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A 10 LEVEL FINE MESH FORECAST FOR AUSTRALIA AND NEW ZEALAND

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ABSTRACT

A 24-hour forecast for Australia, produced using the Bushby-Timpson 10 level model, is described. The results, while containing certain errors, are encouraging and suggest the need for further study of fine mesh models capable of forecasting rain and other weather in Australia and New Zealand.

INTRODUCTION

The British Meteorological Office has been developing over the past few years a limited area fine mesh 10 level numerical forecasting model suitable for the prediction of rainfall over the British Isles. This paper describes an experimental application of the model to give a 24-hour forecast for a region covering part of Australia and New Zealand. One of the principal reasons for the experiment was to test the feasibility of fine mesh forecasts in regions where the observational data coverage is relatively sparse.

BRIEF DESCRIPTION OF MODEL

The model has been developed from the basic formulation given by Bushby and Timpson (1967), but incorporates later modifications and improvements described by Benwell and Timpson (1968), Bushby (1968) and Gadd and Keers (1970). A complete description of the current state of the forecasting scheme is given by Benwell *et al* (1970), so details need not be given here. The equations have the hydrostatic pressure p as the vertical coordinate, motion being predicted on the 10 pressure surfaces p = 1000mb, 900mb............, 100mb. The model is governed by the following set of equations:

(a) two horizontal momentum equations evaluated at each pressure level

$$\frac{\partial u}{\partial t} = \text{terms involving } u, v, \omega, h \quad \ldots\ldots\ldots(1)$$

$$\frac{\partial v}{\partial t} = \text{Terms involving } u, v, \omega, h \quad \ldots\ldots\ldots(2)$$

(b) the thermodynamic and humidity equations evaluated mid-way between each pressure level

$$\frac{\partial h'}{\partial t} = \text{terms involving } u, v, \omega, h', r \quad \ldots\ldots\ldots\ldots (3)$$

$$\frac{\partial r}{\partial t} = \text{Terms involving } u, v, \omega, h', r \quad \ldots\ldots\ldots\ldots (4)$$

(c) the tendency equation evaluated on the 1000mb surface

$$\frac{\partial h_{1000}}{\partial t} = \text{terms involving } u, v, \omega, h_{1000}, H \quad \ldots\ldots\ldots\ldots (5)$$

(d) the continuity equation

..........(6)

where:

u and v are the horizontal wind components
$\omega = Dp/Dt$ represents vertical motion in pressure coordinates
h is the height of the pressure surface h' in the 'thickness' i.e. the distance separating two adjacent pressure surfaces
r is the humidity mixing ratio
h_{1000} is the height of the 1000mb pressure surface
H is the height of the topography
m is the map scale factor.

Starting from an initial balanced distribution of u, v, ω, h and r equations (1) to (5) are stepped forwards in time to give forecast values of u, v, h', r and h_{1000}. The contour heights h are then found from h_{1000} and h' by successive addition while ω is calculated by integrating equation (6) with respect to p. The equations were solved on a rectangular cartesian 95 by 63 grid constructed on a polar stereographic map projection, the variables being staggered in both space and time in a manner suggested by Eliassen (1956) and Phillips (1962), and the time integration being a two step procedure similar to the Lax Wendroff method (Richtmyer 1962). The contour height h and the humidity mixing ratio r were held at points on a primarary 48 by 32 grid having a grid length at 45°S of about 93km (109km at the pole) (Fig 1), while the wind components u, v and ω were held at intermediate grid points. This is the same grid as was used by Bushby and Timpson except that, due to the map projection, the grid length is slightly smaller in these latitudes. To ensure numerical stability a time step of 80 seconds was necessary.

The right hand sides of the equations (1) to (5) contain not only the advective, rotational and pressure forcing terms associated with the large scale motion, but also terms expressing the flux gradient and exchange properties of sub-grid scale processes such as horizontal diffusion, cumulus convection, the formation of rain and clouds, turbulent boundary layer transfer, diurnal radiation, etc. The precise formulation of these terms will not be discussed here but in general it is the same as described by Benwell *et al.* (1970). The only change of importance is the value of the assumed surface relative humidity (associated with the vertical flux of heat and moisture over land) - a value of 50 percent being thought more appropriate than the 80 percent relative humidity adopted for the European area (In latter versions of the model the surface humidity is made dependent on local climatic factors).

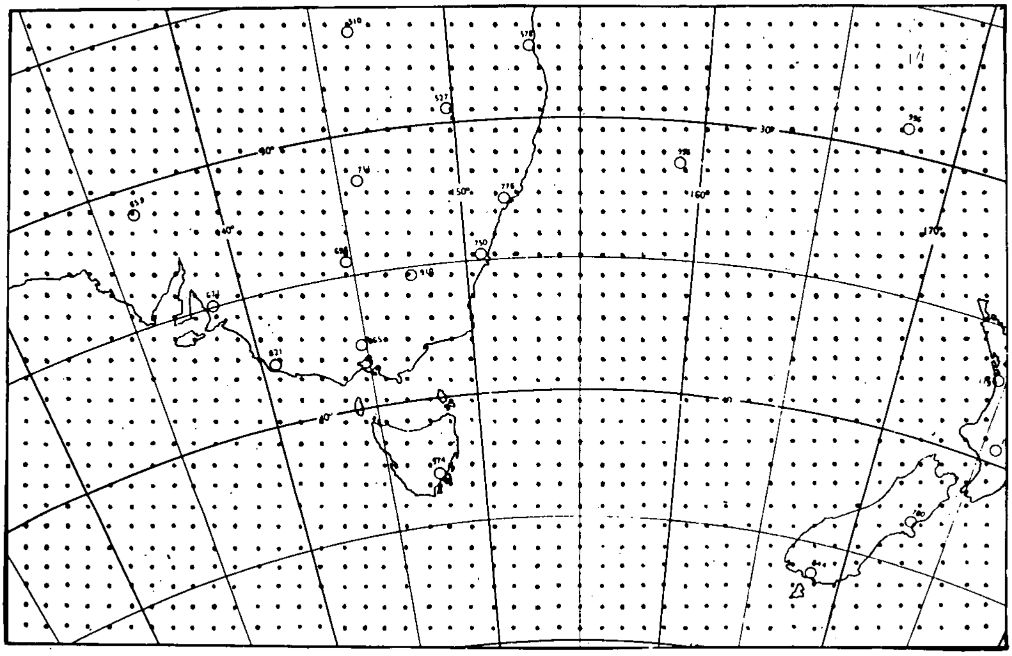

Fig. 1 The Forecast Area

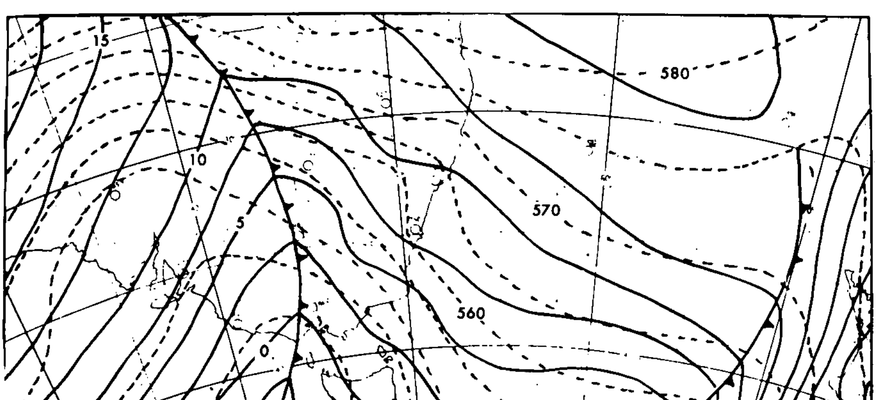

Fig. 2 Initial Contour Patterns (2300 GMT 9.8.67)
1000 mb (———) at 2.5 Decametre Intervals
500 mb (------) at 5 Decametre Intervals

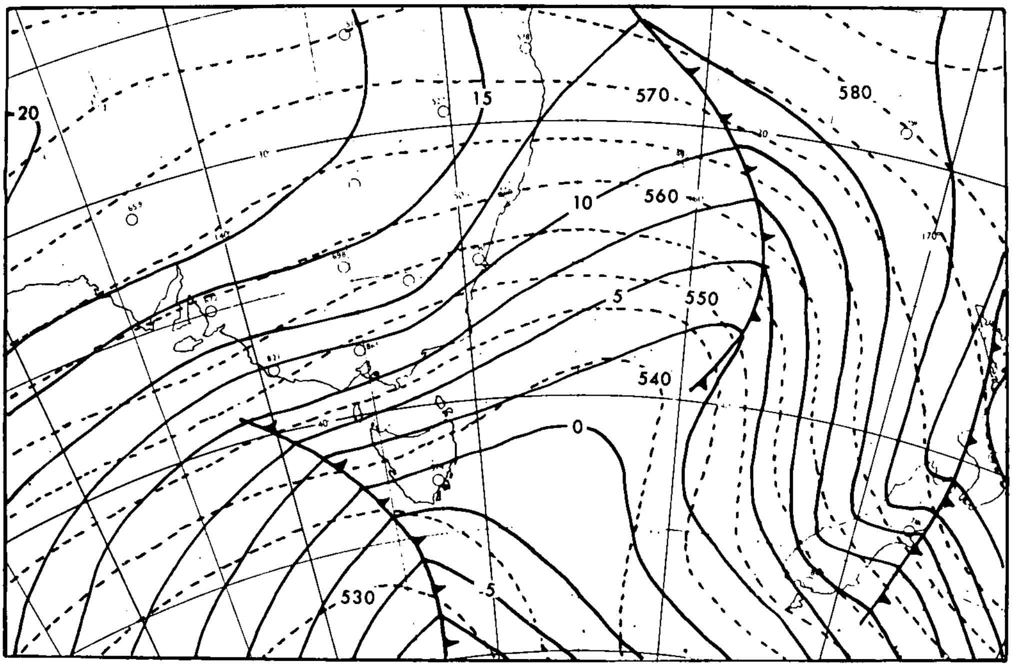

Fig. 3 Observed Contour Patterns (2300 GMT 10.8.67)

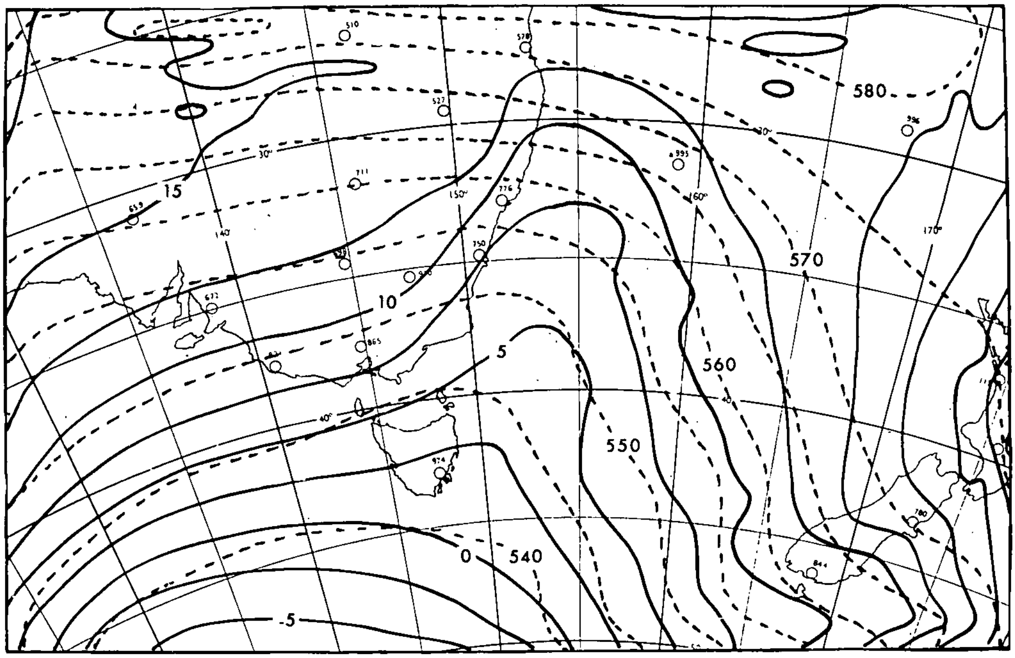

Fig. 4 Forecast Contour Patterns (2300 GMT 10.8.67)

FORECAST PRESSURE PATTERN

The date chosen for the forecast was 9 August 1967 with initial time 2300GMT. The initial 1000mb and 500mb contours are shown in Fig 2; Fig 3 shows the situation 24 hours later. During this period the major trough over Australia, which at the surface was initially lying approximately north-south along longitude 144°E, moved rapidly eastwards into the Tasman Sea while at the same time a small depression west of Tasmania associated with the trough filled and disappeared. Another trough moved more slowly eastwards across South Island New Zealand. In the 10 level forecast (Fig. 4) the speed of movement of the Australian trough was underestimated. A likely reason for this error is that the trough was held back artificially by the assumed boundary conditions (in the model contour heights are kept constant in time around the lateral boundaries). A similar effect has been noted by Benwell and Bushby (1970) for a British Isles forecast. Another point of interest is an excessive rise in pressure in the forecast. This feature has been found in several predictions for the British Isles area and has been explained in terms of the finite difference approximation for the balance equation in the initialisation procedure (Benwell *et al*). If simple centred differences are used for the derivatives a spurious rise of pressure occurs during the early part of the forecast. Later versions of the program have been modified to include difference approximations for the balance equation consistent with the finite difference form of the forecast equations and the pressure rise has been eliminated. The 500mb forecast is subject to similar faults for similar reasons.

RAINFALL FORECAST

Forecast 24-hour accumulation of rainfall is shown in Fig 5 the strong influence of topography on the predicted rainfall distribution is immediately apparent with a maximum accumulated rainfall of 9.09 mm in the Snowy Mountains area and 12.15 mm in the New Zealand Alps. Comparison with the observed rainfall accumulation is difficult because of the localised nature of rainfall distribution. Nevertheless Fig 6 displays predicted grid point accumulations for the forecast period (2300 GMT 9 August 1967 - 2300 GMT 10 August 1967) with the 24 hour rainfall observed during the period starting at 0900 EST on 10 August (2300 GMT 9 August 1967 - 2300 GMT 10 August 1967), the observations being averaged over grid squares surrounding the appropriate grid points (only grid squares containing at least three observations are shown). The forecast values are generally somewhat lower than is observed, mostly differing by a factor of between a half and a third. In Tasmania, however, the forecast is particularly poor and this is probably due to an inaccurate initial humidity analysis over the Australian Bight (where there are no upper air observations). The observed rainfall figures for New Zealand (not shown in Fig 6) are some 6 to 8 times higher than the forecast values shown in Fig 5. This is probably due partly to the proximity of the boundary (around which there is an artificial high diffusion zone three grid lengths wide which damps spurious boundary waves) and also to the difficulty in obtaining a representative observed mean frequency extreme local variation in rainfall which must inevitably occur in so mountainous a region.

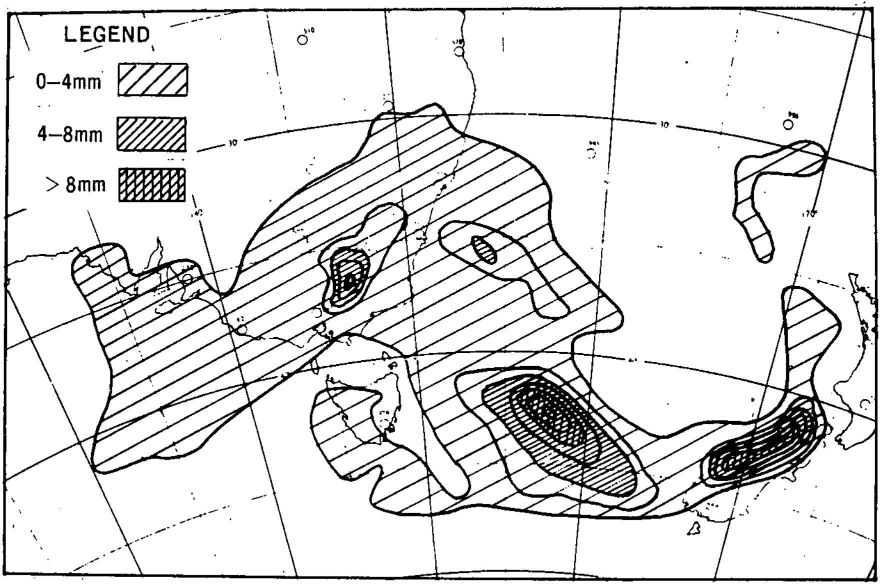

Fig. 5 Forecast Rainfall Totals (mm) for 24 Hours from 2300 GMT 9.8.67

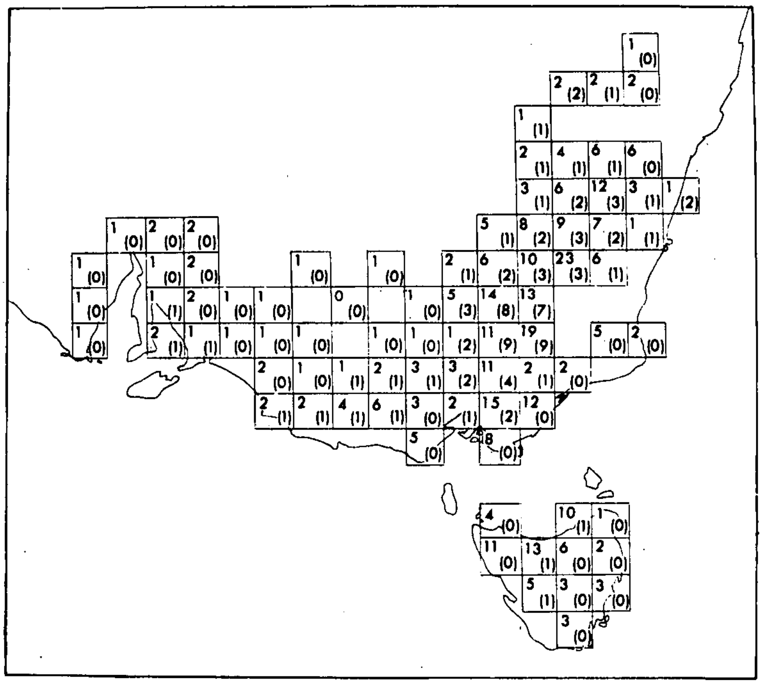

Fig. 6 Comparison of observed and forecast accumulated rainfall (mm) for grid squares containing at least three observations (Forecast values in parenthesis)

CONCLUSION

The forecast described in this paper is by nature an experiment, but the results are encouraging, in spite of certain errors. Nevertheless there is considerable scope for improvement in the representation of physical phenomena peculiar to the climate of this region (which differs in many respects from that of northwestern Europe). Such modifications, together with improved analyses aided by satellite observations, may be expected to remedy many deficiencies of the present formulation.

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