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Thunderstorms and their Impact on Atmospheric Chemistry

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Thunderstorms and lightning have an important impact on chemistry in the atmosphere, especially on the nitrogen oxides (NO) and ozone (O_3) budget in the upper troposphere. In the hot lightning channel, nitrogen and oxygen molecules in the air are dissociated into single N and O atoms. During the rapid cooling of the channel, these atoms and molecules may recombine to form nitrogen oxides (NO). NO plays an important role in the production of O_3. It acts as a catalyst during the photochemical oxidation of hydrocarbons and carbon monoxide (CO) producing O_3. On the other hand, O_3 plays an essential role in atmospheric chemistry since it determines the oxidizing capacity of the troposphere and acts as an important greenhouse gas.
The strongest source of nitrogen oxides in the upper troposphere originates from lightning-induced nitrogen oxides (LNOx) and not from aircraft exhaust. In the past 20 years, we studied LNOx in a number of airborne field experiments accompanied with model simulations. Airborne in situ trace gas measurements and lightning measurements were performed in thunderstorms over Europe, Brazil, Australia, West Africa, and Central United States. In addition, microphysical measurements from radar and remote trace species measurements (lidar and satellites) were used to demonstrate the strong impact of thunderstorms on the upper troposphere – lower stratosphere trace gas composition. The most powerful thunderstorms (e.g. isolated supercells and organized mesoscale convective systems, partly with overshooting tops) that produced most LNOx were probed in the United States (in the Tornado Alley) and in Australia (the famous Hector thunderstorm). In the Tornado Alley, overshooting thunderstorms developed that injected considerable amounts of pollutants into the lower stratosphere. In the anvil outflow, O_3 mixing ratios were frequently enhanced due to photochemical production and downward transport from the stratosphere; however, the latter process dominated the measured O_3 enhancements in the storms.
Summarizing three decades of research activities on this topic (considering theoretical and laboratory studies as well as surface-, airborne-, and satellite-based measurements) the best estimate of the annual global LNOx source and its uncertainty range was estimated to 5 ± 3 Tg a^{-1}.

Figure 1: Falcon flight on 29 May 2012 in severe convection over Oklahoma: view from the cockpit (Photo: A. Minikin, DLR).