EMS Annual Meeting Abstracts
Vol. 8, EMS2011-346, 2011
11th EMS / 10th ECAM

Forecasting the weather
- ensemble techniques
in probabilistic weather prediction

Numerical Aspects of Physical Parameterization

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The NWP model can be considered as a numerical implementation of the known physical laws governing the atmospheric processes. However, this procedure is not straightforward, even apart from multiple of technical numerical implementation issues, because we have to decide how to deal with the processes that are not resolved by the model grid, but that have critical influences to the evolution of model-resolved processes. Convection (both dry and moist, shallow and deep) is probably the best known example of such subgrid-scale processes in large-scale NWP models. The problem of representing these subgrid-scale physics is called the parameterization.

Parameterization is not purely a technological problem as often considered by our community. The present author insists that the parameterization must be considered as a fundamental scientific problem consisting of many good scientific questions at various different levels.

At the most fundamental level, the problem must be formulated in a physically consistent manner. In short, we should avoid "hand waving". Instead, a parameterization must be constructed in stepwise manner from the accepted physical laws. At each step of the formulation reduction, it must be made clear what approximations or hypotheses are introduced. These approximations and hypotheses must be stated in such manner that they can be verified either by observation or more direct numerical simulations.

The author has proposed the mode decomposition as a main guiding principle for achieving such stepwise logical construction of parameterization (QJ, 2005). A complementary, alternative way of looking at the problem is to take a starting point of parameterization as that of posing a geometrical constraint to full subgrid-scale processes.

For example, for the case of mass-flux convection parameterization, its basic premise resides on subdividing the grid box domain into various sub-segments with constant values (at each vertical level). In classical example of Arakawa and Schubert (1974), the whole grid box is subdivided into a homogeneous background environment and ensemble of convective plumes. The author proposes to call this principle the segmentally-constant approximation (SCA) in more general sense.

A self-contained prognostic (predictable) model can be constructed by introducing only this purely geometrical constraint (SCA) for the mass-flux parameterization into a full physical model. Application of this procedure to the nonhydrostatic anelastic model is named NAM-SCA (MWR, 2010). Basic working of NAM-SCA will be presented.

However, more importantly, this deconstruction of the logic of the mass-flux parameterization reveals a very different level of issues: formulation of subgrid-scale parameterization must be consistent with numerical algorithm adopted in the host NWP model. In other words, formulation of physical parameterization must also be carefully designed from numerical aspects.

From a purely numerical point of view, it transpires that SCA is nothing other than a finite volume approach. This perspective furthermore, suggests a possibility of regarding the whole physical parameterization as an issue of numerical algorithms. Along this line of arguments, the author is going to argue that the current physical parameterization must gradually be replaced by highly-flexible adaptive mesh refinements under a finite volume approach.