ON THE GENERAL PROBLEM OF PARAMETERIZATION OF

SUB-GRID PROCESSES

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Although the spectrum of atmospheric motions and processes in general is a continuous one, only a limited number of scale - phenomena are realized in a given large - scale atmospheric situation and at various locations within the atmosphere. Non - linear interactions between various scales of motions lead to transitions to other preferred modes, as it is the case in problems of thermal convection. The flux of energy in the spectrum of atmospheric motions as well as all kinds of transports of atmospheric properties within the range of all scales are controlled, as we know for long, by the large - scale atmospheric conditions, together with the action of external parameters, e. g. of the earth's surface.

The general meteorological prediction problem does not only consist of large - scale forecasting alone. On one hand, local short - term prediction with high accuracy will remain one of the most important goals of meteorological prediction. On the other hand, comprehensive models of the general circulation are needed for testing stochastic forecasting models of climatic changes. As figure 1 shows, a comprehensive large - scale model with fairly high horizontal and vertical resolution forms the basis for the solution of all major prediction problems. Much progress has been achieved in the case of large - scale and short - term prediction, neglecting sub - grid processes and radiation effects at all. Models for long - term prediction (and for the general circulation) have to take into account all these effects in a parametrized form, i. e. as functions of large - scale parameters. A very large number of empirical assumptions
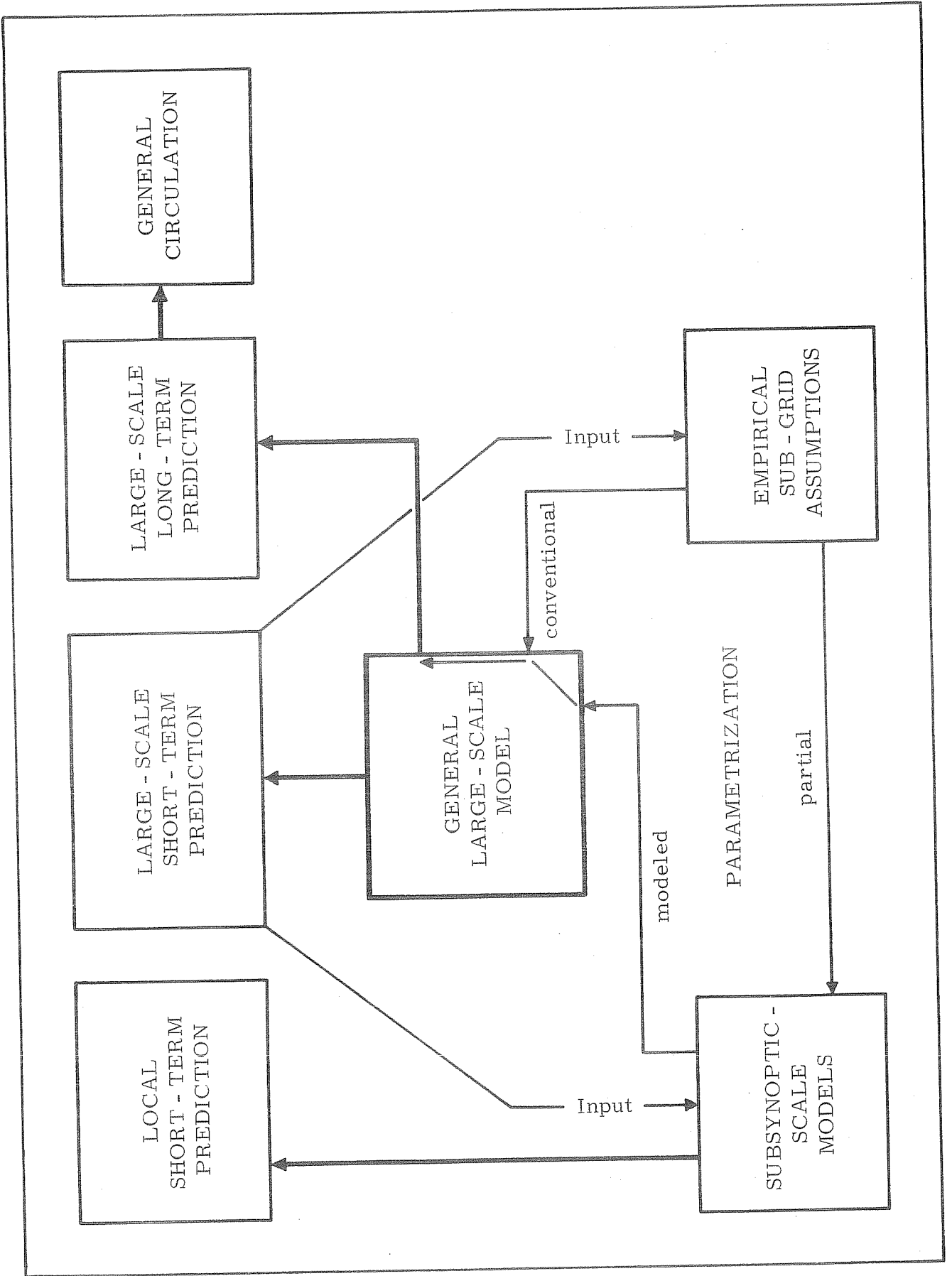
Figure 1 : The general prediction problem

on sub - grid parametrization do exist. This type of conventional para-
metrization has led to quite successful modeling of the general circulation
of the atmosphere.

In the author's opinion, much care must be taken when this type of para-
metrization is applied to medium - range prediction. In many cases, not
only the prediction of large - scale structures will justify the effort, but
also local short - term and medium - range prediction of weather will be
needed. This can be achieved only, if a sufficient number of subsynoptic -
scale models are available, which get their input from a large - scale
prediction model. On the other hand, this variety of subsynoptic - scale
models can be used for another type of parametrization, which could be
called "parametrization by direct modeling of subsynoptic - scale pro-
cesses". A certain amount of empirical assumptions on certain sub - grid
processes is still needed for that type of parametrization, especially in
cases where these processes are stochastic.

With regard to the response time of interactions between various scales
of motion there are remarkable differences. Within a developed large -
scale situation the atmosphere itself and (or) local physical and geo-
graphical conditions may lead to the realization of a large number of
subsynoptic - scale processes within a very short response time in the
order of hours. All those processes may vanish within a short period
of time and will not give rise to feed - back effects to the large - scale
flow. Only if the situation is sufficiently persistent, the in time and
space integrated effect will react on the large - scale flow with a response
time of several days.

In the author's opinion, the different response times connected with
transitions within the spectrum of subsynoptic - scale motions and of
those with the large - scale situation form the major problem when dealing
with the proper choice of averaging the system of equations. When
dealing with comprehensive three - dimensional models, so far, the

effects of all subsynoptic - scale processes have been put together by utilizing a single (in many cases not precisely defined) averaging operator. This method is justified if only small - scale turbulent processes do exist together with large - scale flow. However, if the spectrum of subsynoptic - scale processes fills the former mentioned gap between two pronounced scales, we know that the problem of parametrizing gets a new dimension in complexity. Many of those processes cannot be considered stochastic within a large - scale grid. This is especially true for deep convection (as in the tropics), and for many orographically caused motion systems. It might be necessary to model such phenomena in detail in cases, in which the large - scale situation favors the development of such modes. A second step would be to determine the relevant feed - back influences on the large - scale flow by horizontal averaging or by other means.

One demonstrative example of this type of modeling and parametrization was given by the author in [1]. In this paper, the integration over the entire planetary boundary layer (barotropic) led to a two - dimensional forecasting equation for the mean horizontal wind vector, that depends on the pressure distribution at the top, on the horizontal stress vector at the bottom, and on the divergence of the correlation between the "eddy" wind components. The latter represent a type of Reynolds' stress which is produced by vertical averaging. Utilizing a model for the vertical wind structure in the atmosphere, this term is not parametrized but modeled in a fairly complicated manner, which has no connection with usual parametrization assumptions. Numerical experiments with that model predicted the non - stationary behaviour of the field of vertical motion at the top of the boundary layer in terms of the prescribed be-haviour of the pressure field in that level [2]. In some sense, there are analogues with techniques used in the theory of wind - driven ocean currents.

This method of successive averaging (in the former case averaging with regard to small - scale turbulence effects was assumed to be already
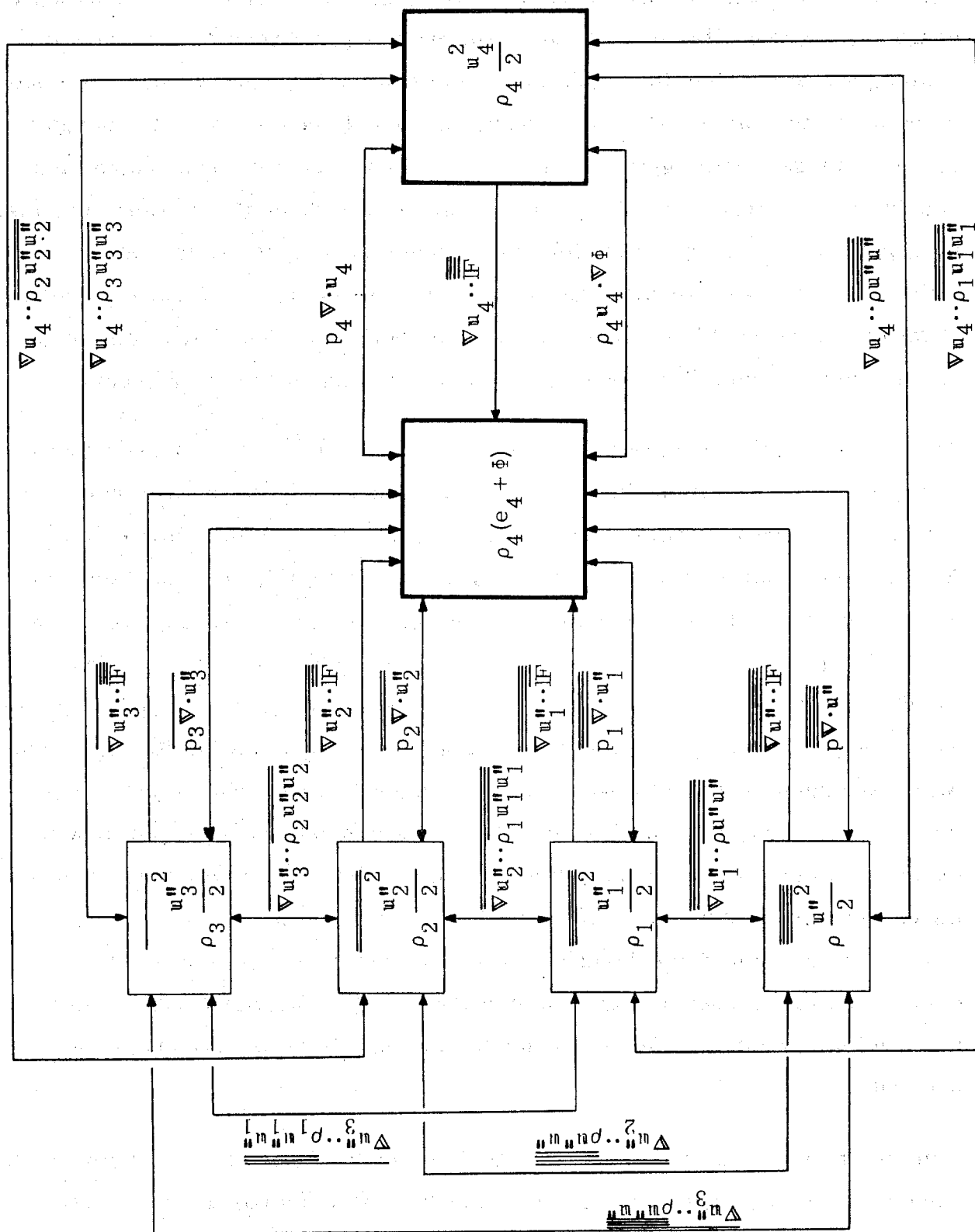
Figure 2 : Energetical interactions between four pronounced scales of atmospheric motions

performed), with vertical averaging as the second step, is very useful in formulating atmospheric models, as far as the correct and complete boundary conditions at the earth's surface are an integral part of the model. In addition, modeling or parametrizing of correlation products produced by vertical averaging in each of the higher layers may be superior to the conventional vertical differencing methods. A further advantage would be that additional horizontal averaging could lead to incorporation of subsynoptic - scale effects caused by properties of the earth's surface. In a paper of that kind [3], this method was proposed for applications in physical oceanography.

Successive averaging with operators that do not introduce boundary conditions is much easier to perform. Assuming that the spectrum of atmospheric processes consists of pronounced spectral bands, successive band - pass analysis of the system of equations gives some insight into the mechanism of energy transfer between the various groups of processes [4]. The following figure 2 is based on the assumption that only four pronounced bands of atmospheric processes do exist. u'' denotes small - scale turbulent fluctuations at one end, and u_4 denotes the wind vector of the large - scale flow at the other end of the spectrum. As usual, p means pressure, ρ density, e internal energy, Φ geopotential, $\mathbb{F}$ the molecular friction tensor. Many of the terms with the bars can be parametrized, some of them should be modeled. It is even possible to derive prognostic equations for some of the correlation products, as was proposed in a general fashion in [5].

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