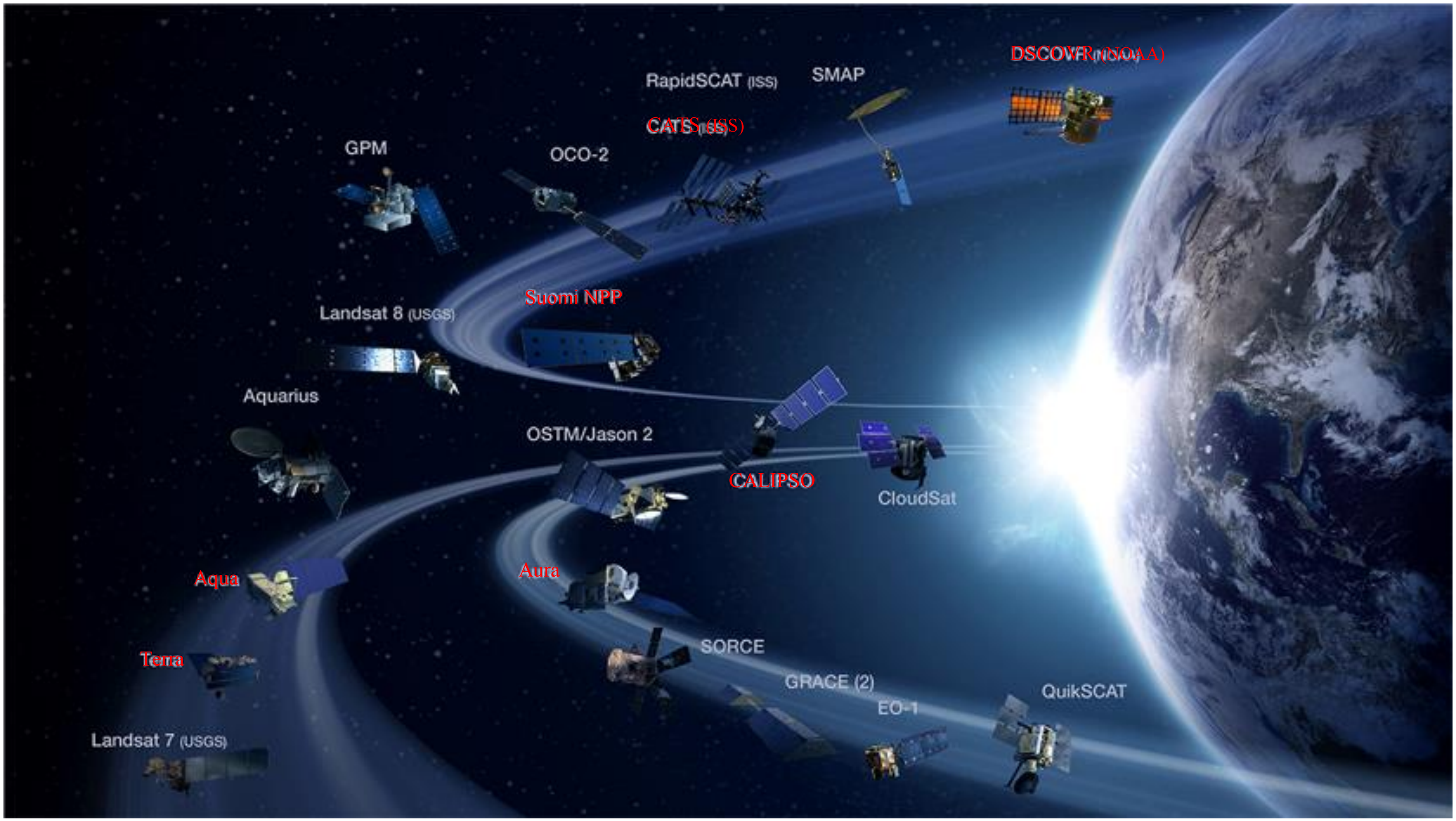
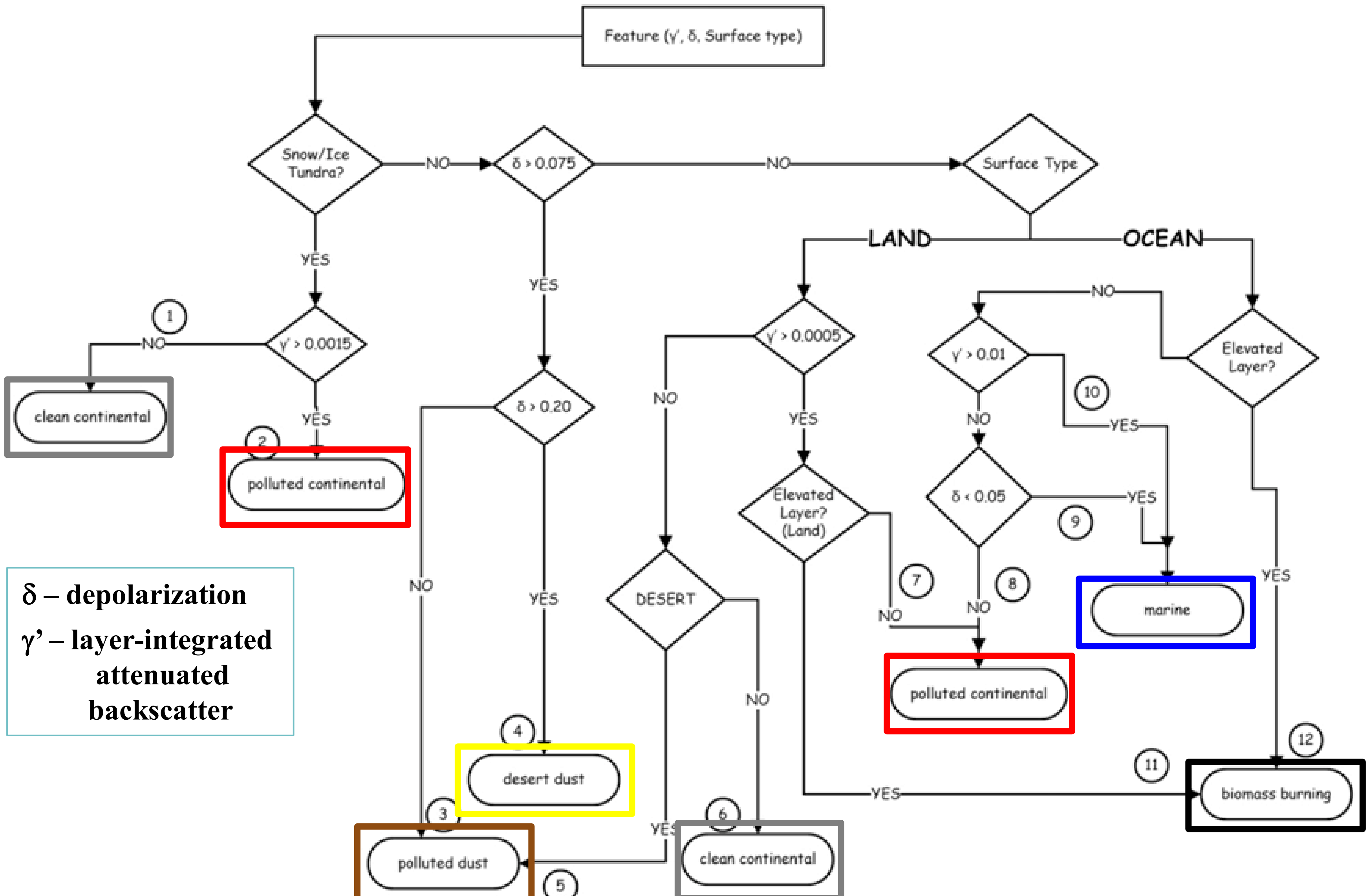
Mapping Aerosols Properties Globally

Ralph Kahn
NASA/Goddard Space Flight Center



The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (*CALIPSO*) Classification

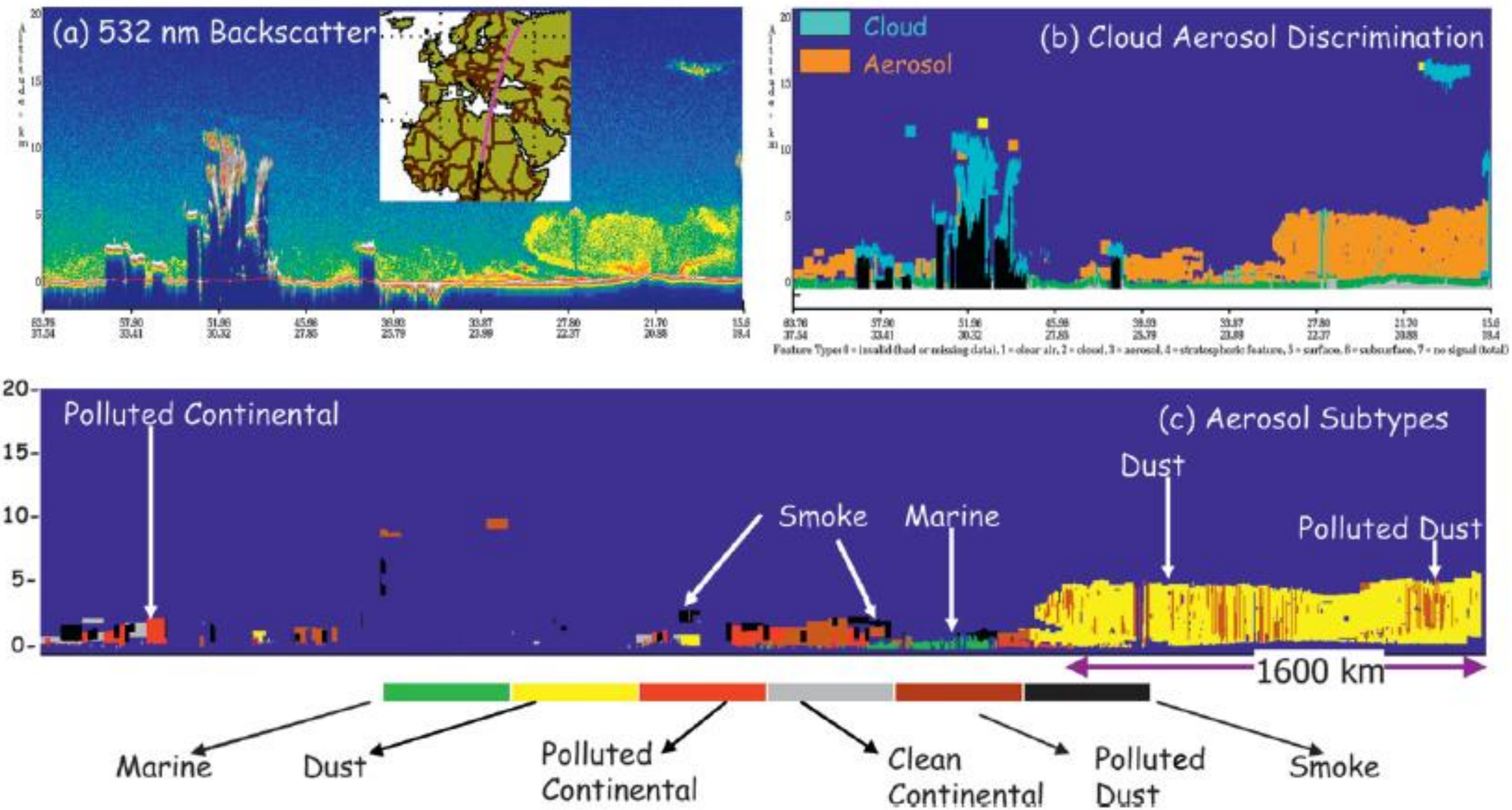


δ – depolarization

γ' – layer-integrated attenuated backscatter

Omar et al., JAOT 2009

CALIPSO 6-Grouping Aerosol Type Classification

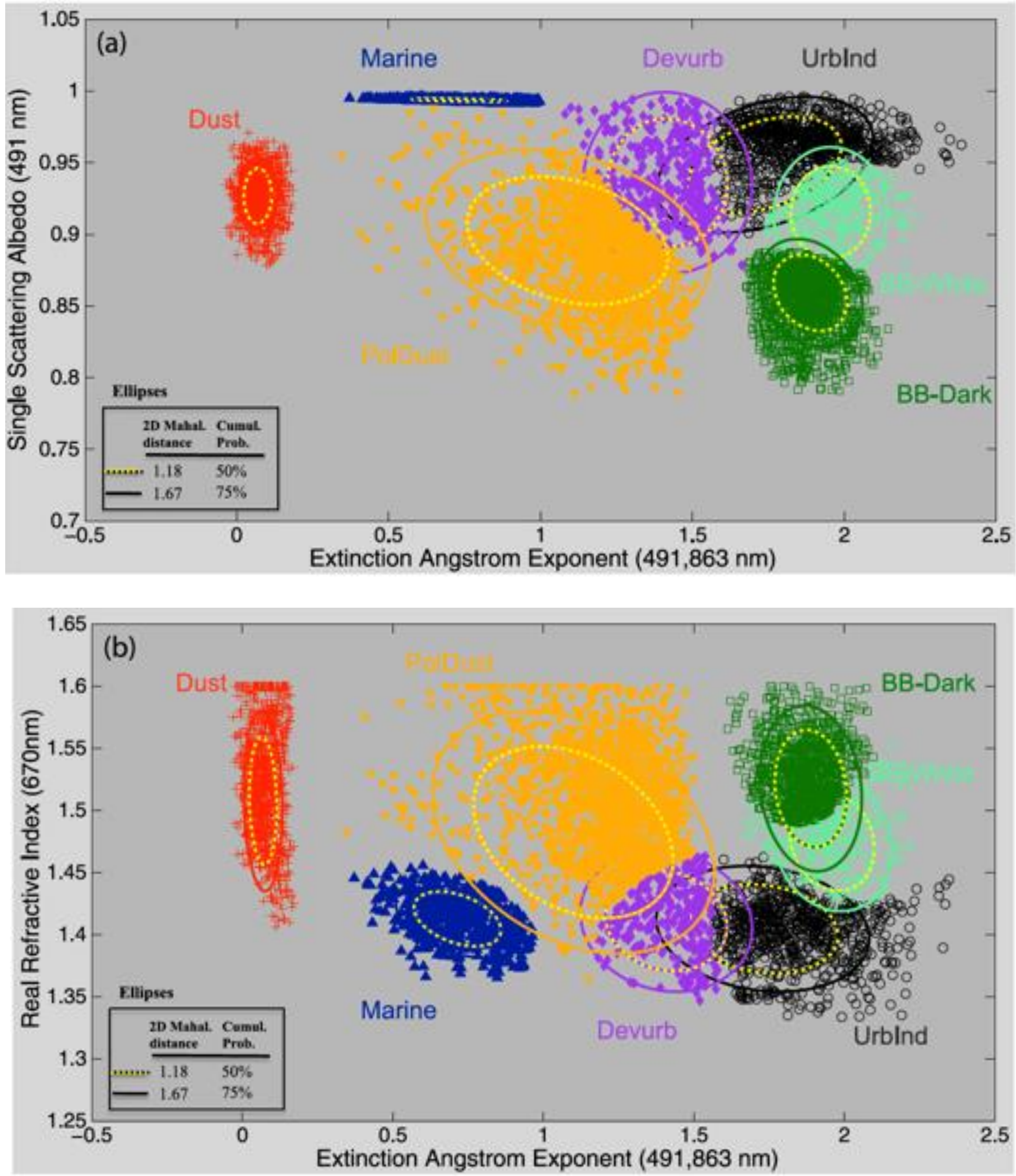


Omar et al., JAOT 2009

AERONET Aerosol Type 7-Grouping Classification

Four-parameter AERONET-derived classification:

- **$EAE_{491,863}$**
- **SSA_{491}**
- **RRI_{670}**
- **$dSSA_{863-491}$**



7 Groupings SSA_{491} vs. Extinction ANG

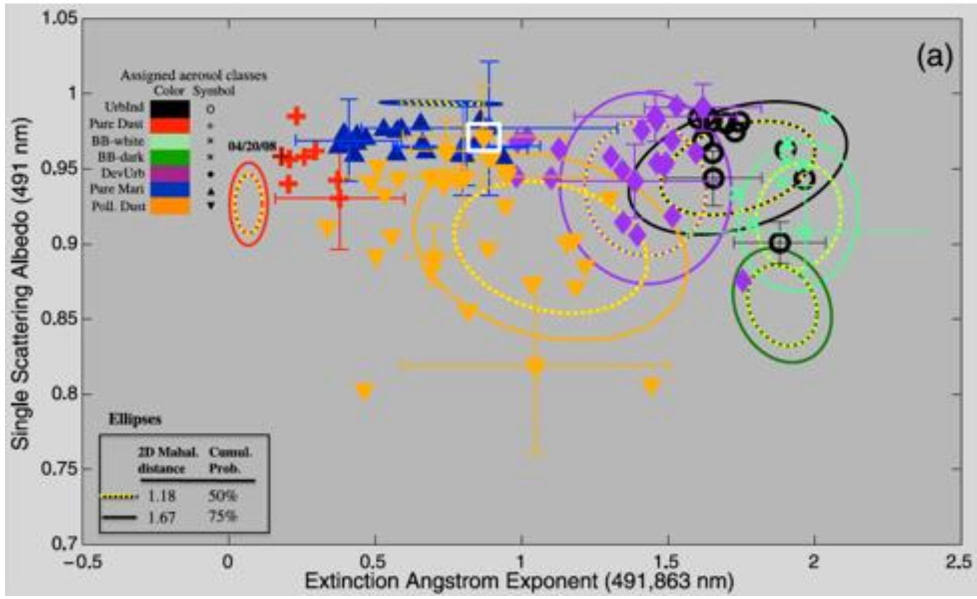
7 Groupings Real RI_{670} vs. Extinction ANG

Russell et al. JGR 2014

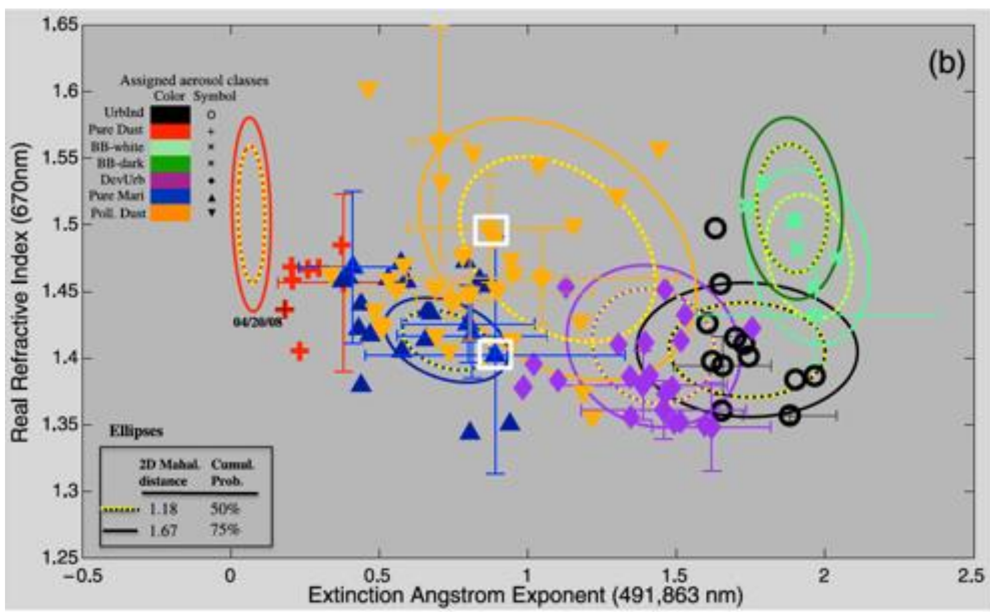
PARASOL data at Forth Crete projected onto the AERONET Aerosol Type Classification

Four-parameter AERONET-derived classification:

- **$EAE_{491,863}$**
- **SSA_{491}**
- **RRI_{670}**
- **$dSSA_{863-491}$**



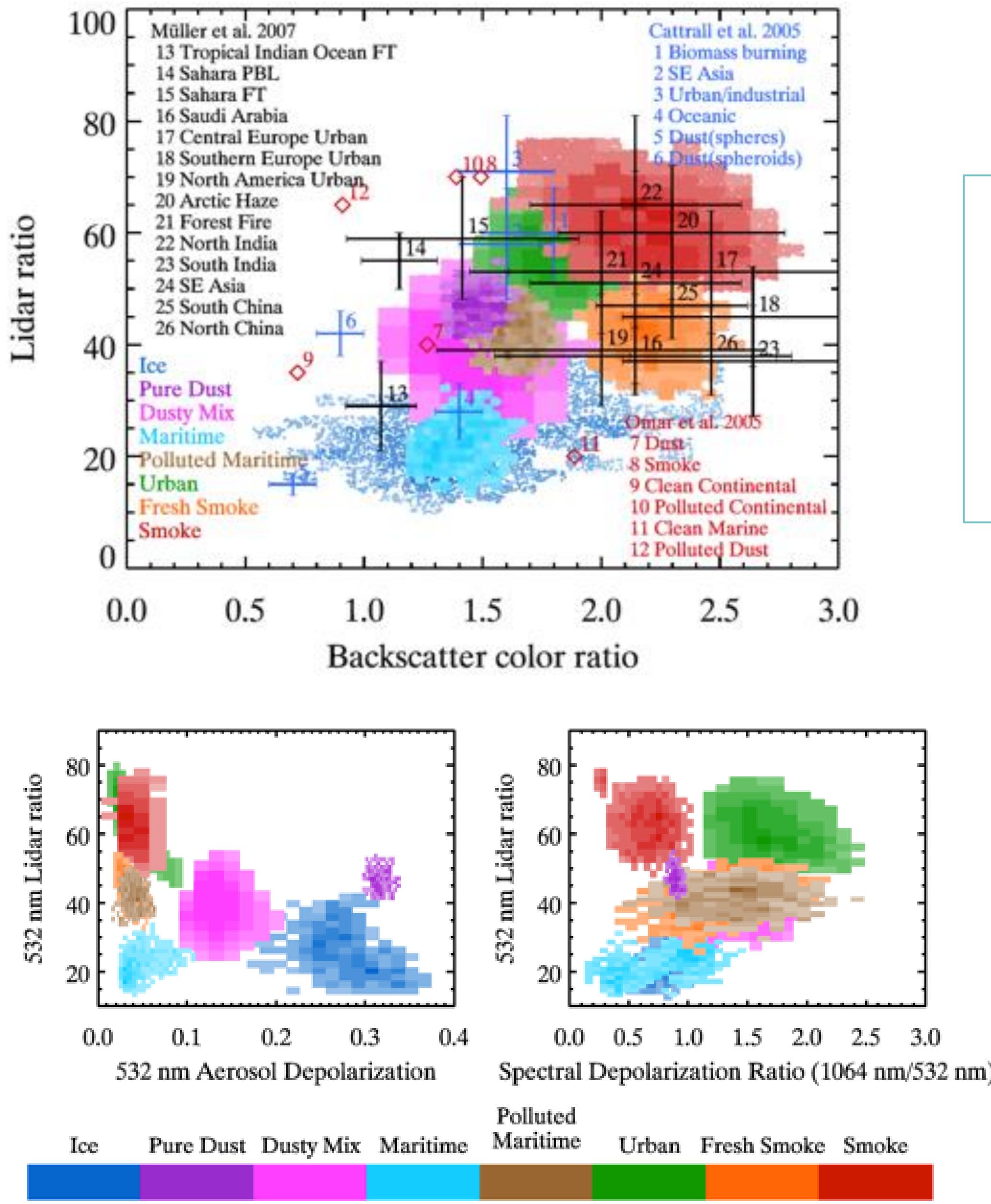
7 Groupings
SSA_{491} vs.
Extinction ANG



7 Groupings
Real RI_{670} vs.
Extinction ANG

Russell et al. JGR 2014

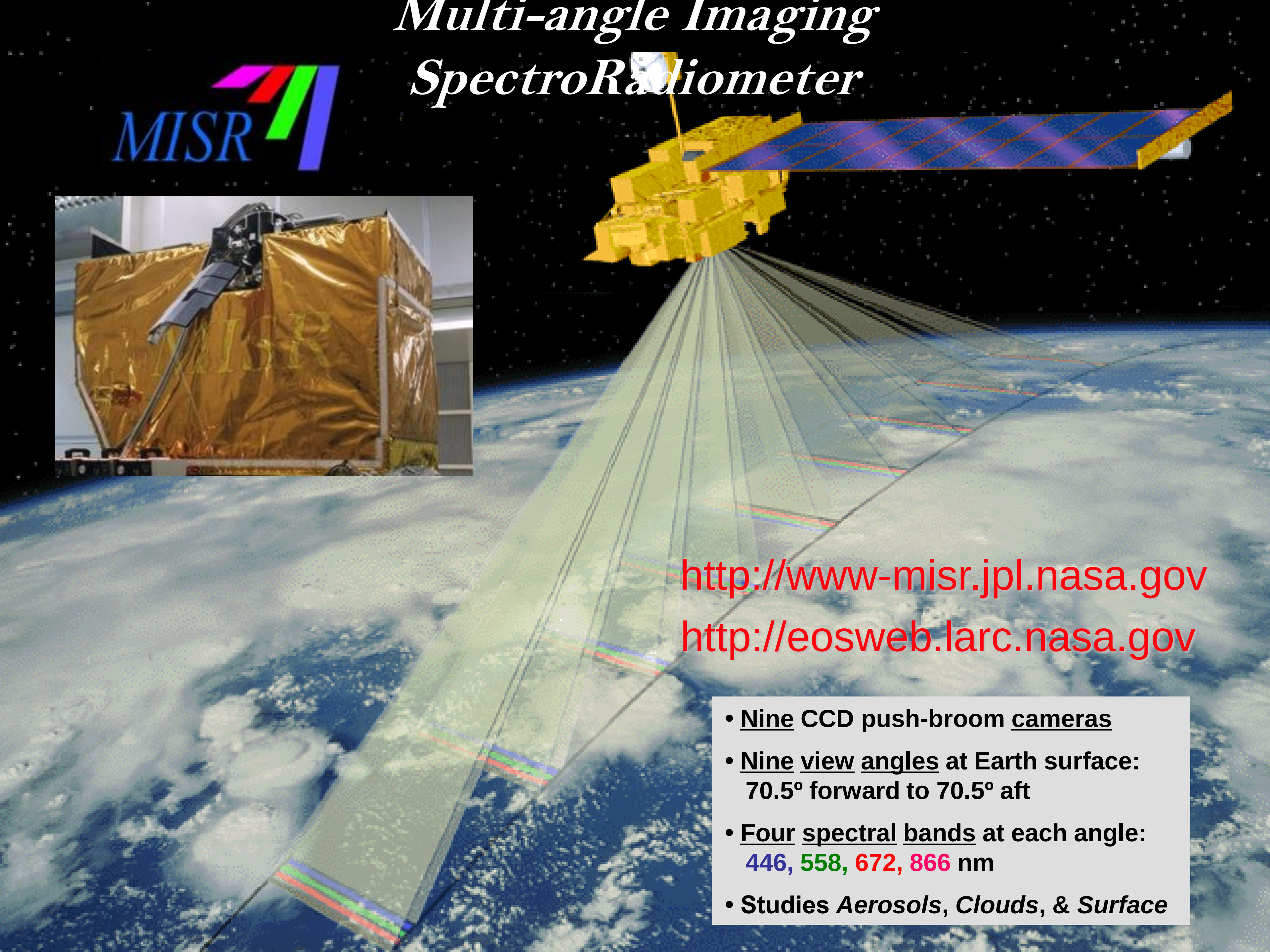
HSRL Aerosol Type 8-Grouping Classification



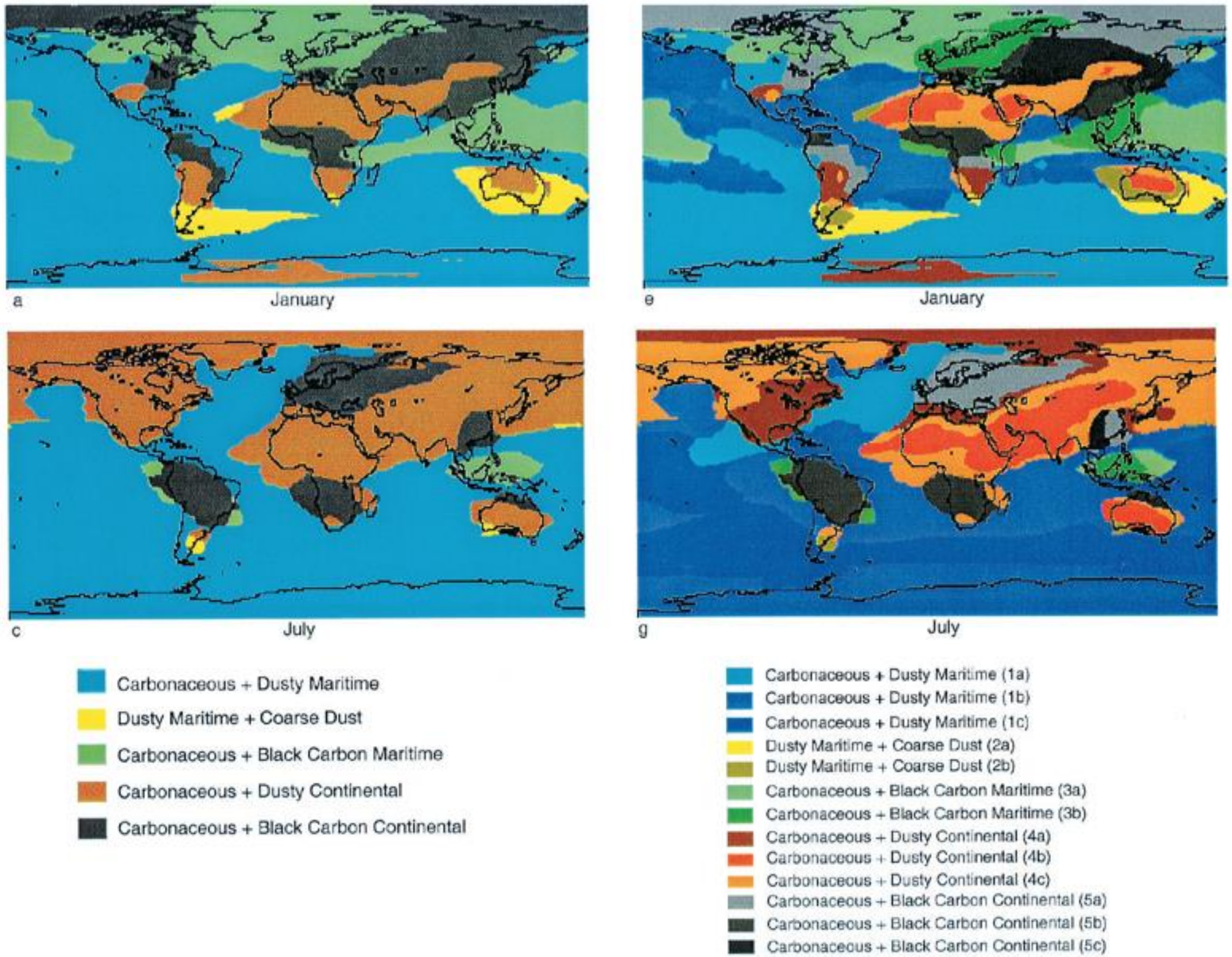
Four-parameter AERONET-derived classification:

- α_{532}/β_{532}
- β_{1064}/β_{532}
- δ_{532}
- $\beta_{1064}/\delta_{532}$

Burton et al. JGR 2012

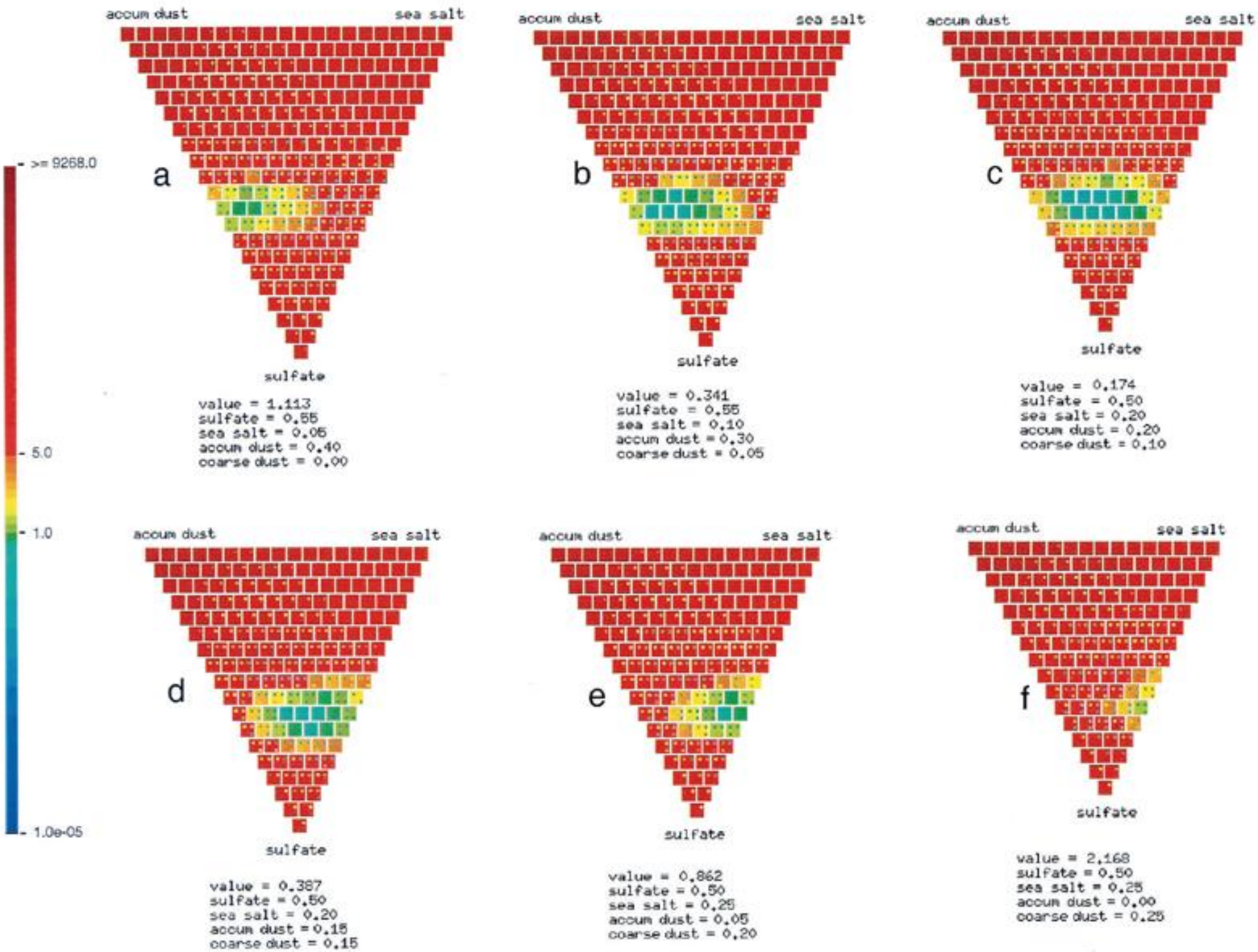

Multi-angle Imaging
SpectroRadiometer
MISR
http://www-misr.jpl.nasa.gov
http://eosweb.larc.nasa.gov
• Nine CCD push-broom cameras
• Nine view angles at Earth surface: 70.5º forward to 70.5º aft
• Four spectral bands at each angle: 446, 558, 672, 866 nm
• Studies Aerosols, Clouds, & Surface

Model-based Aerosol Type Clustering for *MISR* Sensitivity



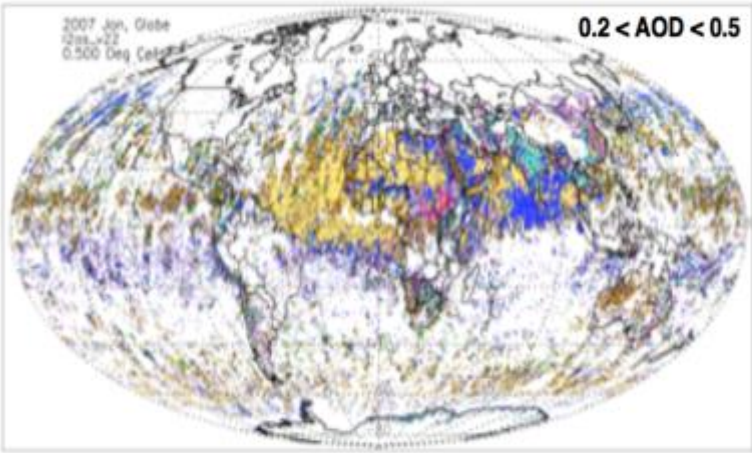
Kahn et al. JGR 2001

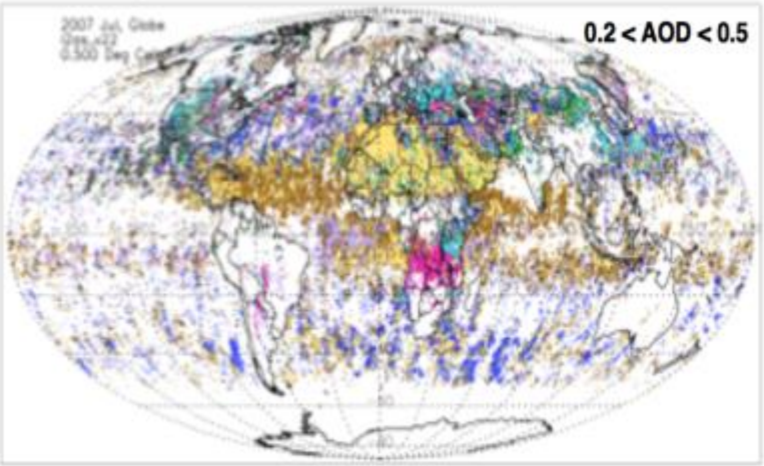
MISR Aerosol Type Discrimination Sensitivity Study



Kahn et al. JGR 2001

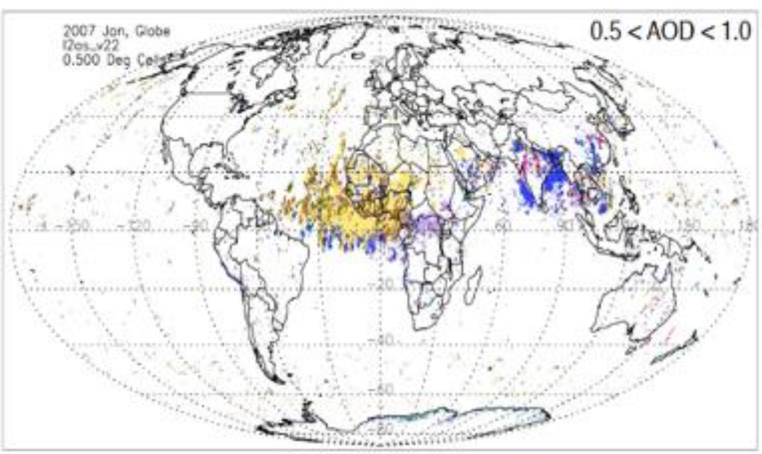
MISR Aerosol Type Discrimination

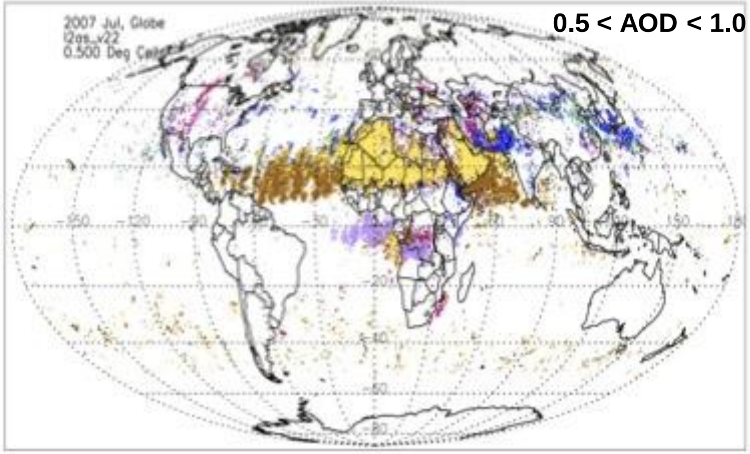




January 2007

July 2007





1-10 11-20 21-30 31-40 41-50 51-62 63-70 71-74 Mixture Group

Spherical, non-absorbing

Non-spherical

Spherical, absorbing

Kahn & Gaitley JGR 2015

Aerosol Type Validation Approach

- No ***"Ground Truth"*** except from Field Campaigns (***Golden Days***)

  -- Unlike ***Spectral AOD*** (and ***ANG***) from AERONET
  Particle Properties are derived with ***many more assumptions***

  -- ***Very few*** MISR-AERONET Sky-scan Coincidences

- MISR ***Self-consistency*** Tests

  -- ***Qualitative***, but useful

  -- ***Regional*** and ***Temporal Behavior*** vs. ***Expectation***

- MISR ***Comparisons*** with AERONET proxies

  -- Compare ***Seasonal***, ***Inter-annual*** patterns ***statistically***

  -- ***Fine-mode Fraction*** (FMF)

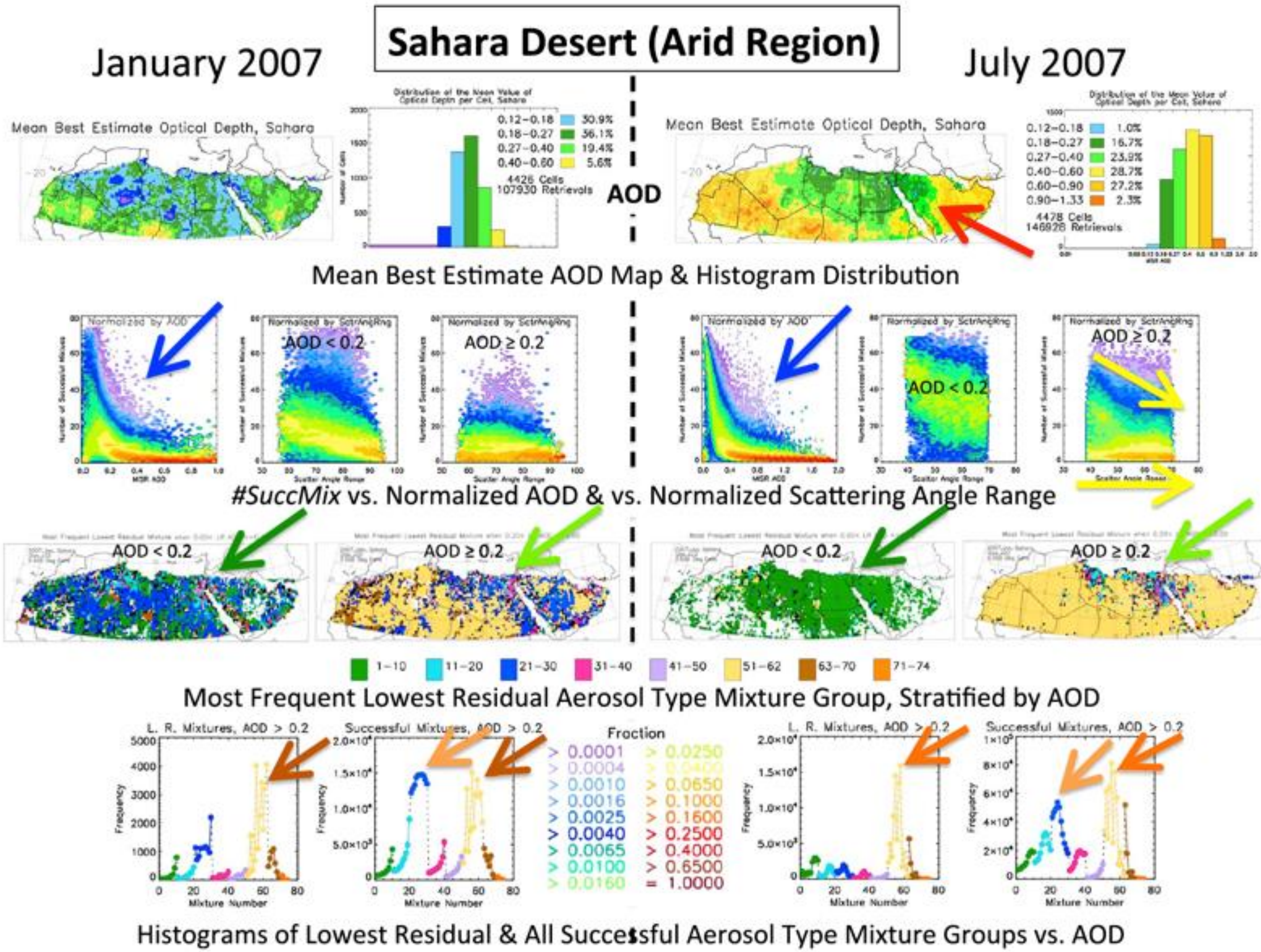
  -- ***Effective radius*** (r_e) and ***variance*** (σ) [two modes – ***issue with def. of "modes"***]

  -- ***Single-scattering albedo*** (*SSA*) [for AOD_440 > 0.4; AERONET SZA > 50°]

  -- ***Sphericity*** (*"%Sph."*) [for AERONET ***ANG*** < 1.0 only – few MISR cases w/AOD>0.2]

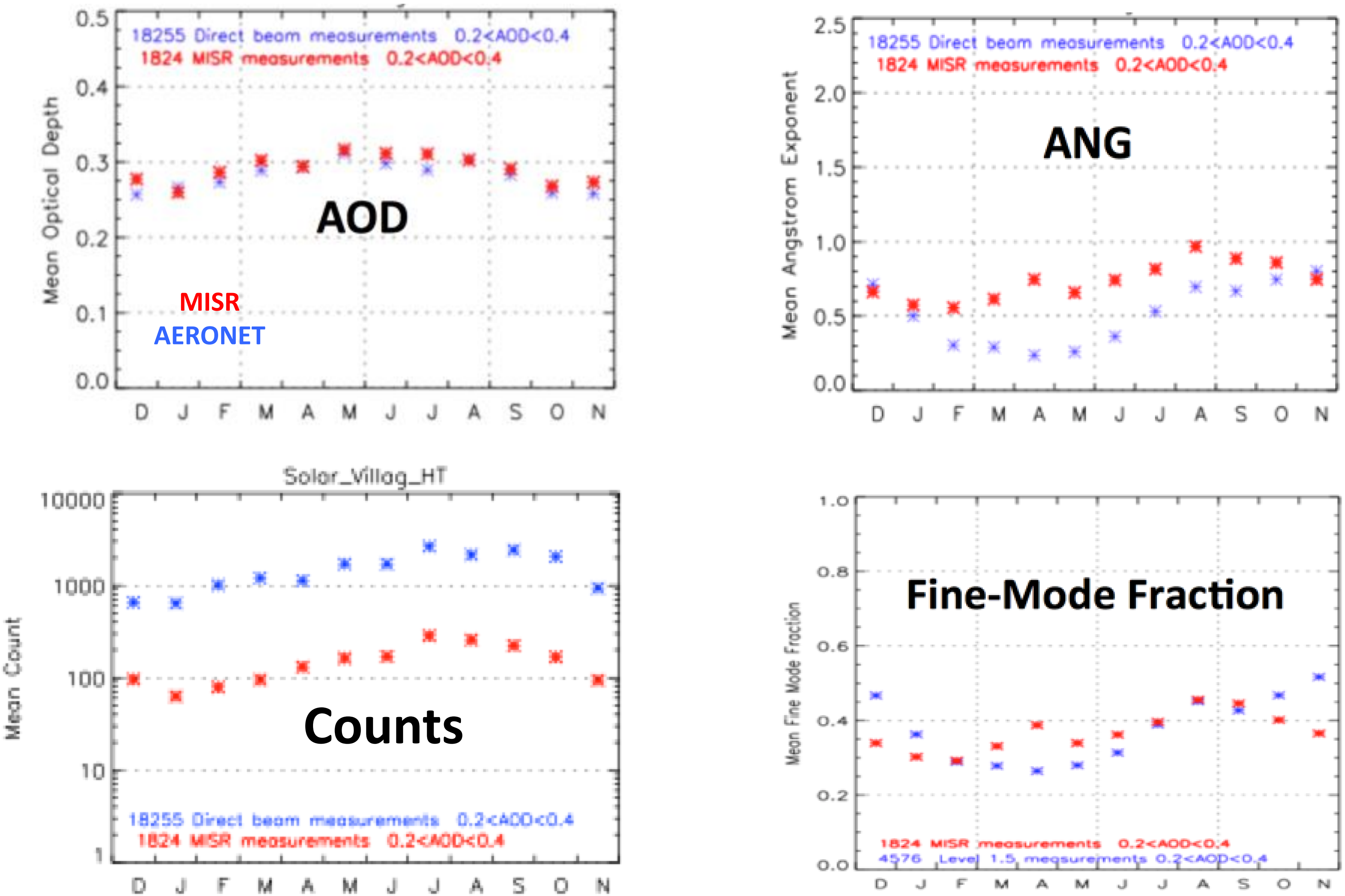
Kahn & Gaitley, JGR, 2015

MISR Aerosol Type Discrimination



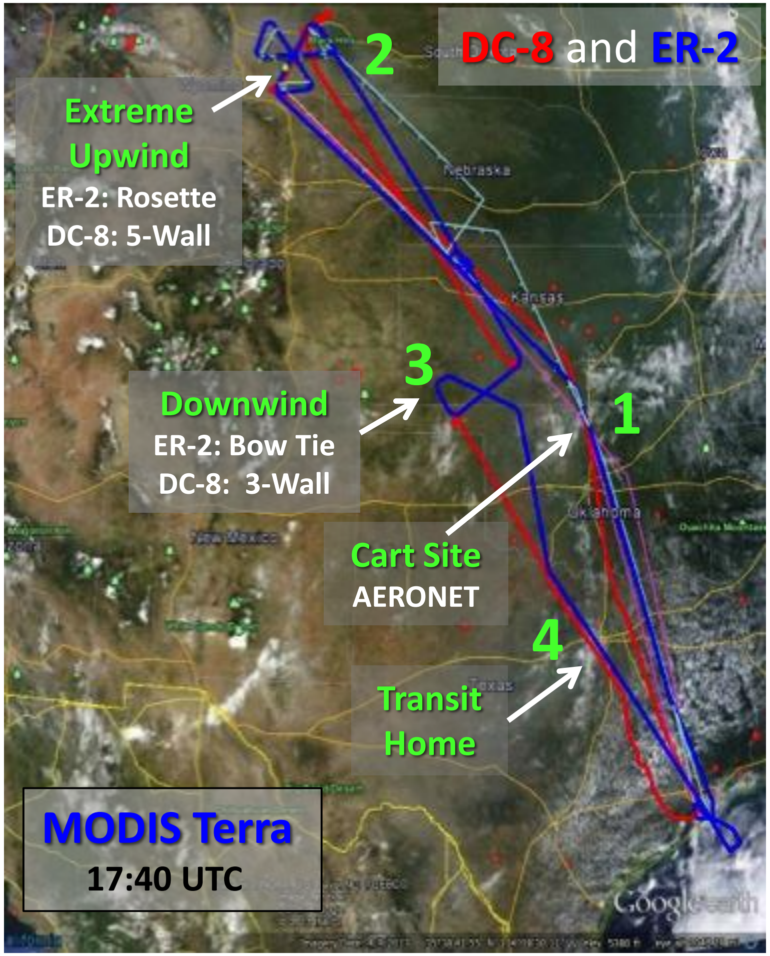
Kahn & Gaitley JGR 2015

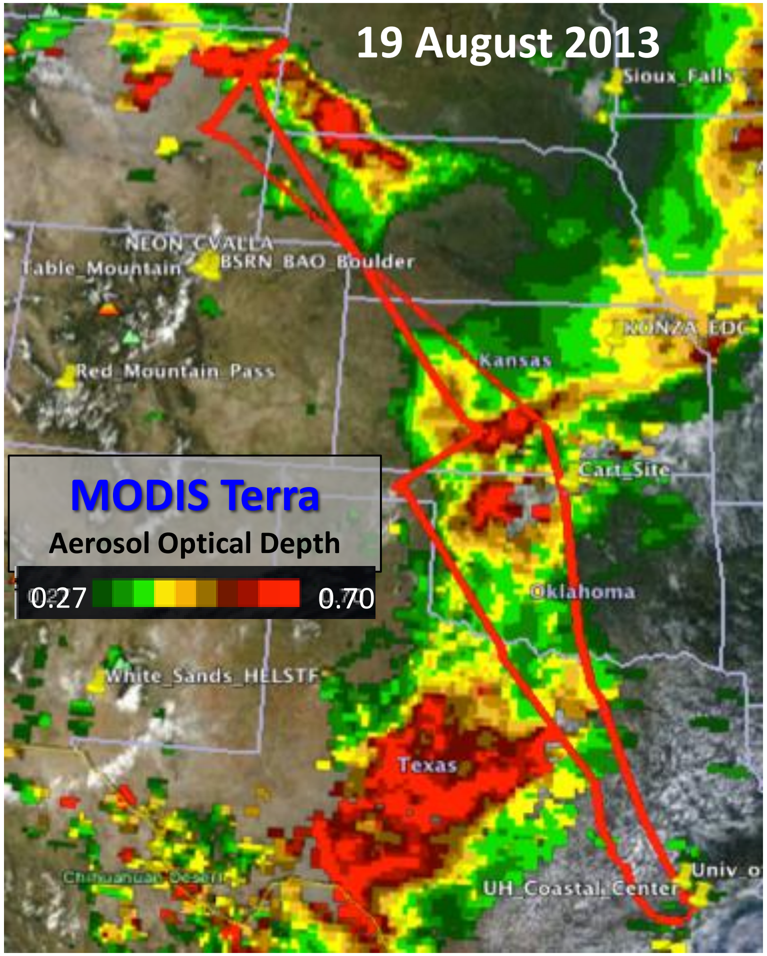
Statistical *Comparisons* with AERONET – *Solar Village*



Kahn & Gaitley JGR 2015

A Three-way Street: *MISR & MODIS* Provide Context, *SEAC⁴RS* Provides Detail, & *Models* Complete the Picture





MISR Research Aerosol Retrieval

MISR components & Mixtures for the 774-mixture set

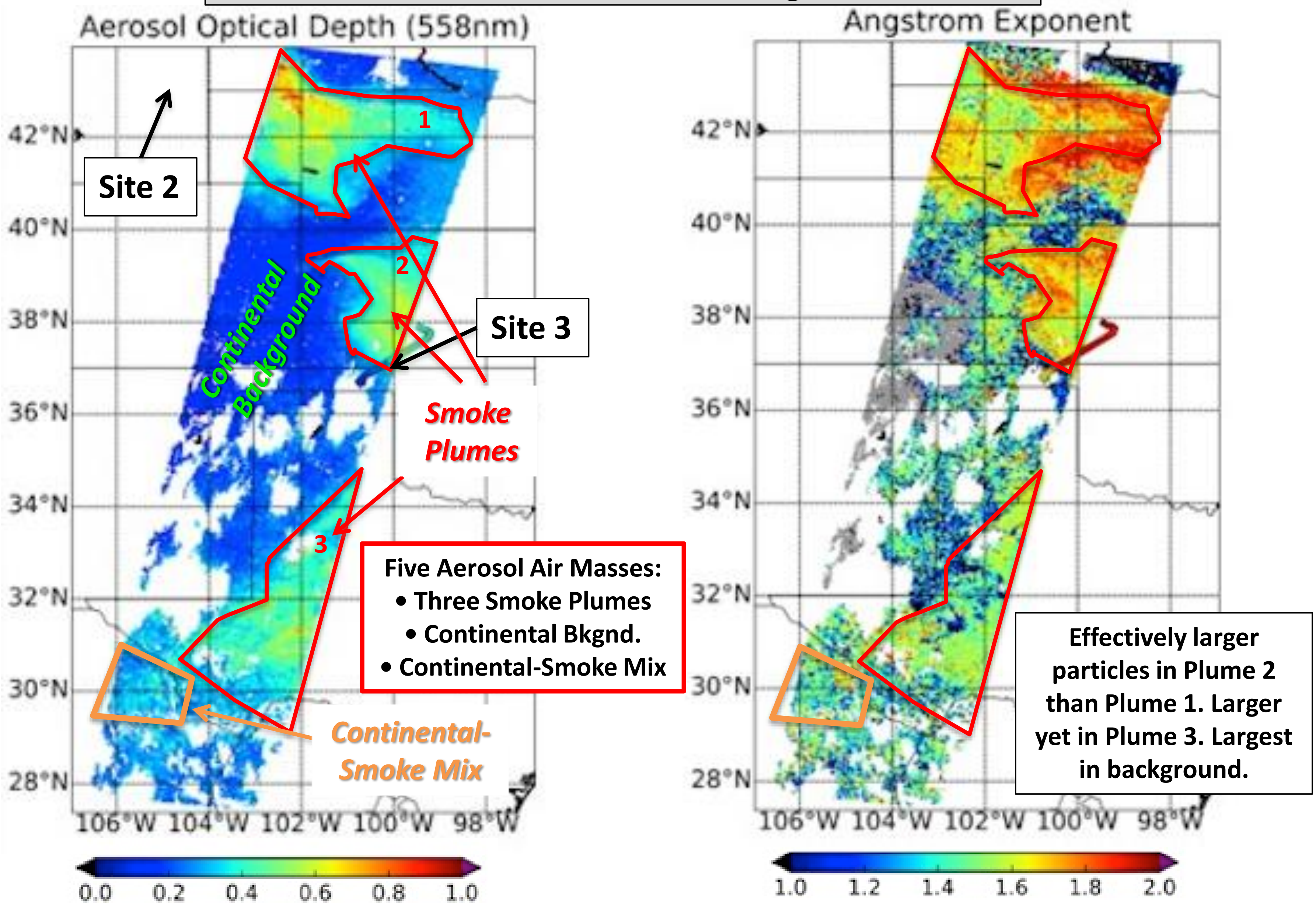
Component name	r_1 (μm)	r_2(μm)	r_e (μm)	σ	E(B/G)	E(R/G)	E(NIR/G)	n_r(G)	SSA(B)	SSA(G)	SSA(R)	SSA(NIR)	g(G)
sph_nonabs_0.06	0.002	0.329	0.056	1.650	1.947	0.548	0.226	1.520	1.000	1.000	1.000	1.000	0.357
sph_nonabs_0.12	0.003	0.747	0.121	1.700	1.512	0.669	0.357	1.500	1.000	1.000	1.000	1.000	0.597
sph_nonabs_0.26	0.005	1.690	0.262	1.750	1.185	0.820	0.576	1.450	1.000	1.000	1.000	1.000	0.717
sph_nonabs_0.57	0.008	3.805	0.568	1.800	0.993	0.972	0.877	1.410	1.000	1.000	1.000	1.000	0.750
sph_nonabs_1.28	0.013	8.884	1.285	1.850	0.956	1.039	1.082	1.370	1.000	1.000	1.000	1.000	0.769
sph_abs_0.12_0.80_flat	0.003	0.747	0.121	1.700	1.461	0.687	0.378	1.500	0.818	0.822	0.825	0.828	0.604
sph_abs_0.12_0.80_steep	0.003	0.747	0.121	1.700	1.453	0.698	0.403	1.500	0.838	0.822	0.801	0.756	0.604
sph_abs_0.12_0.90_flat	0.003	0.747	0.121	1.700	1.488	0.677	0.367	1.500	0.910	0.912	0.913	0.915	0.601
sph_abs_0.12_0.90_steep	0.003	0.747	0.121	1.700	1.484	0.683	0.379	1.500	0.920	0.912	0.900	0.875	0.601
dust_grains_mode1_h1	0.100	1.000	0.754	1.500	0.895	1.065	1.079	1.510	0.920	0.977	0.994	0.997	0.711
spheroidal_mode2_h1	0.100	6.000	2.400	2.000	0.989	1.019	1.050	1.510	0.810	0.902	0.971	0.983	0.772
baum_cirrus_De=10um	2.000	9500.000	5.000	n/a	1.000	1.000	1.000	1.317	1.000	1.000	1.000	1.000	0.787
baum_cirrus_De=40um	2.000	9500.000	20.000	n/a	1.000	1.000	1.000	1.317	1.000	1.000	1.000	1.000	0.810
baum_cirrus_De=100um	2.000	9500.000	50.000	n/a	1.000	1.000	1.000	1.317	1.000	1.000	1.000	1.000	0.869

* r_1, r_2 are the upper and lower limits of the component particle size distribution; r_e is effective radius (μm), σ is the log-normal size distribution width, E is the spectral ratio of extinction cross-section, g is the asymmetry parameter; dust grain and spheroid optical properties from Kalashnikova et al. (2005); cirrus from Baum et al. (2005).

Component 1	Component 2	Component 3
spherical_nonabsorbing_0.06	spherical_nonabsorbing_1.28	spherical_nonabsorbing_0.57
spherical_nonabsorbing_0.12	spherical_nonabsorbing_1.28	spherical_nonabsorbing_0.57
spherical_nonabsorbing_0.26	spherical_nonabsorbing_1.28	spherical_nonabsorbing_0.57
spherical_nonabsorbing_0.06	dust_grains_mode1_h1	spheroidal_mode2_h1
spherical_nonabsorbing_0.12	dust_grains_mode1_h1	spheroidal_mode2_h1
spherical_nonabsorbing_0.26	dust_grains_mode1_h1	spheroidal_mode2_h1
spherical_nonabsorbing_0.06	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_nonabsorbing_0.12	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_nonabsorbing_0.26	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_absorbing_0.12_0.80_steep	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_absorbing_0.12_0.80_flat	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_absorbing_0.12_0.90_steep	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
spherical_absorbing_0.12_0.90_flat	spherical_nonabsorbing_1.28	dust_grains_mode1_h1
baum_cirrus_De=10um	–	–
baum_cirrus_De=40um	–	–
baum_cirrus_De=100um	–	–

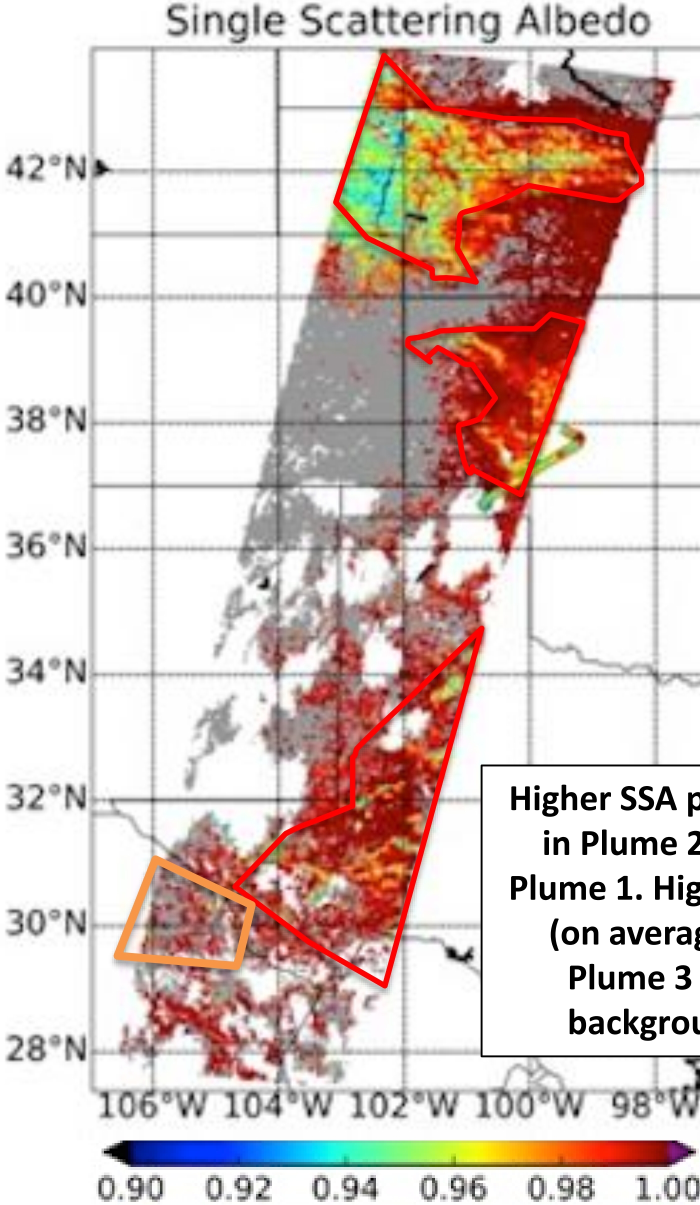
MISR SEAC^{4}RS Field Campaign

Research Retrievals 19 August 2013

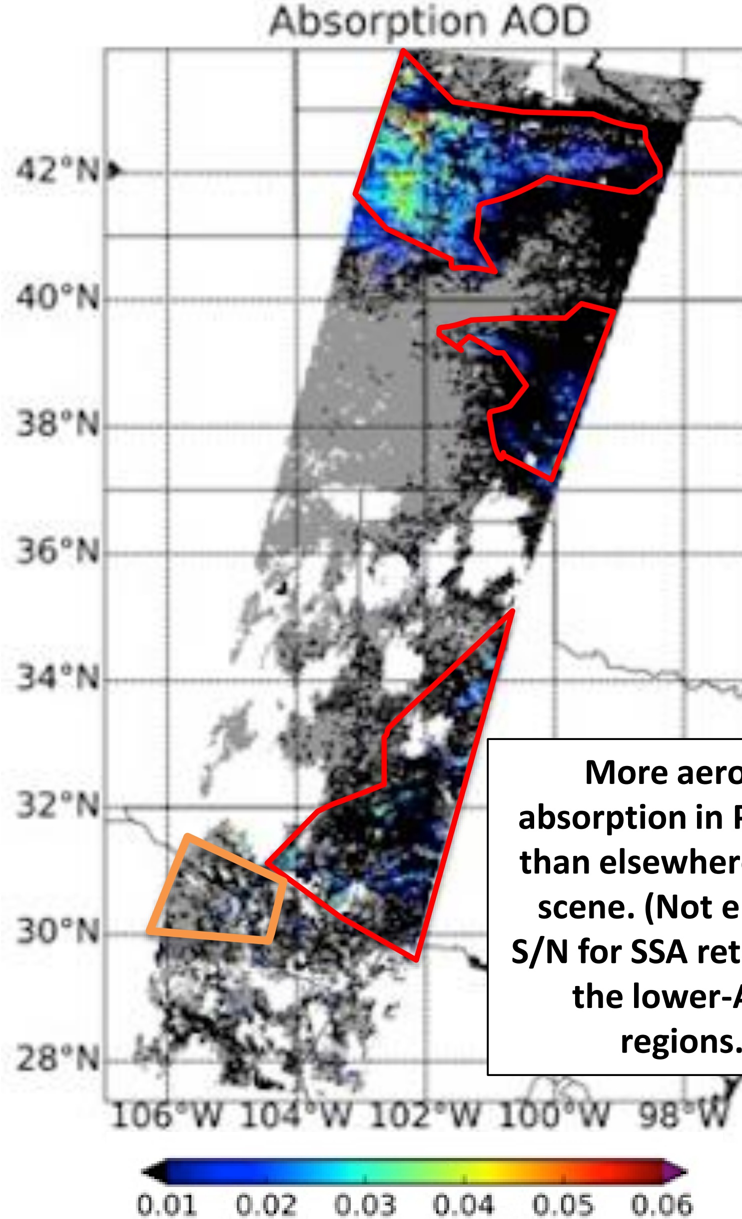


MISR SEAC^{4}RS Field Campaign

Research Retrievals 19 August 2013



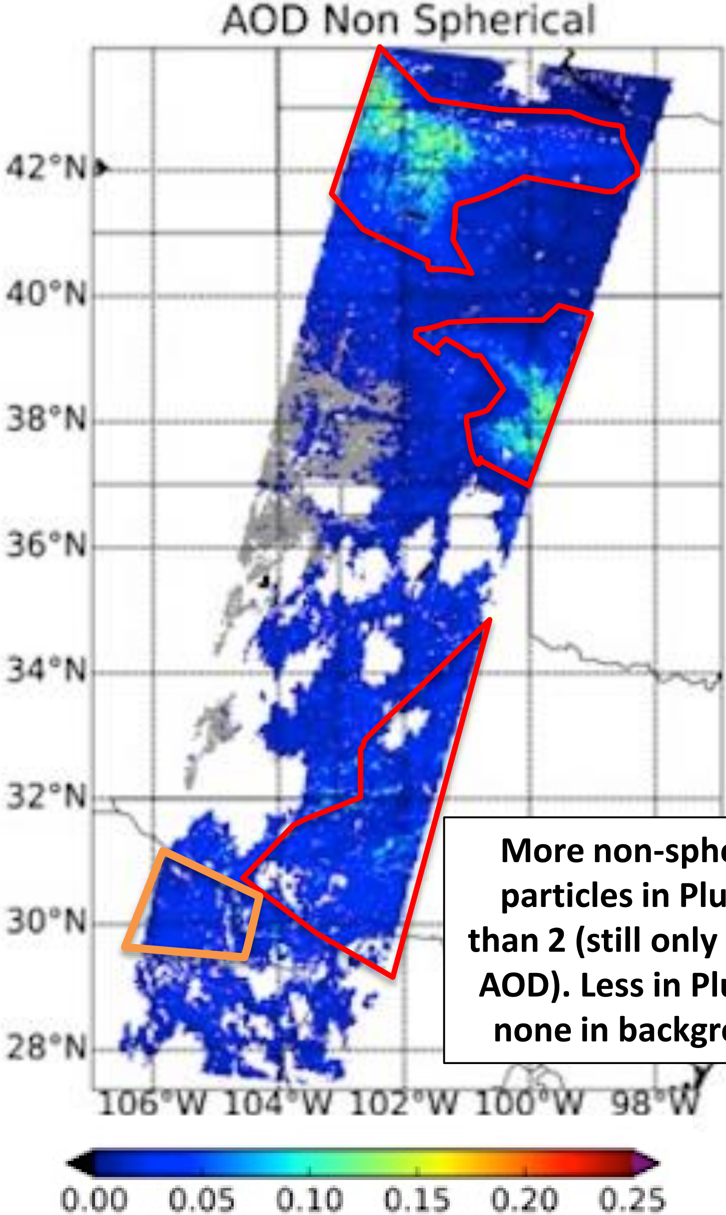
Higher SSA particles in Plume 2 than Plume 1. Higher still (on average) in Plume 3 and background.



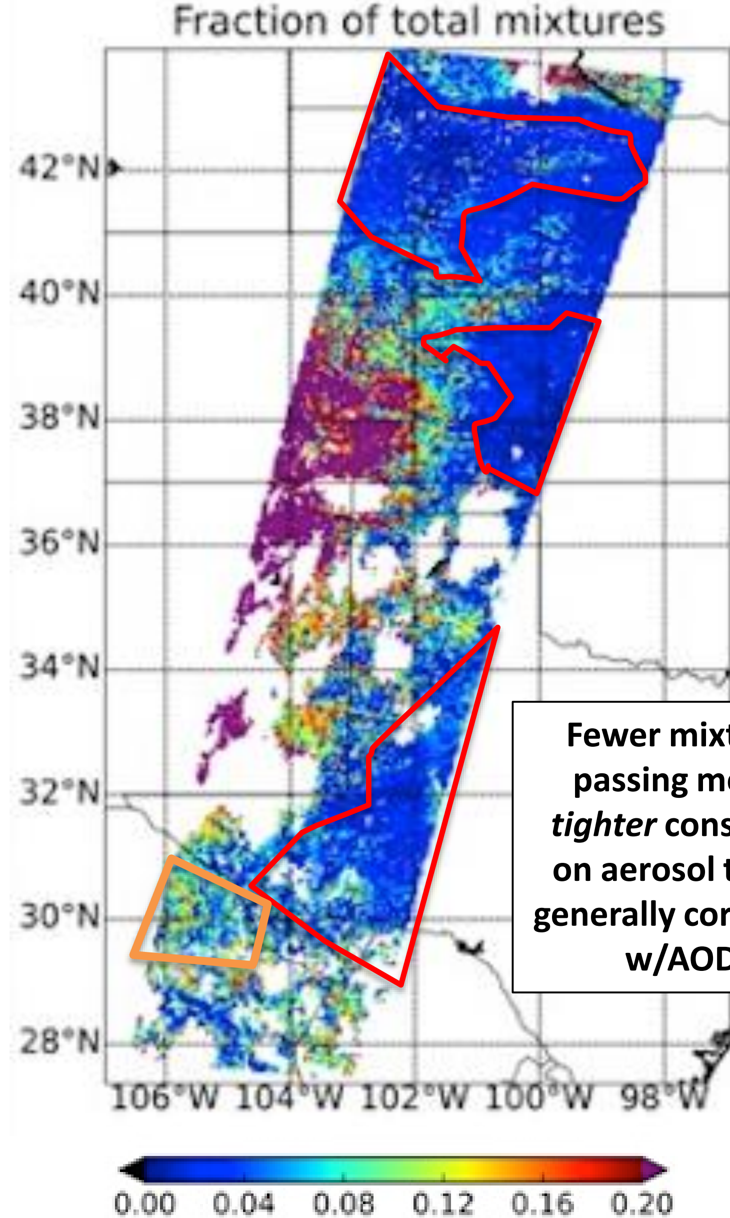
More aerosol absorption in Plume 1 than elsewhere in the scene. (Not enough S/N for SSA retrieval in the lower-AOD regions.)

MISR SEAC⁴RS Field Campaign

Research Retrievals 19 August 2013

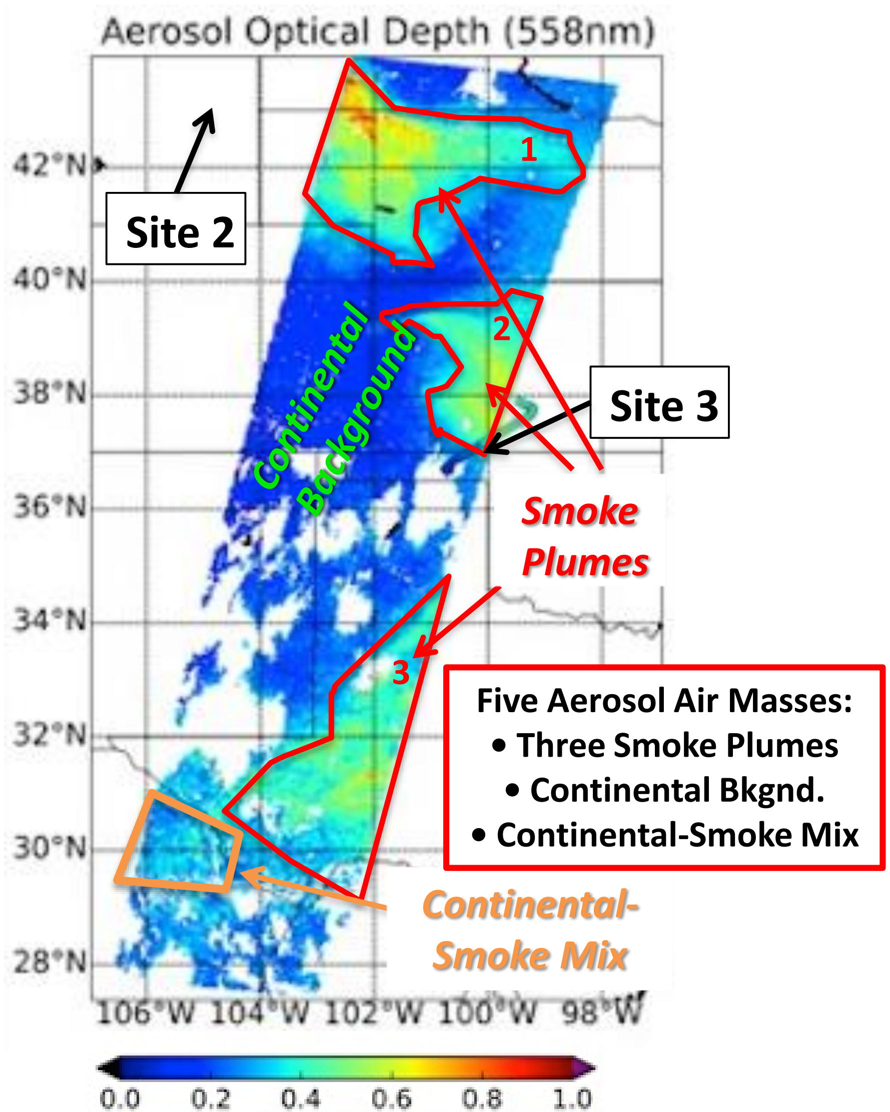


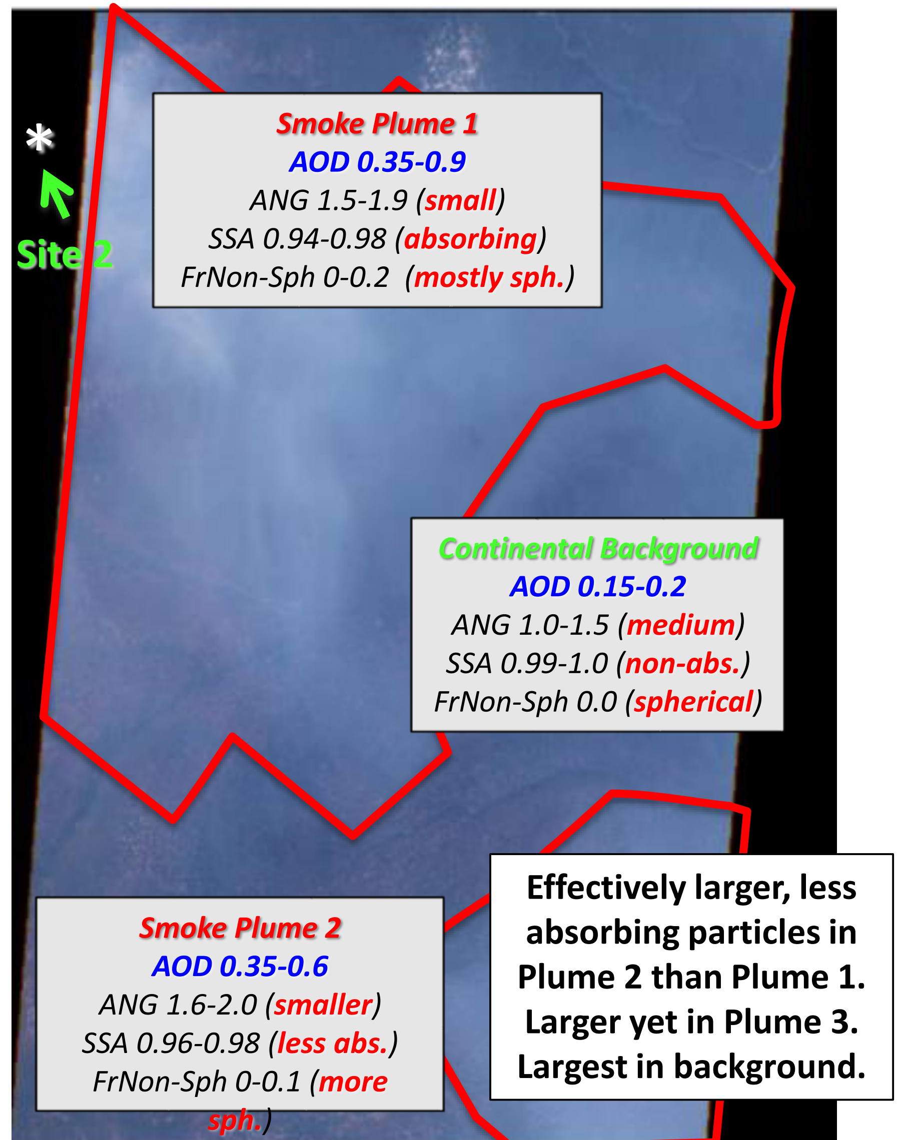
More non-spherical particles in Plume 1 than 2 (still only <~ 15% AOD). Less in Plume 3; none in background.



Fewer mixtures passing means *tighter* constraint on aerosol type – generally correlates w/AOD.

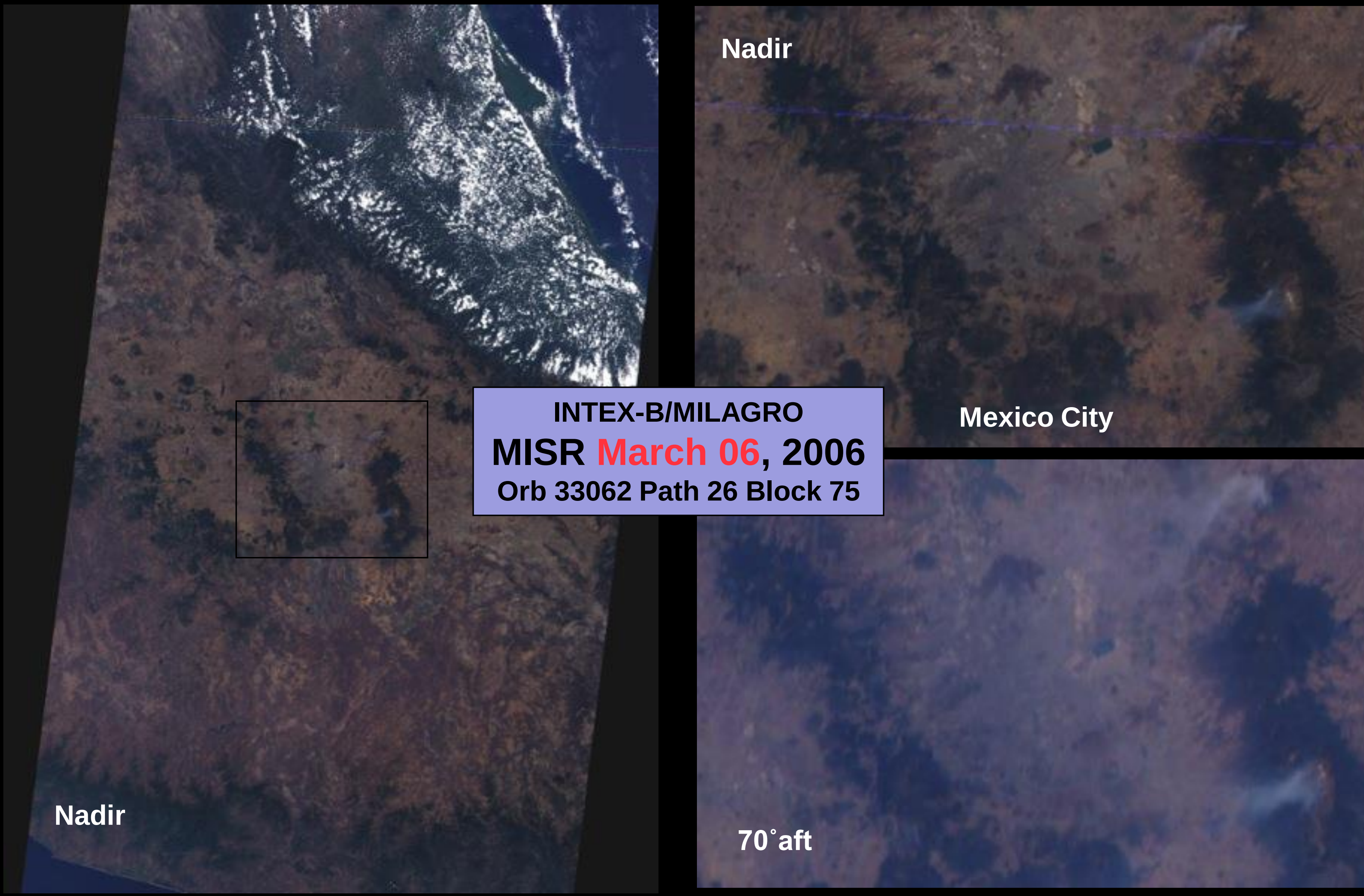
SEAC^{4}RS – MISR Overview 19 August 2013





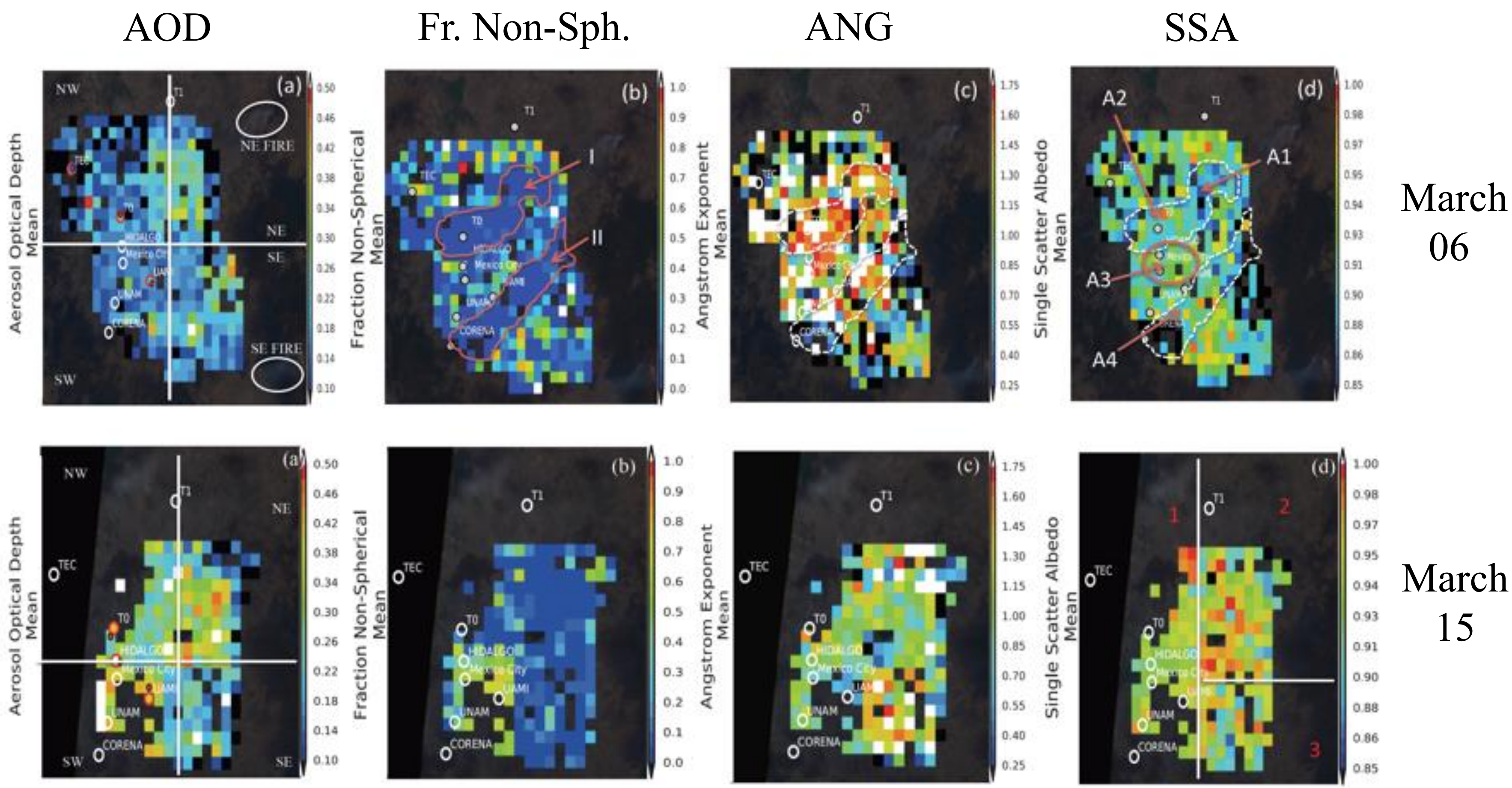
Passive-remote-sensing ***Aerosol Type*** is a ***Total-Column-Effective***, ***Categorical*** variable!!

Mapping AOD & Aerosol Air-Mass-Type in Urban Regions



Patadia et al.

Urban Pollution AOD & Aerosol Air Mass Type Mapping
INTEX-B, 06 & 15 March 2006



Aerosol Air Masses: ***Dust*** (non-spherical), ***Smoke*** (spherical, spectrally steep absorbing), and ***Pollution*** particles (spherical, spectrally flat absorbing) dominate specific regions

Patadia et al., ACP 2013

SAM-CAAM

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

[This is currently a ***concept-development effort***, not yet a project]

***Primary Objectives*:**

- **Interpret and *enhance 15+ years of satellite aerosol retrieval* products**

- ***Characterize statistically particle properties* for major aerosol types globally,**

  to provide detail unobtainable from space, but needed to *improve*:

  -- Satellite aerosol *retrieval algorithms*

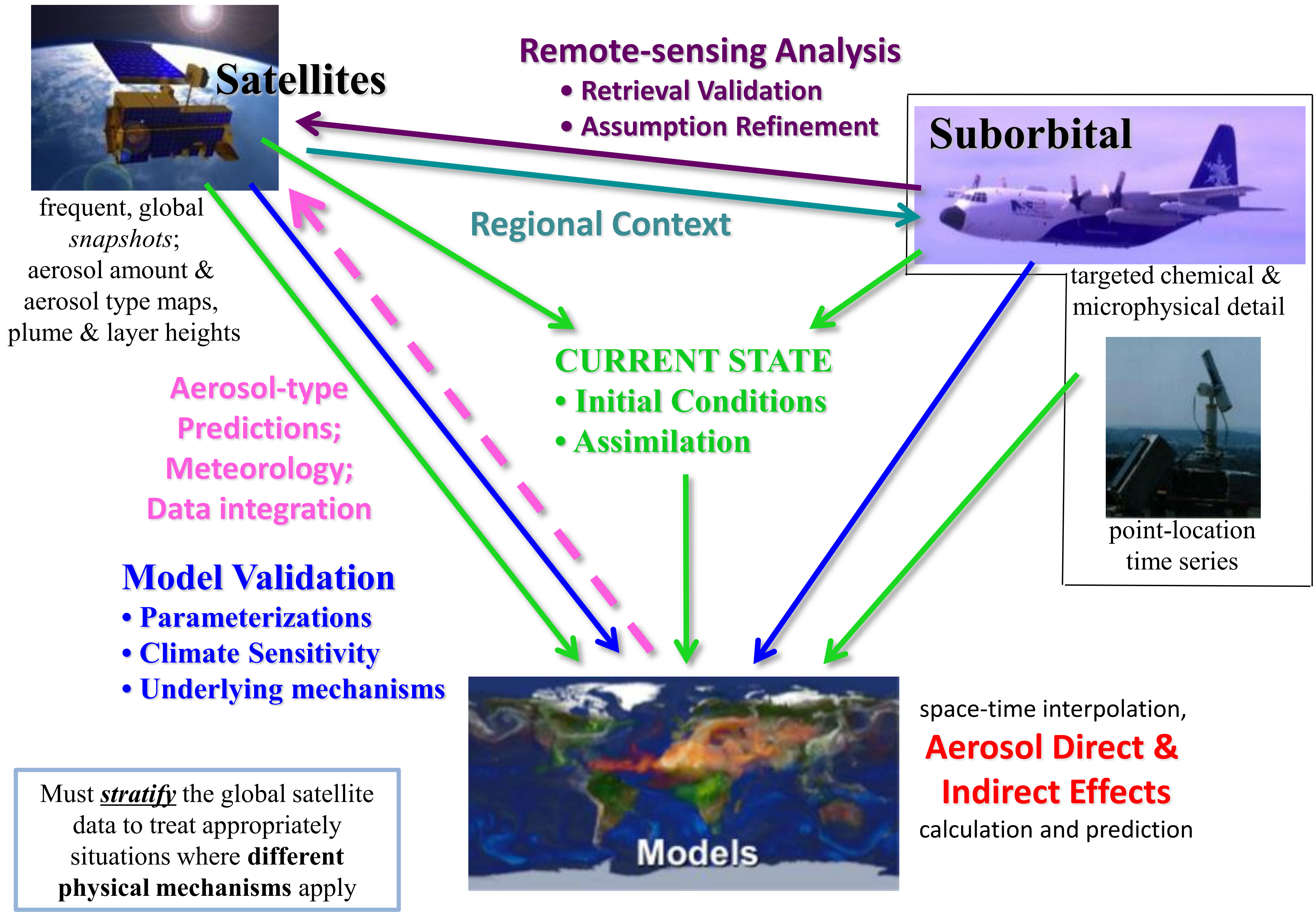
  -- The *translation between satellite-retrieved aerosol optical properties*

SAM-CAAM ***Concept***

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

- ***Dedicated Operational Aircraft*** – routine flights, 2-3 x/week, on a continuing basis
- ***Sample Aerosol Air Masses*** accessible from a given base-of-operations, then move; project science team to determine schedule, possible field campaign participation
- Focus on *in situ* ***measurements required*** to characterize particle ***Optical Properties***, ***Chemical Type***, and ***Mass Extinction Efficiency*** (MEE)
- ***Process Data Routinely*** at central site; instrument PIs develop & deliver algorithms, upgrade as needed; data distributed via central web site
- Peer-reviewed Paper identifying ***4 Payload Options***, of varying ambition; subsequent selections based on agency buy-in and available resources

SAM-CAAM is feasible because:
Unlike aerosol amount, ***aerosol microphysical properties tend to be repeatable*** from year to year, for a given source in a given season



Adapted from: Kahn, Survy. Geophys.