Modeling under uncertainty of fluid flow and compaction processes at sedimentary basin scale

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ABSTRACT

Sedimentary basins occupy depressions of the Earth's crust where different materials deposit along geologic times. Numerical simulation of compaction processes in sedimentary basins is relevant to a number of fields, e.g. for the characterization of petroleum systems, or the understanding of large scale hydrologic behavior (e.g., compaction-driven flow or development of fluid overpressure). Modeling basin scale compaction requires to consider mechanical compaction due to the overburden of the deposited sediments. Geochemical processes (e.g., mineral precipitation/dissolution) may also heavily affect the effective properties of the system. Basin compaction takes place over large characteristic evolutionary scales (millions of years, Ma) and spatial dimensions (km). In this context direct measurements for the characterization of the key processes at the pertinent scale are typically scarce or if not lacking altogether, and therefore the boundary conditions and the model parameters are generally poorly constrained.
In this communication we present a suite of numerical tools which we developed to study the propagation of uncertainty from input parameters to key target outputs of basin compaction models, e.g. temperature, pressure and porosity vertical profiles. The methodology we employ relies on the construction of polynomial surrogate models in the form of generalized Polynomial Chaos Expansions (gPCE). These allow performing large number of model runs (typically required in uncertainty propagation and model calibration procedures) at reduced computational costs. Our work is grounded on preliminary results obtained for systems composed by a single geomaterial [1, 2]. We focus here on the extension of the methodology to realistic cases where different geomaterials are present. In this context, state variables and model parameters may displace severe variations across the interfaces between different lithological units, e.g. between shale and sandstone units. A key challenge in these conditions is that output variables are typically non-smooth (or discontinuous) functions of the model parameters. We present a numerical procedure which is designed to overcome this issue. We discuss the capabilities of our methodology through a number of numerical tests, which include numerical assessment on realistic synthetic cases, as well as interpretation of porosity and pressure distributions in real sedimentary basins.

REFERENCES

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