Robust Eco-Efficient Aircraft Routing

How to minimize the climate impact of aviation?

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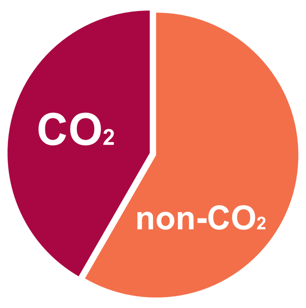
✌ The Facts

Aviation is responsible for about 3.5% of global warming [1].



Non-CO_2 effects such as contrails and NO_x induced O_3 make up two-thirds of the global warming contribution of aviation [1, 2]. Air traffic is projected to grow by 3.6% to 3.8% annually for the next twenty years [3, 4].

🎯 Research Objective

→ **Determine the impact of uncertainties on aviation's mitigation potential.**

RQ1 // What uncertainties exist and how do they propagate?

RQ2 // What weather conditions and climate forcers limit the mitigation gain?

RQ3 // What limits in mitigation gain can we expect due to airspace constraints?

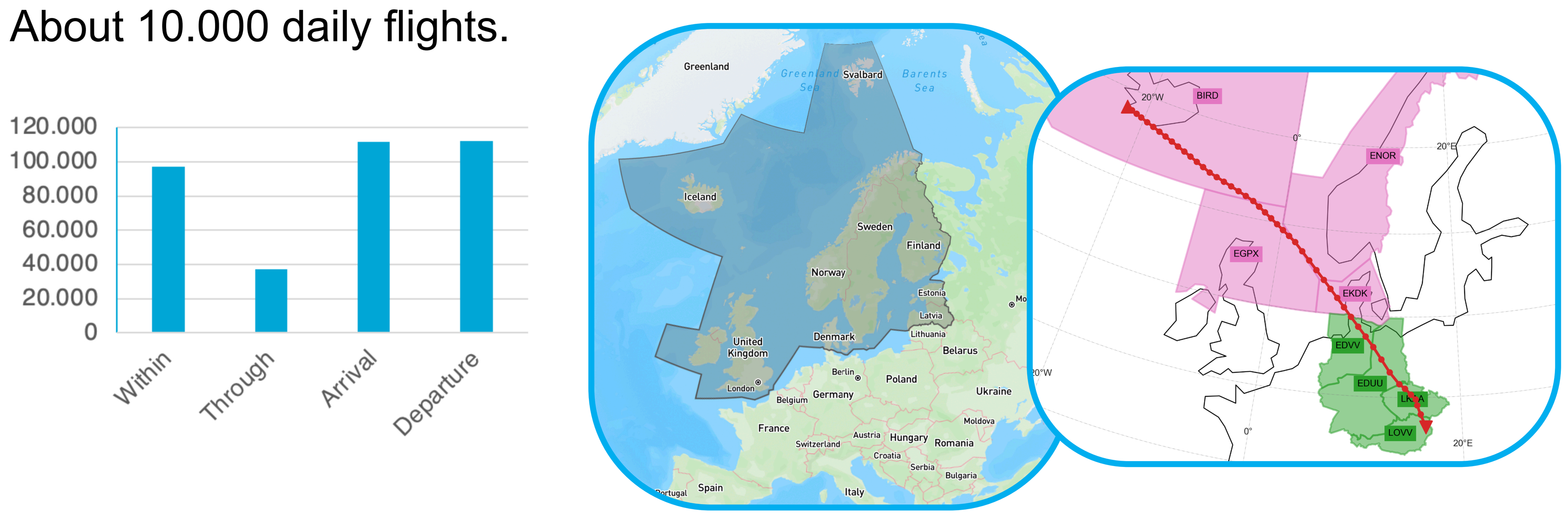
🤓 Uncertainties in 10 seconds

- Non-CO_2 effects depend on meteorological conditions at cruise-level such as temperature and relative humidity.
- Predicting these parameters is challenging and comes with uncertainty.
- One can include uncertainties in models using ensemble forecasting.
- An example is the ECMWF 10-member ensemble for global atmospheric data.

Figure: ECMWF Ensemble Weather Forecasting.

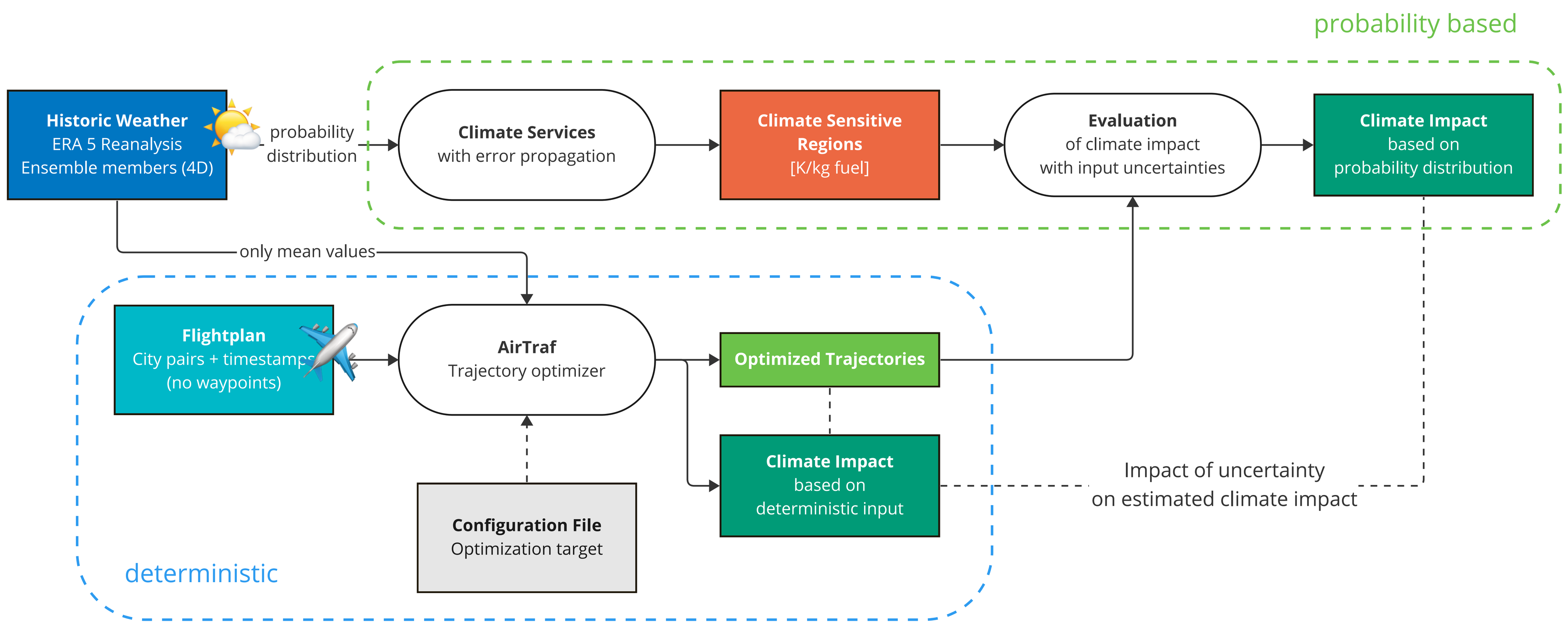
🧭 Study Area: Borealis

About 10.000 daily flights.



Figures: (left) Borealis flights for June 2019 based on EUROCONTROL data. (middle) Borealis area. (right) Example for an 'Departure' flight from Reykjavík to Vienna.

🎲 Methodology

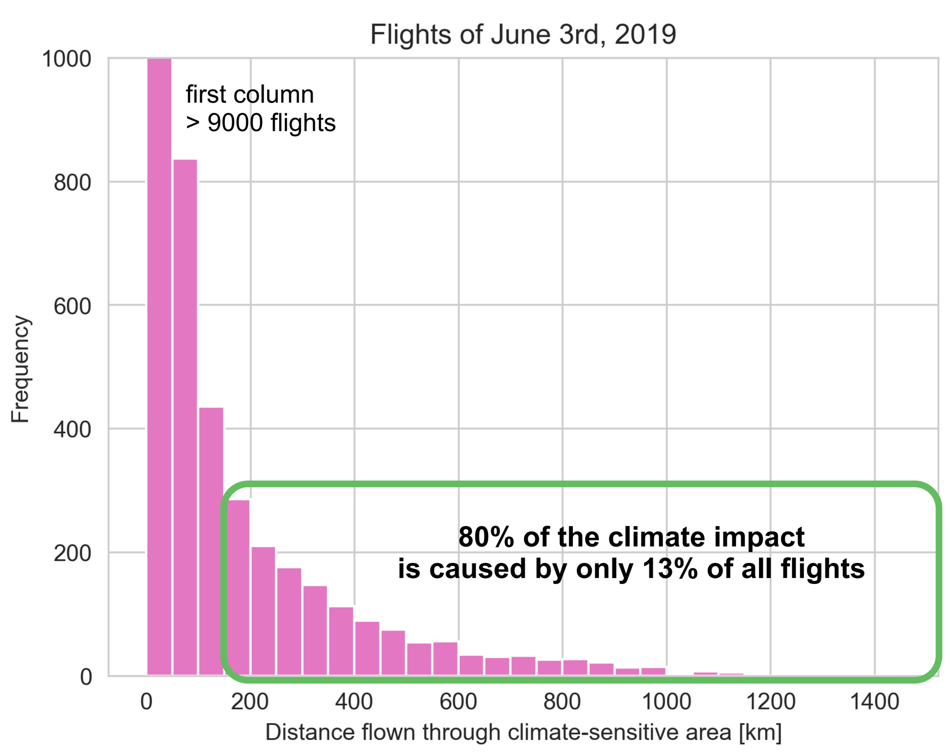


1. Classify uncertainties into: input data, models, scientific understanding
2. Quantify uncertainties using error propagation and Monte-Carlo simulations
3. Determine discrepancy in mitigation gain

Figure: weather data and air traffic data are fed into climate services (aCCFs = algorithmic Climate Change Functions [5], CoCiP = Contrail Cirrus Prediction model [6]) and a trajectory optimizer to determine the mitigation gain of climate- and cost-optimized routes.

🏃 First Results

- Implemented an algorithm to filter air traffic data for Borealis in linear time.
- Developed a method to calculate the weighted distance flown through climate-sensitive areas for flights and rank them.
- Implemented error propagation into aCCFs for O_3 and CH_4.



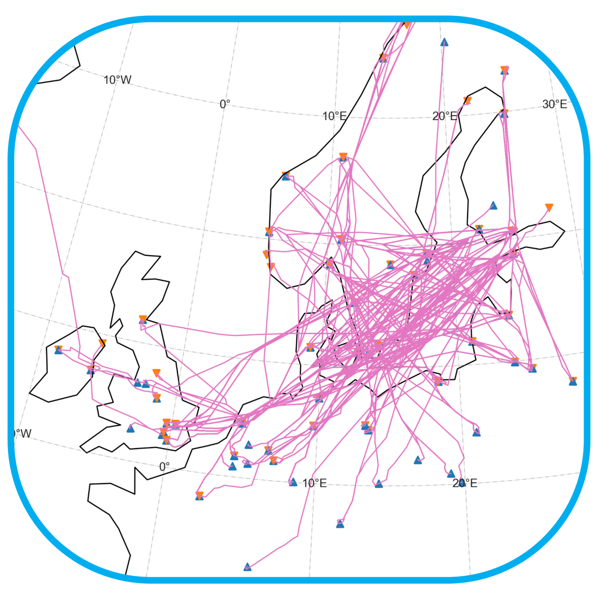
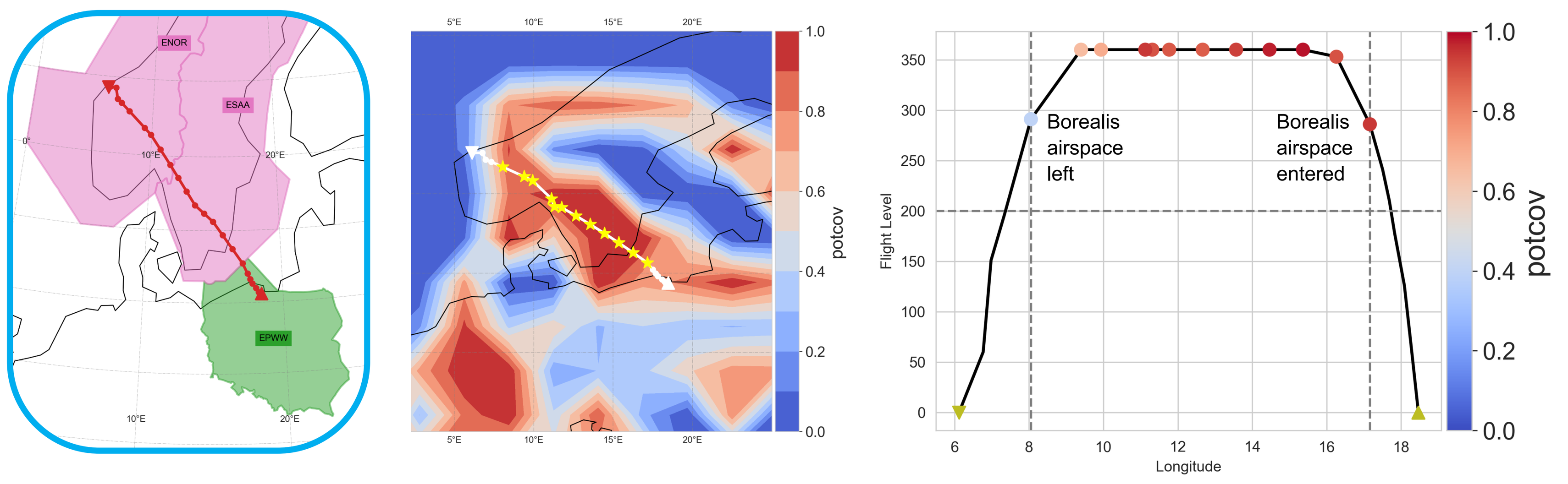


Figure: All flights with >= 30% of flown distance through climate-sensitive regions.



Figures: (left) 'Destination' flight from Gdánsk to Ålesund. (middle) Potential contrail coverage from EMAC simulation with flight trajectory. (right) Evaluated waypoints at 4D position of stars from middle figure. Timestamp: June 3rd, 2019, 07:00 UTC.

🚀 What's next?

- Find out how weather patterns are linked to "big-hit" flights.
- Run a Monte-Carlo simulation to quantify the uncertainties within AirTraf.
- Visualize the mitigation potential on a 'shaded' Pareto front.

📖 References

[1] Lee, David S., et al. "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018." Atmospheric environment 244 (2021): 117834.

[2] Grewe, Volker, et al. "Feasibility of climate-optimized air traffic routing for trans-Atlantic flights." Environmental Research Letters 12.3 (2017): 034003.

[3] Airbus. (2023). Global Market Forecast 2023-2042 (tech. rep.).

[4] Boeing. (2023). Commercial Market Outlook 2023-2042 (tech. rep.).

[5] Yin, Feijia, et al. "Predicting the climate impact of aviation for en-route emissions: The algorithmic climate change function submodel ACCF 1.0 of EMAC 2.53." Geoscientific Model Development 16.11 (2023): 3313-3334.

[6] U. Schumann. (2012). A contrail cirrus prediction model. Geoscientific Model Development, 5(3), 543– 580.

[List of Figures]: https://www.ecmwf.int/en/about/media-centre/focus/2017/fact-sheet-ensemble-weather-forecasting

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