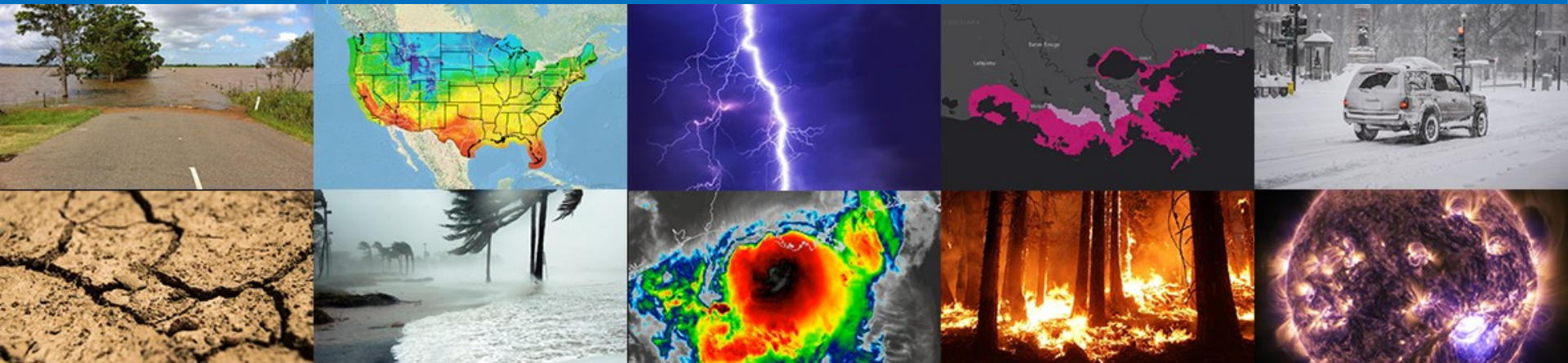
NATIONAL WEATHER SERVICE

JEDI-Based Atmospheric Composition Data Assimilation Progress at EMC

October 10, 2024

Cory R Martin

With contributions from: Hyundeok Choi, Jianping Huang, Daryl Kleist, Jeff McQueen, Ivanka Stajner, Andrew Tangborn, Yaping Wang, Hongli Wang, Ruifang Li, Jérôme Barré, and others



Target Applications

- GFS/GEFS
  - Medium-range weather forecasting
  - Global aerosols using GOCART
- AQM
  - N. America air quality prediction
  - Full chemistry with CMAQ
- SFS
  - Subseasonal-to-seasonal prediction
  - Global aerosols, perhaps future GHGs?

GFSv17 Aerosol DA Plans

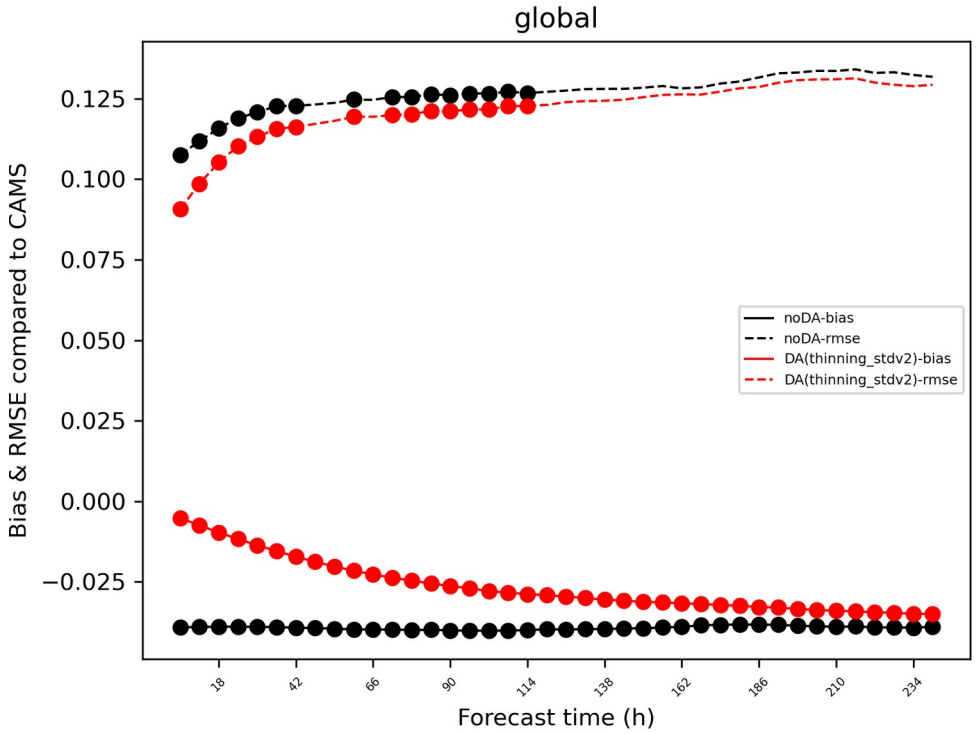
Currently one of the few (only?) operational centers to not have aerosol DA initializing their aerosol prediction system

- **6-hourly cycles 4x a day with early and late cycles**
  - Early cycle to initialize the GEFS long forecasts (one aerosol analysis provided, up to the ensemble forecast group to decide if/how to perturb)
  - Late cycle to initialize the high resolution GDAS forecast (without radiative feedback)
- **Analysis resolution C384L127 (~0.25 deg); background resolution C1152L127 (~9km)**
- **3DVar FGAT with 3-hourly backgrounds**
- **VIIRS EPS 550nm AOD from S-NPP, N20, N21**

AOD Assimilation Impact

Student T-test suggests that (somewhat limited sample size) VIIRS AOD assimilation can have a significant impact on the model's forecast of AOD.

"Significant" reduction of RMSE out to ~5 days and mean bias reduction out to 10+ days are possible.



Work/figures courtesy Yaping Wang, SAIC@EMC

Thinning vs Superobbing

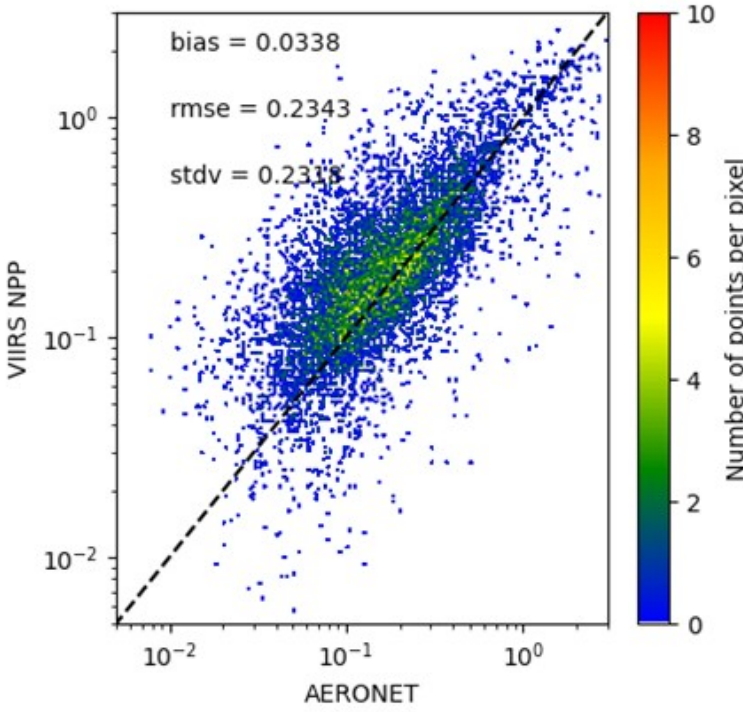
VIIRS observations are ~750m, far too dense to assimilate all.

- **DA generally assumes observations are independent and not correlated, which isn't the case here.**
- **Two main ways to handle this:**
  - Thinning - select only every n-th observation, either randomly, or with some sort of space/time structure
  - superobbing - averaging/binning several observations into one new observation
- **Aiming to have ~one observation per model grid point**

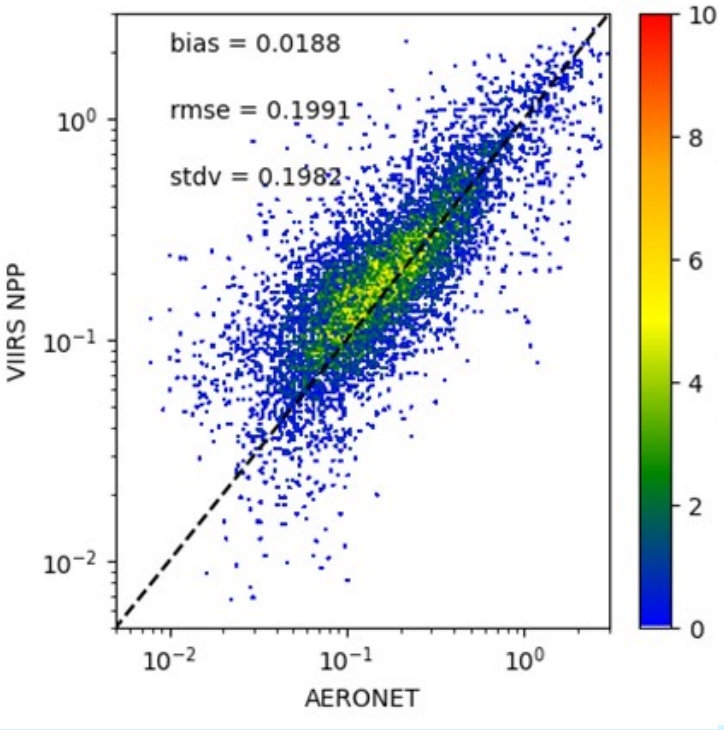
Yaping Wang

Thinning vs Superobbing

Thinned



Superobbed

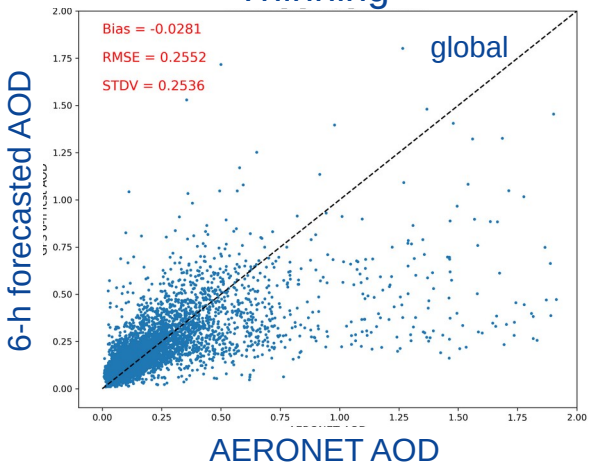


Yaping Wang

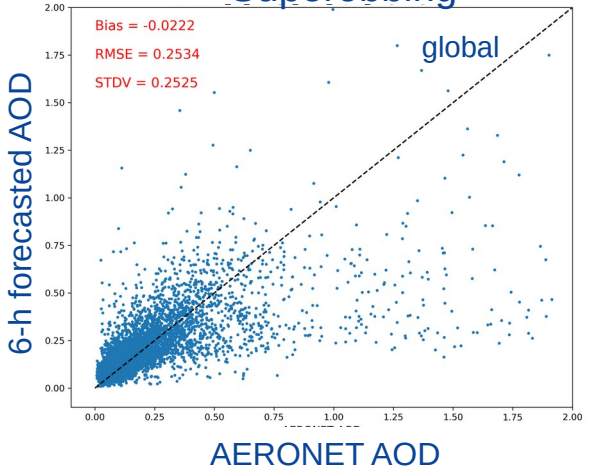
GOCART 6-h forecast verified against AERONET AOD

(01 Aug 2021 - 14 Aug 2021)

Thinning



Superobbing



On global scale, superobbing reduces the mean bias, RMSE and STDV, compared to thinning.

	North America		Europe		South America		Africa		East Asia	
	Thin	Superob	Thin	Superob	Thin	Superob	Thin	Superob	Thin	Superob
BIAS	-0.0735	**-0.0669**	**0.0172**	0.0199	-0.0099	**-0.0043**	-0.0158	**-0.009**	**0.0027**	0.0085
RMSE	0.3644	**0.3631**	0.0904	**0.0882**	**0.1128**	0.1225	0.1275	**0.1216**	0.1867	**0.1767**

Yaping Wang

Quality Control and Error Assignment

- **Basic QC of the VIIRS AOD product include:**
  - Rejecting ‘low quality’ obs as defined by NESDIS
  - Inflating errors when obs differ significantly from the forecast
  - Fixing the valid ob range from 0 to 4.9 AOD
  - Only using observations between 60N-60S
- **Exploring the use of Variational Bias Correction**
  - Biases between platforms that can be corrected with changes in coefficients every analysis cycle
  - Normally, this uses an independent anchor but ECMWF/CAMS has used NOAA-20 to anchor other VIIRS obs

Variational Bias Correction

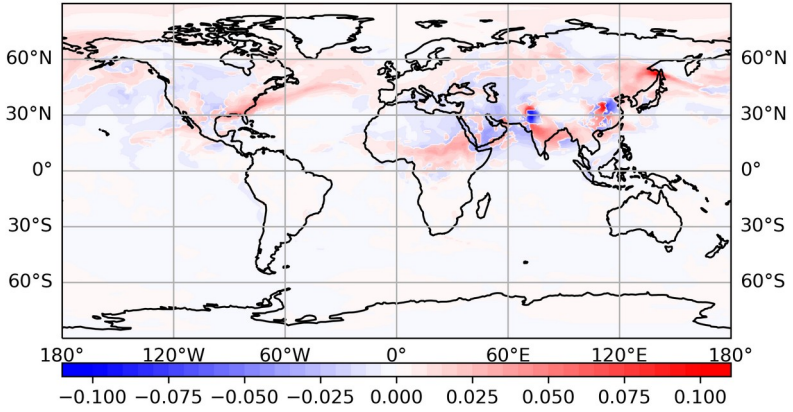
Exploring multiple bias predictors:

Difference of absolute error against CAMS

(VarBC (**sulfate**) - CTRL)

Positive: VarBC has smaller error

Negative: CTRL has smaller error



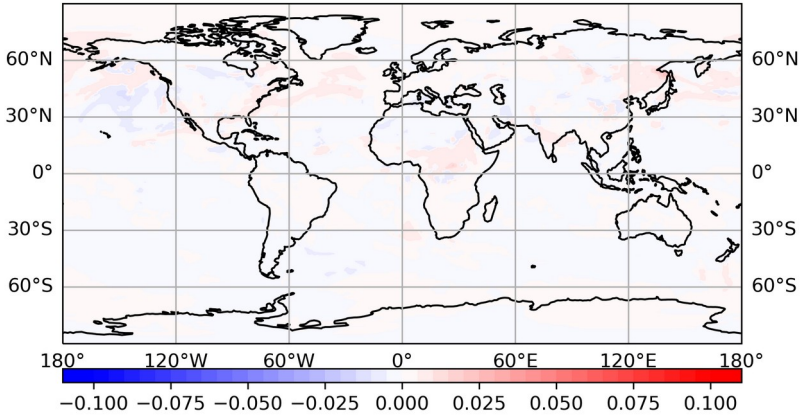
VarBc reduces the error over east Asia, central Africa, Europe and east North America.

Difference of absolute error against CAMS

(VarBC (**Constant**) - CTRL)

Positive: VarBC has smaller error

Negative: CTRL has smaller error



Not much impact

Yaping Wang

Error Covariance Estimation and Tuning

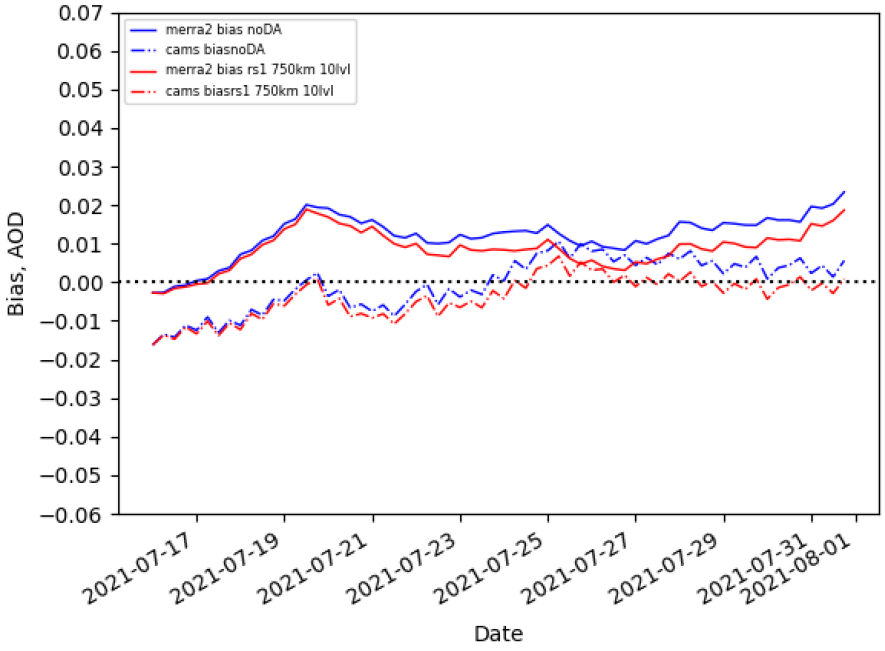
Because we are running a 3DVar analysis, the background error covariance matrix is essential to the performance of the system.

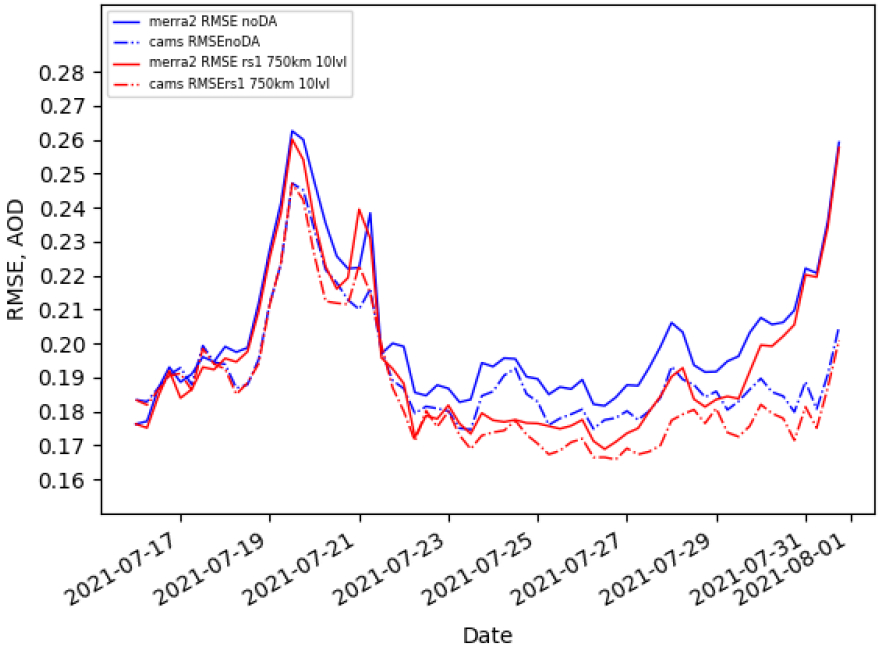
Multiple methods for computing B have been explored:

- **“NMC Method” (lagged forecast pairs)**
- **“BUMP” estimates from an offline ensemble**
- **Time varying covariance**
  - Uses background from each cycle to compute variance from neighboring gridpoints

Our plan is a hybrid of the 2nd and 3rd approaches

Comparisons to MERRA2 and CAMS





DA is improving the forecast, but still more tuning is needed!

Andy Tangborn

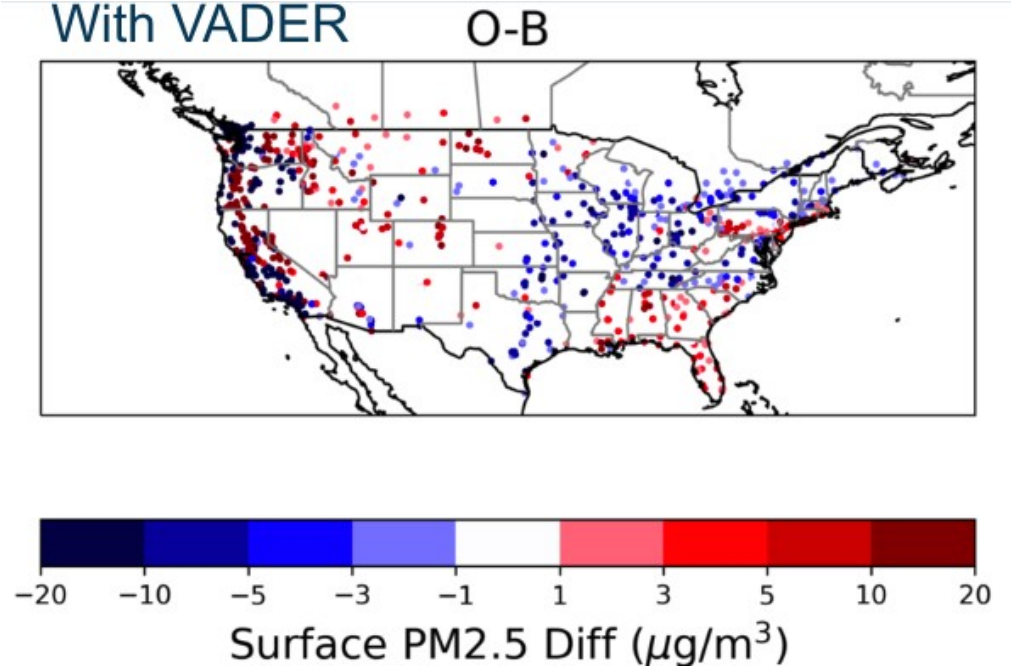
Regional AQ DA

AQMv7 features UFS coupled regional FV3 with CMAQ, but no DA for initialization.

- Nitrogen dioxide (NO_2) from TROPOMI (EMC)
- TEMPO (JCSDA + EMC)
- AOD and PM (GSL)
- Future: state + emissions adjustment through strongly coupled DA; GeoXO

Regional AQ DA

Surface PM2.5 Assimilation



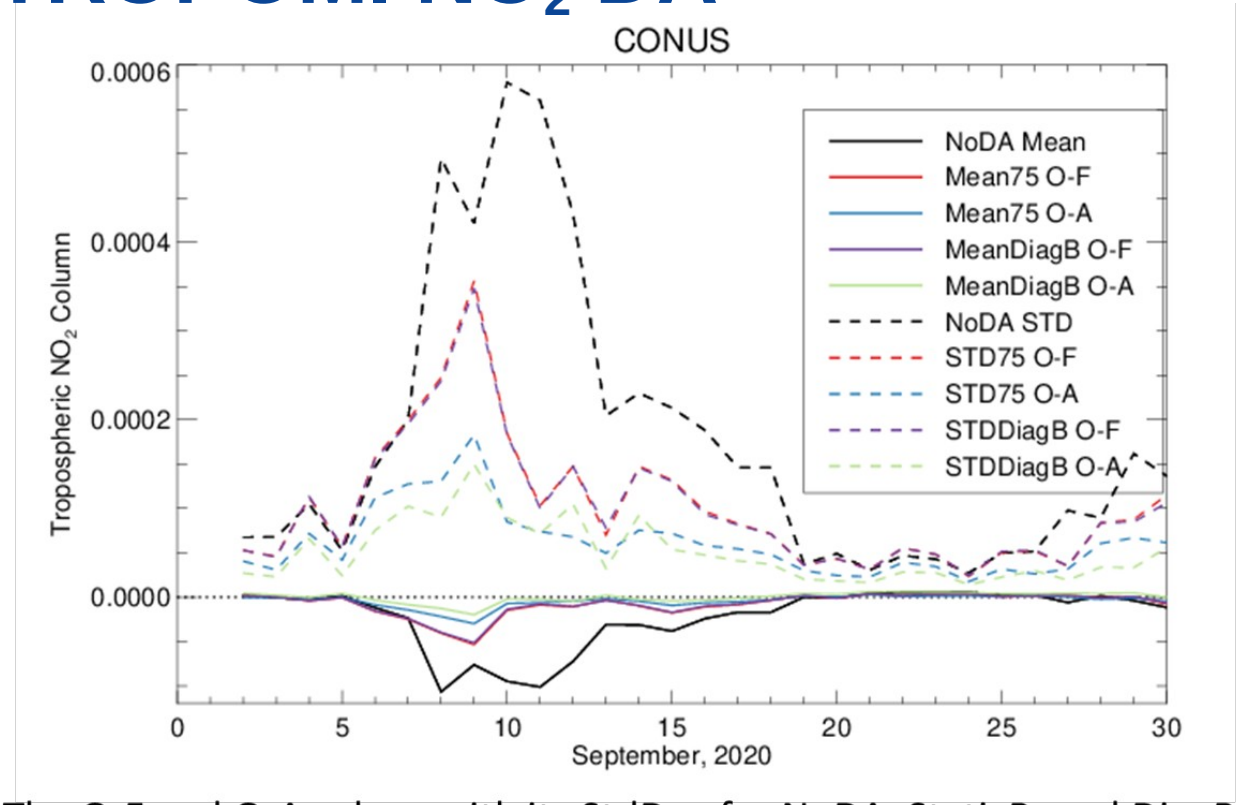
Work at GSL on generic PM2.5 variable transform in JEDI/VADER

VADER is a generic variable change tool, as part of JEDI, that can convert from different models to other fields (like CMAQ species to PM2.5)

Hongli Wang, Ruifang Li

TROPOMI NO_2 DA

- The JEDI DA capability was added to the regional model workflow. The Plot shows the O-F and O-A from the prototype cycling for NCEP's air quality model with JEDI NO_2 DA.
- Large departures the second week of Sept. due to wildfire NO_2 overestimated in the model, reduced by DA
- Tuning of B matrix similar to that being done in the global system, leveraging lessons learned

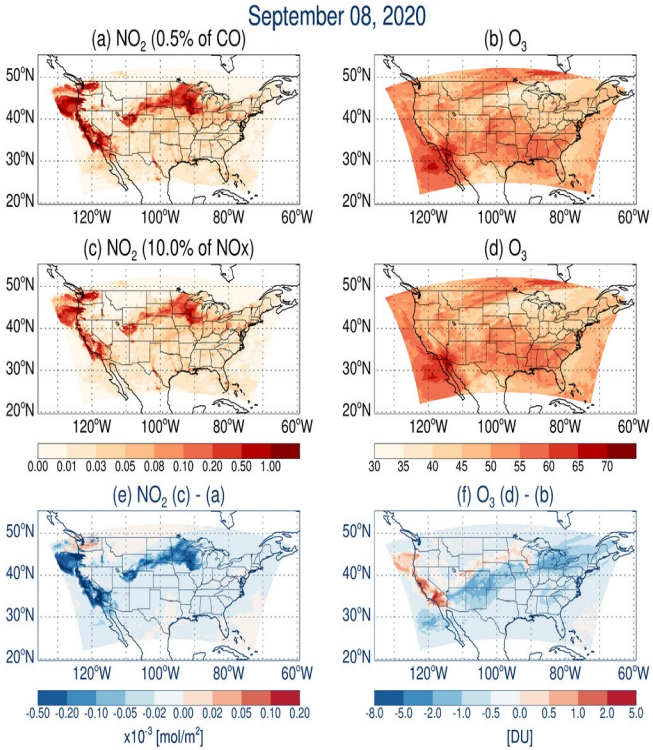


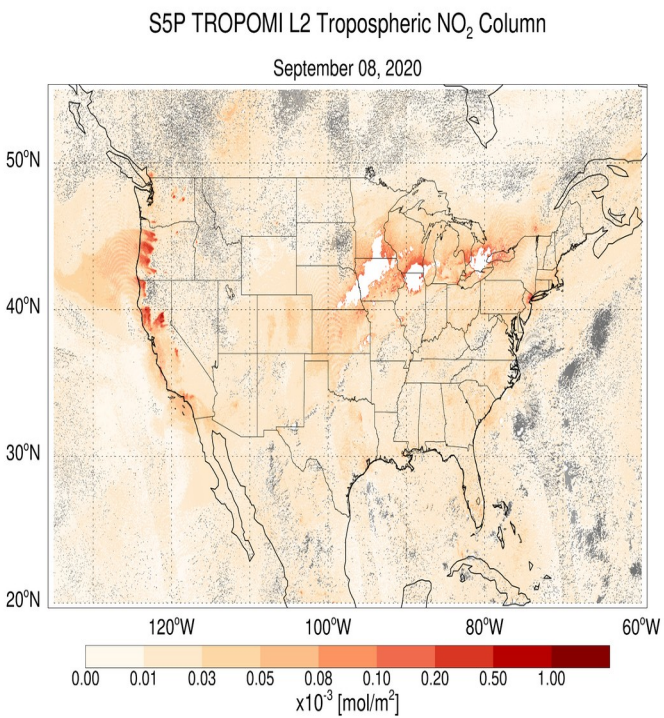
The O-F and O-A values with its StdDev for NoDA, StaticB, and DiagB.

Hyundeok Choi

TROPOMI NO_2 DA

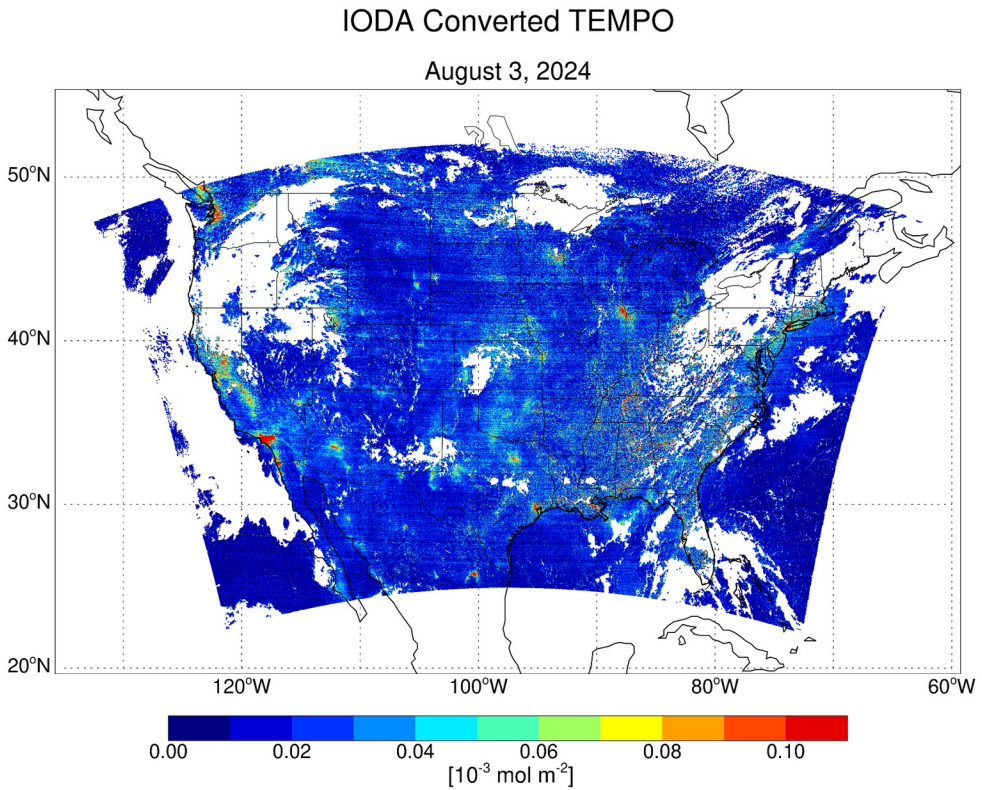
- Testing of NOx emissions has shown that changes in how the emissions for wildfires are defined are better fitting the TROPOMI NO_2 obs, which in turn, improve O_3 prediction
- This is important because DA is not great at fixing systematic biases, but can help identify them!





Hyundeok Choi

Initial TEMPO Work



- TROPOMI is limited to early afternoon only, so we will need geostationary observations for best impact
- JEDI's biggest strength is the ability to quickly leverage developments from other groups
- Thanks to efforts by JCSDA core staff, TEMPO is already usable in JEDI (observation preprocessing and forward operators)
- Work will need to be done to properly assimilate in our AQM-based system (superobbing, errors, QC, etc.)

Summary

- Work is progressing on NCEP's first operational global aerosol analysis capability
  - JEDI-based system
  - Climatological background error covariance tuning + quality control and advanced observation usage testing is happening now
  - Target to implement as part of GFSv17/GEFSv13
- Regional AQ DA efforts are underway but less mature
- Longer term plans to include ensemble methods, simultaneous state and emissions estimation, and strongly coupled with the atmospheric DA

Questions

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