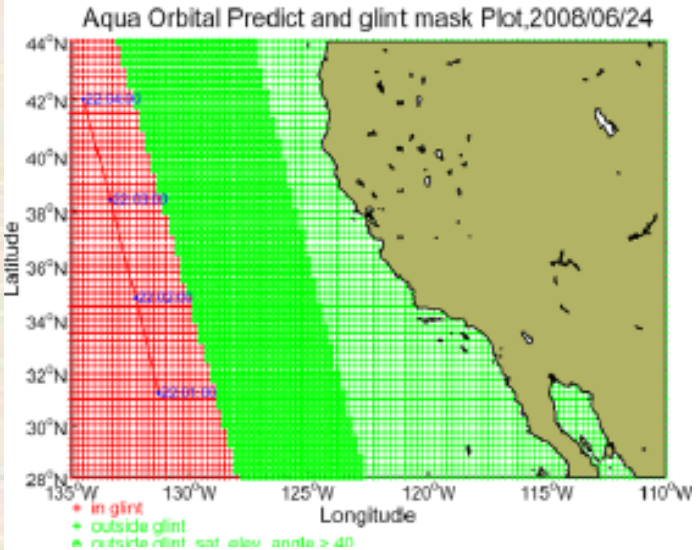
in ARCTAS Summer

Data Flt No.	Date, 2008	Track	Comments
11	22 Jun	Moffett-Monterey Bay-Big Sur-Moffett	Power plant plume, CAR circles, ship plume, AERONET, lidar, Terra, sonde, wildfire smoke.
12	24 Jun	Moffett-Los Angeles-Moffett	Plume crossings for 14 ships. Profiles under Terra & Aqua. Ocean BRDF (calm & 50-kt winds). Fire plumes & pollution plumes.
13 & 14	26 Jun	Moffett-Edmonton-Cold Lake	Lake Tahoe smoke radiation study in DC-8 lidar curtain & under Terra. Lake albedo & BRDF. Central Valley smoke gradient legs.

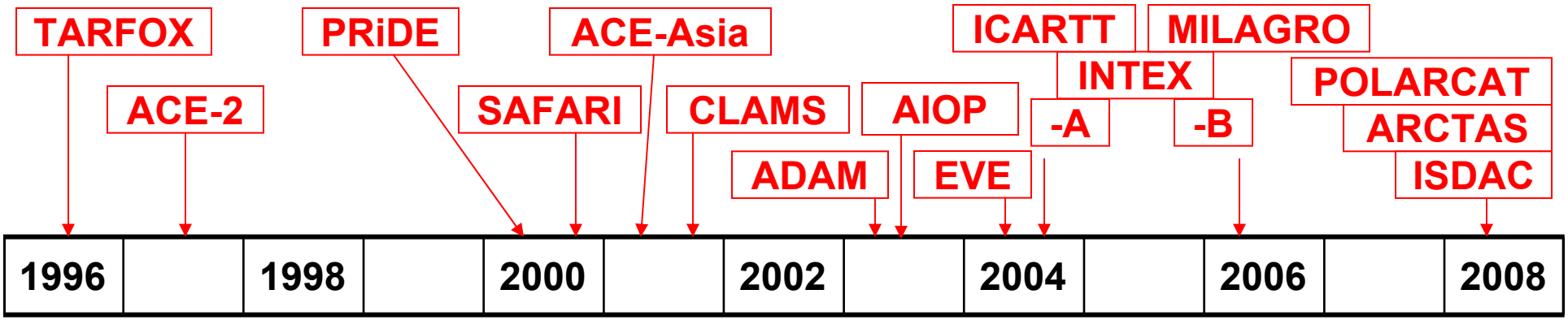
http://www.espo.nasa.gov/arctas/flightDocs.php

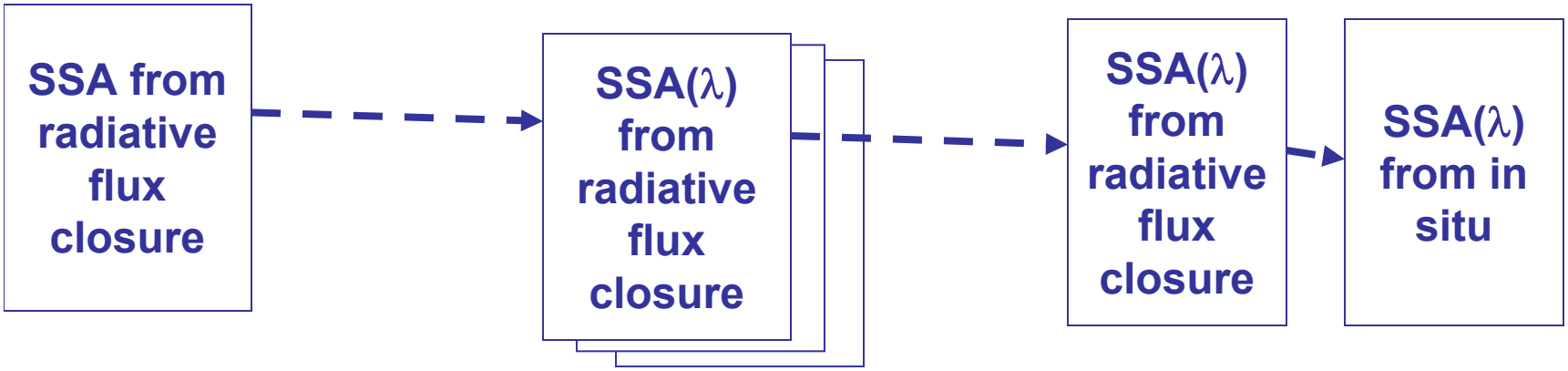
P-3B Data Flight #12, 24 Jun 2008





A Chain of Field Experiments Measuring Aerosols & Their Effects on Atmospheric Radiation

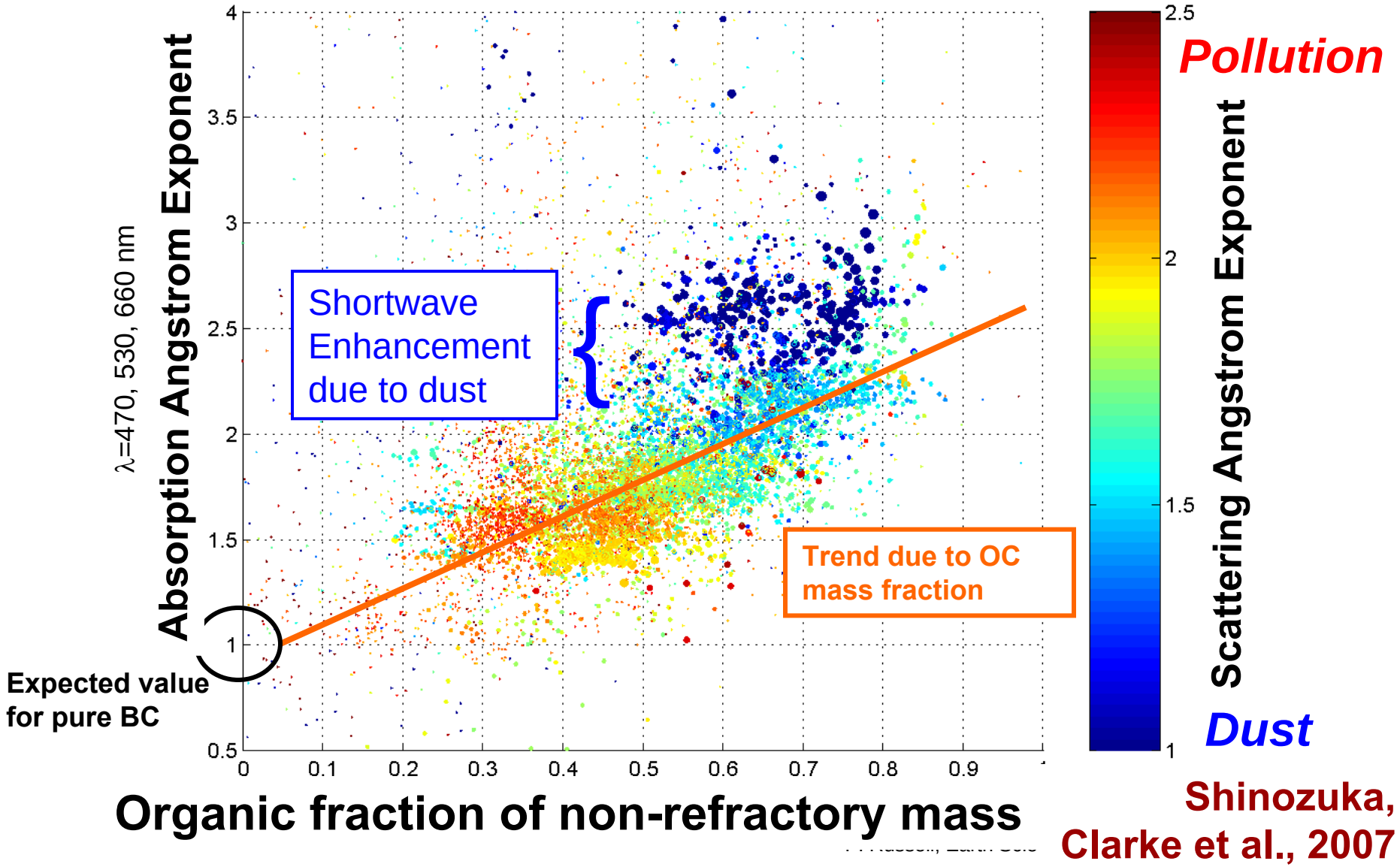




Wavelength dependence of absorption over Mexico is linked to both the organic carbon component (AMS - J, Jimenez, P. DeCarlo) and dust.
Model and remote sensing implications for SSA etc.

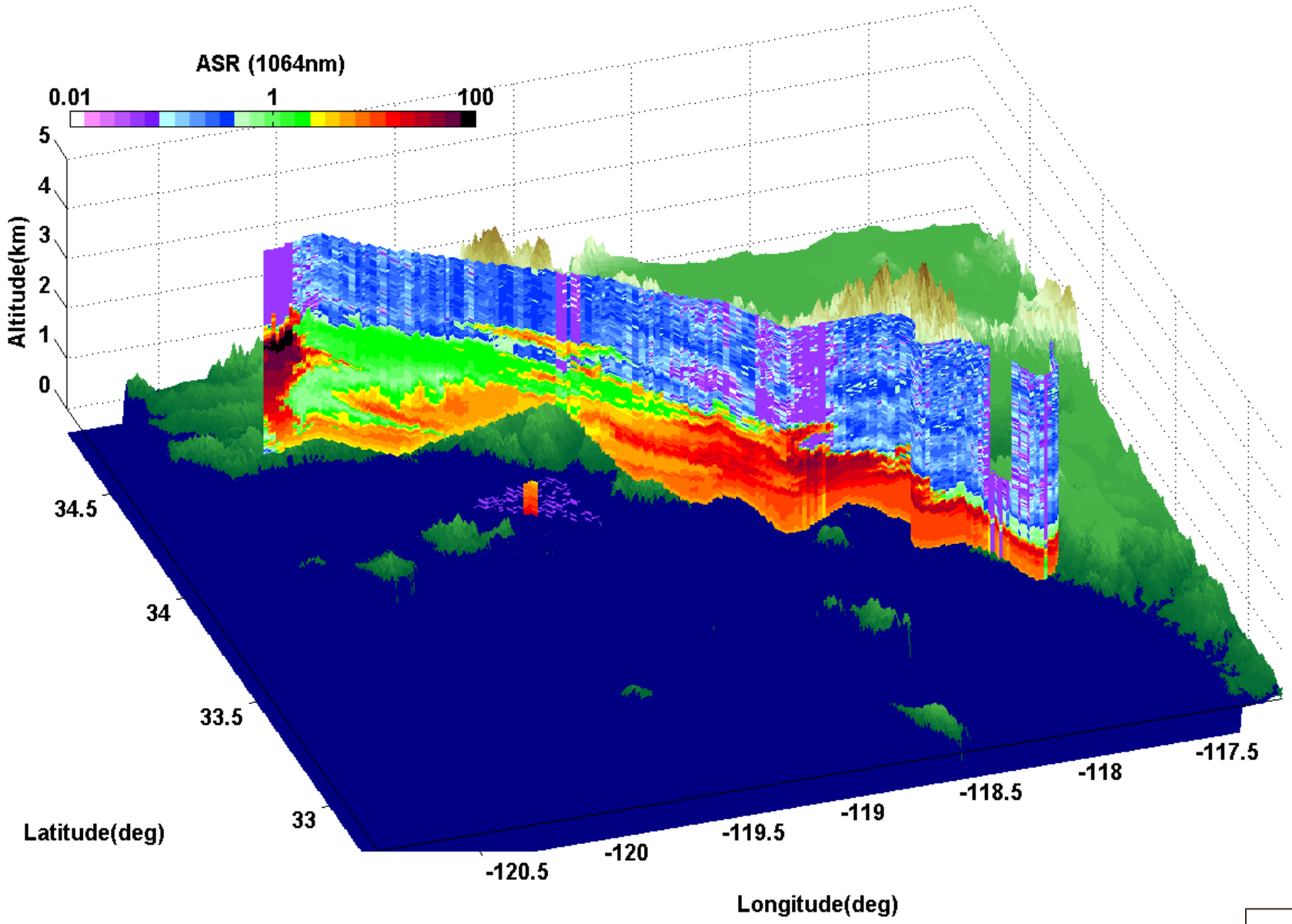
HIGEAR Hawaii Group for Environmental Aerosol Research

Aerosol Optics



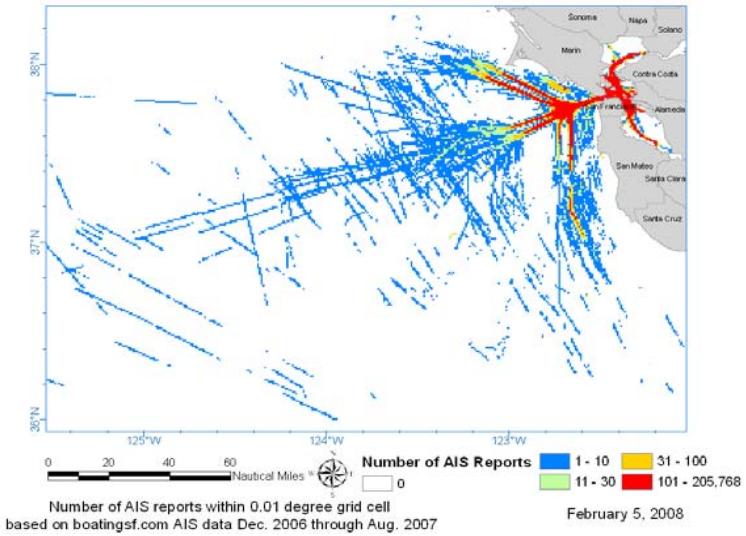
Shinozuka, Clarke et al., 2007

DC-8 Lidar curtain, 24 Jun 2008



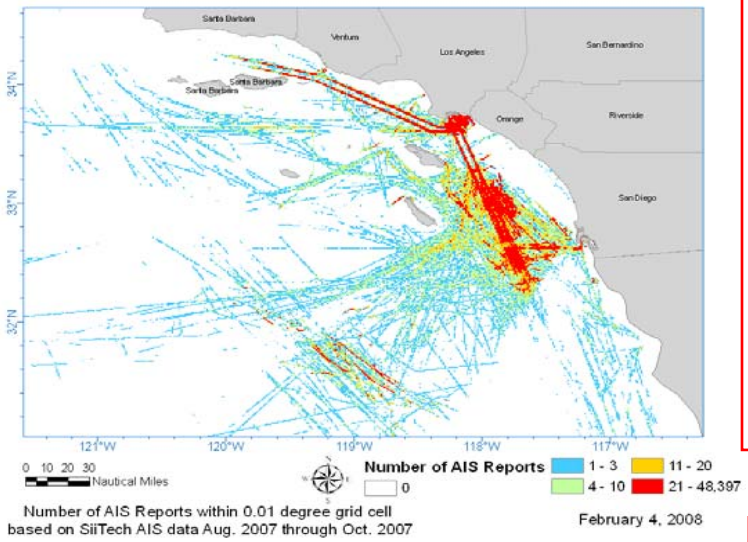
Hair, …

Emissions of primary aerosol and aerosol precursors (SO_2, VOC's) by ship traffic have the potential to affect cloud droplet number, drop size, and the albedo of marine stratus off the coast of California



Number of AIS reports within 0.01 degree grid cell
based on boatingsf.com AIS data Dec. 2006 through Aug. 2007

February 5, 2008

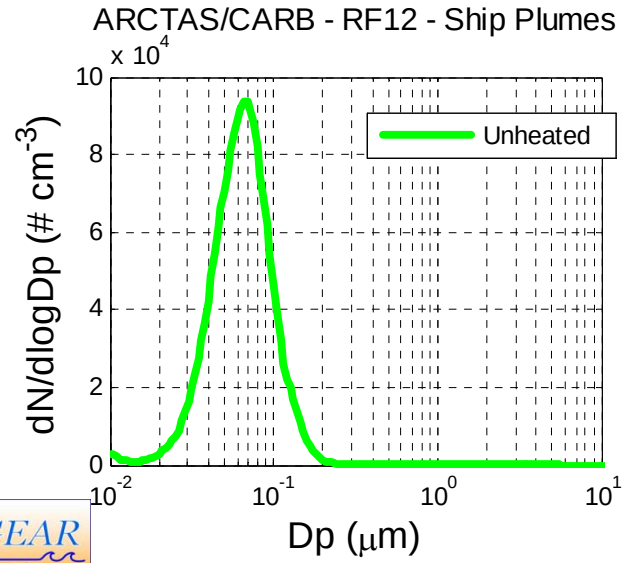


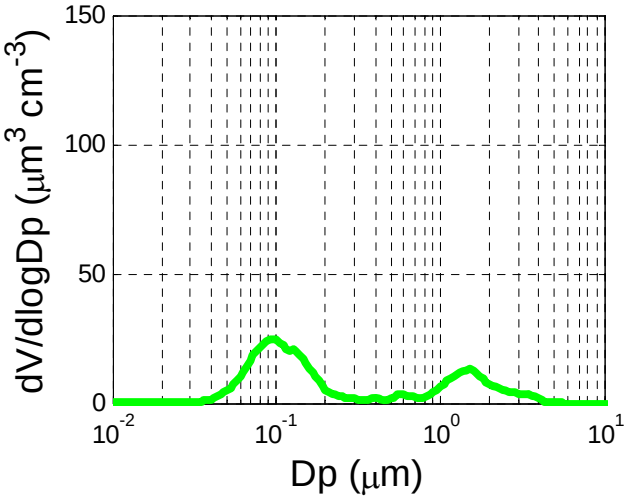
Number of AIS Reports within 0.01 degree grid cell
based on SiiTech AIS data Aug. 2007 through Oct. 2007

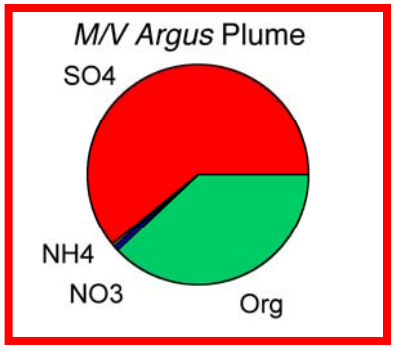
February 4, 2008

S1	cargo
S2	Anastasia
S3	Mearsk Kimi
S4	Xin Quing Huang Vao
S5	BM Mimosa
S6	Ever Liberty
S7	Zim Mediteranean
S8	Marigold
S9	Santa Monica
S10	Frisco Mizar
S11	Andromeda Leader
S12	Bum Evn
S13	Lu He
S14	NYK Argus

Fresh emissions from ships have high particle number ~10^5 cm^{-3}, but smaller mean diameters. Numbers tend to decrease, while diameter increases as the plumes age

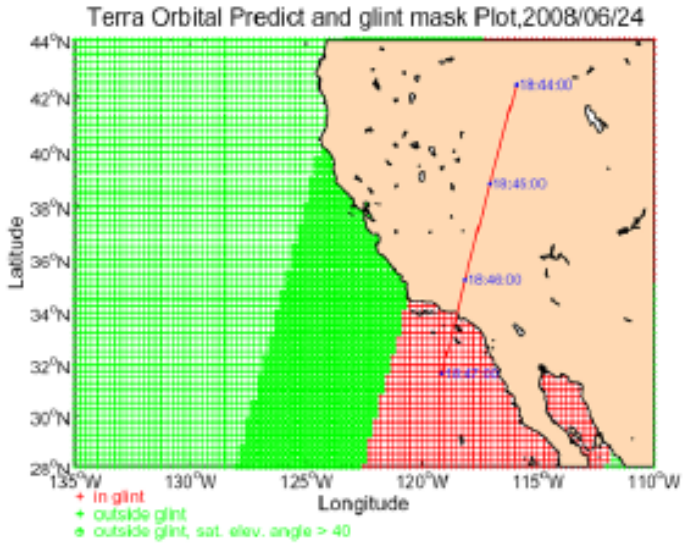


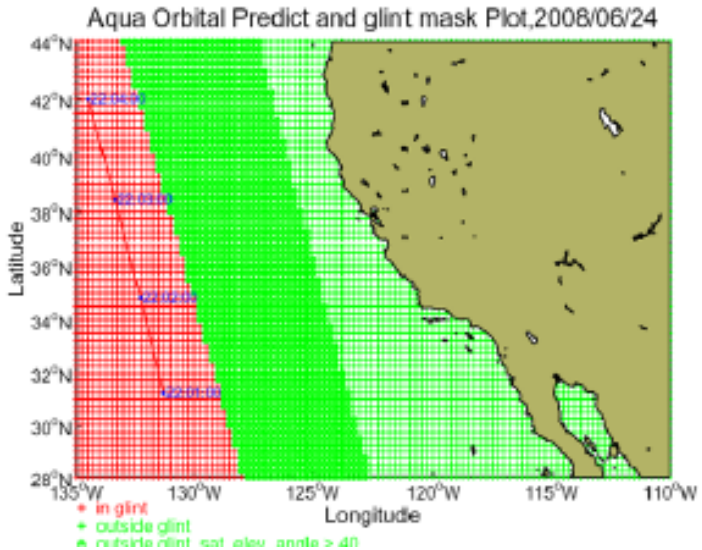




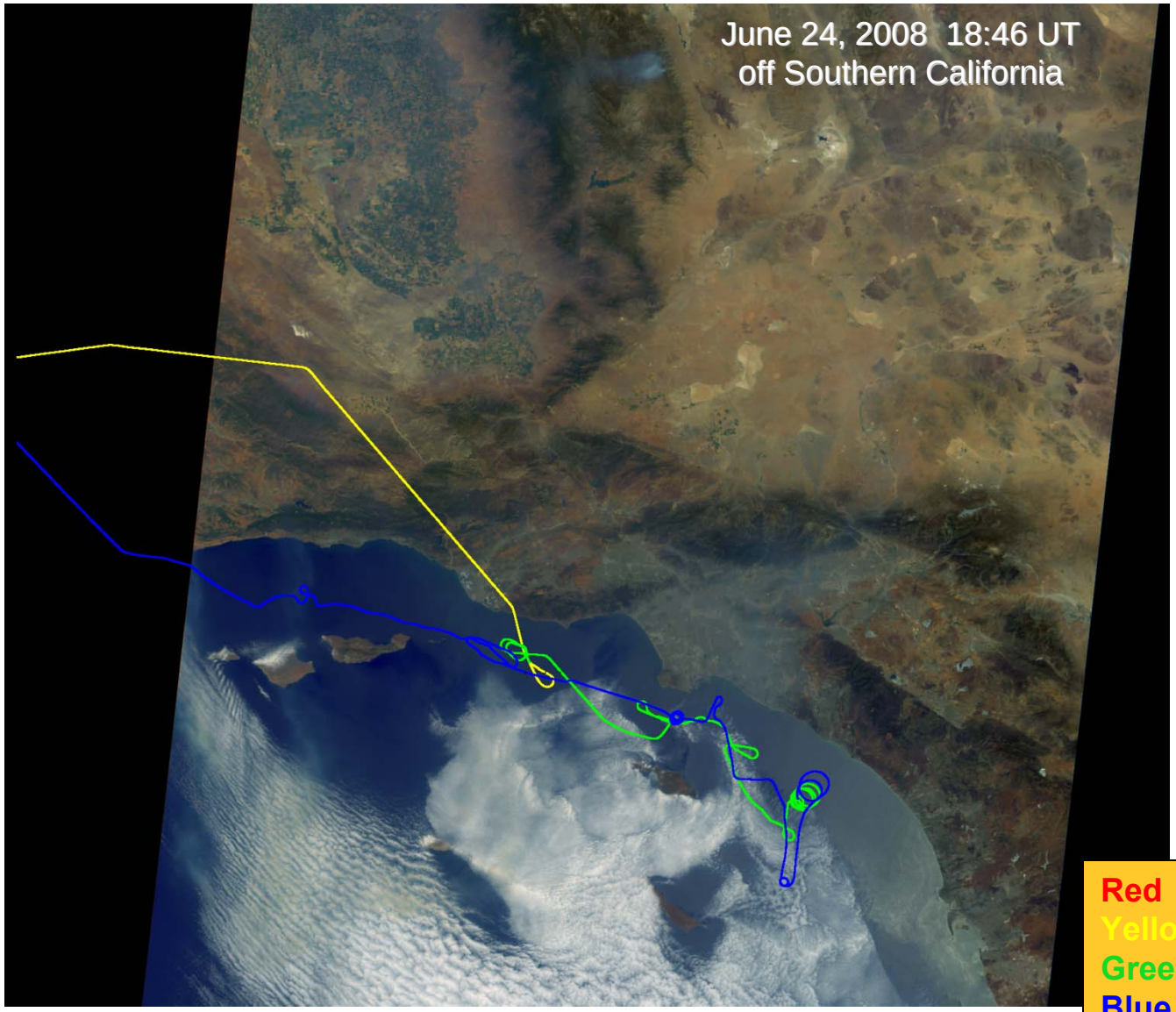
P-3B Data Flight #12, 24 Jun 2008:

Actual flight track P3b in green, DC-8 in red





ARCTAS MISR w/P3 Trajectory – June 24, 2008



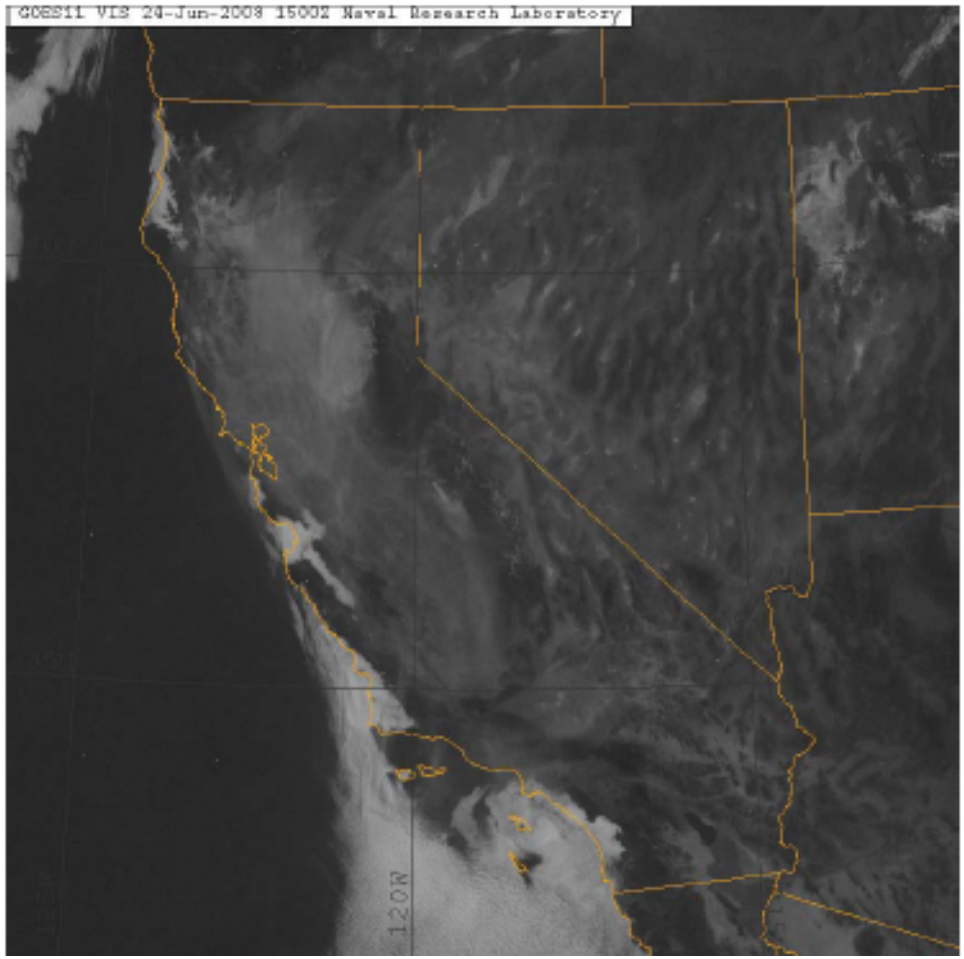
Red – within 1 hr
Yellow – within 2 hrs
Green – within 3 hrs
Blue – > 3 hrs

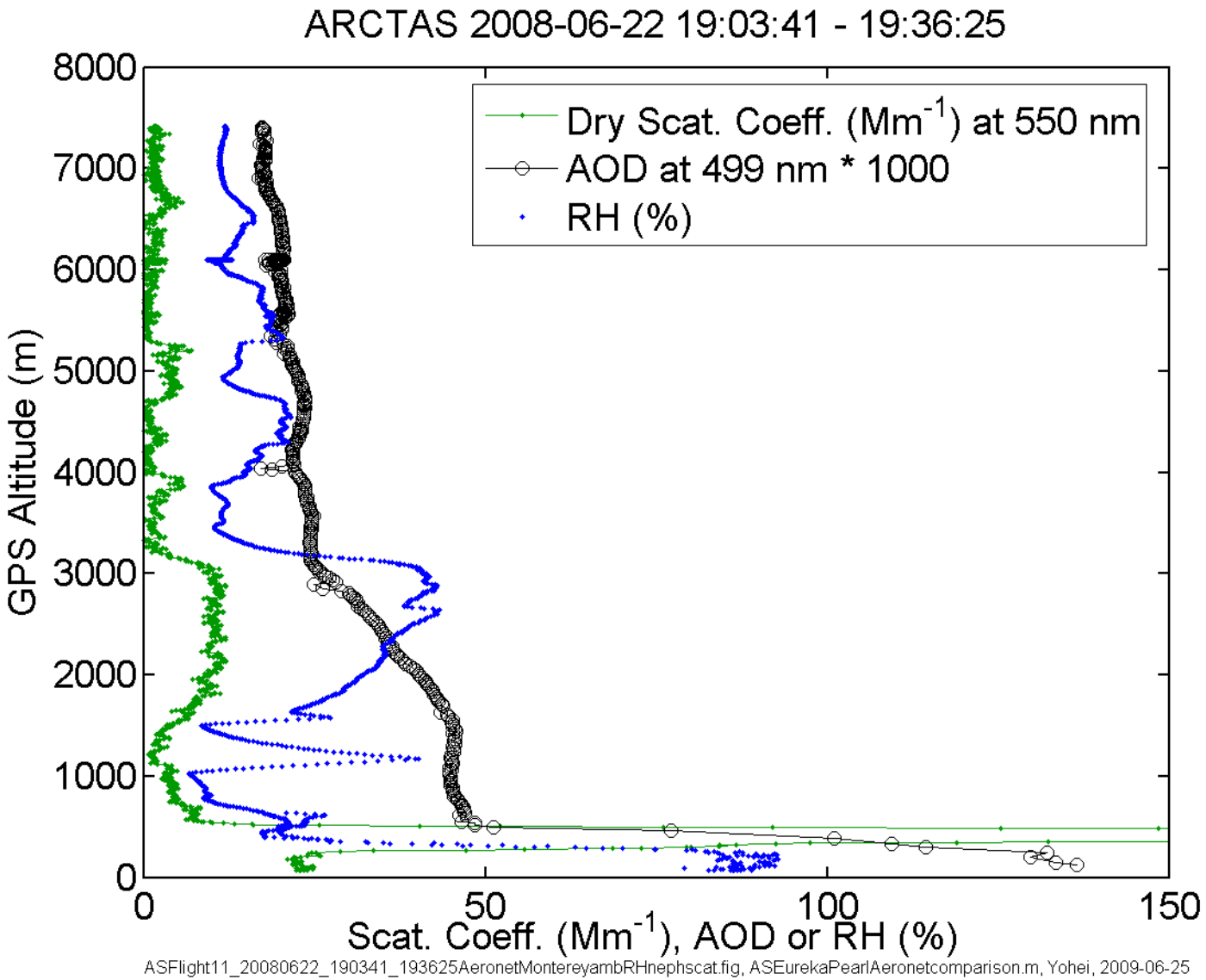
M. Davis and R. Kahn NASA/GSFC

Flight Report
ARCTAS P-3B Data Flight 12, flown 24 Jun 2008 (CARB Science)
Submitted by Antony Clarke

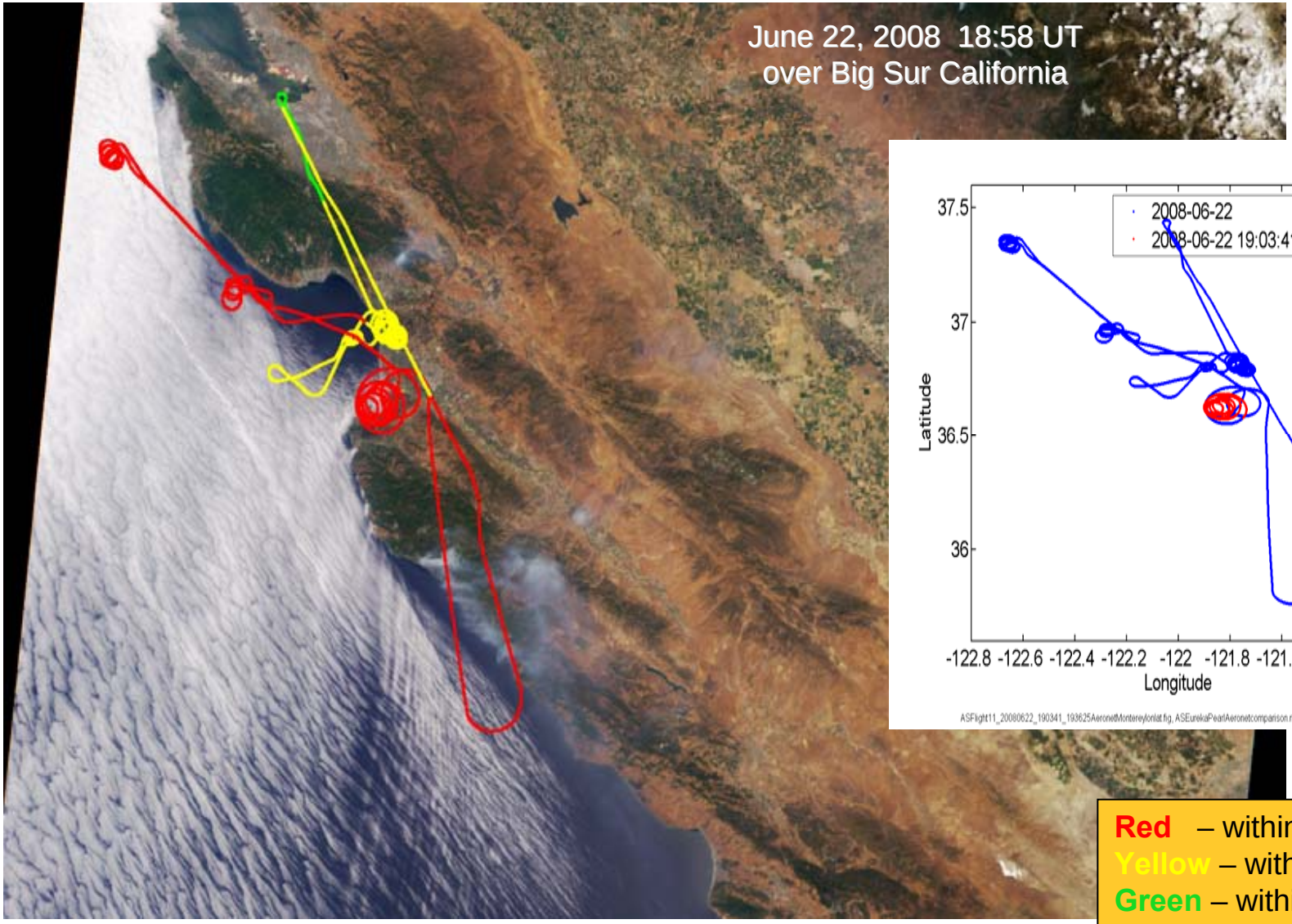
Objectives

1) Characterize multiple ship plumes between San Francisco and Los Angeles
2) Ship plume – cloud interactions if possible
3) Spiral near Terra MODIS overpass (1147 PDT, 1847UT)
4) Spiral near Aqua MODIS overpass (1501PDT, 2201 UT,)
5) Aerosol gradients - coast to offshore
6) CAR circles, radiation legs




ARCTAS 2008-06-22 19:03:41 - 19:36:25
Dry Scat. Coeff. (Mm-1) at 550 nm
AOD at 499 nm * 1000
RH (%)
GPS Altitude (m)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
50
100
150
Scat. Coeff. (Mm-1), AOD or RH (%)
ASFlight11_20080622_190341_193625AeronetMontereyambRHnephscat.fig, ASEurekaPearlAeronetcomparison.m, Yohei, 2009-06-25

ARCTAS MISR w/P3 Trajectory – June 22, 2008



Red – within 1 hr
Yellow – within 2 hrs
Green – within 3 hrs
Blue – > 3 hrs

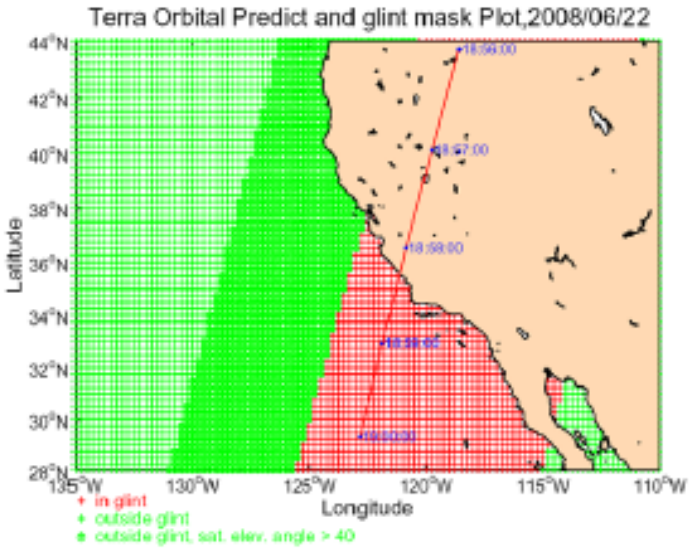
M. Davis and R. Kahn NASA/GSFC

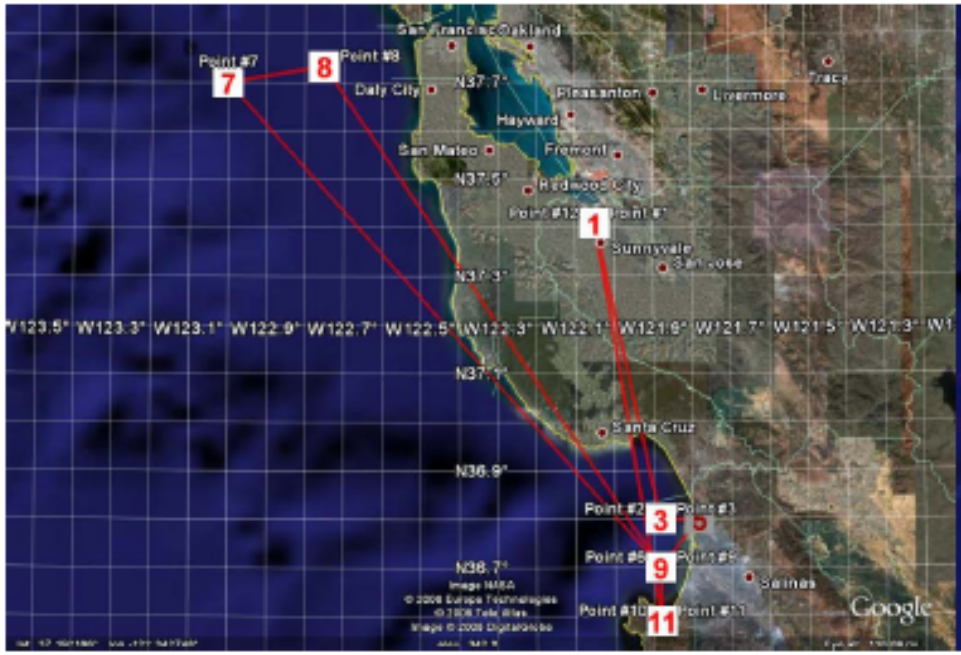
P-3B Data Flight #11, 22 Jun 2008:

Power plant plume, CAR circles, ship plume, AERONET, Terra, sonde, wildfire smoke.

Flight Report
ARCTAS P-3B Data Flight 11, flown 22 Jun 2008 (Test/Science)
Submitted by Phil Russell

Objectives
1) Leak tests, other instrument preliminary checkout
2) Sample Moss Landing Power Plant plume
3) CAR circles, radiation legs
4) Look for ships & plumes near Farallon Islands & Golden Gate. Possible aerosol-cloud study.
5) AERONET, MPL comparison over NRL Monterey
6) CAR circles, radiation legs
7) Spiral up with radiosonde near Terra MODIS overpass time (1158 PDT)

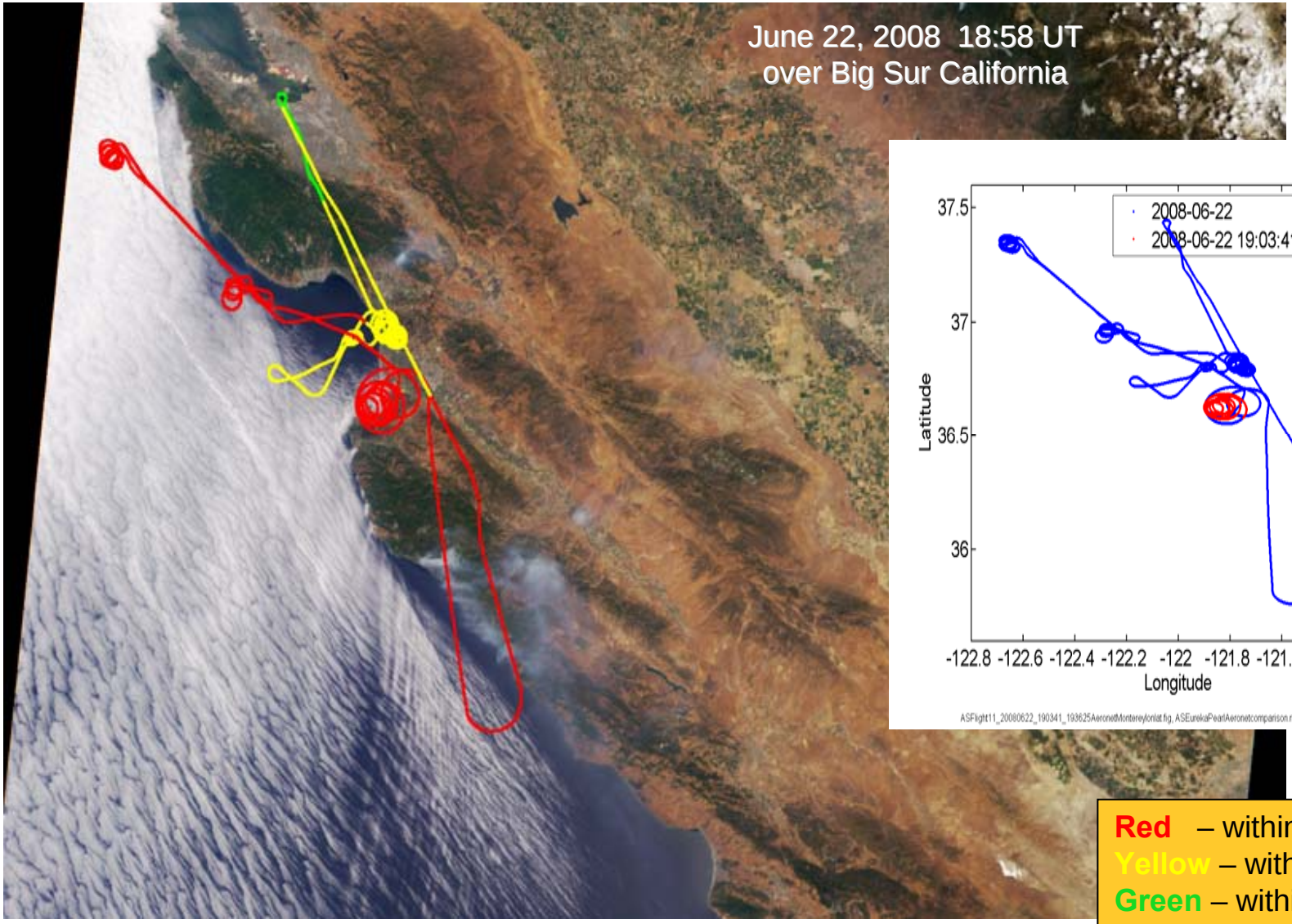




Planned flight track

Actual flight track

ARCTAS MISR w/P3 Trajectory – June 22, 2008



Red – within 1 hr
Yellow – within 2 hrs
Green – within 3 hrs
Blue – > 3 hrs

M. Davis and R. Kahn NASA/GSFC

California Coastal Aerosol during ARCTAS-CARB: Ships, Wildfires and Background Air

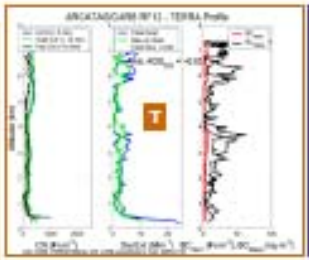
A. Clarke, S. Howell, O. McNaughton, S. Freitag, V. Kapustin, V. Brekhovskikh, P. Russell, J. Redemann, Y. Shinozuka, J. Livingston

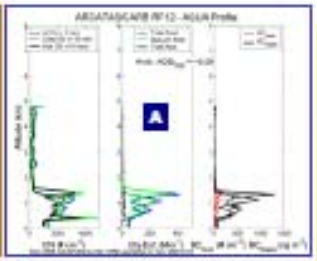
Vertical profiles were flown under Terra and Aqua satellites during the Pab CARB flight. In-situ particle condensation nuclei (CN), light scattering and black carbon (BC) are shown. AATS transmittance also measured spectral aerosol optical depth (AOD).

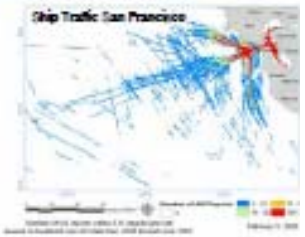
Terra was in clean offshore air with AOD aloft dominated by scattering. Absorption by BC indicates long range pollution transport. Enhanced sea-salt scattering is evident below 500m.

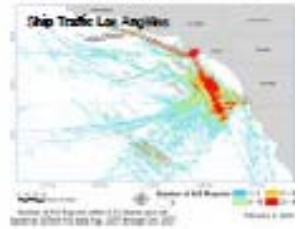
Aqua was at the southern end of flight with enhanced aerosol (scales changed) below 1.5km dominated by biomass burning from California wildfires. Note less pollution near surface.

Layer (profile bottom minus top) AOD a interpolated to 550nm from AATS values and calculated by integrating in-situ measured extinction are in good agreement for the Aqua profile.









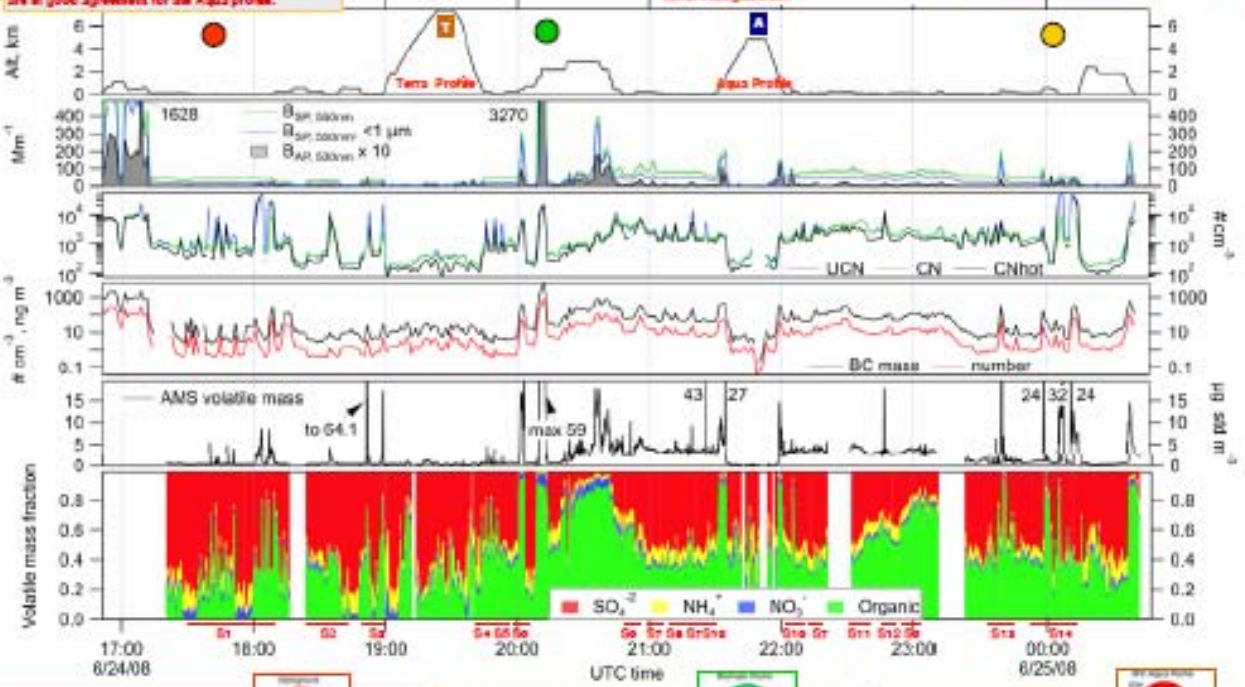
Flight Track Information and Data

The CARB Pab track above is shown as a time series to the right for various measured parameters. The flight started at the south end of San Francisco Bay proceeding northwest and followed the route to Los Angeles and back indicated by the white arrows. The three colored circles indicate sample locations for the three aerosol types shown below. These are clean marine, biomass wildfires and ship plumes.

From top down on the panel to the right are shown:

- Pab altitude including the Terra and Aqua profile locations.
- Total (green) and submicron (blue) light scattering and light absorption (x10) coefficients for the dry aerosol.
- Ultrafine Condensation Nuclei (UCN > 3nm), CNtrue sun and heated (300C) CNhot (black) number concentrations.
- Black Carbon (BC) mass (black) and number (red) measured by the single particle soot photometer (SP2).
- Total volatile mass measured by the aerosol mass spectrometer (AMS). Off-scale values indicated by numbers.
- Mass fractions of sulfate, nitrate, ammonium and organic aerosol from the AMS.
- Ships sampled identified by Sx at bottom of plot.

Note that clean background air is dominated by sulfate aerosol while both biomass burning and ship plumes have elevated organic components.



Ship Plumes

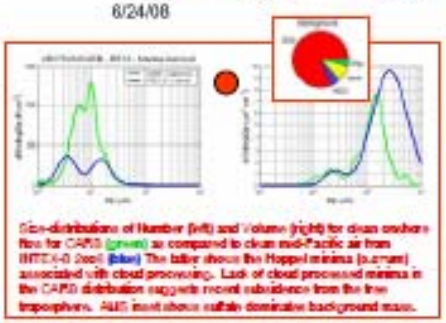
The flight track started with the ship traffic areas near San Francisco down to Los Angeles (above). Fourteen ships were encountered (below) with emission that varie for almost none (S7 - Marigold) to large (S4- Xin Quing Huang Hai). Most had a large organic component.

SHIPS

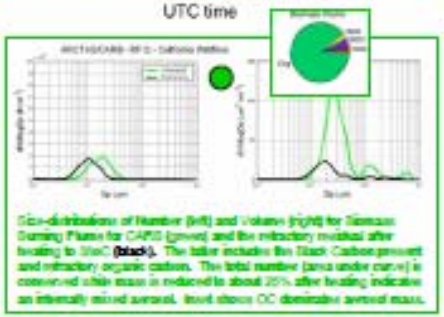
S1- cargo	S8-Marigold
S2-Anatolais	S9-Santa Monica
S3-Maersk Kimi	S10-Frisco Mizar
S4-Xin Quing Huang Hai	S11-Andromeda Leader
S5-Ski Monaco	S12-Busn Bin
S6-Ever Liberty	S13- La He
S7-Zim Mediterranean	S14- NYK Argus

This work supported under NASA ARCTAS grant NNX08AF56G

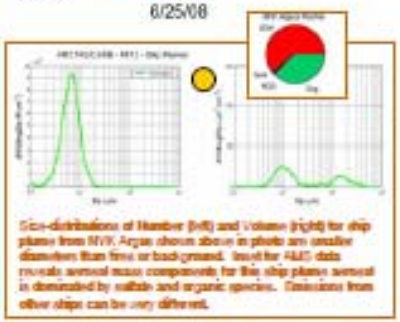
The three panels to the right show number and volume distributions for background, fire and ship aerosol sampled at the locations indicated above. Areas under each plot are proportional to total number or volume respectively. Note the difference in vertical scales and diameters for each. Pie charts indicate mass fraction of volatiles from the AMS.



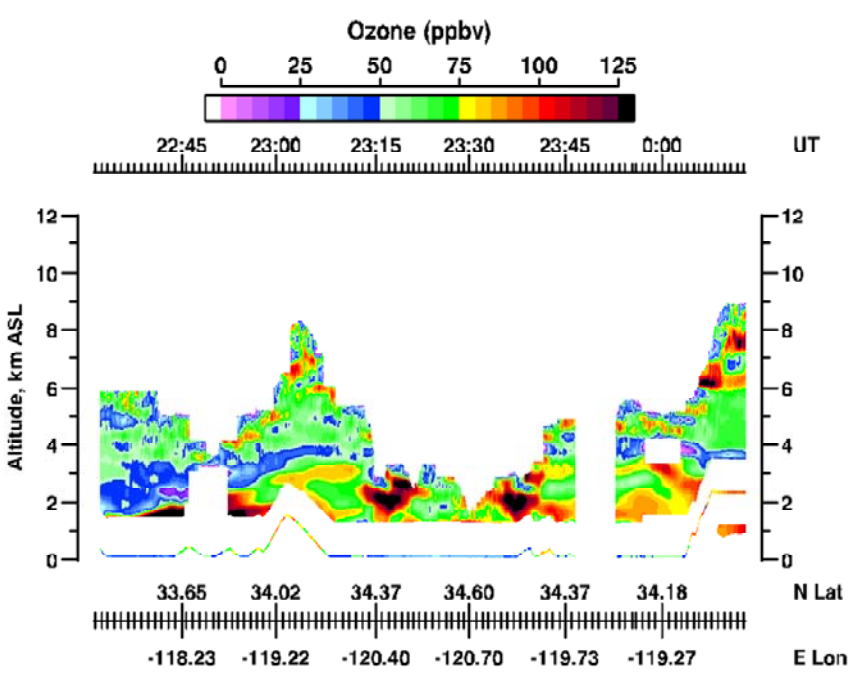
Size-distributions of Number (left) and Volume (right) for clean onshore flow for CARB (green) as compared to clean mid-Pacific air from INTEX-B 2006 (blue) The latter shows the Hoppel minima (curves) associated with cloud processing. Lack of cloud processed minima in the CARB distribution suggests recent subsidence from the free troposphere. AMS inset shows sulfate dominates background mass.

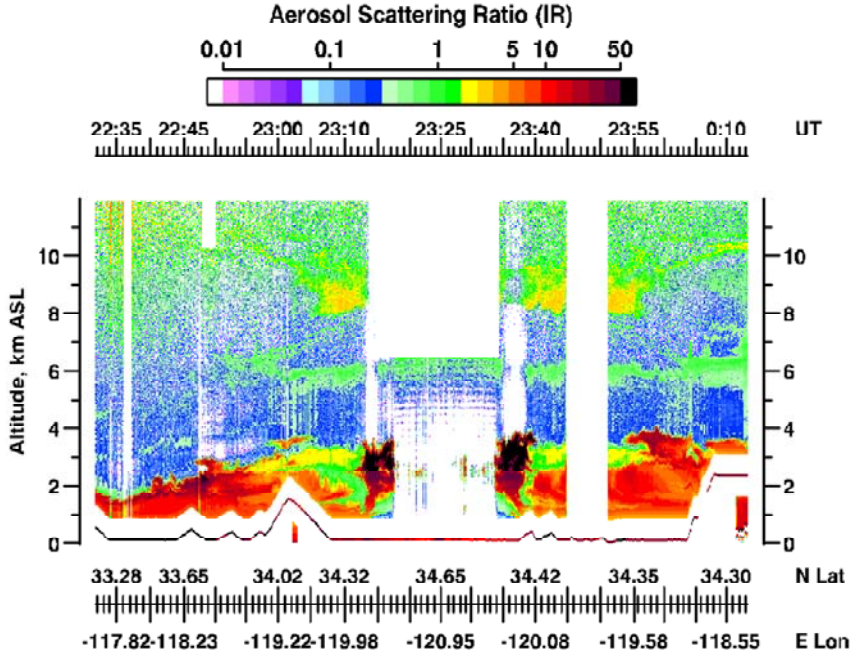


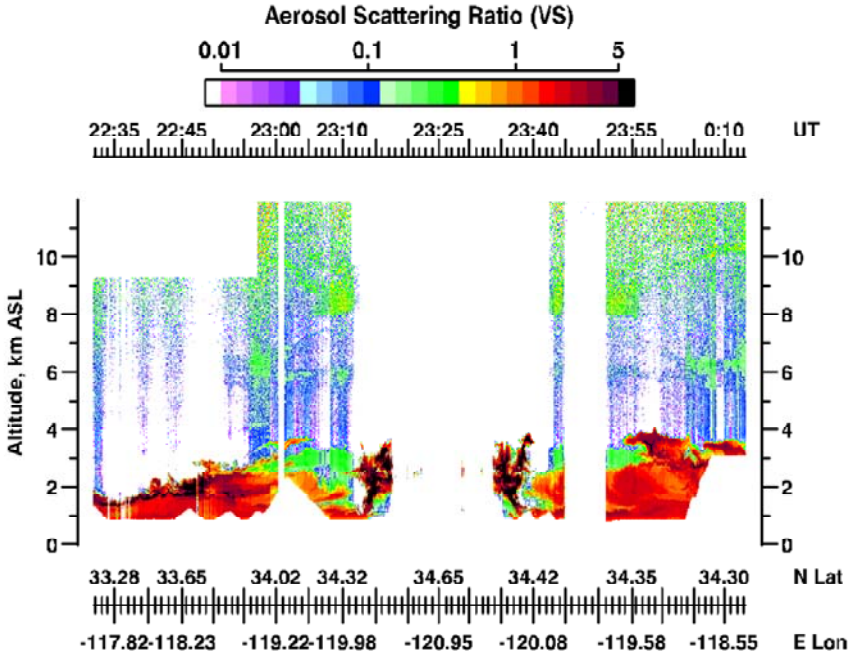
Size-distributions of Number (left) and Volume (right) for Biomass Burning Plume for CARB (green) and the refractory residual after heating to 300C (black). The latter includes Bm Black Carbon present and refractory organic carbon. The total number (area under curve) is conserved while mass is reduced to about 25% after heating indicative an internally mixed aerosol. Inset shows OC dominates aerosol mass.

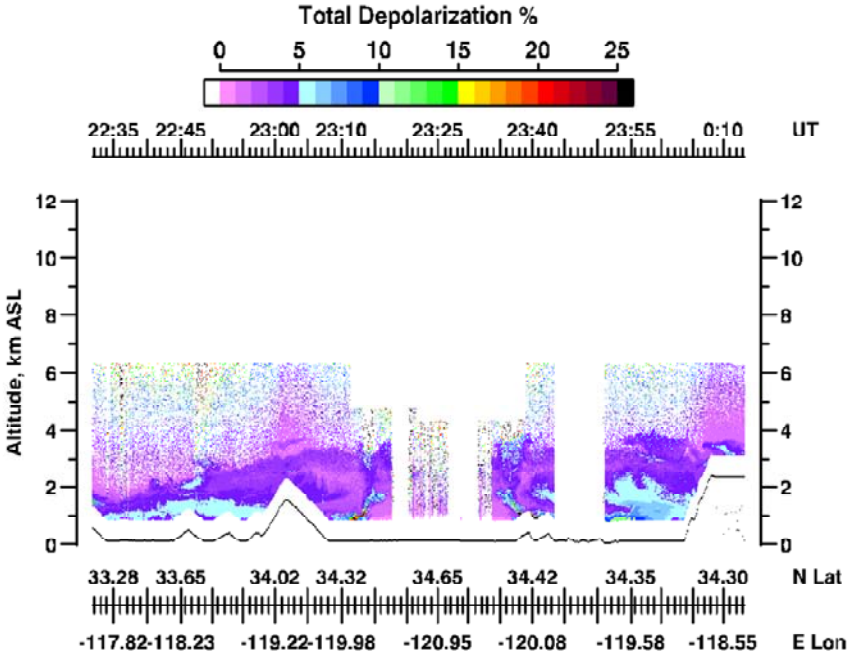


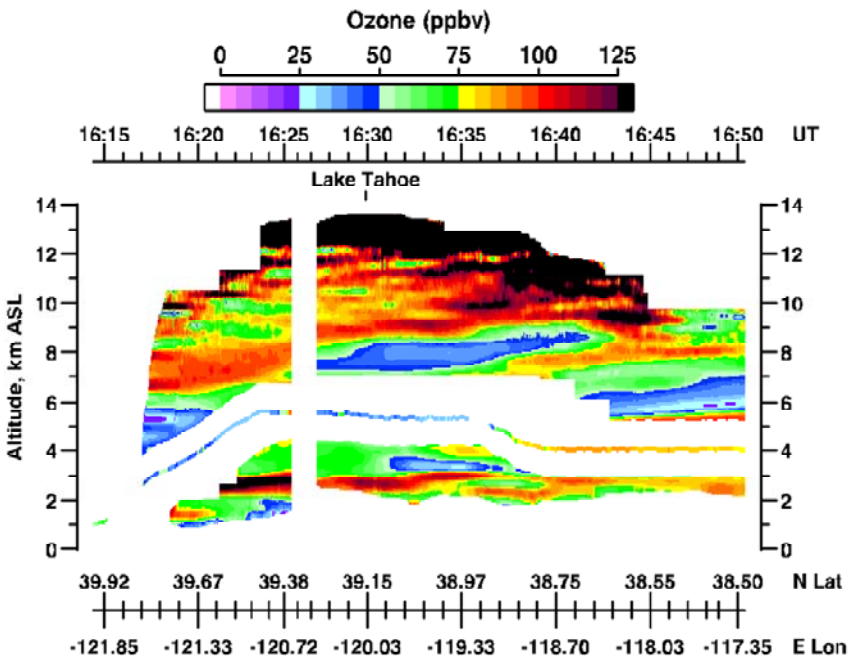
Size-distributions of Number (left) and Volume (right) for ship plumes from NYK Argus shown above in photo are smaller diameters than fires or background. Inset for AMS data reveals aerosol mass components for this ship plume aerosol is dominated by sulfate and organic species. Emissions from other ships can be very different.

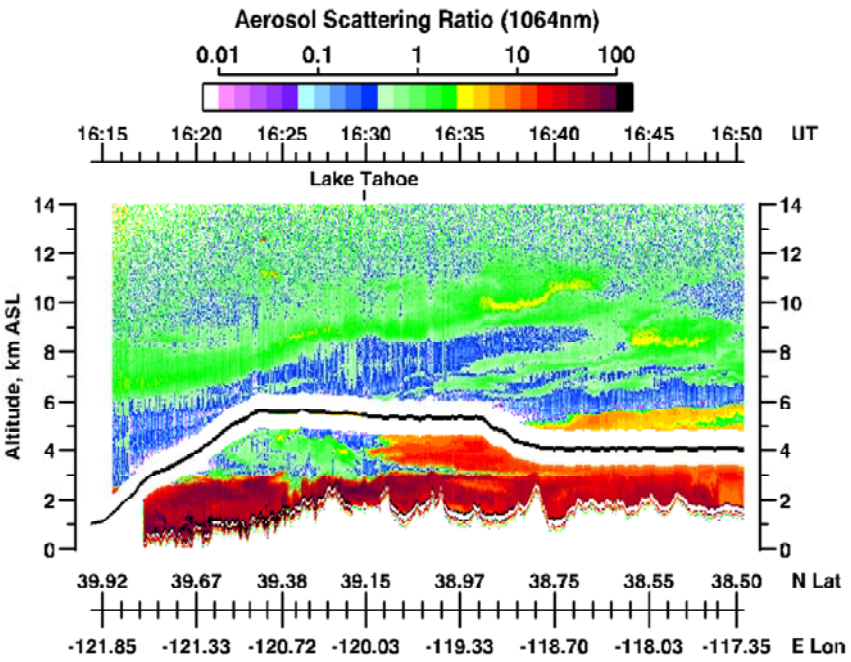

Ozone (ppbv)
0 25 50 75 100 125
22:45 23:00 23:15 23:30 23:45 0:00 UT
Altitude, km ASL
0 2 4 6 8 10 12
33.65 34.02 34.37 34.60 34.37 34.18 N Lat
-118.23 -119.22 -120.40 -120.70 -119.73 -119.27 E Lon

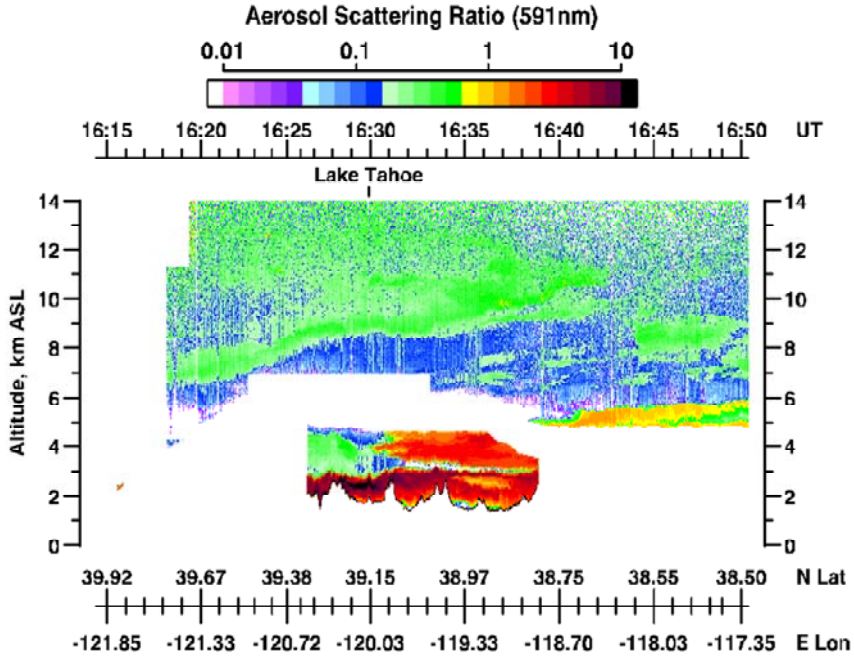

Aerosol Scattering Ratio (IR)
0.01 0.1 1 5 10 50
22:35 22:45 23:00 23:10 23:25 23:40 23:55 0:10 UT
Altitude, km ASL
0 2 4 6 8 10
33.28 33.65 34.02 34.32 34.65 34.42 34.35 34.30 N Lat
-117.82-118.23 -119.22-119.98 -120.95 -120.08 -119.58 -118.55 E Lon

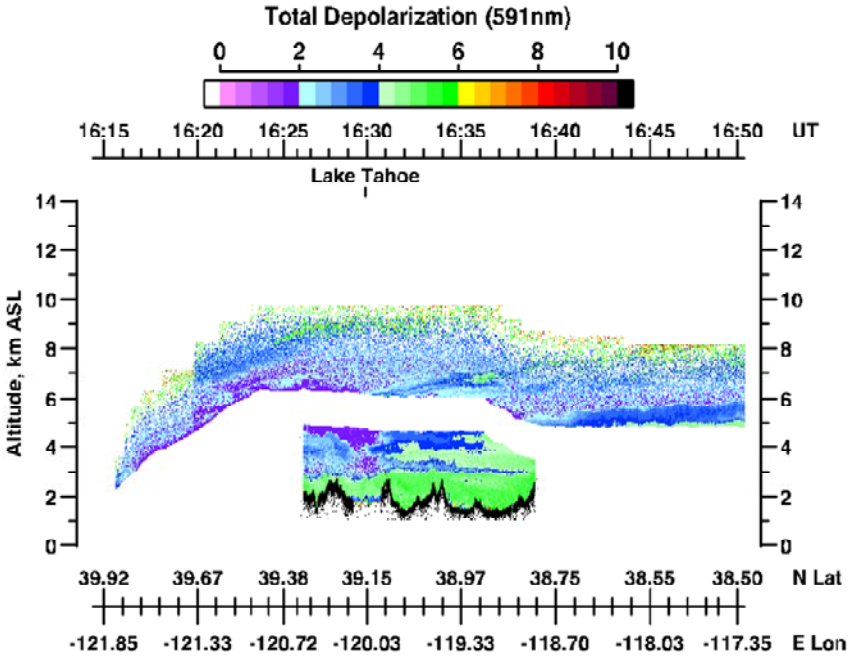

Aerosol Scattering Ratio (VS)
0.01 0.1 1 5
22:35 22:45 23:00 23:10 23:25 23:40 23:55 0:10 UT
Altitude, km ASL
0 2 4 6 8 10
33.28 33.65 34.02 34.32 34.65 34.42 34.35 34.30 N Lat
-117.82-118.23 -119.22-119.98 -120.95 -120.08 -119.58 -118.55 E Lon


Total Depolarization %
0 5 10 15 20 25
22:35 22:45 23:00 23:10 23:25 23:40 23:55 0:10 UT
Altitude, km ASL
0 2 4 6 8 10 12
33.28 33.65 34.02 34.32 34.65 34.42 34.35 34.30 N Lat
-117.82-118.23 -119.22-119.98 -120.95 -120.08 -119.58 -118.55 E Lon


Ozone (ppbv)
0 25 50 75 100 125
16:15 16:20 16:25 16:30 16:35 16:40 16:45 16:50 UT
Lake Tahoe
Altitude, km ASL
0 2 4 6 8 10 12 14
39.92 39.67 39.38 39.15 38.97 38.75 38.55 38.50 N Lat
-121.85 -121.33 -120.72 -120.03 -119.33 -118.70 -118.03 -117.35 E Lon

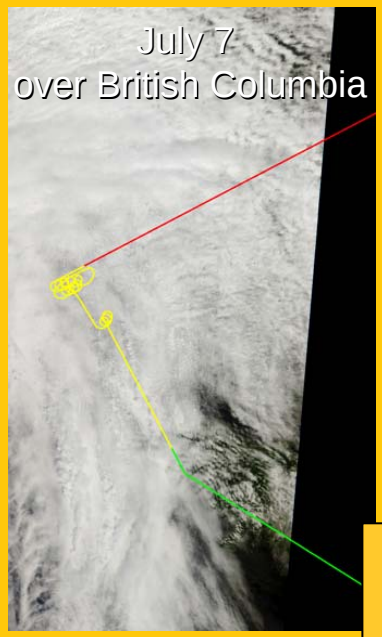

Aerosol Scattering Ratio (1064nm)
0.01 0.1 1 10 100
16:15 16:20 16:25 16:30 16:35 16:40 16:45 16:50 UT
Lake Tahoe
Altitude, km ASL
0 2 4 6 8 10 12 14
39.92 39.67 39.38 39.15 38.97 38.75 38.55 38.50 N Lat
-121.85 -121.33 -120.72 -120.03 -119.33 -118.70 -118.03 -117.35 E Lon

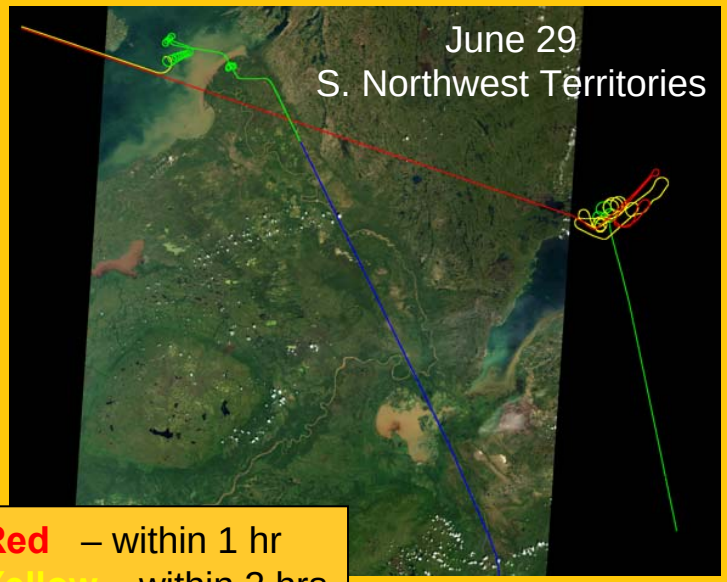

Aerosol Scattering Ratio (591nm)
0.01 0.1 1 10
16:15 16:20 16:25 16:30 16:35 16:40 16:45 16:50 UT
Lake Tahoe
Altitude, km ASL
0 2 4 6 8 10 12 14
39.92 39.67 39.38 39.15 38.97 38.75 38.55 38.50 N Lat
-121.85 -121.33 -120.72 -120.03 -119.33 -118.70 -118.03 -117.35 E Lon


Total Depolarization (591nm)
0 2 4 6 8 10
16:15 16:20 16:25 16:30 16:35 16:40 16:45 16:50 UT
Lake Tahoe
Altitude, km ASL
0 2 4 6 8 10 12 14
39.92 39.67 39.38 39.15 38.97 38.75 38.55 38.50 N Lat
-121.85 -121.33 -120.72 -120.03 -119.33 -118.70 -118.03 -117.35 E Lon

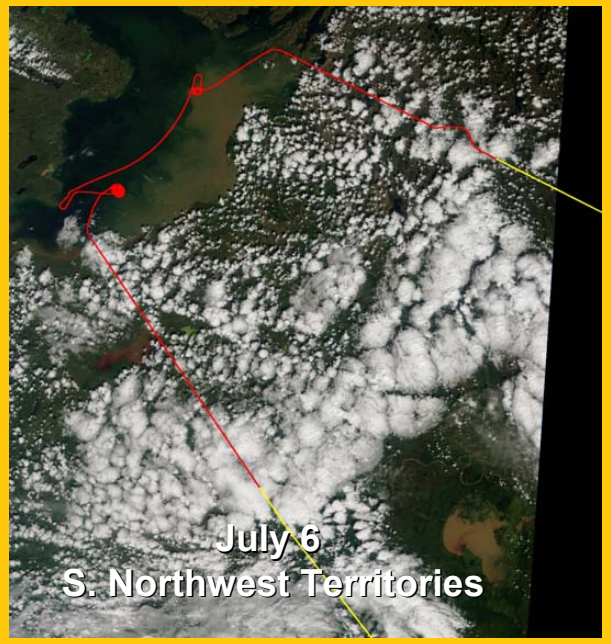
MISR – Eight P3 Coincidences for Summer ARCTAS

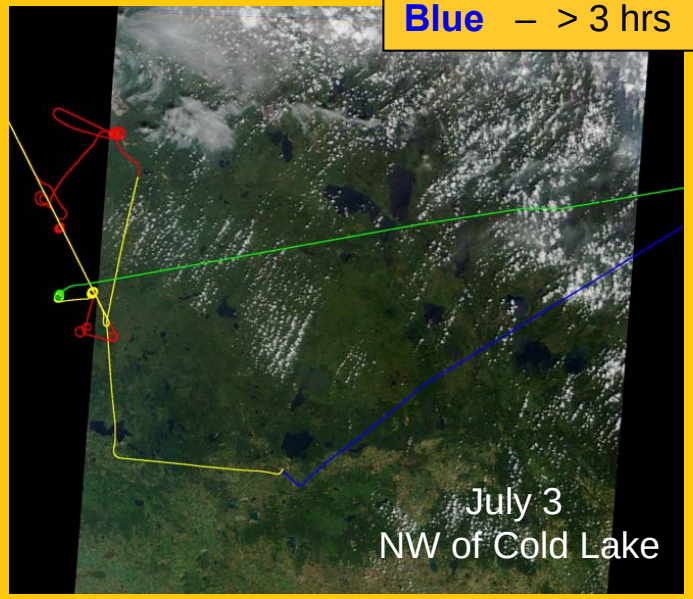
+ July 2 & July 9
Saskatchewan/Manitoba border

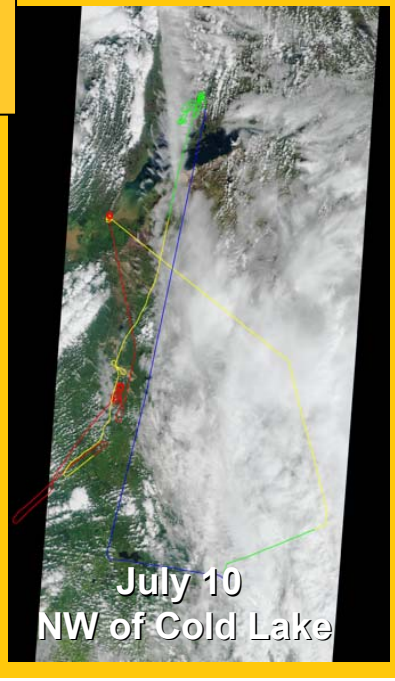




Red – within 1 hr
Yellow – within 2 hrs
Green – within 3 hrs
Blue – > 3 hrs







Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS)

A NASA contribution to IPY and the international POLARCAT initiative

http://cloud1.arc.nasa.gov/arctas

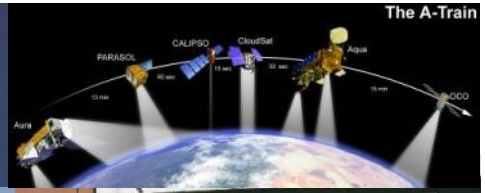
Conducted in spring and summer 2008 with the following foci:

1. **Long-range transport of pollution to the Arctic** (including arctic haze, tropospheric ozone, and persistent pollutants such as mercury)
2. **Boreal forest fires** (implications for atmospheric composition and climate)
3. **Aerosol radiative forcing** (from arctic haze, boreal fires, surface-deposited black carbon, and other perturbations)
4. **Chemical processes** (with focus on ozone, aerosols, mercury, and halogens)

April 2008: ***Fairbanks and Barrow, Alaska; Thule, Greenland***

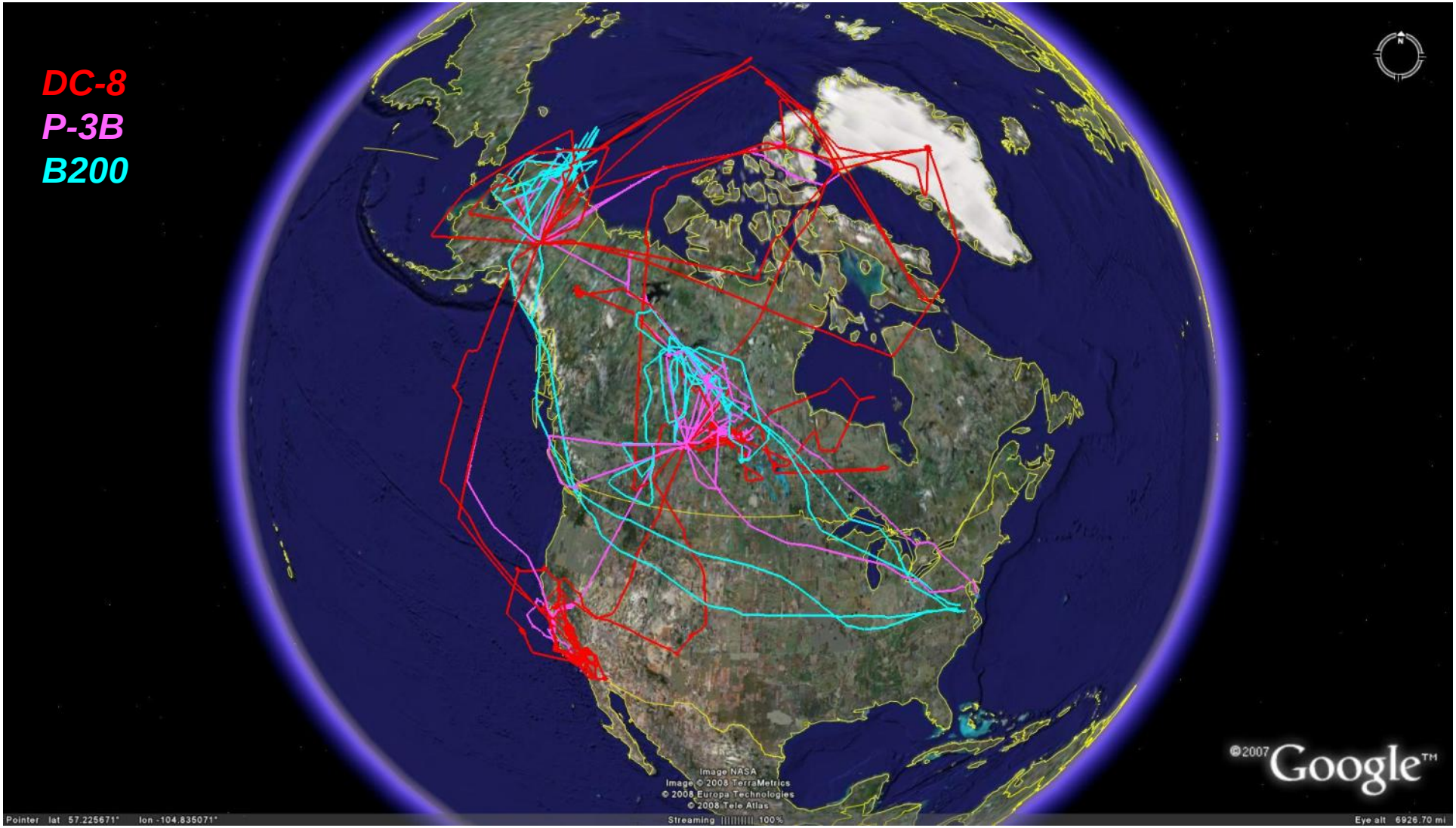
July 2008: ***Cold Lake, Alberta; Yellowknife, NW Territories***

Partners: ***NASA, NOAA, DOE, NSF, Canada, France, Germany***



Slide courtesy Jim Crawford, HQ Mgr TCP

	DC-8 (185 flight hours)	P-3B (158 flight hours)	B-200 (150 flight hours)
Spring (1-20 April)	9 sorties	8 sorties	27 sorties
California (18-24 July)	4 sorties	1 sortie	
Summer (26 Jun-13 July)	9 sorties	12 Sorties	21 Sorties



Aerosol-Radiation Connections in ARCTAS

Example Science Results

- 2 Spring Flights (of 8 P-3B)
- 2 Summer Flights (of 13 P-3B)

(See also other talks & posters)

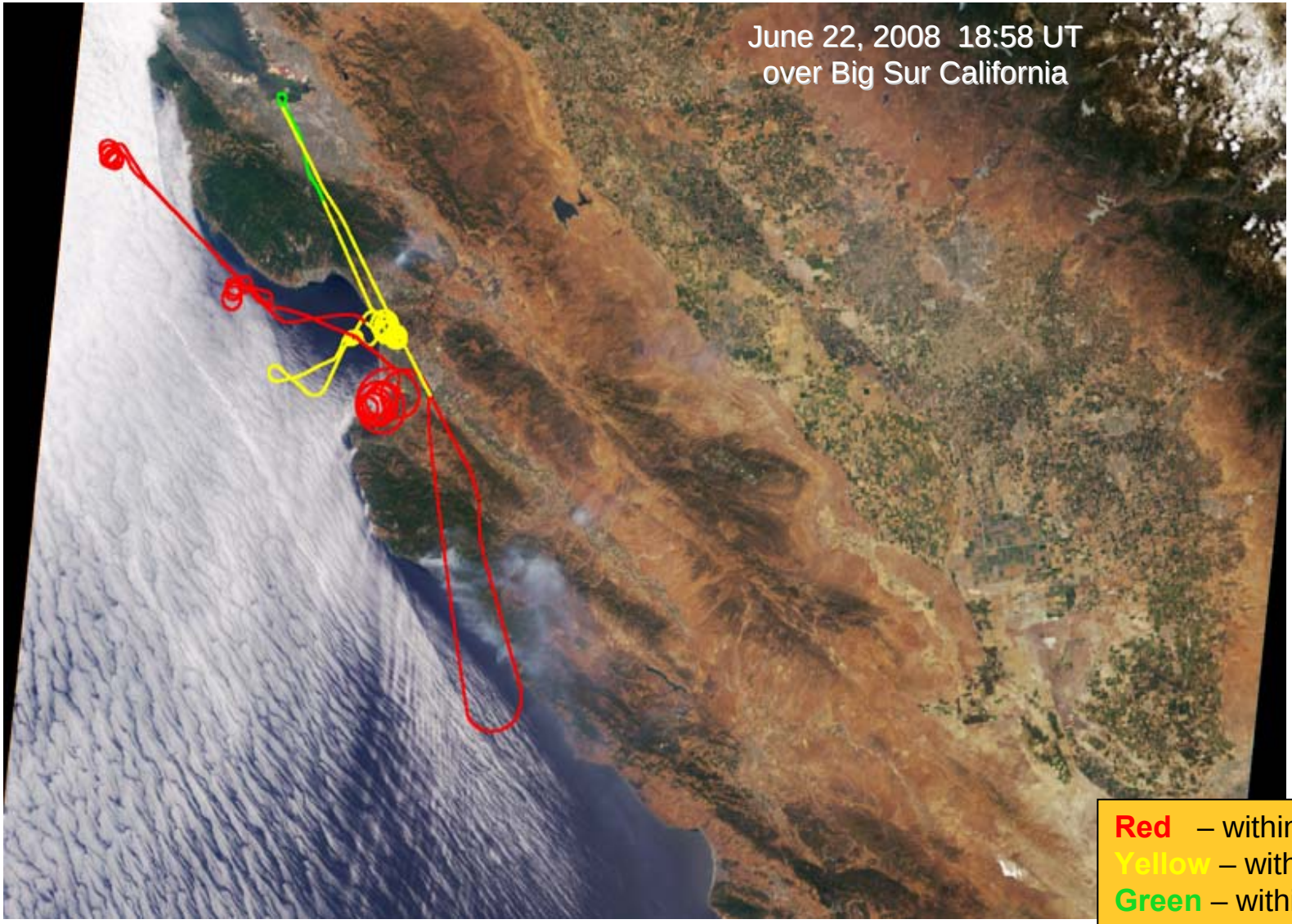
Aerosol-Radiation Connections in ARCTAS

Example Science Results

- 2 Spring Flights (of 8 P-3B)
- 2 Summer Flights (of 13 P-3B)

(See also other talks & posters)

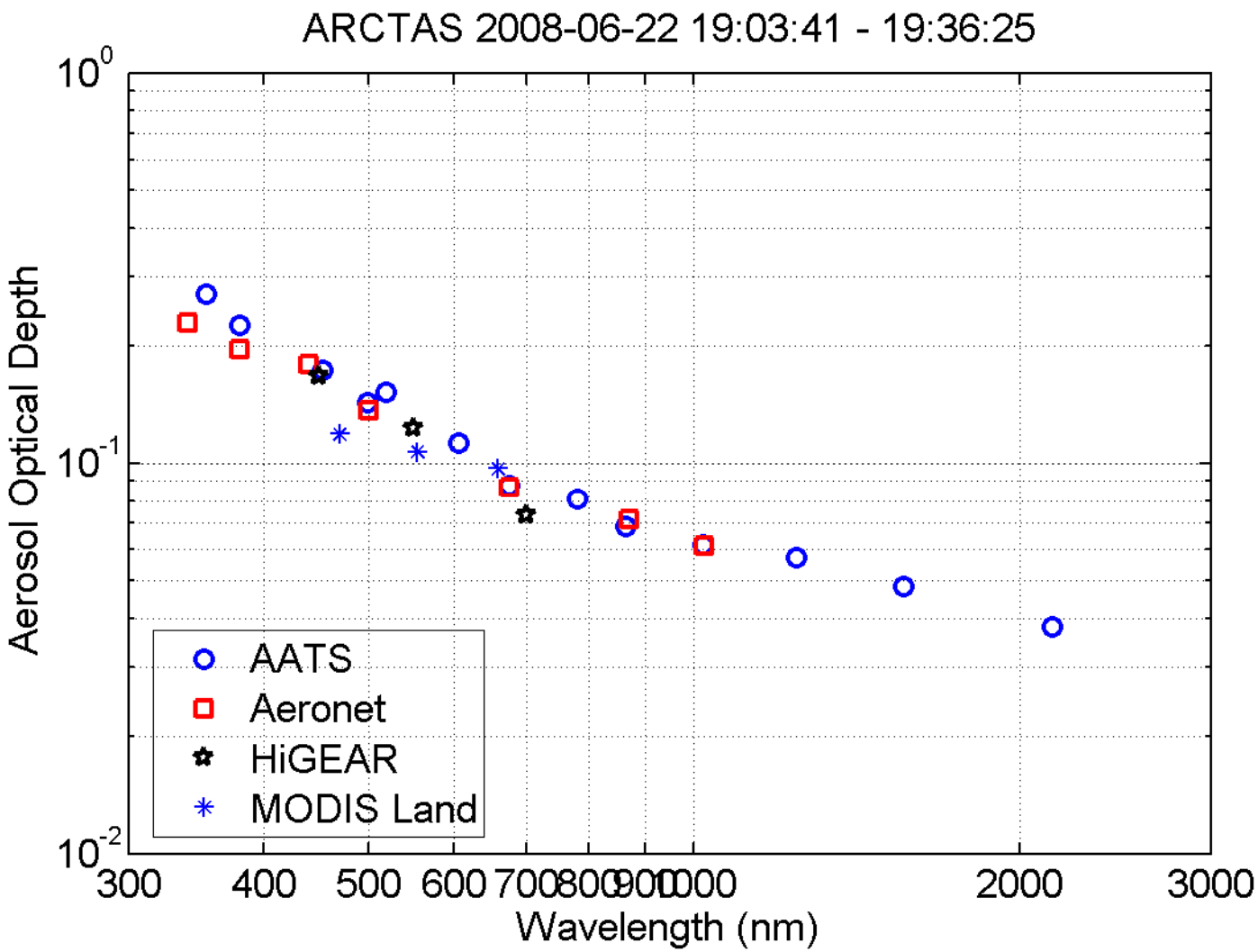
ARCTAS MISR w/P3 Trajectory – June 22, 2008



Red – within 1 hr
Yellow – within 2 hrs
Green – within 3 hrs
Blue – > 3 hrs

M. Davis and R. Kahn NASA/GSFC

•AATS, HiGEAR and AERONET agree within 10%+0.02. (good.)
•The 519 nm AATS AOD is higher than those at other wavelengths suggest. (this channel needs to be investigated.)

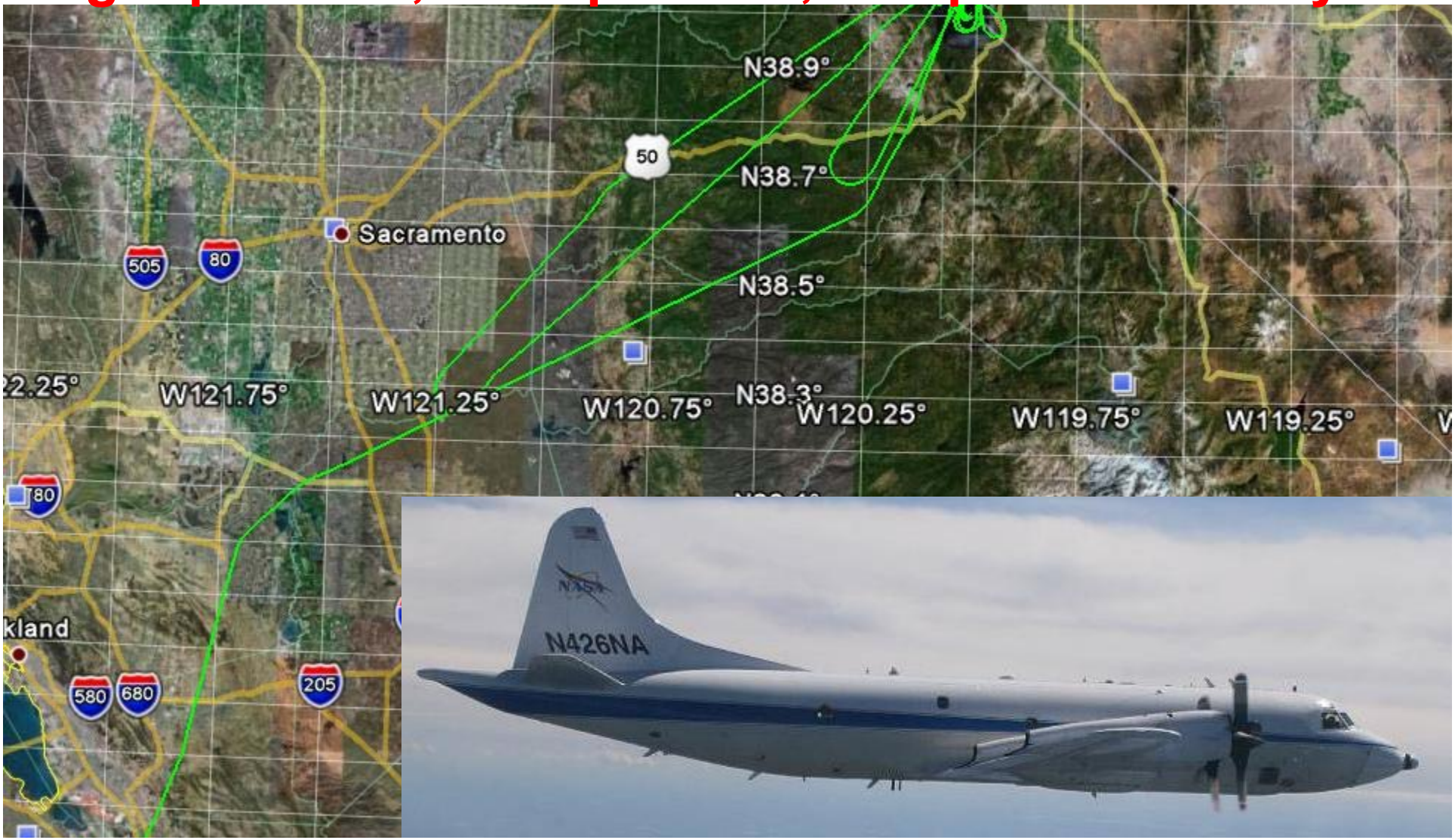


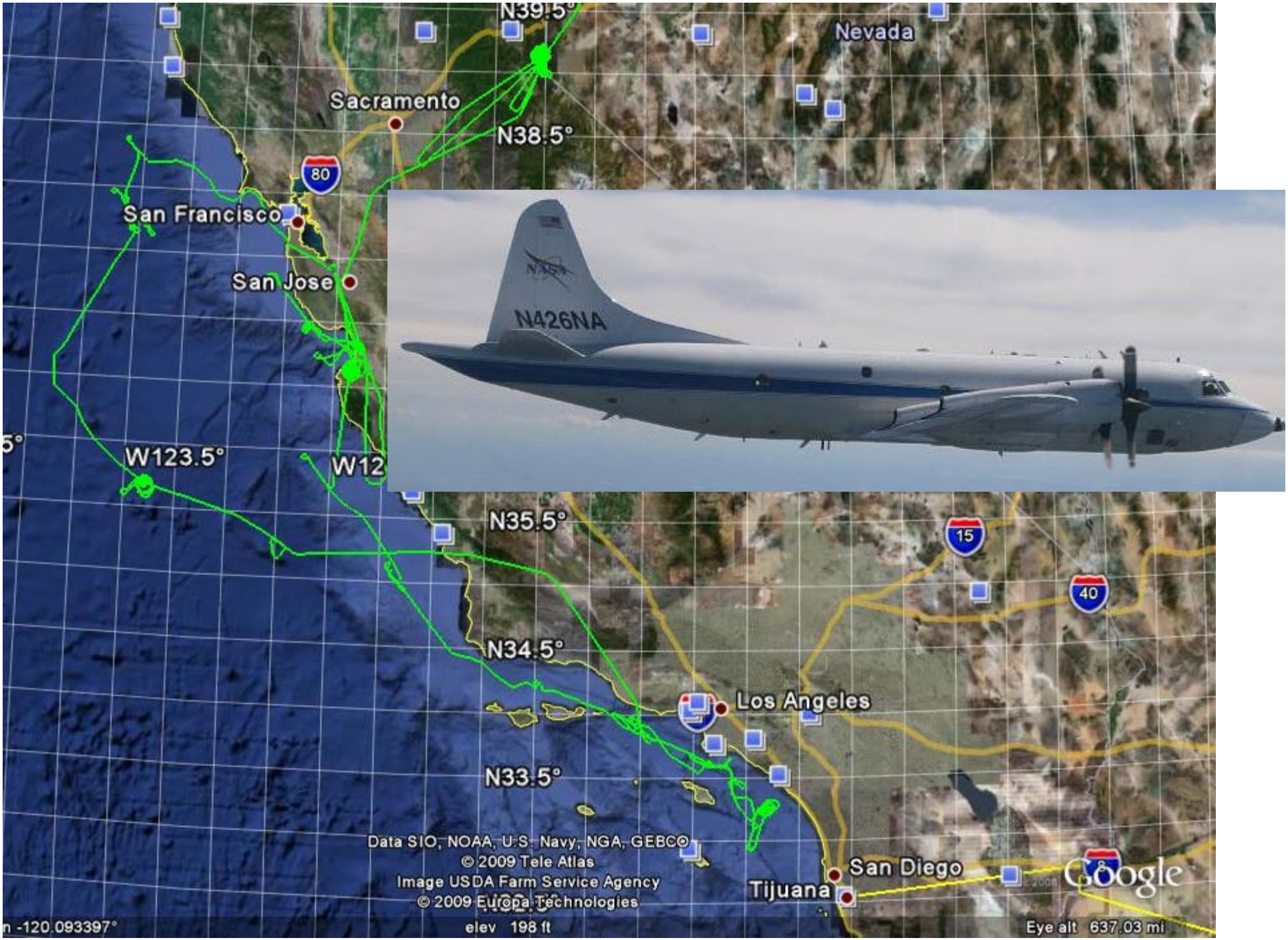
ASFlight11_20080622_190341_193625AeronetMontereyAATSd.fig, ASEurekaPearlAeronetcomparison.m, Yohei, 2009-06-23

N37.5°
San Jose
N37.3°
N37.1°
N36.9°
N36.7°
Salinas
W122.7°
W122.3°
W121.9°
W121.5°
N36.5°
N36.3°
N36.1°
N35.9°
N35.7°
Image © 2009 DigitalGlobe
© 2009 Tele Atlas
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Europa Technologies
elev 0 ft
N38.5°
5
N37.5°
San Jose
California
Fresno
N36.5°
W122.5°
W121.5°
W120.5°
W119.5°
W118.5°
N35.5°
N34.5°
N33.5°
Image © 2009 DigitalGlobe
© 2009 Tele Atlas
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Europa Technologies
elev 1215 ft

California P-3B measurements during ARCTAS-CARB:

Flight patterns, example data, and potential analyses




N39.5°
Nevada
Sacramento
N38.5°
80
San Francisco
San Jose
N426NA
W123.5°
W12
N35.5°
15
40
N34.5°
Los Angeles
N33.5°
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2009 Tele Atlas
Image USDA Farm Service Agency
© 2009 Europa Technologies
San Diego
Tijuana
Google
-120.093397°
elev 198 ft
Eye alt 637.03 mi