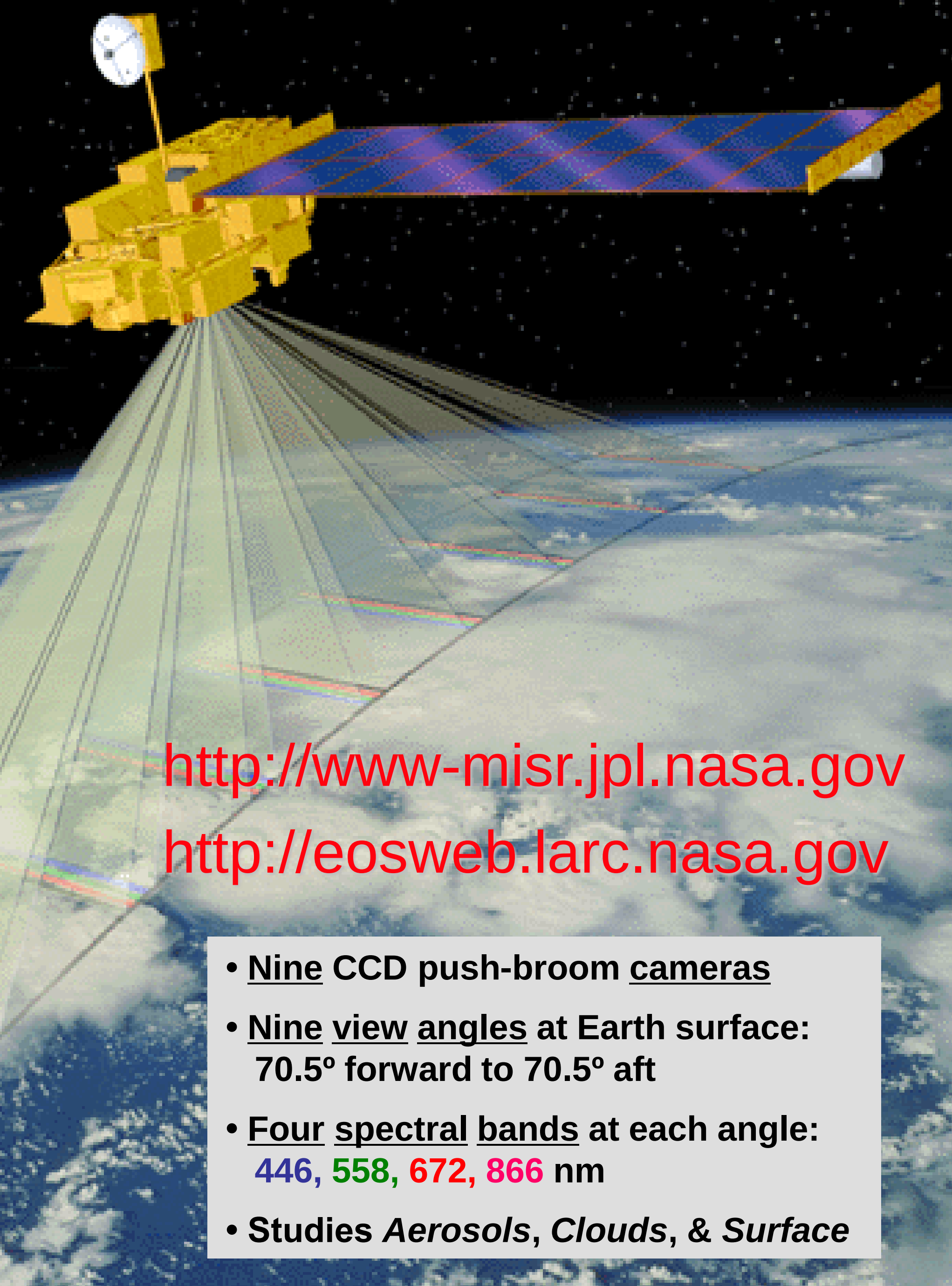
MISR

MISR Aerosol Type Strengths & Limitations

Ralph Kahn

NASA Goddard Space Flight Center



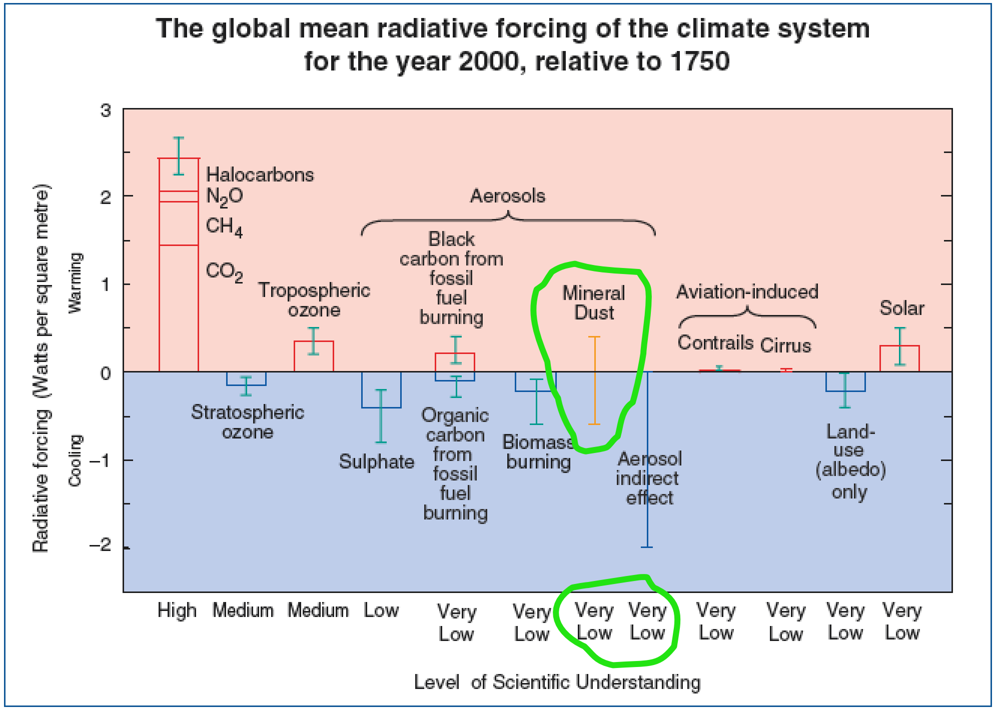
http://www-misr.jpl.nasa.gov

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***

NASA

Even DARF and Anthropogenic DARF are *NOT* Solved Problems (Yet)



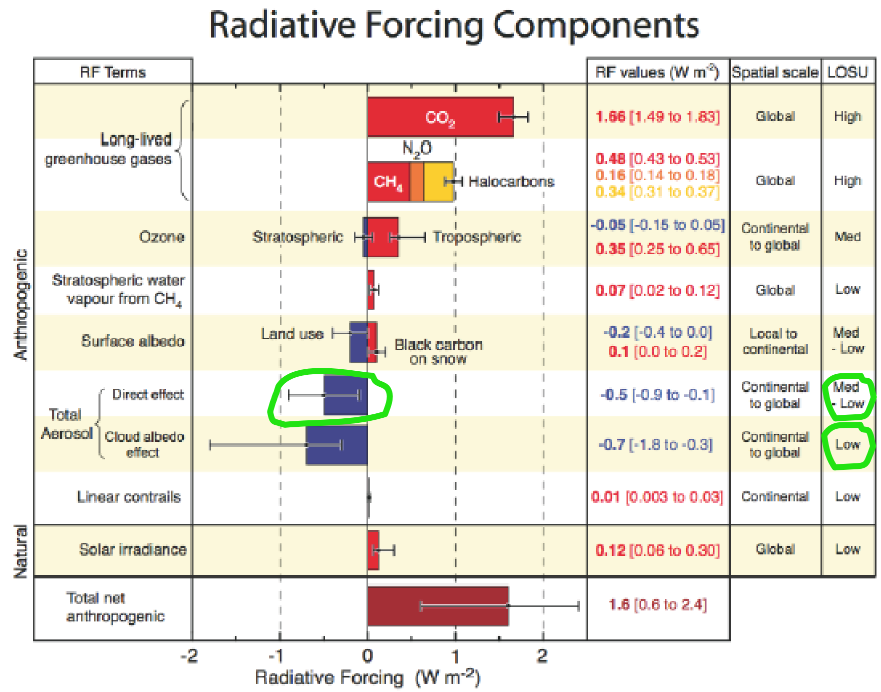
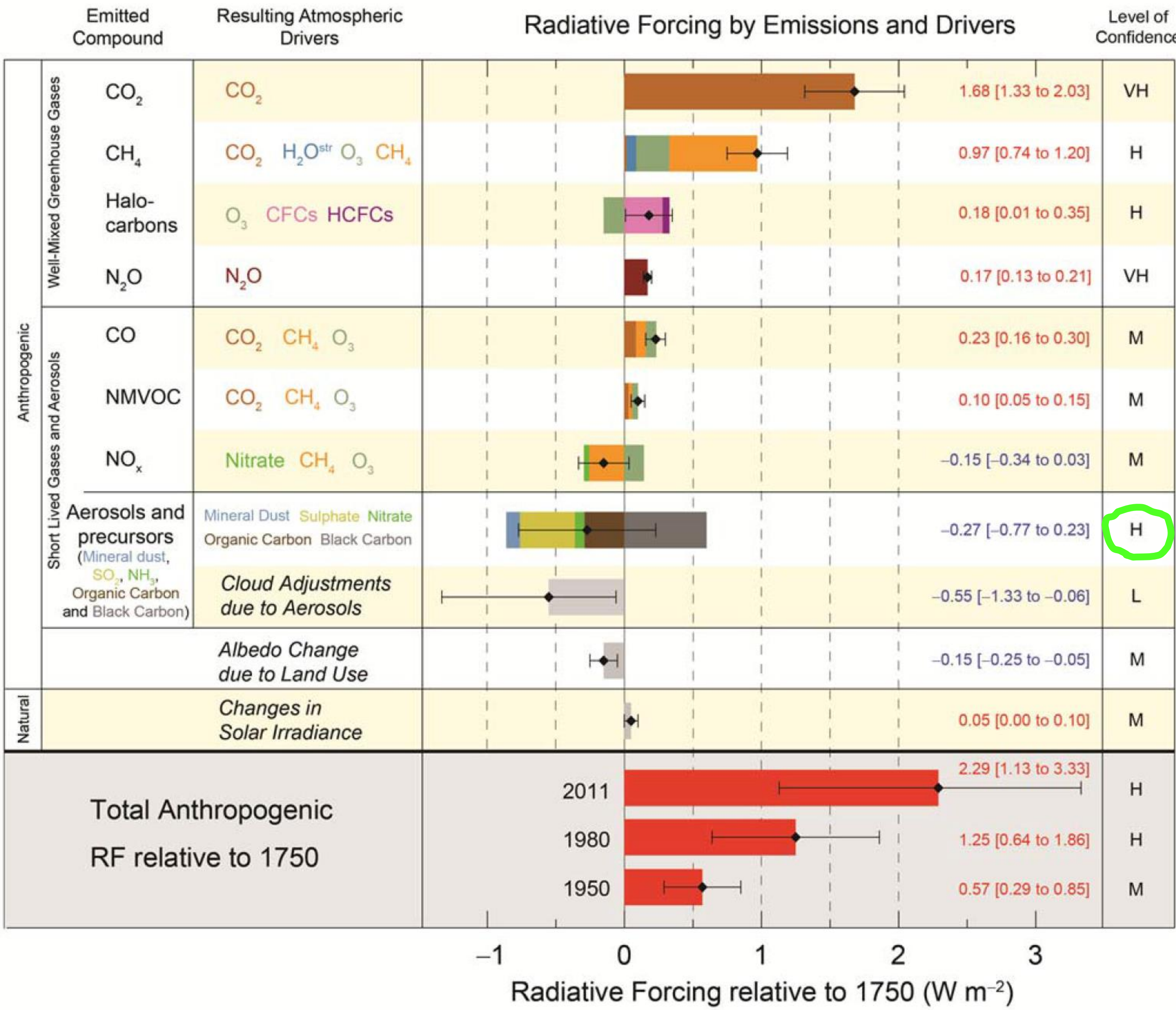


FIGURE SPM-2. Global-average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. Range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}

IPCC AR3, 2001
(Pre-EOS)

IPCC AR4, 2007
(EOS + ~ 6 years)

The *Current* Assessment of Climate Forcing Factors



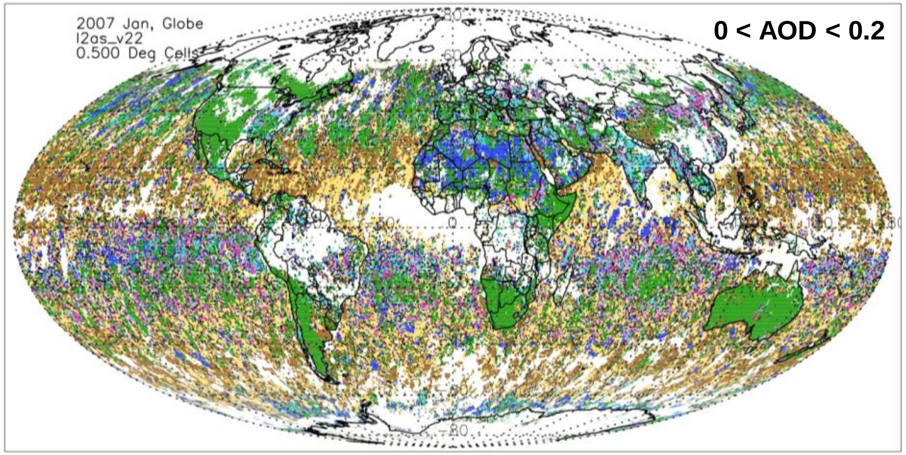
Global **average, & compared to other uncertainties in the models –** ***What about aerosol type?!***

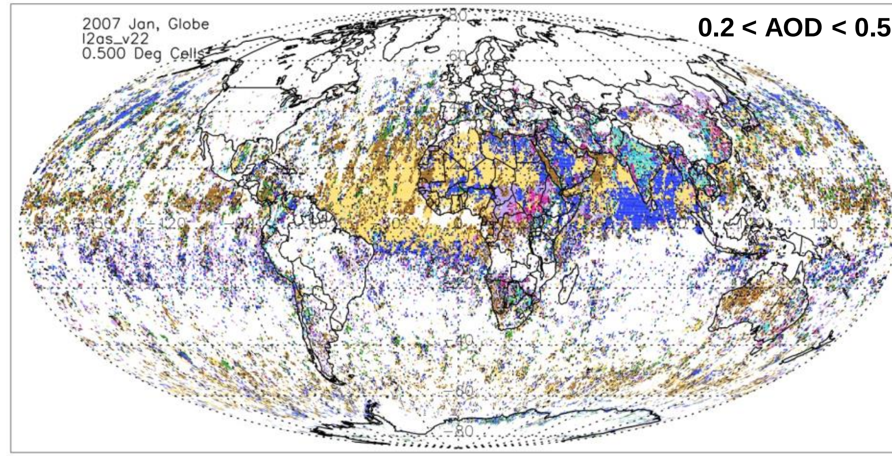
IPCC ***AR5*** *2013*

Can CMIP continue to use ***Model Diversity*** as a primary measure of ***Model Uncertainty?***

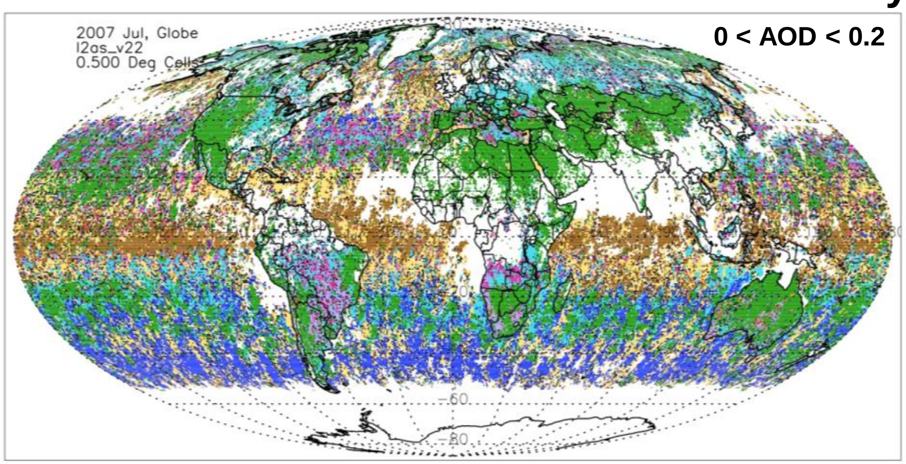
Global Distribution of MISR Most Frequently Retrieved Mixture Group

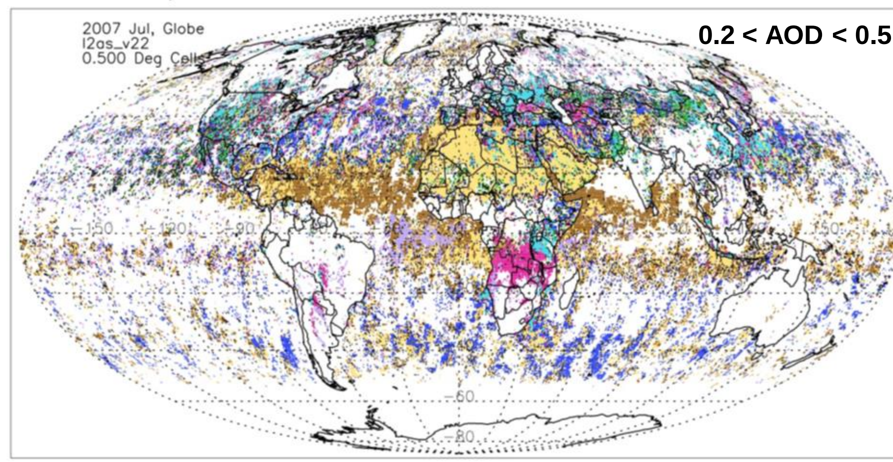
January 2007





July 2007





Mixture Group

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

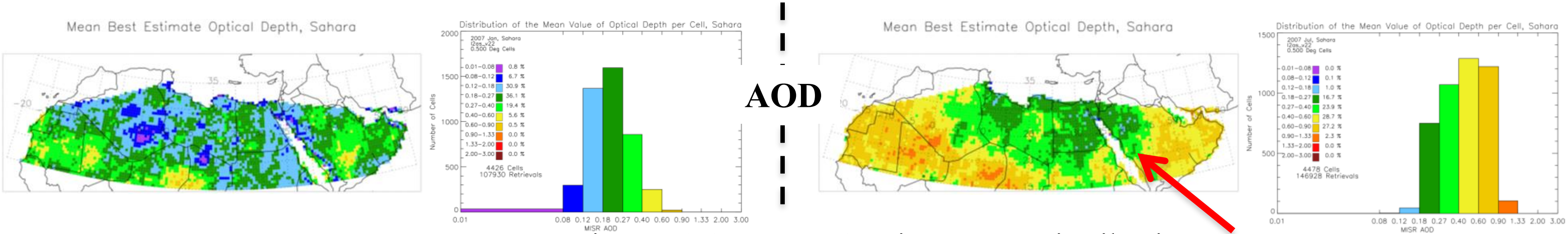
Spherical, non-absorbing

Non-spherical

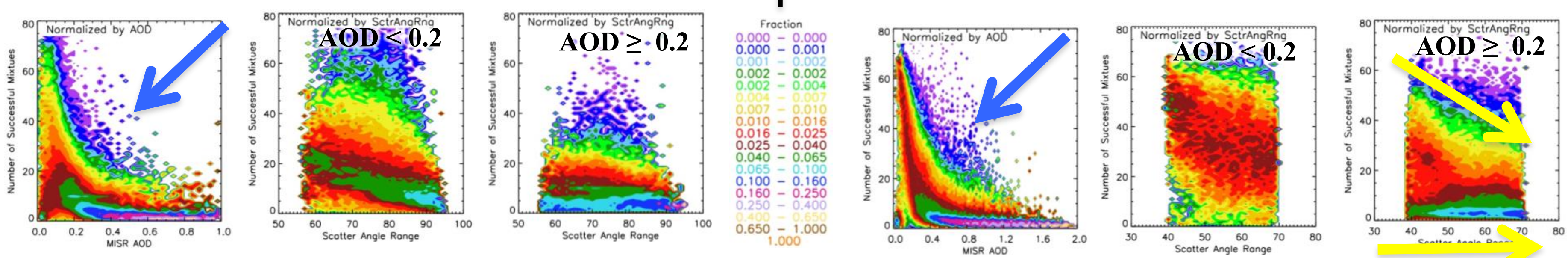
Spherical, absorbing

Kahn, Gaitley, et al. JGR, submitted

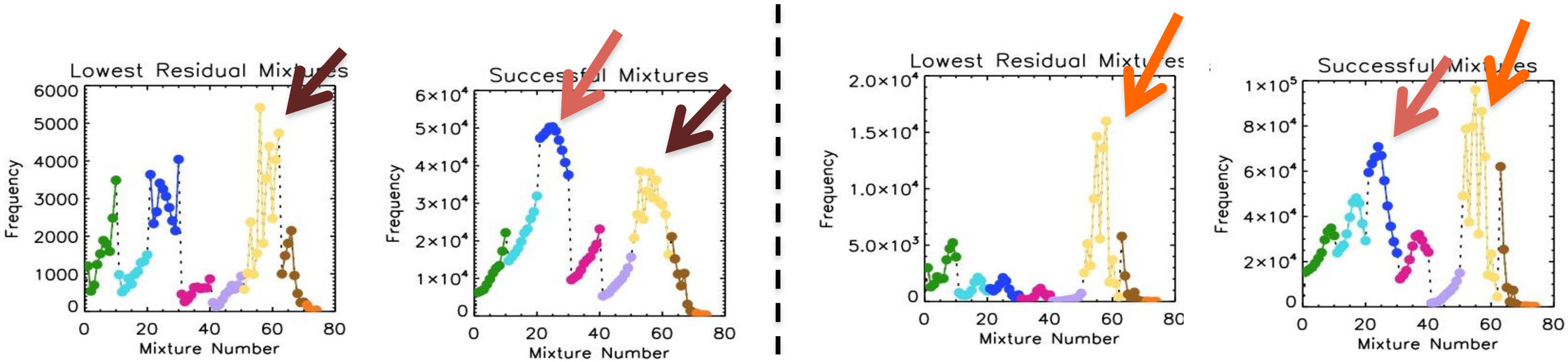
January 2007 **Sahara Desert** July 2007



Mean Best Estimate AOD Map & Histogram Distribution

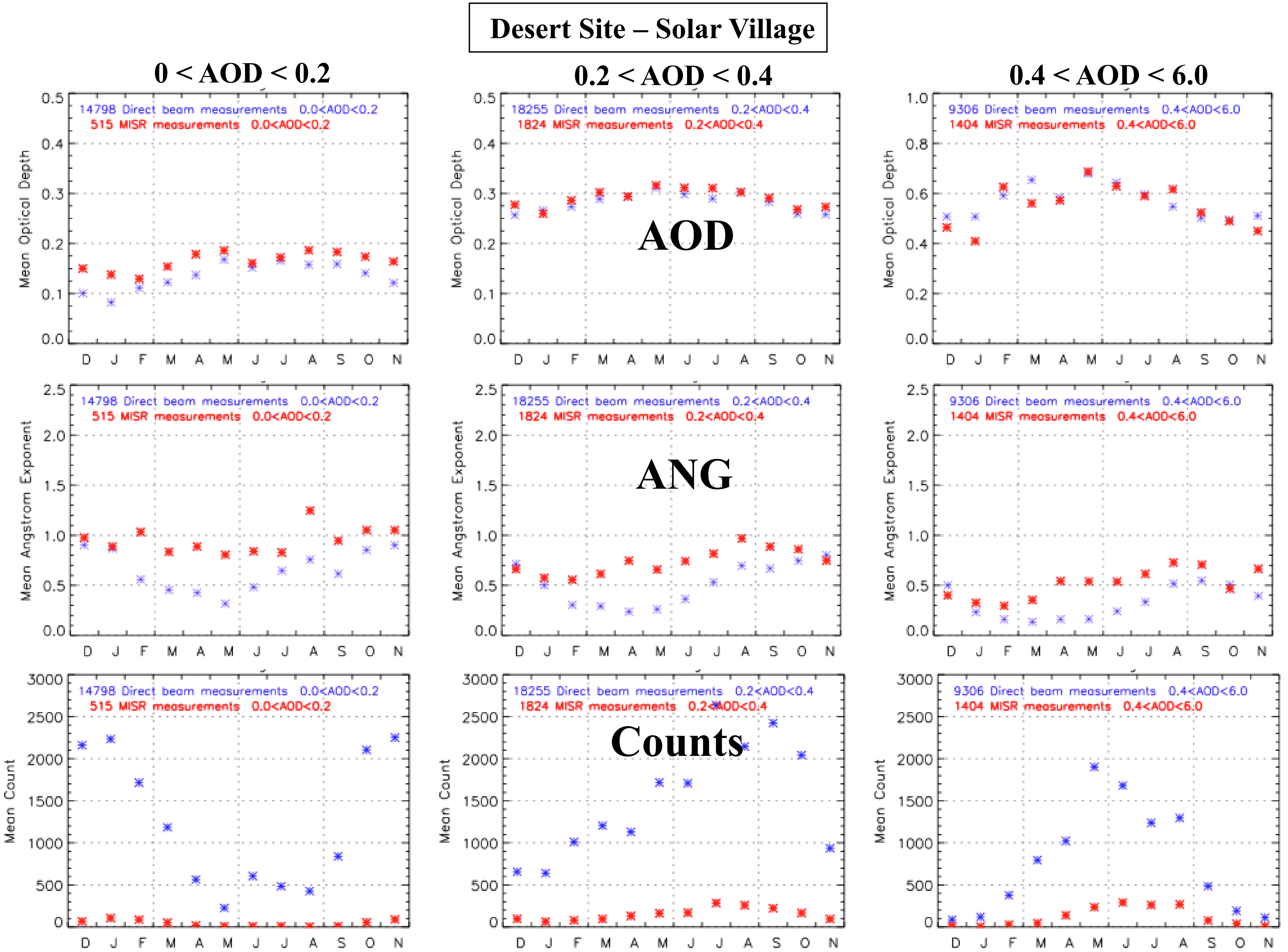


#*SuccMix* vs. Normalized AOD & vs. Normalized Scattering Angle Range



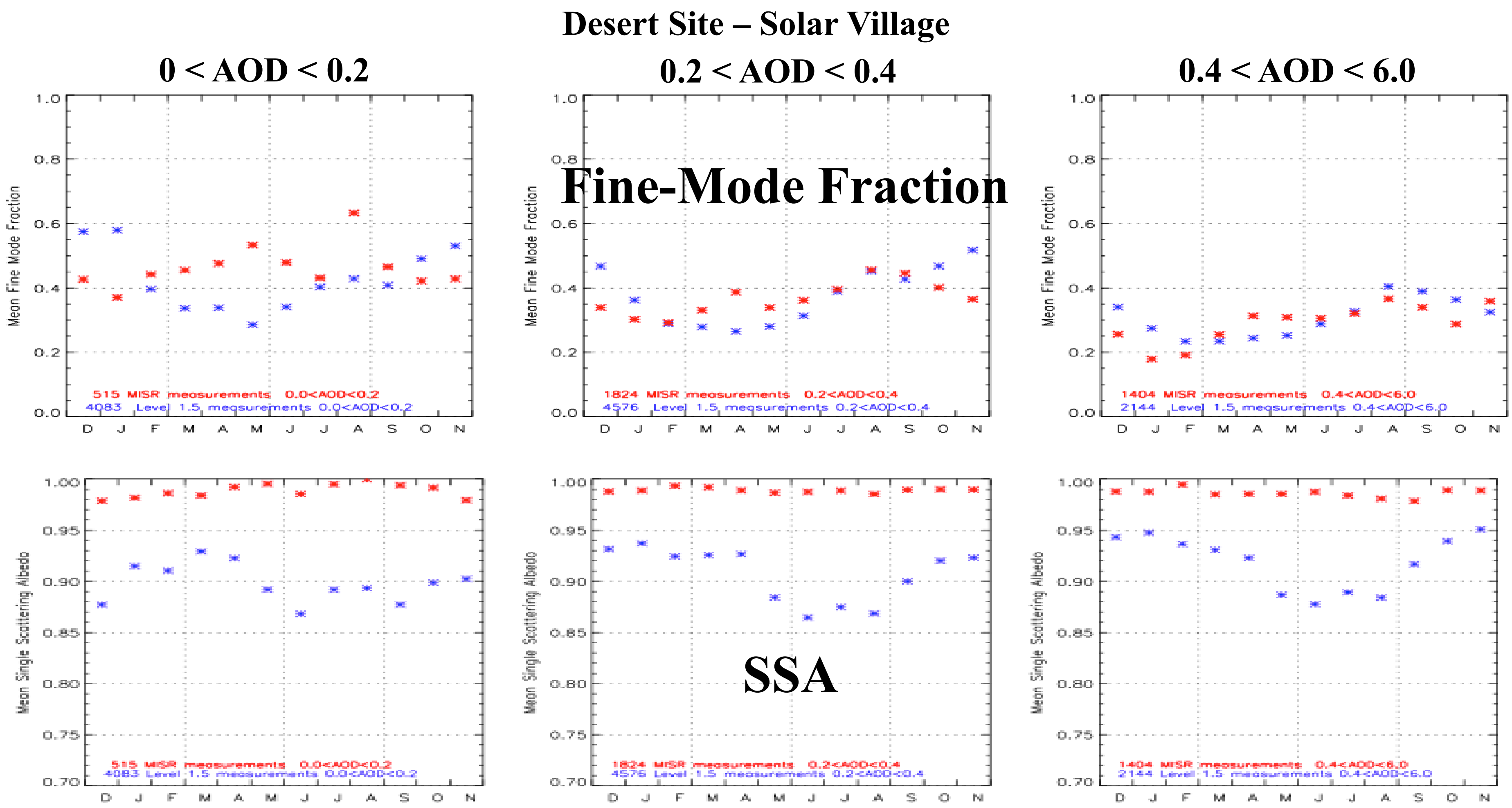
Histograms of Lowest Residual & All Successful Aerosol Type Mixture Groups

Kahn & Gaitley, JGR submitted



Desert Site – Solar Village
0 < AOD < 0.2
0.2 < AOD < 0.4
0.4 < AOD < 6.0
AOD
ANG
Counts
14798 Direct beam measurements 0.0<AOD<0.2
515 MISR measurements 0.0<AOD<0.2
18255 Direct beam measurements 0.2<AOD<0.4
1824 MISR measurements 0.2<AOD<0.4
9306 Direct beam measurements 0.4<AOD<6.0
1404 MISR measurements 0.4<AOD<6.0
Mean Optical Depth
Mean Angstrom Exponent
Mean Count
D J F M A M J J A S O N

Figure 5

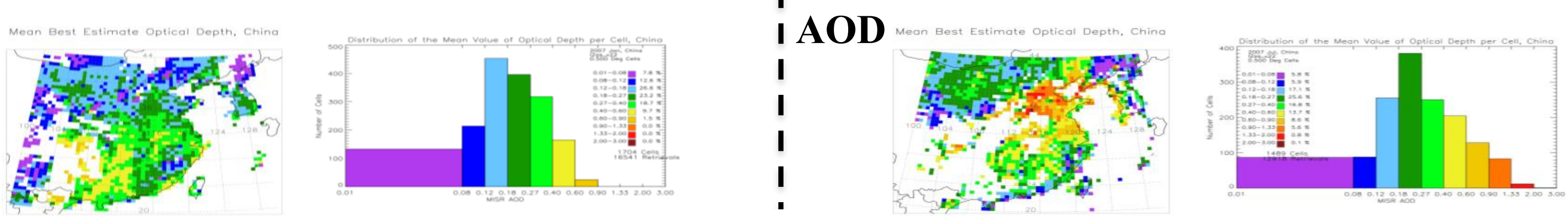


Desert Site – Solar Village
0 < AOD < 0.2
0.2 < AOD < 0.4
0.4 < AOD < 6.0
Fine-Mode Fraction
SSA
Mean Fine Mode Fraction
Mean Single Scattering Albedo
D J F M A M J J A S O N
515 MISR measurements 0.0<AOD<0.2
4083 Level 1.5 measurements 0.0<AOD<0.2
1824 MISR measurements 0.2<AOD<0.4
4576 Level 1.5 measurements 0.2<AOD<0.4
1404 MISR measurements 0.4<AOD<6.0
2144 Level 1.5 measurements 0.4<AOD<6.0

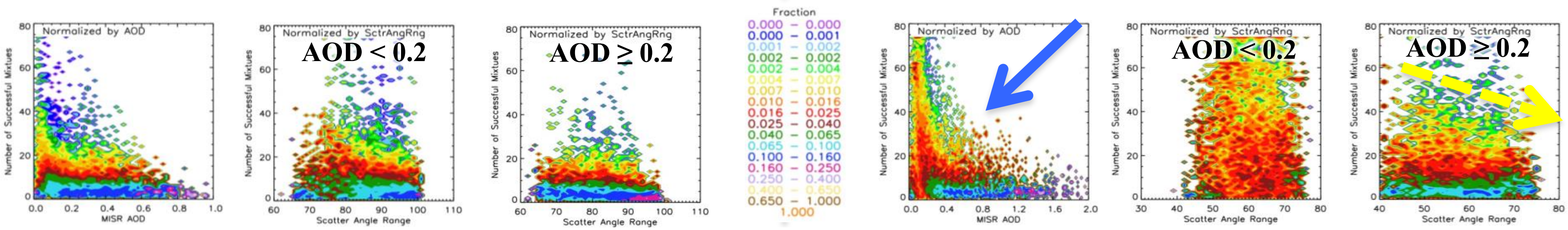
Figure 5

Eastern China (Pollution)

January 2007 | **July 2007**

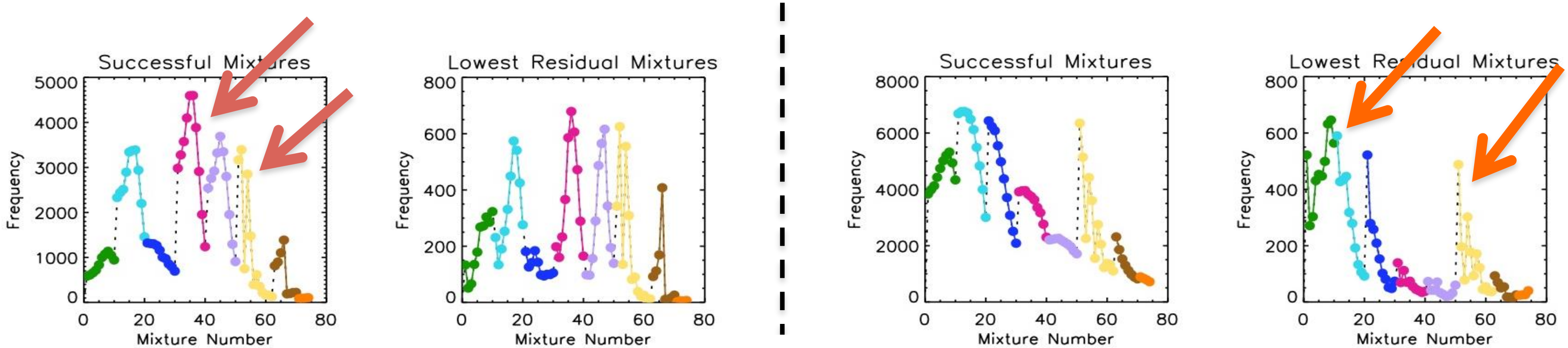


Mean Best Estimate AOD Map & Histogram Distribution



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

Retrieval sensitivity varies ***enormously*** with retrieval conditions

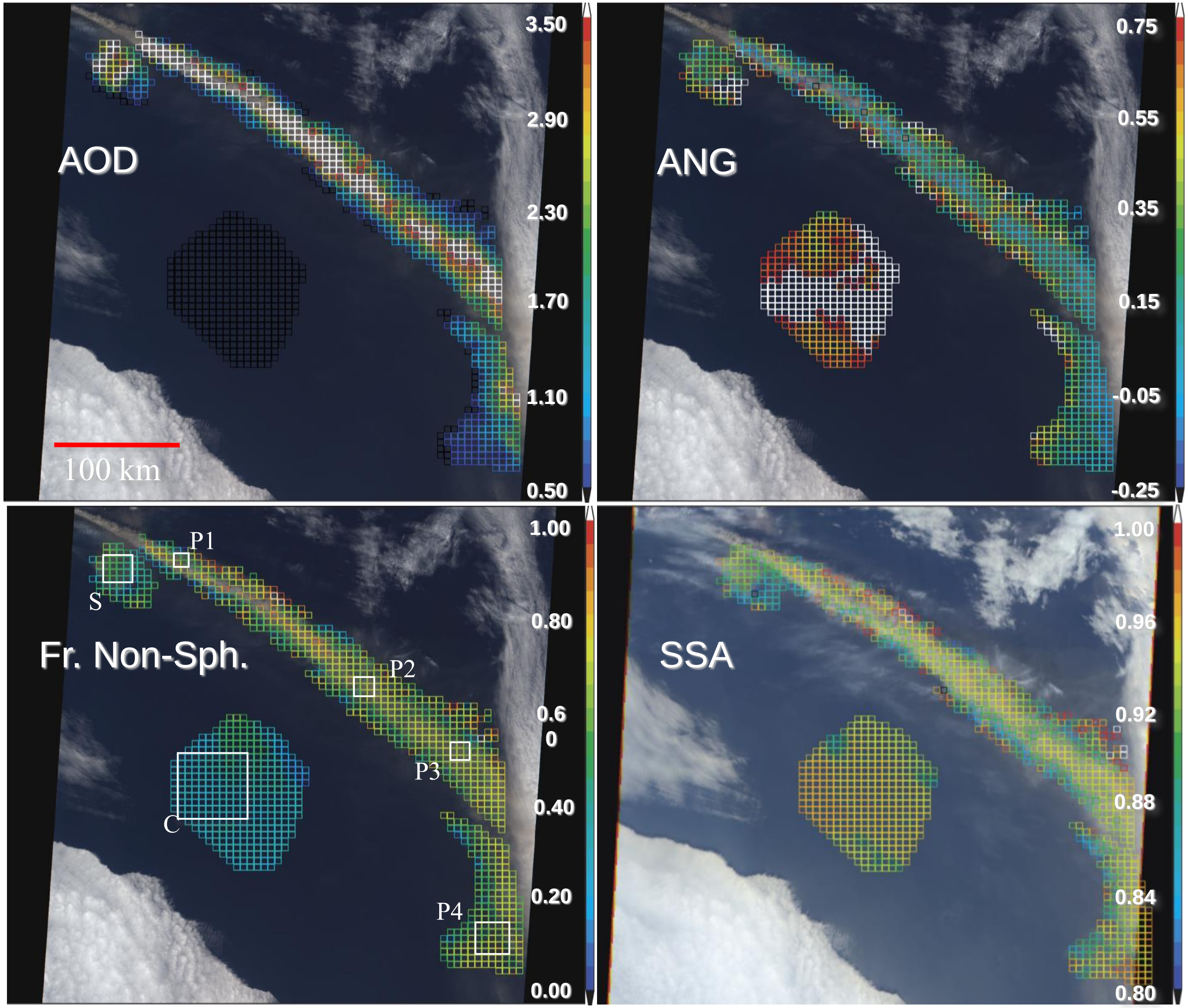


Histograms of Lowest Residual & All Successful Aerosol Type Mixture Groups

Kahn & Gaitley, JGR submitted

*MISR Research **Aerosol Retrievals***

Iceland Volcano 07 May 2010 Orbit 55238 Path 216 Blk 40

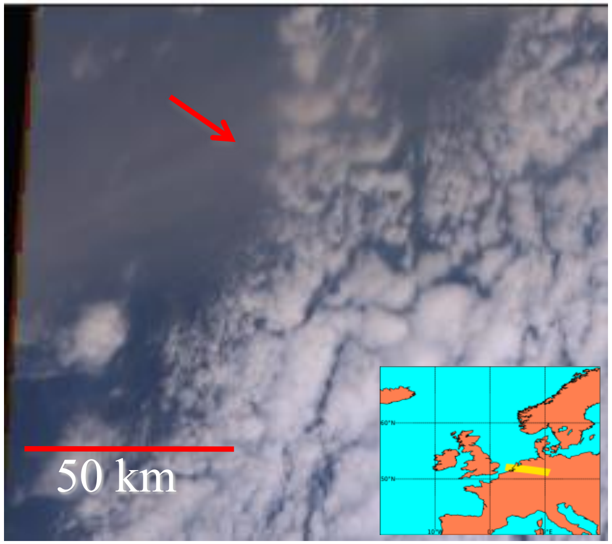


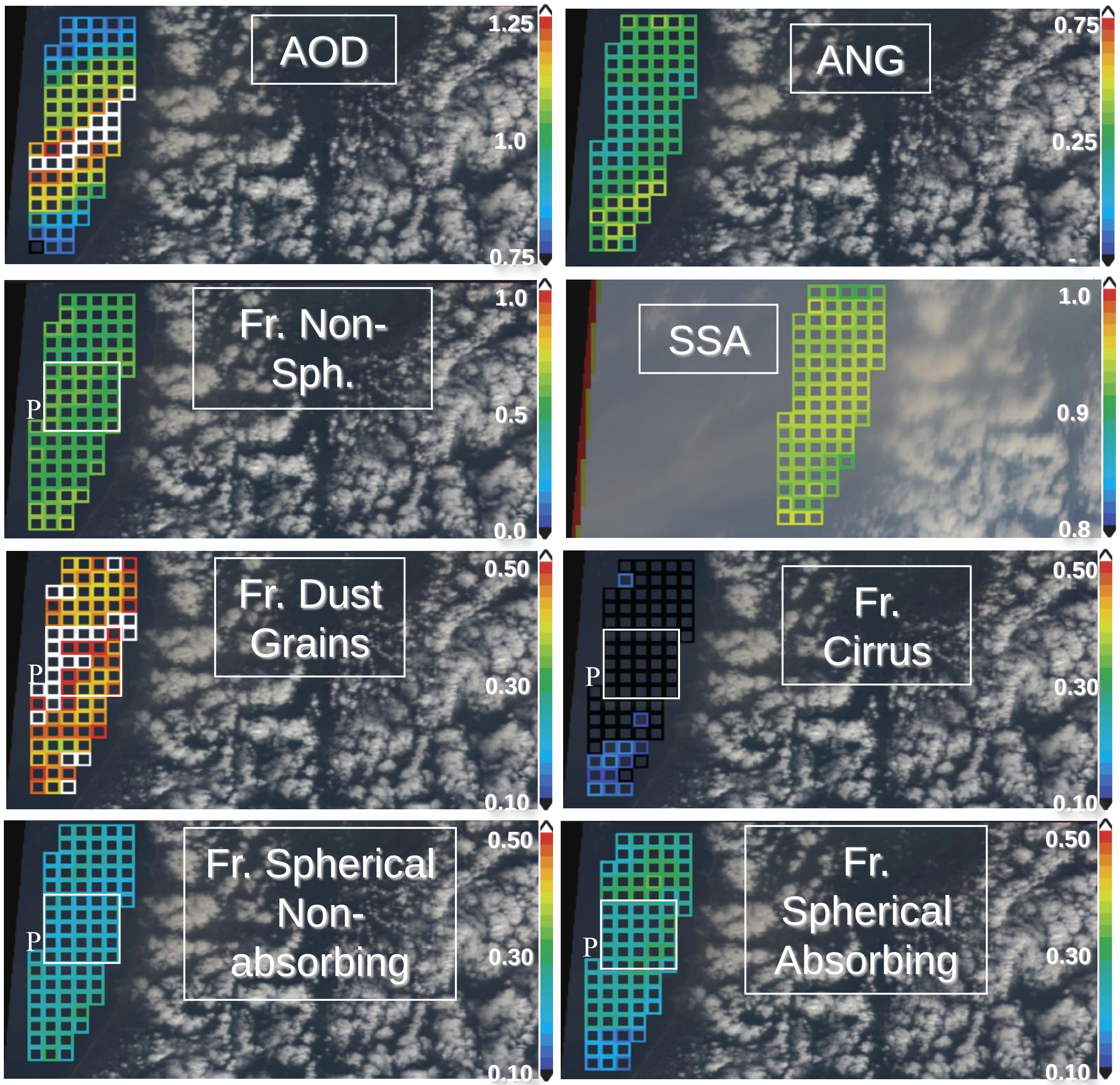
Plume Particles

- Distinct from background
  - -- ***larger***, ***darker***
  - -- ***much higher AOD***
- ***Non-spherical*** dominated
- Brighten downwind
- Tend to decrease in size downwind

Kahn & Limbacher, ACP 2012

MISR Research Aerosol Retrievals
16 April 2010 Orbit 54931 Path 197 Blk 49 UT 10:45



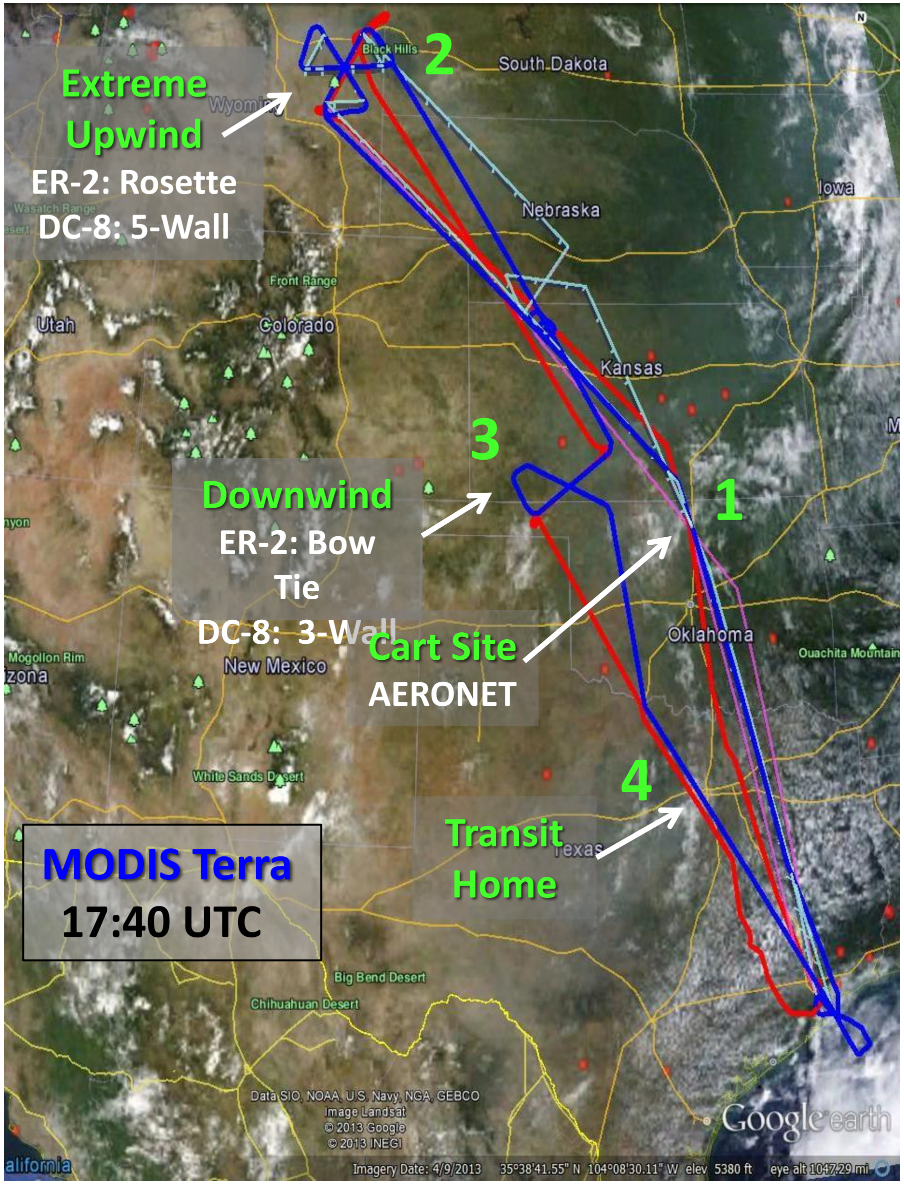


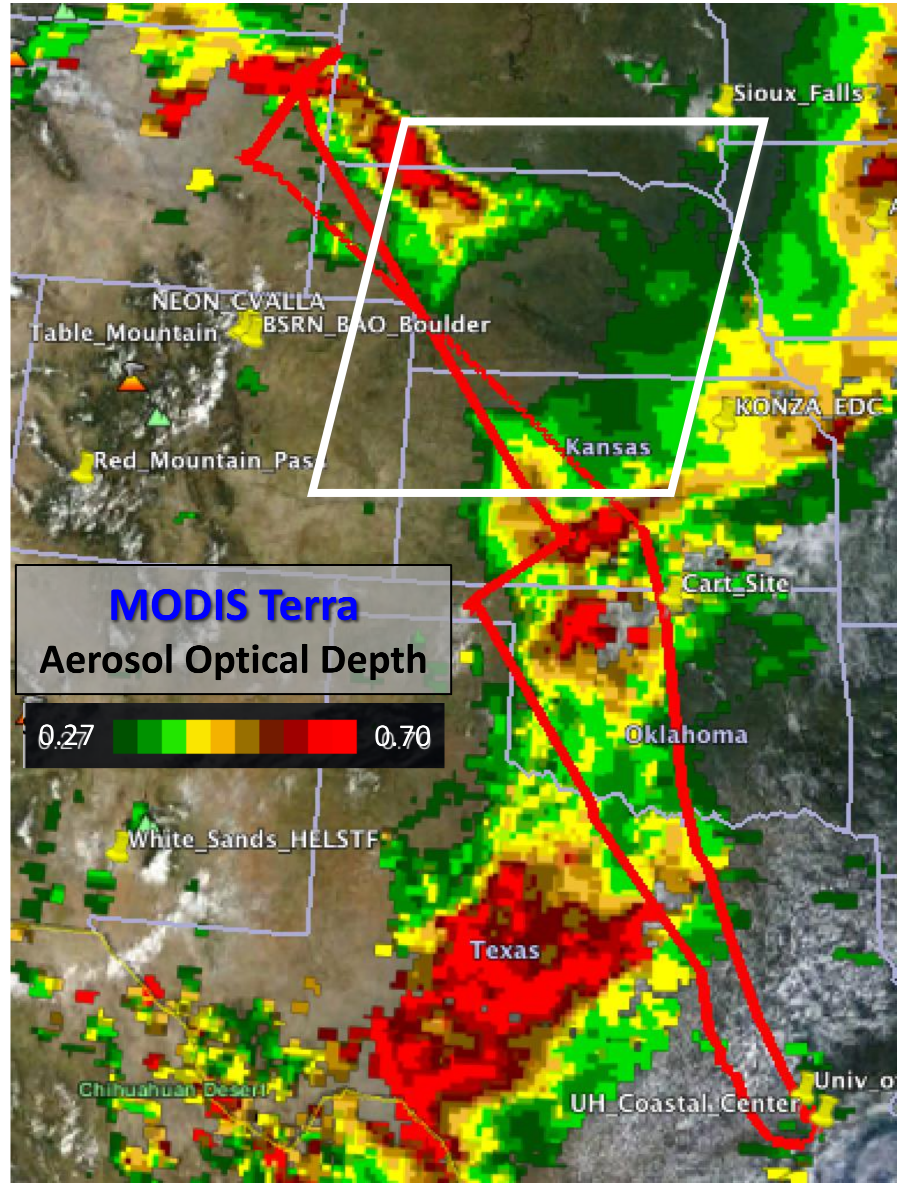
- ***1-2 days downwind*** of Iceland volcano source
- Distinctly ***high AOD*** (peak >1.25)
- Retrieved ~50% AOD ***non-spherical*** dust grains
- ***Medium*** particles ~ no "cirrus"
- Model ***back-trajectory needed*** to identify plume confidently

Kahn & Limbacher, ACP 2012

SEAC⁴RS Campaign DC-8 and ER-2 Flights

Monday, 19 August 2013

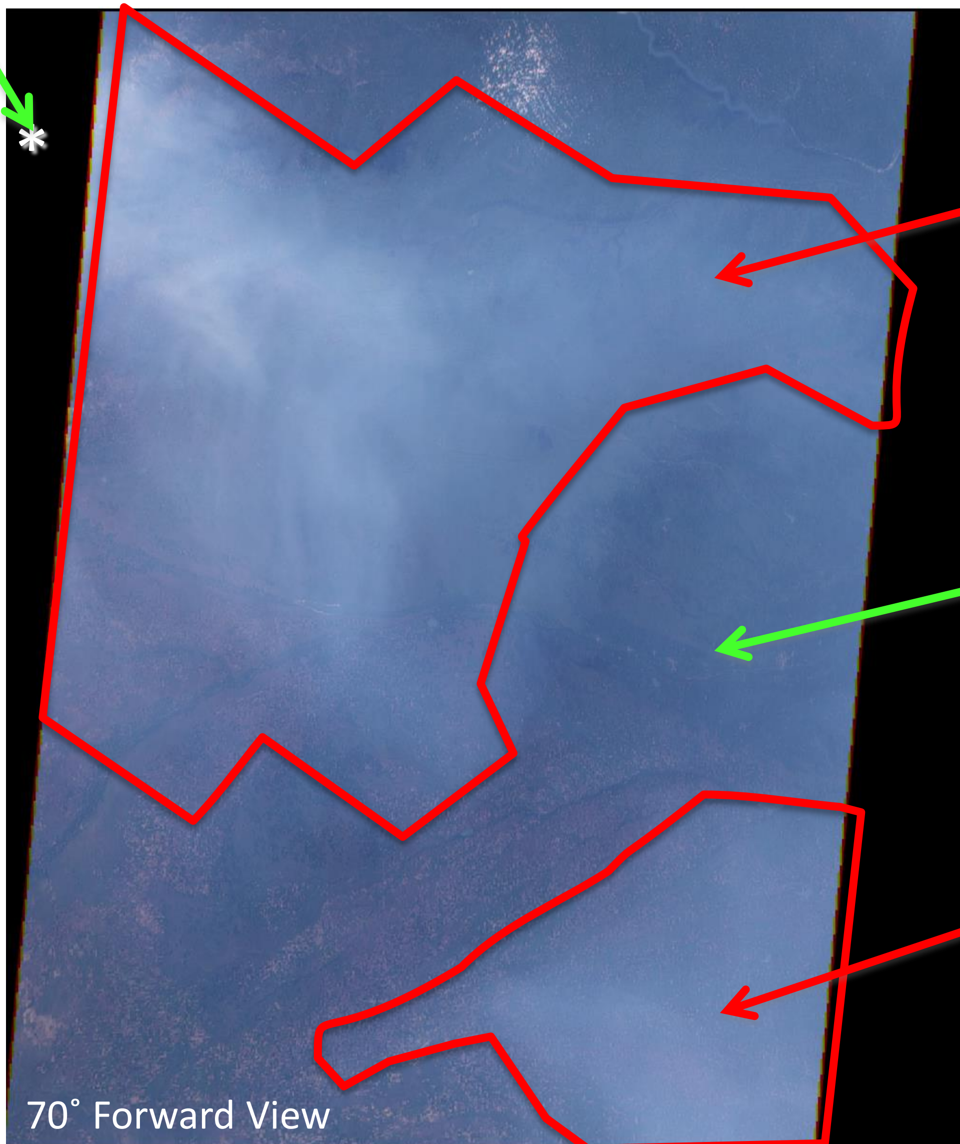




MISR **Aerosol Type** (Research Algorithm)

SEAC^{4}RS Campaign *Smoke Plumes*, 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**)*

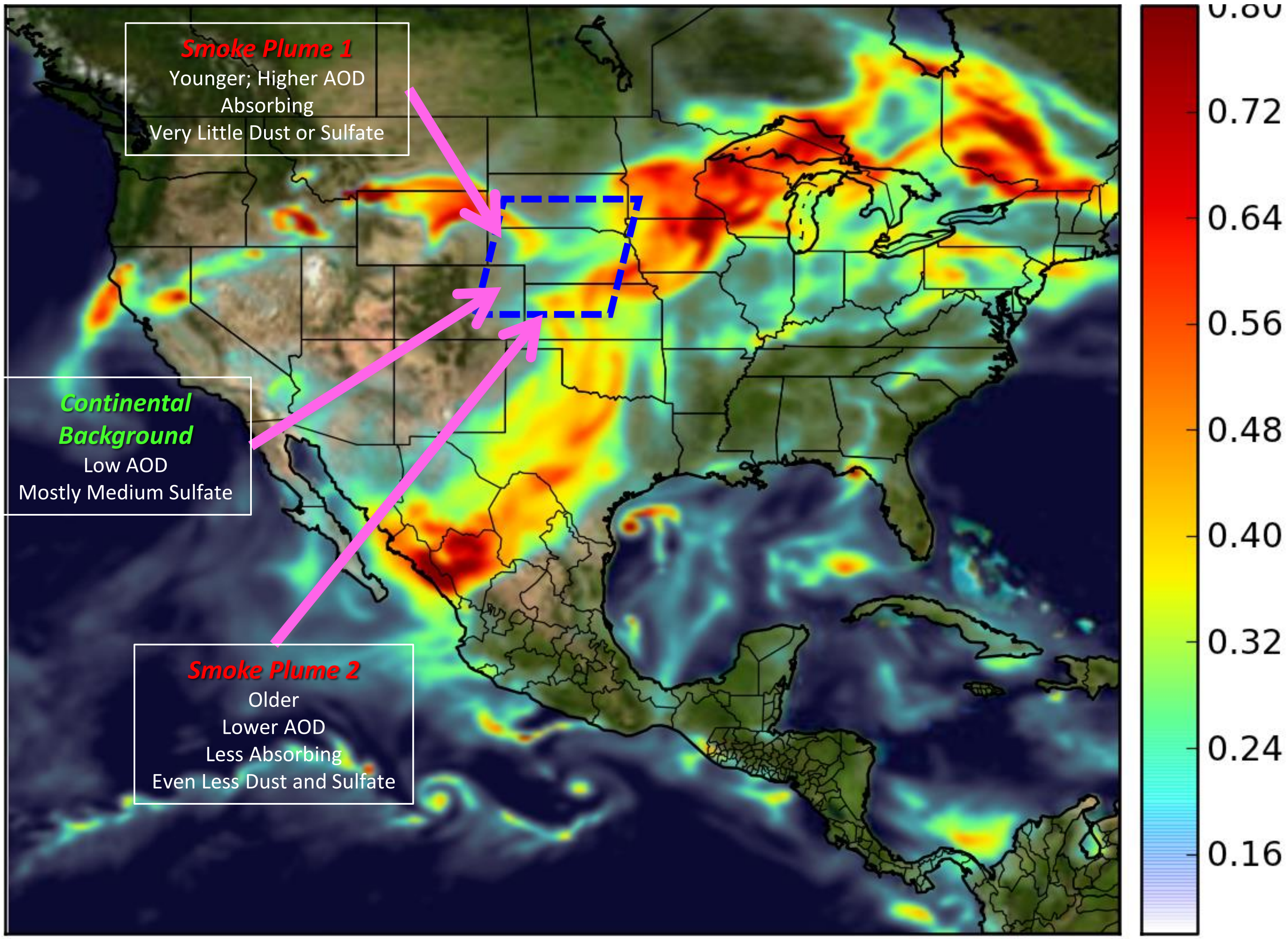
*SSA 0.96-0.98 (**less absorbing**)*

*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

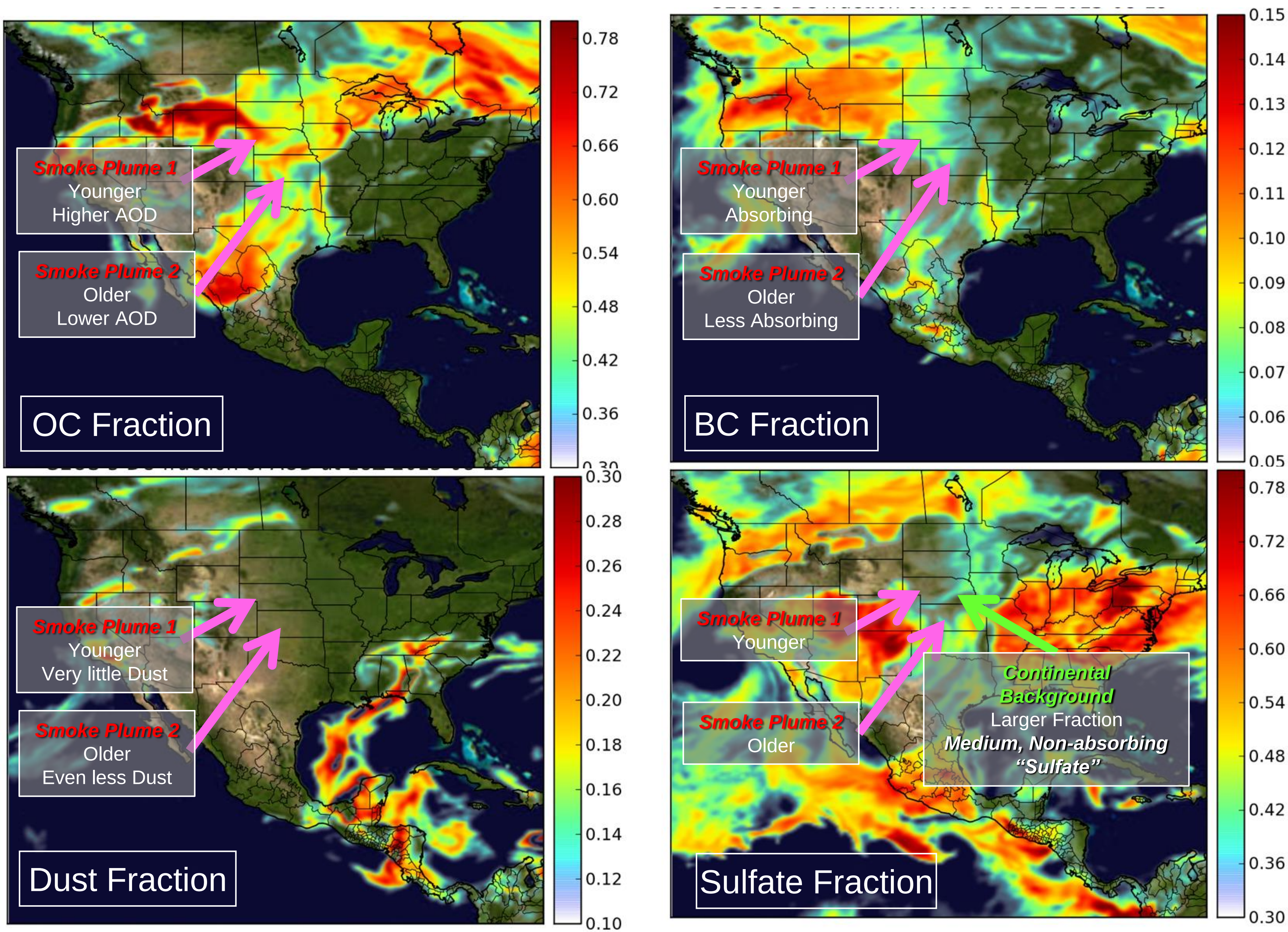
19 August 2013 18 UTC



GEOS-5 Team – DaSilva & Randles

GEOS-5 MODEL Aerosol Type

19 August 2013 18 UTC



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

MISR Aerosol V22 Standard Algorithm Upgrade Possibilities

- Based on ***10 Years of Validation*** Data

  -- ***Higher Spatial Resolution Product*** (4.4 km/retrieval)

  -- ***Low-light-level*** gap & quantization noise

  -- ***High-AOD underestimation*** of AOD (*missing **low-SSA** particles; high real refr. index*)

  -- Missing ***Medium-mode*** particles (r_{eff} ~ 0.57, 1.28 µm)

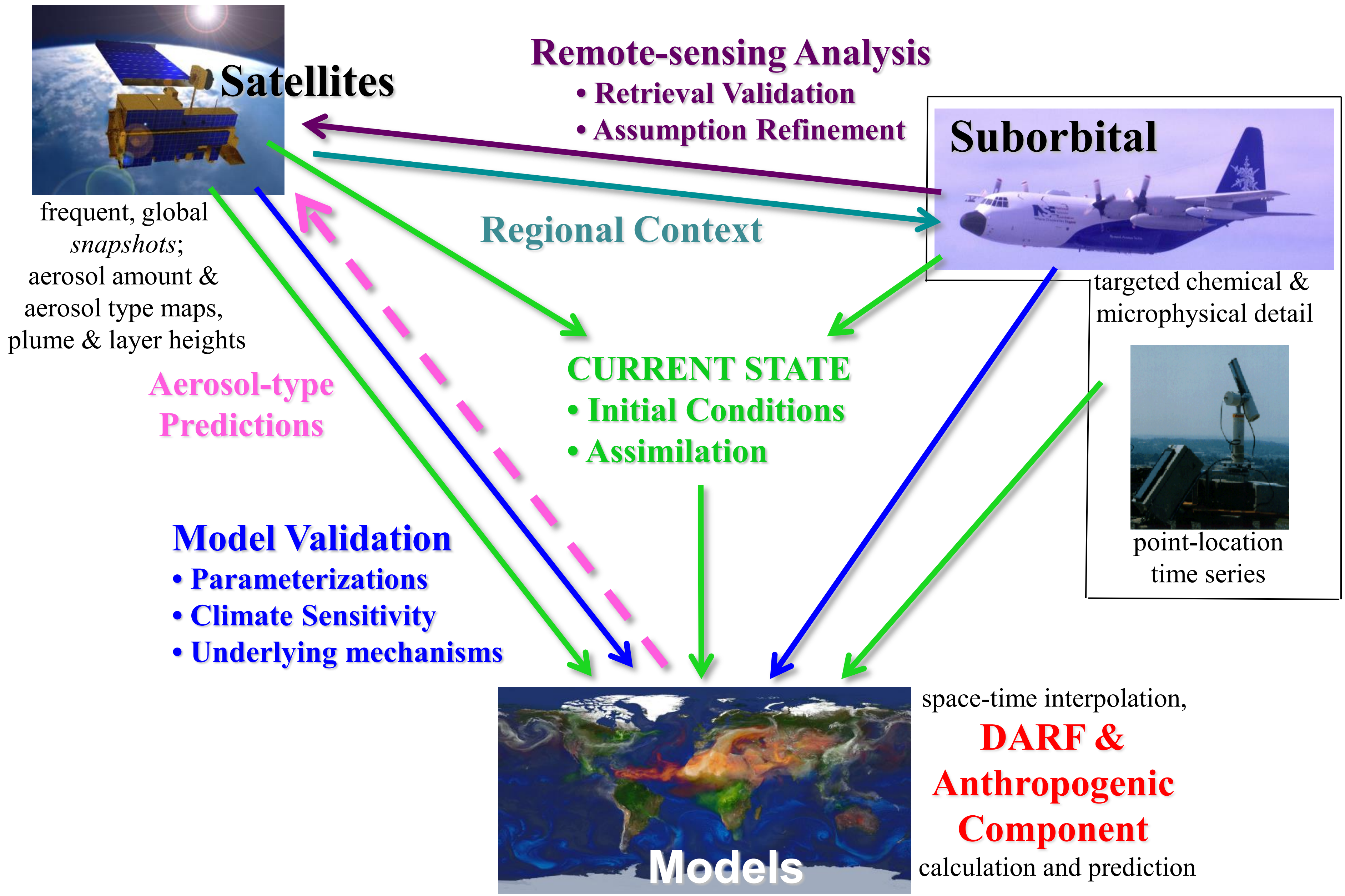
  -- More spherical, ***absorbing particles*** (*SSA* ~ 0.94, 0.84, maybe 0.74)

  -- ***Mixtures of smoke & dust*** analogs; more ***Bi- and Tri-modal*** spherical mixtures

  -- ***Flag*** indicating when there is insufficient sensitivity for ***particle property*** retrieval
  (possibly different retrieval path under this condition)

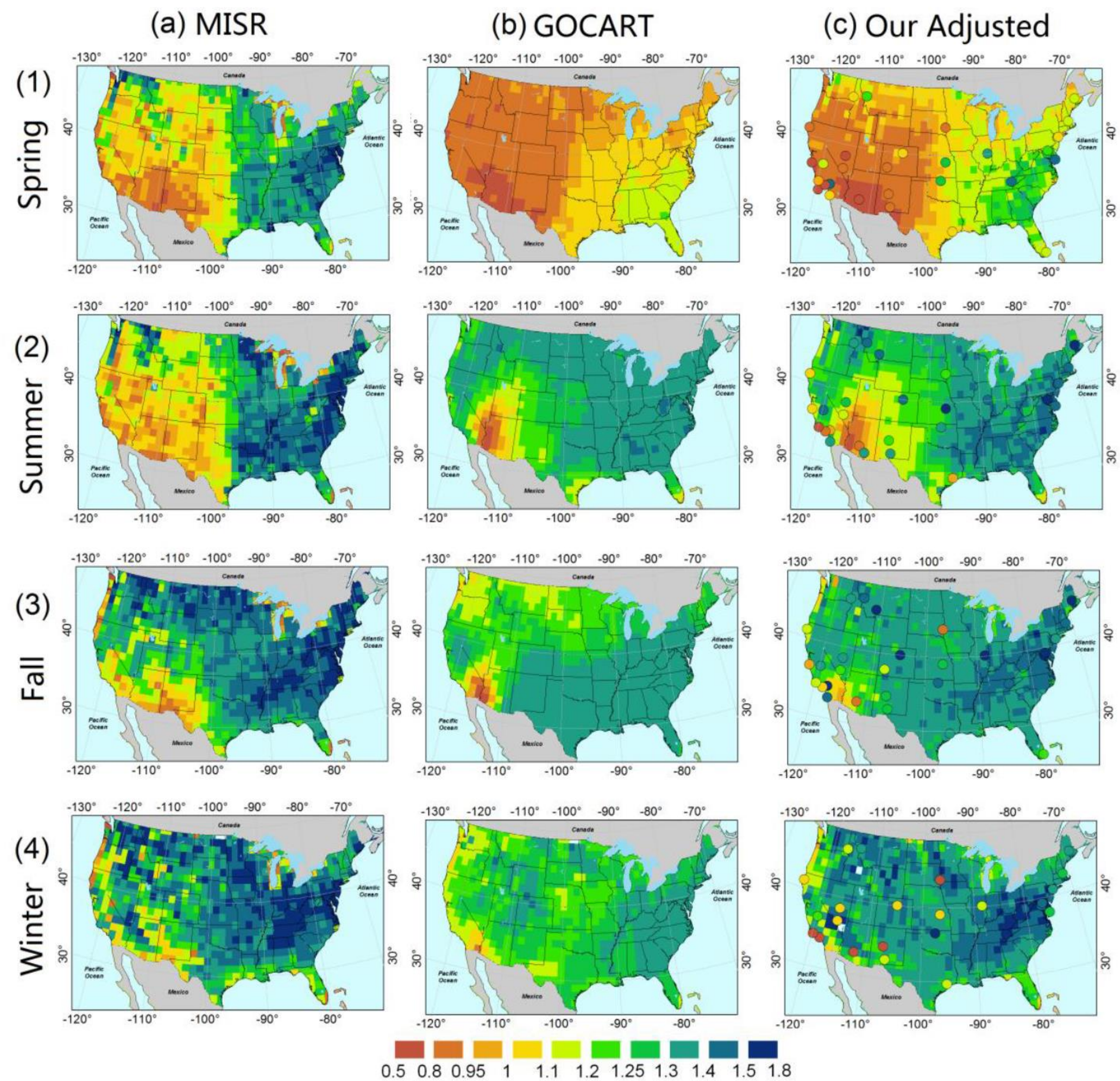
  -- Lack of a good ***Coarse-mode Dust Optical Analog*** remains an issue

Kahn et al., JGR 2010



Kahn, Survy. Geophys. 2012

GoCART Model Aerosol-Type Constraint for *Low AOD*



ANG

From Among the passing mixtures, ***ANG*** and ***AAOD*** are constrained by the model

S. Li, R. Kahn, et al. AMT Submitted

<u>SAM-CAAM</u>

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

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

***<u>Primary Objectives</u>*:**

- **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 *<u>improve</u>*:

  -- 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
- White Paper to identify ***3-4 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

Backup Slides

SAM-CAAM *Required Measurements*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

1. AEROSOL PROPERTIES FROM *IN SITU* MEASUREMENTS & INTEGRATED ANALYSIS

	Abbrev.	Required Measurement
1	EXT	Spectral Extinction
2	ABS	Spectral Absorption
3	GRO	Hygroscopic Growth
4	SIZ	Particle Size
5	CMP	Particle Type (a composition constraint)
6	PHA	Single-scattering Phase Function
7	MEE	Mass Extinction Efficiency
8	RRI	Real Refractive Index

SAM-CAAM *Required Measurements*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

2. METEOROLOGICAL CONTEXT

	Abbrev.	Required Measurement
9	CO	Ambient Gases (CO + O_3 + NO_2)
10	T; P; RH	Standard Ambient Meteorological Variables
11	LOC	Geographic Location

3. AMBIENT REMOTE-SENSING CONTEXT

	Abbrev.	Required Measurement
12	A-EXT & A-ABS	Ambient Spectral Extinction & Absorption
13	A-PHA	Ambient Particle Phase Function
14	A-CLD	Ambient Cloud & Large-Particle Size/Type
15	HTS	Aerosol Layer Heights

SAM-CAAM *Technology / Payload Options*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

- ***A Broad Range of possibilities*** is under consideration

  -- From ***off-the-shelf*** to ***research*** instruments

  -- ***Capability vs. resource demand*** tradeoffs determine selections for the four (more and less ambitious) payload options

- This effort will produce a ***BAMS Paper*** summarizing the suggestions

Required Measurement		Payload Option A	Payload Option B	Payload Option C	Payload Option D (add. objectives)	Lead Author(s)
AEROSOL PROPERTIES FROM *IN SITU* MEASUREMENTS AND INTEGRATED ANALYSIS						
1	EXT spectral extinction	Internal 1-color CAPS	3-color CRD	6-channel 3-color CRD (2 size cuts – 1&10 µm; 4 ch @ low RH)	Option C + UV and/or near-IR	**Murphy**; **Ogren**
2	ABS spectral absorption	CLAP + [CRD (#1); neph (#6)]	Option A	Dual 3-channel NOAA CLAP (2 size cuts – 1&10 µm @ low RH) [matched to (#1 EXT), neph (#6)] + SP2	Option C + PA (photoacoustic)	**Ogren**; **Murphy**

Example Payload Options (*preliminary*)