Fast generation of prior for Bayesian estimation problems in fluid mechanics

Resseguier V.[1,2], Picard A. M. [1], Ladvig M. [1], Heitz, D.[2]
[1]Lab, SCALIAN DS, Rennes, FRANCE
[2]OPAALE, INRAE, Rennes, FRANCE

We are interested in real-time estimation and short-term forecasting of 3D fluid flows, using limited computational resources. This is possible through the coupling between data, numerical simulations and sparse fluid flow measurements. Here, the term data refers to numerical simulation outputs.
To achieve these ambitious goals, synthetic (i.e. simulated) data and intrusive surrogate models drastically reduce the problem dimensionality – typically from 10^7 to 10. Unfortunately, even with corrections, the accumulated errors of these surrogate models increase rapidly over time due to the chaotic and intermittent nature of fluid mechanics. Therefore, deterministic predictions are hardly possible outside the learning time interval. Data assimilation can alleviate these problems by (i) providing a set of simulations covering probable futures (without increasing the computational cost) and (ii) constraining these online simulations with measurements.
We addressed this Uncertainty Quantification (UQ) problem (i) with a multi-scale physically-based stochastic parameterization called "Location uncertainty models" (LUM) [1-3] and new statistical estimators based on stochastic calculus, signal processing and physics [3]. The deterministic ROM coefficients are obtained by a Galerkin projection whereas the correlations of the noises are estimated from the residual velocity, the physical model structure, and the evolution of the resolved modes. We solved problem (ii) with a particle filter [4].
Whether we consider UQ [3] or DA [4] applications, our method greatly exceeds the state of the art, for ROM degrees of freedom smaller than 10 and moderately turbulent 3D flows (Reynolds number up to 300).

[1] **Resseguier V.** & al. (2017a). Geophys. Astro. Fluid. https://hal.inria.fr/hal-01391420/document
[2] **Resseguier V.** & al. (2020a). Arch. Comput. Method. E., 1-82. https://hal.inria.fr/hal-02558016/document
[3] **Resseguier V.** & al. (2020b, accepted). SIAM/ASA J Uncert. Quantif. PDF (preprint)
[4] **Resseguier V.** & al. (2021, under review). *In J. Comp. Physics*. PDF (preprint)