Climate Impacts of African Biomass Burning Aerosols

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Motivation

In Africa, around 90% of fires are human-caused. Aerosols from biomass burning directly impact our climate by reflecting and absorbing sunlight.

Figure 1: Smoke aerosols from agricultural burning.

CloudSat 2B-FLXHR-Lidar

CloudSat radiative fluxes and heating rates product (FLXHR-Lidar) provides new observational-based estimates of the aerosol direct radiative effect:

$$DRE = \left(F^{\downarrow} - F^{\uparrow}\right)_{aero} - \left(F^{\downarrow} - F^{\uparrow}\right)_{noaero} \quad (1)$$

FLXHR-Lidar estimates vertically-resolved SW/LW fluxes consistent with cloud and aerosol retrievals from CloudSat, CALIPSO, and MODIS.

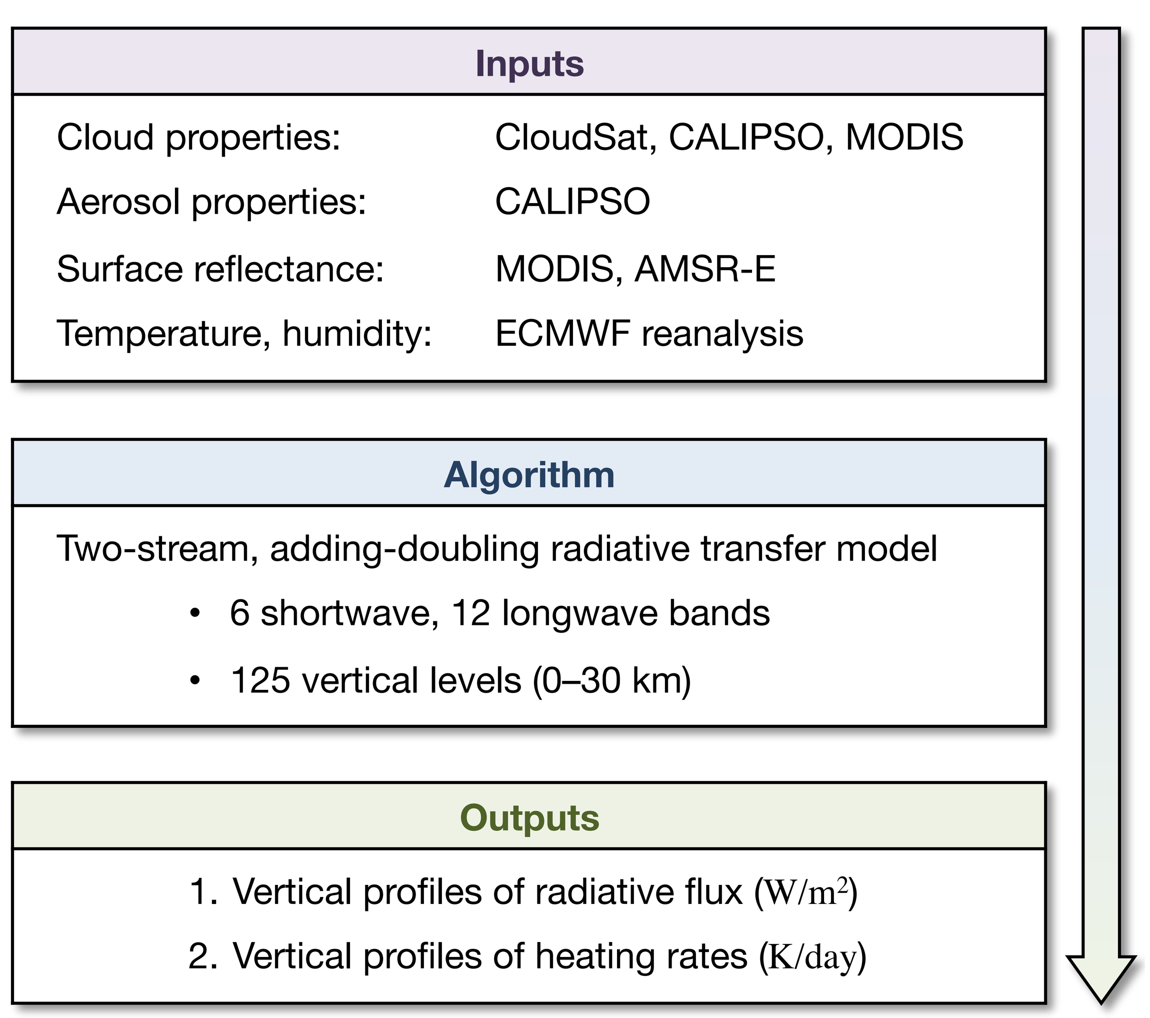

Figure 2: Flowchart of the FLXHR-Lidar algorithm.

Using retrieved SW fluxes, we quantify the aerosol DRE over the SE Atlantic. The optical properties of aerosols are obtained from the SPRINTARS model and matched to CALIPSO-detected aerosol layers.

Observed

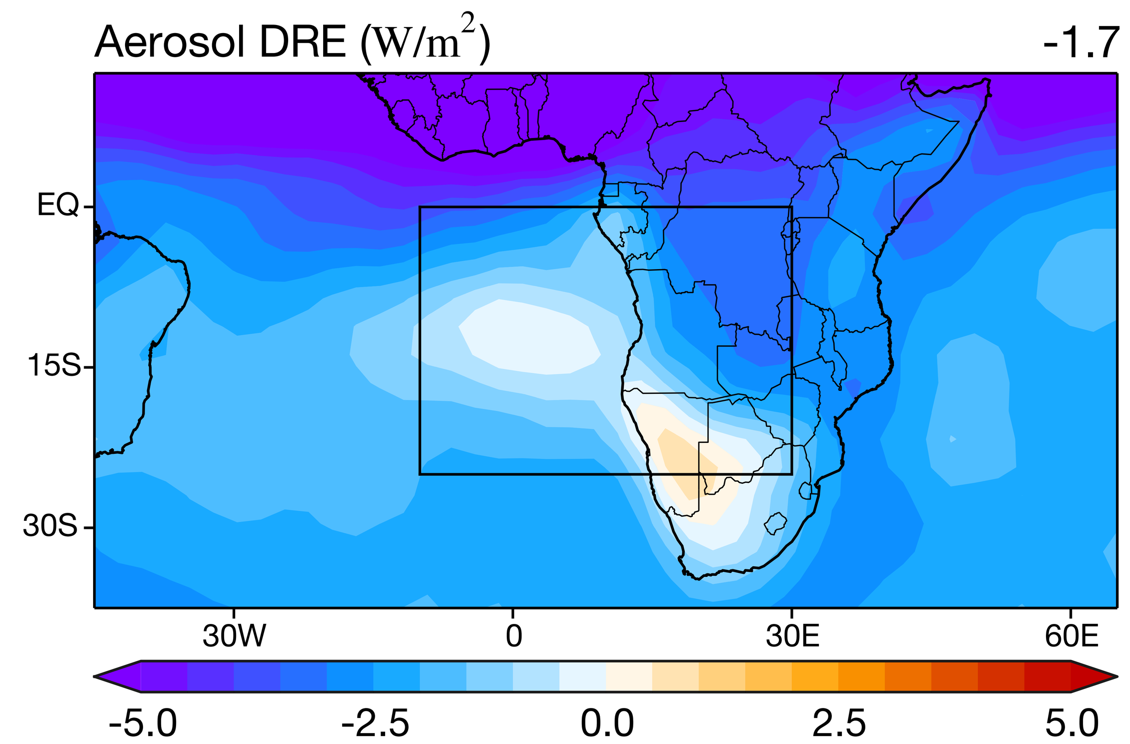

Figure 3: Annual mean all-sky DRE from FLXHR-Lidar, averaged over 2006-2011.

Table 1: Observed TOA DRE (W/m^2)

	Clear-sky	Cloudy-sky	All-sky
Land	-3.2	-1.1	-2.0
Ocean	-2.9	-0.3	-1.4
Total	-3.1	-0.6	-1.7

Modeled

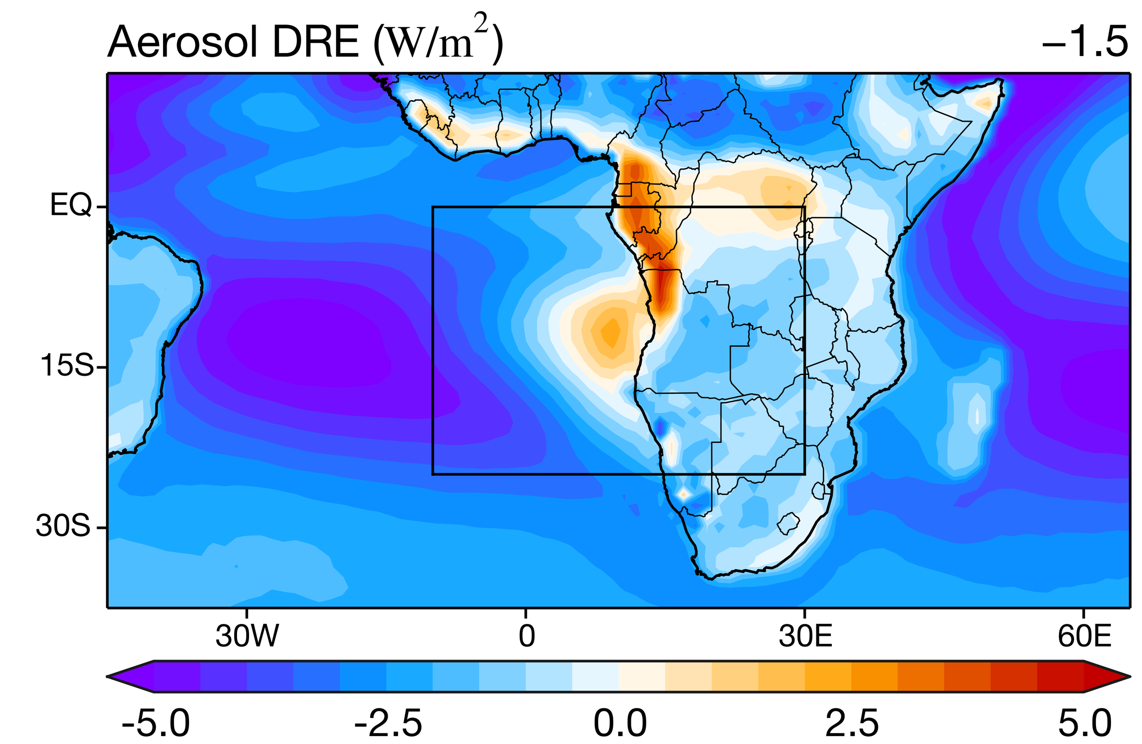

Figure 4: Annual mean all-sky DRE from CESM-CAM5, averaged over 2000-2005.

Table 2: Modeled TOA DRE (W/m^2)

	Clear-sky	Cloudy-sky	All-sky
Land	-3.5	+1.2	-0.7
Ocean	-5.8	+0.5	-2.2
Total	-4.9	+0.9	-1.5

Seasonal Cycle

Under certain conditions, aerosols exert a positive DRE over ocean. There are two main ingredients:

- Absorbing aerosols (e.g. smoke)
- Underlying clouds

The SE Atlantic is a natural laboratory for observing this unique phenomenon. During biomass burning season (shaded), smoke lofted over marine clouds often produces a positive radiative effect.

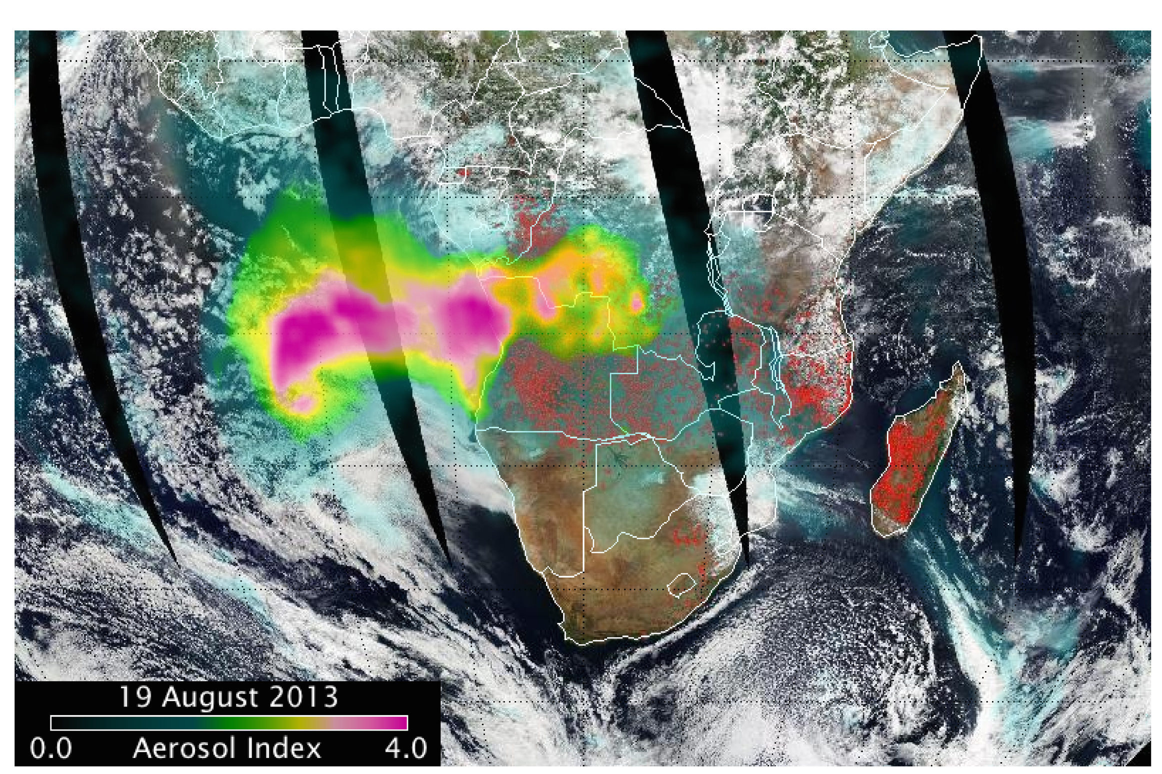

Figure 5: Example of African biomass burning as seen by the OMPS Aerosol Index (courtesy NASA/GSFC).

Both model and obs show good agreement in the annual mean DRE, despite a shift in the timing.

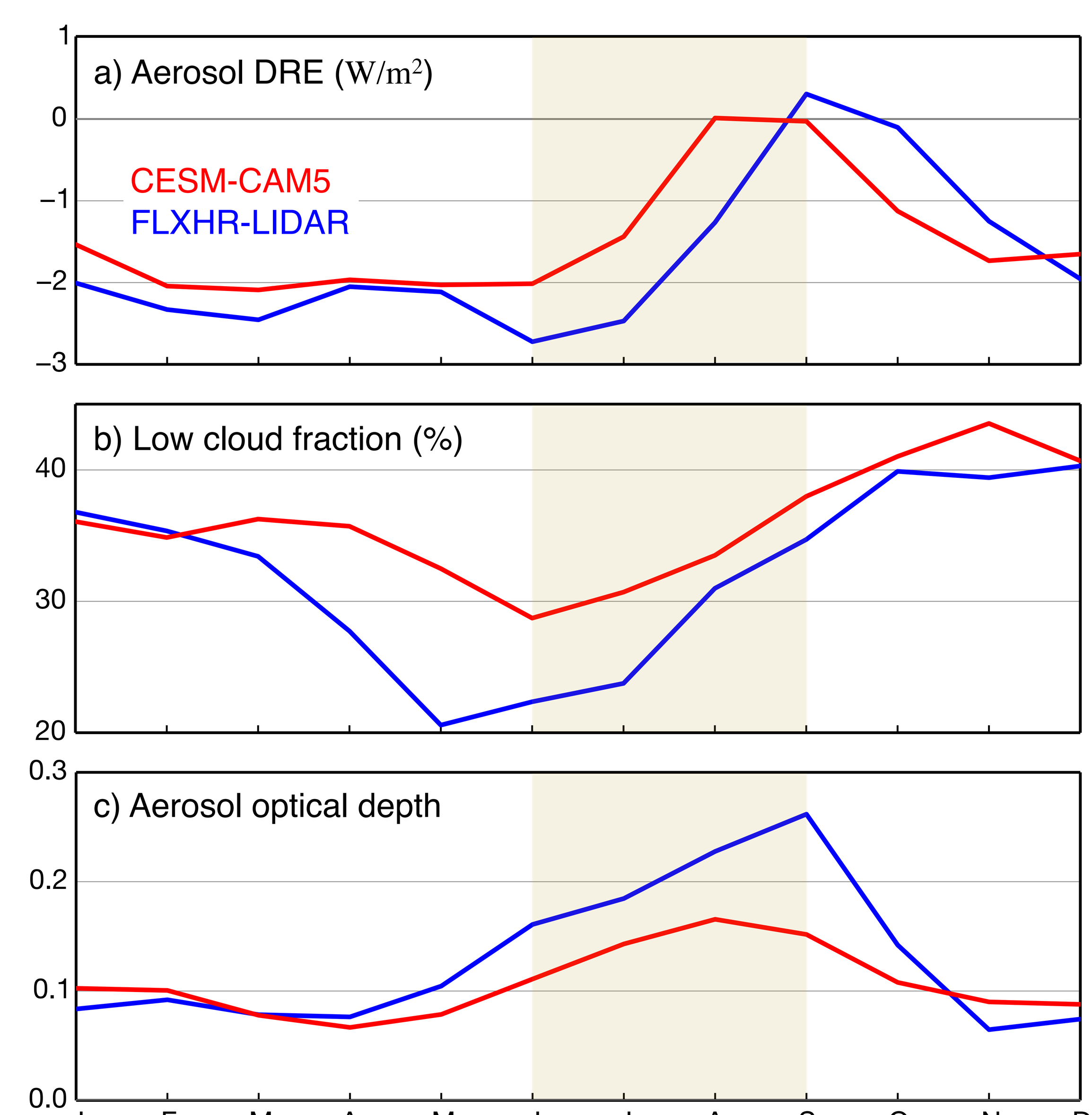

Figure 6: Monthly mean estimates of (a) aerosol DRE, (b) low cloud fraction, and (c) AOD over the SE Atlantic.

Global Implications

Over global ocean, positive aerosol DRE coincides with increasing cloudiness. However, CESM-CAM5 predicts around 10% fewer clouds than observed, suggesting that model biases in DRE over ocean are driven primarily by errors in cloud cover as opposed to errors in aerosol optical properties.

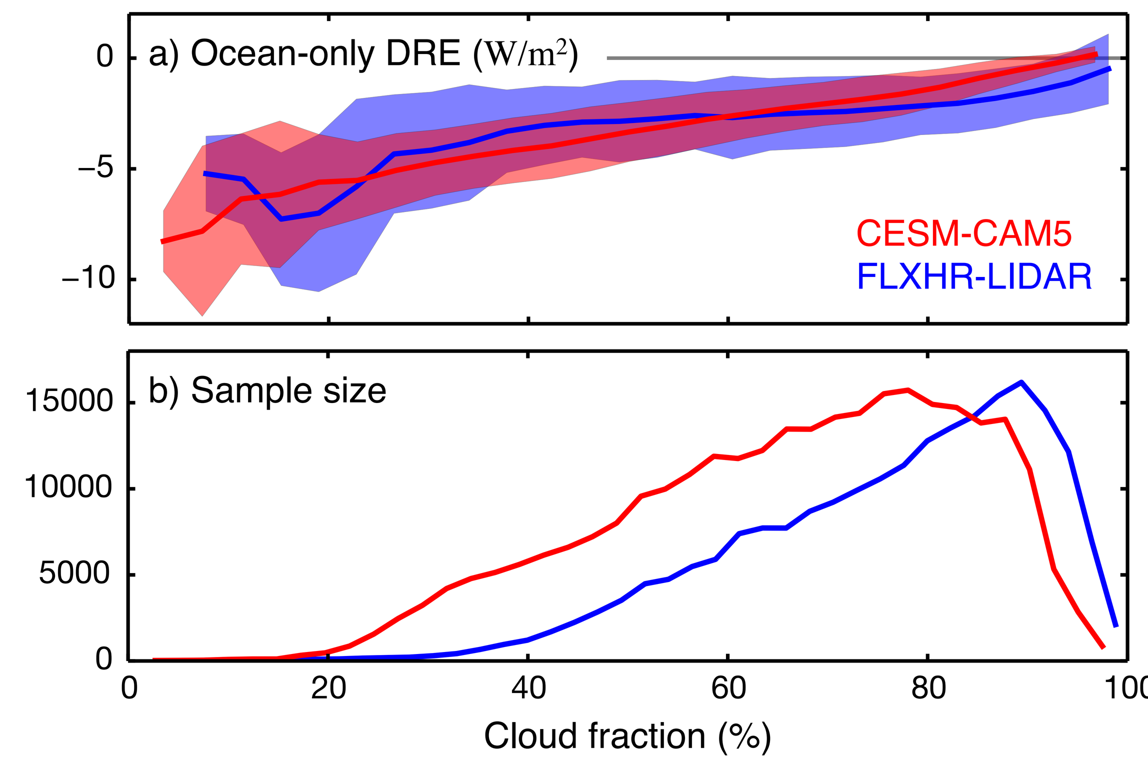

Figure 7: PDFs of (a) all-sky DRE and (b) sample count over global ocean, as a function of cloud fraction.

A better understanding of aerosol impacts requires a more realistic representation of global cloud cover in addition to an improved representation of aerosol sources and optical properties.

The Big Picture

Satellite observations provide constraints necessary for improving climate models. This study has three main takeaways:

1. There is good overall agreement in all-sky DRE.
2. Large differences over the SE Atlantic are likely due to biases in cloud cover.
3. Known model biases in marine clouds impact the timing and magnitude of aerosol radiative effects.

References

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