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# How Soil Moisture Variation Can Affect Horizontal Ground Heat Exchangers Performances: the Iter Project Case Study

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## ABSTRACT

The performance of very shallow geothermal systems (VSGs), interesting the first 2 m of depth from ground level, is strongly correlated to the kind of sediment locally available. These systems are attractive due to their low installation costs, less legal constraints, easy maintenance and possibility for technical improvements.

The Improving Thermal Efficiency of horizontal ground heat exchangers Project (ITER) aims to understand how to enhance the heat transfer of the sediments surrounding the pipes and to depict the VSGs behavior in extreme thermal situations.

In detail five geothermal helical heat exchangers installed horizontally and surrounded by five different soil mixtures used as backfilling materials have been monitored under the same climatic conditions and tested under different operation modes. Changes of soil moisture content, ground temperature and running condition have been monitored in the ITER test site and the main results are here presented. The data collected highlight the relationship between VSGs performances and natural or induced ground temperature and soil moisture variations.

## 1. INTRODUCTION

Shallow geothermal energy is a reliable thermal energy source used mainly for indirect heating and cooling of residential, industrial or tertiary buildings (Sanner et al.2003). It involves the exploitation of low temperature geothermal resources, as soil and groundwater (temperature range 5–30 °C), abundant around the world and available at relative small depths (on average around 100–150 m depth), by means of ground source heat pumps (GSHPs) (Schelenz et al 2017). This technology consists of three main sections: (i) the Earth connection, represented by heat exchangers, responsible for extracting (injecting) heat from (into) the ground; (ii) the geothermal heat pump, able to transfer heat between the ground and the building; (iii) the heat distribution system, that distributes the heat in the building (Bi et al. 2009).

When the heat carrier fluid circulates inside heat exchangers and is physically separated from the rock/soil and surrounding environment, the system is known as a closed loop system (Galgaro et al 2015). In this case, the Earth connections can be realized both by vertical and horizontal ground heat exchanger. The former is preferred when the installation area is limited and is characterized by high installation costs due to drilling operation. The latter, located slightly below the Earth's surface (1–2 m depth), known also as very shallow geothermal (VSG) systems, is attractive due to its merits of low installation cost and less restricted legal constraints and easy maintenance, even if ample ground areas are required (Florides et al 2004; Han et al 2017).

The performance of a VSG system, as horizontal collectors or special forms is strongly correlated to the kind of sediment at disposal and suddenly decreases in case of dry-unsaturated conditions in the surrounding soil. For example, the coefficient of performance (COP), a technical parameter measuring the heat pump efficiency, suddenly decreases when the soil is dry and improves when an increase of the water content is noticed (Drefke et al., 2017; Farouki, 1981; Leong et al., 1998; Wu et al., 2015). Therefore, it is worthy of interest a better comprehension of how the different soil typologies (i.e. sand, loamy sand...) and their water content affect and are affected by the heat transfer exchange with heat collectors (Nagy and Körmendi 2012; Angelino and Sanner 2013). In fact, since 1980, soils have been studied and used also as heat reservoirs in geothermal applications, either as a heat source (in winter) or sink (in summer) coupled mainly with heat pumps (Ochsner et al. 2001; Chong et al. 2013).

In this paper part of the ITER European Project results are shown. Key challenge of this project is to understand how to enhance the heat transfer of the sediments surrounding the pipes, taking into account the interactions between the soil, the horizontal heat exchangers and the surrounding environment. An overview of the complete laboratory and field test outcomes on different materials (coarse sand, loamy sand etc ...) and environmental conditions can be found in Di Sipio and Bertermann (2018a, 2018b, 2017a, 2017b). Since the available experimental data are often scattered, incomplete and do not fully support thermo-active ground structure modeling, here is provided an overview of the physical-thermal properties variations under different moisture and load conditions for five mixtures, used both in laboratory and in the field test site (Di Sipio and Bertermann, 2017b, 2018a). In addition, the interactions between ground temperature, volumetric water content (VWC), precipitation and thermal conductivity monitored in situ under the same thermal stress have been analysed.

## 2. METHODOLOGY

### 2.1 ITER case study

The ITER project test site is located in Eltersdorf, about 10 km south-west from the city of Erlangen (Bavaria, Germany) (Fig.1).

Hosted on the property of REHAU AG & Co company, partner of the project, it consists of a trench 6.0 m wide, 5.0 m long and 1.1 m depth, divided in five sectors of the same size (1.2 x 5.0 x 1.1 m) (Fig.1b).

In each sector a surface collector system (helix probe, 3 m long, 0.4 m wide) is installed between 0.6 and 1 m depth below the ground level, equidistant from the boundaries. In order to thermally isolate every trench from the adjacent one and the surrounding ground, the outer and intermediate walls are made of XPS (extruded polystyrene, 2 cm thick) panels, characterized by very low thermal conductivity value ($\lambda$ = 0.035 $Wm^{-1}K^{-1}$) (Fig.1b). Moreover, the groundwater flow is not affecting the system because locally the piezometric level is on average at about 10 m depth. Then the trenches are filled in with five soil mixtures as backfilling material, tested also in laboratory (Fig.1b-2a):

- fine sand 0-1 mm (fs);
- fine sand 0-1 mm with 15% bentonite (fs15B);
- sand 0-5 mm (s);
- sand 0-5 mm + 15% bentonite (s15B);
- sandy clay (SC);

The fine sand (fs) and the sand (s) selected for the test field are both sieved materials commonly used in constructions, provided with a well-defined grain size, ranging between 0-1 mm and 0-5 mm respectively. The fs is a grey white fine sand, while s is a reddish coarser sand, whose mineralogical phases consist mainly of quartz and feldspar. These pure materials are mixed with bentonite, amounting to 15% of the total weight, in order to obtain two soil mixtures whose physical-thermal behaviors in time is expected to differ from the original components. The bentonite (B) used in this project comes from Denmark and is made of several clay materials, where montmorillonite is dominant (> 60%). Finally, the sandy clay (SC), representative of a natural soil, shows a very high content of silicon oxide and clay minerals (i.e. illite, smectite).

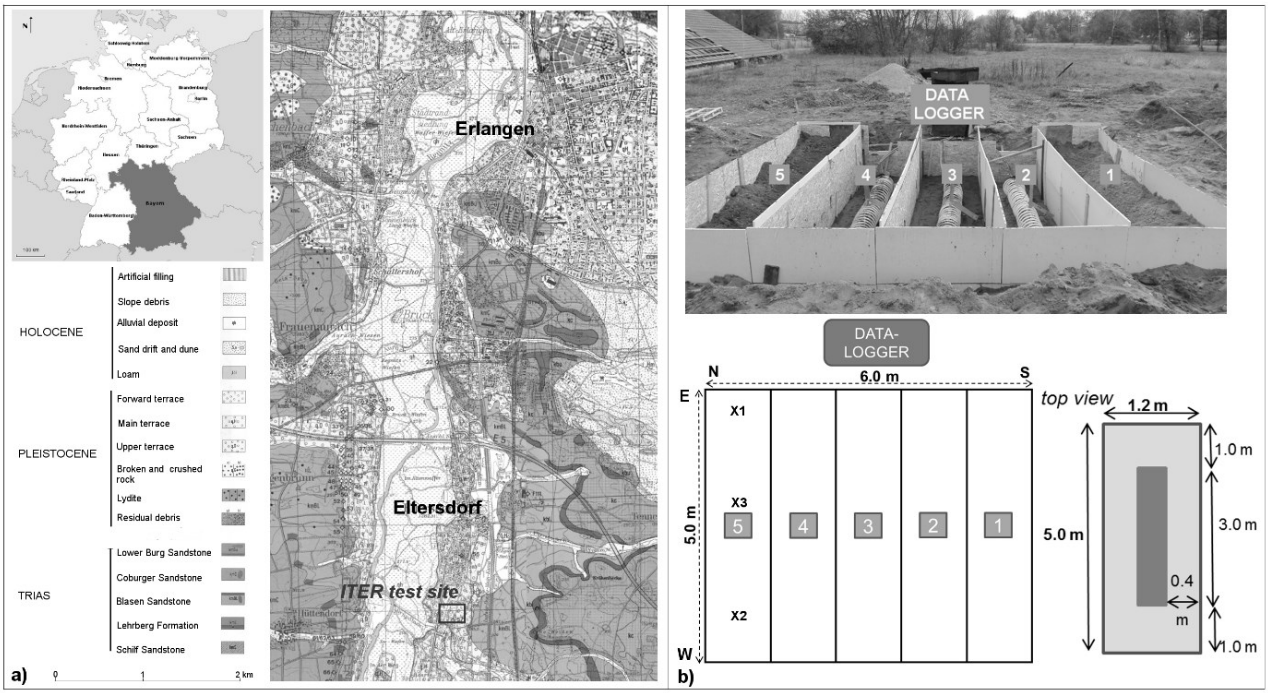


**Figure 1: ITER Project test site location in Eltersdorf, Bavaria, Germany: (a) location and geological characterization of the area; and (b) installation of the 5 helix probes covered with different soil mixtures: Moreover a top view scheme of the trench and of a single sector, together with the location of surface measurement points (X1-X2-X3) is shown in (b) [modified by Di Sipio and Bertermann 2017b].**

### 2.2. The in-situ Monitoring System

Three main data acquisition systems have been conceived in order to collect information directly from (i) the helix system, (ii) the surrounding environment and (iii) the backfilling material on surface (Fig.2b-c). Several sensors focused on the helix systems allows one to record every 5 min in two dataloggers data related to:

- the ground temperature inside and outside each helix (six sensors/helix, 30 sensors in total);
- the undisturbed ground and surface temperature (two sensors) outside the trench;
- the fluid temperature running in and out the helix system (two sensors);
- the speed flow inside the helix (one sensor);
- the speed flow between the helix and the absorber (four sensors);
- the surface temperature of the absorber (two sensors);
- the volumetric water content (VWC) at 0.60 m depth, that is at the top of each helix (five sensors).

In detail, the temperature sensors are constituted by Pt-1000 class B resistance thermometers (accuracy of ± (0.30 °C + 0.005 X the reading temperature)). In each sector they are installed (Fig.2b):

(1) at the helix inlet (A), at 0.80 m depth below the ground surface (bgl) and 4 m away from the east (E) margin;
(2) at the helix center (B), at 0.80 m depth (bgl) and 2.5 m away from E margin;
(3) at the helix end (C), at 0.80 m depth (bgl) and 1 m away from E margin;
(4) at the helix end (D) at 0.80 m depth (bgl) and 0.5 m away from E margin;
(5) at the helix center (E), at 0.40 m depth (bgl) and 2.5 m away from E margin;
(6) at the helix center (F), at 0.30 m depth (bgl) and 2.5 m away from E margin;
(7) outside the test site ($T_{ground}$), near the datalogger, at 0.60 m depth (bgl);
(8) outside the test site (Tsurf), near the datalogger, at 0.10 m depth (bgl).

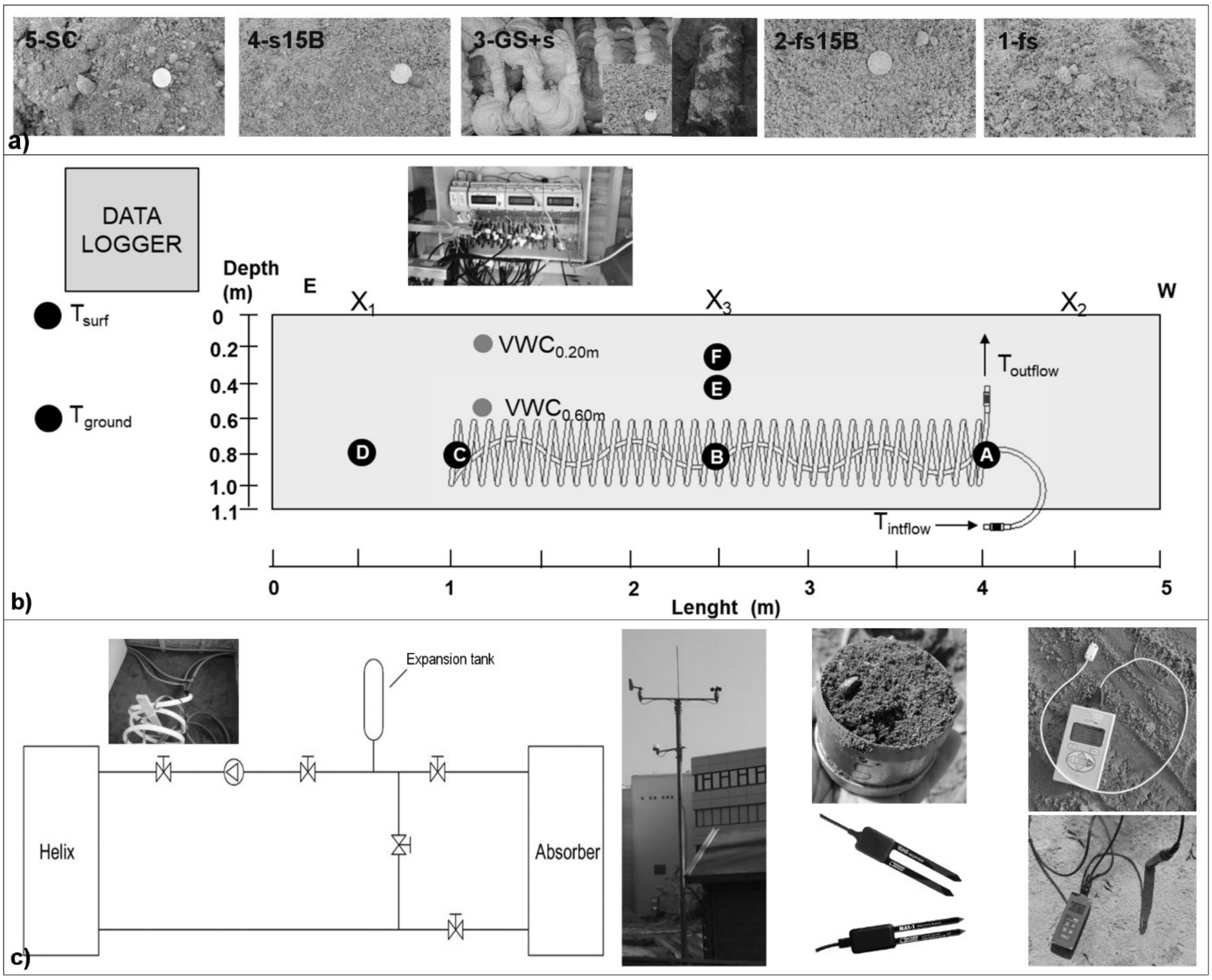


**Figure 2: Monitoring system in Eltersdorf: (a) soil mixtures used as backfilling material in each trench (SC = loamy sand; s15B = sand 0–5 mm + 15% bentonite; GS+s = commercial products surrounded by sand 0–5 mm; fs15B = fine sand 0–1 mm + 15% bentonite; fs = fine sand 0–1 mm); (b) schematic profile showing the location of the temperature (A-B-C-D-E-F-D-$T_{surf}$-$T_{ground}$) and moisture (VWC) sensors, the sampling measurements on surface (X1-X2-X3) and the dataloggers; and (c) from left to right the hydraulic system, the climatic station, the bulk density sampling, the moisture sensors used at 0.20 and 0.60 m bgl, the thermal properties and time domain reflectometry devices used in situ (modified by Di Sipio and Bertermann 2017b).**

Concerning the hydraulic system, the five helix probes are coupled in a Tichelmann configuration, each showing the same flow over 24 h, and are connected to an absorber, able to stress the working condition (heating/cooling). A Tichelmann system, also commonly known as a reverse return system, is a special system for pipe installation in heating engineering offering an equilibrated system with the lowest possible resistance (Riechers 2015). The circuits of the five helix collectors are connected to the same flow and return line and are exposed approximately to equal pressure losses and equal volume flows, in order to have a uniform heating all over the system. A numerical simulation and related error analysis are not dealt with this work, based on the interactions between soils, climate and running heat pumps.

### 2.3. Soil physical-thermal properties characterization

The physical-thermal properties of the sediments selected in the test field have been analyzed both in laboratory and directly in situ, in order to clarify their behavior respectively in a controlled environment or in unsteady conditions, affected by external factors (Di Sipio and Bertermann 2018). The main parameters determined are:

- *grain size* by sieving the sand fraction (<63 µm) of each mixture according to DIN 18123 and then using for the remaining fine particles the Sedigraph III Plus 5125;

- *thermal conductivity* by thermal properties analyzer (KD2Pro apparatus, Decagon Devices,Inc.), operating according to the transient line source method (ASTM D5334-08);
- *moisture content and bulk electrical conductivity* (measured simultaneously) by time domain reflectometry (TDR) device (TRIME IMKO GmBH).
- *bulk density* on duly collected sample according to the DIN 52102;
- *volumetric water content* on duly collected sample according to the DIN 18121;

In accordance with the laboratory working plan, more than 100 samples were prepared, gradually varying the reference material (pure or with additive), the kind of additive (bentonite or clay), the water content (fresh water added gradually to the dry unconsolidated sediment in incremental steps) and the pressure applied. We chose to perform measurements on large volumes of materials (about 56 dm3) rather than the usual laboratory scale in order to make the results comparable with the results given at local scale (i.e. field test), and to minimize the scale effect (Bertermann and Schwarz, 2017; Kömle et al., 2007; Moya et al., 1999).

At first, in laboratory, each mixture (about 60 kg) is naturally dried in a ventilated room at standard temperature and pressure condition. Once dried, the material is collected and subjected to parameter acquisition. During each phase, measurements of bulk density and volumetric water content are performed together with acquisition of moisture content, bulk electrical resistivity and thermal properties values. The entire measurement procedure is repeated for each mixture under different water content and incremental load steps (+0, +1, +3, +5 tons). In fact, fresh water is added gradually to the anhydrous soil until its field capacity is overcome, while it goes from unconsolidated till consolidated condition. In this way a complete set of data is obtained, available to be compared with the values acquired in situ.

Then, at the ITER Project test site in Eltersdorf, measurements of thermal conductivity and moisture content are collected monthly since November 2015. Given that the needle probe of both devices devoted to these measurements has a length of maximum 10 cm, the acquired data relate solely to the surface material, more affected by climatic fluctuations. Three measurement point have been selected for each sector at a distance of 1.0 (X.1), 2.5 (X.3) and 4 m (X.2) from the eastern boundary of the test field (Fig.2b). However, occasionally, so as not to rework too much the sediments, samples are collected for determining later in laboratory the bulk density and volumetric water content of the soils, in order to validate the measurements and compare them with the laboratory results. The samples are collected both on surface and a depth of 0.2 and 0.4 cm from the ground level. In the latter case, data acquisition by IMKO and KD2Pro is also foreseen, in order to understand the parameter variation with depth.

### 3. RESULT AND DISCUSSION

In order to understand the thermal trend at different depth and in different GSHPs operative mode (only fluid circulation or extraction/injection of heat) in each sector at disposal, an overview of the underground temperature data recorded inside the same kind of material is discussed (Fig.3). The system is running in heating mode (24 h/day) three times from November 2015 till May 2017 (16 March–19 April 2016, 10–28 November 2016 and 2 March–22 May 2017), forcing freezing conditions and a significant decrease of soil temperatures inside the helix (Fig.3). The project is focused on detecting the reaction of soil and collectors to extreme situations, highlighting differences and similarities between the five sectors under the same climatic conditions in different VSGs operation modes.

As the T trend at different depths is similar in all sectors, only the measurements performed in sector 2 (fs15B) are showed as representative (Fig.3). The selected interval (15 October 2016–15 December 2016) comprehends the running of the system in heating mode (10–28 November 2016). During the whole timeframe the external temperature ($T_{air\_surf}$) naturally decreases from about 12 to 2 °C. The area up to 0.80 m depth, when only fluid circulation is present, is sensitive to short-term temperature variations, damped with depth (hourly average). However, as soon as the heat extraction is activated, the sensors inside the helix and near its top show a sudden decrease of temperature, no more affected by $T_{air\_surf}$ fluctuations, with the lowest values registered in B. Sensor E, located 0.20 m above the helix top, is affected by the GSHP system, while sensor F, only 0.30 m above, shows fluctuations according to air temperature changes. Sensor D, 0.50 m away from the helix east margin, is completely unaffected by the GSHP activation: its trend follows that of the undisturbed ground temperature ($T_{ground}$) registered outside the trench, at 0.60 m depth (Fig.2b). Therefore, the effects of the helix in the surrounding soil are no longer observable at 0.50 m distance from the margins and 0.30 m above the top, so it is reasonable to consider the T registered on sensor D ($T_D$) as the undisturbed underground temperature for each mixture used as backfilling material.

When the heat exchanger is not operational, the soil temperature differences between the inside ($T_B$) and outside ($T_D$) of the helix are negligible ($\Delta T \approx 0$ °C). Instead, in the heating period (10-28/11/2016) is it possible to notice that:

- $T_D$ never drops below 0 °C when the heat pump is running, showing a mean value of about 4.5, 5.2, 4.3, 4.7, 4.5 °C in sector 1-2-3-4-5 respectively;
- $T_B$ average values of about -5.3, -5.2, -4.0, -5.0 °C for (fs), (fs15B), (s), (s15B) sectors are determined. No direct measurements are available for loamy sand (SC) sector, due to sensor B malfunction, but a value of about 5 °C is plausible;
- $T_{ground}$ shows a mean value of about 5.2 °C;
- $T_{surf}$ has a mean value of 2.5 °C

Moreover, as the heating mode begins, the ground temperature inside the helix drops suddenly below 0 °C, reaching and maintaining a constant value (about -6, -5, -4 °C in B, A and C sensors respectively) during the whole heating period and then recovering a value similar to $T_{ground}$ after the heat pump shutdown. When T remains constant below 0 °C, the phase change between water and ice takes place, latent heat is released, and the time required to expand the freezing front in the surrounding ground increases (Nikoosokhan et al 2015; Xu et al 2011). No further drop of temperature is noticed, so complete freezing is not reached, and the helix take advantage from the release of latent heat during the phase change process (Neuberger et al 2014).

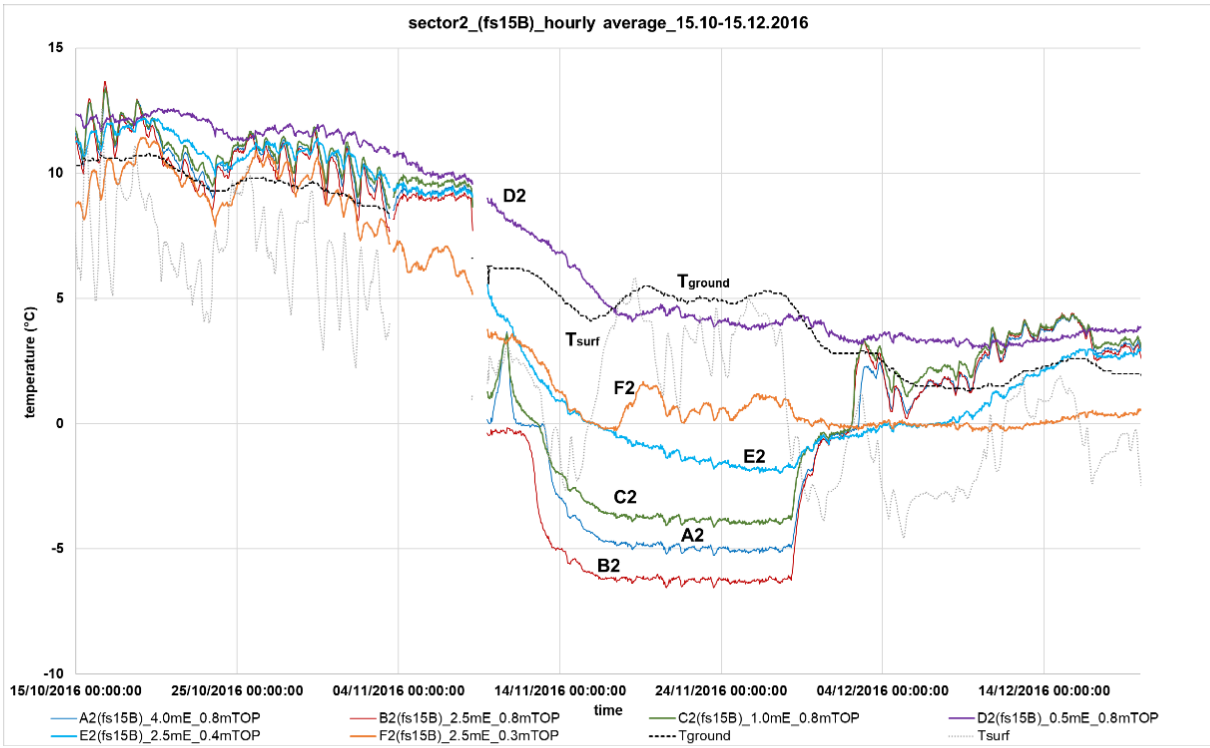


**Figure 3: Temperature trend registered in the five ITER Project sectors between 15/10/2016 and 15/12/2016: T (hourly average) recorded in sector 2 (fs15B as backfilling material).**

Given that a strong T decrease is observed along the vertical ($T_B$, $T_E$, $T_F$) and horizontal ($T_C$, $T_B$, $T_A$) profiles of the helix when the system is running (10.-28.11.2016), it is interesting to verify, once stopped the GSHP, when the temperature rises again towards the $T_{surf}$ values, allowing to start the heat energy potential refurbishment (Fig.4). In the T depth profiles for sector 1 two main behaviors are identified, typical of *non-operating* (i.e 15/10, 5/11, 15/12) and *operating* (i.e. 10-15-20.11) conditions. Both show an initial increase of T values deepening from 0.30 to 0.40 m bgl as expected in the colder season. Then, a quite stable temperature characterizes the former, up to 0.80 m depth, while a strong decrease of T between 0.40 and 0.80 m depth identifies the latter (Fig.4c). Once shutting down the heat pump on 28/11/2016, the non-operating behavior is completely recovered after 1 week (5/12), while already after 3 days (1/12) the temperature difference between 0.40 and 0.80 m depth is annihilated. Moreover, the ground temperature recorded at all depths at the end of the heat extraction period are lower than those noticed at the beginning, in agreement with the general $T_{air\_surf}$ trend already described.

Along the horizontal profile all the sensors are located at the same depth (0.80 m), corresponding to the central axis of the helix, oriented E-W. A steady temperature is registered in the four measurement points during non-operating period. In this case the recorded data reflects the progressive lowering of the outside air temperature, so before and after running the system the values range respectively between 9-11 °C and 2-4°C. At the beginning of the heat extraction (10/11), a sudden drop of T is observed, with the lowest values belonging to B sensor and undisturbed condition in D. After 3 days (1/12) from the shutting down, the Ts inside the helix begin to be similar again, but only after 2 weeks (10/12) they reach the same value of the undisturbed condition (Fig.4d). In the same period the illuminance trend diminishes over time, even if strong day by day oscillations are observed, due to cloudy and sunny days following one another. The relative humidity of the air and the wind speed have average value of 86 % and 0.74 m/s, while several precipitation events are recorded. Moreover, the data related to soil moisture content monitoring at 0.20 and 0.60 m depth, recorded since 15/11 and 3/11 respectively, are shown. At 0.20 m depth, the VWC is affected by precipitation: due to the porosity of the material (a fine sand) a small increase of moisture content is observed instantly on surface during the precipitation event of 19/11, while in depth no visible effects are noticed (Fig.4b).

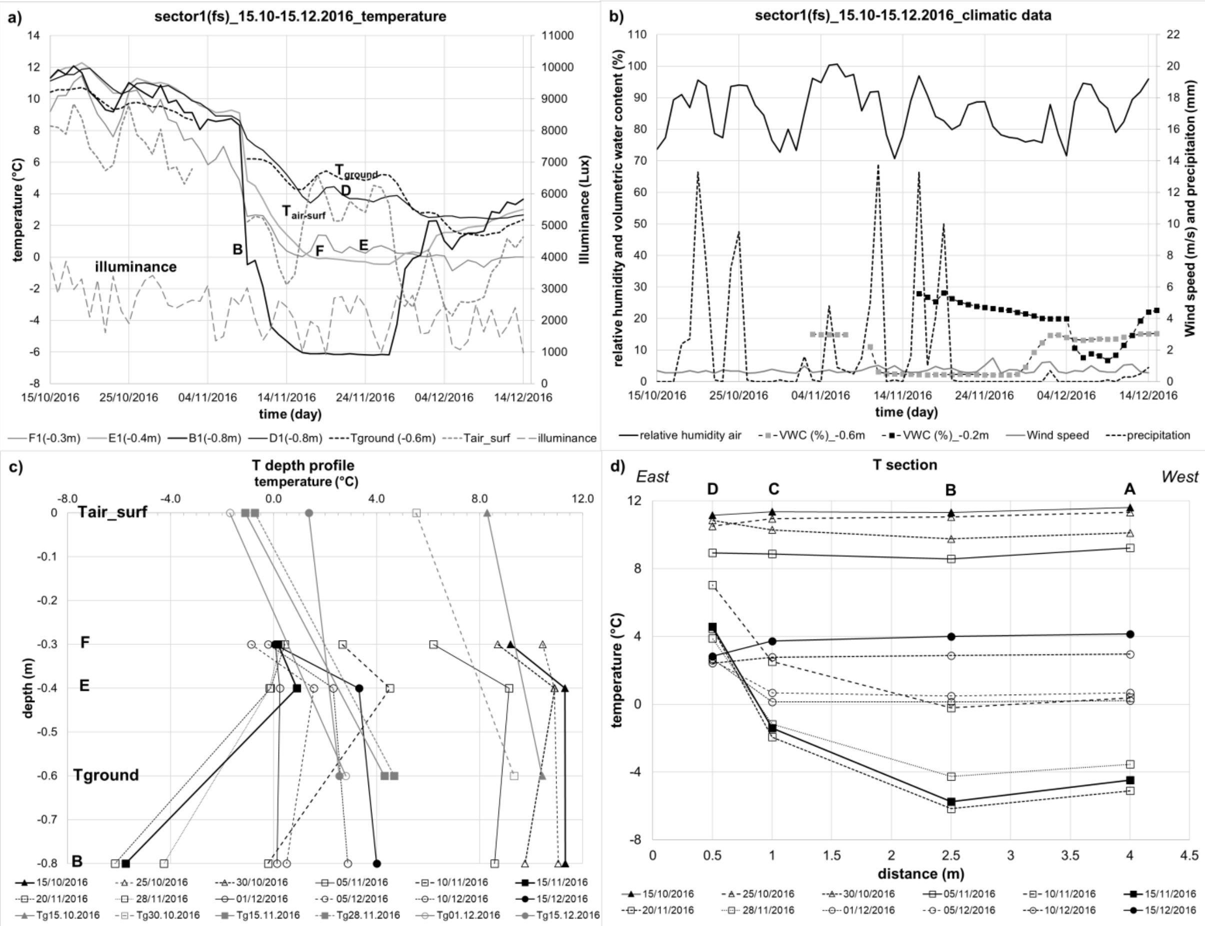


**Figure 4: Comparison of temperature and climatological data expressed as daily average in sector 1 (fs) from 15/10/2016 up to 15/12/2016. (a) Air and ground temperature variations registered at different depths together with illuminance data; (b) relative humidity, wind speed, precipitation and soil moisture content variation in the same period; (c) vertical temperature profile connecting sensor B with the outside temperature; (d) temperature section changes along the E-W axis of the helix (modified by Di Sipio and Bertermann 2017b).**

### 3.1. Thermal conductivity of soil

The monthly measurements of thermal conductivity ($\lambda$) and moisture content (MC) performed at the test field in Eltersdorf show how and in which extent, under the same climatic conditions, the soil mixtures thermal properties are affected by the ability to retain water.

The five mixtures (fs, fs15B, s, s15B, SC) have been placed in situ in nearly dry condition (volumetric water content $\approx$ 5%) and then have increased or reduced their water content according to the meteorological variations. On this regard, the time domain reflectometry (TDR) is a reliable tool to easily detect the moisture content on surface (Di Sipio and Bertermann 2017a), while at greater depth soil moisture sensors detecting VWC values are used since November 2016.

In detail, the relationship between $\lambda$ and MC clearly identifies the five backfilling materials (Fig.5a). The coarse (s) and fine (fs) sand are characterized by a rapid increase of $\lambda$ with a limited increase of MC. In fact, the majority of their values is grouped in a narrow MC interval (0÷10 %). The average thermal conductivity is 1.1 $Wm^{-1}K^{-1}$ for the coarse sand and 1.2 $Wm^{-1}K^{-1}$ for the fine sand. Highest value of heat transfer capacity belongs to the loamy sand (SC), that reaches an average $\lambda$ value of 2.0 $Wm^{-1}K^{-1}$. Finally, the thermally enhanced backfilling material created for the project (fs15B, s15B) reveal on surface (first 10 cm depth) a better thermal performance than the corresponding pure material (fs, s), with an average $\lambda$ value of about 1.4 $Wm^{-1}K^{-1}$. Therefore, summarizing, we found that on surface $\lambda_{\text{loamy sand}} > \lambda_{\text{bentonite mixtures}} > \lambda_{\text{pure sand}}$. This outcome agrees with the laboratory results, where the volumetric water content instead of the moisture content has been considered (Fig.5b).

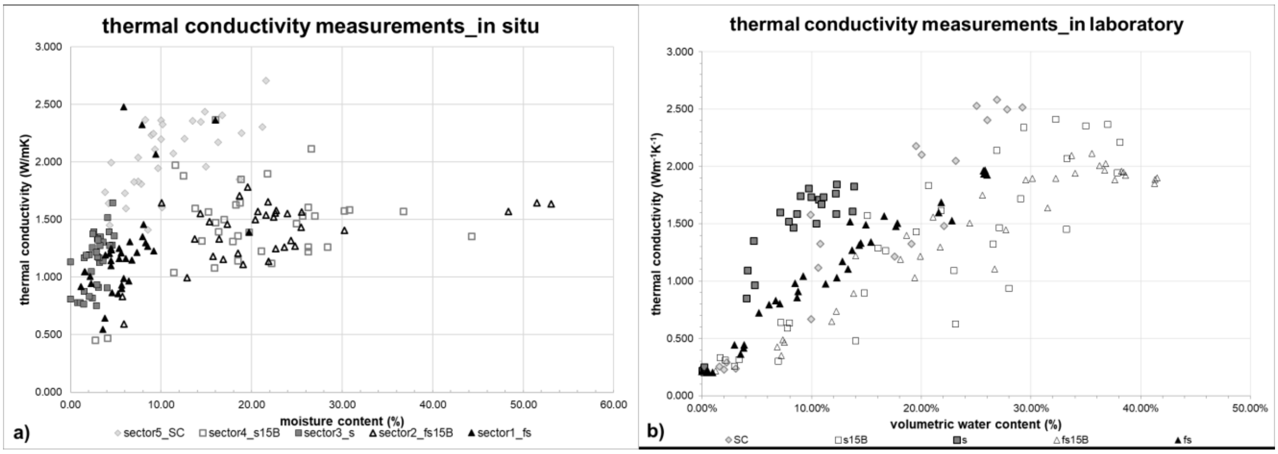


**Figure 5: (a) Relationship between thermal conductivity and moisture content for the five ITER mixtures used on site; (b) relationship between thermal conductivity and volumetric water content for the five ITER mixtures determined in laboratory under different saturation and pressure condition**

A first evaluation of the experimental heat exchange obtained at the test site considered as a whole is provided hereafter. Due to the Tichelmann configuration it is not possible to differentiate the contribution of each sector to the heat extraction process. On this regard, numerical simulations are planned in the future. However, it is still possible to provide a first heat extraction rate of the whole five horizontal helical ground heat exchangers.

As shown in Fig.2, the heating period runs from 10 till 28 November 2016. The corresponding overall experimental heat exchange rate ($Q$ in W) is calculated by the following equation:

$$1)\qquad Q = \dot{m}C_p(T_o - T_i)$$

where $\dot{m}$ is the flow rate of water (kg/s), $C_p$ is the specific heat of water (J/ (kg K)), and $T_o$ and $T_i$ are the outlet and inlet temperatures (° C) of water, respectively. Then, the heat exchange rate per unit tube length ($\bar{Q}$ in W/m) is simplified as follow:

$$2)\qquad \bar{Q} = Q/L$$

where L is the total tube length, equal, in this case, to 200 m, since the length of each helical pipe (m) is 40 m (REHAU 2012).

At the beginning of the experiment, between 10 and 16 November 2016, the heat exchange rate per unit tube length shows the highest value (range between 7 and 5 W/m), due to the higher temperature difference between the ground soil around the helix and the circulating water (Fig.6). After that, the heat exchange rate declines slightly and tends to be constant ($\bar{Q}$ about 4.5-5 W/m)). The reason is because with increases in the operation time, the heat extraction from the vicinity of the helixes occurred. As a result, the surrounding ground soil thermal energy degraded and decreased the temperature difference between the soil around the horizontal heat exchangers and the circulating water inside the tube. To summarize, when the system runs in heating mode (10-28/11/2016), the heat exchange rate per unit tube length is about 5.22 W/m on average.

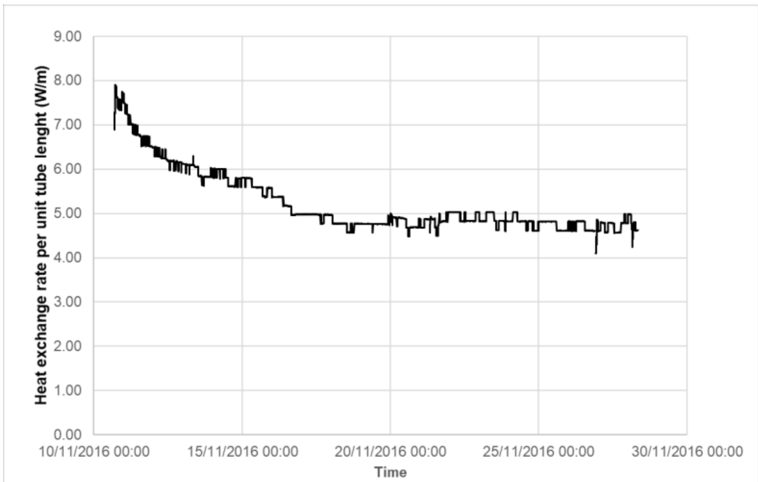


**Figure 6: Heat exchange rate per unit tube length (W/m) for the 5 helixes considered as a whole, when the system is running in heating mode (10-28/11/2016).**

## 4. CONCLUSION

The long-term investigation of soil temperatures, environmental parameters and soil characterizations provided by ITER Project contribute to understand the influence of several factors on very shallow geothermal systems, as helix Earth collectors. In the ITER project test site in Eltersdorf, the data collected over more than one year in the same environmental condition allows to recognize the effects of meteorological parameters on five different soil bodies.

At first, the influence of air and soil temperature variation during the heating and stagnation period of ground heat exchanger is analyzed. In all five soils tested in situ, when the system is not running, the amplitude of $T_{ground}$ waves is already reduced at 0.60 m depth compared to $T_{air\_2m}$ and $T_{air\_surf}$. When the heat pump is running, $T_{ground}$ variations induced by the helix are no longer noticed at 0.30 m from the top and 0.50 m from the lateral margins of the helix itself and the lowest T values are always recorded in the middle of the helix (sensor B). Moreover, horizontal and vertical temperature profiles determined through the helix axes show small T variations on monthly and daily basis, related to the influence of air temperature fluctuations in depth. On monthly base a non-operating (i.e., 15 October, 5 November, 15 December 2016) and operating (i.e., 10, 15, 20 November 2016) behavior, typical of "switching off" and "switching on" mode of the heat pump, are easily identified. They allow a preliminary evaluation of the recovery time needed to re-establish undisturbed $T_{ground}$ conditions, that is about one week along the vertical profile and two weeks along the horizontal section.

Due to the low burial depth of installation (0.60–1.0 m depth) the helix performance is still affected by daily and monthly temperature amplitude fluctuations, but this effect is limited compared to thermal conductivity variations induced by different soil moisture content. In fact, the thermal properties of the soil mixtures measured in situ together with the soil moisture content show the following pattern $\lambda_{loamy\ sand} > \lambda_{bentonite\ mixtures} > \lambda_{pure\ sand}$. A decrease of water content with depth is observed (no groundwater flow is present), followed as expected by a reduction of thermal conductivity. In detail, in coarse sand material a gradual decrease of moisture content implies a rapid decrease of thermal conductivity, while on bentonite mixtures or loamy sands, the reduction is more gradual. Then, these materials are promising for a better performance of the helix if initial adequate moisture conditions (>12.5%) are provided and maintained over time. In fact, according to literature, a VWC content below 12.5% decreases the performance of a shallow geothermal system while a VWC over 25% improve it (Leong et al 1998). In ITER Project test site, at 0.60 m depth only (fs15B) overcame this restraint in a long time and is expected to provide the better performance together with GS, whose thermal properties are considered invariant.

In addition, a preliminary evaluation of the experimental heat exchange rate per unit tube length of the entire system is provided when the system is running in heating mode (10-28/11/2016). However, due to the Tichelmann configuration selected to couple the five helixes, it is not possible to differentiate directly the contribution of each helix, so, next future, numerical simulations are planned to contribute to solve this aspect.

## ACKNOWLEDGMENT

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