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Control-Relevant Fast Proxy Modelling of CO_2 Storage Operation in Deep Saline Aquifers

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Given the many unknowns in the early phase of developing a CO_2 sequestration hub, parametric uncertainty analysis using full physics models for CO_2 storage operation is computationally expensive (e.g. Essen et al. 2013). In this work, we will focus on developing of control-relevant proxy models from spatio-temporal data of downhole pressure and temperature during 8 years of CO_2 storage operation at the Aquistore CCS site in Saskatchewan.

Aquistore is a research project with the aim to demonstrate that geological CO_2 storage in deep saline aquifer is a safe and practical solution to mitigate greenhouse gas (GHG) emissions at scale. Aquistore represents the geological storage component of the SaskPower's Boundary Dam Integrated CCS project (Rangriz Shokri et al. 2019; Movahedzadeh et al. 2021). CO_2 is captured form an adjacent coal fired power plant and transported through a pipeline either for enhanced oil recovery projects in the region, or in the absence of EOR demand, for CO_2 disposal into a deep saline aquifer. Since 2015, Aquistore has safely stored over 500 ktonnes of CO_2 (as of February 2023) through a 3.4 km deep injection well. There is one observation well, drilled 151 m away from the injector to monitor the arrival of CO_2; the observation well is now used to monitor the CO_2 plume pressure through a bubble tube system (Talman et al. 2022). The target formations for CO_2 injection are the clastic Deadwood and the Black Island sandstone member of the Winnipeg Formation. A primary seal of ~30 m thick shaly Icebox member of the Winnipeg Formation and a secondary seal of the Prairie Evaporite assure the geological containment of the injected CO_2 (Rostron et al. 2014; White et al. 2016).

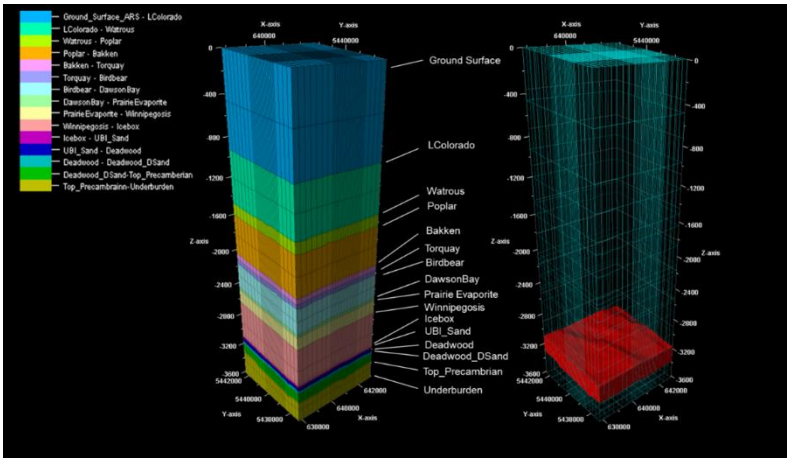

Figure 1: Aquistore's geological and mechanical earth models with description of formations (after Rangriz Shokri et al. 2019)

Aquistore's injection and observation wells are equipped with numerous monitoring technologies, including wellhead pressure and temperature sensors, permanently installed tubing- and casing-conveyed pressure and temperature gauges, and Distributed Temperature and Acoustic Sensing (DTS/DAS) strings along the length of both wells (Rangriz Shokri et al. 2021). Given the very limited number of current large-scale geological CO_2 storage projects, high tempo-spatial resolution monitoring of CO_2 injection, collected from multiple sensors at Aquistore, provides real field data to constrain and train full-physics and proxy models of CO_2 storage operation in deep hyper saline aquifers.

In order to test the applicability of fast proxy models for geological CO_2 storage, we initially built a coupled reservoir geomechanical model to history match the Aquistore injection history. The geological model includes permeability anisotropy and a lateral flow barrier in order to honor the observed directionality in the spread of CO_2 from time-lapse seismic surveys (White et al. 2021). Next, we formulated the proxy model for the pressure and temperature based on proper orthogonal decomposition (POD) and system identification (Chatterjee 2000; Narasingam et al. 2017); this enables visualization and forecasting of the entire pressure/temperature field variations using a set of basis vectors and time-varying coefficients.

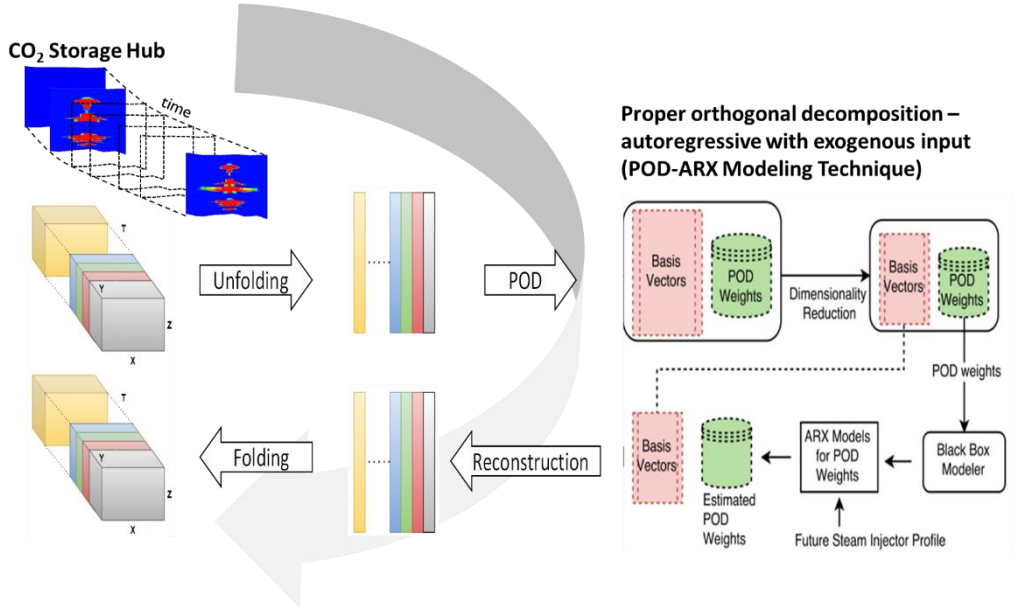

Figure 2: Reviewing and evaluating POD-based proxy model with the Aquistore CO_2 injection data

The POD-based proxy models will be used to estimate the well injection capacity and the CO_2 plume extension over the storage lifetime. The training and validation of POD-based proxy models include the injectivity performance of the storage and overlying caprock formations from Aquistore. The impacts of changes of injection temperature or injection rate will be also taken into account.

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