E-CONTRAIL Project: **Artificial Neural Networks for the Prediction of Contrails and Aviation Induced Cloudiness.**

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# Sustainable Skies Conference: Contrails in Focus

7-8 November 2023

EUROCONTROL's Brussels HQ

# The project

E-CONTRAIL

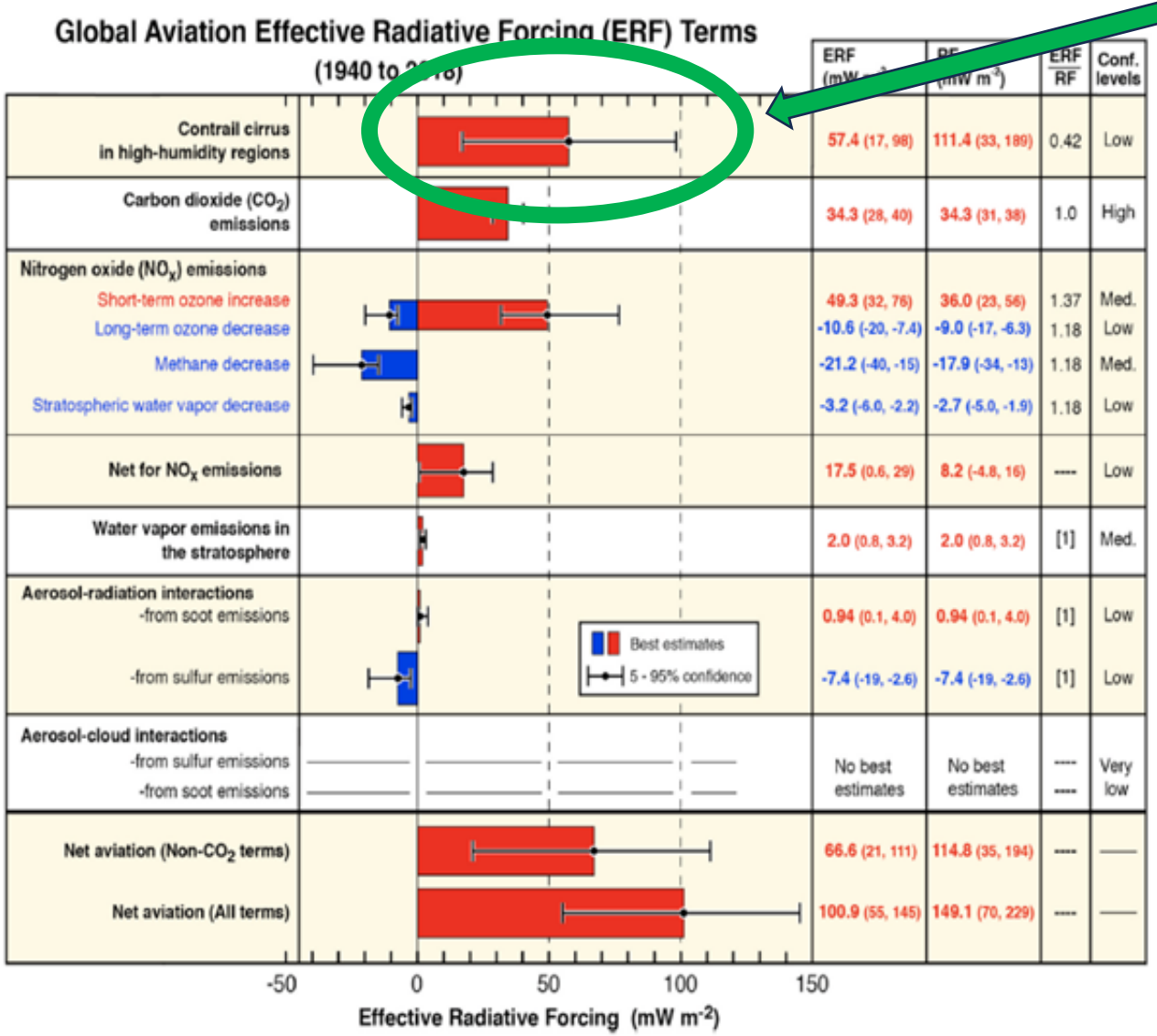

**This project has received funding from the SESAR Joint Undertaking (JU) under grant agreement No 101114795. The JU receives support from the European Union's Horizon Europe research and innovation programme and the SESAR JU members other than the Union.**





Project Started in Jun. 2023


# Motivation




Let et al., 2021

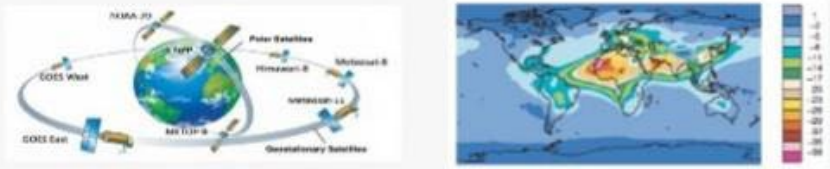
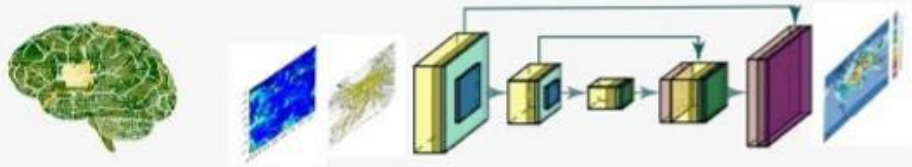
## Focus:

- Conditions for contrail Formation/Persistence; duration? How to predict ISSR?
- RF estimation (including cooling/warming)?
- Models and metrics?

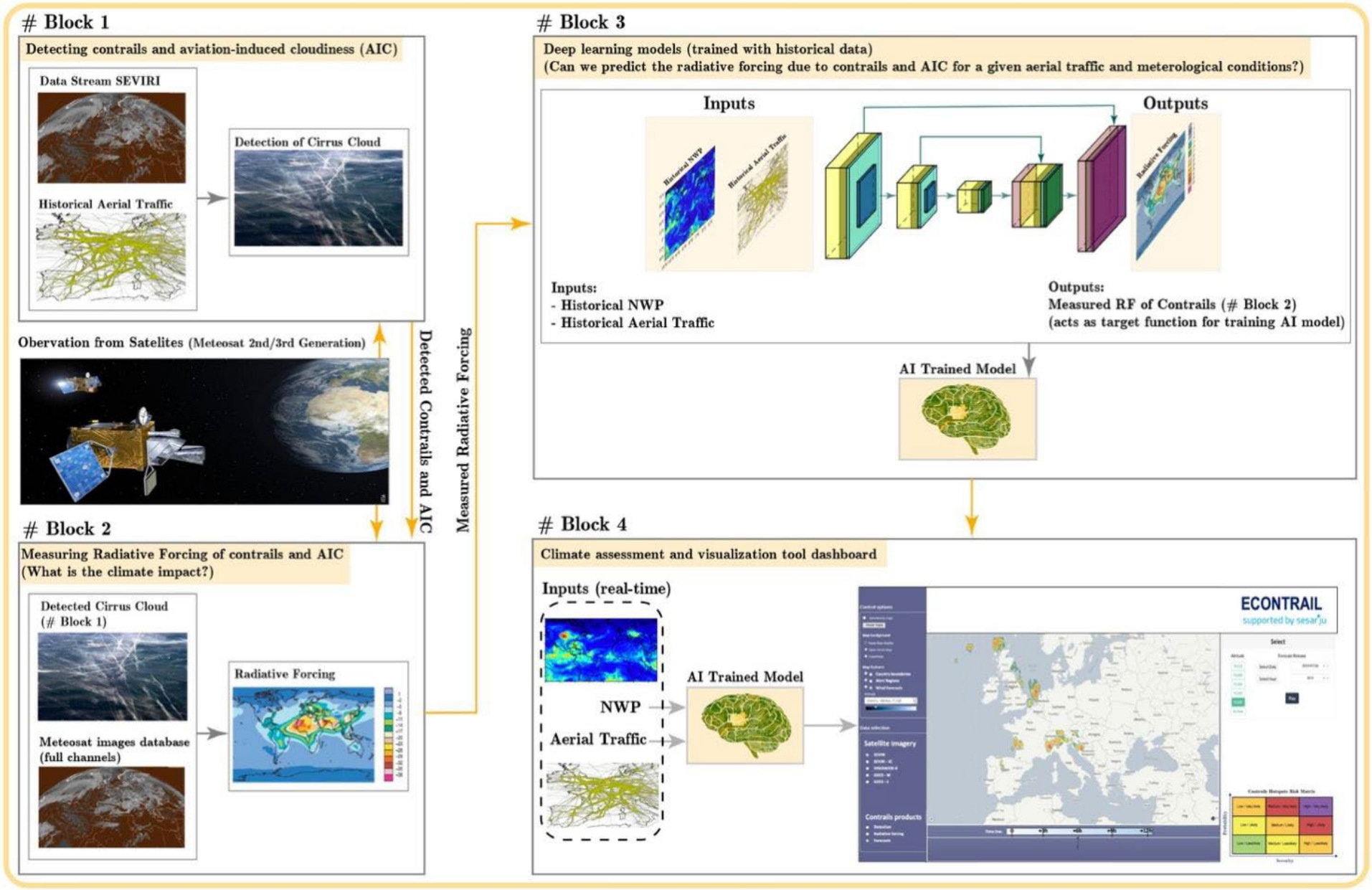
| Research Questions (RQ) |
|---|
| RQ#1 (linked to O-1): Can we develop remote-sensing algorithms (including cloud detections and the synchronization with aerial traffic) to detect contrail and aviation-induced cloudiness? |
| RQ#2 (linked to O-2): Can we integrate ice-cloud radiative models with a satellite retrieval scheme to measure contrail and aviation-induced cloudiness radiative forcing over the full diurnal cycle? |
| RQ#3: Can we develop novel deep-learning models to predict the forcing of contrails with high accuracy and spatiotemporal resolution? |
| RQ#4: Can we obtain critical information about contrails (detection, climate impact, forecasts) in a single visualization dashboard? |

# Goals

**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.**

| 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.   | ✓ | ✓ | ✓ |

# Overall Concept

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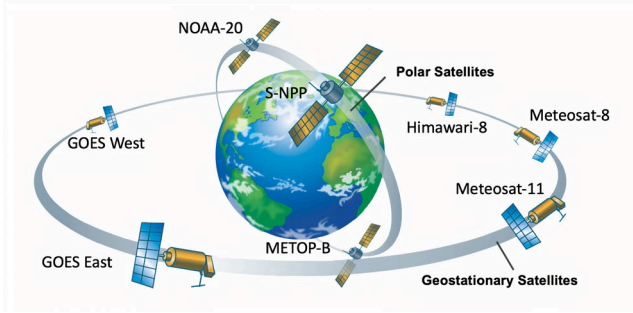
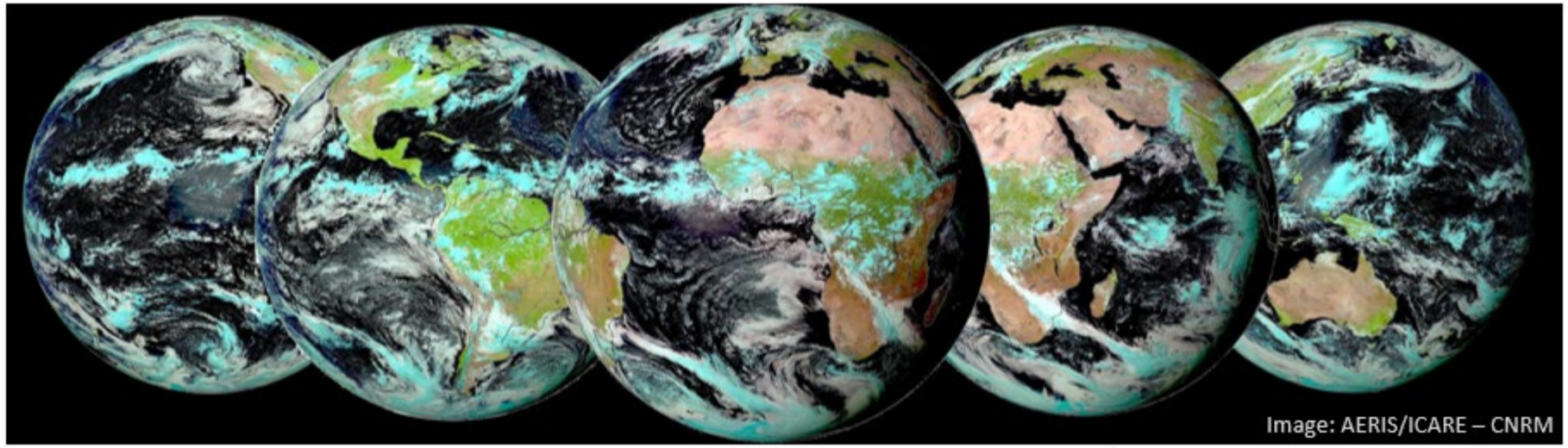
# Contrail Detection - Data (Geostationary Sat.)




FOCUS

| Colour (ash/dust RGB) | GOES-E / **ABI** | GOES-W / **ABI** | MSG-11 / **SEVIRI** | MSG-8 / **SEVIRI** | HIMAWARI-8 / **AHI** |
|---|---|---|---|---|---|
| **RED** lin. combo. [channel in µm] | $[12.3]^{rad} - [10.3]^{rad}$ | $[12.3]^{rad} - [10.3]^{rad}$ | $[12.0]^{rad} - [10.8]^{rad}$ | $[12.0]^{rad} - [10.8]^{rad}$ | $[12.4]^{rad} - [10.4]^{rad}$ |
| **GREEN** lin. combo. [ch. in µm] | $[11.2]^{rad} - [8.4]^{rad}$ | $[11.2]^{rad} - [8.4]^{rad}$ | $[10.8]^{rad} - [8.7]^{rad}$ | $[10.8]^{rad} - [8.7]^{rad}$ | $[10.4]^{rad} - [8.6]^{rad}$ |
| **Blue** lin. combo. [ch. in µm] | $[10.3]^{rad}$ | $[10.3]^{rad}$ | $[10.8]^{rad}$ | $[10.8]^{rad}$ | $[10.4]^{rad}$ |




GOES-W / **ABI** GOES-E / **ABI** MSG-11 / **SEVIRI** MSG-8 / **SEVIRI** HIMAWARI-8 / **AHI**

| Assumptions |
|---|
| Geographical scope limited to EUROPE and half of the North Atlantic. |
| We will use the Meteosat Second Generation (MSG) data from years 2018 to 2022.<br><br>Resolution of MSG is low!<br><br>We will use the Meteosat Third Generation (MTG) data from years 2023 (when available) to 2024 |



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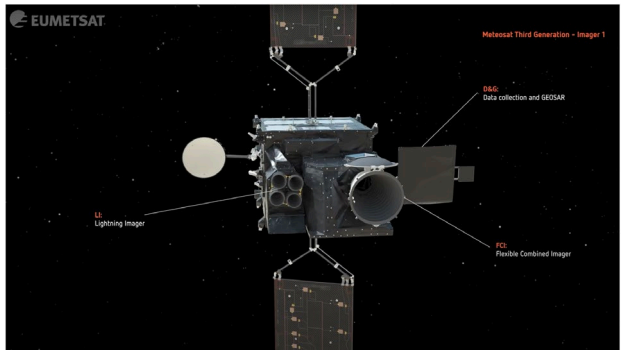
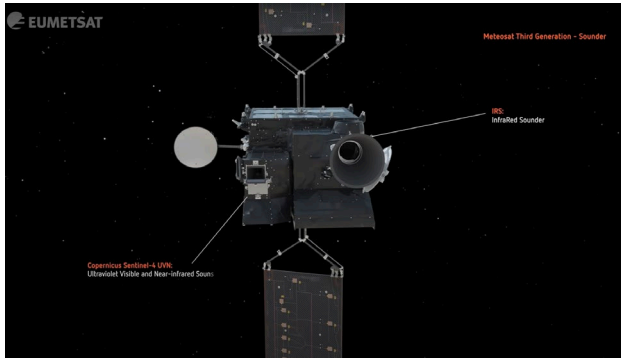
# Contrail Detection - Data
## (MTG)

MTG series will comprise 4 imaging (MTG-I) and 2 sounding satellites (MTG-S)
The first satellite, MTG-I1, was launched on 13 December 2022.




**FEATURES:** On the MTG-I satellites, FCI will scan the full Earth disc every **10 minutes using 16 spectral channels** at **very high spatial resolutions, from 2 km to 0.5 km (depends on the channel)**. In 'fast imagery mode' it will be capable of a repeat cycle of 2.5 minutes over a quarter of the disc.

**(Same Resolution as GOES-ABI)**

**FEATURES: 16 Spectral bands (including the cirrus band at 1.3 μm)**

**(Very similar as GOES-ABI)**

All in all, with the MST in Europe we could ambition to replicate the activities developed in US (Google & MiT)

Frist, we need to put efforts in creating a labelled dataset of contrails in Europe.

# Contrail Detection - Methods

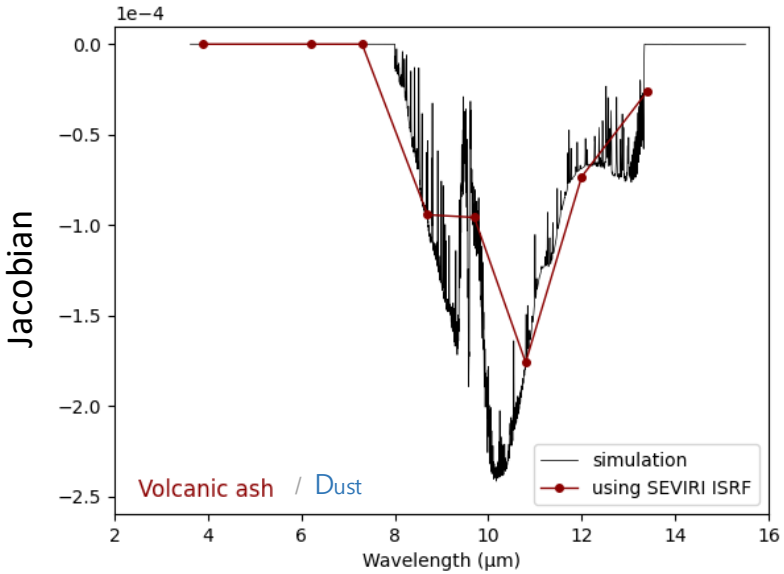
We are exploring two approaches:

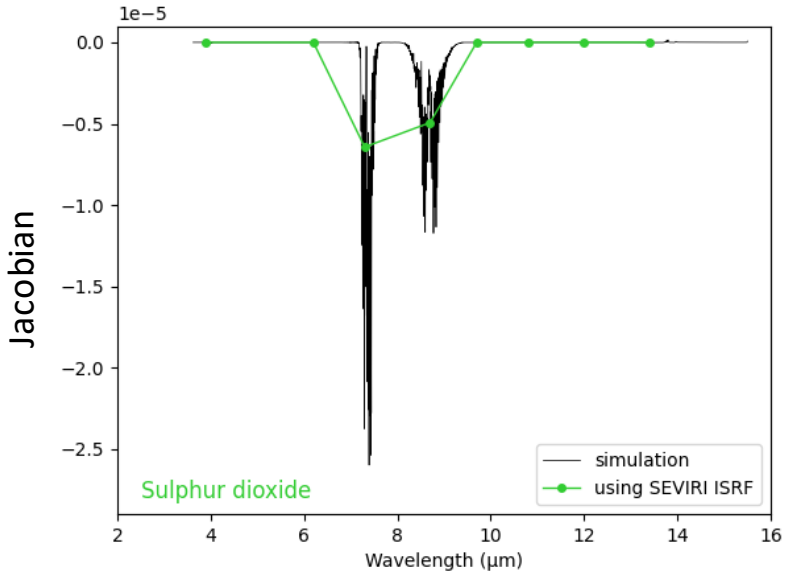
- Machine Learning:
  - Hough Transform and Instance Segmentation
  - Working (so far) on GOES and the Google Dataset
  - We intend to use it on the MTG for EUROPE (transfer Learning)

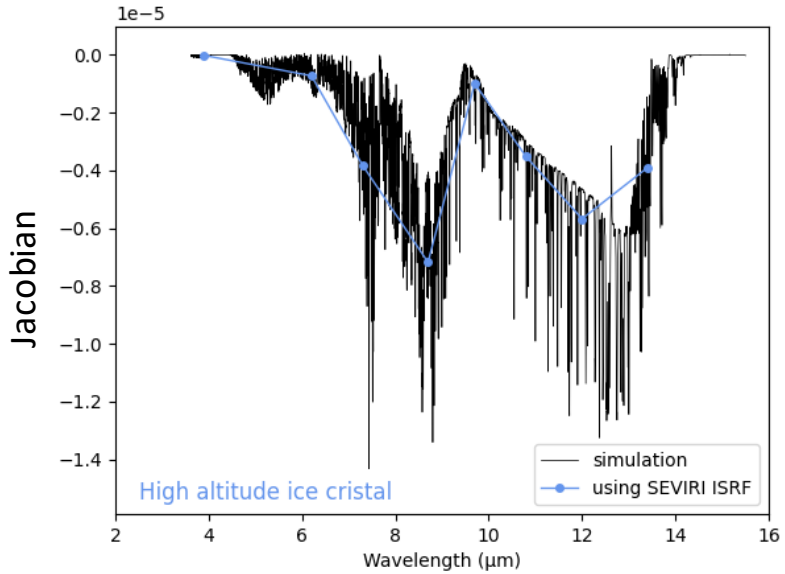
- Multiespectral approach:
  - COBRA → The Covariance-Based Retrieval Algorithm for contrails detection using geostationary imagers

# COBRA technique applied to dust/ash and $SO_2$

## Can we extrapolate the results on dust/ash/$SO_2$ to ice crystals?





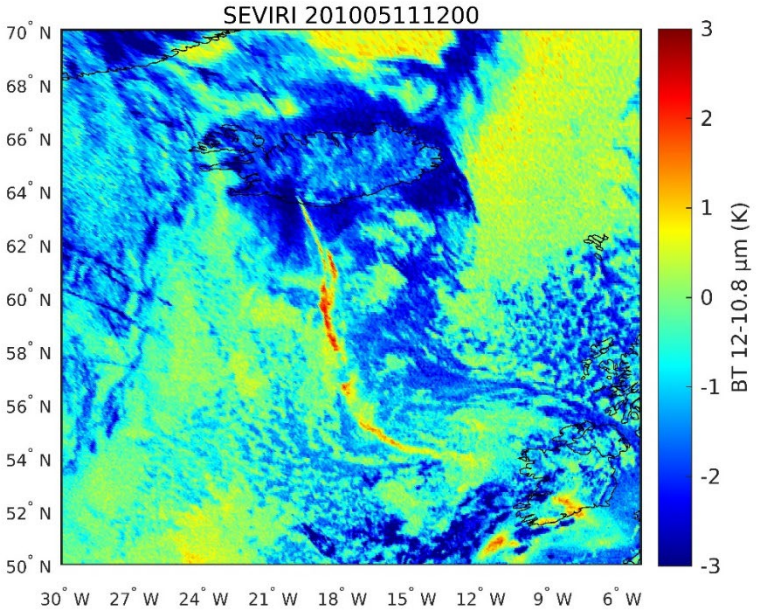




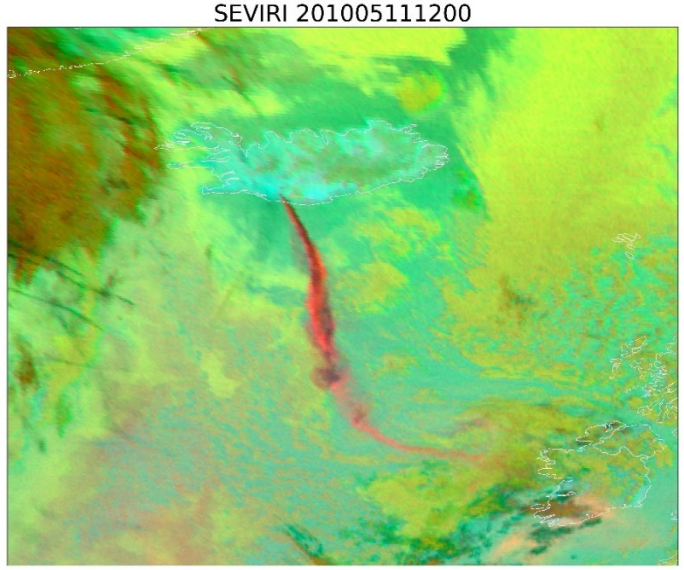

Black: high-resolution simulations
Brown / Green / Blue: data convolved and sampled @ SEVIRI

# COBRA technique applied to dust/ash and $SO_2$

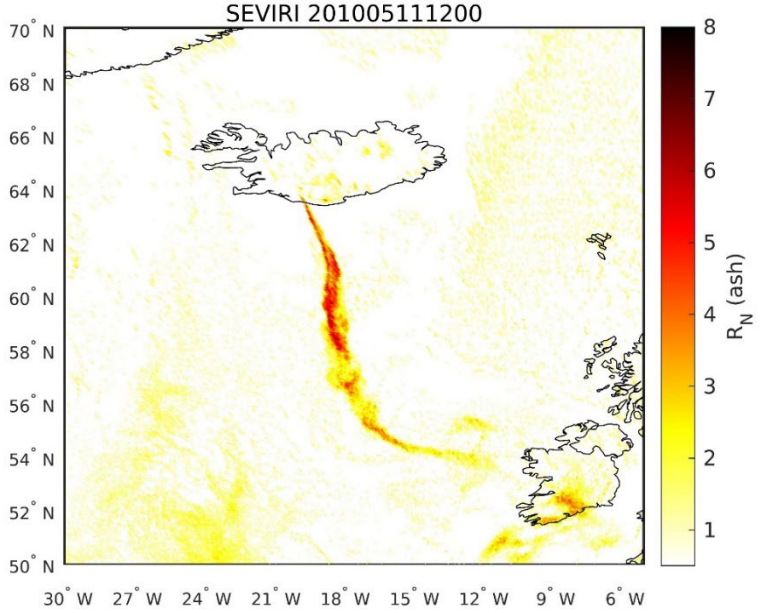
**Brightness Temperature Diffference**




**Ash RGB composite**



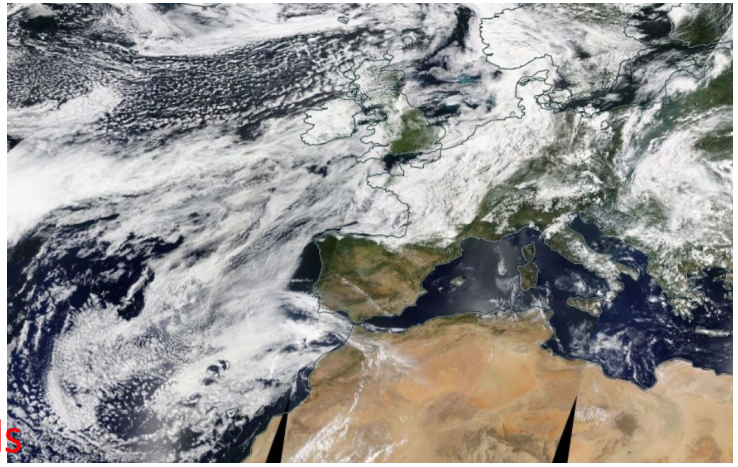

**COBRA detection**




**Eyjafjallajökull, 11 May 2010**

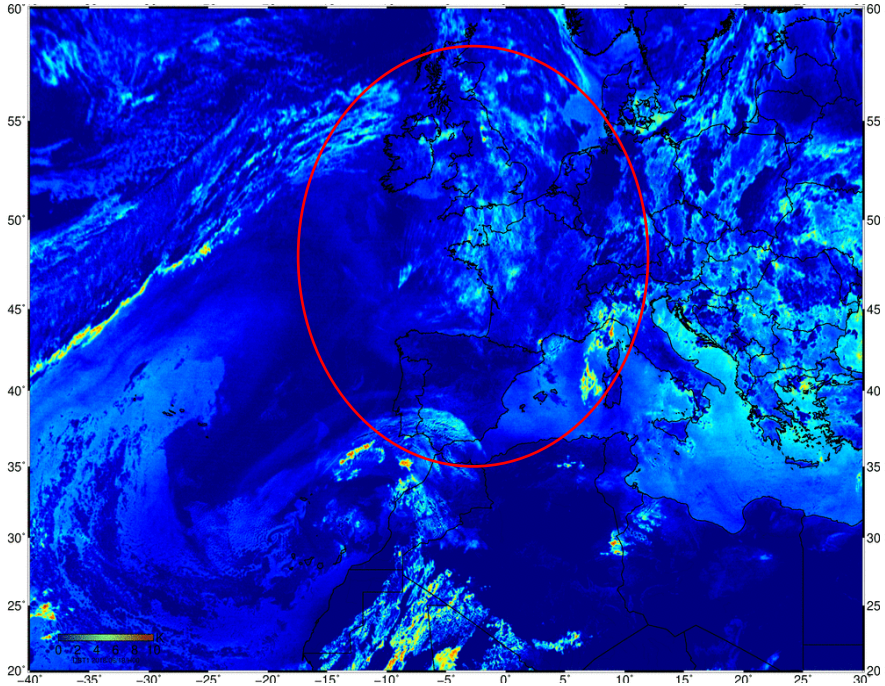
# Preliminary results from COBRA

## (using synthetic spectral ice crystal signature)

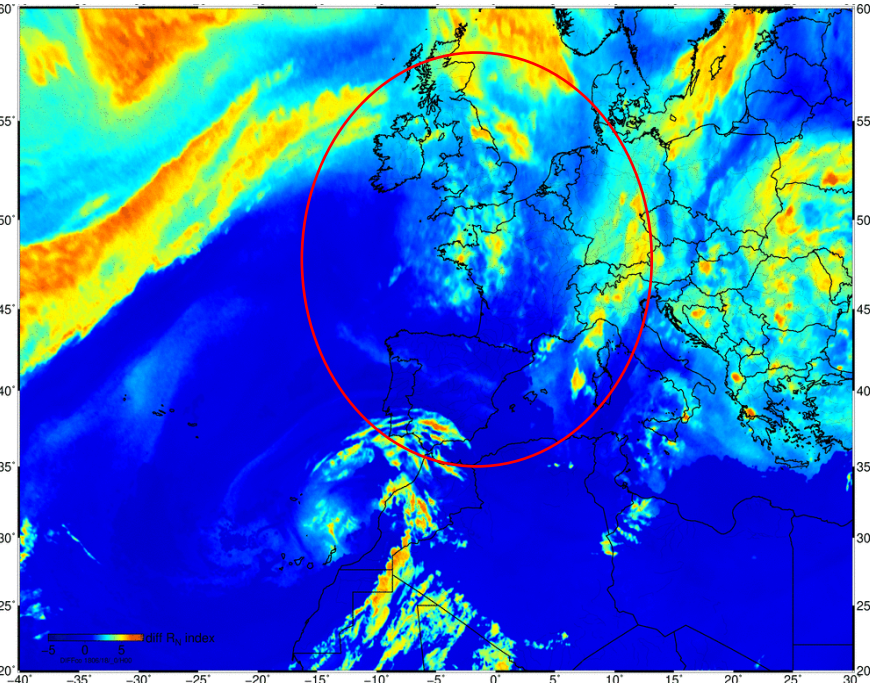


Seems potentiality to detect ice clouds but…
We still need to differentiate contrails vs clouds
In addition: MSG reolution does not seem to be fine enough to detect linear contrails

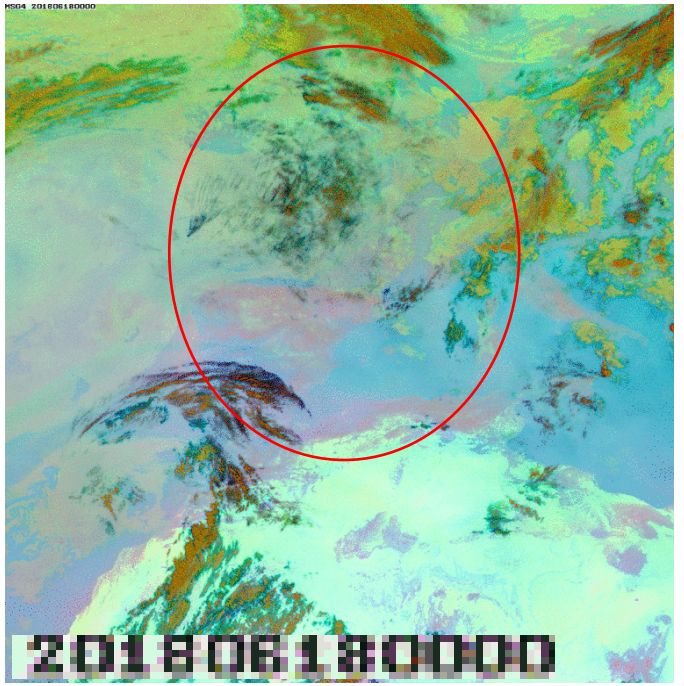
**Brightness Temperature Diffference**



**New COBRA product**

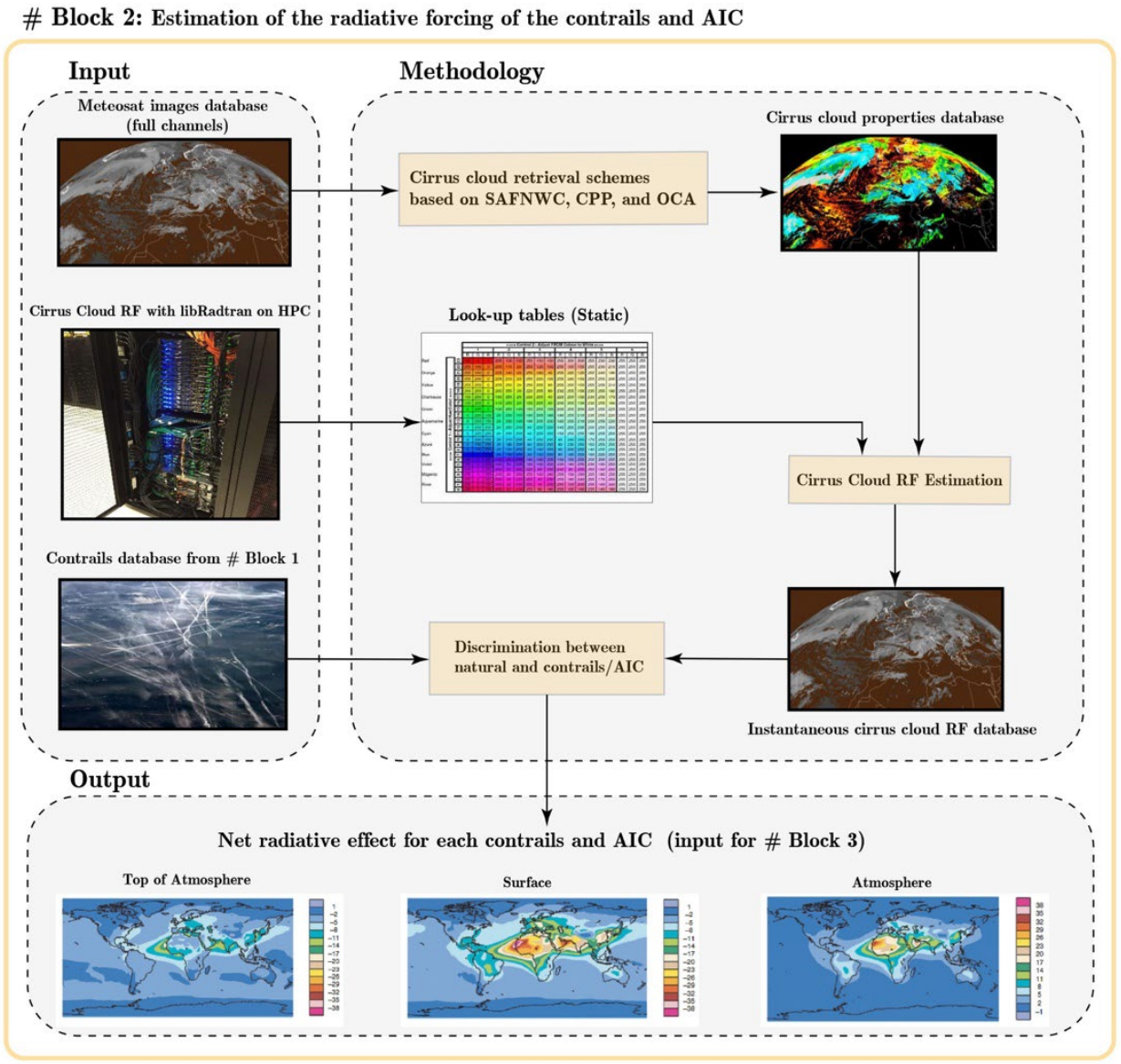


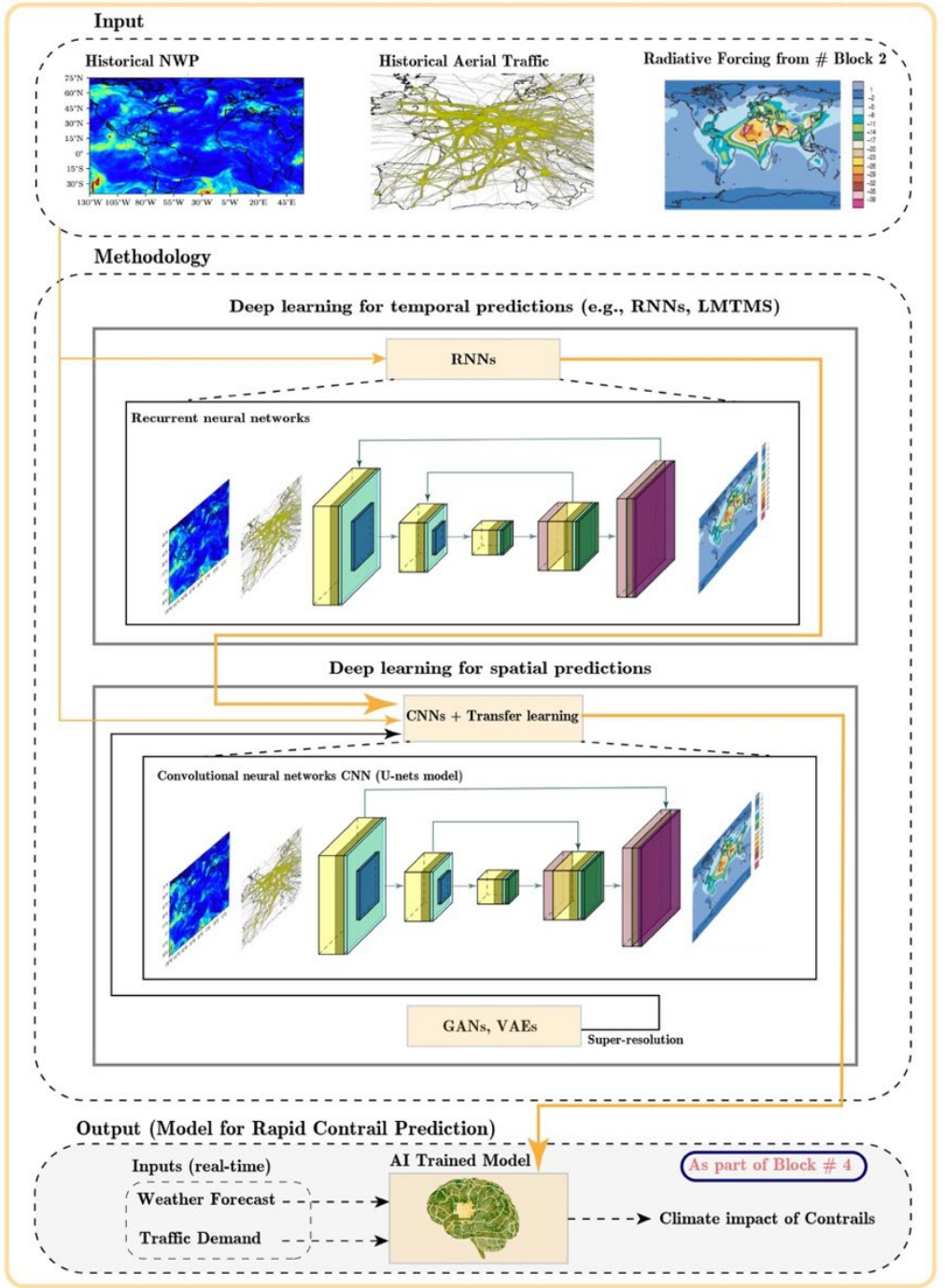
**Ash RGB composite**



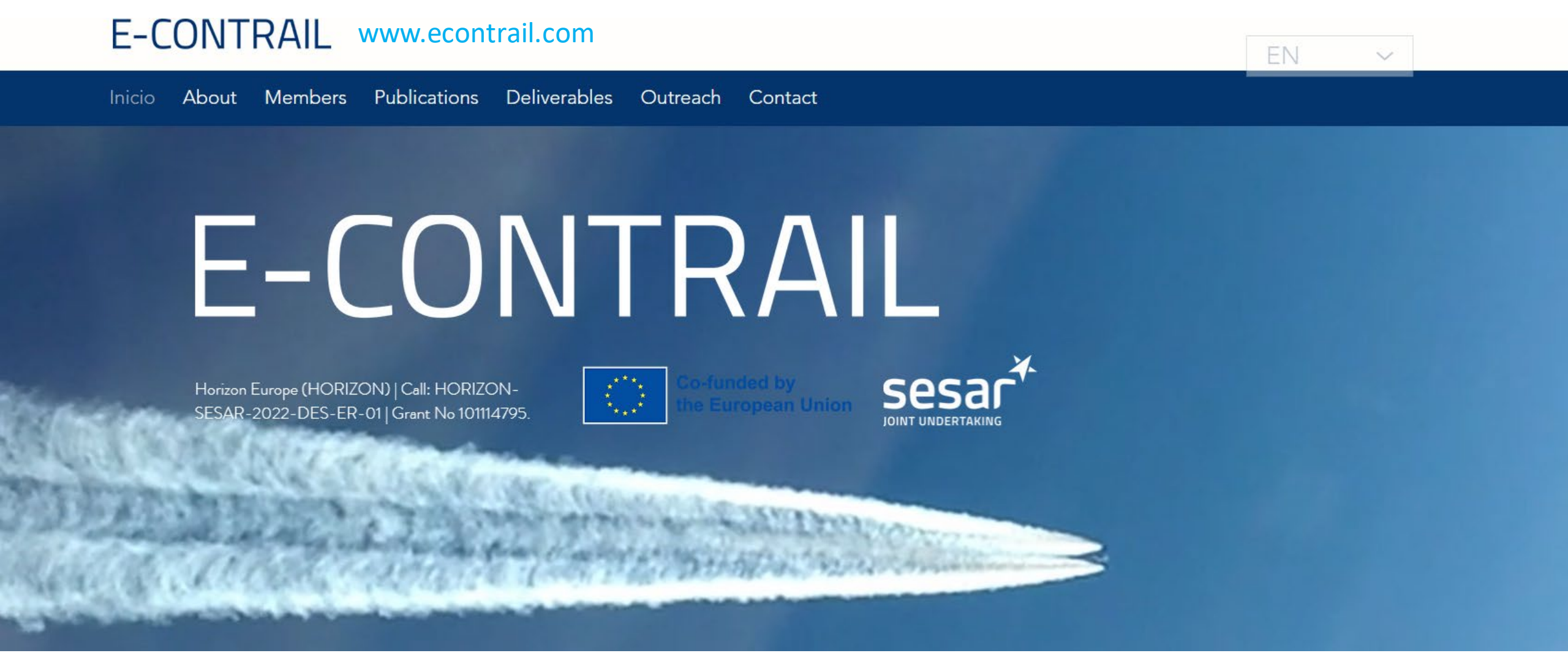

**Contrail detection on 18 June 2018**

# Methods for RF and AI.



# E-CONTRAIL Website and Media

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