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Observations of Microphysical Properties and Radiative Effects of Contrail Cirrus and Natural Cirrus over the North Atlantic

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Contrail cirrus represent the largest aviation radiative forcing (RF) component on climate. However, the evolution of individual contrails to embedded contrail cirrus and the difference of properties of contrail cirrus and natural cirrus clouds are still not completely resolved. The ML-CIRRUS (Mid Latitude Cirrus) campaign was motivated by these questions and deployed a comprehensive set of in situ and remote sensing instruments aboard the German HALO aircraft to investigate them.

This study shows findings concerning comparisons between contrail cirrus and natural cirrus through combining airborne in situ measurements and MSG (Meteosat Second Generation) satellite remote sensing as well as detailed radiative transfer model (RTM) simulations for one case over West of Ireland in the North Atlantic Region during the ML-CIRRUS experiment on 26 March 2014. CiPS (Cirrus Properties from SEVIRI) and APICS (Algorithm for the Physical Investigation of Clouds with SEVIRI) were developed to retrieve cloud properties using thermal and solar observations of MSG. Using the linear regression and a neural network, RRUMS (Rapid Retrieval of Upwelling irradiances from SEVIRI) is able to estimate outgoing longwave radiation (OLR) and reflected solar radiation (RSR) at top-of-atmosphere (TOA). Comparing remote sensing derived microphysical properties with airborne measurements, CiPS is sensitive to thin cirrus layers while APICS enhances the accuracy for higher optical thickness. As for radiative effects, a TOA RSR and OLR estimation method was developed based on RTM simulations exploiting in situ measurements, observations and ERA5 model atmospheric data for both cirrus and cirrus-free regions.

As the result we find, based on average values of in situ data along the HALO flight track, that the radii for contrail cirrus are about 27% smaller than those of natural cirrus. Particle sizes increase from contrails to embedded contrails and later decrease slightly in the subsaturated environment. The evolution of optical thickness from MSG appears to be controlled by ambient relative humidity, with higher values for embedded contrails than for contrails in supersaturated conditions and smaller values in subsaturated conditions. In general, TOA broadband irradiances estimated from our simulations compare well with RRUMS outputs and CERES/GERB products, indicating that our atmospheric models provide a good representation of reality and can thus be

used to determine RF of the ice clouds probed during this flight. To this end, ice clouds are removed from the atmosphere input to the RTM to approximate the conditions unaffected by contrails, embedded contrails, and natural cirrus. The RF results indicate cirrus warming during the early morning period. Contrails net RF increases by a factor of 3.5 after evolving into embedded contrails. On average, the net RF of contrails and embedded contrails is more strongly warming than that of natural cirrus.

This study will possibly be of interest for related researches on assessing the climate impacts of natural cirrus and contrail cirrus and formulating mitigation options.