Predicting Fire Aerosols and their Impact on Subseasonal to Seasonal Forecasting

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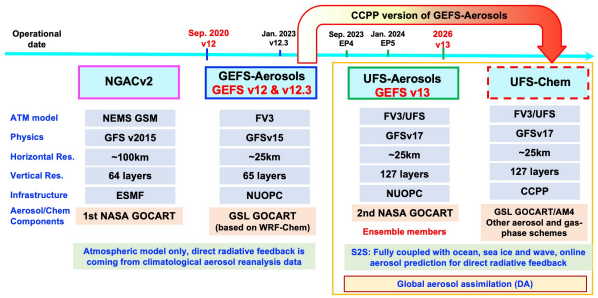
Introduction

- **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 deposition, dust and fire emission.

NOAA's Global Aerosol/Chemistry Forecast Systems

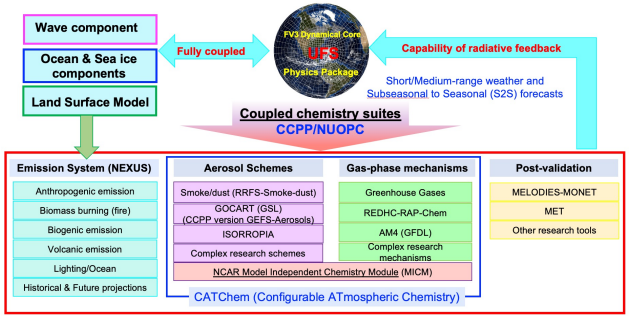


Comparisons between UFS-Aerosols and UFS-Chem

	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.)

UFS-Chem development

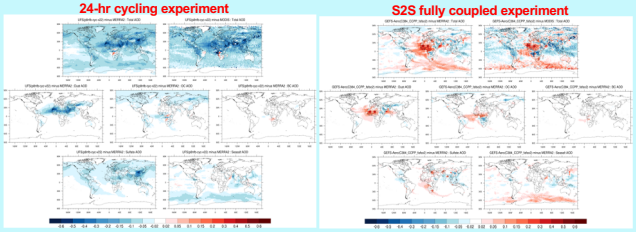
UFS-Chem Framework



Implementation of inline large-scale wet removal within Thompson MP for aerosols (HR3 UFS)

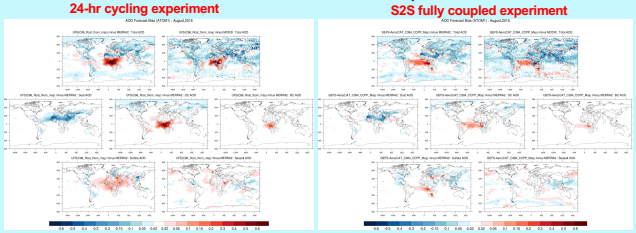
AOD biases with respective to MERRA-2 and MODIS, GBBEPx v003, August 2016

Offline wet removal scheme in GSL-GOCART module



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).

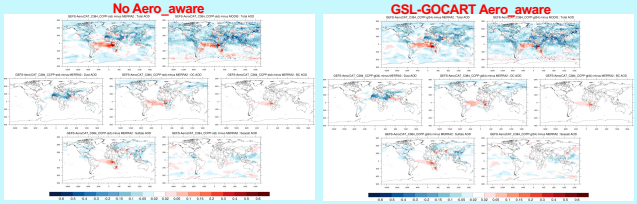
Inline wet removal scheme in Thompson MP

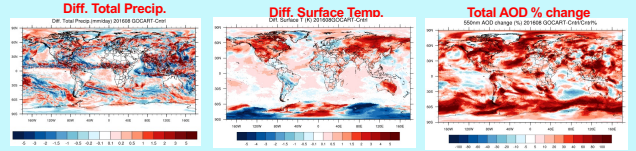


After implementing the inline large-scale wet removal calculation into Thompson MP scheme for predicted aerosols, the AOD biases shows greater consistency between the cycling experiment and the S2S fully coupled experiment compared to the offline scheme, particularly noticeable for sea salt AOD.

Implementation of online predicted aerosols (GSL-GOCART) into the Thompson MP aerosol_aware scheme for aerosol indirect feedback

AOD biases with respective to MERRA-2, August 2016

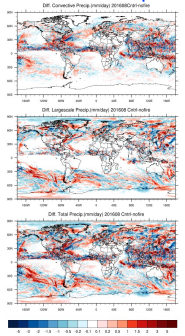




Differences in total precipitation, surface temperature and the AOD percentage change between the S2S prediction with GSL-GOCART aerosol_aware and without aerosol_aware settings.

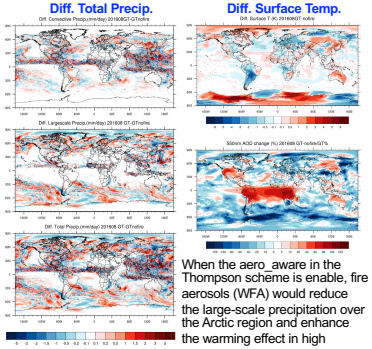
Impacts of fire aerosols in S2S predictions

Direct and semi-direct feedback
No Aero_aware
Standard run minus no fire emission run



Fire aerosols exhibit a cooling effect across most of the Antarctic regions, western North America, and central and northeastern Europe.

Direct and semi-direct + indirect feedback
GSL-GOCART Aero_aware
Standard run minus no fire emission run

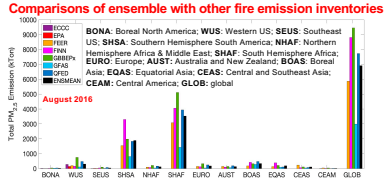


When the aero_aware in the Thompson scheme is enable, fire aerosols (WFA) would reduce the large-scale precipitation over the Arctic region and enhance the warming effect in high latitude regions.

Global fire emission diversities and ensemble emission development

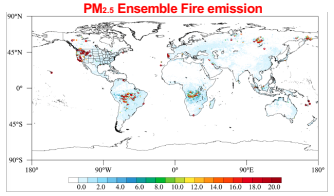
We build a global daily fire ensemble emission at 0.1 x 0.1 degree resolution with 7 long-term fire emission products including Canadian Fire Emissions Prediction System (CFFEPS), Global Fire Assimilation System (GFAS), US EPA fire emission inventory, NASA Fire Energetics and Emissions Research (FEER), 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.

Comparisons of ensemble with other fire emission inventories

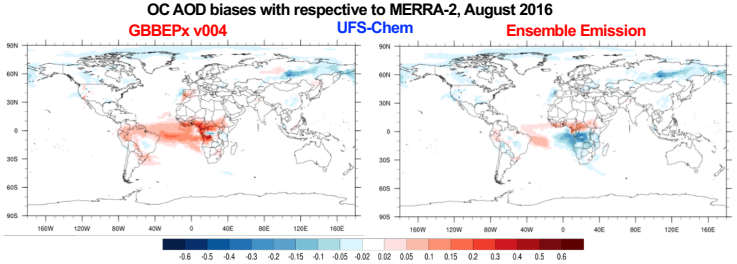


BONA: Boreal North America; **WUS**: Western US; **SEUS**: Southeast US; **SHSA**: Southern Hemisphere South America; **NHAF**: Northern Hemisphere Africa & Middle East; **SHAF**: South Hemisphere Africa; **EURO**: Europe; **AUST**: Australia and New Zealand; **BOAS**: Boreal Asia; **EQAS**: Equatorial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

$PM_{2.5}$ Ensemble Fire emission



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.
- Inline aerosol large-scale wet removal has been implemented in the Thompson MP, resulting in significant improvements in S2S aerosol predictions in UFS-Chem. Based on the CCPP-coupled GSL GOCART in UFS-Chem, we have also initiated the development and implementation of the indirect feedback in Thompson aerosol-aware microphysics scheme, with preliminary S2S results available.
- Recognizing the uncertainties associated with fire emission and the importance of fire aerosols, 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.