Development of Hybrid Ensemble-Variational Aerosol Data Assimilation System with JEDI

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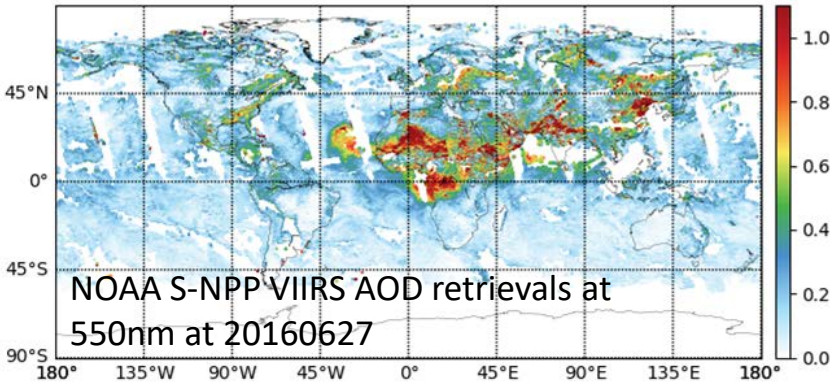
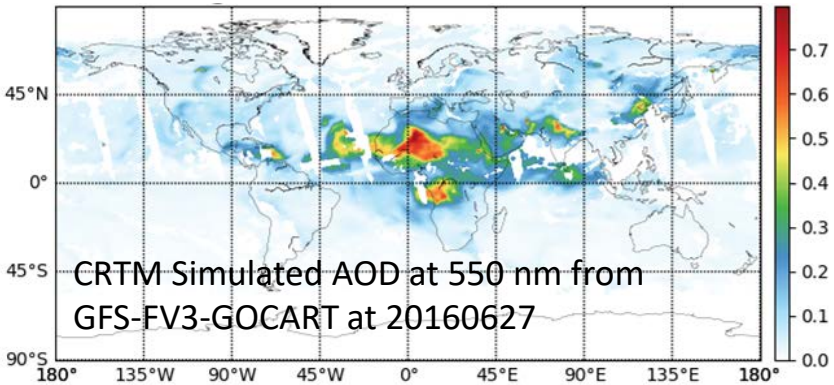
Outline

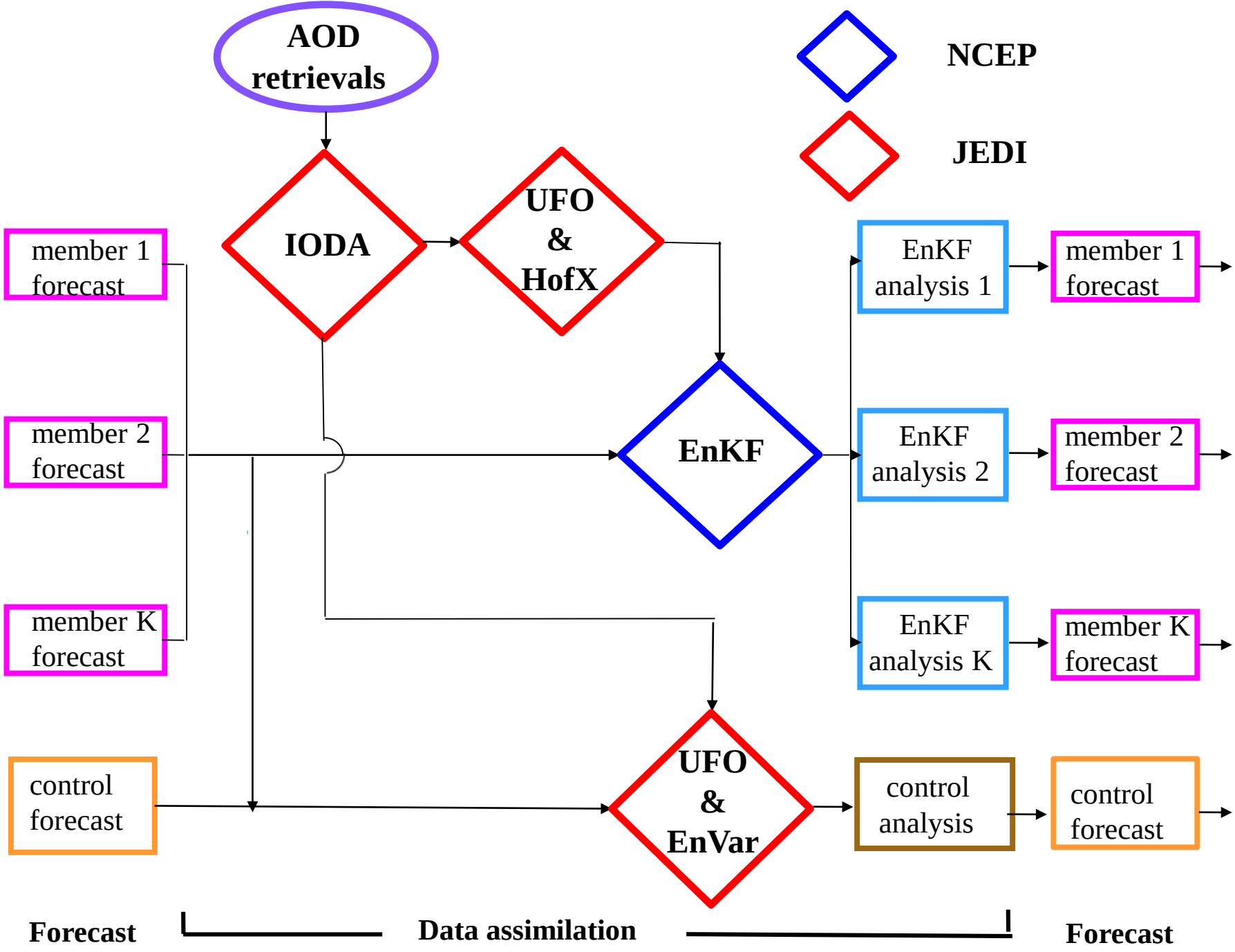
- JEDI-based Hybrid Ensemble-Variational Aerosol Data Assimilation System
- Assimilation Experiments and Evaluation using METPlus
- Ongoing/Future Work

JEDI-based Hybrid Ensemble-Variational Aerosol Data Assimilation System

- Data assimilation (DA) combines model forecasts (background) with information from observations to obtain the best estimate of the true state.
- Joint Effort for Data assimilation Integration (JEDI) - the next-generation unified DA system is being developed at JCSDA.
- Developed 3DEnVar-FGAT ensemble-based DA capability within JEDI for assimilating AOD retrievals to improve global aerosol analyses and forecasts:
  - Thinning of MODIS and VIIRS 550 nm AOD retrievals and formatting in IODA;
  - AOD observation operator using aerosol optical properties in the Community Radiative Transfer Model (CRTM) and included in UFO;
  - FV3-JEDI interface for GOCART aerosols for variational minimization;
  - Modified NCEP's EnKF to operate on native FV3 grid (using until KF's available in JEDI);
  - HofX Forward operator for EnKF;
  - All integrated within NCEP's operational global DA workflow for the future operational application.



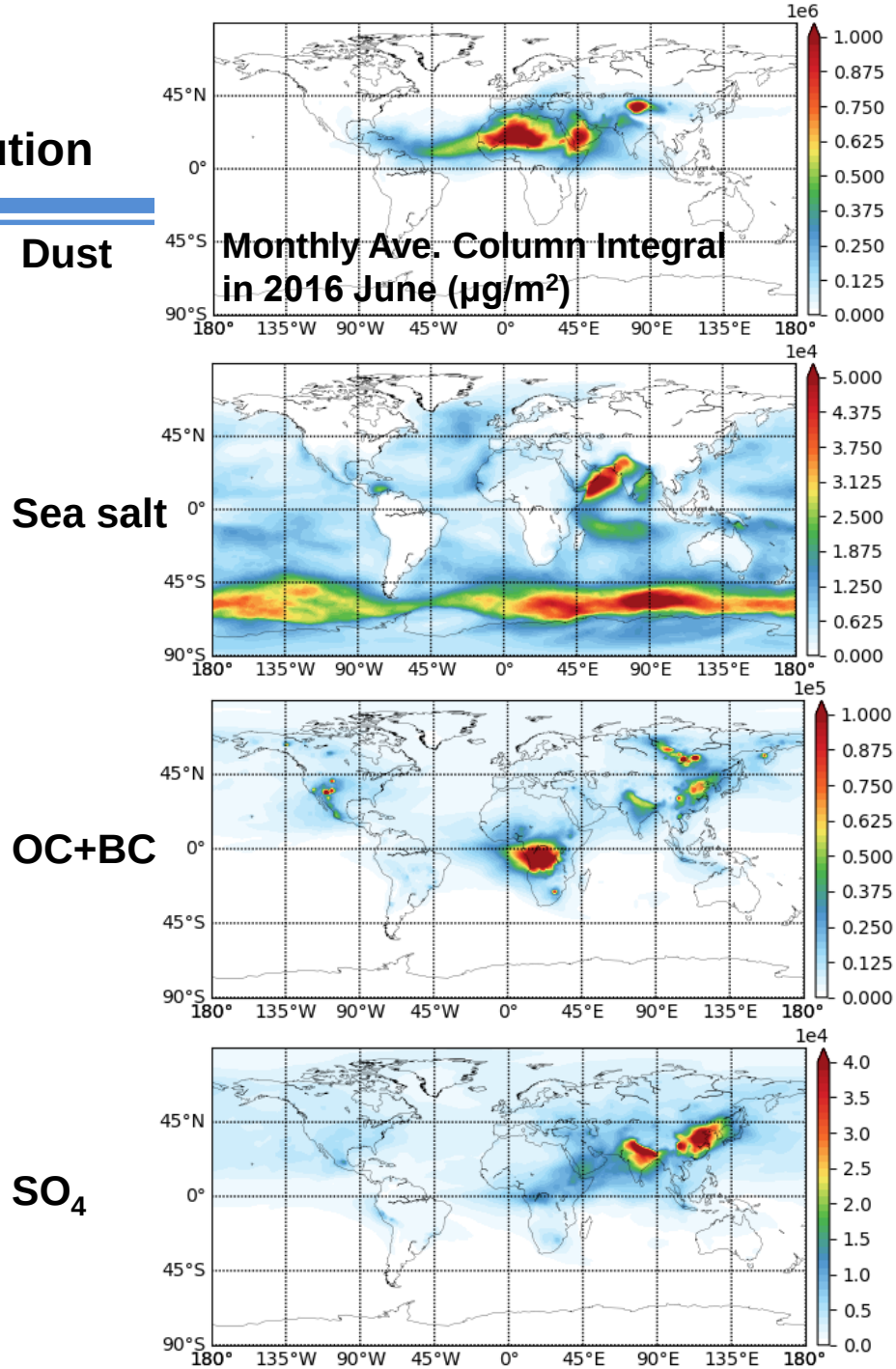



AOD retrievals
NCEP
JEDI
IODA
UFO & HofX
member 1 forecast
member 2 forecast
member K forecast
EnKF
EnKF analysis 1
EnKF analysis 2
EnKF analysis K
member 1 forecast
member 2 forecast
member K forecast
control forecast
UFO & EnVar
control analysis
control forecast
Forecast
Data assimilation
Forecast

GFS-FV3-GOCART Model

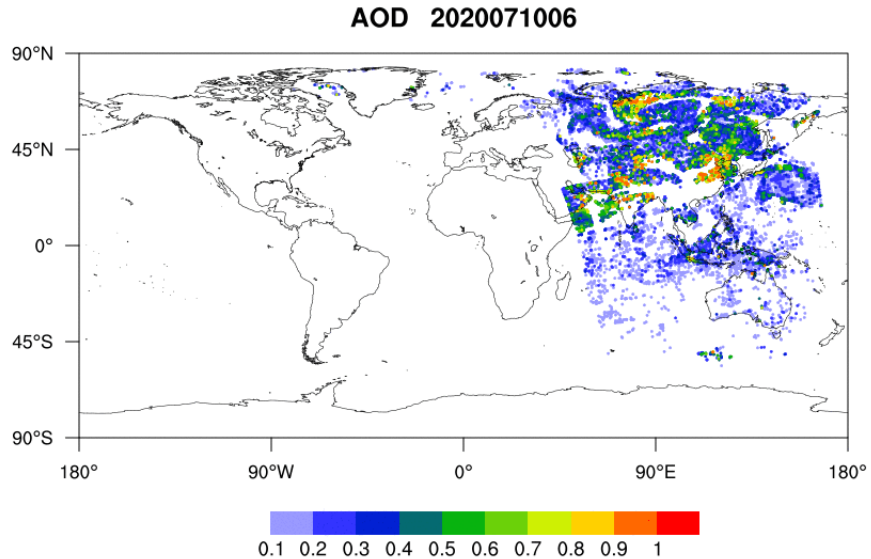
--- GEFS-Aerosols model at reduced resolution

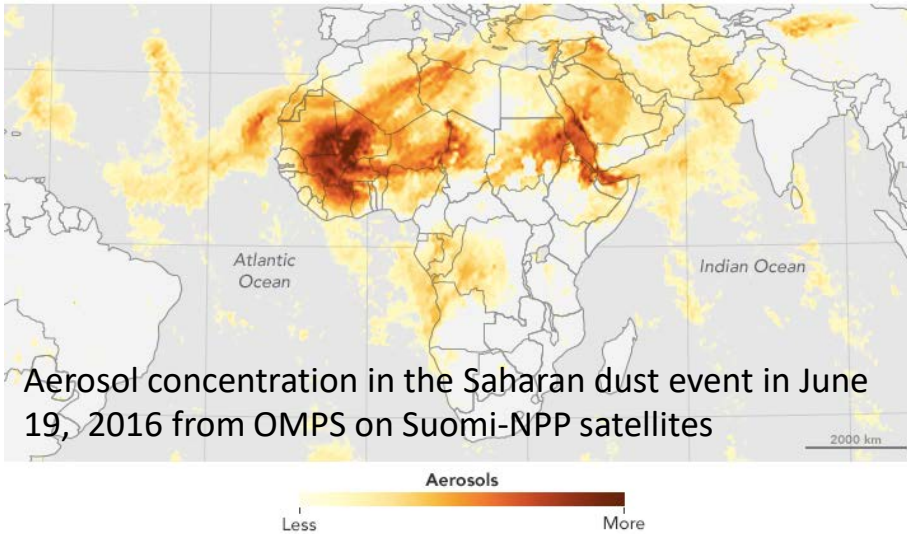
- FV3-based GFS coupled with the Goddard Chemistry Aerosol Radiance and Transport (GOCART) aerosol scheme at C96 (~100 km)
  - Dust with five size bins
  - Sea salt with five size bins
  - Hydrophobic and hydrophilic organic and black carbon
  - Sulfate
- Blended Global Biomass Burning Emissions Products (GBBEPx) and Fire Radiative Product (FRP)
- Chemistry coupled with the core meteorological model via NUOPC interface



AOD Assimilation

- AOD retrievals at 550 nm derived from NOAA VIIRS onboard the Suomi-NPP satellite
- Six-hourly AOD assimilation within 3 hours of the analysis time
- Serial EnKF and 3D-EnVar to calculate increments for aerosol concentration
- Meteorological variables are corrected by adding regridded increments from operational GDAS analyses.
- 20-member ensemble at C96 (~100km)
- Cycled AOD DA experiments were performed in June 2016 after three-week model spin-up in May 2016.
- A parallel experiment without AOD DA was performed for comparison.

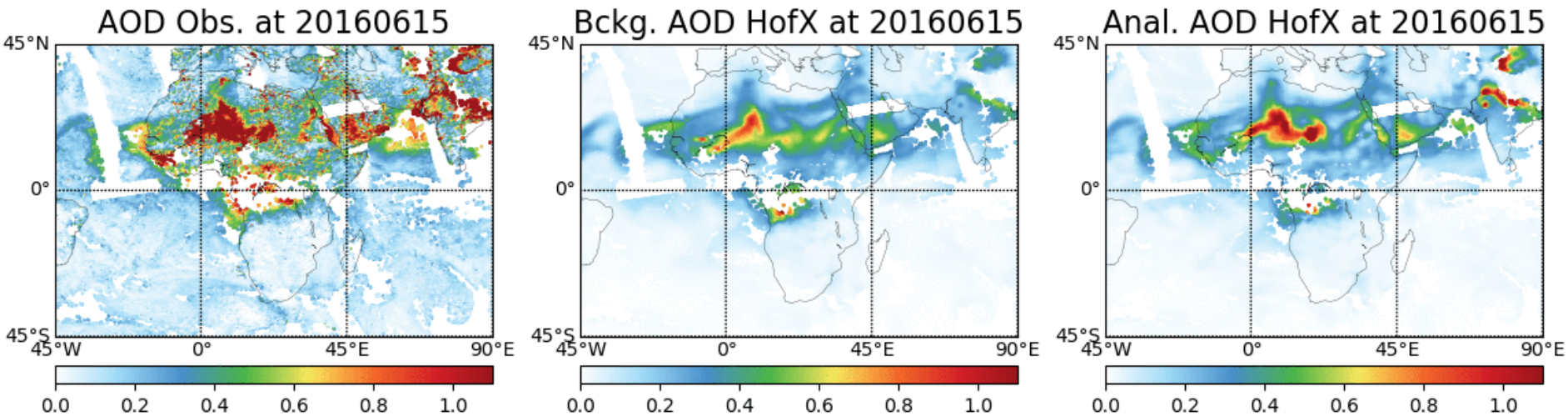




Aerosol concentration in the Saharan dust event in June 19, 2016 from OMPS on Suomi-NPP satellites

(Photo from https://earthobservatory.nasa.gov/images/88251/atmosphere-aw

AOD DA Impact on Saharan Dust Storm in June 2016 – an example



AOD retrievals at 550nm

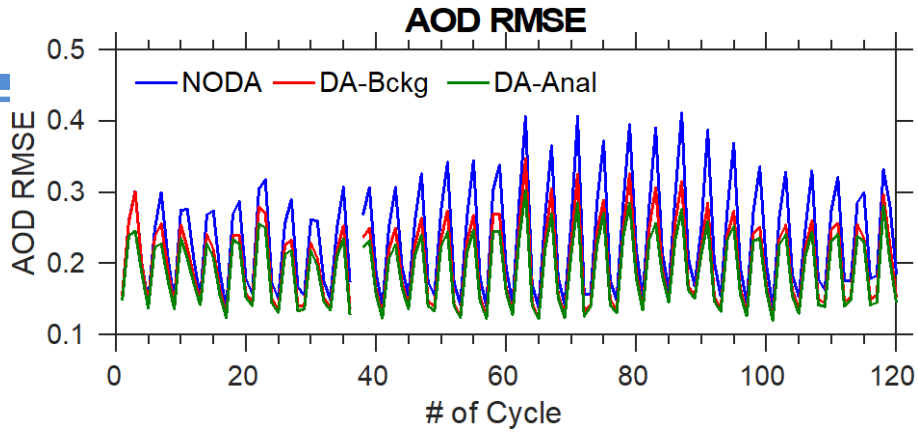
CRTM-simulated AOD at 550nm **before** AOD DA

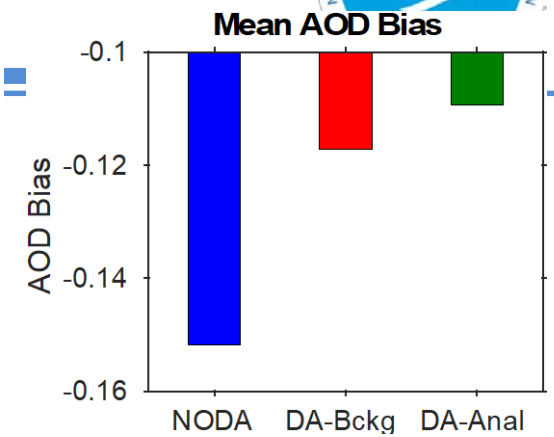
CRTM-simulated AOD at 550nm **after** AOD DA

- Assimilation of AOD improves the intensity and pattern of the dust storm.

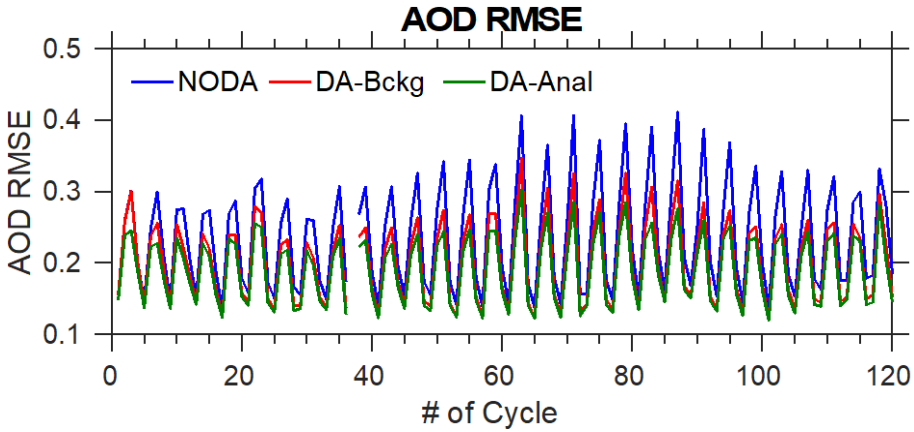
Innovation Statistics of VIIRS AOD at 550nm

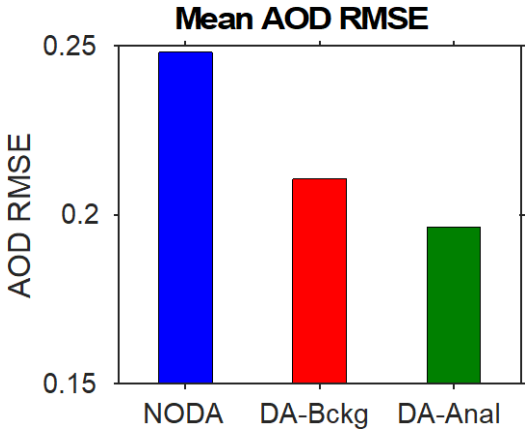
Bias





RMSE

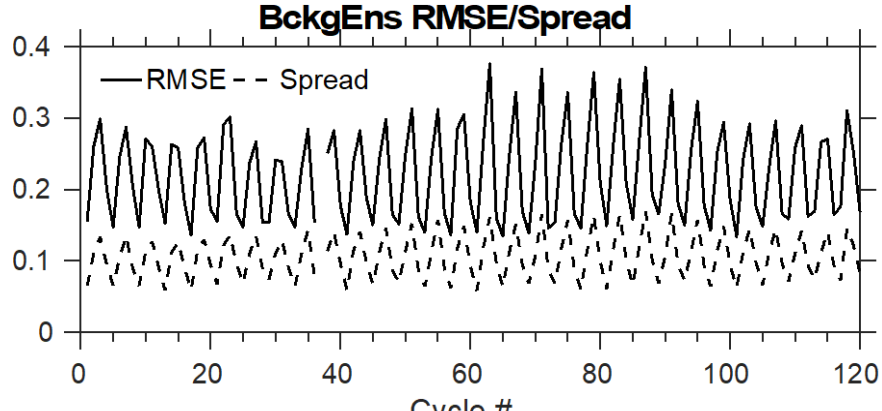




NODA: 6-hour forecasts in exp. without AOD DA.

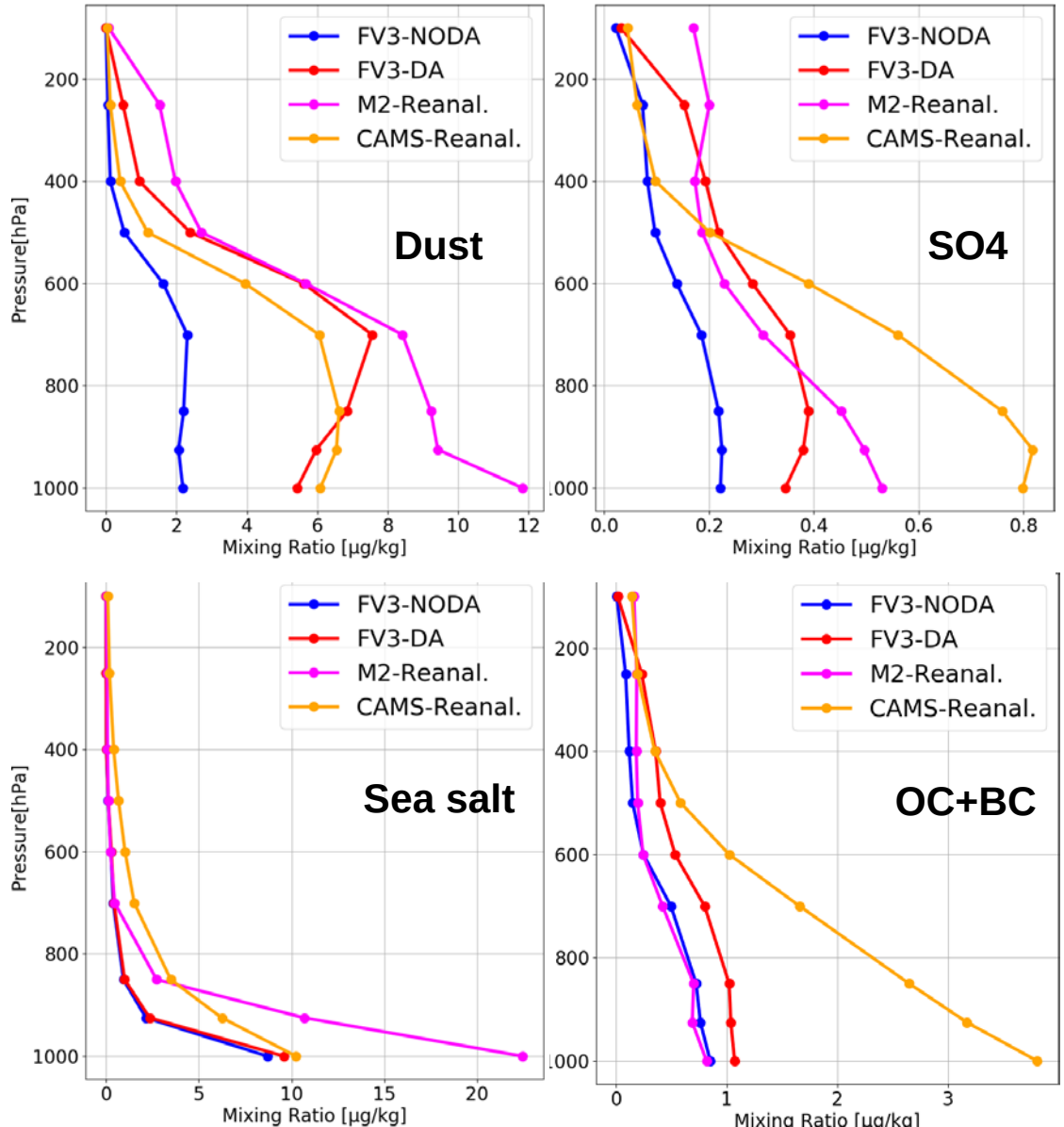
DA-Bckg /DA-Anal: 6-hour background/Analysis in exp. with AOD DA.

Ens. Bckg. Err /Spread



- Assimilation of AOD at 550nm reduces negative bias and error of simulated AOD at 550nm.
- Insufficient spread in background ensemble.

Monthly and Globally Averaged Mixing Ratio Profiles of Aerosol Species
--- 6-hour Forecasts Comparison with/without AOD DA



FV3-NODA: GFS-FV3-GOCART model 6-hour forecasts without AOD DA

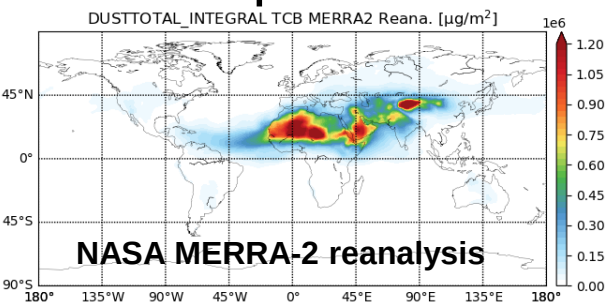
FV3-DA: GFS-FV3-GOCART model 6-hour forecasts with AOD DA

M2/CAMS-Reanal: NASA MERRA-2/ ECMWF CAMSiRA reanalysis

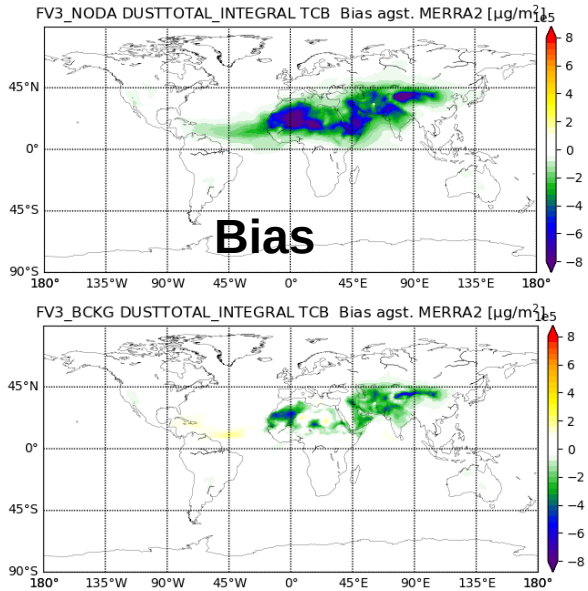
- After AOD assimilation, FV3-DA better matches NASA/EC reanalyses than FV3-NODA for dust and SO4.
- Due to insufficient spread for sea salt, difference between FV3-NODA and FV3-DA is relatively small.
- Largely different mixing ratio profiles between NASA and EC reanalyses suggest large uncertainty of aerosol forecasts and DA.

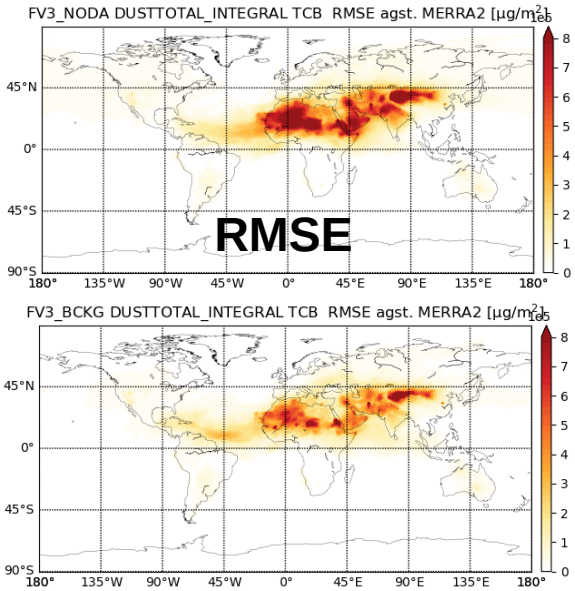
Monthly Averaged Dust Column Integral
--- 6-hour Forecasts Comparison with/without AOD DA

FV3-NODA



FV3-DA





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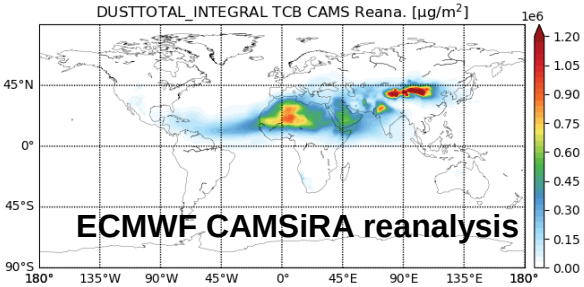
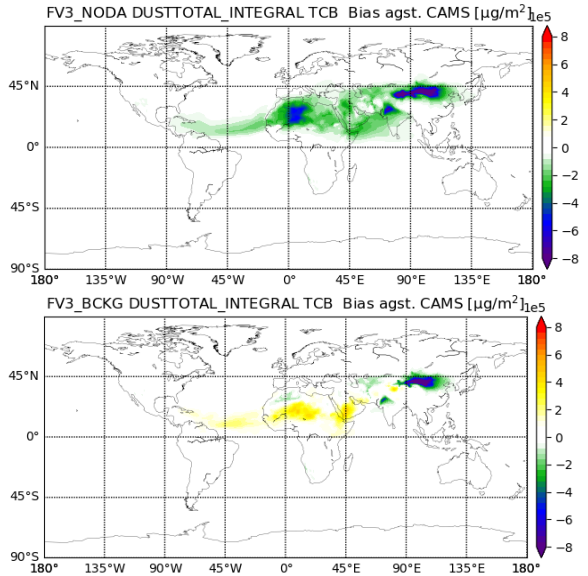
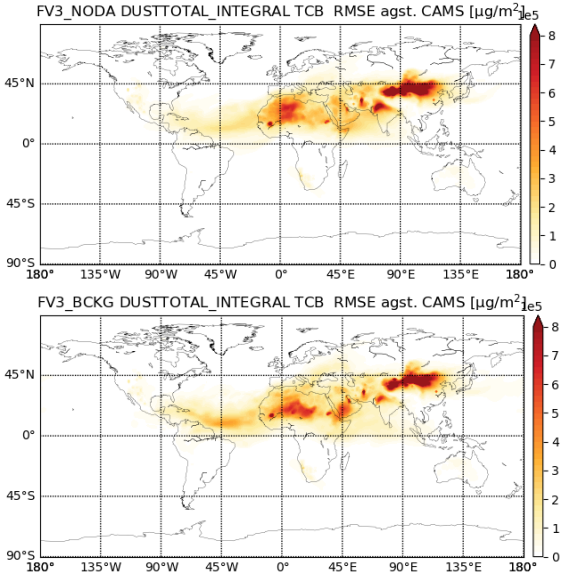


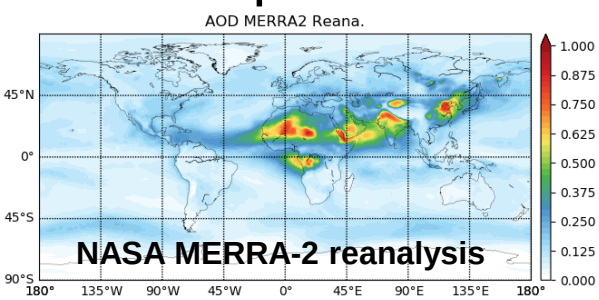
FV3-DA



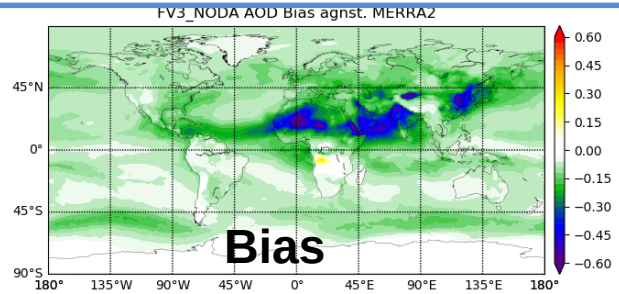


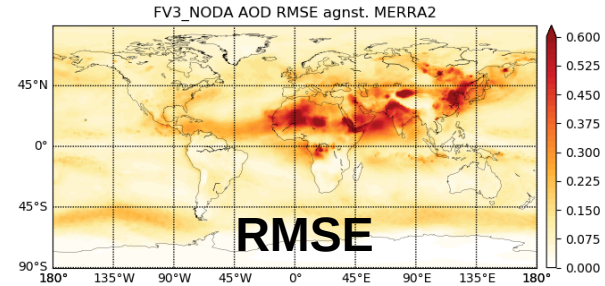
Monthly Averaged AOD at 550 nm
--- 6-hour Forecasts Comparison with/without AOD DA

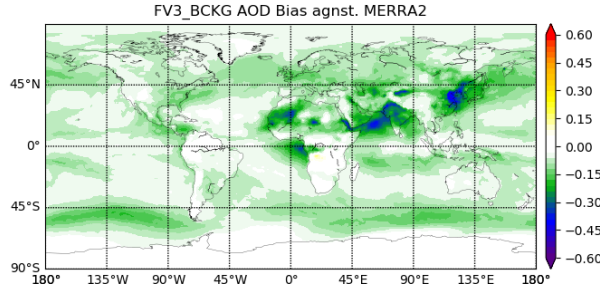
FV3-NODA

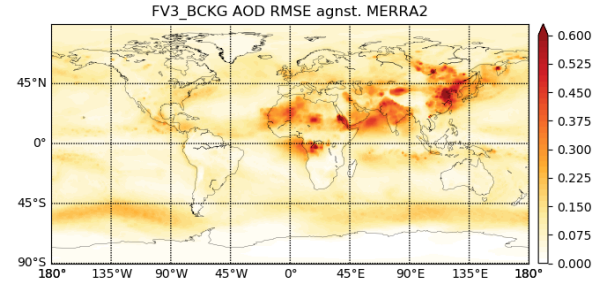


FV3-DA

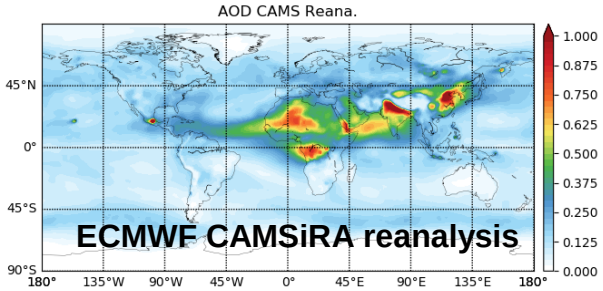




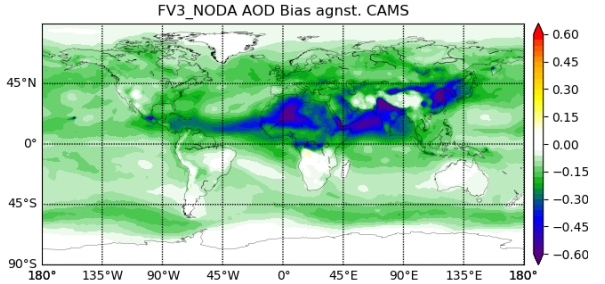


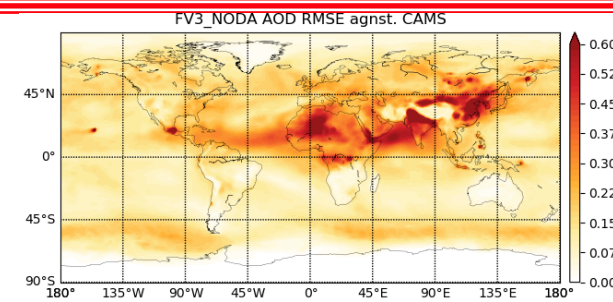


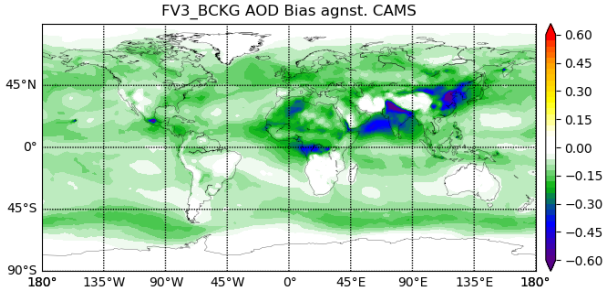
FV3-NODA

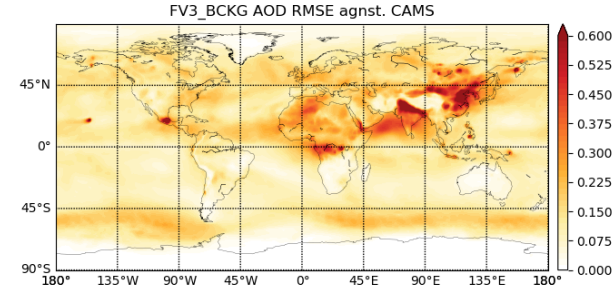


FV3-DA









Ongoing/Future Work

- Verify model AODs against the AErosol RObotic NETwork (AERONET) observations at different wavelengths and against a variety of independent retrievals.
- Develop static B-matrix for aerosol species.
- Recenter ensemble analysis around control analysis.
- Develop dual-resolution capability for ensemble and control.
- In collaboration, improve representation of radiative properties of aerosols in CRTM; in parallel, develop forward AOD operator based on NASA's tables.
- Employ variational bias correction so that model biases are accounted for in the assimilation.
- Improve system performance through ensemble spread increased by stochastic perturbations to emissions and parameterizations.
- Account for the non-Gaussian error distribution of AOD.

Thanks for your attention!

Questions?

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