3D-EnVar Aerosol Assimilation System for Global Aerosol Forecasting and Reanalysis at NOAA/OAR

Mariusz Pagowski[1,2], Bo Huang[1,2], Shih-Wei Wei[3,4], Arlindo da Silva[5], and Sarah Lu[3,4]

Collaborators:

Cory R. Martin[6], Andrew Tangborn[6,7], Daryl T. Kleist[6],
Shobha Kondragunta[8],
Maryam Abdi-Oskouei[4], Jérôme Barré[4], Cheng Dang[4], Ben Johnson[4], and the JEDI Team

[1]CIRES, CU Boulder
[2]NOAA/OAR/GSL
[3]SUNYA,
[4]UCAR/Joint Center for Satellite Data Assimilation
[5]NASA/GMAO
[6]NOAA NWS NCEP EMC
[7]IMSG at NCEP EMC
[8]NOAA NESDIS STAR

Near-Real Time Aerosol Assimilation System

(since August 2021, https://ruc.noaa.gov/projects/nrt/)

❑ **MODEL: Global Ensemble Forecast System - Aerosols (GEFS-Aerosols):**

- FV3 dynamical core (six tiles) and GFS physics;
- GOCART with 15 aerosol tracers;
- 64 levels at ~100km resolution.

Currently switching to a new NOAA model **UFS-Aerosols**

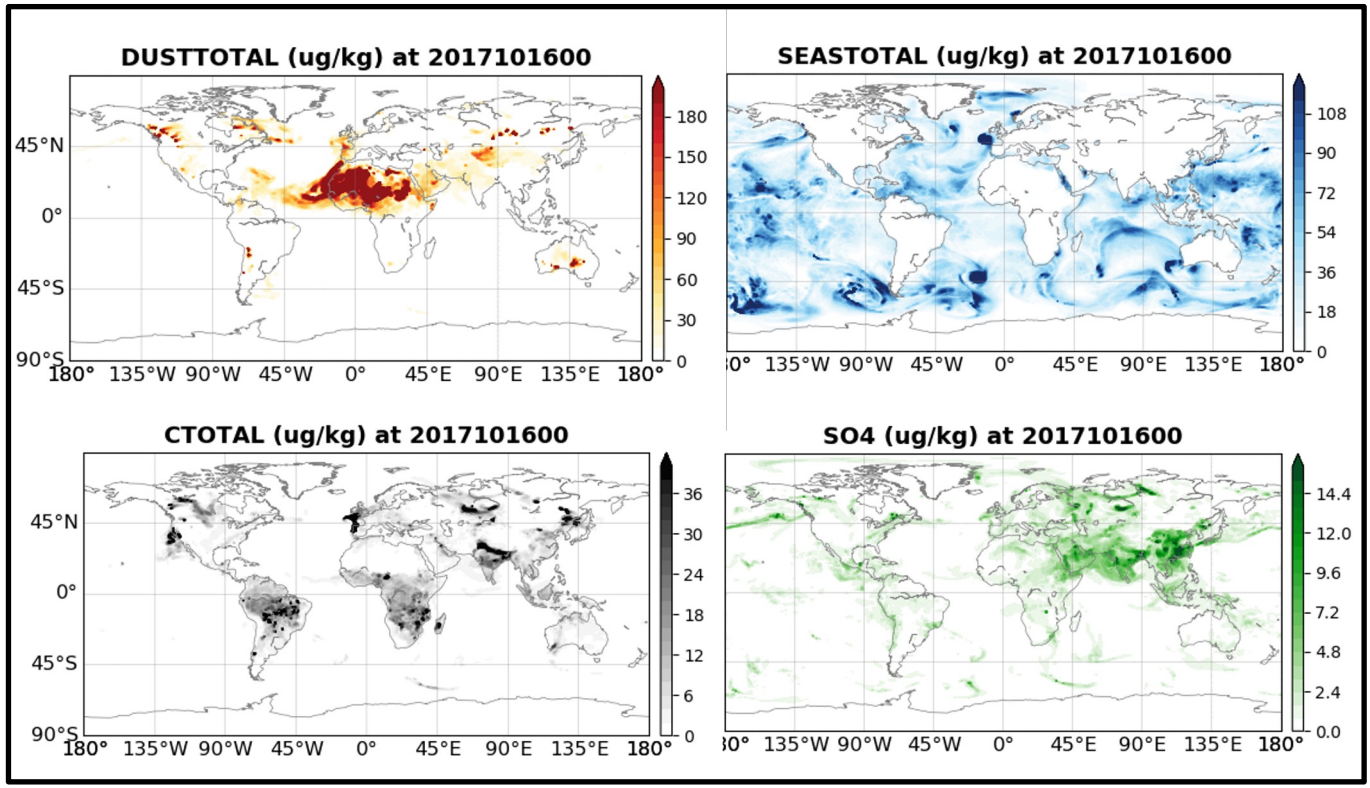
- GOCART2G: 15 GOCART tracers + 3 nitrate bins (from NASA);
- NOAA's Fengsha dust scheme;
- NOAA's GBBEPx wildfire emissions;
- 127 levels at ~50km resolution.

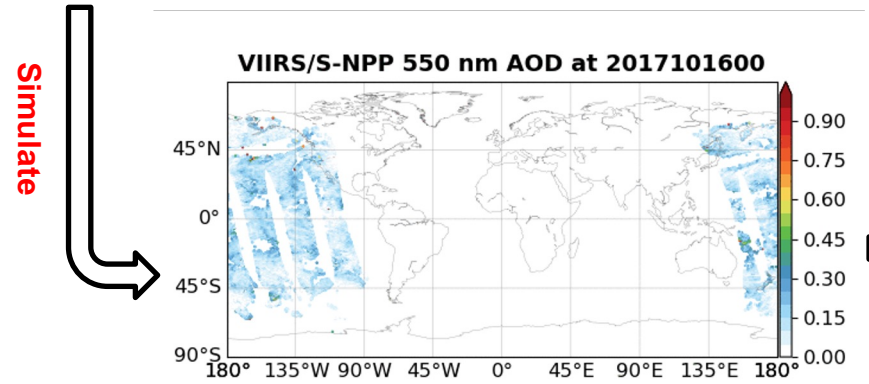
❑ **OBSERVATIONS: AOD 550nm:**

- NOAA-SNPP VIIRS retrievals produced by NOAA/NESDIS (combined DT&DB);
- 750 m pixels sampled at ~50km.

❑ **ASSIMILATION: JEDI-Based 3D-EnVar:**

- Observation operator using GMAO's aerosol scattering look-up tables;
- Ensemble of 20 members with perturbed emissions plus Control using met analyses;
- EnVar and LETKF to obtain analyses.



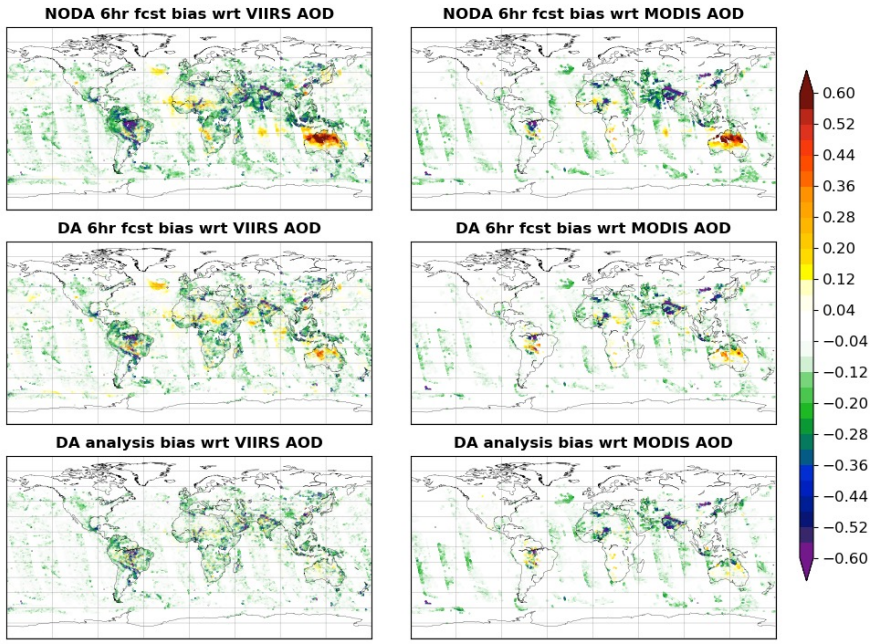


Huang, B., M. Pagowski, S. Trahan, C. Martin, A. Tangborn, S. Kondragunta, and D. Kleist, 2023: JEDI-Based Three-Dimensional Ensemble-Variational Data Assimilation System for Global Aerosol Forecasting at NCEP, JAMES, https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022MS003232.

Near-Real Time Aerosol Assimilation System

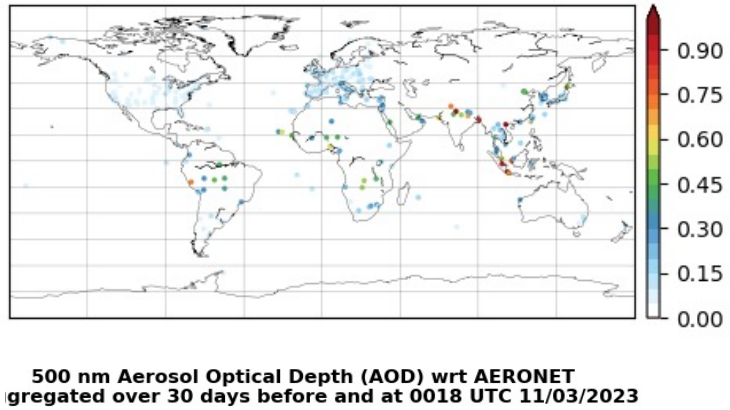
(since August 2021, https://ruc.noaa.gov/projects/nrt/)

AOD 550nm VIIRS and MODIS



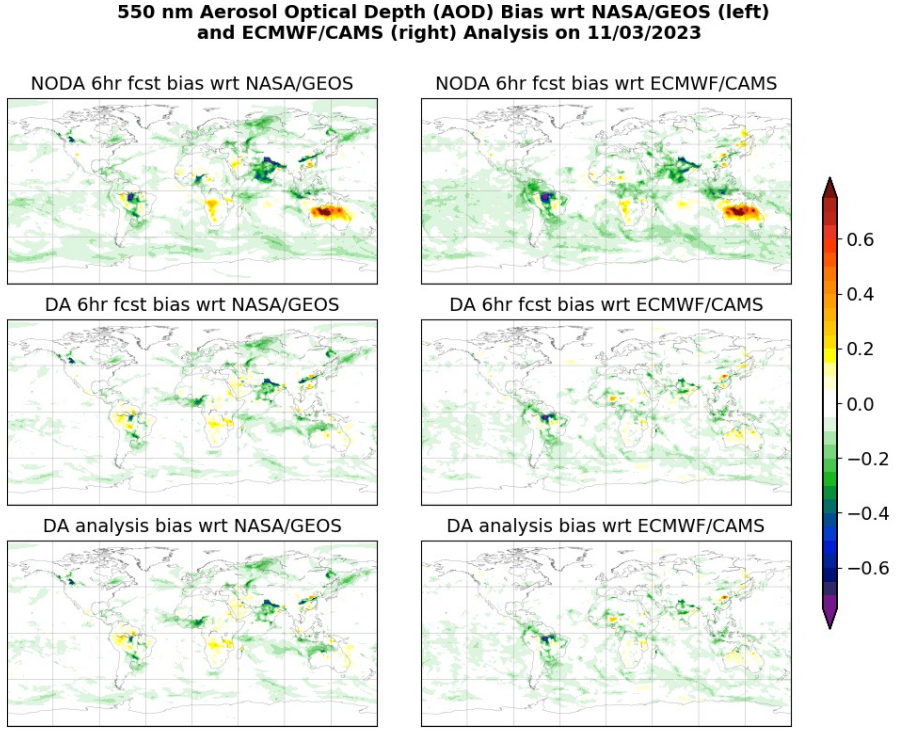
Sample Plots

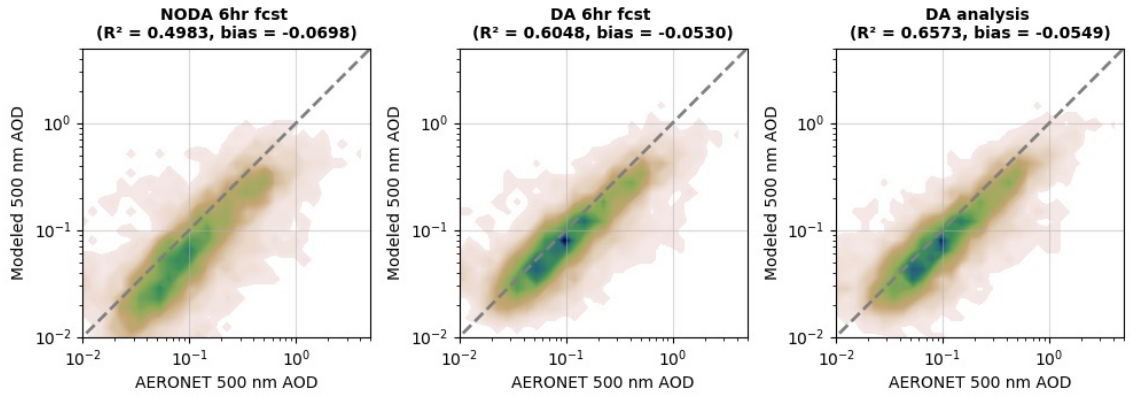
AOD 500nm AERONET



500 nm Aerosol Optical Depth (AOD) wrt AERONET
gregated over 30 days before and at 0018 UTC 11/03/2023

AOD 550nm GEOS and CAMS 550 nm





Components of the Reanalysis System
NARA v.1 (NOAA Aerosol ReAnalysis version 1)

- **MODEL: same as NRT.**

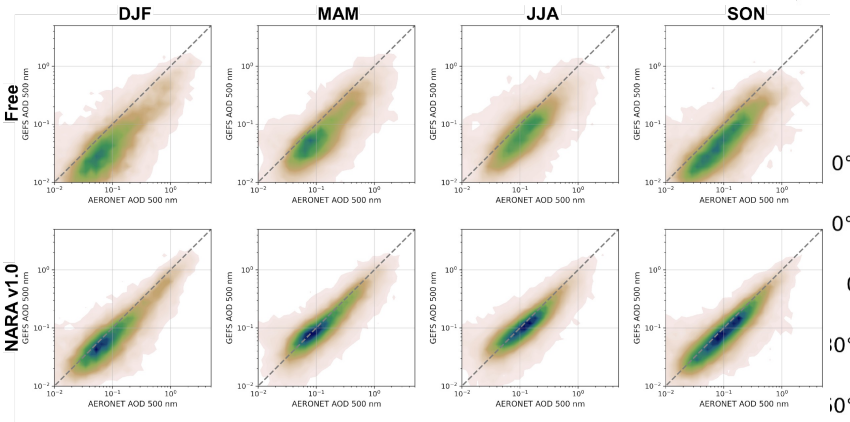
- **OBSERVATIONS: NASA GMAO's Neural Network Retrievals (NNR) of AOD**
  - Multi-wavelengths AODs obtained from satellite radiances trained on AERONET using neural network approach (but used only AOD 550nm).

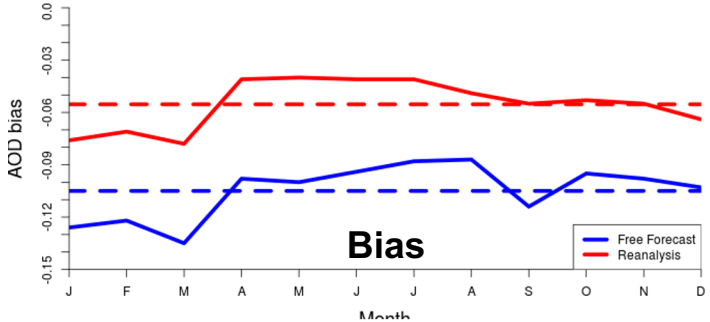
- **ASSIMILATION: similar to NRT but 40 members**
  - Prototype reanalysis for 2016, now ongoing project for 2018-2022 with UFS-Aerosols model and NOAA-SNPP VIIRS AOD 550nm retrievals.

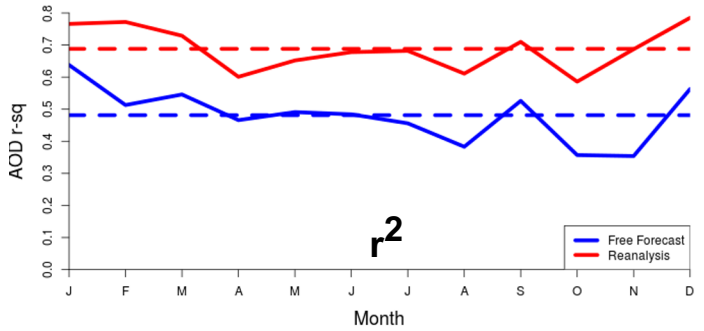
The NOAA Aerosol Reanalysis version 1.0 (NARA v1.0): Description of the Modeling System and its Evaluation, Wei, S.-W., M. Pagowski, A. da Silva, C.-H. Lu, and B. Huang, 2023: EGUsphere, https://doi.org/10.5194/egusphere-2023-35

NARA v.1 Evaluations and Comparisons

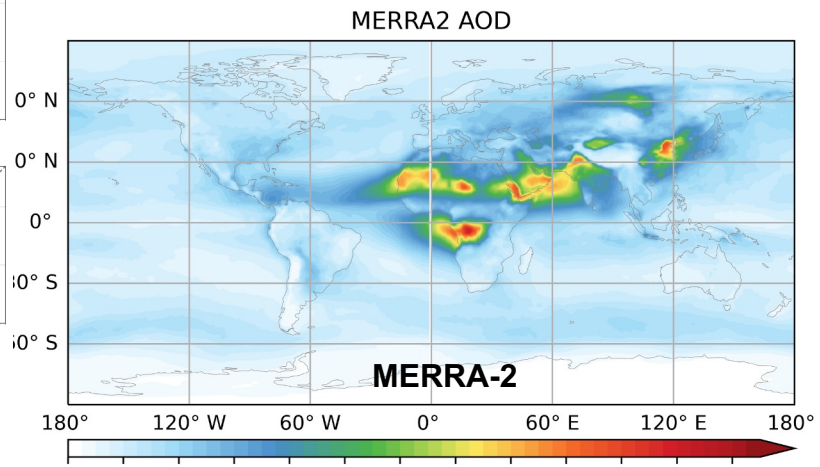
AOD 500nm: Free Run and NARA v.1 vs. AERONET

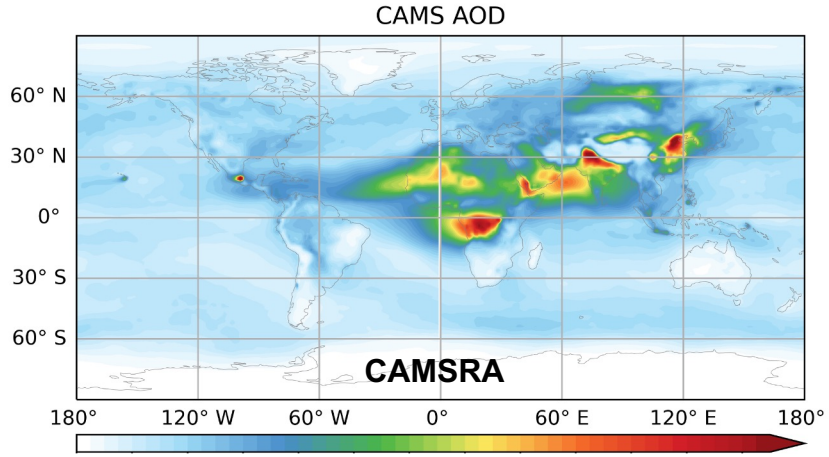


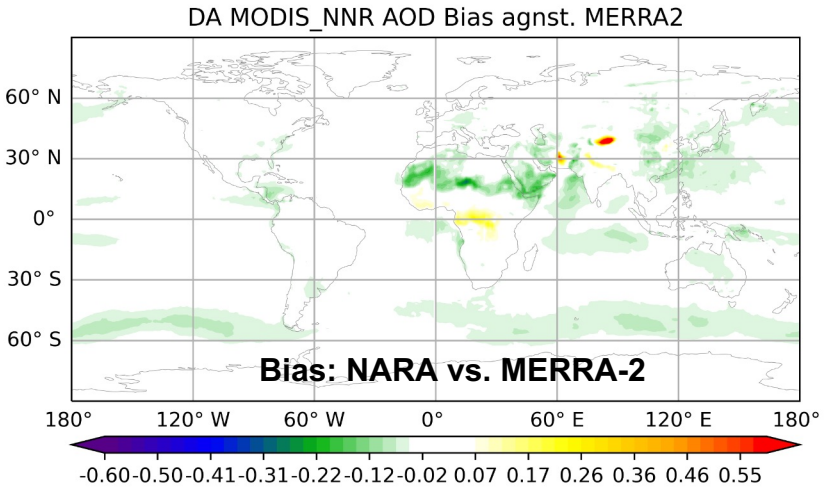


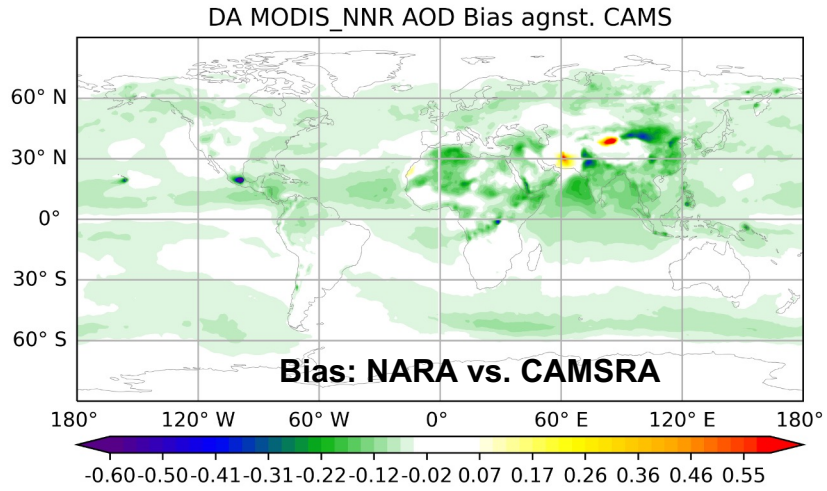


AOD 550nm: NARA v.1, MERRA-2, and CAMSRA June - August 2016

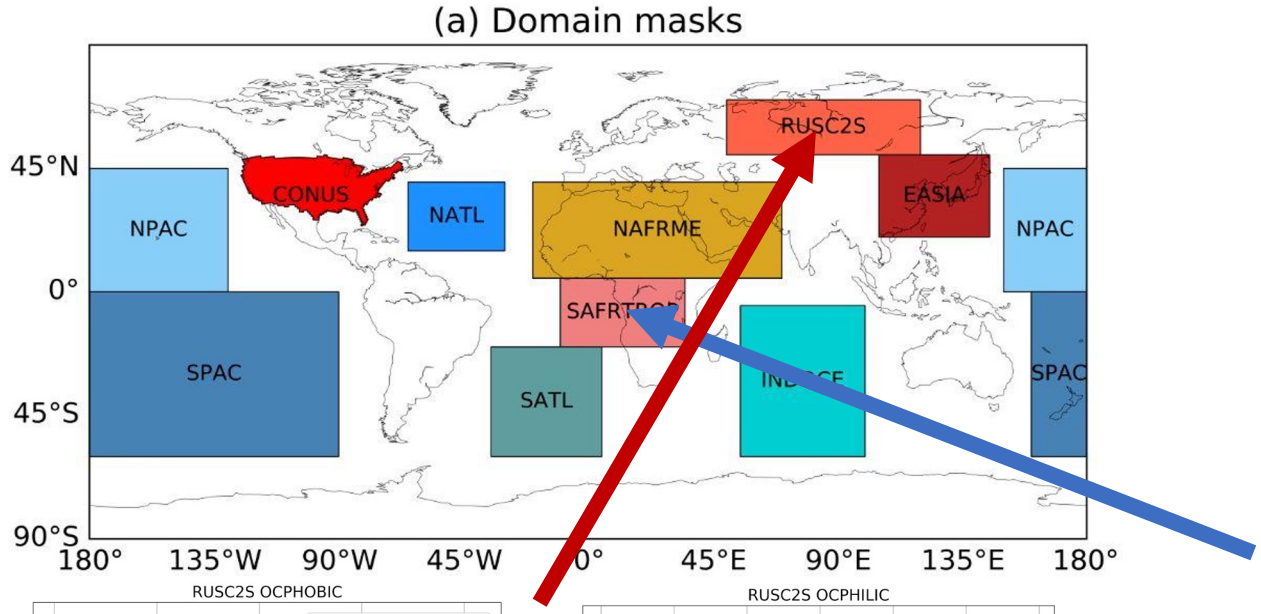


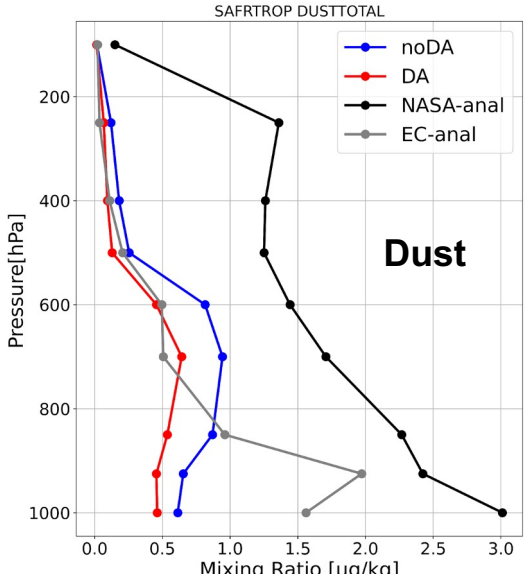




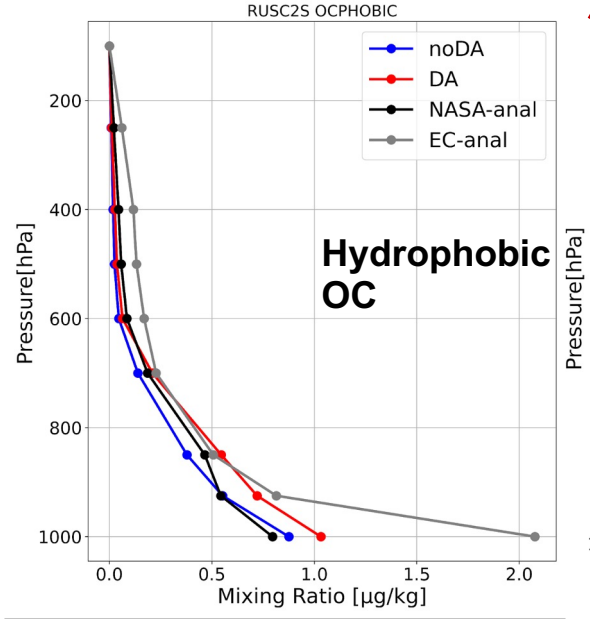


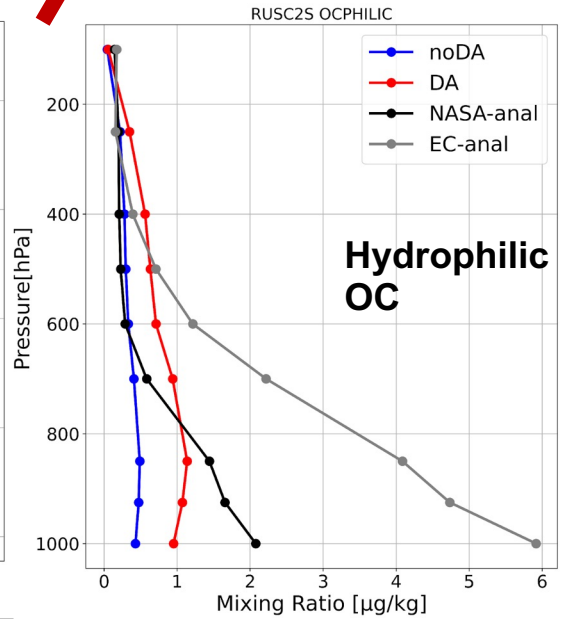
NARA v.1 Comparisons

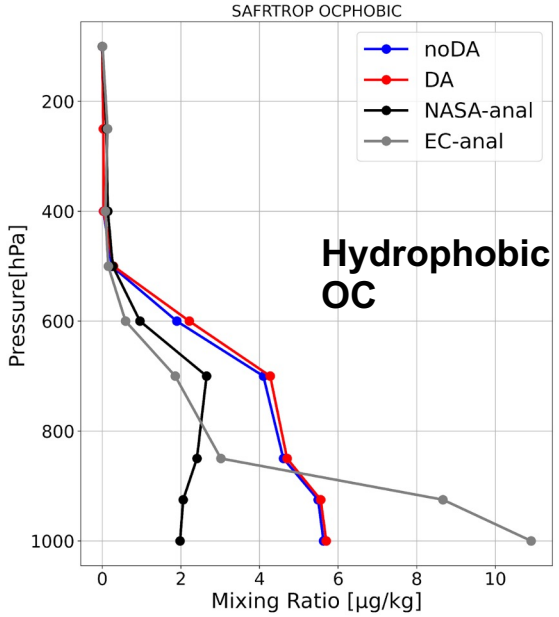


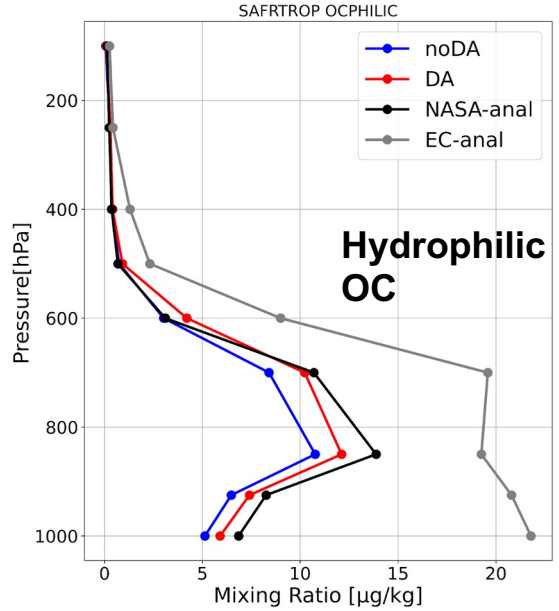


Free Run
NARA v.1
MERRA-2
CAMSRA

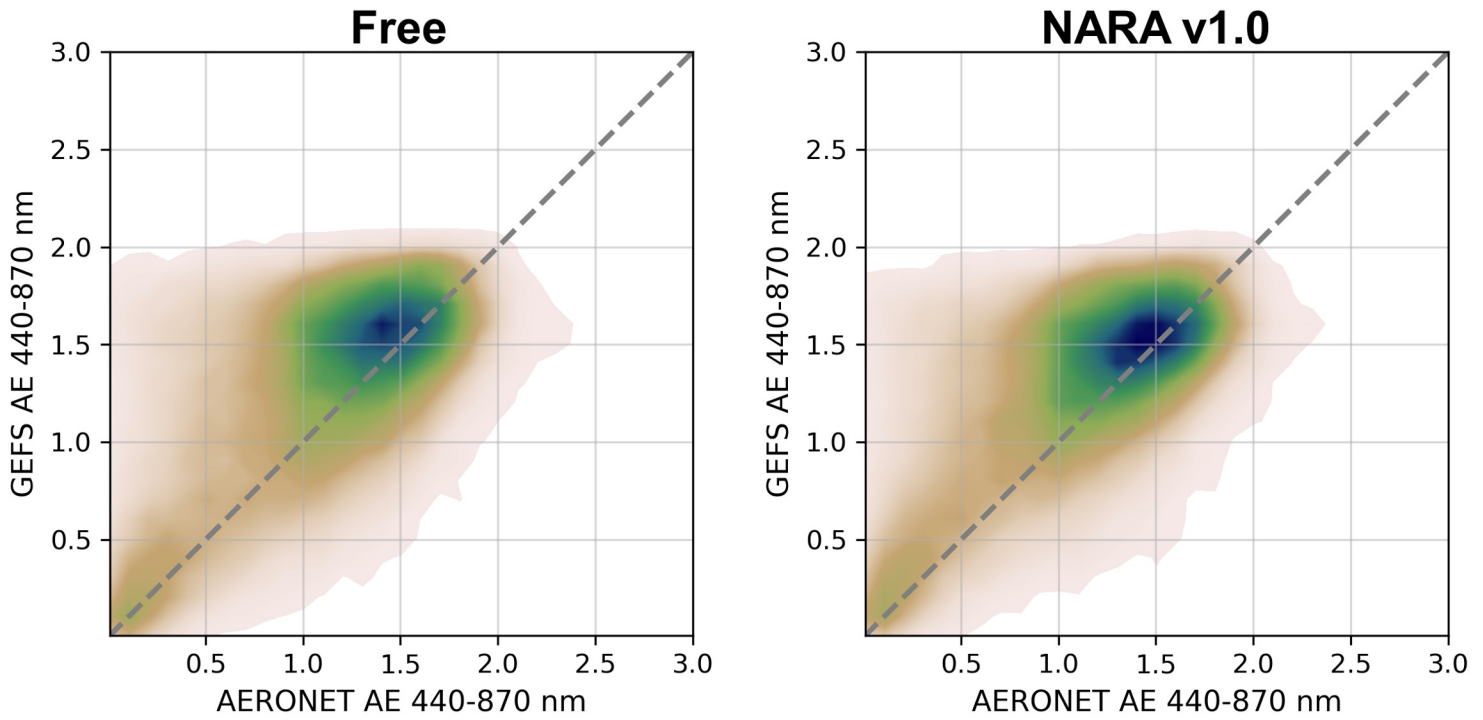








NARA v.1 vs. AERONET



$$AE(\lambda_1, \lambda_2) = -\frac{log(AOD(\lambda_1)/AOD(\lambda_2))}{log(\lambda_1/\lambda_2)}$$

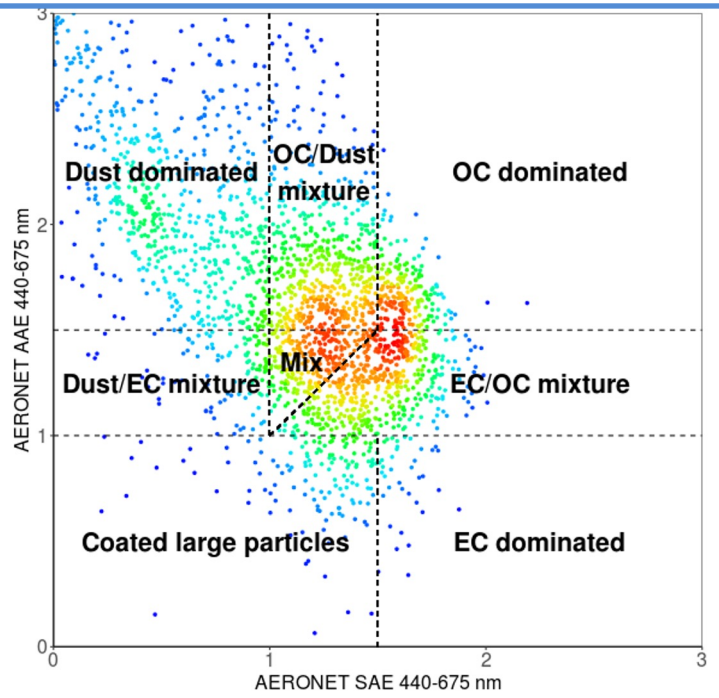
Ångström Exponent

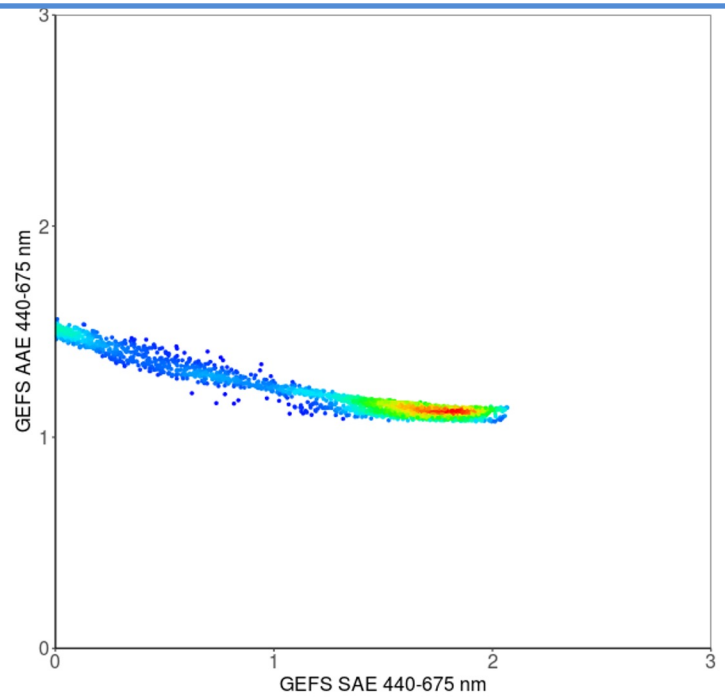
- Large scatter against AERONET.
- Marginal impact of the assimilation of AOD 550 nm on AE i.e. size distribution and composition of particles.

NARA v.1 vs. Almucantar AERONET

$$AAE = -\frac{\log\left(AAOD(\lambda_1)/AAOD(\lambda_2)\right)}{log\left(\lambda_1/\lambda_2\right)} \quad (1)$$

$$SAE = -\frac{log\left(SAOD(\lambda_1)/SAOD(\lambda_2)\right)}{log\left(\lambda_1/\lambda_2\right)} \quad (2)$$



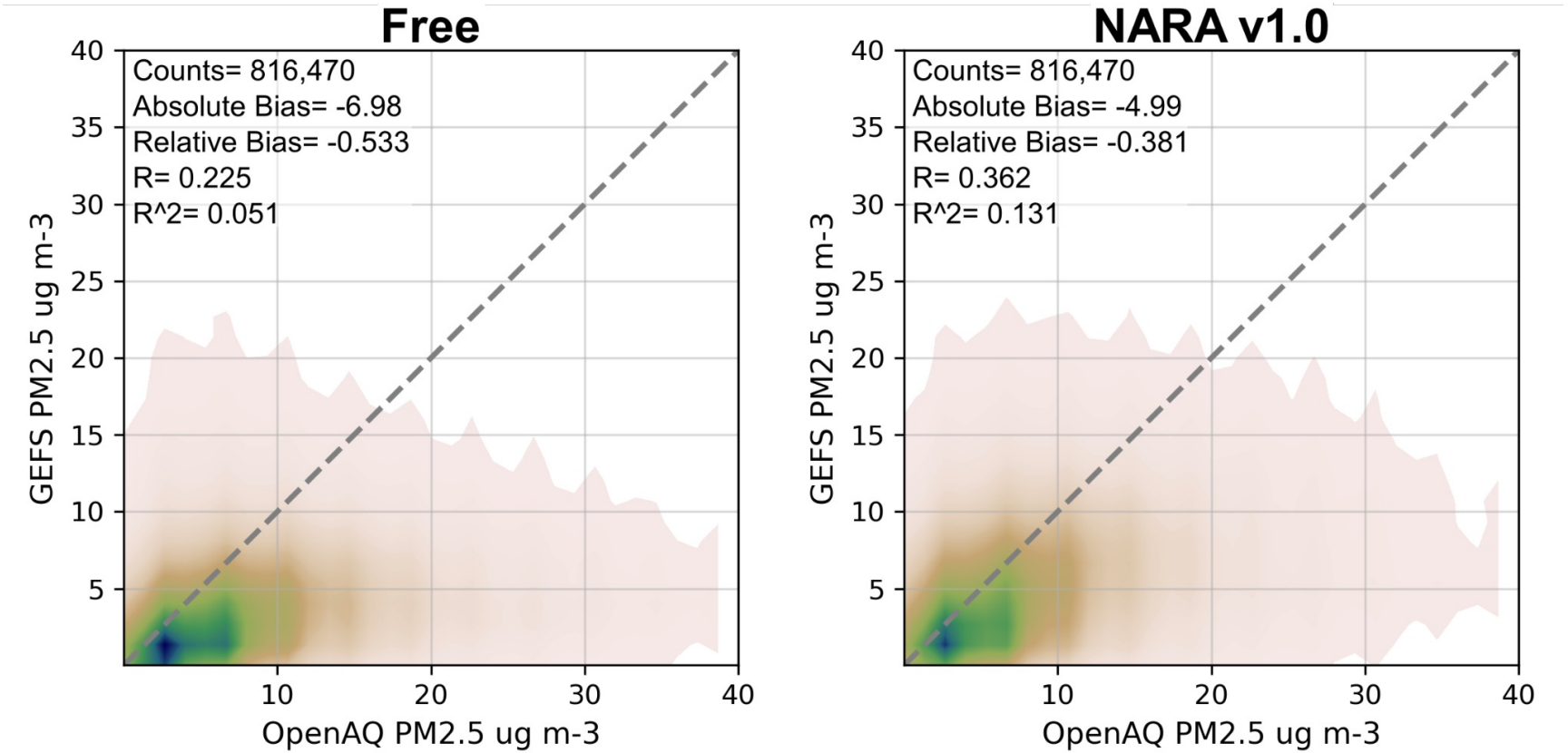


Absorption Ångström Exponent - expression of aerosol composition
Scattering Ångström Exponent - expression of particle size distribution

(Cazorla et al., Atmos. Chem. Phys., 13, 9337–9350, 2013)

- Poor representation of absorption by aerosols in the model.
- As on the previous page, assimilation of AOD 550 nm has practically no impact on size distribution of particles and their composition (Free Run, not shown, nearly identical to the analysis).
- How accurately can impact of aerosols on radiation be represented in this model?

NARA v.1 vs. OpenAQ



Equally poor or worse statistics for aerosol species vs. IMPROVE network over North America

Summary

- Renalyses differ markedly when the actual concentrations of aerosol species are compared though they tend to concur on AOD 550nm.
- Bulk aerosol schemes such as GOCART have poor representation of aerosol absorption.
- These two conclusions put in doubt accuracy of modeling aerosol-meteorology interactions with the current parameterizations.