In this issue

European Centre for Medium-Range Weather Forecasts

Shinfield Park, Reading, Berkshire RG2 9AX, UK

Fax: . . . .+44 118 986 9450

Telephone: National 0118 949 9000

International . . . .+44 118 949 9000

Public Web site . . . . .http://www.ecmwf.int

Member States' Web site . . . . . .http://wms.ecmwf.int

Front Cover

Gasherbrum in good weather – *see article on page 3.*

Editorial

The press release on the following page announces the decision by Council to admit the Czech Republic as an ECMWF Co-operating State; this brings the number of Co-operating States up to five. Council has also decided that the former Socialist Federal Republic of Yugoslavia is no longer a Member State; the total number of Member States is now seventeen.

On page 3 Mike Cullen describes ECMWF forecasts that were available during a mountaineering expedition in northern Pakistan. Forecasting details of the weather at very high altitudes in a part of the world where there are no local observations provides a very severe test for the ECMWF model. However, as Mike describes, guidance derived from ECMWF forecasts gave good indication, up to four days ahead, on the likely breaks in spells of fine weather, and on the onset and duration of snow associated with disturbances in the jet stream and with interactions with the monsoon flow to the south.

It is a general perception that weather-related damage due to severe weather events has become more frequent in recent decades. As a result, there is an increasing demand from both the public and the commercial world for forecasts sufficiently far ahead to enable damage limitation measures to be taken. As Roberto Buizza explains in the article on page 7, the best way of providing forecasts of the risks of severe weather is to examine the probability density of meteorological states based on forecasts from an ensemble of equally likely initial analyses. He illustrates the technique by examining ensemble forecasts for two intense precipitation events that occurred in northern Italy in November 1994 and in October 2000.

The ECMWF has embarked on a programme to replace desktop workstations with Linux-based PCs. Richard Fisker and his colleagues describe the features of the new systems (page 12), including the hardware, the software that has been installed, the Windows 2000 configuration, and the integration of the PCs into the ECMWF computer environment. Very few problems have been encountered, and users of the new equipment are very pleased with the facilities that are available and with the hardware reliability.

Peter White

Changes to the Operational Forecasting System

No change has been made to the operational system between 12 June 2001 and the time of printing of this newsletter.

Future Changes

Pre-operational testing of an important set of changes for the operational system has started in October. All components of the system are affected:

- More data are activated (QuikSCAT data for sea winds, less thinning of aircraft observations, more intelligent thinning and better scan correction of ATOVS radiances)

- Pre-processing (bias correction) of SSMI data and redundancy checks for SYNOP, SHIP, DRIBU, AIREP, TEMP and PILOT observations are refined;
- 4D-var analysis algorithms are upgraded: pre-conditioning is added to the minimisation, resulting in a 40% reduction of the number of adiabatic iterations; correlation functions slightly revised (compacted); the radiative transfer model used to assimilate satellite radiances has been completely re-written; the observation time slot has been reduced from 1 hour to 30 minutes.
- Model changes include a new finite-element vertical discretization, small changes in the convective precipitation scheme and supersaturation checks, and an improved temporal scheme for oceanic wave generation;
- Initial EPS perturbations in the tropics are included. The perturbations are generated for a maximum of four target areas by Gaussian sampling of the five leading diabatic singular vectors for each area. The Caribbean (0–25°N and 100–60°W) is always a target area, as is every tropical storm of category larger than 1 between 25°N and 25°S. (In the event that these criteria produce more than four target areas, the closest areas are merged.)

More on the impact of these changes on the model performance will be reported in the next newsletter.

François Lalaurette

PRESS RELEASE – 1 AUGUST 2001

Czech Republic joins European Centre for Medium-Range Weather Forecasts

On 1 August 2001 the Czech Republic concluded a Co-operation Agreement with the European Centre for Medium-Range Weather Forecasts (ECMWF), thus allowing full access to the vast range of operational weather forecasts produced by the super-computer system of ECMWF. The Agreement was signed by Milos Kuzvart, Minister of the Environment of the Czech Republic, and by Dr David Burridge, Director of ECMWF, following detailed negotiations that began in 1995.

The conclusion of the Agreement was welcomed by Dr. Ivan Obrusnik, Director of the Czech Hydrometeorological Institute. "Accurate weather forecasts up to 10 days ahead, particularly of the severe weather that affects our country from time to time such as floods or storms, are essential," said Dr. Obrusnik. "Up to now we have not been able to forecast weather, and especially precipitation, for longer than 2 to 3 days ahead. Forecasts from ECMWF will extend our forecasting capability into the range from 3 to 10 days ahead, not only for severe weather but also for common daily forecasts so needed for public. ECMWF is widely acknowledged to produce the world's most accurate predictions in the medium range. The impressive improvement in the accuracy of the Centre´s forecasts in recent years has been a major stimulus to our efforts to conclude this Agreement."

The ECMWF Director Dr. Burridge also welcomed the conclusion of the Agreement. "ECMWF has concluded similar Agreements with Iceland, Hungary, Croatia and Slovenia", said Dr. Burridge. "We have contacts with many other States in central and east Europe, and we look forward to helping also those States - which have already concluded Association or Europe Agreements with the European Union – to improve their operational weather forecasts soon."

http://www.ecmwf.int

Dr David Burridge, Director,
ECMWF
Shinfield Park
Reading
RG2 9AX
England

Tel: 0118 949 9104
Int (+44) 118 949 9104
Fax: 0118 986 9450
David.Burridge@ecmwf.int

Dr Ivan Obrusnik, Director
Czech Hydrometeorological Institute
Na Sabatce 17
143 06 Praha 4
Czech Republic

Tel: (+420 2) 401 65 03

Fax: (+420 2) 401 0800
obrusnik@chmi.cz

Forecasts for the Karakoram mountains

During June and July 2001 I took part in an expedition to the mountain of Gasherbrum II. This is an 8035m peak in the Karakoram range, about 25km south of the neighbouring peak, K2. The expedition was organised by Jagged Globe UK. The weather in the Karakoram is notoriously unsettled and many accidents have occurred, on K2 in particular, as a result of bad weather. The expedition carried a satellite phone for members of the expedition to use to maintain limited contact with home. I took advantage of this telephone to compare ECMWF analyses and forecasts with the weather on site. On my return home, I was able to make a more detailed study of the forecasts and compare them with my experience on the expedition. Forecasting for the area is very difficult because of lack of surface-based observations, and the very large effects of the mountains. The Karakoram range extends about 1000km in a north-west south-east line and is about 200km wide. It closely adjoins the Hindu Kush to the west and the Himalayas to the south-east. The latter extend south-east for a further 2000km. The mountains form a barrier between very arid regions to the north-west and north-east, and the relatively moist air to the south fed by the monsoon. The mountains are at 35°N. This is far enough north for disturbances to the subtropical jet stream to be important, even in midsummer. However, the region can also be affected by the upstream influence of monsoon disturbances. This article describes some of the sequences of weather we experienced and how well they were predicted.

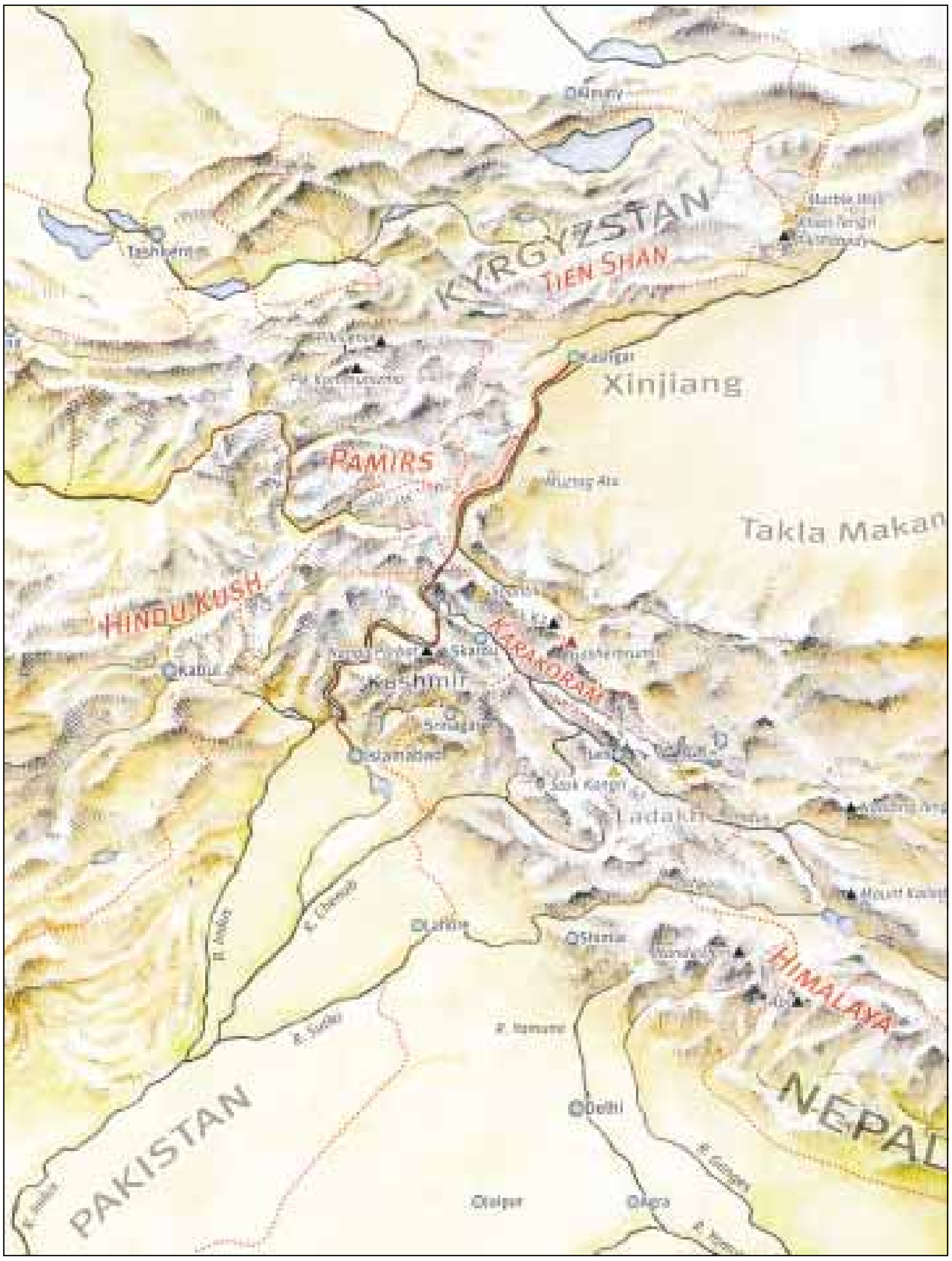
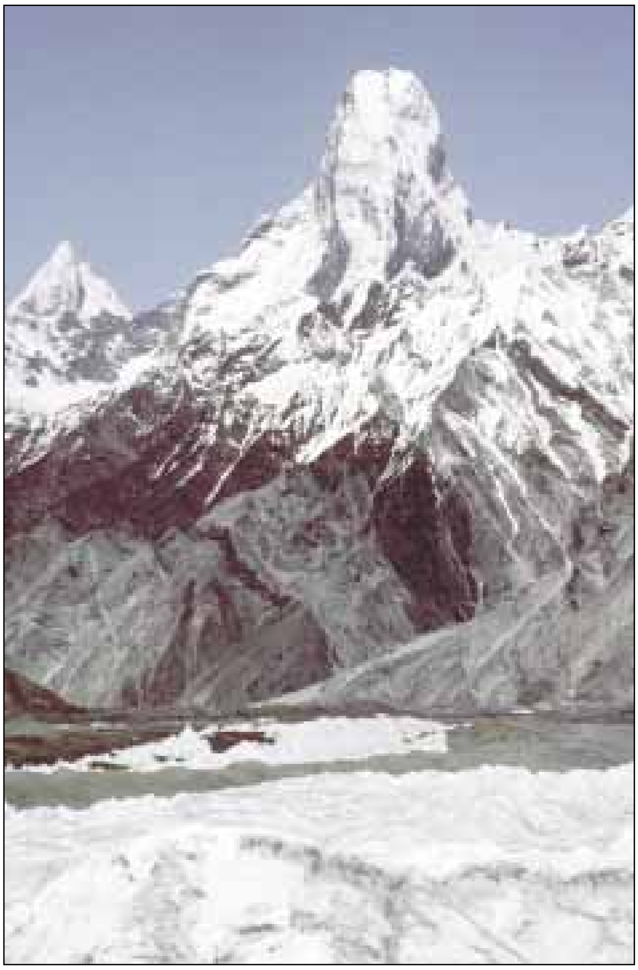


Figure 1 Map of the expedition area. The Karakoram range extends about 1000 km in a north-west south-east line and is about 200 km wide. It closely adjoins the Hindu Kush to the west and the Himalayas to the south-east. The latter extend south-east for a further 2000 km.



The Mustagh tower. *(Photograph: M. Cullen)*

The expedition leader, David Hamilton, has 15 years experience of the Karakoram in summer. His experience is that the weather alternates between fine spells lasting 5–6 days and disturbed spells lasting 3–4 days. In June, the fine spells can be very clear. In July, the upstream effect of the monsoon means that completely clear weather is unusual. Success in climbing the mountains depends on correctly forecasting these spells of weather, since it takes at least four days to do a round trip from Base Camp to the summit, even when fully acclimatised.

At the beginning of the walk-in we had a spell of exceptionally fine and hot weather that lasted for 5 days. However, the last two days approaching Base Camp were marked by cloud with overnight rain, becoming snow as we got close to Base Camp at 5150m. The first wet night caught some of us out, as we thought our kitbags were waterproof. Checking on the ECMWF analyses for this period showed that the fine spell was linked to a northern position of the jet stream, and the disturbed spell occurred when the jet stream crossed the mountain range. Thus, a key component of the forecast to look out for was the jet-stream position. Forecasts made at the time we reached Base Camp indicated a period of reasonable weather for the first few days of the climb, but disturbed weather at the end of the week (21–22 June).

The first part of the climb consisted of finding a route to Camp 1 (5950m) through a complicated icefall, which had to be marked with flags. As the snow melted with the advance of summer, the flags had to be drilled into holes in the ice. This part of the climb is relatively sheltered and we could usually get up and down whatever the weather. Very early starts were needed because the sun gets unbearable after 9 a.m. and the snow conditions become dangerous. Therefore, the day usually began with a midnight breakfast and 1 a.m. departure. The reasonable weather allowed us to find a route safe from avalanches, though it crossed several large crevasses. However, at the end of the week several of us had a difficult return to Base Camp in heavy snow, during the predicted disturbed spell.

The task in the second week was to set up Camp 2 (6500m). This involved fixing ropes up the steepest part of the climb. Two sections have a slope of 55-60°. This needed a spell of good weather. Forecasts from Monday 24 June, illustrated in the first meteogram, (Figure 3), indicated a long spell of fine weather starting on Tuesday evening and extending till the following Monday. In fact, the clear weather started a day early, with a sharp frontal clearance on Monday evening. There was then a long fine spell as predicted. This spell was generated by an upper ridge, associated with a marked northward movement of the jet stream (Figure 4) that was accurately forecast. By the end of the week, Camp 2 had been established and most of us were ready to move up to sleep in it. The forecast from Thursday 28 June, the second meteogram, (Figure 6), confirmed that the fine weather would last till the following Monday. This proved to be the case, and gave time for ropes to be fixed up to Camp 3 (6950m) by a Japanese expedition climbing alongside us. Most of our members were able to make a day trip to Camp 3 carrying gear and gaining good acclimatisation.

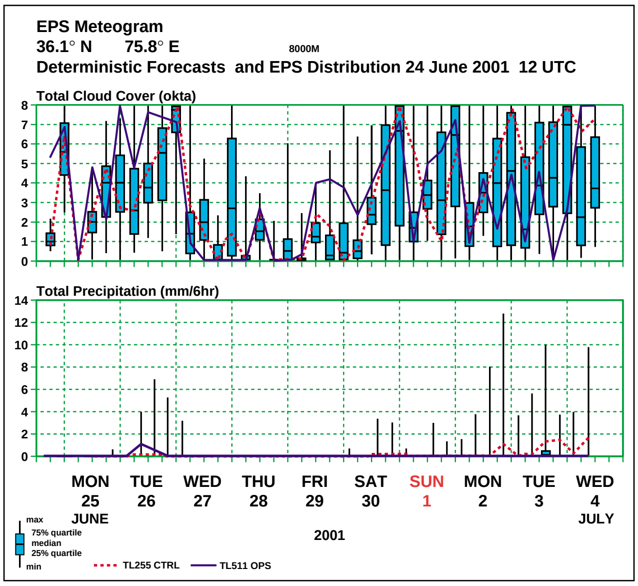


Figure 3 Meteogram at (35.1°N, 75.8°E) covering the period 24 June to 4 July 2001.

Since we had to leave Base Camp on 14 July at the latest, we had to plan for a summit bid as early as possible. On Monday 2 July several of us were in Camp 2 in a position to attempt the summit, and prepared plans to go up to Camp 3 on 4 July and attempt the summit on the 5th. The jet stream was in a stable position to the north (figure 8), and looked right for a summit bid. However, during the afternoon upper clouds increased *(see photograph below of clouds over Gasherbrum)*, and by the next morning snow was falling at Base Camp, gradually spreading up the mountain. This lasted for the next two days, and we had to abandon the summit bid. This breakdown had, in fact, been well forecast by the meteogram from 28 June, though this forecast did not predict that the poor weather would stop again on Thursday 5 July. The forecast from Sunday 1 July was very accurate, *(see the third meteogram – Figure 7)*. If we had had this forecast at the time, we would have been able to cancel the summit bid and bring everyone down to Base Camp before the bad weather started. This spell of poor weather occurred with a stable northern position of the jet stream (Figure 8) and was presumably associated with a monsoon disturbance to the south. This episode showed that the ECMWF model was also able to predict this type of disturbance.

After the break in the weather, the fine spell returned, as predicted on 1 July. Five out of seven of the expedition members, together with David Hamilton and Ali Raza, a high altitude porter, reached the summit on 9 July. David has reached the summit twice before, curiously on 9 July on both occasions. Several members of two Japanese expeditions also reached the summit on the same day, and on two subsequent days. We then had to plan our return to Rawalpindi. This involves crossing a high pass (5600m). Though the climbers were well acclimatised for this, 45 porters carrying all the luggage and wearing training shoes or sandals also had to cross. We were able to obtain forecasts for this period, which were for bad weather *(see the fourth meteogram – Figure 9)*, associated with a major disturbance to the jet stream. Several other expeditions who were still planning to reach the summit were taking an interest in our forecast information by this time. On the Sunday afternoon the cloud built up, as forecast, and snow started during the night. At the 1 a.m. start time, the porters refused to move. Unfortunately, the snow then continued for another 24 hours. By this time the porters wanted to go anyway, and we had a very slow and difficult crossing. The snow eventually died out on Tuesday evening after 48 hours. The forecast predicted the onset

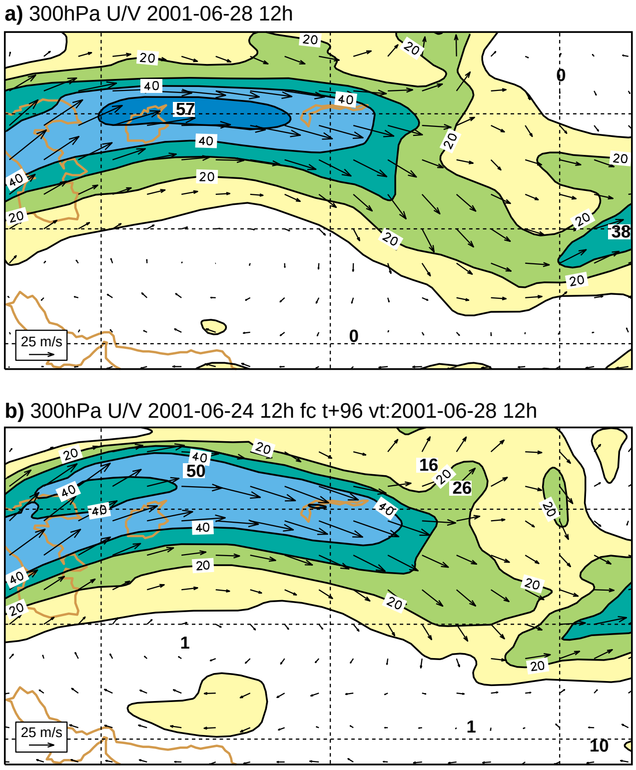


Figure 4 a) The analysis and **b)** the 96-hour forecast for 12 UTC 28 June 2001 of the wind speed and direction at 300 hPa over the Himalayan area. The central latitude / longitude intersect is at (36°N, 76°E).

Clouds over Gasherbrum. *(Photograph: M. Cullen)* well, but kept the snow going for four days (it was just as well that that part was inaccurate). We then had a smooth return by air to Rawalpindi

In general, the forecasts seemed to be accurate up to four days ahead in predicting the general weather patterns. The EPS seemed to be able to predict both the disturbances associated with the jet stream and those coming from the south associated with the monsoon. However, the forecasts were not reliable after four days, often prolonging periods of bad weather incorrectly. The expedition was excellently led, and was a very memorable experience (though I have to own up to being one of the two members who didn't reach the summit!).

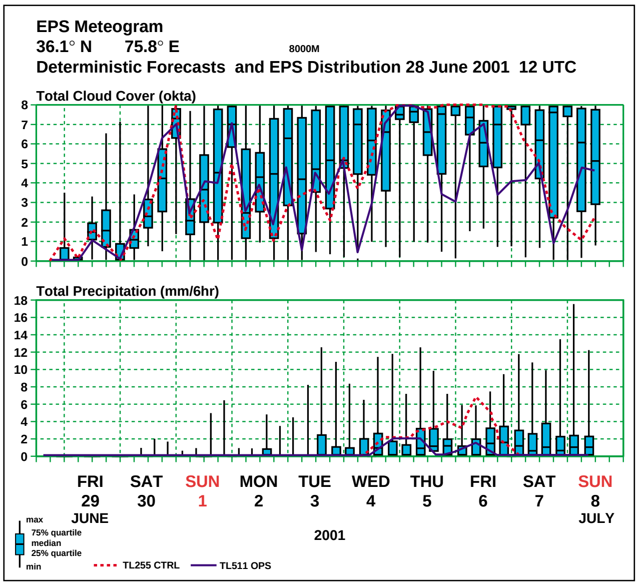


Figure 6 Meteogram at (35.1°N, 75.8°E) covering the period 28 June to 8 July 2001.

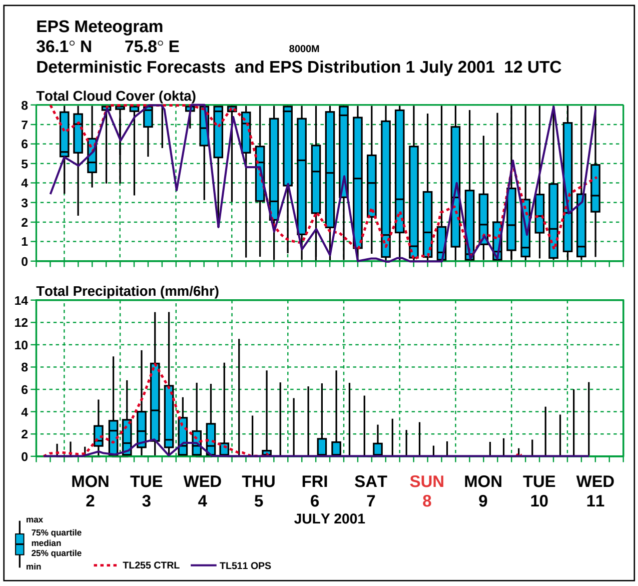


Figure 7 Meteogram at (35.1°N, 75.8°E) covering the period 1 July to 11 July 2001.

Acknowledgements

To Deborah Salmond, who supplied analyses and forecast information on the occasions I managed to get through on the phone, and Anders Persson, who trained Deborah to be a forecaster.

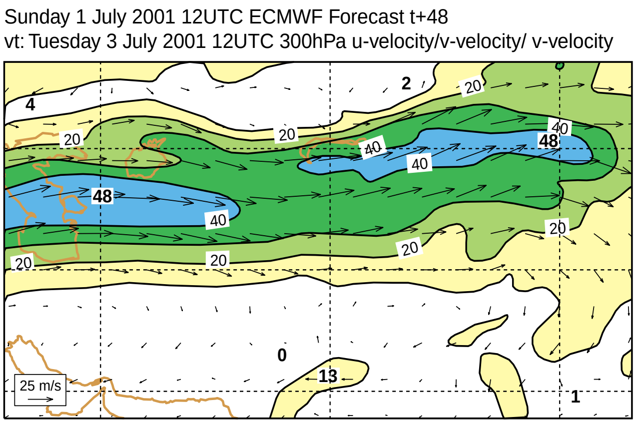


Figure 8 The 48-hour forecast for 12 UTC 3 July 2001 of the wind speed and direction at 300 hPa over the Himalayan area. The central latitude / longitude intersect is at (36°N, 76°E).

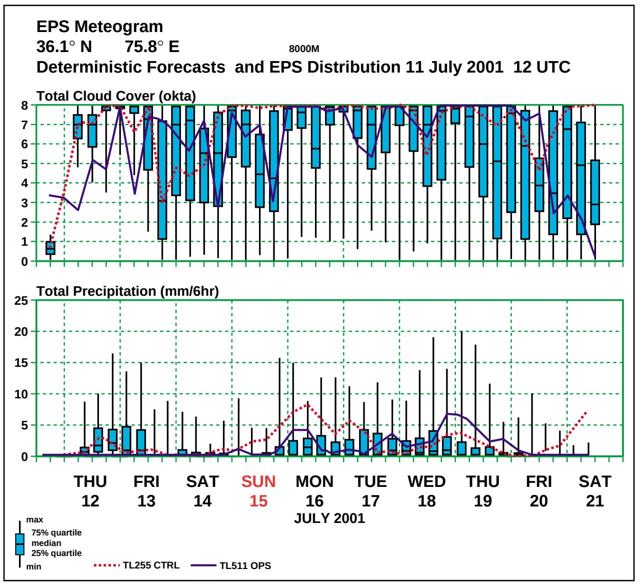


Figure 9 Meteogram at (35.1°N, 75.8°E) covering the period 11 July to 21 July 2001.

Snow on the journey home.
(Photograph: M. Cullen)

Mike Cullen

Weather risk management with the ECMWF ensemble prediction system

There have been several surveys of the impacts of recent occasions of severe weather *(see the suggestions for further reading at the end of this article)*. Damage due to the December 1999 French storm has been estimated to be about $10 billion. The average 1955–1999 annual damage over the US due to tornado, hurricane and flood stands at about $12 billion. Insurance companies have paid out $91.8 billion in losses from weather-related natural disasters in the period 1990–1998. In the United States, average costs of $16 billion are incurred annually for weather-related damages. Weather-related damage due to severe weather events has become more frequent in the past 10 years, and there is an increasing demand from both the public and the commercial world for weather information (data, forecasts) to manage weather-risk exposures.

Single deterministic categorical forecasts may fail to predict the intensity, the spatial location or the temporal occurrence of severe weather events. A more complete approach to numerical weather prediction is to estimate the time evolution of the probability density function of forecast states. The ECMWF Ensemble Prediction System (EPS), based on a finite number of numerical integrations, is a practical tool that can be used to estimate the time evolution of the probability density function of forecast states.

Attention in this article is focused on intense precipitation events that can cause severe damage, and on the potential use of EPS probabilistic predictions for risk assessment. Two main issues are discussed:

- What is the skill of the EPS probabilistic precipitation predictions?
- How can the EPS probabilistic predictions be used to assess weather-related risks?

The ECMWF Ensemble Prediction System

At ECMWF, the EPS became part of the daily operational forecasting system on 19 December 1992. It started with 33 members run with a spectral triangular truncation T63 and 19 vertical levels. From 11 December 1996 to 21 November 2000 the EPS was based on 51 members at T_L159L40 resolution (i.e. a 40-level spectral triangular truncation T159 with linear grid, equivalent to a grid spacing of about 120km at mid latitudes). On 21 November 2000, the EPS resolution was increased to T_L255L40, which is equivalent to a spatial grid spacing of about 80km at mid-latitudes.

The EPS includes a scheme to simulate model uncertainties due to random model error in the parametrized physical processes. For each day d, 50 perturbed initial conditions are defined by adding initial perturbations to the operational (T_L511L60) analysis interpolated to the EPS resolution. The day d initial perturbations are defined using so-called singular vectors growing in the forecast range between day d and day d+2 at the initial time, and singular vectors growing between days d-2 and day d at the final time. The initial perturbations are scaled to have local amplitudes comparable to analysis error estimates.

Quality of the EPS probabilistic precipitation prediction

The quality of a forecasting system is described by the statistical characteristics of the joint distribution of forecasts and observations. This implies that many scalar measures are required to describe the EPS forecast quality or, in other words, that each measure describes a particular aspect of the correspondence between forecasts and observations. For reasons of space, this article presents only a limited set of

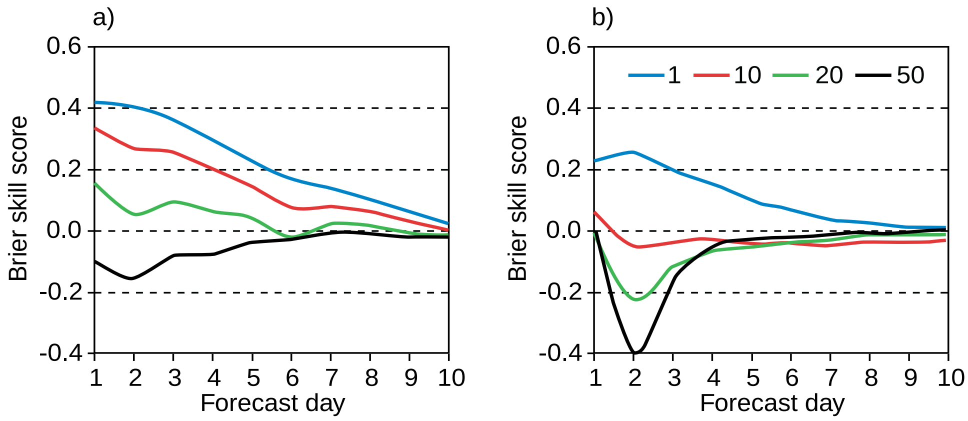


Figure 1 The Brier skill scores for (a) winter and (b) summer for the EPS probabilistic prediction of 1 mm/day (blue line), 10 mm/day (red line), 20 mm/day (green line) and 50 mm/day (black line).

results; the reader is referred to the list at the end of this article (and the references therein) for descriptions of more complete studies of the quality of EPS forecasts.

One of the most commonly used measures of the quality of probabilistic forecasts is the "Brier score". The Brier score measures the mean-square error of probabilistic forecasts; it ranges from 1 for a perfect forecast to 0 for an unskilful one. The "Brier skill score" is defined as the fractional improvement in the Brier score of the EPS forecasts over forecasts based on climatology.

Figure 1 shows the Brier skill score of the EPS probabilistic prediction of 1, 10, 20 and 50 mm/day of precipitation over the United States during the cold (November – March) and warm (May - September) seasons. The results are based on precipitation forecasts interpolated onto a regular 1.25° (latitude-longitude grid from the 51 $\times T_L$159L31 EPS during the three years 1997–1999, verified against the River Forecast Center's data averaged on the same grid; this dataset includes approximately 5000 stations reporting 24-hour accumulated precipitation valid at 12 UTC. Figure 1 shows that accuracy is higher in winter than in summer, with the skill depending on the precipitation threshold. The EPS forecasts of precipitation in excess of 50 mm/day show no skill, but the EPS forecasts of more than 20 mm/day are skilful up to forecast day 6 in winter and day 2 in summer. Precipitation is more predictable in winter than in summer, presumably because the synoptic forcing is stronger and convection is less prevalent in the winter. An investigation into the capability of EPS forecasts to discriminate precipitation events using the area under a "relative operating characteristics" curve as a quality measure concluded that, according to this measure, the forecasts for all four thresholds were skilful in both seasons.

An EPS precipitation verification against observations over Australia for a three-year period confirms these results. A similar verification has not yet been performed over Europe because of the lack of a single database bringing together all the observations from the high-density networks within each of the countries of the continent. To overcome this problem the 0–24 hour ECMWF high-resolution forecast has been used as a proxy for verification purposes. The conclusions of a study based on this database were qualitatively in line with earlier results for other regions of the world. The comparison of the performance of the old coarse-resolution (T_L150L31) and the new high-resolution (T_L255L40) ensemble system for 87 cases indicates that forecasts from the new high-resolution EPS are more accurate. The results indicate a gain in predictability of between 12 and 36 hours.

The sensitivity of the EPS performance to ensemble size and resolution

Ensemble size and model resolution are two key parameters that define the configuration of an ensemble prediction system. On the one hand, it is desirable to have fine resolution in physical space so that the model is able to simulate events with the spatial scale of interest, and on the other hand it is desirable to have a fine resolution in probability space to be able to sample adequately the tails of the forecast probability distribution function. Given that the computer resources available for operational weather prediction are limited, it is necessary to find the right balance between model spatial resolution and ensemble size.

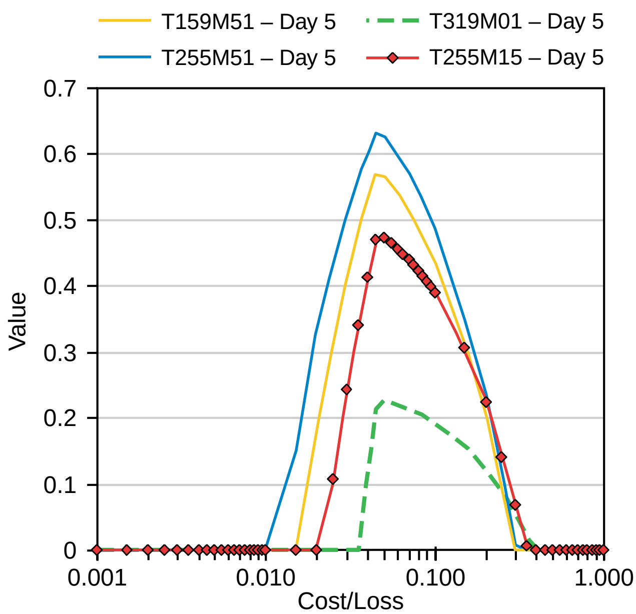


Figure 2 The cost-loss value curves for day-5 EPS precipitation forecasts of more than 20 mm/day over the U.S.A. verified at rain gauge sites, averaged for 57 winter cases for four forecasting systems: 51*T_L159L31 (blue line), 51*T_L255L31 (yellow line), 15*T_L255L31 (red line with diamonds) and single T_L319L31 (dashed green line).

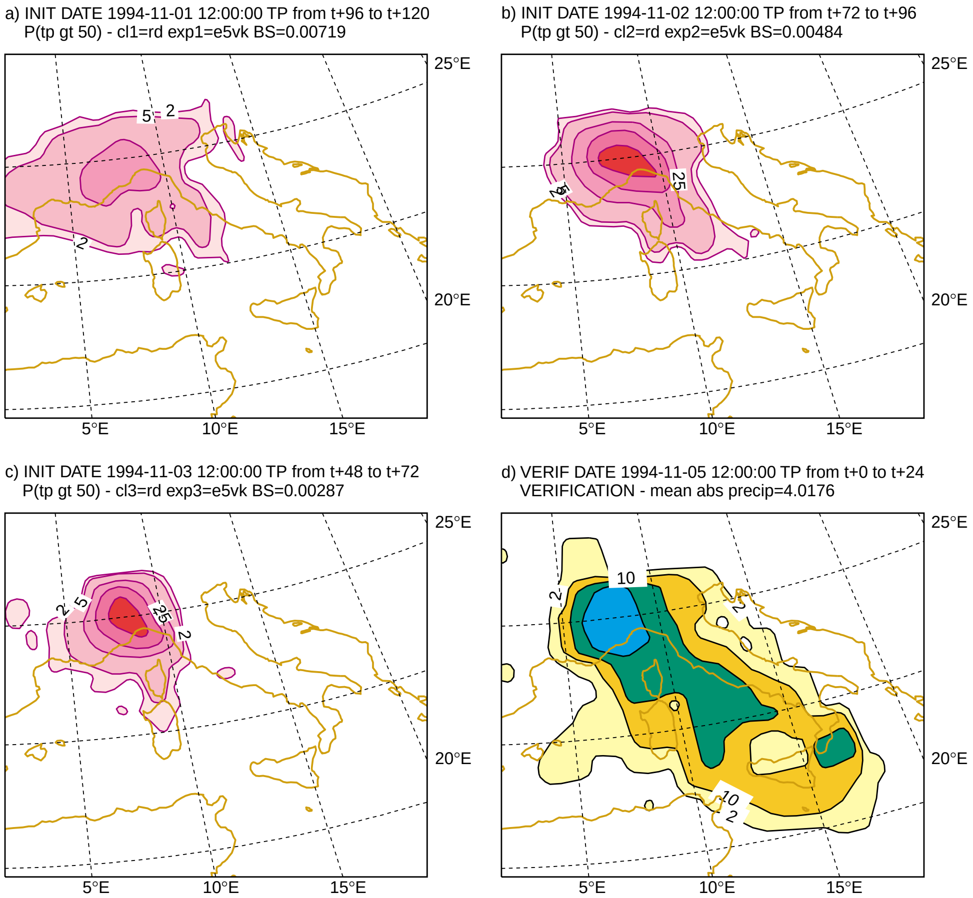


Figure 3 Piemonte, Italy 1994. (a) The EPS forecasts for the event "24-hour precipitation in excess of 50 mm", started on 29 October and valid between 12 UTC 5 November and 12 UTC 6 November (t+168h to 192h). (b) As (a) but for the forecasts started on 31 October (t+120h to t+144h). (c) As (a) but for the forecasts started on 2 November (t+72h to t+96h). (d) The proxy for the verifying observations, defined as the 24-hour T_L319L31 forecast started on 5 November. Contour isolines are 2, 5, 25, 50 and 75% for probabilities, and 2, 10, 25 and 50 mm/day for precipitation.

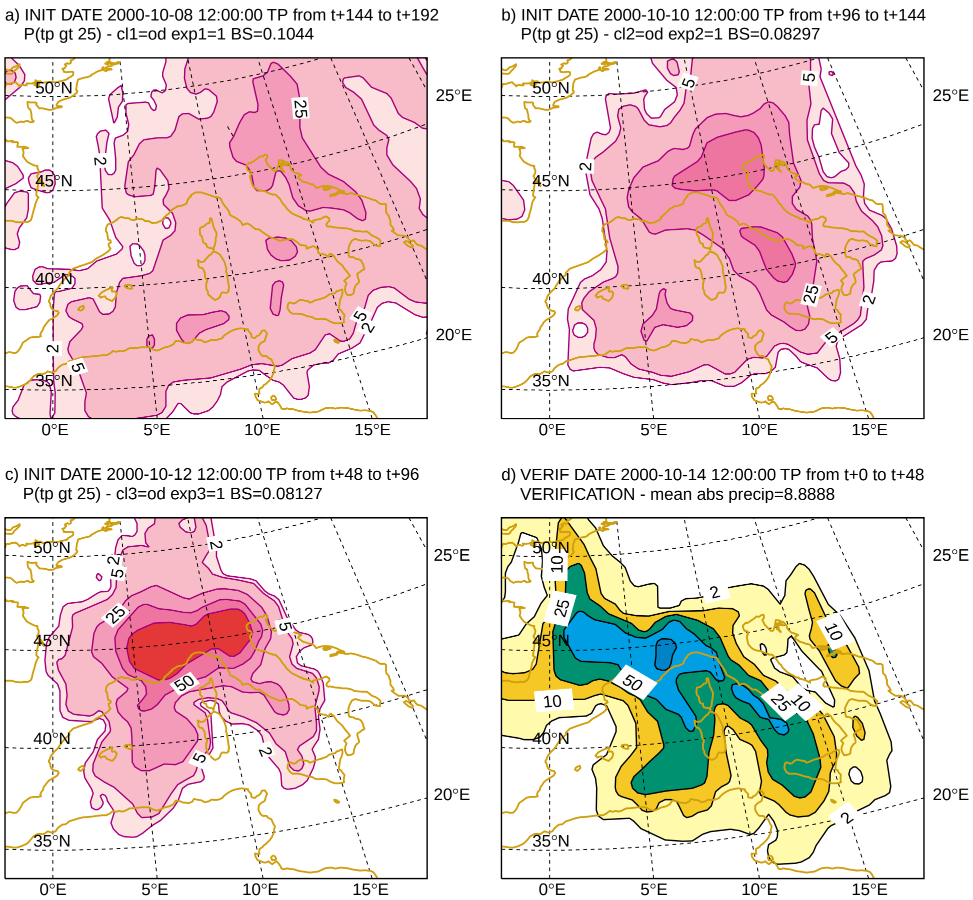


Figure 4 Piemonte, Italy, 2000. (a) The EPS forecasts for the event "48-hour precipitation in excess of 50 mm", started on 8 October and valid between 12 UTC 14 October and 12 UTC 16 October (t+144h to 192h). (b) As (a) but for the forecasts started on 10 October (t+96h to t+144h). (c) As (a) but for the forecasts started on 12 October (t+48h to t+96h). (d) The proxy for the verifying observations, defined as the 48-hour T_L319L31 forecast started on 14 October. Contour isolines are 2, 5, 25, 50 and 75% for probabilities, and 2, 10, 25 and 50 mm/day for precipitation.

The sensitivity of the EPS performance to ensemble size and resolution has been evaluated in terms of the "potential economic value" estimated using a static cost-loss decision model for a dichotomous event. According to this type of decision model a decision-maker can choose to pay a cost *C* to protect against a possible loss *L* (with *L* greater than *C*); if protective action is not taken then the decision-maker incurs a loss *L*, if the adverse event occurs.

Figure 2 shows four cost-loss potential-economic-value curves for the day 5 prediction of the event "precipitation in excess of 20 mm/day" for 57 winter cases, with the EPS forecasts verified at rain-gauge sites. Three curves show the potential economic value for forecasting systems that require approximately the same amount of central-processor-unit (CPU) time; that is, for the three experimental runs: a 51-member T_L159L31 ensemble, a 15-member T_L255L31 ensemble and a single T_L319L31 deterministic forecast. The fourth curve refers to a 51-member T_L255L31 ensemble. Figure 2 indicates that, if the CPU cost is not an issue, increasing the horizontal resolution improves the potential value. However, if the CPU cost is a limiting factor, a larger ensemble size is more important than a higher resolution, especially for small cost-loss ratios. Thus, if the potential economic value of the 20 mm/day precipitation prediction is the most important quality measure used to define the optimal ensemble configuration, then a large-size low-resolution ensemble system is to be preferred to a small-size high-resolution one. It should be stressed that these results are based on raw forecast probabilities defined as the number of ensemble members predicting the event divided by the total membership; the sensitivity to ensemble size may change if distribution-fitting is applied to the EPS probability forecasts.

Precipitation prediction of two flooding events over Italy

In November 1994 and in October 2000 two intense precipitation periods caused severe flooding over northern Italy. Both events occurred during the autumn, a period of the year when the water vapour content of near-surface air masses over the Mediterranean may still be high due to the relatively high sea surface temperatures. Also, local orographic forcing in the region acts to reinforce local ascent.

Very intense precipitation hit Piemonte in northern Italy (45(N, 8(E) between 5 and 6 November 1994. The single deterministic forecast provided by the EPS control proved to be very accurate (not shown). Figure 3 shows the 51 x T_L255L40 EPS probability of "24-hour precipitation in excess of 50mm" verifying between 12 UTC on 5 and 6 November, predicted at lead times of 4, 3 and 2 days from the start of

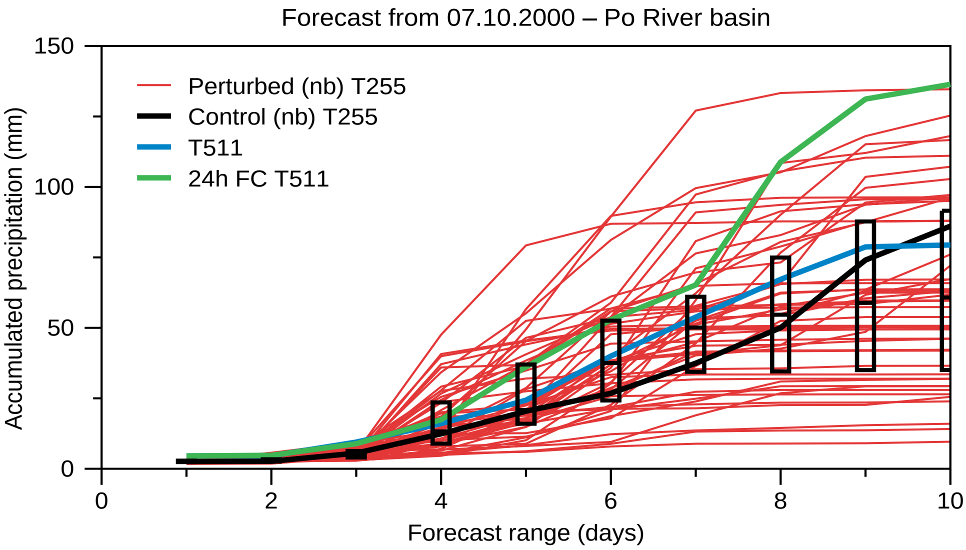


Figure 5 Accumulated precipitation averaged over the Po river catchment area predicted on 7 October 2001 by the EPS perturbed members (thin, red line), the EPS control forecast (blue line) and the T_L511L60 forecast (black line). The green line shows the proxy for the verifying observations given by the accumulated precipitation in the subsequent 24-hour T_L511L60 forecasts.

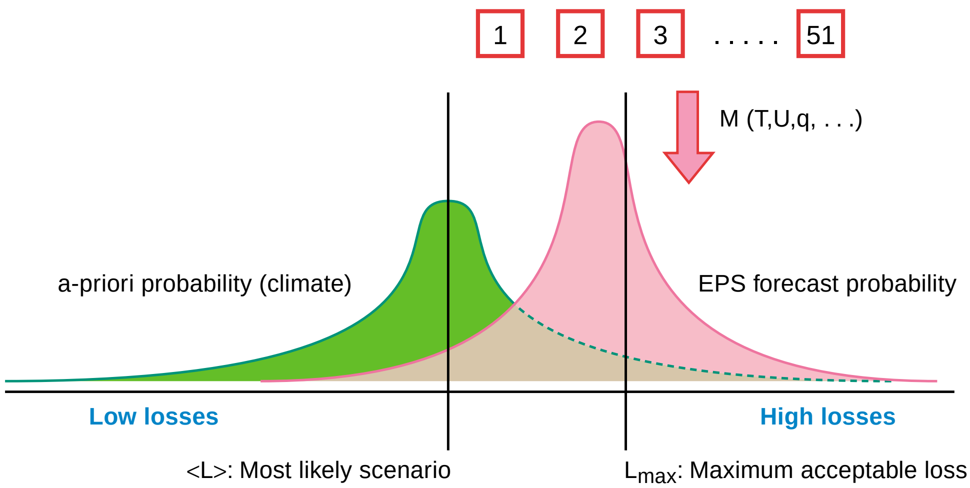


Figure 6 Schematic of the information flow from the ensemble forecasts to the utility distribution function. The EPS single-member weather forecasts (top boxes) can be used as an input to the utility models for predicting the probability distribution function of the utilities (bottom).

the rainy period. The results indicate a very consistent signal, with probability values of 2-30% for the longest lead-time increasing to 60–100% for the shortest lead-time over the location where more than 50mm was observed. These probability forecasts support the forecasts by the deterministic forecast.

Heavy and prolonged precipitation over the catchment area of the Po river (north-western Italy) associated with a cut-off low over the Mediterranean caused severe damage between 14 and 16 October 2000. The single deterministic forecast provided by the EPS control issued on successive days proved rather inconsistent and failed to predict more than 50mm of rainfall 96 hours before the event (not shown). Figure 4 shows the 51*T_L255L40 EPS probability of "48-hour precipitation in excess of 50mm" verifying for accumulations over the two-day period between 12 UTC on 14 and 16 October, predicted with lead times of 4, 3 and 2 days before the start of the precipitation period. The EPS probability forecasts show a westward shift of the area of maximum probability as the lead-time decreases, the forecast with a two-day lead time indicating a 30-60% probability of more than 50mm over the two-day period in the region where this amount is observed. In contrast to the Piemonte case, the EPS forecasts proved to be essential in assessing the possibility of precipitation in excess of 50mm.

The EPS precipitation forecasts have been used to predict the average precipitation over the Po river catchment area. Figure 5 shows the average accumulated precipitation over the Po river catchment area predicted by the EPS started on 7 October. The average accumulated precipitation given by the 24-hour T_L511L60 forecast can be used as a proxy for the observed value. Figure 5 shows that the proxy for the observations is within the EPS forecast range. The EPS gives an 8% (26%) probability of a 10-day total accumulated precipitation of more than 100mm (75mm) over the catchment area.

Risk management with the EPS

The ability to provide forecasts far in advance of the occurrence of severe weather events is necessary in order to improve the quality of systems designed to issue early warnings of potentially severe damage. Timely precipitation forecasts are necessary for driving hydrological models used in flooding forecasting.

Single deterministic forecasts predict only one possible future scenario, say the most probable one, while ensemble systems based on multiple integration can be used to estimate the whole probability distribution function of forecast states. Some users may, in fact, be more interested to know the probability that a rare event will or will not occur, rather than to know the most likely scenario.

Given an individual characterised by a weather-dependant utility U, weather forecasts from each member of an ensemble system can be transformed into a forecast of the probability distribution of the utility. Figure 6 is a schematic of the information flow from forecasts generated by an ensemble system to the utility probability density function estimated using model M. Ensemble forecasts can be used to update and refine an a-priory estimate of possible losses estimated using climatology, and to quantify the probability that a "maximum acceptable loss" L_{MAX} can occur.

This approach has been followed to predict energy demand using ensemble predictions of surface wind, temperature and cloud cover, using a model M that translated each weather state into an energy-demand scenario. It was demonstrated that errors in energy-demand prediction could be reduced by using ensemble forecasts. Similar approaches can be followed using static/dynamic decision models to find the optimal sequence of actions that minimise weather-related losses.

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Roberto Buizza

Linux experience at ECMWF

During the 1990s, ECMWF converted from using an interactive mainframe accessed via terminal emulation using PCs to Unix workstations, initially from SUN and then, as a result of tendering for workstations and server, from SGI. The Unix workstations provided a significantly better working environment for users, benefiting from high resolution bit-mapped displays, increasingly powerful graphics providing improved facilities for visualisation and local processing power. The X-Windows system also provided substantial gains in productivity by allowing users to login to several remote systems simultaneously. The Centre subsequently developed various software packages that take advantage of Unix and the X-Windows – in particular, Metview and XCDP/SMS.

In 1999, in order to prepare for a new tender for desktop systems and servers, the feasibility of using PCs running Linux was investigated. No significant drawbacks were discovered, so it was agreed that Linux-based PCs could be tendered.

After evaluation of the various solutions tendered, IBM was selected to provide PCs running Linux for the desktop systems and RS/6000 SP servers running AIX for the servers. The first batch of twenty PCs was installed in September 2000; at the time of writing, the Centre now has one hundred and thirty PCs, of which forty are in the process of being delivered to users.

Linux Distribution

When first investigating the feasibility of using Linux, several Linux distributions were tried. The main difference between the various distributions is the installation tools that come with the distributions and, for some distributions, the 'package manager' that is used to install software. However, the resulting system is often very similar, since all distributions use basically the same Linux kernel, the GNU software utilities (compilers, libraries etc), X-Windows etc. An increasing volume of commercial software is becoming available for Linux. Although these may be advertised as being only available for certain distributions (e.g. Red Hat), in practice, they will usually work with other distributions.

At ECMWF, the SuSE distribution is used, since it worked well on the systems tested and has so far supported the various hardware combinations that have been employed. However, if at some future time it was found that there were problems using the SuSE distribution that could be solved by using an alternative distribution, then the Centre would change distributions.

Integration into the ECMWF Environment

The Linux systems at ECMWF are integrated into the existing environment in a very similar manner to the way the SGI workstations have been integrated. In particular, all Linux systems are cloned from an initial set-up. They use NIS (Network Information System) to allow users to login to any system using the same username and password. Currently the Linux systems are purely NIS clients, the NIS master and slave servers are SGI systems.

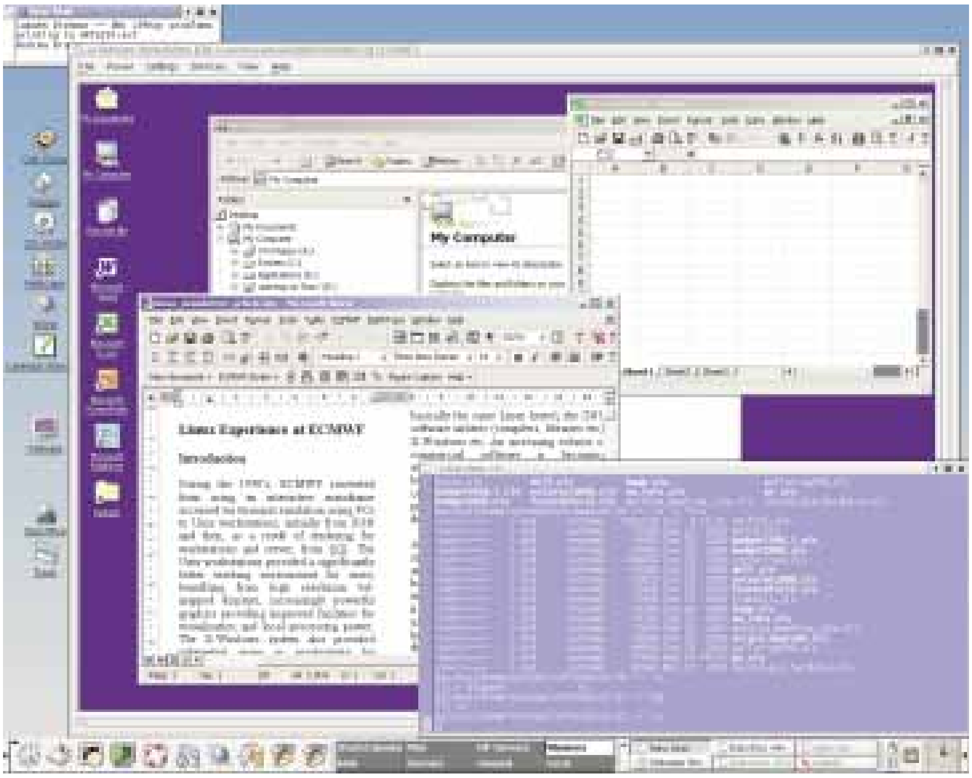
The Linux systems mount file systems from ECMWF's Highly Available NFS fileserver; this includes the HOME file system and /usr/local, which contains binaries for the Linux PCs. Other file systems from the SGI and IBM servers will also be mounted as required using automount.

For printing, the Linux system use the same method as used on the SGI workstations – lpr is used to send files to the central print server system (an lpd server – currently an SGI workstation), from which files are then sent to the appropriate physical printer.

The Linux systems are remotely managed in the same way as the SGI systems are managed, from a central system which can be used to update the remote systems; this can range from updating or installing a single file on the remote system, to installing a complete package.

Hardware Configuration

The PCs that have been installed are IBM Intellistations (60 'M-Pro's, 70 'E-Pro's). They all have Pentium III processors, ranging from 733 to 933 MHz, with 384 MB of memory – the M-pros have RAMBUS memory, the E-Pros have SDRAM), IDE hard disks (13.5 to 20 GB) and Matrox G400 or G450 graphics cards. All the systems have 21" IBM Monitors.



A Linux desktop with VMware running Windows 2000. Within the Windows system, Explorer, Word and Excel are running.

Linux Software

Most of the software available on the Linux systems is installed from the SuSE distribution CDs. A small number of commercial applications are also used (these were already being used on the SGI systems): Crisp (GUI text editor), Portland Group FORTRAN 90 Compiler, Totalview Debugger, SniFF+ (source code browser). Such software is not installed locally on each system, but is installed in /usr/local, which is a shared NFS file system mounted on each system. This is the same way that such software is made available on the Centre's SGI systems.

Naturally, software developed within ECMWF has also been ported onto the Linux systems, in particular Mars client software, Metview and XCDP.

Desktop Configuration

There are various options for the graphical interface provided on the desktop systems, the most well known are KDE and Gnome. At ECMWF, KDE is used, since it provides facilities most similar to the SGI desktop; in particular it allows menus to be customised, icons placed on the desktop and also provides virtual desks or screens. Users can still customize many aspects of the interface to their own preferences.

In order to provide easy access to ECMWF-specific facilities, an ECMWF menu item has been added to the KDE menu, and icons added to the background. This includes menus to start remote terminals on ECMWF's general-purpose SGI servers, to start Metview etc.

Microsoft Windows Software

One of the most significant benefits of using Linux on standard Intel PCs is the possibility to use VMware Workstation to provide a virtual machine which can run a different operating system – in the Centre's case, it is used to allow Windows 2000 to be run at the same time as Linux. The Windows 2000 desktop appears as a separate Window under the Linux system. The figure shows a Linux desktop with VMware running Windows 2000. Within the Windows system, Explorer, Word and Excel are running. Other applications commonly used include Dreamweaver, Visio and Navision (the Centre's accounting and human resources system).

VMware is a commercial product from VMware Inc. (www.vmware.com). VMware is not an emulator like SoftWindows, which provides a virtual PC under various Unix systems with RISC processors (Sun, SGI etc.). VMware runs only on Intel 32-bit x86 compatible processors, Pentium II 266 MHz or better. Applications running on a virtual PC can perform comparably to those running on real machines. The host operating system can be Windows NT 4 or 2000, or Linux; the guest operating system running on the virtual PC can be any operating system that runs on an x86 processor – Windows, Linux, OS2, BeOS etc. At ECMWF, the host system is Linux; the guest system is Windows 2000 Professional.

Using Windows under VMware

The Windows 2000 configuration at ECMWF uses two virtual disk drives (C: & D:); these are actually Linux files stored in a special partition on the PCs hard disk drive. Two drives (i.e. files) are used because of file size limitations in the Linux kernel – files cannot be larger than 2GB, which consequently restricts the size of each drive to 2GB.

Users can access their normal HOME files, as these are made available as the H: drive using Samba, running on the Linux system. Samba is a public domain product which allows Windows clients to access files from Unix systems. The /tmp file system on the local hard disk drive is also made available via Samba (E: drive). The users profile, which contains the user's personal preferences, is saved in a directory in the user's HOME file system when the Windows system is shutdown. VMware also allows the Windows system to access the local floppy and CD-ROM drives.

Various options for networking the Windows system are available. At ECMWF, "bridged" networking is used, so that each Windows system is in effect connected directly to the network, with its own host name (typically host-vm, where host is the hostname of the Linux system). To other systems on the network, the Windows system appears as a totally independent system on the same Ethernet as the host. This also allows the use of a remote shell daemon for Windows to facilitate a limited amount of remote management, in particular keeping the virus checking knowledge database up-to-date on each VMware/Windows system.

For most purposes, the virtual PC provided by VMware is a normal PC. There are some limitations, however. In particular, some physical devices are not currently supported, e.g. writeable or re-writeable CD-ROM drives (CD-R, CD-RW). VMware includes the ability to run in "Full Screen" mode, rather than within an X-Window; however, this currently only works on systems with the older Matrox G400 graphics card when running XFree86 Version 3.

System Cloning

When a new batch of PCs arrives at the Centre, they are cloned from an existing system by booting them using the standard SuSE boot CD, then using a CD written at the Centre, the system hard disk is partitioned and the minimal system software needed to clone the system is copied from the CD into the /spareroot partition. The system is then booted from /spareroot, and the system partitions are copied over the network from a system that has already been set-up. By making use of multicast networking techniques, a batch of systems can be simultaneously and efficiently cloned from one master system. IP addresses and hostnames are assigned at boot time using DHCP.

Once systems have been initially cloned, they can be re-cloned by remotely booting them from the /spareroot partition, and then copying the system partitions over the network from a master system. This method is used for major versions of the system. The VMware partitions, which contain the Windows system disks, can be copied over the network without booting the system, provided VMware is not running.

Problems

Naturally, in a project of this nature, some problems should be expected. The first problem experienced was caused by a change of graphics card. The first batch of IBM Intellistation PCs purchased came with Matrox G400 cards, whereas the subsequent batches have Matrox G450 cards. The first batch was configured with XFree86 Version 3 (XFree86 is the open source X11 server software), however this did not work with the G450 cards. Fortunately, XFree86 Version 4 was then available and this supports the G450.

Unfortunately the latest Version 4 of XFree86 does not directly provide support for "8 bit visuals". This caused problems with Metview Version 1 and with displaying PV-Wave (running on an SGI server), since these both use 8-bit graphics. A workaround involving the use of a second X-server has been implemented, but this is not particularly convenient. The latest version of Metview uses 24 bit graphics, and it is also possible to use PV-Wave with 24 bit graphics.

The version of the C-Shell (csh) which is included in the SuSE Linux distributions is "tcsh", which is an upwards compatible extended version; there are numerous extensions, the most useful is command line editing similar to that available in the Korn Shell. One difference is that "tcsh" uses the TAB character for filename completion, instead of the ESC character.

Successes

ECMWF's users are very pleased with the Linux systems, since they provide the facilities they require for their day-to-day work - email access, web browsing, easy access to Microsoft Word etc., file editing, visualization using Metview, postscript viewers and PDF viewing etc. The response times from the systems are usually excellent, although since the systems are dependent on servers, response times can vary.

The systems are exceedingly stable and the hardware is very reliable.

Use of the Linux/VMware systems for Administration Users

Since the introduction of the Linux/VMware/Windows 2000 systems was so successful, the Centre decided to test the suitability of this system as a replacement for the Windows NT4 desktop systems used by secretaries and within the Administration Department. A few such users were given the Linux-based systems together with Windows 2000 systems with the few extra applications they required installed. No problems were found, in fact the users involved in the trial found the whole system, particularly the virtual desks provided by KDE, very easy to use. Therefore, all such users now have, or will receive soon, Linux-based systems.

There are several advantages for the Centre by adopting this approach. There will be no need to run Microsoft Domain Servers to provide account authentication, since the Linux systems use only Unix/NIS accounts and passwords. Once the migration from SGI workstations has been completed, all desktop systems used in the Centre will be essentially the same (apart from the power of the PCs), making support easier, allowing knowledge spread by peers. This will also allow cascading of systems, so that as newer more powerful systems are purchased, the older systems can be given to users with less demanding requirements. The use of Microsoft Software with its well known exposure to security problems will be restricted to a small environment, and this environment can easily be recreated should major corruption occur.

Support Issues

So far, ECMWF has encountered very few problems that were not solved in house. Support from SuSE has been used to tackle a couple of problems, in particular the 8-bit graphics problems mentioned earlier, and also a problem with using Totalview to debug a program using a dynamic shared library. The response from SuSE was rapid and satisfactory in both cases.

Current Status and Plans

As stated earlier, the Centre has 130 IBM Intellistation PCs currently used by technical and administration users. Scientific and Meteorological users have more demanding requirements, particularly for visualisation and computation. Configurations, which meet these requirements, are currently being evaluated, and it is anticipated that the first batch of some 20 systems will be installed towards the end of 2001. All Scientific and Meteorological users will be migrated from SGI workstations to Linux PCs during 2002 and 2003.

The Linux system itself will be kept up to date as required. SuSE typically release major new versions every 6 months. However, the lack of problems encountered means that there is no great pressure for systems to be constantly upgraded to the latest release.

Conclusions

For these systems to work well they need to be reasonably modern machines, with at least 450 MHz Pentium III processors, and sufficient memory; even 384 MB (as most of the Centre's PCs have) may be insufficient when running several Linux applications and VMware simultaneously.

For ease of managing the systems, it is important to keep the number of different types of PCs as low as possible. This applies particularly to the graphics card and the type of hard disk.

The Linux desktop systems at ECMWF work and work well. The experience has been very positive. ECMWF users get the best of both worlds – a Unix system with its versatility, ease of use, reliability and manageability together with a Windows system to provide access to applications only available under Windows.

Richard Fisker, Jean-François Guéganton, Petra Kogel and Stuart Mitchell

ECMWF publications

Technical Memoranda

324 **M. Matricardi** and **R. Saunders**: A fast radiative transfer model for simulation of IASI radiances, *December 2000*

326 **T. Palmer**, **Č. Branković**, **R. Buizza**, **P. Chessa**, **L. Ferranti**, **B. Hoskins**, **A. Simmons**: A review of predictability and ECMWF forecast performance, with emphasis on Europe, *December 2000*

335 **P. Prior** (Compiler): Report on the thirteenth meeting of Member State Computing Representatives, 3-4 May 2001, *August 2001*

336 **Smith**, **L.A.**, **M.S. Roulston** and **J. von Hardenberg** End to end ensemble forecasting: Towards evaluating the economic value of the Ensemble Prediction System, *March 2001*

337 **Molteni**, **F.**, **R. Buizza**, **C. Marsigli**, **A. Montani**, **F. Nerozzi** and **T. Paccagnella**: A strategy for high-resolution ensemble prediction. Part 1: Definition of representative members and global-model experiments. *May 2001*

338 **Marsigli**, **C.**, **A. Montani**, **F. Nerozzi**, **T. Paccagnella**, **S. Tibaldi**, **F. Molteni** and **R. Buizza**: A strategy for high-resolution ensemble prediction. Part 2: Limited-area experiments in four Alpine flood events, *May 2001*

339 **Morcrette**, **J-J.** The surface downward long-wave radiation in the ECMWF forecast model, *July 2001*

340 **Cherubini**, **T.**, **A. Ghelli** and **F. Lalaurette**: Verification of precipitation forecasts over the Alpine region using a high-density observing network, *June 2001*

341 **Janssen**, **P.A.E.M.**, **J.D. Doyle**, **J. Bidlot**, **B. Hansen**, **L. Isaksen** and **P. Viterbo**: Impact and feedback of ocean waves on the atmosphere, *August 2001*

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ESA Contract Report

M. Janiskova: Preparatory studies for the use of observations from the Earth Radiation Mission in Numerical Weather Prediction. ESA Contract Report, *May 2001*

ECMWF Calendar 2001

Nov 5 – 9	**Workshop** – *Reanalysis*	
Nov 12 – 16	**Eighth ECMWF Workshop on Meteorological Operational Systems**	
Nov 26	**Tech. Advisory Committee**	*Extraordinary*
Nov 27	**Finance Committee**	*Extraordinary*
Dec 10 – 11	**Council**	*55th*

Index of past Newsletter articles

This is a list of major articles published in the ECMWF Newsletter series. Articles are arranged in date order within each subject category, with the most recent article first (articles superseded by more up-to-date articles have been omitted). 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 sites

ECMWF's public web site is: http://www.ecmwf.int
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	Ext
Director	
David Burridge	001
Deputy Director and Head of Research Department	
Anthony Hollingsworth	005
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Dominique Marbouty	003

	Ext
ECMWF switchboard	000
Advisory	
Internet mail addressed to Advisory@ecmwf.int	
Telefax (+44 118 986 9450, marked User Support)	
Computer Division	
Division Head	
Walter Zwieflhofer	050
Computer Operations Section Head	
Claus Hilberg	300
Networking and Computer Security Section Head	
Matteo Dell'Acqua	356
Servers and Desktops Section Head	
Richard Fisker	355
Systems Software Section Head	
Neil Storer	353
User Support Section Head	
Umberto Modigliani	382
User Support Staff	
John Greenaway	385
Norbert Kreitz	381
Dominique Lucas	386
Carsten Maaß	389
Pam Prior	384
Computer Operations	
Call Desk	303
Call Desk email: cdk@ecmwf.int	
Console – Shift Leaders	803
Console fax number +44 118 949 9840	
Console email: ops@ecmwf.int	
Fault reporting – Call Desk	303
Registration – Call Desk	303
Service queries – Call Desk	303
Tape Requests – Tape Librarian	315

	Ext
Software libraries (eclib, nag, etc.)	
John Greenaway	385
ECMWF library & documentation distribution	
Els Kooij-Connally	751
Meteorological Division	
Division Head	
Horst Böttger	060
Applications Section Head	
John Hennessy	400
Graphics Section Head	
Jens Daabeck	375
Operations Section Head	
François Lalaurette	420
Meteorological Analysts	
Antonio Garcia Mendez	424
Anna Ghelli	425
Meteorological Operations Room	426
Data Division	
Division Head	
Adrian Simmons	700
Data Assimilation Section Head	
Erik Anderson	627
Satellite Section Head	
Jean-Nöel Thépaut	621
Diagnostic & Predictability & Seasonal Forecasting Project	
Tim Palmer	600
Reanalysis Project (ERA)	
Saki Uppala	366
Model Division	
Division Head	
Martin Miller	070
Numerical Aspects Section Head	
Mariano Hortal	147
Physical Aspects Section Head	
Anton Beljaars	035
Ocean Waves Section Head	
Peter Janssen	116
Computer Co-ordinator	
David Dent	702
Education & Training	
David Richardson	333