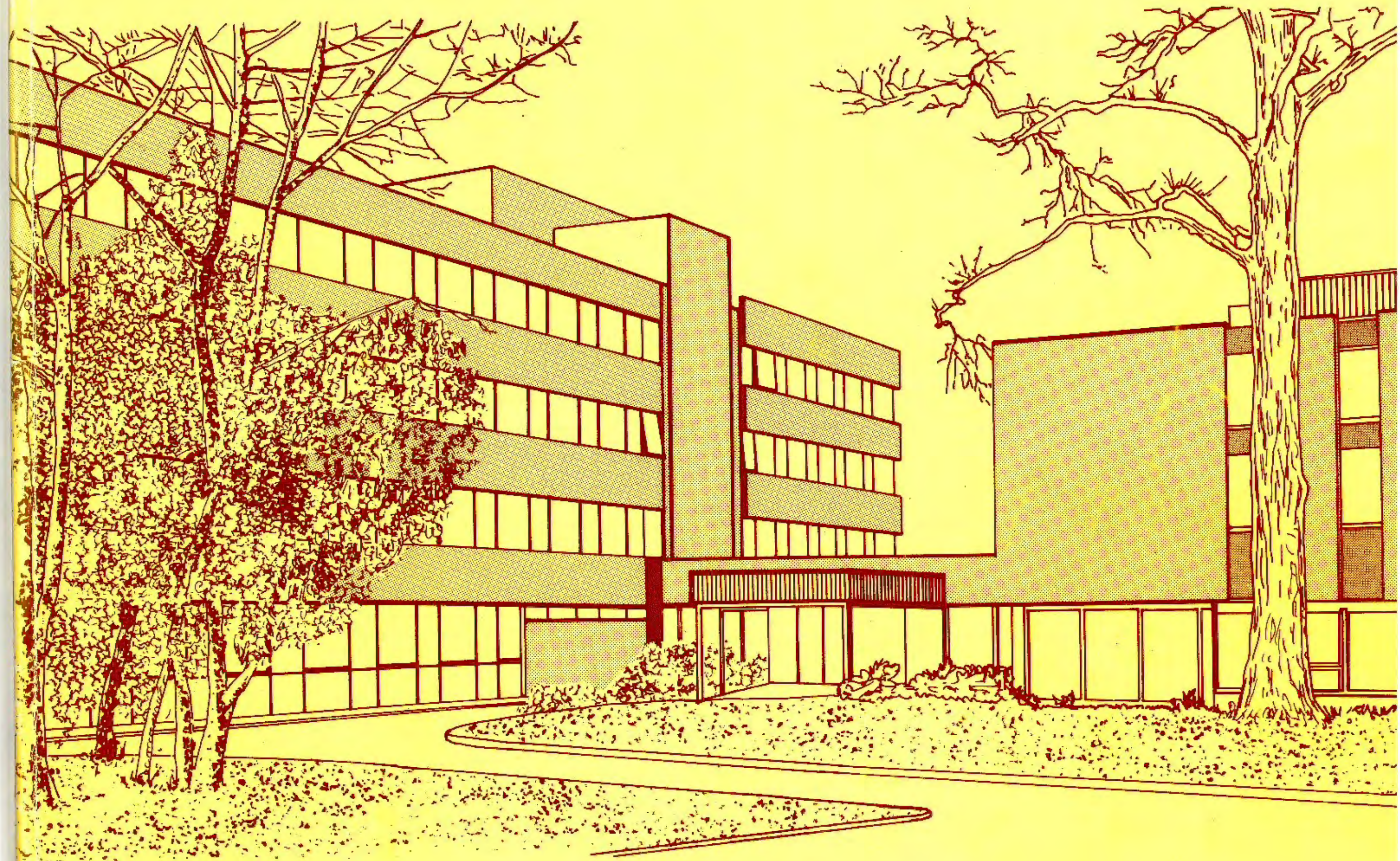
Annual Report 1984



European Centre for Medium Range Weather Forecasts

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FOREWORD

I am very pleased to contribute to the ECMWF Annual Report of 1984, a year which has seen much development at the Centre with a notable increase in the programme of numerical experimentation following the introduction of the Cray X-MP into operational service.

The successful and (from the users' point of view) smooth replacement of the Cray 1-A with its successor, the Cray X-MP, was a real achievement, and reflects the skill and dedication of the Centre's staff whose expertise has been once more demonstrated.

The various sections of this Report serve to emphasize the scientific and technical advances made by the Centre during the year, the improvement in quality of the forecasts and the increasing usefulness of the Centre's products to its Member States. The Member States are, with the help of the Centre, making more and more use of the Centre's products, facilities and services.

I am happy to have been re-elected to serve as President of the Council for a further year, and on a personal note I look forward to continuing a close and fruitful association with the work of the Centre.

I wish to express my thanks to my colleagues in the Council and its Committees, in particular their Chairmen, to the Director, Dr. Lennart Bengtsson, and to the staff of the Centre for their efforts and hard work during the year. I would like to say how grateful I am for the assistance I received from the staff during my first term as President of the Council.

Some of my colleagues at the 20th session of the Council expressed their appreciation at the sense of enthusiasm of the team of the Centre. I take this opportunity to associate myself with this sentiment, and to congratulate all concerned on behalf of the Council.

Professor L.A. Mendes Victor

The console, computer hall, ECMW

INTRODUCTION

Operations Department

Reliable production of operational forecasts, and development of the Centre's computing and technical facilities to meet the demands of the Member States (as they exist at present and as they were foreseen to develop with increasing access to the Centre's computing system), the demands of the research programme and the needs of operational activity, have continued to dominate the work of the Operations Department during 1984. The Cray X-MP, delivered and installed in late 1983, was brought into full operational production during the year and the Cray 1-A was removed. The performance of the Cray X-MP has been very satisfactory with respect to both speed and reliability.

Use of the Centre's mainframe by the Member States continued to increase; the total usage for 1984 at 1.1 million units was more than double that used during 1983.

Following Council approval of the Centre's proposal that the present telecommunications system be replaced earlier than originally planned, the Centre carried out intensive preparatory work which led to the issuing of an Invitation to Tender for a new telecommunications system on 19 July; replies were being actively considered at the end of the year in preparation for a meeting of Member States representatives to consider this early in 1985.

The initial configuration of the data handling processor, the IBM 4341, had been installed in late 1983. In September 1984 the remaining parts of the system, including the cartridge store and the tape drives, was completed. The design of the Meteorological Archival and Retrieval System (MARS) was complete by the end of the year.

Various components of the Loosely Coupled Network (LCN) which will link the Centre's computers via a high-speed channel were installed during 1984. Full performance was being expected for early 1985.

Forecast quality was carefully monitored during the year, as a routine verification of the Centre's forecast and with special care and extra effort when the changes to the forecasting system were made. Information was collected from the Member States on their application and use of the Centre's products.

Research Department

During the past year many important milestones have been reached in the Research Department. The operational forecasting system has been improved in many respects. Major changes have been made to the operational analysis system (improved statistics, revised data selection algorithms), and a revised orography, a diurnal cycle, and a new radiation scheme were introduced into the operational forecasting system. The formalism developed for the analysis statistics, which are derived from statistics of the structure of short range (6 hour) forecast errors, is new; it offers many possibilities, such as an improvement in the resolution of the analyses, which still have to be explored. A brief discussion of the analysis changes and the significance of short range forecast error statistics for the analysis problem is given in later sections of the Report.

More than a year's statistics on the performance of the operational spectral model - it replaced the grid point model in April 1983 - show that it has clearly improved the skill of the operational forecasts. In particular, the

The library, ECMWF

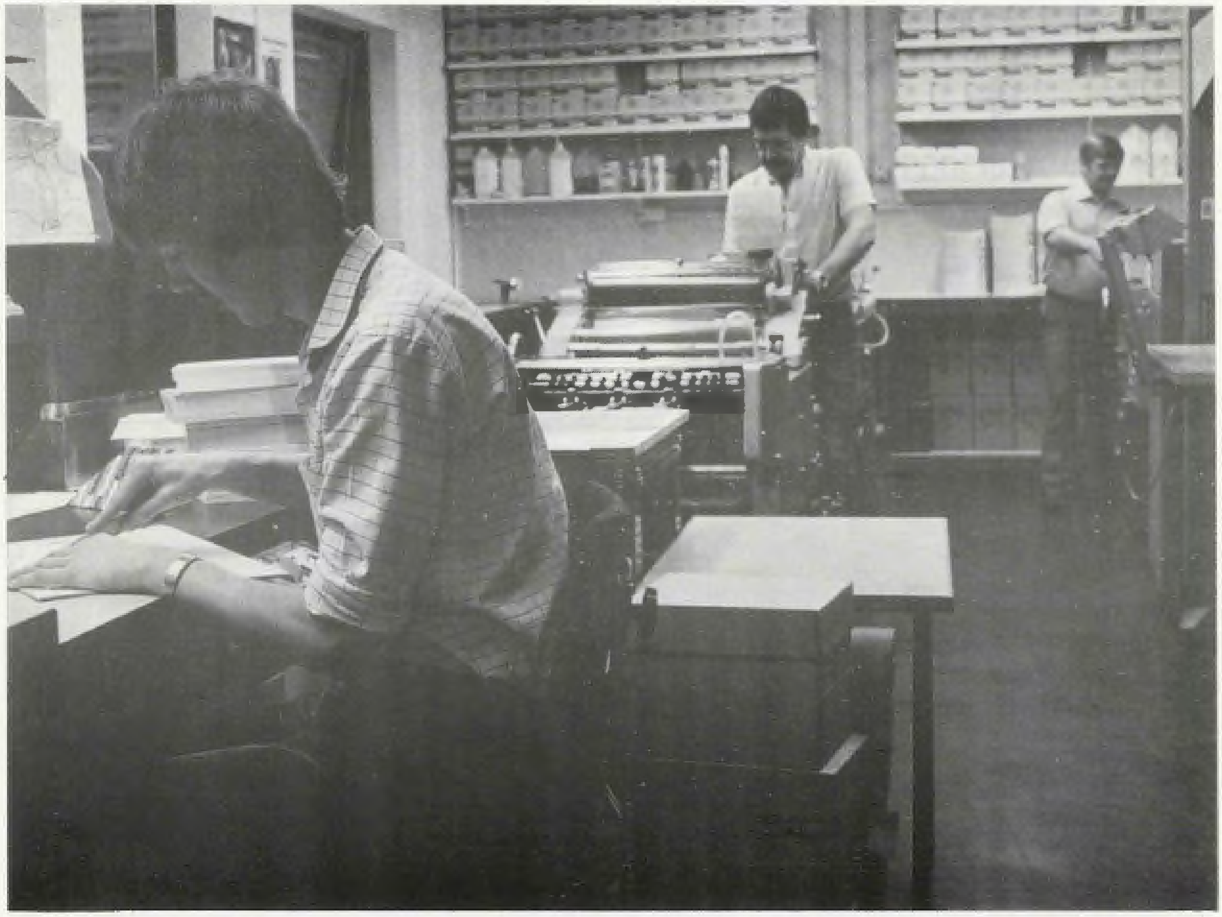
treatment of baroclinic waves has improved; their speed, development and decay are now simulated more correctly. However, the character of the mid-latitude systematic (mean) forecast errors has not changed, though the interannual variability of these errors may conceal the impact of model changes. The sensitivity of such model errors to changes in physical parameterization are discussed elsewhere in this Report.

The work on the new high resolution forecasting system - high resolution model, revised physical parameterization and a high resolution analysis scheme - has gone well. The experimental results from the high resolution model are most encouraging. Improvement is evident for all scales of motion and is greatest at the surface. At the end of the year, the planned implementation date for the high resolution model was 1 April 1985.

Administration Department

The provision of administrative support to the Centre continued to dominate the work of the Administration Department during 1984. This included aspects of finance and supplies, and personnel and general services. During the year, the level of security at the Centre was enhanced. The Department provided advice and assistance to the Director on administrative, financial and legal aspects of the work of the Centre, including the conduct of its relations with the Co-ordinated Organisations. Liaison was maintained with the various authorities of the United Kingdom concerning the non-permanent residential status of the Centre's expatriate staff. The Department provided assistance in contract negotiations, including those related to the new telecommunications system.

Lennart Bengtsson



The print room, ECMWF

DEVELOPMENTS IN PHYSICAL PARAMETERISATION

Introduction

Following the implementation of the spectral model into operations in April 1983, a special effort was put into monitoring the performance of the new forecasting system and improving the quality of the forecast products. This has led to a thorough evaluation of the systematic errors of the model and of the way in which physical processes are represented since this is believed to be the origin of most of the errors. The formulation of advanced physical parameterisation schemes is also a way of improving the forecast of weather elements of direct interest to the user - such as surface variables, cloudiness and precipitation. These general ideas have been used as a guide to the development of physical parameterisation during 1985. In this section of the Report, three aspects of this work will be described: the representation of the diurnal cycle, the design of a new radiation scheme and the development of improved convection schemes. The first two of these led to operational changes in 1984, and it is expected that there will be changes to the convection scheme in 1985.

Implementation of the diurnal cycle

The main effect of the diurnal cycle of solar radiation on the atmosphere occurs through the periodic heating of land surfaces, this heating being transmitted vertically by boundary layer processes; some secondary effects are related to the absorption of solar radiation by cloud layers. The overall impact on the large-scale dynamics of the atmosphere is complex and rather weak on timescales associated with medium range forecasts. This has been confirmed by various experiments carried out at ECMWF which showed that the impact of the diurnal cycle on large-scale forecasts did not appear to be significant during days 0-7. However, the simulation of the diurnal cycle leads to obvious benefits for the description of weather elements such as temperature, cloudiness and convective precipitation. The meteogram in Fig. 1 clearly illustrates the diurnal variation of cloud and temperature, for a European location, though the effects are much increased in tropical regions.

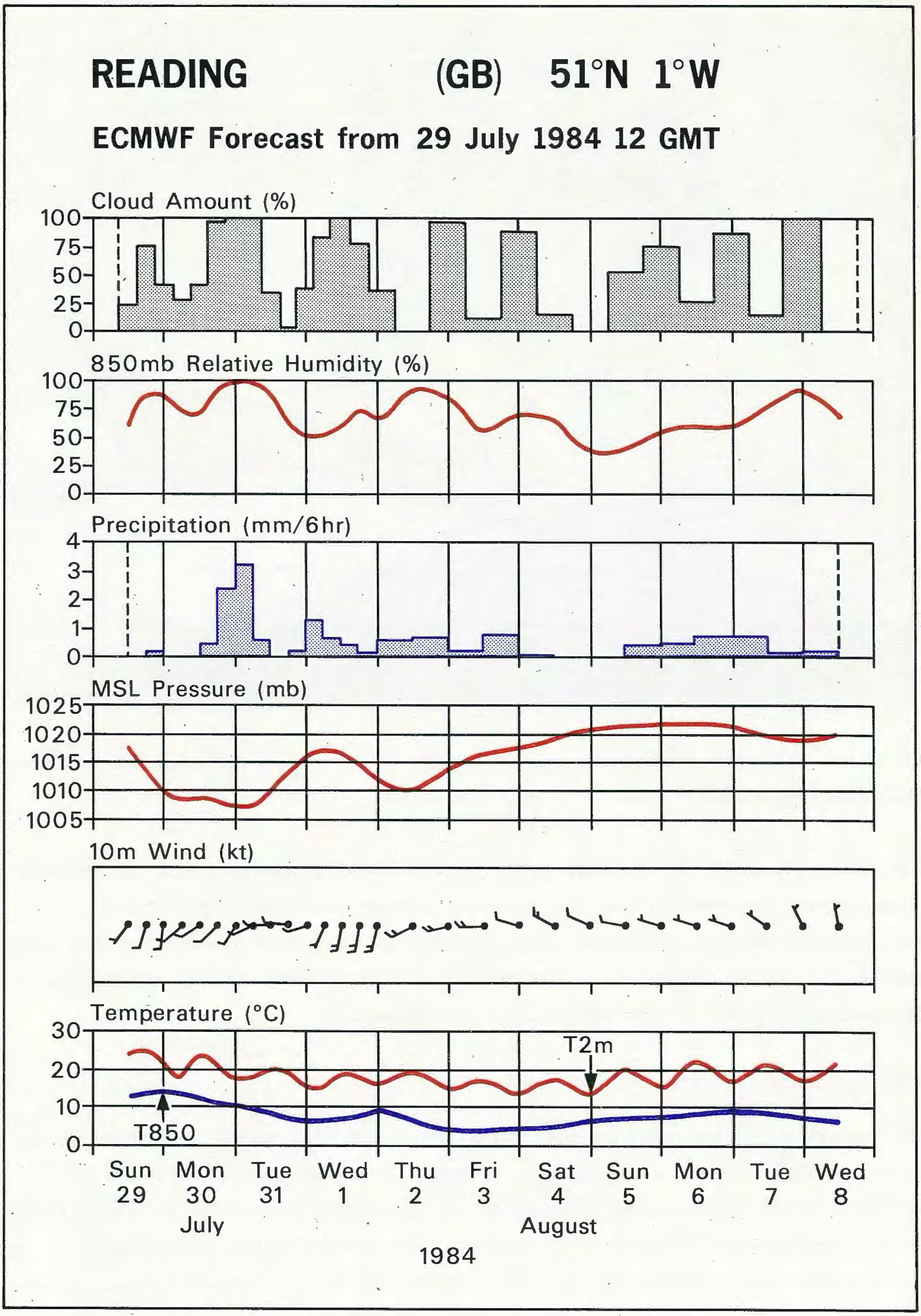


Fig. 1 Illustrates the diurnal variation of cloud and temperature, for a European location, though the effects are much increased in tropical regions.

After an extensive period of experimentation, the diurnal cycle was introduced into the operational model on 1 May 1984.

The main effect of the diurnal cycle on the model's behaviour is to produce a significant increase in the net surface flux of sensible heat in the sub-tropics and mid-latitudes, thus improving the energy balance of the model. The effect on net evaporation and precipitation is very small, except for a diurnal modulation of the convective precipitation.

New radiation scheme and the representation of clouds

The radiation scheme used in the operational spectral model performed in an unsatisfactory way in the presence of small cloud amounts. This led to the development of a new scheme, based on the so-called "exponential sum fitting" of the transmission functions of various atmospheric gases (water vapour, CO_2 and ozone). For operational use the scheme had to be simplified and optimised without losing its accuracy; the result was the development of a Fast Exponential Sum Fitting Technique (FESFT) for infra-red computations. Tests of the new scheme revealed that it produced a consistent improvement in the objective scores in the 4-10 day range. This is mainly apparent in the temperature scores and can be related to the improved treatment of the effect of cloud on the infra-red fluxes. The temperature bias is much reduced in most of the troposphere where the previous scheme had been too sensitive to low cloud amounts and produced considerable erroneous cooling. The new scheme was implemented operationally on 4 December 1984.

In parallel with the work on the radiation scheme, a detailed assessment has been made of the current operational cloud scheme. It showed that the present scheme gives a reasonable description of the total cloudiness in the extra-tropics, but is less successful in the tropics where the clouds are often convective in origin. In particular the main deficiencies were:

- the diurnal variation of tropical cloudiness was not well represented,
- the large areas of subtropical stratocumulus and fair weather cumulus were absent,
- the amount of cirrus associated with the ITCZ was consistently underestimated.

A new scheme has been developed, based on a diagnostic approach in which empirical relationships between cloudiness and model variables are used to calculate the amount of cloud. Convective cloudiness and anvil cirrus are derived from the model's convective scheme, whilst the amount of layer cloud is determined by the relative humidity, vertical velocity and static stability.

Preliminary results from trials of the scheme are very encouraging, with the major shortcomings of the operational scheme being largely rectified. An example of the distribution of low cloud (cumuliform and stratiform) for day 1 of a forecast using the new and operational schemes are shown in Fig. 2. Note that there is a marked increase in sub-tropical cloudiness with the new scheme; the transition from the dense frontal cloud of the extra-tropics to the broken convective regions of the tropics is striking. In particular the scheme has successfully captured the area of cloudiness off the western seaboards of the major continents.

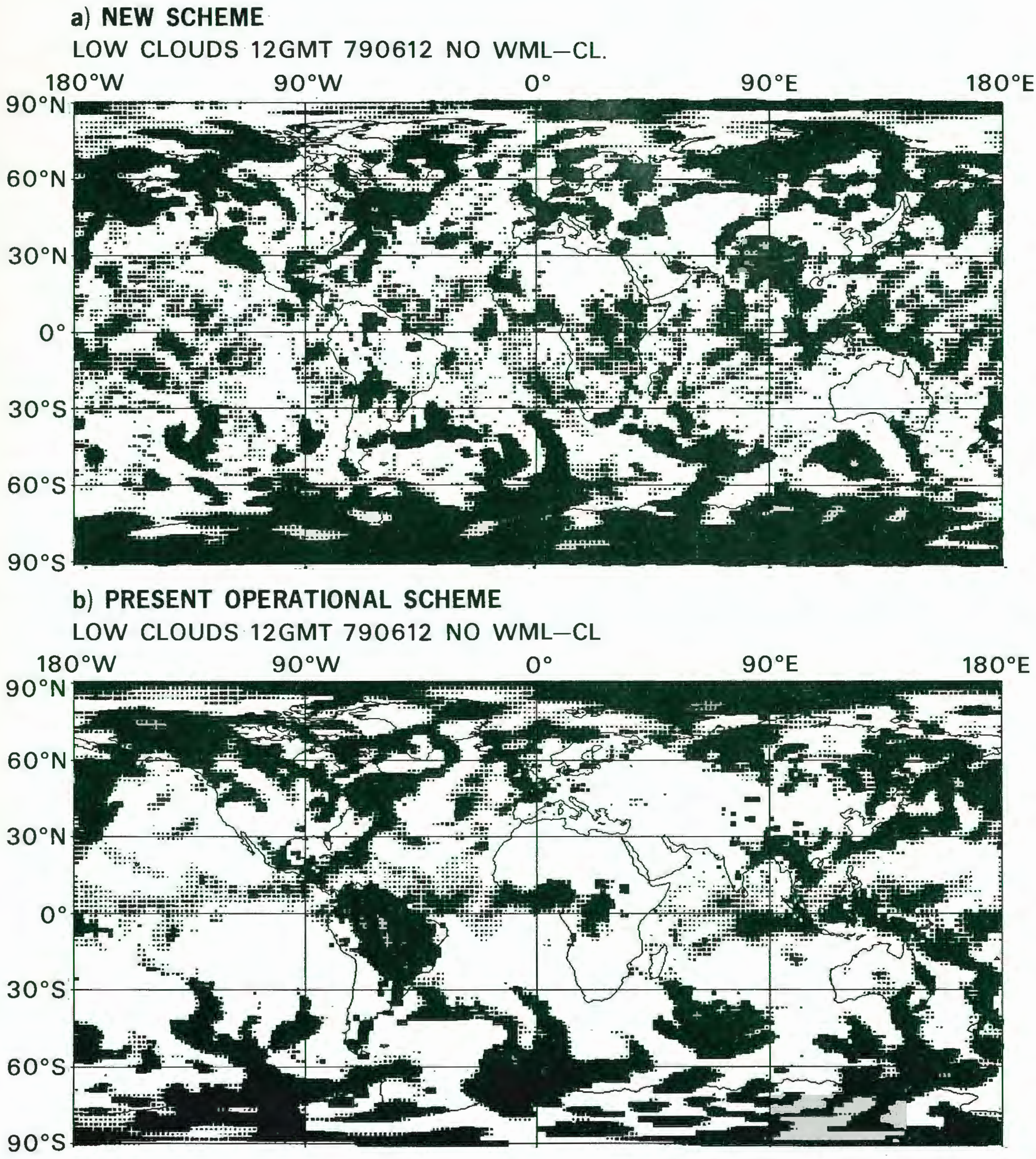


Fig. 2 Distribution of low cloud for day 1 forecast. a) new scheme b) operational scheme.

Development of convection schemes

Research into convection schemes is motivated by the deficiencies observed in the simulation of the tropical and sub-tropical flow, and of the temperature and moisture structure of the atmosphere in the tropics. These deficiencies, common to many atmospheric models, have a large impact on the systematic errors and are mainly due to defects in the representation of both deep and shallow moist convection. During 1984 two important developments have occurred in the representation of convection: the first is a further modification of the operational Kuo formulation and the addition of a shallow convection scheme; the second is based on a new approach to thermodynamic adjustment which can be used for both deep and shallow convection.

The Kuo convection scheme has been modified to overcome its tendency to generate atmospheric states which are too moist and too cold, particularly in the tropics. A parameter, which determines the partitioning of heating and moistening, was modified in such a way that the convective heating is increased. A shallow convection scheme has been developed to run in conjunction with the Kuo scheme. It takes into account the turbulent exchanges of heat and moisture at the top of the boundary layer, and thereby maintains a more realistic thermal state in the tropics. The impact of the shallow convection scheme on the general tropical circulation is beneficial; in particular the trade winds and monsoon flow are improved.

A series of experiments using the modified Kuo scheme and the shallow convection scheme show a significant improvement in the quality of the forecasts, with the impact being largest in the tropics and sub-tropics. This is illustrated by the zonal mean temperatures deviations from the observed derived from forecasts using the operational and revised schemes (Fig. 3a,b). Tests are being carried out with a view to implementing the modified set of parameterisation schemes during 1985.

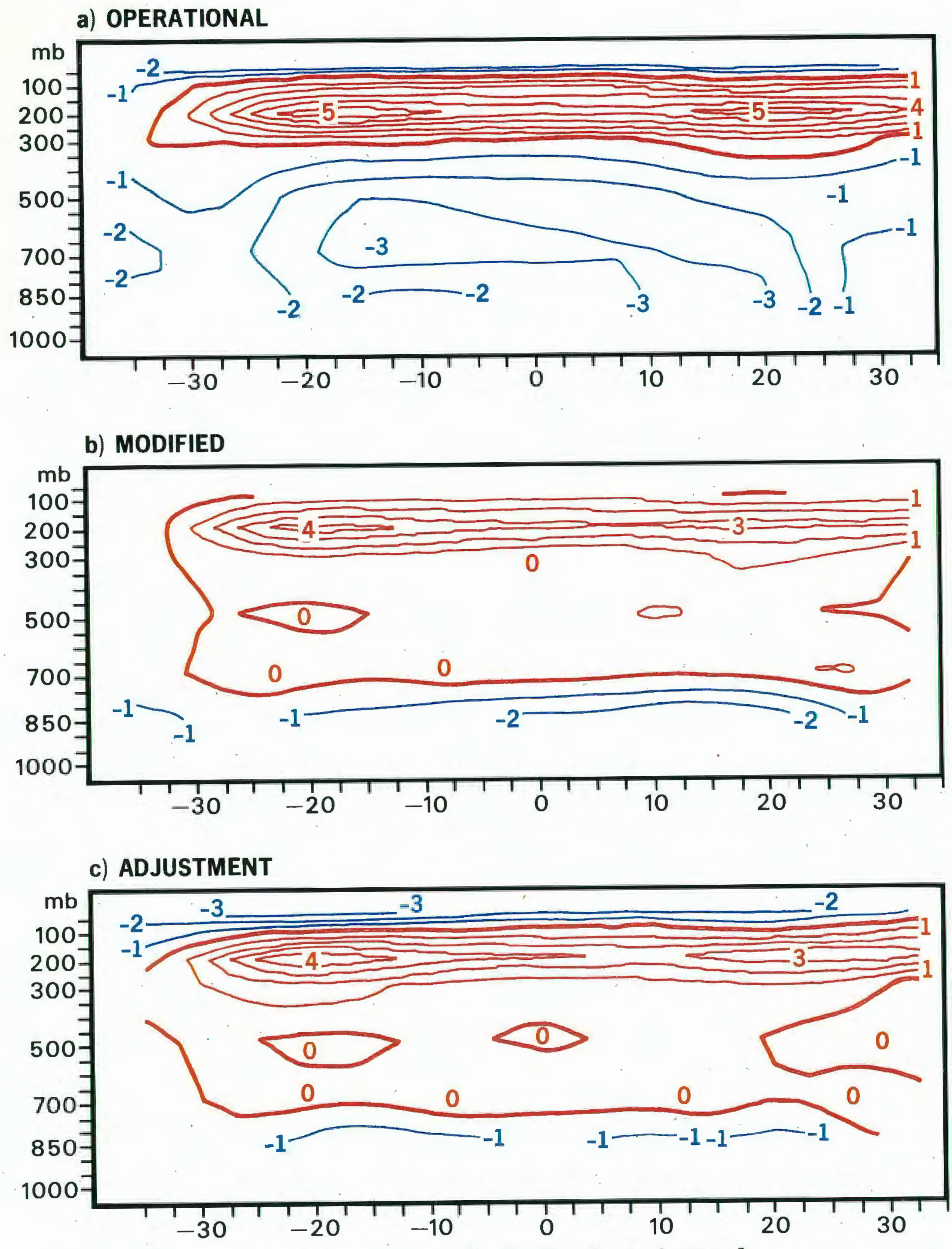


Fig. 3 Zonal mean temperature deviation from observed
(days 5-5-10) for a sample forecast using (initial data
15 July 1983)
a) Operational scheme
b) Modified schemes (new Kuo scheme plus shallow convection)
c) Adjustment scheme.

As well as modifying the Kuo convection scheme, a new approach for parameterising heat and moisture transports by deep (precipitating) and shallow (non-precipitating) convection has been developed. It is based on the general concept of adjustment following recent studies of atmospheric thermodynamic structure by Dr. A.K. Betts who was a Visiting Scientist at the Centre during 1984. The primary objective of the scheme is to ensure that the local vertical structure for temperature and moisture is realistically constrained in the presence of convection. This is achieved by parameterising the sources and sinks of heat and moisture by simultaneously adjusting the model profiles towards observationally based structures which are computed for each point at each timestep.

Ten-day forecasts using the adjustment scheme indicate a marked improvement in the representation of the tropical circulation, which subsequently affects temperature regions. Part of the impact is certainly related to the parameterisation of shallow convection, whilst part is probably due to the better thermodynamic structure throughout the tropical troposphere. The improvement brought about by using this scheme is illustrated by comparing Figs. 3a and 3c. Although the present version of the scheme can be improved further, experience so far is very encouraging.

Many of the developments described in this Report, with the exception of the adjustment scheme, are likely to be included in the high resolution forecasting system. However, research will continue on the improvement of convection schemes and on the parameterisation of other processes believed to have an impact on the quality of the forecast.

D. Dent, numerical aspects section, and J. K. Gibson, meteorological application sectio

EXPERIENCES WITH THE CRAY X-MP AT ECMWF

The Cray X-MP was delivered to the Centre in November 1983 and underwent extensive acceptance tests before entering service on 13 March 1984.

The ECMWF Cray X-MP system has 2 central processing units (CPUs), 2 million words of memory, 16 million words of SSD (Solid-state Storage Device) and was installed with additional discs and controllers. Towards the end of 1984 six additional discs (bringing the total to sixteen) and a disc I/O processor were installed. The clock cycle time is 9.5 nanoseconds, the memory bank cycle time is 38 nanoseconds. Four parallel memory access ports are available to each processor giving a memory access rate eight times that of the Cray-1.

The move from the Cray 1-A to the Cray X-MP went very smoothly with virtually no code changes being needed. Although the Cray 1-A was retained for a further 3 months, to act as a back-up in case of problems with the X-MP, it was never used in this role. During 1984 the reliability of the Cray X-MP at 99% was better than the Cray 1-A ever achieved, and its mean time between hardware failures at 176.7 hours was twice the average for the Cray 1-A during its life at the Centre.

The workload and throughput of the machine rose steadily through the year. In its 42 weeks of production the machine delivered 11.25 million units, compared to 4.7 million for the Cray 1-A for all of 1983. In the last 3 months of 1984 the Cray X-MP delivered units equivalent to an annual total of 15.5 million. Thus the throughput in those last 3 months was equal to 3.3 times the throughput of the Cray 1-A, thus exceeding the criterion on throughput laid down at the time of acquisition.

The multitasking spectral model on the CRAY X-MP

The ECMWF spectral model is an excellent example of a computer application which can benefit from multitasking (i.e. having separate tasks or jobs running on the two processors at the same time) in that the forecast runs are time critical and require a large proportion of main memory. In a separate section of this Report, the scientific aspects of the development of the high-resolution model are discussed.

The Cray X-MP computer configuration is capable of allowing a single job to make simultaneous use of two central processing units. The multi-tasking version of ECMWF's numerical prediction model is designed to make use of the dual-processing facilities of the Cray X-MP.

Multi-tasking using the CRAY X-MP

Multitasking is of benefit only when there is sufficient parallelism to use more than one CPU to perform the computations at a faster rate than could be achieved by a single processor, allowing for extra overheads necessarily incurred by the multi-tasking control mechanism.

There are certain basic requirements for a problem to be a suitable candidate for multi-tasking. First, the problem must be divisible into a set of tasks which will form a balanced load over the number of CPU's available. Secondly, tasks must be of sufficient length to justify the overheads of multi-tasking. Data stored by tasks should be mutually distinct, and tasks should not alter data which are required as input to possible simultaneous tasks. Computational independence and storage independence are problems which require careful and detailed attention.

The ECMWF T106 Spectral model

The single tasked version of the ECMWF spectral model was designed with multi-tasking in view, but without knowledge of the details of the multi-tasking eventually to be used.

Figure 4 illustrates the partitioning of control for the two scan version of the model within the time stepping system. The forecast is advanced by a time interval of 12 minutes each time step. Thus 1200 such steps are required to complete a ten day forecast.

The code for the forecast model is written in FORTRAN. In general, the 1977 ANSI standard is followed closely, but Cray FORTRAN extensions are used to manage memory and address variables.

The Multitasking spectral model

The multitasking problem was approached using a limited subset of the software features available, viz starting tasks, waiting for tasks to complete, and setting locks (which temporarily suspend parallel execution). This approach avoided computer code which would be difficult to test in a single processor environment. It reduced the planning exercise to defining groups of routines that could execute in parallel, and locating critical regions in such routines that would require locks to be set.

The first section of the code chosen for multitasking was that dealing with the grid point computations. Provided sufficient grid point values could be retained in memory, it would be possible to compute a Northern Hemisphere row and a Southern Hemisphere row in parallel.

A second area concerned computations in Fourier space. In general these could be split into symmetric and antisymmetric parts, depending on the nature of the coefficients being updated. The initial computations to produce Fourier coefficients for Northern and Southern hemisphere latitude rows are split into parallel tasks. The Legendre transformations are then executed in parallel.

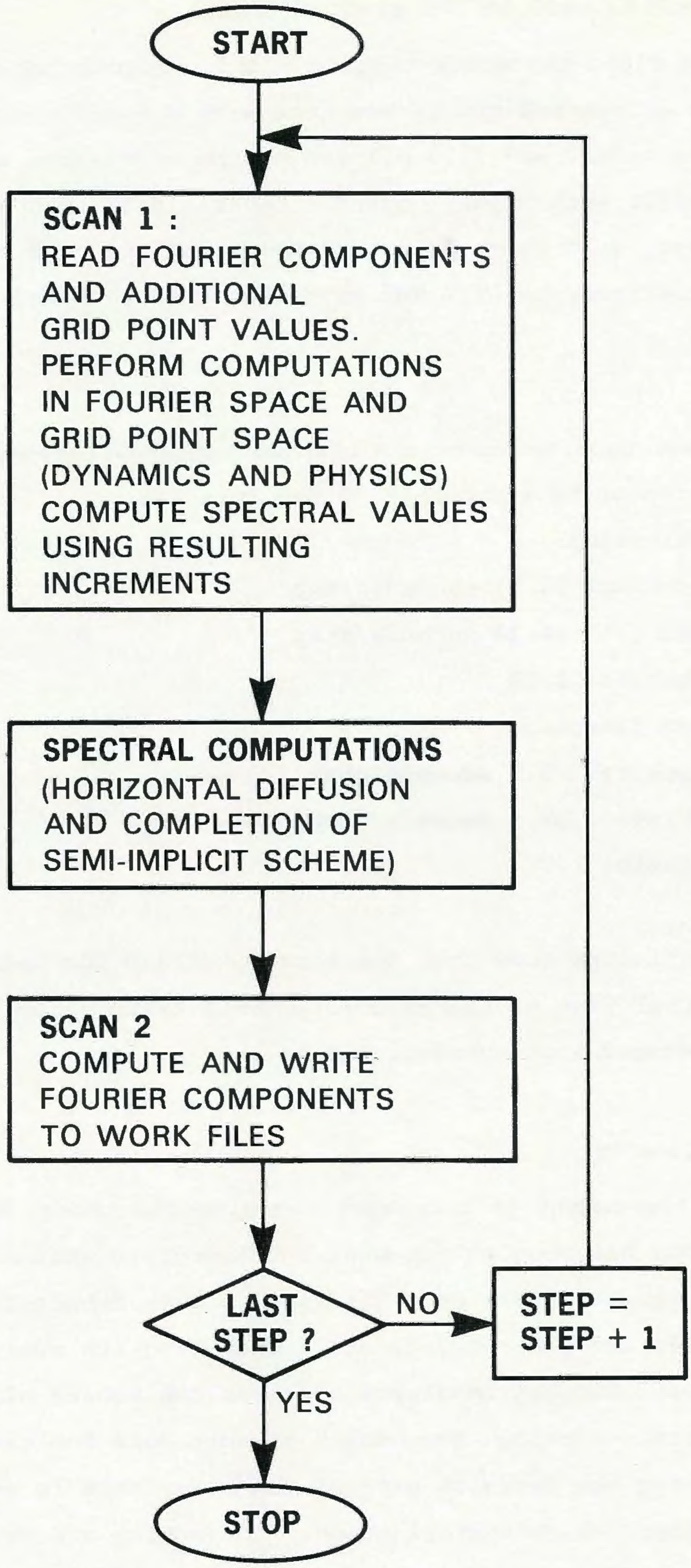


Fig. 4 Organisation of computation into two scans within one time-step loop; the loop is repeated 1200 times for a ten-day forecast.

Computer resources used by the spectral model

At resolution T106, the multi-tasking model required 1.8 million of the 2 million words of central memory compared with 1.5 million words for the single-tasking model, and 15.3 million of the 16 million words of the SSD. There are 3 major work files, Legendre coefficients (0.9 MW) which are read twice each step, grid point data (8.7 MW) which are read and written each step, and Fourier coefficients (5.7 MW) which are also read and written each step.

Timings

All the timings reported here are elapsed times corresponding either to a single time step or to a complete 10 day forecast.

For a normal timestep:

single tasking: 25.36 seconds/step

multitasking: 14.28 seconds/step

speedup ratio: 1.78

For a radiation timestep:

single tasking: 75.0 seconds/step

multitasking: 39.4 seconds/step

speedup ratio: 1.9

More detailed timings show that the total overhead for task management is about 0.7% of the total time of the forecast. This is acceptably small, and can probably be reduced with schedule tuning.

Future improvements

By measuring the amount of time spent outside the tasks, it can be seen how much of the code has been multitasked and therefore what additional improvements might be made in the future (see figure 5). Task imbalances lead to one CPU being idle while the other CPU is still executing its corresponding parallel task. One reason for the imbalance concerns the nature of the computation in grid-point space. Although the amount of work done for each latitude line is exactly equal for the dynamics part of the code, this is not always true in parts of the physical parameterisation. Convection and condensation calculations are affected by synoptic conditions and will therefore vary in space and time. The magnitude of these variations in terms of computing expense has not yet been measured.

The computer hall, ECMWF

Another reason for the imbalance concerns software which is used to protect critical regions of code in some 20 places, mostly for statistic gathering purposes. Some random I/O is carried out to a single dataset which is common to both tasks. Splitting this dataset will eventually allow overlap of this I/O within tasks. Modifications to the Cray operating system are awaited to enable this to be done.

Since the manufacturers have a good record for increasing the efficiency of their software over the course of time, and since the multitasking software is relatively new, ECMWF are confident that further improvements will be achieved.

DATA HANDLING

During 1984, the IBM 4341 configuration, used as the basis for the Data Handling System, was enhanced in a number of ways by the addition of further hardware which was ordered in 1983. Enhancements included a CPU processor increase in power of around 10%, additional magnetic tape decks, disc drives and controllers and a 3850 Mass Storage Subsystem which provides access to 35 Gigabytes of data without manual intervention.

The Common Filing System, CFS, obtained from Los Alamos National Laboratories in the USA was successfully installed on the ECMWF configuration and linked via the CDC Loosely Coupled Network to the CDC Cyber computers. At the end of 1984 the CFS software was undergoing modifications to allow it to enter service and these were expected to be complete early in 1985.

The Loosely Coupled Network (LCN) was delivered and installed during 1984 and at the end of the year work was advanced to bring the LCN system to the point where it would pass its contractual acceptance tests. The LCN system was in regular daily use from mid 1984 for CFS testing and to provide a connection between the Cyber 825 system and the Cyber 835 and 855 systems.

The Cyber/Cray station was enhanced by Control Data to allow it to act as a "gateway" system between the Cray and the LCN system using a CDC Cyber 825 as a gateway computer.

Work has also proceeded on the Meteorological Archival and Retrieval System (MARS) subsystem to allow meteorological data to be easily stored and retrieved using the CFS system. By December 1984, testing of the software was advanced and the system was expected to begin to provide a service to the Centre's meteorologsts during the second quarter of 1985.

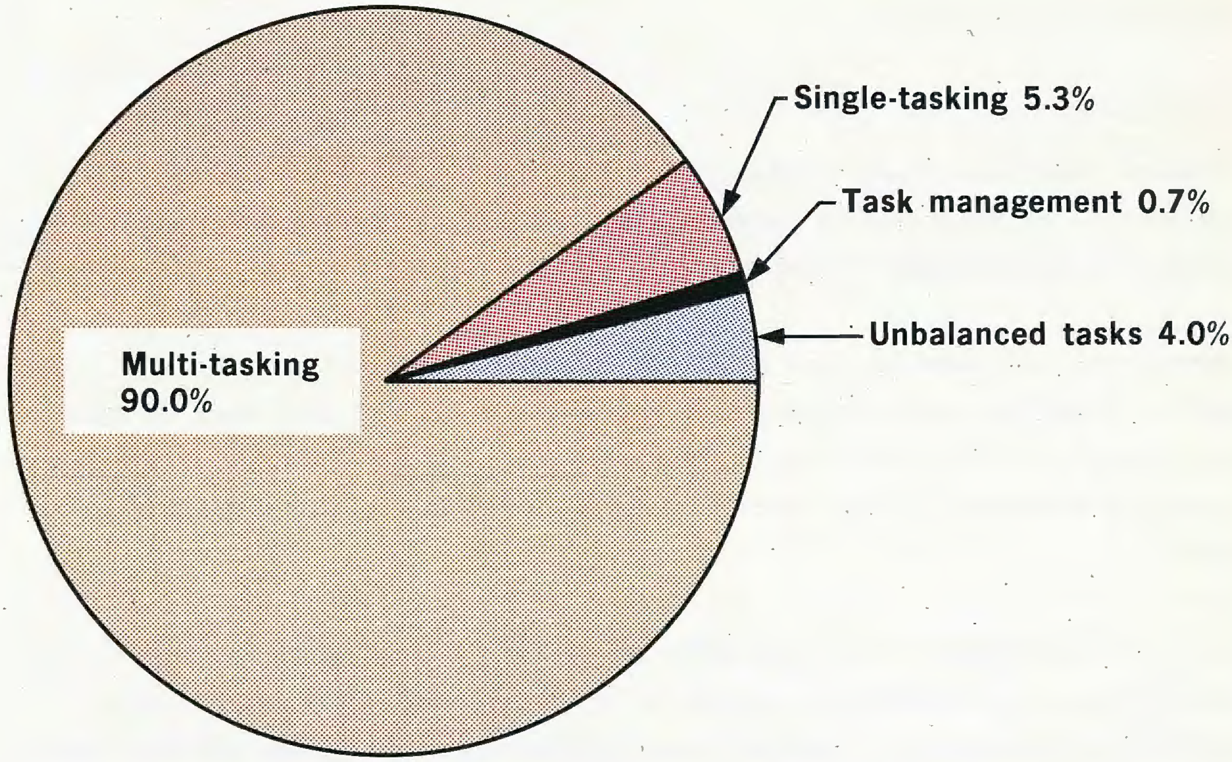


Fig. 5 Multi-tasking inefficiencies, including single-tasking and unbalanced tasks.

Work in progress on the graphics project

GRAPHICS AT ECMWF

Introduction

Computer-generated graphics plays an increasingly important role in nearly all aspects of meteorology, from being a tool for monitoring observations to presenting the forecast to the public.

Operational and research work at the Centre relies heavily on graphics. It is used on a routine basis for monitoring the observational data used as input to the Centre's model as well as for plotting model output. Graphics is also used to generate charts for the Centre's regular publications and verification work.

The first graphics hardware and software system at the Centre was developed nearly ten years ago and has proven to be an excellent tool for the Centre's staff. In the meantime, however, some of the requirements for graphics have changed. On the hardware side many new devices have become available with improved resolution and enhanced intelligence which means that more information can be presented in a better way. Another way to improve the presentation is to use colour and this is now available as standard for terminals. Colour hardcopy devices are however still rather slow compared to black and white devices. The improved quality in resolution and colour is now to a suitable standard to allow use directly for reproduction. On the software side this means that device independence became a desirable attribute for a new graphics system. An important requirement for the Centre's work was a user interface which is easier to use and more flexible. Furthermore the functionality and flexibility of the new system should be enhanced, so that more complex presentations could become easier.

It was envisaged that to design and implement a second generation graphics system special effort would be needed and a Graphics Project Group was established at the beginning of 1984. The main duties of the group have been to develop graphics systems and to take care of many of the ongoing tasks within graphics. The group has been supervised by a steering group with members from the Operations and Research Departments.

The major achievements of the Graphics Project Group in 1984 have been the Meteogram system, design and implementation of first phase of the new graphics system MAGICS, and participation in the selection and installation of graphics hardware.

The meteogram system

The first development project to be completed was the Meteogram system. With this system meteograms, based on on-line data or data from the ECMWF archives, can easily be plotted. The meteograms can be generated for any place on the globe and will display, for a 10-day forecast in black and white or colour, the cloud amount, 850 mb relative humidity, precipitation, mean sea level pressure (MSL), 10 m wind, and temperature at 2 m and 850 mb.

With the interactive command driven processor METGRAM, users at the Centre can very easily generate a batch job sequence to retrieve the data for the meteograms and plot them. The data retrieval, data manipulation and post processing of the graphics output is performace on the Cyber whereas the generation of the meteograms is done by a Cray job.

The usage of this interactive command driven system has so far ranged from being a tool when testing changes in the forecast model to visualisation of the forecast, for example a daily colour display of meteograms for selected places. An example of such a meteogram is shown on page 9.

MAGICS

The most important project for the group is the Meteorological Application Graphics Integrated Colour System (MAGICS). This system will provide, step by step, a full range of general meteorological graphics applications, eventually replacing the existing graphics package. The system will initially be accessible as a subroutine library and later on via an interactive command driven processor. Emphasis has been put on a user-friendly interface that can be extended without difficulty while the system grows.

The system is based on the Disspla graphics subroutine library which gives us many advantages including full colour support and, if needed, very high quality output. Also device independence is guaranteed which for the user means that the graphics output from a program can be easily plotted on current and future graphics devices.

The first part of MAGICS, initially to be available on the Cray computer, will contain contouring based on the Conicon package (University of Bath). This package is designed to draw the contours of continuously differentiable fields. The contours themselves consist of pieces of conic sections (ellipses, parabolas, hyperbolas) joined as continuously differentiable functions (thus smoothing is never needed).

Emphasis has been placed on simplicity, making it easy for the user to define the contour levels required and the attributes to draw them with.

Selection of graphics hardware

This year an A3 sized laser plotter has been chosen to become the future main output device for black and white graphics. The main advantages of the laser plotter are that they will produce plots in high resolution on standard paper and that the resource-demanding vector-to-raster conversion is built into the device. For colour hard copy output, an A3 sized high resolution graphics colour ink jet has been chosen so colour plots, including maps with shaded areas, can be produced.

A high resolution graphics colour terminal to be used for an operational plot display system, based on MAGICS, has been selected. The local segment storage of the terminals gives very fast access to locally stored pictures which can be used for rapidly switching between different combinations of fields or showing a sequence of time steps for the same fields.

MONITORING OF OBSERVATIONAL DATA RECEIVED AT ECMWF

With ever improving forecast models and analysis systems, observational data used in Numerical Weather Prediction (NWP) is being seen to form the weakest link in the chain with respect to both its availability and quality. Realising this, the Centre has enhanced its efforts in monitoring the data that form the basis of its operational forecasting activity. The main aspects of this data monitoring are the availability of data and areal coverage (see Fig. 6), the timeliness of arrival, completeness of reports and adherence to standard coding practices, and finally but at least of equal importance, the quality and representativity of the data. Statistics on availability and timeliness are being collected regularly and automatically, and the content of reports, areal coverage and coding practices are systematically monitored using interactive procedures.

The accuracy of the first-guess and analyses fields in the Centre's data assimilation system is sufficiently high to allow these fields to be used as yardsticks for the evaluation of the quality of observations when they are compared with these fields. Systematic deviations of individual observations from 6-hour forecast fields can be largely attributed to instrument errors. Random deviations, although dependent on sampling technique, climatological variance and local quality of the first-guess fields can be compared for different observation platforms or observing systems. Statistics have been gathered for several observation types and analysed on a monthly basis. These regular monitoring exercises have helped in identifying problems with individual data sources.

Monthly values of standard deviation, root mean square differences and biases have been calculated for either individual stations (Temps, Synops, Ships) or specified latitude/longitude boxes for space-based observations (Satem and Satobs) and Aireps. Figure 7 shows as an example, the bias and standard deviation of the geopotential height in radiosonde reports for station 01001 for the month of October 1984. Stations or observing systems with poor data quality have been excluded from the ECMWF analyses by adding them to a list of suspect stations. These stations are regularly compared with the analyses and other data, leading to revisions of the composition of the list. New problems with individual stations or platforms that are identified are normally dealt with in two ways.

In the first instance, the data affected are excluded from the analyses to avoid further degradation of the analysed fields. As a further step, the relevant data producers are contacted either directly or through the WMO and their attention is drawn to the problems found. In several cases this has led to a quick response and a lasting improvement of the situation, to the benefit of all users of the data.

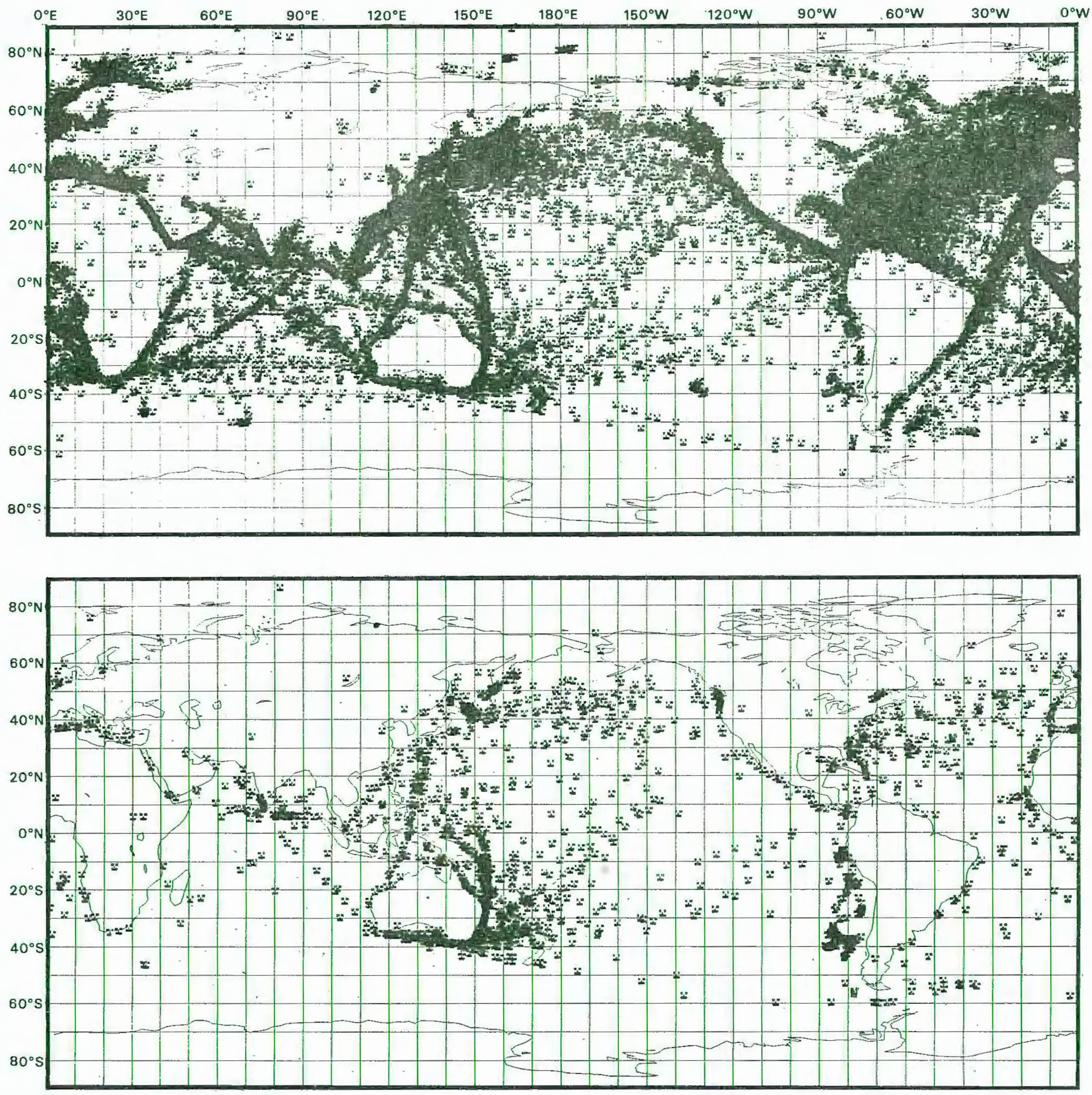


Fig. 6 Coverage of September 1984 SYNOP-SHIP 12Z ± 3 hours data received up to 24 hours after observation time (top) and data received too late for use in the ECMWF operational data assimilation system i.e. with a delay of at least $8\frac{1}{4}$ hours after observation time (bottom).

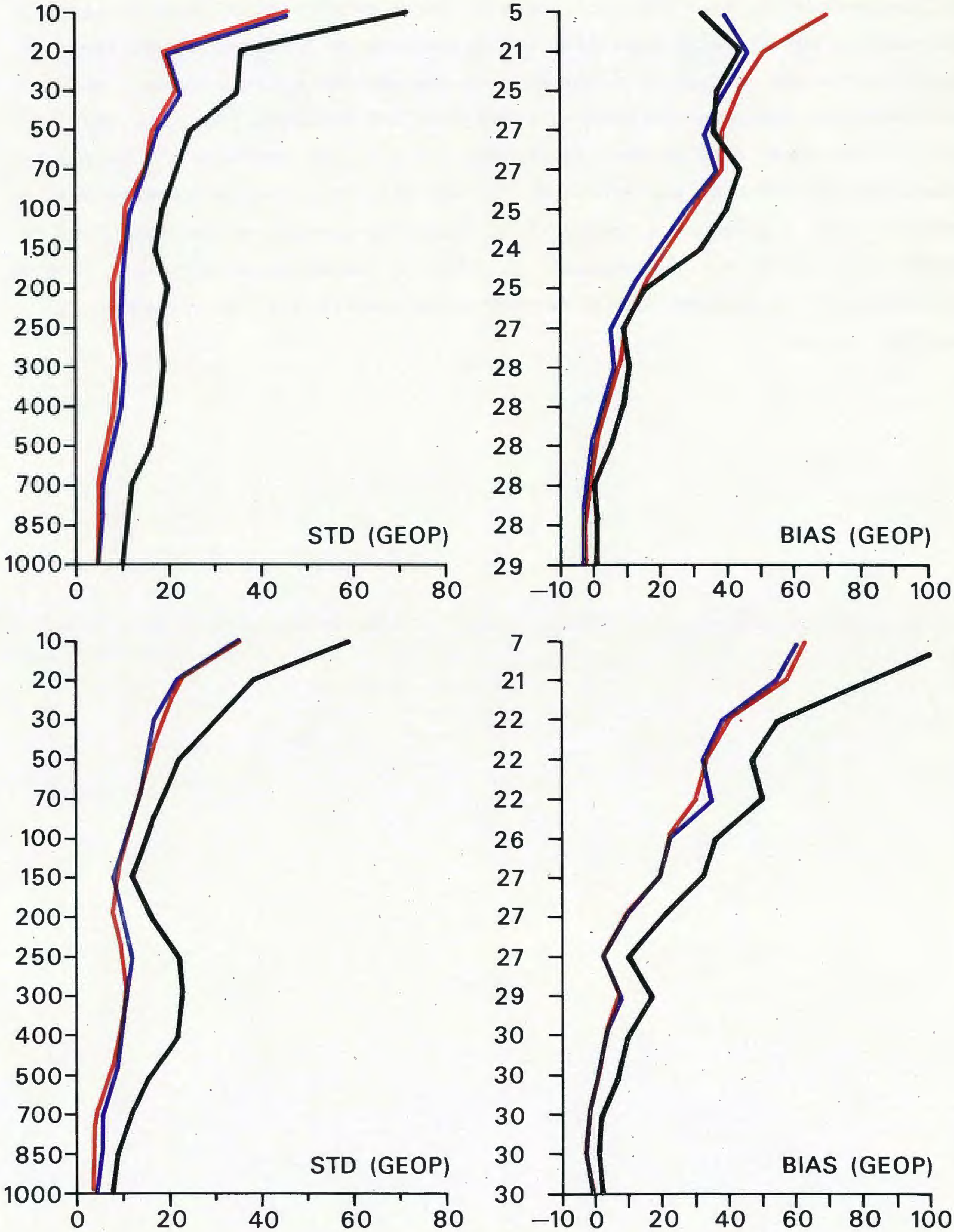
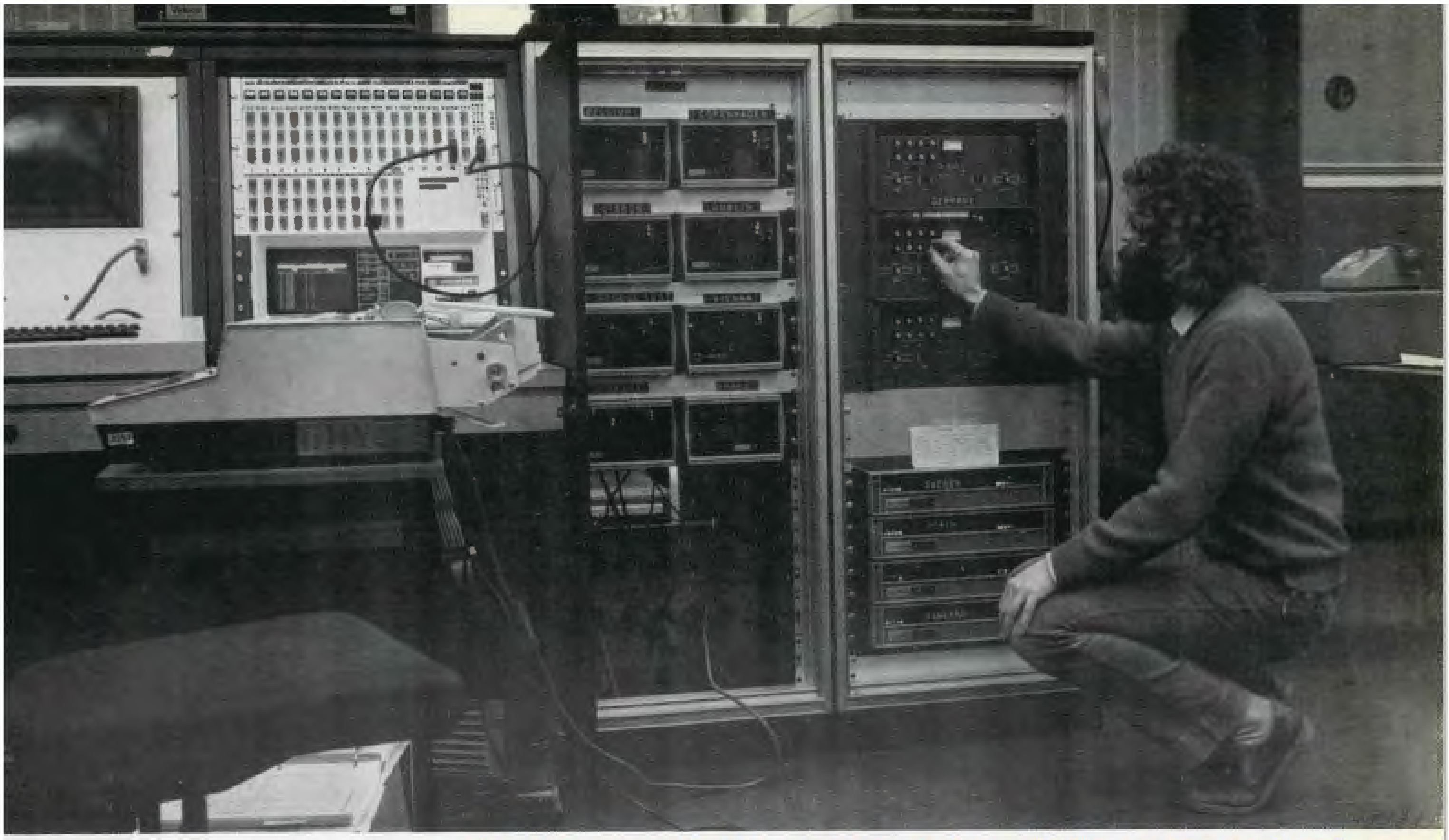


Fig. 7 Bias and standard deviation of the geopotential height of radiosonde reports, station 01001, October 1984.

The growing awareness of the importance of close monitoring of observational data used in NWP was also seen from the attendance of representatives from several major NWP centres at a Workshop on the use and quality control of meteorological observations held at ECMWF from 6-9 November 1984. At this workshop the importance of data monitoring and the free exchange of its results between the NWP centres was stressed. It was also felt that monitoring results should be made available to operators of observing systems as feedback, and to the WMO Secretariat for information. In order to guarantee an efficient flow of information it is planned that such monitoring results will be exchanged in standard formats.



The telecommunication system linking ECMWF to its Member States

USE OF ECMWF FORECASTS IN THE MEMBER STATES

In order to provide an updated inventory of the use of ECMWF products, the Centre collected, as in the previous year, information on this subject from the Member States and published a report on the application and use of ECMWF products in Member States, including verification results.

The report demonstrates that the Centre products have become an integral part of the work in the European meteorological offices. Most Member States have introduced extended or medium range forecasts into their operational routine. There is now evidence that the ECMWF forecasts have become the main, and in some cases the only basis of medium range forecasting in the Member States. Six types of processing applied to the Centre's numerical output locally at the national meteorological services are detailed in Figure 8.

Figure 9 summarizes the various types of post-processing and gives the number of countries which apply the techniques either operationally or on an experimental basis. The figure also shows the end users and areas of application of medium range forecasts, which have increased steadily since the Centre began operational forecasting in 1979. All the areas of application originally envisaged when the Centre was set up are now covered in many of the Member States.

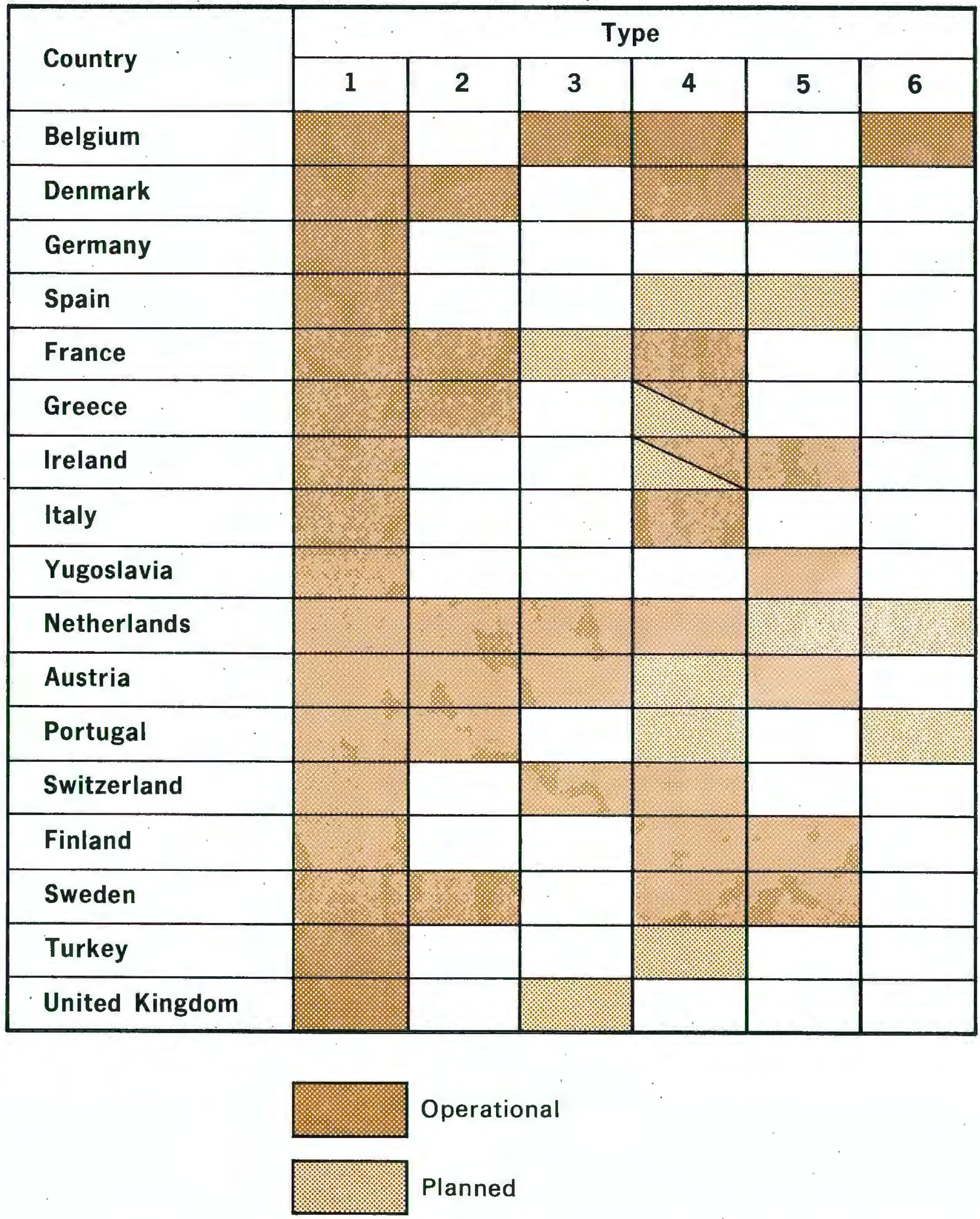


Fig. 8 Summary of the different types of post-processing applied to ECMWF forecast products in individual Member States

1. Graphical output for conventional interpretation of numerical forecasts
2. Direct model output
3. Diagnostics
4. Statistical interpretation
5. Driving other atmospheric models
6. Driving non-atmospheric models

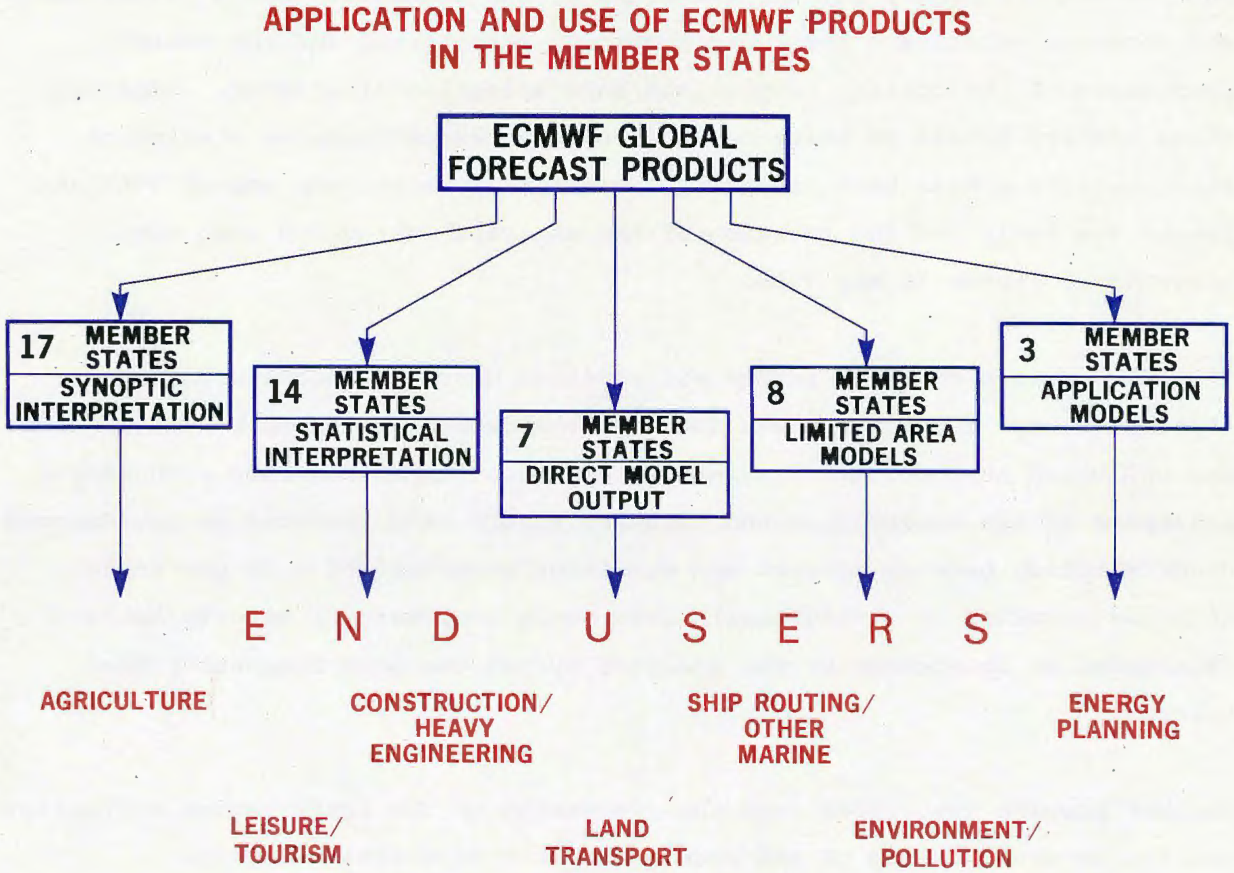


Fig. 9 Application and use of ECMWF products in the Member States.

CHANGES TO THE ECMWF ANALYSIS SYSTEM

Data assimilation includes not only an interpolation of irregularly distributed observations to a regular mesh, but also a decision-making process to identify erroneous data and to evaluate the representativeness of observations. The basic quantities of a statistical interpolation scheme, such as that of ECMWF, are the estimates of the amplitudes of the observation and forecast errors and their 3-dimensional structures, and the tuning parameters of the quality control and data selection algorithms. Ideally, these numbers should be based on the system's own performance statistics. Such statistics have been collected operationally since the end of 1982 and formed the basis for the revision of the analysis introduced into the operational system in May 1984.

In addition to a complete review and revision of the forecast error statistics, new error estimates for most observing systems were derived from the collected statistics. Reasonable rejection limits combined with proper estimates of the observation and forecast errors have resulted in an improved discrimination between correct and erroneous observations. In particular, this has resulted in stratospheric radiosonde geopotential reports being considered as inaccurate by the analysis system far more frequently than before.

Another problem identified from the processing of the assimilation statistics was the imcompatibility of the model-generated 10 m winds with the corresponding observed winds over land areas. An approximate geostrophic balance is assumed in extratropical areas between height and wind observation departures, i.e. differences between observed and six hour forecast values. Ageostrophic observation departures are consequently strongly damped by the analysis scheme and the resulting analysis may be unrepresentative of the observed data. The use of 10 m wind observations produced a surface pressure analysis that was not faithful to the surface pressure reports. However, by excluding the 10 m wind from the analysis, a good surface pressure analysis was obtained.

Algorithms for an extensive and homogeneous data selection were developed to reduce discontinuities between analysis areas and to choose a more representative set of observations than previously.

In regions of high data density the analysis is performed in three vertical slices. However, the height analysis is then poorly defined in the absence of height information and spurious temperature errors appear between the analysis slices. The reference level problem has now been solved by anchoring the upper air thickness analyses to the 700 mb height analysis.

The formulation of the forecast error structures described in another section of this report was also implemented. This, combined with a reduced error length scale, improved the horizontal resolution of the analysis system in extratropical regions.

Very little has been known about the tropical short-range forecast errors, and in statistical interpolation schemes it has been assumed that they are similar to the observed variations of the tropical atmosphere. However, from the processing of the assimilation statistics, it was found that the structure of the six hour forecast errors differs markedly from the climatological structures. The main contribution to the geopotential forecast error comes from the external mode, while the internal modes predominate in the real atmosphere. In contrast to the climatological structure, the wind forecast error has a very short height scale and as a consequence the influence of wind observations is limited to only a few analysis levels making it possible to analyse sharp structures.

Two measures of the success of any analysis change are firstly the amount of information rejected by the initialisation and second the quality of the short-range forecast. Although the amplitude of the analysis increments have the same magnitude as before, the mass and wind fields are in better balance as measured by the reduced initialisation changes.

The strongest impact from the analysis revision has been seen in the tropics. Fig. 10 shows the 6 hour forecast error of the zonal wind as measured against observations for summers 1983 and 1984. A reduction of the error amplitudes of between 0.5 and 1 m/s is evident at most levels. Significant improvements are also evident in extratropical regions (Fig. 11).

The representation of ITCZ as judged by the rainfall distribution during the first day of the forecast improved significantly as a result of the analysis changes.

This analysis revision, and especially the new formulation of the structure functions, provides the framework for a future high resolution analysis system.

STRUCTURE OF SHORT-RANGE FORECAST ERRORS

The basic purpose of the analysis scheme is to interpolate scattered and noisy observations of a variety of atmospheric parameters to a regular grid in such a way as to filter out all the noise, while retaining all the meteorological information. The analysis scheme has to recognise patterns of forecast error by comparing a short range forecast with the latest observations. The pattern recognition procedure works best if a complete statistical description of the forecast errors is available to it.

Up to now the statistical description of the forecast errors in use at the Centre has been somewhat crudely based on measurements of the height field errors; the description of the wind field errors was derived from the height field by a set of overly simple ad-hoc assumptions. Using the methods of turbulence theory, a new and complete formalism has been developed to describe the height field and wind field errors, and the statistical relations between them. The theory provides a set of coupled differential equations for the auto-correlations and cross-correlations of the geopotential, stream-function and velocity potential errors, in which the inhomogeneous terms are the measured velocity and height correlations.

Fig. 10 The standard deviation of the difference between observations and 6-hour forecast of the zonal wind for June-August 1983 and 1984 for the tropics (20^{o}N-20^{o}S). Units: m s^{-1}

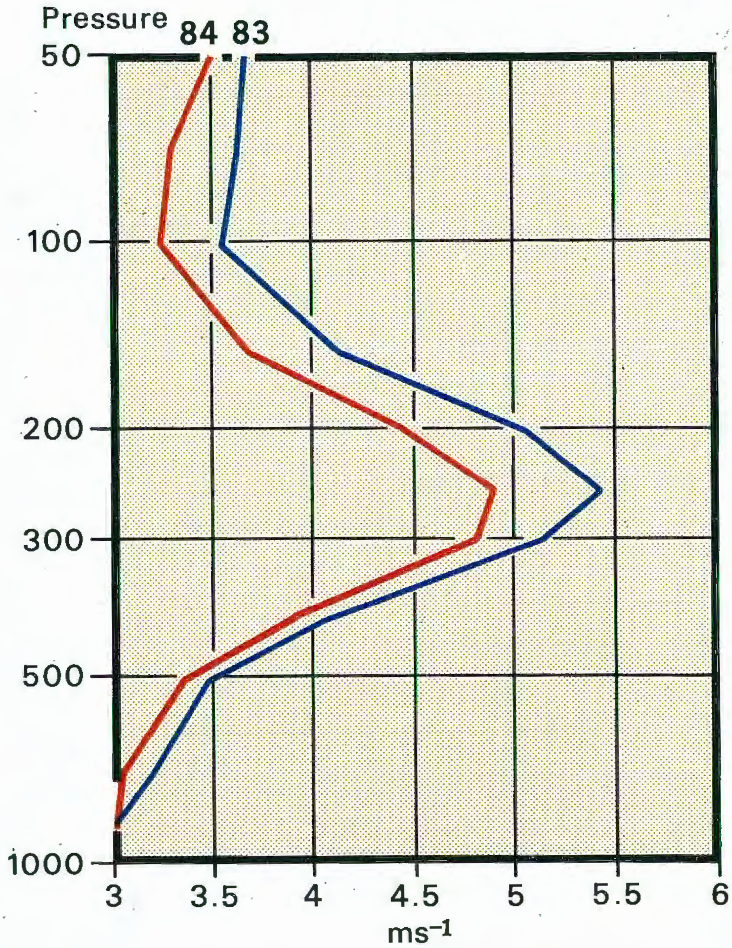


Fig. 11 As for Fig. 10 but for extra tropical regions.

The new scheme removes the need for ad-hoc empiricism and provides a rational basis on which to improve the resolution and meteorological sophistication of the analysis as a function of geographical region and data coverage. This approach enables one to deduce an optimal set of structure functions for the current analysis system, and to update these as the analysis/forecast system evolves. The new results have already been exploited to increase the resolution of the analysis, both vertically and horizontally. Further enhancements in analysis resolution will be possible as the model is upgraded.

In addition to the direct effects on analysis resolution, a number of further results may be expected from these developments. Accurate determinations of observational errors have been made for some radiosonde types, and the methods can be extended to all types of observational data. This information is essential for the quality control system, and for the optimal blending of observational and forecast information in the analysis.

One of the most difficult problems in practical analysis is the optimisation of the analysis over the oceans where the data coverage is sparse and heterogeneous. The developments outlined above are being exploited in simulation studies where the model Atlantic is extended to cover the area of Europe; some of the European radiosonde data are then used to simulate the oceanic network, and the rest are used to derive the statistical stucture of the oceanic forecast errors. It is expected that simulation experiments of this kind will improve the accuracy of the analyses over the oceans.

Finally the statistical description of the forecast errors is intrinsically interesting, and will find many applications in studies of predictability, of the evolution of the dynamical balance of the model and of the evolution of the error spectrum in the early stages of the forecast. As an example Fig. 12 shows the spectrum of the non-divergent wind 6 hour forecast errors over a data rich area. The change of the error spectrum with height is of considerable interest. At low levels the k^{-2} spectrum suggests that the major forecast errors are associated with incorrect positioning of

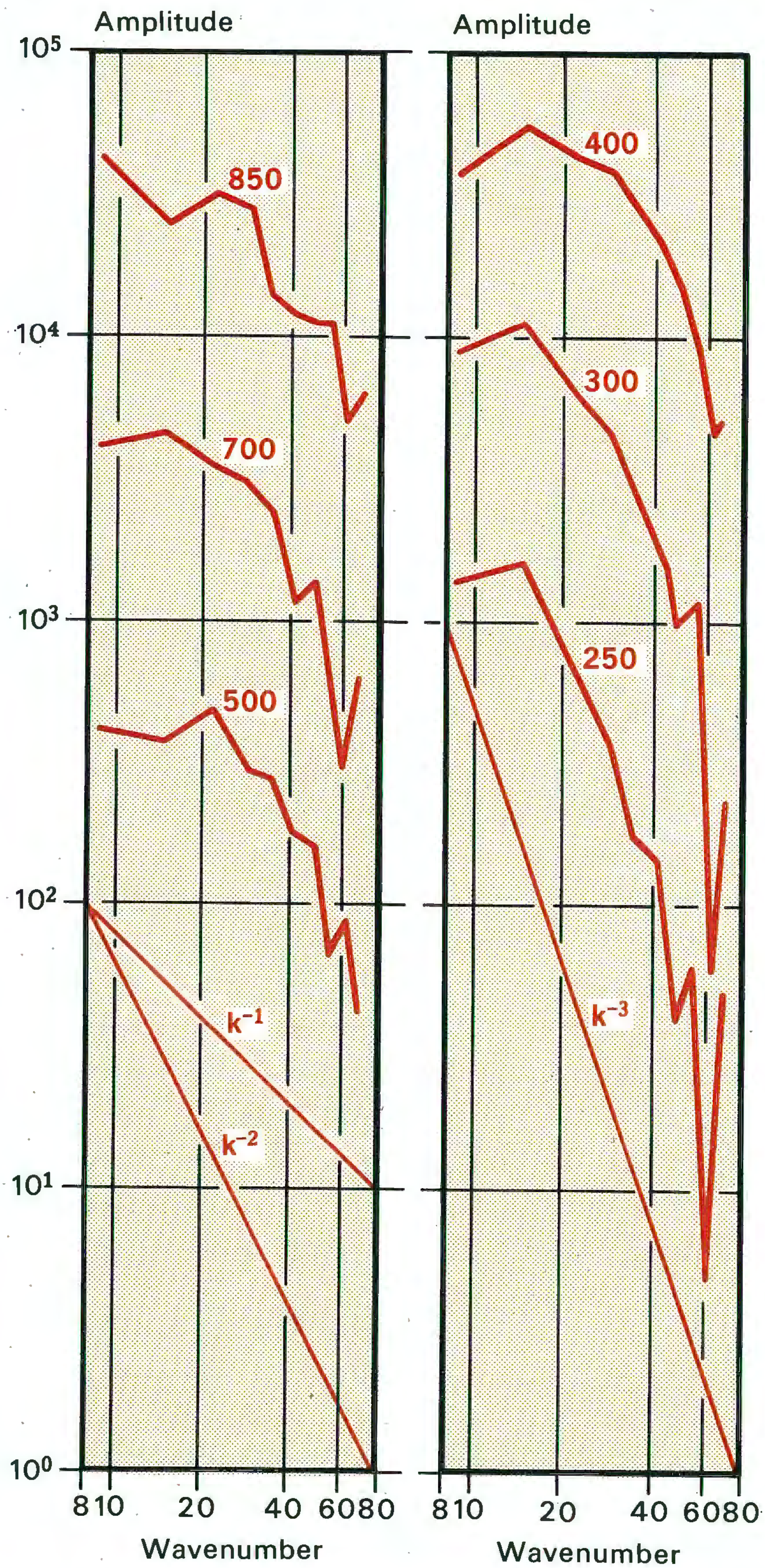


Fig. 12 Shows the spectrum of the non-divergent wind 6 hour forecast errors over a data rich area.

frontal discontinuities. In the upper troposphere by contrast, the spectral peak at baroclinic wavenumbers together with the sharp drop in the spectrum at high wavenumbers suggests that the major forecast errors are associated with the amplitudes and phases of the baroclinic waves.

This and other evidence suggested that the most important analysis errors in the upper troposphere were related to the statitics used in the analysis of the thermal wind field. These statistics were modified as part of an extensive revision of the analysis system in May 1984. Fig. 10 compares the verification of 6-hour forecasts against radiosondes for the summer seasons of 1983 and 1984. A clear improvement in forecast quality is evident for the later forecasts. Radiosonde observation errors near 250 mb are around 4 to 5 ms^{-1}; it can be calculated that the reduction in forecast error is from about 4 ms^{-1} to less than 3 ms^{-1}.

These theoretical developments provide a systematic framework for the development of the Centre's analysis system; the example given is indicative of the improvement which can be expected.

MODEL SENSITIVITY TO SEA SURFACE TEMPERATURES IN EXTENDED INTEGRATIONS

A number of extended range prediction experiments performed in the past at ECMWF have shown a sensitivity of the simulated tropical circulation to the specification of sea surface temperatures (SST). The impact of SST's on the mid-latitude circulation appeared according to these experiments to be smaller than could have been expected from observational studies. This was attributed to the coarse resolution of the model used for these studies.

The occurence of an intense El Nino SST anomaly during winter 1982/83 (Fig. 13) provided an ideal test case to investigate further the influence of SST anomalies on the large scale flow.

Two extended range integrations were carried out using the operationally analysed data for January 1, 1983 as initial conditions. The first experiment (control) used a purely climatological SST distribution, while in the second experiment the observed El Nino anomaly, as provided by the Climate Analysis Centre, Washington, was superimposed on the climatological SST in the tropical Pacific region.

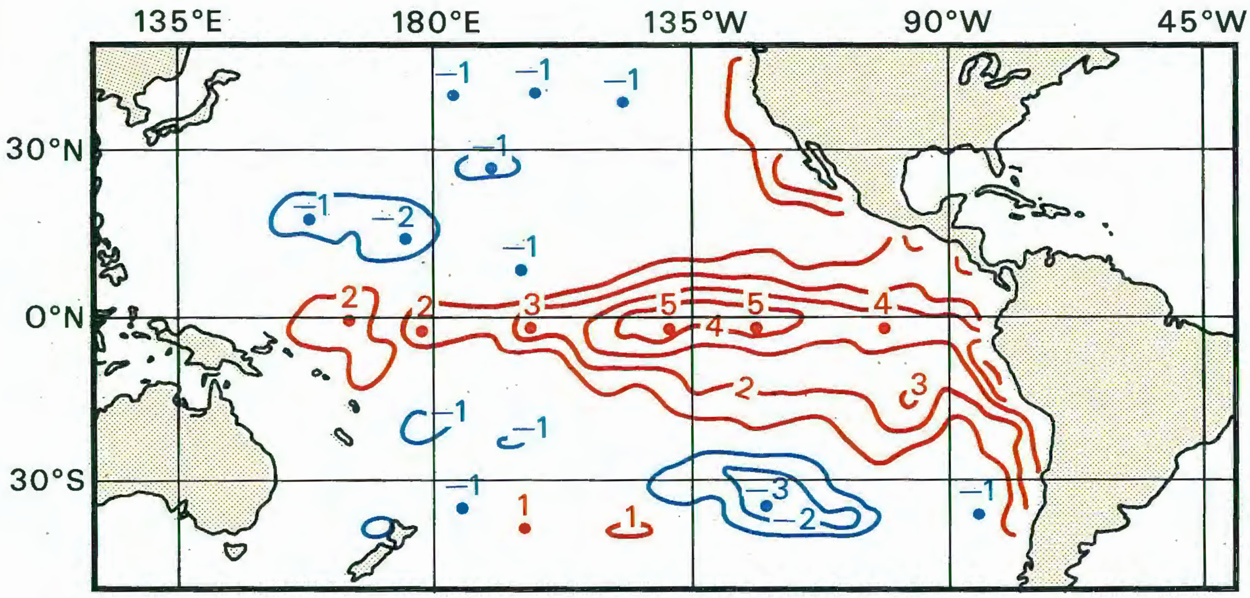


Fig. 13 Observed El Niño SST anomaly during winter 1982/83.

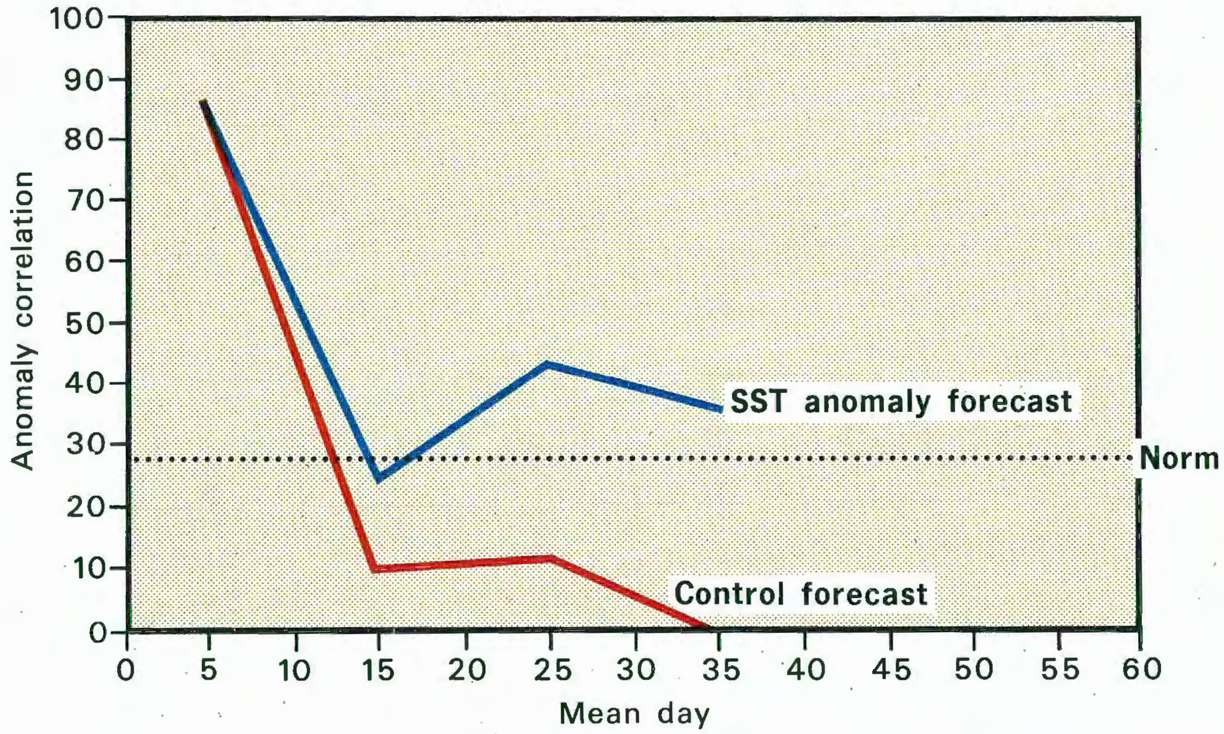


Fig. 14 Ten-day mean anomaly correlation scores for two extended-range forecasts, the control forecast using climatological values of the sea surface temperatures (SST), the anomaly forecast using the values of SST observed during the El Niño phenomenon.

Fig. 14 shows the 10 day mean anomaly correlation coefficients for these experiments. Time mean averages rather than individual days are used to evaluate extended range predictions because it is hoped that these mean fields can be used to forecast "Grosswetterlagen". In the first 10 days the impact of the anomaly on the mid-latitudes is only small. During the later stages of the integration, the skill of the forecast with the observed SST anomaly is measurably higher than the skill of the control experiment. It is noteworthy that the objective skill in the period from day 20 to 30 is higher than the skill for day 10 to 20, a phenomenon which appears to be common to a number of experimental extended range forecasts and may be associated with forcing at the lower boundary.

An estimate of the quality of the 10 day mean forecast can be obtained by comparison with forecasts using the model's climate derived from a multiyear integration as the predictor. Under the assumption that the skill of these predictions follows a Gaussian distribution, only 2.5% of them will exceed the threshold value "norm" (the dotted line in Fig. 14) by chance. The skill score of the experiment with the SST anomaly is noticably higher than this threshold value, while it is lower for the control forecasts. This implies that the model integration using observed SST anomalies carries meaningful information about the state of the atmosphere well into the 30 day time range, while the control forecast using the climatological values of the SST has scores below those of a forecast using the model's climate.

DEVELOPMENT OF THE HIGH RESOLUTION SPECTRAL MODEL

Intensive effort during 1984 has been dedicated to two parallel streams of work necessary for the preparation of an operational high resolution spectral model which will make maximum use of the features of the CRAY X-MP.

Technical development has been carried out to optimize the code and thus allow a spectral model with a T106 truncation (i.e. with a mesh size 60% of the present one) to meet the operational requirements with respect to timing etc. This has involved in particular:

- making full use of the SSD to remove most I/O overheads.
- production of a multi-tasking version (achieving a 1.75 efficiency ratio over the single-tasking code at the end of the year).
- further optimization of the code (including some developments allowing use of a longer timestep).

As a result, the first operational version of the T106 spectral model will require about the same time resources on the CRAY X-MP as the T63 version on the CRAY 1A in April 1983. Further information is provided in the section of this report on "Experiences with the CRAY X-MP".

The scientific work has been mostly of an experimental nature and can be divided into two broad categories: choice of an appropriate orography and resolution experiments.

Experiments on three different orographies at the T106 resolution have been carried out: mean, mean+σ and mean+$\sqrt{2}\sigma$ (σ being the subgrid standard deviation of the orography), and on two orographies at the T63 resolution: mean and mean+ 2σ, the latter being the present operational orography. So far experiments have been carried out on 18 situations - the 15th day of each month from May 1983 to October 1984. The results confirm the beneficial impact of an envelope orography in winter, with increased benefit at T106 compared to T63. In contrast to the T63 results, no detrimental impact has been found in summer at the higher resolution. In addition the lower envelope (mean+σ) provides results very similar to the higher one (mean+$\sqrt{2}\sigma$) at T106 resolution, and so the lower envelope has been selected for the first operational model in order to minimise unwanted local effects.

Some experiments with a significantly finer vertical resolution in the troposphere were carried out with the T63 model on 8 cases, but these showed a surprising lack of sensitivity. Therefore the main emphasis has been put on investigating the effect of increasing the horizontal resolution. Comparing T106 and T63 forecasts it was found that there were objective improvements, quasi-systematic up to D+4, with the higher resolution model at both 500mb and 1000mb, and in all scales of motion; indeed the improvements as measured by the anomaly correlation score are larger than those found when comparing the T63 spectral model and the N48 gridpoint model (see Fig.15). On several occasions important synoptic differences were found over Europe (for an example see Fig.16). A very large positive impact can also be seen in some local products (such as precipitation as shown in Fig. 17) which respond to the better representation of the orography and can benefit considerably from quite small synoptic scale improvements.

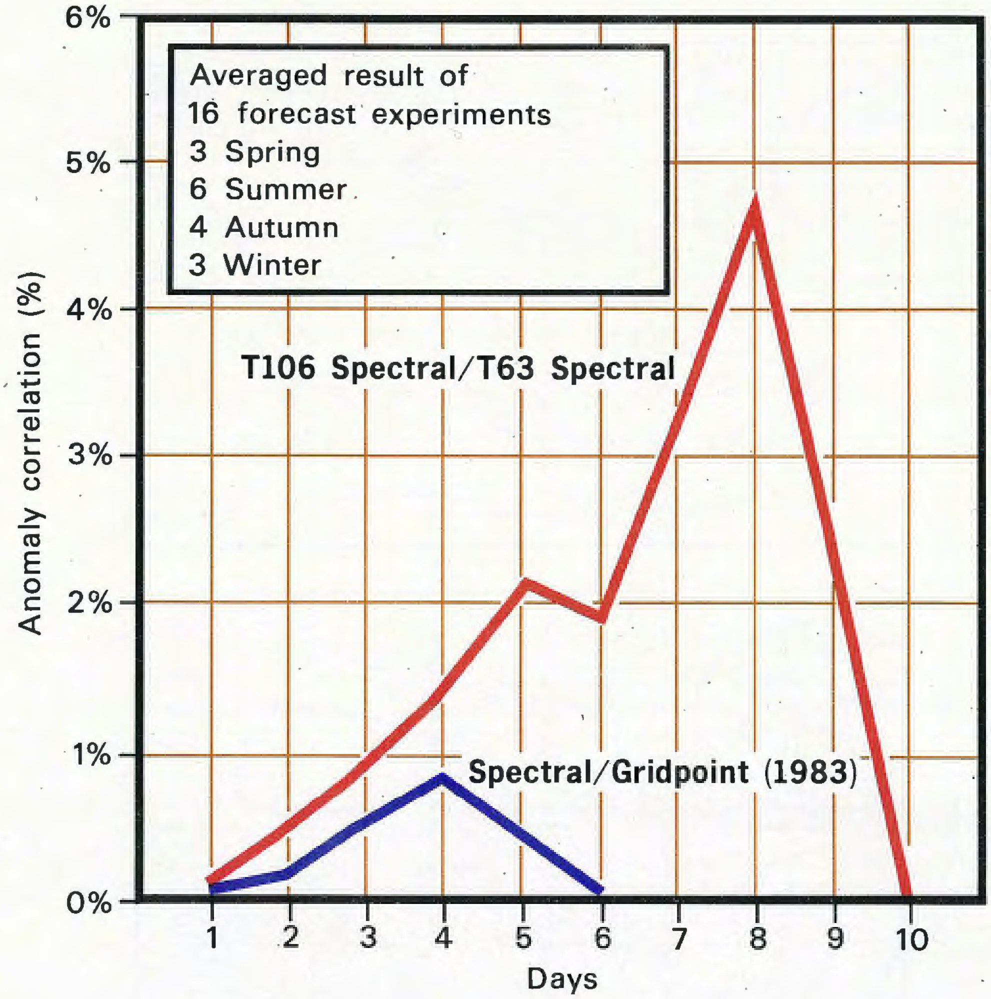


Fig. 15 Improvement in anomaly correlation scores obtained using the T106 model compared to those obtained using the T63 model.

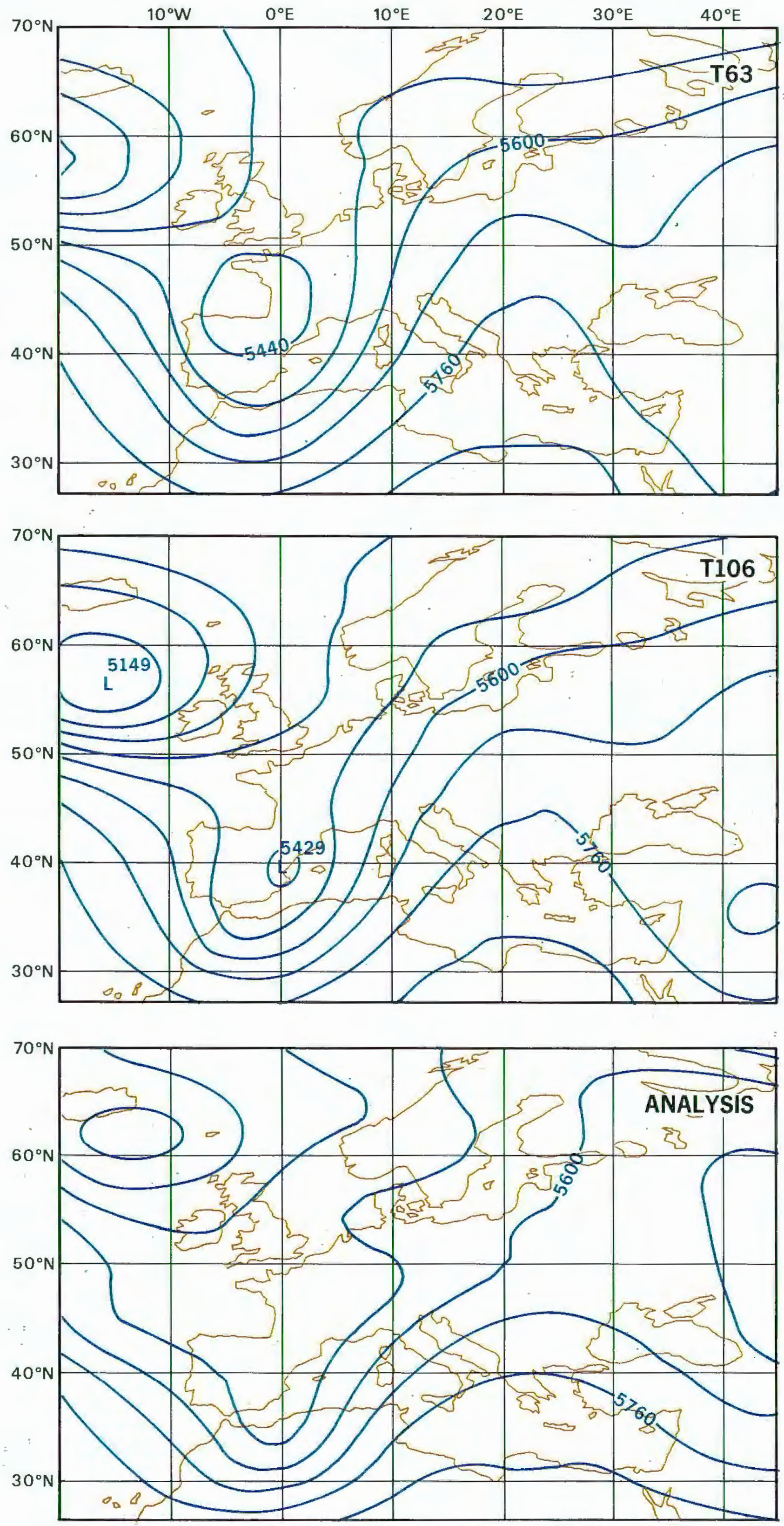


Fig. 16 500 hpa charts of analysed geopotential (bottom) and 5-day forecast by the T63 model (top) and by the T106 model (middle).

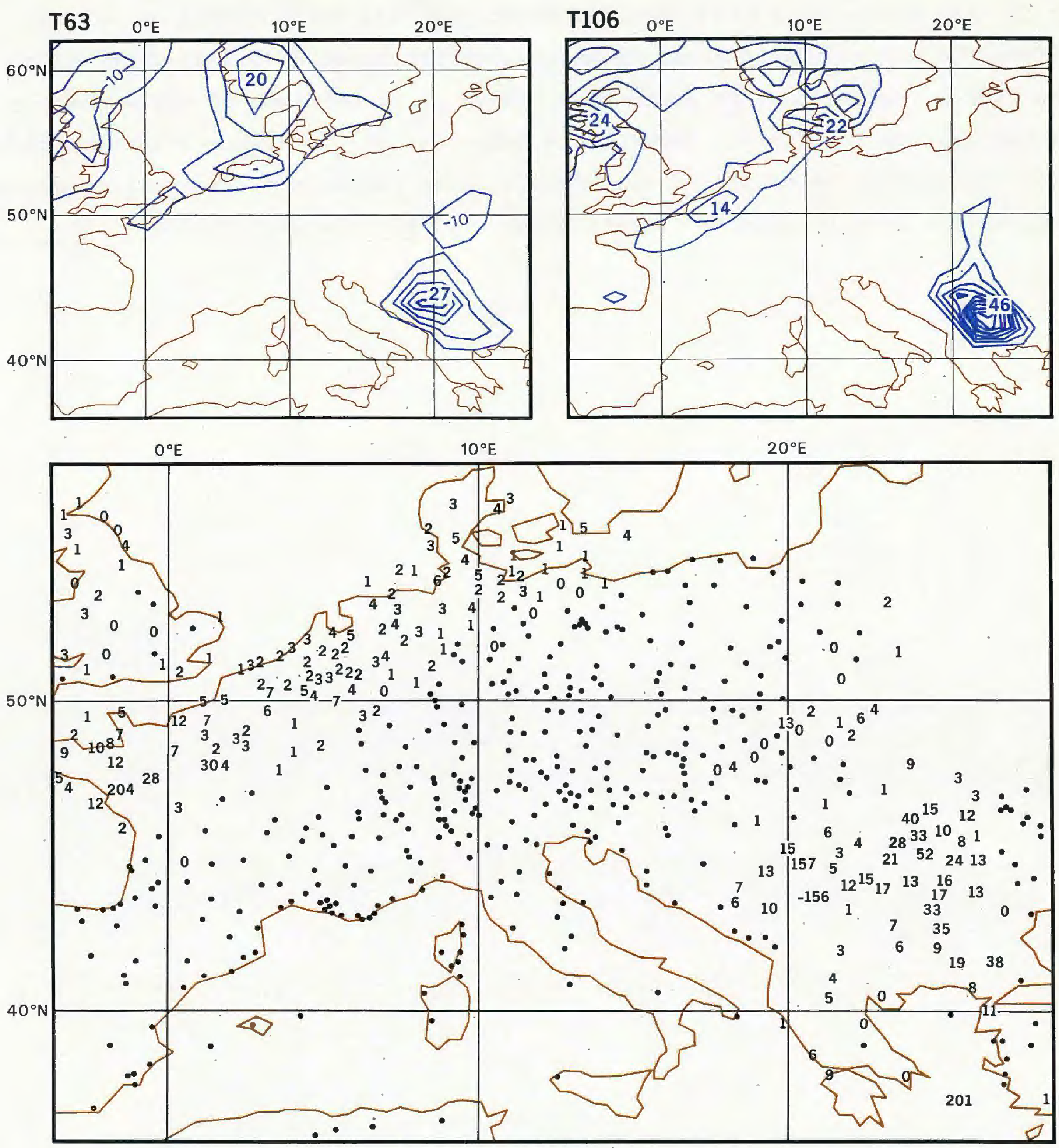


Fig. 17 Rain forecast over Europe between forecast days D+3 and D+4 by the T63 model (top left) and by the T106 model (top right), together with the corresponding observed rainfall (bottom).

It is also worth noting that besides minor problems which should be solved before the operational change, no serious deficiencies have been observed at the higher resolution. In particular, there is no evidence of any worsening of the systematic errors. However the behaviour of the high resolution model will continue to be monitored very carefully by the Centre, taking into account information from the Member States, after its operational implementation.

PERSONNEL

There are 38 posts in the Research Department, 75 in the Operations Department, and 29 in the Administration Department (including Directorate and Financial Comptroller). Of these 142 authorised posts at the Centre, 134 were filled on 31 December 1984. Additionally, several visiting scientists and consultants worked at the Centre during the year; further details are contained in another section of this report. Efforts continued to widen the geographical distribution of staff, and during 1984, staff from all 17 Member States were employed at the Centre. The table below shows the 1984 geographical distribution of staff.

Distribution of staff by categories and states

STATE	CATEGORY					
	hg	A	B	C	L	Total
Belgium		1				1
Denmark		4				4
Germany, Federal Republic of		17	6		1	24
Spain			1			1
France		7	2			9
Greece		2				2
Ireland		5	1			6
Italy		4		1		5
Yugoslavia		2	1			3
The Netherlands		1	4			5
Austria		3				3
Portugal			1			1
Switzerland			1			1
Finland		4	1			5
Sweden	1	3				4
Turkey		1				1
United Kingdom		21	33	5		59
	1	75	51	6	1	134

FINANCE

The Centre's Budget 1984 was adopted by the Council at its 18th session held on 23-24 November 1983. The approved total revenue and expenditure for the year 1984 was £8,978,500 - an increase of £374,900 (+4.36%) over the Budget 1983, which, in view of the cost-of-living increase in the U.K. by 4.8%, represented a 0.44% reduction in real terms.

The budgetary expenditure was mainly met by the financial contributions of the Member States, to which are added the proceeds of taxation, staff contributions to the Pension Scheme, bank interest, and other miscellaneous revenue. Fig.18 shows the total actual expenditure in each of the years 1976-1984 on staff, computer costs and other expenditure

The Member States' contribution towards the 1984 Budget were estimated to amount to £7,805,800. Fig. 19 shows the percentage distribution of Member States' financial contributions in the period 1982-1984.

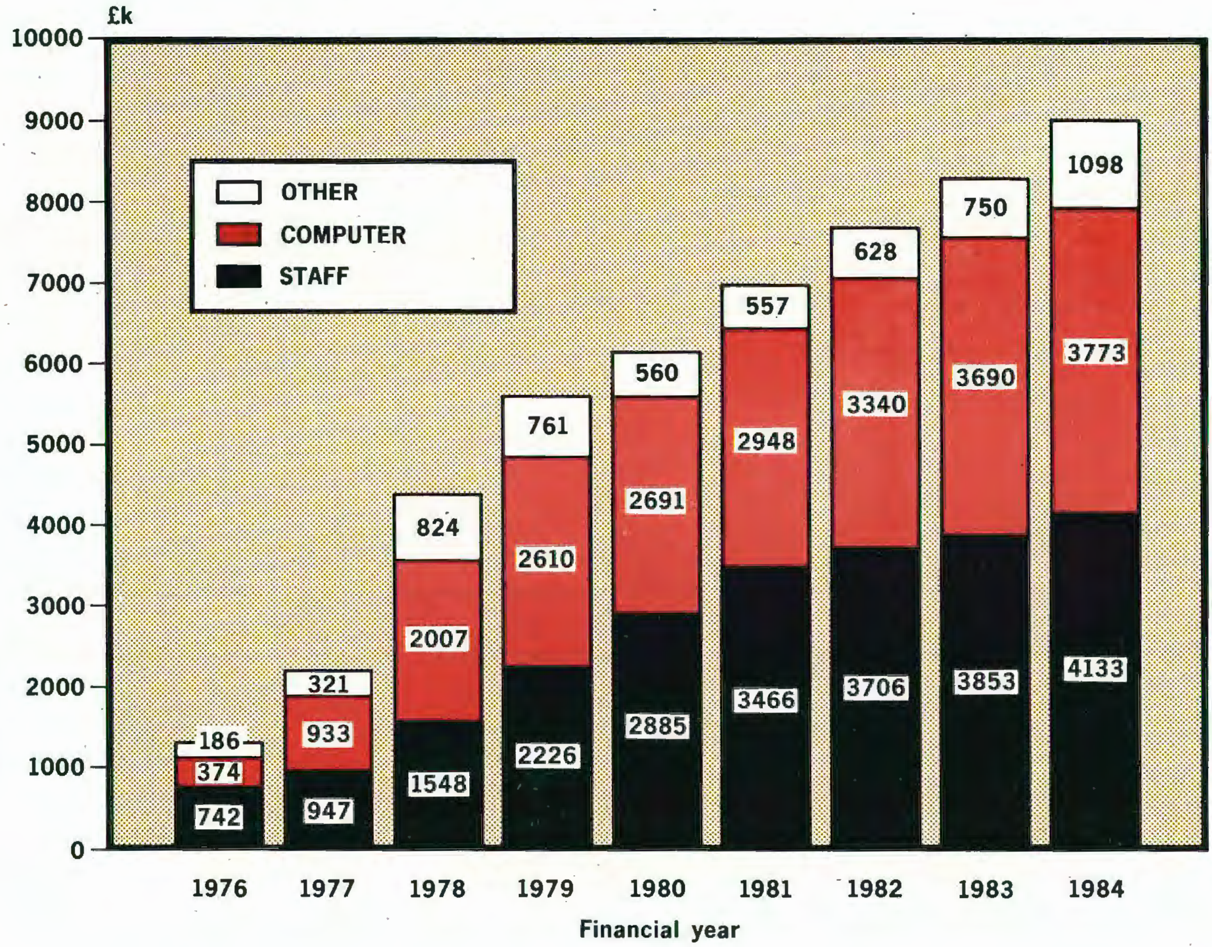


Fig. 18 Expenditure on staff, computer operations and other items during 1976-84.

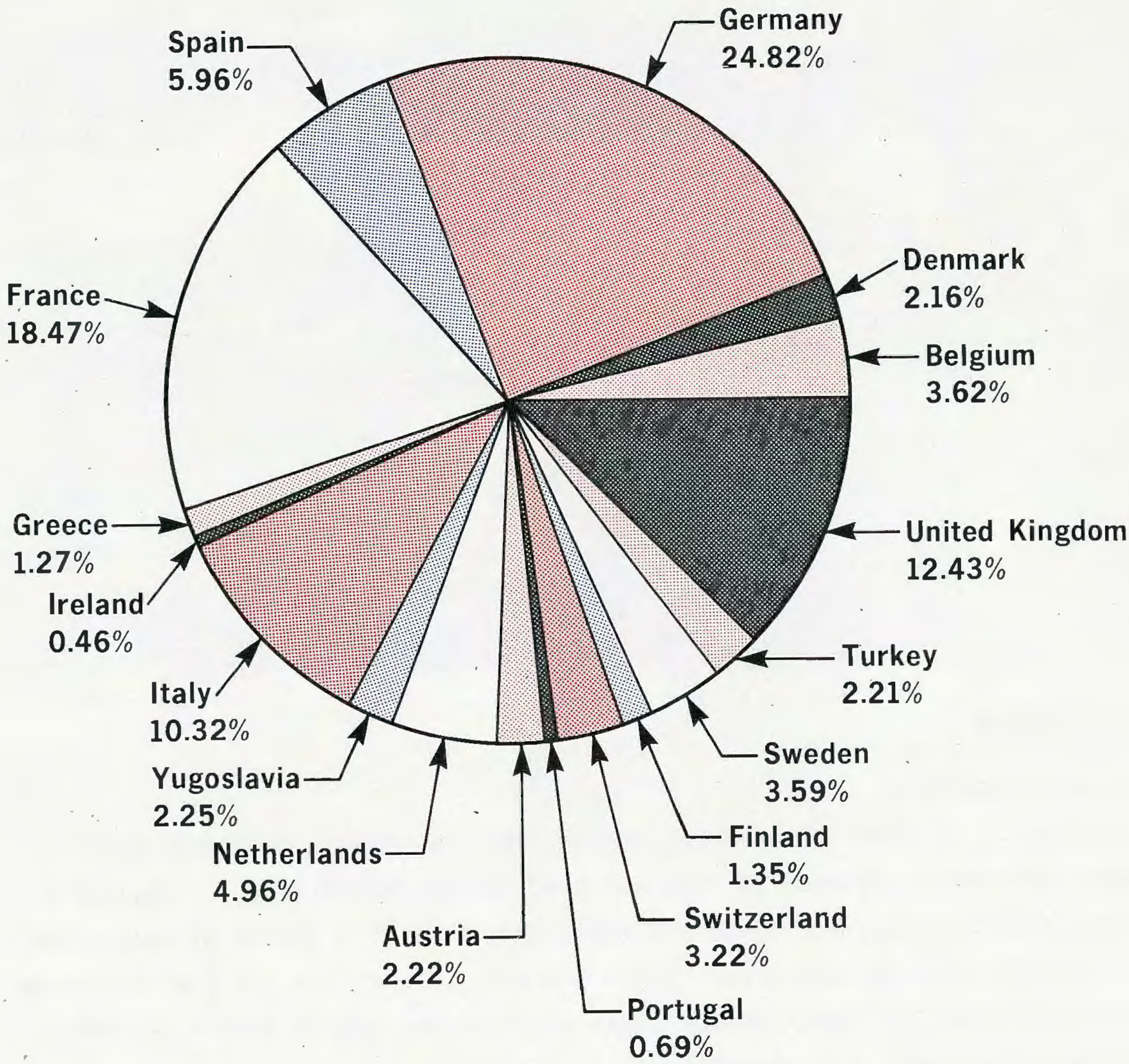


Fig. 19 Percentage distribution of Member States' contributions for 1982-1984.

At its 20th session held on 21-23 November 1984, the Council approved the new scale of contributions for the period 1985-1987, and these are indicated in brackets.

	1982-84	(1985-87)		1982-84	(1985-87)
	%			%	
Belgium	3.62	(3.06)	Netherlands	4.96	(4.64)
Denmark	2.16	(1.82)	Austria	2.22	(2.17)
Germany	24.82	(22.41)	Portugal	0.69	(0.72)
Spain	5.96	(5.96)	Switzerland	3.22	(3.17)
France	18.47	(18.43)	Finland	1.35	(1.51)
Greece	1.27	(1.23)	Sweden	3.59	(3.44)
Ireland	0.46	(0.53)	Turkey	2.21	(1.76)
Italy	10.32	(11.33)	United Kingdom	12.43	(15.66)
Yugoslavia	2.25	(2.16)		100.00	(100.00)

The classroom at ECMWF

EDUCATION

Seminar/workshop

The Seminar on DATA ASSIMILATION SYSTEMS AND OBSERVING SYSTEM EXPERIMENTS WITH PARTICULAR EMPHASIS ON FGGE was held at the Centre from 3-7 September, 1984. It was co-sponsored by WMO and formed part of a series of specialised scientific seminars which have taken place in preparation for the forthcoming Conference on the Global Weather Experiment to be held in Sweden in 1985. The Seminar had three main objectives:

- to review the characteristics of the FGGE observing system,
- to provide an up-to-date review of 4-dimensional data assimilation, and to assess the results from different analysis systems and the effects on medium range forecasts,
- to review recent results from observing system experiments (OSE's) and observing system simulation experiments (OSSE's).

Due in part to the co-sponsorship of WMO it was possible to have a wide selection of lecturers; there were 14 external lecturers from various Member States, USA, Australia and Japan. Also there were 32 other participants from 12 Member States.

After the Seminar, many of the participants stayed at the Centre for a two-day workshop. Two working groups were set up to consider data assimilation systems, and OSE's and OSSE's. Each group reviewed recent achievements, and made suggestions about possible avenues of research and considered how future research could be conducted.

A report of both the Seminar and Workshop is in preparation.

Workshops

From 8-9 May 1984 the Operations Department held a workshop with the theme SATELLITE COMMUNICATIONS FOR ECMWF? The objective was to establish the feasibility of a satellite based communications system for the dissemination of the Centre's daily forecasts, and to investigate how it could be implemented. It included descriptions of Centre's requirements and its present telecommunications system. External experts described their knowledge of, and experience in, various aspects of satellite communications, and there was a presentation by the Centre of possible dissemination strategies using satellite links. Agreement was reached on the general kind of system which would satisfy the Centre's requirements.

There is good evidence that the quality of data assimilation schemes is very dependent on the "front-end" processing of the basic observational data. Therefore it was decided to hold a meeting which would provide a forum for discussing aspects of observation processing and analyses which receives little attention in the formal literature. The resulting workshop on THE USE AND QUALITY CONTROL OF METEOROLOGICAL OBSERVATIONS FOR NUMERICAL WEATHER PREDICTION was held from 6-9 November 1984, and was jointly organised by the Operations and Research Departments. Initially there were presentations covering

- availability and quality control of meteorological observations
- quality control and selection algorithms in operational data assimilation.

The working groups then examined these topics in detail and made many recommendations about development which would be beneficial to both the Centre and the general meteorological community.

A workshop on CLOUD COVER PARAMETERISATION IN LARGE SCALE NUMERICAL MODELS - DESIGN, VALIDATION AND DYNAMICAL IMPACT, held on 26-28 November 1984, was arranged by the Research Department. Its purpose was to exchange information concerning recent developments in cloud cover parameterisation schemes. Emphasis was put on the validation of the schemes against observations, mainly obtained from satellites, and on the understanding of their impact on the radiation field and dynamics of the atmosphere. The presentation fell into two broad categories

- the representation and impact of clouds

- the verification of cloud prediction schemes.

The working groups discussed various aspects of those topics, but a common theme throughout all the discussions was the problem of verifying cloud schemes.

The Operations Department also held a workshop on USING MULTIPROCESSORS IN METEOROLOGICAL MODELS from 3-6 December 1984. The Centre recognises that the next generation of supercomputers will contain a large number of separate processors: however a full understanding of how to use a number of processors simultaneously for the same program is lacking. Thus the workshop was arranged to investigate this problem in general, and the particular problem of using such machines for running atmospheric models. Presentations were given by staff from various scientific institutions interested in these problems, and from manufacturers of such machines. Discussions were then held to consider how these machines might be used in their multiprocessor mode for numerical weather prediction.

The proceedings of the workshop on satellite communications has already been published, and the other proceedings are in preparation.

Meteorological training course

The objective of the training course is to assist Member States in advanced training in the field of numerical weather forecasting. The course was divided into four modules, each lasting two weeks.

M1: Dynamical meteorology and numerical methods

M2: Numerical weather prediction - analysis, initialisation and adiabatic formulation

M3: Numerical weather prediction - diabatic processes and the representation of orography

M4: Use and interpretation of ECMWF products

The content of the course was similar to that of previous years, though the structure of the first three modules was revised so as to reduce the overlap between modules and thereby make each module more cohesive. This change may partly explain the increase in the number of participants who attended just one module.

In total 48 students attended one or more modules. Of those 38 were from 15 Member States and 9 were from non-Member States (Algeria, China, Hong Kong, Israel, Malta, Morocco, Philippines and the USA). All request for places from Member States were met, though 8 applicants from non-Member States could not be accepted due to lack of space and facilities. Most of the non-Member State participants were supported by WMO.

Computer training course

The Centre's courses are designed to help both Member States and Centre staff become proficient at using ECMWF's extensive computer facilities. They assume some knowledge of computer systems in general, and then orientate users to the Cray X-MP and Cyber facilities. Two one-week courses were held at the Centre from 6-17 February; there were 15 participants from 10 Member States, togethere with 13 Centre staff. Individual tuition was also given to visitors from Member States and to Centre staff as the need arose.

During the first half of the year various courses were given by Cray Research lecturers to Centre staff on detailed use of the Cray X-MP, in particular on multi-tasking.

Visits to meteorological services

The Centre continued the series of missions to the meteorological services the Member States. The object of these visits is to ensure a continuing exchange of information between the Centre and the primary users of its forecasts. Four visits had been undertaken in 1983, and this year joint delegations from the Operations and Research Department visited the remaining meteorological services. Seminars were given on the Centre's current and planned operational and research activities, and much time was allowed for discussions with the staff of the weather services concerning their experience of using the Centre's products. The presentations were received with great interest, and the exchange of views and information proved to be fruitful to all concerned.

THE COUNCIL AND ITS COMMITTEES

The sessions and meetings of the Council and its Committees held during 1984 were as follows:

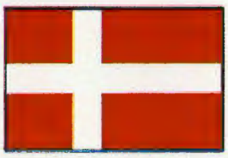
Council	19th and 20th sessions, 3-4 May and 21-23 November
Finance Committee	31st and 32nd sessions, 5-6 March and 25-27 September
Scientific Advisory Committee	12th session, 12-14 September
Technical Advisory Committee	7th session, 18-20 September

The representatives of the Member States and those who attended meetings in 1984 are listed hereafter (code: C = Council; FC = Finance Committee; TAC = Technical Advisory Committee; CR = Computer representative; obs = observer). Also listed are the Meteorological Contact Points (MC).

Belgium

J. van Isacker (C); M. Deloz (FC obs.); W. Struylaert (TAC and CR); E. de Dycker (MC)

Denmark



A. Wiin Nielsen (C); L. Asmussen (C and FC); Mrs. A.M. Jorgensen (TAC); P. Henning (CR); H. Voldberg (MC)

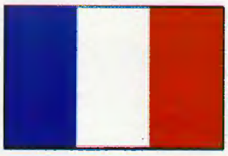
Federal Republic of Germany

E. Lingelbach (C); H.-G. Schulze (C); U. Gärtner (C and FC Vice-Chairman); P. Appel (C and FC); R. Lamp (TAC and CR); Dr. Rüge (MC)

Spain

C.M. Contreras Vinals (C); P. Rodriguez Franco (C); M. Gonzalez Blanch (FC); B. Orfila (TAC); M. Hortal (CR); R. Font Blasco (MC)

France

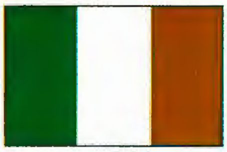


J. Labrousse (C); R. Watrin (C); M. Rochas (C); M.A. Martin Sané (C); J.G. de Wargny (C and FC); P. Cossevin (FC); R. Watrin (FC); M. Trochu (TAC); J.P. Bourdette (CR)

Greece

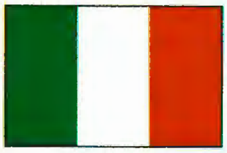
S. Linardos (C); G. Barbounakis (TAC); J. Iakovou (CR); A. Kakouros (MC)

Ireland



D.L. Linehan (C); W.H. Wann (C and TAC: Chairman); D. Murphy (CR); P.M.P. McHugh (MC)

Italy



A. Zancla (C); M. Mariani (C); T. Diomede (FC); A. Izzo (FC); G. Faraco (TAC); S. Pasquini (TAC and CR)

Yugoslavia

Mr. Delijanic (C); M. Jovasevic (TAC); M. Gavrilov (CR; S. Nickovic (MC)

The Netherlands

H. Tennekes (C), J. van Tiel (C); Th. Voerman (C); A.P.M. Baede (TAC: Vice-Chairman); J. van Dijk (CR); W.M. Reinten (MC);

Austria

K. Cehak (C and FC: Vice-Chairman); G. Wihl (TAC and CR); H. Gmoser (MC)

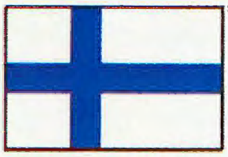
Portugal

L.A. Mendes Victor (C: President); R.A.C. Carvalho (C); V. Rabaca (FC); S. Cristina (TAC); M.J. Rodriguez de Almeida (CR); M.I.S.A. Barros Ferreira (MC)

Switzerland

Th. Gutermann (C), H.P. Müller (FC); M. Haug (TAC); G. Siegwart (CR); M. Schönbächler (MC)

Finland



E. Jatila (C); J. Paananen (C and FC); J. Riissanen (C); P. Nurminen (TAC); T. Hopeakoski (CR); P. Kukkonen (MC)

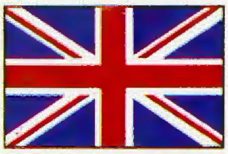
Sweden

L. Ag (C); C.G. Sundelius (C); S. Bodin (C); B. Hellroth (TAC); G. Bleckert (TAC); S. Orrhagen (CR); R. Joelsson (MC)

Turkey

M.C. Özgül (C, TAC, CR, MC); K. Öncüler (C);

United Kingdom



S. Cornford (C and FC obs); J.T. Houghton (C); G.J. Day (C and FC: Chairman); A. Gilchrist (C obs); M.W. Stubbs (FC); K. Burford (FC); D.H. Johnson (TAC); R. Wiley (TAC); P. White (TAC); A. Dickinson (CR); C. Flood (MC)

The members of the Scientific Advisory Committee, who are appointed in their personal capacity and not as national representatives, were:

F. Bushby - Chairman (U.K.); J.-C. André (France); E. Holopainen (Finland); B. Hoskins (U.K.); L. La Valle (Italy); B. Machenhauer (Denmark); J. Peixoto (Portugal); H. Pichler (Austria); H. Reiser (Federal Republic of Germany); R. Sadourny (France); C.J. Schuurmans (The Netherlands); H. Sundqvist (Sweden).

CONSULTANTS AND VISITING SCIENTISTS

The Centre received many visits in the course of the year, from consultants, experts and visiting scientists, whose expertise was drawn upon to augment the range and efficiency of the work done at the Centre. Some visitors devoted an hour or two at the Centre to giving lectures to staff, others stayed for several months to tackle particular problems. It is impossible to list all those who have contributed in such a way to the Centre's work; however, the most notable projects carried out, and those who worked on them, are the following:

Dr. J.R. Bates
Meteorological Service, Dublin, Ireland
Developed a semi-Lagrangian scheme for the Centre's grid-point model.

Mr. T. Benson
United Kingdom
Provided MVS systems programming support on the IBM computer system and also general support for the CFS (Common File System) project.

Dr. A.K. Betts
West Pawlett, Vermont, USA
Investigated a new approach for parameterising convection based on a thermodynamic adjustment method.

Dr. G.J. Cats
K.N.M.I., De Bilt, Netherlands
Contributed to the analysis of observing system experiments based on FGGE data.

Mr. M. Gleicher
United States of America
Provided support for the Cyber interfaces to the CFS (Common File System) project.

Dr. M. Kanamitsu
Japan Meteorological Agency, Tokyo, Japan
Assessed the forecast capability of the Centre's model in tropical regions and took an active part in the development of the high resolution forecasting system.

Mr. G. Kelly

ANMRC, Melbourne, Australia

Investigated the use of satellite soundings in the data assimilation and made plans for future use of satellite temperature and humidity profiles at higher resolution.

Dr. H. Köhler

Federal Republic of Germany

Organised the multi-tasking framework for the MARS control modules on the IBM.

Dr. U.C. Mohanty

Indian Institute of Technology, Delhi, India

Undertook studies of the sensitivity of the tropical forecasts to several variants of the convective parameterisation

Dr. F. Molteni

Geodata and ENEL, CRTN, Milan, Italy

Performed a pilot study on the use of lagged-average forecasting techniques for the monthly prediction of time-mean meteorological fields.

Mrs. G. Müller

Fachhochschule Würzburg-Schweinfurt, Federal Republic of Germany

Carried out various programming tasks connected with the Centre's database of computer performance data as a summer student.

Dr. J.W. Münch

University of Siegen, Siegen, Federal Republic of Germany

Reviewed the user manual for the MARS system (the planned meteorological archive system) and commented on it from an external user viewpoint.

Mr. A. Persson

SMHI, Norrköping, Sweden

Investigated the usefulness of spectrally filtered model output and provided guidance on the application of filtered fields for medium range weather forecasting.

Mr. T. Raggett

United Kingdom

Provided extensions to, and gave general support on, the LCN (Loosely Coupled Network) software running on the IBM system.

Dr. A Sutera

Centre for the Environment and Man, Hartford, USA

Studied the theory of atmospheric blocking and the problem of blocking, and sought evidence of bimodality in the observed amplitude of planetary waves in the northern hemisphere winter.

Dr. P. Swarztrauber

NCAR, Boulder, Colorado, USA

Initial investigations were carried out into possible ways that future multiprocessor computer systems could be used on meteorological models. A joint paper was then presented at the workshop held subsequently at the Centre.

Dr. Dr. Vasiljevic

F.H.I., Belgrade, Yugoslavia

Engaged in the development of the softare for the new analysis system.

Dr. A.C. Wiin-Nielsen

Meteorological Institute, Copenhagen, Denmark

Carried out research in dynamic meteorology with particular emphasis on the study of the predictability of large-scale atmospheric flow.

Dr. Wu Guo-xiong

Institute of Amospheric Physics, Peking, China

Continued his studies of the mechanical forcing due to mountains and its affects on the mean meridional circulation.

Miss E. Willbanks

LASL, Los Alamos, New Mexico, USA

Installed the latest version of CFS (Common File System) and then gave support for it on the IBM system.

ANNEX 1
ECMWF publications 1984

Technical reports

No.40	Daley, R.	SPECTRAL CHARACTERISTICS OF THE ECMWF OBJECTIVE ANALYSIS SYSTEM
No.41	Klinker, E. and M. Capaldo.	SYSTEMATIC ERRORS IN THE BAROCLINIC WAVES OF THE ECMWF MODEL
No.42	Wiin-Nielsen, A.C.	ON LONG STATIONARY AND TRANSIENT ATMOSPHERIC WAVES
No.43	Betts, A.K. and M.J. Miller,	A NEW CONVECTIVE ADJUSTMENT SCHEME
No.44	Mohanty, U.C., R.P. Pearce, and M. Tiedtke,	NUMERICAL EXPERIMENTS ON THE SIMULATION OF THE 1979 ASIAN SUMMER MONSOON
No.45	Guo-xiong Wu and Shou-jun Chen	THE EFFECT OF MECHANICAL FORCING ON THE FORMATION OF A MESOSCALE VORTEX

Seminar/workshop proceedings

NUMERICAL METHODS FOR WEATHER PREDICTION (Volumes I and II)
SEMINAR 5-9 SEPTEMBER 1983

CONVECTION IN LARGE-SCALE NUMERICAL MODELS
WORKSHOP 28 NOVEMBER - 1 DECEMBER 1983

Manuals

RESEARCH MANUAL 3 (Meteorological Bulletin M1.6/2)
ECMWF FORECAST MODEL - PHYSICAL PARAMETERISATION
Edited by J.-F. Louis.

The Centre also continued to publish regular issues of the ECMWF Newsletter, Computer Bulletins, Forecast Reports, Meteorological Bulletins, and the Operational Data Assimilation System - Daily Global Analysis.

ANNEX 2
External publications by members of staff 1984

Arpe, K.	ANALYSEN- UND VORHERSAGEBERWERTUNG Promet, 1/84, 30-40.
Bengtsson, L.	THE ECMWF GENERAL CIRCULATION MODEL AND ITS OPERATIONAL IMPLEMENTATION. Proceedings of a conference on National Planning of Research Strategy and its Variability, Feb.26-27, 1984, Indian Inst.of Technol., New Delhi.
Bengtsson, L.	OPERATIONAL MEDIUM RANGE WEATHER PREDICTION AT ECMWF. 10th Conference on Weather Forecasting and Analysis, June 25-29, 1984, Clearwater Beach, Fla., Amer.Meteor.Soc., 206-300.
Bengtsson, L.	DIE MITTELFRISTIGE WETTERVORHERSAGE Promet, 1/84, 2-7.
Bengtsson, L.	VORGESCHICHTE, ZIELSETZUNG UND AUFBAU DES EZMW. Promet, 1/84, 1-2.
Böttger, H.	ASPEKTE DER OPERATIONELLEN ARBEIT AM EZMW. Promet, 1/84, 23-29.
Capaldo, M., and L. Dell'Osso	NUMERICAL EXPERIMENTS FOR A CASE OF CYCLOGENESIS OF THE NORTH-ADRIATIC SEA. Short- and Medium Range Weather Prediction Research Publication Series No.13. WMO/TD No.19, 461-747.
Chen, S.J., and L. Dell'Osso	NUMERICAL PREDICTION OF THE HEAVY RAINFALL VORTEX OVER EASTERN ASIAN MONSOON REGION. J.Meteor.Soc.Japan, 58, 730-747.
Dell'Osso, L.	HIGH RESOLUTION EXPERIMENTS WITH THE ECMWF MODEL: A CASE STUDY. Mon.Wea.Rev., 112, 1853-1883.
Dell'Osso, L.	OROGRAPHY, OROGRAPHIC FORCING AND THEIR EFFECTS. Short- and Medium Range Weather Prediction Research Publication Series No.13, WMO/TD No.19, 453-460.
Dell'Osso, L. and D. Radinovic	A CASE STUDY OF CYCLONE DEVELOPMENT IN THE LEE OF THE ALPS ON 18 MARCH 1982. Beitr.Phys.Atmos., 57, 369-379.
Dümenil, L. and E. Ruprecht	A DIAGNOSTIC TEST OF THE CLOSURE ASSUMPTION IN ARAKAWA AND SCHUBERT'S CUMULUS PARAMETERIZATION SCHEME. Quart.J.Roy.Meteor.Soc., 110, 1180-1186.

Gray, P., D. Dixon and G.R. Hoffmann — LARGE DATABASES IN A METEOROLOGICAL ENVIRONMENT. Applications of Optical Digital Data Disk Storage Systems, Ed. by W.M. Deese and M. Carasso. Proceedings SPIE 490. 34-38.

Heckley, W.A. and A.E. Gill — SOME SIMPLE ANALYTICAL SOLUTIONS TO THE PROBLEM OF FORCED EQUATORIAL LONG WAVES. Quart.J.Roy.Meteor.Soc., 110, 203-217.

Hollingsworth, A. and S.K. Dash — STABILITY OF A STATIONARY ROSSBY WAVE EMBEDDED IN THE MONSOON ZONAL FLOW. Contrib.Atmos.Phys., 57, 546-547.

Ji, L.R., and S. Tibaldi — NUMERICAL EXPERIMENTS OF THE SEASONAL TRANSITION OF GENERAL CIRCULATION OVER ASIA. Part 1. Advances in Atmos.Sc., Academia Sinica, 1, 128-139.

Simmons, A.J. and L. Bengtsson — ATMOSPHERIC GENERAL CIRCULATION MODELS: THEIR DESIGN AND USE FOR CLIMATE STUDIES. The Global Climate, J.T. Houghton, Ed., Cambridge Univ.Press, 37-62.

Tiedtke, M. — DAS VORHERSAGEMODELL. Promet, 1/84, 16-23.

Tiedtke, M. — THE EFFECT OF PENETRATIVE CUMULUS CONVECTION ON THE LARGE-SCALE FLOW IN A GENERAL CIRCULATION MODEL. Beitr.Phys.Atmos., 51, 201-215.

Wergen, W. — DATENASSIMILATION. Promet, 1/84, 7-16.

Woods, J.A. — SPECIFICATION OF REQUIREMENTS FOR EXTRA OBSERVATIONAL DATA. Avignon Workshop on the Future European Programme in Space Meteorology, June 1984. ESA/STAG(84)3, Annnex 7, 1-11.