REQUEST FOR A SPECIAL PROJECT 2013–2015

MEMBER STATE: GERMANY

Principal Investigator[1]: Dr. Andreas Dörnbrack

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Other researchers:

Dr. Christian Kühnlein
Dr. Piotr K. Smolarkiewicz

Project Title:

Source **S**pectra for **C**onvectively Generated Gravity Waves – **A**daptive **N**umerical Simulations

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** DESCAN	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2012	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☒

Computer resources required for 2013-2015: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2014.)	**2013**	**2014**	**2015**
High Performance Computing Facility (units)	200000	200000	200000
Data storage capacity (total archive volume) (gigabytes)	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 April 2012

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 an annual progress report of the project's activities, etc.

Principal Investigator: Dr. Andreas Dörnbrack

Project Title: Source Spectra for Convectively Generated Gravity Waves – Adaptive Numerical Simulations

Extended abstract

Source Spectra for Convectively Generated Gravity Waves Adaptive Numerical Simulations

There is an intimate relationship between convective activity and gravity waves. As evident from air- and space-borne observations, numerical simulations, and theoretical considerations, convective thermals excite gravity waves in the overlaying stably stratified atmosphere and in regions of subsidence between individual updrafts. Due to the broad variety of spatial and temporal scales, convection is one of the most important but highly uncertain tropospheric sources of gravity waves propagating into the middle atmosphere (Fritts and Alexander, 2003, Hoffmann and Alexander, 2010).

In our work, we focus on the generation of gravity waves in the upper troposphere and lower stratosphere by mesoscale convective systems or cloud clusters. High resolution numerical simulations with solution adaptive moving meshes[2] are applied to estimate their propagation characteristics in terms of wavelengths, frequencies, amplitudes, and phase speeds. This work differs from previous studies which simulated gravity wave generation for individual convective thermals (e.g. Bretherton and Smolarkiewicz, 1989). It is hypothesized that cloud clusters are able to produce a spectrum that covers a broad range of frequencies and phase speeds. Knowledge of the phase speed distribution is particularly important because, according to Eliassen and Palm's (1961) first theorem, when waves are dissipated in a mean flow, they tend to accelerate (or decelerate) the latter toward the phase speed of the waves.

Specification of gravity waves from non-stationary sources as propagating mesoscale convective systems is even more complex than from stationary sources as orography. Especially, for a better representation of gravity wave drag in global circulation models it is necessary to know this spectrum in relation to the excitation processes and to develop gravity wave source spectrum parameterizations that are physically based.

Since 2005, the main numerical tool of our research has been the all-scale geophysical fluid solver EULAG (Prusa et al., 2008 and references therein). This advanced non-hydrostatic anelastic model has been applied for a broad range of atmospheric processes. Recently, EULAG was extended by allowing for time-dependent ambient states. This new method allows prescribing time-dependent, slowly varying large-scale processes in a small and high-resolution model domain to investigate the impact of transient processes on smaller scales. If necessary, we will apply also this methodology for the proposed project. During the recent three years, I supervised the PhD thesis of C. Kühnlein "Solution-adaptive moving mesh solver for geophysical flows" (2011) which introduces new numerical schemes into EULAG, which allow for local grid refinement in regions of interest.

Specific tasks of our project are:

[2] The possibility to use solution adaptive moving meshes in the numerical model EULAG was created by the recently finalized and defended dissertation of Christian Kühnlein and published in Kühnlein et al. (2012).

- three-dimensional cloud resolving model simulations of radiative–convective equilibrium of an idealized ensemble of noninteracting, pointlike cumulus clouds; simulations with different radiative cooling rates are used to give a range of cloud densities, while imposed vertical wind shear of different strengths is used to produce different degrees of convective organization; this work is based on the numerical simulations by Cohen and Craig (2006a, b) and will be extended by higher model top height and larger spatial resolution,

- comparison with the numerical simulations of Cohen and Craig (2006b); detailed analysis of the gravity wave properties in the numerical simulation results,

- extension of the setup to non-stationary, propagating cloud systems by applying the possibility of prescribing transient environmental states in the equations solved in EULAG.

References

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Cohen, B. G. and G. C. Craig, 2006a: Fluctuations in an equilibrium convective ensemble. Part I: Theoretical formulation. *J. Atmos. Sci*., **63**, 1996–2004.

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Eliassen, A., and E. Palm, 1961: On the transfer of energy in stationary mountain waves, *Geofys. Publ.*, **22**, 1-23 .

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