# Minimization of airlines operations climate impact by Trajectory Optimization

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## Context

Airline operations entail important climate impacts some of which are not taken into account [1][2]. **In addition to the contribution of CO2** to climate change, we will also take into account **Condensation Trails** (or Contrails) and NOx.

Contrails warming impact only takes place **over its lifetime**. Contrails impact is important when it **persists** for a long time, especially at night when its warming effect is no longer compensated by its cooling effect [3].

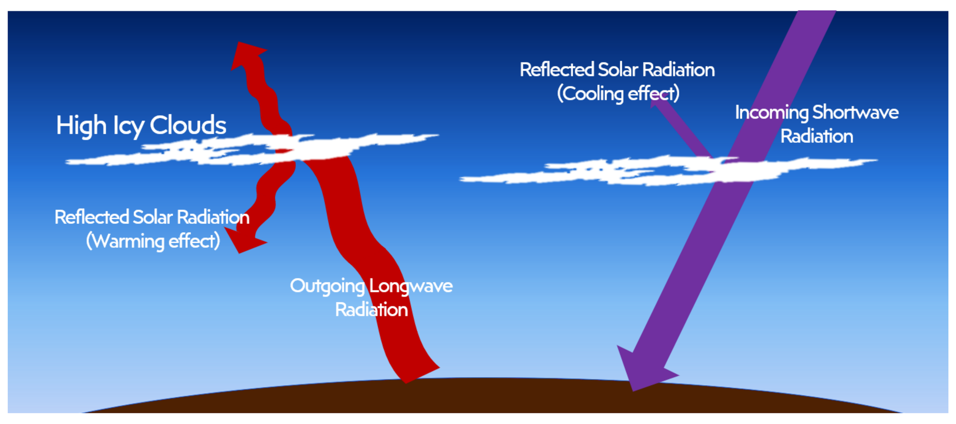


Figure 1: Cooling and Warming effects of high icy clouds like contrails

Figure 2: Condensation Trails, or Contrail of an Airbus A380

There is no method today for predicting contrail persistence that would be fast enough to be used effectively in a trajectory optimization algorithm, and accurate enough to ensure that we do not risk increasing our climate impact rather than improving it [3].

## Objectives

- To design and develop the means and tools necessary to **evaluate the climate impact associated with individual aircraft trajectories**.
- To optimize trajectories **integrating climate aspects** through realistic simulations in order to **evaluate the potential benefits** but also other effects such as **economic impacts**.
- Implement **robust multi-objective optimization** algorithms based on these data in order to better take into account the **uncertainties** that may be associated to it.

## Persistent contrail areas prediction

We need a way to **predict in which area an aircraft will emit persistent trails** depending on weather conditions, and other factors (aerosols, season, traffic density...). We use **machine learning** methods based on image segmentation algorithms, to learn what type of weather condition lead to contrail persistence :

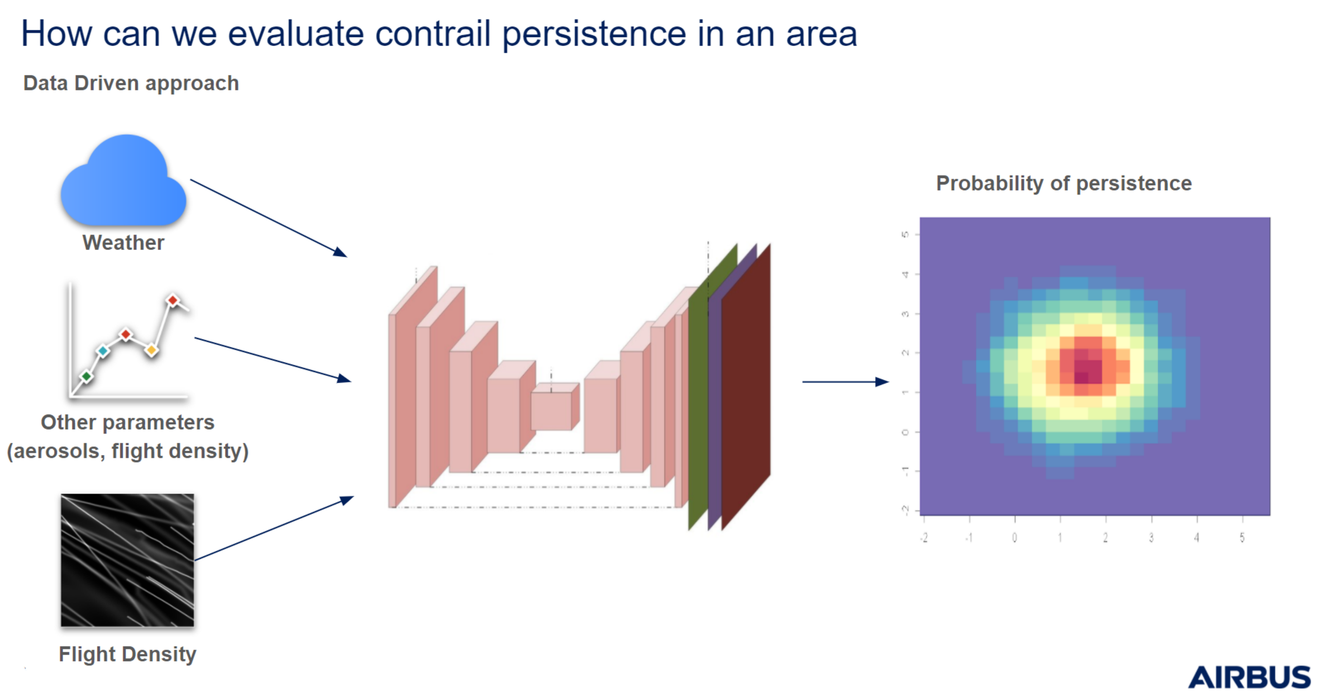


Figure 3: Model predicting persistence probability

To generate a dataset of examples to train our model, we need a large number of "ground truth examples" of contrail persistence. Because of the scale of the problem, we need an automatic way to generate these examples. As there is no reliable and available algorithms to detect and list actual cases of contrail persistence [4] [5], our own model will be built.

## Contrail Detection From Satellite Pictures

We adapted a **infrared vision product** supposed to allow visualisation of dust in the atmosphere to **cirrus highlighting**.

We build a **detection and object tracking model** to follow the detected contrail over its lifetime, using a human labeled dataset of Landsat-8 pictures [4] to pre-train our algorithm, and then fine-tune it using GOES pictures.

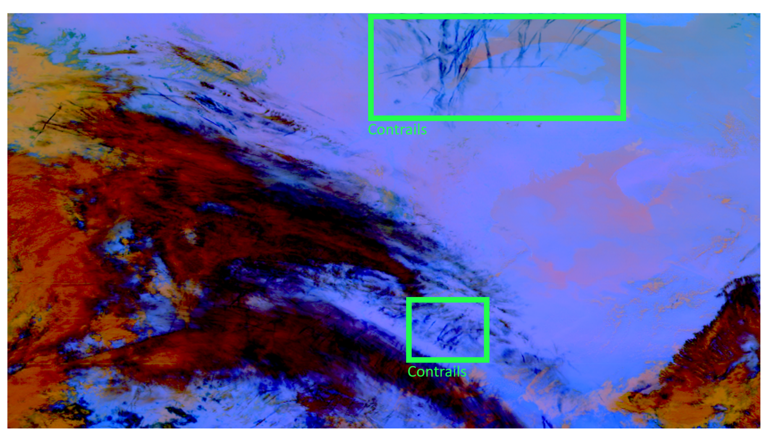

Figure 4: Persistent contrails on GOES "DustRGB" picture

## Multiobjective Trajectory Optimization

Our goal is to propose a method allowing companies to minimize their operation's climate impact in a way that would be **compatible with economic constraints**.

It is a multi objective optimization problem, in which we need to minimize :

- The flight duration
- The amount of fuel burnt during the flight
- The impact of persistent contrails emission
- The impact of NOx emissions

The appearance and the persistence of contrails requires specific conditions [3]. Avoiding the creation of persistent contrails would therefore be **equivalent to avoid dynamic obstacles**.

These "obstacles" (the potential persistent contrails formation zones) are moving with the wind, but they can also change shape, appear and disappear. These dynamic behaviors are caused by temperature or humidity changes, apparition of clouds which makes relative humidity decrease, wind shifts...

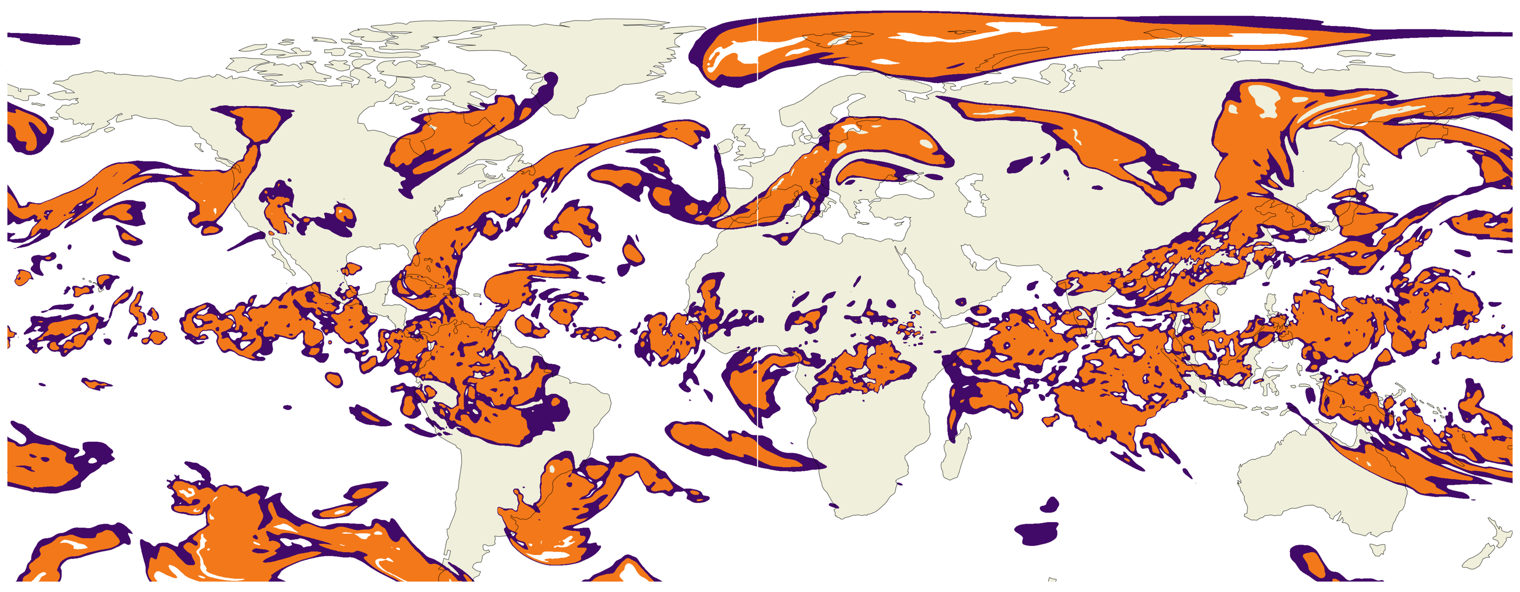

Figure 5: Potential Persistent contrails areas

Trajectories will be optimized in presence of **wind**, taking into account the **flight dynamics**. Trajectories will also follow the airways, as we work from the point of view of airlines.

We will then need to measure the uncertainties associated with this multi criterion approach, especially since we built some parts of the climate impact metrics ourselves.

## References

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[4] McCloskey, Kevin, Scott Geraedts, and Brendan Jackman. 'A Human-Labeled Landsat-8 Contrails Dataset'. Tackling Climate Change with Machine Learning Workshop at ICML 2021.
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