REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: GERMANY

This form needs to be submitted via the relevant National Meteorological Service.

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Project Title: Deep Vertical Propagation of Internal Gravity Waves

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** DEHALO	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☒

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	500 000	500 000	500 000
Accumulated data storage (total archive volume)[2]	(GB)	80	80	80

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): 30 June 2017

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

[2] 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.

Principal Investigator: Dr. Andreas Dörnbrack

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Extended abstract

During the recent years, ground-based and airborne Rayleigh lidar measurements of temperature perturbations in the middle atmosphere show gravity wave activity covering a large spectrum of frequencies and vertical and horizontal wavelengths. An understanding of the different wave modes in the middle atmosphere 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 are missing. Therefore, the integrated forecast system (IFS) of the ECMWF will serve to fill this gap by providing these data globally. One example of the feasibility to simulate stratospheric gravity waves is documented in Dörnbrack et al. (2017). Idealized numerical simulations will complement the combined analysis of data and IFS output. Thus, the project is based on three ingredients.

(1) Middle Atmospheric Temperature Observations

During the Deep Propagating Gravity Wave Experiment (DEEPWAVE) 2014 as well as during two extensive campaigns in Scandinavia in 2013 and 2015/16, ground-based as well as airborne lidar measurements were conducted (Fritts et al., 2016, Kaifler et al. 2016, Ehard et al., 2017, Portele et al., 2017, Bramberger et al., 2017, Wagner et al., 2017, Witschas et al., 2017).

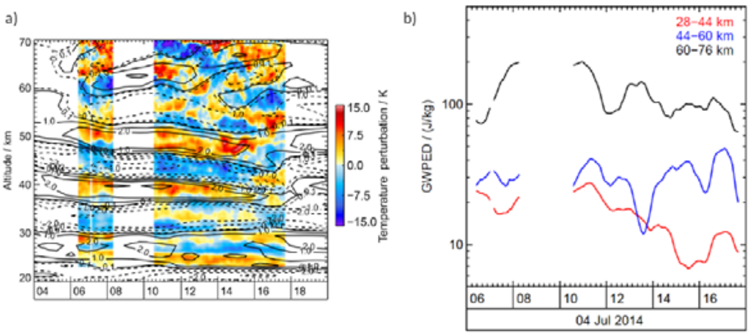

Figure 9. a) Temperature fluctuations based on measurements of the DLR Rayleigh lidar in Lauder. Horizontal axis is the time axis, vertical axis gives the altitude and the color coding refers to temperature fluctuations. Black contours show temperature fluctions based on ECMWF IFS simulations. b) GWPED for stratosphere, stratopause and mesosphere derived from Lidar measurements in Lauder. The horizontal axis is the time axis and the vertical axis denotes GWPED in a logarithmic scale.

Figure 1: Example of middle atmosphere lidar observations of mountain waves excited by strong flow over the Southern Alps of New Zealand (from Bramberger et al., 2017).

Figure 1 shows a selected example from the paper by Bramberger et al. (2017) documenting the close agreement of the observed phase lines and the results of the IFS for one particular event. It also shows the large temporal variability of the gravity wave activity during the 12 hour observational period. However, the striking agreement does not reflect in the amplitudes which are simulated much to low compared to the observations. Besides the understanding of particular cases (quantification of gravity wave parameters such as wavelengths, periods, phase speeds, group velocities, frequency and wavenumber spectra, potential and kinetic energy densities, and momentum fluxes) with the help of IFS data, there is a need to understand the scales, the intermittency, and the seasonal variability of middle atmospheric gravity waves as the associated breaking and momentum deposition drives the meridional residual circulation.

Therefore, our institute will be deploying two autonomous lidar systems at the southern tip of South America to study the deep vertical propagation of a global “gravity wave hot spot” and to understand its overall importance. The observational results will be further compared with mountain wave activities observed in New Zealand and Northern Scandinavia and with data from the IFS. Furthermore, the combination of observations at different geographical locations together with process modelling (EULAG, point 3) will allow for a better understanding of the importance of “hot spots”.

(2) Integrated Forecast System

Middle atmospheric lidar temperature observations conducted during December 2015 above Finland were compared to two sets of simulations by the IFS. One of the simulations is the operational cycle 41r1 with a horizontal resolution of 16 km and the other is the e-Suite 69 (later cycle 41r2) with a 9 km horizontal resolution. A remarkable agreement between both ECMWF IFS simulations and the lidar temperature observations is found below 45 km altitude. Above 45 km altitude, within the sponge layer of the ECMWF IFS, both simulations depict lower temperatures than the observations, with the high-resolved ECMWF IFS version showing the largest cold bias. Test runs of the ECMWF IFS were analysed and compared to the lidar observations to investigate the effect of the high-resolution horizontal grid. This work is documented in the paper by Ehard et al. (2017). In collaboration with the numerical aspect section (contacts: Nils Wedi and Sylvie Malardel), the collaboration (exchange of data and information as well as IFS test runs) will be continued focussing on the height region above the stratopause.

(3) EULAG

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. As a first case, we consider the flow above Auckland Island (Eckermann et al. 2016). For this purpose, the anelastic version of EULAG was run and initial profiles were constructed from ECMWF IFS operational analyses and one hourly forecasts extended to an altitude of 100 km.

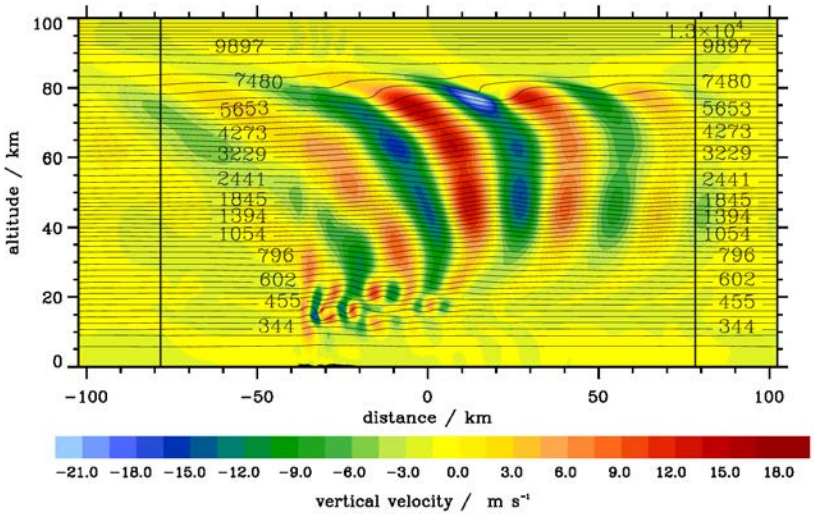

Figure 2: Vertical velocity (m s^{-1}, color coded) and potential temperature (K, black lines) for the flow over Auckland Islands (located at -40 to -30 km distance). .

Figure 2 exemplifies a preliminary result proving the ability of EULAG to simulate the deep atmospheric response of the flow across a small obstacle as the Auckland Islands. 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 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.

The computer hours will mainly be spent for numerical simulations with the geophysical flow solver EULAG. First 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.

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