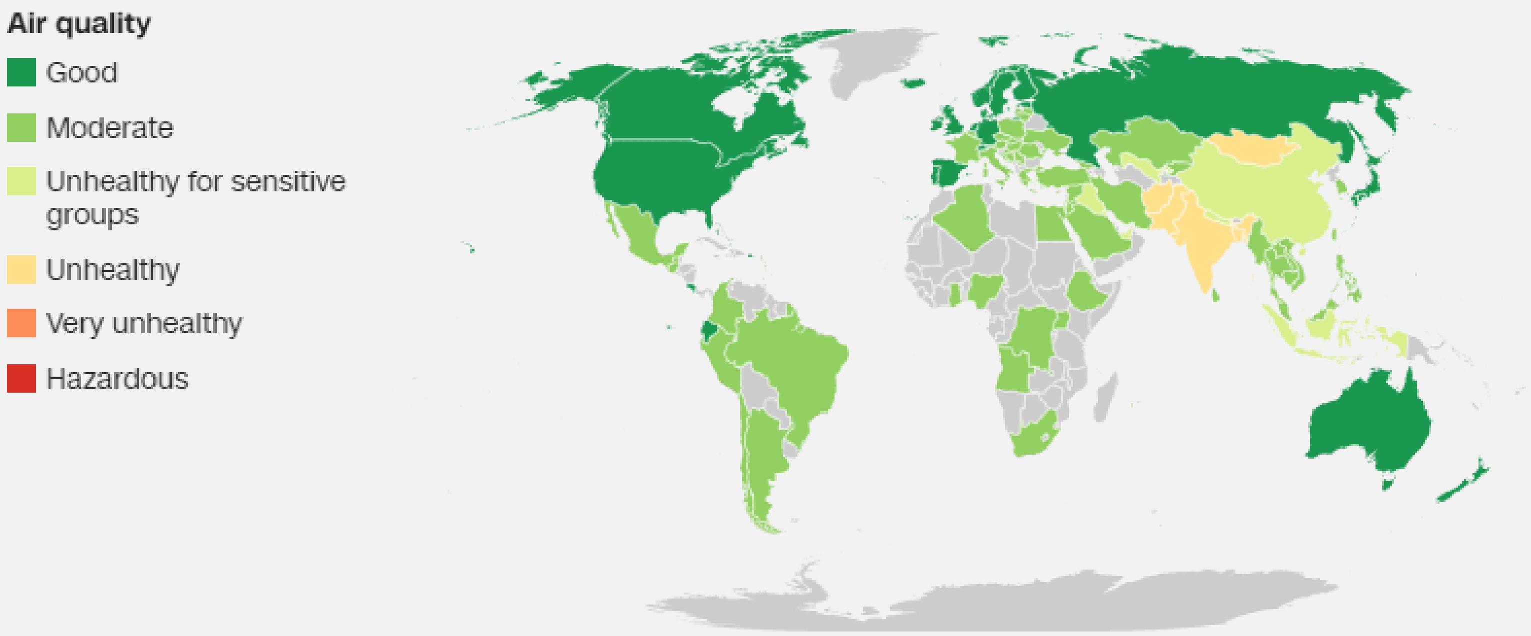
Air pollution across the world in 2019

A new report found that Asian countries and territories dominated the list of most air polluted regions in 2019. The map below shows pollution by country and territory using the US Air Quality Index.



Country	Air quality	PM2.5*
Bangladesh	Unhealthy	83.3
Pakistan	Unhealthy	65.8
Mongolia	Unhealthy	62
Afghanistan	Unhealthy	58.8
India	Unhealthy	58.1
Indonesia	Unhealthy for sensitive groups	51.7

https://www.cnn.com/2020/02/25/health/most-polluted-cities-india-pakistan-intl-hnk/index.html

Aerosols and Air Quality Session

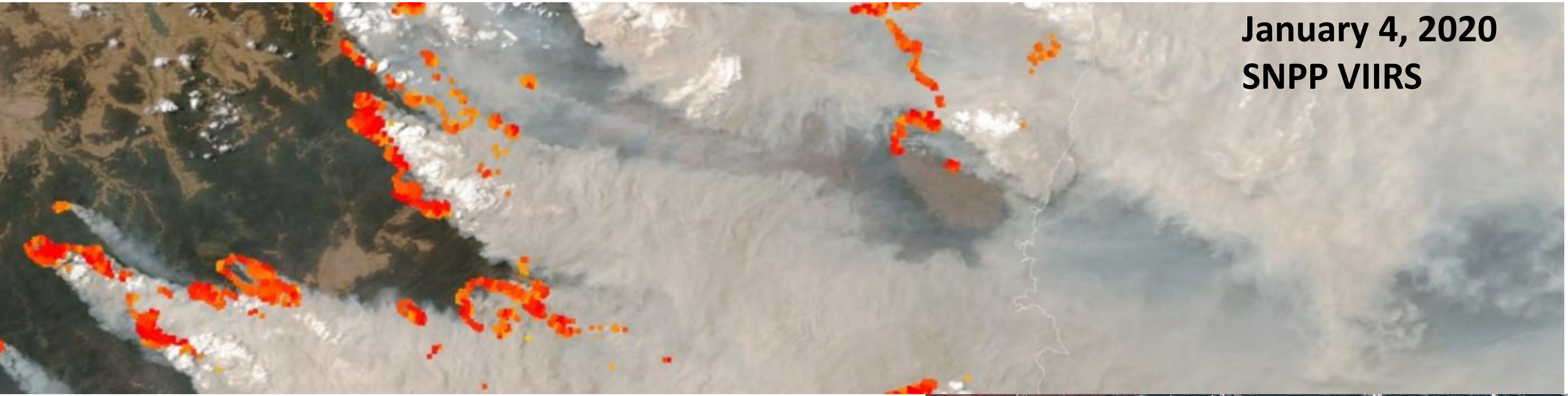
Moderated by Shobha Kondragunta

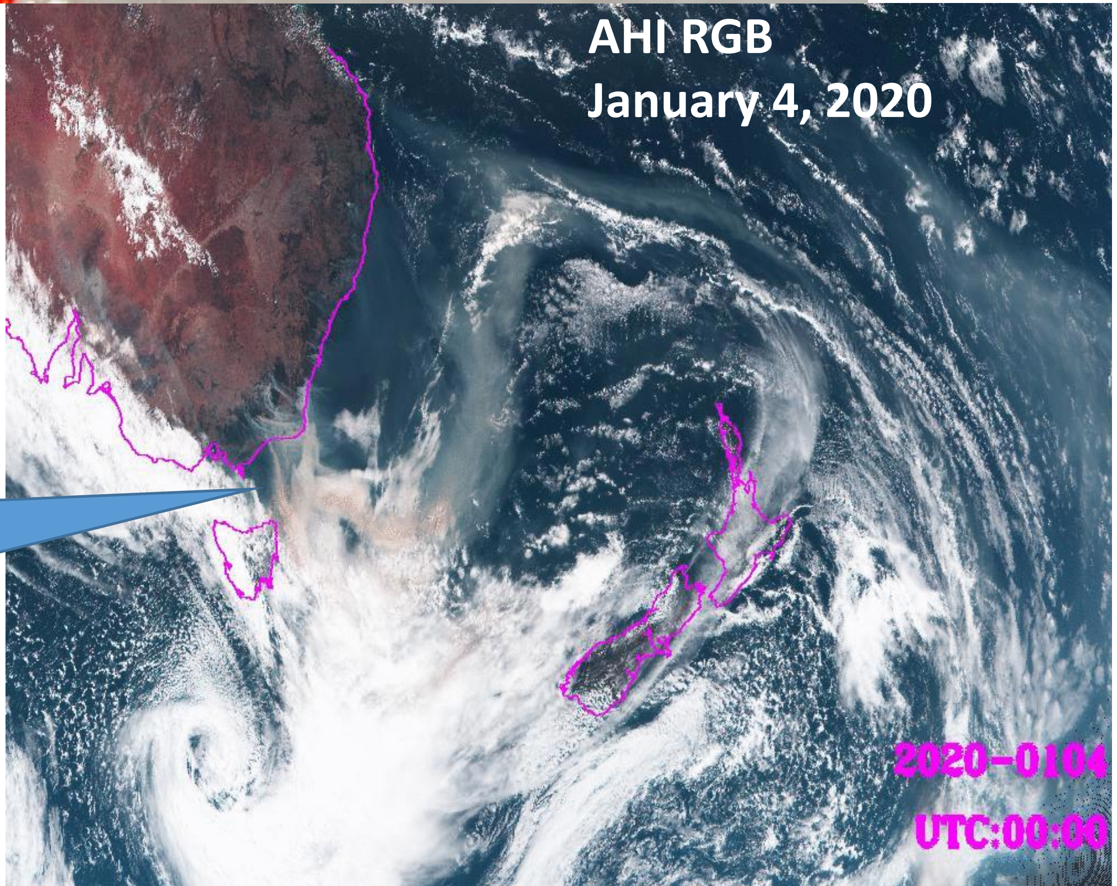
Lead, GOES-R Aerosols/Atmospheric Chemistry/Air Quality

Co-lead, JPSS Aerosols

NESDIS Center for Satellite Applications and Research

Estimated 7 million deaths annually globally

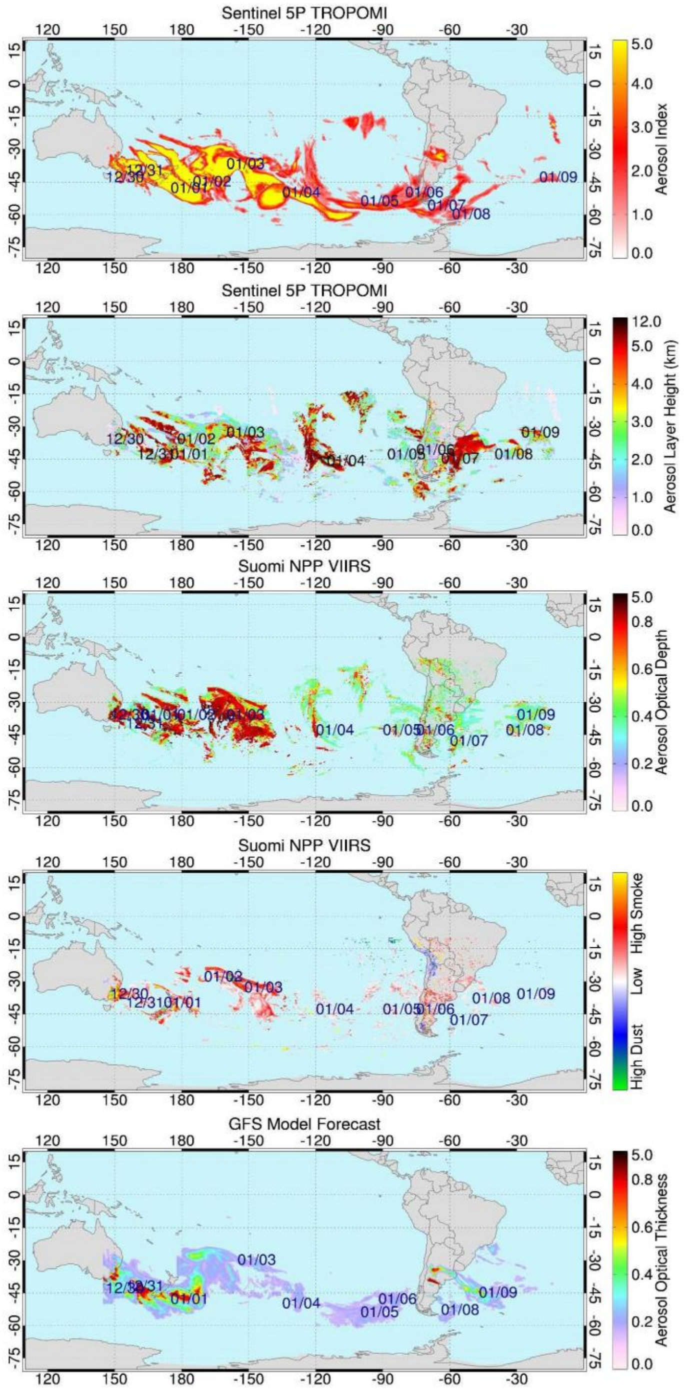




Smoke is brown and thick near fire sources and smoke is grey and thin once aged and away from sources

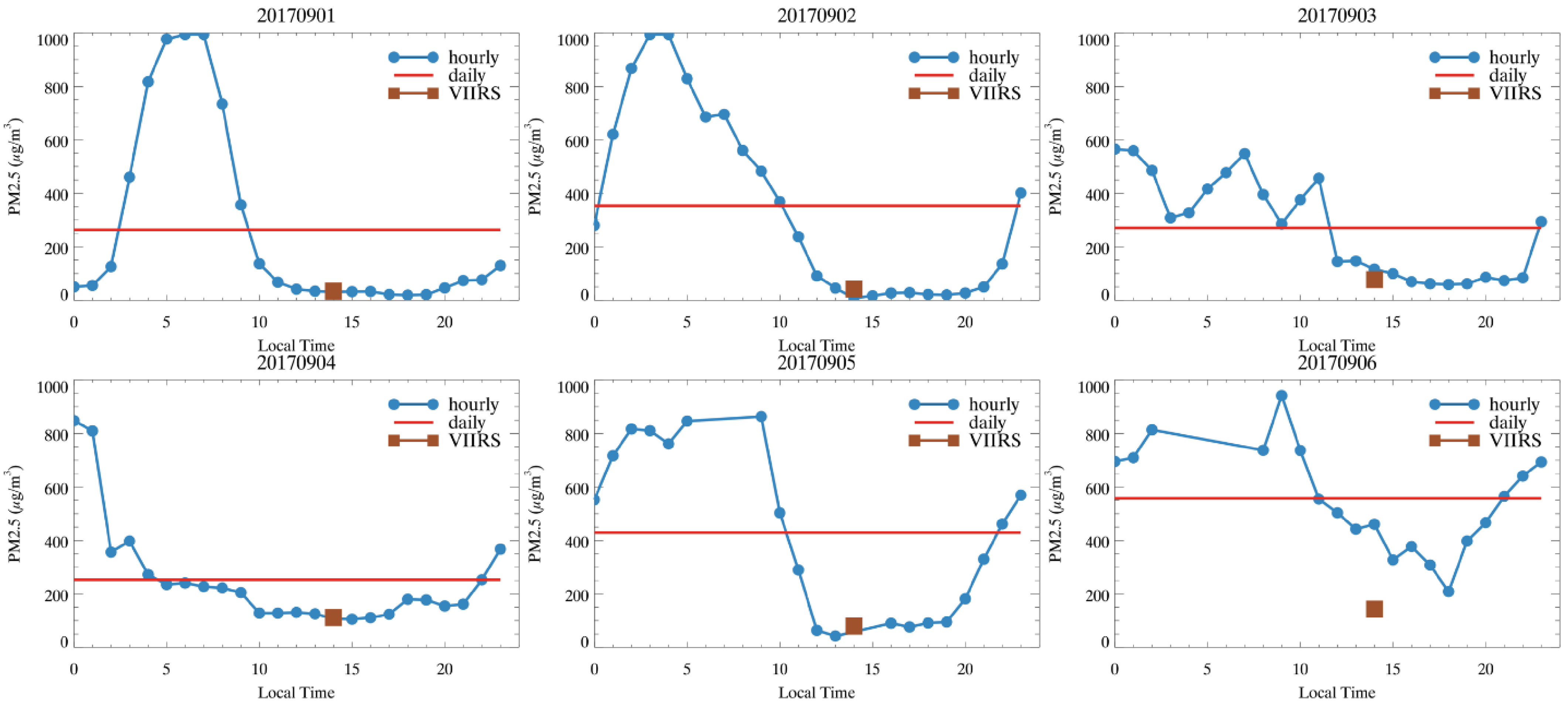
Global Transport of Smoke

- In less than eight days, smoke got transported from Australia to South America
- Smoke moved at altitudes of 10 km to 20 km over the ocean
- Local sources of smoke aerosols mixed in with transported smoke over South America
- UV based products give good coverage as smoke over clouds can be retrieved
- VIIRS aerosol products have gaps due to clouds
- NCEP's aerosol prediction model (GEFS-aerosol) captured the transport but aerosols were scavenged faster than what was observed by satellites



Kondragunta (STAR) and Wei (IMSG)

Scaling AOD to PM2.5 for Air Quality Applications



Zhang (IMSG) and Kondragunta (STAR)

Scales of Environmental hazards/events

- Spatial: Global
  - Polar-orbiting satellite sensors of all kinds needed to understand the phenomena
- Temporal: Sub-hourly
  - Geostationary satellite sensors crucial to capture rapidly changing events

We do not breathe daily-average PM2.5 and air pollution knows no political boundaries.

We, as a community, have to advance the science for applications !!!

Panel

User representatives

- Brad Pierce – University of Wisconsin - Madison
- Ivanka Stajner – National Weather Service
- Edward Hyer – Naval Research Laboratory

Algorithm/Product Developers

- Istvan Laszlo – NESDIS Center for Satellite Applications and Research
- Ralph Khan – NASA Goddard Space Flight Center
- Rob Levy – NASA Goddard Space Flight Center

Agenda for the Aerosols and Air Quality Breakout Session
February 27, 2020
Morning: Room 4552-53 NCWCP
Afternoon: Suite 3250 ESSIC building across the street

Time	Topic	Presenter
8:30 – 10:30 AM	**User Presentations**	
	Satellite aerosol products and regional air quality models	Daniel Tong (ARL)
	Aerosol assimilation in regional and global aerosol models	Mariusz Pagowski (OAI
	Aerosol products and HRRR model	Ravan Ahmadov (OAR)
	Product Developers Presentations	
	VIIRS EPS AOD validation	Hongqing Liu (STAR)
	Bias correction approach for GOES-16 AOD	Hai Zhang (STAR)
	GOES-16 AOD algorithm improvements to address diurnal bias	Mi Zhou (STAR)
	Algorithm to scale AOD to PM2.5	Hai Zhang (STAR)
	Aerosol (smoke and dust) detection	Pubu Ciren (STAR)
	Legacy GOES AOD applications	Shobha Kondragunta (STAR)
	Open Discussion	
	Aerosol product uncertainties	All
	Quality flags	All
	User requests	All
1:00 -3:00 PM	**Open Discussion**	
	Continue Open Discussion	All
	AerosolWatch and JSTAR Mapper tutorial	Amy Huff (STAR)

2020 JPSS/GOES Proving Ground / Risk Reduction (PGRR) Summit

Application Area: Air Quality/Aerosols

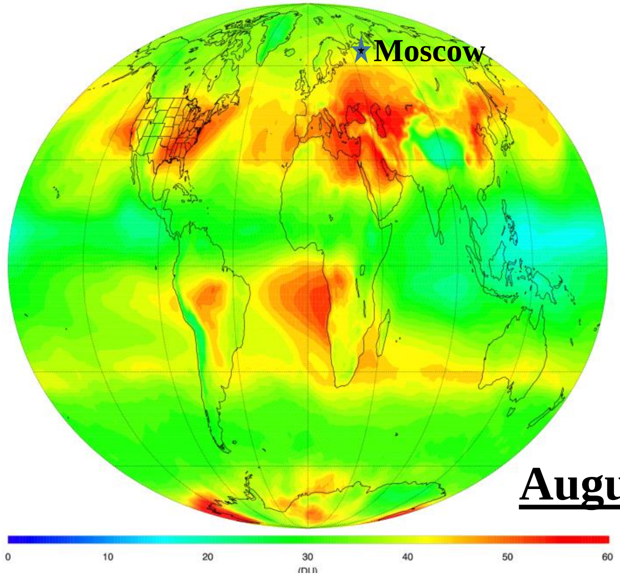
Brad Pierce
UW-Madison
Space Science and Engineering Center (SSEC)

User Perspective:
Global Chemical and Aerosol Data Assimilation and Forecasting

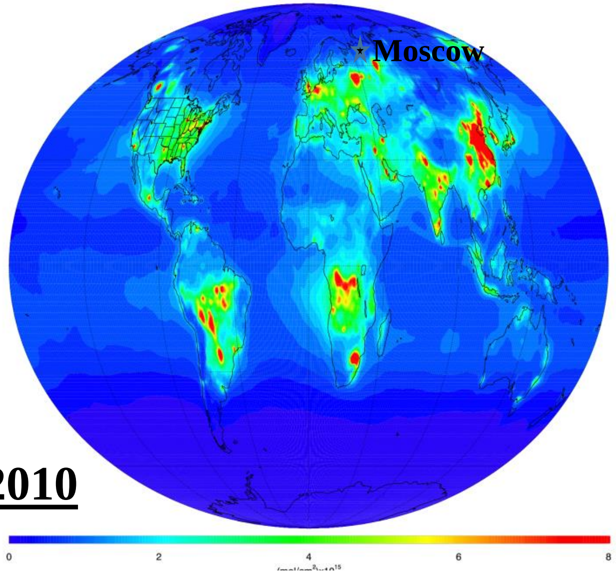
- What I do
- Decision process
- How satellite data are currently being used
- Improved use of satellite data for Air Quality/Aerosols

What I do: Global Chemical Data Assimilation

Tropospheric Ozone (MLS/OMI)

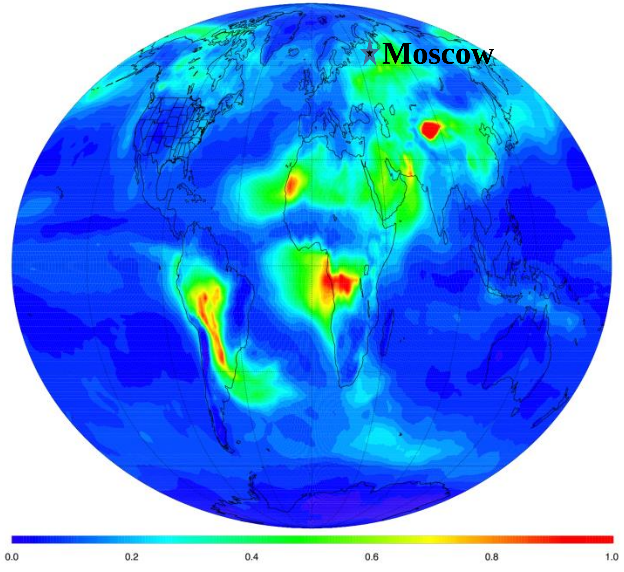


Tropospheric NO2 (OMI)

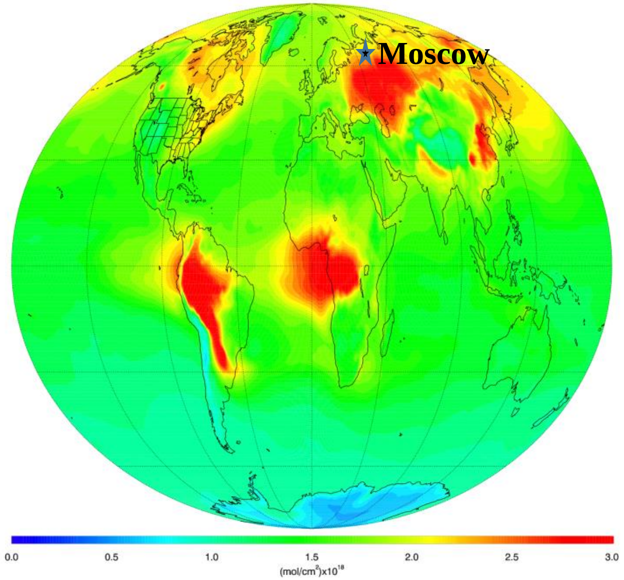


August 2010

Aerosol Optical Depth (MODIS)



Carbon Monoxide (AIRS)



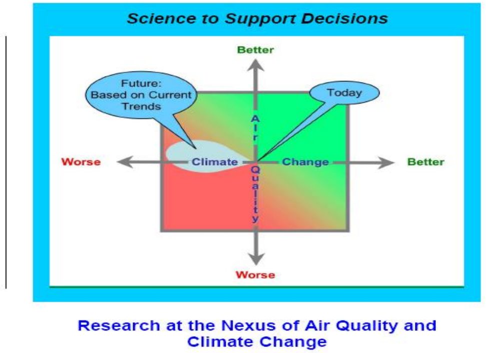
RAQMS Aura Chemical Reanalysis in support Air Quality Applications (NASA Applied Science/Aura Science Team)

Utilize the Real-time Air Quality Modeling System (RAQMS) in conjunction with the NOAA Operational Gridpoint Statistical Interpolation (GSI) 3-dimensional variational data assimilation (DA) system to conduct a multi-year (2006-2016) global chemical and aerosol reanalysis using NASA Aura and A-Train measurements

Russian News: 6.6 times normal for carbon monoxide, and 2.2 times for aerosols on August 7, 2010

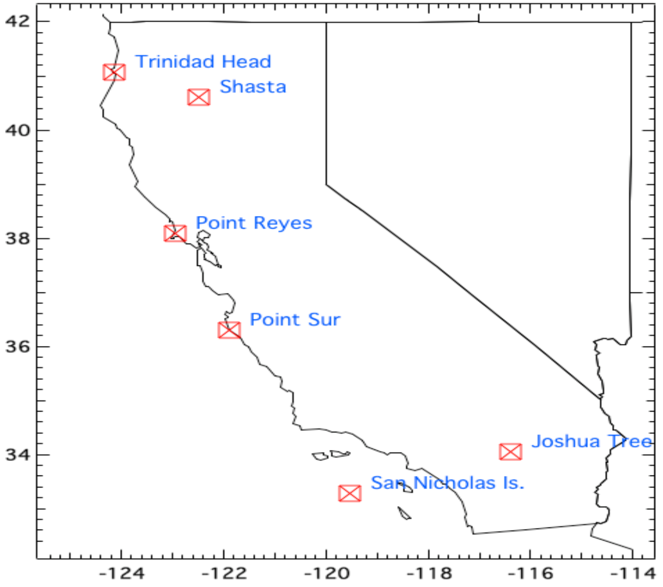
Decision process: Aura Chemical Reanalysis Verification

CalNex-2010 O_3 sondes – Owen Cooper (NOAA ESRL)

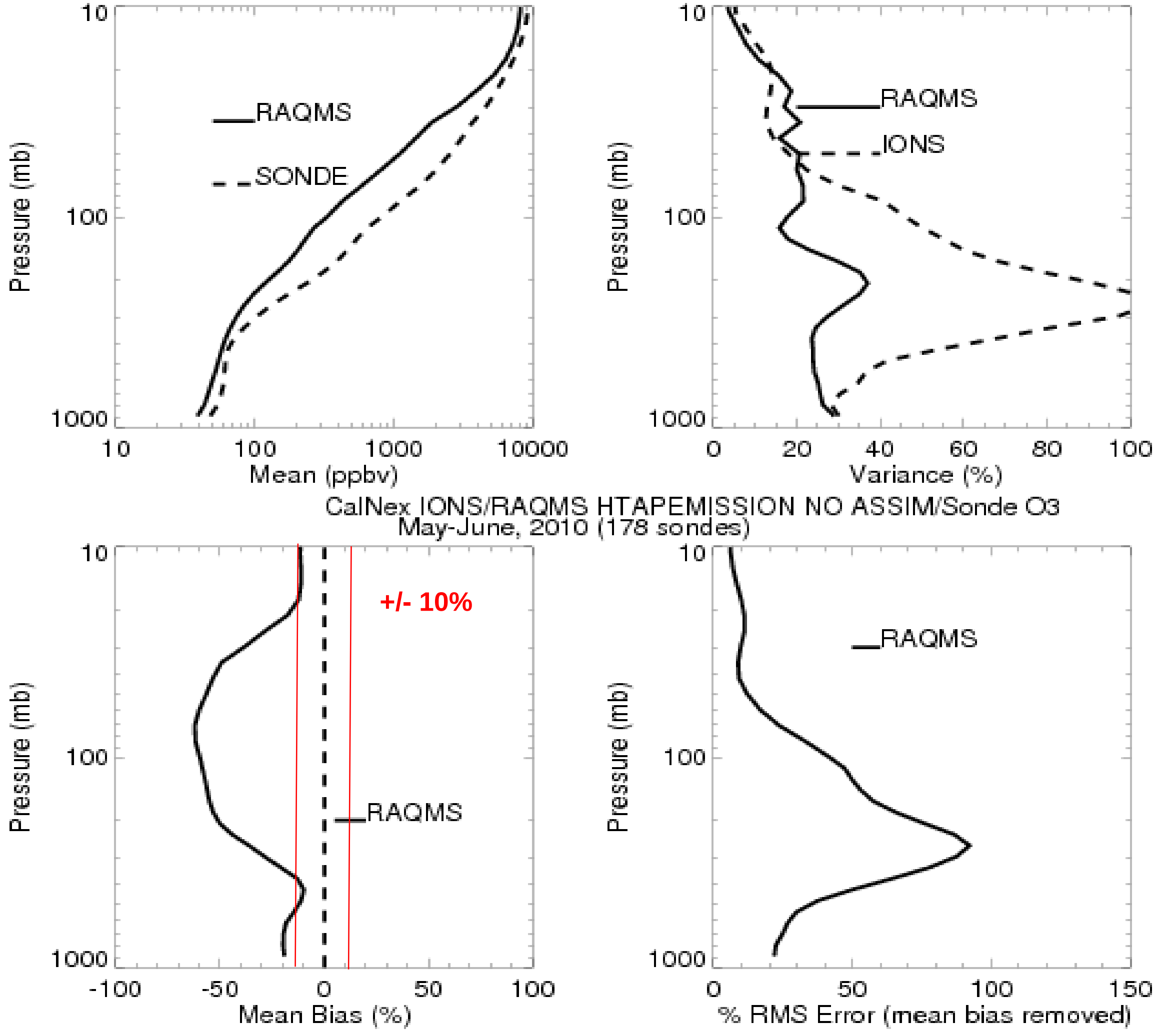


May-June, 2010

CalNex was organized by the California Air Resources Board (CARB) and NOAA to investigate scientific issues at the nexus between air quality and climate change.



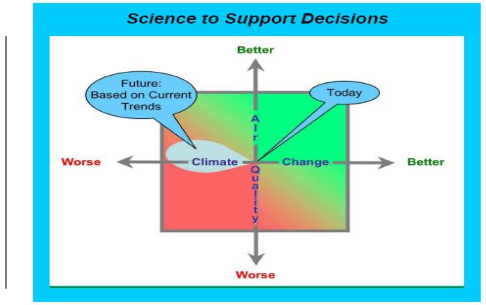
RAQMS baseline (no assimilation) underestimates ozone and ozone variance in the stratosphere and troposphere



CalNex ozonesonde measurements provide an opportunity to assess the impact of **MLS and OMI O3** assimilation on ozone within the Aura Reanalysis along the California coast

Decision process: Aura Chemical Reanalysis Verification

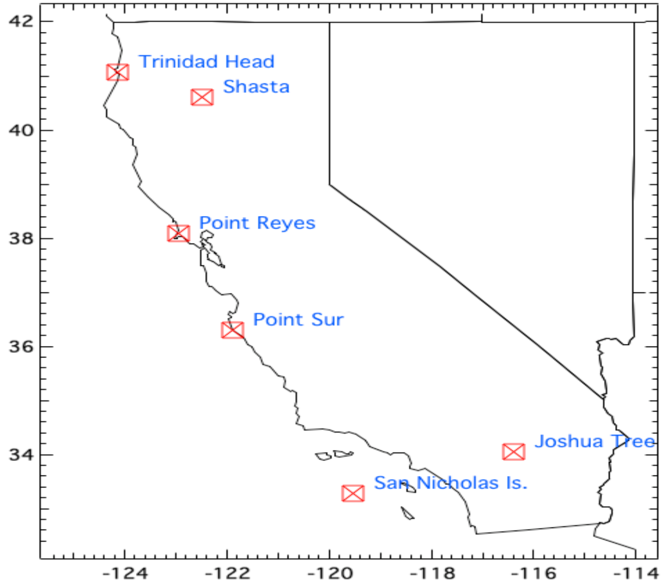
CalNex-2010 O_3 sondes – Owen Cooper (NOAA ESRL)



Research at the Nexus of Air Quality and Climate Change

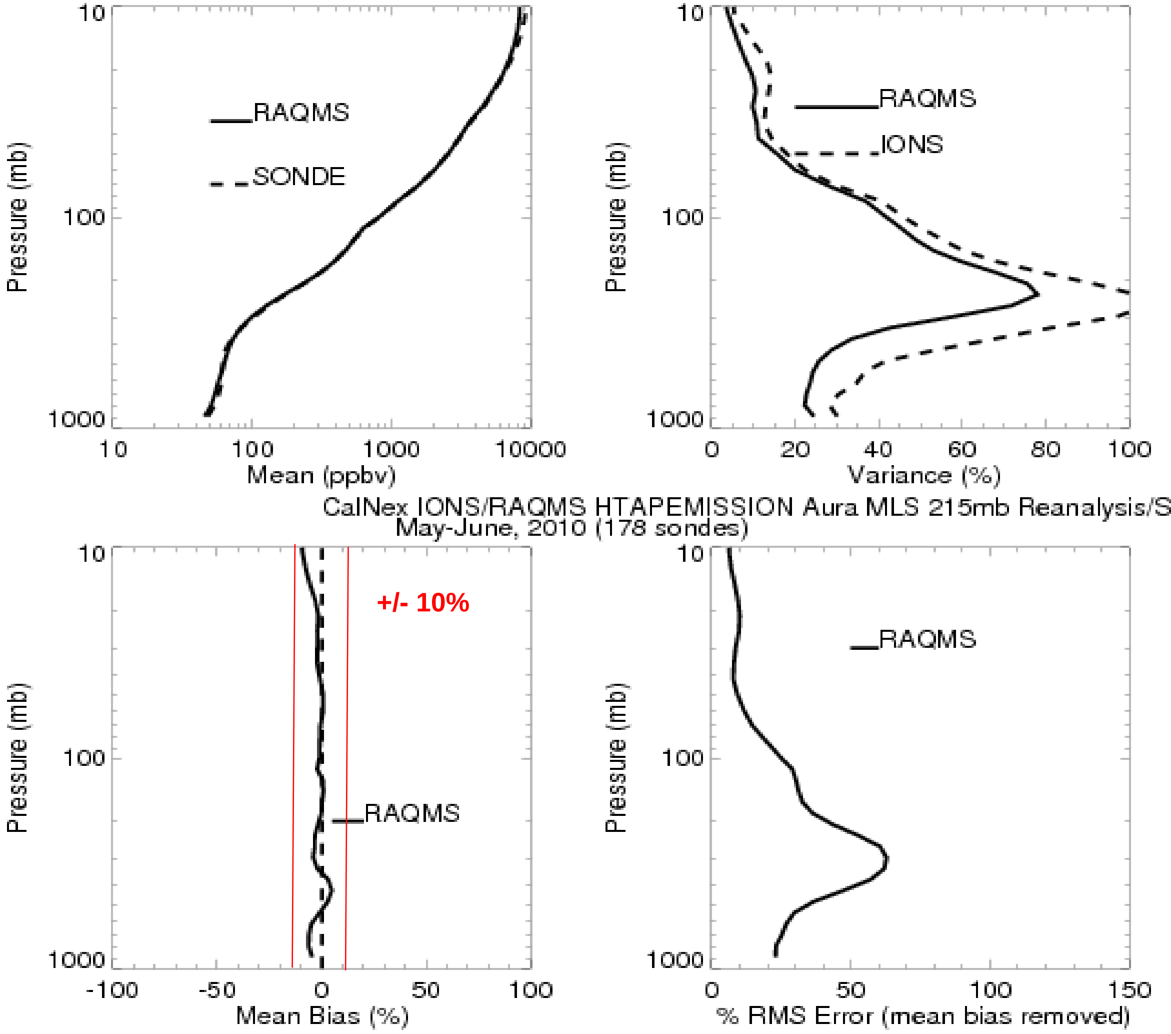
May-June, 2010

CalNex was organized by the California Air Resources Board (CARB) and NOAA to investigate scientific issues at the nexus between air quality and climate change.



RAQMS Aura Reanalysis improves ozone and ozone variance in the stratosphere and troposphere:

Improved estimates of background ozone for Air Quality Forecasting



CalNex ozonesonde measurements provide an opportunity to assess the impact of **MLS and OMI O3** assimilation on ozone within the Aura Reanalysis along the California coast

How satellite data are currently being used: TROPOMI Exploitation

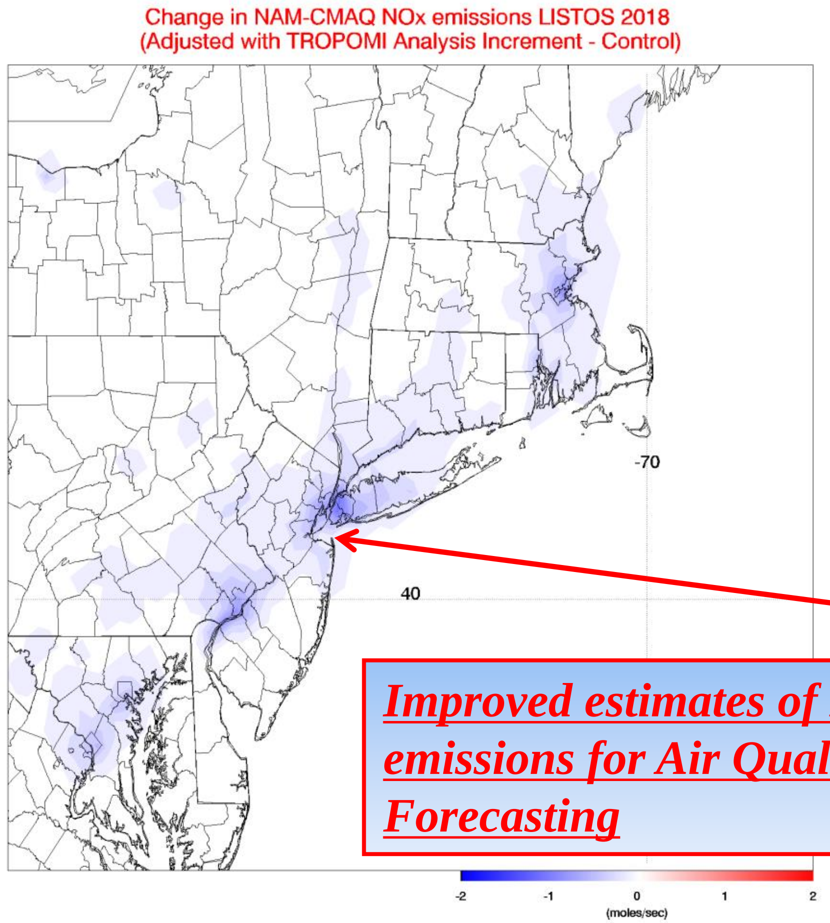
Off-line Constraints on Urban NOx Emissions within NAM-CMAQ using TropOMI Tropospheric NO2 Retrievals

1) Calculate monthly mean NO_2 Jacobian (β) from a 15% NO_X emission reduction perturbation experiment following *Lamsal et al.* 2011

2) Calculate monthly mean NO_2 analysis increment ($\Delta\Omega$) using NAM-CMAQ/GSI TROPOMI NO_2 assimilation
   a. NOx emission sensitive background errors (to correct NAM-CMAQ emissions)

3) Adjust NAM-CMAQ NO_x emissions using Jacobian and average analysis increment
   a) Only adjust daytime emissions since TROPOMI does not provide night time constraints

Assimilation of TropOMI NO2 results in (~20%) reductions in NOx emissions over NYC during July-August 2018



$$\frac{\Delta E}{E} = \beta \times \frac{\Delta\Omega}{\Omega}.$$

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta\Omega}{\Omega}$$

$$\frac{\Delta E}{E} = \beta \times \frac{\Delta\Omega}{\Omega}.$$

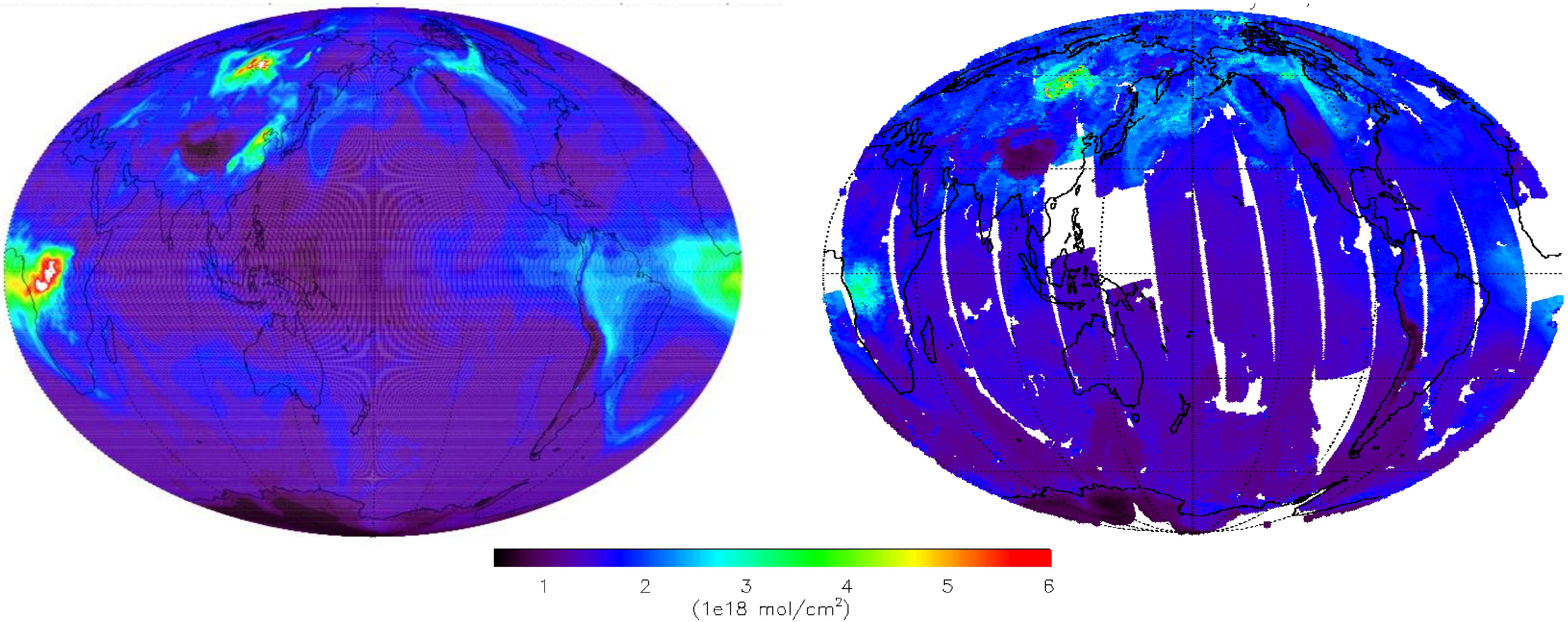
Improved estimates of NOx emissions for Air Quality Forecasting

Supported by FY18 NOAA/NESDIS Office of Projects, Planning and Analysis (OPPA) Technology Maturation Program (TMP) Funding

Improved use of satellite data for Air Quality/Aerosols: Unified Forecasting System Atmospheric Composition Model (UFSACM) data assimilation

We have implemented RAQMS unified stratosphere/troposphere chemical mechanism into an experimental version of the UFSACM as part of the UFS Aerosol and Atmospheric Composition (AAC) working group.

UFSACM-RAQMS Column CO July 22, 2019 **JPSS NUCAPS Column CO July 22, 2019 (PM orbits)**

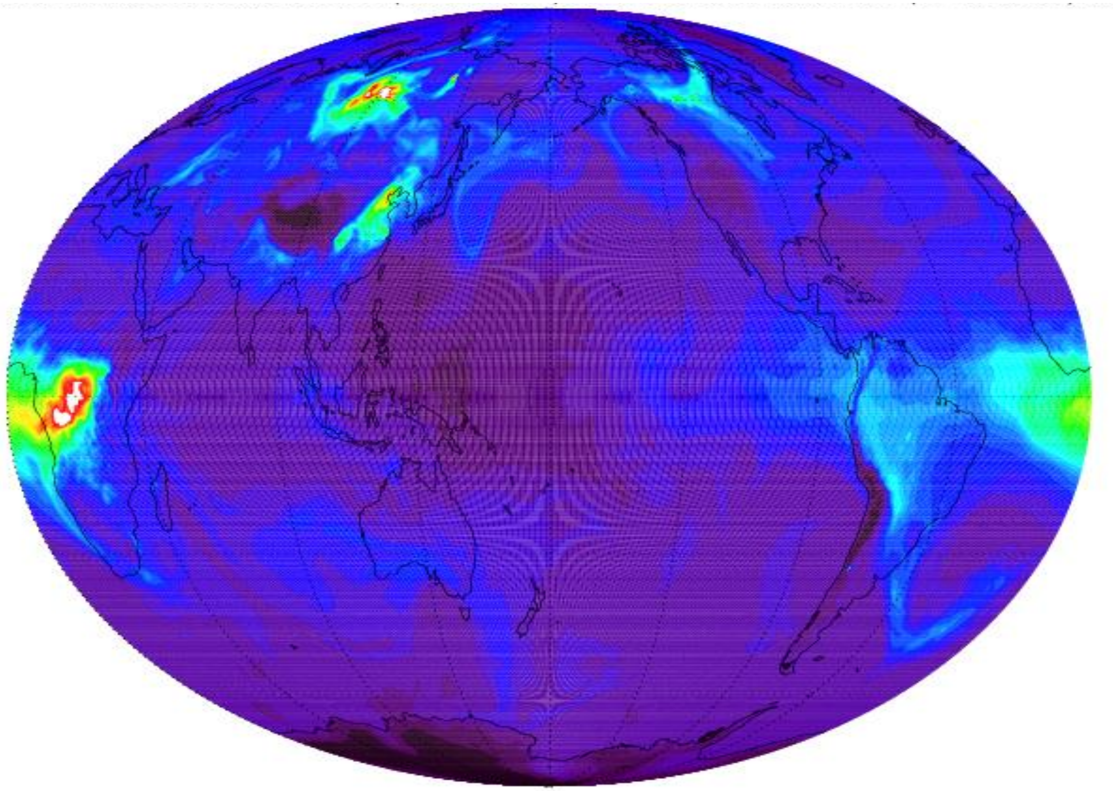


Supported by FY17 NOAA OAR Research Transition Acceleration Program (RTAP) Funding

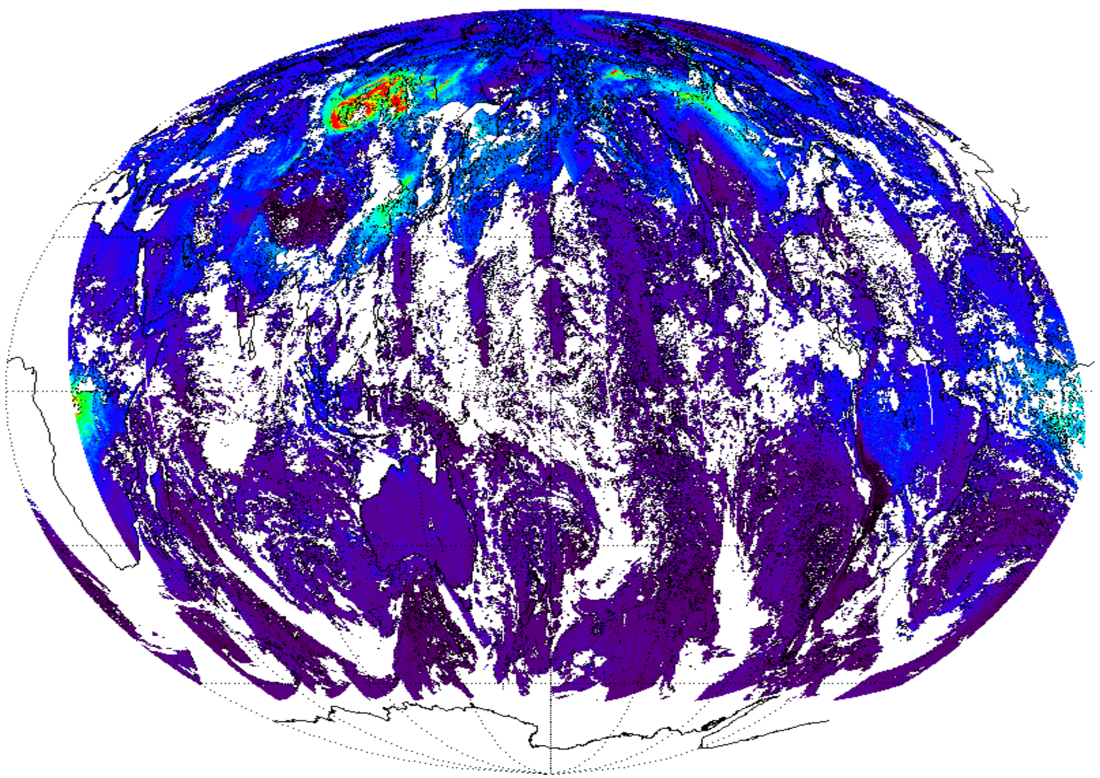
Improved use of satellite data for Air Quality/Aerosols: Unified Forecasting System Atmospheric Composition Model (UFSACM) data assimilation

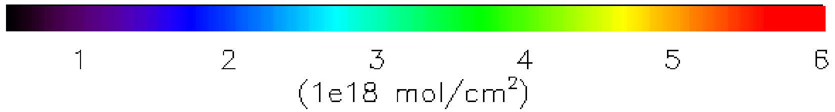
Assimilation of TROPOMI (reflected solar, total column) and JPSS NUCAPS (thermal emission, mid-troposphere) CO into the UFSACM to constrain boundary layer CO

UFSACM-RAQMS Column CO July 22, 2019



TROPOMI Column CO July 22, 2019 (PM orbits)





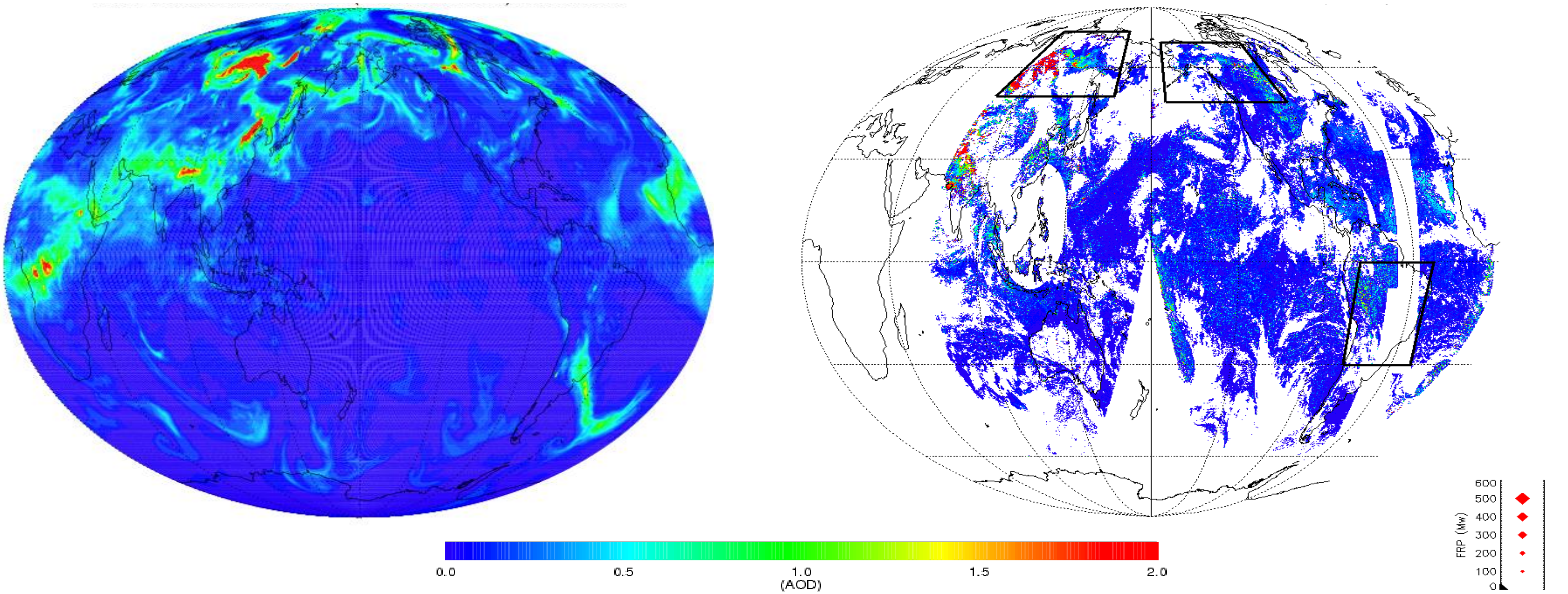
Supported by FY19 NOAA/NESDIS Office of Projects, Planning and Analysis (OPPA) Technology Maturation Program (TMP) Funding

Improved use of satellite data for Air Quality/Aerosols: Unified Forecasting System Atmospheric Composition Model (UFSACM) data assimilation

Assimilation of ABI and AHI aerosol optical depth (AOD) into the UFSACM to constrain diurnal aerosol loading

UFSACM-GOCART AOD July 22, 2019

ABI (GOES-16&17) and AHI AOD July 22, 2019 (PM orbits)

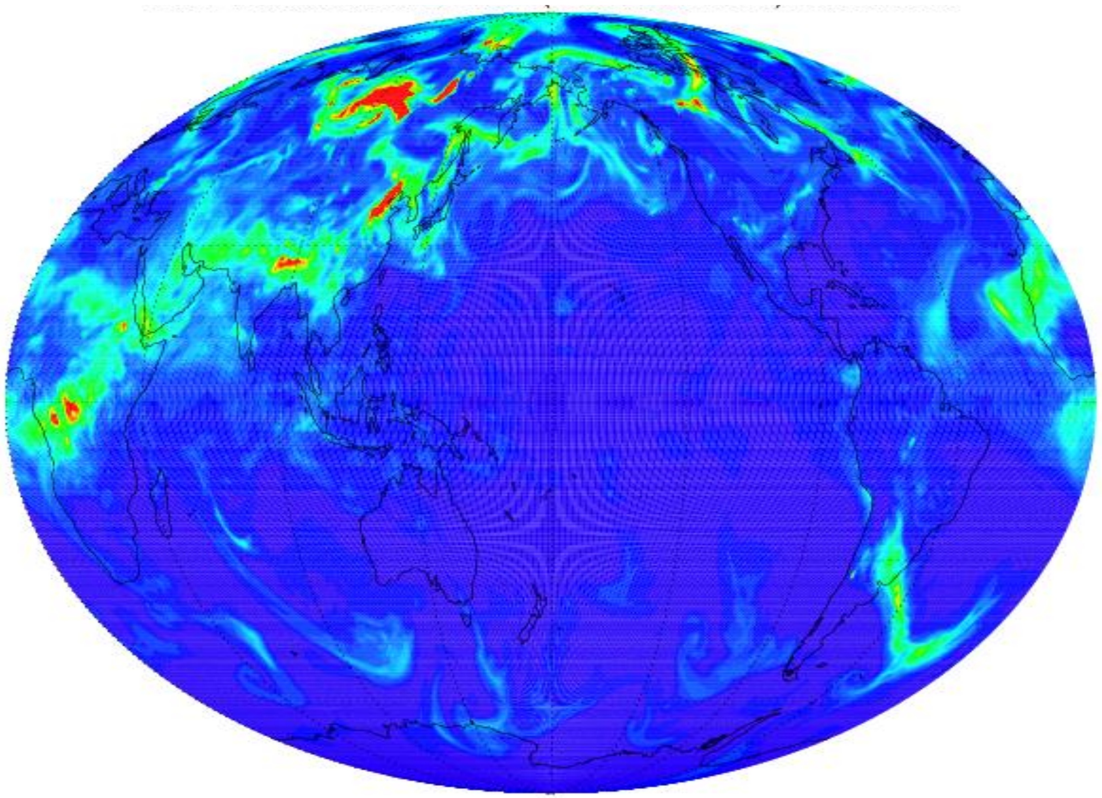


Submitted to the FY19 NASA ROSES A.33 Research from Geostationary Satellites Solicitation

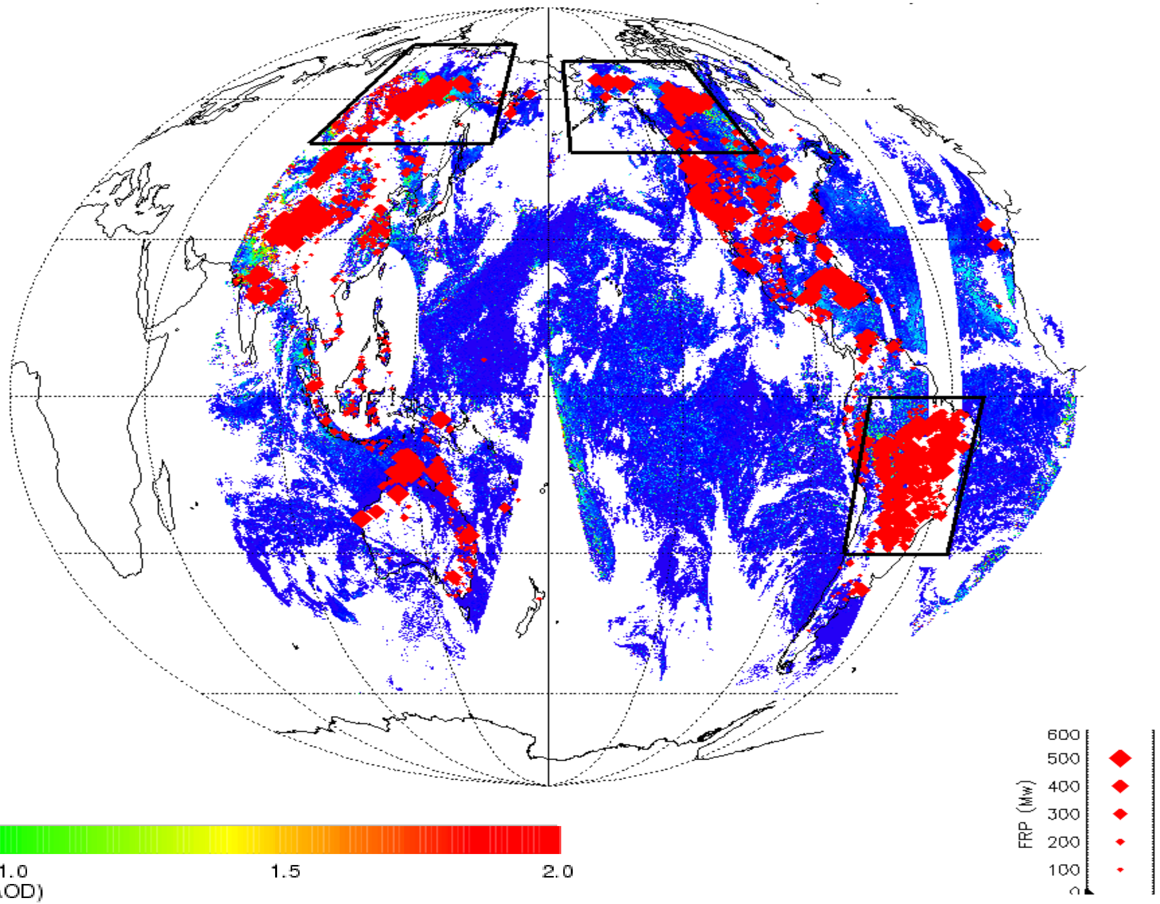
Improved use of satellite data for Air Quality/Aerosols: Unified Forecasting System Atmospheric Composition Model (UFSACM) data assimilation

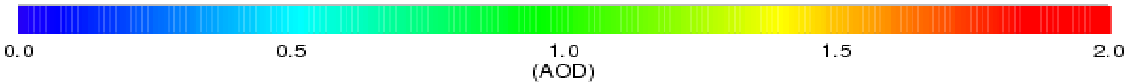
Incorporation of ABI and AHI WF-ABBA Fire Radiative Power (FRP) into the UFSACM to constrain diurnal wildfire emissions

UFSACM-GOCART AOD July 22, 2019



ABI (GOES-16&17) and AHI AOD/FRP July 22, 2019





Submitted to the FY19 NASA ROSES A.33 Research from Geostationary Satellites Solicitation

Improved use of satellite data for Air Quality/Aerosols: Unified Forecasting System Atmospheric Composition Model (UFSACM) data assimilation

UFSACM C196 (0.5^{o}) Wall-clock comparisons: 48hr FX August-September 2019
(10 ivy nodes each with 20 processors on S4)

GOCART	GOCART/RAQMS
28 tracers	87 tracers
32 minutes	111 minutes

User Needs:

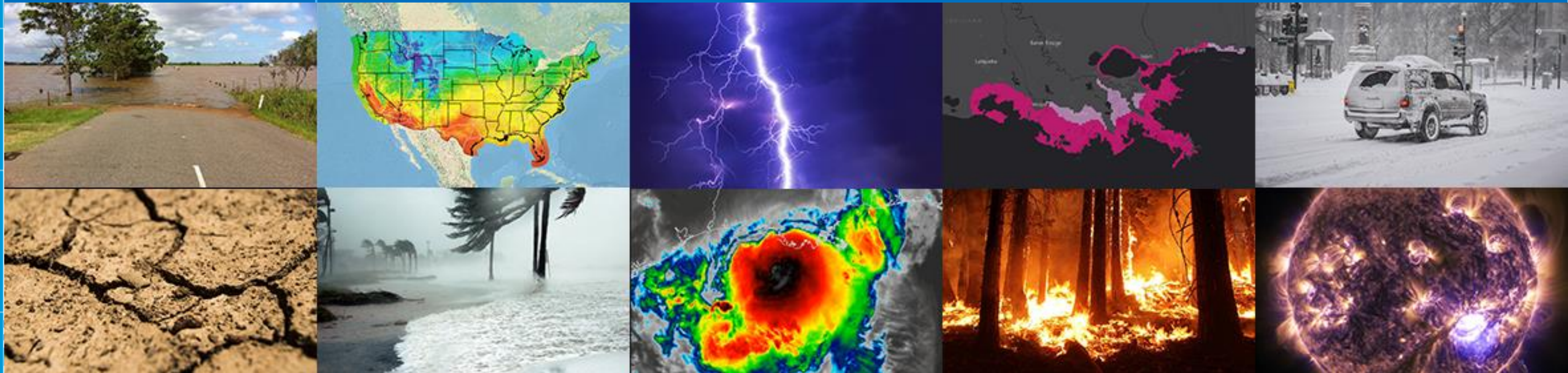
- Chemical data assimilation:
  - Need to predict both stratospheric and tropospheric chemistry to utilize satellite trace gas retrievals (***true for S2S as well***)
  - Need averaging kernels and apriori information to assimilate NUCAPS retrievals
  - (***available in science code***)
- Aerosol Data Assimilation:
  - Need common AOD algorithms for both ABI and AHI
  - Need common fire detection retrievals for ABI and AHI
  - Need terrain corrected WF-ABBA fire detection for high resolution wildfire emission inventories

Air quality and aerosol predictions at NOAA/National Weather Service

NATIONAL WEATHER SERVICE

February 25, 2020

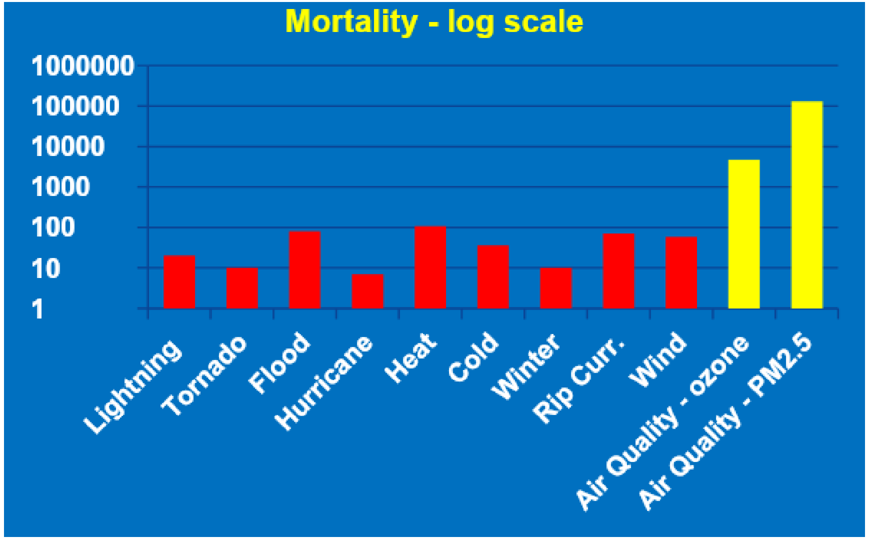
Ivanka Stajner (Deputy Director, NOAA/NWS/NCEP/EMC)
and
NOAA's Regional Air Quality and Global Aerosol Prediction Team

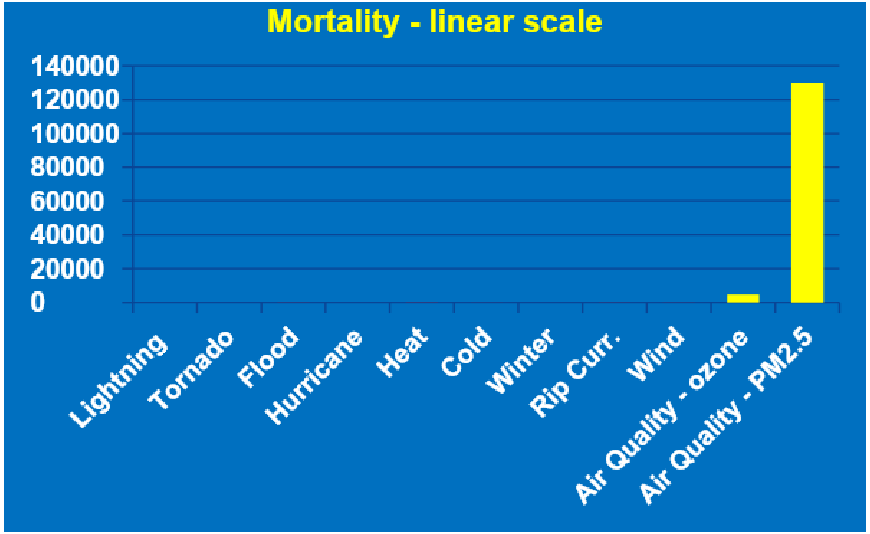


Outline

- Why does air quality prediction matter?
- Partnership for air quality forecasting
- Regional air quality prediction
- Global aerosol prediction
- Summary and challenges

Societal Impacts of Weather and Air Quality





Red: Weather fatalities for 2018 (source: https://www.weather.gov/hazstat/)

same data - linear scale

Yellow: Air Quality mortality for 2005 (source: Fann et al., Risk Analysis, 2012 https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1539-6924.2011.01630.x)

In the United States, annual mortality from poor air quality (over 100,000) substantially exceeds mortality from all other weather phenomena (530).

Customers

The main customers for NWS air quality (AQ) forecast guidance are **state and local environmental agencies** who issue official AQ forecasts for their respective areas.

These official AQ forecasts are disseminated to the public through various outside channels including AirNow.gov web site, media, mobile applications and through NWS Weather Forecast Offices (WFOs).

Additionally, NWS AQ forecast guidance is distributed directly to the **general public** on maps at https://airquality.weather.gov/,

in grib files, and as a web service at

https://idpgis.ncep.noaa.gov/arcgis/rest/services/NWS_Forecasts_Guidance_Warnings

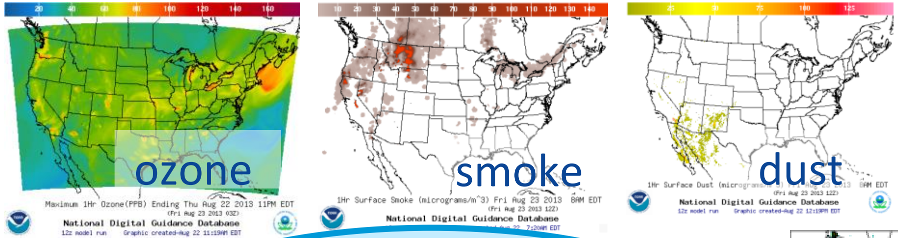
The web service is used by **partner agencies**:

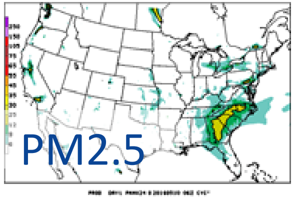
- the Centers for Disease Control (**CDC**) for vulnerability assessment
- the Environmental Protection Agency (**EPA**) in their Smoke Sense mobile application.

Air Quality Forecasting Partnership

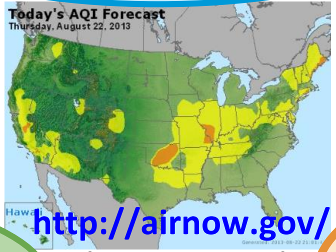
- Exposure to fine particulate matter and ozone pollution leads to premature deaths of over 100,000 annually in the US *(Fann, 2011, Risk Analysis)*
- Air quality forecasting in the US relies on a partnership among NOAA, EPA, state and local agencies
- NOAA air quality forecasting team includes NWS, OAR and NESDIS

http://airquality.weather.gov/

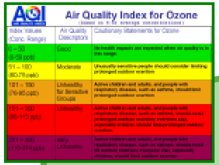




NOAA
integrate, evaluate and improve models; provide operational AQ predictions



http://airnow.gov/



EPA
maintain national emissions, monitoring data, develop AQ models; disseminate/interpret AQ forecasts

State and local agencies
provide monitoring data & emissions; provide AQI forecasts

National Air Quality Forecast Capability

Operational predictions at http://airquality.weather.gov

over expanding domains since 2004

Ozone and PM2.5

Linked numerical prediction system

Operationally integrated on NCEP's supercomputer

- NOAA/EPA Community Multiscale Air Quality (CMAQ) model
- NOAA/NCEP North American Mesoscale Forecast System (NAM) weather prediction

Observational Input:

- EPA emissions inventory, AirNow for bias correction
- NESDIS fire locations

Gridded forecast guidance products 2x daily nationwide

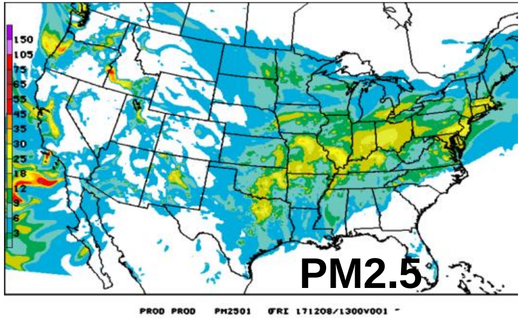
- At airquality.weather.gov and ftp-servers (12km resolution, hourly for 48 hours).
- On EPA servers

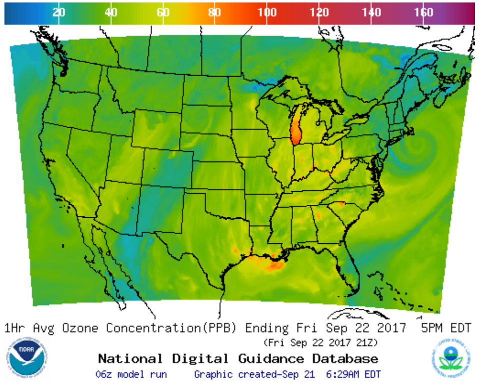
Verification, near-real time:

- Ground-level AirNow observations of surface ozone and PM2.5

Customer outreach/feedback

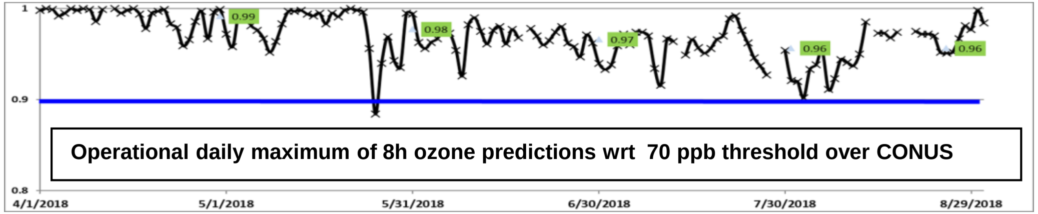
- State & Local AQ forecasters coordinated with EPA
- Public and Private Sector AQ constituents





Ozone

Operational ozone CONUS, wrt 70 ppb Threshold



Maintaining prediction accuracy for lowered warning threshold and under changing pollutant emissions

National Air Quality Forecast Capability

Smoke and dust

Emission sources

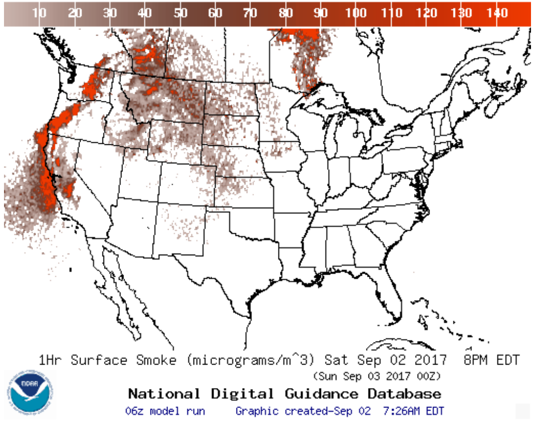
- **Smoke: NESDIS detects wildfire locations from satellite imagery. Emissions estimated by USFS BlueSky system.**
- **Dust: Source regions with emission potential are from MODIS deep blue climatology for 2003-2006. Emissions are modulated by wind and soil moisture.**

HYSPLIT model with NAM meteorology for transport, dispersion and deposition

- **Smoke: daily, nationwide**
- **Dust: 2x per day, CONUS**

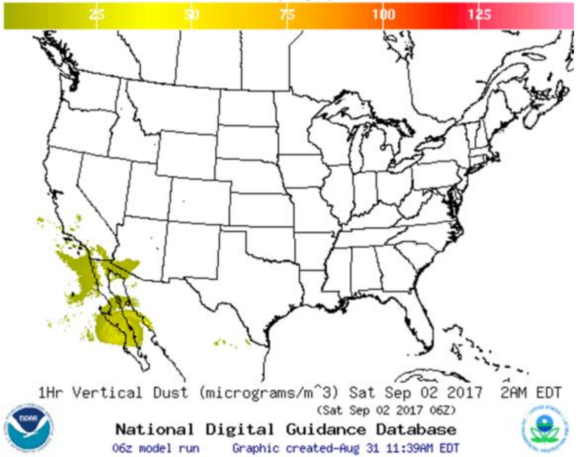
Satellite products developed for verification

Operational predictions at http://airquality.weather.gov



Smoke

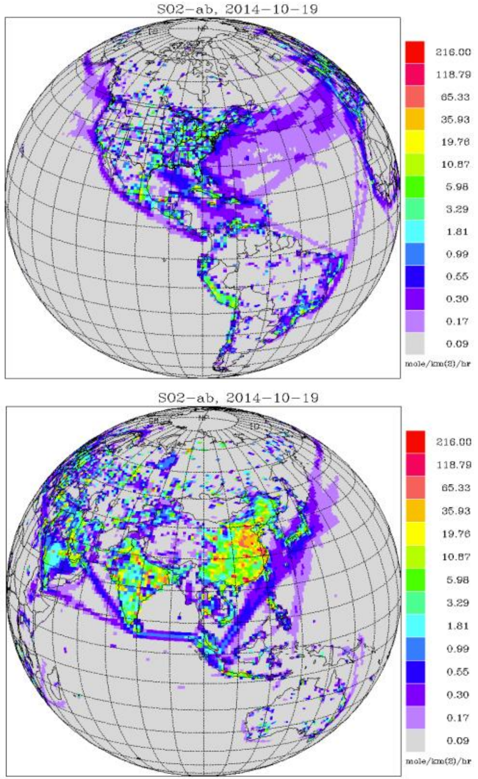
Dust



Satellite data use:
- Emissions
- Verification

HRRR smoke is planned to transition to operations this year.

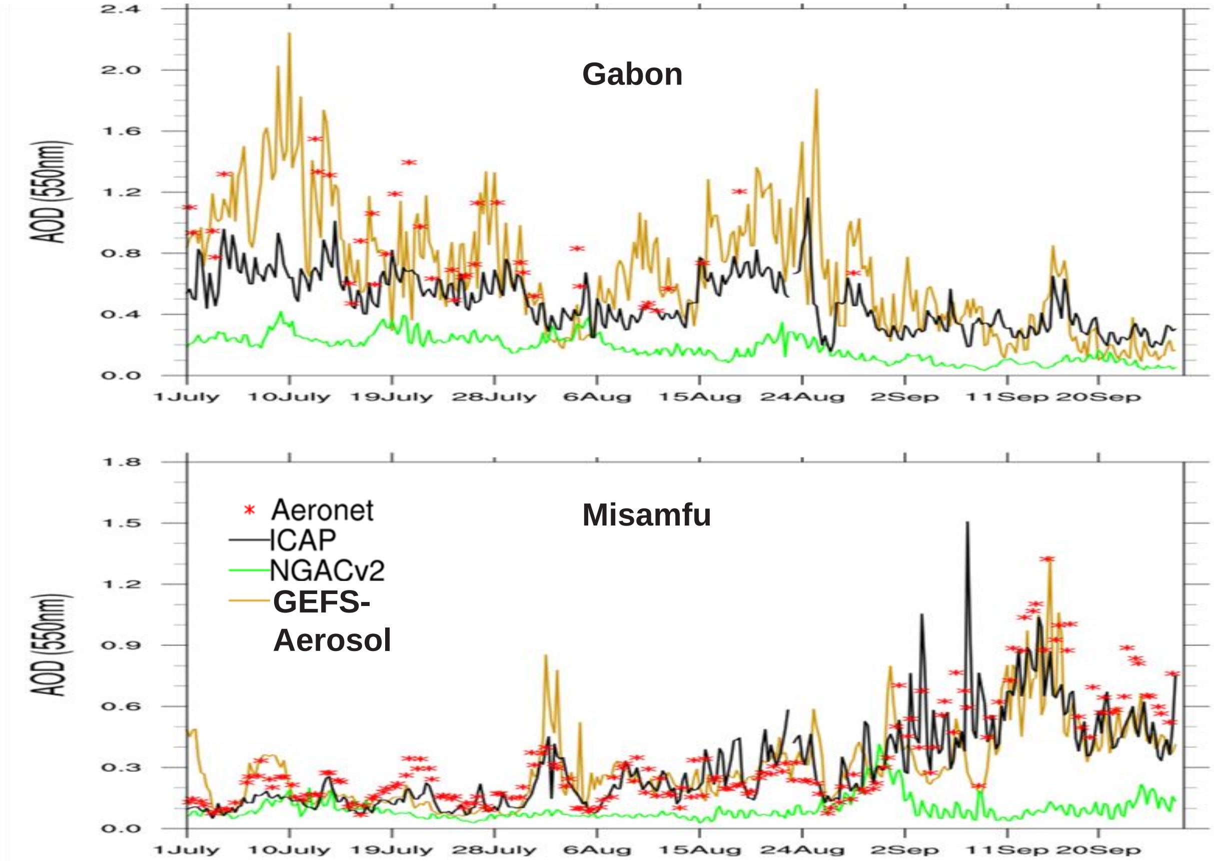
GEFS-Aerosol member



CEDS-2014 SO2 emissions

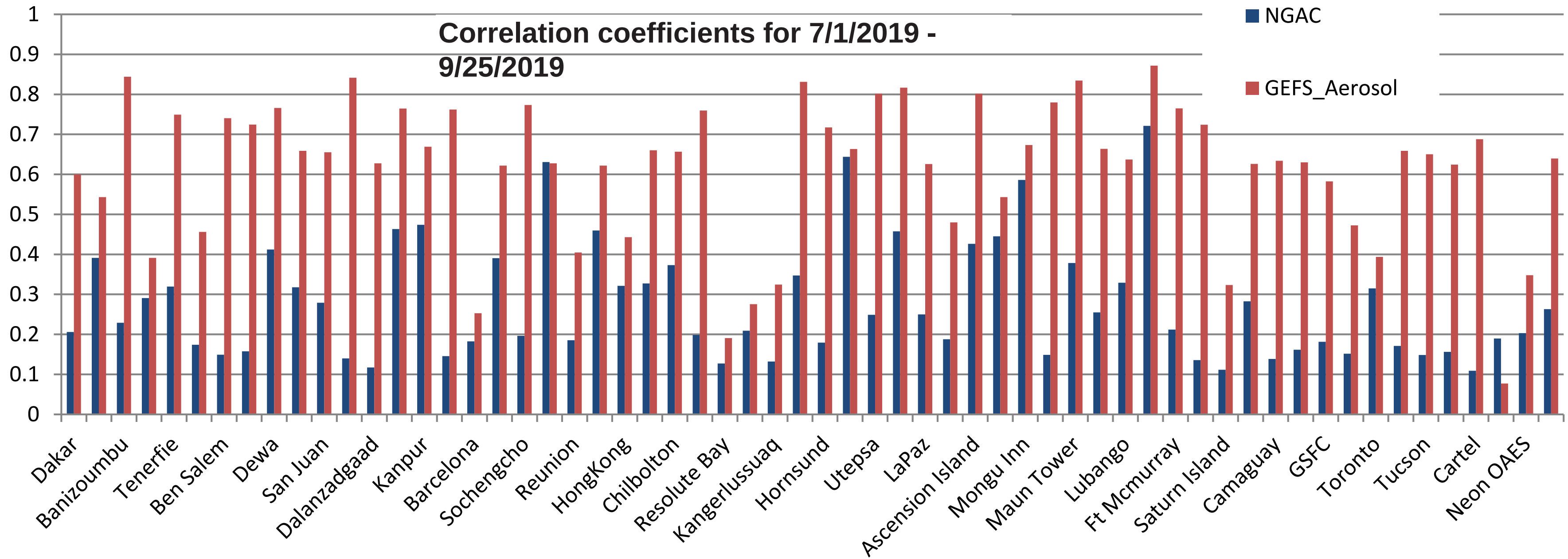
- Plans to replace operational NGACv2
- GEFS meteorology (based on GFSv15) at C384 (~25 km), 64 levels, to 120 hrs, 4x/day
- Inline aerosol representation based on GOCART
- Sulfate, Organic Carbon, Black Carbon, Dust, Sea Salt
- **Emissions**: CEDS-2014 (SO_2, PSO_4, POC, PEC), GBBEPx biomass burning, FENGSHA dust, GEOS-5 sea salt, marine DMS
- Initial conditions: cycled for aerosols, but from GFSv15 analysis for meteorology
- Smoke plume rise: Wind shear dependent 1-d cloud model to simulate tilt of plume. Fire Radiative Power is used to calculate convective heat flux and determine injection height
- Tracer transport and wet scavenging are included in Simplified Arakawa-Schubert (SAS) scheme. Fluxes are calculated positive definite. Scavenging coefficient is α=0.2 for all aerosol species.

AERONET comparisons



Comparison against AERONET AOD in Africa. GEFS-Aerosol tracks observed total AOD magnitude and variability much better than NGAC in western (Gabon) and eastern (Misamfu) Africa.

Correlations with AERONET



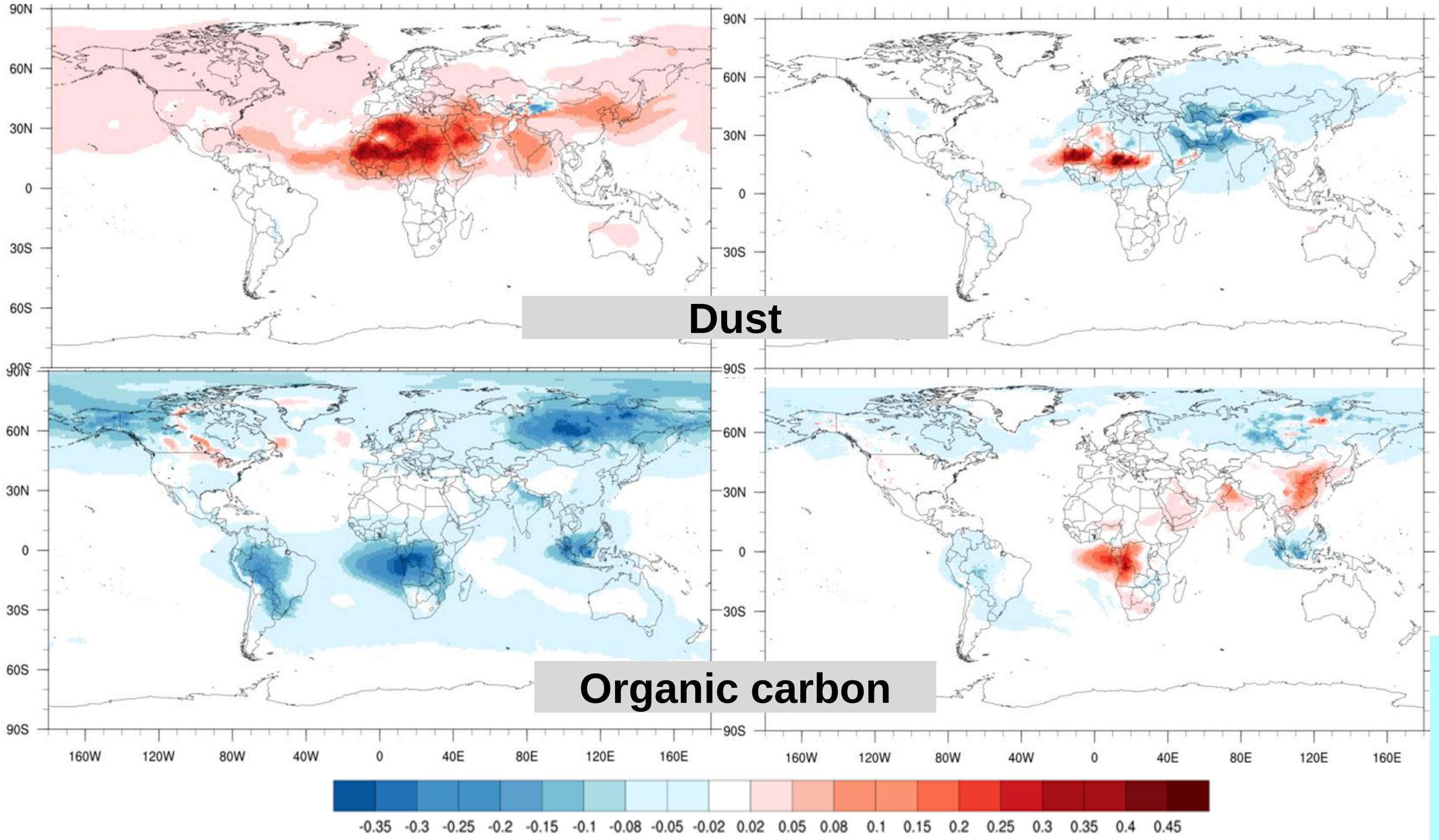
Correlations with AERONET AOD are higher for GEFS-Aerosols (red) than for NGAC (blue): 0.61 vs 0.27 on average.

NGAC day 1 prediction – GEOS-5 analysis

550 nm AOD, 7/5/19-10/31/19

GEFS-Aerosol day 1 prediction – GEOS-5 analysis

550 nm AOD , 7/5/19-10/31/19



Biases with respect to GEOS-5 analyses (which assimilate satellite AOD) are smaller for GEFS-Aerosols (right) than those for NGAC (left) for dust, organic carbon and sulfate aerosols (not shown).

Satellite AOD data are also used for verification

Summary, plans and challenges

Summary:

- NWS provides national ozone, PM2.5, smoke, dust predictions. Partnership to provide AQ forecasts
- NWS is testing global GEFS-Aerosol. It shows great improvements - plans to implement this year.
- Satellite data used mostly for emissions and verification of predictions.

Plans:

- Assimilation of satellite AOD into GEFS-Aerosol - testing has begun
- Assimilation of satellite AOD and NO_2 data into CMAQ coupled with a high resolution weather model

Selected challenges:

- **Emissions** (specification & prediction of biomass burning & dust emissions; timely updates of anthropogenic emissions)
- **Data Assimilation** (integral quantities observed – AOD is integral over all aerosol species and vertically; loss of satellite instrument sensitivity for gaseous composition in PBL; observation biases and QC)
- Process representation (e.g. PBL, complex terrain and coastal areas)
- Chemical mechanisms, e.g. SOA
- Computational resources
- Representation of long-range transport - chemical boundary conditions for regional prediction

Motivation – Navy Requirements for EO/Aerosol Research

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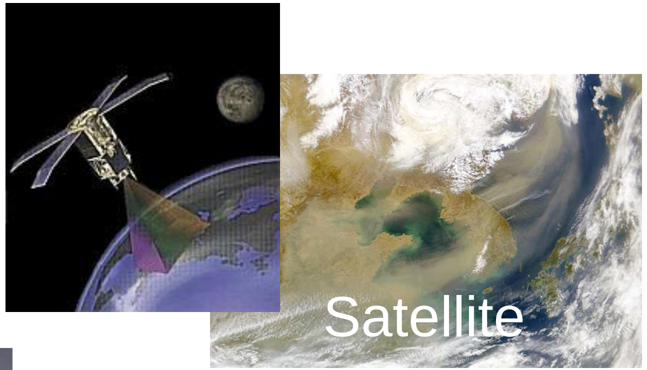
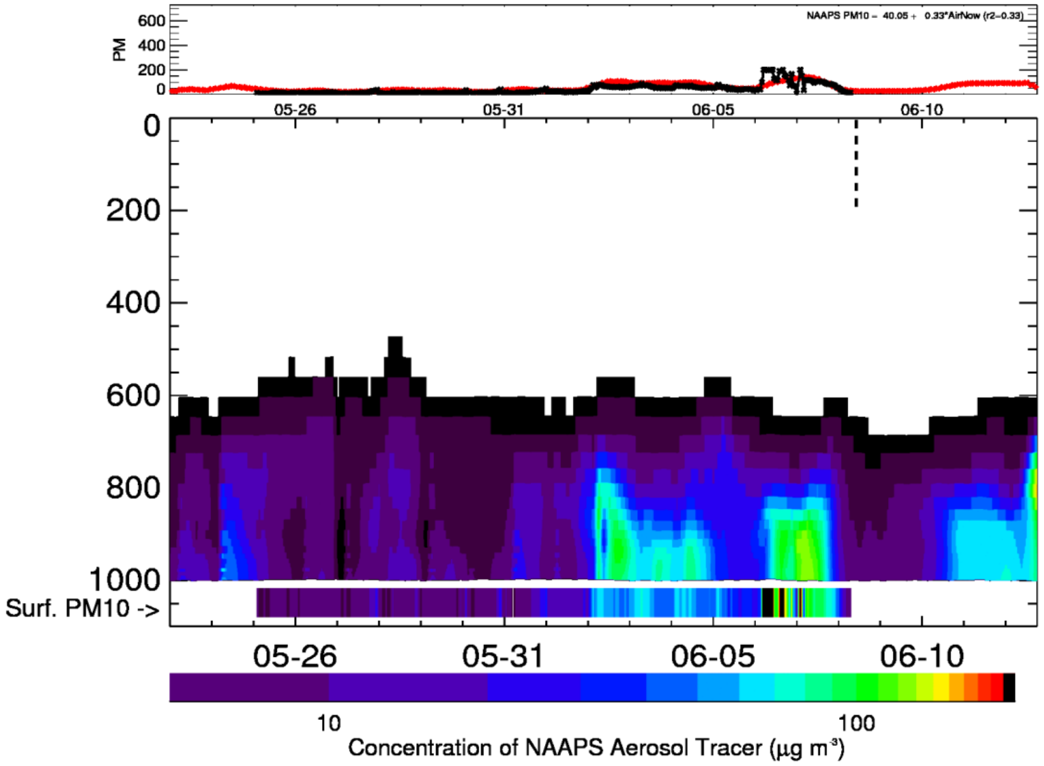
- Atmospheric environment (aerosols, clouds) can have a significant impact on visibility and EO conditions:
  - Passive sensors: Visibility for operations; EO/IR sensors, satellite sensors
  - Active sensors: Directed energy; laser communications; laser radar; precision guided munitions illumination



Goal: Measure, model, and predict the impact of the environment on naval operations, and EO/IR sensors and weapon systems

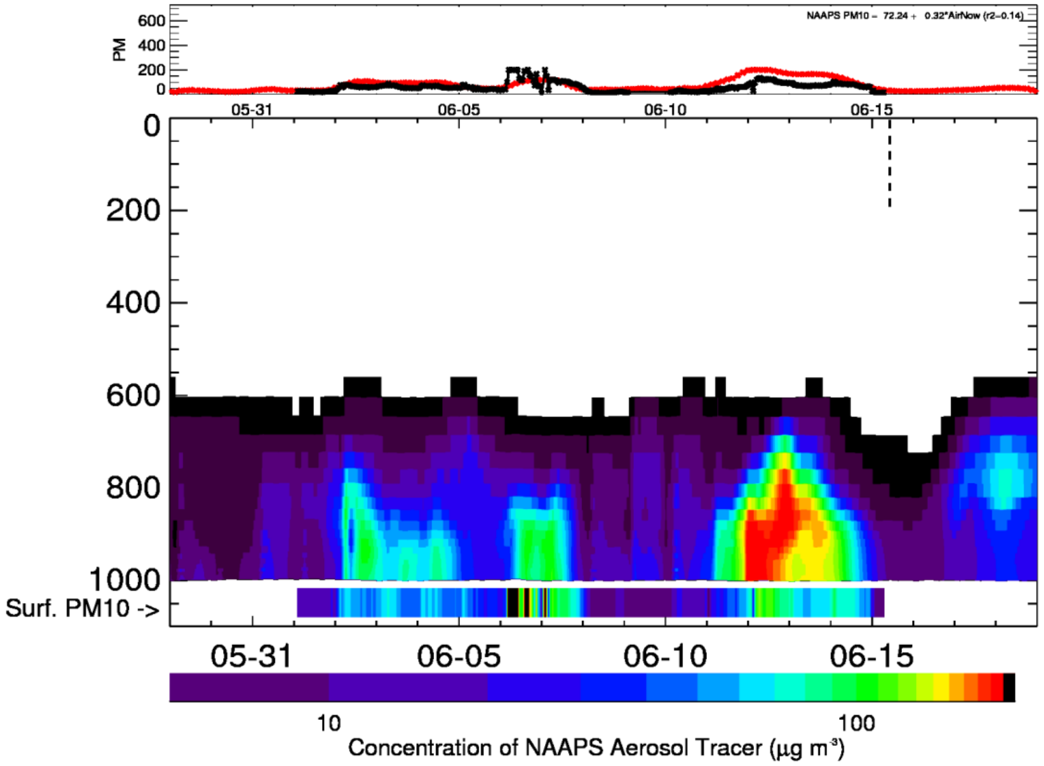
Predicting Large PM Events: Puerto Rico June 2018

- Black Line / Stripe at bottom: EPA AirNow PM2.5, Cataño, Puerto Rico
- Red Line / Curtain: Navy Aerosol Analysis and Prediction System
- Large surface PM event 6/1-6/8 captured in the model
- Model Predicts high PM on 6/12
- How'd the model do?



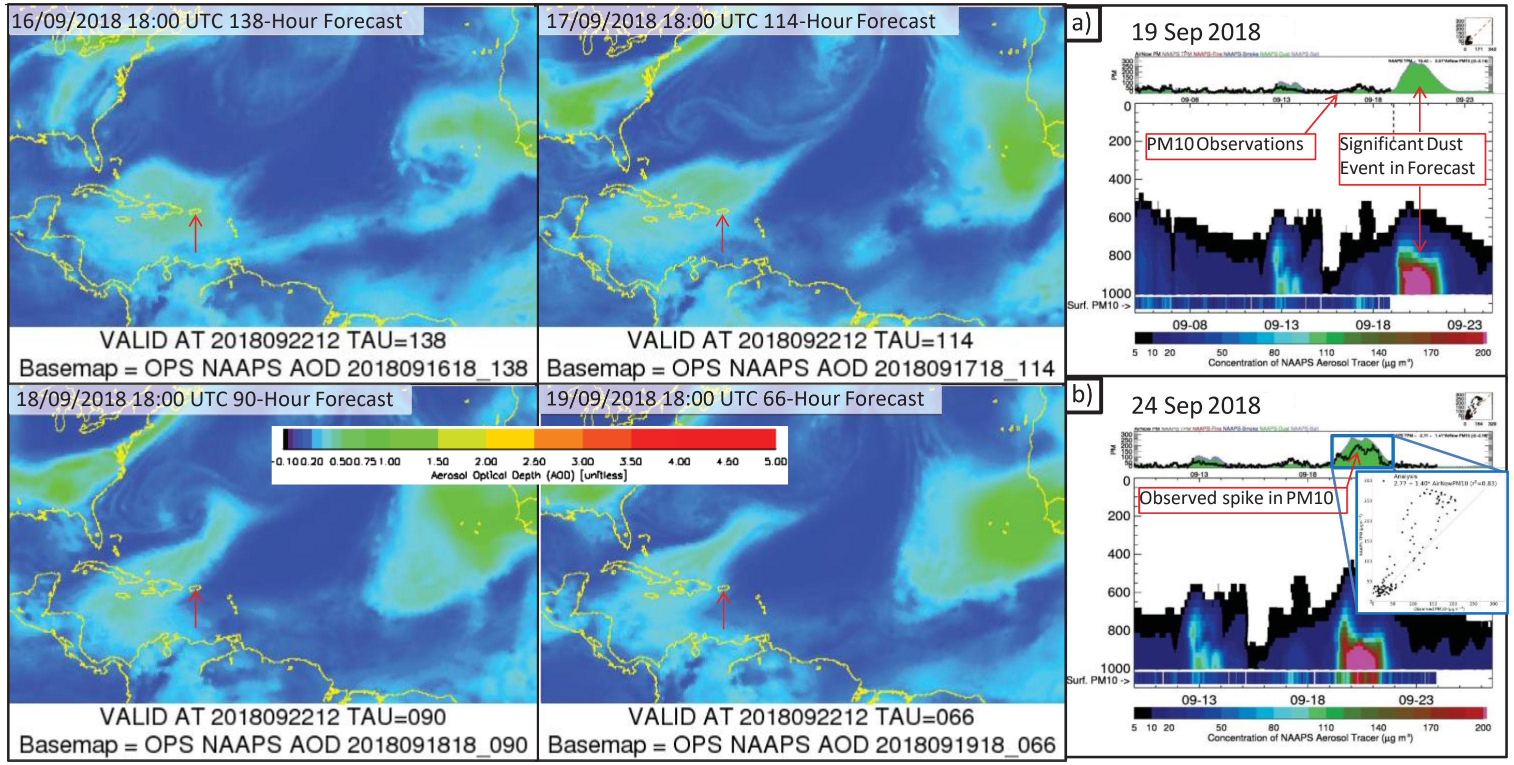
Predicting Large PM Events: Puerto Rico June 2018

- Black Line / Stripe at bottom: EPA AirNow PM2.5, Cataño, Puerto Rico
- Red Line / Curtain: Navy Aerosol Analysis and Prediction System
- 6/12: Surface PM >100ug/m3
- NAAPS overpredicts but captures timing
- So, the model can predict long-range PM2.5 events at this location?



Predicting Large PM Events: Puerto Rico September 2018

- Left: Evolution of NAAPS forecast AOD
- Right: Verification vs AirNow PM2.5
- At PR, event was predicted multiple days ahead
- Shape of forecast event changed drastically

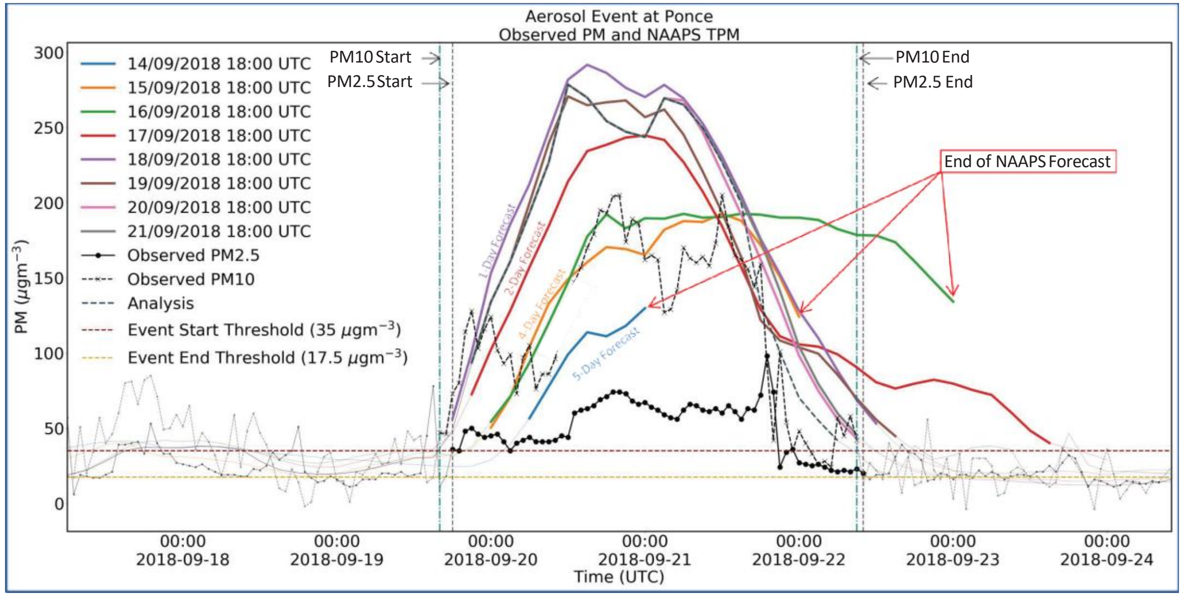


The four panels above show the 16/09/2018 18UTC, 17/09/2018 18UTC, 18/09/2018 18UTC, and 19/09/2018 18UTC NAAPS forecasts for 22/09/2018 at 12:00 UTC. These maps show the modeled aerosol optical depth (AOD) near the end of the observed event. The Ponce site is marked by the red arrow. The time-height curtains to the right show the NAAPS TPM forecast (a) and analysis (b) compared to the observed PM10, as well as the vertical extent of the plume. While the magnitude of the event remained similar between each forecast, the 16/09/2018 18UTC 138-hour forecast showed the dust plume had a broad spatial extent, and covered all of Puerto Rico. In subsequent runs, the plume was forecast as more elongated and westward of Puerto Rico.

Camacho et al., AGU 2018

Predicting Large PM Events: Puerto Rico September 2018

- Black: observed PM2.5 from AirNow
- Early forecasts (blue, yellow) show surface event but lagged start
- Starting with 2-day forecast, timing matches observed event well
- Magnitude rapidly converges to a value that's too high
- Does this indicate a problem with the AOD-to-mass conversion? Or is it something else?



Predicting Large PM Events: Puerto Rico July 2018

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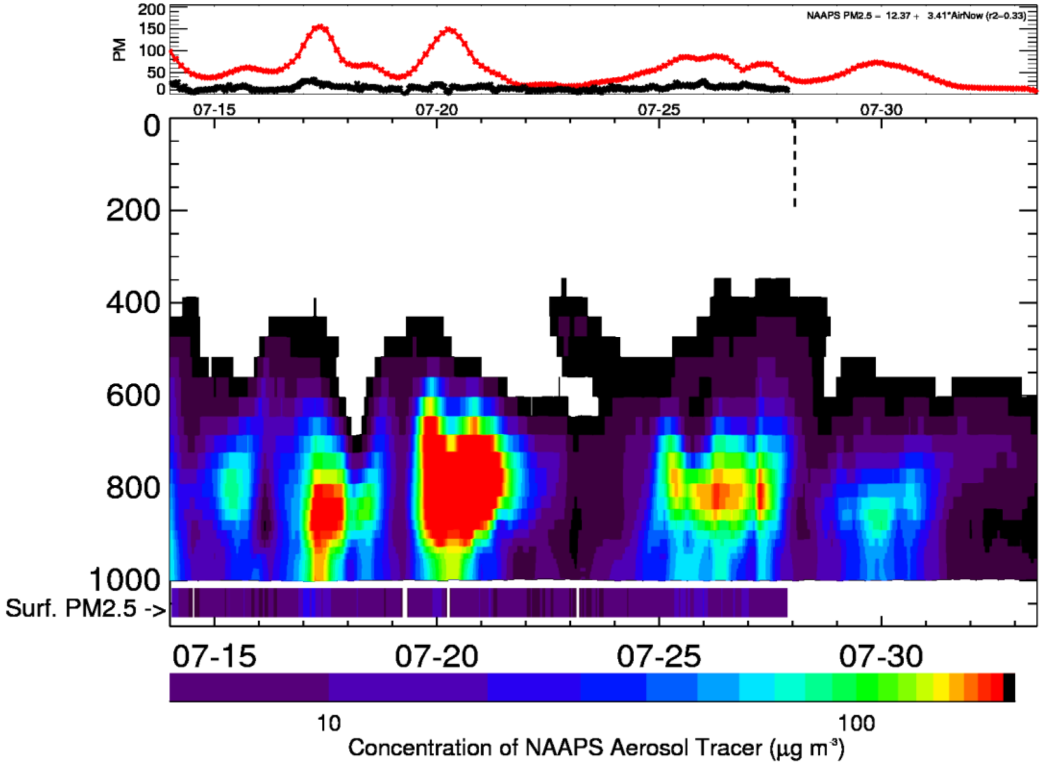
- Black Line / Stripe at bottom: EPA AirNow PM2.5, Cataño, Puerto Rico
- Red Line / Curtain: Navy Aerosol Analysis and Prediction System
- July events severely overpredicted by NAAPS
- In this case, numerical diffusion is at fault (aerosol was aloft, model erroneously mixed to surface)



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Final Slide

Model constrained by AOD used to predict PM2.5

1. Very sensitive to mass conversion
    1. Mass extinction efficiency
    2. Particle size distribution
2. Very sensitive to vertical mixing
    1. Model PBL
    2. Numerical Diffusion
3. AOD to PM: It works, where and when it works

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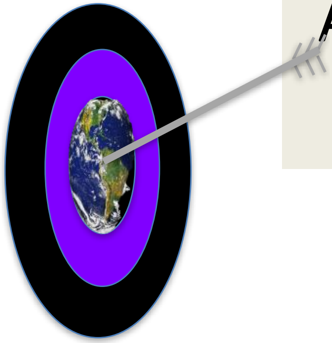
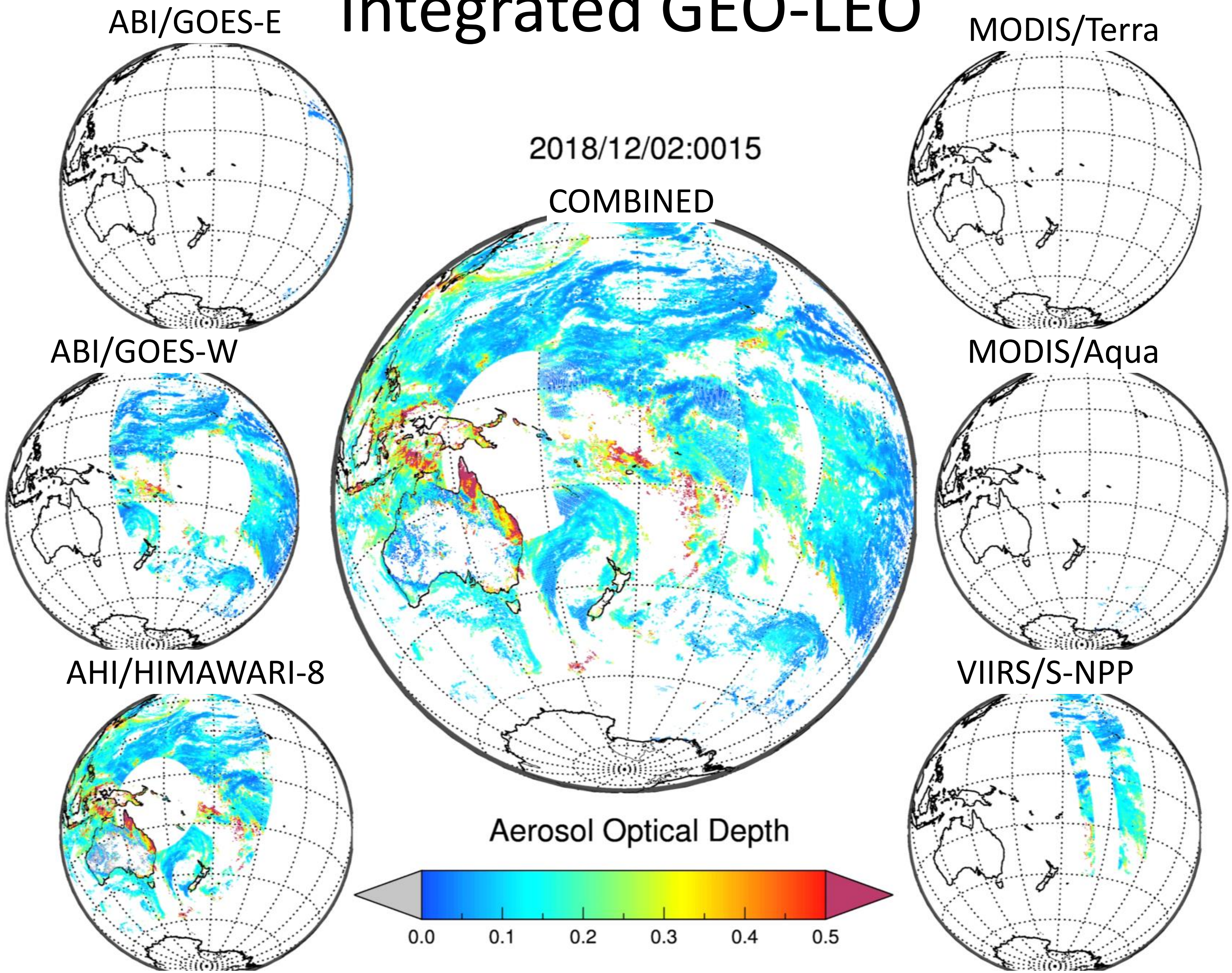
THANK YOU!



Aerosol retrieval from all sorts of imagers: An integrated view of global aerosol

Robert C. Levy (NASA-GSFC), robert.c.levy@nasa.gov

Integrated GEO-LEO



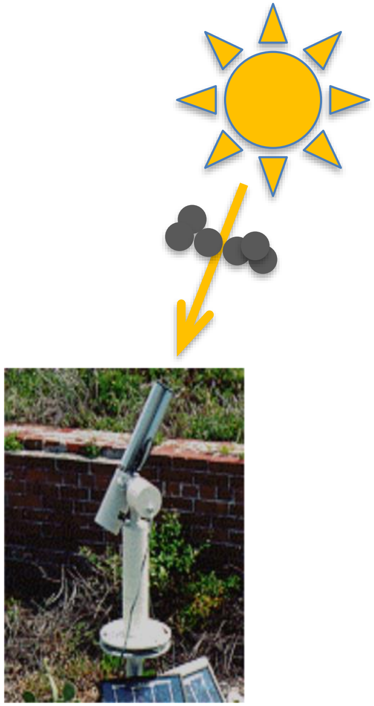
Aerosols (why do we care?)

- They affect visibility
- They affect human health and morbidity
- They enable clouds and precipitation
- They have roles in Earth's chemical cycles (carbon, sulfate, etc)
- They have roles in biology (e.g. transport nutrients)
- They directly impact the radiative budget
- They are both natural and manmade
- They are inhomogeneous in space and time
- Their distributions are changing
- The science of aerosols is truly "interdisciplinary"

- **We have many "users" with many different needs.**

Haze over Maryland: Marufu, Doddridge, Taubman, Dickerson

Global Climate Observing System (GCOS)
Aerosol Optical Depth (AOD)
climate data record (CDR):

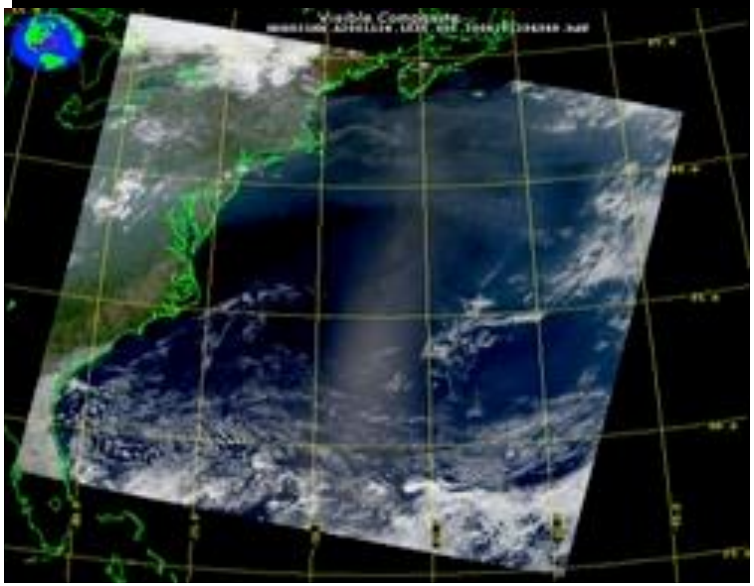


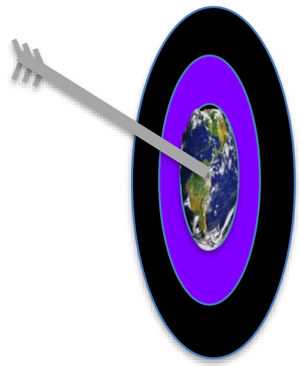
Target metric	Target
Horizontal Resolution	5-10 km, globally
Accuracy	MAX(0.03 or 10%)
Stability / bias	<0.01 / decade
Time Length	30+ years
Temporal Resolution	4 h

Aerosol Retrieval algorithm

What a sensor observes

May 4, 2001; 13:25 UTC
Level 1 "reflectance"

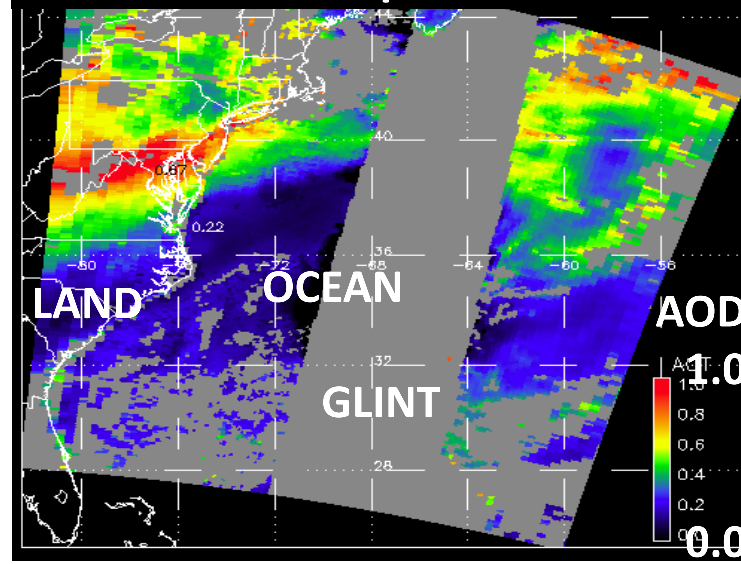




"Retrieval Algorithm"

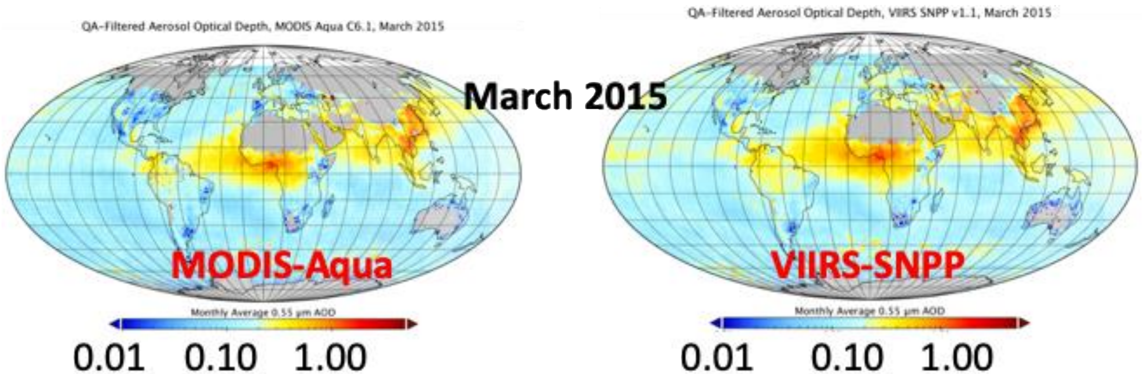
Attributed to aerosol (AOD)

May 4, 2001; 13:25 UTC
Level 2 "product"



Retrieve: AOD at 0.55 µm, spectral AOD (AE), Cloud-cleared reflectances, diagnostics, quality assurance

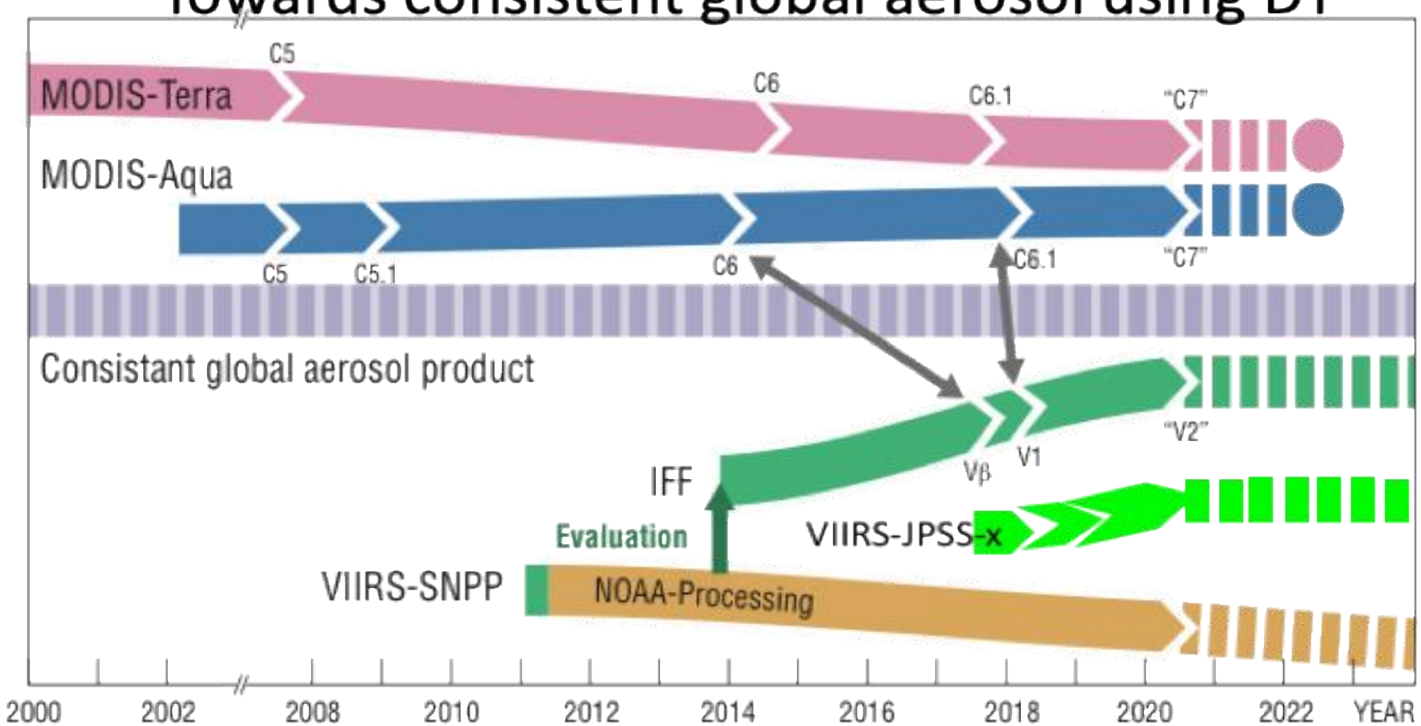
MODIS → VIIRS
(NASA "Dark Target" algorithm)



Of course, the devil is in the details…….

Working on defining "data continuity"

Towards consistent global aerosol using DT

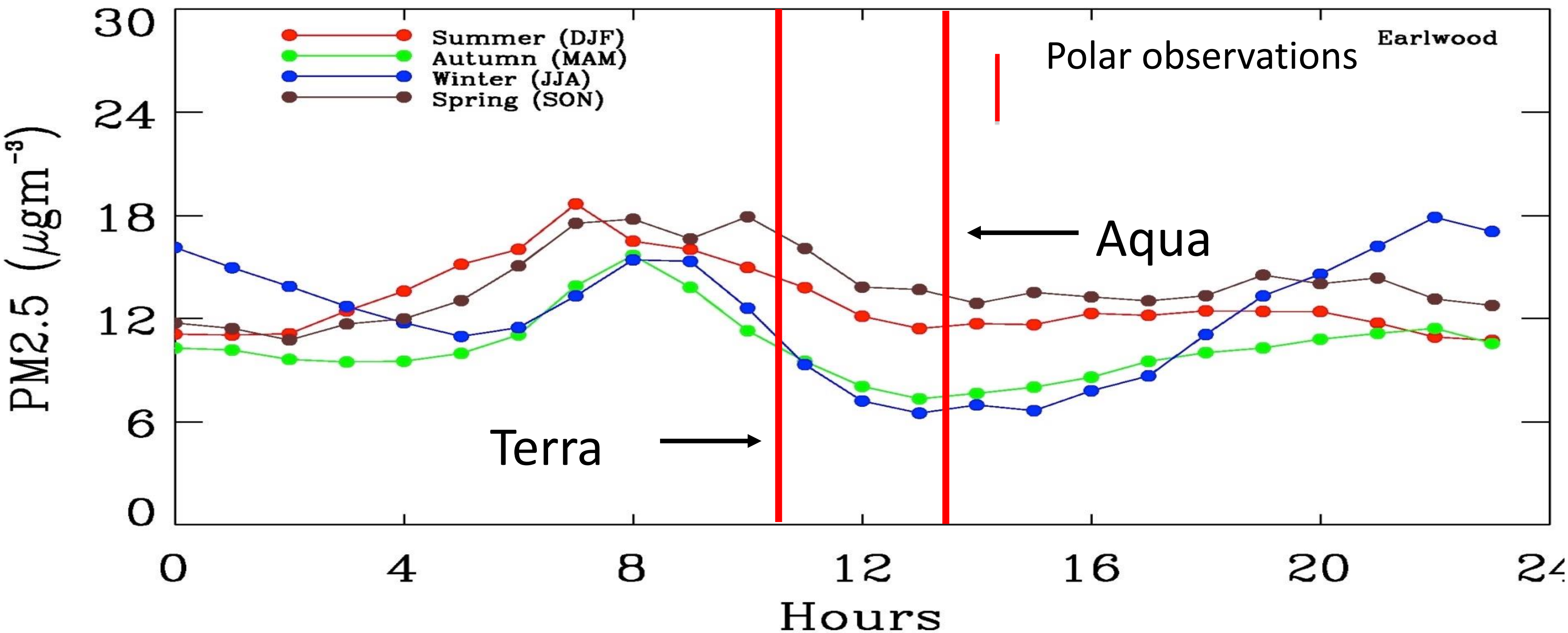


GCOS AOD CDR: Where are we now?

Target metric	Target
Horizontal Resolution	5-10 km, globally
Accuracy	MAX(0.03 or 10%)
Stability / bias	<0.01 / decade
Time Length	30+ years
Temporal Resolution	4 h ????

- With MODIS on Terra and Aqua, we approach Resolution, Accuracy and Stability
- With addition of VIIRS (on Suomi-NPP, and JPSS1-4) we will meet Time Length
- Now what about global temporal resolution?

Breaking the Temporal Barrier! (why we need for PM2.5)



Source: P. Gupta

And west into Asia (Himawari)

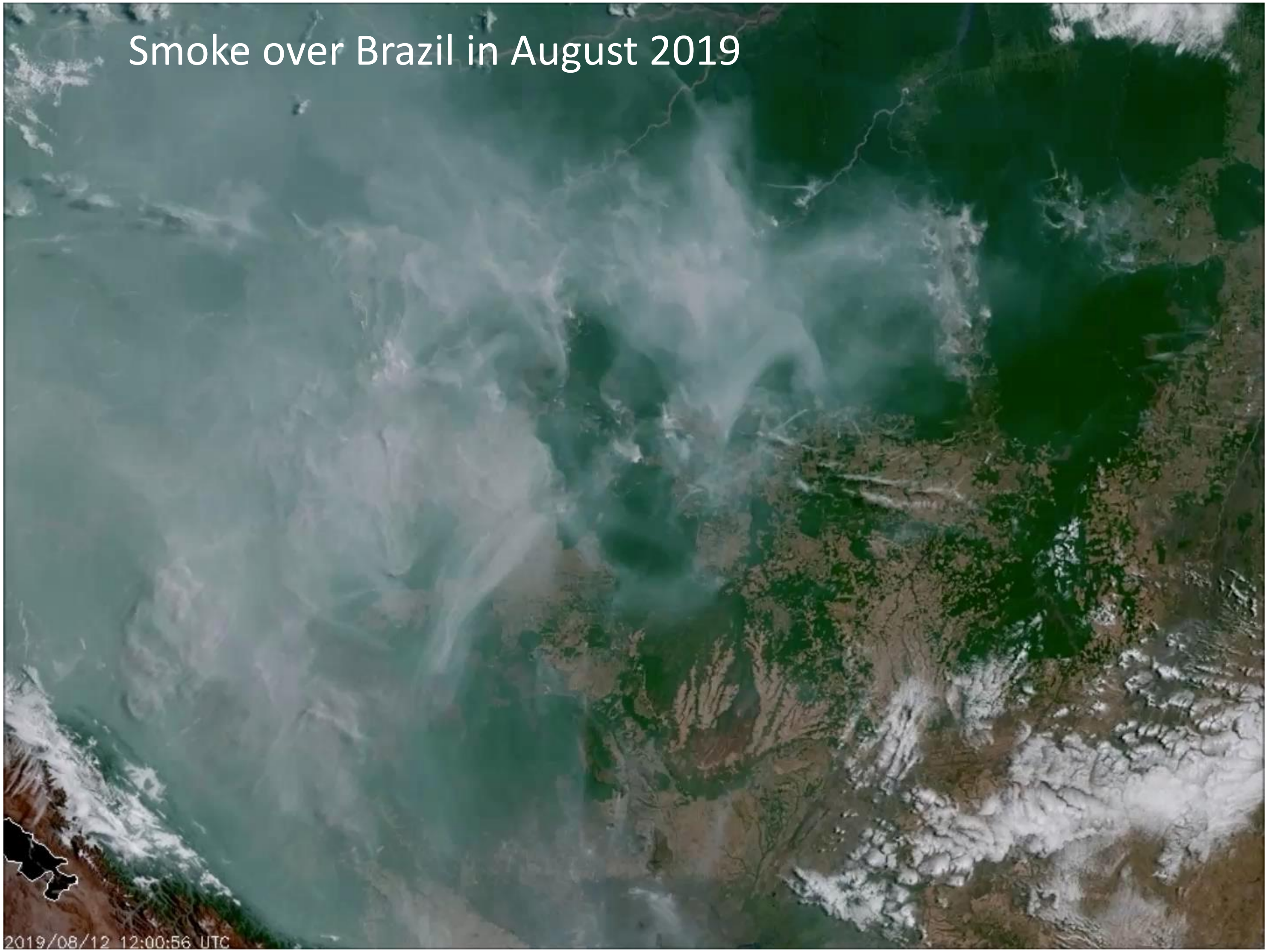
ABI = Advanced Baseline Imager on GOES-16 (East) and GOES-17 (West)

AHI = Advanced Himawari Imager on Himawari-8 (Japan),

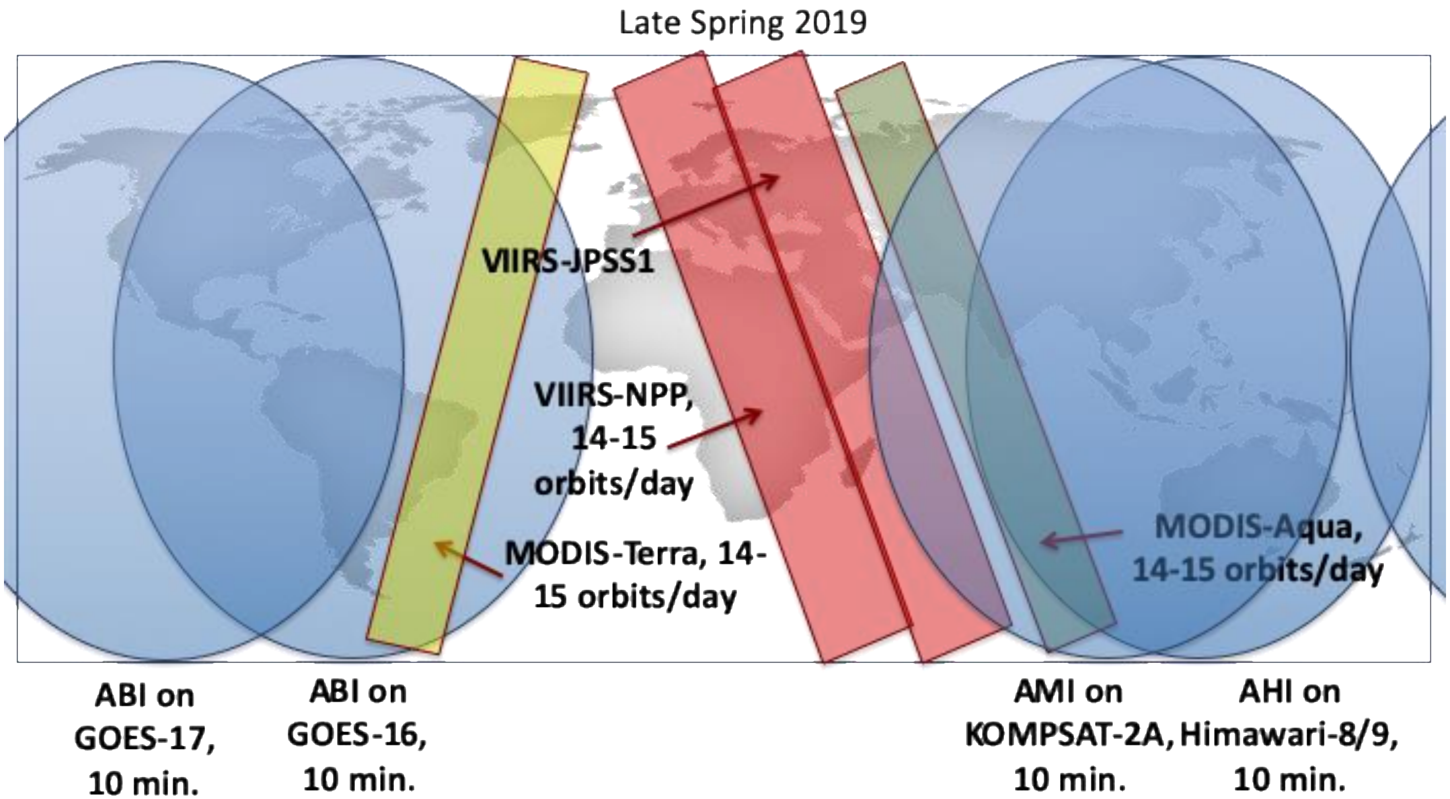
and

AMI = Advanced Meteorological Imager on KOMPSAT-2A (Korea)

What we get from GEO: Temporal resolution!



Our GEO-LEO "MEaSUREs" project:
Provide a 'best of' aerosol product every 30 minutes



- Create a product (and provide to the public) that merges the GEO and LEO
- Can we observe climatology (and diurnal cycle and transport)???
- Anticipate Meteosat Third Generation (MTG) FCI sensor over Europe & Africa!

Port algorithms to GEO

Spectral/Spatial: AHI / ABI ≈ MODIS / VIIRS

	MODIS	VIIRS	AHI	ABI
Blue	0.47/0.5	0.49/0.75	0.47/1.0	0.47/1.0
Green	0.55/0.5	0.55/0.75	0.51/1.0	
Red	0.66/0.25	0.67/0.75	0.64/0.5	0.64/0.5
NIR	0.86/0.25	0.86/0.75	0.86/1.0	0.86/1.0
NIR	1.24/0.5	1.24/0.75		
Cirrus	1.38/0.5	1.38/0.75		1.38/2.0
SWIR	1.61/0.5	1.61/0.75	1.61/2.0	1.61/1.0
SWIR	2.11/0.5	2.25/0.75	2.25/2.0	2.25/2.0

Some challenges (e.g. lack of "cirrus" 1.38 band on AHI, lack of 1.24 for sediments);

Green band: MODIS/VIIRS @ 0.55 μm, AHI @ 0.51 μm, ABI @ none

In the end, we will report AOD at 0.55 μm for everyone!

Same products as MODIS, including spectral AOD, cloud-cleared reflectance, etc

How do we merge?

- Definitely need to “grid”
- Choose which sensor(s) are advantageous due to angles and projection (Parallax?)
- Strategy for dealing with Quality & Confidence.

Who “wins”?

Some questions

- What do users actually want?
- How do users get data?
- How should NASA/NOAA work together?
- Are there elephants in room?

What do users actually want?

- AOD/AE is (at best) a proxy for air quality
- AOD/AE is (at best) a proxy for radiative effect/forcing
- Assimilation into models is moving toward using *reflectances/radiances* rather than retrievals (consistent with optical properties inside models)

- What resolution? What time scale? Better to have more data/less accuracy? Less data/more accuracy?

How do users get data?

- NASA uses "DAACs" to search and order for data
  - MODIS from one site, VIIRS from another, GEO from a third? Also, MISR from another and I expect TEMPO from another.
  - New tools such as WorldView help, but still hard to get 'the data'.

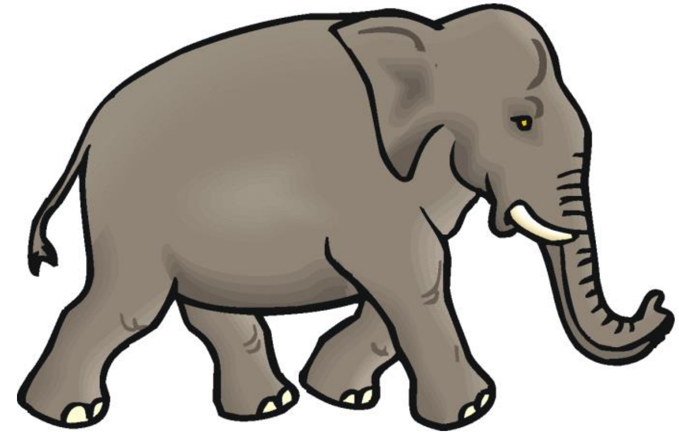
- NASA VIIRS versus NOAA VIIRS? Confusion?
- Soon to be NASA GEO versus NOAA GEO. More confusion?

- GEO data are HUGE! Our full-disk (10x10 degradation from native pixel) retrieval is 2TB/year per sensor. If you want climate data, you have to archive a lot.

How should NASA/NOAA work together?

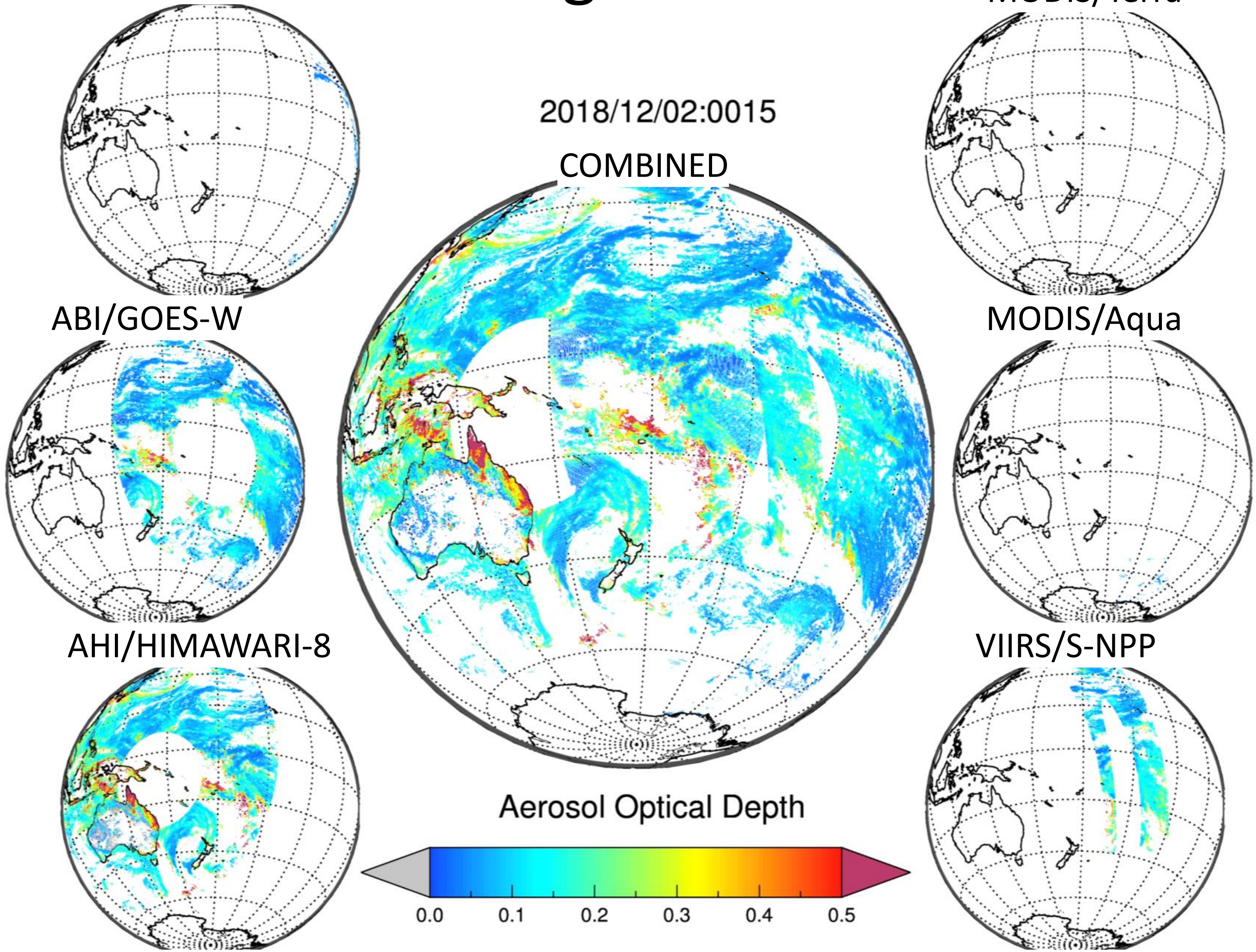
- Right now we have ≥2 audiences:
  - Weather-ready products (ingest directly into forecast systems, operational use)
  - Climate-ready products (can wait, better to be consistent and free of sensor/calibration artifacts, science use, reprocessing)
- We are both producing ‘aerosol’ products from imagers.
- Yes, I collaborate with Shobha and STAR team for new ideas and issues, but we have very different bosses! (unless you count taxpayer)

Elephants in room? (Opportunities?)

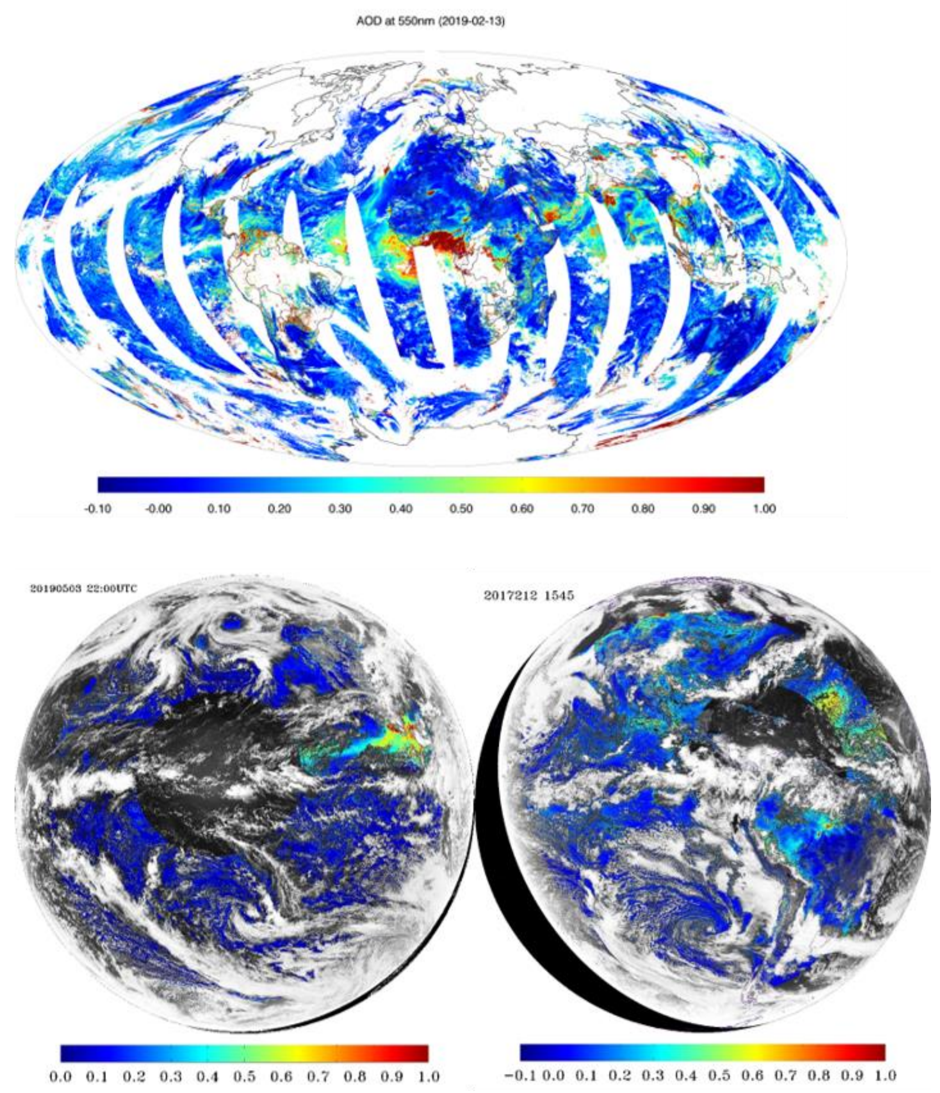


- Neural Net/Machine Learning versus Physical Retrieval. How much should I invest in these tools to put myself out of business?
- How ‘quantitative’ should we expect satellite derived PM2.5 to become?
- GEMS was just launched, and TEMPO soon. How do we work with those extensive datasets?
- How do we ensure funding for long-term records (e.g. 30+ years with a good, but consistent algorithm?).

Integrated all



AND MORE SENSORS (FCI, NOAA-20, JPSS2-4, etc)!



JPSS and GOES-R AOD Products - Current Status

Istvan Laszlo (NOAA),
Hongqing Liu (IMSG)
Mi Zhou (IMSG)

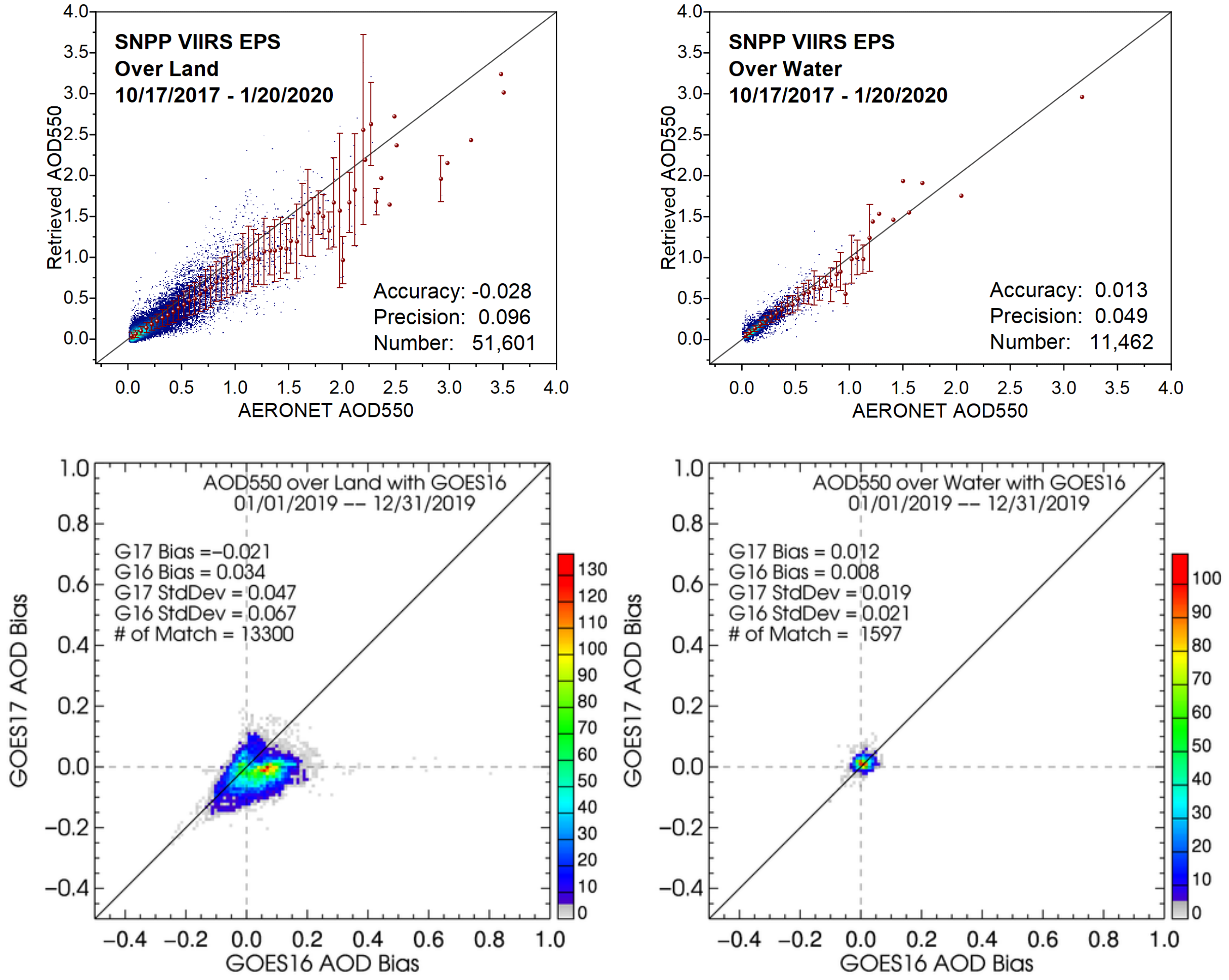
February 26, 2020

Operational AOD Products

Product availability by satellite

- ***JPSS***
  - **SNPP**
    - **IDPS**: 01/23/2013 (Validated)
    - **EPS**: 07/06/ 2017 (Validated)
  - **NOAA-20**
    - **EPS**: 03/07/2019 (Validated)
- ***GOES-R***
  - **GOES-16**
    - Baseline: 07/25/2018 (Provisional)
  - **GOES-17**
    - Baseline: 01/01/2019 (Provisional)
  - EPS version is coming in early 2021
- Data before Provisional Maturity is not recommended for quantitative studies.

AOD product quality

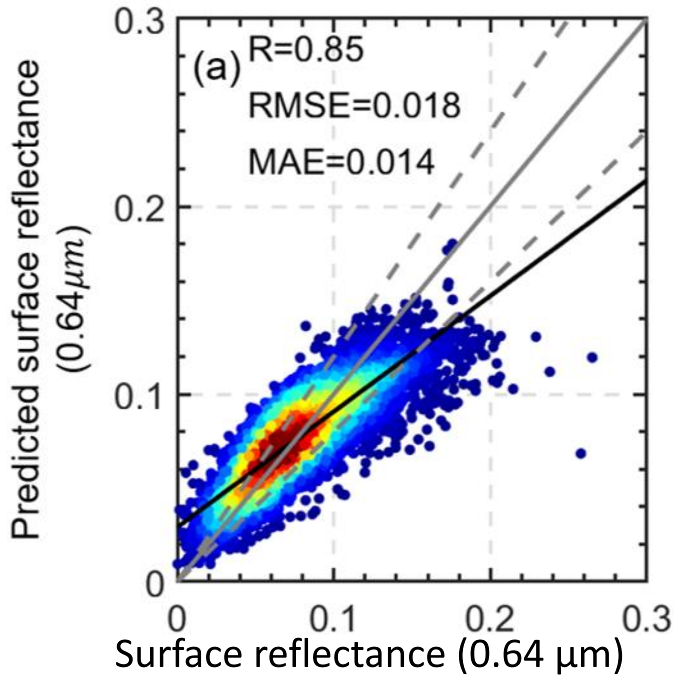


Surface Reflectance Relationship – AHI Example

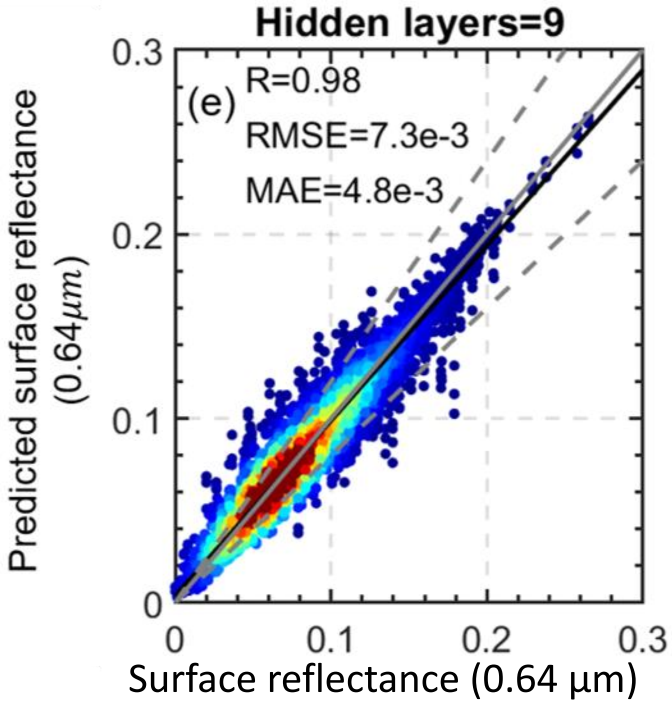
- **Traditional (DT)**

$$r_{red} = a + b\, r_{SWIR}$$

$$a|b = f(\theta, NDVI)$$

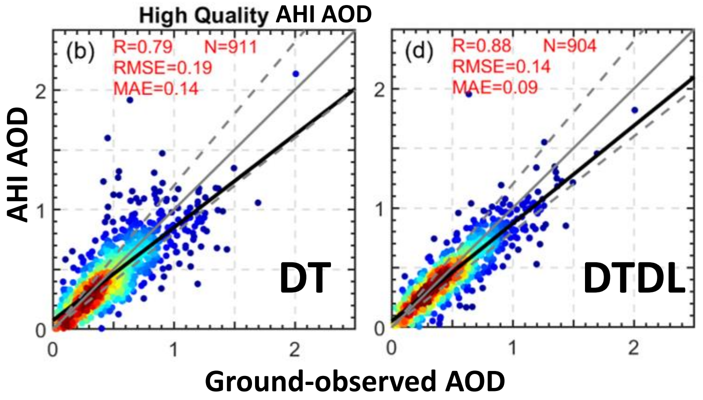


- **AI (DTDL)**
  - Multi-layer artificial neural network (ANN) model based on Bayesian Regularization.



T. Su, I. Laszlo, Z. Li, J. Wei, S. Kalluri, 2020

- DTDL improves AOD retrieval



- DTDL improves representation of diurnal cycle of AOD.

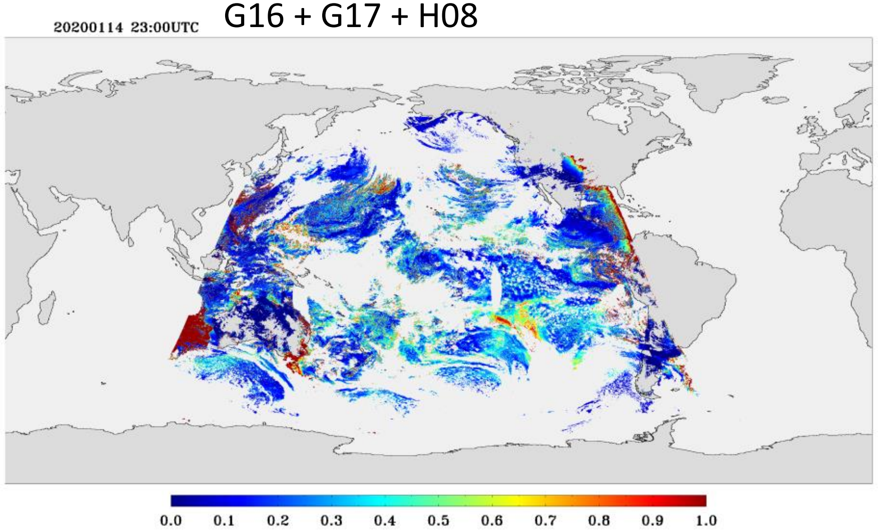
In the works:

- ABI AOD product with empirical bias correction (H. Zhang et al.).
- Traditional surface reflectance relationships accounting for view and solar angles.
- Both improve representation of diurnal cycle of AOD.

"Merged" AOD products

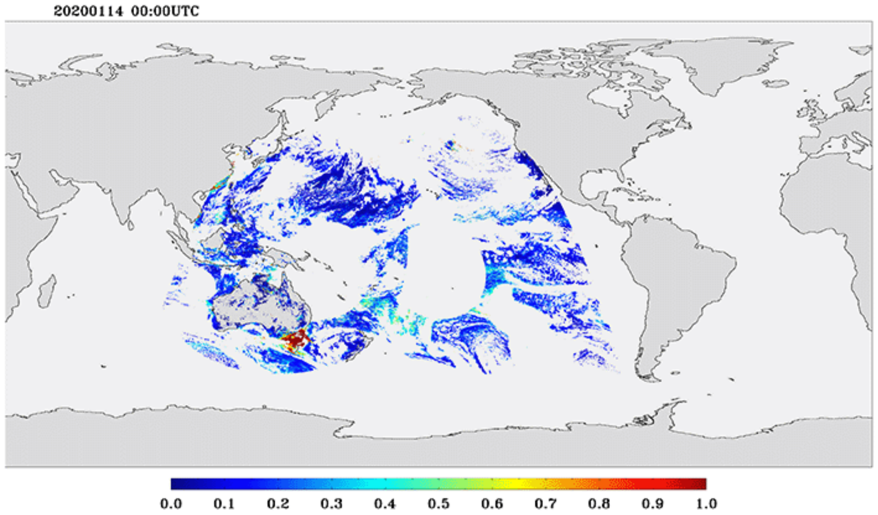
550-nm high-quality AOD on Jan 14, 2020 from **SNPP** (*first*) and ~50 min later from **NOAA-20** (*second*).

G16 + G17 + H08



550-nm AOD on Jan 14, 2020 at 23:00 UTC from G16, G17 and H08.

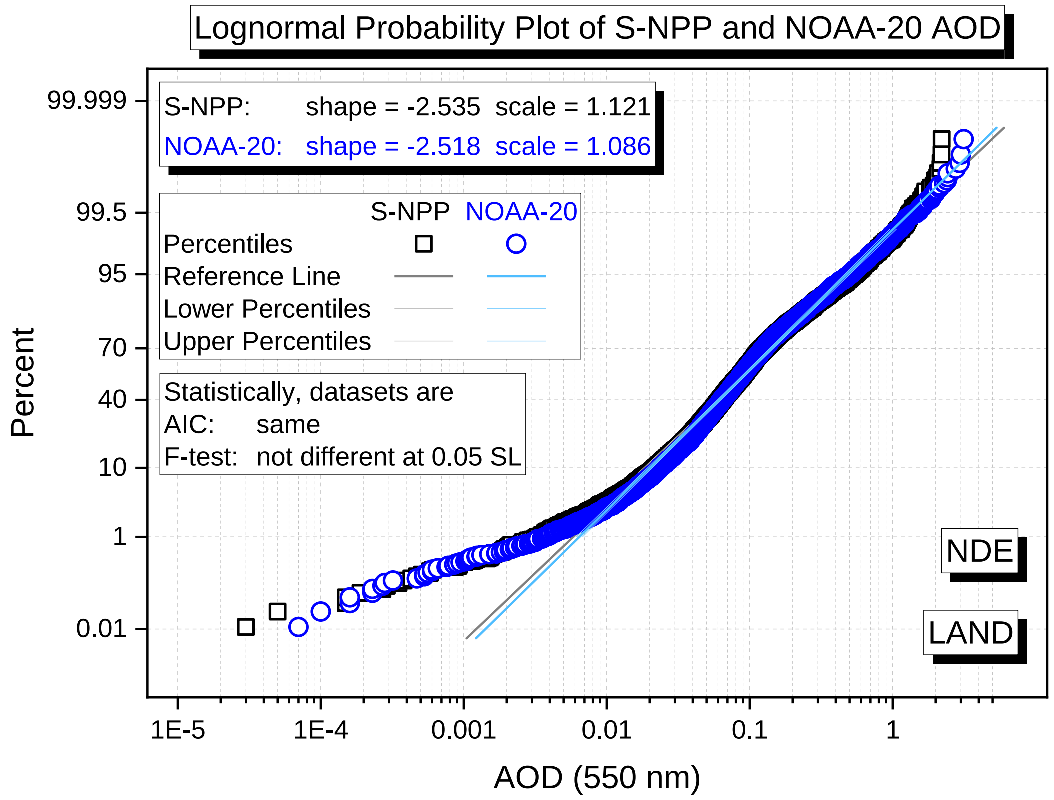
All AODs are plotted.

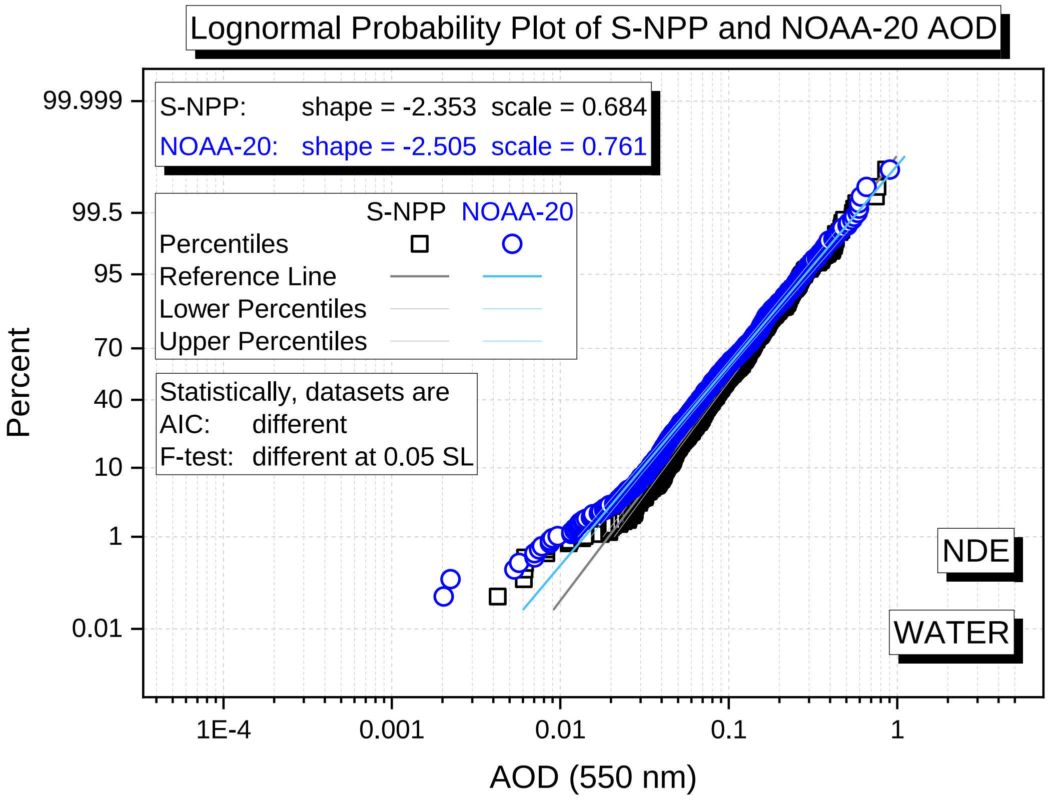


Same as above, but AODs every 30 min between 00:00-23:30 UTC.

Only medium- and high-quality AODs are plotted.

Quantifying Similarity

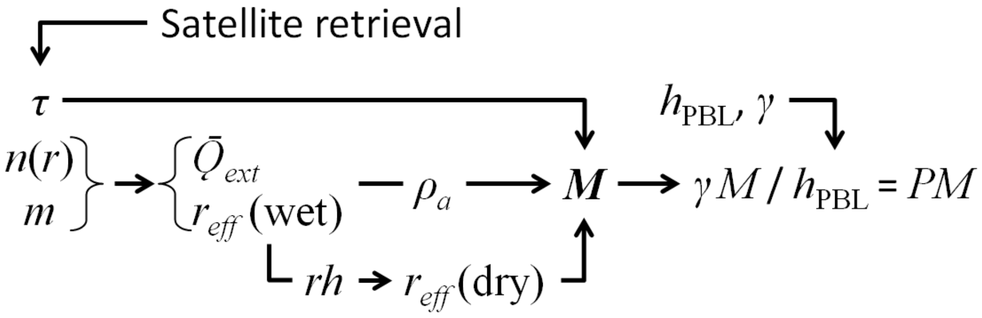


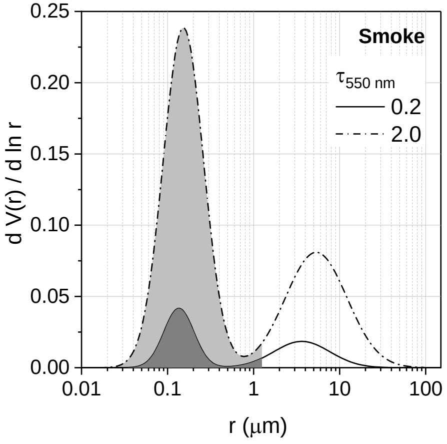


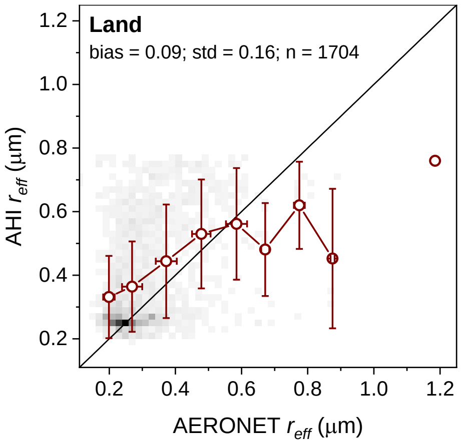
- High-quality NOAA-20 AOD over land over AERONET sites: 09/28/2018 – 04/11/2019.
- Difference over water is result of NOAA-20 VIIRS observed reflectances being consistently lower than S-NPP for all RSBs. NOAA-20 AOD agrees better with AERONET.

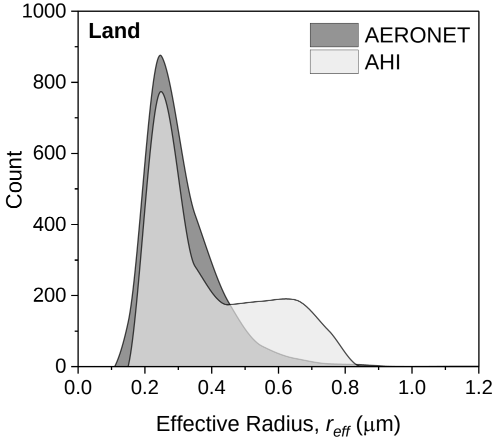
Aerosol Particle Size, Mass Concertation & Uncertainty Estimate

- Angstrom exponent over ocean
  - only a proxy for size
- Size and mass concentration from "retrieved" aerosol model



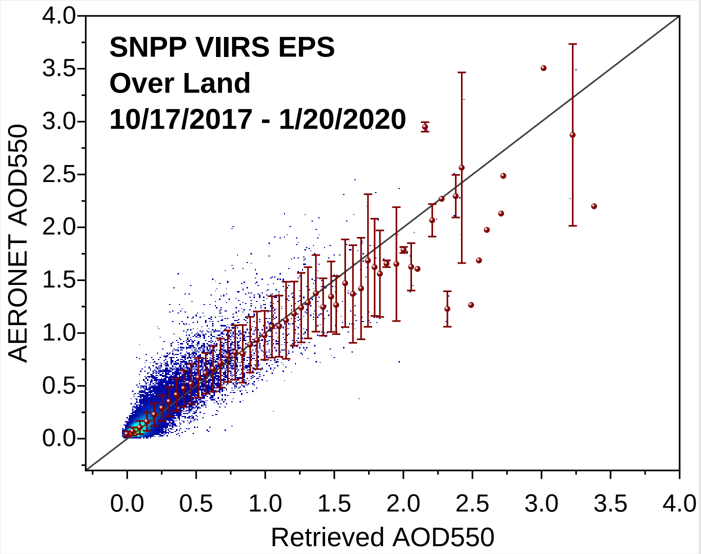






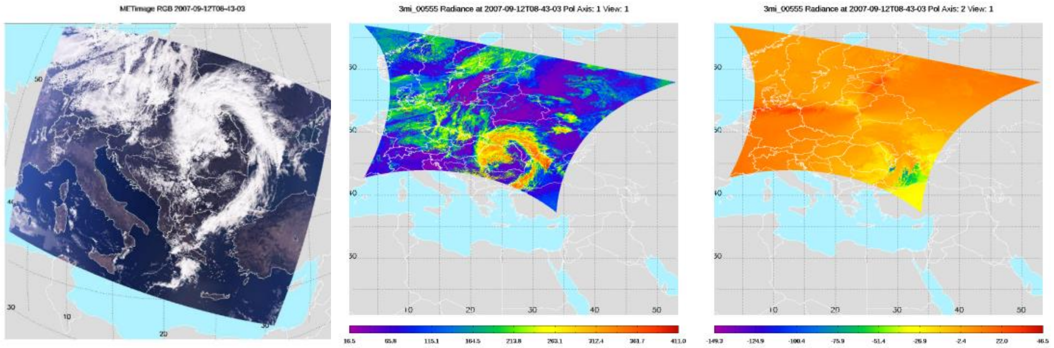
- Alternative solution to derive $PM_{2.5}$ from AOD (Zhang & Kondragunta)
  - apply climatology of AOD-to-$PM_{2.5}$ relationship (van Donkelaar), but …
  - adjust coefficients of relationship based on real-time observations of $PM_{2.5}$ from ground network (H. Zhang).

- Estimating AOD uncertainty
  - (very) preliminary thoughts



Future NOAA and non-NOAA AOD Products

- **Metop-SG (EUMETSAT)**
  - morning polar orbit
  - **METImage**
    - swath: 2,670 m, spatial resolution: 500 m, 11 bands in 443-2,250 nm.
  - **3MI**
    - swath: 2,200 m, spatial resolution: 4,000 m, 12 bands in 410-2,130 nm (9 with polarization)
  - PLD: 2023
- **PACE (NASA)** Polarimeters:
  - **SPEXone** (Spectro-polarimeter for Planetary Exploration)
    - 385-770 nm in 14-45 nm steps for polarization, 5 angles
  - **HARP2** (Hyper Angular Research Polarimeter)
    - 4 bands between 440 and 870 nm, 10-60 angles depending on band.
  - PLD: 2022-2023



- *Products from polarimeters*:
  - AOD
  - Size distribution
  - Complex refractive index
  - Single scattering albedo
  - Height

- **Meteosat Third Generation (MTG-I)**
  - geostationary
  - Flexible Combined Imager (FCI)
  - PLD: Q4 2021

BACKUP SLIDES

Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)

- PACE (NASA) Polarimeters
  - **SPEXone** (Spectro-polarimeter for Planetary Exploration)
    - swath: 100 km,
    - spatial resolution: 1 km with 2.5 km sampling distance,
    - bands: 385-770 nm in 14-45 nm steps for polarization,
    - 5 angles
  - **HARP2** (Hyper Angular Research Polarimeter)
    - swath: 1,556 km km,
    - spatial resolution: 1 km with 3 km sampling distance,
    - bands: 4 between 440 and 870 nm,
    - 10-60 angles depending on band.
  - PLD: 2022-2023

JPSS/MetOp-SG/GOES-R sensor intercomparison – “Aerosol” Bands

	VIIRS			METimage		3MI			ABI
		Wavelength	FWHM	Wavelength	FWHM	Wavelength	FWHM	P	
VNIR	M1	412	20			410	20	Y	
	M2	445	18	443	30	443	20	Y	
	M3	488	20			490	20	Y	470
	M4	555	20	555	20	555	20	Y	
	M5	672	20	668	20	670	20	Y	640
	M6	746	15	752	10	763	10	N	
				763	10	765	40	N	
	M7	865	39	865	20	865	40	Y	865
				914	20	910	20	N	
SWIR	M8	1240	20	1240	20				
	M9	1378	15	1375	40	1370	40	Y	1378
	M10	1610	60	1630	20	1650	40	Y	1610
	M11	2250	50	2250	50	2130	40	Y	2250
LWIR	M12	10763	1000	10690	500				11200
	M13	12013	950	12020	500				12300

Wavelength (nm).

FWHM: full-width at half-maximum (nm).

P: polarization measurement.

Swath (km)

VIIRS	METimage	3MI
3,060	2,670	2,200

Spatial resolution (m)

VIIRS	METimage	3MI
750	500	4,000

Onboard calibration

VIIRS	METimage	3MI
Yes	Yes	No

	GOES-16	GOES-17
*Beta Maturity	05/24/2017	08/27/2018
Drift with Data Gap	11/30/2017 – 12/14/2017	10/24/2018 – 11/13/2018
Reach Operational Position	12/17/2017	11/14/2018
***Provisional Maturity**	**07/25/2018**	**01/01/2019**
Switched M3 to M6	04/02/2019	04/02/2019
B02 Gain Value Correction	04/23/2019	04/27/2019

***Data available since Beta maturity**

***Provisional maturity data is recommended for the community to use**

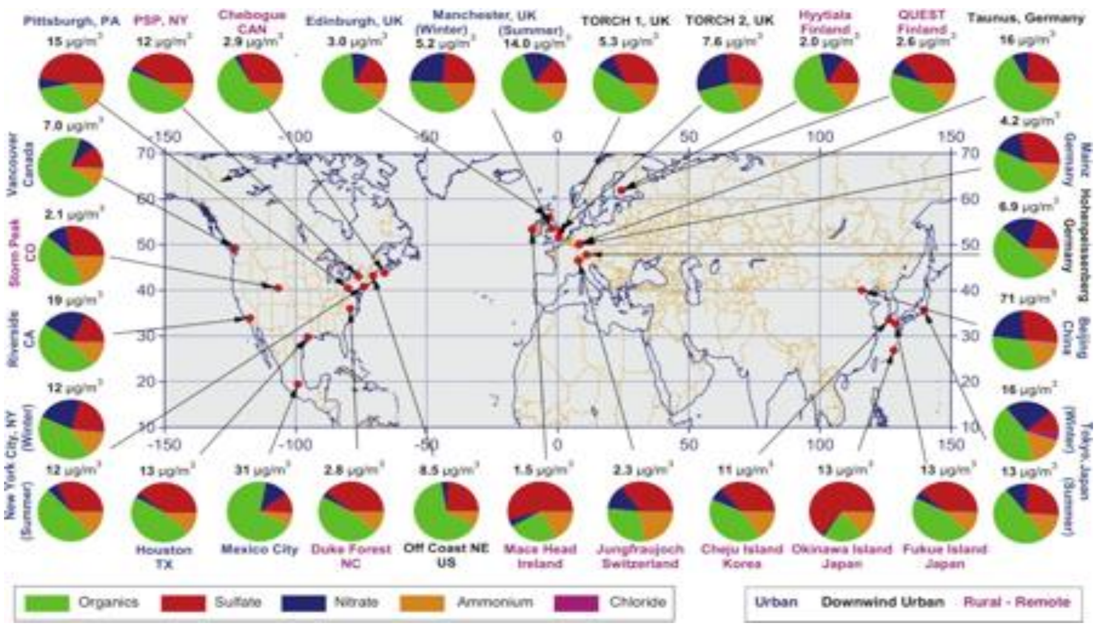
Aerosol Splinter Meeting

- Thursday, February 27
- 8:30 AM to 10:30 AM EST in conference room 4552-4553, 4th floor of the NCWCP building.

- Reconvene at 1:00 PM in Suite 3250 of the ESSIC building located at 5825, University Research Court, College Park, MD. This building is across the NCWCP building.

Aerosols & Air Quality – Spacecraft Contributions

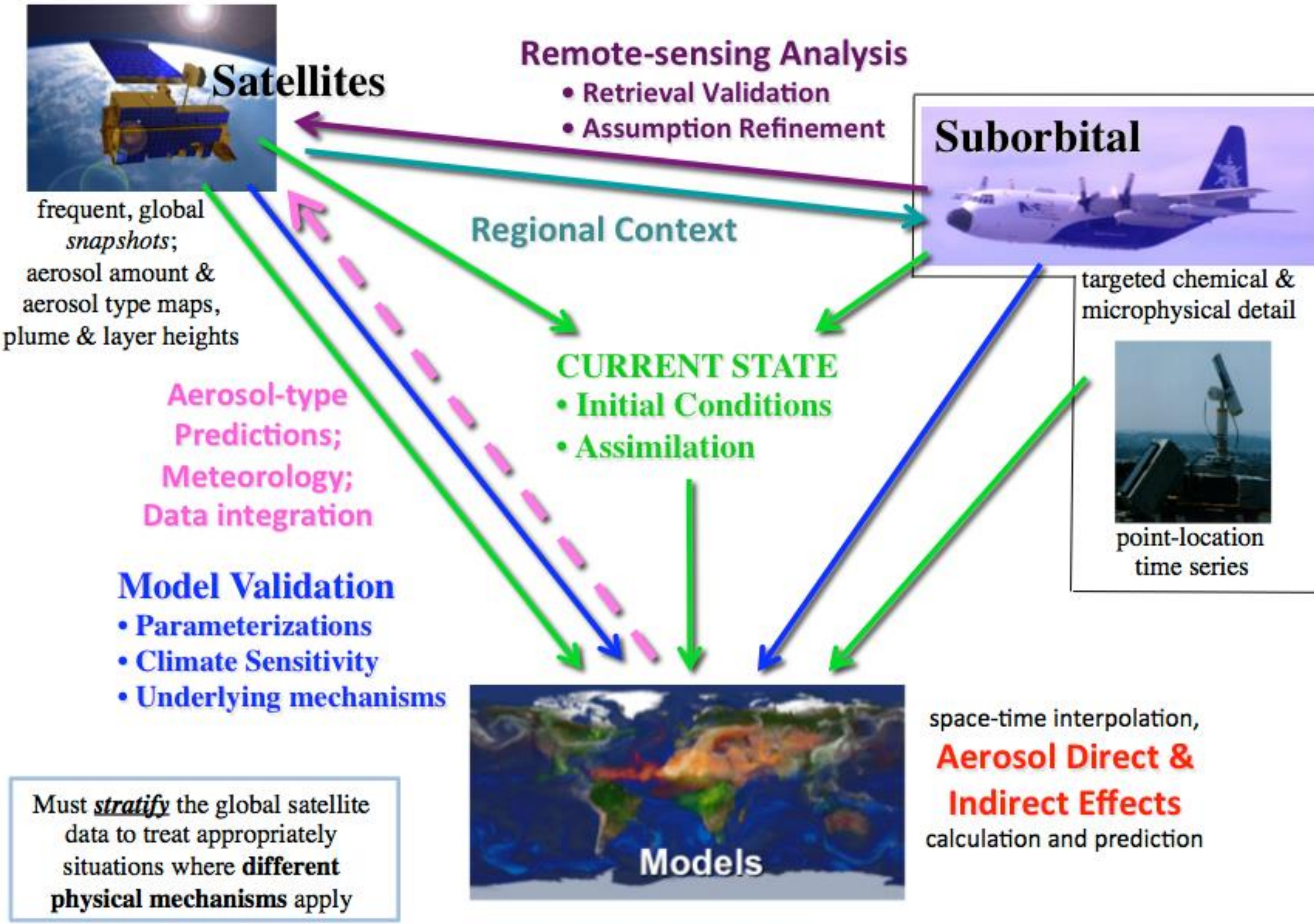
Ralph Kahn NASA/Goddard Space Flight Center



Surface-based mass-spec aerosol composition measurements

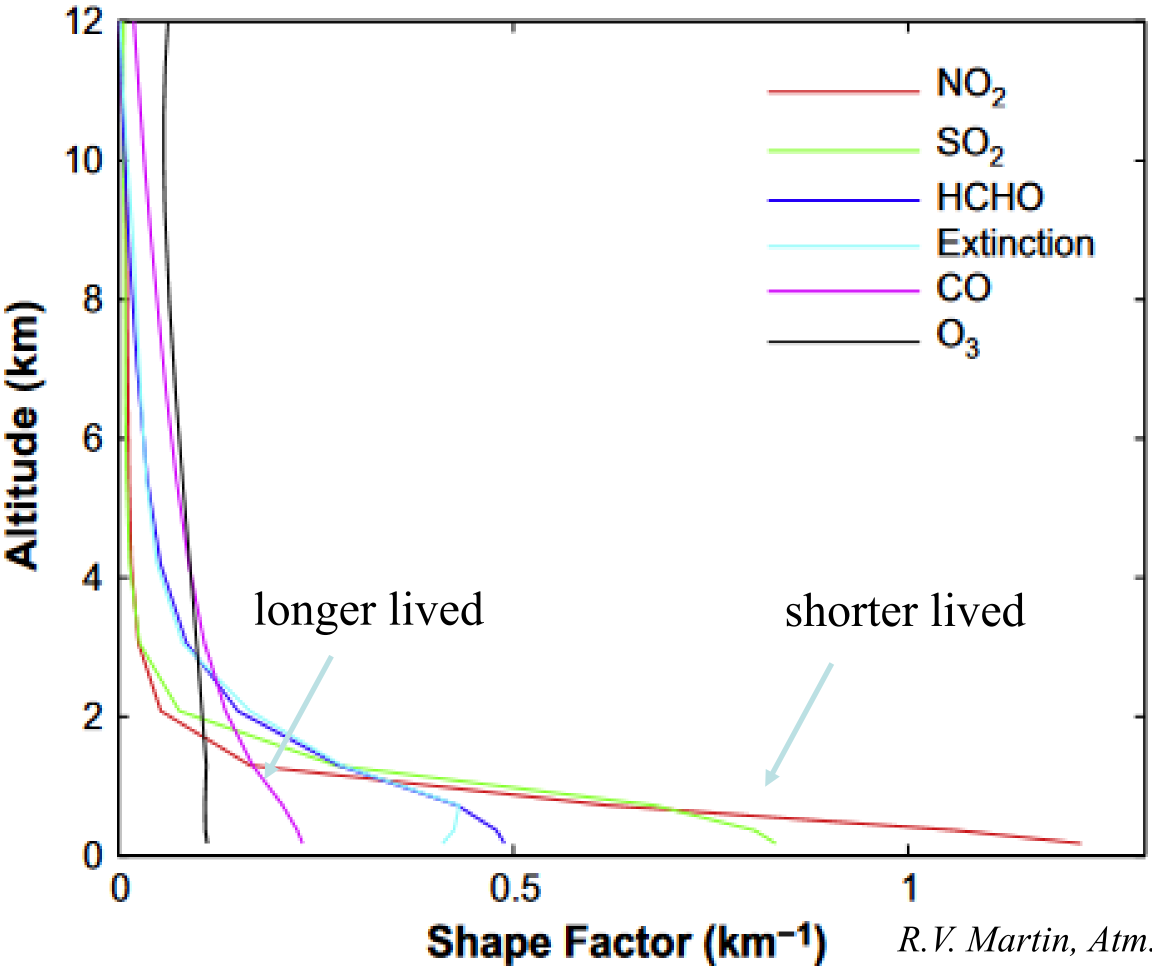
Zhang et al., GRL. 2007

- **Need to isolate *Near-surface* aerosol component**
- **Detailed *Chemical Speciation* often required**
- **Need sufficient *Spatial-Temporal Coverage* to capture severe events**
- ***High Spatial Resolution* often required** (e.g., in Urban areas)



Adapted from: Kahn, Survy. Geophys. 2012

• Need to isolate *Near-surface* aerosol component



R.V. Martin, Atm. Env. 2008

Gas meas. nadir resolution:

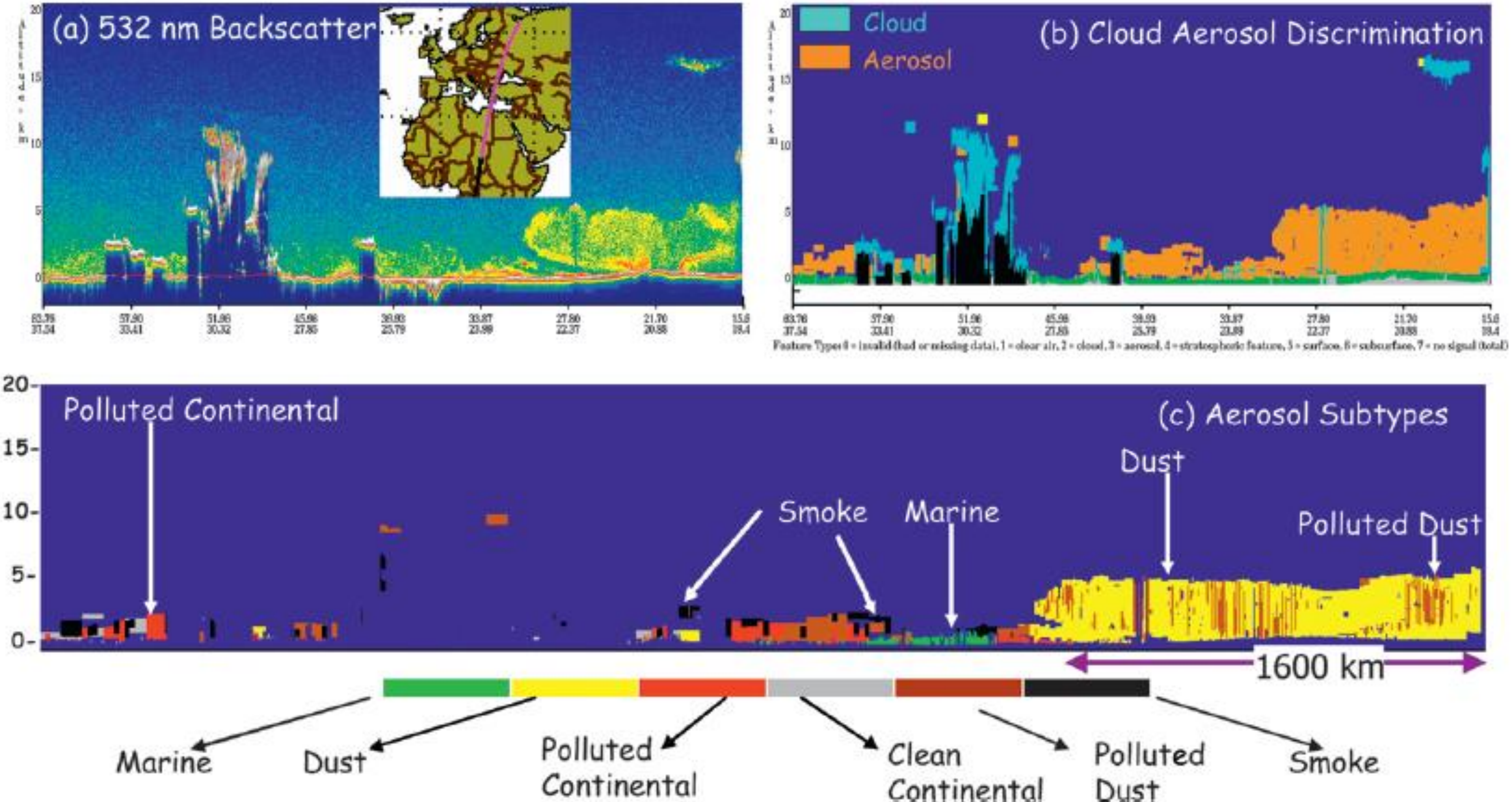
TOMS 1979 – 50 x 50 km^2
Aura/**OMI** 2004 – 13 x 24 km^2
SNPP **OMPS** 2011 – 50 x 50 km^2
TROPOMI 2017 – 7 x 3.5 km^2

Coarse spatial resolution needed for adequate Signal/Noise

- **NO_2** , **SO_2**, **HCHO** are Shorter Lived – ***Often Closer to the Surface***
- **For Aerosols, *scaled AOD* using a transport model;**
  ***lidar validation* where available**

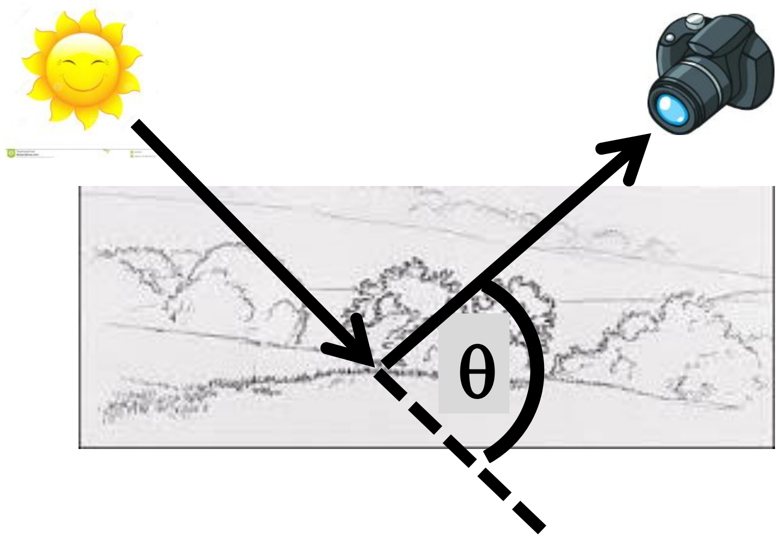
• Detailed *Chemical Speciation* often required

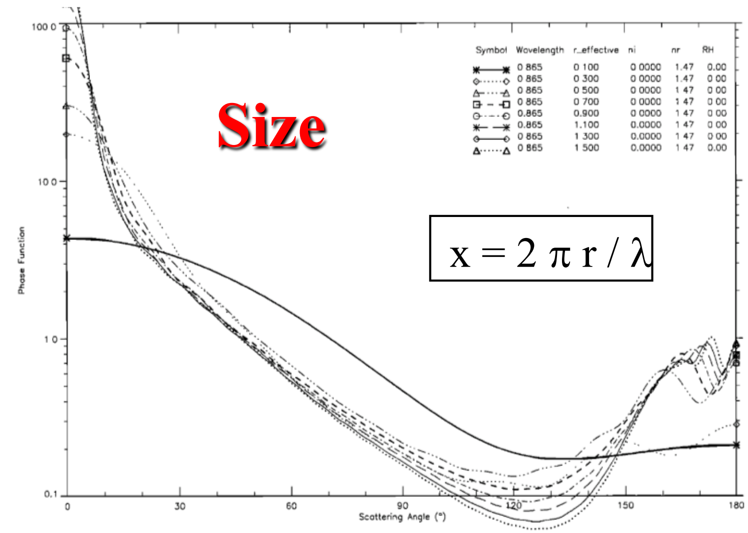
CALIPSO 6-Grouping Aerosol Type Classification

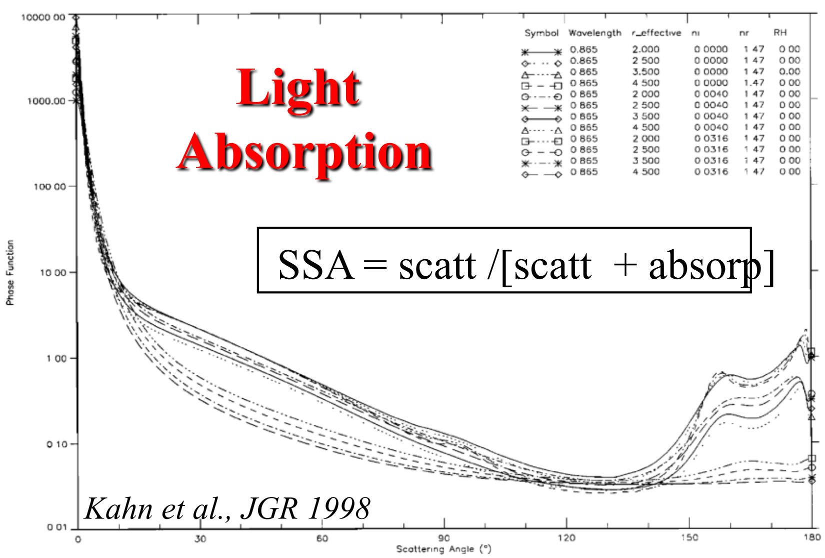


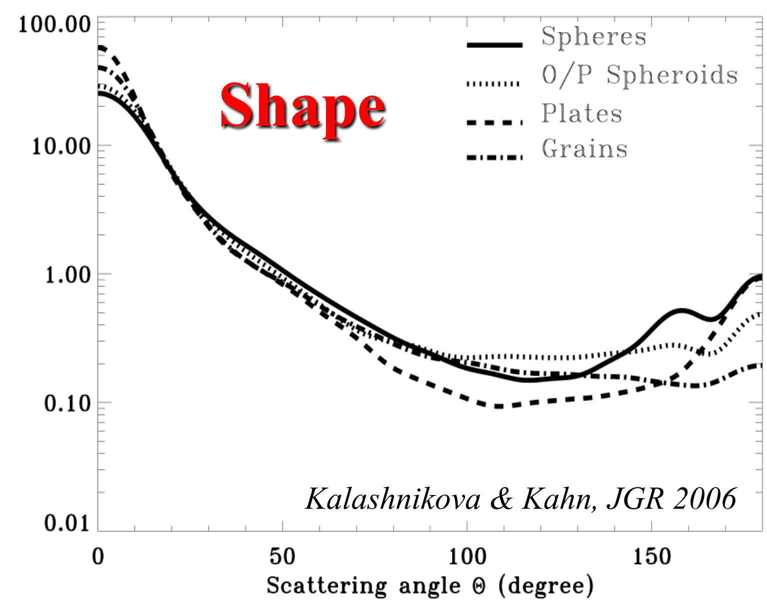
Omar et al., JAOT 2009

• Detailed *Chemical Speciation* often required

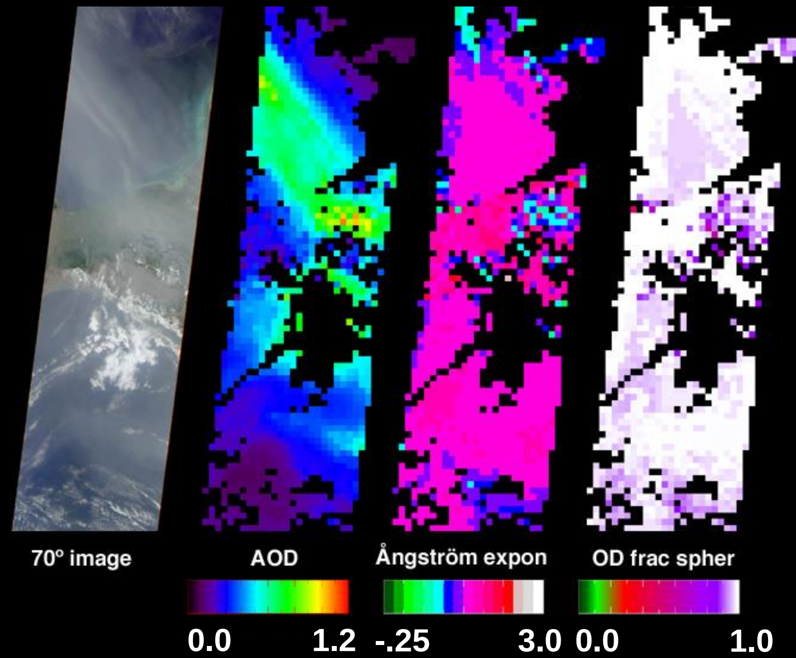








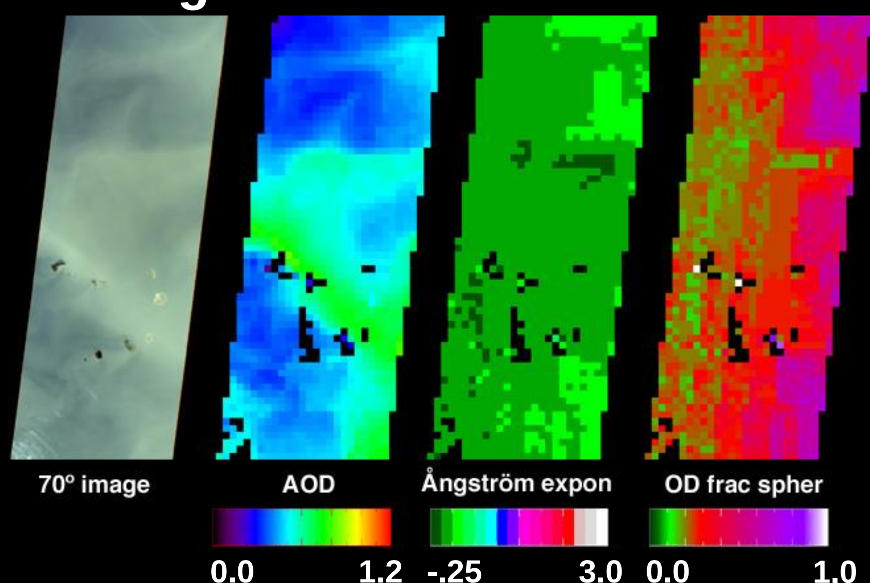
Smoke from Mexico -- 02 May 2002



Aerosol:
Amount
Size
Shape

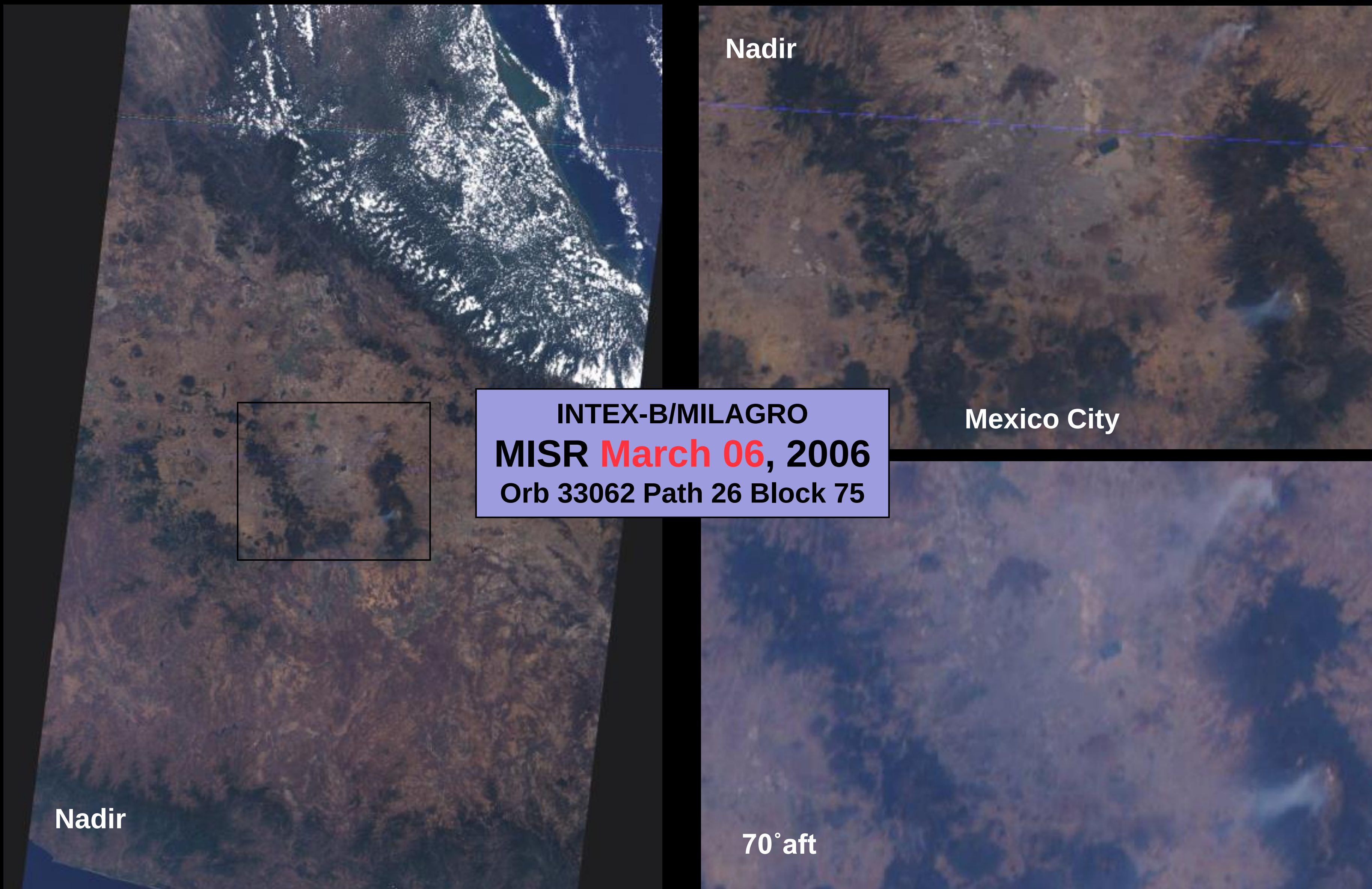
Medium
Spherical
Smoke
Particles

Dust blowing off the Sahara Desert -- 6 February 2004



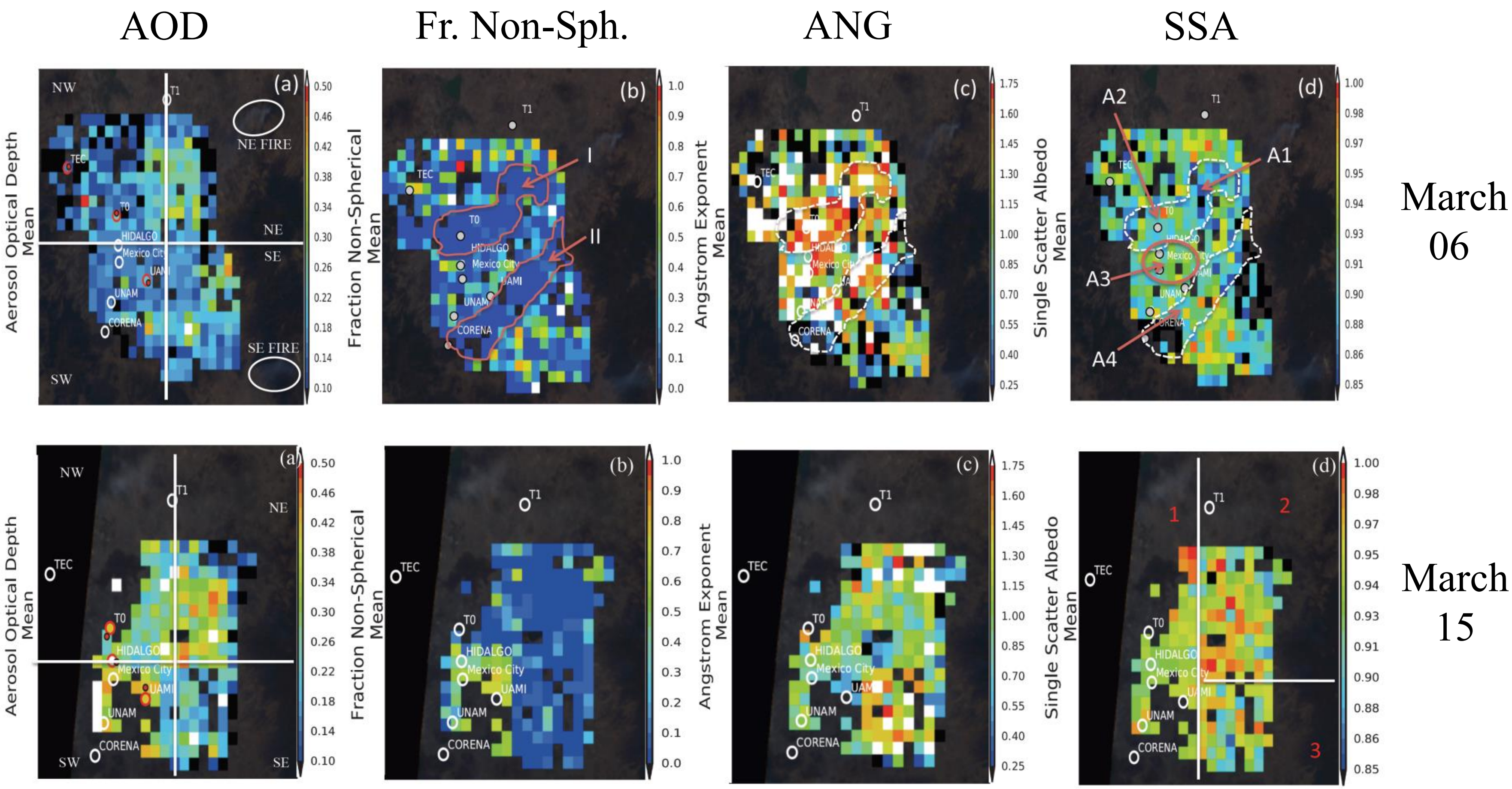
Large
Non-Spherical
Dust
Particles

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



Patadia et al.

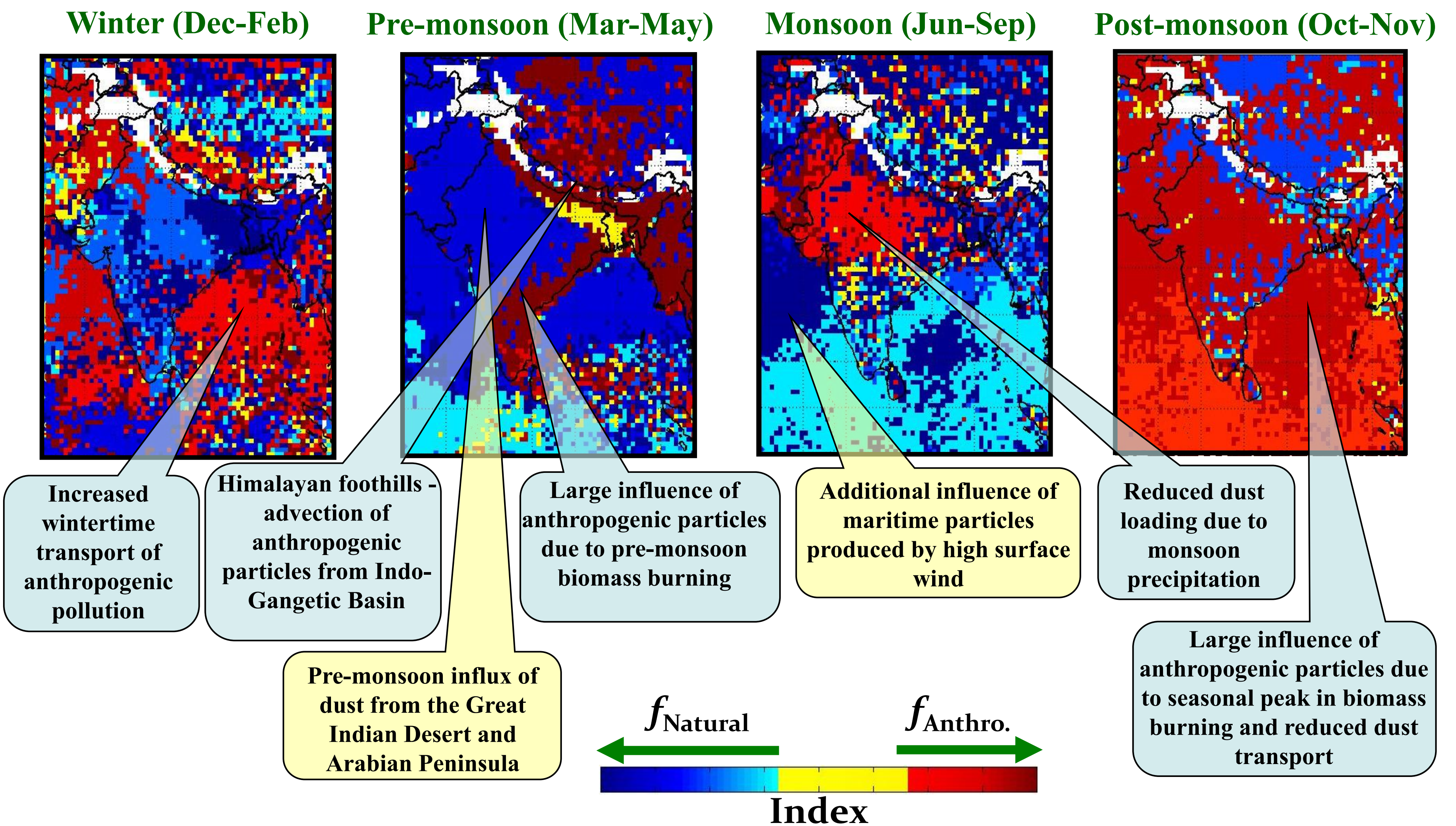
Urban Pollution AOD & Aerosol Air Mass Type Mapping
INTEX-B, 06 & 15 March 2006



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

Characterizing seasonal changes in anthropogenic and natural aerosols w.r.t. preceding season over the Indian Subcontinent



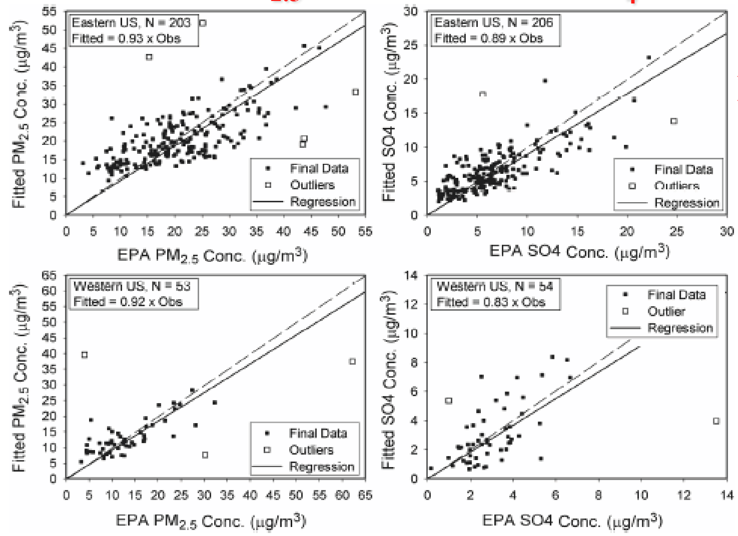
Index uses MISR-retrieved ***particle shape*** and ***size*** constraints to separate natural from anthropogenic aerosol

Dey & Di Girolamo JGR 2010

MISR - GEOS-Chem Regression Model To Map Near-surface Aerosol Component

$PM_{2.5}$ **SO_4**

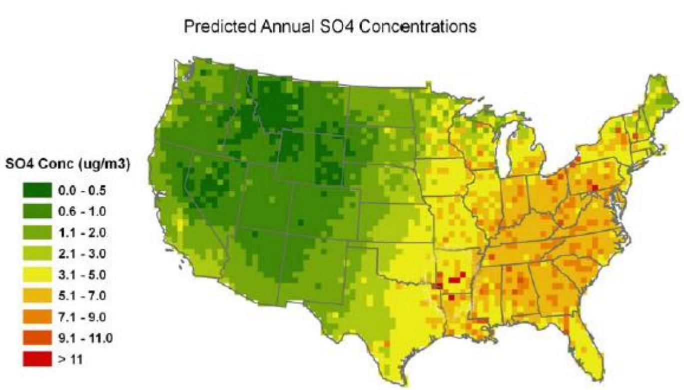
***MISR*-Constrained Model**

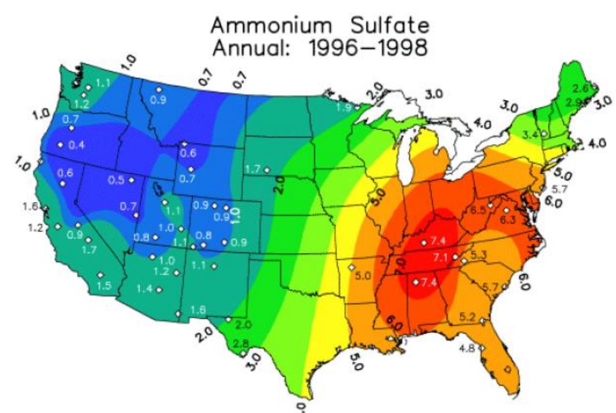


Eastern US

Western US

EPA *Surface* Measurements





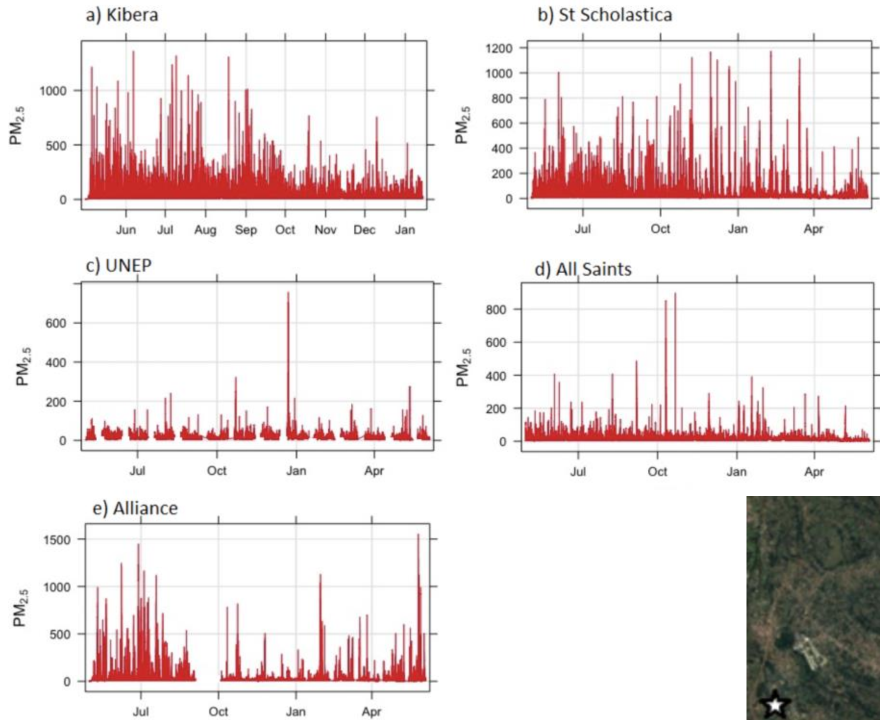
MISR / GEOS-CHEM ***Retrieval*** ***Surface*** network (IMPROVE) measurements

- Using MISR ***Particle Shape*** as well as AOD to constrain model --> much better result
- Can add column ***Size*** and ***SSA*** information when MISR retrieval is more robust

Y. Liu et al, JAWMA 2007

Five Surface-based Low-Cost Optical Particle Counters (OPCs)

Multi-Regression Analysis – Nairobi May 2016 – March 2017



- GEOS-Chem model used to scale MISR AOD to ***near-surface component***
- MISR size distribution used to ***extrapolate from five overlapping OPC size bins*** 0.56 - ~2 μm
- OPCs used to constrain ***surface concentration***

de Souza et al, *RSE* 2020, submitted

MISR Research Algorithm Retrieval Aerosol Properties

Properties Provides:

- **Regional AOD Snapshots**
- ***Size (S, M, L)***
- ***Spherical vs. Non-Spherical***
- ***Absorbing vs. Non-Absorbing***

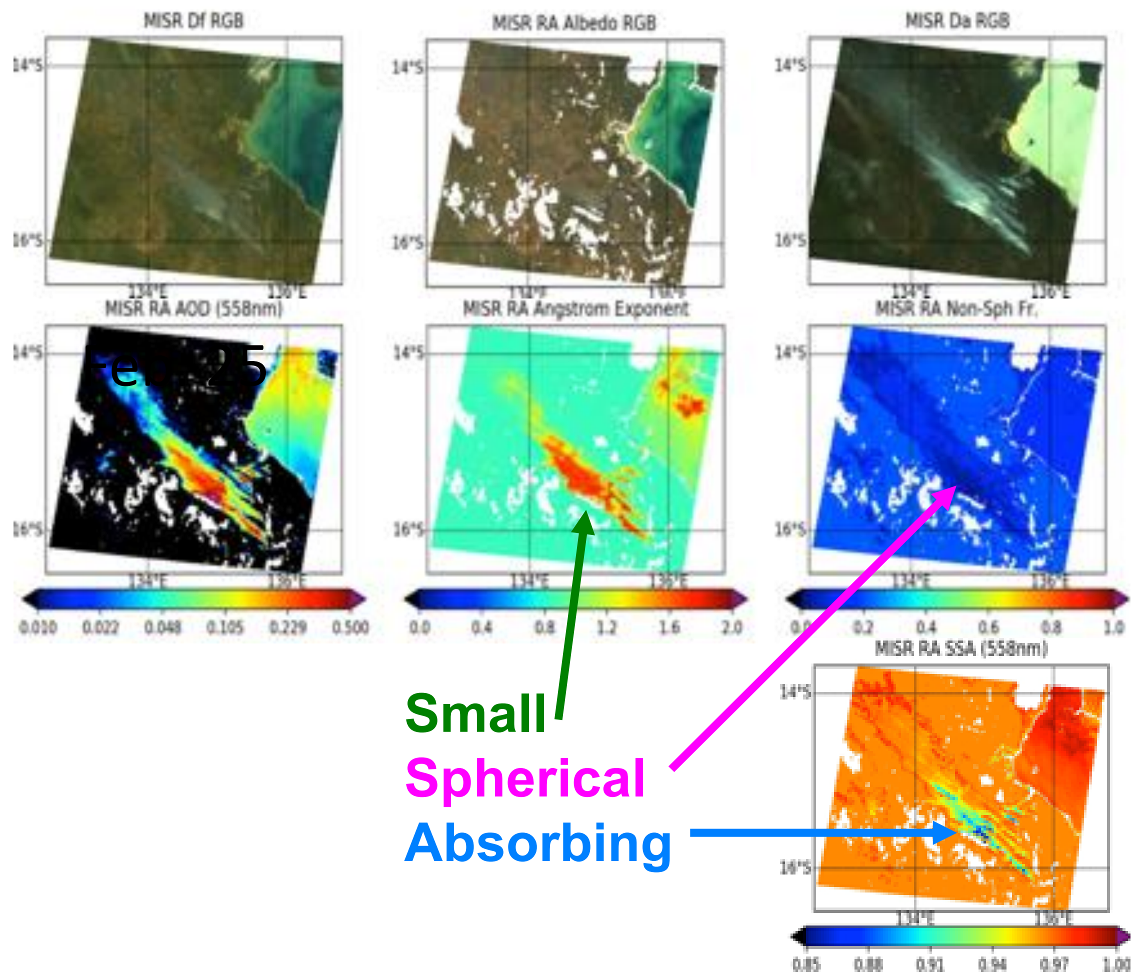
Hydrated Species Partitioning by Microphysical Properties

	Spherical	***Non-Spherical***
Scattering	II, SS, OM, LAC	Dust
Absorbing	OM, LAC	Dust

$$RM\,[\mu g/m^3] = C_{II} + C_{OM} + C_{SS} + C_{LAC} + C_{Dust}$$

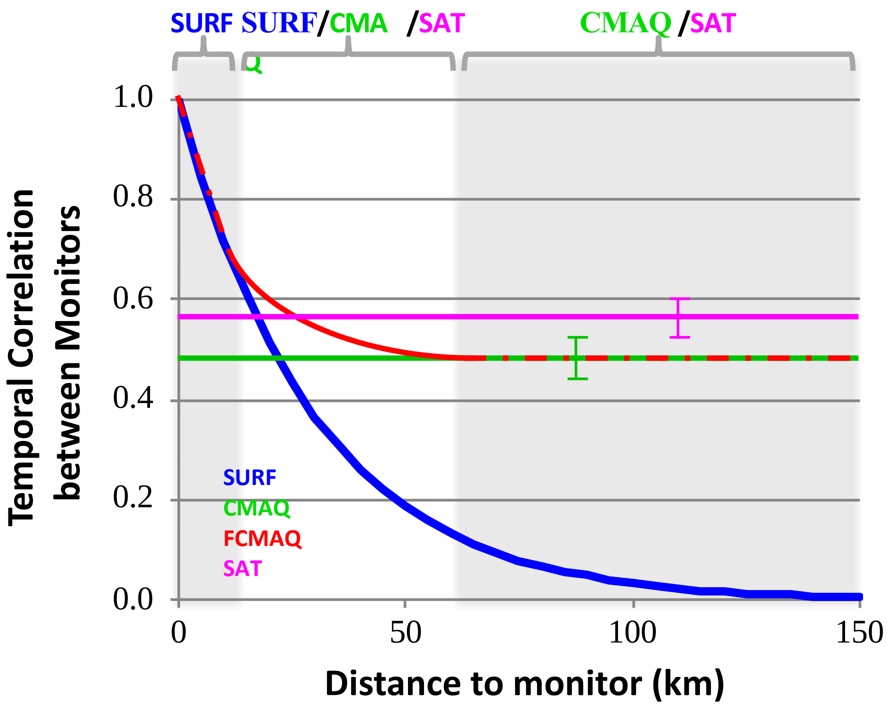
C_{II} = Inorganic Ions [µg/m³]
C_{SS} = Sea Salt [µg/m³]
C_{OM} = Organic Matter [µg/m³]
C_{LAC} = Light Absorbing Carbon[µg/m³]
C_{Dust} = Dust [µg/m³]

Biomass-Burning Northern Australia: 6/6/2012



Friberg et al., ACP 2018

Data Fusion Method Weighting Function



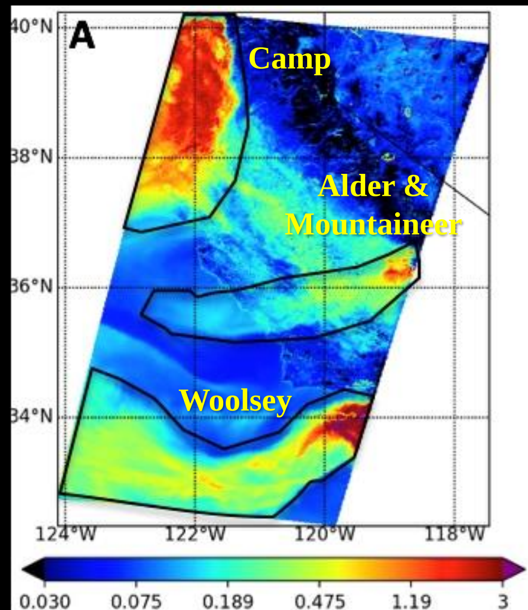
Daily Optimized Fused Fields | *Estimated 2 mo. Mean Fields* | *Daily Interpolated SURF Ratio Fields* | *Weighting Factor* | *Daily Adjusted CMAQ Results Ratio Fields*

Friberg et al., 2016, 2017, 2018

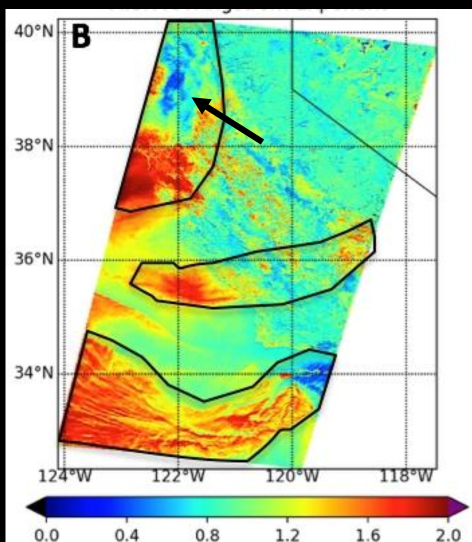
Camp Fire, California

Research Algorithm Retrievals 09 November 2017

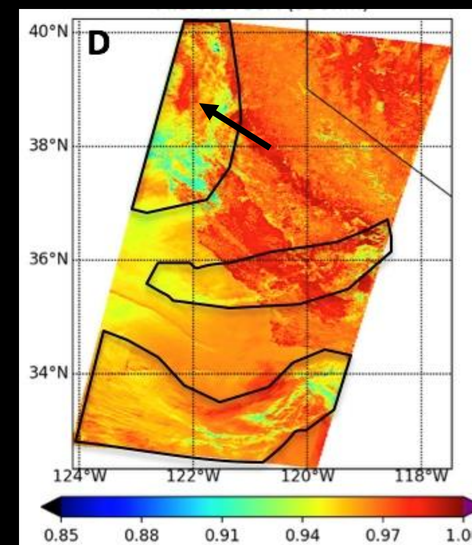
MISR/RA AOD (558 nm)

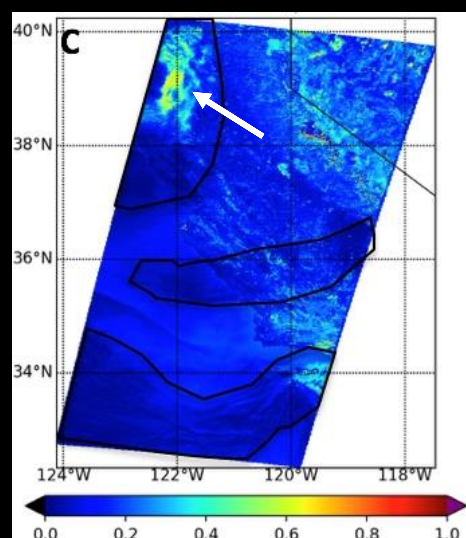


MISR/RA Angstrom Exponent



MISR/RA SSA (558 nm)





MISR/RA Non-SphFr.

Smoke over Paradise (relative to forest):
Larger, Brighter, more Non-Spherical

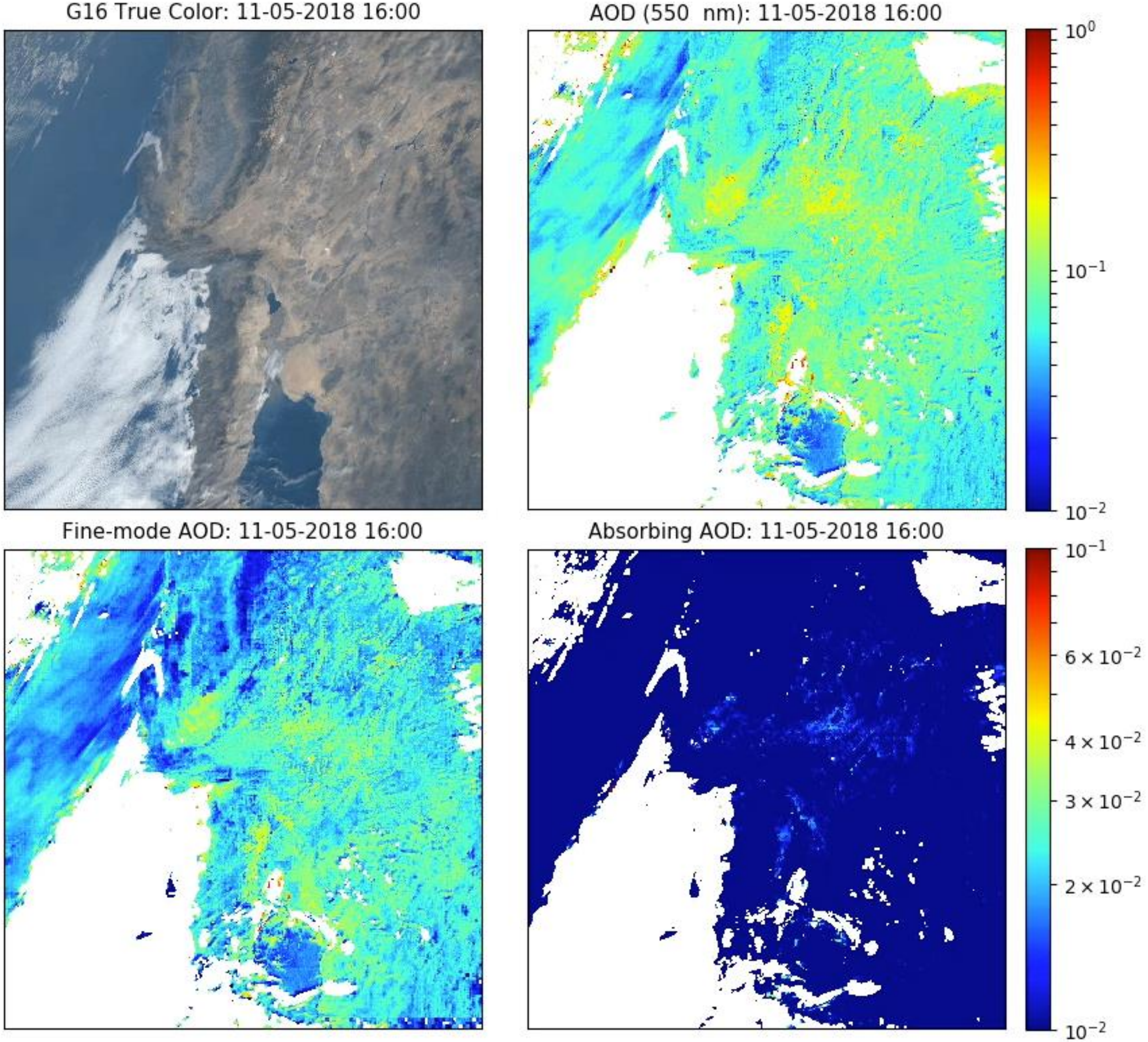
R. Kahn, *EOS*, Feb. 2020

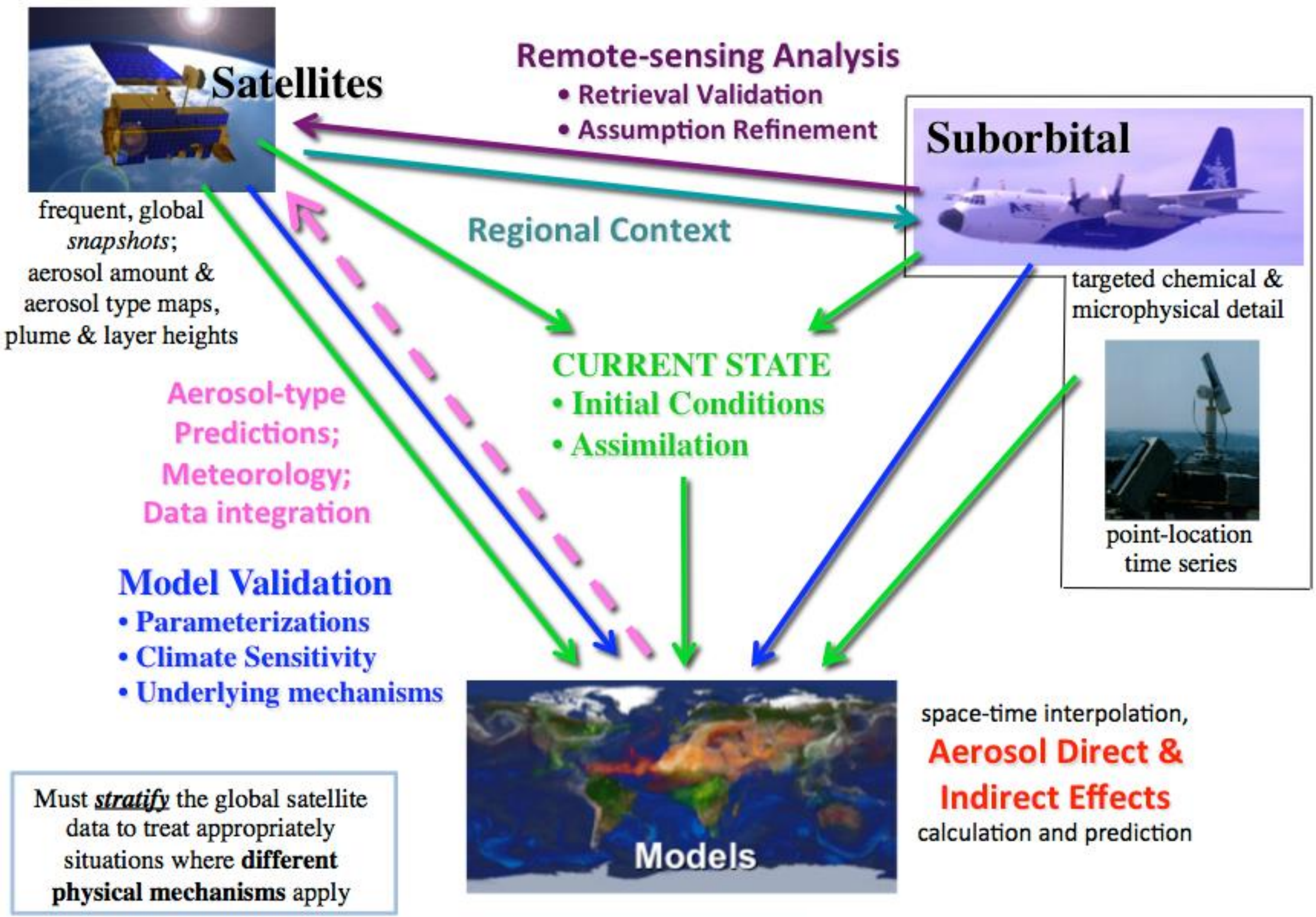
Multi-Angle Geostationary Aerosol Retrieval Algorithm

James Limbacher PhD Thesis Project

- Every **5-15 minutes**:
  - -- **Fine-mode fraction** (averaged over 5x5 pixels)
  - -- **550 nm AOD** (retrieved for each pixel/time)
- **Daily** (for each pixel):
  - -- Fine-mode **effective radius**
  - -- Fine-mode **spectral SSA**
  - -- Coarse-mode **sphericity**

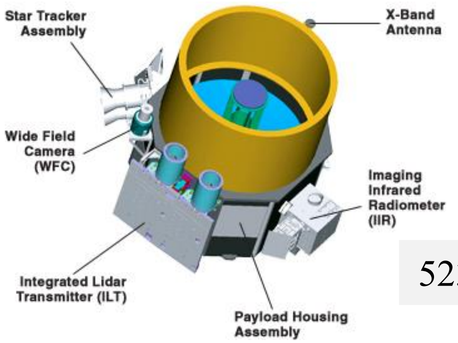
Camp Fire: 11/8-11/9 (2018): **GOES-R Only**





Adapted from: Kahn, Survy. Geophys. 2012

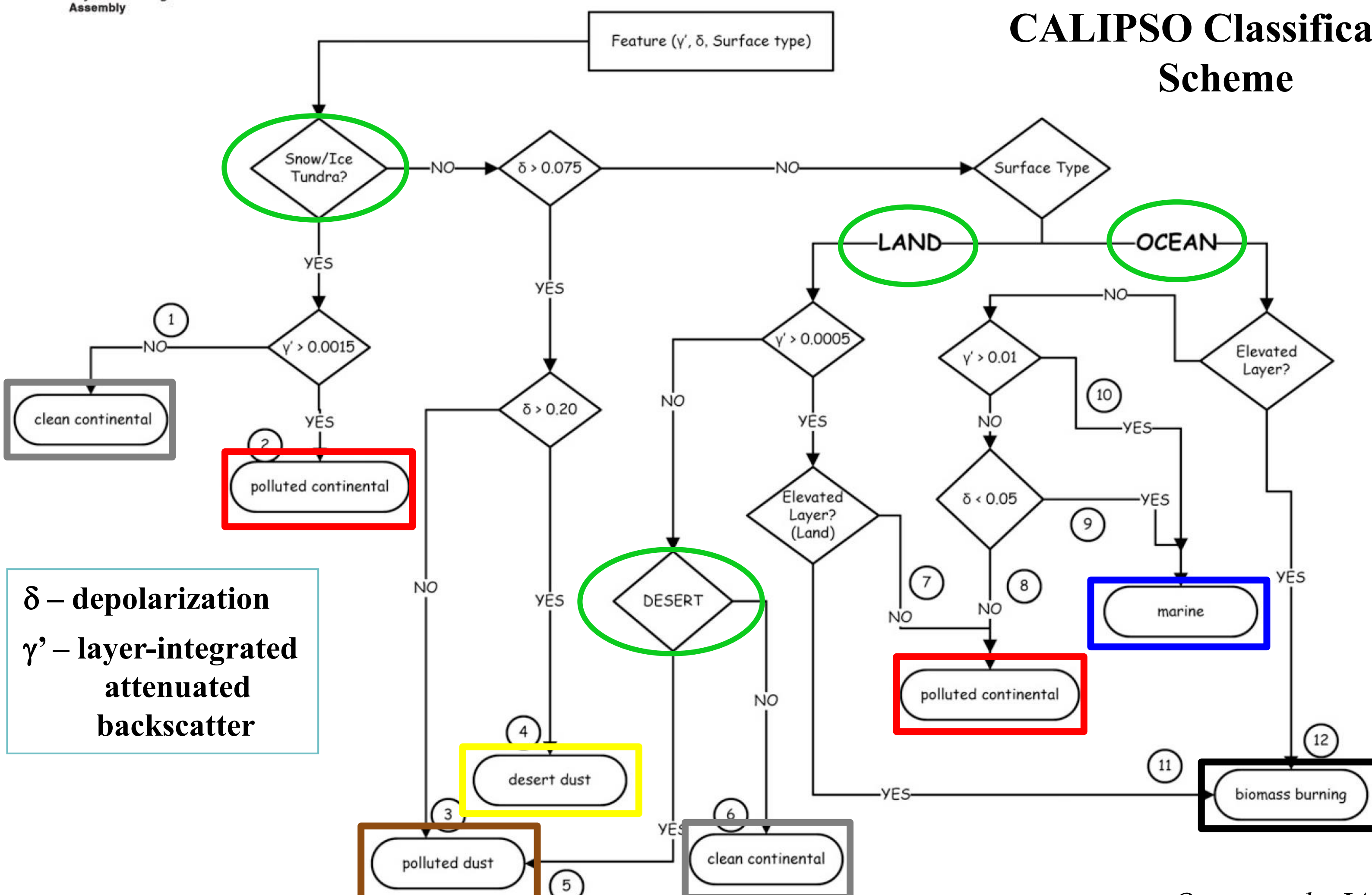
Backup Slides



CALIPSO 6-Type Interpretive Aerosol Classification Scheme

523 and 1064 nm channels; ~100m horizontal resolution

CALIPSO Classification Scheme

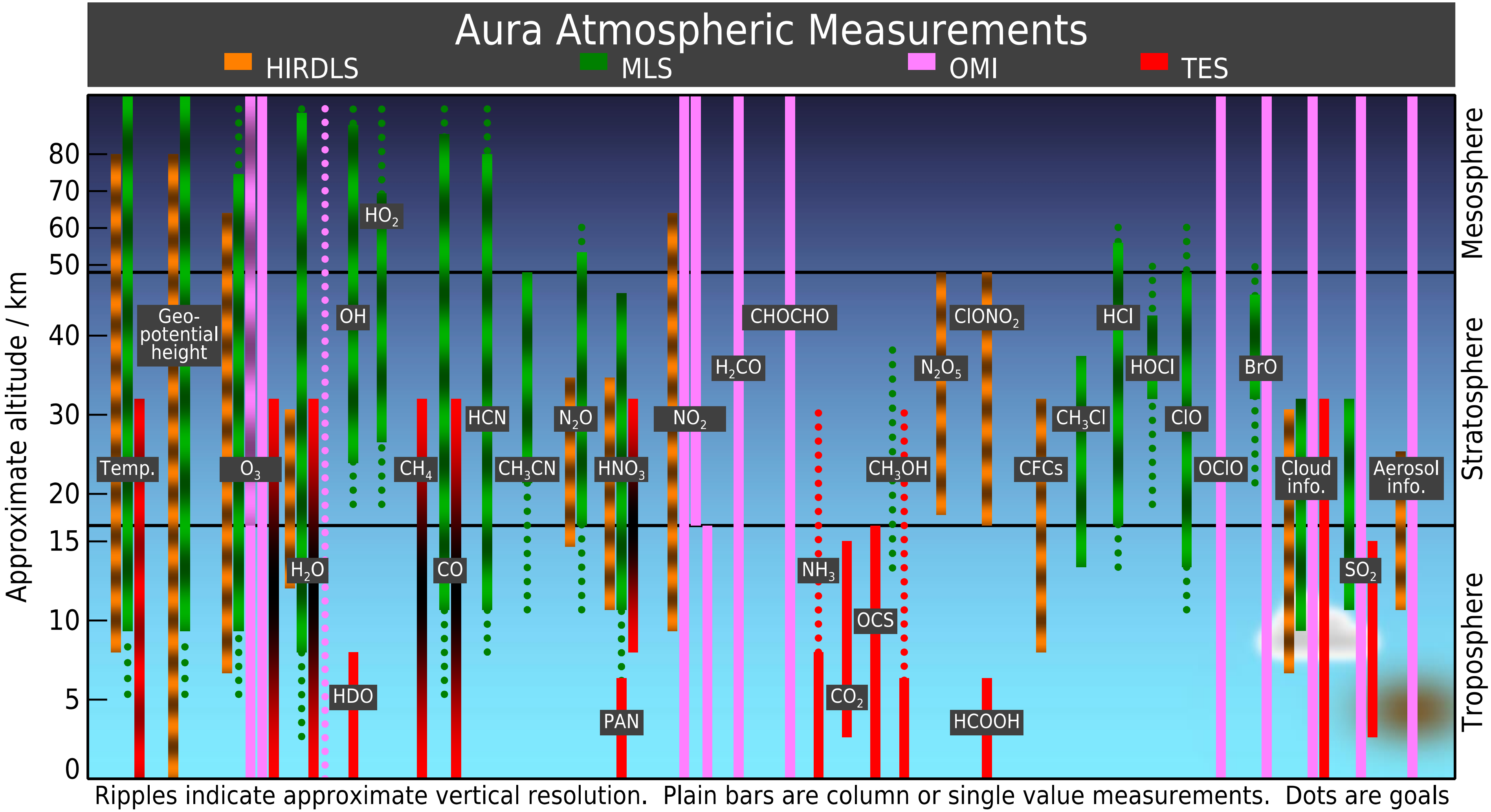


δ – depolarization

γ' – layer-integrated attenuated backscatter

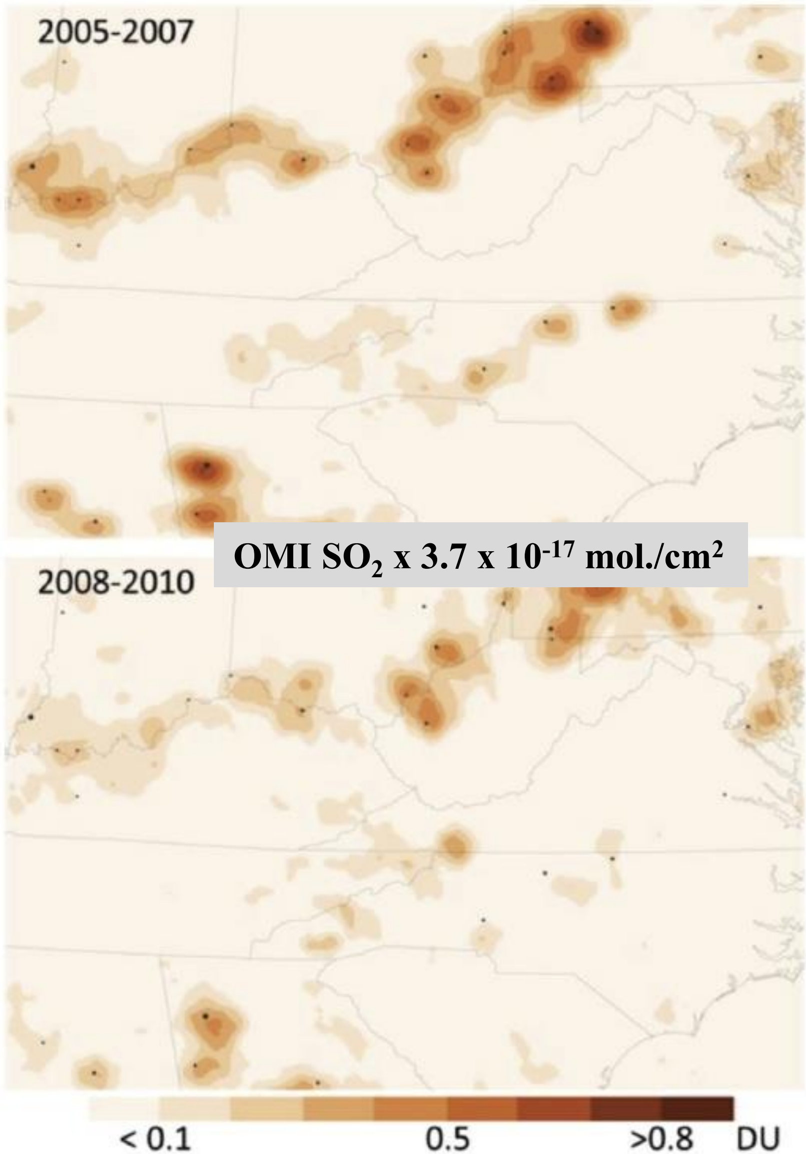
Omar et al., JAOT 2009

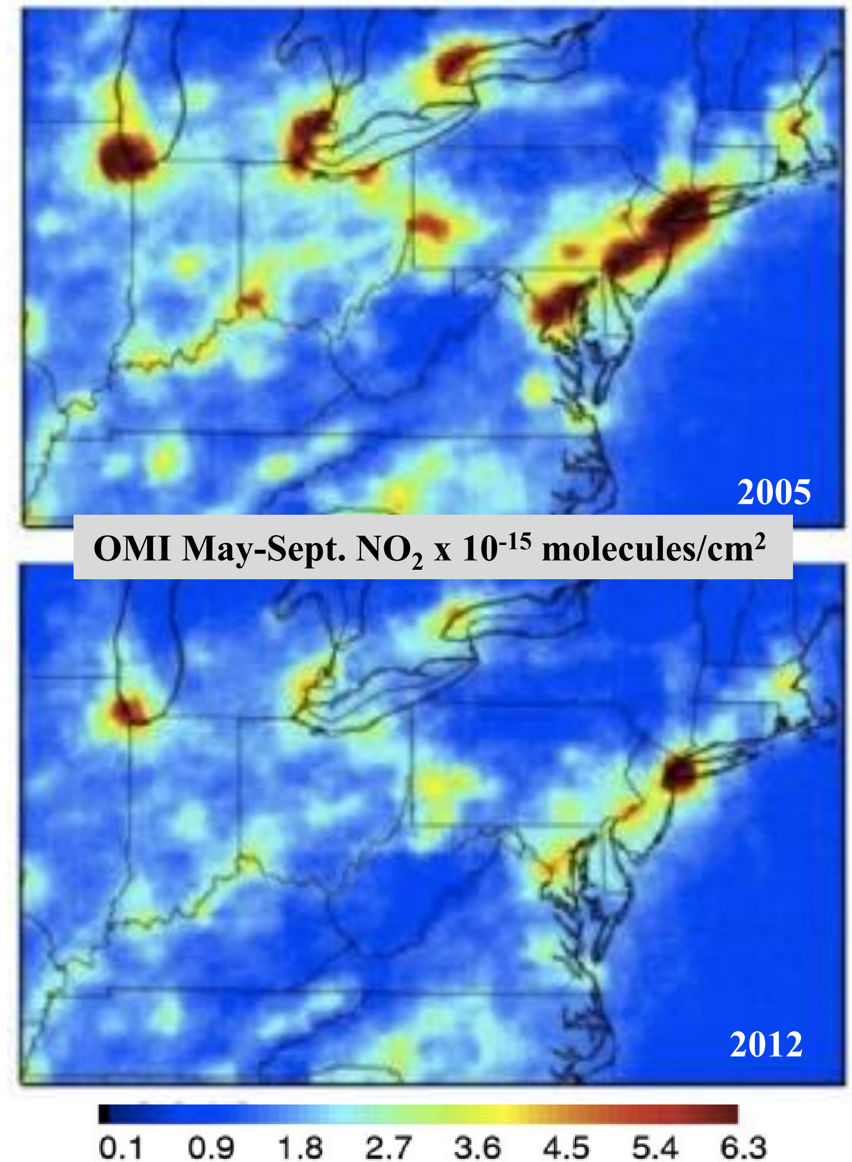
Gas Retrievals are more Species-specific But also Difficult to Resolve Vertically



Aura Project Publication

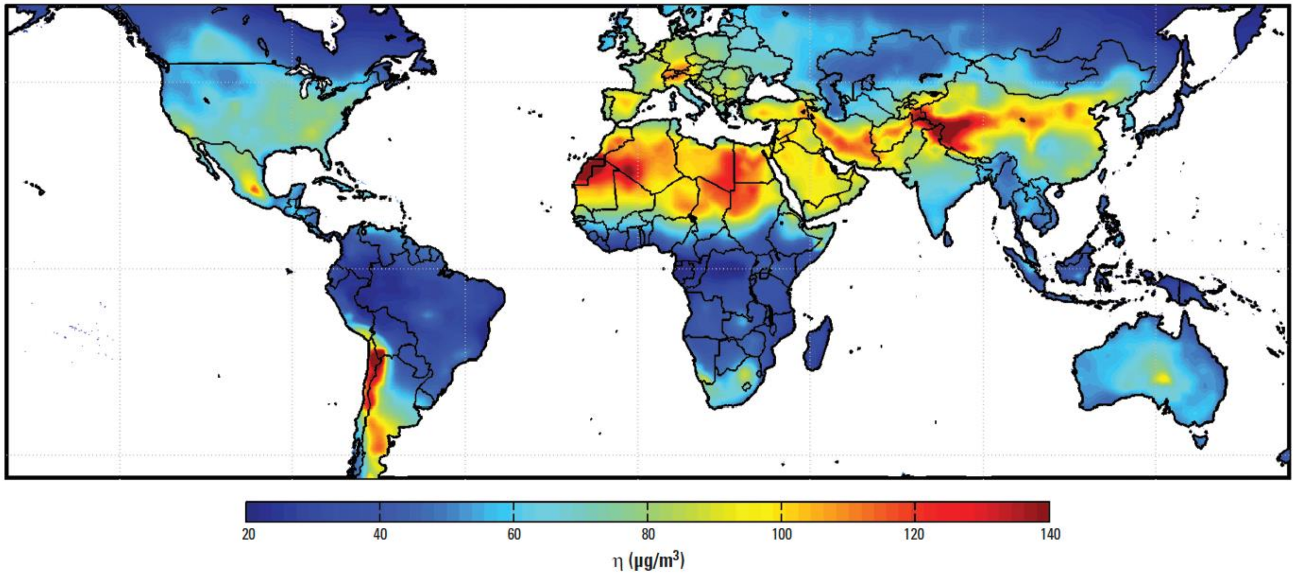
SO_2, NO_2 from OMI (Ozone Monitoring Instrument) UV *Spectra*



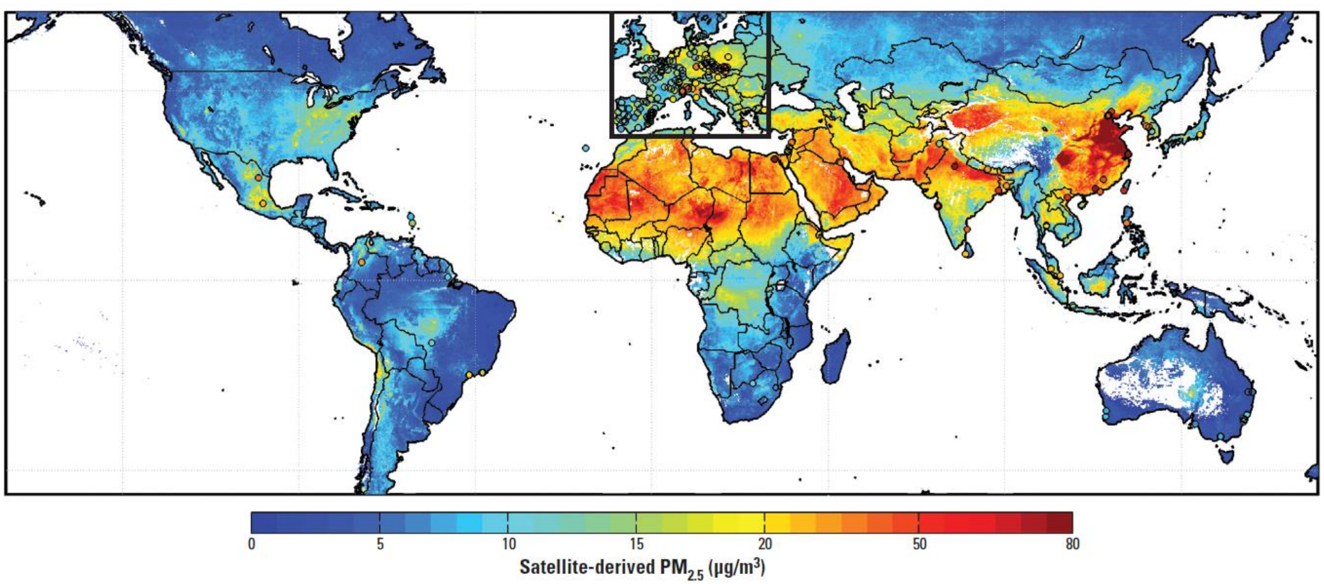


Duncan et al., Atm. Env. 2014

Air Quality: BL Aerosol Concentration
[MISR + MODIS] AOD & GEOS-Chem Vertical Distribution



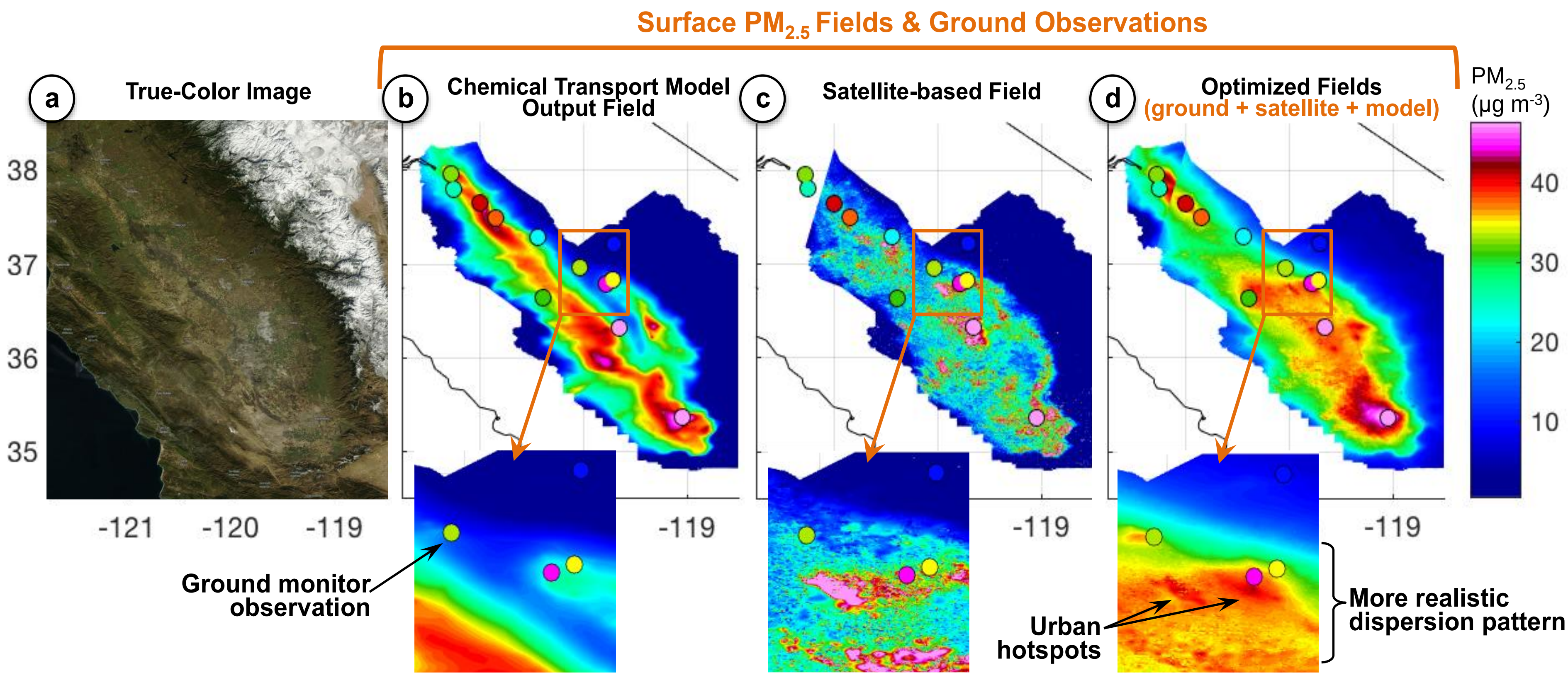
[BL $PM_{2.5}$] / [Total-col. AOD]
2001- 2006



Derived $PM_{2.5}$

Van Donkelaar et al., Environ. Health Prespect. 2010

A Close-up of the Results using the Physical Approach



Science Question: How can we use aerosol data from satellites and ground monitors to improve regional air quality (AQ) model predictions of airborne fine particles?

Impact: Satellite aerosol-attribute products provide regional context and decrease error and uncertainty in surface AQ characterization.

Friberg et al., ACP 2018