# CHARTS : AN INTERACTIVE GRAPHICS SYSTEM FOR THE DISPLAY OF METEOROLOGICAL FIELDS USED AT THE IRISH METEOROLOGICAL SERVICE

J.E.M. Hamilton
Meteorological Service, Glasnevin Hill, Dublin, Ireland.

## 1. INTRODUCTION

CHARTS is a command-driven interactive system for the display of meteorological fields which is used operationally at the Irish Meteorological Service (IMS). It was introduced in 1982 and since then has undergone a process of gradual development. Important features of the system are the user-friendly command language and the ability to display derived fields such as thickness charts (Hamilton 1984, 1987).

## 2. COMPUTER SYSTEM AND DATA HANDLING

The present IMS computer system consists of two DEC PDP-11/40's, used for communications, and a DEC-2050 mainframe used for numerical weather prediction (NWP) and graphics. The link to ECMWF is via the PDP-11's. CHARTS runs on the DEC-2050 and the link between the mainframe and the communications computers is via magnetic tape transfer. The PDP-11's are currently being replaced by VAX-780's.

We receive approximately 1300 products from ECMWF every day. The data decoding takes place on the DEC-2050 and each field parameter for a given forecast length and for a given area is put into a separate file. Parameters are not sorted by level and so a file can contain values of a parameter at a number of levels. The file names obey a naming convention which indicates the area, the date, the forecast length and the parameter.

Numerical forecast products are also received from the UKMO in GRID-code form and are decoded and stored in files on the DEC-2050. The file format and the file naming conventions are similar to those used for ECMWF files.

The Service runs its own numerical weather prediction model twice a day and the fields from this model are also stored. Finally the IMS runs an ocean-wave model.

## 3. DERIVED FIELDS

Programs have been developed by Sheridan (1986) to calculate some derived fields from the ECMWF data and to store them in files with the same format and with the same naming convention as the raw ECMWF fields. At present the following parameters are calculated :

(a):Freezing level

(b):Stability index

(c):Height of cumulonimbus tops

The freezing level is calculated by performing linear interpolation on a table of geopotential heights and standard level upper-air temperatures. The stability calculation is based on work described by Showalter (1953), Galway (1956), Carlson et al (1980), and Colby (1984). The top of the convective cloud is found by lifting a parcel of air from the surface level until its temperature equals that of the environment.

Other derived fields include a snow indicator (i.e. the probability of snow given that precipitation is falling), based on work by Boyden (1964), and the wet bulb potential temperature (which is used as an aid in locating fronts). These quantities are not stored as files but are calculated within the CHARTS program, as required.

## 4. NEED FOR AN INTERACTIVE SYSTEM

The grid point data produced by the various numerical models must be translated into graphical form before the forecaster can use it. In practice, this usually means that the data is contoured (Hamilton 1981), although wind fields are generally displayed as WMO wind-arrow symbols. The plots can be displayed by computer using a graphical device such as a pen plotter, an electrostatic plotter, a graphics terminal or even a lineprinter. Obviously, it is not possible to plot all the fields and so a selection must be made of the most useful products. Unfortunately, the optimum selection of products will vary with the weather situation and the nature of the forecast and so a fixed product list will always be a compromise. Hence, the ideal is to allow the duty forecaster to access the data base of model output directly so that he/she can display whatever products seem most appropriate in given circumstances.

CHARTS is an interactive graphics system which allows the forecaster to make such a selection. Output can be displayed on a colour graphics VDU or on a dot-matrix printer. A particularly useful aspect of the design is that the forecaster can display not only the primary products stored in the date base (such as forecasts of pressure) but he/she can also generate and plot secondary quantities (such as forecasts of pressure changes) obtained by combining two or more fields in the data base. This later option increases the number of available products enormously.

## 5. BASIC DESIGN GOALS AND DECISIONS

The design goals have been to produce a system which is easy to learn, simple in operation but nevertheless powerful enough to allow an experienced forecaster to access the data base with as few commands as possible. The system has been designed simply as an interrogation interface between the user and the data base of numerically forecast fields. The user can display forecast fields but he/she cannot modify the data base.

In designing the system we started by considering the parameters which must be specified to completely identify a primary (i.e. non-derived) meteorological field and we identified the following parameters : (a) field variable (e.g. pressure, temperature etc.), (b) verifying time for the forecast, (c) geographical area, (d) level in the atmosphere and (e) the identity of the forecast model.

Next we considered the ways in which a meteorologist might want to interact with the data base and we identified the following possible tasks :

(a):The user might wish to examine charts of a particular field variable (such as pressure or temperature). Typically the forecaster would want to look at a sequence of charts of the variable perhaps at different verifying times (e.g. the one day forecast, the two day forecast etc.) or at different levels. Alternatively he/she might wish to look at the same forecast over a number of different geographical areas. However, in many cases the meteorologist would want to produce a sequence of charts which differed in only one parameter.

(b):In other cases the user might want to interact with the data base to produce secondary products such as tendency charts (i.e. charts showing the change in a field variable over time) or thickness charts (i.e. charts obtained by differencing fields of geopotential in the vertical). In both these cases the requirement was to subtract one field from another point by point. Alternatively the user might want to add fields (point by point) - perhaps to calculate a running mean.

In the light of these considerations we reached the following design decisions :

(a):The system uses a command processor rather than a menu system. One particular advantage of this approach is that it makes it easy to request secondary quantities (i.e. quantities obtained by adding or subtracting fields). Thus, for example, if the forecaster is interested in a plot of the pressure change over a two day period from the start of the forecast, the most natural way to express this time interval is as : 'FORECAST=2DAY-ANAL' (i.e. plot the difference between the pressure, as forecast two days hence and its analysed value at the present time). It is quite cumbersome to request the computation of such a difference using a menu system.

(b):An important feature of the system is that all parameters have default values which remain in effect until changed. This means the user need not concern himself/herself with setting little used parameters. Also, once a parameter has been set by the user, it is not necessary to reset it until required. Thus if the user requests a plot of (say) temperature then this will automatically set the default for the field variable to temperature. Then future plot requests, which do not specify a field variable, will assume that the forecaster still wants to see a temperature map.

(c):Many of the parameters have numerical values (e.g. the length of a forecast is a number of days or hours, the level in the atmosphere is measured in millibars etc.). It is cumbersome to input such values using a menu system but simple with a command processor. Most of the numerical values have an associated unit (such as days, hours etc.) and, provided the forecaster indicates the unit, this makes it easy for the command processor to recognise the parameter being referred to. Thus, for example, '3DAY' is obviously a forecast length and not a level in the atmosphere.

(d):The system has a HELP facility which can guide the user in choosing parameters.

(e):The user need only type the minimum number of letters to allow an unambiguous recognition of the command string.

## 6. COMMAND FORMAT

The basic command format used by the system is as follows (where 'COMMAND>' is a prompt from CHARTS) :

```
COMMAND>VERB PARAMETER1=VALUE1,PARAMETER2=VALUE2,PARAMETER3=VALUE3,...
```

where the VERB is a command to the system to perform some action (such as 'PLOT', 'HARDCOPY' etc.) and where the various PARAMETERs are optional. Examples of PARAMETERs are the area of the chart ('AREA'), the field variable for plotting ('FIELD'), the forecast length ('FORECAST') and the colour of the plot ('COLOUR'). Examples of VALUE's are pressure ('FIELD=PRESSURE'), blue ('COLOUR=BLUE') and 36HOURS ('FORECAST=36HOURS'). Thus, if the user wishes to set the colour of the plot to red he/she types 'COLOUR=RED', while if he/she omits the colour parameter the program uses the current value.

## 7. ABBREVIATED COMMANDS

Much of the power of the system lies in its ability to deal with abbreviated commands. The command recognition algorithm is discussed in detail by Hamilton (1984). In this section we present a summary of the workings of the command interpreter.

The following table shows the basic command structure. This table is a much-abbreviated version of the command definition table used in the full version of CHARTS :

| VERB | PARAMETER | VALUE |
|---|---|---|
| PLOT | AREA | IRELAND |
| | | ATLANTIC |
| | LEVEL | SURFACE |
| | | *MB |
| | FIELD | PRESSURE |
| | | GEOPOTENTIAL |
| | | TEMPERATURE |
| | | WINDARROWS |
| | | ISOTACHS |
| | FORECAST | *DAYS |
| | | *HOURS |
| | | ANALYSIS |
| | MODEL | IMS |
| | | ECMWF |
| | COLOUR | BLUE |
| | | RED |
| | | GREEN |
| | | MAGENTA |
| | | CYAN |
| | | YELLOW |
| | | WHITE |
| HARDCOPY | SIZE | FULL |
| | | HALF |
| | | QUARTER |
| EXIT | | |
| HELP | | |

The '*' indicates a numerical value (i.e. *DAYS could be 10DAYS or 2DAYS etc.). Note how the VERB's, PARAMETER's and VALUE's are arranged in a tree structure with the VERB's at level-1, the PARAMETER's at level-2 and the VALUE's at level-3.

The CHARTS command interpreter starts by trying to identify the command verb. As shown, the possibilities are PLOT, HARDCOPY, EXIT and HELP. (However, the full implementation of CHARTS contains additional commands such as OVERPLOT, CANCELHARDCOPY, STATUS, OBEY and RESET).

Generally, it is only necessary to type sufficient initial letters of the VERB, PARAMETER or VALUE to enable the program to make an unambiguous identification. Thus, it is only necessary to type the first letter of the VERB's PLOT and EXIT since they both start with different letters. However, it is necessary to type at least the first two letters of the VERB's HELP and HARDCOPY to distinguish between them.

The command PARAMETER's and VALUE's can be abbreviated in a number of ways. For concreteness let us suppose the user wants to specify the IMS model. The unabbreviated command is :

```
COMMAND>PLOT MODEL=IMS
```

The user can abbreviate this command to 'PLOT M=I'. The program recognises the 'M' to the left of the equals sign as 'MODEL' and then matches the 'I' (to the right of the equals sign) against the possible VALUE's for this PARAMETER viz. IMS, ECMWF and UKMO. A more interesting abbreviation is for the user to type 'PLOT IMS'. Since there is no equals sign specified the program checks the VALUE (viz. IMS) against all the level 3 possibilities and it finds an unambiguous match with IMS. However, if the user typed 'PLOT I' the match would be ambiguous and the program would respond with an error message indicating that MODEL=IMS, AREA=IRELAND and FIELD=ISOTACHS are all possibilities.

The use of units with numbers removes ambiguity and eliminates the need to type an equals sign. Thus 'PLOT 500' is ambiguous since it could mean PLOT FORECAST=500HOURS, PLOT FORECAST=500DAYS or PLOT LEVEL=500MB. However PLOT 500MB could only mean PLOT LEVEL=500MB.

Using the techniques of abbreviating commands, the user can request a 2 day forecast of surface pressure (from the ECMWF model) by typing :

```
COMMAND>PLOT 2DAY SURF PRESS ECMWF
```

which the command interpreter will interpret as :

```
COMMAND>PLOT FORECAST=2DAY,LEVEL=SURFACE,PARAMETER=PRESSURE,MODEL=ECMWF
```

The system is designed around the use of defaults. Once a value is specified for any parameter it remains in force until changed. This helps to reduce the amount of typing required to request a given plot.

## 8. DIFFERENCE CHARTS

The system allows the user to request difference charts in an easy way. The following examples show the use of this option :

```
COMMAND>PLOT 3DAY-24HOUR 500MB TEMP
COMMAND>PLOT 500-1000MB GEOPOTENTIAL
COMMAND>PLOT ECMWF-IMS PRESSURE
```

The first example produces a tendency chart of temperature, the second a thickness chart and the third the difference between the IMS and ECMWF models in forecasting pressure.

The ability to plot difference charts is particularly useful for displaying daily rainfall amounts, since the rainfall forecasts are stored as accumulated values from the start of the forecast.

## 9. TREATMENT OF ERRORS

If the user types an unrecognised command string the program ignores the command and prints an error message indicating the part of the command which is unrecognised.

If the user type an ambigious command the program replys by listing all possibilities. The command is ignored.

The user can difference the PARAMETER's 'LEVEL', 'FORECAST' and 'MODEL'. A request for any other type of difference chart (e.g. 'PARAMETER=WIND-PRESSURE') results in an error.

If the user requests a chart which is not available (e.g. PLOT 32HOUR SURFACE PRESSURE) the program replies with an appropiate error message.

The program only looks at sufficient leading letters in the command VERB, PARAMETER or VALUE to make an unambiguous match. Later letters (even if misspelled) are ignored. This allows the program to catch and correct many typing errors.

The program has an interrupt facility to enable the forecaster to interrupt a plot if he/she is unhappy with it. Simply typing 'I' (for interrupt) followed by 'RETURN' returns the user to command level.

## 10. HELP FACILITIES

The user friendliness of the system is increased by an extensive HELP facility. This means there is no need to remember all of the VALUE's for all of the PARAMETER's.

The user can get a brief description of the system (and instructions on the use of the HELP facility) by typing HELP.

The user can type '?' instead of a command VERB to get a list of all command VERB's with a brief description of each. Thus typing '?' gives :

```
Legal COMMANDS are:
PLOT        Main plotting Command
HARDCOPY    Produce hardcopy of screen
EXIT        Exit from the CHARTS program
HELP        Print help file on use of the system
```

Similarly, typing '?' after a VERB will give a list of PARAMETER's. For example, typing 'PLOT ?' will produce the following HELP message :

```
PARAMETER's for COMMAND : PLOT
AREA     Area for plotting
LEVEL    Level in the atmosphere
FIELD    Field for plotting (e.g. pressure)
FORECAST Length of the forecast
MODEL    Identification of the forecasting model
COLOUR   Colour of the plot
```

Finally, if the user types 'PLOT AREA=?' the system will respond with the following HELP screen. (Note that this example is abbreviated).

```
VALUE's for PARAMETER : AREA
ATLANTIC  Main atlantic chart
IRELAND   Area around Ireland
```

## 11. OTHER FACILITIES

The 'HARDCOPY' verb allows the forecaster to produce a hardcopy of the plot on the screen. The plot is rescaled (by a sub-job on the host computer) before output, in order to produce a chart at the correct scale for overlaying with the forecasters working maps and charts. A simple copy of the screen buffer of the graphics VDU would not produce a chart with this property. The hardcopy is produced using a dot matrix printer. While the hardcopy is being produced the graphics terminal is still available to the forecaster for the display of charts.

There are facilities for superimposing plots. The user can superimpose a field on the existing plot by using the OVERPLOT rather than the PLOT command. Any number of plots can be superimposed in this manner.

## 12. STORING COMMANDS IN A FILE

The user can store a set of commands in a file (called an OBEY file) and then run the system in batch mode with the help of the file. This facility is particularly useful for producing hardcopies of a standard set of plots. The command processor scans from left to right and so the user can override defaults in the OBEY file by appending a character string to the end of each line (since the command PLOT RED BLUE will produce a BLUE plot). Thus suppose the file MYPLOT contains the command :

```
PLOT 3DAY SURFACE PRESSURE ECMWF
```

then the user can produce this plot by typing :

```
COMMAND>OBEY FILE=MYPLOT
```

Alternatively, the user can produce a plot of the 4 day forecast by appending the string '4DAY' to the end of each line in the file with the command :

```
COMMAND>OBEY FILE=MYPLOT,STRING='4DAY'
```

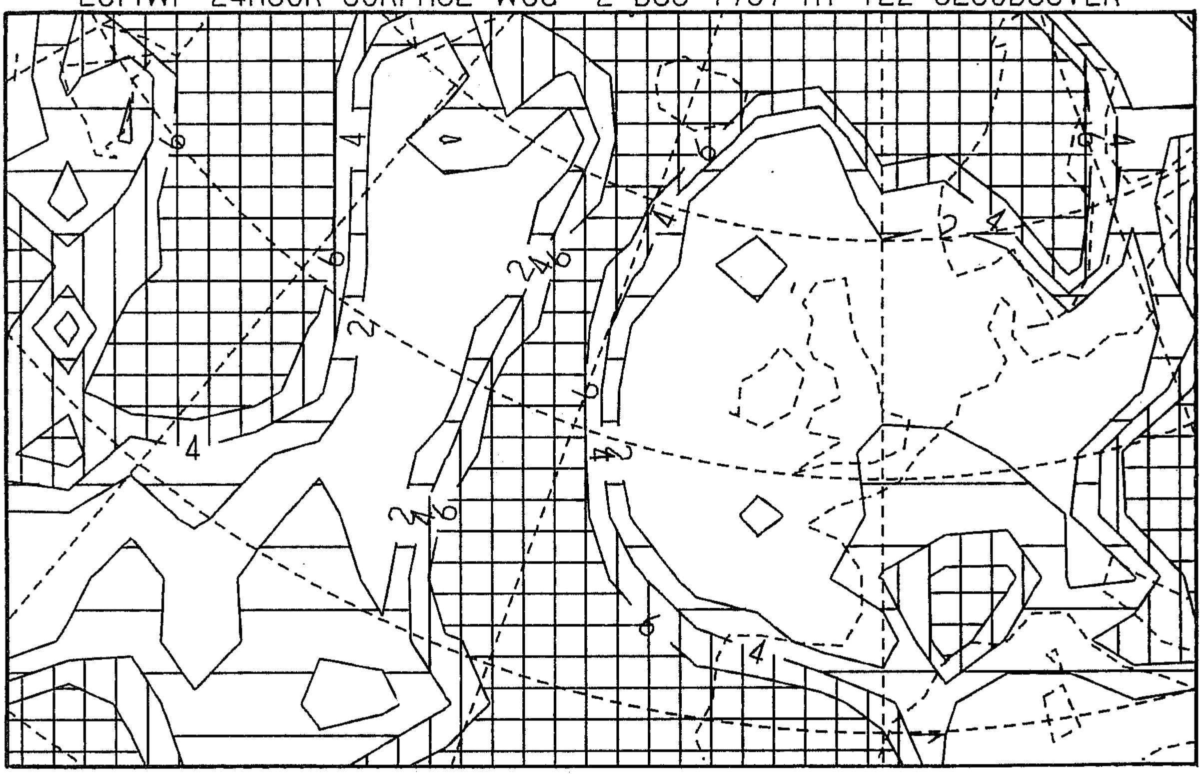
An OBEY file can contain any number of commands and usually consists of a sequence of PLOT commands interspersed with HARDCOPY commands. There are facilities to only execute a portion of the commands in the file. The portion required can be selected by searching the file for the occurrence of two text strings with the parameter names BEGIN and END.

An OBEY file can contain comments (to help with documentation). A comment is a line beginning with the character '*'.

## 13. FINAL REMARKS

Much of the design effort has gone into the command processor to produce a user friendly but powerful system. The use of defaults, the specification of units with numerical VALUE's and the exhaustive search of the command definition tree has produced a command structure reasonably close to English.

ECMWF 24HOUR SURFACE Wed 2 Dec 1987 AT 12Z CLOUDCOVER



IMS 24HOUR SURFACE Thr 3 Dec 1987 AT 0Z PRESSURE

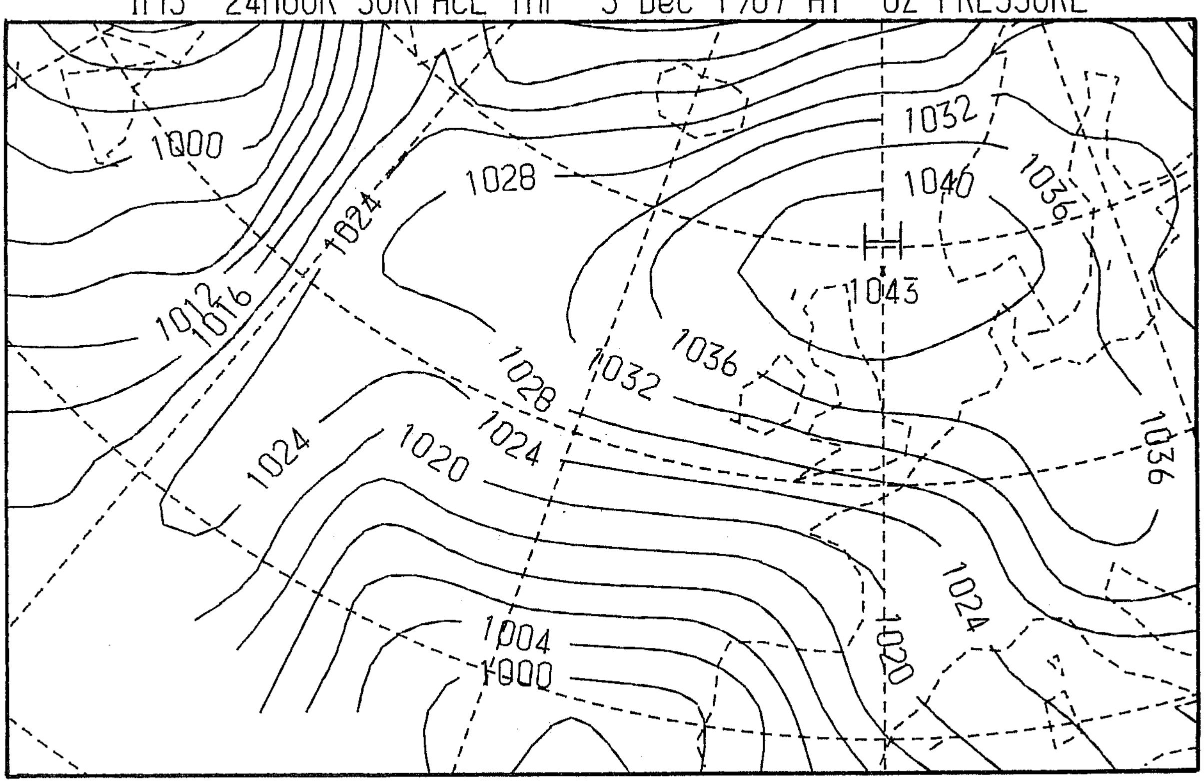



**Figure 1 : Sample plots produced by CHARTS. The top plot shows an ECMWF 24-hour forecast of cloud-cover; the bottom an IMS 24-hour forecast of pressure.**

The system has been well received by the forecasters and has been in daily operational use at the headquarters of the IMS since May 1982. In 1985 the system was extended to Shannon airport and in 1986 to Dublin airport.

The hardware configuration consists of a Digital Equipment Corporation DEC-2050 mainframe computer with 512 Kilowords of core. The display terminal is a DEC GiGi 8-colour graphics terminal with a resolution of 768 dots horizontally by 280 dots vertically. The response time is typically about 5 seconds between typing a command and the start of plotting. During this period the program accesses the data base, contours the field and stores the plot as a set of vectors. Only when this entire process is completed does the actual drawing begin. The drawing can take up to 30 seconds, depending on the complexity of the plot, but at this stage the user has the option of interrupting the plotting (by hitting the 'I' key followed by 'RETURN'). A hardcopy using the dot matrix printer takes about 5 minutes. Figure 1 shows some sample plots.

## 14. REFERENCES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