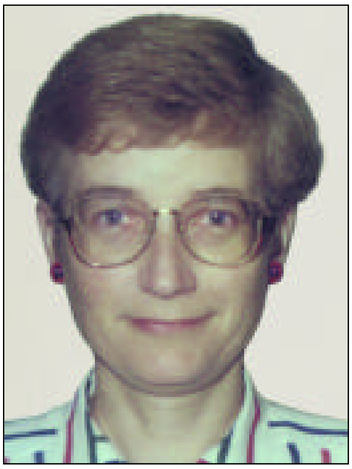

Sadly, Elizabeth Blades, our Head of Personnel, died at the age of 51 on 11 September – her long and courageous fight against cancer over.

Elizabeth joined the Centre at its beginning in the Spring of 1975 and over the years she did many jobs in the Centre's Administration Department and the Directorate. From the start everything that she undertook was done enthusiastically and professionally and she quickly gained the respect of her bosses. Her versatility, intelligence and good organization enabled her to make effective contributions to the work of the Co-ordinated Organizations committees on remuneration, pensions and general staff matters. Delegates from other organisations to these committees appreciated her wisdom and commonsense and she established a wide circle of friends throughout Europe.

When I joined the Centre in 1975 Elizabeth was already established as the expert on travel and purchasing and on my arrival she sent me a list of strict instructions to be followed to the letter - a tough lady brought in to keep irresponsible and disorganised scientists in line, at least that's what I thought. But I needn't have worried, "that Blades woman" turned out to be a curly-haired (then she was in her "bubbles" period) smiling plump 30-year old with a keen eye and ear for the humorous moment. One of her great loves was the theatre and she shared this with an inner-circle of friends, rapidly becoming one of my best sources of advice for Stratford-on-Avon plays and the London theatre. Despite gruelling operations and cancer treatments she kept this part of her life going almost to the very end.

Elizabeth's life was a rich one, both professional and private, and she has left behind many friends and acquaintances who were enriched by her company. I am sure that they will remember and admire her for her courage and, more importantly, cherish memories of the pleasure of her company.

David Burridge, Director

In this issue

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Cover

The use of SSM/I total column water vapour is one of several recent changes to the assimilation system (see page 2 for more details).

Editorial

ECMWF introduced its 4D-Var analysis system into operational use in November 1997. There have been several improvements added since then, in particular when the coupled atmospheric ocean wave model was introduced. The article on page 2 describes some of these improvements.

Recently several ECMWF Technical Memoranda have been published on various aspects of both the 4D-Var and 3D-Var analysis systems. Summaries of four of these are given on pages 8 to 9.

A year ago a first report was given on ECMWF's involvement with the new high-speed European Internet backbone (TEN-34), via a project known as DAWN. This project aims to evaluate the network from the point of view of meteorological applications, by developing some specific applications that could make use of the much higher speeds. An update on this project is now given (page 9), covering in particular the Internet based interface to ECMWF's data archive (MARS).

The main mathematical software library used at ECMWF is that from the Numerical Algorithms Group (NAG). News about the latest releases is given on page 13.

Changes to the Operational forecasting system

Recent changes

METEOSAT5/INDOEX SATOB products have been introduced in the data assimilation with effect from 12 August 1998.

A formulation of uncertainties associated to physical processes (stochastic physics) was introduced on 21 October 1998 in the ECMWF Ensemble Prediction System.

Planned changes

- A version of the reference model with extended vertical domain and possibly increased planetary boundary layer resolution should also be tested soon.

François Lalaurette

Recent improvements to the ECMWF 4D-Var data assimilation system

The 4D-Var assimilation system (Rabier et. al. 1998) was introduced operationally at ECMWF on 25 November 1997 (see ECMWF Newsletter 78, winter 1997/98). Since that date several improvements to the use of both conventional and satellite data have been made as part of the Cycle 18R6 package.

For conventional data the main changes are the use of hourly surface observations from frequently reporting stations (instead of six hourly), and the use of radiosonde temperatures at all reported levels in place of geopotential height, winds, and humidities on standard pressure levels. These variables are now used at significant as well as standard levels. Also the 10m-wind observation operator was unified for all observation types.

For satellite data SSM/I total column water vapour is now assimilated, more of the TOVS radiances over land and the new high-density cloud motion winds are used and the assimilation of the scatterometer winds has been revised. These changes are described briefly below and more details can be found in the relevant ECMWF memoranda. At the same time the wave model was coupled to the atmospheric model; the implementation and impacts of this were described in Newsletter 80, summer 1998.

The overall impact of these changes on the forecasts was clearly beneficial when compared with the operational system at the time, as can be seen in Figure 1 for 64 cases averaged over both hemispheres for the period 16 April to 18 June 1998 when the new package was run as an e-suite in parallel to operations. As a result of the positive impacts on the forecasts shown in Figure 1 these changes were introduced into ECMWF operations on 29 June 1998.

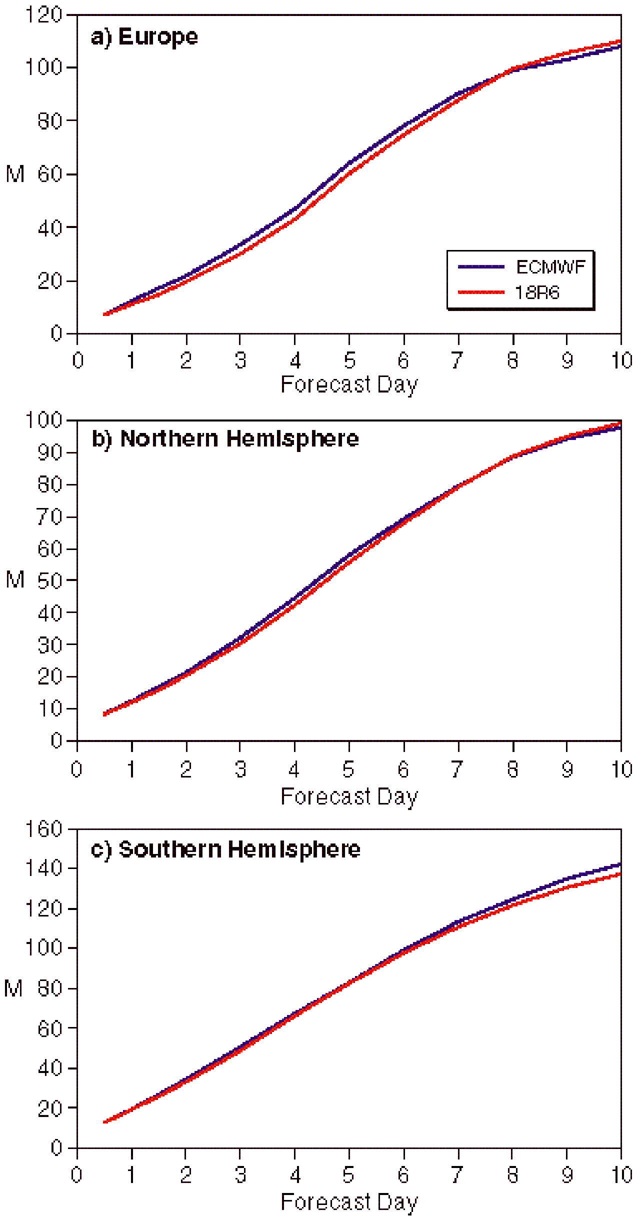

Figure 1: *500 hPa geopotential, root mean square of forecast error for Europe and the two hemispheres for the period 16 April to 18 June 1998. Both the 18R6 forecasts and the corresponding operational forecasts are shown.*

Use of hourly surface observations

There are many surface stations around the world (SYNOP and DRIBU) that report more than once every six hours. Most assimilation systems, however, use only one report from each station in each six-hour assimilation cycle. This has been the case in ECMWF's OI and 3D-Var systems as well as in its first operational 4D-Var system. The 4D-Var system has now been changed so that it makes use of this additional information.

In the observation screening for 3D-Var, observations are selected for assimilation in such a way that preference is given to the observations closest to the centre of the assimilation time window (3D-screening), i.e. closest to 00, 06, 12 and 18 UTC, for the 4 assimilation cycles. In 4D-Var, the model fields are made available hourly and the observations are accordingly organised into one-hour time slots. Observations are selected within each time slot independently. Preference is given to the observation closest to the centre of the time slot (4D-screening). The assimilation system has been prepared such that either 3D or 4D-screening can be performed in 4D-Var. The number of surface observations used increases with 4D-screening. Typically, the number of SYNOP surface pressure and wind observations increases by a factor of two, and for DRIBU observations by a factor of three. The number of TOVS radiances also increases with 4D-screening, as the satellite orbits overlap in the polar areas and the hourly thinning procedure retains more reports there.

With up to six observations from each station, 4D-Var with 4D-screening becomes vulnerable to isolated biased observations. This was found over the Antarctic region where the model first guess surface pressures can have

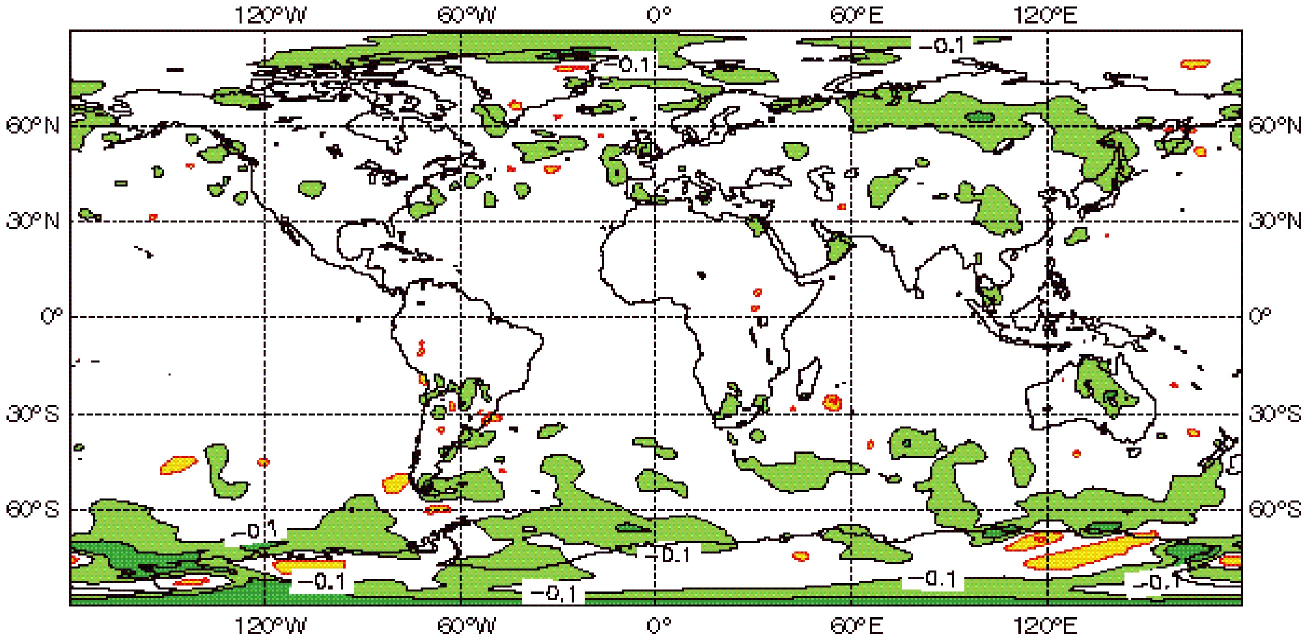

Figure 2: *1000 hPa geopotential height rms of difference in analysis increments between a 4D-Var experiment and its control. The experiment uses 4D-screening, serial correlation of observation error and joint variational quality control of time series of surface pressure and height data, and the control uses 3D-screening. The period is 11-24 Nov 1997. The contours are 0.35, 0.5, 0.75, 1.0, 1.5, 2.0 and 3.0 decametres. Green colour indicates areas where the rms of analysis increments is smaller in the experiment.*

large biases against some synoptic stations over the high orography and so cause deterioration of Southern Hemisphere forecast performance. We have addressed the bias problem by introducing serial correlation of observation error and by modifying the variational quality control of the time series of SYNOP and DRIBU surface pressure and height data. Serial correlation of observation error of a Gaussian form shifts the emphasis from the mean observed value to the tendency information in the time series. The variational quality control is modified to check all data from the time series for each station jointly, so that it rejects or accepts whole time series. These two developments successfully solved the initial difficulties with consistent biases between the first guess and observations, and also act as a conservative targeted bias correction scheme removing most of the detrimental effect of the biased time series. Experimentation has shown that the accuracy of the background 1000 hPa height fields has improved. Arelevant measure for the accuracy of the background field is the rms of the analysis increments. The more consistent the background is with the observations, the smaller is the rms of analysis increments (Figure 2). The improvement is largest over mid-latitudes and polar areas. The forecast impact is small, yet significantly positive at 1000hPa for most areas up to forecast ranges of 4 days.

Revision to use of radiosonde and pilot data

To date only a limited amount of the available data from sondes (TEMPs and PILOTs) have been used in the ECMWF data assimilation schemes. A maximum of 15 levels has been extracted from the sondes, choosing the data at, or nearest to, the standard pressure levels. This practice has remained unchanged during the transitions from OI to 3D-Var to 4D-Var.

Radiosonde reports contain both temperatures and geopotential heights. In 3D/4D-Var there is no preference for using heights rather than temperatures, and the extra cost of additional levels is negligible. Reported standard level geopotential heights are considered more representative than temperatures, because the standard level heights are obtained by integration of the complete measured profile of temperature (which is only available to the observer). The reported `significant level data' of temperature and wind are those data that depart significantly from the surrounding parts of the profile, i.e. the local extreme points. The significant level data are thus less representative than the standard level data are. On the other hand, they provide potentially important information on boundary layer structure, fronts, jet maxima and the tropopause, which will become more valuable as model resolution increases.

Data assimilation experiments with 4D-Var indicated a distinct benefit from using all reported wind, temperature and humidity data from TEMPs and PILOTs. The mean rms forecast scores for 500 hPa averaged over 35 days in two separate periods showed a clear improvement in the Northern Hemisphere. There are several advantages of using temperatures instead of heights:

- the observation operator for temperature is very simple, whereas height depends on surface pressure, and the vertical integration of temperature and specific humidity.

- Bias corrections may be simpler
- Every datum in a profile of height data depends on the surface pressure observation
- Variational quality control is cheaper for assumed uncorrelated data, such as temperature.
- It is much easier to detect (and reject) gross errors in the surface pressure and the temperature data separately, than in the heights, which is a combination of the two.

Use of more TOVS radiances over land

Traditionally only those TOVS channels, which are not sensitive to the surface, have been assimilated over land due to the difficulties of characterising the land surface emissivity at infrared and microwave frequencies. Over the ocean and sea-ice a much wider range of channels has been used as the sea and ice surface radiative temperatures are well estimated from the model fields. However the continued reductions in the radiosonde network prompted investigations into using more of the TOVS radiances over land to counteract the loss of upper air balloon data.

The use of TOVS radiances in 3/4D-Var since the introduction of Cycle 16R4 in August 1997 is given in Table 1 which lists in plain font the observation errors and surface types over which the TOVS radiances are used. The channel designations are listed for each of the TOVS instruments (HIRS, MSU and SSU). In summary the stratospheric sounding channels (HIRS 1-3, MSU-4 and SSU 1-3) were assimilated everywhere for clear and cloudy radiances and HIRS-12 is assimilated everywhere for clear radiances. These channels do not "see" the surface (with the possible exception of high mountains).

However there are further sub-sets of channels, which primarily sense the upper troposphere and are only slightly influenced by the surface. After some preliminary experimentation HIRS channels 4-6, 11, and MSU-3 were added to the list of channels assimilated over land and sea/ice. The observation errors assumed for the new channels used over land are given in italics in Table 1. The land/ice surface emissivity assumed in the forward model was unity for the HIRS channels and 0.9 for the microwave channels. However to ensure the surface only had a minor contribution to the radiance the data selection blacklist was modified to assimilate only HIRS channels 1-3 and SSU channels over topography higher than 1500m. In addition radiances from HIRS channel 8 (window channel) are now assimilated over sea and sea-ice in 4D-Var which only became possible with the new RTOVS radiance product available since autumn 1997. HIRS channel 8 radiances also allow a better detection of cloud contamination than was possible with HIRS channel 10, which was previously used. These changes resulted in an increase in the total number of radiances assimilated north of 20N by 10%.

Before operational implementation two 15 day assimilation experiments were run to test the revised use of TOVS radiances during May 1997 and December 1997. The impact of assimilating the TOVS radiances over land in terms of mean analysed 500hPa temperature differences

Channel Number	4D-Var usage	Sea	Sea-ice	Land
HIRS-1	All	1.40K	1.40K	1.40K
HIRS-2	All	0.35K	0.35K	0.35K
HIRS-3	All	0.30K	0.30K	0.30K
HIRS-4	Only clear	0.20K	0.20K	*0.20K*
HIRS-5	Only clear	0.30K	0.30K	*0.30K*
HIRS-6	Only clear	0.40K	0.80K	*0.80K*
HIRS-7	Only clear	0.60K	1.20K	—
HIRS-8	*Only clear*	*1.00K*	*2.00K*	—
HIRS-10	Only clear	0.80K	1.60K	—
HIRS-11	Only clear	1.10K	1.10K	*1.10K*
HIRS-12	Only clear	1.50K	1.50K	1.50K
HIRS-13	Only clear	0.50K	1.00K	—
HIRS-14	Only clear	0.35K	0.70K	—
HIRS-15	Only clear	0.30K	0.60K	—
MSU-1	QC check	—	—	—
MSU-2	All*	0.30K	1.00K	—
MSU-3	All*	0.22K	0.22K	*0.22K*
MSU-4	All	0.25K	0.25K	0.25K
SSU-1	All	0.60K	0.60K	0.60K
SSU-2	All	1.00K	1.00K	1.00K
SSU-3	All	1.80K	1.80K	1.80K

** Only clear radiances used for latitudes < 30°*

***Table 1:** TOVS radiance observation errors assigned in 1D-Var. The errors used in 4D-Var are currently 1.5 times these values. Figures in italics show where changes were made for CY18R6.*

(experiment-control) for the Northern Hemisphere is shown in Figure 3. The only significant differences are over Russia where the analyses with the use of TOVS data are on average 1 deg K colder in the mid-troposphere. Some differences in specific humidity were also seen with the main difference being an increase in total column water vapour in the Tropics of 2.5% for the May period but less for the December period. The forecast impacts for Europe were positive or neutral at all forecast ranges for both periods compared to operational forecasts. Over the N. Hemisphere the impacts were positive at all forecast ranges for the May period and neutral for the December period. For the S. Hemisphere and Tropics the forecast impacts were neutral.

Assimilation of SSM/I total column water vapour

Since 24 February 1998 SSM/I (Special Sensor Microwave/Imager) 1D-Var (one dimensional variational method, Phalippou, 1996) retrievals have been produced as part of the operational suite, namely total column

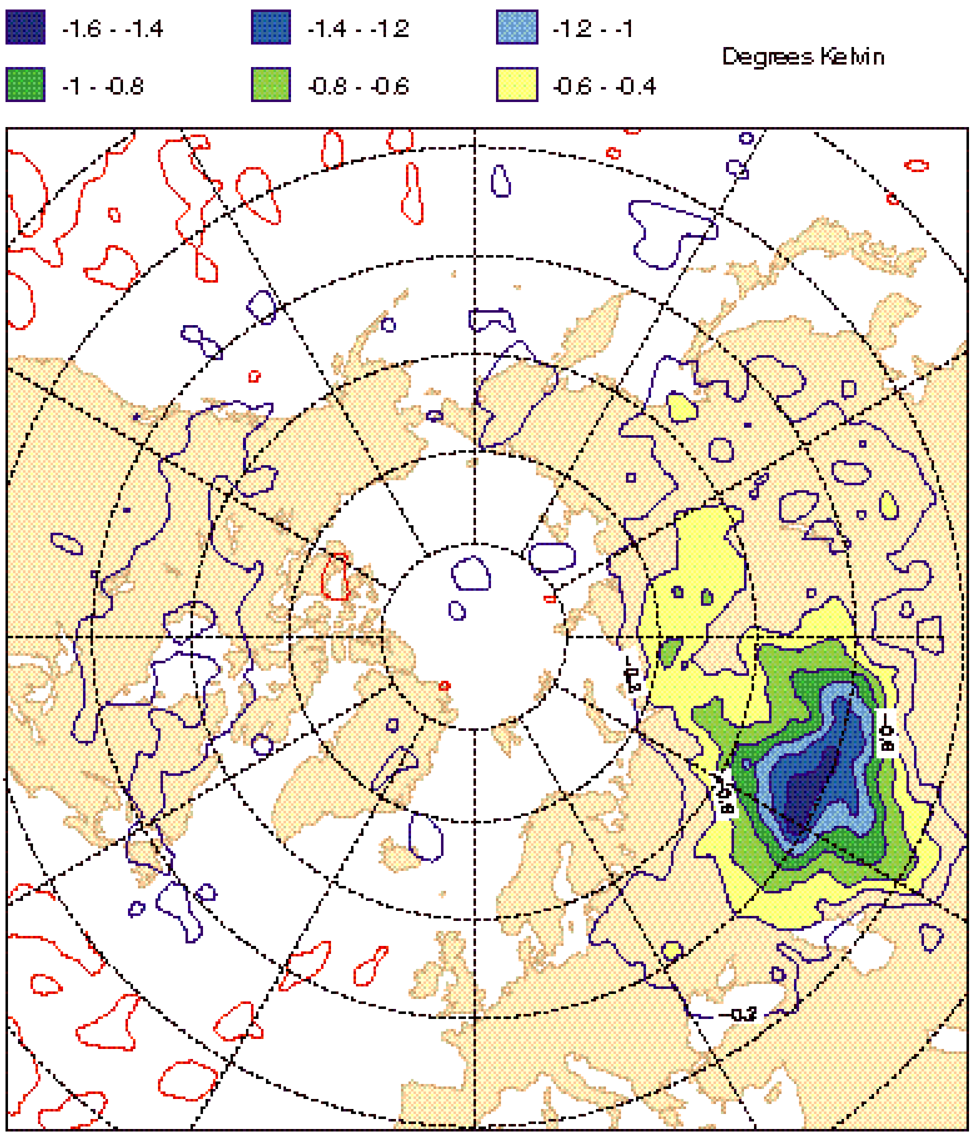

Figure 3: *The difference in temperature at 500hPa between 15 analyses in May 1997 with and without the extra TOVS channels used over land. The contours are in intervals of 0.2 K and the colours start at differences greater than 0.4 K according to the legend. Red contours are positive differences and blue negative differences.*

water vapour (TCWV), cloud liquid water path and surface wind speed. Comparisons of the first guess and SSM/I 1D-Var derived TCWV over the oceans has shown that the model tends to be too dry in the Tropics and Southern Hemisphere as previously shown by (Vesperini, 1998). The assimilation of TCWV derived from the SSM/I 1D-Var was tested within both the 3D-Var and 4D-Var assimilation systems and was included as part of the CY18R6 changes. Initially only radiance data from the DMSP-F13 satellite are being used. About 1300 to 1500 retrievals are assimilated at each cycle with a spatial sampling of about 250 km in latitude and longitude. It is intended to increase the coverage by also using radiances from the F-14 satellite in the near future.

In order to assess the impact of assimilating the SSM/I TCWV on the analyses and forecasts, two 15-day experiments were run in the 4D-Var assimilation system, as for the use of TOVS over land. The primary impact of assimilating SSM/I TCWV in 4D-Var is on the model humidity fields where more water vapour is included in the lower tropospheric humidity, particularly in the areas which are too dry, i.e. in the Tropics (2 to 3% increase) and Southern Hemisphere (5 to 6% increase) as shown in Figure 4.

The experiments with SSM/I TCWV gave neutral to positive impacts on the Northern Hemisphere geopotential forecasts during the two periods; the impact in the Southern Hemisphere seems to be dependent on the season, slightly positive in winter, neutral in summer. The forecasts of geopotential height are generally improved in the lower troposphere. In the Tropics the vector wind scores are neutral to slightly positive when compared with observations.

Changes to use of cloud motion winds

Meteorological observations from geostationary satellites are primarily wind observations provided by the tracking of clouds or water vapour features in subsequent satellite images. One recent change on 3 March 1998 was a revised method by NESDIS to derive GOES satellite winds (Velden et al., 1998). The changes included a smaller processing segment used for the selection of suitable tracers, their assignment to a vertical level, and the actual tracking scheme. This has led to a marked increase

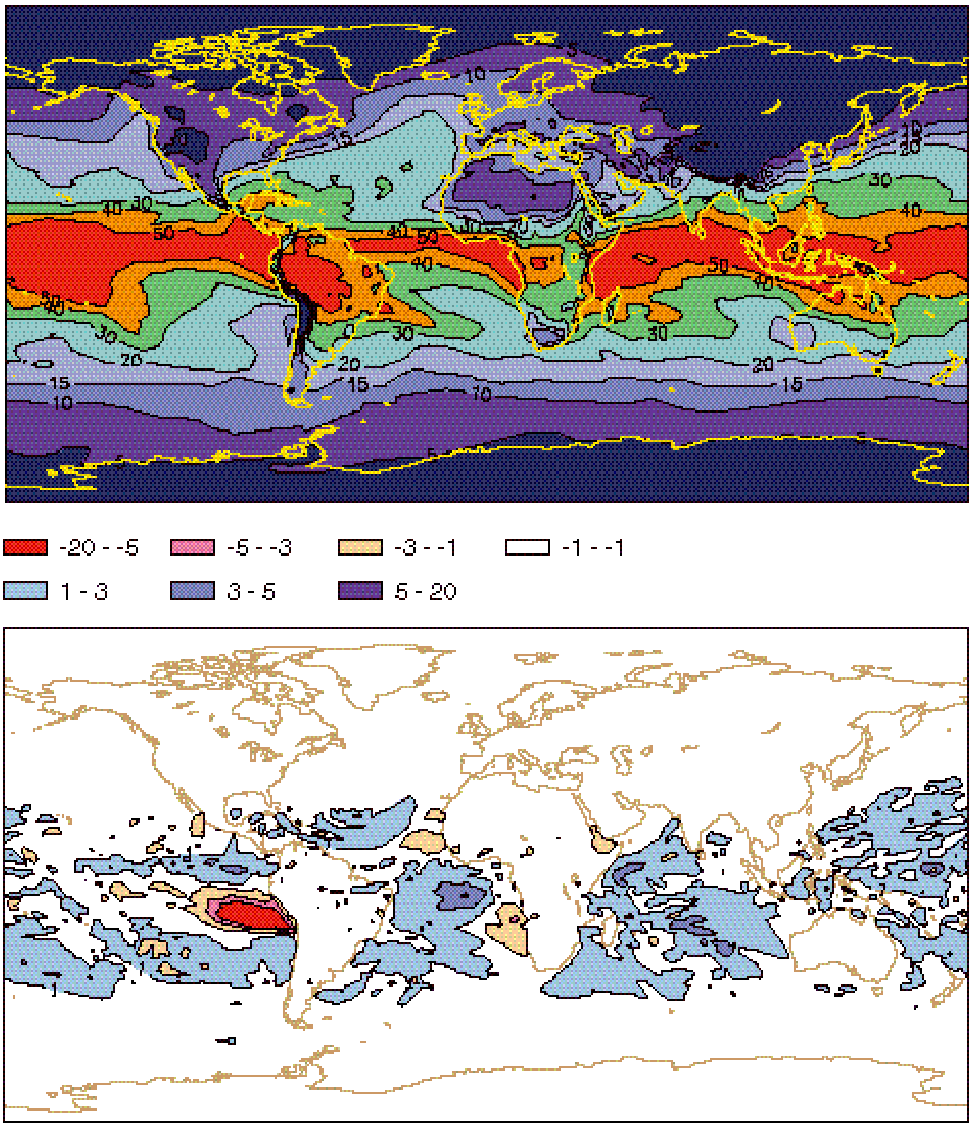

Figure 4: *Mean fields computed over the 28 November - 15 December 1997 period:*

(top) TCWV from the experiment analysis (24.70 kg.m^{-2} global mean).

(bottom) TCWV difference between the experiment and the control analyses (0.42 kg.m^{-2} global mean).

Units are in kg.m^{-2}.

of the observation density by a factor three to ten depending on the tropospheric level. The smaller processing segment not only enhances information in areas with previously good coverage but also enables the extraction of winds which were not accessible at the coarser resolution providing entirely new information (e.g. cyclonic systems in the South Pacific). These wind observations can have a direct impact on the geopotential analysis at 300 hPa as demonstrated in Figure 5.

However, the assimilation of the high-density GOES winds initially led to a slight degradation of the forecast in the Northern Hemisphere. One possible explanation for this is the mismatch between the resolution of the observations and the current T63 spectral truncation of the variational analyses. Therefore an additional thinning step was implemented which ensures a minimum horizontal and vertical distance between satellite winds. The impact of both the full data set and the thinned dataset during the observation screening was assessed by assimilation and forecast experiments. They showed the thinning eliminated any negative forecast impact in the N. Hemisphere and therefore the enhanced data set is used everywhere.

Use of Scatterometer Winds

An inconsistency in the IFS has been that the assimilation of low level winds from different observation types (e.g. buoys, SYNOPs and scatterometer) has employed different observation operators. For the scatterometer winds, instead of using a simple logarithmic wind-law (neutral stratification), we now use an operator based on the Monin-Obukhov surface layer which takes stratification into account (Cardinali et al.; 1994). There is then just one single observation operator for 10m winds for all observation types. The scatterometer bias corrections have been recalculated to reflect this.

Another change is that the roughness length, z_0, used for the calculation of 10m scatterometer winds now uses the model z_0 rather than the observed winds used previously. This change together with the coupling of the wave model to the atmospheric model has resulted in a reduction in the standard deviation between scatterometer and model first-guess wind speed from 1.80 ms^{-1} to 1.67 ms^{-1}.

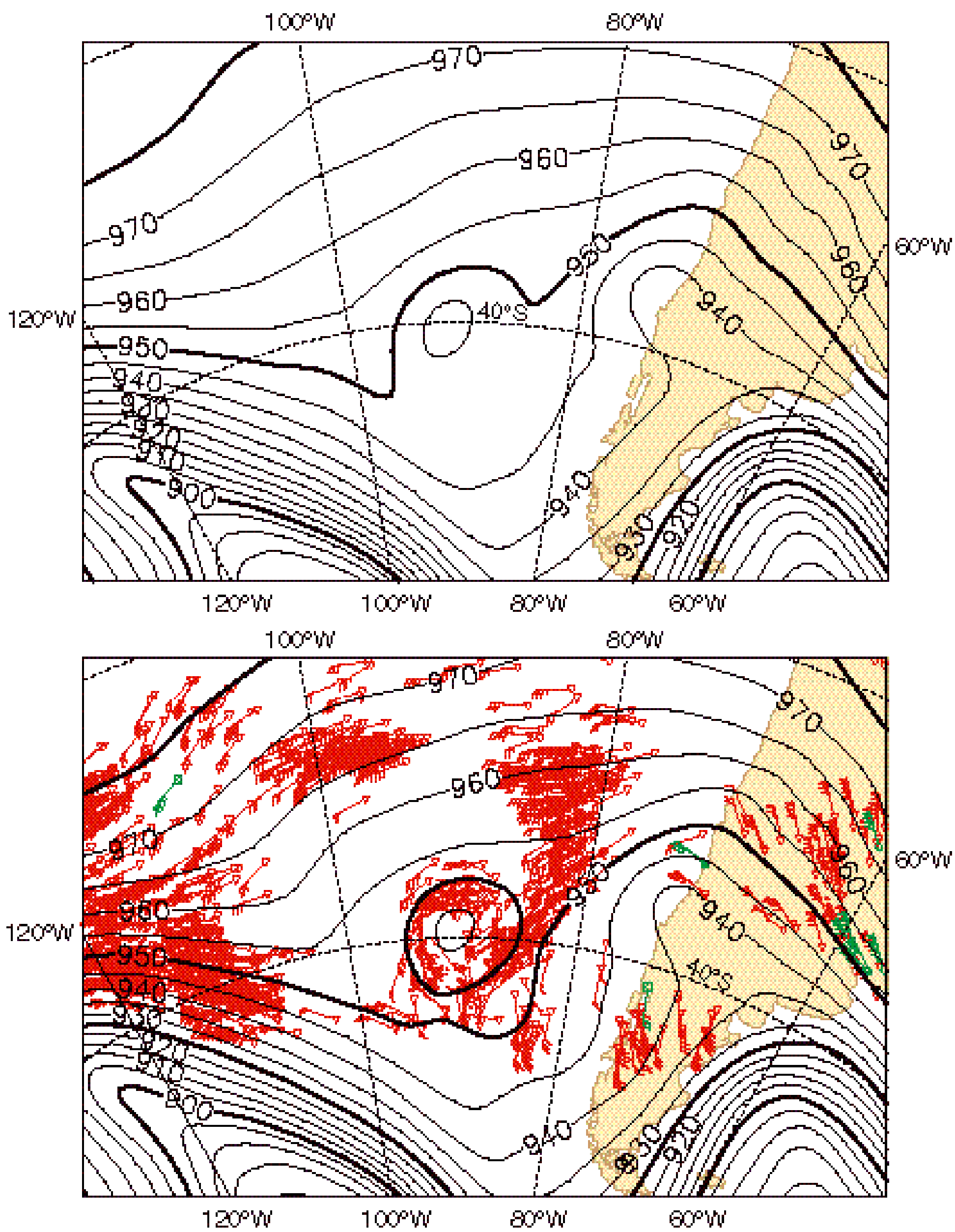

Figure 5: *Impact of high-density GOES wind observations on the 300 hPa geopotential analysis for 00UTC on 10 February 1998. The top panel was the operational analysis and the lower panel the revised analysis using the high density GOES winds. Also plotted are the GOES observations between 250 and 350 hPa and a few sparse TEMP, SHIP, PILOT observations, plotted in green.*

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Summary of ECMWF Technical Memorandum 240

Recent experiments on 4D-Var and first results from a simplified Kalman Filter

F. Rabier, J-F. Mahfouf, M Fisher, H. Järvinen, A. Simmons, E. Andersson, F. Bouttier, P. Courtier, M. Hamrud, J. Haseler, A. Hollingsworth, L. Isaksen, E. Klinker, S. Saarinen, C. Temperton, J-N. Thépaut, P. Undén, and D. Vasiljević

Four-dimensional variational assimilation (4D-Var) has been extensively tested at high resolution on the FUJITSU, and compared with three-dimensional variational assimilation (3D-Var). To validate the migration a 2-week period studied on the CRAY was repeated at higher resolution on the FUJITSU, with a similar improvement brought by 4D-Var. Then, a more thorough investigation of the poor performance of 4D-Var in the Tropics revealed some problems in the way the adiabatic non-linear normal mode initialisation of the increments was performed. Going from four outer loops to only one (as in 3D-Var) helped to reduce the problem, together with a change to the new background formulation and an initialisation of only the small scales. Tropical scores then became only marginally worse for 4D-Var than for 3D-Var.

Twelve weeks of experimentation with the one outer-loop 4D-Var and the new background formulation have been studied. In the medium range, the improvement is more pronounced in the Southern Hemisphere. In the short-range, each two to three-week period has been found to be positive. The better short-range performance of the 4D-Var system was also shown by the fits of the background fields to the data. The comparison of forecasts to data in the Northern Hemisphere up to day 10 confirms the better scores for 4D-Var. In individual synoptic cases corresponding to interesting IOPs during the FASTEX period, 4D-Var is seen to perform better than 3D-Var during rapid cyclogenesis.

A first comprehensive set of linear physics has been developed for 4D-Var applications. First, it has been evaluated by comparing the evolution of analysis increments with respect to non-linear integrations including the full physics. Abetter agreement of the evolved increments is found when the physics is included. The inclusion of this package in a 4D-Var '2-update' configuration has a positive impact on the performance of the analysis in the tropics, with a reduction of the spin-down of precipitation in the subsequent forecasts, and improved wind scores. The averaged extratropical scores averaged over 8 weeks show a slight improvement brought by the physics.

Some structure functions were illustrated in the 4D-Var case for a height observation inserted at the beginning of the assimilation window, in the middle or at the end. The dynamical processes seem to be relevant, even on a short 6-hour assimilation period. More influence of the dynamics could be taken into account by properly cycling 4D-Var using a simplified Kalman filter (SKF), which is currently being developed, and whose feasibility has been demonstrated.

Summary of ECMWF Technical Memoranda 241-243

The ECMWF implementation of three-dimensional variational assimilation (3D-Var)

Part I: Formulation

P. Courtier, E. Andersson, W. Heckley, J. Pailleux, D. Vasiljević, M. Hamrud, A. Hollingsworth, F. Rabier and M Fisher

In the first part of this three-part paper, the formulation of the ECMWF implementation of 3D-Var is described. In the second part, the specification of the structure function is presented, and the last part is devoted to the results of the extensive numerical experimentation programme which was conducted.

The 3D-Var formulation relies on a spherical harmonics expansion in a similar way as the ECMWF OI relied on a Bessel functions expansion. This formulation is introduced using convolution algebra over the sphere expressed directly in spectral space. It is shown that all features of the OI statistical model can be implemented within 3D-Var. Furthermore a non-separable statistical model is described. In the present formulation, geostrophy is accounted for through a Hough modes separation of the gravity and Rossby components of the analysis increments. As in OI the tropical analysis remains essentially non-divergent and with a weak mass-wind coupling. The observations used, as well as their specified statistics of errors are presented together with some implementation details.

In the light of the results, 3D-Var was operationally implemented at the end of January 1996.

Part II: Structure functions

F. Rabier, A. McNally, E. Andersson, P. Courtier, P. Undén,
J. Eyre, A. Hollingsworth and F. Bouttier

The 3D-Var structure functions are evaluated from the statistics of the differences between two forecasts valid at the same time. Results compare satisfactorily with the existing literature. Non-separability of the correlation functions is a pervasive feature. Accounting for non-separability in 3D-Var is necessary to reproduce geostrophic characteristics of the statistics such as the increase of length-scale with height for the horizontal correlation of the mass variable; sharper vertical correlations for wind than for mass and shorter horizontal length-scale for temperature than for mass. In our non-separable 3D-Var the vertical correlations vary with total wave number and the horizontal correlation functions vary with vertical level.

Part III: Experimental results

E. Andersson, J. Haseler, P. Undén, P. Courtier, G. Kelly, D. Vasiljević, Č. Branković,
C. Cardinali, C. Gaffard, A. Hollingsworth, C. Jakob, P. Janssen, E. Klinker, A. Lanzinger,
M. Miller, F. Rabier, A. Simmons, B. Strauss, J-N. Thépaut and P. Viterbo

In this third and final part of the paper we assess the performance of the three-dimensional variational data assimilation scheme, in the light of the results from the extensive pre-operational programme of numerical experimentation. Its performance is compared with that of the previous operational scheme at ECMWF, which was based on Optimal Interpolation. The main features of the new scheme are illustrated, in particular the effects of non-separable structure functions and the improved data usage. TOVS cloud-cleared radiances are for example used directly without a separate retrieval step. Scatterometer data are assimilated in the form of ambiguous winds with the ambiguity removal taking place within the analysis itself. Problems encountered during the tests are discussed and the solutions implemented are explained.

The over-all impact on forecast accuracy in the troposphere of the Northern Hemisphere extra-tropics is neutral for geopotential and positive for wind and temperature. The impact is neutral in the tropics, and significantly positive in the Southern Hemisphere. The stratospheric analyses and forecasts have improved in all regions. Other positive results include a clear improvement in near-surface wind analyses over oceans, in particular in the vicinity of tropical storms. This is predominantly due to the assimilation of scatterometer wind data.

These papers have been published in Q. J. R. Meteorol. Soc. (1998), 124; (1783-1807), (1809-1829), (1831-1860).

Ten-34 and DAWN - an update

As described in ECMWF Newsletter no. 77 (Autumn 1997) the Dawn project has been monitoring the performance of the TEN-34 network to demonstrate its capability in meeting the requirements of a number of advanced applications used in weather forecasting.

The following advanced meteorological applications were selected to demonstrate the remote preparation of computational experiments and the real-time visualisation of model result fields across the TEN-34 network:

- Coupled Atmosphere/Ocean Models
- Distributed Model Suite
- Modeller's Workbench Type (WWW based)

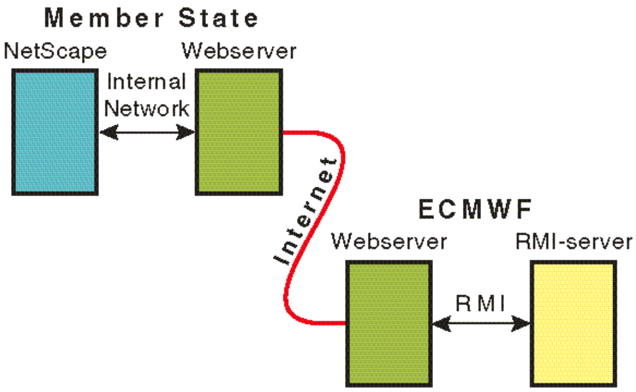
ECMWF worked on the Modeller's Workbench application, while Météo France and DWD performed the tests for the Coupled Atmosphere/Ocean Models and Distributed Model Suite respectively.

In addition, network latency and throughput tests have been done over an extended period to check if the TEN-34 network can indeed support these applications.

Modeller's Workbench (WWW based)

This application demonstrated the potential use of ECMWF's Meteorological Archive and Retrieval System (MARS) over the TEN-34 network, using a typical Web interface based on WWW mechanisms extended by Java classes.

Two separate network requirements result from this application. The first involving user authentication is highly interactive, requiring low latency. The second, the transfer of the results of the retrieval to the user's environment using methods comparable to FTP, requires sufficient bandwidth to transfer 10-50 Mbytes of data within a reasonable time.



For this application ECMWF has developed software that allows secure access via the Internet. This software consists of:

– A user-interface to the ECMWF-MARS service
– Communication software

The basic mechanism is as follows:

There are two servers, one at the Member State side and one at ECMWF. The user-interface is installed on the Member State's server, while the actual services are run at ECMWF by means of an RMI-server. RMI is the Remote Method Invocation mechanism of Java.

When the MARS request has been performed, the results are sent back to the Member State via the Internet.

To accomplish all of this, communication software has been developed to allow the two to communicate in a secure way.

MARS-Interface

MARS is ECMWF's Meteorological Archiving and Retrieval System. It is a large archive containing meteorological data from the past 20 years. Member State users frequently need data that is stored in this archive and until now such data has been retrieved via the Member State leased lines.

For the Internet based MARS interface, the following software has been developed:

– A user interface consisting of Java-applets, which is installed on the Member State's server.
– An RMI server installed at ECMWF. This carries out the actual MARS request.

After the user has specified the data he wants to extract from MARS via the user interface, the request is submitted to ECMWF and the data is extracted from the archives. The time to execute such MARS requests can range from some minutes to several hours, depending on the data the user has requested.

After extracting the data from the archive, it is sent to the Member State via the Internet using another ECMWF software package, ECCOPY. ECCOPY is the standard tool used by Member States to copy data from ECMWF to themselves. Originally it used the leased lines to transfer the data but it has recently been amended to be able to use the Internet as a transport medium.

Finally, the RMI server sends an e-mail to the user to indicate his MARS-request has finished. This e-mail also contains the log report of his MARS request.

Performance requirements:

The table on page 11 shows the summary of the requirements on the network.

Network test results

Most of the observations were started in May 1997. Also, additional special tests were done to check the requirements defined above.

In order to discuss the trends some representative weeks have been selected, namely:

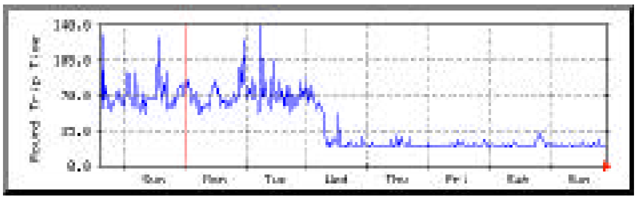
1997: Weeks 31 (DWD only), 34 (Météo France only), and 48; 1998: Week 9

Latency tests to DWD-Germany

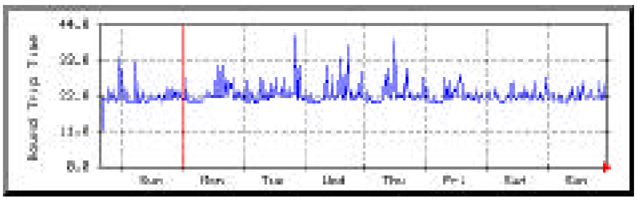
The first graph shows the Round-Trip-Time (RTT) from ECMWF to Germany in the week that Germany was connected to TEN-34 (Week 31 1997). This to show that it brought an improvement.

As can be seen, the latency on this connection is quite constant.

Week 31, Mon 4 August - Sun 10 August 1997:

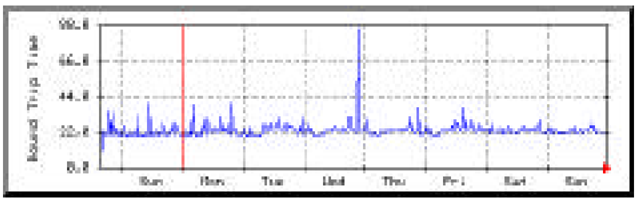


Week 48, Monday 1 December - Sunday 7 December 1997:



Max RTT: 41 ms, average RTT: 22 ms

Week 9, Monday 2 March - Sunday 8 March 1998:



Max RTT: 87 ms, average RTT: 23 ms

Table 1: Performance requirements: The summary of the requirements on the network.

	Size Mbytes	Key usage period	Max RTT (ms)	Through-put (kbits/s)	Max. transfer time (s)
Telnet		I	600		
Ftp	0.5	II		64	64.0
Ftp	50	II		1000	409.6
X-Clients		I	50		
Client server applications data transfer volume < 500 kb/min	0.1	I		1000	0.8
Client server applications data transfer volume > 500 kb/min	1	I		2000	4.1
WWW applications (standard)	0.5	I		1000	4.1
	1	I		1000	8.2

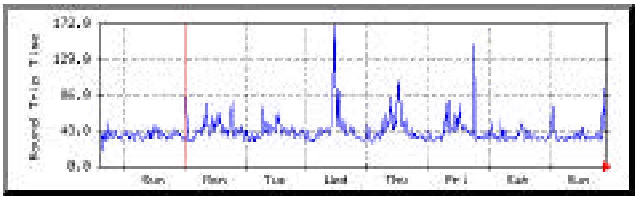
Meteorological Applications	Size Mbytes	Key usage period	Max RTT (ms)	Through-put (kbits/s)	Max. transfer time (s)
Coupled atmosphere/ocean model *Data transfer every 30 s during one simulation of 1.5 hours duration*	0.5	II	50	4096	1.0
Distributed model suite *Data transfer in large blocks (approx. 500 Mbytes each)*	4300	III		4778	7200
Modellers workbench WWW based (MARS access)		I			
Interaction part	0.3	I		4096	0.6
Data transfer part up to . . .	50	I+II		4096	100.0

Key Period usage (UTC)	
07:00 – 18:00 Weekdays	I
24 hours / all day	II
04:00 to 08:00 and 18:00 to 20:00	III

Latency tests to Météo France

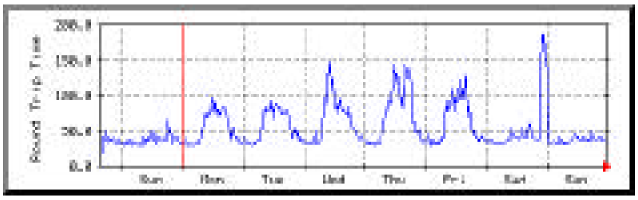
These are the results of the latency tests to Météo France.

Week 34, Mon 25 August - Sun 31 August 1997



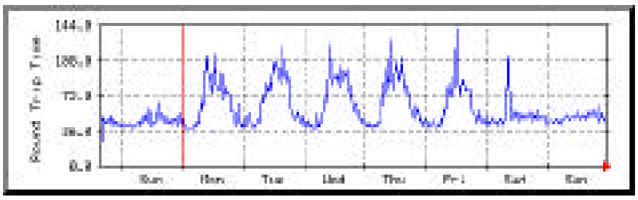
Max. RTT: 171 ms, average RTT: 42 ms

Week 9, Monday 2 March - Sunday 8 March 1998



Max. RTT: 186 ms, average RTT: 54 ms

Week 48, Monday 1 December - Sunday 7 December 1997



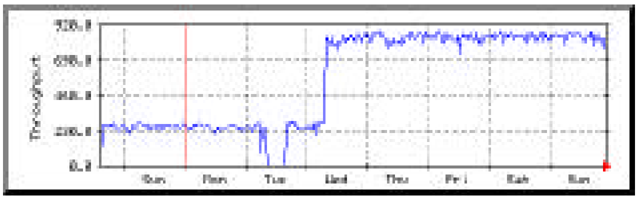
Max. RTT: 142 ms, average RTT: 59 ms

The connection to Météo France is heavily loaded and a clear daily variation is visible. During working hours the latency is double the average value.

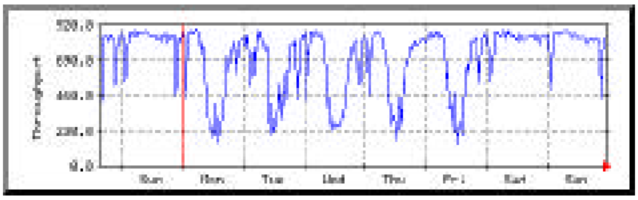
Throughput Measurements to DWD-Germany

The following pictures show the throughput measurements for a buffer size of 8 k.

Week 31, Mon 4 August - Sun 10 August 1997

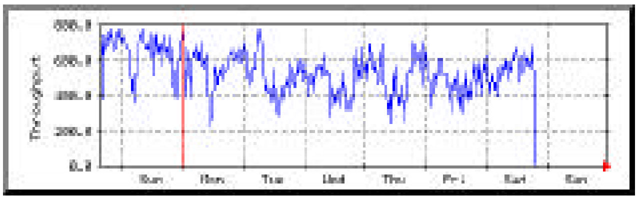


Week 48, Monday 1 December - Sunday 7 December 1997



Max. throughput: 893 kbits/s, average throughput 713 kbits/s

Week 9, Monday 2 March - Sunday 8 March 1998:



Max throughput: 783 kbits/s, average throughput: 541 kbits/s

The first graph shows the throughput to DWD during the week DWD was connected to TEN-34 (Week 31), increasing the line speed from 2 Mbps to 34 Mbps. Note that ECMWF is connected to the Internet at 8 Mbps.

The connection is never so heavily used that there is bad congestion. Even during working hours, there is always at least 200 kbps available.

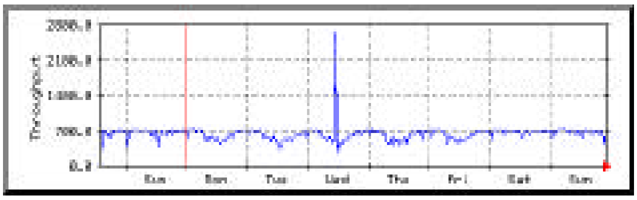
The fact that the throughput sometimes goes to zero doesn't mean that the line is unavailable. Sometimes there were computer problems with one of the test computers.

Throughput Measurements to Météo France

The connection to France is more heavily loaded; it is only a 2Mbps link.

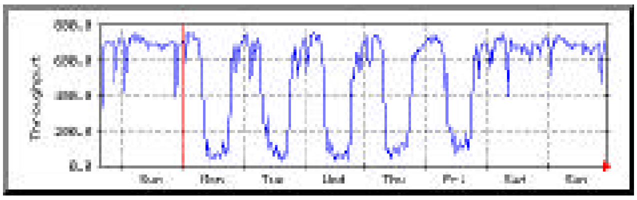
These graphs show that the connection between ECMWF and Météo France is now close to saturation during working hours. The Internet link to Météo France thus seems to be too slow to fulfil the demands of the meteorological application. Nevertheless a test suite using the coupled model has been started.

Week 34, Mon 25 August - Sun 31 August 1997



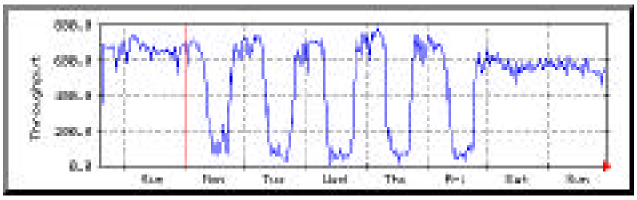
Max. throughput 2681 kbits/s, average throughput 651 kbits/s

Week 48, Monday 1 December - Sunday 7 December 1997



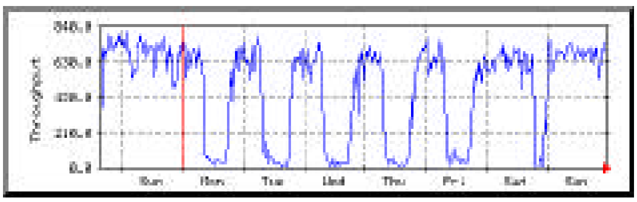
Max. throughput 756 kbits/s, average throughput 525 kbits/s

Week 1, Monday 5 - Sunday 11 January 1998



Max. throughput: 784 kbits/s, average throughput: 499 kbits/s

Week 9, Monday 2 March - Sunday 8 March 1998



Max. throughput: 810 kbits/s, average throughput: 482 kbits/s

The reason for the lack of throughput seems to be primarily due to the poor connection between Météo France and the TEN-34 network.

Discussion

As shown in the graphs, daily variance is visible in both connections, adversely influencing the transfers between Météo-France and ECMWF much more than to DWD.

DWD's conditions for transferring data to and from ECMWF are much better. The required parameters are nearly all reached. Therefore we expect a good performance for the Distributed Model application over this connection.

Météo France will experience long delay times, especially while transferring large amounts of data. Their interactive applications will not run very smoothly because of the poor latency.

Outlook

The results from the network tests will be used to tune the applications and system parameters to improve performance.

In the future a centralised entry point via Internet to ECMWF will be via HTTP://www.ecmwf.int/ecmwf/index.html. To support a high security level this access point is protected by a SecurID login procedure. A global login via this point, removing the present need for multiple requests for SecurID codes, is being investigated.

Heinz Richter

NAG News

In ECMWF Newsletter 66 details were given of the changes to the NAG library at Mark 16. This present article gives details of the changes made in the most recent versions - Marks 17 and 18. Mark 17 is the current default version, Mark 18 will shortly replace it as the default version.

Full details of both these versions are contained in the ECMWF Help and Information section of the ECMWF Web pages via the path: -

Local documentation —> Libraries —> NAG

The 'News' pages contain the full lists of routines that have been added, modified, or deleted, giving, where relevant, recommended replacement routines. Also listed are those routines that are being superseded and will therefore be removed at a future Mark.

As Mark 18 is the version which is guaranteed to be millennium (year 2000) compliant we intend to make it the default fairly soon. Therefore you are urged to try Mark 18 as soon as possible. Details of how to use the library at Mark 18 on the various platforms is given below:

- **SGI**

```
f77 -r8 -lnag_n32_m3 prog.f
```

The library name stands for Complib SGI Maths, compiled with -n32 and -mips3 flags.

- **Fujitsu**

```
libselect -v new -r 64 naglib
frt -Ad prog.f -Wl,"$NAGLIB"
```

Features introduced at Mark 17

A variety of new facilities and improvements in areas of existing coverage were introduced at Mark 17. It has a total of 1152 documented routines, of which 43 were new at that Mark. Some specific changes were:

- One new chapter was introduced – F11 – Sparse Linear Algebra, containing ten routines covering the solution of real sparse symmetric linear systems using iterative techniques. The chapter includes conjugate gradient and Lanczos algorithms, incomplete Cholseky, SSOR and Jacobi preconditioning, plus support routines. At Mark 18 the chapter has been extended to treat non-symmetric systems (see below).
- Anew 3-D complex discrete Fourier transform routine was included in the C06 chapter.
- Coverage in the differential equations chapters was extended with:
  - new collocation methods for the boundary value problem in ordinary differential equations (Chapter D02)
  - an upwind scheme using a numerical flux function based on a Riemann solver for first order partial differential equations in conservative form in one spatial dimension (with re-meshing facilities and coupled differential algebraic systems) (Chapter D03)
- An enhanced routine for computing the minimum of a sum of squares was included in the E04 chapter.
- There were eight new Black Box routines, which exploit existing F08 routines, for computing:
  - selected eigenvalues and eigenvectors of real non-symmetric, real symmetric, complex non-symmetric and complex Hermitian linear systems (Chapter F02)
  - real and complex equality-constrained linear least-squares, and real and complex Gauss-Markov linear models (including weighted least-squares) (Chapter F04)
- Thirteen of the new routines were in the Statistics chapters. They included facilities for:
  - partial correlations (Chapter G02)
  - scaling (Chapter G03)
  - analysis of variance (Chapter G04)
  - multiway table analysis (Chapter G11)
  - Cox's proportional hazard (Chapter G12)
  - Kalman filter (Chapter G13)

Routines Revised at Mark 17

Optimisation

- Improvements to the diagnostic facilities of E04JAF and E04KAF were made.

Linear Algebra

- A minor correction has been made to F06ZPF (CHERK/ZHERK) and F06ZRF (CHERK2/ZHERK2).
- Algorithmic improvements were made to F08MEF (SBDSQR/DBDSQR) and F08MSF (CBDSQR/ZBDSQR)

to improve the efficiency of the computation of singular values and to increase the relative accuracy obtained for small singular values.

Statistics

- The options available in G02BXF and G03AAF were extended.
- Algorithmic improvements to G02DAF were made to improve the efficiency of the computation of leverages.
- In G04BBF the computation of treatment means for non-orthogonal designs were adjusted to correspond to least-squares means.
- In G08AKF a correction were made to the way that the required probability is calculated from the computed lower tail probability.

New Features of Mark 18

At Mark 18 a variety of new facilities have been introduced, plus improvements made in some existing areas. Mark 18 contains a total of 1108 documented routines. There are 35 new routines at this Mark, extending the areas of ordinary differential equations (ODEs), partial differential equations (PDEs), interpolation, optimisation, sparse linear algebra, and operations research (OR). Some specific changes are:

- Coverage in the differential equations chapters (D02 and D03) has been extended by the following additions:
  - a simple driver interface for the integration of a system of first order ODEs using a fixed order Runge–Kutta method until a user-specified function is zero (Chapter D02)
  - new approximate and exact Riemann solvers for 1-D Euler equations (Chapter D03)
  - the solutions of time dependent second order PDEs in 2-D using adaptive mesh refinement (Chapter D03)
- New routines for generating and evaluating interpolants to 2-D and 3-D scattered data sets (using a modified Shepard interpolant) are included in the interpolation chapter (Chapter E01).
- The most significant additions to the optimisation chapter (Chapter E04) are as follows:
  - new routines to solve sparse LP and QP problems (including MPSX data-handling capabilities)
  - new routines for unconstrained minimisation with an extended parameter list to replace existing routines with reserved names
  - a new reverse communication routine for constrained minimisation using a sequential quadratic programming method
- Coverage in the sparse linear algebra chapter (Chapter F11) has been extended to provide iterative methods and preconditioners for real non-symmetric linear systems of equations.
- A new routine for finding the shortest path through a network is included in the operations research chapter (Chapter H).

Documentation

Aconcise summary of the purpose of all current routines in the Library is given in the document 'Summary of the Contents, Mark 18'. This document is in the ECMWF Help and Information section of the ECMWF Web pages mentioned earlier.

The complete manual can be viewed via an X-mode terminal window using the SGI Insight viewer. For readers unfamiliar with Insight it is a method of viewing on-line documentation which is in a special format. Typically SGI manuals are viewed with this utility. However the same file format is used for NAG's on-line manual, a Textware facility called DynaText, and hence it too can be viewed with Insight.

To use Insight you must first ensure that you have allowed your terminal to display a window from the host where you are running Insight. This host will be ecgate1 for Member State users.

Then to read the NAG manuals type: -

```
nagbooks
```

Insight starts up, with access to two books - the (NAG) Fortran77 Library Mark 18, and a Readers Guide. Just highlight the book you want and click on Open (bottom right hand side). You can easily find any routine or Chapter, or skip to a specific routine using the Search facility. Click on the Readers Guide if you want to learn how to use NAG's DynaText.

It is also possible to print out an individual section to a printer. However be aware that the pagination is not very good.

If you do not have access to an X-mode terminal you can still use the old NAG on-line help system by typing:–

```
naghelp
```

John Greenaway

ECMWF Calendar 1998

Nov 3 - 4	Policy Advisory Committee	Nov 16 - 20	8th Workshop on *The use of Parallel Processors in Meteorology – Towards Teracomputing*
Nov 2 - 4	Workshop - *Diagnosis of Data Assimilation Systems*	Dec 1	Advisory Committee of Co-operating States *10th*
Nov 9 - 13	Workshop - *WGNE/GCSS/GMPP – Cloud processes in large-scale models*	Dec 2-3	Council *49th*

ECMWF Publications

Technical Memoranda

No.254 **Gregory**, **D**., **J-J**. **Morcrette**, **C**. **Jakob** and **A**. **Beljaars**: Introduction of revised radiation, convection, cloud and vertical diffusion schemes in to Cy18r3 of the ECMWF integrated forecasting system. – July 1998

No. 256 **Viterbo**, **P**., and **A.K**. **Betts**: The forecast impact of changes to the albedo of the boreal forests in the presence of snow. – August 1998

No.257 **Douville**, **H**., **Viterbo**, **P**., **Mahfouf**, **J-F**, and **A.C.M**. **Beljaars**: Sequential soil moisture analysis in the presence of integral and prescribed errors using the ECMWF single column model. – September 1998

No.259 **Ehrendorfer**, **M**. and **F**. **Bouttier**: An explicit low-resolution extended Kalman filter: Implementation and preliminary experimentation. – September 1998

Workshop Proceedings

Sixth Workshop on Meteorological Operational Systems 12-17 November 1997