SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018
Project Title:	Ice-supersaturation and cirrus clouds and their feedbacks to tropopause dynamics
Computer Project Account:	SPDESPIC
Principal Investigator(s):	Prof. Dr. Peter Spichtinger (JGU Mainz) Dr. Klaus Gierens (DLR Oberpfaffenhofen)
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Name of ECMWF scientist(s) collaborating to the project (if applicable)	…………………………………………………………… ……………………………………………………………
Start date of the project:	February 2016
Expected end date:	December 2018

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)	200000	0	200000	0
Data storage capacity	(Gbytes)	500	0	500	0

Summary of project objectives

(10 lines max)

We investigate ice supersaturation and cirrus clouds in the upper troposphere and their interaction with tropopause dynamics and radiation. We want to address the following research questions:

- What are the dominant formation mechanisms for ice crystals in the tropopause region under certain environmental conditions?
- What is the radiative impact of cirrus clouds in the tropopause region in terms of net contribution and vertical profiles of heating rates?
- How often does shallow cirrus convection occur and how does it determine exchange processes at the tropopause?
- How are enhanced water vapour and tropopause inversion layer correlated? What is the role of cirrus clouds for the tropopause inversion layer?
- What are the atmospheric conditions that give rise to contrails with particularly strong warming impact?

Summary of problems encountered (if any)

(20 lines max)

No problems encountered so far.

Summary of results of the current year (from July of previous year to June of current year)

1. Conditions for contrails with high positive radiative forcing

Contrails affect climate if they are persistent, that is, if they are located in an ice-supersaturated region (ISSR). They do this by reflecting sunlight back to space (cooling) and by blocking thermal radiation from the Earth surface and lower atmosphere (warming). Radiative forcing (RF) is a measure for the immediate radiative impact of a contrail. A negative value means that the short-wave cooling effect dominates while a positive value signifies a net warming. During night, there is always net warming since sunlight and thus it's possible reflection is absent. In most (daytime) cases there is substantial cancellation of the warming and cooling effects, but occasionally (in particular during night) the long-wave warming effect dominates such that the respective contrail has a particularly strong contribution to climate warming. This is a Big Hit, and such contrails should be avoided already in the flight planning phase. Such an avoidance strategy needs of course a reliable prediction of the conditions under which contrails actually are that strong climate warmers.

The topic of this study is how situations with strong warming contrails can be characterised and whether and how reliably it is possible to predict them. For this we use forecast data from the ERA-Interim Reanalysis valid at 1-30 April 2006, 3-24 h in 3 h steps and all initialised at midnight each day. The analysis is confined to pressure levels 200, 250, and 300 hPa. The study region is 40°W to 20°E and 30 to 60°N. The data are used in 1°×1° spatial resolution.

First, temperature and relative humidity are used to check whether contrails are possible, applying the Schmidt-Appleman criterion. If contrails are indeed possible it is further checked whether there is ice supersaturation. As ISSRs (ice supersaturated regions) appear implausibly patchy if the real condition for ISS, namely *RHi* > 100% is used, we apply a correction of 5% and define ISSRs as regions with *RHi* > 95%. All computations of water vapour available for condensation take this 95% as base value.

The calculation of shortwave and longwave radiative forcing is done using the parameterisation given by Schumann et al. (2012), which uses radiation quantities and albedo from the forecasts.

This initial one month study shows what in principle has to be done to reach the aforementioned goal, but it suffers from insufficient statistics and autocorrelation. The remedy of these two problems is to employ a larger data set. But one robust result can be derived already from the preliminary analysis, namely that most Big Hits occur during night, which is advantageous because air traffic is not so dense and rerouting is easier than during day.

2. Quality of ERA water vapour data

We used in situ water vapour measurements as obtained from the MOZAIC/IAGOS project. The MOZAIC data provide a good temporal and spatial coverage over some parts in the Northern hemisphere, especially over the North Atlantic region (http://www.iagos.org/).

In a first step we compared the water vapour measurements with the ERA water vapour fields. In order to have a reliable intercomparison we collect MOZAIC data in the respective ERA grid boxes. We compared relative humidity with respect to ice (RHi) as well as absolute humidity (water vapour mixing rations) and temperature measurements.

We had to re-evaluate the data, since it turned out that the agreement is not as worse as we have seen in a first step. The one-to-one correlation is not too bad, however the level of supersaturation is less pronounced in ERA, as expected Also small scale features of ice supersaturation are not well kept in the ERA data set. We also investigated the data statistically using different thresholds and treating coarser resolutions of the measurement data. It is planned to submit a manuscript about this comparison by end of 2018.

3. Cirrus climatologies as seen from ERA data

Because of the slow progress in part 2, we are still working on climatologies of frequency of occurrence of ice clouds in the tropopause region. For this purpose cloud ice content were used in combination with threshold values.

4. Investigations of warm conveyor belts as seen from ECWMF data

In a first investigation, different cases of warm conveyor belts with strong outflow in the tropopause region, leading to cirrus clouds were identified using ECMWF data. These cases are currently evaluated in order to identify possible different ice cloud structures, i.e. formation pathways as "liquid origin" or "in situ formation" (see Wernli et al, 2016). The ECMWF data will be used as initial/boundary conditions for ICON simulations, which will be used to clarify the different possible formation pathways. This is work in progress.

List of publications/reports from the project with complete references

N/A

Summary of plans for the continuation of the project

(10 lines max)

- Foot the search for Big Hit contrail conditions on a larger data base comprising at least one year of forecast data.
- Extension of case studies (combination of ECMWF data and in situ measurements)
- Further assessment of water vapour and cloud variables in ERA data using MOZAIC data
- Investigation of horizontal/vertical extensions of ISSRs and ice clouds using ERA data
- Radiative transfer calculations for clouds as extracted from ECMWF analysis/reanalysis data