JOINT UNDERTAKING

E-CONTRAIL

D5.7 Concept outline

Deliverable ID:	**D5.7**
Project acronym:	**E-CONTRAIL**
Grant:	**101114795**
Call:	**HORIZON-SESAR-2022-DES-ER-01**
Topic:	**HORIZON-SESAR-2022-DES-ER-01-WA1-6**
Consortium coordinator:	**Universidad Carlos III de Madrid**
Edition date:	**03 April 2025**
Edition:	**02.00**
Status:	**Official**
Classification:	**PU**

Abstract

The E-CONTRAIL project explores the mitigation of climate impacts associated with contrails and aviation-induced cloudiness, focusing on their radiative forcing (RF). Utilizing artificial neural networks and advanced remote sensing technologies, the project aims to predict and quantify the environmental footprint of these non-CO2 emissions in aviation. The concept outlined in this deliverable focuses on the development of a Climate Hotspot Prediction Service, which will inform operational adjustments in air traffic management to reduce aviation's environmental impact. The methodology is validated through detailed scenario analysis and performance assessment, targeting TRL1 maturity by project completion.

E-CONTRAIL

Authoring & approval

Author(s) of the document

Organisation name	Date
Universidad Carlos III de Madrid	19/03/2025

Reviewed by

Organisation name	Date
UC3M	19/03/2025
BIRA	25/03/2025
KTH	25/03/2025
RMI	25/03/2025

Approved for submission to the SESAR 3 JU by

Organisation name	Date
UC3M	19/03/2025
BIRA	25/03/2025
KTH	25/03/2025
RMI	25/03/2025

Rejected by

Organisation name	Date

Document history

Edition	Date	Status	Organisation author	Justification
00.01	20/08/2024	Initial Draft	UC3M	Draft
00.02	21/08/2024	Internal review	UC3M	Sent for internal review
01.00	05/09/2024	Submission	UC3M	
02.00	03/04/2025	Submission	UC3M	

Copyright statement

Disclaimer

E-CONTRAIL

ARTIFICIAL NEURAL NETWORKS FOR THE PREDICTION OF CONTRAILS AND AVIATION INDUCED CLOUDINESS

E-CONTRAIL

This document is part of a project that has received funding from the SESAR 3 Joint Undertaking under grant agreement No 101114795 under European Union's Horizon Europe research and innovation programme.

We provide a high-level summary of the project E-CONTRAIL:

Contrails and aviation-induced cloudiness effects on climate change show large uncertainties since they are subject to meteorological, regional, and seasonal variations. Indeed, under some specific circumstances, aircraft can generate anthropogenic cirrus with cooling. Thus, the need for research into contrails and aviation-induced cloudiness and its associated uncertainties to be considered in aviation climate mitigation actions becomes unquestionable.

We will blend cutting-edge AI techniques (deep learning) and climate science with application to the aviation domain, aiming at closing (at least partially) the existing gap in terms of understanding aviation-induced climate impact.

The overall purpose of E-CONTRAIL project is to develop artificial neural networks (leveraging remote sensing detection methods) for the prediction of the climate impact derived from contrails and aviation-induced cloudiness, contributing, thus, to a better understanding of the non-CO2 impact of aviation on global warming and reducing their associated uncertainties as essential steps towards green aviation.

Specifically, the objectives of E-CONTRAIL are:

- O-1 to develop remote sensing algorithms for the detection of contrails and aviation-induced cloudiness.
- O-2 to quantify the radiative forcing of ice clouds based on remote sensing and radiative transfer methods.
- O-3 to use of deep learning architectures to generate AI models capable of predicting the radiative forcing of contrails based on data- archive numerical weather forecasts and historical traffic.
- O-4 to assess the climate impact and develop a visualization tool in a dashboard.

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Table of contents

EUROPEAN PARTNERSHIP

Co-funded by the European Union

List of figures

List of tables

1 Executive summary

The E-CONTRAIL project seeks to address the significant but often overlooked climate impacts of contrails and aviation-induced cloudiness, which contribute to global warming beyond the effects of CO2 emissions alone. This deliverable outlines the conceptual framework for developing a predictive service that leverages cutting-edge AI and remote sensing to model the radiative forcing (RF) associated with these phenomena.

The project's concept is built on four key methodological blocks: contrail tracking, estimation ofRF, AI-driven prediction models, and the development of a visualization tool. These elements are integrated into the proposed E-CONTRAIL Climate Hotspot Prediction Service, which will predict airspace regions with significant climate impact, enabling stakeholders—such as airlines, ANSPs, and policy makers—to implement mitigation strategies in real-time.

Operational scenarios are designed to evaluate the applicability of the prediction service across different temporal scales, from short-term flight planning to longer-term airspace management. The project's expected outcomes include a significant reduction in the uncertainty of climate impact assessments, enhanced decision-making capabilities for stakeholders, and the establishment of a foundation for future exploratory research within SESAR's framework.

Ultimately, E-CONTRAIL aims to achieve TRL1 maturity for its Climate Hotspot Prediction Service, laying the groundwork for further development and application in reducing aviation's non-CO2 climate impacts. This deliverable represents a crucial step towards aligning air traffic management with global climate goals, contributing to the EU's ambition of climate-neutral aviation by 2050.

EUROPEAN PARTNERSHIP
Co-funded by the European Union

2 Introduction

2.1 Purpose of the document

E-CONTRAIL project is a SESAR exploratory research project. As such, the purpose of the document is to introduce the Exploratory Research Plan for Solution "E-CONTRAIL Climate Hotspot Prediction Service".

The purpose of this concept outline is to secure the application of scientific best practices when assessing the technological readiness of the solutions presented by E-CONTRAIL project. For this purpose, we will first define the concept underpinning the project and then, define the solution.

2.2 Intended readership

The intended readership for this Deliverable, focusing on the Concept Outline, comprises aviation researchers, industry innovators, regulatory authorities, and SESAR program stakeholders. This document is tailored to guide and inform those actively engaged in experimental research endeavours aimed at enhancing air traffic management and advancing the SESAR program's objectives.

2.3 Background

There is no previous project or activity in which E-CONTRAIL is building up.

2.4 Structure of the document

The document begins with an abstract, followed by an executive summary providing a concise overview. The introduction outlines the document's purpose, intended readership, background, structure, and includes a glossary of terms and a list of acronyms. The concept is outlined in Section 3, covering the problem statement, the concept description, estimated performance contributions, and key assumptions. Section 4 details the proposed solutions. The document concludes with a comprehensive reference section, encompassing applicable and reference documents.

2.5 Glossary of terms

Term	Definition	Source of the definition
Non-CO_2	Effect of aviation due to nitrogen oxides (NOx), vapour trails and cloud formation triggered by the altitude at which aircraft operate (i.e., not related to CO_2 emissions).	www.transportenvironment.org
Contrails	When water vapour is released from jet engines at altitude under certain high humidity conditions (ice supersaturated regions) it can condense into exhaust carbon particles as well as into	www.iata.org

EUROPEAN PARTNERSHIP
Co-funded by the European Union

	atmospheric aerosols. If the air is sufficiently humid, the water vapour can condense further into crystals and a cloud can be formed. Such clouds, formed from the condensation of exhaust aircraft water vapour, are called condensation trails or contrails.	
Aviation Induced Cloudiness	Aviation-induced cloudiness (AIC) is defined to be the sum of all changes in cloudiness associated with aviation operations.	https://archive.ipcc.ch
Radiative Forcing	Radiative Forcing (RF) is what happens when the amount of energy that enters the Earth's atmosphere is different from the amount of energy that leaves it. Energy travels in the form of radiation: solar radiation entering the atmosphere from the sun, and infrared radiation exiting as heat. If more radiation is entering Earth than leaving—as is happening today—then the atmosphere will warm up. This is called radiative forcing because the difference in energy can force changes in the Earth's climate.	https://climate.mit.edu

Table 1: Glossary of terms

2.6 List of acronyms

Term	Definition
aCCF	*algorithmic Climate Change Functions*
AIC	*Aviation-induced Cloudiness*
ATM	*Air traffic management*
CoCiP	*Contrail Cirrus Prediction Model*
CNN	*Convolutional Neural Network*
DES	*Digital European Sky*
ERF	*Effective Radiative forcing*
ERP	*Experimental Research Plan*
EXE	*Exercise*
GA	*Grant agreement*
GAN	*Generative Adversarial Network*
GHG	*Greenhouse Gas*
HE	*Horizon Europe*
ID	*Identifier*
KPA	*Key performance area*
KPI	*Key performance indicator*
LSTM	*Long-Short Terms Memory*
MSG	*Meteosat Second Generation*

MTG	*Meteosat Third Generation*
OSED	*Operational service and environment description*
RF	*Radiative Forcing*
SESAR	*Single European sky ATM research*
SESAR 3 JU	*SESAR 3 Joint Undertaking*
TRL	*Technology readiness level*
VAE	*Variational AutoEncoder*

Table 2: List of acronyms.

3 Concept outline

3.1 Problem statement

3.1.1 Context and motivation

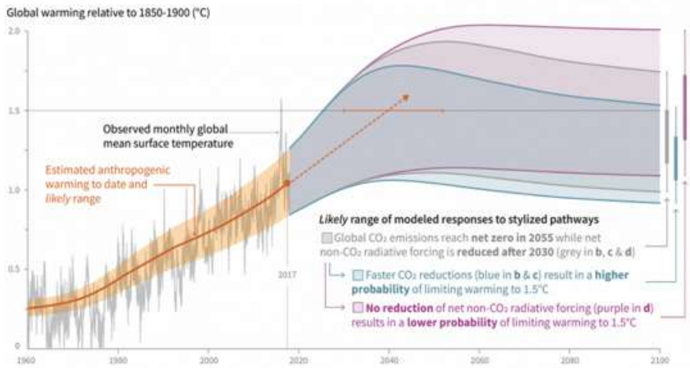


Figure 1: Observed global temperature change and to responses to anthropogenic emissions and forcing pathways. Global Warming of 1.5 Degrees. IPCC

The imperative to address climate change has reached a critical juncture. The global target of limiting the Earth's temperature increase to '2°C' above pre-industrial levels (considered to be the upper and potentially irreversible threshold), with an even more stringent goal of staying below 1.5°C, underscores the urgency for comprehensive mitigation strategies across all sectors. See Figure 1. The transportation sector, particularly aviation, plays a pivotal role. Beyond the immediate concern of carbon dioxide (CO2) emissions, the aviation sector's impact extends to other non-CO2 effects (notably contrails and aviation-induced cloudiness), further accentuating its contribution to global warming. The social dimensions of this challenge emphasize the need for innovative and effective solutions.

In parallel with the urgent need for climate mitigation, the planet is witnessing a revolution around the possibility of using Artificial Intelligence (AI) techniques in various fields. In recent years, the availability of large amounts of data ('big data') and the leap forward in computing power have paved the way toward unprecedented levels of Deep Learning (DL) performance and automation. Indeed, in a recent survey [4], the authors claim that AI can enable the accomplishment of 134 targets across all the goals established in the 2030 Agenda for Sustainable Development. This includes Earth sciences (climate change and meteorological prediction) and the aviation domain. However, the very effectiveness of these techniques comes with a significant caveat. Deep learning operates, factually, as a 'black box,' rendering its decision-making processes opaque and inscrutable. This lack of transparency raises ethical and social concerns, challenging established principles of accountability, trust, and fairness. Recognizing the potential threats, ongoing regulatory efforts in Europe aim to establish guidelines that address the transparency and accountability of AI systems [3] . In this context, the ethical dimensions of AI are paramount, especially when applied to critical domains like Earth sciences (climate change mitigation) and the aviation sector. Striking a balance between the power of AI and the imperative of transparency is pivotal for fostering trust and ensuring responsible AI deployment that aligns with societal values.

3.1.2 State of the art on climate-conscious aviation

The strategies pursued to reduce aviation-induced climate impact over the last two decades (e.g., new generation of jet engines in A320Neo/B737Max, composite materials in A350/B787, European Union (EU) programs such as Clean Sky and the Single Sky ATM Research (SESAR) have followed a common, win-win pattern for airlines and linked economical agents: they have sought to reduce fuel burnt, claiming that their strategies are climate-friendly due to fuel burnt being proportional to CO_2 emissions. However, global aviation emissions contribute to anthropogenic climate change by warming the Earth's near-surface atmosphere through both CO_2 and non-CO_2 emissions. The latter have been practically ignored in the past. This is, in part, because they are not yet fully understood and still linked with high uncertainties.

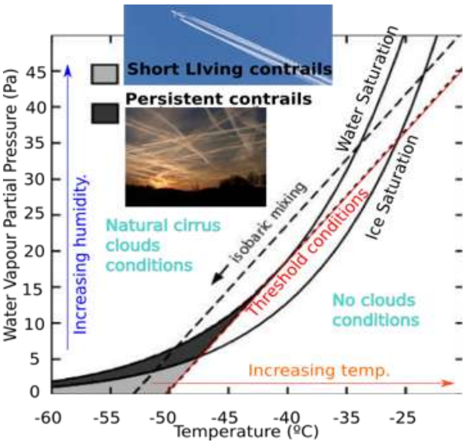


Figure 2: Schmidt-Appleman criterion.

Non-CO_2 emissions associated with air traffic comprise water vapour (H_2O), nitrogen oxide (NO_x), sulphur oxides, and soot. Not all non-CO_2 emissions have a direct effect on climate. NO_x emissions are not radiatively active themselves, but they are responsible for the chemical production of the greenhouse gas (GHG) ozone (O_3) and the destruction of the GHG methane (CH_4). Furthermore, contrails, and contrail-cirrus can form in ice-supersaturated regions (Schmidt-Appleman Criterion, see Figure 2) and alter the radiation budget (effective radiative forcing -ERF-). ERF includes all tropospheric and land surface adjustments, whereas RF only includes the adjustment due to stratospheric temperature change [5]. Figure 3 illustrates the breakdown of aviation ERF terms [2]. It provides state-of-the-art estimates (and their uncertainties) of the global aviation climate impact for individual forcing components. The largest contributions are due to contrail-cirrus formation and aviation-induced cloudiness (57% of the ERF), and overall, non-CO_2 forcings represent about 2/3 of the aviation ERF. Nonetheless, the understanding is still incomplete, and this is reflected by the fact that non-CO_2 terms (in particular, those of contrails and aviation-induced cloudiness) are also the ones with the largest uncertainties.

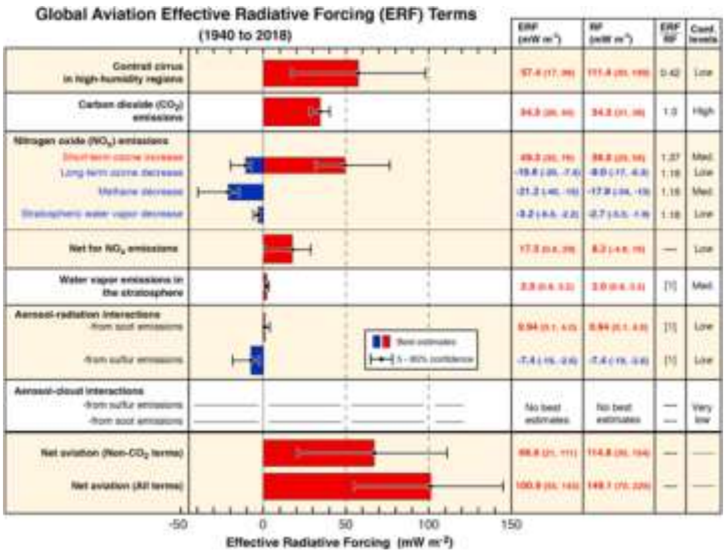


Figure 3: ERF from the global aviation 1940-2018. Best estimates and confidence intervals (5% and 95% percentiles) given. Red bars indicate warming and blue bars cooling effects.

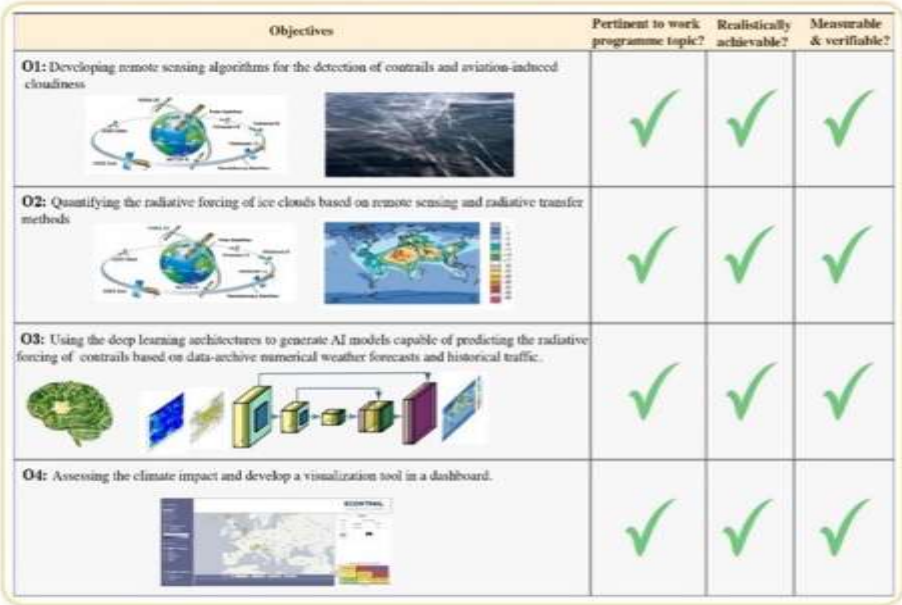
Contrails effects show large uncertainties: they are subject to meteorological, regional, and seasonal variations, yet each is individually characterized by different spatiotemporal scales. Indeed, under some specific circumstances, aircraft can generate contrails with cooling effects (ERF < 0). Thus, together with continuing the decarbonisation, **the need for research into contrails (and other non-**

CO_2 effects) and their uncertainties to be considered in aviation climate mitigation actions becomes unquestionable.

3.1.3 Overall purpose of E-CONTRAIL

The overall purpose of E-CONTRAIL project is to develop artificial neural networks (leveraging remote sensing detection methods to estimate radiative forcing and effective radiative forcing) for the prediction of the climate impact derived from contrails and aviation-induced cloudiness, contributing, thus, to a better understanding of the non-CO_2 impact of aviation on global warming and reducing their associated uncertainties as essential steps towards green aviation.

The specific objectives are included in Figure 4, including its achievability, measurability, and verifiability.



Objectives	Pertinent to work programme topic?	Realistically achievable?	Measurable & verifiable?
O1: Developing remote sensing algorithms for the detection of contrails and aviation-induced cloudiness	✓	✓	✓
O2: Quantifying the radiative forcing of ice clouds based on remote sensing and radiative transfer methods	✓	✓	✓
O3: Using the deep learning architectures to generate AI models capable of predicting the radiative forcing of contrails based on data-archive numerical weather forecasts and historical traffic.	✓	✓	✓
O4: Assessing the climate impact and develop a visualization tool in a dashboard.	✓	✓	✓

Figure 4: Specific Objectives of ECONTRAIL

3.1.4 Self-Assessment of the Problem Statement

Within the problem statement, we aim at answering the following questions:

- Has the ATM problem/challenge/need(s) that innovation would contribute to solve been identified?
- Where does the problem lie?
- Has the ATM problem/challenge/need(s) been quantified that justify the research done?

The answer is affirmative: the environmental impact of aviation has been identified as a clear challenge. The climate impact of aviation has been quantified [2] showing a relatively large impact of contrails and aviation-induced cloudiness. The numbers are, however, subject to very large uncertainties. This motivates our research.

3.2 Concept description and operational scenarios

Contrails or condensation trails form when the water vapour, a product of exhaustion in the aircraft motor, mixes with the freezing cold air at cruising altitude. The water vapour condenses or instantly freezes into ice crystals, forming an elongated ice cloud, with cloud base usually at heights from 7,000 to 12,000m above ground. Contrails evaporate quickly if the ambient air is dry but can persist if the ambient air is humid enough, turning into induced-cirrus clouds (what we term herein aviation-induced cloudiness).

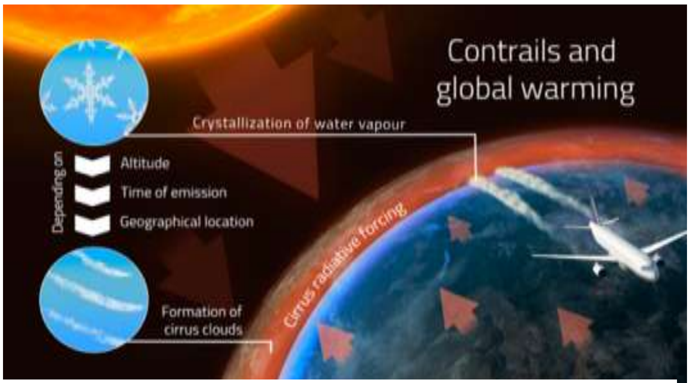


Figure 5: Schematic Figure of Contrails and its impact in the radiative forcings of the planet

Like natural clouds, linear contrails and aviation-induced cloudiness, modify the energetic balance of the planet. In a stable climate, Earth's incoming energy from the Sun is approximately equal to the energy emitted towards space as reflected sunlight and thermal radiation. Climate drivers, or forcings, alter this equilibrium causing a change in the energy flux defined as effective radiative forcing (ERF) and typically measured in Watts per square meter (Wm-2). The ERF allows to measure the strength of a climate altering agent and to compare the warming or cooling contribution of heterogeneous climate forcing. Figure 5 illustrates it.

In short, E-CONTRAIL's methodology leverages on remote sensing to estimate the radiative forcing (RF) of contrails and aviation-induced cloudiness. Algorithms to discriminate natural cloudiness from induced cloudiness are needed. The resulting estimation are passed over as target functions to the AI module, which exploits deep learning to find the spatial and temporal relations between the inputs (in this case, numerical weather forecasts and traffic demand) and the output, which is the target function (in this case, the estimated RF).

3.2.1 Overall Concept and Methodology

The overall concept underpinning E-CONTRAIL is sketched in

Figure 6. In this structure, one can identify the four blocks (See Table 3). The methodological blocks correspond, one to one, with the four specific goals of the project.

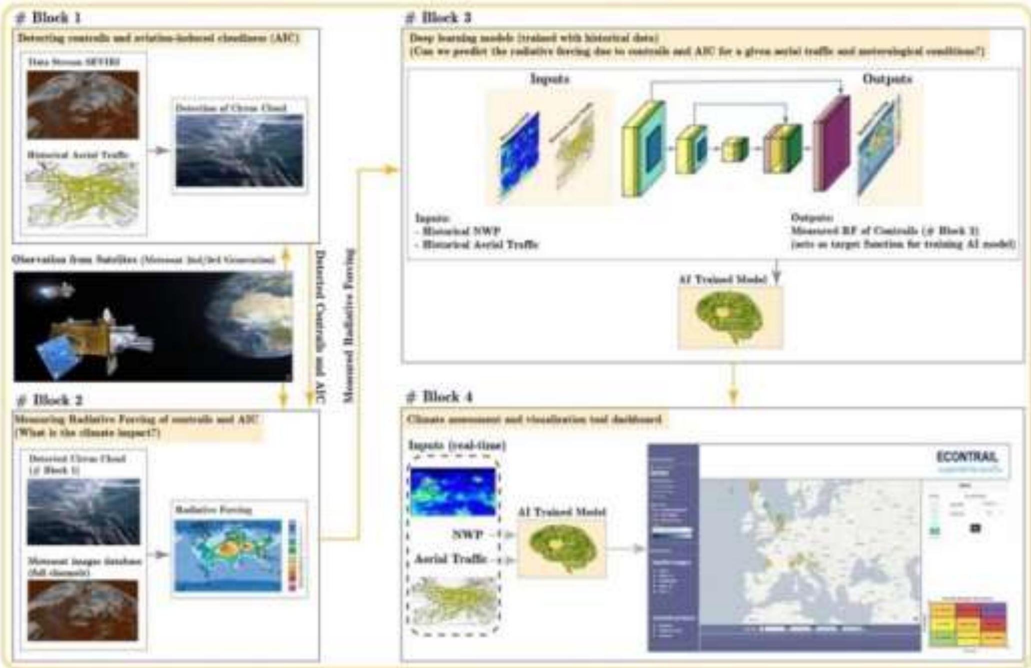


Figure 6: Overall concept of E-CONTRAIL project.

Block 1: Contrail tracking and aviation-induced cloudiness	**Input:** data archive from the 3rd gen. of Meteosat satellite imaginary & aerial traffic **Method #1**: Brightness Temperature Difference (BTD) method to isolate the signature of an ice-crystal using remote-sensing imaginary. **Method #2**: Covariance-Based Retrieval Algorithm. Multispectral algorithm to detect the existence of contrails and aviation-induced cloudiness. **Method #3**: Air traffic synchronisation for the discrimination of contrails and aviation-induced cloudiness and natural clouds. **Output:** Maps of contrails and aviation-induced cloudiness
Block 2: Estimation of the radiative forcing of the contrails and Aviation-Induced Cloudiness (AIC)	**Input:** data archive from the 2nd and 3rd generation of Meteosat satellite imaginary. **Method #1**: Retrieval of ice cloud properties using the multi-spectral imager aboard the Meteosat Second Generation (MSG) and Third Generation (MTG) satellites. **Method #2**: Derive Look-Up Tables (LUTs) for ice cloud radiative forcing. **Method #3**: Combine cloud retrieval and LUTsfor the measurement of time- and space-dependent radiative forcing by ice clouds. **Method #4**: Discrimination between natural and aviation-induced cirrus clouds. **Output:** Maps of contrails and aviation-induced cloudiness radiative forcing.
Block 3: Deep learning models for the prediction of contrails and AIC climate impact	**Input #1:** Data archive air traffic demand (as planned) and numerical weather forecasts (ensemble); observations of coming the output of Block 2. **Method #1:** Recurrent Neural Networks **Method #2:** Convolutional neural networks **Output #1:** AI-Model trained
Block 4: Assessment and visualization tool	**Input:** AI-Model trained (output of Block 3) and real-time weather forecasts and traffic demand. **Method #1**: Implementation of a user-friendly dashboard interface based on the GeoServer open-source server, relevant for sharing geospatial data. **Output:** Demonstration of E-CONTRAIL dashboard tool.

Table 3: E-CONTRAIL Blocks description

3.2.2 Operational/Technical context

Contrails are aviation-induced high-altitude clouds whose appearance depends on the atmospheric conditions. While the impact of aviation on the changing climate of the Earth by the emission of greenhouse gases such as CO_2 can be measured conveniently, it is not the case for contrails that fall in the category called "non-CO_2 impact". To assess this impact, we are concerned in E-CONTRAIL by the detection of contrails (i.e., flagging pixels in satellite imagery as containing a contrail or not) and by the quantification of their radiative forcing (RF) properties. As some contrails may have a cooling effect by reflecting more solar radiation and other a warming effect by capturing infrared radiation, it is important to study contrails in different geographic regions, seasons and times of the day.

When it comes to the operational/Technical context, we should address our attention to the conceptual Block #4, which defines the aviation contrail detection products (ACDP) and has two main subobjectives:

- The first subobjective (4.1) is to benchmark the E-CONTRAIL solution and to compare the results with existing models/methods (comparison of assessments with aCCF and CoCiP models).
- The second subobjective (4.2) is the implementation of a visualization tool dashboard, tailoring the information to the stakeholders. The idea is to provide a prediction/forecast (24h ahead of time) with the volumes of airspace (including geolocation and altitude) that are expected to largely contribute to the climate impact if the aircraft overfly these regions.

In D4.2 [1], we described the methodology and achievements of Task 2.4 (WP2) and Task 4.1 (WP4). These two tasks are strongly linked, as the RF of aviation obtained in Task 2.4 is used by Task 4.1 for building the E-CONTRAIL ACDP data archive. The outputs of Task 4.1 will be used to complete:

- the subobjective (4.1) with the comparison assessment and validation using ACDP data, and
- the subobjective (4.2) with the visualization tool dashboard of the ACDPs.

The comparison of assessments and the visualization tool dashboard of the climate impact of contrails require ACDPs. Figure 2 presents a comprehensive diagram of Tasks 2.4 and 4.1, with the links between WP4 and the other WPs. The red arrow symbolises the developments tackled in D4.2.

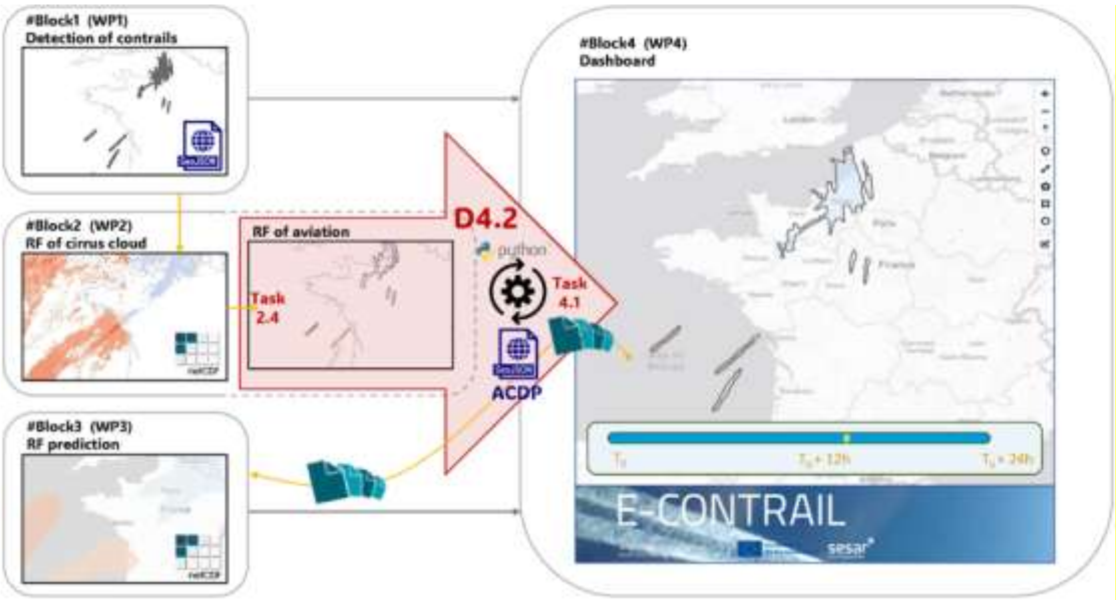


Figure 7: Methodological diagram of the tasks described by this report, with links between WPs.

The aviation contrail detection products (ACDP) rely on inputs from the other WPs:

- input of contrail tracking and aviation-induced cloudiness (AIC) from WP1 (#Block1),
- input of aviation RF from WP2 (#Block2), and
- input of AI-prediction of climate impact and potential RF from contrails from WP3 (#Block3).

The E-CONTRAIL dashboard (or visualization tool) combines detection of contrails and the associated RF, with predictions from deep-learning models. Figure 7 shows the relations between this work (part of WP4), and WP1, WP2 and WP3. The tools is aimed to be used by different ATM stakeholders (mainly dispatchers/airlines and NM/ANSP, yet MET providers) to take better-informed decisions (at temporal look-ahead times of 1h to 24h) towards climate mitigation, particularly when it comes to contrails and aviation-induced cloudiness.

3.2.3 Stakeholders

The involvement of Stakeholders to qualitatively assess the presentation of results in E-CONTRAIL dashboard will be also key.

Aviation Industry/ Airline operators: Contrails which heighten the effect of global warming may account for more than half (57%) of the entire climate impact of aviation [2]. However, more research is needed to bring knowledge about contrails and chemical interactions in the atmosphere to a level at which the aviation industry can be more confident about the route forward. The uncertainty distributions (see [2]). show that non-CO_2 forcing contributes about 8 times more than the CO_2 to the overall uncertainty in the aviation net forcing. **With our accurate prediction of persistent contrails and radiative forcing, we will enable the aviation industry to carry out operational changes and prompt mitigatory actions (such as navigation avoidance and others).**

Policy makers: Decarbonisation of aviation sector will continue (e.g., alternative fuels, electrical aircraft), however, requires high investments and results in stranded assets (aircraft, engines, etc.). Policy makers are increasingly looking for modernization of the Air Traffic Management (ATM) not only to consider both CO_2 and non-CO_2 effects in the long term, but also to enable short-term actions to mitigate aviation-induced climate change. The quantification of the cost linked to flying green and the development of indicators is mandatory to pave the road towards establishing fees and incentives. **Therefore, the results of E-CONTRAIL are highly relevant, and will result in actionable policy insights, to fast track the modernization of ATM.**

The ANSPs and the network manager can also benefit from E-CONTRAIL solution: **they can define volumes of airspace that are highly sensitive to climate change, thereby issues restrictions if they deem them necessary.**

The Met Offices can also benefit from E-CONTRAIL solution: **they can integrate the climate models into their meteorological services.**

3.2.4 Key scenarios

The operational scenarios in which the E-CONTRAIL solution could be used are linked to the time-ahead the information is available to the different stakeholders and their roles and responsibilities:

- NM & ANSP: D-1 (24 hours ahead of time) to take actions regarding the managing of the airspace under their sovereignty. A potential usage would be issuing flying restrictions.
- Flight Dispatchers: D0 (1-3 hours ahead of time) to take actions regarding the managing of the flights under their operation. A potential usage would be generating flight plans that take into consideration areas of formation of contrails.

Needless to say, it should be mentioned that E-CONTRAIL is an exploratory research project focused on the fundamental science. Thus, the involvement of stakeholders and definition of scenarios/use cases falls out of the scope of the project.

3.2.5 Potential limitations, weaknesses and constraints

Most of the limitations are linked to the availability/quality of data:

- A first limitation has to do with the low spatial-temporal resolution of MSG data. As MTG (with higher spatial and temporal resolutions) becomes available (if it does before the end of the project), we would try to conduct a small analysis to understand the level of significance.
- A second limitation is the lack of a labelled dataset of contrails in Europe as it does exist in US.
- A third limitation has to do with the lack of on-board observations of atmospheric conditions, especially those related to humidity.

3.3 Expected performance outcome

The main contribution of E-CONTRAIL in terms of Key Performance Areas (KPA) is on the environment, particularly on better understanding non-CO2 impacts.

The outcome related to the Environment specified in the call (as a high level ambition at European level) was: achievement of the objectives of a 55% reduction in greenhouse gas emissions by 2030 and net-zero greenhouse gas emissions by 2050, from a gate-to-gate perspective, by introducing new concepts enabling proper modelling of non-CO2 emissions and their impact on optimum green trajectories, taking into account the expected interoperability with new entrants (i.e., U-space flights)

E-CONTRAIL's R&I goals will enable advanced AI-powered prediction of the radiative forcing of contrails and aviation-induced cloudiness, thereby enabling non-CO2 emission related climate mitigation actions by the aviation industry. Our unique contributions towards 55% reduction in climate impact of aviation by 2030 and climate neutrality by 2050 (a context indicator for reduction of 55% GHG emissions) will be:

1. Introducing AI driven models to predict, 24 hours in advance, the climate impact of contrails and aviation-induced cloudiness with 80-90% accuracy. We expect to achieve this accuracy based on the results obtained in our previous research activities related to predicting thunderstorms using AI [6]
2. Reducing the uncertainty in the climate impact (measured in terms of Radiative Forcing (RF) and/or Effective Radiative Forcing (ERF)) of contrails and aviation-induced cloudiness. We expect to contribute to this research on contrails and other non-CO2 effects by comparing E-CONTRAIL's AI-Driven approach with existing methods (e.g., the aCCFs) by better understanding the atmospheric conditions (related to ice-supersaturated regions) in which contrails form and persist.

By 2030, E-CONTRAIL will work towards the following, specific impact targets that will lead to the reduction of aviation-induced climate impact:

1. Identify contrail cirrus-forming in ice-supersaturated regions of the atmosphere and its radiative forcing.
2. Enable more efficient navigational avoidance & operations management and, therefore, the climate impact is reduced by 20-50%
3. Optimize airlines' operational costs and the climate impact. Trade-off solutions will be obtained, expecting an increase of the operational costs ranging from 0.5% to 3% to achieve climate mitigation reduction of 20-50%.
4. Developing indicators that enable the concept of green trajectories for the first time, and the quantified indicators lead evidence-based policy making (fees and incentives for the airlines to compensate the extra costs).

All in all, our Climate Hotspot Prediction Service can be used as a meteorological enabler for the airlines and flight dispatchers towards reducing in 20-50% the aviation-induced climate-impact by 2030 via climate-optimized trajectories, at an increased operational cost ranging from 0.5% to 3% [7].

3.4 Key assumptions

Assumption ID	Assumption title	Assumption description	Justification	Impact Assessment
Assu #1	Europe	Geographical scope limited to EUROPE and half of the North Atlantic. Due to the lack of a labelled dataset in Europe, we will train our models with data in US and then extrapolate the resulting model to US.	It is obvious, due to the funding, that we must focus on Europe.	We will label a small dataset in Europe to compare the validation scores.
Assu #2	Spatial and temporal resolution driven by MSG data.	We will use the Meteosat Second Generation (MSG) data from years 2022-2024.	We wanted to use the Meteosat Third Generation (MTG) data, but they are still not available	MSG has lower spatio-temporal resolution than MTG.

Table 4. E-CONTRAIL Key assumptions

4 Proposed SESAR solution

Proposed solution title	Proposed solution definition	Proposed solution description	Maturity at project start	Maturity at project end
E-CONTRAIL Climate Hotspot Prediction Service			*TRL0*	*TRL1*

Table 5. E-CONTRAIL proposed solution

Operating (Sub)-Environment: *The candidate SESAR solution targets in-route volumes of airspace where contrails are relevant. It is intended for use by flight dispatchers, airlines, ANSPs, and the Network Manager to provide performance benefits in these operational environments.*

5 Plan for next R&I phase

Still pending.

We are currently finalizing the experiments; no conclusions can be drawn yet. We will include the open problems and next R&I phase in the final version of experimental research report.

6 References

6.1 Applicable documents

This concept outline complies with the requirements set out in the following documents:

Project and programme management

[1] D4.2: Definition of E-CONTRAIL Aviation Contrails Detection Products and Archive. E-CONTRAIL, August 2024.

6.2 Reference documents

[2] Lee, D. S., Fahey, D. W., Skowron, A., Allen, M. R., Burkhardt, U., Chen, Q., ... & Wilcox, L. J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. Atmospheric Environment, 244, 117834.

[3] European Parliament. (2021). "Proposal for a Regulation of the European Parliament and of the Council Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52021PC0206.".

[4] Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Fellander, A., Langhans, S.D., Tegmark, M., Fuso Nerini, F. (2020). "The role of artificial intelligence in achieving the Sustainable Development Goals." Nature Communications 11, 233.

[5] Smith, C. J. a. K., Ryan J and Myhre, Gunnar and Alterskjær, Kari and Collins, William and Sima, Adriana and Boucher, Olivier and Dufresne, Jean-Louis and Nabat, Pierre and Michou, Martine and others (2020). "Effective radiative forcing and adjustments in CMIP6 models." Atmospheric Chemistry Physics 20: 9591–9618.

[6] Jardines, Aniel and Eivazi, Hamidreza and Zea, Elías and Simarro, Juan and García-Heras, Javier and Soler, Manuel and Otero, Evelyn and Vinuesa, Ricardo, **Thunderstorm Prediction During Pre-Tactical Air-Traffic-Flow Management Using Convolutional Neural Networks**. *Expert Systems with Applications*. 10.1016/j.eswa.2023.122466

[7] Abolfazl Simorgh, Manuel Soler. *Pathways to Sustainable Aviation: Aligning Flight Plans with Climate Goals*, Communications Earth & Environment. 03 June 2024, PREPRINT (Version 1) available at Research Square https://doi.org/10.21203/rs.3.rs-4355046/v1