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	2017
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)	100 000	0	200 000	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?

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)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

1. 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.

In the first investigations we found that ERA does not represent ice supersaturation in a realistic way. A simple one-to-one comparison showed weak correlations between in situ measurements and ERA data along the flight track. 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. In a climatological sense the comparison is not too bad; however, details of the investigation are subject of future investigations. It is planned to submit a manuscript about this comparison by end of 2017.

2. Cirrus climatologies as seen from ERA data

The ERA data were used for compiling climatologies of frequency of occurrence of ice clouds in the tropopause region. For this purpose cloud ice content were used in combination with threshild values. In comparison with satellite data, the climatologies show good agreement. This own product of cirrus climatologies will be used for future work.

3. Case studies on ice clouds and ice supersaturation over Northern Germany

We extended our previous work on case studies of ice clouds and ice supersaturation as measured during aircraft campaigns over Northern Germany.

During two aircraft campaigns in spring and autumn 2013 several situations of ice supersaturated regions (ISSRs) and cirrus clouds were investigated. For a better understanding of the processes of formation and evolution of ISSRs and cirrus clouds we use trajectory calculations and large eddy simulations.

For each case in the measurement campaign (ca. 8 relevant measurement flights) ECMWF analysis and 3 hourly forecasts were used as input for the trajectory tool LAGRANTO. The trajectories were started along the flight track of the aircraft and calculated backwards time in order to investigate the dynamical situation and especially vertical motions in the upper troposphere. Along these trajectories boxmodel calculations were carried out in order to investigate the onset of nucleation and the formation and evolution of the ice clouds. In addition the estimated mean vertical updrafts together with temperature and humidity data from ECMWF operational analyses were used to run the large eddy simulation model EULAG together with a detailed ice microphysics.

In a joint evaluation of ECMWF analysis data, trajectory calculations , satellite measurements and model calculations we could determine different intersting cases, which are currently further investigated and prepared for publications:

(a) in situ nucleation of ice clouds
A rare case of ice nucleation during the measurement could be found, the analysis of the ECMWF data indicated that the nucleation was triggered by slow upward motions. The investigations using model calculations showed that different nucleation pathways (heterogeneous or homogeneous nucleation) might have led to this event; however, a clear distinction is not possible.

(b) shallow cirrus convection
The ECMWF data indicate that during one flight the environmental situation was potentially unstable close to the tropopause; thus, the measured cirrus clouds might be formed via shallow cirrus convection, as suggested in former but more idealised investigations (Spichtinger, 2014). We will investigate this case in future in more details, using EULAG simulations.

(c) gravity wave induced cirrus clouds
A case of wave driven ice clouds could be determined from the analysis of ECMWF data; the air flow over mountains of Scotland leads to formation of ice clouds, which were later measured over Northern Germany in the downstream of the air flow. This case will be further investigated using EULAG simulations.

4. Tropopause dynamics, water vapour and ice clouds

We extended our investigations about the correlation between the so-called tropopause inversion layer (TIL) and water vapour in the tropopause region. First investigations show that the TIL is very strong at occurrence of high relative humidities in the tropopause region and, in contrast, is quite weak at dry conditions. We will investigate this correlation in more details in future, since the interaction between these two "features" is not clear at all. Former investigations claimed a correlation between TIL and water vapour mixing rations but not relative humidity. We are currently using data from longer time intercals and for other situations in order to clarify the correlation between TIL and water vapour and ice clouds.

5. 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.

List of publications/reports from the project with complete references

N/A

Summary of plans for the continuation of the project

(10 lines max)

- 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
- Investigations on the interaction between tropopause dynamics and ice clouds at case studies, as derived from ECMWF analysis data
- Model simulations with EULAG for certain idealized situations
- Radiative transfer calculations for clouds as extracted from ECMWF analysis/reanalysis data