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Smoke injection heights from fires in North America: analysis of 5 years of satellite observations

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Abstract. We analyze an extensive record of aerosol smoke plume heights derived from observations over North America for the fire seasons of 2002 and 2004–2007 made by the Multi-angle Imaging SpectroRadiometer (MISR) instrument on board the NASA Earth Observing System Terra satellite. We characterize the magnitude and variability of smoke plume heights for various biomes, and assess the contribution of local atmospheric and fire conditions to this variability. Plume heights are highly variable, ranging from a few hundred meters up to 5000 m above the terrain at the Terra overpass time (11:00–14:00 local time). The largest plumes are found over the boreal region (median values of ~850 m height, 24 km length and 940 m thickness), whereas the smallest plumes are found over cropland and grassland fires in the contiguous US (median values of ~530 m height, 12 km length and 550–640 m thickness). The analysis of plume heights in combination with assimilated meteorological observations from the NASA Goddard Earth Observing System indicates that a significant fraction (4–12%) of plumes from fires are injected above the boundary layer (BL), consistent with earlier results for Alaska and the Yukon Territories during summer 2004. Most of the plumes located above the BL (>83%) are trapped within stable atmospheric layers. We find a correlation between plume height and the MODerate resolution Imaging Spectroradiometer (MODIS) fire radiative power (FRP) thermal anomalies associated with each plume. Smoke plumes located in the free troposphere (FT) exhibit larger FRP values (1620–1640 MW) than those remaining within the BL (174–465 MW). Plumes located in the FT without a stable layer reach higher altitudes and are more spread-out vertically than those associated with distinct stable layers (2490 m height and 2790 m thickness versus 1880 m height and 1800 m thickness). The MISR plume climatology exhibits a well-defined seasonal cycle of plume heights in boreal and temperate biomes, with greater heights during June–July. MODIS FRP measurements indicate that larger summertime heights are the result of higher fire intensity, likely due to more severe fire weather during these months. This work demonstrates the significant effect of fire intensity and atmospheric structure on the ultimate rise of fire emissions, and underlines the importance of considering such physical processes in modeling smoke dispersion.

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