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## Exploring the Potential of History Matching for Land Surface Model Calibration

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With the growing complexity of land surface models used to represent the terrestrial part of wider Earth system models, the need for sophisticated and robust parameter optimisation techniques is paramount. Quantifying parameter uncertainty is essential for both model development and more accurate projections. History matching is an emerging technique in climate science for uncertainty quantification. Using Gaussian process emulators, history matching allows us to rule out parts of parameter space that lead to model outputs being inconsistent with observations. In this presentation, we assess the power of history matching by comparing results to variational data assimilation, commonly used in land surface models for parameter estimation. Although both approaches have different setups and goals, we can extract posterior parameter distributions from both methods and test the model-data fit of ensembles sampled from these distributions. Using a twin experiment, we test whether we can recover known parameter values. Through variational data assimilation, we closely match the observations. However, the known parameter values are not always contained in the posterior parameter distribution, highlighting the equifinality of the parameter space. In contrast, while more conservative, history matching still gives a reasonably good fit and provides more information about the model structure by allowing for non-Gaussian parameter distributions. Furthermore, the true parameters are contained in the posterior distributions. We then consider history matching's ability to ingest different metrics targeting different physical parts of the model, helping to reduce parameter space further and improve model-data fit. We find the best results when history matching is used with multiple metrics; not only is the model-data fit improved, but we also gain a deeper understanding of the model and how the different parameters constrain different parts of the seasonal cycle. We conclude by discussing the potential of history matching in future studies.