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	2024
Project Title:	Diabatic processes and their impact on extratropical dynamics and the hydrological cycle
Computer Project Account:	SPCHBOJO
Principal Investigator(s):	Dr. Hanna Joos, Dr. Michael Sprenger
Affiliation:	Institute for Atmospheric and Climate Science, ETH Zürich, Switzerland
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Dr. Richard Forbes
Start date of the project:	1. January 2024
Expected end date:	31. Decemeber 2026

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)	-	-	500 000	71740
Data storage capacity	(Gbytes)	-	-	9 Tb	

Summary of project objectives (10 lines max)

Our special version of the IFS, allowing for hourly output of all temperature and moisture tendencies, will be used in order to investigate the impact of diabatic processes on extratropical dynamics and the hydrological cycle. More precisely we will investigate the importance of diabatic processes for the formation of (i) clear air turbulence near the tropopause region and (WP1) (ii) a sting jet in an extratropical cyclone (WP2), (iii) the impact of surface radiative cooling on the storm track regions (WP3) and (iv) the moisture sources for warm conveyor belts (WP4).

Summary of problems encountered (10 lines max)

We did not encounter any problems

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

In the following 2.5 years we plan to perform several case study simulations in order to investigate the research questions that are listed above. Whereas we already started the work on clear air turbulence and sting jets, the work on warm conveyor belt moisture sources and the impact of surface radiation on the storm track will only begin at the end of 2024 or the beginning of 2025.

List of publications/reports from the project with complete references

So far there are no publications because the project only started in January 2024.

Summary of results

WP1: Potential Vorticity Modification and Clear Air Turbulence in the Tropopause Region (Franco Lee, Dr. Michael Sprenger)

For this work package, the IFS version allowing for hourly output of all physical tendencies has been implemented to the model version CY47R3b and carefully tested, which is essential not only for this work packages but also for the ongoing special project. In autumn 2023, simulations of two case studies of clear air turbulence (CAT) have been performed, one related to Rossby-wave breaking (RWB) over the North Atlantic (29 August 2019) and one related to a warm conveyor belt outflow to the south of Japan (24 December 2019). The used model resolution is TCo1279, with hourly output of standard, as well as temperature and momentum tendency fields.The tendency fields are used to calculate potential vorticity (PV) rates due to turbulence (and other processes), which are then accumulated along backward trajectories as developed in an earlier special project by Spreitzer et al. (2019) and Attinger et al.(2019). As an example, Figure 1 left, shows the accumulated PV changes for the Rossby-wave case on 29 August 2019 and Figure 1 right, shows the change in PV due to the different diabatic processes along backward trajectories started from the blue triangle in the left panel.

In addition to the aforementioned two cases, two further cases have been simulated at TCO1279 resolution. One is related to a RWB case over the United States (10 January 2020), the second case is related to a widespread turbulence outbreak over the United States on 05 February 2020. For both cases, temperature and momentum tendencies are written out at hourly resolution to allow for a detailed study on how turbulence affects PV and thus the tropopause.

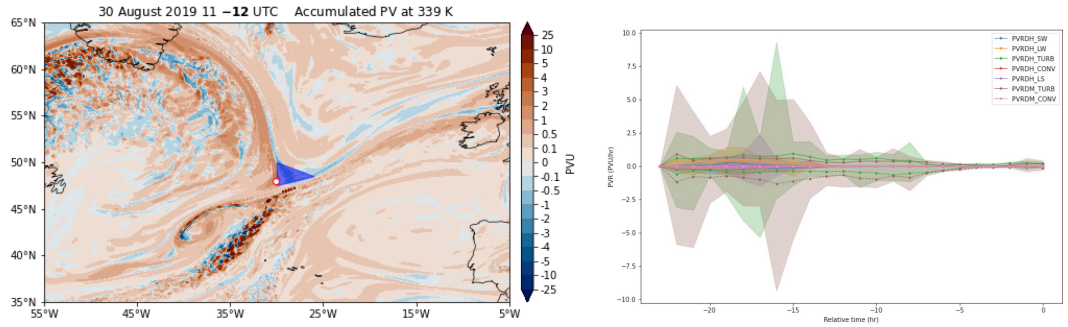

Fig. 1: (Left) Accumulated PV along 12-hour backward trajectories. (Right) Decomposition of the PV rates (in PVU/hour) according to several processes (long- and short-wave radiation, turbulence, convection) along backward trajectories started at the southern tip of a Rossby-wave event over the North Atlantic. The turbulence contribution is separated into a part due to turbulent heating and momentum transport.

WP 2: Sting jet in storm Ciarán (Dr. Ambrogio Volonté (University of Reading), Dr. Hanna Joos, Franco Lee)

We used the IFS model CY46R3 with a resolution of TCo1279 (~9km) and hourly output of all temperature tendencies to performed a case study simulation of storm Ciarán which occurred in November 2023 in the eastern North Atlantic. The storm featured a small-scale region of extremely strong low-level winds (> 50 m/s at 850 hPa) belonging to the airstream called “sting jet”. Sting jets develop along local in-cloud regions of moist and, in most intense cases, dry symmetric instability on the cold side of the bent-back front. This instability is then released as the sting jet descends out of the cloud-head tip. Dry symmetric instability is indicated by negative potential vorticity (PV) and the IFS simulation does indeed display a region of negative PV (see Fig. 2) and can therefore be used in order to investigate its formation. To do so, we will calculate Lagrangian air parcel trajectories starting from the region of negative PV and trace all temperature and momentum tendencies along these trajectories in order to understand the formation mechanism of negative PV in the cloud head and to assess the relative importance of the different diabatic processes.

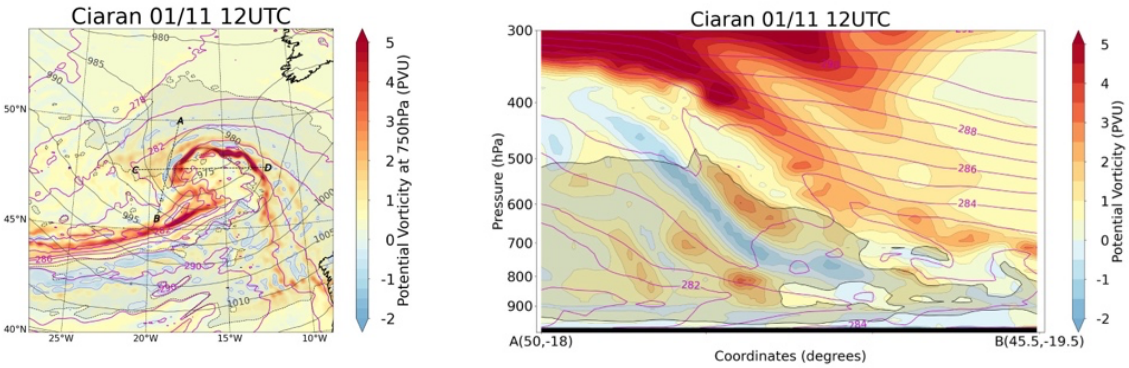

Fig. 1: Potential vorticity at 750 hPa on 1 November 2023, 12 UTC (left) and vertical cross section along line A-B (right). Courtesy of Dr. Ambrogio Volonté.