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Stochastic transport to quantify errors in geophysical fluid dynamic simulations

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Despite the increasing accuracy of geophysical flows observations and numerical simulations, full resolution is far beyond our current technological capacities. Progress will occur as measurements and simulations are optimally combined using a quantification of the error in these two information sources. Quantifying resolution-induced uncertainties remains a challenge in computational fluid dynamics. Thus, we propose to introduce stochasticity into the fluid dynamics equations. Properties of the fluid are transported by a combination of resolved and unresolved velocities. The latter is assumed to be random and uncorrelated in time but correlated in space. Two similar but independent approaches – location uncertainty (LU) and Stochastic Advection by Lie Transport (SALT) – have followed this path. The first conserves kinetic energy whereas the second conserves helicity and circulation. Both approaches rigorously brings multiplicative noises and turbulent dissipations into transport equations.

Several methods exist to specify the small-scale velocity statistics and thereby fully parametrize these random models. After presenting the LU and the SALT formalisms, the talk will numerically compare two tuning-free parametrizations: a data-driven heterogeneous one (Cotter et al. 2018) and a self-adaptive homogeneous one (an improvement of Resseguier et al., 2017). For a Surface Quasi-Geostrophic (SQG) flow, both parametrizations lead to similar and accurate uncertainty quantification. A non-stationary and heterogeneous modulation based on an important third-order moment – the energy flux – will also be discussed. In particular, this methods maintains sharp straight fronts while enabling eddies and meanders in more turbulent regions.

References:

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