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Supervised rock-mass storage of thermal energy produced by a thermal solar panel

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Introduction and objectives

The use of solar thermal collectors provides a very intermittent heat production that is time offset with respect to requirement. SOLARGEOTHERM is a 3-years project aiming to study and modelize the possibility of storing the energy produced by solar thermal collectors into dry rock. An experimental site has been designed to monitor the storage and recovery of the thermal energy produced by solar collector and transferred to the underlying rock thanks to 3 vertical geothermal probes.

Experimental set up


(a) (b)

Fig. 1 : Experimental site : (a) Thermal solar panels, (b) Geothermal probes

Montauriol quarry (Pyrénées Orientales)
- 42 m² of solar panels collectors (Fig.1)
- 3 boreholes (A, B, C) of 200 m depth (Fig.4)
- 3 measurement boreholes (D, E, F) of 20 m depth
- 1 Dry cooler 6 kW_{th}

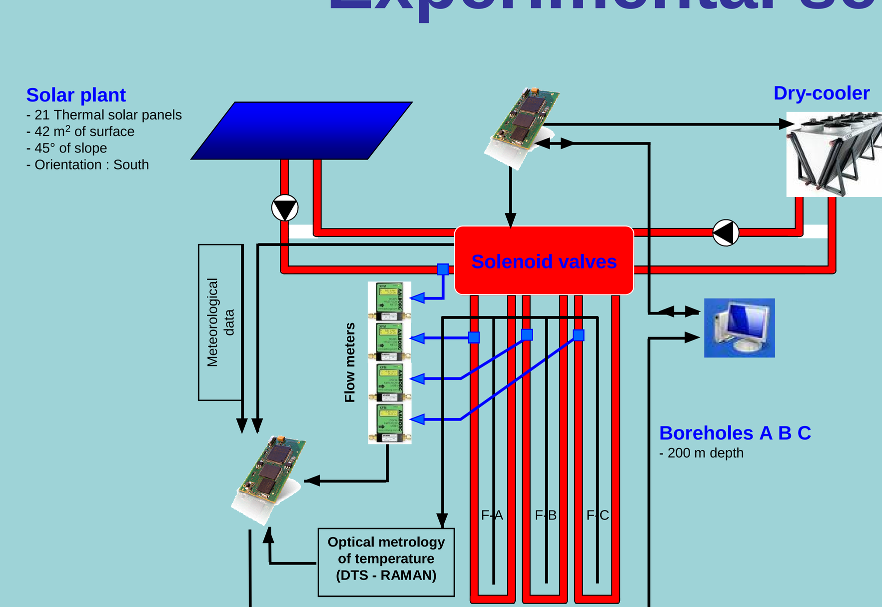

Fig. 2 : Synoptic of the system

3 zones of study :
- Solar loop
- Geothermal loop
- Thermal load

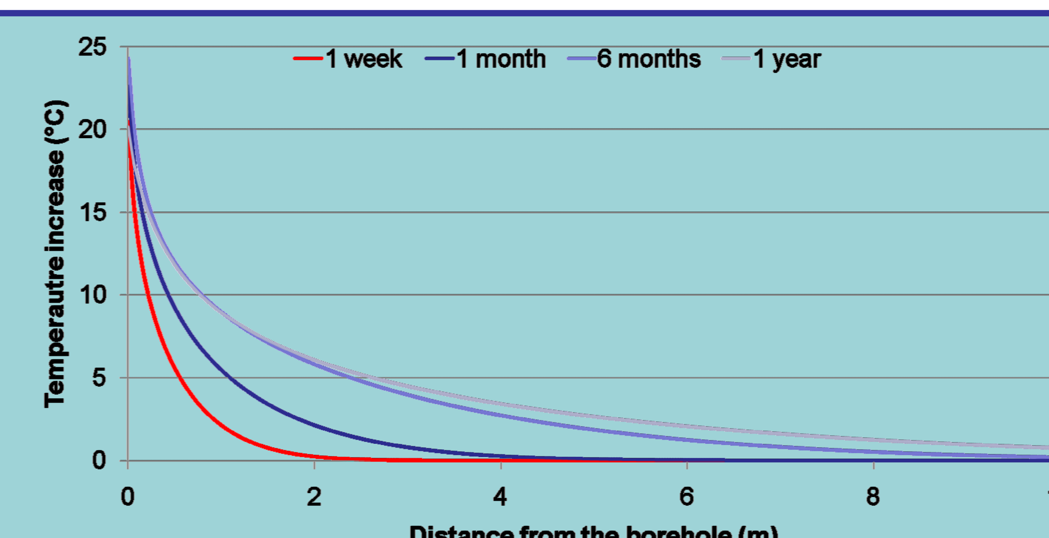

Figure 3: Simulation of the borehole radial influence

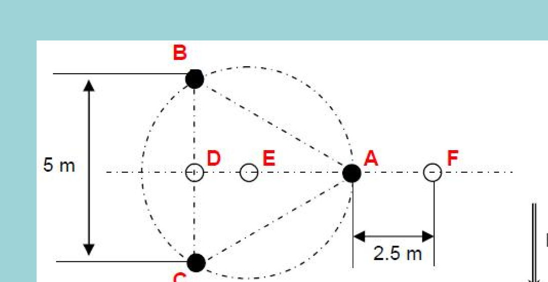

Fig. 4 : Borehole geometry

The optimal solution to obtain an important rock-mass temperature raise and to avoid the risk of a collision between the boreholes in depth is a distance of 5 m (2 x 2.5 m)

Thermal response test

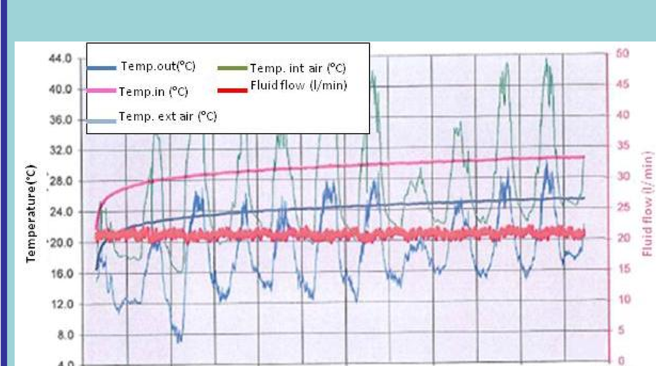

Fig. 5 : Thermal response test results

- Injection of a known thermal power into a geothermal probe
- Initial temperature of soil
- Inlet and outlet temperature
- Fluid flow

Finite line source model

$$T(r,t)=T_0+\frac{q}{4\pi\lambda}\int_{\frac{r^2}{4\alpha t}}^{\infty}\frac{e^{-u}}{u}du \cong T_0+\frac{q}{4\pi\lambda}\left[\ln\left(\frac{4\alpha t}{r^2}\right)-\gamma\right]$$

$$T_0+\frac{q}{4\pi\lambda}\left[\ln\left(\frac{4\alpha t}{r^2}\right)-\gamma\right]=k\times\ln(t)+m$$

$$\overline{T}(t)=k\times\ln(t)+m$$

$$k=\frac{q}{4\pi\lambda} \Rightarrow \lambda=\frac{q}{4\pi k}$$

- T0 is the initial ground temperature (°C)
- λ is ground thermal conductivity (W.m-1.K-1)
- q is heat flux injected by unit of length (W.m-1)
- α is the ground thermal diffusivity (m².s-1)
- r is the radius of the geothermal probe (m)
- γ is the Euler constant (0.5772)

Thermal shock

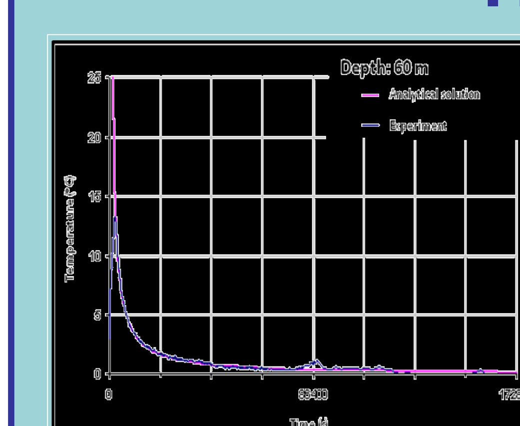

Fig. 6 : Thermal answer of the rock mass

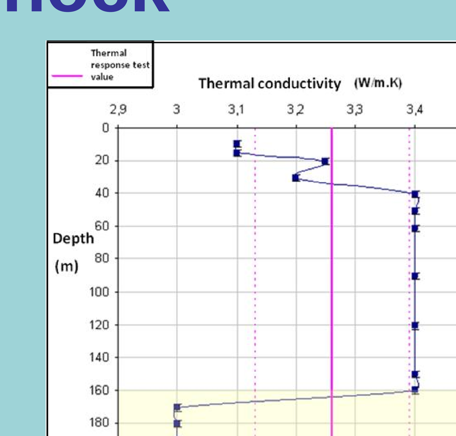

Fig. 7 : Local values of thermal conductivity given by thermal shock

- Generation of a sharp pulse of heat flux to the rock mass like a Dirac (1m³ of water at 70°C during one hour)
- Observation of the borehole thermal answer
- Use of line source model defined by Carlsaw et Jaeger

Modeling of the rock-mass

Simulation made with the software COMSOL

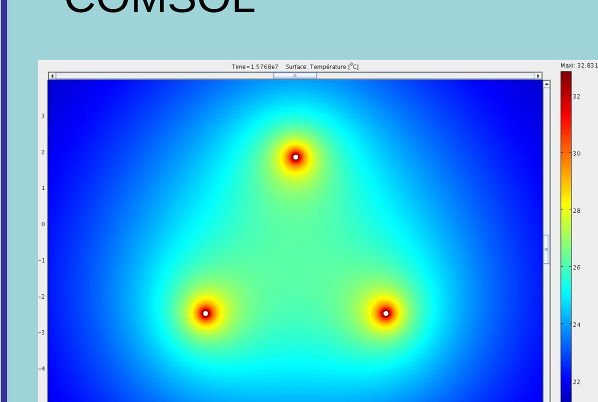

Fig. 8 : Simulation of the energy storage obtained after 6 months

3D « simulated » by 2D surfaces every 10 meters

Simulation of 6 months of storage with theoretical meteorogical data

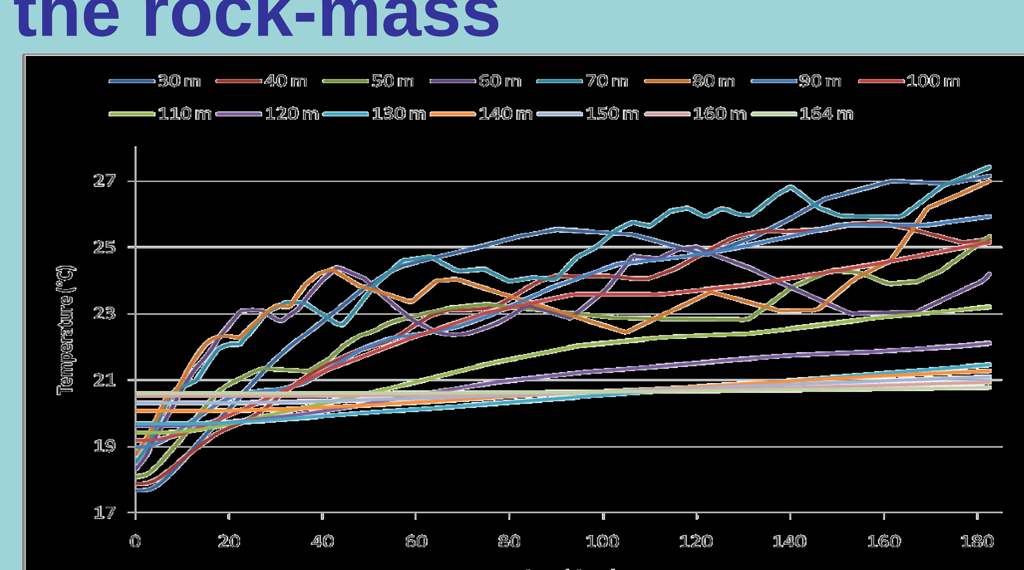

Fig. 9 : Temperature evolution during 6 months at the centre of the 3 boreholes

Perspectives

Acquisition of a complete storage/recovery cycle

Modeling of the 3 boreholes and their thermal interactions during the heat storage & recovery cycles

Integration of real meteorological data in the analytical model

Define storage/release strategies using fuzzy logic methodology and predictive control