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Global climate modelling of contrails and their climate impact

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Contrails cause an alteration in the Earth's radiation budget, via their shortwave (SW) albedo effect, i.e. they reduce the amount of SW radiation reaching the Earth, and their longwave (LW) greenhouse effect, i.e. they reduce the amount of LW radiation leaving from Earth to space. Existing studies have shown that for persistent contrails, their LW radiative forcing (RF) effect is larger than their SW effect, meaning that contrails cause a positive net RF, and therefore a warming. As reported by the IPCC fourth assessment, current best estimates of this net positive RF still have an uncertainty factor of three caused by a low level of scientific understanding, mainly due to limited knowledge on contrail optical properties and contrail coverages. As air traffic is expected to experience a significant increase, the contrail warming effect may become stronger and, therefore, the development of more reliable models that can accurately estimate contrail formation and their radiative impact is crucial.

The current study develops a new contrail parameterisation for the UK Hadley Centre Climate Model HadGEM2. One of the greatest strengths of this parameterisation is its ability to allow for a variable optical depth, which, along with the contrail coverage, is estimated during the parameterisation process as a three-dimensional variable. Thus, geographical distributions of the contrail coverage and optical depth are obtained and compared with those reported by other existing studies. With these distributions, radiative transfer models are employed in order to evaluate the contrail RF. The current study presents RF estimations from both off-line and on-line radiative transfer calculations based on the Edwards-Slingo radiation model. The stronger high cloud masking effect on contrails observed in the on-line calculations is investigated and a possible explanation is given, based on the significant correlation between the existence of contrails and that of natural clouds.

Results from thirty-year slab-ocean model runs including this new contrail parameterisation are also presented, with emphasis on estimating the contrail climate sensitivity and the contrail impact on temperature, precipitation, cloud cover and daily temperature range.