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Teaching with OpenIFS at Stockholm University: leading the learning experience

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Teaching with OpenIFS at Stockholm University: leading the learning experience

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The OpenIFS project (http://www.ecmwf.int/research/openIFS.html) at ECMWF started in December 2011. It provides for research and teaching at academic institutions an easy-to-use version of the model that is part of the operational IFS (Integrated Forecasting System). The OpenIFS model is based on IFS cycle Cy38r1and includes all of the forecast capability but without the data assimilation: the documentation of this cycle is at:

- http://www.ecmwf.int/research/ifsdocs/CY38r1/index.html.

Figure 1 shows the Arrhenius Laboratory hosting the Department of Meteorology, Stockholm University (MISU). In 1947 Carl-Gustaf Rossby arrived back in Sweden from the USA to strengthen research at the newly created MISU. Since then MISU has grown to become an international research environment with professors such as Bert Bolin, which continues to have a world-wide impact. Today MISU has an extensive research programme and offers undergraduate, Master's and PhD degrees. The OpenIFS initiative provides the opportunity for our students to get to know and 'familiarise' themselves with operational NWP models. The OpenIFS model was run for the first time outside ECMWF by our MSc students in November 2012 within the framework of our numerical weather prediction (NWP) course. The students' task was to simulate the Lothar storm that hit parts of Europe in December 1999. We undertook the adventure of running the OpenIFS on the high performance computer (HPC) Triolith, owned and operated by the Swedish National Supercomputer Center (NSC) at Linköping University campus, about 150 km south of Stockholm.

To complement the theoretical part of the NWP module the students were given small projects using OpenIFS, which allowed them to put into practice some of what they have learned in the lectures. The various experiments performed by the students are described and the future outlook is discussed in the following sections.

Figure 1 Department of Meteorology, Arrhenius Laboratory, Stockholm University (MISU), http://www.misu.su.se/

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Experiments

The topic of the projects for this year was to investigate the Lothar storm that swept across Europe during 24–26 December, 1999, and severely affected northern France, Switzerland and Germany (*Ulbrich et al.*, 2001). The main reason for selecting this storm is its severity and, most importantly, the fact that it was not well captured by the ECMWF forecasting system at the time. The students were asked to change some model parameters, run the model and then compare the forecasts. All forecasts in this experiment start at 12 UTC on 24 December and are run for five days. The model outputs are saved every six hours.

In principle, all model parameters such as those pertaining to the numerical scheme (e.g. time step and resolution), or physical parametrization (e.g. surface roughness or asymptotic mixing length) could be tweaked. In this particular project the students changed only four parameters, namely the horizontal resolution, gravity wave drag, surface momentum transfer and rain autoconversion rate. The students performed two runs for each parameter, with and without a change, and analyzed the resulting differences in the forecasts.

Discussion of the model runs

The first parameter the students changed was the spectral resolution. Two model runs were performed with the resolutions T511 (approx. 40 km) and T255 (approx. 80 km), both with 60 model levels.

Figure 2 shows the four-day forecast of mean-sea-level pressure (MSLP) and the 10-metre wind for 12 UTC on 28 December. There is a clear enhancement of the low pressure system over Switzerland and Germany with winds reaching 14–20 ms^{-1} at T511 but not at T255. The jet over the Atlantic west of Ireland is also significantly enhanced at the higher resolution as is the one to the east of Iceland. The values of the wind speed remain, however, significantly lower than those observed. *Wedi et al.* (2012) show how ultra-high horizontal resolution (T7999 ~2.5 km) is necessary to more accurately model the extraordinarily high wind speeds observed, particularly over mountainous regions of Europe.

The impact of changing the gravity wave drag was investigated by doubling and halving a parameter that determines its magnitude. The largest effect was obviously obtained when the gravity wave drag was doubled. Figure 3 shows an example of the difference in MSLP, gravity wave stress and instantaneous zonal surface stress between the doubled and the control forecast experiments. The gravity wave stress is larger where expected – over the mountains. A modest increase in MSLP is also obtained over northeastern France and parts of Germany in agreement with the expected change due to the increased gravity wave drag. Perhaps the most interesting feature, and somewhat unexpected, is the rather large area with MSLP changes west of Norway, since this is not located downstream from major topography. It might not have had an impact on Lothar, but it is as large as anywhere else and illustrates the complex and chaotic behaviour of the atmosphere, where a local change can have remote effects.

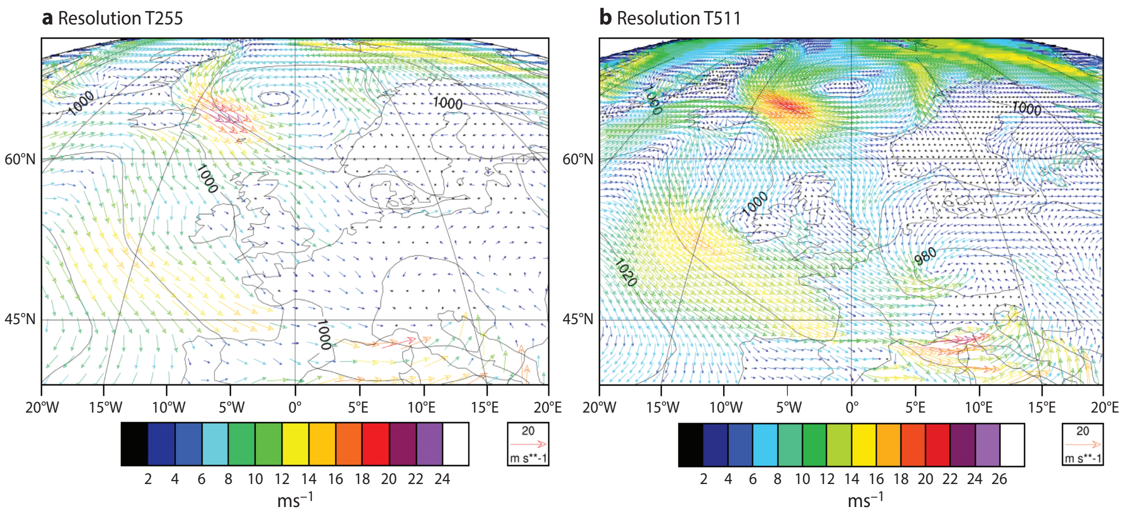

Figure 2 Four-day forecast of mean-sea-level pressure (contours) and 10-metre wind for 12 UTC on 28 December for (a) T255 and (b) T511. Contour interval 10 hPa. Figures supplied by Sara Broomé, Kristoffer Molarin and Nina Svensson (the MSc students).

Another physical parameter of importance in the dissipation of weather systems is the surface drag which is responsible for the momentum transfer from the atmosphere to the surface. This is dependent on the surface momentum transfer coefficient which in turn is a function of the surface roughness and static stability. In this experiment the transfer coefficient was reduced by 20% and results compared with the control simulation. Figure 4 shows an example of the difference, in MSLP and instantaneous zonal surface stress, between the reduced surface momentum transfer experiment and the control (original) forecasts for 06 UTC on 28 December.

A large effect of changing the surface stress is found over western France where a large increase of MSLP (7–9 hPa) is observed, with widespread changes in MSLP across most of Europe and the northern North Atlantic. However, there is some indication of a pressure decrease over some parts of southern and eastern Europe that could be an indication of an eastward shift of the low pressure system.

The students examined the effect of the rain conversion rate parameter on the low pressure system by doubling and halving the original value of the rain autoconversion rate coefficient. No noticeable change is obtained, however, in the forecasts between the two experiments.

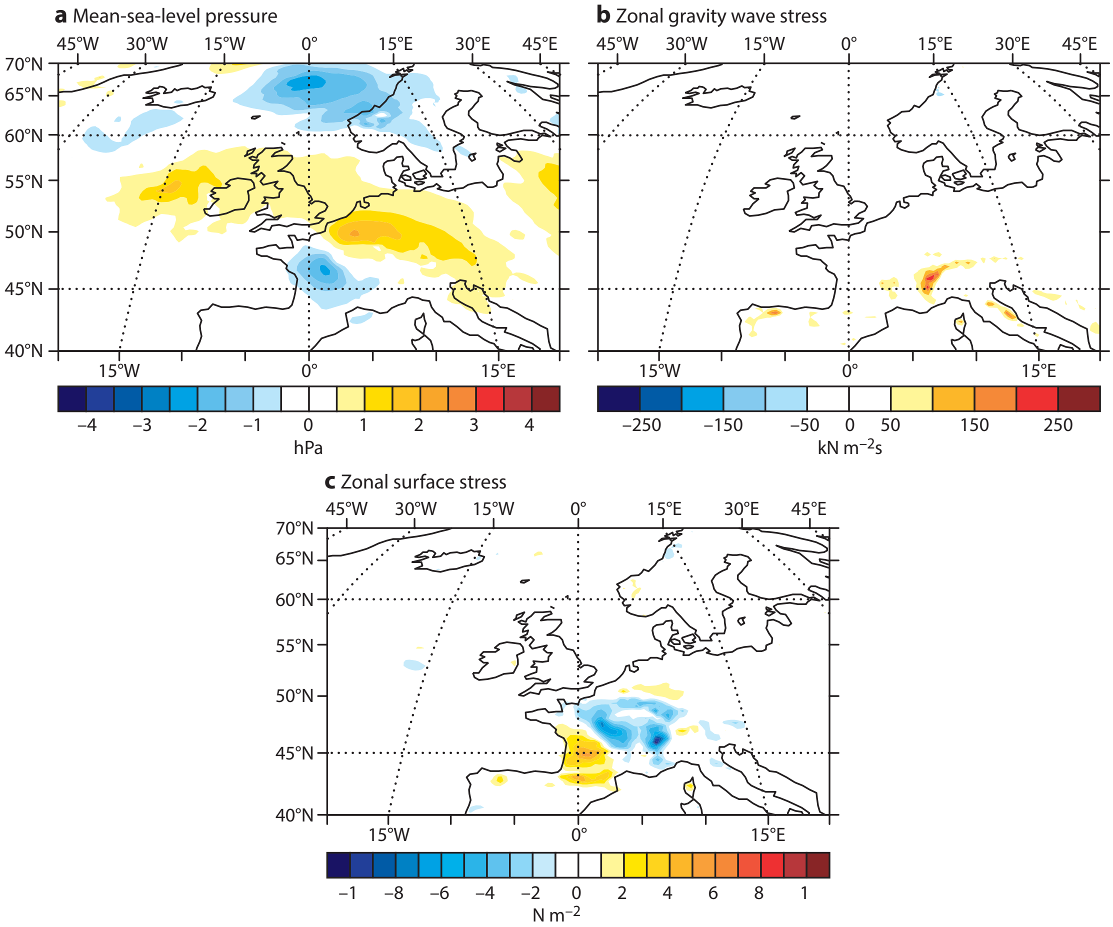

Figure 3 Difference in (a) mean-sea-level pressure, (b) zonal gravity wave stress and (c) instantaneous zonal surface stress between the 66-hour forecasts with a doubling of the gravity wave drag and the control at 06 UTC on 27 December.

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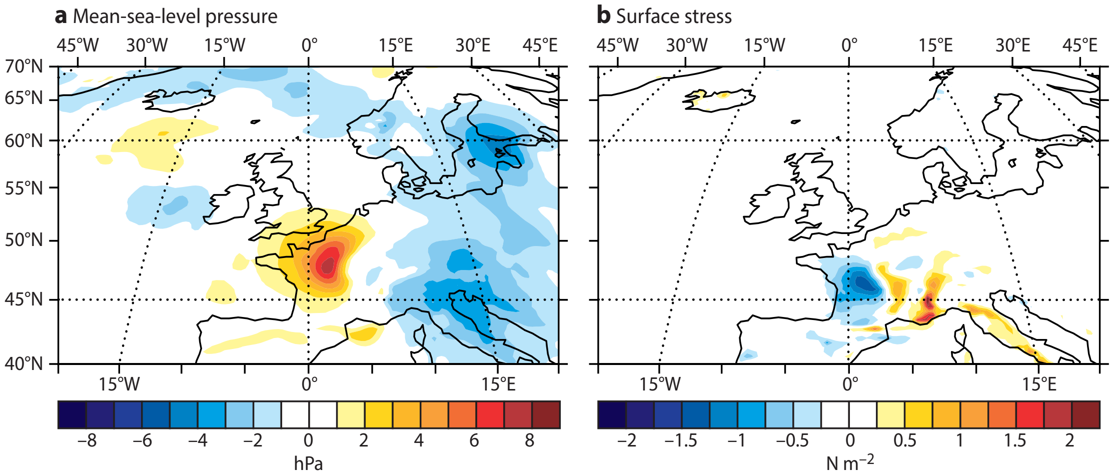

Figure 4 Difference in (a) mean-sea-level pressure and (b) surface stress between the 66-hour forecasts obtained with a reduced surface momentum transfer and the control at 06 UTC on 27 December.

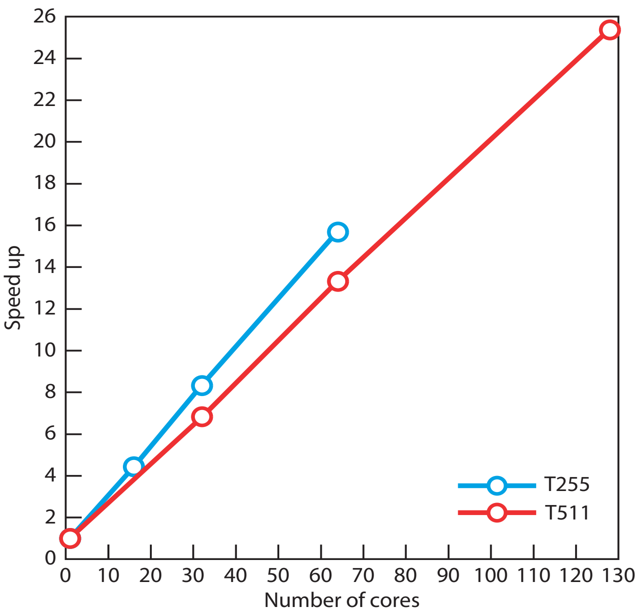

Figure 5 Speedup curves for the five-day forecasts for T255 and T511 with increasing cores on the Triolith cluster.

OpenIFS technical aspects

A rapid turnaround in generating results is key to successful use of OpenIFS for teaching. For these experiments, the students installed and ran OpenIFS on the Triolith cluster at the National Supercomputer Centre (NSC), the largest supercomputer in Sweden consisting of 1200 compute nodes. Each node has two 8-core Intel SandyBridge processors, giving a total of 19,200 cores with a theoretical compute capacity of 338 TFlops placing it 83rd on the Top500 list (November 2012). We used the gfortran compiler suite with OpenMPI and the model was run in mixed MPI/OpenMP mode. At T255, a 5 day forecast on 16 cores took 25 minutes; T511 took 100 minutes on 32 cores. Figure 5 shows how the model scaled as the number of cores was increased.

Summary and outlook

Running the OpenIFS on our platform was a learning experience for both the students and the supervisors. The students, in particular, learned a great deal about weather forecast models. They commented: “It was a great experience to work with the real thing”. The simulations did not give a good indication of the timing or location of the storm, as the resolutions used in these runs were too low to capture the event accurately. It is hoped that in the future we will be able to run the model with its operational resolution (T1279L60).

Improving the model runs on Triolith is still in progress and some more work will be needed. In particular, it would be very useful to be able to change the initial conditions and choose different storms. One of our future objectives is to use ERA reanalyses to enable evaluation of the forecasts.

As well as teaching, another important objective for the future is to promote the use of OpenIFS as a research tool. Having easy access to a modern global NWP model provides an opportunity for researchers to, for example, use it as a test bench for process-related research, something that could feedback on model development at ECMWF. Using it first for a MSc course provided the leverage to get the infrastructure in place, and hopefully researchers will now take advantage of this.

These results are indicative of the good collaboration between ECMWF and MISU in establishing the first use of OpenIFS.

Further reading

Wedi, N.P., M. Hamrud, G. Mozdzynski, G. Austad, S. Curic & **J. Bidlot,** 2012, Global, non-hydrostatic, convection-permitting, medium-range forecasts: progress and challenges. *ECMWF Newsletter* **No. 133.** 17–22,
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