

Injection of lightning-produced NO_x, water vapour, wildfire emissions, and stratospheric air to the UT/LS as observed from DC3 measurements

H. Huntrieser¹, M. Lichtenstern¹, M. Scheibe¹, H. Aufmhoff¹, H. Schlager¹, T. Pucik¹, A. Minikin¹, B. Weinzierl¹, K. Heimerl¹, D. Fütterer¹, I. B. Pollack^{2,3}, J. Peischl^{2,4}, T. B. Ryerson², A. J. Weinheimer⁵, S. Honomichl⁵, B. A. Ridley⁵, J. W. Hair⁶, C. F. Butler⁶, M. J. Schwartz⁷, B. Rappenglück⁸, L. Ackermann⁸, K. E. Pickering⁹, K. A. Cummings¹⁰, M. I. Biggerstaff¹¹, D. P. Betten¹¹, and M. C. Barth⁵

[1] {Institut für Physik der Atmosphäre, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen, Germany}

[2] {NOAA, Boulder, CO, USA}

[3] now at {Atmospheric Science Department, Colorado State University, Ft. Collins, CO, USA}

[4] {CIRES, University of Colorado, Boulder, CO, USA}

[5] {NCAR, Boulder, CO, USA}

[6] {NASA Langley Research Center, Hampton, VA, USA}

[7] {Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA}

[8] {Department of Earth & Atmospheric Sciences, University of Houston, TX, USA}

[9] {Atmospheric Chemistry and Dynamics Laboratory, NASA Goddard Space Flight Center Greenbelt, MD, USA}

[10] {Department of Atmospheric & Oceanic Science, University of Maryland, College Park, MD, USA}

[11] {School of Meteorology, University of Oklahoma, Norman, OK, USA}

In summer 2012 the Deep Convective Clouds and Chemistry Project (DC3) field campaign investigated a number of severe thunderstorms over the Central U.S. and their impact on the upper tropospheric (UT) – lower stratospheric (LS) composition and chemistry. In addition, during DC3 some of the largest and most destructive wildfires in New Mexico and Colorado state history were burning, influencing the air quality in the DC3 thunderstorm inflow and outflow region. Besides three instrumented aircraft platforms measuring a variety of trace species in-situ and remotely (e.g. CO, O₃, SO₂, NO_x, VOC, CN, and black carbon), dense networks of ground-based instruments (e.g. radar and lightning) complemented the airborne measurements. Satellite measurements (e.g. GOES, MODIS, and GOME-2) and model forecasts (e.g. WRF-Chem and FLEXPART) were used to monitor the rapid development of the thunderstorms (which frequently developed huge anvils with overshooting tops) and the spread of smoke plumes in the vicinity of the storms. In-situ probing of fresh and aged (12-24 h) anvil outflows showed injection of lightning-produced NO_x and wildfire emissions into the UTLS. Vertical cross sections of lidar and Doppler radar measurements supported these observations and gave detailed information on dynamical processes within and in the vicinity of the storms. Besides very strong updrafts in the storm core, surrounding downdrafts caused a direct in-mixing of O₃-rich LS air masses into the boundaries of the anvil outflow. The wrapping of O₃-rich LS air masses around and below the anvil outflow was also a prominent feature in several storms. The in-situ probing of the aged anvil outflow showed a pronounced influence on the UT composition and chemistry with average O₃ enhancements in the range of 20-50 nmol mol⁻¹ and evidence of new particle formation. A 10-year global climatology of H₂O data from Aura-MLS confirms that the Central U.S. is a preferred region for convective injection into the LS.