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Navy Aerosol Analysis and Prediction System: Status and Updates

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International Cooperative for Aerosol Prediction
Monterey, California
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In This Talk

- *Navy Aerosol Analysis and Prediction System (NAAPS)*
- *Status by components*
  - *Forecast model update*
  - *Cylc update*
  - *DA update*
  - *Expanded verification*
- *NAAPS as a tool for science*
  - *NAAPS-reanalysis*
  - *Multi aerosol reanalyses intercomparison*
  - *Global AOD Trend*
  - *Arctic study*

Navy Aerosol Analysis and Prediction System (NAAPS)

The Navy forecasts global aerosol transport to support tactical operations and decision-making

- ***Global forecasts 4x/day of dust, biomass burning smoke, sea salt, anthropogenic and biogenic fine aerosols.***
- ***1/3-degree spatial resolution***
- ***35 vertical levels from surface to 100hPa***

1. Can you tell us when this is coming?
2. How long until we can see again?

Haboob dust.18 July 2009
Phoenix Sky Harbor Intl.

Wildfire
26 October 2007
Channel Islands Air National Guard Base

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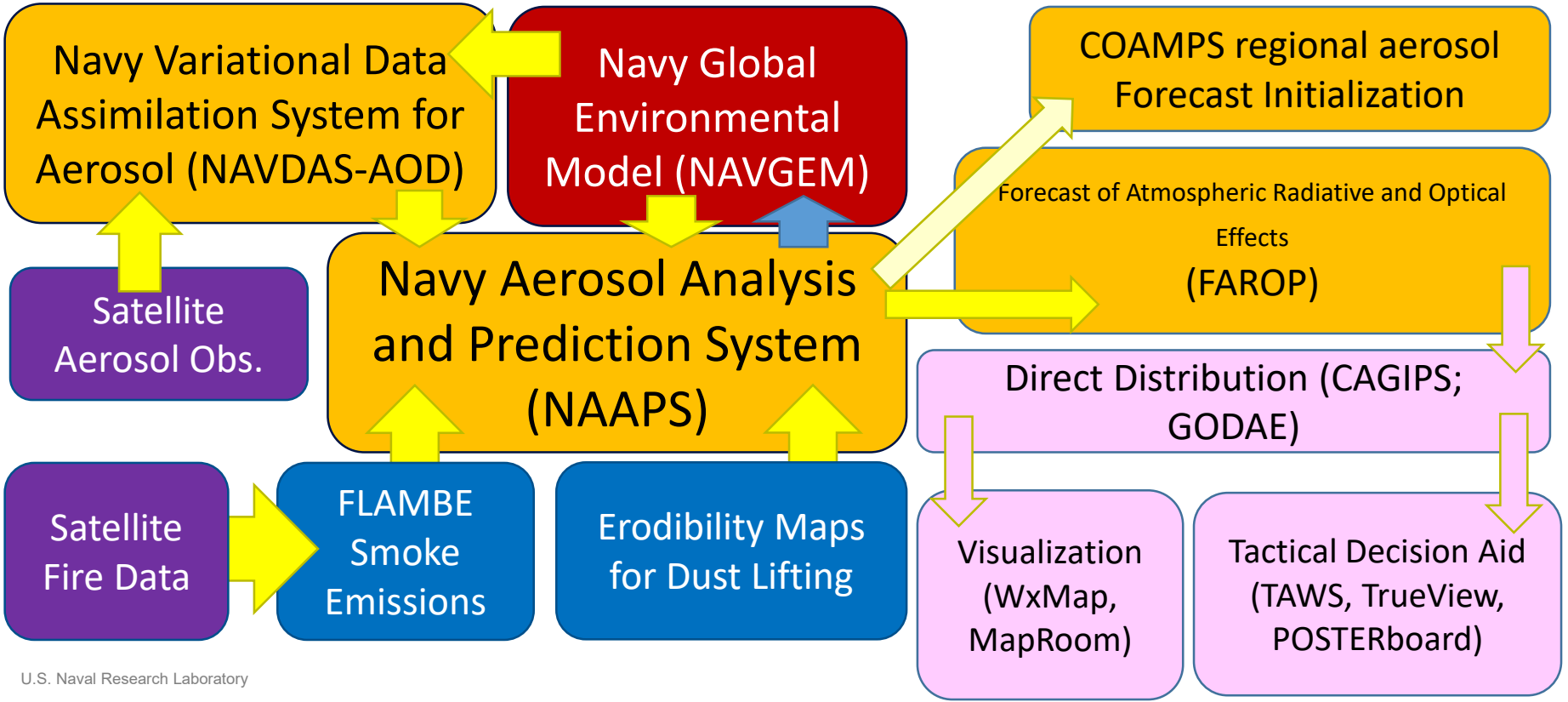
Navy Operational Aerosol Ecosystem

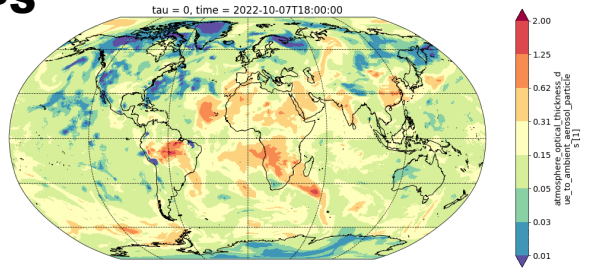


NAAPS 2.0: an advance to facilitate more advances – skill upgrades

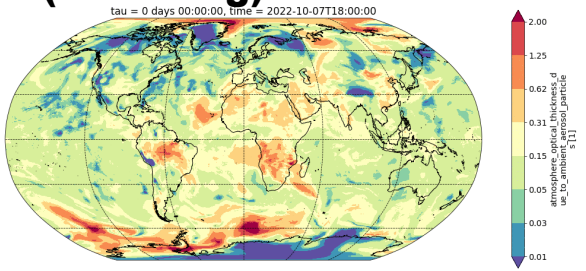
Forecast skill improvements in NAAPS 2.0

- Increased horizontal resolution to 0.25 degree
- 2DVAR at full model resolution
- Fixed some bugs in NAVDAS-AOD climatology and numerics (interpolation)
- NRT runs underway, still in “shakeout”

OPS



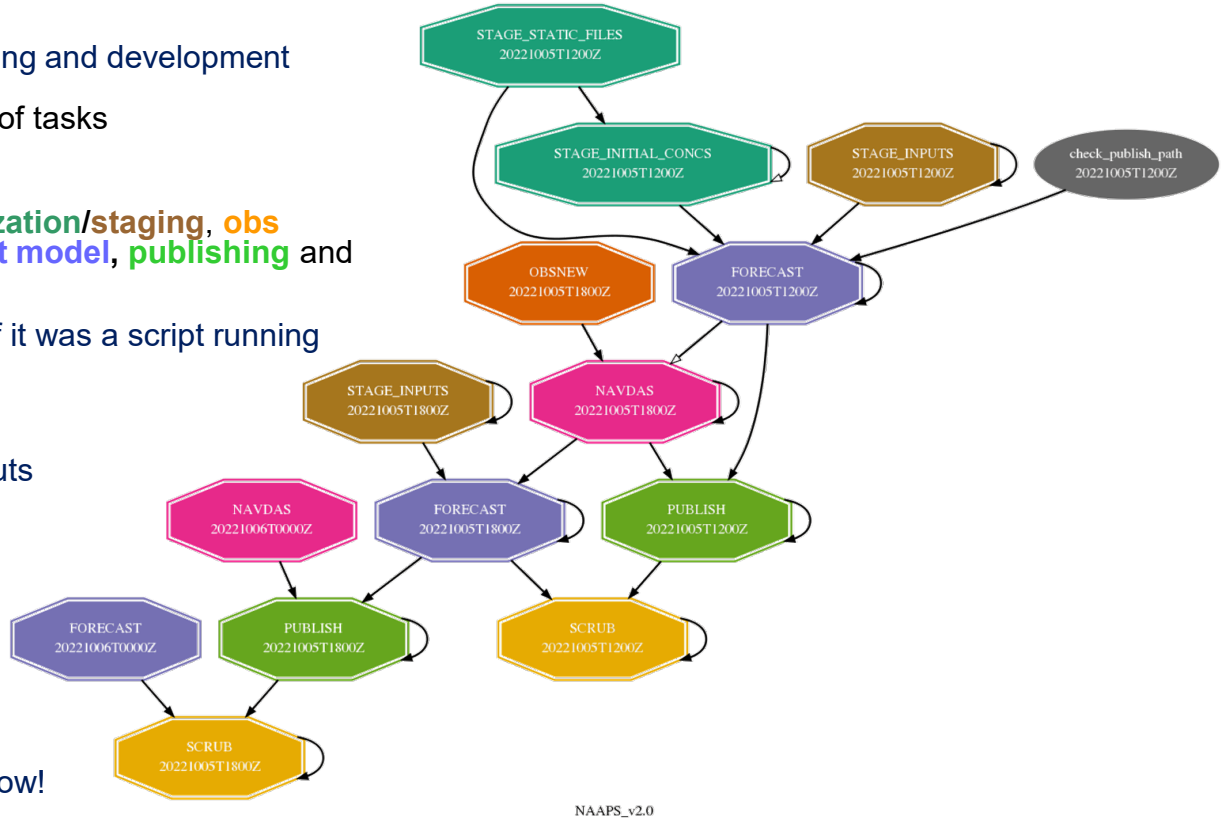
NEW(in testing)



NAAPS 2.0: an advance to facilitate more advances – cylc workflow

Cylc: a power tool for cycling forecast, debugging and development

- NAAPS 2.0 suite manages dozens of tasks
  - Sequential and simultaneous
  - Grouped into families: initialization/staging, obs processing, DA and forecast model, publishing and cleanup
- Cylc lets us work with the suite as if it was a script running interactively in iPython or IDL
  - Pause suite after any task
    - examine intermediate outputs
    - Modify configurations
    - Modify scripts
    - Modify source code
    - and recompile binaries
  - Start again
    - from any point in the workflow!



NAAPS_v2.0

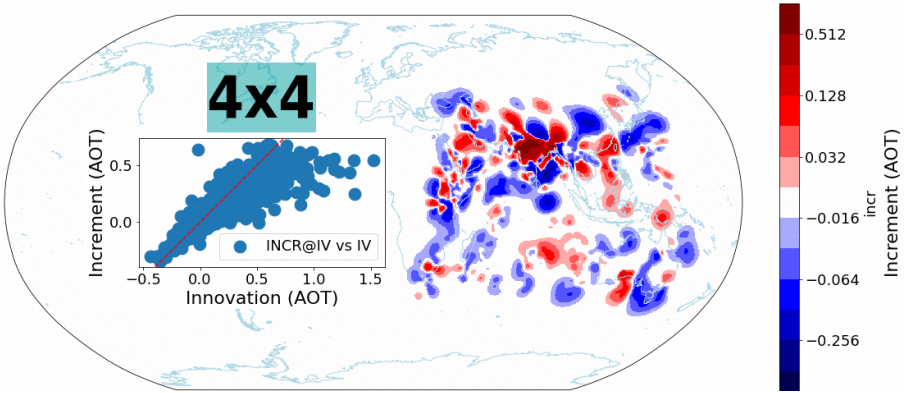
NAAPS 2.0: an advance to facilitate more advances – NAVDAS-AOD in Python

2D variational AOD assimilation is a simple method with many, many significant permutations

- Forward calculation: model space --> control variable
- And of course model uncertainty
- Ob processing(*) (and conversion to control variable)
- And of course ob uncertainty
- Computation of increment based on innovation(*)
- Generation of initial condition based on increment

All steps except (*) are now implemented in pure Python

Super-simple testbed to quickly evaluate permutations to both data and methods



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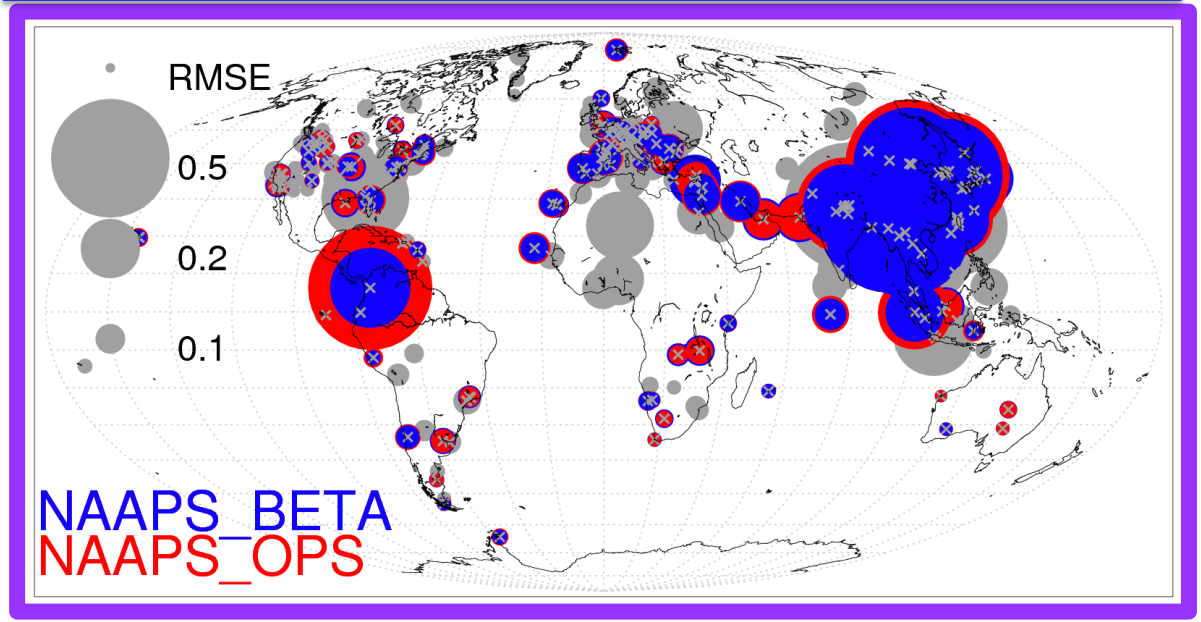
Verification Pathways for NAAPS/FAROP

Parameter	Units
Concentration	mg/m^{-3}
Scattering Extinction / Total Extinction	km^{-1}
Aerosol Particle Asymmetry	NA
Aerosol Optical Depth	NA
Visible Range	M

AERONET 550nm AOD has been the verification used for NAAPS verification since NAAPS v1.0



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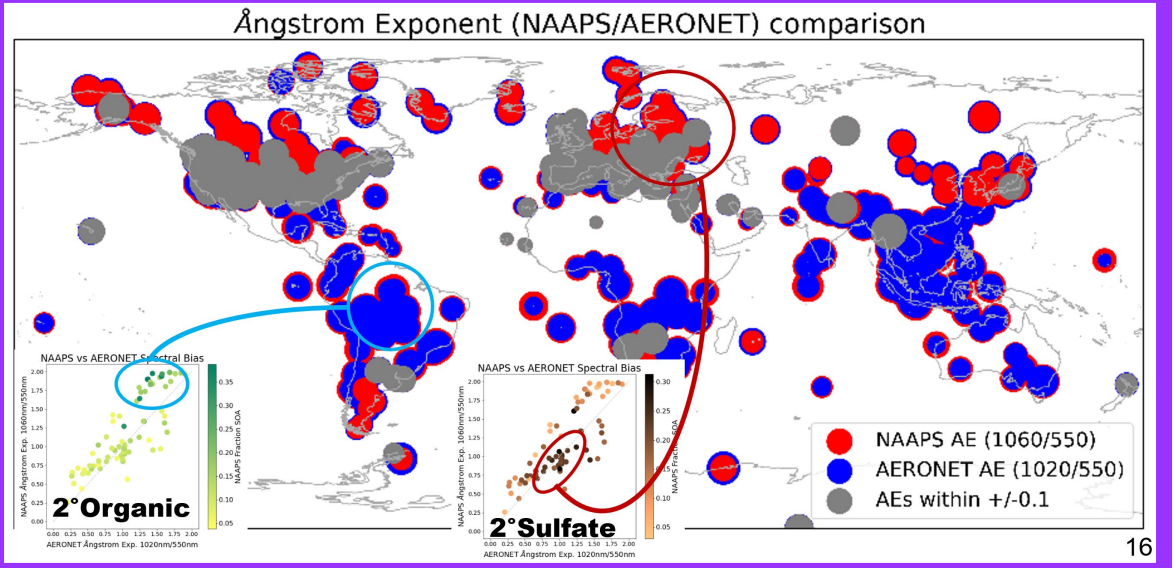
NRL has begun to unlock advanced AERONET verification (multi-wavelength analysis, almucantar retrievals)



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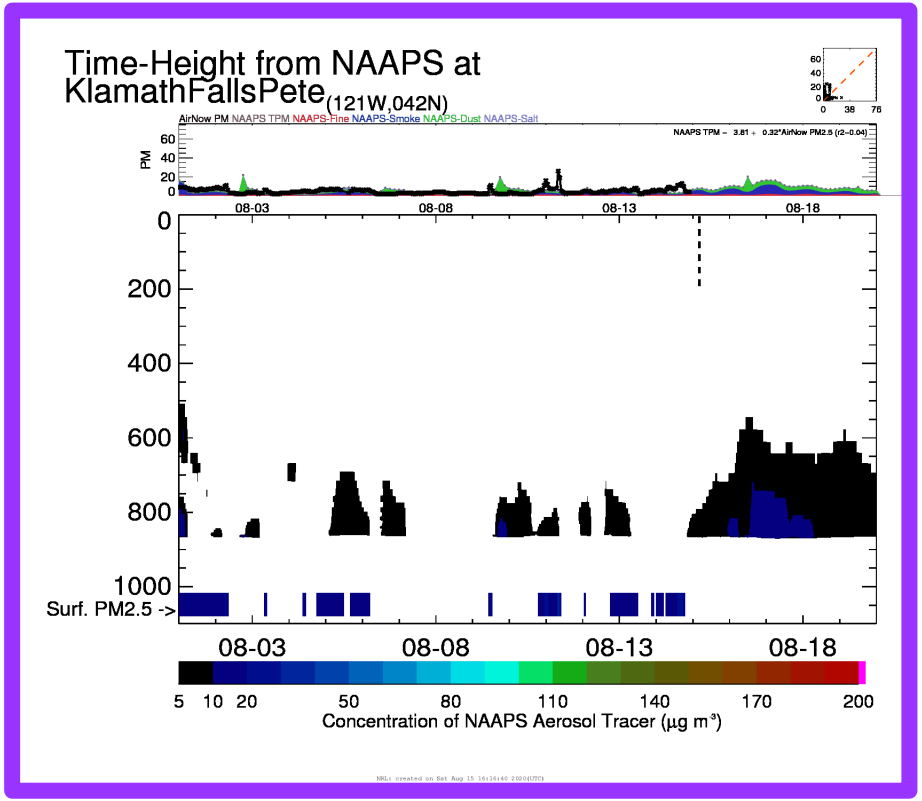
NRL verifies NAAPS against EPA AirNow surface PM (US stations only)



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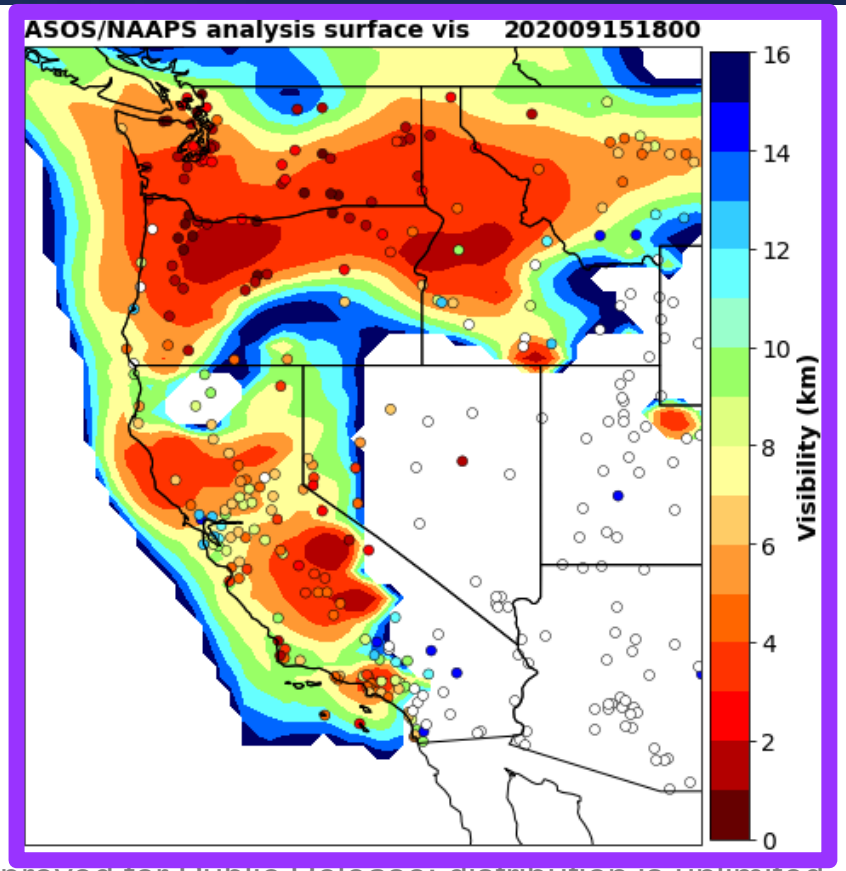
NRL has (re)built a surface visibility verification capability using ASOS



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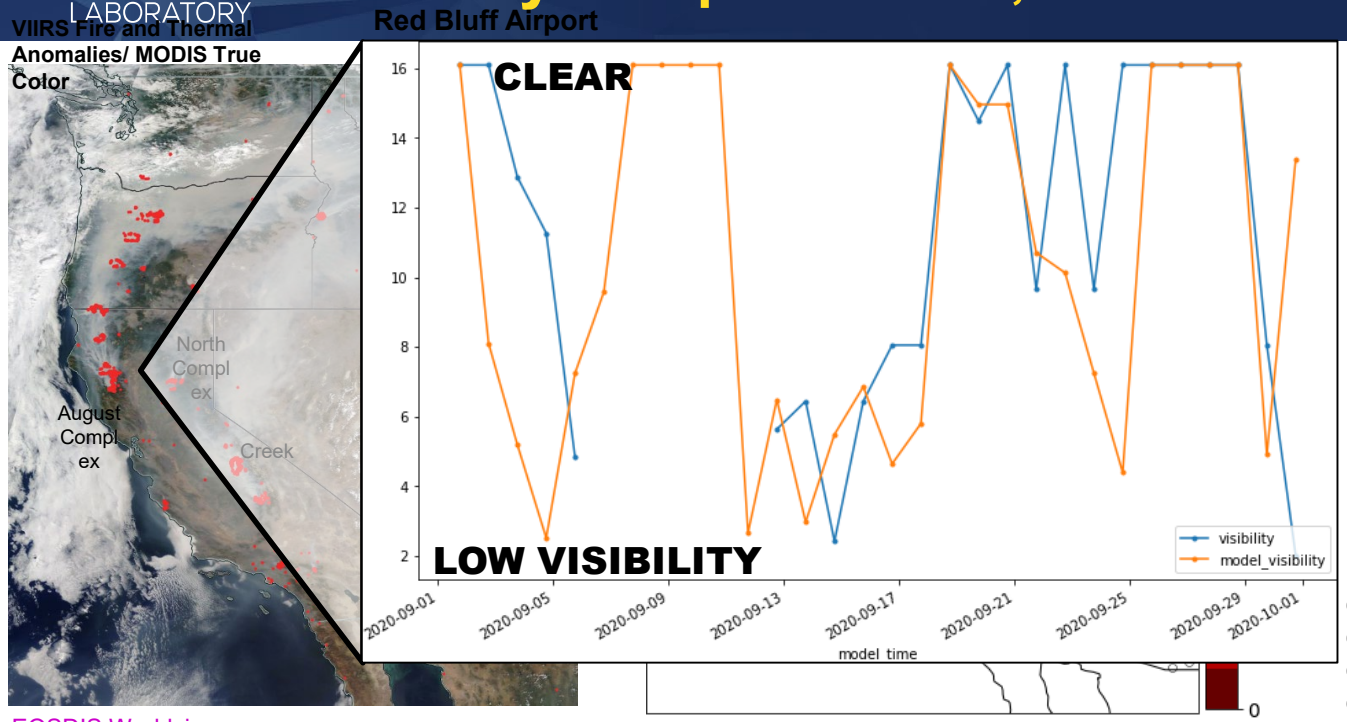
Assessing aerosol impacts through the lens of visibility – September 15, 2020 Western U.S. Wildfires



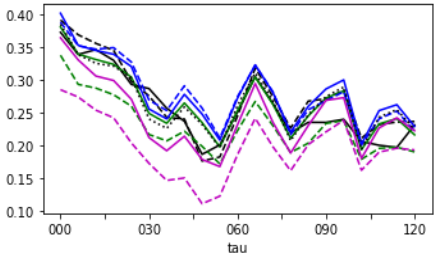
NAAPS surface visibility derived from surface extinction

Surface visibility for 5% detection contrast following Koschmieder model:

$$Visibility = 3/b_{ext}$$

ASOS data for FAA/NWS stations obtained from NOAA.

Sept 2020 WCONUS NAAPS verification (Heidke skill score for events <5km) (vs forecast length, Lines are different QC)



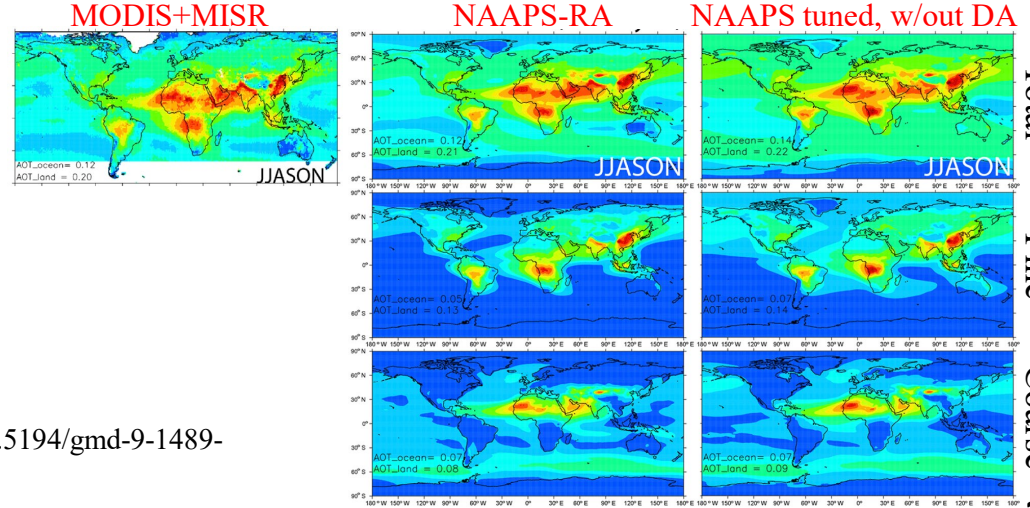
EOSDIS Worldview (nasa.gov)

Satellite shows swaths of smoke across the West U.S. But what are the impacts at different levels of the atmosphere? At the surface?

Can we estimate these impacts? How can we verify those estimates?

NAAPS-RA v1

- NAAPS 4D chemical transport model w/ NOGAPS/NAVGEM NWP analysis fields
- Species: anthropogenic and biogenic fine (ABF, organics included), dust, smoke and sea salt.
- End product: global 1x1 deg lat/lon, 6hrly, modal AODs @550nm 2003-2019.
- Assimilates fused QA/QCed MODIS C5 AOD and MISR AOD through NAVDAS-AOD (2Dvar).
- Use FLAMBE MODIS-only 2-day-max product for biomass burning emission.
- Regionally (16 regions) tuned smoke and dust emissions.
- Aerosol removal parameters tuned using AOD assimilation corrections.
- CMORPH (a satellite product) precipitation replaced model precipitation over the Tropics.
- Fine, coarse and total AODs @550nm validated with AERONET.
- Tuning on the sources and sinks is equally important as AOD data assimilation upon model performance.



Citation: Lynch, P., et. al. Geosci. Model Dev., 9, 1489-1522, doi:10.5194/gmd-9-1489-2016, 2016

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AOD Reanalyses Intercomparison

- **Aerosol Reanalyses:**

NRL NAAPS-RA speciated AOD at 550 nm (Lynch et al. 2016): 2003-2019
NASA MERRA2 speciated AOD at 550 nm (Randles et al. 2017): 2003-2019
ECMWF CAMSRA speciated AOD at 550 nm (Inness et al. 2019) : 2003-2019
JMA JRAero speciated AOD at 550 nm (Yumimoto et al., 2017); 2011-2019.
Multi-Reanalysis-Consensus based on the three/four reanalyses.

- **Remote Sensing :**

MODIS v6 QA/QCed AOD at 550 nm
AERONET V3L2 (Giles et al, 2019) with Spectral Deconvolution Algorithm (SDA, O'Neill et al. 2001, 2003)

Method:

- The 550 nm AOD was employed as the benchmark parameter for this study.
- Use fine mode (FM) and coarse mode (CM) AOD derived from AERONET with SDA.
- The species of interest: biomass burning (BB) smoke, anthropogenic and biogenic fine aerosols (ABF) in NAAPS, and its equivalent of sulfate for MERRA-2, CAMSRA and JRAero, dust and sea salt aerosols.
- Sum of OC/OA+BC used to approximate BB smoke from CAMSRA, MERRA-2 and JRAero.

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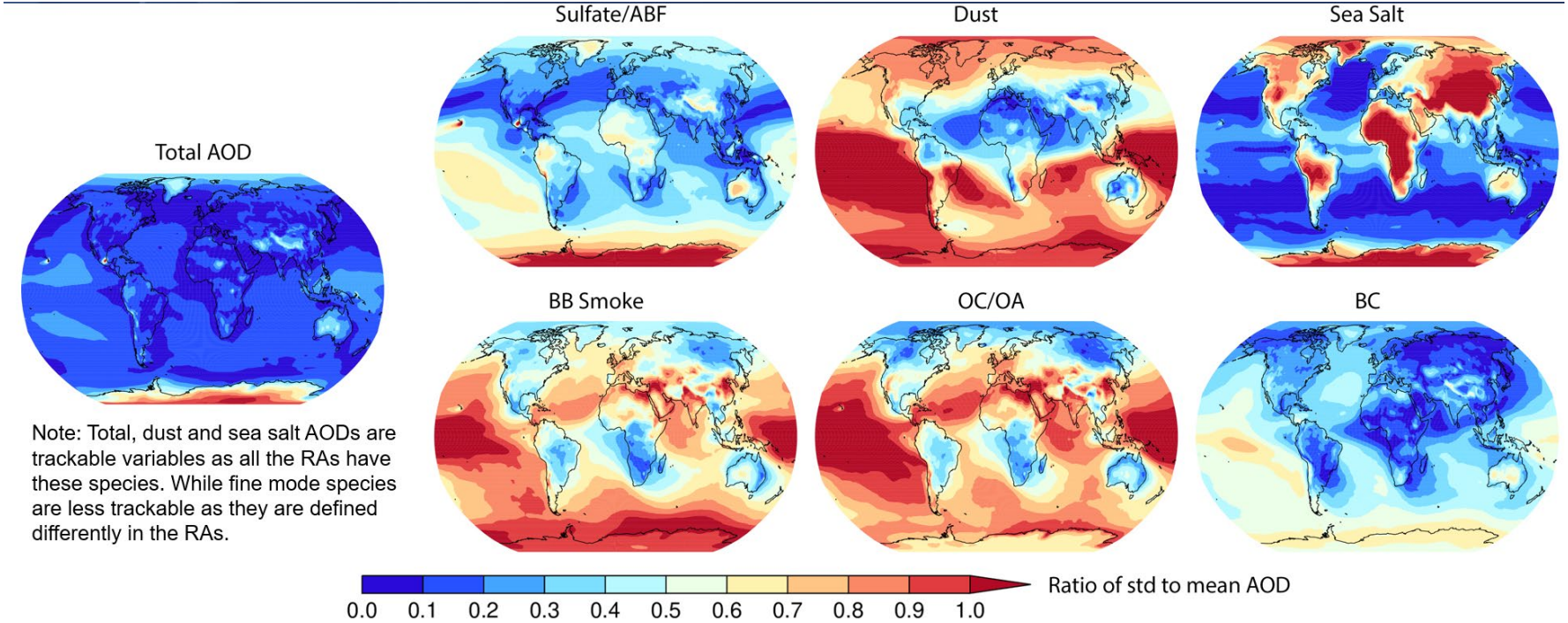
Reanalyses AOD Spread



Note: Total, dust and sea salt AODs are trackable variables as all the RAs have these species. While fine mode species are less trackable as they are defined differently in the RAs.

Relative spread (ratio of standard deviation of the reanalyses AOD to the mean)

- Small for total AOD (except for polar regions and a few hotspots),
- But can be large for speciated AODs, especially in regions remote to aerosol sources.

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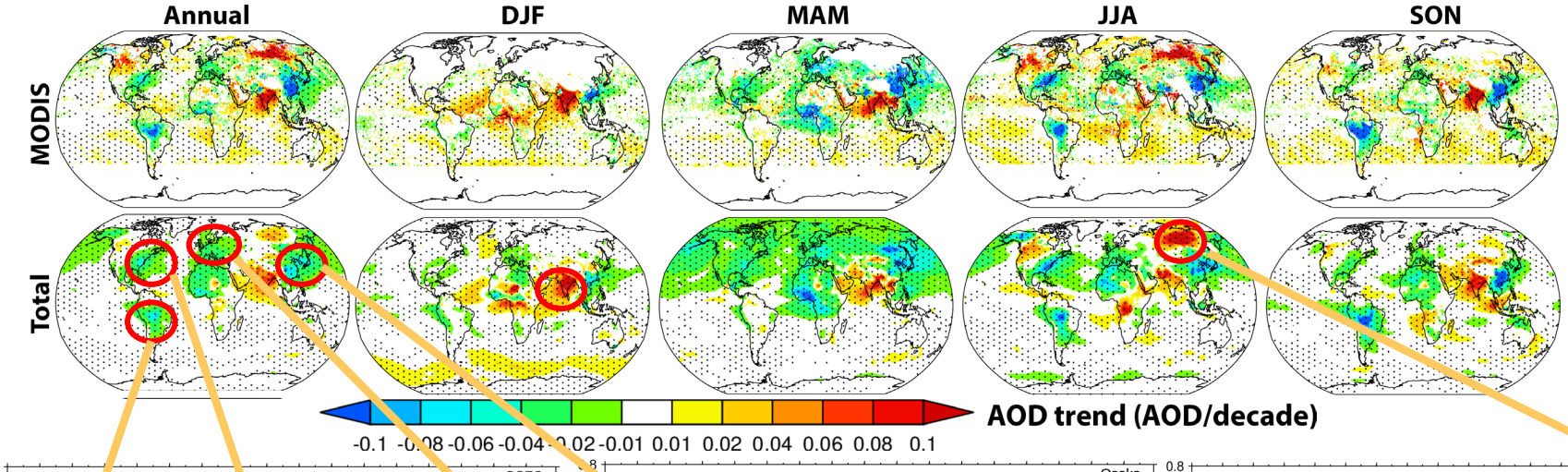
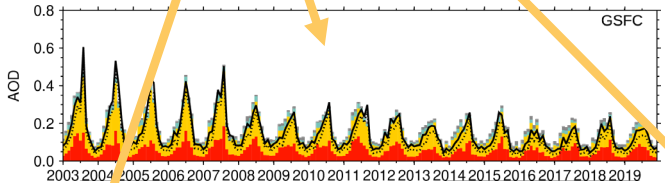
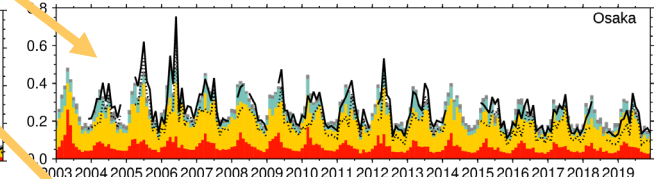
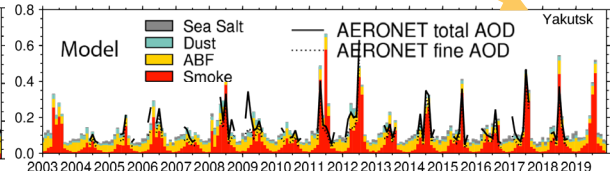
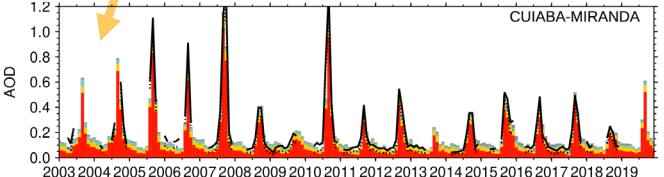
AOD trend (2003-2019)

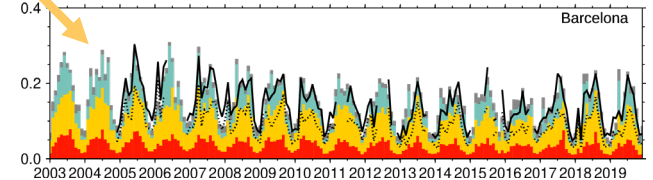












- Sulfate/ABF decreases in East US. Europe, East Asia, resulted from anthropogenic emission reductions; Increases in India.
- BB smoke: decreasing trend in South America and increasing trend in Boreal regions (especially in JJA).

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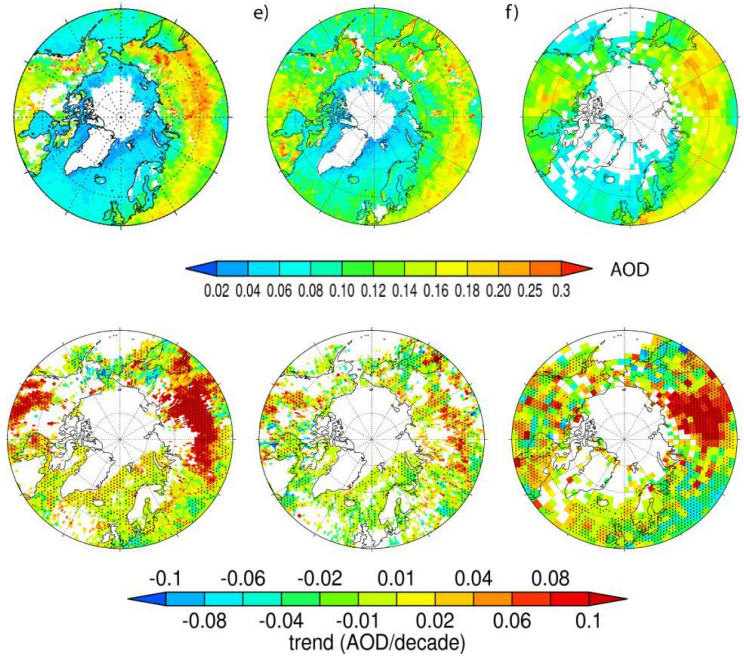
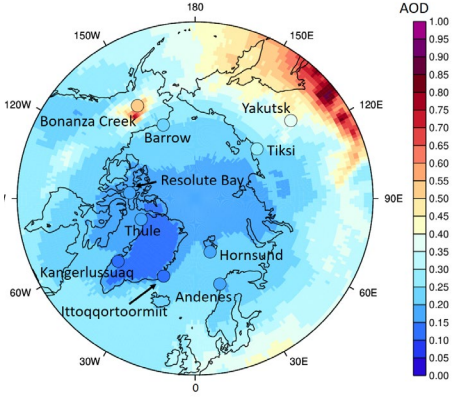
Arctic spring and summertime AOD baseline : climatology, trend, and statistics of extreme events

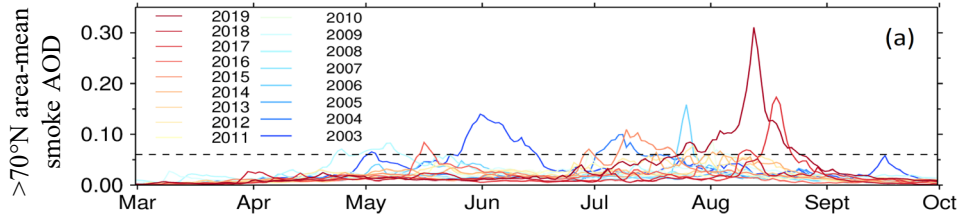


Citation: Xian et al., ACP 2022a, 2022b



AOD at 95th percentile for the March-August time frame from the NAAPS-RA and ten AERONET sites (2003-2019).

- Total AOD exhibits a general negative trend in the Arctic in MAM, and strong positive trends in most North America, Eurasia boreal regions in JJA.
- Extreme AOD events are largely attributable to FM AOD events (notably ***BB smoke transport events*** in general). Extreme Arctic AOD events also show, as noted for BB smoke AOD, large seasonal and interannual variability.
- ***Shift of extreme AOD events from spring-summer to summer season*** **during 2003-2019**



Development of NAAPS-RA v2 in progress

NAAPS-RA v1

- Global 1x1 deg lat/lon & 6hrly
- 2003-2020
- Driven by NOGAPS/NAVGEM analysis
- Output of AOD @550nm
- Assimilation of MODIS C5 +MISR v22 AOD @550nm
- Validation: AERONET modal AOD @550nm; field campaigns (e.g., 7SEAS; SEAC^{4}RS; KORUS-AQ, PISTON; CAMP^{2}Ex); PM2.5 & PM10

NAAPS-RA v2

- Global 1/3 or ¼ deg lat/lon & 3hrly
- Better 3-D product & better resolved lower troposphere (~14 vs. ~6 levels below 850hpa)
- Driven by NAVGEM 2.0 reanalysis.
- More info on chemical speciation.
- Enhanced spectral properties (across UV to IR)
- More complete representation of light absorption
- Assimilation of newer and better AOD retrieval products, e.g., MODIS C6 DT, DB.
- Validation: AERONET modal AOD @ multi-spectrum; MPLNET extinction profiles; surface PM2.5 and PM10; ever expanding field data holdings.

V2 Implication: broader applications, more users.

Acknowledgements

Thanks!

- Data providers
- Sponsors
- *You, the audience!*

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