Airlines for America®

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April 2024

Addressing Non-CO_2 Emissions from Aviation

Airlines for America® (A4A)[1] and our members are committed to addressing climate change and working to achieve net-zero carbon emissions by 2050. U.S. airlines have dramatically improved fuel efficiency and reduced emissions by investing billions in fuel-saving aircraft and engines, innovative new technologies, cutting-edge route optimization software and sustainable aviation fuels (SAF). As a result, U.S. airlines have improved their fuel efficiency over 145% since 1978, saving over 5.9 billion metric tons of carbon dioxide (CO_2), which is equivalent to taking more than 29 million cars off the road every year for over 40 years.

A4A's commitment to climate and sustainability includes improving the understanding and addressing the climate impact of non-CO_2 emissions. While CO_2 is the only significant greenhouse gas emitted from aircraft, other non-CO_2 impacts from aviation, including from the formation of contrails, also affect climate.

Summary of the Science Behind Non-CO_2 Climate Impact

Aircraft engines emit more than just CO_2 – including water vapor, carbon monoxide, nitrogen oxides (NO_x), sulfur oxides, hydrocarbons, and particulate matter. The aviation sector has addressed the local air quality impacts from these emissions through technology standards, with emission standards set by the International Civil Aviation Organization (ICAO) and enacted by the U.S. Environmental Protection Agency (EPA) for NO_x, hydrocarbons, and non-volatile particulate matter (nvPM). In addition to local air quality impacts, science has shown that these emissions can have impacts on our climate when emitted at cruising altitude.

Contrails are trails of water vapor emitted from aircraft engines that condense and freeze around suspended particles at high altitude under certain atmospheric conditions. As can be observed when looking up at airplanes in the sky, contrails are not formed on all flights, and instead only when certain atmospheric conditions, including temperature and humidity levels, are present. Research suggests that aviation-induced cloudiness, or cirrus clouds caused by persistent contrails from aircraft, is estimated to be the largest contributor to warming by non-CO_2 emissions, but with large uncertainties in the magnitude of the warming. Some of these emissions lead to positive effective radiative forcing (ERF) (i.e. warming), and others leading to negative ERF (i.e. cooling), and chemical interactions involving pollutants leading to unknown

[1] A4A is the principal trade and service organization of the U.S. airline industry. A4A's members are: Alaska Air Group, Inc.; American Airlines Group, Inc.; Atlas Air Worldwide Holdings, Inc.; Delta Air Lines, Inc.; FedEx Corp.; Hawaiian Airlines; JetBlue Airways Corp.; Southwest Airlines Co.; United Airlines Holdings, Inc.; and United Parcel Service Co. Air Canada, Inc. is an associate member.

responses.[2] Despite some overly precise claims about the level of warming caused by contrails, current scientific understanding has a wide range of uncertainty regarding the overall warming associated with contrails – ranging from 0.5- to 3-times the average ERF of CO_2. A4A recognizes that contrails have an overall warming effect and supports action to address contrail-related warming, including further research to reduce scientific uncertainty.

Areas of Research and Investigation

The aviation sector, governments, academic institutions, and research organizations are actively undertaking research to improve understanding of and reduce uncertainty around contrail-related warming. The research initiatives can be characterized into two main areas: 1) understanding potential impacts and improving scientific knowledge; and 2) exploring potential options to mitigate contrails.

1. **Understanding Warming Impacts of Contrails**

Contrail formation and climate effects – Further research is needed to improve understanding of the warming and cooling effects of contrails, including the climate impact relative to CO_2 emissions and to reduce the current levels of uncertainty. Additional research is needed to better understand the atmospheric conditions, locations and times of day and year that are most conducive to contrail formation. While it is likely that there will be continued uncertainty and gaps in knowledge due to the complexities of modeling atmospheric climate changes, it is critical to prioritize improved understanding as it should form the basis of any actions, policies or decisions related to mitigating contrails.

Contrail observation, prediction, and verification – Additional weather data and improved modeling capabilities are essential to accurately observe and predict contrail formation. Weather data, especially for humidity, is vital to inform and improve weather, climate, and contrail prediction models. Additional observational data, including from a new generation of meteorological sensors, is needed to identify contrail formation and the type (warming or cooling). This data, along with improved modeling capabilities, will be fundamental to be able to accurately identify when and where contrails form, noting that present contrail prediction models may be overestimating persistent contrail formation.[3] The currently available contrail observation data and prediction tools do not provide an adequate basis for implementing new policies or actions for mitigating contrails. In fact, attempting to mitigate contrail formation based on currently available data and tools could lead to increased CO_2 emissions with long-lasting warming effects with a low confidence of mitigating warming contrails.

2. **Potential Contrail Mitigation Options**

The second area of research and investigation is to explore potential options for reducing or mitigating the warming impact of non-CO_2 emissions. The aviation sector is supporting efforts to evaluate the potential for changing flight paths (navigational avoidance) to reduce contrail-

[2] See https://doi.org/10.1039/d3ea00091e

[3] See https://doi.org/10.1088/1748-9326/ac38d9

related warming, to understand whether SAF can reduce contrails and to develop new aircraft and engine technologies.

Navigational avoidance/operational changes – One area of active investigation is whether flight paths can be adjusted to avoid contrail formation, and several airlines have undertaken flight trials to assess the real-world potential for avoiding contrails. To date, research and flight trials have shown that contrails can be avoided by adjusting the flight path of an individual flight, but the existing limitations in the ability to predict and confirm contrail formation are not yet reliable enough to avoid contrails with confidence.

Continued research and assessment of navigational avoidance, alongside improved scientific understanding and prediction capabilities, are critical. At the same time, it is essential to distinguish between near-term research and assessment activities and future implementation of operational changes on a widespread scale to avoid contrails.

There are many challenges to address before pursuing navigational avoidance at scale, including addressing safety considerations, reducing uncertainty related to contrail warming, avoiding tradeoffs associated with emitting more CO_2 and increasing confidence in predicting and observing contrail formation. Extensive cross-industry collaboration, with government regulators and air navigation service providers, will be necessary to identify limitations and constraints to potential avoidance operations on the entire air traffic network.

Sustainable aviation fuels – There has been research assessing the impact that SAF use has on contrail formation. Most types of SAF have lower levels of aromatic hydrocarbons compared to conventional jet fuel which, when burned, reduces the number of particles for the emitted water vapor to condense and freeze upon. One study suggests, "meaningful reductions in aviation's climate impact could therefore be obtained from the widespread adoption of low aromatic fuels, and from regulations to lower the maximum aromatic fuel content."[4] But this is just one data point. Further research is needed on the potential of SAF and other low aromatic jet fuels as a contrail mitigation tool once we have widespread availability.

Aircraft and engine technology – There are questions of whether new aircraft engine technologies could be developed to lower emissions, such as NO_x and nvPM. Governments should continue to fund research to develop and evaluate aircraft and engine technologies and fuels that balance reductions in CO_2 and non-CO_2 emissions. A4A will continue to support the U.S. government's Aviation Sustainability Center and Continuous Lower Energy, Emissions, and Noise programs that bring together academia and the aviation industry to answer research questions, including to help fill in non-CO_2 knowledge gaps. Understanding the tradeoffs between CO_2 and non-CO_2 emissions in new engine technologies is also important as ICAO looks to strengthen existing emission standards.

[4] See https://doi.org/10.1038/s43247-021-00174-y

A4A member airlines are working with other stakeholders on the following initiatives:

- Air Canada and Hawaiian Airlines through the In-Service Aircraft for a Global Observing System (IAGOS)[5] – instrumented long-haul aircraft to measure atmospheric composition, including humidity.
- American Airlines with Breakthrough Energy and Google Research[6] - testing whether it is possible to identify ISSRs and determine whether pilots could avoid contrail formation in flight when supplied with ISSR prediction data.
- Delta Air Lines with the Massachusetts Institute of Technology (MIT) Laboratory for Aviation and the Environment[7] - building tools to predict contrail forming regions and experimentally validate contrail avoidance and resulting environmental impact, thus informing possible operational mitigation tools and technology.
- Southwest Airlines with General Electric (GE) Research[8] - developing a real-time, in-flight prediction system for persistent contrails lasting more than five hours. Also with Google Research, conducting a series of desktop trials with Google's contrail prediction model to evaluate alternatives to planned routes that would have created contrails.
- United Airlines with Boeing, NASA, DLR, FAA, and GE Aerospace[9] - conducting test flights to measure how SAF affects contrails and non-CO_2 emissions.

A4A's Approach to Addressing Non-CO_2 Climate Impact

A4A advocates for a data-driven, fact-based approach to addressing the climate impact of non-CO_2 emissions from aviation. Priority should be placed on understanding climate science, reducing uncertainties, identifying knowledge gaps, addressing those gaps and evaluating the options for reducing contrail-related warming. We are committed to these efforts.

We support:

- Further research, including additional federal academic funding, to improve understanding of the warming and cooling effects of contrails and to reduce the current levels of uncertainty related to the warming effect. It is imperative that to understand the warming effect relative to CO_2. We must avoid premature actions that may have unintended warming consequences, particularly given the long lifetime of CO_2 in the atmosphere.

- Efforts to improve prediction and observation of contrails through additional weather data, particularly for humidity, and improved modeling capabilities. This must be a

[5] See https://www.iagos.org

[6] See https://news.aa.com/news/news-details/2023/American-Airlines-participates-in-first-of-its-kind-research-on-contrail-avoidance-CORP-OTH-08/default.aspx

[7] See https://news.delta.com/deltas-latest-climate-collaboration-tackles-warming-contrails-mit

[8] See https://arpa-e.energy.gov/technologies/exploratory-topics/aviation-contrails

[9] See https://www.boeing.com/features/2023/12/737-10-dc-8-team-up-to-test-sustainable-fuel

collaborative effort that includes funding for technology development and sensor installation, cooperation from airlines to install humidity sensors and public/private partnership—even citizen science—on model validation.

- Research initiatives and studies to evaluate potential measures to mitigate non-CO_2 and contrail-related warming, including the potential for navigational avoidance (especially at scale), reduced contrails from SAF and new aircraft and engine technologies.

- Ensuring that efforts to address contrails are based on consensus scientific understanding and consider potential environmental tradeoffs (including CO_2 as a long-lived greenhouse gas), safety and economic impacts. These efforts must focus on understanding impacts at scale. A4A calls on governments to coordinate and collaborate across agencies and with aviation stakeholders to evaluate environmental tradeoffs, safety, and economics.

- Avoiding premature regulatory approaches that are not substantiated by scientific understanding or evidence but lead to increased fuel burn, CO_2 emissions, costs, and regulatory burden on the aviation sector. Further, countries and regions should avoid unilateral regulatory approaches to addressing international aviation operations.