# SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

| | |
|---|---|
| **Reporting year** | 2021………………………………………………….…… |
| **Project Title:** | Sensitivity of diabatically enhanced outflow on error representation in ensemble prediction…………………….…… ……………………………………………………….…… |
| **Computer Project Account:** | spdepick.…………………………………………….…… |
| **Principal Investigator(s):** | Moritz Pickl……………………………………………. Christian M. Grams………………………………….…… |
| **Affiliation:** | Karlsruhe Institute of Technology (KIT)………………… |
| **Name of ECMWF scientist(s) collaborating to the project** (if applicable) | Simon Lang……………………………………………. Martin Leutbecher…………………………………….... |
| **Start date of the project:** | 01.01.2020…………………………………………….. |
| **Expected end date:** | 31.12.2022………………………………………..…….. |

## Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

| | | Previous year | | Current year | |
|---|---|---|---|---|---|
| | | Allocated | Used | Allocated | Used |
| **High Performance Computing Facility** | (units) | 700.000 | 11.047 | 650.000 | 0 |
| **Data storage capacity** | (Gbytes) | 15.000 | 0 | 31.000 | 0 |

## Summary of project objectives (10 lines max)

The project aims to investigate the effect of ensemble configuration (i.e. model physics perturbations and initial condition perturbations) on diabatically driven, rapidly ascending air streams, such as warm conveyor belts in the extratropics and tropical convection. This is done by running senitivity experiments with different model uncertainty schemes (e.g. SPPT, SPP). Rapdily ascending air streams are detected in a Lagrangian framework using trajectory analysis.

## Summary of problems encountered (10 lines max)

So far, no problems have emerged in this project

## Summary of plans for the continuation of the project (10 lines max)

So far, the main focus of the project was on the effect of SPPT and initial condition (IC) perturbations on rapidly ascending air streams. For the remaining part of the project, the effect of other model uncertainty schemes / perturbation techniques on the trajecotires will be evaluated.

## List of publications/reports from the project with complete references

Pickl, M., Lang, S.T.K., Leutbecher, M. and Grams, C.M.: The effect of stochastically perturbed parametrisation tendencies on rapidly ascending air streams (in preparation)

## Summary of results

First year (Jan 2020 - Jun 2020)

In the beginning of the project, the main focus was on the technical implementation of a trajectory computation tool (based on the Lagrangian Analysis Tool (Lagranto), Sprenger and Wernli, 2015) into the IFS suite. This implementation enables to detect warm conveyor belts (WCBs) and other rapidly ascending air streams in an efficient, embarrassingly parallel manner, without the need of storing high-resolution model-level data offline. Besides this technical implementation, a case study was conducted in order to find a suitable model setup and parameters for the trajectory computation for a systematic investigation. We decided to run the simulations at a resolution of TCo399 with 21 ensemble members and compute the trajectories based on both 1°/6 hourly and 0.25°/1 hourly output fields. For details, see the corresponding progress report from 2020.

In the case study, we found that the occurrence of warm conveyor belts is decreased when model physics perturbtions through SPPT are deactivated, pointing towards a sensitivity of rapidly ascending air streams on the SPPT-scheme. However, as this was only evaluated for one single case in the North Atlantic region, it was unclear whether this is a systematic effect, or if it only occurred in this case.

Second year (Jun 2020 - Jun 2021)

In order to elaborate on the question whether the observed effect from the case study is systematic, a set of sensitivity experiments was conducted (REF with SPPT and IC-perturbations, no-SPPT with only IC-perturbations, and no-INI with only SPPT), with a total of 32 initialisations run out to 12 days lead time with 21 ensemble members. Rapidly ascending air streams are detected by starting 48h forward trajectories in the planetary boundary layer, which are subsequently filtered by an ascent of at least 600 hPa within 48 hours to retain only the most rapidly ascending air streams. As the trajectory starting points are distributed over the whole globe, not only WCBs in the extratropics, but also tropical convection is detected.

The results show that SPPT systematically increases the frequency of the rapidly ascending trajectories, compared to the experiment without SPPT. The effect occurs almost globally, but its magnitude depends on the region: In the tropical regions, the frequency difference between REF and no-SPPT is the largest, with an increase of more than 5% in the experiments with activated SPPT. In the extratropical strom tracks, the effect is weaker (2-4%; see Figure 1e). This increased frequency by SPPT reduces the negative bias in the tropics and in the North Atlantic, where the experiment without SPPT strongly underestimates the outflow frequencies compared to a reference data set based on the operational high-resolution analysis (ANA). However, in the Southern Hemisphere and parts of the North Pacific, the increase through SPPT leads to an overestimation of the trajectories (Figure 1c and d). In contrast to SPPT, IC-perturbations do not have a systematic influence on rapidly ascending air streams (Figure 1f).

As a consequence of the regional differences of the effect of SPPT, with a larger impact in the tropics than in the extratropics, the distribution of the trajectory characteristics (such as the latent heating rate) are modified by SPPT, leading to a shift of the latent heating rates towards higher values. However, the characteristics of the trajectories are not directly changed: When regarding the latent heating rate separately for a strongly heated (tropical) and a weakly heated (extratropical) regime, the heating rates are not changed within the regimes when SPPT is activated (Figure 2b).

The classification of the trajectories into the two heating regimes emphasizes the role of latent heating for the effect of SPPT on the rapidly ascening air streams: In the upper heating regime, SPPT has a much larger impact on the number of trajectories than in the lower regime, which explains the regional differences between tropics and extratropics (Figure 2a).

The influence of SPPT on the whole spectrum of vertical velocities can be understood by analysing the distributions of vertical velocities in a Eulerian way between the experiments. With SPPT, very fast vertical velocities (< -1 Pa/s) occur more often than without SPPT. This is balanced by a general increase of downward motions aswell as reduced upward motion of slow velocities (not shown).

The effect of SPPT on the frequency of the trajectories does not depend on the forecast lead time, but is constant throught the forecast (not shown). Together with the fact that the trajectory properties are not altered by SPPT, this shows that SPPT directly impacts the distribution of vertical velocities. The pathway of how SPPT systematically influences the trajectories is therefore not via altered environmnetal conditions (e.g. moisture accumulation in the inflow region of the trajectory), but the interaction of the perturbations with the highly non-linear dynamics of diabatically driven rapid ascents.

Figures:

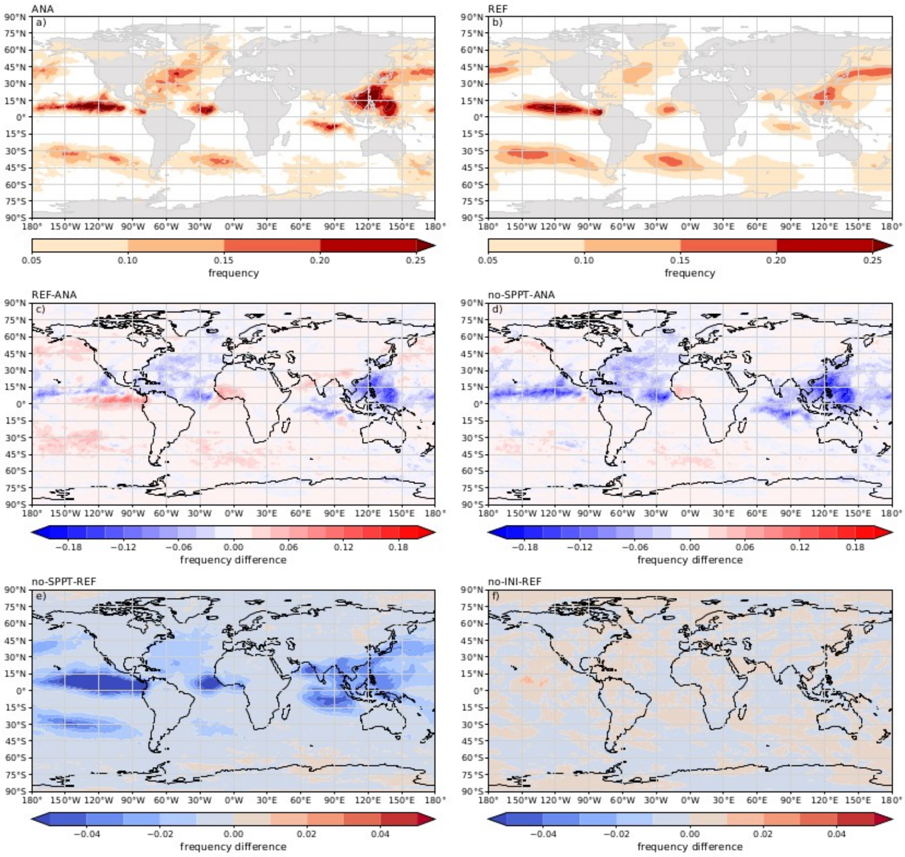


*Figure 1: Frequency maps of trajectories reaching the upper troposphere above 400 hPa over all forecasts (32),lead times (41) and ensemble members (20). a) Experiment REF, b) interpolated analysis, c) difference between REFand the interpolated analysis, d) difference between no-SPPT and the interpolated analysis, e) difference betweenno-SPPT and REF, and f) Difference between no-INI and REF*

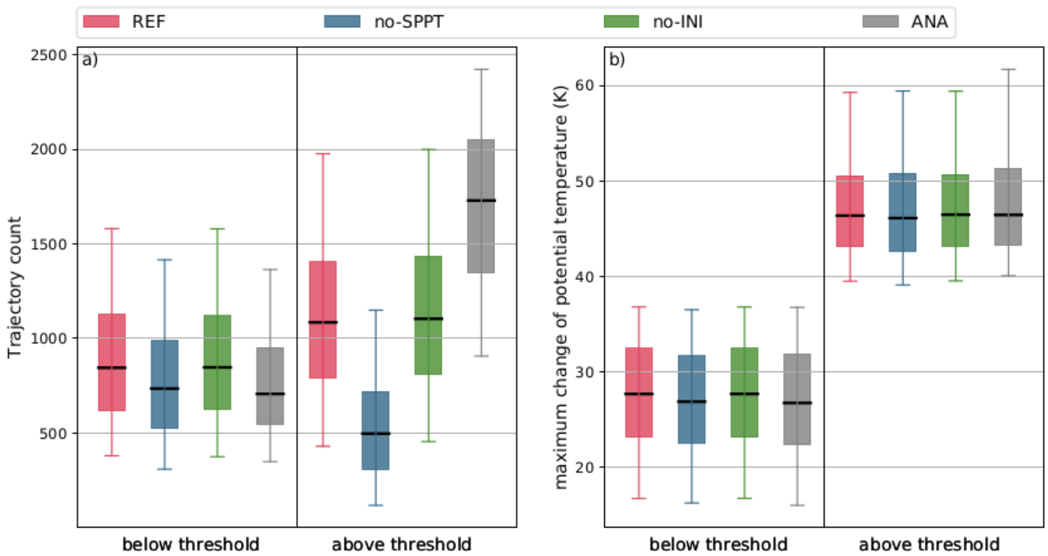


*Figure 2: a) Trajectory count, b) latent heating of all trajectories in the experiments REF, no-SPPT, no-INI and the interpolated analysis (ANA) separated for the twolatent heating regimes below (left) and above (right) the threshold of 38K*