Reducing the Hydrologic and Geochemical Uncertainty for Modeling Uranium Migration at the Hanford 300 Area by Assimilating Multi-scale and Multi-type Data

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Background

Hanford IFRC Site

Source: PNNL-17034
Modeling Challenges - Uncertainties from various sources

- Hydrologic uncertainties
- Geochemical uncertainties
  - Initial uranium distribution
  - Surface complexation process models and parameters
  - River water intrusion
- Microbial uncertainties?
Experimental data

- Uranium desorption experiment at Hanford IFRC (March 2011)
  - Injection rate: 10 gpm
  - Injection duration: 353 hours
  - Injected concentrations:
    - U(VI) 6.2 μg/L, Cl⁻ 210 mg/L

Uranium released from smear zone at water table
Sequential data assimilation

Hydrologic data assimilation
Permeability

Geochemical data assimilation
Initial U(VI)

Tracer

Uranium

Time [Hours]
Bayesian data assimilation

- Method of Anchored Distributions (MAD) [Rubin et al., 2010, WRR]
- Ensemble Kalman Filter (EnKF) [Evensen, 1994, JGR; 2003, Ocean Dynamics]

Multi-Scale Multi-Type Data

Type A:
local, direct/regression
e.g., K, grain size, …

Type B:
Nonlocal, indirect
e.g., pumping test, tracer test, …

MAD/EnKF

Property Field

Parameters: Structural + Anchors
Prior Ensemble of K Field

2-D Transmissivity Inverted from Constant Injection Tests

Ensemble of 3-D K Field

(Murakami et al., 2011)
Iterative EnKF Updating

Prior

Forward Simulation (PFLOTRAN)

2-26

Simulated

Observed

Posterior
Results for Tracer Breakthrough

Prior

Iteration 1

Iteration 7

Simulated

Observation
logK Field

Prior

Iteration 1

Iteration 7
Geochemical Data Assimilation Results

Prior

Iteration 1

Iteration 3

Uniform Initial U
Geochemical Data Assimilation Results: Ensemble of 3D initial U

Prior

Iteration 1

Iteration 3
Next steps

- Study process model uncertainties
- Integrate more data into higher-elevation characterization, e.g., BEU data at the site

- Expand to field scale
Next steps

Spatial temporal abiotic variables: permeability, pH, redox state

Spatial temporal dynamics of microbial community

Data Assimilation

UQ

Observations

Hydro-geochemical modeling
Conclusions

- Migration of U(VI) plume at Hanford site is largely impacted by the flow dynamics and heterogeneous U(VI) sources.

- Characterizing hydrologic and geochemical uncertainties in complex system is one step closer to coupled modeling of hydrologic, geochemical, and microbiological processes.

- EnKF is efficient (~100s - 1000s of realizations) in assimilating both hydrologic and geochemical data for uncertainty reduction.

- High performance computing codes (i.e., PFLOTRAN) contribute to the success of implementing computationally intensive data assimilation techniques.

- The capabilities developed for characterizing spatial heterogeneity through statistical data assimilation is applicable to other areas, such as terrestrial ecosystem science.
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