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Approaches for Subgrid Parameterization: Does Scaling Help?

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Arguably the scaling behavior is a well-established fact in many geophysical systems. There are already many theoretical studies elucidating this issue. However, the scaling law is slow to be introduced in "operational" geophysical modelling, notably for weather forecast as well as climate projection models.
The main purpose of this presentation is to ask why, and try to answer this question.
As a reference point, the presentation reviews the three major approaches for traditional subgrid parameterization: moment, PDF (probability density function), and mode decomposition. The moment expansion is a standard method for describing the subgrid-scale turbulent flows both in the atmosphere and the oceans. The PDF approach is intuitively appealing as it directly deals with a distribution of variables in subgrid scale in a more direct manner. The third category, originally proposed by Aubry et al (1988) in context of the wall boundary-layer turbulence, is specifically designed to represent coherencies in compact manner by a low–dimensional dynamical system. Their original proposal adopts the proper orthogonal decomposition (POD, or empirical orthogonal functions, EOF) as their mode-decomposition basis. However, the methodology can easily be generalized into any decomposition basis.
The mass-flux formulation that is currently adopted in majority of atmospheric models for parameterizing convection can also be considered a special case of the mode decomposition, adopting the segmentally-constant modes for the expansion basis.
The mode decomposition can, furthermore, be re-interpreted as a type of Galarkin approach for numerically modelling the subgrid-scale processes. Simple extrapolation of this re-interpretation further suggests us that the subgrid parameterization problem may be re-interpreted as a type of mesh-refinement problem in numerical modelling. We furthermore see a link between the subgrid parameterization and downscaling problems along this line.
The mode decomposition approach would also be the best framework for linking between the traditional parameterizations and the scaling perspectives. However, by seeing the link more clearly, we also see strength and weakness of introducing the scaling perspectives into parameterizations.
Any diagnosis under a mode decomposition would immediately reveal a power-law nature of the spectrum. However, exploiting this knowledge in operational parameterization would be a different story. It is symbolic to realize that POD studies have been focusing on representing the largest-scale coherency within a grid box under a high truncation. This problem is already hard enough.
Looking at differently, the scaling law is a very concise manner for characterizing many subgrid-scale variabilities in systems. We may even argue that the scaling law can provide almost complete subgrid-scale information in order to construct a parameterization, but with a major missing link: its amplitude must be specified by an additional condition. The condition called "closure" in the parameterization problem, and known to be a tough problem.
We should also realize that the studies of the scaling behavior tend to be statistical in the sense that it hardly provides complete information for constructing a parameterization: can we specify the coefficients of all the decomposition modes by a scaling law perfectly when the first few leading modes are specified?
Arguably, the renormalization group (RNG) is a very powerful tool for reducing a system with a scaling behavior into a low dimension, say, under an appropriate mode decomposition procedure. However, RNG is analytical tool: it is extremely hard to apply it to real complex geophysical systems.
It appears that it is still a long way to go for us before we can begin to exploit the scaling law in order to construct operational subgrid parameterizations in effective manner.