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First step of data assimilation technique Parametric Kalman Filter adaptation to Space Weather

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Space weather is of interest to the satellite industry as the quantity of radiation can rapidly change in the Earth's radiation belts during solar events (called geomagnetic storms). Radiation belts dynamics are complex and modelled at ONERA by an advection-diffusion equation with added sources and losses terms: the Salammbô model. For several years, data assimilation has been used to reduce the uncertainties inherent to imprecise physics and numerical assumptions used in the Salammbô model alone. An Ensemble Kalman Filter has thus been developed and the overall process has been optimized from the physics-based point of view.

To improve the benefits of data assimilation and thus the accuracy of the prevision, we are considering the implementation of a Parametric Kalman Filter (PKF) [1,2,3]. We think it is a pertinent choice to reduce computational costs and use the information on the uncertainties dynamics brought by the evolution equation. The PKF also allows direct access to the variance and correlation length-scale within the domain, helping with uncertainty estimation. The prevision step of the PKF uses the dynamics of a system to yield the dynamics for a set of parameters (usually the variance and a local anisotropy tensor). These parameters are then used to approximate the covariance matrix coefficients used for the analysis and uncertainty estimation.

As mentioned above, the data assimilation technique currently used at ONERA is a slightly adapted Ensemble Kalman Filter (EnKF) which has mostly been used as a black box to merge the model prevision and the observations. In order to better understand uncertainties dynamics in the case of radiation belts, we run diagnostics on the ensemble to compute the PKF parameters and study their dynamics as propagated by the EnKF. This study shows encouraging results regarding the compatibility of the Salammbô model with the PKF.

Following the work of O.Pannekoucke in [1] and using SymPKF library [4], we find the dynamics of the parameters for a 1D heterogeneous diffusion equation resembling the equation governing the radiation belts. This test case allows for quick and easy study of particularities not covered in [1,2] such as boundary conditions handling with the PKF.

During my presentation I will introduce the PKF and the ensemble diagnostics with examples related to the Salammbô model. I will then compare the way we handle boundary conditions for the EnKF and the PKF.

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