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PUBLICATION POLICY

The *ECMWF Newsletter* is published quarterly. Its purpose is to make users of ECMWF products, collaborators with ECMWF and the wider meteorological community aware of new developments at ECMWF and the use that can be made of ECMWF products. Most articles are prepared by staff at ECMWF, but articles are also welcome from people working elsewhere, especially those from Member States and Co-operating States. The *ECMWF Newsletter* is not peer-reviewed.

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Quality management certification

In January this year, ECMWF's Quality Management System (QMS) was officially certified, which accredits its compliancy with the ISO 9001:2008 standard. This is without any doubt an important achievement. However the comment that will come to mind of many readers is: "why wasn't it done earlier?". Let's consider this and show why it was done now and why it is still important.

Quality management has developed over the last decade in the meteorological world. This was clearly a consequence of the development of services for more and more customers, resulting in the need to ensure user satisfaction. In addition, in some cases these customers required that their providers' QMS be certified. There were debates within WMO over whether meteorology should adopt ISO standard or develop its own. It quickly became clear that developing a specific standard was not an option. But it also became clear that developing QMS in the meteorological world was not easy. Whether this was due to meteorological specificities or to the standards themselves is debatable. But the result was that in most cases the adoption of these QMS introduced important overheads and proved a costly business.

ECMWF remained out of this mainstream for two main reasons. The first one was that it was felt that the gains of developing a certifiable QMS did not justify the overheads and would not balance the impact on a research organisation such as ECMWF. The second one was simply that ECMWF users did not request it. However this did not prevent ECMWF developing internal quality management processes which were necessary to satisfy our Member States' requirements and to provide the high level of reporting which they request from us. In addition the development of our web services, that included comprehensive and updated descriptions of our processes, also contributed to this development.

The situation regarding certification changed recently. The fist evolution is that our Member States indicated that a QMS certification of ECMWF would help them. The reason is that, as ECMWF is an outsourced process for their own products and services, the QMS of Meteorological Services requests that they ensure control over this process. This control is very simple if ECMWF's QMS itself is certified. The second evolution came with the 2008 version of ISO 9001 which offered an improved framework more relevant for research activities and with reduced overheads.

Our initial assumption was that ECMWF had already developed most of the necessary elements of a certifiable QMS and that the remaining necessary overheads were affordable and would be justified by the expected additional benefits. Our initial evaluations confirmed these assumptions and showed that there would be no negative impact, in particular on our research activity. Rather on the contrary, the focus on continual improvement, which is one of the main components of an ISO 9001:2008 QMS, will help ECMWF maintain the high level of quality of its products and services. The certification process was launched at the end of last year and was successful. This will further facilitate the use of ECMWF data and products by all our users in the Member States and Co-operating States.

Dominique Marbouty

New items on the ECMWF website

ANDY BRADY

Web Re-engineering Project releases ecCharts beta to forecasters

In May 2008, ECMWF began a project (the Web Re-Engineering Project – WREP) to develop a new web-based service for forecasters that would provide (compared to the existing website forecast products) both enhanced functionality (tailored products and interactivity), increased reliability and standards-based access using web map services (WMS). In December 2010 the first beta test release of ecCharts was provided for forecasters. See the news item starting on page 7 for more details.

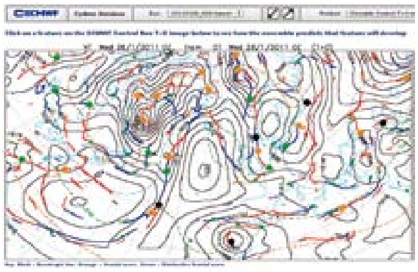
- http://www.ecmwf.int/eccharts/

Historical Annual Reports

ECMWF's Annual Report provides an overview and a broad, non-technical description of the Centre's main activities. It also gives an indication of future plans of ECMWF. The current annual report is for 2009. A new addition in this area, from our document archives, are the annual reports from 1976 to 1991.

- http://www.ecmwf.int/publications/annual_report/1976-1991/

Extra-tropical cyclones



Web-based products have been made available that aim to represent, objectively, the location and behaviour of near-surface synoptic-scale features in the ensemble and deterministic forecasts in a variety of ways. The features represented are those typically associated with adverse weather (warm/cold fronts shown as lines and cyclonic features shown as spots consisting of barotropic lows, frontal waves and diminutive waves).

- http://www.ecmwf.int/products/forecasts/cdb/

New Director-General of ECMWF from July 2011

MANFRED KLÖPPEL

At its 74th session on 7-8 December 2010, the ECMWF Council unanimously appointed Professor Alan Thorpe as the next Director-General of ECMWF. He will start from 1 July 2011 and he will succeed Mr Dominique Marbouty, ECMWF Director-General since 2004.

Since 2005, Professor Alan Thorpe has been the Chief Executive of the UK's Natural Environment Research Council (NERC), which is the largest funder of environmental science research in the UK universities and institutes. NERC employs around 2,700 people and operates research aircraft, ships and facilities like supercomputing and Antarctic bases. Prior to that Alan had a period as Director of the Hadley Centre for Climate Prediction and Research and a long career as an academic at the University of Reading. His research has been on the dynamics and predictability of organised convective storms and extra tropical weather systems and latterly on climate; he has published over 110 papers in atmospheric science. He has played major roles in international programmes such as FASTEX and THORPEX.

Professor Alan Thorpe. The new Director-General of ECMWF from 1 July 2011

Professor Thorpe said: "I am really excited to be joining ECMWF in July 2011. It has a pre-eminent position as a world-leading centre for numerical weather prediction. I look forward to leading ECMWF as it develops even more skilful forecasts in the medium-range, including hazardous weather events, and beyond. To be the Director-General will be a challenge and a privilege."

ECMWF's plan for 2011

DOMINIQUE MARBOUTY

The ECMWF plan for 2011 flows directly from the four-year programme of activities 2011–2014, adopted by the ECMWF Council at its 74th session in December 2010 (the programme itself is available at http://www.ecmwf.int/about/programmatic). The main drivers of this programme remain:

- Improving and verifying early warning for severe weather.
- Supporting our Member States, in particular by developing interoperability, providing them with relevant products and giving feedback into the observing system.
- Preparing ECMWF for future challenges, in particular by adapting our codes for massively parallel supercomputer architecture and modelling in the "grey-zone" (i.e. between 2 and 10 km grid resolution where convective processes are partially-resolved).

The first main milestones concerning forecasting systems upgrades in 2011 will be the implementation of the second weekly run of the monthly forecasting system on Mondays, expected in June. Closer to the end of the year there will be the increase in vertical resolution to 137 levels (from 91 currently) and implementation of the new seasonal forecasting 'System 4'. Also the MACC (Monitoring Atmospheric Composition and Climate) system for atmospheric composition, funded by GMES, will start running in near-real-time in May.

Several other developments will be implemented as part of the various new cycles throughout the year. In particular, they will include:

- Use of the ensemble of data assimilation in 4D-Var to estimate flow-dependent background errors in order to reduce analysis errors, particularly in regions with quickly developing weather systems.
- Assimilation of ground-based radar data.
- Improved physical parametrizations concerning in particular vertical diffusion, land surface and cloud schemes.

In addition, a new ocean model (NEMO and NEMOVAR) will be used in the ensemble prediction systems extending beyond 10 days (including System 4).

The project of reorganising the IFS code to make it more modular (OOPS: Object Oriented Programming System) will enter its main development phase. The goal is to simplify the maintenance of the forecasting system and facilitate new scientific and algorithmic developments. It will make it easier to develop and test new concepts for more scalable data assimilation systems such as weak-constraint 4D-Var and Ensemble Kalman Filter (EnKF).

To support these developments, some reorganisation will affect the Research Department. The ocean surface wave group will be merged with the ocean assimilation and modelling activities in a new Marine Aspects Section that will be part of the Predictability Division. The diagnostic activity will become a cross-cutting task involving all sections on common themes: for this year, the themes will concern severe weather, tropical uncertainty and boundary layer processes.

The ERA-CLIM project will start this year. It will prepare the input data and assimilation systems necessary for the next generation ECMWF reanalysis, spanning the entire 20th century. The target for the finalisation of this next generation reanalysis (tentatively called ERA-20C) is 2017. However several pilot reanalyses will be made available before that date: a century-long low resolution reanalysis will start in 2011.

The new GRIB edition 2 will be

Major achievements in 2010

The plan for 2011 will build upon our 2010 achievements which included:

- The implementation of three new cycles including the following important developments: increased horizontal resolution in January, Ensemble of Data Assimilation in June, and new cloud parametrization scheme and new surface analysis schemes for snow and soil moisture in November.
- The successful provision of early warnings for the major severe weather events that occurred in 2010, in particular the winter storm Xynthia that affected Western Europe in February, the floods in Pakistan in July, and the heat wave in Russia in August.
- The positive outcome of the various committee subgroups, with the following being of particular note:
  - The TAC subgroup on green computing concluded that the ECMWF infrastructure is remarkably energy-efficient and will be fit for hosting the next generations of supercomputers.
  - The ground breaking work of the TAC subgroup on verification measures, resulting in particular in the introduction of new headline scores to evaluate ECMWF forecasts.
- The preparation of the ERA-CLIM project, coordinated by ECMWF, which was selected for funding by the EU research programme (FP7).
- The entry into force of the amended convention on 6 June 2010. It will allow new Member States to join ECMWF and several have started this procedure. It also broadens ECMWF mission statement towards Earth-system monitoring, and opens the possibility of developing third-party funded activities.
- A comprehensive overhaul of ECMWF's financial practices, culminating in the adoption of new financial regulations by the Council in December. This will allow ECMWF to move to the recognised international accounting standards (IPSAS).

introduced in the Centre's operational suites as part of the first cycle upgrade which is expected in spring. GRIB 2 will affect model-level data and is a necessary step before the vertical resolution increase. It will also provide standard encoding for many fields such as probabilities, support better compression algorithms, and provide the higher accuracy required for new parameters such as chemical concentration.

Work on development of new products will continue. An important milestone will be the operational release of 'ecChart' expected in June: ecChart is the application developed by the Web Re-engineering Project that was tasked with enhancing ECMWF web services for forecasters: it is an interactive service and supports features such as zooming, panning and on-demand production of customised plots. Developments of products and verification will concentrate on weather-related outputs such as visibility and freezing level, and on regime changes.

Following the decision made by| the ECMWF Council to extend the current contact with IBM for the high-performance computing facility (HPCF) by one year until mid-2014, the installation of the enlarged phase 2 will start this summer. In the end it will be composed of about 1,500 nodes representing about 48,000 processors, and delivering an aggregate peak performance of about 1.4 petaflops.

Specific emphasis will be put on the Centre's archive. There will be a review the archive policy and the development of the data handling system to ensure that the Centre will be able to cope with the increased amount of data produced by the HPCF Phase 2. The provision of archived data to external users will also be reviewed following the Council's decisions to remove archive data charges and to make the data service a core activity.

Following the entry into force of the amended Convention the first new Member States are expected to join ECMWF in 2011: the process is already well advanced for Iceland and Slovenia and several other current Co-operating States are starting it. This will further enlarge the community of States contributing to and benefiting from the common European asset that is ECMWF.

74th Council session on 7–8 December 2010

MANFRED KLÖPPEL

Under the chairmanship of its President, Mr Wolfgang Kusch (Germany), the Council held its 74th session at the ECMWF headquarters.

The Council congratulated the Director-General on the Centre's main achievements since its last session in June 2010, noting the following in particular.

- Model cycles 36r2 and 36r4 were implemented on 22 June and 9 November 2010. A new method for providing initial-time perturbations for the EPS was introduced in cycle 36r2, as well as differences between members of an ensemble of data assimilations (EDA). Cycle 36r4 included a new cloud parametrization scheme and new surface analysis schemes for snow and soil moisture. The scores of the deterministic and the ensemble prediction system had improved due to these modifications.
- Good early warnings were provided for several major severe weather events (e.g. severe floods in Liguria in October, and the Russian heat wave and the heavy floods in Pakistan during the summer).
- Iceland and Slovenia submitted formal applications on 28 October and 6 December 2010 to become ECMWF Member States.
- Co-operation agreements with Bulgaria and Israel entered into force on 12 July and 28 October 2010, bringing the number of Co-operating States to 15.
- Comparisons with other global forecasting centres had shown that ECMWF continues to maintain its lead.

Besides several decisions made on financial and staff matters (such as adoption of Reports from the Co-ordinating Committee on Remuneration), the main results of this session were as follows.

- ***Appointment of a new Director-General***. The Council unanimously approved the appointment of Professor Alan Thorpe as the new ECMWF Director-General from 1 July 2011 (see the news item on page 2).
- ***New Co-operating and Member States***. The Council unanimously authorised the Director-General to conclude co-operation agreements with the former Yugoslav Republic of Macedonia and with Bosnia and Herzegovina. Also the Council unanimously agreed to vote by correspondence on Iceland's and on Slovenia's application for full membership early in 2011.
- ***Computer Facility***. The Council unanimously authorised the Director-General to conclude a one-year extension to mid-2014 for IBM's service contract for the High Performance Computer Facility (HPCF), based on the current money stream. This extension will give ECMWF a scientifically valuable increase in compute resources in mid-2012. This will enable ECMWF to make faster progress in addressing the scalability issues within the ECMWF data assimilation system. It represents the same good value for money as achieved in the initial procurement.
- ***Four-year programme of activities***. The Council unanimously adopted a four-year programme of activities for the years 2011–2014.

Other important decisions made were as follows.

- ***Financial Regulations***. The Council unanimously adopted amendments to the Financial Regulations which mainly address the need to align them to established good practice and to comply with International Public Sector Accounting Standards (IPSAS).

◆ ***Integrated Forecasting System (IFS)***. The Council approved a three-year pilot project aimed at making the IFS more easily accessible to European academia, thus strengthening the link with universities and creating a pool of scientists with IFS experience.

◆ ***Budget 2011***. The Council approved the budget for 2011 with an increase of 5.0% in terms of Member States' contributions compared to 2010. The budget increase results from earlier decisions made by the Council on the Centre's pension schemes and the financing of the current HPCF.

◆ ***Scientific Advisory Committee***. The Council unanimously re-appointed Prof Heikki Järvinen for a second term of office and appointed Prof Johannes Orphal (Karlsruhe Institute of Technology), Prof Wilco Hazeleger (Koninklijk Nederlands Meteorologisch Instituut, KNMI), and Dr Roger Saunders (UK Met Office) to the Scientific Advisory Committee (SAC) for a first term of office.

The Council unanimously elected Mr François Jacq (France) as President of the Council, and Prof Ricardo Garcia-Herrera (Spain) as Vice-President of the Council, both for a first term of office of one year.

Dr Mark Rodwell gave a lecture to the Council on "*Diagnostics of the ECMWF Forecasting System*".

Use of high-performance computing in meteorology

GEORGE MOZDZYNSKI

Every second year ECMWF hosts a workshop on the use of high-performance computing in meteorology. The 14th workshop in this series took place from 1 to 5 November 2010 and was attended by over 100 participants from Meteorological Services, research institutions and computer vendors, coming from 18 different countries. The emphasis of this workshop was on running meteorological applications at sustained teraflops performance in a production environment, and in particular on the future scalability of NWP codes and the tools and development environments to facilitate this.

At the workshop there were 45 presentations covering a wide range of topics including:

◆ High-performance computing at various forecasting centres.

◆ Current and future products from vendors of supercomputers.

◆ Developments in parallel computing techniques.

◆ Tools to exploit the power of supercomputers.

Of note, four of these talks were on the use of General Purpose Graphics Processing Units (GPGPUs) which are now being used as accelerators on the world's fastest supercomputers. It will be interesting to follow such developments at future workshops, and in particular whether GPGPUs can be successfully applied to NWP or Climate Forecasting.

The keynote talk on the subject of Exascale Computing was given by Prof Thomas Sterling where he outlined the need for a dramatic change in programming paradigm and hardware model to achieve Exascale performance – machines 1,000 times faster than the world's fastest computer today.

Presentations from this workshop can be found at the following web location:

● http://www.ecmwf.int/newsevents/meetings/workshops/2010/high_performance_computing_14th/presentations/

Logo for the workshop. It illustrates an example of partitioning for the current IFS operational model at T1279 resolution (about 16 km grid spacing) when run in a configuration having 1024 partitions. One of these partitions covering part of the UK is highlighted to show the actual location of the 2090 grid columns (each having 91 levels) in this partition. In each such partition the IFS can use up to 8 processor cores to perform the calculations required in that partition.

Applying for computing resources for Special Projects

UMBERTO MODIGLIANI

Each year users within one of ECMWF's Member States may apply for computing resources as a 'Special Project'. These are of a scientific or technical nature and are likely to be of interest to the general scientific community. Such projects can be undertaken in co-operation between several institutions, nationally or internationally. The decision to treat a project request as a Special Project application is made ultimately by the Director of the National Meteorological Service of the project's Principal Investigator. Some European organisations with which ECMWF has concluded Co-operation Agreements may apply for resources for a Special Project, with such a request to be considered by the Director of ECMWF. The Special Projects that are continuing or starting in 2011 are given in the item starting on page 31 of this edition of the *ECMWF Newsletter*.

The allocation of computing resources for Special Projects is decided by the ECMWF Council. The guidelines for distribution currently state that a maximum of 10% of the computing resources available to Member States may be allocated to Special Projects. 20% of that 10% is set aside as a reserve for allocation by ECMWF directly (following consultation with the Chairs of the Technical Advisory Committee and the Scientific Advisory Committee) either to late applicants or to projects which have exhausted their allocation before the end of the year.

If you wish to begin work on a Special Project in 2012 then an application form should be completed and sent to ECMWF via the Director of the appropriate National Meteorological Service. The form needs to reach ECMWF by 30 April 2011. Requests will be reviewed by the Scientific Advisory Committee and Technical Advisory Committee in October and then approved (or not) by the ECMWF Council at its meeting in December 2011. If the 30 April deadline is missed, applications can still be made as limited resources are set aside specifically for ad hoc allocations. The various application forms are available from:

- http://www.ecmwf.int/about/special_projects/

Due to the large oversubscription of computing resources available to Special Projects, a new procedure was implemented in 2008 for the handling of applications for computing resources for Special Projects.

- Each project will have a well-defined duration, up to a maximum of three years, agreed at the beginning of the project.
- The amount of resources requested by each project for each year cannot exceed more than 8% of the total amount of resources available for that year. For 2011 the maximum resource that could be allocated to any project was designated as 7,200 kunits of HPCF and 32,000 gigabytes of Data Storage.
- To avoid accepted Special Project requests needing a reduction by more than 20%, the lowest ranking Special Projects requesting large amounts of computing resources may not be accepted.

More information about Special Projects can be found by going to the web address that has already been given.

Non-hydrostatic modelling

NILS WEDI, SYLVIE MALARDEL, AGATHE UNTCH

A three-day workshop on non-hydrostatic modelling was held at ECMWF from 8 to 10 November 2010. The workshop brought together about 35 leading experts in the field of non-hydrostatic modelling to discuss recent developments in this area and to provide recommendations on how to prepare ECMWF's Integrated Forecasting System (IFS) for global atmospheric modelling at future high to ultra-high resolutions.

Participants in the workshop on non-hydrostatic modelling. About 35 participants attended the workshop held at ECMWF from 8 to 10 November 2010.

The workshop started with a series of fifteen invited presentations on the status of and recent developments in non-hydrostatic modelling at major NWP centres and atmospheric research institutions from around the world. These presentations and the programme can be viewed at:

- http://www.ecmwf.int/newsevents/meetings/workshops/2010/Non-hydrostatic_Modelling/presentations/

In the second part for the workshop, the participants broke out into three parallel working groups and discussed, among others, the following topics.

- The viability and competitiveness of some of the key elements of the IFS at very high resolution: the spectral transform method, the semi-implicit method and the semi-Lagrangian advection.
- The strengths and weaknesses of alternative approaches taken in the development of non-hydrostatic dynamical cores.
- Alternatives to the fully-compressible Euler equations and their suitability for global NWP in the non-hydrostatic regime.
- Conservation requirements.
- Scaling properties of the various numerical solvers on the massively parallel platforms of the future.
- Experience with the unification of general circulation and cloud-resolving models.
- Consistent physics-dynamics coupling for the fully-compressible model.
- Issues arising in the 'grey zone' with

partly resolved physical processes.
- Test cases and strategies to assess model performance in the non-hydrostatic regime.

The working groups made valuable recommendations and suggested potential avenues for ECMWF to explore. These will guide research and development at the Centre in the area of non-hydrostatic modelling in the coming years. This guidance is timely as the Centre plans to upgrade its operational resolution to 10 km by about 2015, beyond which it is essential for the Centre to have an efficient, accurate and robust non-hydrostatic model.

The workshop closed with a plenary session during which the conclusions and recommendations of the three working groups were presented and discussed by all participants. A full report of the workshop will be published in the forthcoming workshop proceedings, available by following the links from:
- http://www.ecmwf.int/publications/

The organisers would like to thank the participants for making this workshop a very successful and enjoyable event.

New interactive web tool for forecasters

ANDREW BRADY

In 2007 it was becoming clear that the forecast charts that ECMWF provided on its website for use by Member States' forecasters were in need of a significant enhancement. We began talking to forecasters about their requirements. It was clear – more interactivity was needed, particularly the abilities to:
- Change the area by zooming and panning the view.
- Have more flexibility for the display of EPSgram information and the facility to change probability thresholds.

The service above all had to be as reliable as possible and would also need to provide a method for batch systems to access products in a standard well-defined way.

In May 2008, ECMWF began a project to develop a new web-based tool and a suitable backend infrastructure that would not only meet current forecaster requirements but would be flexible enough to enable future development of new functions. In December 2010 the first beta release of the tool was provided to forecasters.

Basic description

The ECMWF ecChart/forecaster service is a web-based interface that forecasters can use to explore ECMWF's medium-range forecast products. It is possible to configure what you are looking at: for example you can change the geographical area, choose the combination and order of graphical layers to display in a map image, modify the visual style which applies to each layer, or change the threshold for a probability calculation.

The number of forecast parameters that are available has been increased and, as with the existing web, animation of the charts is also provided. It is possible to click on points on a chart or search for cities to get a set of meteograms. Meteogram types that are available include 10-day, 15-day and Wave EPSgrams and there are also EPS cumulative distribution functions (CDF) and the extreme forecast index (EFI). It is also possible to mix both geographic locations and data parameters in composite meteograms. Finally, there is an Open Geospatial Consortium (OGC) Web Map Service (WMS), ecChart/wms, that can be used by WMS aware clients to display ECMWF chart products.

The server architecture

- Three web servers using Varnish.
- Three Django/Python web application servers.
- Four servers in a virtualised cluster using Xen to provide a high availability platform for Service Orientated Architecture (SOA) functionality and databases.
- Two servers acting as an active/passive JSON object store (using MongoDB).
- Sixteen servers that are used to store all the required GRIB data, do on-demand computation, render graphical layers using Magics++ and stack the graphical layers together to create an image file that can be served back to the web browser.

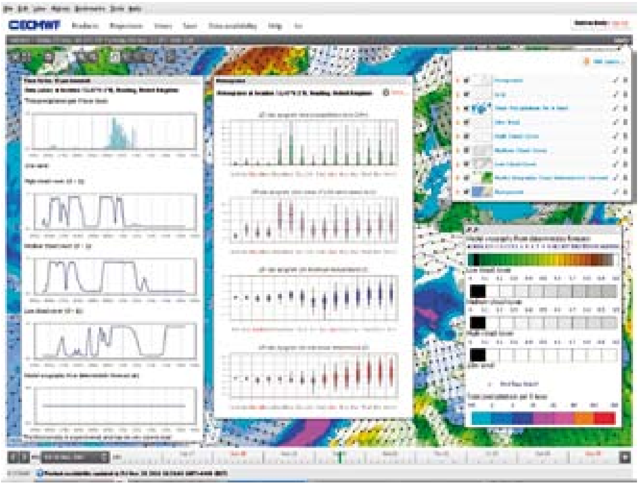
'Your Room' becomes 'ecChart/dashboard'

There is a replacement for the well used '*Your Room*' of the existing website. This is called '*ecChart/dashboard*' and is considerably more flexible than '*Your Room*'. It is possible to store maps and meteograms as widgets and group them together in tabs. The model we have used is based on iGoogle. A useful feature is the ability to have some interactivity across all the widgets in one tab, so for example it is possible to animate multiple charts in synchronisation.

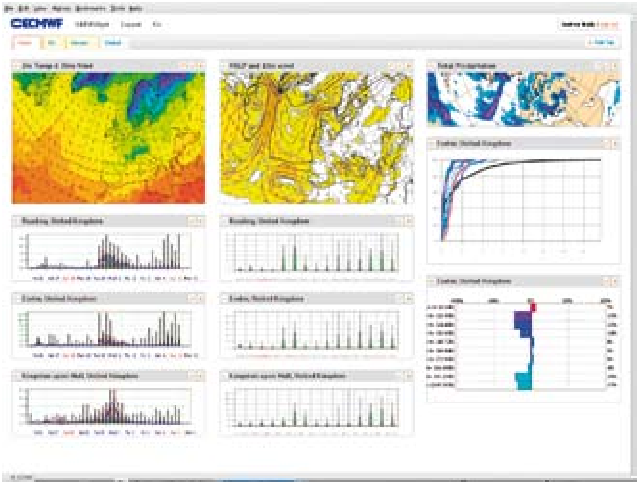
The technical architecture

We are using a total of twenty-eight dual-Xeon rack-mount servers. This may seem like a lot of servers but this many servers are needed for three reasons:
- Plots are produced on-demand.
- Responsiveness of the overall service is critical.
- Sufficient hardware is needed to provide high availability (HA).

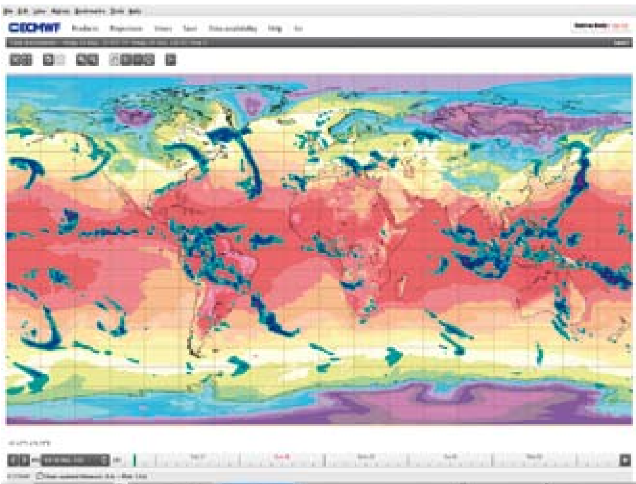
For example without the need for HA we could immediately reduce the number of servers required from twenty eight to twelve. Currently we are able to serve most of the charts in well under five seconds: not bad at all considering the amount of work required to actually produce a high quality chart (i.e. retrieval, computation, creating graphical layers and generating a png).



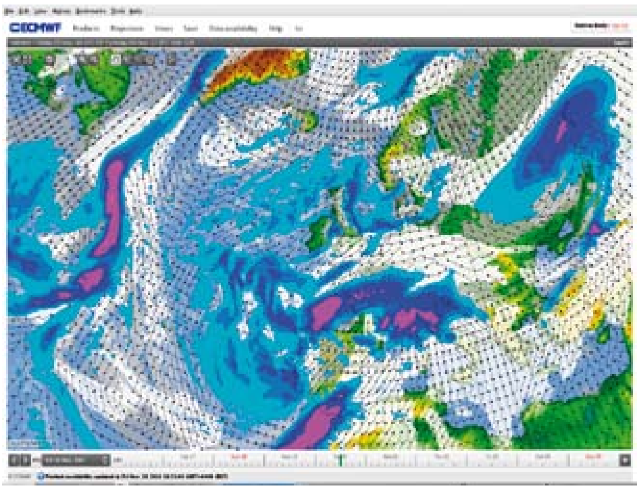
ecChart/forecaster: time-series, meteograms, forecast product constituent layers and layer legends. Graphical maps can be created from any of the graphical layers that ECMWF provide. Each layer has a selection of visual styles. Zooming in and out, panning and changing between pre-defined areas and projections is supported as is animation, time stepping of and navigation through previous forecast base times.



ecChart/dashboard: forecast widgets, including chart products (2-metre temperature, wind speed and accumulated precipitation), meteograms, EFI information. Widgets can be organised within a tab or moved between tabs. Widgets can also be edited, for example to change the geographic location of a meteogram. Limited interaction of all widgets on a tab is also available (e.g. animation).



ecChart/forecaster: global chart of 2-metre temperature overlaid with six-hour accumulated precipitation. Forecasters can choose which layers they want to see on a map and create their own products from all the information provided.



ecChart/forecaster: European view of precipitation and low, medium, high clouds over orography. It is possible to zoom in and out, select from pre-defined country areas, and change thresholds and accumulation periods in layers were relevant.

The architecture uses a service-orientated approach to generating the plots on demand which means we distribute the sub-component tasks of creating a plot across multiple servers and combine the results. This orchestration enables some tasks to be run in parallel which is how we achieve the response. Caching is also used throughout the architecture but the benefits are somewhat limited because of the amount of flexibility offered by the web interface and because we don't using tiling.

When will the service be generally available?

For now, the tool is only being made available to operational forecasters because the computer infrastructure required is quite significant and we need to understand how users will put a load on this infrastructure.

After we make the service operational for forecasters and we have confidence in the stability of the service, we will evaluate how to make similar services available to other communities.

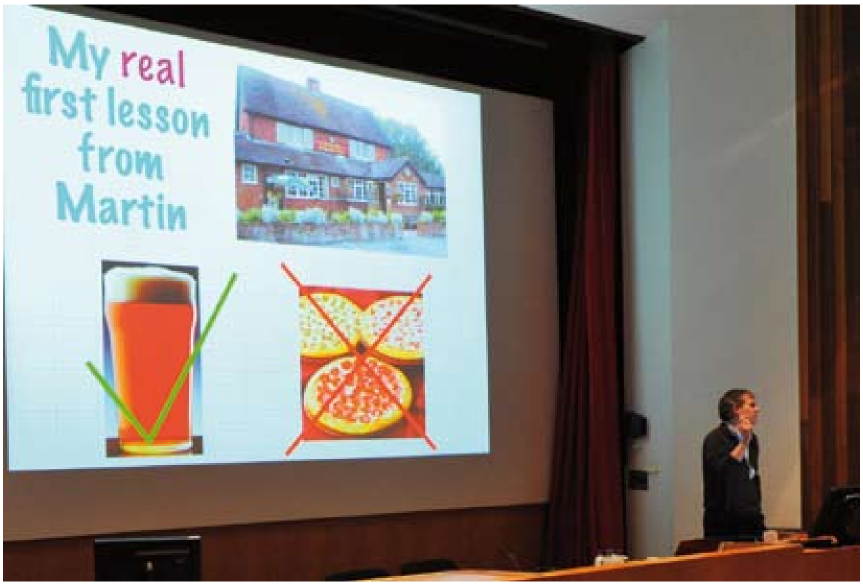
More information

Future articles in the *ECMWF Newsletter* will provide more detail on the architecture behind the ecChart/ services and we will focus on the component solutions that we have used and had to develop to provide the service.

If you have a specific question, please raise it with your Computing Representative (see page 36 of this edition of the *ECMWF Newsletter*) or User Support contact.

Symposium in honour of Martin Miller

ERLAND KÄLLÉN



Martin Miller retired from ECMWF as Head of Model Division in December 2010 after 27 years of service at ECMWF. On 6 January a symposium was held at ECMWF to honour his research and leadership in meteorology. Colleagues and friends from all over the world came to participate in the event, including those from Australia, USA and Europe. In a series of presentations we were given an overview of the research areas and institutes where Martin has been active. His early work on convection modelling was referred to several times as being groundbreaking and having inspired many subsequent studies both in meteorology and oceanography.

The importance of Martin's contributions at ECMWF as well as in the international meteorological community in moving the science methods and forecast quality forward was particularly stressed. Martin has been a key link between research and operations at ECMWF, overseeing the introduction of new model cycles and monitoring forecast scores as well as the synoptic quality of the forecasting system.

His contributions to the management of ECMWF have been many and important; in addition his friendly personality has always made people feel comfortable in their roles and duties at ECMWF. Many of us have greatly benefited from his willingness to help and his deep knowledge of science as well as the inner workings of ECMWF.

In addition to recognising Martin's achievements, the symposium offered many amusing insights into the research environments at Imperial College in London, where Martin started his career, and ECMWF over the past three decades. A very enjoyable and informative day ended with a reception in the ECMWF restaurant.

Forecast performance 2010

ERIK ANDERSSON, DAVID RICHARDSON

EACH YEAR, comprehensive verification statistics are prepared to evaluate the performance of all the components of the ECMWF forecasting system. A verification summary is presented to the ECMWF advisory committees and the Council. The views of ECMWF's Technical Advisory Committee about the operational forecasting system are given in Box A. A couple of this year's main results are shown here.

Overall performance in the medium-range

Long time series of skill scores reflect the combined impact of all the improvements made to the forecast system over the years: increased resolution, improved forecast model, better data assimilation, and the availability of many more satellite observations.

The overall performance of the deterministic forecasting system is summarised in the anomaly correlation (ACC) scores for 500 hPa height shown in Figure 1 for Europe since 1980. The skill of the deterministic forecast has been consistently good throughout 2010, with the average anomaly correlation remaining above 60% to around day 8 for every month.

In February 2010 the average monthly ACC remained above 60% throughout the 10-day range of the deterministic forecast for both the European region and the northern hemisphere: the ACC score was 67% at day 10 for the northern hemisphere and 61% for Europe. These are the highest scores ever reached by the forecasting system. The 2009/10 winter season has been unusual over the northern hemisphere, with a strong negative phase of the North Atlantic Oscillation and Arctic Oscillation circulation patterns. These are typically associated with cold weather in northern Europe and more active weather systems and heavy rainfall affecting south-west Europe. The exceptional scores are partially a result of the large anomalies this winter; however, the high scores for the ECMWF model confirm that it has performed consistently well in predicting these anomalous weather conditions. The ACC scores for other NWP Centres have also been particularly high during this period last winter, but ECMWF maintains its lead.

Tropical cyclone forecast accuracy

Developments of the forecasting system have resulted in substantial improvements to the quality of tropical cyclone forecasts in recent years. Average position and intensity errors for the deterministic medium-range forecasts of all tropical cyclones (all ocean basins) over the last seven 12-month periods are shown in Figure 2. For the last three years, the forecast has on average predicted the location of tropical cyclones three days ahead to within 200 km of the observed position. This compares with position errors of around 300 km in previous years. The model has a tendency to move the tropical cyclones more slowly than is observed, showing a speed bias of on average one km/hour. The increase in resolution in January 2010 significantly reduced the tropical cyclone intensity errors, continuing the improvements made in earlier model upgrades.

A — Overall view of ECMWF's Technical Advisory Committee, 6–9 October 2010

In regard to its overall view of the operational forecasting system the Committee:

i. congratulated ECMWF on the consistently good results from all its forecasting systems in the previous year, in particular for the outstanding forecasts produced in February, when scores for the northern hemisphere and Europe reached their highest level ever, and on maintaining its leading position in global weather forecasting;
ii. was encouraged by the clear positive impact from the introduction of the ensemble of data assimilations and by the promise shown by the new cloud microphysics;
iii. was encouraged to learn that monthly forecasts for temperature are beginning to show some evidence of skill out to week 3, in particular during high-impact episodes such as the recent extreme temperatures experienced in Europe this winter and Russia this summer;
iv. appreciated the continued positive trend shown in the verification of severe events;
v. noted that the skill of the ensemble prediction system, already high, continues to increase, both in absolute terms and in relation to other centres;
vi. welcomed the increased use of ensemble products in the Member States for input into downstream models and at longer time ranges;
vii. was pleased to note that the scores for ECMWF wave forecasts continue to improve and maintain their lead over other centres' forecasts;
viii. with respect to deterministic forecasts of weather parameters:
   - acknowledged that precipitation forecasts show some improvement at day 3-4 but there remains a tendency to overpredict light rain;
   - noted, with some concern, that the significant cold bias over Europe at night continued during the last winter and spring;
   - noted that the severity of the cold temperatures during the last winter had emphasised model problems with snow depth and density but was encouraged by the work which has been undertaken to improve the snow analysis and forecasts.

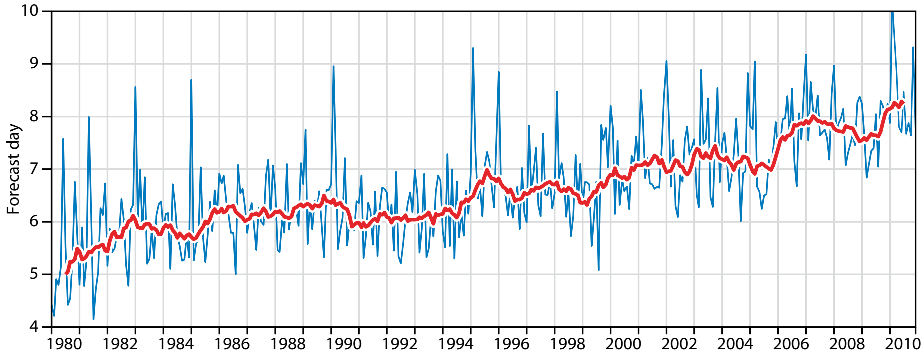


Figure 1 Deterministic forecasting system performance for Europe. Forecast range (days) at which the monthly mean (blue) and 12-month running mean (red) anomaly correlation for 500 hPa height operational 12 UTC forecasts reaches 60%. This score has been consistently high over the last year. The last month included in the statistics is September 2010. The resolution of the forecast model was T63 (320 km) initially, and was increased to T106 in 1987, T213 in 1993, T319 in 2000, T511 in 2001, T799 in 2006 and T1279 (16 km) in January 2010.

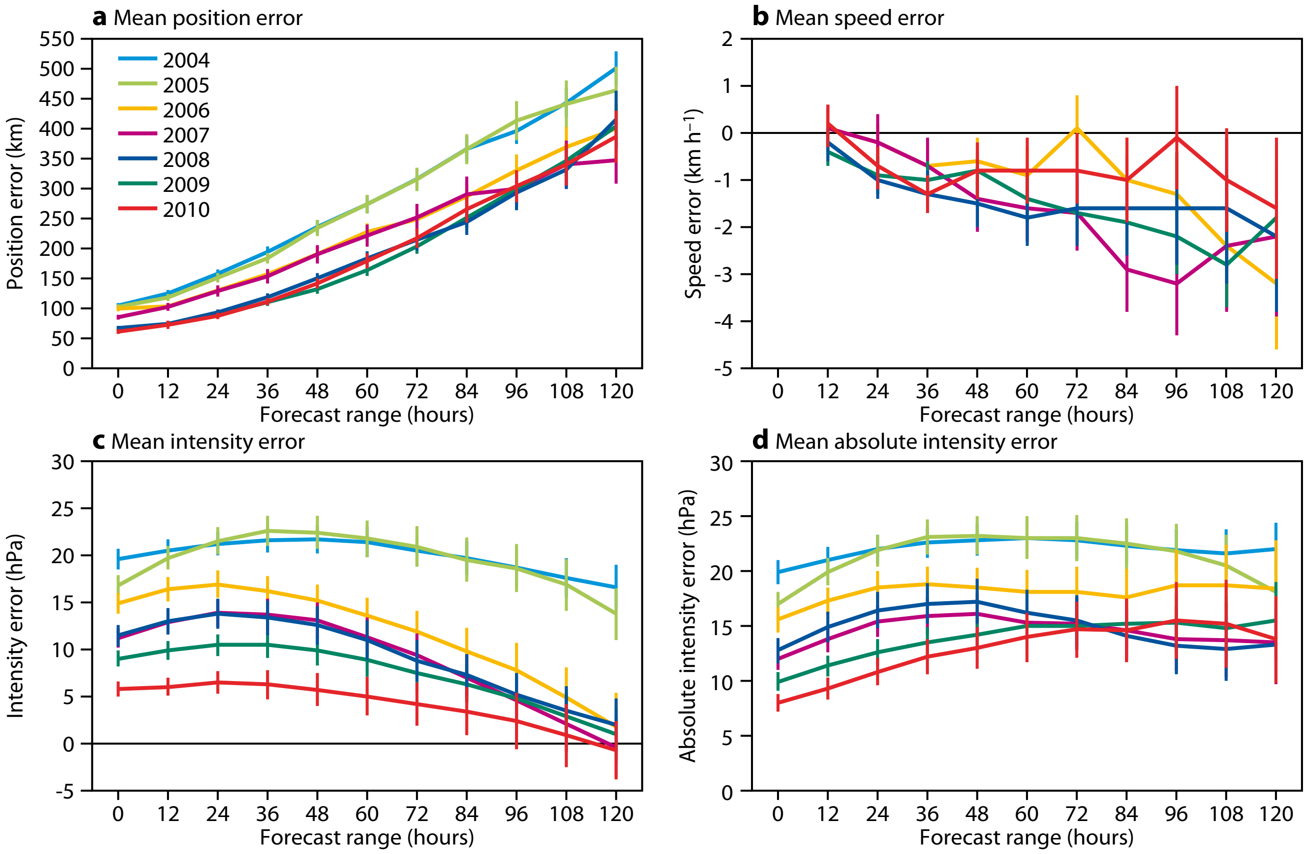


Figure 2 Verification of tropical cyclone predictions from the operational deterministic forecast. Results are shown for 12-month periods ending on 30 November. (a) The mean position error. (b) The mean speed error (negative values indicate that the forecast speed is too slow). (c) The mean intensity error (bias) in the cyclone core pressure (positive error indicates the forecast pressure is less deep than observed). (d) The mean absolute intensity error of the core pressure. The uncertainty in the scores in indicated by the 90% confidence interval (based on T-test); there are substantially fewer events at later forecast steps than earlier in the forecast and hence there will be greater uncertainty in the scores at the later ranges. Verification is against the observations reported in real-time via the GTS.

FURTHER READING

The complete set of annual results is available in ECMWF Technical Memoranda on "*Verification statistics and evaluations of ECMWF forecasts*", downloadable from:
www.ecmwf.int/publications/library

Verification pages have been created on the ECMWF web server and are regularly updated. Currently they are accessible at the following addresses:

- Medium range: http://www.ecmwf.int/products/forecasts/d/charts/medium/verification/
- Monthly range: http://www.ecmwf.int/products/forecasts/d/charts/mofc/verification/
- Seasonal range: http://www.ecmwf.int/products/forecasts/d/charts/seasonal/verification/

Note: All forecasting system cycle changes since 1985 are described and updated at: http://www.ecmwf.int/products/data/operational_system/index.html

Simulation of the Madden-Julian Oscillation and its impact over Europe in ECMWF's monthly forecasts

FRÉDÉRIC VITART, FRANCO MOLTENI

THE MADDEN-JULIAN Oscillation (MJO) (*Madden & Julian*, 1971) is a tropical large-scale oscillation dominated by periods of 30–60 days and zonal wavenumber-1 propagating eastward. It is the main source of predictability in the tropics on time scales exceeding one week but less than a season. The maximum convective activity associated with the MJO occurs over the warm waters of the Indian Ocean and western Pacific where the MJO moves eastward at a relatively low speed (5 ms^{-1}) whereas in the western hemisphere the MJO is less well coupled to convection and propagates faster (15 ms^{-1}).

The MJO is not a regular oscillation. Instead it is episodic and its speed of propagation and duration vary from case to case. Also there is a strong seasonality, with more MJO events in winter and spring, and a strong interannual variability. This makes the prediction of the MJO a challenging task for NWP models.

The MJO has a large impact on the atmospheric circulation not only in the tropics, but also in the northern extratropics (see *Ferranti et al.*, 1990, for example). Several studies suggest that this impact is due to mid-latitude Rossby wave propagation. Since the MJO has a significant impact on the northern hemisphere weather, it is important for monthly forecasts to have skill not only in predicting the evolution of the MJO, but also in simulating the MJO teleconnections.

For a long time the IFS (Integrated Forecasting System) was not able to maintain the amplitude of an MJO event for more than a few days. Over the recent years, the representation of the MJO has improved dramatically (Figure 1), thanks mostly to changes in the model's physics introduced in Cy32r3 on 6 November 2007 (*Bechtold et al.*, 2008). Now the IFS is able to maintain the amplitude of the MJO for more than 30 days, which makes it possible to evaluate the teleconnections associated to the MJO in the model integrations.

This article describes the ability of the monthly extension of ECMWF's Ensemble Prediction System (EPS) to predict the MJO and its teleconnections in the sub-seasonal time range from a series of model hindcasts covering a 20-year period (1989–2008).

Experimental setup

A series of hindcasts has been performed for the 20-year period 1989 to 2008. The hindcasts start on the 15th of each month and are 46-days long to cover the next full calendar month. For each starting date, the hindcast consists of an ensemble of 15 members: a control and 14 perturbed forecasts. The version of the IFS used in this experiment is Cy32r3, which was operational from November 2007 until June 2008. As mentioned earlier, this version of the IFS showed a clear improvement in the representation of the MJO compared to previous versions.

The configuration of the hindcast is the same as the one used for operational monthly forecasts at ECMWF, except for the length of the forecasts (46 days instead of 32 days for the operational monthly forecasts) and the horizontal resolution. For the hindcasts:

- The IFS is first integrated for 10 days with a resolution of T399 (about 50 km resolution) and 62 vertical levels. The IFS is forced by persisted sea-surface temperature anomalies.
- At day 10, the horizontal resolution is lowered to T255 (about 80 km resolution) till the end of the forecast. The IFS is coupled to the HOPE oceanic general circulation model every 3 hours.

The initial conditions are taken from ERA-40 until 2001 and ECMWF operational analysis after 2001, and the ensemble perturbations are produced in the same way as in the operational monthly forecasts. More details about the model configuration can be found in *Vitart et al.* (2008).

MJO skill scores

The methodology for assessing the skill to predict the MJO follows *Gottschalck et al.* (2009). The Wheeler-Hendon Real-time Multivariate MJO (RMM) index (*Wheeler & Hendon*, 2004) has been applied to all the model hindcasts and to ERA-Interim over the period 1989–2008 to (a) evaluate the skill of the monthly forecasts in predicting MJO events and (b) produce composites for different phases of the MJO. The RMM index captures the MJO very well and is widely used to depict MJO activity.

The RMM index is calculated by projecting the forecasts or analysis onto the two dominant combined empirical orthogonal functions (EOFs) of outgoing longwave radiation (OLR), and zonal winds at 200 and 850 hPa averaged between 15°N and 15°S. It has been applied to daily anomalies relative to the 1989–2008 climate instead of the absolute value of the field, in order to remove the impact of seasonal cycle. In addition, a 120-day running mean has been subtracted to remove the variability associated with ENSO (El Niño-Southern Oscillation).

- The positive (negative) phase of EOF2 describes suppressed (enhanced) convection over the Indian Ocean and enhanced (suppressed) convection over the West Pacific.

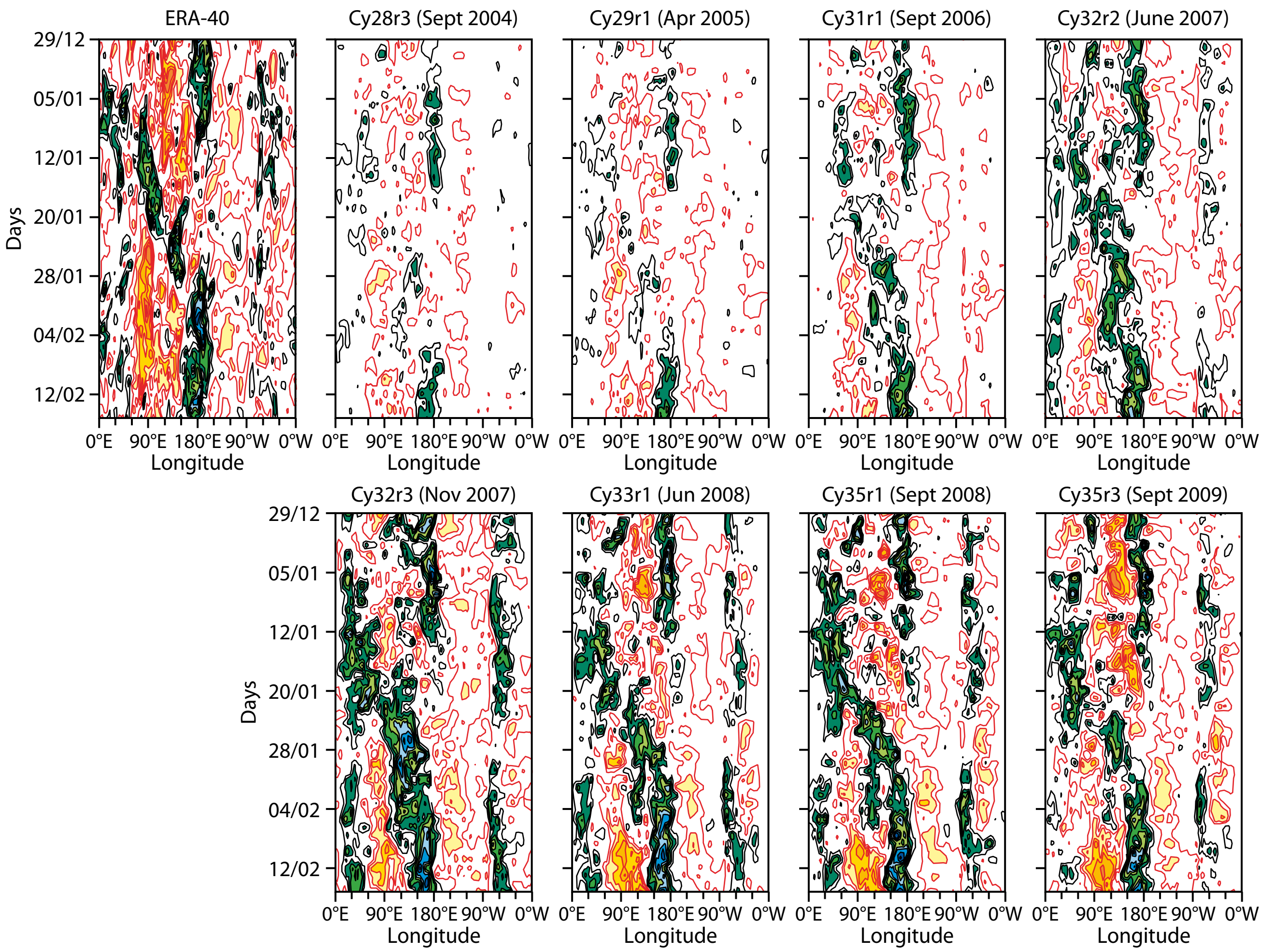


Figure 1 Hovmöller diagrams of the averaged outgoing long-wave radiation (OLR) between 10°S and 10°N from 29 December 1992 to 15 February 1993 as analysed by ERA-40 and obtained from daily forecasts with Cy28r3 to Cy35r3. Each forecast verifies at the 15-day lead time. Red shading denotes warm OLR anomalies (negative phase of the MJO) and blue shading cold anomalies (convectively active phase of the MJO).

- The positive (negative) phase of EOF1 describes enhanced (suppressed) convection over the maritime continent region.

Analysis and forecasts can be projected onto those two EOFs to describe the phase of the MJO in terms of time series of two principal components that vary mostly on the time scale of the MJO. The time series that form the index are referred to as the Real-time Multivariate MJO series 1 (RMM1) and series 2 (RMM2). These can be plotted as a succession of points in the two-dimensional phase space spanned by RMM1 and RMM2, in such a way that the MJO is described by a clockwise propagation in the phase space (Figure 2). The RMM1-RMM2 phase space can be divided into eight sections representing a specific phase of the MJO (see example in Figure 2).

- Phases 2 and 3 (negative EOF2) correspond to enhanced convection over the Indian Ocean.
- Phases 4 and 5 (positive EOF1) correspond to the MJO over the maritime continent.
- Phases 6 and 7 (positive EOF2) correspond to the MJO over the western Pacific.
- Phases 8 and 1 (negative EOF1) correspond to the active phase of the MJO in the western hemisphere.

Bivariate correlation and bivariate root mean square (RMS) error between the model and reanalysis RMM1 and RMM2 are used to evaluate the skill of the dynamical model in predicting the MJO. We consider that the forecast is skilful when the anomaly correlation is higher than 0.5. According to Figure 3a, the model ensemble mean has skill to predict the evolution of the MJO up to about day 23. RMM1 and RMM2 display similar correlations.

The model potential predictability is evaluated using the ‘perfect model’ assumption: an ensemble member is considered to be the ‘truth’ and the ensemble mean is validated against this ensemble member. According to Figure 3a, the model displays a potential predictability exceeding 45 days, which is far beyond the MJO predictability limit found by *Waliser et al.* (2003). Since the model has skill to predict the evolution of the MJO for only about 23 days, this result suggests that there is large scope for improvement of the skill score for the MJO forecasts.

Figure 3b shows that the bivariate RMS error of the ensemble mean reaches the RMS error obtained with climatology after day 30. It can also be seen that the ensemble spread is always smaller than the RMS error, which suggests that the ensemble spread is too small in this version of the IFS.

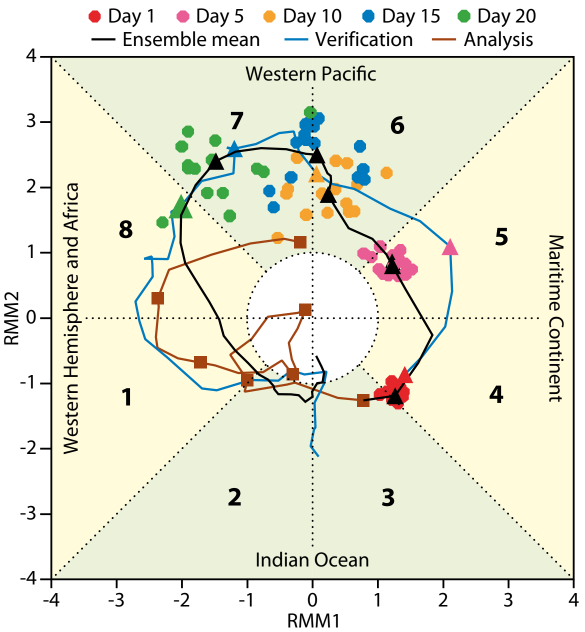


Figure 2 Projection of an observed MJO event (blue line) onto the RMM1-RMM2 phase space, for the period from 15 May 1997 to 16 June 1997. The brown line shows the observed MJO propagation during the 30 days preceding 15 May 1997. The black line represents the ensemble mean 32-day forecast starting on 15 May 1997. The points on the projection are separated by 5 days and correspond to individual ensemble member forecasts at days 1, 5, 10, 15 and 20. The coloured triangles correspond to the analysis at days 1, 5, 10, 15 and 20 for comparison with the forecast trajectories.

The results shown in Figure 3 indicate that the ECMWF model has useful skill up to at least day 20. However, the simulation of the MJO in this set of hindcasts suffers a few problems (see *Vitart & Molteni*, 2010 for more details): the propagation of the MJO is in general too slow compared to observations, and the simulated MJOs have often difficulties crossing the maritime continent. Statistically the percentage of MJO events which do not cross the maritime continent is higher in the model than in observations. In those cases, the convection can be locked over the maritime continent until the end of the 46-day forecast.

Impact of the MJO on Euro-Atlantic weather regimes

Using reanalysis data covering the period 1974–2007, *Cassou* (2008) showed that the impact of the MJO on European weather is the strongest about ten days after the MJO is in phase 3 or phase 6. The impact on the North Atlantic Oscillation (NAO) is as follows.

- The probability of a positive phase of the NAO is significantly increased about ten days after the MJO is in phase 3 (phase 3+10 days), and significantly reduced about ten days after the MJO is in phase 6 (phase 6+10 days).
- The probability of a negative phase of the NAO is reduced about ten days after the MJO is in phase 3 (phase 3+10 days), and increased about ten days after the MJO is in phase 6 (phase 6+10 days).

The impact of the MJO on two other Euro-Atlantic weather regimes, the Atlantic Ridge and Scandinavian blocking, is much weaker.

In the model simulations, the impact of the MJO on the frequency of a positive NAO, negative NAO, Atlantic Ridge and Scandinavian blocking has been evaluated. As in the reanalysis, the largest impact of the MJO in the model simulations is on the frequency of a positive NAO (Figure 4). In the model simulations, the probability of a positive NAO increases (decreases) during the days following an MJO event in phase 3 (phase 6). The amplitude of this impact (about 20% after 10 days) is smaller than in ERA-Interim (about 40% after 10 days).

Overall, the model displays a 10% decrease in the probability of a negative NAO (NAO–) in the 10-day period following an MJO event in phase 3 and a 12% increase in the 10-day period following an MJO event in phase 6 (Figure 4). The sign of this variation of NAO– probability is consistent with ERA-Interim and *Cassou* (2008). The model also simulates an impact of the MJO on the probability of an Atlantic Ridge with an overall decrease after an MJO in phase 3 (66% of

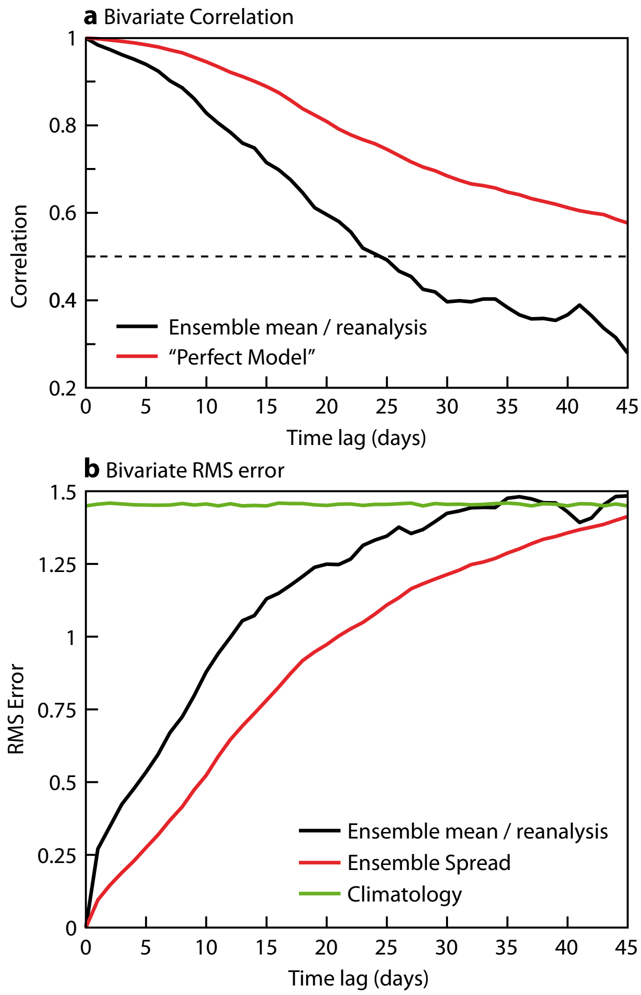


Figure 3 (a) Bivariate correlation and (b) bivariate RMS error between analysis and forecast RMM1 and RMM2 time series as a function of the forecast lead time for the period November to April 1989–2008 (black lines). In (a) the red line shows the bivariate correlation obtained by considering one ensemble member to be the truth (perfect model assumption). In (b) the green line shows the RMS error obtained with climatology and the red line represents the ensemble spread.

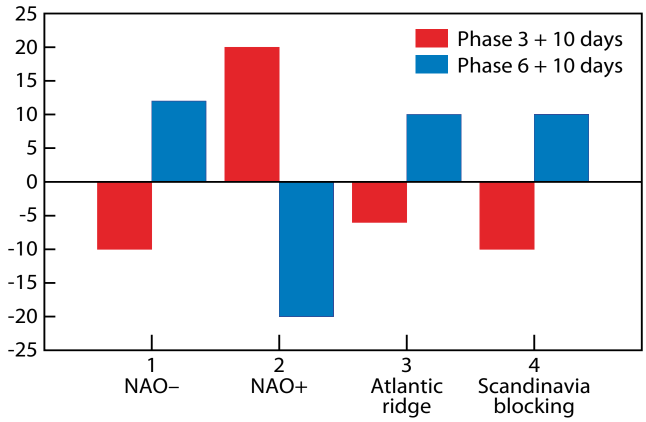


Figure 4 Variation of the percentage of days with NAO+, NAO–, Atlantic ridge or Scandinavian blocking 10 days after an MJO in Phase 3 (red bars) or Phase 6 (blue bars).

ensemble members) and an increase following an MJO in phase 6 (75% of ensemble members). Overall this represents a decrease or an increase of about 10% in the probability of an Atlantic Ridge by day 10 following an MJO respectively in phase 3 or 6 (Figure 4).

Overall, the impact of the MJO on the weather regimes in the set of hindcasts is consistent with ERA-Interim, but the amplitude of the impact is smaller in the model than in ERA-Interim. This could be due to model errors or to a sampling issue with the reanalysis (20 years compared to the equivalent of 300 years of model simulations). For instance, *Vitart & Molteni* (2008) have shown that some ensemble members simulate an impact of the MJO on weather regimes similar to ERA-Interim.

Since the MJO simulated by the model has an impact on the Euro-Atlantic weather regimes, it is likely to impact the 2-metre temperature and precipitation anomalies over Europe. Consider the anomalies of 2-metre temperature at phase 3+10 days (Figure 5a) and phase 6+10 days (Figure 5b). In the days following an MJO in phase 3 (phase 6), the model tends to predict warmer (colder) 2-metre temperatures over Europe as in the reanalysis but with smaller amplitude. Over North America and North Africa, the 2-metre temperature anomalies following an MJO in phase 3 or 6 are generally consistent in the model and reanalysis, except over North America for phase 6, where the cold anomaly simulated by the model is not at the same place as in the reanalysis.

The monthly extension of the EPS also simulates an impact of the MJO on European precipitation consistent with reanalysis. Ten days after an MJO in phase 3 (phase 6), the model simulates wetter (dryer) conditions over North Europe and more (less) precipitation over southern Europe as in the reanalysis (not shown).

Impact of the MJO on monthly forecast probabilistic skill scores

The 120 15-member ensemble forecasts (all the forecasts starting on 15 October, November, December, January, February and March 1989–2008) have been classified as a function of the presence or not of an MJO event in the initial conditions. About 55% of the 120 cases have an MJO in the initial conditions (outside the central circle in Figure 2). This MJO event can be in any phase. Probabilistic skill scores computed for all the cases with an MJO event in the initial conditions are then compared to the probabilistic skill scores computed for all the cases with no MJO event in the initial

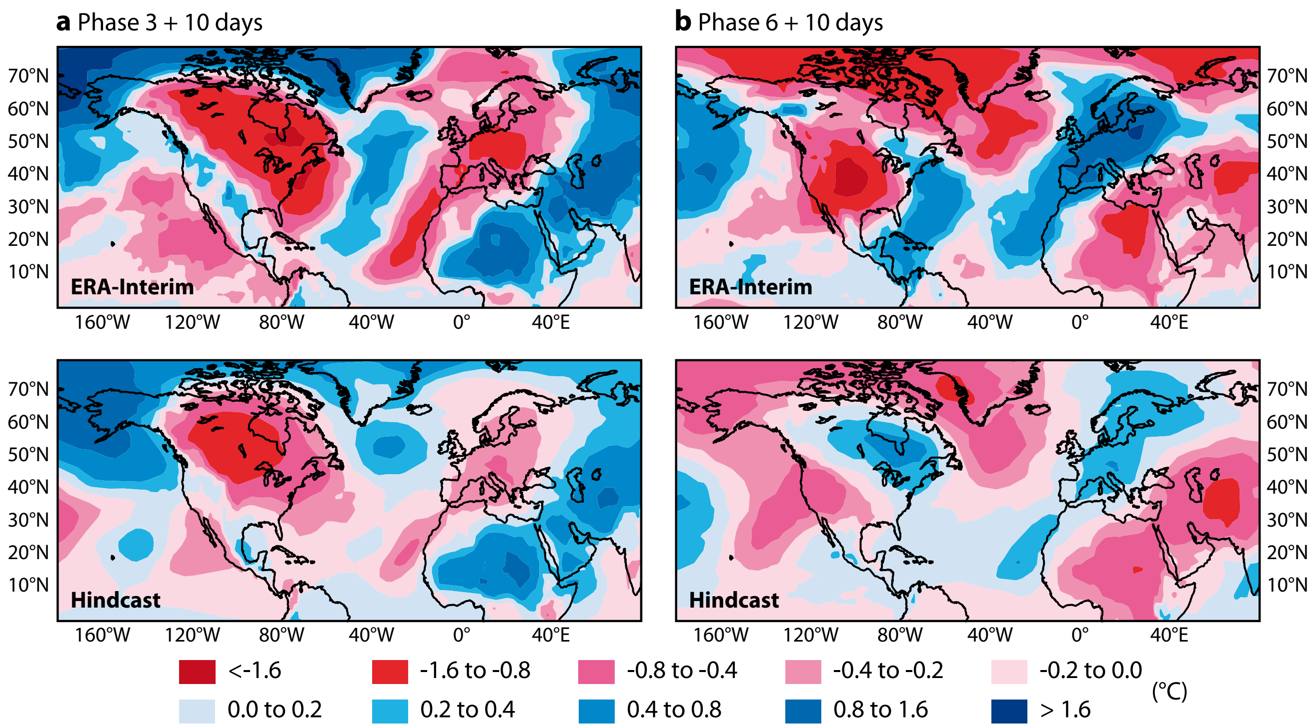


Figure 5 Composites of 2-metre temperature anomalies (a) 10 days after an MJO in phase 3 and (b) 10 days after an MJO in phase 6 in ERA-Interim (top panels) and in the hindcasts (bottom panels).

conditions (inside the central circle in Figure 2). The probabilistic skill scores applied include the Relative Operating Characteristic (ROC) and Brier Skill Scores of the probability that 500 hPa geopotential height, 850 hPa temperature or total precipitation over the northern extratropics (north of 30°N) are in the upper or lower tercile, for the weekly periods days 5–11, 12–18, 19–25 and 26–32. For precipitation and temperature, only land points have been considered. The definition of the weekly periods (days 5–11, 12–18, 19–25 and 26–32) corresponds to the one used in the operational monthly forecast products provided by ECMWF.

The Brier Skill Scores for the probabilities to be in the upper tercile are shown in Figure 6. The results for the low tercile probabilities (not shown) are similar. The results obtained with the ROC scores (not shown) are also similar. According to Figure 6, the Brier Skill Scores are not affected by the presence of an MJO in the initial conditions for the day 5–11 forecasts, except for precipitation with statistically significantly higher skill scores when there is an MJO in the initial conditions. For days 12–18, the Brier Skill Scores are significantly higher when there is an MJO in the initial conditions. For instance, the presence of an MJO in the initial conditions more than doubles the Brier Skill Score of 500-hPa geopotential height at this time range. The difference is statistically significant within the 10% level of confidence using a 10,000 bootstrap re-sampling procedure.

The period of 19–25 days is a time range often considered as having very low predictability and reliability in the extratropics. Therefore it is interesting to notice that when there is an MJO event in the initial conditions, the forecasts over the northern extratropics have a positive Brier Skill Score for 500 hPa geopotential height and temperature at 850 hPa for days 19–25, suggesting that those probabilistic forecasts are likely to be useful at this time range. When there is no MJO in the initial conditions, the day 19–25 forecasts have very low ROC area (close to 0.5) and negative Brier Skill Score, indicating that those forecasts have low skill and are not reliable. This result is confirmed by the reliability diagrams (Figure 7) of the probability that 850-hPa temperature is in the upper tercile for northern extratropics and Europe.

Over Europe, the day 19–25 probabilistic forecasts display some reliability, with a reliability curve close to the diagonal, when there is an MJO in the initial conditions (red line in Figure 7). However, the probabilistic forecasts are unreliable (almost flat curve) when there is no MJO in the initial conditions (blue line in Figure 7). This result suggests that the MJO represents a major, if not the main, source of predictability in the northern extratropics at this time range. This also demonstrates that the skill at this time range is not always as low as previous studies suggested and forecasts at this time range can be potentially useful over the northern extratropics. From a practical point of view, this result also suggests that the users of ECMWF's monthly forecasts could use the presence of an MJO in the initial conditions to decide if the monthly forecasts of days 19–25 should be trusted or not.

For days 26–32, the presence of an MJO in the initial conditions also improves the probabilistic skill scores, but the probabilistic scores are very low, even with an MJO in the initial conditions.

Overall model performance and future developments

The ECMWF 46-day hindcasts show some notable skill in predicting the evolution of the MJO (about twenty days of

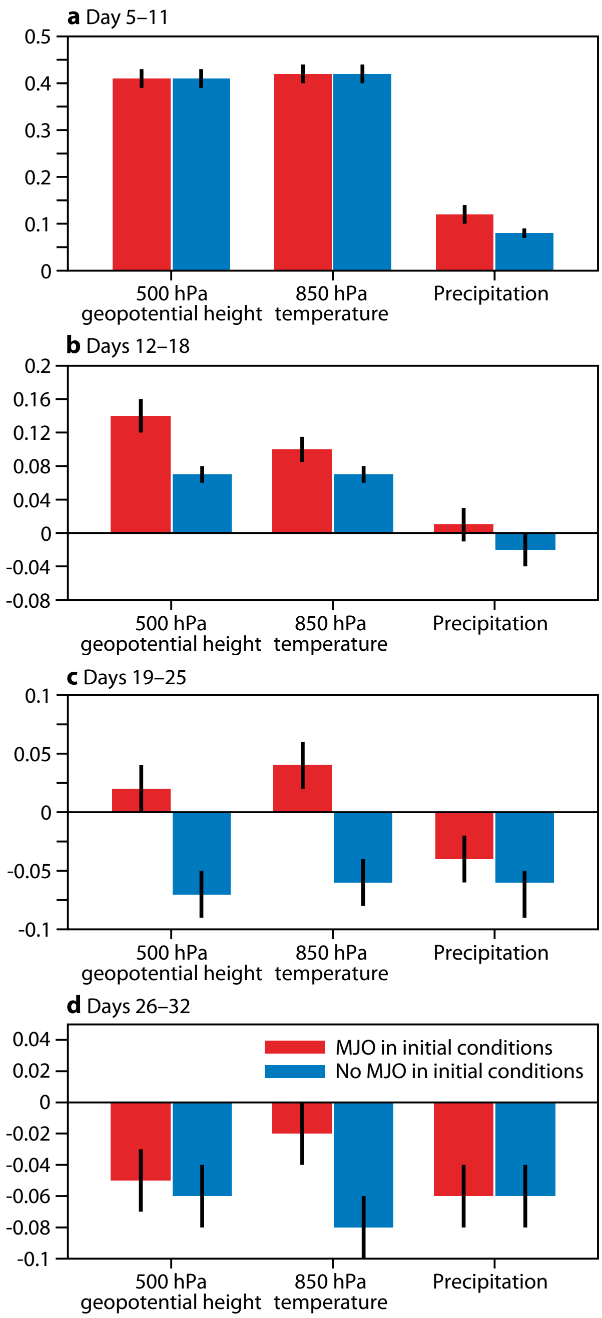


Figure 6 Brier Skill Scores of 500 hPa geopotential height, 850 hPa temperature and precipitation for days 5–11, 12–18, 19–25 and 26–32. The red bars show the scores obtained when there is an MJO in the initial conditions. The blue bars show the scores when there is no MJO in the initial conditions (amplitude of the MJO index less than 1 standard deviation). A 10,000 bootstrap re-sampling procedure has been applied to compute the 5% level of confidence (vertical black lines).

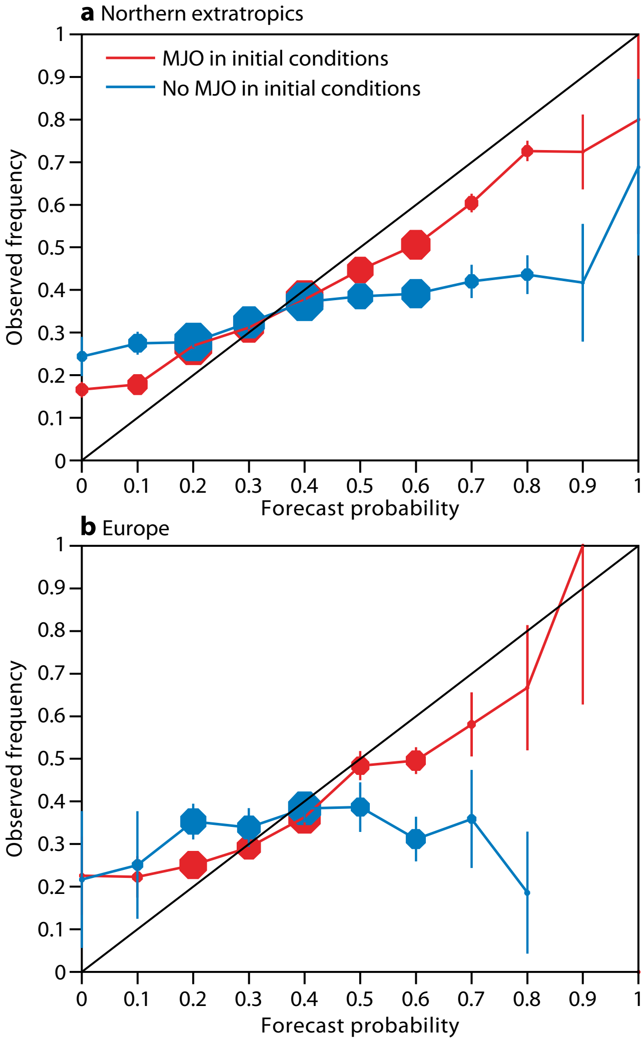


Figure 7 Reliability diagrams of the probability that the 850-hPa temperature is in the upper tercile for the days 19–25 for (a) northern extratropics and (b) Europe. The red (blue) curves represent the reliability diagram obtained with all the cases with an MJO (no MJO) in the initial conditions. The volume of the symbols is proportional to the number of cases in the probability bin. A 10,000 bootstrap re-sampling procedure has been applied to compute the 5% level of confidence (vertical lines). The numbers in the figures indicate the Brier Skill Scores. Only land points have been included in the calculation of the reliability diagram and the Brier Skill Scores.

predictability). However, the MJO simulated in this set of hindcasts tends to be too slow and has often difficulties crossing the maritime continent. Statistically, the percentage of MJO events which do not cross the maritime continent is higher in the model than in observations. Of all those problems, the too slow propagation of the MJO is probably the most serious issue for the ECMWF's current monthly forecasts, particularly for the longer time range (days 19–25 and 26–32). This problem and the difficulty of the MJO crossing the maritime continent may cause the forecast to be out of phase with observations after twenty days in some occasions.

In the extratropics, the model simulates an increase in the probability of a positive NAO following an MJO in phase 3 (enhanced convection over the eastern Indian Ocean) and a decrease following an MJO in phase 6 (suppressed convection over the eastern Indian Ocean). Overall, the model teleconnections in the extratropics are generally consistent with ERA-Interim, but they tend to be too weak over Europe.

The impact of the MJO on the extratropical forecast skill was investigated. Results show that the MJO has no significant impact for days 5–11, except for precipitation but has a positive impact for days 12–18, 19–25 and 26–32. This impact is statistically significant for days 12–18 and 19–25. The impact of the MJO is particularly important for days 19–25 with the model showing almost no skill at all when there is no MJO in the initial conditions, but the day 19–25 probabilistic forecasts become reliable and skilful when there is an MJO in the initial conditions. This suggests that it is possible to know *a priori* if a monthly forecast will be reliable or not. Those results also suggest that improvements in the representation of the MJO in the ECMWF model are likely to lead to improved monthly forecast skill.

Woolnough et al. (2007) have shown that coupling the atmospheric model to a high vertical resolution ocean mixed-layer model can impact the speed of the simulated MJO events through its impact on the diurnal cycle and intraseasonal variability of sea-surface temperature. Therefore coupling the IFS to a high vertical resolution ocean model, as in *Woolnough et al.* (2007), may help the atmospheric model to produce faster MJO events, which could lead to more realistic MJO teleconnections and enhanced skill in the extratropics.

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Use of the ECMWF EPS for ALADIN-LAEF

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GEERT SMET, FLORIAN WEIDLE

THE CHAOTIC and highly non-linear nature of the atmosphere means that small errors in initial conditions or in the model itself can grow rapidly and become large over time, even in a matter of hours. Most NWP centres have applied the ensemble prediction technique as the dynamical way of accounting for the forecast uncertainty. The optimal design of an ensemble prediction system (EPS) strongly depends on the quantification of uncertainties due to errors in initial conditions, model formulation and physical parametrizations. Compared to global EPSs, additional challenges posed for a skilful LAMEPS (limited area model ensemble prediction system) include, for example, the problem of quantifying the uncertainties due to errors in lateral boundary conditions.

In recent years, several LAMEPSs have been developed and run operationally in the Member States. All of them uses dynamical downscaling of the ECMWF EPS for generating atmospheric initial condition perturbations, though hardly any use methods for perturbing the initial state of the land surface. Here are some examples of the use of the ECMWF EPS.

- The perturbations for the LAMEPS at the Norwegian Meteorological Institute are provided from a version of the ECMWF EPS with dry targeted Singular Vectors (SVs) over northwestern Europe.
- COSMO-LEPS (Consortium for Small scale Modelling Limited-area Ensemble Prediction System) follows a strategy of using representative members to downscale the ECMWF EPS; the representative members are chosen from clusters of ECMWF EPS forecasts.
- The experimental multi-model system called GLAMEPS (Grand LAMEPS) being developed by HIRLAM and ALADIN institutes employs the downscaling of the ECMWF EPS.

At ZAMG (ZentralAnstalt für Meteorologie und Geodynamik), the Central European regional ensemble system ALADIN-LAEF (Limited Area Ensemble Forecasting) has been developed – see *Wang et al.* (2011) for more information. This initiative has been part of the LACE (Limited Area Modelling in Central Europe) international project. ALADIN-LAEF has run quasi-operationally since 2007 and now employs the following.

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Figure 1 ALADIN-LAEF domain and model topography. The inner area bounded in red is the domain used for verification.

- Blending method for dealing with the atmospheric initial condition perturbations, which combines the large-scale forecast uncertainty predicted by a global EPS with the small-scale perturbations resolved by a limited area model (LAM).
- Non-Cycling Surface Breeding (NCSB) technique for generating initial surface condition perturbations.

Also different ALADIN physics configurations are used for dealing with the uncertainties due to model errors.

We verified the performance of ALADIN-LAEF over a two summer months during the MAP (Mesoscale Alpine Project) D-PHASE Operations Period in 2007 (*Rotach et al.*, 2009). The results show that ALADIN-LAEF compares favourably with the ECMWF EPS for most surface weather parameters (*Wang*, 2010).

In this article we briefly describe the use of ECMWF EPS perturbations in the Blending and NCSB techniques for the quantification of ALADIN-LAEF atmospheric initial and surface condition perturbations. We also present some verification results. Since the main products of ALADIN-LAEF are the forecasts of surface weather variables, we focus on the verification of variables such as precipitation, 2-metre temperature and 10-metre wind.

Configuration of ALADIN-LAEF

The core of ALADIN-LAEF is based on the operational limited-area model run at ZAMG with a horizontal resolution of 18 km and 37 vertical levels (see *Wang et al.*, 2006 for details about the governing equations, physical parametrization and numerical algorithms). Figure 1 shows the ALADIN-LAEF integration domain which covers much of Europe and a large part of the Atlantic.

There are 17 ensemble members in ALADIN-LAEF, of which the first 16 members are perturbed. Their lateral boundary condition (LBC) perturbations are provided by the first 16 members of the ECWMF EPS (*Leutbecher & Palmer*, 2008). The 17th ALADIN-LAEF member contains ICs (initial conditions) and LBCs from the ECMWF EPS control forecast.

Blending method

For perturbing atmospheric initial conditions in a LAMEPS, there are at least three key requirements:

- The LAM perturbations should be consistent with the perturbation coming through the lateral boundary.
- The scale of the perturbation should be in accordance with the scales of variability resolved by the model.
- The IC perturbations should be effective immediately from the initial time.

The dynamical downscaling of ensembles from a global model for generating atmospheric initial perturbations, which is used in most operational LAMEPSs, is incapable of meeting the second and third of these requirements. An alternative is the Breeding technique that, when applied to LAMEPS, creates the perturbations including, in principle, all scales resolved by the LAM. It has been successfully implemented in the SREF (Short Range Ensemble Forecasting) system at NCEP (National Centers for Environmental Prediction) for atmospheric initial perturbations while the ensemble of LBCs required for SREP is obtained from the global ET (Ensemble Transform) ensemble.

For ALADIN-LAEF the natural choice for the LBC perturbations are those from ECMWF EPS forecasts. This is not only because of the similarity in model physics in the ECMWF EPS and ALADIN, but also the quality of ECMWF EPS forecasts and their operational availability at ZAMG.

The atmospheric initial perturbations for the ECMWF EPS are generated using the Singular Vector (SV) technique (*Buizza & Palmer*, 1995). This is an appropriate method for medium-range forecasting, but it is still unclear whether it is appropriate for use in LAMEPS. Research on LAM SVs is in a very early stage; the design of the SVs is surely not optimal for a short-range ensemble, which has to quantify the uncertainties in the analysis. Furthermore, the SV technique is computationally expensive.

To make use of ECMWF EPS perturbations, we use Blending for generating atmospheric initial perturbations for the ALADIN-LAEF. Blending combines the large-scale uncertainty generated by the ECMWF SVs with the small-scale uncertainty generated by Breeding with the ALADIN model (ALADIN-Breeding). A combined perturbation has the feature that its large-scale part is from ECMWF SVs, and the small-scale part is from ALADIN-Breeding.

We believe that the new perturbations meet the three key requirements for LAMEPS IC perturbations. Through ALADIN-Breeding the perturbations provided by Blending attempt to give the best estimate of the actual errors in the initial analysis based on the past information about the flow, whereas the SVs contain future information of possible forecast error. On the large scale, the atmospheric initial perturbations are now consistent with the LBC perturbations, with both of them being based on the ECMWF SV perturbations. The small-scale uncertainty in the analysis is more detailed and accurate due to the higher resolution and more balanced orographic/surface forcing of the ALADIN-Breeding. This should be a better representation of the uncertainties than interpolated large-scale perturbations from the global model.

Blending is a spectral technique using a standard digital filter (in our case a non-recursive low-pass Dolph-Chebyshev digital filter). The core principle is to apply a digital filter to the perturbed initial states from the ECMWF SVs and ALADIN-Breeding on the original ALADIN grid but at a lower spectral resolution. This resolution is defined by the blending ratio, which depends on the scales that can be analyzed by the driving model rather than on the ones it can predict. The difference between those filtered fields represents a large-scale increment. This increment contains almost pure low-frequency perturbation information, which is then added to the original high-frequency signal of the perturbed high-resolution LAM analysis (i.e. to the ALADIN-Breeding analysis). The combination (blending) of both spectra is performed in the transition zone. The detailed description and discussion of Blending, in particular the technical implementation in ALADIN-LAEF, are given in *Bellus et al.* (2011).

In the implementation of Blending, the ALADIN-Breeding perturbations are generated in sets of positive and negative pairs around a control analysis. The ALADIN-Breeding has the following features: (a) cold start, (b) 12-hour cycle, (c) two-sided and centred around the control analysis, (d) wind components, temperature, moisture and surface pressure perturbed at each level and model grid-point, and (e) no regional variation in rescaling.

Evaluation of Blending

To evaluate the Blending, comparisons with downscaling and ALADIN-Breeding have been carried out – the set-up of the comparison is described in Table 1. Note that in the experiment we did not apply the land surface perturbations and the multi-physics for the model perturbations in ALADIN-LAEF. This makes it possible to have a clean comparison between Blending, Downscaling and Breeding.

The ALADIN-LAEF forecasts started at 00 UTC and run for 54 hours. Observations are used for the verification of surface weather variables. The verification is performed at the obser-

Experiment	Upper-air initial perturbation
Downscaling	Downscaling of ECMWF EPS
Breeding	ALADIN-Breeding
Blending	Blending ECMWF EPS with ALADIN-Breeding

Table 1 Description of experiments 'Downscaling', 'Breeding' and 'Blending' used to evaluate the Blending technique. ALADIN-LAEF is configured with initial perturbations generated by using downscaling, Breeding and Blending. The same lateral boundary perturbations from the ECMWF EPS forecast and the same land surface analysis from ECMWF EPS control are applied in those experiments. No multi-physics is in use in the experiments.

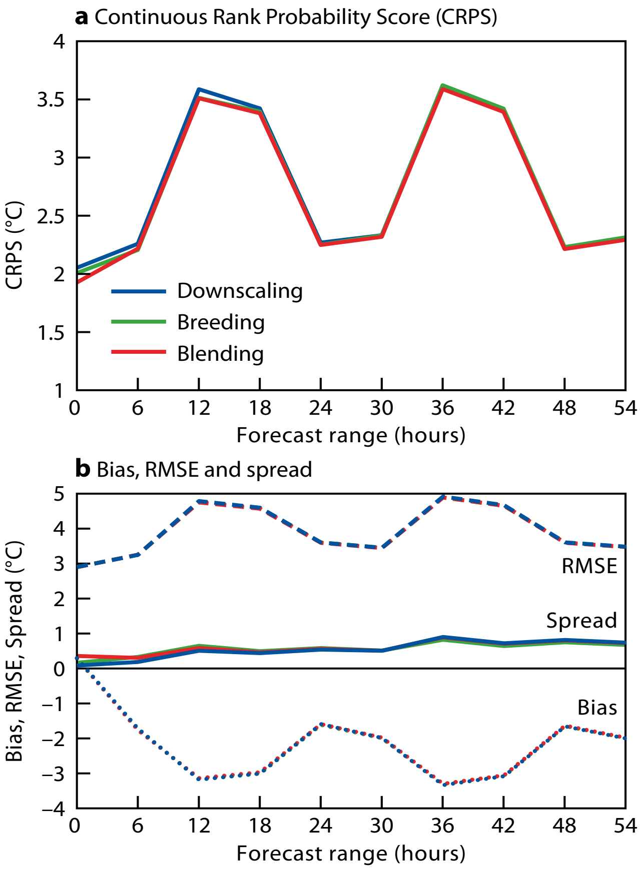

Figure 2 Verification of 2-metre temperature forecasts from ALADIN-LAEF for experiments 'Downscaling', 'Breeding' and 'Blending' using (a) Continuous Rank Probability Score and (b) Bias, RMSE of the ensemble mean and ensemble spread. Scores are averaged over the verification domain (see Figure 1) for the period from 20 June to 20 August 2007.

vation location so we interpolated forecast values to the observation site for smoothly varying fields, such as 2-metre temperature, 10-metre wind speed and surface pressure. For precipitation, which has strong spatial gradients, the observation is matched to the nearest grid point. No observation uncertainties were taken into account in the verification. The verification is performed for a limited area of the forecast domain over Central Europe (see Figure 1) for which 1,219 SYNOP stations were used in this study.

Figures 2 and 3 show the comparison of Blending, downscaling and ALADIN-Breeding for ALADIN-LAEF 2-metre temperature and 12-hours accumulated precipitation forecasts for a two-month period. Regarding the probabilistic score measured by the CRPS (Continuous Rank Probability Score), the benefit of using Blending is quite clear, particularly in the first 24 hours of the forecast; the positive impact of Blending can also be seen in the growth of ensemble spread, which is larger for Blending than the spread for downscaling and ALADIN-Breeding. Downscaling underperforms in the first 24 hours. This demonstrates that downscaling of ECMWF SV perturbations is not optimally designed for the early forecast range. We notice that Blending does not improve the RMSE (Root Mean Square Error) of ensemble mean of the 2-metre temperature.

In the later forecast period downscaling performs the same as Blending; this is obviously due to the impact of the LBC perturbations. Blending has the same large-scale perturbations as in downscaling, which are consistent with the LBC perturbations. ALADIN-Breeding initializes a larger spread in the early hours, but the growth of perturbations is slower than Blending and downscaling. The generation of perturbations by ALADIN-Breeding conflicts somehow with the LBC perturbations from the ECMWF SVs – this impact becomes clear after 30 hours into the forecast.

From Figure 2b we see that the introduction of Blending has little impact on improving the bias of the 2-metre temperature forecast. It is remarkable that there is a strong cold bias in the ALADIN-LAEF temperature forecast and a large error in the surface initial conditions. This is largely due to the different surface parametrization schemes used in the ALADIN and ECMWF models. It is this inconsistency, in particular in the soil moisture and soil temperature, that introduces a strong cold bias in the 2-metre temperature. The deficiency can be reduced to some extent if the model surface from ECMWF is replaced by the one from the ARPEGE surface analysis.

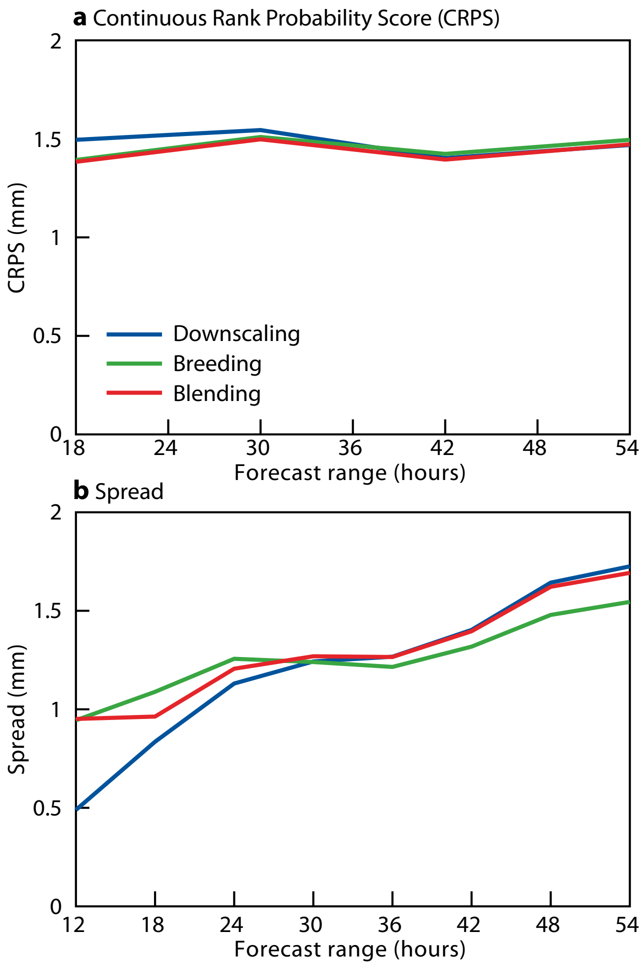

Figure 3 Verification of 12-hour accumulated precipitation forecasts from ALADIN-LAEF for experiments 'Downscaling', 'Breeding' and 'Blending' using (a) Continuous Rank Probability Score and (b) ensemble spread. Scores are averaged over the verification domain (see Figure 1) for the period from 20 June to 20 August 2007.

Non-Cycling Surface Breeding (NCSB)

Initial surface perturbations are introduced in ALADIN-LAEF by applying NCSB (*Wang et al.*, 2010; *Smet*, 2009). It uses short-range surface forecasts driven by a perturbed atmosphere and a pseudo-Breeding method. As with Breeding, the simulation of growing error is started by introducing perturbations in the atmosphere. The perturbed atmosphere is not random, but downscaled from a global EPS. The regional model is then integrated up to 6 or 12 hours with the perturbed atmospheric initial conditions and LBCs, but the same initial surface state. The difference between the 6- or 12-hour surface forecasts and the corresponding new surface analyses is rescaled, and then added to the corresponding new surface analysis. This pseudo-breeding run is restarted every time with a new perturbation of the atmosphere obtained from the global EPS. This non-cycling feature ensures that the surface initial perturbations in LAMEPS are only driven by the atmospheric perturbations from the global EPS. In a cycling mode, in which the impact of the short-range LAM forecast is put into the surface initial conditions continuously, model-drifting problems will be very probably introduced after several months.

Implementation of NCSB

In the implementation of NCSB in ALADIN-LAEF, the perturbed atmospheric initial conditions are downscaled from the first 16 initial perturbations of the ECMWF EPS. Also LBC perturbations are obtained from the forecasts of the corresponding ECMWF EPS members. The multi-physics approach is applied for the quantification of model uncertainty. When coupling ALADIN with ECMWF, the different land surface parametrizations in the ECMWF model and ARPEGE/ALADIN cause inconsistencies (e.g. in terms of the cold bias in the forecast). This deficiency can be reduced to some extent if the model surface analysis from ECMWF is replaced by the one from the ARPEGE surface analysis.

The use of ECMWF EPS perturbation for generating surface initial perturbations in ALADIN-LAEF valid at time t can be summarized as follows.

- IC perturbations valid at time t-12 h from the ECMWF EPS are downscaled to ALADIN-LAEF.
- The corresponding ECMWF EPS forecasts are used to provide the LBC perturbations of ALADIN-LAEF.
- The ECMWF surface is replaced with the ARPEGE surface in the initial conditions at time t-12 h.

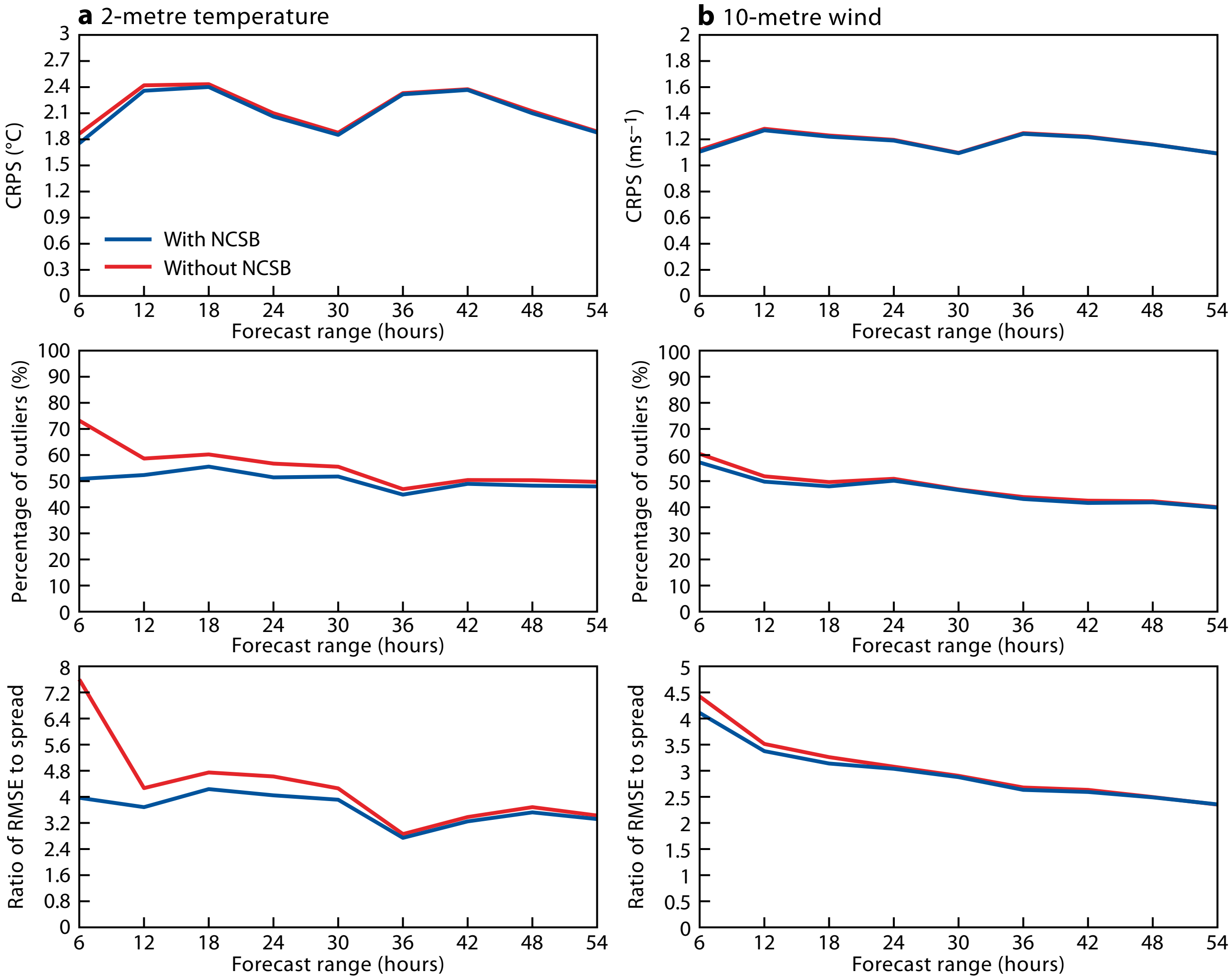

Figure 4 Verification of (a) 2-metre temperature forecasts and (b) 10-metre wind forecasts from ALADIN-LAEF for experiments ‘With NCSB’ and ‘Without NCSB’ using Continuous Rank Probability Score (left), percentage of outliers (centre) and ratio between RMSE and ensemble spread (right). Scores are averaged over the verification domain (see Figure 1) for the period from 20 June to 20 July 2007.

After ECMWF EPS perturbations are prepared for NCSB, ALADIN-LAEF members are started at time t-12 h and are then integrated up to 12 hours with the multi-physics option. The resulting 12-hour ALADIN-LAEF surface forecasts, valid at time t, are considered as perturbed surface conditions; these are similar to those using Breeding.

Performance of NCSB

We now consider the performance of NCSB. The experiments carried out make a comparison between ALADIN-LAEF with and without NCSB. All the experiments have the same upper-air initial perturbations (downscaling of ECMWF EPS), lateral boundary perturbations (coupling with ECMWF EPS), model perturbations (multi-physics) and surface analysis (ARPEGE).

The superior performance of using NCSB can be seen in Figure 4. This shows the verification in terms of CRPS, outlier statistics, and the ratio between RMSE of the ensemble mean and ensemble spread for 2-metre temperature and 10-metre wind forecasts from ALADIN-LAEF with and without NCSB. The outperformance of NCSB is more evident in the early forecast range up to 24 hours. A small but positive impact on reliability and resolution from the CRPS score are obtained for NCSB 2-metre temperature forecasts. Fewer outliers and better ratio between the error of ensemble mean and ensemble spread of the NCSB 2-metre temperature and 10-metre wind forecasts are an indication of improved statistical consistency with NCSB.

It is noted that the CRPS of surface weather variables does not increase significantly with the forecast lead-time as it does for the upper-air weather variables. This indicates the difficulty the ALADIN model has in predicting the surface weather variables in the short range with high skill.

Conclusions and future developments

The use of ECMWF EPS perturbations in ALADIN-LAEF can be summarized as follows:

- ECMWF EPS large-scale perturbations are combined with small-scale perturbations from ALADIN-Breeding by using Blending for the atmospheric initial perturbations in ALADIN-LAEF.
- ECMWF EPS initial perturbations are used to drive ALADIN-LAEF surface initial perturbations by using the NCSB technique.
- ECMWF EPS forecasts provide the LBC perturbations for ALADIN-LAEF.

Verification has shown the benefits of use of ECMWF EPS perturbations in ALADIN-LAEF with Blending and NCSB, with the impact being particularly remarkable in the 24-hour forecast. These benefits are due to (a) the introduction of surface initial perturbations driven by the ECMWF EPS atmospheric perturbations in NCSB, and (b) the sound large-scale perturbations from the ECMWF EPS and the consistency between the IC and LBC perturbations.

Future work will focus on better representation of uncertainties related to the model surface physics (e.g. introduction of stochastic surface physics in the ALADIN-LAEF). Experiments on the use of ETKF/ET (Ensemble Transform Kalman Filter/ Ensemble Transform) instead of breeding for generating the small-scale perturbation in Blending will also be carried out.

Whilst conducting the experiments presented in this work, two main upgrades to the ECMWF EPS have been implemented. One is the increase of horizontal resolution from T399L62 to T699L62 and the other is the introduction of EDA – the ensemble of data assimilations (*Buizza et al.*, 2010; *Isaksen et al.*, 2010). We have put much effort into the technical adaptation of ALADIN-LAEF to take account of those changes to the ECMWF EPS. Consequently, some statements made earlier concerning the nature of the SVs in the Blending method are no longer valid as a result of the introduction of EDA. It is conceivable that the benefit of the blended perturbation technique is potentially reduced, as the EDA perturbations should adequately represent initial uncertainty from the initial time in contrast to using SVs. The possible impact of those upgrades on the performance of ALADIN-LAEF, particularly its ability to add value to the ECMWF EPS, will be investigated in the near future.

FURTHER READING

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Metview 4 – ECMWF's latest generation meteorological workstation

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VERSION 4 builds on the flexible and proven modular structure of previous versions of the Metview meteorological workstation. The system continues to offer an interactive user interface for users to combine and process data from various sources with visual definitions to generate complex meteorological plots. Besides the interactive user interface, Metview offers a very powerful batch system through its macro programming language. An article in the previous *ECMWF Newsletter* (No. 125, Autumn 2010, 30–32) described the Macro language changes for version 4 in more detail.

This article provides an overview of the new features of Metview 4, along with the main differences from Metview 3 from the user's point of view.

Information about how to run Metview 4 is given in Box A.

How to run Metview 4 — A

At ECMWF, version 4 is available internally on Linux workstations and clusters, and on the Ecgate server, by using the command metview4. We recommend that external users who run Metview 3 also install Metview 4 in parallel until they are happy that the new version can replace their current Metview installation.

Motivation for Metview 4

Thanks to its service-oriented architecture, Metview's functionality is divided into separate modules which work together, but can be upgraded individually.

Metview makes use of a number of external packages to process and visualise data. In recent years some of these libraries have been replaced, for example GRIBEX with GRIB_API and MAGICS 6 with Magics++. Metview has undergone some changes to cater for this. Other, more general, third-party libraries such as Motif have ceased development and are in urgent need of replacements. Consequently Motif is being replaced incrementally within Metview by Qt.

Metview 4's use of GRIB_API throughout provides full compatibility with GRIB editions 1 and 2. In addition the support for data in NetCDF format, especially conforming to the CF convention, has been improved. Through the use of Magics++ for the visualisation and a new framework for user interfaces, Metview now provides more interactive functionality within its Display Window. Together with other improvements, Metview can now be built as a 64-bit application, handle larger data sets and provide more user interactivity.

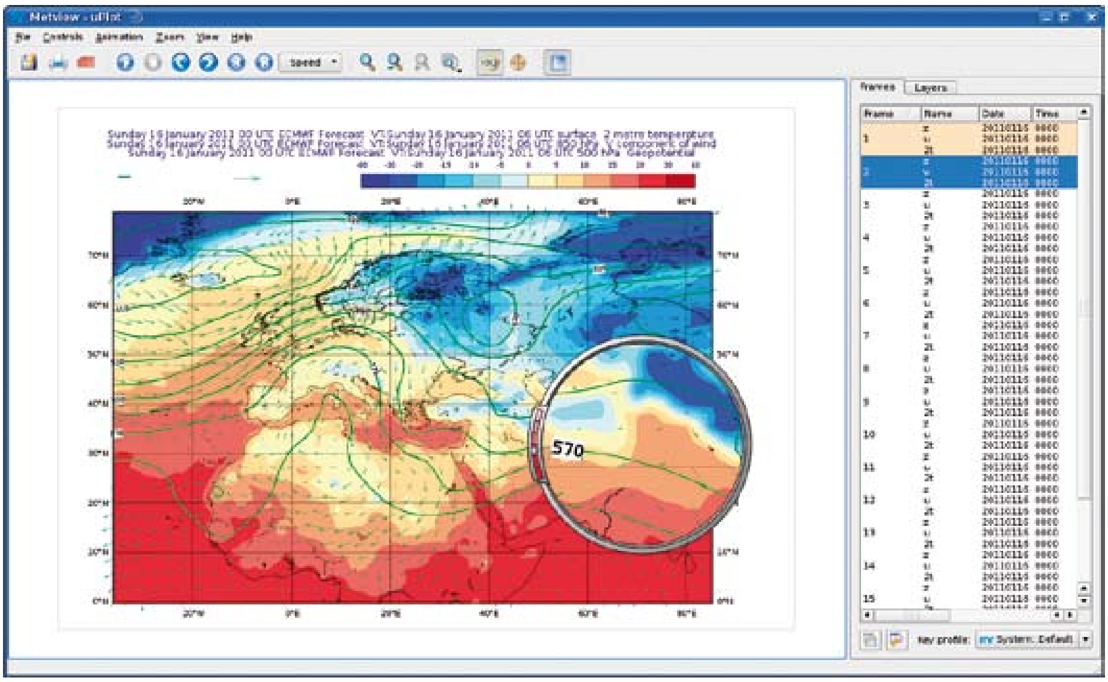

Figure 1 The new visualisation module of Metview 4. Icons on the top let the user interact with the display, while the menu on the right enables browsing through frames and layers.

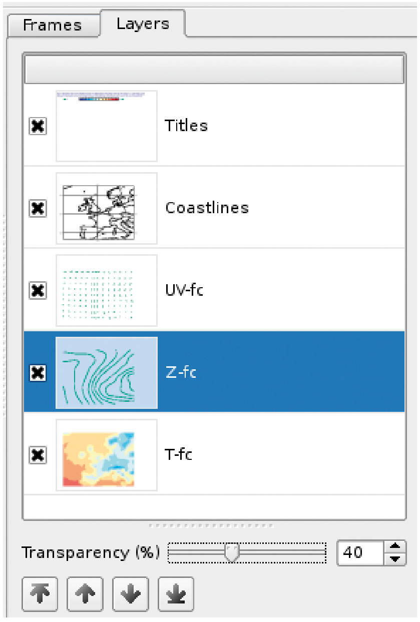

Figure 2 The Layers tab allows the user to reorder the plot layers (either using the buttons or by dragging and dropping) and set the transparency of each.

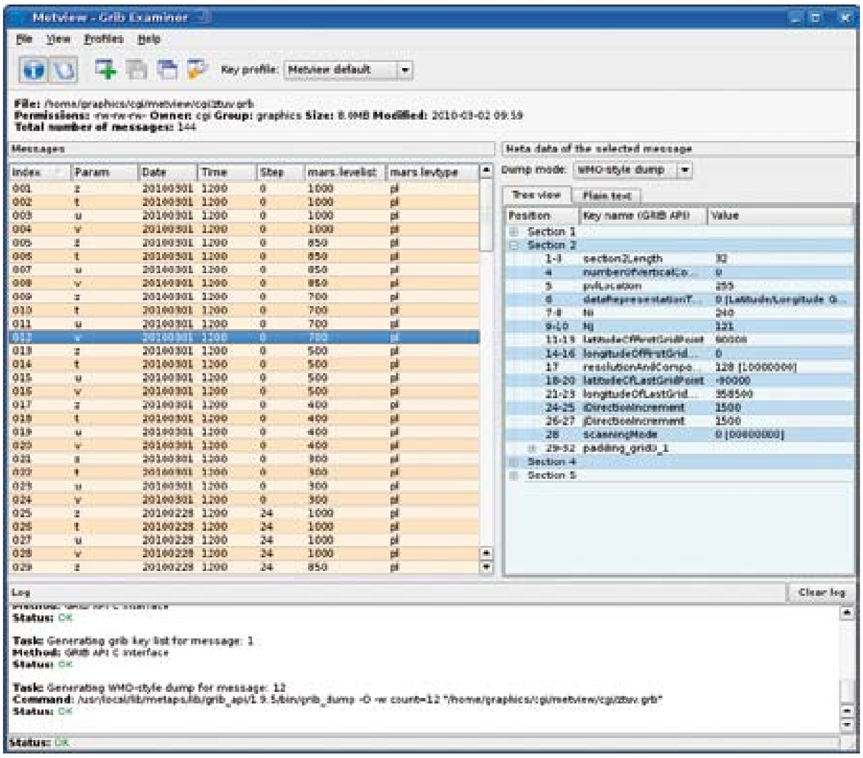

Figure 3 The GRIB examiner in Metview 4 offers a powerful way to inspect data. Meta-data can be displayed in many user-configurable ways from an intuitive interface.

New Display Window

The main visible change for interactive users of Metview is the newly designed display module, called uPlot (Figure 1). The module has been re-written to take advantage of Magics++ for its plots. Its toolbars can be removed or detached and docked elsewhere on the window. Also its panes can be resized. These settings are remembered each time you close a Display Window.

By default the new control area is on the right of the Display Window. This area is subdivided into tabs and allows the user to easily browse the data and alter the plot.

All the plots are listed in the Frames tab; this panel allows users to step through all the plots. Pressing the left and right cursor keys also moves between plots. Each column provides a piece of meta-data about the fields (queried through keys) – clicking on the column headings sorts the frames. The keys can be grouped into a user-configurable 'key profile', and multiple profiles can be set up.

Beside the Frames tab is the Layers tab (Figure 2), providing a quick way to toggle plot layers on or off. The Layers tab can also be used to alter the transparency of any layer, although when the plot is saved, not all graphics file formats support transparency. A user should imagine looking down through the layers, with the top layer closest to their eye.

The magnifying glass provides a way for an analyst to examine small numbers and symbols. On its left-hand side the control adjusts the magnification scale. The glass can be resized and moved with the mouse. Various options are available to zoom the display and a user can select a previous view in the zoom history.

The Display Window also has, among other features, animation controls, an anti-aliasing option for smoothing the plots, the ability to send a plot to a printer or file (multiple output formats may be generated in one go), and a button to create a macro that will automatically re-create the plot.

Data examiners

To allow analysts and researchers to examine meteorological data, Metview 4 provides new, more powerful, data examiners. In addition to the existing NetCDF and geopoints examiners, new tools for inspecting GRIB and BUFR data are available. To examine a GRIB file, right-click on its icon and select 'examine' from the context menu. The GRIB examiner will appear, as illustrated in Figure 3.

The left-hand pane contains a list of all the messages (fields) in the GRIB file; when one is selected, the meta-data

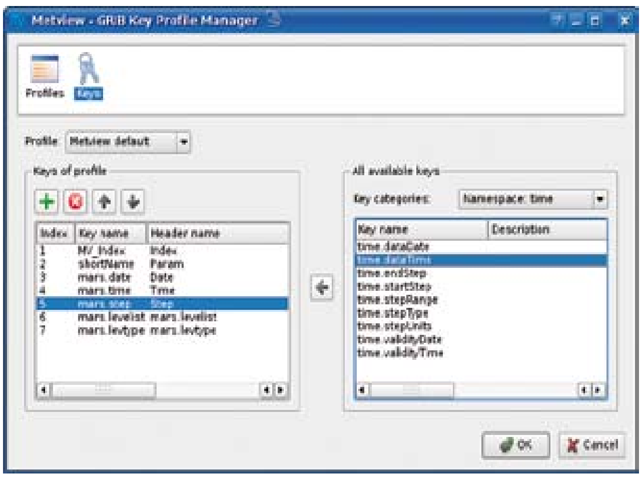

Figure 4 The GRIB examiner can be configured to show different user-defined selections of keys.

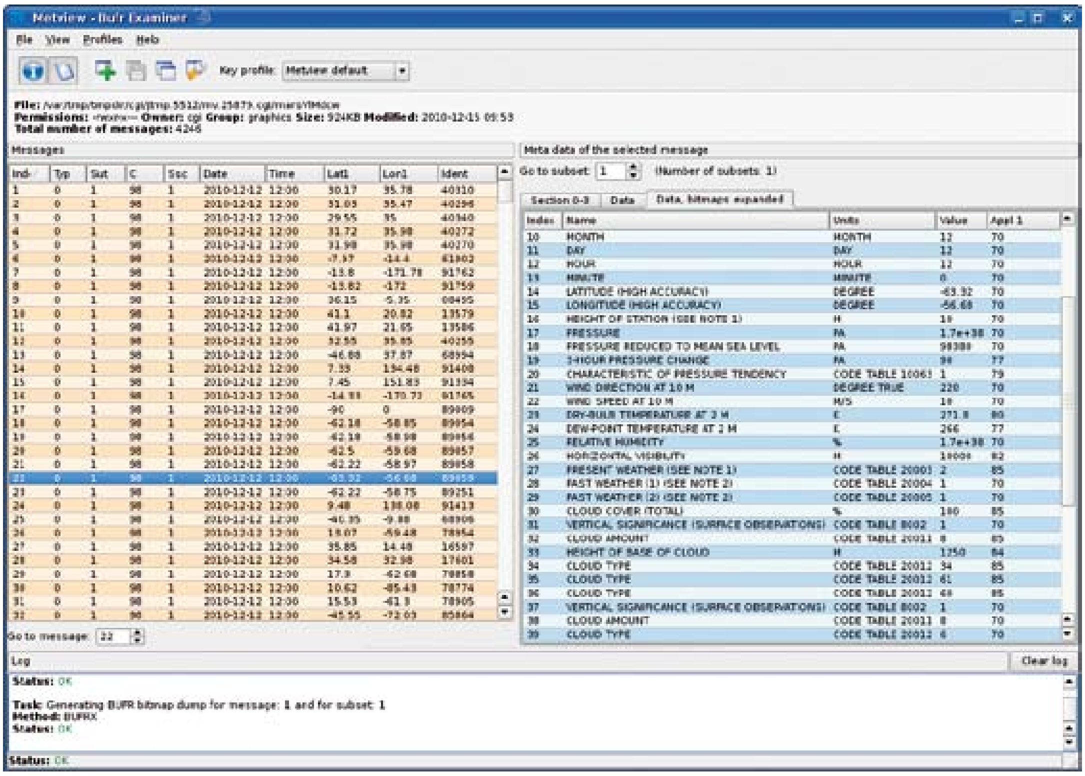

Figure 5 The BUFR examiner has a similar look and feel to the GRIB examiner, providing an easy and powerful way to inspect BUFR data.

on the right-hand-side is updated for that message. A number of options allow different ways of viewing the meta-data.

By clicking on the column headings in the messages pane the messages can be sorted. The columns represent GRIB_API keys, and can be configured using the buttons at the top, or from the Profiles menu – see Figure 4. Multiple key profiles can be set up and shared with the Display Window.

Internally, Metview's GRIB examiner uses both the `grib_dump` command and GRIB_API's programming interface to display the meta-data – the log window at the bottom will convey any error or warning messages to the user.

The BUFR examiner follows a similar design to the GRIB examiner and is shown in Figure 5.

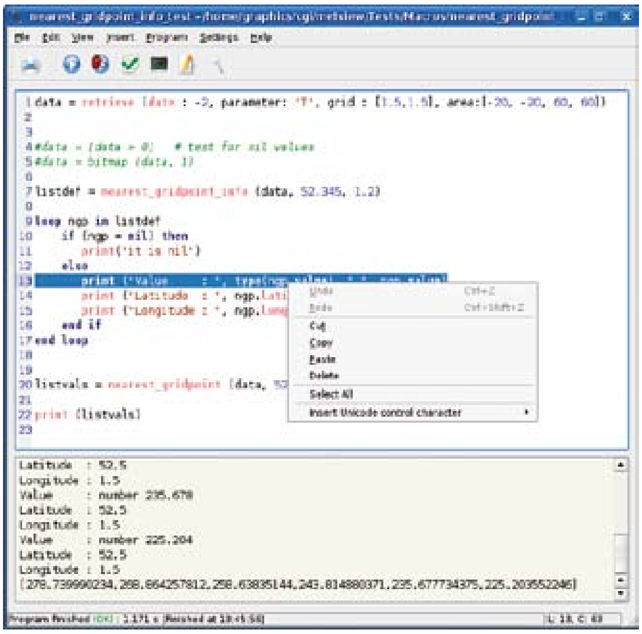

Figure 6 The new Macro Editor gives users powerful code editing facilities, allowing faster development cycles.

New Macro Editor

Analysts and researchers can leverage even more power out of Metview by using its macro scripting language. The new Macro Editor provides all the functionality of the previous one and more, and is much more user-friendly. One of the most powerful features of Metview's Macro Editor has been the ability to drop Metview icons into it, automatically generating the equivalent macro code. This facility has been retained, along with the ability to run macros directly from the editor.

This Macro Editor behaves more intuitively than the previous version with regards to copy & paste, and has an 'undo' feature. It also gives the user control over the use of tabs and spaces, and by default automatically indents text by the same amount as on the previous line (see the Settings menu). Line numbers can be displayed down the left-hand side and the Macro code is syntax highlighted (Figure 6). Some basic functionality is provided for interactive help: a list of available macro functions is provided, a set of pre-prepared skeleton code templates is available and 'icon functions' such as `pcont()` have a special help dialogue which lists the available parameters and values. The Macro Editor extends its power to the editing of MagML (the XML interface to Magics++) files, shell scripts and plain text files.

ODB Visualisation

Metview's interface to ECMWF's Observational DataBase (ODB) has been redesigned and now enables users to

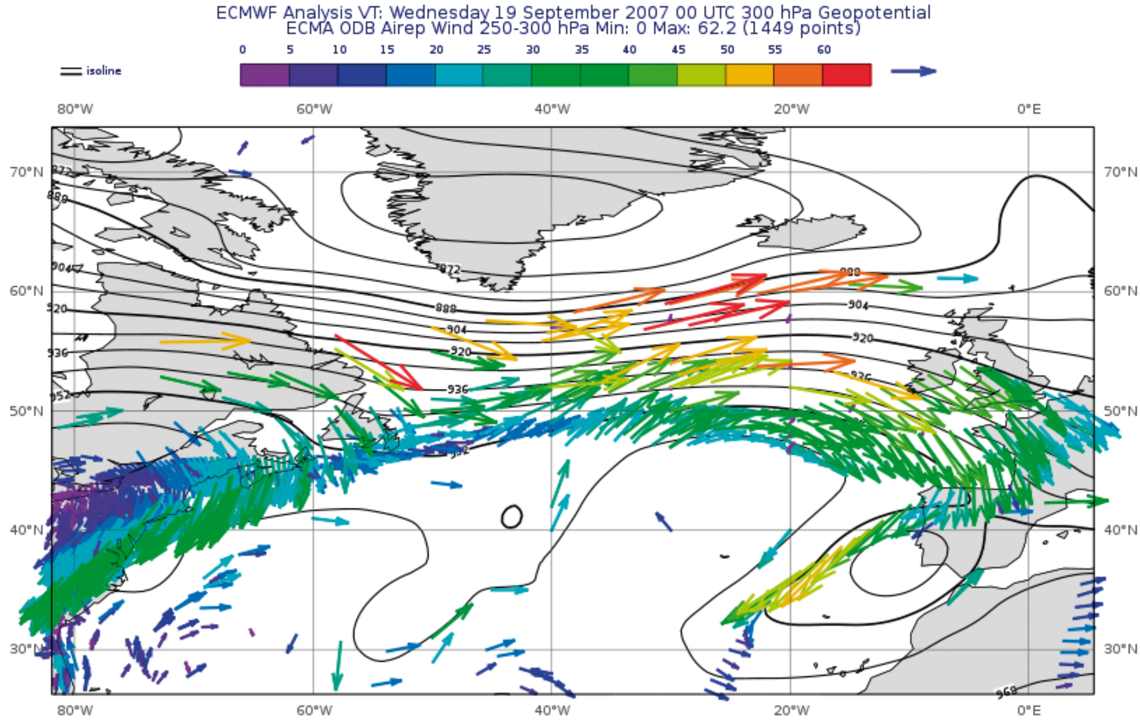

Figure 7 Wind data from an ODB overlaid with isolines of geopotential from GRIB data.

examine, filter, plot and process ODB data within the Metview environment. These actions are available both in the interactive user interface and in the Macro language.

The contents of ODB data can be inspected via the ODB examiner, which is the latest development of the new data examiners. Users can write and perform ODB/SQL queries and visualise the resulting data using the *ODB Manager* icon. This icon provides a quick and easy way to generate maps with symbol and wind plotting out of the ODB data. Both symbol and wind plotting in Metview 4 now benefit from the improved functionalities of Magics++: the most important novelty is that the colour palette can be automatically generated for the plots, just like it has been available for the *Contouring* icon. This feature makes ODB plot generation much easier.

ODB data can be overlaid with any other data types in Metview as shown in Figure 7.

Support for OGC web services

The Open Geospatial Consortium (OGC) defines a number of standards for serving and retrieving geospatial data over the web. One of these is the Web Map Service (WMS), which focuses on geographical maps. This server-oriented concept fits neatly into Metview's architecture and so a WMS client was developed for Metview 4. This allows users to overlay Metview charts with maps provided by other organisations. Figure 8 shows snapshots of how these WMS layers can be queried and how they look overlaid in the Display Window.

Work on Metview's OGC clients is still ongoing and ECMWF's Graphics Section is actively involved in the work of the MetOcean Domain Working Group of the OGC to promote the use of OGC standards within meteorology.

Other changes since Metview 3

One of the aims of Metview 4 is to utilise the new plotting features of Magics++. This requires many icons to be updated, specifically the visual definition icons such as *Contouring* and *Coastlines*. To avoid interfering with Metview 3's existing icons, Metview 4 defines a new set. These icons look the same as the old ones, but have some different parameters available. Metview 3's icons continue to work as normal (with some possible changes in behaviour), but they will appear slightly greyed out. Figure 9 shows this difference.

Metview 4 will not allow the direct creation of new instances of the 'old' icons, but the new ones can be found in the desktop drawers and in the New Icon desktop menu. From the point of view of macros, these icons have different icon-function names with the 'p' prefix replaced with an 'm'; instead of `pcoast()` we have `mcoast()` etc.

Although old icons will still work in Metview 4, users may wish to convert some of them to the new formats in order to use the new parameters available; this can be done with the icon editors. As an example, suppose there is a *Contouring* icon from Metview 3 which a user wishes to convert into a Metview 4 *Contouring* icon. In Metview 4, a new contour icon should first be created and opened for edit. The old icon is now dropped into the icon editor and the parameters that are valid in the new icon will be transferred; clicking the *Apply* button will save the new icon.

With the aim of allowing Metview 3 and Metview 4 to be run side-by-side, Metview 4 now stores the system settings in a new folder. Everything which was previously stored in the `~/metview/Metview` folder is now stored in `~/metview/System`. This includes default icons, icon templates, the contents of icon drawers and Metview's

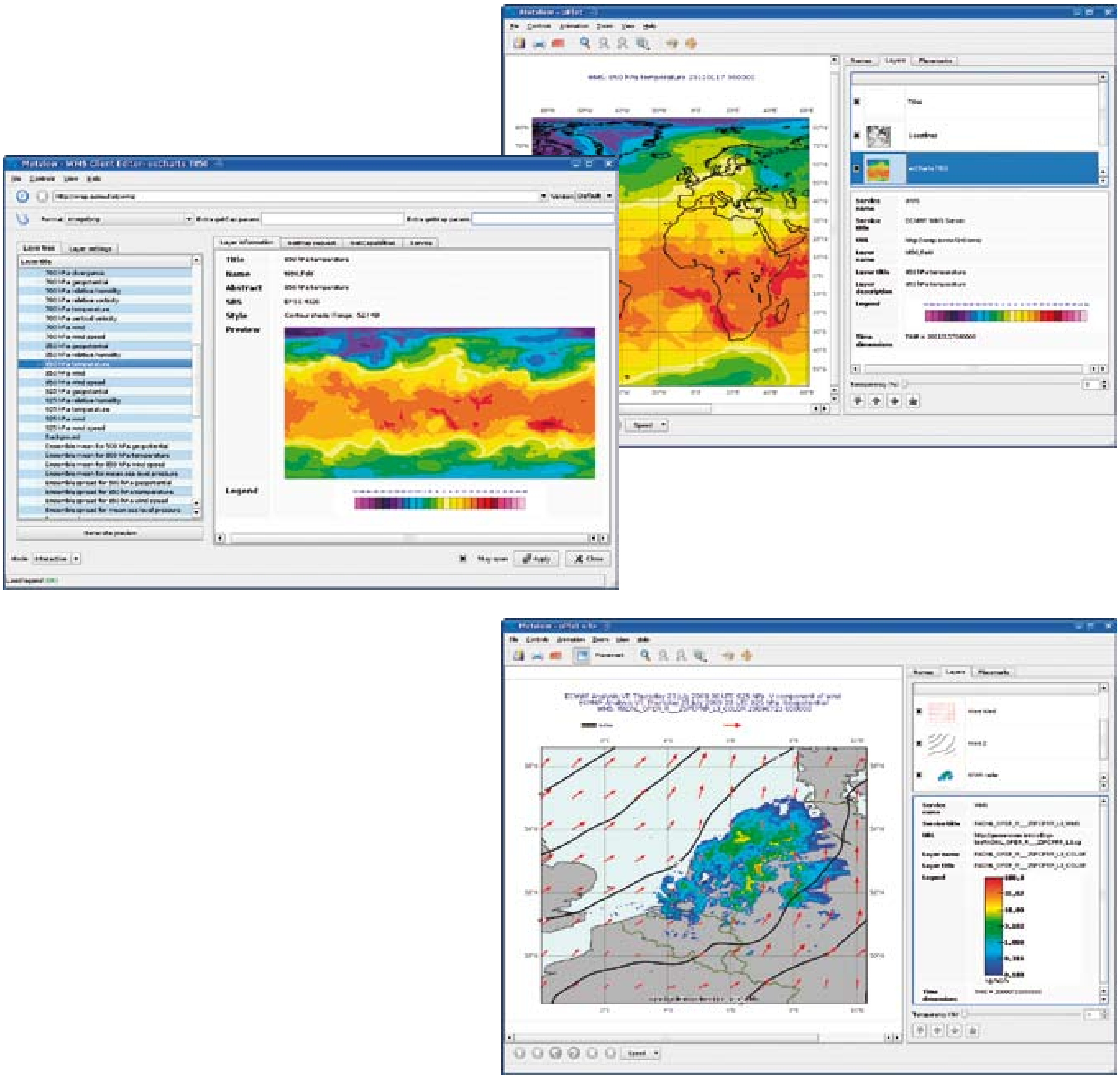

Figure 8 Interface to select layers provided by a WMS server, in this case ECMWF's ecCharts (left), and the resulting plot (top right). A further example shows radar data from KNMI's WMS server overlaid with forecast data from ECMWF's MARS archive (bottom right).

preferences. These will be initially set to the new defaults, so any user-created icon drawers or defaults set up in Metview 3 will not automatically be available (although old icons can still be copied across to the new folders).

Figure 9 A contour definition icon from Metview 3 and Metview 4.

Future developments

Metview 4 is still under active development. Layout options and overlay controls are being improved, making complex plots easier to produce. Also enhanced interactivity within icon editors will make Metview an even more powerful tool for data query.

Work is also in progress to make more use of the macro language's built-in `vector` data type. Many macro functions, for example `gridvals()`, currently return a long list of numbers; the `list` is a very useful general-purpose structure for storing elements of any type, but the `vector` is optimised for sets of numbers and the performance difference can be very significant. Metview 4 will introduce a much richer set of functionality for the `vector` data type, and functions which currently return a long `list` of numbers will now return a `vector`. Because the access of `list` and `vector` elements is identical, users should not have to change any code in order to take advantage of this.

User feedback is important for improving Metview, and users are encouraged to send their suggestions by e-mail to metview@ecmwf.int.

Green computing

SYLVIA BAYLIS

IN RECENT years, environmental awareness has increased but economic pressures have also led to organisations paying closer attention to the costs, especially energy costs, of IT operations. If energy use can be reduced, carbon emissions will reduce too, bringing environmental benefit. This is particularly relevant at centres such as ECMWF where supercomputers and their associated infrastructure have large electricity needs.

Given the need to minimise energy use, a study was undertaken with the aim of having an environmentally-friendly green supercomputer installation, with particular focus on energy efficiency and low carbon footprint. This will set the scene for the future when the power and cooling requirements of supercomputers may increase significantly which will pose major engineering and budgetary challenges.

Typical data centres use twice the electrical power required by their computer equipment, whereas ECMWF uses less than an additional 50% of energy for its infrastructure, on top of that used to power the IT equipment. This reflects the importance that was attached to increasing energy efficiency during computer and infrastructure procurements in previous years.

This article describes the measures that have been taken to reduce energy consumption in the computer building at ECMWF and considers some options for further reductions.

Where is the energy used?

The electricity used by a supercomputer of given computational power is fixed as far as the user is concerned. Manufacturers of supercomputer equipment have realised that they must limit the increase in electricity consumption of future hardware to be within electrical load limitations of major data centres and for running costs to be affordable. The infrastructure supporting a supercomputer consumes large amounts of electricity that contributes to the running costs of the data centre and to the carbon footprint.

To reduce the energy consumption in an individual data centre it is necessary to know how much power each piece of equipment uses. This leads to a requirement to measure both the total energy use of a data centre and how this is divided amongst the components. To find out how much electricity each piece of equipment uses, ECMWF installed power meters around the site. Half hourly readings are collected via a LAN and the central software logs all meter parameters: voltage, current, power factor, power and energy. The meters allow ECMWF to measure the electricity usage at power distribution unit level for computer equipment and at individual unit level for infrastructure such as chillers. Readings from the meters are recorded so that, over time, changes in the energy efficiency of the computer building can be assessed and quantified.

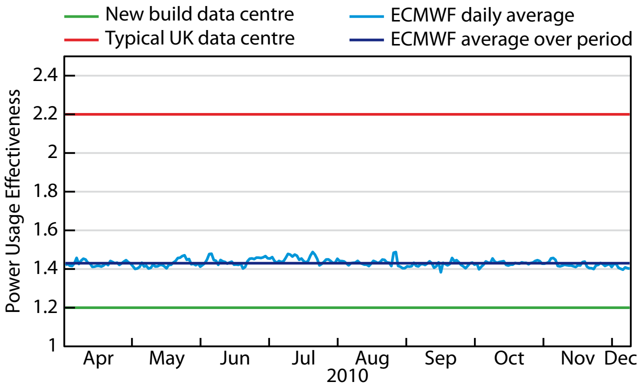

Figure 1 Values of the Power Usage Effectiveness (PUE) for the ECMWF computer building compared with a typical UK data centre and a new build data centre.

Comparing supercomputer data centres

In a typical data centre the overall energy consumption is determined by the infrastructure, computer and other hardware, software, and how the system is managed. To compare the energy efficiency of one computer centre with another there is a need for standard metrics. The measure that is used at ECMWF is the Power Usage Effectiveness (PUE) that measures the efficiency of the environment around the supercomputer. PUE is defined as the 'total power input to the data centre' divided by 'power input to computers'.

The PUE of a typical data centre is about 2 although there are data centres with PUEs exceeding 4. New data centres are being constructed with the aim of consuming only 10–20% additional energy for the infrastructure corresponding to a PUE in the range 1.1 to 1.2, but these centres are generally only suitable for standard IT servers and not supercomputers (see Box A). A small number are attempting to reduce their PUE further by re-using their waste heat. This is not possible for all data centres; it depends on the temperature of the waste heat, its location in relation to any potential users, and the viability of transporting the heat. Also, heat is produced all year but might not be wanted by the users in summer (e.g. for district heating systems).

ECMWF Power Usage Effectiveness

ECMWF has been measuring its energy consumption since spring 2010 to calculate its PUE for the computer building. The power input to the computer building is calculated by subtracting the electricity consumed by the two office buildings and the conference building from the total electricity consumption for the site. This takes into account all losses within the main power distribution equipment (i.e. transformers and Uninterruptible Power Supply (UPS) systems). As the power input to the computers is known, the PUE can be determined. There is not sufficient sub-metering to enable small loads such as street lighting and ancillary buildings to be quantified.

ECMWF calculates PUE every 30 minutes from the half-hourly consumption data provided by its electricity supplier, and half-hourly data obtained from power metering equipment installed throughout the site. Averages for a day, week and month are then produced based on the half-hourly PUE figures. The intention is to build a rolling average over time to obtain the annual average for the computer building. Analysis of the data shows that the PUE of the computer building is about 1.45 (see Figure 1), with the computer building extension, where there are few non-supercomputer racks, having a lower PUE than the main computer hall. A ratio of 1.45 means that for every kilowatt of electricity used directly by the computer systems an additional 0.45 kW is attributed to the ancillary services, such as cooling and lights, and losses in the power distribution system.

Power losses at ECMWF

Power distribution system

The energy losses associated with power handling and distribution on-site are likely to be between 1% and about 10% of the site load. The type of Uninterruptible Power Supply (UPS) chosen will make most impact on the additional energy use. ECMWF uses a rotary UPS to protect the site from loss of power due to loss of mains electricity. It works by using the incoming electrical supply to turn a flywheel that itself is connected to an integrated generator. If the National Grid supply is lost, the flywheel continues spinning and feeding energy into the electrical distribution system long enough for a diesel engine to cut-in and drive the generator. When power is flowing normally through the UPS from the National Grid, the UPS conditions the power supply, e.g. by removing transient spikes. These UPS machines are about 96% efficient. Static UPS machines, which support the computer equipment power load on batteries between the occurrence of a mains failure and the start of the backup generators, are typically 90% efficient. However, improvements in static UPS technology in recent years has increased efficiency to around 95% for the newest such machines.

There are also losses of 2–3% in the transformers which convert the incoming 11 kV supply from the National Grid into 400 V supplies for the site. Further, small, losses occur in the electrical distribution system comprising switchboards in the basement of the computer building, power distribution units in the computer halls and all the associated cables.

Figure 2 One of ECMWF's Turbocor based chillers.

Cooling system

The centralised chilled water systems at ECMWF use packaged air-cooled chillers incorporating Turbocor compressors (see Figure 2) that are designed to be more efficient at part load and at low ambient air temperatures. Traditional screw or reciprocating compressor based chillers are most efficient at full load, and the efficiency variation with ambient temperature is minimal. The average annual efficiency for a Turbocor based chiller is between 5.5 and 6.5, as opposed to being in the range 3 to 3.5 for a more traditional style chiller. This means that a Turbocor chiller uses half as much electricity as a conventional chiller to provide the same cooling. All chillers at ECMWF operate at less than full load because they are run in a redundant mode with spare capacity available, and they run continuously throughout the year as in most data centres. Consequently the saving to be made using Turbocor compressors is significant.

Current green data centres

Several UK data centres that advertise their 'green' credentials (PUEs less than 1.2) were visited as part of the study, to examine the technology in use and its applicability to meet supercomputer infrastructure requirements. These centres were a mixture of hosting sites and showcase green facilities operated by IT vendors.

Although there were interesting approaches to energy efficiency at the data centres, they were, in general, not applicable to the ECMWF data centre. Most made the assumption of equipment being in fixed, standard size racks, and that future equipment would also fit these racks. The cooling methods were designed for air cooled equipment with a maximum heat output around 20 kW per rack, and the cooling methods used could not be modified to provide chilled water directly to cool equipment, such as supercomputer racks.

ECMWF uses supercomputer equipment which, in general, is installed in custom racks and is replaced every two to three years. Successive supercomputer systems are likely to have different size racks in differing configurations. As the lifetime of the data centre building is many times that of the supercomputer systems, flexibility in the design and layout of the data centre is needed; the adaptations for each new system are likely to reduce the efficiency of the data centre as a whole.

Reducing energy usage

Electricity distribution system

Power losses in the on-site electricity distribution system are more or less fixed. The only way to reduce the losses would be to run all or part of the computer equipment from

Figure 3 External view of a typical free cooling module. Photograph provided courtesy of Keysource (www.keysource.co.uk).

raw mains to remove the losses in the UPS. This would have an impact on the resilience of the computers and is not suitable at an operational centre where the computers are required 24 hours per day. These losses are small when compared to the power used by the cooling systems for the computer equipment.

Cooling

Over the last few years ECMWF has had a programme of replacing old, relatively inefficient chillers with new chillers based on Turbocor compressors. As described above, these have reduced the electricity used by the chilled water systems. The most efficient cooling option can only be determined from a detailed analysis of a specific site, operating conditions, loads etc. The solution may also be influenced by the level of resilience required.

There can be little doubt that the most efficient cooling method is the use of 'free cooling' by using the ambient (external) air to cool the air or water that provides the direct cooling to equipment in the data centre (see Figure 3). Raising the internal design temperatures and consideration of the location may allow 'free cooling' to operate for the majority if not all operating hours. Where lower temperatures are required for water-cooled systems such as ECMWF's supercomputers, free cooling can still be an effective option but will be available for less hours.

The main disadvantage of free cooling systems is that plant and equipment tends to be larger to take the maximum advantage of small temperature differences. This increases capital costs and space requirements but these costs will often be justified by life cycle cost analysis. The most important factor however is that free cooling systems will significantly reduce carbon emissions that would otherwise arise from the generation of electricity to drive mechanical cooling systems.

Data centre design and layout

Other measures that can be used to increase the energy efficiency of a data centre involve changes to the layout of equipment. These are mainly relevant for air-cooled (non-supercomputer) equipment and are only likely to be practical to implement when a major change of IT hardware is taking place.

Air-cooled computer equipment works by drawing air from the computer hall into the equipment cabinets, passing it across the equipment, and venting it into the computer hall. Air typically enters the data centre under the floor, passes through vents in front of the cabinets containing the equipment and then is extracted through vents mounted high in the walls. There are two ways of increasing the effectiveness of the cold air supply.

- ***Cold aisle containment***. This uses a physical partition so that all the cold air goes directly into the equipment racks and there is little recirculation or mixing with hot air. Cold aisle containment increases the external temperature at which free air becomes ineffective.
- ***Hot aisle containment***. With this approach the air passed across the equipment is vented directly into return ducts.

Modelling the airflow within the computer hall allows the system to be optimised to use the minimum amount of cold air. This system works best with equipment that fits into standard racks so that computer equipment can be changed without having to modify the cold/hot aisle containment.

It may also be possible to increase the temperature in the data centre. General purpose IT equipment is manufactured to operate within standard temperature and humidity ranges – known as the ASHRAE standards. These standards have evolved with time, and equipment being manufactured now is capable of being used reliably at higher temperatures than older equipment. Raising the temperature of computer halls can make a large difference to the cost of cooling. However, ECMWF has so little non-supercomputer IT equipment that raising the air temperature would have minimal impact on the cost of cooling.

Carbon neutrality

As well as reducing the energy consumption on the site ECMWF has investigated ways of working towards carbon neutrality. The strategies available are:

- Purchase 'green' electricity through a conventional supplier;
- Invest in a supplier of renewables, 'earmarking' some of the renewable energy for use by ECMWF – the benefits being that the price can be negotiated explicitly (and thus is less susceptible to market variations) and that the source can be identified;
- Site a data centre where it is possible to generate renewable energy. In practice, as ECMWF does not wish to be a power generator, this may be a variant on the second option.

Of these options, the second is least affected by the location of the data centre and has the potential for electricity price stability. However, this is a long-term option which requires further study.

In the short term, the first option is being pursued. 'Green' tariffs are available from most large energy providers based on the premise that a proportion of the electricity supplied is generated from sustainable sources. At present the sustainable proportion is only in the order of 10%, although this is likely to increase over the next few years if government policy objectives are to be achieved. However, it is unlikely that a significantly higher proportion of grid-supplied energy will be produced from sustainable sources in the near future. The demand for green electricity exceeds the available supply. Much of the green electricity in UK is reserved for local government which has the most stringent targets for sustainable operations and reduction of carbon footprint. The shortage has produced a rise in the cost of renewable energy and, so called, Good Quality Combined Heat and Power (GQCHP). For the contract starting from April 2011, ECMWF's electricity provider will supply 25% of its electricity from renewable and GQCHP sources on a cost neutral basis. Use of green energy in the long term is being pursued.

What next?

ECMWF operates a very large computing system, by commercial standards, and of necessity uses infrastructure equipment that can deliver low unit costs without having to share its use. The trend for supercomputers is to move to watercooling (for which there are no standard configurations), higher density (resulting in greater floor loading than for conventional IT), and non-standard racks. Together these mean that each new supercomputer installation will need changes to the supporting infrastructure. As the infrastructure is changed the opportunity will be taken to install more energy efficient equipment, where possible. Alongside this, ECMWF is looking at options for the use of free cooling to provide at least part of the required data centre cooling capacity.

Special Project computer allocations for 2011–2012

The allocations for 2011 have been approved. The figures for 2012 indicate what has been requested.

Member State		Institution	Project title	2011 HPCF (units)	2011 Data storage (Gbytes)	2012 HPCF (units)	2012 Data storage (Gbytes)
Continuation Projects							
Austria	1	Univ. Vienna (Haimberger)	Bias estimation of historic in-situ upper air data	10,000	500	–	–
	2	Univ. Graz (Kirchengast)	Climate monitoring by advanced spaceborne sounding and atmospheric modelling	30,000	300	–	–
	3	Univ. Innsbruck (Mayr)	Advanced investigation methods for Foehn	150,000	1,000	80,000	1,100
	4	Univ. of Natural Resources and Applied Life Sciences, Vienna (Seibert)	Modelling of Tracer Transport (MoTT)	30,000	100	–	–
France	5	CNRM/GMAP, Méteo-France (Fischer)	Investigation of coupling the ALADIN and AROME models to boundary conditions from ECMWF and ERA model data	130,000	800	–	–
	6	CERFACS (Rogel)	Seasonal to interannual predictability of a coupled ocean-atmosphere model	10,000	150	–	–
	7	CERFACS (Weaver)	Variational data assimilation with the OPA OGCM	1,000,000	10,000	–	–
Germany	8	FU Berlin (Cubasch, Kirchner)	Investigation of systematic tendency changes and their influence on the general circulation simulated with climate models	20,000	2,000	–	–
	9	DLR (Doernbrack)	Influence of non-hydrostatic gravity waves on the stratospheric flow field above Scandinavia	100,000	80	–	–
	10	DLR (Doernbrack)	Support tool for HALO missions	50,000	80	–	–
	11	Univ. Cologne (Elbern)	GEMS: work package WP_RAQ_2	2,200,000	15,000	–	–
	12	DLR / MPI Chemistry, Mainz (Eyring, Steil)	Impact of anthropogenic emissions on tropospheric chemistry with a special focus on ship emissions	100,000	4,000	–	–
	13	Univ. Köln (Fink)	Interpretation and calculation of energy budgets	120	30	–	–
	14	Univ. Karlsruhe (Gantner, Schädler, Vogel)	Mesoscale modelling using the DWD Lokal-Modell	180,000	800	–	–
	15	DLR (Gierens)	Ice-supersaturation and cirrus clouds	200,000	100	–	–

Member State		Institution	Project title	2011		2012	
				HPCF (units)	Data storage (Gbytes)	HPCF (units)	Data storage (Gbytes)
Germany	16	MPI, Hamburg (Hagemann)	Regional downscaling of ERA-40 data and validation of the hydrological cycle	700,000	5,800	–	–
	17	DLR (Hoinka)	Climatology of the global tropopause	500	10	–	–
	18	MPI, Hamburg (Jacob)	Regional ensemble prediction	104,000	8,500	–	–
	19	Univ. Karlsruhe (Jones)	The impact of tropical cyclones on extratropical predictability	350,000	3,000	–	–
	20	DLR (Keil, Craig)	Ensemble modelling for the improvement of short-range quantitative precipitation forecasts	120,000	150	–	–
	21	FU Berlin (Langematz)	Chemistry-climate model simulations for WMO ozone assessment	2,650,000	9,900	–	–
	22	Leibniz-Institut, Univ. Kiel (Latif)	Seasonal to decadal forecasting with coupled ocean-atmosphere general circulation models	5,500,000	14,000	–	–
	23	IMK-IFU (Laux)	Statistical analysis of the onset of the rainy season in the Volta Basin (West Africa)	10	0	–	–
	24	DLR (Mayer)	Remote sensing of water and ice clouds with Meteosat second generation	20,000	20	–	–
	25	Alfred Wegener Institute, Potsdam (Rex)	Ozone and water vapour transport with the residual circulation	200	200	–	–
	26	Alfred Wegener Institute, Potsdam (Rinke)	Sensitivity of HIRHAM	100	10	–	–
	27	FZ Jülich (Schultz)	Global atmospheric chemistry modelling	625,000	25,000	–	–
	28	FU Berlin (Ulbrich, Leckebusch)	Investigations of storms in forecasts, hindcasts and climate model simulations on daily to seasonal and climatological timescales	5,000	2,000	–	–
	29	Univ. Bremen (Weber)	Chemical and dynamical influences on Decadal Ozone Change (CANDIDOZ)	10	10	–	–
	30	Univ. Mainz (Wirth)	Water vapour in the upper troposphere	1,000	20	–	–
	31	Univ. Hohenheim (Wulfmeyer, Bauer)	Real-time assimilation of observations of key prognostic variables and the development of aerosol operators (RAPTOR)	300,000	2,500	–	–
Italy	32	ARPA-SIM (Di Giuseppe, Marsigli)	Flow dependent Error statistic for Satellite data Assimilation in Regional model (FEAR)	450,000	100	–	–
	33	ARPA-SIM (Marsigli)	Testing the impact of model perturbations applied to the COSMO model at a convection-permitting scale over Italy	450,000	100	450,000	100
	34	ARPA-SMR, Emilia Romagna UK MetOffice (Montani, Mylne)	Limited-area ensemble forecasts of windstorms over Northern Europe	490,000	200	–	–
	35	ARPA-SMR, Emilia Romagna MeteoSwiss (Montani, Walser)	Improvements of COSMO limited-area ensemble forecasts	1,200,000	550	–	–
	36	ARPA-SMR, Emilia Romagna Italian Met. Service (Paccagnella, Montani, Ferri)	Limited area model targeted ensemble prediction system (LAM-TEPS)	495,000	800	–	–
	37	Univ. Genova (Parodi)	High resolution numerical modelling of intense convective rain cells	50,000	200	–	–

Member State		Institution	Project title	2011		2012	
				HPCF (units)	Data storage (Gbytes)	HPCF (units)	Data storage (Gbytes)
Italy	38	ARPA-SMR, Emilia Romagna & UCEA (Pavan, Esposito)	Seasonal Prediction for Italian Agriculture (SPIA)	10	100	–	–
	39	CNMCA (Torrisi, Marcucci)	Limited Area Ensemble Kalman Filter	2,500,000	800	–	–
	40	CNMCA (Zauli, Torrisi)	Tuning COSMO-ME to H-SAF requirements	2,300,000	800	–	–
Netherlands	41	KNMI (Drijfhout)	Modelling past greenhouse worlds with EC-Earth: Understanding past and predicting future response to high greenhouse gas levels	400,000	200	–	–
	42	KNMI (Haarsma)	Patterns of climate change: coupled modelling activities	2,400,000	2,000	–	–
	43	KNMI (Haarsma)	Storm Tracks in a Warmer Climate	300,000	500	–	–
	44	KNMI (Hazeleger)	EC-Earth: developing a European Earth System model based on ECMWF modelling systems	7,000,000	15,000	–	–
	45	KNMI (Huijnen)	Global reactive gases modelling in GEMS and MACC: Towards an operational assimilation and forecasting system for tropospheric reactive gases	100,000	250	–	–
	46	KNMI (van den Hurk)	Participation in GLACE-2	100,000	580	–	–
	47	KNMI (van Meijgaard)	Multi-annual integrations with the KNMI regional climate model RACMO2	499,000	5,000	–	–
	48	KNMI (van Meijgaard)	Regional modelling of the Greenland surface mass balance for key episodes in the past and the future	499,000	5,000	–	–
	49	KNMI (van Noije)	Global atmospheric chemistry modelling with EC-Earth: Understanding past and predicting future tropospheric ozone in a changing climate	300,000	500	–	–
Norway	50	NILU (Eckhardt)	FLEXPART transport simulations for the International Polar Year and further model development	20,000	100	–	–
	51	DNMI (Frogner)	TEPS – Targeted EPS for Europe	700,000	600	–	–
	52	Univ. Oslo (Isaksen)	Ozone as a climate gas	50,000	5	–	–
	53	DNMI (Iversen)	GLAMEPS – Grand Limited Area Model Ensemble Prediction System	7,200,000	32,000	–	–
	54	DNMI (Iversen, Kristiansen)	REGCLIM: optimal forcing perturbations for the atmosphere	600,000	1,000	–	–
	55	DNMI (Randriamampianina)	Tuning of HARMONIE assimilation and forecast systems	500,000	2,000	–	–
Portugal	56	Univ. Lisbon (Soares)	HIPOCAS-SPEC	0	10	–	–
Spain	57	Univ. Illes Balears (Cuxart)	Study of the stably stratified atmospheric boundary layer through large-eddy simulations and high resolution mesoscale modelling	96,000	200	–	–
	58	Institut Catala de Ciencies (Doblas-Reyes)	Assessment of the limit of initial-condition useful skill in interannual climate prediction	1,461,000	2,435	–	–
	59	Univ. de Castilla-La Mancha (Gärtner)	Analysis of land surface-atmosphere interactions through mesoscale simulations	450,000	1,000	–	–
	59	Univ. de Castilla-La Mancha (Gärtner)	Analysis of land surface-atmosphere interactions through mesoscale simulations	450,000	1,000	–	–
	60	Univ. Basque Country (Saenz)	Mesoscale meteorological reanalysis over the Iberian Peninsula	0	1,000	–	–
Sweden	61	SMHI (Robertson)	GEMS/MACC – Global and regional earth-system monitor using satellite an in situ data	300,000	20	–	–

Member State		Institution	Project title	2011		2012	
				HPCF (units)	Data storage (Gbytes)	HPCF (units)	Data storage (Gbytes)
Switzerland	62	Institute for Atmospheric and Climate Science, ETH Zurich (Lohmann)	Cloud Aerosol Interactions	300,000	200	–	–
United Kingdom	63	ESSC, Univ. Reading (Bengtsson)	Predictability studies with emphasis on extra-tropical and tropical storm-tracks and their dependence on the global observing systems	300,000	300	–	–
	64	Univ. Reading (Haines)	Using data assimilation in a high-resolution ocean model to determine the thermohaline circulation	1,000,000	7,000	–	–
	65	Univ. Reading (Innes)	Using weather forecasting approaches to understanding the Madden-Julian Oscillation in the ECMWF Integrated Forecasting System	400,000	800	–	–
	66	Univ. Reading (Kaiser-Weiss)	Assimilation of trace gas retrievals using quasi-optimal assimilation	150,000	1,000	150,000	1,000
	67	Manchester Metropolitan Univ. (Lee)	Determining the relative roles of NO_x and CO_2 emissions from aviation in climate change	200,000	800	–	–
	68	Univ. Reading (Methven)	Moist Singular Vectors and African Easterly Waves	75,000	150	–	–
	69	Keele University (Shrira)	Direct numerical simulations of 2-d freak waves	100,000	100	–	–
	70	BAS, Cambridge (Turner)	Assessment of ECMWF forecasts over the high latitude areas of the Southern Hemisphere	0	1	–	–
ICTP	71	ICTP (Kucharski)	Dynamical downscaling of seasonal predictions with a regional climate model	500,000	2,000	–	–
	72	ICTP (Kucharski)	Interactions between the Atlantic Ocean, African monsoon, the Indian and Pacific Oceans using the EC-Earth and IFS modelling systems	500,000	1,000	500,000	1,000
	73	ICTP (Tompkins)	Use and value of ECMWF short-range and seasonal forecast products for developing countries in terms of end-user impact variables	300,000	100	300,000	100
JRC	74	JRC-IES (Bergamaschi)	Inverse modelling of atmospheric CH_4 and N_2O	500,000	375	–	–
	75	JRC-IES (Dentener)	Pollution in world regions: Source Receptor calculations with the global atmospheric chemistry model TM5	220,000	200	–	–
New Projects							
Germany	1	Univ. Munich (Groenemeijer, Craig)	Large-scale and local control of severe weather: towards adaptive ensemble forecasting	300,000	500	300,000	500
Italy	2	ISMAR-CNR (Bertotti)	Effect of rain on the growth and evolution of sea waves	250,000	200	250,000	200
Netherlands	3	KNMI (Onvlee)	The Hirlam-B project	2,500,000	8,500	3,000,000	9,000
	4	KNMI (Selten)	The role of clouds in model bias and climate sensitivity	300,000	600	300,000	600
Sweden	5	SMHI (Undén)	European regional re-analysis for monitoring and observations	2,000,000	8,000	2,500,000	12,000
JRC	6	JRC (Dosio)	Climate change impacts on the European ecosystems and assessment of forest fires risk	300,000	200	300,000	200
Total requested				**55,690,950**	**211,136**	**8,130,000**	**25,800**

Special Projects finishing in 2010

Member State		Institution	Project title
Denmark	1	DMI (May)	Numerical experimentation with the EC-Earth system with special focus on the Mediterranean region
	2	DMI (Yang)	Decadal climate change experiments of EC-Earth at high resolution and with top atmosphere
Germany	3	Univ. Munich (Egger)	Land surface-atmosphere interaction
	4	MPI, Hamburg (Jungclaus)	Community Simulations of the last Millennium (COMSIMM)
	5	MPI, Hamburg (Niemeier)	Climate impact of clouds and aerosols
	6	Ruhr-University Bochum (Pahlow)	Optimisation of water management by using ensemble forecasts
Italy	7	ISMAR-CNR (Cavaleri)	Evaluation of the performance of the ECMWF meteorological model at high resolution
	8	ISAC-CNR (Maurizi)	GEMS: BOLCHEM
Netherlands	9	KNMI (Onvlee)	The Hirlam-A project
	10	KNMI (van Weele)	Global chemistry-transport modelling of natural reactive greenhouse gases
	11	KNMI (Selten)	Climate Change Studies using the IFS system
	12	KNMI (Siebesma)	Rain in Cumulus
Norway	13	DNMI (Benestad)	Seasonal predictability over the Arctic region – exploring the role of boundary conditions
Switzerland	14	Institute for Atmospheric and Climate Science, ETH Zurich (Storelvmo)	Aerosol influence on clouds, precipitation and climate in EC-Earth
JRC	15	JRC-IES (Dentener)	The linkage of climate and air pollution: simulations with the global 2-way nested model TM5
	16	JRC-IES (Dosio)	Coupling a regional climate model to a biogeochemical land-surface model in the study of climate change impacts on the European ecosystem

Member State computer allocations for 2011

Member State	HPCF (kunits)	Data Storage (Gbytes)
Belgium	30,611	137,398
Denmark	26,108	117,184
Germany	124,545	559,018
Spain	58,760	263,741
France	99,078	444,707
Greece	25,397	113,992
Ireland	22,650	101,666
Italy	84,069	377,343
Luxembourg	17,282	77,569
Netherlands	40,819	183,214
Norway	27,516	123,505

Member State	HPCF (kunits)	Data Storage (Gbytes)
Austria	27,675	124,218
Portugal	23,011	103,286
Switzerland	31,594	141,810
Finland	23,691	106,335
Sweden	30,344	136,197
Turkey	28,870	129,582
United Kingdom	104,289	468,099
Allocated to Special Projects	55,691	211,136
Reserved for Special Projects	18,000	80,000
Total	**900,000**	**4,000,000**

TAC Representatives, Computing Representatives and Meteorological Contact Points

Member States	TAC Representatives	Computing Representatives	Meteorological Contact Points
Belgium	Dr D. Gellens	Mrs L. Frappez	Dr J. Nemeghaire
Denmark	Mr L. Laursen	Mr T. Lorenzen	Mr G. Larsen
Germany	Dr D. Schroeder	Dr E. Krenzien	Mr T. Schumann
Greece	Col E. Lekkas	Lt Col M. Manoussakis	TBC
Spain	Mr E. Monreal	Mr R. Corredor	Mr A. Alcazar
France	J-M. Carrière	Mr D. Birman	Ms N. Girardot
Ireland	Mr P. Halton	Mr P. Halton	Mr G. Fleming
Italy	Dr S. Pasquini	Dr C. Gambuzza	Dr T. La Rocca
Luxembourg	Mr J. Santurbano	Mr J. Santurbano	Mr J. Santurbano
Netherlands	Mr T. Moene	Mr H. de Vries	Mr J. Diepeveen
Norway	Dr R. Skålin	Ms R. Rudsar	Mr P. Evensen
Austria	Dr G. Kaindl	Mr M. Langer	Dr H. Gmoser
Portugal	Mrs T. Abrantes	Mr L. Cardoso	Mr N. M. Moreira
Switzerland	Dr S. Sandmeier	Mr P. Roth	Mr E. Müller
Finland	Dr J. Damski	Mr M. Aalto	Mr P. Nurmi
Sweden	Mr F. Linde	Mr R. Urrutia	Mr F. Linde
Turkey	Mr M. Fatih Büyükkasabbaşi	Mr F. Kocaman	Mr M. Kayhan
United Kingdom	Dr A. Dickinson	Mr R. Sharp	Mr A. Radford
Co-operating States			
Bulgaria	Prof. Dr G. Kortchev	Prof. Dr G. Kortchev	Prof. Dr G. Kortchev
Croatia	Mr I. Čačić	Mr V. Malović	Mr Č. Branković
Czech Republic	Ms A. Trojakova	Mr K. Ostatnický	Mr F. Sopko
Estonia	Mr T. Kaldma	Mr T. Kaldma	Mrs M. Merilain Mrs T. Paljak
Hungary	Dr L. Bozó	Mr I. Ihász	Mr I. Ihász
Iceland	Mr H. Björnsson	Mr V. Gislason	Mrs S. Karlsdottir
Israel	Mr I. Rom	Mr V. Meerson	Mr N. Stav
Latvia	Mr A. Bukšs	Mr A. Bukšs	Ms A. Ņižņika
Lithuania	Mrs V. Auguliene	Mr M. Kazlauskas	Mrs. V. Raliene
Montenegro	Mr A. Berber	Mr A. Marčev	Ms M. Ivanov
Morocco	Mr H. Haddouch	Mr M. Jidane	Mr K. Lahlal
Romania	Dr A. Bell	Mr R. Cotariu	Ms M. Georgescu
Serbia	Ms L. Dekic	Mr V. Dimitrijević	Mr B. Bijelic
Slovakia	Mr J. Vivoda	Mr O. Španiel	Dr M. Benko
Slovenia	Mr J. Jerman	Mr P. Hitij	Mr B. Gregorčič
Observers			
EUMETSAT	Mr M. Rattenborg	Dr S. Elliott	Dr K Holmlund
WMO	Mr M. Jarraud		

ECMWF Council and its committees

The following provides some information about the responsibilities of the ECMWF Council and its committees. More detail can be found at:

http://www.ecmwf.int/about/committees

Council

The Council adopts measures to implement the ECMWF Convention; the responsibilities include admission of new members, authorising the Director-General to negotiate and conclude co-operation agreements, and adopting the annual budget, the scale of financial contributions of the Member States, the Financial Regulations and the Staff Regulations, the long-term strategy and the programme of activities of the Centre.

President: Mr François Jacq (*France*)

Vice President: Mr Ricardo Garcia-Herrera (*Spain*)

Policy Advisory Committee (PAC)

The PAC provides the Council with opinions and recommendations on any matters concerning ECMWF policy submitted to it by the Council, especially those arising out of the Four-Year Programme of Activities and the Long-term Strategy.

Chair: Mr Alain Ratier (*France*)

Vice Chair: Prof Petteri Taalas (*Finland*)

Finance Committee (FC)

The FC provides the Council with opinions and recommendations on all administrative and financial matters submitted to the Council and shall exercise the financial powers delegated to it by the Council.

Chair: Mr Sergio Pasquini (*Italy*)

Vice Chair: Mr Detlev Frömming (*Germany*)

Scientific Advisory Committee (SAC)

The SAC provides the Council with opinions and recommendations on the draft programme of activities of the Centre drawn up by the Director-General and on any other matters submitted to it by the Council. The 12 members of the SAC are appointed in their personal capacity and are selected from among the scientists of the Member States.

Chair: Dr Heikki Järvinen (*Finnish Meteorological Institute*)

Vice Chair: Dr François Bouttier (*CNRM/GMAP Météo-France*)

Technical Advisory Committee (TAC)

The TAC provides the Council with advice on the technical and operational aspects of the Centre including the communications network, computer system, operational activities directly affecting Member States, and technical aspects of the four-year programme of activities.

Chair: Mr Leif Laursen (*Denmark*)

Vice Chair: Mr Roar Skålin (*Norway*)

Advisory Committee for Data Policy (ACDP)

The ACDP provides the Council with opinions and recommendations on matters concerning ECMWF Data Policy and its implementation.

Chair: Mr Klaus Haderlein (*Germany*)

Vice Chair: Mr Frank Lantsheer (*Netherlands*)

Advisory Committee of Co-operating States (ACCS)

The ACCS provides the Council with opinions and recommendations on the programme of activities of the Centre, and on any matter submitted to it by the Council.

Chair: Mr László Bozó (*Hungary*)

Vice Chair: Mr Milan Dacić (*Serbia*)

ECMWF Calendar 2011

March 28 – May 25	Training Course – Numerical Weather Prediction
March 28 – April 1	*Numerical methods, adiabatic formulation of models and ocean wave forecasting*
April 4 – 14	*Parametrization of subgrid physical processes*
May 4 – 13	*Data assimilation and use of satellite data*
May 16 – 25	*Predictability, diagnostics and extended-range forecasting*
April 4–5	Joint ECMWF/ECOMET Workshop for Catalogue Contact Points
April 6–7	Advisory Committee for Data Policy (*12th Session*)
April 18 – 19	Policy Advisory Committee (*31st Session*)
April 27 – 28	Finance Committee (*88th Session*)
May 23 – 24	Security Representatives' Meeting
May 24 – 26	Computer Representatives' Meeting
June 8 – 10	Forecast Products – Users' Meeting
June 16 – 17	Council (*75th Session*)
June 21 – 24	Workshop on 'Representing model uncertainty and error in numerical weather and climate prediction models
September 6 – 9	Seminar on 'Data assimilation for atmosphere and ocean'
September 26 – 28	Introduction to ECflow for SMS users
October 3 – 5	Scientific Advisory Committee (*40th Session*)
October 5 – 7	Technical Advisory Committee (*43rd Session*)
October 10 – 14	Training Course – Use and interpretation of ECMWF products for WMO Members
October 10 – 11	Finance Committee (*89th Session*) *To be confirmed*
October 12 – 13	Policy Advisory Committee (*32nd Session*)
October 17	Advisory Committee of Co-operating States (*17th Session*)
October 31 – November 4	13th Workshop on 'Meteorological operational systems'
November 8 – 10	Workshop on 'Diurnal cycles and the stable atmospheric boundary layer (GABLS)'
December 6 – 7	Council (*76th Session*)

ECMWF publications (see http://www.ecmwf.int/publications/)

Technical Memoranda

639 **Abdalla, S., P.A.E.M. Janssen & J.-R. Bidlot:** Jason-2 OGDR Wind and wave products: random error estimation. *December 2010*

638 **Radnoti, G., P. Bauer, A. McNally, C. Cardinali, S. Healy & P. de Rosnay:** ECMWF study on the impact of future developments of the space-based observing system on Numerical Weather Prediction. *December 2010*

637 **Rodwell, M.J., T. Jung, P. Bechtold, P. Berrisford, N. Bormann, C. Cardinali, L. Ferranti, T. Hewson, F. Molteni, N. Wedi, M.A. Balmaseda, G. Balsamo, M. Bonavita, R. Buizza, M. Dahoui, A. Garcia-Mendez, M. Leutbecher, P. Lopez, Y. Trémolet & F. Vitart:** Developments in diagnostics research. *October 2010*

ERA Report Series

7 **Tavolato, C. & L. Isaksen:** Data usage and quality control for ERA-40, ERA-Interim and the operational ECMWF data assimilation system.

6 **Balmaseda, M.A. & K. Mogensen:** Evaluation of ERA-Interim forcing fluxes from an ocean perspective.

5 **Balsamo, G., S. Boussetta, P. Lopez & L. Ferranti:** Evaluation of ERA-Interim and ERA-Interim-GPCP-rescaled precipitation over the U.S.A.

4 **Poli, P.:** List of observations assimilated in ERA-40 and ERA-Interim (V1.0).

ESA Contract Report

20244/07/I-LG **Munoz Sabater, J., P. de Rosnay & A. Fouilloux:** Milestone 2 Tech Note – Parts 1/2/3: Operational pre-processing chain, collocation software development and offline monitoring suite. *December 2010*

Proceedings

ECMWF/GLASS Workshop on Land Surface Modelling and Data Assimilation and the Implications for Predictability, *9-12 November 2009*.

Responsibilities of Representatives and Contact Points

THERE ARE a variety of Representatives and Contact Points within ECMWF's Member States and Co-operating States who liaise with staff at ECMWF. The role of these Representatives and Contact Points is given below. Note that:

- The purpose of the Technical Advisory Committee (TAC) is covered on page 37 in the item about '*ECMWF Council and its committees*'.
- A list of TAC Representatives, Computing Representatives and Meteorological Contact Points is given in the table on page 36.

Computing Representatives

Computing Representatives co-ordinate the registration of users of ECMWF computing services, and represent their organisation in matters relating to the use of ECMWF computing facilities and the attendance to the Computer User Training Course. They play a very important role in improving the information flow and facilitating various administrative transactions between ECMWF and countries that have access to ECMWF's computing services. They liaise with the Head of Computer Division and User Support at ECMWF. Meetings of the Computing Representatives are held at ECMWF annually. For more information on these meetings see:

www.ecmwf.int/newsevents/meetings/computing_representatives/

Meteorological Contact Points

Meteorological Contact Points receive information from ECMWF about the meteorological aspects of the operational forecasting system, including the high-resolution deterministic model, ensemble forecast system, seasonal forecasts and the 'Boundary Conditions for Limited Area Modelling' optional project. They are encouraged to provide feedback concerning the performance of the forecasting system to ECMWF. In addition they may refer to the Head of Meteorological Operations Section or any of the Meteorological Analysts at ECMWF if they wish to discuss aspects of the daily model output.

Security Representatives

Security Representatives represent their organisation in matters relating to computer and network security, and receive information about ECMWF's security arrangements. They liaise with the Security Officer at ECMWF. Meetings of the Security Representatives are held at ECMWF annually. For more information on these meetings see:

www.ecmwf.int/newsevents/meetings/security_representatives/

Telecommunication Technical Contacts

Telecommunication Technical Contacts deal with day-to-day matters concerning the Regional Meteorological Data Communication Network (RMDCN). They liaise with the Head of the Networking and Computer Security Section and Computer Operators at ECMWF. A list of contacts is available at:

rmdcn.ecmwf.int/About_RMDCN/Contact_Names/

Catalogue Contact Points

Catalogue Contact Points are the primary contact for external organisations wishing to receive real-time ECMWF products via one of the ECMWF Member States or Co-operating States. A list of contacts is available at:

www.ecmwf.int/products/catalogue/delivery.html

The Catalogue of ECMWF real-time products is available at:

www.ecmwf.int/products/catalogue/

Index of newsletter articles

This is a selection of articles published in the *ECMWF Newsletter* series during the last five years.
Articles are arranged in date order within each subject category.
Articles can be accessed on the ECMWF public website – www.ecmwf.int/publications/newsletter/index.html

Useful names and telephone numbers within ECMWF

Telephone

Telephone number of an individual at the Centre is:

International:	+44 118 949 9 + three digit extension
UK:	(0118) 949 9 + three digit extension
Internal:	2 + three digit extension

e.g. the Director-General's number:
+44 118 949 9001 (international),
(0118) 949 9001 (UK) and 2001 (internal).

E-mail

The e-mail address of an individual at the Centre is:
firstinitial.lastname@ecmwf.int

e.g. the Director-General's address: D.Marbouty@ecmwf.int

For double-barrelled names use a hyphen
e.g. J-N.Name-Name@ecmwf.int

ECMWF's public web site: http://www.ecmwf.int

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Deputy Director-General & Director of Operations	
Walter Zwieflhofer	003
Director of Research	
Erland Källén	005
Director of Administration	
Ute Dahremöller	007
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Division Head	
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Computer Operations Section Head	
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Call Desk email: calldesk@ecmwf.int	
Console – Shift Leaders	803
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Lars Isaksen	852
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Reanalysis Section Head	
Dick Dee	352
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Division Head	
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Predictability & Diagnostics Section Head	
Roberto Buizza	653
Seasonal Forecasting Section Head	
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Division Head	
Peter Bauer	080
Numerical Aspects Section Head	
Agathe Untch	704
Physical Aspects Section Head	
Anton Beljaars	035
Ocean Waves Section Head	
Peter Janssen	116
GMES / MACC Coordinator	
Adrian Simmons	700
Education & Training (Acting)	
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Els Kooij-Connally	751