ASCENT 021 Improving Climate Policy Analysis Tools

Project Lead Investigator

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- Tasks:
    1. Preparation of APMT-Impacts Climate Version 24 development
    2. Investigation of contrail and contrail-cirrus in aviation climate models
    3. Support FAA analyses of national and global policies with relation to climate change and environmental impacts
    4. Support knowledge transfer

Project Funding Level

$450,000 FAA funding and $450,000 matching funds. Sources of match are approximately $120,000 from MIT, plus 3rd party in-kind contributions of $114,000 from Byogy Renewables, Inc. and $216,000 from Oliver Wyman Group.

Investigation Team

Dr. Steven R. H. Barrett, Principal Investigator
Dr. Robert Malina, Project Management and Alternative Fuel Expert
Dr. Raymond Speth
Dr. Florian Allroggen, since October 2016
Dr. Philip Wolfe, Tasks 1, 3 and 4
Lawrence Wong, Task 2
Carla Grobler, Task 1, since September 2016

Project Overview

The objective of ASCENT Project 2014-21 is to facilitate continued development of climate policy analysis tools that will enable climate impact assessments for different policy scenarios at 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 2014-21 are (1) to continue the development of a reduced-order climate model for policy analysis consistent with the latest literature and scientific understanding; and (2) to support FAA analyses of national and global policies as they relate to climate change and environmental impacts.

In the current reporting period, these objectives have been addressed through (i) preparing the development of the version 24 code of APMT-Impacts Climate to replace APMT-Impacts Climate version 23; (ii) investigating the role of contrail and contrail-cirrus in aviation climate models through exploring the physical and chemical mechanisms of contrail formation and aviation-induced cloudiness; (iii) supporting FAA analyses of national and global policies, such as the preparation of the aircraft CO_2 standard for the ICAO CAEP/10 meeting in February 2016; and (iv) facilitating knowledge transfer to FAA-AEE and other research groups.

Task 1 – Preparation of APMT-Impacts Climate Version 24 development

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Objectives

The ASCENT 21 work aimed at preparing the development of APMT-Impacts Climate Version 24 to replace the year-2015 operational version. This work is needed to reflect the most recent scientific consensus in APMT-Impacts Climate. The main objectives under Task 1 are threefold.

1.1 FAA's Aviation Climate Change Research Initiative (ACCRI) Phase II has identified significant climate responses from tropospheric nitrate impacts and stratospheric water vapor impacts (Lee et al., 2009). Version 24 is prepared to assess the impacts of these forcers and the uncertainties linked to these impacts.

1.2 After evaluating APMT-Impacts Climate with the Office of Management and Budget (OMB), APMT-Impacts Climate is supposed to be amended to produce output which is consistent with the results from the Interagency Working Group (IAWG)'s Social Cost of Carbon (SCC).

1.3 For APMT-Impacts Climate Version 24, other metrics and distributions such as atmospheric CO_2 concentrations, climate sensitivity distributions, and measures of inflation will be updated to reflect the most recent scientific consensus in the model.

Research Approach and Accomplishments

To effectively model aviation's impact on the environment for policy analyses, fast, efficient, and robust tools are needed. Therefore, the APMT-Impacts Climate Model was developed as a reduced-order model to probabilistically project aviation's impact on climate using both physical and monetary impact metrics. The APMT-Impacts Climate Module adopts the impulse response approach (Hasselmann et al., 1997; Sausen and Schumann, 2000; Shine et al., 2005). The effects modeled include long-lived CO_2, the intermediate-lived impact of NO_x on methane (NO_x-CH_4) and its associated primary mode interaction on ozone (NO_x-O_3 long), the short-lived effects of NO_x on ozone (NO_x-O_3 short), the production of aviation induced cloudiness, sulfates, soot, and H_2O. A detailed description of past versions of APMT-Impacts Climate can be found in Marais et al. (2010), Mahashabde et al. (2011) and Wolfe (2012).

APMT-Impacts Climate is supposed to provide estimates of radiative forcing, temperature change, and climate damages from all aviation short-lived climate forcers for which there is appropriate scientific consensus. Following Lee et al. (2009), these forcers should include black carbon, tropospheric water vapor, short-lived ozone production from NO_x, longer-lived methane and ozone destruction from NO_x feedbacks, sulfates, and direct production of aviation-induced cloudiness. As long-term (long-lived) ozone change is already incorporated in APMT-Impacts Climate and indirect effects of soot and sulfate are discussed through aviation-induced cloudiness, the impacts of aviation nitrates, stratospheric water vapor, and aviation black carbon have been identified to be included in APMT-Impacts Climate Version 24.

Based on feedback from the OMB, the ASCENT 21 team has included the IAWG's Social Cost of Carbon (SCC) into APMT-Impacts Climate. In doing so, the standard APMT-Impacts Climate output routinely allows for direct comparison of its results to the SCC results. To account for aviation's non-CO_2 climate impacts, further steps towards computing derived ratios have been initiated. These metrics provide an estimate for the ratio of non-CO_2 to CO_2 impacts for different endpoint metrics such as Global Warming Potential (GWP), Integrated Temperature Potential or Net Present Value of damages.

In order to reflect the most recent scientific consensus in APMT-Impacts Climate, further updates to APMT-Impacts Climate have been identified. For example, climate sensitivity distributions as discussed by Roe and Baker (2007) will be considered to improve consistency with computation of the IAWG SCC values. Furthermore, predicted data, such as atmospheric CO_2 concentrations and measures of inflation will be updated.

Milestones

The first milestone surpassed this year under Task 1 of ASCENT-2014-21 was to prepare a draft of the Requirements Document for the Development of APMT-Impacts Climate Version 24. This milestone was achieved in February 2016. FAA-AEE has provided feedback to this document during the year. The planned development of APMT-Impacts Climate Version 24 has not been completed due to pending final approval of the document. A drafted framework version for use by the developers has been prepared and will continue to be revised as the Requirements Document is finalized.

For the other milestones under Task 1, including model evaluation and inter-comparisons, FAA and LAE have agreed to replace this work with model outreach for APMT-Impacts Climate and with running APMT-Impacts Climate for the evaluation of a potential CO_2 standard. In particular, this included briefings of the OMB for evaluating APMT-Impacts Climate, which has further informed the requirements for developing APMT-Impacts Climate Version 24. These additional milestones, which had not been included into the proposal, have been accomplished as agreed between FAA and LAE.

Publications

Reports

Wolfe, P., Barrett, S. R. H., Wong, L. M. K., Jacob, S. D. (2016). Requirements Document for Future Iterations of the Aviation Environmental Portfolio Management Tool – Impacts Climate Model, Laboratory of Aviation and the Environment

Peer-reviewed literature

Brasseur, et al. (2016). Impact of Aviation on Climate: FAA's Aviation Climate Change Research Initiative (ACCRI) Phase II. BAMS. 2016.

Outreach Efforts

- ASCENT advisory board presentation/poster (Fall 2015, Spring 2016, and Fall 2016)
- AGU Conference: Aviation Panel Attendance (Fall 2015)
- Office of Management and Budget Briefing (Winter 2015/2016)

Student Involvement

Under Task 1, *Dr. Philip Wolfe* has focused his work on scoping the development of APMT-Impacts Climate Version 24. Philip Wolfe graduated in September 2015 and accepted a post-doctoral research position through the MIT Department of Aeronautics and Astronautics.

Carla Grobler (Ph.D. Student, MIT) has started working on APMT-Impacts Climate in September 2016. Her primary work focuses on APMT-Impacts Climate Version 24 development and validation, and on applying the model for analyzing derived ratios and for conducting policy analyses.

Plans for Next Period

In the next year, we will further enhance FAA's capabilities to perform rapid environmental policy assessment by developing APMT-Impacts Climate Version 24, and by performing verification and validation of the new model. Furthermore, we will perform code sensitivity and uncertainty analyses, capturing multiple years of model development since the last sensitivity analysis.

Second, we will develop and validate a supplemental module that would replicate models used in US Regulatory Impact Assessments. Under the guidance of the OMB, the IAWG has promulgated guidance for incorporating external costs of direct CO_2 and methane emissions in domestic Regulatory Impact Analyses. As part of APMT-Impacts Climate v24 updates, estimates of social damages from CO_2 emissions using IAWG numbers will permanently be included in the APMT-Impacts Climate outputs. To further account for the non-CO2 impacts, we will compute derived ratios which provide an estimate for the ratio of aviation's non-CO_2 to CO_2 climate impacts.

Task 2 – Investigation of contrail and contrail-cirrus in aviation climate models

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Objectives

Aviation-induced contrail and contrail-cirrus, referred to as aviation-induced cloudiness (AIC), has been found to potentially be the largest radiative forcing impact of aviation (Lee et al., 2009; Burkhardt and Kärcher, 2011). At the same time, AIC is one of the most uncertain environmental impacts of aviation (Burkhardt et al., 2011). Recent work from ACCRI Phase II has better constrained the current climate-related uncertainty from aviation-induced cloudiness. However, further work is needed to understand the role of AIC on the climate, and the impact of modeling assumptions on temperature and damage projections. The objective of this research is to explore the physical and chemical mechanisms of contrail formation and aviation-induced cloudiness. This leads to threefold objectives for ASCENT 21 under Task 2.

2.1 Apply and support the extension of a 3D contrail model, which has been used for the US and, more recently, for the global domain, as a tool to facilitate the development of a reduced-order contrail model
2.2 Support the extension of the contrail model, e.g. the development of a novel computation scheme for sub-grid variation in ice supersaturation
2.3 Explore published satellite contrail observations data to use the data for validation of the contrail code

Research Approach and Accomplishments

Under the ASCENT Project 21 project, the ASCENT 21 team has investigated the significance of contrail and contrail-cirrus to aviation climate models. More specifically, the Contrail Evolution and Radiation Model (CERM), a physically realistic 3D model of dynamical and microphysical processes from the jet phase at contrail formation to the diffusion phase as contrail-cirrus (Caiazzo, 2015), has been applied to explore the physical and chemical mechanisms of contrail formation and aviation-induced cloudiness.

In particular, the ASCENT 21 team has been trained to use CERM and supported the extension of CERM from the US domain to the global domain. This model, once validated, will be used to facilitate the development of a reduced-order model to estimate climate impacts from global contrail and contrail-cirrus in the future. Furthermore, the ASCENT 21 team has supported the development of a novel computation scheme to assess sub-grid variation in ice supersaturation in CERM. This novel scheme uses a fine set of reanalyzed meteorological data coupled with a probability density function approach to estimate the proportion of a cell that is expected to be supersaturated and to drive contrail formation and growth.

Lastly, to validate the contrail code and to further constrain the uncertainty of contrail- and contrail-cirrus-induced climate impacts, a comparison of contrail coverage, and microphysical properties between CERM-modeled results and satellite observation for the northern hemisphere was initiated. The work has been aiming to develop an extensive comparison study between observed and simulated contrails in the northern hemisphere.

Milestones

Under Task 2 of ASCENT-2014-21, the research team delivered a comprehensive status update on modelling aviation cloudiness and contrails in Spring 2016.

Publications

Peer-reviewed literature

Brasseur, et al. (2016). Impact of Aviation on Climate: FAA's Aviation Climate Change Research Initiative (ACCRI) Phase II. BAMS. 2016.

Outreach Efforts

ASCENT advisory board presentation (Spring 2016)

Student Involvement

Lawrence Wong (Ph.D. Student, MIT) has led research on contrail and aviation-induced cirrus for ASCENT Project 21. His research is in exploring the physical and chemical mechanisms of contrail formation and aviation-induced cloudiness in the present and under future conditions.

Plans for Next Period

We will continue investigating the role of contrail and contrail-cirrus in aviation climate models. We will improve modeling of climate impacts of contrails and aviation-induced cirrus in CERM, focusing on the validation of CERM with satellite observation data and improving our understanding of non-linearities in contrail formation. The latter analyses are highly significant since, for instance, the growth of aviation in high traffic corridors may lead to saturation and newer engine technology changes the critical temperature for contrail formation. Ultimately, this work will allow for more robust assessments of the climate impact from contrails and contrail-cirrus in a reduced-order model such APMT-Impacts Climate.

Task 3 – Support FAA analyses of national and global policies with relation to climate change and environmental impacts

Massachusetts Institute of Technology

Objectives

APMT-Impacts Climate has become a powerful rapid assessment tool for aviation climate impact assessments at the FAA. Thus, it is routinely used for analyses of national and global policies affecting aviation, such as for analyses in preparation of the ICAO CAEP/8, and ICAO-CAEP/9 meetings. In the current reporting period, the ASCENT 21 project has supported policy analyses for negotiating a potential CO_2 standard in preparation of the ICAO CAEP/10 meeting in February 2016.

Research Approach and Accomplishments

The APMT-Impacts Climate tool has been adapted and applied for conducting impact assessments of aviation-related policies. For example, Mahashabde et al. (2011) used the APMT-Impacts Climate tool to study the impacts and social costs of a NO_x emissions standard and Wolfe et al. (2014) applied APMT-Impacts Climate to investigate the distribution of aviation environmental costs. The results were included as technical appendices to US Information Papers at ICAO-CAEP meetings (CAEP/8 and CAEP/9).

As part of this year's work on ASCENT 21, the team provided modeling and technical support to the CAEP analysis of a CO_2 standard for CAEP/10, particularly in modeling short-lived climate forcers, in developing scientific and economic lenses, and in investigating climate-noise trade-offs and co-benefits. Furthermore, the ASCENT 21 team has supported the analysis of a CO_2 standard through usability updates to APMT-Impacts and setting up more than 100 policy scenario runs of APMT-Impacts Climate and Noise. The results have been presented as part of two US Information Papers at the 10th meeting of ICAO CAEP and has been presented to the Office of Management and Budget.

Milestones

Under Task 3 of ASCENT 2014-21, no milestones had been planned. However, FAA and LAE have agreed to replace milestones on APMT-Impacts Climate model evaluation and inter-comparisons with model outreach and with running APMT-Impacts Climate for the evaluation of a potential CO_2 standard. Besides briefings of the OMB for evaluating APMT-Impacts Climate (see Task 1), the ASCENT 21 team has been asked to support the ASCENT 14 team, which needed to apply APMT-Impacts Climate and Noise for the analysis of a CO_2 standard in preparation of the CAEP/10 meeting. These additional milestones have been accomplished as agreed between FAA and LAE

Publications

Reports

Brenner, M., Yutko, B., Wolfe, P., Dedoussi. I., et al. (2015): US cost-benefit analysis of ICAO CO_2 standard stringency options. ICAO CAEP Information paper.

Outreach Efforts

- AGU Conference: Aviation Panel Attendance (Fall 2015)
- Office of Management and Budget Briefing (Winter 2015/2016)
- ICAO CAEP Meeting: The climate code methodology and current valuation techniques were presented as part of a review of cost-benefit tools (Spring 2016)

Student Involvement

Under Task 3, Dr. Philip Wolfe provided input to the Policy Assessments.

Plans for Next Period

We will continue to support FAA analyses of national and global policies as they relate to climate change and environmental impacts. ICAO CAEP is currently considering the introduction of a nvPM-emission standard for international aviation, for which air quality impacts will be a definite cost/benefit driver, and for which there may be trade-offs or co-benefits in climate. Efforts will be required from the ASCENT 21 team to assist with the application of the tool in the CAEP nvPM standard evaluation, to ensure that the input and outputs are handled correctly, the assumptions are clearly stated, that assumptions on nvPM emissions are aligned with air quality tools, and that the outputs are correctly interpreted.

Task 4 – Support knowledge transfer
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Objectives
Through transferring APMT-Impacts Climate knowledge to FAA and other research groups, the application of a standardized assessment tool for aviation's climate impacts is encouraged.

Research Approach and Accomplishments
Transferring APMT-Impacts Climate knowledge to FAA and other research groups has been regarded as an enabler for the application of APMT-Impacts Climate for policy analyses. In the current year, knowledge transfer was conducted on the basis of the training modules developed for FAA knowledge transfer. With UIUC, climate code capabilities were taught for future code review; new researchers on the ASCENT 21 project were trained; and ASCENT 48 researchers were coached to apply APMT-Impacts Climate for assessing a potential nvPM aircraft engine standard.

Milestones
Training has been provided to researchers as needed, including the following sessions:
- FAA Tools Training on APMT-Impacts Climate (Fall 2015)
- Tools Training for UIUC to teach and review Climate Code Capabilities (Spring 2016)
- Tools Training for new ASCENT 21 researchers (Fall 2016)
- Tools Training for ASCENT 48 researchers to teach APMT-I Climate Capabilities for policy analysis (Fall 2016)

Student Involvement
Dr. Philip Wolfe has used his multi-year APMT-Impacts Climate experience from being the primary developer of the code for the knowledge transfer.

Plans for Next Period
The ASCENT 21 team will provide APMT-Impacts Climate Coaching as requested. In addition, once the Version 24 code is validated, the team will transfer operational capabilities to FAA-AEE.

References

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Wolfe, P., et al. (2014). Near-airport distribution of the environmental costs of aviation. *Transport Policy* 34, 102-108.