# THE USE OF GRAPHICS IN THE RESEARCH DEPARTMENT AND THE FGGE WORK AT THE CENTRE

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## 1. Introduction

The research department of ECMWF is responsible for development of the Centres data assimilation scheme and forecast model. This includes both basic research in areas of relevance to medium range weather forecasts and more applied evaluations of the present as well as future versions of the system.

In addition the Centre has been one of the two level III-b centres in the Global Weather Experiment (FGGE), with the task of analysing the data into Global Analyses for the year 1979. During the processing of the FGGE data, computer graphics were used extensively for monitoring of the data-assimilation. Several types of output were produced on a regular basis, and other types could be requested when needed. Many of the graphical tools used during the FGGE processing are used generally in the research and development work, and I will in this presentation give a series of examples of the types of graphical output that have been found to be valuable.

## 2. Data Assimilation for FGGE

The Global Weather Experiment "FGGE", has been called "the biggest international scientific experiment ever undertaken". More than 120 countries participated actively, and the main research objectives of the experiment as formulated by the Joint Organizing Committee (JOC) for GARP (the Global Atmospheric Research Programme) are as follows:

- To obtain a better understanding of atmospheric motion for the development of more realistic models for weather prediction
- To assess the ultimate limit of predictability of weather systems
- To design an optimum composite meteorological observing system for routine numerical weather prediction of the larger-scale features of the general circulation

- To investigate, within the limitation of a one-year period of observation, the physical mechanisms underlying the fluctuations of climate in the time range of a few weeks to a few years and to develop and test appropriate climatic models.

ECMWF was selected as one of the two level III-b producers, i.e. producers of global analyses for the full FGGE year, Dec 1978 - Nov 1979. For every 12th hour during the full year and every 6th hour during two "Special Observing Periods" each of two months duration global analyses on 15 vertical levels and a horizontal resolution of $1.875^{o}$ both in latitude and longitude have been produced.

The processing of the FGGE data is a tremendous task. The total number of observations for the whole FGGE year (II-b data set) amounts to around $15.10^{6}$ or 40000/day where one complete radiosonde observation or one synop is counted as one observation. Stored on magnetic tapes, including all control information, this corresponds to around $4.10^{9}$ bytes. After having transformed this data set into a set of analysed and dynamically derived fields (III-b data set) the total amount of information is approximately the same or $4.10^{9}$ bytes. This information is stored on about 100 magnetic tapes with a packing density of 1600 bpi.

The data arrived at the Centre on magnetic tapes from the so called Space Based and Special Observing Systems Data Centre in Norrköping Sweden, and the final analyses have been archived in the two World Data Centres for Meteorology in Asheville, N.C., U.S.A., and Obninsk, Kalngn District, U.S.S.R.

(FGGE is briefly described on a few slides).

For the level III-b production we have used basically the operational ECMWF data assimilation system, but since many new and untested observing systems were used the requirements for quality control were even higher than in the day to day operations. For this reason, the FGGE production was run in a "batch" mode, which made the monitoring much more flexible than in the Centre's operational watch under the "Supervisor".

In the following we will show some examples of the graphical output used for the monitoring. In addition to graphical output, numerical output in the form of lineprinter listings was also used. For one cycle (i.e. 6 hours) about 8 metres of Versatec plots were produced.

### Data coverage

Plots of data coverage on global maps with distinction between the different types of observing systems were produced for each 6 hour period of data from a data rich time.

### Plotted observations

Plotting of observed values on top of analysed maps is essential for the monitoring. Since the ECMWF facilities for observation plotting are very rudimentary, much work had to be put into a temporary solution for the FGGE monitoring. The examples show a surface map, a 200 mb tropical wind analysis and a map of satellite thickness (layer mean temperature).

### Data acceptance - rejection

During the data assimilation the observations are subject to quality controls in several steps. Records are kept of the outcome of those tests. The example shows the rejected observations during a typical analysis.

### Analysis maps

Hemispheric maps and tropical maps showing the final analysis were produced for each analysis time.

### Cross-sections

Show the vertical structure of the analysis, and at least one serious error was first spotted during close examination of such cross sections.

R.M.S. - fit

The fit of the analysis to the data is an obvious factor to monitor. In the FGGE production simple graphs of the r.m.s. - fit and bias of

(first guess - observed)
(uninitialized analysis - observed)
(initialized analysis - observed)

were continuously plotted for the different observing systems.

## 3. Research work

The FGGE analyses constitute an unprecedented data base for diagnostics of the general circulation of the atmosphere. Work has only just begun to study the material which will be used for research during many years to come. The research work can be divided into some categories. Synoptic studies aim at a better understanding of individual meteorological phenomena, and of how our analyses and forecast models treat these phenomenons. In "climatological" studies we investigate different types of means and variances. Finally in forecast experiments we study the effect of models and data on the predictability.

### 3.1. Synoptic studies

Streamline charts

Streamlines, i.e. lines that in each point are parallel to the velocity vector, are used extensively by tropical meteorologists. The three slides show streamlines and superimposed isotachs. The shading is added manually, and is essential to visualize the systems.

Special cross sections

This slide shows a cylindrical cross-section, i.e. the fields have been averaged cylindrically around a centre point (left of graph). In some cases the deviation from a mean is shown.

### Cloud simulation

In the ECMWF forecast model, clouds are not carried as a specific forecast parameter, but for radiation calculations, "clouds" are determined from the humidity and vertical velocity fields. These clouds are plotted on the raster plotter with white for 8 octas and black for 0 octas. The two slides show such a "cloud" image, and a verifying image from Meteosat.

## 3.2 "Climatological" studies

Studies of average fields over shorter and longer periods give insight into mean features of the general circulation of the atmosphere.

### Mean maps

Maps of mean fields, and maps of the difference to previously known climatologies have already shown very interesting results. The slide shows that the previously known climatology for July severely underestimated the intensity of the Southern Hemisphere Circulation.

### Streamlines and isotachs

Streamlines and isotachs of global mean fields are used in many general circulation publications. Again the shading is done manually. Compare with the map without shading.

### Velocity potential maps

These maps show dramatically what happens when the Asian summer monsoon starts.

### Cross-sections of different quantities

A very common way of displaying general circulation features. Shading is again manual.

### Box-diagrams

This slide was coded from scratch.

## 3.3 Forecast experiments

Most research is in the form of forecast experiments, where forecasts are run and verified against observations, analyses and other forecasts. Forecast experiments are run to

- test new formulations in the forecast model itself
- compare different forecast models
- evaluate new formulations of the analysis system, the final proof of an analysis system is the forecast it produces
- study the impact of different observing systems (Observing System Experiments)

In addition to the "synoptic" and "climatological" diagnostics already mentioned, some specific graphical output is used for forecast evaluation.

### Maps of Forecasts and Analysis

Maps of Forecasts and Analysis and of differences between them.

### Anomaly Correlation and RMS error

Comparison of forecasts and analyses, and between different forecasts. A standard package has been available for a considerable time, and is used extensively in the research department.

### Verification against observations

Since the analyses are biased towards the forecast model used, the previous verification may sometimes give biased scores. To avoid this, the fit of observations to the forecasts are plotted. The figures show an example of such plots.

## 4. Conclusions and recommendations

Computer graphics proven to be an invaluable tool for the research and development work at ECMWF. It has, so far, almost entirely been in the form of "batch" preparation of raster plots on electrostatic plotter. Interactive work on terminals (Tektronix) has not gained the popularity among the research staff that was, perhaps, anticipated. One reason for this may be the programming effort involved in preparing new products. Also, the

necessity to reload model output from archive tapes to on-line discs is a complication. Finally, the time spent waiting for the Tektronix to finish the plot is experienced to be too long for many people.

For "batch" jobs, the same criticism does not apply, since the scientist generally submits a batch job to produce the output he wants, and then spends his time doing something else. The ECMWF plotting packages provide the basic tools necessary to plot many types of graphs. A considerable amount of programming is still, however, necessary to get the final product needed. When a particular plot has been produced once, the JCL and FORTRAN is normally kept as a procedure for easy rerun of the same plots on other cases. There is however no central documentation and maintenance of these procedures, which has caused a considerable amount of double work among research scientists.

In order to avoid double work when plotting maps of analyses and forecasts, with or without observations, a high level plotting package, using the ECMWF Graphics Package, has been developed in the FGGE section. The purpose of the package is to provide the interface to the formats of the archived analyses, observations and forecasts, select map projection, map scale, area, parameters, contour-intervals, types of isolines, and windflags, labels, etc. The package is very flexible, and the facilities are maybe best described by showing an example of a batch-job using the package. All selections of options are done through the FORTRAN "NAMELIST" facility, where the namelist can either be prepared individually for a new map, or kept as a file for re-runs of standard map selections.

In our experience the main requirements for a graphics package suitable for research work are:

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|---|---|
| High level | Plots of analyses, observations and forecast, maps of arbitrary areas for arbitrary parameters should be possible without any coding. |
| Flexibility | New types of graphs should be easy to implement. |
| Fast return | In house plotting is essential |

The present ECMWF plotting package, with the extensions described by O'Sullivan, Pümpel and here provides the necessary facilities.

Certain additions and improvements are however needed to make full use of the technical facilities already available at ECMWF. The main deficiencies are listed below.

· Plotting of observations This is absolutely essential for both research and operational monitoring. The present obs - plotting package is rudimentary and should be updated as soon as possible.

· Shading Shading is a very good means of enhancing the information in a plot. Shading facilities are easily implemented on planned systems such as the AYDIN, but a simple shading routine in the present electrostatic plotters is also needed.