Simulations and reduced order modeling of CO_2-cement systems

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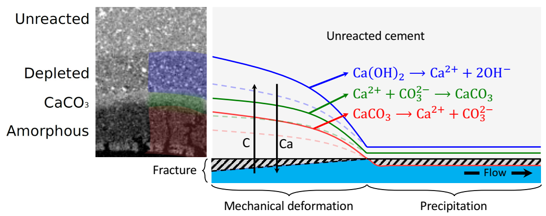
Cement and CO_2 Interactions

- Cement in damaged wells will be in contact with brine and CO_2.
- Reaction between cement and carbonated brine results in altered cement layers with different physical and chemical properties.
- Reactions can also result in calcite precipitation within the fracture.



Reaction front locations and fracture aperture reduction

Coupled chemical, mechanical, transport model

- **Two-phase flow model**
  - Mass balance for brine and CO_2.
  - Extension of Darcy's law to multiphase flow:

$$\boldsymbol{v}_i = -\frac{k k_{r,i}}{\mu_i}(\nabla p_i - \boldsymbol{g}\rho_i)$$

- **Reaction front model**
  - Transport between the fronts is via diffusion:

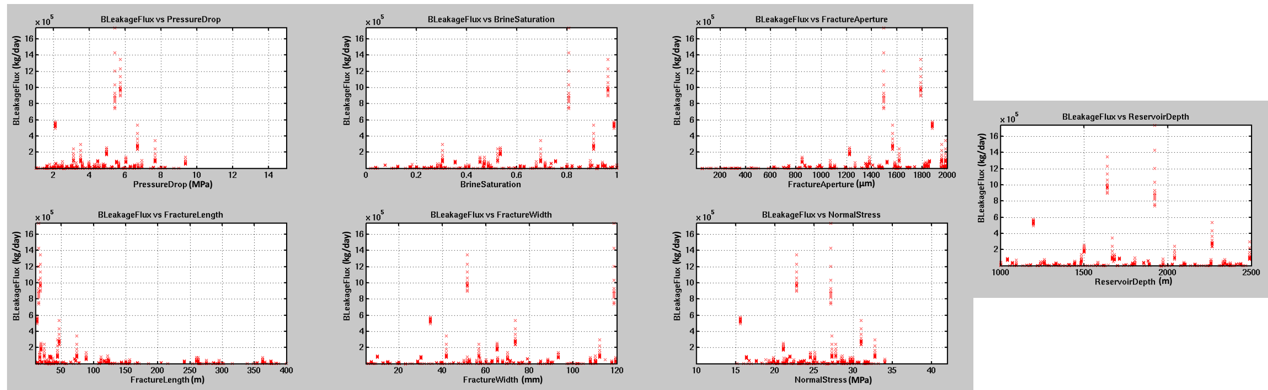
$$\frac{\partial}{\partial x}\left(D_{eff}\frac{\partial[\mathrm{E}]}{\partial x}\right) = 0.$$

  - Front movement is controlled by diffusion or reaction based on which phenomenon is slower:

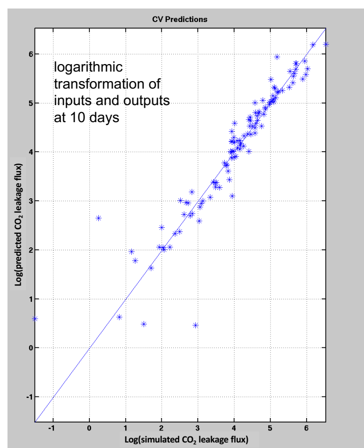
$$[[c_{\mathrm{E}}(1-\phi)]]v_{front} = -\left[\left[D_{eff}\frac{\partial[\mathrm{E}]}{\partial x}\right]\right] or - r_{\mathrm{E}}.$$

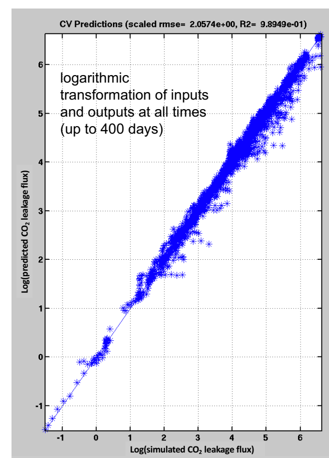
- **Mechanical model**
  - Altered cement has lower stiffness, which may also lead to fracture sealing. This is captured by coupling the mechanical response of the fracture to the extent of reaction.

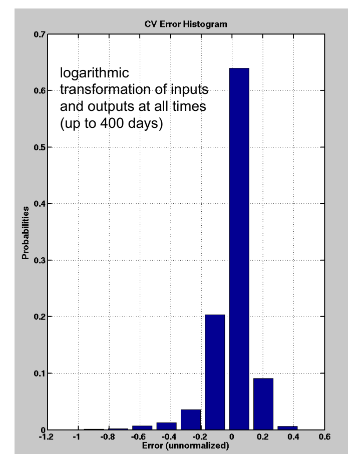
CO_2 and brine fluxes were calculated over a wide range of parameter space



Logarithmic inputs and outputs yield reduced order models that capture the simulated CO_2 fluxes







- Quasi-Newton sampling and multivariate adaptive regression splines are used to construct dynamic ROM for CO_2 leakage rate
- Our results suggest that, for dynamic ROM, temporal coordinate might need to be separated out from other inputs
- In the future work, we will compute ROM coefficients for each time step then construct ROM for these time-varying coefficients

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