CLIMOP

Climate assessment of innovative mitigation strategies towards operational improvements in aviation.

This project has received funding from European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N°875503.

Climate assessment of innovative mitigation strategies towards operational improvements in aviation

Modeling the climate impact of contrails with Lagrangian trajectories

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11th EASN International Conference
2 September, 2021 | virtual

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Background and Motivation

Aviation has impacts on climate through its emissions of gases and particles that change the ‘greenhouse’ properties of the atmosphere, contributing to climate warming and climate change. (IPCC, 1999)

The share of aviation amongst all anthropogenic climate impact is about 3-5%.
Considering the projected growth of air traffic for the next decades, aviation’s share of the total anthropogenic climate impact is expected to increase further. (Lee et al., 2021)

Consequently, intergovernmental organizations, aircraft manufacturers and operators, and the research community are focusing on technological, operational and regulatory options for climate impact mitigation.

Impact of non-CO_2 effects need to be understood and quantified in order to develop sustainable aviation.

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The ClimOP Project

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ClimOP Project

ClimOP – <u>**CL**</u>imate assessment of <u>**I**</u>nnovative <u>**M**</u>itigation strategies towards **OP**erational improvements in aviation

- Identify, evaluate and support the implementation of **mitigation strategies to initiate and foster operational improvements** which reduce the climate impact of the aviation sector.

- **Addresses both the non-CO2 and CO2 impacts simultaneously**

- Define **actions and recommendations for policymakers** by proposing a set of most promising and harmonized mitigation strategies.

- **Duration:** from 01/01/2020 till 30/06/2023
- **EU funding, DG Aeronautics**
- **Consortium:** 8 partners from 5 countries

Amigo (IT) | İTÜ (TR) | IATA (ES) | SEA (IT)

Deep Blue (IT) | Royal NLR (NL) | TU Delft (NL) | DLR (DE)

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Current status

Identified the 11 most promising Operational Improvements (OI's)

The OIs covers 4 key areas:

- Ground operations
- Terminal Maneuvering Area (TMA) operations
- Network and in-flight operations
- Operations at a regulatory level

Short term implementation, long term benefits

Each OI has different **pros and cons**, evaluation is important

#	Area of operation	Selected OI
1	Network / in-flight	Flying low and slow
2	Network / TMA	Continuous climb/descent operations
3	Network/in-flight	Free routing in high-complexity environment / flexible waypoints
4	Network/in-flight	Climate-optimised flight planning
5	Network/in-flight	Wind/weather-optimal dynamical flight planning
6	Network/Trajectory	Strategic planning: merge/separate flights; optimal hub-spokes/point-to-point operations
7	Network/Trajectory	Climate-optimised intermediate stop-over
8	Ground	Single engine taxiing / E-taxi (tow truck or tug wheel) and hybrid taxi
9	Regulatory	Promote "climate-friendly" flights
10	Ground/Airports	Electrification of ground vehicles and operations
11	Ground/Airports	Upgrade of the existing airport infrastructure for the reduction of environmental impacts

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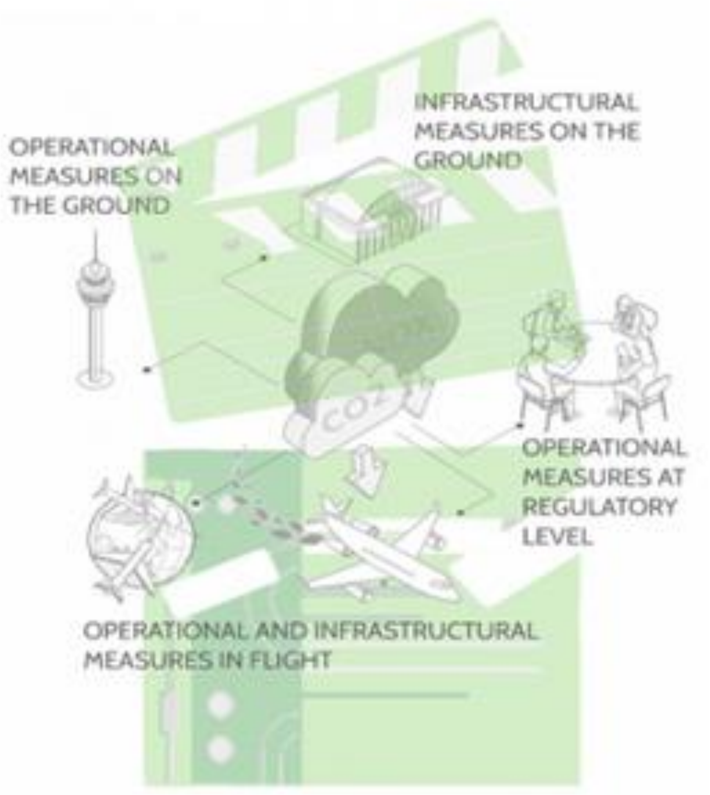
Next steps towards greener aviation operations



- ClimOP aims to define a common air traffic scenario to assess the climate impact of each action under the same operational and technological conditions.
- Model development is completed this year, mature results are planned for mid-2022
- OIs will be refined via **several validation activities**
- At the end of its lifespan, ClimOP will deliver **a set of mitigations strategies to reduce the climate impact of aviation.**

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Modelling contrail climate impact on Lagrangian trajectories

(ClimOP OI: CLIM (Climate optimized trajectories)

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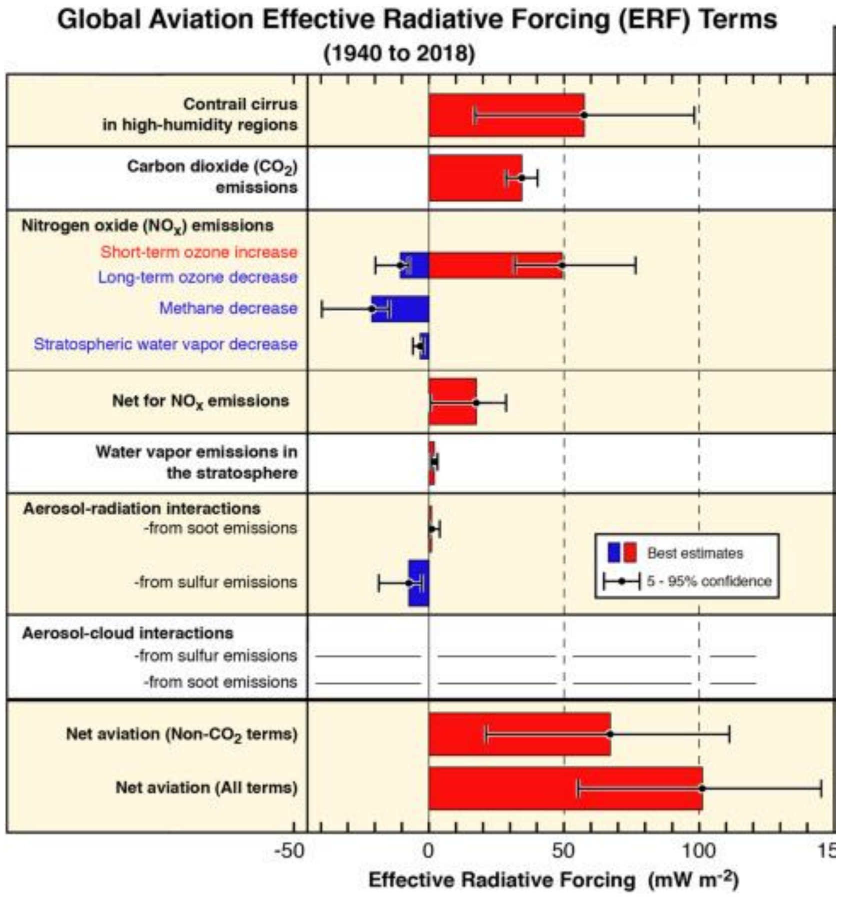
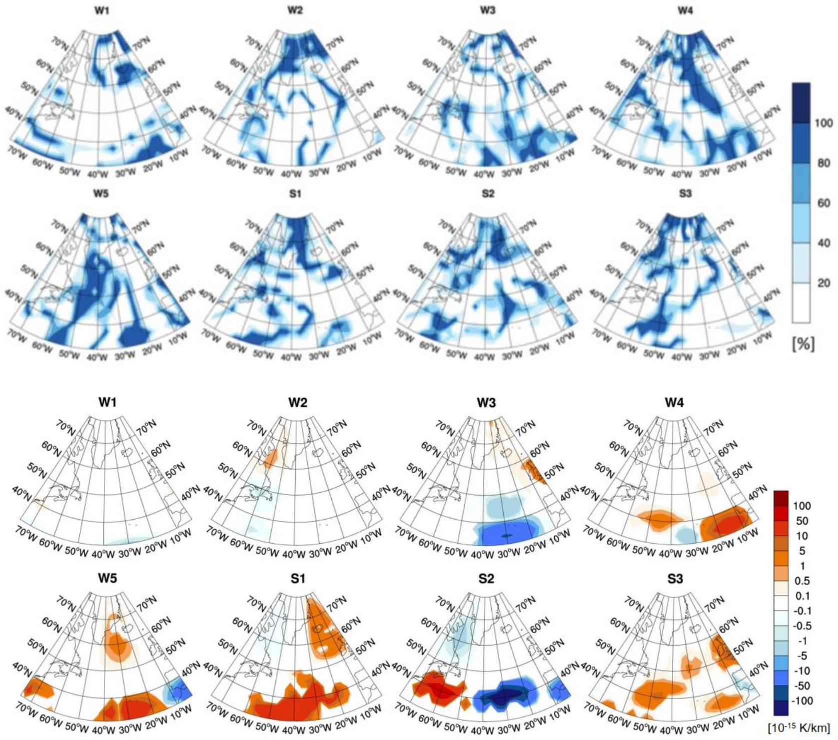
Motivation and Scope



(Climate forcing terms from global aviation, Lee et al. 2021)

- Contrail-cirrus provides the largest contribution (~57mWm^{-2}) to global aviation effective radiative forcing (Lee et al. 2021)
- Potential contrail coverage and CCFs calculated with a Lagrangian approach vary with weather patterns (Frömming et al. 2021)
- Large remaining uncertainties in magnitude in part due to incomplete representation of key processes



(Potential contrail coverage (top) and climate change functions (bottom) for different weather situations, Frömming et al. 2021)

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Concept

Investigate formation and life cycle of contrails on Lagrangian trajectories and quantify climate impact for different emission locations (so called time-regions)

- Evaluation of physical processes controlling the climate impact of contrails.
  - Analysis on Lagrangian trajectories
  - Dependences on geographical location, altitude and time
  - Impact of the actual meteorological situation
  - Microphysics (formation process, lifecycle, particle loss, melting time)
  - Parametrization of radiative properties (short wave, longwave)
  - Model representation (resolution, accuracy ,functionalities)

- Comparison of key variables with observational data (comprising temperature and humidity)
- Adjust or expand parametrization developed for Lagrangian trajectories

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Analysis and Evaluation: Potential Contrail Coverage

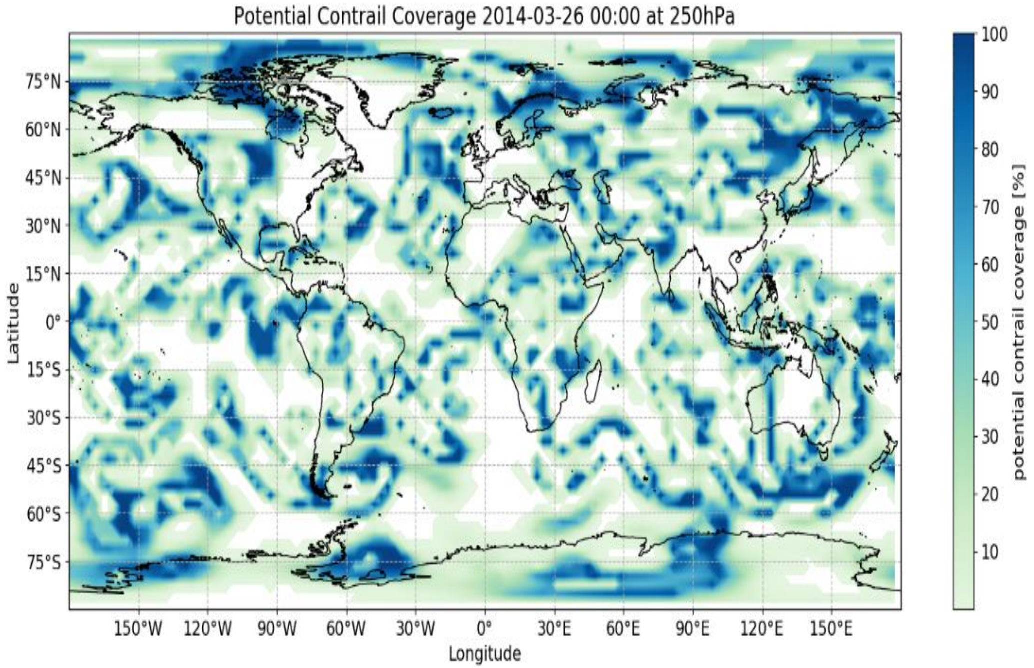

Figure: Potential Contrail Coverage for 26 March 2014, 250 hPa

- Numerical simulation are performed with the global climate model EMAC which offers a modular approach for specific functionalities

- **Setup**: ECHAM5 with T42L41 (2.8°x2.8°, 41 vertical layer)
- **Modules**: ATTILA, LGTMIX, LGGP, RAD, CONTRAIL, …

- Potential Contrail Coverage for 250 hPa considering the Schmidt-Appleman criterion and saturation vapour pressure (ice)

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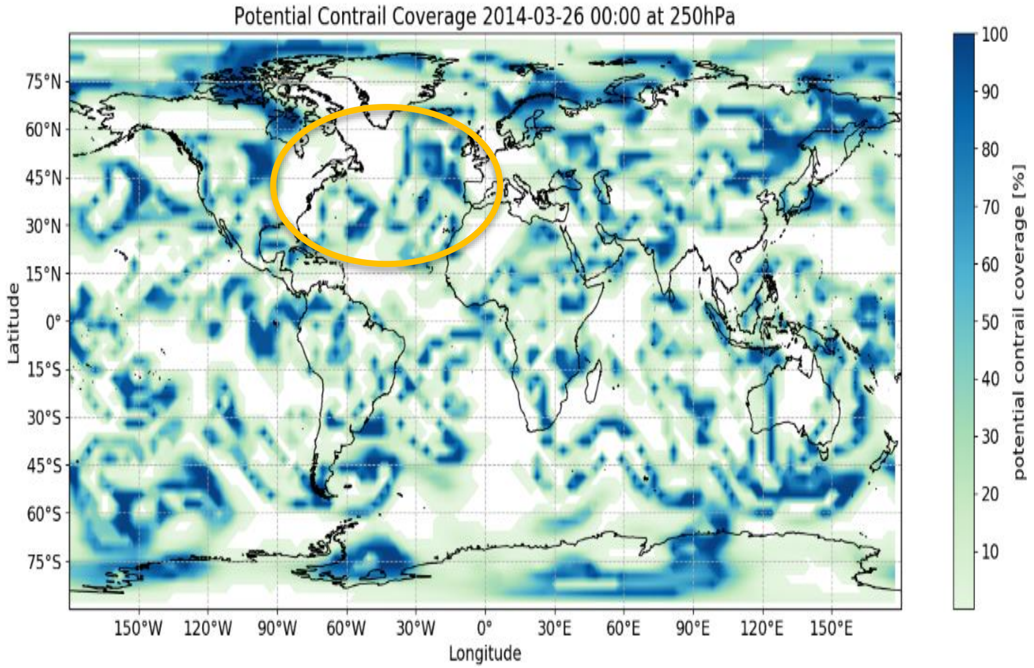

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Comparison of key variables with observational data

Atmospheric parameters sampled along HALO aircraft trajectory with high temporal and spatial resolution

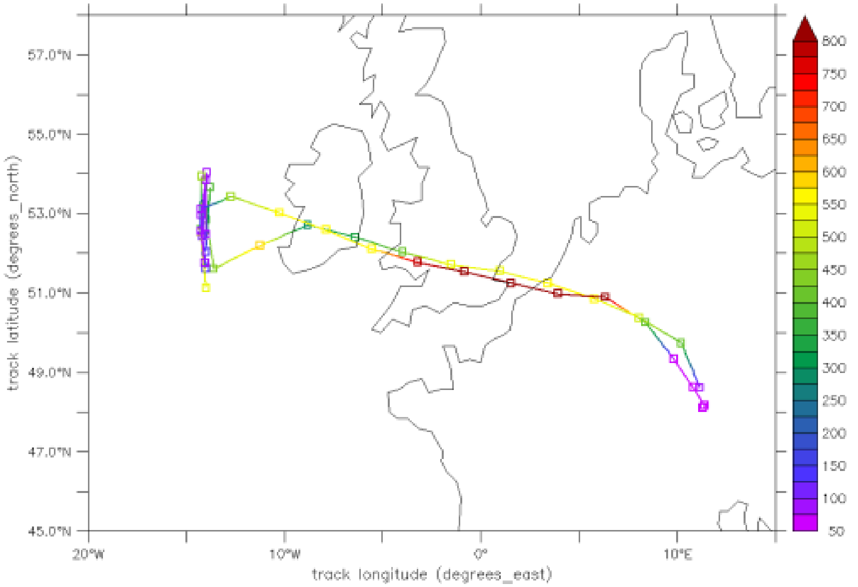

Figure: Flight Path

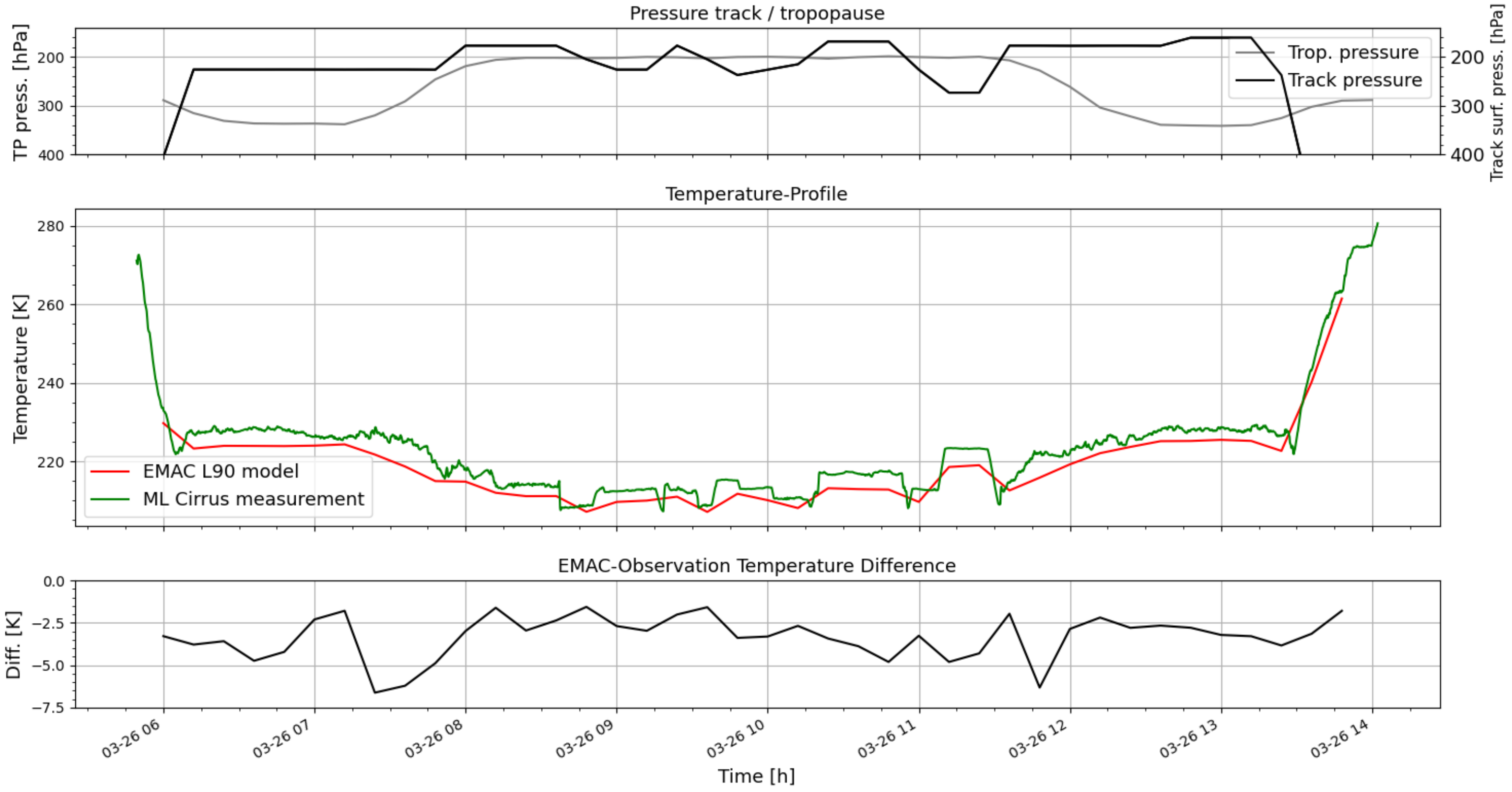

Figure: Comparision of temperature data for 26 March 2014, EMAC time resolution 12 minutes, Model grid T42 (about 2.8°)

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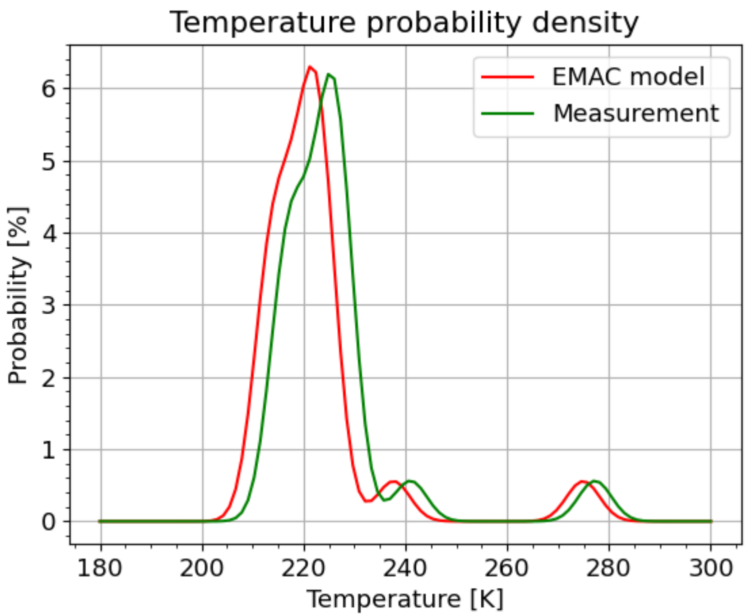
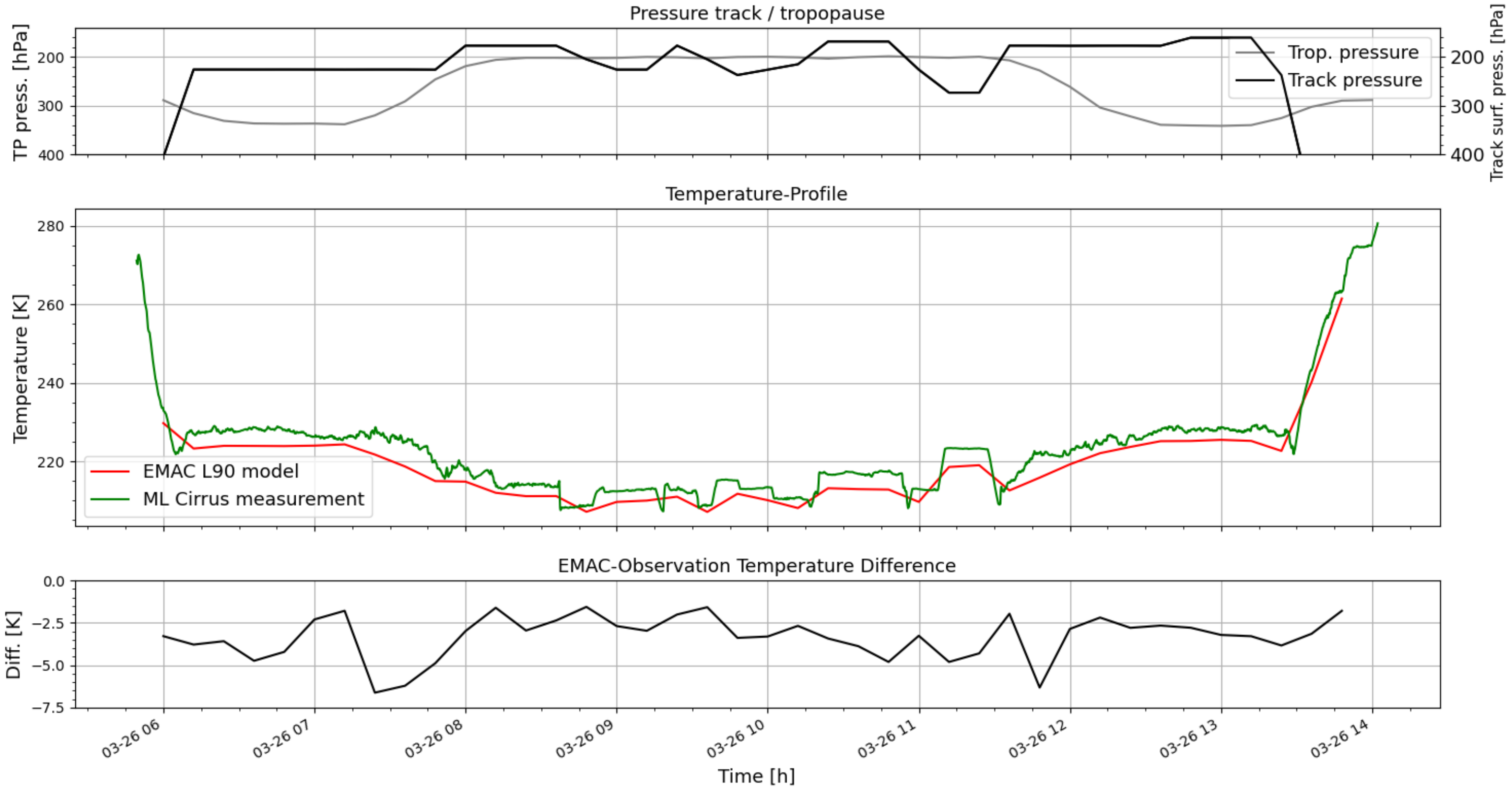
Comparison of key variables with observational data



- 2-5 K difference between EMAC model data and observation data



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Methods and Model – Experiment design

- Base model: ECHAM5 with L41
- Each Simulation: **32 time-region-grid points**
- Lagrangian Transport Module ATTILA
- Water vapor pulse emissions are released on the start point of each trajectories
- Life cycle of contrails is investigated on **Lagrangian trajectories** (50)
- Microphysics are calculated in the air parcels transported on these trajectories

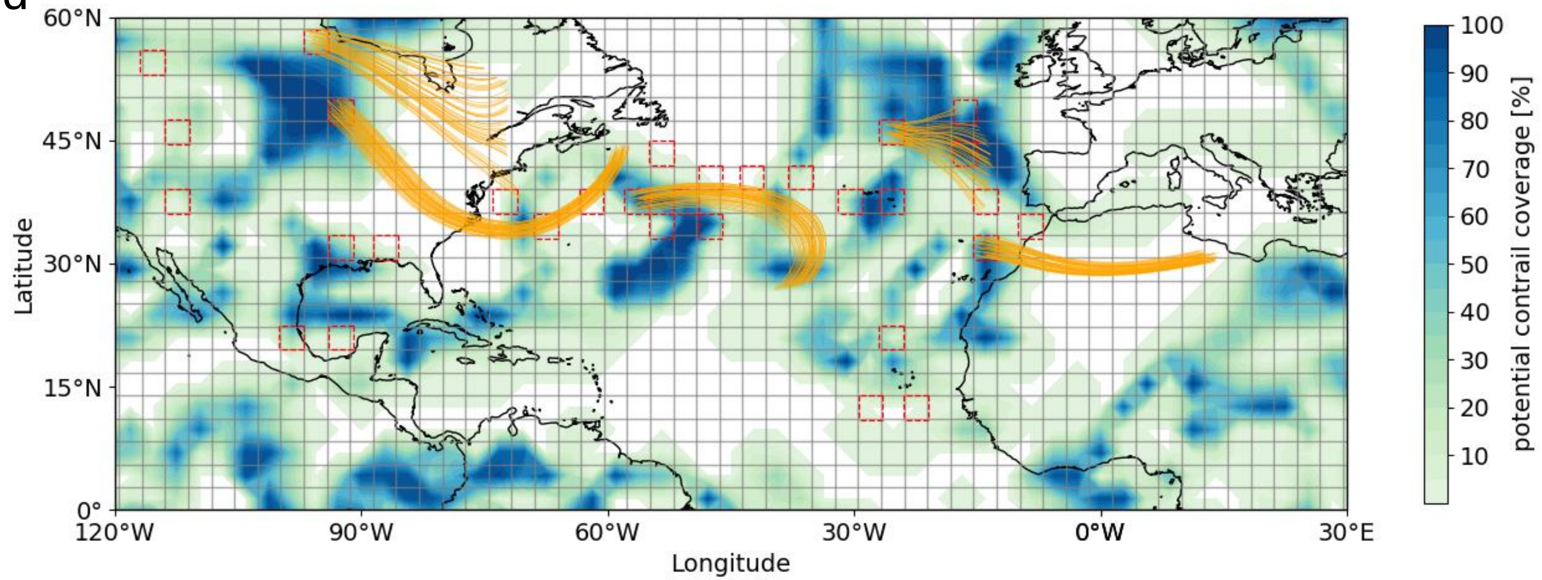

Figure: Potential contrail coverage for 26 March 2014 at 250 hPa (blue), Location of time-region grid points (red) and examples for lagrangian trajectories (orange)

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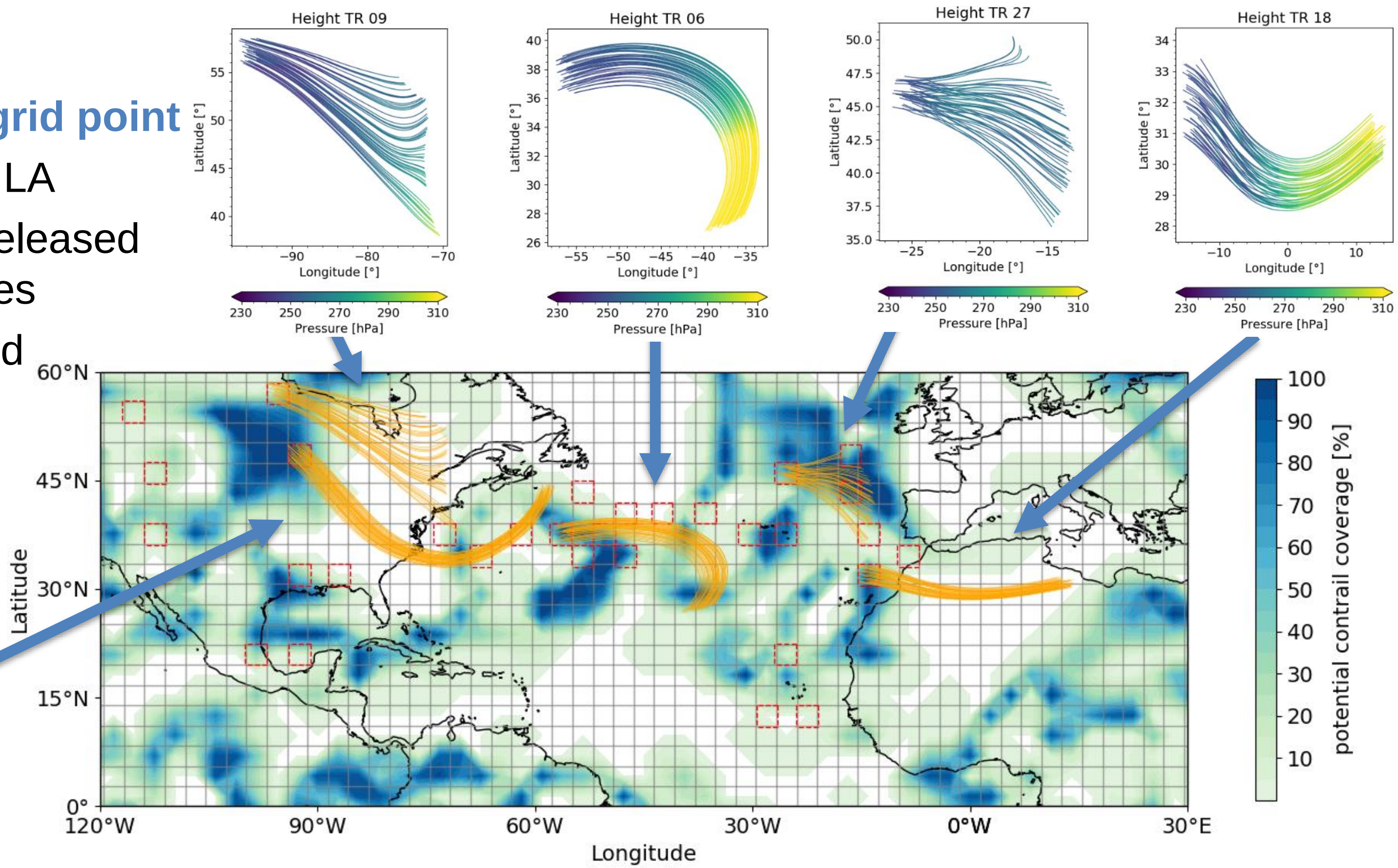

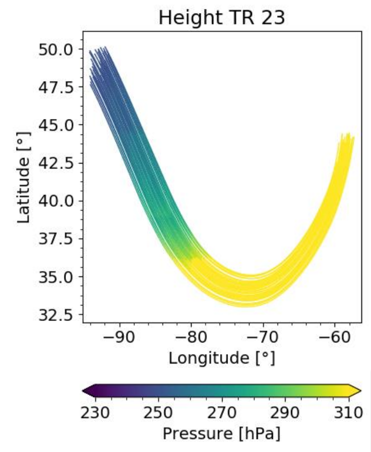

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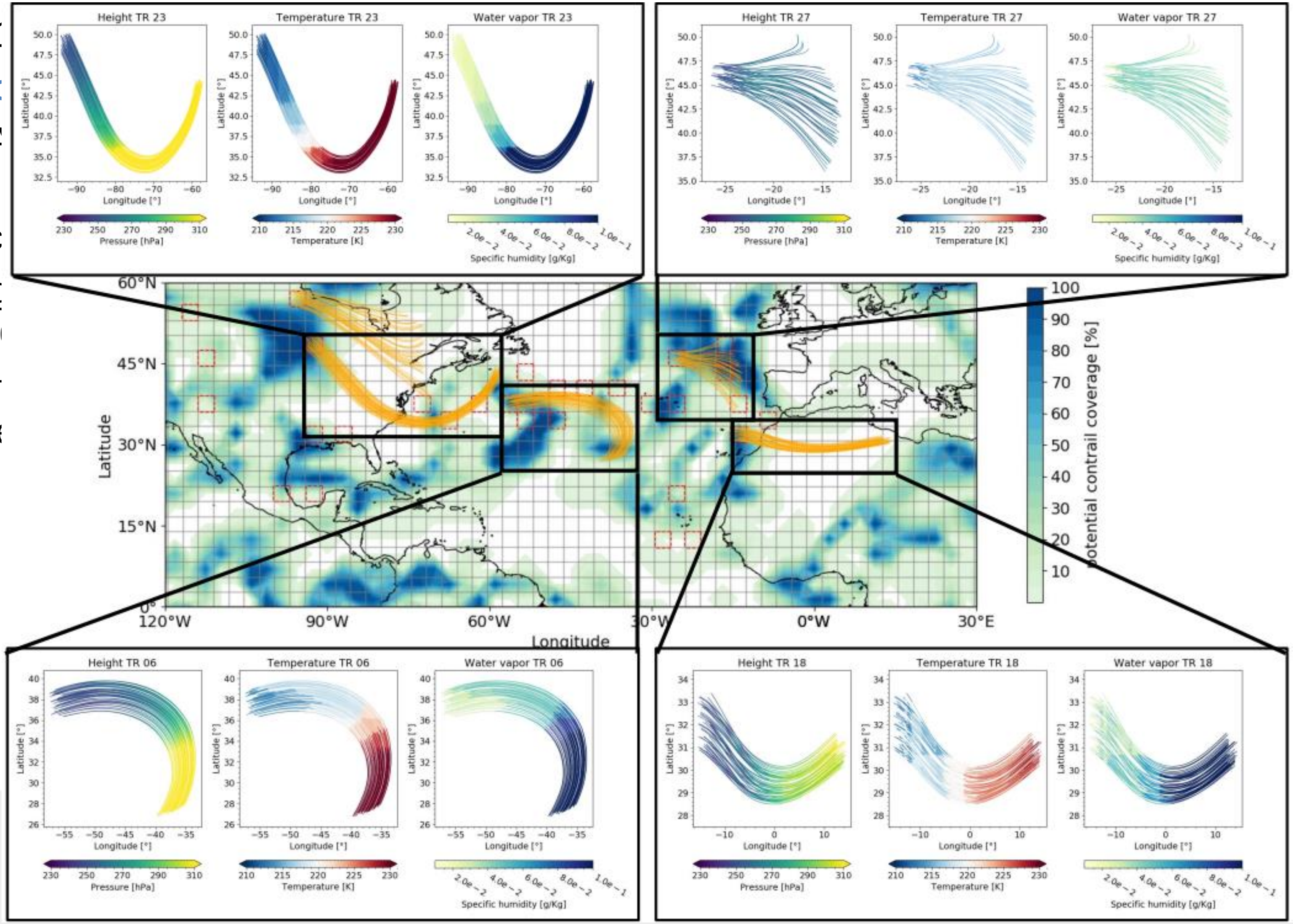

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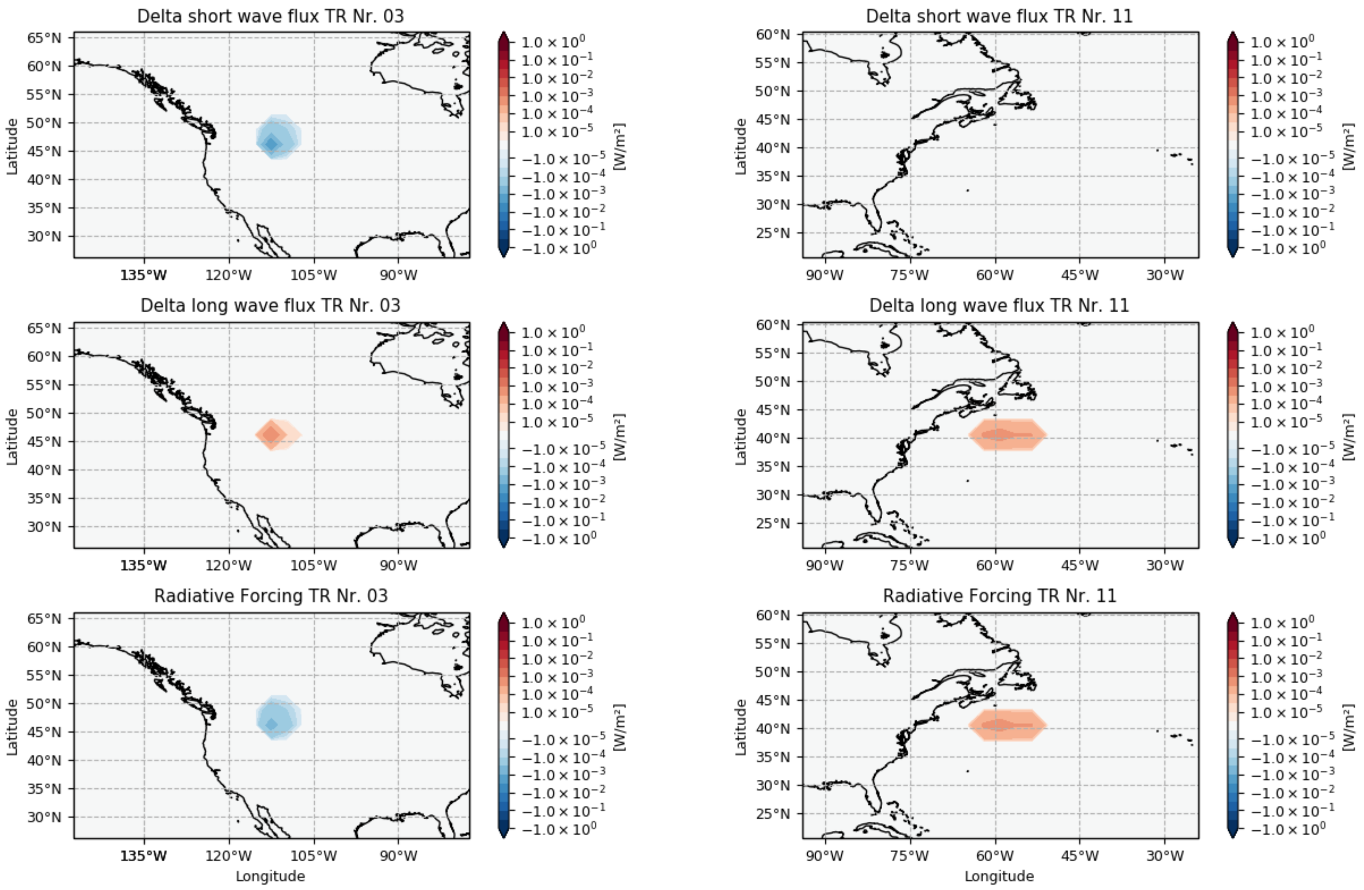
Analysis and Evaluation: Impact on Radiation



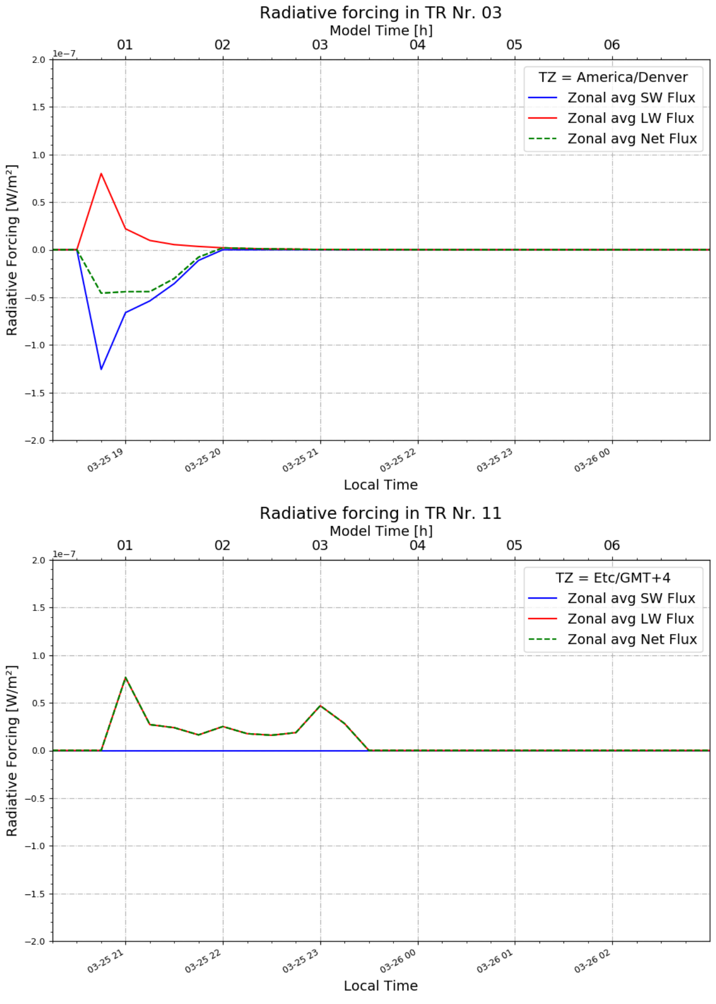


Figure: Radiative forcing for different time regions

Integration of radiative impacts over the lifetime of the contrail (perturbation) mapped back to the emission location > Climate Change functions (CCF)

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Perspective and implementation: Climate impact functions in different geographic regions

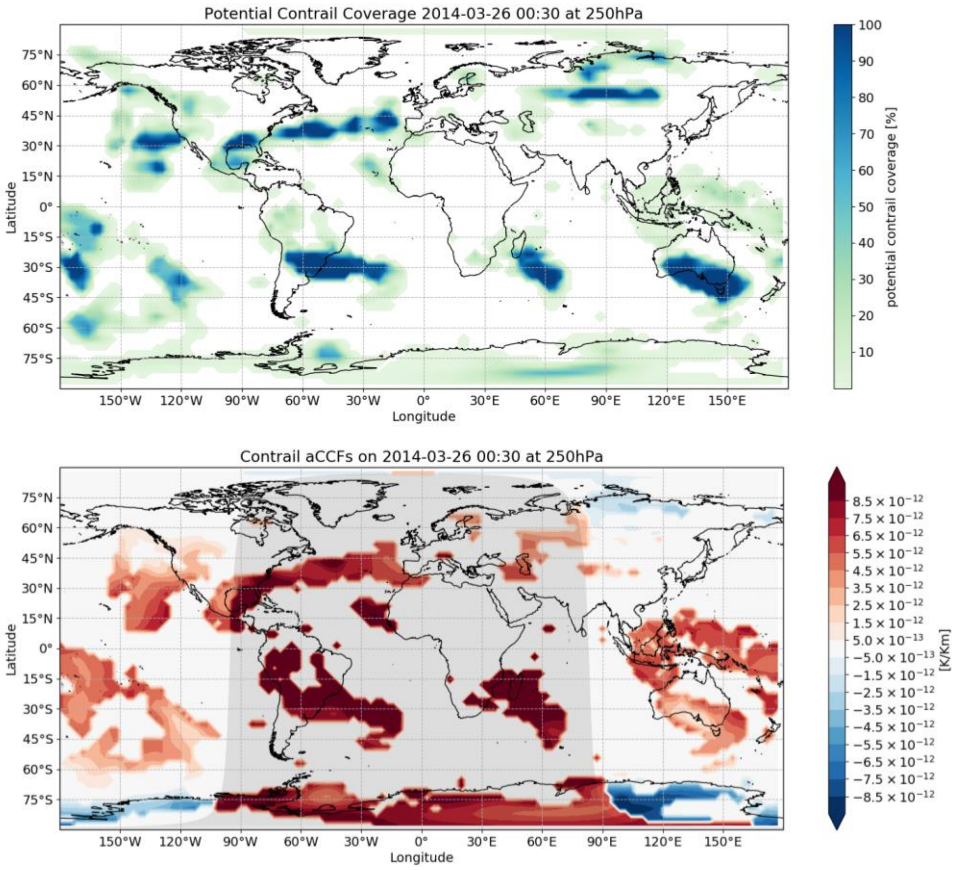

Figure: Top: Potential Contrail Coverage for 26.03.2014 00:30 at 250 hPa.
Bottom: Day and Night aCCFs calculated with the formula from Irvine 2017.

- Warming effect of night contrail > day contrails
- Cooling effect on the day contrails in higher latitudes
- Impact stronger at lower altitudes

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Summary and Conclusion

- The ClimOP project will investigate in the CLIM OI the mitigation potential from climate-optimized aircraft trajectories while considering total climate impact (comprising CO_2 and non-CO_2 effects).

- A Lagrangian approach applied in EMAC allows to calculate CCFs for non-CO_2 effects. Temperature discrepancy between the EMAC model and observational data exists, **adjustments** to the EMAC model might be necessary.

- Newly developed Climate Change Functions for contrail impacts will allow to provide updated estimates for different regions on the globe (OI CLIM).

- It is important to take a closer look on how climate impact functions vary in different regions and what this means for **mitigation potential** through climate-optimized flight trajectories.

- The results will be used in the ClimOP Project to identify, evaluate and support the implementation of **mitigation strategies to initiate and foster operational improvements** which reduce the climate impact of the aviation sector.

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Thank you for your attention

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