A Possibilistic Interpretation of Ensemble Predictions: Experiments on the Imperfect Lorenz 96 Model

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Ensemble forecasting has gained popularity in the field of numerical medium-range weather prediction as a means of handling the limitations inherent to predicting the behaviour of a high dimensional, nonlinear system, showing high sensitivity to initial conditions. Small strategical perturbations of the initial conditions, and in some cases, stochastic parameterization schemes of the atmosphere-ocean dynamical equations allow to sample the possible future scenari in a Monte Carlo-like approximation. Results are generally interpreted in a probabilistic way by fitting a probability density function to the ensemble of weather forecasts, using information from historical archives to optimize parameters.

These probabilistic forecasts are now used jointly with the traditional, deterministic, high-resolution prediction as a means of quantifying the uncertainty surrounding weather prediction. However, the probabilistic interpretation of ensemble forecasts is regularly criticized for not being reliable, especially for predicting extreme events [3]. This is due to the chaotic nature of the dynamics of the atmospheric system as well as the fact that ensemble of forecasts are not, in reality, produced in a probabilistic manner [1]. The development of extreme weather generally involves interactions between small-scale features of the atmosphere, that are strongly nonlinear. The evolution of such interactions is thus very sensitive to small errors, leading to poor performances of a probabilistic interpretation of ensemble forecasts in these cases.

To address these limitations, we propose here a novel approach: a possibilistic interpretation of ensemble predictions (EPS) for nonlinear dynamical systems. This approach takes inspiration from a fault mode effect analysis in a possibilistic framework, as developed in [2]. Here the 'effects' are the ensemble predictions and the 'fault' the corresponding actual weather scenario that has to be deduced from the 'effects' and some a priori possibilistic distributions of the expected effects generated by a given fault. The possibilistic distributions are tuned based upon a dynamical analysis of the information content of the EPS at hand and a probabilistic analysis of the EPS distribution over a training archive, used in a Bayesian manner.

Our approach is tested on a low-dimensional surrogate model of the atmospheric dynamics, the Lorenz 96 model (L96). We reproduce the methodology developed in [4] to produce ensemble predictions from an imperfect L96. Standard skill metrics and diagrams are computed to compare the performances (reliability, resolution and shadowing times) of our approach to those of a classical probabilistic interpretation. We analyse in particular the added-value of this possibilistic framework for the prediction of extreme events compared to a standard probabilistic approach.

References

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