Algorithm for searching for optimal placement of new wells

in combination with Waiwera reservoir simulator

GeoModel closing conference

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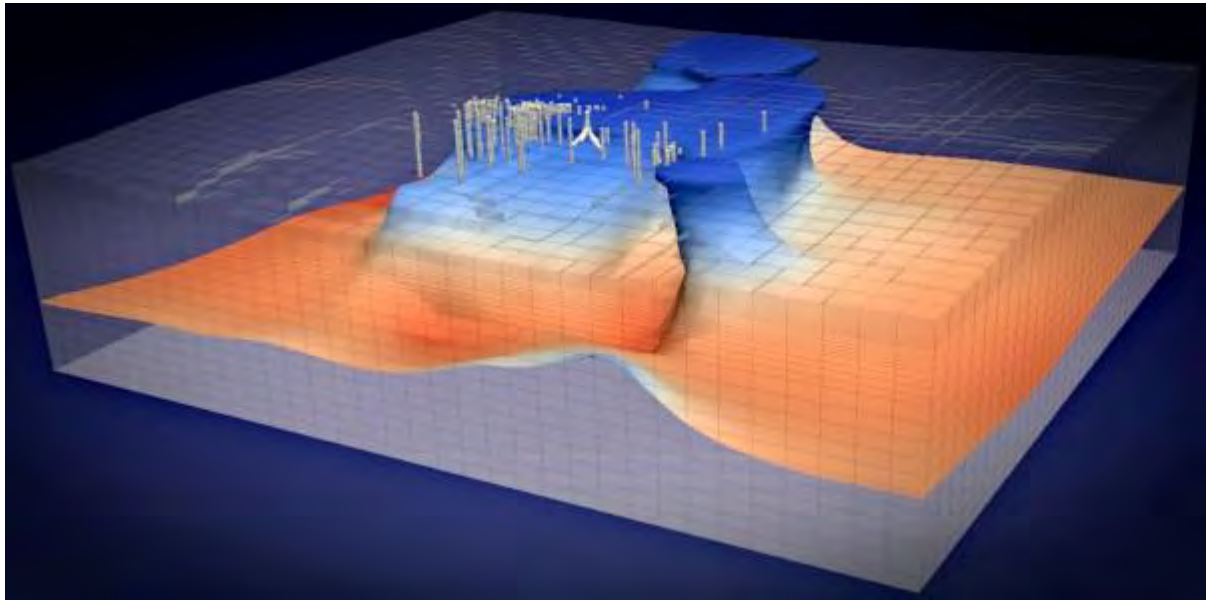
Goals

- Placement of production wells can greatly affect yield
- Drilling is expensive
- Well placement can affect sustainability
- How to leverage our knowledge of the geothermal field to achieve the desired results
- GeoModel: Develop tool/algorithm for solving this problem

Simulation (Waiwera)

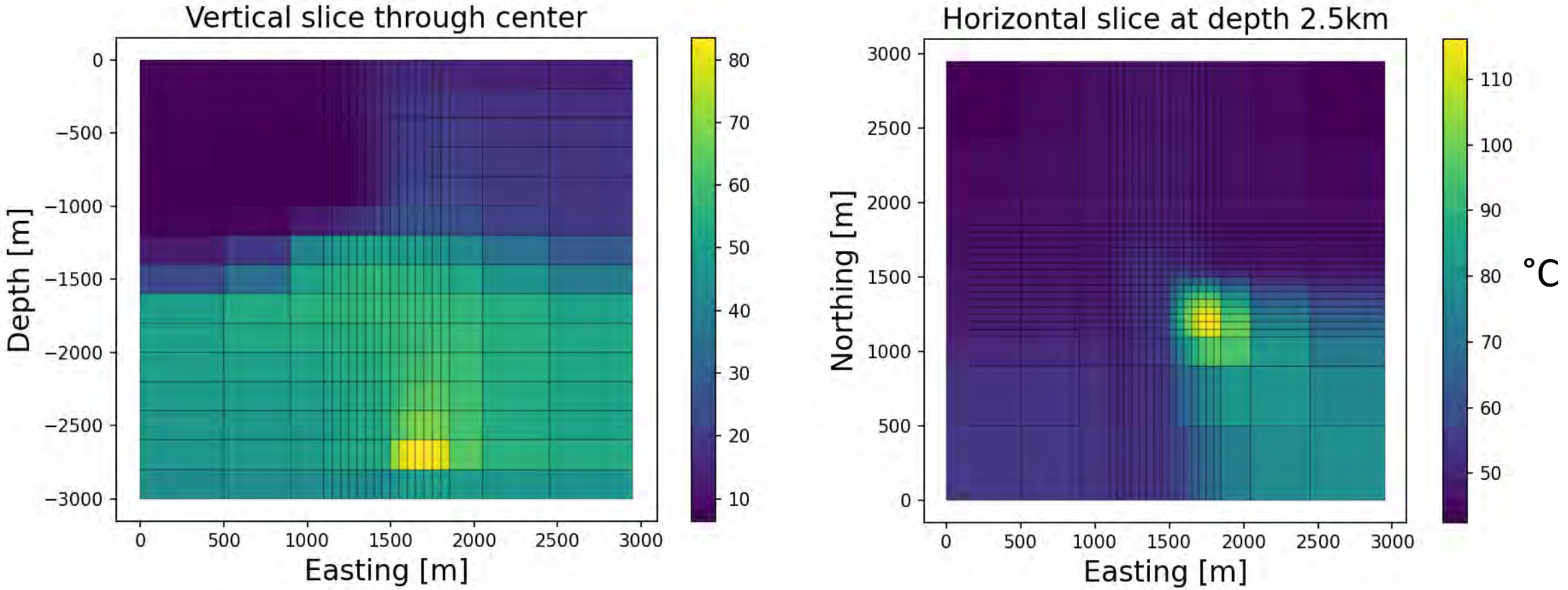
- Model the field as a collection of blocks in a mesh
- Determine time evolution using conservation laws for each block (cell)
- Open source, free license
- Similar to TOUGH
- Will be used to do the actual simulation



Example field (synthetic case)

3km x 3km x 3km cube
6615 cells

Temperature distribution

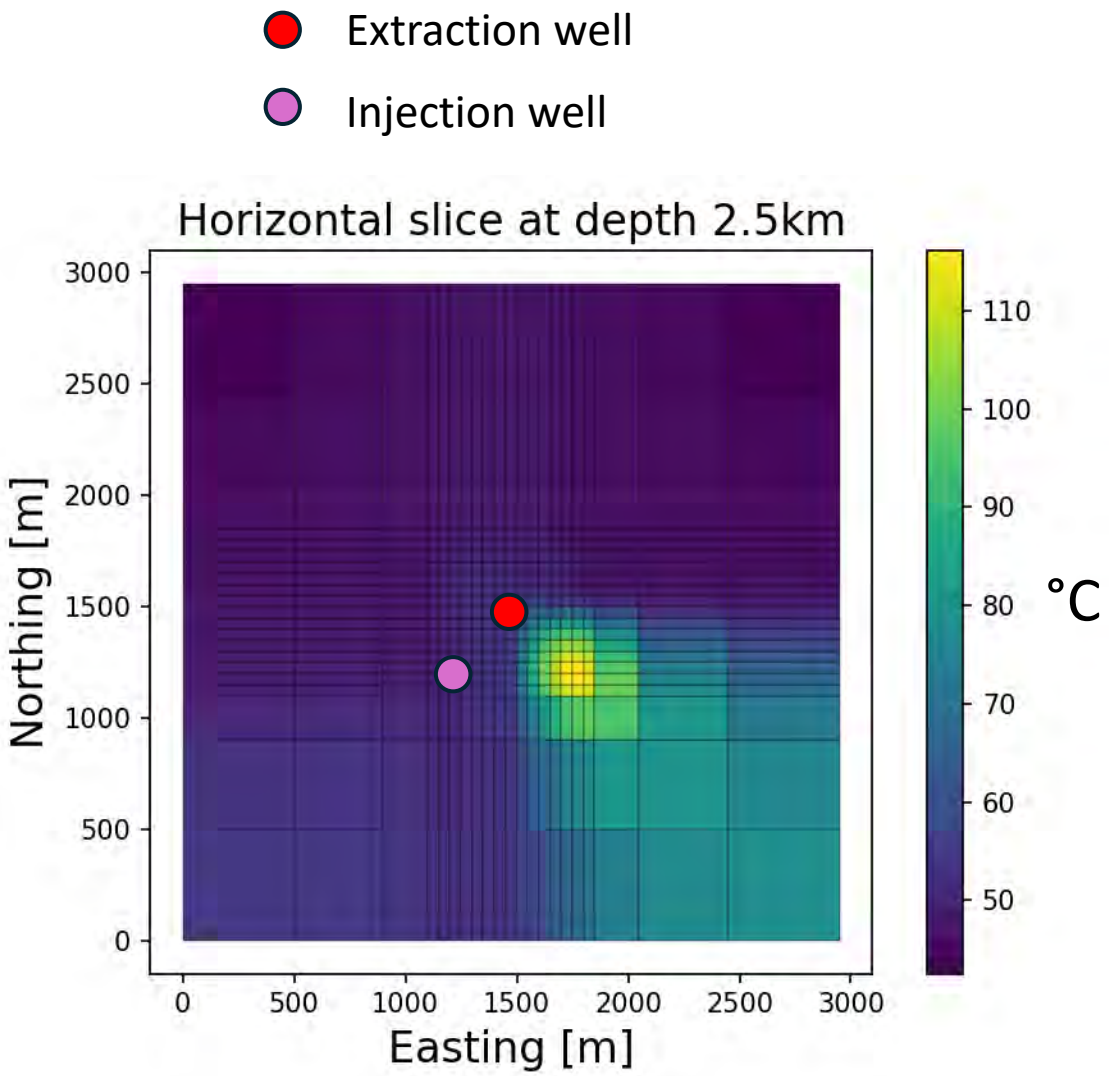


Simulating production

- Add a production well and reinjection well
- Extract 100 kg/s
- Reinject 100kg/s at 40°C
- Simulate 50 years

- Injection well at (1175, 1175)
- Extraction well at (1475, 1475)

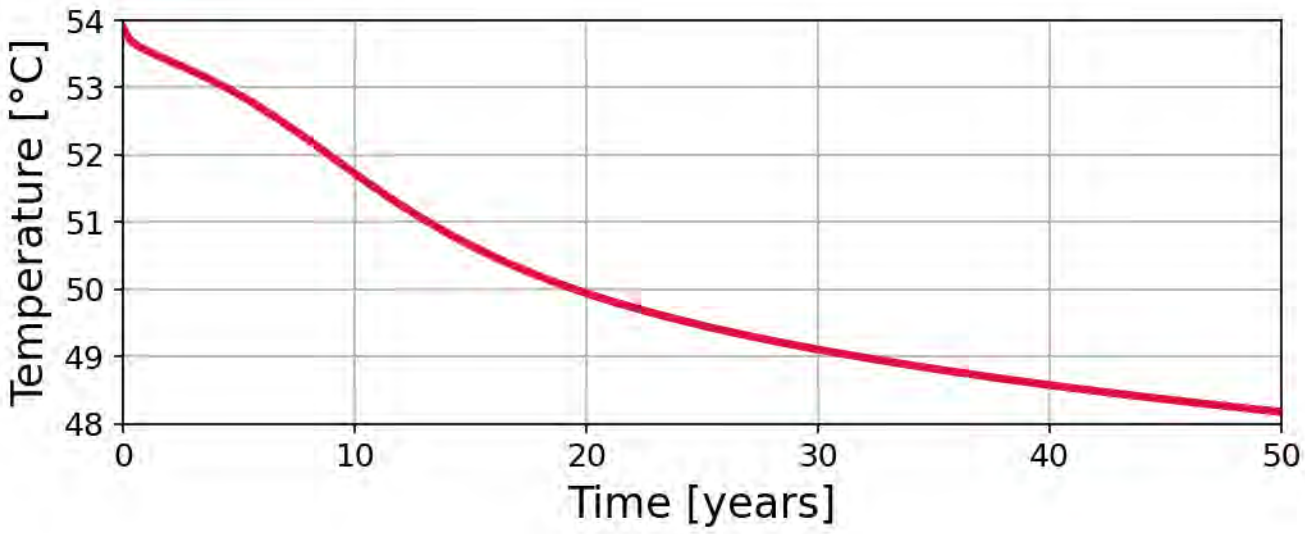
- Simulate with Water-Energy equation of state



Simulation outputs

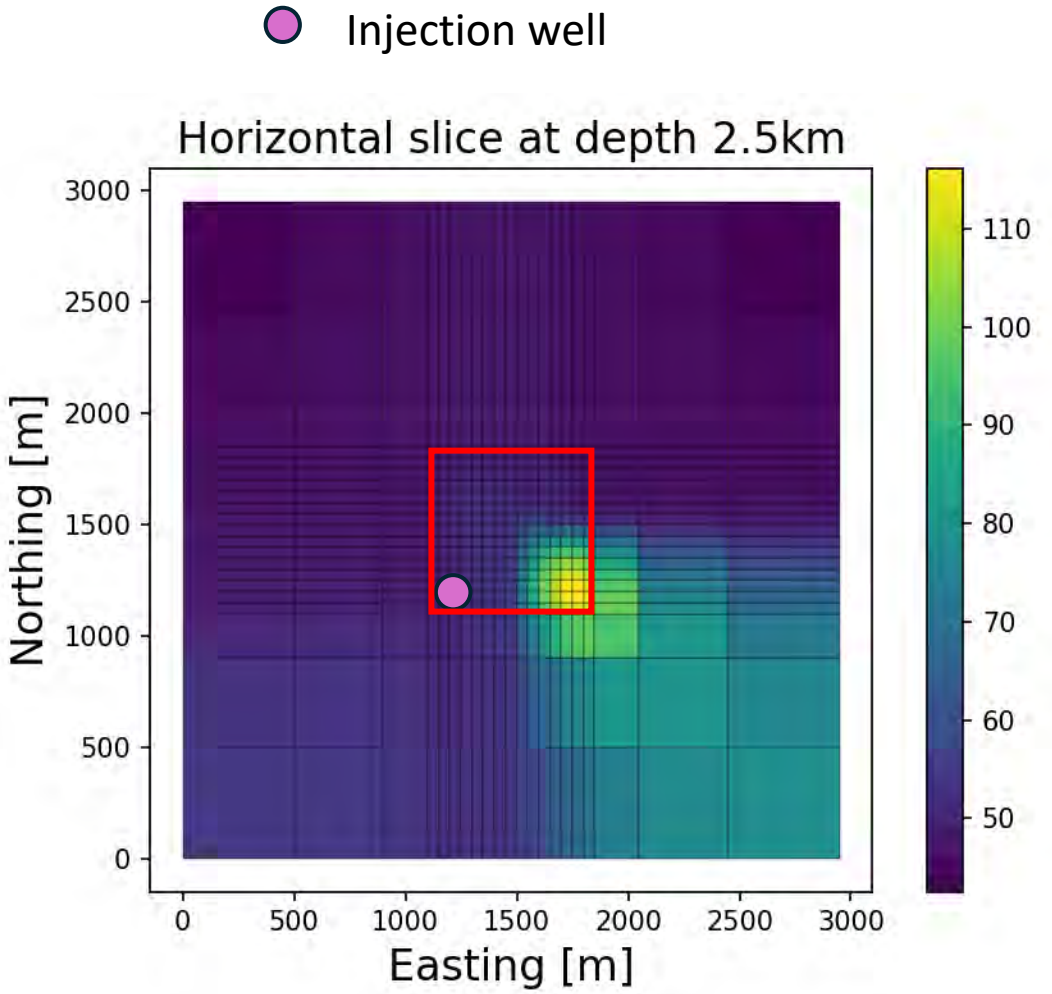
- Various outputs fully describe the thermodynamic state:
  - Temperature
  - Pressure
  - Phase
  - Flux
  - Phase saturation
  - Phase density
  - Etc…

Time evolution of temperature
at the point of extraction



Optimizing production location

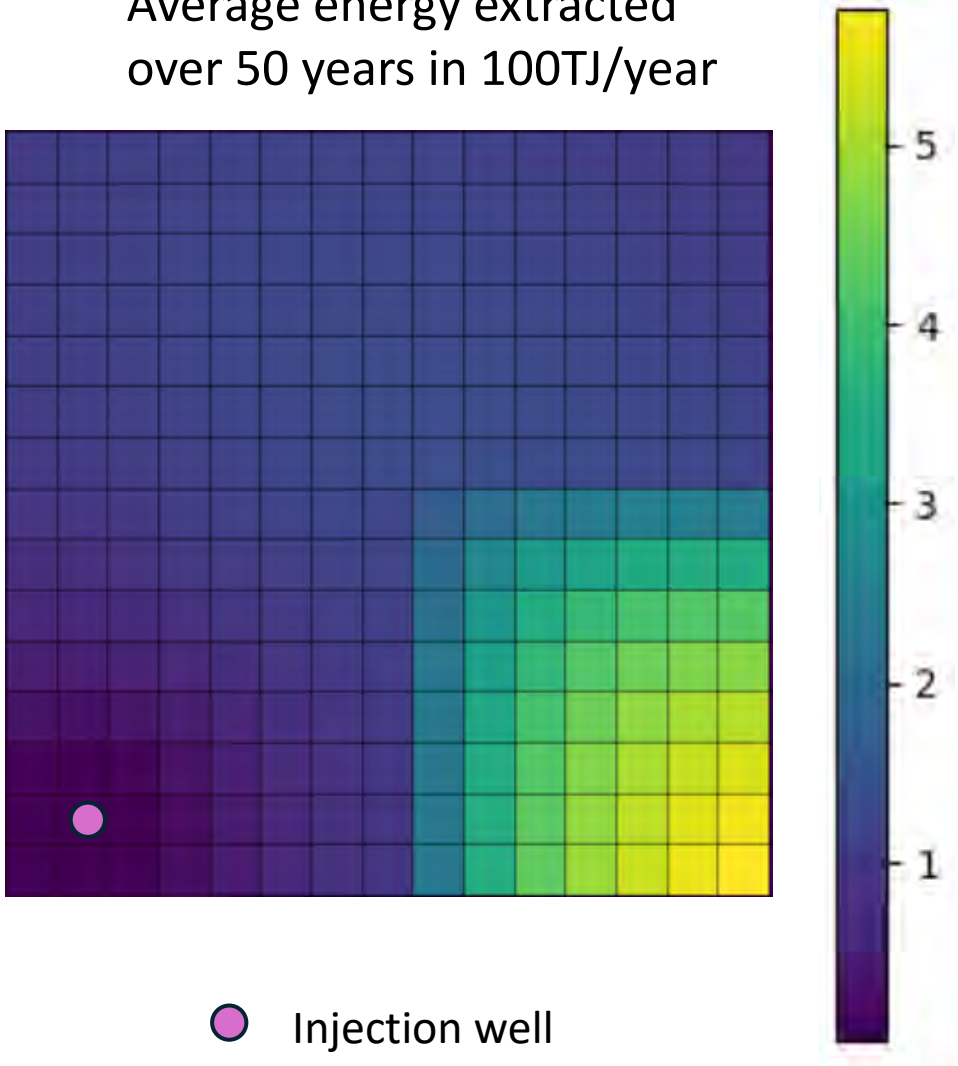
- Perform simulation for many different well placements
- Organize the outputs and make the available for optimization calculations
- As a test, optimize the current syste for total energy extracted over 50 years
- Test all spots in the fine centre mes (red square)
- Reinjection is stationary



Results 1: Energy extracted

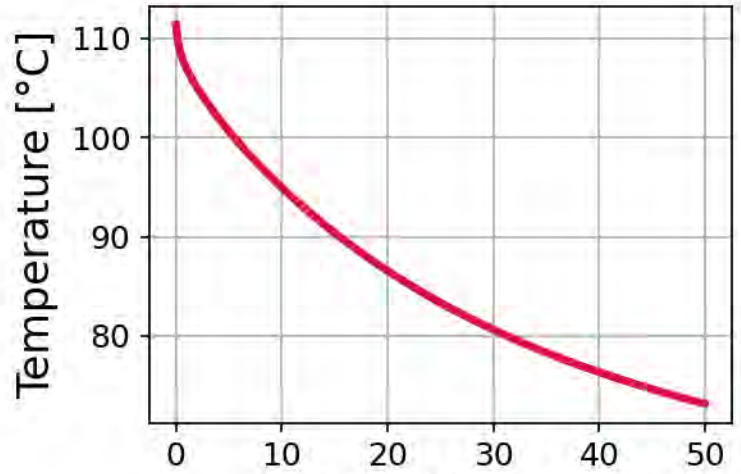
- Visualization of the fine grid coloured by average energy extracted per year
- 15x15 grid, squares are 50m x 50m
- Values range from 0.5TJ to 570TJ per year
- Lowest values located near injection site
- Highest values in the high temperature corner

Average energy extracted over 50 years in 100TJ/year

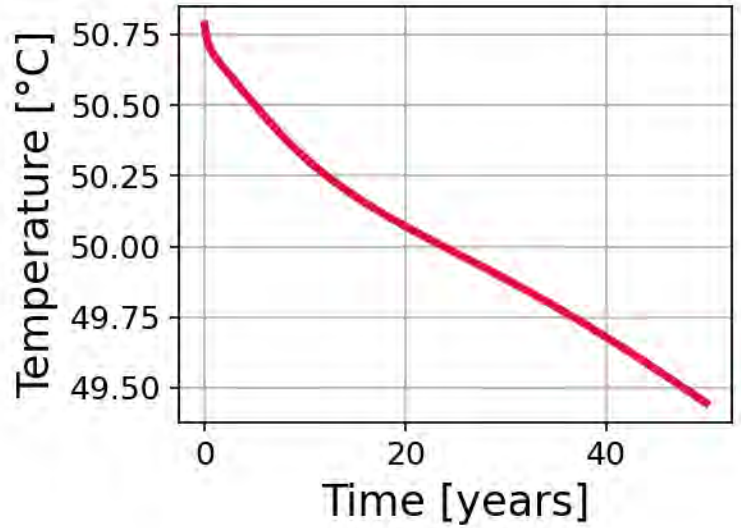


Results 2: Temperature at extraction site

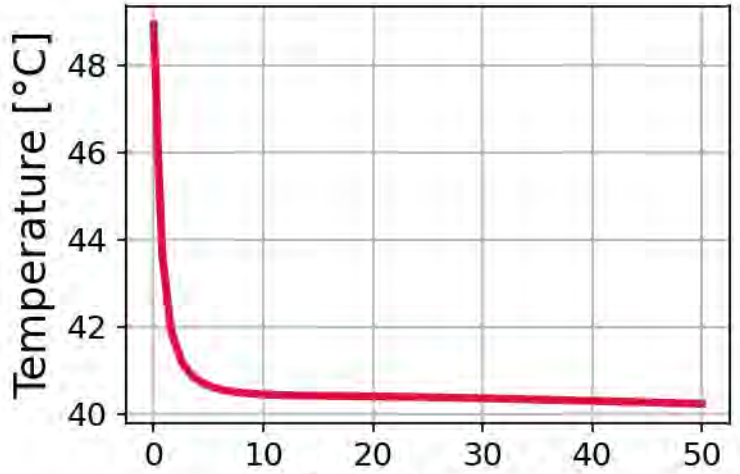
Highest energy output



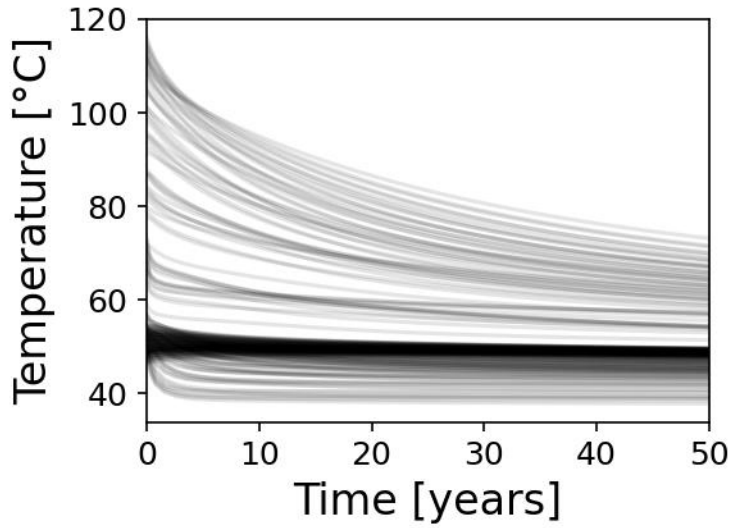
In “cold zone”



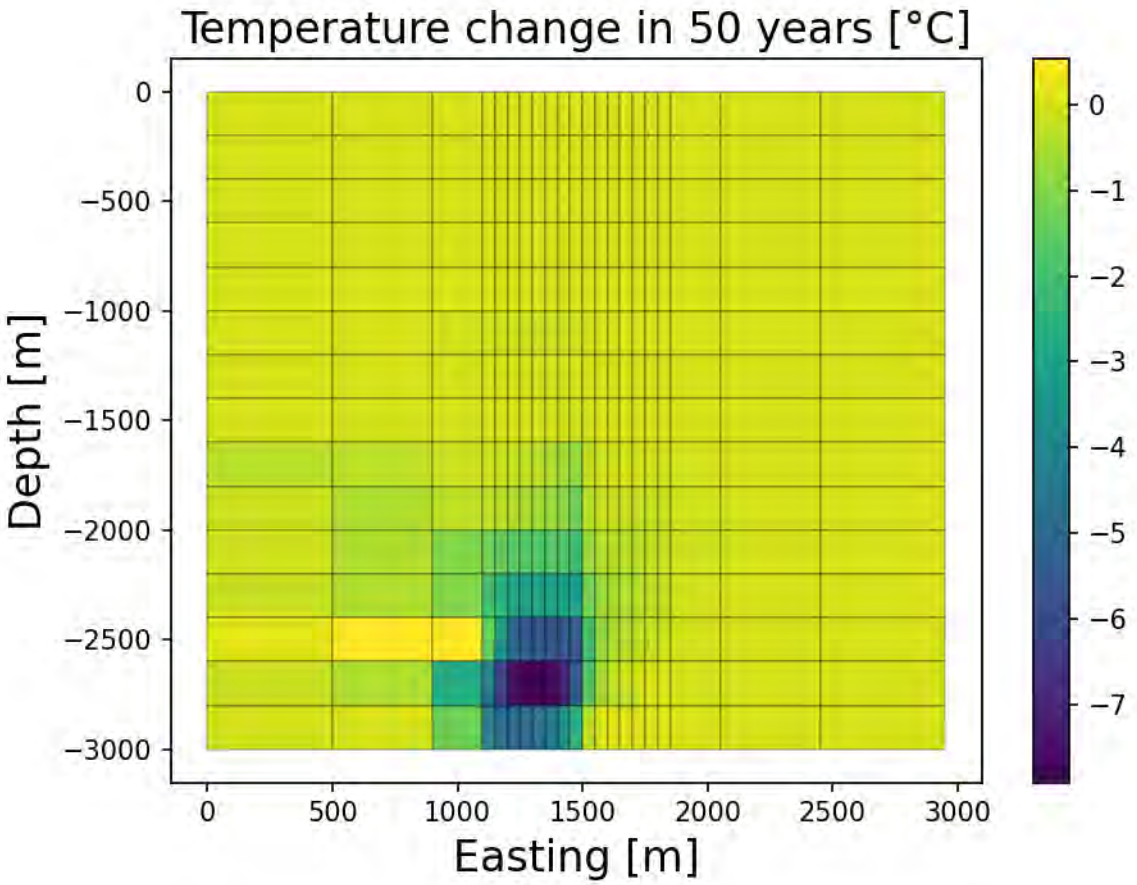
Near injection well

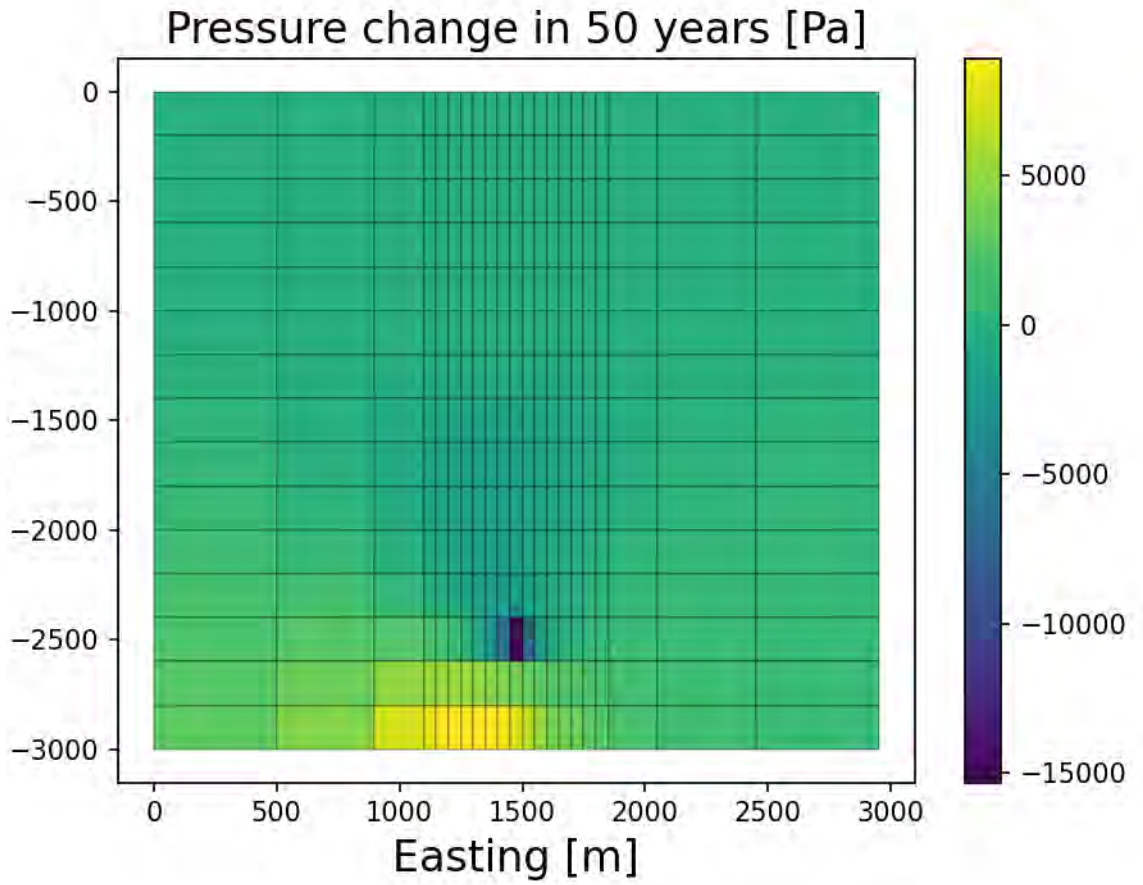


All cells

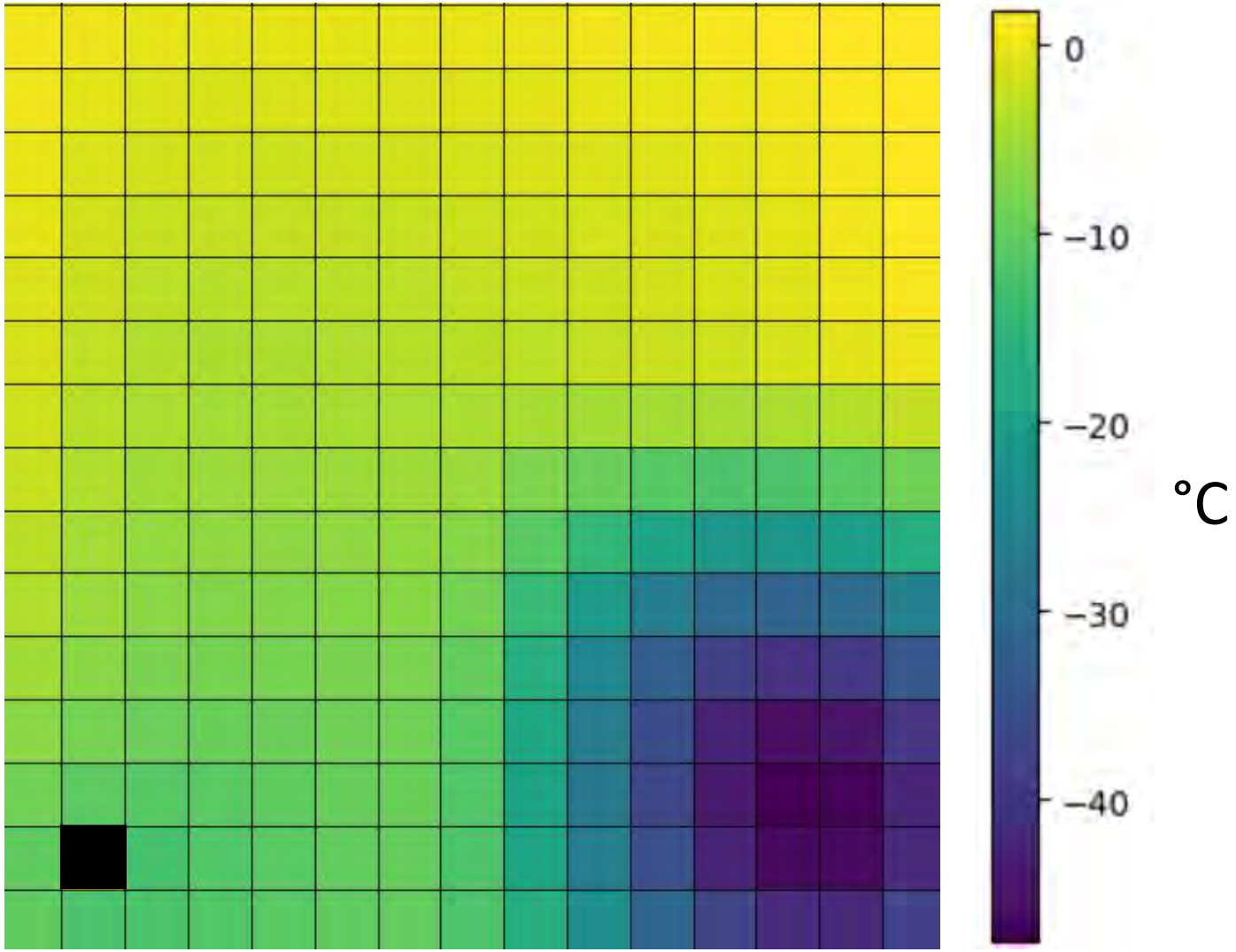


Results 3: Changes in temperature & pressure





Results 3.5: Changes in temperature



Optimizing for different criteria

- With the wealth of outputs available from the Waiwera simulations, the operator can optimize for their desired results

Example code

- Package aims to abstract tedious record keeping and file management

```python
from geomodel import LocationOptimizer

base_input = "./model_parameters.json"  # description of geological system properties
background_state = "./background.h5"    # waiwera initial conditions
mesh_file = "./mesh.h5"                 # spatial mesh location
test_locations = "./well_locations.txt" # operator defined locations to test

def evaluation_function(h5_file):
    # user defined evaluation function
    return score

optimizer = LocationOptimizer(base_input, background_state, mesh_file)
optimizer.moving_sink(
    coords_from_file=test_locations,
    rate=-100,
)

optimizer.run()
optimizer.evaluate(evaluation_function)
```

- Required inputs from operator:
  - Mesh file
  - Geothermal system parameters
  - Initial state for simulation (Waiwera output)
  - List of test coordinates to be simulated

Runtime

- This example was run with a grid size of 6615 cells
- Each production simulation was completed in ~25 seconds
- Full ensemble computed in ~90 minutes, with 224 simulations completed sequentially
- Larger mesh increases runtime
- Lots of opportunity for parallelization, HPC use

Summary

- Multiple simulations completed using Waiwera and Python
- Waiwera for simulation, Python for management and evaluation
- Gives good results for simple test case
- Should enable operators to find optimal locations based on their specific criteria