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Effects of three-dimensional photon transport on the radiative forcing of realistic contrails

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Estimates of the radiative forcing (RF) of line-shaped contrails and contrail-cirrus exhibit a high level of uncertainty. In most cases, 1D radiative models have been used to determine the RF on a global scale. In this study, we quantify the effect of neglecting the 3D radiative effects of realistic contrails – that is, approximating contrails by plane-parallel, infinitely wide, horizontally homogeneous slabs as usual. Calculating the 3D effects of an idealized contrail of elliptical shape like in Gounou and Hogan (2007) with the 3D radiative transfer model MYSTIC ("Monte carlo code for the phYsically correct Tracing of photons in Cloudy atmospheres") (Mayer 2009) produced comparable results: as in Gounou and Hogan (2007) the 3D effect (i.e. the difference in RF between a 3D calculation and a 1D approximation) on contrail RF was of the order of 10 % in the longwave and shortwave respectively. The 3D effect on the net (shortwave plus longwave) radiative forcing, however, can be much larger, since the shortwave and the longwave RF largely cancel during the day. For the investigation of the 3D effects of more realistic contrails the meteorological and microphysical input was provided by simulations of a 2D contrail-to-cirrus LES (large-eddy simulation) model (Unterstrasser and Gierens 2010a). In order to capture some of the real variability in contrail properties we studied two modeled contrail evolutions from 20 min up to 6 h in an environment with either high or no vertical wind shear. This study revealed that the 3D effects show a high variability under realistic conditions since they depend strongly on the optical properties and the evolutionary state of the contrails. The differences are especially large for low elevations of the sun and contrails spreading in a sheared environment. Thus, a parameterization of the 3D effects in climate models would need to consider both geometry and microphysics of the contrail.

References:

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