Evaluating the Impact of Cloud-Aerosol-Precipitation Interaction (CAPI) Schemes on Rainfall Forecast in the NGGPS

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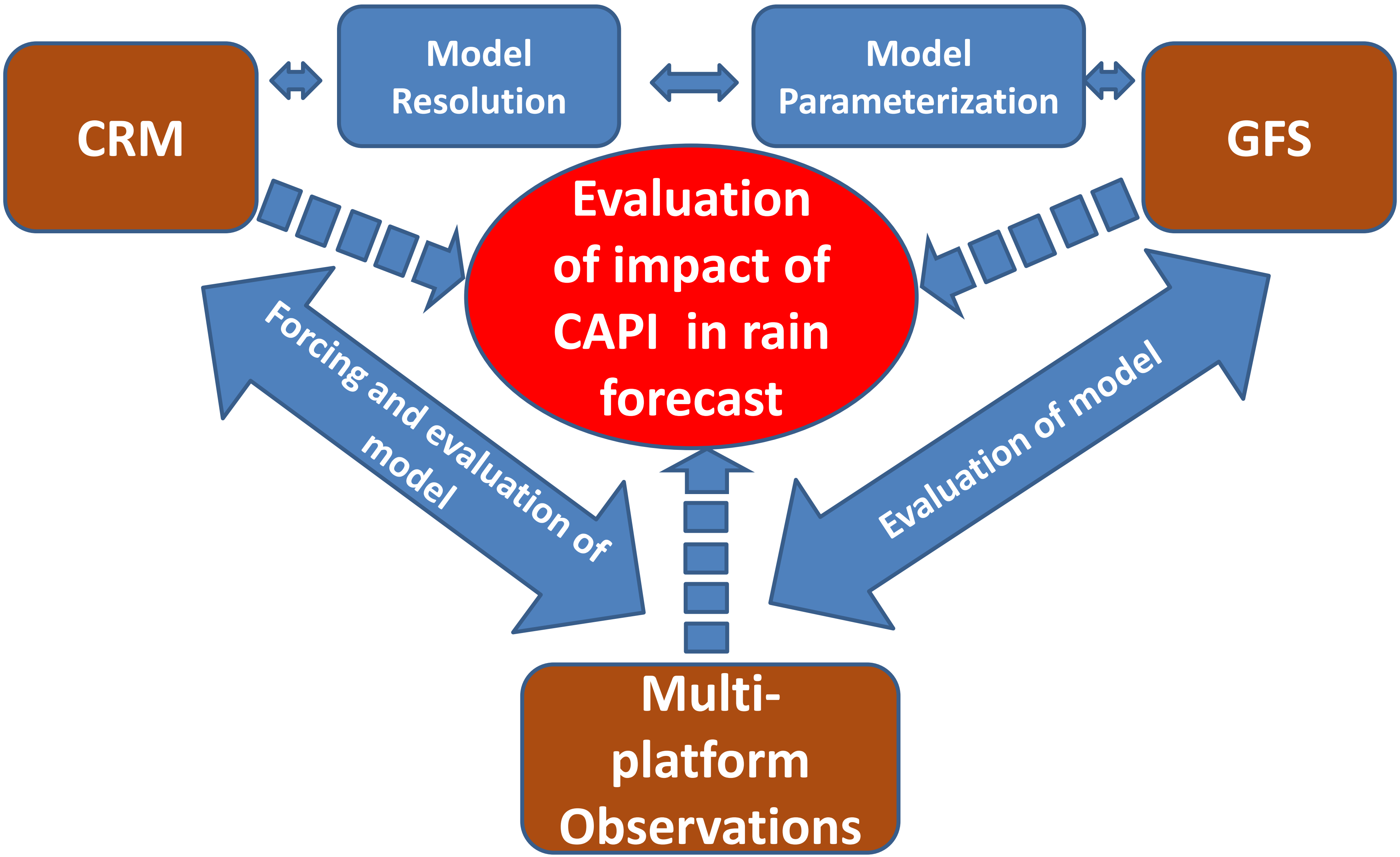
Major Tasks

1. Use a variety of observation datasets to identify and quantify the impact of aerosol on cloud and precipitation. Investigate any dependence of model biases on aerosol properties under different meteorological conditions.

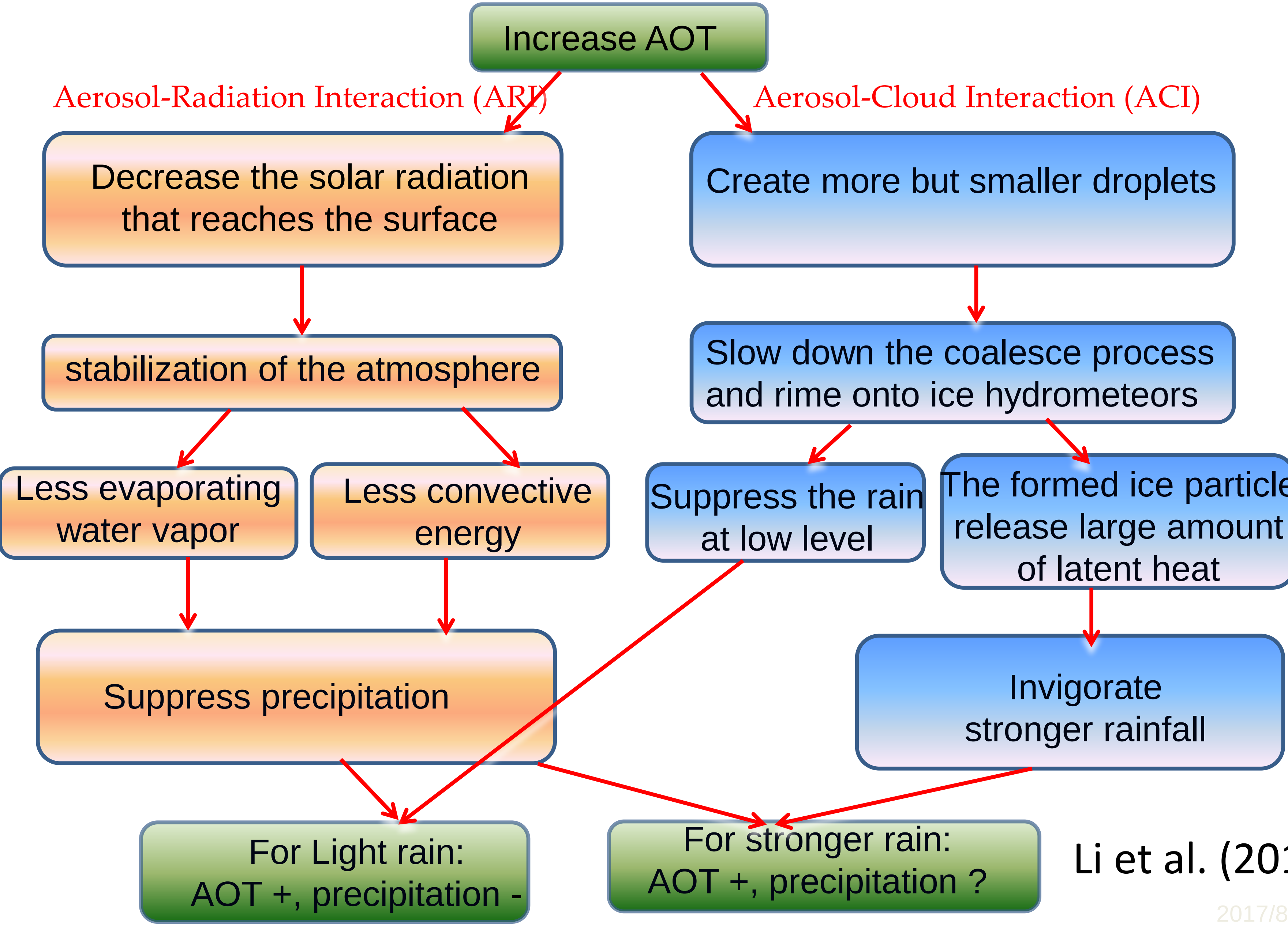
2. Evaluate the performance of the GFS baseline model in simulating clouds and precipitation in order to identify/attribute any forecast errors to aerosol-cloud-precipitation interactions.

3. Select certain cloud systems, run the CRM with NGGPS-selected parameterization schemes, and compare the CRM against GFS/NGGPS results .

The paradigm of our approach

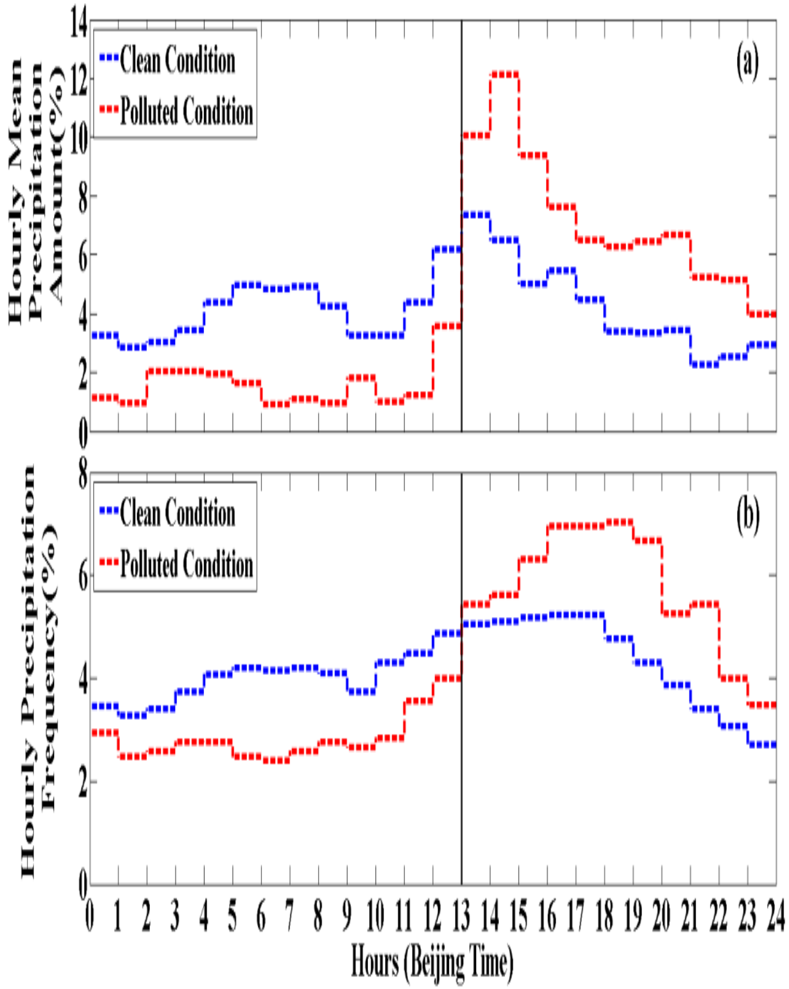


Mechanisms of CAPI

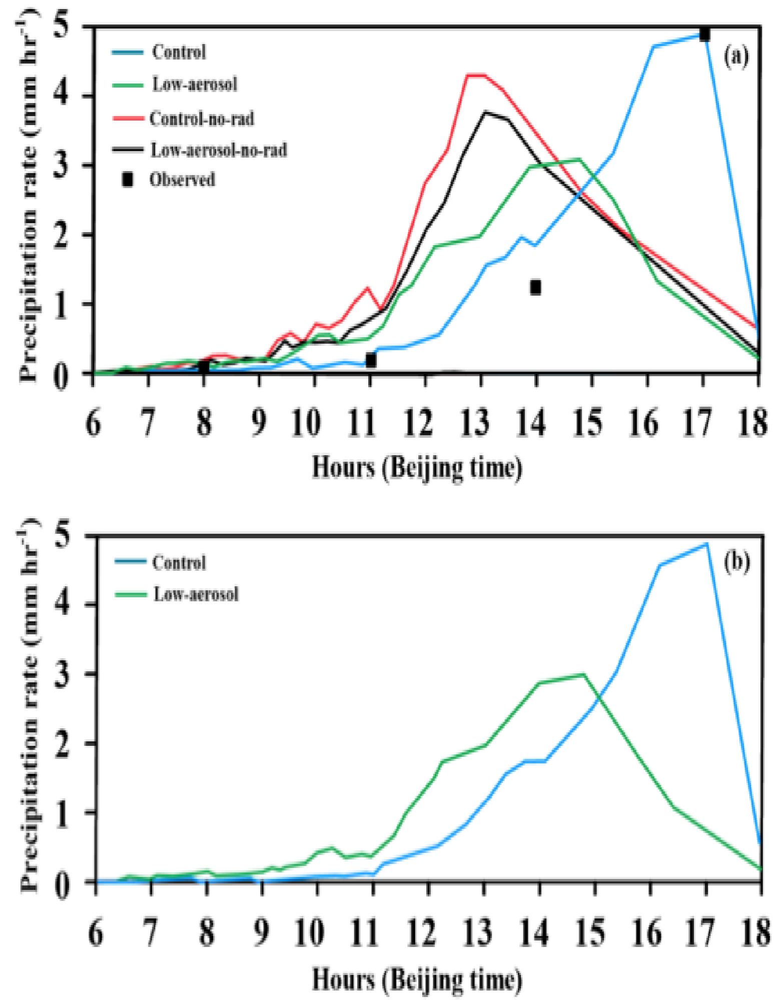


Li et al. (2017)

Diurnal Cycle of Rainfall from Deep Clouds Contrast between Clean & Dirty Air

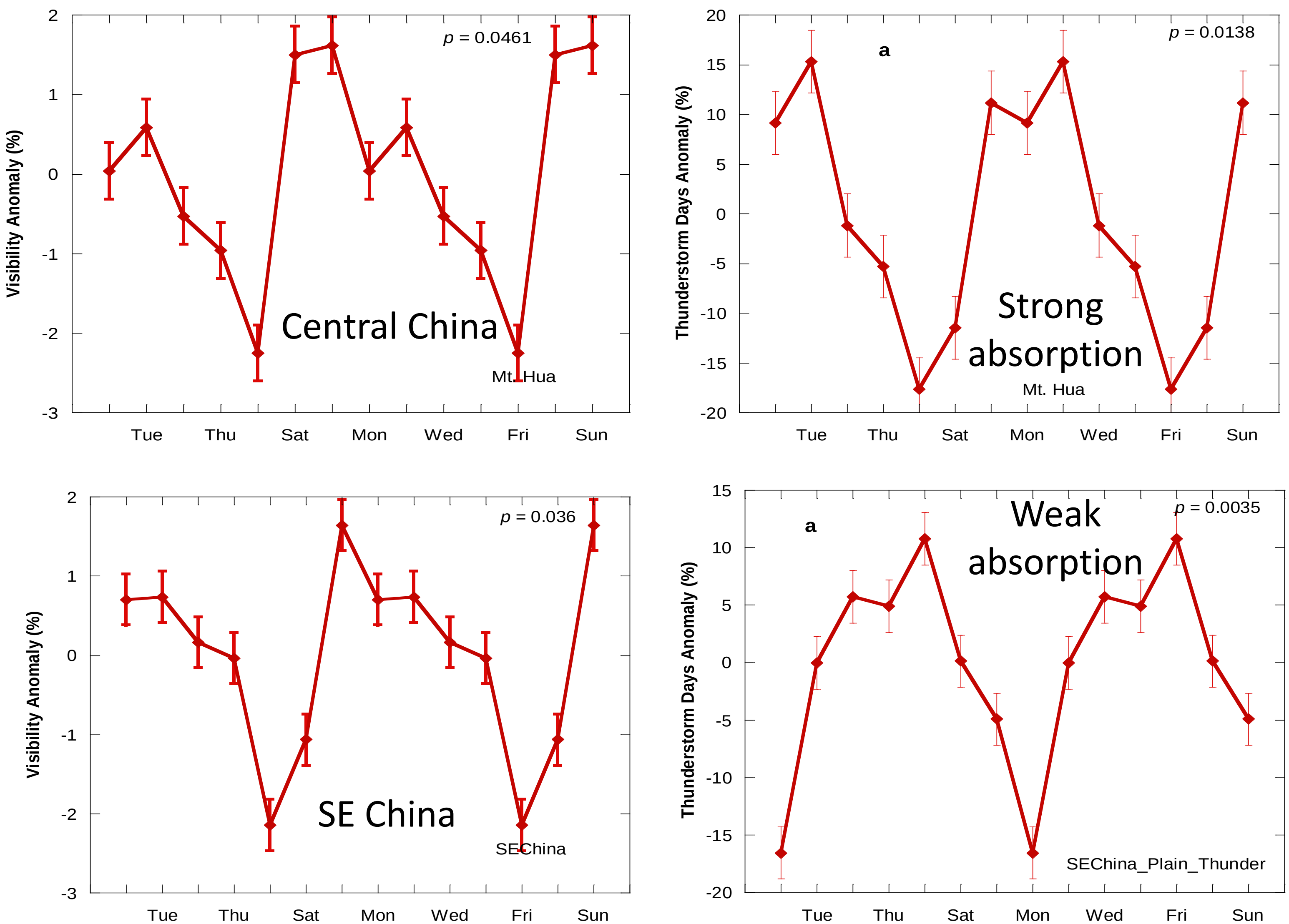


Guo et al. (2016, JGR)



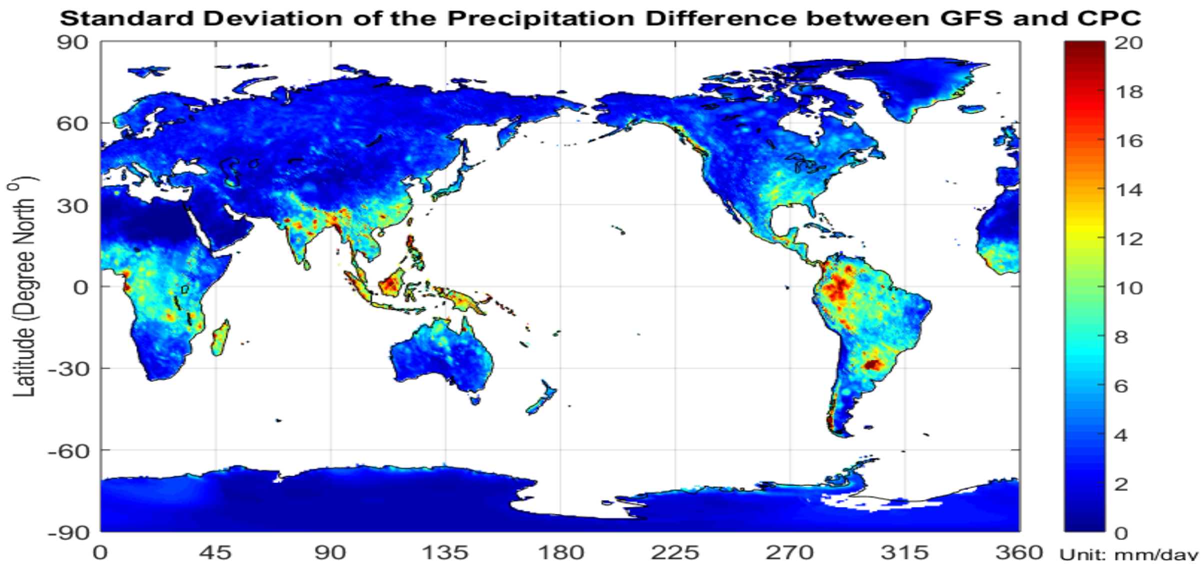
Lee et al. (2016, JGR)

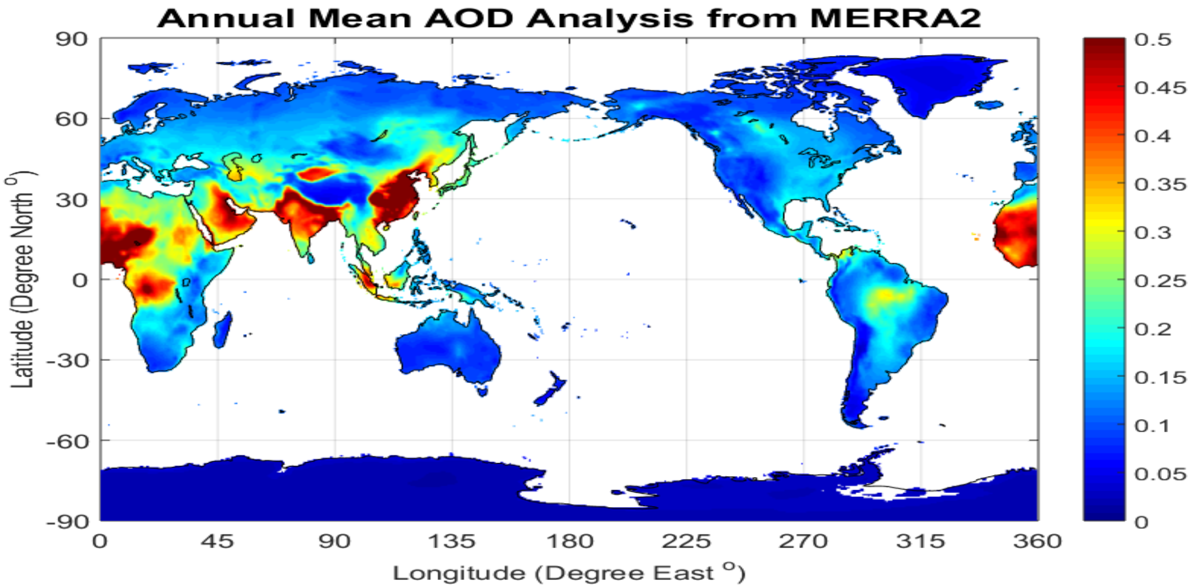
Visibility Thunderstorms



Yang et al. (2016, GRL)

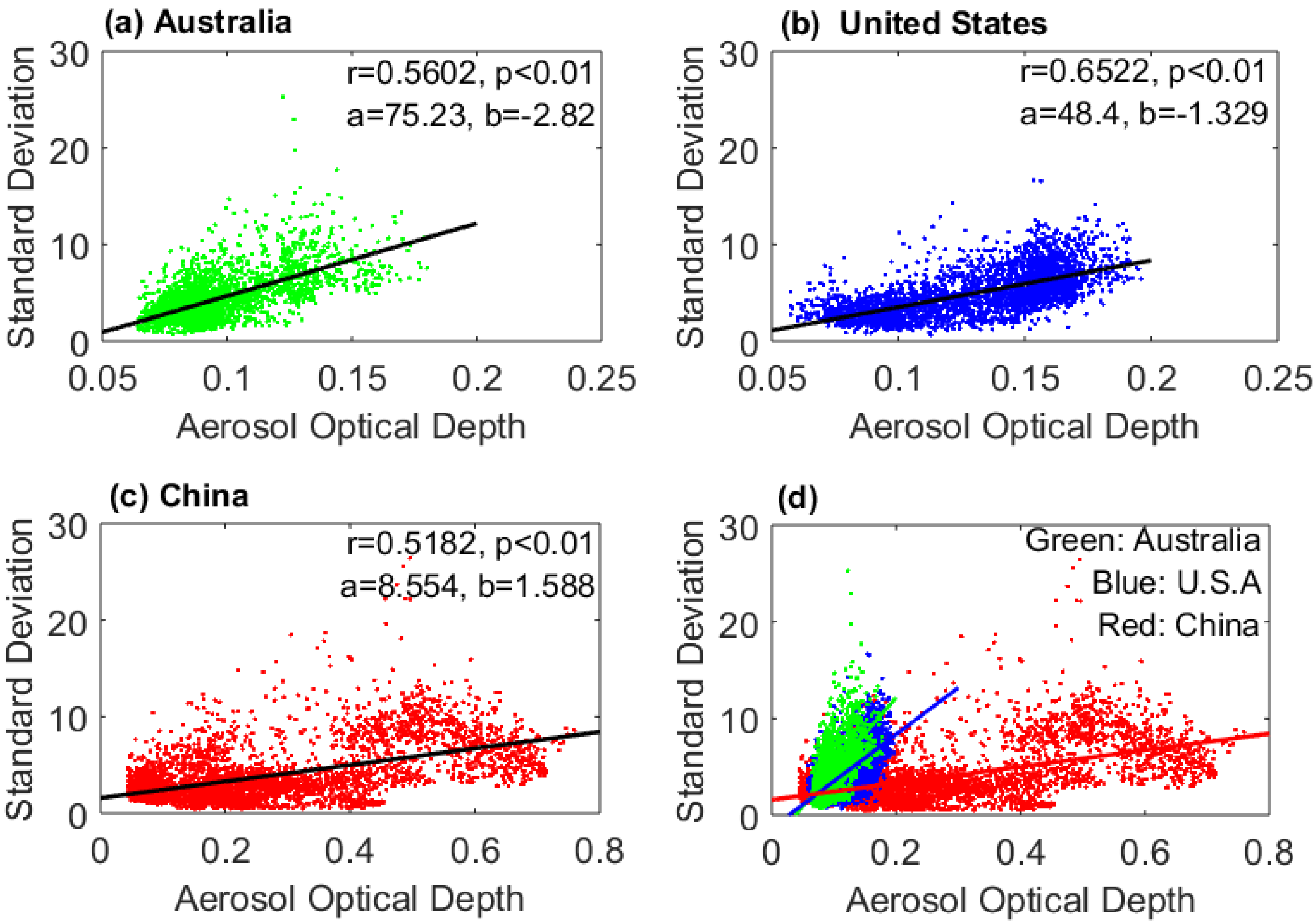
GFS Precipitation Model Error and Aerosol Loading





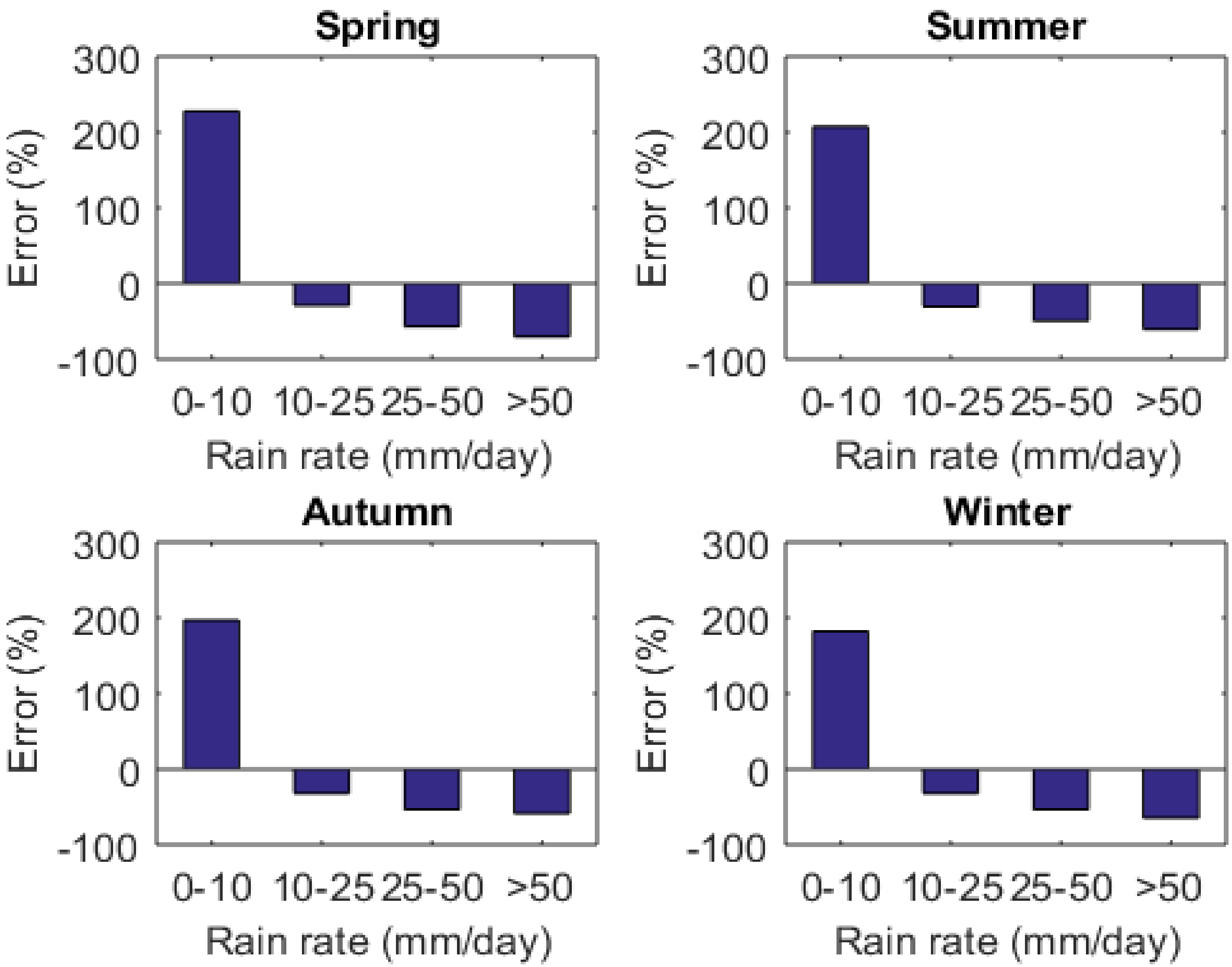
Jiang et al. (2017, ACPD)

Standard Deviation of Rainfall Forecast Error and Aerosol Loading



Jiang et al. (2017, ACPD)

GFS overestimates light rain and underestimates heavy rain



Jiang et al. (2017, ACPD)

A Close-up look at the problem for Marine St Clouds

Global Forecast System

- NCEP GFS forecast output at 1 degree resolution. Output is 3-h intervals and start from 00Z.

Satellite observations

- MODIS Terra MOD08 level 3 product for cloud properties and AOD.
- AIRS Level 3 product for atmosphere temperature profiles.
- CERES EBAF-surface product for surface fluxes.
- CALIPSO aerosol vertical profiles

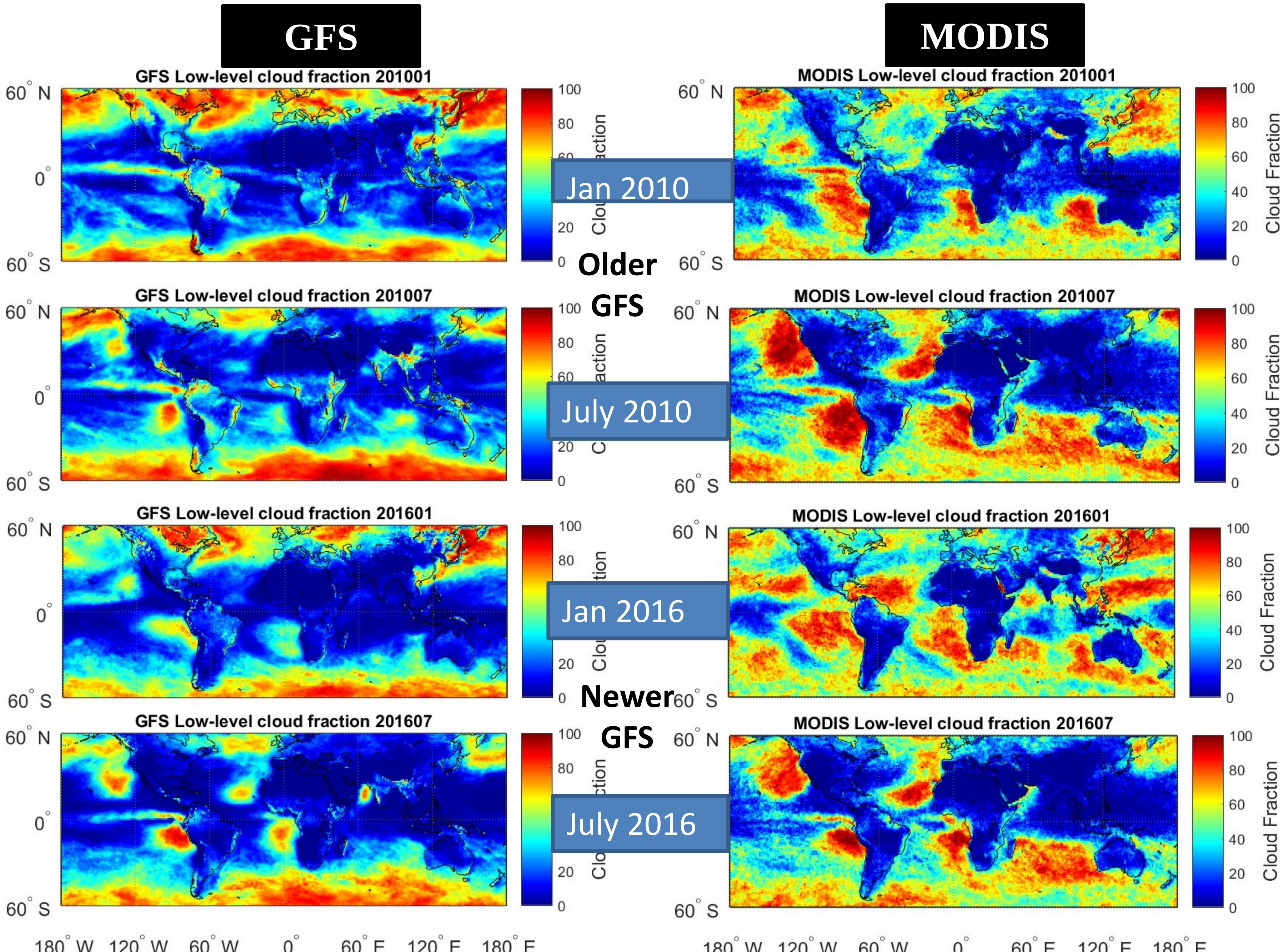
Surface ARM observations

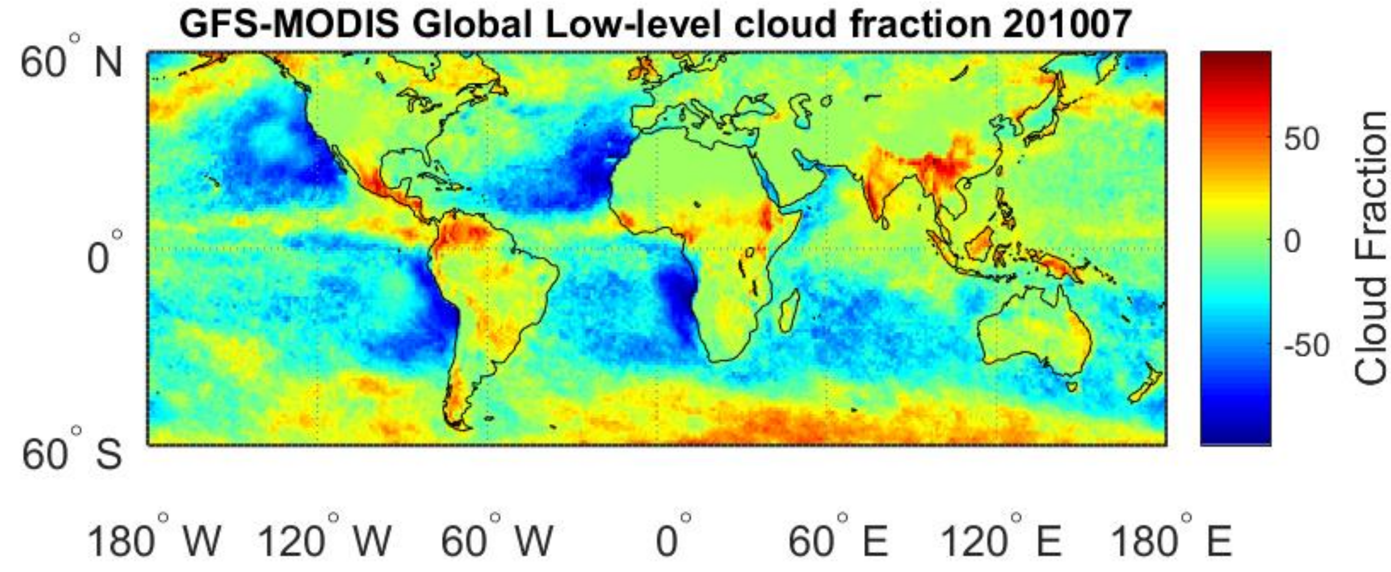
- Azores ARM field experiment

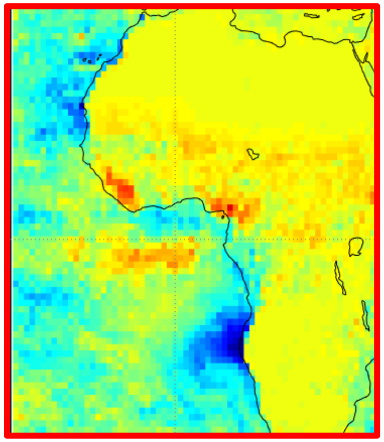
Study area & time

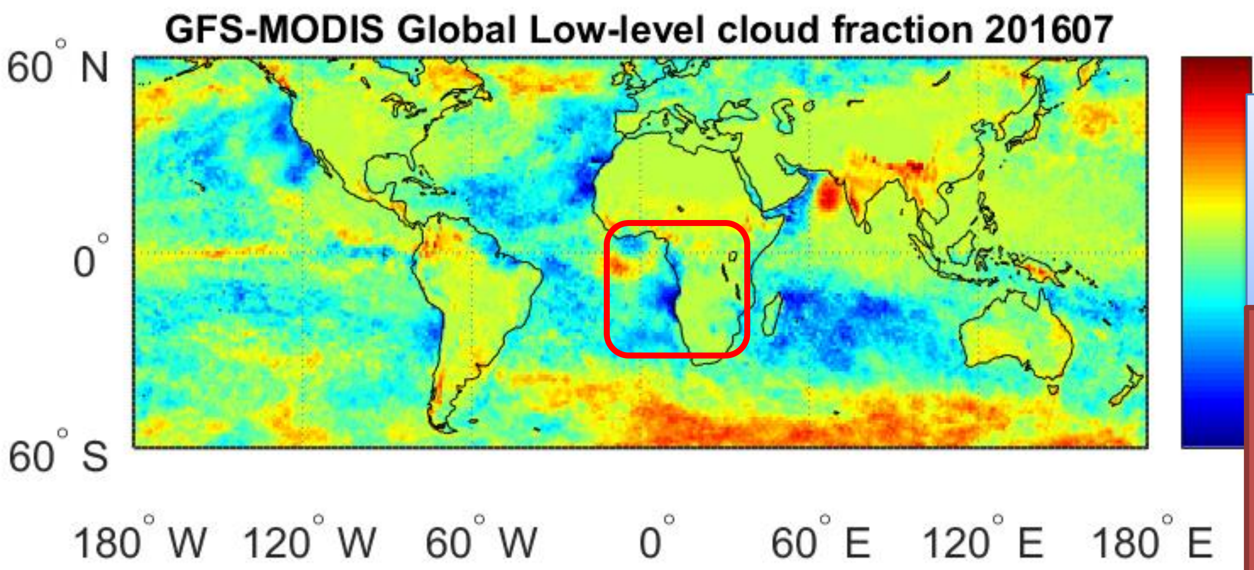
Focus on the southeast Atlantic ocean and west coast of southern Africa in 2016.

Comparison of Low Clouds from GFS & MODIS







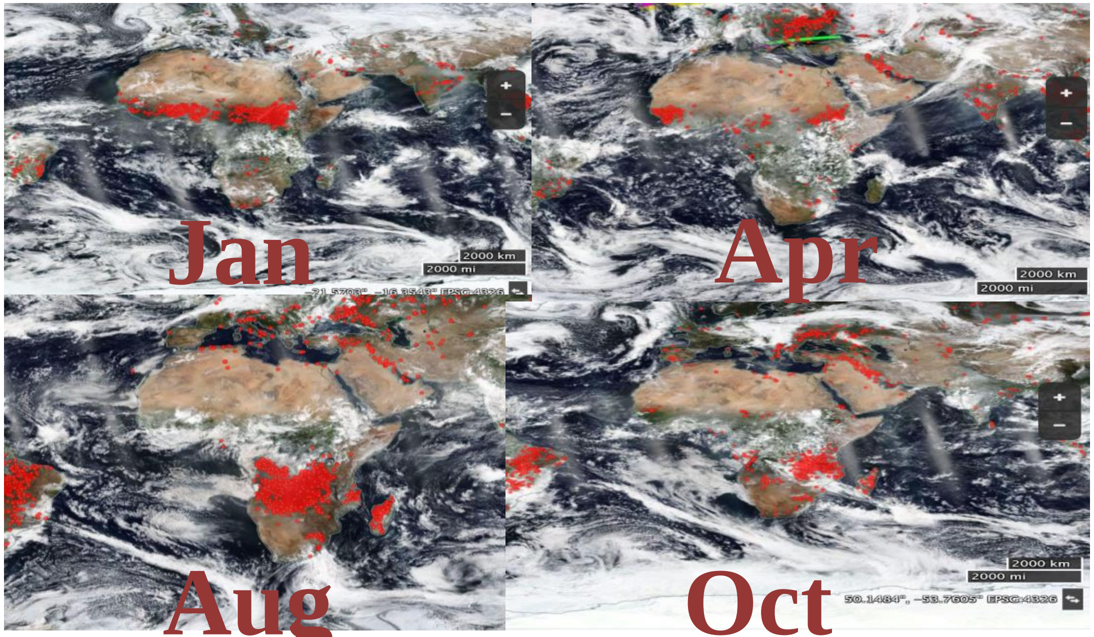


Is it possible the negative bias might related to the biomass burning aerosols ?

Many observations and modeling studies show that absorbing aerosols above the marine stratocumulus clouds tends to increase the cloud cover.

The new SC scheme does not destroy stratocumulus clouds off the west coasts of America and Africa as the old scheme does. (Han &Pan 2011)

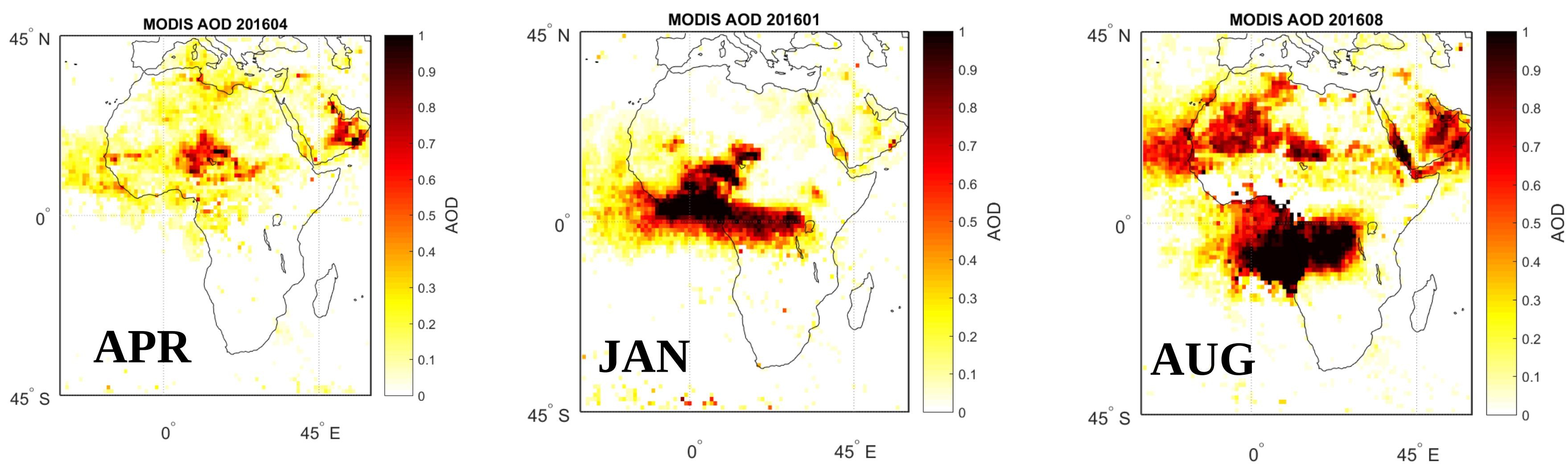
Fire and Thermal anomalies



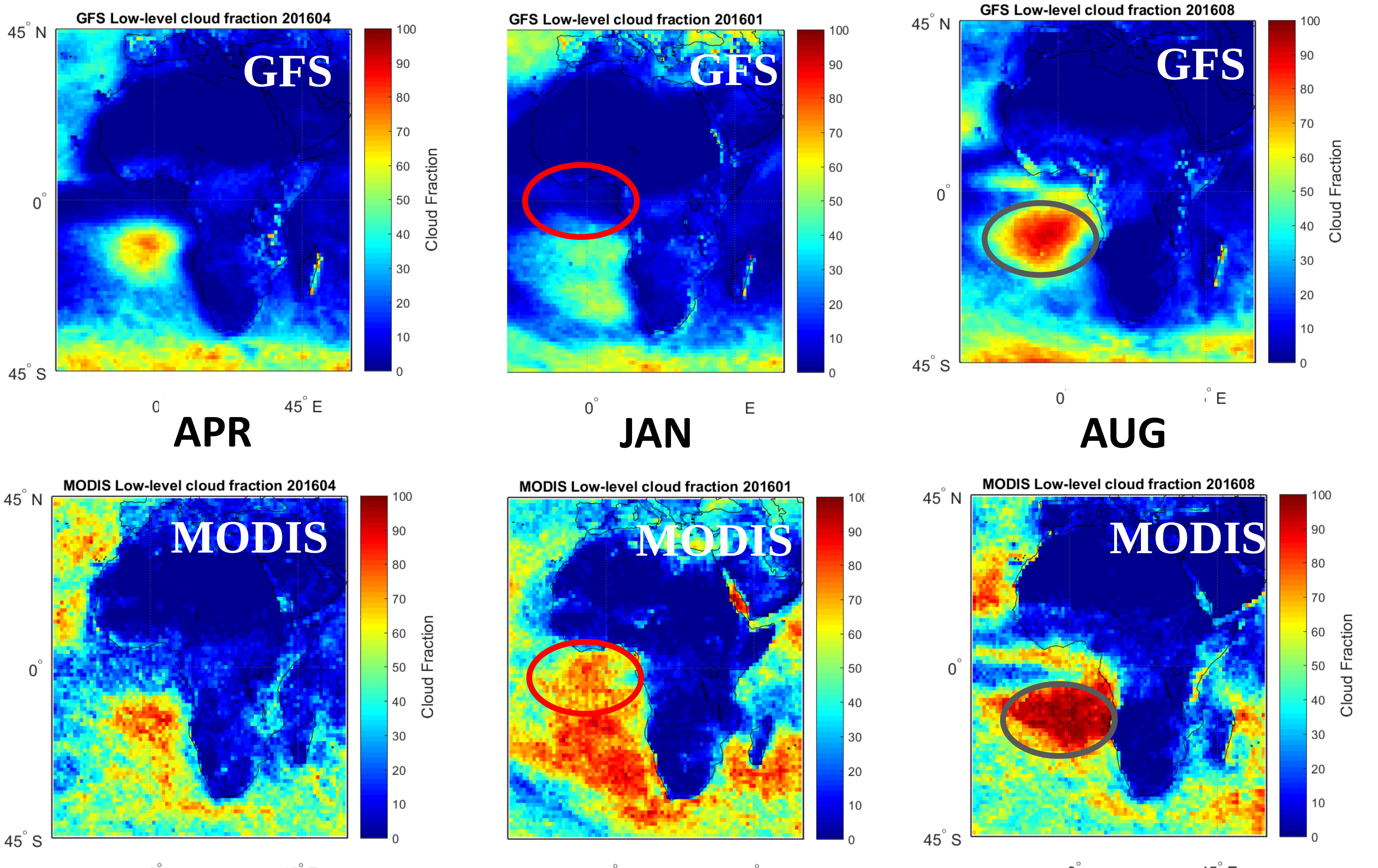
worldview.earthdata.nasa.gov/

Most biomass burning events occur during Aug (Jan) in the south(central) Africa but fewer during April.

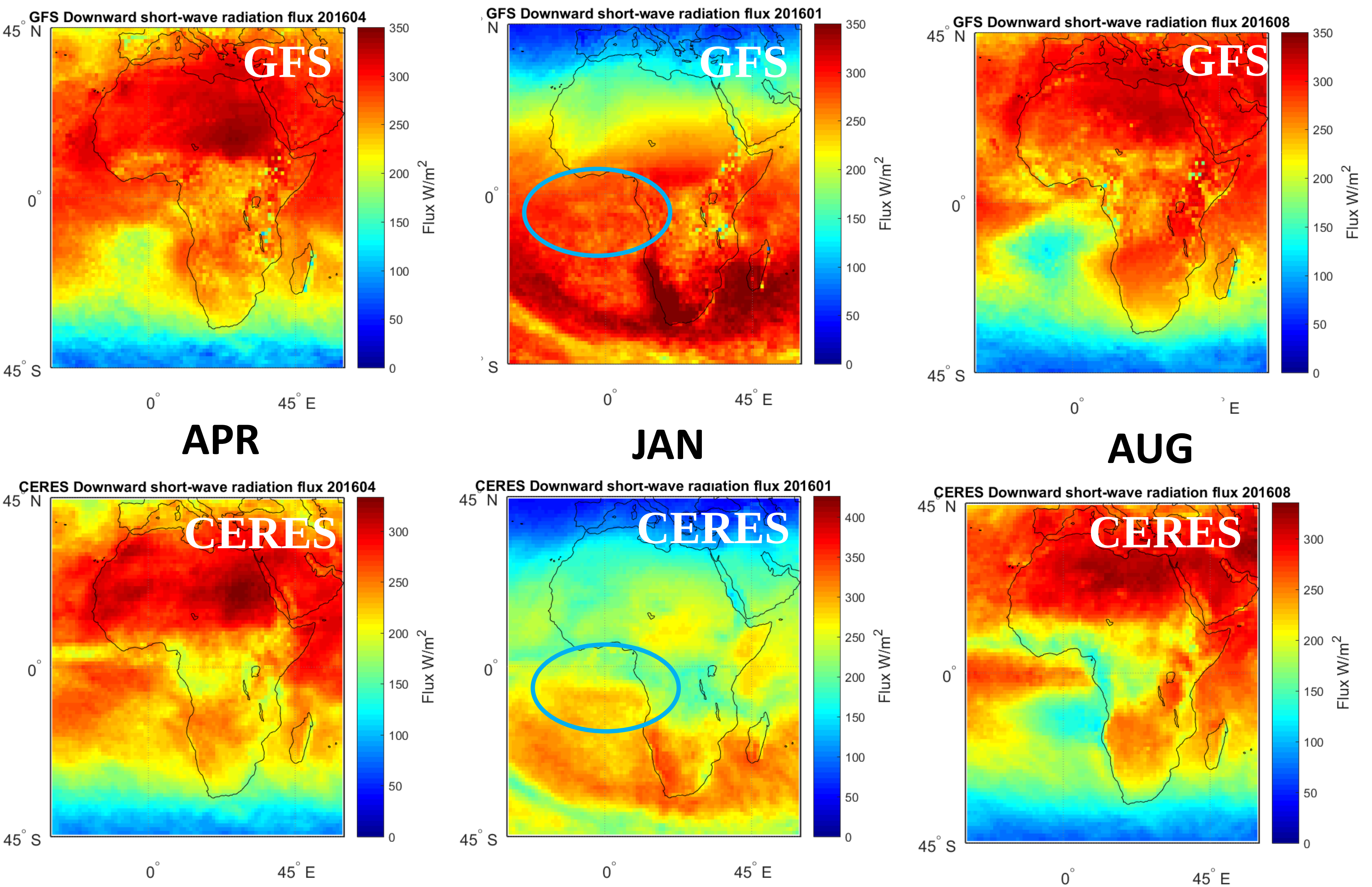
MODIS monthly AOD



Low-level cloud fraction

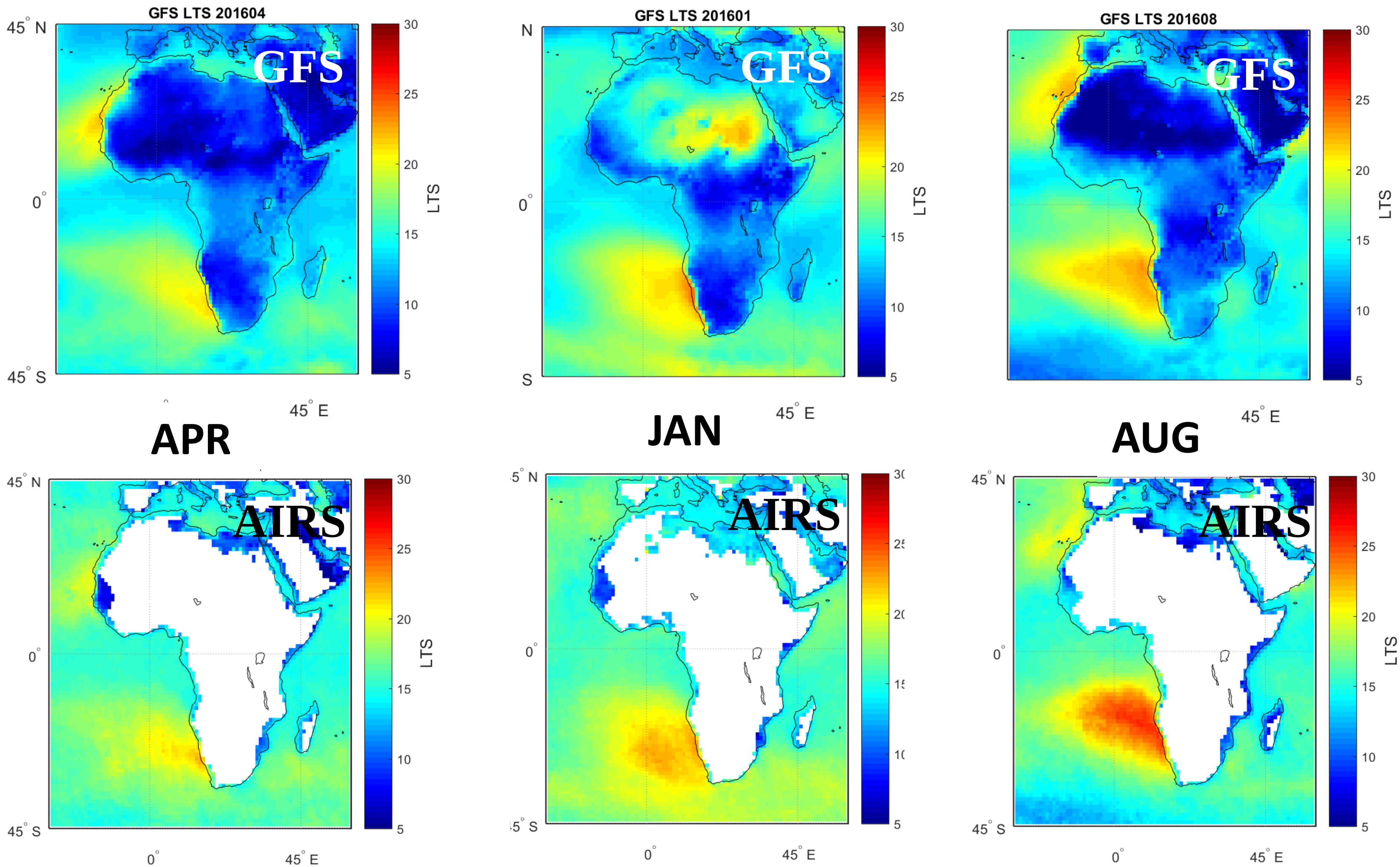


Downward shortwave radiation

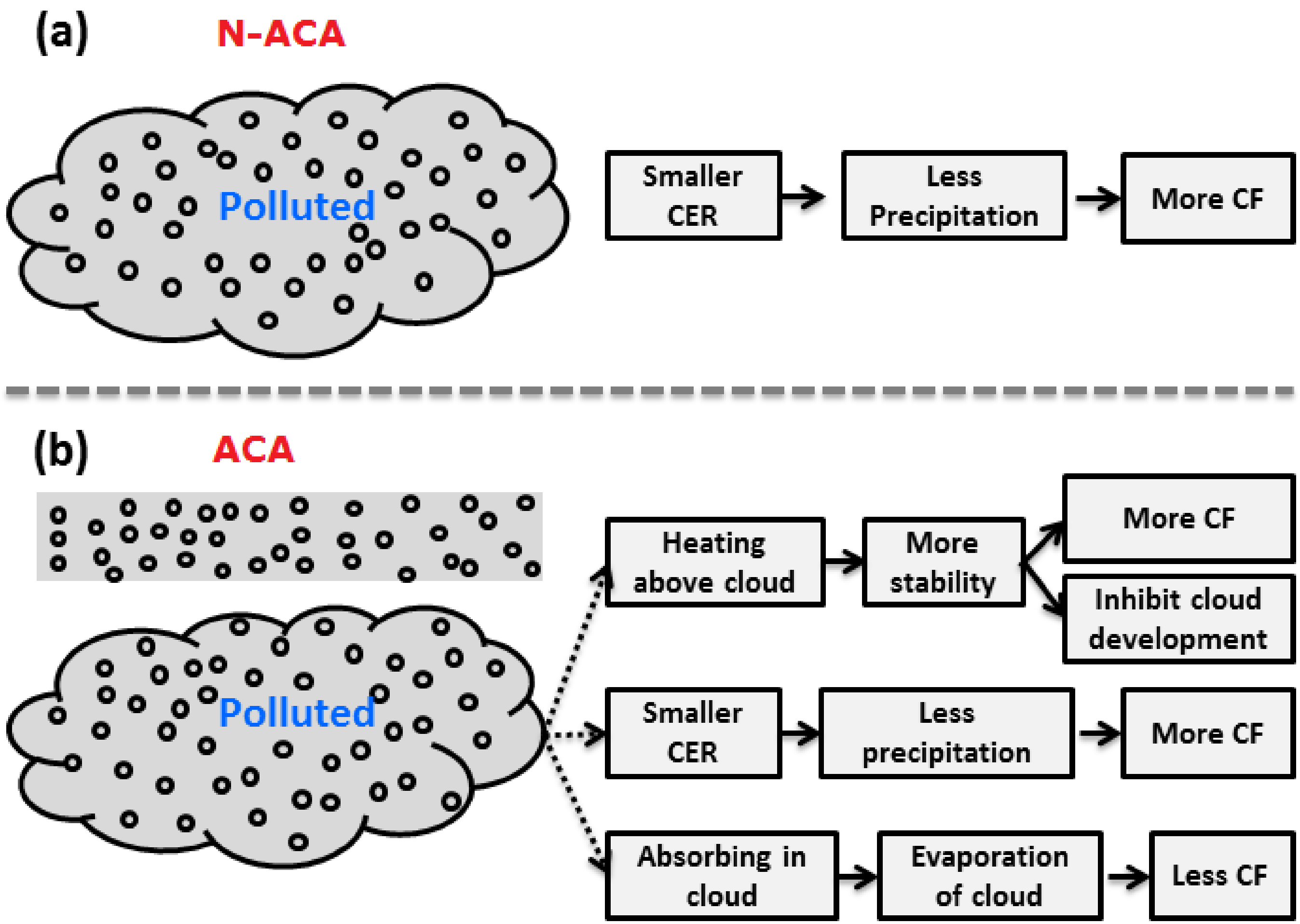


Lower-troposphere stability (LTS)

$LTS = \theta_{700} - \theta_{1000}$

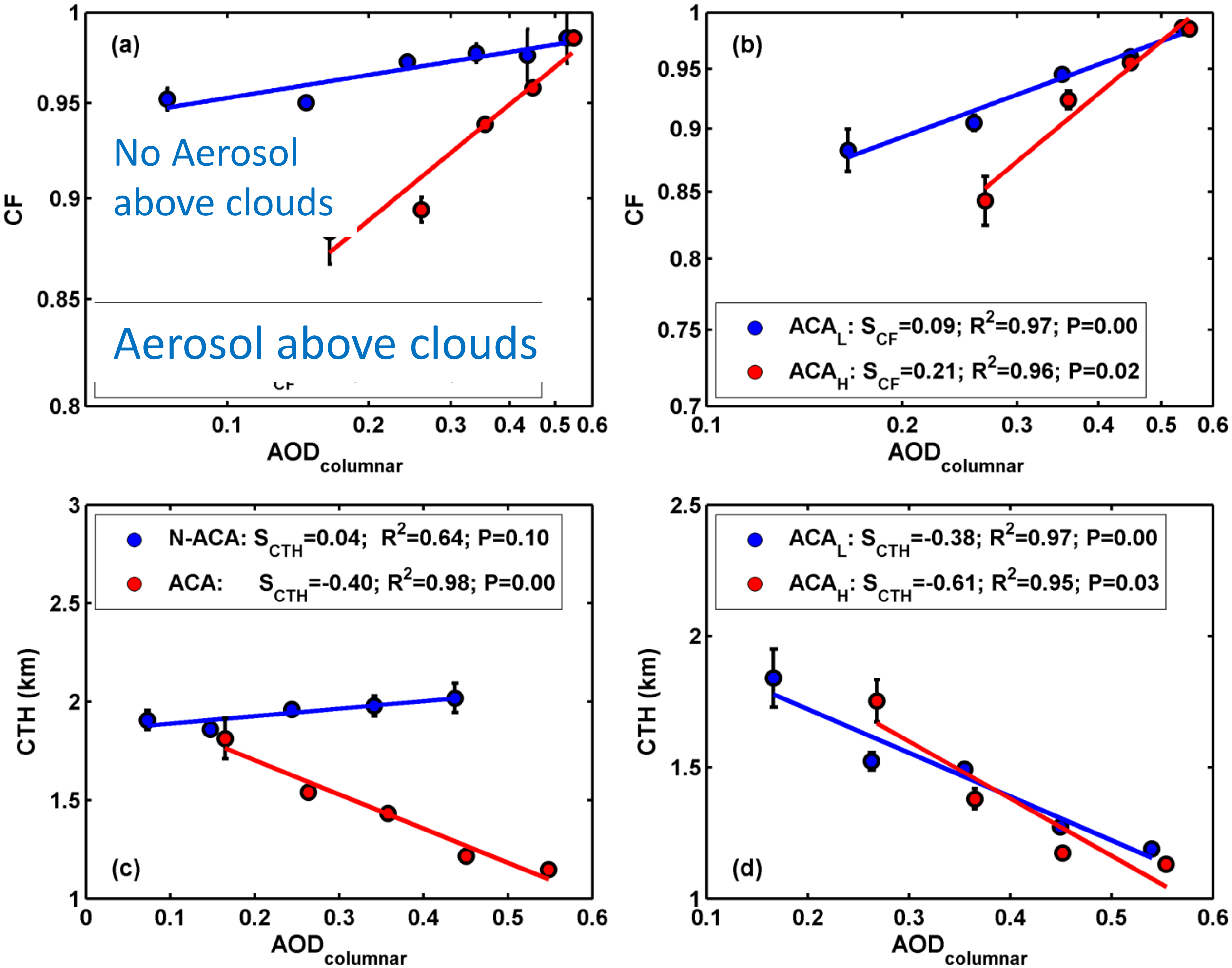


Mechanisms of
Aerosol & Marine PBL Clouds Interactions



Liu and Li (2017, in preparation)

Change of Cloud Fraction with Aerosol Loading



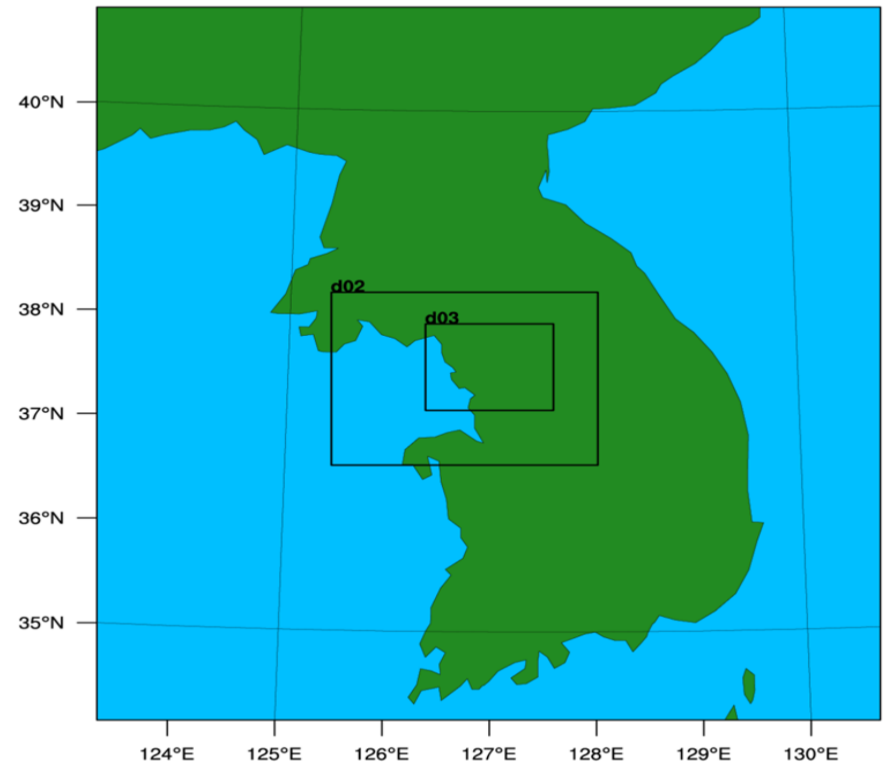
CF (a and b) and CTH (c and d) as a function of $AOD_{columnar}$ for (a and c) ACA and N-ACA cases (red and blue dots and lines, respectively) and (b and d) with ACA_L and ACA_H (blue and red dots and lines, respectively).

- Significant increase in CF for both cases;
- Stronger increase in CF for ACA (ACA_H) than N-ACA (ACA_L) cases;
- For N-ACA cases, CTH increases slightly, while for ACA cases, CTH significantly decreases;
- Stronger increase in CF for ACA_H than ACA_L cases;

Liu and Li (2017, in preparation)

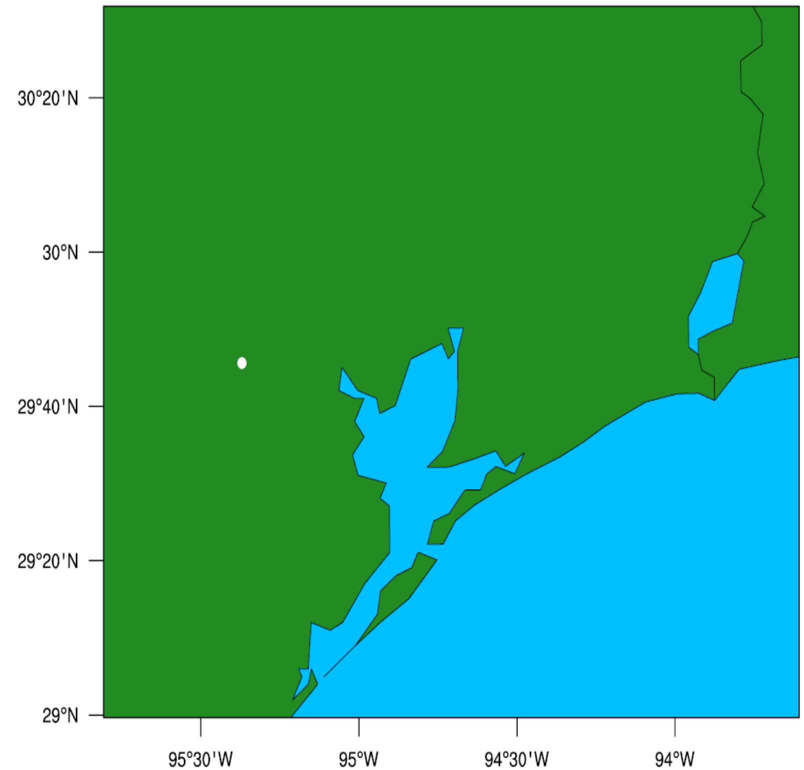
WRF simulations to test the effects of model resolution and ACI

Seoul case (D03)



- A mesoscale system of convective clouds, 37.57° N, 126.57° E
- 09:00 LST (local solar time) July 26th – 09:00 LST July 27th 2011

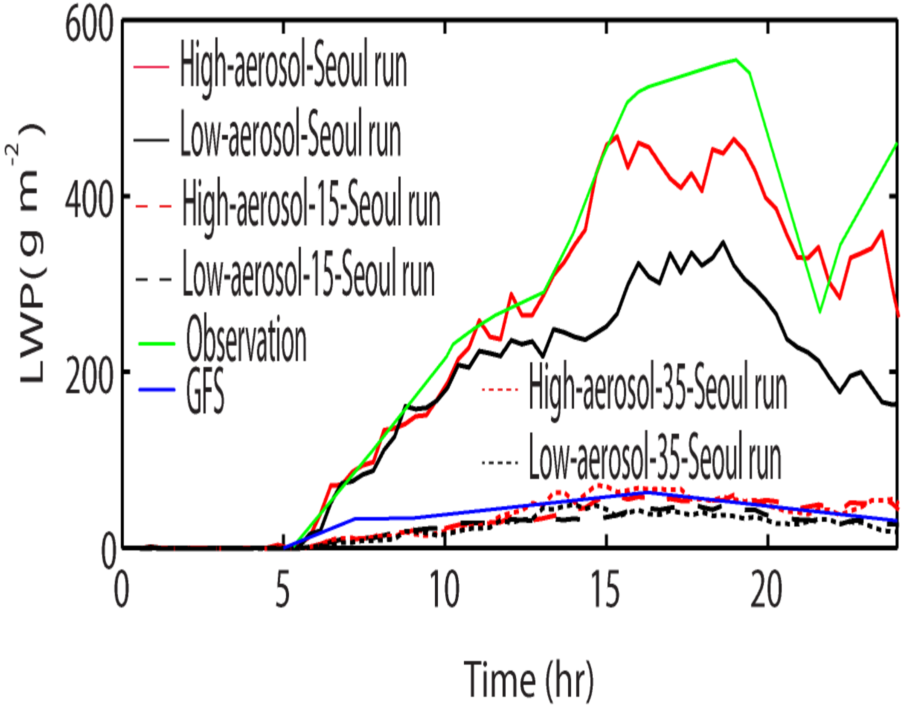
the Houston case



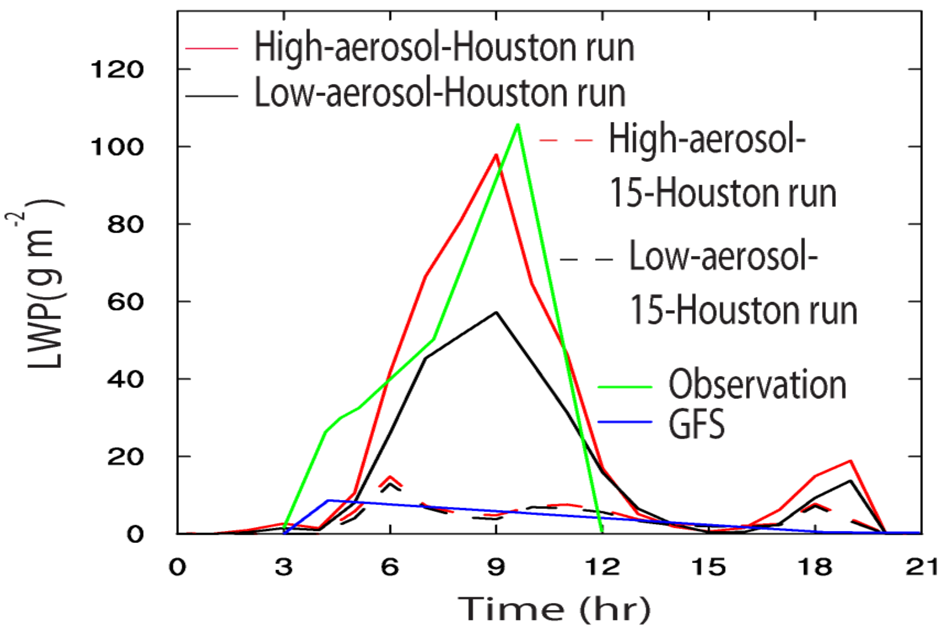
- A mesoscale system of convective clouds 29.42° N, 94.45° W
- 07:00 LST June 18th – 03:00 LST June 19th in 2013

Liquid-water path

Seoul case



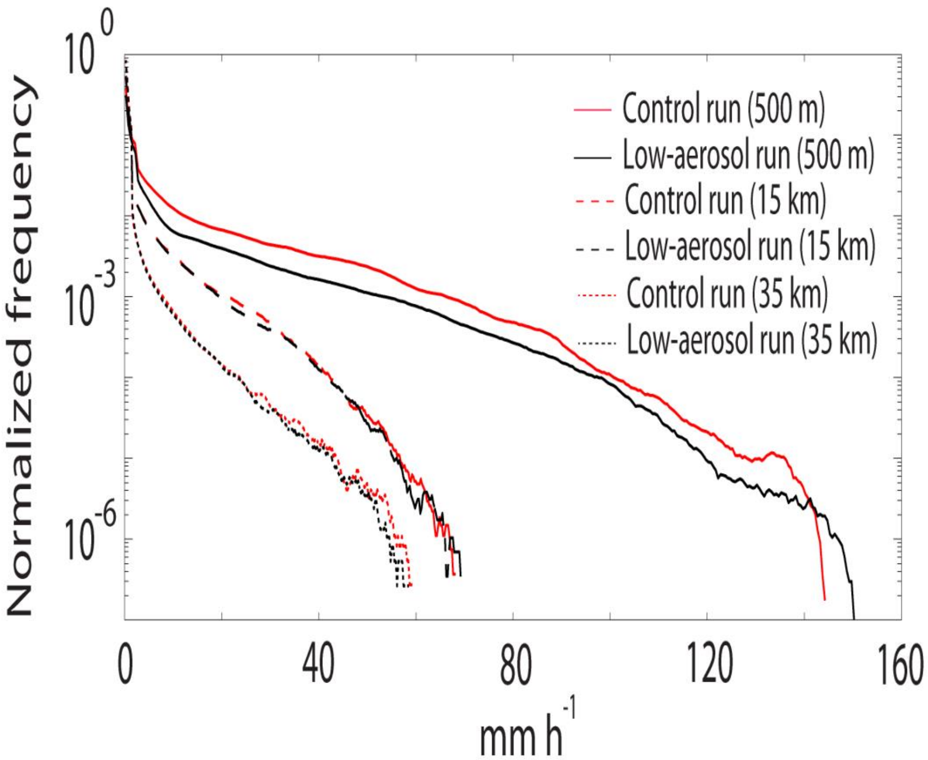
Houston case



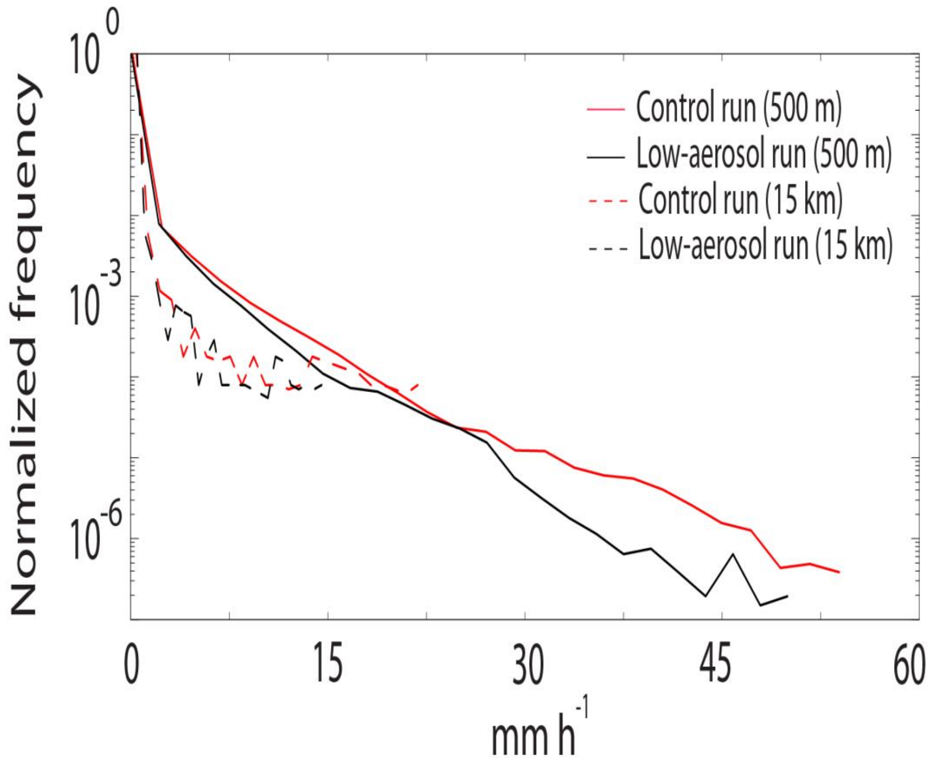
Lee et al. (2017, ACPD)

Precipitation frequency

Seoul case



Houston case



Lee et al. (2017, ACPD)

Improve Cloud & Aerosol Parameterizations in the NGGPS by Identifying Model Deficiencies and Finding Solutions using Observations and Model Simulations

1. Effects of model resolutions and microphysics parameterizations on the simulations of clouds, precipitation, and their interactions with aerosols in the GFS.

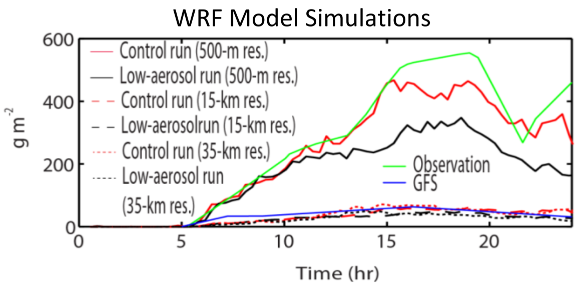


Figure 1. Sensitivity tests of modeled cloud water content to varying resolution and aerosol loading.

Findings

a) The GFS severely underestimates LWP due largely to the coarse resolution.

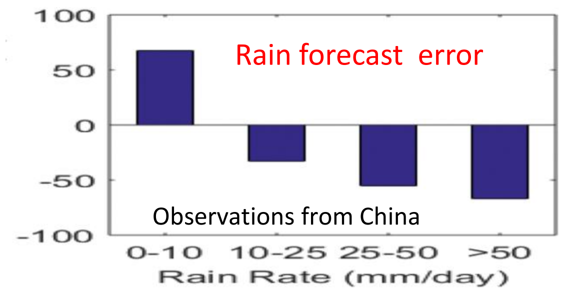
b) The coarse resolution causes an underestimation of aerosol effects on clouds.

c) Despite sub-grid parameterizations, the coarse resolution is still a major problem in accounting for aerosol-cloud interactions.

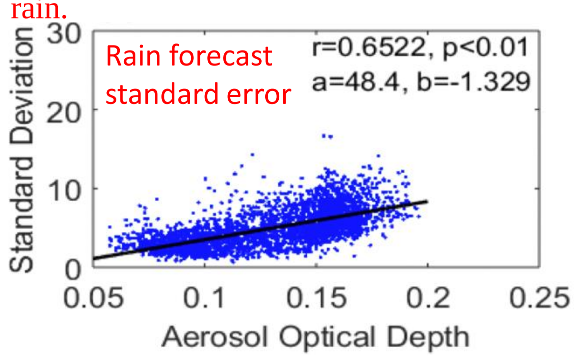
Publications

Lee, S.-S. et al., 2017: Effects of resolutions and microphysics parameterizations on the simulations of clouds, precipitation, and their interactions with aerosol, ACP (under review).

2. GFS systematically overestimates rainfall for light rain but under-predicts it for heavier rain.



Finding: At least a part of the error may be accounted for by a lack of aerosol effects that suppress light rain and enhance heavy rain.

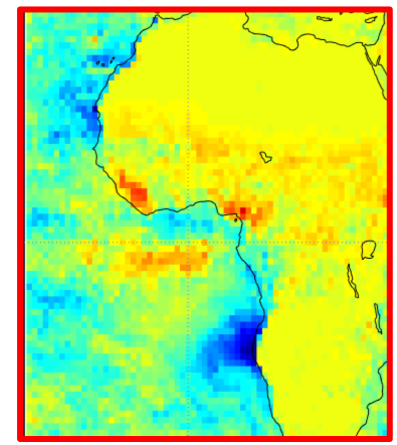


Publications:

Jiang, M., Z. Li, et al., 2016: Impact of aerosols on precipitation from deep convective clouds, *J. Geophys. Res. – Atmos.*, 121, doi:10.1002/2015JD024246.

Jiang, M., Z. Li, et al., 2017, Potential influences of neglecting aerosol effects on the NCEP GFS precipitation forecast, ACP under revision.

3. Evaluation of the GFS model in cloud properties and meteorological variables using observations from mu



Finding: The underestimation of low clouds has been improved in general but still persists over regions of strong absorbing aerosol.

Publications:

Liu, J., Z. Li, and M. Cribb, 2016: Response of marine boundary layer cloud properties to aerosol perturbations associated with meteorological conditions from the 19-month AMF-Azores campaign, *J. Atmos. Sci.*, 73, doi:10.1175/JAS-D-15-0364.

Liu, J., and Z. Li, 2017, Aerosol Indirect Effect on Marine Boundary Layer Clouds in Cases with and without an Above-Cloud Aerosol Layer, in preparation.

Future studies needed

- Continue to examine GFS performance in simulating clouds, and other meteorological variables under the different aerosol conditions using satellite and ground measurements
- Close-up investigation on aerosol effects on rainfall (physical analysis), with particular attention towards interactions between dynamic and thermal variables susceptible to aerosol.
- Better understanding how small-scale updrafts control the sensitivity, frequency distributions of updrafts.
- Understanding the development of turbulence and cumulus schemes on cloud simulations in the GFS/NGGPS

Thank you !