Leveraging environment footprint reduction in operations, including non-CO_2

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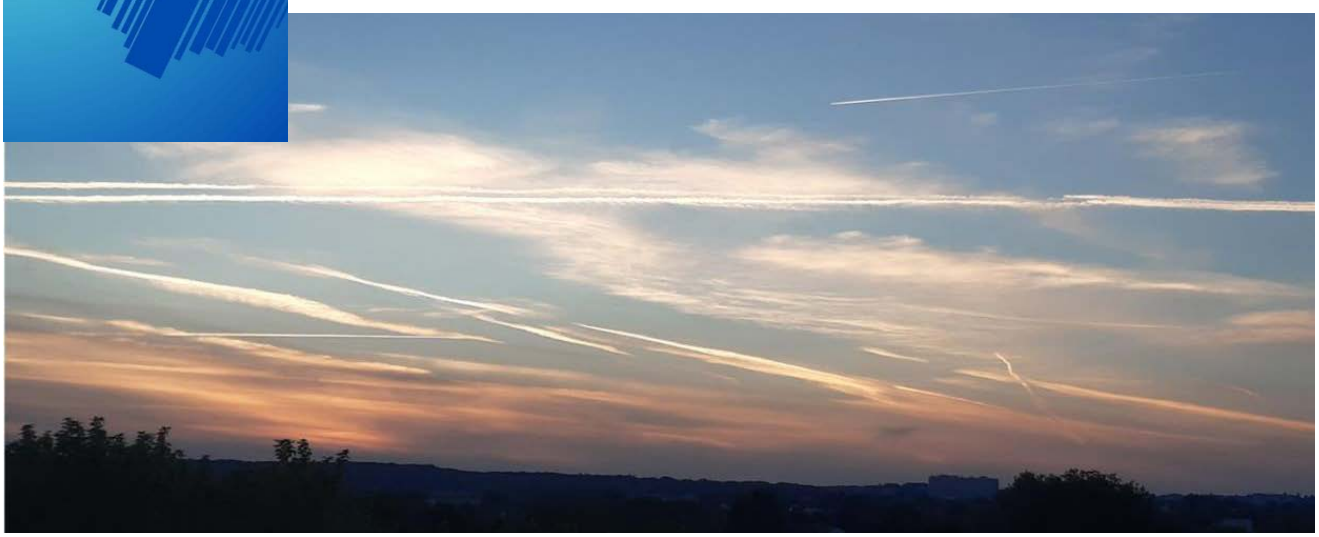

The state-of-the-art scientific assessment of Lee et al, 2021[1] estimated that aviation represented about 3.5% of total anthropogenic Effective Radiative Forcing (ERF) in 2018, and that non-CO_2 emissions accounted for about two thirds of that aviation-attributable impact. However, it also points out that the uncertainties around the contribution of non-CO_2 emissions on aviation's ERF are around eight times higher than those related to CO_2 emissions.

Optimising individual flight trajectories with a climate objective has long been proposed as a potentially effective way to reduce the climate impact of some non-CO_2 emissions. This is particularly true with respect to contrails, whose formation, evolution into cirrus clouds and ultimately climate impact, depend largely on the local weather conditions and hence on flight trajectory. To a lower extent, this is also true with respect to NO_x, the impact of which varies with time and location of emissions.

1 Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., Doherty, S. J., Freeman, S., Forster, P. M., Fuglestvedt, J., Gettelman, A., De León, R. R., Lim, L. L., Lund, M. T., Millar, R. J., Owen, B., Penner, J. E., Pitari, G., Prather, M. J., Sausen, R. and Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmos. Env., 244, 1–29.

Addressing flight operations is obviously a question of inclusion of all involved stakeholders and collaboration. That is Airbus's ambition with CICONIA, a SESAR3 project launched in 2023 and due to complete in 2026.

CICONIA focuses on improving the understanding of the non-CO_2 effects of aircraft, and in particular of persistent contrails, in real en-route operating conditions, how they can be measured and how they can be considered in more efficient operational schemes, engaging a representative sample of all concerned stakeholders as project partners: universities and research centres (DLR, ONERA, Imperial College of London, UPC, NLR, ENAC, Breakthrough Energy), MET providers (METEO FRANCE, IAGOS), aircraft manufacturers (AIRBUS and BOEING), airlines including their pilots and their dispatchers in Operational Control Centre (OCC) (AIR FRANCE, SWISS, EASYJET), the Network Manager (NM) and Air Navigation Service Providers (ANSP) (NATS, DSNA) and their air traffic controllers.

CICONIA's goal is to support the development of environmentally effective, economically balanced, and operationally viable mitigation measures from the short to medium term. CICONIA aims to develop solutions to prepare the overall ecosystem (including aircraft, ATC systems, weather etc.) to operate in this context.

Our top three challenges are:

1. **To improve weather forecasting capabilities, including persistent contrail regions, tailored for operational mitigation concepts.**

As usual in meteorology, forecast reliability depends on the quality and density of the observations fed into the numerical model. CICONIA is evaluating these observation means, including aircraft measurement with IAGOS and Airbus aircraft, pilot observation reports with the Air France COOP program, and satellite images, lidars and ground based cameras with Airbus Defense and Space, ONERA, Meteo France, EUROCONTROL and Imperial College. The added value and requirements for new and complementary sources of information data like aircraft humidity sensing will be further defined.

An important aspect is to incorporate the level of confidence of the forecast – which can never be absolute – into operational decision-making. This is managed using ensemble forecast methodology, which consists of providing multiple distributions of the calculated forecast, based on variations of the input parameters around their uncertainty range. Sometimes, or in certain areas, the distribution of the ensemble is very narrow, raising the confidence in the forecast, and at other times, the results are less convergent, lowering the probability. Providing that confidence level together with the forecast itself enables a more informed decision making, something that CICONIA is exploring.

2. **To improve climate impact assessments tailored for operational mitigation concepts, at aircraft trajectory level and larger-scale traffic, and define a quality-controlled climate-oriented MET service.**

Predicting where contrails can form and persist is a paramount input, but is not sufficient to determine how strong their warming (or cooling) impact is. Furthermore, a true climate-optimised flight trajectory must take into account all climate forcers: contrails, but also other contributors, including NO_x, H_2O and of course, CO_2 emissions.

To deliver a usable climate impact assessment, a Climate MET service requires several inputs and sub-models, on top of weather forecast. Thanks to simulation work within CICONIA, we are testing their importance and usability, for example:

- Accurate aircraft and engine performance models, and how emissions evolve during the flight (aircraft and engine type, mass, fuel burn, CO_2, H_2O, NO_x, propulsion efficiency, particles) and how the fuel composition may affect some of them. In CICONIA, we are using and evaluating EUROCONTROL BADA and Poll-Schumann models, and comparing the results with Airbus and Boeing Flight Management System (FMS).
- We also need models about how aircraft emissions generate contrails and NO_x effects. To be as complete as possible, we use the CoCiP[2] model (contrail cirrus prediction model that covers the radiative effect of

2 Schumann, U.: A contrail cirrus prediction model, Geosci. Model Dev., 5, 543–580, 2012.

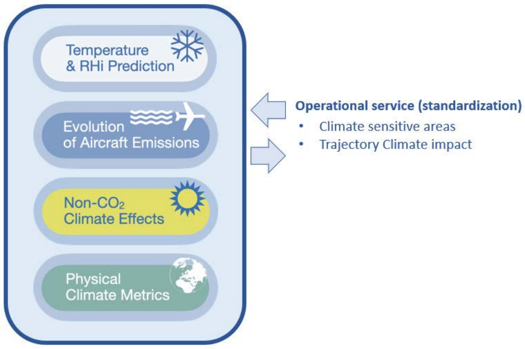

FIGURE 1: Modular definition of a Climate MET service

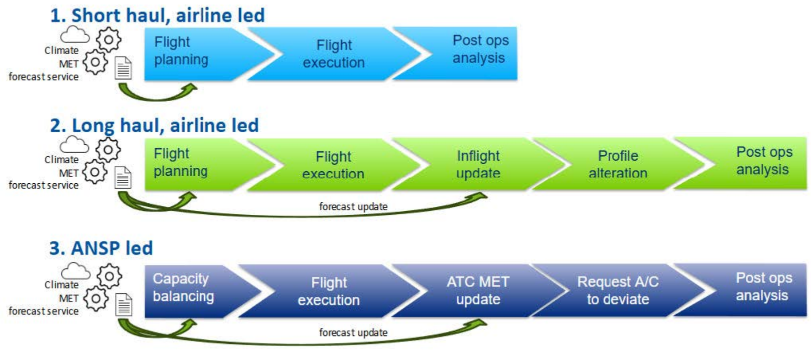

FIGURE 2: CICONIA CONOPS.

individual contrails only) and the aCCFs[3] (algorithmic Climate Change Functions, e.g. mathematical formulation for estimating the temporal and spatial climate effects of both CO_2 and non-CO_2 emissions produced by individual flights and at traffic level). We compare them and identify their convergence and divergence aspects.

- We also need the use of appropriate climate metrics. As each metric weighs the effects of each climate forcer differently, we are testing in CICONIA the use of different metrics and time horizons, and analysing their influence on trajectory optimization and on potential climate benefits. This might be an additional help to operators to better assess the impact of these climate-metric-dependent optimized trajectories on their daily activities (see Figure 1).

An efficient Climate MET service must feature these two key characteristics:

- **Standardized interfaces**: its inputs, calculation time and outputs must be designed so that the service can be incorporated into flight planning by Airlines or ANSP tools. For that purpose, a level of standardisation will be required.
- **Modularity**: as science progresses, better models will be developed. The Climate MET service must be able to substitute them without changing the interfaces. This can be achieved with a modular architecture.

3. To define and assess potential Concepts of Operations, in order to provide policy makers with widely agreed recommendations.

The operational analysis covers the full trajectory-based operations (TBO) cycle envisaged by SESAR from planning to execution. The proposed assessment of the CONOPS (Figure 2) impact will integrate climate impacts (due to both CO_2 and non-CO_2 emissions in operations), economics (re-routing costs, training, equipment), and impact on operations.

Three main concepts have now been selected for further evaluations through simulations and live trials during winter 2025-2026:

- First, for short haul flights, the airline dispatcher will use the climate MET Service to optimise the flight plan with the climate aspect. The forecast service is intended to provide data that is stable enough to avoid having to take into account updates during the short flight.

  The dispatch process is often automated for short haul, and we still have to further assess how this use case can be integrated and automated in legacy operations. Additionally, impacts of numerous simultaneous re-routing demands might introduce congestion. This is currently under work in CICONIA.

3 Dietmüller, S., Matthes, S., Dahlmann, K., Yamashita, H., Simorgh, A., Soler, M., Linke, F., Lührs, B., Meuser, M.M., Weder, C., Grewe, V., Yin, F. and Castino, F.: A python library for computing individual and merged non-CO_2 algorithmic climate change functions: CLIMaCCF V1.0. – Geoscientific Model Development Discussions, 1–33, DOI: 10.5194/gmd-2022-203, 2023.

At this moment, this use case is seen as promising, because of its simplicity and anticipation aspect that gives time for operational coordination.

- Secondly, an extension of this first use case for long haul flight, is to consider that the meteorological conditions can evolve during the flight. It is therefore envisaged that the airline proposes a change in the flight path during the flight to maintain climate benefits. The order of magnitude of the possible updates is under analysis. The aircraft is airborne, and the re-routing has to take into account a stronger constraint with onboard fuel. The collaborative decision making between airline, pilot, and ATC needed to validate the re-routing proposal is under consolidation.

- And finally, the Climate MET service can as well bring capabilities at network and ATC levels.

  In pre-tactical, the network operators could as well benefit from their full knowledge of the existing airspace capacity to influence the traffic flows toward climate optimized re-routing that could be proposed to airlines in pre-tactical.

  As well, during the flight, ANSPs and especially FMP (Flow Management Position) could propose climate-optimized re-routing options.

Progress to date is encouraging, collaborations need to continue

CICONIA believes that airline-led trajectory optimization is the most promising short term approach to non-CO_2 climate impact mitigation, based on reliable forecast tools, and on the consideration that the most anticipated trajectory is the easiest to integrate for ATC.

The collaboration between individual airlines optimizing their flight, and the ATC and Network, will help solve forecasted traffic congestion, which are only considered at the moment as induced capacity reductions.

Provisions for inflight re-routings require consideration, due to intrinsic instability of meteorological conditions, involving a more complex, real time collaborative decision making between pilots and ATC, Airline Operational Centres, with Network considerations.

A harmonized understanding of the climate response of flights is a key enabler for all our operational stakeholders. For coherent operational decisions, we need a standardized Climate MET service, providing meteorological and climate forecasts and nowcasts with their level of confidence. Additional evaluations and trials need to be further developed to reach as soon as possible an introduction into daily operations.