Project 021 Improving Climate Policy Analysis Tools

Massachusetts Institute of Technology

Project Lead Investigator

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University Participants

Massachusetts Institute of Technology (MIT)

- PIs: Steven R. H. Barrett, Florian Allroggen (co-PI)
- FAA Award Number: 13-C-AJFE-MIT, Amendment Nos. 004, 017, 024, 037, and 042
- Period of Performance: August 1, 2014, to August 31, 2020 (via no-cost extension)
- Tasks for current period (September 1, 2019 to August 31, 2020)
    - No additional funding was provided for the project for this reporting period. All tasks were previously finalized, but outreach was conducted on the following Task:
        1. Derive and publish marginal climate costs per unit of aviation emissions for rapid assessments of emissions interventions

Project Funding Level

FAA provided $600,000 in funding and $600,000 in matching funds were contributed by: approximately $162,000 from MIT, and third-party in-kind contributions of $114,000 from Byogy Renewables, Inc. and $324,000 from Oliver Wyman Group.

Investigation Team

- Prof. Steven R. H. Barrett, PI, MIT (All tasks)
- Dr. Florian Allroggen, co-PI, MIT (All tasks)
- Dr. Raymond Speth, co-investigator, MIT (All tasks)
- Dr. Sebastian Eastham, MIT (All tasks)
- Carla Grobler (PhD student), MIT (All tasks)

Project Overview

The objective of ASCENT Project 21 is to facilitate continued development of climate policy analysis tools that will enable impact assessments for different policy scenarios at the global, zonal, and regional scales and will enable FAA to address its strategic vision on sustainable aviation growth. Following this overall objective, the particular objectives of ASCENT Project 21 are (1) to continue the development of a reduced-order climate model for policy analysis consistent with the latest scientific understanding; and (2) to support FAA analyses of national and global policies as they relate to long-term atmospheric and environmental impacts.

For the current reporting period, no additional funding was provided, and the project team finalized all tasks in previous years. During the current period, the team led additional outreach efforts and finalized the documentation of the project and its results.

Task 1 – Derivation of Marginal Climate Costs Per Unit Aviation Emissions

Massachusetts Institute of Technology

Objectives

Aviation emissions have been found to cause 5% of global anthropogenic radiative forcing (RF) and ~16,000 premature deaths annually due to impaired air quality (Eastham & Barrett, 2016; Lee et al., 2009; Yim et al., 2015). When aiming to reduce these impacts, decision makers often face trade-offs between different emission species or impacts in different times and locations. To inform rational decision-making, the objective of this Task is to compute aviation's marginal climate and air quality impacts per tonne of species emitted during different flight stages and by emission location. This Task has been completed in collaboration with ASCENT Project 20.

Research Approach

The research approach involves applying Aviation environmental Portfolio Management Tool - Impacts Climate (APMT-IC) to calculate costs for full flight emissions by running APMT-IC for an emissions pulse in 2015. Impacts per unit of precursor emissions are derived by normalizing each of the short-lived forcers by its respective precursor emissions.

Full flight results are computed using APMT-IC and landing and takeoff (LTO) and cruise impacts are obtained by modifying the LTO and cruise RF per unit of fuel burn. LTO RF results are based on the global warming potential values for ground emissions from the Intergovernmental Panel on Climate Change (IPCC) report (Myhre et al., 2013), whereas cruise radiative impacts are calculated as the difference between the Aviation Climate Change Research Initiative (ACCRI) (Brasseur et al., 2016) full flight radiative impacts and the LTO results. Climate results are derived for discount rates ranging from 2% to 7%.

A detailed description of the research approach can be found in the publication (see below).

Milestones

Results were derived as described above. The journal paper was prepared and submitted to *Environmental Research Letters*, where it was reviewed, accepted, and published (Grobler et al., 2019).

Major Accomplishments

Results were successfully derived using APMT-IC. Our results indicate that three components are responsible for 97% of climate and air quality damages per unit fuel burn, with individual contributions of NO_x at 58%, CO_2 at 25%, and contrails at 14%. Air quality impacts account for 64% of total impacts. A sensitivity study was conducted to find the contribution of each of the uncertain Monte Carlo input variables to the observed output variance. We found uncertainty in the climate sensitivity and the Dynamic Integrated Climate-Economy model (DICE) damage function to be the largest drivers in the output uncertainty.

This work was submitted and published in *Environmental Research Letters*.

Publications

Peer-reviewed journal publications:

Grobler, C., Wolfe, P.J., Dasadhikari, K., Dedoussi, I.C., Allroggen, F., Speth, R.L., Eastham, S.D., Agarwal, A., Staples, M.D., Sabnis, J. & Barrett, S.R.H. (2019). Marginal climate and air quality costs of aviation emissions. *Environmental Research Letters*, 14 114031, https://doi.org/10.1088/1748-9326/ab4942

Outreach Efforts

Presentations:

- A summary of the paper approach and results were presented to the FAA (November 2019).
- Presented at Aerospace Europe conference in Bordeaux in February 2020.
- Presented at the Fall ASCENT Meeting (September 2020).

FAA funding was acknowledged in all presentations.

Student Involvement

The outreach activities were completed by Carla Grobler (PhD student, MIT).

Awards

Carla Grobler received the ASCENT Joseph Hartman best paper award.

Plans for Next Period

There are no further research plans under this project. The project has ended.

References

Brasseur, G.P., Gupta, M., Anderson, B.E., Balasubramanian, S., Barrett, S., Duda, D., Fleming, G., Forster, P.M., Fuglestvedt, J., Gettelman, A. & Halthore, R.N. (2016). Impact of aviation on climate: FAA's aviation climate change research initiative (ACCRI) phase ii. *Bulletin of the American Meteorological Society*. 97(4), pp.561-583

Eastham, S.D. & Barrett, S.R.H. (2016). Aviation-attributable ozone as a driver for changes in mortality related to air quality and skin cancer. Atmospheric Environment. 144 17–23

Lee, D.S., Fahey, D.W., Forster, P.M., Newton, P.J., Wit, R.C.N., Lim, L.L., Owen, B., & Sausen, R. (2009). Aviation and global climate change in the 21st century. *Atmospheric Environment*, 43 3520–37, http://dx.doi.org/10.1016/j.atmosenv.2009.04.024

Myhre, G., Shindell, D., Bréon, F., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Lamarque, J., Lee, D., Mendoza, B., Nakajima, T., Robock, A., Stephens, G., Takemura, T., & Zhang, H. (2013). Anthropogenic and natural radiative forcing. Contribution of Working Group I Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P.M. (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press] https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Chapter08_FINAL.pdf.

Yim, S.H.L., Lee, G.L., Lee, I.H., Allroggen, F., Ashok, A., Caiazzo, F., Eastham, S.D., Malina, R. & Barrett, S.R.H. (2015). Global, regional and local health impacts of civil aviation emissions. *Environmental Research Letters*, 10 034001