Minimizing CO_2 leakage risk by storage in multi-layered geological settings

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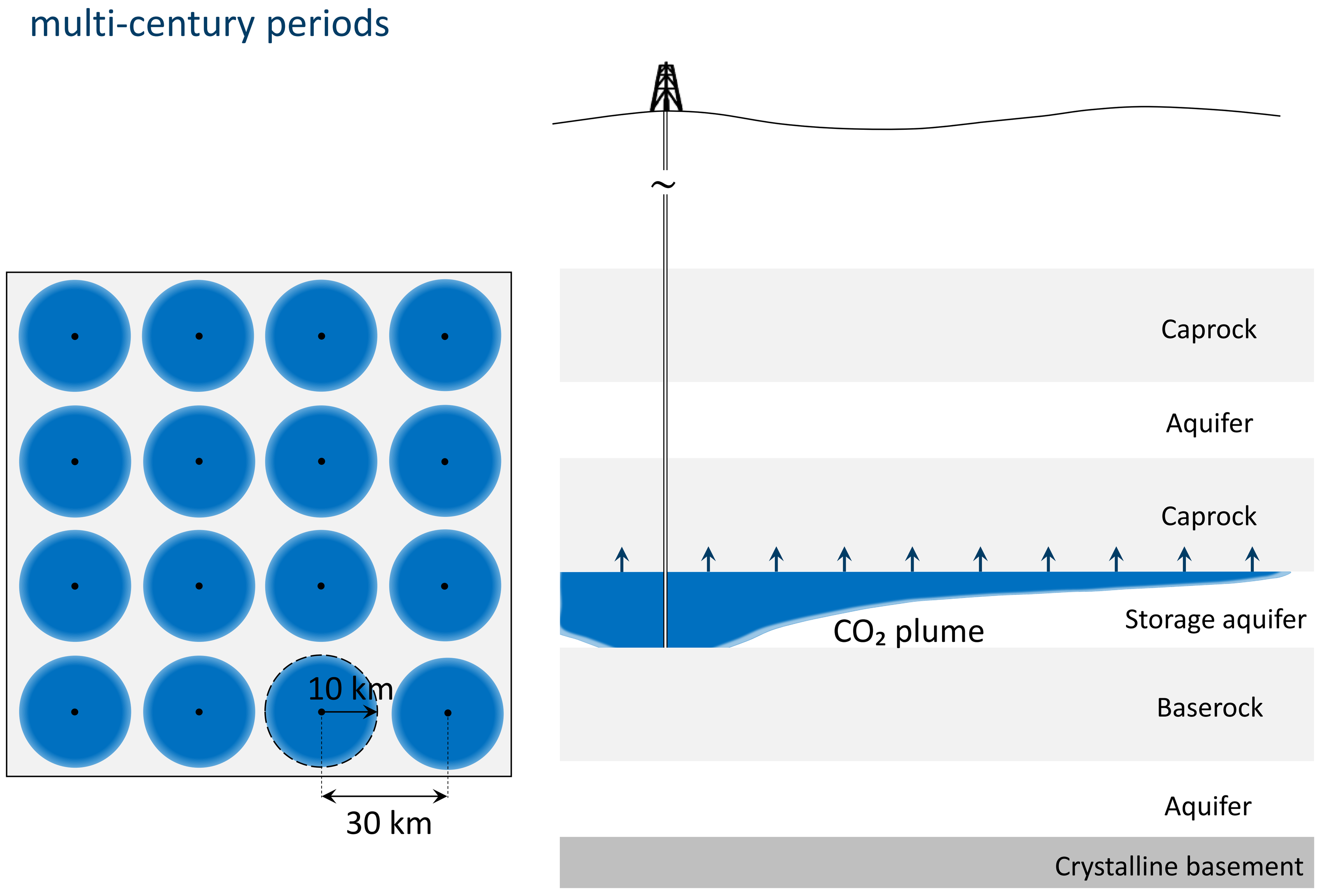
Abstract

Carbon capture and storage (CCS) in deep geological formations at the scale of gigatonnes per year is an integral component of any real-world solution to mitigate the climate change crisis. The safety and effectiveness of CCS require that the injected CO_2 permanently resides underground. Herein, we present a computationally efficient, physically-sound numerical model to constrain the CO_2 leakage risk following basin-wide injections and over geological time scales (millions of years), much longer than any assessments performed so far. Simulation results show that the geological setting imposes a primary control on the CO_2 leakage potential. A repetitive layering of aquifers and sealing rocks will significantly hamper CO_2 migration toward the surface, ensuring a secure road toward achieving climate targets.

Introduction

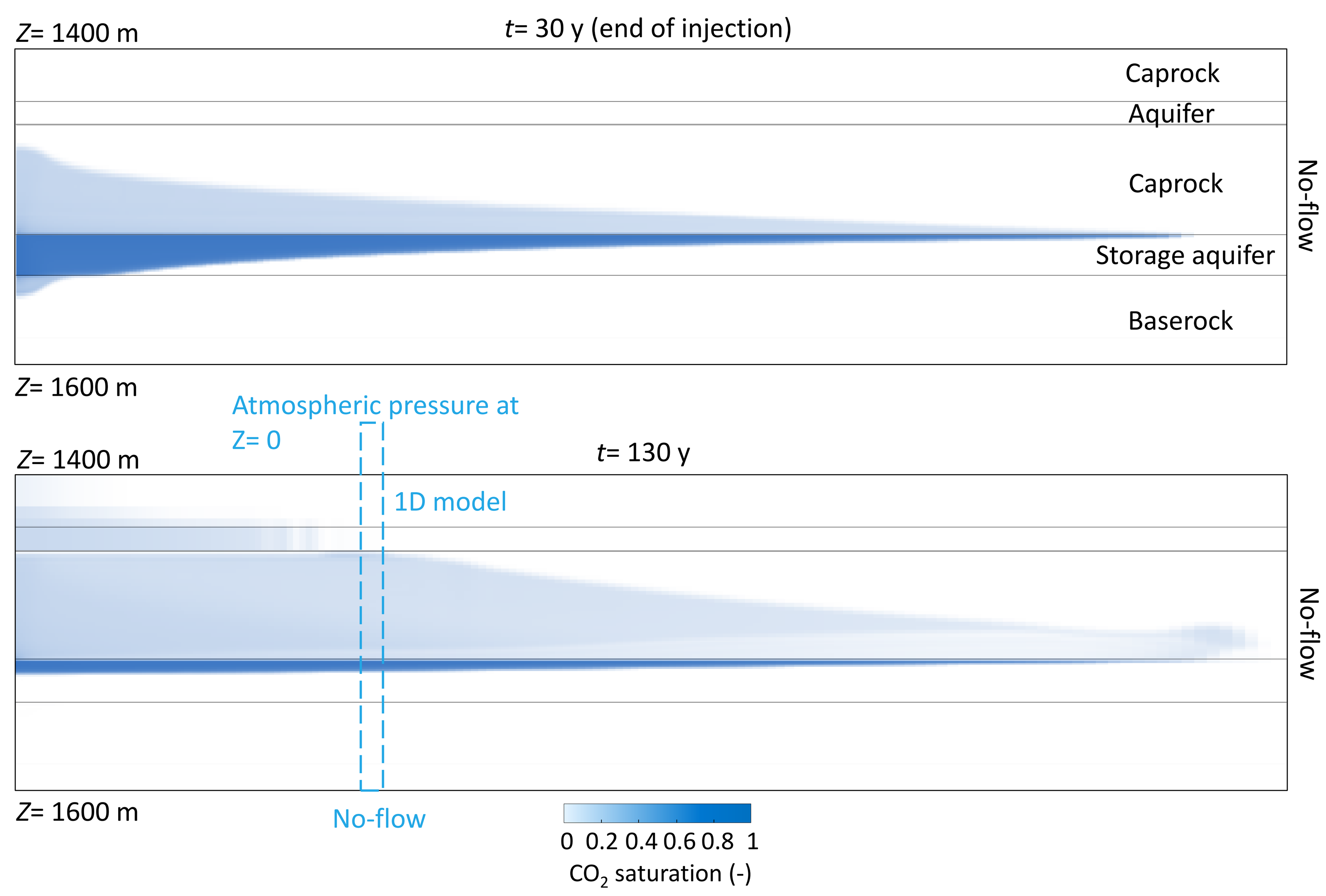
Assessment of the effectiveness of large-scale CCS requires basin-scale numerical simulations of subsurface CO_2 flow and transport through rock layers toward the surface. Such simulations are computationally demanding, limiting the existing estimates of the CO_2 leakage potential to multi-century periods



Dense grids of wellbores are required to achieve Gt scale injection rates

Numerical models

Once injection stops, the lateral CO_2 movement slows down and the plume reshapes vertically by buoyancy. A 1D model of CO_2 flow and transport can well capture dynamics of upward CO_2 migration in the long term. We simulate vertical CO_2 migration through geological layers for 1 million year.

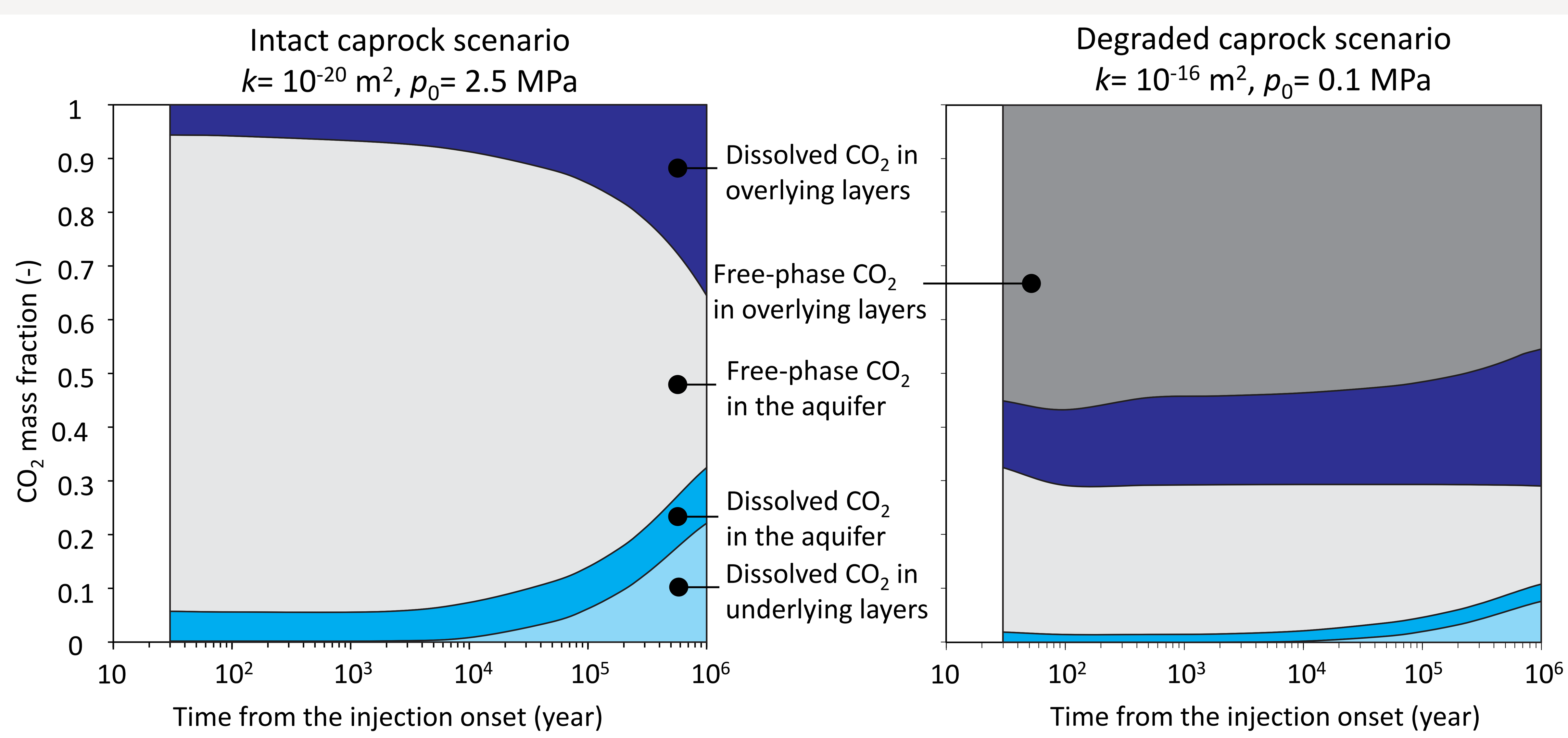


1D model allows us to address basin-wide CO_2 leakage at affordable computational costs

Results

If caprocks are intact (low permeability and high capillary entry pressure), CO_2 migration out of the storage aquifer will be dominated by molecular diffusion, which is an intrinsically slow transport process. Growing amounts of CO_2 dissolves in water with time and are safely trapped deep underground.

If caprocks are degraded (high permeability and low capillary entry pressure), the low capillarity allows CO_2 leakage in free phase into overlying formations. New CO_2 traps could form below secondary caprocks that keep CO_2 far from the surface.



A combination of secondary traps and dissolution contain CO_2 deep underground over geological time scales

Conclusions

- A sequence of caprocks and aquifers, even if the caprocks are pervasively fractured, should allow for secure containment of gigatonnes of CO_2 in the subsurface over geological time scales.
- Accurate characterization and continuous monitoring of the subsurface holds the key for secure geologic CO_2 storage.

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