Effect of solar radiation on underground temperature values and heat supply around a ground coupled heat pump based on meteorological data, Debrecen

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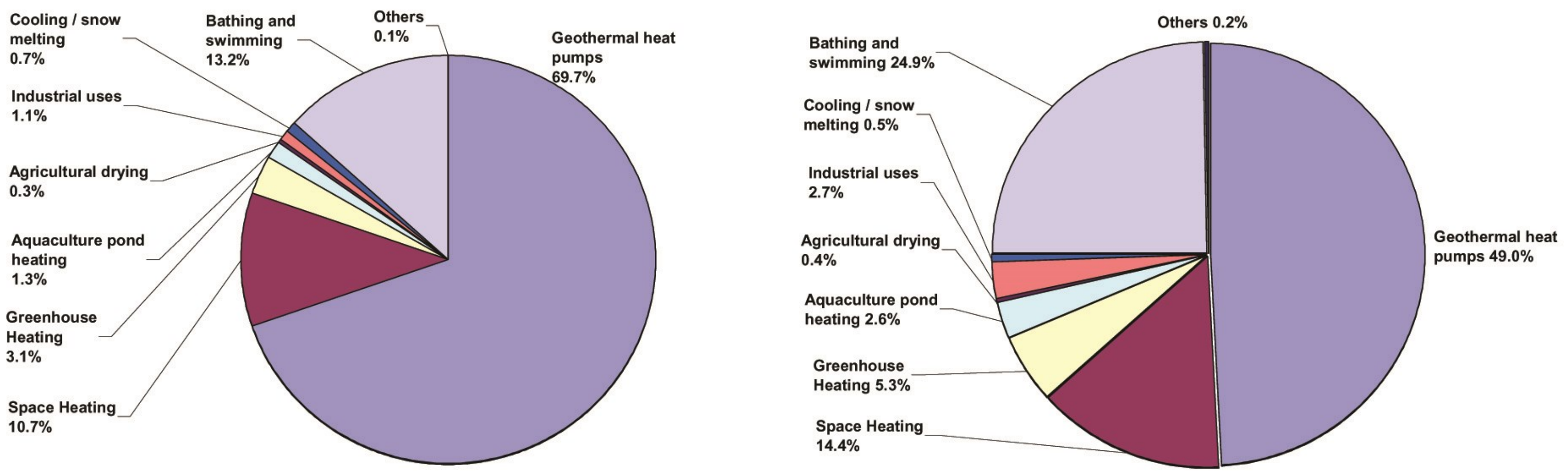
Introduction

- Heat pump system is the main utilization type in geothermal energy with dynamic growing.



Lund et al. 2010

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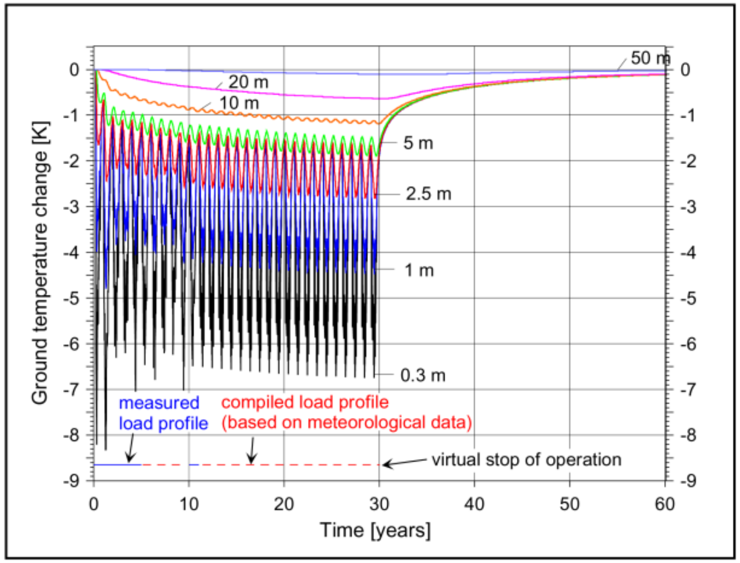
- These systems usually need summer recovery for optimal running and to avoid overcooling.



Eugster – Rybach 2000

Introduction

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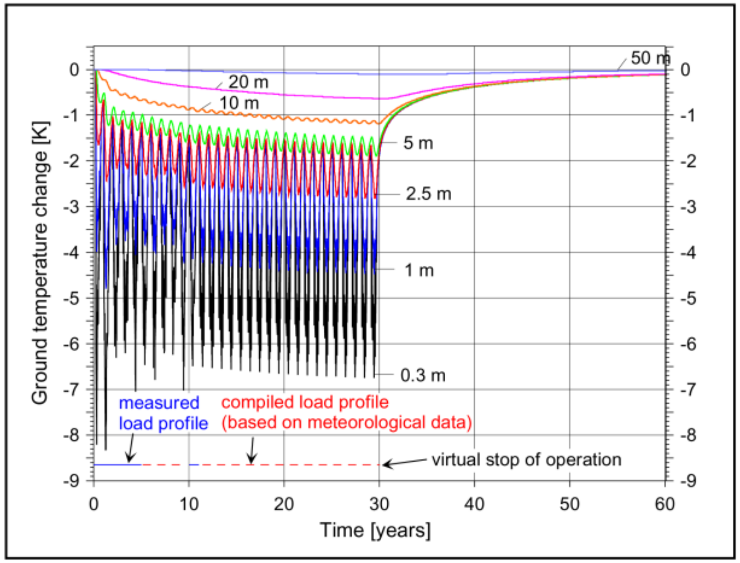
- These systems usually need summer recovery for optimal running and to avoid overcooling.

- How significant is the role of solar irradiation in the summer recovery?

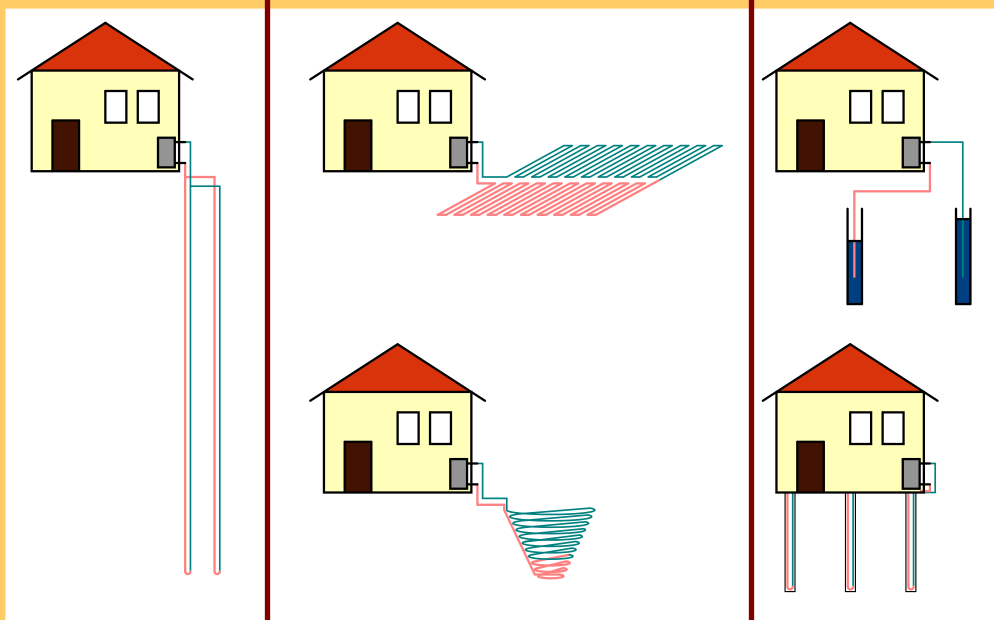


Eugster – Rybach 2000

Main types of ground loops

„soil” collectors,
trenches
(1.5 m – 2.5 m)

borehole heat exchangers
(up to 100 m – 150 m)



wells
(2 m – 10 m)

pile heat
exchangers
(5 m – 20 m)

geothemal heat
baskets (1 m – 5 m)

affected by solar radiation

Source of data

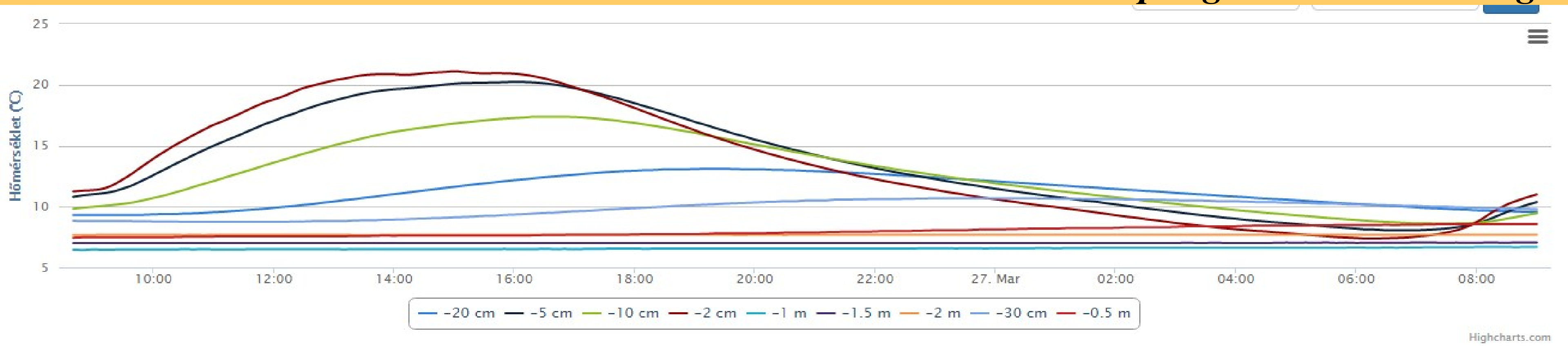
soil temperature at depths of

- 2 cm
- 5 cm
- 10 cm
- 20 cm
- 30 cm
- 50 cm
- 100 cm
- 150 cm
- 200 cm

air temperature at 2 m

solar irradiance

1 s sampling and 10 min average



Theoretical temperature models

- In our approximation the solar irradiance have effect on the temperature of the upper soil layers, which can modify the temperature of the underground and also the air temperature.

- sum of sinusoidal functions

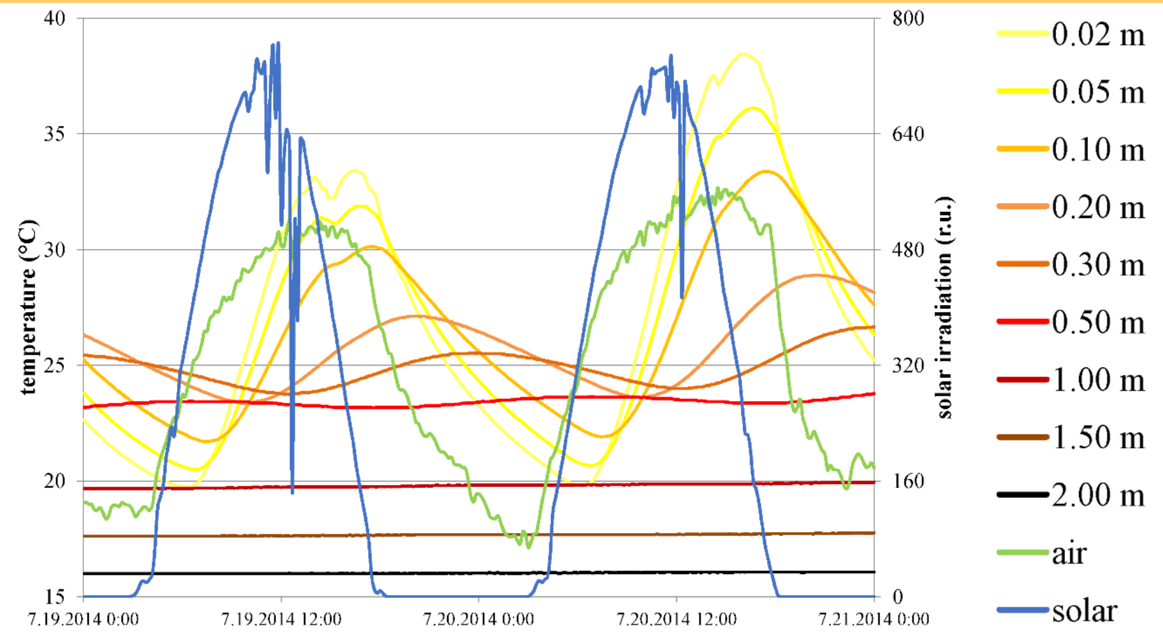
$$T(z,t) = T_0(z=0) + Gz + A_y e^{-z\sqrt{\omega_y/2\alpha}} \cos(\omega_y t + \phi_y - z\sqrt{\omega_y/2\alpha}) +$$

$$+ A_d e^{-z\sqrt{\omega_d/2\alpha}} \cos(\omega_d t + \phi_d - z\sqrt{\omega_d/2\alpha})$$

$$\alpha(A) = \frac{(z_2 - z_1)^2 \omega_y}{2\left[\ln A(z_1) - \ln A(z_2)\right]^2}$$

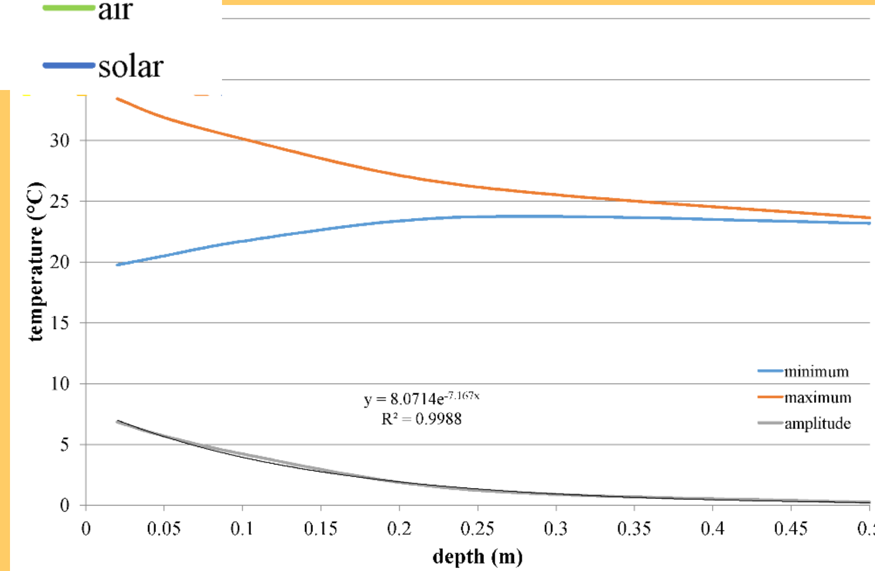
$$\alpha(\phi) = \frac{(z_2 - z_1)^2 \omega_y}{2(\phi_2 - \phi_1)^2}$$

Results – daily temperatures



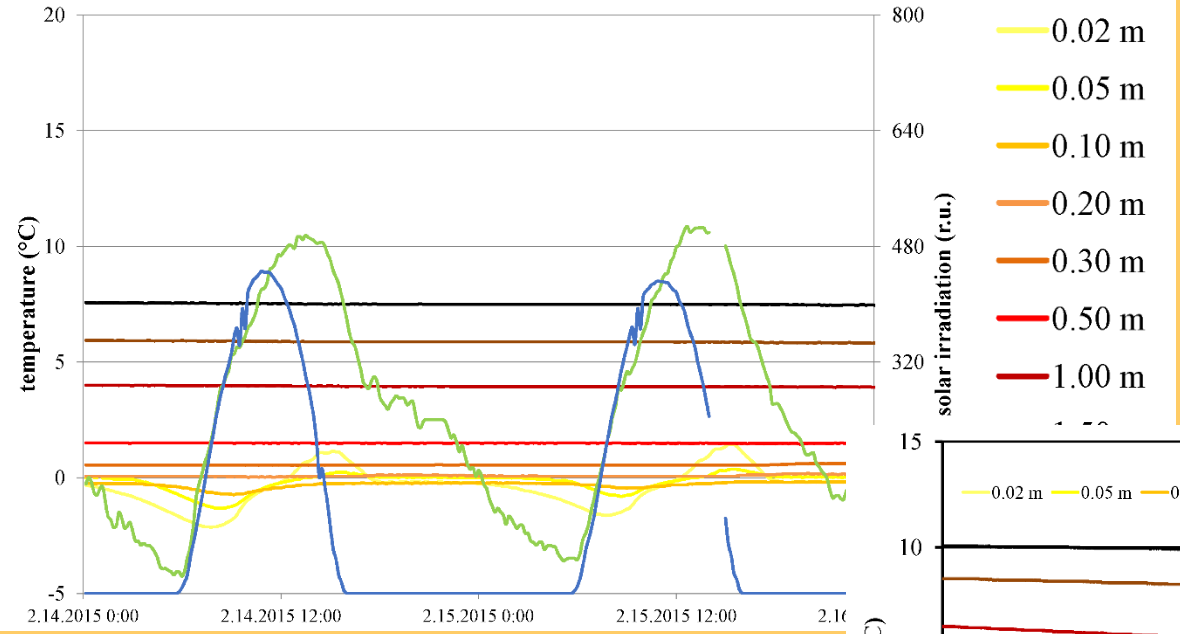
daily penetration: 1 m

summer days

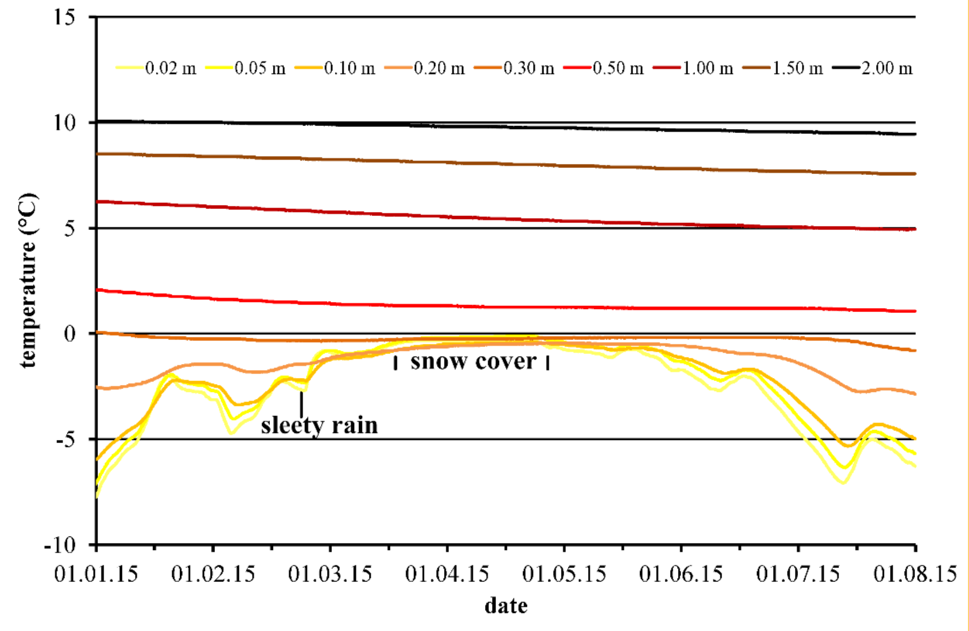


thermal diffusivity $7.1 \cdot 10^{-7}\ m^2/s$

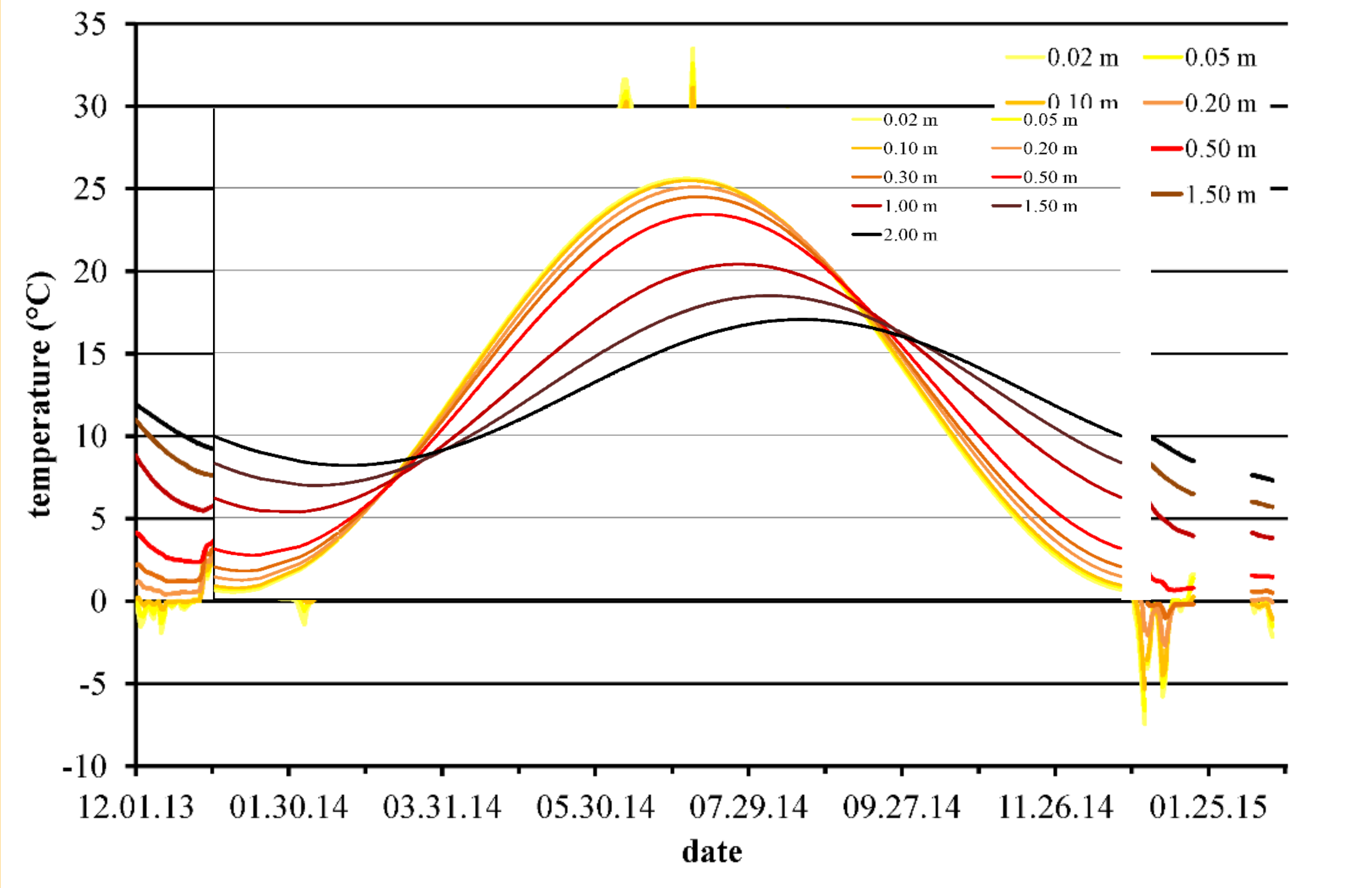
Results – daily temperatures



winter days

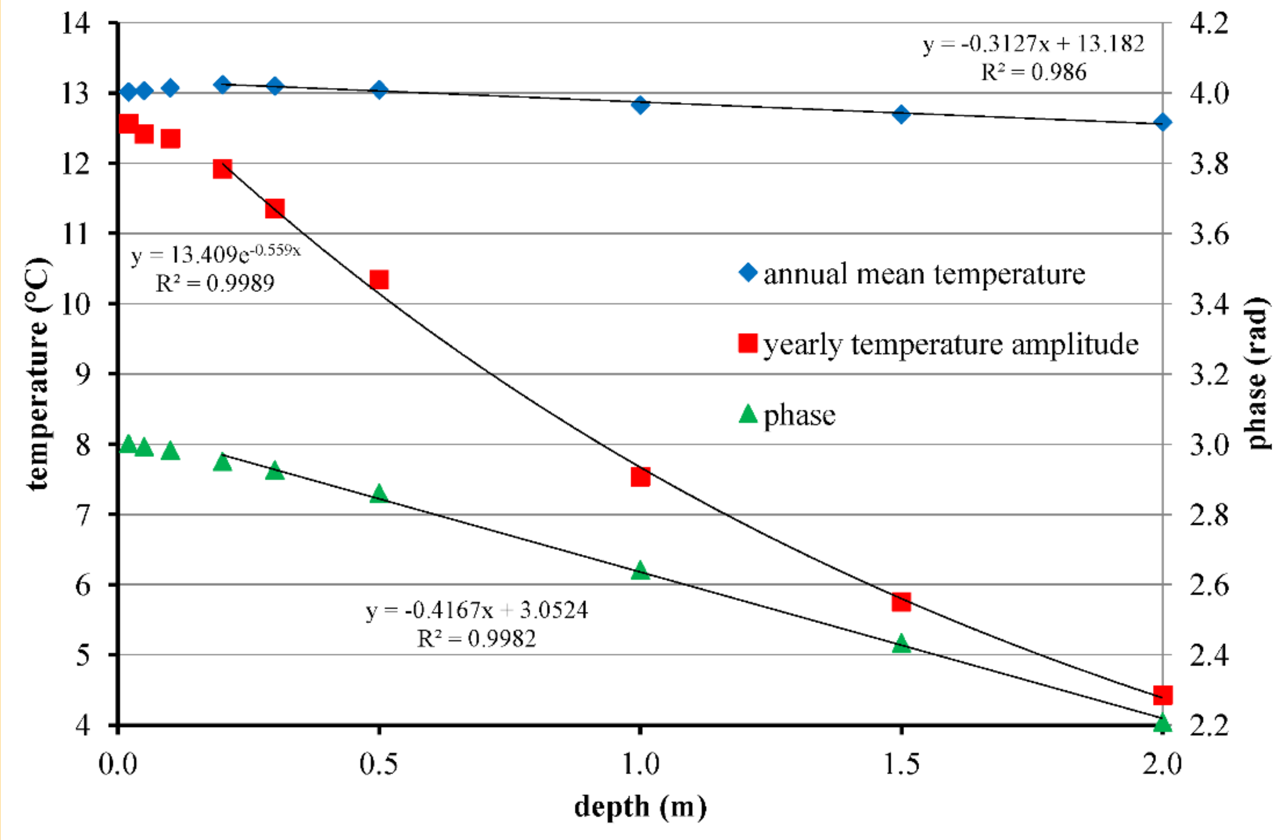


Results – yearly temperatures



$$T(z,t) = T_0(z) + A_y(z) \cdot \cos(\omega_y t + \phi_y(z))$$

Results – yearly temperatures



depth range (m)	$\alpha(A_y)$ (m^2/s)	$\alpha(\phi)$ (m^2/s)
0.10–0.20*	$7.8 \cdot 10^{-7}$	$9.9 \cdot 10^{-7}$
0.20–2.00**	$3.2 \cdot 10^{-7}$	$5.7 \cdot 10^{-7}$

Conclusions

- thermal effect of irradiation can be detected only in shallow geothermal systems, the horizontal and upward energy flow is more important in the recovery
- installation depth of these systems is small, the undisturbed temperature of it is the lowest at the end of the heating season
- artificial temperature drop is intensified by natural processes
- environmental effects of overcooling:
  - soil freezing deeper
  - SPF value decreasing
  - the operation costs increasing.

The effect of irradiation is not enough to supply the extracted energy, thus thermal energy storage is recommended.

Conclusions

Analysing the climate of the Danube Region the natural supply by irradiation is more effective in areas with the following characters:

- high irradiation values in both seasons and mild winter (SOUTH);
- high probability of long spells of snow cover during cold winter and also of hot summer (EAST);
- higher cooling demand than heat demand with good possibilities of thermal energy storage (SOUTH).

Other possible „strategy” for more efficient recovery:

- installing the shallow heat exchangers below buildings

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Thank you for you attention!