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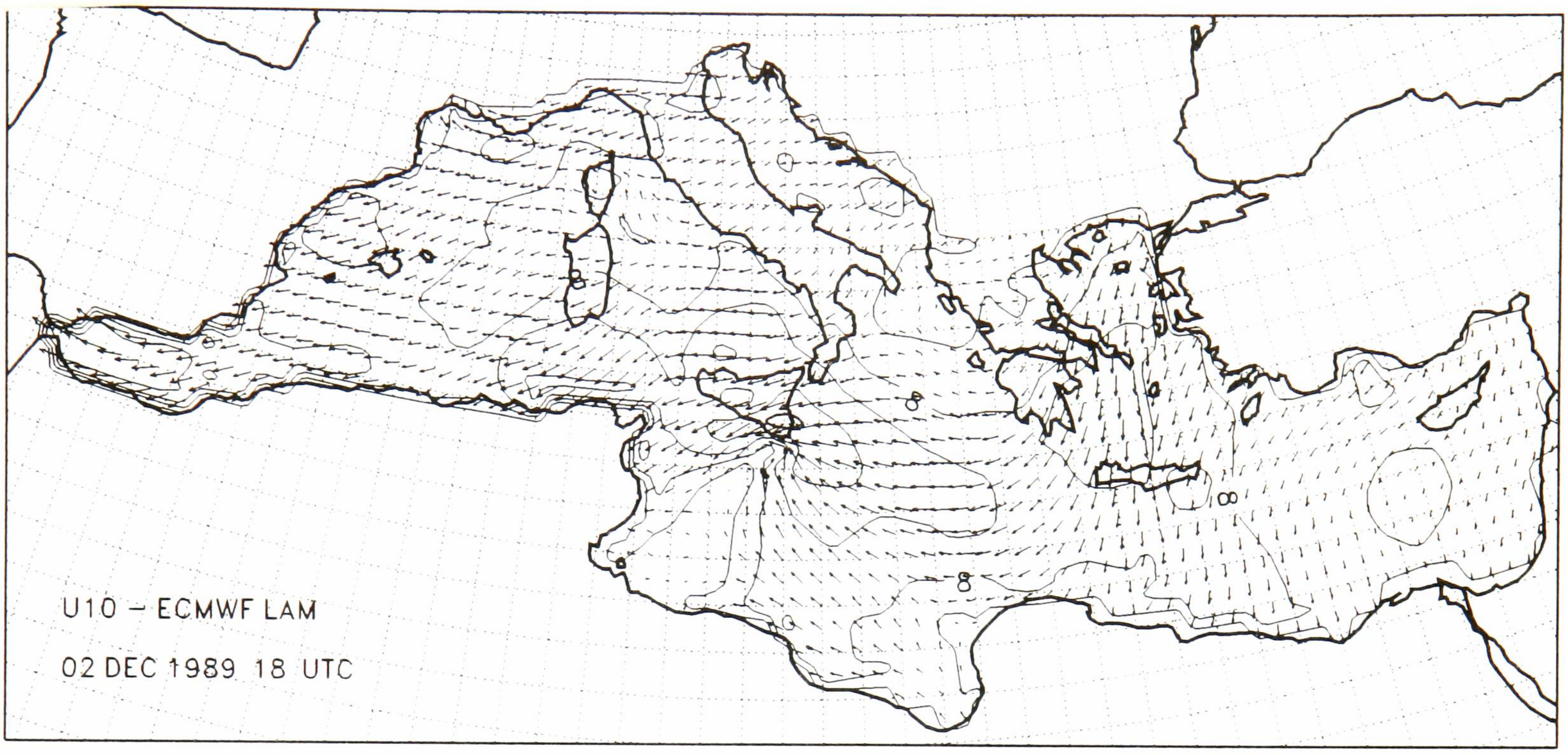

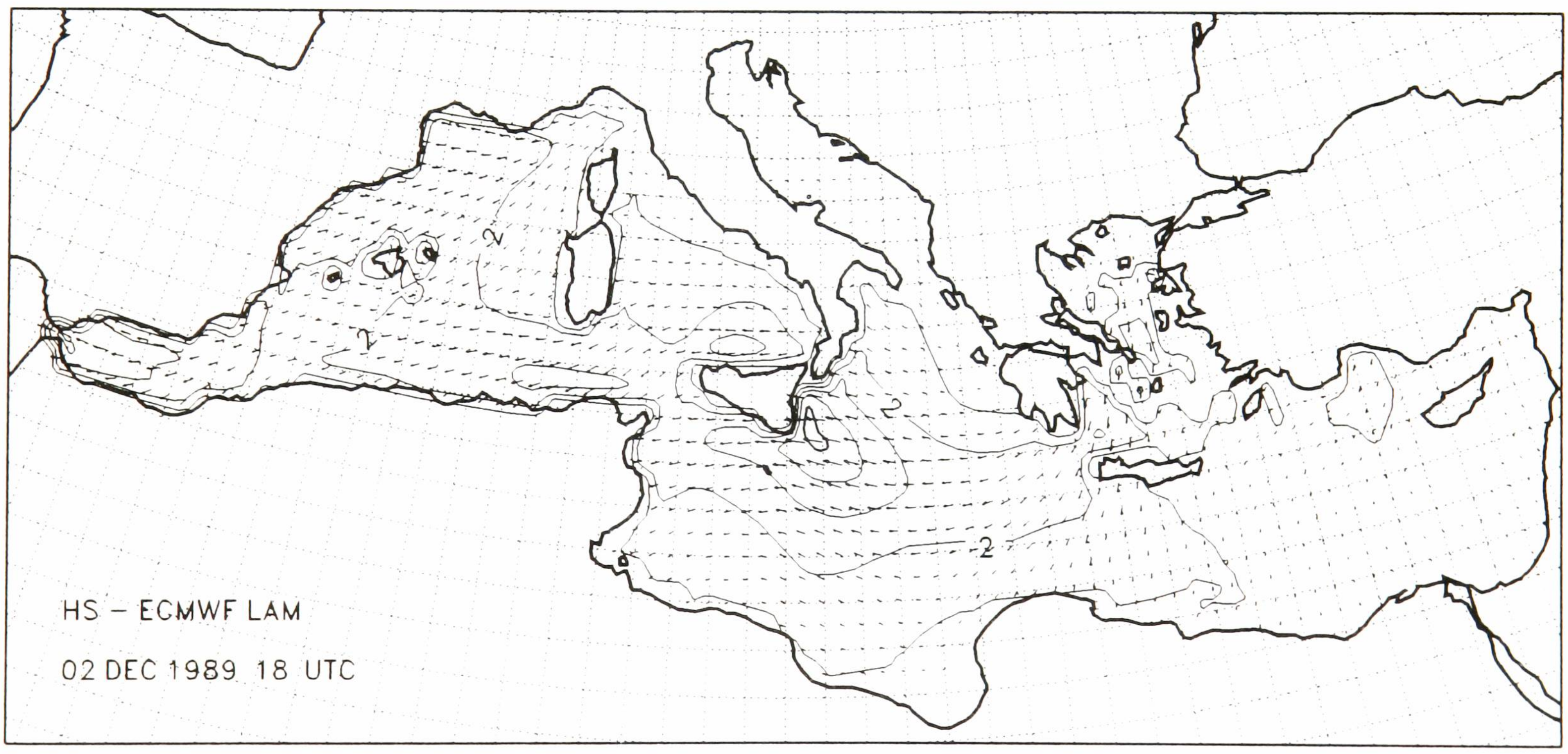

Shinfield Park, Reading, Berkshire RG2 9AX, England. Telephone: U.K. (0734) 499000,
International (+44 734) 499000, Telex: 847908 ECMWF G, Telefax (0734) 869450

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen terme

IN THIS ISSUE

COVER: Products of LAM in high resolution experiment: 20 ms^{-1} wind on eastern coast of Sicily at 18 UTC on 2 December 1989 (above) and wave map for same time (below). See article "GORBUSH - a storm in the Mediterranean Sea", page 4.

This Newsletter is edited and produced by User Support.

The next issue will appear in June 1991.

It is my pleasure, as the newly-appointed Director of the Centre, to introduce this first ECMWF Newsletter of 1991.

Although new to this appointment, I have, as a scientist and Head of Research, been involved in the work of the Centre since its inception, and can congratulate my predecessors on the achievements of the past fifteen years, made under their aegis.

The Centre's plans have received enthusiastic support from the ECMWF Council, which has provided a good financial basis for the future. I shall put emphasis on our operational forecasting services, the development of our computer system, long-term plans and our programmes of research and education. I shall also strive to strengthen scientific and technical co-operation with institutions of the Member States, and I hope that closer co-operation with institutes in other countries will also be achieved. Such co-operation has always been stimulating and rewarding.

I hope that in the years to come we will emulate the high level of achievement attained in the past, and I know that I can depend on the enthusiasm of all those connected with the Centre to attain this.

\- David Burridge
Director

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This first Newsletter of 1991 contains an article outlining the Computing Division's present status and plans for the near future.

There is an article describing the newly-installed CYBER 962, and another introducing the forthcoming new MARS manual. Developments in the field of massively parallel computing, which are being followed with interest by the Centre, are also described.

On the meteorological side, there is description of experiments made jointly by ECMWF and ISDGM, applying the Centre's global model, a limited area model and the third-generation wave model to the weather conditions causing the storm which affected the Gorbachev-Bush summit at Malta in December 1989.

As is customary, this first issue of 1991 contains information on the allocation of computer resources for the year, the current lists of Member States' representation in the TAC, their Computer Representatives and their Meteorological Contact Points, and the announcement of the annual ECMWF Seminar to be held in September 1991.

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CHANGES TO THE OPERATIONAL FORECASTING SYSTEM

Recent changes

On 12 February 1991 a change was introduced in the analysis so that the departures of the observations are now calculated against a first-guess valid at the time of the observation, obtained by interpolation from first-guess at 3, 6 or 9 hours range. Therefore, asynoptic observations are used more consistently.

This change increases the accuracy of the analyses. It should also improve the handling of small scale features in the forecast in certain situations, such as rapid cyclogenesis. A small positive impact on the forecast is expected on average.

Planned changes

A new procedure for the quality control of satellite temperature profiles will be implemented; a pre-selection will be performed before the data are passed to the analysis, making use of the high resolution cloud-cleared radiances received from NESDIS.

The first-guess checks of wind and humidity data will be enhanced.

Revisions will be made to the diagnostic cloud scheme, including a reduction in the incidence of non-precipitating cloud over the oceans. For cloud/radiation interaction, maximum overlap assumption will replace the present random overlap assumption.

The annual mean surface albedo will be revised.

A small amount of vertical diffusion in the free atmosphere will be re-introduced. (It was set to zero for statically stable conditions in January 1988; the new setting will be significantly smaller than the 1987 setting.)

It is also planned to implement a model with a substantially higher resolution later in the 2nd quarter of 1991, depending on satisfactory results from further benchmarking.

- Bernard Strauss

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GORBUSH: A STORM IN THE MEDITERRANEAN SEA

Introduction

It can happen that the location or the circumstances of an important meeting between Heads of States are more memorable than the reason for, or the outcome of, the meeting itself. Many remember the meeting between President Bush and President Gorbachev in Malta on 2 December 1989, because of the disruption caused by a major storm, which itself became the subject of investigation from the oceanographic and meteorological point of view. At the Istituto per lo Studio della Dinamica delle Grandi Masse (ISDGM) in Venice, Luciana Bertotti and Luigi Cavaleri were interested in reproducing the storm using an advanced wave model (The WAM-DI Group, 1988). The ISDGM has a "special project" at ECMWF for the application of a third generation wave model in the Mediterranean Sea. Here at ECMWF, we were interested in investigating the impact of the horizontal resolution of our model on both the atmospheric and oceanographic simulations. The effectiveness of high resolution meteorological models, embedded in the global ones, in enhancing the details and position of small scale meteorological events, has already been demonstrated. The combination of high resolution atmospheric models and advanced wave models had yet to be tested. We started by baptising the storm: "GORBUSH".

Synoptic description

It was the combination of a stationary system of high pressure centred over Central Europe and a fast moving "desert depression" that caused the strong wind and high seas that disrupted the meeting between President Gorbachev and President Bush on 2 December, 1989. The "desert depressions" originate just south of the Atlas Mountains or over the Sahel in West Africa, on the southern fringe of the Sahara desert. They can cross the North-African desert and, as in this case, the Mediterranean Sea. These depressions seldom last longer than a few days, and seldom reach higher than 700 hPa. They are characterized by a warm southerly wind ("Gibli" in Libya) that usually causes sand storms. The peculiarity of this particular desert depression lies in its merging with the circulation associated with the high pressure over Europe.

A "desert depression", associated with a small 500 hPa trough, located just south of the 35°N parallel on 1 December, 12 UTC, appears, at the surface, as a closed low off the coast of Libya at 06 UTC 2 December (Fig. 1a). The synoptic charts of the Meteorological Service of Malta show the merging of the warm surface southerly flow from Africa with the colder easterly flow associated with the high pressure over Europe. This gave rise to a thermal front and 35 kt (about 17 ms) wind over the southern tip of Sicily and over Malta at 06 UTC 2 December. Twelve hours later, at 18 UTC 2 December (Fig. 1b), the wind increased to 40 kt (about 20 ms) over the region between southern Sicily and Malta, where the sea wave height was estimated at between 4 and 5 metres.

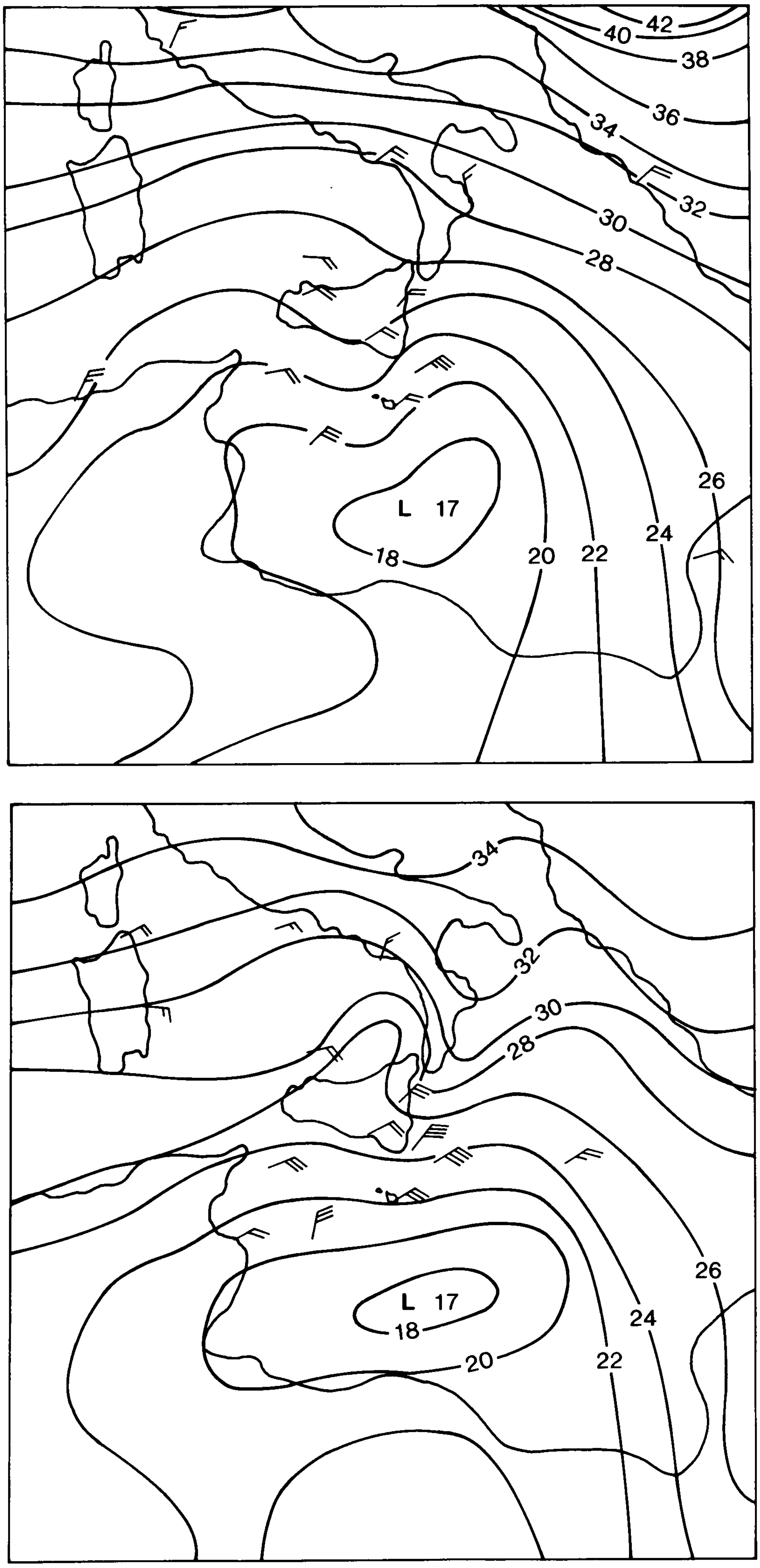

Fig. 1: MSLP and wind from the synoptic map of the Meteorological Service of Malta for 06 UTC (a) and 18 UTC (b) 2 December, 1989.

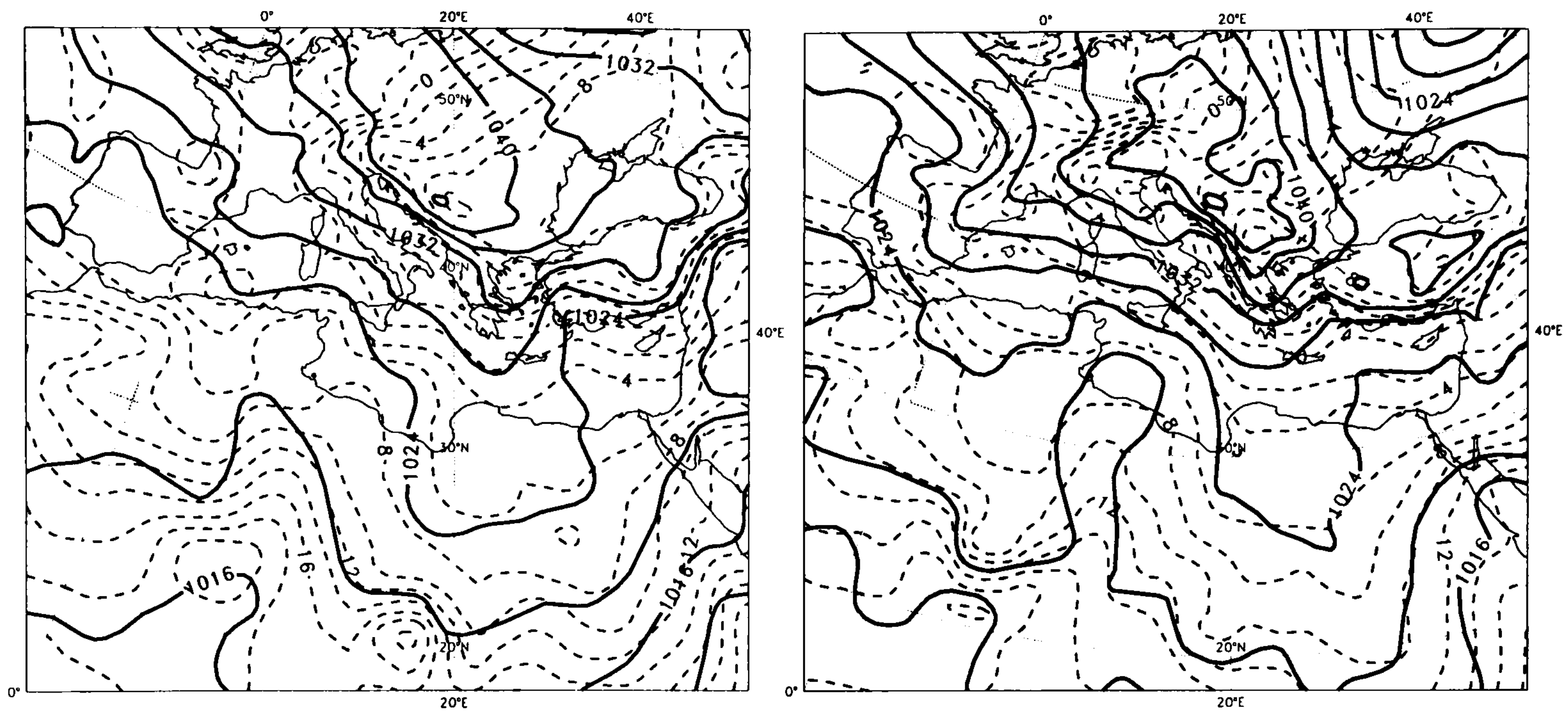

Fig. 2: MSLP (solid lines) and temperature at 850 hPa (dashed lines) for the analysis at 12 UTC 1 December, 1989 (a), and the global forecast at T+18, verifying at 6 UTC 2 December, 1989 (b). Contours every 4 hPa, and 2 degrees.

Numerical results

We used both the global (GM) and limited area models (LAM) of the Centre, with resolution of about 125 and 40 km grid size respectively, and the WAM model at 0.5 degrees resolution. The WAM wave model uses the friction velocity obtained from the atmospheric model as an input. It represents the wave conditions by a two dimensional spectrum, in frequency and direction, and governs the wave conditions through the energy balance equation to describe propagation, growth and dissipation of the wave field. The meteorological experiments were both started from the analysis of 12 UTC, 1 December 1989 (Fig. 2a). The mean sea level pressure chart from the GM at T+18 (Fig. 2b) shows the "desert depression" as an area of low pressure moving northwards fast. The 850 hPa temperature field depicted in the same maps shows a tongue of warm air being advected towards the Mediterranean Sea. The southerly flow of warm air accompanying the "desert depression" creates a thermal front when merging with the cold easterly wind from the area of surface high pressure centred over Europe. This can be clearly seen in Fig. 3a, which shows the forecast 10 metres wind at 06 UTC 2 December. At 18 UTC (Fig. 3b), 12 ms^{-1} maximum wind reached the eastern part of Sicily. Results from the high resolution experiment show that the LAM produces a more pronounced cyclonic circulation, so that a much stronger wind can already be seen at 6 UTC, 2 December (Fig. 3c). The cyclonic circulation intensifies and at 18 UTC 2 December, a 20 ms^{-1} maximum wind hits the eastern coast of Sicily (Fig. 3d), in agreement with the observations. The dry air advected from the African coast over the sea is confined below 850 hPa. At about the same level, easterly cold air from the high pressure is advected over the region. Moist air is then lifted over the narrow frontal zone.

Fig. 4 shows the wave maps corresponding to Fig. 3. Here the vector length is proportional to the wave height, pointing in the direction of the mean flow. The maximum height is reached on the south-western corner of Sicily, while at Malta the wave height does not exceed 2 metres for the GM at this time. In the LAM experiment however, the wave response, consistent with the intensification of the wind field, shows a peak wave height of over 5 metres, with a much stronger gradient in the peak area. This is a clear indication in itself of the gradient of the input wind field. The circulation of the field is also now much more pronounced on the west side of the low, to the west of Malta. The wave height at Malta has increased to over 3 metres - a more realistic value than the GM results for the conditions reported in the area of the Gorbush storm at this stage.

As a matter of interest to meteorologists, some characteristic differences in the wind (Fig. 3) and wave (Fig. 4) maps can be noted. In the wind maps there is a strong circulation of the flow around the low which protrudes into the Ionian Sea. The wave maps show a smoother field, with lesser gradients for both modulus and direction. This is characteristic of wave fields, since they result not only from the instantaneous wind field, but from the integrated effect in space and time of the overall input. Consequently, and this is particularly true when the sea is already well developed, the wind waves do not react immediately to a sudden change of the wind direction.

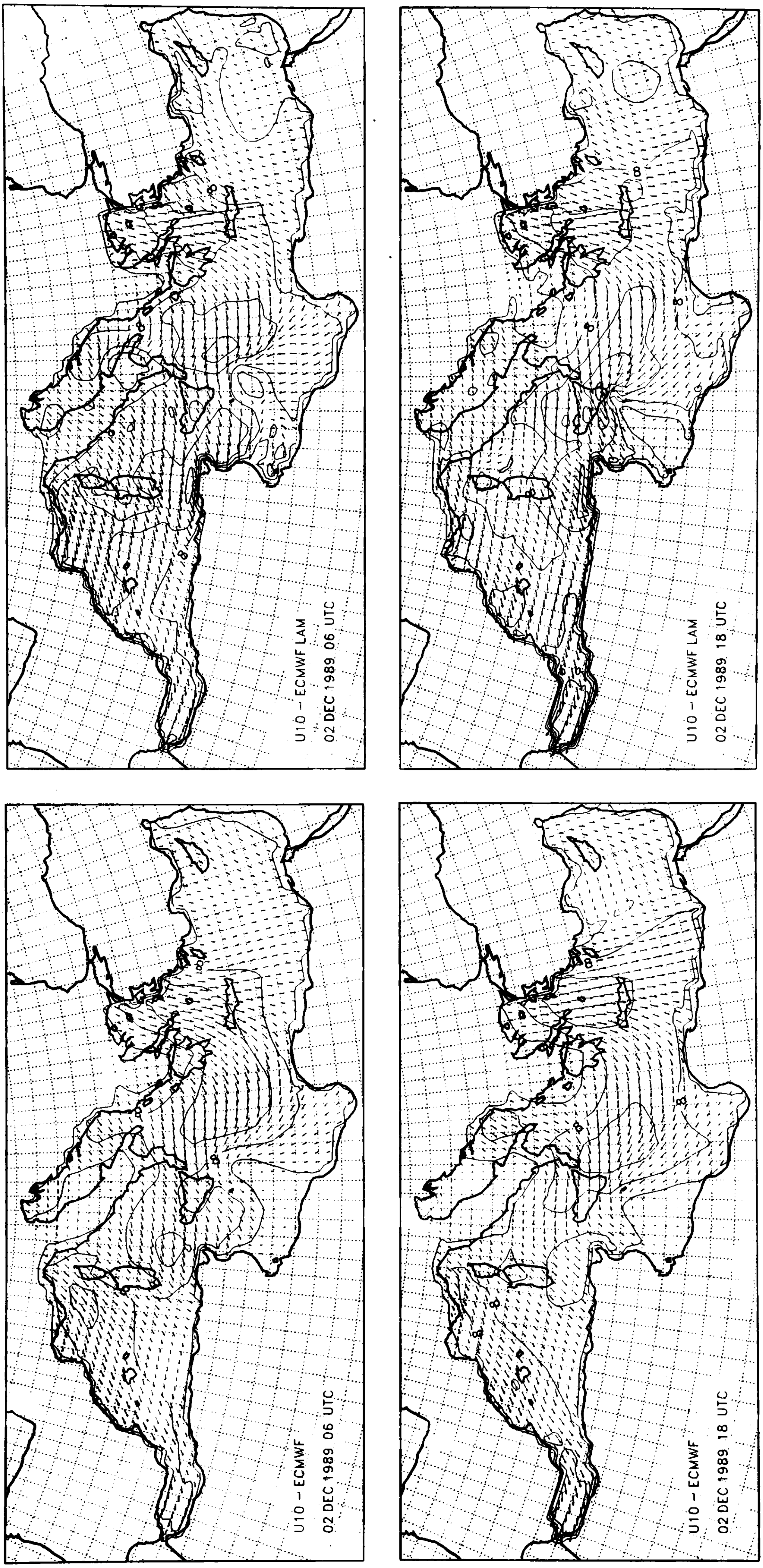

Fig. 3: 10 metre wind forecast at 06 UTC and 18 UTC 2 December 1989, from the global model (left) and the limited area (right). Contours every 4 m/s .

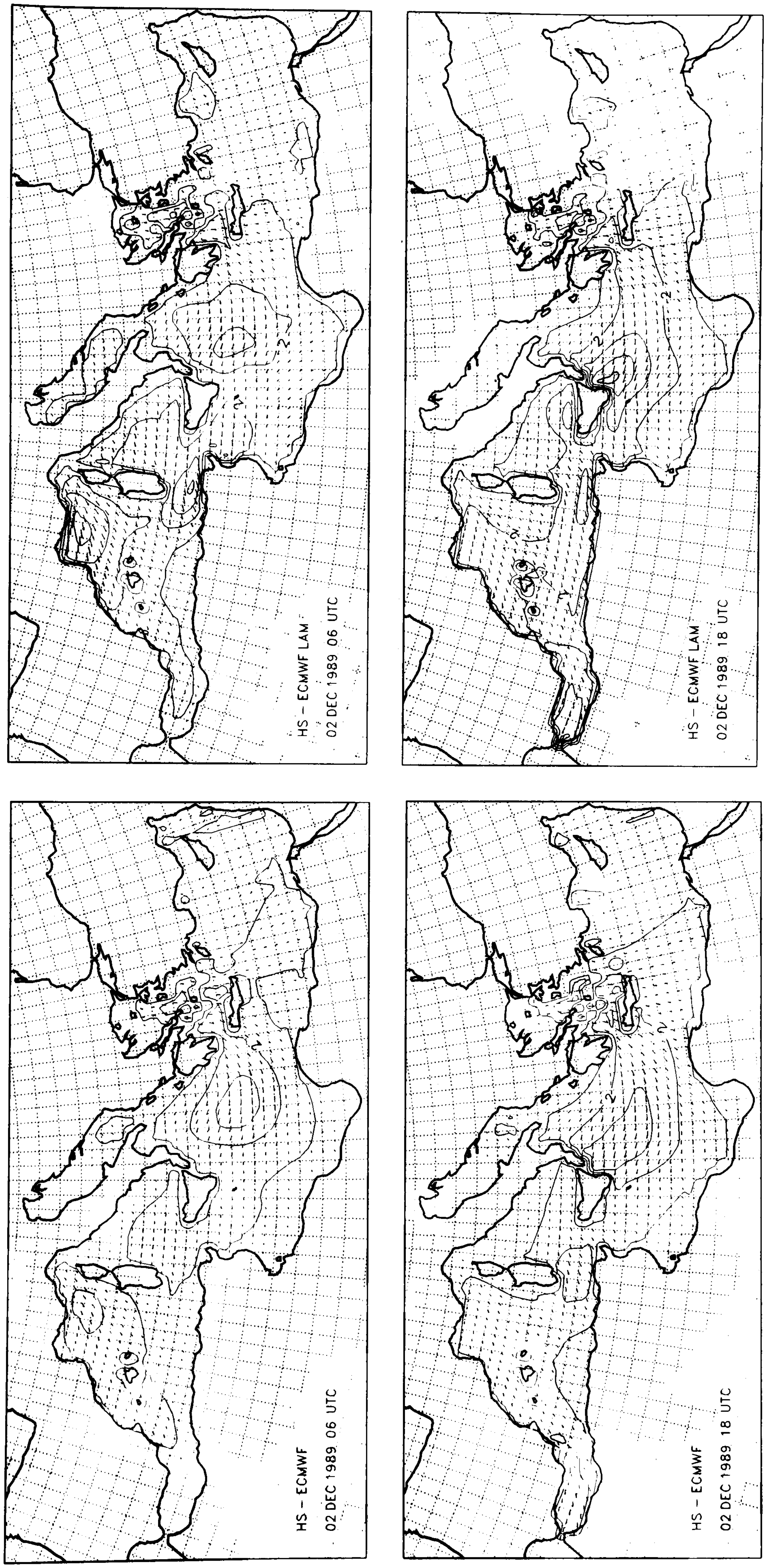

Fig. 4: Distribution of the significant wave height (Hs, in metre) contemporary to the maps of Fig. 3. Contours every metre.

Rather there is selective action on the different frequencies of the spectrum. The higher frequencies react first, leading to a gradual change in the wave field.

Conclusion

The global and limited area ECMWF models, at T106 and T333 resolution respectively, gave a fair description of the "desert depression" approaching the Mediterranean Sea and the subsequent merging of the southerly with the easterly flow. The good forecast of the position of the low led to a fair forecast of the surface wind by the GM. The results were further improved by the LAM by deepening the low, strengthening the wind, increasing the spatial gradients and localizing the maximum wind in the correct area. Strengthening the wind led to a similar strengthening of the wave field, up to the values recorded by the directional buoys located nearby, and visually reported in Malta. The error in the exact location of the low has been estimated at a lower value than the grid size of the LAM. This may be enough to cause a wrong estimate of the wind direction, and underlines the need for a higher resolution in the case of small, but strong, phenomena. In itself, however, this would not suffice. In the present study the positive results of the LAM are closely linked to a good description of the situation provided by the GM. The LAM has enhanced the details of the field. Had the GM drastically missed the position of the low, the LAM would have given similarly poor results. In such cases, moreover, the high resolution can lead to a magnification of the error.

References

The WAM-DI Group, 1988: The WAM model - A third generation ocean wave prediction model.J.Physic.Ocean.,18,1775-1810.

- Lorenzo Dell'Osso, Luciana Bertotti, Luigi Cavaleri

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COMPUTER DIVISION'S STATUS AND PLANS

(This article is based on a talk given by G.-R. Hoffmann to all Centre staff on 7 December 1990.)

The past year has seen one of the biggest changes for users of ECMWF's computer system since the Centre opened, namely the switch from COS to UNICOS. With the basic changeover now complete, the year ahead will see a consolidation of the UNICOS service, the first stages of a replacement for the IBM data handling system, and the development of workstations.

Overall there has been much change in the Computer Hall, with major moves of equipment made. Further moves are planned in 1991 to remove obsolete equipment, and to make space for new equipment.

Because of the substantial effort of manpower required during 1990 to migrate all software to UNICOS, there was less to spare for checking on operational problems. The result was a rise in the number of forecasts over 1 hour late. It will thus be a priority task during 1991 to bring the number of delayed forecasts back to its previous level.

CRAY

With its successful installation, acceptance and operation, the CRAY Y-MP is now the Centre's principal "compute engine". All main facilities are operational, but some, e.g. RQS, need more work to make them acceptable. The year ahead will be spent in tuning the system, learning the complexities of its scheduler, and generally consolidating the service.

RQS is the VAX-based software that handles batch job submission from Member States and Centre VAX users to UNICOS. This software, provided by Cray Research (UK), is currently only at a beta release stage and is suffering from several problems which make the Member State batch service unreliable. Intensive work is in hand, with Cray Research, to improve it. The first official release is due around June 1991.

Towards the end of the year a benchmark of the CRAY Y-MP/16 will take place to ensure that this machine, due to be installed in mid 1992, will meet our contractual requirements with regard to performance.

With regard to software there will be a major upgrade of UNICOS itself, to release level 6. This should take place in the first half of 1991.

Data handling

A review of the Centre's archiving policy was conducted in 1990, as a result of which a new policy has been adopted for 1991 and beyond. Because of the increased resolution foreseen in future models, much more data will be stored and much more link traffic generated. This will put pressure on the data handling system, which already holds 2.8 Tbytes of data, some 1.6 Tbytes of which are MARS data.

The first step is the replacement of the IBM 3851 Mass Storage System. A string of Comparex disks has been installed to provide an extra 60 Gbytes capacity, and additional memory and channels have been added. Then in February the 3851 was switched off and removed. In May the Centre takes delivery of two StorageTek ACL systems. These are robot devices that automatically store and load the standard 3480 200 Mbyte cartridges on which all the Centre's data is now archived. Each module contains about 5000 cartridges. Another two ACLs will be added in 1992 and 1993 respectively.

During 1991 an Invitation To Tender will be issued for an upgrade or replacement of the IBM 3090 processor itself. Installation of the replacement will then take place in January 1992.

Cybers

In December 1990 a Cyber 962 was installed. This machine is to replace the two existing Cyber 855s, which are now old technology and proving expensive to maintain. Although it has the same CPU capacity as one Cyber 855, the new Cyber has much more memory and higher disk transfer speeds, plus a more reliable disk subsystem. The new machine will therefore provide a better NOS/VE service, in the period up to the termination of this service, i.e. in 1993. Other advantages of the Cyber 962 are that it is much smaller, saving on floor space, and more economical to run.

The NOS/VE system itself will continue to be upgraded to keep us in step with the latest releases from CDC.

Print services

New plotters were introduced in 1990, improving the previous poor service considerably. These provide A3/A4 black and white plots. At the same time, two A3 colour plotters have been put into service to replace the aged Benson. All these new plotters are PostScript devices.

Workstations

The Centre now has approximately 20 SUN SPARC stations, plus a few DEC stations. These workstations are all UNIX based, running the de facto standard interfaces of X-windows, either the Motif or Open Look graphical user interface, and TCP/IP network connections. During 1990, they were used primarily as window devices to UNICOS in order to speed the migration process, a task for which they seem very suitable. The aim now is to develop further services on them, including

- provision of an "office" environment comparable to that on PCs;
- provision of an interface to ECFILE, and hence to MARS;
- provision of UNICOS batch queue access;
- investigation of how to replicate NOS/VE type services, e.g. integrated editors and save code utilities;
- investigation of other local computing services, e.g. Fortran, MAGICS, METVIEW;
- consideration of enhancement of the file server capacity;
- monitoring the balance of work on all these machines.

The ultimate objective is to provide, via these workstations, a superior service to both NOS/VE and the PC-based services now in general use. A development plan for these workstations has been circulated within the Centre for comment.

VAXs

There are no plans for major enhancements to the VAX system during 1991. In fact, one old VAX 11/750 has been withdrawn from service, and it is hoped that during 1991 another 11/750 can be disposed of. The VAX load should also decrease slightly during the year in a couple of respects. As the new plotters do not require external vector to raster conversion, the VAXs no longer have to do this task. The telecommunications load on the VAXs will also reduce as France, and then Germany, switch to 64 Kbps Ethernet links. However, an increased load will be seen as more meteorological data is taken each day; this is especially true as more satellite data becomes available.

During 1990 one worrying aspect of the VAX service was the increased frequency of problems, some of which resulted in lengthy downtimes and delays. These are being carefully analysed, and hopefully the situation will improve during 1991.

Links

With machines being upgraded, higher resolution models planned, and more incoming data to handle, there is now a need to improve the various links substantially.

As noted above, during 1991 two Member States will move to 64 Kbps links. This is in addition to the existing 64 Kbps link already operational to the UK Met Office. All these new links will be TCP/IP based running via Ethernet LAN bridges.

During 1991 experiments will be conducted with an Ultranet system that was delivered at the end of 1990. This is a channel speed series of links between the Cray, IBM and 3 SUN systems. Ultranet will be used to develop software which will be needed to replace the existing LCN/RHF 50 Mbits/sec links with a FDDI based network of 100 Mb/s. Looking further ahead, the Centre hopes to investigate the so-called HiPPI type of link, for possible installation in 1993. This type of link runs at 800 Mbits/sec.

\- Andrew Lea

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ECMWF'S CYBER 962

The Cyber 962 provides a general-purpose computing facility based on NOS/VE, with CDCNET and TCP/IP connections to a variety of other machines, plus a channel connection to the Cray Y-MP. Its primary use is for general interactive work such as job preparation and submission, source code maintenance, etc., plus Cray job monitoring and control via the NOS/VE Station. It also provides various TCP/IP-based services such as NFS, FTP, and LPD.

Installation

On 16 December 1990 the 962 and the DAS (Disk Array Subsystem) were delivered to ECMWF. All installation milestones were passed on time, and on 2 February 1991 the production services were moved from the 855 to the 962, according to plan. No user impact was observed.

The service so far has proved to be very satisfactory, and has shown significant improvements in performance. The memory and I/O bottlenecks which had existed are now relieved, and users note markedly improved responsiveness. During peak periods, CPU, memory and I/O are used in balanced proportion, and there is reserve capacity in all resources.

The Cyber 962 Hardware

The Cyber 962-11 is a general-purpose air-cooled mainframe computer of modern design. The ECMWF machine has 64 Mbytes of central memory, ten independent peripheral processors, and eight high-speed data channels (six 10 MB/sec channels and two 25 MB/sec channels).

The 5830 Disk Array Subsystem (DAS) is a state-of-the-art storage device. The DAS as installed at ECMWF is configured with the following capabilities:

* Disk array control modules.
* Rotating mass storage with a single-spindle transfer rate of 6 MB/sec.
* Parallel mode operation, with disk arrays providing up to 24 MB/sec.
* Parity protection, allowing one spindle to parity protect an array.

It is most notable that parallel mode operation and parity protection are performed entirely by the control modules, and are thus transparent to the operating system and applications and impose no additional load on the host computer.

The ECMWF DAS has two 25 MB/sec parallel control modules, accessing ten gigabytes of rotating storage configured as parity-protected arrays for permanent files, with serial disks for temporary files. Loss of user data due to hardware malfunction appears to be extremely unlikely. Control modules and disks are all contained in one cabinet occupying 0.8 square metre of floor space.

Hardware Summary

The following table gives a comparison of the main hardware characteristics of ECMWF's new 962 and the old NOS/VE 855 system.

HARDWARE CHARACTERISTICS	962	855
Clock cycle time (ns)	11	64
Relative peak computation rate (ECMWF numeric tests)	1.15	1.0
Size of main memory (MBytes)	64	32
Type of disks	5833	895
Number of disks	13	16
Size of disks (GBytes)	1.0	0.53
Data disk space (GBytes)	10.0	8.5
Parity disk space (GBytes)	3.0	-
Disk channels (Number*MBytes/s)	2*25.0	4*3.0
Disk transfer rate (MBytes/s per spindle)	6.0	3.0
Volume transfer rate (MBytes/s per parity array on DAS)	18.0	3.0

- Dieter Niebel

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A VIEW ON MASSIVELY PARALLEL COMPUTING

1. Use of parallel processing in meteorology

Since 1984 ECMWF has followed developments in massively parallel computing by arranging biennial workshops on the Use of Parallel Processors in Meteorology. The fourth such workshop took place on 26-30 November 1990 and focused on software environments for parallel computers. Since 1989 the Centre has also participated in the ESPRIT project Genesis, which aims to promote the use of massively parallel computers by developing tools to program them, with strong emphasis on the requirements of application developers.

Massively parallel computers have until now only been used experimentally by meteorologists. One of the reasons has been the lack of reliable vendors and guaranteed upgrade paths on the market, another the high programming threshold for writing code on such machines. The main reason, however, has been uncertainty as to whether massively parallel computers can really deliver the superior performance expected from them.

This last factor has been addressed during the last five years or so by a number of meteorological centres, including NCAR, USA, UKMO, NMC Washington, KNMI, ECMWF, and many universities, by porting kernels and even complete models onto massively parallel machines. The results have been encouraging, with good levels of parallel efficiency reached, but negative factors have also emerged; programming is tedious and codes often have to be rewritten for every new machine. On the other hand, vector supercomputers have been able to keep ahead of massively parallel supercomputers in sustainable peak performance. Hence, despite the high parallel efficiency attained on massively parallel computers, we have still to see a full operational weather model running faster on a massively parallel supercomputer than on a vector supercomputer.

2. Programming distributed memory parallel computers

The most notable division in programming parallel computers is between programming models for distributed memory and for shared memory. In using distributed memory, it is cumbersome to write code where references to different parts of a single data structure have to be made by explicit message passing, with buffering and other associated complications.

Three principal ways to solve this problem have been suggested. Firstly, there are a number of novel parallel languages that explicitly include parallelization constructs. Many of these are very elegant and often have sound parallel semantics. The main objection to novel languages is the pre-eminent status of Fortran in scientific computing. It would be mandatory for a novel parallel language to provide the ability to link Fortran modules. Novel languages would often be used as communication harnesses only.

The second avenue is provided by subroutine libraries and higher level software packages, use of which is increasing. High level tools are, however, most often written using Fortran and the task of parallelization is merely transferred to software vendors.

Although libraries can help with some aspects of parallelization, programming in general would be much easier with some form of shared memory. The third proposed solution to the programming problem is a virtual shared memory.

The main problem in implementing virtual shared memory is in managing the logical complexity of efficiently mapping a shared data structure to a distributed memory with limited long-range communication capacity. One solution would be to limit shared memory to a small number of large data structures. Page traffic could be conducted at object, rather than page, level, allowing for more efficient high volume data transfer. Allowing the user to request access to a segment of a shared data structure in advance, and imposing the location of any such segment by hand if necessary, would be means of boosting efficiency significantly while retaining most of the convenience.

I/O may also have to be different on a massively parallel system compared to a vector supercomputer. In centralized file systems the host computer is a severe bottleneck The most economical way to provide a great deal of I/O capacity on a massively parallel computer is by using distributed SCSI disk systems attached to processing nodes but these create a problem analogous to that of a distributed memory. It would therefore seem natural to use them for memory mapped I/O alone; to store data structures rather than files. A conventional file system could be provided at the host to be accessed with a high-speed network running, for example, the HIPPI protocol. The problems related to the management of massively large data sets in an operational environment have not yet been properly addressed by most parallel computer manufacturers.

3. Impact of architecture

Apart from programming differences, the most significant difference between shared memory supercomputers and massively parallel computers is probably data access. Massively parallel computers are mainly advocated because of superior capacity and cost effectiveness in computation. Algorithms are mainly studied from the point of view of parallelizability of computation. In the case of meteorological models it seems that there is much potential as far as parallelization of computation goes; however, there are serious potential problems in data access.

3.1. Global data access characteristics of meteorological algorithms

In addition to data allocation requirements imposed by the geometry of the earth, each numerical algorithm has its own characteristic computational geometry. A rectangular two-dimensional grid with nearest neighbour connectivity is the natural data dependency graph of explicit grid point methods without Fourier filtering. This assumes that vertical columns are stored within individual processing nodes. This is justified by the intense vertical data dependencies in the parametrization. Fourier filtering introduces data dependency along every full latitude in a neighbourhood of the poles (see Fig. 1).

Spectral methods are global and the dimension of their data dependency graphs grows logarithmically with resolution. They display strong data dependency in both latitudinal and longitudinal directions, requiring intermediate transposition if all individual Fourier and Legendre transforms are to be performed within individual processing nodes. Because of the need for tensor-product grids in spectral methods, this dependency is orthotropical and does not extend beyond the latitude and the longitude of each grid point (see Fig. 2). The internal data dependency structure of the Fast Fourier Transform is a hypercube, which is a compressed butterfly network (see Fig. 3).

In other branches of fluid dynamics, multigrid methods have gained in popularity. It is possible that they will play a rôle also in weather modelling. They share the basic grid-like nearest neighbour data dependency structure of grid point methods. In addition to this, multigrid methods also display a pyramidal dependency structure due to the coarse grid correction procedure they employ (see Fig. 4).

Data dependency graphs are weighted, the weight along each edge being the volume of communication along it. The basic structures described above have an essentially uniform weight distribution. This means that the potential communication volume required at each processing node grows logarithmically with the number of nodes when implementing spectral methods, whereas, with explicit grid point and multigrid methods, it remains constant.

As a whole, global weather models will be increasingly dominated computationally by physics and nonlinear dynamics, both of which involve almost purely local computations. Therefore, the effective parallelization of the linear part of the dynamics may not be crucial to performance in the end.
A particular numerical technique that is most likely to be employed in spectral and grid point models alike is semi-Lagrangian advection. Semi-Lagrangian advection is, in principle, similar to a grid point method in its data dependency pattern. The set of nearest neighbours extends up to five grid lines away, similar to a high order grid point method. This strains both communication links and local memory.

3.2. Mapping weighted dependency graphs onto parallel topologies

In an ideal situation a massively parallel computer should have so rich a topology that any edge in the dependency graph of any relevant algorithm can be mapped onto a single physical link - even when the communication volume is taken into account. In practice, this is seldom the case. A relevant measure of the success of this mapping is the average or maximal expansion any edge in the dependency graph is subjected to in the mapping, i. e. over how many consecutive links edges of the dependency graph have to be stretched.

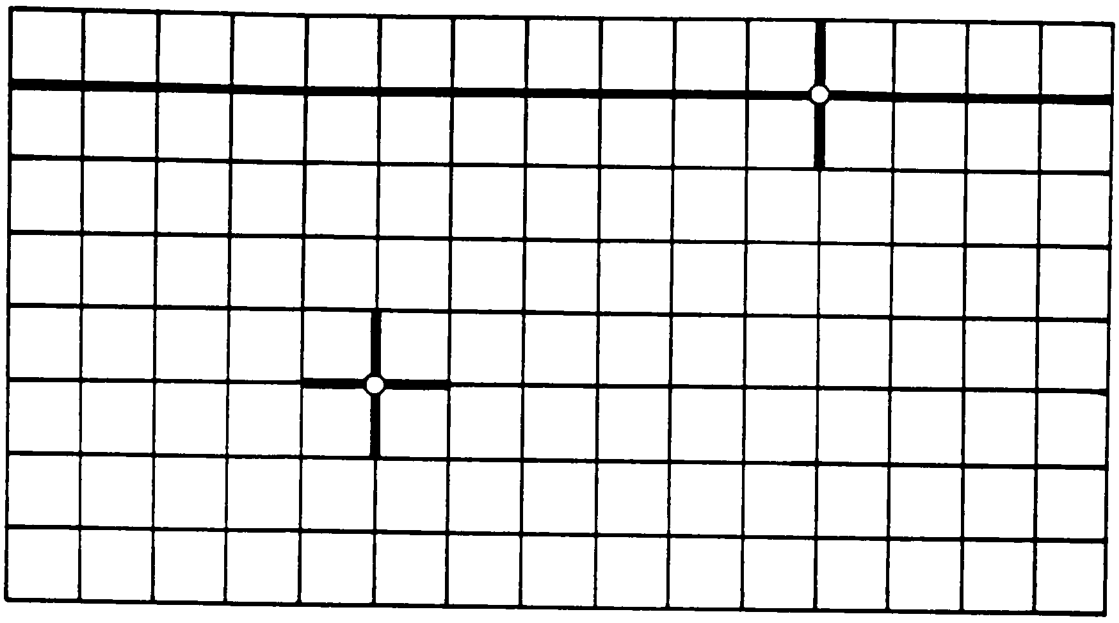

Fig. 1: Grid topology of an explicit scheme. Thick lines show data dependency patterns when the grid is mapped onto a sphere and Fourier filtering is used.

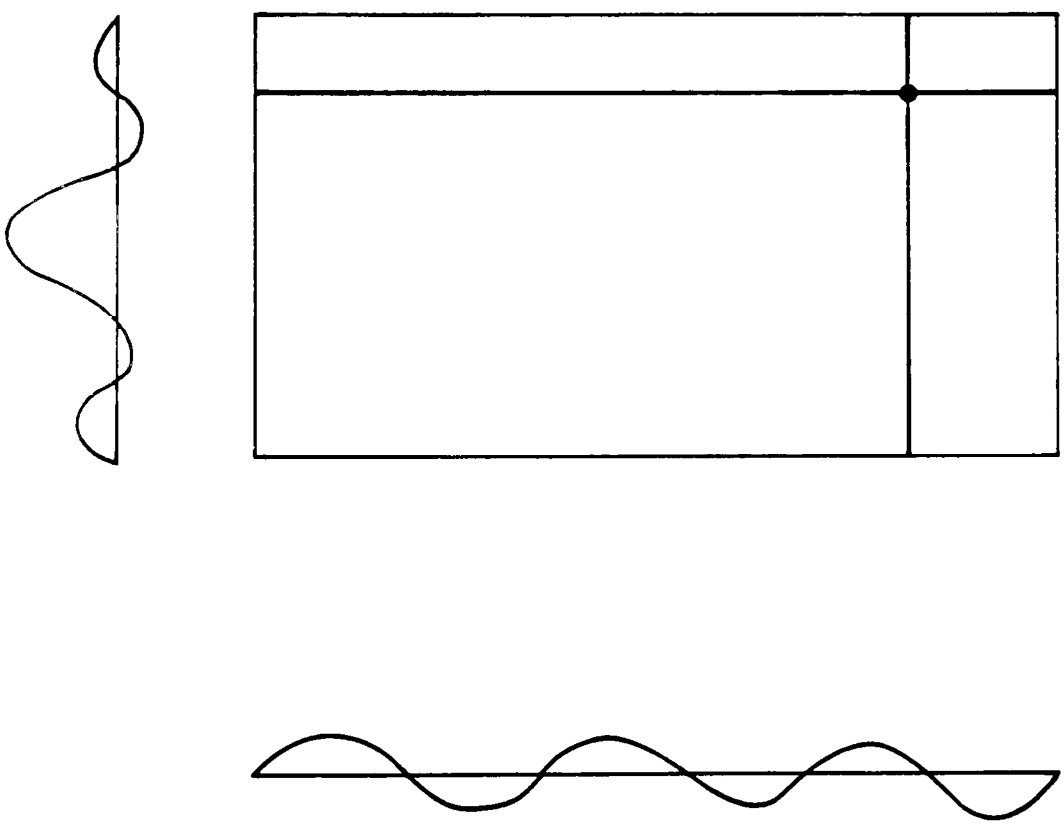

Fig. 2: A global two dimensional tensor product basis is a tensor product of two one dimensional global bases: every point is dependent on every other point on the longitude and the latitude it is on.

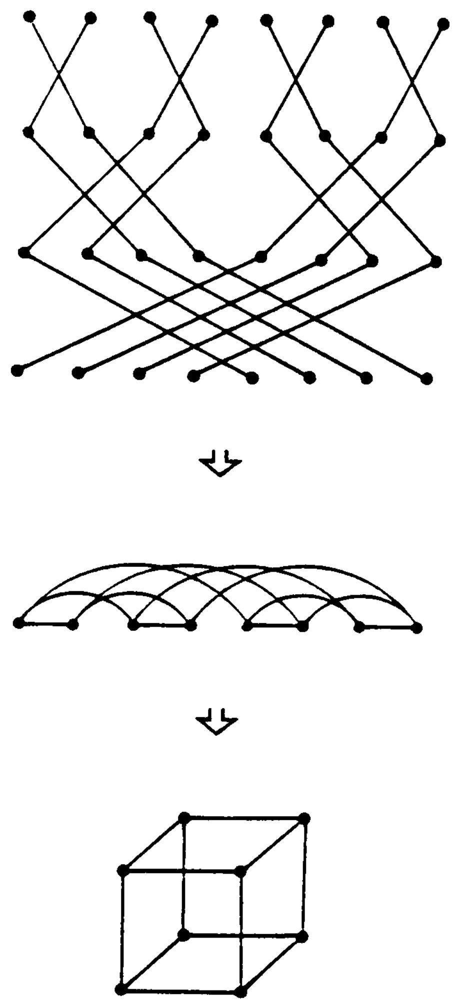

Fig. 3:

Fast Fourier Transform as a hypercube. The butterfly depicts data flow in the FFT. If we compress the butterfly and insert an edge between all nodes that need to communicate, the emerging pattern is a one dimensional rendering of the edges in a hypercube.

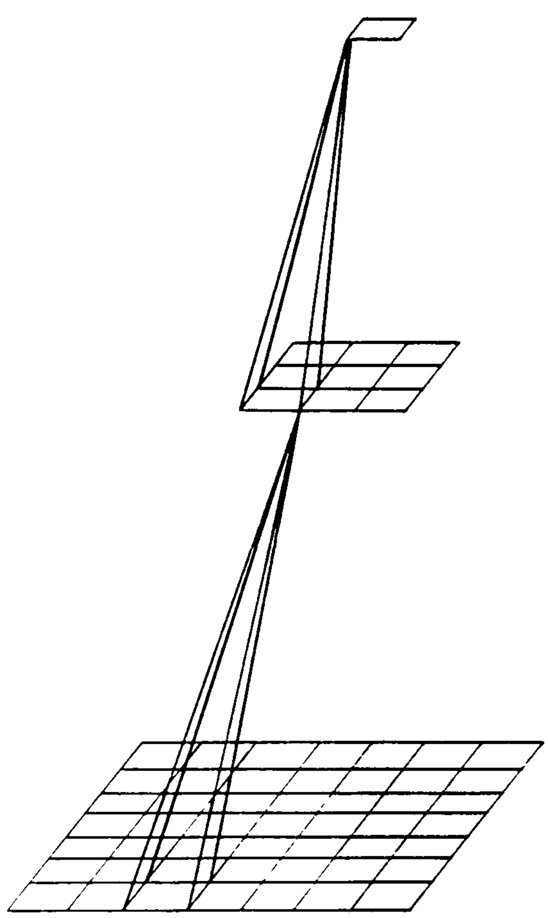

Fig. 4:

Pyramidal topology of a multigrid algorithm. Only some of the vertical edges are shown.

Obviously, dense dependency graphs are more demanding of parallel interconnection topology. An entirely global data access, a cross-bar, can be geometrically represented as a simplex (a triangle in two dimensions, a tetrahedron in three, and so forth (see Fig. 5)).

Since grid point methods have sparse interconnection topologies, they would seem more readily suitable for massively parallel computers. However, even they suffer from Fourier filtering and in practice the suitability of any particular parallel computer to any particular algorithm will have to be studied individually. When the topology is rich enough, spectral methods can be very competitive.

3.3. Local memory access

There is yet another constraint on the performance of massively parallel computers caused by data access requirements. With the present organisation of meteorological algorithms, they need to access data in local memory at the same rate as they carry out floating-point computations. Unfortunately, massively parallel computers are normally crucially dependent on slow DRAM memories. Hence, no matter how fast individual processors might be, the benefit is lost without a high degree of memory interleaving, which, so far, few parallel computers have implemented.

4. Initial results

Benchmarks have been executed on an Intel iPSC/2 hypercube and a Suprenum parallel computer in collaboration with Saulo Barros, Gesellschaft für Mathematik und Datenverarbeitung in Bonn (GMD) and University of Sao Paulo. Two codes for solving the Helmholtz equation on the sphere are compared. Several 2-D Helmholtz equations are solved at every time step in all totally or partially implicit global, multilayer weather models. The combination of having to solve an elliptic equation and the spherical geometry has been identified as the most prominent algorithmic problem in implementing operational global weather models on massively parallel computers.

The first code uses a spherical full multigrid algorithm developed by Saulo Barros at GMD. The second code is a spectral code using spherical harmonics as basis functions, written by Tuomo Kauranne and Saulo Barros. It uses a FFT routine written by Clive Temperton from ECMWF,and computes Legendre coefficients with routines from the package SPHEREPACK by Paul Swarztrauber and John Adams from NCAR.

Both codes run with reasonably good parallel and vector efficiency on the Intel. The multigrid code has a better serial complexity but is less efficient to vectorize and parallelize. When solving a Helmholtz equation on a 128 x 256 grid, the speedup when going from one processor to 32 processors is 15 for scalar and 9 for vectorized code. The speedup due to vectorization is 2.3 on a single processor but only 1.4 on 32 processors. These figures improve significantly with larger problems.

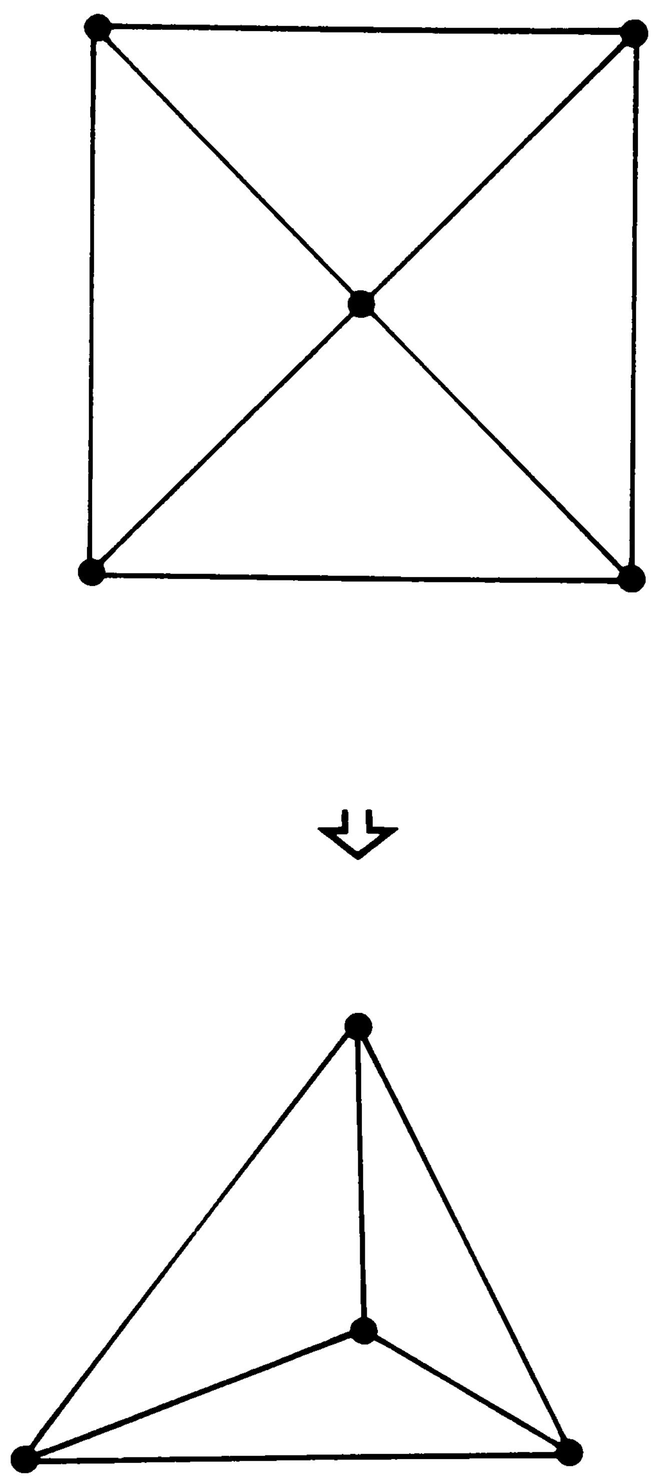

Fig. 5: A cross-bar connection between four processors is a two dimensional rendering of a simplex. In the case of four processors this is a tetrahedron.

The execution time of the spectral code is dominated by the Legendre Transforms. Their structure is simple and easy to vectorize. Parallelization overhead consists of two global transpositions. The parallel speedup when going from one to 32 processors is roughly 26 for scalar and 25 for vectorized code. Vector speedup is 3.3 for one processor and 3.1 for 32-processor implementations. In the scalar single processor case, multigrid is 3.2 times faster than the spectral method, which is to be expected on the basis of its optimal complexity. When both codes are parallelized and vectorized, however, the spectral method is 1.2 times faster than multigrid. With still larger problems, multigrid would be the faster method.

5. Outlook

The market for massively parallel computers is still very unsettled. Companies come and go almost on a monthly basis and only a few have had sustained existence. Virtually all sales to date of massively parallel computers have been for experimental purposes. Typically, these have been heavily subsidized from public funds. There are signs that this pattern is beginning to change, with a number of major computer manufacturers announcing plans to produce massively parallel supercomputers.

Due to the difficulty of programming and lack of portability, as well as weakness of performance due mainly to lack of global communication bandwidth, it seems that massively parallel computers may never attain the same generality as present vector supercomputers. Instead, they will be used as special-purpose scientific and engineering engines. Although not able to execute dusty deck Fortran codes efficiently, they seem to be generally capable to solve most partial differential equations quite fast. These continue to form the hard core of scientific and engineering computing, and in particular numerical weather prediction.

Performance estimates made for the operational model with techniques such as semi-Lagrangian advection on a reduced grid seem to confirm a pattern also seen in the benchmarks between spectral and multigrid methods. It seems that in general the advantage that more sophisticated algorithms have over simple brute force techniques diminishes when they are implemented on a parallel computer because of their inferior parallelizability. The converse also holds; very fast but unconventional computers lose some of their edge over slower but more robust computers because the latter can efficiently implement fast and sophisticated algorithms. Data access is the most fundamental constraint when solving partial differential equations such as the ones used in weather models on parallel computers.

Massively parallel computers will have to compensate for the above-mentioned deficiencies by providing clearly superior peak performance and performance/price ratio. A factor of around ten would be required before the majority of scientific programmers will start to consider massively parallel computers seriously for their production work. Good programming tools would, of course, assist their acceptance greatly.

It may be that in the future current and massively parallel supercomputers will increasingly coexist. A supercomputer site such as ECMWF generally needs some robust supercomputer capacity in addition to a fast model engine. Getting data out of a massively parallel computer may also be a substantial task. Having a fast vector supercomputer as a front-end could be very helpful. Networking will give more and more researchers access to a wide range of computers. This can lead quite naturally to increased specialization in computing facilities. Hence, provided that massively parallel computers can realize the expectations of Teraflop range performance placed on them, there will be a niche in which they can succeed. Specialized supercomputer sites such as operational weather forecasting centres may well be among the first to benefit from this.

- Tuomo Kauranne*

* This work has been partially supported by the European Commission through the ESPRIT project P2702: GENESIS

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COUNCIL GUIDELINES ON DISTRIBUTION OF COMPUTER RESOURCES

At its 33rd session in December 1990 the Council of ECMWF adopted new guidelines on the distribution of computer resources, which have been applied as from 1991. The new guidelines are as follows:

(i) At least 25% of the supercomputer system shall be made available to the Member States, as well as sufficient resources for data storage to support each Member State's work on the supercomputer system (however, the total data storage for Member States should not exceed 10% of the total data storage at any one time).

(ii) A maximum of 10% of the computer resources available to the Member States may be allocated for "special projects", approved by Council except as under (iii) below.

(iii) 10% of the maximum available Special Project resources shall be set aside; this proportion shall be allocated directly by the Centre to applicants from the Member States, after consultation with the Chairmen of the SAC and TAC. Applications should be submitted via the Director of the relevant national meteorological service. Awards should subsequently be reported to the Council. In deciding these awards the following guidelines will be followed:

- (a) priority will be given to new applicants, but existing oversubscribed projects could be given further support later each year;
- (b) any new projects so supported should have a scientific content consistent with that expected of Special Projects, as laid out in the guidelines for the assessment of proposals.

(iv) After computer resources have been allocated to Special Projects (up to the 10% maximum allowed) 35% of the remainder will be allocated equally among the Member States and 65% allocated proportionally to their financial contribution to the Centre.

(v) Each Member State should submit an estimate, by 30 April each year, of its computing requirements on the ECMWF computing system for special projects.

(vi) The allocated capacity should be used evenly throughout the year. The allocation will be nominally divided pro rate into 13 four week periods. In the event of very heavy usage, the Centre is authorised to restrict a Member State to twice its pro rate allocation in any given accounting period.

(vii) Unused resources should be at the disposal of the Centre.

(viii) An interactive service shall be made available to Member States to provide job preparation and out inspection facilities.

(ix) No charge should be made to the Member States for use of the Centre's computer resources.

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COMPUTER RESOURCE ALLOCATION TO MEMBER STATES IN 1991

Table 1: Allocation of CRAY resources and data storage to Member States in 1991 (including a 10% reserved allocation for Special Projects)

COUNTRY	Data (Gbytes)	Cray (kunits)
BELGIUM	31,07	13.5
DENMARK	26,38	11.5
GERMANY	134.35	58.3
SPAIN	47.30	20.5
FRANCE	109.81	47.7
GREECE	21.15	9.2
IRELAND	18.99	8.2
ITALY	95.73	41.5
YUGOSLAVIA	23.57	10.2
NETHERLANDS	38.62	16.8
NORWAY	24.93	10.8
AUSTRIA	28.38	12.3
PORTUGAL	19.96	8.7
SWITZERLAND	35.01	15.2
FINLAND	25.68	11.1
SWEDEN	33.28	14.4
TURKEY	23.36	10.1
UNITED KINGDOM	92.12	40.0
SPECIAL PROJECTS	82.81	40.0
T O T A L	912.50	400.0

Table 2: Special Projects Allocations 1991
(converted to CRAY Y-MP units)

MEMBER STATE	INSTITUTION	PROJECT TITLE	1991 RESOURCES REQUESTED Cray Kunits	CFS Gbytes
<u>Continuation Projects</u>				
Austria	Institut f.Meteorol. & Geophysik, Vienna (Hantel)	Subsynoptic vertical heat fluxes: Comparison diagnosed vs. modelled data	1.33	1.5
France	CNET/CRPE (Eymard)	Determination of ocean surface heat fluxes using satellite data and the ECMWF model	1	1.4
	Univ.of Science & Technology, Lille (Vesperini/Fouquart)	Use of earth radiation budget data for verification of ECMWF cloud and radiation outputs	0.67	1
	CNRM, Toulouse (Planton)	Impact of land-surface processes on atmospheric circulation	6.67	2
Germany	Institute f. Geo-physics & Meteorol., Cologne (Speth)	Interpretation and calculation of energy budgets	0.5	0.4
	GKSS, Geesthacht (Rockel/Raschke)	Parametrization of radiation and clouds for use in general circulation models	0.67	0.2
Italy	Istituto per lo Studio della Grandi Masse, Venezia (Cavaleri)	Testing and applications of a third generation wave model in the Mediterranean Sea	1.67	0.2
	FISBAT-CNR, Istituto di Fisica "A.Righi", Bologna (Speranza)	Statistical properties of a symmetrically forced atmospheric circulation	0.33	0.5

Table 2 continued

MEMBER STATE	INSTITUTION	PROJECT TITLE	1991 RESOURCES REQUESTED Cray Kunits	CFS Gbytes
Netherlands	KNMI, De Bilt (Komen)	Testing and evaluation of a third generation ocean wave model at ECMWF	15	2
	KNMI, De Bilt (Siegmund)	Analysis of a CO_2-experiment performed with a GCM	1	0.1
	KNMI, De Bilt (Kattenberg)	North Atlantic ocean modelling	2	2
	KNMI, De Bilt (Haarsma/v.Dorland)	CO_2 transient atmosphere model	2.5	1
	KNMI, De Bilt (Cuypers/Duijnkerke)	Large eddy simulation of stratocumulus clouds	1	1
Sweden	SMHI, Norrköping (Gustafsson)	The HIRLAM 2 project	6.67	5
United Kingdom	Meteorol. Office, Bracknell (Rawlins)	Model intercomparison project	0.67	1
Yugoslavia	Univ. of Belgrade, Belgrade (Mesinger)	Contamination modelling	1.17	1
<u>New Projects</u>				
Finland	Finnish Met. Inst., Helsinki (Uppala)	Propagation study	6.67	12
France	CRMD/EERM, Paris (Joly/Malardel)	Frontal waves	3.33	1
Germany	Met. Institut der Univ. Hamburg (Roeckner)	Modelling the earth's radiation budget and evaluation against ERBE data	20	5
Netherlands	KNMI, De Bilt (Können)	Climatological scenarios	0.83	1

Reserve (to be allocated by ECMWF)	9.13	0.7
TOTAL REQUESTED	82.81	40
AMOUNT AVAILABLE	91.25	40

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MARS NEWS

When the initial version of MARS under UNICOS was released, it provided users with the same facilities as were available under the COS version. Since then there have been a number of modifications and extensions.

Access to the Fields Data Base (FDB) on the Cray Y-MP now includes the automatic calculation of u and v wind components from the FDB fields of vorticity and divergence, when u and v are requested. The Cray Y-MP FDB contains the last 2 days of operational data, whereas the Cray X-MP FDB contained only 1 day.

The separate utilities for the Research Department to create, list, and remove experiments from the MARS archives have now been included in the main MARS system. Access to Research Department FDBs has been improved.

The MARSINT interpolation package has been modified to handle data at T213 resolution, and includes efficient memory management.

As new experiments require the archiving of more meteorological parameters than before, MARS has been modified to allow 2 continuation lines for values, instead of only one.

Observations from 10 July 1990 onwards have been archived in MARS. Back-archiving is in progress, starting from 1 October 1986 up to the present time (currently archiving June 1989). Data from 1979 onwards will be added when the period October 1986 to July 1990 is complete. A full set of retrieval and selection facilities is in preparation. A limited set of facilities is currently under test by in-house users - at the moment the smallest subset of data that can be retrieved is one BUFR data type, for one octant of the globe for one 3 hour period.

Modifications have been made recently to ECFILE, and this should have a significant effect in speeding up MARS file transfers.

A new MARS User Guide is in preparation, describing in more detail all the above and other changes to the system. A draft will be issued shortly. The guide will be issued as both a Meteorological Bulletin and Computer Bulletin.

- John Hennessy

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OBSOLETE MANUALS, BULLETINS AND NEWS SHEETS

Now that the Cray COS (and NOS/BE) service has terminated, several manuals, bulletins and news sheets can be thrown away.

Manuals

All Cray COS specific manuals can be disposed of. Note that some manuals, e.g. CFT77, are common to both COS and UNICOS, and hence can be retained for UNICOS use if they are still up to date, i.e. valid for UNICOS 5.

ECMWF staff who are disposing of manuals are reminded that unwanted binders should be returned to Administration (H. Brimacombe, G. Krieg) rather than thrown away.

Bulletins

The following can be disposed of:

B1.0/1, B1.2/1, B1.6/1, B2.2/1, B2.7/1, B3.2/1, B4.1/2, B4.4/1, B4.9/1,
B4.9/2, B4.9/3, B4.9/4, B4.10/2, B5.2/1, B5.2/2, B5.2/3, B5.2/6, B5.2/11,
B6.3/1, B6.3/2, B6.5/1, B6.7/1, B6.7/2, B6.7/3, B6.7/4, B7.1/1, B7.1/2,
B7.2/1, B7.7/1, B8.1/1, B8.1/2, B8.1/3, B8.1/4, B8.3/2

News Sheets

The following can be thrown away:

89, 135, 158, 187, 194, 201, 208, 226, 227, 241, 244.

A list of those still valid is given later in this Newsletter.

- Andrew Lea

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STILL VALID NEWS SHEETS

Below is a list of News Sheets that still contain some valid information which has not been incorporated into the Bulletin set or republished in this Newsletter series (up to News Sheet 264). All other News Sheets are redundant and can be thrown away.

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

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TABLE OF TAC REPRESENTATIVES, MEMBER STATE COMPUTING REPRESENTATIVES AND METEOROLOGICAL CONTACT POINTS

Member State	TAC Representative	Computing Representative	Met. Contact Point
Belgium	Dr W Struylaert	Mme L Frappez	Dr J Nemeghaire
Denmark	Dr A M Jørgensen	Mr P Henning	Mr G R Larsen
Germany	Dr R Lamp	Dr R Lamp	Dr Rüge
Spain	Mr T Garcia-Meras	Mr J Juega	Mr R Font Blasco
France	Mr J Goas	Mr J Toussaint	Mr J Goas
Greece	Mr G Barbounakis/ Mr D Katsimardos	Mr I Iakovou	Mr A Kakouros
Ireland	Mr J Logue	Mr L Campbell	Mr T Sheridan
Italy	Dr M Capaldo	Dr S Pasquini	Dr M Conte
Yugoslavia	Dr S Nickovic	Mr T Stojiljkovic	Mr S Nickovic
Netherlands	Mr S Kruizinga	Mr S Kruizinga	Mr G Haytink
Norway	Mr K Björheim	Ms R Rudsar	Mr O Nielsen
Austria	Dr G Wihl	Dr G Wihl	Dr H Gmoser
Portugal	Mr A P Da Costa Malheiro	Mrs M de Lourdes Barreito Leitao	Mrs M Barros Ferreira
Switzerland	Mr M Haug	Mr B Bachofner	Mr M Schönbächler
Finland	Dr M Alestalo	Mr T Hopeakoski	Mr P Kukkonen
Sweden	Mr H Larsson	Mr S Orrhagen	Mr R Joelsson
Turkey	Mr F Geyik	Mr F Geyik	Mr F Geyik
United Kingdom	Dr R Wiley	Dr A Dickinson	Mr C R Flood

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ECMWF/WCRP WORKSHOP ON
CLOUDS, RADIATIVE TRANSFER AND THE HYDROLOGICAL CYCLE
12 - 15 NOVEMBER 1990

This is a time of considerable activity in the study of clouds, radiation and the hydrological cycle. New results and new data sets are becoming available from a number of major observational projects. These data sets provide extensive new possibilities for the validation of the parametrization schemes in existing NW and AGC models. They also provide a basis for the development of more accurate parametrizations. These developments are of interest both to the weather prediction and to the climate modelling communities. It is therefore appropriate that the workshop was supported by both ECMWF and WMO's World Climate Research Programme.

The aim of the workshop was to bring together

(i) those involved in producing the data sets,

(ii) those concerned with the problems of using the data sets for model validation, and

(iii) those engaged in the development of new parametrization schemes,

in order to discuss current scientific problems and future lines of research and development.

Experience has shown that the results of workshops such as this are of great value to developments at ECMWF and elsewhere.

The workshop discussions were organised in three working groups. One group discussed the data sets themselves. There was then a discussion of the problems of using the data for model validation, while a third group discussed the new developments in parametrization stemming from the observational and validation studies.

The working group reports and the papers presented will be published by ECMWF as Workshop Proceedings.

- Els Kooij-Connally

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THE ECMWF ANNUAL SEMINAR

The 1991 ECMWF Seminar is entitled ***Numerical Methods in Atmospheric Models,*** and will take place during the week 9 to 13 September 1991.

There have recently been significant developments in numerical techniques in atmospheric models used for weather prediction and climate studies. Particularly worthy of mention is the semi-Lagrangian method which enables more efficient model integrations and offers potential benefit in the treatment of the humidity field and other variables through use of shape-preserving interpolation. The move of global models towards higher resolution has prompted renewed interest in the comparison of spectral, finite-difference and finite-element techniques. Therefore, it is timely again to devote the annual ECMWF seminar to the numerical methods for atmospheric models, in order to provide an up-to-date review which should benefit both the Centre and the Member States.

The seminar will cover the following topics:

* Horizontal and vertical discretizations: spectral, finite difference and finite element methods; adaptive grids; piece-wise parabolic methods;
* Time discretization, including semi-Lagrangian methods;
* Co-ordinate systems and boundary conditions;
* Numerics for physical parametrizations;
* Numerical aspects of variational methods;
* Practical experience of numerical formulations in NWP problems.

The format of the Seminar will be the same as in previous years - formal lectures by invited speakers and staff from the Centre, followed by publication of the proceedings of the Seminar. Further details about the Seminar and registration forms will be mailed to all national meteorological services as well as a number of universities and institutes in the Member States in due course.

- Els Kooij-Connally

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ECMWF CALENDAR 1991

4-22 March	Computer user training course
6-7 March	Finance Committee - 46th session
28 March (pm)-1 April	***ECMWF holiday***
8 April - 7 June	Meteorological training course:
	Met 1 Numerical methods, adiabatic formulation, data assimilation, satellite data - 8-26 April
	Met 2A Parametrisation - 29 April-10 May
	Met 2B General circulation, systematic errors & predictability - 13-17 May
	Met 3 Use & interpretation of ECMWF products - 28 May-7 June
6 May	***ECMWF holiday***
24-27 May	***ECMWF holiday***
11-14 June	Symposium: Use of NWP products in medium-range weather forecasting in Europe
18-19 June	Council - 34th session
26 August	***ECMWF holiday***
9-13 September	Workshop: Fine-scale modelling for parametrisation schemes
30 Sept.-2 October	Scientific Advisory Committee - 19th session
2-4 October	Technical Advisory Committee - 16th session
8-10 October	Finance Committee - 47th session
13-15 November	Workshop: Predictability
18-22 November	Workshop: Meteorological operational systems
3-4 December	Council - 35th session
24-26 December	***ECMWF holiday***

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ECMWF PUBLICATIONS

Technical Memorandum No. 174 — The impact of North Atlantic tempship radiosonde data on the ECMWF analysis and forecast

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INDEX OF STILL VALID NEWSLETTER ARTICLES

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

METEOROLOGY (cont.)

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* T indicates the original Technical Newsletter series

USEFUL NAMES AND 'PHONE NUMBERS WITHIN ECMWF

		Room*	Ext.**
Director	- David Burridge	OB 202	2001
Head of Operations Department	- Michel Jarraud	OB 010A	2003
ADVISORY OFFICE - Open 9-12, 14-17 daily		CB Hall	2801 (Bleeper 139)
Other methods of quick contact:	- Telex (No. 847908)		
	- Telefax (No. 869450)		
	- VMS MAIL addressed to ADVISORY		
REGISTRATION			
Project Identifiers	- Pam Prior	OB 225	2384
User Identifiers	- Tape Librarian	CB Hall	2315
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Console	- Shift Leaders	CB Hall	3333
Reception Counter	- Tape Librarian	CB Hall	2315
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Group Leader	- Jens Daabeck	OB 016	2375
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Head of Research Department (Acting)	- Anthony Hollingsworth	OB 118A	2070
Computer Co-ordinator	- David Dent	OB 123	2702

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* CB - Computer Block   OB - Office Block

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

EARN/Bitnet: The ECMWF address on the EARN/Bitnet network is UKECMWF. Individual staff addresses are the first 8 characters of their surname, e.g. the Director's address is BURRIDGE@UKECMWF

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