The added value of EarthCARE for contrail detection and radiative impact assessment

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Artificial Neural Networks for the Prediction of Contrails and Aviation Induced Cloudiness

Co-funded by the European Union

EUROPEAN PARTNERSHIP

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Multi-sensor Physics-Informed Contrail Detection, Radiative Forcing Estimation & Interactive Climate Analytics

Co-funded by the European Union

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Outline

I. Motivation

II. Lessons Learned from E-CONTRAIL 1

III. Why EarthCARE?

IV. E-CONTRAIL 2 Objectives & Methodology

V. An EarthCARE Case Study

VI. Conclusions

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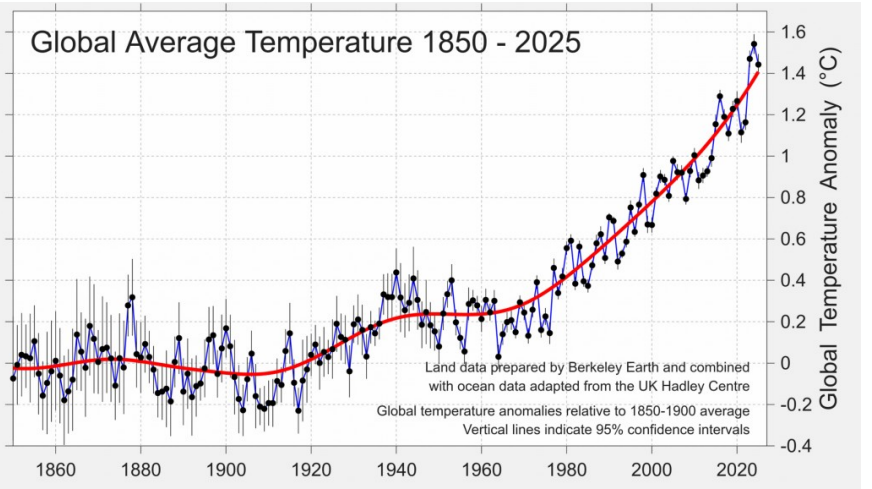
Contrails are:

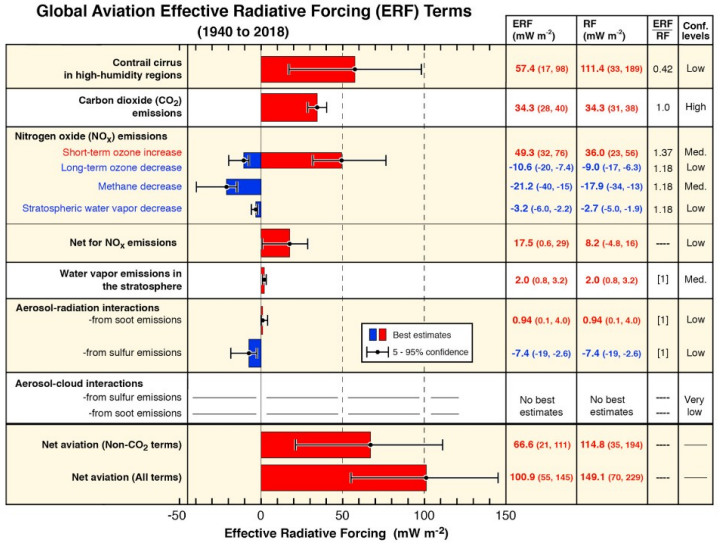
- ice clouds
- formed in ice supersaturated regions (**ISSRs**)
- responsible for up to **57 %** of the aviation climate impact

Climate impact:

- Often expressed as net Radiative Forcing (RF): sum of shortwave (SW) & longwave (LW) RF



Source: https://berkeleyearth.org/global-temperature-report-for-2025/



Source: Lee et al. (2021)

Global studies:

The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018

D.S. Lee [a,*], D.W. Fahey [b], A. Skowron [a], M.R. Allen [c,n], U. Burkhardt [d], Q. Chen [e], S.J. Doherty [f], S. Freeman [a], P.M. Forster [g], J. Fuglestvedt [h], A. Gettelman [i], R.R. De León [a], L.L. Lim [a], M. T. Lund [h], R.J. Millar [c,o], B. Owen [a], J.E. Penner [j], G. Pitari [l], M.J. Prather [k], R. Sausen [d], L. J. Wilcox [m]

+ 111.4 mW/m²

Global aviation contrail climate effects from 2019 to 2021

Roger Teoh[1], Zebediah Engberg[2], Ulrich Schumann[3], Christiane Voigt[3,4], Marc Shapiro[2], Susanne Rohs[5], and Marc E. J. Stettler[1]

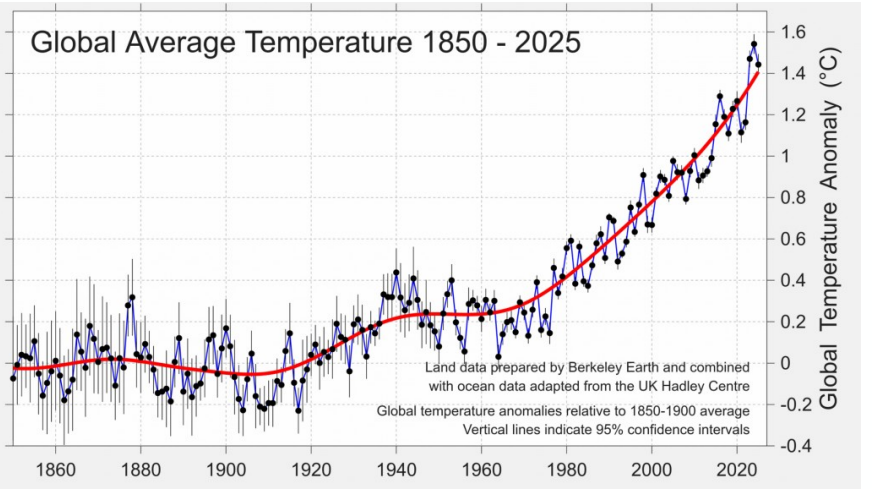
+ 62.1 mW/m²

Radiative forcing by persistent contrails and its dependence on cruise altitudes

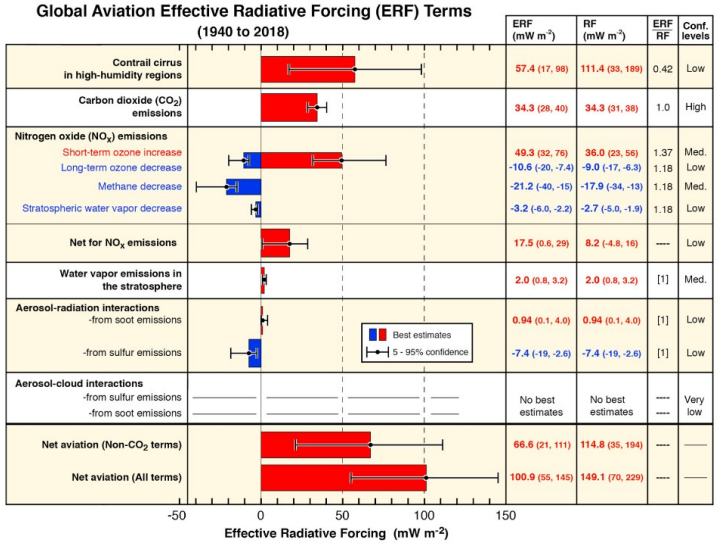
Gaby Rädel[1] and Keith P. Shine[1]

Received 2 July 2007; revised 13 December 2007; accepted 3 January 2008; published 8 April 2008.

+ 6 mW/m²



Source: https://berkeleyearth.org/global-temperature-report-for-2025/



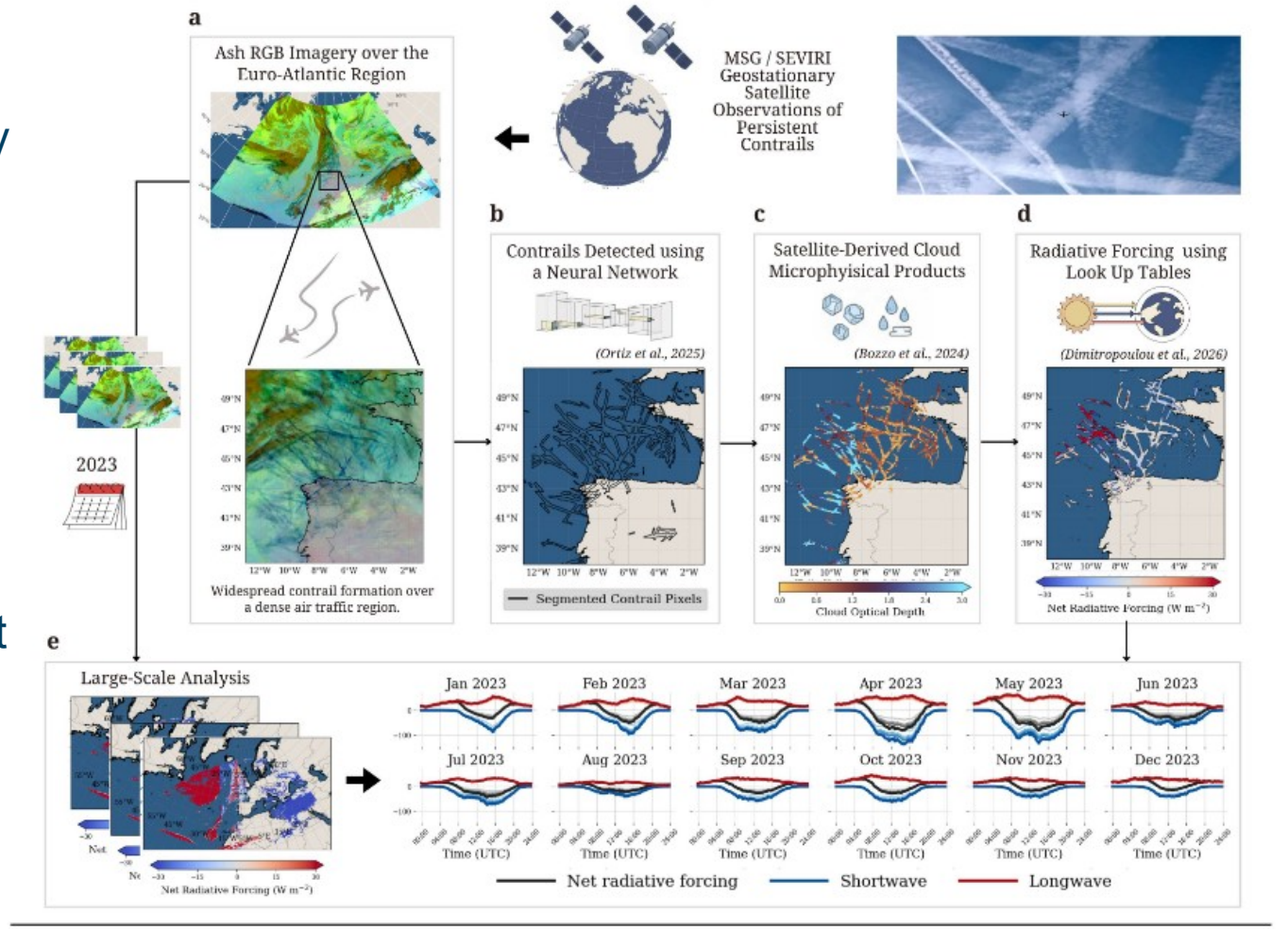
Source: Lee et al. (2021)

Contrail observation & detection

- Lack of contrail datasets labelled in geostationary imagery above Europe
- Existing contrail datasets lack info on clouds' physical properties → Essential to evaluate models & estimate radiative impacts

Radiative forcing of contrails

- Limited detectability & characterization by current operational cloud retrieval algorithms
- Inaccurate representation of contrails' microphysical & radiative properties → Often biased



Source: Ortiz et al. (2026) - Under revision in npj Climate and Atmospheric Science

MSI

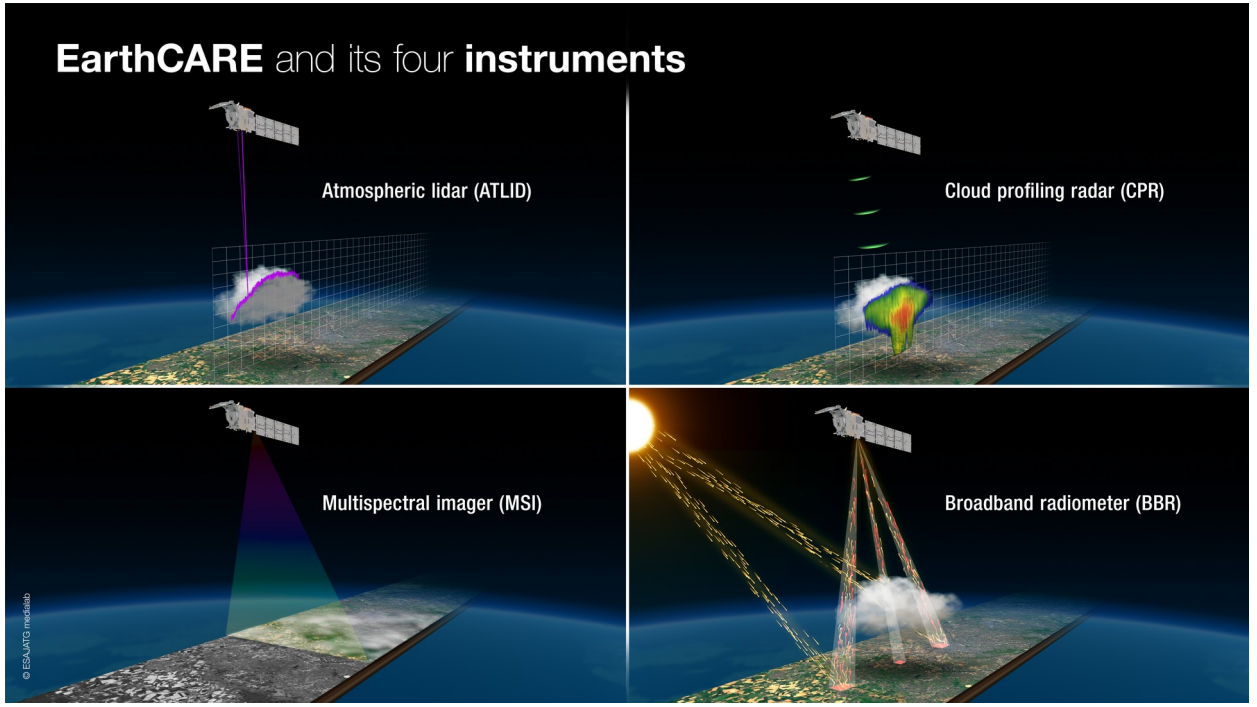
- High-resolution imagery
- Creation of a global contrail dataset with info on clouds' microphysical properties (**MSI_COP_2A**)

ATLID

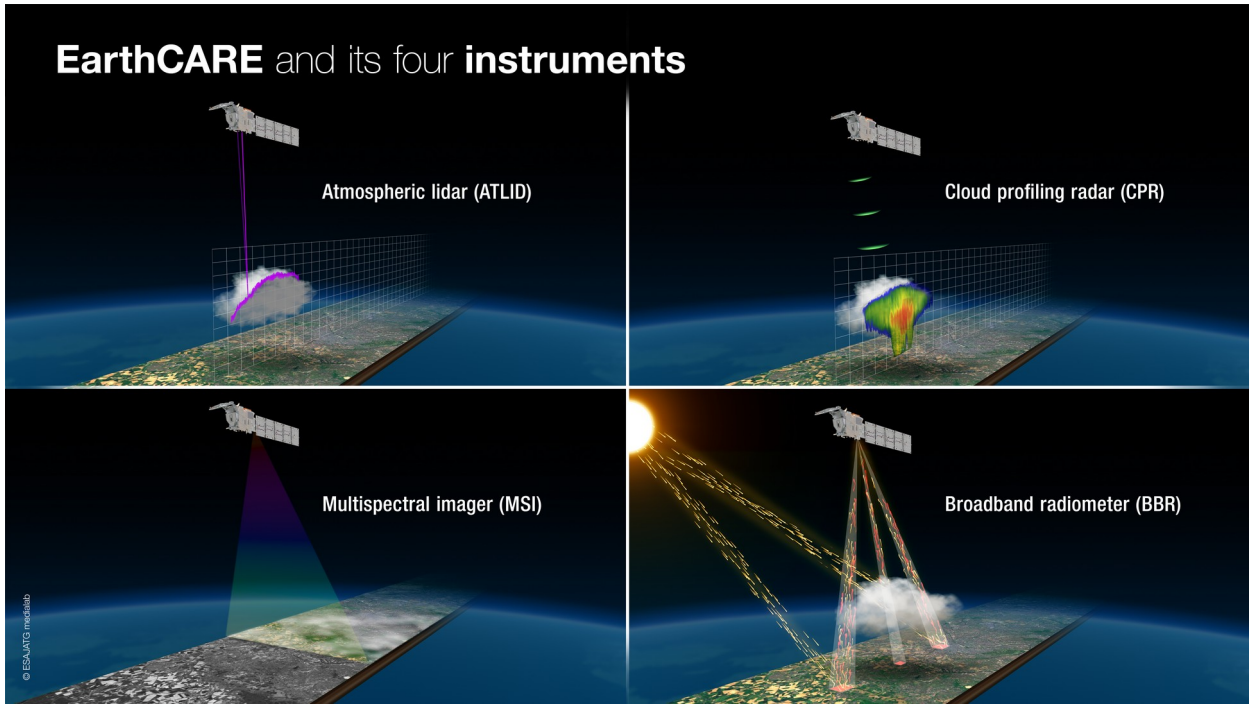
- Accurate Cloud-Top Height (**ATL_CTH_2A**), Cloud Optical Thickness (COT), Ice Water Content, & Cloud Effective Radius (**ATL_ICE_2A**)

BBR

- SW and LW TOA flux (**BMA_FLX_2B**) and radiance (**BBR_SNG_1B**) observations

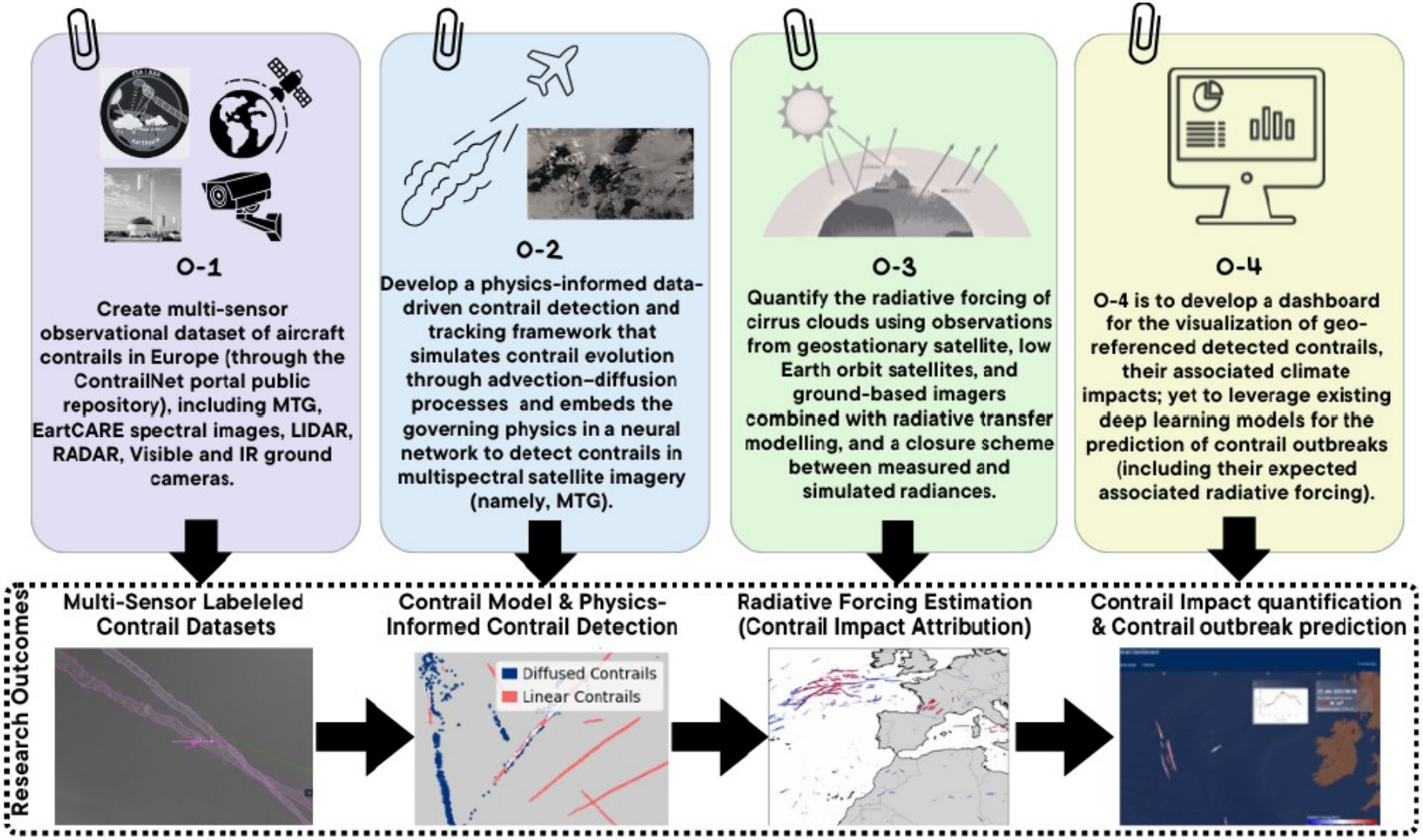


Source: https://www.airbus.com/en/newsroom/press-releases/2024-05-heaven-sent-earthcare-to-study-clouds-and-climate



Source: https://www.airbus.com/en/newsroom/press-releases/2024-05-heaven-sent-earthcare-to-study-clouds-and-climate

→ From a **retrieval-and-modelling framework** (E-CONTRAIL 1) towards an **observation-constrained framework** supported by **EarthCARE observations** for retrieval improvement and validation (E-CONTRAIL-2)


O-1
Create multi-sensor observational dataset of aircraft contrails in Europe (through the ContrailNet portal public repository), including MTG, EartCARE spectral images, LIDAR, RADAR, Visible and IR ground cameras.
O-2
Develop a physics-informed data-driven contrail detection and tracking framework that simulates contrail evolution through advection–diffusion processes and embeds the governing physics in a neural network to detect contrails in multispectral satellite imagery (namely, MTG).
O-3
Quantify the radiative forcing of cirrus clouds using observations from geostationary satellite, low Earth orbit satellites, and ground-based imagers combined with radiative transfer modelling, and a closure scheme between measured and simulated radiances.
O-4
O-4 is to develop a dashboard for the visualization of geo-referenced detected contrails, their associated climate impacts; yet to leverage existing deep learning models for the prediction of contrail outbreaks (including their expected associated radiative forcing).
Research Outcomes
Multi-Sensor Labeleled Contrail Datasets
Contrail Model & Physics-Informed Contrail Detection
Diffused Contrails
Linear Contrails
Radiative Forcing Estimation (Contrail Impact Attribution)
Contrail Impact quantification & Contrail outbreak prediction

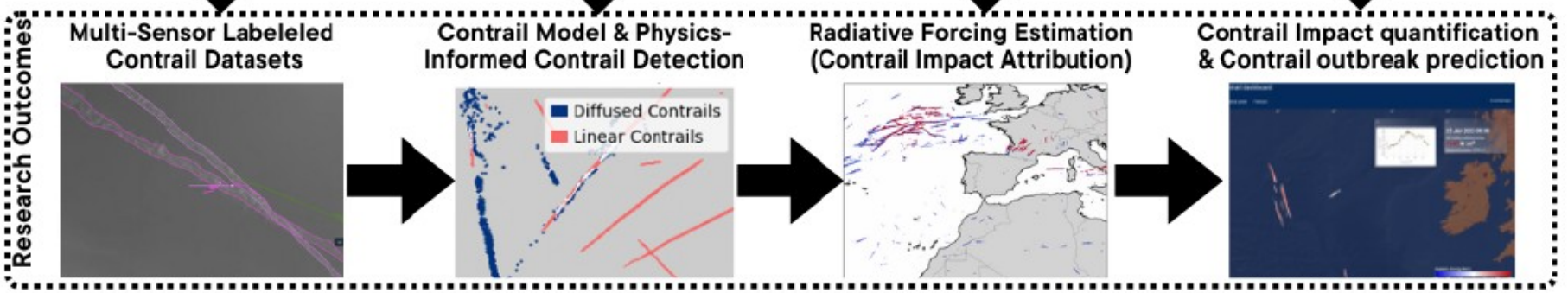
Co-located MTG/FCI – EarthCARE dataset with flight info

Validation of the contrail detection algorithm with EarthCARE

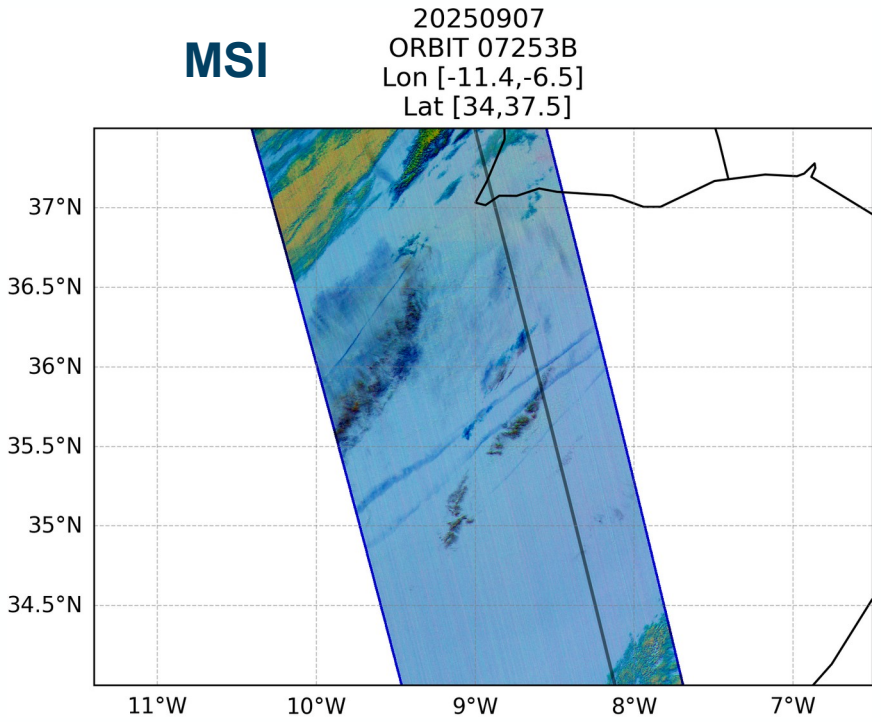
Build a cloud retrieval scheme with the aid of EarthCARE & validate the flux estimates with EarthCARE

O-4

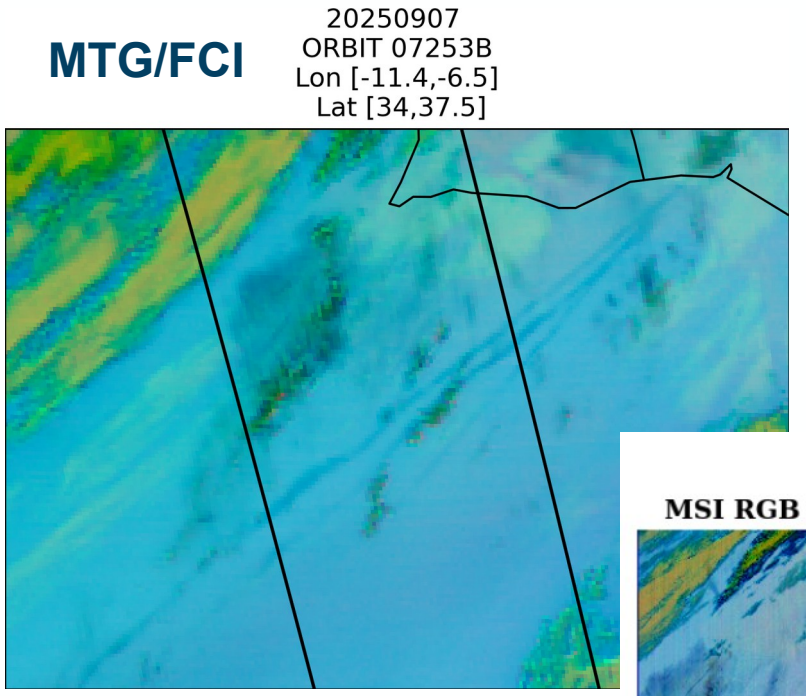
O-4 is to develop a dashboard for the visualization of geo-referenced detected contrails, their associated climate impacts; yet to leverage existing deep learning models for the prediction of contrail outbreaks (including their expected associated radiative forcing).



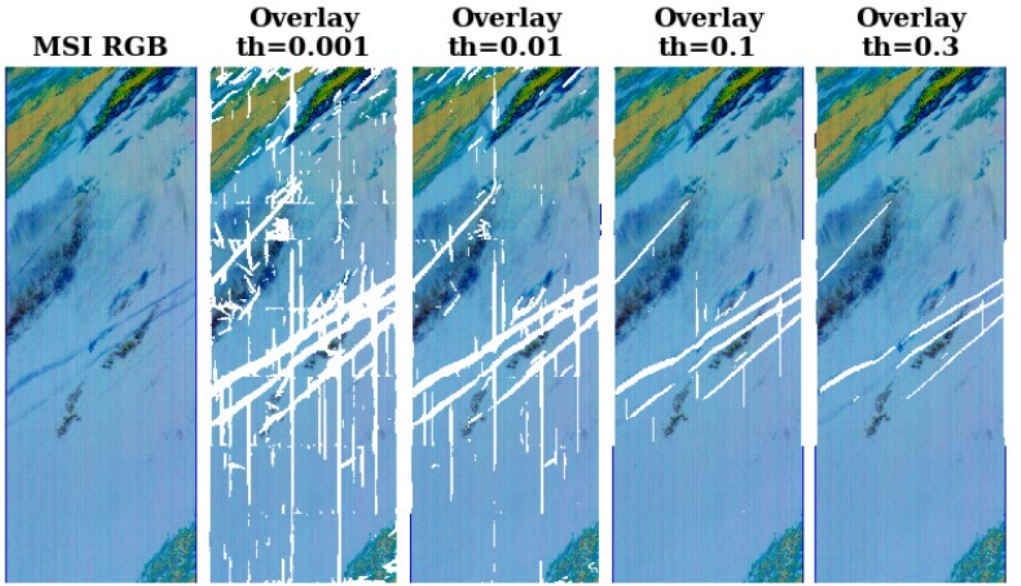
MSI



MTG/FCI

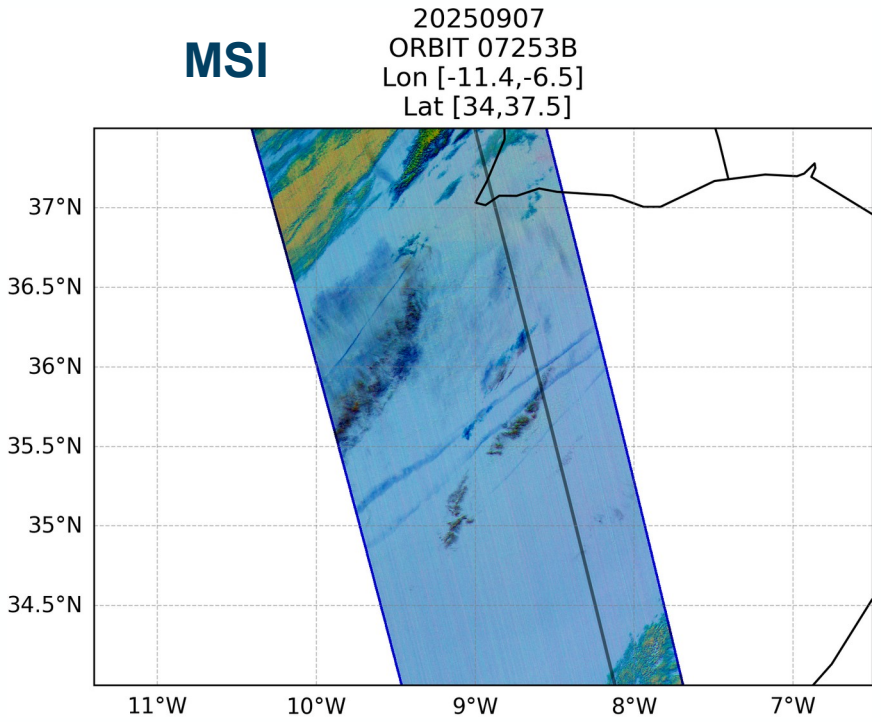


Contrail detection on MSI

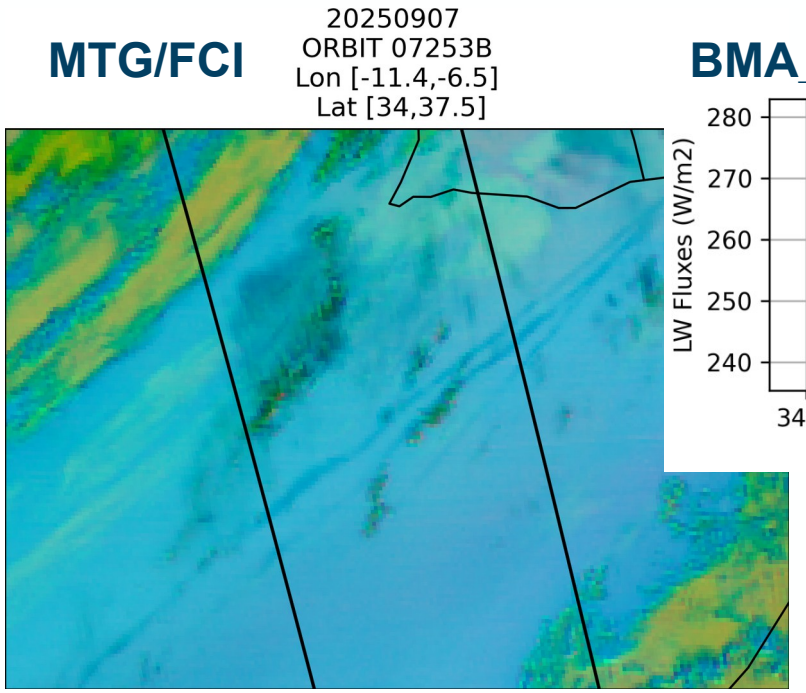


Work of Irene Ortiz (UC3M)

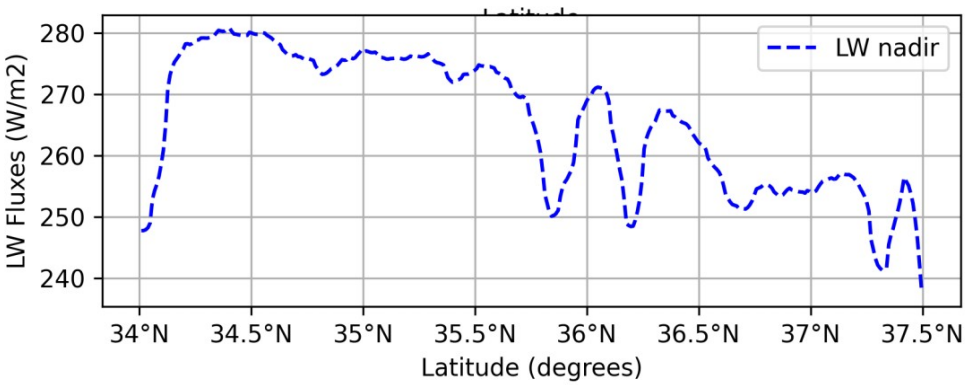
MSI



MTG/FCI



BMA_FLX_2B



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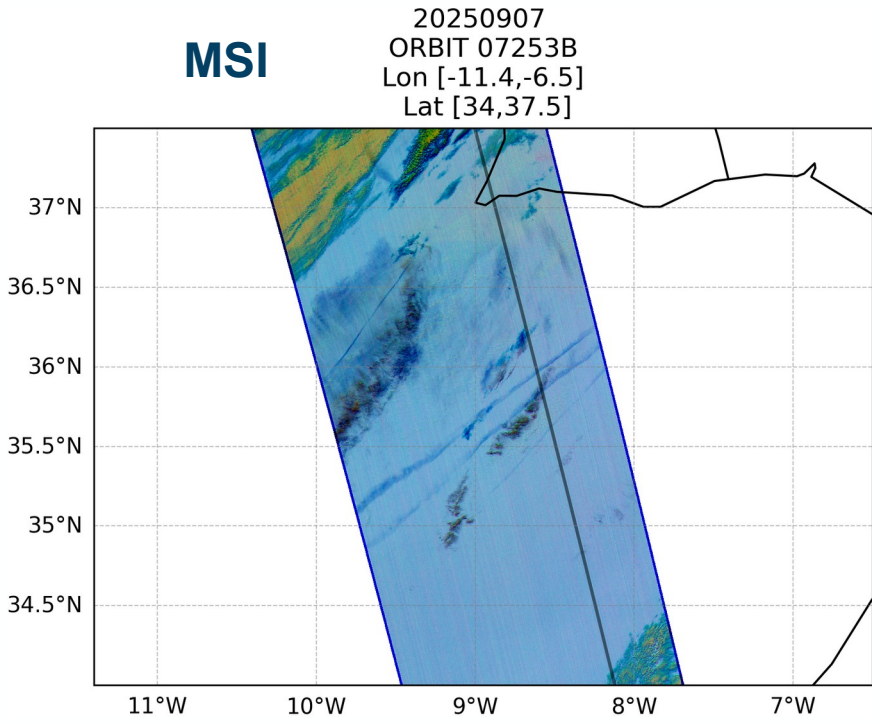
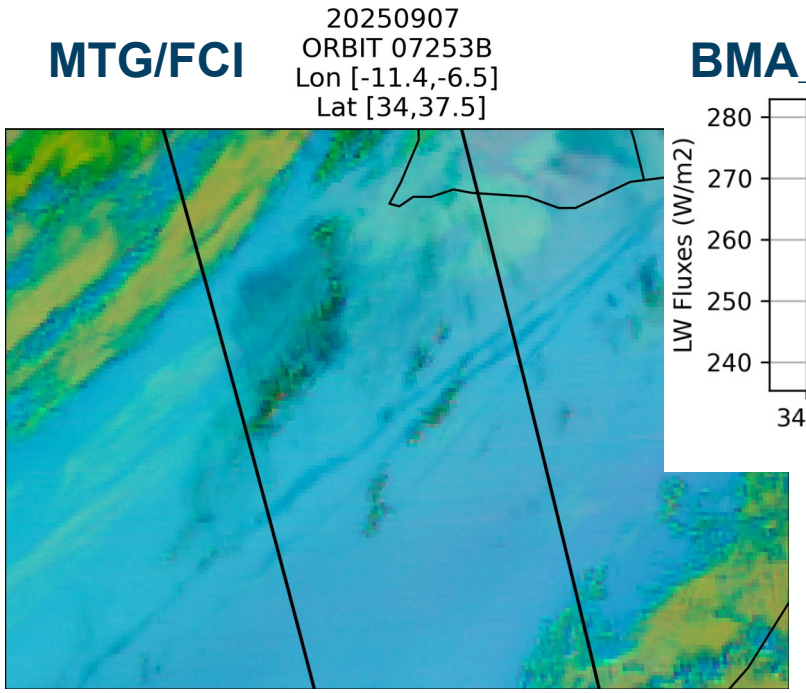
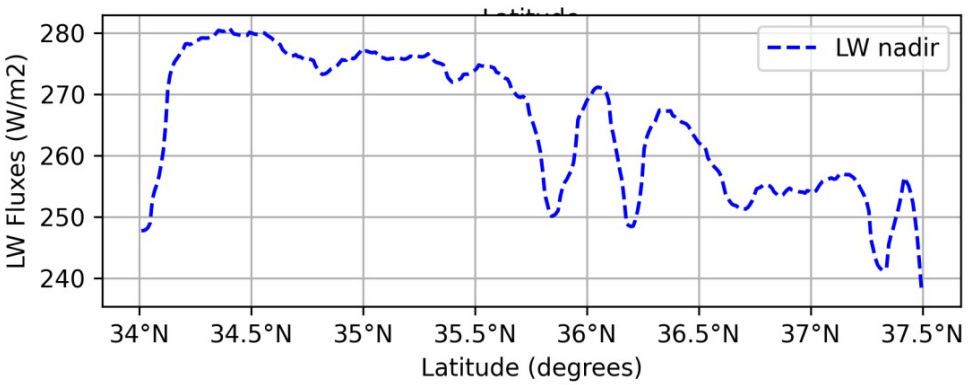


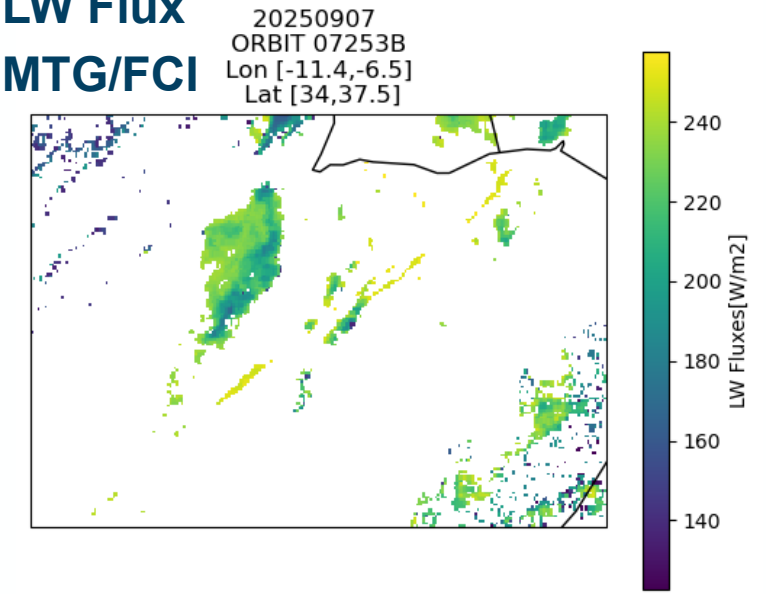
MTG/FCI



BMA_FLX_2B



LW Flux MTG/FCI



MSI

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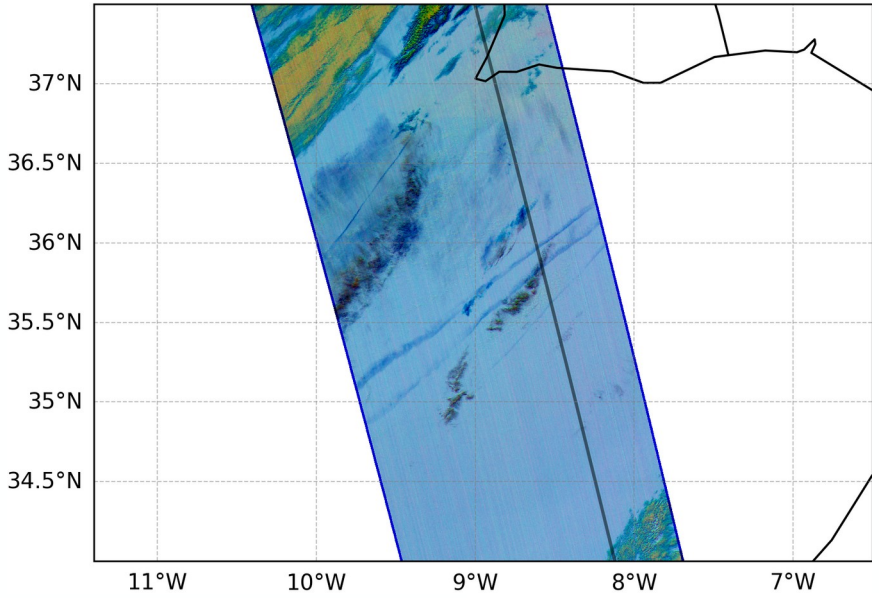
ORBIT 07253B
Lon [-11.4,-6.5]
Lat [34,37.5]



MTG/FCI

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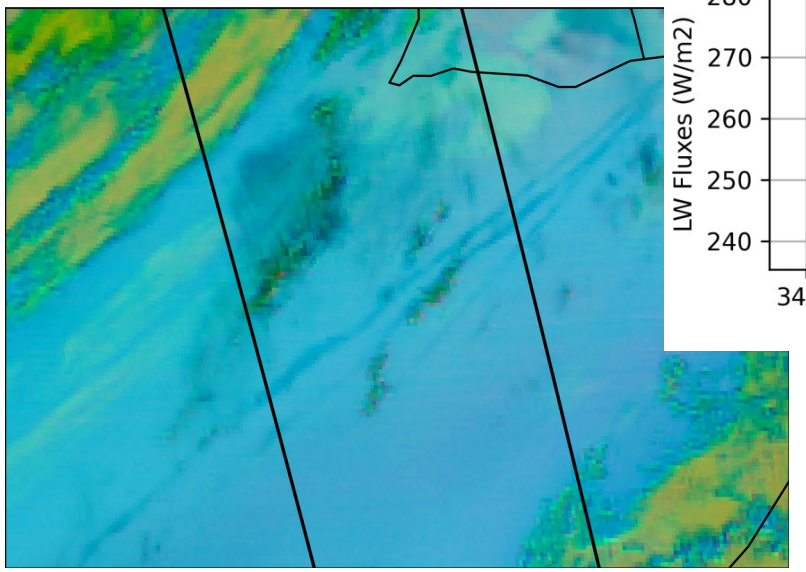

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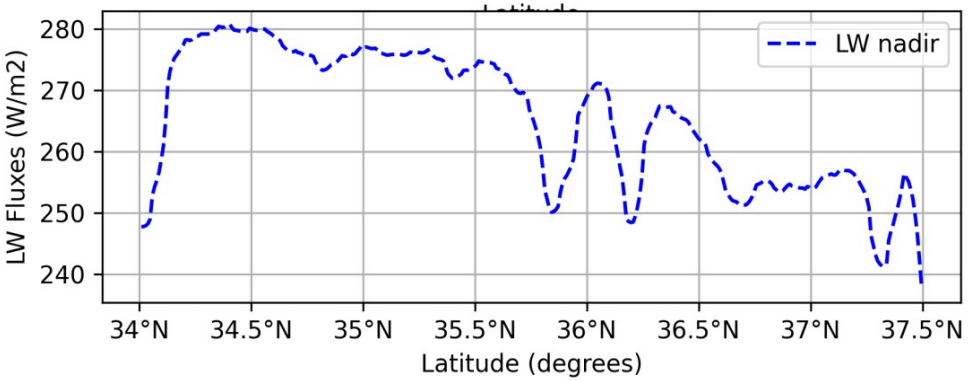

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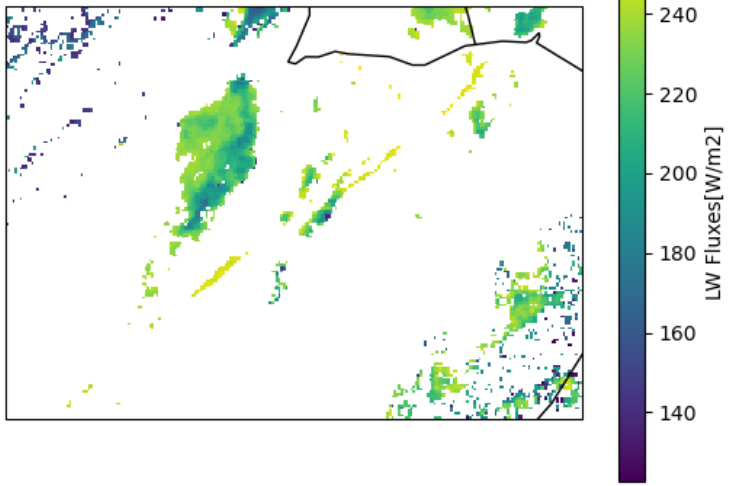
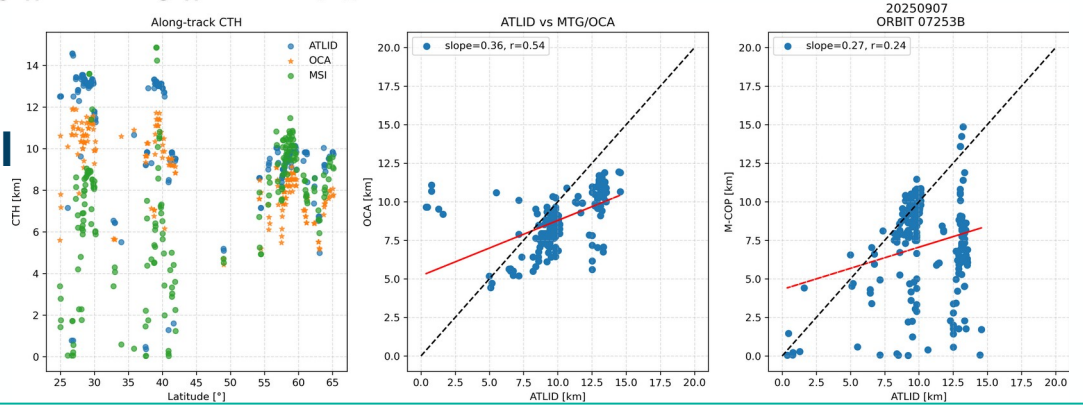


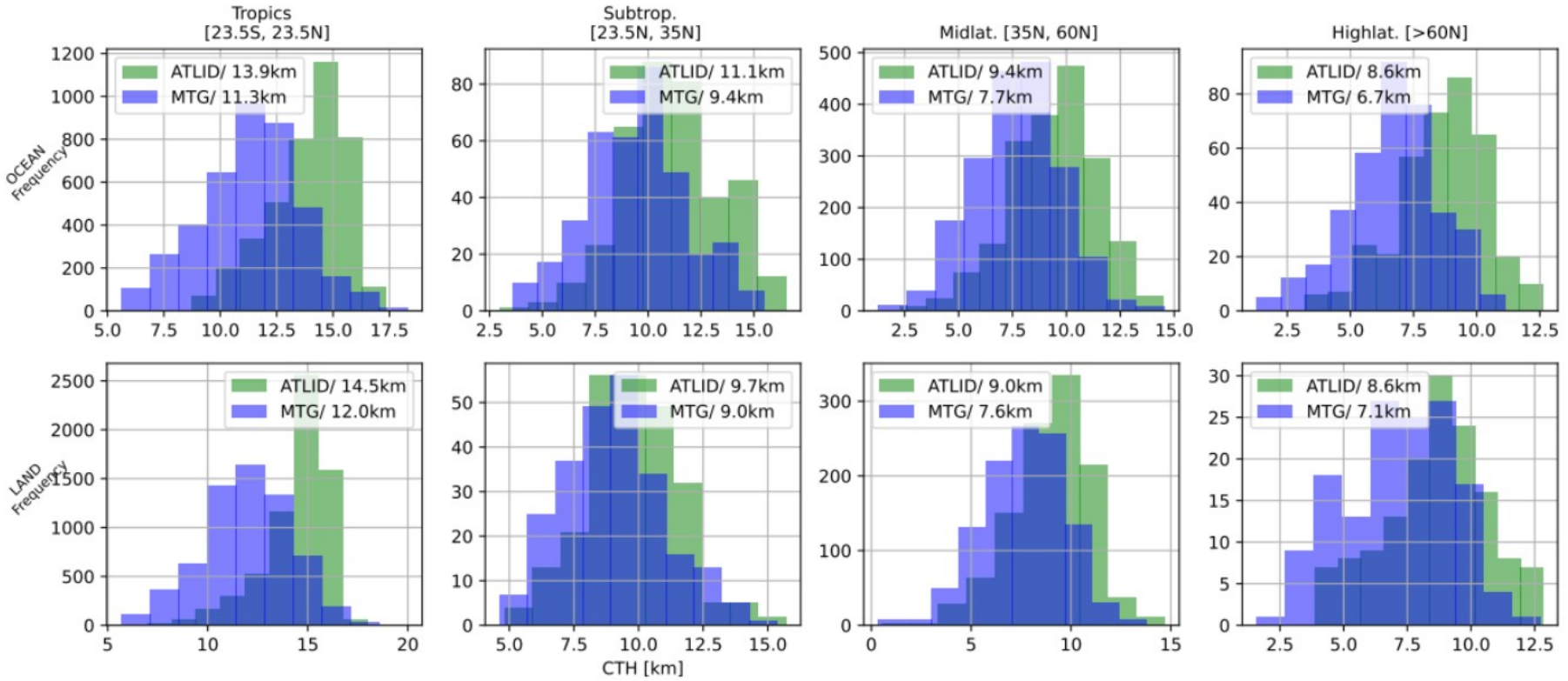
CTH:

- MTG/FCI
- ATLID
- MSI



One step further the Case Study:

- A_CTH vs. CTH from MTG/FCI (OCA)



→ **Check also poster P009 “Ice cloud altitudes with ATLID and MTG-FCI-OCA”**

- **E-CONTRAIL** identified key uncertainties in contrail detection & RF estimation
- **EarthCARE** provides unique combination of measurements to adress these uncertainties
- **E-CONTRAIL 2** will integrate MSI, ATLID, and BBR observations to improve detection, cloud characterization & RF assessment
- **Preliminary results** demonstrate significant added value

Thank you

https://www.econtrail.com

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