Parameter estimation for subgrid modeling in geophysical flows

Master of applied mathematics (Research) *(A PhD funding is foreseen)*

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Context

In turbulent geophysical flows, like in the ocean or the atmosphere, the action of unresolved scales on resolved scales must be modeled because a full representation of all the relevant scales is uncomputable with the available computational power. Numerical models therefore contain so-called subgrid-scale parameterizations to account for key processes too small to be resolved by the computational grid. An example of such subgrid-scale parameterization is the gradient model (e.g. Dubos, 2001) which has been recently reformulated as a linear combination into compressional, stretching and rotational effects (Balarac et al., 2013). Since the respective weights of these effects in the linear combination are unknown, the use of the gradient model requires parameter tuning to be usable for practical applications. The tuning of such unknown parameter values is generally either done using observations and/or high-resolution numerical simulations. This latter source of information is considered in the context of this work.

Objectives

In this internship we will consider the prediction of a two-dimensional scalar field transported by a turbulent flow analytically defined. The scalar field could represent the concentration of chemical species transported by winds or oceanic currents. First, the problem of finding the parameter values in the subgrid gradient model will be formulated as an optimization problem. An objective (a.k.a. cost or fitness) function will have to be defined, that quantify in some sense the proximity between a solution at coarse resolution and the high-resolution numerical experiments. Then, a numerical optimization procedure will be implemented in a black-box setting. We propose to consider two widely used stochastic optimization methods: the simulated annealing and the CMA-ES (e.g. Bartoli, 2001; Hansen, 2011) that will have to be tuned in an appropriate way. Finally, the performance and the results obtained with those two optimization techniques will be studied. Depending on the work progress, the deterministic gradient model could be then replaced by a stochastic subgrid model (e.g. Cooper & Zanna, 2015).

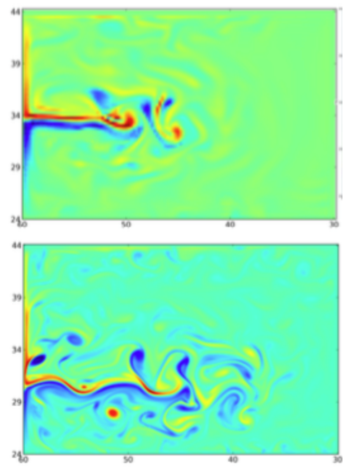

Figure 1 Vorticity from the NEMO ocean model in an idealized configuration. top: 25 km resolution; bottom: 8 km resolution

Prerequisites

- Knowledge of PDEs and optimization techniques
- Programming in Fortran and/or Matlab and/or Python

References

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