December 14, 2017

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Modelling heat and mass transfer around and above magma intrusions with HYDROTHERM and TOUGH2

Outline

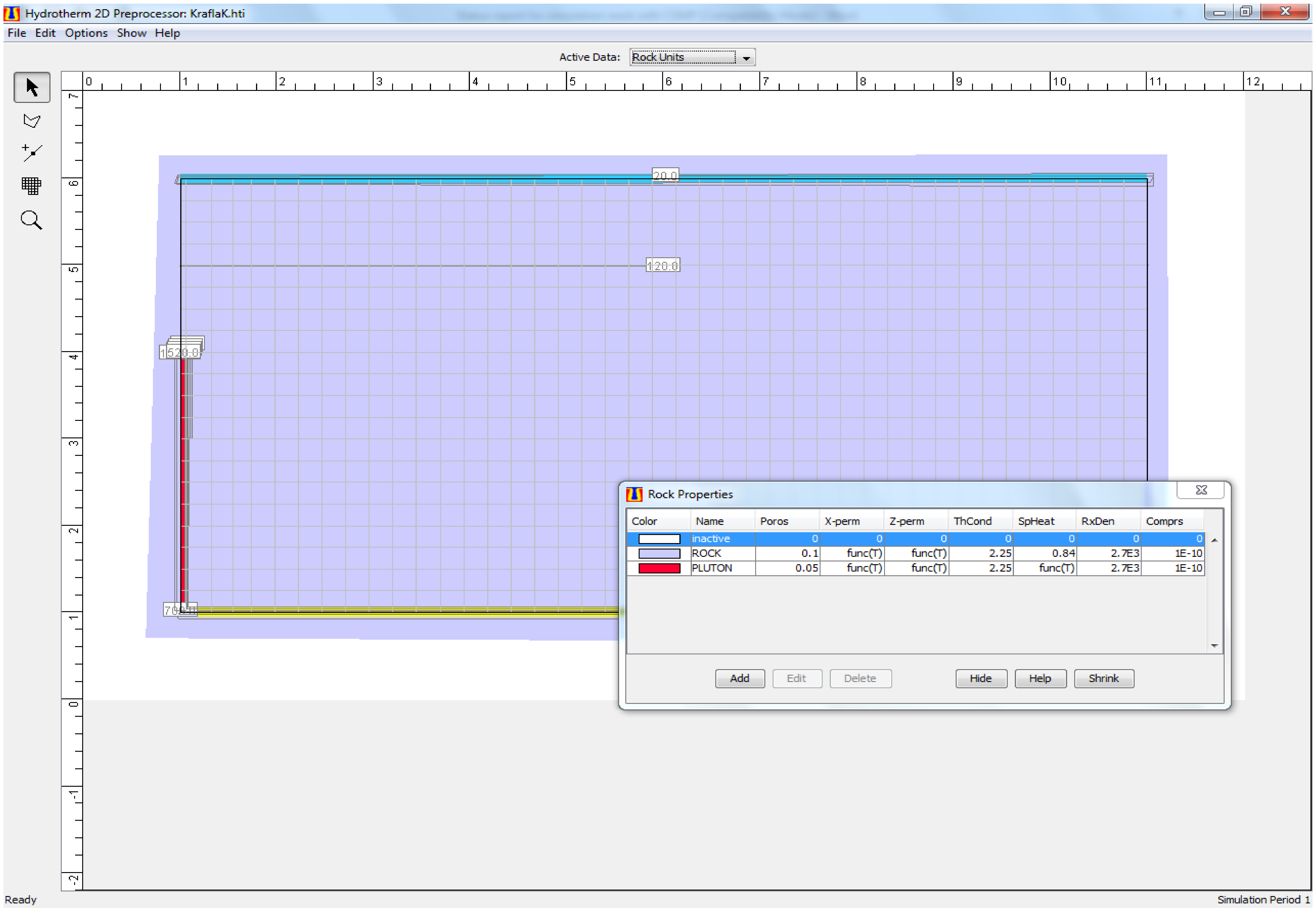
- 2D simulations of a narrow magma intrusion using Hydrotherm.
- Comparison of 3 different geometries of magma intrusions in 3D using TOUGH2.
- Conclusions

Hydrotherm

GEORG DRG

- Handles pure water phases up to temperatures of 1200°C and pressures up to 1000 MPa
- Uses finite difference method, very convienient graphical user interface for 2D simulations.
- Has 3D simulation capabilities but with no graphical user interface.

Setup of the simulation using the graphical interface.



Setup of the simulation in Hydrotherm

GEORG DRG

- 50 m wide and 3 km high 900 °C magma intrusion injected into a 10 km wide and 5 km deep system.
- The system starts out with uniform background rock and 100 °C/km linear temperature gradient.
- The brittle-ductile transition is set in the range 750 ± 100 °C.

Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

The Brittle Ductile Transition in Experimentally Deformed Basalt Under Oceanic Crust Conditions: Evidence for Presence of Permeable Reservoirs at Supercritical Temperatures and Pressures in the Icelandic Crust

Violay, M.[1], Gibert, B. [1], Mainprice, D. [1] Evans, B.[2], Pezard, P.A. [1], Flovenz, O.G.[3], Asmundsson, R.[4]

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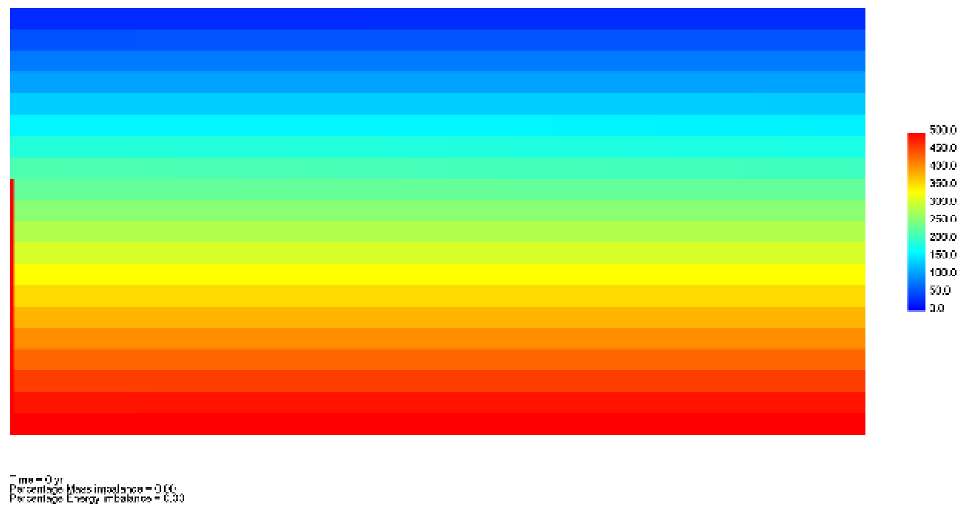
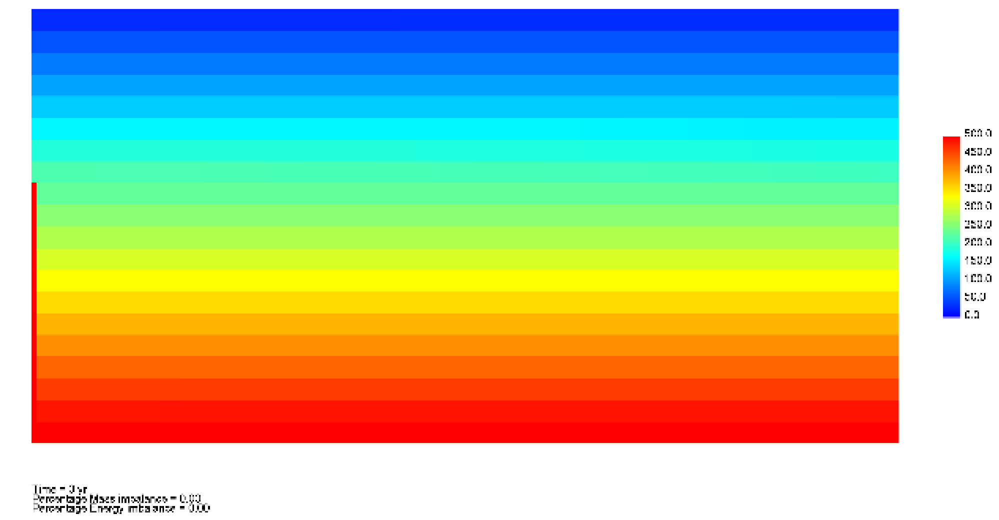
4 ISOR, Iceland Geosurvey, Rangarvöllum, Akureyri, 603, Iceland

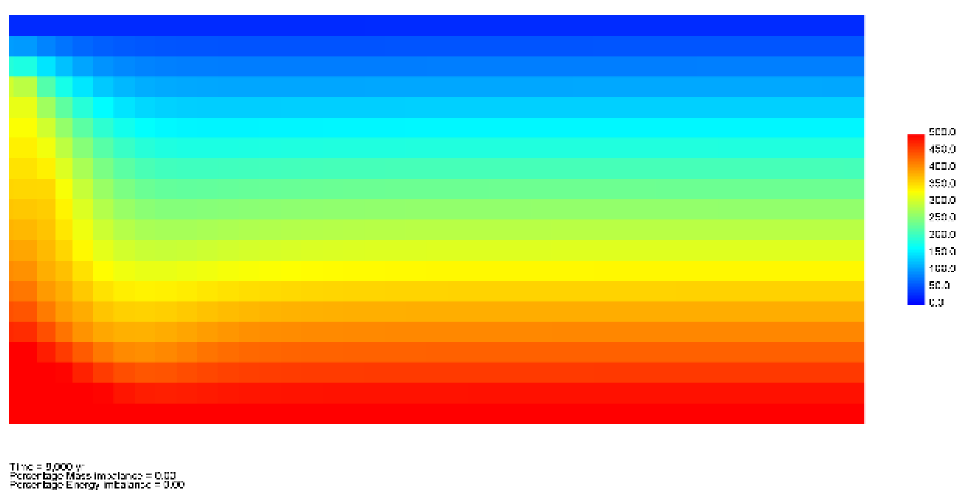
Two different values of background permeability.

GEORG DRG

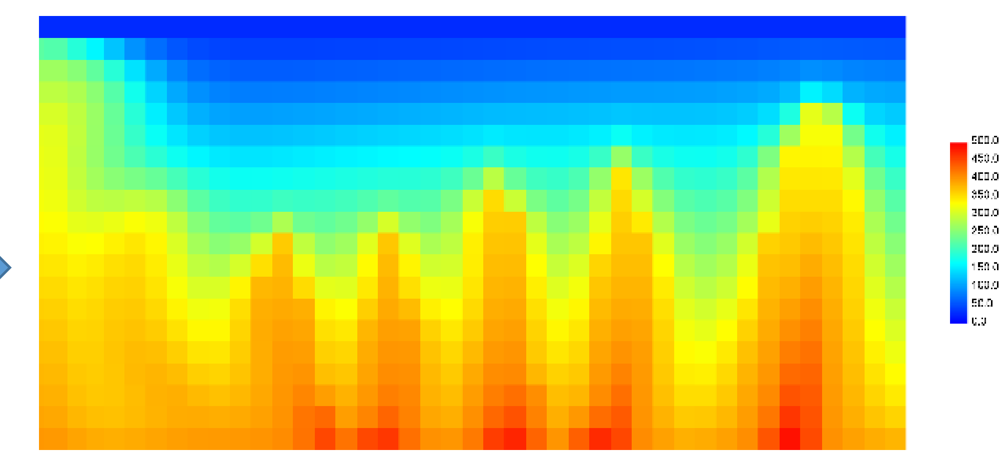


Start of simulation

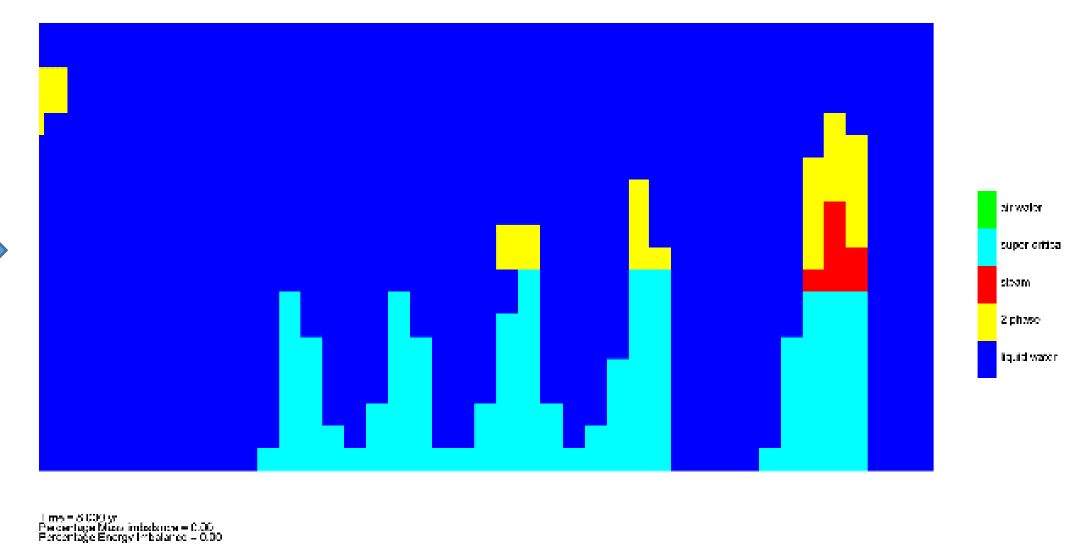




8000 years



Plot of phases

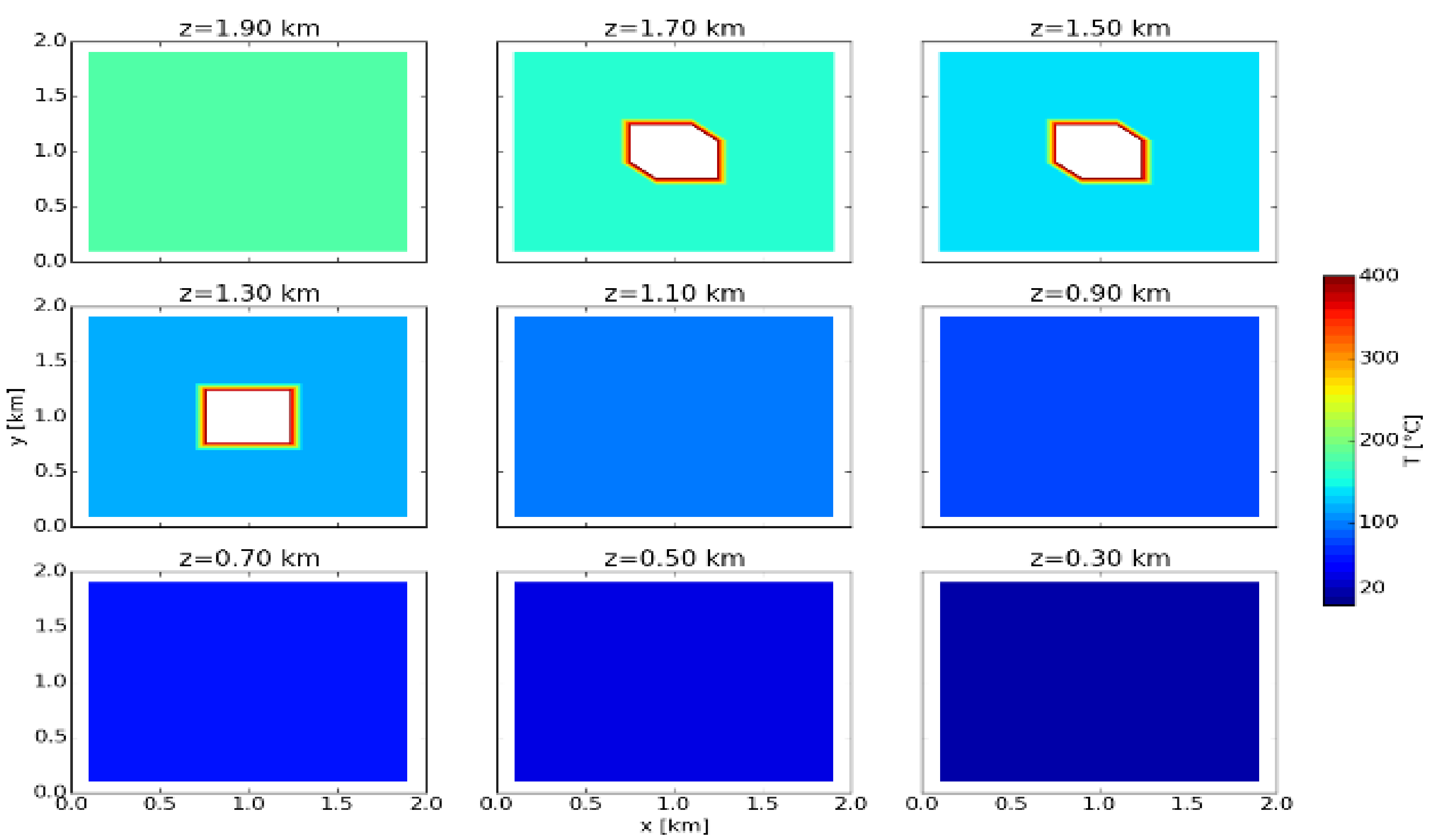


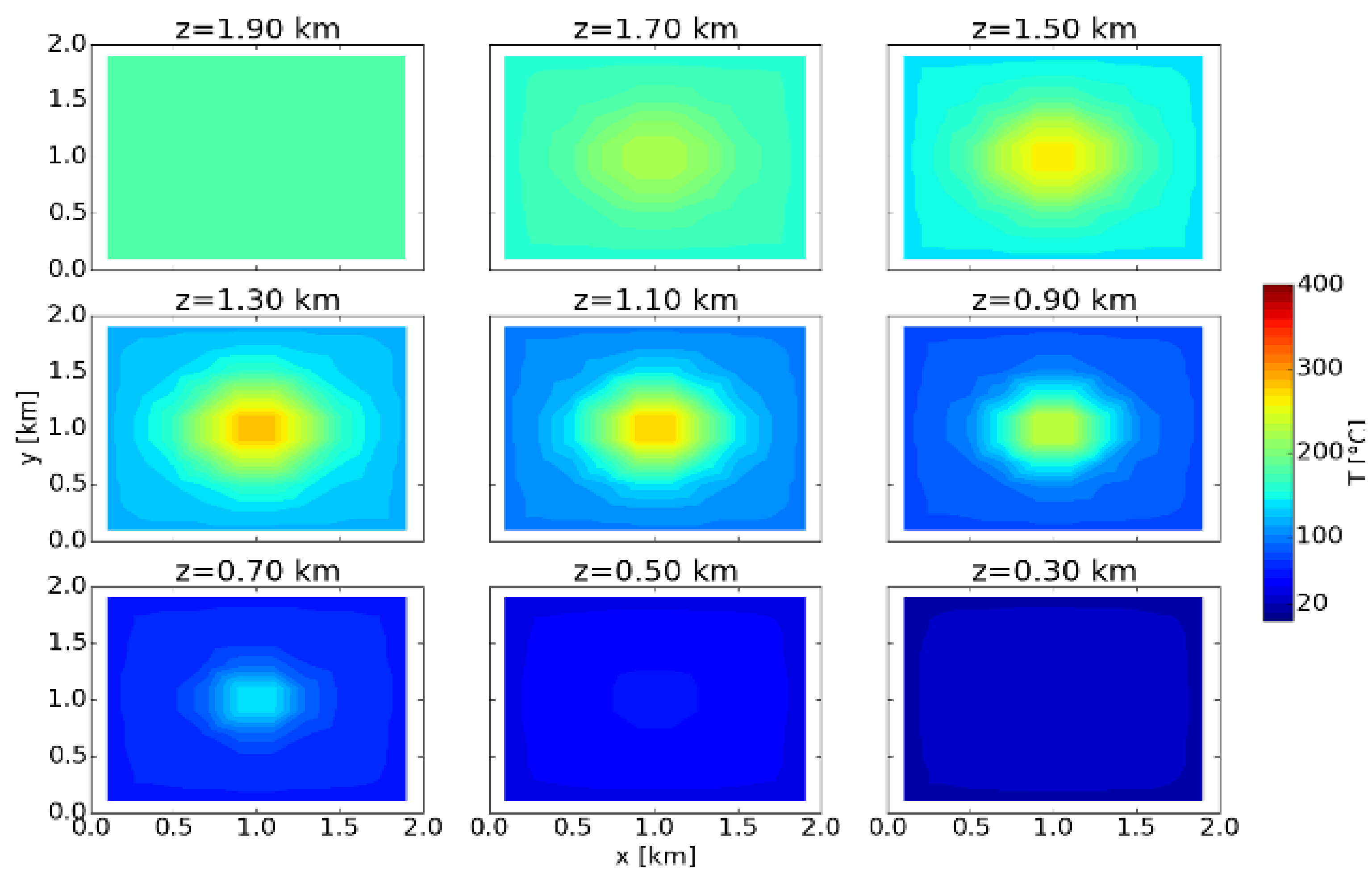
$k = 1 \times 10^{-16} m^2$ (0.1 mD)

$k = 5 \times 10^{-16} m^2$ (0.5 mD)

3D simulations of magma intrusion.

- Technically possible in CSMP++,… but not fully implemented?
- Possible with Hydrotherm,… but not very stable.





- Maybe possible in TOUGH2 with the new supercritical equation-of-state module?

TOUGH2 supercritical capabilities

- The new supercritical module makes iTOUGH on par with Hydrotherm.
- Temperature depended permeability and heat capacity capabilities available (hidden in the sourcecode) in the iTOUGH code.
- Pre and post processing done with pyTOUGH:

  „How I Learned to Stop Worrying and Love TOUGH2"

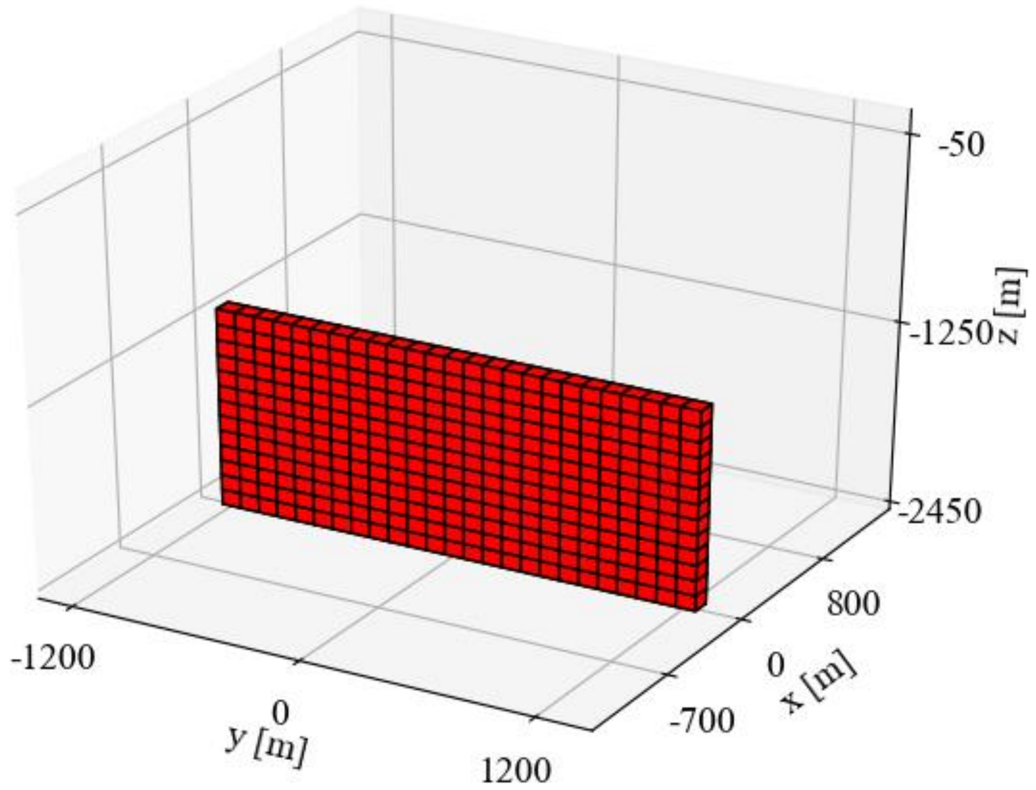
Setup of background system

- The magma intrusion is in a cube with 2500 m sides and an uniform bacground rock. The system is subdivided into cubes with side lengths of 100 m.
- The background has a 100 °C/km linear temperature gradient, hydrostatic pressure and fixed temperature and pressure at top and bottom.
- Below temperature of the brittle-ductile transition the permeability in both background and intrusion rocks is $k = 5 \times 10^{-16}\, m^2$ (0.5 mD).

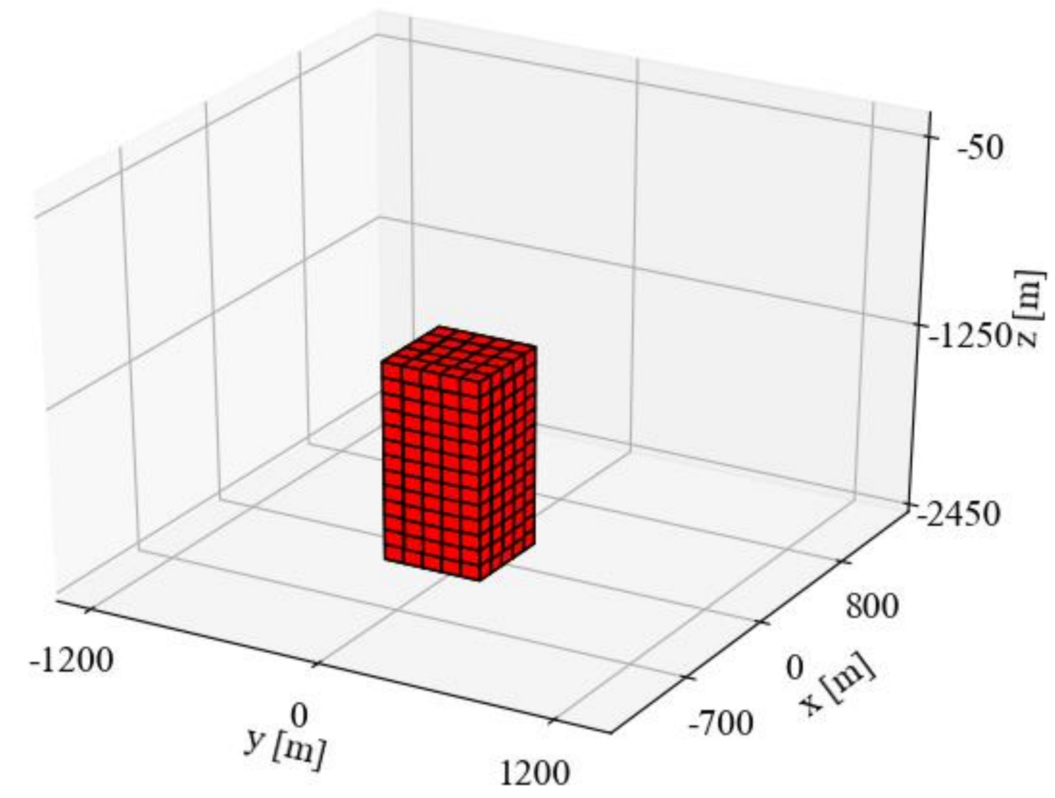
Temperature dependant properties

- Between 600 °C and 700 °C the permeability falls log-linearly by 9 orders of magnitude.
- From 800 °C to 750 °C heat capacity fall by 2 order of magnitude to crudely simulate effects of latent heat.
- In the intrusions the pressure is twice the hydrostatic pressure and begin with initial temperature of 900 °C.

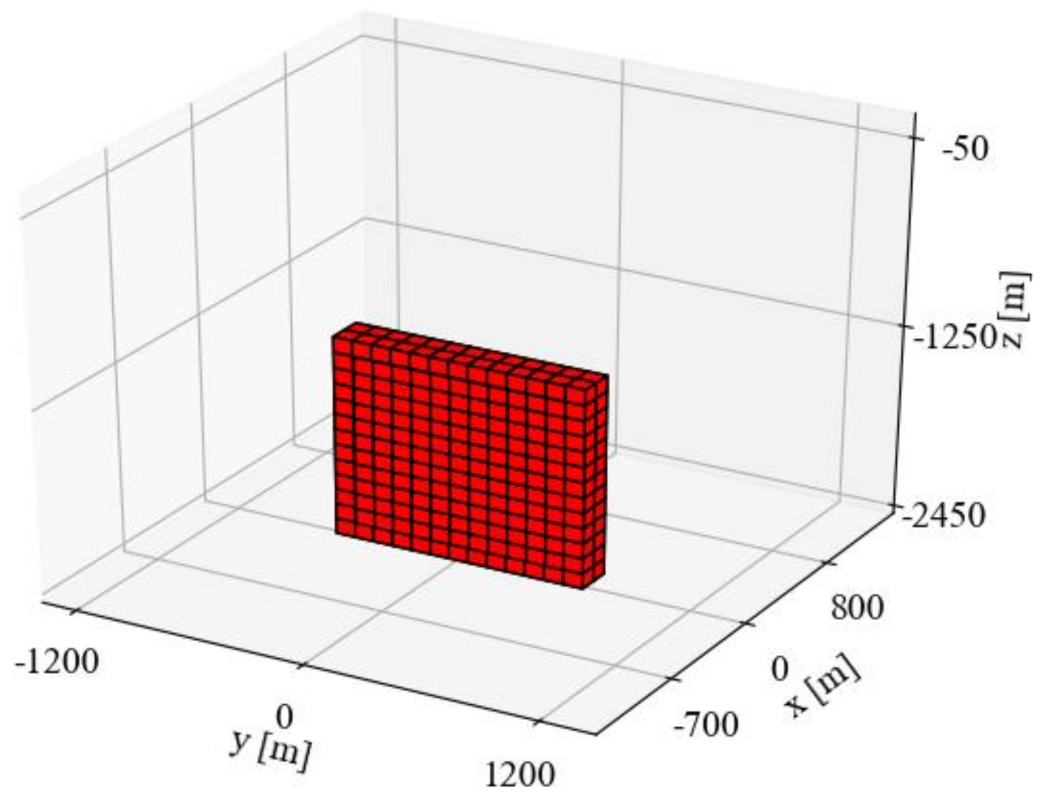
The three geometries of intrusions



Dike-like intrusion (semi-2D)
Dimensions: $100\ m \times 2500\ m \times 1300\ m$

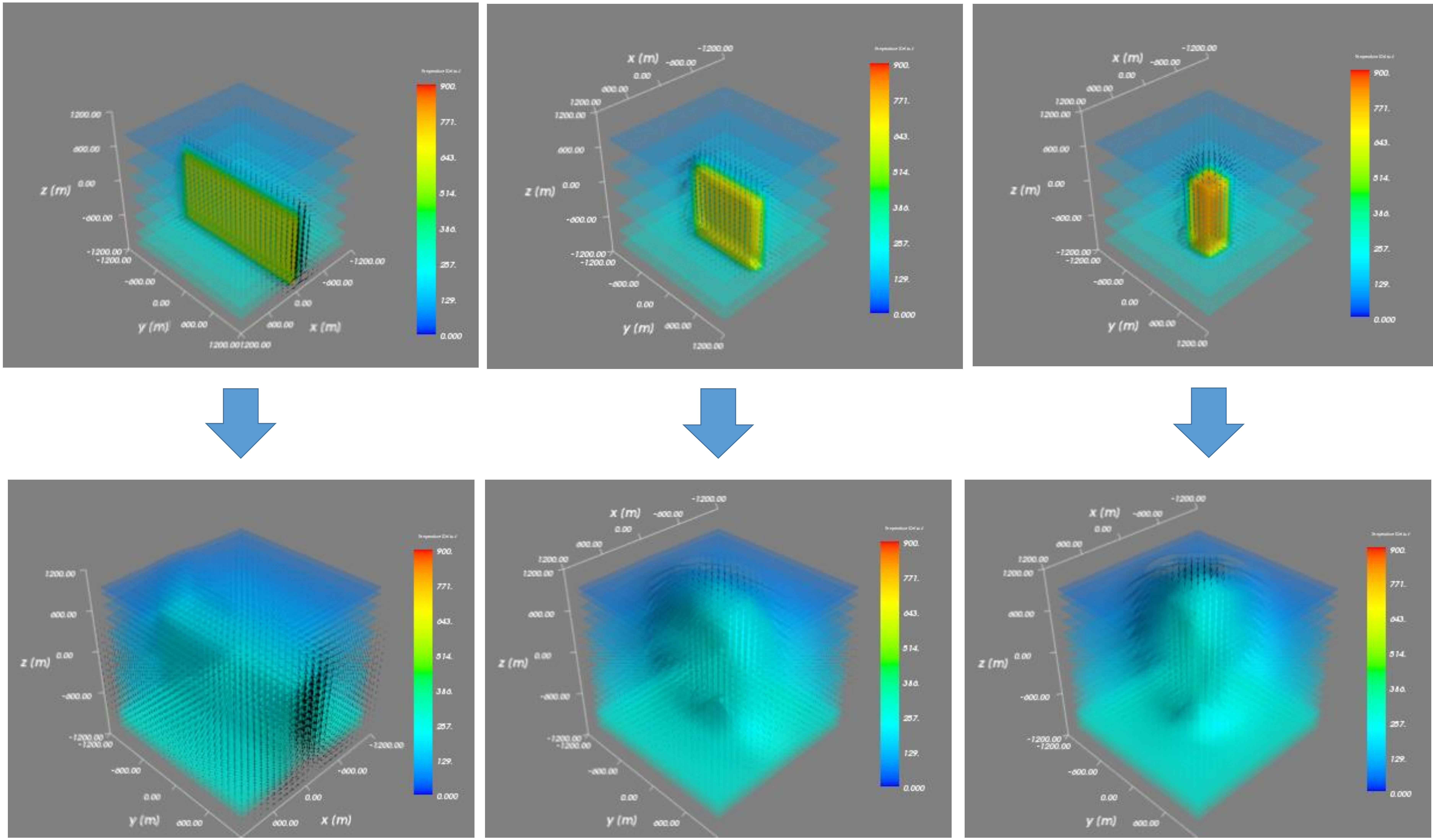


Pillar-like intrusion
$500\ m \times 500\ m \times 1300\ m$

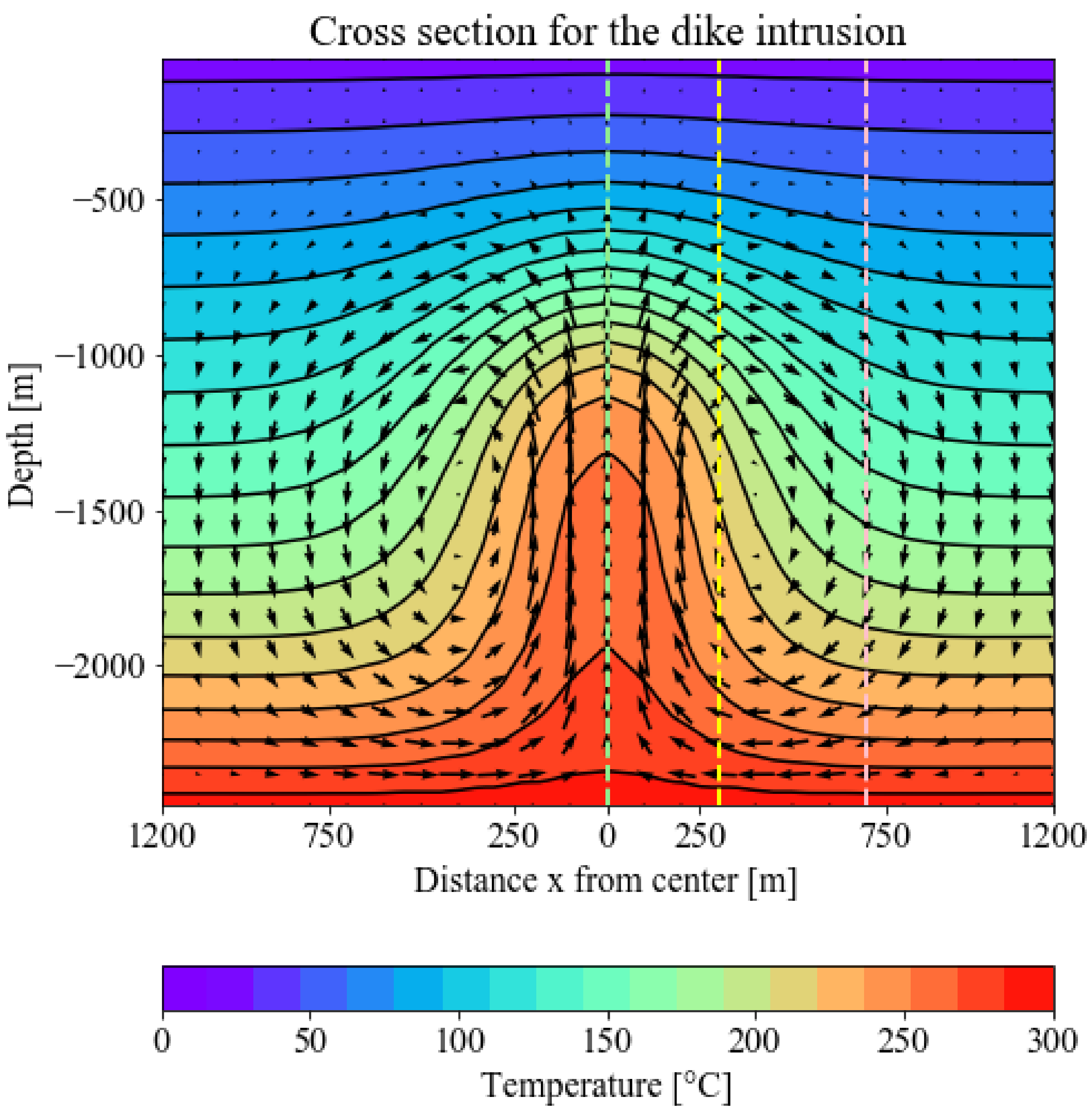


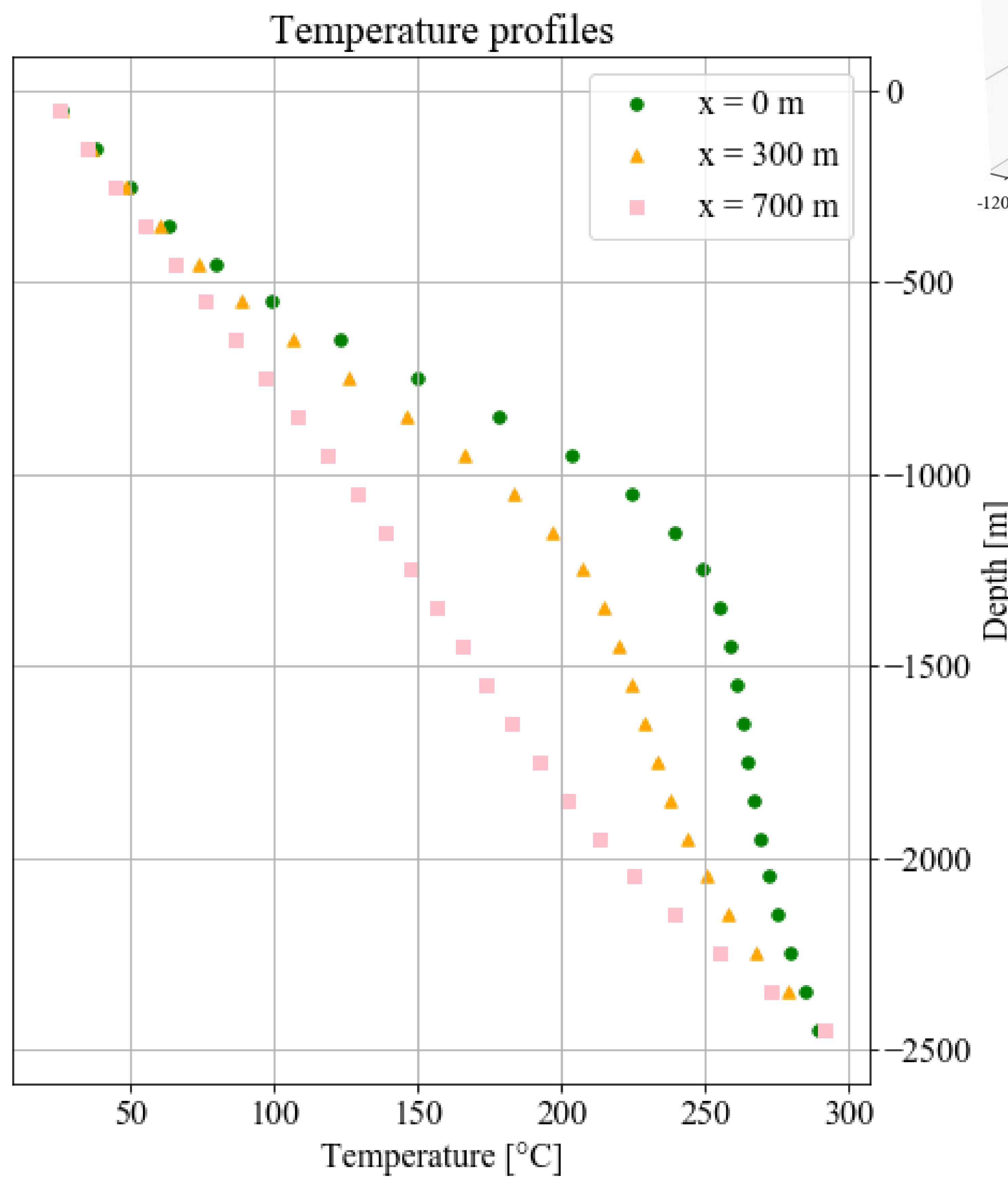
Limited dike intrusion
Dimensions: $200\ m \times 1300\ m \times 1300\ m$

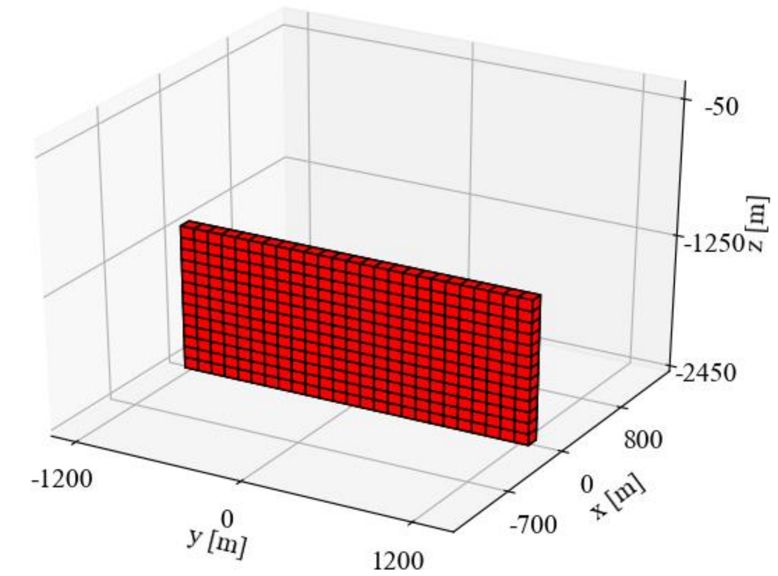
Snapshots of the systems after 200 years and 5000 years



Cross section of the dike system after 5000 years

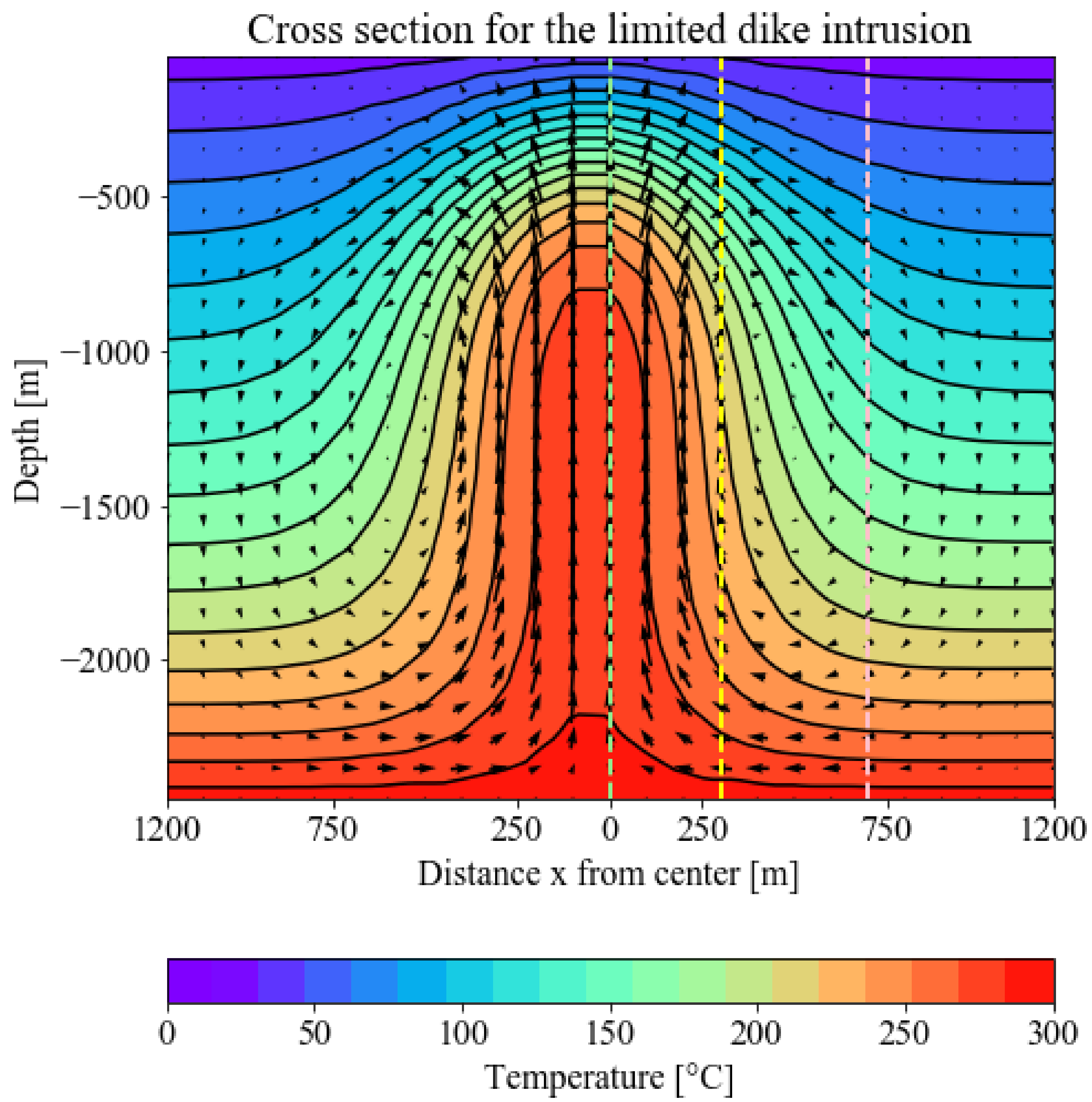


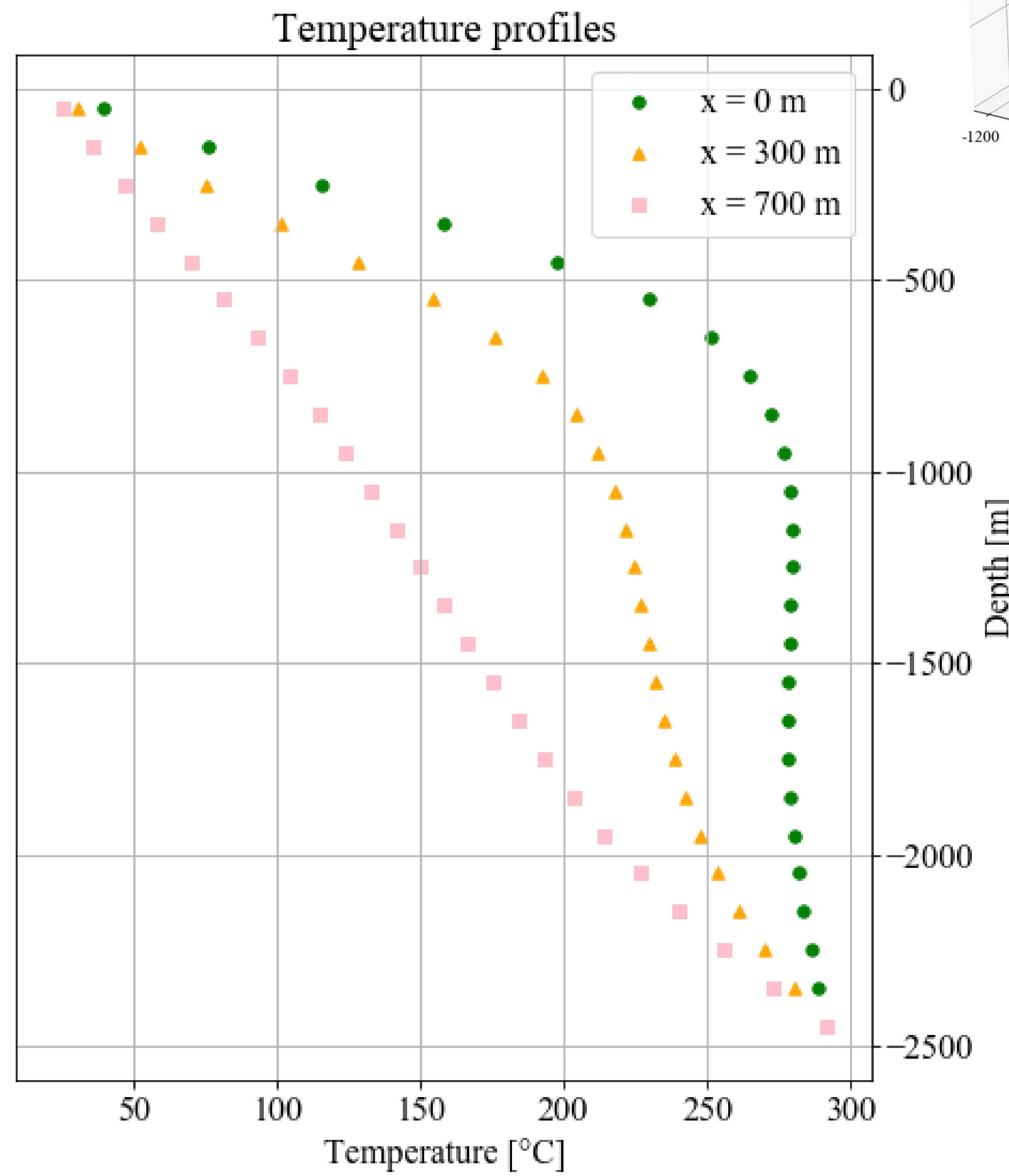


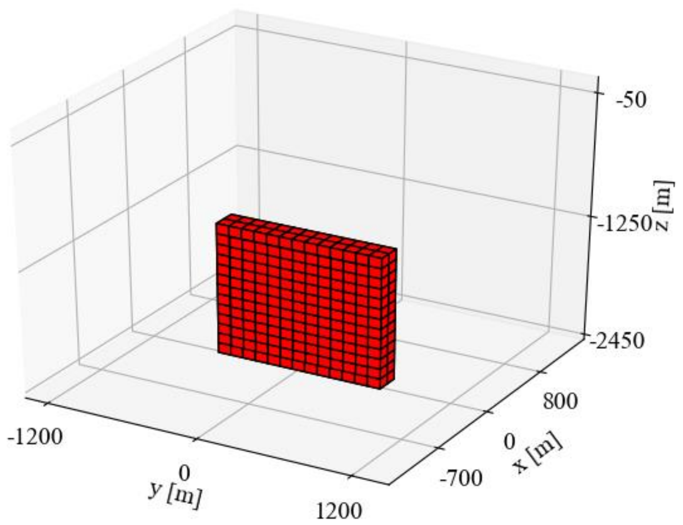


Very clear convection cells

Cross section of the limited dike system after 5000 years

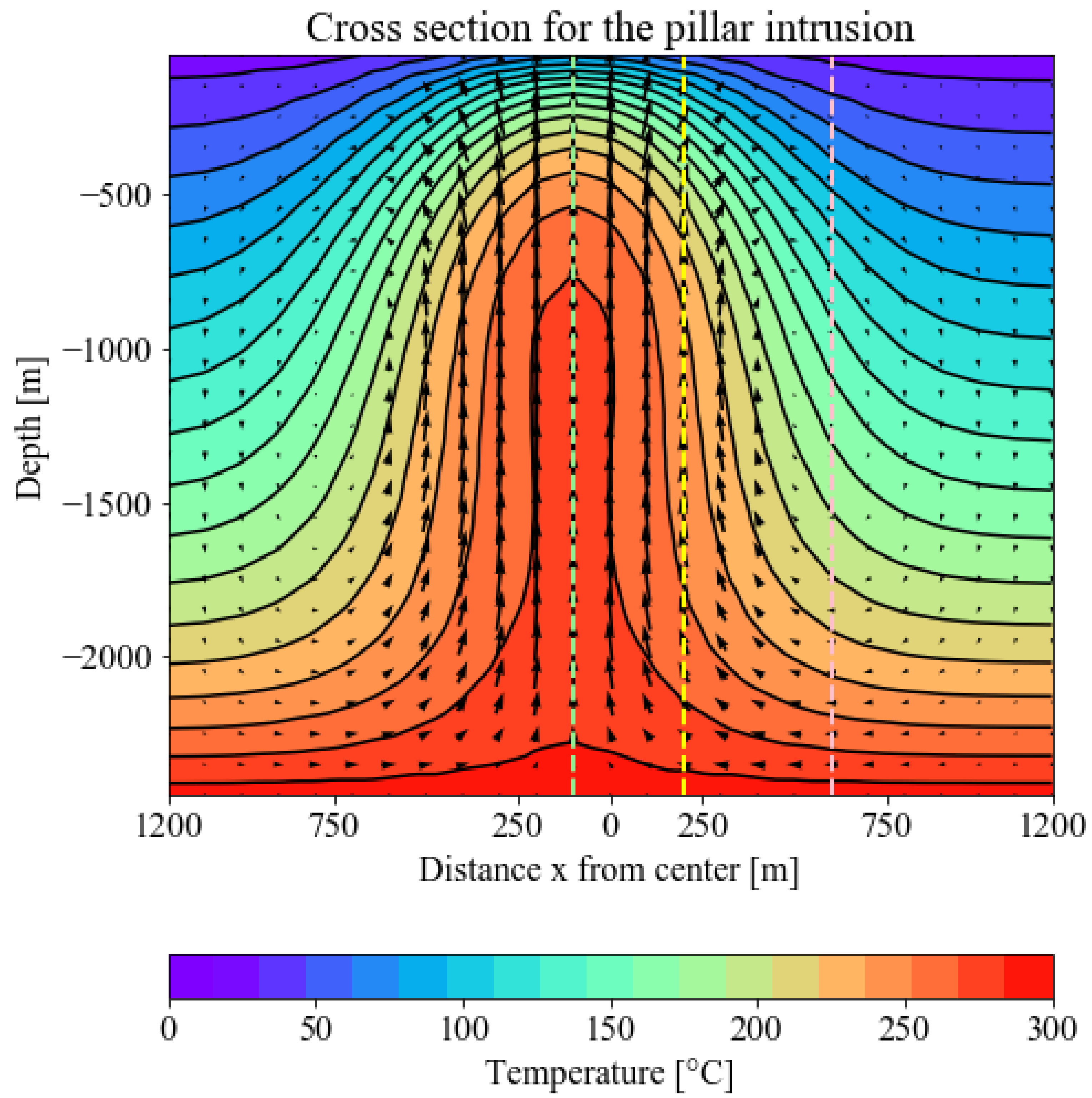


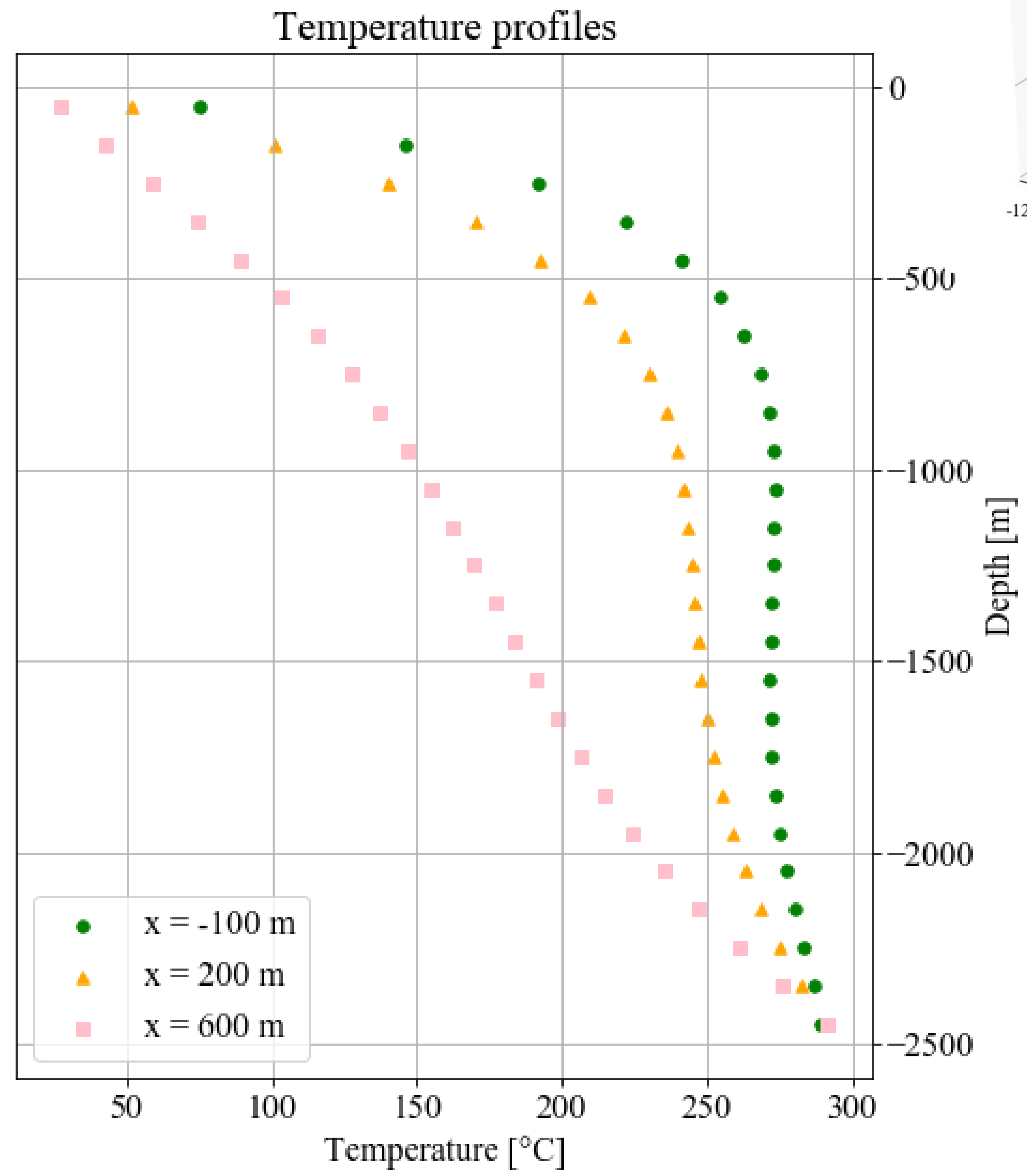


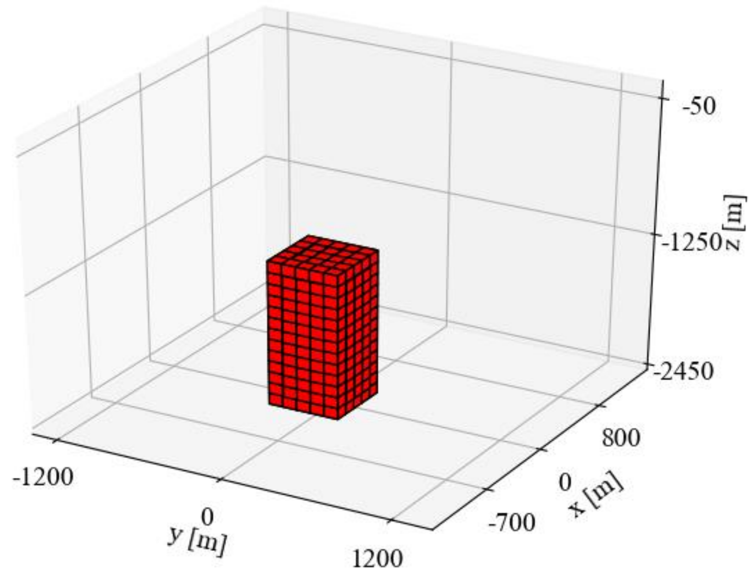


Stronger uppflow than downflow, larger plume.

Cross section of the pillar system after 5000 years

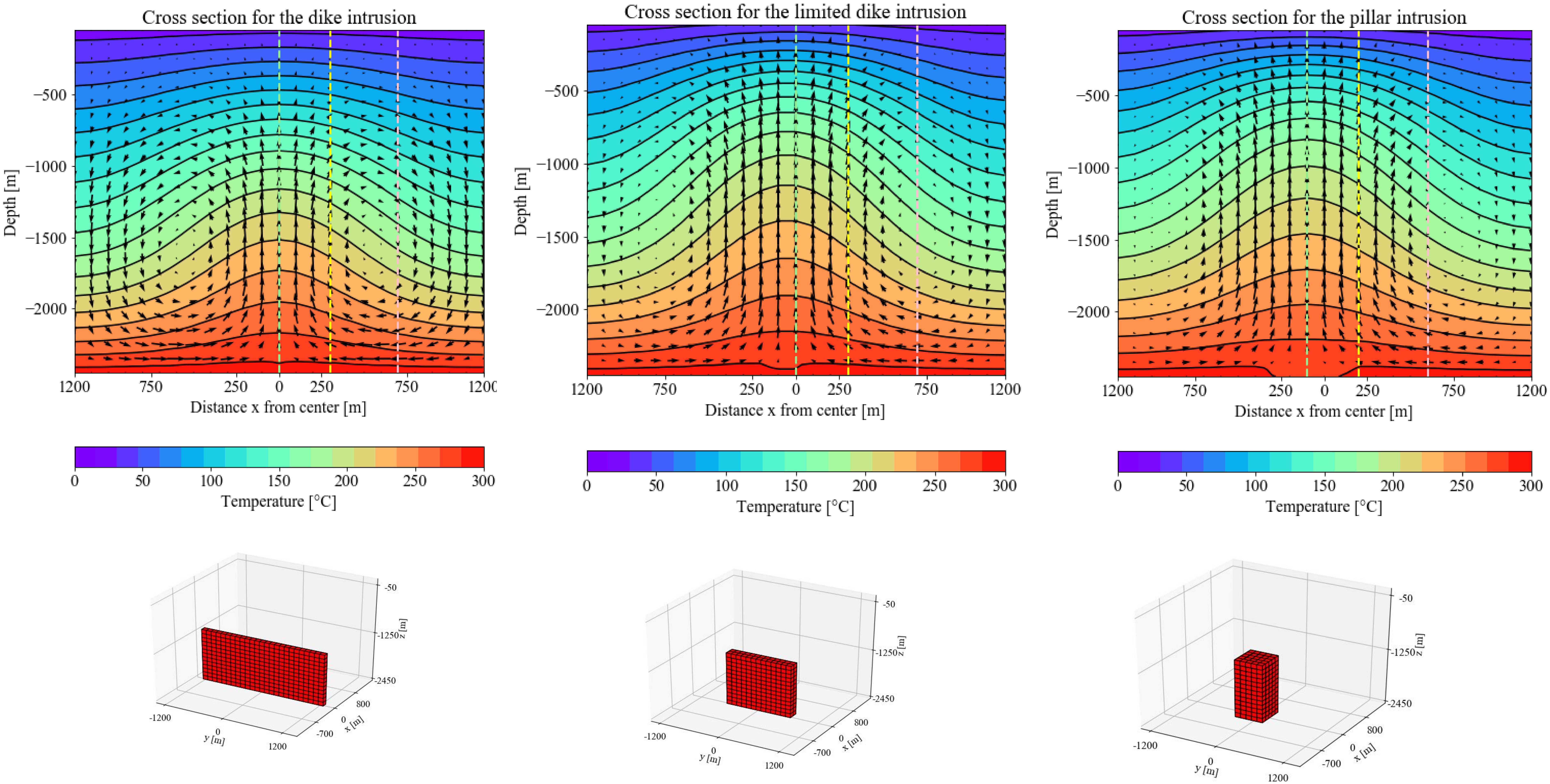






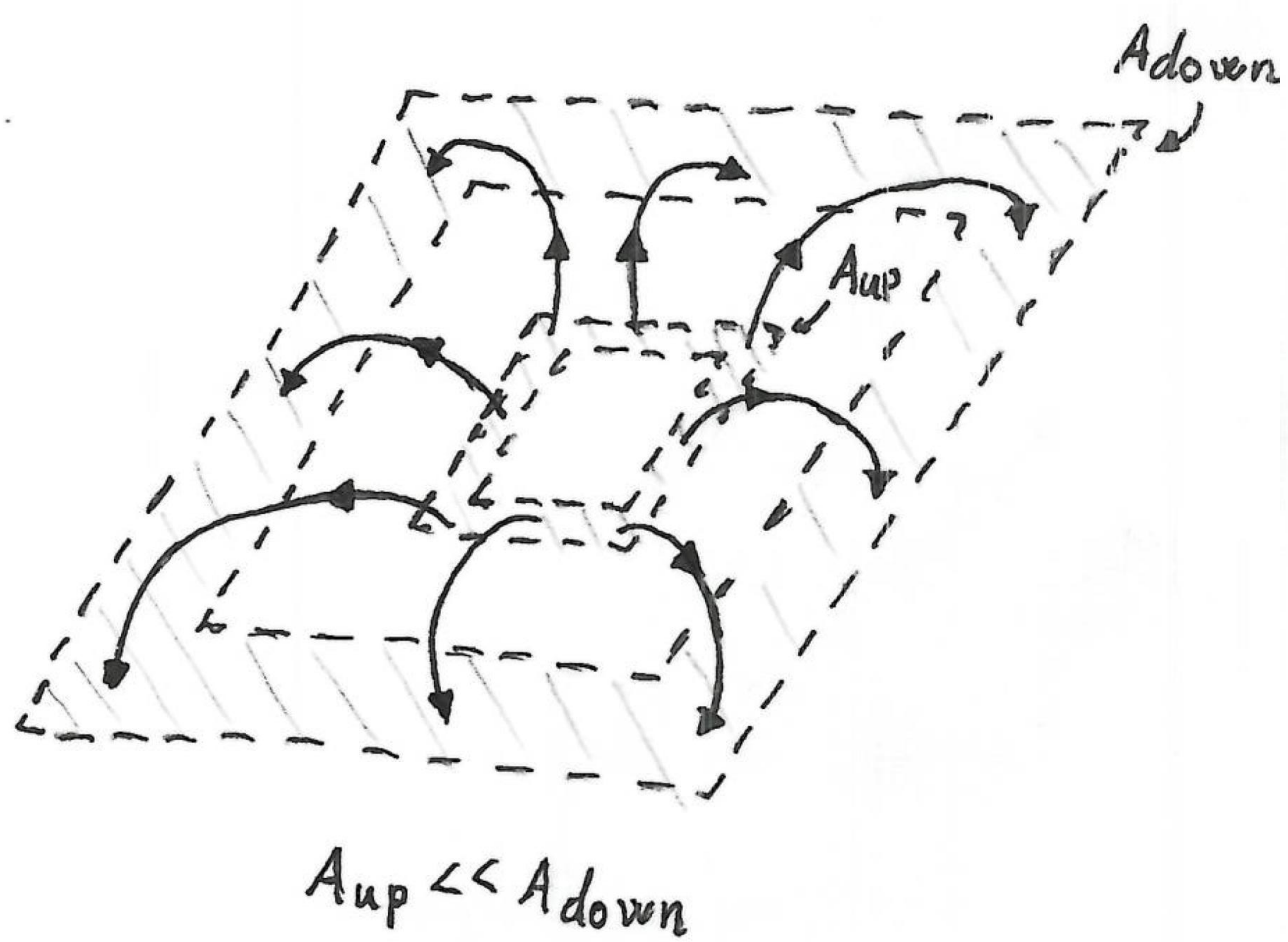
Much stronger uppflow than downflow.

Cross sections of the systems after 20000 years

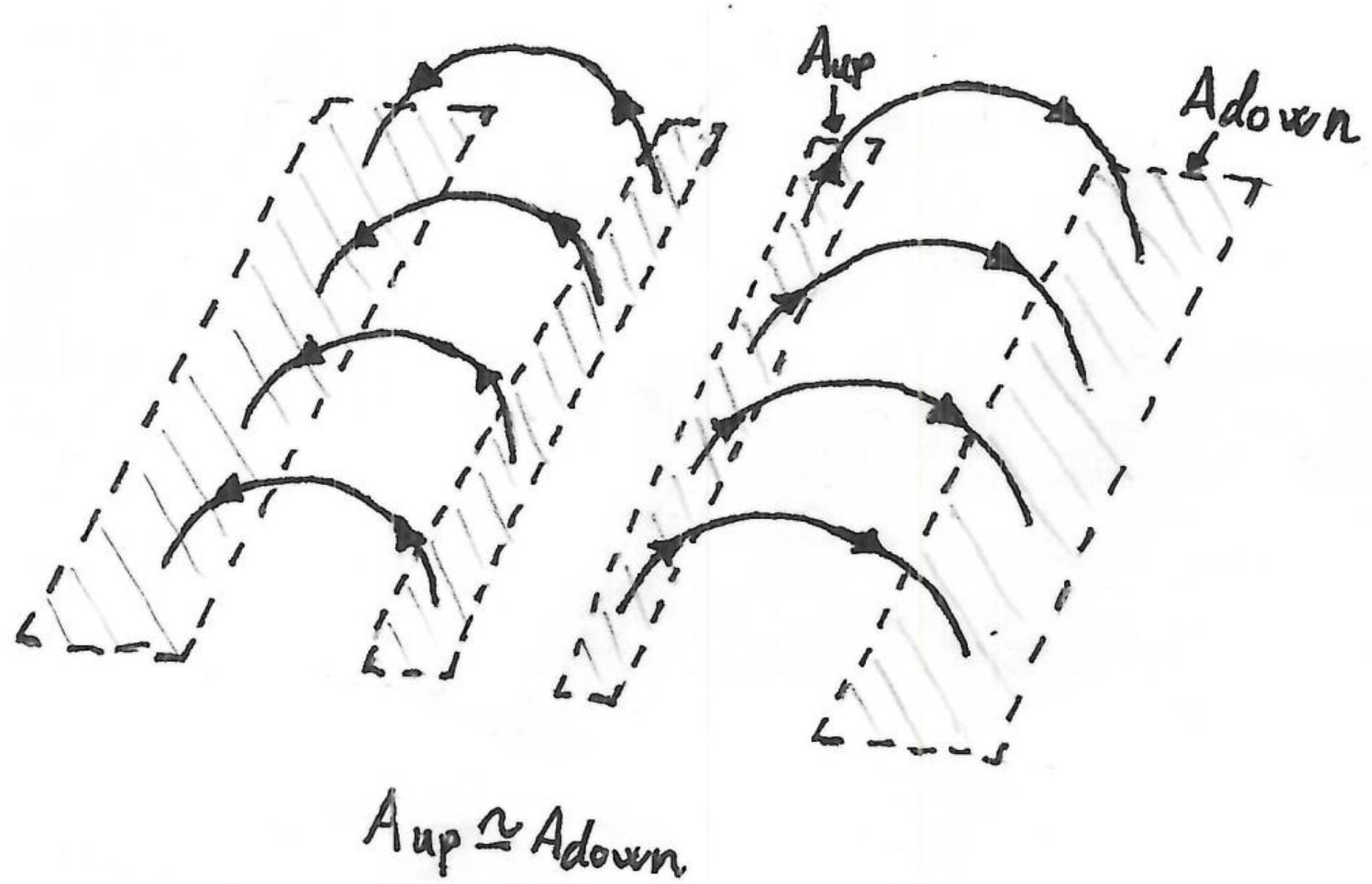


The plumes become similar, but not the fluid flow

Why do we not get clear convection cells in the 3D systems?



Flow in a 3D system



Flow in a semi-2D system

Conclusions

- Effects of magma intrusions are more localised in 3D simulations than in 2D.

- Strong convections cells that appear in 2D simulations are supressed in 3D.

- 2D simulations is still be appropriate if the underlying system is 2D, e.g. if the permebility is anisotropic.