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Investigation of Observation Quality on Variational Data Assimilation Methods

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Abstract

Data assimilation (DA) is a computational technique that statistically combines observational data with numerical simulations based on an underlying mathematical model to enhance prediction accuracy. A variational DA approach is described herein, with the overarching objective of investigating its predictive performance under various observational conditions. Variations in the observational data frequency, density, and uncertainty and their impact on the resulting DA predictions are all examined. The mathematical model considered here is the simplified one-dimesional partial-differential equation representative of more complex fluid dynamic transport descriptions: the one-dimensional scalar viscous Burgers' equation. The latter has been selected due to both its simplicity and well-posedness. Steady and unsteady solutions of Burgers' equation are considered with different DA objectives ranging from the optimization of initial conditions for unsteady solutions initial value problems to the optimization of boundary data in the case of solutions to boundary value problems. Beginning with arbitrary initial or boundary data, a perturbation is added to represent the inaccurate (un-assimilated) solution and the objective of the variational DA approach is then to retrieve the "exact" solution or truth based on observations that are synthetically added at some specified frequency, density, and uncertainty in terms of the desired exact solution. The present investigation provides insight into various observation-related factors affecting the robustness of variational DA algorithms. The latter will assist in future implementation of such DA methods, potentially reducing the level or amount of observational data required to achieve accurate predictions.