The Role of Lightning in Controlling Interannual Variability of Tropical Tropospheric Ozone and OH and Its Implications for Climate

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Nitrogen oxides ($NO_x \equiv NO + NO_2$) produced by lightning make a major contribution to the production of the dominant tropospheric oxidants (OH and ozone). These oxidants control the lifetime of many trace gases including long-lived greenhouse gases, and control the source-receptor relationship of inter-hemispheric pollutant transport. Lightning is affected by meteorological variability, and therefore represents a potentially important tropospheric chemistry-climate feedback. Understanding how interannual variability (IAV) in lightning affects IAV in ozone and OH in the recent past is important if we are to predict how oxidant levels may change in a future warmer climate. However, lightning parameterizations for chemical transport models (CTMs) show low skill in reproducing even climatological distributions of flash rates from the Lightning Imaging Sensor (LIS) and the Optical Transient Detector (OTD) satellite instruments. We present an optimized regional scaling algorithm for CTMs that enables sufficient sampling of spatiotemporally sparse satellite lightning data from LIS to constrain the spatial, seasonal, and interannual variability of tropical lightning. We construct a monthly time series of lightning flash rates for 1998-2010 and 35°S-35°N, and find a correlation of IAV in total tropical lightning with El Niño. We use the IAV-constraint to drive a 9-year hindcast (1998-2006) of the GEOS-Chem 3D chemical transport model, and find the increased IAV in LNO_x drives increased IAV in ozone and OH, improving the model's ability to simulate both. Although lightning contributes more than any other emission source to IAV in ozone, we find ozone more sensitive to meteorology, particularly convective transport. However, we find IAV in OH to be highly sensitive to lightning NO_x, and the constraint improves the ability of the model to capture the temporal behavior of OH anomalies inferred from observations of methyl chloroform and other gases. The sensitivity of OH is explained using photochemical reaction rates which show a "magnification" effect of the initial lightning NO perturbation on OH primary production, HO_x recycling, and OH loss frequencies. This influence on OH may represent a negative feedback, if lightning increases in a warming world.