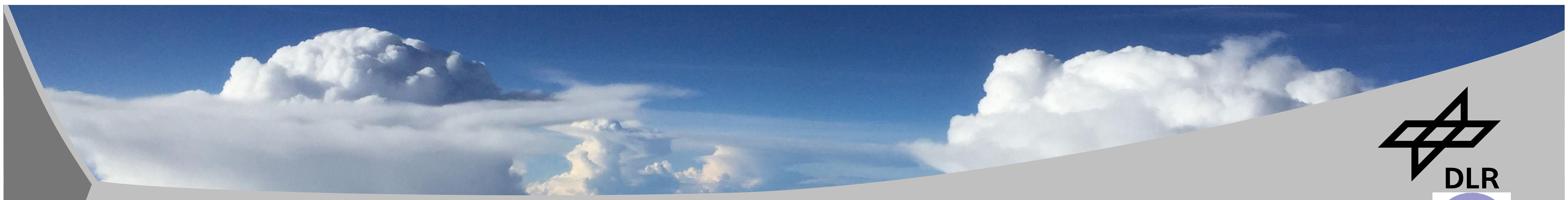

Eco-efficient flight trajectories – Using a Lagrangian approach in EMAC to investigate contrail formation in the mid latitudes

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- Aviation is seeking for ways to **reduce its climate impact** caused by CO_2 emissions and non-CO_2 effects. While the effects of CO_2 on climate are independent of location and situation during release, non-CO_2 effects such as contrail formation vary depending on meteorological background.
- The ClimOP Project aims to estimates the mitigation potential of climate optimized aircraft trajectories, building on concepts established in previous studies that investigated the influence of different weather situations on aviation's contribution to climate change, identified climate sensitive regions and generated data products which enable air traffic management (ATM) to plan for climate optimized trajectories [3,4].
- In research presented here, a Lagrangian approach is further developed to determine the sensitivity of the atmosphere to aviation emissions with respect to climate effects in order to identify **climate optimized aircraft trajectories**.

Motivation and Scope

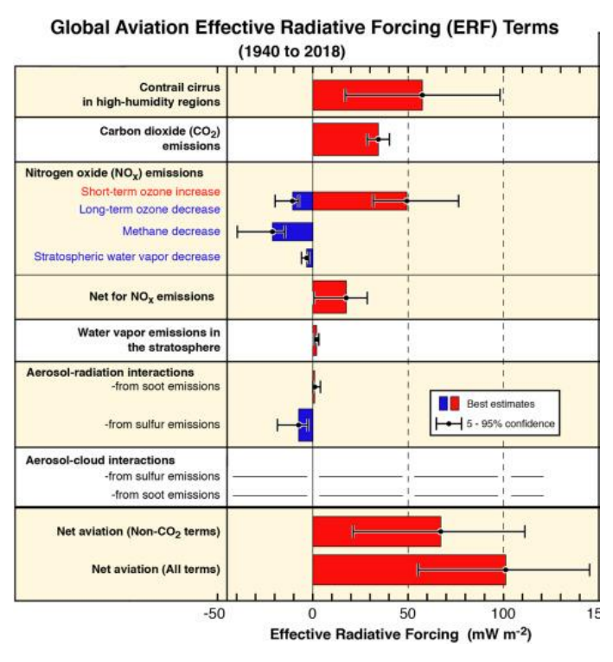

Figure: Climate forcing terms from global aviation [3].

- Contrail-cirrus (57%) are the largest contributors to the **effective radiative forcing** of global aviation, with large uncertainties in magnitude in part due to incomplete representation of key processes [3].
- A **Lagrangian approach** can be used to derive 4-dimensional Climate Change Functions (CCFs) [2,4].
- Potential contr. coverage and CCFs are strongly influenced by weather patterns [2].
- Are the **essential conditions and processes** for the formation and life cycle of contrails realistically represented in the EMAC model? Are adjustments necessary?

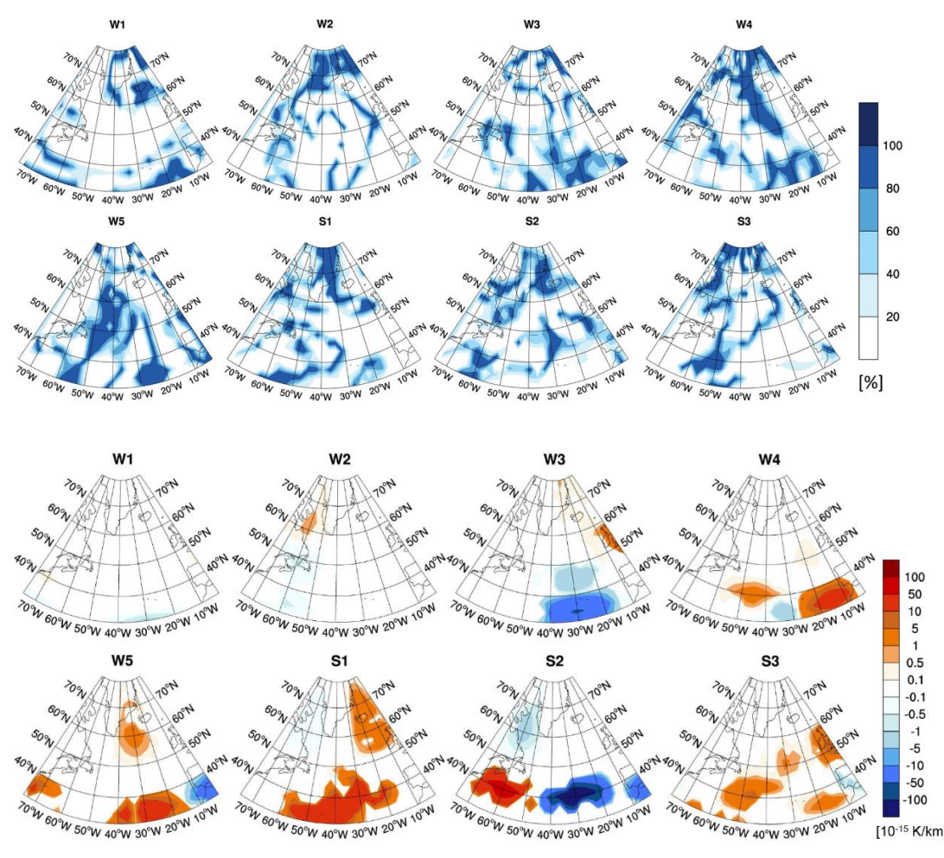

Figure: Potential contrail coverage (top) and climate change functions (bottom) for different weather situations [2].

Meteorology contrail formation: EMAC vs aircraft observations

- Comparing temperature and humidity based on airborne observations (HALO measurement campaign, CARIBIC/IAGOS) and different EMAC model setups.

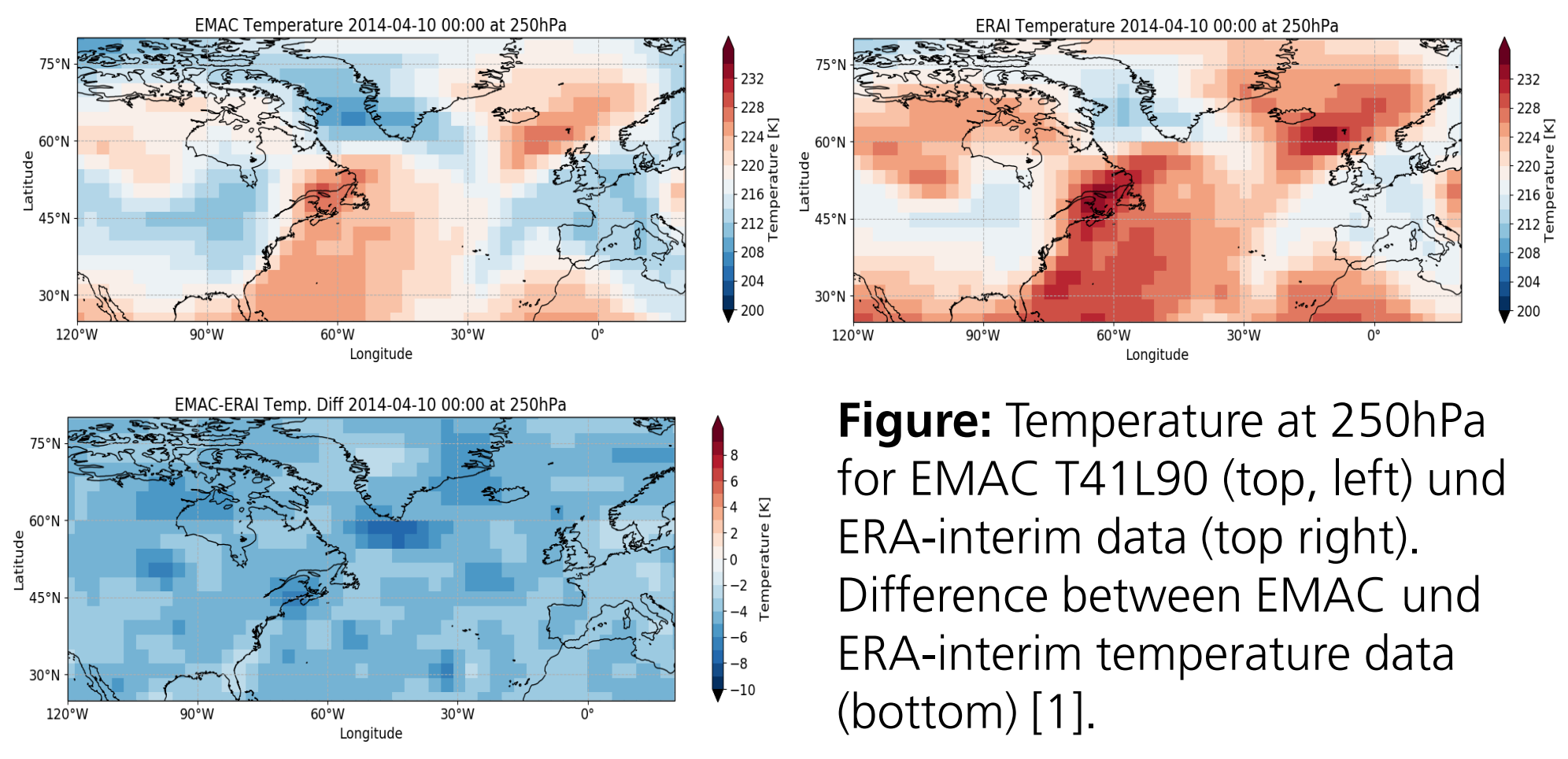

Figure: Temperature at 250hPa for EMAC T41L90 (top, left) und ERA-interim data (top right). Difference between EMAC und ERA-interim temperature data (bottom) [1].

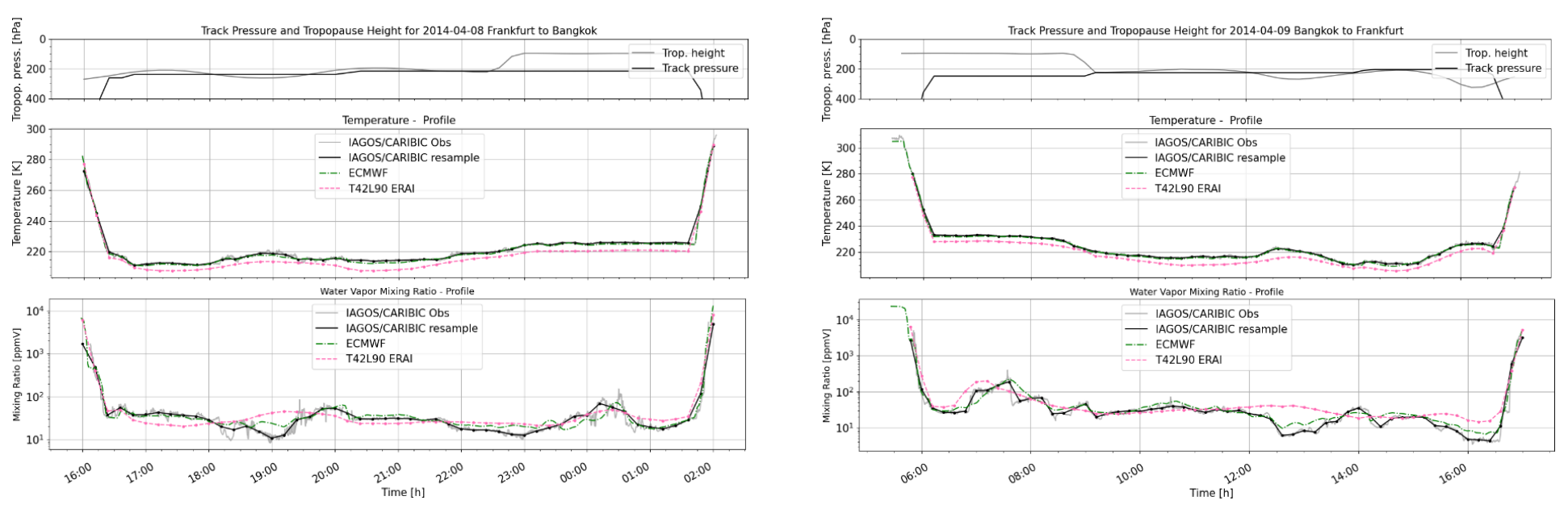

Figure: Flight from Frankfurt to Bangkok on 08 April 2014 return flight on 2014 04 09. IAGOS Aircraft measurements for temperature and humidity compared with different EMAC setup and ECMWF data[1].

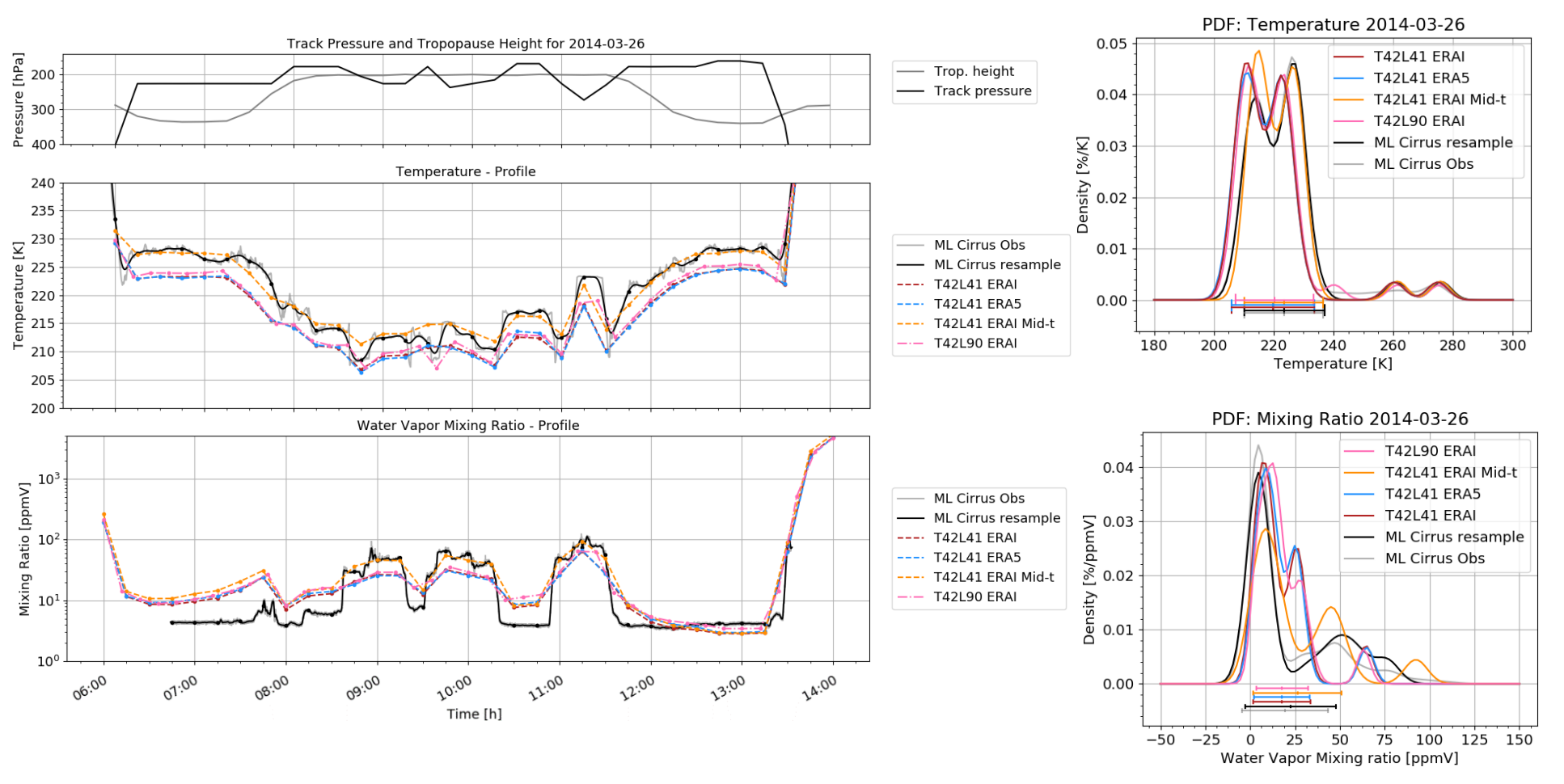

Figure: Comparison of temperature and humidity data for 26 March 2014 along flight trajectory (left), Probability density function for temperature and humidity (right). Model grid T42 (about 2.8°), L90/L41 vertical, ML-Cirrus data from FISH and BAHAMAS instrument [1].

- All aircraft observations shows a systematic **cold bias** (for temperature below 235K) and a dry bias (in the troposphere).

Lagrangian Approach

- Lagrangian concept to study development and radiative impact of contrails in EMAC/ATTILA.

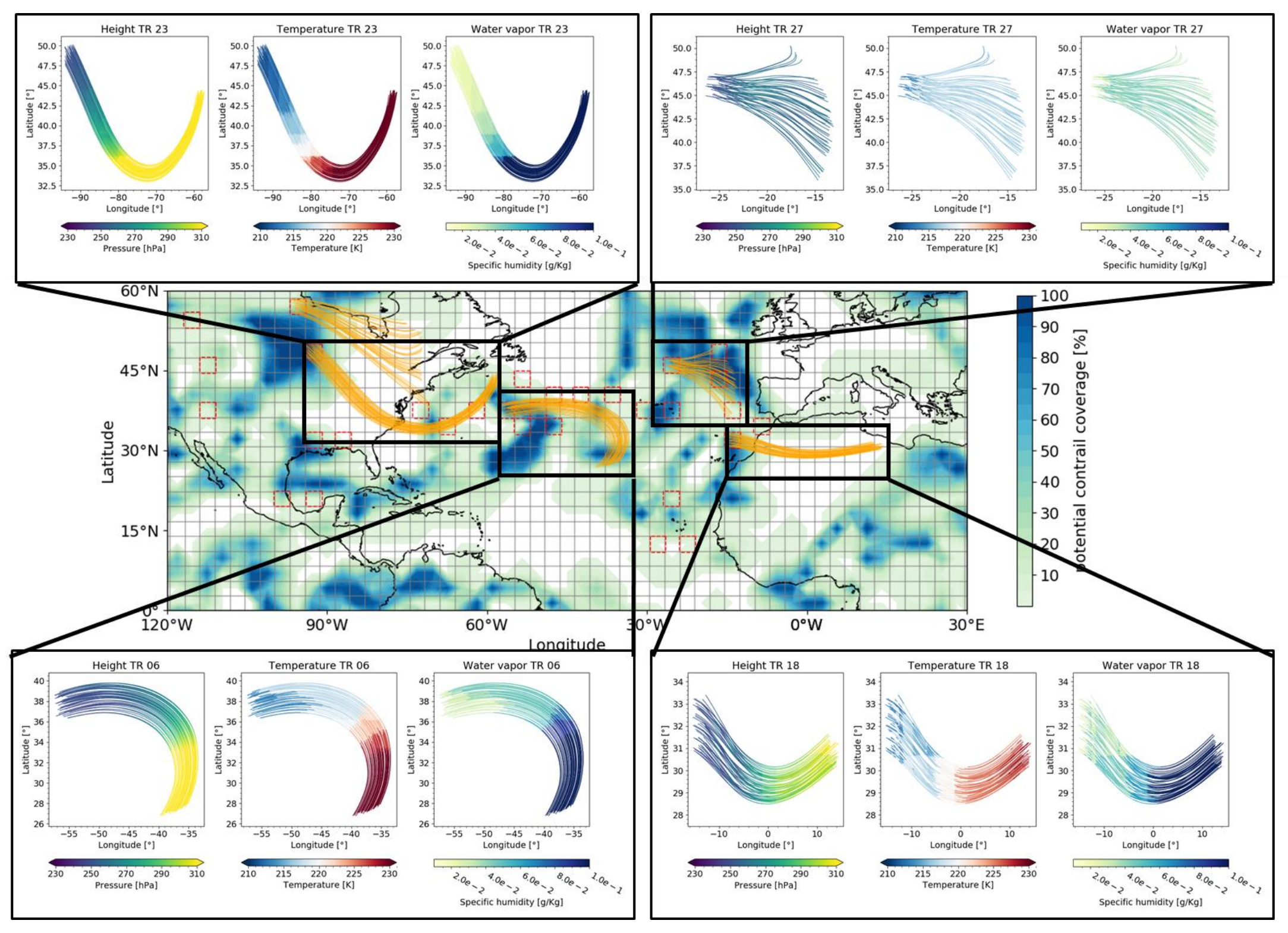

Figure: Potential contrail coverage for 26 March 2014 at 250 hPa (blue), location of time-region grid points (red) and examples for Lagrangian trajectories (orange). Boxes show the behavior of the trajectories [1].

Temperature comparison (EMAC vs. ML-Cirrus observations)

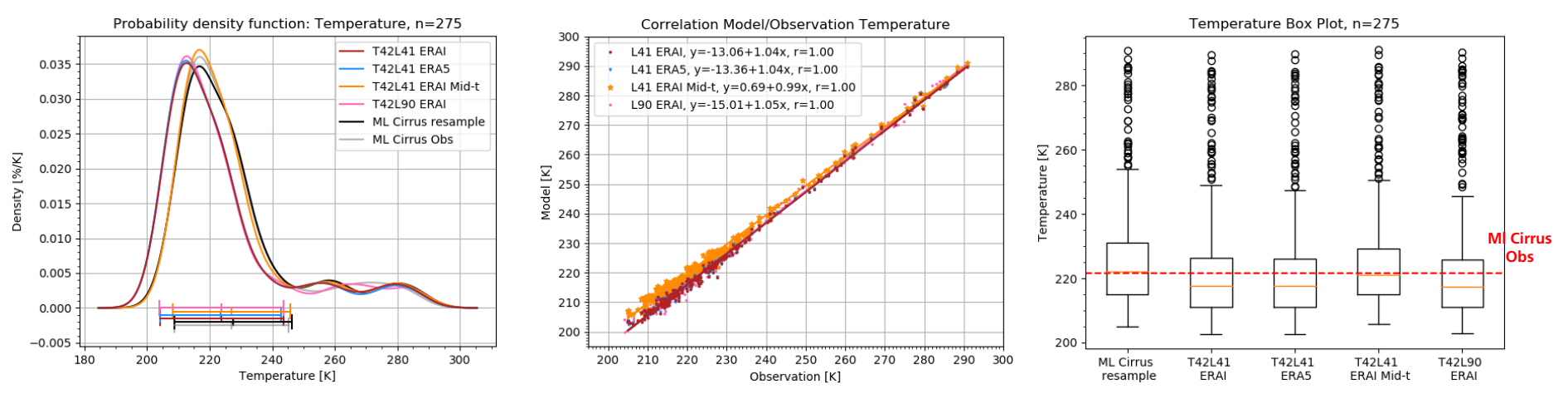

Figure: Probability density function of model and observational temperature data for the ML-Cirrus time period (left). Correlation between observational data and model data (middle). Boxplot for all datasets (right) [1].

- **Temperature difference** between observations and simulation (up to **5 K**).
- **Strong correlation** between model and observational data.

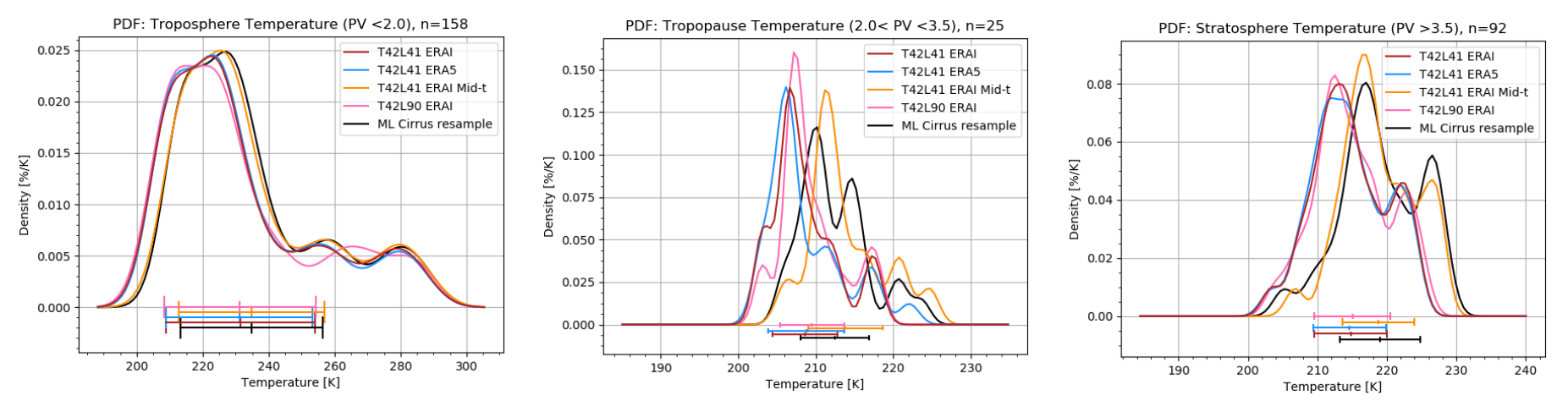

Figure: Probability density function of model and observational temperature data for the troposphere (left), stratosphere (right) and the tropopause region (middle) (ML-Cirrus period) [1].

- Similar temperature bias in troposphere and in stratosphere (~3-5 K).
- Strong **lapse rate change** impact on the tropopause data.

Water vapor comparison (EMAC vs. ML-Cirrus observations)

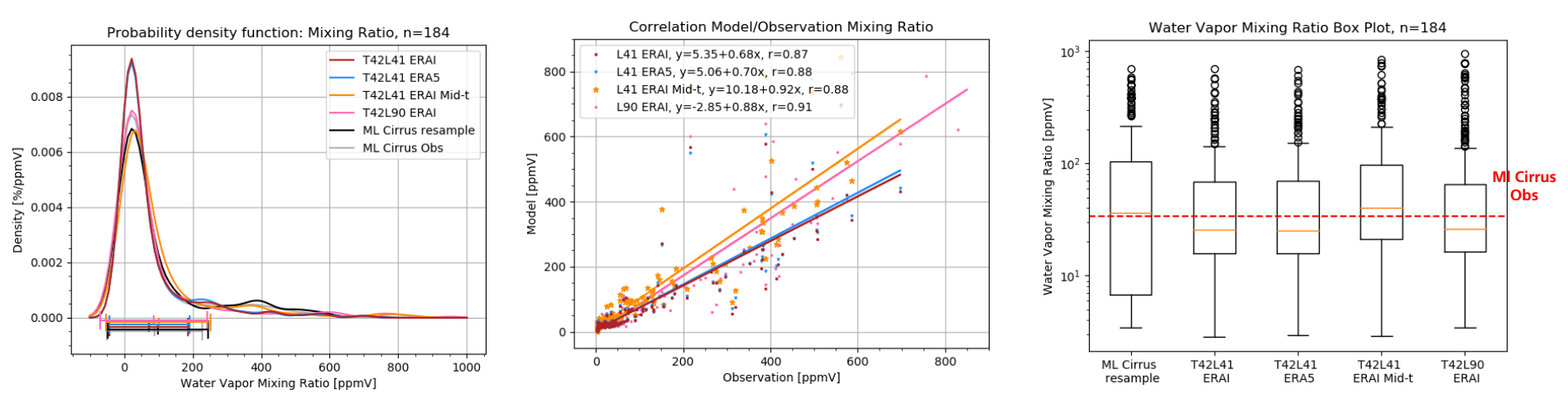

Figure: Probability density function of model and observational humidity data for the ML-Cirrus time period (left). Correlation between observational data and model data (middle). Boxplot for all datasets (right) [1].

- Mixing ratio is **similar for dry regions**, but differs for humid values between 200 and 400 ppmV.
- Increased correlation for L90 simulation due to reduced output interval (15->12m).

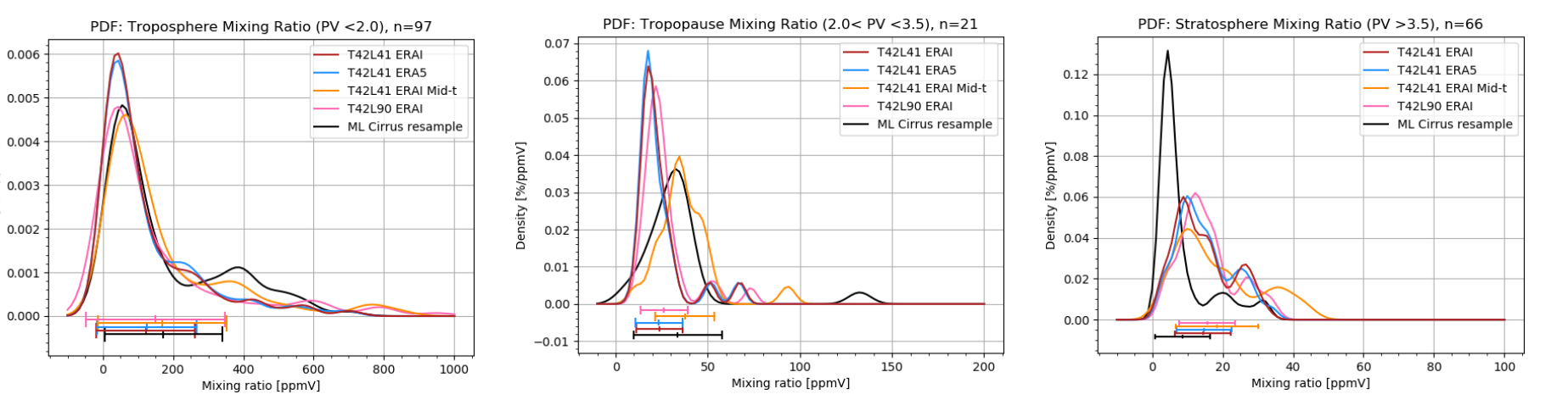

Figure: Probability density function of model and observational humidity data for the troposphere (left), stratosphere (right) and the tropopause region (middle) (ML-Cirrus period, Fish sensor) [1].

- EMAC shows higher mixing ratio values in the stratosphere compared to obs. data.
- Opposite in the troposphere, improvement with mid temp. nudging.

Perspectives and Plans:

- Systematic cold bias and dry bias between EMAC and aircraft measurements differs with nudging concept.
- Impact on relaltive humidity, ISSR and potential contrail coverage, adjustments necessary.
- Expand analysis distinguishing different seasons and regions and evaluate existing algorithmic Climate Change Functions (aCCFs) prototypes.
- Novel CCF data will be used to calculate **climate optimized flight trajectories** within ClimOP project.

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