THE AIRCRAFT EMISSIONS MODEL: FUTURE AVIATION SCENARIO TOOL (FAST)

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Abstract. Investigations into the environmental impacts from aircraft emissions on global climate generally involve research communities (engineers, experimentalists and scientists), policy makers (government and regulatory bodies), aircraft and engine manufacturers and stakeholders (air navigation service providers, airports, and airlines). These communities work collaboratively, seeking solutions for an environmentally sustainable aviation industry. Software infrastructure plays a core and fundamental role in environmental impact studies, since global assessments cannot be directly measured but rather need to be modelled from empirical data. Models are needed to assess the impacts, inform policy makers and evaluate mitigation strategies. The software tool central to these activities are the aircraft emissions models. In this paper, we present the aircraft emissions model, FAST (the Future Aviation Scenario Tool). FAST, is one of only three emissions models that have been approved by the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) for aircraft greenhouse gas modelling. It is a modular software system that can be used to produce 3D gridded emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), non-volatile particulates (nvPM) and distances, over various temporal resolutions. FAST uses aircraft-engine specific fuel flow data calculated by the aircraft performance software, PIANO; coupled with emissions indices to generate an emissions profile for a specific aircraft payload, cruise altitude and mission distance. These profiles are applied to route specific information (frequency and distance) to determine the global emissions. Finally, we will present case studies on how these emissions have been used in impact models to estimate their climate burden.

Keywords: aircraft emissions models, CO_2, NO_x, nvPM

INTRODUCTION

Aircraft engines emit a variety of chemical species, which includes carbon dioxide (CO_2), nitrogen oxides (NO_x), water vapour and particulates. These emissions can directly affect climate, or indirectly by altering atmospheric concentrations (e.g. ozone) and trigger cloud formation (contrails, contrail-cirrus and soot-cirrus). In this paper, we present the aircraft emissions model, FAST (the Future Aviation Scenario Tool). We will present case studies on how these emissions have been used in different applications.

AIRCRAFT EMISSIONS MODEL: FAST

FAST, is one of only three emissions models that have been approved by the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) for aircraft greenhouse gas modelling. It is a modular software system that can be used to produce 3D gridded emissions of CO_2, NO_x, nvPM and distances, over various temporal resolutions. The basic structure of the FAST aircraft emissions model is illustrated in Figure 1 (left panel). FAST uses aircraft-engine specific fuel flow data calculated by the aircraft performance software, PIANO; coupled with emissions indices to generate an emissions profile for a specific aircraft payload, cruise altitude and mission distance. The emissions indices, including the various speciation could be derived from ground measurements or when possible, in-service tests. The emission profiles are applied to route specific information (frequency and distance) to determine the 3D global emissions, across temporal resolutions. Atmospheric and climate scientists then use the FAST emissions in impact models to estimate their environmental burden. The linkages between FAST and other climate impact models are illustrated in Figure 1 (right panel).

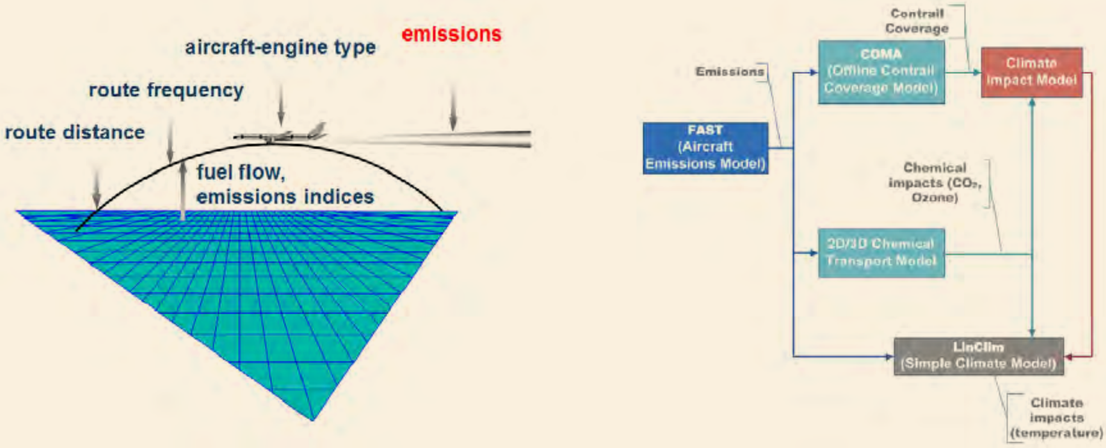

Figure 1. Basic structure of the aircraft emissions model, FAST (left panel) and linkages between FAST and other climate impacts model (right panel).

CASE STUDIES

Over the years, the FAST model has been used in ICAO-CAEP activities such as CAEP trends analysis, CO_2 Standard Stringency assessment and Market-Based Measures (MBMs). It has also been applied in several research projects and these provided an outlook on the spatial and vertical distributions of present day and future aviation emissions, including aviation contribution to total anthropogenic emissions. Example outputs from past projects are presented in Figure 2 (EU FP6 Integrated Project QUANTIFY), Figure 3 (EU Framework 7 Project REACT4C) and Figure 4 (EU Framework 7 Project TEAM_Play).

EU FP6 INTEGRATED PROJECT QUANTIFY

QUANTIFY (Quantifying the Climate Impact of Global and European Transport Systems) is the EU FP6 Integrated Project with the objective of quantifying the impact of air, sea and land transport on global climate. The 4D global aircraft emissions (CO_2, NO_x, particulates and distance travelled) were estimated for the year 2000 by FAST. The base year movements and emissions were used as baseline for projections to the year 2020, 2050 and 2100. A selection of these results are illustrated in Figure 2.

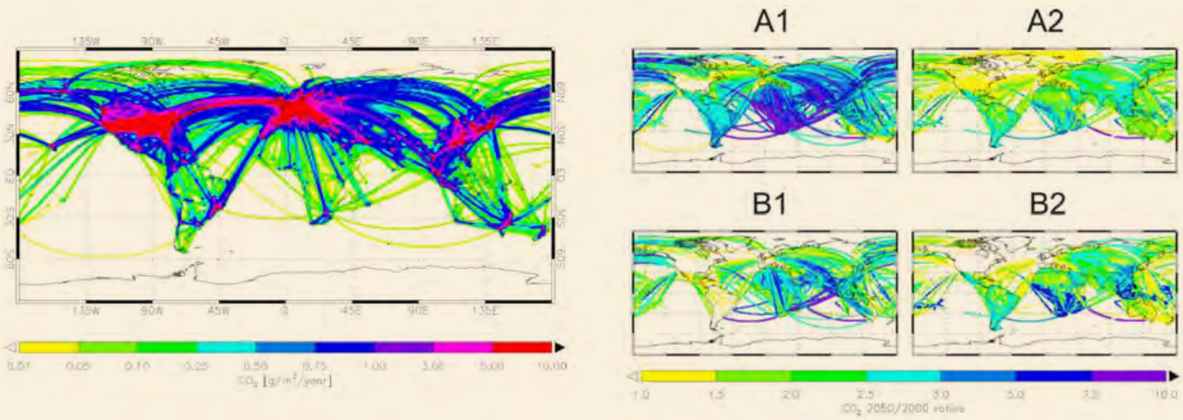

Figure 2. CO2 aviation emissions in 2000 (left panel) and CO_2 2050/2000 ratios in IPCC SRES A1, A2, B1 and B2 emission storylines (right panel) from EU FP6 QUANTIFY (Owen et al., 2010).

EU FP7 PROJECT REACT4C

REACT4C (Reducing emissions from aviation by changing trajectories for the benefit of climate) is the EU FP7 Project with the objective of investigating the potential of climate-optimised flight routing as a strategy to reduce the aviation sector's impact on the atmosphere. In this project, FAST was used to generate a 4D global aircraft emissions similar to QUANTIFY, but for the year 2006 and with more representative aircraft types. The 2006 movements and emissions were then used as baseline for a sensitivity analysis, whereby the cruise altitudes were shifted higher and lower by 2,000 ft or one flight level. A sample of the baseline results is illustrated in Figure 3.

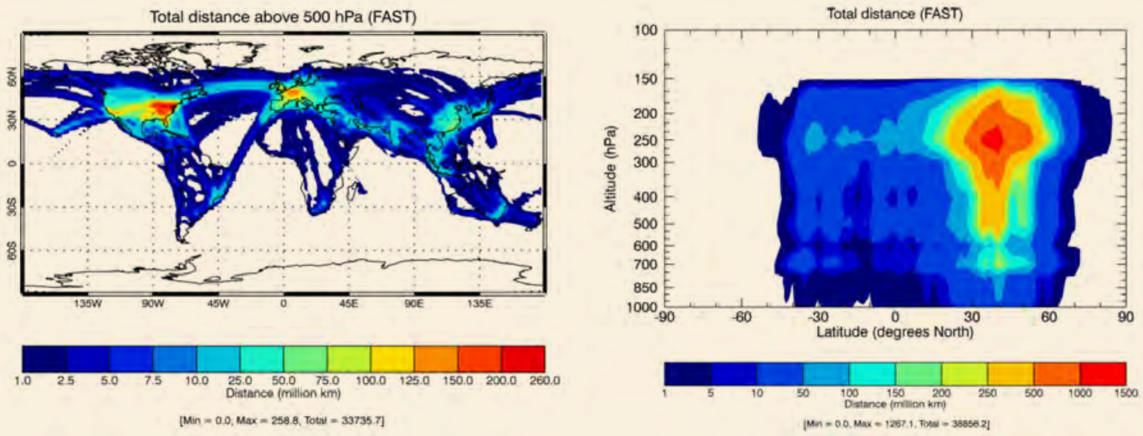

Figure 3. Total distance travelled in the regions where contrails may form (left panel) and distance travelled profile (right panel) for 2006 from the EU FP7 project REACT4C.

EU FP7 PROJECT TEAM_PLAY

TEAM_Play (Tool Suite for Environmental and Economic Aviation Modelling for Policy Analysis) is the EU FP7 Project with the objective of setting up a working tool suite that could be used for policy assessment and strengthening the European modelling capability, and hence ensuring a sustainable growth for the air transport industry when it comes to environmental, social and economic issues. In this project, FAST was used to generate the global aircraft emissions for the year 2006, 2026 and 2050. These global results were used in two experiments by two simple climate models; the first is a pulse emission experiment with the pulse being the 2026 and 2050 CO_2 emissions; and the second a transient experiment where the aircraft and background emissions were assumed to evolve over time. A sample fuel trend from 1940 to 2050 for aviation emissions is illustrated in Figure 4 (left panel) and the resulting CO_2 and non-CO_2 radiative forcing estimates from the simple climate model, LinClim, is depicted in Figure 4 (right panel).

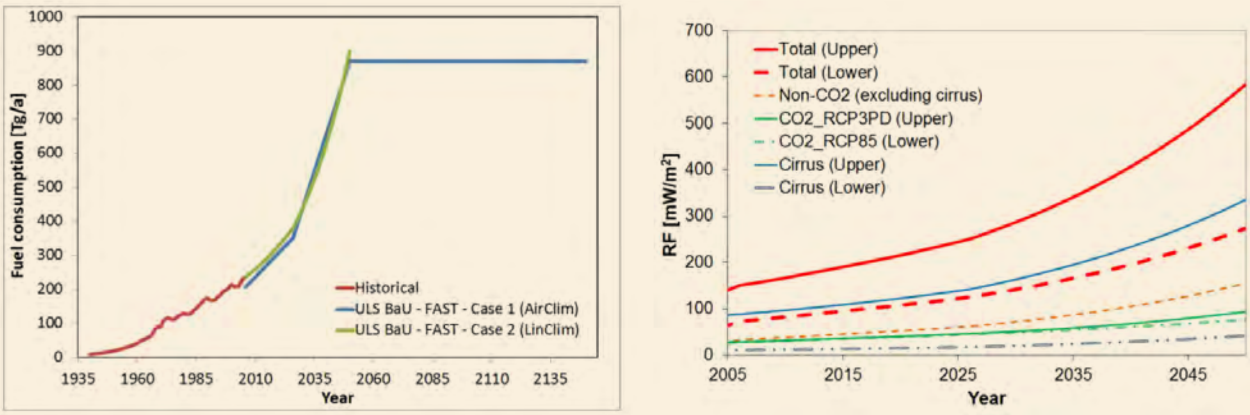

Figure 4. Total annual fuel consumption [Tg/a] from 1940-2005 (Lee et al., 2009) and 2006-2150 for FAST (left panel) and selected RF results from LinClim simulations with FAST input (right panel) from the EU FP7 project TEAM_Play.

SUMMARY

Case studies presented in this paper show the capability of FAST as a modular software that has the capability and robustness to produce output for different applications. It has been validated and verified by the international aviation community and provided diversity to aircraft emissions modelling. It has been used to support studies into the quantification and mitigation of aviation impacts on climate change, taking into account technological and operational options and policy instruments.

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