Simulating Aerosol Direct Effect on Subseasonal Prediction Using a Coupled UFS with GEFS-Aerosols Model

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Unifying Innovations in Forecasting Capabilities Workshop

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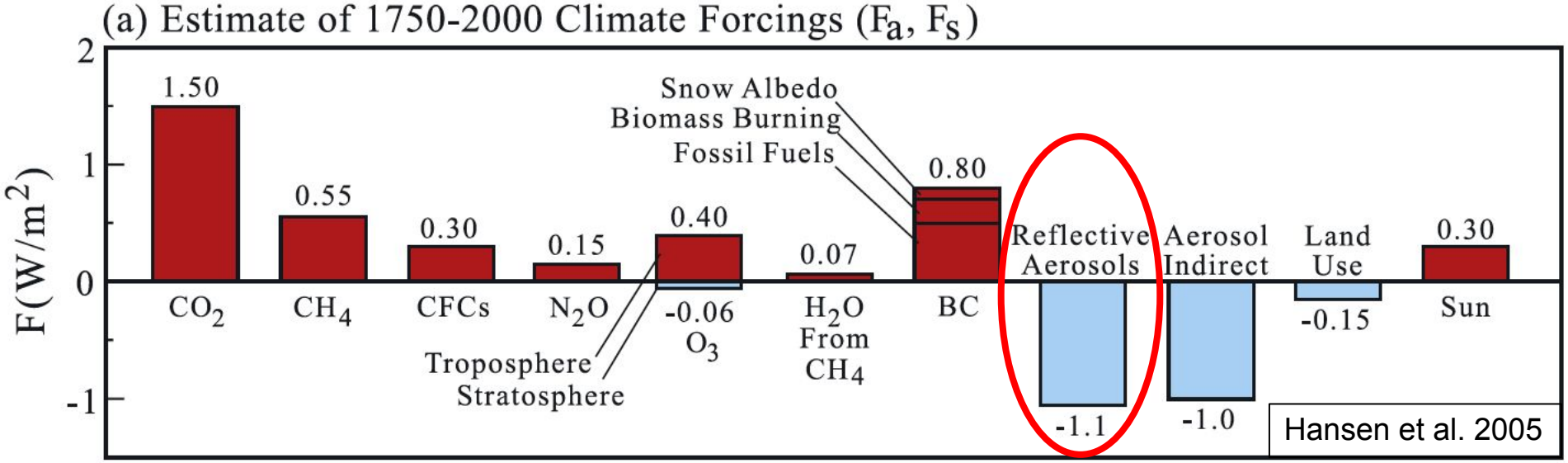
Motivation



- Aerosol effects play an important role in Earth's climate and are a key part of climate models (e.g., Mitchell 1971; Hansen et al. 2005; IPCC 2013)
- Aerosol effects are shown to impact on NWP and extreme weather events like tornado and hurricane (e.g., Haywood et al. 2005; Grell and Baklanov 2011; Saide et al. 2015; Pan et al. 2020)
- Common alternatives of aerosol treatment in the model
  - Ignore aerosols and its effect on radiation
  - Prescribe climatological aerosol properties
  - Use prognostic aerosols (e.g. WRF-Chem and GEFS-Aerosols in this study)
- A large spread of aerosol optical depth (AOD) in modeled aerosol properties (e.g., Xian et al. 2018)

Unified Forecast System (UFS) Components

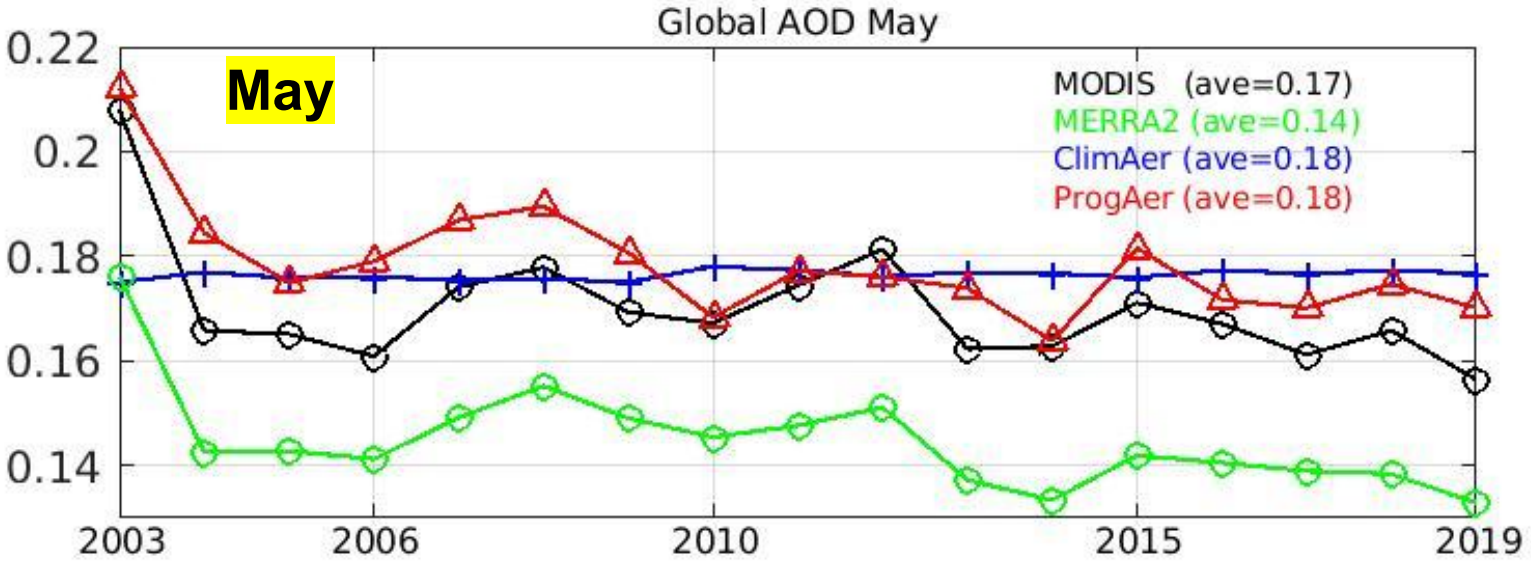
Components	Models	Resolution	Initial Conditions
Atmosphere	FV3+GFSv16	25km, 64 layers	CFSR
Ocean	MOM6	¼°, 40 layers	NCEP/CPC (2011-2016) CFSR (other times)
Sea Ice	CICE6	¼°	NCEP/CPC
Wave	WW3	½° x ½°	(rest)
Aerosol	GOCART	same as atmosphere	30-day spin-up (from zero)

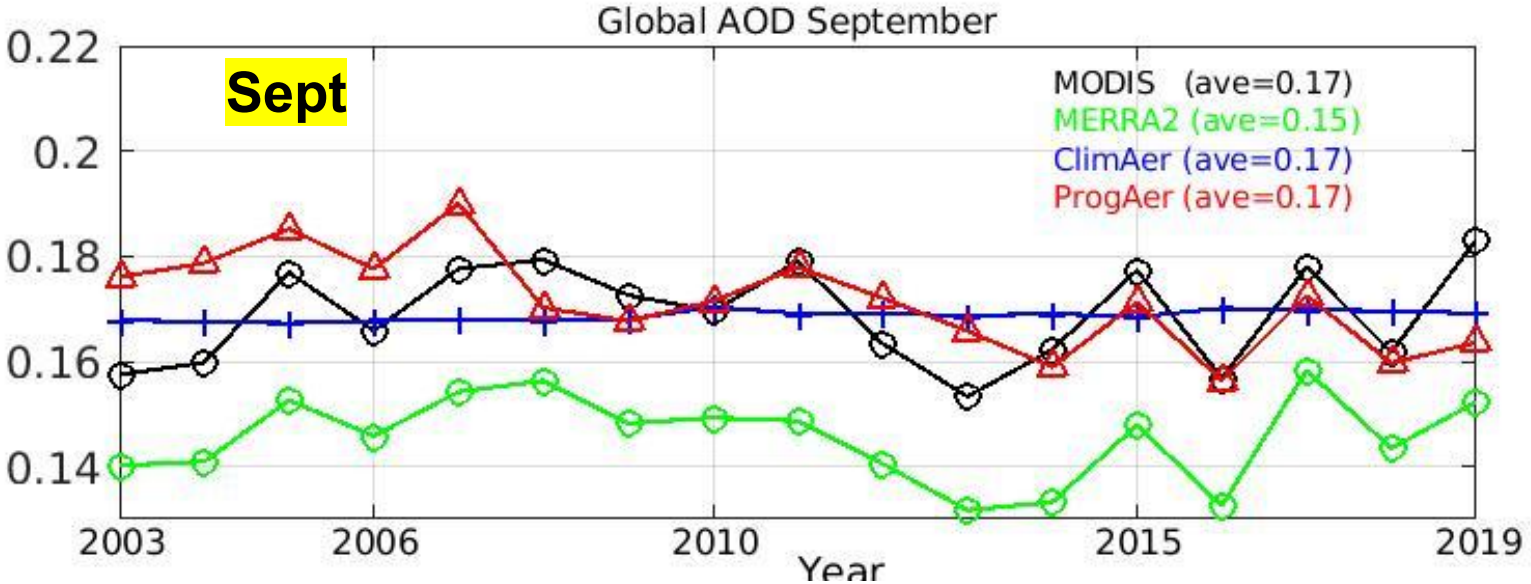
Experiments 32-day integration, starting from May 1/Sept. 1, 2003-2019, with 5 ensemble members

- "*ProgAer*" runs: prognostic and time-varying aerosols from GOCART
- "*ClimAer*" runs: GOCART inactive (using aerosol concentrations from "*ProgAer*" monthly climatology)
- "*NoAer*" runs: GOCART inactive (no aerosol interaction is considered)

"*ProgAer*" costs 20% - 25% extra compared to "*ClimAer*"

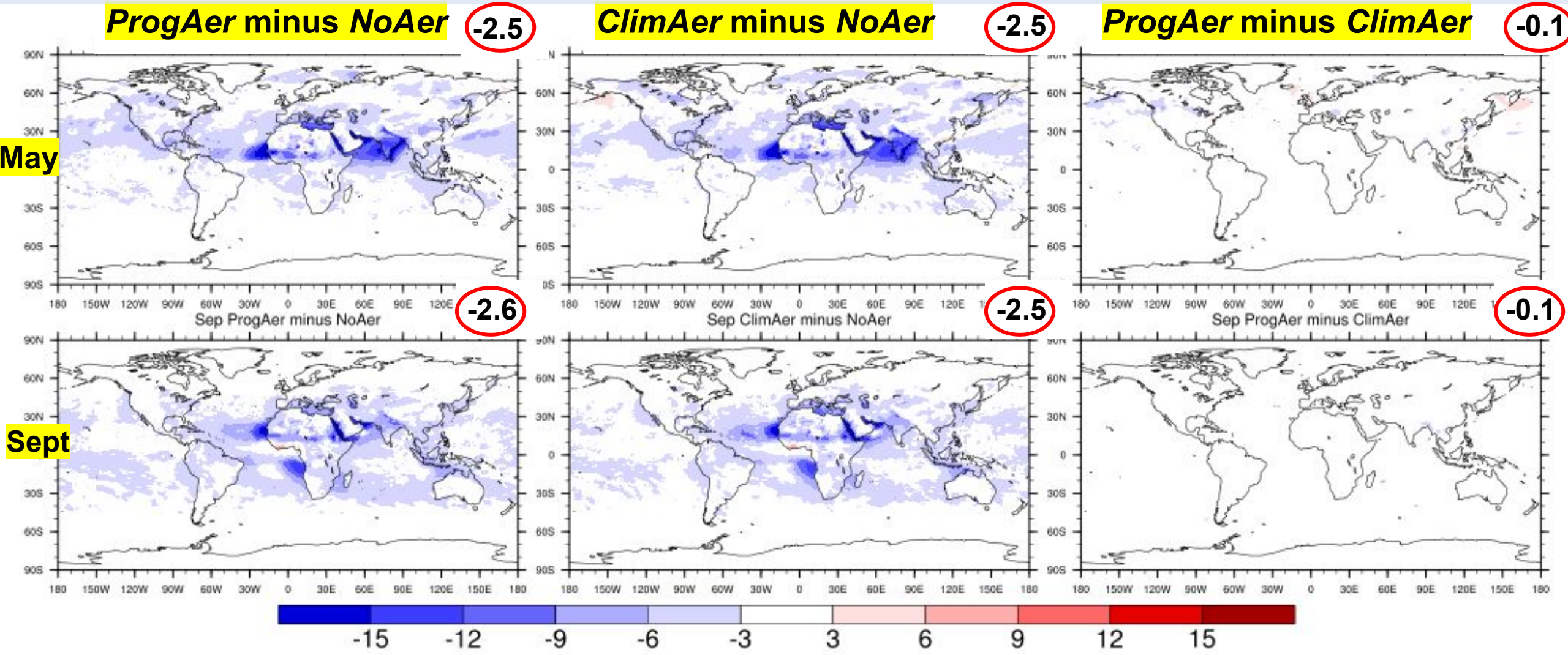
Global Aerosol Optical Depth (AOD_{550})





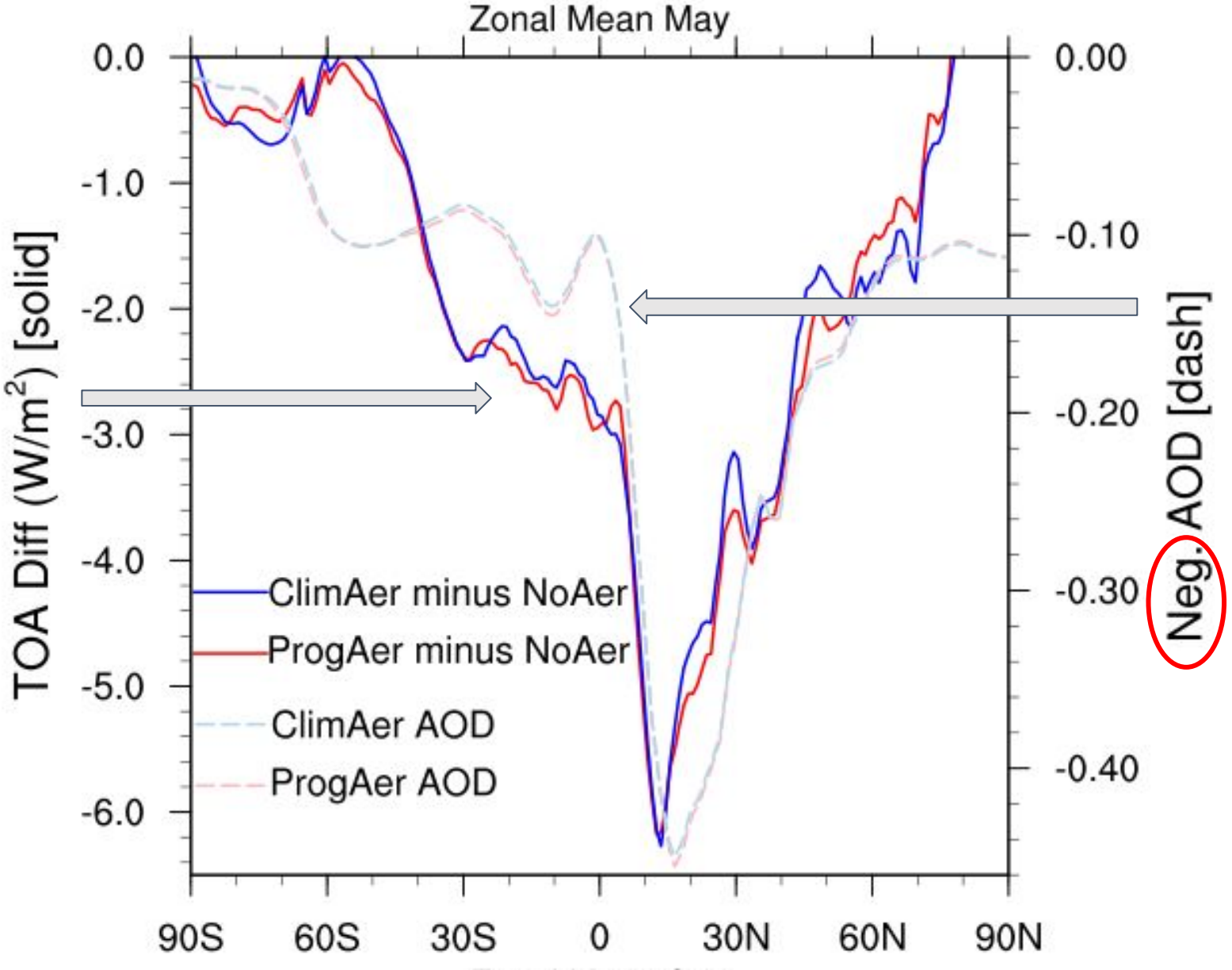
- Global monthly AOD in the *ProgAer* runs is able to capture the AOD variability seen in MODIS in 2003 - 2019;
- AOD from the *ClimAer* runs is close to the mean of AOD in *ProgAer* runs;
- Global AOD from MERRA2 is the lowest

Mean Radiative Forcing (RF) TOA (W/m^2) 2003-2019



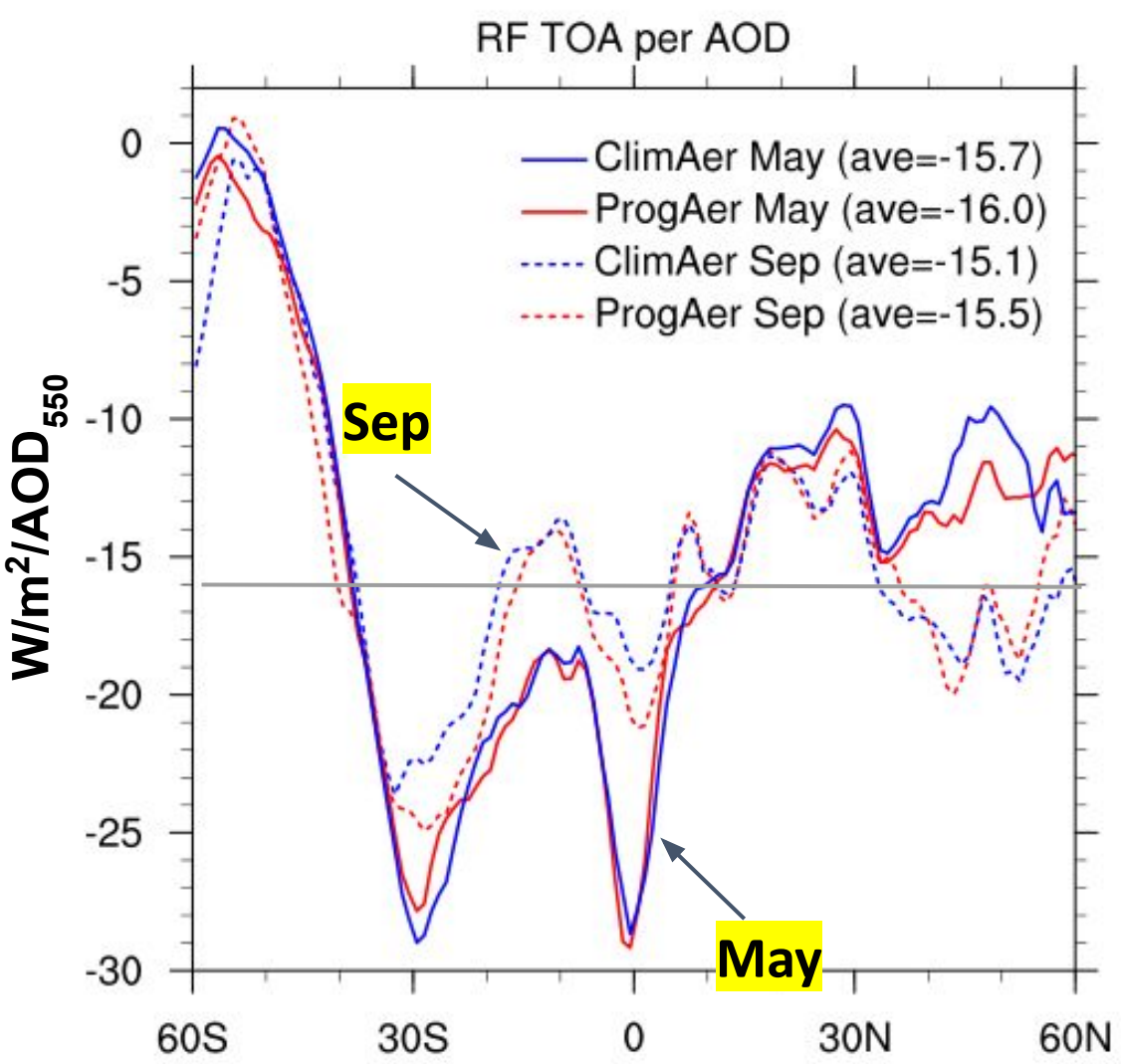
- RF at TOA is about **-2.5 W/m^2** in the *ProgAer* runs related to the *NoAer* runs
- RF in the *ClimAer* runs is similar to that in the *ProgAer* runs

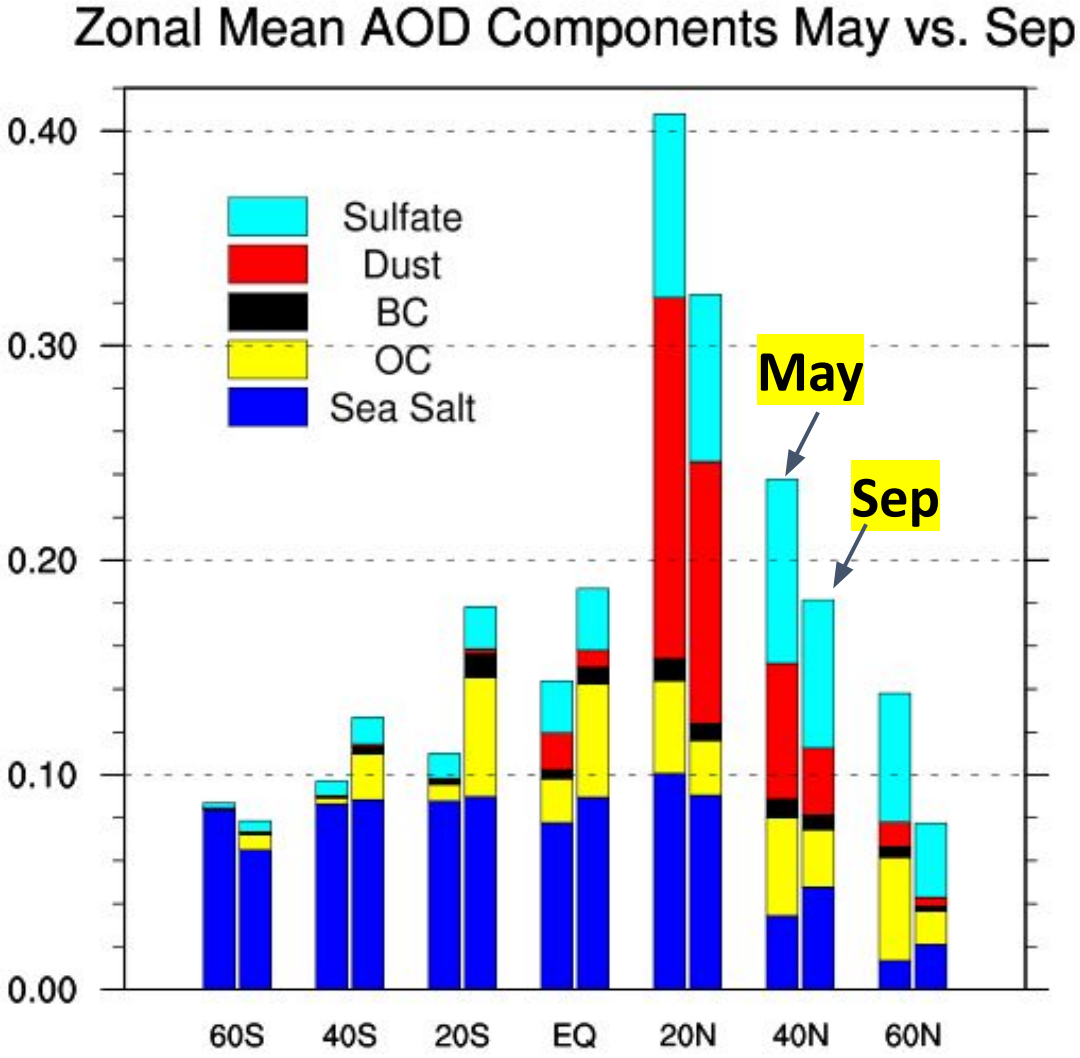
Modeled ΔRF (W/m^2) & AOD_{550} May 2003-2019



There is a high correlation between ΔRF and AOD

Modeled ΔRF per AOD_{550}





The different ratios between May and Sept may have to do with aerosol compositions

Summary

- This is amongst first attempts to quantify aerosol-radiation interaction using the coupled atm-ocn-ice UFS with GOCART for subseasonal applications
- A negative radiative forcing in the aerosol-radiation interaction is estimated to be -2.5W/m^2 in the *ProgAer* runs comparing to *NoAer* runs, consistent with -1W/m^2 from IPCC AR5 comparing to 1750; the RF change at TOA is about -16W/m^2 per AOD
- The modeled aerosols impact on precipitation (semi-direct effect) is not obvious with a single-moment microphysics as expected; work is under way to switch to a double-moment microphysics
- Between model runs *ProgAer* and *ClimAer*, the estimated aerosol-radiation interaction is very similar, suggesting a possible alternative of replacing the costly chemistry module with the modeled aerosol concentration climatology in the subseasonal applications.