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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 The ECMWF Newsletter is not peer-reviewed.

Editor: Bob Riddaway

Typesetting and Graphics: Rob Hine

Any queries about the content or distribution of the ECMWF Newsletter should be sent to Bob.Riddaway@ecmwf.int

Contacting ECMWF

Shinfield Park, Reading, Berkshire RG2 9AX, UK

Fax: . . . .+44 118 986 9450
Telephone: National 0118 949 9000
International . . . .+44 118 949 9000
ECMWF Web site . . . . .http://www.ecmwf.int

Front cover

Storm surge barrier in Zeeland, The Netherlands, which was built after the storm disaster in 1953.

EDITORIAL

Our changing forecast model

ECMWF's forecast model (the IFS model) has been undergoing important upgrades in its physical parametrizations during the past two years, and more are on the way.

Cycle 31r1, introduced on 12 September 2006, contained a set of revisions to the cloud scheme, namely supersaturation with respect to ice and a more accurate discretization and fall speed for ice particles. Another major change was the replacement of the old and unrealistic "orographic roughness length" by a modern orographic form drag.

With Cycle 32r2, introduced on 12 June 2007, further revisions to the orographic drag were made, and the representation of ice particles was further improved. However the main change in this cycle was the replacement of the shortwave radiation scheme by the Rapid Radiative Transfer Model, developed by AER, Inc. This new model has 14 spectral intervals, and supports an advanced representation of cloud-radiation interactions called McICA (Monte-Carlo Independent Column Approximation). This provides an elegant solution to the long-lasting problem of optimizing the cloud superposition between two model levels. Further information about the new radiation package can be found in *ECMWF Newsletter No. 112*.

Finally on 6 November 2007 a major change of the convection scheme was introduced (Cycle 32r3). The use of the "large-scale moisture convergence" was discontinued, and the scheme will now use only the properties of the convective updraft. This brings the IFS in line with recent theories of convection, and results in a major change in the model activity as documented in this issue of the *ECMWF Newsletter* (see page 29). In addition, the soil hydrology was completely revised and geographical variations in soil texture were introduced for the first time in the IFS, resulting in a more realistic representation of the soil moisture reservoirs. The vertical diffusion above the boundary layer was also improved.

Further work is currently addressing the overall consistency of the cloud processes and the representation of shallow cumulus by a dual mass-flux approach.

Such extensive and rapid changes in the model physics have not taken place for many years. Due to these various upgrades the systematic errors of the IFS model have been considerably reduced. This benefits not only the medium-range forecasts but also the assimilation of observations. In addition the changes provide an enhanced ability to represent the Earth's climate in long integrations coupled with ocean, sea-ice and land surface models. In fact our IFS is getting much closer to being a true "Earth System Model".

Philippe Bougeault

ECMWF's plans for 2008

DOMINIQUE MARBOUTY

THE four-year programme of activities 2008–2011, adopted by the ECMWF Council at its 68th session in December, provides the backbone of our plans for 2008 (the programme is available at www.ecmwf.int/about/ programmatic). These plans will build upon our 2007 achievements which included:

◆ Supercomputer procurement.
◆ Aggressive action to ensure the prompt operational use of MetOp data.
◆ Successful forecasts of several major severe weather events in Europe (e.g. the extreme winds associated with storm Kyrill which affected Western Europe in January, flooding in the UK in July and the storm-surge in the North Sea in November).
◆ Coordination of the preparation of the MACC (Monitoring Atmospheric Composition and Climate) proposal for the developments of atmospheric services to support GMES (Global Monitoring for Environment and Security).

In December the Council accepted the Centre's proposal to select IBM for the provision of our next supercomputer and decided a further increase of the funding from 2011. The new machine will be installed in steps throughout 2008, starting with an initial test system in May and the first cluster being ready for trial in the autumn. Meanwhile, several infrastructure systems – power, cooling, networks and archive – will be enhanced, and our various operational suites will be prepared for the migration. The new supercomputer facility will provide increased performance by a factor of five (to 19 teraflops sustained), allowing for the resolution of the model to be increased from 2009.

Most of ECMWF's activity is dedicated to improving our forecasting system, with a particular focus on severe weather. These improvements will, as usual, be incorporated in new cycles of the model and implemented throughout the year. They will include assimilation of many more satellite data, several important developments of the wave model and a specific effort on improving the ensemble in the tropics. It is worth noting that, as presented in the editorial, we will finalise a cycle of general upgrade of the IFS physics which started in 2006. Another effort, in collaboration with Aladin and Hirlam, will be dedicated towards modularization of the code so as to simplify its maintenance.

Effort will be put on the development of verification. It will include finalising a revision of the verification application and database and implementing new verifications (e.g. for Extreme Forecast Index (EFI) and ensemble waves). First and foremost, however, will be developing ways of verifying forecasts of severe weather events. ECMWF will lead a verification review to be undertaken in WMO.

Another specific focus will be on the development of products, mainly through web services. This will include developing clickable charts allowing additional information to be obtained – such as a probability distribution or EPSgram.

Two important new datasets are expected this year. The first one will be the re-forecast dataset providing a permanently updated set of re-forecasts for calibration. Such a dataset will allow many new product developments by the Member States. The second one will be the Interim reanalysis covering the period 1989 to present: it will improve significantly reanalysis quality over the satellite era. An important feature is that the Interim reanalysis will be continued and updated in delayed mode, i.e. with a few weeks delay.

Further developing the Centre's support to the European Union has been an important element in ECMWF policy over the recent years and will be continued. Our main contribution is directed to the GMES initiative, in particular to the development of the atmospheric services component for which we are currently coordinating the GEMS project (which deals with global monitoring of atmospheric gases and aerosols and improved air quality forecasts). Several GEMS developments are expected this year, including air chemistry reanalyses. As mentioned earlier a follow-up project (MACC) has been prepared and will be discussed with the commission with a view to it starting in 2009. Another important theme will be to prepare and secure funding for the next generation reanalysis (ERA-75).

Following discussions with the Council, it was agreed that ECMWF will review and continue to improve its governance and financial management. This year's focus will be on:

◆ Developing a long-term solution for the Centre's pensions' payments.
◆ Considering changing accounting and auditing policies to new international standards.
◆ Developing a scheme for activity-based costing.
◆ Preparing a technical risk analysis.

The number of States supporting ECMWF will continue to increase. New States are expressing interest in developing co-operation with ECMWF. Also the process of accepting the amended Convention is making good progress and is expected to be finalised by the remaining Member States this year. It will open the door for new States (or current Co-operating States) to join ECMWF as Members.

Finally this year we want to dedicate serious effort to the long-term future of the ECMWF forecasting system. The pilot project on the non-hydrostatic dynamical core will be pursued and we expect to reach conclusions as to its suitability of the IFS for higher resolution beyond 2015. We will also start a new project concerning the scalability of our codes on massively parallel machines, in particular the data assimilation system. Future supercomputers are likely to be composed of hundreds of thousands of processors and we need to evaluate how our codes should evolve in order to run efficiently on such machines. This work will be crucial in defining the necessary priorities for ECMWF in the coming years.

The plan sets out an ambitious programme of work, but we are confident that the plan will be implemented and lead to improved services for Member States and the wider meteorological community.

New items on the ECMWF web site

ANDY BRADY

Release of ECMWF Calendar 2008

The 2008 ECMWF Calendar is the official timetable for all major events that are planned to be held at the Centre, including meetings of Council and its committees, training courses and workshops.

www.ecmwf.int/newsevents/calendar/2008.html

Presentations from the Workshop on Meteorological Operational Systems

The 11th Workshop on Meteorological Operational Systems was held from 12 to 16 November 2007. The objective of the workshop was to review the state of the art of meteorological operational systems and to address future trends in the use and interpretation of medium- and extended-range forecast guidance, operational data management systems and meteorological visualisation applications. See page 10 for a report about the workshop.

www.ecmwf.int/newsevents/meetings/workshops/2007/MOS_11/

Presentations from the Ensemble Prediction Workshop

The Workshop on Ensemble Prediction was held from 7 to 9 November 2007. This workshop reviewed the most recent advances in ensemble techniques applied to data-assimilation and forecast systems for predictions ranging from days, through months and seasons, to multi-annual timescales. See page 14 for a report about the workshop.

www.ecmwf.int/newsevents/meetings/workshops/2007/ensemble_prediction/

Workshop on GPS Radio-Occultation

A joint ECMWF-EUMETSAT/GRAS SAF Workshop on GPS Radio-Occultation will be held at the Centre from 16 to 18 June 2008. The aim of the workshop is to consider the various assimilation approaches, publicise the assimilation software developed by the GRAS-SAF consortium, review the latest assimilation experiments with GPS RO measurements, and promote the value of these measurements in the context of POST-EPS. Workshop attendance is by invitation only.

www.ecmwf.int/newsevents/meetings/workshops/2008/GPS_radio_occultation/

Workshop on High Performance Computing in Meteorology

Every second year ECMWF hosts a workshop on the use of high performance computing in meteorology. The emphasis of the 13th Workshop on High Performance Computing in Meteorology will be on running meteorological applications at sustained teraflops performance in a production environment, and on the application specific developments required to move towards petaflops computing. The workshop is planned to be held from 3 to 7 November 2008 (exact dates to be confirmed).

www.ecmwf.int/newsevents/meetings/workshops/2008/high_performance_computing_13th/

ECMWF Annual Seminar 2008

Increasingly parametrization work focuses on how processes interact with each other and the dynamics, and whether the feedbacks are represented realistically. This is particularly relevant at very high resolution where part of a process might be resolved. The emphasis of the 2008 Seminar, to be held from 1 to 5 September, will be on the interaction of parametrized processes with the resolved dynamics.

www.ecmwf.int/newsevents/meetings/annual_seminar/2008/

Workshop on Atmosphere-Ocean Interaction

A Workshop on Atmosphere-Ocean Interaction will be held at the Centre from 10 to 12 November 2008. The workshop will address the requirements for ocean-atmosphere coupling from the very short time scales to the monthly time range with a focus on ocean near-surface processes. Workshop attendance is by invitation only.

www.ecmwf.int/newsevents/meetings/workshops/2008/ocean_atmosphere_interaction/

Changes to the operational forecasting system

DAVID RICHARDSON

Implementation of cycle Cy32r3

A new cycle of the ECMWF forecast and analysis system, Cy32r3, was introduced on 6 November 2007. The new cycle includes significant changes to the model physics, including the convection scheme, that increase the model activity in the tropics. The main changes included in this cycle are:

- ◆ New formulation of convective entrainment and relaxation timescale.
- ◆ Reduction in free atmosphere vertical diffusion.
- ◆ New soil hydrology scheme.
- ◆ New radiosonde temperature and humidity bias correction.
- ◆ Increase in the number of radio occultation data from COSMIC.
- ◆ Assimilation of AMSR-E, TMI and SSMIS window channels (clear sky).
- ◆ Assimilation of SBUV (NOAA-17, NOAA-18) and monitoring of OMI ozone data.

The main changes to the EPS included in this cycle are:

- ◆ Initial perturbation amplitude reduced by 30%.
- ◆ Singular vectors targeted on tropical cyclones are computed with the new moist physics package in the tangent-linear and adjoint models (as

used in the operational in 4D-Var since Cy32r3).

More information about the impact of the Cy32r3 changes on atmospheric variability is given in the article starting on page 29.

Planned changes

The monthly extension to VarEPS is now undergoing pre-operational testing. This will lead to the full integration of the Monthly System and VarEPS and will enable users to be provided with EPS output uniformly up to 32 days ahead, once a week. It will also introduce a coupled ocean-atmosphere model for the forecast range day 10 to 15 for the 00 UTC based forecast on a daily basis.

Celebration of Tony Hollingsworth's life

DOMINIQUE MARBOUTY

TONY HOLLINGSWORTH, who died on 29 July 2007, was employed at ECMWF from March 1975 until his death. A full account of his key role in the development of the Centre and his involvement in various other international activities can be found in the article by David Burridge in *ECMWF Newsletter No. 113*.

Due to Tony's long association with ECMWF, his wife Breda asked whether the Centre would host a celebration of Tony's life. I considered it an honour for the Centre to be involved in such an event. Also I was delighted that there would be an opportunity for Tony's many friends and colleagues to celebrate the outstanding contribution he made to many aspects of meteorology.

The event was held on 3 November with over 120 people attending. As well as a presentation from me, there were presentations from three other people who had worked with Tony at ECMWF: David Burridge, Lennart Bengtsson and Adrian Simmons. All these focussed on Tony's achievements and the qualities that made him such a delightful friend and colleague. It was clear that Tony had made a significant contribution to the success of ECMWF, and that he would be sorely missed.

During the proceedings there was some cello music played by Tony's daughter, Déirdre. The final presentation was from Tony's son, Cormac. He described the many ways in which Tony had been a loving father and husband.

At the end of the formal part of the proceeding refreshments were served. I am sure that Tony would have approved of the convivial atmosphere and the bringing together of people from different aspects of his life.

Nothing will take away the feeling of loss for Breda, Déirdre and Cormac, but I hope that the celebration of Tony's life and the demonstration of the widespread admiration and affection for Tony will at least be a small comfort to them.

Cormac Hollingsworth speaking at his father's memorial service held at ECMWF.

Two new Co-operation Agreements

MANFRED KLÖPPEL

TWO NEW Co-operation Agreements have been signed. On 1 November 2007 an agreement was signed between ECWMF and Slovakia which came into force on 1 January 2008. Also an agreement was signed with Montenegro on 5 November with effect from the day of signature. Montenegro and Slovakia are ECMWF's 11th and 12th Co-operating States.

Where a Co-operation Agreement has been established, the Co-operating State:

- ◆ Has exactly the same access to ECMWF products as a Member State (e.g. dissemination, MARS and software).
- ◆ Has access to servers (ECGATE) but does not have a supercomputer allocation.

The needs of the Co-operating States are overseen by the Advisory Committee of Co-operating States. This committee provides the ECMWF Council with opinions and recommendations on the programme of activities of the Centre, as well as giving consideration to any matter submitted to it by Council.

To date Co-operation Agreements have been concluded with the Czech Republic, Croatia, Estonia, Hungary, Iceland, Lithuania, Montenegro, Morocco, Romania, Serbia, Slovakia and Slovenia.

In 2005 the Council decided to amend ECMWF's Convention that restricts membership to the current 18 Member States. Once the amended Convention has been ratified by all Member States, "new" countries will be eligible to apply for full Member State status.

Ensemble Prediction Workshop, 7–9 November 2007

ROBERTO BUIZZA, RENATE HAGEDORN, FRANCO MOLTENI, TIM PALMER

A THREE-DAY workshop on Ensemble Prediction was held at ECMWF from 7 to 9 November 2007. Detailed information about the workshop can be found at:

www.ecmwf.int/newsevents/meetings/workshops/2007/ensemble_prediction

About sixty participants from around the world met to discuss progress in:

◆ The representation of uncertainties in initial conditions (e.g. ensemble data assimilation, ensemble transform Kalman filter, bred vectors, singular vectors).

◆ Model formulation (e.g. multi-model ensembles, perturbed parameter ensembles, stochastic parametrization).

◆ Validation and calibration methods.

◆ Use of ensemble forecasts in hydrological prediction.

In the first part of the workshop, twenty speakers from Europe, Canada, Japan, Korea and the USA reviewed the current status of operational ensemble forecasting systems. They also discussed research plans and future developments designed to further increase the value of probabilistic ensemble prediction. In the second part of the workshop, discussions were held in three working groups that focused on key areas of research and development.

Representation of initial condition and model uncertainty

The first working group focused on issues related to the representation of initial conditions and model uncertainty. During the discussion, it was pointed out that it is difficult to separate the contribution to forecast error due to initial condition uncertainty from that due to model uncertainty. Although a clear separation cannot be achieved, it was recognized that model uncertainty makes a significant contribution to initial condition uncertainty. Possible ways to diagnose the contribution to forecast error associated with model error have been suggested – these are based on a perfect model assumption and on initializing forecasts using the Ensemble Kalman Filter.

On the merit of multi-analysis/multi-model approaches to ensemble prediction, there was a clear consensus that the multi-model approach to ensemble prediction is an extremely pragmatic and useful mechanism for sampling model uncertainty. However, it was recognized that this approach should not be used to avoid the difficult problems of improving the representation of model uncertainty or reducing model errors and biases.

The working group spent some time discussing the trade off between ensemble size and ensemble member resolution, and concluded that this issue needs to be revisited with the goal of potentially increasing the resolution of the ensemble members.

Methodologies for downscaling and calibration of ensemble forecasts

The second working group discussed the relative merits of methodologies for the downscaling and calibration of ensemble forecasts on different time scales. As far as calibration is concerned, results from various approaches indicated a consistent benefit in terms of skill scores for

weather parameters. There was general consensus about the usefulness of generating re-forecast data for medium-range, monthly and seasonal ensemble forecasts. It was pointed out that unresolved issues on the choice of optimal methodologies, re-forecast versus ensemble size, and the actual increase of forecast skill could only be addressed by carrying out research on extensive sets of re-forecasts.

Downscaling issues were mostly discussed in the context of seasonal forecasts, an area where the advantages (and disadvantages) of dynamical versus statistical methods are still to be properly evaluated. The working group agreed that, so far, evidence to justify the additional complexity and computing requirements of dynamical downscaling is limited. However, results presented at the workshop on a reduction of false-alarm rates in downscaled simulations with a regional climate model warrant further investigation. The degradation of results arising from the use of boundary conditions at 12-hour versus 6-hour frequency in dynamical downscaling was also pointed out.

Verification and application of Ensemble Prediction Systems

The third working group focused its discussions on the verification and application of Ensemble Prediction Systems. The topics discussed included the most appropriate choice of verification measures, statistical significance of results, accounting for the uncertainty of verification data, avoidance of false skill, verification of rare/extreme events, and communication of probabilistic forecasts.

The working group made some recommendations concerning the design and testing of forecast systems, stating that, based on predictability theory, medium-range and later-range forecasts should be issued in probabilistic form. Therefore, the prime aim of ECMWF should be to provide the tools to predict a reliable and sharp probability density function (PDF) of the atmospheric state rather than just a single deterministic high-resolution forecast. The PDF should be based on all available information, i.e. the EPS and the high-resolution deterministic forecast. Consequently, the EPS should be given the same level of attention as the deterministic forecast system.

It was recommended that research on how to best combine high-resolution deterministic forecast and EPS should be continued at ECMWF. It was, however, also stated that a user/application-specific combination may be superior to a generic combination. In such cases, the production of an optimally combined PDF would fall into the responsibility of Member States or individual end-users.

Key message

The workshop closed with a plenary discussion during which the key conclusions of the three working groups were analyzed by all participants. The key message that can be drawn from the plenary meeting is that many groups are working to improve the current ensemble prediction systems, and that work is progressing towards the development of a complete probabilistic approach to the data assimilation and forecasting problem.

A wealth of ocean data makes its appearance on the public web at ECMWF

ALBERTO TROCCOLI,
FRANCISCO J. DOBLAS-REYES

IN *ECMWF Newsletter No. 113* (page 4) there was a news item about ENSEMBLES public data dissemination in which it was reported that ocean data would be available in the near future. Rather quicker than expected a wealth of ocean data has now been made available on the OPeNDAP server installed at ECMWF under the EU project ENSEMBLES (ensembles.ecmwf.int/thredds/catalog.html). In fact, limited amounts of ocean data were made publicly available on the ECMWF OPeNDAP server under the FP5 EU project ENACT (www.ecmwf.int/research/EU_projects/ENACT/), but a greatly expanded data set is now available which may trigger the interest of more people. This is the first time that such an extensive dataset with homogeneous NetCDF Climate and Forecast (CF) Metadata conventions for either atmospheric or ocean variables has been created and made available to the public.

The ENSEMBLES ocean data are from two sources.

- *Data assimilation analyses* covering the 48-year period 1959–2006 – currently the longest period for publicly available ocean analyses.
- *Retrospective forecasts* (or *hindcasts*) – from three experiments, two covering the period 1991–2001 and one covering the period 1960– 2006.

The analyses are available both in a regular grid to allow an easier inter-comparison between different models and in the original model grid (more information about the ocean analyses is in the article in *ECMWF Newsletter No. 113*, pages 8–16). At present these data are available for the ECMWF model but within the framework of ENSEMBLES, results from other models should be available soon.

The main difficulty in making the data available, once they have been produced, is to ensure that the NetCDF files destined for the OPeNDAP server follow well defined standards. Extensive work has been undertaken for the atmospheric data also, as discussed in the news item mentioned above. However, new conventions have been introduced for the ocean data in order to make them CF-compliant. This process, together with the actual preparation of the CF-

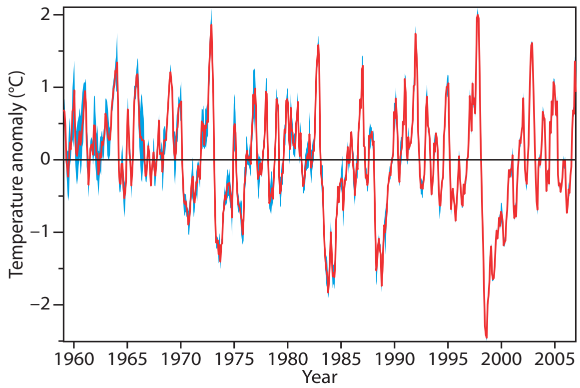
Examples of data retrieval

An example of how data can be retrieved using free software such as *nco* (nco.sourceforge.net) is given here. In this example the *nco* command (ncks) is requesting the temperature (the three-dimensional *thetao* field) along the equator (-d latitude,0) for the upper 1000 m (-d level), for the 1959–2006 period (-d time for the 576 months) and for the five ensemble members (-d ensemble):

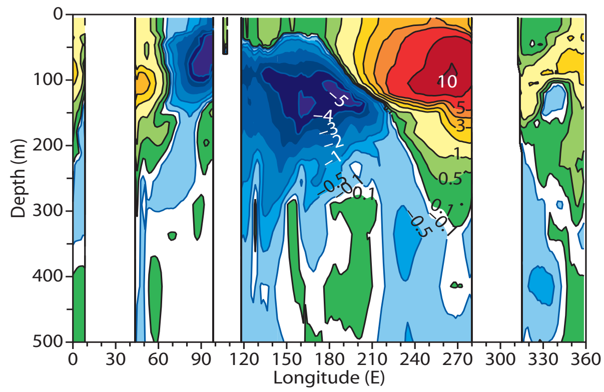
```
ncks -a -h -v thetao,time_bnd -d latitude,0. -d level,0.,1000. -d
time,0,575,1 -d ensemble,0,4,1 -O -o fileout.nc -p
http://ensembles.ecmwf.int/thredds/dodsC/ocean/ecmwf/eg thetao
```

By applying this command to programming/visual languages such as IDL one can analyse these data in a relatively easy way. For instance, the figures illustrated here were produced using a simple code which is available on request or at: www.ecmwf.int/research/EU_projects/ENSEMBLES/data/data_dissemination.html.

In both cases illustrated here, the results change only marginally when fields are taken on the regular grid rather than on the original grid.



Time series of the temperature anomaly of the ocean analysis on the regular grid averaged over the top 300 m and over the Niño3.4 region. The blue envelope represents the full spread of the five members. The absence of spread, as in the present period, indicates that observations are numerous and provide a strong constraint to the analyses.



The equatorial section of the analysed temperature anomaly for the ensemble mean for the month of December 1997 (close to the peak of the 1997/98 El Niño event).

compliant NetCDF, is one that has required intensive work, involving others at ECMWF and elsewhere.

The main advantage of the OPeNDAP server (www.opendap.org) is the targeted remote data access. This means that only portions of data (e.g. equatorial cross-sections) need to be physically retrieved (the *targeted* part) and this operation can be carried out without visiting directly the web page where the server and the data reside (the *remote* part). As a consequence, computer codes can be written that access targeted data from more than one OPeNDAP servers, even at different locations.

More sophisticated data analyses than those illustrated here are certainly possible and we would like to encourage all those interested in using historical oceanic data as well as long hindcasts to start exploiting our targeted remote data access facility.

Signing of the Co-operation Agreement between ECMWF and Montenegro

MANFRED KLÖPPEL

ON 5 November 2007, Predrag Nenezic, Minister of Tourism and Environment of Montenegro, and Dominique Marbouty, Director of ECMWF, signed a co-operation agreement in Podgorica, Montenegro. Luka Mitrovic, Director of the Hydrometeorological Institute of Montenegro, attended the signing ceremony.

Predrag Nenezic stated: “The European Centre for Medium-Range Weather Forecasts is the world leader in its area of numerical weather prediction and we are proud of having concluded this co-operation agreement with this organisation. Its products will greatly assist the Hydrometeorological Institute of Montenegro in fulfilling its mission, in particular with regard to the protection of life and property. I am confident that both ECMWF and the Hydrometeorological Institute of Montenegro will benefit to a great extent from their close co-operation in meteorology.”

Dominique Marbouty said: “ECMWF’s worldwide leadership in the field of numerical weather prediction is based on close collaboration with the meteorological community. Governments recognise the necessity of improving the quality and accuracy of numerical weather

Dominique Marbouty, Director of ECMWF, and Predrag Nenezic, Minister of Tourism and Environment of Montenegro, signing a co-operation agreement in Podgorica, Montenegro on 5 November 2007.

prediction, allowing them above all advance warning of severe weather events, such as storms, heat waves and floods. I am looking forward to close collaboration with the Hydrometeorological Institute of Montenegro, which will now have access to our products, especially medium-range and seasonal weather forecasts."

Luka Mitrovic said: "This co-operation agreement is a significant milestone for the Hydrometeorological Institute of Montenegro. The data from ECMWF's supercomputer system will be vital for improving the overall quality of our forecasts and for our warning services, in particular giving the public and the responsible authorities early advice on the likelihood of extreme weather events. Our meteorological and technical staff will benefit immensely from increasing their contacts with their colleagues at ECMWF. We will be using ECMWF's products to extend both the range and the validity of our forecasts to the benefit of the people of Montenegro. We very much welcome this agreement."

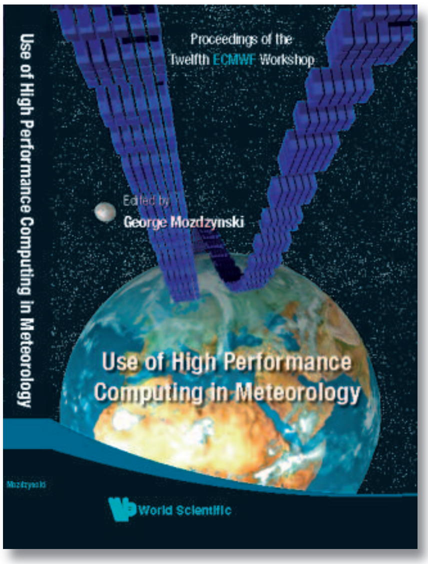
Book about high performance computing in meteorology

GEORGE MOZDZYNSKI

EVERY second year ECMWF hosts a workshop on the use of high performance computing in meteorology. These bring together manufacturers, computer scientists, researchers and operational users to share their experiences and to learn about the latest developments.

The last workshop was held from 30 October to 3 November 2006. Its context was the sustained performance at ECMWF now being 4 Teraflops averaged over the main IFS applications. This represents an 80,000 fold increase over the last 25 years. Will computer vendors be able to continue this kind of increase in the next 25 years? Will power consumption ultimately constrain performance by that time? Will the applications at ECMWF be able to run efficiently on computers that have just ten times the number of processes that we have today? These are just some of the questions addressed by the workshop. Consideration was also given to Linux clusters and parallel algorithms. The presentations from the workshop can be found at:

www.ecmwf.int/newsevents/meetings/workshops/2006/high_performance_computing-12th/presentations



The papers from the workshop present the state of the art in the use of parallel processors in the fields of meteorology, climatology and oceanography. They have now been published by World Scientific under the title "*Use of High Performance Computing in Meteorology – Proceedings of the Twelfth ECMWF Workshop*". The book is aimed at graduate students, academics and researchers specializing in high performance computing. Further information about the book can be found at:

www.worldscibooks.com/compsci/6638

ECMWF workshops and scientific meetings in 2008

BOB RIDDAWAY

Workshop on "Use of GPS radio-occultation" (16 to 18 June 2008)

A joint ECMWF-EUMETSAT/GRAS SAF workshop will be held to consider the assimilation of GPS radio-occultation (GPS RO) measurements. The aim of the workshop is to:

- Outline the strengths and weaknesses of the various assimilation approaches.
- Publicise the assimilation software developed by the GRAS-SAF consortium.
- Review assimilation experiments with GPS RO measurements using various assimilation strategies.
- Promote the value of these measurements in the context of EUMETSAT's Post-EPS.

Workshop attendance is by invitation only. Further information is available from:

www.ecmwf.int/newsevents/meetings/workshops/2008/GPS_radio_occultation

ECMWF 2008 Annual Seminar on "Parametrized physical processes and their dynamical interactions" (1 to 5 September 2008)

Increasingly models are being developed and used at higher resolutions. However, many physical processes remain unresolved and need to be parametrized. Even the highest resolution limited area models still need a parametrized representation of shallow convection, turbulence, microphysics, radiation and land surface processes. Schemes for deep convection and subgrid orography will still be needed in the foreseeable future for global NWP and climate models.

The seminar will give an overview of the relevant issues. Emphasis will be on the interaction of parametrized processes with the resolved dynamics. Increasingly, parametrization work focuses on how processes interact with each other and the dynamics, and whether the feedbacks are represented realistically. This is particularly relevant at very high resolution where part of the process (e.g. convection) might be resolved. Interactions and feedbacks act at all scales from planetary and synoptic scales to meso-scales (e.g. cloud/radiation interaction with the general circulation, boundary layer turbulence with cyclones, land surface processes with precipitation at the meso-scale and the interaction of convection with tropical variability). Consideration will also be given to the role of cloud resolving models in studying interactions and developing parametrization schemes, and on the need for stochastic components in schemes.

A registration form and further information is available from:

www.ecmwf.int/newsevents/meetings/annual_seminar/2008

Thirteenth Workshop on "High performance computing in meteorology" (3 to 7 November 2008)

The emphasis of this workshop will be on achieving sustained teraflops performance in a production environment, and on developing a vision for getting towards Petaflops computing. The aim is to provide a venue where:

- ◆ Users from ECMWF's Member States and around the world can report on their experience and achievements in the field of high performance computing during the last two years; plans for the future and requirements for computing power will also be presented.
- ◆ Vendors of supercomputers will have the opportunity to talk to managers and end users of meteorological computer centres about their current and future products.
- ◆ Meteorological scientists can present their achievements in the development of parallel computing techniques and algorithms, and can exchange ideas on the use of supercomputers in future research.
- ◆ Computer scientists can give an update on their efforts in providing tools which will help users to exploit the power of supercomputers in the field of meteorology.

Included will be a discussion of the challenges of creating a computer centre infrastructure for High Performance Computing.

Attendance at the workshop is by invitation and will be limited to around 100 people. If you are interested in attending, please go to:

www.ecmwf.int/newsevents/meetings/workshops/2008/high_performance_computing_13th

Workshop on "Ocean-atmosphere interaction" (10 to 12 November 2008)

The workshop will address the requirements for ocean-atmosphere coupling from the very short time scales to the monthly time range with a focus on ocean near-surface processes. The question to be discussed will include:

- ◆ Which processes need to be taken into account?
- ◆ What is the impact of air-sea processes on atmospheric phenomena?
- ◆ Which models are the most appropriate at different timescales, and what are the implications of seamless forecasting?

Workshop attendance is by invitation only. Further information about this workshop will be available at:

www.ecmwf.int/newsevents/meetings/workshops/2008/ocean_atmosphere_interaction

68th Council session on 10–11 December 2007

MANFRED KLÖPPEL

CHAIRED by its President, Dr Adérito Vicente Serrão from Portugal, the ECMWF Council held its 68th session in Reading on 10–11 December 2007.

Besides several decisions on financial and staff matters (e.g. adoption of Reports from the Co-ordinating Committee on Remuneration), the main results of the 68th session were as follows.

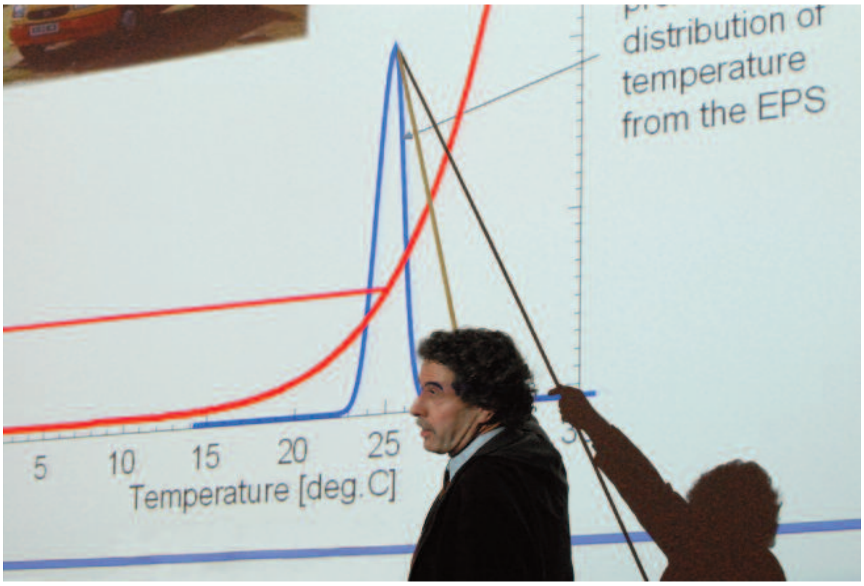
- ◆ **High Performance Computing Facility (HPCF).** The Council unanimously authorised the Director to enter into a Service Contract with IBM UK Ltd to replace the HPCF at the Centre from 2009 onwards. The Council also agreed unanimously to increase the HPCF budget by £1million from 2011 on top of the additional £3.5million from 2009 onwards already agreed in December 2006.
- ◆ **Four-year Programme of Activities**. The Council unanimously adopted the updated "Four-Year Programme of Activities" for the period 2008–2011 (for further information see www.ecmwf.int/about/programmatic/).
- ◆ **Budget 2008**. Council unanimously agreed that Member States' contributions to the budget for 2008 would increase by 3.0% over the budget for the previous year.
- ◆ **Pension Scheme**. The Council adopted the investment policy as proposed by the Centre for the funds in the dedicated pension account of the Funded Pension Scheme.
- ◆ **Governance and financial management**. The Council noted ECMWF's vision for the development of the management practices at the Centre:

"ECMWF is committed to an ongoing process of reviewing and improving its management policies to ensure that it:

- *Delivers best value for Member States.*
- *Monitors and further improves its high level of efficiency.*
- *Is well positioned to address future technological and scientific challenges in order to maintain its worldwide acknowledged leadership position in Numerical Weather Prediction."*

The Council agreed that the following points should be given priority: (a) development of a long-term solution for the pension issue, (b) consideration of the introduction of International Public Sector Accounting Standards (IPSAS) and standards of the International Organisation of Supreme Audit Institutions (INTOSAI), (c) consideration of the introduction of activity-based costing, (d) conduct a technical risk analysis and manage the identified risks, (e) review of the strategic risk analysis and the management of the identified risks, and (f) review of the financial strategy. The Council agreed to the Centre's road map to address these issues.

◆ **Conditions for new Member States joining ECMWF**. The Council agreed on the calculation method of the Single Additional Contribution for new Member States, in particular for former Co-operating States. New membership to ECMWF is possible when the amended Convention is ratified by all current Member States (to date 11 Member States have ratified).



Dr Tim Palmer (Head of Probabilistic Forecasting and Diagnostic Division at ECMWF) giving a lecture to Council on *"Ensemble Prediction System – 15 years on"*.

◆ **Products**. The Council agreed to (a) make a subset of ECMWF wave products available to WMO Members in support of extreme sea state forecasting, and (b) add several EUROSIP (EUROpean Seasonal-to-Inter-annual Prediction) multi-model ensemble products to the Catalogue of ECMWF real-time products.

◆ **Appointment of new Auditor**. The Council appointed Mr José Manuel Adán Carmona as auditor and Ms Mercedes Rodriguez Tarrida as deputy auditor (both from Spain) for the financial years 2008–2011.

◆ **Scientific Advisory Committee**. Council appointed Dr Bouttier, Dr Rodriguez-Camino and Dr Adrian for a second term of office.

◆ **Election of President and Vice-President**. Dr Adérito Vicente Serrão from Portugal and Mr Wolfgang Kusch from Germany were re-elected as President and Vice-President of the Council, respectively, for a second term of office of one year.

Dr Tim Palmer (Head of Probabilistic Forecasting and Diagnostic Division at ECMWF) gave a lecture to Council on "*Ensemble Prediction System – 15 years on*" showing the impressive development of the EPS techniques at the Centre from the beginnings in the early 1990s until today and outlining the future potential of EPS.

11th Workshop on Meteorological Operational Systems

HORST BÖTTGER, ALFRED HOFSTADLER, BAUDOUIN RAOULT, DAVID RICHARDSON, STEPHAN SIEMEN

THE 11th Workshop on Meteorological Operational Systems was held at ECMWF on 12 to 16 November 2007. The objective of the workshop was to review the state of the art of meteorological operational systems and to address future trends in:

◆ The use and interpretation of medium- and extended-range forecast guidance (Session 1)

◆ Operational data management systems (Session 2)

◆ Meteorological visualisation applications (Session 3)

The workshop proved to be very popular with over 80 participants from ECMWF Member States and Co-operating States, and from other parts of Europe and beyond.

The presentations given in Session 1 addressed in particular the post-processing of direct model output to meet user requirements. It was noted that extended-range forecasts out to a month and for the season require model bias corrections before they can be passed to the users. Several presentations addressed the use of forecasts in weather risk management, mainly using probabilistic forecast information. Also consideration was given to applications based on predictions of severe weather events. The weather alarm and warning system in Europe is now much developed and there is an increasing

demand for early warnings of severe weather, mainly in the range of 3 to 5 days.

In Session 2, several presentations discussed the emerging new distributed information systems, such as the WIS (WMO Information System) and the system created to handle the TIGGE (THORPEX Interactive Grand Global Ensemble) data exchange and data service. Providing the users with efficient interfaces for data mining and retrieval and ensuring interoperability were seen as the primary tasks when creating these systems.

Several operational data manipulation and visualization systems were presented in Session 3. Also there were demonstrations of some systems during the exhibition.

Three working groups were established to discuss issues relevant to the session topics.

Working group on severe and high-impact weather events

The working group discussed the requirements for forecasting severe and high-impact weather events, focusing particularly on early warnings for the medium-range.

The Extreme Forecast Index (EFI) was noted to be widely used as an alert to forecasters of a potential severe event. A number of suggestions were made for additional EFI parameters to allow alerts to be provided for a wider range of situations, including snowfall and minimum temperature. There was also interest in the ongoing work to develop products to complement the EFI. Probabilities of exceeding thresholds relative to the climate distribution and warnings expressed in terms of return periods were considered to be potentially valuable additional information.

The operational ECMWF tropical cyclone tracking was considered to be very useful, and development of products showing tropical cyclone genesis during the forecast was encouraged. It would be worthwhile investigating corresponding products for extra-tropical cyclones.

In general the direct model output is not provided to the end users. Rather, statistical post-processing procedures are applied. A variety of methods, including Model Output Statistics (MOS), Kalman filtering and "Perfect Prognosis" are used, often incorporating locally available observations. Such procedures can add significant value to the products delivered to end users and are considered essential to provide skilful forecasts for specific locations. While care must be taken using some of these tools for severe weather events, there are procedures that are suitable for such situations. It is important to calibrate longer-range (monthly and seasonal) forecasts with the help of re-forecast datasets to account for model error. Recent research has shown that there is also potential benefit from using re-forecast datasets to calibrate medium-range model output. The planned ECMWF re-forecasts from the unified monthly/VarEPS system will allow users to calibrate medium-range forecasts to complement the current statistical downscaling.

The verification of severe weather events was acknowledged to be an important but difficult topic. It was noted that this is an area of active research, but a substantial amount of work remains to be done.

Working group on interoperability

Traditionally Meteorological Services have been very successful at establishing interoperability within their community. Strong governance through WMO allowed the definition of well defined and agreed standards and methods. Increasingly there has been the need to participate in interdisciplinary activities, mainly driven by commercial, scientific and humanitarian interests, but also new legal requirements like the European INSPIRE directive. Consequently it has been necessary to review and adjust these standards in a way that will allow the Meteorological Services to interoperate with a much wider community in the near future.

The Internet was seen as a successful example of the benefit of interoperability: a small set of simple, stable, non-proprietary and accepted standards that connect the information providers to a large, partly unknown user community, leading to unforeseen usage of the published information.

Similarly, it was recommended that the meteorological community should use a limited number of standards that impose minimal constraints on the users. This would open up a large variety of information from many different providers to known and unknown user groups who might also find new ways to make use of our data sets.

To continue the analogy, the Internet standards cover data formats (HTML), transfer protocols (HTTP) and requesting mechanisms (URL). Again, the meteorological community must define similar standards:

◆ **Data formats**: GRIB, BUFR, CF-NetCDF, (GML_BUFR), GeoTIFF, KML, GIF, PNG, JPG.
◆ **Transfer protocols**: (s)ftp, http(s), DVB, OGC Web Services, SMS, VOICE, RSS.
◆ **Requesting mechanisms**: WMO file naming convention, OGC Query language.

The use of XML based data formats was discussed. Because of the support by industry and the wealth of available tools these formats are very popular. On the downside, the representation in XML can be bloated and produce very large files, and processing such files can be CPU intensive. Furthermore, the XML format is just an agreed syntax and does not specify any semantics. Such semantics are defined in data schemas that still need to be defined and agreed upon. For these reasons, it would be best for use of XML to be limited to the exchange of small data items with other communities. It was agreed that within the meteorological community, data exchange should continue to be driven by efficiency.

There was general agreement that OGC (Open Geospatial Consortium)/ ISO standards will play an important role in the near future. Both the European INSPIRE directive and Eurocontrol, for example, have decided to define OGC compliant data representations based on GML (Geography Markup Language). Meteorological Services are already in the process of building expertise on OGC but more collaboration is needed. Better coordination of the activities could lead to a common reference implementation of OGC compliant web services for meteorological data, which could be proposed to WMO for standardisation.

Working group on visualisation and web applications

The working group discussed the possibility of porting a meteorological workstation from a desktop application to a web application, a so-called rich internet application. The idea was fuelled by many talks at the workshop which indicated an increasing trend of providing web-based products to forecasters and clients. Also recent developments in web technologies have meant that many web applications have appeared and had much success, increasing the expectations of web users.

It became clear that the time is not yet right for a web-based workstation. The reasons mentioned were:

◆ Calculations performed using substantial local resources are still required in meteorology.
◆ User interface toolkits are not mature enough – fast changing and not yet future safe.
◆ Download of (initial) application can be a challenge for network bandwidth.

In addition there were many questions raised which would need to be addressed before larger web applications could be developed:

◆ How scalable will the applications be?
◆ How to deal with demand, and therefore availability, which can be weather dependent?
◆ Are there any development tools (debugging and profiling)?
◆ How can a web application be operationally maintained?
◆ What are the licences and legal issues?
◆ How can the security be guaranteed?

Further it was questioned whether a full featured web-based meteorological application should be the aim of developments. The desktop based workstation has progressed well over the last decade and gives good services to forecasters.

Instead of heavy rich internet applications, the possibility of using smaller, lighter web applications was discussed. These would be tailored to the need of the users. Accepted standards could be used to exchange information from different disciplines. Standards already considered by many are the web services defined by the OGC. See also the conclusion of the working group on interoperability.

A further workshop to exchange experience on OGC/GML, covering both data management and graphics, would be beneficial to facilitate such cooperation.

Further information

The findings of the working groups were presented and discussed in a final plenary session which concluded an informative and successful workshop. Summaries of the working groups along with the workshop programme and presentations can be found at:

www.ecmwf.int/newsevents/meetings/workshops/2007/MOS_11/index.html

New High Performance Computing Facility

MANFRED KLÖPPEL

At its 68th session on 10-11 December 2007, the ECMWF Council authorised the Director to enter into a service contract with IBM United Kingdom Ltd to replace the High Performance Computing Facility (HPCF) at the Centre from 2009 onwards. The contract between ECMWF and IBM UK Ltd was signed on 20 December 2007.

IBM will provide a POWER6 system for the period 2009–2010, to be replaced with a future POWER system for the period 2011 to mid-2013. The new computer system will enable ECMWF to further improve its global NWP models, in particular by increasing the horizontal resolution of the models and by making the best use of satellite data.

Severe weather is predicted to become more frequent and more intense in some parts of the world under climate change. ECMWF will contribute to mitigating the effects of climate change by providing early warnings of severe weather. This is seen as a key contribution to help society adapt to the dangers and threats associated with global warming. The increased time gained by such warnings will be crucial to save lives, enabling people to be evacuated from endangered areas (e.g. in the event of the storm surges in the North Sea, such as in November 2007), or to take precautionary action to avoid major threats to goods during severe storms, such as 'Kyrill' in January 2007.

Ms C Isaac and Mr A Sharples of IBM signing the contract with the Director of ECMWF, Dominique Marbouty, for the next High Perfomance Computing Facility at ECMWF.

ECMWF Educational Programme 2008

ELS KOOIJ-CONNALLY

ECMWF has an extensive education and training programme to assist Member States and Co-operating States in the training of scientists in numerical weather forecasting, and in making use of the ECMWF computer and archive facilities.

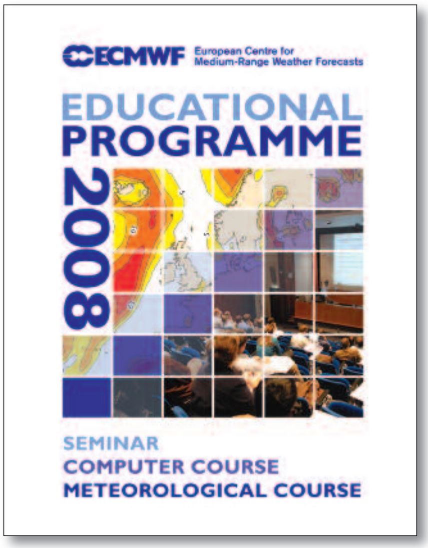
A booklet has been prepared that describes the content of the courses and methods of applications. The training courses consist of modules that can be attended separately. Since the courses do not vary much from one year to another someone may decide to attend different modules in separate years. The courses fall into three broad categories.

◆ **Use of computing facilities**. This provides an introduction to ECMWF's computing and archive facilities. The topics covered include SMS/XCDP, GRIB API, MARS, MAGICS, METVIEW and use of supercomputing resources. The course is aimed at both current and potential users of the Centre's facilities.

◆ **Use and interpretation of ECMWF products**. This discusses the ECMWF products in operational weather forecasting available to the Member States. It is mainly aimed at forecasters or people with forecasting experience.

◆ **Numerical Weather Prediction**. This covers various aspects of research in NWP at ECMWF, including data assimilation and use of satellite data, numerical methods and adiabatic formulation of models, parametrization of diabatic processes, and predictability, diagnostics and extended-range forecasting.

In addition there is a one-week seminar consisting of a series of lectures dedicated to one specific topic. In 2008 the subject is "*Parametrized physical processes and their dynamical interaction*". More details about the seminar are given in the news item on page 8.



The booklet describing the educational programme can be obtained by contacting Els-Kooij.Connally@ecmwf.int.

Alternatively information can be accessed via the ECMWF website by going to:

www.ecmwf.int/newsevents/training/2008

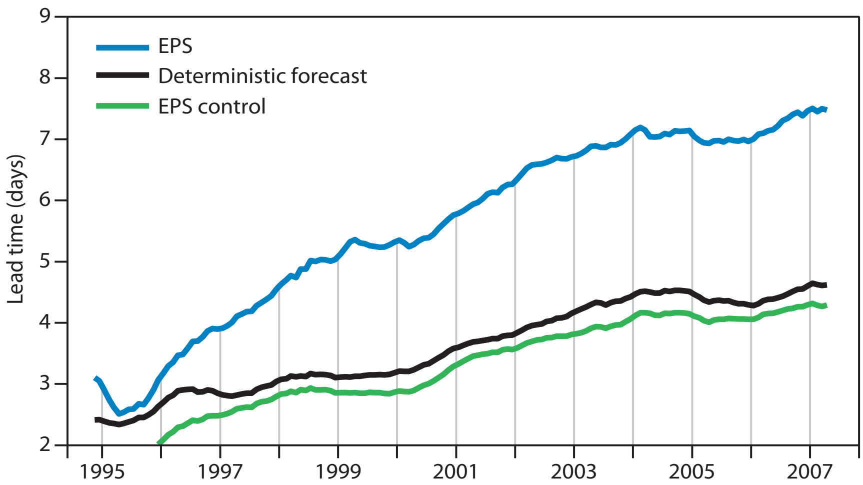
Fifteenth anniversary of EPS

TIM PALMER, ROBERTO BUIZZA

DECEMBER 2007 saw the fifteenth anniversary of the ECMWF Ensemble Prediction System (EPS). In fact the EPS was run in real time from November 1992, but EPS products were disseminated from December onwards. In those days, the EPS ran just three days a week; full daily running began in May 1994. Since September 2006, the EPS has been extended to 15 days with a variable resolution (VAREPS) system: T399 up to forecast day 10 and T255 afterwards, with initial uncertainties simulated using singular vectors and a stochastic representation of model uncertainties. A summary of progress and developments over the last 15 years is described in *ECMWF Tech. Memo. No. 540*.

Although the first operational ensemble forecast system was implemented at the Met Office in the 1980s (for monthly forecast customers), the operational implementation of the EPS at ECMWF saw a real explosion of activity in operational probabilistic forecasting worldwide. This activity continues to the present day and global ensemble forecasts have become part of the operational suites of ten meteorological centres: ECMWF, BMRC, CMA, CPTEC, FNMOC, JMA, KMA, Met Office, MSC and NCEP. Other centres (e.g. Météo-France, Spanish Instituto Nacional de Meteorología, Norwegian Meteorological Institute and COSMO Consortium incorporating the German, Greek, Italian, Polish, Romanian and Swiss National Meteorological Services) are running or testing short-range regional ensemble systems.

In December 2007, eight of the ten organizations (ECMWF, BMRC, CMA, JMA, KMA, Met Office, MSC and NCEP) are delivering medium-range global forecasts and one centre (Météo-France) is deliverying short-range regional forecasts to the TIGGE (THORPEX Interactive Grand Global Ensemble) archive at ECMWF. Also CPTEC has started sending test data.



Lead time (days) at which the Ranked Probability Skill Score of 850 hPa temperature for the northern hemisphere extra-tropics has dropped to a value of 0.3 for the EPS (blue), the high-resolution deterministic forecast (black) and the control forecast of the EPS (green). The threshold of 0.3 has been selected so that the lead time of the EPS in 2006 corresponds to the lead time at which the high-resolution deterministic forecast loses useful skill in terms of anomaly correlation. The Ranked Probability Skill Score is computed using a climatological distribution as reference forecast – a value of 1 corresponds to a perfect deterministic forecast and a value of 0 to no skill compared to climatalogy. The lead times are computed from low-pass filtered monthly scores.

After the implementation of the medium-range ensemble, use of ensemble prediction has become commonplace on all timescales; seasonal and short-range ensemble forecast systems were developed later in the 1990s, and climate-change ensembles and ensembles of analyses were (and continue to be) developed in the current decade.

The EPS has become a standard tool in the forecast office, and is used routinely by a number of commercial and humanitarian organisations for whom a quantifiable estimate of forecast uncertainty is paramount. This year saw reports of very valuable probabilistic flood predictions issued using hydrological models driven by the EPS (e.g. the flooding of two rivers in Bangladesh in the summer of 2007).

The beginning of 2008 will see the range of VAREPS extended to 32 days once-a-week, when the 15-day VAREPS and the coupled ocean-atmosphere monthly ensemble systems are joined into a unified ensemble system ranging from day 0 to day 32.

Although in the early days it was not clear whether the EPS would have a permanent place in the operational schedule, one can safely say that the EPS is here to stay! We look forward to the next 15 years of developments in ensemble-based operational probabilistic forecasting.

Meteorological centres producing global ensemble forecasts

- ECMWF
- Australian Bureau of Meteorology (BMRC)
- Chinese Meteorological Administration (CMA)
- Brazilian Centro de Previsão de Tempo e Estudos Climáticos (CPTEC)
- United States Fleet Numeric Meteorological Operational Center (FNMOC)
- Japanese Meteorological Administration (JMA)
- Korean Meteorological Administration (KMA)
- Met Office
- Meteorological Service of Canada (MSC)
- National Centres for Environmental Prediction (NCEP)

Toward a forecast of aerosols with the ECMWF Integrated Forecast System

JEAN-JACQUES MORCRETTE, LUKE JONES, JOHANNES KAISER, ANGELA BENEDETTI, OLIVIER BOUCHER

A PART of the EU-funded GEMS project (which concerns global environmental monitoring using satellite and in situ observations), a prognostic representation of aerosols is being developed in the ECMWF Integrated Forecast System (IFS) in both its analysis and forecast modules. In this short note, consideration is given to the forward modelling, outside of the analysis.

The forecast model

An experimental version of the forecast model now accounts for five tropospheric aerosol types (i.e. sea-salt, desert dust, organic matter, black carbon and a sulphate-related variable, SO_2). Both the sea-salt and dust are each represented by three bins, whose limits are chosen as to have roughly 10%, 20% and 70% of the mass of each aerosol type in the various bins. The package of physical parametrizations dedicated to aerosol processes is standard. Sources of sea-salt and desert dust are interactive with surface and near-surface variables of the model. The surface flux of sea-salt aerosols is parametrized from the 10-m wind at the free ocean surface. For the production of desert dust, the source depends on the 10-m wind, soil moisture, the UV-visible component of the surface albedo, and the fraction of cover by vegetation when the surface is snow-free. Other aerosol sources are taken from monthly-mean climatologies or inventories (Global Fire Emission Database, Speciated Particulate Emission Wizard, Emission Database for Global Atmospheric Research) until more temporally-resolved data based on satellite observations are provided as part of the GEMS project.

All aerosols undergo sedimentation, and dry and wet deposition (this last one by large-scale and convective precipitation). For organic matter and black carbon, two components, hygrophobic and hygrophilic, are considered. SO_2 is considered as one variable with no explicit chemistry included. Recent developments in the model dynamics and package of physical parametrizations allow the aerosols to be advected, and the vertical diffusion and the mass-flux convection schemes to account explicitly for tracers such as aerosols. The wet and dry deposition schemes are standard, whereas the sedimentation of aerosols follows closely the scheme recently introduced for the sedimentation of ice particles.

AFFILIATIONS
Jean-Jacques Morcrette, **Luke Jones**,
Johannes Kaiser, **Angela Benedetti**: ECMWF, Reading, UK
Olivier Boucher: Met Office, Exeter, UK

At present, the model prognostic aerosols are not interactive with the radiation scheme and are therefore passive tracers. However, their optical thickness is evaluated at different wavelengths as diagnostic quantities that can be compared to surface measurements such as those taken by AERONET (Aerosol Robotic Network) or derived from satellite measurements like those of MODIS (Moderate Resolution Imaging Spectroradiometer).

The analysis module has been developed and is currently running for GEMS's official reference study period, 2003–2004. The analysis ingests MODIS aerosol optical depth observations and uses the total aerosol mixing ratio as the control variable. Results so far are encouraging and show the capability of the analysis to draw to the observations.

For the results presented here, there is no assimilation of any data related to aerosols. The model is run from a given starting date in a series of 12-hour forecasts starting every 12 hours from the ECMWF operational analysis. The model aerosols are free-wheeling. They start from null concentrations of aerosols on the starting date. Then the various aerosols spin up for about 8–12 days (the time their contents establish themselves), with the aerosols produced from their surface emission fluxes, and going through the physical processes (dry deposition, sedimentation, wet deposition). After 12 hours of the forecast the aerosols are stored and passed as initial conditions for the next forecast starting 12 hours later. This is in essence not very different from what is done within a transport model, except that the aerosol processes are fully consistent with the dynamics and all physical parametrizations.

Some results

Since 1 June 2007 this experimental version of the forecast model, which includes prognostic aerosols and runs at T159L91, produces near-real time aerosol forecasts that are available from the ECMWF web site at:
www.ecmwf.int/products/forecasts/d/inspect/catalog/research/gems/aer/

Figure 1 illustrates the potential of the future aerosol forecasts. For an ascending orbit over Africa (Figure 1(a)), a classification of cloud and aerosol produced by the CALIPSO Science Team (Figure 1(c)) is compared with the corresponding model cloud and aerosol (Figure 1(d)). Even for this relatively low horizontal resolution (T159), the ECMWF model generally produces the cloud and aerosol in the proper location both horizontally and vertically. Over the same orbit, the total aerosol optical depth at 550 nm produced by the model is compared to the equivalent optical depth retrieved from MODIS observations over ocean and dark land surfaces

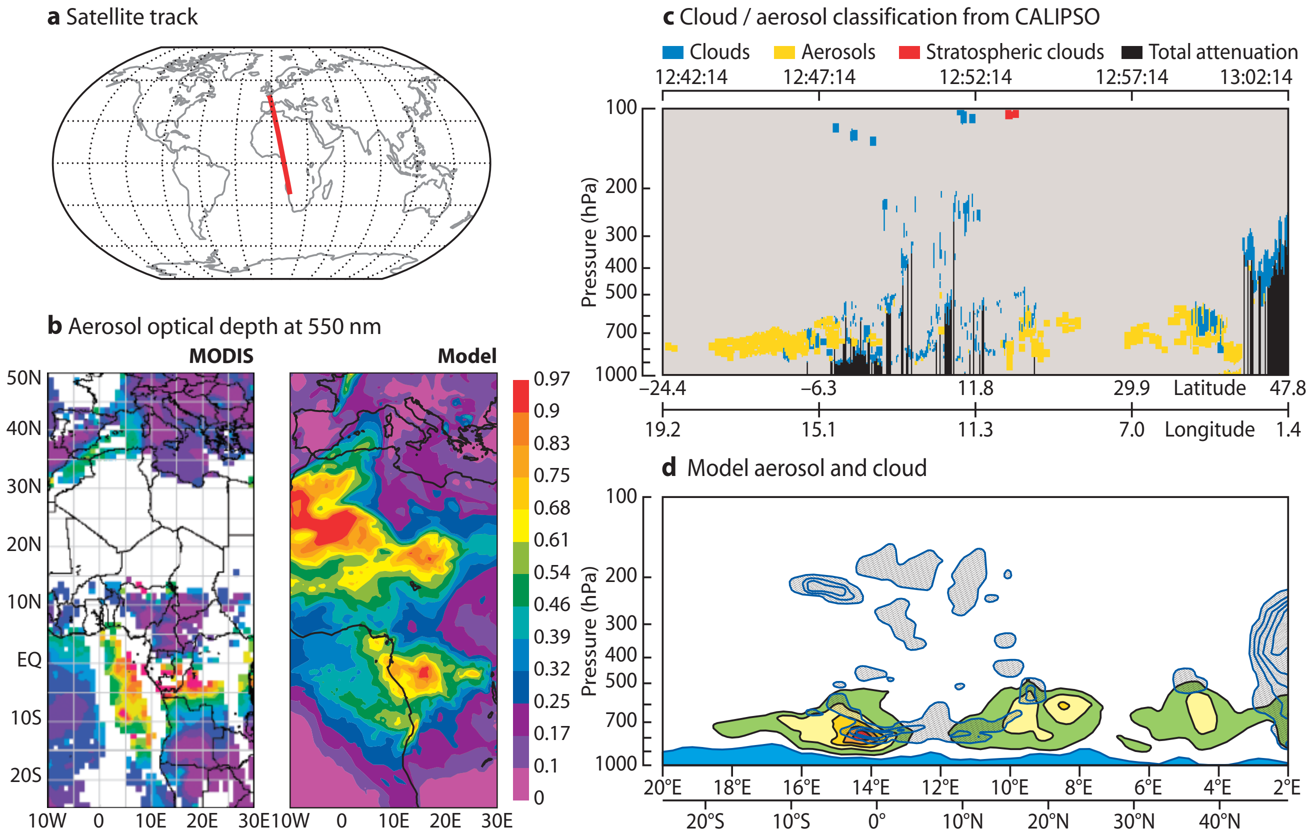


Figure 1 (a) The orbit of the A-train of satellites on 16 July 2007 between 1242 and 1302 UTC. (b) The aerosol optical depth at 550 nm derived from MODIS-Aqua observations (left) and produced by the ECMWF forecast model (right). (c) The cloud/aerosol classification derived from CALIPSO measurements along the orbit shown in panel (a). (d) The cross-section along the same orbit as used for (c) showing the aerosol (yellow) and cloud (blue) quantities produced by the ECMWF forecast model. The MODIS and CALIPSO data were downloaded from the NASA Giovanni server.

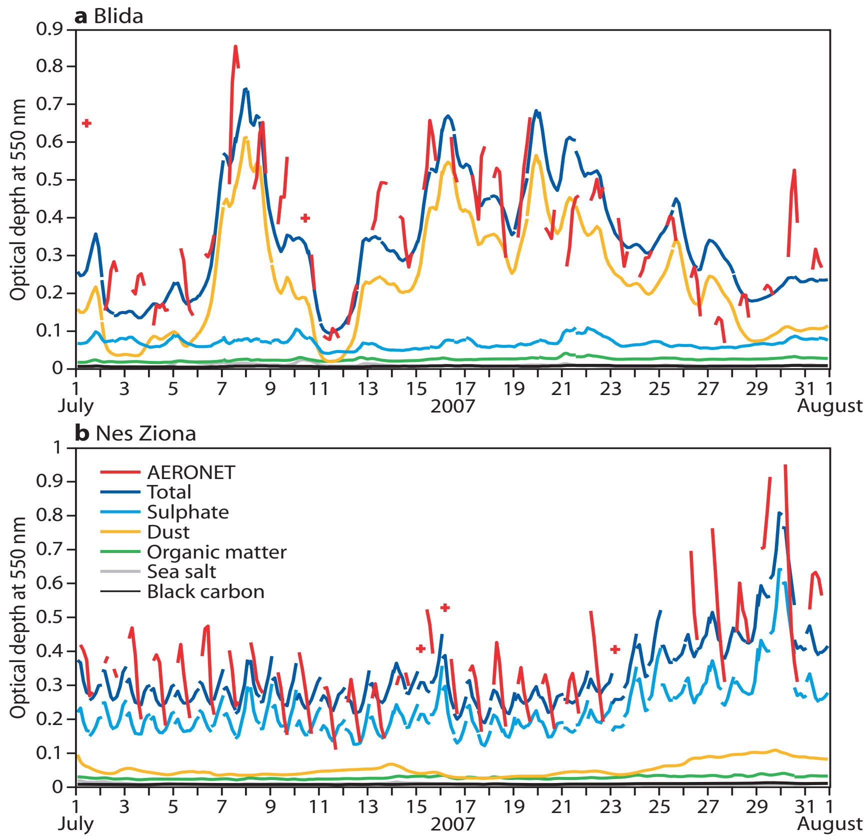


Figure 2 The observed optical depth at 550 nm from AERONET stations at (a) Blida and (b) Nes Ziona for July 2007 compared to the values from the model (total optical depth plus contributions from various aerosols). Dust aerosols dominates the optical depth at Blida, whereas sulphate aerosol dominates in Nes Ziona. Data for Blida and Nes Ziona were obtained from the AERONET web site. Thanks go to B. Holben, A. Karnieli and M. Boughedaoui for their efforts in establishing and maintaining the Blida and Nes Ziona AERONET sites.

in the absence of extended cloud cover (Figure 1(b)). For desert dust, the agreement is usually good reflecting the high quality of the initial conditions and of the atmospheric motions in the subsequent 12-hour forecast. Over Central Africa, the sources of sulphate, and organic and black carbon aerosols linked to biomass burning are well represented in the inventories, and the agreement on the optical depth of the plume moving towards the South Atlantic is also good.

As a further example, Figure 2 compares the model aerosol optical depth at 550 nm over Blida (Algeria) and Nes Ziona (Israel) to that derived from AERONET surface observations at those stations for July 2007. These results show that the model describes reasonably well the temporal variability of the aerosols. The model also captures the dominant aerosol type, dust in Blida and sulphate in Nes Ziona.

The quality of the results depends not only on the dynamics of the model and the adequacy of the aerosol physical parametrizations, but also on the representativeness of the sources. With the exact sources of aerosols (in particular, those of anthropogenic origin) not available in real time, the aerosol analysis, through the assimilation of aerosol-related observations, will provide initial conditions representative of the true aerosol burden in the atmosphere. The development of a successful aerosol analysis is therefore fundamental to the quality of the subsequent aerosol forecast. Here the forecast model including prognostic aerosols was shown to provide a reasonable basis for this analysis.

FURTHER READING

Morcrette, J.-J., P. Bechtold, A. Beljaars, A. Benedetti, A. Bonet, F. Doblas-Reyes, J. Hague, M. Hamrud, J. Haseler, J.W. Kaiser, M. Leutbecher, G. Mozdzynski, M. Razinger, D. Salmond, S. Serrar, M. Suttie, A. Tompkins, A. Untch & **A. Weisheimer**, 2007: Recent advances in radiation transfer parametrizations. *ECMWF Tech. Memo. No. 539*.

A new partitioning approach for ECMWF's Integrated Forecast System

GEORGE MOZDZYNSKI

SINCE the mid-1990s the Integrated Forecast System (IFS) at ECMWF has used a two-dimensional scheme for partitioning grid-point space to MPI tasks where MPI is a protocol for the data exchange and synchronisation between the executing tasks of a parallel job. While this scheme has served ECMWF well there has still been some areas of concern, namely:

- Communication overheads for IFS reduced grids at the poles to support the Semi-Lagrangian scheme.
- The halo requirements needed to support the interpolation of fields between model and radiation grids. The halo is an area of a task's memory reserved for data that is owned by neighbouring tasks.

These issues have been addressed by the implementation of a new partitioning scheme called EQ_REGIONS which is characterised by an increasing number of partitions in bands from the poles to the equator. The number of bands and the number of partitions in each particular band are derived so as to provide partitions of equal area and small 'diameter'. The EQ_REGIONS algorithm used in IFS is based on the work of Paul Leopardi, School of Mathematics, University of New South Wales, Sydney, Australia.

IFS parallelisation

The Integrated Forecast System (IFS) at ECMWF consists of a large suite of software used primarily to produce a daily ten-day forecast. Key components of the IFS include the processing of observations, a 4D-Var analysis, a ten-day forecast model at T799L91 resolution, and a fifteen-day ensemble prediction system (EPS). The EPS comprises a control forecast at T399L62 resolution and a further 50 forecasts at T399L62 using perturbed initial states. These run out to ten days, when the resolution is truncated to T255L62 before completing the runs out to fifteen days.

The key parallelisation scheme for IFS was developed in the mid-1990s (*Barros et al.*, 1995; *Isaksen & Hamrud*, 1996). This scheme consists of a series of data transpositions between grid-point space, Fourier space and spectral space as shown in Figure 1. With this approach, the complete data required is redistributed at these stages of a time step so that the computations between two consecutive transpositions can be performed without any inter-process communication.

The focus of this article is the distribution of data in grid-point space where the bulk of the IFS computations take place for the physics and dynamics aspects of the model. This two-dimensional distribution of grid-point space to 256 MPI tasks is shown in Figure 2(a) using an Aitoff projection. Here each task is associated with a single partition. This projection allows us to easily see the main features of this distribution for the whole globe, with 16 north-south bands (or sets) and 16 east-west bands, where 16 is the square root of 256. For 512 tasks there is no exact square root, so the nearest factors of 512 are used, namely, 32 north-south bands and 16 east-west bands, as shown in Figure 2(b). The reason for having more north-south bands than east-west bands in this case is down to performance, as IFS applications run marginally faster this way. Finally, Figure 2(c) shows a case for 1024 MPI tasks.

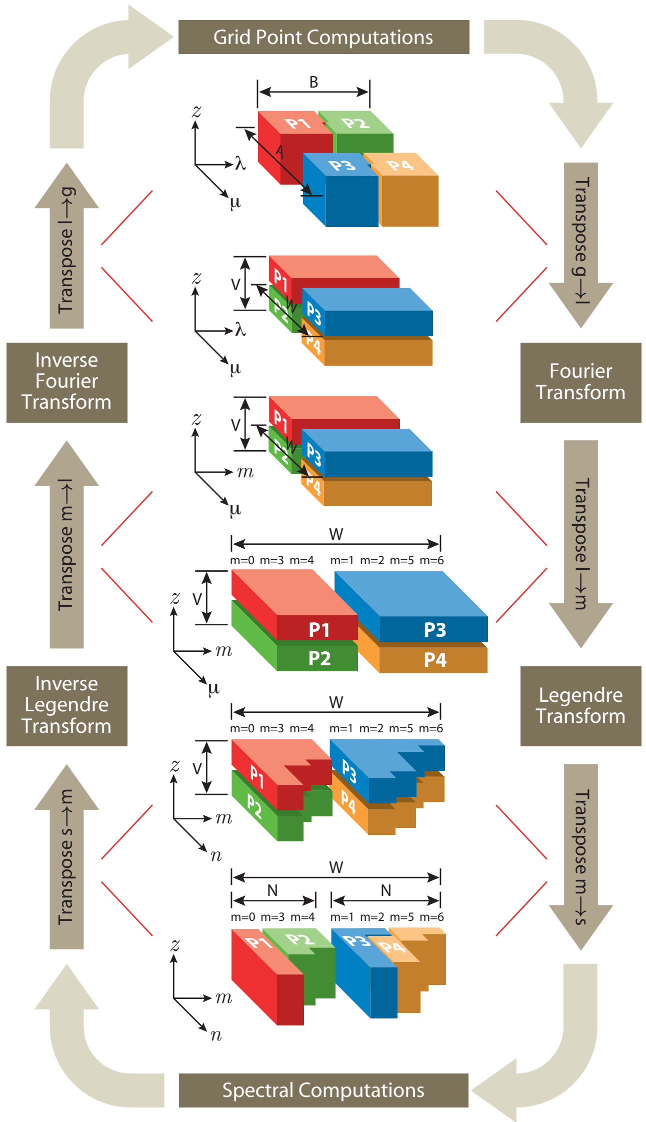


Figure 1 IFS model time step showing data transpositions.

The Semi-Lagrangian scheme in the IFS requires data from neighbouring tasks, the width of this halo being a function of the maximum possible wind speed and the time step. It is clear that the ideal shape for two-dimensional partitions (hereafter referred to as 2D partitions) to achieve the smallest halo area is square-like. However, the 2D partitions shown in Figure 2 are more rectangular than square-like with a width to height ratio of 2:1 or 4:1, and further they have a nasty 'cake' feature for those partitions at the poles. These polar partitions present a problem as they not only require a large halo area, but also that this halo area requires communication with all partitions converging on the relevant pole. Reducing the number of north-south bands and increasing the number east-west bands would make partitions more square-like at the equator, however this would only make matters worse at the poles with the increased communication. Some attempts to resolve the polar halo problems were made by using a different partitioning strategy for the first and last partitions (i.e. a polar cap). However, these developments only made a small difference on performance and sometimes had a negative effect. What was required was a new approach for the partitioning of grid-point space.

There are clearly many approaches to partitioning a sphere, a good example being that of *Lemaire & Weill* (2000) which uses constant area quadrangles as shown in Figure 3. However, many of these approaches share little in common with the IFS 2D partitioning; as a result they would require a major effort (many person years) to incorporate any of them into the IFS.

EQ_REGIONS

The EQ_REGIONS partitioning scheme (*Leopardi*, 2006) appeared attractive from the beginning, as can be seen in Figure 4 for a sphere with 33 partitions. This practical algorithm came with a MatLab package titled *Recursive Zonal Equal Area Sphere Partitioning Toolbox* which can be found at http://eqsp.sourceforge.net/. As a comparison IFS 2D partitioning would need 11 bands

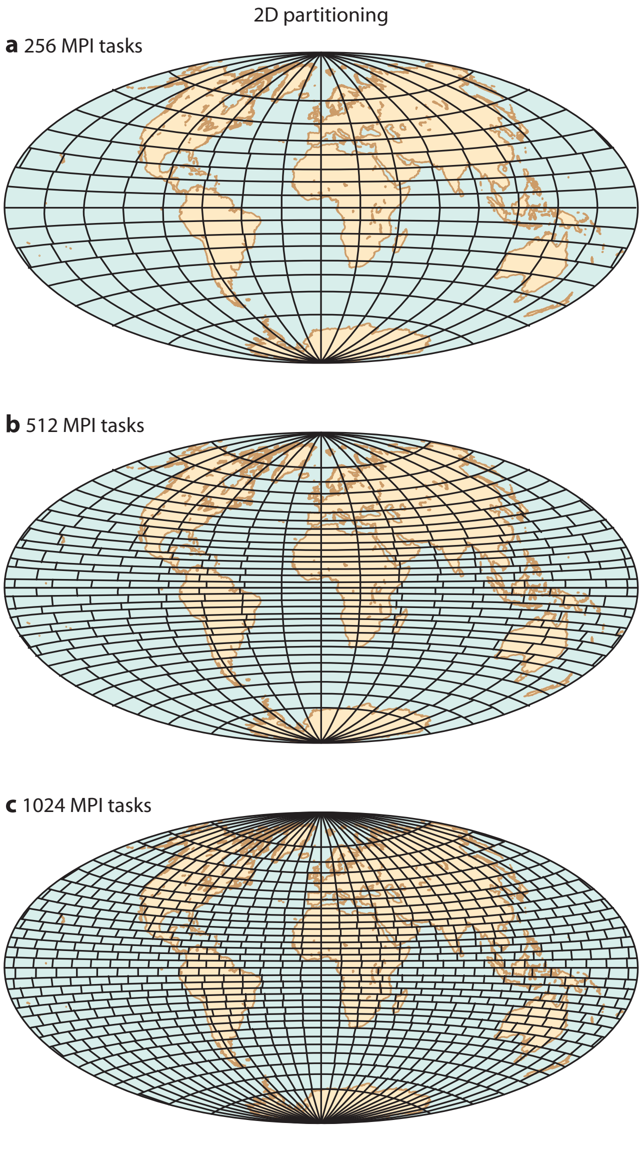


Figure 2 2D partitioning of grid-point space to (a) 256 MPI tasks, (b) 512 MPI tasks and (c) 1024 MPI tasks for the T799 model.

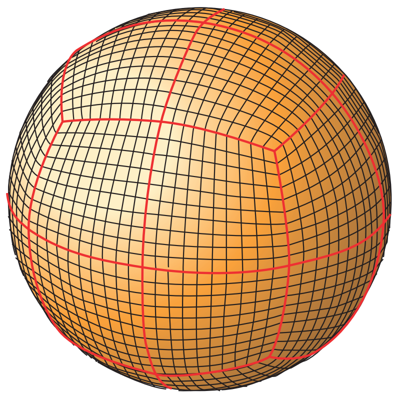


Figure 3 Partitioning the sphere with constant area quadrangles (taken from *Lemaire &Weill*, 2000).

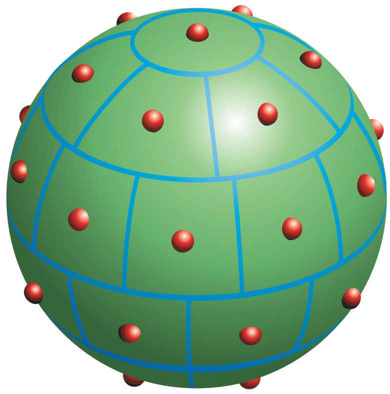


Figure 4 Partitioning of a sphere into 33 regions using the EQ_REGIONS MatLab package.

north-south and 3 bands east-west for this number of partitions. The reason why EQ_REGIONS was attractive is due to the similarity between the IFS 2D bands and what EQ_REGIONS calls collars – the partitioning of a sphere resulting in two polar caps plus a number of collars with increasing partition counts as we approach the equator.

The description of the algorithm and mathematical proof are described in great detail in *Leopardi* (2006). This algorithm results in partitions of equal area and small 'diameter'. However, this would not be sufficient for an IFS implementation, as the density of grid-points on the globe varies with the latitude, the greatest density being at the poles and the least density at the equator. This imbalance is 13% for a T799 model with 512 partitions when using the EQ_REGIONS algorithm to provide the bounds information (start/end latitude, start/end longitude) for each partition as shown in Figure 5.

The solution to this imbalance issue was to use the EQ_REGIONS algorithm to only provide the band information, i.e. the number of north-south bands and the number of partitions per band. Then the IFS partitioning code would use this information in a similar way to that used for 2D partitioning, resulting in an equal number of grid-points per partition. With this approach there was only one new data structure (an single-dimensioned array) used to store the number of partitions in each band.

The results for this balanced EQ_REGIONS implementation can be seen in Figure 6(a) for 256 partitions, Figure 6(b) for 512 partitions and Figure 6(c) for 1024 partitions. The characteristic features of this partitioning approach are square-like partitions for most of the globe and polar caps, together with a significant improvement in the convergence at the poles.

From a code point of view the differences between the old 2D partitioning and the new EQ_REGIONS partitioning are relatively simple as shown in Box A.

Radiation Grid

Radiation computations in the IFS (as in other models) are very expensive and to reduce their relative cost we both reduce the frequency of such computations (i.e. every hour for a T799 model) and run these computations on a coarser grid than the model grid. This coarse grid was initially a sampled model grid (*Dent & Mozdzynski*, 1996) but more recently a reduced grid (linear) was used which gave a small improvement in meteorological skill. As an example, for a T799 model grid (843,490 grid points) the corresponding radiation grid would be T399 (213,988 grid points), with an approximate ratio of 4:1. Of course to use this reduced radiation grid we must interpolate data from the model

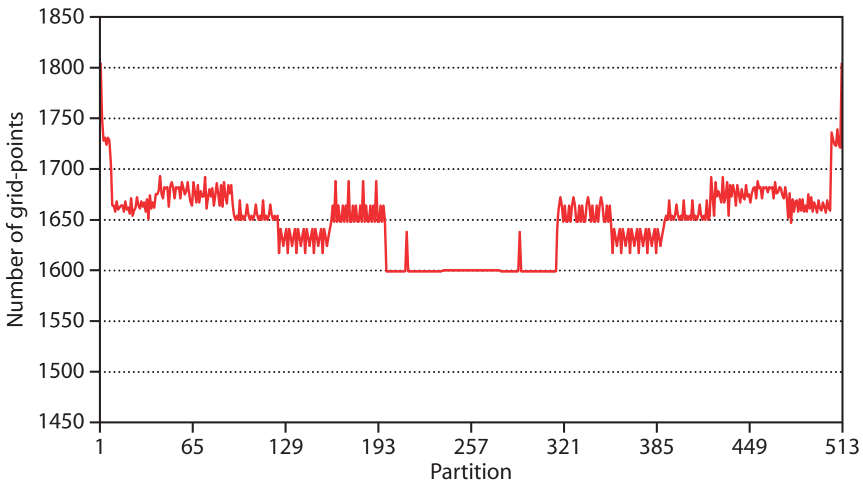


Figure 5 Number of grid-points per partition for T799 resolution using EQ_REGIONS 'area' partitioning for 512 tasks.

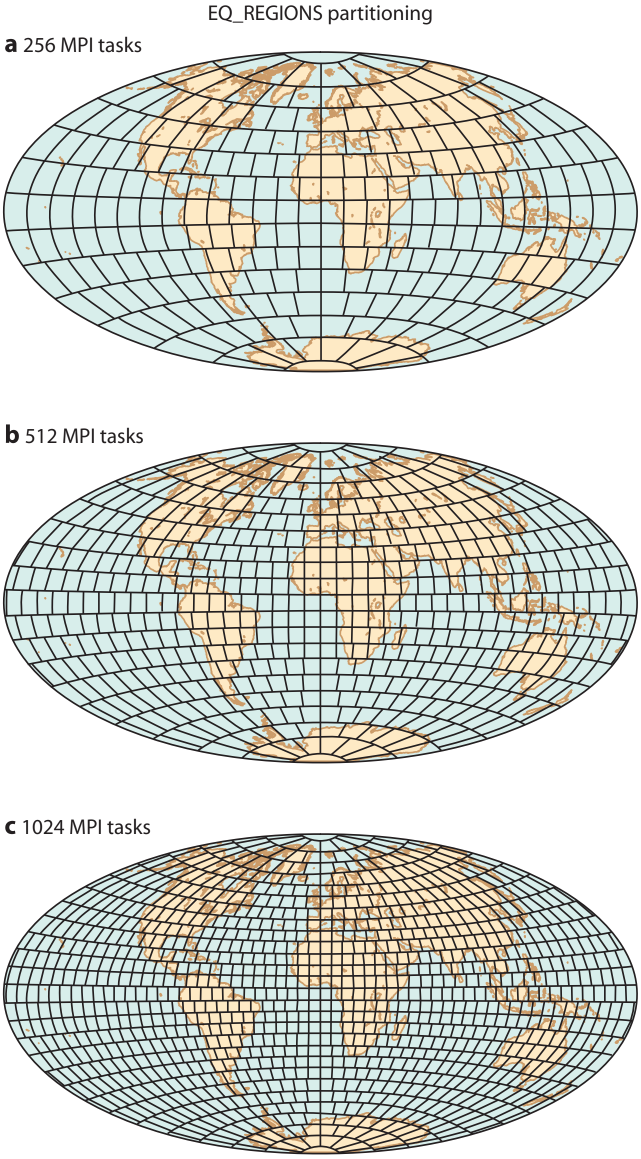


Figure 6 EQ_REGIONS partitioning of grid-point space to (a) 256 MPI tasks, (b) 512 MPI tasks and (c) 1024 MPI tasks for the T799 model.

Box A

Coding differences between 2D and EQ_REGIONS partitioning

For the 2D partitioning there were loops such as:

```
DO JB=1,NPRGPEW
   DO JA=1,NPRGPNS
      ...
   ENDDO
ENDDO
```

where NPRGPEW and NPRGPNS are the number of east-west and north-south bands (or sets).

For EQ_REGIONS partitioning loops were simply transformed into:

```
DO JA=1,N_REGIONS_NS
   DO JB=1,N_REGIONS(JA)
      ...
   ENDDO
ENDDO
```

where N_REGIONS_NS is the number of north-south EQ_ REGIONS bands. N_REGIONS(:) is an array containing the number of partitions for each band. In total some 100 IFS routines were modified with such transformations. It should be noted that the above loop transformation supports both 2D and EQ_REGIONS partitioning, i.e. to use 2D partitioning, a simple namelist variable would be set LEQ_REGIONS=F, which would result in the following initialisation:

```
N_REGIONS_NS=NPRGPNS
N_REGIONS(:)=NPRGPEW
```

grid required for the radiation computations and after such computations interpolate data back to the model grid from the radiation grid, in both cases using 12 point bi-dimensional interpolations.

Two approaches are possible for such interpolation. The first approach would be to send each field to a separate task using a global gather operation, perform the interpolation and then return the data by using a global scatter operation. This approach has the disadvantage that global operations are relatively expensive on today's parallel computers, particularly when the number of fields (variables × levels) to interpolate is less than the number of tasks being used. The second approach, the one used in IFS, was to use a halo for the data required from neighbouring tasks and perform the interpolations locally. This approach was assumed to be better as all tasks are used for the interpolation and only local communication is used. The second approach also had an advantage from a code maintenance viewpoint as the routines needed for supporting the halos already existed for the Semi-Lagrangian scheme and could easily be used for the radiation interpolation.

However, there was a downside to this second approach. The halos required for the radiation interpolations were much larger than one would expect, particularly for large numbers of tasks. It was only after the geographic position of some partitions that required large halos were plotted that the problem was understood. Figures 7 and 8 show the model and radiation partitions (using 2D partitioning) for task 201 (Africa partition) and task 11 (Polar partition) of 512 for a T799 model and T399 radiation grid. One would have expected partitions for two different grids to be at the same geographic position, as they use the same partitioning code. The reason this is not the case stems from the definition of these two grids, one is clearly not a projection of the other. Differences between these two grids are due to the requirements for equal spacing of grid points in each grid (with the exception of polar latitudes). In addition there is a need for the number of points on the same line of latitude to be divisible by factors 2, 3, and 5 – a requirement for the Fourier transforms (see Figure 1).

It is now interesting to see the effect of using EQ_REGIONS partitioning and how it addresses the above problems. To make a fair comparison, tasks 220 and 4 were chosen that by comparison had a relatively large halo but also were located in comparable geographic positions (Africa and Polar) to tasks 201 and 11 for 2D partitioning. This can be seen in Figures 9 and 10 respectively.

The conclusion of this comparison is that EQ_REGIONS partitioning requires smaller halos than 2D partitioning for the interpolation when using the same number of tasks. This translates into less data being communicated and therefore improved performance. To take this further Figure 11 shows graphically the halo area (total halo grid points including a partition's own grid points) for all tasks for the radiation grid interpolation. The top two lines show the halo area required for interpolating from the model to the radiation grid and the bottom two lines for interpolating from the radiation to the model grid. In both cases it can clearly be seen that EQ_REGIONS partitioning results in smaller halos when compared with 2D partitioning.

4D-Var

Besides the model and radiation grids presented earlier, there is another grid used in 4D-Var analyses – it is part of the J_b wavelet scheme (*Fisher*, 2003; *Fisher*, 2004) within the minimisation steps of a 4D-Var cycle. The grid used in this scheme is a 'full grid', where all latitudes contain the same number of points. For the J_b wavelet scheme many such grids of increasing resolution are used (the wavelet scales) from some minimum truncation (default being T21) up to the resolution of the minimisation step. As an example, for a T255 minimisation step, wavelet grids are used at T255, T213, T159, T127, T95, T63, T42, T30, and T21. This can present a problem when scaling to large numbers of tasks as the lowest trunction T21 only has 2048 grid points for a full grid (32 latitudes

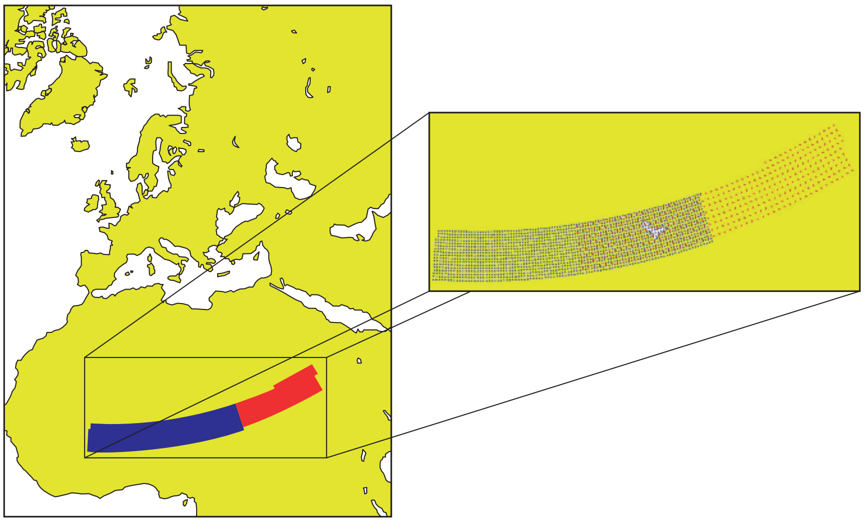


Figure 7 2D partitioning – model (blue) and radiation (red) partitions for task 201 (Africa partition) of 512 tasks for a T799 model/T399 radiation grid.

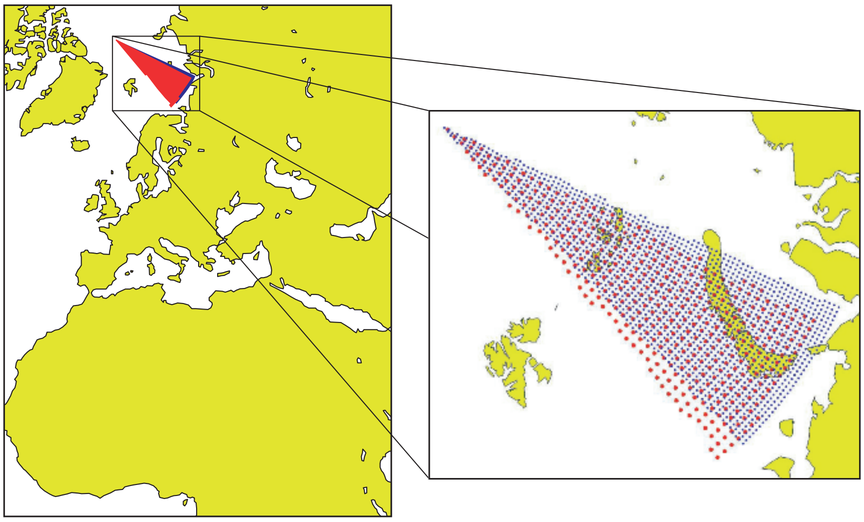


Figure 8 2D partitioning – model (blue) and radiation (red) partitions for task 11 (Polar partition) of 512 tasks for a T799 model/T399 radiation grid.

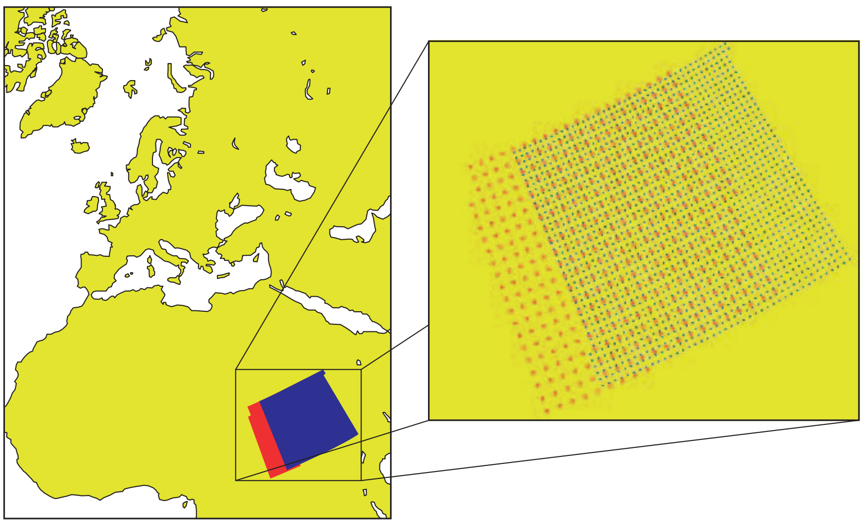


Figure 9 EQ_REGIONS partitioning – model (blue) and radiation (red) partitions for task 220 (Africa partition) of 512 tasks for a T799 model/T399 radiation grid.

each with 64 points). Of course the performance of the J_b wavelet code is dominated by the higher wavelet scales so one should not pay too much attention to the low resolutions. Unfortunately, when testing EQ_REGIONS partitioning it was exactly the lowest resolution that presented a problem; the problem being a constraint of IFS partitioning code that required that a line of latitude could not be split more than once between bands (or A-sets). For 2D partitioning this was not found to be a problem.

After some investigation and discussion with the author of the J_b wavelet scheme a solution was found. The solution was simply to use reduced grids (preferably linear grids) instead of full grids. It was decided to implement this unconditionally as it was realised that the overall performance of a 4D-Var cycle improved by about 2% independent of whether 2D partitioning or EQ_REGIONS partitioning was used. The reason for this performance improvement was obvious, about 30% fewer grid points were used compared with full grids in the above scheme. The wavelet scales used were preset in some large data files, so it was not practical in this implementation to change these. Further, some of these scales were not linear grids (e.g. T213 is a quadratic grid). In the near future it is planned to reset the wavelet scales so that all have corresponding linear grids. This is expected to further improve the overall performance of 4D-Var by an additional 1%.

Performance

In Table 1 there is a comparison of the performance of a T799 forecast model and 4D-Var analysis when using 2D and EQ_REGIONS partitioning. The advantage in using EQ_REGIONS was measured at 3.9% for the forecast model and 2.7% for the 4D-Var analysis. For 4D-Var the 2% improvement gained by using reduced grids for the J_b wavelet grids discussed in the previous section is not included in the latter 2.7%.

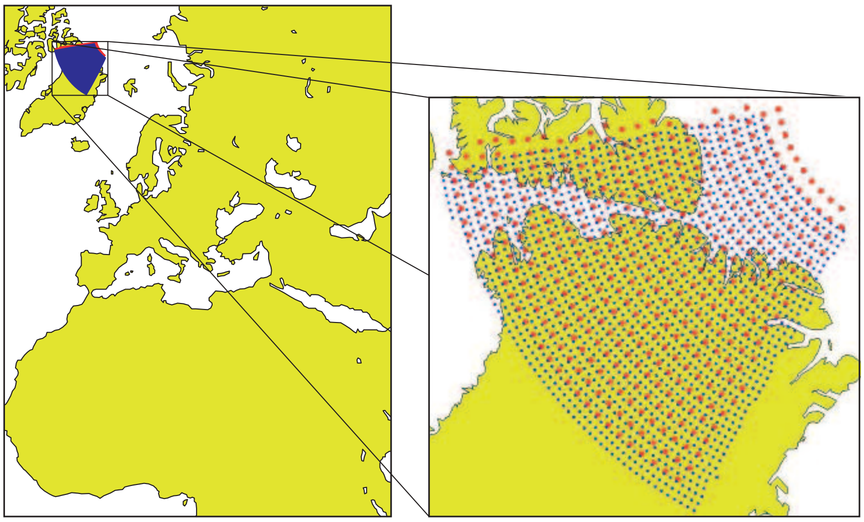


Figure 10 EQ_REGIONS partitioning – model (blue) and radiation (red) partitions for task 4 (Polar partition) of 512 tasks for a T799 model/T399 radiation grid.

While the overall performance advantage for using EQ_REGIONS may only be a few percent, one should bear in mind that IFS applications have had many years of code optimisation and finding even a few percent is increasingly rare. 'Rich pickings' are often found in new code, but less so with code that has been around a long time.

By inspecting some low-level timers in the IFS, it can be seen that some areas of code are now running faster due to a combination of reduced halo sizes used for the Semi-Lagrangian scheme and radiation grid interpolation, and the associated reduction in memory use (always good for performance). However, it can also be seen that there is an increase in the communications used for the transposition of data between grid-point space and Fourier space (see Figure 1). This increased communication is due to the fact that the distribution of latitudes in Fourier space is a very close match to the north-south bands when using 2D partitioning. The transposition to Fourier space from grid-point space requires complete latitudes

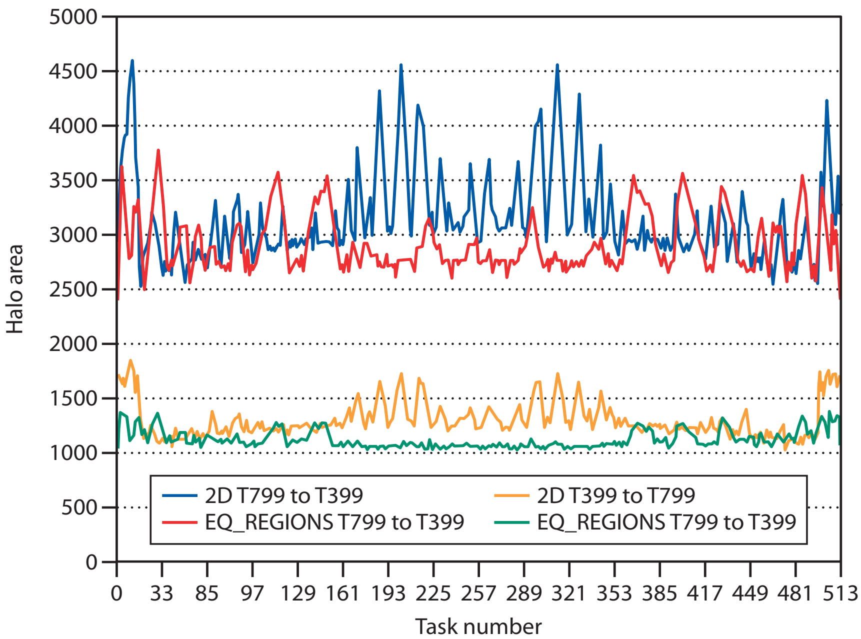


Figure 11 Comparing EQ_REGIONS and 2D partitioning requirement for Halo Area (total halo grid points including a partition's own grid points) for radiation grid interpolation for a T799 model/T399 radiation grid.

Application	Tasks × Threads	2D partitioning (seconds)	EQ_REGIONS partitioning (seconds)	2D/ EQ_REGIONS speed-up
Model	512 × 2	3648	3512	1.039
4D-Var	96 × 8	3563	3468	1.027

Table 1 Comparing the performance of 2D partitioning and EQ_REGIONS partitioning for a T799L91 IFS model and 4D-Var analysis.

as the first dimension, with model levels being distributed as the second dimension. For systems with many CPUs per node (such as ECMWF's IBM p5-575 clusters) a relatively large part of this communication can be performed within each node (when using 2D partitioning). We know that intra-node communication via memory is faster than inter-node communication via the Federation switch. Therefore this seems a reasonable explanation why 2D partitioning is better for this particular communication phase. This scenario naturally changes when truly large numbers of tasks (thousands) or thinner nodes are used. In both these cases, most of the data in such transpositions (if not all transpositions) will need to be communicated via the systems switch, with further gains to EQ_REGIONS over 2D partitioning. Time will tell.

EQ_REGIONS partitioning was introduced in IFS cycle Cy31r2 (November 2006) as the default partitioning scheme for grid-point space. This new partitioning approach together with ongoing developments should allow IFS to continue to scale well on todays and future high performance parallel computers.

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Probability forecasts for water levels at the coast of The Netherlands

HANS DE VRIES
KNMI, DE BILT, THE NETHERLANDS

ACCURATE storm surge forecasts are of paramount importance for a country which, like The Netherlands, has an important part of its economic activity and population concentration close to the coast in a part of the country which is near or even below sea level. The primary usage is for coastal defence and the operation of the storm surge barriers in the Oosterschelde and the Nieuwe Waterweg, the entrance to the harbour of Rotterdam. But the forecasts are also used for assisting shipping traffic in and out of the Rotterdam harbour and by inland water management boards to assess their ability to sluice water into the sea at low tide in case of heavy rainfall.

Forecasts are issued by KNMI, the Royal Netherlands Meteorological Institute, in close cooperation with the Storm Surge Warning Service (SVSD) of Rijkswaterstaat, the Public Works and Water Management Authority. When there is a severe storm surge, the SVSD takes the final responsibility for the water level forecasts that are issued and warns other appropriate authorities.

The standard tool available for numerical operational storm surge forecasts is the two-dimensional shallow-water model WAQUA/DCSM98. This model covers all of the NW European Continental Shelf, which includes the North Sea, with a resolution of 8 km. Figure 1 shows the area covered by the model and the water depths. The atmospheric forcing for day-to-day forecasts for up to 48 hours ahead is provided by the 10-metre wind and mean sea level pressure from KNMI's operational HIRLAM limited area model. This system provides sea level forecasts four times per day. A steady-state Kalman filter is used to assimilate water level observations from tide gauges on the east coast of Britain and the Dutch coast.

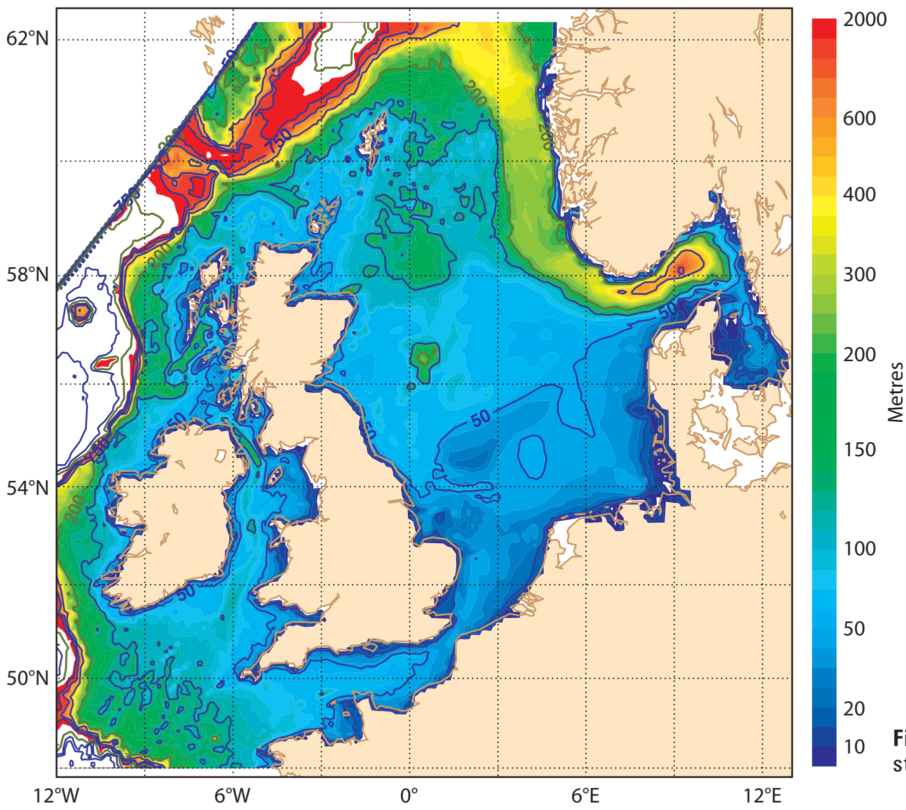

Figure 1 Depth map of the WAQUA/DCSM98 storm surge model.

Recently, there has been growing attention to the increased possibility of and the vulnerability to flooding due to the effects on sea level and storm climate caused by global warming. This has prompted the extension of the forecast range, together with the need for information on the uncertainty of the forecasts. ECMWF's Ensemble Prediction System (EPS) is an obvious candidate to provide input for such forecasts. A comparatively simple model which calculates surges using a statistical technique had already been coupled to the EPS to produce forecast plumes. But now, the increased capacity of computers allows for a water level ensemble based on the numerical two-dimensional storm surge model, which is generally more accurate and also more flexible in its output. The results of this ensemble are being used to produce probability forecasts for water levels in selected locations.

The forecasting system

WAQUA/DCSM98 with input from the EPS has been running in real-time experimental mode since February 2007. With data from the winter 2003/04, hindcasts have been run to establish the calibrations which are needed to generate probability forecasts from the ensembles. Results for eight locations along the coast of The Netherlands are presented on the Internet. Figure 2 gives an example of a forecast.

Probabilities derived from the ensembles are represented by bars with varying thickness and colours to indicate the range. Astronomical extremes are given as black crosses and observations, if already available, as red circles. Also shown are the levels defined by the SVSD to indicate the severity of the surge. The probabilities never span the full 100% range. One reason is that the derivation of the probabilities explicitly allows for a small fraction of the forecasts to lie outside the ensemble. Also ensemble members might be so close together, especially at the edge of the ensemble, that parts of the probability density function collapse. For forecasts less than 48 hours ahead, lack of spread in the ensemble makes more of the probability fall outside the ensemble and generally not more than the 25% to 75% interval can be determined.

The forecasts are being used, for example, for medium-range planning of the personnel required in case of a severe storm. But there is also a keen interest from inland water management boards. They use the information on predicted low-tide levels for medium-range planning of the regulation of inland water levels when heavy rainfall is forecast.

In November 2007 a storm occurred which reached the alarm level for the whole of the Dutch coast, except for Vlissingen in the south where it fell just a few centimetres short. In Hoek van Holland the water reached the highest level since the disaster in 1953. It was the first time in more than 30 years that warnings and alarms had to be issued for the entire Dutch coast. The storm surge barriers in the Oosterschelde and the Maeslantkering and Hartelkering near Rotterdam had to be closed, the latter two for the first time in the event of a storm surge. The high levels were successfully captured as far as five days ahead. Figure 2 shows the forecast for Hoek van Holland three days ahead. Such forecasts are used to decide whether to close the barriers near Rotterdam.

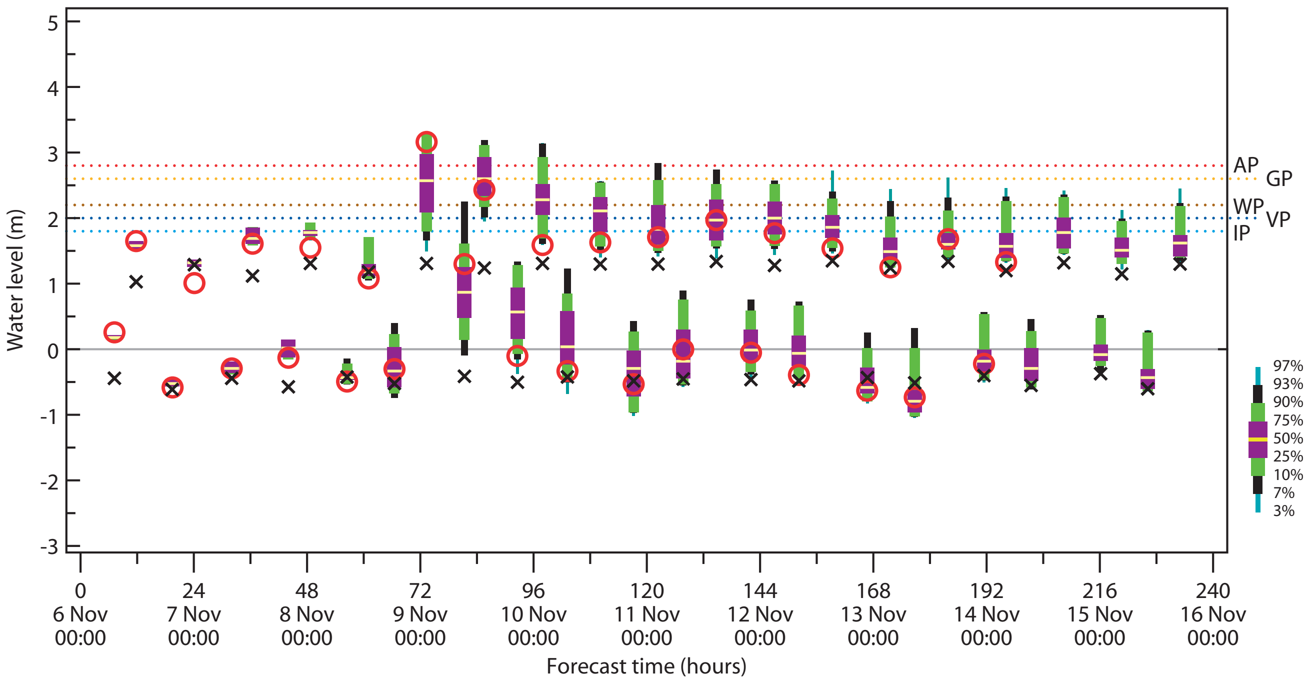

Figure 2 Example of a probability forecast for Hoek van Holland (00 UTC on 6 November 2007). Astronomical extremes are given as black crosses and observations as red circles. The horizontal lines indicate the levels defined by the SVSD to indicate the severity of the surge: information (IP), pre-warning (VP), warning (WP), storm surge (GP) and alarm level (AP).

Calibration of deterministic forecasts

The transformation of the 'raw' ensemble forecasts into probability forecasts and an evaluation of their quality involved several steps.

The first step was the validation of deterministic water level forecasts with input from the deterministic high-resolution ECMWF atmospheric model. This was done for the period September 2003 to April 2004, a recent winter which contained a reasonable amount of storm surges. As one of the validation tools, the correlation between forecast tidal extremes and observations is used. Figure 3(a) shows the correlation for IJmuiden. This is essentially a scatter plot which has been transformed into a two-dimensional histogram. The contour lines indicate the density of the points, starting from 10% below the highest level and go logarithmically down to single points. The deviation from the main diagonal, as seen in Figure 3(a), indicates a systematic under-prediction of surges.

As storm surge forecasts with input from HIRLAM do not suffer from such systematic under-prediction, a comparison was made between the 10-metre wind fields (i.e. the main input to the storm surge model) from HIRLAM and the ECMWF model. This comparison is shown in Figure 4 for a collection of wind fields for the same forecast time from stormy periods. As in Figure 3, this gives the densities of the two-dimensional histogram of the wind speeds over the North Sea from HIRLAM and the ECMWF model interpolated to the grid points of the storm surge model. It shows an under-prediction for higher wind speeds. To quantify this, averages and standard deviations of the densities have been calculated perpendicular to the main diagonal; these are shown by the dashed (average) and red lines (average ± standard deviation). For wind speeds below 8 m s^{-1} the averages lie close to the main diagonal, but the excess above this is on average 14% less in the ECMWF model than in HIRLAM. The green line in Figure 4 summarises this. Similar plots for wind directions show no systematic differences.

A rerun of the storm surge model shows that applying a wind correction of +14% on the excess of 8 m s^{-1} indeed removes the systematic under-prediction of the results. This is shown in Figure 3(b). For the control run of the EPS the same correction is found.

Calibration of the ensemble

To assess the quality of the sea level ensemble and derive probabilities, forecast ensembles have been regenerated for the winter 2003/04, both with and without the correction of the wind speed described earlier. The ensembles are studied by means of Rank Histograms, also known as Talagrand Diagrams. To construct these, a ranking from low to high is established for the forecasts for each of the tidal extremes for each of the sea level ensembles. This gives unequally spaced forecast intervals for each of the tides, which are unique for every ensemble forecast and for every tidal extreme.

For an ideal forecasting system the realization of the sea level is equally likely to fall in either of these intervals, including two for everything below or above the ensemble. The Talagrand Diagram is a histogram of these realizations. Its shape characterises the forecasting system. In the ideal case where all intervals are populated equally, the histogram is flat. An ensemble system with too little variation between the members

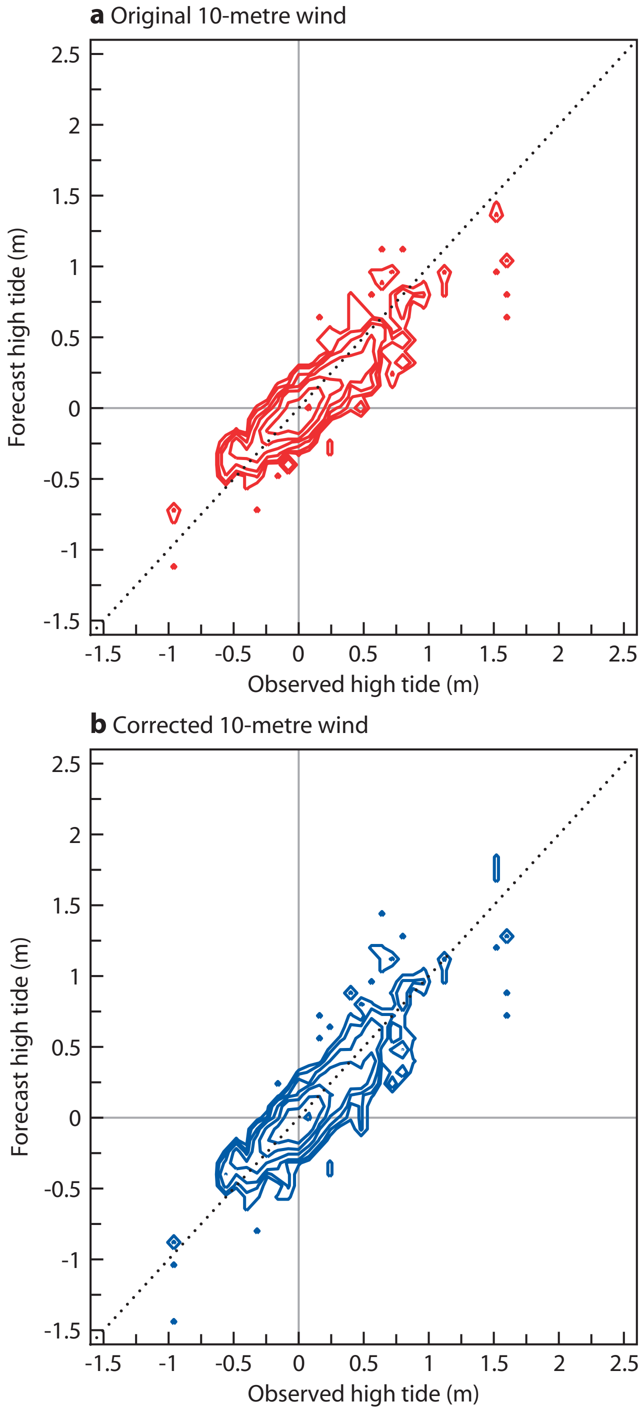

Figure 3 Validation of deterministic forecasts from T+48 to T+96 for high tides for IJmuiden with (a) original 10-metre wind and (b) corrected 10-metre wind.

leads to realizations which are often at the edges or outside of the ensemble, and hence gives a u-shaped histogram. However, too much variation gives under-population of the edges and hence a bell shape. A skew diagram indicates under- or over-prediction. The Talagrand Diagram can be summed to get a so-called Cumulative Rank Histogram (CRH). This gives the relation between ensemble probabilities and observed frequencies. An additional advantage of the CRH over the Talagrand Diagram is that the former smooths out the scatter between the different intervals and hence gives a clearer characterisation of the system.

Figure 5 gives an example of a Talagrand Diagram and the corresponding CRH. The diagrams have been produced from all high tide forecasts from 60 to 96 hours ahead for Hoek van Holland. The red curves are without the correction of the 10-metre wind and the black curves include this correction.

The under-population of the lower and over-population of the higher forecast intervals indicate that the ensemble considerably underestimates the surges. Although the correction of the 10-metre wind works the right way and brings down the fraction of the forecasts where the observation is higher than the ensemble, from 12% to 8% in this case, it is not enough by far. Moreover, the under-population of the lower forecast intervals does not change significantly. An explanation for that can be found in the observation that the lower surges that populate these bins are caused by lower winds for which the correction is smaller.

These features are typical for the whole range of the Dutch coast and all forecast ranges from 48 hours ahead. For ranges up to 48 hours the diagrams are characterised by too little variation in the ensemble members. This, however, is a well-known feature of the EPS. In order to overcome the under-prediction, various correlations between ensemble parameters and observations have been investigated. The most promising is the relation between the standard deviation of the ensemble and the difference of the ensemble mean from the observation as illustrated in Figure 6; this figure shows an increase of the average difference with ensemble width.

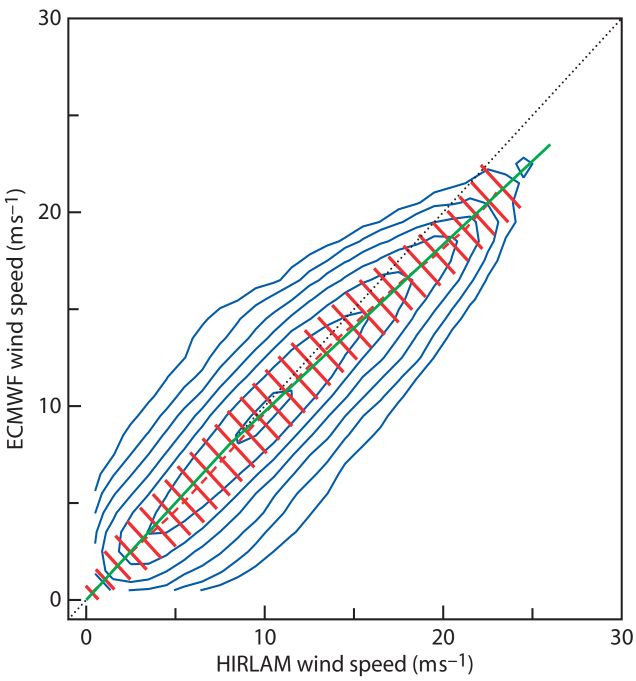

Figure 4 Correlation between HIRLAM and ECMWF winds for stormy periods. Averages and standard deviations of the densities calculated perpendicular to the main diagonal are shown by the dashed (average) and full red lines (average ± standard deviation).

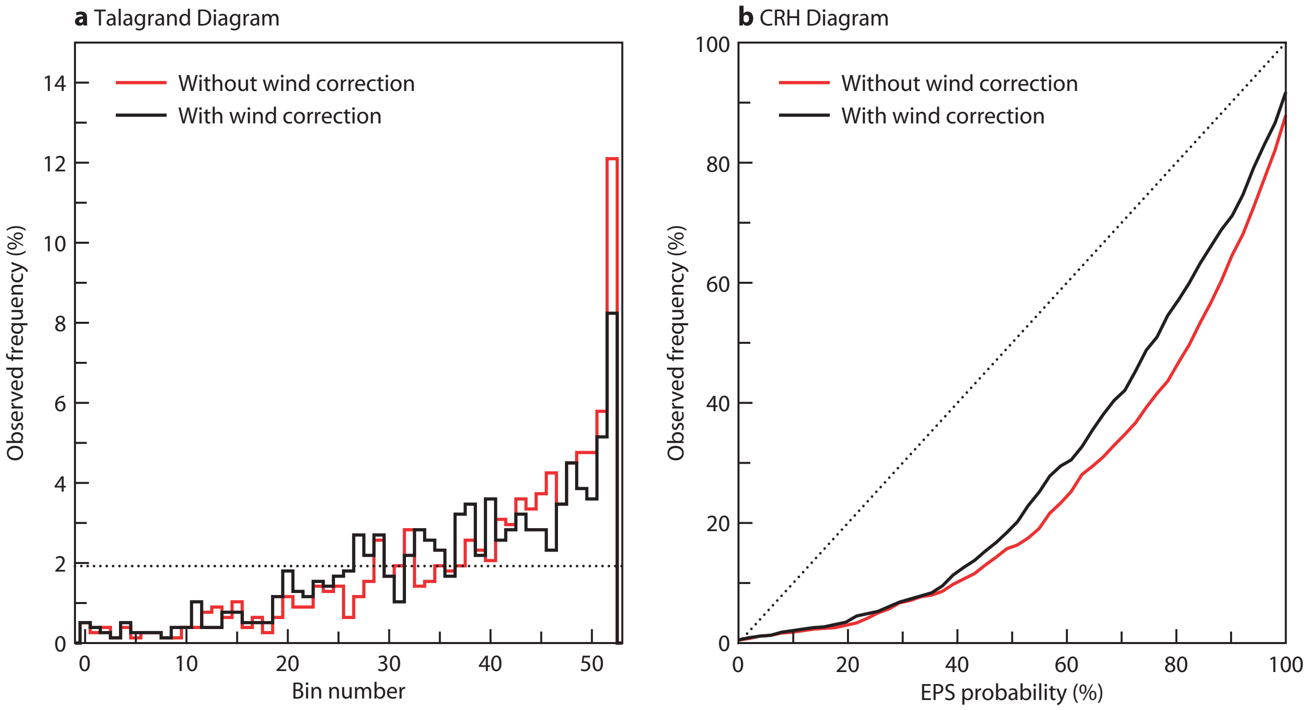

Figure 5 (a) Talagrand Diagram and (b) CRH diagram for all high tide forecasts from T+60 to T+96 for Hoek van Holland without corrections to the ensemble. The red lines are without the 10-metre wind correction, the black lines include the correction.

For positive surges there is an increasingly negative difference between the ensemble mean and the observations and for negative surges this difference gets more and more positive. This trend points to a bifurcation in the probability density function for the larger surges, positive or negative. A number of ensemble members does catch this surge, but others do not and the standard deviation of the ensemble as a whole increases.

From this relation a simple correction has been constructed to bring the average difference back to zero by shifting the ensembles according to their standard deviation. The Talagrand Diagrams, regenerated with this correction, exhibit a very much improved shape and the systematic under-prediction has been removed, as shown in Figure 7.

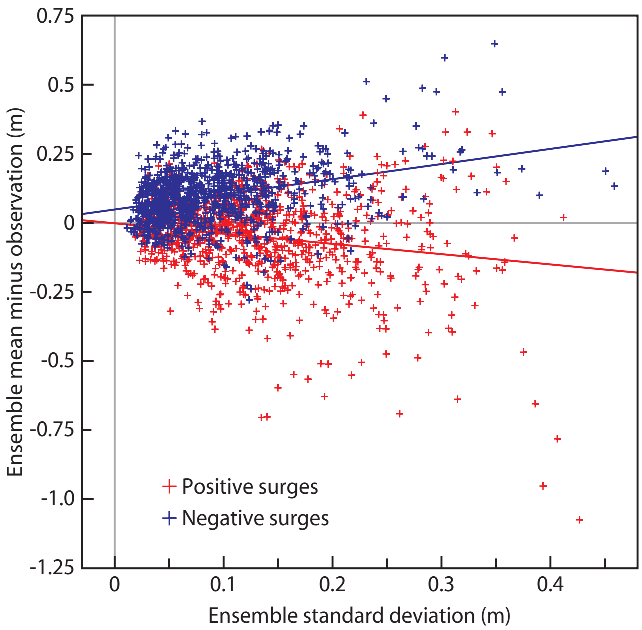

Figure 6 Ensemble mean minus observation versus ensemble standard deviation. Red crosses are from positive surges, blue crosses from negative surges.

Skill of the forecasts

The corrected CRHs can be used to calculate calibrated probabilities from the ensemble forecasts. To validate these, the Brier Skill Scores for the exceedance of different levels have been determined. The sample climatology has been used as reference. As an example, Figure 8 gives the Brier Skill Scores for the exceedance of a range of surge levels for 36 hours starting from day 2 and day 5 for IJmuiden for low (black curves) and high tides (red) and both with the corrected (solid) and the uncorrected (dashed) CRH diagrams.

For surges between -0.5 m and +0.8 m there is skill, even after day 5, when the corrected CRH is used. Outside this surge range there were only a few cases during the period, which makes the results statistically insignificant and the Brier Scores vary wildly.

For the results shown in Figure 8 the 10-metre wind correction was applied, but without the wind correction the results are similar. This means that, although the correction improves the deterministic forecast, it can be omitted for the generation of the probability forecasts. Therefore, it is not applied in the real-time ensemble system.

Because the 10-metre wind correction can be omitted for the generation of the probability forecasts, recalibration becomes easier. The ensembles do not have to be rerun once a new 10-metre wind correction

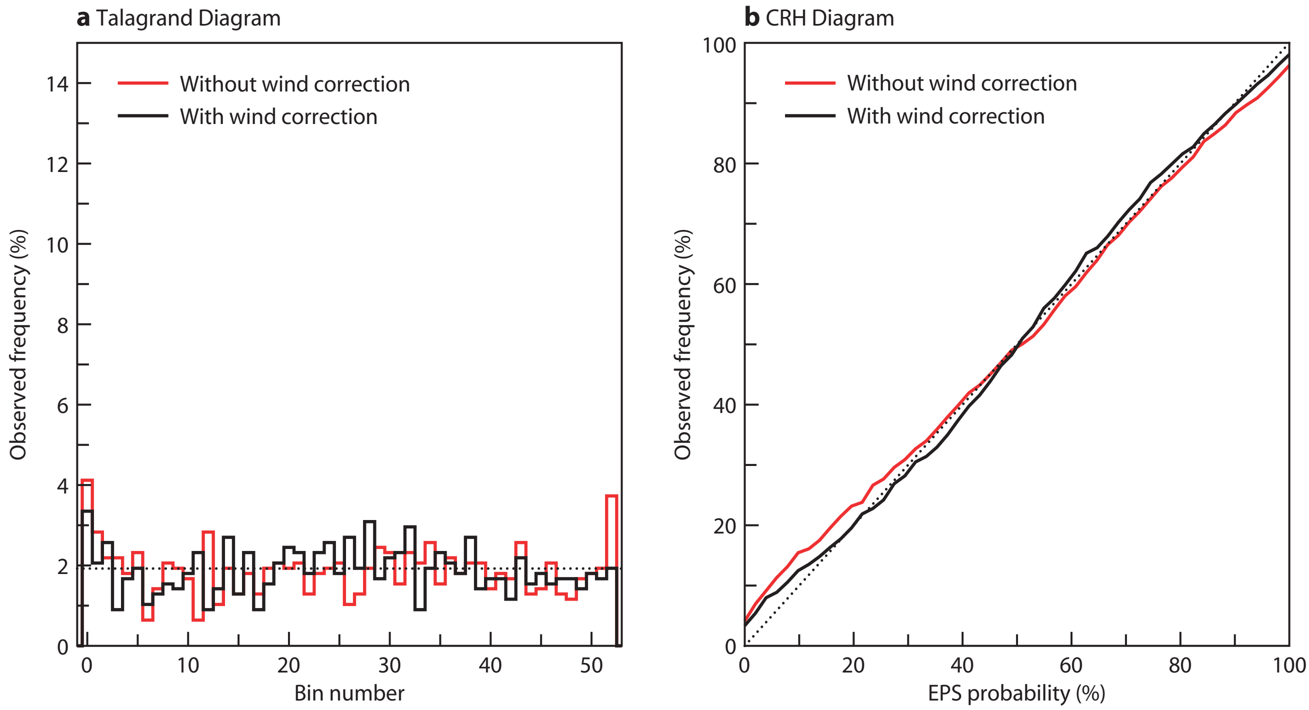

Figure 7 (a) Talagrand Diagram and (b) CRH diagram for all high tide forecasts from T+60 to T+96 for Hoek van Holland with corrections to the ensemble. The red lines are without the 10-metre wind correction, the black lines include the correction.

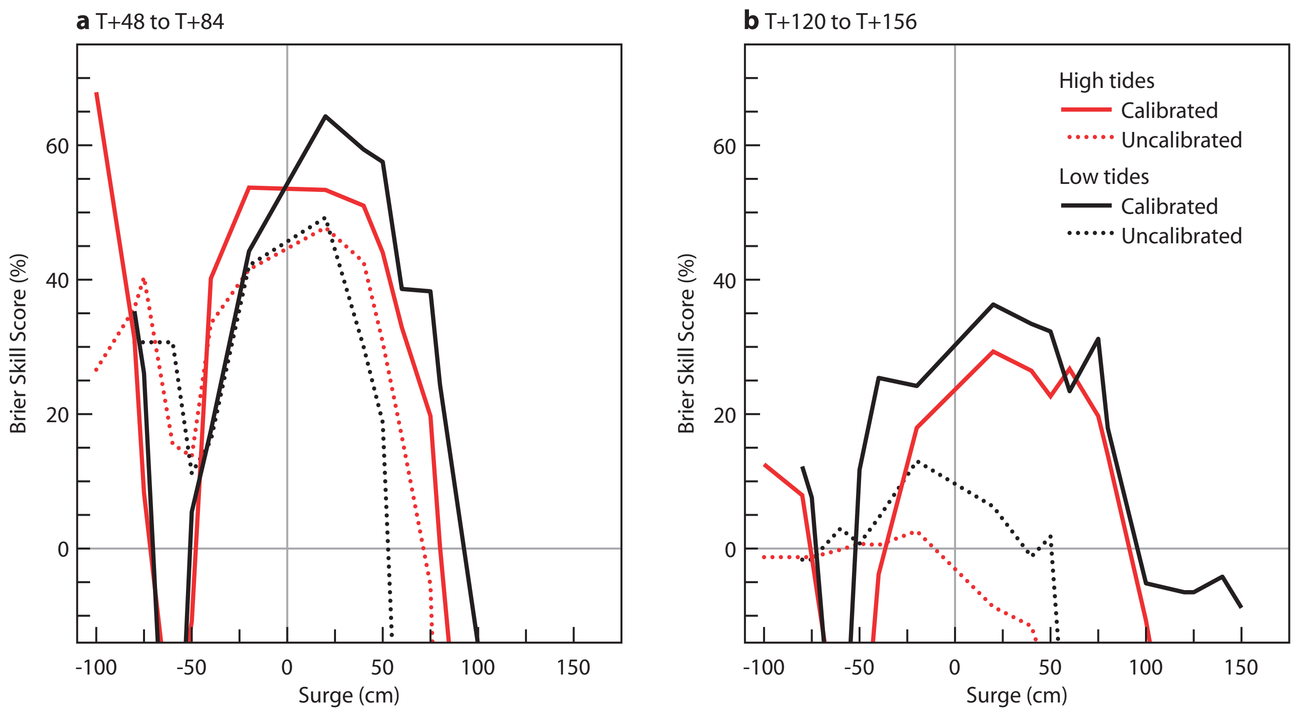

Figure 8 Brier Skill Scores for different forecast intervals for IJmuiden: (a) T+48 to T+84 and (b) T+120 to T+156. Black curves are for low tides, red curves for high tides. The solid curves are for the calibrated, dashed curves for uncalibrated probabilities.

has been established, but a new calibration for the ensemble can simply be derived from the forecasts that have already been generated.

Recalibration

A drawback of a calibrated forecasting system is that the calibration should be maintained, especially after changes in the underlying forecasting models. A major change of the deterministic atmospheric model and EPS occurred in February 2006 when the resolution of both was upgraded. The calibrations of both the deterministic water level forecasts and the water level ensemble were re-established from the data for September 2006 to March 2007. A fortunate advantage for this purpose was that this winter, like the one of 2003/04, contained several significant storm surges.

Corrections for the 10-metre wind from the deterministic model have reduced from 14% extra for the excess of 8 m s^{-1} to 11% for the excess of 10 m s^{-1}. Also the calibrations for the ensembles have changed, but the under-prediction is still present and can be corrected for in the same way as described earlier.

Future developments

The medium-range probability forecasts have found an important application in providing guidelines for the planning of activities. For short-range forecasts there is also a desire for uncertainty information, which will help decision making, e.g. in case of a storm surge for the closing of storm surge barriers. The EPS unfortunately does not help on these time scales, but other possibilities include the use of an ensemble of storm surge models which are in use by various institutions around the North Sea or input for the storm surge model from a HIRLAM ensemble which is under development.

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Advances in simulating atmospheric variability with IFS cycle 32r3

PETER BECHTOLD, MARTIN KÖHLER, THOMAS JUNG, MARTIN LEUTBECHER, MARK RODWELL, FREDERIC VITART

Forecasting the state of the atmosphere involves the prediction of a slowly evolving mean equilibrium state (also referred to as the climate) and the temporal and spatial variations around this state. Predicting the amplitude and phase of the planetary, synoptic and mesoscale perturbations is not an easy task. This is especially so in the tropics where with decreasing latitude the radius of influence (also called Rossby radius of deformation) over which a given perturbation impacts on the background flow extends to infinity. Consequently the perturbations can actually circle the entire tropical belt.

Issues related to atmospheric variability as predicted using ECMWF's Integrated Forecast System (IFS) particularly concern the following.

- A decrease in amplitude of tropical synoptic and planetary-scale activity within the first ten days of the forecast.
- A slight underestimation of mid-latitude synoptic activity in the medium range.
- A lack of growth of the ensemble spread in mid-latitudes in the Ensemble Prediction System (EPS) that is compensated by choosing large initial perturbations.
- An underestimation in the total amount of precipitation and the amplitude of the annual cycle over the tropical continents.

Some of these issues are not specific to the IFS, but are shared by many global atmospheric modelling systems.

The relative activity of a model can be defined as the standard deviation of forecast anomalies divided by the standard deviation of observed (i.e. analysed) anomalies from the ERA-40 climatology. Figure 1 shows the relative activity as a function of forecast lead time for forecasts with model cycle 32r2 (hereafter Cy32r2) that was operational between 5 June 2007 and 6 November 2007, and cycle 32r3 (Cy32r3) that became operational on 6 November 2007 and which is the topic of this article. Relative activity is shown for 850 hPa temperatures in the northern and southern hemispheres (poleward of 20°), and for 925 hPa temperatures in the tropics. The 850 hPa temperature variations in mid-latitudes are a good measure of cold and warm advection associated with synoptic systems, whereas tropical temperatures variations at the 925 hPa level are representative of the low-level convergent/divergent circulations.

Figure 1 indicates that Cy32r2 slightly underestimates mid-latitude atmospheric activity, but more importantly underestimates activity in the tropics. This problem was also present in all previous cycles. In contrast, in Cy32r3 model activity is close to the climatology within the first ten days in both the mid-latitude and tropical regions. Indeed the dots show that the activity is significantly better compared to Cy32r2 at the 95% confidence level. The higher, but more realistic level of atmospheric activity has been achieved without compromising classical deterministic forecast scores.

In the rest of this article we consider the main features introduced with Cy32r3 and their impact on the model climate and deterministic forecasts. We also discuss the consequences of the model changes for the EPS and the monthly forecasts.

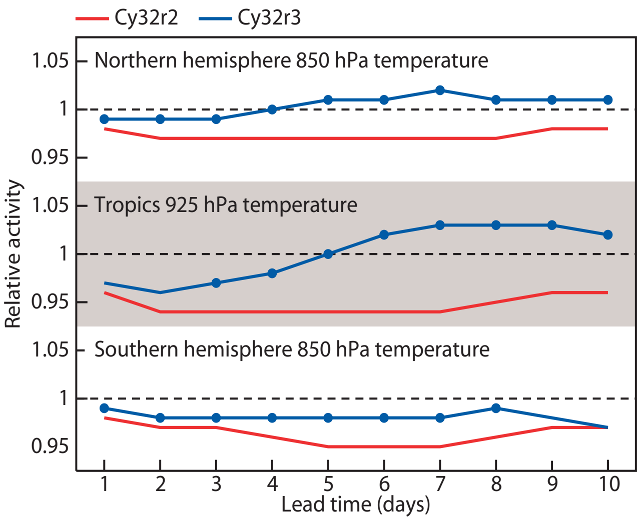

Figure 1 Relative activity in Cy32r2 and Cy32r3 as a function of forecast lead time for 850 hPa temperatures in the northern and southern hemispheres, and tropical temperatures at 925 hPa. The relative activity is defined as the ratio between the standard deviation of forecast anomalies and the standard deviation of anomalies from an ERA-40 based climatology. The blue dots denote improvements that are significant at the 95% confidence level.

Features of Cy32r3

The two main physical processes that lead to the generation of kinetic energy in the atmosphere are radiative cooling/heating and convective heating, with the differential radiation being the actual driving force of the general circulation. On sufficiently large space and time scales the two processes are in quasi-equilibrium above the boundary layer. Inside the boundary layer, it is the turbulent diffusion that regulates the exchanges of momentum and heat between the surface and the atmosphere, and the dissipation of kinetic energy. Therefore, from a physical point of view, one would suspect one of these processes as being responsible for the lack of model activity. Recently, the radiation scheme received a substantial upgrade with a new shortwave code and the introduction of McICA (Monte Carlo Independent Column Approximation) (*Morcrette et al.*, 2007), so that the focus is now on convection and vertical diffusion. However, there exists another source of kinetic energy dissipation in the model. This is the numerical diffusion that is inherent to the interpolations in the semi-Lagrangian advection scheme, but this source of dissipation is not affected by the changes associated with Cy32r3.

Before Cy32r3 the formulation of deep convection imposed a strong coupling between the convection and the large-scale dynamics through an entrainment formulation based on the large-scale moisture convergence. This, together with an iterative procedure, leads to a nonlinear feedback between the large-scale flow and convection that is difficult to control. Therefore, it was decided to remove any imposed large-scale control of the convection through the ω field (where $\omega = dp/dt$) or the moisture convergence, and to let the model find its own equilibrium. As a first step the convection scheme has been rendered quasi-linear which facilitates the optimisation of parameters. The entrainment is set proportional to the relative humidity of the environment based on the observations showing that convective cloud development is controlled by mid-tropospheric relative humidity. Furthermore the entrainment is scaled with a vertical function decreasing exponentially with height thereby mimicking an ensemble of clouds. The convective adjustment time is no longer a constant varying with model resolution (720 s at T799, and 3600 s at T159). Instead the adjustment time is a quantity equivalent to the estimated convective turnover time scale with a weak resolution dependency of a factor of two between model resolutions of T799 and T159. Finally, rain evaporation below convective clouds is set to occur with environmental relative humidities of less than 0.9 (0.7) over water (land). Different values are used over land and water in order to account for differences in the horizontal variability of the water vapour field.

Furthermore it has been realised for some time that for both stably stratified boundary layers and outside the boundary layer the model turbulent mixing, which is intended to reduce static and shear instabilities, is too strong. The consequence is that stratocumulus layers tend to be eroded, and the vertical shear of the wind is reduced. However, it turns out that stronger vertical diffusion is beneficial for deterministic forecast scores. Therefore, as a pragmatic step, it was decided to interpolate the diffusion coefficients between the former *Louis et al.* (1982) formulation in the surface layer and the formulation given by the Monin-Obukhov theory higher in the free troposphere.

Cy32r3 also contains two other major changes.

◆ A change in the soil hydrology scheme including a soil texture map and a new set of hydraulic properties for unsaturated soils, as well as a sub-grid surface runoff.
◆ A new bias correction scheme for radiosonde temperature and humidity data as a function of solar elevation and radiosonde type.

These changes have a beneficial impact on soil moisture and surface runoff. They also lead to a slightly moister analysis in the free atmosphere that more closely fits the observations.

In addition Cy32r3 includes changes in the assimilation and observing system. These concern an increase in the number of radio occultation data from COSMIC and use of additional sources of satellite data (see Table 1).

Changes to the IFS, particularly to the physical and numerical aspects, require thorough testing. It is impossible to cover all of them here, but some key diagnostics of the model climate and the quality and activity of the forecasts will now be discussed.

Model climate

Figure 2 compares the precipitation average from the Global Precipitation Climatology Project (GPCP, a merger of raingauge data and satellite-derived rain-

Instrument	Platform
AMSR-E (Advanced Microwave Scanning Radiometer – Earth Observing System	Aqua
(SSMIS) Special Sensor Microwave Imager/Sounder	Defense Meteorological Satellite Program (DMSP)
TMI (TRMM Microwave Instrument)	Tropical Rainfall Measuring Mission
SBUV (Solar Backscatter Ultraviolet)	NOAA-17/NOAA-18
OMI (Ozone Monitoring Instrument)	Aura

Table 1 Additional sources of satellite information used in Cy32r3.

rates) for the December to March period with the values obtained from long integrations at resolution T159L91 for Cy31r1, Cy32r2, and Cy32r3.

- Cy31r1 has been operational between 12 September 2006 and 5 June 2007; it is also the cycle used in the Interim Reanalysis and the current seasonal forecasting system known as System 3. This cycle (and previous cycles) underestimates precipitation over the tropical continents, but overestimates precipitation over the Pacific Inter Tropical Convergence Zone (ITCZ) and the southern Indian Ocean.
- Cy32r2 with the revised radiation scheme reduces the precipitation biases, especially the convective rainfall over the tropical continents, due to stronger cloud-radiative feedback and a better description of surface shortwave heating.
- With Cy32r3 the overall rainfall distribution is further improved everywhere, including a better land sea contrast, apart from an overestimation of convective precipitation in the West Pacific. The global average precipitation rate is reduced from 3.0 to 2.9 mm/day (which is more in line with observational estimates). Also the tropical troposphere becomes significantly moister between 850 and 600 hPa (not shown).

The rainfall changes in Cy32r3 not only reflect a local effect due to the changes in convection, but also reflect changes in the large-scale circulation and the transport of moisture from the subtropics to tropical regions. Finally, take a closer look at the precipitation rates averaged over the Amazon basin and parts of the Andes (Figure 3). It is noticeable that compared to a special set of raingauge data (*Betts et al.*, 2005) Cy32r3 also improves the amplitude of the annual cycle of rainfall which has been rather flat in previous IFS cycles.

The tropical activity in the long integrations is effectively evaluated with so called wavenumber-frequency diagrams for either Outgoing Longwave Radiation (OLR), 850 hPa winds or 200 hPa velocity potential. Theory (*Gill*, 1980) says that an equatorial local heat source generates, amongst others, westward moving Rossby waves with phase speeds around 5 m s^{-1}, and eastward moving Kelvin waves with phase speeds of 15–20 m s^{-1}.

Figure 4 compares the wavenumber-frequency spectra of the predicted OLR averaged over the latitude band 10°S–10°N to spectra of the OLR observed by NOAA satellites. Notice the relative lack of power in the easterly modes (Kelvin waves) in Cy31r1 and Cy32r2. However, Cy32r3 realistically represents both Rossby and Kelvin mode activity, but now somewhat overestimates the power in the low-frequency low-wavenumber range. The dominant mode in the OLR spectrum within the positive wavenumber 1–2 band and frequency range of 20–60 days (0.05–0.016 cycles per day in Figure 4) is

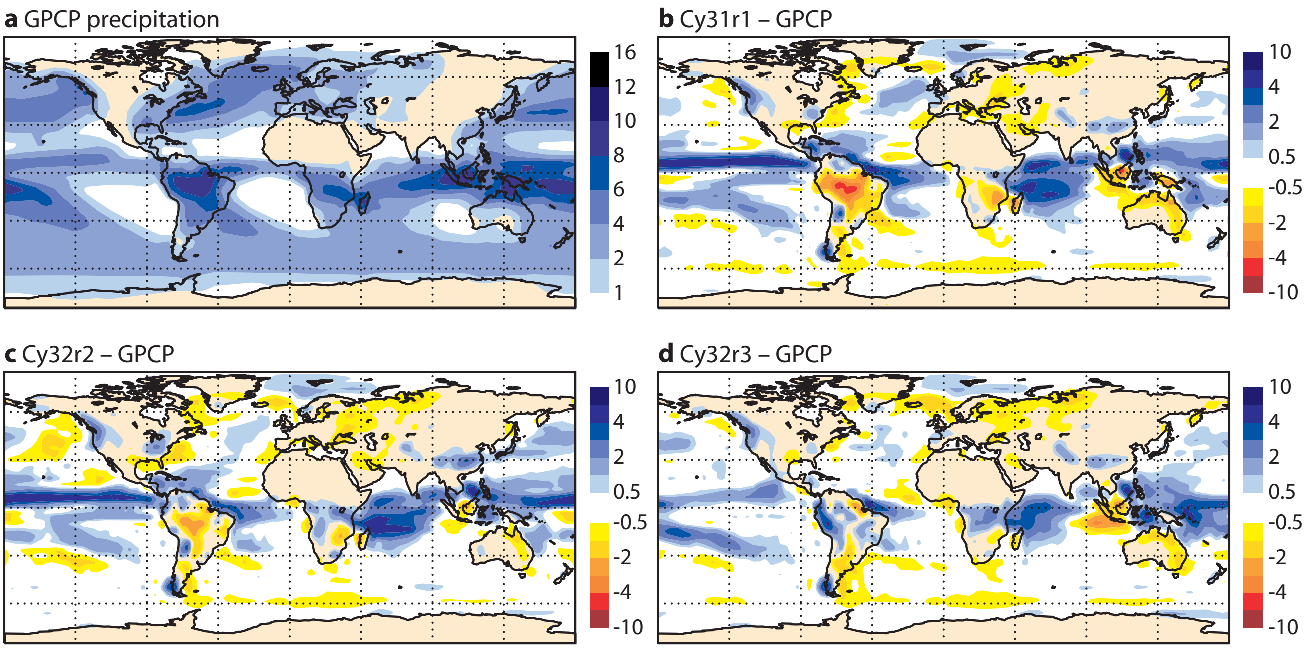

Figure 2 (a) Average precipitation rate (mm/day) for December, January and February 1990-2005 from GPCP. (b) Difference between the seasonal type integration at resolution T159 with Cy31r1 and GPCP. (c) and (d) As (b) but for Cy32r2 and Cy32r3.

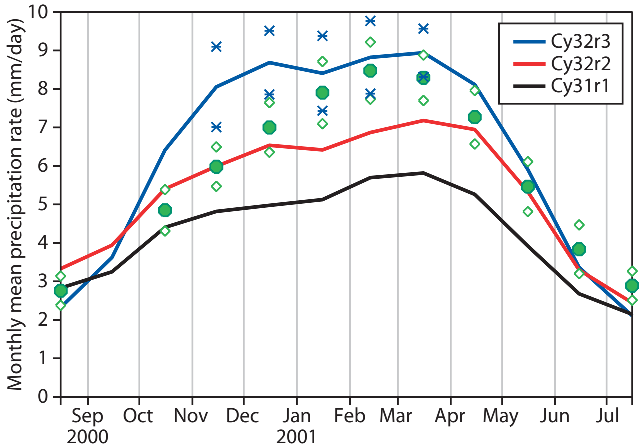

Figure 3 Annual cycle of monthly mean precipitation rates (mm/day) for Amazonia obtained from a one-year integration of a four-member T159 ensemble with Cy31r1 (black), Cy32r2 (red) and Cy32r3 (blue). The raingauge observations are denoted by the green dots and the standard deviations of monthly mean precipitation rates for the observations and Cy32r3 are denoted by green diamonds and blue crosses, respectively.

a signature of the Madden-Julian Oscillation (MJO). The increased wave activity in Cy32r3 also has a beneficial impact on temperatures and winds in the stratosphere and mesosphere as Rossby and Kelvin waves propagate vertically through the atmosphere. However, the increased wave activity (and associated momentum transfer during wave breaking events) is not sufficient to produce the observed Quasi-Biannual Oscillations (QBO) in the modelled stratospheric zonal winds in the tropics.

Deterministic forecasts

Cy32r3 has been tested in the full T799 (25 km) resolution analysis/forecast cycle for ten months from January to October 2007. Figure 5 summarizes the forecast performance of all available 00 and 12 UTC forecasts using the anomaly correlations (i.e. correlation of forecast anomalies with analysis anomalies) for the 1000 and 500 hPa geopotentials in the northern and southern hemispheres at resolution T63 (300 km) based on an ERA-40 climate. In the southern hemisphere Cy32r3 improves over Cy32r2 at all lead times. As indicated by

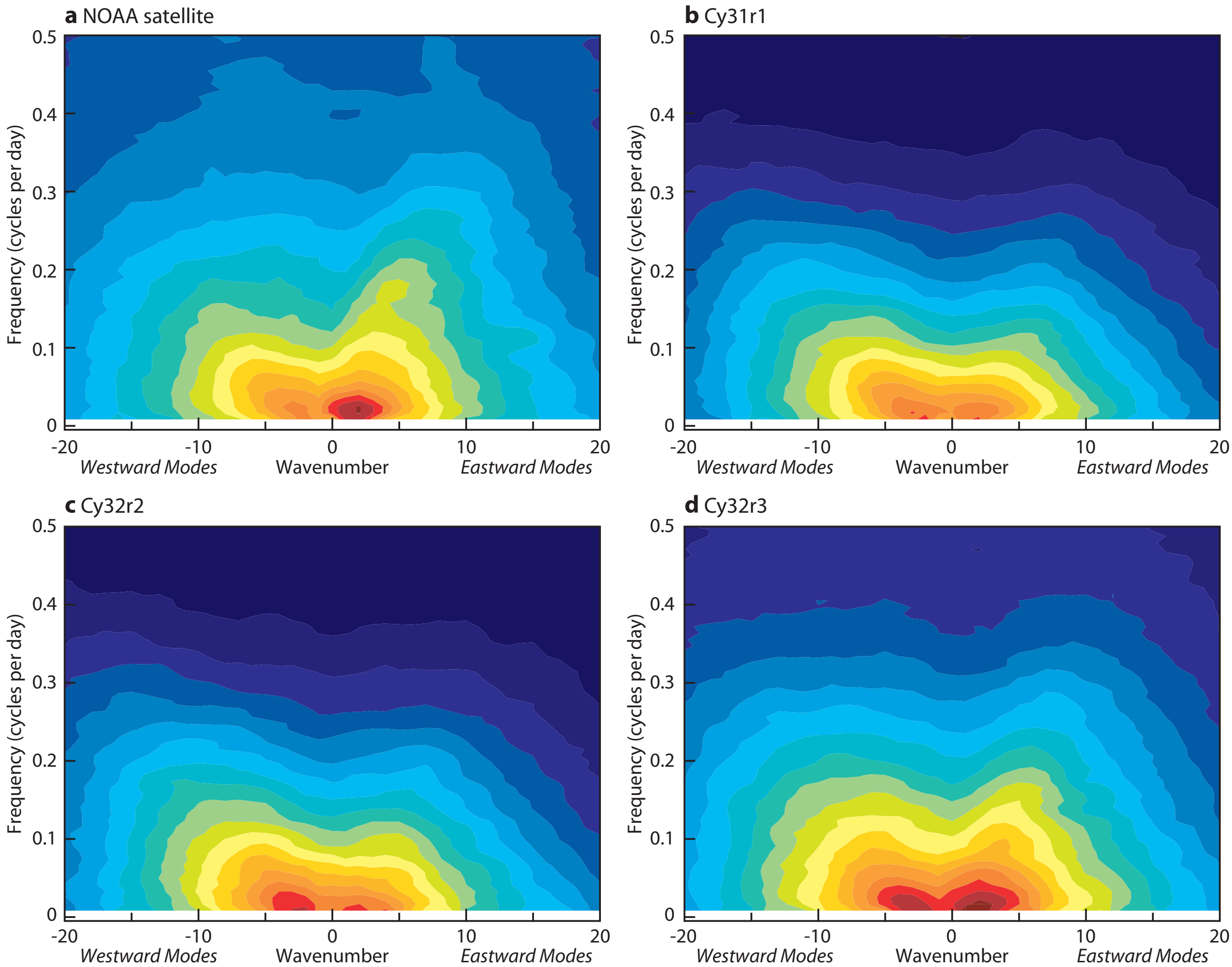

Figure 4 Power in the frequency (cycles per day) and wavenumber space for the Outgoing Longwave Radiation (OLR) in the 10°S–10°N tropical region from (a) NOAA satellite observations. (b), (c), (d) The corresponding results to (a) but for 15 winter runs (1990–2005) with Cy31r1, Cy32r2 and Cy32r3.

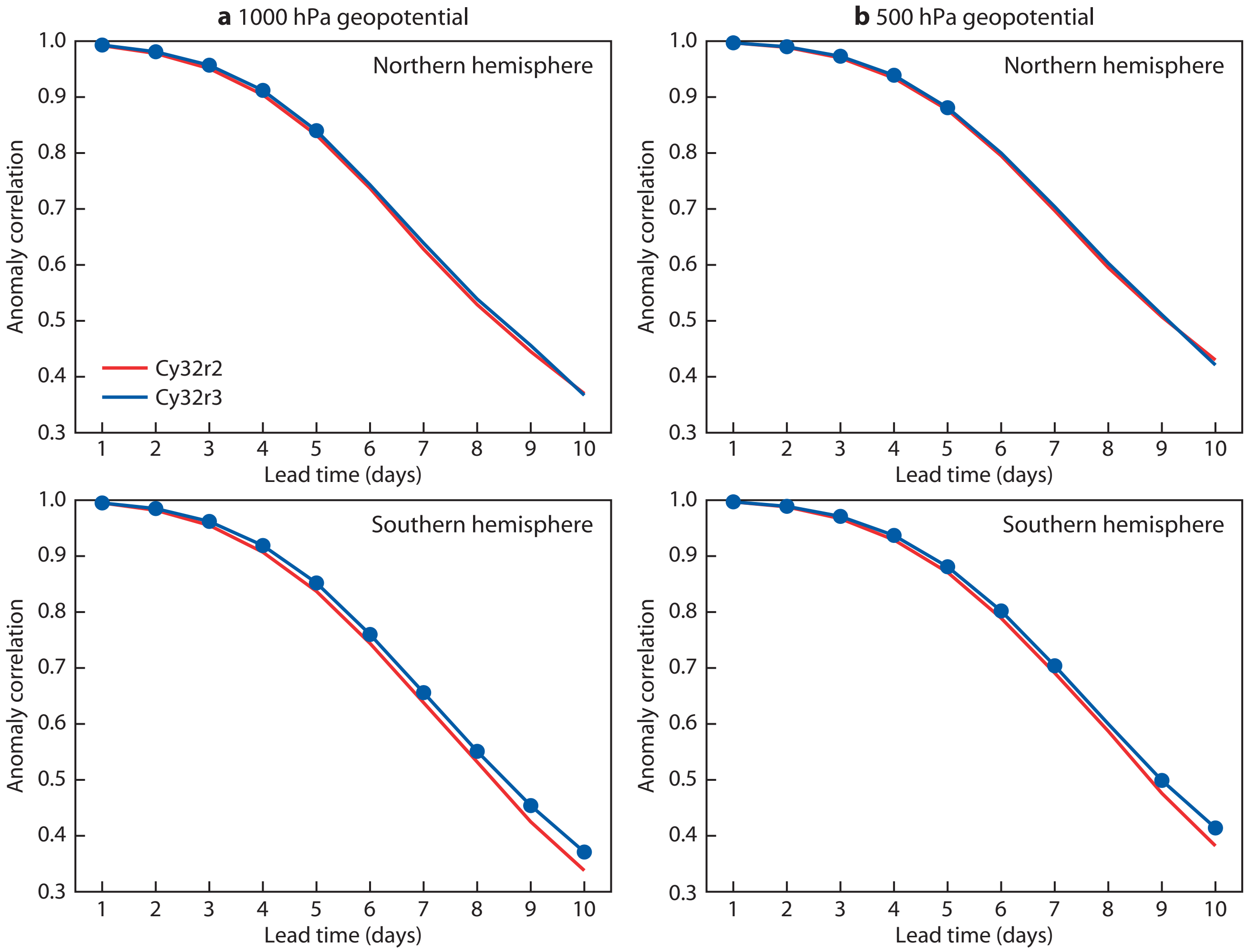

Figure 5 Average anomaly correlations for Cy32r2 and Cy32r3 as a function of forecast lead time for the northern hemisphere (20°N–90°N, top panel) and southern hemisphere (20°S–90°S, bottom panel) for (a) 1000 hPa geopotential and (b) 500 hPa geopotential for January to October 2007. The blue dots denote improvements that are significant at the 95% confidence level.

the dots in Figure 5 these improvements are statistically significant. In the northern hemisphere the improvements are smaller and only statistically significant during the first five days. In spite of higher model activity the deterministic scores are neutral or even improved. In addition Figure 1 gives an indication of a slight over-activity in Cy32r3 in the northern hemisphere after day 5 which seems to compromise somewhat the scores in the medium range.

A comparison with surface synoptic data over Europe is given in Figure 6 for precipitation, two-metre temperature, cloud cover and ten-metre wind direction.

- The precipitation between the two cycles shows a small but significant improvement in the short-range precipitation forecasts (Figure 6(a)).
- The two-metre temperature warm bias over Europe during summer is reduced in Cy32r3, adding a cooling of 0.3 K near the surface (Figure 6(b)). This cooling is associated with a 1–2% increase in cloud cover, particularly due to shallow clouds (Figure 6(c)).
- The bias in ten-metre wind direction is also reduced by a few degrees, and now remains nearly constant with forecast lead time (Figure 6(d)). The wind direction bias actually corresponds to an underestimation of the wind turning (veering) with height, a problem that is present in many models.

The near-surface improvements are a combined effect of the revised shallow convection, the reduction in turbulent diffusion, and the better description of the soil moisture.

Since August 2005 the IFS has produced forecast-generated satellite images. These correspond to brightness temperatures (BTs) computed from the RTTOV (Radiative Transfer model for TOVS, ATOVS and Other Vertical sounders) in the 10.8 µm infrared band and the 6.2 µm water vapour band that can be directly compared to observed BTs from Meteosat 8 and Meteosat 9. As the infrared BTs have values that are very close to the actual cloud top temperatures, the synthetic images are an excellent tool for indirectly verifying the model clouds (cloud cover and condensate content) and the synoptic and convective activity associated with cloud systems.

Figure 7(a) shows the infrared satellite image from Meteosat 9 for 1 July 2007 for large parts of Europe and North Africa, with the corresponding six-hour forecast images with Cy32r2 and Cy32r3 given in Figures 7(b) and 7(c). Generally the model gives a good representation of the mid-latitude synoptic cloud systems, but has more difficulty with tropical convection. It seems, however, that Cy32r3 reproduces more realistic tropical convection associated with the African Easterly Waves between the equator and 5°N (two waves are apparent in Figure 7).

As a quantitative verification, time series from 15 June to 14 July 2007 of spatial correlations and mean errors between daily 6–24 hours forecast and observed infrared BTs are plotted in Figure 8. The errors exhibit a diurnal cycle with the largest positive biases and lowest correlations occurring during night. This indicates that the forecasts have difficulty in producing long-lived convective systems that extend into the night. With

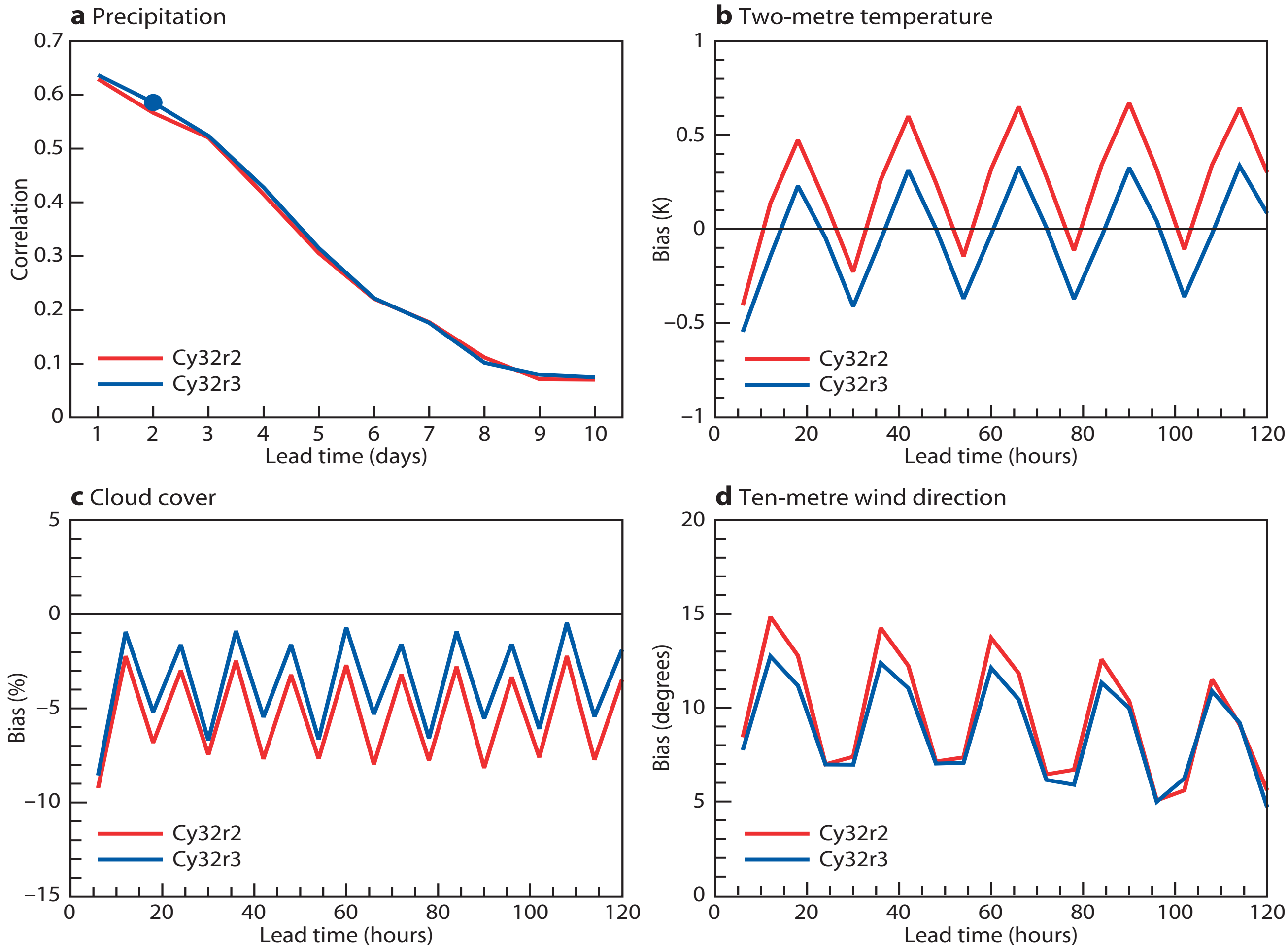

Figure 6 Evaluation of the high-resolution deterministic forecasts with Cy32r2 and Cy32r3 against surface synoptic observations for Europe as a function of forecast lead time: (a) correlation of precipitation, (b) bias of two-metre temperature, (c) bias of cloud cover and (d) bias of ten-metre wind direction. Data is for summer 2007.

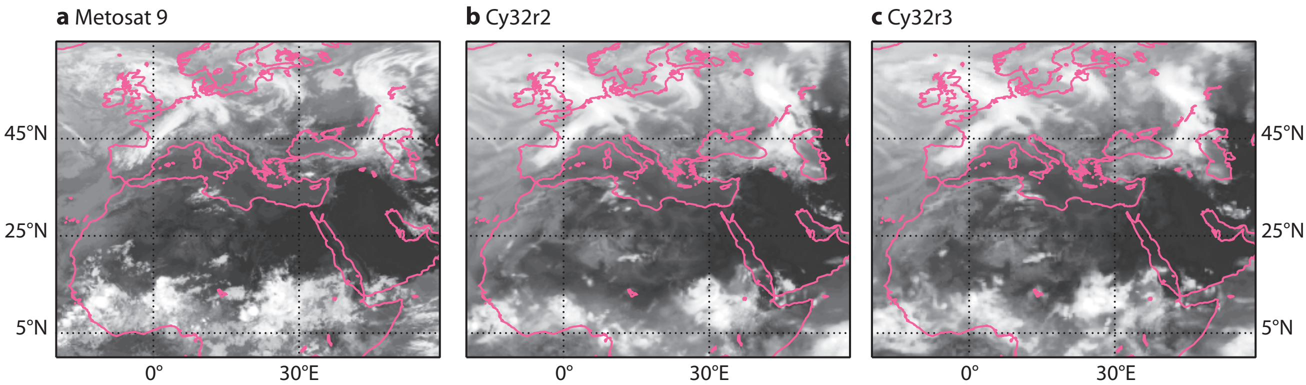

Figure 7 (a) Observed infrared 10.8 μm brightness temperatures (BTs) from Meteosat 9 for 06 UTC on 1 July 2007. (b), (c) The corresponding RTTOV generated BTs from six-hour forecasts with Cy32r2 and Cy32r3.

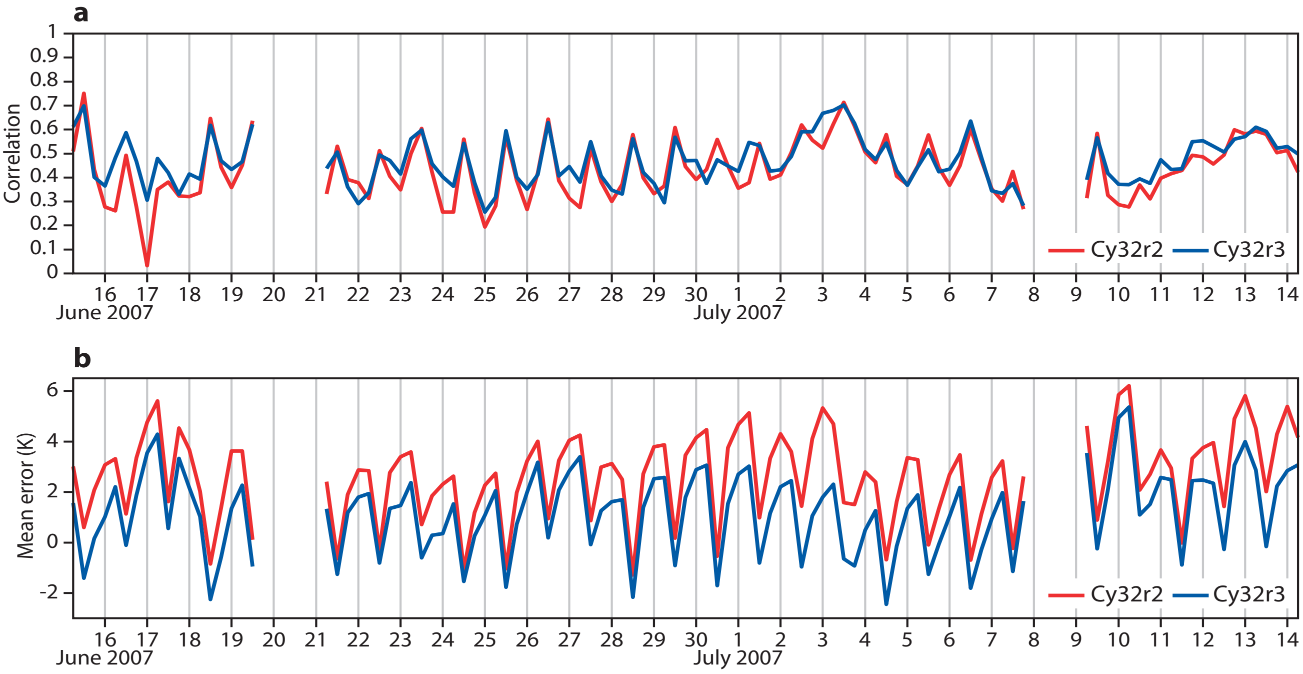

Figure 8 Time series from 15 June to 14 July 2007 of (a) correlation and (b) mean error of forecast synthetic 10.8 μm BTs obtained with Cy32r2 and Cy32r3 against Meteosat 9 observations. Data points correspond to daily forecasts with lead times 6, 12, 18 and 24 hours that are area-averaged over Central Africa (20°S–20°N, 20°W–30°E); missing data are blanked.

Cy32r2 the average spatial correlation between observed and forecast BTs is about 0.5. Cy32r3 slightly improves this correlation, and in particular improves the warm bias in the forecast which becomes smaller than 1 K. The improvement in Cy32r3 can be linked to the more intense continental convection and larger upper-level convective detrainment, producing more and colder anvil clouds, and to an improved analysis using the new radiosonde bias correction scheme. Applying the same type of verification for Europe (not shown), the two cycles produce nearly identical results, but correlations between observed and forecast BTs are much higher with values around 0.8.

The Ensemble Prediction System

The characteristics of perturbation growth in the EPS were significantly changed due to the convection and vertical diffusion changes in Cy32r3. In a statistically consistent ensemble, the RMS error of the ensemble mean (computed over a sufficiently large sample) should match the ensemble standard deviation (*Palmer et al.*, 2006). For Cy32r2, the ensemble spread and the ensemble mean RMS error agree well from about day 5 onwards (Figure 9(a)). However, the good agreement from day 5 can only be achieved by using a large initial perturbation amplitude which results in an over-dispersive ensemble during the earlier forecast ranges.

Initial experimentation with the new convection and diffusion scheme indicated that the physics changes results in a significant increase in the ensemble standard deviation. This offered the opportunity to reduce the initial perturbation amplitude in order to improve the agreement between spread and ensemble mean RMS error at all forecast ranges. First, a reduction of the initial perturbation amplitude by 20% was tested in a sample of 13 summer and 13 winter cases. Results indicated that a further reduction of the initial perturbation amplitude was required and it was decided to reduce the initial perturbation amplitude by 30% in Cy32r3.

The faster perturbation growth due to the convection and diffusion changes, together with the reduced initial perturbation amplitude, results in an improved overall agreement between ensemble spread and ensemble mean RMS error in Cy32r3 (Figure 9(b)). The EPS no longer suffers from an over-dispersion in the early forecast ranges. The EPS evaluation for Cy32r3 is based on nearly seven weeks of daily ensemble forecasts from June, August and September 2007. The improved match between ensemble spread and ensemble mean RMS error are statistically significant (see confidence intervals in Figure 9).

The Ranked Probability Skill Score (RPSS) evaluates the mean squared error of the predicted probabilities. In terms of this score the probabilistic prediction of 850 hPa temperature is significantly better in Cy32r3 than its predecessor in both hemispheres and at all forecast ranges (Figure 10(b)). For 500 hPa geopotential, the impact of Cy32r3 is neutral in the northern hemisphere and positive in the southern hemisphere (Figure 10(a)). Note, that there is no simple relationship between the probabilistic skill and the deterministic skill of the ensemble mean. For instance, while the impact of Cy32r3 on the RPSS of 500 hPa geopotential in the northern hemisphere is neutral, Cy32r3 has a positive impact on the RMS error of the ensemble mean (again with more than 99% statistical significance). By the same token, the

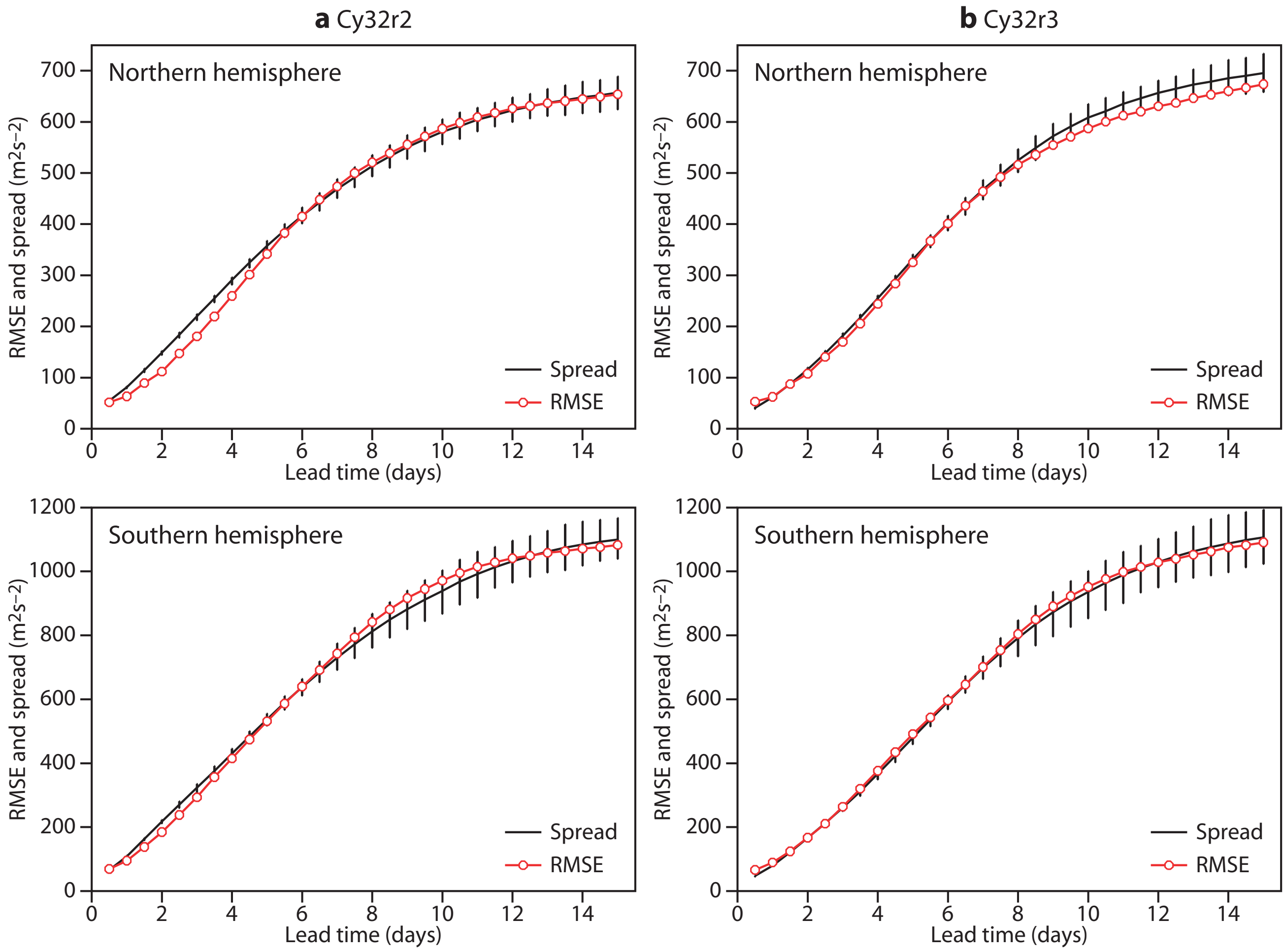

Figure 9 Ensemble standard deviation (spread) and ensemble mean RMS error (RMSE) as a function of forecast lead time for 500 hPa geopotential for the northern hemisphere (20°N–90°N, top panel) and southern hemisphere (20°S–90°S, bottom panel) for (a) Cy32r2 and (b) Cy32r3. Statistics are based on 69 cases during June to September 2007. The vertical bars are confidence intervals based on bootstrapping the dates in the sample of cases. If the spread falls within the bars, the ensemble is not significantly over- or under-dispersive (the probability of the spread being above or below the bar by chance is 1%).

impact on the RMS error of the ensemble mean is neutral for 850 hPa temperature in the northern hemisphere while a statistically significant positive impact was noted for the RPSS.

In addition to the changes already mentioned, the tangent-linear and adjoint model in the singular vector computation targeted on tropical cyclones use the new moist physics package in Cy32r3. The new package has been used operationally in 4D-Var since Cy32r2. Preliminary experimentation over 27 summer cases with the new moist physics package in the EPS singular vector computations indicates an improved reliability of forecasts of tropical cyclone strike probability and neutral impact on ensemble spread and skill scores in the extra-tropics.

Monthly forecasts and the Madden-Julian Oscillation

The Madden-Julian Oscillation (MJO) is the dominant mode of intraseasonal predictability in the tropical atmosphere. Therefore, it is important that the monthly forecasting system accurately predicts its onset and evolution.

To assess the skill of the monthly forecasting system to predict an MJO event, 32-day coupled ocean-atmosphere integrations using a five-member ensemble have been performed for each day between 15 December 1992 and 31 January 1993 (46 ensemble integrations); this period corresponds to the Intense Observing Period (IOP) of TOGA-COARE. The MJO is diagnosed in these integrations using a method based on the technique of *Wheeler & Hendon* (2004). Combined Empirical Orthogonal Functions (EOFs) of OLR, 200 hPa velocity potential and 850 zonal wind averaged over 10°N–10°S are calculated using ECMWF operational data between 2002 and 2004. The EOF analysis is performed on the anomalies relative to the seasonally evolving climatology. The first two EOFs, which represent 18% and 17% of the variance respectively, describe variations associated with the MJO. Observations and forecasts are then projected onto these two EOFs. Different cycles from Cy28r3 onward (operational implementation 29 April 2004) have been run for the control period in order to assess the impact of changes in the physics on the skill of the monthly forecast system to predict an MJO event.

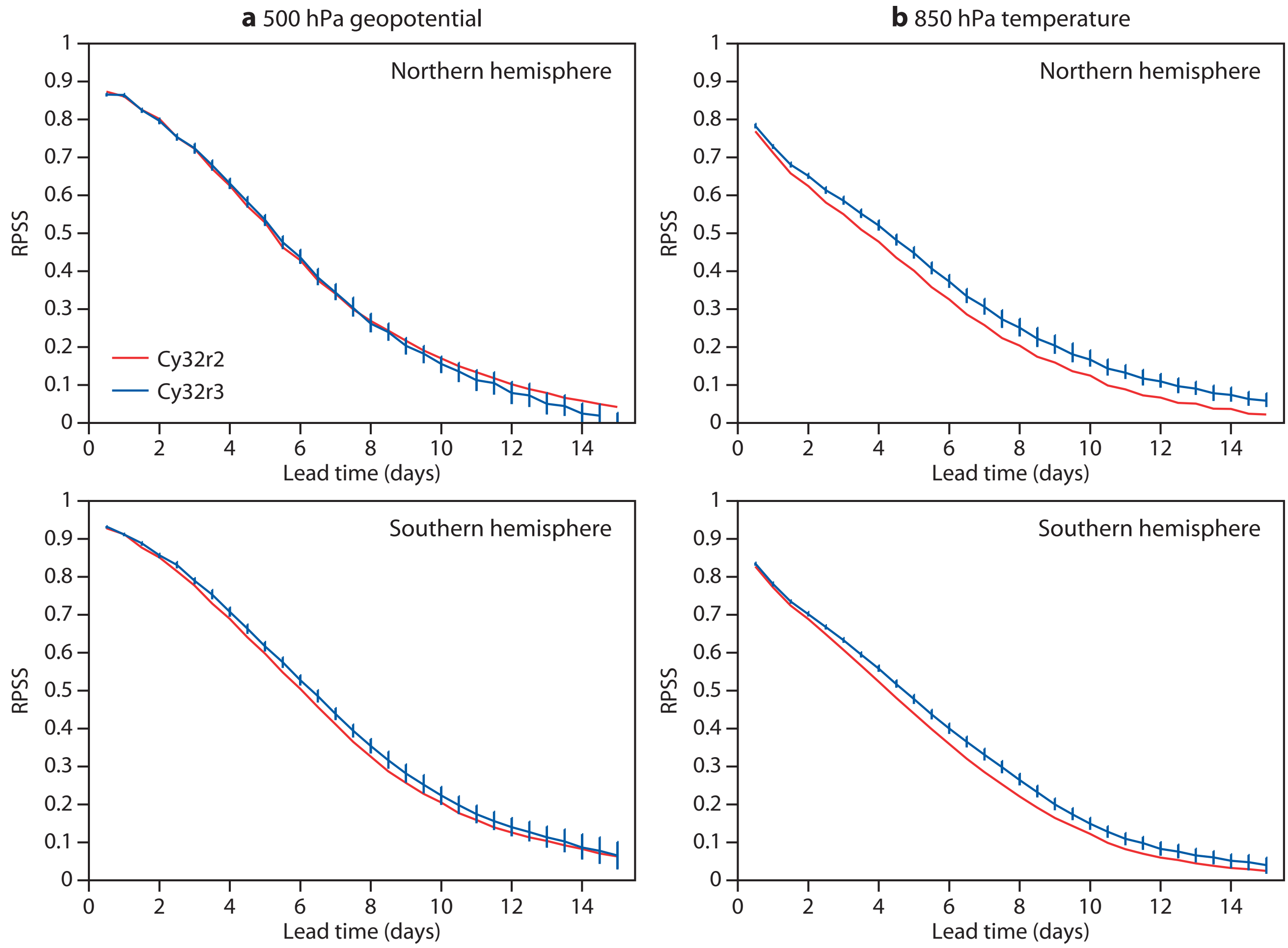

Figure 10 Ranked Probability Skill Score (RPSS) for Cy32r2 and Cy32r3 as a function of forecast lead time for the northern hemisphere (20°N–90°N, top panel) and southern hemisphere (20°S–90°S, bottom panel) for (a) 500 hPa geopotential and (b) 850 hPa temperature. The RPSS is determined for ten climatologically equally likely categories. Cy32r3 is significantly better (worse) than Cy32r2 at the 99% level if the red curve lies below (above) the vertical bars.

Figure 11 shows the amplitude of Principal Component 1 (PC1) averaged over the 46 integrations and the five members of the ensemble as a function of the forecast time. Results are similar for Principal Component 2 (PC2). Before Cy32r3, all versions of the IFS shared the same problem, namely a rapid drop in the amplitude of PC1 and PC2; the drop in the amplitude of the MJO can be seen in Figure 11. For instance, with Cy28r3 the MJO loses 25% of its amplitude after only five days of integrations, about 33% by day 10, and about 50% by day 20. This means that the impact of the MJO on the extra-tropics was likely to be strongly underestimated in those cycles. On the other hand Figure 11 shows that Cy32r3 is the first IFS cycle able to sustain the amplitude over the whole period of the integration. This is an important result since it implies that, for the first time, the monthly forecasting system may now be able to adequately represent the impact of the MJO on the extra-tropics.

Figure 12 illustrates the progress made in the representation of the MJO with the IFS. In Cy28r3 the OLR anomalies are very weak by day 15. Each new cycle increases the amplitude of the OLR anomalies (results are similar for velocity potential at 200 hPa and zonal wind at 850 hPa), and with Cy32r3 the OLR anomalies by day 15 are as intense as in ERA-40. However, the propagation of the MJO with Cy32r3 is slower than in the analysis. In particular, the model has some difficulty propagating the convection from the Indian Ocean to the Pacific, and instead tends to maintain the convection over the Indian Ocean for too long. This deficiency may be related to an overestimation of convective precipitation over the maritime continent.

Concluding remarks

Apart from overall satisfactory forecast scores, the most positive outcome of implementing Cy32r3 is that it is possible to reasonably represent the atmospheric variability on a wide variety of time and space scales using a conventional set of physical parametrizations, without necessarily having to specifically use an explicit global representation of convection (as has been discussed in recent forums). This might come as a surprise, but considering that the modes discussed here are also eigenmodes of the (dry) atmosphere (*Wedi & Smolarkiewicz*, 2007), it seems reasonable to assume that it should be

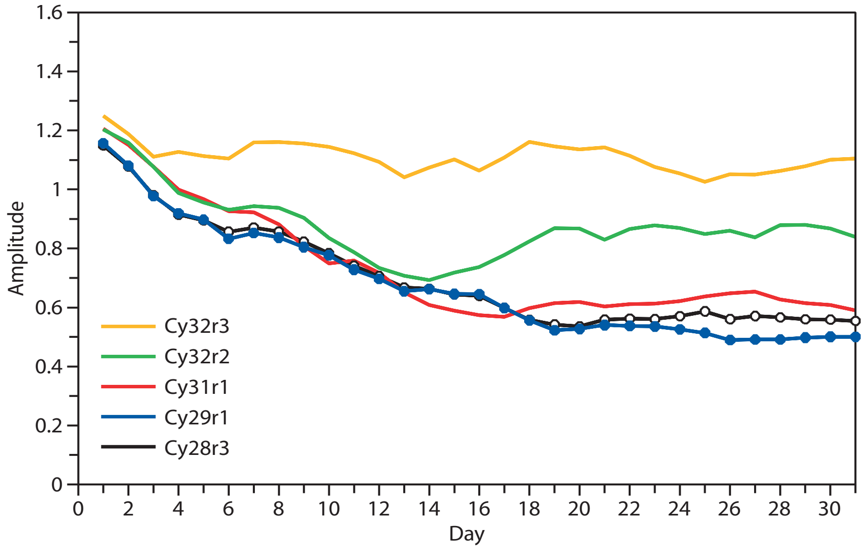

Figure 11 Amplitude of the first combined EOF of Outgoing Longwave Radiation (OLR), 200 hPa velocity potential and 850 hPa zonal wind as a function of forecast lead time from Cy28r3 to Cy32r3. The amplitude constitutes an average over each ensemble member and the 46 cases.

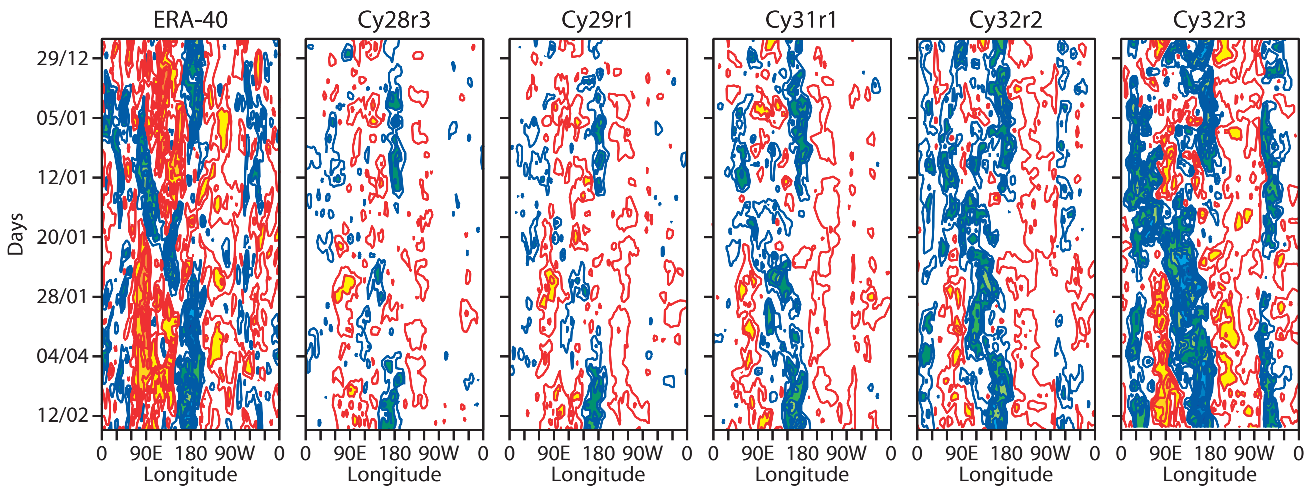

Figure 12 Hovmöller diagrams of the averaged Outgoing Longwave Radiation (OLR) between 10°S and 10°N from 29 December 1992 to 15 February 1993 as analysed by ERA-40 and obtained from forecasts with Cy28r3 to Cy32r3 using concatenated daily forecasts with a 15 day lead time. Red shading denotes warm OLR anomalies (negative phase of MJO), and blue shading cold anomalies (convectively active phase of MJO).

possible to develop a set of physical parametrizations that in some optimal way supports these modes. Furthermore, the results confirm that a good representation of variability comes with a good representation of the mean state.

If anything, the level of model activity in Cy32r3 is slightly overestimated. No attempt was made here to break this down into convection and diffusion components, but it seems to be related to some overestimation of mid-tropospheric moisture (in contrast to a too dry mid-troposphere in previous cycles), and possibly to an increase in wind shear near the trade wind inversion. However, the IFS is still unable to properly represent the stratospheric wind variability associated with the QBO, but current developments indicate that this can be achieved with a scheme that parametrizes the non-orographic gravity wave drag. Finally, there is development of an upgrade of the simplified linear set of physical parametrizations for the assimilation that closely matches the results of the non-linear schemes in Cy32r3. Some further impact on the analysis and the medium-range forecasts (in particular the humidity) in the tropics is expected from this development.

FURTHER READING

Betts, A.K., J.H. Ball, P. Viterbo, A. Dai & **J.A. Marengo**, 2005: Hydrometeorology of the Amazon in ERA-40. *J. Hydrometeorol.*, **6**, 764–774. Also *ERA-40 Project Report 22.*

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Special Project computer allocations for 2008–2010

The allocations for 2008 have been approved. The figures for 2009 and 2010 indicate what has been requested.

Member State		Institution	Project title	2008		2009		2010	
				HPCF units	Data storage	HPCF units	Data storage	HPCF units	Data storage
Austria	1	Univ. Vienna (Haimberger)	Homogenization of the global radiosonde temperature and wind dataset	5,000	500	X	X	X	X
	2	Univ. Vienna (Hantel)	Convective fluxes diagnosed from gridscale ECMWF analyses	1,000	100	X	X	X	X
	3	Univ. Graz (Kirchengast)	Climate monitoring by advanced spaceborne sounding and atmospheric modelling	25,000	400	45,000	450	50,000	500
	4	Univ. of Natural Resources and Applied Life Sciences, Vienna (Kromp-Kolb)	Modelling of Tracer Transport (MoTT)	30,000	100	30,000	100	30,000	100
	5	Univ. Vienna (Steinacker)	MESOCLIM – Mesoscale Alpine Climatology	50	10	100	10	100	10
	6	Univ. Vienna (Steinacker)	4D OMEGA FORM – 4 dimensional objective mesogamma analysis of foehn in the Rhine Valley during MAP	100	10	0	0	0	0
Denmark	7	DMI (Amstrup)	Data impact studies in HIRLAM	204,000	4,890	900,000	6,000	X	X
France	8	CNRM/GMAP, Météo-France (Fischer)	Investigation of coupling the ALADIN and AROME models to boundary conditions from ECMWF and ERA model data	30,000	800	30,000	800	30,000	800
	9	CERFACS (Rogel)	Seasonal to interannual predictability of a coupled ocean-atmosphere model	10,000	150	10,000	150	10,000	150
	10	CERFACS (Weaver)	Variational data assimilation with the OPA OGCM	136,000	2,000	150,000	2,000	150,000	2,000
Germany	11	MPI, Hamburg (Bengtsson)	Numerical experimentation with a coupled ocean/atmosphere model	105,000	700	300,000	800	300,000	900
	12	MPI, Hamburg (Bengtsson, Hagemann)	Regional downscaling of ERA-40 data and validation of the hydrological cycle	157,000	3,200	600,000	4,600	680,000	5,400
	13	MPI, Hamburg (Budich)	Global atmospheric chemistry modelling	290,000	6,720	500,000	9,000	500,000	10,000
	14	Freie Univ. Berlin (Cubasch, Kirchner)	Investigation of systematic tendency changes and their influence on the general circulation simulated with climate models	10,000	1,000	20,000	1,500	20,000	2,000
	15	ISET (Czisch)	Evaluation of the global potential of energy towers	100	20	100	20	100	20
	16	DLR (Doernbrack)	Influence of non-hydrostatic gravity waves on the stratospheric flow field above Scandinavia	136,000	80	150,000	80	150,000	80
	17	Univ. Munich (Egger)	Landsurface-atmosphere interaction	150	10	150	10	150	10
	18	Univ. Cologne (Elbern)	GEMS: work package WP_RAQ_2	96,000	750	100,000	750	100,000	750
	19	DLR & MPI Chemistry, Mainz (Eyring, Steil)	Impact of anthropogenic emissions on tropospheric chemistry with a special focus on ship emissions	173,000	2,110	400,000	4,000	400,000	4,000

Member State		Institution	Project title	2008 HPCF units	2008 Data storage	2009 HPCF units	2009 Data storage	2010 HPCF units	2010 Data storage
Germany	20	MPI, Hamburg (Feichter)	Climate impact of specific economic sectors	100,000	2,220	220,000	7,000	150,000	5,000
	21	DLR (Gierens)	Ice-supersaturation and cirrus clouds	170,000	100	200,000	100	200,000	100
	22	DLR (Hoinka)	Climatology of the global tropopause	500	10	500	10	500	10
	23	MPI, Hamburg (Jacob)	Regional ensemble prediction	43,000	2,190	84,000	6,500	92,000	7,500
	24	Univ. Karlsruhe (Jones)	The impact of tropical cyclones on extratropical predictability	232,000	450	300,000	450	300,000	450
	25	MPI, Hamburg (Jungclaus)	Community simulations of the last millennium (COMSIMM)	386,000	2,000	2,000,000	2,000	2,000,000	2,000
	26	DLR (Keil, Craig)	Ensemble modelling for the improvement of short range quantitative precipitation forecasts	96,000	100	100,000	100	100,000	100
	27	Univ. Karlsruhe (Kottmeier)	Mesoscale modelling using the DWD Lokal-Modell	10,000	50	10,000	50	10,000	50
	28	Leibniz-Institut Univ. Kiel (Latif)	Seasonal to decadal forecasting with coupled ocean-atmosphere general circulation models	764,000	7,900	1,500,000	8,000	X	X
	29	IMK-IFU (Laux)	Statistical analysis of the onset of the rainy season in the Volta Basin (West Africa)	10,000	30	10,000	30	10,000	30
	30	DLR (Mayer)	Remote sensing of water and Ice clouds with Meteosat Second Generation	30,000	20	50,000	20	50,000	20
	31	Ruhr-University Bochum (Pahlow)	Optimisation of water management by using ensemble forecasts	2,000	3	2,000	3	2,000	3
	32	Alfred Wegener Institute, Potsdam (Rex)	Ozone and water vapour transport with the residual circulation	200	200	200	200	200	200
	33	Alfred Wegener Institute, Potsdam (Rinke)	Sensitivity of HIRHAM	100	10	100	10	100	10
	34	Univ. Koln (Speth)	Interpretation and calculation of energy budgets	100	10	120	15	120	15
	35	Univ. Bremen (Weber)	Chemical and dynamical influences on decadal ozone change (CANDIDOZ)	20	20	20	20	20	20
	36	Univ. Mainz (Wirth)	Water vapour in the upper troposphere	1,000	20	1,000	20	1,000	20
	37	Univ. Hohenheim (Wulfmeyer, Bauer)	Real-time assimilation of observations of key prognostic variables and the development of aerosol operators (RAPTOR)	334,000	2,000	1,000,000	2,000	1,000,000	2,000
Ireland	38	Met Éireann (Mc Grath)	Community Climate Change Consortium for Ireland (C4I)	20,000	2,000	30,000	2,000	30,000	3,000
Italy	39	CNMCA (Bonavita, Torrisi)	Limited area ensemble Kalman Filter	392,000	500	1,400,000	500	1,800,000	500
	40	ISMAR-CNR (Cavaleri)	Evaluation of the performance of the ECMWF meteorological model at high resolution	157,000	150	221,500	150	221,500	150

Member State		Institution	Project title	2008		2009		2010	
				HPCF units	Data storage	HPCF units	Data storage	HPCF units	Data storage
Italy	41	ARPA-SIM (Di Giuseppe, Marsigli)	Flow dependent error statistic for satellite data assimilation in regional model (FEAR)	309,000	150	1,000,000	150	1,000,000	150
	42	INGV, Bologna (Manzini)	Middle atmosphere modelling	245,000	2,000	350,000	2,300	40,000	2,700
	43	Osservatorio Astrofisico di Arcetri, Firenze (Masciadri)	Forecasting of the optical turbulence for Astronomy applications with the MesoNH mesoscale model coupled with ECMWF products	4,000	30	4,000	30	4,000	30
	44	ISAC-CNR (Maurizi)	GEMS: BOLCHEM	20,000	120	X	X	X	X
	45	ARPA-SMR Emilia Romagna & UK Met Office (Montani, Mylne)	Limited-area ensemble forecasts of windstorms over Northern Europe	180,000	100	620,000	120	640,000	140
	46	ARPA-SMR Emilia Romagna & MeteoSwiss (Montani, Walser)	Improvements of COSMO limited-area ensemble forecasts	148,000	700	420,000	720	440,000	740
	47	ARPA-SMR Emilia Romagna & Italian Met. Service (Paccagnella, Montani, Ferri)	Limited area model targeted ensemble prediction system (LAM-TEPS)	176,000	280	700,000	290	800,000	300
	48	Univ. Genova (Parodi)	High resolution numerical modelling of intense convective rain cells	30,000	200	50,000	200	50,000	200
	49	ARPA-SMR Emilia Romagna & UCEA (Pavan, Esposito)	Seasonal prediction for Italian agriculture (SPIA)	10	100	10	100	10	100
Netherlands	50	KNMI (Hazeleger)	Patterns of climate change: coupled modelling activities	170,000	500	400,000	500	400,000	500
	51	KNMI (Onvlee)	The Hirlam-A project	483,000	6,580	1,250,000	8,500	1,500,000	8,500
	52	KNMI (Siebesma)	Rain in cumulus	170,000	50	250,000	75	300,000	75
	53	KNMI (Selten)	Climate change studies using the IFS system	185,000	500	225,000	500	X	X
	54	KNMI (van Meijgaard)	Multi-annual integrations with the KNMI regional climate model RACMO2	187,000	2,360	500,000	2,500	X	X
	55	KNMI (van Velthoven)	Chemical reanalyses and sensitivity studies with the chemistry-transport model TM4	30,000	100	X	X	X	X
	56	KNMI (van Weele)	Global chemistry-transport modelling of natural reactive greenhouse gases	96,000	100	100,000	100	X	X
Norway	57	DNMI (Frogner)	NORLAMEPS: Limited Area Ensemble Prediction System for Norway	190,000	500	500,000	500	500,000	500
	58	Univ. Oslo (Isaksen)	Ozone as a climate gas	30,000	5	50,000	5	50,000	5
	59	DNMI (Iversen)	GLAMEPS – Grand Limited Area Model Ensemble Prediction System	478,000	5,560	900,000	6,000	900,000	6,000
	60	DNMI (Iversen, Kristiansen)	REGCLIM: optimal forcing perturbations for the atmosphere	232,000	1,000	300,000	1,000	300,000	1,000
	61	DNMI (Tveter)	Optimisation of operational NWP at met.no	140,000	1,000	X	X	X	X

Member State		Institution	Project title	2008		2009		2010	
				HPCF units	Data storage	HPCF units	Data storage	HPCF units	Data storage
Portugal	62	Univ. Lisbon (Soares)	HIPOCAS-SPEC	0	10	0	10	0	10
Spain	63	Univ. Illes Balears (Cuxart)	Study of the stably stratified atmospheric boundary layer through large-eddy simulations and high resolution mesoscale modelling	96,000	200	100,000	200	100,000	200
	64	Univ. de Castilla-La Mancha (Gaertner)	Analysis of land surface-atmosphere interactions through mesoscale simulations	246,000	1,000	700,000	800	700,000	800
	65	Univ. Basque Country (Saenz)	Mesoscale meteorological reanalysis over the Iberian Peninsula	136,000	1,000	X	X	X	X
Switzerland	66	Institute for Atmospheric and Climate Science, ETH Zurich (Lohmann)	Cloud aerosol interactions	201,000	200	250,000	200	250,000	200
United Kingdom	67	ESSC, Univ. Reading (Bengtsson)	Predictability studies with emphasis on extra-tropical and tropical storm-tracks and their dependence on the global observing systems	196,000	200	300,000	200	300,000	200
	68	Univ. Reading (Haines)	Using data assimilation in a high-resolution ocean model to determine the termohaline circulation	207,000	4,670	700,000	7,000	X	X
	69	Univ. Oxford (Hanlon)	Attribution of changes in extreme weather risk using large ensembles of climate model simulations	17,000	150	25,000	150	25,000	150
	70	Univ. Reading (Hoskins)	Moist Singular Vectors and African Easterly Waves	75,000	150	75,000	150	75,000	150
	71	Manchester Metropolitan Univ. (Lee)	Determining the relative roles of NO_x and CO_2 emissions from aviation in climate change	45,000	700	X	X	X	X
	72	DARC, Univ. Reading (Migliorini)	GlobMODEL	129,000	500	X	X	X	X
	73	DARC, Univ. Reading (Migliorini)	Assimilation of geostationary ozone measurements for global ozone monitoring	136,000	1,000	X	X	X	X
	74	DARC, Univ. Reading (O'Neill)	Assimilation of retrieved products from EOS MLS	426,000	2,940	900,000	3,000	900,000	3,000
	75	DARC, Univ. Reading (O'Neill)	How good are simulated water vapour distributions in the UTLS region?	128,000	500	70,000	250	X	X
	76	Keele University (Shrira)	Direct numerical simulations of 2-D freak waves	55,000	100	100,000	100	X	X
	77	BAS, Cambridge (Turner)	Assessment of ECMWF forecasts over the high latitude areas of the Southern Hemisphere	0	1	0	1	0	1

Member State		Institution	Project title	2008		2009		2010	
				HPCF units	Data storage	HPCF units	Data storage	HPCF units	Data storage
ICTP	78	ICTP (Kucharski)	Dynamical downscaling of seasonal predictions with a regional climate model	30,000	500	50,000	500	50,000	500
	79	ICTP (Kucharski)	Decadal interactions between the tropical Indo-Pacific Ocean and extratropical modes of variability in an intermediate coupled model	30,000	300	50,000	300	50,000	300
JRC	80	JRC-IES (Dentener)	The linkage of climate and air pollution: simulations with the global 2-way nested model TM5	55,000	140	110,000	160	120,000	180
New Projects									
Austria	1	Univ. Innsbruck (Ehrendorfer)	The TIGGE data base: atmospheric predictability and Bayesian decision making	9,000	30	9,000	30	9,000	30
Belgium	2	MUMM (Ponsar)	Data assimilation in high resolution hydrodynamic and ecological forecasts of the North Sea	100,000	700	200,000	700	200,000	700
Germany	3	Univ. Frankfurt (Casanova, Ahrens)	Combination of seasonal forecasts by BMA	500	200	500	200	500	200
	4	DLR (Doernbrack)	Support tool for HALO missions	15,000	80	20,000	80	20,000	80
	5	Freie Univ. Berlin (Ulbrich, Leckebusch)	Investigations of storms in forecasts, hindcasts and climate model simulations on daily to seasonal and climatological timescales	5,000	1,000	5,000	1,500	5,000	2,000
Ireland	6	Met Éireann (Mc Grath)	Changes in the North Atlantic climate and impacts for Ireland	20,000	1,000	30,000	1,500	30,000	2,000
Netherlands	7	KNMI (de Vries)	Data assimilation over the North Atlantic (DANA)	65,000	1,000	80,000	10,000	110,000	1,000
	8	KNMI (Haarsma)	Storm tracks in a warmer climate	80,000	500	150,000	500	150,000	500
	9	KNMI (van den Hurk)	Participation in GLACE-2	136,000	580	150,000	580	150,000	580
	10	KNMI (van Meijgaard)	Regional modelling of the Greenland surface mass balance for key episods in the past and the future	187,000	1,500	500,000	1,500	500,000	1,500
Norway	11	DNMI (Benestad)	Seasonal predictability over the Artic Region – exploring the role of boundary conditions	84,000	1,000	160,000	1,000	215,000	1,000
Sweden	12	SMHI (Robertson)	GEMS: MATCH	6,000	1	8,000	4	8,000	4
JRC	13	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	100,000	100	200,000	100	200,000	100
Total allocated				**10,674,830**	**87,420**	**22,926,300**	**113,753**	**19,479,300**	**84,223**

Member State computer allocations for 2008

Member State	HPCF (kunits)	Data Storage (Gbytes)
Belgium	4,466	36,657
Denmark	3,775	30,986
Germany	19,167	157,338
Spain	8,067	66,218
France	14,682	120,523
Greece	3,479	28,560
Ireland	3,186	26,157
Italy	12,280	100,810
Luxembourg	2,511	20,608
Netherlands	5,820	47,777
Norway	3,899	32,007

Member State	HPCF (kunits)	Data Storage (Gbytes)
Austria	4,075	33,451
Portugal	3,337	27,396
Switzerland	4,747	38,966
Finland	3,453	28,345
Sweden	4,377	35,934
Turkey	3,853	31,632
United Kingdom	15,426	126,635
Allocated to Special Projects	10,675	87,420
Reserved for Special Projects	2,725	22,580
Total	**134,000**	**1,100,000**

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 46 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 the next page.

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. 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 every 12 to 18 months.

Meteorological Contact Points

Meteorological Contact Points receive information about the meteorological aspects of the operational forecasting system, including the high-resolution model, EPS, seasonal forecasts and optional projects. They are encouraged to provide feedback concerning the performance of the forecasting system to the Centre. In addition they may refer to the Head of Meteorological Operations Section or the Meteorological Analyst at ECMWF if they wish to discuss any aspect 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.

Telecommunication Contacts

Telecommunication 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.

Catalogue Contact Points

Catalogue Contact Points are the primary contact for external organisations wishing to receive real-time ECMWF data via one of the ECMWF Member States.

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	Prof G.-R. Hoffmann	Dr E. Krenzien	Mr T. Schumann
Greece	Mr D. Kapniaris Mr T. Andreadis	Mr A. Emmanouil	Mr D. Ziakopoulos Mr M. Manoussakis Mr P. Fragkouli
Spain	Mr P. del Rio	Mr E. Monreal	Mr A. Alcazar
France	Mr B. Strauss	Mrs M. Pithon	Mr J. Clochard
Ireland	Mr J. Logue	Mr P. Halton	Mr M. Walsh
Italy	Dr S. Pasquini	Dr C. Gambuzza	Dr T. La Rocca
Luxembourg	Mr C. Alesch	Mr C. Alesch	Mr C. Alesch
Netherlands	Mr T. Moene	Mr H. de Vries	Mr J. Diepeveen
Norway	Mr J. Sunde	Ms R. Rudsar	Mr P. Evensen
Austria	Dr G. Kaindl	Dr G. Kaindl	Dr H. Gmoser
Portugal	Mrs T. Abrantes	Mrs M. da C. Periera Santos	Mrs I. Soares
Switzerland	Dr S. Sandmeier	Mr P. Roth	Mr R. Mühlebach
Finland	Mrs K. Soini	Mr K. Niemelä	Mr P. Nurmi
Sweden	Mr I. Karro	Mr R. Urrutia	Mr M. Hellgren
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			
Croatia	Mr I. Čačić	Mr V. Malović	Mr Č. Branković
Czech Republic	Mr M. Janoušek	Mr K. Ostatnický	Mr F. Sopko
Estonia	Mr T. Kaldma	Mr T. Kaldma	Mrs M. Merilain Mrs T. Paljak
Hungary	Dr Z. Dunkel	Mr I. Ihász	Mr I. Ihász
Iceland	Mr H. Björnsson	Mr V. Gislason	Mrs S. Karlsdottir
Lithuania	To be decided	Mr P. Jalinskas	Mrs. V. Raliene
Montenegro	To be decided	To be decided	To be decided
Morocco	Mr H. Haddouch	Mr M. Jidane	Mr K. Lahlal
Romania	Dr I. Pescaru	Mr R. Cotariu	Mrs T. Cumpanasu
Serbia	Ms L. Dekic	Mr V. Dimitrijević	Mr B. Bijelic
Slovakia	To be decided	To be decided	To be decided
Slovenia	Mr J. Jerman	Mr P. Hitij	Mr B. Gregorčič
Observers			
EUMETSAT	Mr M. Rattenborg	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 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: Dr Adérito Vicente Serrão (*Portugal*)

Vice President: Mr Wolfgang Kusch (*Germany*)

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: Dr Fritz Neuwirth (*Austria*)

Vice Chair: Ms Maria Agren (*Sweden*)

Finance Committee (FC)

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

Chair: Ms Monika Köhler (*Austria*)

Vice Chair: To be elected

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 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: Prof Gerhard Adrian (*Deutscher Wetterdienst*)

Vice Chair: Prof Martin Ehrendorfer (*University of Reading)*)

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: Dr Alan Dickinson (*United Kingdom*)

Vice Chair: Mr Bernard Strauss (*France*)

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: Ms Lillian Wester-Andersen (*Denmark*)

Vice Chair: Mr Colin Cuthbert (*United Kingdom*)

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 Ivan Čačić (*Croatia*)

Vice Chair: Dr Ion Sandu (*Romania*)

ECMWF Calendar 2008

Jan 14–15	SRNWP Interoperability workshop (organised by the Met Office, UK)
Feb 11–Mar 7	Computer User Training Course
Feb 11–12	*Introduction to SMS/XCDP*
Feb 13–14	*GRIB API: library and tools*
Feb 25–29	*Introduction for new users/MARS*
Mar 3–4	*MAGICS*
Mar 5–7	*METVIEW*
Mar 6–7	Meeting of the Council of the European Meteorological Society (EMS)
Mar 10–14	Training Course – Use and interpretation of ECMWF products
Mar 31–May 27	Training Course – Numerical Weather Prediction
Mar 31–Apr 8	*Numerical methods and adiabatic formulation of models*
Apr 9–18	*Predictability, diagnostics and extended-range forecasting*
Apr 21–30	*Data assimilation and use of satellite data*
May 12–22	*Parametrization of diabatic processes*
Apr 7–8	Advisory Committee on Data Policy (*9th Session*)
Apr 8–9	Finance Committee (*80th Session*)
Apr 9–10	Policy Advisory Committee (*26th Session*)
May 6–9	WCRP/WWRP Modelling Summit
May 13–14	Security Representatives' Meeting
May 14–16	Computing Representatives' Meeting
Jun 2–6	Training Course – Use and interpretation of ECMWF products
Jun 9–10	Council (*69th Session*)
Jun 11–13	Forecast Products – Users' Meeting
Jun 12–13	Meeting of the Pensions Administrative Committee of the Co-ordinated Organisations
Jun 16–18	ECMWF-EUMETSAT/GRAS SAF Workshop on "Use of GPS Radio-occultation"
Sep 1–5	Seminar on "Physical Parametrization Processes and their Dynamical Interactions"
Sep 16–17	Trilateral Meeting of the Co-ordinating Committee on Remuneration
Sep 22–26	Training Course – Use of supercomputing resources
Oct 6–8	Scientific Advisory Committee (*37th Session*)
Oct 8–10	Technical Advisory Committee (*39th Session*)
Oct 13–17	Training Course – Use and interpretation of ECMWF products for WMO Members
Oct 13–14	Finance Committee (*81st Session*)
Oct 14–15	Policy Advisory Committee (*27th Session*)
Oct 20	Advisory Committee of Co-operating States (*14th Session*)
Nov 3–7	13th Workshop on "High Performance Computing in Meteorology"
Nov 10–12	Workshop on "Ocean-atmosphere Interaction"
Dec 2–3	Council (*70th Session*)

ECMWF publications

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

Technical Memoranda

545 **Steinheimer, M., M. Hantel & P. Bechtold**: Convection in Lorenz's global energy cycle with the ECMWF model. *November 2007*

544 **Jarlan, L., G. Balsamo, S. Lafont, A. Beljaars, J.C. Calvet & E. Mougin**: Analysis of Leaf Area Index in the ECMWF land surface scheme and impact on latent heat and carbon fluxes: Applications to West Africa. *December 2007*

540 **Palmer, N., R. Buizza, M. Leutbecher, R. Hagedorn, T. Jung, M. Rodwell, F. Vitart, J. Berner, E. Hagel, A. Lawrence, F. Pappenberger, Y.-Y. Park, L. von Bremen & I. Gilmour**: The Ensemble Prediction System – Recent and ongoing developments. *October 2007*

539 **Morcrette, J.-J., P. Bechtold, A. Beljaars, A. Benedetti, A. Bonet, F. Doblas-Reyes, J. Hague, M. Hamrud, J. Haseler, J.W. Kaiser, M. Leutbecher, G. Mozdzynski, M. Razinger, D. Salmond, S. Serrar, M. Suttie, A. Tompkins, A. Untch & A. Weisheimer**: Recent advances in radiation transfer parametrizations. *October 2007*

536 **Orr, A.**: Evaluation of revised parameterizations of sub-grid. *November 2007*

534 **Zagar, N., E. Andersson, M. Fisher & A. Untch**: Influence of the quasi-biennial oscillation on the ECMWF model short-range forecast errors in the tropical stratosphere. *August 2007*

519 **Leutbecher, M.**: On the representation of initial uncertainties with multiple sets of singular vectors optimised for different criteria. *September 2007*

Index of past 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 web site – 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's number is:
+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's address is: D.Marbouty@ecmwf.int

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

Internet web site

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

	Ext
Director	
Dominique Marbouty	001
Deputy Director & Head of Research Department	
Philippe Bougeault	005
Head of Operations Department	
Walter Zwieflhofer	003
Head of Administration Department	
Ute Dahremöller	007

Switchboard	
ECMWF switchboard	000
Advisory	
Internet mail addressed to Advisory@ecmwf.int	
Telefax (+44 118 986 9450, marked User Support)	
Computer Division	
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