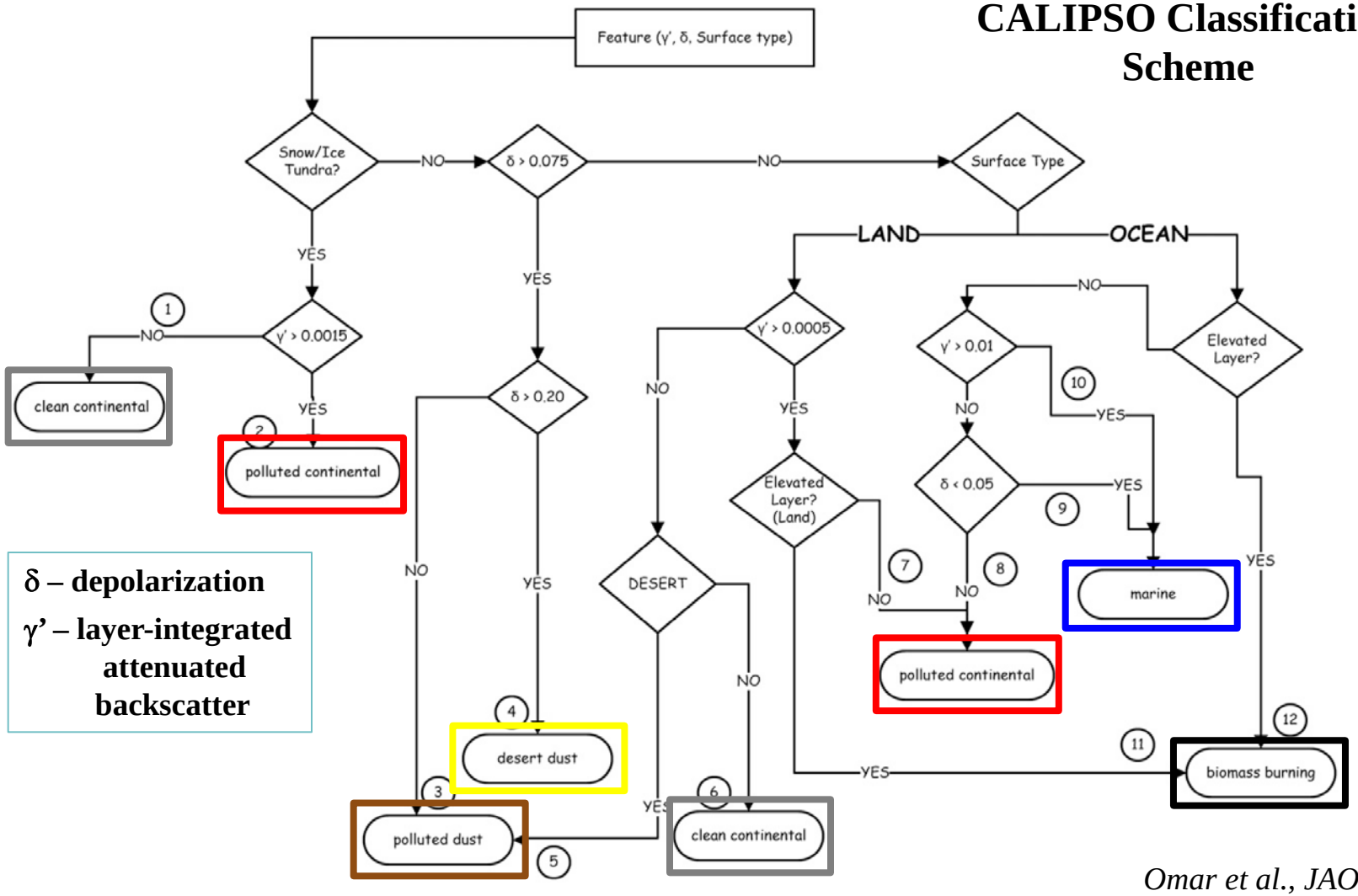
Progress Toward a Global Aerosol Type Climatology

Ralph Kahn

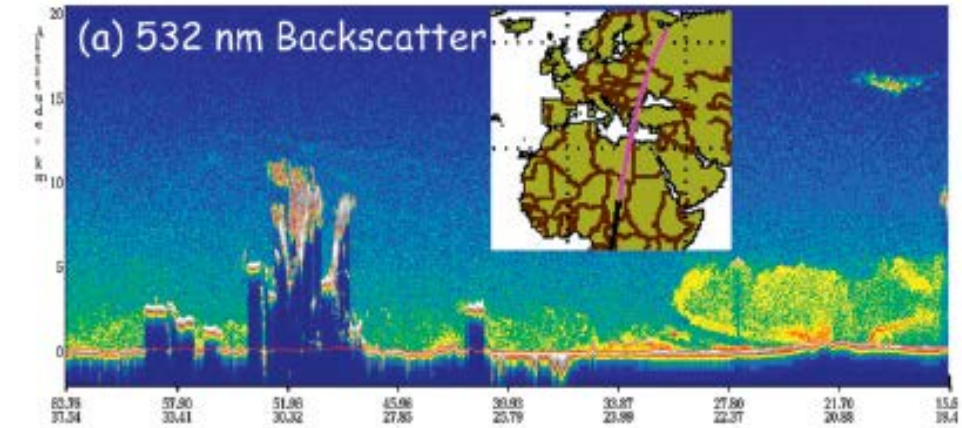
NASA/Goddard Space Flight Center

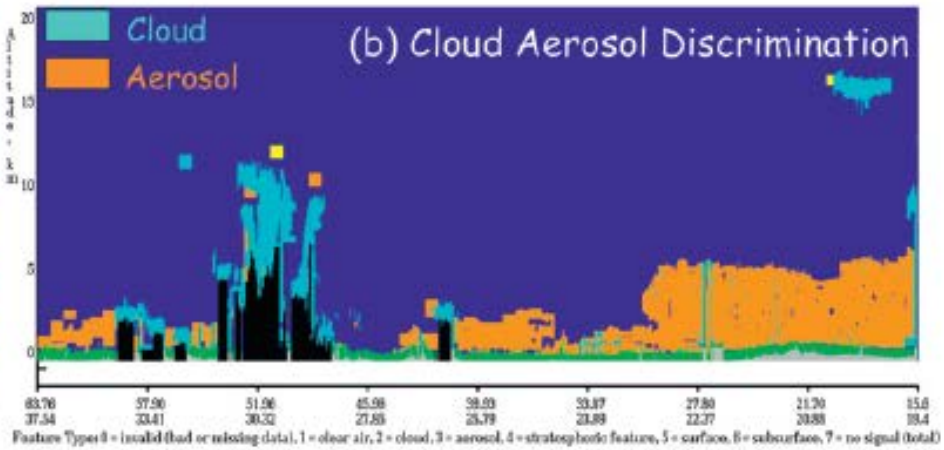
CALIPSO Classification Scheme

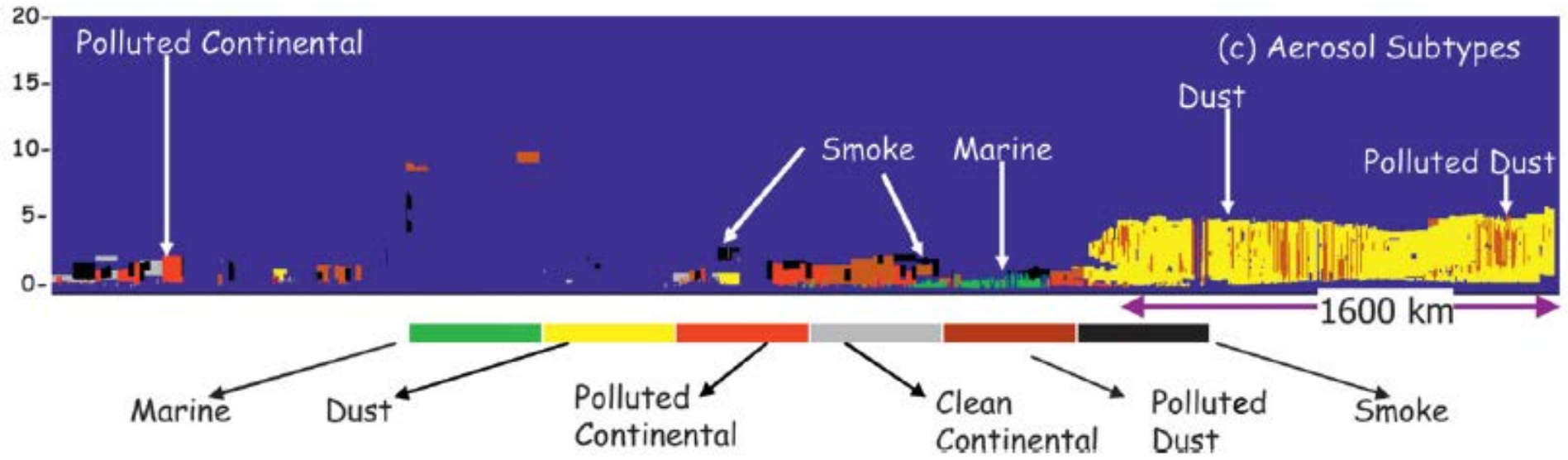


Omar et al., JAOT 2009

CALIPSO 6-Grouping Aerosol Type Classification





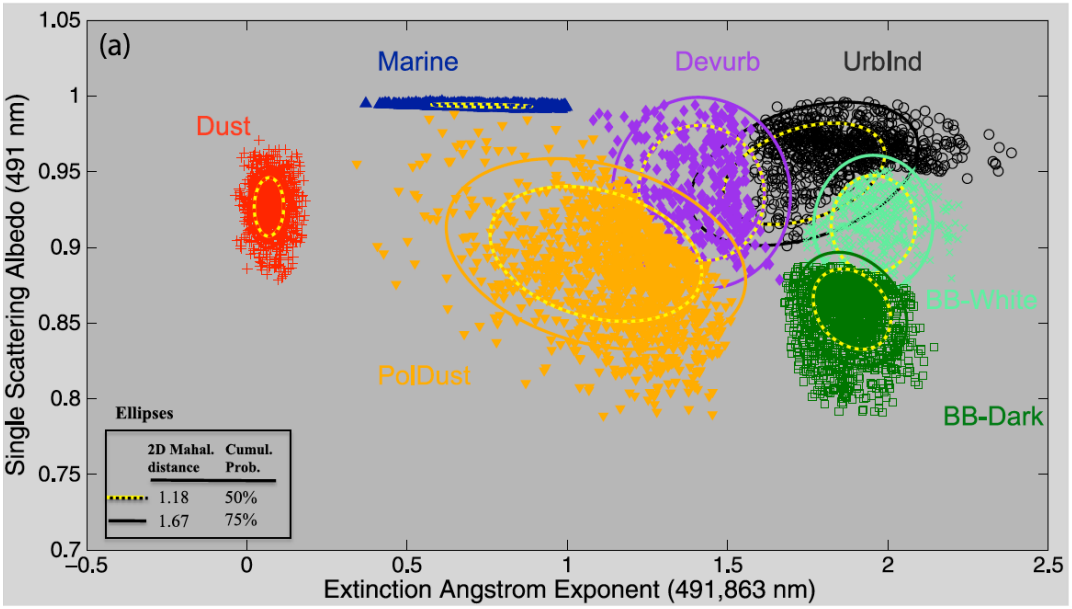


Omar et al., JAOT 2009

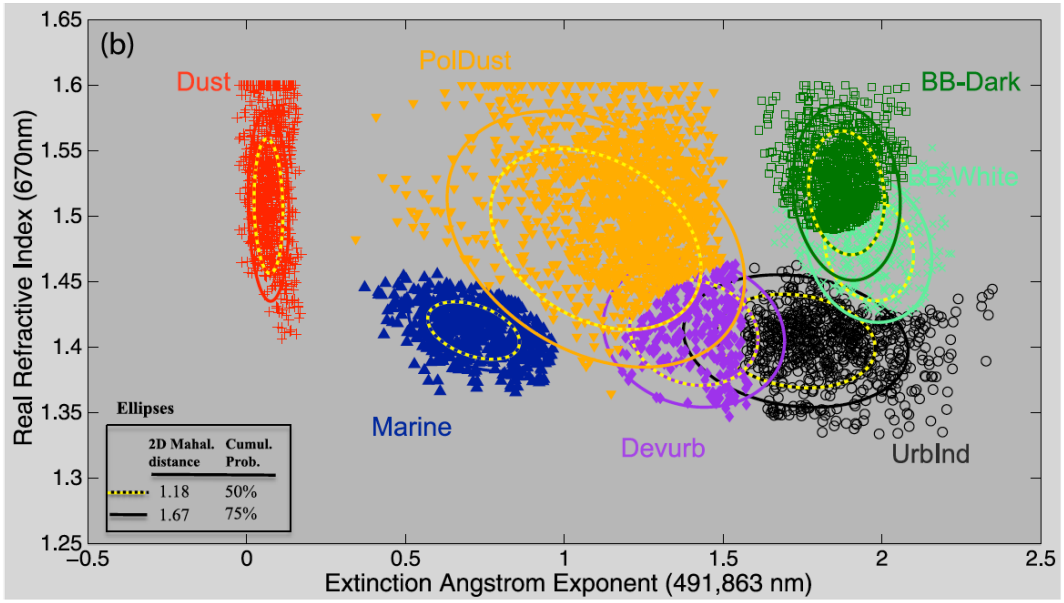
AERONET Aerosol Type 7-Grouping Classification

Four-parameter AERONET-derived classification:

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



7 Groupings SSA_{491} vs. Extinction ANG



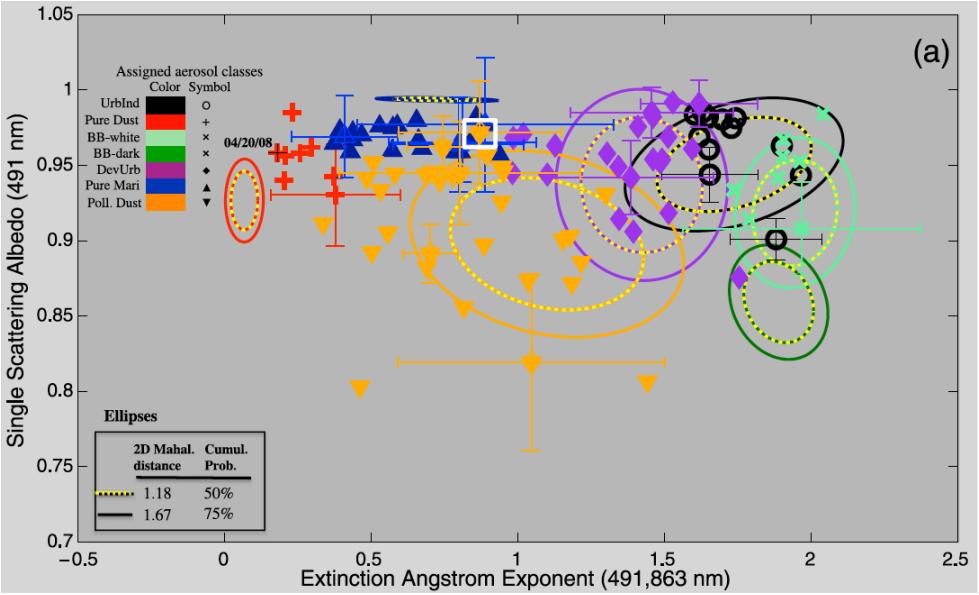
7 Groupings Real RI_{670} vs. Extinction ANG

Russell et al. JGR 2014

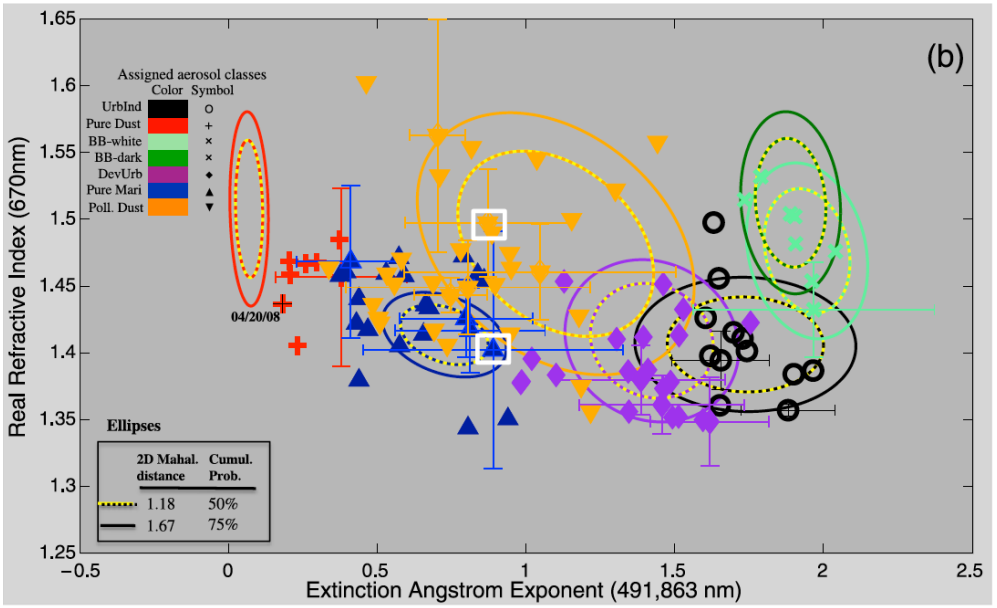
PARASOL data at Forth Crete projected onto the AERONET Aerosol Type Classification

Four-parameter AERONET-derived classification:

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



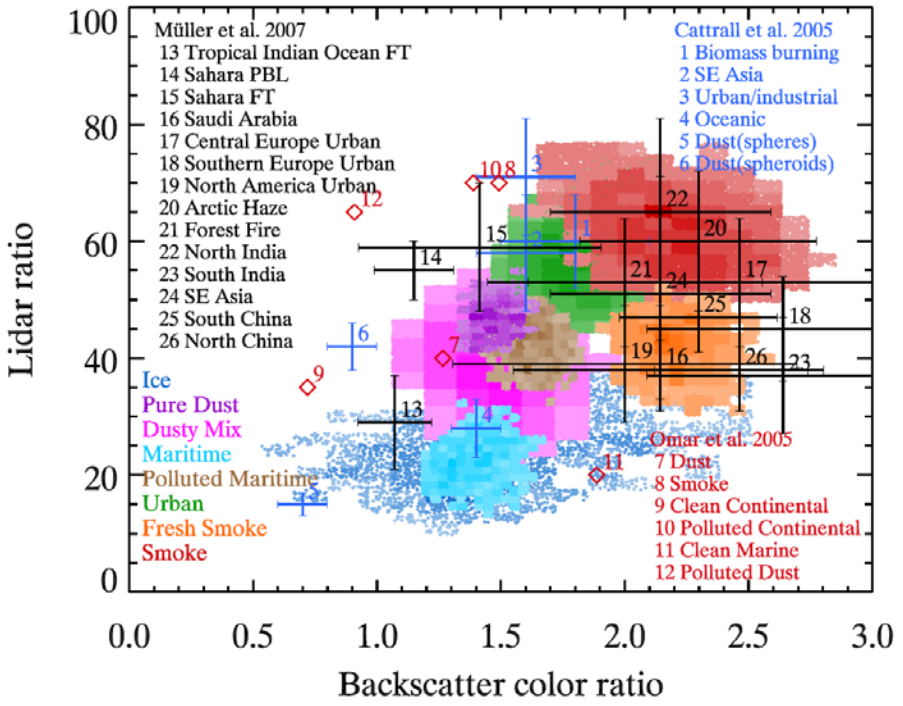
7 Groupings SSA_{491} vs. Extinction ANG



7 Groupings Real RI_{670} vs. Extinction ANG

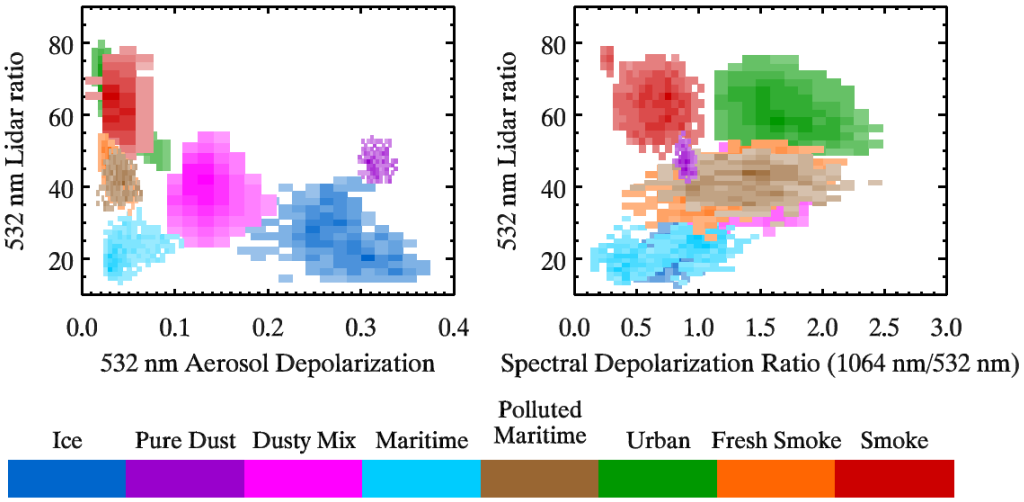
Russell et al. JGR 2014

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

Aerosol_cci

Simple Concept

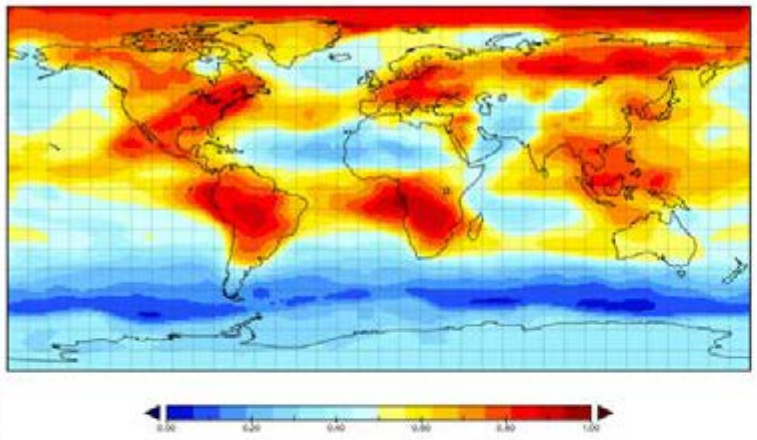
- 4 basic components
  (Dust, Sea Salt, Fine-mode Weakly & Strongly Abs.
- Reflects theoretical information content
- External mixtures with 3 mixing fractions
- Evaluation ongoing of information content

- Output (easier to validate / compare)
  - Fine mode AOD (fine mode / total mixing fraction)
  - Dust AOD (dust / total coarse mode mixing fraction)
  - [AAOD (absorption fraction in fine mode)]

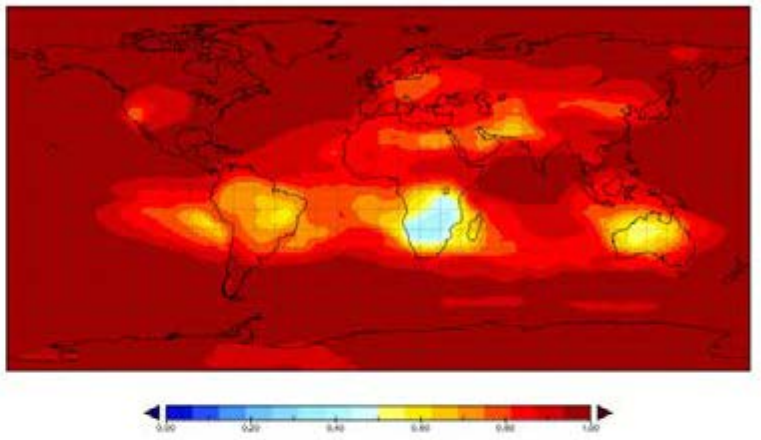
From: Thomas Popp

AOD mixing (fractions) from AEROCOM

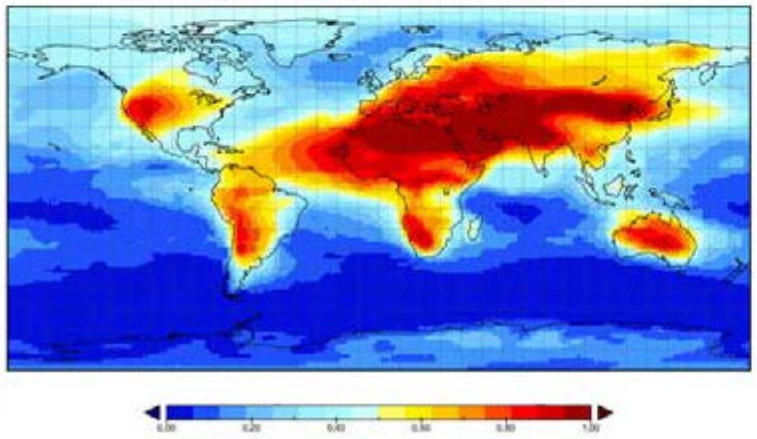
Fine mode fraction



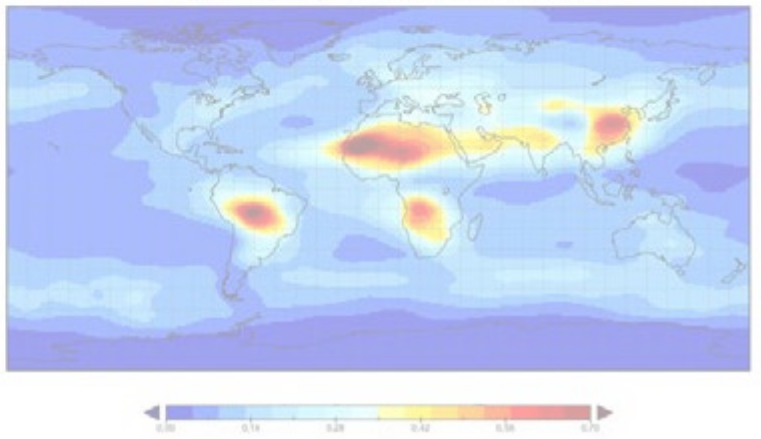
Fraction of the less absorbing component in the fine mode



Fraction of dust in the coarse mode

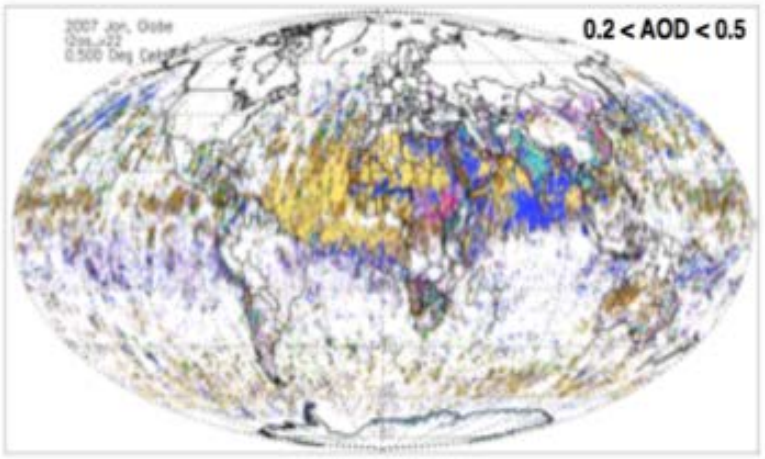


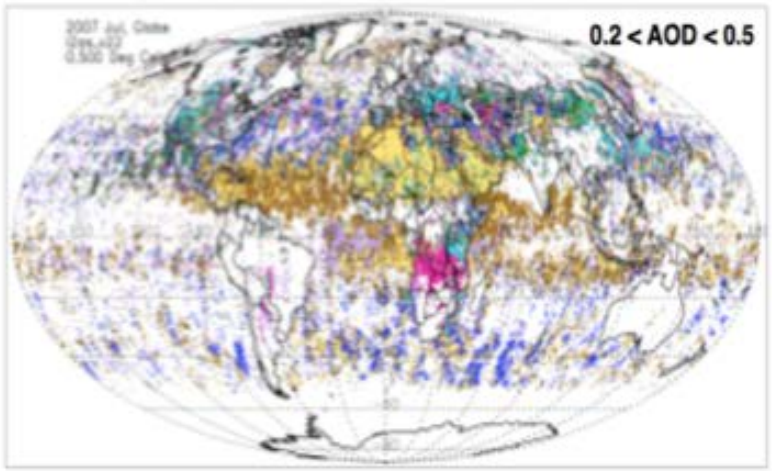
AOD550 (not used as a priori)



From: Thomas Popp

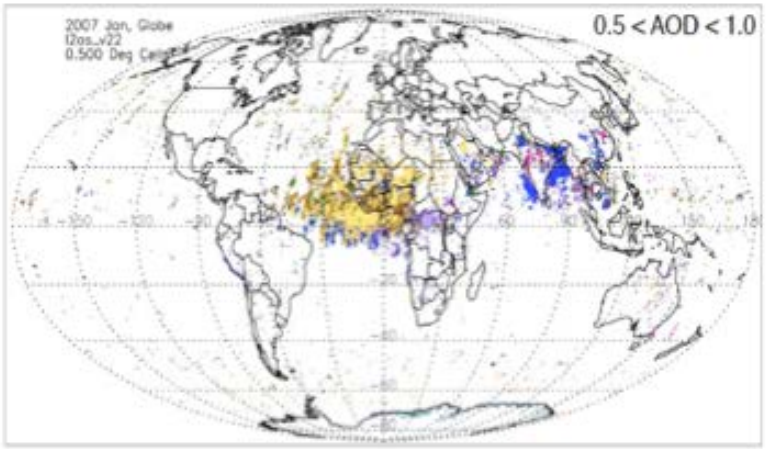
MISR Aerosol Type Discrimination

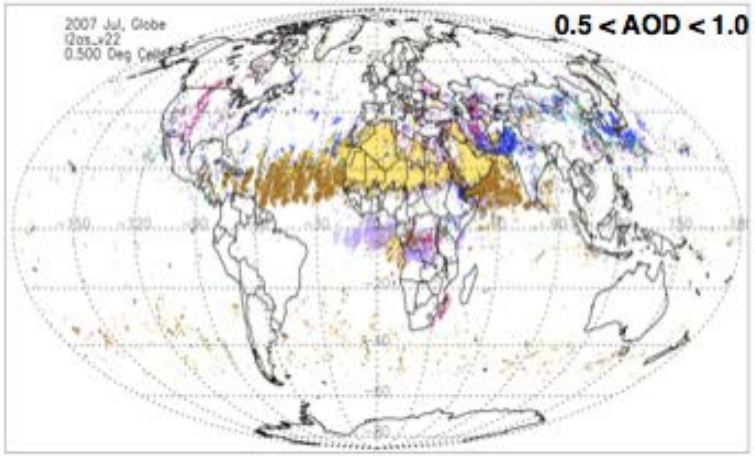




January 2007

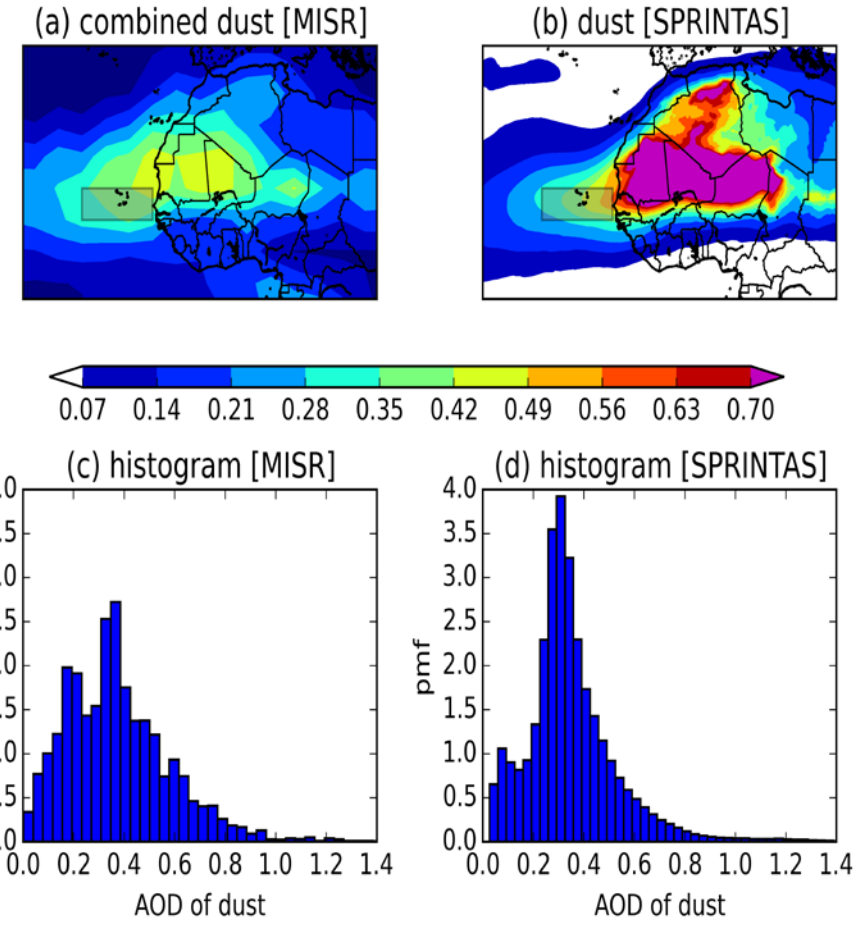
July 2007

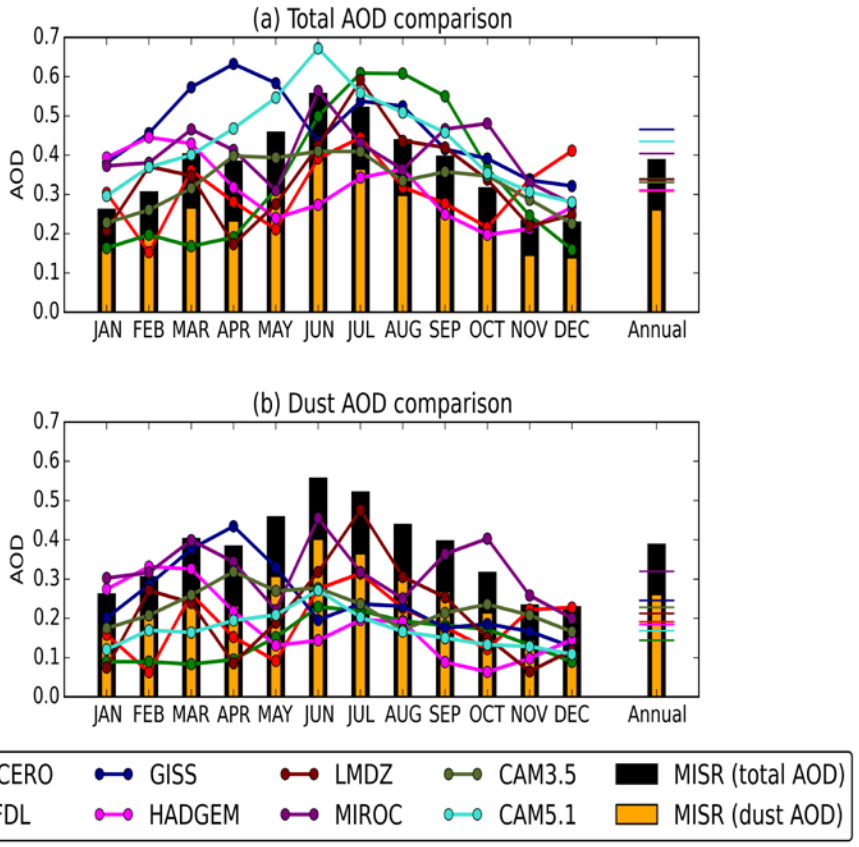




Kahn & Gaitley JGR 2015

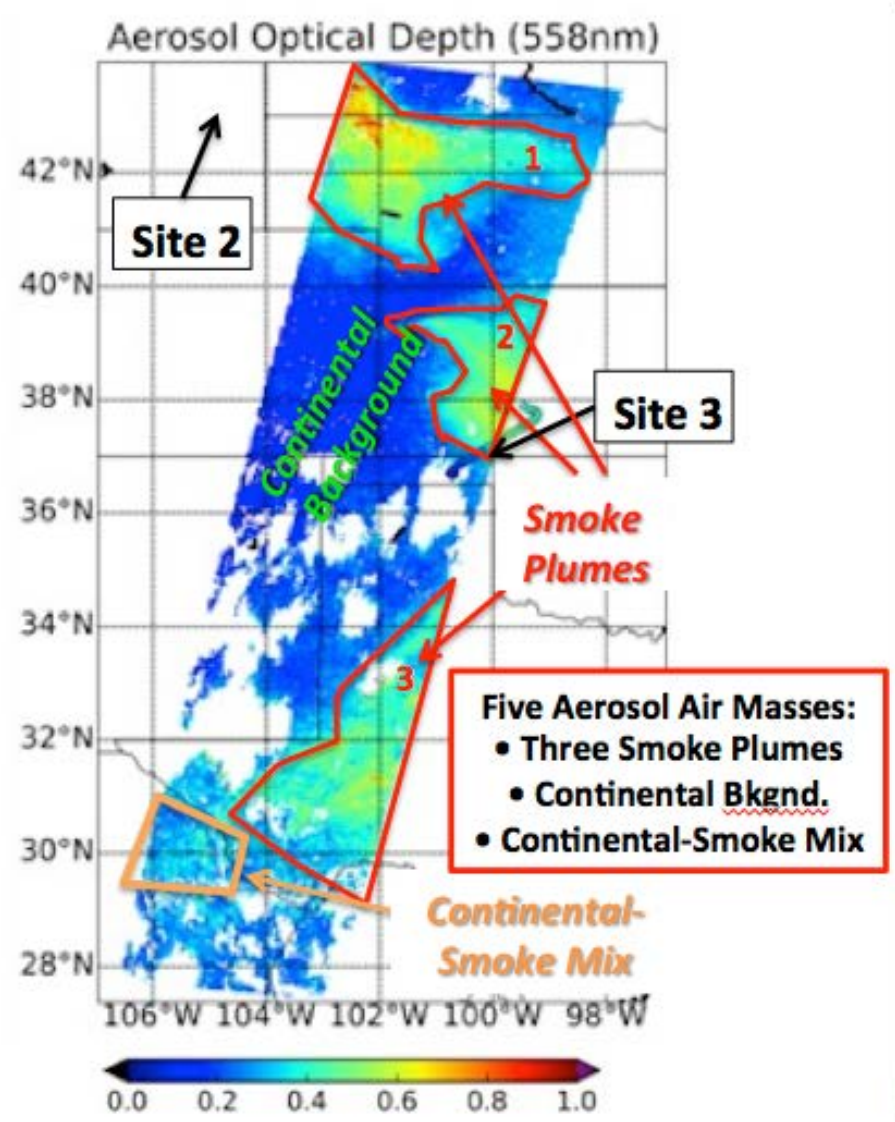
MISR Climatology Dust AOD

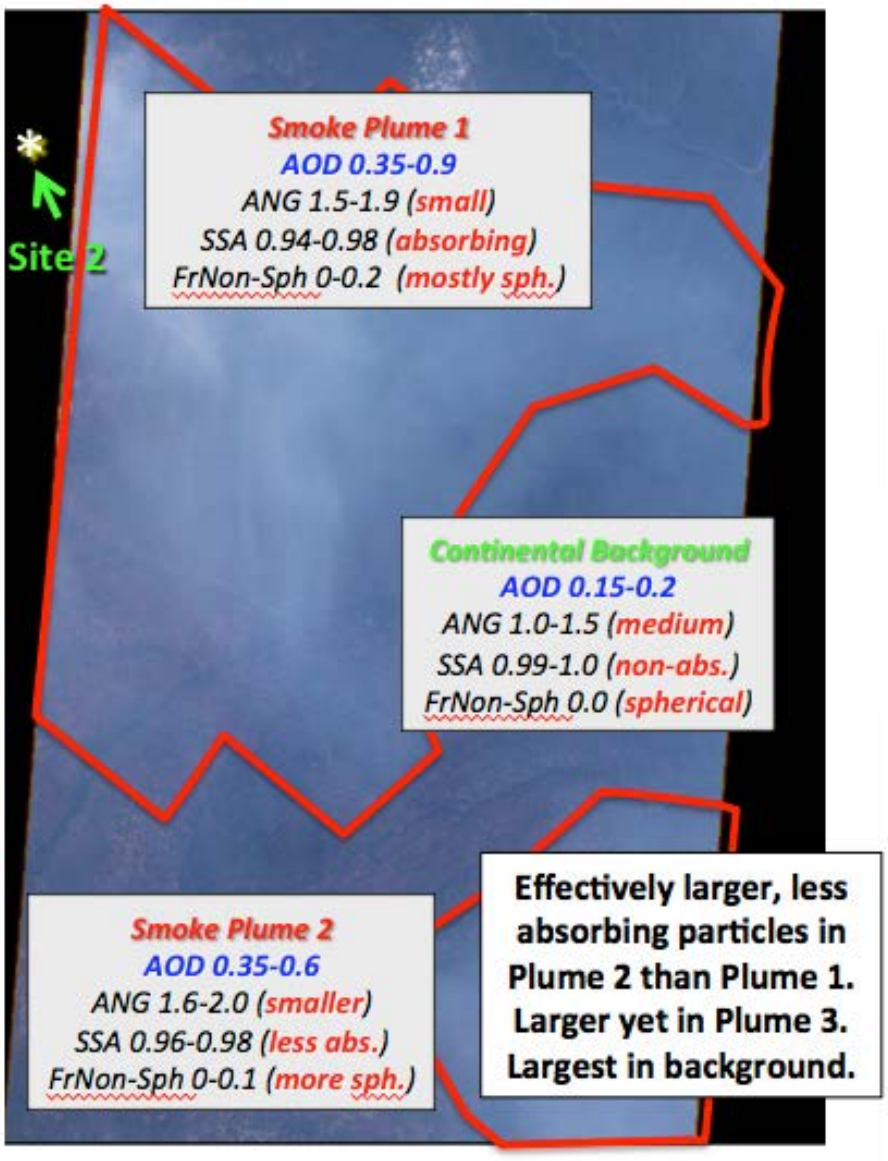




See: Poster by Huikyo Lee, Olga Kalashnikova, Kentaro Suzuki, &Amy Braverman

SEAC⁴RS – MISR Overview 19 August 2013





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

GRASP: Generalized Retrieval of Aerosol and Surface Properties

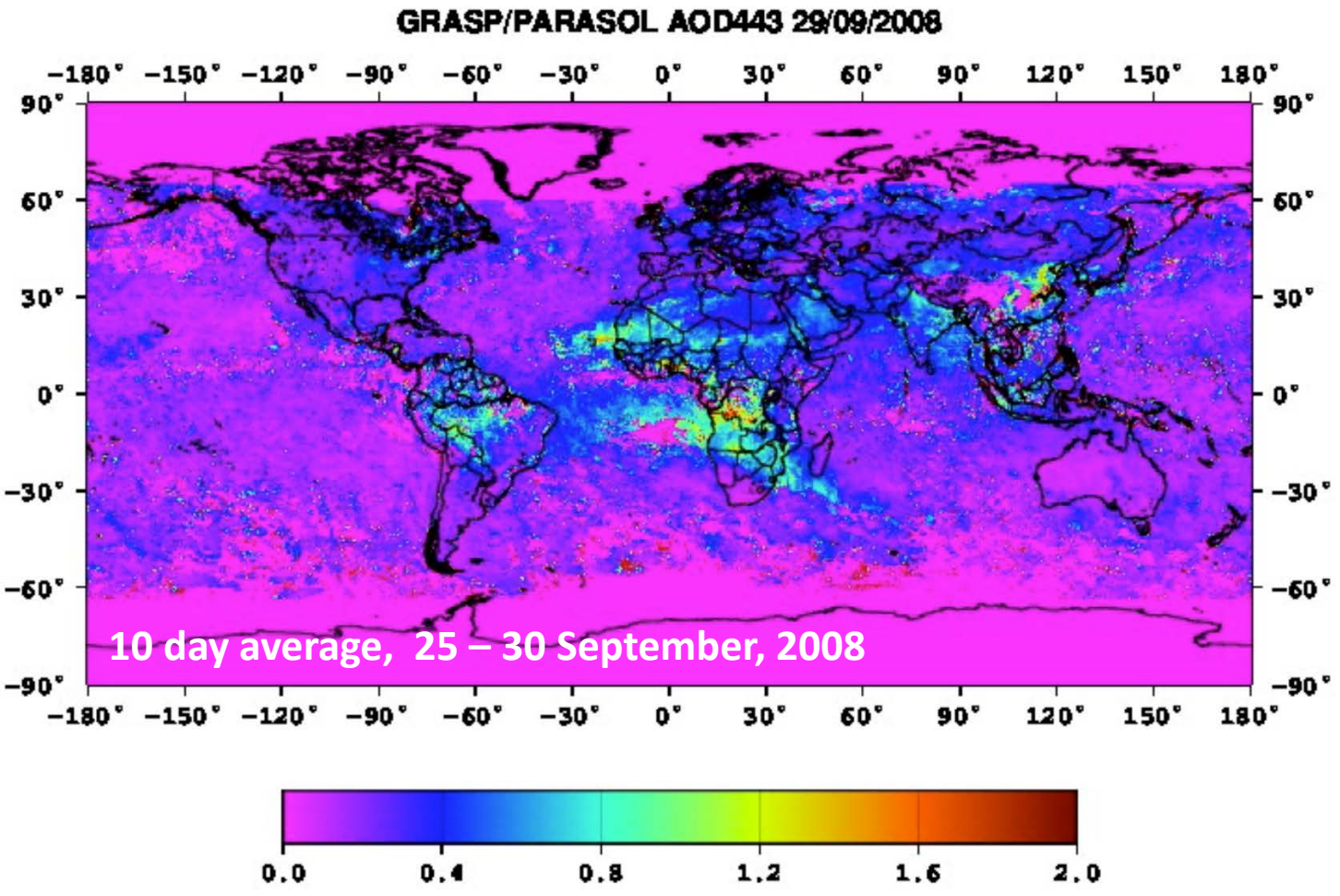
Dubovik et al. 2011, 2014

Open Source

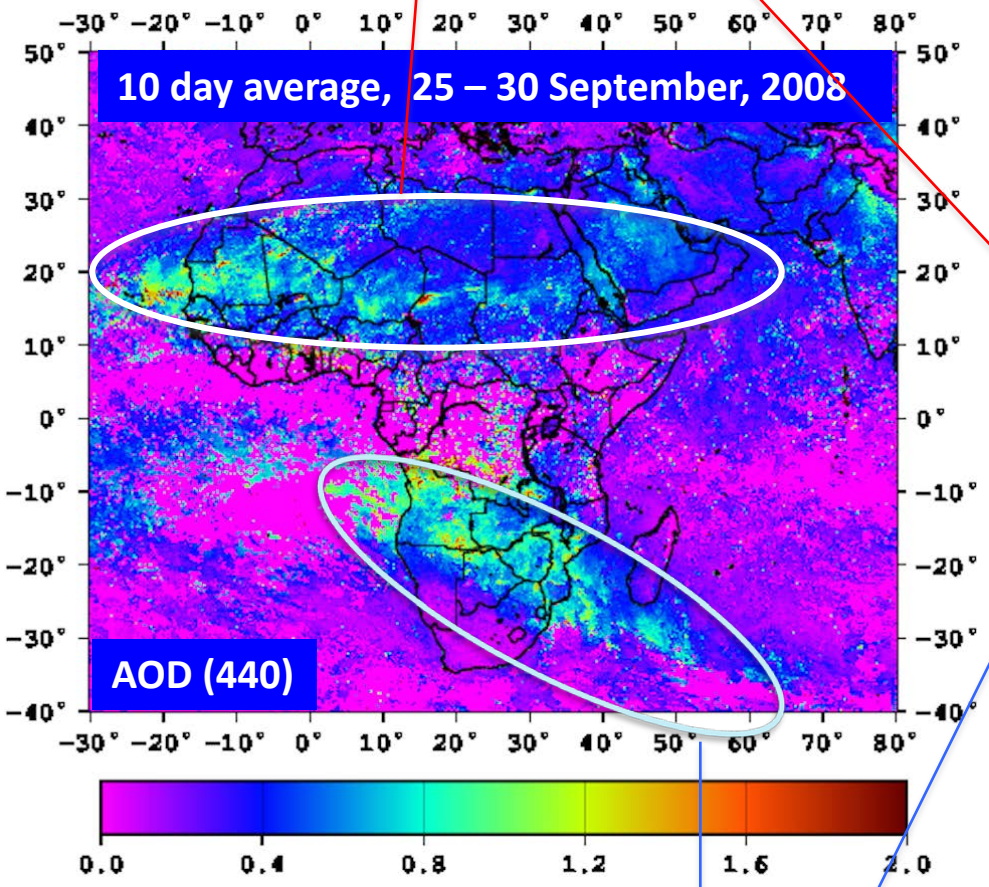
No Location-Specific Assumptions on aerosol and surface **All calculation on the fly**

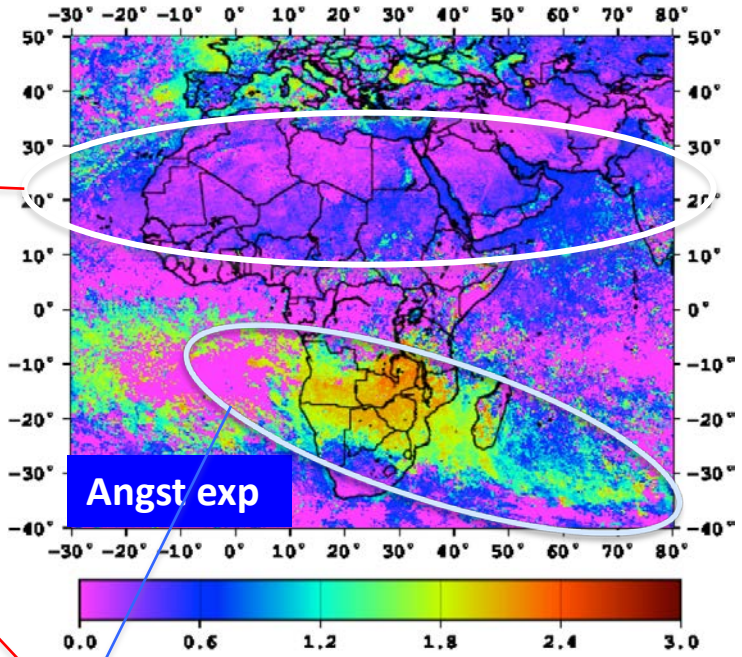
Retrieved parameters: Surface reflectance, aerosol: AOD, SSA, aerosol height, size information, refractive index, aerosol type, etc.

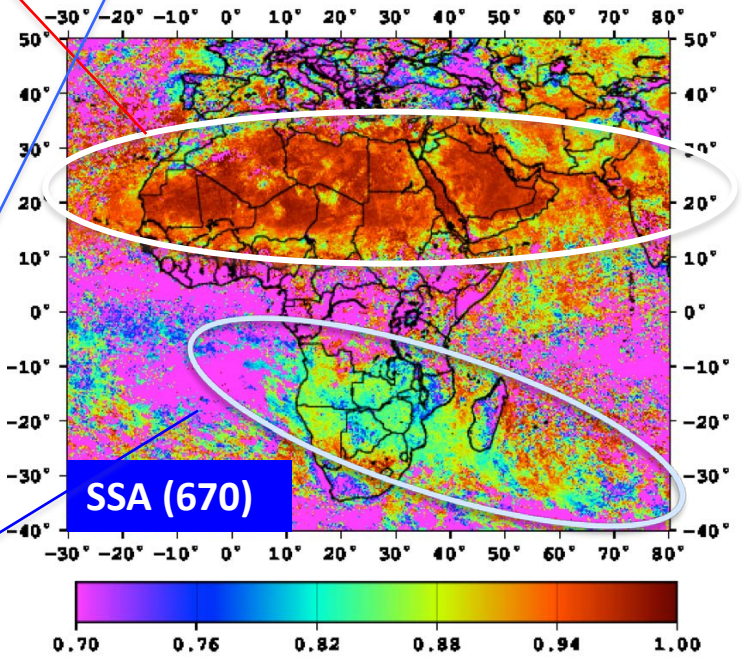
Expected practical advantages: accurate even over bright surfaces, even for high AOD, and for extended set of parameters



GRASP: towards aerosol classification







Desert Dust

Biomass Burning

See: Poster by Oleg Dubovik, Anton Lopatin

Aerosol Type Validation Approach

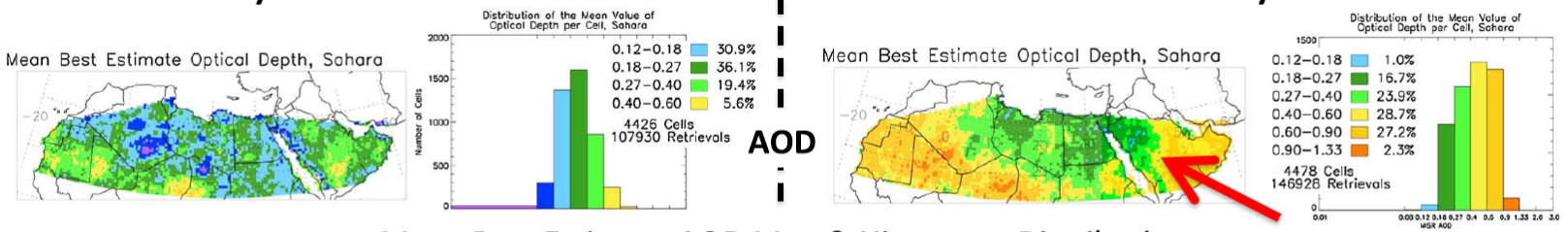
- No ***"Ground Truth"*** except from Field Campaigns (***Golden Days***)
  - -- Unlike ***Spectral AOD*** (and ***ANG***) from AERONET
    Particle Properties derived from AERONET entail ***many more assumptions***
  - -- ***Far fewer*** Satellite-AERONET Sky-scan that Direct-sun Coincidences
- ***Self-consistency*** 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

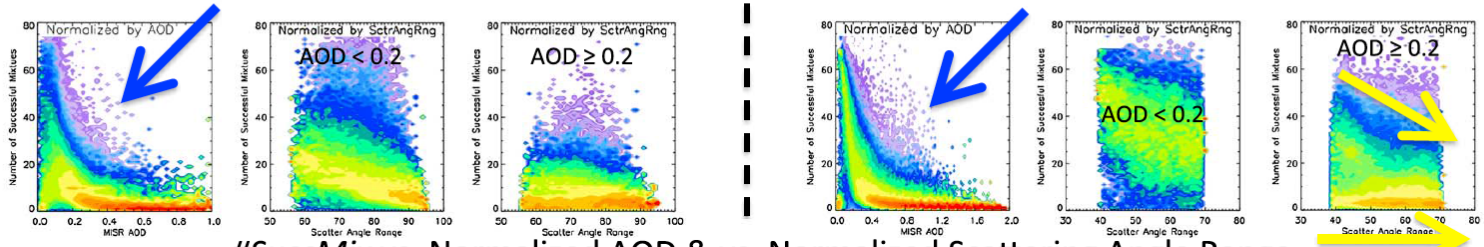
MISR Aerosol Type Discrimination

Sahara Desert (Arid Region)

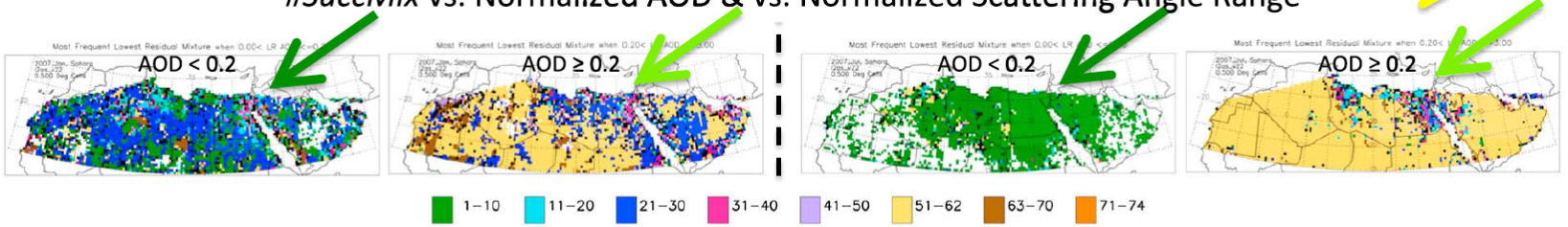
January 2007 | July 2007



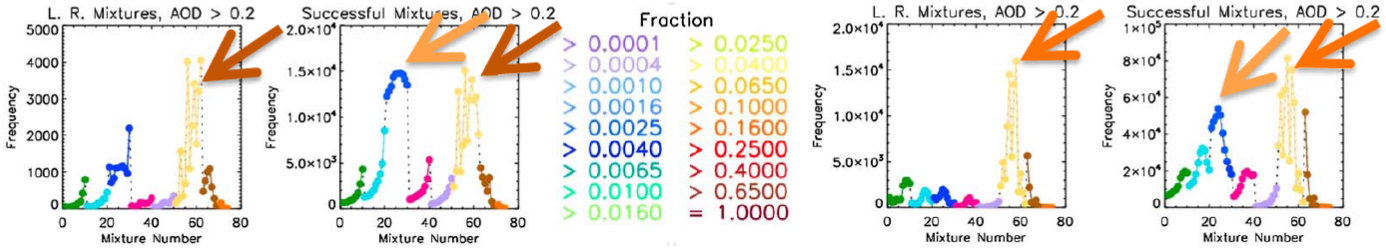
Mean Best Estimate AOD Map & Histogram Distribution



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



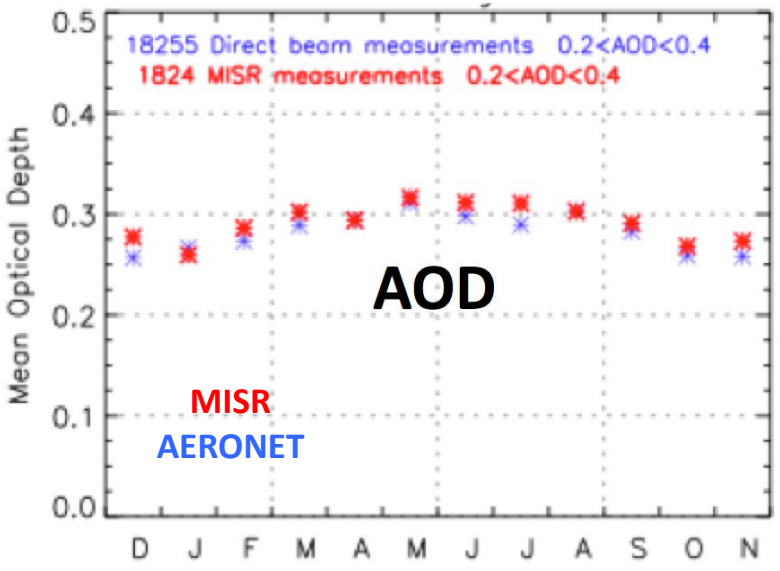
Most Frequent Lowest Residual Aerosol Type Mixture Group, Stratified by AOD

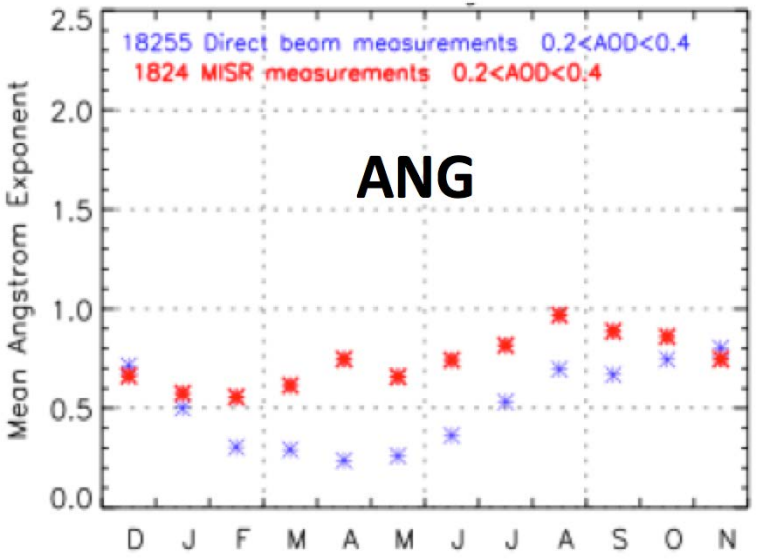


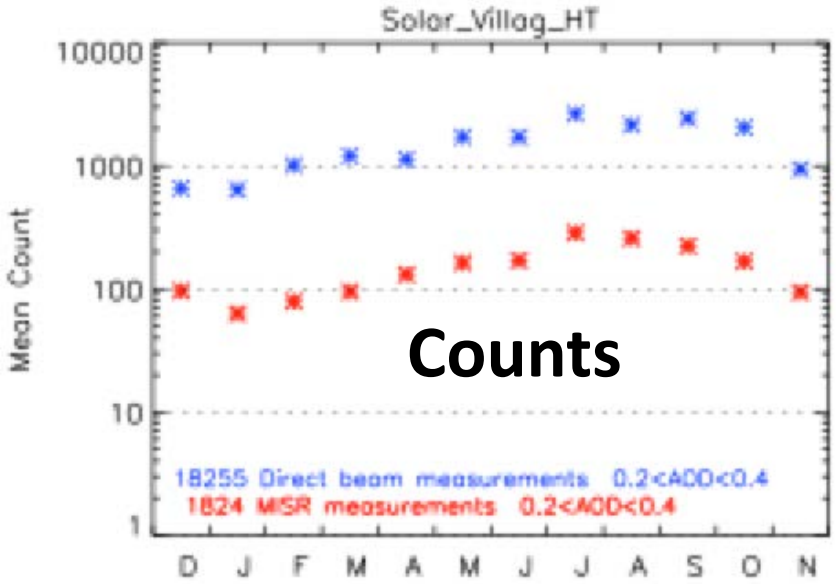
Histograms of Lowest Residual & All Successful Aerosol Type Mixture Groups vs. AOD

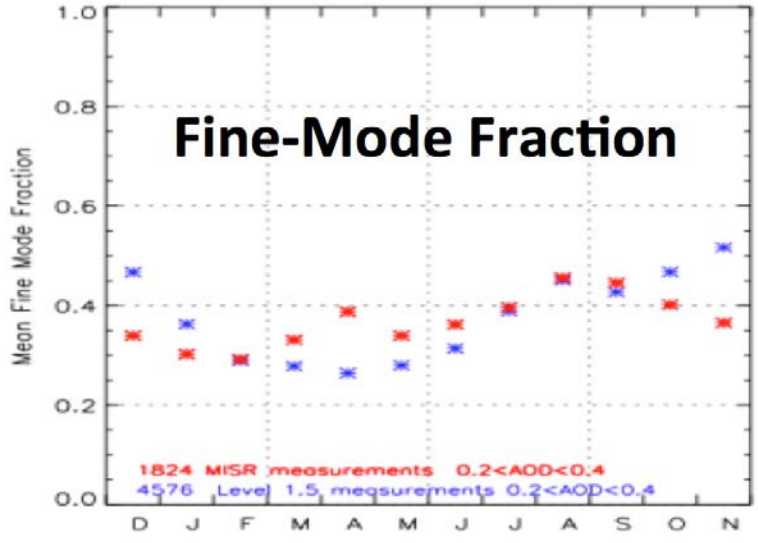
Kahn & Gaitley JGR 2015

Statistical *Comparisons* with AERONET – *Solar Village*









Kahn & Gaitley JGR 2015

Satellites

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

Remote-sensing Analysis
- Retrieval Validation
- Assumption Refinement

Suborbital

targeted chemical & microphysical detail

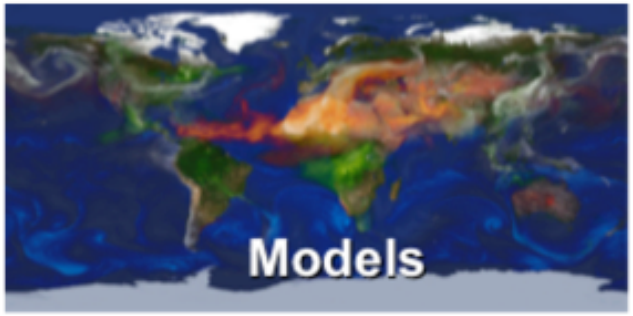
point-location time series

Regional Context

CURRENT STATE
- Initial Conditions
- Assimilation

Aerosol-type Predictions; Meteorology; Data integration

Model Validation
- Parameterizations
- Climate Sensitivity
- Underlying mechanisms



space-time interpolation,

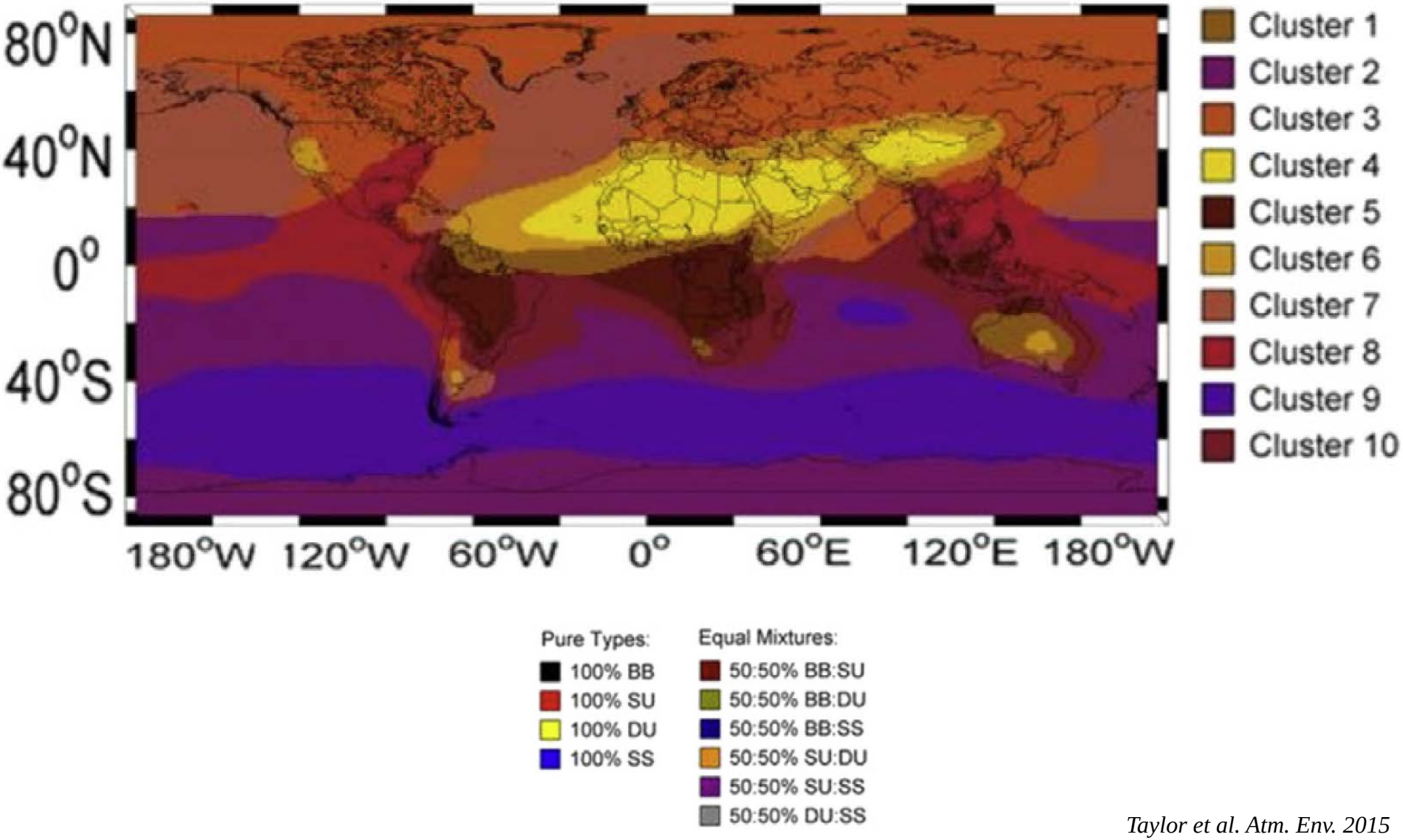
Aerosol Direct & Indirect Effects

calculation and prediction

Must ***stratify*** the global satellite data to treat appropriately situations where **different physical mechanisms** apply

Adapted from: Kahn, Survy. Geophys.

GoCART *Model-Based Aerosol-Type* Clustering



Taylor et al. Atm. Env. 2015

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

Aerosol Type Summary

- Remote-sensing can provide optical constraints interpreted as particle ***Size, Shape, and Indices of Refraction***

- A ***further*** interpretative step, entailing additional assumptions, reports particle ***Chemical Composition***

- Remote-sensing ***sensitivity to particle properties is much more dependent than AOD on retrieval conditions***

- ***Validation Data*** for aerosol type are very limited

  -- ***Model simulations*** and ***In Situ measurements*** can help