SPECIAL PROJECT PROGRESS REPORT

Reporting year	2015
Project Title:	Upscale transport of uncertainty
Computer Project Account:	SP DEADEN
Principal Investigator(s):	Prof. George Craig
Affiliation:	Meteorologisches Institut Ludwig-Maximilians-Universität Theresienstrasse 37 80333 München
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	2011
Expected end date:	2016

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)	400.000	370.540	400.000	188.321
Data storage capacity	(Gbytes)	2 TB	1.66 TB	2 TB	1.67 TB

Summary of project objectives

The purpose of the part of the project that has been conducted in the current period is to create a link between analytic results predicting the time and length scales of upscale error growth with simulations of a real-time weather event on a large domain over Europe (Selz and Craig, 2015). The main focus is to understand the physical process that sets the time- and length scales of upscale error growth on the mesoscales. The hypothesis is that gravity waves are being generated on small scales in the difference field, propagate upscale and ultimately adjust on a length scale that is of the order of the Rossby radius of deformation. If the hypothesis is correct, diagnostics evaluating upscale error growth and determining time- and length scales employed by Selz and Craig (2015) (such as diDTE, Ro) should depend on the Coriolis parameter f.

Summary of problems encountered (if any)

No problems.

Summary of results of the current year

To test the hypothesis, that the only parameter determining the time- and length scales of upscale error growth on the mesoscales is the Coriolis parameter f, high-resolution idealized simulations of a convective cloud field were performed for three different f values (f0=1.03126 10^(-4) 1/s, f1= 1.5*f0, f2=2*f0) with the COSMO 5.0 model using ECMWF computing resources. The COSMO 5.0 model was used in idealized mode with an initial sounding with high CAPE (Payerne radio sounding of a convective day). The soil temperature was increased by 3K and kept constant throughout the simulation. For a large scale cooling of the atmosphere, the COSMO radiation scheme was used (note that the sun was switched off for simplicity). Three control simulations (CTRL) were run for 110 hours. After a spin-up time of 50h, in each of the CTRL simulations the simulated 3D temperature field was perturbed with an uncorrelated grid scale noise with zero mean and a variance of 0.01 K (perturbation run, PERT). For comparability with the real-case simulations of Selz and Craig (2015), all 6 runs were performed on a large domain of 4500 x 4500 km. The diagnostics employed by Selz and Craig (2015), such as the domain integrated difference total energy (diDTE) and the Rossbynumber (RO), were computed for the difference fields (CTRL-PERT) resulting from the idealized simulations and compared for the three different f-values.

The horizontal wind field at the tropopause level is displayed in Figure 1 for the CTRL f0 run for 52 hours as an example. Note that the forced simulations of a convective cloud field in a rotating atmosphere are not approaching an equilibrium, but rather organize in intensifying cyclones that are separated by a length scale of the order of the Rossby radius of deformation. Nevertheless, the evaluated time-span of 50-110h has been carefully chosen such that the background flow can be considered as stationary.

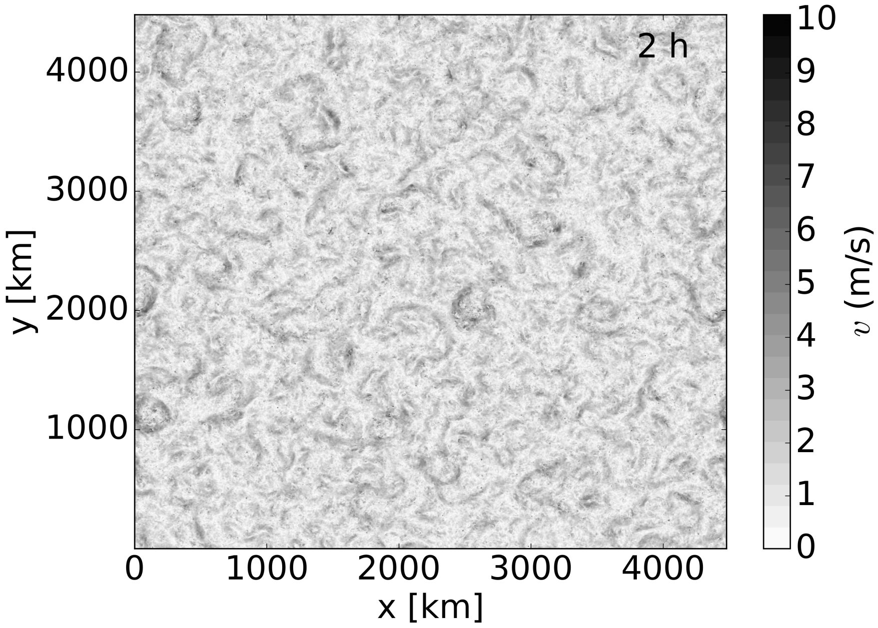

Figure 1: *Absolute value of the horizontal wind at z=10 km for the CTRL simulation with f0 at 52 hours simulation time*

In Figure 2, the diDTE (as defined in Selz and Craig, 2015) is displayed for the f0, f1 and f2 runs for the 60 h of perturbation lead-time. The S-, M- and L- scales are scaled with the respective f-values and cover the ranges S: [0-200km], M: [200-1000], L:[>1000km] for f0.

Selz and Craig (2015) suggested the following functional fit for the diDTE as a function of time:

$$diDTE(t) = d0 * exp\left(\frac{r}{s}[1 - exp(-st)]\right) exp\,(gt)$$

If the working hypothesis, that the time-and length scales of the second stage of upscale error growth on the mesoscales are set by the geostrophic adjustment process, is correct, then the inverse of the s-parameter (the ‘adjustment time scale’) of the M-scales is expected to scale linearly with f.

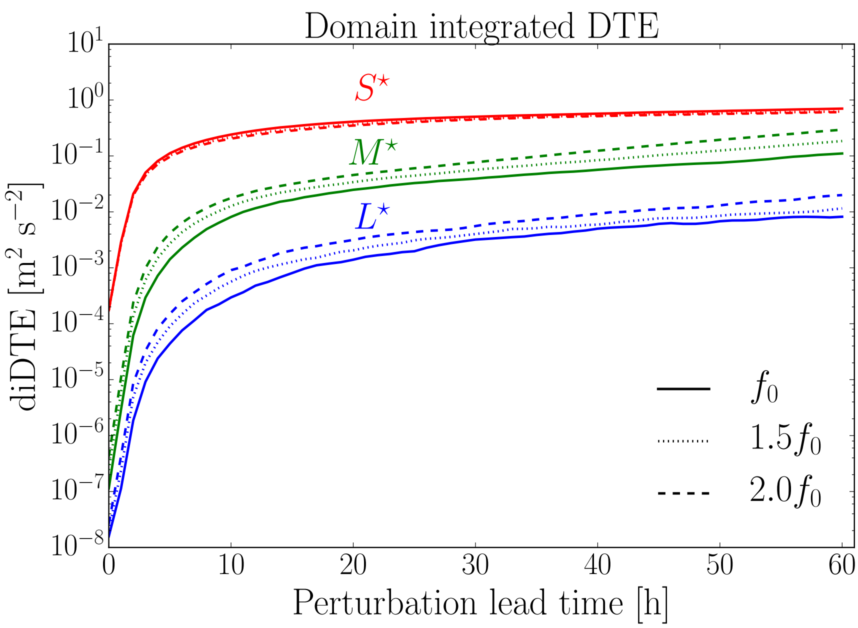

Figure 2*: diDTE for the 60 h of perturbation lead-time and the S, M, L scales for the f0, f1 and f2 runs*

The following values were found for s-parameter of the functional fit of the diDTE of the M-scales:

	f0	f1	f2
1/s	2.9 +/- 0.06	2.64 +/- 0.05	2.49 +/- 0.04

The inverse s-parameter is plotted for the three f-values in Figure 3. Thus, the inverse s-parameter scales linearly with f, which supports our hypothesis.

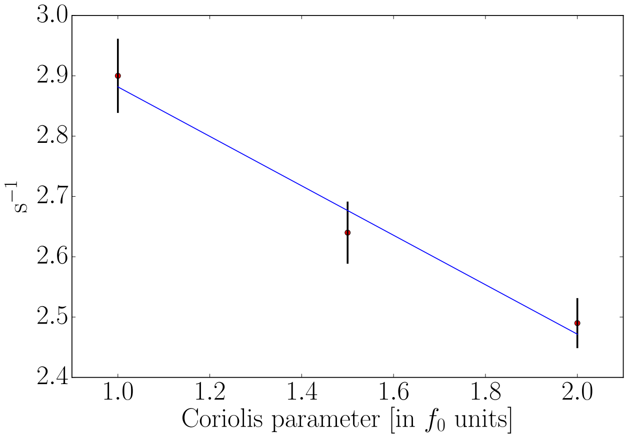

***Figure 3**: Inverse s-parameter for the three f-values*

Another diagnostic employed by Selz and Craig (2015) is the Rossbynumber, which is the ratio between a vorticity and divergence norm and thus describes the amount to which the perturbations are (geostrophically) balanced. A Rossbynumber below unity indicates that rotation dominates over divergence and in Selz and Craig (2015) it was found that the Rossbynumber of the medium scales drops below one earlier than the Rossbynumber of the large scales. The Rossbynumber in the idealized simulations of the scaled medium ranges is shown in Figure 4 for the three f values. It can be seen, that the drop of the Rossbynumber below one, i.e. the time after the first balanced motions appear in the difference fields of the convective cloud field, depends linearly on f. This further supports our hypothesis that the timescale of upscale error growth on the mesoscales is set by the geostrophic adjustment process.

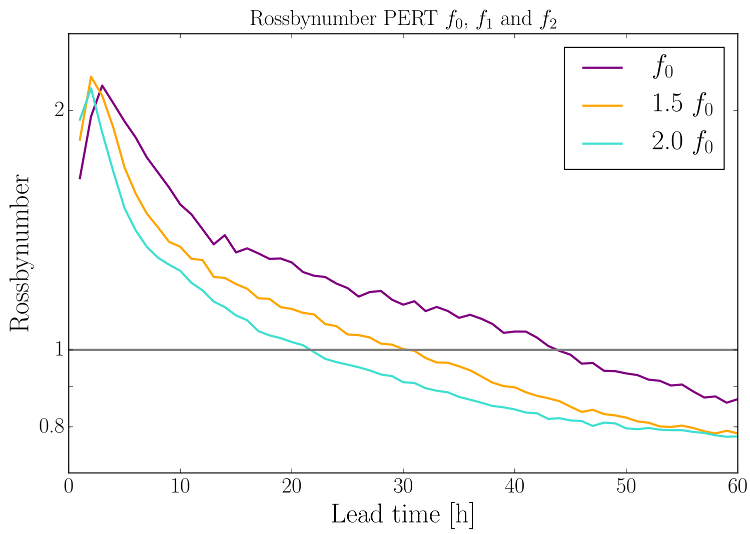

***Figure 4:** Rossbynumber of the scaled medium scales as a function of perturbation lead-time*

A publication of this study is currently in preparation and was presented in the Waves2Weather Research Area A meeting in May in Munich.

June 2016

List of publications/reports from the project with complete references

Rasp, S., T. Selz, and G. C. Craig, 2016: Convective and slantwise trajectory ascent in convection-permitting simulations of mid-latitude cyclones. Journal of the Atmos. Sciences, under review.

Selz, T. and G. C. Craig (2015): Upscale error growth in a high-resolution simulation of a summertime weather event over Europe, Mon. Weather Rev., 143, 813-827

Summary of plans for the continuation of the project

The remaining computing resources will be used to do a fourth simulation with another f value.