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Offline parameter estimation using EnKF and maximum-likelihood error covariance estimates

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Parameterizations of physical processes represent an important source of uncertainty in climate models. These processes are governed by physical parameters and most of them are unknown and generally manually tuned. This subjective approach is excessively time demanding and gives inefficient results due to flow dependency of the parameters and potential correlations between each other. Moreover, in case of changes in horizontal resolution or parameterization scheme, the physical parameters need to be completely re-evaluated. To overcome these limitations, recent works proposed to estimate the physical parameters objectively using filtering and inverse techniques.

In this presentation, we investigate this way and propose a novel offline parameter estimation approach. More precisely, we build a nonlinear state-space model resolved into a EnKF (Ensemble Kalman Filter) framework where (i) the state of the system corresponds to the unknown physical parameters, (ii) the state evolution is driven as a Gaussian random walk, (iii) the observation operator is the physical process and (iv) observations are perturbed realizations of this physical process with a given set of physical parameters. Then, we use an iterative maximum-likelihood estimation of the error covariance matrices and the first guess or background state of the EnKF. Among the error covariance matrices, we estimate the one for the state equation (Q) and the observation equation (R) respectively to keep into account correlations between physical parameters and the flow dependency of the parameters. The proper estimation of covariances instead of arbitrarily prescribing them and estimate inflation factors ensures the convergence to the optimal physical parameters.

The proposed technique is implemented and used to estimate parameters from the subgrid-scale orography scheme implemented in the ECMWF (European Centre for Medium-Range Weather Forecasts) and LMDZ (Laboratoire de Météorologie Dynamique Zoom) models. Using a twin expriment, we demonstrate that our parameter estimation technique is relevant and outperforms the results with the classical EnKF implementation. Moreover, the technique is flexible and could be used in online physical parameter estimations.