Evaluation of the impacts of biomass burning aerosols on the NASA GEOS Sub-Seasonal Climate Forecasts

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Introduction

Introduction – During the Austral winter, vegetation fires severely affect the tropical forest and savannah-type biomes in the South American (SA) and African (Af) continents. Biomass burning (BB) aerosols interact with solar radiation and affect the cloud microphysics properties. Therefore, changing the radiation budget, hydrological cycle and global circulation patterns over disturbed areas. This study aimed to evaluate the impact of the lack of more realistic BB emissions on the performance of the sub-seasonal climate forecasting of the Goddard Observing System global circulation model (GEOS-S2S, Rienecker et al., 2008) over the South American (SA) and African (Af) continents.

Model experiments configuration

Model experiments configuration – Model experiments included emissions for dust, sea salt, anthropogenic, and BB aerosols (Darmenov & da Silva, 2015) (Fig. 1), and accounted explicitly for aerosol interactions with clouds (2-moment cloud scheme, Barahona et al., 2014), and radiation (RRTMG rad. scheme, Morcrette et al., 2008).

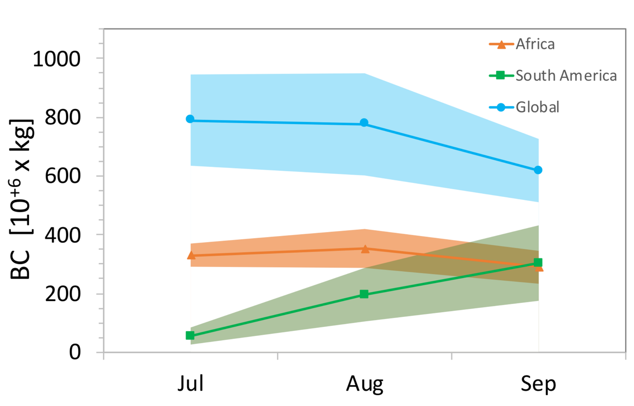

Table 1: On the right, model experiments configuration.

Figure 1: On the left, monthly mean black-carbon QFED emissions from 2000 to 2015. The shaded areas depict the standard deviation of the mean.

Model		GEOS-S2S
Resolution		56 km
Members		4 (15, 20, 25, 30)
Simulation period		Jun-Nov; 2000-2015
Analysis period		Jul-Sep; 2000-2015
Exp.	AERO_CTL	Daily QFED emissions
	AERO_CLM	Monthly mean QFED emissions

Climate forecast skill for aerosol optical depth (AOD)

Climate forecast skill for aerosol optical depth (AOD) – The GEOS-S2S AOD seasonal (JAS) distribution is in good agreement with MERRA-2 (Fig. 2).

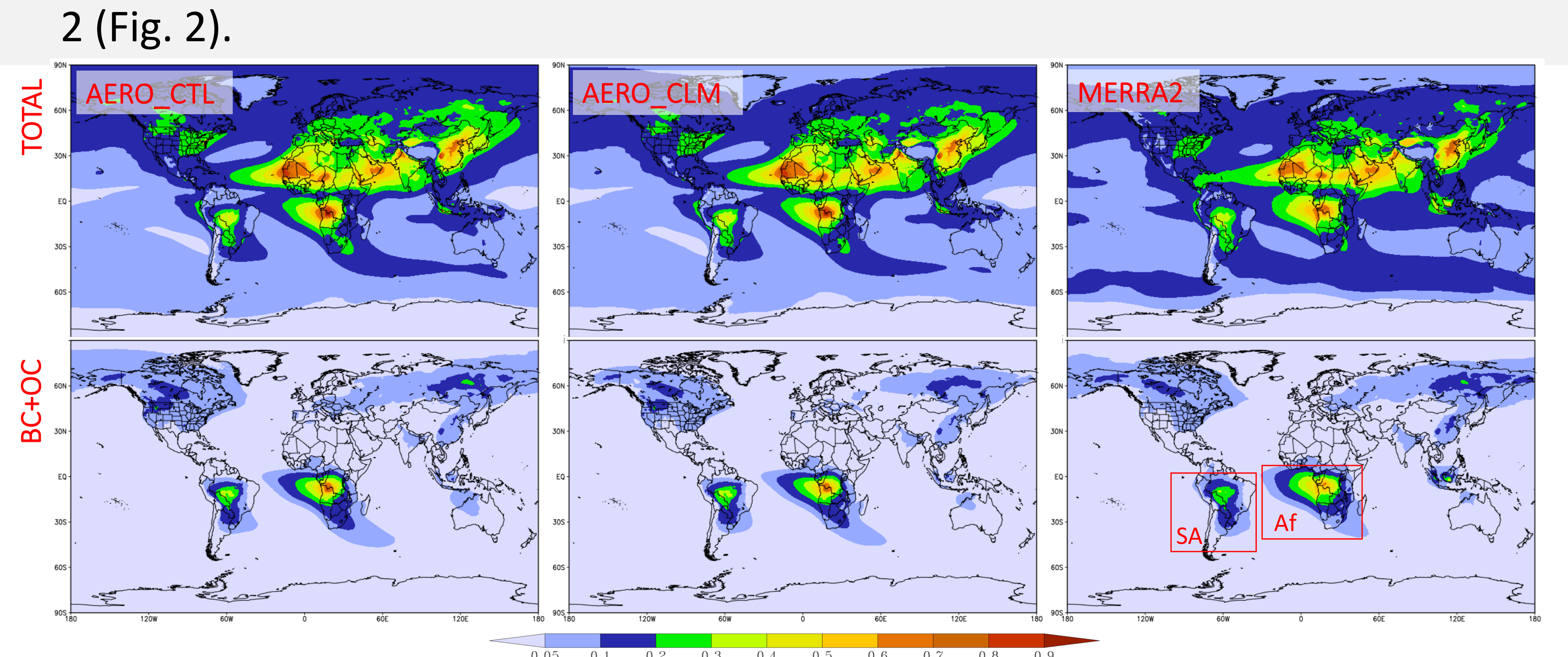

Figure 2: The mean global distribution of total (on top) and the sum of black-carbon and organic carbon (BC+OC) (on the bottom) AOD at 550nm for JAS (2000 to 2015) from the AERO_CTL and AERO_CLM GEOS-S2S experiments and MERRA2.The red boxes on the last map depict the areas used to calculate the statistical metrics.

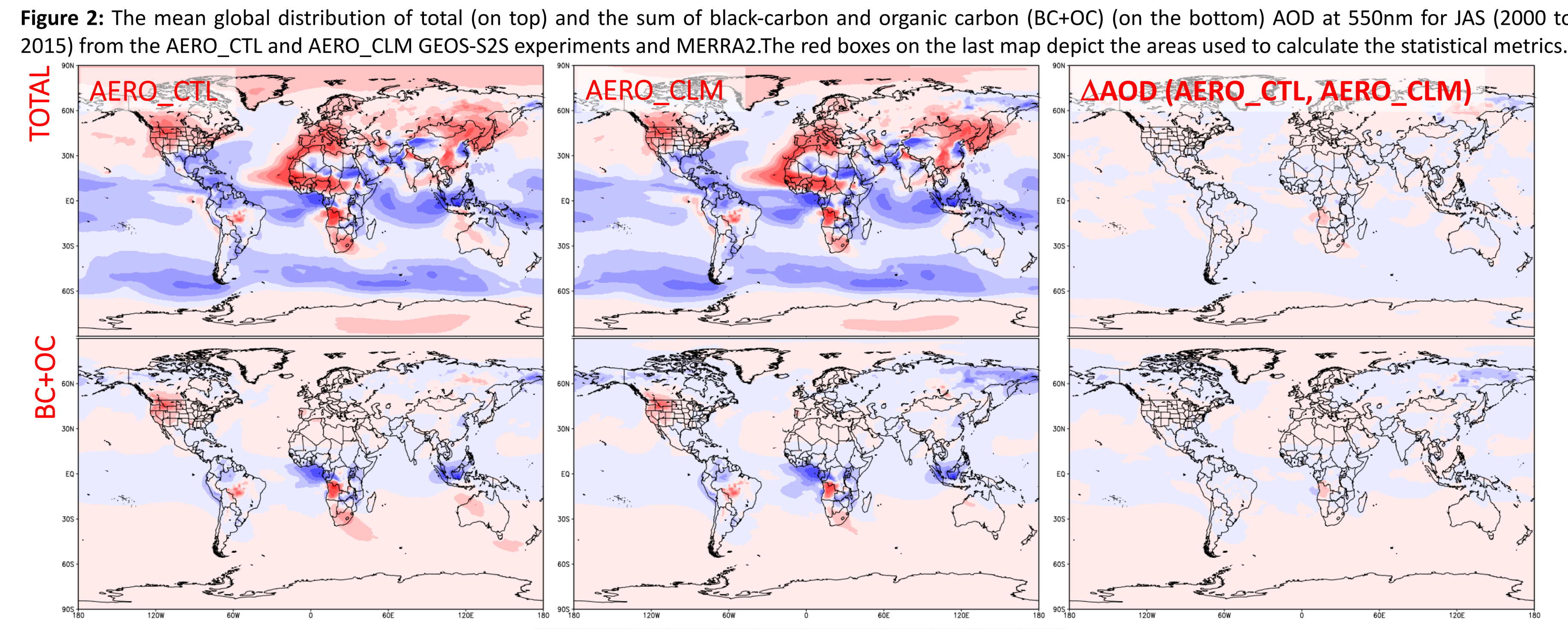

Figure 3: *Total (on top) and BC+OC (on the bottom) AOD mean biases from AERO_CTL (on the left) and AERO_CLM (in the middle) experiments relative to MERRA2 for JAS from 2000 to 2015, and the difference of AOD between the two experiments (on the left).*

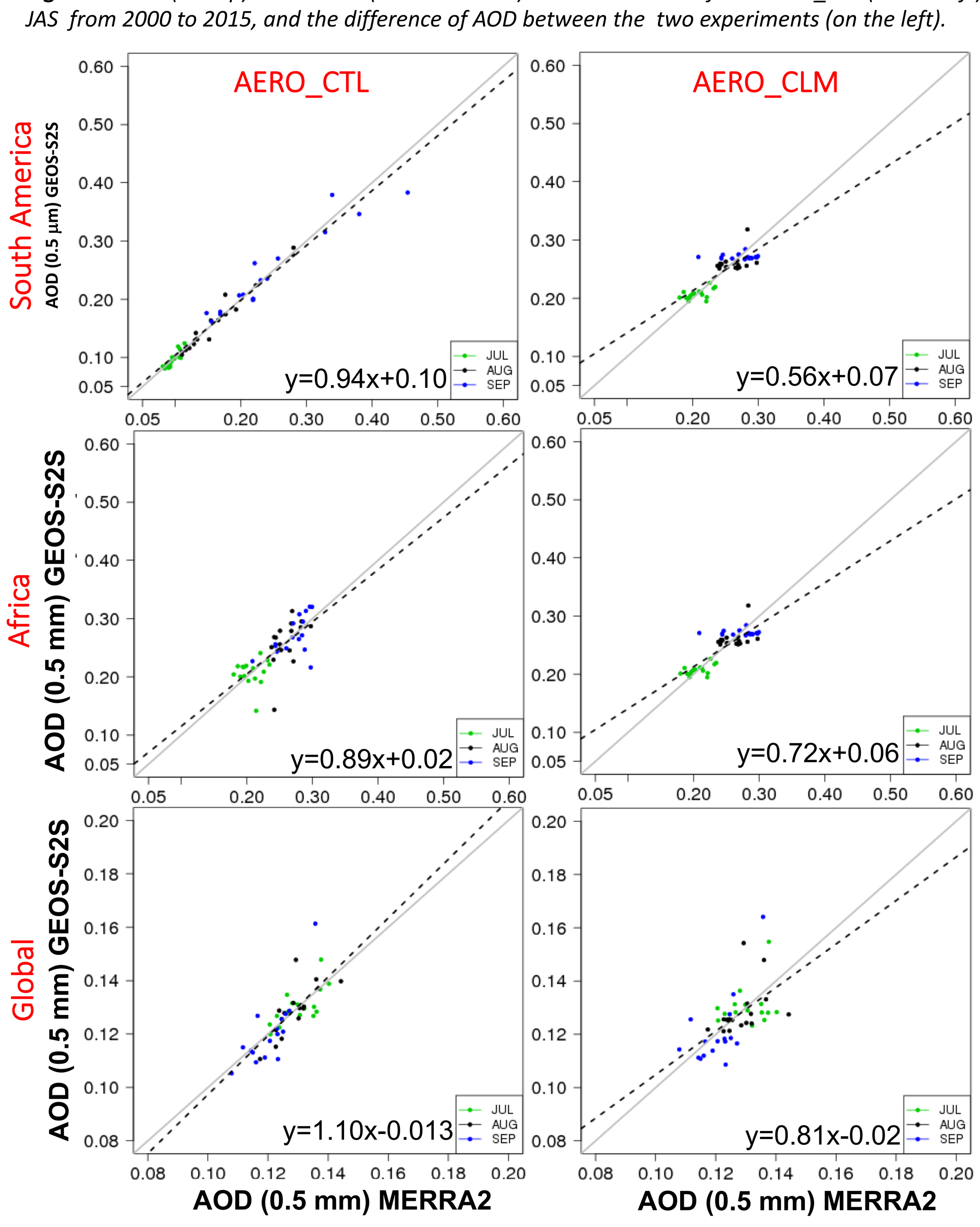

Table 2: Statistical metrics for the MERRA2 and GEOS-S2S experiments comparison.

		AERO_CTL	AERO_CLM
South America	R^2	0.97	0.70
	RMS	0.07	0.22
	Bias	0.001	0.002
Africa	R^2	0.47	0.70
	RMS	0.12	0.07
	Bias	-0.005	0.002
Global	R^2	0.65	0.35
	RMS	0.006	0.06
	Bias	-0.001	-0.001

Figure 4: On the left, monthly mean total AOD averaged for the period 2000-2015 from MERRA2 versus GEOS-S2S AERO_CTL (on the left) and AERO_CLM (on the right) experiments for SA (top), Af (middle), and global (bottom) domains. Statistics are computed in natural log-transformed AOD space.

The seasonal (JAS) AOD climatology smooths the impact of the aerosol BB emissions used. However, the AOD monthly mean values reveal the its effects, particularly for the SA region. (Fig. 4 and Tab. 2).

The GEOS-S2S skills in predicting AOD were higher for the AERO_CTL experiment compared to AERO_CLM, except over land for the Af region. Although, it is worth noting that AERO_CTL had better skills over the ocean for the same region (Fig. 5).

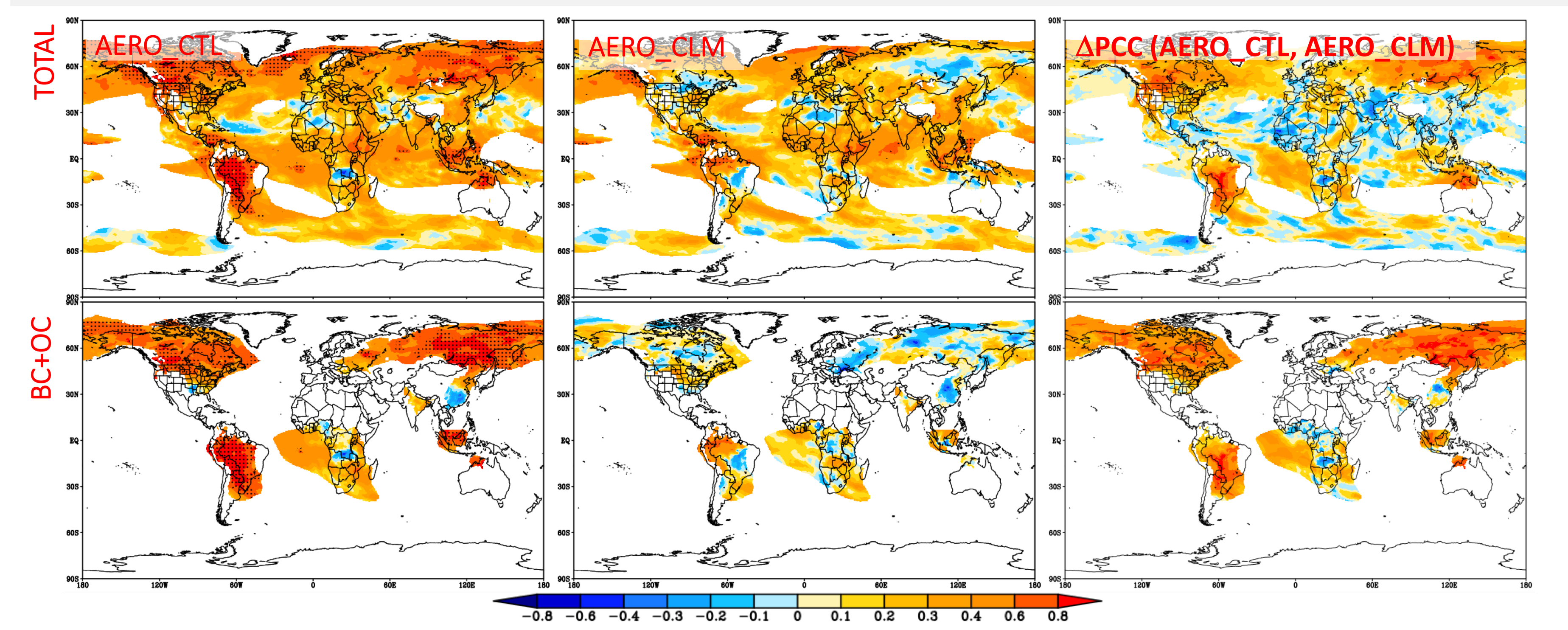

Figure 5: *Pearson correlation for the total (on top) and (BC+OC) (on bottom) AOD from the AERO_CTL (on the left) and AERO_CLM (in the middle) experiments relative to MERRA2 for JAS from 2000 to 2015, and the difference between them (on the right). The Pearson correlation coefficients (PCC) were masked for MERRA2 AOD values above 0.1 and 0.05 for the total and (BC+OC) AOD, respectively. Stippling represents 95% confidence limit.*

Climate forecast skill for 2-meter temperature (T2M)

Climate forecast skill for 2-meter temperature (T2M) – The GEOS-S2S T2M from both experiments fairly represented the global pattern of the MERRA2 reanalysis (Fig. 6). The BB emissions perturbation caused small, both positive and negative, scattered changes on the T2M biases. However, there was a notable reduction of the T2M bias on the South Pole. The GEOS-S2S skills for T2M over land were especially high over SA and Af areas, where the correlation index values were typically above 0.6 (Fig. 7). There were small, both positive and negative, scattered changes on the skills for T2M. More expressive, we observed the deterioration of the T2M results for the AERO_CTL experiment over the Eastern US, Eastern Europe, and West Asia. On the other side, there was an enhancement of model skills for the AERO_CTL experiment over the South Pole.

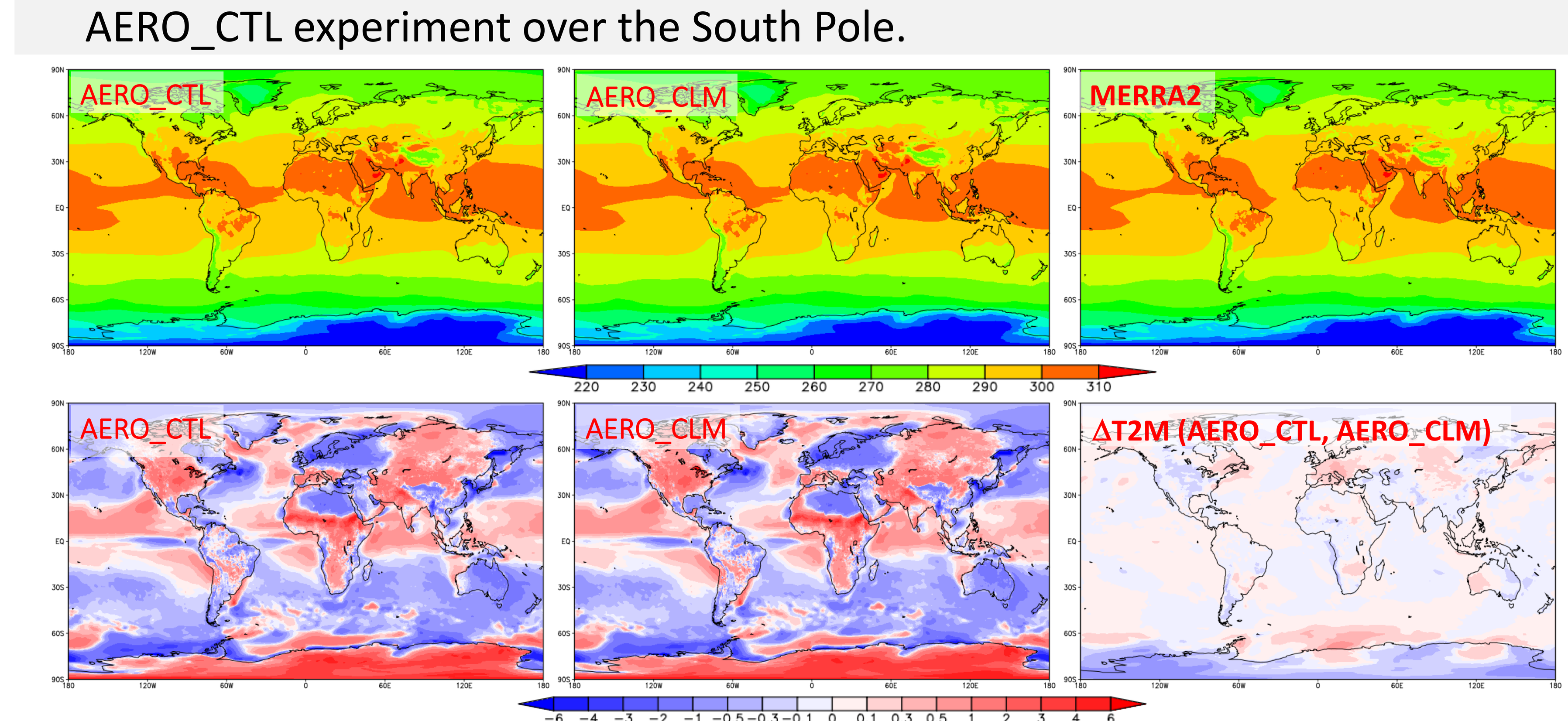

Figure 6: *On the top, T2M from the AERO_CTL (on the left), AERO_CLM (in the middle) experiments and MERRA2 (on the right). On the bottom, the T2M biases for AERO_CTL (on the left) and AERO_CLM (in the middle) experiments relative to MERRA2 for JAS from 2000 to 2015, and the difference of T2M between the two experiments (on the right).*

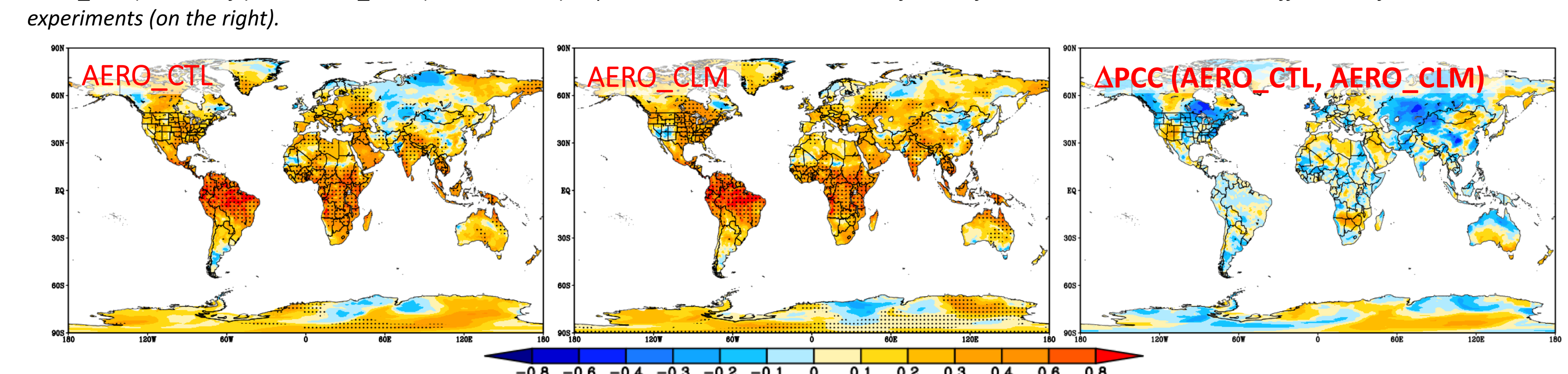

Figure 7: *Pearson correlation for T2M over land from the AERO_CTL (on the left) and AERO_CLM (in the middle) relative to MERRA2 for JAS from 2000 to 2015, and the difference between them (on the right). Stippling represents 95% confidence limit.*

Highlights

- A proper representation of the BB emissions, instead of the climatology, improved the GEOS-S2S AOD climate forecast, particularly for SA.
- For Af, the GEOS-S2S's ability to predict the AOD decreased over land as it increased over the ocean with the use of QFED daily emissions. These results suggest that climatology may reasonably represent the Af emissions, but the representation of aerosols in the region is highly sensitive to other processes that are more dependent on meteorology, such as aerosol removal.
- There was a significative impact of the BB emissions on the GEOS-S2S prediction of T2M (and other meteorological variables, not shown) in the North Hemisphere and the South Pole, which need to be further investigated.

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