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Vertical profiles of lightning-produced NO_2 enhancements in the upper troposphere observed by OSIRIS

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Abstract. The purpose of this study is to perform a global search of the upper troposphere ($z \geq 10$ km) for enhancements of nitrogen dioxide and determine their sources. This is the first application of satellite-based limb scattering to study upper tropospheric NO_2. We have searched two years (May 2003–May 2005) of OSIRIS (Optical Spectrograph and Infrared Imager System) operational NO_2 concentrations (version 2.3/2.4) to find large enhancements in the observations by comparing with photochemical box model calculations and by identifying local maxima in NO_2 volume mixing ratio. We find that lightning is the main production mechanism responsible for the large enhancements in OSIRIS NO_2 observations as expected. Similar patterns in the abundances and spatial distribution of the NO_2 enhancements are obtained by perturbing the lightning within the GEOS-Chem 3-dimensional chemical transport model. In most cases, the presence of lightning is confirmed with coincident imagery from LIS (Lightning Imaging Sensor) and the spatial extent of the NO_2 enhancement is mapped using nadir observations of tropospheric NO_2 at high spatial resolution from SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography) and OMI (Ozone Monitoring Instrument). The combination of the lightning and chemical sensors allows us to investigate globally the role of lightning to the abundance of NO_2 in the upper troposphere (UT). Lightning contributes 60% of the tropical upper tropospheric NO_2 in GEOS-Chem simulations. The spatial and temporal distribution of NO_2 enhancements from lightning (May 2003–May 2005) is investigated. The enhancements generally occur at 12 to 13 km more frequently than at 10 to 11 km. This is consistent with the notion that most of the NO_2 is forming and persisting near the cloud top altitude in the tropical upper troposphere. The latitudinal distribution is mostly as

expected. In general, the thunderstorms exhibiting weaker vertical development (e.g. $11 \leq z \leq 13$ km) extend latitudinally as far poleward as 45° but the thunderstorms with stronger vertical development ($z \geq 14$ km) tend to be located within 33° of the equator. There is also the expected hemispheric asymmetry in the frequency of the NO_2 enhancements, as most were observed in the northern hemisphere for the period analyzed.

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