Extratropical Influence on the Extent of Biomass Burning Aerosol-Cloud Interactions in the Southeast Atlantic

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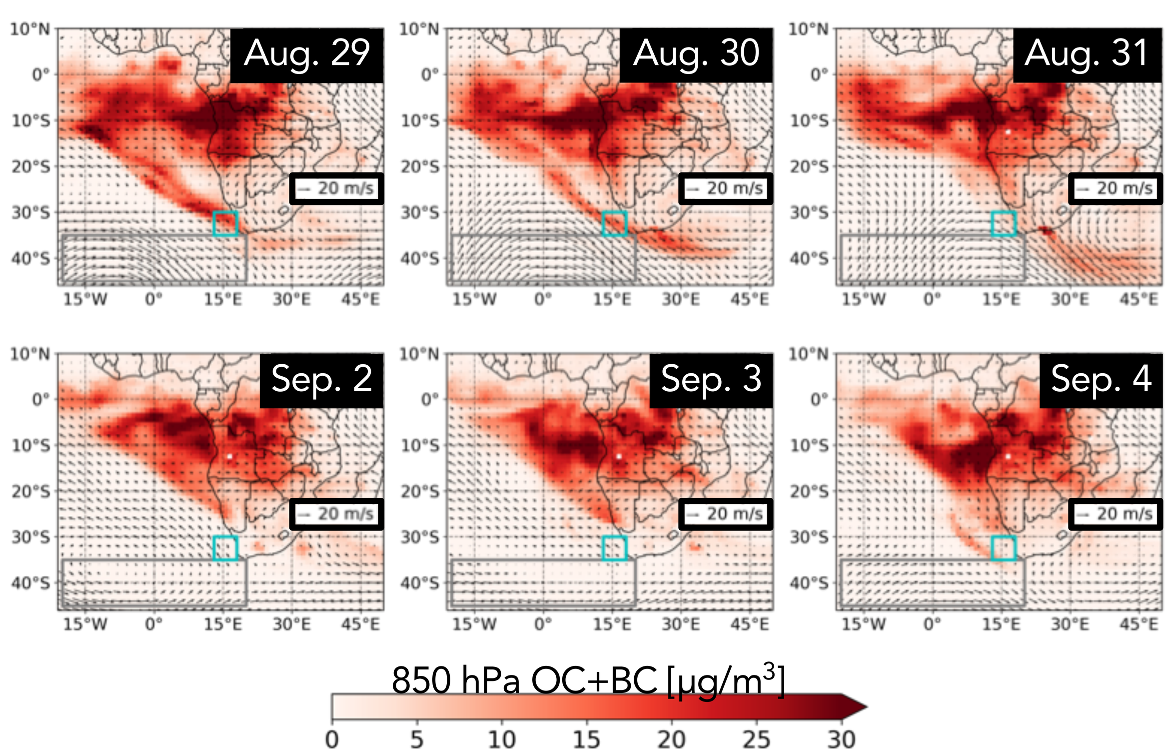
Motivation: Aerosol-cloud interactions (ACI) represent one of the largest sources of uncertainty in estimates of changes in Earth's radiative balance. The southeast Atlantic Ocean (SEA) region is an ideal natural laboratory to study ACI because widespread fires in south-central Africa during the biomass burning season (~July-October) produce large quantities of smoke, much of which is blown offshore where it overlies and mixes into a large expanse of stratocumulus clouds. Mixing smoke aerosol into the marine boundary layer (MBL) can increase the availability cloud condensation nuclei (CCN), which can lead to increases in cloud droplet number concentration (N_d) and subsequent changes in cloud microphysical and macrophysical properties and cloud radiative forcing.

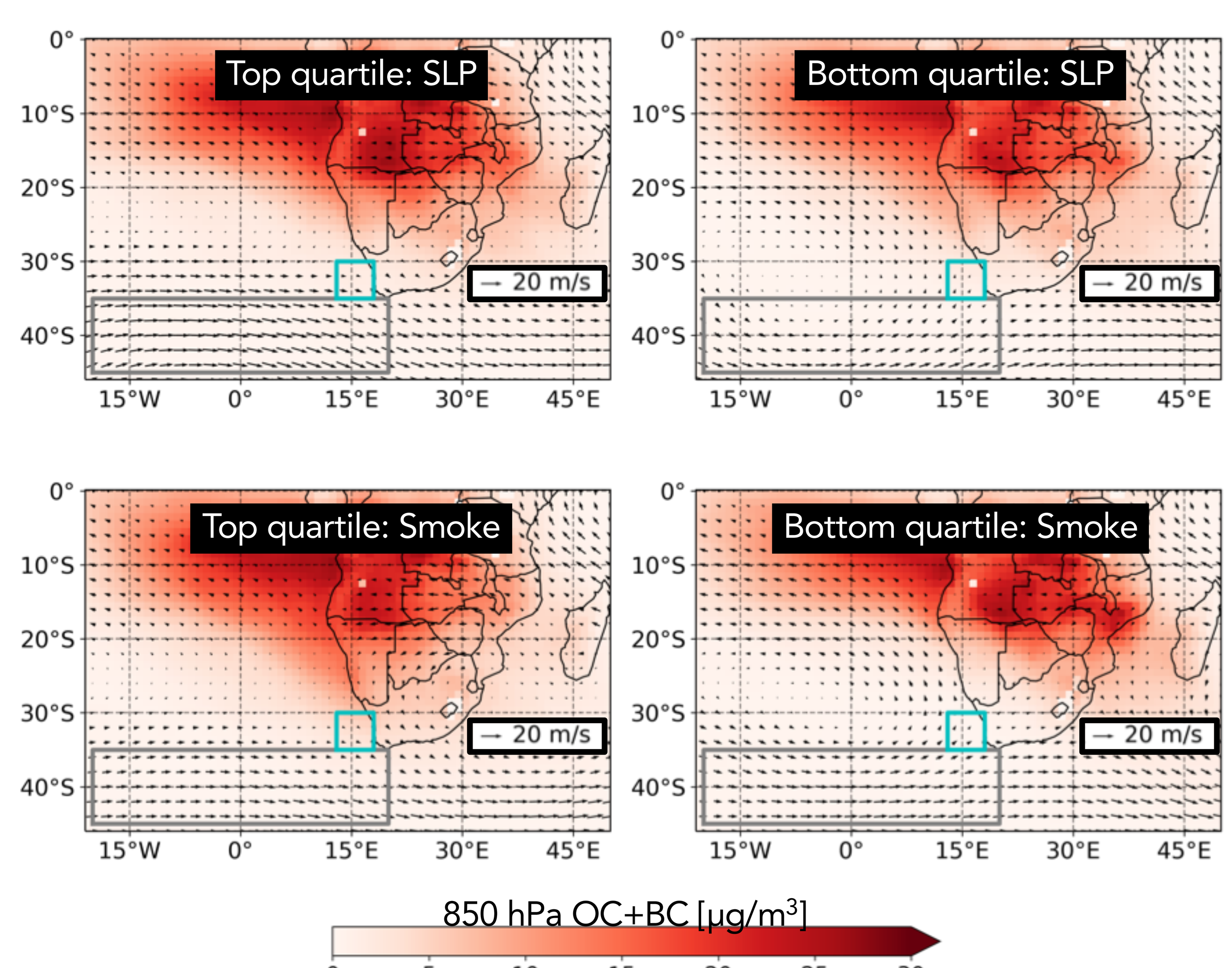
The SEA region has recently experienced an intensive period of observation by land and air, including the NASA ObseRvations of Aerosols above CLouds and their intEractionS (ORACLES) aircraft campaign based out of Namibia in September 2016 and São Tomé and Príncipe in August 2017 and October 2018. Early results from the ORACLES-2016 deployment [*Diamond et al., 2018*] have demonstrated that the observational challenge in assessing ACI may be greater than previously recognized because the accumulation of above-cloud aerosol entrained over the course of days often matters more than instantaneous smoke-cloud contact in determining MBL properties. A corollary of this finding is that the impact of smoke above the MBL in the southernmost reaches of the SEA will be manifested upstream days later due to the prevailing southerly MBL flow.



The passage of midlatitude cyclones was observed to influence the location of the smoke plumes and cloud decks during the ORACLES-2016 deployment. **Figure 1** shows the days leading up to the first two routine flights of that deployment. The first flight, August 31st, had much higher values of MBL aerosol and N_d than the second, September 4th, despite the two flights having similar above-cloud smoke conditions. The days before August 31st experienced anomalously high values of above-cloud (~850 hPa) smoke in the southern portion of the SEA region, possibly in connection with a midlatitude cyclone (see 850 hPa winds), that led to longer cumulative smoke-cloud contact by the time of our observation. In contrast, there were low above-cloud smoke concentrations leading up to our observations on September 4th, meaning the smoke and clouds we observed had only recently come into contact. This study is motivated by the question of whether the apparent midlatitude influence seen in this case can be observed systematically in the SEA region in September.

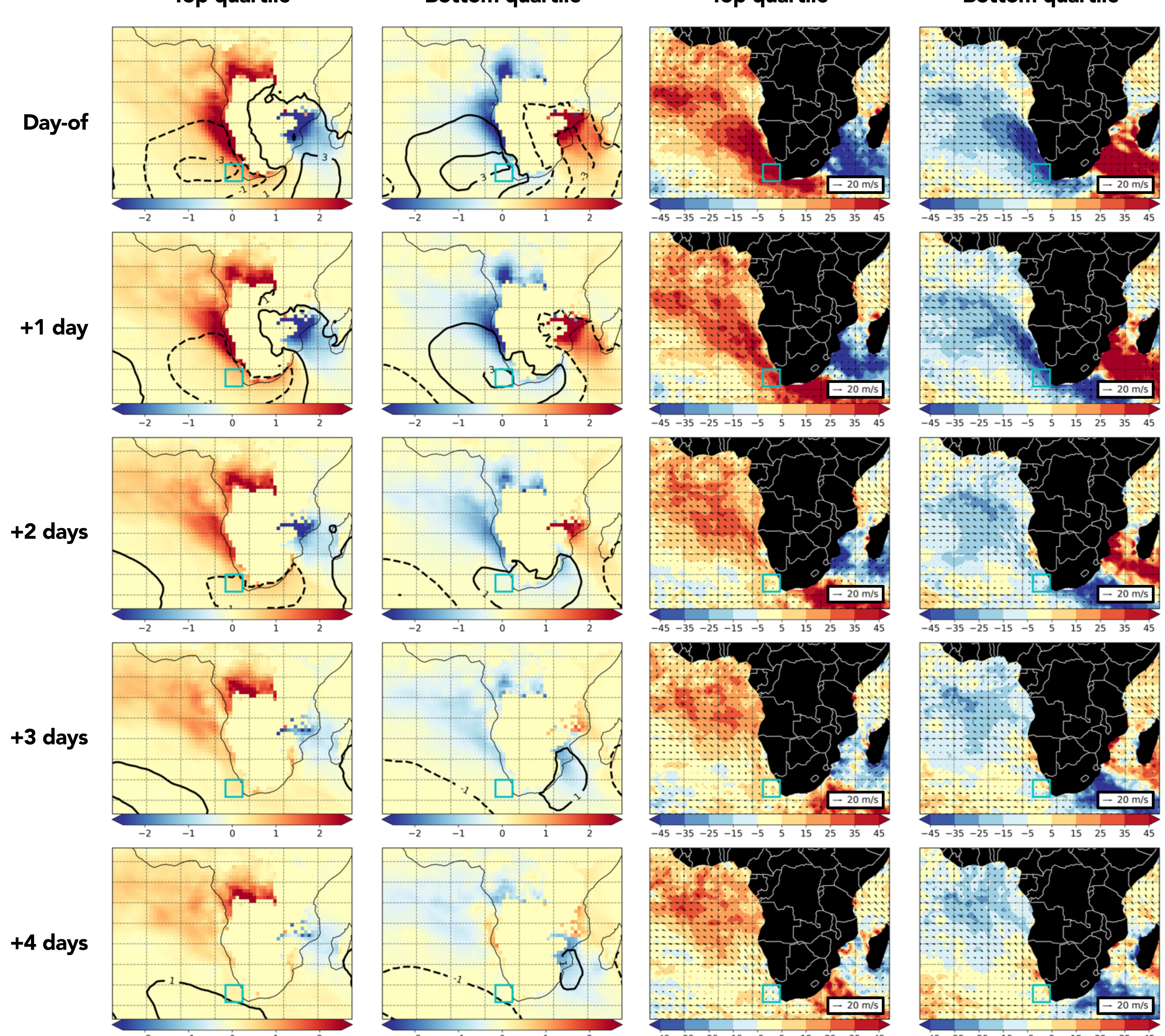
Methods: All meteorological and aerosol data are from the MERRA-2 reanalysis and remotely-sensed N_d is from the MODIS-based Bennartz-Rausch [2017] adiabatic warm cloud product. "Smoke concentrations" are calculated as the sum of organic carbon (OC) and black carbon (BC). Analysis is restricted to the month of September to avoid conflating synoptic and seasonal variability and to the years 2003-2015 where MERRA-2 and the N_d product have overlapping data.

Composites are produced by averaging over the top and bottom quartiles of sea-level pressure (SLP) between 20°E-20°W and 35-45°S (grey box in Figures 1 and 2) and 850 hPa smoke between 13-18°E and 30-35°S (cyan boxes in Figures 1, 2, and 3). **Figure 2** shows the differences in 850 hPa winds (quivers) and smoke concentrations (shading) between using the two indices. Low (high) pressure is not generally associated with high (low) extratropical smoke loading, but relatively high (low) extratropical smoke loading is generally associated with low (high) pressure. The main results shown in Figure 3, therefore, use the top/bottom quartile composites of the 850 hPa smoke index instead of the pressure-based index.



Take-home point: Anomalies in above-cloud smoke can propagate upstream over the course of days via entrainment into the marine boundary layer and subsequent advection.

Figure 3. Composites of MBL (950 hPa) smoke concentration anomalies and winds, surface pressure anomalies, and relative anomalies of N_d for the top and bottom quartiles of 850 hPa smoke concentrations in the cyan box on the day of the smoke anomaly and up to four days after the anomaly. Positive (negative) anomalies in both MBL smoke and N_d propagate upstream of the initial positive (negative) above-cloud anomaly over the course of several days. Columns separate the quantities of interest by quartile and rows by time after the initial anomaly.



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References:

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