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Knowledge, transparency, refutability, and consequences: Using models to evaluate geologic repositories

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Current knowledge of a geologic repository includes knowledge about data and their errors; knowledge about possible physical, chemical, and biological processes, and their interactions; knowledge about possible hydrologic and geologic frameworks; knowledge about past and future changes in system dynamics and characteristics; and knowledge about potential future development and use of the repository. Model development and analysis methods ideally integrate all of this knowledge, produce the transparency and refutability acknowledged as necessary to useful models of any environmental system; and provide clear understanding of consequences for the geologic repository, including quantification of uncertainty. Yet many model development and analysis methods fail to achieve this goal. For example, many methods fail to properly account for data error and spend many model runs exploring unrealistic error assumptions that are rarely clearly presented to modelers and model users. Many methods expend huge computer resources to address nearly pathologic model nonlinearities which are often programming and numerical artifacts that fail to represent the intended system behavior. Finally, many methods are unfamiliar to people using model results so that transparency and refutability is not achieved by those most in need of understanding likely consequences. This work suggests that ideas for including data error (including epistemic error) in model development and analysis, referred to as error-based weighting, and ideas about addressing nonlinearity, referred to as robust models, can be used to greatly improve model transparency and refutability, and achieve greater and more defensible long-term understanding of system dynamics and consequences for geologic repositories.

This talk will discuss error-based weighting and robust models, and outline a model development and analysis approach that uses 10s to 100s of model runs instead of the 1,000s to 100,000s of runs required by many other methods. Results suggest that the more computationally frugal methods can capture about 70% of the insight for 2% of the model runs. This rapidly obtained insight can be used directly and, if practical, to design clearly focused computationally demanding numerical analyses. Also, when one conceptual model can be analyzed relatively quickly, consideration of more alternative conceptual models becomes possible. This produces a more defensible uncertainty evaluation of simulated consequences, such as predictions. Here, we highlight analyses related to predictions, including confidence intervals. Also included are the OPR (Observation-PRediction) and PPR (Parameter-PRediction) statistics, precursors to the Predunc and Predvar statistics in PEST. These statistics all use the model to identify new measurements of state variables and system characteristics most important to reducing prediction uncertainty. Methods for evaluating what might be several future climate or development scenarios are briefly discussed. The examples demonstrate that the proposed set of methods provide a rich environment for evaluating many questions commonly of interest when developing and evaluating geologic repositories. Consistent use of these methods, along with other methods as practical, would serve to achieve greater transparency and refutability in the simulation of geologic repositories.