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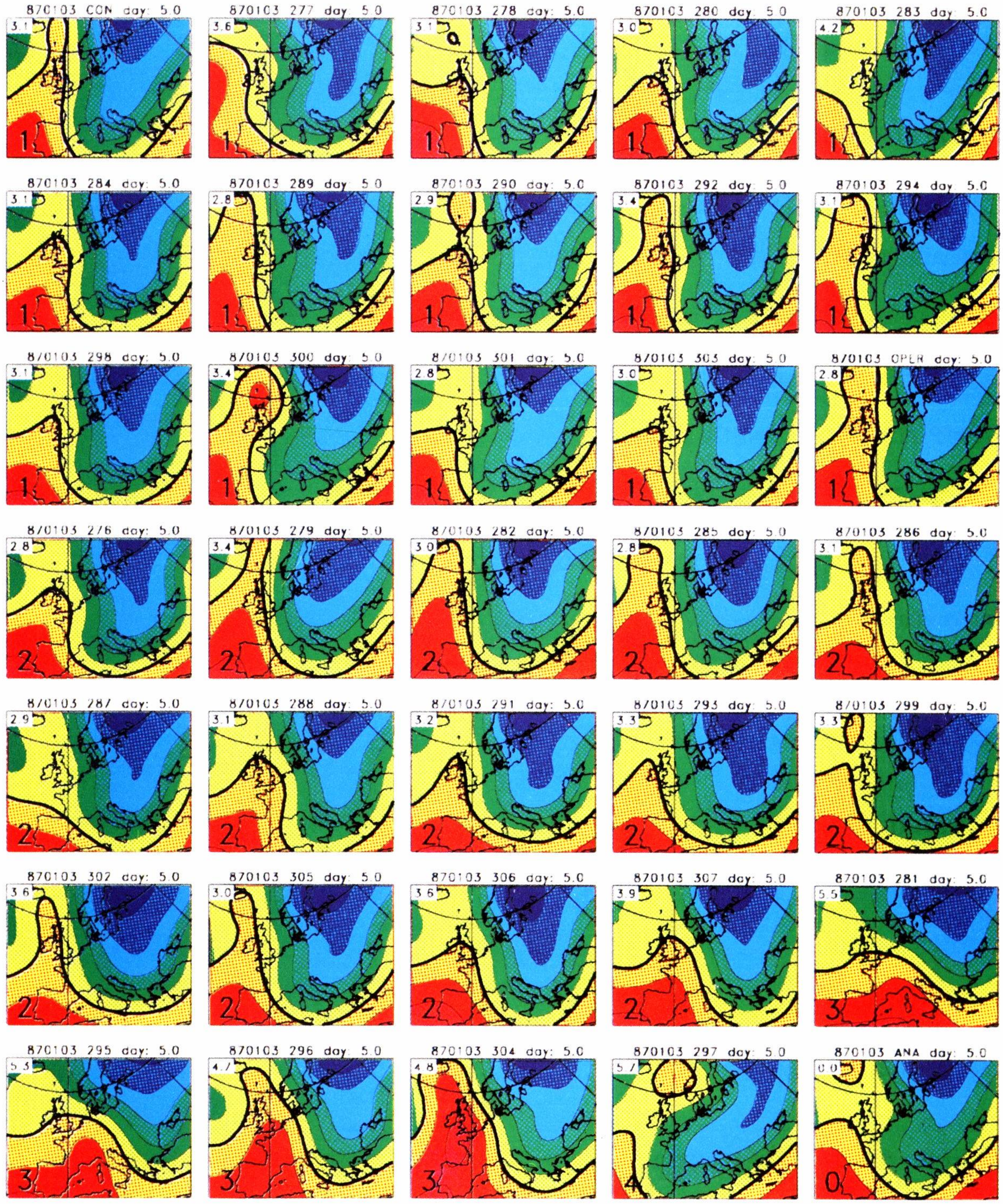

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Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen terme

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METEOROLOGICAL

COMPUTER USER INFORMATION

GENERAL

COVER: 850 hPa temperature from an ensemble of T63L19 integrations at day 5, initialised on date of 3 January 1987. The black contour is 0C, and the (colour) contour interval is 5C. The control forecast is shown in the first row, first column. The verifying analysis is shown in the last row, last column.

This Newsletter is edited and produced by User Support.

The next issue will appear in September 1992.

There is a strong emphasis on the meteorological in this issue of the Newsletter, with an article on present and proposed activities in the field of ensemble forecasting, followed by an evaluation of the performance of the ECMWF model in tropical cyclone track forecasting for storms occurring over the North Pacific in 1990 and 1991.

Users of the Centre's computing facilities will find important information, in particular in the articles on "UNICOS 7 - additions and differences", and "Subroutine name changes in the (CRAY) NAG Library".

A brief description of the recent additions and alterations to the Centre's Headquarters Building is also given.

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ROB BRINKHUYSEN

It is with great sadness that we record the tragic and untimely death of Rob Brinkhuysen, a much loved former colleague, in a road accident in early April.

Rob was born in Rotterdam in 1943. He studied Physics and later Mathematics at the Technical University in Delft. He then joined the Mathematical Centre, a semi-independent institution in the field of applied mathematics and informatics. This Centre later merged with other institutes to become the computational centre of Amsterdam University. During this phase of his career Rob was involved in creating a national network of academic computer centres.

Rob joined ECMWF early in 1976 and was rapidly promoted to Head of the Computer Division in the Operations Department. Rob was a man of calm and clear thought, able to make realistic assessments of opportunities and difficulties. He was determined to achieve the best possible results with the resources available, and had a marvellous way of bringing out the very best in the people he worked with. He played a key role in the design, selection and installation of the Centre's first computer complex. The multi-faceted system he helped to design has served the Centre well for many years.

Rob was a charming and optimistic man, with a subtle mind and infectious good humour. His interests were wide-ranging: he played recorder and was an avid listener to music; he cared deeply about the visual arts; he had a broad interest in natural science and its instruments; he was an avid and omnivorous reader. He was also a sportsman with a keen interest in sailing and hockey. Last, but not least, he was a devoted husband and father. We treasure the memory of the pleasure of his company.

Rob returned to the Netherlands in mid-1980 and joined KNMI, where he was appointed Head of the Computer Division and later Director of the Technical Department. He was instrumental in transforming KNMI's Computer Department into a modern facility.

In 1986 he left KNMI to join the James Martin software house. In this capacity he was responsible, among other things, for the management of a European data network which took him to many European countries. In 1988 he joined one of the major Dutch banks, the RABO-bank, where he was in charge of their extensive computer facilities until a bizarre road accident took his life.

Rob is survived by his widow Anne Marie, who had a miraculous escape in the accident, and by his sons Maarten, currently at medical school in Rotterdam, and Sander, who is finishing secondary school. We tender them our sincere sympathy.

ECMWF Director & Staff

Rob Brinkhuysen (right) with HRH Prince Charles, demonstrating activities in the Computer Hall on the occasion of the Opening of ECMWF Headquarters, 15 June 1979

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CHANGES TO THE OPERATIONAL FORECASTING SYSTEM

Recent changes

The time step of the model was set to 15 minutes on 24 March 1992.

A change was introduced on 12 May 1992 to resolve the problem with the stability of the model (correction of an error in the code of the convection scheme). Several other technical changes were implemented on the same day, in particular an optimisation of the radiation calculations.

On 2 June 1992, a change to the determination of sea ice in the SST analysis was introduced, leading to an improved description of the ice edge.

Planned changes

A procedure will be implemented to process the cloud-cleared radiance data received from NESDIS to retrieve the temperature profiles to be passed to the analysis. The retrieval is based on a variational inversion technique.

Humidity data from SYNOP observations will be excluded from the analysis.

- Bernard Strauss

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ENSEMBLE PREDICTION

Introduction

This coming winter, we hope to conduct an experiment to introduce ensemble prediction to Member States. An ensemble forecast will be made on a regular basis, and a selection of products will be disseminated. Each ensemble will comprise about 30 to 40 integrations of the T63L19 model, the integrations differing only in their initial conditions. These differences are consistent with our uncertainty in the initial state, and are chosen to project onto the dynamical instabilities of the flow during the first day of the forecast period. The disseminated products reflect the amount the initial small differences amplify during the forecast period, and therefore give an estimate of forecast reliability.

Chaos and predictability in a simple model

The potential value of ensemble forecasting can be illustrated quite effectively using the prototype chaotic model discovered by Lorenz in his search for a simple way to characterise the limited predictability of the atmosphere. Fig. 1 shows the famous Lorenz attractor, superimposed on which are three ensemble forecasts, started from different parts of the attractor. The attractor describes the "climate" of this simple model in phase space; it is inhomogeneous in structure with two symmetric regimes represented by the two "butterfly wings". The real atmosphere also appears to have regime structure giving rise, for example, to blocked and zonal flow. The ensembles of initial points are shown as small heavy dots around some point on the attractor. The distance of the dots from this centre point represents the uncertainty in determining the initial conditions for the integration.

In Fig. 1a, all members of the integration make the transition from left to right hand regime; as such, the regime transition is very predictable. Put another way, the relatively small dispersion of the ensemble implies that the probability of a regime transition is extremely high. In Fig 1b, the forecast ensemble diverges more rapidly. By the end, the best one can say is that there is about a 60% chance that there will be no regime transition, and about a 40 % chance that one will occur. In the final example, the final forecast dispersion is very large, and forecast evolution is essentially unpredictable.

It has been argued that the essence of medium-range forecasting lies in the prediction of changes in large-scale weather type. As such, these examples illustrate problems for current medium-range forecasting practice. Returning to Fig. 1, suppose we were only given a single forecast from each of the three ensembles, and that in each case this single forecast indicated a regime transition; from these alone we would not know that in the first case the forecast transition was reliable, whilst in the last case it was utterly unreliable.

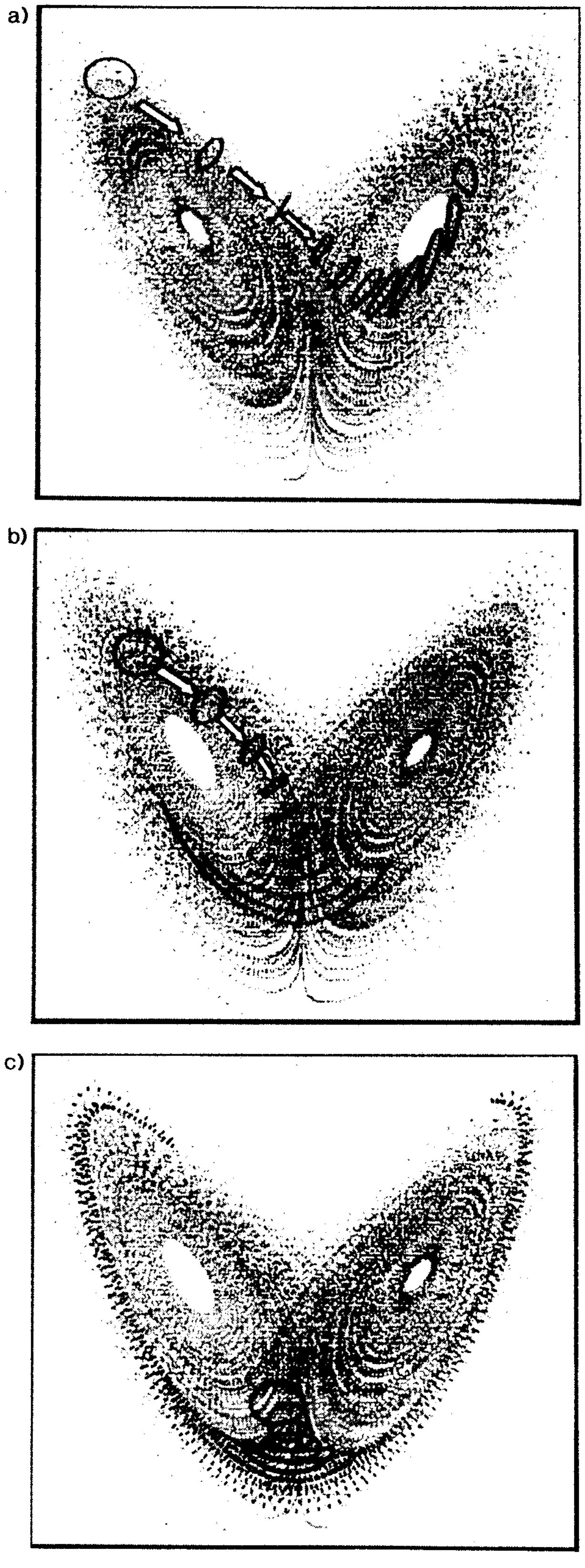


Fig. 1 a)-c) Three ensemble integrations of the 3-component Lorenz model shown in phase space, superimposed on the attractor set (or climate) of the model. The ensemble of initial points differ only in their position on the attractor.

Estimating atmospheric predictability

The above example illustrates the point that for finite predictions, predictability depends on initial state. In this sense predictability is a variable of the atmosphere, just as temperature and rainfall are.

Unfortunately, it is not straightforward to apply the ensemble idea illustrated for the Lorenz equations, to complex numerical weather prediction (NWP) models. For example, whilst a state in the Lorenz model is described by just three numbers, a state in the current ECMWF model requires several million. Put another way, whilst the number of independent ways (or phase-space directions) to construct an initial perturbation in the Lorenz model is very limited, it is, for all practical purposes, limitless for the ECMWF model. Given constraints on computer time, especially for operational forecasting, one can only investigate the effect of a few perturbations.

A simple strategy for generating initial perturbations might be to choose them randomly in some sense. This idea underlies the concept of Monte-Carlo forecasting as it was originally envisaged. Unfortunately this idea does not work for weather forecasting. For example, if the perturbations are not in appropriate meteorological balance, they will be damped by initialisation. In this situation, failure of the ensemble to experience significant dispersion in the early part of the forecast period need not imply that the atmosphere is especially predictable.

This problem of ensemble dispersion overestimating forecast reliability has been endemic to most strategies for ensemble prediction. The dangers of underestimating the error of a prediction scheme was illustrated vividly during the recent British general election, where the actual error of most opinion polls greatly exceeded their estimated error, presumably because of factors (phase-space directions!) not taken into account. These polls were subsequently most strongly criticised, not for the errors themselves, but for the overestimation of their accuracy. There may be lessons to be learnt here for estimating the error of weather forecasts!

At ECMWF we have been developing an almost contrary philosophy to that of random generation of perturbations. Specifically we choose those perturbations which are the most linearly unstable in the short range. Basically, we try to avoid perturbations that will deviate little from the control, on the basis that integration of such perturbations would be a waste of computer time. (However, their effect can be implicitly taken into account through the *a priori* probability of the control or unperturbed forecast.) As such, it is hoped that small ensemble dispersion will be a reasonably reliable indicator of forecast reliability. The details of the calculations that produce these perturbations are described in two technical papers published this year in the proceedings of the 1991 ECMWF workshop on "Recent Developments in Predictability", and are not repeated here. However, the tools required for these calculations are those used in variational data assimilation, and those that will be required for linear stochastic-dynamic error prediction.

Following an initial study, we have further developed the above technique, and tested it on a 24-ensemble case study. Each ensemble in this case study comprised 32 individual T63 integrations. One of these developments ensured that the perturbations were reasonably consistent with analysis error. To do this we made use of the estimate of analysis error variance that is a by-product of the Optimal Interpolation analysis technique. Using this we attempted to make sure that the amplitude of the initial perturbations was consistent with data density.

The set of initial perturbations we have used in this experiment is far from random. In this sense it is certainly an abuse of the original concept to describe our ensemble integrations as "Monte Carlo" forecasts. Nevertheless, the phrase carries a vivid reminder of the probabilistic character of the forecast technique, and, perhaps, is not a bad way of describing the method, at least informally.

Some ensemble products

A description of the 24-member ensemble is being documented for the 1992 Scientific Advisory Committee; the document will also be published as a technical memorandum. We will therefore avoid duplication and refer the interested reader to these forthcoming papers. Of more relevance here would be to outline some of the products we have been developing from the ensembles. These will help to define the set of products for dissemination during the experiment described in the Introduction.

The front cover of this Newsletter shows the individual members of one of these ensembles at day 5 of the forecast. The initial date was 3 January 1987. The field illustrated is 850hPa temperature over Europe. The ensemble includes not only the T63 control forecast (1st row, 1st column), but also the T106 operational forecast (3rd row, last column). The verifying analysis is shown in the last row, last column.

In general, forecast dispersion on this European scale starts to become significant at about day 5. We can see this from the ensemble forecasts on the front cover. For example, the forecasts in the third and fourth columns of the last row give a very different impression of the possible temperature over western Europe - one showing a warm tongue pushing north, the other a cold tongue plunging south-west!

However, despite these differences, the majority of forecasts give a broadly similar synoptic pattern, with the cold tongue oriented in a more-or-less north to south direction. Whilst the eye makes a reasonably good attempt at assimilating the common elements of the forecasts, it is obviously necessary to process objectively the information from the ensemble in a more digestible form. The probability forecast product appears to be the most suitable tool.

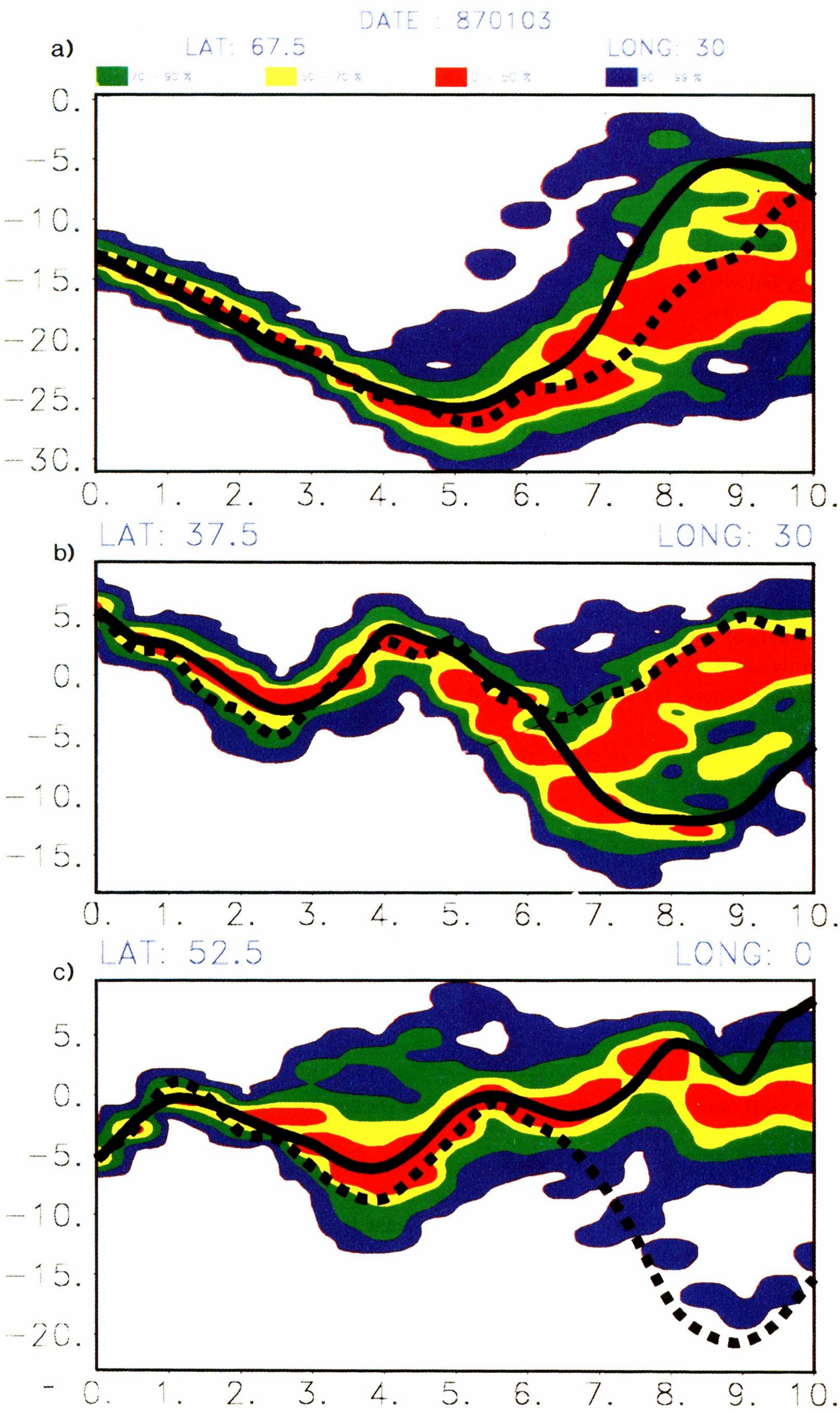


Fig. 2 a)-c) Confidence intervals for the ensemble forecast from 3 January 1987 of 850hPa temperature. Shown at three grid points throughout the forecast range. Contours shown are 99%, 90%, 70% and 50%.

Fig. 2 shows forecasts of the 850 hPa temperature confidence interval for three gridpoints of the forecast from 3 January 1987, throughout the forecast range (15 days). At any forecast time the probability contours (99%, 90%, 70% and 50%, denoted by the boundary between the different colours) bound a range of temperature values. So, for example, 70% of the ensemble forecast temperatures fall within the range (or possibly ranges, see below) bounded by the 70% contours (the boundary between yellow and green). The dispersion of the ensemble can therefore be judged by the spreading of the probability contours with forecast time. Superimposed are the control forecast (solid line) and the verifying analysis (dashed line). (It should be remarked that when calculating these confidence intervals, a Gaussian smoother was applied over the range of variation of the ensemble values. The width of this smoother, fixed throughout the forecast range, was such that the confidence interval estimates in the first couple of days or so of the forecast are artificially broad.)

Fig. 2a indicates a region in which the forecast dispersion is relatively small up to day 5. Here the forecaster for this particular region could predict with confidence the cooling trend, within a possible error bar of three degrees or so. Beyond day 5 the ensemble clearly indicates a warming trend, though the magnitude of this trend is now much more uncertain. For this region, up to day 5, the most likely evolution according to the ensemble is close to the control, and also close to the verifying analysis. Between day 5 and day 9 it appears that the most likely evolution according to the ensemble is more skilful than the control.

Fig. 2b shows the forecast evolution at a second gridpoint. Up to day 6 the falling, rising and falling temperature trend of the control forecast is supported by the ensemble. At day 7 there is a bifurcation in the probability distribution. This bimodal distribution suggests that there is no single "most likely" forecast evolution, but two distinct almost equiprobable possibilities - a continuation of the cooling trend, and a return to warmer conditions. As it happens the control forecast followed the path of one of the forks, and the verifying analysis took the other. (In a parallel universe the control and analysis might have swapped roles!)

By definition, a probability forecast cannot be considered wrong if the verifying analysis lies in a region of low probability - though of course one would not want this to happen too often. An example of this is shown in Fig. 2c. Between day 6 and day 9 at this gridpoint, there was a strong cooling trend in the verifying analysis. Only one member of the ensemble captured this development well, and this is indicated by the 99% contour line dipping down at day 9.

The ability to give some warning of possible extreme weather is clearly an important test of the ensemble. Fig. 3 shows a map giving the probability at day 7 that the 850hPa temperature is either at least 10K warmer than climatology, or at least 10K colder than climatology. The anomaly of the control and the verifying analysis is also given. Note that whilst the control forecast missed the westward extension of the cold pool over parts of Scandinavia, the ensemble prediction indicates a 10% a probability of extreme cold conditions for this area.

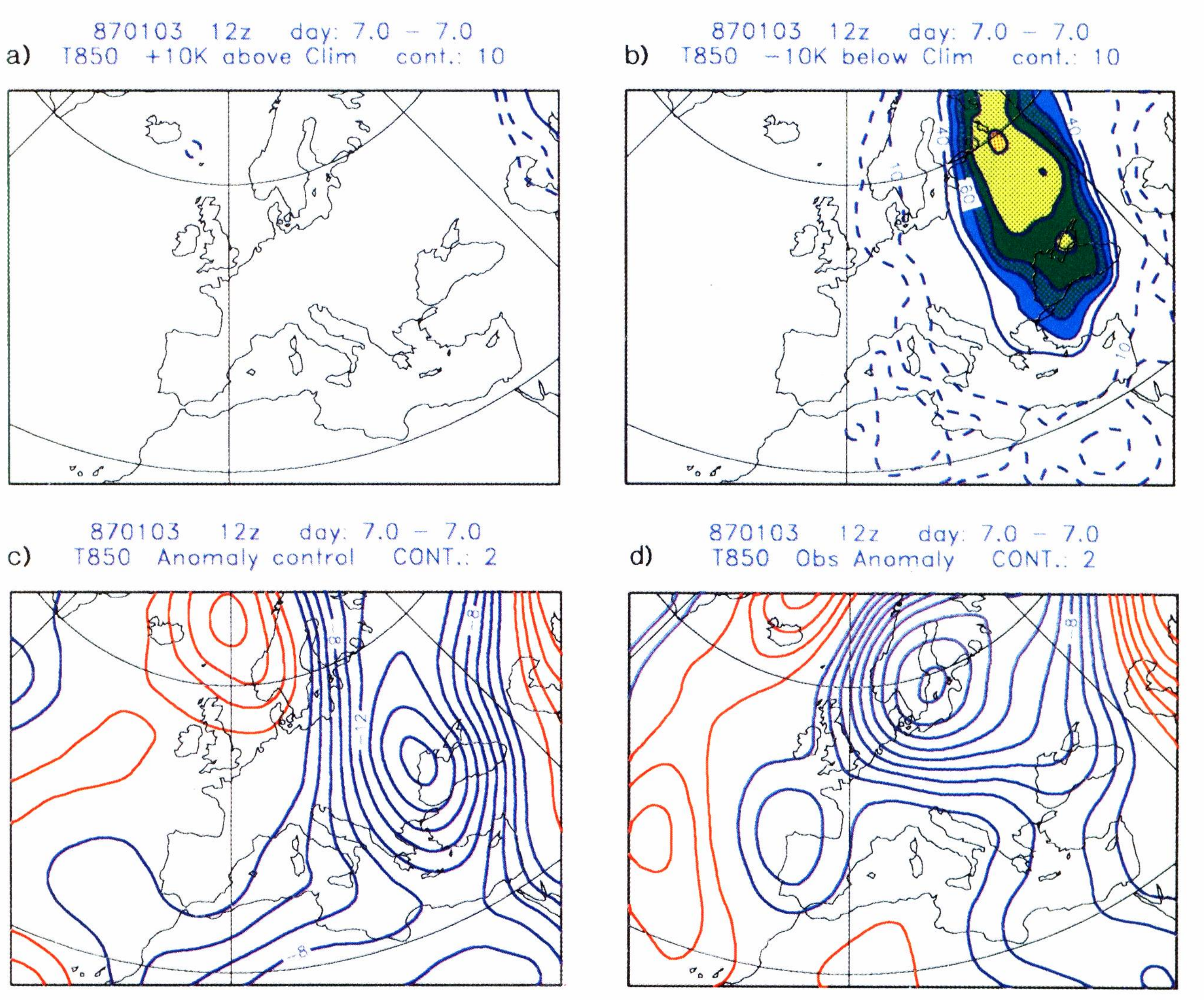


Fig. 3 Day 7 forecast of 850hPa temperature from 3 January 1987.
a) the probability that temperatures are at least 10K above climatology
b) the probability that temperatures are at least 10K below climatology
c) the forecast anomaly of the control
d) the observed anomaly

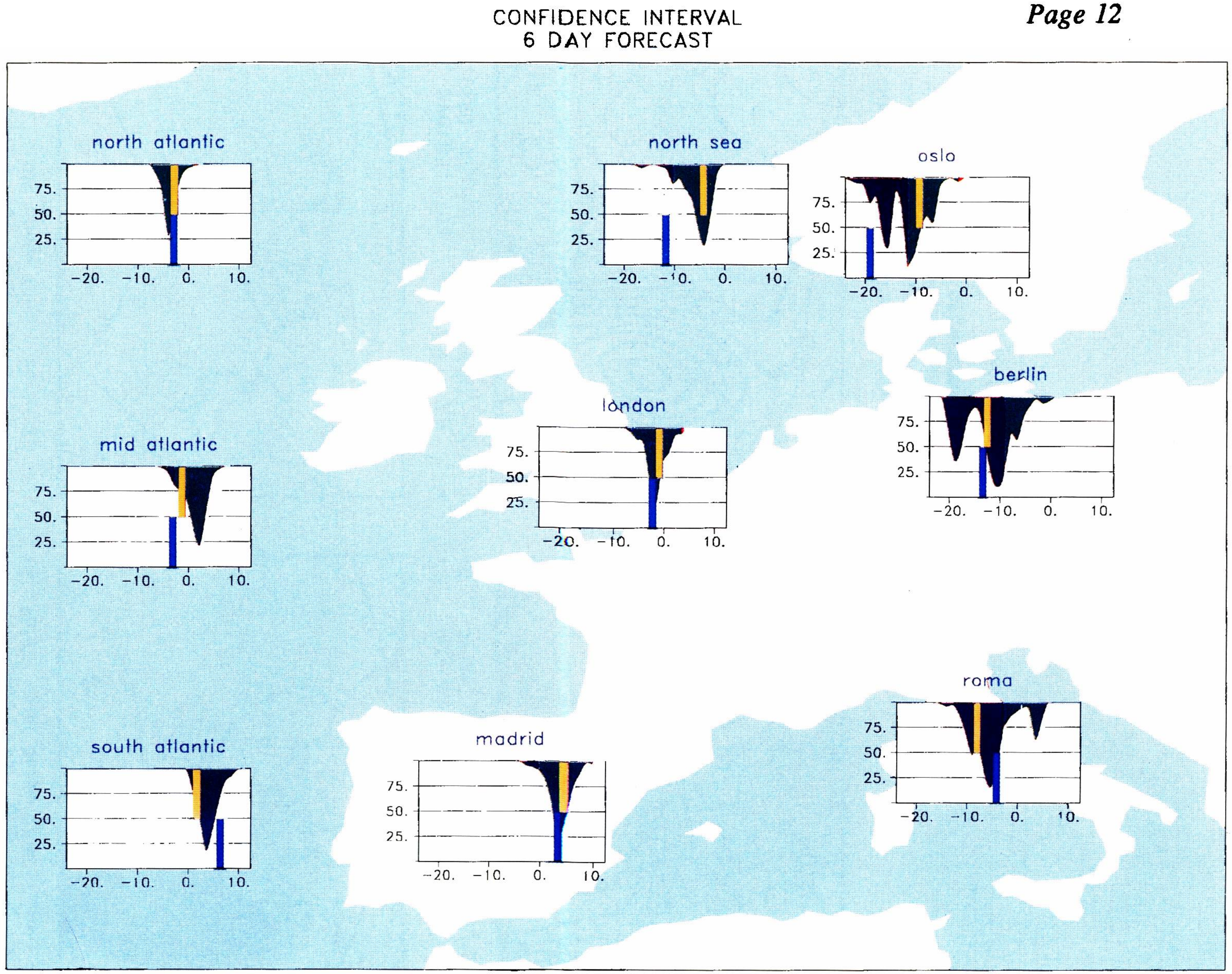
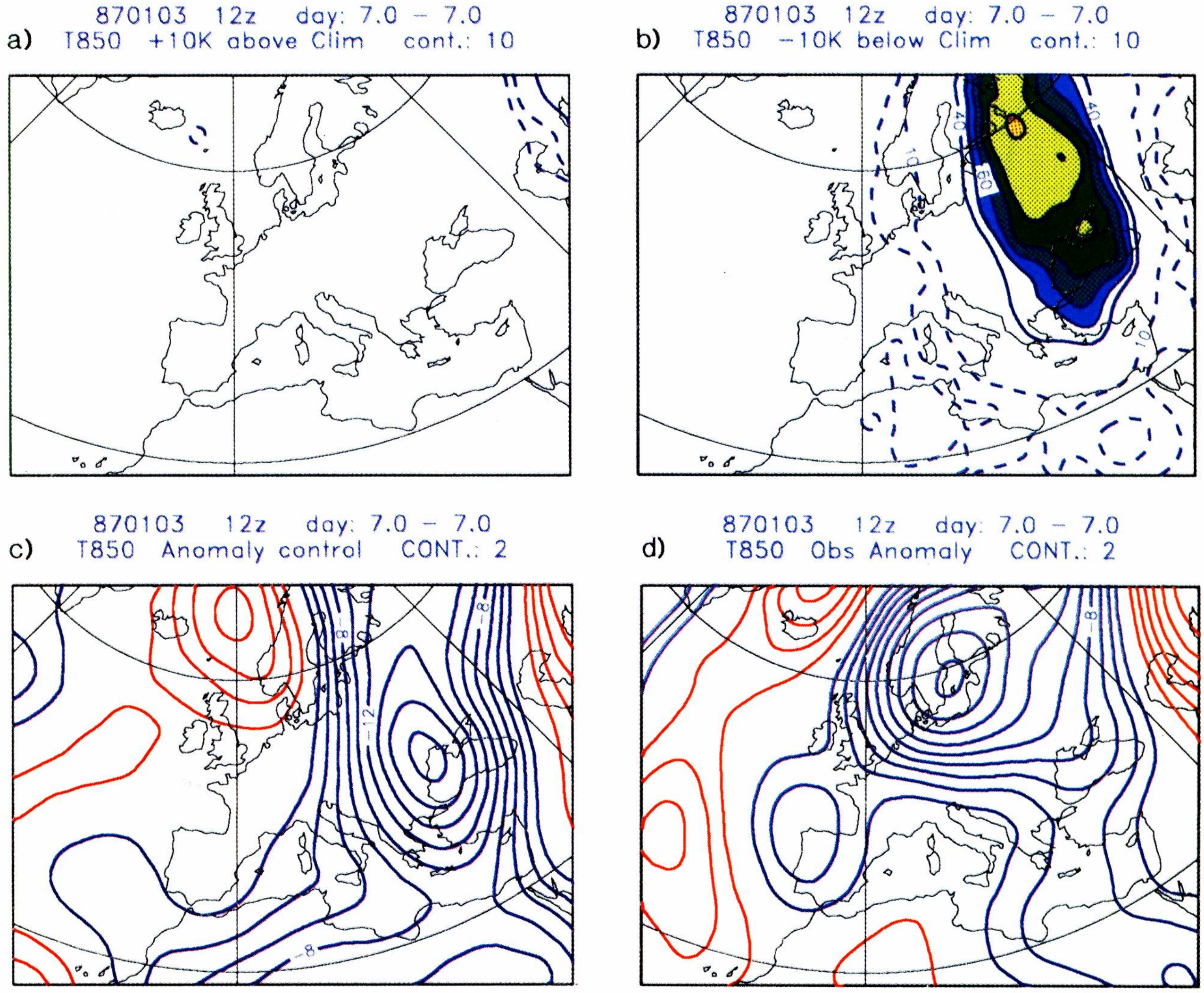


Fig. 4 Confidence intervals for day 6 the ensemble forecast from 3 January 1987 of 859hPa temperature at a variety of cities and oceanic points. Green shading denotes temperature within 5K of climatology, blue and red are for colder or warmer temperatures than this, respectively.



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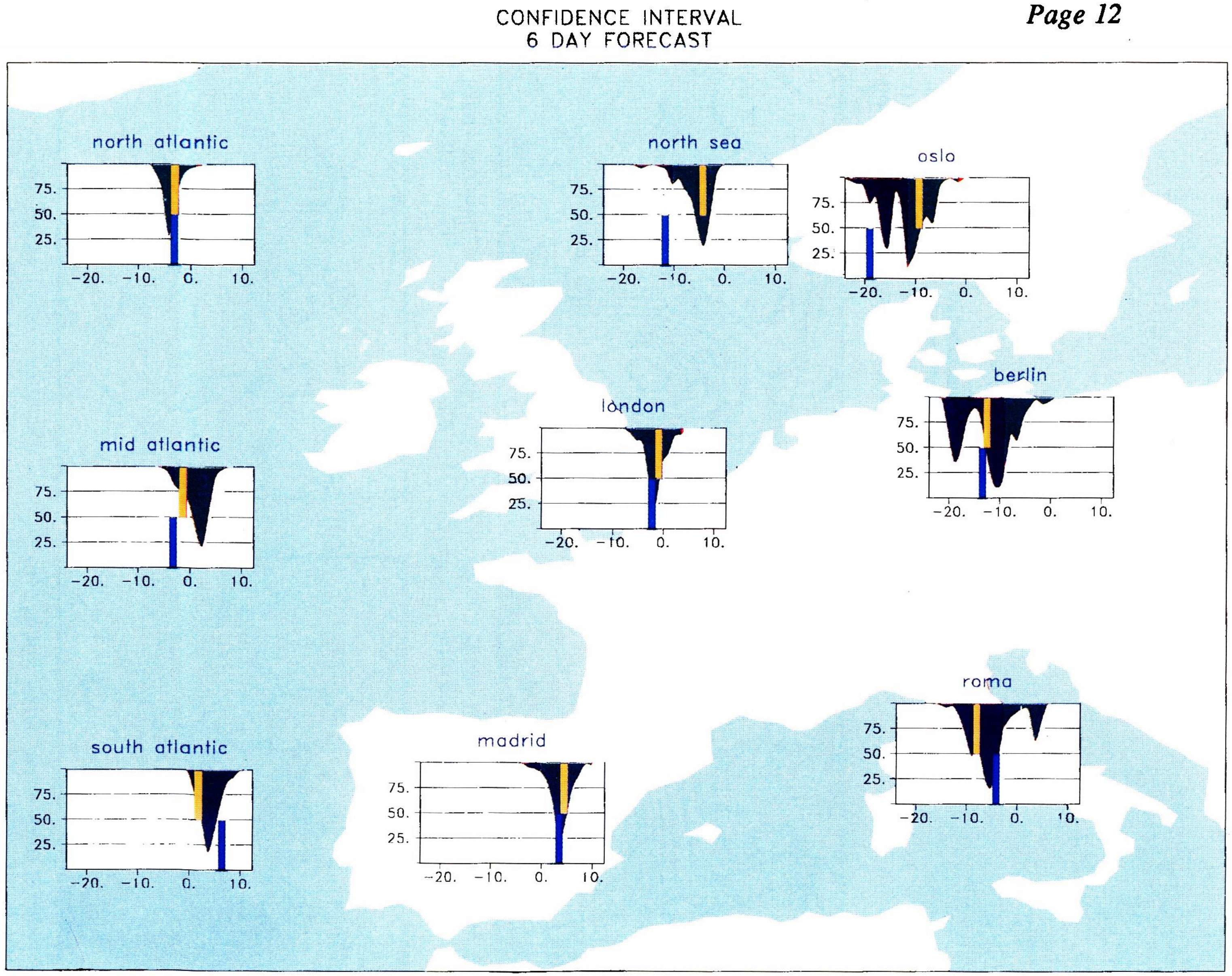

Fig. 4 Confidence intervals for day 6 the ensemble forecast from 3 January 1987 of 859hPa temperature at a variety of cities and oceanic points. Green shading denotes temperature within 5K of climatology, blue and red are for colder or warmer temperatures than this, respectively.

Fig. 4 shows the estimated forecast confidence intervals at various points at day 6 of the forecast. The control forecast (orange bar) and verifying analysis (light blue bar) are also shown. For cities such as Madrid or London (or an oceanic point such as the north Atlantic), the probability distribution has relatively small standard deviation, and the ensemble suports the control. By contrast, for Oslo and Berlin, the distribution is multi-modal. For Oslo, the control forecast indicates a temperature of about -9C, whilst the ensemble forecast indicates a maximum probability of -11C, a distinct secondary maximum of -16C, and a low probability of colder temperatures. The verifying temperature for Oslo was about -19C (falling to -23C at day 7). For Berlin, there is a secondary maximum at -19C which, at day 6, does not appear to verify. However, on the next day, Berlin temperatures dropped to -18C. Green shading in Fig. 4 denotes approximately climatological temperatures, blue and red denote anomalously cold and warm respectively.

The possibility of bimodal, or indeed multi-modal behaviour of the forecast pdfs suggest that the forecast flow itself may cluster into a small number of different types. We have applied a hierarchical clustering algorithm to reduce the set of maps shown in the front cover to a set of 4 (which, together, explain just over 50% of the variance of the total ensemble). Associated with each cluster is a population density, which can be interpreted as a probability estimate for that cluster.

The clusters are shown in Fig. 5, with the cluster population shown in brackets in the top right hand side of the cluster map. The rms error of the cluster is shown at the bottom right side of each cluster map. In this case the error of the clusters increases as the population decreases, so that cluster 4, with the cold tongue, has just one member and largest rms error. (This behaviour is certainly not always true; at day 9 of this forecast, for example, the cluster analysis generates a cluster with just one member that is more skilful than any other more densely populated cluster. However, in general it has been found that the clusters with large population are more skilful than clusters with small population.) For all the cases we have examined, there is at least one cluster that is more skilful than the control; in this case both clusters 1 and 2 are.

Synoptically, the difference between clusters 1 and 2 is not very great. Collectively this pattern is overwhelmingly more probable than the "northward-pushing warm tongue" of cluster 3, or the "south-westward plunging cold tongue" of cluster 4. The forecaster would be able to issue the cluster 1/2 forecast with reasonable confidence, though should keep an eye on later forecasts for evidence that either clusters 3 or 4 were in fact developing.

Future developments

Just as deterministic NWP developed from modest beginnings, so (it is hoped!) the ensemble forecast will evolve to become an indispensible part of the medium-range forecast product.

Of course, the technique is only as good as the basic model. Model systematic errors could have a very detrimental effect on the perception of the ensemble forecast. For example, an apparent low probability of a certain type of blocking in an ensemble could be quite erroneous if the model

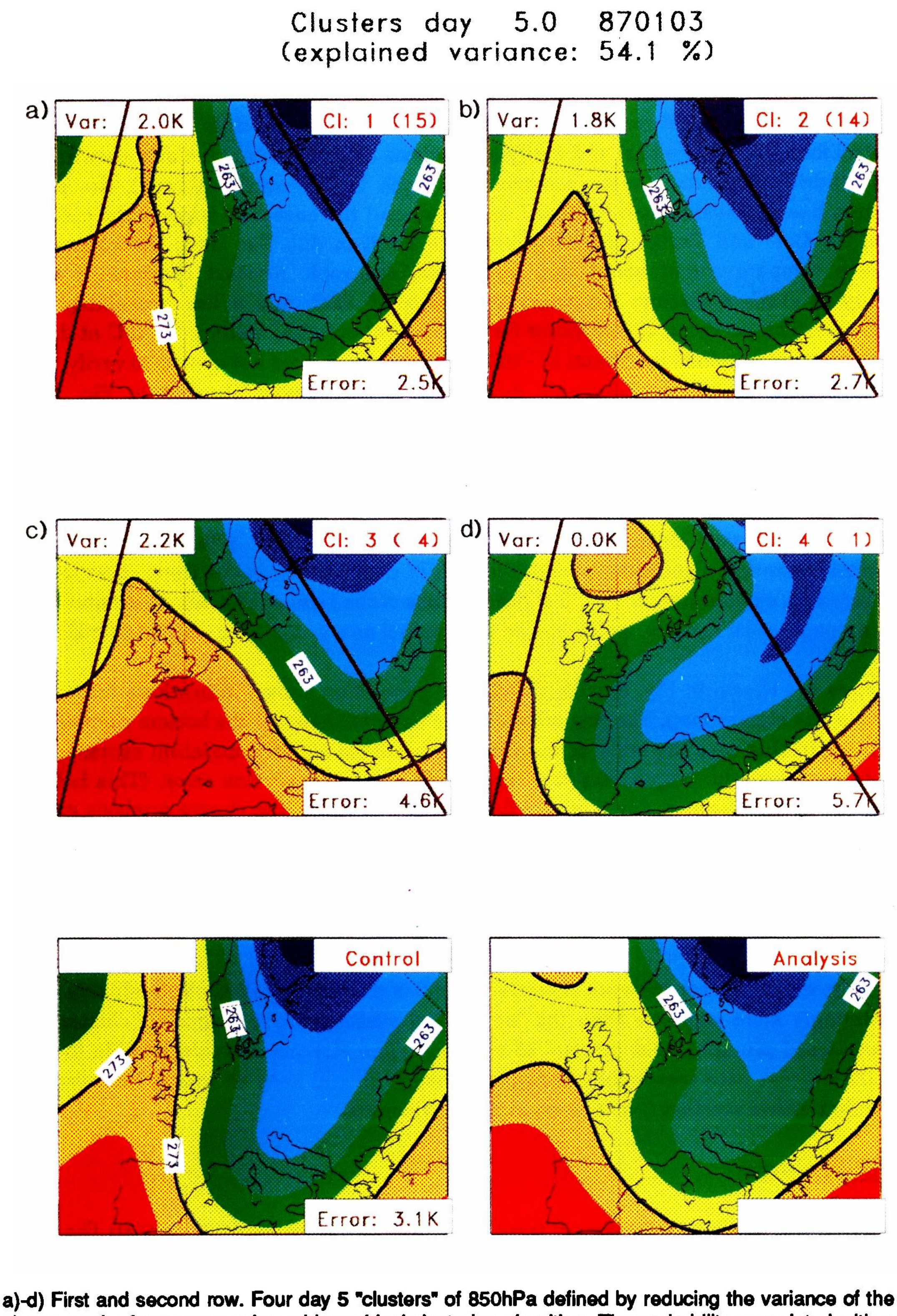

Fig 5. a)-d) First and second row. Four day 5 "clusters" of 850hPa defined by reducing the variance of the ensemble shown on the front cover using a hierarchical clustering algorithm. The probability associated with each cluster can be obtained from the cluster population (in brackets at top right hand corner of each panel), respectively 15, 14, 4, and 1. The rms error of each cluster is shown at the bottom right hand corner of each diagram. The straight lines shown in the panels indicate boundaries within which the clustering was made. Last row. The control forecast and verifying analysis.

climate seriously underestimates the frequency of that type of block. As such, development and testing of physical parametrizations will continue to be an essential component of research for ensemble forecasting.

It is important to refine further the techniques to generate the initial perturbations. At present we do not use possible information concerning estimates of analysis error covariances. Increasingly this type of information will become available as a result of research into variational data assimilation.

As computer power increases, and numerical techniques become more efficient, we have to consider whether it would be more beneficial to integrate the ensemble with a higher resolution model, or to increase the size of the ensemble. With a larger ensemble, the probability estimates will in general become more reliable. Indeed, we believe that an ensemble size of 100 or more members would be desirable. On the other hand, with a higher resolution (eg T106) model, estimates of the probability of extreme wind speeds and extreme precipitation rates may become more reliable.

Finally, there is the crucial question of product development. We have given some examples of possible products in this article based on the 850hPa temperature. Products for other variables, based on both instantaneous and time-average states are possible. Deciding on the most useful products will depend on a feedback between Member States and ECMWF.

Acknowledgements

The development of the ensemble forecast system as presented in this paper is the result of work by Franco Molteni and Robert Mureau in the Predictability section, and Philippe Chapelet, a consultant from METEO-FRANCE in the Meteorological Operations section at ECMWF.

- Tim Palmer

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PERFORMANCE OF THE ECMWF MODEL IN TROPICAL CYCLONE TRACK FORECASTING OVER THE WESTERN NORTH PACIFIC DURING 1990-1991

Introduction

In this article, an evaluation of the performance of the ECMWF model in tropical cyclone (TC) track forecasting for storms which occurred over the western North Pacific in 1990 and 1991 is presented.

In August and September 1990, four concurrent field experiments were conducted over the western North Pacific to study TC movement. These experiments were the SPecial Experiment Concerning Typhoon Recurvature and Unusual Motion (SPECTRUM) conducted by the Typhoon Committee of the Economic and Social Commission for Asia and the Pacific (ESCAP)/World Meteorological Organization (WMO), the Tropical Cyclone Motion Experiment (TCM-90) carried out by the US Navy, the TYPHOON-90 Experiment of the USSR, and the Taiwan Area Typhoon Experiment (TATEX). During Intensive Observation Periods (IOPs), surface and upper-air observations were made at increased frequencies and data were also received from additional sites. Most of these data were transmitted via the Global Telecommunication System (GTS) and received by ECMWF to initialize the model. It would therefore be interesting to assess the impact of the enhanced data on the model forecasts and compare the results with those obtained outside the experiments.

In September 1991, the high resolution ECMWF operational analysis and forecasting system at T213 31 levels replaced the old T106 19 level system. The effective horizontal resolution of the T213 model in the free atmosphere is around 100 km at half wavelength. Although the horizontal resolution of the new operational system may still not be quite adequate for the purpose of TC track forecasting, a comparison of the performance of the T213 and T106 models should be able to reveal the changes, if any, due to the increase in resolution.

Data and methodology

Best-track data compiled by the Royal Observatory, Hong Kong and/or RSMC Tokyo - Typhoon Center were used as the "ground-truth" in the verification of ECMWF forecasts. In order to avoid the difficulties of identifying the centres of ill-defined model vortices which correspond to weak TCs, only tropical storms, severe tropical storms, and typhoons were considered. Nevertheless, there were still a number of cases in which the centres of the model TCs were ill-defined and hence could not be identified, although they only accounted for less than 10 % of the cases considered. No attempts were made to study the phenomenon of TC genesis in the model.

Forecasts at T+24, T+48 and T+72 hours were verified. The forecast error E_M for each case was expressed in terms of the great circle distance between the forecast position and the verifying best-track location. Forecasts based on the persistence (PER) method were also computed by linear extrapolation of the 12 hour movement implied by the best-track positions at the initial time T and at T-12 hours, and the corresponding errors E_P were obtained. The relative error compared to the PER method (R) was calculated for each case using

$$R\ (\%) = 100 \cdot \frac{E_P - E_M}{E_P + E_M}$$

If the model performs better than the PER method (i.e., $E_M < E_P$), then R has a positive value. Otherwise, R is less than or equal to zero. In other words, R is a measure of the skill of the model relative to the PER method.

Apart from R, the two components of the ECMWF forecast errors were also computed so as to identify any systematic error. Using a rotated co-ordinate system with the Y-axis parallel to the observed storm motion over the corresponding forecast interval, the cross-track (CT) and along track (AT) error components were obtained. The sample was also categorized according to the three different stages of TC movement: BEFORE, DURING and AFTER recurvature. These stages were determined by the direction of the 48-hour actual TC movement.

Verification results

Figure 1 shows the skill of the ECMWF forecasts as given by the average relative errors <R> for the different stages of TC movement and various samples. Without considering the different stages of movement, it is apparent from Figure 1 (a) that both the enhanced observational data during the field experiments and the increase in resolution of the T213 model brought about similar improvement (around 5 to 10 %) in the skill of the ECMWF model in TC track forecasting. The model also performed better than the PER method starting at T+24 hours for these two samples. Although <R> is rather small at T+24 hours, it rises to around 20 % and 25 % at T+48 and T+72 hours respectively. The mean forecast error for the "SPECTRUM 1990" sample is the smallest for T+24 hour forecasts (151 km) whereas the mean errors for the "T213 1991" sample are thc smallest for T+48 and T+72 hour forecasts (248 km and 355 km respectively). Apart from

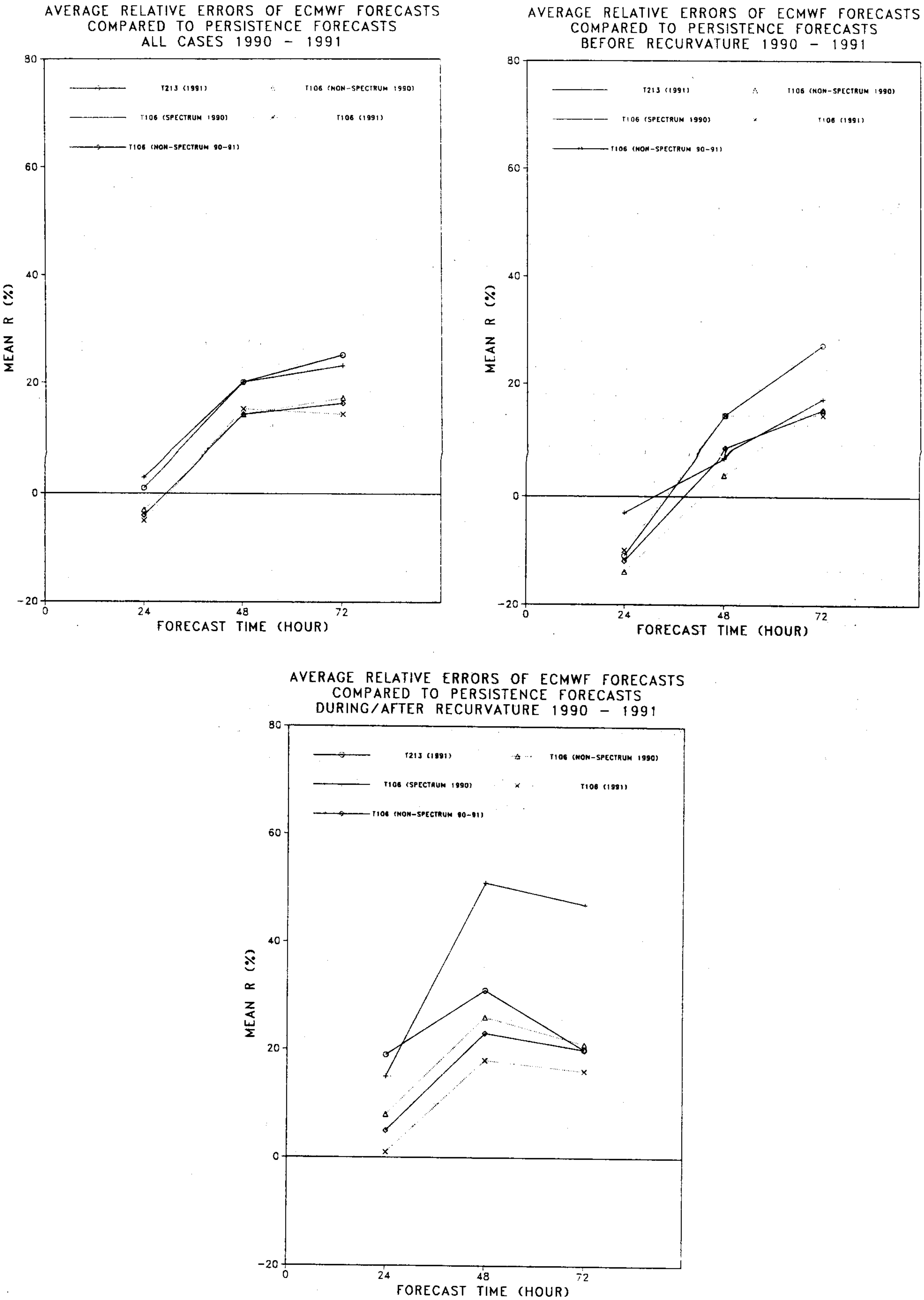

Figure 1 - Skill as Given by the Average Relative Errors of ECMWF Forecasts Compared to Persistence Forecasts 1990-1991

(a) **ALL Cases** **(b)** **BEFORE Recurvature**
(c) **DURING/AFTER Recurvature**

the small forecast errors, the corresponding standard deviations for these two samples are also less than the others.

For the BEFORE recurvature cases, the model still performed best (in terms of forecast errors) at T+24 hours for the "SPECTRUM 1990" sample and at T+72 hours for the "T213 1991" sample, with errors of 151 km and 301 km respectively. However, Figure 1 (b) shows that the model could not "beat" the PER method at T+24 hours even with enhanced observational data or higher resolution. In fact, at T+24 hours, the model performed significantly better only during the experiment period. The T213 model does not have any superiority over the T106 model in this respect. Nonetheless, the opposite is true at T+72 hours - there is a more than 10 % improvement of the T213 forecasts compared with the other samples. This improvement is also found at T+48 hours although the magnitude is somewhat less. Judging from these results, it becomes apparent that the increase in observational data density (both temporal and spatial) contributed to improvement of the ECMWF forecasts only at T+24 hours. It can therefore be postulated that the positive impact of the enhanced data was gradually off-set by the inadequacy of the T106 model to simulate the structure and development of TCs. On the other hand, the increase in resolution of the T213 model brought about improvement after 24 hours irrespective of the relatively low skill at T+24 hours.

Since the numbers of cases for the DURING and AFTER recurvature samples are small, these two stages are combined and the corresponding <R> plots are shown in Figure 1 (c). It can be seen that there is a general trend of increase in skill (relative to the PER method) from T+24 to T+48 hours and a subsequent decrease at T+72 hours. The T+24 and T+48 hour skills are also larger than those for the BEFORE stage. This is thought to be due to the model's capability in forecasting recurvature correctly whereas the PER method should not be able to do so. However, the decline in skill at T+72 hours cannot be easily understood. It should also be noted that the decrease pertaining to the "T213 1991" sample is the most significant and the T213 model appears to have no additional skill over the T106 model in this respect.

Systematic bias

Figure 2 shows the plots of the mean CT and AT error components for the different stages of movement and various samples. Considering ALL cases (Figure 2 (a)), it is obvious that the T106 model forecasts have a significant right-hand systematic bias (or northward bias in an earth-oriented coordinate system), i.e., the model tends to forecast early recurvature of TCs. The T213 model forecasts, on the other hand, have the least systematic bias although the tendency to forecast early recurvature has not been removed completely. It is also surprising that the "SPECTRUM forecasts" give the most significant right-hand bias.

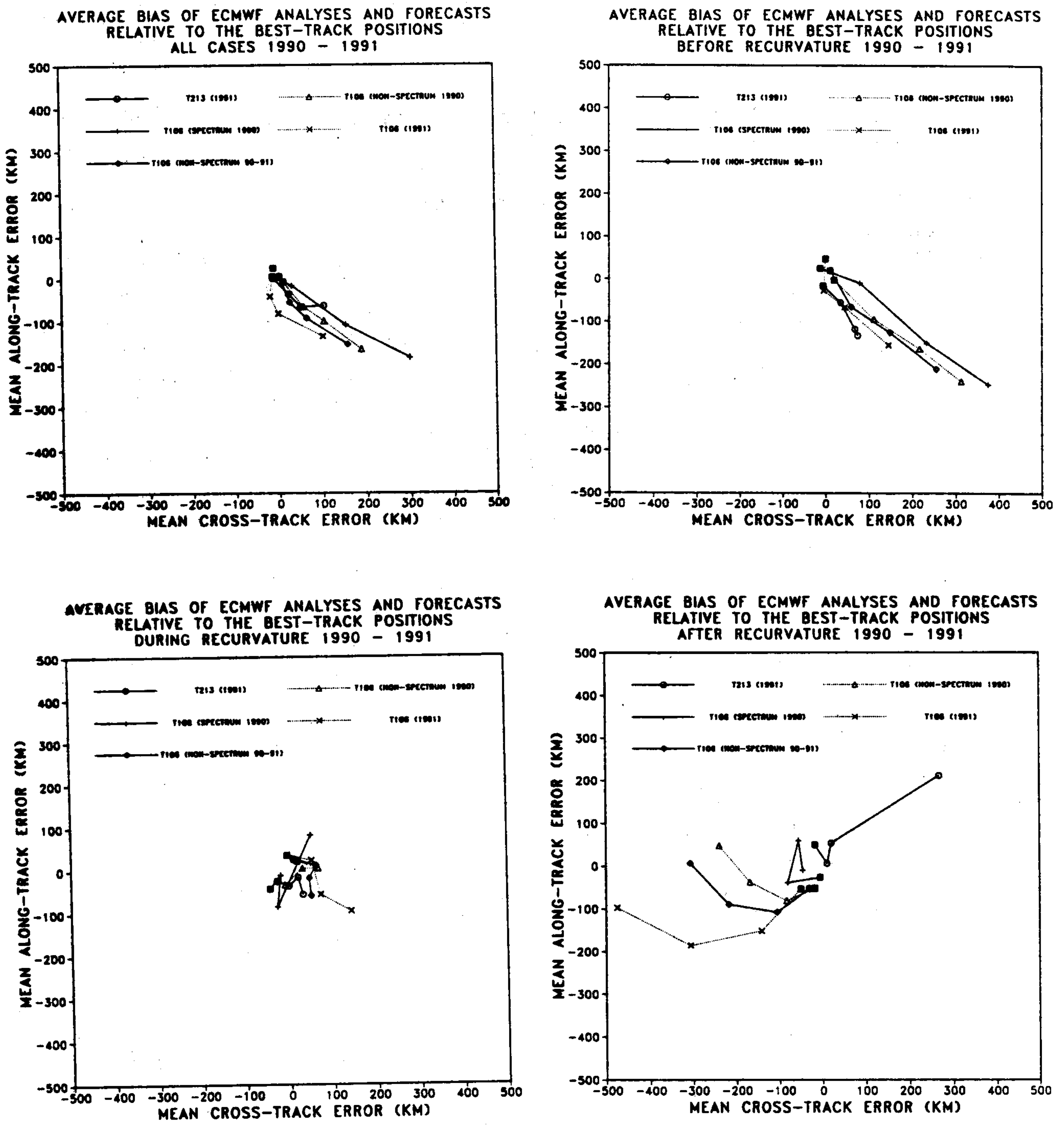

Figure 2 - Average Bias of ECMWF Analyses and Forecasts Relative to the Best-track Positions 1990-1991

(a) ALL Cases **(b) BEFORE Recurvature**
(b) DURING Recurvature **(d) AFTER Recurvature**

(Analyzed TC Positions Marked by Squares)

The systematic bias is in fact dominated by the BEFORE recurvature cases (Figure 2 (b)). It can be seen that the T213 forecasts remain the least biased whereas the "SPECTRUM forecasts" are still the worst in this regard. In addition, a definite trend in the decrease in bias can be seen: from "SPECTRUM 1990" to "Non-SPECTRUM 1990", "T106 1991" and finally "T213 1991". There is not any significant systematic bias nor difference between the different samples for the DURING recurvature cases (Figure 2 (c)).

Although the numbers of cases for the AFTER recurvature cases are relatively small, Figure 2 (d) suggests systematic biases of different nature. On the one hand, the T106 forecasts all have left-hand bias and the most significant one pertains to the "T106 1991" sample. On the other hand, the T213 forecasts seem to behave differently with a fast right-hand bias at T+72 hours. This may account for the decrease in skill at T+72 hours observed in Figure 1 (c).

Lastly, it is interesting to note that despite the relatively large systematic errors observed for the forecasts, there is no such bias in the analyzed TC positions (marked by squares in Figure 2).

Summary and discussions

The enhanced observational data collected during the field experiments in 1990 led to improvement of the ECMWF model in TC track forecasting, especially at T+24 hours for the BEFORE recurvature TCs and also possibly at T+48 and T+72 hours for the DURING/AFTER recurvature TCs. However, the T106 model, limited by its resolution to resolve the detailed structure of TCs, failed to perform better at T+48 and T+72 hours for the BEFORE recurvature TCs despite the enhanced data.

The higher resolution T213 model is found to perform better than the T106 model in TC track forecasting. This improvement is three-fold:

(a) reduction in forecast errors and increase in skill relative to the PER method, especially at T+48 and T+72 hours for the BEFORE recurvature TCs,

(b) reduction in the right-hand systematic bias relative to the best-track (or the northward bias in an earth-oriented coordinate system), and

(c) reduction in the standard deviation of the forecast errors.

However, while the enhanced observational data collected during the field experiments led to improvement in the T+24 hour forecasts for BEFORE recurvature cases, the T213 model T+24 hour forecasts do not show any improvement over the T106 model forecasts. The drop in skill of the T213 model at T+72 hours for the DURING/AFTER recurvature cases is also a surprising and disturbing result although the sample size is relatively small.

Lastly, in order to understand the inadequacy of the T213 model, cases with large forecast errors were also studied. It was found that the T213 model could still have very large right-hand bias for BEFORE recurvature TCs although on the average it should be better than the T106. Furthermore, the model had difficulty in representing TC vortices realistically in the analyses for a number of cases. Also, its performance deteriorated when multiple TCs co-existed. It appears that the lack of observational data over the tropical oceans is still a major problem for accurate TC track forecasting.

- C.M. Shun
Royal Observatory, Hong Kong

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UNICOS 7 ADDITIONS AND DIFFERENCES

In the near future we will upgrade the operating system to UNICOS Release 7. As a general rule, a new operating system release is never totally different from the previous one. With the documentation now available, we can confirm that UNICOS 7 follows that same rule - only some minor user-related changes are implemented.

In the following paragraphs, we will try to point out the most common differences. For more information about this release, please contact User Support.

1. Compilers supported

The following compilers will be supported with UNICOS 7:

- cf77 Fortran compiling system 5.0 or later
- Cray standard C 3.0 compiler or later (cc command)
- Pascal 4.2 compiler or later
- CAL version 2 assembler.

The UNICOS 7 release does not support the CFT Fortran compiler (cft command) and the Cray C compiler (pcc command).

2. Fortran application tools

This release includes some new Fortran application tools, such as a Fortran browser (xbrowse), a Fortran listing generator (cflist) and a Fortran static analyser (cflint).

3. Performance analysis tools.

Some new performance analysis tools are provided. The most important one is the jumptrace tool, giving similar performance information to the flowtrace tool, but at the program instruction level.

4. SEGLDR

Two directives that could reduce the size of the executable program have been added to the link editor.

OMIT: inform the loader that a specific module should not be included in a program;

SOFTREF: declare that all reference to a particular external symbol should be soft.

5. UPDATE

The source code maintenance utility update is no longer available in this release.It has been replaced by a new utility, nupdate, giving several extensions including major speed improvements, and directory format program libraries. A utility for automatic conversion of old program libraries into the new format is also available.

6. Message system

Most of the performance utilities and the CAL2 assembler have been added with this release to the message system (explain).

7. Flexible File I/O

Some improvements can be obtained when working on a direct access unformatted file by selecting specific combinations of the different layers of the I/O system.

8. Fortran mathematical library (libm)

As of UNICOS 7, libm version 2 becomes the default mathematical library. Use 'cf77 -lmv1 prog.f' to refer to the previous version. This new library can give slightly different (more accurate) results.

9. Some Fortran I/O changes

Some more error checks are made on Buffer in/out statements. Using these statements with a direct-access file or with a formatted file will no longer be possible. Some stricter error checks are also made during an additional OPEN of a file that is currently open.

Buffer in/out statements support the use of character data as of UNICOS 7.

Numerical input and output conversion functions have been modified, giving more accuracy. Note that answers could change when making double-precision conversions.

Tabs can be used as blanks in NAMELIST and list-directed input.

10. Operating system enhancements

Due to a new intra-queue priority algorithm, the -p option of the qsub command is no longer valid.

The man command is now compatible with the unix BSD 4.3 man command. This involves some changes in the available options.

The real time clock has been changed to a date and time base (previously a zero-based integer).

The ISHELL() library routine uses a new system call, which reduces memory usage drastically. This means that the pshell command becomes obsolete.

11. UNICOS 8 preview

As of UNICOS 8, sh will no longer be the Bourne Shell, but will become the POSIX Shell. The POSIX Shell will be similar to the Korn Shell. The Bourne Shell will become osh under UNICOS 8 and will be removed with UNICOS 9.

Many other minor or more specific changes have been made to UNICOS 7. Most of them will be documented in the UNICOS User Commands Reference Manual, publication SR-2011. A copy of the full UNICOS 7 Release Notice is available at the User Support section; it will be added later to the docview utility.

- Dominique Lucas

Reference:

Cray Research publication, UNICOS 7.0 RELEASE NOTICE, Field Test Draft 3/92.

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SUBROUTINE NAME CHANGES IN THE (CRAY) NAG LIBRARY

From Mark (version) 14 onwards Cray single-precision implementations of the NAG library have a new naming convention for all the primary (user-callable) routines. Currently ECMWF is running Mark 13 as the production version using the older convention. This article explains ECMWF's migration plans regarding the changeover to Mark 14.

Name changes

From Mark 14 the following changes will be made to the NAG library on the Cray. The last letter of each user-callable routine has changed from F to E. Thus, for example, C06EKF now becomes C06EKE. Subsidiary routines and common block names also change in a slightly more complex way. Thus routine G11SAU becomes SAUG11 (first 3 characters swapped with the last 3). Finally, common blocks such as AC02AD are renamed as ADC02A.

The reason for these changes are to bring the Cray NAG library into conformity with other machines where NAG routines in double-precision implementations end in F and single-precision ones end in E. The above series of name changes is made so that sites may, if they wish, have both double-precision and single-precision implementations co-existing. Note, however, ECMWF has no plans to provide a double-precision implementation of the NAG library on the Cray.

ECMWF users of the NAG library on the SUN workstations should be aware that the SUN implementation is double-precision. Hence the calling programs will be incompatible between the two machine types (even though both have roughly equal significant digits of precision!).

Migration plans

Because of the incompatibility of names, the Mark 14 version of the NAG library is now being made available as a "next" product under the name $NAGNEXT, so that users can change over to the new names in a controlled manner.

After a reasonable period of time, i.e. about 2 months, Mark 14 will become the default. After that time, the current (Mark 13) production version, with the old naming convention, will remain available as an "old" version. Note that the C90 implementation of the production NAG library will **only** use the new names.

The name $NAGNEXT will continue to reflect a tested implementation of the next version of the NAG library. Thus the Mark 15 version of the library, which is due to be available for Cray Y-MP's sometime this summer, will become the "next" $NAGNEXT after Mark 14 goes into production.

New routines

As with previous versions of the NAG library some new routines have been added, others withdrawn and yet others revised at Mark 14.

Many of the 160 new routines are in two new chapters entitled:

G03 - Multivariate Analysis

X05 - Date and Time Utilities

Some 66 of the 160 new routines are in the statistics chapters. They include facilities for:

- statistical distribution functions, allowing for non-integer degrees of freedom and non-central distributions (G01);
- linear regression modelling, allowing for: weights; rank deficient models; adding or deleting observations or variables; standardized residuals and influence statistics; and model selection routines (G02);
- generalized linear models (G02);
- principal component analysis; canonical correlation analysis; canonical variate analysis (G03);
- non-parametric statistics (G08);

New routines have been introduced in other chapters of the library for:

- roots of complex polynomials (C02);
- solutions of systems of nonlinear equations, by reverse communication (C05);

- inverse Laplace transforms (C06);
- elliptic P.D.E's (D03);
- Volterra equations of the 2^{nd} kind (D05);
- bi-cubic spline interpolation and evaluation;
- constrained nonlinear least-squares problems;
- real and complex QR factorization and related operations (F01);
- matrix storage conversion (F01);
- real and complex SVD (F02);
- mixed integer LP (H);
- special functions (S);
- printing matrices (X04);
- date, time and CPU time (X05).

The F06 chapter now includes the Level 3 BLAS (Basic Linear Algebra Subprograms) and the Sparse Level 1 BLAS.

Efficient performance on vector-processing machines has been extended to routines in other areas including:

- linear algebra (F01, F02, F04, new and revised routines)
- linear regression (G02, new routines)
- non-linearly constrained optimization (E04, revised routine)
- random number generators (G05, new routines)
- multidimensional quadrature (D01, new routine)
- P.D.E.'s (D03, new routine).

In selected implementations of the library NAG has provided modified versions of some frequently used linear algebra routines using block algorithms which call Level 3 BLAS. On some machines these can achieve much better performance than the usual versions which call the Level 2 BLAS.

Withdrawn routines

The following routines have been withdrawn from the NAG Fortran Library at Mark 14. Warning of their withdrawal was included in the Mark 13 Library manual, together with advice on replacements. The relevant Chapter Introduction documents give more detailed guidance.

Withdrawn routine	**Recommended replacement**
D02QAF)	
D02XGF)	D02QFF and associated routines
D02XHF)	
F01CAF	F06QHF
F01CBF	F06QHF
F01CFF	F06QFF
F01CMF	F06QFF
F01DEF	SDOT/DDOT/F06EAF
F02WBF	F02WEF
F02WCF	F02WEF
F05ABF	SNRM2/DNRM2/F06EJF
X02ADF	X02AJF and X02AKF
X02AEF	X02AMF
X02AFF	X02AMF
X02BAF	X02BHF
X02BCF	X02AMF
X02BDF	X02AMF

Routines for withdrawal at Mark 15

The following routines will be withdrawn at Mark 15, since improved replacement routines have been included in the library. Users are advised now to stop using routines scheduled for withdrawal and use the recommended replacement routines instead. The relevant Chapter Introduction gives further guidance on how to changeover a call to the new form.

Routine scheduled for withdrawal	Recommended replacement
C02ADF	C02AFF
E01ACF	E01ADF and E02DEF
F01CDF	F01CTF
F01CEF	F01CTF
F01CGF	F01CTF
F01CHF	F01CTF
F01LZF	F02SWF and F02SXF
F01QAF	F01QCF
F01QBF	F01QJF
F02SZF	F02SYF
H02BAF	H02BBF

Other routines are listed as superseded but will not be withdrawn until Mark 16, at the earliest. For reasons of space this list is not included here.

<u>How to use the Cray NAG Mark 14 library</u>

The Mark 14 NAG library has been compiled and tested under cft77 version 5 and is now available. Just replace $NAGLIB with $NAGNEXT on the segldr statement.

If you have any questions regarding any aspect of these changes please contact User Support.

- John Greenaway

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INTERNET ACCESS

Internet is an international "network of networks". It interconnects many academic, research and some commercial networks into one large network. This allows access to a large number of sites by electronic means.

ECMWF is now connected into Internet via a 64 kb/s link to the UK academic network (JANET); that network in turn is connected to Internet via a router. The router performs such necessary functions as address and protocol translation.

Internet provides the following basic services:

- electronic mail
- file transfer (ftp)
- interactive access to remote systems (telnet).

Two ECMWF Computer Bulletins (B3.4/2 and B3.4/3) have just been published which give some initial information on how to use the above services. However, the scope and uses of Internet are a large topic, a full treatment of which is beyond these bulletins. A useful guide has been written by Brendan P. Kehoe ("Zen and the Art of the Internet", or "A Beginner's Guide to Internet") and is available via Internet itself. A copy has been transferred to ECMWF and is available in two files in the UNIX/UNICOS directory /usr/local/information/write_ups, with the file names:

Internet_zen_ps	Postscript version
Internet_zen	UT Text version.

ECMWF's address via Internet is

ecmwf.co.uk
or 136.156.00.00

Mail should be addressed as follows:

uid@ecmwf.co.uk
or FirstinitialLastname@ecmwf.co.uk
or Firstname.Lastname@ecmwf.co.uk

where **uid** is the person's three character user identifier at ECMWF.

For example, mail can be addressed to myself (my user identifier is usa) in any of the following ways:

usa@ecmwf.co.uk
ALea@ecmwf.co.uk
Andrew.Lea@ecmwf.co.uk

Please note the following points about Internet access and usage.

1. ECMWF does not currently permit interactive access to be initiated from an Internet remote host into any ECMWF service. However, ECMWF users can initiate outgoing interactive sessions to remote hosts.

2. ECMWF does not currently permit file transfers to be initiated from an Internet remote host. This is for security reasons, so that unauthorised access is not made to any ECMWF service.

   However, any ECMWF user can initiate a file transfer session by logging onto an ECMWF machine, and then making an outgoing connection to a remote host. Once that session has been set up, file transfer can then be carried out in either direction.

3. The UNICOS system at ECMWF is not considered to be an interactive system. Hence, please do not use it for Internet access. Internet access can be achieved from any UNIX workstation, from NOS/VE, or from VAX/VMS.

4. As stated above, ECMWF's Internet connection is via the UK University network known as JANET. ECMWF users of Internet are therefore obliged to observe the conditions of use of JANET, an extract from which has been given in ECMWF Computer Bulletin B3.4/2 (Integrated electronic mail services). Your attention is drawn to these conditions.

5. Each host that connects to Internet does so on a voluntary basis. In particular this means that no host is obliged to provide all services, for example, hosts often do not permit interactive access. Also, it means that there is no obligation on a host to be connected on a continuous basis. Hosts can, and do, go down for long periods for a variety of reasons. In addition, the network itself can become congested or go down without warning. Thus, be aware that these services are provided on an "as is" basis only, do not solely rely upon them for critical items. For example, when sending an important mail message via Internet, then also send a copy via fax or post, as there is no way in Internet to check if the message has successfully reached its destination.

- Andrew Lea

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ECMWF COMPUTER BULLETINS - CURRENT STATUS

Following the withdrawal of many bulletins after the Cyber NOS/BE and Cray COS services had terminated (see ECMWF Newsletter March 1991, No. 53, page 30), a further rationalisation has been carried out. The following ECMWF Computer Bulletins are now obsolete and can be thrown away: B0.2/2, B1.2/2, B3.4/1, B5.2/7, B5.2/12, B5.2/13.

Updates of the following bulletins are in progress or have been done: B0.1/1, B1.0/2, B1.0/3, B1.5/1, B2.8/1, Index, Classification and Contents.

Finally, three new bulletins have been recently distributed: B2.8/2, B3.4/2, B3.4/3.

Therefore, the up-to-date set of ECMWF Computer Bulletins (excluding those specialist ones on restricted distribution) are as shown below.

Reference	Title
B0.1/1(4)	ECMWF division management and personnel list
B0.2/3	Security
B1.0/2	An introduction to the VAX interactive system
B1.0/3	Introduction to the UNICOS system of ECMWF
B1.1/2(2)	Naming conventions and registration procedures
B1.5/1(1)	Advisory services
B2.5/1(1)	NOS/VE service - self tuition notes
B2.5/2(1)	Summary of ECMWF provided features in NOS/VE
B2.8/1(1)+	Terminal emulators for PCs - a basic introduction
B2.8/2+	An (outgoing) fax service for PC users
B3.4/2	Integral electronic mail services
B3.4/3	INTERNET
B3.5/1	Data transmission to and from Member States
B4.1/1	New features of Fortran 77
B4.1/3	Bit operations in Fortran
B5.2/5(1)	ECMWF meteogram system
B5.2/8(2)	Reference manual for MAGICS

Reference	Title
B5.2/9(2)	User's guide for MAGICS
B5.2/10	Pocket guide for MAGICS
B5.2/14(3)+	The diagnostic and plotting package BPP
B6.0/1	Software libraries available at ECMWF
B6.1/1(1)	The ECMWF software library ECLIB
B6.1/2	Program library documentation standard
B6.1/3	ECLIB documentation
B6.7/2(9)	MARS user guide
B7.6/1	FORMAL reference manual
B7.6/2	FORMAL for pedestrians
B8.2/1	Supporting incoming/outgoing magnetic tape at ECMWF
B8.3/1(2)	ECFILE concepts
B8.3/3	ECFILE access from NOS/VE
B8.5/1(1)	Alphanumeric Microfiche

NOTE:

+ Bulletins issued within ECMWF only

- Andrew Lea

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STILL VALID NEWS SHEETS

Below is a list of News Sheets that still contain some valid information which has not been incorporated into the Bulletin set (up to News Sheet 280). All other News Sheets are redundant and can be thrown away.

No.	Still Valid Article
204	VAX disk space control
205(8/7)	Mispositioned cursor under NOS/VE full screen editor
207	FORMAL changes under NOS/VE
212	MFICHE command from NOS/VE
214	NAG Fortran Library Mark 12 News Sheets on-line
224	Job information cards
230	Access to AB printer via NOS/VE CDCNET
235	VAX public directory - how to create
236	Alternative VAX graphics service for in house users
247	Use of CFSPATH/TARGET parameter within MARS retrievals
248	Changes to the Meteogram system
253	Copying/archiving NOS/VE catalogs to ECFILE Copying complete UNICOS directories to ECFILE
254	UNICOS carriage control
260	Changes to PUBLIC directories for VAX users
261	Meteogram system on UNICOS

No.	**Still Valid Article**
265	Lost UNICOS outputs submitted via RJE or VAX Microfiche changes
266	Reminders on how to import/export magnetic tapes
267	Checking on your UNICOS account usage
268	Changes to WMO FM 92 GRIB
270	Changes to the Meteogram system
271	New ECFILE features on UNICOS
276	UNICOS 6 differences Periodic deletion of all Cray /tmp files
277	UNICOS 6 (more differences)
280	UNICOS on-line documentation: docview Further UNICOS differences

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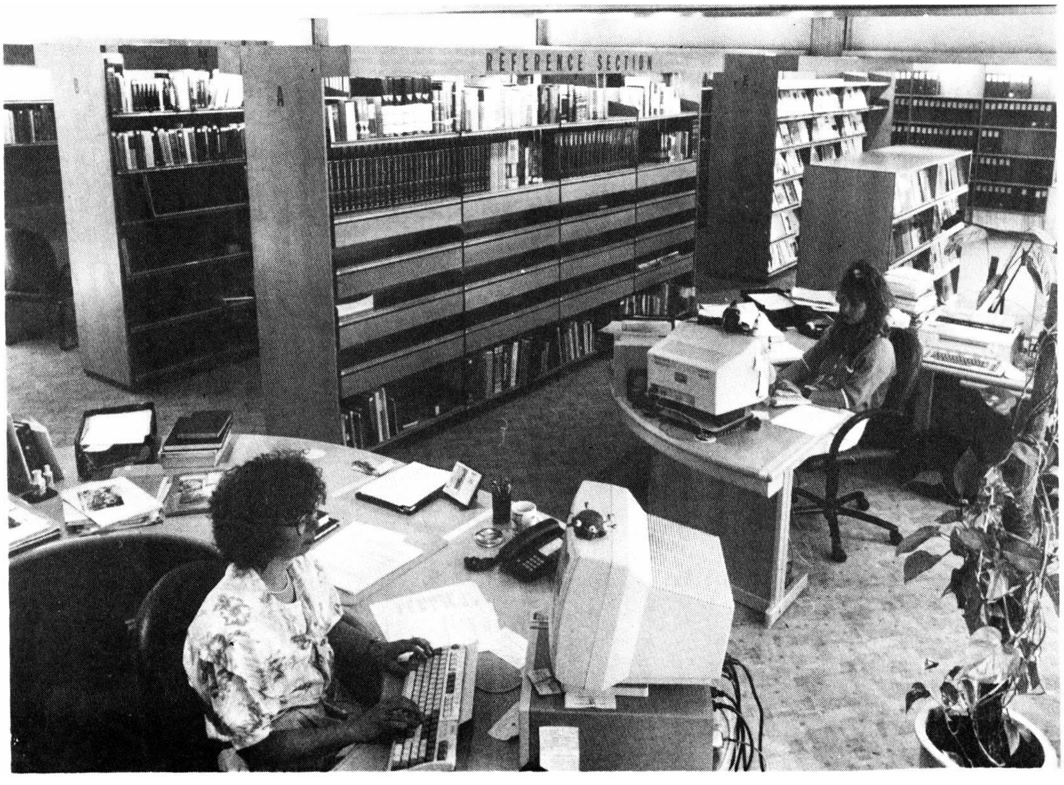
ADDITIONS AND ALTERATIONS TO THE CENTRE'S HEADQUARTERS BUILDING

Recent visitors to the Centre will have noticed a major alteration to the Headquarters Building, with the completion of the new Library behind the Reception Area. The library extension has been built to occupy the whole of the raised area between the Office Block and the Conference Block; the building consists of a steel framework with concrete floor and roof. The interior of the Library has polished wood on the pillars and ceiling to harmonise with the wood of the bookshelves. The lighting has been designed to give good illumination for reading, while retaining the softness appropriate for its surroundings.

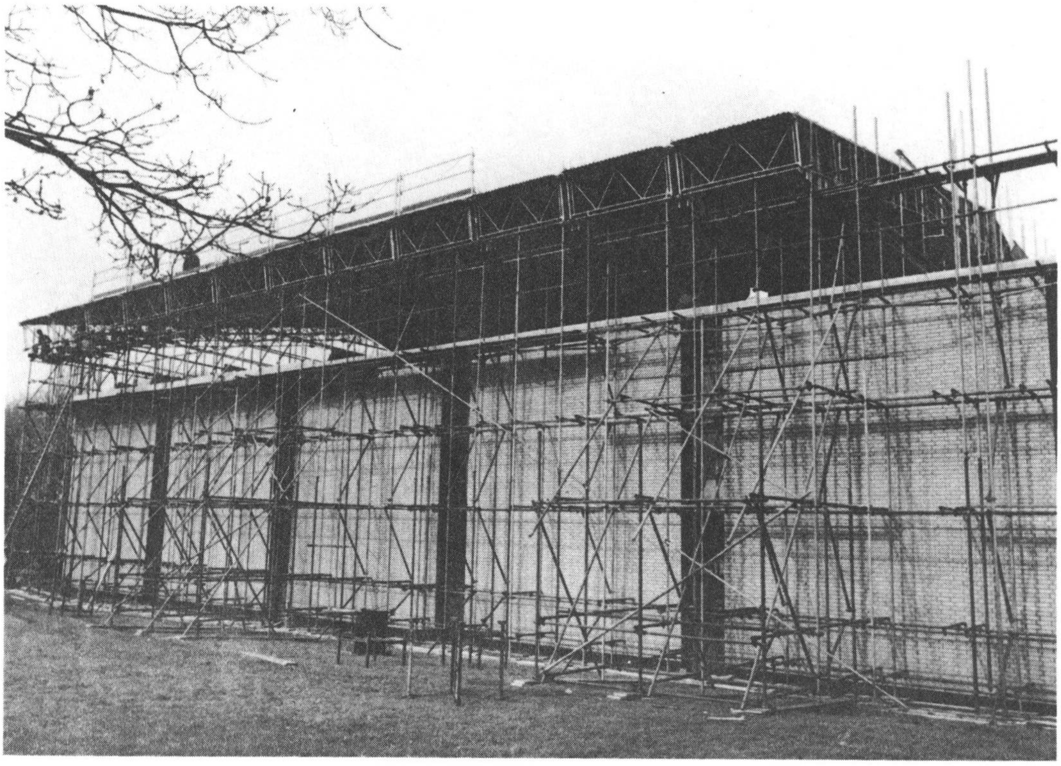
The construction of the new Library extension was not without problems, the most notable being that the excavations for the foundations filled with water from an underground source. This problem was resolved, however, and work completed to schedule. The Library was moved down from the third floor of the Office Block just before Easter; this operation required a grand total of 400 removal creates to move the library contents to their new home. The shelving from the old Library was repositioned in the new area, and augmented.



An interior view of the new Library

The opportunity provided by the construction of the Library has been seized to increase the office space at the Centre, by the addition of twelve new offices above the new Library, linking the first floor of the Office Block with the Concourse in the Conference Block. The old Library area has also been converted into offices, and a new Artwork Office and Dark Room.

For the past few months the Computer Hall has been enveloped in scaffolding and polythene as contractors employed by PSA have worked, first on one half and then the other, to render the roof watertight. To achieve this, the second, outer roof, installed a few years ago has been removed. The faults in the original roof were then exposed and repaired. Over that, a layer of insulation material was added, its top surface being sealed with a special waterproof coating. This provides a totally watertight outer layer with a high expansion factor to accommodate variations in temperature.



The Computer Hall with scaffolding and temporary roof shelter

Finally, the need to provide additional electrical supplies along with diesel backup for the support of the Cray Y-MP/90 and future computers meant that a new building had to be provided to house the equipment. This new **Energy Centre** is 14.5 metres wide, 12.5 metres deep and 5 metres high and stands on a sloping site on the north west side of the computer building.

Since there are houses some 30 metres from the energy centre it was necessary to design the building so that the minimum of noise will be heard outside. This, unfortunately, was not done with the original diesel house, and local residents have been inconvenienced over the years as a result.

The energy Centre houses one 1 MVA (800 kW) power conditioning system with diesel backup and a second system is due to be delivered in September 1992. These are supplied by a Belgian company, Euro Diesel SA, and are the first units to be installed in the UK. A fuller description of the Euro Diesel system will appear in a later newsletter.

The installation work included extensive electrical distribution work, requiring excavation of a 2-metre deep trench across the roadway behind the computer building, and various modifications to the basement of the computer building and the plant room.

Heavy equipment being lifted into the new energy centre

The Cray Y-MP/8, IBM and telecommunications equipment are currently connected to the system and enjoy immunity from electrical power problems. The C90 will be connected as soon as it is delivered, probably necessitating that part of the Y-MP/8 load be disconnected.

- Peter Gray

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ECMWF CALENDAR 1992

31 Aug	***ECMWF holiday***
7-11 Sep	Seminar: Validation of weather predictions and large-scale simulations over the European area
28 - 30 Sep	Scientific Advisory Committee - 20th session
28 - 30 Sep	Member States' Computer Representatives - 7th meeting
30 Sep - 2 Oct	Technical Advisory Committee - 17th session
6 - 8 Oct	Finance Committee - 49th session
9 - 12 Nov	Workshop: Variational assimilation with emphasis on 3-dimensional aspects
23 - 27 Nov	Workshop: Parallel processing
2 - 3 Dec	Council - 37th session
24 - 28 Dec	***ECMWF holiday***

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ECMWF PUBLICATIONS

Workshop Proceedings: New developments in predictability, 13-15 November 1991

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INDEX OF STILL VALID NEWSLETTER ARTICLES

This is an index of the major articles published in the ECMWF Newsletter series. As one goes back in time, some points in these articles may have been superseded. When in doubt, contact the author or User Support.

METEOROLOGY

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USEFUL NAMES AND 'PHONE NUMBERS WITHIN ECMWF

		Room*	Ext.**
DIRECTOR	- David Burridge	OB 202	2001
HEAD OF OPERATIONS DEPARTMENT	- Michel Jarraud	OB 010A	2003
ADVISORY: Available 9-12, 14-17 Monday to Friday			2801
Other methods of quick contact:	- Telex (847908 ECMWF G) - Telefax (+44 734 869450) - VMS MAIL addressed to ADVISORY - Internet mail addressed to Advisory@ecmwf.co.uk		
REGISTRATION			
Project Identifiers	- Pam Prior	OB 225	2384
User Identifiers	- Tape Librarian	CB Hall	2315
COMPUTER OPERATIONS			
Console	- Shift Leaders	CB Hall	2803
Reception Counter	- Tape Librarian	CB Hall	2315
Tape Requests	- Tape Librarian	CB Hall	2315
Terminal Queries	- Norman Wiggins	CB 026	2308
Telecoms Fault Reporting	- Michael O'Brien	CB 028	2306
DOCUMENTATION - Distribution	- Els Kooij-Connally	Library	2751
LIBRARIES (ECLIB, NAG, etc.)	- John Greenaway	OB 226	2385
METEOROLOGICAL DIVISION			
Division Head	- Horst Böttger	OB 007	2060
Applications Section Head	- Rex Gibson	OB 101	2400
Operations Section Head	- Bernard Strauss	OB 004	2420
Meteorological Analysts	- Andreas Lanzinger	OB 003	2425
	- Ray McGrath	OB 005	2424
	- Anders Persson	OB 002	2421
Meteorological Operations Room	-	CB Hall	2426

			Room*	Ext.**	Bleeper
COMPUTER DIVISION					
Division Head	-	Geerd-R. Hoffmann	OB 009A	2050	150
Systems Software Sect.Head	-	Claus Hilberg	CB 133	2350	115
User Support Section Head	-	Andrew Lea	OB 227	2380	138
User Support Staff	-	Antoinette Alias	OB 224	2382	154
	-	John Greenaway	OB 226	2385	155
	-	Norbert Kreitz	OB 207	2381	156
	-	Dominique Lucas	OB 206	2386	139
	-	Pam Prior	OB 225	2384	158
Computer Operations Section Head	-	Peter Gray	CB 023	2300	114
Security, Internal Networks and Workstation Section Head	-	Walter Zwieflhofer	OB 142	2352	145
GRAPHICS GROUP					
Group Leader	-	Jens Daabeck	OB 016	2375	159
RESEARCH DEPARTMENT					
Head of Research Department	-	Anthony Hollingsworth	OB 119A	2005	
Computer Co-ordinator	-	David Dent	OB 123	2702	

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* CB - Computer Block
OB - Office Block

** The ECMWF telephone number is READING (0734) 499000, international +44 734 499000, or direct dial to (0734) 499 + last three digits of individual extension number, e.g. the Director's direct number is (0734) 499001.

DEC MAIL: Contact scientific and technical staff via VMS MAIL, addressed to surname.

Internet: The ECMWF address on Internet is **ecmwf.co.uk**
Individual staff addresses are firstname.lastname, e.g. the Director's address is David.Burridge@ecmwf.co.uk