Thermal impact assessment of groundwater heat pumps (GWHPs)

Der Geothermiekongress – Essen (Germany, 29/11/2018)

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Politecnico di Torino

The GRETA project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme.

The GRETA project

- near-surface **G**eothermal **RE**sources in the **T**erritory of the **A**lpine space
- Fostering shallow geothermal energy acting on:
  - Knowledge
  - Regulation
  - Geo-referenced data
  - Energy planning

Interreg Alpine Space Greta

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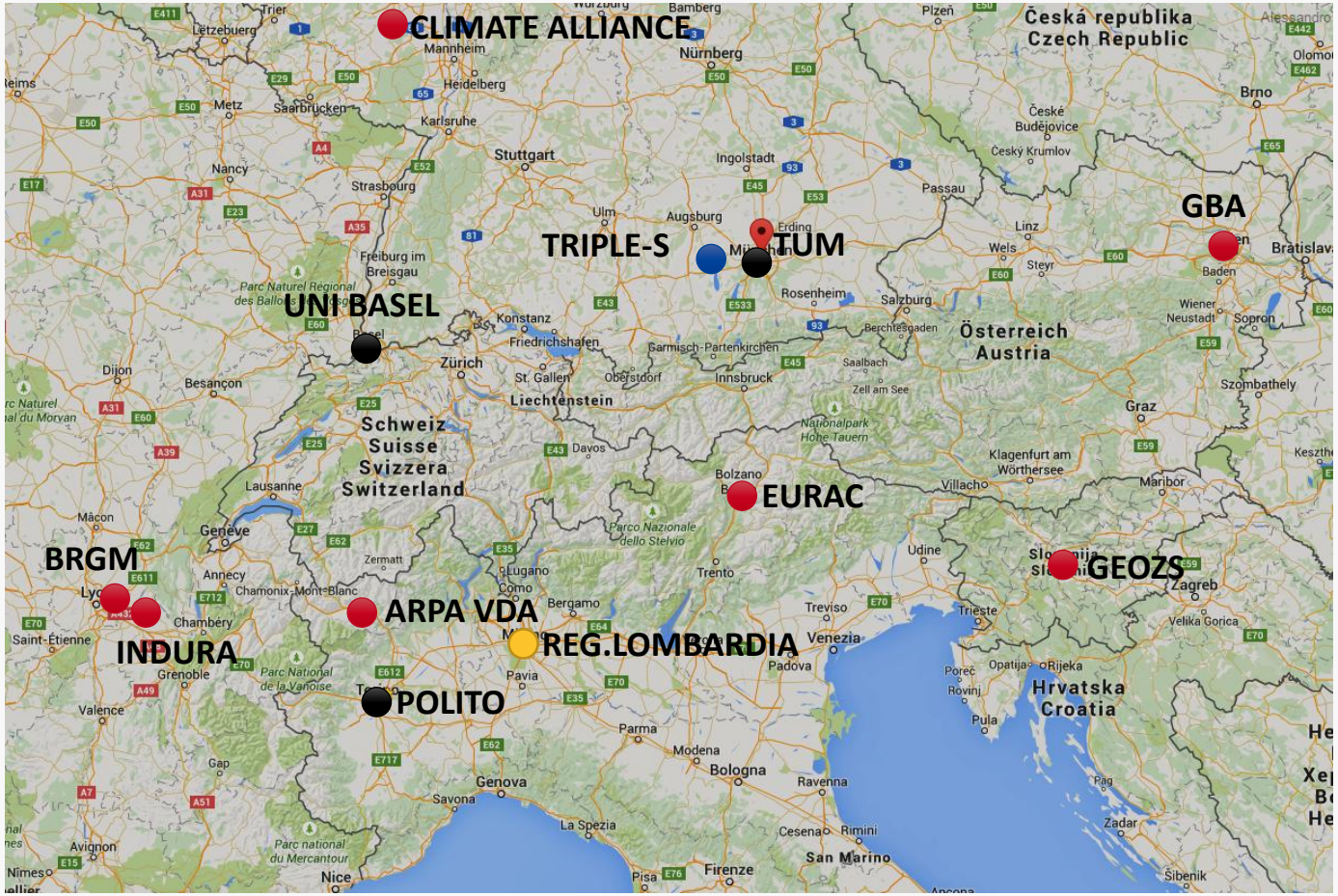
GRETA project partners



- **University**
- **Public administration**
- **Public body**
- **SME**

+ **Leader: TUM**
+ **Work Packages:**
  + WP1 Management
  + WP2 Regulation (GEOZS)
  + WP3 Operational criteria (GBA)
  + WP4 Mapping (POLITO)
  + WP5 Energy Planning (EURAC)
  + WP6 Interaction (ARPA VDA)
  + WP7 Communication (BRGM)

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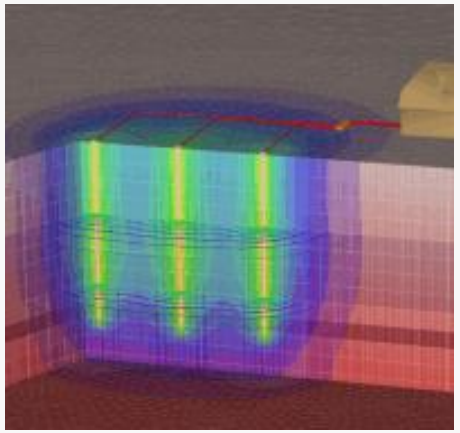
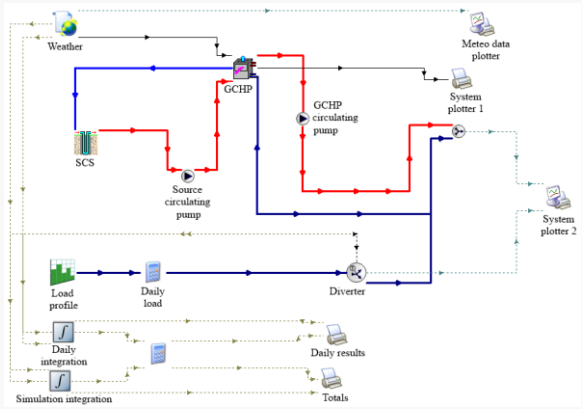
WP3 – Operational criteria

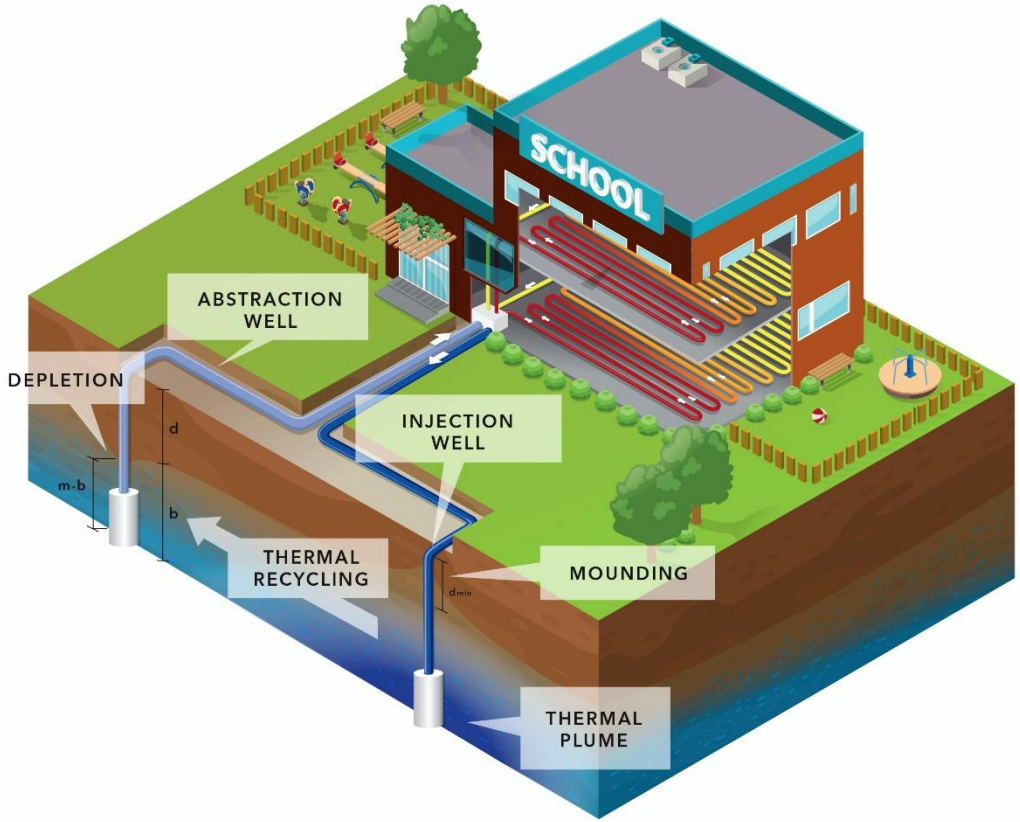
- Fields of intervention:
  - Technologies:
    - Closed-loop
    - Open-loop
  - Existing installations:
    - Good practice examples
  - Operational and design issues:
    - Literature reviews
    - Focus groups with stakeholders
    - Original research



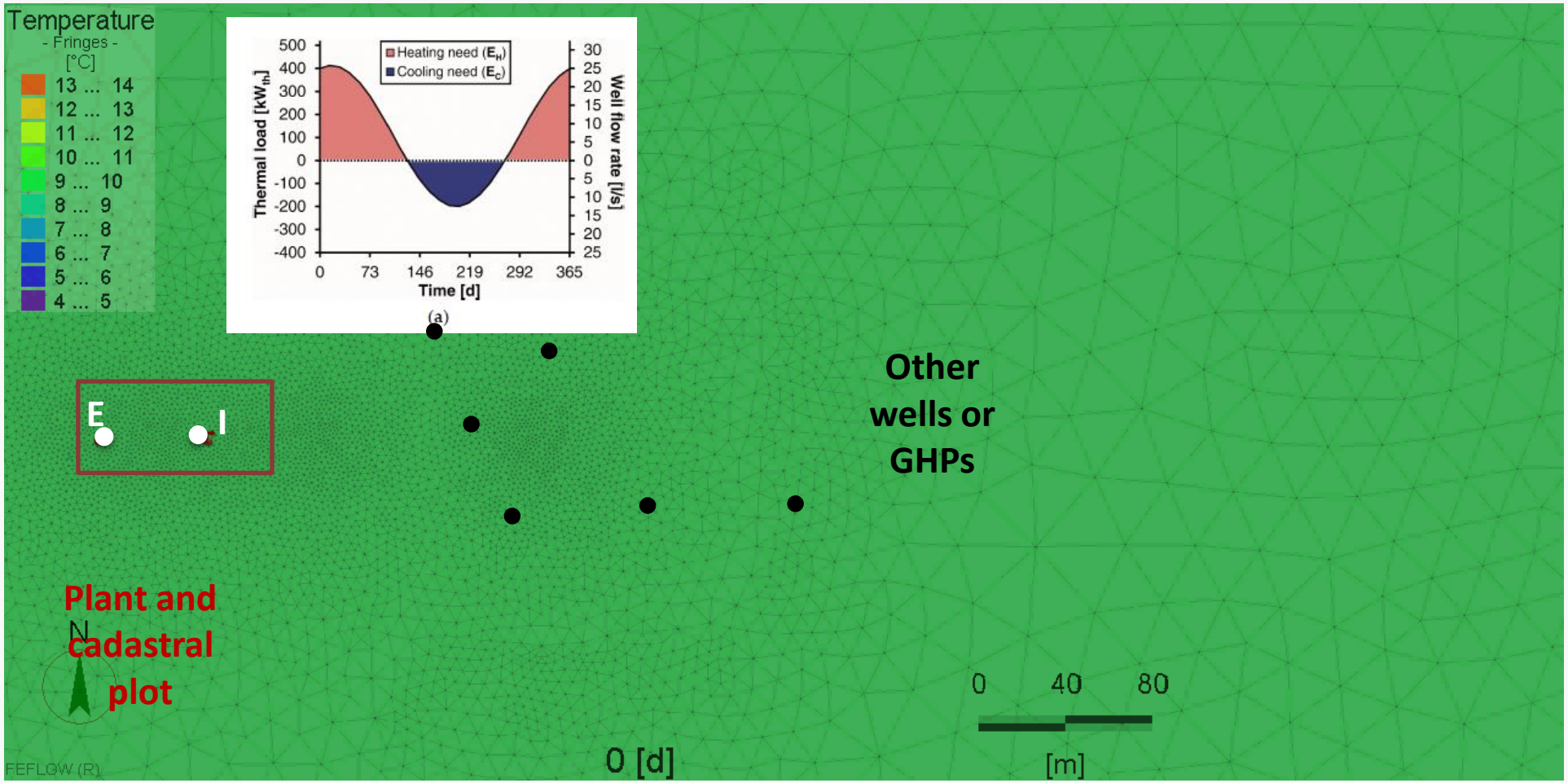


Design issues of GWHPs

- Advantages:
  - Scale economies
  - Smaller area required
  - Higher efficiency
- Issues/limits:
  - Drawdown at abstraction well
  - Uprising at injection well
  - Thermal recycling
  - Thermal plume propagation downstream the well doublet



Propagation of thermal plumes from GWHPs



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Land management of GWHP plumes: an example

POLITO

Heat transport in saturated porous media

+ Which are the driving factors of GWHPs' plume propagation?

$$(\lambda + \rho_w c_w v_D \alpha_L)\frac{\partial^2 T}{\partial x^2} + (\lambda + \rho_w c_w v_D \alpha_T)\left(\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2}\right) - \rho_w c_w v_D \frac{\partial T}{\partial x} = \rho c \frac{\partial T}{\partial t} - H$$

Conduction **Dispersion** **Advection** **Source/sink**

+ Modelling assumptions:
  + Boundary conditions
  + 2D or 3D?
  + Thermal load time resolution
+ Is any analytical formula available?

energies

MDPI

Article

Thermal Impact Assessment of Groundwater Heat Pumps (GWHPs): Rigorous vs. Simplified Models

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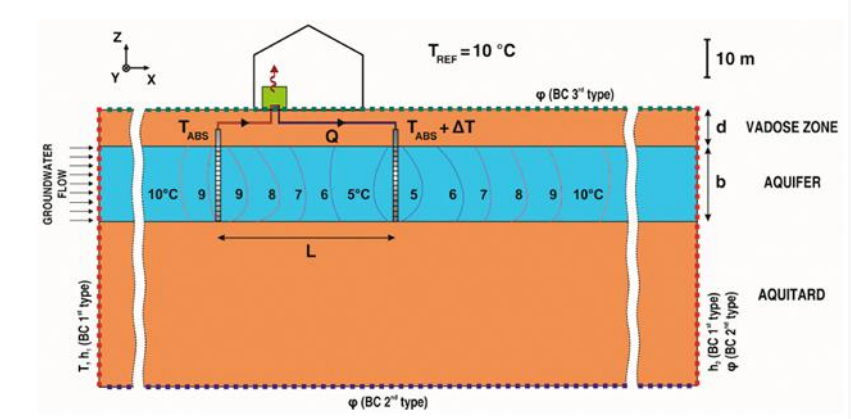
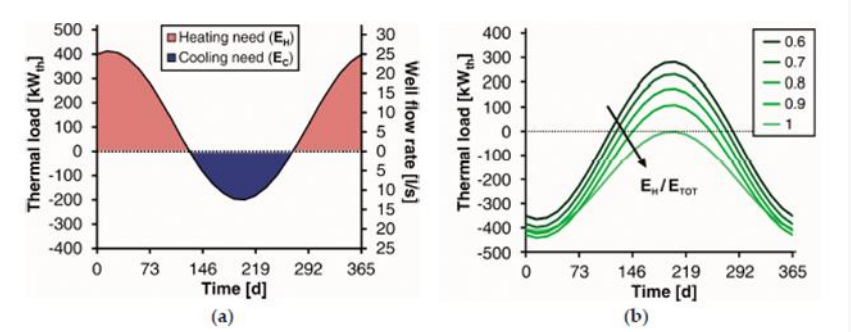
Numerical modelling with FEFLOW

- Well doublet with sinusoidal thermal load
- Geometry:
  - 6000x3000 m mesh
  - 3 main layers (vadose zone, aquifer, aquiclude)
- Flow BC:
  - 1st kind hydraulic heads US-DS
  - 4th kind abstraction-injection wells
- Heat BC:
  - 1st kind:
    - US temperature
    - Injection well (ΔT)
  - 2nd kind no-flux from bottom
  - 3rd kind temperature-dependent flux from g.s.



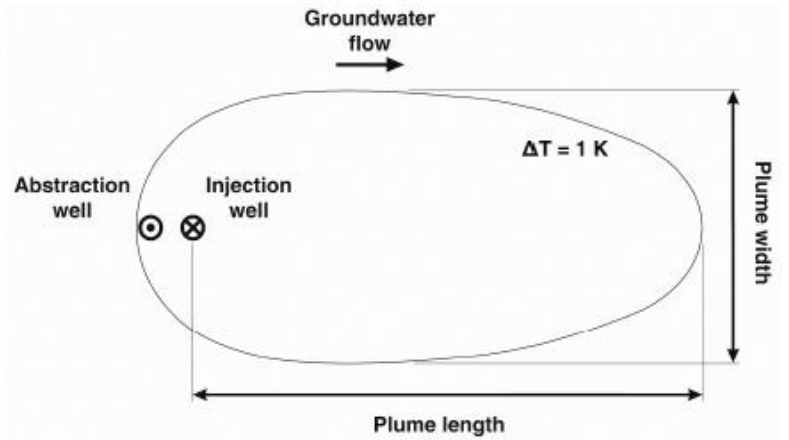
Modelling assumptions



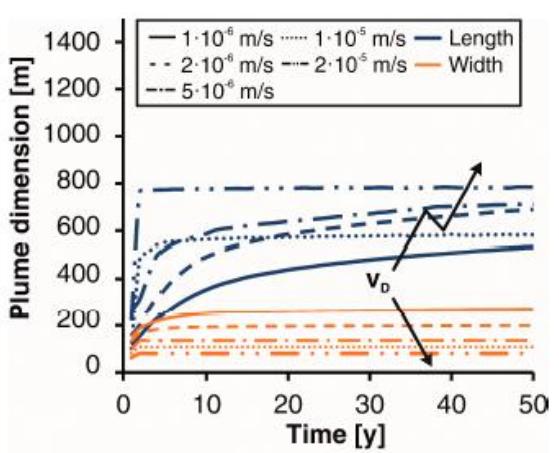
Thermal load

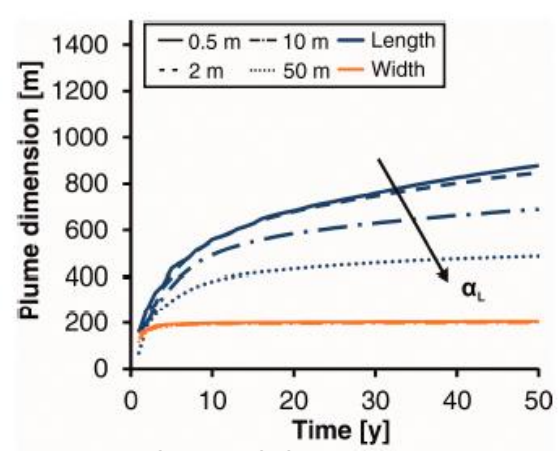
Sensitivity analysis results (1/3)

Thermal plume dimensions

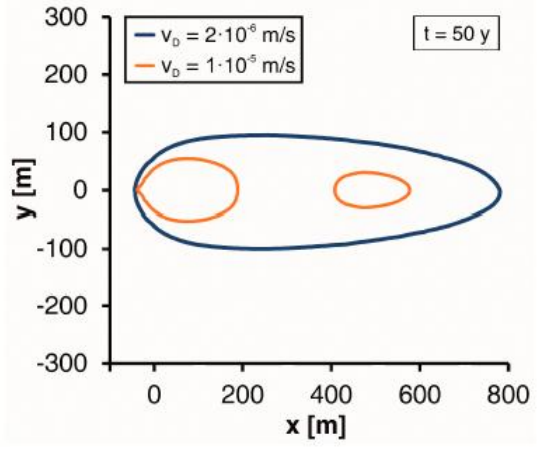


Influence of Darcy velocity





Thermal dispersivity



Plume separation

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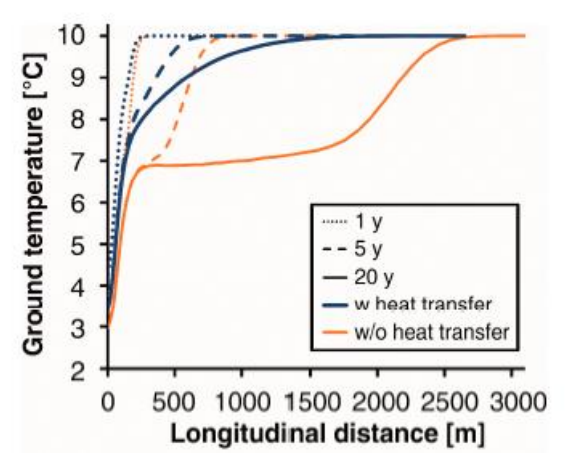
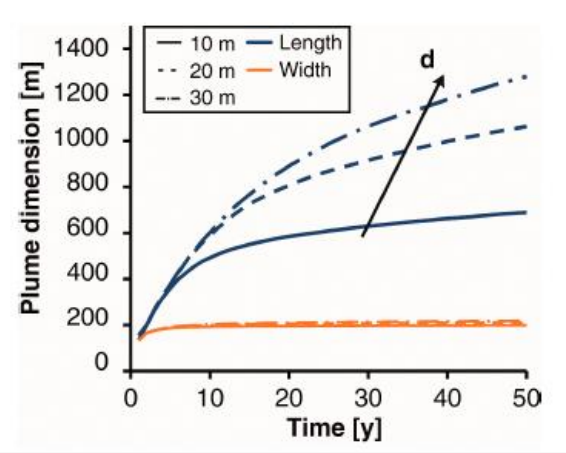
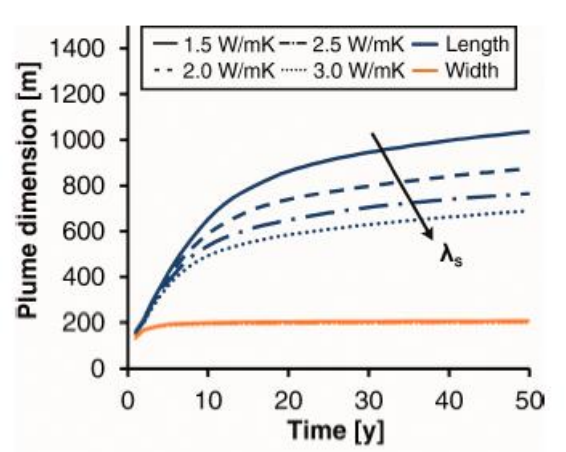
Sensitivity analysis results (2/3)

Ground surface BC: no-flux or 3rd kind BC?

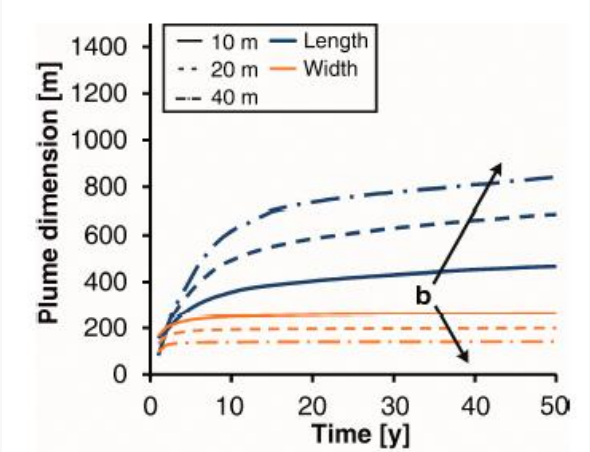


Depth to water table





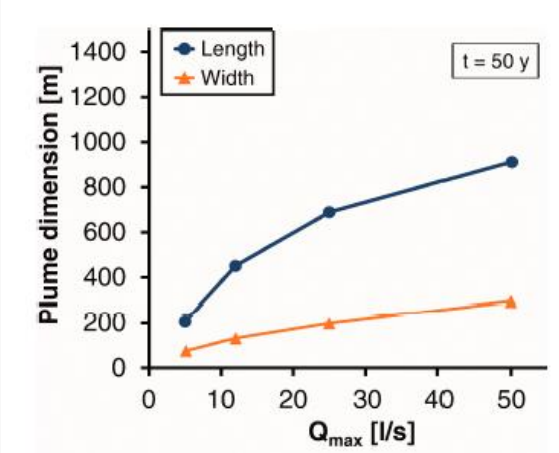
Thermal conductivity



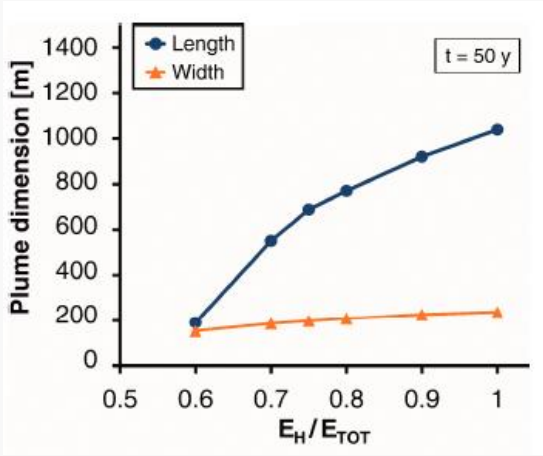
Aquifer saturated thickness

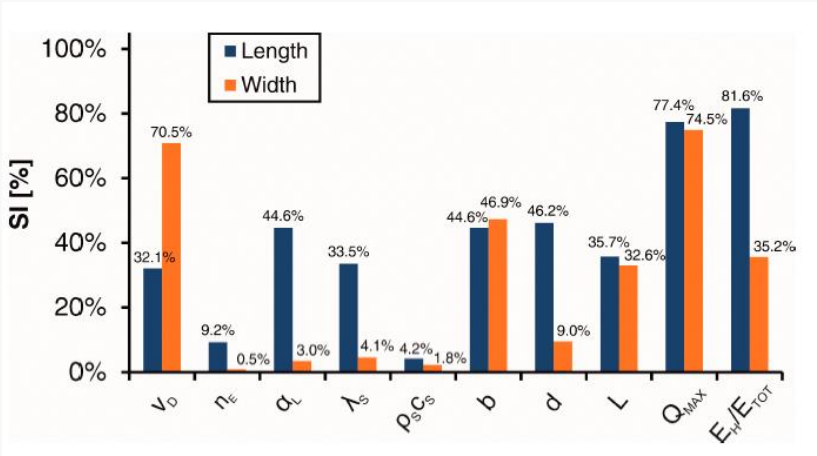
Sensitivity analysis results (3/3)

Flow rate / thermal power



Load imbalance





Sensitivity index

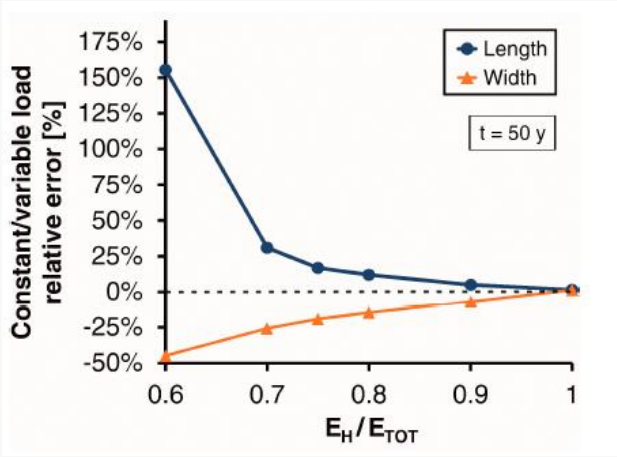
Simplifying assumptions

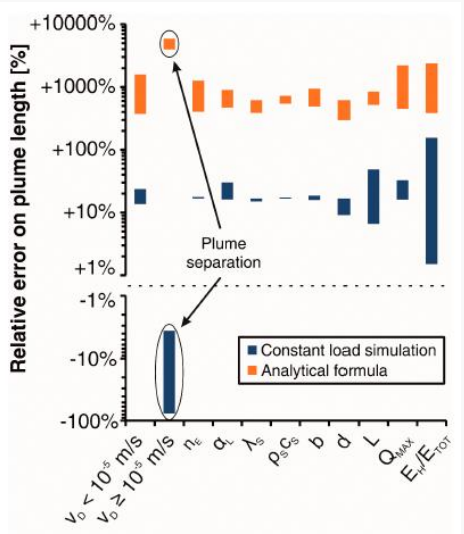
- Constant thermal load:
  - Acceptable with sufficiently unbalanced thermal loads
  - Plume length overestimated
  - Plume width underestimated
- Analytical solutions:
  - Plume width precise/sligthly overestimated using:

$$W_{pl} = \frac{Q_{max} \cdot (1 - RR_{max})}{Ti}$$

- Plume length generally overestimated with:

$$L_{pl} = v_{th} \cdot t$$





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Summary

+ Thermal plume assessment is key for GWHP management
+ Three heat transport mechanisms: advection, dispersion, conduction
+ Key parameters:
  + Darcy velocity
  + aquifer thickness
  + flow rate
  + heating/cooling ratio
+ Heat exchange with atmosphere
+ Simplifications:
  + analytic solutions for plume width
  + constant thermal load for plume length

energies

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Thank you for your attention!!!!

- GRETA project
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…e altri ancora!

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