

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. i.e., 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 $\sim 0.5^\circ$, 72 hybrid sigma/pressure levels; GOCART interactive aerosol model, cloud indirect effect (2-moment cloud microphysics); MERRA-2 generation cryosphere
- OGCM: MOM5, $\sim 0.5^\circ$, 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

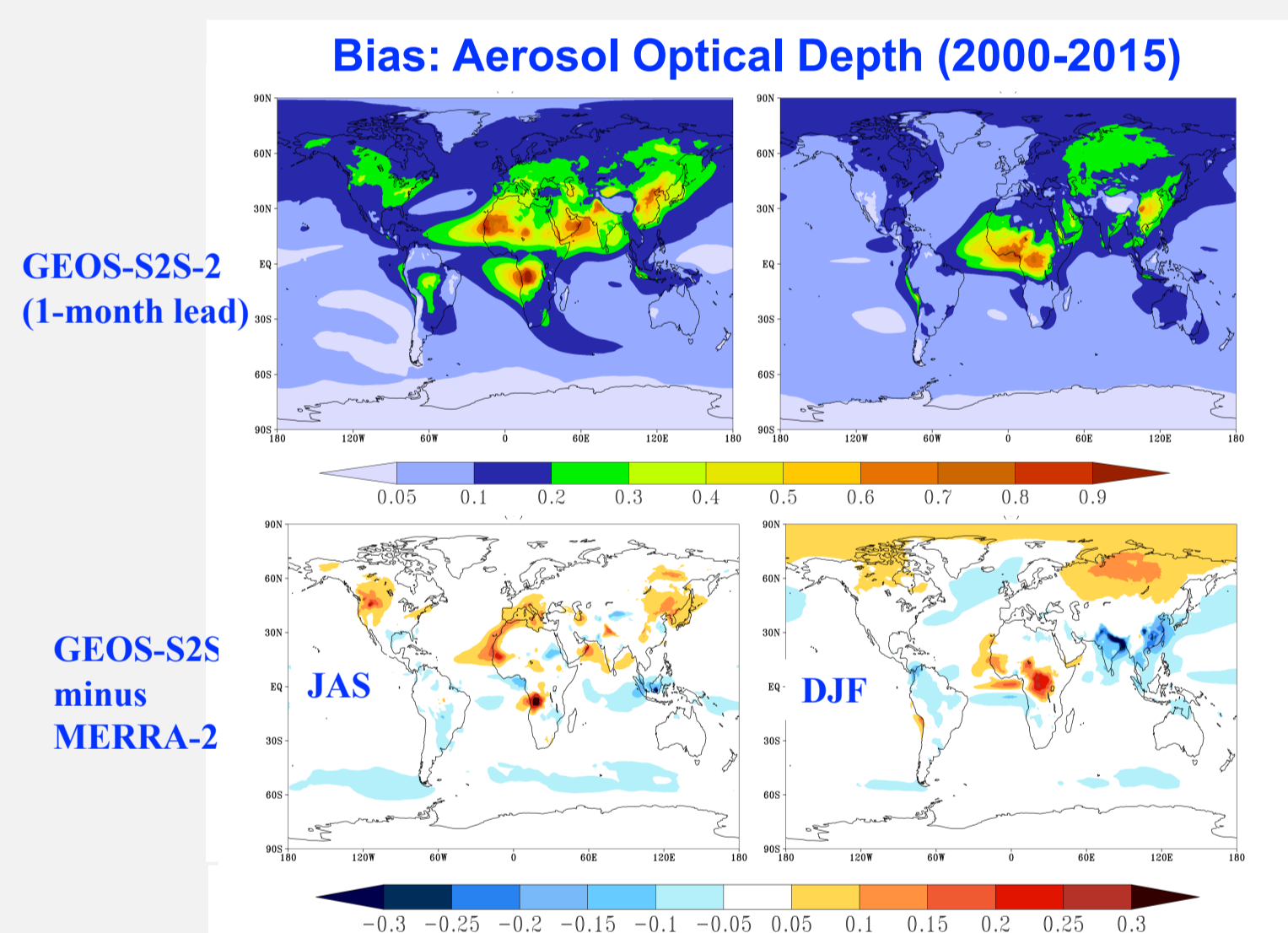
GMAO's GEOS S2S coupled Ocean Data Assimilation system runs in near real time and is used to initialize our sub/seasonal forecasts. Results are generally examined in terms of anomaly from some climatology, derived from a series of retrospective forecasts.

| | 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 |

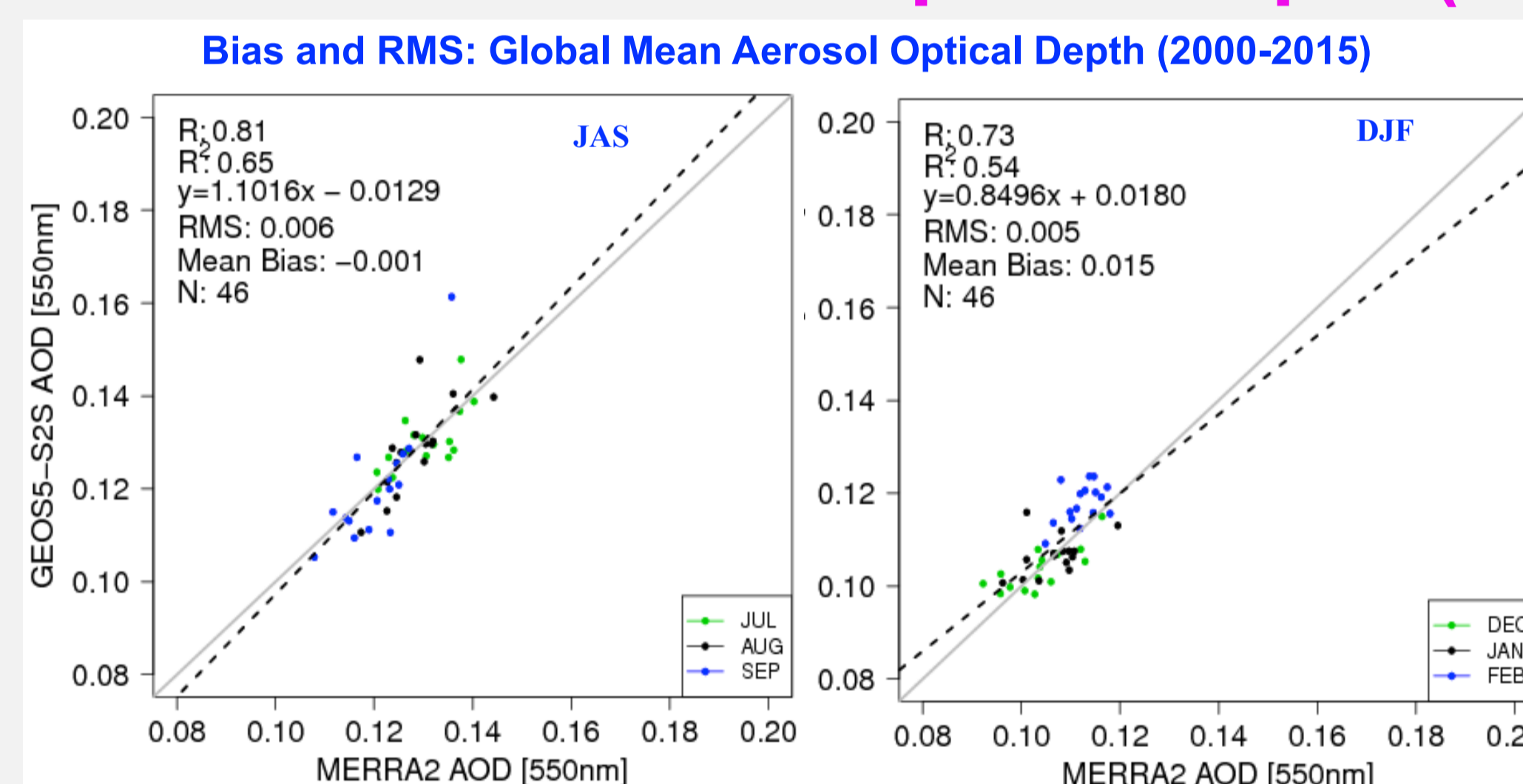
The sequence of experiments analyzed here are the retrospective seasonal forecasts initialized each May starting from 1999 to the present

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

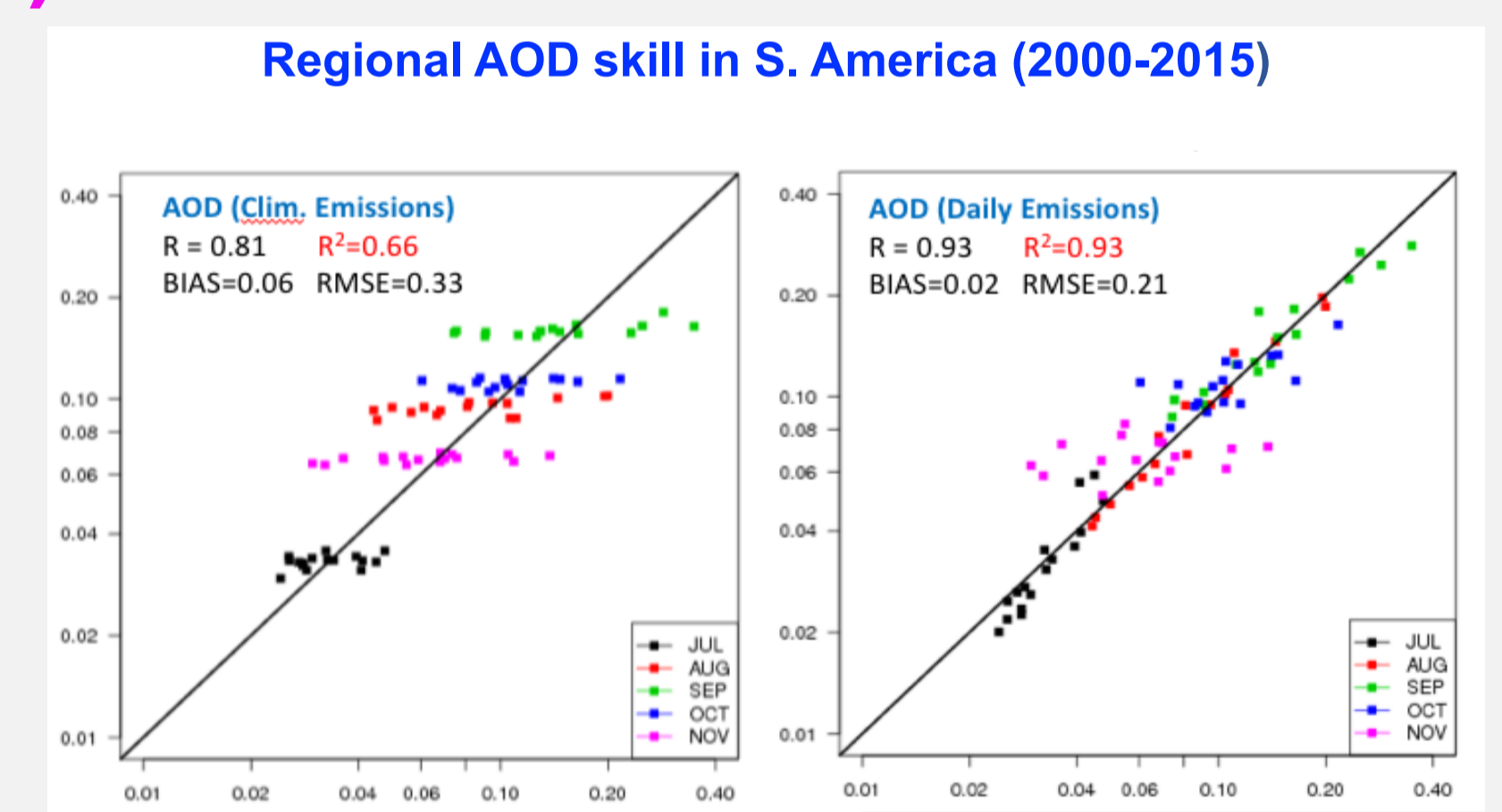
Evaluation of Aerosol Optical Depth (AOD)



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.

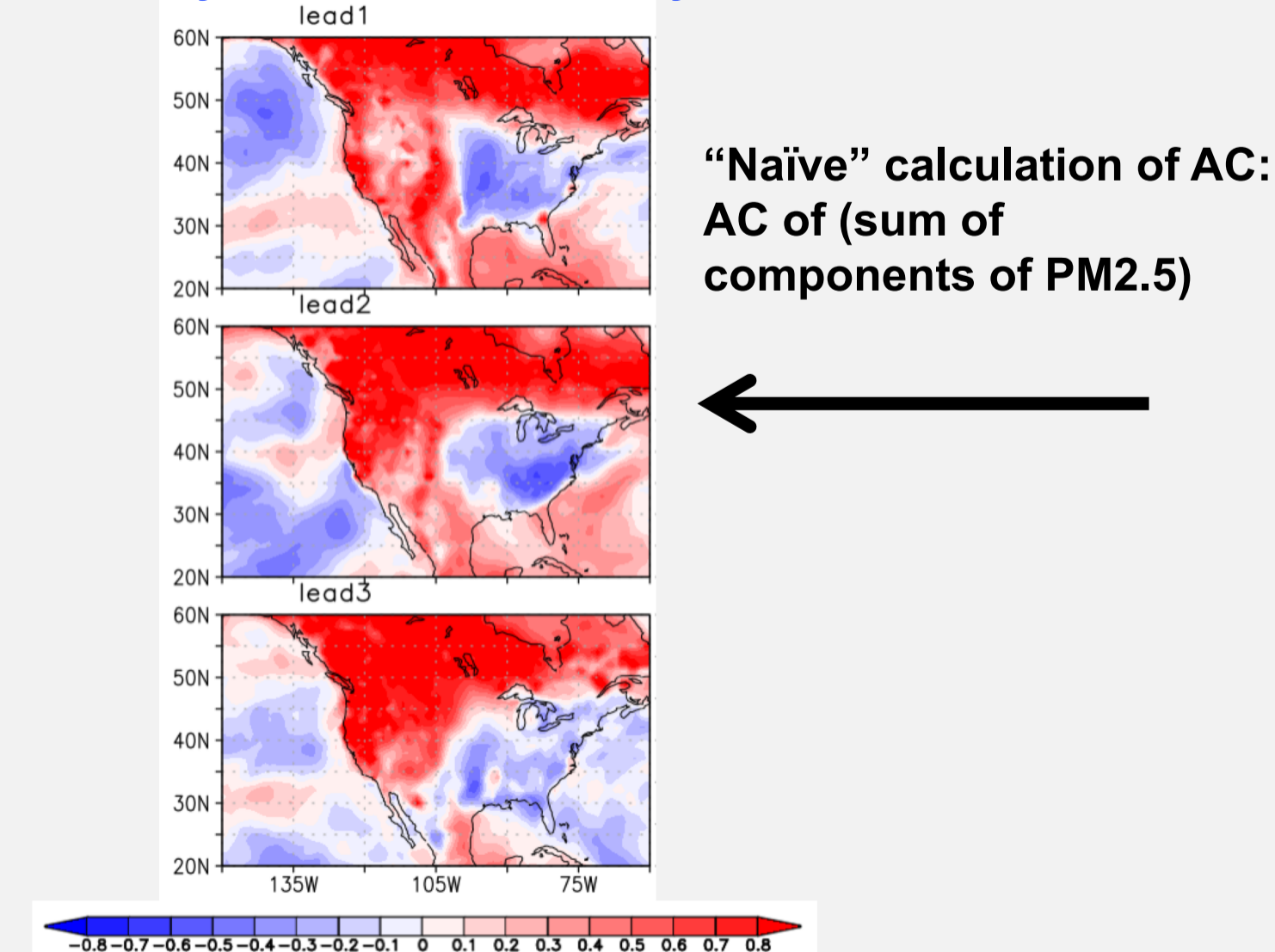


Skill critically dependent on skill of biomass burning emissions, climatological emissions not adequate for predicting interannual variability of AOD

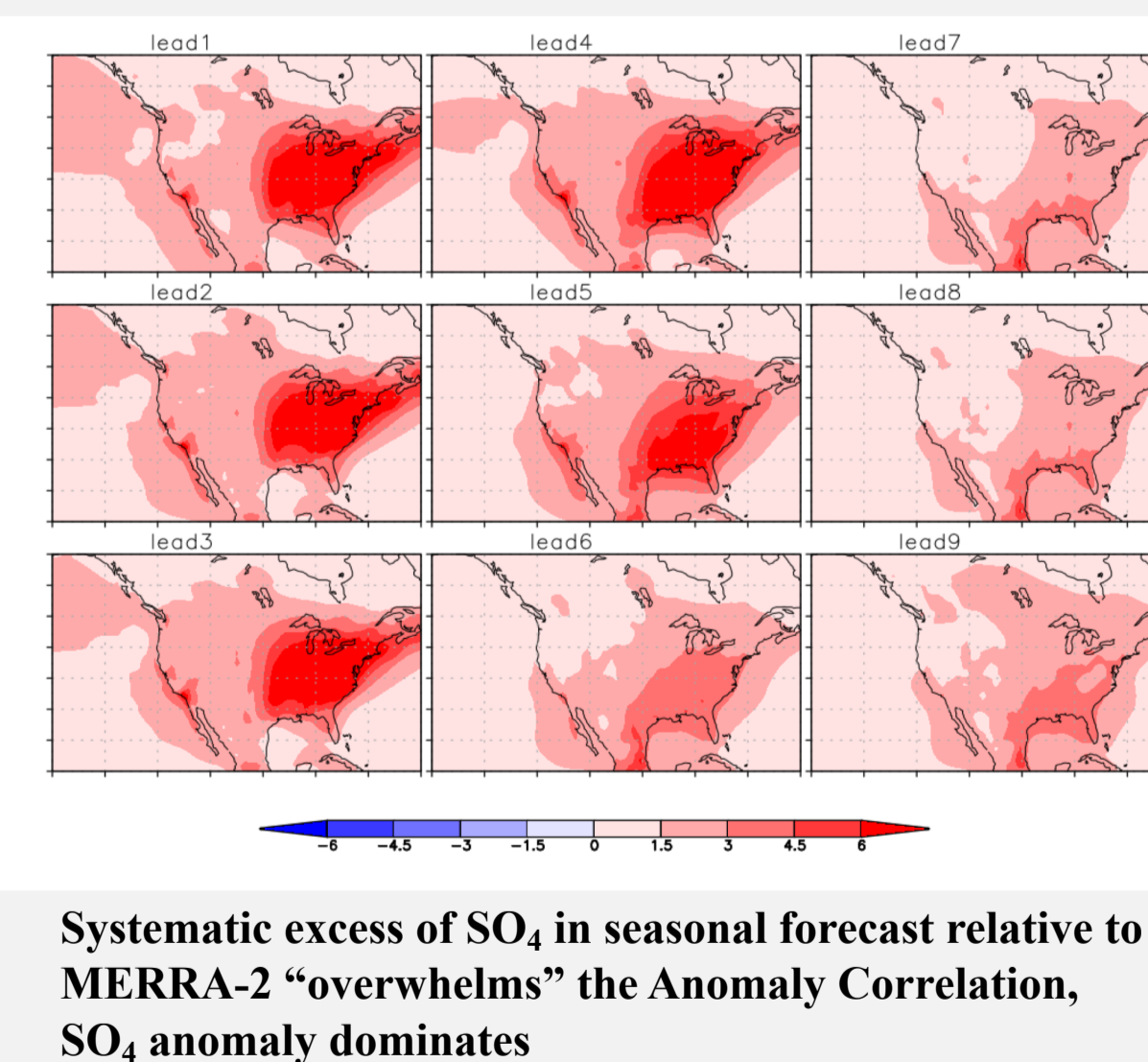
Predictive biomass burning algorithm needed for skillful seasonal AOD forecast

Evaluation of Air Quality – Anomaly Correlation of PM2.5

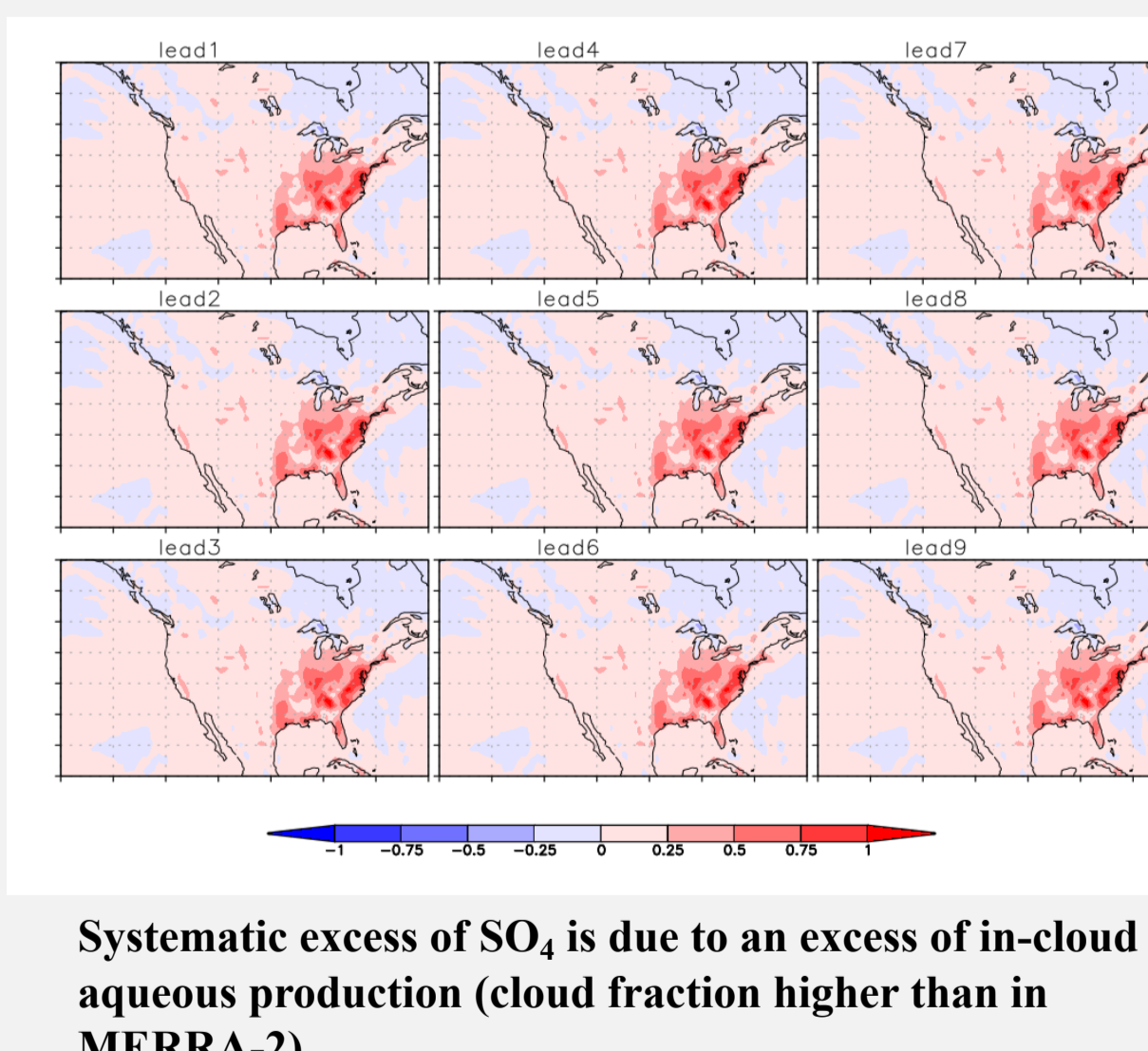
Anomaly Correlation from May initial conditions



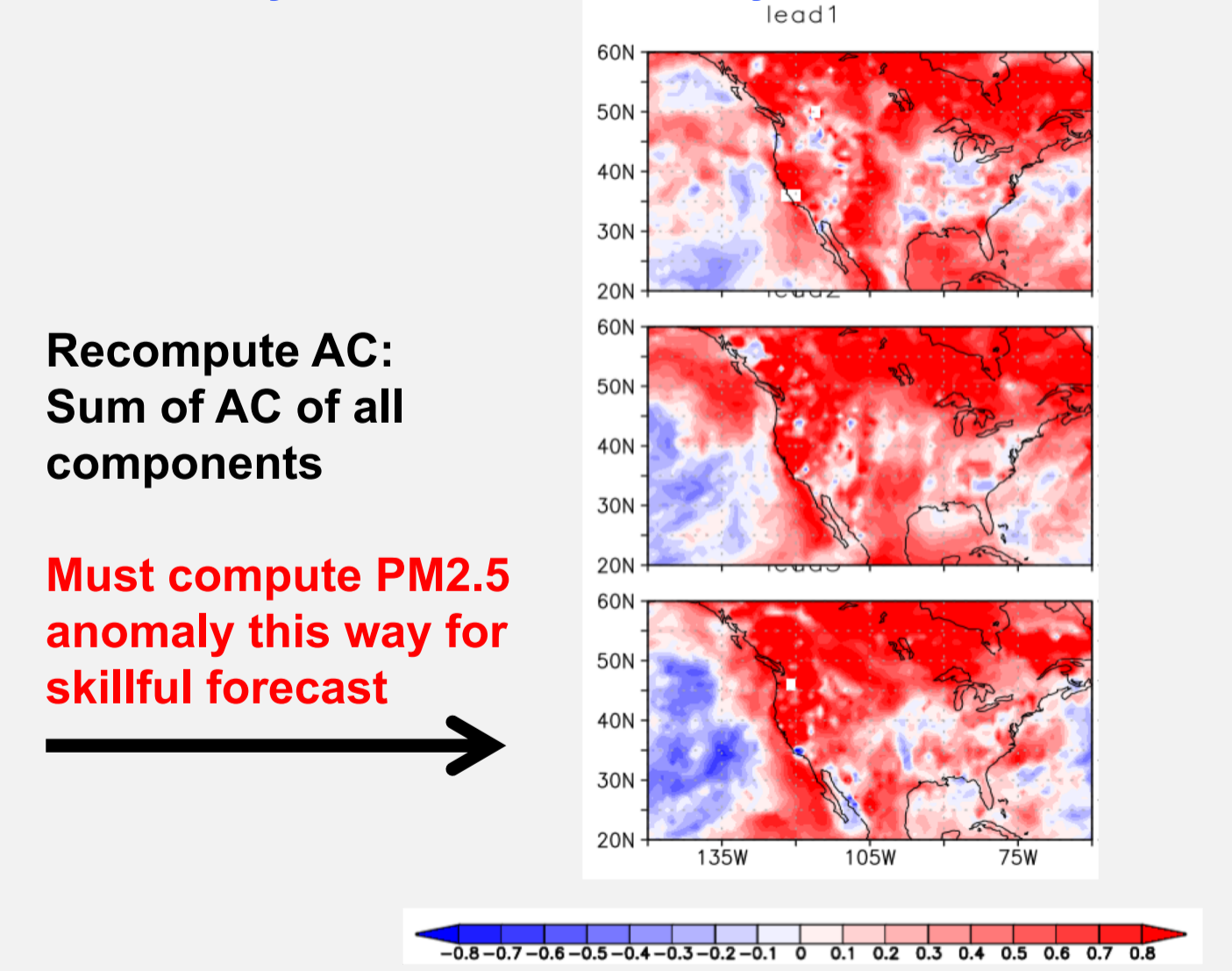
SO₄ Bias relative to MERRA-2



SO₄ In-cloud Production difference from MERRA-2



Anomaly Correlation from May initial conditions



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"