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GIS-mapping model of low entalphy geothermal potential in Southern Italy (VIGOR PROJECT)

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ABSTRACT

Low enthalpy geothermics is based on the exploitation of the thermal energy generated and stored in the Earth by means of ground source heat pump systems (GSHP). These systems, which take advantage from the fact that the ground temperature is almost constant, are able to exchange heat with the ground with relatively shallow boreholes (depth typically about 100 m and generally lower than 200 m). The aim of the study, carried out in the frame of the geothermal assessment of the VIGOR Project, is to create a digital cartographic instrument, based on Geographic Information System (GIS). This outcome is not only devoted to geothermal aims, but also open to all geological uses. The resulting database will be easily accessible, upgradeable, and able to synthesize geological knowledge of the underground thermal properties. In this way, a useful tool for territorial planning and environmental control is obtained and will be made available. Knowledge about the physical and thermal parameters has to be supported by thematic maps. The work done suggests a methodological approach able to define the features that mainly influence the ability of the ground to "geoexchange". Geological and thermodynamic properties are recorded in a dedicated geo-database. The corresponding digital thematic maps can be combined, by means of a suitable algorithm, to determine the geothermal potential map. Examples from Apulia region are discussed.

1. INTRODUCTION

Shallow geothermal energy and applications of new technologies could replace air-source heat-pump systems to reduce the use of conventional energy resources (Nam and Oaka, 2011). In Italy, where over 20% of total energy consumption is due to domestic heating, the use of this renewable energy is being considered to improve the energy performance of buildings (Gemelli *et al*., 2011). Ground source heat pump systems (GSHPs), which are coupled with the ground by means of borehole heat exchangers (BHEs), provide an efficient and environmentally friendly technology for temperate zone. GSHPs can be installed at virtually any location (Rybach and Sanner, 2000), since low enthalpy heat occurs ubiquitously at 'normal' temperatures in the relatively shallow subsurface (Banks, 2008). Thanks to these systems, a more comfortable temperature than air conditioning can be reached and maintained together with a significant reduction of electrical energy use in buildings (Noorollahi *et al*., 2009).

The need of a regional evaluation of power potential of this resource requires the knowledge of low enthalpy geothermics supported by a cartographic tool. Nam and Oaka (2001) studied the macro-availability potential in the 23 wards of Tokyo, in order to make optimal use of ground source heat pump systems. Noroollahi *et al*. (2008) analysed spatial associations between geothermal exploration and environmental evidence layers using GIS as a decision-making tool to determine the appropriate sites for exploratory. Gemelli *et al*. (2011) presented a GIS-based energetic-economic model of low temperature geothermal energy applied to the Italian Marche region. Busby *et al*. (2009) discussed some of the geological factors that influence the performance and hence design of a GSHP system.

In general, a complete and updated geographic information system (GIS) supporting data organization and data processing allows to create thematic and synthesis maps in international recognized format, and a geothermal GIS provides a powerful tool for the evaluation of the geothermal potential.

The next session outlines how a specific map of exchanged energy has been created, and how the interactive geo-database, that collects all geological properties, has been built. The aim of the presented approach is the development of a geothermal resource assessment tool, able to organize and provide all necessary information for the design and installation of GSHP plants. It is worth to note that the tool is also characterized by easy accessibility and updatability.

2. ANALYSIS AND MAPPING

The investigation has been carried out within the framework of the VIGOR Project, aimed at assessing the geothermal potential of the Regions of Convergence (Campania, Apulia, Calabria, Sicily), in Southern Italy. In these four regions lithological, thermal, hydrogeological and constraints data characterizing surface and shallow properties of the ground, were collected and stored in a dedicated digital archive. About 7000 drilling log data were also stored and organized in a dedicated geo-database .

After defining the parameters that mainly influence “geoexchange” ground ability and organizing the related data, it was necessary to define the main factors that impact on the design of the ground component of a GSHP. To this aim, it was decided to choose a case reference, i.e., residential building of 100 m^2 having standard insulation. Analytical simulations with Earth Energy Designer (EED) have been carried out in order to obtain the length of borehole heat exchangers of GSHP systems able to supply thermal (cooling and warming) energy to the case reference for 20 years. The annual energy profile, with monthly resolution, have been estimated on the base of local climatic conditions.. The used software package estimates the specific exchanged energy for several combinations of BHEs. These results can be used to render every parameter in a thematic map.

The first important variable is the temperature of the ground, which is almost constant with time for a defined depth. Note that such a temperature stability leads to significant advantages of GSHPs in terms of heating and cooling efficiency with respect to air coupled HPs (Busby, 2009). It is possible to evaluate the ground temperature (Fig. 1), at a specific depth, by means of Fourier’s Law of heat conduction:

$$Q = -\lambda \nabla T \,, \qquad [1]$$

where Q is the geothermal flux (W/m^2), λ is the thermal conductivity (W/m°K) and ∇T is the geothermal gradient (°K/m). The gradient can be estimated from the average annual air temperature. In particular, the algorithm proposed by Claps *et al.* (2003) characterizes the average annual air temperature map of Italy considering latitude and elevation of defined points, with grid spacing of 100 m. For the purposes of the VIGOR Project, this algorithm has been modified and simplified in order to analyze the subsurface of the Convergence Regions.

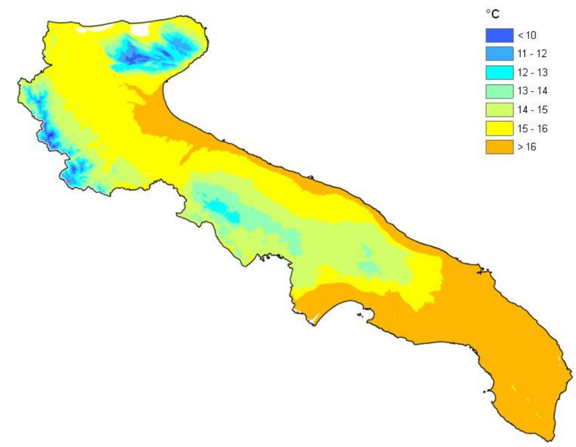

Figure 1: Estimated ground temperatures map of Apulia Region at 50 m depth.

The shallow geothermal flux in all the Italian territory has been studied by Cataldi *et al.* (1995). The corresponding parameters for the Convergence Regions have been extracted and added to the developed database.

Thermal conductivity values have been assigned to the lithological outcrops from bibliographic data (Italian Geological Map, scale 1:250000), and then validated by means of laboratory measurements. For each quaternary deposit, stratigraphic data have been collected from the drilling logs and bibliographic thermal conductivity has been assigned to every recognized lithology. In the Convergence Regions the shallow geology is often very complex, with changes along the depth and along the East and North directions. For this reason, a simplified stratigraphic model has been preferred. The use of Modalstrata, a specific MATLAB toolbox developed to improve the correlation of the stratigraphic succession (Cultrera *et al.*, 2012), has lead to a new stratigraphic description for each studied area. The new, regularized model, defined on a 3-km side regular grid, has 5 m vertical, regular steps. For each grid node and depth step, the most common lithology is recognized from the distribution of the lithologies shown by the near well logs. The corresponding thermal conductivity is used as typical value for this grid node and depth step. A weighted average thermal conductivity value has been computed for each new stratigraphy. In this way, a thermal conductivity map for quaternary deposits for the first 100 m depth has been obtained. Finally, the lithology and stratigraphical conductivity maps have been joined and added to the database. Data from thermal conductivity, geothermal flux and ground temperature maps have been combined to generate the exchange energy map.

Besides mere technical-economic considerations, constraints related to the land use or other factors could act on the use of geothermal energy. For this reason, the Apulia hydrogeological restriction map (Fig 2) is layered over the exchanged energy map in order to give examples of areas where the geothermal resources can be rationally used.

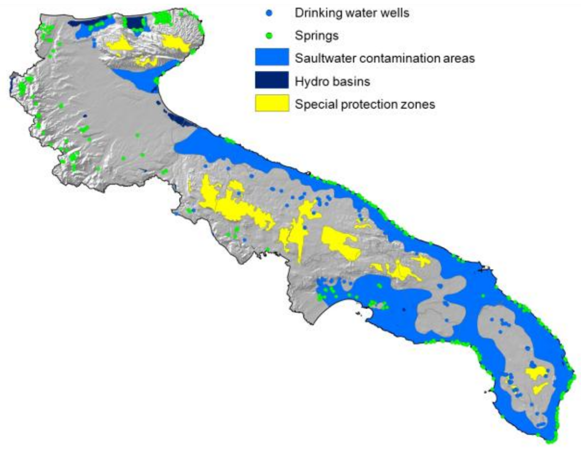

Figure 2: Constrains map of Apulia Region.

3. CONCLUSIONS

The present paper describes the current state of development of a GIS-mapping model useful for planning of low enthalpy geothermal energy exploitation. This development is an on-going task, therefore other results are expected, in particular a map of the energy exchange potential.

An important achieved outcome is the creation of a geo-database where sets of layers in different formats are recorded. The included information is related to ground temperature, geothermal flux and conductivity maps. Moreover, information about thousands of well logs is included, together with a stratigraphic model obtained from the corresponding data.

The geo-database, the energy exchanged map and the constraints map may support policy makers for decisions concerning promotion, use or subvention of GSHP technology.

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