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Airborne measurements of the nitric acid partitioning in persistent contrails

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Abstract. This study reports the first systematic measurements of nitric acid (HNO_3) uptake in contrail ice particles at typical aircraft cruise altitudes. During the CIRRUS-III campaign cirrus clouds and almost 40 persistent contrails were probed with in situ instruments over Germany and Northern Europe in November 2006. Besides reactive nitrogen, water vapor, cloud ice water content, ice particle size distributions, and condensation nuclei were measured during 6 flights. Contrails with ages up to 12 h were detected at altitudes 10–11.5 km and temperatures 211–220 K. These contrails had a larger ice phase fraction of total nitric acid (HNO_3^{ice}/HNO_3^{tot} = 6%) than the ambient cirrus layers (3%). On average, the contrails contained twice as much HNO_3^{ice} as the cirrus clouds, 14 pmol/mol and 6 pmol/mol, respectively. Young contrails with ages below 1 h had a mean HNO_3^{ice} of 21 pmol/mol. The contrails had higher nitric acid to water molar ratios in ice and slightly higher ice water contents than the cirrus clouds under similar meteorological conditions. The differences in ice phase fractions and molar ratios between developing contrails and cirrus are likely caused by high plume concentrations of HNO_3 prior to contrail formation. The location of the measurements in the upper region of frontal cirrus layers might account for slight differences in the ice water content between contrails and adjacent cirrus clouds. The observed dependence of molar ratios as a function of the mean ice particle diameter suggests that ice-bound HNO_3 concentrations are controlled by uptake of exhaust HNO_3 in the freezing plume aerosols in young contrails and subsequent trapping of ambient HNO_3 in growing ice particles in older (age > 1 h) contrails.

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