REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Germany

Principal Investigator[1]: Dr. Andreas Dörnbrack

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Project Title:

Gravity Waves and Turbulence over the Andes

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** DESCAN	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2021	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☒

Computer resources required for 2021-2023: (To make changes to an existing project please submit an amended version of the original form.)		**2021**	**2022**	**2023**
High Performance Computing Facility	(SBU)	500 000	500 000	500 000
Accumulated data storage (total archive volume)[2]	(GB)	80	80	80

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Extended abstract

In austral spring 2019, the SouthTRAC mission was conducted in South America. The SouthTRAC campaign was a joint atmospheric research project by German research centres and universities within the DFG HALO-SPP 1294 framework in close collaboration with partners from Argentina, Chile, and other international organizations. In late 2019, the German High Altitude and Long Range Research Aircraft HALO was relocated to Tierra del Fuego (Río Grande) at the southern tip of South America in order to perform atmospheric measurements of meteorological quantities and trace gases at southern hemispheric mid- and high-latitudes. The aircraft was equipped with a set of 13 instruments allowing a comprehensive study of the atmospheric state, composition and dynamical parameters by in-situ sampling and down-, up- and sideways-pointing remote sensing instruments. The extensive aircraft campaign was conducted in two phases taking place in September/October and November 2019, respectively, covering the late winter and spring season. The HALO measurements were accompanied by ground-based measurements (e.g., lidar, radar, radiosondes) and measurements on board a glider operating from El Calafate.

Of special interest for this special project are the airborne lidar measurements of internal gravity waves in the middle atmosphere by the Airborne Lidar for Middle Atmosphere research (ALIMA[2]), the high-resolution flight level turbulence data collected by the Basis HALO Measurement and Sensor System (BAHAMAS) on board the research aircraft HALO, and the wind and temperature observations from the glider. These different measurements shall be analysed and brought into a meteorological context.

For this purpose, the access to operational data, to reanalyses as well as to the high-performance computer resources is requested. The special project is embedded in two national research projects in Germany. (1) "Investigation of the life cycle of gravity waves" in the research initiative "Role of the Middle Atmosphere in Climate" funded by the German Ministry of Research and Education. (2) “Processes and climatology of gravity waves” in the research unit “Multiscale Dynamics of Gravity Waves” funded by the German Science Foundation.

[22] ALIMA is a powerful iron-resonance and Rayleigh lidar system for airborne measurements in the middle atmosphere, including the stratosphere, mesosphere and lower thermosphere. The high temporal resolution of 2 minutes allows the detection of short period atmospheric gravity waves. This is important because high frequency waves contribute the largest share to the gravity wave-induced momentum flux.

The project is structured into three parts.

(1) Analysis of the turbulence observations and comparison with CAT diagnostics implemented at the ECMWF

In preparation of the SouthTRAC campaign, Dr. Martina Bramberger from our institute and Dr. Peter Bechthold from ECMWF implemented two primary indices for predicting Clear-Air Turbulence (CAT) into the IFS. These are the Ellrod-Index predicting turbulence in highly sheared flows with strong horizontal deformation and an index related to convectively-induced turbulence. The CAT forecasts of the IFS have been used during the field campaign to guide HALO flights and were archived in MARS. The goal of the planned work is to use these archived predictions and to compare them with the flight level data of HALO.

(2) Meteorological analysis and comparison of our observations with different IFS products

In addition to the airborne observations, ground-based Rayleigh lidar measurements of temperature perturbations in the middle atmosphere have been conducted during the recent years since November 2017. They reveal a large spectrum of frequencies and vertical and horizontal wavelengths of the observed gravity waves. An understanding of these different wave modes in the middle atmosphere observed both by the airborne and ground-based lidars is still lacking. Especially, the link of the observed gravity wave activity to possible sources in the troposphere as well as in the stratosphere is difficult to establish as 3D data of wind and temperature in high spatial and temporal resolution and covering larger areas are missing. Therefore, the meteorological analyses and forecasts of the various IFS products will fill this gap.

(3) High-resolution numerical simulation of selected cases

Idealized numerical simulations will complement the combined analysis of the observational data and the IFS output. The geophysical flow solver EULAG is used to simulate the flow over the mountain ranges where ground-based and airborne middle atmosphere lidar measurements are available. In the project, extensive numerical experimentation will be conducted to study the middle atmospheric gravity waves for a series of different geographical locations and atmospheric conditions.

The computer hours will mainly be spent for numerical simulations with the geophysical flow solver EULAG. Tests with a version covering the altitude range from the surface to 180 km reveal about 2000 SBUs for a 2D simulation of the 2D flow over an isolated mountain ridge. As different parameters of the numerical scheme and the atmospheric background conditions have to be varied, I expect about 200 000 SBU per year for the necessary runs. Furthermore, planned 3D simulation will increase the computational effort. A rough estimate gives about 300 000 SBU which sum up to the applied 500 000 SBUs.

(4) Preparation of upcoming airborne field campaigns

A next mission using an advanced version of ALIMA on board of HALO will be the WAVEGUIDE mission planned for autumn 2021. The basic idea it to investigate the vertical coupling between the troposphere and middle atmosphere by internal gravity waves via the polar night jet in the northern hemisphere. The specific tasks include studies to investigate the focusing of gravity waves into the PNJ. The advanced ALIMA version is also able to observe the breaking and secondary sources of gravity waves in the upper stratosphere and mesosphere. One goal of this project part is to conduct a preparatory study outlining possible generic flight paths. Secondly, we are going to use IFS predictions to guide the actual flight operations. Furthermore, high-resolution numerical simulations will go along with the observational activities.

Submitted papers related to the project:

1. **Dörnbrack, A**., Kaifler, B., Kaifler, N., Rapp, M., Wildmann, N., Garhammer, M., Ohlman, K., Payne, J., Sandercock, M., and E. Austin, 2020: Unusual appearance of mother-of-pearl clouds above El Calafate, Argentina (50° 21′ S, 72° 16′ W). *Weather*, submitted 24 April 2020.

2. Kaifler, N., B. Kaifler, **A. Dörnbrack**, M. Rapp, J. L. Hormaechea, and A. de la Torre, 2020: Lidar observations of large-amplitude mountain waves in the stratosphere above Tierra del Fuego, Argentina. Submitted to *Scientific Reports* on 20 April 2020.

3. Pautet, P.-D., M. J. Taylor, D. C. Fritts, D. Janches, N. Kaifler, **A. Dörnbrack**, and J. L. Hormaechea, 2020: Mesospheric Mountain Wave Activity in the Lee of the Southern Andes, *J. Geophys. Res*. Submitted 9 June 2020