EMS Annual Meeting Abstracts
Vol. 10, EMS2013-475-1, 2013
13th EMS / 11th ECAM

The dependence of contrail formation on the weather pattern and altitude in the north Atlantic

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Persistent contrails, which form when aircraft fly through cold ice-supersaturated regions (ISSRs), are an important climate impact of aviation. Here, we analyse contrail formation conditions in the north Atlantic flight corridor using two different methods. First, a synoptic weather pattern analysis links contrail formation conditions to specific meteorological features. Second, Lagrangian trajectories are used to follow ice-supersaturated air parcels, and determine the duration of ice-supersaturation, which is an upper-bound on the lifetime of a contrail formed within that air parcel. Both methods identify cold ISSRs at typical aircraft cruise altitudes over the north Atlantic flight corridor in twenty-one years of ERA-Interim data. The results of the weather pattern analysis show in greater detail the locations of contrail formation conditions than the climatological picture; cold ISSRs occur over the orography of Greenland, on the southern side of the jet stream and around the northern edge of high-pressure ridges. For each weather pattern the minimum-time route through it is different for eastbound and westbound flights and different to great circle routes, as the position and intensity of the jet stream varies with the large-scale weather pattern. Along minimum-time routes through the different weather patterns, the probability of contrailing is 1-10%, and can increase or decrease with height, depending on the weather pattern; this indicates that contrail climate impact cannot be mitigated simply by flying higher. This also shows that assuming that aircraft take great circle routes, instead of more realistic time-optimal routes can lead to large errors in estimated contrail occurrence. Using Lagrangian trajectories we show that contrails which form over the north Atlantic region typically have a duration of less than 6 h, although 5% have a duration of at least 24 h.