I N T R O D U C T O R Y   R E M A R K S

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The very first numerical models which were developed more than 20 years ago were drastic simplifications of the real atmosphere and they were mostly restricted to describe adiabatic processes. For prediction of a day or two of the mid tropospheric flow these models often gave reasonable results but the result deteriorated quickly when the prediction was extended further in time. The prediction of the surface flow was unsatisfactory even for short predictions. It was evident that both the energy generating processes as well as the dissipative processes have to be included in numerical models in order to predict the weather patterns in the lower part of the atmosphere and to predict the atmosphere in general beyond a day or two.

Present-day computers make it possible to attack the weather forecasting problem in a more comprehensive and complete way and substantial efforts have been made during the last decade in particular to incorporate the non-adiabatic processes in numerical prediction models.

The physics of radiational transfer, condensation of moisture, turbulent transfer of heat, momentum and moisture and the dissipation of kinetic energy are the important processes associated with the formation of energy sources and sinks in the atmosphere and these have to be incorporated in numerical prediction models extended over more than a few days.
The mechanisms of these processes are mainly related to small scale disturbances in space and time or even molecular processes. It is therefore one of the basic characteristics of numerical models that these small scale disturbances cannot be included in an explicit way. The reason for this is the discretization of the model's atmosphere by a finite difference grid or the use of a Galerkin or spectral functional representation.

The second reason why we cannot explicitly introduce these processes into a numerical model is due to the fact that some physical processes necessary to describe them (such as the local buoyance) are a priori eliminated by the constraint of hydrostatic adjustment. Even if this physical constraint can be relaxed by making the models non-hydrostatic the scale problem is virtually impossible to solve and for the foreseable future we have to try to incorporate the ensemble or gross effect of these physical processes on the large scale synoptic flow.

The formulation of the ensemble effect in terms of grid-scale variables (the parameters of the large scale flow) is called parameterization.

For short range prediction of the synoptic flow at middle and high latitudes very simple parameterization has proven to be rather successful.

The dissipation of kinetic energy in the boundary layer can be taken care of by computing the Ekman flux through an assumed stationary boundary layer. The vertical flux through the boundary layer is proportional to the geostrophic vorticity, ξ_g

$$\omega = -k_1 \xi_g$$

The effect of latent heat release can also be incorporated by calculating the vertical flux of humidity through a layer of a given depth (thickness proportional to the depth in which precipitation occurs). This gives

$$\frac{\delta Q}{dt} = -L\frac{dq_s}{dt} \sim -L\omega\frac{\partial q_s}{\partial p}\ ;\ \omega < 0$$

This simple parameterization of latent heat gives at first approximation reasonably accuracy to incorporating at least the effect of latent heat in well-developed weather systems (cyclones).

A third fundamental effect is the transfer of heat (sens.+lat.) from the oceans to the atmosphere which during the winter season is a first order heat source at middle and high latitudes. This can approximately be achieved by a bulk analogy to heat conduction. The heat flux is regarded as proportional to the temperature difference between air and sea with a coefficient which is virtually zero in the case where the air temperature is the highest, since this stabilizes the air and suppresses buoyancy. We therefore have

$$\left(\frac{\delta Q}{dt}\right)_{air} = c_p k_2 (T_{sea} - T_{air})\ ;\ T_{sea} > T_{air}$$

Usually radiation processes have not been included in short range prediction since it is assumed that they have limited effects on the short time scale with respect to the synoptic flow.

For extended integration beyond 3 - 4 days as well as for more accurate and detailed forecasting on a small scale the simple parameterization system outlined above is insufficient. In particular for extended integration a consistent treatment of the physical processes is an absolute necessity.

Great progress has recently been made towards a much more sophisticated way of parameterizing the sub-grid scale physical processes in numerical weather prediction, although so far not many systematic studies to evaluate the impact on weather forecasting have been undertaken.

For medium range weather forecasts the parameterization of the sub-grid scale processes is a central problem and a more accurate and comprehensive treatment of the physical processes in the atmosphere is necessary in order to improve the forecasts.

The third Seminar given by the European Centre for Medium Range Weather Forecasts had selected the parameterization of the physical processes in the free atmosphere as the topic. The seminar was given during the first two weeks of September 1977.

The main lectures were given by Professor Arnt Eliassen, University of Oslo, Dr. Ray Bates, Irish Meteorological Office, Dublin, Dr. Clive Rodgers, University of Oxford and Dr. Hilding Sundqvist, University of Stockholm.
Professor Eliassen dealt with problems connected with flow over mountains and in particular how steep mountains affect the atmosphere.
Dr. Bates reviewed the work in the parameterization of convective processes.
Dr. Sundqvist described the way precipitation processes in general could be parameterized in numerical weather prediction.
Finally, Dr. Rodgers gave a detailed expose of the treatment of radiative processes in the atmosphere.

Contributions on individual topics were given by members of the Centre's staff, who also presented the Centre's planned parameterization system.

The present volume contains the papers presented during the seminar.

The Centre extends its thanks to all those who contributed, both as participants and lecturers and to the U.K. Meteorological Office for providing such suitable accommodation.