Assessing the impacts of increasing extreme heat events on aircraft takeoff from an interdisciplinary perspective

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Extreme heat conditions negatively affect aircraft performances and airport's capacity and efficiency. An increase in the magnitude and in the frequency of high-temperature extremes due to climate change would impact aviation operations, with further socio-economic, environmental and even health consequences. This study assess the future impacts of rising high-temperature extremes on aircraft takeoff performance in the Euro-Mediterranean region. The problem is addressed as follows: 1) the future evolution of high-temperature extremes is studied, and 2) the potential induced impacts are assessed in terms of the pollutant emissions by the aircraft engine, in particular, of nitrogen oxides (NOx), and engine performances, and in terms of the aircraft's Maximum TakeOff Weight (MTOW).

Before assessing the potential impacts of future changes in high-temperature extremes, the past and future evolution of these events over a list of major and regional airports is analysed from observations and climate model projections. The daily maximum near-surface air temperature (TX) in summer is used. First, the magnitude of extreme values observed in recent decades is characterized, and trends in summer TX percentiles are computed as well. A robust increase is generally found over the airports for all percentiles. Second, climate models are evaluated in present climate in these terms over the airports. Simulations performed with Regional and Global Climate Models (RCMs and GCMs) are considered in a multi-ensemblist approach. In particular, the state-of-the-art Euro-CORDEX multi-RCM ensemble and the ensemble of driving GCMs from CMIP5 are used. The two ensembles are compared to each other. Results show that there is no generally prevailing added value in RCMs for the study of the magnitude of high-temperature extremes nor for their temporal trends at the airport scale, despite their higher spatial resolution. Third, the future changes in summer high-temperature extremes are assessed for different time horizons and different climate change scenarios. A robust future increase in summer TX extremes is found for all the airports: up to +3.2ºC by the near term and up to +8.5ºC by the long term, under the severe scenario, with larger changes projected by the GCMs over the same locations.

In the second part of the study, the potential future increase in the levels of NOx emissions is assessed using an industrial tool for analysing the engine performance and pollutant emissions. The input value for the ambient temperature is declared as the future magnitude of summer TX extremes over the airports, which was estimated from the climate projections. A general increase is found in the levels of NOx emissions over the selected airports. It could lead to an increase in absolute NOx emissions at takeoff of the order of a few percentage points in future extreme events: up to nearly +4% and +6% by the near and medium term, respectively. The potential future decrease in aircraft's maximum carrying capacity induced by the future increase in summer TX is assessed for each airport, following an empirical law for degrading the Maximum TakeOff Weight (MTOW) curves in Aircraft Characteristics for Airport Planning. This empirical law was provided by AIRBUS for three different aircrafts representing long-, medium and short-range couriers. The future reductions in MTOW are generally of the order of tones for the long- and medium-range aircrafts, which could result in weight restrictions corresponding to tens of passengers and/or in delays or cancellations. The short-range aircrafts would experience little to no impact on the MTOW.

Despite the robust positive trend found for the levels of NOx emissions and the MTOW limitations, there are large uncertainties in the magnitude of the impacts analysed here. They mainly arise from uncertainties in climate projections that would need to be narrowed for the design of adaptation and/or mitigation strategies in the future.

This study assess some of the maximum potential impacts that climate change may have on general aviation operations in the coming decades. It illustrates the magnitude of the negative effects that the increase in high-temperature extremes would have on aircraft takeoff performance in terms of pollutant emissions, engine performance and MTOW limitations. Moreover, it highlights the positive feedback loop between the rising temperatures and the rising NOx emissions from aviation. In addition, this work provides new methodologies to assess the impacts of climate change on aircraft takeoff at any airport in the world.

Aviation operations at Euro-Mediterranean airports will be likely impacted by the increase in high-temperature extremes in the future. Adaptation and resilience strategies should be designed and deployed. This would require collaboration with airlines, aircraft and engine manufacturers and other stakeholders.