The NOAA global Aerosol ReAnalysis (NARA)

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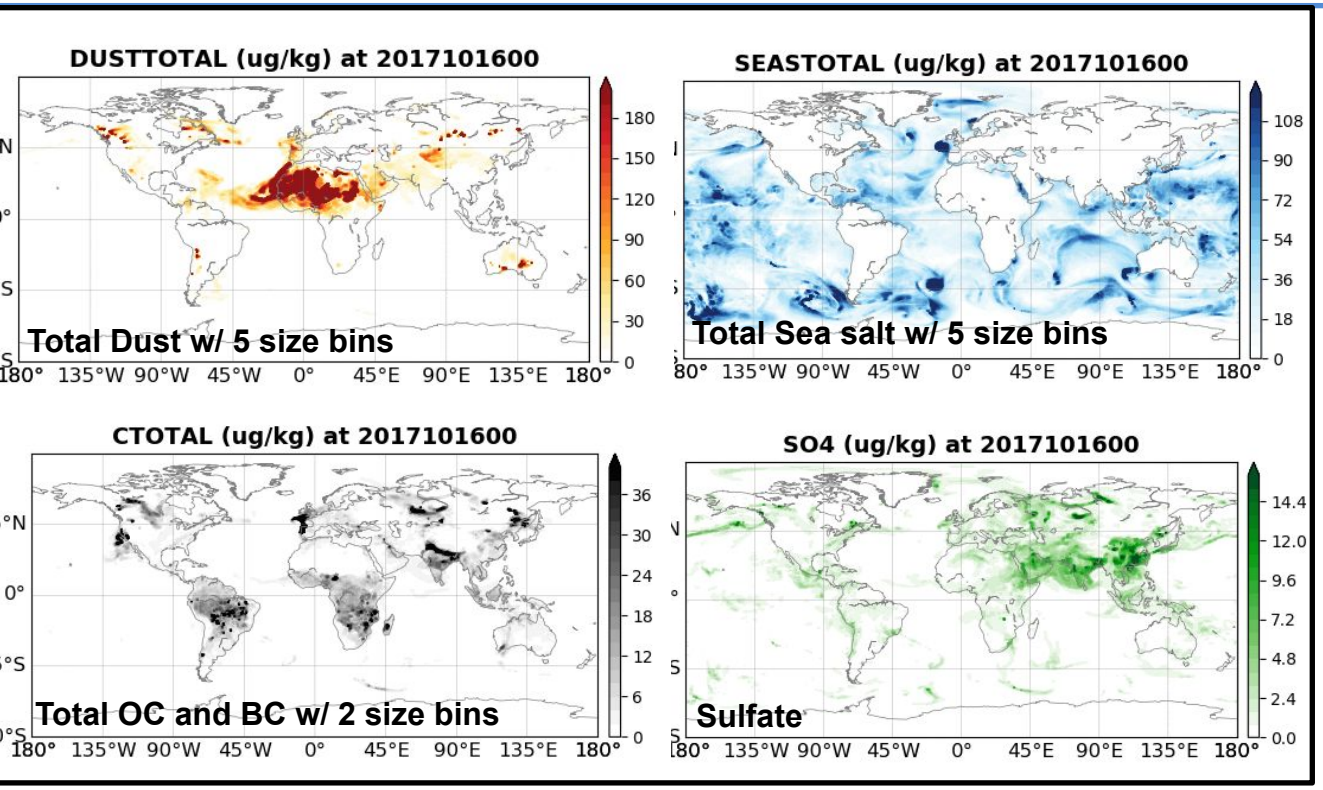
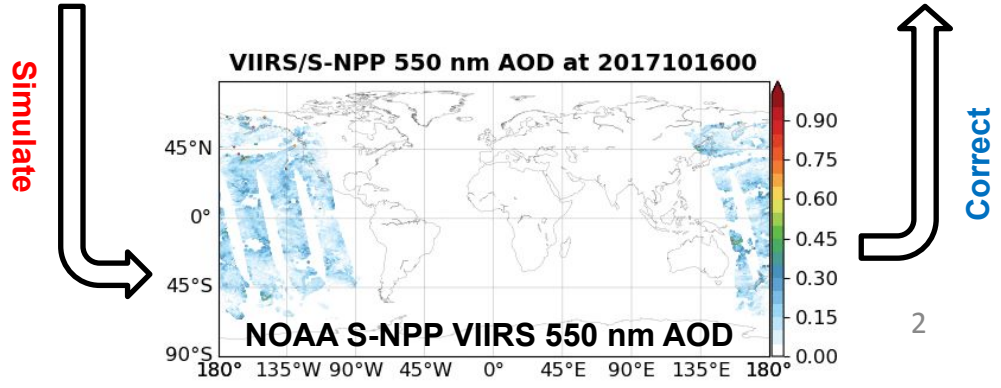
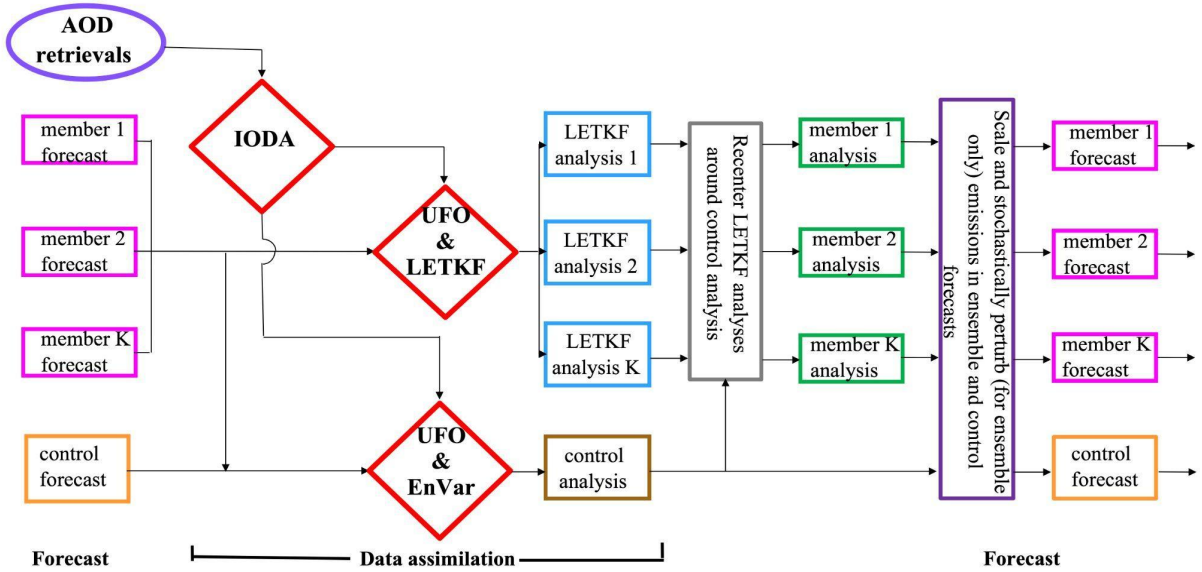
S2S Community Workshop, Boulder CO, June 5-7 2024

JEDI-based ensemble-variational aerosol data assimilation system for NARA





- **MODEL**: NOAA's global aerosol model based on NASA's GOCART aerosol module (GEFS-Aerosols and UFS-Aerosols)
- **OBSERVATIONS**: 2D Aerosol Optical Depth (AOD) retrievals at 550 nm that represents total extinction of solar radiation by aerosols over an atmospheric column
- **DA SYSTEM**: Ensemble-Variational based on JEDI (Joint Effort for Data assimilation Integration, *Huang et al.,2023; Wei et al., 2024*)



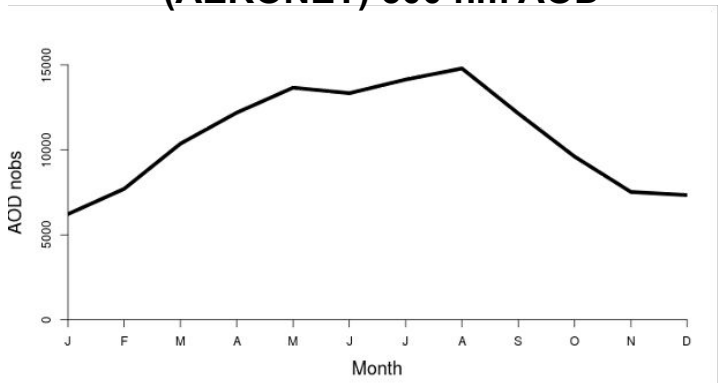
The first-ever NOAA global Aerosol ReAnalysis (NARA) version 1 for Year 2016 (Wei et al., 2024, GMD)

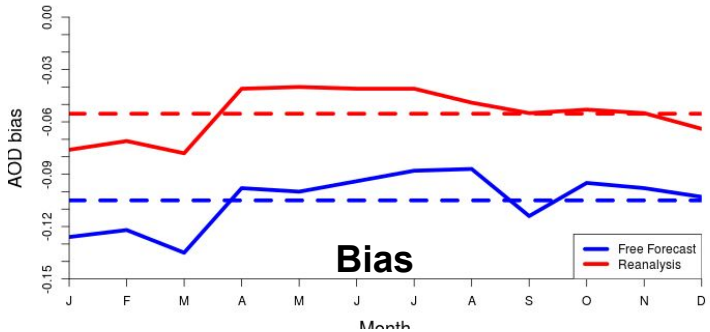
- **OBSERVATIONS: NASA/GMAO's MODIS Neural Network Retrievals (NNR) AOD at 550 nm**
  - Multi-wavelengths AODs obtained from satellite radiances trained on AERONET using neural net approach (Randles et al. 2017)
- **MODEL: Global Ensemble Forecast System - Aerosols (GEFS-Aerosols,** Zhang et al., 2021)
- **DA CONFIGURATION:**
  - Observation operator using GMAO's scattering look-up tables;
  - 1 control plus 40-member GEFS-Aerosols ensemble forecasts at C96L64;
  - Perturbed aerosol emissions in ensemble forecasts;
  - EnVar and LETKF to obtain analyses;

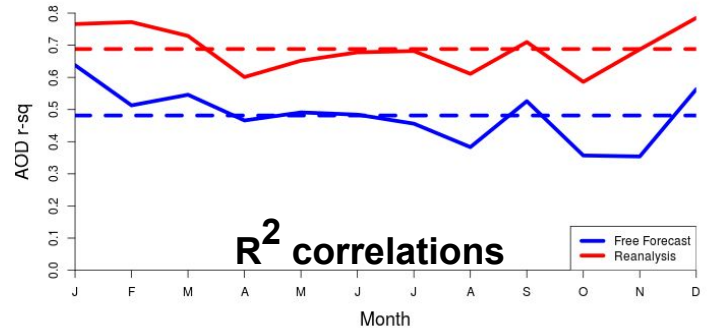
Acknowledgement: "Joint NOAA-NASA Development of a Data Assimilation System for Aerosol Reanalysis and Forecasting" funded by NOAA's Climate Prediction Office's Modeling, Analysis, Predictions, and Projections Program (2018-2022).

Evaluation against AERONET, MERRA-2 and CAMSRA

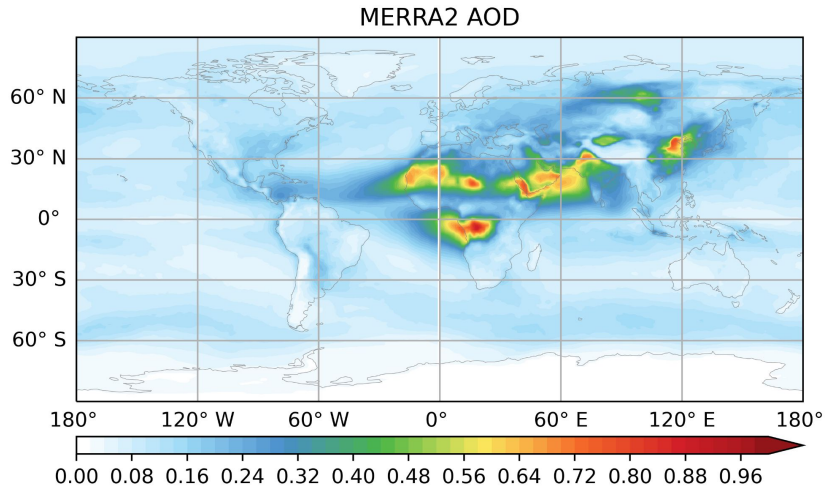
Monthly Time-Series of verification against Aerosol Robotic Network (AERONET) 500 nm AOD



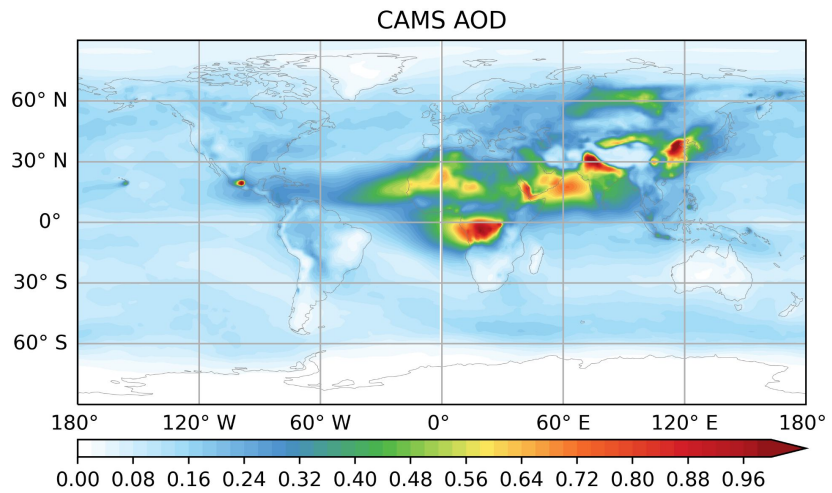




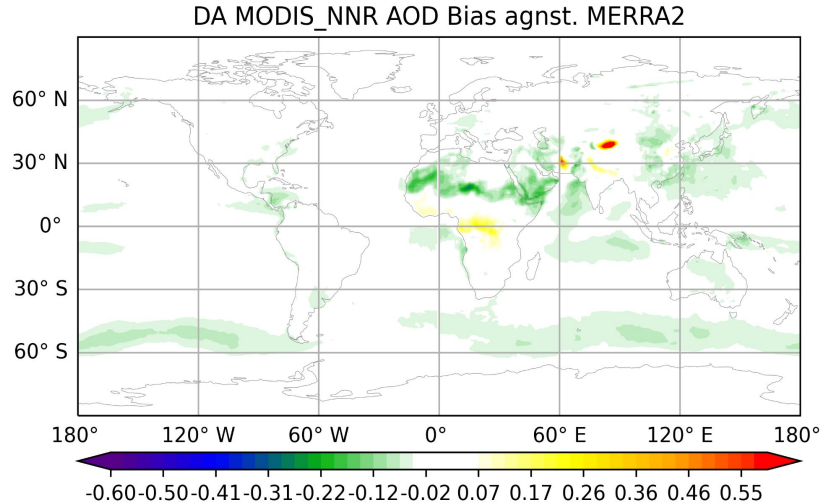
550 nm AOD reanalysis comparison among GEFS-Aerosols, NASA MERRA-2 and ECMWF CAMSRA in June - August 2016



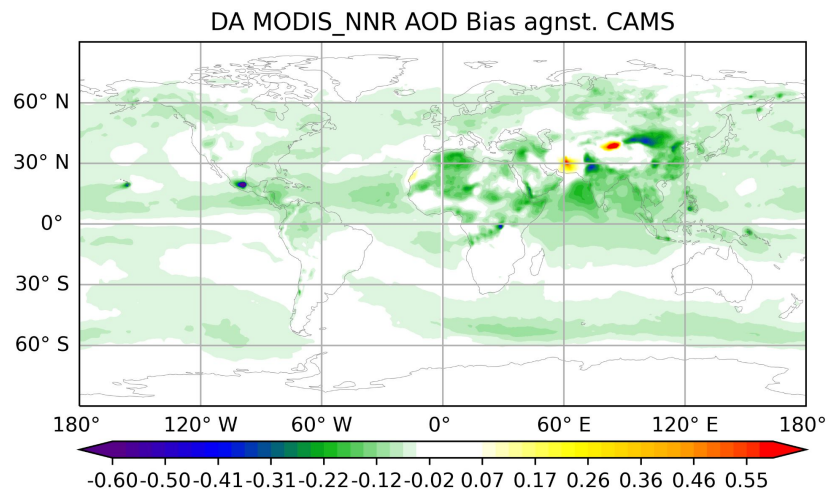
NASA MERRA-2 550 nm AOD



ECMWF CAMSRA 550 nm AOD

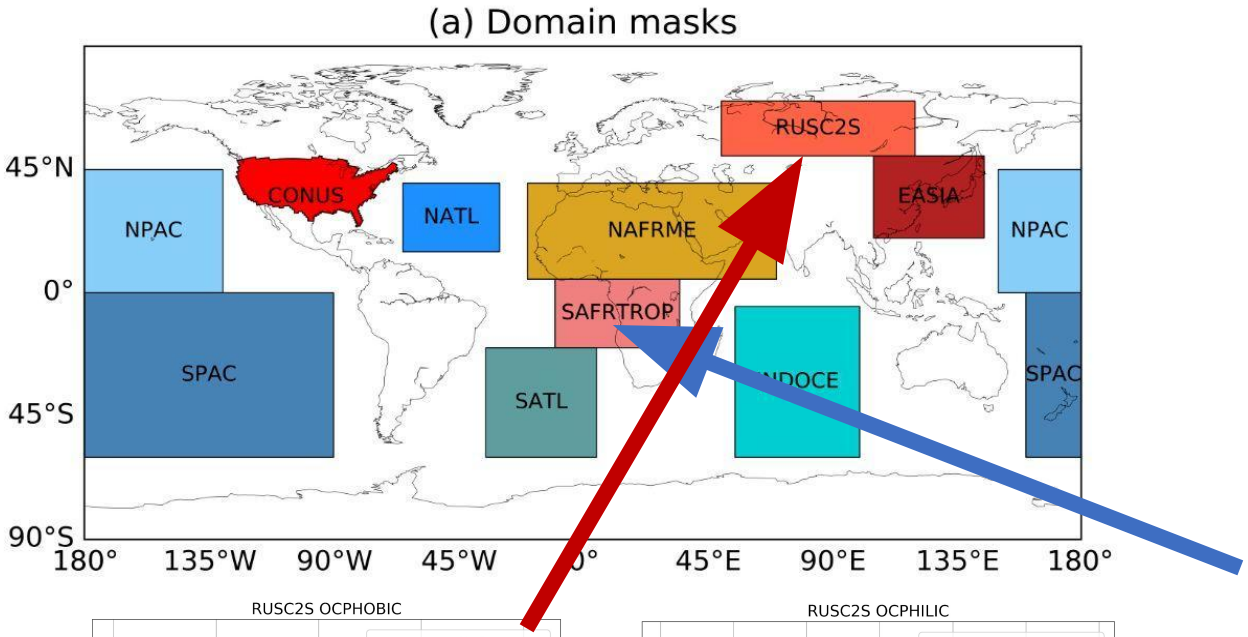


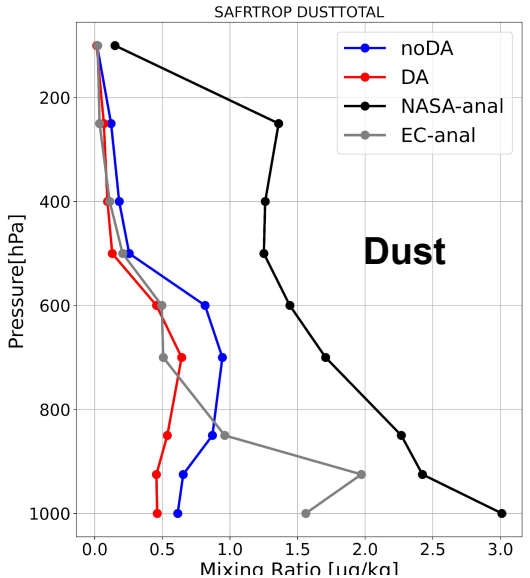
GEFS-Aerosols bias against NASA MERRA-2



GEFS-Aerosols bias against ECMWF CAMSRA

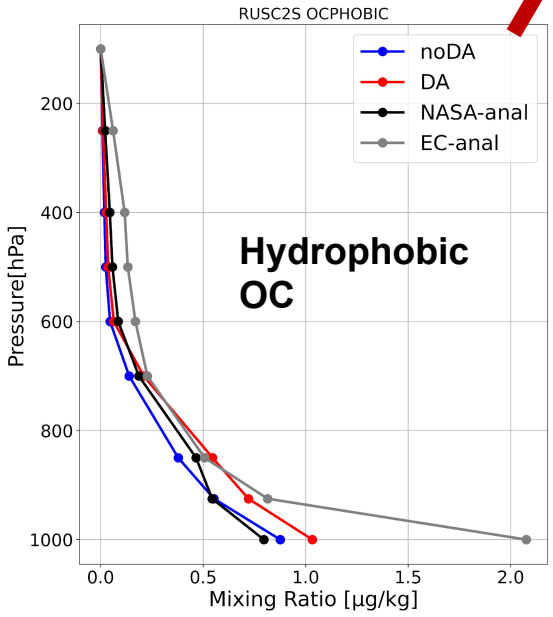
Sample Aerosol Profiles in MERRA-2, CAMSRA, and NARA v.1 in August 2016

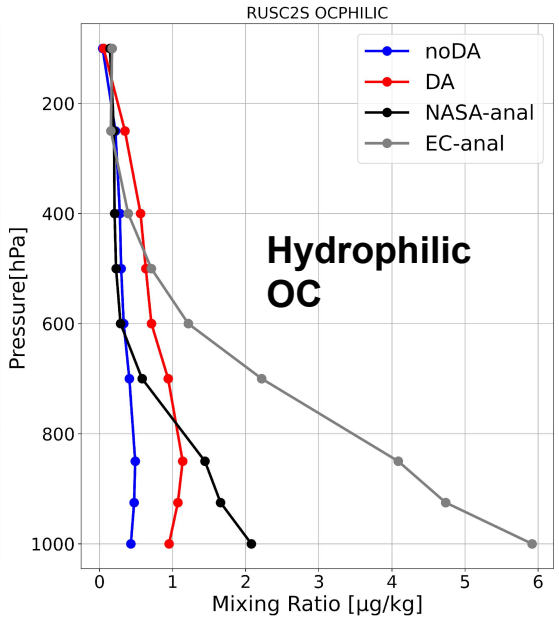


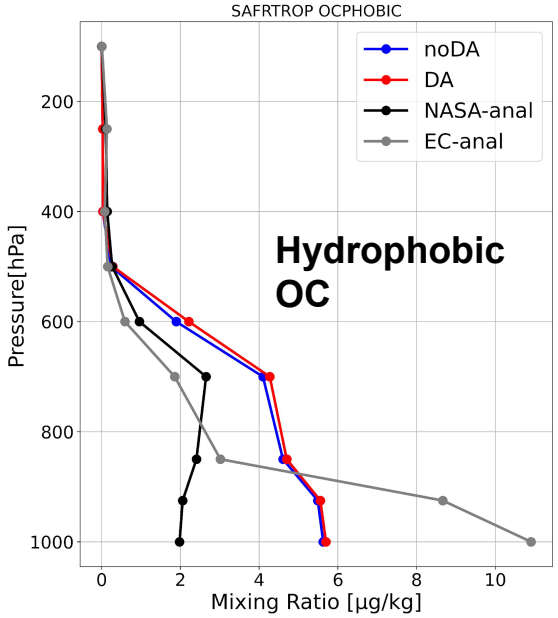


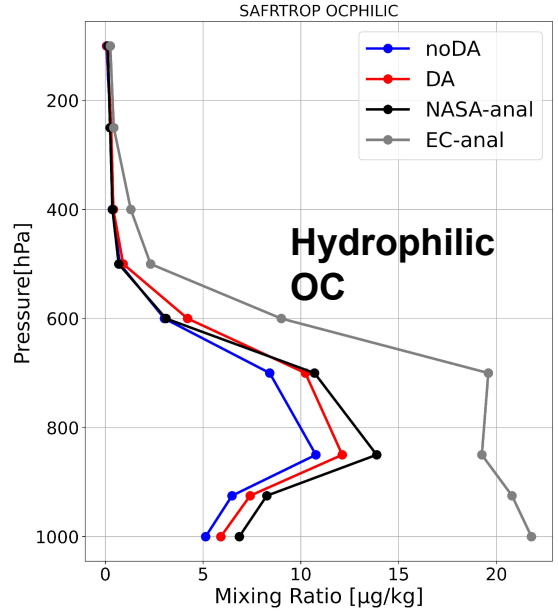
GEFS-Aerosols FreeRun 6h fcst
GEFS-Aerosols Reanalysis
NASA MERRA-2 Reanalysis
ECMWF CAMSRA Reanalysis

- Assimilation of the 2D integral AOD retrievals at 550 nm alone is not sufficient to constrain 3D aerosol mass missing ratios in the model.









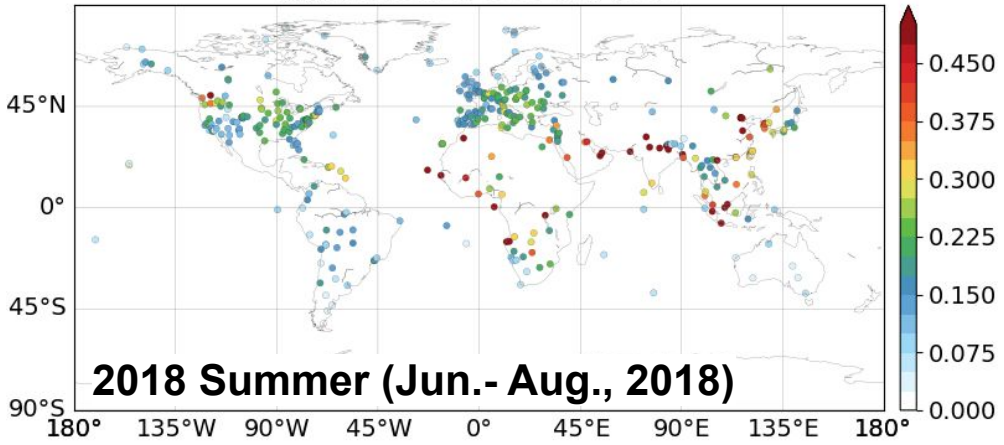
NOAA global Aerosol ReAnalysis (NARA) version 1 for Year 2018-2022
(production ongoing)

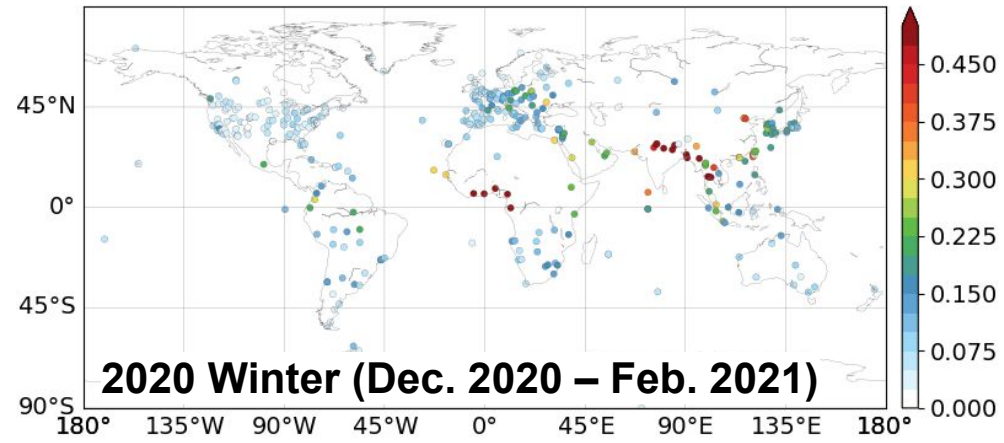
- **OBSERVATIONS:** NOAA/NESDIS 550 nm AOD retrievals from S-NPP VIIRS (Visible Infrared Imaging Radiometer Suite) instruments (Huang et al. 2016)
- **MODEL:** Unified Forecast System - Aerosols (UFS-Aerosols, based on NASA's GOCART2G)
- **DA CONFIGURATION:**
  - Observation operator using GMAO's scattering look-up tables;
  - 1 control plus 40-member UFS-Aerosols ensemble forecasts at C96L127;
  - Perturbed aerosol emissions in ensemble forecasts;
  - EnVar and LETKF to obtain analyses;

Acknowledgement: "Development of a Global Aerosol Reanalysis at NOAA in Support of Climate Monitoring and Prediction" funded by NOAA's Weather Program Office's Climate Testbed Program (2022-2024).

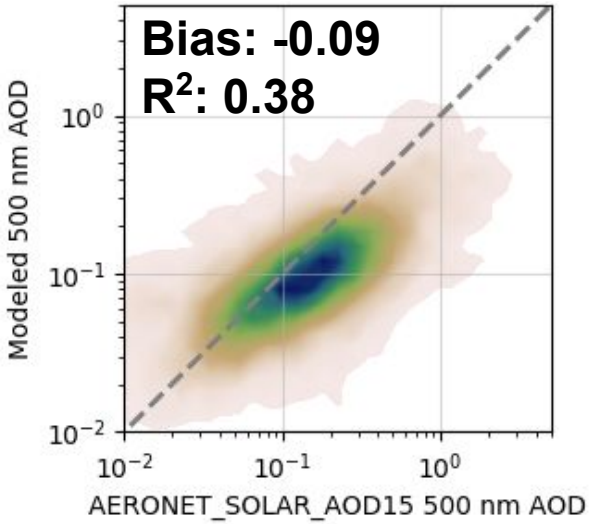
Verification against NASA AERONET 500 nm AOD

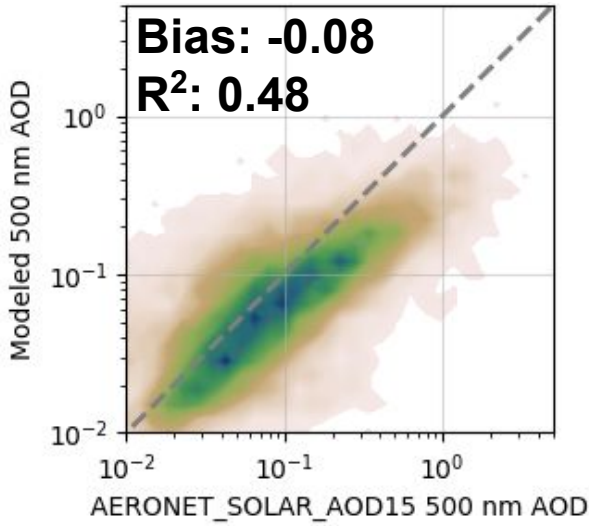
Aerosol Robotic Network (AERONET) AOD at 500 nm
(https://aeronet.gsfc.nasa.gov/)



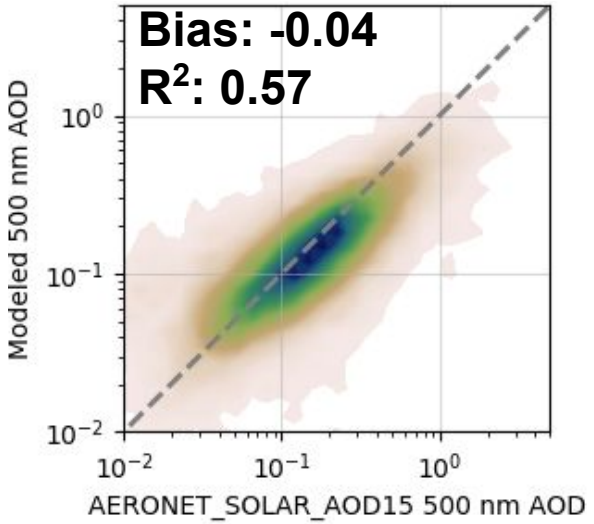


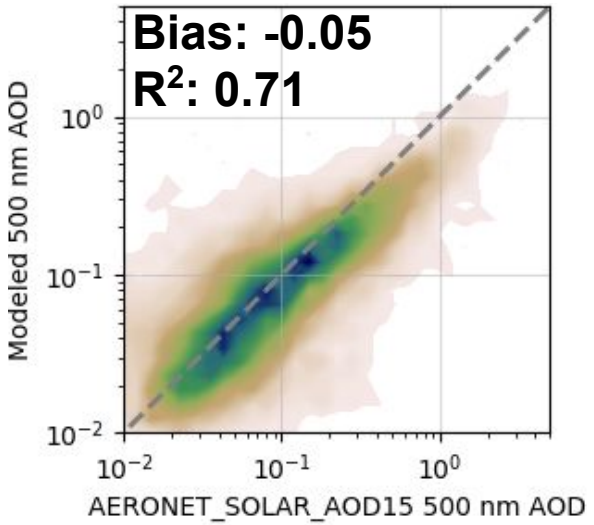
FreeRun





Reanalysis



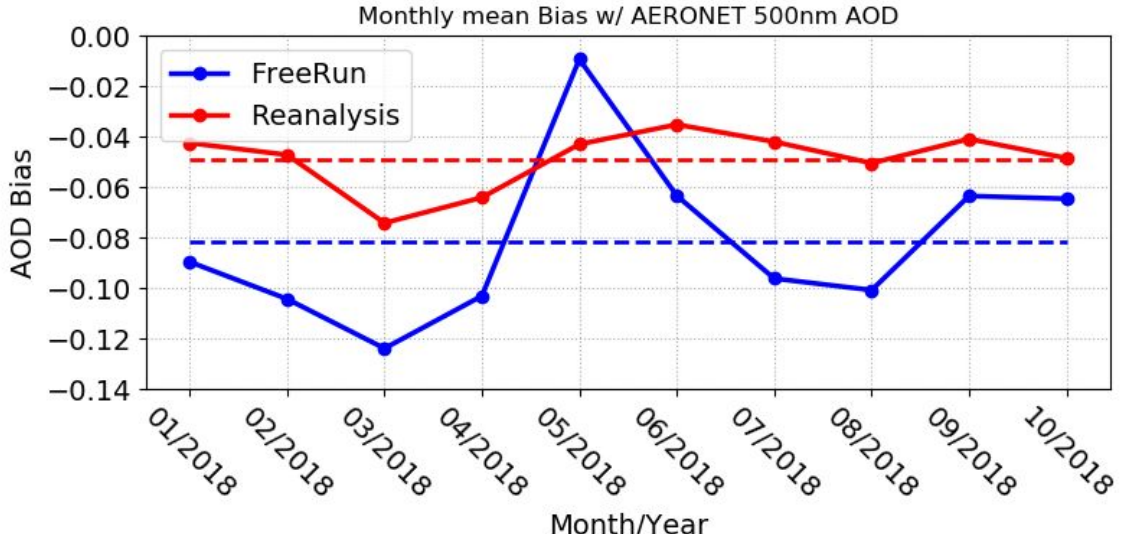


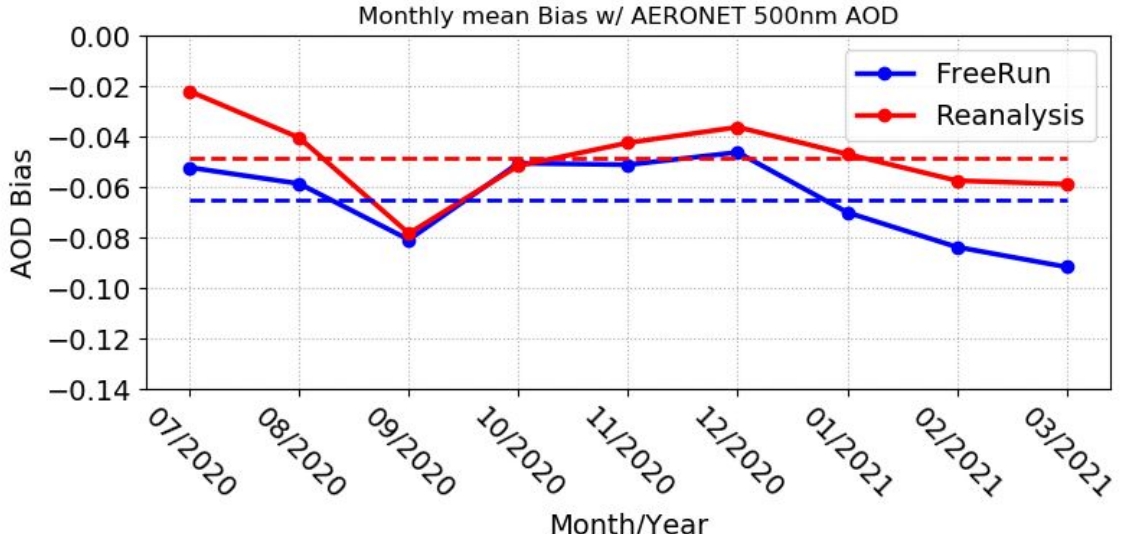
Monthly mean bias and R^2 against NASA AERONET 500 nm AOD

Jan. – Oct., 2018

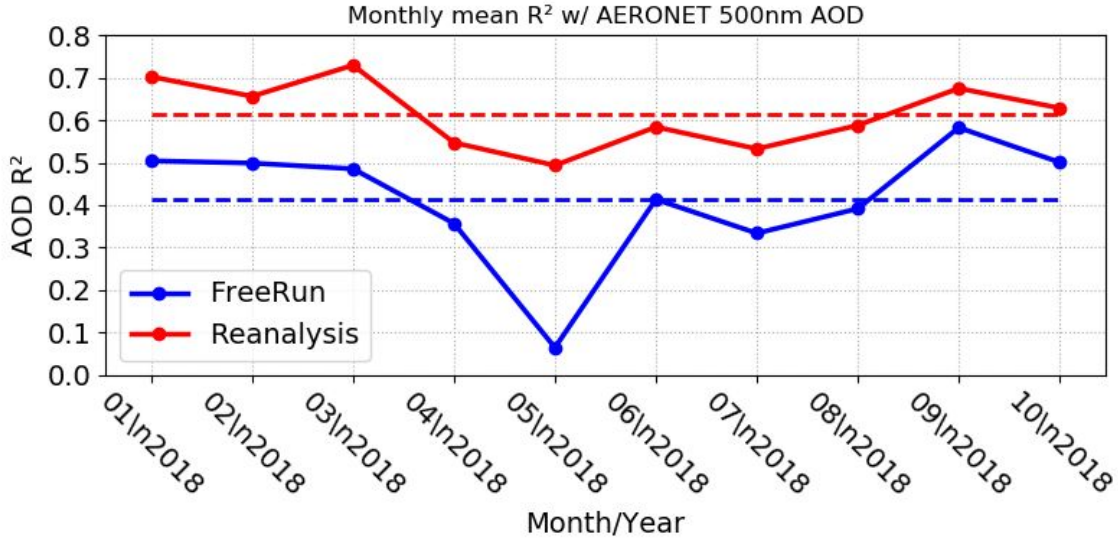
Jul. 2020 – Mar. 2021

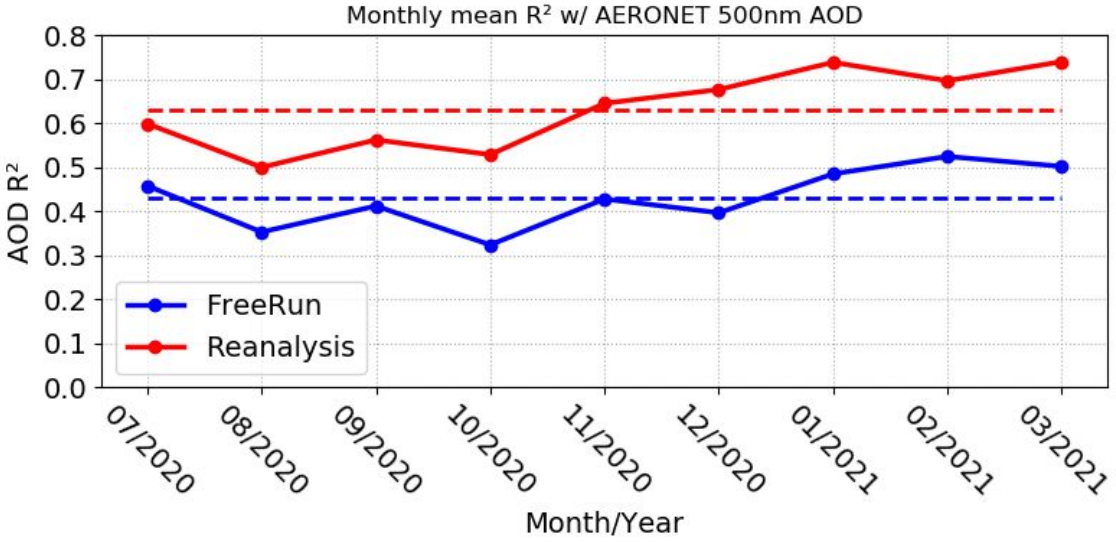
Bias





R^2



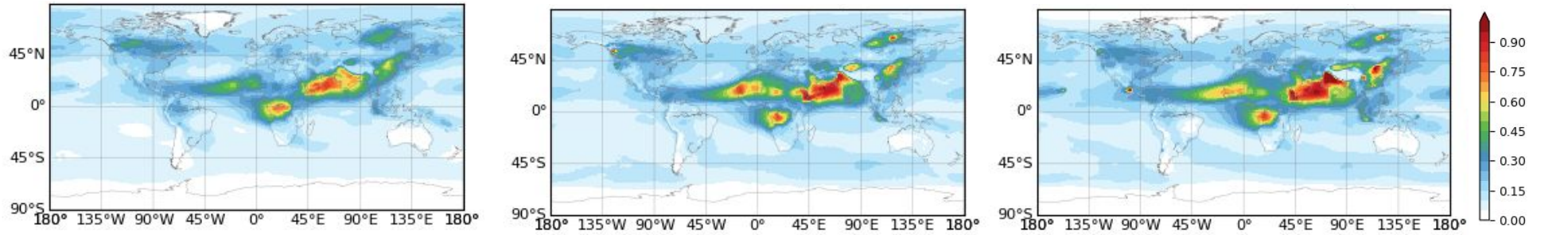


Comparison with NASA/MERRA-2 and ECMWF/CAMS-ERA4 AOD reanalyses

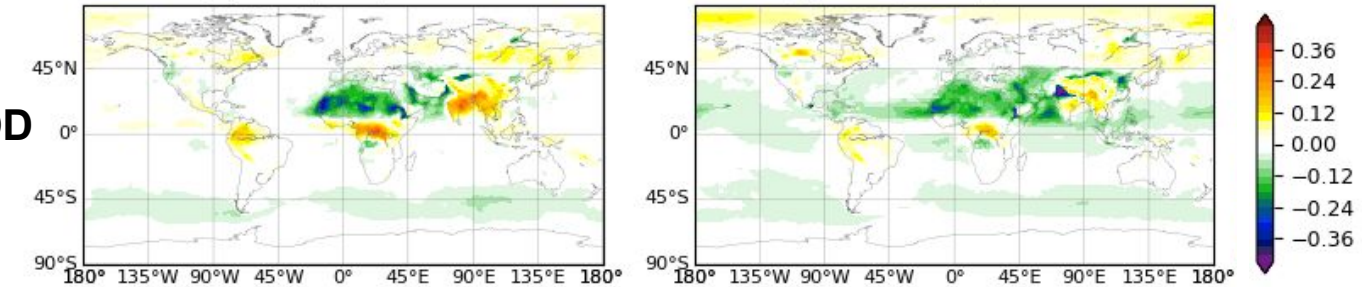
NARA | MERRA-2 | CAMS-ERA4

2018 Summer

AOD



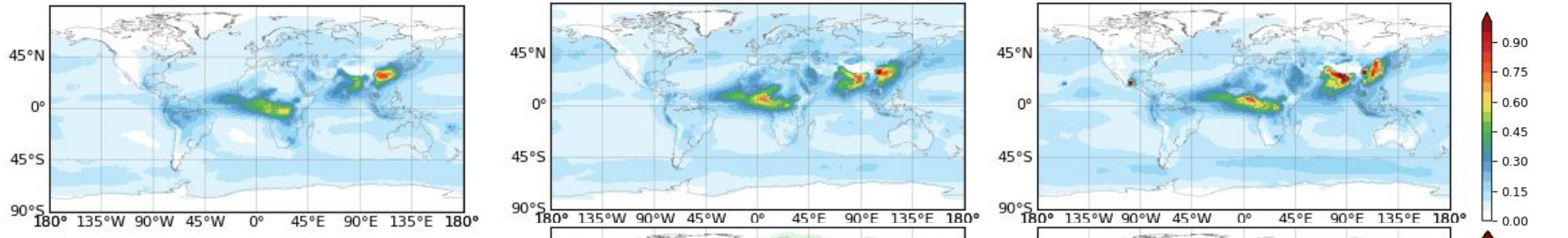
NARA AOD bias



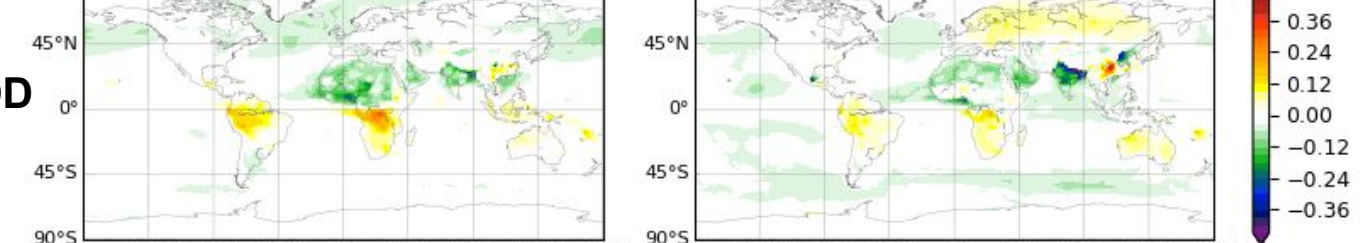
- Underestimated AOD in NARA over North Africa is likely attributed to the dust scheme in the UFS-Aerosols model.

2020 Winter

AOD

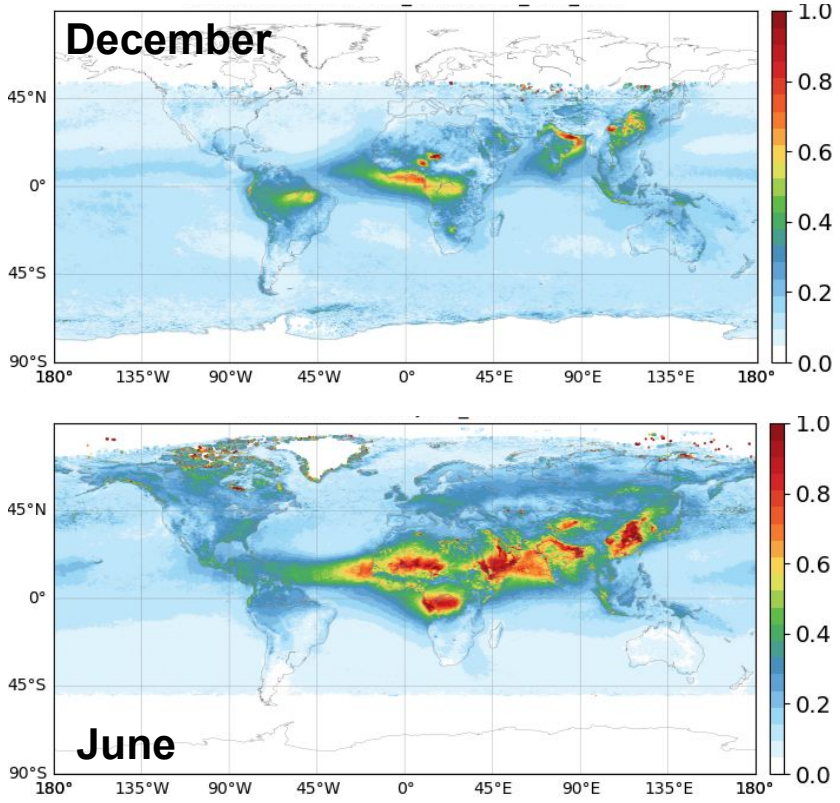


NARA AOD bias

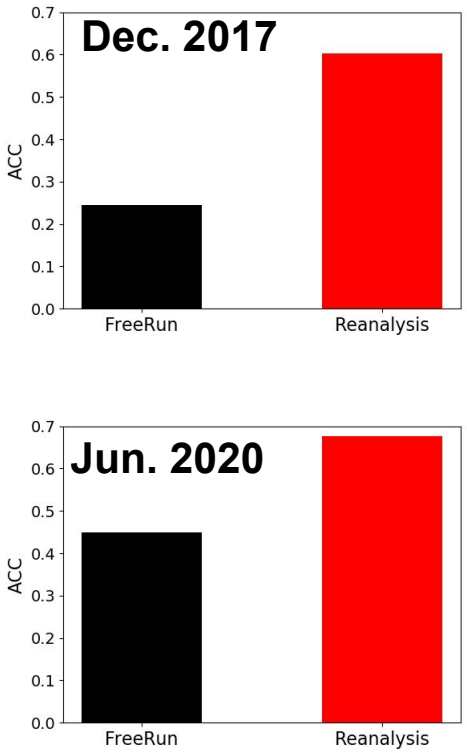


Anomaly Correlation Coefficient (ACC) w.r.t. NESDIS VIIRS AOD climatology --- 5-day UFS-Aerosols forecasts initialized at 00Z in Dec. 2017 and Jun. 2020

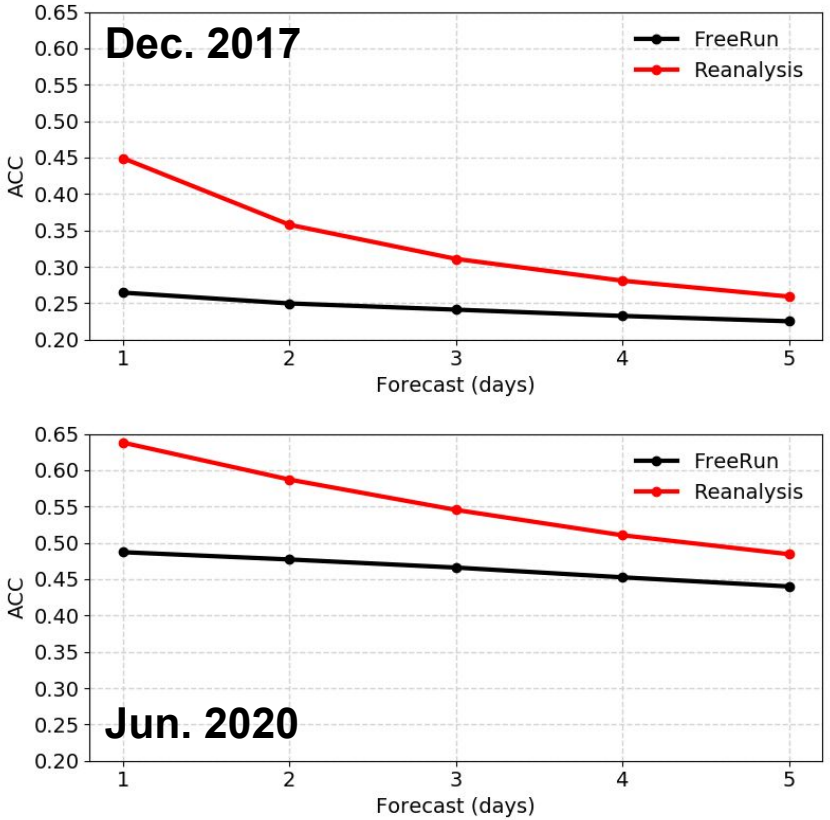
NESDIS VIIRS 550 nm AOD Clim. (2012-2019)



IC AOD ACC at 00Z



5-day forecast AOD ACC



- Anomalies were computed for 5-day forecasts and VIIRS AOD retrievals relative to NESDIS VIIRS AOD retrieval climatology.
- The reanalyses (red in the bar plots) at 00Z in both assimilation experiments has ACC >= 0.6.

Assimilate advanced aerosol retrievals from NASA PACE to improve aerosol representation in UFS-Aerosols in collaboration with NASA, UMBC and SRON at Netherlands

- NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission with the primary Ocean Color Instrument (OCI) and two complementary **multi-wavelength multi-angular polarimeters (MAPs)** was launched in Feb. 2024. It presents an exceptional opportunity to retrieve more detailed aerosol characterization with unprecedented accuracy from space.

- We will extend in JEDI to simultaneously assimilate various PACE aerosol retrievals (beyond 550 nm AOD) to improve aerosol physical and absorption properties in UFS-Aerosols.

  - 550 nm AOD retrievals from PACE OCI that will replace MODIS to retire soon;
  - Multi-wavelength AOD retrievals including UV band;
  - Fine-mode fraction of AOD;
  - Single scattering albedo;
  - and more …

Acknowledgement: "Improving Aerosol Representation in NOAA's UFS-Aerosols Model through Assimilation of Advanced Aerosol Retrievals from NASA's PACE Mission" funded by NOAA's Climate Program Office's CPO's Earth Radiation Budget (ERB), and Atmospheric Chemistry, Carbon Cycle and Climate (AC4) programs (2024-2027).

Reanalysis Products and Data Access

- **Variables** : 550 nm AOD and fifteen aerosol mass mixing ratios (dust and sea salt in five size bins, hydrophobic and hydrophilic black and organic carbon, and sulfate)
- **Spatial coverage:** Half degree over the globe at a single level for AOD and at sigma levels (64 for Year 2016 and 127 for Year 2018-2022) for aerosol mass mixing ratios.
- **Temporal coverage**: 4-times daily for Year 2016 (completed) and Year 2018-2022 (production ongoing)
- **Dataset Format and size**: CF metadata standard, NetCDF4 format.
- **Access:**
  - **Year 2016:** https://esrl.noaa.gov/gsd/thredds/catalog/retro/global_aerosol_reanalysis/catalog.html
  - **Year 2018-2022**: currently completed in Jan. – Oct. 2018 and Jul. 2020 – Mar. 2021, and now stored on NOAA HPSS available upon request.

References

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Thanks for listening!