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Inverting the quasi-geostrophic PV equation using a stochastic projection method under the uncertainty formulation of the static stability

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The quasi-geostrophic potential vorticity (PV) equation represents a (diagnostic) elliptic stochastic partial differential equation (SPDE). The stochasticity emerges from the uncertainty in the parameters such as the static stability or the PV itself. Hence, the solution, i.e. the streamfunction Ψ, is a random variable that has to be described by a probability distribution.

Here we present a stochastic solver for the stochastic quasi-geostrophic PV equation. The method regards uncertainty as generating a new dimension. The solution of Ψ within the new dimension is discretized using orthogonal polynomials of the random component, the so called polynomial chaos or Karhunen-Loeve expansion. The spatial dimensions are discretized by spherical harmonics on 10 vertical layers. The respective coefficients are obtained using a Galerkin approach. The solution leads to a coupled linear system in vertical layers and probability space for each spherical hamonic.

A general method to derive the distribution of the stochastic solution of Ψ is by Monte Carlo methods. However, Monte Carlo methods consume large resources of computer time. The stochastic projection method constitutes a much more efficient solver for the SPDE, at least for low dimensional systems. Results are presented for the noise induced drift. It is shown, that the solution strongy depends on how the stochasticity is formulated in the stochastic equations.