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A 10-level atmospheric model and frontal rain

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SUMMARY

A 10-level primitive equation model suitable for studying the dynamics of fronts and frontal rainfall is described. The atmosphere is assumed to be hydrostatic and inviscid and the effects of friction and topography are ignored. Latent heat due to evaporation and condensation is incorporated in the thermodynamic equation. No distinction is made between the ice and water stage and the atmosphere is assumed to be dry above 300 mb. The horizontal grid length is 40 km. The results of one 24-hr integration are described in detail.

1. INTRODUCTION

Numerical weather prediction has now reached the stage where forecasts of pressure patterns on the scale of anticyclones and depressions can be computed for up to three days ahead. Many National Meteorological Offices produce numerical forecasts which range in period from 24 to 72 hours and which vary from simple barotropic forecasts to those based on multi-level baroclinic models. Although some problems remain to be solved, the standard of these forecasts is as good as, if not better than, those produced by conventional methods. It is clear that numerical weather prediction can be advanced in two main ways; by extending the useful period of the forecast and by increasing the amount of detail in the forecast. This paper describes a numerical experiment designed to investigate atmospheric disturbances on the scale of fronts. This model has been developed for two main purposes; the study of the dynamics of fronts and the prediction of frontal rainfall.

Observations from the free atmosphere are available only from aerological sounding stations. These are separated by distances of at least several hundred kilometres and by very much greater distances over the oceans. Thus it is not possible to specify the detailed structure of fronts in the data which are used as the initial conditions for a forecast. It has been necessary to start the integrations from smooth but realistic fields of motion, temperature and humidity in the expectation that the characteristic concentration of gradients will develop gradually at the frontal surface if the problem has been properly formulated.

It is recognized that the quasi-geostrophic formulations of the dynamical equations become increasingly inaccurate as they are applied to systems with a scale less than 1,000 km. Ageostrophic motions are clearly very important in the vicinity of fronts and it is desirable to use the basic first order hydrodynamic and thermodynamic equations applicable to an inviscid hydrostatic atmosphere. These equations are frequently referred to in the literature as the primitive equations of motion. Charney (1955), Hinkelman (1957, 1959) and Smagorinsky (1958, 1963) are among the early workers who demonstrated that it is possible to use the primitive equations in dynamical meteorology on the synoptic scale, whereas it had previously been thought that it was necessary to use the quasi-geostrophic approach in order to filter out unwanted noise from the equations.

