Thermal Modelling of Intermediate CO_2 Storage in Crystalline Bedrock

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Introduction

- If shipping is used for the transportation of CO_2, the CCS chain requires intermediate storage.
- The Finnish bedrock is not suitable for the permanent storage of CO_2, however, it could be utilized as an intermediate storage medium.
- In this work we investigated the thermal effects of the storage of liquid CO_2 (−40 °C) in a crystalline rock environment.
- The storage of cold CO_2 creates an expanding frozen zone around the store which acts as a seal preventing leakage.

Modelling and simulations

- To simulate the thermal effects of the storage of cold CO_2 in warm bedrock (+7…+10 °C), we used Finite Element modelling to solve the heat equation

$$\rho \cdot C_p \cdot \frac{\partial T}{\partial t} = \nabla \cdot (\lambda \cdot \nabla T) + Q_{\mathrm{radiogenic}}$$

- Groundwater was assumed to remain immobile but latent heat release and absorption was taken into account.
- The storage of cold CO_2 in warm bedrock creates a large temperature gradient between the store and bedrock. This effect was considered by using two storage scenarios:
  1. Storage of CO_2 directly in warm bedrock.
  2. Storage of CO_2 in bedrock after an initial cooling period which was used to cool the store walls to −40 °C.
- Two store geometries (single and dual cavern; see Figure 1) and three store depths (50, 100 and 200 m) were modelled.
- Storage was simulated 100 years into the future.

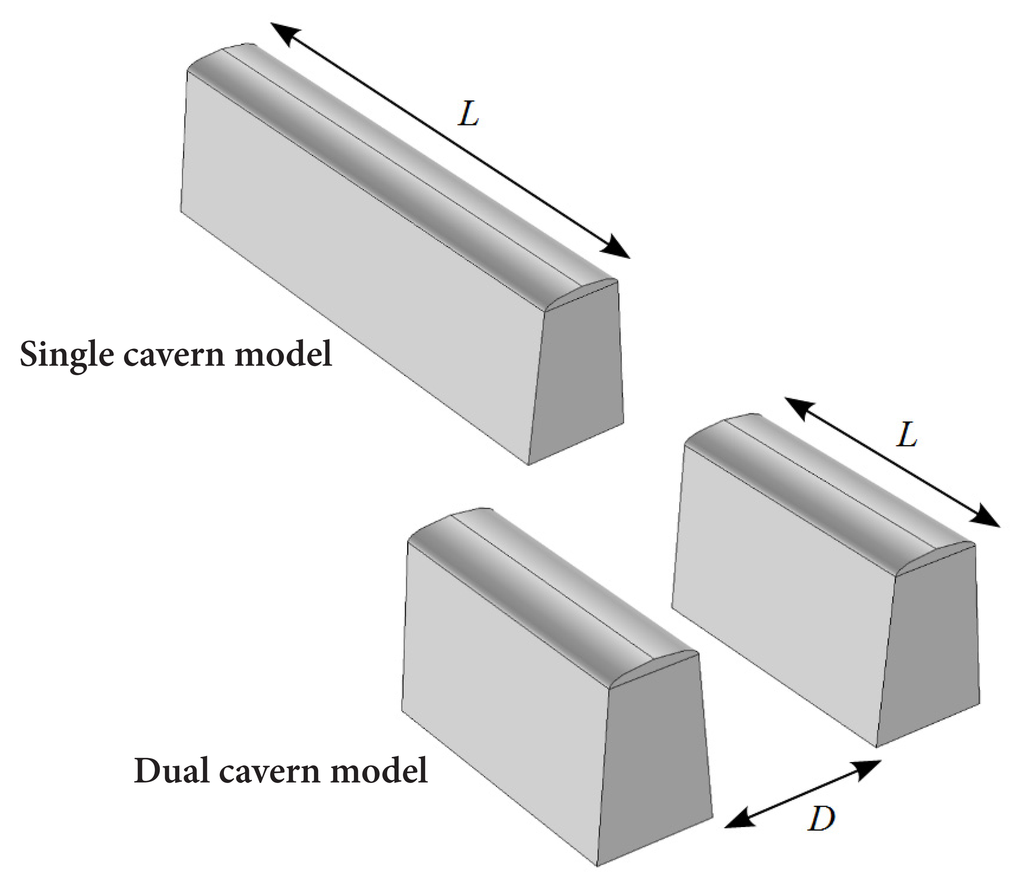

Figure 1. The store geometries modelled.

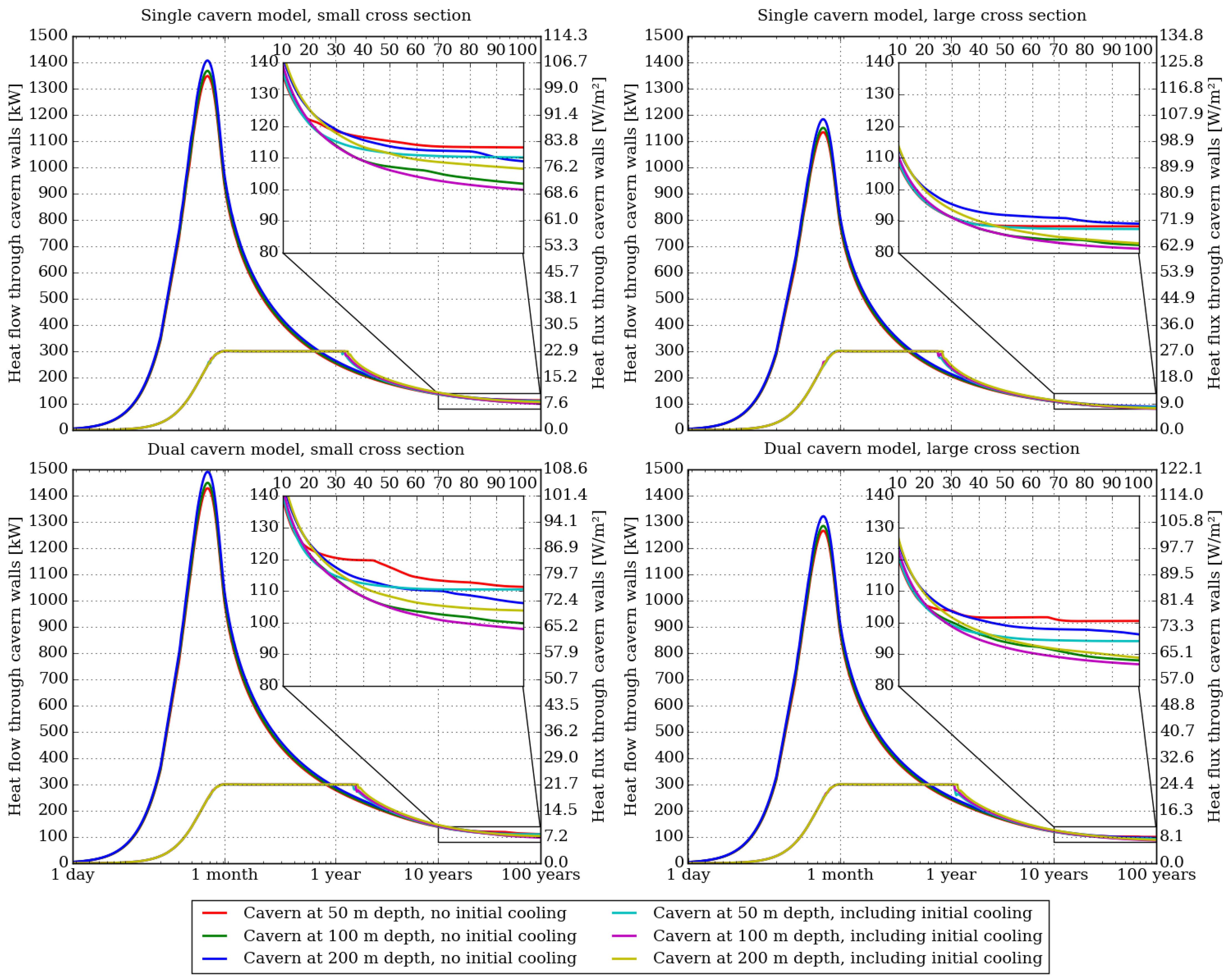

Figure 2. Heat flow and heat flux into the store during the simulations.

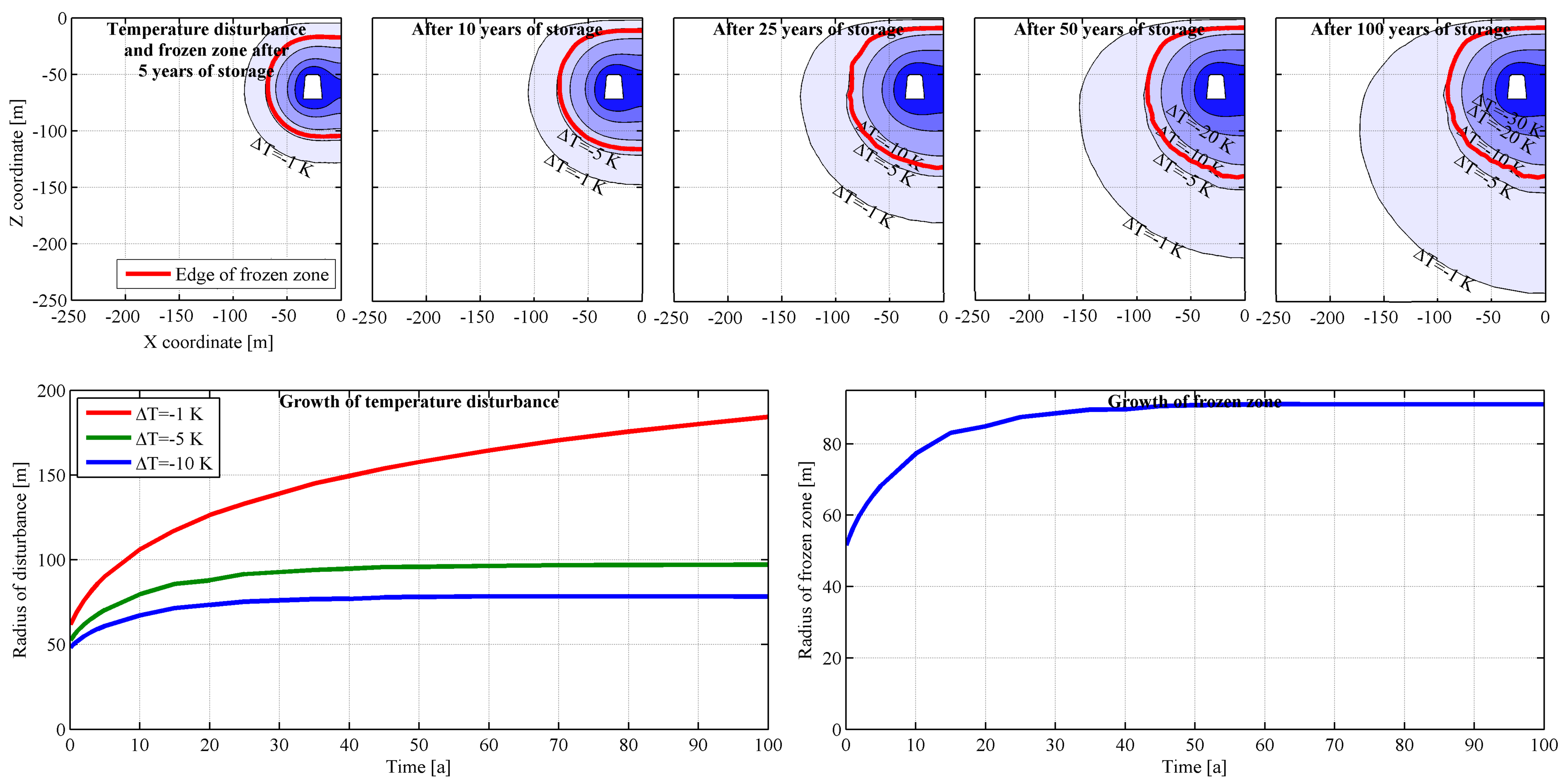

Figure 3. The frozen zone and temperature disturbance created by the storage of cold CO_2.

Results and conclusions

- Figure 2 shows the heat flow and flux into the store in all 24 simulations.
- If CO_2 is stored directly in warm bedrock, megawatt cooling capacity is required.
- The optimal store geometry minimizes the wall surface area. Thus, a spherical store would be the most ideal geometry.
- The optimal store depth is between 50 and 200 metres.
- Figure 3 shows an example of the evolution of the temperature disturbance and frozen zone in one simulation.
- The temperature disturbance expands rapidly during the beginning of storage and may induce thermal tensile stress.
- The heat removed from the CO_2 vapour during re-liquefaction could be utilized for space heating purposes.