National Aeronautics and Space Administration

Ames

Discovery Innovations Solutions

Determination of Aerosol Properties and Airmass Types Based on Sky Radiance and Solar Direct-Beam Measurements during SEAC^{4}RS

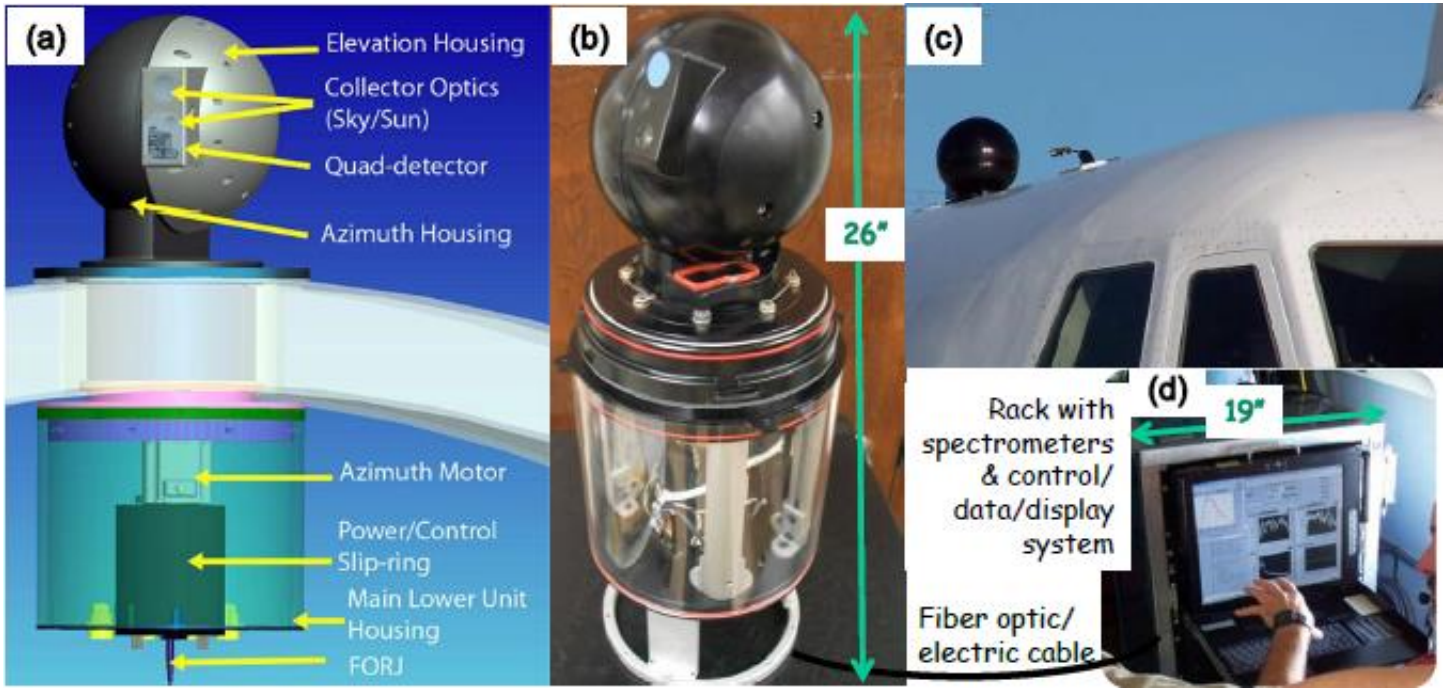
J. Redemann, C. J. Flynn, Y. Shinozuka, P. B. Russell, M. Kacenelenbogen, M. Segal-Rosenheimer, J. M. Livingston, B. Schmid, S. LeBlanc, S. Schmidt, S. E. Dunagan, R. R. Johnson

4STAR: a collaborative research effort between NASA Ames, PNNL and NASA Goddard

Contents:

1) **Overview of 4STAR**
2) **4STAR operating modes**
3) **Big picture: 4STAR sky radiance measurements and relation to AERONET**
4) **Examples of 4STAR sky radiance measurements in SEAC4RS**
5) **Example sky radiance aerosol retrievals**
6) **Use of sky radiance measurements for aerosol and airmass type classification**
7) **Outlook for future work**

4STAR: SPECTROMETER FOR SKY-SCANNING, SUN-TRACKING ATMOSPHERIC RESEARCH



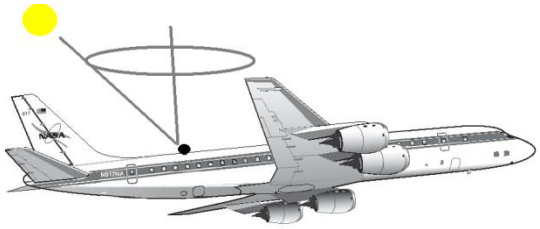
(a) Design for 4STAR tracking/scanning head and can.
(b) Head and can as built.
(c) 4STAR head on G-1 aircraft. (d) Rack and contents flying on G-1.

4STAR: SPECTROMETER FOR SKY-SCANNING, SUN-TRACKING ATMOSPHERIC RESEARCH - **OPERATING MODES**

Direct sun tracking:

- **AOD** at 100s of wavelength, **Angstrom exponent**
- aerosol extinction profiles
- **O_3**, **NO_2** and **CWV** (demonstrated); CO_2, CH_4, OH, Formaldehyde (desired)
- Thin cirrus cloud properties

See poster by Michal Segal-Rosenheimer in session 2

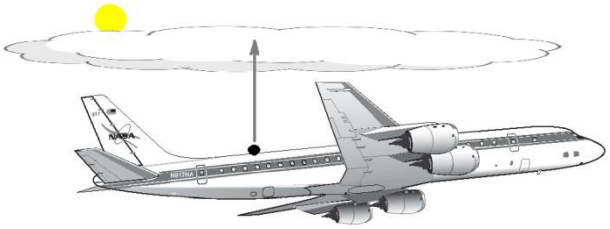


Sky scanning:

Almucantar and Principal plane

- **Sky Radiances**
- AERONET-like aerosol size distribution, index of refraction, SSA, asymmetry factor, sphericity*

This talk



Zenith viewing:

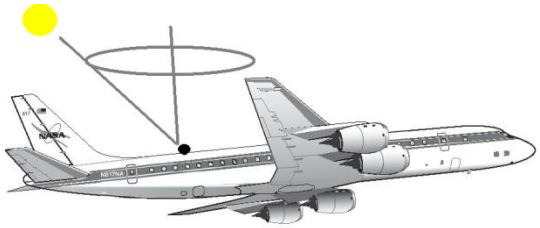
- Cloud property retrievals (**COD, cloud droplet effective radius**)*

* With SSFR measurements

3863 mins (screened)	64 sky scans	327 mins

4STAR: SPECTROMETER FOR SKY-SCANNING, SUN-TRACKING ATMOSPHERIC RESEARCH - **OPERATING MODES**

Direct sun tracking



Sky scanning

Direct-beam and sky scan retrievals can be combined to classify airmass and particle type

Input parameters for our two clustering techniques: aerosol- and plume-type.

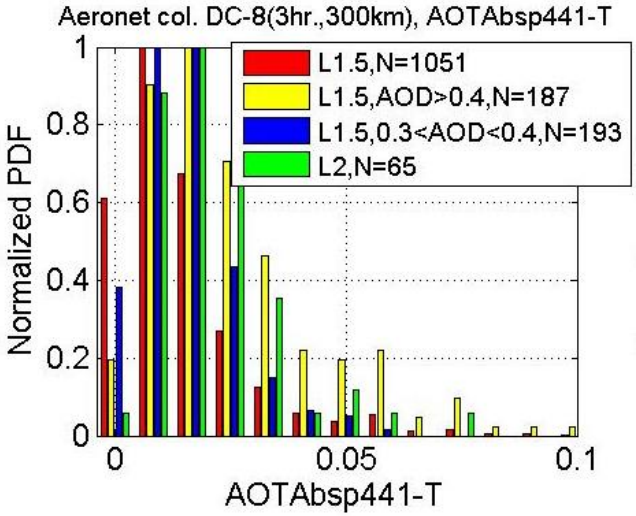
	$EAE_{491,863}$	SSA_{491}	$dSSA_{863-491}$ (=SSA_{863}-SSA_{491})	RRI_{670}	O_3	NO_2	H_2O
*Aerosol type	+	+	+	+			
Plume type	+[1]	+[2]			+	+	+

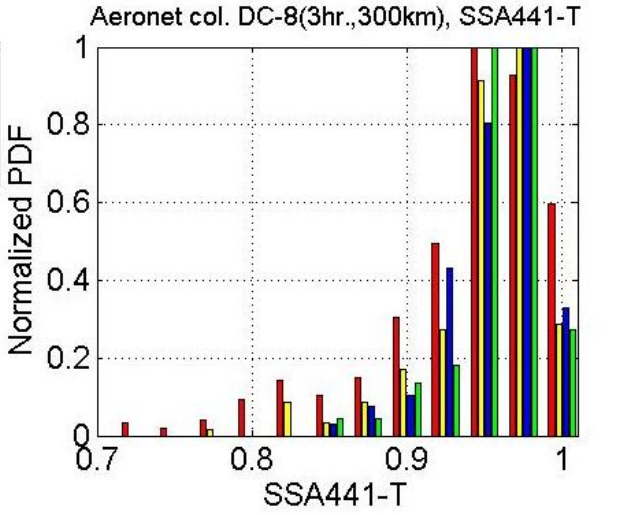
*other parameters that might be used include: IRI_{670}, $AAE_{491,863}$, Vol_f/Vol_t, %Spheres

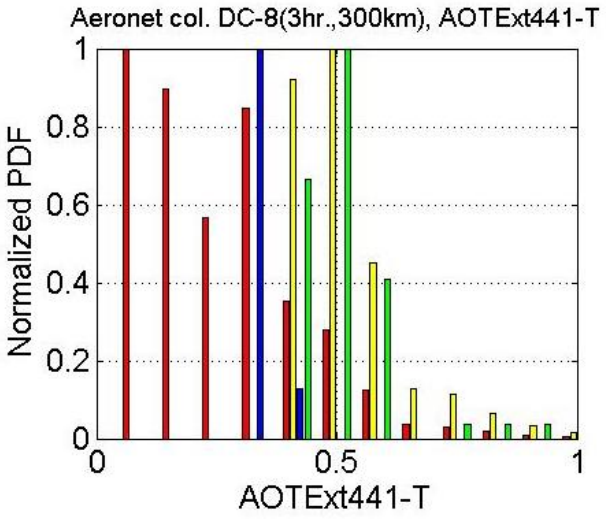
1 – wavelength dependence EAE is used (i.e. 400-1600 nm)

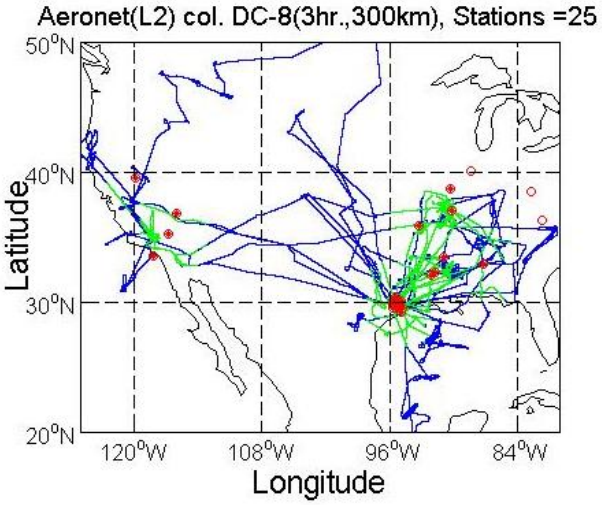
2 – potential use in the future

AERONET obs of aerosol microphysics → scarcity of L2 retrievals coincident with the DC-8 → need for 4STAR obs



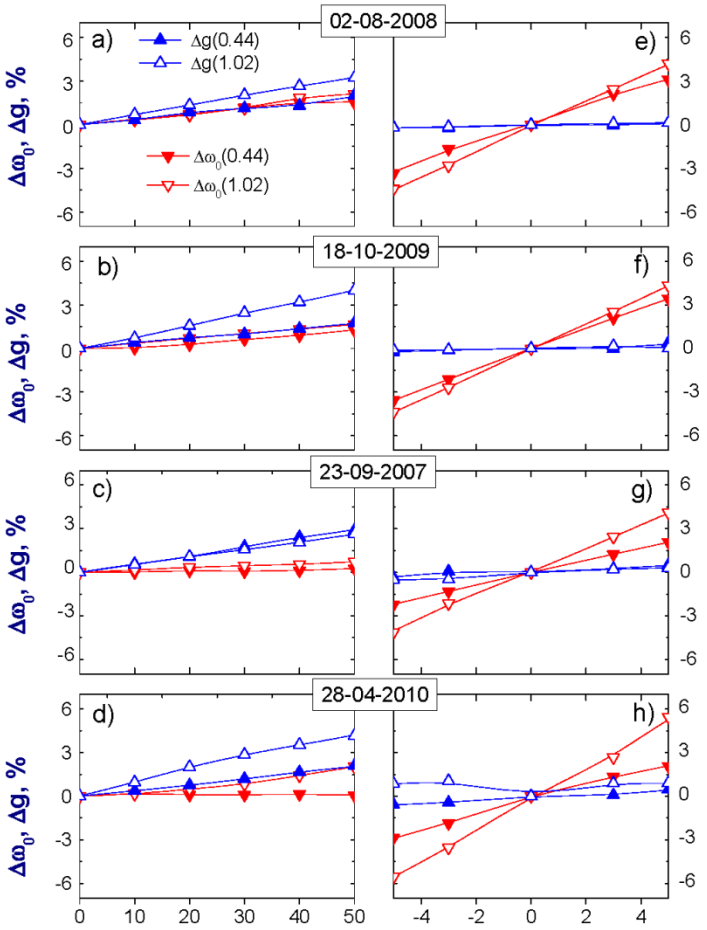






AERONET microphysics retrievals during SEAC^{4}RS:

- L2 retrievals require AOD>0.4 and symmetry of almucantar sky scans
- 3 times as many L1.5 with 0.3<AOD<0.4 as L2 retrievals
- Secondary peak in ssa between 0.8 and 0.9 in those L1.5 retrievals
- Can AERONET data set be extended?



Near-sun radiance enhancement [%]

Calibration radiance off-set [%]

Previous sensitivity studies with 4STAR sky radiance retrievals

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Article

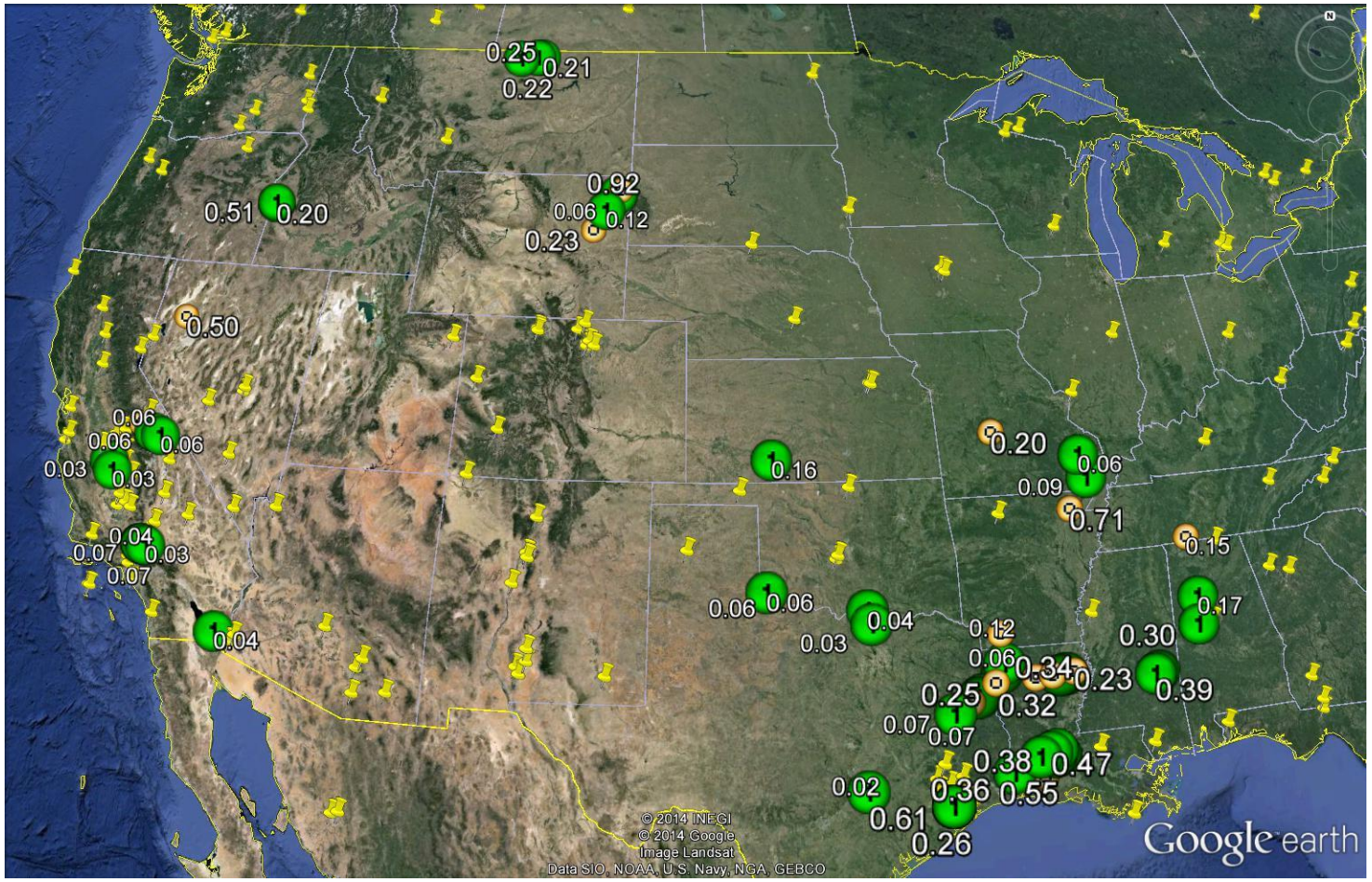
Initial Assessment of the Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR)-Based Aerosol Retrieval: Sensitivity Study

Evgueni Kassianov [1,*], Connor Flynn [1], Jens Redemann [2], Beat Schmid [1], Philip B. Russell [3] and Alexander Sinyuk [4]

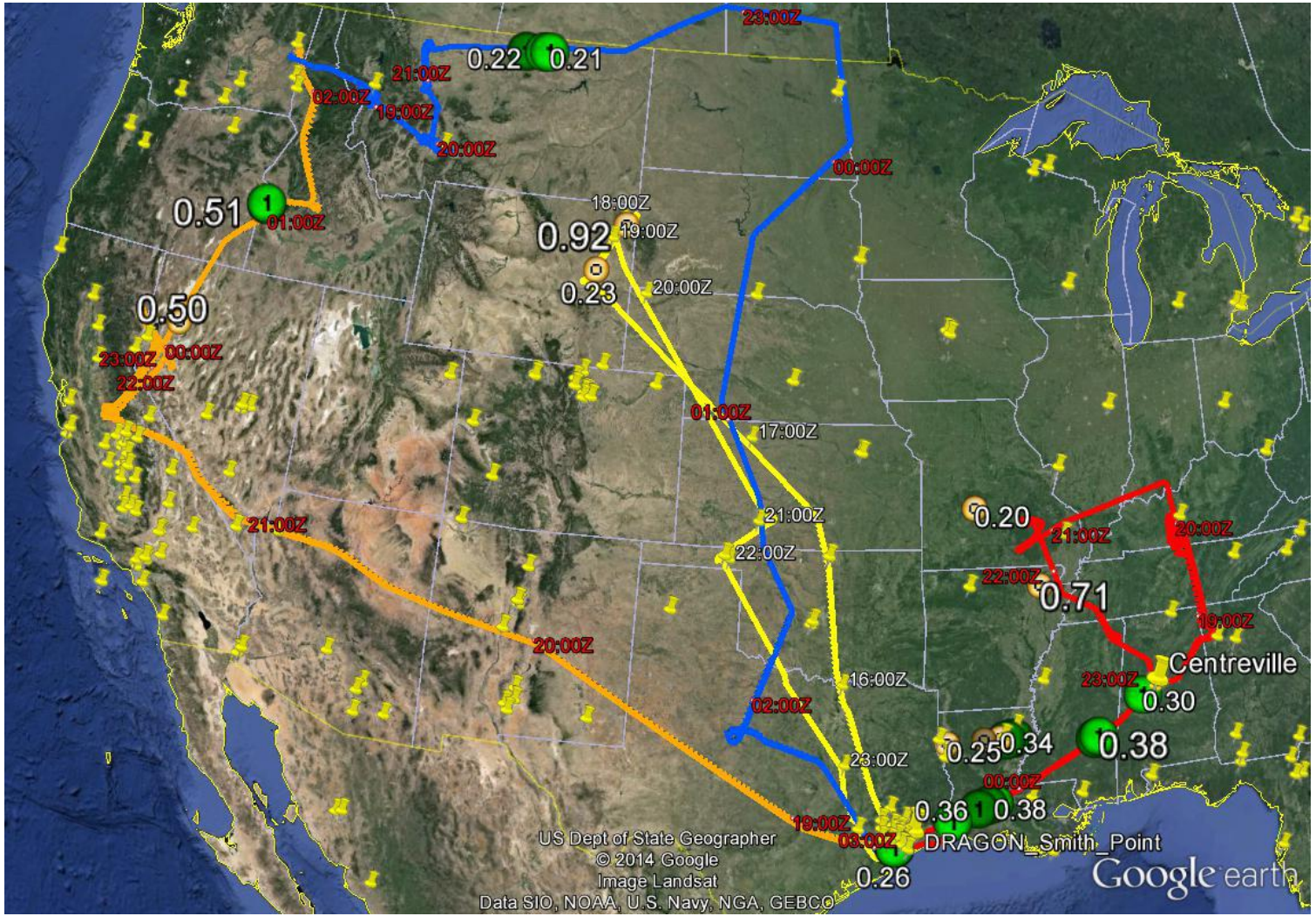
4STAR observations to support specific SEAC4RS objectives

Date	NAM/ convection	Cirrus	SEUS chem.	Industrial	Biogenic	Smoke	Air Quality/ Pollution	Sky scans	Cloud mode
Aug 2		+				+			
Aug 5								1	
Aug 6		+				+	+	2	
Aug 8	+	+				+	+	3	
Aug 12			+		+			2	?
Aug 14		+	+			+		1	+
Aug 16	+			+		+	+	2	
Aug 19						+		5	
Aug 21		+	+			+		2	+
Aug 23			+					2	+
Aug 26						+		2	
Aug 27	+					+		3	
Aug 30			+		+		+	7	+
Sep 2	+							2	+
Sep 4	+								+
Sep 6	+	+	+		+			1	
Sep 9			+			+		6	
Sep 11			+		+	+	+	1	
Sep 13	+	+							+
Sep 16		+	+		+	+	+		+
Sep 18									
Sep 21									
Sep23			+	+	+	+	+		+
	7	8	10	2	6	13	7	42	

Availability of 4STAR sky radiance measurements (numbers represent 4STAR AOD at 440nm)

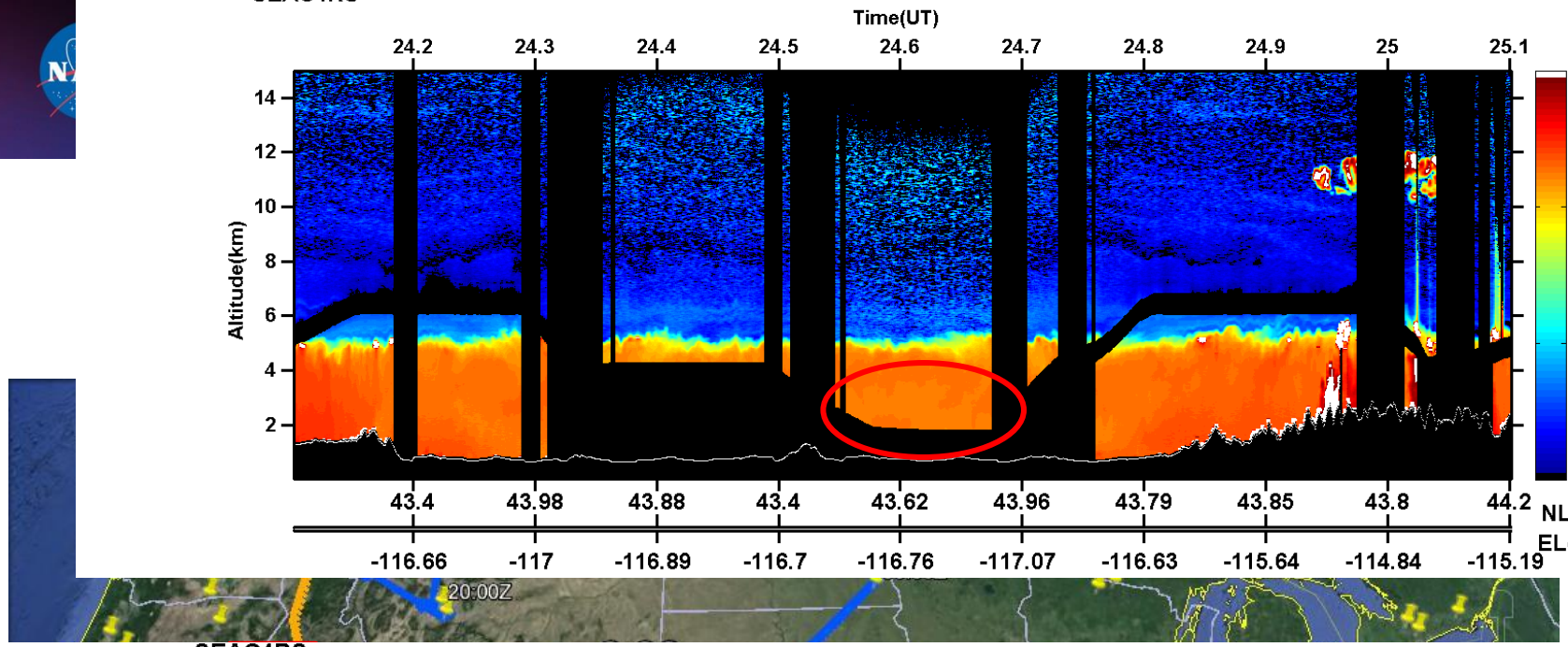


Availability of 4STAR sky radiance measurements (numbers represent 4STAR AOD at 440nm)



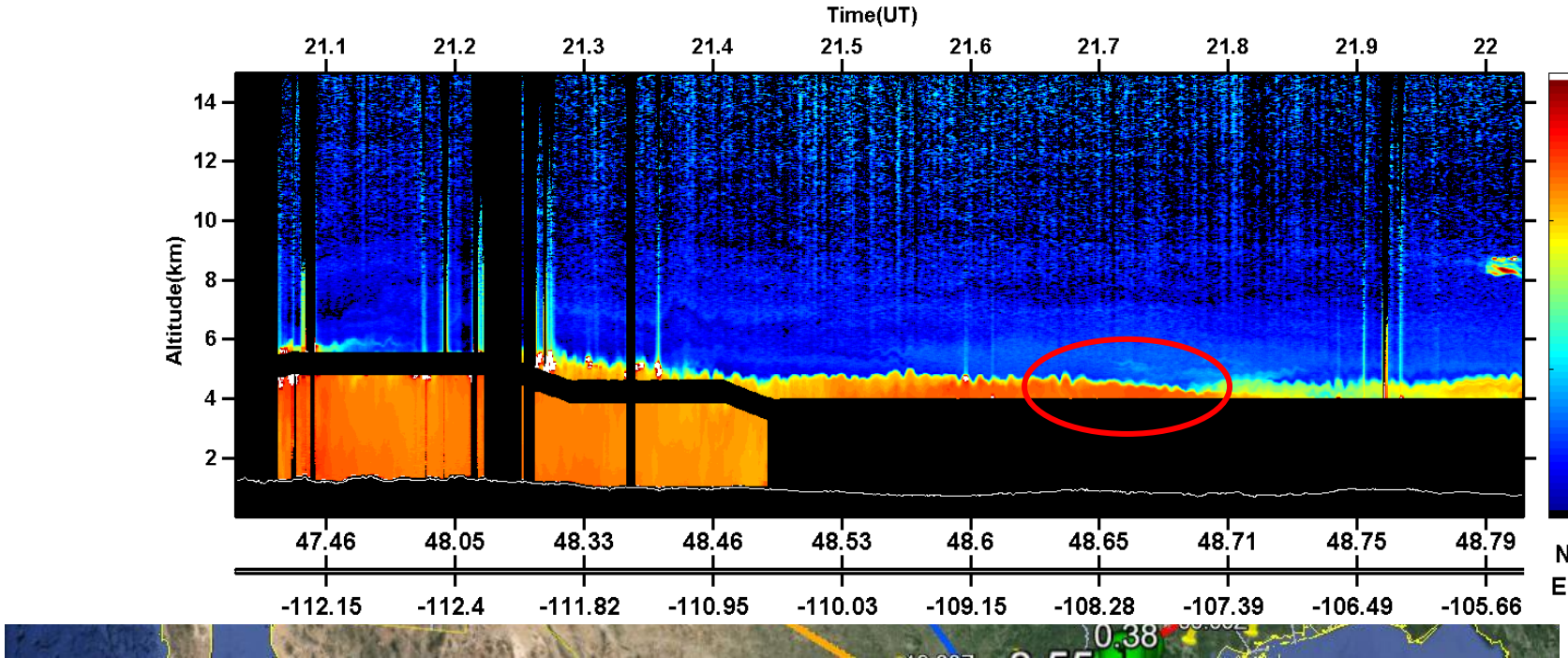
SEAC4RS

20130826



SEAC4RS

20130827



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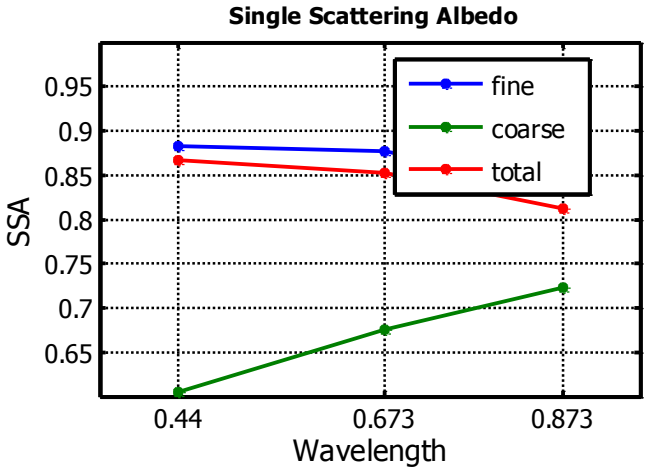

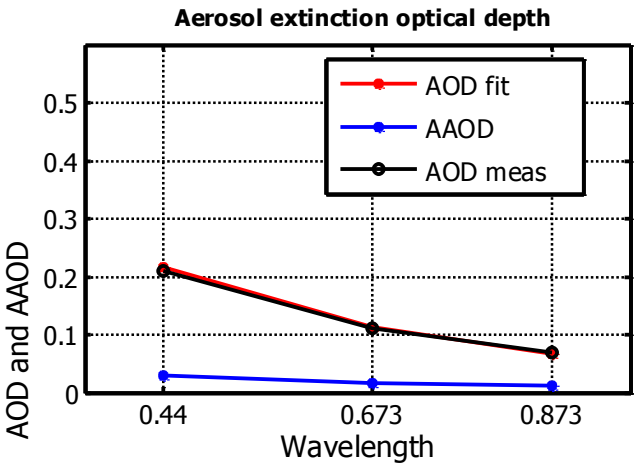

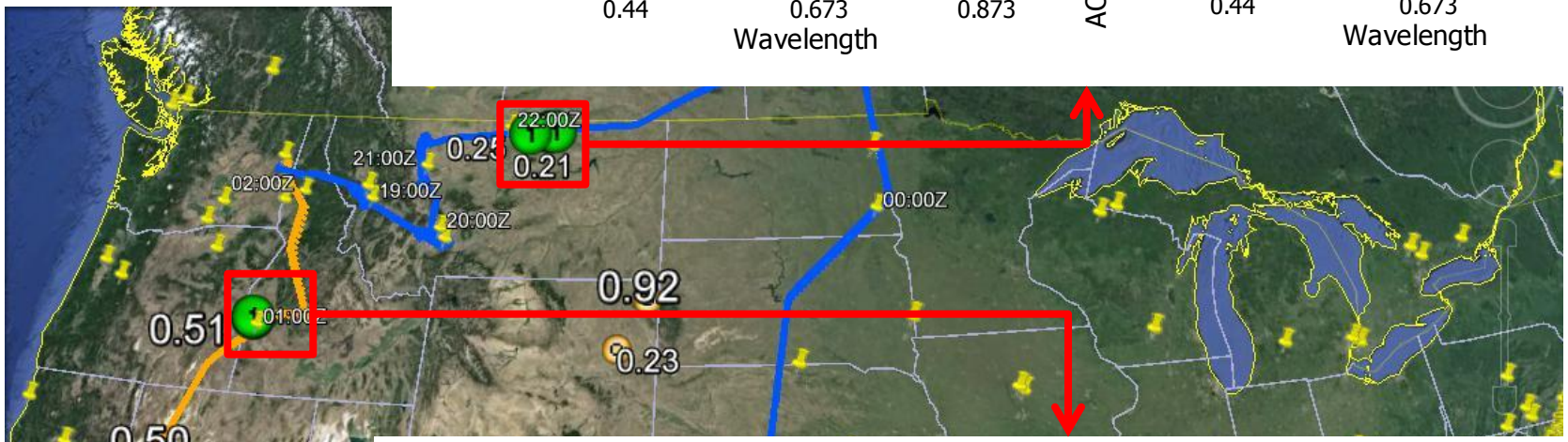

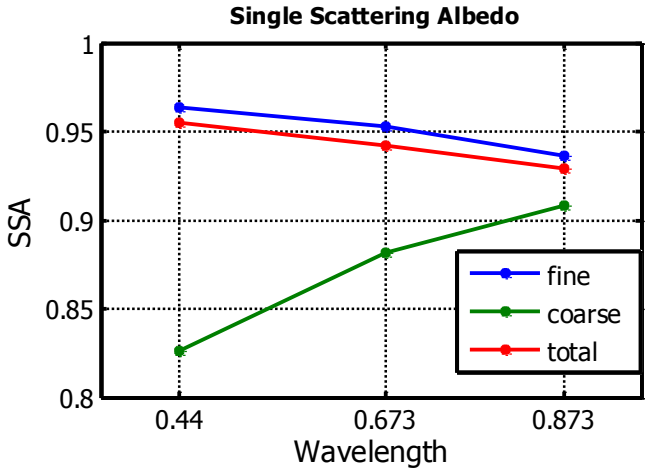

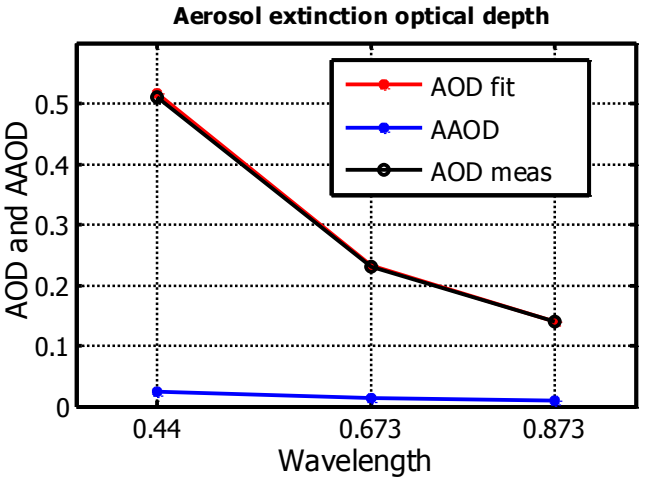

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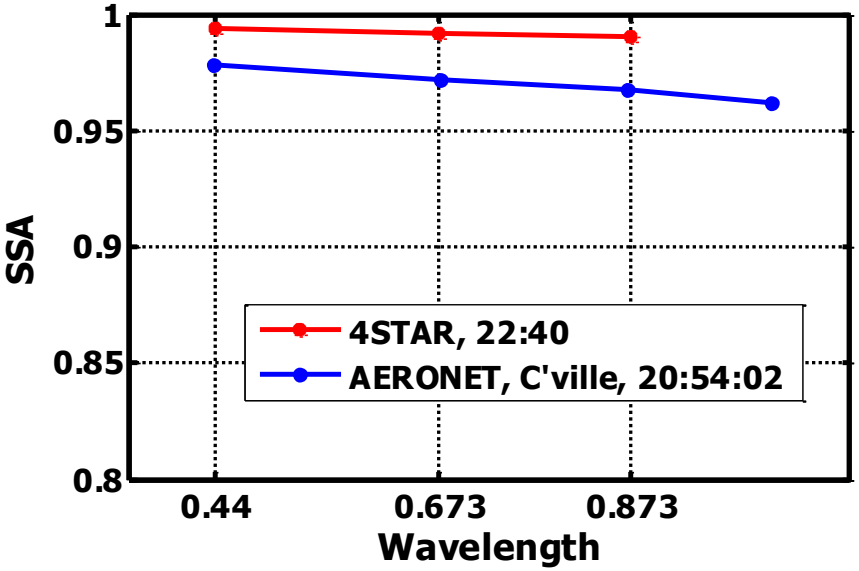
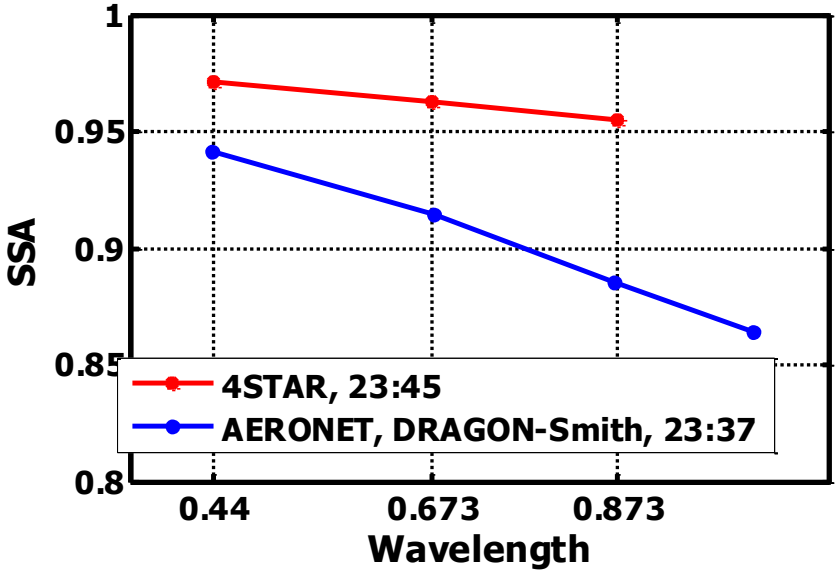
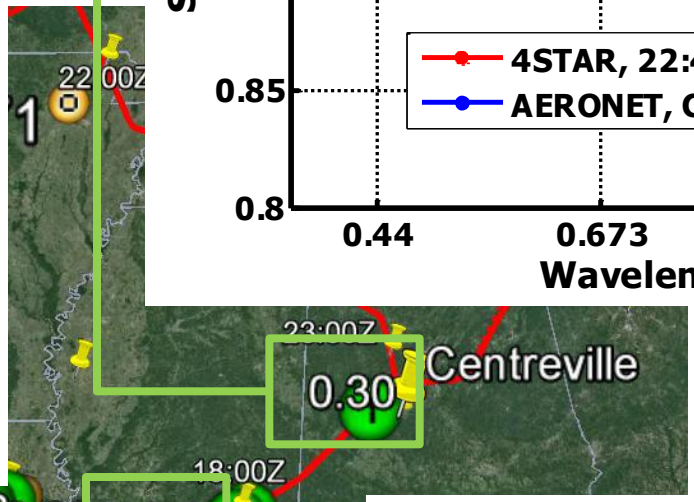
Discovery Innovations

4STAR sky scan: 20130830_124_SKYA
Single Scattering Albedo

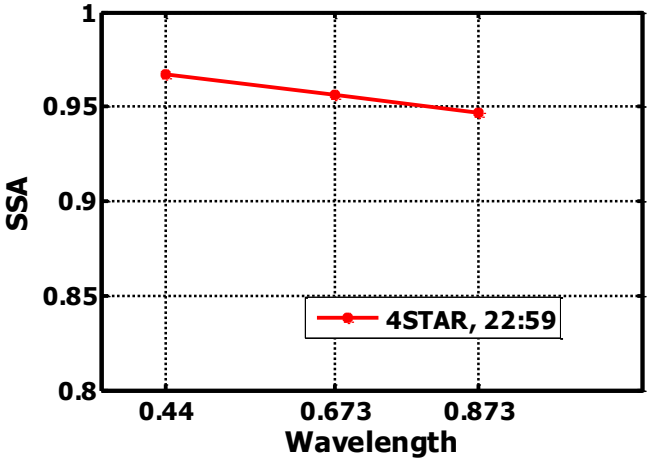


4STAR sky scan: 20130830_139_SKYA
Single Scattering Albedo

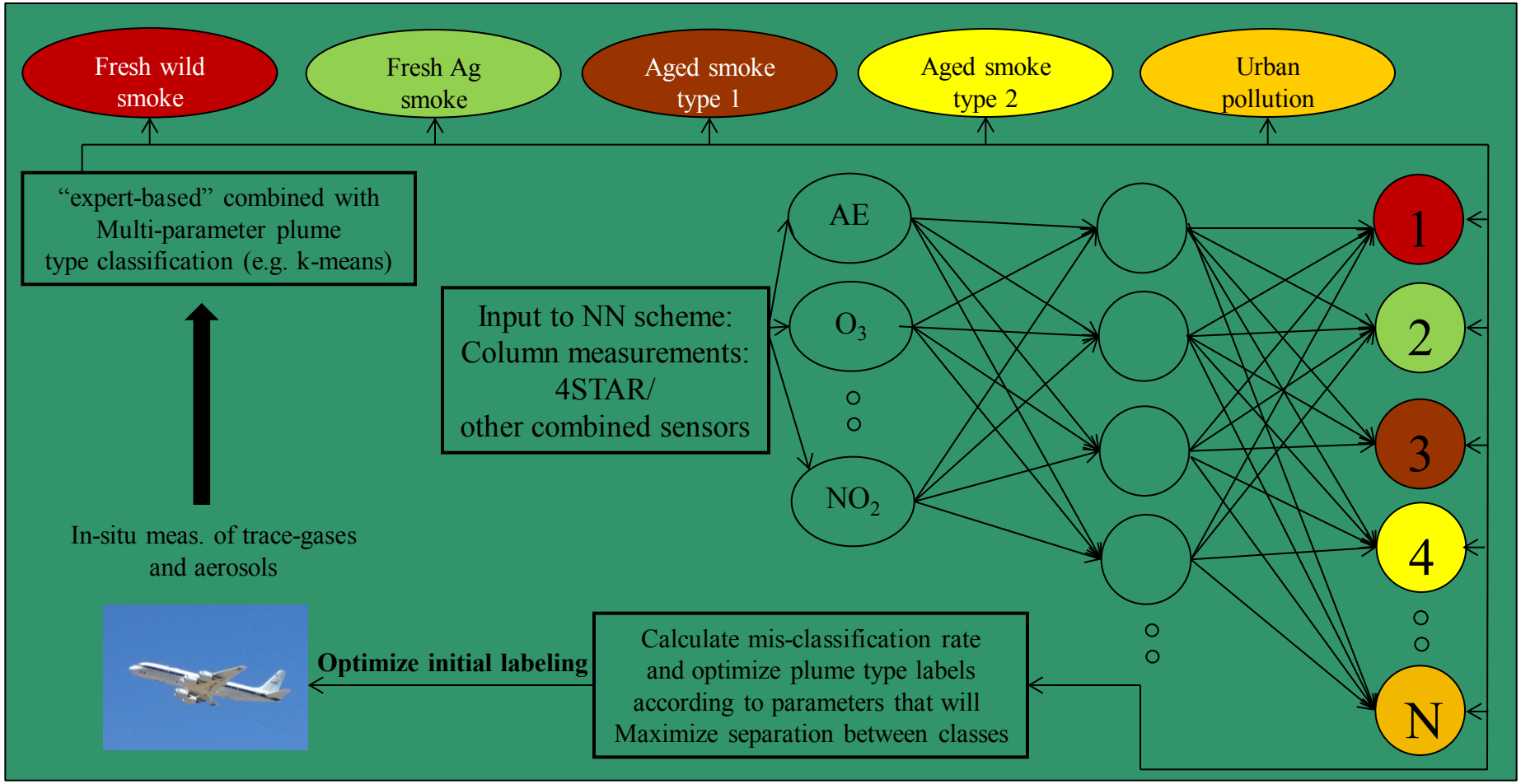




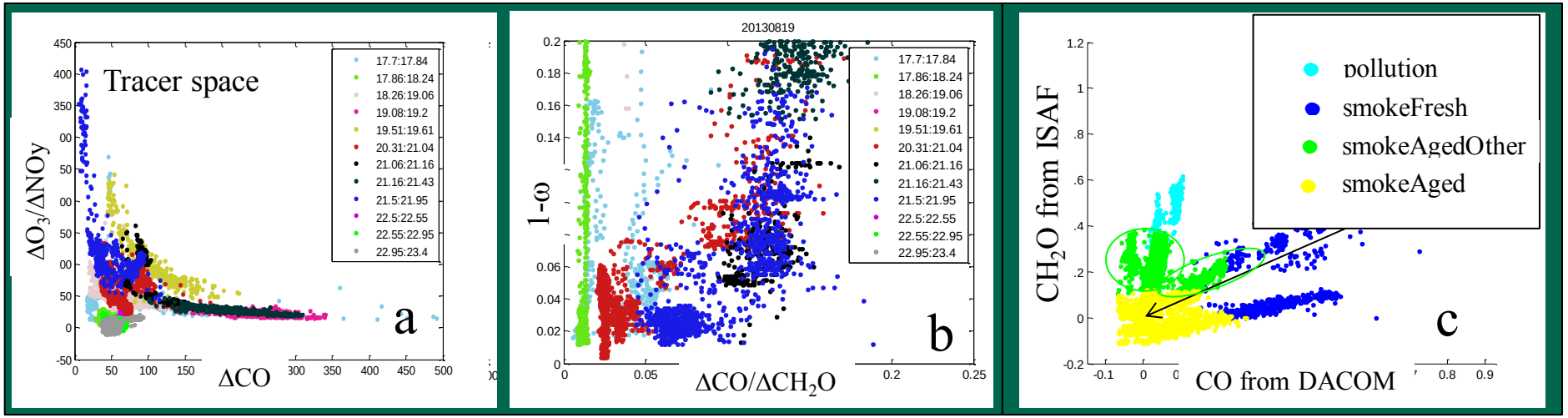
4STAR sky scan: 20130830_127_SKYA
Single Scattering Albedo

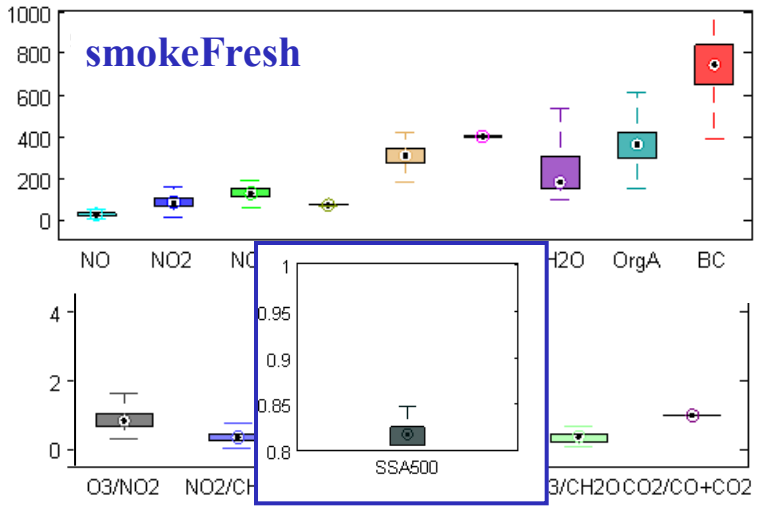


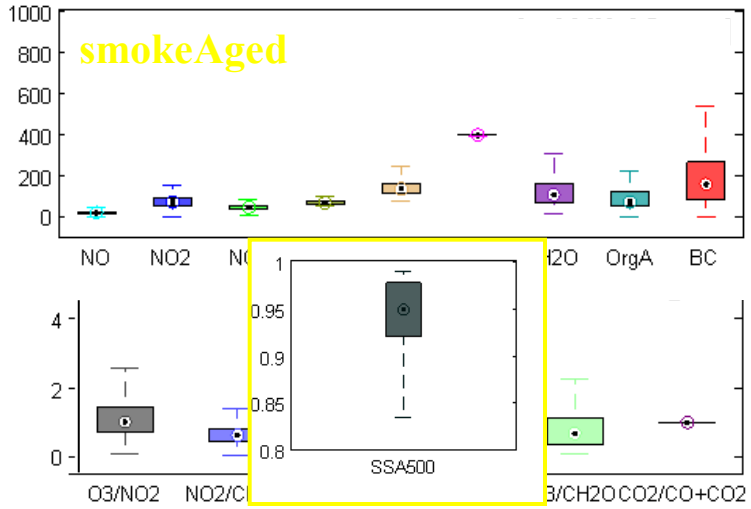
Utilization of 4STAR/other combined aerosol and gas space-borne sensors (e.g. OMI/GEO-CAPE,GEMS) to infer airmass type classification



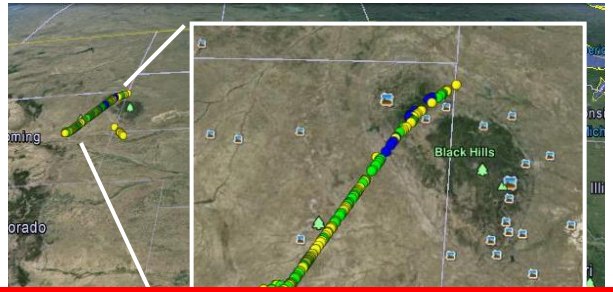
Example of how *in-situ* plume type characterization are made (Aug-19 flight case study)

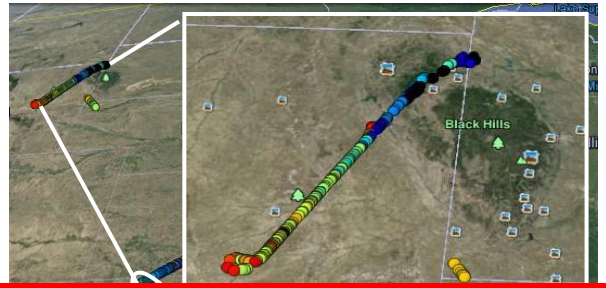


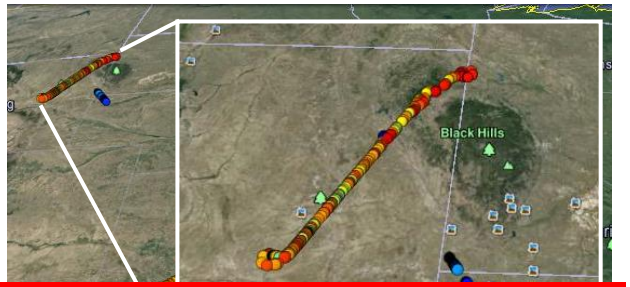




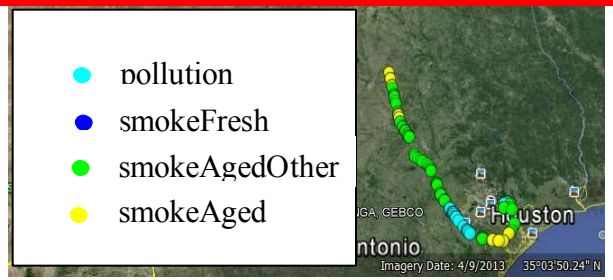
Example of how aerosol and gas column measurements correspond with *in-situ* plume type characterization and what are possible pitfalls (Aug-19 flight case study)







I am interested in making use of the SEAC4RS *in-situ* data to come up with a unified/rigorous method to improve plume type labeling (e.g. add CH_3CN, HCN as BB tracers and isoprene as biogenic) that will be relevant for air pollution and radiative budget studies and would appreciate contribution from *in-situ* PI's and others

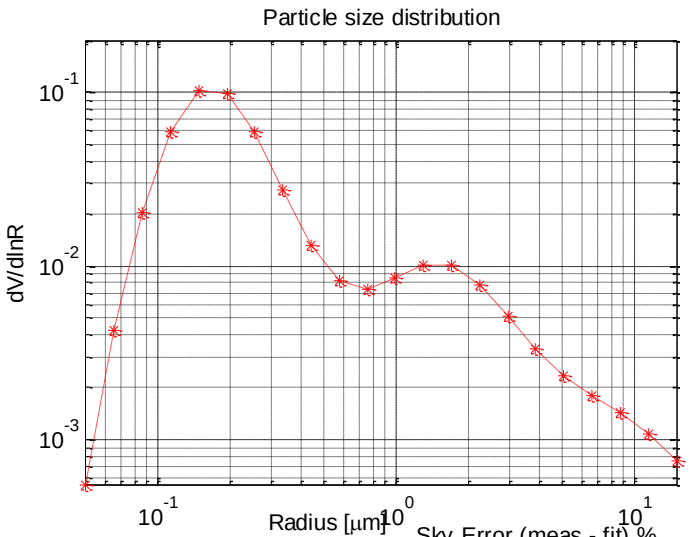


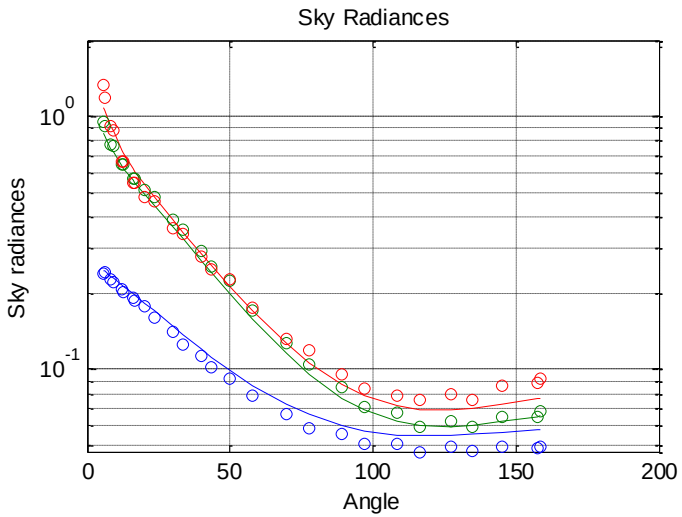
Preliminary results using the above scheme with inputs for column measurements is shown for 8 plume types during SEAC^{4}RS (poster by Segal-Rosenheimer et al.)

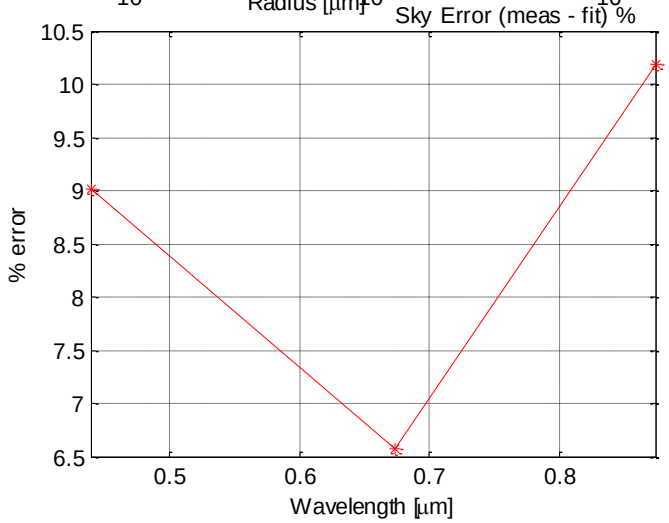
Future work with SEAC^{4}RS 4STAR sky radiance data:

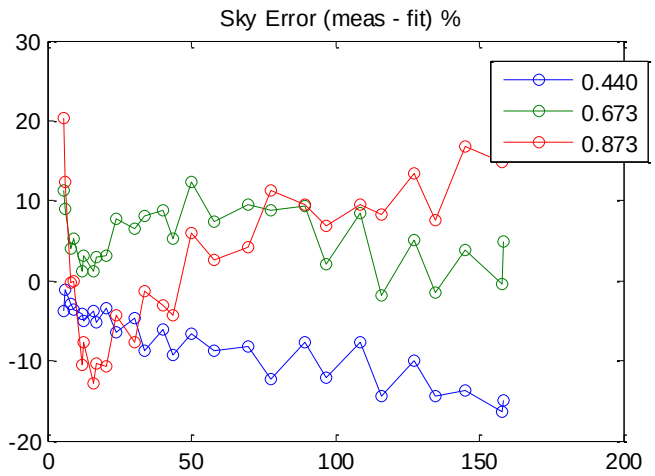
1) Evaluate the 3-way consistency between sky radiances measured by 4STAR, modeled based on airborne in situ observations, and measured by ground-based AERONET Cimel sunphotometers for all suitable cases in the SEAC4RS field campaign.
2) Compare the 4STAR- and AERONET-derived L2 (high AOD) aerosol particle properties with airborne in situ measurements.
3) Use clustering analyses previously developed in our group to combine AERONET observations (AOD, AE, AAOD, Absorption AE, refractive index) and 4STAR data (same as AERONET, plus column trace gas retrievals) to determine aerosol type and airmass characteristics.
4) Investigate the validity of AERONET L1.5 aerosol retrievals as a function of aerosol loading and particle type to assess whether the global AERONET data set may be extended to fill in some of the sampling gaps for specific aerosol or airmass types.

4STAR sky scan: 20130830_139_SKYA









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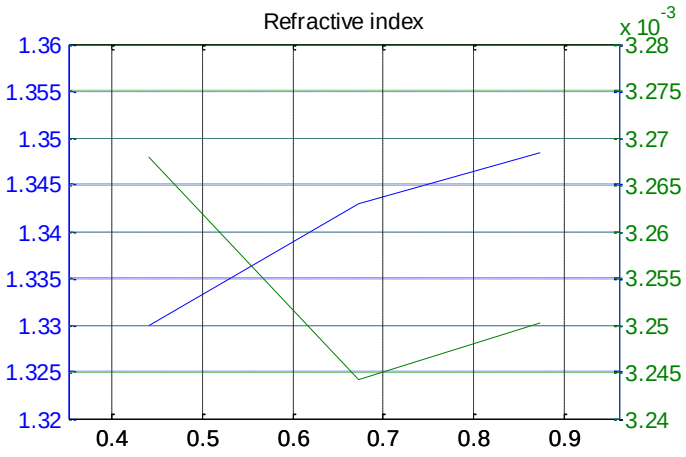
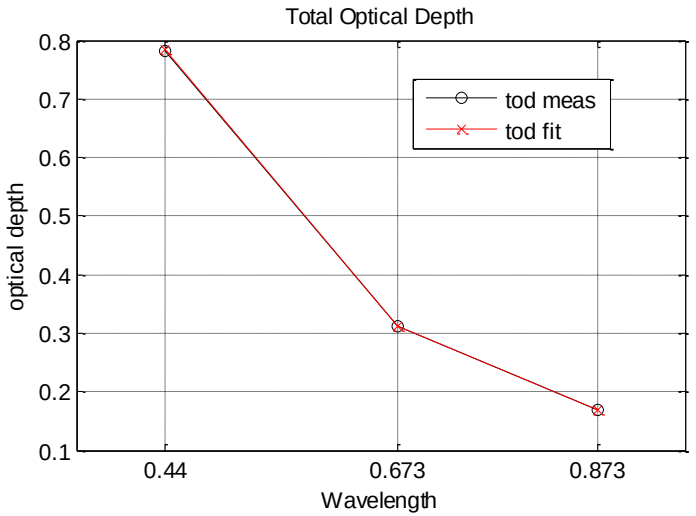
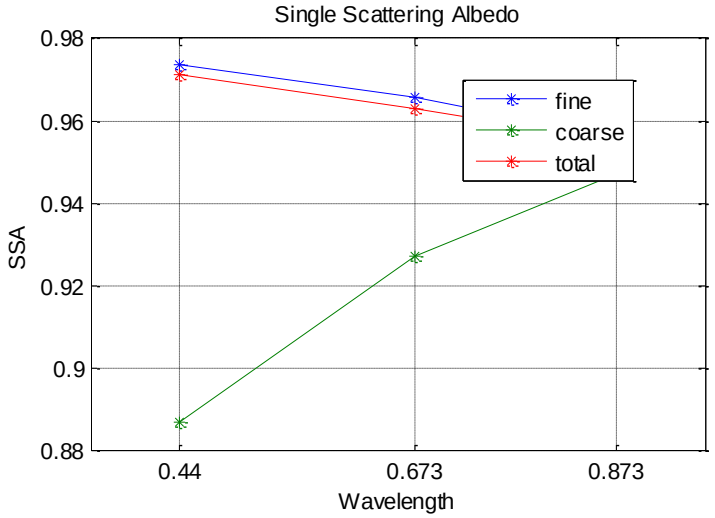
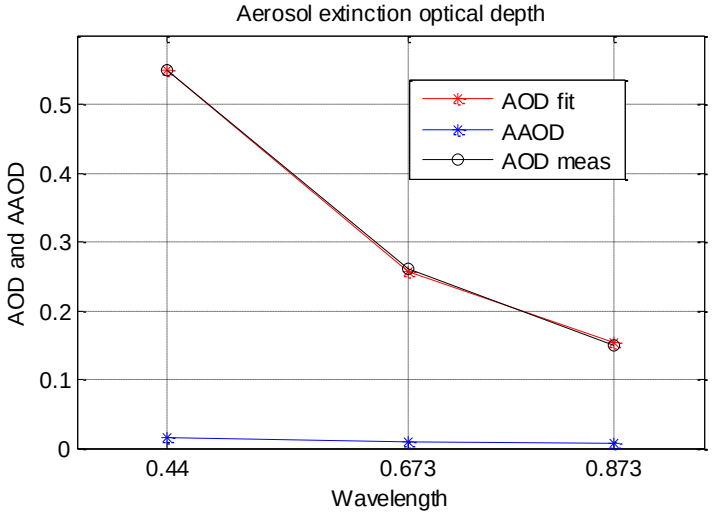
4STAR sky scan: 20130830_139_SKYA









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