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Mechanistic emulation of numerical models

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Abstract: During the early part of the last century there was a fantastic effort in the development of analytical solutions for various scientific problems. This largely came to a halt for two reasons: (1) the easy problems had been solved, and (2) the development of more flexible numerical models on powerful computer platforms. More recently, the use of Monte Carlo simulation-based probabilistic analyses has led to a realisation that numerical models are often computationally too expensive for practical purposes. Consequently, there is an emerging effort to develop statistical emulating technology. Whilst such approaches provide statistically consistent results, there is a concern that the physical basis and understanding is lost. Instead, it is proposed that we should seek to mechanistically emulate our numerical models. The idea is to use numerical simulation to gain insights as to possible simplifying assumptions that ultimately lead to bespoke analytical solutions to the problems of concern. Three Earth Science related examples are presented leading to new analytical solutions for transient divergent flow and transport from aquifer emplaced injection well, toughness dominated near surface hydraulic fracture propagation and Joule-Thomson cooling due to CO₂ injection in depleted oil and gas reservoirs.

References:

- Mathias, SA 2010. Transient divergent flow and transport in an infinite anisotropic porous formation. *Ground Water* 48(3): 438-441.
- Mathias, SA, Fallah, AS & Louca, LA 2011. An approximate solution for toughness-dominated near-surface hydraulic fractures. *International Journal of Fracture* 168: 93-100.
- Mathias, SA, Gluyas, JG, Oldenburg, CM & Tsang, CF 2010. Analytical solution for Joule-Thomson cooling during CO₂ geo-sequestration in depleted oil and gas reservoirs. *International Journal of Greenhouse Gas Control* 4: 806-810.