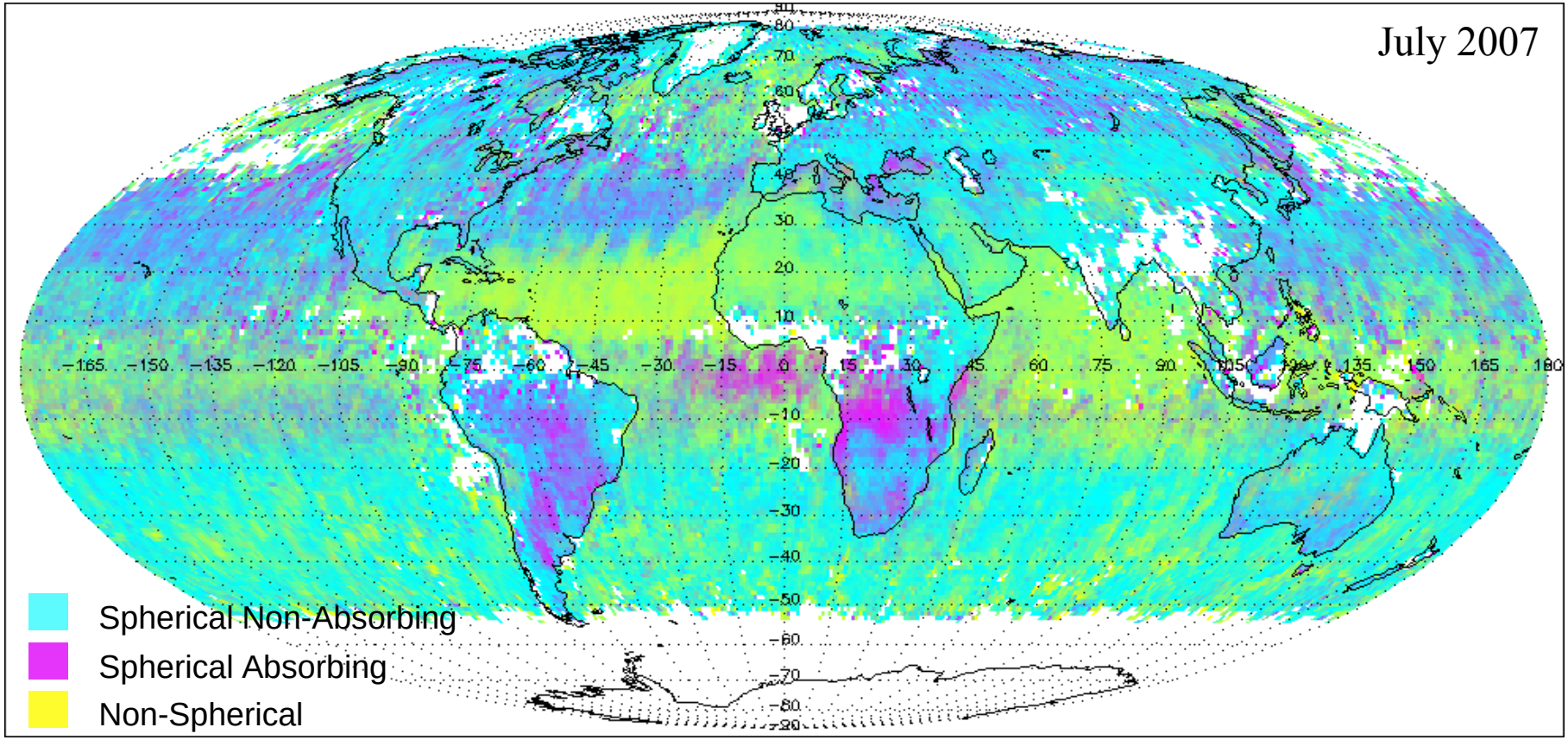
We Are Getting Better at Aerosol Type

Ralph Kahn

NASA Goddard Space Flight Center



Kahn et al., JGR 2010

Multi-angle Imaging SpectroRadiometer

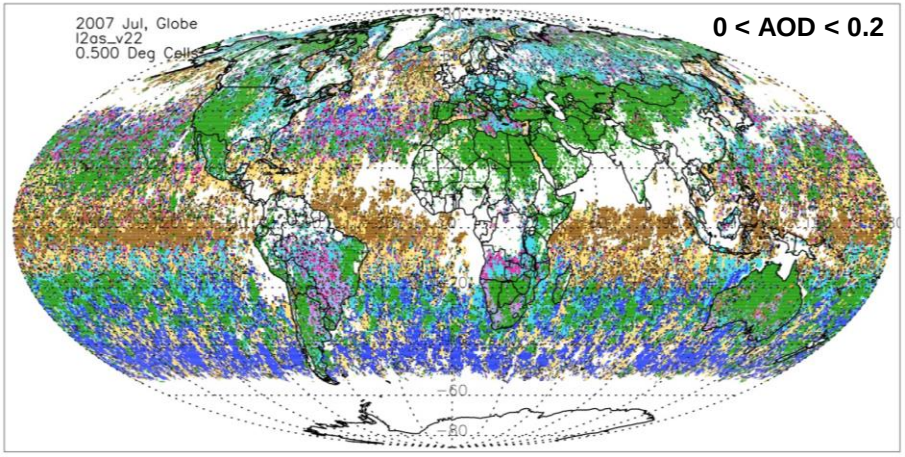
MISR

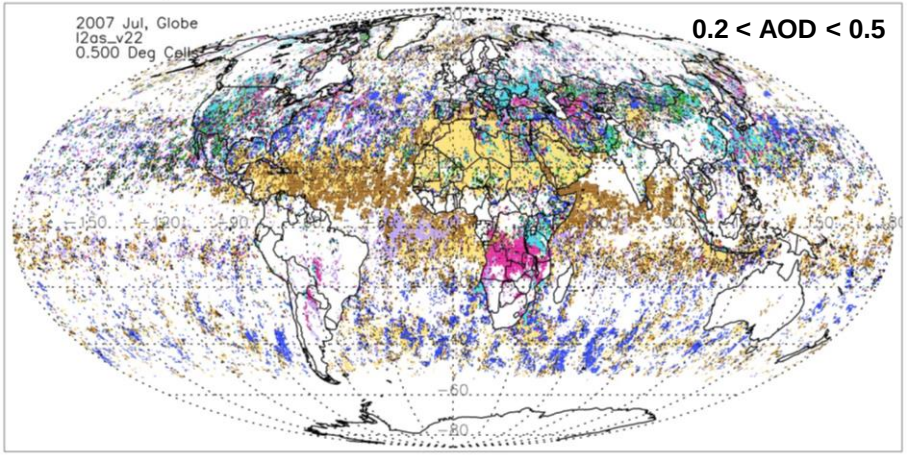
http://www-misr.jpl.nasa.gov

http://eosweb.larc.nasa.gov

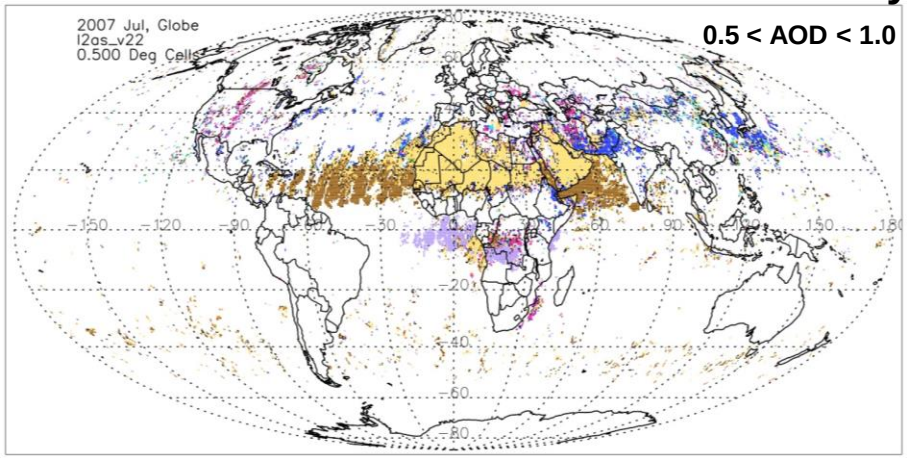
- **Nine CCD push-broom cameras**
- **Nine view angles at Earth surface: 70.5º forward to 70.5º aft**
- **Four spectral bands at each angle: 446, 558, 672, 866 nm**
- **Studies *Aerosols*, *Clouds*, & *Surface***

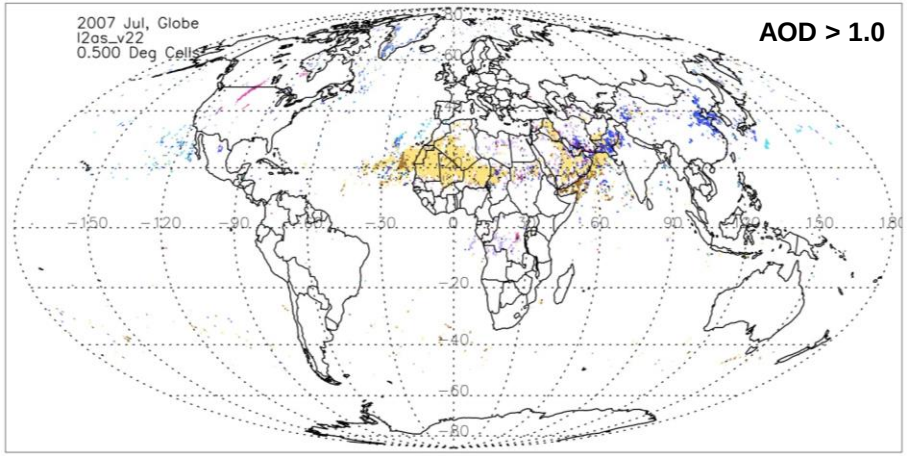
Global Distribution of MISR Most Frequently Retrieved Mixture Group





July 2007





Mixture Group

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

Spherical, non-absorbing

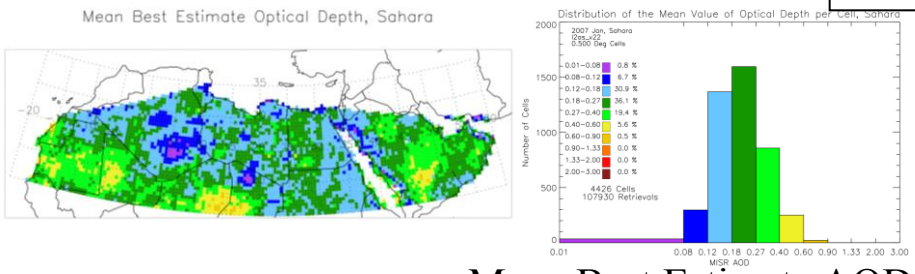
Non-spherical

Spherical, absorbing

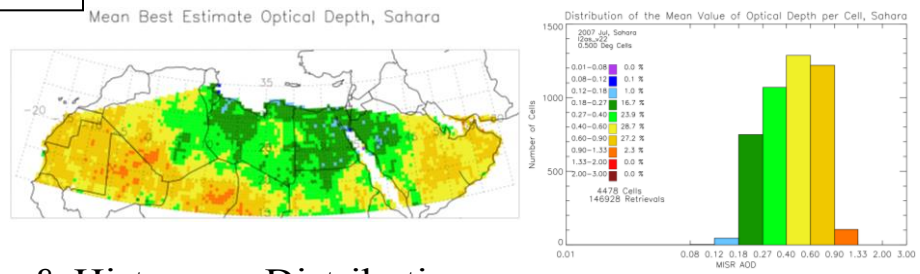
Kahn, Gaitley, et al. in preparation

Sahara

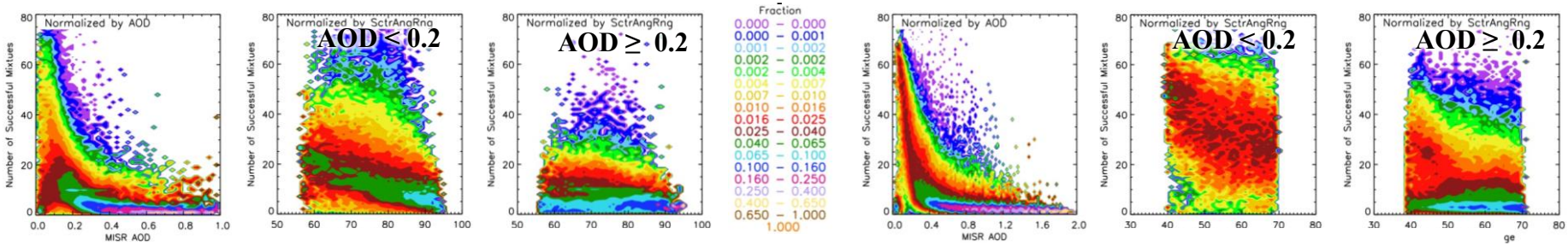
January 2007



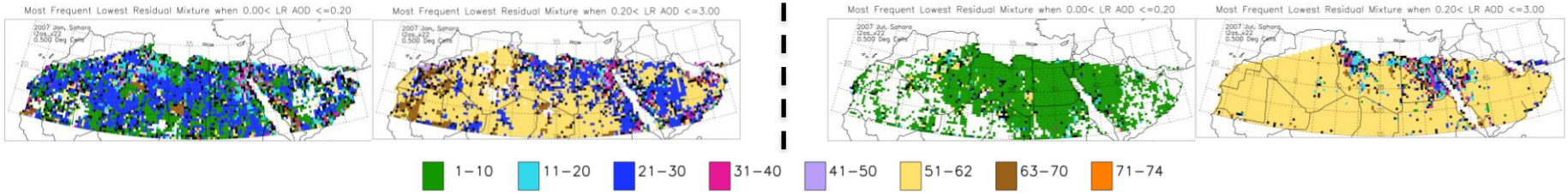
July 2007



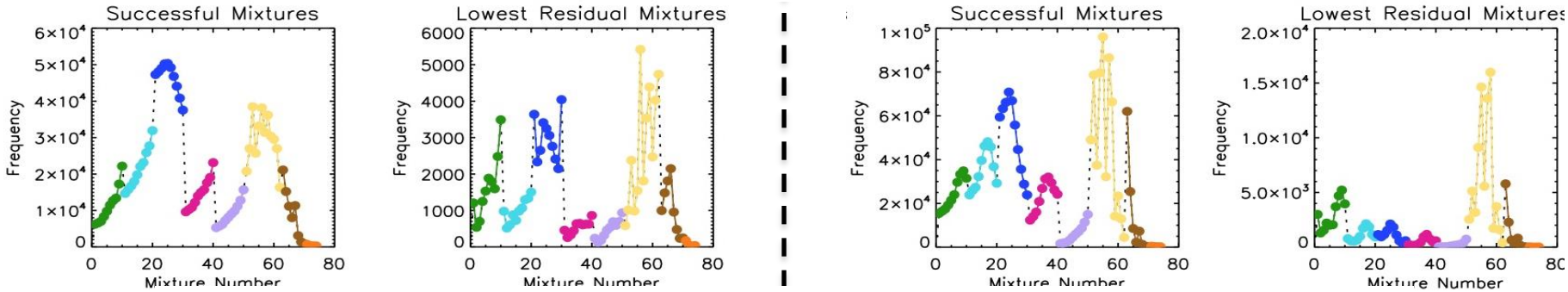
Mean Best Estimate AOD Map & Histogram Distribution



Number of Successful Mixtures vs. Normalized AOD & vs. Normalized Scattering Angle Range



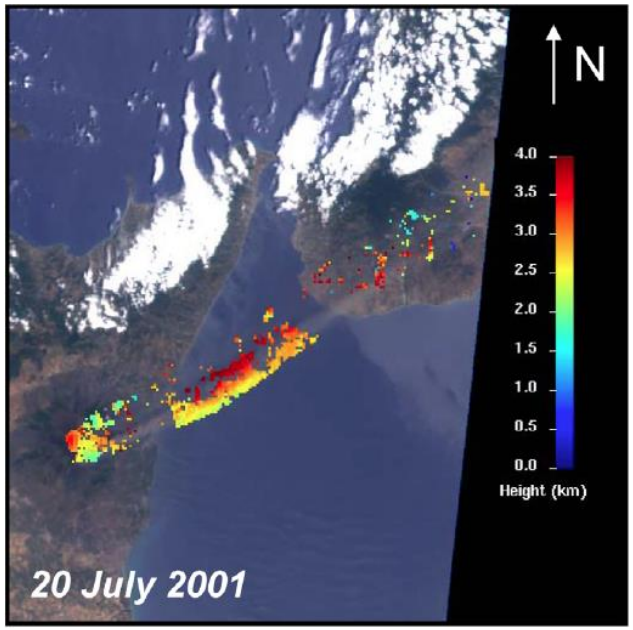
Most Frequent Lowest Residual Aerosol Type Mixture Group, Stratified by AOD



Histograms of Lowest Residual & All Successful Aerosol Type Mixture Groups

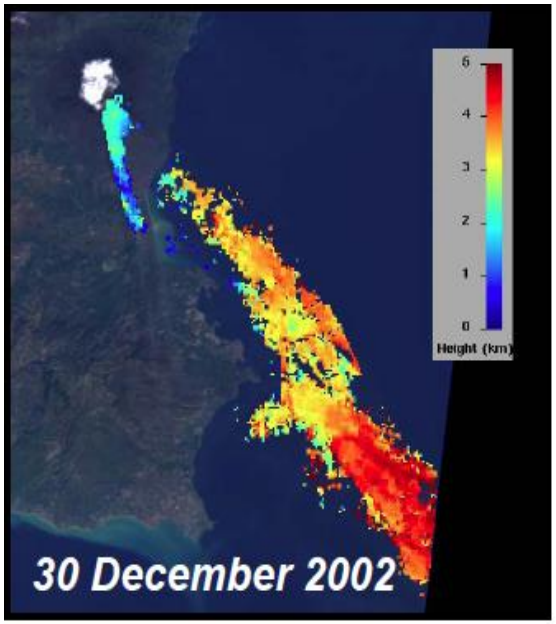
Mount Etna Plume Height and Eruption Style from MISR

Scollo, S. R.A. Kahn, D.L. Nelson, M. Coltelli, D.J. Diner, M.J. Garay, and V.J. Realmuto
MISR observations of Etna volcanic plumes. *J. Geophys. Res*. 2012



MISR nadir-viewing, true-color image showing Etna, with stereo-derived plume height superposed

29 Sept. 2006 – MISR retrieved mostly small spherical particles, indicating a sulfate/water-dominated plume



MISR stereo heights for the ash-dominated plume on 30 December 2002

Indications of Eruption Strength:

- ***Plume Height*** from MISR stereo imaging
- ***Ash to Sulfate/Water particle AOD ratio*** from MISR-retrieved particle shape and size

MISR Stereo-Derived Aerosol Type (size & shape)
Mt. Etna, 11 Events May 2000 - Nov. 2006

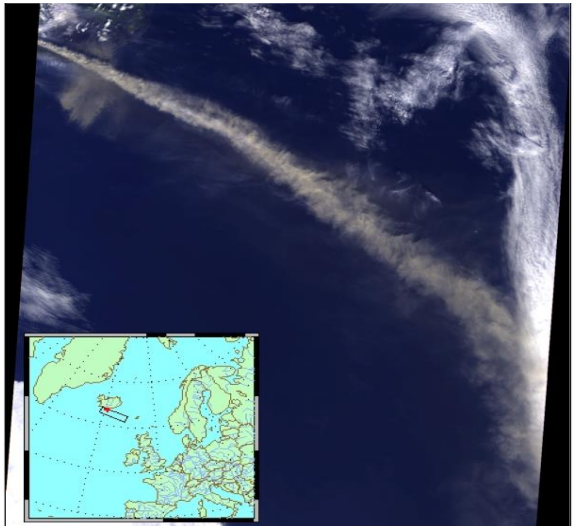
§Etna Eruption Time (UTC)	Mean AOD	AOD Range	AOD Sph. Fraction Mean	AOD Sph. Fract. Range	Small	Med	Large
***Ash*-Dominated, Both MISR & Surface Obs.**			**Mostly *Large*, *Non-Spherical***				
27 Oct 2002 at 10:00$	0.31	[0.04 0.58]	0.42	[0.1 1]	0.31	0.23	0.46
23 Dec 2002 at 09:54	0.11	[0.09 0.12]	0.43	[0.4 1]	0.40	0.11	0.49
30 Dec 2002 at 10:04$	0.11	[0.04 0.14]	0.76	[0 1]	0.35	0.16	0.49
***Sulfate/Water*-Dominated, Both MISR & Surface Obs.**			**Mostly *Small*, *Spherical***				
29 July 2001 at 10:01	0.18	[0.15 0.25]	0.93	[0.6 1]	0.77	0.09	0.13
23 Nov 2002 at 09:42$	0.13	[0.07 0.19]	0.97	[0.2 1]	0.56	0.24	0.20
08 Jan 2003 at 09:54	0.15	[0.13 0.16]	0.95	[0.8 1]	0.49	0.08	0.43
29 Sept 2006 at 09:52	0.22	[0.15 0.26]	0.87	[0.6 1]	0.75	0.13	0.12
16 Nov 2006 at 09:46	0.08	[0.05 0.13]	0.94	[0.6 1]	0.67	0.08	0.25
25 Nov 2006 at 09:46	0.10	[0.05 0.15]	1	[1 1]	0.61	0.03	0.36
Particle Type Surface Validation Data Lacking							
23 May 2000 at 10:08$	0.36	[0.26 0.38]	0.25	[0.2 0.4]	0.23	0.35	0.42
01 Jun 2000 at 10:02	0.14	[0.03 0.22]	0.89	[0.4 1]	0.72	0.15	0.13

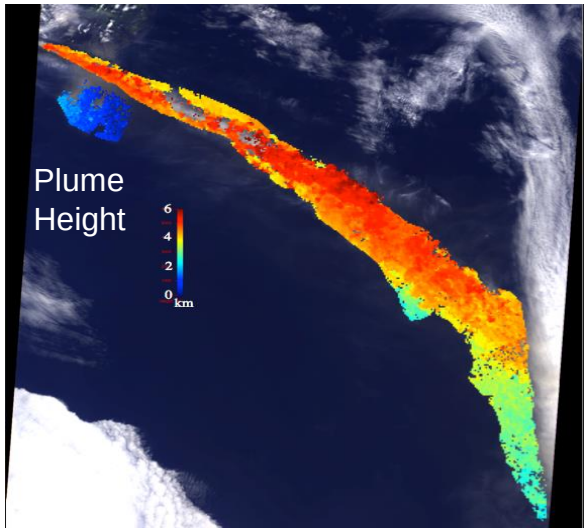
§ AOD Sph. Fraction Mean = Mean MISR-retrieved green band AOD value attributed to spherical particles
AOD Sph. Fract. Range = Range of MISR-retrieved green band AOD fraction attributed to spherical particles
Small = MISR-retrieved green-band AOD fraction of particles having small size (<0.35 μm radius)
Med = MISR-retrieved green-band AOD fraction of particles having medium size (0.35 < 0.7 μm radius)
Large = MISR-retrieved green-band AOD fraction of particles having large size (>0.7 μm radius)
$ Volcanic ash detected by MODIS

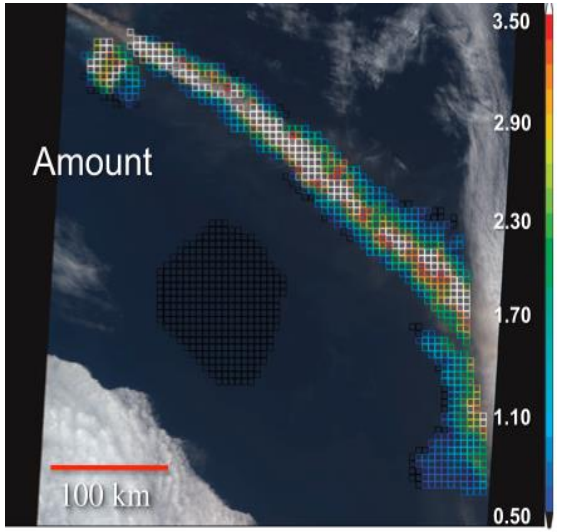
Scollo et al., JGR 2012

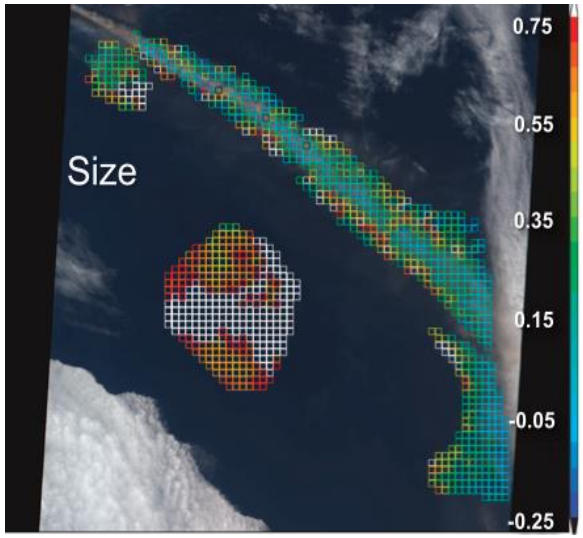
Volcanic Plume Properties: Height, Particle Size, Shape, Brightness

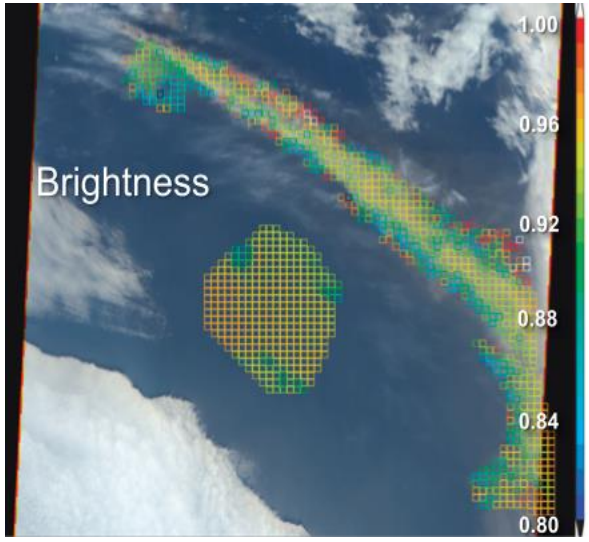
MISR Observations – Iceland Volcano Eruption ***07 May 2010***

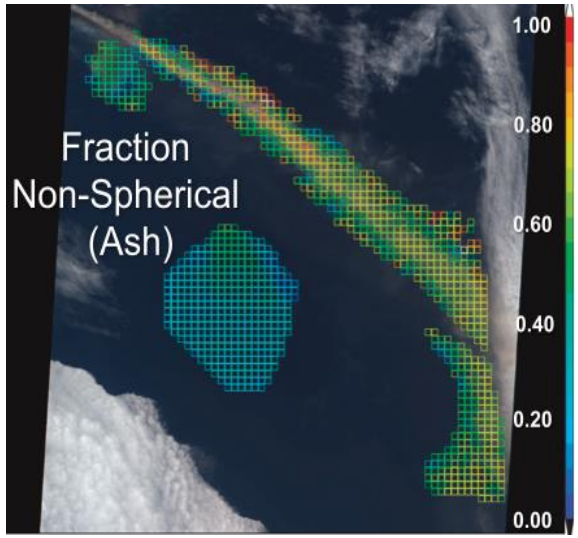












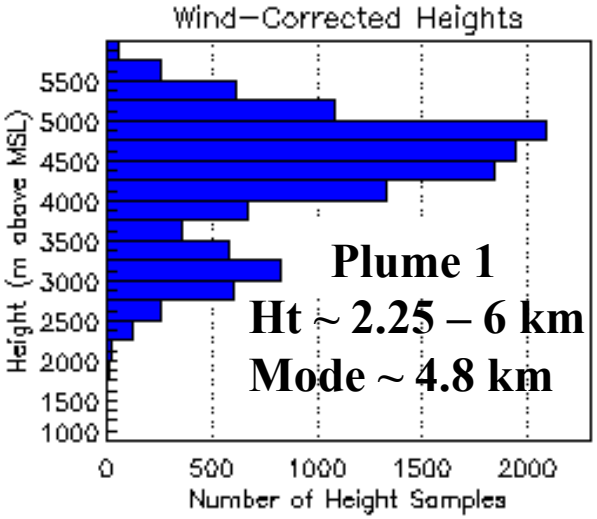
Kahn & Limbacher, ACP 2012

Plume Particles vs. Background:

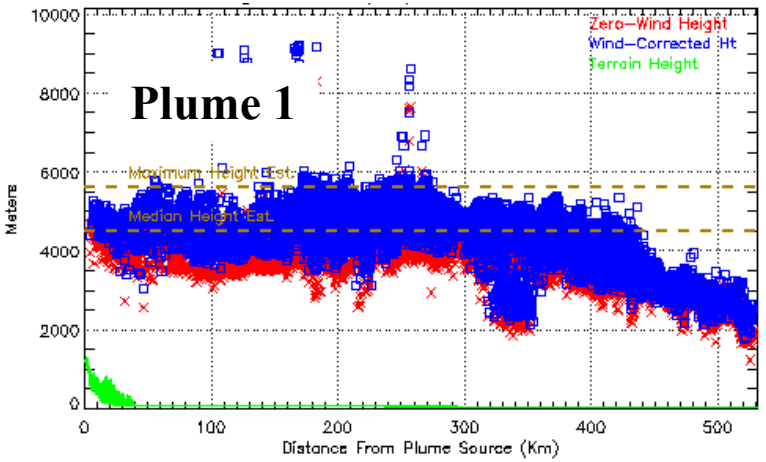
Larger, ***darker***, ***more non-spherical***, ***much more abundant***; ***Tend to brighten & decrease in size downwind***

MISR Stereo-Derived Plume Heights

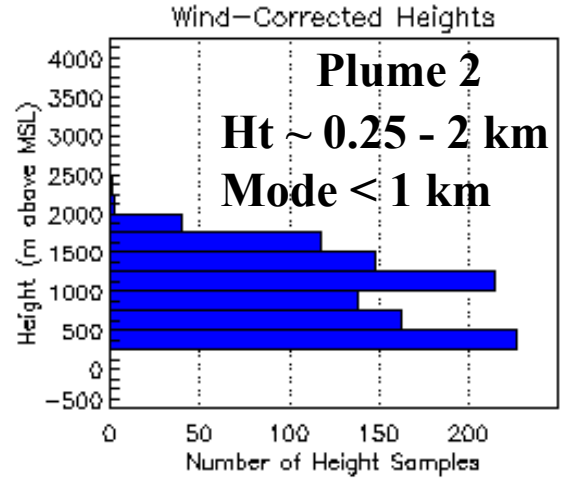
07 May 2010 Orbit 55238 Path 216 Blk 40 UT 12:39

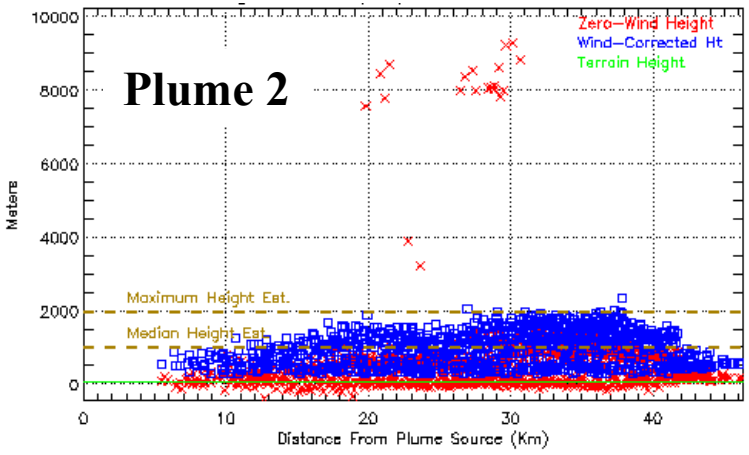


Height: Blue = Wind-corrected



n: 055238−B40−V1

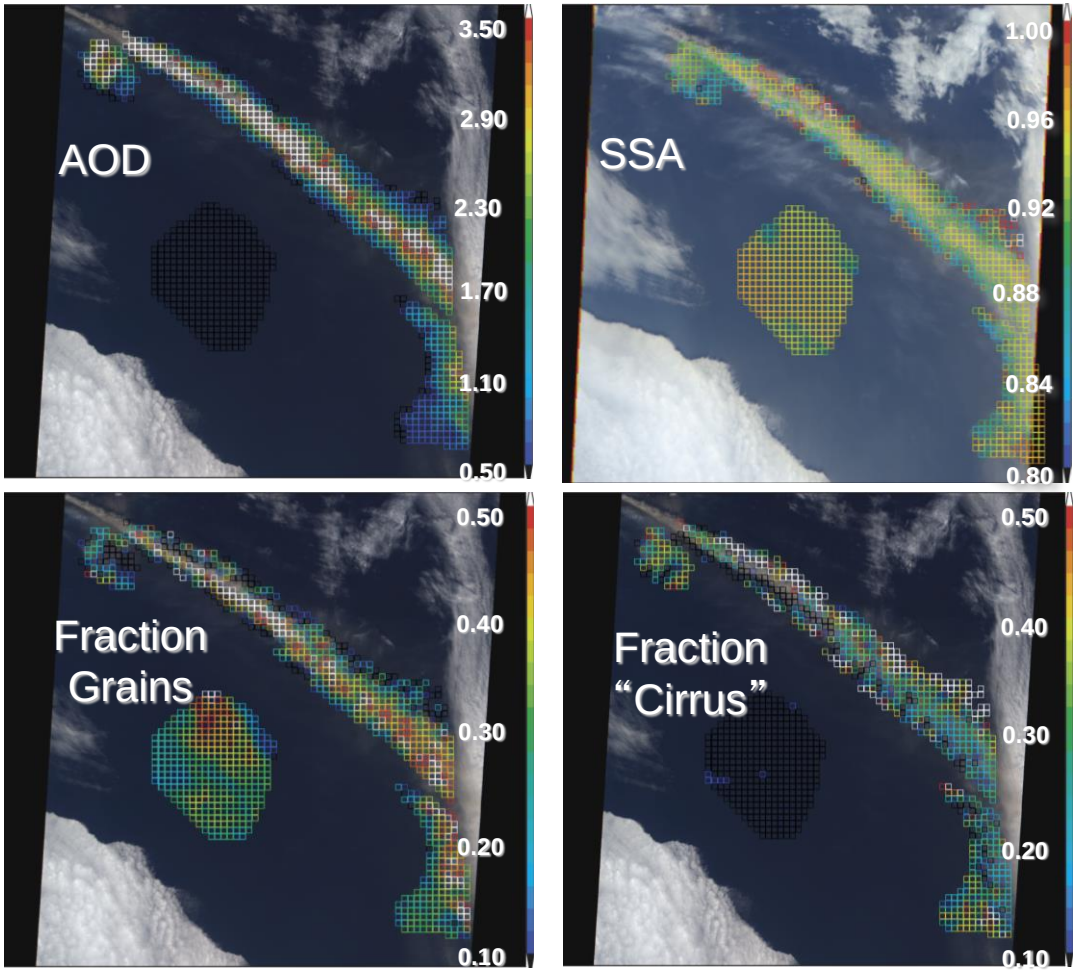




D. Nelson and the MISR Team

Eyjafjallajökull Volcanic Plume Properties

07 May 2010 plume, Orbit 55238, Path 216, 12:39 UTC



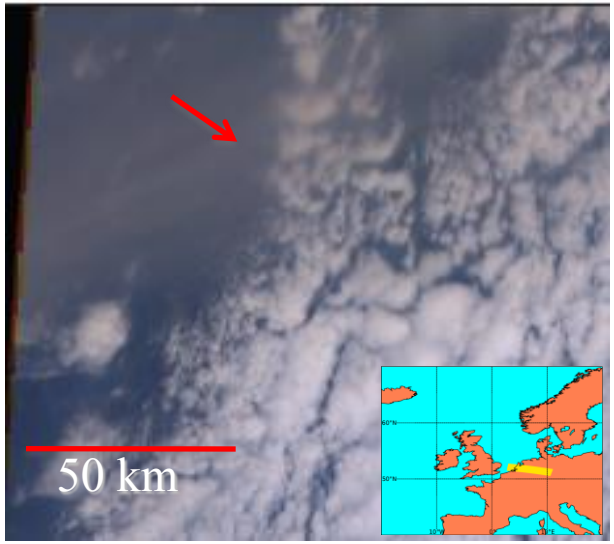
Climatology begins with case studies

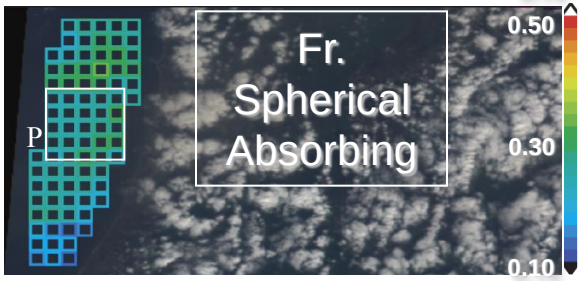
- **Volcanic Ash:** Retrieved as a mix of ***Grains***, ***Cirrus***, and ***Spherical Absorbing*** optical analogs
- **Global 13^{+}-year Data Set:** About a dozen volcanoes active around the globe at any one time
- **Retrieval Validation:** Need coincident ground-truth particle amount & type data

Kahn & Limbacher 2012

*MISR Research **Aerosol Retrievals***

16 April 2010 Orbit 54931 Path 197 Blk 49 UT 10:45

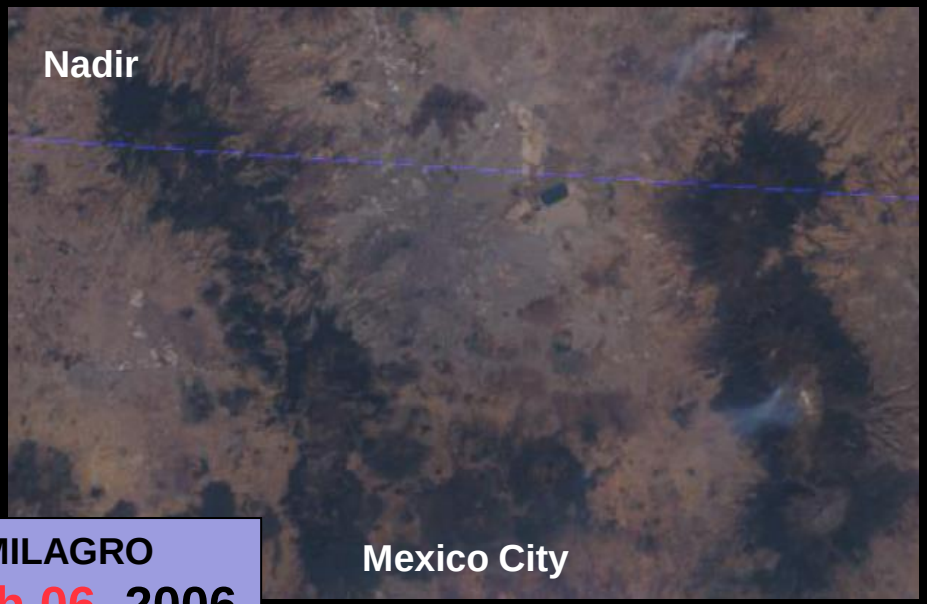




- ***1-2 days downwind*** of Iceland volcano source
- Distinctly ***high AOD*** (peak >1.25)
- Retrieved ~50% AOD ***non-spherical*** dust grains
- ***Medium*** particles ~ no "cirrus"
- Model ***back-trajectory needed*** to identify plume confidently

Kahn & Limbacher, ACP 2012

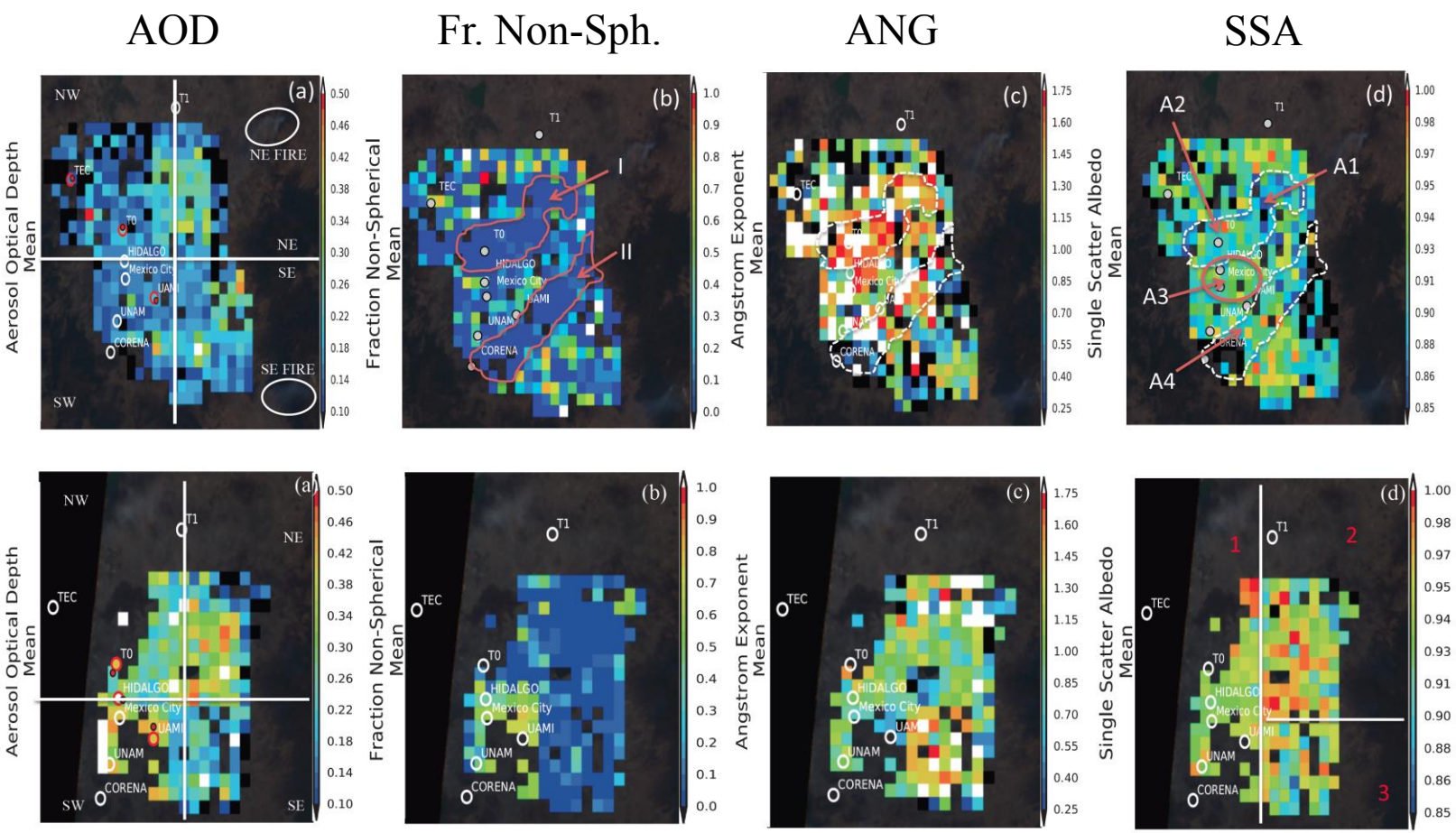
Mapping AOD & Aerosol Air-Mass-Type in Urban Regions



INTEX-B/MILAGRO
MISR March 06, 2006
Orb 33062 Path 26 Block 75

Patadia et al.

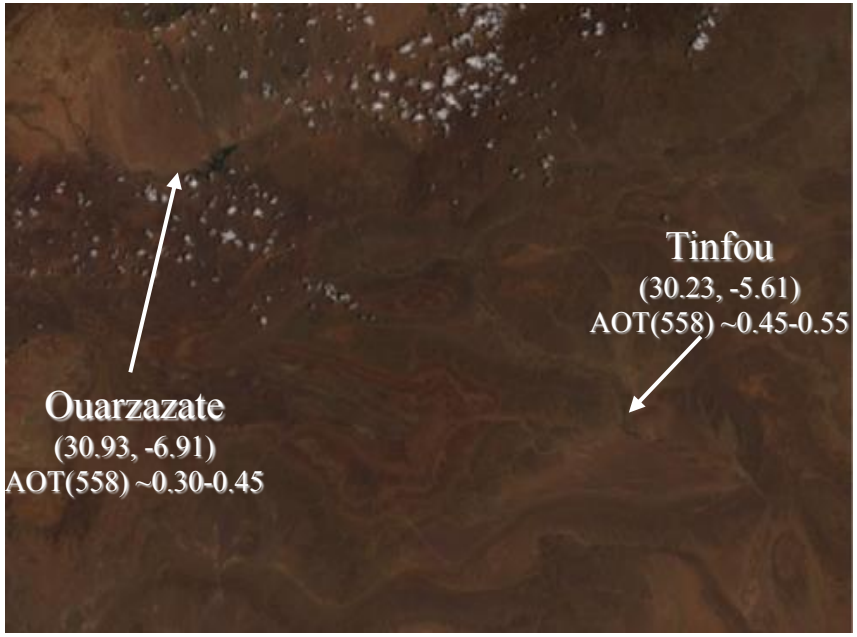
Urban Pollution AOD & Aerosol Air Mass Type Mapping
INTEX-B, 06 & 15 March 2006

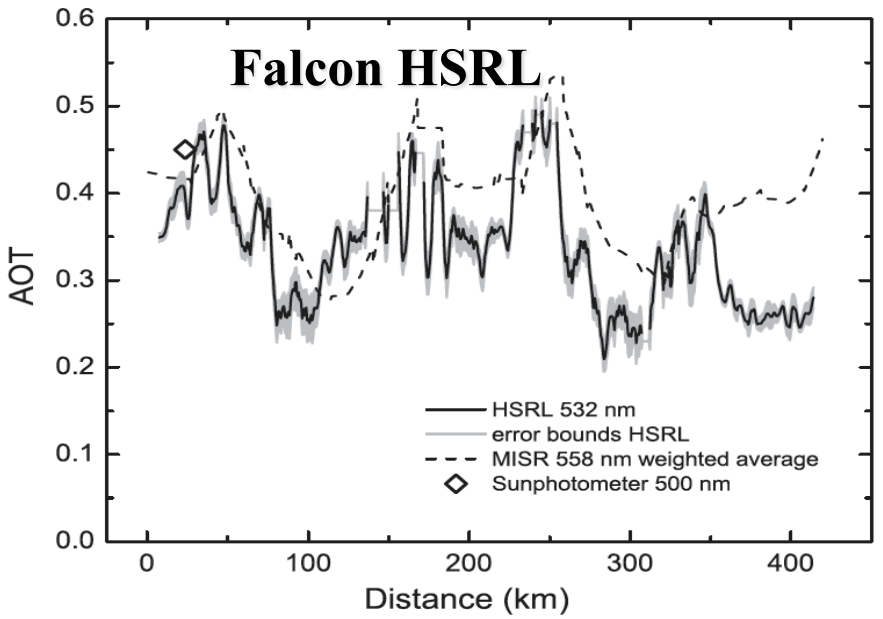


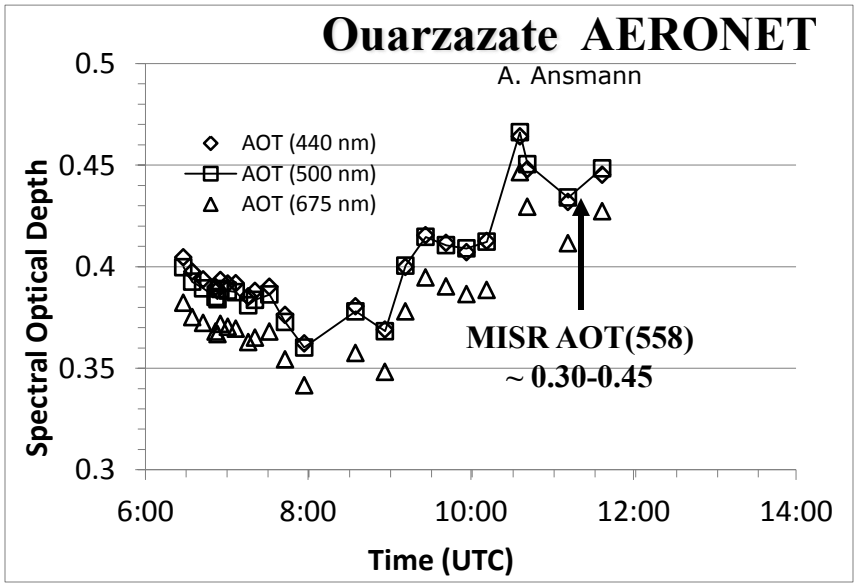
Aerosol Air Masses: ***Dust*** (non-spherical), ***Smoke*** (spherical, spectrally steep absorbing), and ***Pollution*** particles (spherical, spectrally flat absorbing) dominate specific regions

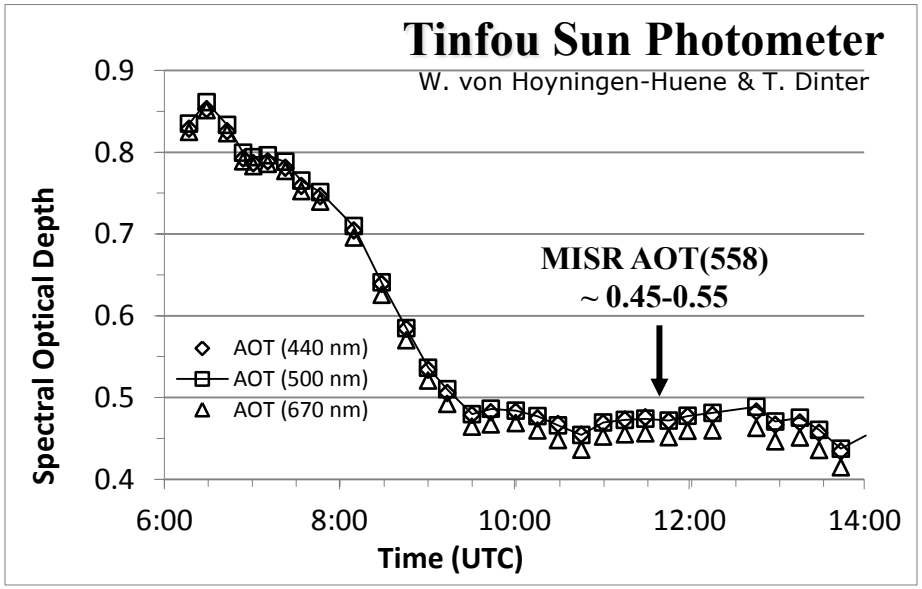
Patadia et al. ACP, in press 2013

SAMUM Campaign Morocco – June 04, 2006



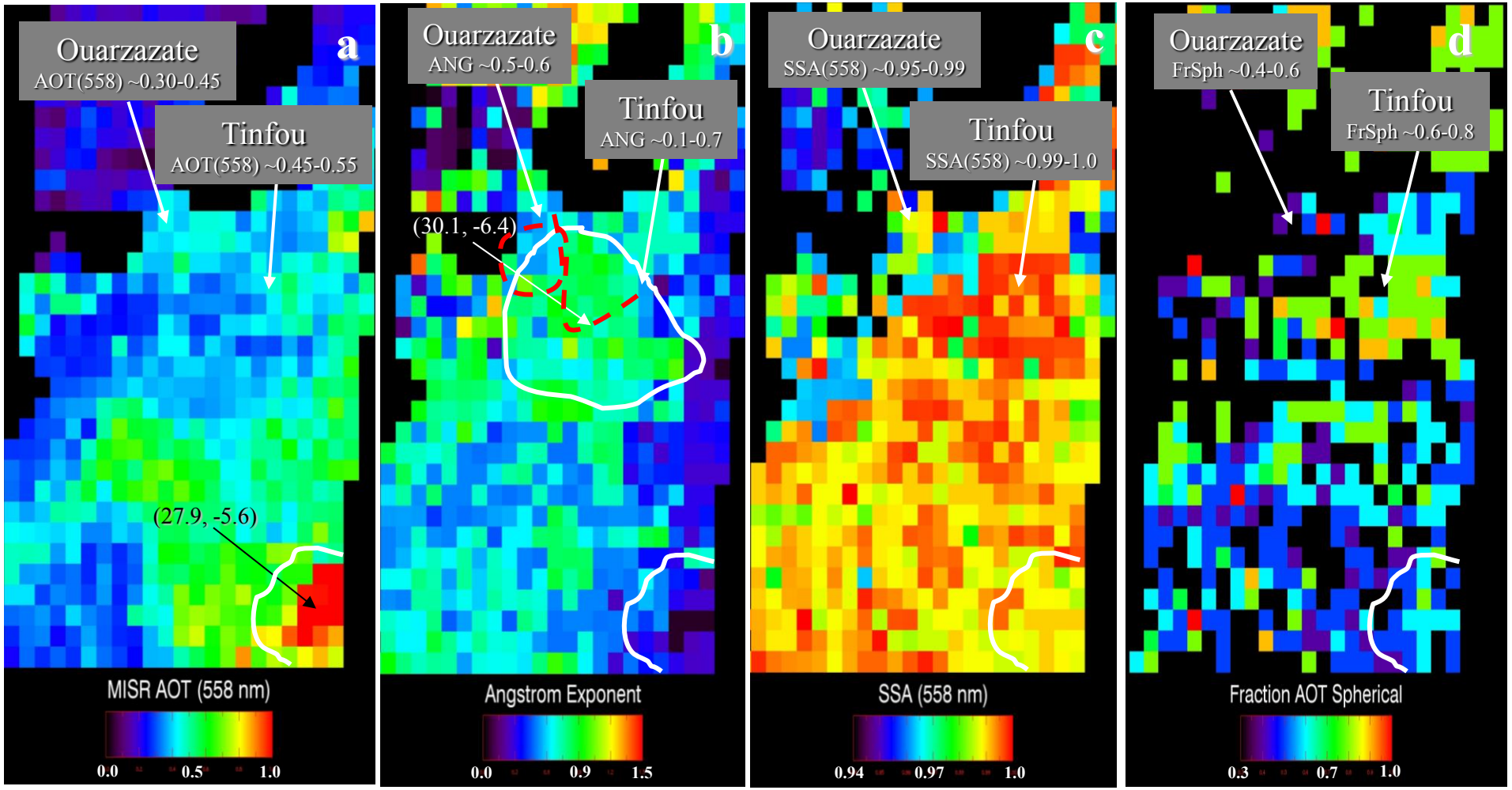






MISR SAMUM Aerosol Air Masses (V19) - June 04, 2006

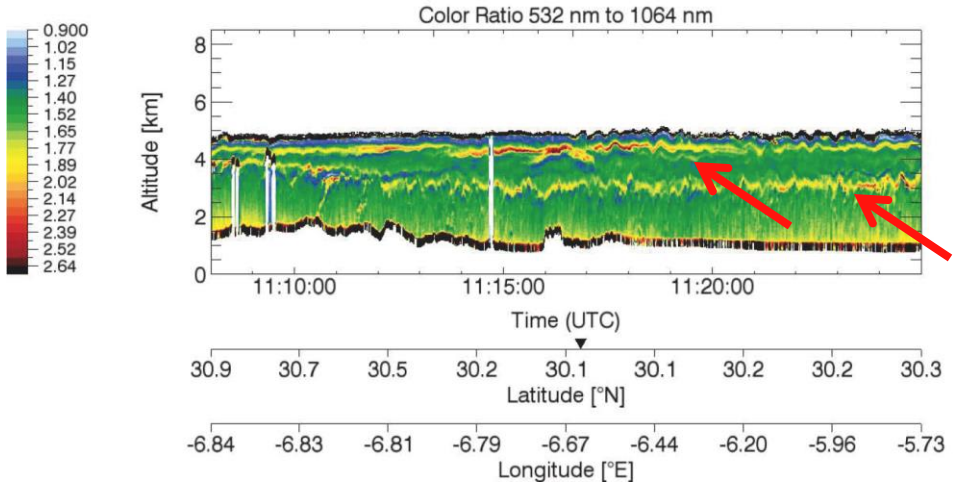
Orbit 34369, Path 201, Blocks 65-68, 11:11 UTC



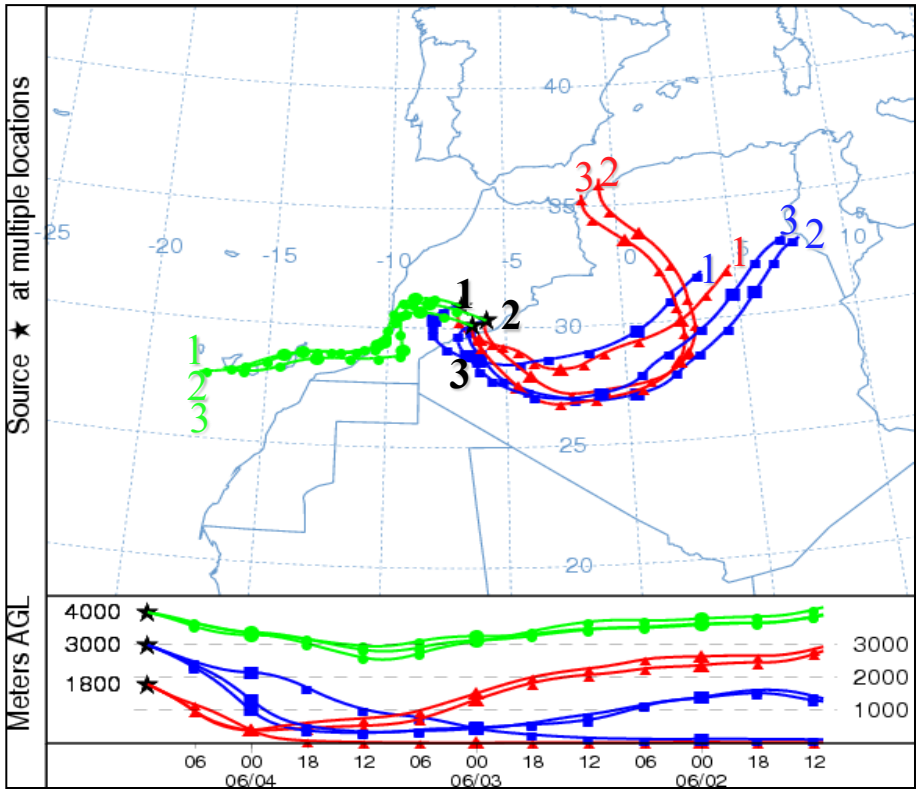
- A **dust-laden density flow in the SE** corner of the MISR swath
- **High SSA, ANG** & **Fraction Spherical** region SE of Ouarzazate, includes Zagora

Kahn et al., Tellus 2009

MISR SAMUM Aerosol Air Mass Validation - June 04, 2006



Falcon F-20 HSRL
- Thin layers of small, bright particles

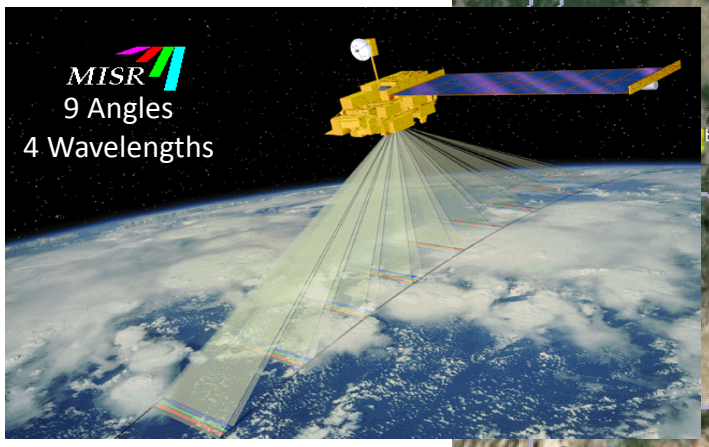


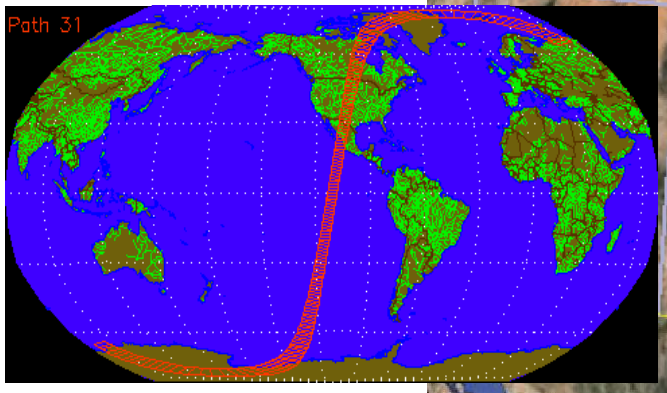
NOAA/HYSPLIT Back Trajectories
-Source in N Algeria for 2, 3 but not 1.

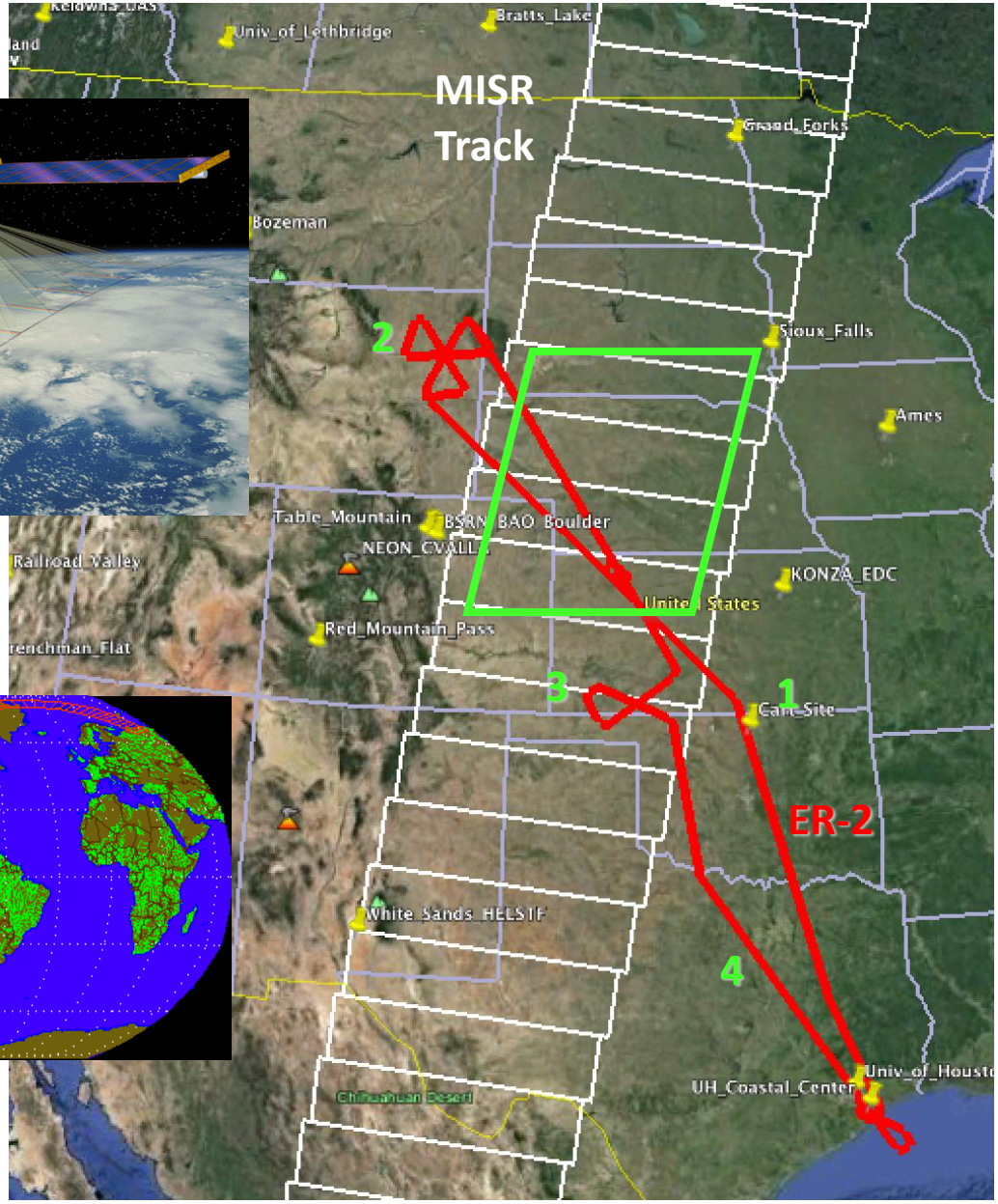
Kahn et al., Tellus 2009

SEAC⁴RS Field Campaign: Monday, 19 August 2013

MISR Overpass 17:40 UTC







17:40 UTC
Path 031
Orbit 72716

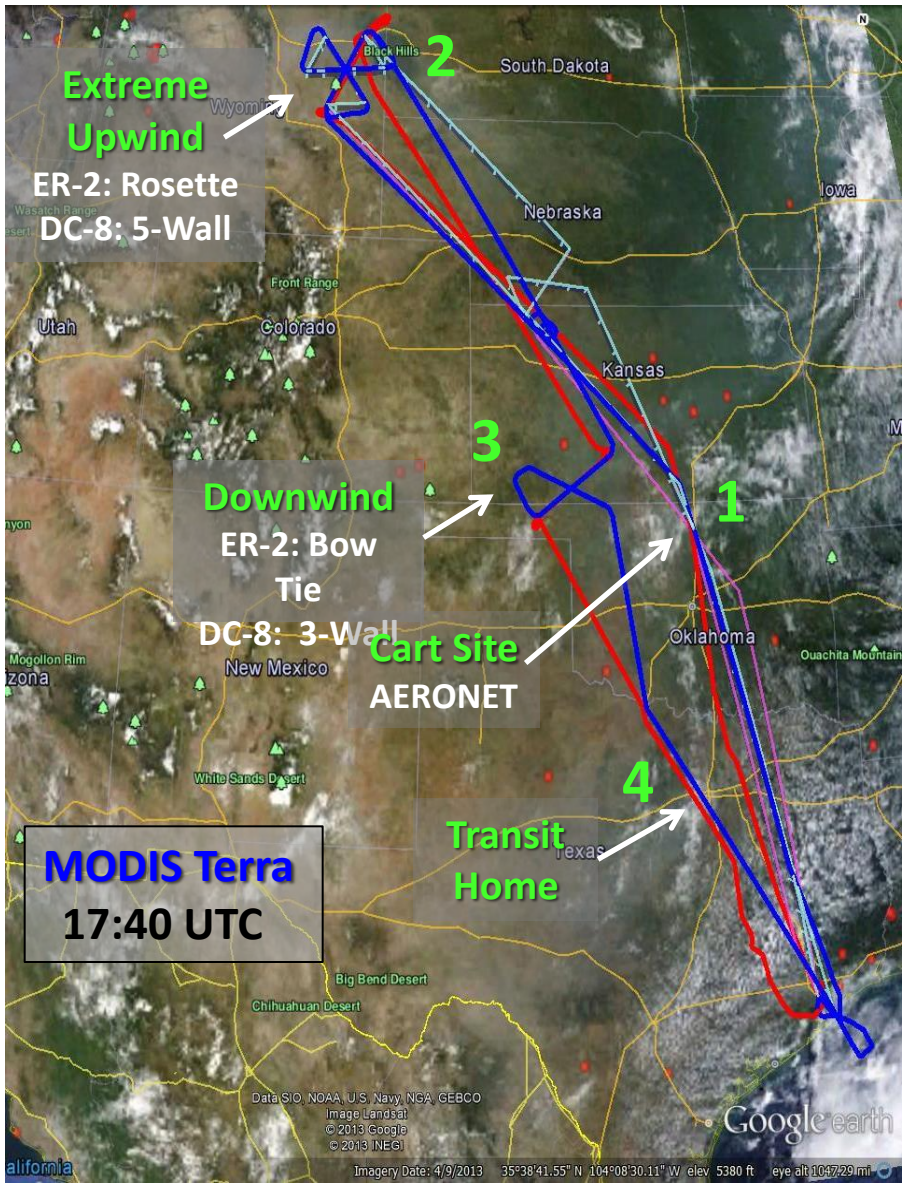
South Dakota

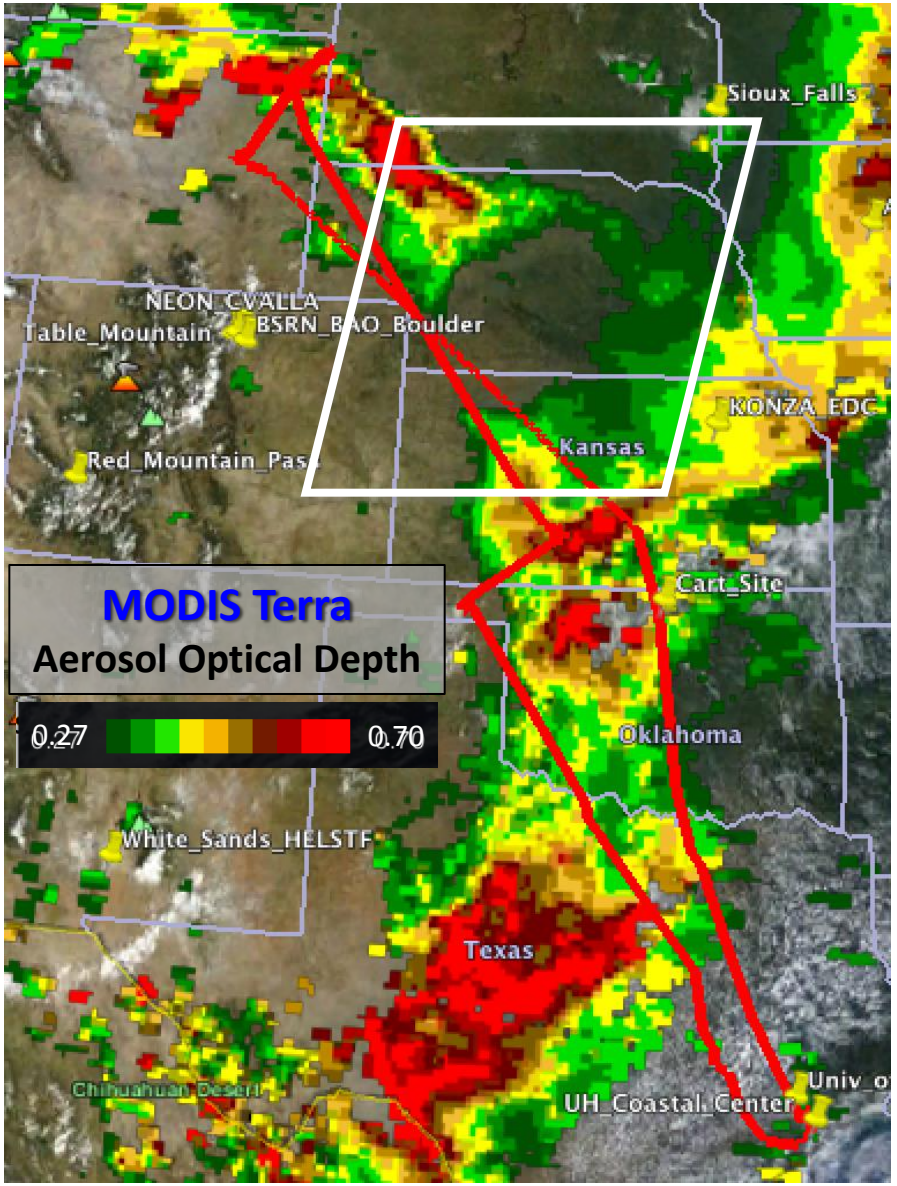
Nebraska

Kansas

SEAC^{4}RS Campaign DC-8 and ER-2 Flights

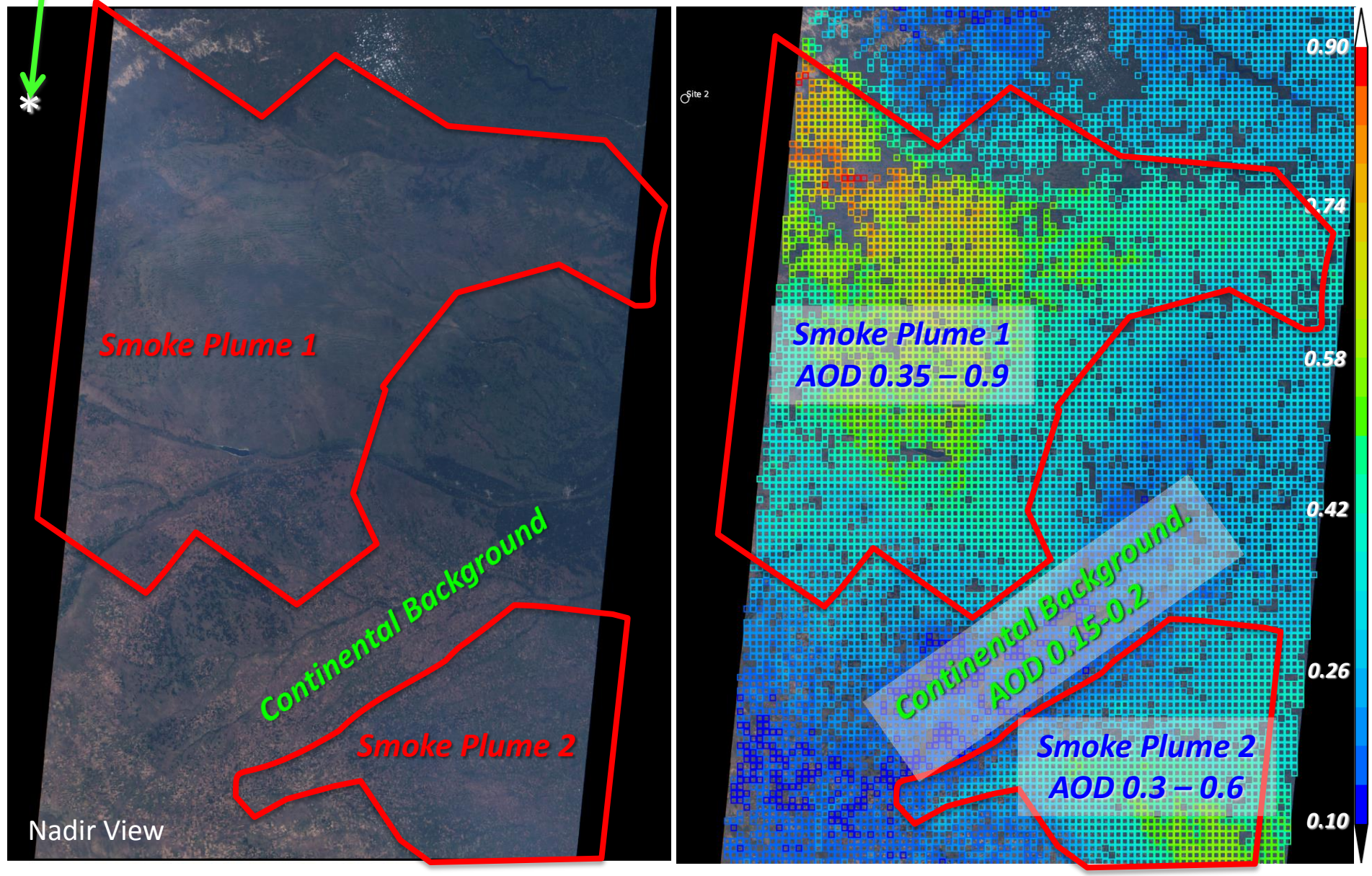
Monday, 19 August 2013





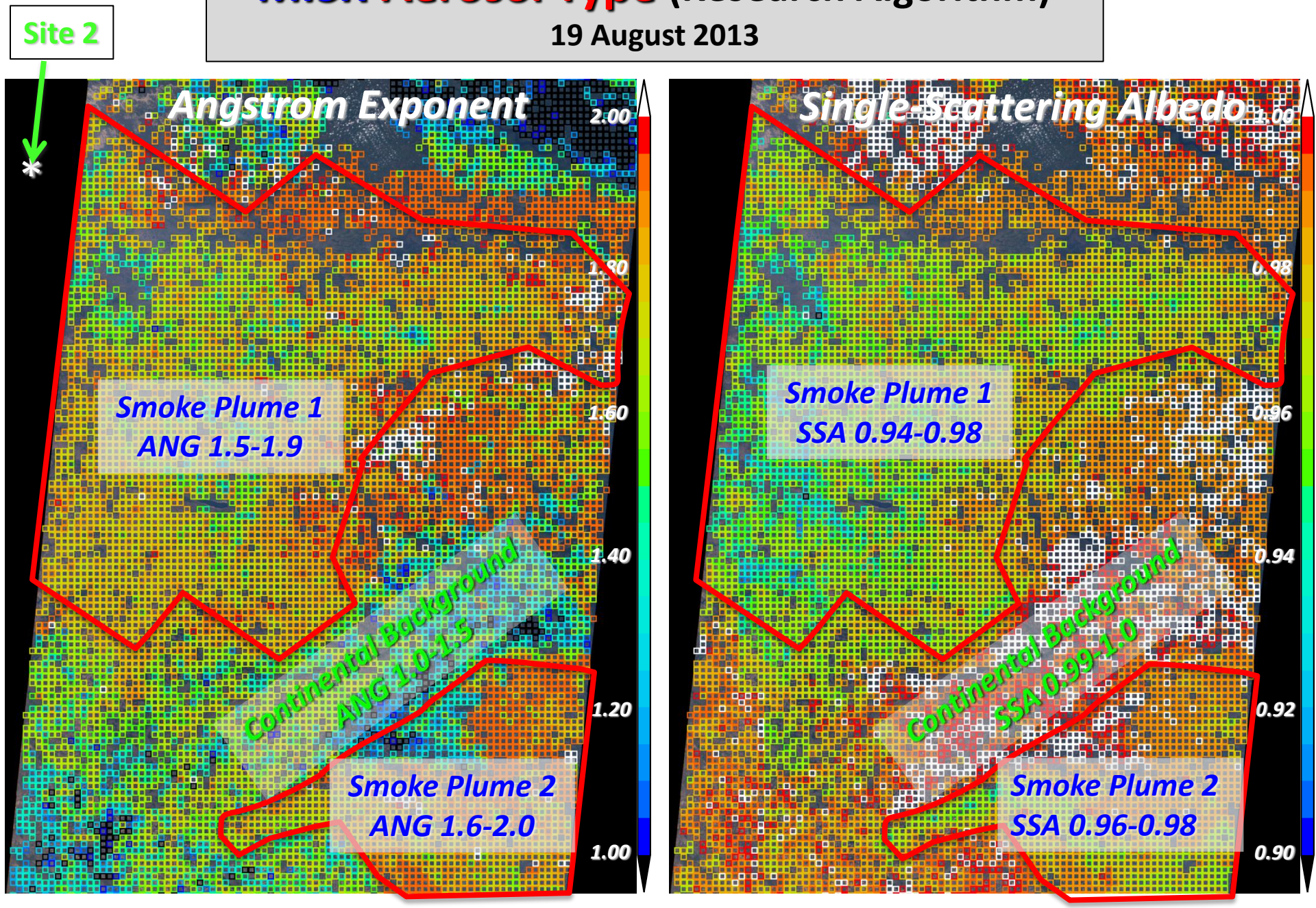
MISR Aerosol Optical Depth (Research Algorithm)

19 August 2013



MISR Aerosol Type (Research Algorithm)

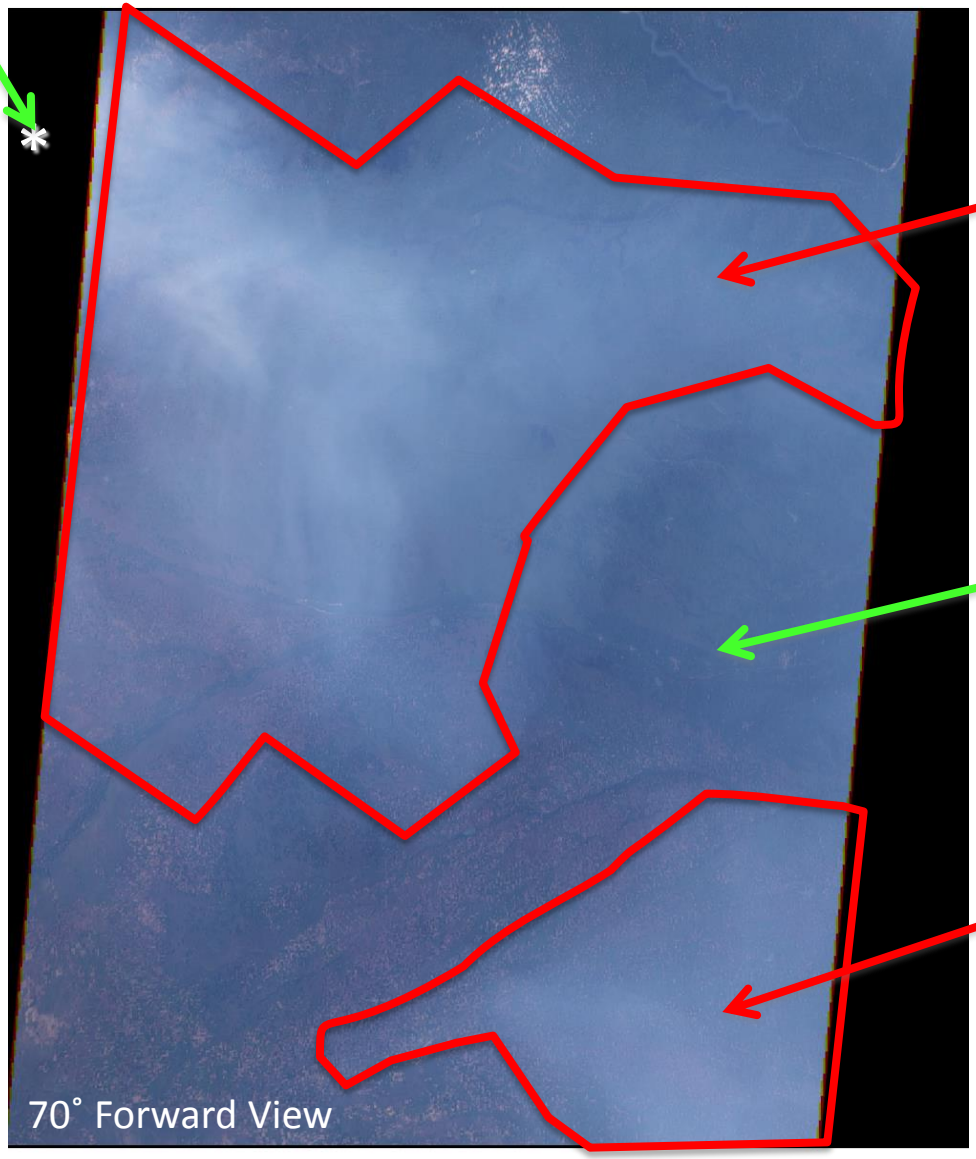
19 August 2013



MISR Aerosol Type (Research Algorithm)

19 August 2013

Site 2



Smoke Plume 1
AOD 0.35-0.9
*ANG 1.5-1.9 (**small**)*
*SSA 0.94-0.98 (**absorbing**)*
*FrNon-Sph 0-0.2 (**mostly spherical**)*

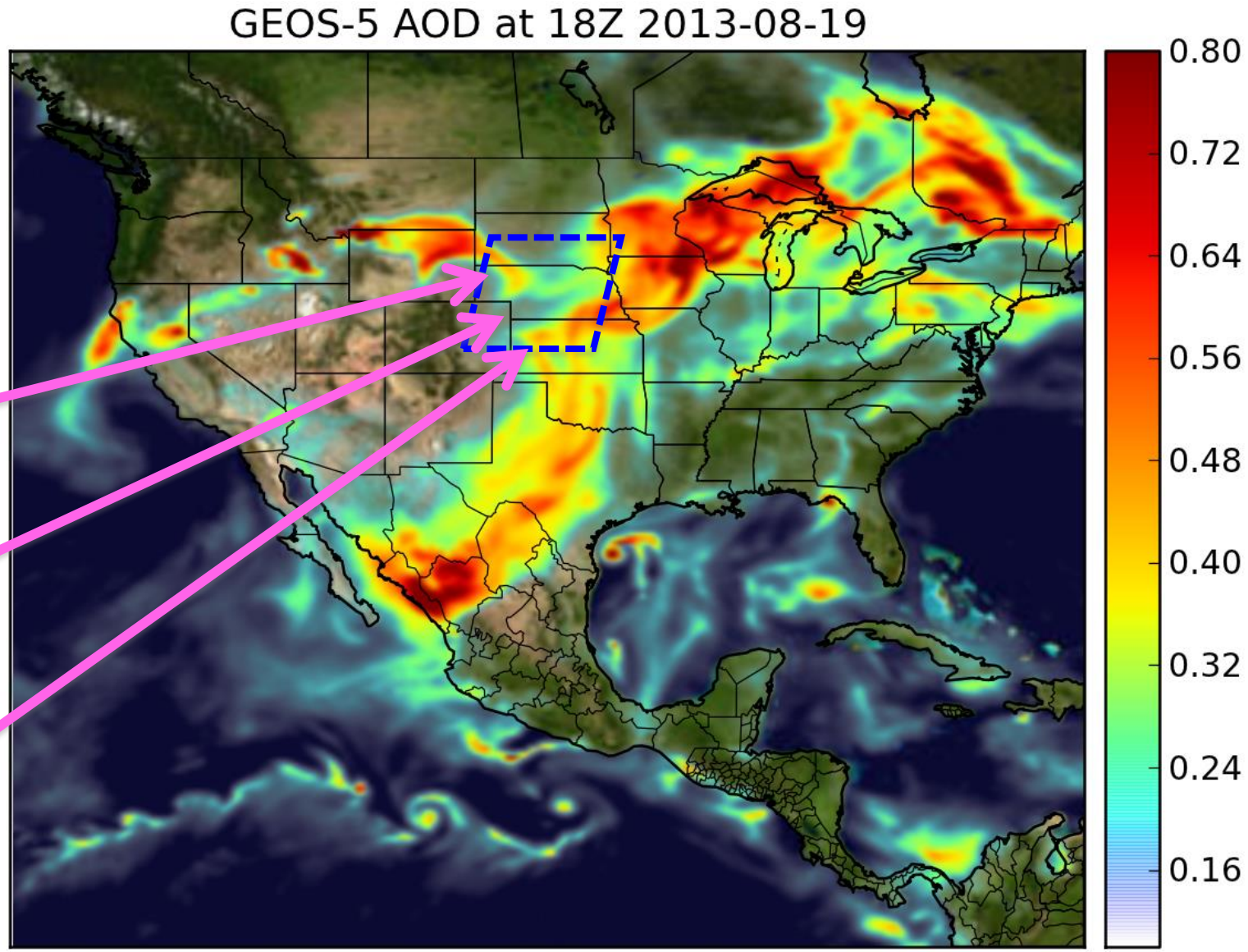
Continental Background
AOD 0.15-0.2
*ANG 1.0-1.5 (**medium**)*
*SSA 0.99-1.0 (**non-absorbing**)*
*FrNon-Sph 0.0 (**spherical**)*

Smoke Plume 2
AOD 0.35-0.6
*ANG 1.6-2.0 (**smaller**)*
*SSA 0.96-0.98 (**less absorbing**)*
*FrNon-Sph 0-0.1 (**more spherical**)*

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

GEOS-5 MODEL Aerosol Optical Depth

19 August 2013 18 UTC



Smoke Plume 1
Younger
Higher AOD

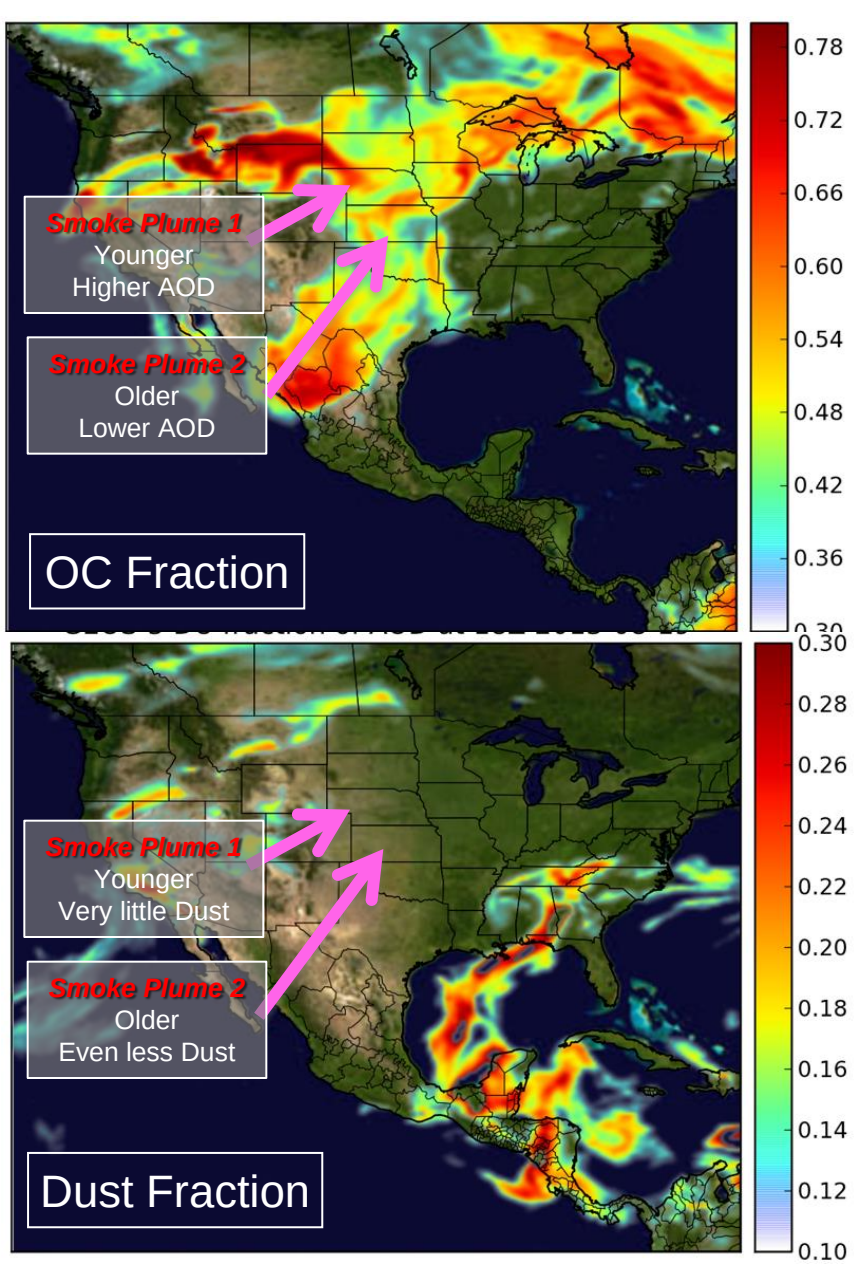
Continental Background
Low AOD
Sulfate

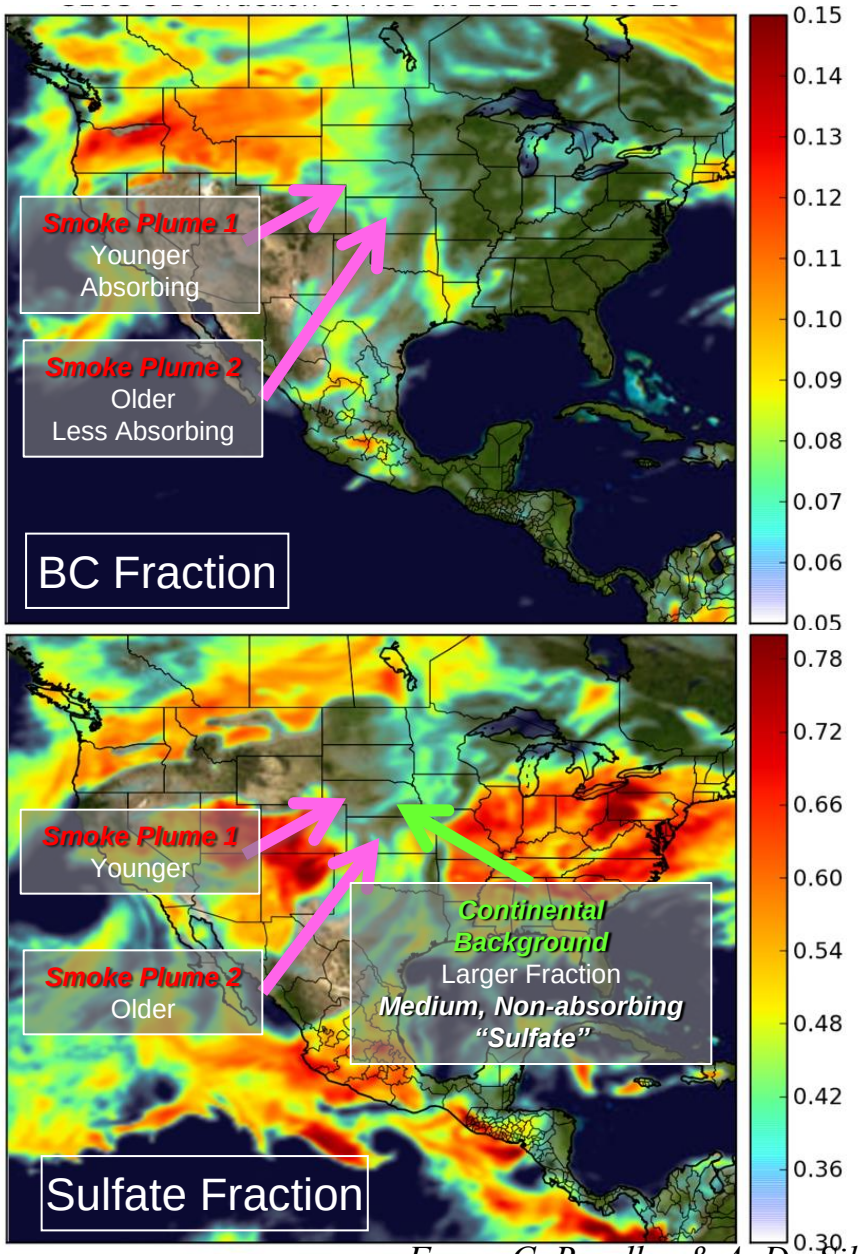
Smoke Plume 2
Older
Lower AOD

From: C. Randles & A. Da Silva

GEOS-5 MODEL Aerosol Type

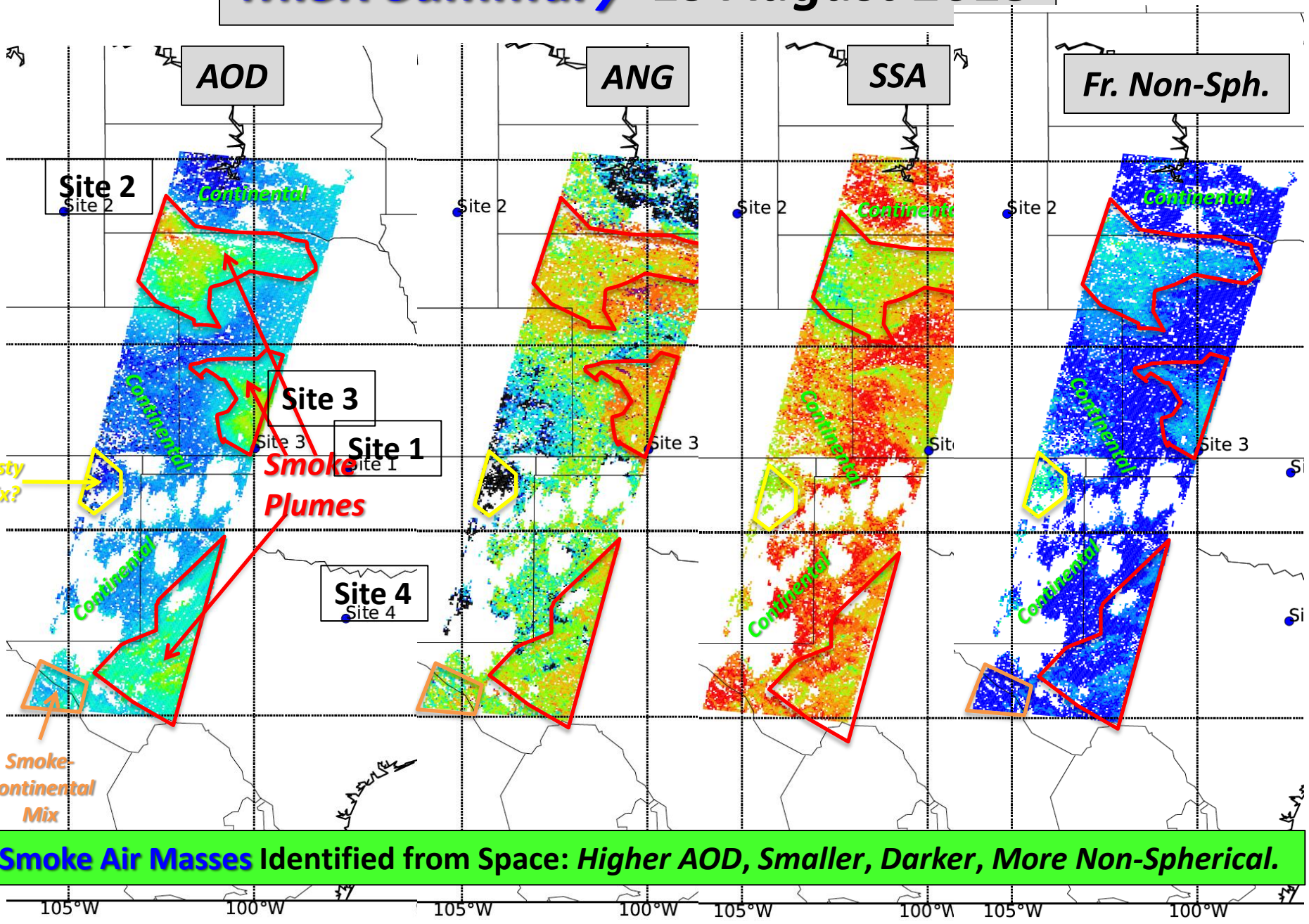
19 August 2013 18 UTC





From: C. Randles & A. Da Silva

MISR Summary 19 August 2013



Smoke Air Masses Identified from Space: *Higher AOD, Smaller, Darker, More Non-Spherical.*

Key Attributes of the MISR **Version 22** Aerosol Product

- **AOT Coverage** – ***Global but limited sampling*** on a monthly basis
- **AOT Accuracy** – Maintained even when particle property information is poor
- **Particle Size** – ***2-3 groupings reliably***; quantitative results vary w/conditions
- **Particle Shape** – ***spherical vs. non-spherical robust***, except for coarse dust
- **Particle SSA** – useful for ***qualitative*** distinctions
- **Aerosol Type Information** – diminished when ***AOT < 0.15*** or 0.2
- **Particle Property Retrievals** – ***improvement expected*** w/algorithm upgrades
- **Aerosol Air-mass Types** – ***more robust*** than individual properties

PLEASE READ THE QUALITY STATEMENT!!!

… and more details are in publications referenced therein

Satellites

frequent, global *snapshots*; aerosol amount & aerosol type maps, plume & layer heights

Remote-sensing Analysis
- Retrieval Validation
- Assumption Refinement

Suborbital

Regional Context

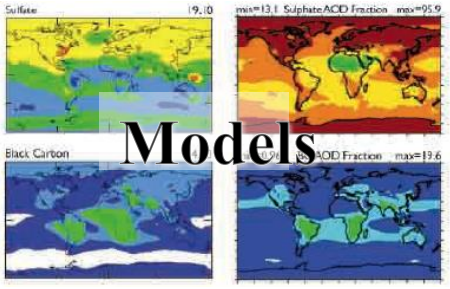
targeted chemical & microphysical detail

point-location time series

Aerosol-type Predictions

CURRENT STATE
- Initial Conditions
- Assimilation

Model Validation
- Parameterizations
- Climate Sensitivity
- Underlying mechanisms



Models

space-time interpolation,

DARF & Anthropogenic Component

calculation and prediction

Kahn, Survy. Geophys. 2012