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NO_x production by lightning in Hector: first airborne measurements during SCOUT-O3/ACTIVE

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Abstract. During the SCOUT-O3/ACTIVE field phase in November–December 2005, airborne in situ measurements were performed inside and in the vicinity of thunderstorms over northern Australia with several research aircraft (German *Falcon*, Russian M55 *Geophysica*, and British *Dornier-228*. Here a case study from 19 November is presented in detail on the basis of airborne trace gas measurements (NO, NO_y, CO, O_3) and stroke measurements from the German LIghtning Location NETwork (LINET), set up in the vicinity of Darwin during the field campaign. The anvil outflow from three different types of thunderstorms was probed by the Falcon aircraft: (1) a continental thunderstorm developing in a tropical airmass near Darwin, (2) a mesoscale convective system (MCS), known as Hector, developing within the tropical maritime continent (Tiwi Islands), and (3) a continental thunderstorm developing in a subtropical airmass ~200 km south of Darwin. For the first time detailed measurements of NO were performed in the Hector outflow. The highest NO mixing ratios were observed in Hector with peaks up to 7 nmol mol^{-1} in the main anvil outflow at ~11.5–12.5 km altitude. The mean NO_x (=NO+NO_2) mixing ratios during these penetrations (~100 km width) varied between 2.2 and 2.5 nmol mol^{-1}. The NO_x contribution from the boundary layer (BL), transported upward with the convection, to total anvil-NO_x was found to be minor (<10%). On the basis of Falcon measurements, the mass flux of lightning-produced NO_x (LNO_x) in the well-developed Hector system was estimated to 0.6–0.7 kg(N) s^{-1}. The highest average stroke rate of the probed thunderstorms was observed in the Hector system with 0.2 strokes s^{-1} (here only strokes with peak currents ≥10 kA contributing to LNO_x were considered). The LNO_x mass flux and the stroke rate were combined to estimate the LNO_x production rate in the different thunderstorm types. For a better comparison with other studies, LINET strokes were scaled with Lightning Imaging Sensor (LIS) flashes. The LNO_x production rate per LIS

flash was estimated to 4.1–4.8 kg(N) for the well-developed Hector system, and to 5.4 and 1.7 kg(N) for the continental thunderstorms developing in subtropical and tropical airmasses, respectively. If we assume, that these different types of thunderstorms are typical thunderstorms globally (LIS flash rate ~44 s^{-1}), the annual global LNO_x production rate based on Hector would be ~5.7–6.6 Tg(N) a^{-1} and based on the continental thunderstorms developing in subtropical and tropical airmasses ~7.6 and ~2.4 Tg(N) a^{-1}, respectively. The latter thunderstorm type produced much less LNO_x per flash compared to the subtropical and Hector thunderstorms, which may be caused by the shorter mean flash component length observed in this storm. It is suggested that the vertical wind shear influences the horizontal extension of the charged layers, which seems to play an important role for the flash lengths that may originate. In addition, the horizontal dimension of the anvil outflow and the cell organisation within the thunderstorm system are probably important parameters influencing flash length and hence LNO_x production per flash.

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