Fire Aerosol Predictions and its Impact on Subseasonal to Seasonal (S2S) forecasts in NOAA's Global Aerosol Forecast Systems

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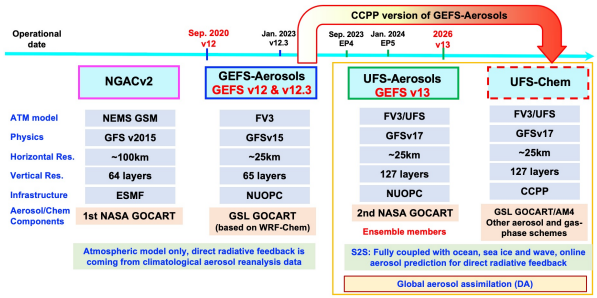
Introduction

- **UFS-Aerosols:** the second-generation of UFS coupled aerosol system has been collaboratively developed by NOAA and NASA since 2021, which embeds NASA's 2nd-generation GOCART model in a National Unified Operational Prediction Capability (NUOPC) infrastructure. It is planned to be implemented into the Global Ensemble Forecast System (GEFS) v13.0 for ensemble prototype 5 (EP5) experiments early this year.
- **UFS-Chem:** an innovative community model of chemistry online coupled with UFS, which is a wide collaboration between NOAA Oceanic and Atmospheric Research (OAR) laboratories and NCAR. The aerosol component based on the current operational GEFS-Aerosols v12.3, has been implemented into UFS-Chem utilizing the Common Community Physics Package (CCPP) infrastructure with updates to wet

NOAA's Global Aerosol/Chemistry Forecast Systems



Comparisons between UFS-Aerosols and UFS-Chem

	UFS-Aerosols		UFS-Chem
Aerosol emissions from nature source (e.g. dust and sea salt)	NASA sea salt scheme, Fengsha dust	Same	NASA sea salt scheme, Fengsha dust
Aerosol emission from Anthropogenic emission and Fires emission	CEDS_2019 version (aviation from HTAP etc., GBBEPx or QFED	Similar	CEDS_2019 version, GBBEPx
Fire Plume-rise module	None	different	Online plume-rise module based on FRP and Met. fields
Aerosol dry deposition and settling	From NASA_GOCART	Similar	Based on WRF-Chem GOCART
Aerosol large Wet removal	From NASA_GOCART	Different	Inline calculation in Thompson MP scheme
Aerosol convective wet scavenging and convective transport	FV3GFSv17 SAS scheme	Same	FV3GFSv17 SAS scheme
Simple chemical reactions (sulfate, OC, BC)	From NASA_GOCART	Similar	Based on WRF-Chem GOCART
AOD computation based on NASA look-up table	Online calculation (capability of aerosol radiative feedback in GFS)	Same	Online calculation (capability of aerosol radiative feedback in GFS)
Other aerosol or gas-phase chemistry schemes	Option to add nitrate, ammonium and brown carbon	Different	Complex aerosol and gas-phase chemistry schemes (e.g. AM4 etc.)

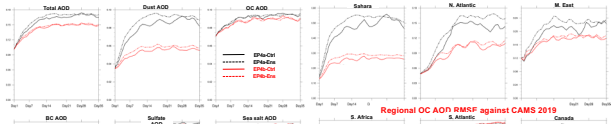
Application of UFS-Aerosols in S2S Predictions

Ensemble Prototype 4 (EP4) experiments 201710-201909, once per week for 35-day forecast

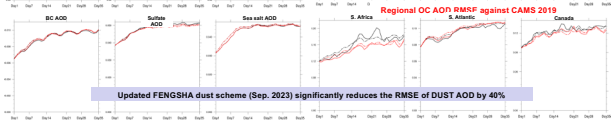
- 10 ensemble members with perturbations applied to Met. Fields, aerosol direct radiative feedback is from online aerosol model of NASA GOCART.
- **EP4a:** QFED fire emission, CEDS 2019 anthropogenic emission, FENGSHA dust scheme (2022).
- **EP4b:** Scaled QFED fire emission and updated FENGSHA dust scheme (Sep. 2023).

Global AOD RMSE against CAMS 2019

Regional Dust AOD RMSE against CAMS 2019



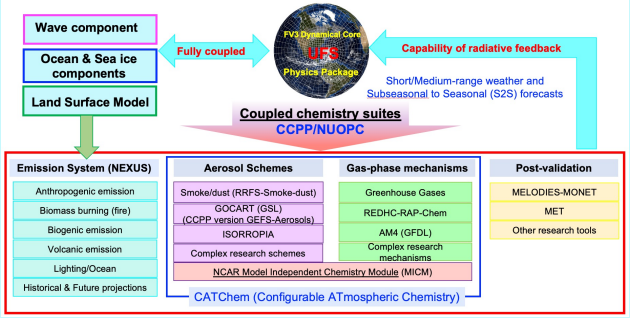
Regional OC AOD RMSE against CAMS 2019



Updated FENGSHA dust scheme (Sep. 2023) significantly reduces the RMSE of DUST AOD by 40%

UFS-Chem development

UFS-Chem Framework

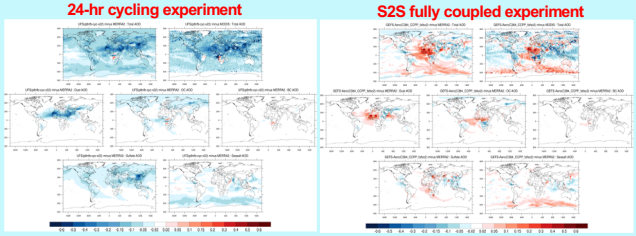


Inline implementation of large-scale wet removal within Thompson MP for GSL-GOCART aerosols

AOD biases with respective to MERRA-2 and MODIS, GBBEPx v003, August 2016

Offline wet removal scheme in GSL-GOCART module

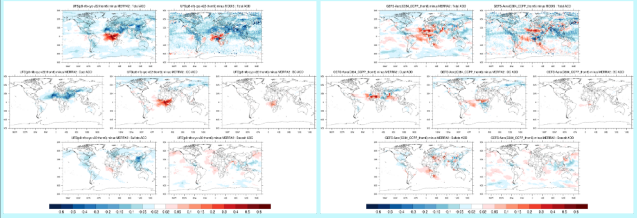
24-hr cycling experiment | **S2S fully coupled experiment**



With identical model configurations, the AOD biases manifest in two different directions. The cycling experiment demonstrates underprediction across all aerosol AOD, whereas the S2S fully coupled experiment exhibits overprediction over extensive regions (such as sea salt AOD). This discrepancy is attributed to the offline wet removal scheme (from WRF-Chem GOCART).

Inline wet removal scheme in Thompson MP

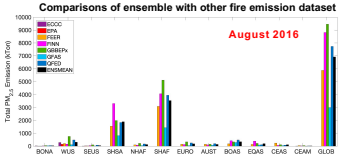
24-hr cycling experiment | **S2S fully coupled experiment**



After implementing the inline large-scale wet removal calculation into Thompson MP scheme for predicted aerosols, the AOD biases shows greater consistency between the cycling experiment and the S2S fully coupled experiment compared to the offline scheme, particularly noticeable for sea salt AOD.

Integrating the online predicted aerosols (GSL-GOCART scheme) into the Thompson MP aerosol_aware scheme to for aerosol indirect feedback is currently underway.

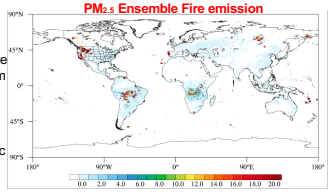
Global fire emission diversities and ensemble emission development



BONA: Boreal North America; **WUS**: Western US; **SEUS**: Southeast US; **SHSA**: Southern Hemisphere South America; **NHAF**: Northern Hemisphere Africa & Middle East; **SHAF**: South Hemisphere Africa; **EURO**: Europe; **AUST**: Australia and New Zealand; **BOAS**: Boreal Asia; **EQAS**: Equatorial Asia; **CEAS**: Central and Southeast Asia; **CEAM**: Central America; **GLOB**: global

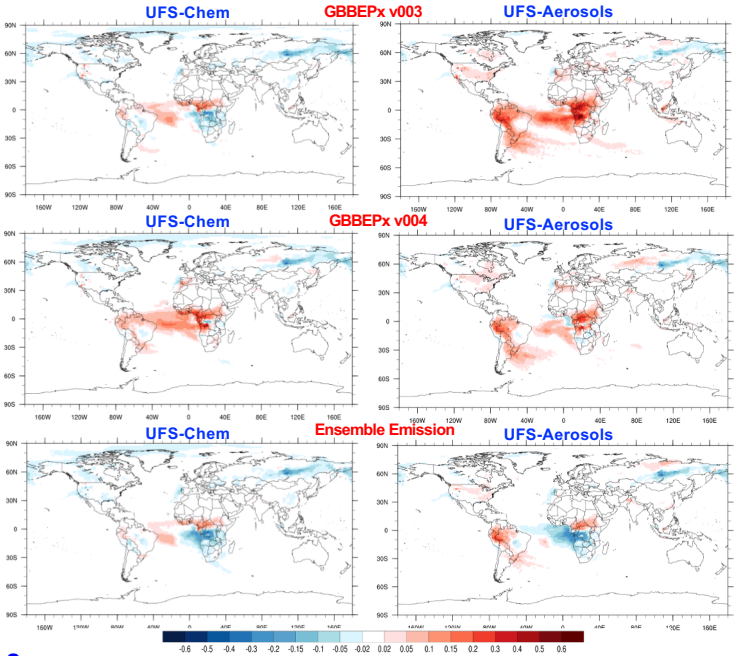
We build a global daily fire ensemble emission at 0.1 x 0.1 degree resolution with 7 long-term fire emission products including Canadian Fire Emissions Prediction System (CFFEPS), Global Fire Assimilation System (GFAS), US EPA fire emission inventory, NASA Fire Energetics and Emissions Research (FEER), NASA Quick Fire Emissions Dataset (QFED), Fire Inventory from NCAR (FINN), and NOAA Blended Global Biomass Burning Emissions Product (GBBEPx). There are 8 variables including Fire Radiative Power (FRP), $PM_{2.5}$, Black Carbon (BC), Organic Carbon (OC), CO, NH_3, NO_x, and SO_2.

$PM_{2.5}$ Ensemble Fire emission



Fire Aerosol predictions in the S2S forecasts

OC AOD biases with respective to MERRA-2, August 2016



Summary

- The development of UFS-Chem model has been launched; an innovative community model that incorporates chemistry online coupled with UFS. Its initial development involved a collaboration between NOAA OAR laboratories and NCAR, utilizing the CCPP infrastructure to connect the gas and aerosol chemistry modules with the rest of the model.
- Recognizing the uncertainties associated with fire emission, a key factor impacting the model performance, we have initiated further studies to improve fire emission for S2S predictions. This effort will benefit both the operational implementation of GEFSv13 and the development of UFS-Chem.