Near-Real-Time Global Aerosol Data Assimilation and Forecasting at NOAA/OAR/GSL

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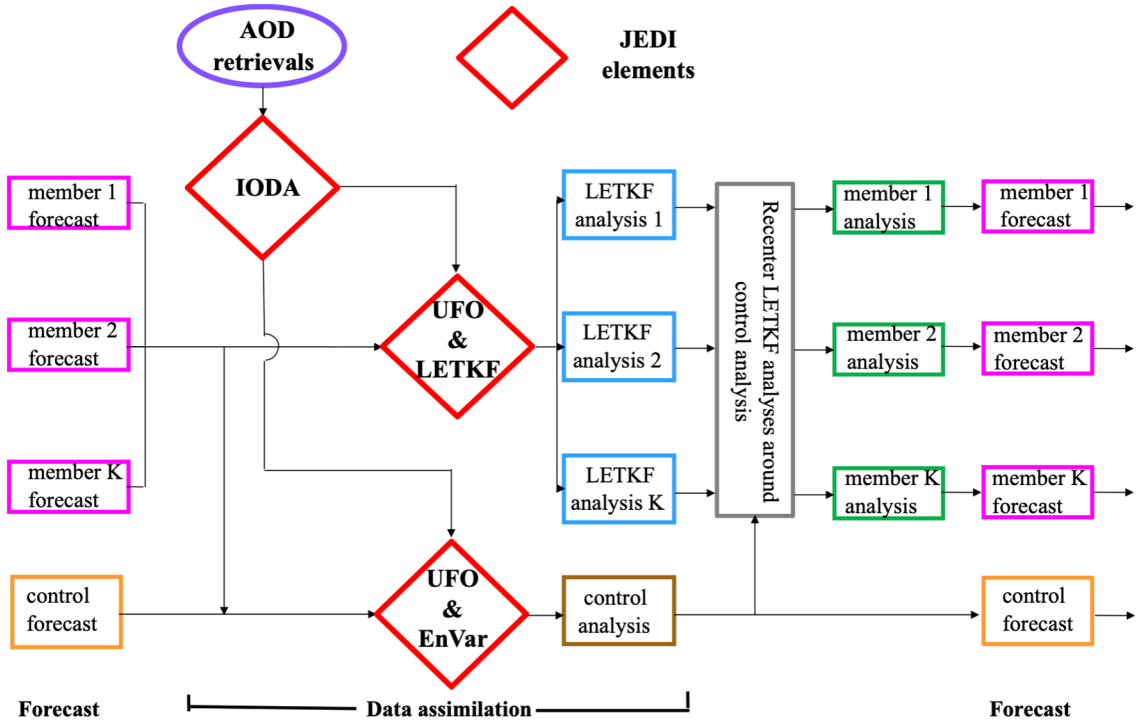
Background

- The Global Ensemble Forecast System - Aerosols (GEFS-Aerosols) was transitioned to operations at NCEP/EMC in September 2020 to provide global aerosol forecasts.
  - It relies on the Finite-Volume Cubed-Sphere (FV3) dynamical core, the Global Forecast System (GFS) physics and the aerosol parameterization based on the Goddard Chemistry Aerosol Radiance and Transport (GOCART) model.
  - GEFS-Aerosols forecasts are currently not constrained by observations.

- **The goal is to develop global aerosol DA capability for GEFS-Aerosols at NCEP/EMC.** An ensemble-variational (EnVar) aerosol data assimilation (DA) capability has been developed within the Joint Efforts for Data assimilation Integration (JEDI) led by the Joint Center for Satellite Data Assimilation (JCSDA).

- The DA system is in the third year of development. It is at Readiness Level 7 as its capability has been demonstrated in an operational setting and being tested in a near-real-time (NRT) environment at NOAA/OAR/GSL. Further work in collaboration with EMC continues to facilitate its transition to operations.

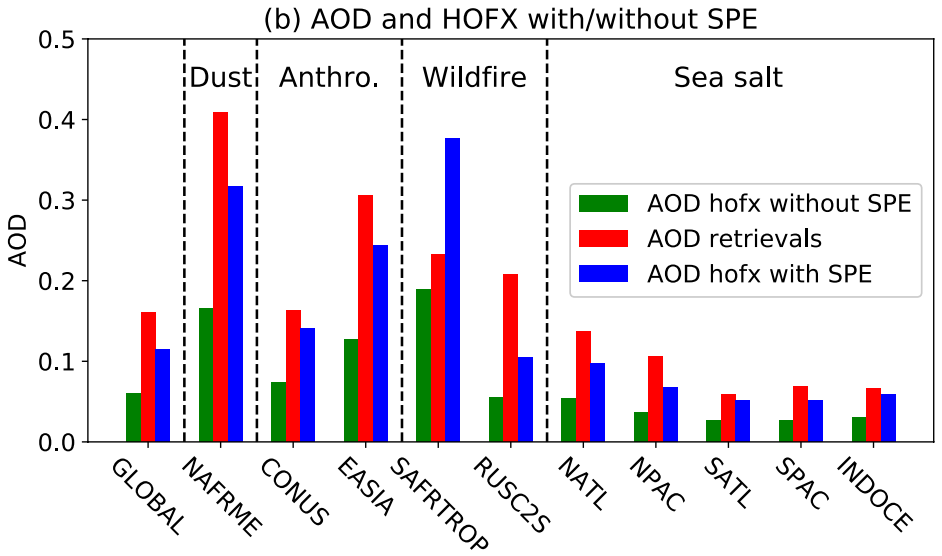
JEDI-based global aerosol DA



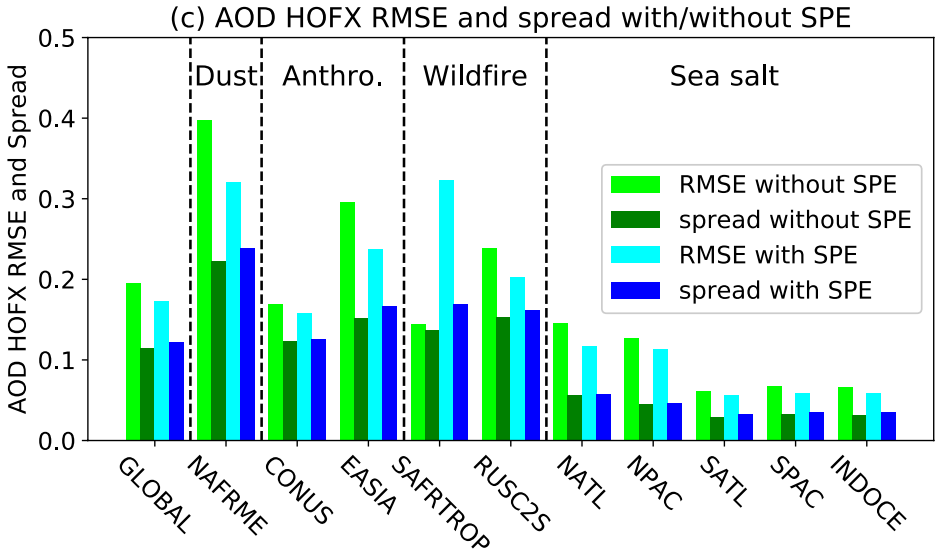
- **AOD**: Aerosol optical depth (AOD) at 550 nm;
- **JEDI**: Joint Effort for Data assimilation Integration -- a collaborative effort led by JCSDA;
- **IODA**: Interface for Observation Data Access;
- **UFO**: Unified Forward Operator;
- **LETKF**: Local Ensemble Transform Kalman Filter
- **EnVar**: Ensemble-Variational solver.

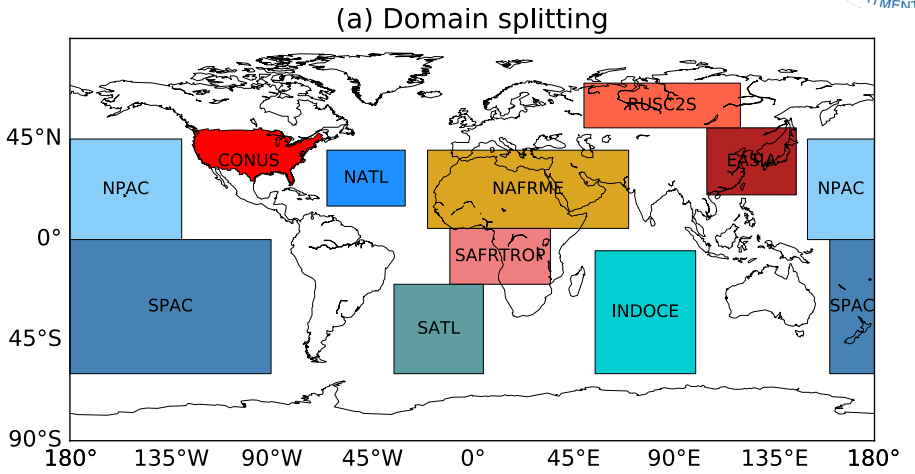
Stochastically-Perturbed Emissions (SPE) based on ECMWF's Stochastically Perturbed Parametrization Tendency (SPPT) scheme to alleviate modeled AOD bias and ensemble spread deficiency

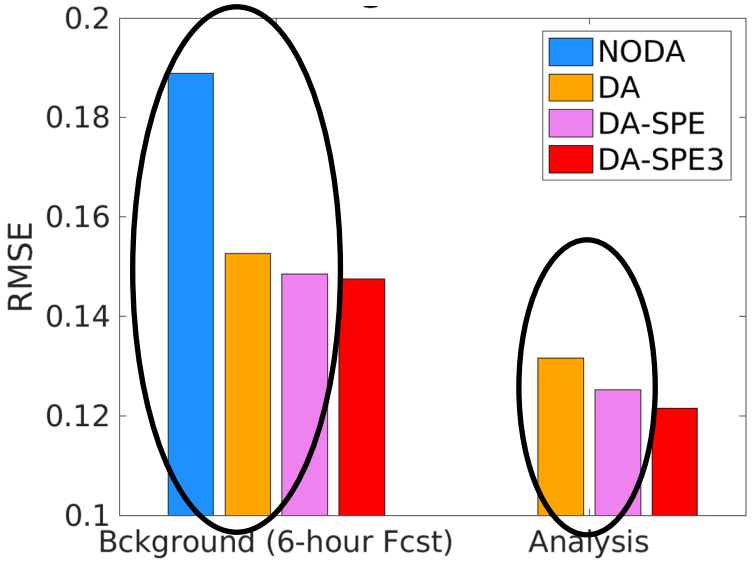
Simulated VIIRS AOD vs VIIRS AOD retrievals **(used to define emission scaling factors (=2.0) to correct modeled AOD bias and increase ensemble background spread)**



Simulated VIIRS AOD error and spread (20 members, used to **define emission perturbation standard deviation (=2.0) to increase ensemble background spread)**





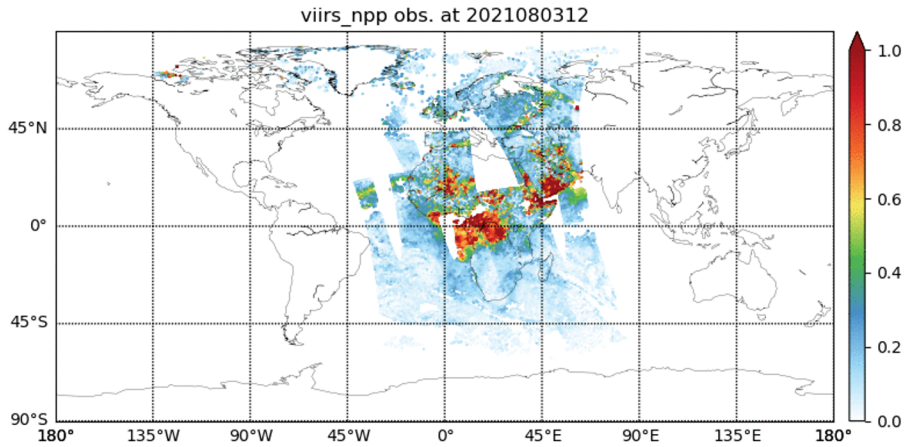


- Applying SPE is able to improve ensemble error-spread consistency and the fitting of the 6-hour forecast and analysis to VIIRS AOD at 550 nm.

NRT experiment design

- Six-hourly assimilation of AOD retrievals at 550 nm derived from NOAA VIIRS onboard the Suomi-NPP satellite;
- 3D-EnVar and LETKF for aerosol update;
- LETKF analysis recentered around EnVar analysis;
- NASA-LUTs for AOD forward operator calculation;
- Meteorological variables corrected by adding regridded increments from operational GDAS analyses;
- 1-control plus 20-member ensemble at C96 (~100km) using GSL's CCPP version of GEFS-Aerosols model for aerosol forecasts;
- Evaluation was performed for the period of July 09 - Sept. 30 2021.

NOAA S-NPP VIIRS AOD retrievals at 550 nm (~ 50 km resolution)

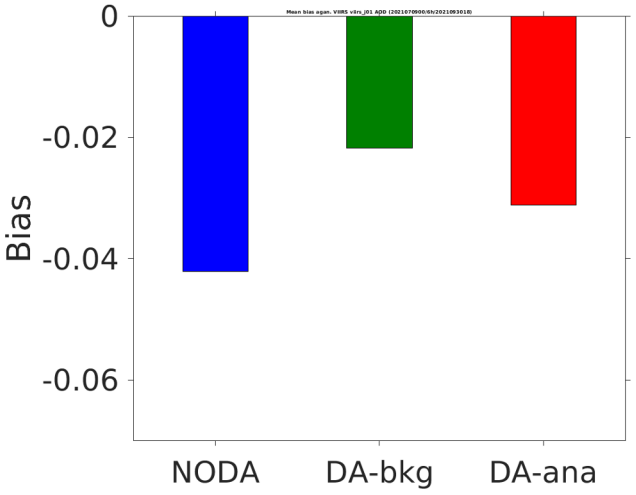


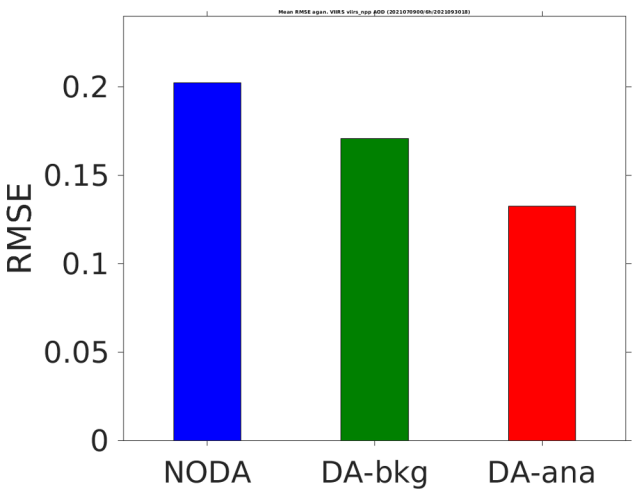
	AOD DA	Ensemble members	Stochastically-perturbed emissions		
NODA	No	N/A	No		
DA	Yes	20		07/09 – 09/01 2021	09/02 – 09/30 2021
			Scaling factors /perturbation SD for Dust	2.0 / 2.0	1.2 / 2.0
			Sea salt	2.0 / 2.0	1.2 / 2.0
			Anthropogenic	1.5 / 2.0	1.2 / 2.0
			Wildfire	1.1 / 2.0	1.0 / 2.0

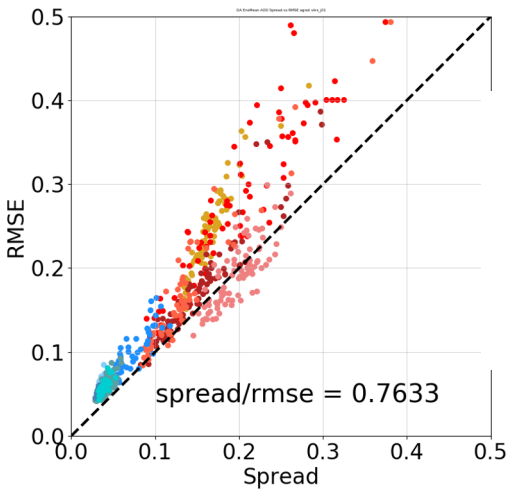
Bias and RMSE against NOAA-20 VIIRS AOD and Aqua MODIS AOD at 550nm (07/09 - 09/30, 2021)

Bias | **RMSE** | **ensBckg RMSE vs Spread**

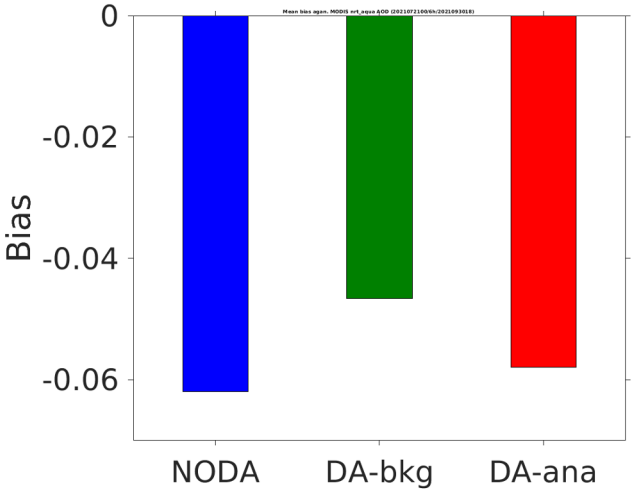
Against NOAA-20 VIIRS AOD at 550nm

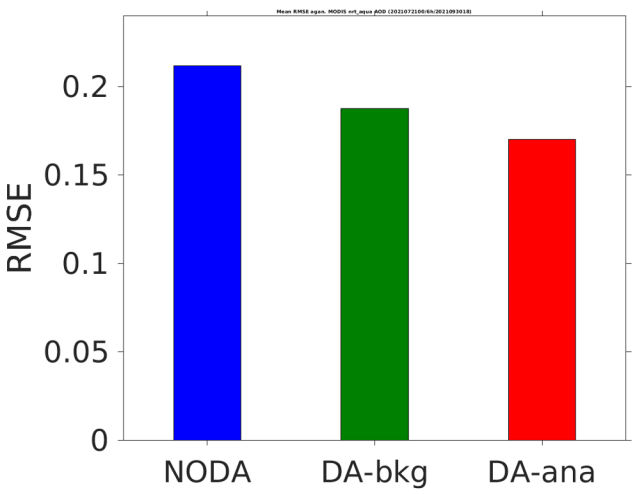


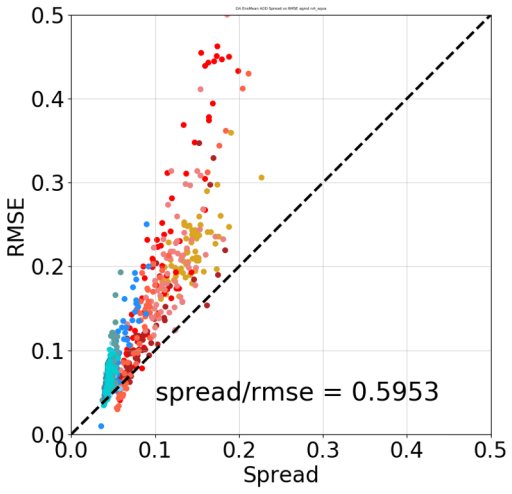




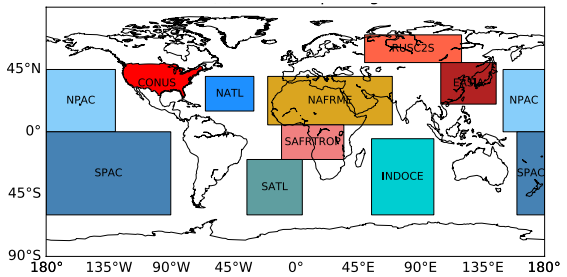
Against Aqua MODIS AOD at 550nm







- **NODA**: 6-hour forecasts in NODA exp.
- **DA-bckg/anal**: background (6-hour forecasts)/analysis in DA exp.



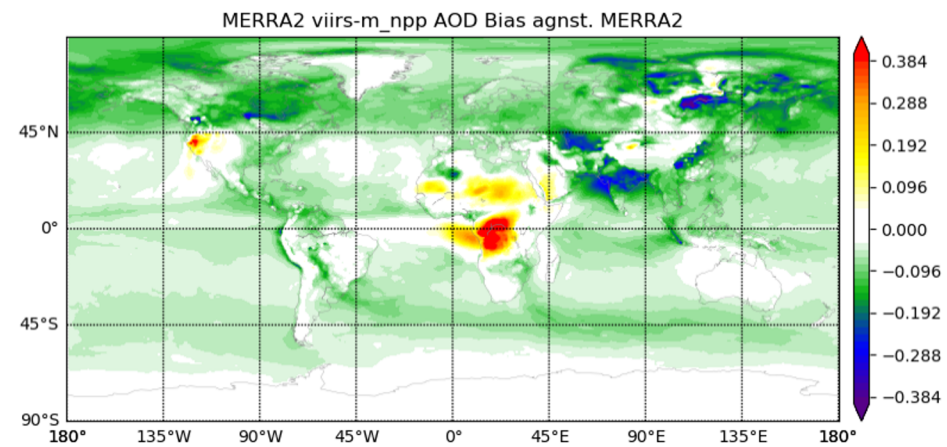
- ❑ Assimilation of VIIRS AOD at 550 nm efficiently reduces bias and root-mean-squared error of simulated AOD.
- ❑ Overall smaller negative bias in DA-bckg than DA-anal is due to relative large positive bias in fire regions such as Amazon, and central Africa, likely caused by too large fire emissions from GBBEPx or too large scaling factors for wildfire emissions.

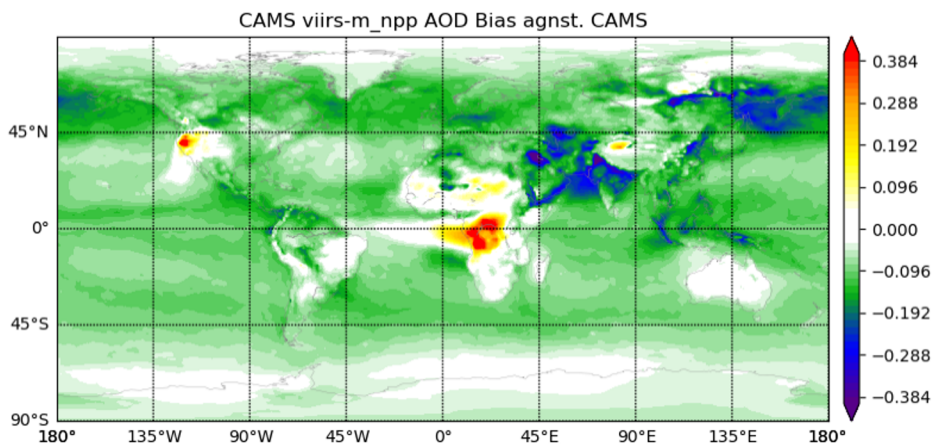
Temporally averaged AOD bias at 550nm against NASA and ECMWF analyses (07/09 - 09/30, 2021)

Bias agan. NASA analysis

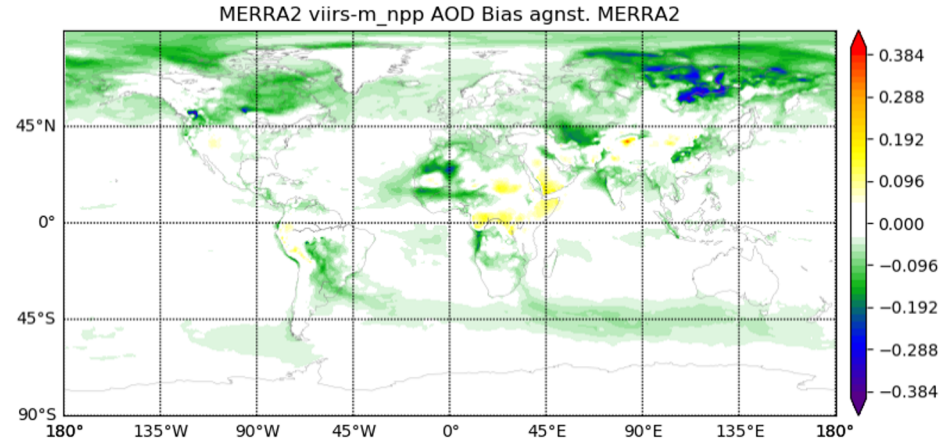
Bias agan. ECMWF analysis

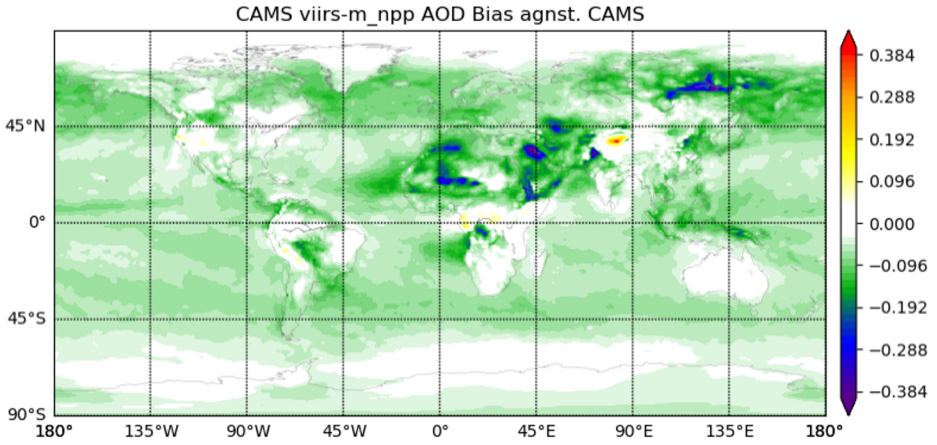
NODA 6-hour fcst





DA analysis (similar figures for DA background)

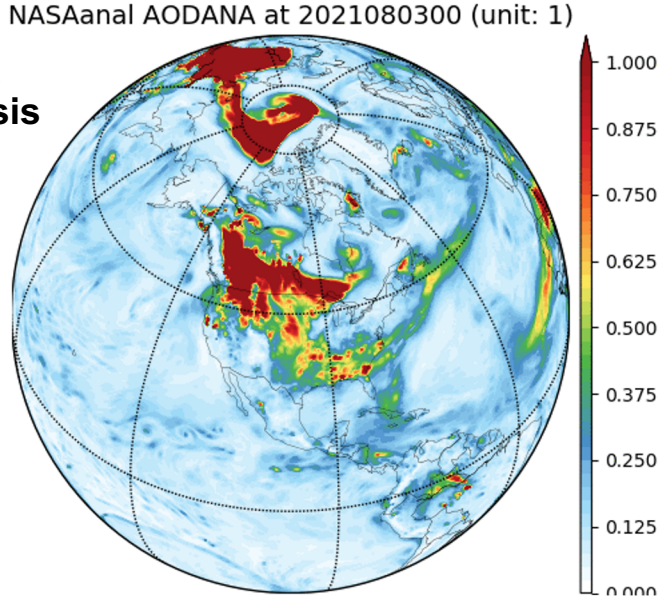




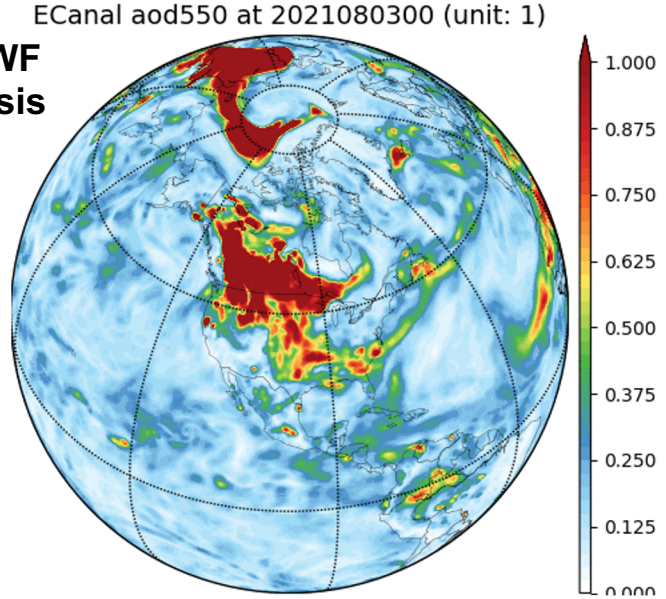
- DA generally shows clear reduced AOD bias than NODA except for regions close to the Arctic when against NASA analyses. This is likely due to lack of AOD observations in these regions that further causes large uncertainty of simulation of the wildfire event in Siberia in July and August 2021 (heavy smoke spreads over the Arctic, see animation in the next slide).
- Root-mean-errors show similar pattern as the bias.

Comparison of AOD at 550nm in an Oregon wildfire event for August 3-9, 2021

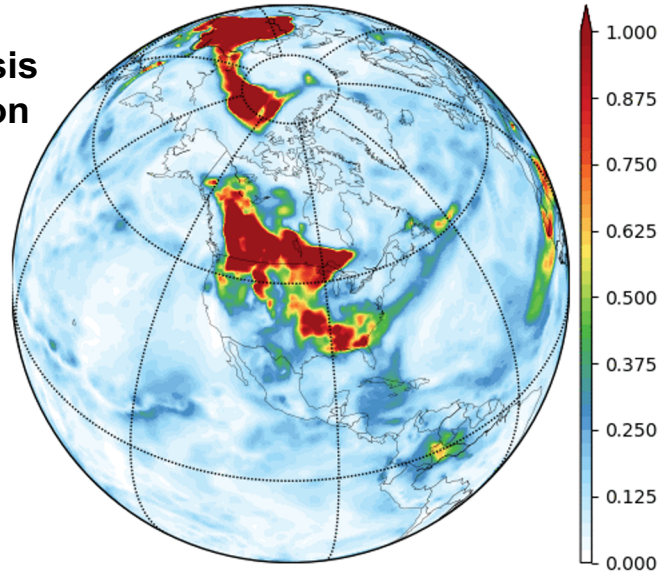
NASA analysis



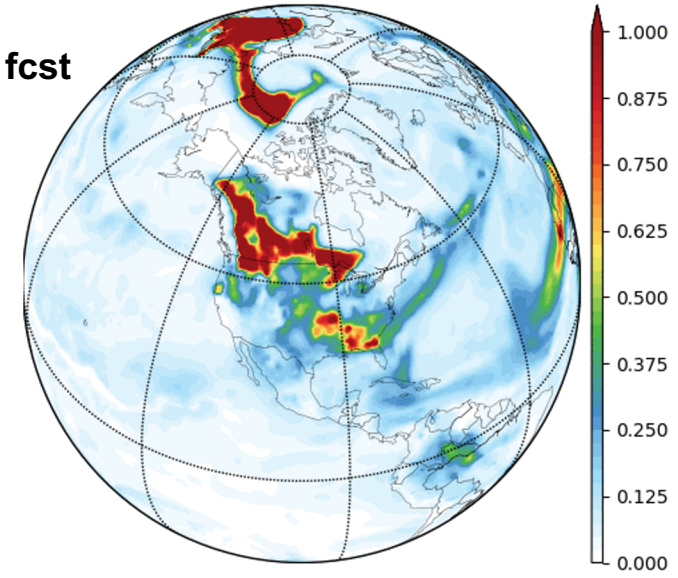
ECMWF analysis



DA Analysis (similar animation for DA 6-hour fcst)



NODA 6-hour fcst



- At much lower resolution, DA analysis shows very good AOD agreement with analyses from NASA and ECMWF.

Summary

- JEDI-based global aerosol DA system has been developed for operational GEFS-Aerosols to improve aerosol forecasts. The system currently falls in RL 7, and is being demonstrated in NRT at NOAA/OAR/GSL and is planned for transition to operations at NCEP/EMC.

- Cycled NRT experiments in July-Sept., 2021 show that assimilation of AOD retrievals is able to improve simulated AOD, aerosol concentrations (not shown) by comparing with independent AOD retrievals, and NASA and ECMWF analyses.

- To further improve the performance of this system, ongoing work includes
  - further tuning emission scaling factors;
  - adding new JEDI capabilities, such as variational bias correction and static background error covariance;
  - exploring effective strategies of increasing ensemble spread and accurately estimating AOD errors.

Thanks for your attention!

Questions?

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