Near Real-Time Sub/Seasonal Prediction of Aerosol and Air Quality at the NASA Global Modeling and Assimilation Office

GMAO
Global Modeling & Assimilation Office

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Motivation

NASA/GSFC's Global Modeling and Assimilation Office (GMAO) uses coupled Earth-System models and analyses, in conjunction with satellite and *in situ* observations, to study and predict phenomena that evolve on seasonal to decadal timescales. A central motivation for GMAO is the innovative use of NASA satellite data to improve forecast skill.
GMAO's GEOS S2S system Version 2 (GEOS-S2S-2, Molod et al., 2019) began running in Near-Real Time at the end of 2017. GEOS-S2S-2 includes an interactive aerosol model (GOCART, Chin et al., 2002, Colarco et al., 2010), and the seasonal prediction of aerosol-derived PM2.5 as a measure of air quality is evaluated here.

Issues/Questions about Seasonal Prediction of Air Quality

What is predictable at seasonal time scales and what can be predicted?
Anomaly Correlation is the critical metric for assessing the skill of a forecast. ie., will next month/season be characterized by higher/lower than "normal" conditions? How much? With what probability?

Aerosol models can predict AOD or PM2.5:
AOD is better initialized, PM2.5 more useful.

Other possible options for air quality:
The number of exceedance days in a month/season (need full chemistry or Chemistry Transport Model driven with seasonal forecast meteorology)

Why incur the expense of an interactive aerosol model?
- There may be more useful skill in AOD/PM2.5 seasonal forecasts than from a statistical model or climatology (Benedetti and Vitart, 2018 for AOD)
- May increase weather/subseasonal skill under certain conditions (forecasts of opportunity) such as the impact of dust on tropical cyclone development. (eg., Reale et al., 2011 using GMAO NWP system)
- May increase seasonal skill after a large volcanic event (eg., Aquila et al 2019 using GMAO-S2S-2).
- May increase subseasonal forecast skill (Benedetti and Vitart, 2018)
- Postulated to have an impact on decadal prediction skill (Bellucci et al., 2015)

S2S Version 2: Models and Assimilation

Model
- AGCM: Post MERRA-2 generation, cubed sphere grid at ~0.5º, 72 hybrid sigma/pressure levels; GOCART interactive aerosol model, cloud indirect effect (2-moment cloud microphysics); MERRA-2 generation cryosphere
- OGCM: MOM5, ~0.5º, 40 levels
- Sea Ice: CICE-4.0

Coupled Ocean Data Assimilation System
- atmosphere is "replayed" to "FPIT" (like MERRA-2); precipitation correction over land
- NCEP-like LETKF code/system

Observations
- nudging of SST and sea ice fraction from MERRA-2 data;
- assimilation of in situ Tz and Sz including Argo, XBT, CTD, moorings;
- assimilation of satellite along-track Absolute Dynamic Topography
- sea ice concentration from the National Snow and Ice Data Center

GMAO's Near-Real-Time Sub/Seasonal Prediction Suite

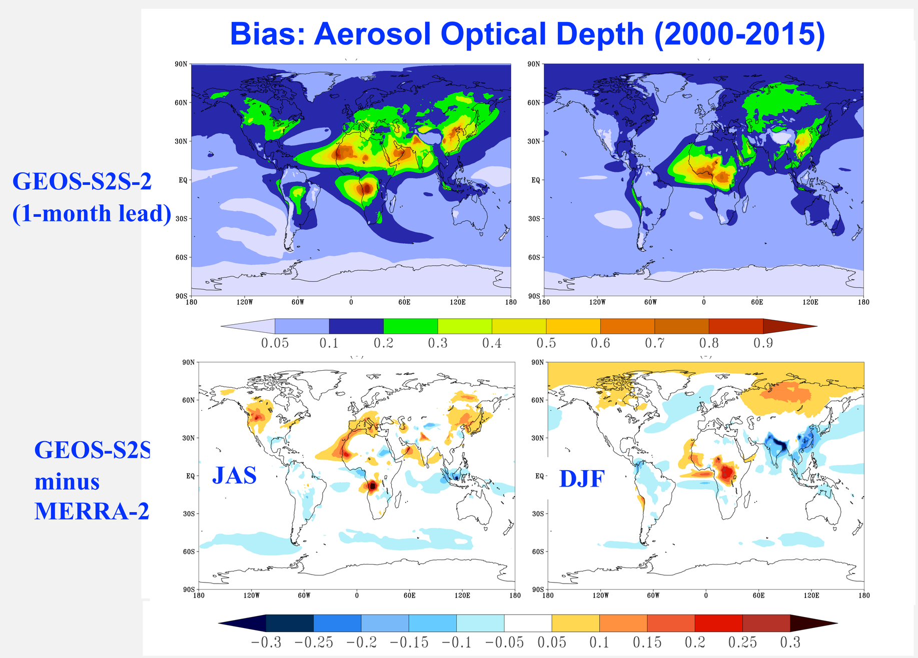
GMAO's GEOS S2S coupled Ocean Data Assimilation system runs in near real time and is used to initialize our sub/seasonal forecasts. Results are generally examined in terms of anomaly from some climatology, derived from a series of retrospective forecasts.

	Subseasonal	Seasonal
Length of Forecast	45 days	9-12 months
Frequency of forecasts	Every 5 days	Every 5 days
Number of Ensembles	4 per start date	Total of 10 per month
Frequency of submission	Once per week	Once per month
Availability	~3 days after real time	Once per month
Initial Conditions from	GEOS ODAS	GEOS ODAS
Retrospective forecasts	1999-2016	1981-2016

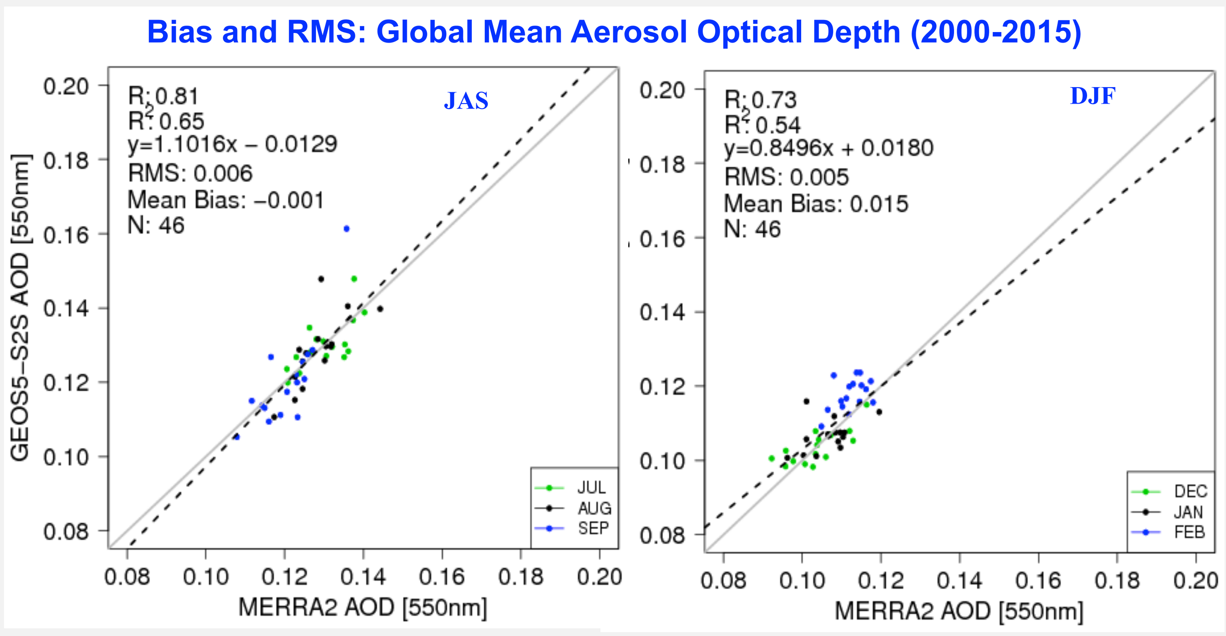
The sequence of experiments analyzed here are the retrospective seasonal forecasts initialized each May starting from 1999 to the present

File Specification: https://gmao.gsfc.nasa.gov/pubs/docs/Nakada1033.pdf

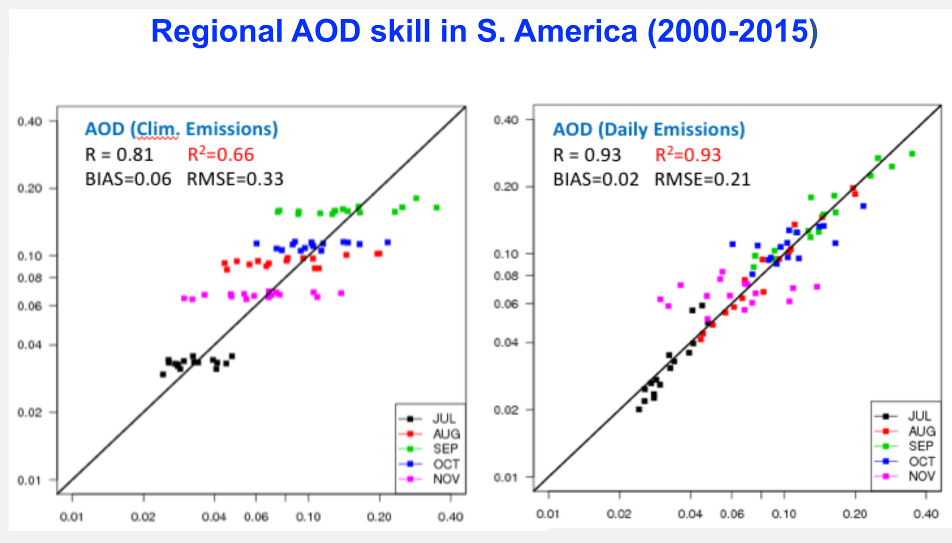
Evaluation of Aerosol Optical Depth (AOD)



Overall, at 1-month lead, the systematic error of the forecast is small as measured against MERRA-2 analyzed AOD. Areas of major disagreement are related to dust advected from the African coast in JAS and biomass burning over central Africa.



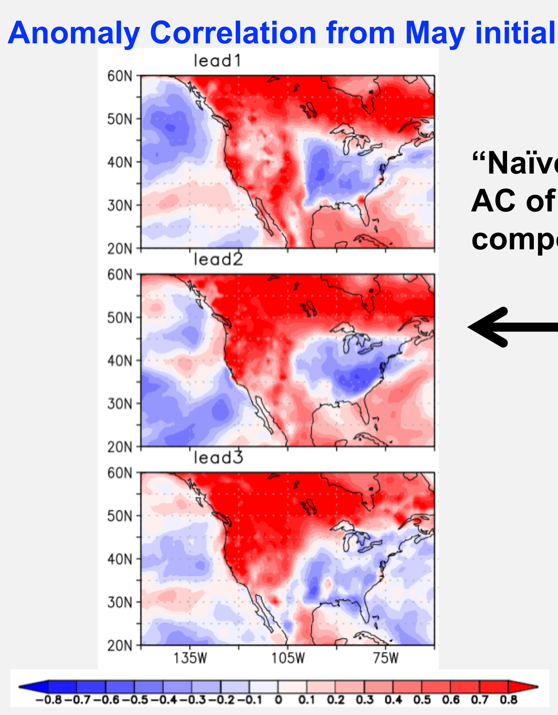
Global mean optical depth at 1-month lead from GEOS-S2S forecasts correlates well with MERRA-2, with slightly better agreement during JAS.



Skill critically dependent on skill of biomass burning emissions, climatological emissions not adequate for predicting interannual variability of AOD

Predictive biomass burning algorithm needed for skillfull seasonal AOD forecast

Evaluation of Air Quality – Anomaly Correlation of PM2.5



"Naïve" calculation of AC: AC of (sum of components of PM2.5)

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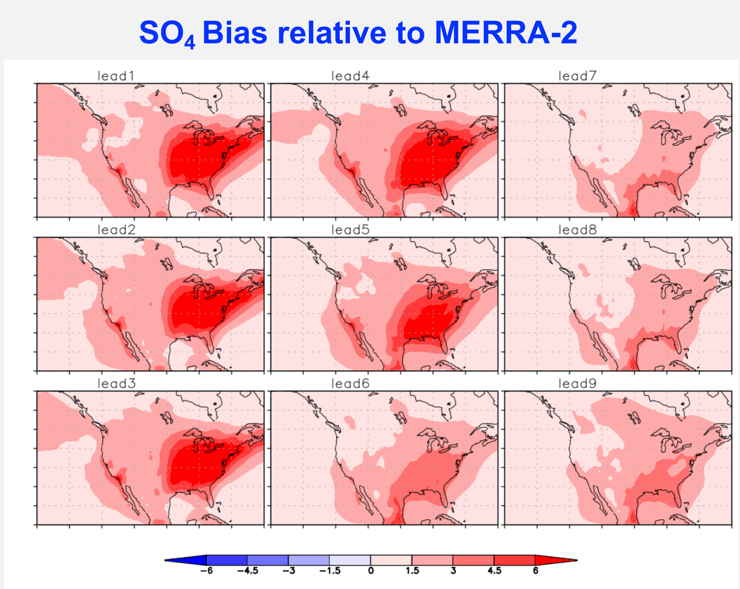
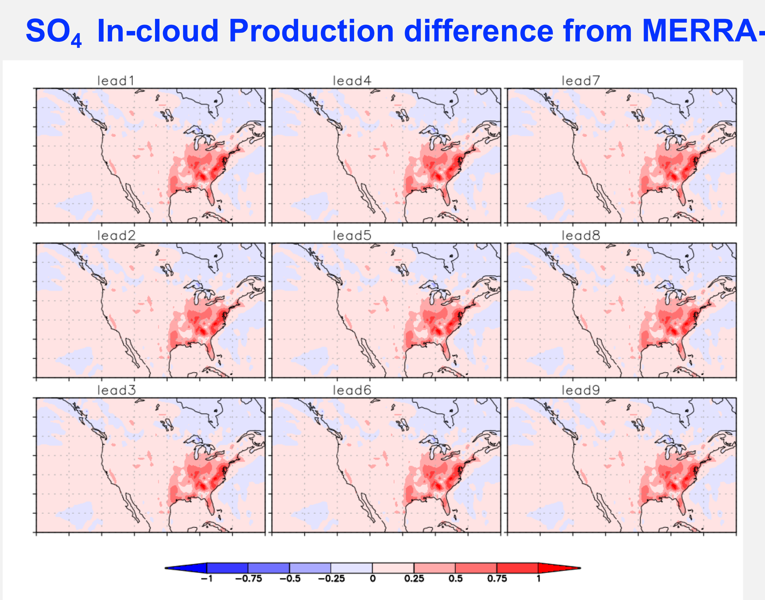


Systematic excess of SO_4 in seasonal forecast relative to MERRA-2 "overwhelms" the Anomaly Correlation, SO_4 anomaly dominates



Systematic excess of SO_4 is due to an excess of in-cloud aqueous production (cloud fraction higher than in MERRA-2)

Recompute AC: Sum of AC of all components

Must compute PM2.5 anomaly this way for skillful forecast

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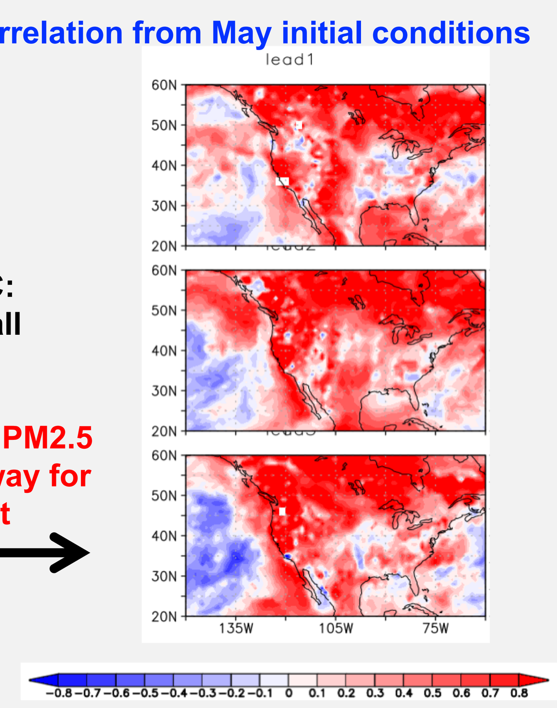

Summary

- Dynamical predictions of PM2.5 on sub/seasonal scale can be skillful
- Bias in one component of PM2.5 can adversely impact skill if care is not taken to provide the proper forecast
- Predictive biomass burning model is needed
- Future work: Assessment of impact of interactive aerosol model on meteorological forecast skill, and to identify "forecasts of opportunity"

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