AGU-SEG Hydrogeophysics Workshop

The Prediction-Focused Approach: An Opportunity for Hydrogeophysical Data Integration in the Critical Zone

POSTER H-9 ABSTRACT #204227

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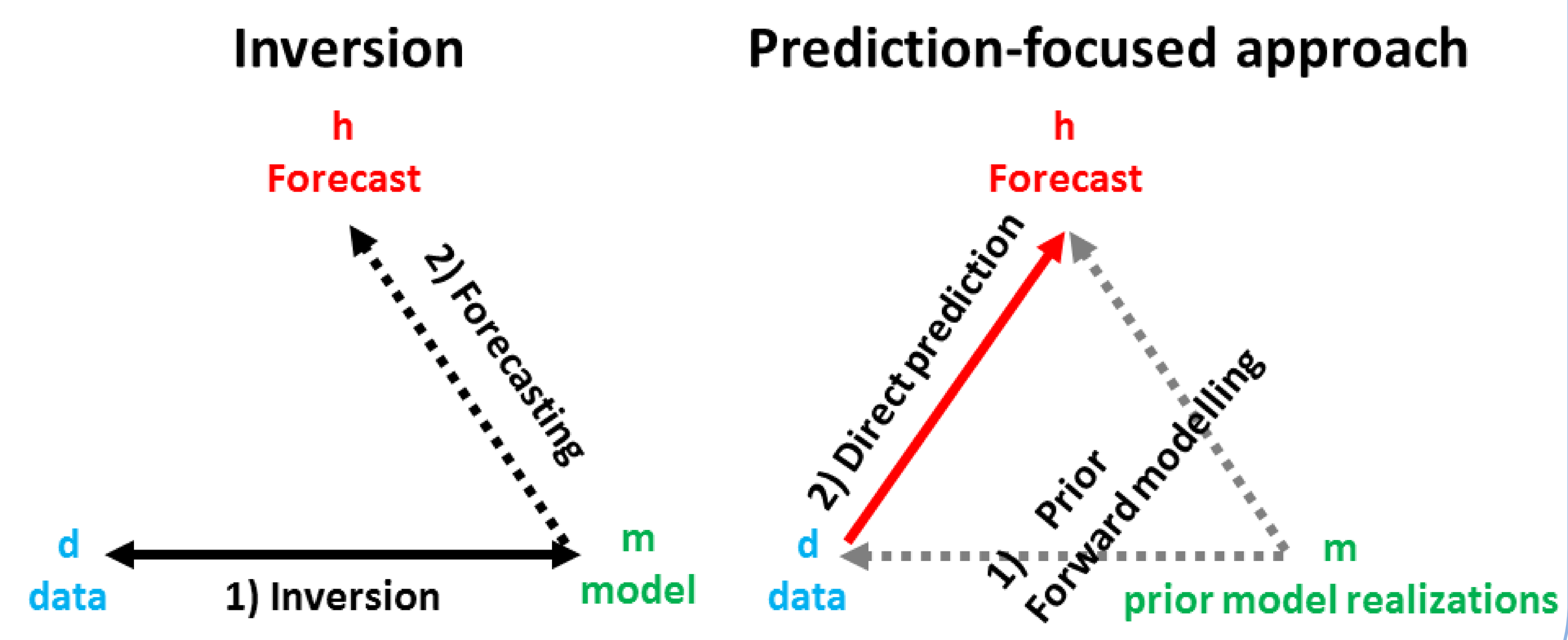
1. Changing the Paradigm : the Prediction-Focused Approach

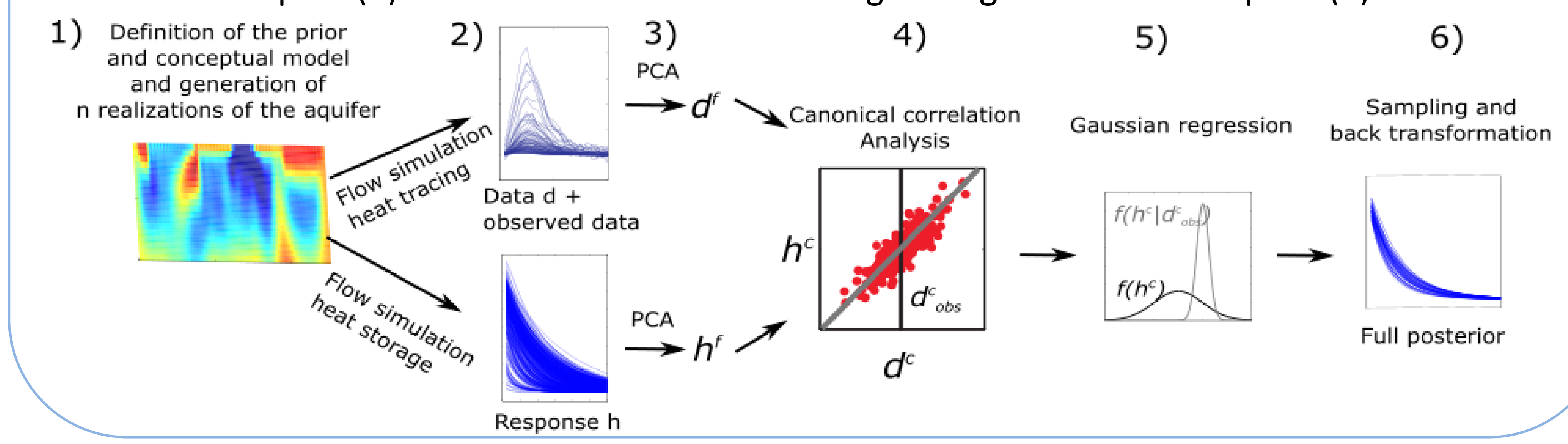
Two important challenges remain in hydrogeophysics: the inversion of geophysical data and their integration in quantitative subsurface models. Classical regularized inversion approaches suffer from spatially varying resolution and yield geologically unrealistic solutions, making their utilization for model calibration less consistent. Advanced techniques such as coupled inversion allow for a direct integration of geophysical data; but, they are difficult to apply in complex cases and remain computationally demanding to estimate uncertainty.

We investigate a prediction-focused approach (PFA) to directly estimate subsurface physical properties relevant in the critical zone from geophysical data, circumventing the need for classic inversions.

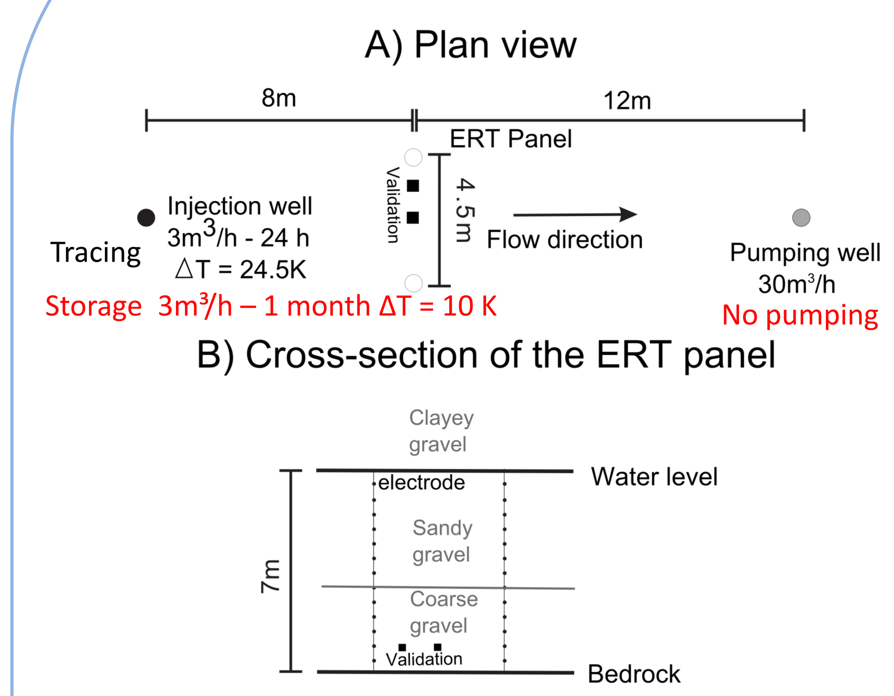


2. Relying on Prior Realizations

In PFA, a prior set of subsurface (synthetic) models (1) for which both data and forecast are computed (2) is used to derive a direct relationship between data and forecast, through dimension reduction techniques (3-4). The posterior distribution of the prediction given the observed data can then be sampled (5) and back transform in the original high dimensional space (6).



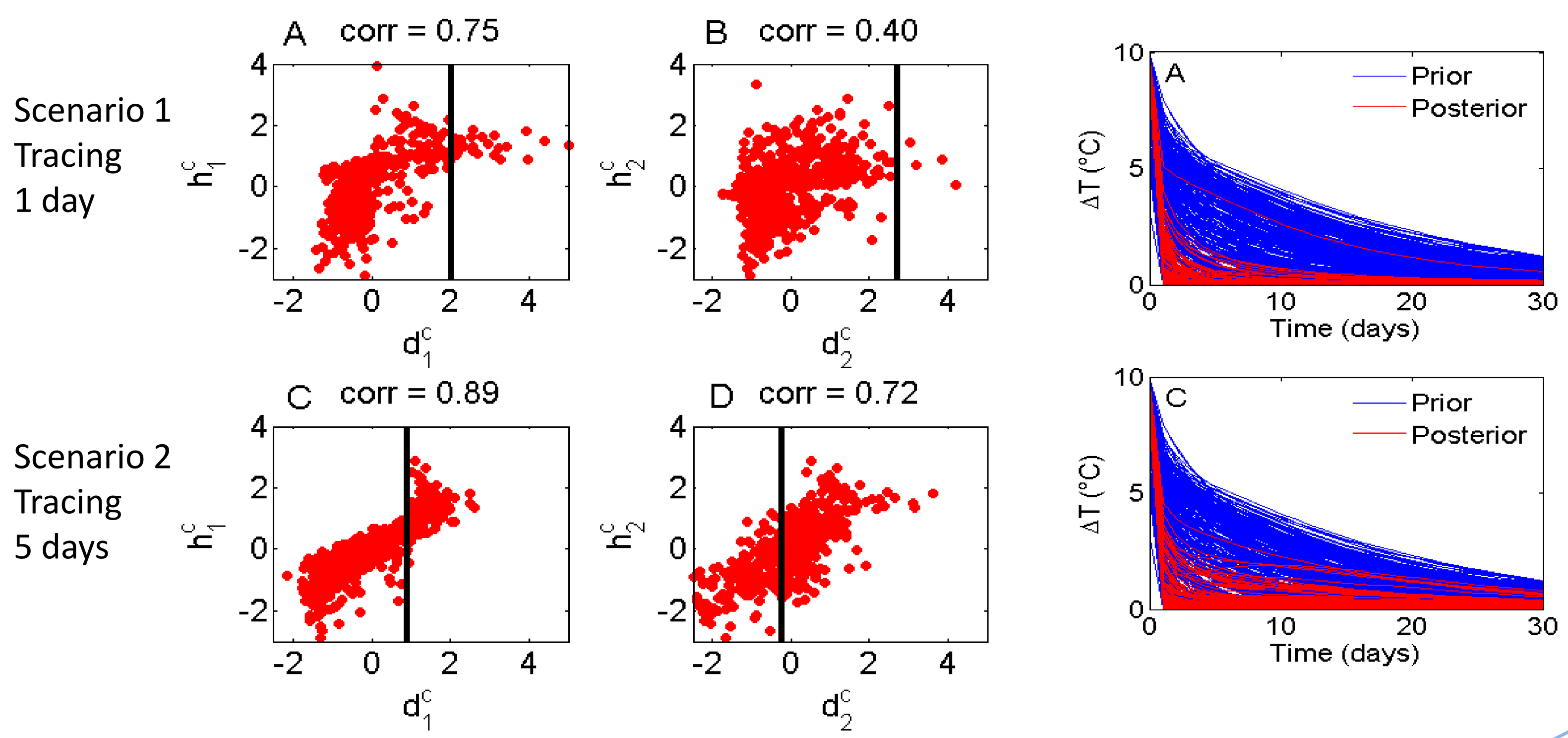
3. Forecasting heat storage from heat tracing experiments



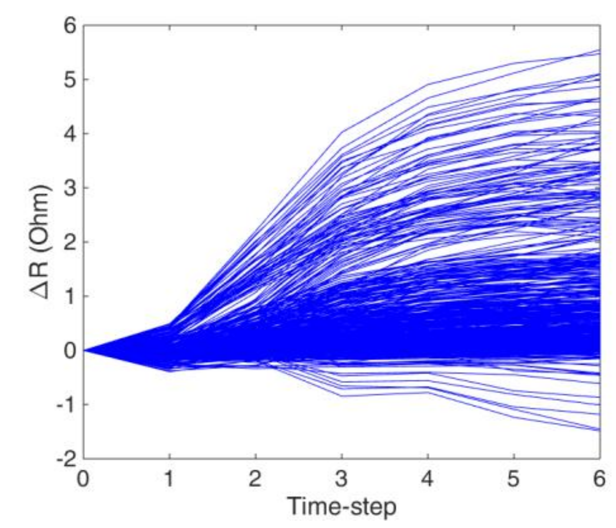
Parameters	Value
Mean of $\log_{10}$ K (m/s)	U[-4 -1]
Variance $\log_{10}$ K (m/s)	U[0.05 1.5]
Porosity	U[0.05 0.40]
Range (m)	U[1 10]
Anisotropy ratio	U[0.5 10]
Orientation	U[-π/4 -π/4]
Gradient (%)	U[0 0.167]
Other parameters	Fixed

The study site is modeled using 500 sequential Gaussian simulations with 7 uncertain parameters including spatial heterogeneity, hydrogeological parameters and boundary conditions. A sensitivity analysis shows that heat storage (1 month) is sensitive to the same parameters as heat tracing monitored using ERT (see 4.). Therefore, the latter can be used to directly forecast heat storage using the PFA approach after dimension reduction using principal component analysis and canonical correlation analysis.

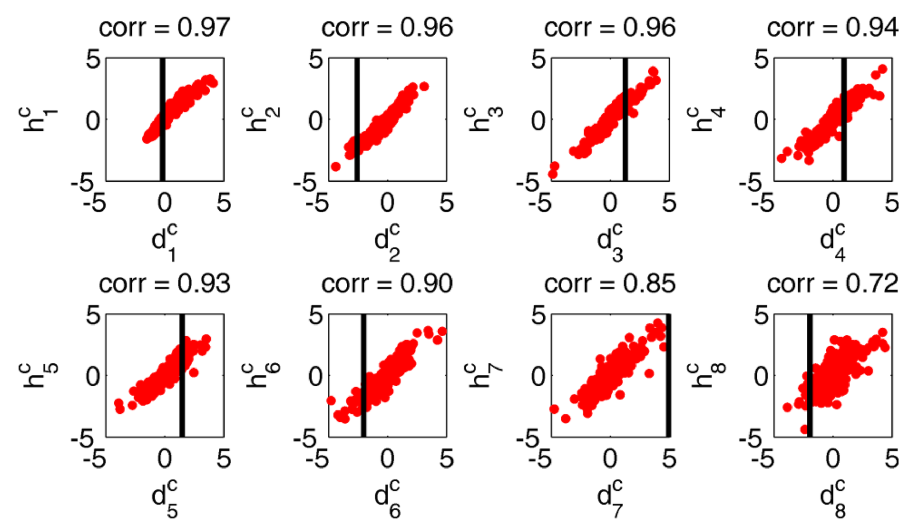
Results of dimensionality reduction using 10 dimension in the data (geophysical heat tracing) and 2 dimensions in the forecast. The linearized relationship is sampled through Gaussian regression to generate the red samples from the posterior distribution of heat storage in the aquifer. The use of heat tracing enables to drastically reduced the uncertainty compared to the prior (blue)

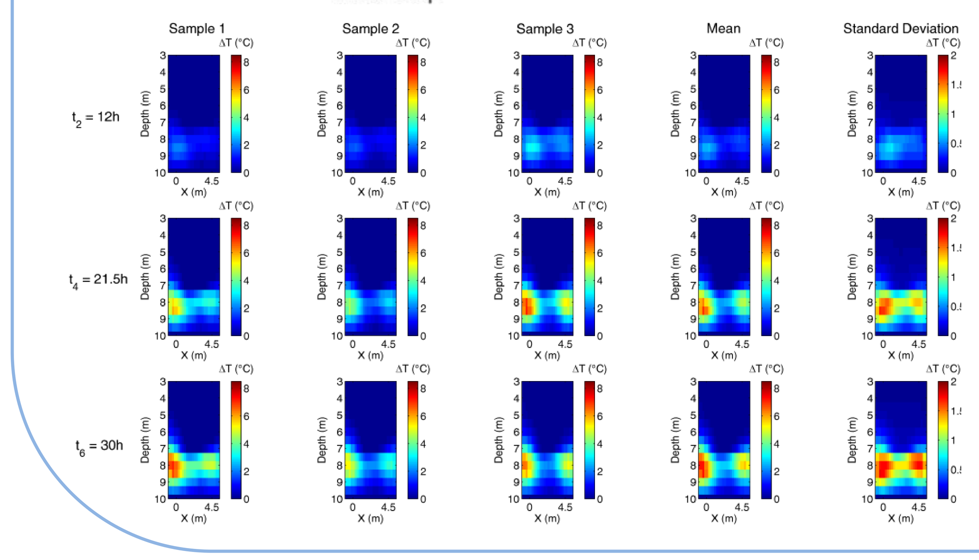


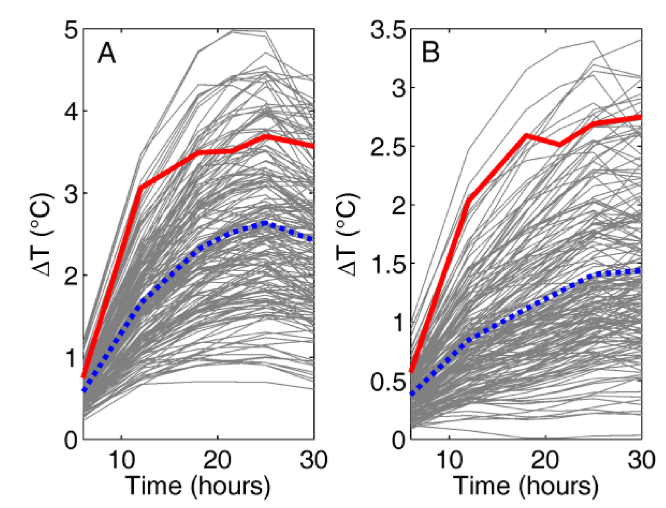
4. Forecasting Temperatures during heat tracing experiments from ERT



Cross-borehole ERT data are collected during the heat tracing experiment and change in electrical resistance are monitored. The simple linear relationship linking temperature and electrical conductivity is used to model geophysical data from groundwater transport simulations required by PFA.







ERT data are used to forecast the spatial distribution of temperature in the aquifer. The correlation is high since data and forecast are colocated. The posterior distribution of temperature is validated using direct measurements in piezometers within the ERT panel.

5. Conclusion et perspectives

- PFA offers a framework to quantify uncertainty if field study
- The method relies on independent prior realizations, it can be fully parallelized
- The definition of a prior consistent with the data is the most important step
- PFA can be used to predict the spatio-temporal distribution of physical properties from geophysics
- PFA can be used to predict future behavior of aquifers
- Future research will focus on the integration of various data types to reduce prediction uncertainty

Hermans et al. 2016. Direct prediction of spatially and temporally varying physical properties from time-lapse electrical resistance data. Water Resources Research, 52, 7262-7283.

Hermans et al. (submitted). Uncertainty quantification of medium-term heat storage from short-term geophysical experiments. Applied Energy.

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