Geologic Carbon Storage of Anthropogenic CO2 in the Navajo Sandstone Formation under Castle Valley, Utah

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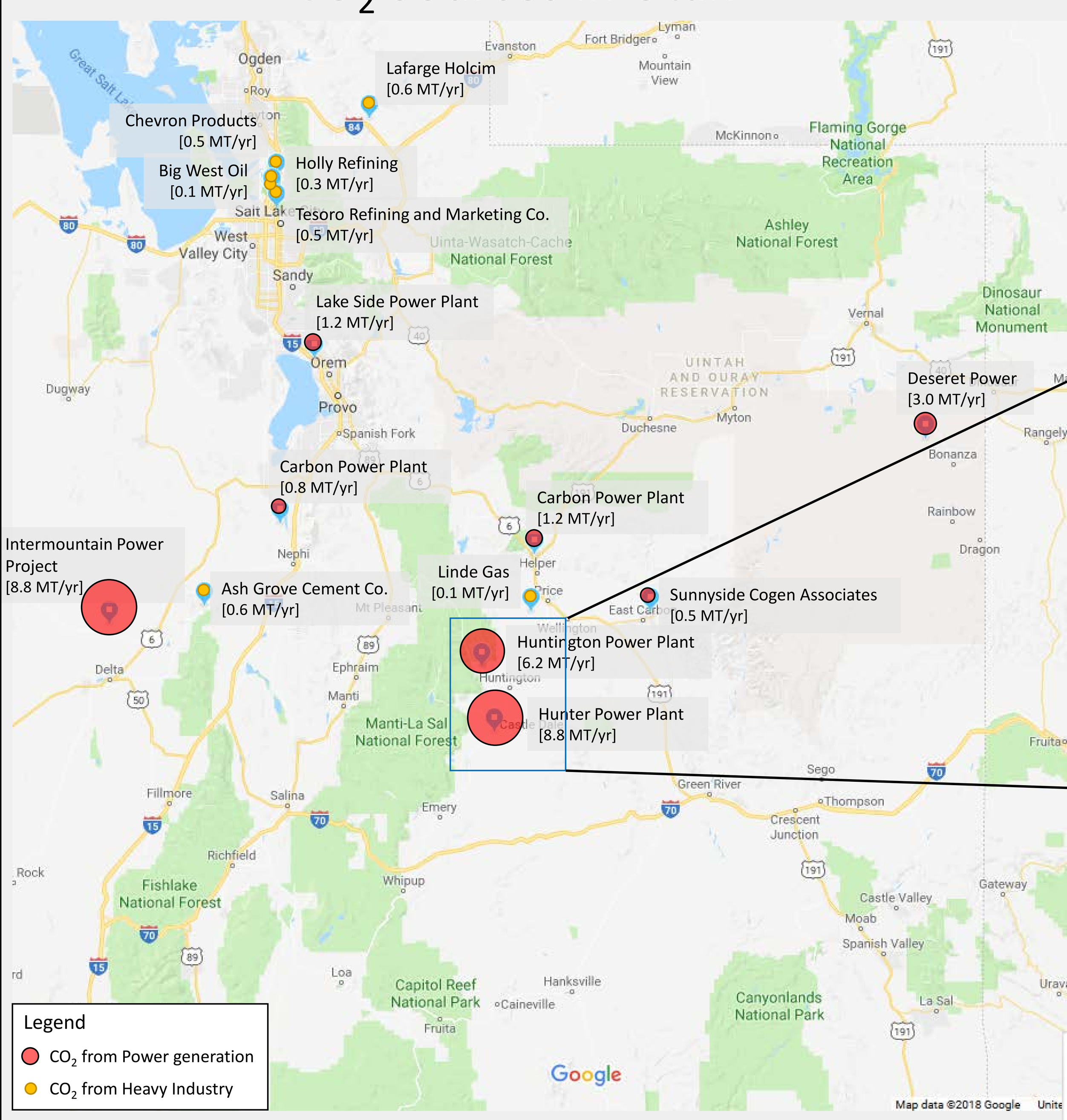
Abstract

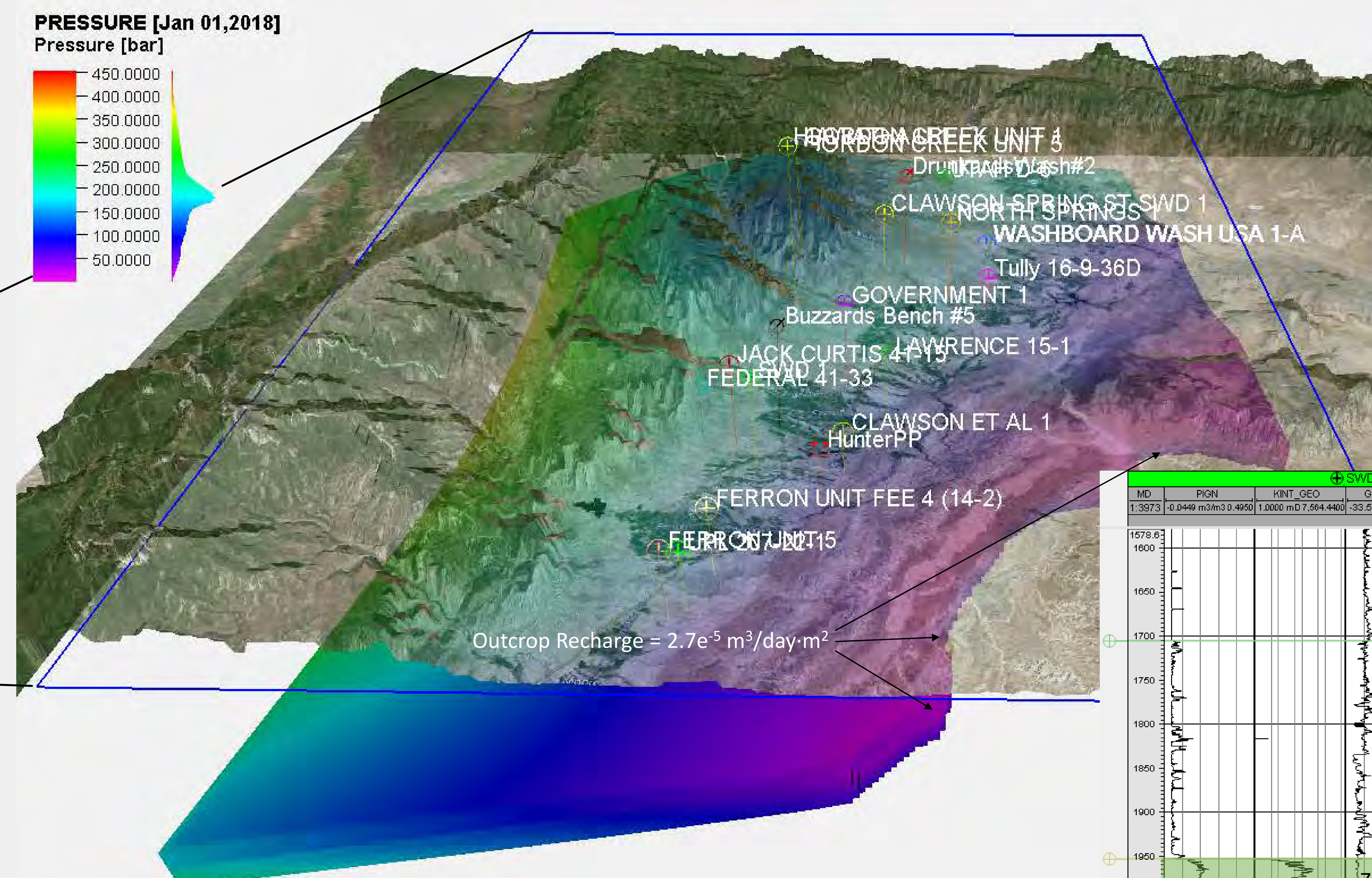
Geologic carbon storage (GCS) is a promising technology for storing large volumes of anthropomorphic CO_2 effectively and permanently. Numerical simulations are an integral part of site selection and characterization for any promising GCS site. In this study we simulate injection of CO_2 for geologic storage in the Navajo Sandstone Formation near Castle Valley, Utah, a promising storage complex for commercial-scale sequestration. Sources of CO_2 include five regional power plants along with CO_2 from heavy industries, like cement, steal, and petroleum refineries.

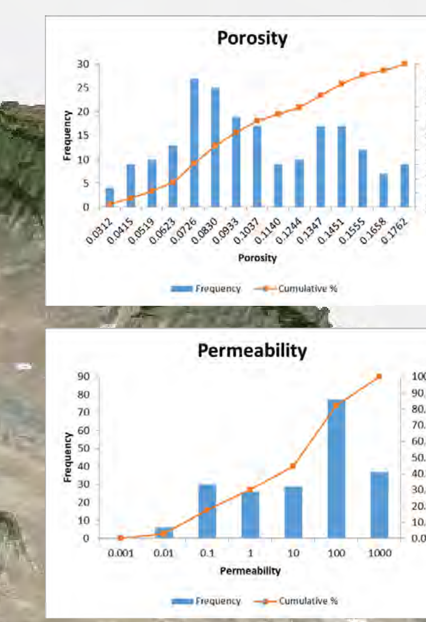
As part of the CarbonSAFE Rocky Mountains Phase I project a regional capacity analysis was undertaken. A geological model of the area encompassing Castle Valley, including the San Rafael Swell, is constructed from well tops, well logs, and outcrop data. Based on this geologic model, we develop a simulation grid that includes the Chinle Formation at the base, the Glen Canyon Formation consisting of the Wingate Sandstone, the Kayenta Formation, and our target injection formation the Navajo Sandstone, and the overlying Carmel Formation, a sealing layer. CO_2 was injected over a 100 year period to simulate future commercial-scale injection to store emissions from the regional sources. We simulated systematic reduction of power generation from coal by shutting down CO_2 sources (from the power plants) after 30 to 40 years of simulation time while maintaining emissions from the other heavy industries. Results indicate that this area has a capacity to securely store more than 1.4 billion tons of CO_2, suggesting the complex is an ideal commercial-scale GCS site. This material is based upon work supported by the Department of Energy under Award Number DE-FE0029280.

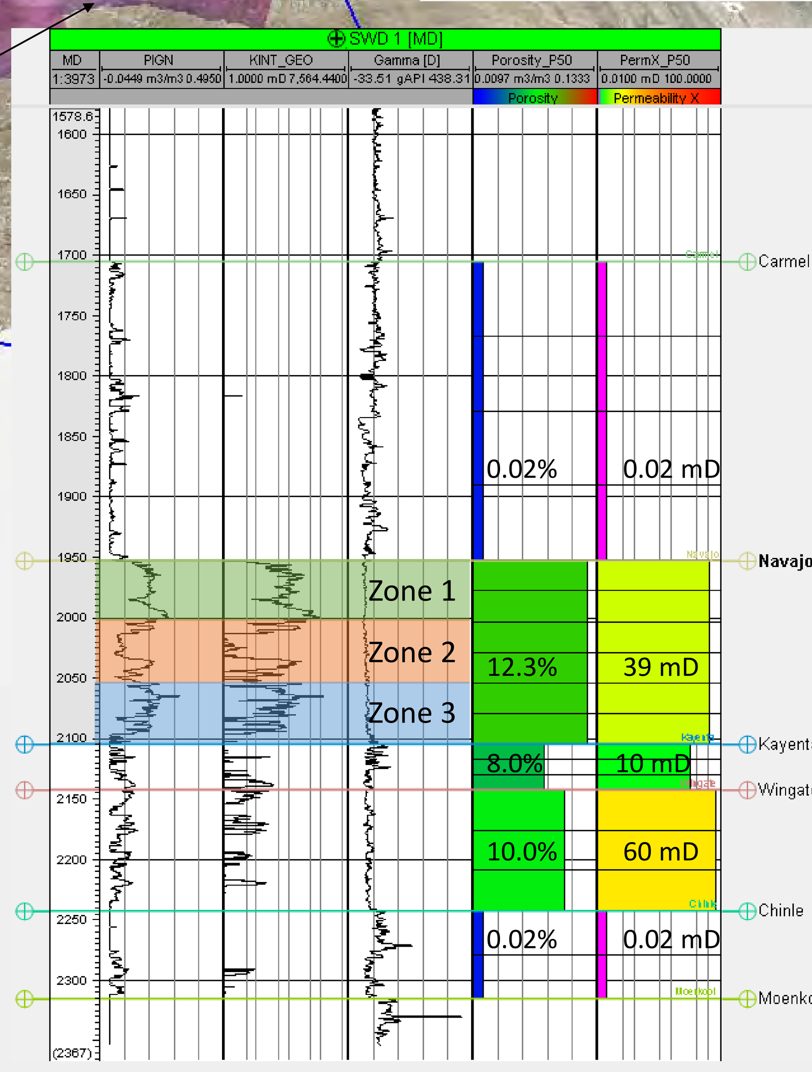
Regional Geologic Carbon Storage Model

CO_2 Sources in Utah



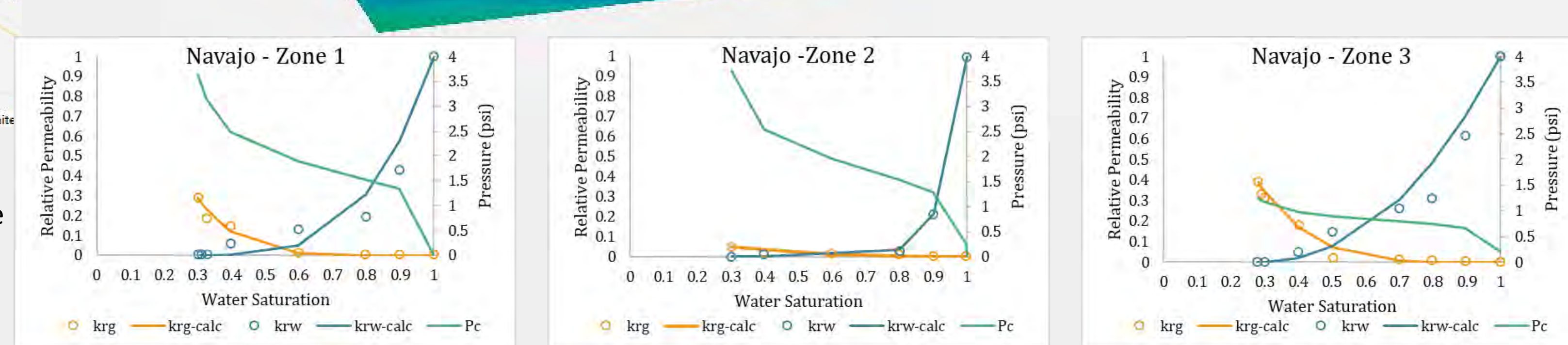






Boundary Conditions:

The lateral boundaries are infinite volume cells so that a constant head is maintained and the top and bottom boundaries are set to no flow. This mimics the regionally continuous nature of the Navajo Sandstone. The outcrop area is modeled as an aquifer recharge zone with a constant flux of 2.7e-5 m3/day·m2 of fresh water. Porosity and permeability data is from two wells about 45 miles southwest of Hunter (Wolverine Federal No. 17-2 and No. 17-3) and one of the salt water disposal wells (SWD #1). Porosity and permeability were also measured from outcrop samples taken from Buckhorn Wash in the San Rafael Swell area.



Relative permeability and capillary pressure relationships for each of the three zones identified in the Navajo Sandstone. The Wingate, Kayenta, Carmel, and Chinle formations were assigned generic relative permeability and capillary pressure curves due to lack of formation specific data.

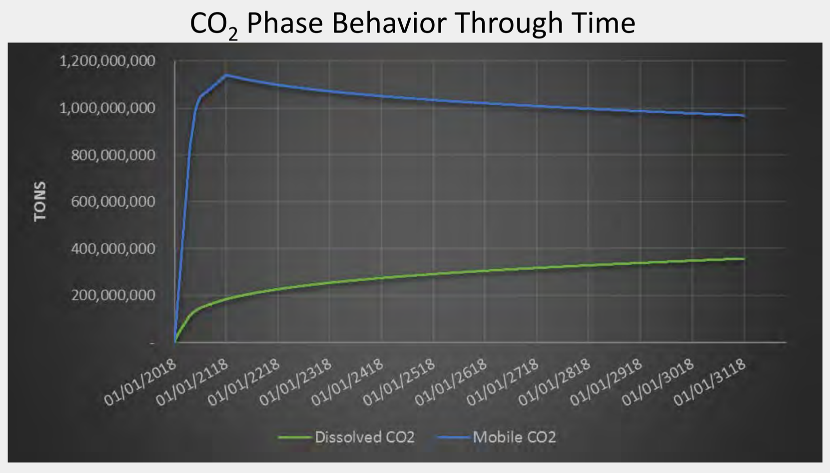
Results from 100 years of CO_2 injection

The goal of this study was to determine if there is sufficient capacity in the Castle Valley area of central Utah to store all of Utah's anthropogenic CO_2 emissions from power generation and heavy industry over the next 100 years. Results indicate that there is capacity for at least 1.4 billion tons of anthropogenic CO_2. We injected into 21 wells over 100 years starting at 33.5 MT/yr for the first 40 years (2018-2058) and then stepped down the injection rate as major point source emitters close, such as the Hunter and Huntington power plants. By year 2068 all emissions from power generation have been stopped and only 2.8 MT/yr of CO_2 injection from heavy industry continues for the next 50 years, until 2118. This is to model the conversion of our power sector from fossil fuels to renewables. By the end of the injection period about 13% of the CO_2 is dissolved in the formation brine, by the end of the simulation that has increased to about 25%, with about 5% trapped as residual gas. There is also very limited plume movement up dip towards the outcrop mainly because of the pressure 'dam' created by the aquifer recharge seen at the outcrop.

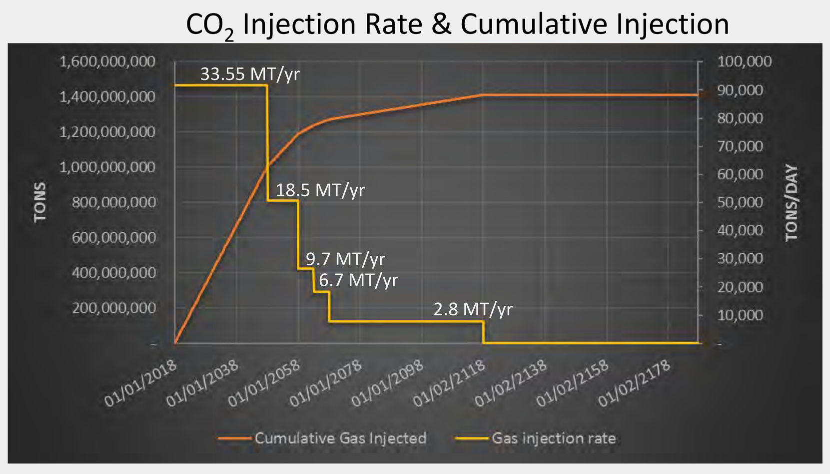
Total Mass CO_2 Injected [tons]	1,412,952,644
Total Mass Mobile Spercritical CO_2 [tons]	968,277,893
Total Mass Trapped Supercritical CO_2 [tons]	70,192,604
Total Mass Dissolved CO_2 [tons]	357,107,434

*all data is for the end of the simulation time (1000 yrs)

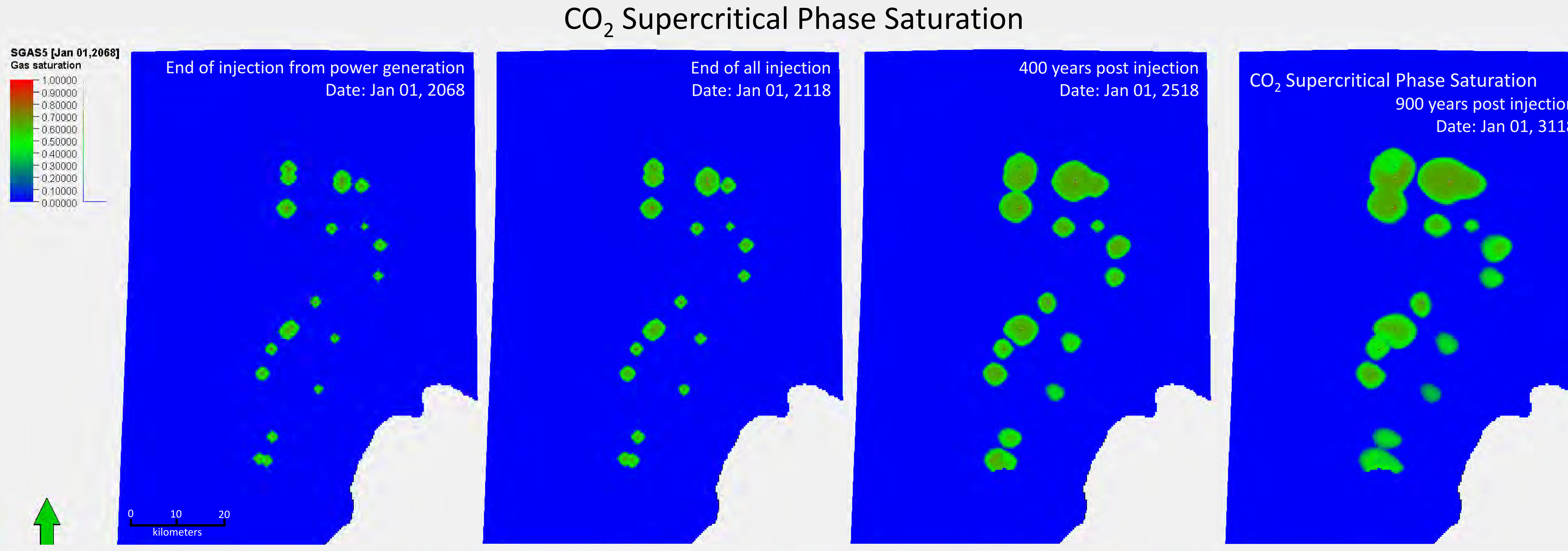
CO_2 Phase Behavior Through Time

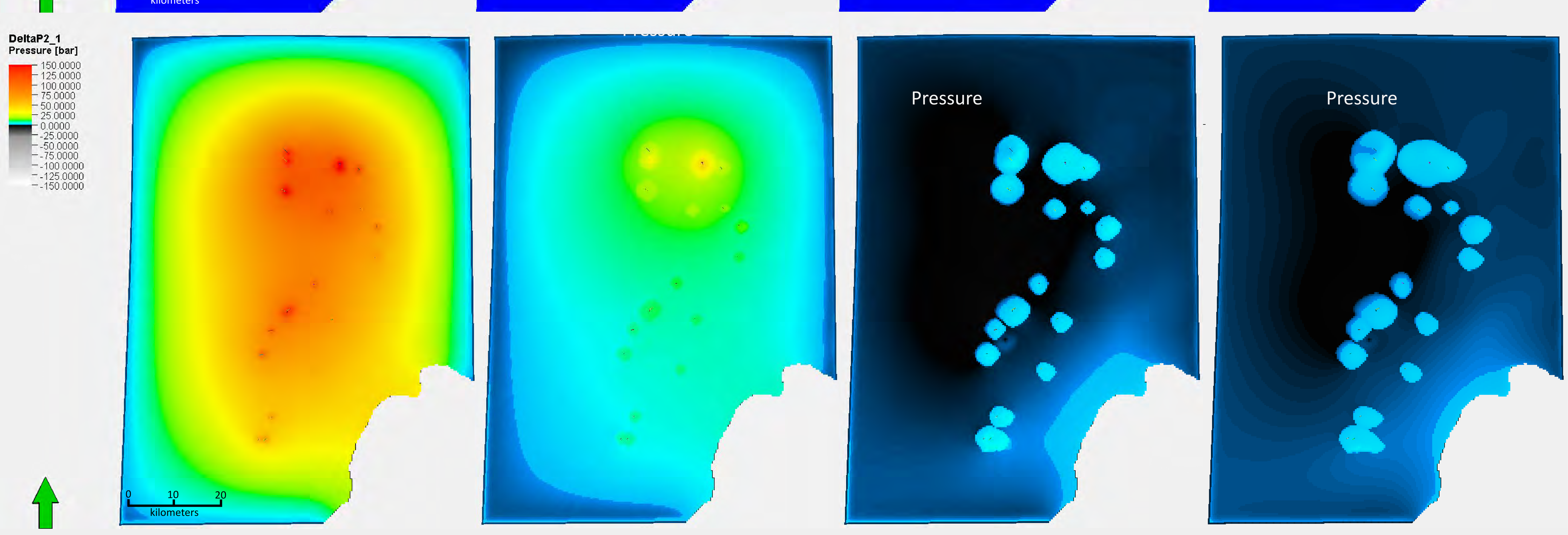


CO_2 Injection Rate & Cumulative Injection



CO_2 Supercritical Phase Saturation





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