Royal Meteorological Society Buchan Prize

Dr. Roberto Buizza, ECMWF

We are delighted to hear that the Royal Meteorological Society has awarded its Buchan Prize jointly to Roberto Buizza (left) and Franco Molteni (right) for their work on Ensemble Prediction.

The Buchan Prize was instituted to commemorate the amalgamation in 1921 of the Scottish Meteorological Society with the Royal Meteorological Society and is in memory of Alexander Buchan, one of Scotland's foremost meteorologists. The Prize is awarded annually to the author of the paper or papers published in the Quarterly Journal, the International Journal of Climatology, or Atmospheric Science Letters (within five calendar years preceding the year of the award), which are considered by the Council of the Society to contain the most important original contribution or contributions to meteorology.

Dr. Franco Molteni, International Centre for Theoretical Physics (ICTP)

In this issue

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Front Cover

ECMWF's new High-Performance Computing Facility (HPCF) and a description of its next generation data-handling system are covered in this issue.

Editorial

On page 3 Anna Ghelli describes some of the benefits of a project to collect high-resolution precipitation data over Europe. By comparing up-scaled fields of observed precipitation with values predicted by the model, she demonstrates that good forecasts of average accumulations were obtained in several European areas during 2001. On page 8 Martin Miller examines ECMWF forecasts of snowfall in the Great Lakes region of North America around Christmas 2001. Although lake-effect snowfall is essentially a mesoscale phenomenon, his analysis indicates that the current operational deterministic model has sufficient resolution to represent the physical changes in the atmospheric boundary layer that drive and focus the convective snowstorms and, as a result, good predictions of snow accumulation were obtained.

The background to two major ECMWF procurements is described in two articles: the new high-performance computing facility (HPCF) on page 11 and the next-generation data-handling system (DHS) on page 15. The main requirements for an upgrade of the high-performance computer are for improved data assimilation, especially of high-resolution data from the next generation of satellite-based remote sensors, and increased horizontal and vertical resolution for 4D-Var and the deterministic forecast system. The evaluation of the competitive tendering procedure resulted in a contract being awarded for a system based on IBM's POWER4 microprocessors; the computer architecture is radically different from the Centre's present HPCF, but it is expected eventually to produce a peak performance of over 20 Tflops. The growth of the ECMWF's data archive from 30 Tbytes in 1997 to over 400 Tbytes in 2001, and an anticipation that growth in the future would continue to be roughly in line with the increase in the power of the HPCF, led to the issue of an invitation-to-tender for a replacement DHS; a proposal from IBM has been selected. The new DHS will be installed in phases. Users will, as now, access the new storage facility via ECFS or MARS, but considerable effort will be involved in migrating the current archive to the new system.

An interesting outline of changes in the Hungarian National Meteorological Service, as it was forced to adapt to different political systems imposed over the past century, is given on page 17 by its current Director, Dr Mersich.

Peter White

Changes to the Operational Forecasting System

On 4 December 2001 a bug fix was introduced into the snow-depth analysis scheme. Since the introduction of CY22r3 (June 2000), snow-depth observations were converted to equivalent liquid water using an erroneous scaling factor; this had little effect on the snow cover but resulted in a significant underestimation of the snow depth where observations were available.

On 22 January 2002, an upgraded version of the model, CY24r3, was implemented. This version includes several important changes that together affect all components of the system (data assimilation, atmospheric and oceanic wave forecasts, EPS):

- More data are now activated (SeaWinds data from QUIKSCAT, 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 observation have been refined;
- 4D-Var analysis algorithms has been upgraded: pre-conditioning has been added to the minimization, resulting in a 40% reduction of the number of adiabatic iterations; correlation functions have been 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 now 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 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.)

Following thorough testing and evaluation of the new model cycle, verification has shown a robust improvement of upper-air scores for all domains and forecast ranges, most notably over the southern hemisphere and at higher levels. Preliminary verification of tropical-cyclone tracks in September and October has also shown significant improvements, both in deterministic and probabilistic modes. Case studies have demonstrated a reduction in the number of occasionally spurious developments of small-scale cyclones over sea.

On 4 March 2002, a new blacklisting procedure was introduced to avoid using AMV (ex-SATOB) winds during time-slots likely to be affected by solar-eclipse problems.

On 5 March 2002, a bug fix was introduced into the post-processing of gust winds in the EPS; prior to that date, the maximum was over the last 6 hours, not 12 hours as it should have been.

On 9 April 2002 an upgraded version of the model, CY25r1, was implemented. This version includes a revised short-wave radiation scheme with variable effective radius of liquid cloud water, retuning of the land-surface parametrization (TESSEL) to reduce winter/spring warm biases in low-level temperatures, improved physics for the oceanic wave model, improved wind-gust post-processing, and the activation of new data streams in the assimilation (water-vapour radiances from Meteosat-7, SBUV and GOME ozone data, European wind profilers). A bug in the convective momentum transfer was also fixed. Verification has shown a small improvement in the upper-air scores, most notably at high levels and over warm continental land masses

François Lalaurette

Verification of precipitation forecasts using data from high-resolution observation networks

Precipitation is undoubtedly of great interest in everybody's daily life. Farmers may be interested because they want to know whether to spray crops with pesticides or not, and water-management bodies may want to know whether to open dams to prevent flooding. As precipitation forecasting is so important, do we know how well our forecasting systems perform? Assessment of forecast performance encompasses a direct comparison of the model forecasts against the observations, or against gridded analyses of the observations themselves. Verification against single observations involves an interpolation procedure to produce a forecast value at the observed location. The underlining philosophy of this approach is to consider the precipitation forecast as a grid-point value. It is also important to remember that comparison of a model forecast with an observation at a single station introduces large representative errors, as the observed value is actually representing a local spatial scale which the forecasting system cannot simulate. *Cherubini et al.* (2002) discussed the performance of a mesoscale model and showed that, to be able to compare a single observation with a model forecast whilst avoiding representativity errors, the spatial resolution of the forecasting system must be less than 9 km. We cannot envisage that such a spatial resolution could be used in global circulation models for quite a long time, if ever.

Verification against gridded analyses supports the idea that precipitation is an areal quantity, and recent studies at ECMWF (*Ghelli and Lalaurette*, 2000; *Cherubini et al.*, 2002) have shown that model forecasts compares better with gridded analyses because the model and observed fields then describe similar spatial scales.

In early 2001 a project started at ECMWF to collect high-density observing network precipitation data. Member States and Co-operating States were invited to collaborate in this extensive effort that will entail the construction of gridded precipitation analyses for Europe. Preliminary results of the project are presented in this article. A gridded analysis is built using the high-resolution data available for the European area. Verification against such an analysis is done for the month of September 2001 in terms of bias. The distribution, and the area-averaged and time-averaged scores are calculated for June, July and August 2001. Finally, a case study is considered showing how a customised use of the deterministic forecast can add value to the forecast itself.

Models and data

The deterministic model used in this study is the ECMWF global circulation model with a spectral resolution of T_L511, corresponding to a spatial resolution of about 40 km in mid-latitudes. There are 60 levels in the vertical.

The observations, received routinely, are 24 accumulated values of precipitation, though the accumulation starting time varies between 06 and 09 local time. The gridded analysis is built using the up-scaling technique described by *Ghelli and Lalaurette* (2000) and consists of allocating each station to a grid box, averaging all the values within each grid box, and assigning the averaged value to the appropriate grid point. The average number of stations per grid box is of the order of 4–5 (obviously, this varies between one country and another depending on the total number of meteorological stations available).

Frequency Bias Index (*FBI*), Equitable Threat Score (*ETS*) and the Hansen-Kuipers Discriminant (also called True Statistics Skill, *TSS*) are used to assess the deterministic model performance. A review of these scores can be found in the paper by *Wilks* (1995). The precipitation thresholds chosen for evaluating the deterministic forecast are 0.1, 1.0, 2.0, 8.0, and 16.0 mm per 24 hours. These thresholds are open; therefore a threshold of 0.1 mm per 24 hours includes all the events with precipitation larger than the specified threshold. Table 1 shows a generic contingency table.

The scores are written as follows:

$$FBI = (a + b) \ / \ (a + c)$$

$$ETS = a - R(a) \ / \ (a + b + c - R(a))$$

where

$$R(a) = (a + b) \bullet (a + c) \ / \ (a + b + c + d)$$

and finally

$$TSS = ad - bc \ / \ (a + c)(b + d)$$

The *FBI* measures the event frequency and has value one for a perfect forecast, and larger (smaller) than one if the system is over (under) forecasting. It does not give any indication on the accuracy of the forecasting system. The *ETS* is a modified version of the Threat Score rendered equitable by taking away the random forecast *R*(a). The *ETS* is zero for a chance and constant forecast, and equals one for a perfect forecast. The *TSS* is equal to zero for a random and a constant forecast, while a rare-event forecast correctly receives a higher score.

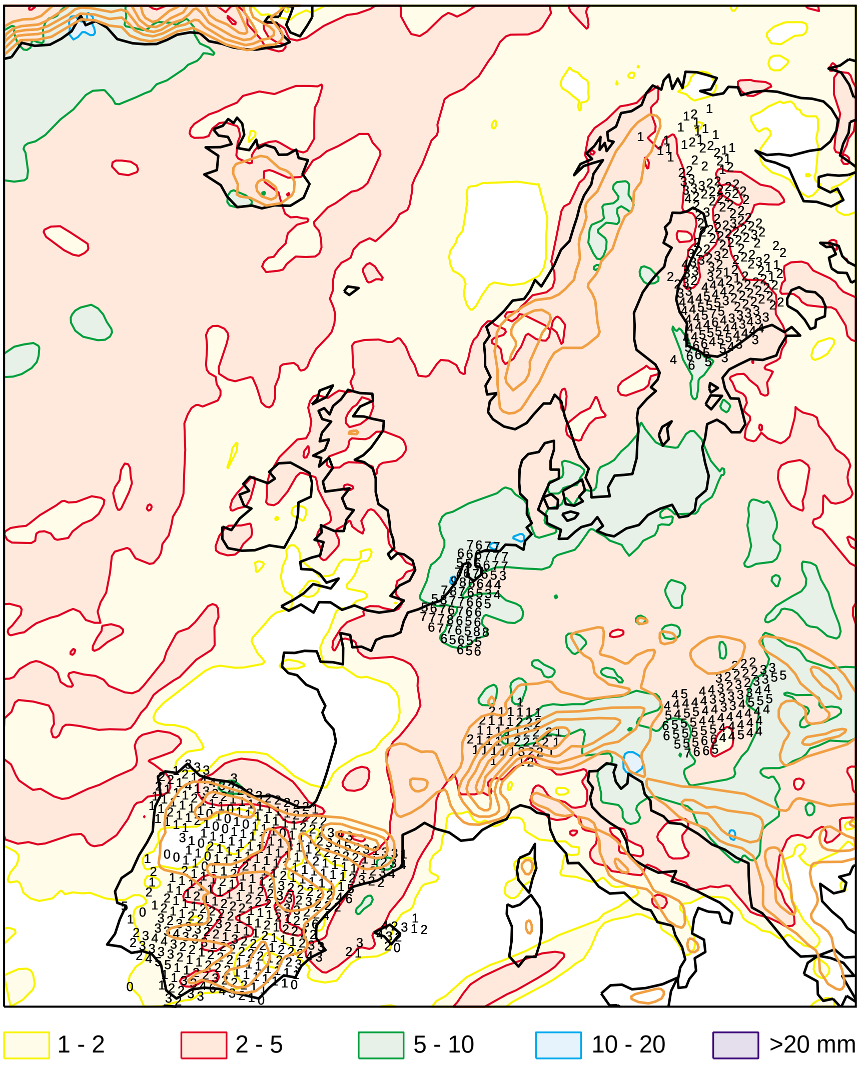

Figure 1 Averaged monthly precipitation forecast field (shaded areas) for September 2001. The analysis of the observed precipitation field averaged over the same period is superimposed (black numbers). The orography is shown as orange contours.

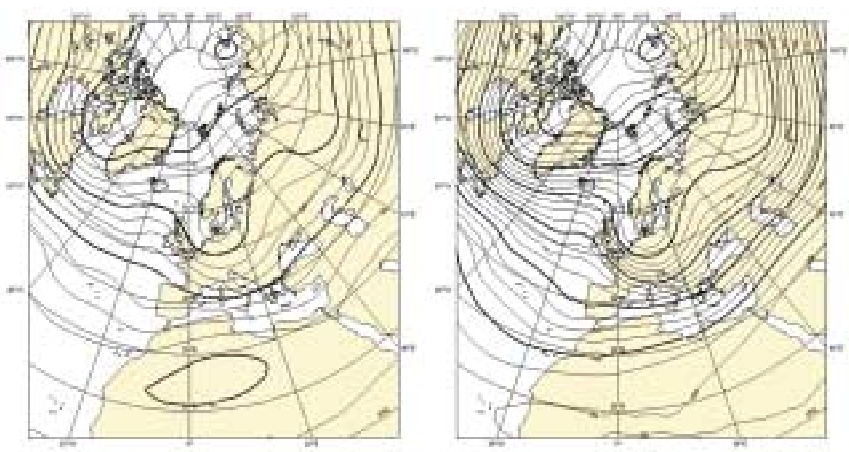

Figure 2 Monthly average geopotential height for September 2001. The left panel shows the 500 hPa and the right panel the 300 hPa.

	Observed YES	Observed NO
Forecast YES	a	b
Forecast NO	c	d

Table 1 Generic contigency table: ***a*** represents the number of correct forecasts, ***b*** is the number of wrong forecasts, ***c*** indicates the number of incorrect forecasts of the 'NO' event and ***d*** shows the number of correct forecasts of the 'NO' event.

Forecast bias for September 2001

Figure 1 depicts the monthly averaged 24-hour accumulated precipitation for September 2001. The shaded areas represent the average forecast precipitation for the range t+42h, while the numbers in black represent the averaged observed precipitation up-scaled to the model grid. In the up-scaling procedure, the land-sea mask has not been used and this results in a precipitation analysis containing values on the sea, even though no sea observations are contained in the high-resolution datasets.

The precipitation forecast largely agrees with the observed distribution pattern in Hungary, Belgium and The Netherlands. The precipitation over the Alps is slightly overestimated and it is probably due to the prevalence of northerly flow (Figure 2) interacting with the mountain range and overestimating the precipitation on the windward side of the mountain chain. The overall value of the bias is -0.07 mm per 24 hours, which indicates a very good agreement between observed and forecast precipitation fields.

The monthly average for September 2001 in the Iberian Peninsula shows a general agreement between the precipitation forecast pattern and the observed values. In the southwest corner of the Peninsula, the observed amounts are higher than the forecast values. This negative bias (forecast minus observed) is due to a frontal system that approached the Iberian Peninsula during the second half of the month, bringing large amounts of precipitation. Maxima of 56 mm per 24 hours were reported in the southwest corner of the Peninsula. This event, because of its large amount of rainfall, heavily influenced the monthly average.

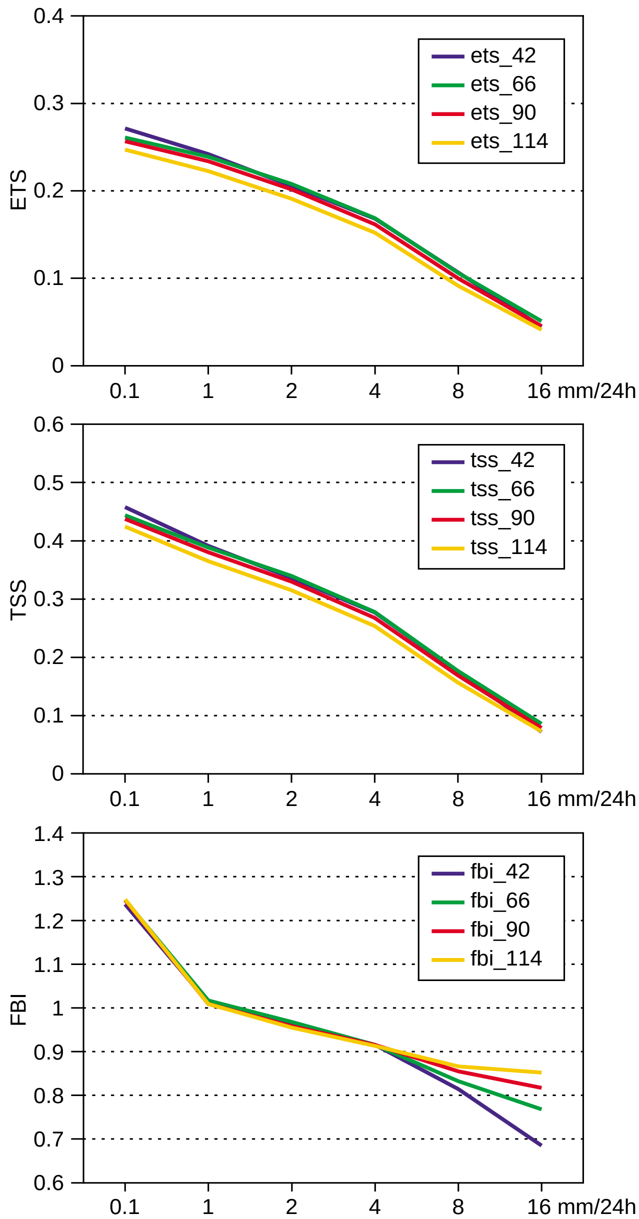

Figure 3 FBI (top panel), TSS (middle panel) and ETS (bottom panel) relative to summer 2001 (June–July–August). The legend indicates the various time steps used.

Results for Summer 2001

In this section, the performance of the model in summer 2001 is assessed using the high-resolution observations available for the whole period (June, July and August). The locations of the observations available are the same as those seen in Figure 1, except for Finland. Even though the dataset is limited, the results are quite interesting, especially for the lower thresholds of precipitation. Higher thresholds are more sensibly affected by sample-size problems.

The FBI, TSS and ETS are plotted in Figure 3 for different forecast ranges and for the thresholds of 0.1, 1.0, 2.0, 4.0, 8.0, and 16.0 mm per 24 hours. The first interesting aspect is that the forecast does not degenerate so quickly as we go to longer time periods. The quantitative precipitation forecast quality exhibits little sensitivity to the forecast length, for all the scores. *Ebert et al.* (2002) showed that the equitable threat score for the ECMWF model over Germany has a strong dependence on the forecast range during the period 1997–2000, which preceded the introduction into operations of the high-resolution deterministic model, T_L511. A more detailed analysis is needed to draw any definite conclusion on the influence of higher resolution on the scores.

The FBI shows noticeable overestimation of rainy events for the 0.1 threshold while, for higher thresholds up to 4.0 mm per 24 hours, the model slightly underestimates the rainy events. The noise due to sample size becomes very important for higher thresholds, and so no valuable conclusion can be drawn. The TSS is in excess of 0.4 for the lower threshold, and decreases for higher thresholds. The ETS shows a similar behaviour, with a skilful forecast for small thresholds and decreasing as the threshold is increased. This behaviour was also found by *Cherubini et al.* (2002) and *Ghelli and Lalaurette* (2000). The ETS maximum is in excess of 0.25, not an unusual value in summer months. In the summertime, the synoptic features are weaker and the model has to rely on a good convective parameterisation. *Ebert et al.* (2002) found that most of the operational numerical weather prediction models examined in an assessment by the Working Group on Numerical Experimentation (WGNE) have a clear decrease in skill in the summertime.

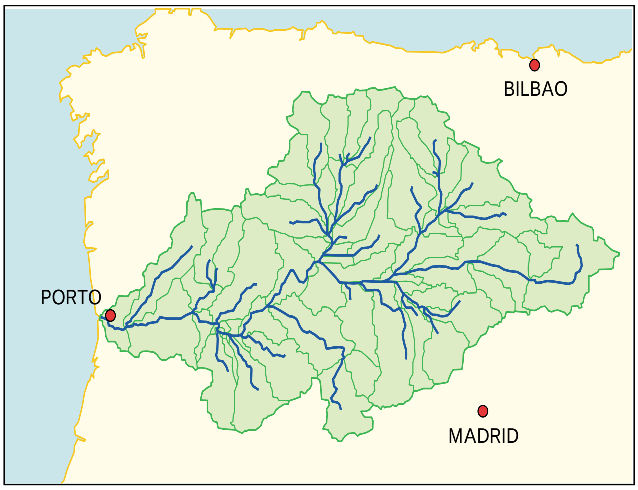

Figure 4 The catchment area of the Duero/Duoro.

Heavy rainfall in Portugal and Spain (February–March 2001)

The end of February and beginning of March 2001 was characterised by heavy and prolonged precipitation over the northern part of the Iberian Peninsula. The persistence of the rain affected the catchment area of the river Duero/Duoro and caused an increase in the levels of rivers with disruption to the population. The Duero/Duoro rises to the northeast of Madrid and runs on the south side of the Cordillera Cantabrica. The catchment area is quite large and encompasses lot of tributaries (Figure 4).

Figure 5 shows the 12 UTC forecast from 2 March 2001 for the t+42h range. The 24-hour accumulated field verifies at 06 UTC 4 March 2001 (accumulated from the previous day at the same time). The numbers represent the observed precipitation (up-scaled to the model grid). The forecast field broadly agrees with the observed with some exception in central Spain where the precipitation is underestimated. The maximum precipitation forecast is located to the northwest of the Peninsula with a maximum of 54 mm per 24 hours. The largest observed values are also in the same area, with an isolated maximum of 124 mm per 24 hours. This large value is either associated with a very local effect or with the quality of the observation itself. In this area the density of the meteorological stations is not high. The upscaling technique tries to use as many observing stations as possible, compromising between representativity problems and loss of information when isolated stations are not considered in the up-scaling technique itself.

Figure 6 represents the observed accumulated precipitation over the period 27 February 2001 to 10 March 2001. The total rainfall for the ten-day period averaged over an area that comprises most of the catchment area of the Duoro/Duero is 130 mm, 70% of which fell in the first five days. Figure 7(a) depicts the area-averaged and time-integrated precipitation forecast from 25 February 2001. The x-axis indicates the forecast range (days) from the forecast start date and the y-axis is the accumulated precipitation. The forecast (black line) compares well with the observed rain (red line) and manages by D+6h to predict an accumulated rainfall of 80 mm. The model predicts most of the precipitation from D+4h to D+5h.

The subsequent forecast (start date 26 February 2001) underestimates the amount of precipitation for all the ranges (Figure 7(b)). At D+6h the forecast precipitation is about 50% of the observed amount. The reason for the poor quality of the forecast is related to the time delay of a low-pressure system (D+2h and D+3h forecast) that moves eastward into the northern part of the Iberian Peninsula. The precipitation field associated with this low is, therefore, delayed leading to an underestimate of the accumulation already by D+3h, which affects the subsequent forecasts. The next forecast (start date 27 February 2001) simulates the observed precipitation better (Figure 7(c)), with an underestimation of the accumulated amount of about 20 mm by D+4h. It is interesting to note that the forecast is already underestimating the observed rainfall at D+1h, and thus the first 24-hour forecast, if used as a proxy for the observed precipitation, may not truly represent the observed field. The forecast started on 28 February 2001 (Figure 7(d)) underestimates the

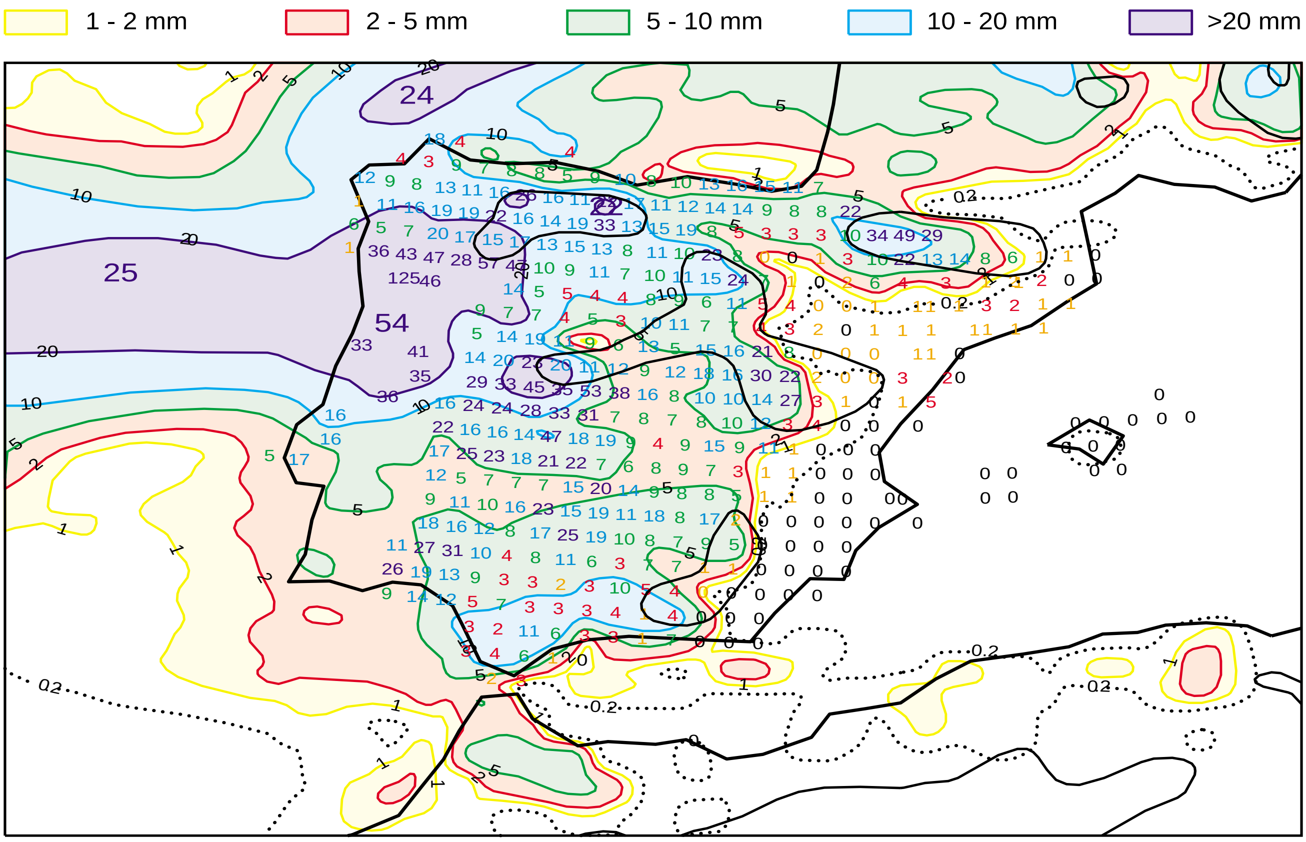

Figure 5 24-hour accumulated precipitation forecast (start date 2 March 2001) verifying on 4 March 2001 at 06 UTC. Shaded areas represent the forecast field and the numbers are the up-scaled observations.

observed precipitation by about 30% at D+3h and D+4h, but by D+6h the forecast precipitation field is in good agreement with the observed rainfall.

This case study is an example of how forecasts could be used for water-management purposes. The area-averaged and time-integrated precipitation forecasts consistently indicated several successive days of rainfall for the Duero/Duoro basin. This weather pattern severely affected the levels of the tributaries and reservoirs, causing disruption to the population.

Observations from some of the high-density observing networks in the Member States and Co-operating States have been used to verify the model performance. Such data provide an invaluable source of information to validate our model. The observations have been up-scaled to represent spatial scales similar to those of the forecasting system.

Verification of forecasting systems is necessary to ascertain their strengths and weaknesses. Fair comparison requires the observations to represent spatial scales similar to those of the forecasting system itself. The procedure presented in this paper tries to up-scale the information contained in the high-resolution observations to the model resolution. This guarantees a fair comparison and, therefore, a better estimate of the forecast value.

The averaged forecast rainfall for the month of September 2001 is in good agreement with the observed precipitation averaged over the same period. Precipitation forecasts over the Alpine regions are problematic and flow dependent. In September the prevalence of northerly flow led to an overestimation of the precipitation amounts on the northern side of the Alps. Further investigation is needed to confirm these results.

The performance of the model during summer 2001 has been assessed with the FBI, TSS and ETS. The FBI showed overestimation of the rain frequency for small thresholds and

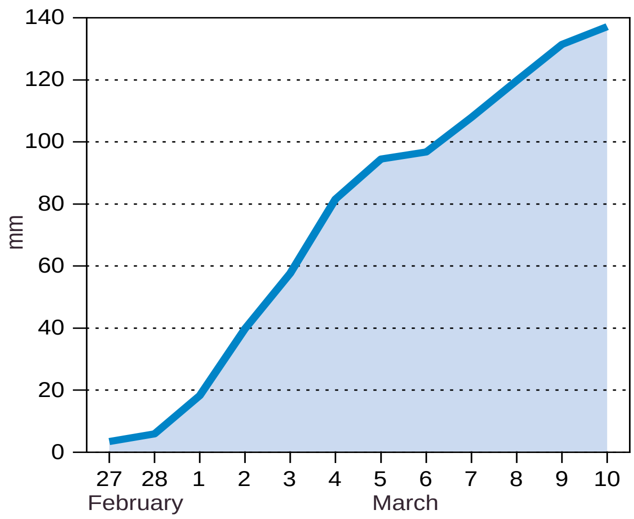

Figure 6 Accumulated observed precipitation for the catchment area of the Duero/Duoro for the period 27 February to 10 March 2001.

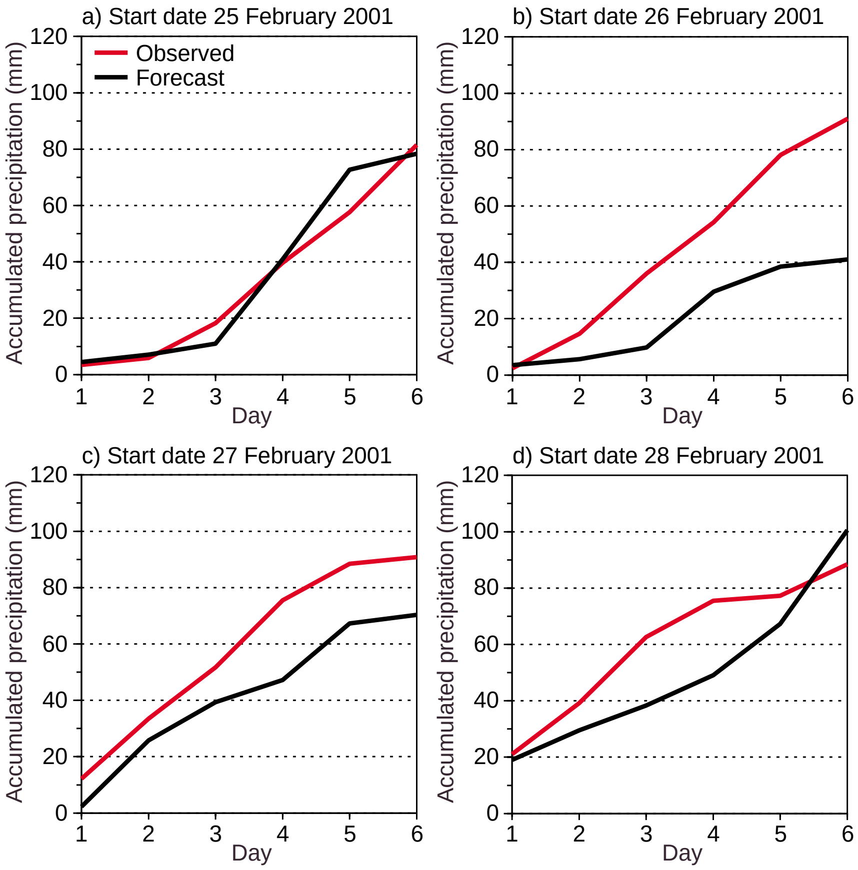

Figure 7 Time integrated precipitation for the catchment area. The six-day forecast start dates are: a) 25 February 2001 b) 26 February 2001 c) 27 February 2001 and d) 28 February 2001. The precipitation is accumulated from day 1 to day 6.

slight underestimation for higher thresholds. The ETS and TSS support the conclusion that the system is more skilful for lower thresholds, while both ETS and TSS values decrease as the threshold increases. Interestingly none of the scores shows dependency on the forecast range.

The case study discussed in the paper relates to a period of heavy rainfall in Spain and Portugal in March 2001. The rainfall lasted for few consecutive days causing the saturation of reservoirs and river basins. Four successive forecasts have been analysed up to D+6h for the Duoro/Duero catchment area. The precipitation forecast has been accumulated over the forecast period and compared with the observed accumulated rainfall. The high-resolution deterministic model succeeds in forecasting the continuous precipitation with some consistency. The forecast of 26 February 2001 shows how a delayed low-pressure system can affect the precipitation in the whole catchment area. The performance of the Ensemble Prediction System could be investigated using the case study presented in this paper. Hollingsworth et al. have assessed the performance of the EPS in forecasting a flood that occurred in the Po valley in Italy. They showed how value could be added to the forecast by using area-averaged and time-integrated forecasts.

The link between precipitation forecasts and water management is very strong and crucial for sustainable development. It is, therefore, important that meteorologists and hydrologists come together to work on new products that add value to what each community can separately produce. The case study presented in this paper is an example of what could be done for Europe with the help of our Member States and Co-operating States.

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Anna Ghelli

Dreaming of a white Christmas!

During the week of Christmas 2001, the TV, always short of news at this time, referred to Buffalo, NY State as the perfect place for a snowy Christmas holiday period. This is immediately recognizable as a lake-effect snowfall as can be seen in the reported snow depths shown in Figures 1(a)–(c). Although there are small amounts in many locations it is striking to see the large depths localized on the eastern ends of the Great Lakes. Between 1200 and 1800 UTC on 27 December 2001, Buffalo, situated right at the eastern end of Lake Erie (the most southerly of the Lakes), recorded 26 cm of fresh snow, with a total accumulation of 89 cm by 1800 UTC. Heavy snow in coastal regions is a notable phenomenon in several parts of the world e.g. the north-west coast of Japan, the east coast of Sweden bordering the Baltic and even the coastal zones of East Anglia and south-east England bordering the North Sea and English Channel. In each case cold continental air advects over relatively warm water and extensive convection forms, bringing heavy and persistent snow to the windward coast. During the first half of the winter, the Great Lakes of North America are open water with surface temperatures a few degrees above zero, and hence can generate a particularly marked form of this phenomenon as described above. The GOES IR imagery, Figure 2, shows the development of cold cloud tops over the Lakes consistent with the above description. The ability to forecast this dramatic weather is the topic of this note.

Lake-effect snow is recognized as a mesoscale event, but its nature is such that it is interesting to know if a global model, such as that run operationally by ECMWF, can represent it, at least to some degree. How did the operational T511 forecast perform? Figure 3 shows an encouragingly good representation by the model using the physics package (CY23r4) current at that time, with nearly 30 cm of snowfall (converted using a factor of ten from water equivalent). The top figure shows the 10 m wind (from midway through the 3-day forecast) superimposed so as to emphasize the mechanism described in the first paragraph, while the bottom figure shows the accumulated grid-point values. Forecasts out to six days were consistently skilful (not shown). Cross-sections along Lake Erie of potential temperature and specific humidity are shown in Figure 4. The planetary boundary layer transformation is very marked, as expected, and surface energy fluxes over the Lakes are in the region of 200–300 W/m^2, roughly equipartitioned between sensible- and latent-heat fluxes.

Tephigrams upwind and downwind of the lake (Figure 5) show how a very cold stable sounding is transformed into a convectively unstable one (up to about 750 hPa). The localized snowfall maxima are generated by the model's convective component, whilst the non-convective component provides the background more widespread snowfall from the developing cloud layer. One assessment of the sensitivity of these results to the forecast system was readily available as the CY24r3 (which included changes to allow precipitation from shallow convection) e-suite was running in parallel at this time; Figure 6 compared with Figure 3(b) shows only small differences. Considering the spatial scales of this phenomenon, the current EPS (T255 resolution) would be expected to have limited abilities. Figure 7 shows this to be the case, with some indications of the effect but that is all. Other ensemble members showed only small variations from this Control result. This is, however, a severe weather event of high predictability that is probably only captured by high enough resolution.

The current operational forecast system has sufficient resolution and physical realism to capture lake-effect snowfall. Boundary-layer air spends up to several hours crossing the Great Lakes and, although represented by only a few grid

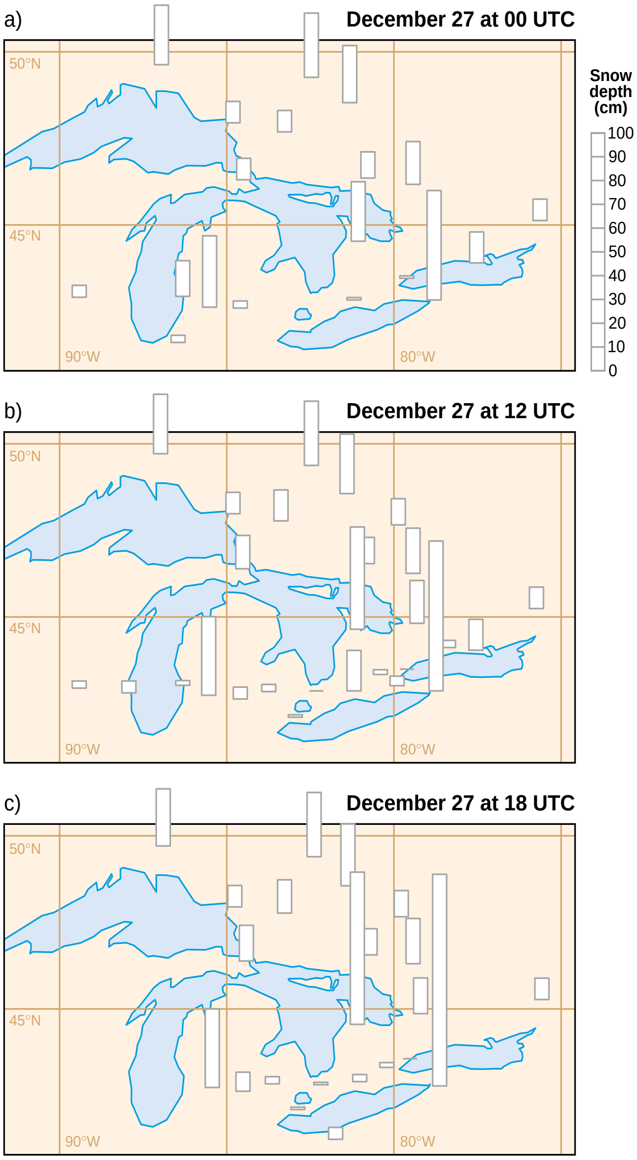

Figure 1 SYNOP snow-depth reports (cm) for three synoptic times.

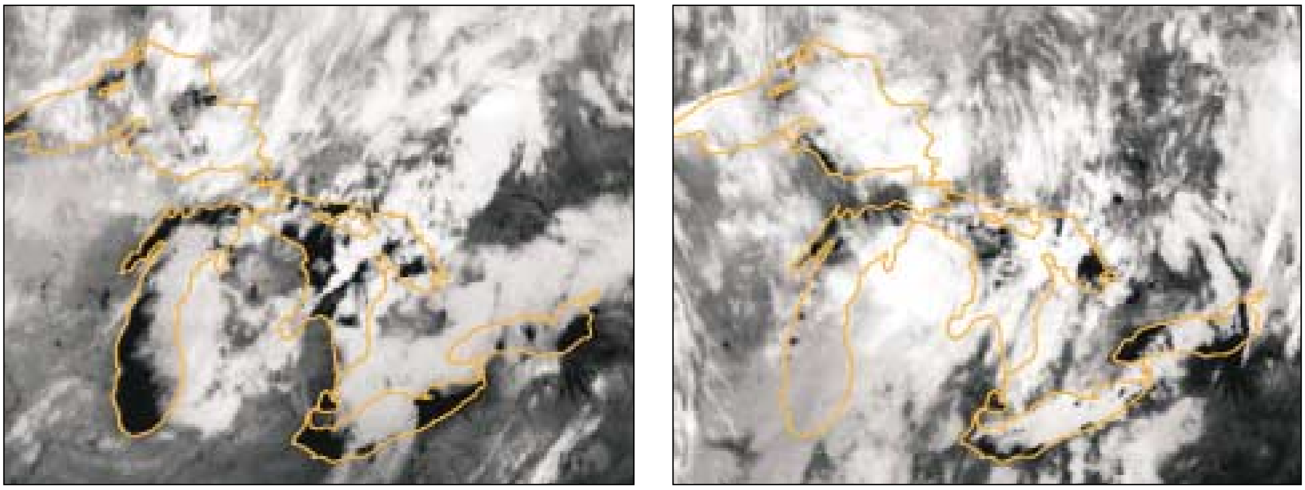

Figure 2 GOES-8 IR imagery for 11:45 UTC and 23:45 UTC on 26 December 2001. *(Courtesy of Christina Köpken)*

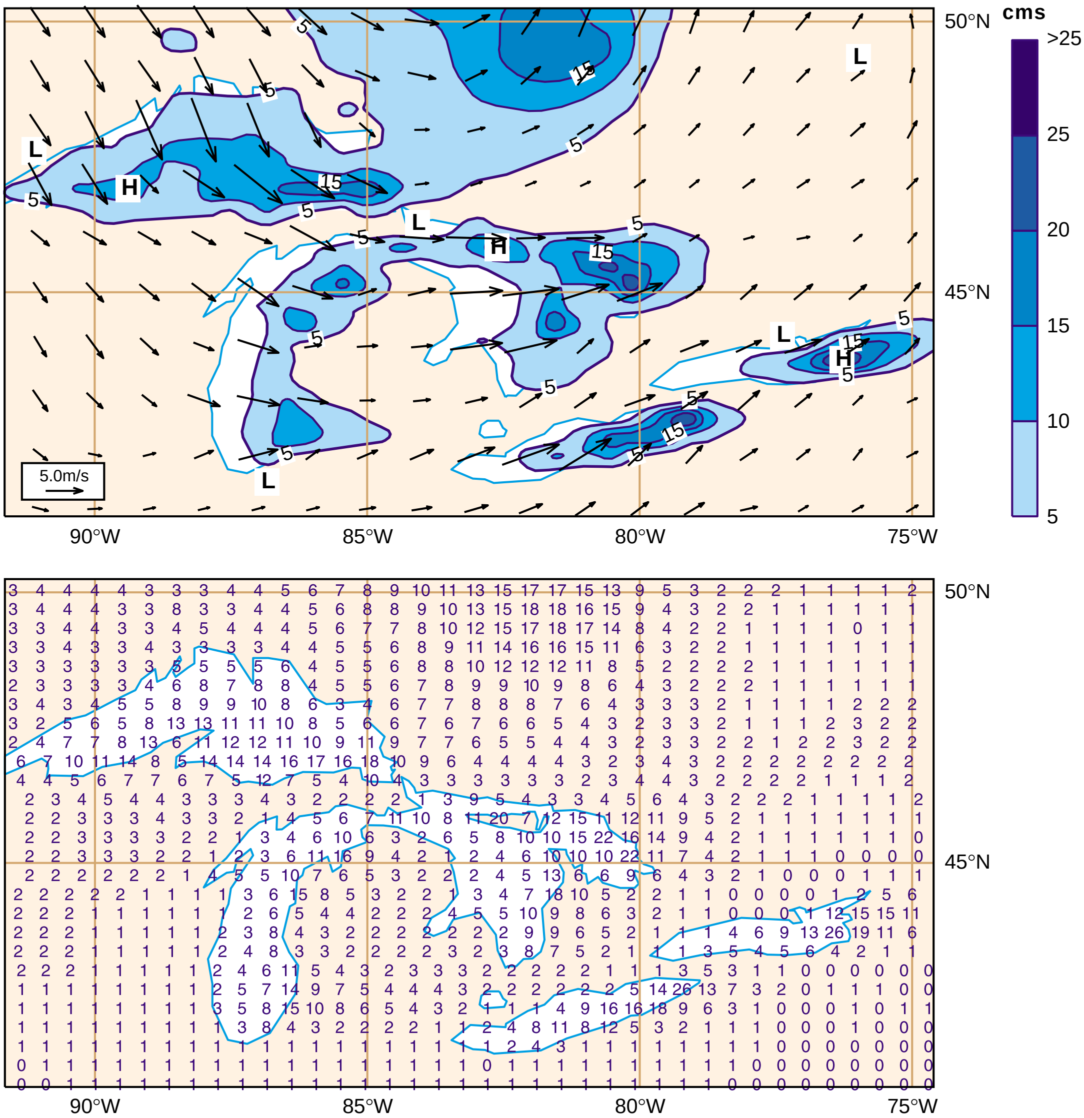

Figure 3 Operational forecast fields of (top) snowfall and 10 m winds from a 72-hour forecast run from 12 UTC 24 December (Snow amounts are calculated as water equivalent × 10), and (bottom) snow amounts (in cms) plotted on the Gaussian grid.

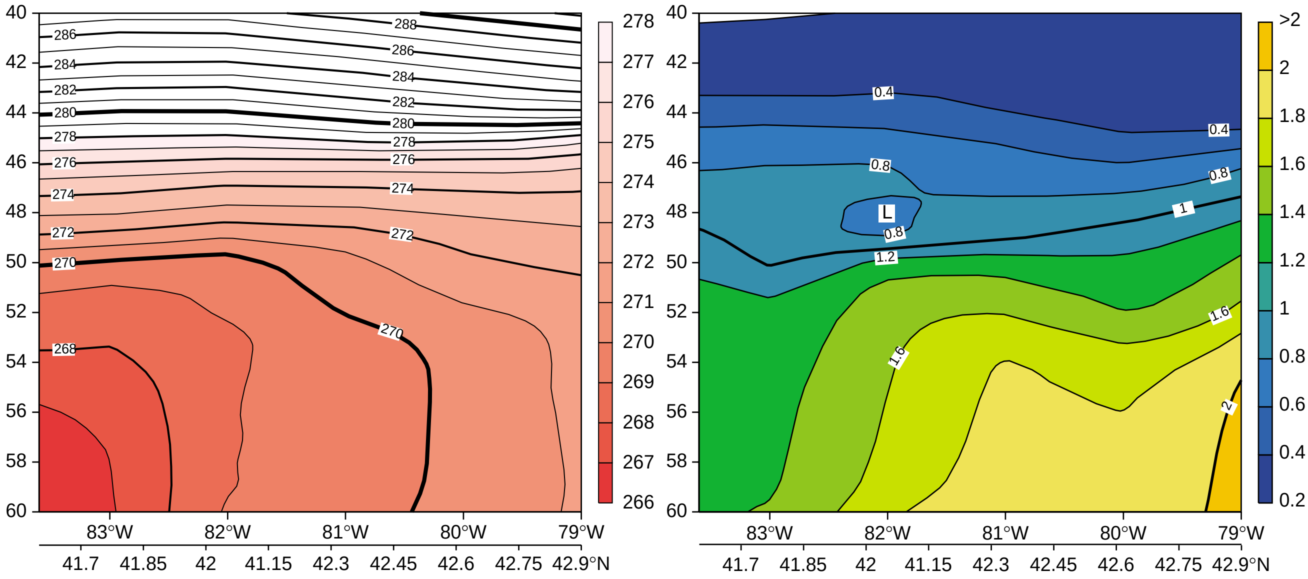

Figure 4 Vertical cross-sections of potential temperature (K) and specific humidity (gm/kg) for an east-west section along Lake Erie. (vertical axis shows model levels (level 45 ~750hPa)

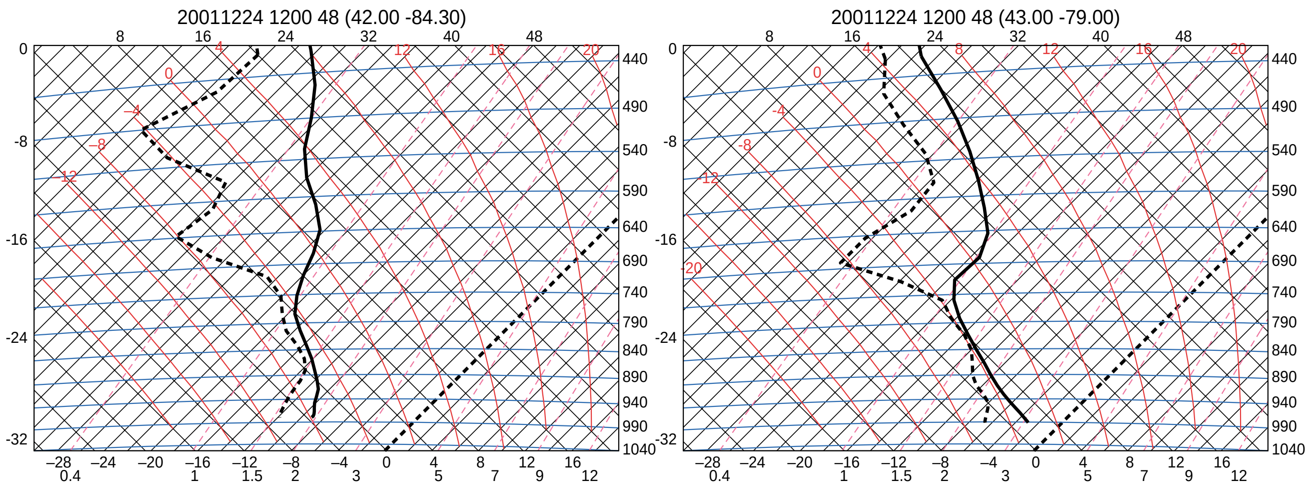

Figure 5 Tephigrams for points at each end of Lake Erie from the 48hr forecast from 24 December at 12 UTC.

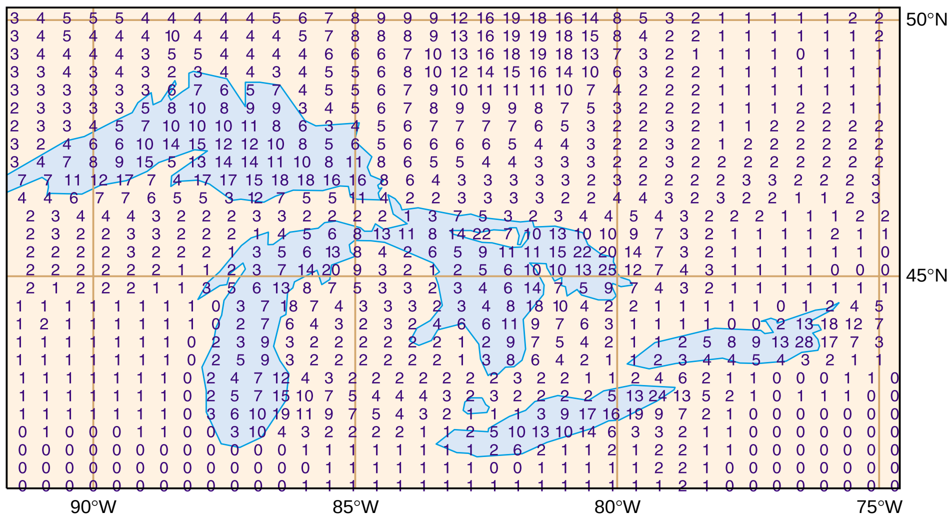

Figure 6 As Figure 3, but for CY24r3 as opposed to CY23r4.

points, the boundary-layer transformation is sufficient to give substantial snowfall in the correct locations. Smaller-scale banding of the precipitation (convective streets) is not captured, with a consequent underestimate of the observed local maxima. This prolonged heavy precipitation occurs when the absolute values of specific humidity are low (less than 2g/kg with changes in humidity of only about 1g/kg). This is because the fluxes of water vapour dominate rather than the absolute values of humidity, but nevertheless it is also a reminder of the importance of measuring and analysing water vapour at relatively low values and temperatures. This example of precipitating convection, occurring in a basically subsiding atmosphere where the relevant 'forcing' is from the surface, is in contrast to most convective precipitation situations. As such, it should be retained as a useful reference test case for any significant physics parametrization changes.

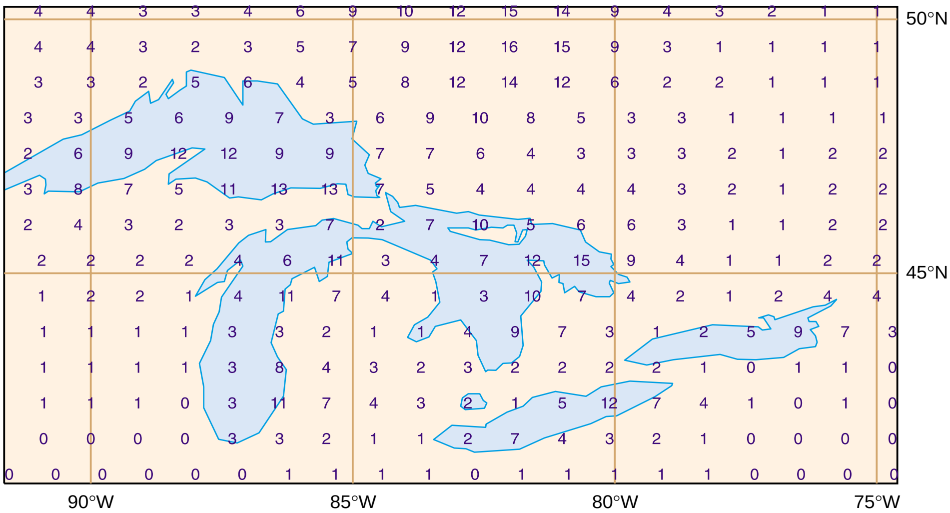

Figure 7 As Figure 3, but for the EPS control forecast.

Martin Miller

The new High-Performance Computing Facility (HPCF)

The procurement process

In December 2000 the ECMWF Council decided on the money stream for the replacement of the Fujitsu systems and authorised the Director of ECMWF to proceed with the acquisition of the replacement system. In March 2001 an Invitation To Tender (ITT) was issued. The tender documents summarised ECMWF's plan for the development of its operational forecasting system between mid-2002 and 2006:

2003 Assimilation of observations of cloud and rain;
Assimilation of high-resolution data from NASA's AQUA satellite;
Increased vertical resolution for all applications.

2005 Increased horizontal resolution in the inner loops of 4D-Var;
Increased horizontal resolution in the outer loops of 4D-Var and the deterministic forecast.

2006 Assimilation of high-resolution data from EUMETSAT's METOP satellite.

The requirements called for a phased implementation and allowed for some flexibility, enabling vendors to adapt their response to their product development plans. In particular, vendors were allowed to propose a three-month shift of the service period.

The ITT required the potential suppliers to commit to performance increases, expressed as factors, over the Fujitsu VPP systems. The required capacities of the disk subsystem, I/O bandwidth and bandwidth of the network interfaces were expressed as a function of these factors, thus ensuring a balanced solution.

The benchmarks used to assess the performance of tendered systems were a combination of tests of the Integrated Forecasting System (IFS) code and kernel tests. For the IFS tests the following cases were requested:

- 4D-Var at T511 resolution with a T255 inner loop; this test included all the programs run in a single 4D-Var 12 hour cycle including observation pre-processing;
- 3D-Var at T511 resolution with a T255 inner loop; this 3D-Var test was included in the benchmark so as to be representative of the analysis runs of the BC optional project;
- A deterministic 10-day forecast at T799 resolution; in addition, a forecast at the same resolution with post-processing enabled was provided to explore basic I/O performance;
- A set of 10-day EPS forecasts at T399 resolution (50/100 members).

Vendors were asked to provide timings for running a fixed number of copies of these tests on their current supercomputer systems and extrapolations for any future systems that they tendered. In contrast, the kernel tests were simple CPU, communications and I/O tests that were used to measure the basic characteristics of current benchmark systems and provide some insight on IFS performance.

The selection

A number of highly competitive tenders were received and the careful evaluation of these tenders took the best part of four months. The comparison of the offers took account of the results of the performance evaluation, the technical aspects of the proposed systems, the migration effort required, the suitability of the systems for Member States' workload, the differences in environmental aspects, the total cost of ownership, the perceived risks and a number of other aspects.

Based on the above comparison the offer from IBM was selected and, following approval by the ECMWF Council, a Service Contract for the provision of high-performance computing resources up to 31 March 2007 was awarded to IBM. At the same time, the service contract with Fujitsu was extended to 31 March 2003.

Figure 1 shows the performance profile of that contract, relative to the performance of the currently installed Fujitsu systems.

Overview of the deliverables

The new system is a departure from the previous supercomputers installed at ECMWF, as it will be the first system that has a scalar architecture, rather than a vector one. The computational basis of the new HPCF is IBM's POWER4 microprocessor. One POWER4 chip comprises two processors (each capable of performing up to 4 floating point instructions per cycle) and a shared level-2 cache.

Since no single application for the new HPCF will require more than half of its computing resources, the ITT permitted vendors to tender two more or less equal clusters. This could be achieved either by partitioning a system, or providing two independent clusters, as was tendered by IBM. It was felt that there could be several advantages in allowing this. Two independent clusters could add significantly to the resiliency of the system, e.g. if one cluster suffered a major failure (such as a hardware fault on the internal switch or crossbar) the other cluster would still provide a service while the fault was rectified. Another reason was increased availability, e.g. a system session that might require a whole cluster to be taken out of production for a period would, in this case, only affect half of the system. The other cluster could continue to run production work. Yet another reason was flexibility in maintaining and upgrading the operating system. It will be possible to install new releases of software on one of the clusters and allow this release to run in production on that cluster while the other cluster runs the earlier software release. If there are stability problems with the new release it should then be possible to run the operational suite of programs in the stable environment of the other cluster, albeit with a delay, as each cluster contains only half of the total resources of the system.

Figure 2 gives a schematic view of the two-cluster configuration and figure 3 provides an overview of the total hardware deliverables (each cluster having one half of the hardware, disk space and sustained performance shown).

The system

The equipment to be delivered in 2002 is an IBM Cluster 1600 system, based on 32-CPU pSeries 690 servers interconnected by a dual-plane switch. It will be installed as two separate clusters, each with 22 pSeries 690 servers running

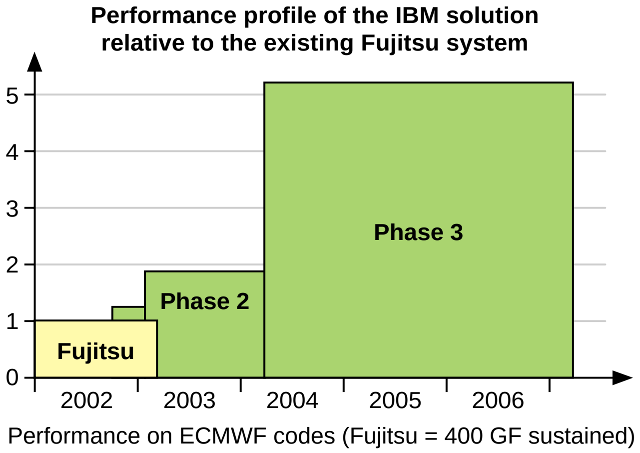

Figure 1 Performance profile of the new HPCF

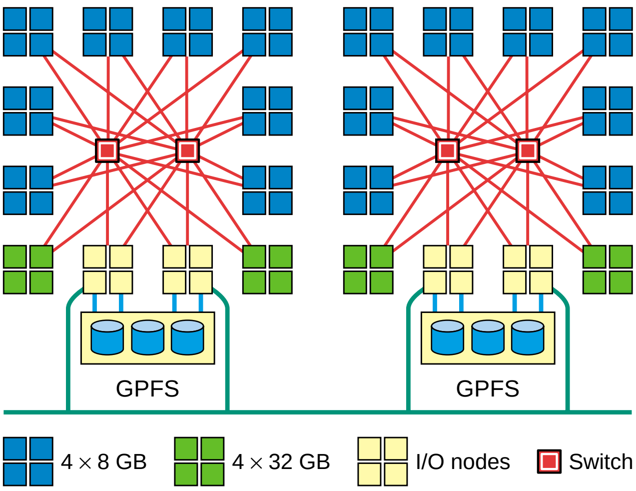

Figure 2 A schematic view of the two-cluster configuration

	PHASE 1	PHASE 2	PHASE 3
Processor	1.3 GHz Power4	1.3 GHz Power4	Faster Power4
Number of processors	1408	~2000	~3000
Interconnect	Dual-Colony (PCI)	Dual-Colony (PCI-X)	Federation
I/O Nodes	8 NH-2	8 NH-2	4 p690 follow-on
Disk space (Fibre Channel)	8.4 TB	2.4 TB	27 TB
Sustained performance	1.3 × VPPs	1.9 × VPPs	5.2 × VPPs

Figure 3 An overview of the total hardware deliverables (each cluster having one half of the hardware, disk space and sustained performance shown).

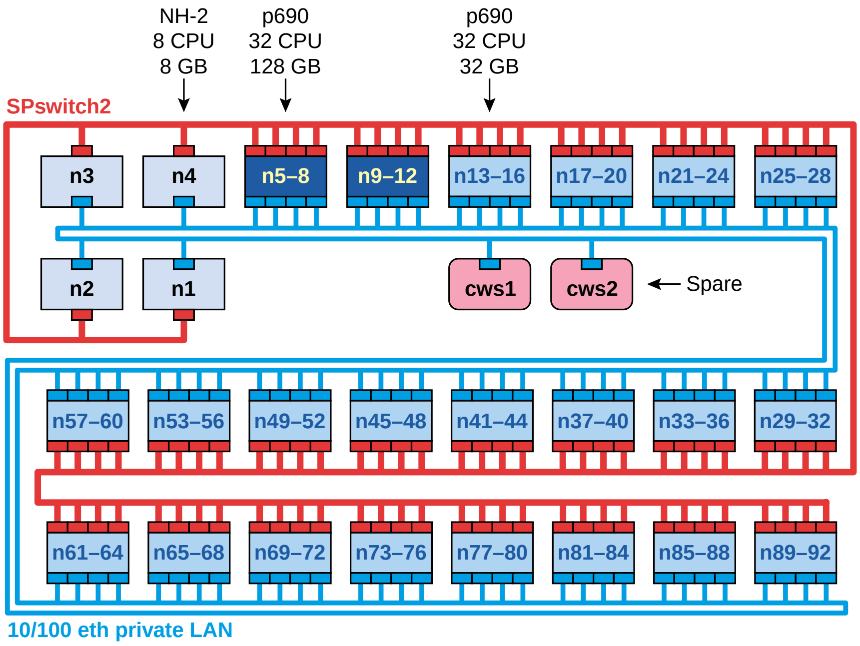

Figure 4 Schematic diagram of one of the Cluster 1600 systems of Phase 1.

the Parallel System Support Program (PSSP) and the AIX 5.1 operating system. Each cluster will have in total about 4.2 TB of FAStT500 fibre channel disks, connected to four 8-CPU nighthawk-2 nodes, which act as I/O servers for the cluster. Each 32-CPU pSeries 690 server will be logically partitioned four ways into 8-CPU LPARs (Logical PARtitions or nodes). The four nighthawk-2 nodes each have 8 GB of memory, while most of the pSeries 690 servers have 32 GB, however two of these have 128 GB of memory. This allows for greater flexibility, especially for programs that require large amounts of memory, but which cannot be converted to parallel programs that could then use the memory systems of multiple nodes.

The switch is a dual-plane SPswitch2 (also called the 'colony' switch) to which each LPAR is connected via two PCI switch adapters, while the nighthawk-2 nodes have two native (mx) adapters that provide better throughput. The two switch planes provide increased performance over that provided by a single plane and also enable the switch to have better resiliency over hardware errors.

Next year each of the two clusters will be upgraded by adding eight 32-CPU p690 servers (two of which will have 128 MB of memory) and by replacing the PCI switch adapters by PCI-X adapters. Extra disk space, in the form of a further 2 TB of FAStT500 or FAStT700 fibre channel disk space, will be added to each cluster.

The pSeries 690 server is the first pSeries system to support logical partitioning. It is a shared multiprocessor (SMP) design based on IBM's new POWER4 chip. The processor subsystem contains from one to four Multi-Chip Modules (MCMs), each of which contains four POWER4 chips and each chip holds two CPUs (running at 1.3 GHz), a shared 1.4 MB L2 cache and an L3 cache controller and directory. Like the pSeries 660, the p690 uses 'chipkill'™ memory and also has the ability to dynamically correct L1 and L2 cache errors as well as to deactivate faulty processors, L2 and L3 cache, LPARs and PCI buses – all of which help to reduce downtime.

The FAStT500 fibre channel disks are the same as those on ECMWF's next generation data-handling system and have been described in another article in this Newsletter detailing that system. Data on these disks will be accessible to any node within the cluster by the use of GPFS, IBM's General Parallel File System. GPFS is a distributed journalled file system that uses token-based mechanisms to ensure file system consistency. It utilises RVSD, the Recoverable Virtual Storage Device facility to share data at a much higher level of performance than other file sharing mechanisms, such as NFS.

Each of the two storage controllers within a FAStT500 disk subsystem has a dual connection to the fibre channel switch fabric. If one controller fails, the FAStT500 subsystem automatically performs a fail-over to the other controller. If the nighthawk-2 node that normally serves data from a FAStT500 subsystem loses contact with that subsystem, or if the node itself crashes, then GPFS will automatically fail-over to the RVSD server on a 'partner' nighthawk-2 that has access to the controllers of that FAStT500. Both types of fail-over are seamless and transparent to the application that is reading or writing data on the disks. The FAStT500 disk subsystem provides for highly-available data at the hardware level, while GPFS and RVSD provide high-availability at the software level.

Programming overview

Migration of applications to the new platform should, in general, be straightforward. For serial codes, which run today on one processor of a VPP system, few changes should be necessary. To a first approximation, one can expect to achieve a sustained performance of about 0.5 GFLOPS, or about the same as a single VPP700 processor for a well-vectorised code.

Although vectorisation of the code is no longer necessary, good performance depends heavily on data access patterns. Since the memory access is relatively slow, it becomes important to make good use of the caching mechanisms that provide faster access to data. Hand optimisation of code can achieve significant improvements.

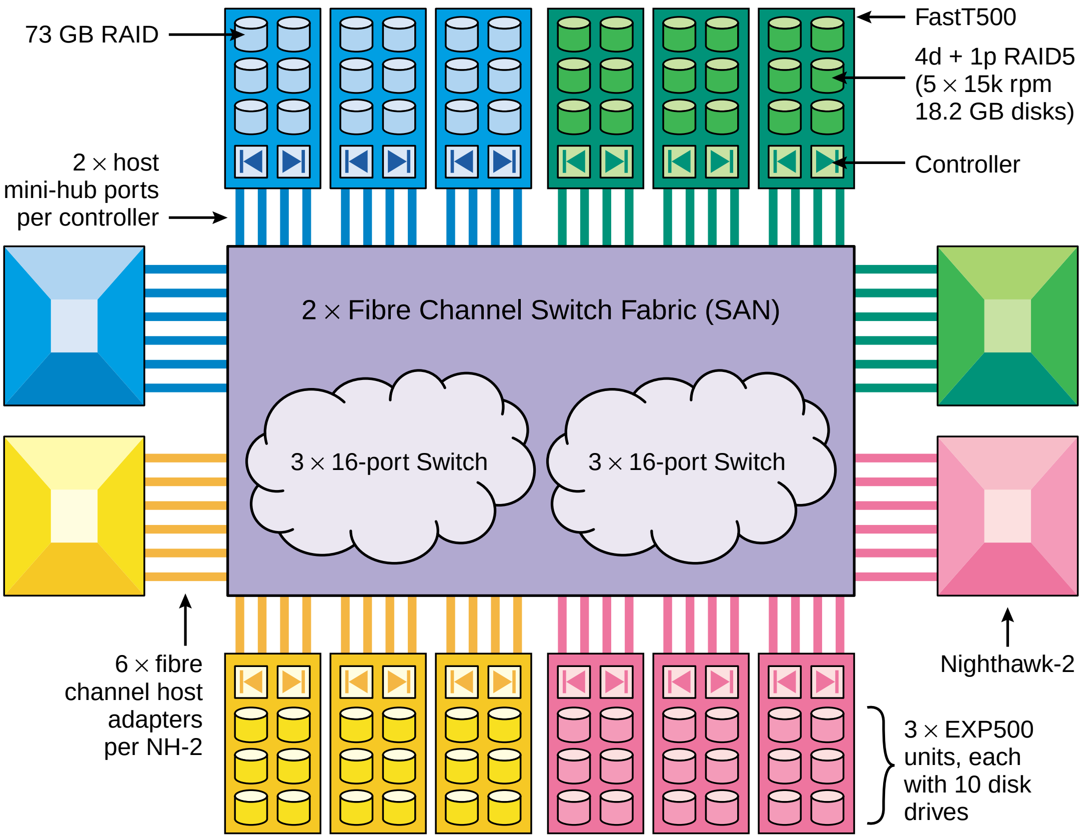

Figure 5 The disk storage area network of one of the Cluster 1600 systems of Phase 1.

For an application that has been made parallel using MPI, some work may be necessary to utilise a different style of message passing. The 'system mailbox', which is available on the VPP systems, is not part of the MPI standard and is not supported on the IBM system. Changing to an 'attached buffer' mechanism will typically overcome this.

Message passing between processors within a node is handled automatically in an efficient way. However, it is possible to parallelise within the shared memory environment of a single node using OpenMP compiler directives. For a serial application where the single processor performance is insufficient, this is often the easiest way to introduce parallelism. Using all 8 processors in the node it should be possible to achieve a sustained performance roughly equivalent to a single VPP5000 processor using this method.

Finally, for sophisticated parallel applications, it is possible to combine message passing between nodes (using MPI) with OpenMP within a node for maximum efficiency.

In 1978 ECMWF took delivery of its first supercomputer, a Cray-1A system. This provided the Centre with sufficient power to enable it begin to provide operational weather forecasts using its then global atmospheric grid-point model. The new HPCF will enable ECMWF to continue to develop its operational forecasting system into the second half of this decade. It is interesting to compare the specifications of this, ECMWF's newest supercomputer, with those of its first.

Specification	Cray-1A (1978)	Dual IBM Cluster-1600 (PHASE2 – 2003)	Ratio (approx)
Architecture	Single vector CPU	2 Clusters of scalar SMPs	
Number of processors	1	~2000	2000:1
Clock speed	12.5 nsec (80 MHz)	0.77 nsec (1.3 GHz)	16.25:1
Peak performance/CPU	160 MFLOPS	5.2 GFLOPS	32.50:1
Peak performance/system	160 MFLOPS	~10.4 TFLOPS	65000:1
Sustained performance	~80 MFLOPS	~1 TFLOPS	12500:1
Memory	8 Mbytes	~2.7 Tbytes	337500:1
Disk Space	2.4 Gbytes	~12.4 Tbytes	5375:1

This is the first in a series of articles concerning the system that will provide ECMWF's high-performance computing facility over the next 5 years. Further newsletter articles will be produced as the system is enhanced and as ECMWF's staff gain experience in using the system and an understanding of how to utilise the full potential of this, ECMWF's latest supercomputer.

David Dent, Neil Storer and Walter Zwieflhofer

A description of ECMWF's next generation data-handling system

In Newsletter 70 (Summer 1995) Dick Dixon introduced what was then to become the Centre's new data-handling system (DHS) and gave an update in Newsletter 78 (Winter 1997/98). He pointed out that, over the years, ECMWF's data archive had grown considerably, from about 100 gigabytes in 1981 to about 30 terabytes at that time. This growth was roughly proportional to the growth of the high-performance computing power available at the Centre (at the end of last year the archive had grown to over 400 terabytes). He explained that the storage system then in use, an IBM ES9000 mainframe running Los Alamos's Common File System (CFS), would not be suitable for the future needs of the Centre and consequently a new system, based on IBM RS/6000 servers, running the ADSTAR Storage Management (ADSM - later Tivoli Storage Manager TSM) software would be installed in three phases, commencing in October 1995. In subsequent years this system was extended and improved.

It became clear in 2000 that this TSM-based system too had its limitations that, without major modifications to the TSM software, would make it unsuitable for the Centre's needs in the future. Consequently, in January 2001, ECMWF issued an Invitation To Tender (ITT) for the next generation of DHS to eventually replace the current one. Of the responses received, ECMWF selected the proposal from IBM, based upon pSeries 660 servers, FAStT500 disks, tape drives, STK 9310 Powderhorn robotic tape silos and the HPSS storage management software.

The pSeries 660 is a member of a new generation of symmetric multi-processor (SMP) servers from IBM, providing scalability using the RS64 processor in various SMP configurations. It has several novel features such as hardware multi-threading, "chipkill" memory technology (protecting the server from failures in memory chips), built-in self-test and persistent processor and memory de-configuration. Other reliability, availability and serviceability features include automatic PCI bus error recovery and system power monitoring and control.

The Fibre Array Storage Technology (FAStT500) disk is an enterprise-class RAID (Redundant Array of Independent Disks) storage server that includes controllers capable of handling various levels of RAID as well as highly-available memory systems and advanced caching software capable of providing scalable I/O. It contains dual-redundant hot-swappable components that help to ensure high-availability of the data it holds.

Like the current DHS, its replacement will be installed in phases. The first phase (Figure. 1), which started in January 2002, will eventually comprise 3 p660 servers, with 5 terabytes of disk space, 1 STK 9310 Powderhorn robotic tape silo and 16 Magstar 3590 follow-on tape drives. The Powderhorn silo will be integrated with the other 4 Powderhorns that form the STK silo complex of the current DHS. The tape drives will be connected to the servers via fibre channel-switch fabric and will form a storage-area network (SAN). This will enable each of the servers to connect to any of the tape drives. The majority of the disk space is provided by FAStT500 fibre channel attached RAID disks. These too are connected to the servers via fibre channel-switch fabric. Network connectivity is provided by gigabit-Ethernet adapters and, for those connections that need to take place over HIPPI, a HIPPI to gigabit-Ethernet bridge is provided.

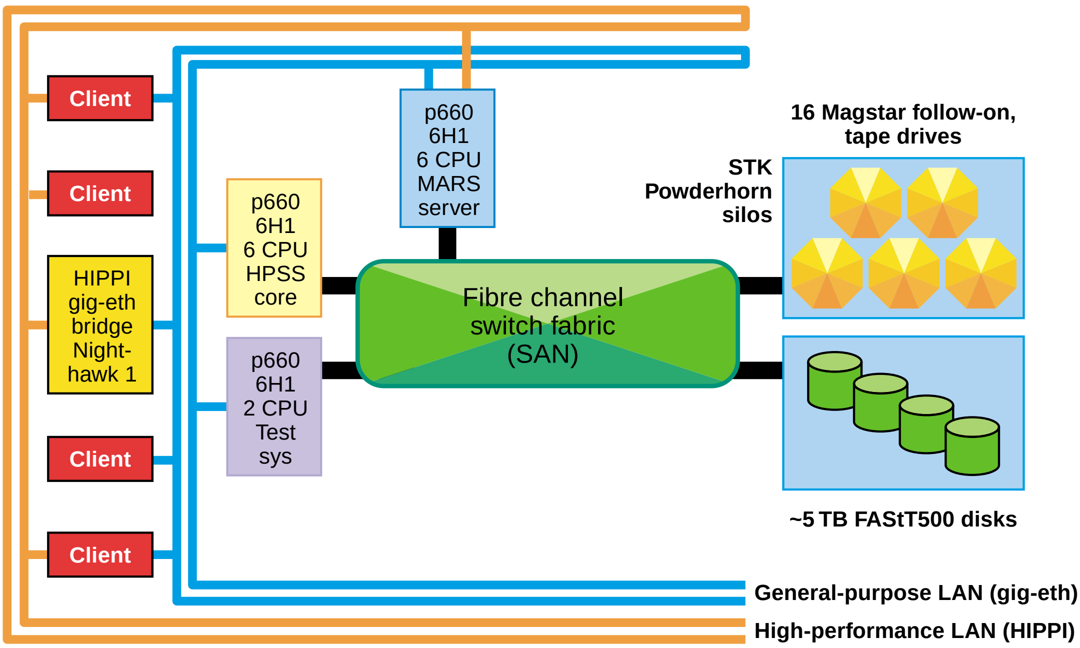

Figure 1 Phase 1 configuration

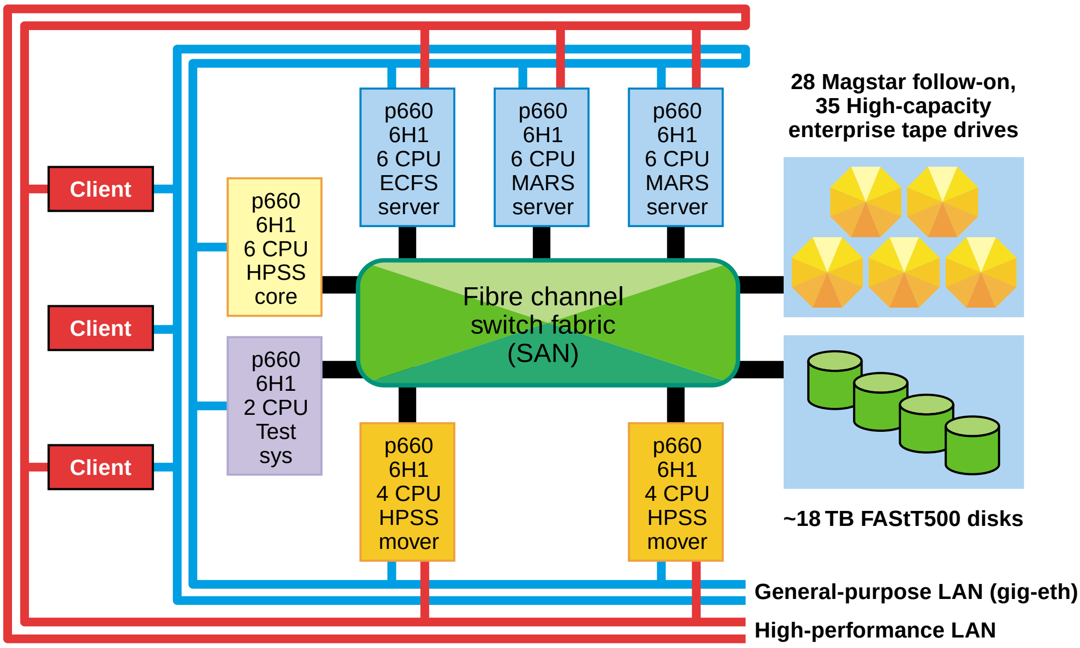

Figure 2 - Phase 2 configuration

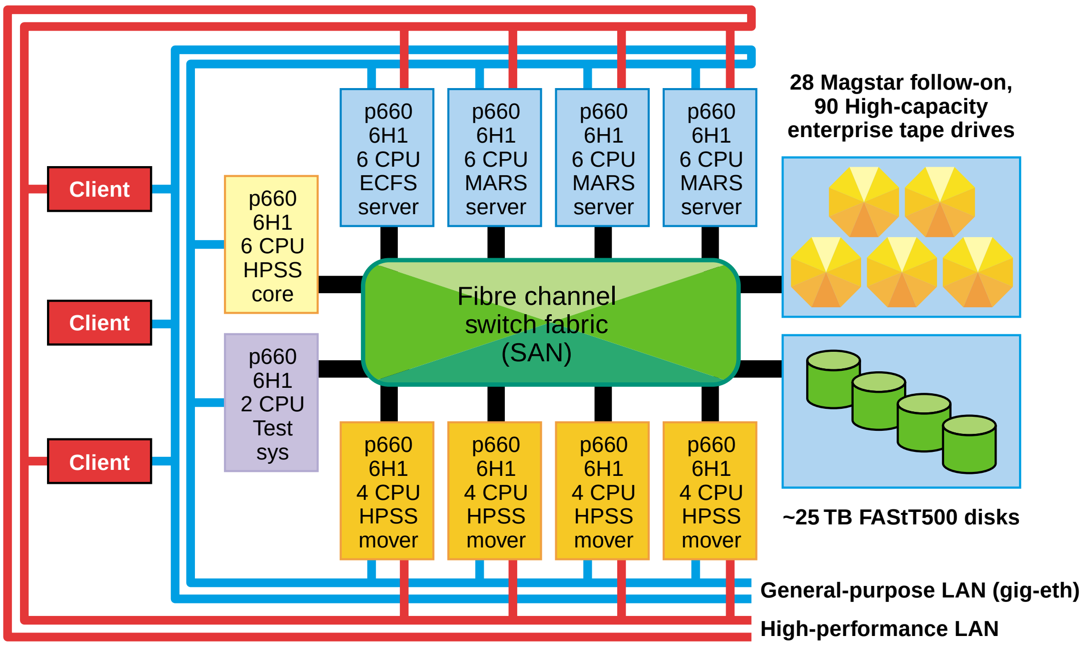

Figure 3 - Phase 3 configuration

Phase 2 (Figure 2) will commence in mid 2003. Additional equipment will be added to the phase 1 system. The system will then comprise seven p660 servers, with approximately 18 terabytes of disk space, the STK 9310 Powderhorn robotic tape silo installed in phase 1, 28 Magstar 3590 follow-on tape drives and 35 next-generation, high-capacity, enterprise-class, tape drives. The SAN infrastructure will be expanded, but no new silos will be required since extra storage capacity for the next generation DHS will be found in the existing silo complex currently used by the older TSM-based DHS, as data is gradually migrated out of that system and onto higher-capacity media in the next-generation DHS. Network connectivity will continue to be provided by gigabit-Ethernet, but in this timeframe it is planned to replace the HIPPI network by a new high-performance network to which the DHS will be connected.

While the equipment for phases 1 and 2 has already been decided, that for subsequent phases is part of a call-off contract. In order to provide the required service for phase 3 (Figure 3), additional equipment will be added to the phase 2 system in 2004. The total configuration for phase 3 is currently planned to consist of 10 p660 servers, with approximately 25 terabytes of disk space, the STK 9310 Powderhorn robotic tape silo installed in phase 1 (plus the four other STK silos that form the silo complex currently used by the older TSM-based DHS), 28 Magstar 3590 follow-on tape drives and 90 next-generation high-capacity enterprise-class tape drives. However, the nature of a call-off contract is such that the types and quantity of additional equipment could change, in the light of ECMWF's experience with the earlier phases.

The data-management software in use throughout all of the phases is IBM's High Performance Storage System (HPSS), which is based on version 5 of the IEEE Mass Storage Reference Model. It uses 'data movers' (specialised software modules), which can execute on different server machines, to send streams of data directly between those servers and the client machines requesting the data. To provide for extremely high transfer rates, it allows data to be transferred in a parallel manner, in several different streams over different network paths from multiple storage devices. This distributed multi-processing nature of HPSS is one of the keys to its scalability. It uses advanced transaction-processing techniques to guarantee security, protection and integrity of data. It supports a variety of tape drives and robotic tape libraries. Further information on HPSS can be found at http://www.clearlake.ibm.com/hpss/ and http://www.sdsc.edu/hpss/.

Users at ECMWF will not themselves use HPSS directly. This software will be one level removed from them. When a user wishes to store or retrieve data on the next generation DHS, he/she will use the ECFS or MARS interfaces to do this. It is these two applications that will use HPSS, to manage the underlying data.

In phase 1, the MARS server responsible for providing access to data from research experiments will be ported to the next generation DHS and a start will be made on migrating these data from the current DHS. This process of migrating data from the current to the next-generation DHS is termed 'back-archiving'. It is estimated that somewhere in the region of 250 terabytes of 'research' data will have to be migrated. The ported MARS research server will recognise where specific research data are archived and will be able to serve this data to its clients, regardless of whether it is on the current or the next-generation DHS. In this way the location of MARS data will be transparent to the user, so he/she will not need to change the MARS data request depending upon whether or not it has been migrated.

In phase 2, the back-archive of MARS Research data will continue, but a start will also be made on porting the ECFS server to the next-generation DHS and migrating the associated user data from the current DHS. It is estimated that somewhere in the region of 200 terabytes of ECFS data will have to be back-archived. The MARS servers responsible for 'operational' data and 're-analysis' data will also be ported and their associated data migrated. It is estimated that somewhere in the region of 200 terabytes of such data will have to be back-archived. It is currently planned that the ECFS server will also recognise where specific ECFS data are archived and will be able to serve these data to its clients, regardless of whether they are on the current or the next-generation DHS. So again, the user should not need to alter the ECFS request depending upon whether or not the data have been migrated. These plans underlie the current thinking about how to provide the ECFS service, but they may change if experimentation with HPSS over the next year identifies better ways of providing an ECFS service.

In phase 3, the migration of data will be speeded up to allow all of this back-archiving to be complete by the end of 2004 or early in 2005. At that time most of the equipment of the current DHS will become obsolete (with the exception of the STK silos) and the service provided by the current DHS will be terminated.

As one can see, the migration to the next-generation DHS will take several years to complete and during that period ECMWF staff will have to support two very different types of data-management software, TSM and HPSS. The costs involved in migrating ECMWF's archive from one data management software solution to another are considerable, in terms of the researching, planning, implementation, resources and manpower involved. However, the choice of HPSS as the data management solution for the next-generation DHS, with its excellent scalability, should allow the Centre to maintain the same data-management software environment for some time to come and to protect the investment that will have to be made over the migration period.

Francis Dequenne and Neil Storer

The Hungarian National Meteorological Service

Presentation by Dr Mersich, Director of the Hungarian National Meteorological Service, to the European Conference on Applications of Meteorology, September 2001

Mr Chairman, Ladies and Gentleman,

In order to be able to present to you the future development of relations between the Hungarian Meteorological Service (HMS) and other European meteorological services, I think it is necessary to summarize the tasks and strategies of the HMS in the past, in particular during the near past. Taking this information as a basis, we can see better the changes and tendencies, and evaluate their results or failures. I consider having a vision for the future as being especially important, because this is what we may still influence positively.

I do not intend to give details here about the operation of the HMS during the nineteenth century, but I would like to mention only as a fact that the extent of our profession in the Carpathian basin was, at that time, on the same level as that of the rest of Europe. The most important tasks were: the harmonization of measurements and analyses, and the organization of data exchange. Our relations developed well in this respect, and not only with the neighbouring countries.

Between the two World Wars the above tasks remained the same, in essence, but the emphasis shifted. In addition to surface observations, upper-air measurements became regular, and weather forecasting was an operational task. Research and development, in the present sense, had also started. However, regular and effective interactions with other meteorologists that could contribute to realizing the research and operational aims were at a low level, at least at the beginning of the period.

When the Second World War was over, the development (or, it may be better to say, the transformation) of knowledge, experience and the political system in the eastern part of Central Europe differed fundamentally from the tendencies in Western Europe. The orientation and objectives of this region turned towards those of the East; a completely different attitude was adopted, first by force and then by acceptance. For both political and ideological reasons, the Russian language was preferred, and all contacts were forced in this direction. Work objectives, results and values gained a different dimension.

Let us mention some examples:

The fact that the voluntary observer network became professional resulted in the weakening both of the voluntary network and of the background of committed non-experts interested in meteorology. It is true that, in return, the reliability of observations became better, but in the situation of the cold war the use and exchange of these advanced data was limited. The open usage of meteorological information under circumstances of general secretiveness resulted in some interesting features, for example good weather always had to be predicted for the 1st of May. Another aspect of the situation was that a need for exaggerated applications of meteorology arose, e.g. there was an increased pressure to develop methods of actively modifying the weather. We also turned towards the East in the technical field; the shortage of instruments and the use of instruments that were not really adequate were typical. The copying of successful instruments without permission occurred as well (e.g. the illegal production of Vaisala radiosondes in the mid 1950s).

Even during the 1980s, large-scale projects were considered important; these were intended to compensate for the use of out-of-date techniques. For example, instead of using well-developed technical procedures, large numbers of people were employed without ensuring that adequate conditions were adhered to for the success of the work.

Apart from these negative aspects, there was also one positive feature. The level of education became better. Also, the political ideology could not cause much damage in the field of natural sciences. Thus, we had many well-educated experts, some of whom had really considerable professional knowledge. However, the utilization and exploitation of their knowledge was regretfully at a low level, and so it was wasted.

Let us now examine how the HMS operated in the middle of the 1970s. It was a purely meteorological service. In contrast to the services of other socialist countries, it did not deal with operational hydrology. Of nearly 580 employees, 190 were university graduates. Nearly half of these were employed for the purpose of research, an important part of the HMS's activities. The sale of data and information on a business basis had also appeared; it amounted to about 10% of the budget. The weather-prediction task was essential, but not of crucial importance. The observing network was instrumented and operated according to WMO recommendations; there were 24 synoptic stations reporting every hour, two radiosonde stations, about 100 climate stations, and 700 rain gauges

The international contacts had four directions:

- The so-called COMECON co-operation covered the entire field of meteorology but was more or less formal in professional aspects. In a political sense, it was successful, and we still remember the elections and debates in WMO in which the uniform but, in number, small socialist block forced its ideas on several occasions onto the less united majority.
- INTERKOSMOS concentrated on satellite meteorology. Its organizational characteristics were the same as those of COMECON. This co-operation took up a lot of time and energy, but its achievements were only moderately successful.
- Co-operation covering the entire field of our profession also existed between academic institutes, but it was even more formal. The two "great achievements" of that time were the automation of protocol writing and the so-called "bez valjutnüj" travel exchange. The protocol was prepared, usually in a form determined in advance and mostly based on material ready on the first day of the meeting. The only problem was the shortage of typewriters with Cyrillic letters. The process of exchange without currency meant that the partners covered a daily allowance for the visitors agreed in advance, but only for a fixed number of days in a barter-like agreement.
- Bilateral co-operation also appeared in embryo. As a matter of fact such relations were tolerated but not supported, because the possibility of Soviet control was not ensured. The first co-operative arrangement of our Service towards the West after the war was established with Austria. It is strange to say that the main essence of these arrangements was to establish human contacts. This aim was achieved successfully, thus establishing a basis for professional co-operation at a later stage.

In the 1980s the position of our Service was more or less unchanged. At the same time some aspects improved, such as an increase in our own income. Staff numbers increased to nearly 1000. We built up and operated a hail-suppression rocket system. The maintenance of relations with the East became more difficult, sometimes we had to persuade colleagues to be willing to travel to the Soviet Union.

A completely different situation characterized the slowly developing co-operation with the West. On the occasion of entering into official relations with the USA for the first time, the lucky participants (who were envied by everyone) handled this as a conspiracy and they nearly ruined their health by overwork in order to achieve success in the co-operation.

Despite our difficulties most of our experts had several important ideas. We believed that our profession was important for the public. We believed that this work could be accomplished best by the national meteorological service.

We were sure that our tasks could be fulfilled best with the support of international co-operation and that we alone were not sufficient to achieve success in our work. We missed intensive relations with the West and we felt that this deficiency was limiting our results. We accepted the noble concept of free and unrestricted exchange of data and we endeavoured to realize this ideal, sometimes even by trickery. We hoped that only political obstacles hindered the exchange of knowledge and methods. We did what we had to do, as we loved our profession. We considered it a mission rather than gainful employment. We thought that deviation from these principles was the fault of the system, which could be improved.

Following the transition in the 1990s caused by the collapse of systems based on communist ideology, the political changes in Hungary were radical. A few years were enough to destroy the earlier structure and to liquidate almost totally the former political system. Economic changes showed an interesting duality. Foreign capital flowed to the newly freed market and changed the situation completely. In the case of the non-negligible minority of intrinsic Hungarian organizations, the economic changes happened less dramatically. Sometimes only the form changed, the individuals and the content remained the same. As a consequence, the transition is still going on in some fields.

As I see it, the most important change, which is in the way of thinking and in the attitude of the general population, is coming about only very slowly. The past ten years do not seem to be enough even to understand and accept the essence of the changes. Without entering into particulars, I would like to emphasize that the political transition in the 1990s found the HMS unprepared. I do not think I am wrong if I assume that the situation was the same in other NMSs of the region. Because of this unpreparedness, we only had the opportunity to follow the changes without influencing them. This situation must be considered crucial because the position of the HMS, which was not very strong and influential in the state apparatus anyway, continued to weaken.

How did all these reflect in the structure, operations and strategy of the HMS?

First, we came to an ethical, then to a managerial and finally to an economic crisis. The transition did not happen in an instant. The premonitory signs of the changes could be felt, but the management and the employees of the Service were uncertain as to how to react. On the one hand, they could not bear to abandon the political position they had been used to during the previous decades and, on the other hand, they had no power or intention to preserve it. Some of them did not even recognize the changes, of course. Indeed, a moral crisis developed. In the first place, we were not concerned about our profession but about our personal past and future. The consequence of this situation was, of course, that the management became uncertain about how to react, and the aims of the meteorological service were not clarified or were even missing altogether. In the meantime, the shocking state of the budget came to light, and thus it was not a surprise that the Service became bankrupt.

An enormous reduction of staff (70%), the entire replacement of the management, and economic restrictions followed. The peaceful existence of a research institute was terminated and disappointment because of the abandonment of earlier plans also occurred. We were in trouble. We asked for international Western European help and trusted in their support. But, apart from some isolated actions, we were left alone. We had to understand that we could count only on ourselves, first of all. We realized that possessing data and information had advantages. We learnt that the love of our profession was not enough; we needed to sell our working capability for our subsistence. Thus, we remained much smaller with many fewer commitments, but with rational thoughts and a lot of experience about international co-operation. I may say that we tried to grow up under the burden.

How have these changes affected the examples listed earlier?

- The observing network was entirely transformed for the second time within 50 years. We automated and reduced. We did not return to a network based on voluntary observers. The elements of the observing network were instrumented and operated according to WMO recommendations (29 stations reporting every hour, two radiosonde stations, nearly 60 climate stations, 506 raingauges, three radars, a lightning localization system, and satellite receivers are all now operating).
- Despite our enthusiasm at the beginning of the 1990s, the principle of unrestricted free exchange of field data has not returned, and something similar to the former situation has now been restored. However, the reason for this limited data exchange is, nowadays, not the secretiveness of the cold war but economic interests.
- There are no longer exaggerated demands for applications. We are gladly at the disposal of our partners, but co-operative projects are based on mutual interest. The pressure for active weather modification has ended. In the technical field have we have turned to the West. The instruments are better, though significant differences between promises and reality are still not rare. Large projects have come to an end; the obstacle to increased intensive development is now only the lack of adequately educated experts. International co-operation is free, but now we have gone to the other extreme, i.e. by now everybody has even forgotten the Russian language.

Let us now see how the HMS is operating in the present day

It is a purely meteorological service with a few activities in the field of environmental protection. Amongst nearly 300 employees, 120 are university graduates, 70 of whom have diplomas in meteorology. A significant part of the activities of the HMS - about two thirds - is connected with operational weather forecasting. Research and development activities amount to a fifth of the total capability. Business activities are providing nearly the half the total budgetary income. Weather prediction is an essential activity.

In addition to WMO, we have international relations almost exclusively with European international organizations, NMSs and with multilateral co-operative programmes. The former orientation towards the East has completely changed. The interest is now directed essentially towards the West and, to a smaller degree, towards Central Europe. In establishing and maintaining these relations, our aims are as follows:

- To adopt and exchange important and useful professional information;
- To participate in the development of new methods and procedures;
- To harmonize, represent commonly and protect our interests.

Knowing the state of the development and economic capacity of our country, and our historical background, we did not expect that our applications to participate in joint projects would be welcomed by all our new partners, nor that we would be drawn immediately into the co-operative programmes that had been established with much effort and attention We accepted that mistrust by the West of an earlier enemy was natural, but we must confess that we did not anticipate such difficulties, and sometimes we felt that we were in vacuum.

Nowadays, our main endeavour is to achieve, as a reliable and useful partner, full membership status of all the significant Western European meteorological co-operative organizations, and to develop well-operating Central European partner relationships. Now we are in a phase of confidence building, and I hope we will be successful.

I would like to list our existing co-operative ventures:

- We are a Co-operating State of ECMWF and EUMETSAT
- We have full membership in ECOMET and participation in some EUMETNET programmes.
- We are members of the LACE co-operation of the Central European countries, of ICCED and of the ALADIN project.
- We have numerous smaller or larger bilateral co-operative projects.

A neglected field of our international relations is co-operation, based on mutual advantage, with private companies and university or academic institutes. All our attempts in this respect have ended in failure. Probably we have not managed to understand the main principles of operation of these organizations and/or our offers have not been particularly attractive. Consequently we are more in competition with them. In the future, co-operation with the private sector may be advantageous, and so is desirable for us.

The detailed analysis above gives me a background for examining alternatives for future co-operation from a special, Central European, point of view. For a Central European NMS the great questions and problems to be solved and the dilemmas for the future seem to be the following:

- Is Europe becoming unified or more divided into regions?
- What will be the level of concentration and/or sovereignty for NMSs?
- What levels of co-operation and/or competition will develop between NMSs?
- Will there be a significant role for the state in pursuing individual initiatives on the part of the government?

I think that there are no simple answers of universal validity to these questions. The age of cold war, with its black or white formula, is over. Concepts that were in contradiction with each other earlier are, and will be, coexisting and exerting influence.

In my opinion it is likely that, in the long term, besides the reduction of useless overcapacity, meteorological activities will be realized through regional co-operation. A tight relationship amongst the 49 sovereign NMSs, with different cultures and stages of development, is unlikely to be feasible, and so co-operation within our continent could be more successfully attained through smaller groups and regions. Nevertheless, in contrast to this, the former socialist countries seem to be endeavouring to build up their Western European relationships separately from one another, usually laying even more stress on these relationships than on Central European co-operation. Thus, it seems likely that these two approaches will exist simultaneously. If we fail to create a Europe of regions, an outcome that cannot be excluded, different interest groups, acting as separate factions, will be established within a unified organization.

Meteorological activities on an adequate level require considerable capital investment, and progress and the solution of problems in meteorology can be realized only with the help of significant resources. It is unlikely that individual governments will be willing to spend more money for this purpose. The solution lies in the concentration of capital and resources. If the different NMSs, and groups of NMSs, give up sovereignty and abandon parallel activities, the necessary concentration of resources can be realized. Organizations dislike giving up sovereignty, but it seems that this principle of "keep through stopping it" is the only good solution.

We have experienced in recent years that competition is good, but tiring. It is easier to agree to form a coalition than to struggle on, but I think we need to choose competition for the sake of development. Competition helps us in finding better solutions and in concentrating capital, though it makes the exchange of data and information more difficult, and weak and inexperienced partners find it impossible. We have to learn from large multinational companies in this respect. They are not in frontal competition with each other, but form communities of interest in order to realize some common tasks. If a competitor becomes weakened, it will be taken over up rather than be liquidated, but its values will be absorbed into the operations of the purchaser.

I do not believe that, in the longer term, the role of states will remain at the same level. In a competitive world, the participation of a state is not advantageous; it is slow, circumstantial and burdened by too many regulations. This is not the case in the private sector. Thus, I believe that private ventures will gain ground in the future.

What strategic ideas does the HMS have in the field of co-operation in the Central European region based on the facts outlined above?

- We accept as a fact that we alone are not able to achieve the essential professional development and, in some fields, even to maintain the present level of expertise.
- We intend to become a full member of the Western European international meteorological organizations. At the same time:

- We would like to strengthen regional co-operation and, without precluding competition, maintain the unrestricted exchange of data.
- We do not think it likely that, in the face of the political unification of Europe, the present structure of NMSs can be maintained, that is meteorological services of each small country attempting to cover the complete sphere of meteorological activities.
- In our opinion, there is only a small chance that the role of the states will remain at the present level, but co-operation and the commercial market might compensate for the loss of sovereignty.

Dr I. Mersich

The ECMWF education and training programme 2002

The ECMWF has an extensive education and training programme to assist Member States and Cooperating States in the training of scientists in numerical weather forecasting, and in making use of the ECMWF computer facilities. The training courses consist of modules that can be attended separately; students may decide to attend different modules in different years. Further details can be found on the ECMWF web site

http://www.ecmwf.int/newsevents/training/

The programme for 2002 is as follows:

Computer Users Course

This course is on the use of ECMWF computer facilities; it consists of five modules of varying length. The objective of the Computer Users Training Course is to introduce users of ECMWF's computer systems to the Centre's facilities, and to explain how to use them. The modules are as follows:

COM 1 (25 February–1 March 2002)	Introduction for new users/ MARS
COM 2 (4–5 March 2002)	MAGICS
COM 3 (6–8 March 2002)	Metview
COM 4 (11–12 March 2002)	SMS/XCdp
COM 5 (date to be announced)	Use of ECMWF supercomputing resources

Students attending any part of the course are assumed to have experience of a computer system elsewhere, to be familiar with ANSI Fortran 77 or 90, to know basic UNIX commands, and to be able to use the *vi* editor. Students can attend any or all of these modules. Each module will consist of lectures and practical sessions. All the lectures will be given in English. A workbook will be provided for each module, together with basic manuals and other relevant documentation, as required.

Meteorological Course

This course is on numerical weather prediction and the use of ECMWF products, and consists of five modules. Four of the five modules emphasise scientific training and one module is aimed at forecasters or people with forecasting experience. The objective of the meteorological training course is to assist Member States in advanced training in the field of numerical weather forecasting. The course modules are as follows:

MET OP–I (14–22 March 2002)	Use and interpretation of ECMWF products
MET OP–II (23–31 May 2002)	Repeat of course MET OP-I, if required
MET PR (8–12 April 2002)	Predictability, diagnostics and seasonal forecasting
MET PA (15–26 April 2002)	Parametrization of diabatic processes
MET NM (29 April–9 May 2002)	Numerical methods, adiabatic formulation of models
MET DA (13–22 May 2002)	Data assimilation and use of satellite data
MET OP–III (14–18 October 2002)	repeat of Met OP–I, if required

Students attending the course should have a good meteorological and mathematical background, and are expected to be familiar with the contents of standard meteorological and mathematical textbooks. Some practical experience in numerical weather prediction is an advantage. All the lectures will be given in English. A set of lecture notes will be provided for the modules on numerical weather prediction; the notes can also be accessed via the ECMWF web site http://www.ecmwf.int/newsevents/training/.

Annual Seminar

The annual seminar consists of a one-week series of lectures dedicated to one specific topic which is different each year. In 2002 it is on 'Recent developments in predictability studies' and it will be held during the week 9–13 September 2002.

The purpose of the 2002 Seminar is to give a pedagogical overview of current issues in predictability studies for both mid-latitudes and the tropics, and ranging over timescales from short-range through medium-range to seasonal and beyond. In addition to theoretical presentations, there will be thorough discussion of the methodology of ensemble predictions, including the choices available for formulating the initial perturbations, and the choices available for dealing with uncertainties in model formulation. Verification issues will also be discussed. Recent developments in data assimilation of relevance to ensemble forecasting will be presented, including the implementation of physics in 4D-Var and singular-vector calculations, and the development of a reduced-rank Kalman filter. Posters providing further information on the programme and application forms will be distributed around May 2002.

Table of Member State and Cooperating State TAC Representatives, Computing Representatives and Meteorological Contact Points

Member State	TAC Representative	Comp. Representative	Met.Contact Points
Belgium	Dr. W. Struijlaert	Mrs. L. Frappez	Dr. J. Nemeghaire
Denmark	Mr. L. Laursen	Mr. N. Olsen	Mr. G. Larsen
Germany	Prof. G.-R. Hoffmann	Dr. E. Krenzien	Mr. D. Meyer
Spain	Mr. A. Rubio Rodriguez	Mr. E. Monreal Franco	Mr. F. Jimenez
France	Mr. B. Strauss	Mrs. M. Pithon	Mr. J. Clochard
Greece	Dr. G. Sakellaridis	Mr. A. Emmanouil	Mr. I. Papageorgiou Mr. P. Xirakis
Ireland	Mr. J. Logue	Mr. P. Halton	Mr. M. R. Walsh
Italy	Dr. S. Pasquini	Dr. G. Tarantino	Dr. G. Maresca
Netherlands	Mr. A.R. Moene	Mr. H. de Vries	Mr. G. Haytink
Norway	Mr. J. Sunde	Ms. R. Rudsar	Mr. P. Evensen
Austria	Dr. G. Wihl	Dr. G. Wihl	Dr. H. Gmoser
Portugal	Mrs. I. Barros Ferreira	Mrs. M.C. Pereira Santos Mr. J.C. Monteiro	Mr. F. Prates
Switzerland	Mr. P. Müller	Mr. P. Roth	Mr. R. Mühlebach
Finland	Mrs. K. Soini	Mr. K. Niemelä	Mr. P. Nurmi
Sweden	Mr. I. Karro	Mr. R. Urrutia	Mr. O. Åkesson
Turkey	Dr. M. Demirtaş	Mr. N. Yaman	Prof. A. Dorum
United Kingdom	Dr. A. Dickinson	Mr. P. Burton	Mr. A. Radford
Cooperating States			
Croatia	Dr. Branko Gelo	Mr. V. Malović	Mr. D. Glasnović
Czech Republic	Mr. M. Janoušek	Mr. M. Janoušek	
Hungary	Dr. I. Mersich	Mr. I. Ihasz	Mr. I. Ihasz
Iceland	Mrs. H.-B. Baldursdottir	Dr. M.Jonsson	Mr. G. Hafsteinsson
Slovenia	Mr. J. Jerman	Mr. M. Kozelj	Mr. B. Gregorčič

Member State computer resource allocations 2002

Member State	Basic allocation	**Fujitsu (kunits)** Deduction for optional boundary condition project	Net allocation	**Data (Gbytes)**
Belgium	443	156	287	2999
Denmark	370	130	240	2507
Germany	2065	0	2065	13986
Spain	687	242	445	4651
France	1429	0	1429	9682
Greece	328	115	213	2225
Ireland	281	99	182	1904
Italy	1144	403	741	7750
Netherlands	550	194	356	3725
Norway	351	123	228	2375
Austria	408	144	264	2766
Portugal	314	110	204	2129
Switzerland	470	165	305	3183
Finland	327	115	212	2213
Sweden	417	147	270	2827
Turkey	376	132	244	2548
United Kingdom	1200	0	1200	8130
Special projects	1240	0	1240	8400
Total	**12400**	**2275**	**10125**	**84000**

Special Project allocations 2002–2003

Member State		Institution	Project title	Priority	2002 Fujitsu units	2002 Data storage	2003 Fujitsu units	2004 Fujitsu units
Continuation Projects								
Austria	1	Univ. Vienna (Ehrendorfer)	Singular-vector-based multivariate normal sampling in ensemble prediction	P1	8000	6	9000	X
	2	Univ. Vienna (Hantel, Haimberger)	Atmospheric general circulation statistics from ERA-40 data	P1	2000	100	1000	X
	3	Univ. Graz (Kirchengast)	Climate monitoring by advanced space-borne sounding and atmospheric modelling	P2	1000	100	1000	1000
Belgium	4	Univ. Louvain (van Ypersele)	Modelling the climate and its evolution at the global and regional scales	P2	10000	440	20000	20000
Denmark	5	DMI (Sattler)	Heavy rain in Europe	P1	35000	200	50000	X
	6	DMI (Yang, Machenhauer)	Detection of changing radiative forcing over the recent decades	P2	79000	440	56300	X
Finland Sweden	7	FMI (Fortelius)	BEEOS in BRIDGE (Better exploitation of existing observations in BRIDGE)	P1	14000	50	20000	20000
France	8	L.A.M.P. (Cautenet)	Chemistry, cloud and radiation interactions in a meteorological model	P2	93	2	93	93
	9	CERFACS (Siefridt)	MERCATOR	P1	140000	1520	200000	200000
	10	CERFACS (Piacentini)	Universal software for data assimilation: variational method for global ocean	P1	10000	150	10000	10000
	11	CERFACS (Rogel)	Seasonal to interannual predictability of a coupled ocean-atmosphere model	P1	10000	150	10000	10000
	12	Univ. Nice, CNRM, UNAM Vernin, Bougeault, Masciadri)	Forecasting optical turbulence for astronomy applications with the MesoNH mesoscale model coupled with ECMWF products	P2	3000	30	3000	3000
	13	LSCE, CEA-CNRS (Claquin/Balkanski/Schulz)	Are the ECMWF weather predictions improved by accounting for mineral dust?	P1	7000	40	11000	11000
Germany	14	Univ. Koln (Speth)	Interpretation and calculation of energy budgets	P2	100	6	100	100
	15	MPI, Hamburg (Bengtsson)	Numerical experimentation with a coupled ocean/atmosphere model	P1	54000	335	120000	170000
	16	MPI, Hamburg (Bengtsson)	Simulation and validation of the hydrological cycle	P1	60000	300	140000	190000
	17	MPI, Hamburg (Manzini)	Middle atmosphere modelling	P1	48000	490	120000	170000
	18	GKSS, Geesthacht (Rockel)	Energy and water-cycle components in regional forecasts, remote sensing and field experiments	P2	10	0.2	10	10
	19	Univ. Munich (Stohl)	Validation of trajectory calculations	P2	750	60	1000	1250
	20	DLR, Wessling (Hoinka/Egger)	Climatology of the global tropopause	P2	3000	10	3000	3000
	21	D.L.R. (Doernbrack)	Influence of non-hydrostatic gravity waves on the stratospheric flow field above Scandinavia	P1	21000	80	35000	40000
	22	MPI, Hamburg (Schultz)	Modelling studies with the global atmospheric chemistry model MOZART	P1	21000	250	30000	15000
	23	Alfred Wegener Institute (A. Rinke)	Sensitivity runs with HIRHAM	P1	10000	100	10000	10000
	24	ISET (G. Czisch)	Evaluation of the global potential of energy towers	P2	500	30	500	500
	25	MPI, Jena (I.C. Prentice)	Biochemical feedbacks in the climate system	P2	30000	100	60000	X
Italy	26	ISDGM-CNR (Cavaleri)	Testing and application of a third generation wave model in the Mediterranean Sea	P1	3000	3	3000	3000
	27	ICTP, Trieste (Molteni)	Non-linear aspects of the systematic error of the ECMWF coupled model	P1	35000	80	50000	50000

Italy	28	ARPA-SMR, Emilia Romagna and Italian Met. Service (Paccagnella/Ferri)	Limited-area model targeted ensemble prediction system (LAM-TEPS)	P1	40000	40	40000	40000
Netherlands	29	KNMI (Siegmund)	Transport relevant for atmospheric chemistry	P2	4000	20	4000	4000
	30	KNMI (Drijfhout)	Agulhas	P2	10000	0	20000	20000
	31	KNMI (Siebesma)	Large Eddy Simulation (LES) of boundary layer clouds	P1	17500	50	30000	35000
	32	KNMI (Kelder)	Data assimilation of chemical species as observed by GOME and SCIAMACHY	P1	2000	10	2000	2000
	33	KNMI (Burgers)	OGCM mixed-layer modules and assimilation	P1	10500	100	X	X
	34	Netherlands Energy Research Foundation (ECN) (de Groot)	RECAB	P2	1000	20	1000	X
Norway	35	Univ. Bergen (Gronas / Kvamsto)	Cloud parametrization in general circulation models	P1	1000	0.5	1000	1000
	36	Univ. Oslo (Isaaksen)	Ozone as a climate gas	P1	10500	5	15000	15000
Sweden	37	SMHI (Unden)	The HIRLAM 5 project	P1	96000	770	250000	500000
Switzerland	38	Univ. Berne (Schupbach)	Classification of atmospheric circulation during extreme events in the Alps	P1	5000	50	5000	5000
United Kingdom	39	Univ. Reading (Hoskins)	Routine back trajectories	P2	4000	4	5000	5000
	40	Univ. Cambridge (Mussa)	Chemical data assimilation	P1	3000	4	3000	3000
	41	Br. Antartic Survey, Cambridge (Turner/Lachlan-Cope)	Assessment of ECMWF forecasts over the high latitude areas of the Southern Hemisphere	P1	0	1	0	0
	42	Univ. Reading (Hoskins)	Moist singular vectors	P1	10000	15	10000	X
	43	ESSC, Univ. Reading (Bengtsson)	Determination of the global water cycle by different observing systems	P1	120000	180	250000	280000
New Projects								
Austria	1	Universitat fur Bodenkultur, Vienna (Kromp-Kolb)	Modelling of tracer transport (MoTT)	P2	500	4.2	500	500
Norway	2	DNMI (Debernard, Haugen, Shi, Saetra, Odegaard)	REGCLIM	P2	50000	370	100000	100000
			Total requested		**990453**	**6715.9**	**1700503**	**1938453**

ECMWF calendar 2002

May 16–17	**Workshop** – *GMES*	
May 23–24	**Security Representatives meeting**	
May 27–28	**Computer Representatives meeting**	
Jun 17–18	**Medium-range forecasts – Users' meeting**	
Jun 19–20	**Seasonal forecasts – Users' meeting**	
Jun 27–28	**Council**	*56th*
Jul 8–10	**Workshop** – *Humidity analysis*	
Sep 9–13	**Seminar** – *Recent developments in predictability studies*	
Sep 25–27	**Scientific Advisory Committee**	*31st*
(Date to be decided)	**Advisory Committee of Co-operating States**	*8th*
Sep 30–Oct 2	**Technical Advisory Committee**	*32nd*
Oct 14–15	**Finance Committee**	*69th*
Oct 14–18	**Meteorological training course** – *Use and interpretation of ECMWF products*	
Oct 17–18	**Policy Advisory Committee**	*17th*
Nov 4–8	**Workshop** – *Use of parallel processors in meteorology*	
Nov 11–15	**Workshop** – *Role of the upper ocean in medium- and extended-range forecasting*	
Dec 2–3	**Council**	*57th*

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*

342 **Simmons**, **A.J.** and **A. Hollingsworth**: Some aspect of the improvement of skill in numerical weather prediction. *September 2001*.

343 **Rizz**, **R.**, **M. Matricardi** and **F. Miskolczi**: On the simulation of up-looking and down-looking high-resolution radiance spectra using two different radiative transfer models. *September 2001*

344 **Van den Hurk**, **B.**, **L. Phil Graham** and **P. Viterbo**: Comparison of land surface hydrology in regional climate simulations of the Baltic Sea catchment. *November 2001*

345 **Matricardi**, **M.**, **F. Chevallier**, **S. Tjemkes**: An improved general fast radiative transfer model for the assimilation of radiance observations. *May 2001*

347 **Andersson, E.**, and **M. Fisher**: Developments in 4D-Var and Kalman Filtering. *September 2001*

348 **Bouttier**, **F.**: The development of 12-hourly 4D-Var. *September 2001*

349 **Leidner**, **S.M.**, **L. Isaksen**, **R.N. Hoffman**: Impact of NSCAT winds on tropical cyclones in the ECMWF 4D-Var assimilation system. *October 2001*.

Seminar Proceedings:

Exploitation of the New Generation of Satellite Instruments for Numerical Weather Prediction, *4–8 September 2000*

ECMWF/EuroTRMM Workshop on Assimilation of clouds and precipitation. *6–9 November 2000*.

ECMWF/EUMETSAT Satellite Application Facility Report

Chevallier, **F.** and **Kelly**, **G.**: Model clouds as seen from space: comparison with geostationary imagery in the 11µm window channel. ECMWF/EUMETSAT Satellite Application Facility Report No. 3, *July 2001*.

ECMWF/EUMETSAT Fellowship Programme Research Report

Köpken, **C**. Monitoring of EUMETSAT WV Radiances and Solar Stray Light Effects. ECMWF/EUMETSAT Fellowship Programme Research Report No. 10, *September 2001*

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*

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

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e.g. the Director's number is:
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