Modeling the dispersion of accidental carbon dioxide leakage to the ocean

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Introduction

Carbon Capture and Storage (CCS) applied at sub-seabed geological reservoirs at oceanic basins has emerged as an additional relevant mechanism to reduce global warming and carbon dioxide (CO_2) atmospheric concentrations. Protection of CCS reservoirs are not well understood. CCS effectiveness is uncertain if CO_2 reaches the ocean accidentally. The last IPCC report (2014) asserts the urgency of implementing CCS if we want to reduce CO_2 atmospheric concentration, summing to further renewable energy investments and CO_2 emission reductions. Sub-seabed CCS can be an applicable, real and effective mechanism for reducing released CO_2 mainly by industry, which are responsible for the highest mundane CO_2 emissions. In theory, oceanic basin geological CO_2 storage should not bring impacts to the carbon balance, as CO_2 would be protected by carbonic hydrates at the upper-boundary geological depository and then this CO_2 would not reach the water column. However, environmental risks are taken and they need to be studied. We will mainly investigate CO_2 phase changes in this process. We will develop a model which simulates an accidental CO_2 leakage from sub-seabed to the ocean at Santos basin, Brazil, mainly considering the CO_2 dispersion (advection and diffusion) by the oceanic currents.

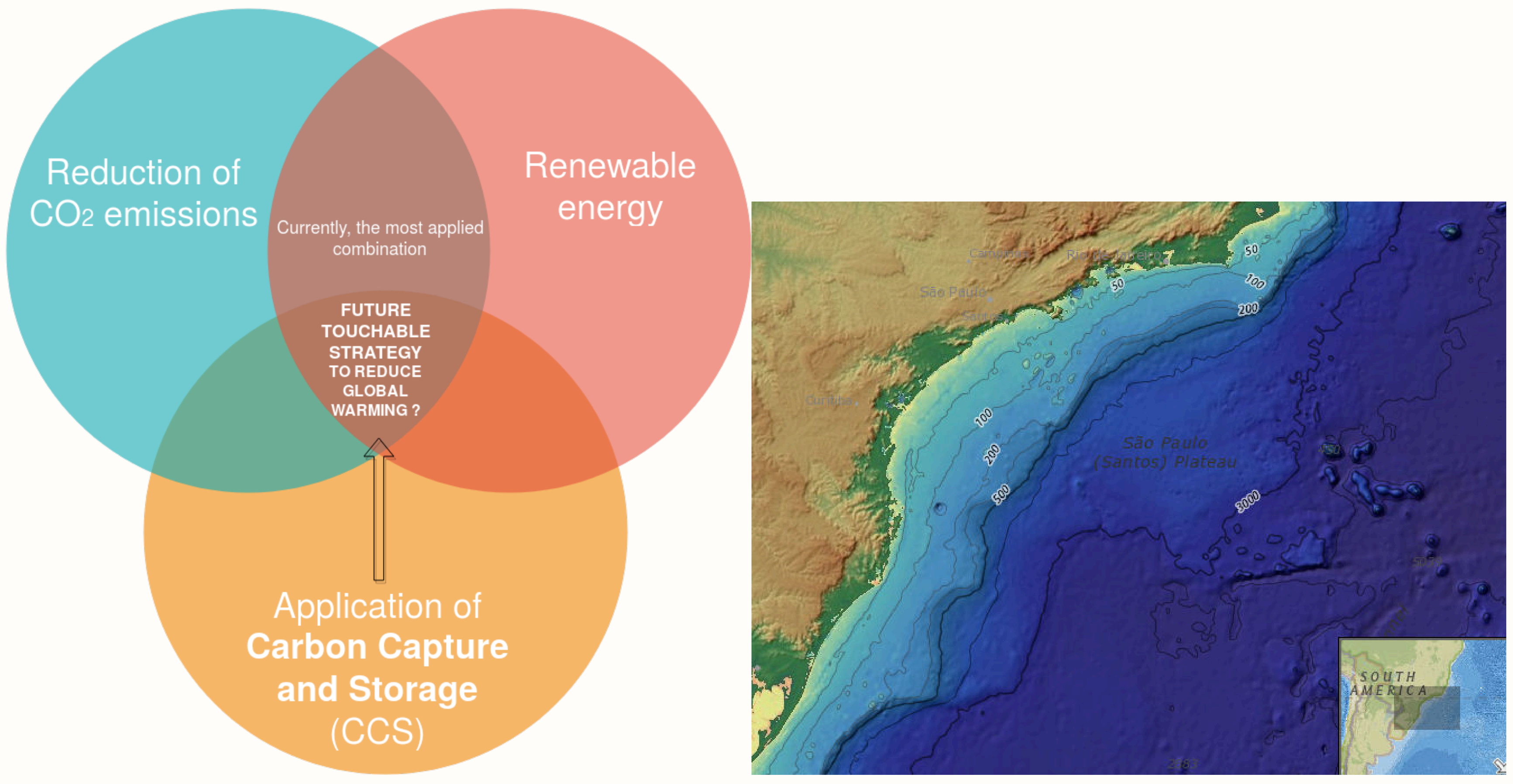

Figure 1: Paths for global warming reduction scheme (left) and map of the Santos Basin oil and gas producing region off the coast of Brazil (right). Source: NOAA (maps.ngdc.noaa.gov/viewers/bathymetry/)

CCS legislation does not exist in Brazil yet (Romeiro, 2014) showing that it is quite a new and promissor topic in Brazil. Our study area is the Santos basin oil producing region off the Brazilian coast. Due to the pre-salt discovery and for being one of the best places to store carbon dioxide in Brazil (Ketzer et al, 2015), we are encouraged to investigate sub-seabed CCS in this area.

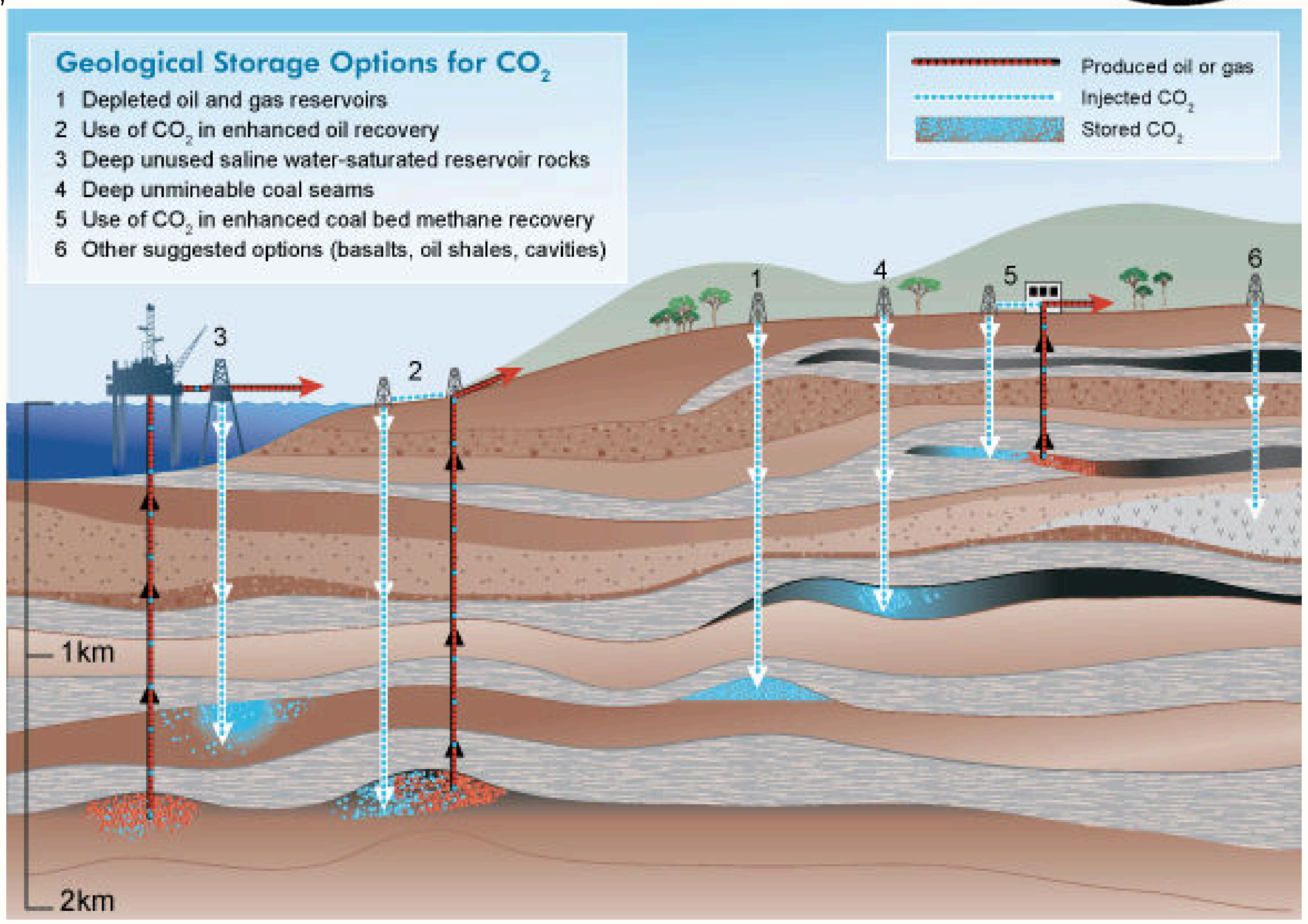

Figure 2: Geological CCS options: 1. Depleted oil and gas reservoirs. 2. Use of CO_2 in enhanced oil recovery. 3. Deep unused saline water-saturated reservoir rocks. 4. Deep unminerable coal seams. 5. Use of CO_2 in enhanced coal bed methane recovery. 6. Other options (basalts, oil shales, cavities). Source: CO2CRC (2015); Aminu et. al (2017).

Hypothesis and Objectives

The scientific hypothesis is that an accidental CO_2 leakage from the seafloor to the ocean will be dispersed by ocean currents, affecting not just local CO_2 concentration, but also far from the source in the ocean circulation. The Santos basin currents will transport rich-CO_2 waters, causing effects in terms of CO_2 concentration. Under this hypothesis, we aim to study CO_2 dispersion by oceanic currents and physical changes in the seawater. The specific objectives are:

- Investigate near and far-field processes that compass the CO_2 concentration changes from seafloor to the sea surface and what would be the CO_2 state (liquid or gas), during and after the leakage;
- Choose the appropriate methodology to simulate CO_2 evolution in the ocean and apply chosen methodology;
- Study CO_2 dispersion considering the advection and diffusion by oceanic currents, including temperature, salinity and pH changes.
- Study different cenarios of accidental CO_2 leakage, at different water depths (pressures), concentrations and state.

Methodology

We will implement a model which incorporates both near- and far-field processes. The model consists of two model domains: domains for smaller-scale non-hydrostatic (in other words, near-field) and for larger mesoscale hydrostatic (far-field) models.

Carbon Capture and Storage and processes background