Physics-Guided Active Learning for Complex Reactive Transport Modeling in Porous Media

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Résumé

Deep geological disposal is one of the main solutions considered for the long-term management of high-level radioactive waste. In France, the Cigéo Project aims to construct an underground repository (500 meters deep, area of 250km^2) on the city of Bure, chosen for its favorable geological properties (Callovo-Oxfordian clay formation), which are expected to prevent radioactivity migration by confining radionuclides. To ensure that the long-term radioactivity levels do not exceed those naturally present in the atmosphere, this project requires accurate predictions of reactive transport phenomena. The focus of this thesis is to precisely model reactive transport in porous media, taking into account diffusion, advection and chemical reactions in the soil. The limitations of the digital reactive transport simulator used at Andra (French national agency on nuclear waste management), in term of complexity and computational cost for solving large-scale and long-term problems, have motivated the exploration of more efficient alternatives, particulary physics-guided machine learning methods. Such approaches incorporate physics directly into the learning process, reducing data requirements and computational cost.

Mots-Clés: Model reduction, Statistical learning, Reactive transport, Gaussian process

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