Mitigation potential of optimized aircraft trajectories and its dependency on weather patterns

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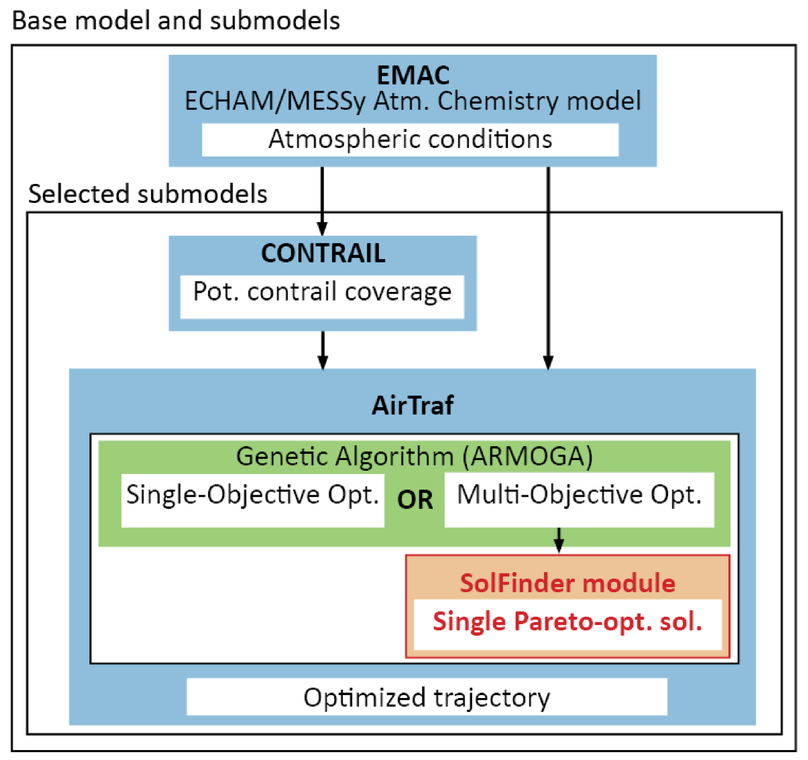
OBJECTIVE

To investigate how atmospheric natural variability affects:

- the potential of contrail avoidance;
- the properties of optimized aircraft trajectories.

MODEL OVERVIEW



The model computes the potential contrail coverage, i.e., the fraction of the model grid-box where persistent contrails can form and persist [3].

MOTIVATION

- Contrail formation and climate impact are higly dependent on the atmospheric conditions at flight time and location.
- Aircraft trajectories can be optimized to reduce climate effects of aviation [1].
- This operational mitigation strategy is affected by strong daily variability [2].

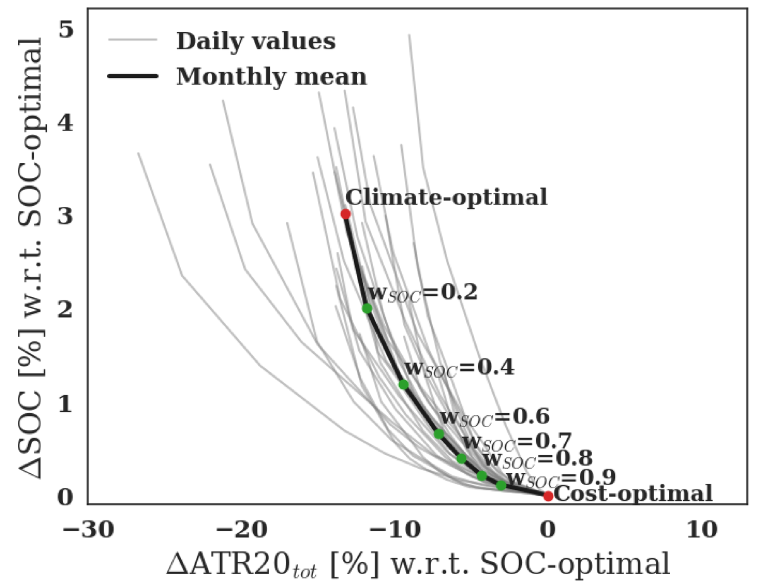
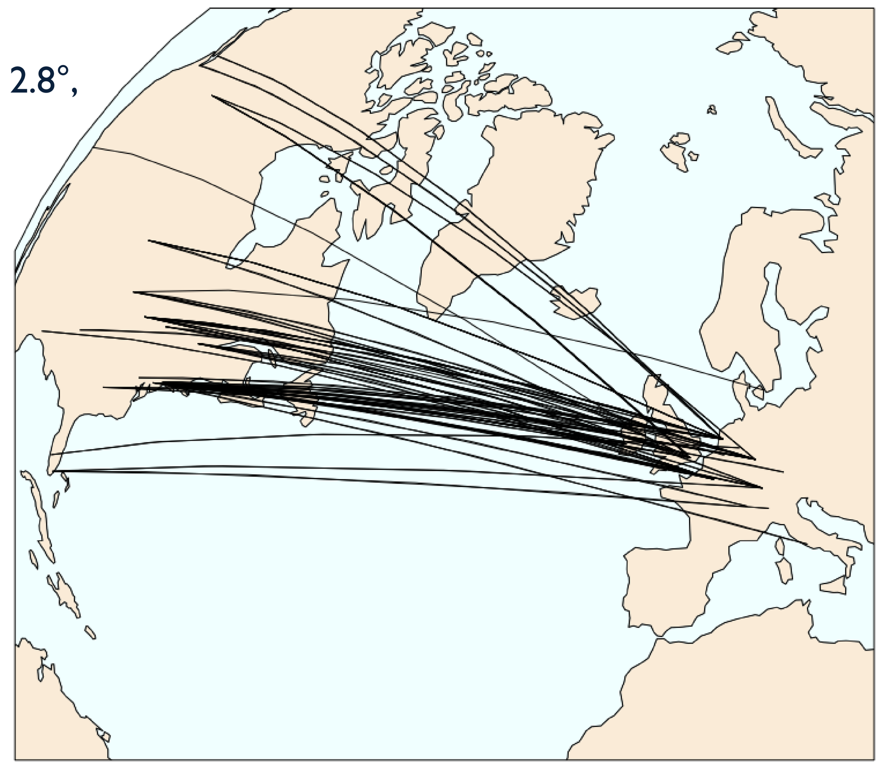


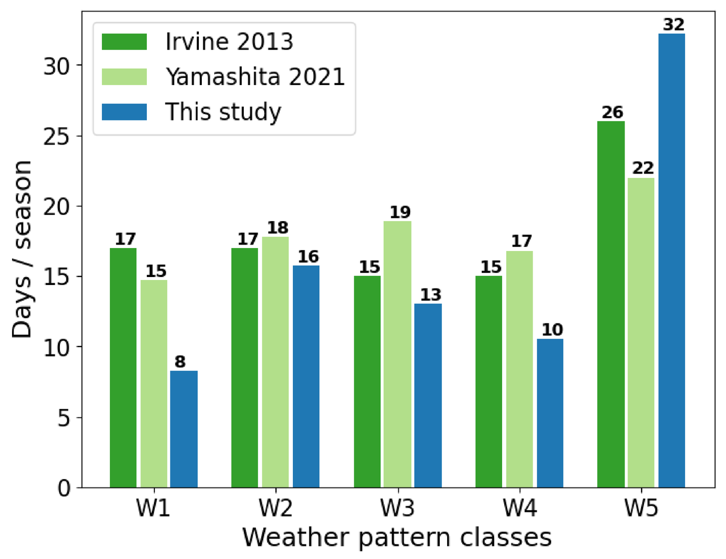
Figure adapted from Fig. 6 in F. Castino et al., Geosci. Model Dev. Discuss. [preprint], 2023.

SIMULATIONS SETUP

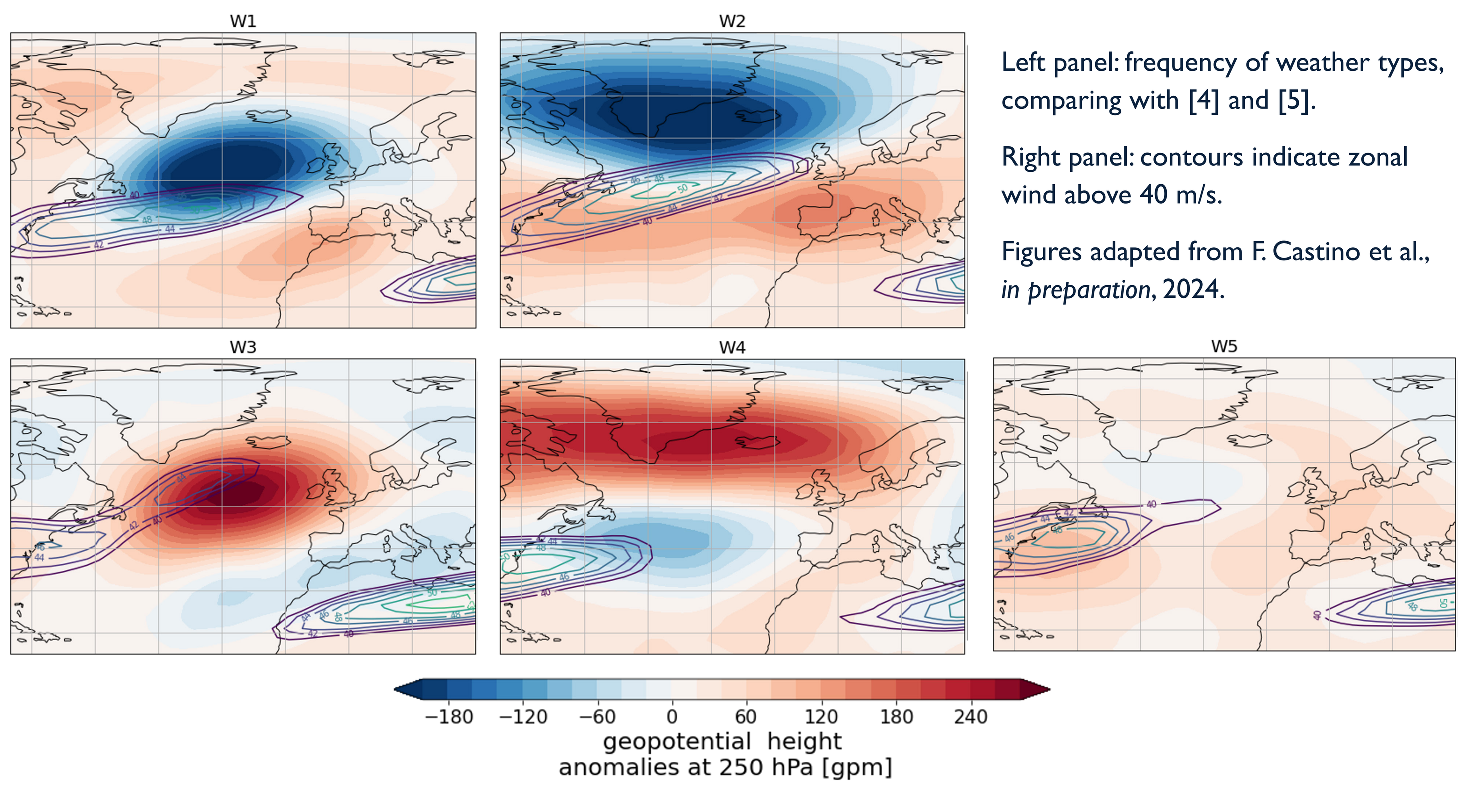
- Resolution: T42L31ECMWF (2.8° x 2.8°, 31 vertical levels)
- Time step: 12 minutes
- Time coverage: winter months from 2015 to 2019
- Air Traffic Sample: 103 routes over North Atlantic, A33x aircraft
- Optimization objectives:
  1. minimal Simple Operating Costs (SOC), defined as the weighted sum of fuel used and flight time (reference scenario);
  2. minimal contrail distance, defined as the distance flown through regions where contrails can form and persist.



WEATHER PATTERN CLASSIFICATION



We classify winter weather patterns by their similarity to the North Atlantic Oscillation (NAO) and the East Atlantic (EA) teleconnection patterns [5].

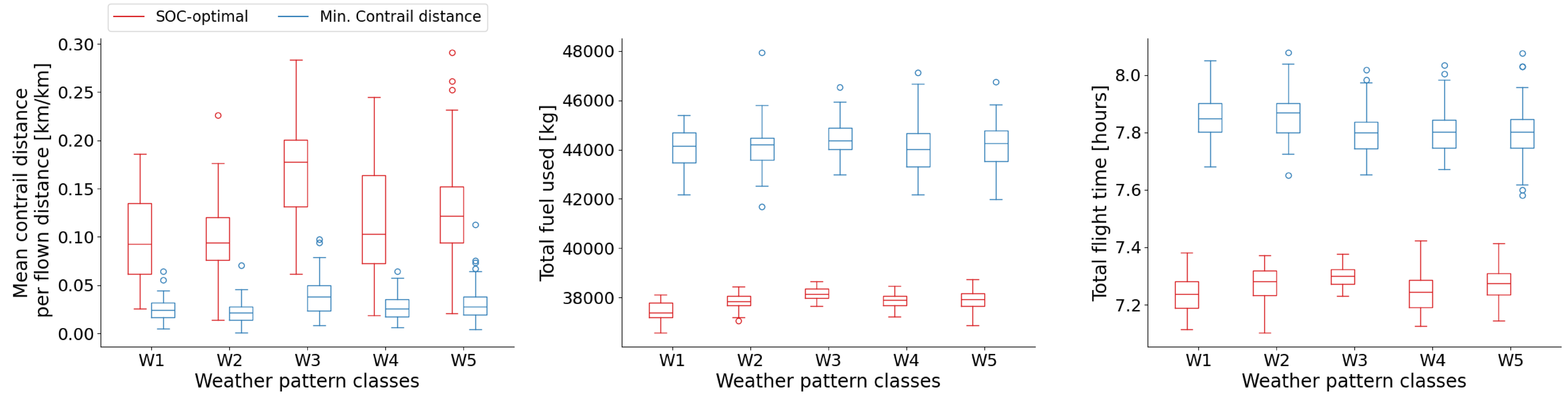


Left panel: frequency of weather types, comparing with [4] and [5].

Right panel: contours indicate zonal wind above 40 m/s.

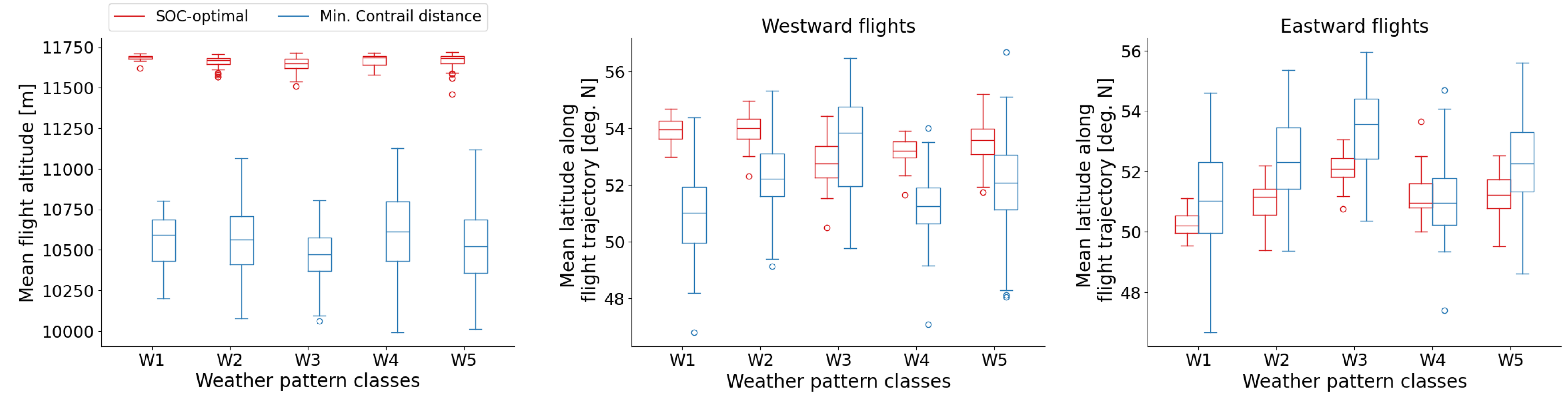
Figures adapted from F. Castino et al., *in preparation*, 2024.

RESULTS - POTENTIAL OF REDUCING CONTRAILS FORMATION



- The highest absolute reduction in contrail distance by changing optimization strategy is found under WP3.
- The fuel used reaches a minimum with WP1.
- Its standard deviation across different days almost doubles introducing contrail avoidance.
- The +7.7% change (average) in flight time can be mitigated selecting trade-off solutions using SolFinder [1, 2].

RESULTS - PROPERTIES OF OPTIMIZED TRAJECTORIES



- The lowest aerodynamic drag is found at higher altitudes.
- Minimal contrail distance is achieved flying lower and in a wider range of flight altitudes.
- Cost-optimal westwards flights tend to avoid the jet stream by flying at higher latitudes.
- To avoid contrails, lower latitudes may be selected.
- Eastwards flights show similar tendencies of flying at lower/higher latitudes under different weather types with both optimization strategies.

CONCLUSIONS AND NEXT STEPS

- We conducted simulations with the ECHAM/MESSy Atmospheric Chemistry (EMAC) model, coupled with its submodels CONTRAIL and AirTraf, to analysie the characteristics of optimized aircraft trajectories under different weather conditions.
- The decision making tool SolFinder will be employed to explore how the weather patterns affect trade-off solutions between aircraft trajectories optimization strategies minimizing economic cost and contrail distance, which reduce penalties in terms of fuel used and flight time.
- In the next step, data generated from satellite observation and in-flight measurements will be considered to evaluate sources of uncertainties introduced, for example, by simulating atmospheric conditions and contrail coverage using the EMAC model.

ACKNOWLEDGMENTS:

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BeCoM — BETTER CONTRAIL MITIGATION

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