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Characteristics of Borneo and Sumatra fire plume heights and smoke clouds and their impact on regional El Niño-induced drought

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During the dry season, anthropogenic fires burn the tropical forests and peatlands of equatorial Asia and produce regionally expansive smoke clouds. We estimated the altitude of smoke from these fires, characterized the sensitivity of this smoke to regional drought and El Niño variability, and investigated its effect on climate. We used the MISR satellite product and MISR INteractive eXplorer (MINX) software to estimate the heights of 382 smoke plumes (smoke with a visible surface source and transport direction) on Borneo and 121 plumes on Sumatra for 2001—2009. In addition, we estimated the altitudes of 10 smoke clouds (opaque regions of smoke with no detectable surface source or transport direction) on Borneo for 2006. Most smoke plumes (80%) were observed during El Niño events (2002, 2004, 2006, 2009); this is consistent with higher aerosol optical depths observed during El Niño-induced drought. Annually averaged plume heights on Borneo were positively correlated to the Oceanic Niño Index (ONI), an indicator of El Niño (r^2 = 0.53). The mean plume height for all El Niño years was 765.8 $\pm$ 19.7m, compared to 711.4 $\pm$ 28.7 for non-El Niño years. The median altitude of all 10 smoke clouds observed on Borneo during 2006 was 1313m, compared to a median 787m for smoke plume grid cells. The area covered by all smoke plumes from 2006 corresponded to approximately three individual smoke clouds. We investigated the climate response to these expansive smoke clouds using the Community Atmosphere Model (CAM). Climate variables from two 30 year simulations were compared: one simulation was forced with fire emissions typical of a dry (El Niño) burning year, while the other was forced with emissions typical of a low (La Niña) burning year. Fire aerosols reduced net shortwave radiation at the surface during August–October by an average of 10% in the region encompassing most of Sumatra and Borneo (90°E–120°E, 5°S–5°N). The reductions in net radiation cooled both ocean (0.5 $\pm$ 0.3°C) and land (0.4 $\pm$ 0.2°C) temperatures during these months. Tropospheric heating from black carbon (BC) absorption increased substantially (20.5 $\pm$ 9.3 W m^{-2}), but was balanced by an overall reduction in latent heating. The combination of decreased SSTs and increased atmospheric heating reduced regional precipitation by 0.9 $\pm$ 0.6 mm d^{-1} (10%). This implies that the vulnerability of ecosystems to fire was increased because the reductions in precipitation exceeded those for evapotranspiration. Together, the satellite and modeling results imply a possible positive feedback loop in which anthropogenic burning in the region intensifies drought stress during El Niño.