Bayesian Information-Gap (BIG) Decision Analysis Applied to a Geologic CO₂ Sequestration Problem

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**BIG UQ**
Bayesian-Information-Gap (BIG) Decision Analysis (DA) combines probabilistic Bayesian methods with non-probabilistic information-gap decision theory using a three-layered approach:

- Inner layer: information-gap to deal with model inadequacy (Here, this is related to the oversimplified physical model.)
- Middle layer: Bayesian analysis to deal with parametric uncertainties (Here, these are related to the location and resistivity of a leaky well.)
- Outer layer: information-gap to deal with uncertainty in the conditional distribution used in the Bayesian analysis (Here, these are related to the fact that the residuals are not a Gaussian white noise.)

Utilizing information-gap decision theory in the outer layer enables a robust decision analysis. The details are described in [1].

**HYDROGEOLOGICAL SETUP**

**SITES**
- Knowns
  - Hydrological parameters: permeability, aquifer thickness, specific storage
  - Injection parameters: injection rate, well geometry
- Unknowns
  - Leaky well parameters: location, resistivity
- Difference between two sites
  - Site 1 contains a leaky well with a lower resistivity than Site 2
  - Therefore, Site 2 is a better injection site

**ROBUSTNESS CURVES**

**OBSERVED DATA**

**PHYSICAL MODEL**
- Semi-analytical model for the setup described above [2]
- Predicts
  - Groundwater flow mixed with CO₂ from lower to upper aquifer
  - Pressure build-up in lower aquifer
  - Pressure build-up in upper aquifer
- Assumes
  - Uniform hydraulic parameters in the upper and lower aquifers
  - Leaky well is present
- Model inadequacy is considered within the BIG analysis

**DECISION SCENARIO**
- A site is to be chosen at which CO₂ will be injected in a deep aquifer
- Injecting at the site must not induce a high over-pressure in the host formation to avoid induced seismicity
- Injecting at the site must not induce a high over-pressure/flow into the overlying aquifer to avoid groundwater contamination
- A pumping test is performed at two locations to evaluate their suitability for CO₂ injection

**IMPLEMENTATION**
- Physical-model independent: easy to utilize new physical models
- Info-gap uncertainty-model independent: easy to utilize new info-gap uncertainty models
- Numerous MCMC samplers available for the Bayesian component
- Runs in parallel
- Implemented in Julia: fast and flexible
- Part of the MADS framework

**CONCLUSIONS**
- Probabilistic analyses are not able to adequately characterize uncertainty in every application
- Subsurface applications are a prime example due to manifold & severe uncertainties
- Combining Bayes theorem with information-gap decision theory provides a viable approach to dealing with uncertainty for these applications

**REFERENCES**