SPECIAL PROJECT PROGRESS REPORT

Reporting year	2017/2018
Project Title:	Upscale impact of diabatic processes from convective to near-hemispheric scale
Computer Project Account:	spdecrai
Principal Investigator(s):	George Craig
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Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	2016
Expected end date:	2018

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)	2.5M	2.44M	2.5M	0.71M
Data storage capacity	(Gbytes)	500GB	379GB	500GB	381GB

Summary of project objectives

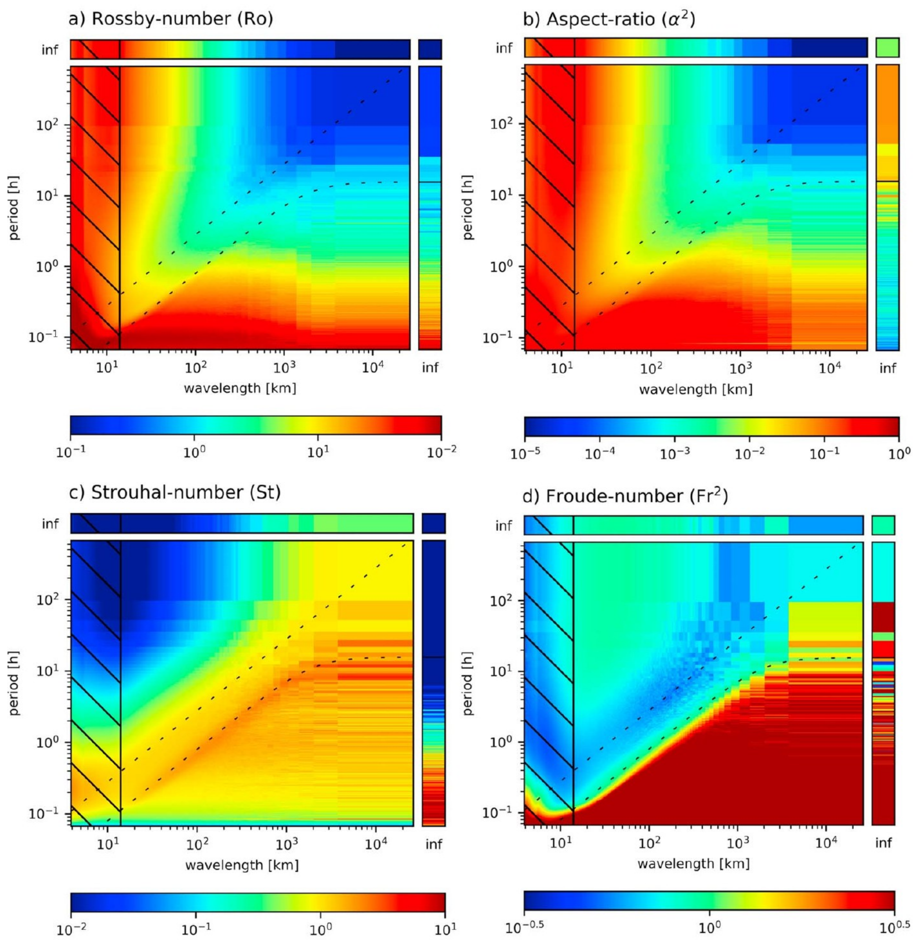
In this project we will investigate the process of upscale propagation of uncertainty in the atmosphere over three orders of magnitude in spatial scale, from convective clouds to hemispheric waves. This will be possible by recent developments in numerical atmospheric modeling (ICON) and stochastic parameterization (Plant-Craig). The non-hydrostatic ICON model allows for local grid refinements while the Plant-Craig convection scheme is able to emulate convective uncertainty at non-convective permitting resolutions. These two tools will form the basis for a series of error growth experiments to address open questions about basic characteristics, mechanisms and the practical importance of upscale error growth in mid-range global weather prediction. In addition we will investigate the presence and definition of meteorological regimes in space and time that define or modify error growth properties.

Summary of problems encountered (if any)

No serious problems encountered.

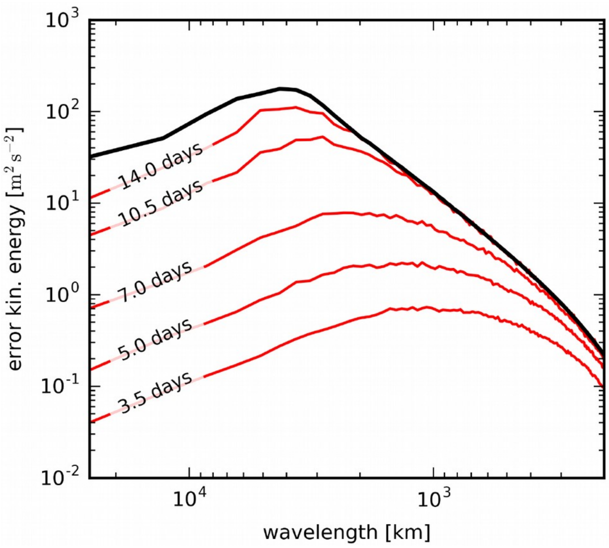
Summary of results of the current year (from July of previous year to June of current year)

A part of the computing time in 2017 (about 750,000 SBUs) was used for a convection-permitting limited area model simulation on a large domain that covers several time the Rossby radius of deformation. A summer time case in 2016 with high convective activity over central Europe was simulated. Simulation time was seven days and a very high output frequency (2 minutes) was used to enable a Fourier transformation in time as well as in space. With this setup dynamical regimes on the mesoscale have been investigated by evaluating the space-time dependence of non-dimensional numbers like Rossby-, Froude- or Strouhal number. The non-dimensional numbers are defined by fractions of the magnitudes of certain terms in the equations of motion and the thermodynamic equation. The results have been published in Craig and Selz, 2018.



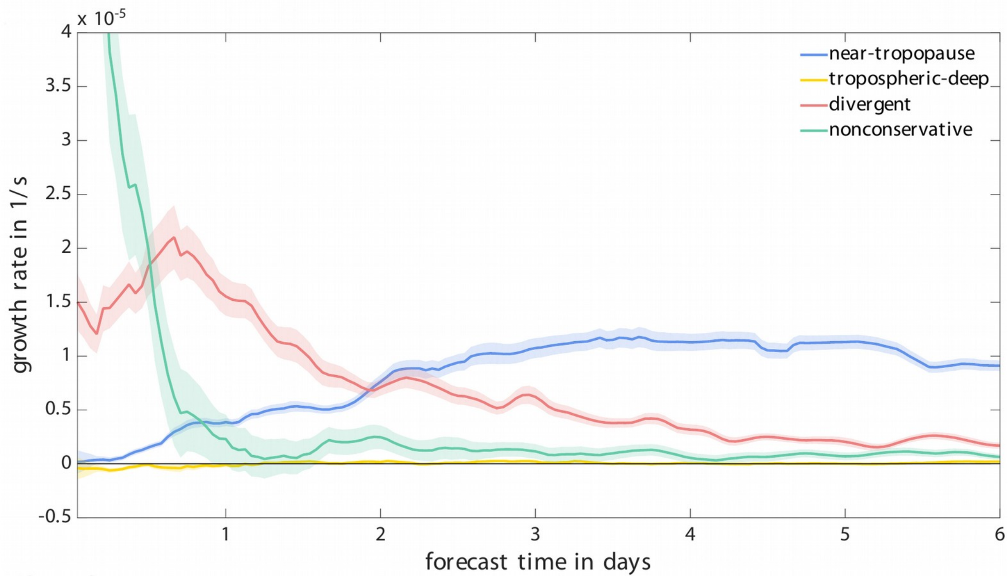
The figure above shows the space-time dependence of four selected non-dimensional numbers. As expected, the Rossby number (Ro) is small for spatial scales larger than about 1000 km and temporal scales larger than about a day. The Strouhal number (St) shows two basic regimes that are oriented along the diagonal: One regime of very low St in the upper left corner and one regime of a maximum in St along the dispersion relation of gravity waves (the lower dashed line). The first regime implies that the Eulerian temporal change of potential temperature is negligible against advection, which is an indication of stationary gravity waves excited by slowly varying large-scale winds over orography. In the second regime on the other hand the Eulerian change dominates advection, which is a property of propagating gravity waves, exited by deep convection. The Froude number (Fr) shows neutral values in both of these regimes but indicates a minimum just above the gravity waves dispersion relation. A low Froude number indicates a small Lagrangian change of the potential temperature compared to the vertical advection of the background stratification. It thus indicates the accuracy of the weak temperature gradient approximation. This approximation has been widely used to analyze tropical convection but the results above suggest that is has some validity in the midlatitudes as well, although it is not as good as e.g. the geostrophic (small Rossby number) approximation on large scales.

The major part of the computing time of the past year has been used to extend and complete global ensemble simulations using the ICON model from DWD and the stochastic convection scheme of Plant and Craig (PC). 12 cases, distributed over one year, each with five ensemble members have been simulated. Goal of these experiments is the estimation of intrinsic limits of predictability that arise from the convection. The main idea is to use the stochastic convection scheme and a cheaper lower spatial resolution instead of a convection-permitting resolution to simulate the convection and its variability. The quantitative results are summarized in Selz, 2018, which is currently under revision.



The figure above shows the error growth in the midlatitudes of the PC-ensemble, averaged over all cases and all members. The red lines show spectra of the error kinetic energy at several forecast lead times. The black line shows the background spectrum. A comparison of these errors to the ECMWF forecasting system has been performed to estimate the potential improvement of current forecasting systems until the intrinsic limit is hit: The 3.5-day error of the PC-ensemble compares to the current ECMWF initial condition uncertainty. The 14-day error of the PC-ensemble compares roughly to the errors of an eight day ECMWF forecast. The additional gap of 2.5 days might be related to the model error. In addition to the PC ensemble, an ensemble using the operational deterministic Tiedtke-Bechthold scheme has also been performed for comparison.

A more qualitative, process-oriented investigation of the PC data set is currently in preparation together with our colleagues from the University of Mainz. This work aims to investigate and distinguish the physical processes that drive the error growth (Baumgart et al., 2018). Here, the spatially integrated error enstrophy is considered and is split into different contributions using PV inversion techniques. The figure below shows the development of these contributions during the first five days: Initially the divergent contribution dominates which indicates that the error growth is mainly driven by convection. After about two days the tropopaus-near (barotropic) contribution becomes most important, indicating that the error growth is now mostly large-scale driven.



Data from the Mars archive (the ERA5-reanalysis) has been used by Selz et al., 2018 to evaluate the Potential Vorticity anomaly over Germany.

List of publications/reports from the project with complete references

Baumgart, M., P. Ghinassi, M. Riemer, V. Wirth, T. Selz and G. C. Craig, 2018: Processes governing the upscale error growth. *In preparation.*

Craig, G. C., and T. Selz, 2018: Mesoscale Dynamical Regimes in the Midlatitudes. *Geophys. Res. Lett.*, **45 (1)**, 410-417.

Selz, T., 2018: Estimating the intrinsic limit of predictability using a stochastic convection scheme. *J. Atmos. Sci.*, under review.

Selz, T., L. Bierdel, and G. C. Craig, 2018: Estimation of the variability of mesoscale energy spectra with three years of COSMO-DE analyses. *J. Atmos. Sci.*, under review.

Summary of plans for the continuation of the project

With the completion of the Plant-Craig ensemble the main goals of the current spatial project have been achieved. The remaining computing time will be used for interesting case studies preferably in the context of the North Atlantic Waveguide and Downstream Impact Experiment (NAWDEX) field campaign.