Evolution of high-temperature extremes over the Euro-Mediterranean region and its impact on aircraft takeoff performance

Victoria GALLARDO[1,2], Emilia SÁNCHEZ-GÓMEZ[3,2], Eleonore RIBER[4], Pedro JIMÉNEZ-GUERRERO[1], Juan Pedro MONTÁVEZ[1]

[1]Regional Atmospheric Modelling Group, Department of Physics, University of Murcia, Murcia, Spain; [2]CECI, Cerfacs/CNRS, Toulouse, France; [3]Météo-France, Toulouse. France; [4]Cerfacs, Toulouse, France

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. The Mediterranean region is a major climate change "hotspot", specially concerned by the increase in high temperatures. This study assess the future impacts of rising high-temperature extremes on aircraft takeoff performance over the Euro-Mediterranean region. The problem is addressed as follows: 1) the future evolution of high-temperature extremes is studied from climate model simulations, and 2) the potential induced impacts are assessed in terms of the levels of pollutant emissions, in particular, of nitrogen oxides (NOx), and engine performance, and in terms of the aircraft's maximum carrying capacity at takeoff.

Before evaluating the potential impacts of future changes in high-temperature extreme events, the past and future evolution of these events over a list of major and regional airports is analysed from observations and climate model simulations and 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. The quantile regression method allows us to obtain the evolution of the shape of the Probability Distribution Function, in particular, the trends of the median and the extremes, and not only the mean trends like the most-commonly used Ordinary Least Squares regression method. A robust increase is generally found over the airports for all percentiles. Some airports experienced a stronger increase in the upper percentiles than in the median or in the lower percentiles, which may be particularly problematic for aviation, and other sectors as well. Second, climate models are evaluated in present climate in these terms over the airports. This is a crucial step for the further assessment of future climate projections and related impacts. Simulations performed with Regional and Global Climate Models (RCMs and GCMs) are considered in a multi-model ensemble approach. In particular, the 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 evolution of summer TX extremes is assessed for different time horizons and different climate change scenarios. A robust increase of the order of few degrees Celsius is found in summer TX extremes in the future for all the airports (up to +3.2ºC in the near term and up to +8.5ºC in the long term, under the severe scenario), with larger changes projected by the GCMs over the same locations. Forth, biases in future climate projections are corrected before the evaluation of the impact on the aircraft takeoff. Both RCMs and GCMs ensembles are considered here, in order not to underestimate climate modelling uncertainties.

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. To the best of our knowledge, this is the first time that data from climate models are used as input to an engine emulator. 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-, mediumand 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 work assessed 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. All this focused on one of the world's most sensitive areas to climate change: the Euro-Mediterranean region. Moreover, it highlights the positive feedback loop between the rising temperatures and the rising NOx emissions from aviation.

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.