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Mitigation potential of optimized aircraft trajectories and its dependency on weather patterns

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The climate impact of a flight is determined not only by the amount of aircraft emissions, but also by the time, location, and specific weather conditions at which such emissions occur. As a result, there is the potential of mitigating the climate impact of a flight by optimizing its trajectory. This operational strategy presents trade-offs between minimizing the climate impact from carbon dioxide (CO_2), which only depends on the amount of emitted CO_2, and minimizing the so-called non-CO_2 effects of aviation, due to the radiative forcing from contrails and contrail cirrus, the perturbation of atmospheric concentrations of ozone and methane caused by NO_x emissions, and H_2O emissions at high flight levels. Moreover, operating costs and climate impact are expected to be conflicting objectives for trajectory optimization (Grewe et al., 2014). The characteristics of the sets of Pareto optimal solutions resulting from such multi-objective optimizations would, however, vary under different atmospheric conditions.

To compare the benefits and costs associated to this operational strategy under different weather patterns, we use the air traffic simulator AirTraf, which optimizes aircraft trajectories based on the atmospheric fields computed by the ECHAM/MESSy Atmospheric Chemistry (EMAC) model (Yamashita et al., 2020). This modelling chain presents the advantage of enabling the analysis of optimized aircraft trajectories over a large number of consecutive days, identifying preferred compromise solutions between multiple optimization objectives (Castino et al., 2023). In the present study, we consider four winter and four summer seasons between 2015 and 2019, optimizing 100 flights over the North Atlantic Corridor (NAC) on each simulation day. Subsequently, we compare trajectories minimizing different objective functions, including fuel used, and the potential formation of contrails along the trajectory. We classify the weather patterns by comparing their similarity to the positive and negative phases of the North Atlantic Oscillation (NAO) and East Atlantic (EA) patterns, applying the methodology presented by Irvine et al. (2013). As a result, we can identify which conditions are correlated to a larger potential of mitigating the climate impact of our air traffic sample, e.g., by reducing the formation of persistent contrails.

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