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:	Diabatic effects in mid-latitude weather systems …………………………………………………………… ……………………………………………………………
Computer Project Account:	SPCHBOJO……………………………………………
Principal Investigator(s):	Hanna Joos and Maxi Boettcher ……………………………………………………………
Affiliation:	ETH Zurich
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Dr. Richard Forbes
Start date of the project:	01 January 2018………………………………………….
Expected end date:	31 December 2020……………………………………….

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)			4’250’000	104’816.2
Data storage capacity	(Gbytes)			71’000	

Summary of project objectives
(10 lines max)

The aim of this special project is to investigate the impact of diabatic temperature tendencies on the dynamics of weather systems, such as extratropical cyclones, diabatic Rossby-waves and blocks. Diabatic temperature tendencies can change the potential vorticity (PV) and so directly influence the wind field and the dynamics. The impact and the importance of the various diabatic processes will be analyzed and quantified. The project builds upon a special IFS version provided by Dr. Richard Forbes which allows to output all diabatic temperature tendencies consisting of microphysical and radiative heating rates as well as tendencies from the turbulence parameterizations.

Summary of problems encountered (if any)
(20 lines max)

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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

The project is sub-divided into the following 4 working packages:

WP 1: Influence of diabatic processes on the dynamics of extratropical cyclones and blocks: a climatological analysis

A detailed assessment of how diabatic process modify potential vorticity (PV) in an extratropical cyclone that occurred in April 2017 over the North Pacific basin using a special IFS version that outputs hourly heating rates of numerous diabatic processes. Using these heating rates, individual PV tendencies were computed and traced along backward trajectories to obtain the individual influence of each diabatic process on every grid point within the case-study cyclone. Further, a technique was developed to identify the regions associated with the cold front, warm front, bent back front and cyclone centre. Thereby, statistics of both positive and negative PV anomalies within each of these features were computed for the entire life-cycle of the cyclone. This analysis yielded insights into the evolution of the most relevant diabatic processes that modify PV. For the low-level negative PV feature behind the cold front we found that long-wave radiation strongly increases PV locally, which is counteracted by a strong negative PV tendency due to turbulent mixing as well as the large-scale cloud forcing. The evaporation of cloud droplets above the trajectory position is the dominant process in reducing PV during the early stages of the cyclone, while the sublimation of snow above the trajectories becomes continuously more important when the cyclone matures. This sequence exemplarily describes changes in the environment of the air parcels that arrive behind the cold front and how these processes are able to modify the evolution of the cyclone. This work is currently in preparation for submission.

WP 2: The impact of subgrid-scale parameterized processes on tropopause level PV

In this work package, the effect of non-conservative processes in terms of modification of PV in the tropopause region is investigated. The output of temperature and momentum tendencies from parameterized physics is used to compute PV tendencies. A reverse domain filling technique is applied to quantify the integrated change of PV along air parcel trajectories and at each grid point within the considered domain. In a simulated case study of a North Atlantic cyclone and an associated downstream ridge, the Lagrangian diagnostic shows, that the vertical diffusion and gravity wave drag schemes are dominant in modifying PV in the vicinity of the tropopause. The impact of these subgrid processes varies between different regions. Among other effects, they change the isentropic PV gradient, in some regions they affect tropopause height, and contribute to stratosphere-troposphere exchange. Longwave radiation, convection, and large-scale cloud processes also affect the tropopause, mainly in the vicinity of upper-level troughs.

WP 3: Case studies of diabatic effects on blocking events

In this project, which started in March 2016, the role of latent heating in atmospheric blocking is investigated. Moist processes, and in particular the release of latent heat in ascending airstreams, can modify the mid-latitude flow and contribute to the formation of prolonged circulation anomalies such as atmospheric blocking. A 37-year climatology based on the ERA-Interim reanalysis data has shown that 50 % of the air masses involved in blocking are heated by more than 2 K (8.5 K in the median) in the 3 days prior to their arrival in the blocking anticyclone (paper in preparation). While this new finding highlights the importance of diabatic processes for blocking formation, the causal link between latent heating and blocking is still not well understood.
In this study, we explore the effect of latent heating on blocking by conducting IFS sensitivity experiments in which the latent heat release during cloud formation will be artificially modified. A first case study (ECMWF Newsletter Number 154) revealed that changes in the latent heat release lead to distinct differences in the blocking life cycle. When latent heating is turned off, the ascent and diabatically-driven upper-level outflow are reduced, the ridge does not amplify and, in the absence of wave-breaking, the block is not initiated. Further experiments for a subset of 3-4 selected blocking events are planned to better understand how the physics within ascending airstreams play a crucial role in the formation, maintenance and decay of blocking anticyclones and in the upper-level wave dynamics in general.

WP 4: Investigation of diabatic processes in NAWDEX cyclones

As a first case study, cyclone Sanchez that has been probed by aircraft measurements over the central North Atlantic during the NAWDEX campaign in October 2016 has been simulated with the IFS TCo639 L137 including output of all temperature tendencies. The particular interest on this cyclone is the cutoff process of the upper-level PV streamer and the diabatic processes which contributed to this.
A Lagrangian diagnostics is applied to identify the diabatic processes that modified temperature and also PV of the air parcels before they arrived near the tropopause. First results reveal that processes that modify temperature and PV in this region are related to the surface cyclone where ascending air and the massive formation of clouds take place. Little impact could be found from convection

compared to large-scale clouds, while radiation and turbulent mixing also seem to play an important role in the modification of PV at the tropopause.

List of publications/reports from the project with complete references

Rodwell, M., Forbes, R. and Wernli, H., 2018: “Why warm conveyor belts matter in NWP”, ECMWF Newsletter, Number 154, doi:10.21957/mr20vg.

Summary of plans for the continuation of the project

(10 lines max)

The project will be continued with the following tasks:

WP 1: Simulation of a longer time period and different seasons to apply the diagnostics developed for the case study in a systematic way.

WP 2: Run further case studies and sensitivity experiments on blocking.

WP 3: Systematic investigation of the impact of cloud microphysical heating rates on the dynamics of weather systems. For this reason, further IFS simulations and sensitivity experiments are planned.

WP 4: Rerun the simulation with an improved detailed output of the diabatic temperature tendencies and continuation of the investigations.