CHAPTER 13

COMPUTER PROGNOSES : TYPES AND USES

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13.1 INTRODUCTION

As a result of the introduction of the United Kingdom 10-level model into operational service in 1972, computer-derived forecast charts (prognoses) are now available for all levels for which traditional, manually drawn charts were produced in the past. For some purposes the objective prognoses can be used directly as they come from the computer. For other requirements, however, there is still a need for subjective amendment of the computer products: the modifications may be slight and affect only a small portion of the chart, or they may be such that the objective forecast may be regarded as guidance material in a mainly subjective process. The way in which a computer prognosis is used depends upon a subjective assessment of its quality and upon the purpose for which it is required.

The quality of a computer prognosis depends upon

(a) the quality of the analysis;

(b) the overall performance of the forecast model;

(c) the performance of the forecast model in the prevailing synoptic situation; and

(d) the way in which the forecast quantities are derived from the output of the forecast model.

13.1.1 The quality of the analyses

The topic of analysis has been discussed in Chapter 11 - Upper-air charts. The computer analysis procedures ensure a high degree of consistency in the vertical, but it is to be expected that the analyses will be better at some of the model's ten levels than at others. For instance, subjective intervention is carried out at the four main analysis levels of 1000, 500, 300 and 100 mb, and, other things being equal, the analyses should be rather better at these levels than at the others. Surface data are comparatively plentiful for the 1000-mb objective analysis, and at 300 mb account is taken of data from aircraft and satellites using objective techniques and, in addition, through a manual intervention process. Rather less accuracy may be achieved at 850,* 700, 400 and 200 mb, where direct analysis is carried out,

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* The 850-mb analysis is not used in the forecast model itself, but is required for the interpolation for the 900-mb and 800-mb levels.

but where intervention has only an indirect effect. Finally, one would expect the errors to be greater for the remaining three levels, 900, 800 and 600 mb, which are obtained by polynomial interpolation from the analysed levels.

It may be inferred that the remarks about the relative accuracy of the analyses at the different levels also apply to the prognoses at those levels, although in the forecast model itself the convective adjustment scheme largely prevents vertical inconsistencies building up.

13.1.2 The overall performance of the model

The performance of the forecast model, in general, may vary from time to time as improvements are introduced. Forecasters should be aware of these changes and the likely effect on the various characteristics of the model. Deficiencies occur in the 10-level numerical forecast model because of the finite size of the grid and the way in which the basic equations need to be handled, while there are also unavoidable approximations in taking physical processes into account.

It should be noted that the meteorologist will have not only the products of the United Kingdom 10-level model, but also computer prognoses from other countries. The properties of the foreign models may well be different from those of the British, and occasionally two models may indicate different meteorological developments. When this happens, the forecaster often has to exercise a fine degree of judgement, based on his experience and knowledge of the models in different synoptic situations.

The performance of the U.K. model varies to some extent with location and height, being least satisfactory near the lateral boundary of the forecast area and the upper and lower boundaries. Errors arise because of the assumption of unchanging conditions near the octagon boundary at about latitude 15°N, but they are unlikely to have a serious effect for the 2- or 3-day forecast, except possibly at times over and near the Mediterranean Sea. In the upper troposphere and lower stratosphere complications are encountered because of the presence of the tropopause and the intense temperature gradients and wind shears associated with the jet streams. In the lower troposphere, and particularly at 1000 mb, the prognoses are affected by the approximations necessary in the allowance for ground topography and physical processes such as evaporation, heat transfer from the surface, and surface friction. There may also be deficiencies in the detail, because of the effect of averaging introduced by the finite-difference approximations. This is most serious in the handling of small-scale features of the surface chart.

13.1.3 The performance of the model in different synoptic types

The performance of the model varies with the synoptic situation: the details may vary from time to time as changes are made to the model, and only a very brief indication of the main features is worth while in this handbook. Most computer models tend to move waves in the westerlies too slowly, particularly short-wavelength mobile features, and especially those that are accelerating. There is also a tendency for the models to be slow in predicting the development of upper highs and lows, and in extending the forward development of jet streams. Near the surface, the model may not deepen developing lows or intensify highs sufficiently, with resulting errors in pressure gradients; conversely, it may not weaken old highs and fill old lows quickly enough. These are all aspects of the computer products that the forecaster must be familiar with, and he must be aware of likely errors and also be ready to use the traditional subjective methods when there is serious doubt about any of the computer products.

13.1.4 Computer output from the numerical forecast model

The output of the forecast model may vary from time to time when the computational scheme is changed, but in general not all the meteorological elements are calculated directly for all grid points. A schematic example of the calculated field is given in Figure 1: this is for the split-explicit scheme (see section 3.4.4 of Chapter 3 - Background to computer models), where the wind components, u and v, are calculated at the mid points of the grid squares, while the values of geopotential, h, are available at each grid point. For the output, however, the forecast quantities are required at the grid points, and in the example below the wind components at the grid points would be obtained by smoothing and interpolation procedures. We now have values of h, u and v at each grid point at the model's ten levels with vertical velocity, ω, and humidity mixing ratio, r, at intermediate levels.

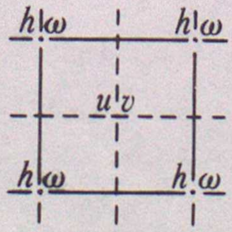

FIGURE 1. Distribution of output variables on the grid

Wind components may be needed for some purposes, but the values of u and v are readily converted to wind speed and direction as required by most users. Also required are wind speed and direction and geopotential at the intermediate pressure levels (850, 250 and 150 mb), and the temperature at 1000, 850, 700, 500, 400, 300, 250, 200, 150 and 100 mb, the pressure and/or heights of the highest $0^{\circ}C$ isotherm (freezing level), the maximum wind speed and the pressure at which it occurs, and the pressure and temperature at the tropopause. The surface pressure is also needed.

The temperature structure of the atmosphere is derived from the heights of the model's ten levels by means of the thickness equation. If Δh is the thickness of the layer between the kth and $(k+1)$th levels, then

$$\bar{T}_{k+\frac{1}{2}} = \frac{g\,\Delta h}{R \log (p_{k+1} / p_k)}$$

where $\bar{T}_{k+\frac{1}{2}}$ is the mean temperature of the layer and is ascribed to the mid point of the layer on a $\log p$ scale. Any superadiabatic layers are reduced to the dry-adiabatic lapse rate and consequent adjustments made to the temperature profile by an iterative procedure. The tropopause temperature and pressure may then be derived according to the standard definition of the tropopause (more than one tropopause may be selected if appropriate), and the height of the tropopause(s) obtained by use of the thickness equation.

Having determined the tropopause height/pressure at each grid point, a profile of geopotential against pressure is derived by fitting two cubic splines to the heights at the ten pressure levels, one curve below the tropopause and one above. (A cubic spline is a piecewise cubic curve such that the first and second derivatives are continuous at the datum points to ensure reasonable smoothness.) The heights at the intermediate levels are read off directly from the splines. The temperatures at all levels are derived from the temperature/pressure profile obtained earlier. The pressure, and height if necessary, of the freezing level may be obtained by interpolation from the temperature profile.

The wind speeds and directions at the intermediate levels are derived from profiles of u and v. As mentioned earlier in this section, horizontal smoothing and interpolation have to be carried out first of all to yield the values of u and v at the grid points, the smoothing process removing roughnesses on the scale of two grid lengths or less, but leaving features of greater dimensions virtually untouched. The vertical profiles of u and v are then evaluated at each grid point, again by fitting cubic splines, and the components are read off the curves at the required levels. Also needed are the maximum wind speed and the pressure at which it occurs. The region near the level of the highest speed, $V = \sqrt{(u^2+v^2)}$, is searched and a derived maximum value of v, according to the vertical profiles, is found. Because of the smoothing processes, however, this speed will generally be too low. To overcome this, the profiles are again searched to find the positions, above and below the maximum, at which the vertical shear is greatest. The tangents to the profiles, representing these maximum wind shears, are then extrapolated to meet at a new estimate of the maximum wind speed and its pressure level. Wind speeds for one or more intermediate heights may as a result have to be amended to fit in with the new profile.

It can readily be seen from the above account that some types of information presented in the computer output are obtained more directly from the forecast model than are other kinds. Temperatures, for example, are derived indirectly. Winds are obtained by smoothing and by interpolation in the horizontal and, for intermediate levels, in the vertical, while the maximum wind is found by extrapolation of profile slopes. In general, these techniques for producing output do not significantly contribute to the forecast errors, but there may be occasions and locations for which the forecasts need to be carefully examined.

13.2 TYPES OF COMPUTER PROGNOSES

Computer prognoses can take on a variety of forms. The data may be given in grid-point form, values of h, T and wind speed and direction being given at each grid point for each level. For this format, the data may be on magnetic or paper tape, ready to be fed directly into another computer for further processing, or they may be printed on charts. Grid-point data, for example, are supplied to British Airways as input for flight-planning programs on their own computer, and data in grid-point form are also transmitted directly to the meteorological services of Belgium and the Netherlands.

The most common output is, however, in the form of isopleths on a chart. For operational forecast purposes at present (1976) the isopleths show the field of any of the following quantities: geopotential, wind speed, temperature at given levels, the tropopause height or pressure and temperature, the maximum wind speed and the pressure at which it occurs, and the freezing level. The charts may be output in 'zebra-print' form produced by a line-printer, alternate spaces between the isopleths being filled with figures while the intermediate spaces are left blank. Isopleths in the more usual form are obtained from a microfilm plotter, a computer-linked device which produces the required fields on film which then has to be developed and from which prints are prepared. The microfilm plotter is a versatile piece of equipment which is also used to produce spot wind and temperature charts over Europe for aviation, and can be used to give tephigrams, cross-sections and other special forms of output.

13.3 USES OF COMPUTER PROGNOSES

Computer prognoses may be divided into three classes according to the way in which they are used in the production of the forecasts actually issued. Firstly, there are those which are issued to the user as they come from the output modules of the computer. An example is the wind and temperature data on magnetic tape for British Airways and the Civil Aviation Authority. The isobaric contour charts issued to outstations are also unmodified computer products. Generally speaking, the data used for flight planning are satisfactory as they come from the computer: errors, for example in the west-to-east movement of troughs and ridges, will often nearly cancel out over a long flight path.

On the other hand, the documentation used for briefing aircrew, for navigation for example, may need modification over some areas, and these form the second category - forecasts which are issued with, at times, some subjective amendment over part of the chart. This applies particularly to charts for levels near the tropopause and the level of maximum wind, where the vertical and horizontal gradients of wind and temperature are strong, and where detail is sometimes inadequately or inaccurately represented in the prognoses. It is in regions near jet streams that the errors are likely to be greatest, and the human forecaster, with his knowledge of the deficiencies of the model and of the synoptic and dynamical climatology of jet streams (see Chapter 8), can modify the computer prognoses with a good chance that the amended version will show some improvement over the original. The forecaster may also have additional information not available for the computer analyses - such as later observations, additional aircraft reports, satellite photographs, etc. - which help to indicate when developments are occurring which have not been captured by the computer model. At jet-stream levels it is usually the isotachs, and rarely the contours, that may be improved by subjective amendment. Modifications are usually necessary only over limited regions, such as the entrance or exit regions of the jet stream. The forecaster, and the user of contour/isotach charts, must remember that the model's winds do not conform to the geostrophic or even the gradient-wind approximation.

The third category of computer prognosis is used by the human forecaster as guidance in what is otherwise mainly a subjective process. This applies almost solely to the preparation of the surface prognosis. The forecaster has the upper-air and surface charts from the octagon model, and the surface and 1000-500-mb thickness charts of the rectangle model to guide him. The rectangle model also produces forecasts of the instantaneous rates of rainfall (with different symbols for convective and dynamical rainfall) and of accumulated rainfall over the whole of the forecast period; these charts help the forecaster considerably in placing fronts on the surface prognoses. Also of assistance in estimating frontal positions are the thermal vorticity charts of the octagon model (see Kirk,[1] and section 2.2.10 of Chapter 2). For reasons discussed in 13.1, the objective surface prognoses are less satisfactory than the forecasts for mid-tropospheric levels: they are most often used as a 'first guess' at the surface prognosis. The forecaster then applies the more traditional techniques to modify and fill in the missing features as necessary. (These methods are described in some detail in Chapter 14 - Surface prognoses.) He will know something of the overall characteristics of the model and of its performance in similar synoptic situations in the past, and this will help him to make up his mind on the likely developments. As with the upper-air prognoses he will have additional and later data, particularly when forecasting from data for 0600 and 1800 GMT, and this may indicate trends not shown by the computer model. The upper-air prognoses are useful in assessing surface developments, and vertical consistency must be maintained; the forecaster's knowledge of the three-dimensional structure of synoptic systems is a valuable asset.

13.4 CONCLUSION

The use of computer models for the production of meteorological analyses and prognoses has made a striking difference to the task of the forecaster. Much of the routine work associated with analysis and forecasting has been automated, but there is still a need for human skills in both the analysis stage and in the preparation and use of the prognoses, where the human being is able to exercise judgement beyond the capabilities of present-day computer logic. It appears that the task of the meteorologist has changed, but not diminished either in magnitude or importance. In discussing this topic, Kirk[2] has this to say: 'The fundamental principle is that objective methods should be used to the fullest extent compatible with the requirement so that judgement can be more effectively exercised at a higher level. It is unnecessary for expert judgement to be employed in circumstances where routine objective techniques can be used to provide an adequate service.'

BIBLIOGRAPHY

1. KIRK, T. H.; Some aspects of the theory of fronts and frontal analysis. Q J R Met Soc, London, 92, 1966, pp. 374-381.
2. KIRK, T. H.; The use of numerical forecasts. Met Mag, London, 103, (Jan.) 1974, pp. 14-20.