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Model mismatch – a hidden and avoidable source of error in using indirect measurements to constrain hydrologic analyses

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Indirect measurement and monitoring methods have greatly enhanced our ability to image the subsurface and to characterize transient hydrologic processes. With their abilities to measure rapidly, inexpensively, nondestructively, and even remotely, these methods have had clear impacts on hydrologic investigations from the pore scale to the basin scale. Early efforts focused on adopting and adapting these tools for hydrologic applications, commonly from planetary, mineral, and petroleum exploration fields. The next stage in improving the accuracy of these methods was aimed at improving calibration relationships to better infer hydrologic properties from other, more easily measured quantities. The current cutting edge is examining the integration of these measurements into multiple-observation networks. Incorporation of indirect measurements into more rigorous hydrologic models will require improved understanding of the uncertainty of indirect measurements. Much of the work done in improving method calibrations can be revisited to describe inherent calibration uncertainties. However, little attention has been paid to errors due to the spatial averaging of indirect methods. Examples are shown for time domain reflectometry, electrical resistivity tomography, and gravity that demonstrate the errors that can be introduced when the underlying conceptual model of property distributions used to interpret instrument responses does not match the underlying conceptual model of physical property distributions in the hydrologic model. A straightforward solution to the problem is presented through the use of truly coupled instrument-response and hydrologic analyses.