Capability of NOAA's Global Aerosol Forecast Models (GEFS-Aerosols and UFS-Aerosols) in Forecasting Fire Events

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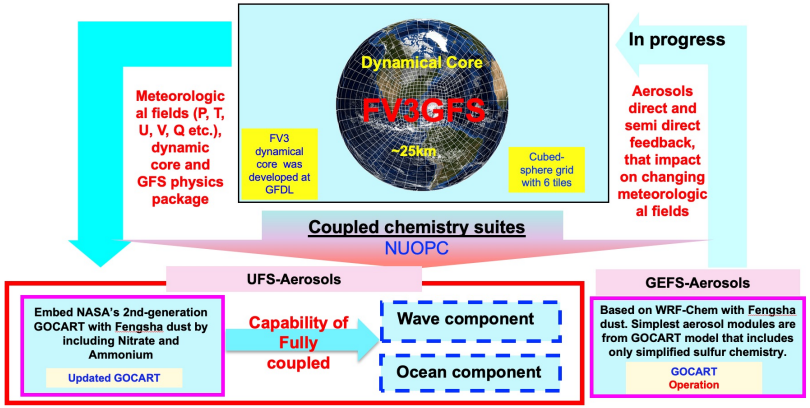
Introduction

- The first generation of aerosol model component based on WRF-Chem and GOCART aerosol modules, featuring the FENGSHA dust scheme along with wildfire emissions updates, has been operational since September 2020 as one of the members of the Global Ensemble Forecast System (GEFS) dubbed GEFS-Aerosols.
- GEFS-Aerosols is also used at NOAA ESRL GSL to provide real-time experimental aerosol forecasts at ~25km horizontal resolution globally from the surface to the top of atmosphere (https://fim.noaa.gov/FV3chem/).
- Recently, the second-generation aerosol model component has been collaboratively developed for the Unified Forecast System (UFS) by NOAA and NASA Global Modeling and Assimilation Office (GMAO), named as UFS-Aerosols. It embeds NASA's 2nd-generation GOCART model and has the capability to fully couple with the ocean and wave models.

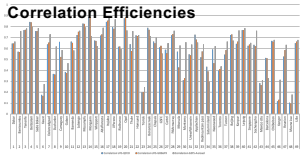
GEFS-Aerosols and UFS-Aerosols



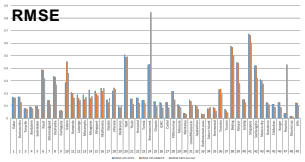
Aerosols Forecast

- **Transport:** Grid-scale transport provided by FV3 dynamical core. Sub-grid transport by PBL and convection in GFS physics. Tracer convective transport and wet scavenging are included in Simplified Arakawa-Schubert (SAS) scheme.
- **GEFS-Aerosols Chemistry:** simplified parameterization of sulfur/sulfate chemistry, hydrophobic and hydrophilic black and organic carbon, 5-bin sea salt, 5-bin dust, volcanic ash.
- **UFS-Aerosols Chemistry:** simplified parameterization of sulfur/sulfate, nitrate and ammonium chemistry, hydrophobic and hydrophilic black and organic carbon, 5-bin sea salt, 5-bin dust.
- **Emission:** Global CEDS and HTAP anthropogenic emission. NESDIS Global Biomass Burning Emission Product (GBBEPx) with FRP used for fire size and location. 1D cloud model is used to calculate injection heights and plume rise emission rates online. Quick Fire Emissions Dataset (QFED). Volcanic ash.
- **Sea-salt and Marine Dimethyl Sulfide: :** NASA GEOS-5 GOCART sea salt scheme. GOCART monthly values of marine dimethyl sulfide as in Lana et al. (2011)
- **Dust:** 5 size bins. FENGSHA dust scheme: Empirical model based solely on soil type for saltation and used in current NAQFC (Tong et al; Baker et al.);
- **Forecast:** Meteorological initial conditions from FV3GFS analysis. Aerosols are cycled as the initial conditions of next time.

Evaluation of global Day 1 AOD prediction for Jul.-Sep. 2019 with AERONET



Generally, the correlation efficiencies of GEFS-Aerosols are much larger that of UFS-Aerosols using either GBBEPx or QFED emissions in most of the sites, which suggests that the plume-rise module may improve the fire predictions.

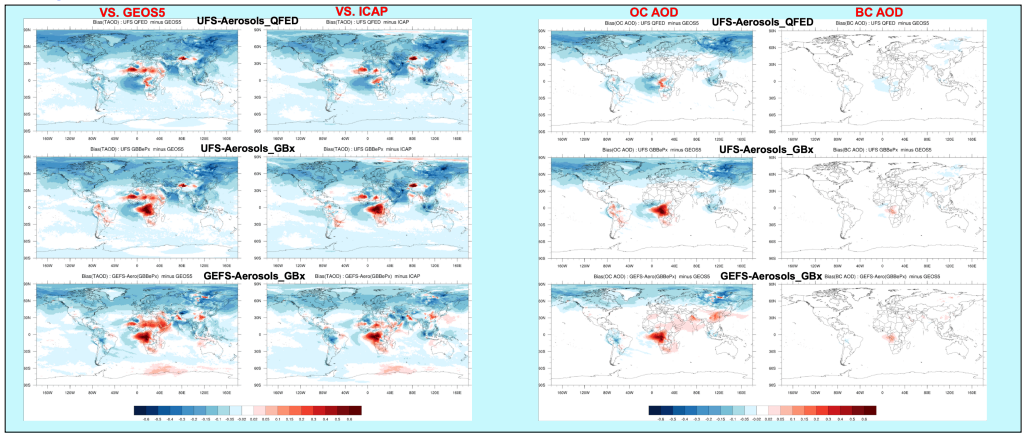


The RMSE of GEFS-Aerosols are the lowest at most of the sites except some peaks at couples of site.
The UFS-Aerosols using GBBEPx emission shows comparable of smaller RMSE than that of using QFED emission.

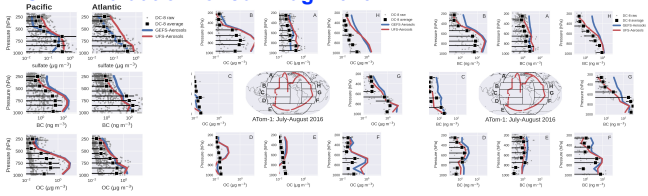
Comparisons between UFS-Aerosols and GEFS-Aerosols

	UFS-Aerosols		GEFS-Aerosols
Emissions from nature source (e.g. dust and sea salt)	Same sea salt scheme, Fengsha dust with updates	Fengsha version	Same sea salt scheme, Fengsha dust
Emission from Anthropogenic emission	CEDS_2019 version, aviation emission etc.	Different	CEDS_2014 version
Fire emission (Fire Plume-rise module)	GBBPEX or QFED (within PBL)	Part different	GBBEPx with FRP and plume-rise
Dry deposition	Based on NASA_GOCART	Similar	Based on WRF-Chem GOCART
Large Wet removal and settling	Based on NASA_GOCART	Different	Based on WRF-Chem GOCART
Convective wet scavenging	Based on FV3GFS SAS	Similar, SAS version	Based on FV3GFS SAS
Simple chemical reactions (sulfate, OC, BC)	Based on NASA_GOCART	Similar	Based on WRF-Chem GOCART
Other Aerosol species (include nitrate and ammonium, or include unspecific PM)	Nitrate and ammonium	Different	unspecific PM2.5 and PM10
AOD computation based on NASA look-up table	Online calculation	Similar	Offline calculation (UPP)

Comparisons between UFS-Aerosols and GEFS-Aerosols



ATOM-1 Evaluation for Jul.-Aug. 2016



- Sulfate is overestimated over over both Pacific and Atlantic in UFS-Aerosols, while is close to the observation in GEFS-Aerosols.
- OC is overestimated over both Pacific and Atlantic in GEFS-Aerosols. UFS-Aerosols modeled OC is comparable as the measurements in the upper levels, but over overpredicted at the low levels over Pacific while underestimated over Atlantic from African fires.
- BC is quite comparable in UFS-Aerosols and GEFS-Aerosols, which is overestimated, especially at the low levels over Pacific.

Summary

- As the 2nd generation global aerosol forecast system based on latest NASA GOCART model, UFS-Aerosols is still under development. Preliminary results from UFS-Aerosols in fire forecasting are nonetheless encouraging, since they are quite close to those provided by the current operational system (GEFS-Aerosols).
- Preliminary UFS-Aerosols experiments show significant overpredictions over southern African fire regions when using GBBEPx fire emission, which is mainly due to overpredicted OC AOD. Otherwise, no significant differences in the AOD between using GBBEPx fire emission and QFED fires emission over most of the areas. Also, using GBBEPx fire emissions shows slightly improvement over part of the underpredicted areas at high northern latitudes .
- Though UFS-Aerosols shows some improvements in fire forecasting, especially the BC concentration vertical profiles, biases seem to still occur in both fire AOD and vertical profile predictions.
- Implementation the plume-rise module into UFS-Aerosols as GEFS-Aerosols, may help to improve the AOD due to fire events, which will be the next step.
- More developments and tuning works are undergoing for UFS-Aerosols, including emissions and wet removal, which may help to further improve the performance of UFS-Aerosols.