How We Can Constrain Aerosol Type Globally

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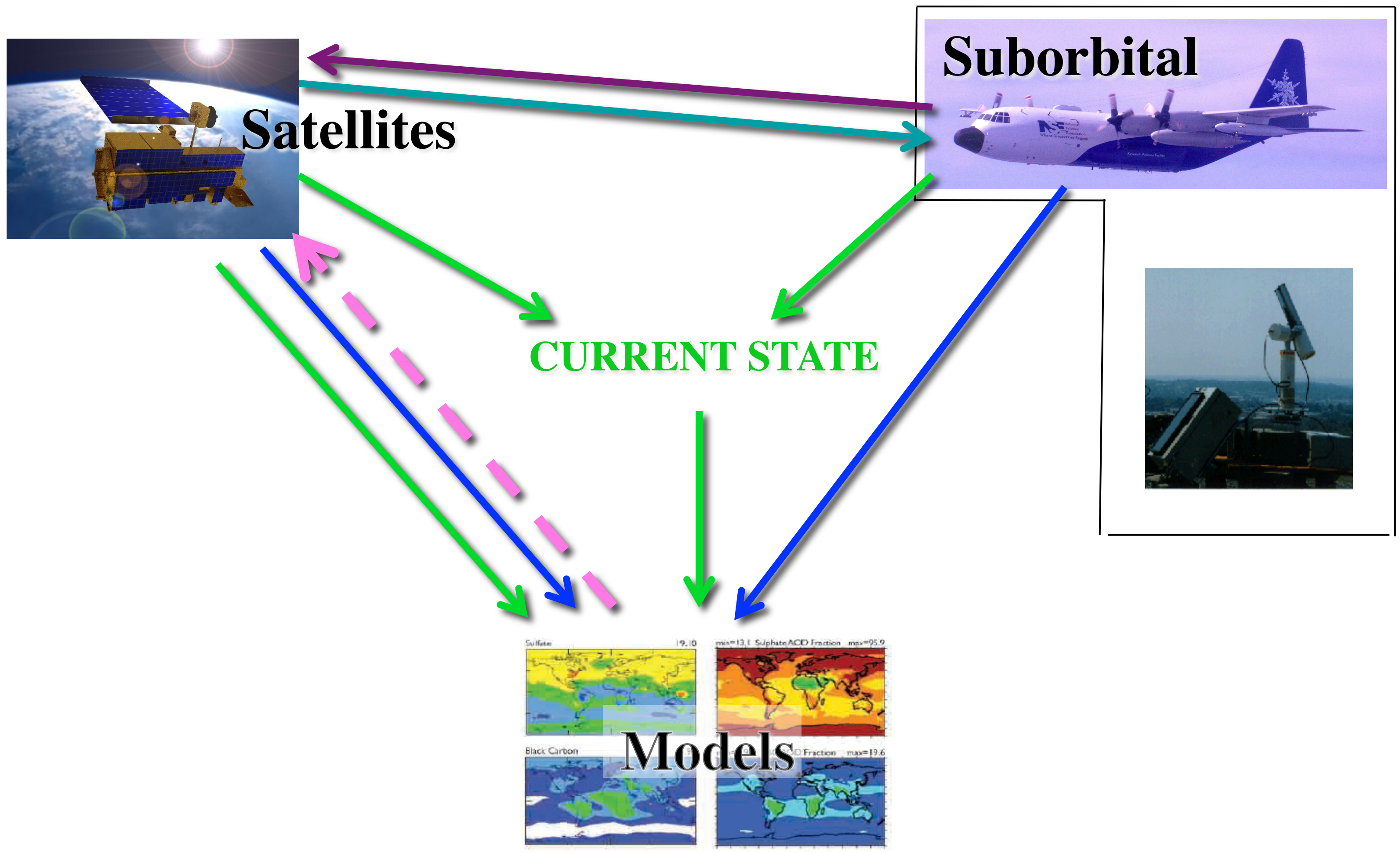
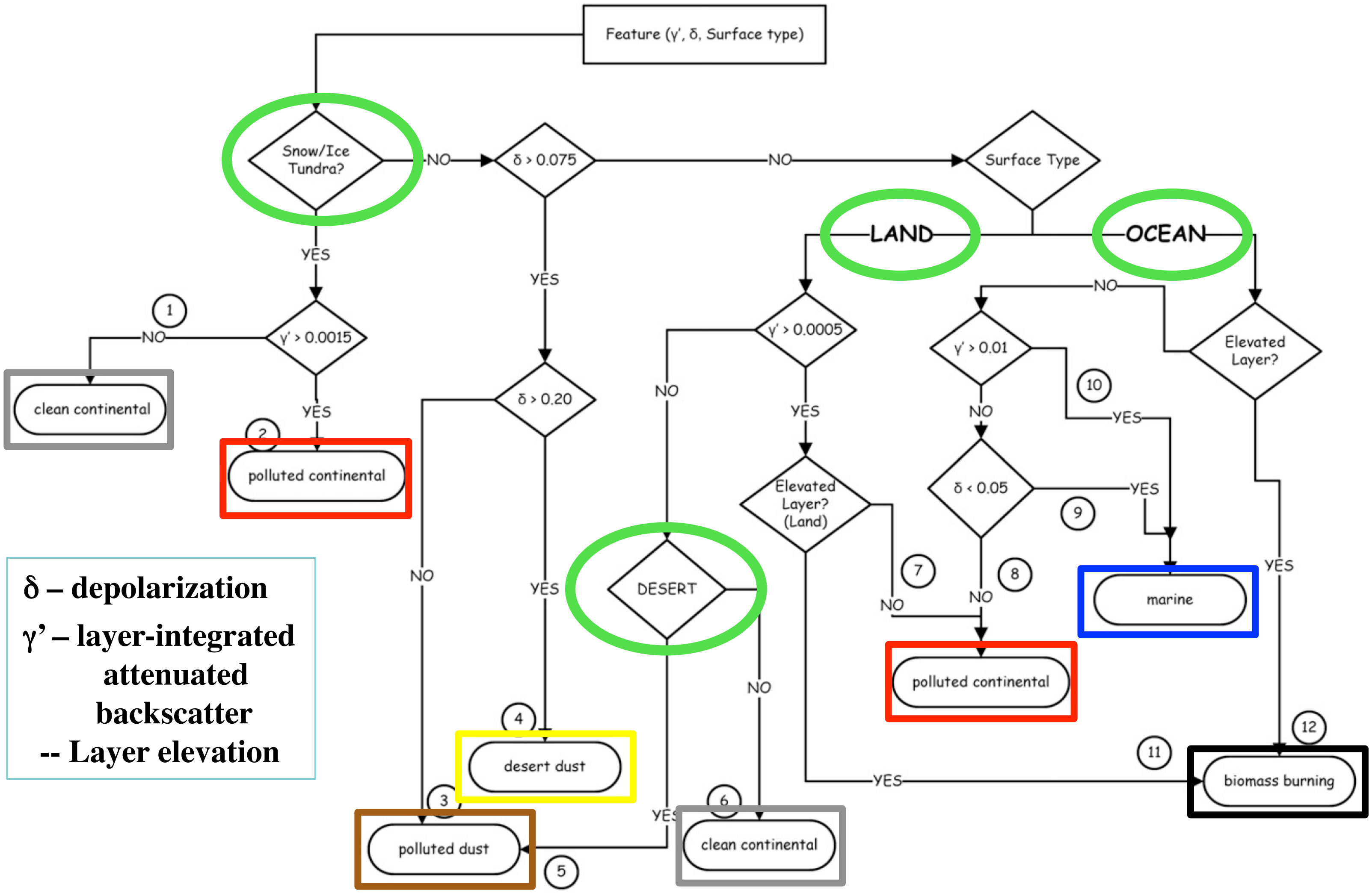


CALIPSO 6-Type *Interpretive Composition* Classification Scheme



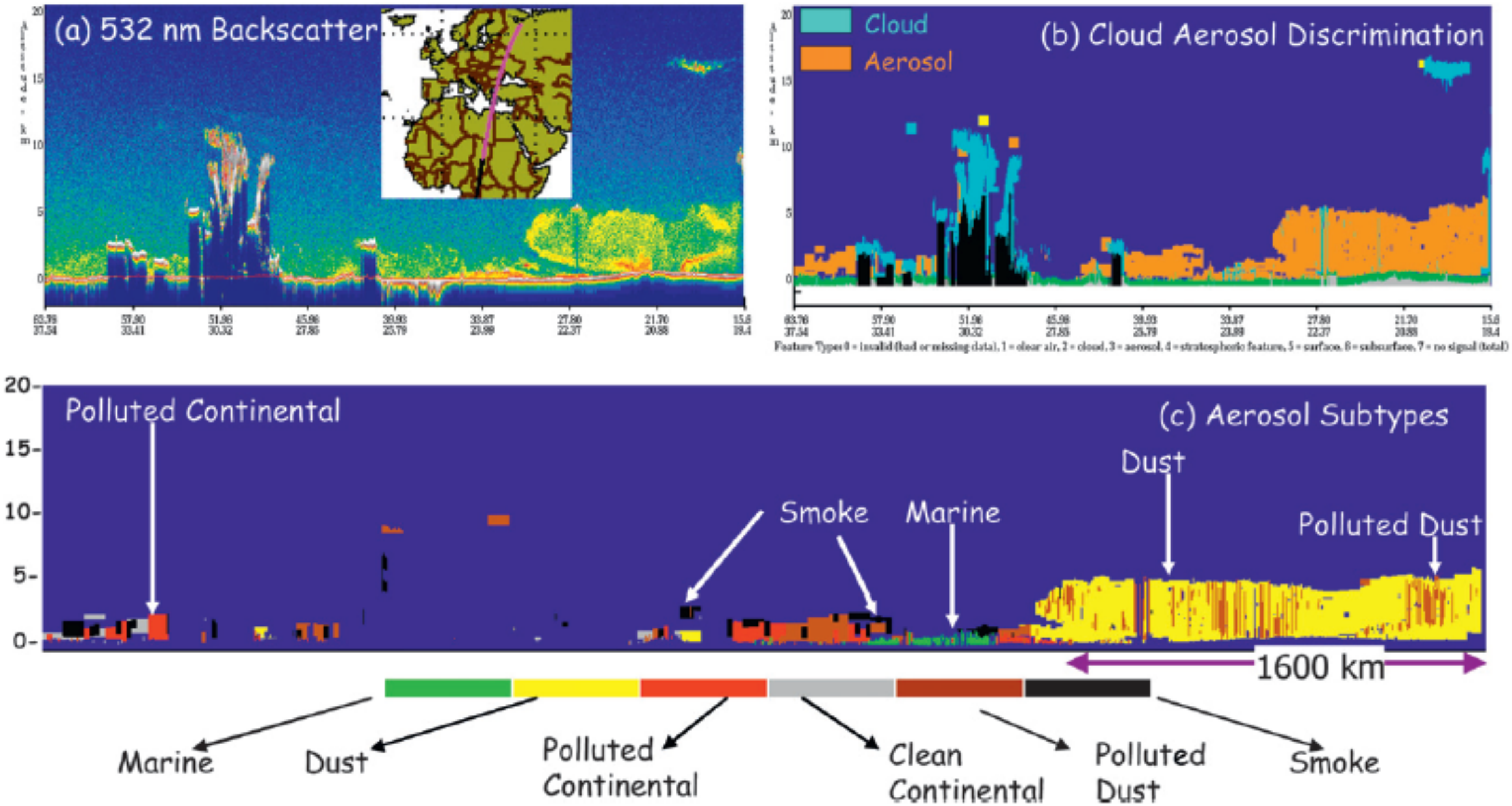
δ – depolarization

γ' – layer-integrated attenuated backscatter

-- Layer elevation

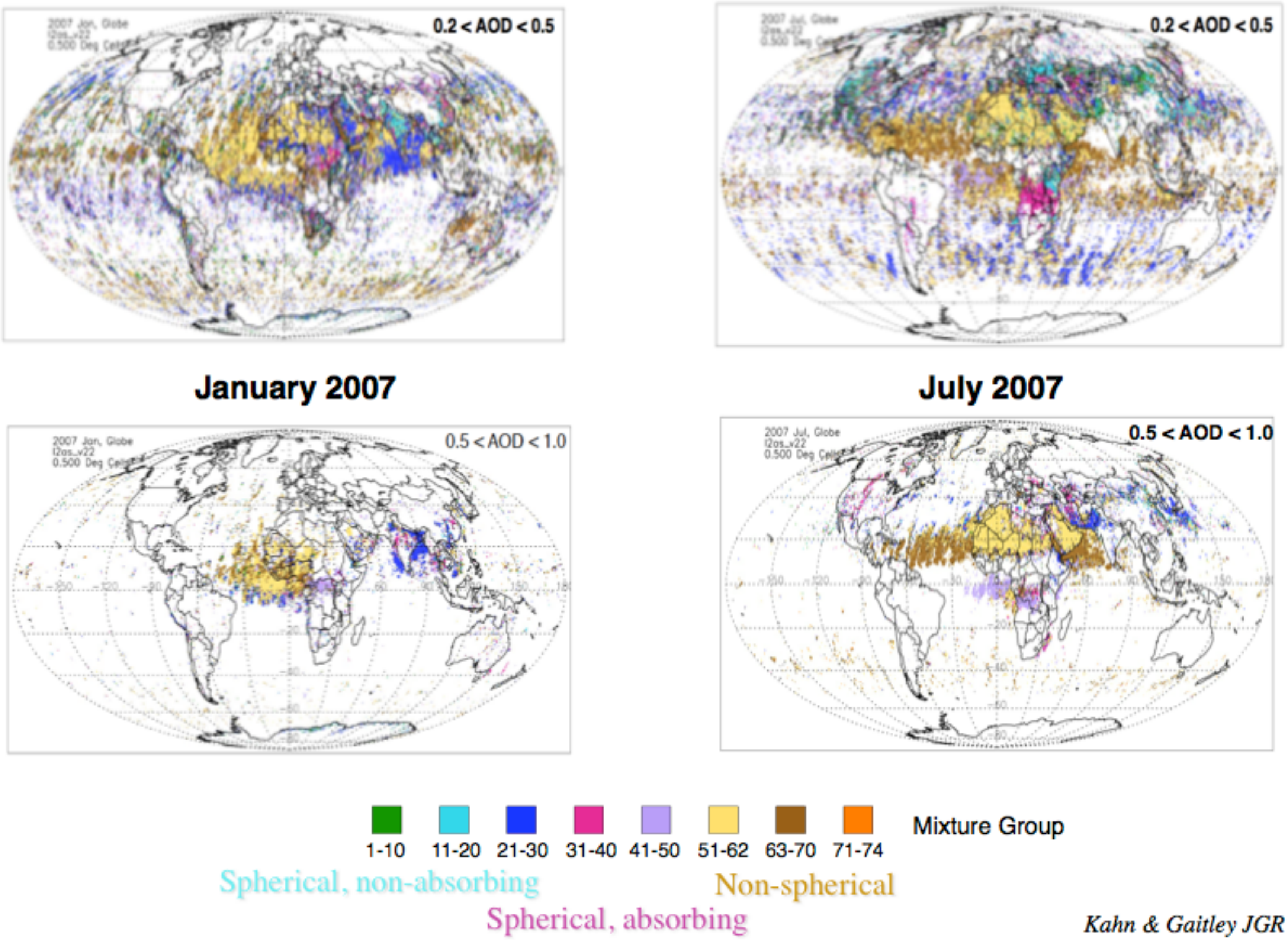
Omar et al., JAOT 2009

CALIPSO 6-Grouping Aerosol Type Classification



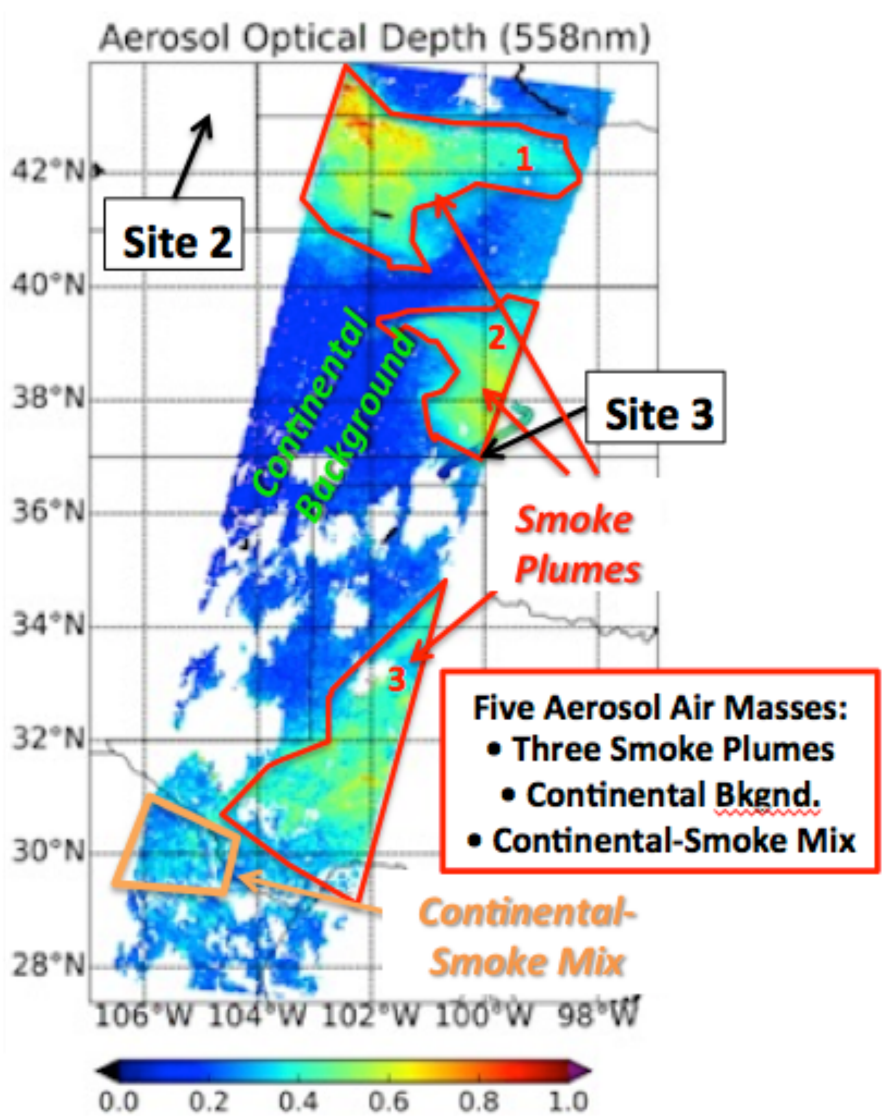
Omar et al., JAOT 2009

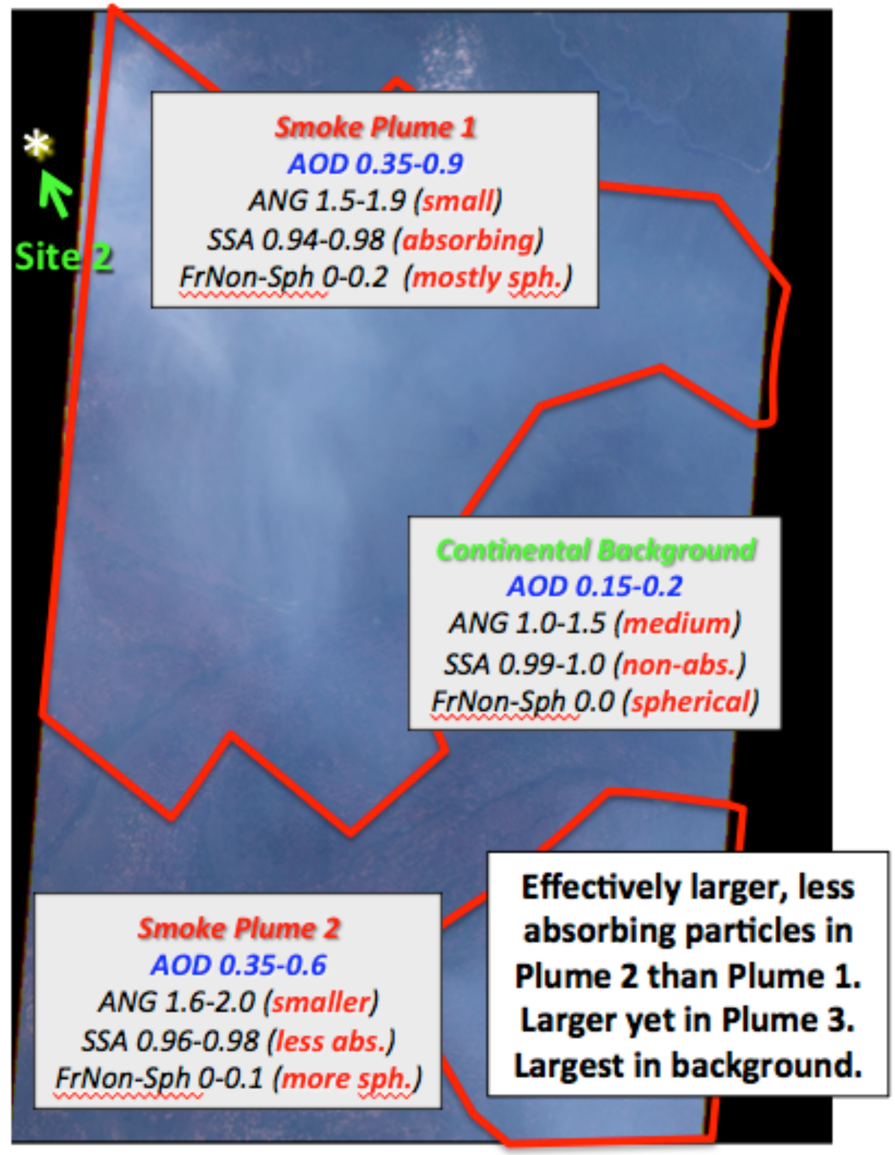
MISR Retrieved-Physical-Properties Aerosol Type Discrimination



Kahn & Gaitley JGR 2015

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





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

Aerosol-Type *Validation* Approach

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

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

  -- ***Far fewer*** Satellite-AERONET Sky-scan that Direct-sun Coincidences

- ***Field Validation*** case studies

- ***Self-consistency*** tests

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

  -- ***Regional*** and ***Temporal Behavior*** (stratified) vs. ***Expectation***

- ***Comparisons*** with AERONET proxies

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

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

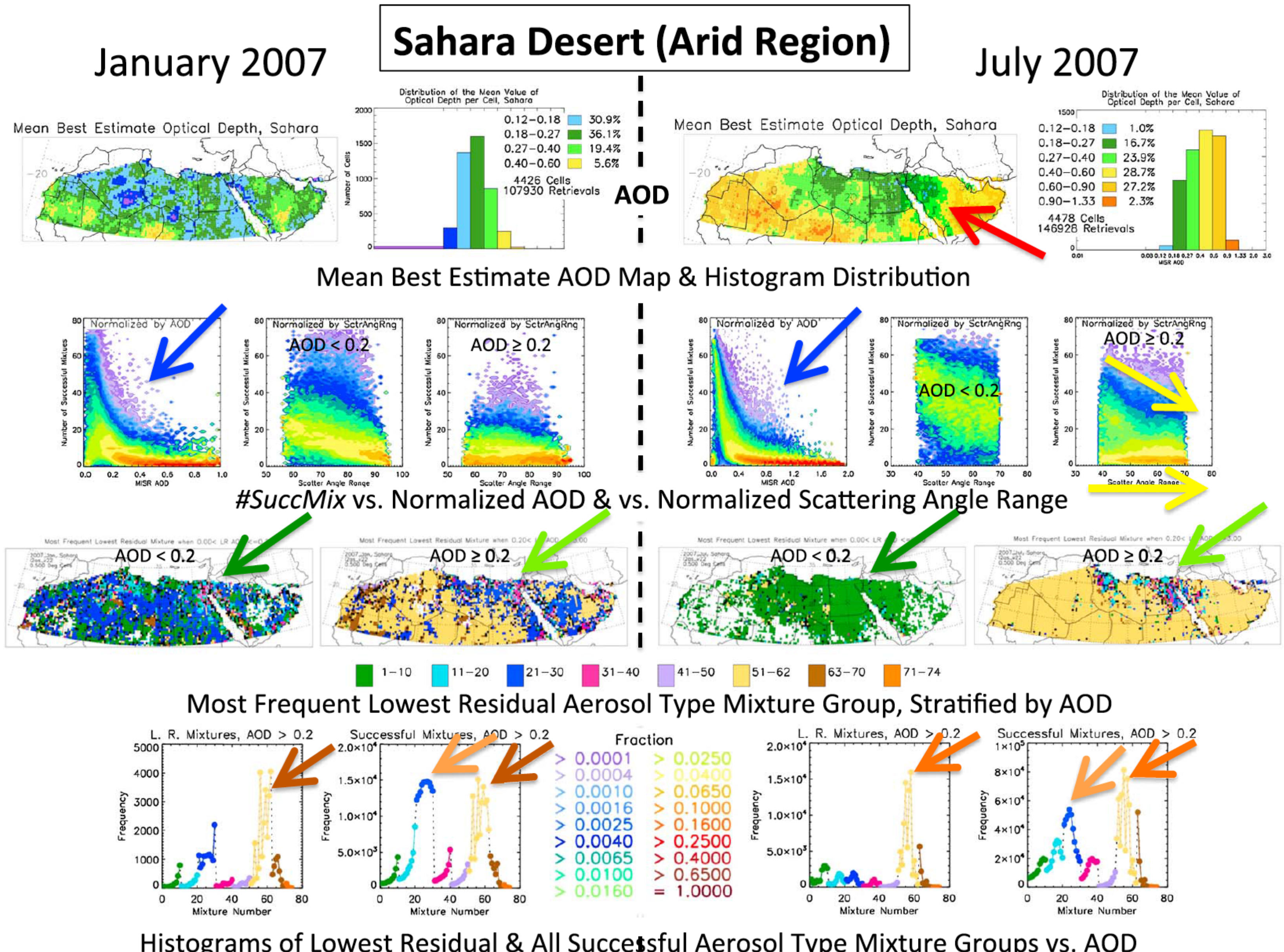
  -- ***Effective radius*** (r_e) and ***variance*** (σ) [two modes – ***issue with def. of "modes"***]

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

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

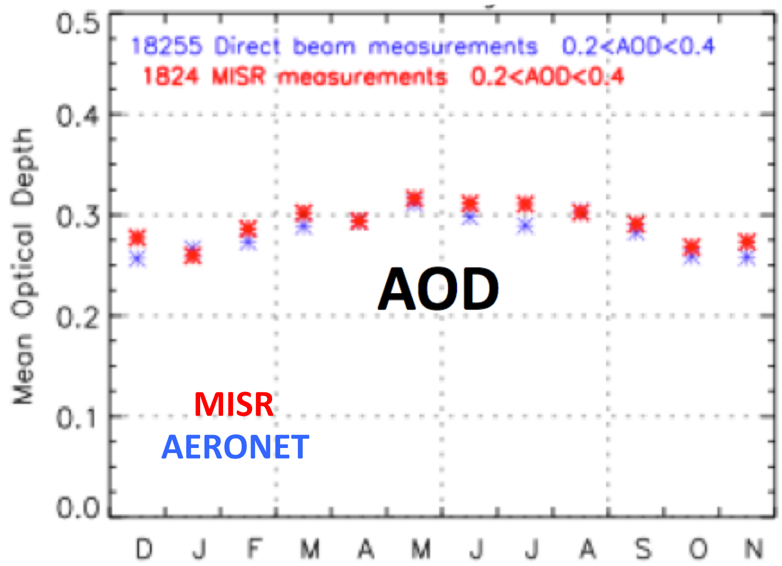
Kahn & Gaitley, JGR, 2015

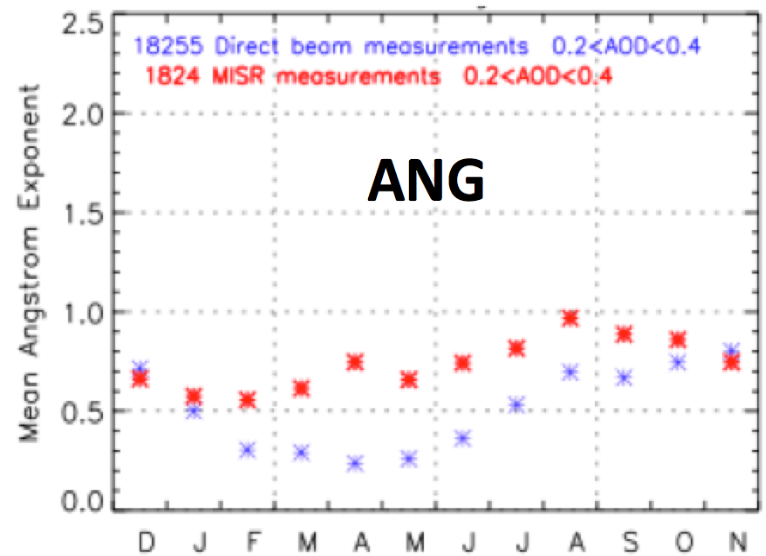
MISR Aerosol-Type "*Validation*"

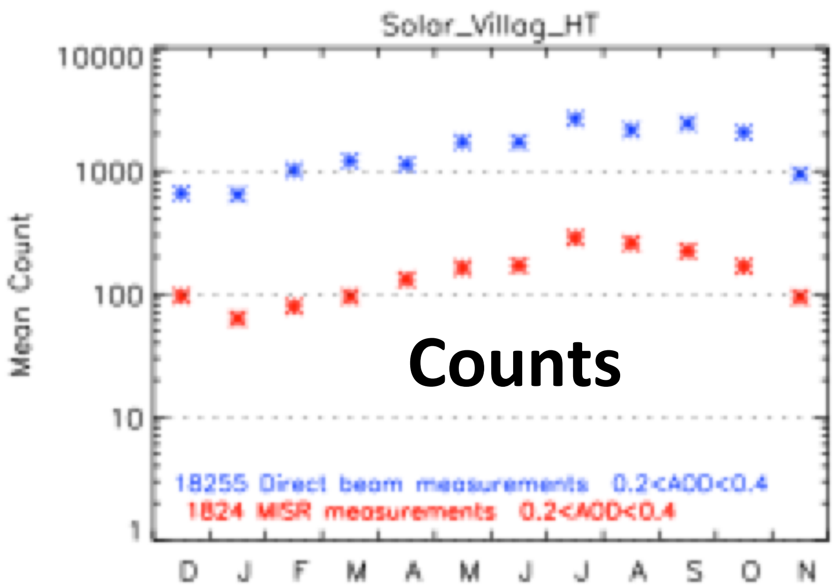


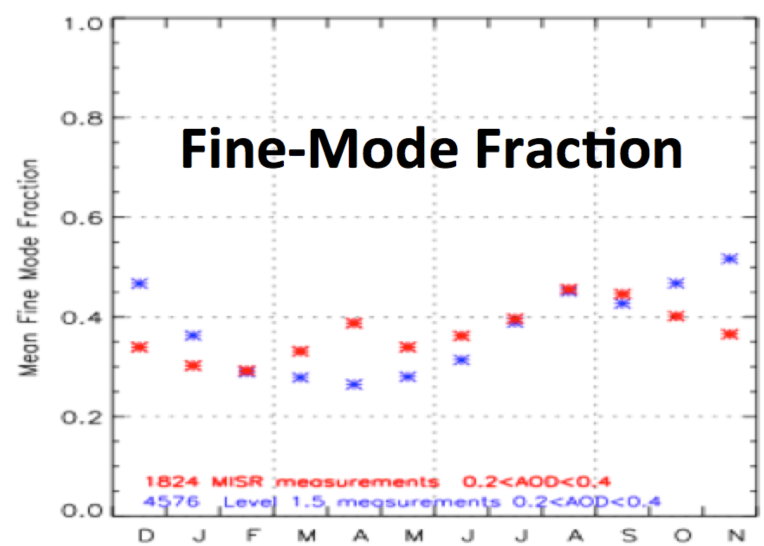
Kahn & Gaitley JGR 2015

Statistical *Comparisons* with AERONET – *Solar Village*

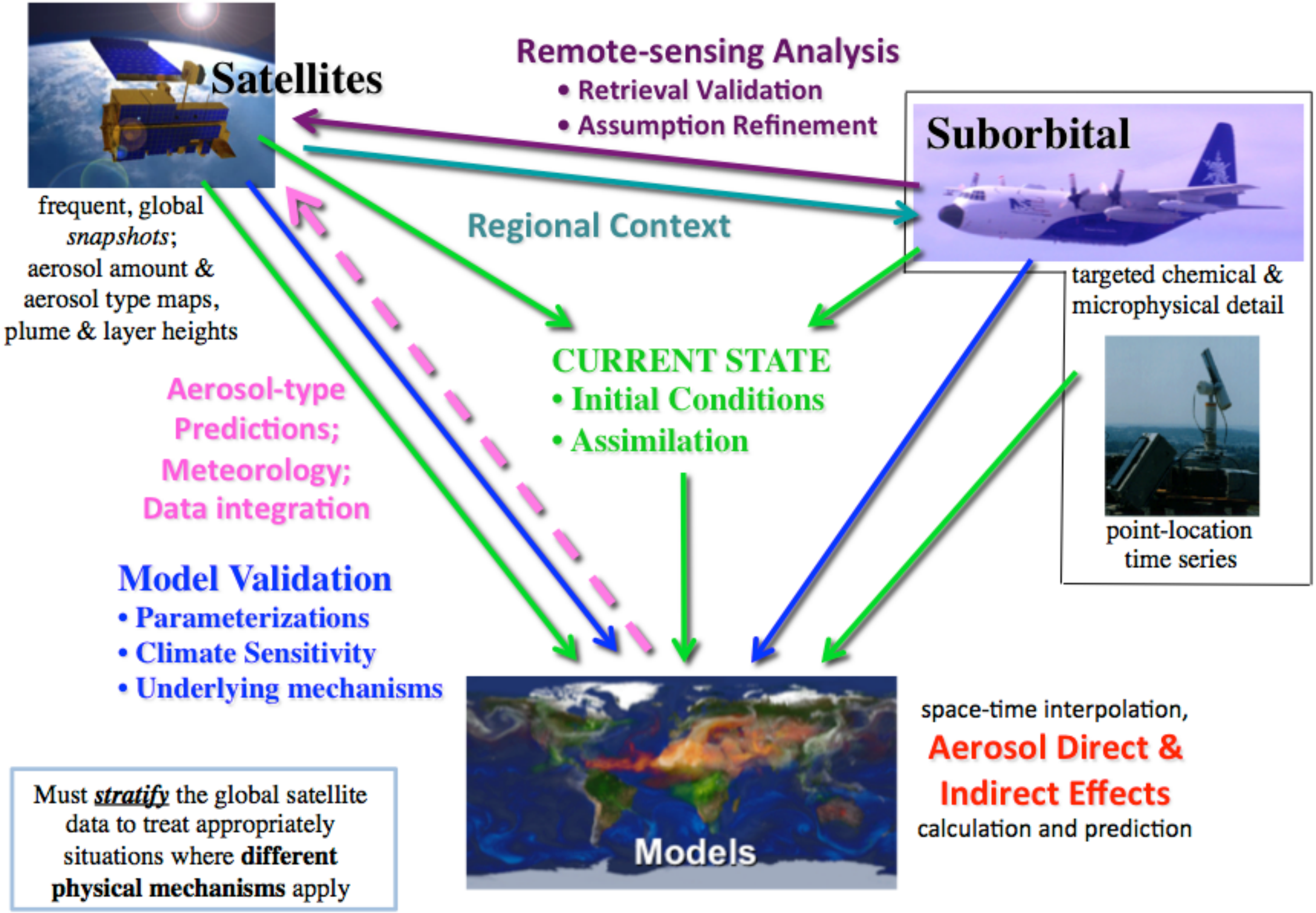






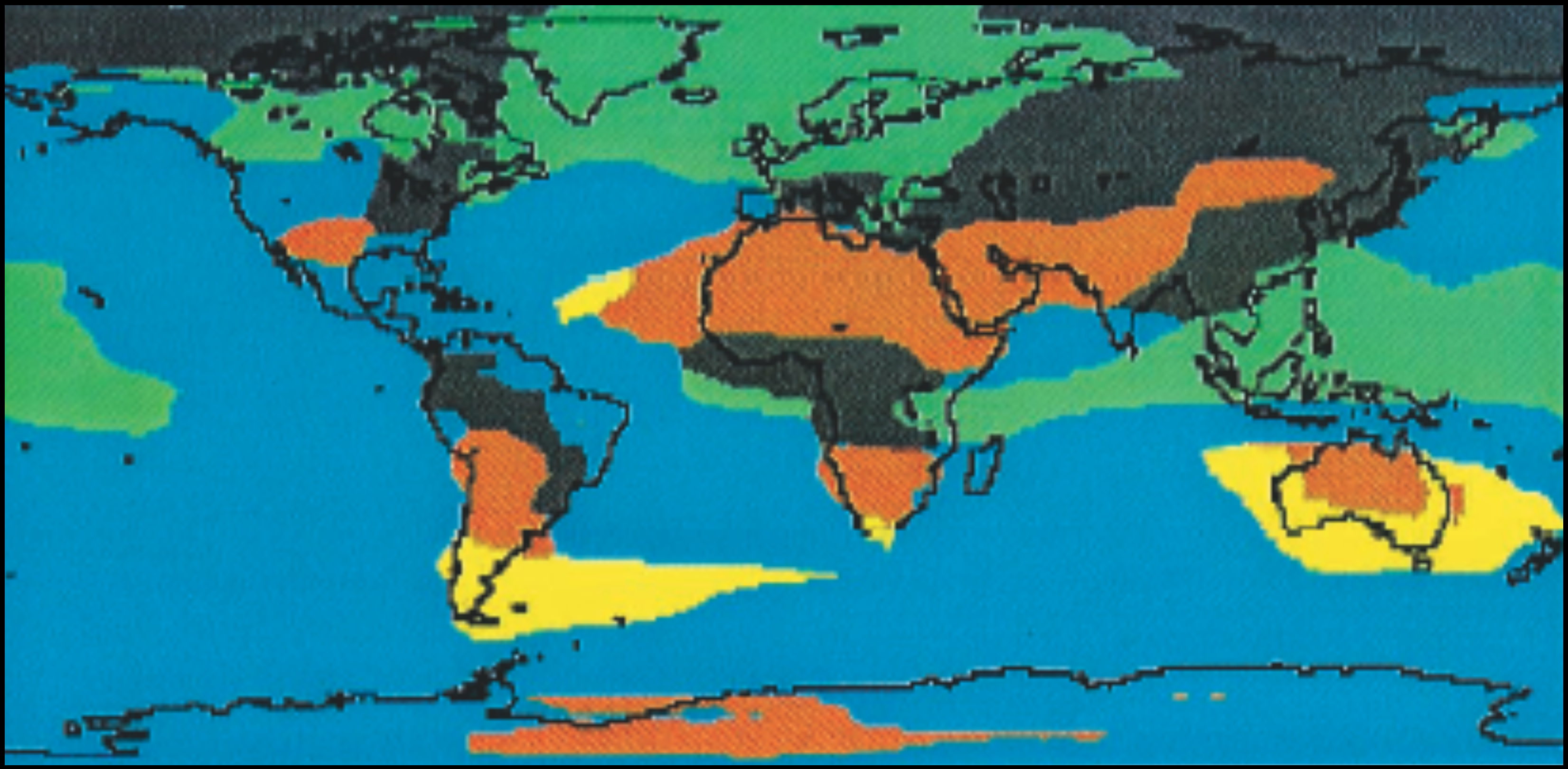


Kahn & Gaitley JGR 2015



Adapted from: Kahn, Survy. Geophys. 2012

Expected **Aerosol-Air-Mass-Type Climatology**

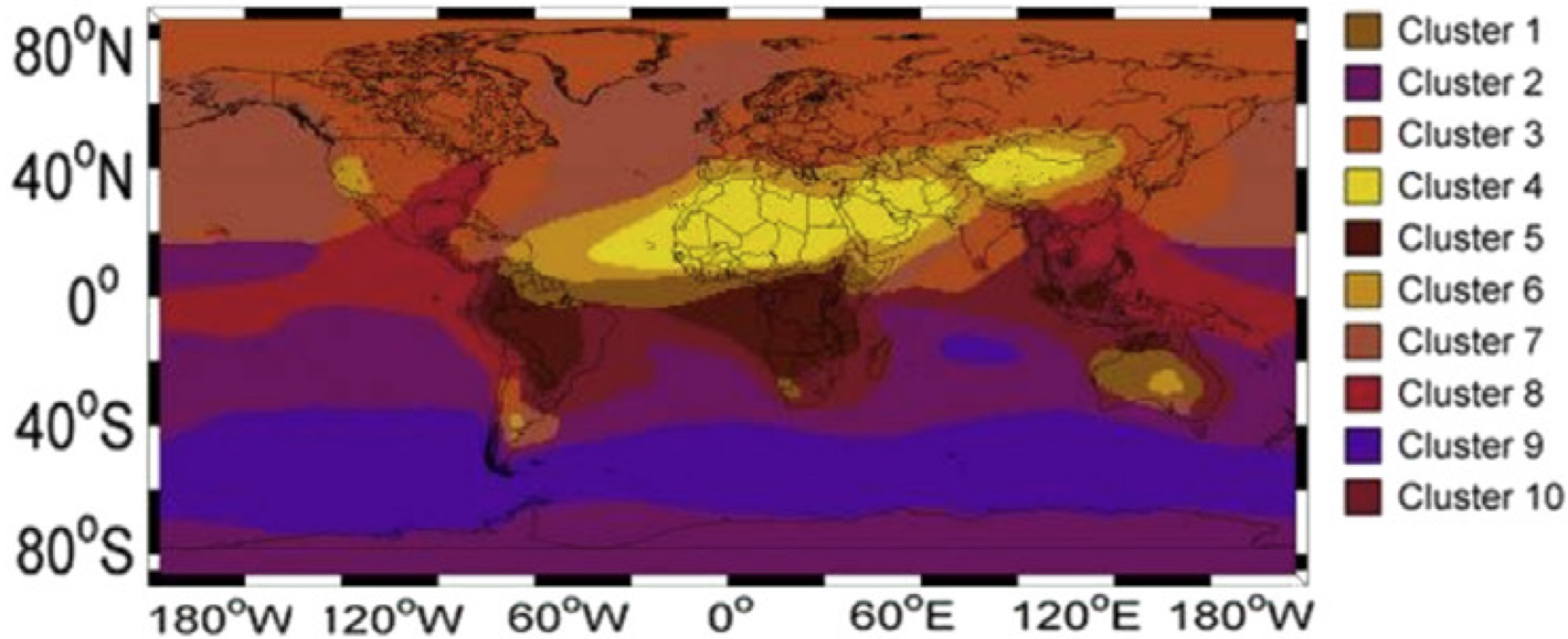


January – aggregated model simulations

Nearly all the data clustered into FIVE Groupings Based on Aerosol Properties

Kahn et al., JGR 2001

*GoCART **Model-Based Aerosol-Type** Clustering*



Pure Types:
- 100% BB
- 100% SU
- 100% DU
- 100% SS

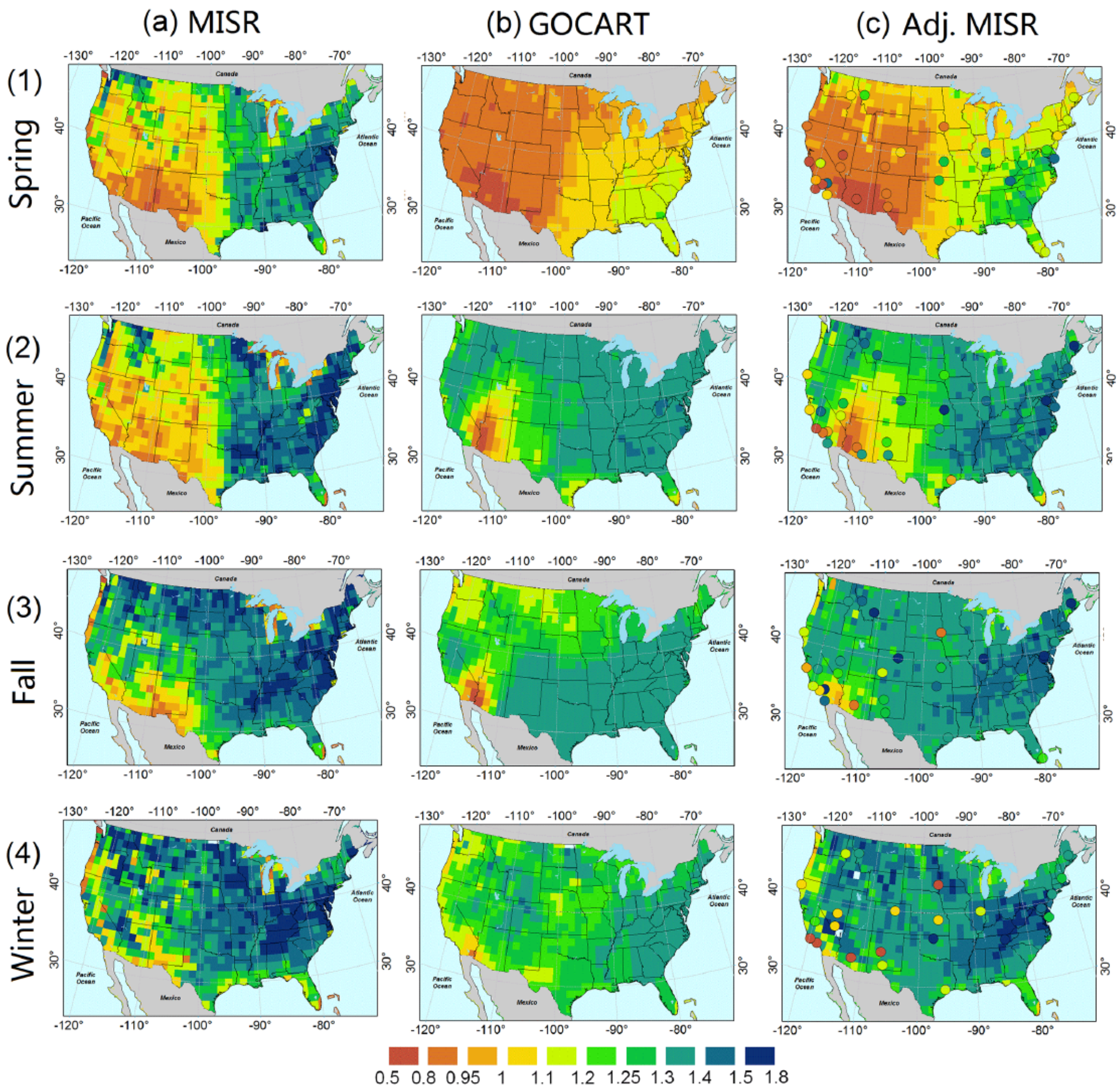
Equal Mixtures:
- 50:50% BB:SU
- 50:50% BB:DU
- 50:50% BB:SS
- 50:50% SU:DU
- 50:50% SU:SS
- 50:50% DU:SS

Six-year aggregate (2000-2006)

Taylor et al. Atm. Env. 2015

Where remote-sensing data are ambiguous, can ***use a model to weights the options***

MISR *ANG*, *AAOD* Results *Constrained by GoCART Model*



ANG

$$\mathrm{Diff}_{\mathrm{ANG}} = |\alpha_{\mathrm{MISR}} - \alpha_{\mathrm{GOCART}}| \leq \varepsilon_{\mathrm{ANG}}$$

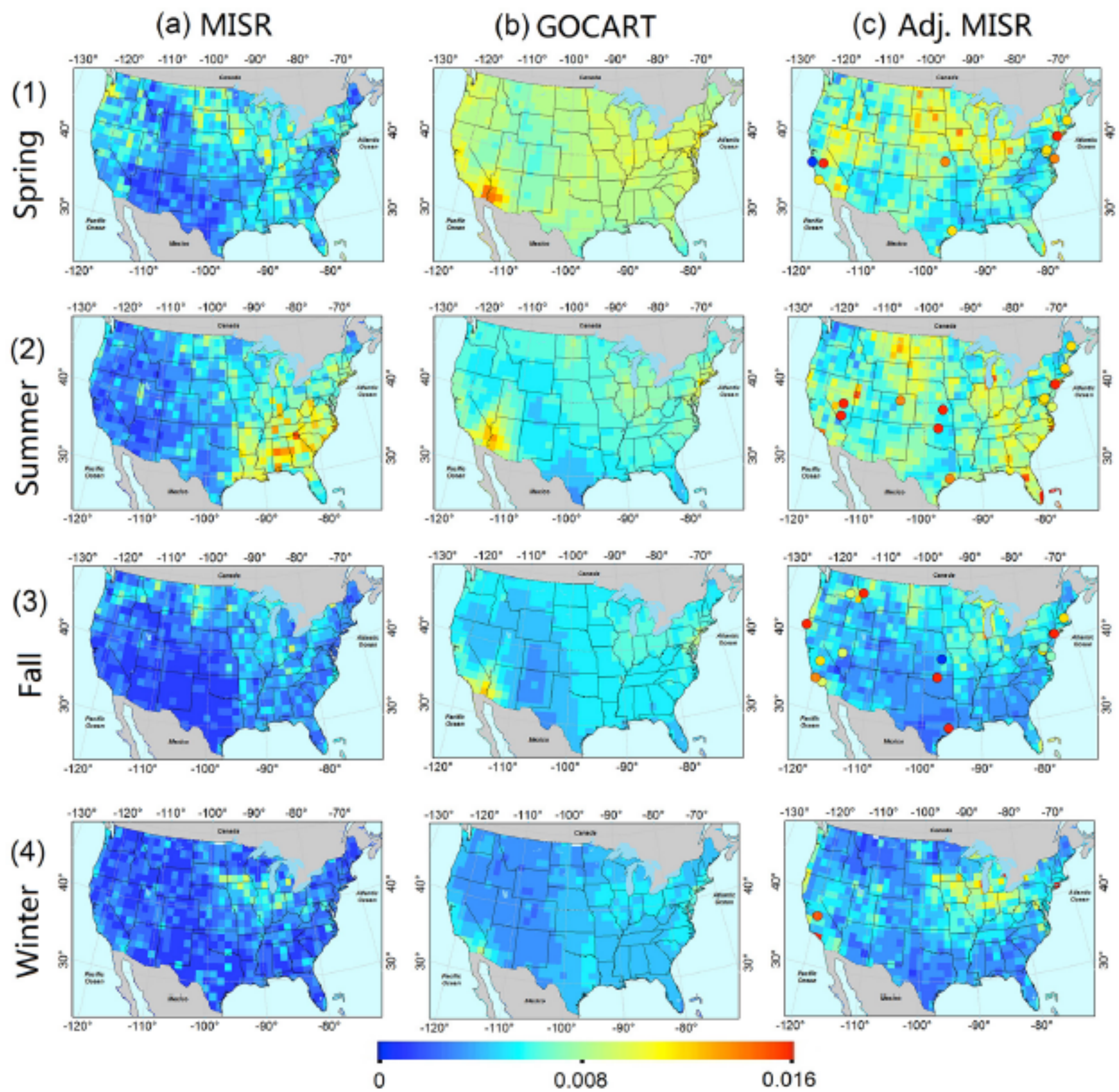
$$\mathrm{Diff}_{\mathrm{AAOD}} = |\mathrm{Fraction}_{\mathrm{MISR\_AAOD}} - \mathrm{Fraction}_{\mathrm{GOCART\_AAOD}}| \leq \varepsilon_{\mathrm{AAOD}}$$

Four years of data (2006-2009)
Seasonally averaged

Shenshen Li et al. AMT 2015

Where remote-sensing data are ambiguous, can ***use a model to weights the options***

MISR *ANG*, *AAOD* Results ***Constrained by GoCART Model***



AAOD

$$\mathrm{Diff}_{\mathrm{ANG}} = |\alpha_{\mathrm{MISR}} - \alpha_{\mathrm{GOCART}}| \leq \varepsilon_{\mathrm{ANG}}$$

$$\mathrm{Diff}_{\mathrm{AAOD}} = \left|\mathrm{Fraction}_{\mathrm{MISR\_AAOD}} - \mathrm{Fraction}_{\mathrm{GOCART\_AAOD}}\right| \leq \varepsilon_{\mathrm{AAOD}}$$

Four years of data (2006-2009)
Seasonally averaged

Shenshen Li et al. AMT 2015

Where remote-sensing data are ambiguous, can ***use a model to weights the options***

<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>*:**

-- the aerosol property *<u>assumptions</u>* in satellite aerosol *retrieval algorithms*

-- the *translation between satellite-retrieved aerosol <u>optical</u> properties and* species-specific aerosol *<u>mass</u>* and size tracked in *aerosol transport & climate models*

SAM-CAAM *Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

I. Aerosol Properties Derived from Integrated Analysis of *In Situ* Measurements

1. ***Spectral extinction coefficient*** (EXT)
   - To constrain satellite Aerosol Optical Depth (AOD) retrievals
2. ***Spectral absorption*** (ABS) or single-scattering albedo
   - To constrain AOD retrievals, and to determine atmospheric absorption
3. ***Particle hygroscopic growth factor*** (GRO)
   - To connect particle properties between instrument and ambient RH conditions
4. ***Particle size*** (SIZ)
   - As a complement to chemical composition discrimination
   - Required for deriving (#7) MEE
5. ***Particle composition*** (CMP)
   - For source and aerosol type identification to connect to model "types"
   - To derive the anthropogenic component
6. ***Spectral single-scattering phase function*** (PHA) [all possible angles]
   - To constrain multi-angle radiance AOD retrievals & calculate radiation fields
   - *Polarized* – to help determine aerosol type, and constrain polarized remote-sensing data

SAM-CAAM *Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

I. Aerosol Properties Derived from Integrated Analysis (continued)

7. ***Mass extinction efficiency*** (MEE) [from integrated analysis of SIZ and CMP]
   - To translate between optical remote-sensing and model parameters
8. ***Real Refractive Index*** (RRI)
   - To constrain AOD retrievals to the level-of-detail required for aerosol forcing

II. Variables Providing Meteorological Context

9. ***Carbon Monoxide*** (CO; also possibly CO_2, NO_2, O_3)
   - As a tracer for smoke, to help distinguish smoke from urban pollution in some cases
10. ***Ambient temperature*** (T) and ***Relative humidity*** (RH)
    - To help interpret ambient measurements
    - To translate between instrument and ambient conditions
11. ***Aircraft 3-D location*** (LOC)
    - To relate aircraft measurements to satellite observations and model results

SAM-CAAM *Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

III. Variables Providing Ambient, Remote-Sensing Context

12. ***Ambient Spectral single-scattering phase function*** (A-PHA) [all possible angles]
    - To constrain remote-sensing AOD retrievals
    - To help calculate radiation fields
    - *Polarized* – to help determine aerosol type, and constrain polarized remote-sensing data

13. ***Ambient Spectral extinction coefficient*** (A-EXT)
    - To constrain remote-sensing AOD retrievals

14. ***Large particle / cloud probe*** (A-CLD)
    - To provide some information about dust and other particles larger than the inlet size cut
    - An independent measure of possible cloud impact on the reliability of other data

15. ***Aerosol layer heights*** (HTS)
    - To determine flight levels for direct sampling
    - To correlate with meteorological conditions
    - As a constraint on trajectory modeling to identify sources and evolution

SAM-CAAM *Payload Options*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

- ***Option A*** – minimal measurement addressing each variable ***in some way***
- ***Option B*** – provides all required variables, but only for ***fine mode***
- ***Option C*** – provides all required variables, for ***fine and coarse mode***
- ***Option D*** – *Option C* + everything else that would be "***nice to have***"

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