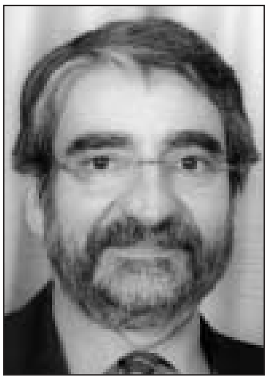

The next Director

At its 59th session in December 2003, Council appointed Dominique Marbouty to become the next Director of the ECMWF, following the retirement of Dave Burridge in June 2004. Dominique will be the fifth Director of the Centre in its 29-year existence.

Dominique is a graduate of the École Polytechnique in Paris, and of the École Nationale de la Météorologie in Toulouse. Between 1977 and 1984 he led a research unit in Grenoble studying snow physics and avalanche prediction. Subsequently he served for five years as Director of the regional meteorological service in Bordeaux. In 1989 he moved to the headquarters of Météo-France and was appointed Deputy Director in 1991. As such he was firstly in charge of operations until 1995, which included responsibility for the observation network, the forecasting organisation, governmental users and the repartition of human resources. In 1995 he took charge of strategy, which included responsibility for international affairs, repartition of the budget, cross services projects and strategic planning.

In 1999 he took over the post of Head of Operations at ECMWF and in 2003 he became its Deputy Director. During his time at the Centre he has overseen a major expansion in its operational services. These have included the development of the Centre's web services, the development and operational implementation of a lot of new products, in particular for severe weather forecasting, two major computer procurements (the high-performance computing facility and the new data-handling facility), the establishment of the Regional Meteorological Data Communications Network linking all WMO Region VI Member States, and the operational introduction of seasonal forecasts and of additional medium-range forecasts from 00 UTC. He was also heavily involved in the complete revision of the rules of distribution of the Centre's products for research and commercial activity, and in the development of the Centre's external policy.

Dominique is 52 and is married to Marie-Claire. They have three grown-up children, Audrey (27), Romain (25) and Martial (22). He has many interests outside his work, including mountain-hiking, running and skiing, as well as reading, going to the cinema and 'do-it-yourself' home improvements. Dominique is also a member of the Royal Meteorological Society, the American Meteorological Society and the Société Météorologique de France.

We offer our congratulations to Dominique on his appointment and wish him well as head of the Centre, where the challenges are likely to prove at least as demanding in the coming years.

In this issue

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Front Cover

Parts of the Po River delta (Italy) dried-up completely in the exceptionally warm summer of 2003 (see article on page 2) ©Daniele Bottau

Editorial

The exceptionally hot temperatures that occurred in many parts of Europe during the summer of 2003 contrasted with the serious flood conditions that were the main feature of 2002 (see ECMWF Newsletter No. 96 page 18 and No. 97 page 2). On page 2 Federico Grazzini, Laura Ferranti, François Lalaurette and Frederic Vitart discuss the medium-range, monthly and seasonal forecasts of these extreme temperatures. The European Commission funded project DEMETER (see ECMWF Newsletter No. 86 page 19), which has just been completed, is discussed on page 8 by Tim Palmer, Francisco Doblas-Reyes and Renate Hagedorn. The three-year project, which involved seven European research institutes, was designed to study seasonal forecasts using a multi-model ensemble system and to consider practical applications relating to malaria and crop-yield predictions. The success of the project has led to a decision to include real-time multi-model ensemble forecasting as part of the operational suite. Another European initiative (on global monitoring of the environment) has encouraged the ECMWF, in partnership with other European meteorological centres, to develop proposals for a project to monitor the global earth system using operational data assimilation techniques; this project will be submitted to the European Commission's Sixth Framework Programme, and an advertisement publicizing the proposal is printed on page 18. Baudouin Raoult gives details of the ECMWF Public Data Server on page 19. This allows researchers to download data, such as those generated by the DEMETER and the ERA-15 and ERA-40 projects, freely from a web server. The data can be made available in a variety of formats.

Peter White

Changes to the Operational Forecasting System

AMSU channel 9 on NOAA-16 has been blacklisted since 13 May 2003.

A new version of the ECMWF model (Cycle 26r3) was implemented on 7 October 2003. The start date of the parallel experimental suite was 1 June 2003. Changes from the previous operational version (Cycle 26r1) include:

- A new formulation of the humidity analysis (modified background-error covariances, a corrected calculation of background errors for SSMI that uses the FASTEM emissivity model over the sea);
- New data streams (AIRS from Aqua, AMSU-B, AMSU-A from Aqua, Japanese wind profilers, Meteosat-5, GOES-9 and GOES-12 water-vapour clear-sky radiances, GOES-12 winds and MIPAS ozone-profile retrievals);
- Passive monitoring of ENVISAT data: SCIAMACHY, GOMOS, and MIPAS;
- A new linear radiation scheme in 4D-var, a new radiation sampling (HALO) and a new aerosol climatology in the full model;
- A relaxation of the convective mass-flux limiter for long time steps (used for the EPS and monthly forecasts);

- New model parameters (EFI, UVB, CAPE, photo-synthetically active radiation, freak waves).

Verification results gathered from the experimental suite and from several months of research experiments indicate that, in general, a significant and consistent improvement in the upper-air (including humidity) forecasts can be expected from this new Cycle of the IFS.

On 7 October 2003, the Roshydromet Administration (Russian Federation) informed the WMO of the interruption of their 12 UTC radio sounding program (only 00 UTC soundings will be operated until further notice).

François Lalaurette

The exceptional warm anomalies of summer 2003

The last two summers in Europe could not be more different in terms of meteorological anomalies. Summer 2002 was fresh and extremely wet in some regions and certainly it will be remembered for the floods that devastated many parts of central Europe. In contrast, after a fairly cold winter and a dry spring, the summer of 2003 was one of the hottest summers on record. In May, temperatures started to soar well above the average, and the warm conditions persisted during the whole summer. In addition to that, a sequence of heat waves augmented the anomalies to unprecedented levels. As a result, many records of maximum daily temperature tumbled across Europe, as well as the seasonal mean values.

The overall impact on society has been remarkable, with severe disruption of activities and heavy losses of life in many European countries. It is outside the scope of this article to give a full description of the related damage, but it worth mentioning the major effects just to appreciate the scale of the disaster. Wild fires burnt for days in Portugal, Spain, France, Italy and Croatia killing hundreds of people. Health authorities estimated that, because of the soaring temperatures, about 14,000 died in France alone, and thousands more casualties were reported in other countries. Drought conditions, with very low water levels in rivers, seriously affected agricultural production and also exposed some countries to electric power shortages due to lack of water for the cooling of the power plants. Furthermore, in response to the heat, an exceptional ablation was observed over the Alpine glaciers. The World Monitoring Glaciers Service in Zurich has estimated an average loss of 3 m of ice compared with an annual average (over the period 1980–2000) of -0.65 m/year. The loss observed this year is the equivalent of a 5-10% reduction of the total volume of Alpine glaciers.

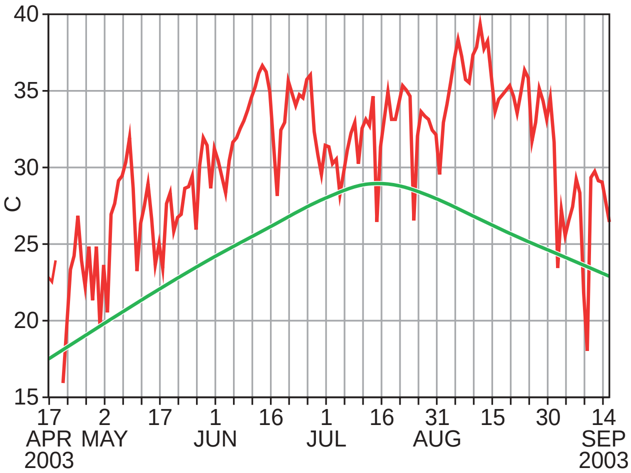

Figure 1 The maximum temperatures (Tmax – °C) recorded at the SYNOP station Milano-Linate, northern Italy. The red line refers to 2003 and the green line refers to the climatological record between 1961–1990.

Was it so hot?

It was certainly unseasonably warm for most of the summer with very long spells of hot days. Synop station at Milano-

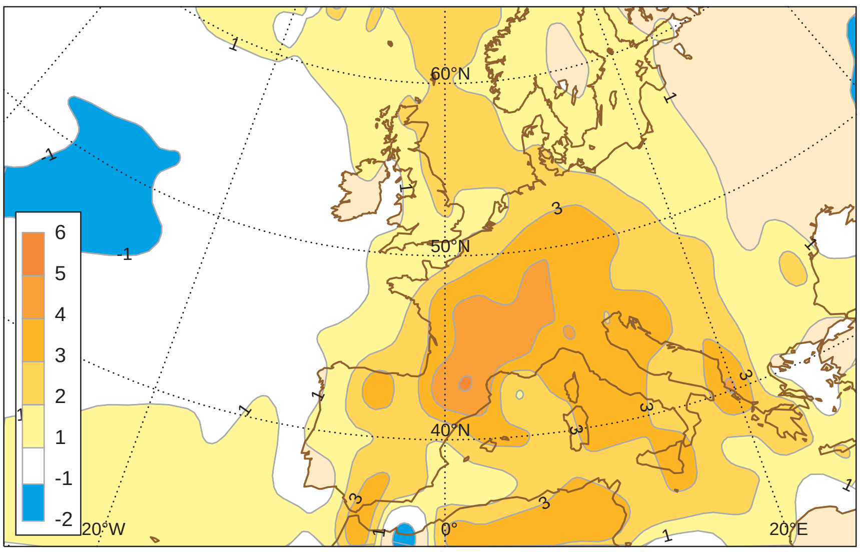

Figure 2 The 2 m temperature anomaly (°C) in summer 2003 with respect to the ERA-40 (1958–2001) reference climate.

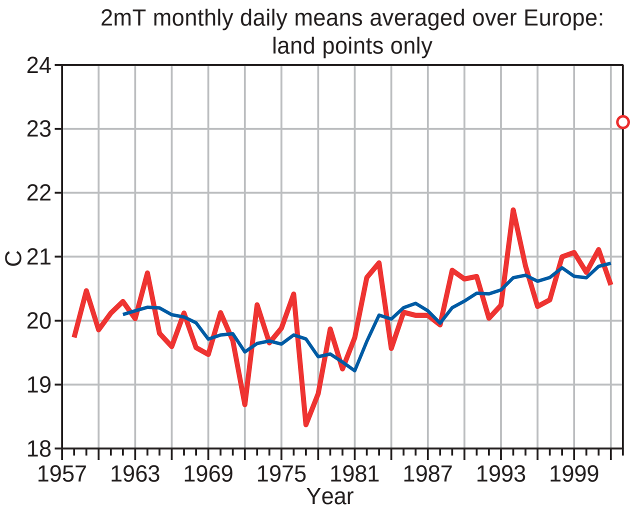

Figure 3: The time-series of the 2 m temperature analyses (°C) averaged over Europe (land points only over (35°N, 10°W) to (50°N, 15°E)) in summer. The red line is from the ERA-40 analyses; the blue line is the ERA-40 five-year running mean values, while the red dot is the operational analysis.

Linate in northern Italy reported, for example, only seven days over the period June to August 2003 when the maximum temperature was below 30°C (figure 1). Over central Europe, the mean air-temperature anomalies for June to August 2003 ranged between about 3–6°C, with the maximum positioned over France and the Alpine region (figure 2).

Time-series of summer mean temperatures averaged over Europe show that the warm conditions experienced during the past summer constitute an unprecedented event when compared with the 45-year period of the reanalysis (1957–2001) (figure 3). The graph shows that, in addition to a general warming trend, there were years warmer than the average, for instance in summer 1982 and 1994. However, during those years, the temperatures never reached the extent of the ones recorded for the past summer. Secular time-series at different sites confirm the rarity the event. Preliminary reports from different meteorological institutions operating around the Alpine region show that such a large departure of the seasonal mean has never been observed in the last 200 years. As already mentioned, record anomalies were not only restricted to the seasonal mean, but many daily maximum temperature records were also exceeded during the intense heat at the beginning of August. Figure 4 shows the maximum temperatures recorded during the first two weeks of August together with the number of days during which the temperatures were above 35°C. Most of Europe experienced temperatures well above 35°C for many consecutive days, with peaks in excess of 40°C. Night-time temperatures also remained at very high values, making the situation even more unbearable. As already discussed in a previous article (*Grazzini and Viterbo* 2003), record-breaking values of sea surface temperature (SST) were observed over the Mediterranean basin, with daily values peaking above 30°C over the western Mediterranean Sea.

Why did it happen?

At the beginning of May the first heat wave raised temperatures over central and Western Europe up to 30°C. After that, a summer regime established over southern Europe, with periods of hot anticyclonic circulation interrupted by few Atlantic frontal systems bringing in fresher air. Strong anticyclonic conditions totally dominated the month of June. Although the persistence of anticyclonic conditions was not as strong as in June, the July temperatures were still above normal. In August the temperature rise peaked thanks

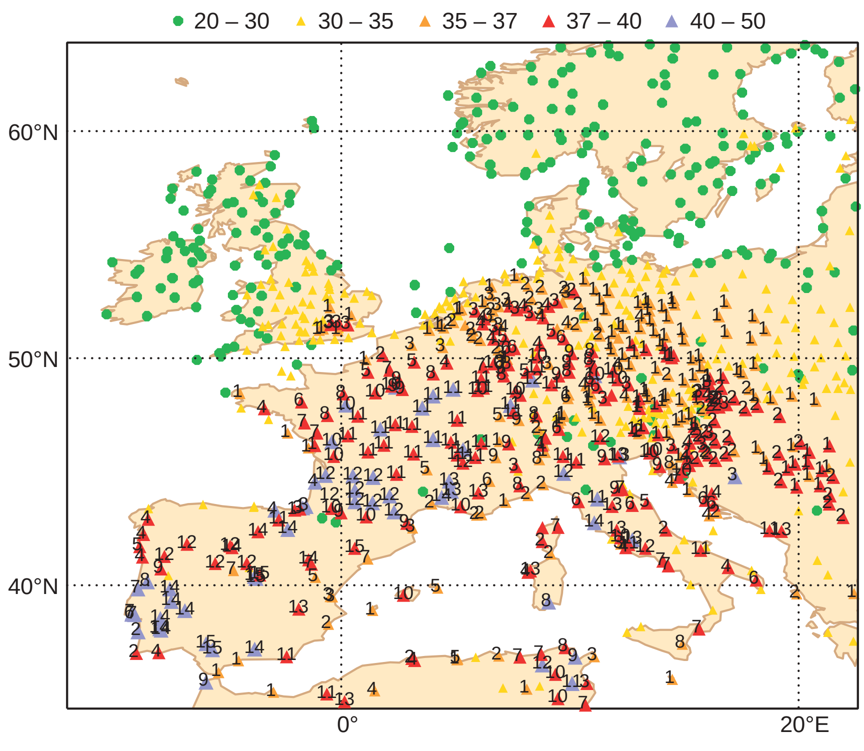

Figure 4 The maximum temperatures (°C) recorded at SYNOP stations during the major heat wave (1–15 August 2003) (see key at the top of the diagram). The numbers represent the number of days with more than 35°C recorded during the same period.

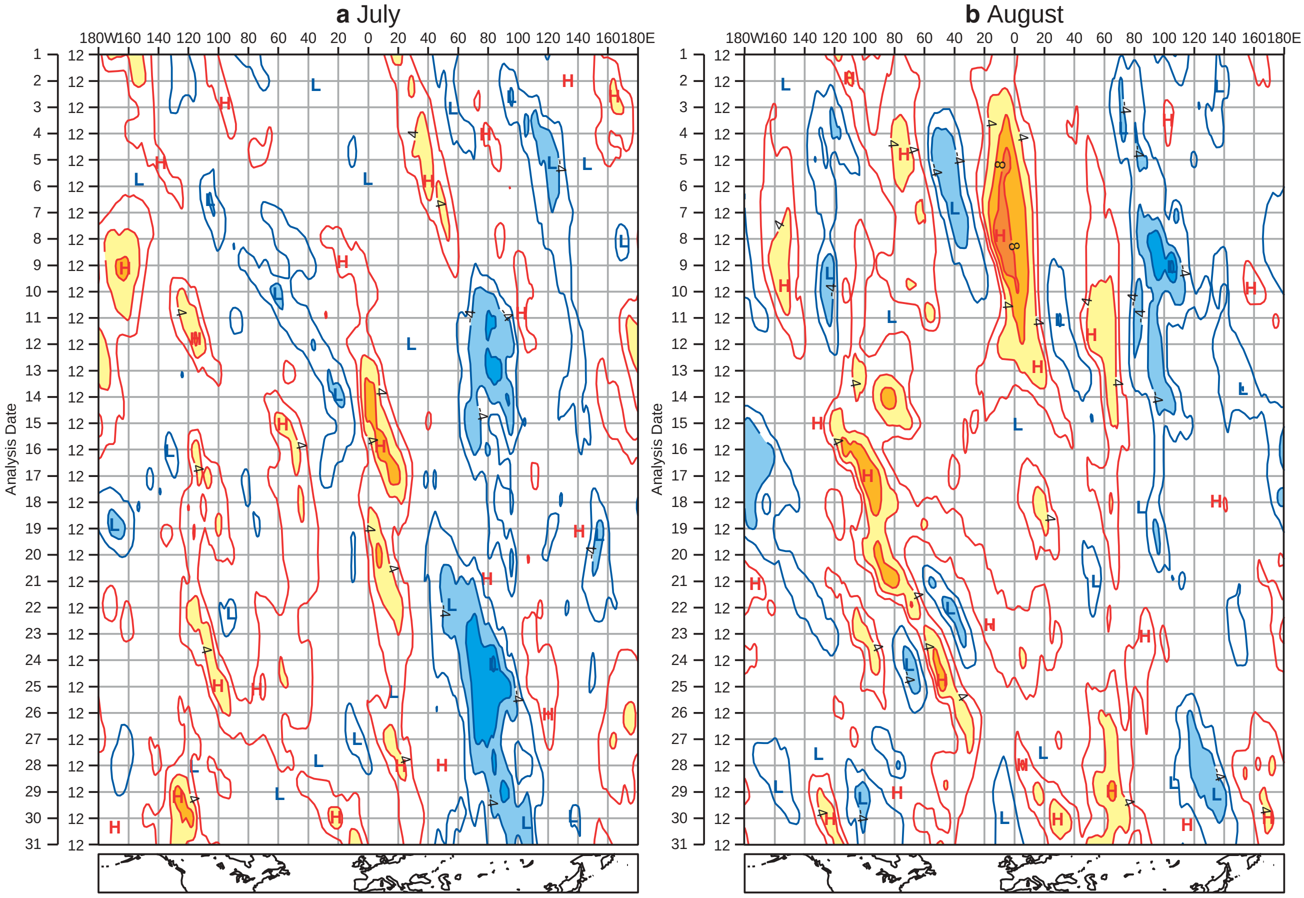

Figure 5 Hovmoller diagrams of the T850 anomaly with respect to a subset (1972–2001) of the ERA-40 analyses averaged over the latitude band 35°N–60°N. Panel (a) refers to the month of July while panel (b) refers to August. The contouring is every 2°C. The shading starts from +4°C for warm anomalies (yellow) and -4°C for cold anomalies (cyan).

to the strongest heat-wave event, which occurred during the first two weeks. In order to analyse the evolution of this series of events from a synoptic point of view, anomalies of 850 hPa temperature (T850) have been plotted as Hovmoller diagrams. The temperature at 850 hPa is a good tracer of air-mass type and is less influenced by local surface conditions. In figure 5 only two Hovmoller diagrams of the T850 anomaly for the months of July and August are shown. We selected these two months because they are characterized by different behaviours. July shows a relative persistence of moderate warm anomalies over Europe, with apparently very weak synoptic forcing (weak wave-packet propagation). This is consistent with the mean 500 hPa geopotential anomaly for July showing a moderate positive signal (figure 6). In contrast, in August the heat wave at the surface was associated with a strong amplification of Rossby waves that reinforced the pre-existing anticyclone over Europe. In terms of pressure fields, there was an overall persistence of anticyclonic conditions during the summer, with positive anomalies in the mean 500 hPa geopotential height from May to August.

In addition to mid-latitude synoptic forcing, other physical/dynamical processes might have jointly contributed to the soaring of 2 m temperatures. Dry soil conditions, due to the dry spring and a very warm Mediterranean sea, may have contributed in increasing the inertia of the anomalies in time and also in producing a positive feedback on individual heat waves, so exacerbating their intensity. On the other hand, the persistence of warm T850 anomalies in the absence of strong synoptic wave propagation is consistent with a possible additional adiabatic warming due to an increase of upper-level convergence and descending motion. At the time of writing, these hypotheses have not been verified and more work needs to be done to fully understand their possible implications.

Understanding the nature of these anomalies can help in addressing the question of whether the past summer is ‘a once-in-a-lifetime event’ or whether it is part of a tendency towards a new climate regime. Studies of extreme events over Europe show that the frequency of such extremes has increased in the last decade, suggesting a change in the climate distribution (*Schär et al.* 2004; *Palmer and Raisanen* 2001). In this context, the extreme departure of the summer 2003 anomalies is the most recent of a series of events contributing to the hypothesis of a change in the distribution of climate.

How good were the forecasts?

In discussing the quality of the operational medium-range and extended-range forecasts, we focus on the major heat wave that affected Europe at the beginning of August. The

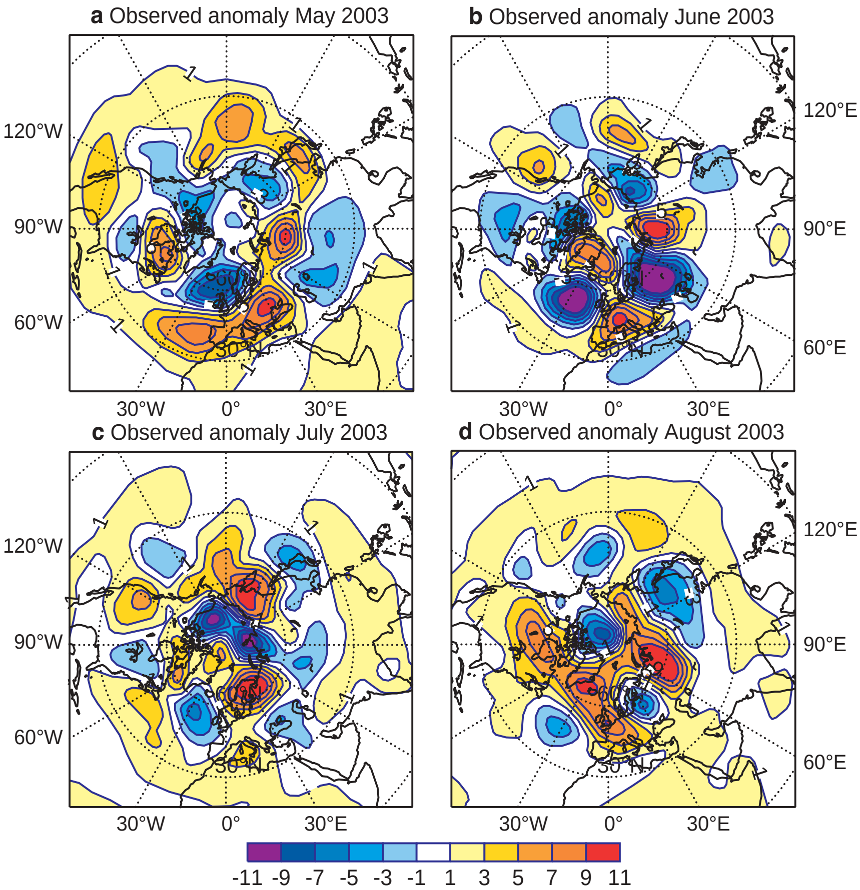

Figure 6 The mean 500 hPa geopotential height anomalies for the months of (a) May, (b) June, (c) July and (d) August 2003. The reference climate is ERA-40.

ECMWF medium-range forecast was quite successful in predicting the large-scale flow associated with the heat wave. In figure 7 the skill of the forecast is measured in terms its ability to reproduce the sharp increase in temperature at 850 hPa over France associated with this event. In the short range (up to 72 h), the model was able to predict correctly the onset, duration and decrease of the anomaly. Despite some inaccuracy of the forecast before the onset the heat wave, the medium-range forecast suggested the correct trend, with decreasing accuracy as the lead-time increased. The Ensemble Prediction System (EPS) ensemble mean was similarly uncertain before the heat-wave onset, but later it proved to be slightly more reliable than the deterministic T511 forecast by reducing inconsistencies in the forecasts. The ensemble mean was more accurate than two consecutive bad forecasts with starting dates 1 and 2 August 2003, especially at D+7.

Good indications for the likelihood of a strong anomaly in 2 m temperature could also be seen with a probabilistic approach. The extreme forecast index (EFI) (*Lalaurette and Van der Grijn* 2003) based on EPS members, consistently showed very high values over large areas of Europe. On some occasions, the EFI showed values close to 100%; meaning that all EPS members predicted unprecedented high temperatures with respect to values indicated in the EPS pseudo-climate; figure 8 shows an example of these cases. This example has been chosen to illustrate the high level of forecast confidence present already in the medium-range, because it is one very important aspect in judging the forecast quality of extreme events. Both the EFI and the probability of exceeding an arbitrary threshold of 35°C gave very strong indications of large anomalies at the right locations. However, the details of the maximum near-surface temperatures were certainly less accurate (due to limitations in the representations of the orography, for example) and, in general, the forecast underestimated the maximum peaks at all ranges. This behaviour is illustrated in figure 9, where the 2 m temperature in the T511 forecast is compared with the values reported by the observing station at Chârtres, near Paris. The underestimation of diurnal temperature is evident for the forecast at the D+5 range. The night-time temperature is colder in the forecast during the onset of the heat wave, but it gets better afterwards. A similar trend, but reduced in amplitude, can also be seen in the D+2 forecasts.

Was it possible to predict the August heat wave more than ten days in advance?

Considering the large spatial/temporal scale of the heat wave, we expect some skill in predicting the event at forecast ranges beyond ten days. An experimental forecast suite, based on an ensemble of 51 coupled atmosphere-ocean integrations, has been run at ECMWF for about a year and it can be used to address the forecast skill between 10 to 30 days (*Vitart* 2003). As an example figure 10 shows the monthly forecast started on 30 July 2003. This forecast gave an excellent indication about the locations of main temperature anomalies in the European area up to 18 days ahead. Almost all members of the monthly forecast predicted a significant heat

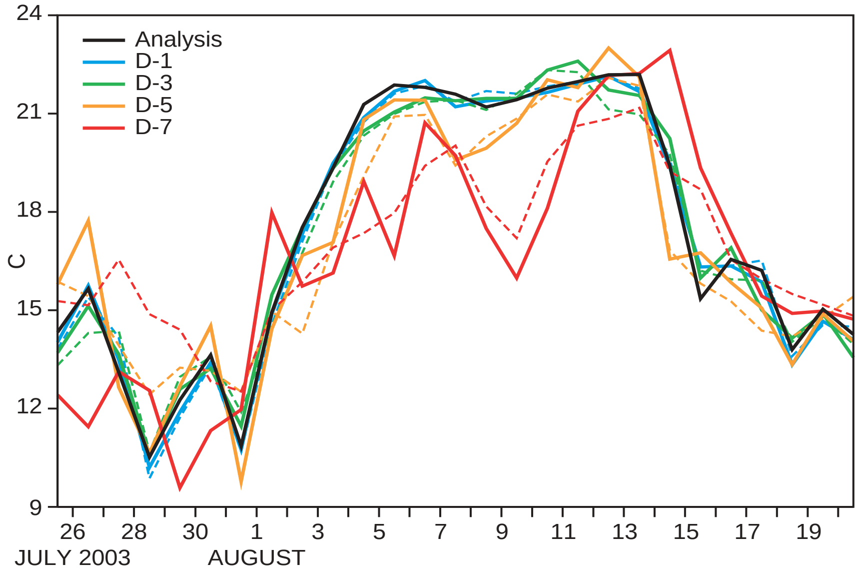

Figure 7 The evolution of the average T850 (°C) over France during the period of the major heat wave. The solid black line represents the analysis. The solid coloured lines represent the T511 medium-range forecasts (full lines) and ensemble-mean forecasts (dashed lines) valid at the same time, but with different lead times as shown by the legend in the figure.

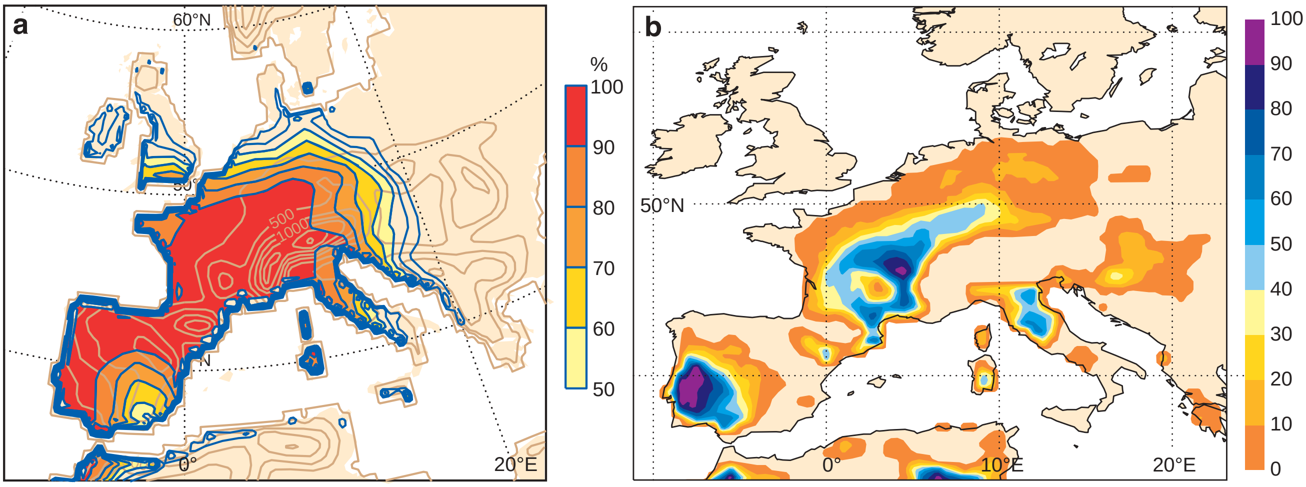

Figure 8: (a) The Extreme Forecast Index for the 2 m temperature D+5 forecast valid at 12 UTC 12 August 20032, and (b) the Ensemble Prediction System forecast of the probability of exceeding 35°C (for the same verification and lead times).

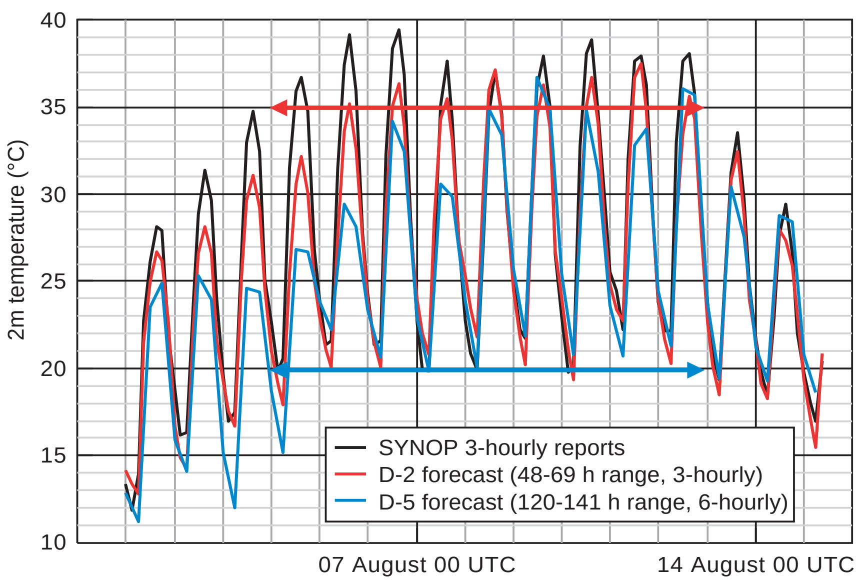

Figure 9 The time-series of temperatures observed at Chartres during the first two weeks in August 2003 (black curve). For each day, the ECMWF 00 UTC forecast from two days before (red) and five days before (blue) are also shown. The horizontal double arrows indicate the nine-day period when the maximum temperatures were above 35°C and the minimum temperatures were above 20°C.

wave, but only few predicted the intensity as strong as the observed one. The forecast initiated at 16 July 2003 still showed positive anomalies at a three-week lead-time (week 3). In week 4 the anomalies were much weaker and were restricted over the sea, mainly associated with the persistence of the sea-surface anomalies in the initial conditions. This result suggests that the August heat wave might have been predictable to a certain level up to two to three weeks in advance.

Was it possible to predict the hot summer, months in advance?

Although several components can contribute to the predictability of extreme anomalies, most of the skill of seasonal predictions comes from the ability to forecast the evolution of the SST anomalies, in particular the El Niño cycle and its impact on the atmospheric circulation. Since the last peak of El Niño in late 2002, the SST anomalies have steadily decreased throughout the central and eastern equatorial Pacific. From April 2003 onwards, atmospheric and oceanic conditions over the El Niño area were near to normal. During such a neutral phase of El Niño, limited skill is expected.

The SST predictions from the seasonal forecasting system were quite successful in reproducing the cooling over the tropical eastern Pacific and the persistence of an SST anomaly pattern over the Atlantic Ocean. However, over the Indian Ocean, positive SST anomalies were not predicted. In this area of warm water, relatively small anomalies (about +0.5°C) can have a significant impact on the monsoon circulation and, in turn, can affect the summer circulation over the Mediterranean basin.

Figure 11 shows the probability pattern for the upper tercile of the 2 m temperature from the ensemble of forecasts started in May 2003, forecasting for the period June-July-August. The upper tercile represents the warmest third of previously predicted summers. Over much of France, probabilities in the range of 50-60% are evident. This might seem quite impressive but, unfortunately, the forecast from April did not indicate such warm conditions over the same area. During the last two weeks of April, the Mediterranean basin warmed quite rapidly. It is possible that the May forecast, by successfully forecasting the persistence of this SST

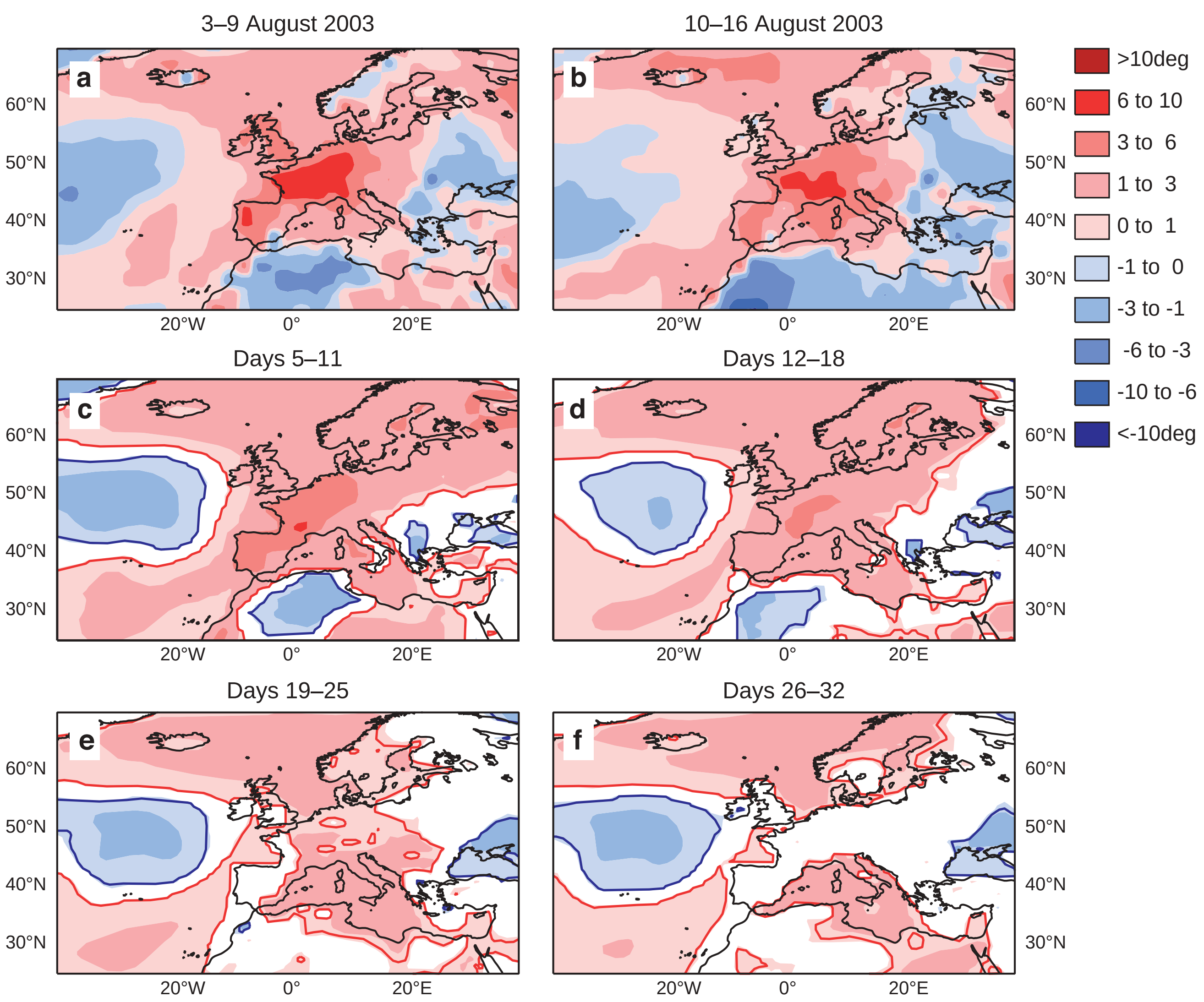

Figure 10: Panels (a) and (b) show the analysed weekly anomalies for the first two weeks of August, and panels (c) to (f) show the corresponding predictions from the monthly forecasting system.

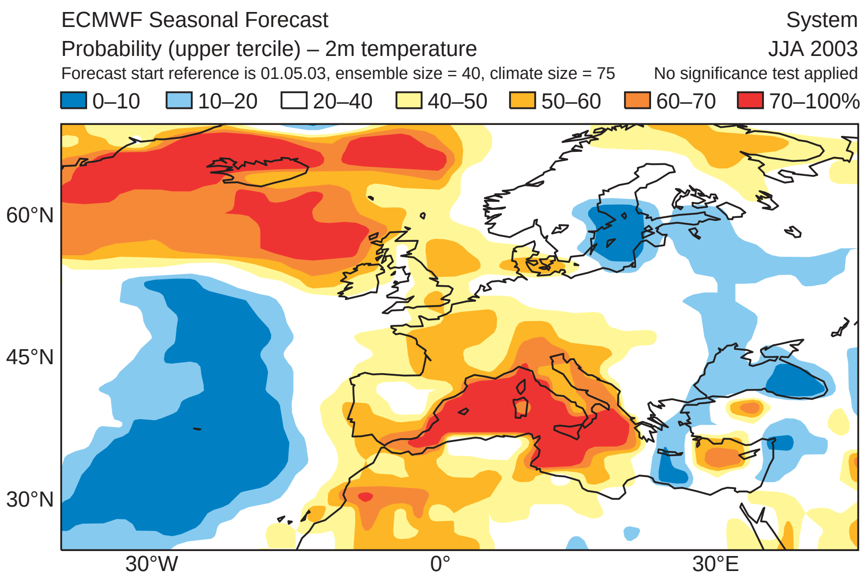

Figure 11 The probability of exceeding the upper tercile of 2m temperature, in the model climate distribution, during June-July–August 2003 given by the seasonal forecasting system. The forecast base-date is 1 May 2003.

anomaly, produced a better signal. However, the warm conditions over the Mediterranean Sea did not help the forecast initiated in June to make realistic predictions for the July to September period.

To what extent such inconsistent forecasts are due to model errors or are related to the 'true' low-predictability level of this event is difficult to establish. Experimentation to address this issue is in progress. Preliminary results seem to indicate that, even with the forcing of observed SST conditions, the European hot summer was difficult to predict. Considering that the spring of 2003 was a rather dry season, it is possible that a lack of soil moisture has contributed to enhancing the local heating. Further analysis is needed to assess the extent of this feedback and its contribution in the predictability.

Acknowledgements

We would like to thank Cristoph Schär (ETH Zurich), the Societá Meteorologica Italiana and the National Meteorogical Service of Croatia who made available reports and comparisons of the summer 2003 anomalies with secular time-series.

Further reading

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F. Grazzini, L. Ferranti, F. Lalaurette and F. Vitart

DEMETER: Development of a European multi-model ensemble system for seasonal to interannual prediction

Seasonal weather forecasts are of potential value to a wide cross-section of society, for personal, commercial and humanitarian reasons. Dynamical seasonal forecasts have been made operationally using ensemble systems with perturbed initial conditions (*Stockdale et al.* 1998, *Mason et al.* 1999). However, if uncertainties in initial conditions were the only perturbations represented in a seasonal-forecast ensemble, then the resulting measures of predictability would not be reliable, the reason being that the model equations are also uncertain. One approach to the representation of model uncertainty in seasonal forecast ensembles relies on the fact that global climate models have been developed somewhat independently at different research institutes. An ensemble comprising such quasi-independent models could, therefore, be thought of as providing a sampling of possible model-equation sets. This is referred to as a multi-model ensemble (*Palmer et al.* 2000). A multi-model ensemble-based system for seasonal-to-interannual prediction has been developed in the European project DEMETER (Development of a European Multi-model Ensemble system for seasonal to inTERannual prediction), a project funded under the European Union's Fifth Framework Environment Programme (see ECMWF Newsletter 86, Winter 1999/00, page 18). The DEMETER system comprises seven state-of-the-art global atmosphere-ocean coupled models installed on a single supercomputer, and has been designed to study the multi-model concept by creating an extensive hindcast database with common archiving and common diagnostic software. The comprehensive evaluation of this hindcast dataset demonstrates substantially enhanced reliability and skill for the multi-model ensemble over a more conventional single-model ensemble approach. In addition, innovative applications of seasonal ensemble forecasts for malaria and crop yield prediction have been carried out. The end-to-end strategy followed in DEMETER deals with several scientific aspects as communication across disciplines, downscaling of climate simulations, and use of probabilistic forecast information in the applications sector, illustrating the economic value of seasonal-to-interannual prediction for society as a whole.

Experiment and data

The DEMETER prediction system comprised the global coupled ocean-atmosphere models of the following institutions: CERFACS (European Centre for Research and Advanced Training in Scientific Computation, France), ECMWF (European Centre for Medium-Range Weather Forecasts), INGV (Istituto Nazionale de Geofisica e Vulcanologia, Italy), LODYC (Laboratoire d'Océanographie Dynamique et de Climatologie, France), MetFr (Météo-France, France), UKMO (Met Office, UK) and MPI (Max-Planck Institut für Meteorologie, Germany). In order to assess seasonal dependence on forecast skill, the DEMETER hindcasts were started from 1 February, 1 May, 1 August, and 1 November. The atmospheric and land-surface initial conditions were taken from the ECMWF reanalysis[1] dataset (ERA-40). The ocean initial conditions were obtained from ocean-only runs forced by ERA-40 fluxes, except in the case of MPI where a coupled initialisation method was used. Each hindcast was integrated for six months and comprised an ensemble of nine members. Hindcasts were produced for the period 1958-2001 (for the exact period covered by each model see Table 1).

In its simplest form, the multi-model ensemble was obtained by merging the ensemble hindcasts of the seven single-model ensembles, thus comprising 7×9 uniformly weighted ensemble members. The performance of the DEMETER system was evaluated from a comprehensive set of hindcasts over a substantial number of years (with the main focus over the period 1980-2001) using ERA-40 data to verify all variables except precipitation, for which the GPCP[2] was used as a reference.

	Period	Number of years
ECMWF	1958–2001	44
MetFr	1958–2001	44
UKMO	1959–2001	43
MPI	1969–2001	33
INGV	1973–2001	29
LODYC	1974–2001	28
CERFACS	1980–2001	22

Table 1 Period and number of years of the hindcasts produced by each of the global coupled models participating in DEMETER.

To enable fast and efficient post-processing of this complex dataset, much attention was given to the definition of a common archiving strategy for all models. A large subset of atmosphere and ocean variables, both daily data and monthly means, was stored into the ECMWF's Meteorological Archival and Retrieval System (MARS, see ECMWF Newsletter 90, Spring 2001). A significant part of the DEMETER dataset (monthly averages of a large subset of surface and upper-air fields) is now freely available for research purposes through a publicly accessible on-line data-retrieval system installed at ECMWF[3]. A snapshot of the data server can be seen in Figure 1. The data available for downloading comprise a variety of gridded monthly-mean fields from all ensemble members, together with the corresponding verifications from ERA-40. Geopotential height, temperature, wind and specific humidity are provided on three tropospheric pressure levels. Total precipitation, low-level wind, two-metre temperature and mean-sea-level pressure are also available. A tool to plot these fields, before retrieving them in gridded form, is also provided. The data can be retrieved in both GRIB and NetCDF formats. This dataset should prove useful for scientists and potential users of seasonal forecasts wishing to assess seasonal predictability for regions and variables of interest, using a truly state-of-the-art multi-model ensemble system. The dataset will also be valuable for training and education purposes.

Given the large amount of data generated, a comprehensive verification system to evaluate the forecast quality of all the DEMETER single-model ensembles, as well as of the multi-model ensemble system, has been developed at ECMWF. The system runs periodically to monitor hindcast production, to control the data quality (and the archival) and to calculate a common set of verification diagnostics based upon WMO standards. The basic set of diagnostics (performed in cross-validation mode) can be accessed on-line[4]. It comprises: global maps and zonal averages of the single-model bias, time-series of specific climate indices, standard deterministic and probabilistic measures of forecast quality, and a comparison of the skill of single-model ensembles with that of multi-model ensembles. Figure 2 shows an example of the information available in this website. It displays the two-metre temperature bias during the boreal spring (one-month lead-time) for one of the experiments carried out with the ECMWF coupled model. Bar menus allow for selection of the model, the variable, the start date and the lead-time. The plots can be retrieved in both Postscript and PDF formats. Some additional features, such as ocean diagnostics, will be added soon.

Multi-model versus single-model seasonal forecast skill

An assessment of the skill of sea surface temperature (SST) over the tropical Pacific suggests that the forecast quality of both the multi-model ensemble and the single models are

1 See http://www.ecmwf.int/research/era

2 The Global Precipitation Climatology Project (GCPC) dataset can be found at http://orbit-net.nesdis.noaa.gov/arad/gpcp/

3 Monthly data can be retrieved in GRIB and NetCDF from http://www.ecmwf.int/research/demeter/data

4 http://www.ecmwf.int/research/demeter/verification

Figure 1 The DEMETER public data server: http://data.ecmwf.int/data/. The server allows the retrieval of horizontal sections of monthly-mean atmospheric fields (both at the surface and at different pressure levels) for the nine-member ensembles produced by the seven coupled models taking part in the project. The fields can be delivered in both NetCDF and GRIB formats. The corresponding ERA-40 fields are also provided to help with the verification of the results. Additionally, a facility that allows the plotting of the fields is available.

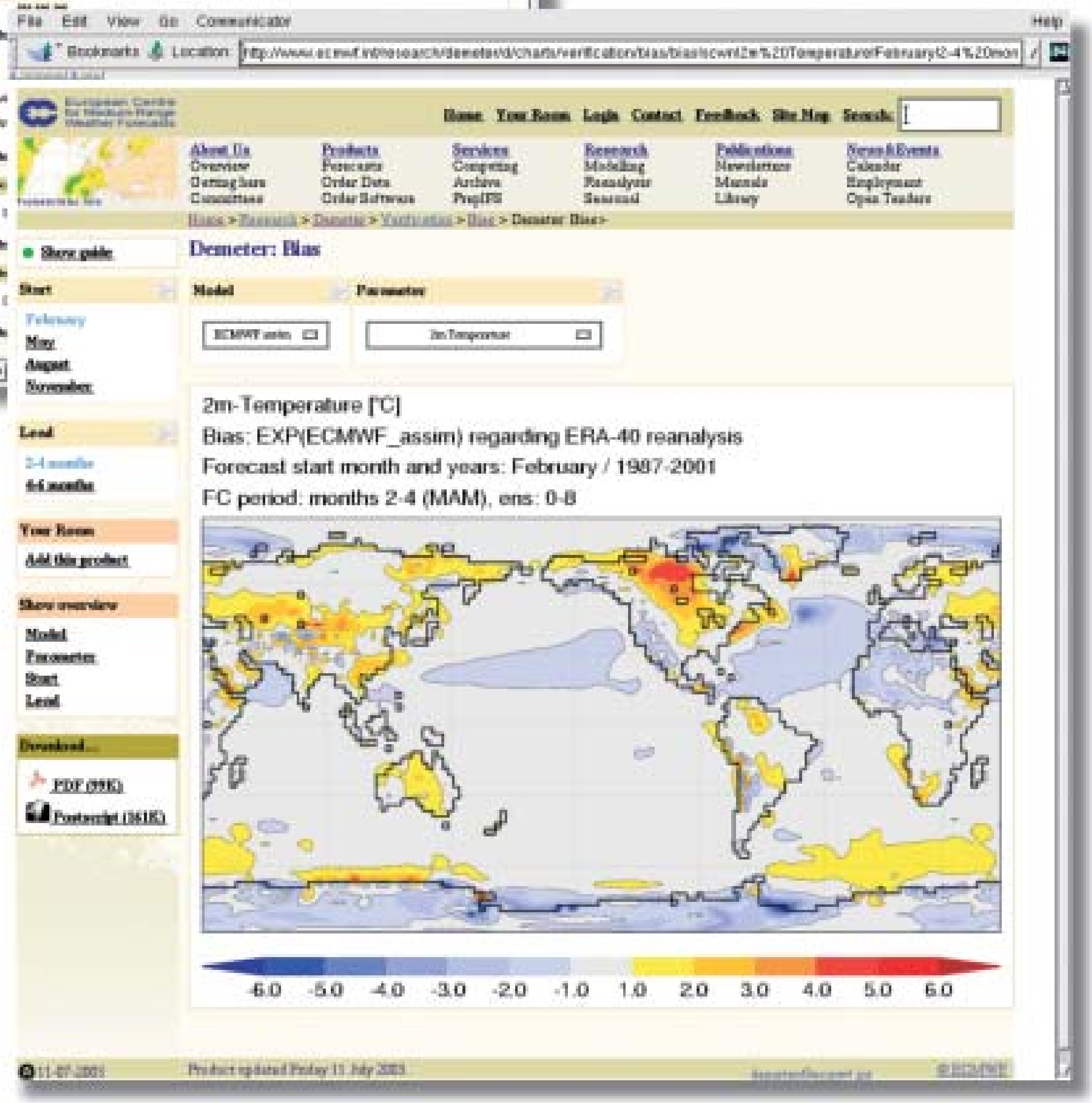

Figure 2 An example of the information available in the DEMETER verification site: http://www.ecmwf.int/research/demeter/verification. The site offers a comprehensive set of verification diagnostics for the different forecast systems available in DEMETER, as well as for different sensitivity experiments. The assessment contains estimates of model bias for a wide range of variables (including zonal averages), time-series of a large set of indices (of precipitation, sea surface temperature, and large-scale patterns of variability), and a suite of verification scores for deterministic and probabilistic hindcasts on global maps and as averages over a set of regions.

comparable with state-of-the-art El-Niño/Southern-Oscillation (ENSO) prediction models and is much better than persistence. Figure 3 shows the time-series of the multi-model seasonal-mean SST anomalies for the period March to May (February start date, one-month lead-time) averaged over the region Niño 3.4 (5°N–5°S, 170°W–120°W). The multi-model ensemble always contains the verification and reproduces satisfactorily the interannual variability of the reference. As a measure of performance, the correlation of the ensemble mean (0.94) and the ranked probability skill score (RPSS) for tercile categories (0.70) are higher than values obtained for a persistence hindcast (0.88 and 0.07, respectively). Similar results are obtained for other seasons. The predictability of the SSTs induces a high skill in other variables over the tropics, as shown in Figure 4 for precipitation. Here, the multi-model seasonal-mean precipitation anomalies for the four start dates (one-month lead-time) averaged over the tropical Pacific (10°N–10°S, 160°E–90°W) is displayed. The interannual variability is well represented, as in the case of the 1982/83, 1987/88 and 1997/98 ENSO events. Different skill measures indicate that the multi-model ensemble-mean skill is close to the best single-model skill almost every year and is the most skilful when the performance is averaged over all years. Table 2 shows the correlation and RPSS for tercile categories for the multi-model ensemble and the seven single-model ensembles. All the values are positive and statistically significant. A superior performance of the multi-model ensemble is also noticed in the case of the probabilistic measure.

In general, the identity of the most skilful single-model ensemble varies with the region and the year. However, in most regions the multi-model ensemble proves to be the most skilful forecast system. In order to assess the higher performance of the multi-model ensemble, different probabilistic skill measures were computed (the Brier skill score and ROC area under the curve) for four events: anomalies above (below)

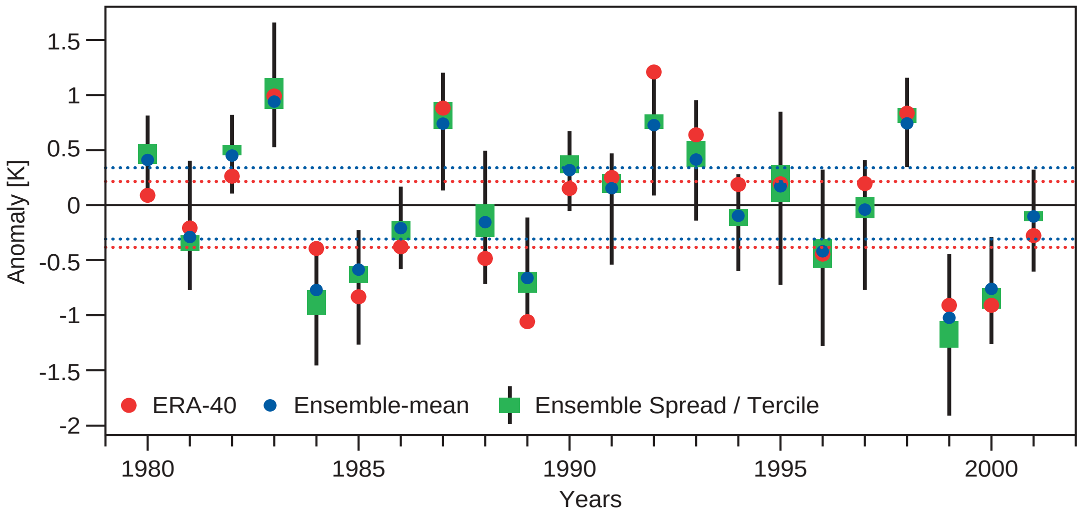

Figure 3 Time-series of the one-month-lead boreal spring (February start date, average from March to May) sea surface temperature averaged over the Niño 3.4 area. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a third of the ensemble members. The blue dots represent the ensemble mean, the ERA-40 values being displayed by red dots. The horizontal dashed lines around the solid zero line indicate the tercile boundaries of the ERA-40 (red) and hindcast data (blue).

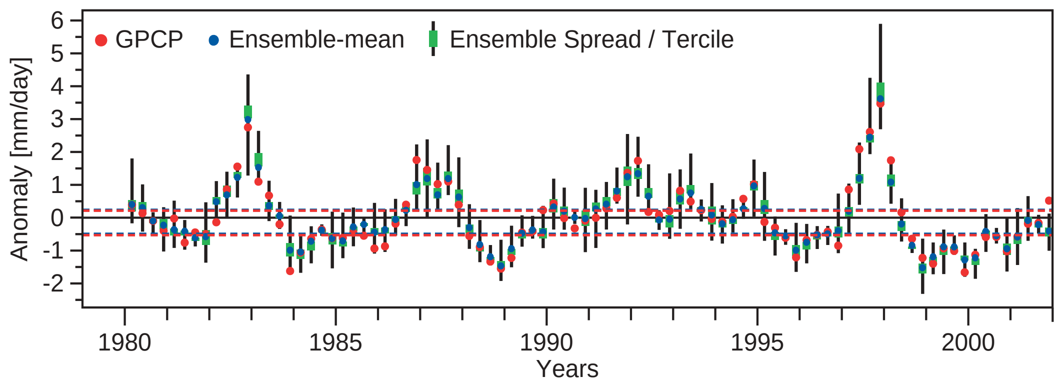

Figure 4 As Figure 3, but for one-month-lead precipitation anomalies (all start dates) averaged over the tropical Pacific area.

the upper (lower) tercile boundary and anomalies above (below) the mean. Figure 5 depicts the Brier skill score for the two-metre temperature seasonal anomalies for the four start dates computed over eight different regions (the northern extratropics, the tropical band, the southern extratropics, North America, Europe, western Africa, eastern Africa, and southern Africa) for the single-model ensembles versus the multi-model ensemble. The superiority of the multi-model approach is overwhelming. Most of the points (99.5%) are found below the diagonal, which indicates a higher Brier skill score for the multi-model emsemble. In addition, most of the skill scores for the multi-model system are positive, whereas most for the single-model ensembles are negative. The figure also displays the number of times that the multi-model skill score beats each single-model ensemble. Decomposing the Brier score, reliability and resolution skill scores have also been computed and are displayed in Figures 5(b) and (c). They demonstrate that the increased skill of the multi-model ensemble with regard to the single-model ensembles is due to an improvement in both the terms of the Brier score. Therefore, the multi-model approach not only generates more reliable predictions, but also increases their resolution. Similar results are found using the ROC area as skill score.

As another example of the superiority of the multi-model ensemble, the reliability diagrams of both the seven single-model ensembles and the multi-model ensemble for the summer (May start date, one-month lead-time) two-metre temperature positive anomalies over Europe (75°N–35°N, 12.5°W–42.5°E) can be seen in Figure 6. The reliability diagram displays the accumulated proportion of forecast probabilities versus the accumulated observed frequency of the event. Every single-model ensemble proves to be over-confident, which is characterized by an excessively shallow slope of the line joining the points in the diagram. On the other hand, the reliability diagram for the multi-model ensemble fits the diagonal much better. This implies that, given a prediction with a specific probability, the multi-model ensemble will verify on average the same proportion of observed events, while the single-model ensembles will assign low (high) probabilities to cases that are observed a higher (lower) proportion of times. Table 3 illustrates the improvement of the multi-model ensemble in terms of the Brier reliability and resolution skill scores. Interestingly, the multi-model ensemble is almost the only one that shows a positive Brier skill score. As commented above, its predictions not only gain in reliability but also in resolution when compared to the single-model ensembles.

The greater probabilistic skill of the multi-model ensemble compared with the single-model skill also leads to increased potential economic value (*Richardson* 2000). For instance, it has been found that, for the predictions described, the potential economic value of the multi-model ensemble outperforms that of most of the single-model ensembles by 15% to 50%, depending on the range of cost/loss ratio considered. This sort of improvement can be observed in Figure 7 for two different events, positive anomalies of two-metre temperature and anomalies above the upper tercile boundary over Europe in summer (May start date, one-month lead-time).

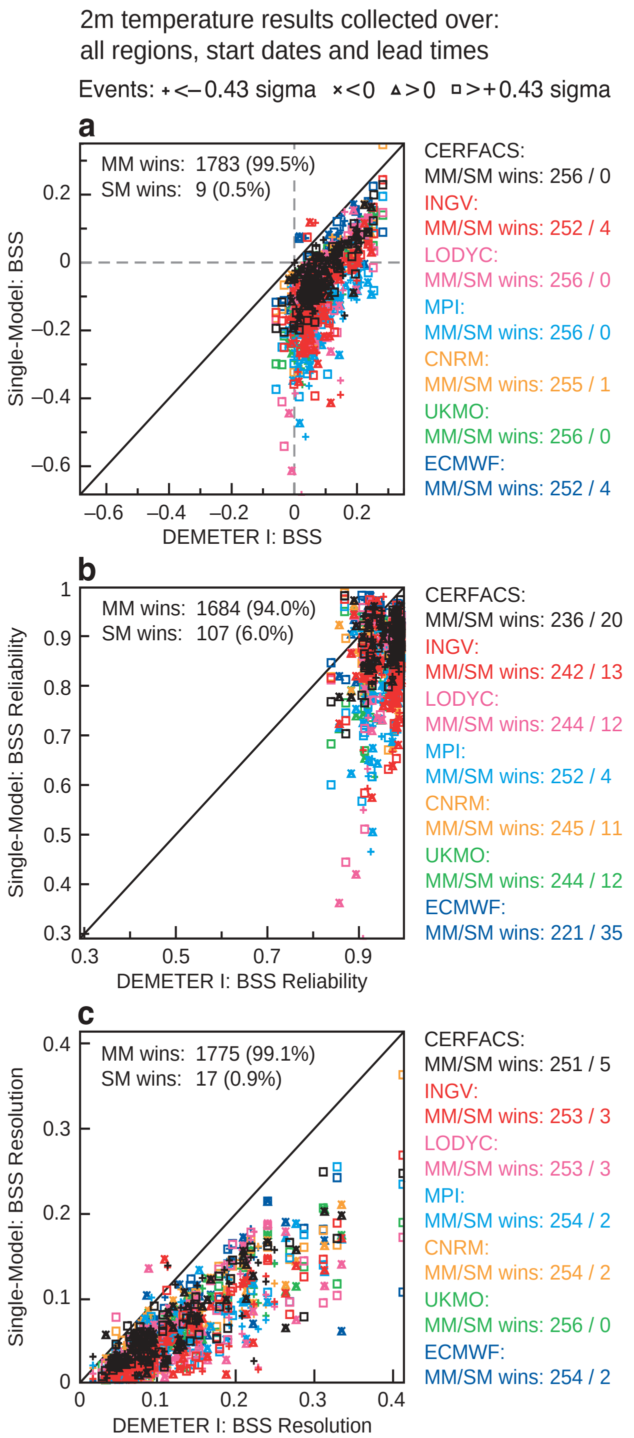

Figure 5 (a) The Brier skill score of the two-metre temperature for the single-model ensembles versus the corresponding skill score for the multi-model ensemble for the period 1980–2001. All start dates, two lead-times (one-month and three-month lead-time), four events (positive and negative anomalies, anomalies above 0.43 times and below -0.43 times the model standard deviation) and eight regions have been plotted. The number and proportion of times in which the multi-model ensemble is better than the single-models is also shown, as well as the number of times the multi-model ensemble beats each single-model ensemble. Panels (b) and (c) are similar to (a), but for the reliability and resolution skill scores, respectively.

Forecast system	Multi-model	ECMWF	MetFr	UKMO	MPI	INGV	LODYC	CERFACS
Correlation	0.95	0.93	0.93	0.92	0.86	0.92	0.95	0.94
RPSS	0.64	0.58	0.54	0.58	0.39	0.60	0.59	0.59

Table 2 Correlation and RPSS (tercile categories) for the different forecast systems used in DEMETER for the seasonal-mean precipitation anomalies for the four start dates (one-month lead-time) averaged over the tropical Pacific during the period 1980–2001.

Forecast system	Multi-model	ECMWF	MetFr	UKMO	MPI	INGV	LODYC	CERFACS
BSS	0.087	0.001	-0.113	-0.021	-0.137	-0.064	-0.033	-0.105
RelSS	0.989	0.924	0.861	0.924	0.836	0.890	0.924	0.858
ResSS	0.098	0.077	0.026	0.055	0.027	0.046	0.044	0.037

Table 3 Brier skill score (BSS), reliability skill score (RelSS) and resolution skill score (ResSS) for the seasonal-mean two-metre temperature positive anomalies for the 1980-2001 summer period (May start date, one-month lead-time) averaged over Europe.

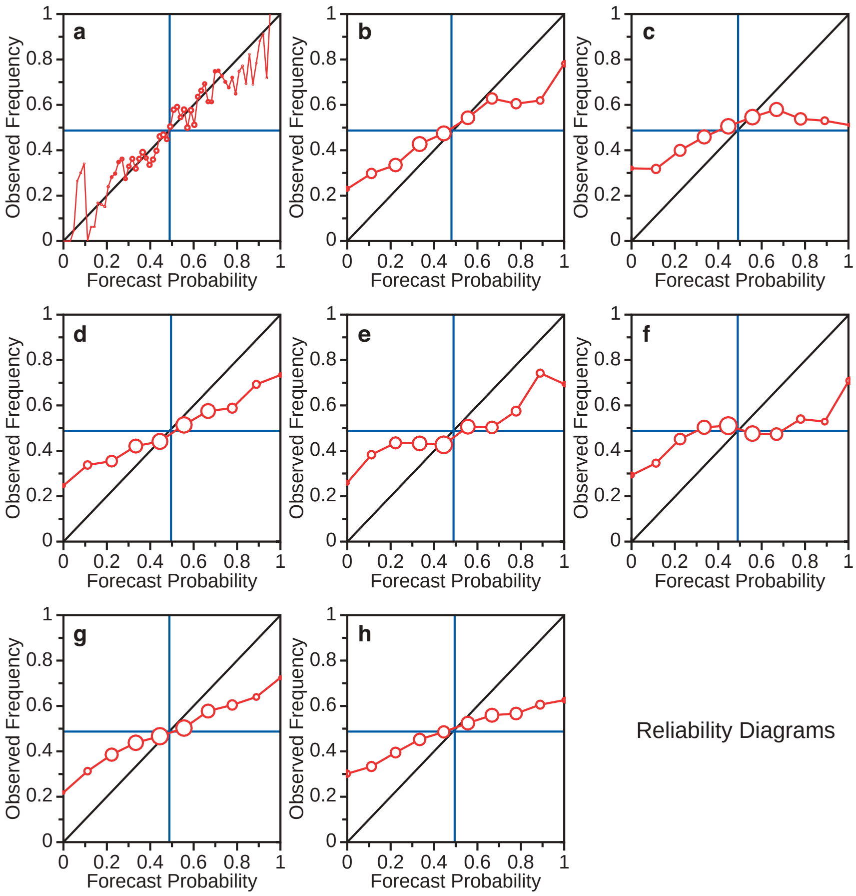

Figure 6 Reliability diagrams for the positive anomalies of seasonal averages of two-metre temperatures in summer (May start date, one-month lead-time) averaged over Europe for the period 1980–2001. The horizontal and vertical blue lines display the average observed frequency and forecast probability of the event. Each plot displays a different forecast system as follows: (a) Multi-model ensemble, (b) ECMWF, (c) MetFr, (d) UKMO, (e) INGV, (f) MPI, (g) LODYC and (h) CERFACS.

In spite of the clear improvement of the multi-model ensemble performance when compared with single-model ensembles, an important question arises. Is the improvement in the multi-model ensemble merely due to the increased ensemble size resulting from collecting all members of the single-model ensembles? In order to separate the benefits that derive from combining models with different formulations from those derived simply from the accompanying increase in ensemble size, a 54-member ensemble hindcast was generated with the ECMWF model alone for the period 1987–1999 using the May start date. Figure 8 shows the reliability diagram for the one-month lead positive anomalies of two-metre temperature in summer over the tropical band (30°N–30°S) for the 54-member single-model ensemble (Figure 8(a)) and the multi-model ensemble (Figure 8(b)). The multi-model ensemble for this example was constructed by randomly selecting 54 members out of the 63 available from the seven single-model ensembles. Although the increase in ensemble size in the single-model results in improved reliability compared with the nine-member ensemble predictions, it still does not outperform the multi-model system with the same ensemble size. This emphasizes that the additional information coming from the other models adds to the improvement seen in the multi-model results. Table 4 shows the skill scores for both forecast systems and illustrate that the multi-model approach improves predictions in terms of reliability and resolution. Similar results are found for other variables and regions.

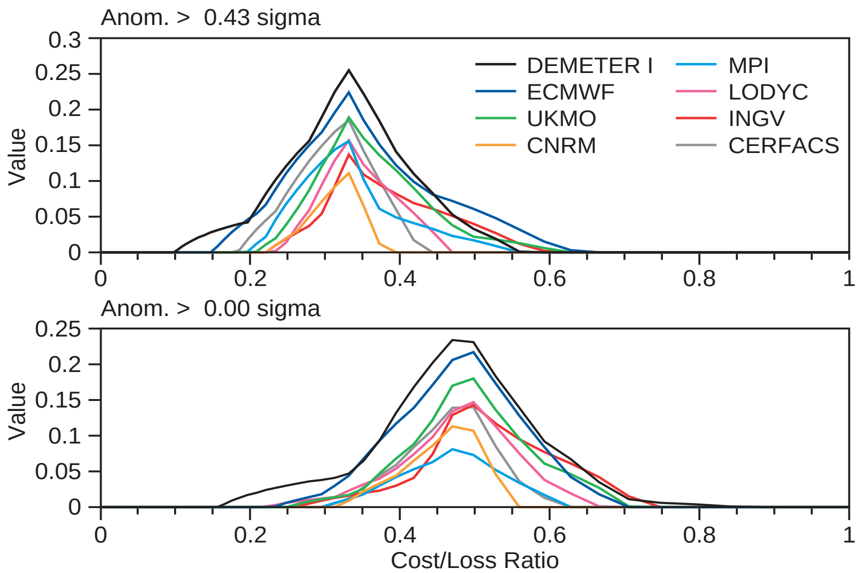

Figure 7 Potential economic value of the two-metre temperature in summer (May start date, one-month lead time) averaged over Europe for the period 1980–2001 for the events (a) anomalies above 0.43 times the model standard deviation and (b) positive anomalies. Each line corresponds to a different forecast system as follows: Multi-model ensemble (red), ECMWF (blue), MetFr (orange), UKMO (cyan), INGV (grey), MPI (cyan), LODYC (purple) and CERFACS (yellow).

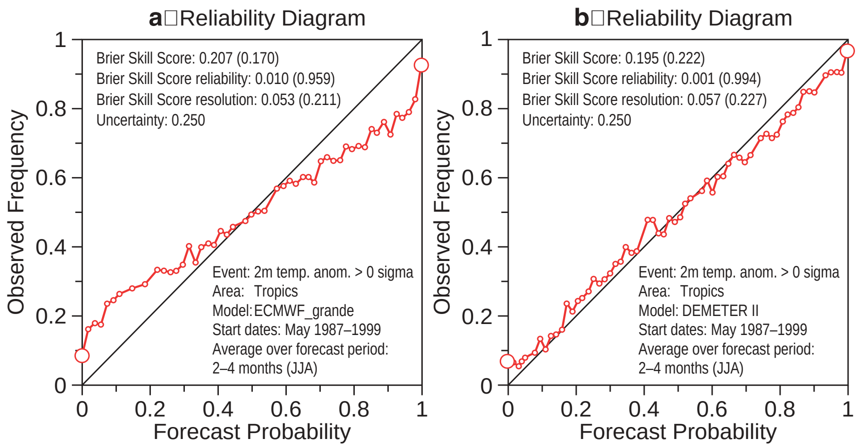

Figure 8 As Figure 6, but for (a) the 54-member ECMWF (single model) ensemble and (b) the 54-member multi-model ensemble for the period 1987–1999.

Figure 9 shows the RPSS (based on tercile categories) for summer anomalies of precipitation over the tropical band for different model combinations, and further discriminates between the improvements in skill attributed to an increase in ensemble size and those due to an increase in the number of models. In the first column, the vertical black bar indicates the range of values that the single-model ensembles cover and the black dot corresponds to their average. In the remaining columns, the RPSS values for all multi-model ensembles that can be constructed by combining two to six single-model ensembles are depicted in red. For each multi-model combination, a single-model ensemble of the same ensemble size was constructed and its value displayed in blue. An increase of the RPSS with the ensemble size can be appreciated in both cases, although the increase is larger for the multi-model than for the single-model ensemble for more than three models (27 ensemble members). For four or more models the multi-model skill is always above the skill of any combination obtained with the large single-model ensemble. This result emphasizes the superiority of the multi-model approach above single-model ensembles in a probabilistic-prediction framework.

Forecast system	Multi-model	Single-ensemble
BSS	0.170	0.222
RelSS	0.959	0.994
ResSS	0.211	0.227

Table 4 Brier skill score (BSS), reliability skill score (RelSS) and resolution skill score (ResSS) for the seasonal-mean two-metre temperature positive anomalies for the 1987-1999 summer period (May start date, one-month lead-time) averaged over Europe.

User applications

The DEMETER project had application partners in agronomy and tropical disease prediction. These users have quantitative application models requiring forecast weather information as input. The models can be directly linked to the output of individual members of a prediction ensemble. The net result is a probability forecast, not of weather or climate, but of a variable directly relevant to the user (for example, in the case of an agronomist, a probability distribution of predicted crop yield). As such, the design of DEMETER was based on the concept of an 'end-to-end' system (*Pielke and Carbone*, 2002), in which users feed information back to the forecast producers.

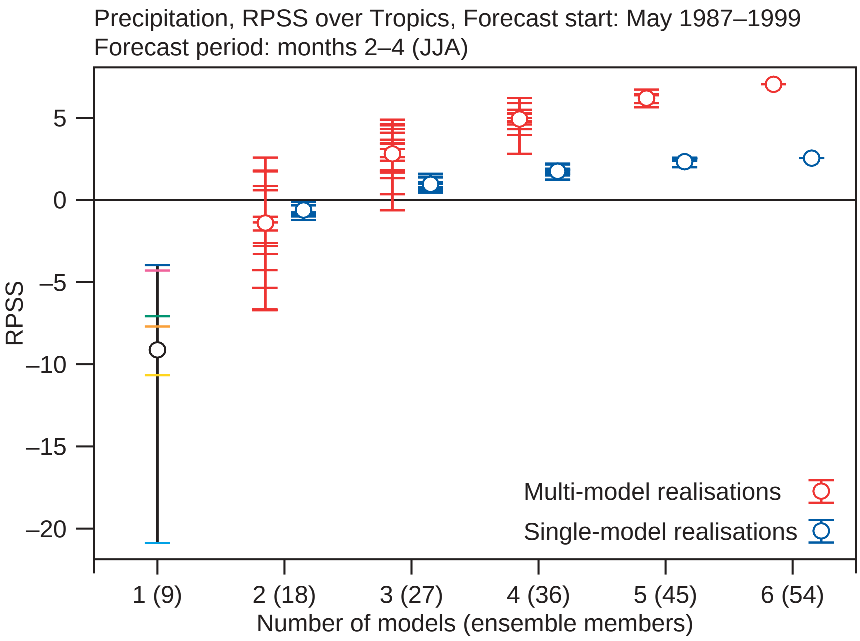

Figure 9 Ranked probability skill score (RPSS) based on tercile categories for summer anomalies of precipitation over the tropical band for different model combinations. In the first column, the vertical black bar indicates the range of values covered by six single-model ensembles (each model represented with a different colour) while the black circle corresponds to their average. The RPSS values for all multi-model ensembles that can be constructed by combining two to six single-model ensembles are depicted in red in the remaining columns. A single-model ensemble of the same ensemble size was constructed for each multi-model combination and the RPSS displayed in blue.

Quantitative application models of the sort used in DEMETER have been derived using data from specific meteorological stations. By contrast, the output from global models represents averages over relatively coarse grids. As such, the statistics of model variables, especially precipitation in regions of steep orography, can differ substantially from the statistics of station data. It is, therefore, necessary to perform some form of downscaling analysis to the numerical-model output, either by some statistical/empirical scheme, or by embedding a high-resolution limited-area model into the global model.

Crop simulation models that estimate crop growth and crop yield, as a function of environmental conditions and management practices, are important tools for decision-makers. The Joint Research Centre (JRC) Crop Growth Monitoring System uses a crop model called WOFOST, and performs crop-yield forecasting through a regression analysis comparing simulated crop indicators at the time of issuing the forecast and historical yield series for the main crops at national and European level. Up to the present time, the statistical model has used crop-growth indicators that are dependent only on meteorological conditions known at the time of issuing the forecast (usually February, see Figure 10). The objective of the research within DEMETER was to create improved crop-growth indicators based on seasonal predictions from the multi-model system; this would bring in additional information for the remaining of the crop season. In the new end-to-end system the crop model was run forced by the downscaled output of the multi-model ensemble to generate the required crop indicators for the end of the season (Figure 10). In this way, a probability density function (PDF) of the crop yield could be derived. Based on the PDF spread, the end-user can directly quantify the benefits and risks of climate-sensitive decisions. Figure 11 shows wheat-yield hindcasts carried out over four years (1995–1998) for Germany (one of the largest European wheat producers) using the multi-model ensemble downscaled data. This plot depicts the quartiles of the ensemble PDF using a box-and-whisker representation, where the blue dot corresponds to the median. The red dot indicates the wheat yield obtained when ERA-40 is used to force the crop model. As an external reference, the black horizontal lines display the Eurostat official yields. Some disagreement between Eurostat and ERA-40 yields is observed, which may be due to the crop model not taking into account the impact of pests or the conditions at harvest. The multi-model ensemble shows a high skill in predicting the ERA-40 values (the red dot is always contained within the range of predicted wheat yield values), although a slight negative bias can be noticed. Similar results are obtained for other countries.

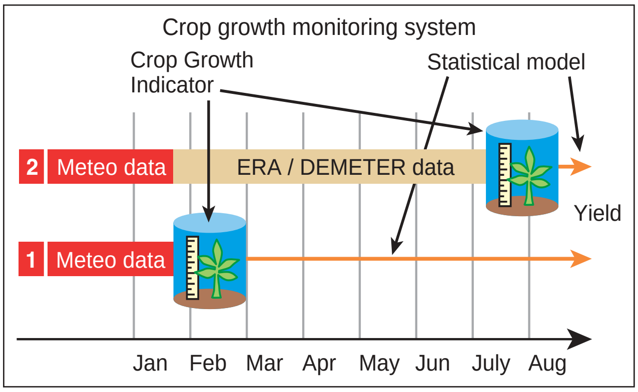

Figure 10 Schematic representation of two different crop-yield forecasting methods. The first method uses a linear regression model trained on historical data with the crop growth indicators available on 1 February as independent variables to predict the crop yield at the end of the season. The second method, on top, uses the predicted crop-growth indicators for August obtained with the crop model run using the seasonal forecast information available on 1 February.

The other application investigated within DEMETER concerns predictions of malaria incidence in Eastern and

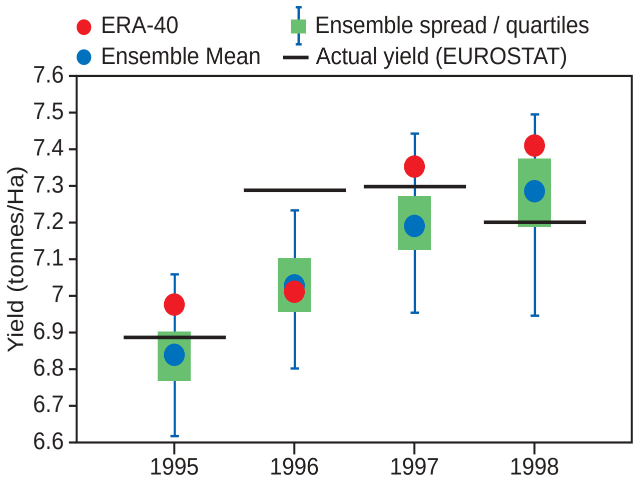

Figure 11 Time-series of the wheat-yield predictions (February start date) for Germany over the period 1995–1998. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a fourth of the ensemble members. The blue dots represent the ensemble median; the wheat yield obtained using ERA-40 data being displayed by red dots. The horizontal black lines correspond to the values recorded by Eurostat.

Southern Africa. Malaria is a disease of extreme importance, given the large amount of people at risk in tropical areas. A typical lag of between two and four months is observed between the peak in the number of people infected with malaria and the peak in the rainfall. This suggests that some predictability of malaria incidence might be obtained if a dynamical malaria model is fed with current weather conditions as well as future climate variability information. Such predictions would obviously be of great benefit to malaria early-warning systems; these incorporate vulnerability assessment, seasonal climate forecasts, weather monitoring and case surveillance for risk areas in Africa (*Thomson et al.* 2000).

A numerical biological model describing malaria processes has been run using data from ERA-40, as well as bias-corrected data from multi-model ensemble predictions. The model simulates the population dynamics of cohorts of mosquitoes, and thus predicts the behaviour of the total mosquito population. Figure 12 presents the seasonal malaria incidence (the proportion of cases accumulated over a month) for the point (0°N, 35°E) (Kenya) for the period 1987–1999. The incidence obtained when forcing the malaria model with ERA-40 data (considered as a reference, given the lack of clinical-case reports) is shown in red. As before, a box-and-whisker representation has been used to represent the predicted incidence PDF. Each whisker and the central box contain a third of the ensemble members, while the blue dot corresponds to the ensemble mean. The inter-annual variability of the reference malaria prevalence is predicted with success, the reference value never being out of the multi-model ensemble range. In addition, the prediction of the onset and duration of intense malaria prevalence events is remarkably precise. The correlation and RPSS for these predictions are displayed in Table 5. Once again, the multi-model ensemble performs as well as the best single-model ensemble, indicating that the advantage of the multi-model approach is transferred through the applications models to the prediction of useful variables. These promising results require further research in which the malaria model is forced with downscaled seasonal-prediction data for larger areas.

Future developments

As a result of the success of DEMETER, real-time multi-model ensemble forecasting is now being established as part of the operational seasonal forecast suite at ECMWF. At the time of writing, plans are well established for the ECMWF, Met Office and Météo-France coupled systems to be included in this multi-model mix. It is possible that other DEMETER models may be included at a later stage. We encourage scientists and potential users of seasonal forecasts to perform their own analysis of the DEMETER data (perhaps to assess skill for specific regions and variables of interest not covered in our standard analysis). More generally, this DEMETER dataset is offered for education and training purposes, both in the developed and developing worlds.

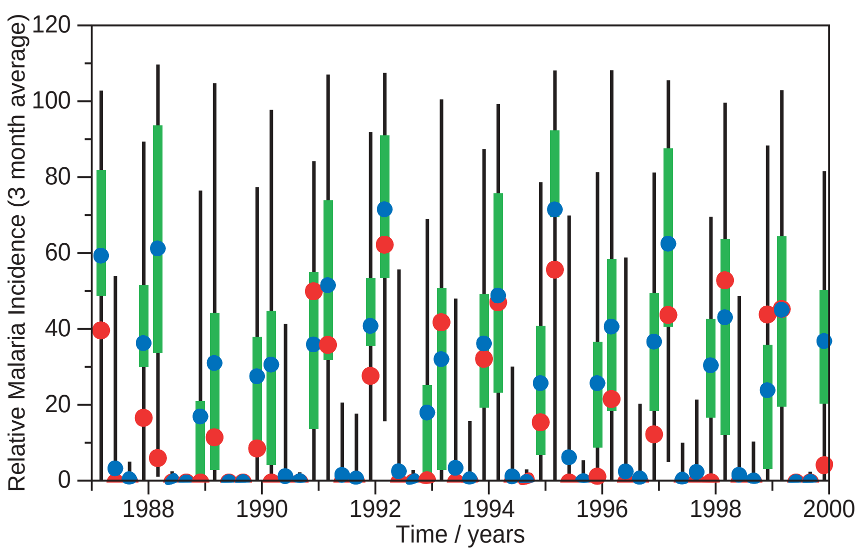

Figure 12 Time-series of the seasonal average of malaria monthly incidence (all start dates) for the point (0°N, 35°E) over period 1987–1999. The range of multi-model ensemble values is depicted using a box-and-whisker representation, with each whisker containing a third of the ensemble members. The blue dots represent the ensemble mean; the malaria incidence obtained using ERA-40 data being displayed by red dots.

Forecast system	Multi-model	ECMWF	MetFr	UKMO	MPI	INGV	LODYC	CERFACS
Correlation	0.50	0.34	0.52	0.36	0.03	0.35	0.29	0.51
RPSS	0.30	0.24	0.23	-0.01	-0.25	0.27	0.26	0.23

Table 5 Correlation and RPSS (tercile categories) for the different forecast systems used in DEMETER for the seasonal-mean monthly incidence for the four start dates (one-month lead-time) at (0°N, 35°E) during the period 1980-1999.

The ECMWF is also a participant with other research groups in a recently approved project ENSEMBLES funded by the European Union. One of the aims of the project is to use a successor system to explore the use of multi-model ensembles, not only on seasonal-to-interannual timescales but also for decadal timescales for which some scientific evidence of predictability has emerged in recent years. For this purpose, it is planned to ensure that the model components used for seasonal-to-decadal ensemble prediction are, as far as is practicable, identical to those used by some of the participants for century-timescale anthropogenic climate change studies. In this way, running essentially the same ensemble systems on timescales for which verification data exists can assess the reliability of century-timescale climate-change projections.

Acknowledgements

The DEMETER project has been funded by the European Union under the contract EVK2-1999-00197. Pierre Cantelaube (JRC, Ispra, Italy) has kindly produced the plot in Figure 11.

FURTHER READING

Articles on atmosphere-ocean modelling

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The DEMETER project participants at the final project meeting, which was held in July 2003 at the Institute for Marine Research in Kiel, Germany.

T.N. Palmer, F.J. Doblas-Reyes, R. Hagedorn

Environmental activities at ECMWF

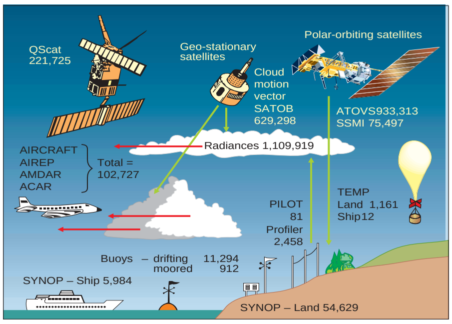
The European Union and the European Space Agency are developing collaborative programmes (referred to as Global Monitoring for Environment and Security – GMES) to address issues of monitoring the global environment for treaty verification purposes, and for coping with natural hazards. ECMWF and the European weather services can play a central support role in GMES and related initiatives, by working with European science networks to develop operationally useful products for GMES.

In partnership with the European meteorological community, the Centre (under the leadership of Tony Hollingsworth) is developing a substantial proposal (GEMS – Global Earth-system Monitoring using Satellite and in-situ data) for submission to the European Union's Sixth Framework programme. This European-wide collaboration will act to catalyse substantial European investments in fundamental science, operational forecasting systems and satellites and ensure practical deliverables, and it will provide vital support to European climate and environmental research. It is proposed to develop by 2007 a comprehensive monitoring system to enable us to assess the distribution, sources and sinks of greenhouse gases, reactive gases and aerosols, and to monitor the land surface and the upper ocean.

The ECMWF is actively contributing to the initiative launched at the Earth Observation Summit in Washington DC in July 2003 by the ad-hoc group on earth observations. The Centre is co-chairing the 'Data Utilisation' subgroup and is also a member of the 'User Requirements' subgroup.

The following advertisement was published in the Parliament Magazine on 17 November 2003.

European Centre Monitors the Environment



The European Centre for Medium-Range Weather Forecasts is an important environmental monitoring centre for Europe. Millions of environmental observations are collected in real time through its global high-speed telecommunications network.

Figure: The numbers of observations from different platforms received at ECMWF in one day

The European Centre for Medium-Range Weather Forecasts (ECMWF) is extending into environmental activities.

WORLD LEADER IN NUMERICAL WEATHER PREDICTION

Established in 1975, ECMWF is renowned worldwide as providing the most accurate medium-range global weather forecasts to ten days and seasonal forecasts to six months. Its products are provided to the European National Weather Services, as a complement to the national short-range and climatological activities.

MONITORING THE ENVIRONMENT

The EC / ESA initiative **GMES** – 'Global Monitoring for Environment and Security' – has requirements similar to those in daily use for the operational forecasting activity of ECMWF:

- Real-time receipt of very large quantities of global environmental data from satellites, aircraft, instrumented balloons, ground- and sea-based platforms, and sub-surface instruments.
- Sophisticated software to manage and analyse the data.
- A powerful computer system.
- A vast and efficient archival and retrieval system.

ECMWF operates the most advanced global data-assimilation systems and models for the dynamics, thermo-dynamics and composition of the Earth's fluid envelope and interacting parts of the Earth-system. It already has one of the world's most powerful computing systems for weather and environment. The system will be upgraded soon to provide more than two Tflops ($2{\times}10^{12}$ operations per second) sustained performance. The ECMWF archive has become a vital research resource for environmental scientists worldwide.

ECMWF is already a major contributor to environmental operations, research and development in Europe. Its work extends naturally to the enhanced environmental monitoring required by the EU in verifying international treaties.

It is preparing for the **GEMS** – 'Global Earth-system Monitoring using Satellite and in-situ data' – proposal in Framework Programme 6. With its partners in the European meteorological community, it intends to develop by 2007 a comprehensive monitoring system for global greenhouse gases and aerosols, and regional air quality.

ECMWF is actively contributing to the **GEO** initiative launched at the Earth Observation Summit in Washington DC in July 2003.

ABOUT ECMWF

Eighteen Member States, including all EU Members as well as Norway, Switzerland and Turkey, now support ECMWF. It has concluded cooperation agreements with six other States: Croatia, the Czech Republic, Iceland, Hungary, Slovenia, and Serbia and Montenegro, and with the World Meteorological Organisation, EUMETSAT and JRC.

Situated 60km west of London England, with a staff of 216, its budget is 36M€.

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Austin Woods and Manfred Kloeppel

The ECMWF public data server

About a year ago, ECMWF started a project to design a system that would allow users to download data freely from a publicly available web server. This data server is principally aimed at research users and is for non-commercial use.

Datasets

DEMETER The first dataset that was made available was the results of the DEMETER project, a multi-model seasonal-prediction experiment. DEMETER is a project funded by the European Union's Fifth Framework Research Programme and involves cooperation between ECMWF and ten other research institutes within Europe. The various partners had a need to exchange and compare their results. The data server has proved to be a success in achieving that goal. The DEMETER project has currently 1.2 million fields on the server, totalling about 24 Gbytes of data. More will be added as various results continue to be produced.

ERA-15 At the end of the ECMWF 15-year reanalysis project, a CD-ROM was created that contained a selection of fields on a 2.5° grid. This dataset was loaded onto the data server. It has 82,000 fields totalling about 1 Gbyte.

ERA-40 The ERA-15 dataset has now been superseded by ERA-40, ECMWF's 45-year reanalysis (from September 1957 to August 2002). A substantial selection of the reanalysis results have been selected and interpolated onto a 2.5° grid. The dataset contains 54 surface parameters and 11 upper-air parameters on 23 standard pressure levels, four times a day for 45 years. In the near future the dataset will also include the corresponding monthly products. The dataset contains about 2.2 million fields, for a volume of about 400 Gbytes.

User interface

The use of this service had to be as simple as possible for the end users. There is a single web page for each dataset from which the user can select any combination of fields (Figure 1). Once fields are chosen, the user is presented with post-processing options such as resolution changes and sub-area extraction. A third web page presents the resulting data for downloading.

Data formats

GRIB All fields are stored on the server in GRIB form, which is the native format of all fields produced at the Centre. GRIB is a WMO standard and decoders are now freely available from the Centre's web site. Although all fields are global, the user can ask for specific areas and resolutions. The system will interpolate the data on the fly, and return the result.

NetCDF Researchers from institutes other than National Meteorological Services, such as universities, are usually not familiar with GRIB formats. It was acknowledged that NetCDF was a popular data format in these communities, and that the data server should provide data in this format.

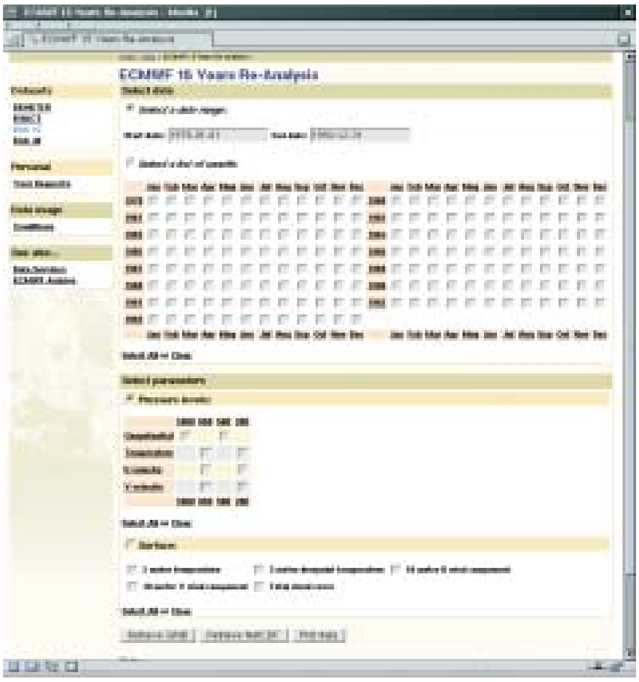


Figure 1 Parameter selection for the ERA-15 dataset.

Most GRIB to NetCDF converters simply recode the GRIB format in NetCDF; they do a one-to-one mapping between GRIB attributes and NetCDF variables. Using the output of such converters still requires knowing the GRIB format in order to understand the content of the NetCDF output. As this was not satisfactory, a new converter has been developed to transform GRIB into NetCDF, trying to follow the established NetCDF conventions as much as possible. This tool is still at an early stage and will be developed further.

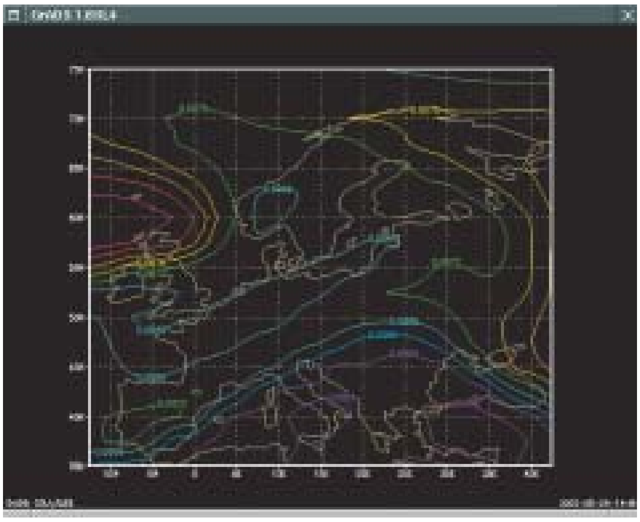


Figure 2 A GrADS display of a NetCDF file containing the 'total column ozone' for the year 1959 over Europe, from the ERA-40 dataset.

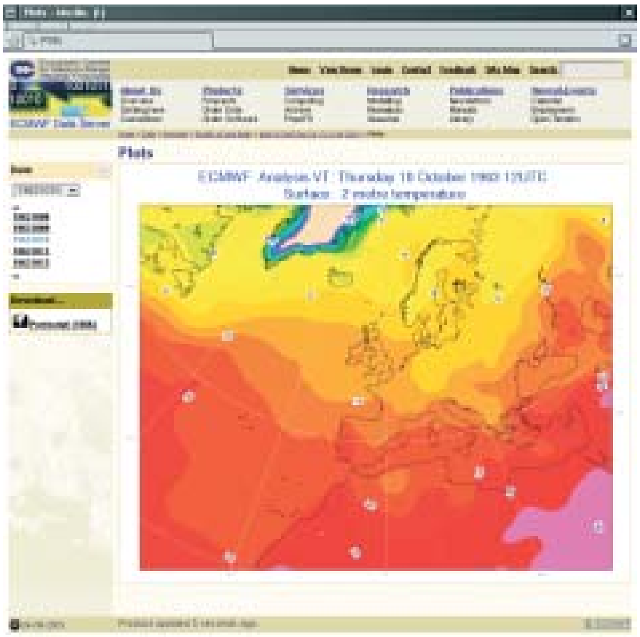


Figure 3 A two-metre temperature plot for the year 1963 from the ERA-40 dataset.

Plots Using Metview, the data server is able to plot the requested fields on a selection of projections and geographical areas (Figures 2 and 3). Plots can by viewed and animated in the user's web browser or downloaded in Postscript format. This facility is useful for a user with small Internet bandwidth, as plots are generally smaller in volume than the raw data. This service provided very little control to the user regarding the choice of plotting attributes, such as contouring, shading, colour selection and legend creation. Work is currently underway to overcome these limitations.

Architecture

Software The data server is based on ECMWF standard tools:

- Apache as a web server, ProFTP for data transfers,
- The 'MARS on the web', a Perl-based web application framework (described in ECMWF Newsletter 90 Spring 2002 p.9),
- The SMS scheduler to manage long user requests, such as plots and conversions to NetCDF,
- Magics/Metview to create the plots,
- The MARS client for data retrievals and interpolations,
- The MARS server for managing the fields.

MARS is the Centre's archive system, capable of managing billions of fields, stored on tapes. A key point of this project was to make a disk-only version of the MARS server that would run on Linux.

Hardware The data server runs on a Dual Intel Pentium III 1400MHz IBM Netfinity x342 with 1 Gbyte RAM running SuSE Linux 7.3 with SMP Linux kernel version 2.4.18.

The service is very successful, especially after the addition of the ERA-40 dataset. About 1000 users from all around the world have downloaded data at a rate of 1 Tbyte a month. As the Centre plans to take part in future research projects, more datasets will be made available on the server.

Further information can be found at the following web links:

Data server	http://data.ecmwf.int/data/
DEMETER	http://www.ecmwf.int/research/demeter/
ERA-40	http://www.ecmwf.int/research/era/
MARS	http://www.ecmwf.int/publications/newsletters/pdf/90.pdf

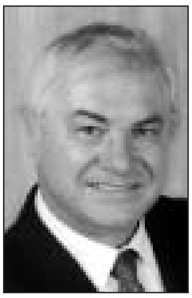
Baudouin Raoult

The ECMWF archive exceeds one petabyte

In December 2003, the amount of data stored in the ECMWF's Data Handling System (MARS and ECFS) exceeded 1 petabyte (1,000,000,000,000,000 bytes, equivalent to the amount of data that can be stored on 1.4 million CDs). This figure covers the primary copy of data stored. In addition, ECMWF keeps a second copy of its most important data.

The Data Handling System now includes 10 times as much data as was stored in early 1999.

Francis Dequenne



The American Meteorological Society

Tony Hollingsworth was elected on 18 December 2003 to serve as a member of the Council of the American Meteorological Society. His term of office wil be for three years starting in January 2004. Tony is one of only a few scientists from outside North America that have been appointed to Membership of the Council.

Co-operation Agreements 2003

By its external policy, which forms an integral part of its Four-Year Programme of Activities (see ECMWF Newsletters 95 and 96), the European Centre for Medium-Range Weather Forecasts welcomes the conclusion of the following co-operation agreements with two States of central and eastern Europe and with two international organisations.

A co-operation agreement with Serbia and Montenegro came into effect on 1 January 2003.

A co-operation agreement with the Joint Research Centre (JRC) of the European Commission came into effect on 6 May 2003.

A co-operation agreement with the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) came into effect on 24 June 2003.

A co-operation agreement with Romania came into effect on 22 December 2003.

PRESS RELEASE

Romania joins the European Centre for Medium-Range Weather Forecasts

A co-operation agreement came into force between Romania and the European Centre for Medium-Range Weather Forecasts ECMWF on 22 December 2003.

ECMWF is an international organisation now supported by 25 European States. Its headquarters situated in Reading England contains a super-computer complex linked by high-speed telecommunication lines to the computer systems of the national weather services of its supporting States. The Centre's computer system contains the world's most sophisticated medium-range prediction model of the global atmosphere and oceans.

The European Centre provides medium-range forecasts of the global weather and ocean waves to ten days ahead, and seasonal forecasts of temperature and rainfall to six months ahead, to the weather services.

Dr David Burridge, the Director of ECMWF, said: "I am looking forward to closer collaboration with the National Institute of Meteorology and Hydrology in extending the use of our medium-range and seasonal weather forecasts for the benefit of the people of Romania. All nations now recognise the necessity of improving the quality and accuracy of advance warning of floods, gales and other severe weather."

Mr Florin Stadiu, State Secretary of Waters Department, said: "After great efforts, Romania has signed the Co-operation Agreement with ECMWF. Standing shoulder to shoulder with the 18 Member States of ECMWF, Romania is now the seventh Co-operating State, which is extremely important for meteorology in Romania. ECMWF's products will greatly assist the National Institute of Meteorology and Hydrology to fulfil its mission including the protection of life and property. I wish both ECMWF and the Institute success in achieving European integration in meteorology."

Mr Ion Poiana, Director of the Institute, said: "The European Centre is the world leader in its area of scientific and technical expertise. The data from its supercomputer system will be vital for improving overall the quality of our forecasting, and for our warning services in advising of the likelihood of extreme weather. We will be using the Centre's products to extend the usefulness of our forecasts as far as possible. Our meteorological staff will benefit from extending their contacts with their colleagues at the European Centre. We welcome this agreement."

Dr David Burridge
Director
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Mr Ion Poiana
Director
National Institute of Meteorology and Hydrology
Sos. Bucuresti-Ploiesti 97
Bucharest 013686
Romania
www.inmh.ro

ECMWF Education and Training Programme 2004

The 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 facilities. The training courses consist of modules that can be attended separately. A student may decide to attend different modules in different years.

In addition to the training courses, every year a seminar and a number of workshops are organized. The subject of these meetings varies from year to year.

The programme for 2004 is as follows:

Computer Users Training Course

The objective of the Computer User Training Course is to introduce users of ECMWF's computing and archive systems to the Centre's facilities, and to explain how to use them. The course is divided into five separate modules. Each module will consist of some lectures and some practical sessions. All the lectures will be given in English. A workbook will be provided for each module, together with basic manuals and other relevant documentation as required.

COM-SMS	19-20 Feb	SMS/XCdp
COM-INTRO	23-27 Feb	Introduction for new users/ MARS
COM-MAG	1-2 Mar	MAGICS
COM-MV	3-5 Mar	METVIEW
COM-HPCF	8-12 Mar	Use of supercomputing resources

Meteorological Training Course

The objective of the meteorological training course is to assist Member States in advanced training in the field of numerical weather forecasting. The course is divided into five modules, one on the description and use of ECMWF products and the remainder on numerical weather prediction. Students attending the course should have a good meteorological and mathematical background, and are expected to be familiar with the contents of standard meteorological and mathematical textbooks. Some practical experience in numerical weather prediction is an advantage. All the lectures will be given in English. A set of lecture notes will be provided for the modules on numerical weather prediction.

ECMWF Products

MET OP-I	15-19 Mar	Use and interpretation of ECMWF products
MET OP-II	7-11 Jun	Use and interpretation of ECMWF products
MET OP-III	11-15 Oct	Use and interpretation of ECMWF products for WMO members

Numerical weather prediction

MET PA	22 Mar-1 Apr	Parametrization of diabatic processes
MET NM	19-28 Apr	Numerical methods and adiabatic formulation of models
MET DA	5-14 May	Data assimilation and the use of satellite data
MET PR	17-21 May	Predictability, diagnostics and seasonal forecasting

Recommended textbooks

Holton, J.R., 1992: An introduction to dynamic meteorology-third edition. *Academic Press*.
Wallace, J.M. and **P.V. Hobbs**, 1977: Atmospheric science: An introductory survey. *Academic Press*.
Haltiner, G.J. and **R.T. Williams**, 1980: Numerical prediction and dynamic meteorology-second edition. *Wiley*. (Module Met NM only)
Students are also advised to consult http://www.ecmwf.int/newsevents/training/index.html.

Annual Seminar

The Annual Seminar in 2004 will be on the topic 'Recent developments in numerical methods for atmospheric and ocean modelling'. The Seminar will present a pedagogical review of recent developments in numerical methods for atmospheric and ocean modelling. Topics to be covered will include the choice of the basic dynamical equations and coordinate systems for different applications, and the virtues of various horizontal and vertical discretizations in the context of a range of resolutions. The choice of time-integration schemes and questions of accuracy and conservation will also be addressed. Issues of efficiency on different computer architectures will also be considered.

Workshops

The following workshops will take place during 2004 (details to be announced later)

Date to be decided	ECMWF high-performance networking workshop
8-10 March	GEWEX workshop on ensemble hydrological predictions
6-10 June	WISE meeting (Waves In Shallow-water Environment)
28 June-1 July	Assimilation of high spectral resolution sounders in NWP
25-29 October	11th workshop on high-performance computing in meteorology
8-11 November	ECMWF/ELDAS workshop on land-surface assimilation

ECMWF publications

A full list of ECMWF publications is available at http://www.ecmwf.int/publications/library/ecpublications/ and recently published Technical Memoranda can be downloaded in pdf format from http://www.ecmwf.int/publications/library/ecpublications/techmemos/tm00.html

Technical Memoranda

398 **Coutinho, M.M.**, **B.J. Hoskins** & **R. Buizza**: The influence of physical processes on extratropical singular vectors. *April 2003*

401 **Keil, C.**, & **C. Cardinali**: The ECMWF Re-Analysis of the Mesoscale Alpine Programme special observing period. *March 2003*.

404 **Anderson, D., T. Stockdale, M. Balmaseda, L. Ferranti, F. Vitart, P. Doblas-Reyes, R. Hagedorn, T. Jung, A. Vidard, A. Troccoli** & **T. Palmer**: Comparison of the ECMWF seasonal forecast Systems 1 and 2, including the relative performance for the 1997/8 El Niño. SAC Report *September 2002/April 2003*.

405 **Wedi, N.** & **P. Smolarkiewicz**: Extending the Gal-Chen & Somerville terrain-following coordinate transformation on time-dependent curvilinear boundaries. *April 2003*

406 **Abdalla, S.** & **H. Hersbach**: Interim report on the technical support for global validation of ERS wind and wave products at ECMWF. *April 2003*

407 **Isaksen, L.** & **P.A.E.M. Janssen**: Impact of ERS scatterometer winds in ECMWF's assimilation system. *May 2003*

408 **Cavaleri, L.** & **L. Bertotti**: The improvement of modelled wind and wave fields with increasing resolution. *June 2003*

409 **Cavaleri, L.** & **L. Bertotti**: The accuracy of modelled wind and waves fields in enclosed seas. *June 2003*

412 **Moreau, E., P. Lopez, P. Bauer, A. Tompkins, M. Janisková,** & **F. Chevallier**: Variational retrieval of temperature and humidity profiles using rain rates versus microwave brightness temperatures. July 2003

Reports

Chevallier, F., P. Lopez, A.M. Tompkins, M. Janisková & **E. Moreau**: The capability of 4D-Var systems to assimilate cloud-affected satellite infrared radiances. NWP Satellite Application Facility Technical Report no. 8, *July 2003*

Betts, A.K., J.H. Ball & **P. Viterbo**: Evaluation of the ERA-40 surface water budget and surface temperature for the Mackenzie River basin. ERA-40 Project Report Series No. 6, *April 2003*

Betts, A.K., J.H. Ball, M. Bosilovich, P. Viterbo, Y. Zhang & **W.B. Rossow**: Intercomparison of water and energy budgets for five Mississippi sub-basins between the ECMWF reanalysis (ERA-40) and NASA-DAO fvGCM for 1990-1999. ERA-40 Project Report Series No. 7, *June 2003*

Bormann, N. & **J-N. Thépaut**: Impact of MODIS polar winds in ECMWF's 4D-Var data assimilation system. EUMETSAT/ECMWF Fellowship Programme Research Report No. 13, *May 2003*.

Workshop Proceedings

ECMWF Workshop on humidity analysis, 8–11 July 2002

New products on the ECMWF web site

ECMWF workshops

Details of workshops held in 2003 and planned for 2004 are given on

http://www.ecmwf.int/newsevents/meetings/workshops/

ECMWF Annual Seminar

The 2003 ECMWF annual seminar was titled 'Recent developments in data assimilation for atmosphere and ocean' and ran from 8 to 12 September at ECMWF. The presentations are now online.

http://www.ecmwf.int/newsevents/meetings/annual_seminar/

Logging onto the ECMWF web site

ECMWF userid and SecurID cardcodes, along with certificates, are now supported for logging into the ECMWF web site. Both login methods give the same level of access so the choice of which to use is down to your preference.

http://www.ecmwf.int/tools/login/

IFS documentation for Cycle 25r1

The scientific documentation for IFS Cycle 25r1 (which became operational on 9 April 2002) can now be downloaded as pdf files from

http://www.ecmwf.int/research/ifsdocs/CY25r1/index.html

Documentation for Cycle 23r4 (which became operational on 12 June 2001) remains available on the web from

http://www.ecmwf.int/research/ifsdocs/CY23r4/index.html

ECMWF Calendar 2004

Feb 3-4	Policy Advisory Committee	20th

Computer User Training Course

Feb 19-20	**COM SMS**	Introduction to SMS/XCdp
Feb 23-27	**COM INTRO**	Introduction for new users/ MARS
Mar 1-2	**COM MAG**	MAGICS
Mar 3-5	**COM MV**	METVIEW
Mar 8-12	**COM HPCF**	Use of supercomputing resources

Mar 8-10 Workshop – GEWEX workshop on ensemble hydrological prediction

Meteorological Training Course

Mar 15-19	Use and interpretation of ECMWF products
Mar 22-Apr 1	Parametrization of diabatic processes
Apr 19-28	Numerical methods and adiabatic formulation of models
May 5-14	Data assimilation & use of satellite data
May 17-21	Predictability, diagnostics and seasonal forecasting

Apr 21-22	Computer Representatives meeting	
Apr 22-23	Security Representatives meeting	
Apr 27-28	Finance Committee	72nd
Apr 28-29	Advisory Committee on Data Policy	5th
Jun 3-4	Council	60th
Jun 6-10	WISE meeting (Waves In Shallow-water Environment)	

Meteorological Training Course

Jun 7-11 Use and interpretation of ECMWF products

Jun 14-16	Forecast products – Users Meeting	
Jun 28-Jul 1	Workshop – Assimilation of high spectral resolution sounders in NWP	
Sep 6-10	Seminar – Recent developments in numerical methods for atmosphere and ocean modelling	
Oct 4-6	Scientific Advisory Committee	33rd
Oct 6-8	Technical Advisory Committee	34th

Meteorological Training Course for WMO Members

Oct 11-15 Use & interpretation of ECMWF products

Oct 12-13	Finance Committee	73rd
Oct *(to be decided)*	Advisory Committee on Data Policy	6th
Oct 14-15	Policy Advisory Committee	21st
Oct *(to be decided)*	Advisory Comm. of Co-operating States	11th
Oct 25-29	Workshop – 11th workshop on High-Performance Computing in Meteorology	
Nov 8-11	Workshop - ECMWF/ELDAS workshop on land-surface assimilation	
Nov 29-30	Council	61st

ECMWF Council

The following gives details of the work of Council at its 59th meeting on 2-3 December 2003

The ECMWF Convention

Considerable progress towards amending the Centre's Convention has been made. One objective is to allow more European States to become Member States of ECMWF. There are now 18 Member States; the Convention allows only States that took part in drafting the convention to become Member States. Other essential changes will also be made to the Convention at the same time.

Co-operation agreements with Estonia and the Slovak Republic

The Director was authorised to negotiate co-operation agreements with Estonia and the Slovak Republic.

New ECMWF Director

Mr. Dominique Marbouty was appointed as Director of ECMWF from 18 June 2004 (see inside front cover).

New President and Vice-President of Council

Prof. Anton Eliassen, Director of the Norwegian Meteorological Institute, and Mr Adérito Vicente Serrao, Director of the Portuguese Instituto de Meteorologia, were elected as President and Vice-President of the ECMWF Council, respectively.

Manfred Kloeppel

Index of past newsletter articles

This is a list of recent articles published in the ECMWF Newsletter series. Articles are arranged in date order within each subject category. Articles in red can be accessed on the ECMWF public web site http://www.ecmwf.int/pressroom/newsletter/index.html

Useful names and telephone numbers within ECMWF

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.Burridge@ecmwf.int

Internet web site

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

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Deputy Director and Head of Operations Department	
Dominique Marbouty	003
Head of Administration Department	
Gerd Schultes	007
Head of Research Department	
Philippe Bougeault	005

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Division Head	
Walter Zwieflhofer	050
Computer Operations Section Head	
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