Journal of materials and Environmental Sciences
ISSN : 2028-2508

JMES, 2017 Volume 8, Issue 1, Page 209-216

http://www.jmaterenvironsci.com/

A GIS- catalog of prospective geothermal areas in Morocco, an answer to climate changes

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Received 18 Aug 2016,
Revised 29 Sept 2016,
Accepted 03 Oct 2016

Keywords

- ✓ climate change,
- ✓ geothermal,
- ✓ cataloging,
- ✓ model

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Abstract

Developing large-scale renewable energy such as geothermal, is nowadays an economic opportunity that can contribute significantly to the reduction of CO_2 emissions to the atmosphere. In this perspective, the development of a catalogue to make prospective geothermal resources data on interoperable system for managing and providing reliable information to professionals and policy-makers to better use of these thermal resources. In this article, we develop a prototype that provides cataloging data on prospective geothermal resources based mainly on OGC standards and ISO 19110 / ISO1911.

1. Introduction

Emissions of greenhouse gas (GHG) resulting from the power production sector have contributed to the significant increase of GHG concentration in the atmosphere. Climate changes mitigation and particularly the Protocol of Kyoto have made the stabilization of greenhouse effect, caused by anthropic activities, a high priority. This can be achieved through mechanisms such as Clean Development Mechanism (CDM) among which geothermal projects may potentially provide an alternative energy to that derived from the traditional power plants which are the main source of CO_2 emissions.

In comparison to other forms of renewable energies, geothermal energy does not depend on weather conditions, and can be exploited for the production of heat as well as electricity. However, it requires an effective exploration to delineate the localization and the characteristics of the available resource, and the determination of the reservoir properties in order to evaluate its energy level and potential.

The Moroccan territory presents interesting surface thermal indices, represented by many hot springs and important reservoirs revealed by oil and hydrogeological wells. The realization of a geoportal and a geo-catalog related to geothermal data in Morocco should take part in setting up a national infrastructure of metadata on prospective renewable energy and geothermal areas in Morocco. These data are presented in the form of GIS (Geographic Information System) providing at a given level of interest (a local community, for example) an evaluation of the geothermal resources. For the authorities as well as for private investments, the proposed geoportal presents a helpful identification tool and a preliminary resource characterization, before engaging in any further investigations.

2. Materials and methods

2.1 Open source metadata cataloging software

2.1.1 Generalist Catalogs

These are Open source cataloging software, used in various contexts and situations. Following the publication of a series of state-of-the-art in the field of free and open source GIS tools [1, 2, 3], a large number of Open source data cataloging tools leading to the realization of a comparison among them according to various

criteria, namely (standard supported, provided web services, output format, operating mode, platform and technology used) Figure1
The majorities of these tools use Java as computer programming language, and operate bothin Linux and Windows systems, but differ in terms of output formats, provided web services and implemented ISO standards.

2.2. GEONETWORK and Modeling Language
Following the description of the different software cited in Figure 1, we see that the technical and functional features are common to other programs. The difference lies mainly in the easier installation on GEONETWORK by the small number of software to install; undeniable advantage in creating a catalog of geothermal metadata
The system provides to a large number of users easy and fast access to data and available space services, as well as to thematic charts that expedite information finding and decision-making. The main aim of the software is to increase collaboration between and within organizations in order to reduce mistakes, improve information (coherence, quality) so as to improve access to a large variety of geographic information and any associated data that are organized and documented in a standard and uniform way. The main features are (Figure 2);

	Tools								
Caractéristiques	**GeoNetwork**	**eXcat**	**Deegree**	**Catalog Connector**	**Geosource**	**Geonode**	**CatMDEdit**	**MetaD**	**Expire**
Version	2.6.4	20090709	3	1.0.1	2.7.3	1.2	4.6.6	4.0.1	1.3
Standards ISO									
INSPIRE			O		O		O		O
Dublin Core	O		O		O	O			
ISO 19115	O	O	O	O	O		O	O	O
ISO 19110	O				O				O
ISO 19119	O		O	O	O		O	O	
ISO 19139	O	O			O	O	O	O	O
Standards OGC									
WMS			O		O	O	O	O	
WFS	O		O		O	O	O		
CSW	O	O	O	O	O	O	O		
WCS	O		O		O		O		
Output									
XML	O	O	O	O	O	O	O	O	O
PDF	O		O		O	O			
Excel						O	O		
ASCI	O				O				
HTML	O		O	O	O	O	O		
Plateforme									
Windows	O	O	O	O	O	O	O	O	O
Linux	O	O	O	O	O	O	O		O
Mode									
Monoposte							O	O	
Client				O					O
Client/Serveur	O	O	O		O	O			
Language									
Java	O	O	O	O	O	O	O		O
Visual Basic								O	
PHP									O

Figure 1: Comparative list of the open source cataloging tools according to the characteristics.

- Local and distributed research
- Downloading of data, documents, pdf and any other content;
- An interactive map which allows the combination of the layers diffused by WMS services;
- Online edition of the metadata by a model system;
- Harvesting and synchronization of metadata between distributed catalogs;
- Groups and management of users;
- A multi-lingual interface Figure 2

GeoNetwork provides an easy to use web interface to search geospatial data across multiple catalogs. The search provides full-text search as well as faceted search on keywords, resource types, organizations, scale; Users can easily refine the search and quickly gets to the records of interests.
UML language captures information on static structure and the dynamic behavior of a system. The modeling tool we used is on the level of the servers. In addition to the Web server, we can have a data server that will host the Database Management System (DBMS). To access it, one uses the universal querying language of the databases: SQL. Below is the architecture of the Web application used.
Open source software is used for each component of web-GIS application. Clients, Web Server, Data Server and Web Map Server are the main components of web-GIS, Figure 3.

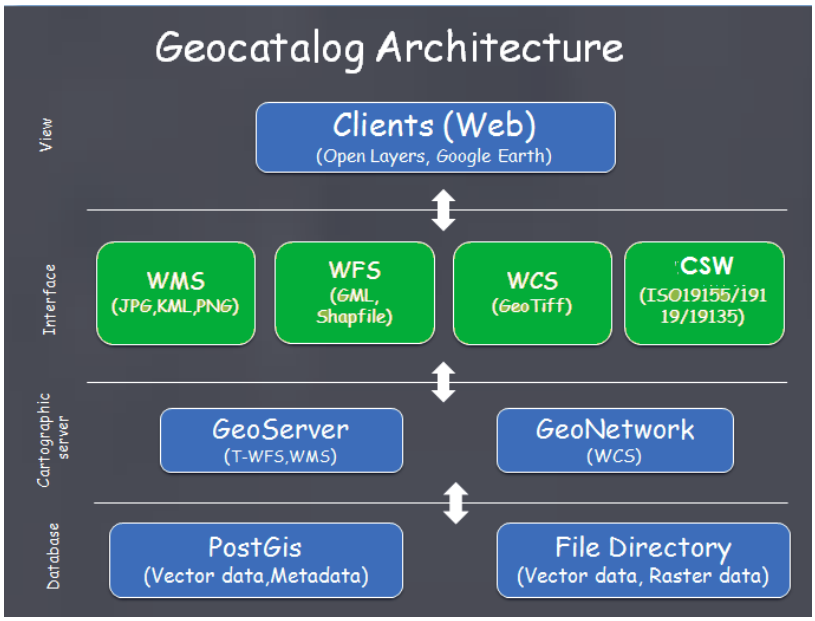

Figure 2: Structure of the GEONETWORK

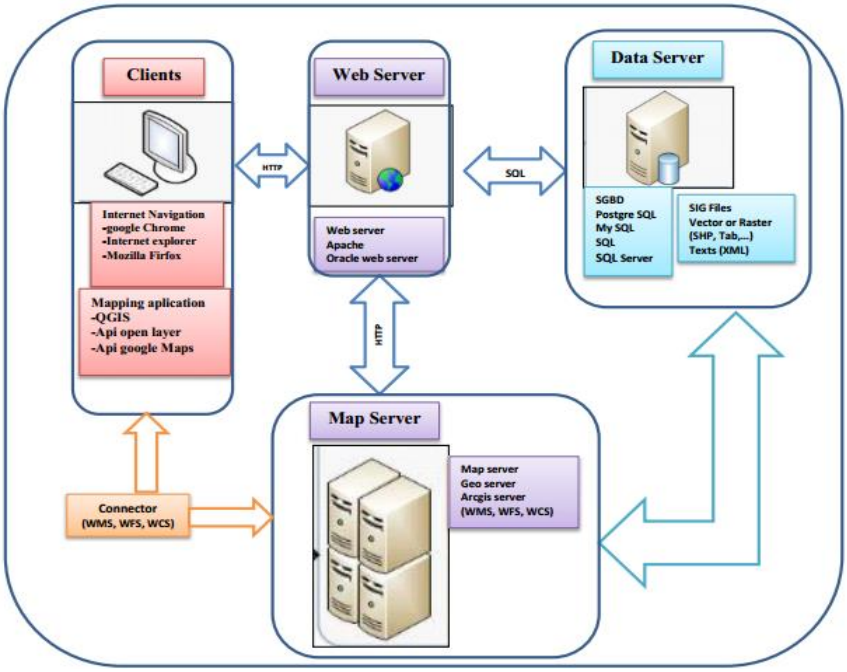

Figure 3: Structure of the application of web-mapping

In this research work; PostgreSQL/PostGIS was used to manage and store the GIS data. A complete, functional open source DBMS, Postgres (as it's commonly referred to) seems to be the most popular for open-source web mapping. It requires OSGeo's PostGIS extension, which comes with the standard Postgres installation, to handle georeferenced data. It is used by Open Street Map, GeoServer, MapServer, and CartoDB. PostGIS is an open source software program that adds support for geographic objects to the PostgreSQL object-relational database. PostGIS follows the Simple Features for SQL specification from the Open Geospatial Consortium (OGC) Figure 2.

After storing GIS data on the database (PostgreSQL/PostGIS), GeoServer is used to publish map and the data from database which is written in Java allows to share, process and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards. GeoServer has evolved to become an easy method of connecting existing information to Virtual Globes such as Google Earth as well as to web-based maps such as OpenLayers, Google Maps and Bing Maps. GeoServer functions as the reference implementation of the Open Geospatial Consortium Web Feature Service (WFS) standard, and also

implements the Web Map Service (WMS), Web Coverage Service (WCS) and Web Processing Service specifications.

3. Results and discussion

3. 1Results

This system allows a complete analysis and an optimal visualization of the various data. It also permits accessing information, and sharing a great amount of invaluable and reliable data from official and trustworthy sources.

The stages that drive the process are illustrated in figure 4.

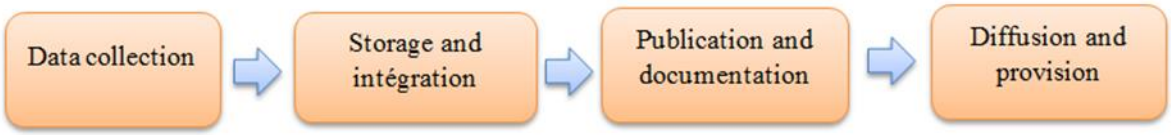

Figure 4: Stages for the provision of the data on the platform

The data used to illustrate the results presented in this article were collected by the research teams and were also recovered from the institutional web sites of the involved stakeholders. The file types: Shapefile, Raster, Excel Table, Word Document, pdf and Web pages that were assembled, treated and spatialized to have these results. Figures 5, 6, 7, 8, 9 and 10.

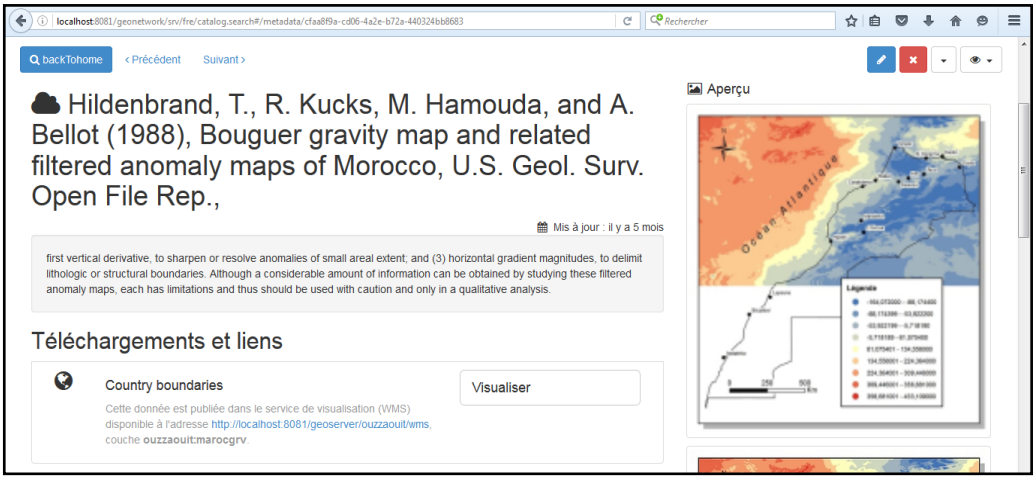

Figure 5: Screenshot of the geo-catalogue representing the chart of gravity

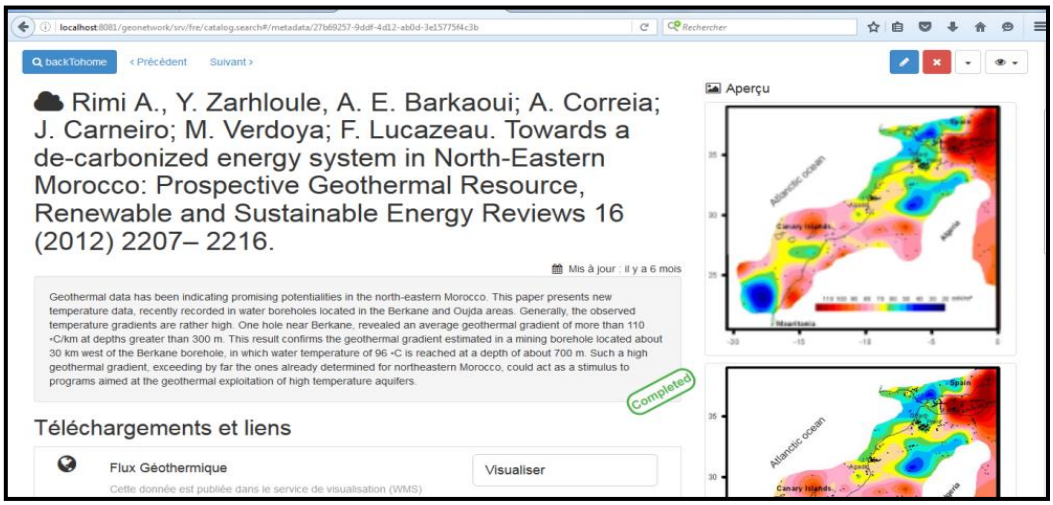

Figure 6: Screenshot of the geo-catalogue representing the heat flow

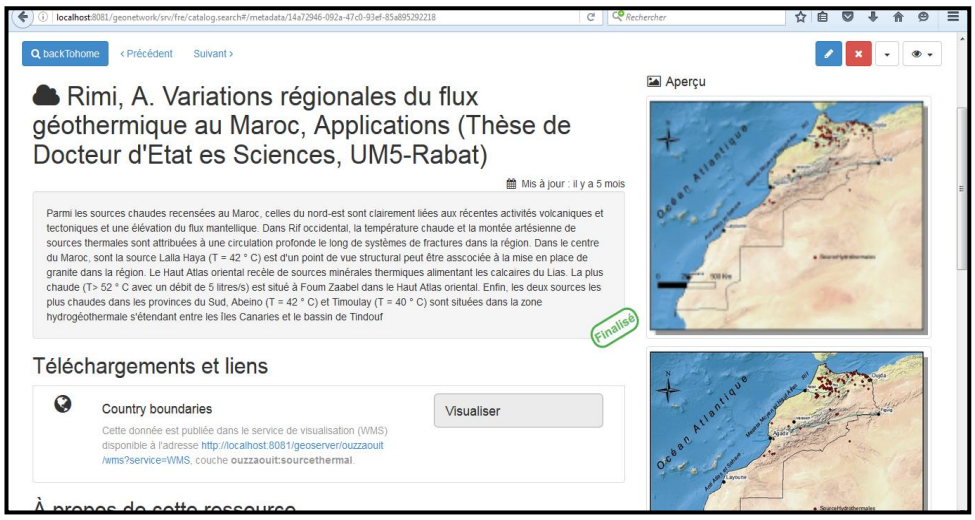

Figure 7: Screenshot of the geo-catalogue representing the distribution map of geothermic sources in Morocco.

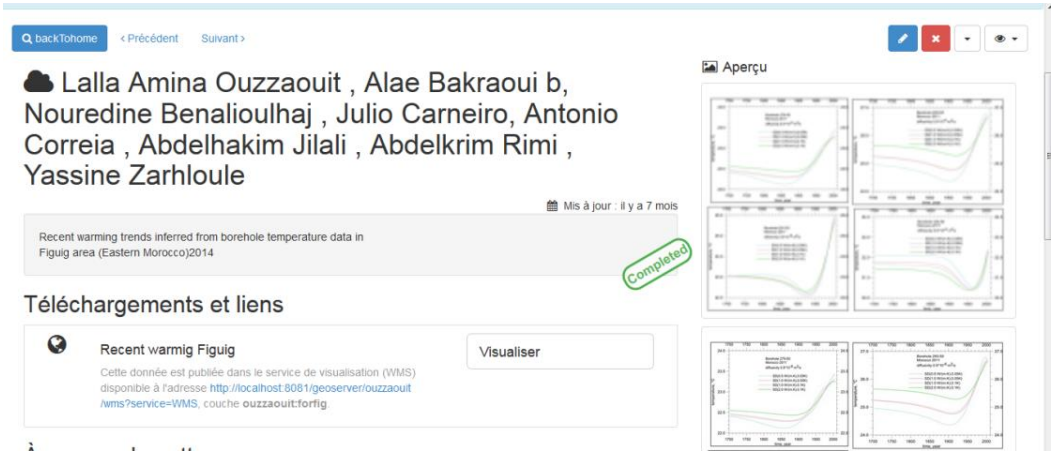

Figure 8: Screenshot of the geo-catalogue representing The GST history variation associated with climate changes using the FSI (Functional Space Inversion) models for the geothermic boreholes 279–50 and 291–50 and 293–50 and 433–50, respectively, in Figuig. [4]

Figure 9: Screenshot of the geo-catalogue representing a map of seismicity in Morocco

Figure 10: Screenshot of the geo-catalogue representing a map of fractured areas in Morocco

Figure 11, represents a screenshot of the geo-portal related to the prospective geothermal zones in Morocco, containing the values of heat flow [5] and the geothermic gradient [6]; the thermal springs [7] are also represented. This geoportal allows having a clear and global vision of the location, as well as values of flow and geothermic gradient with the possibility of identifying each point as indicated in the figure. This function makes it possible to have accurate information on the location, the temperature and the nature of the well or spring .....).

The first studies devoted to the evaluation of the Moroccan geothermal resources go back to [8, 9]. Research and development in the field of geothermic remain the interest of academic researchers [10, to 23]. This research was carried out within the framework of theses of doctorate, PhD or cooperative projects between the Moroccan and universities, from European countries, namely, France, Italy and Portugal and also Tunisia.

Some of these research studies aimed to measure underground temperatures and determine the density of heat flow in many parts of Morocco, and temperatures in groundwater wells. Other studies have focused on the geochemistry of hot springs and hydrothermal modeling. All this research has contributed to further knowledge on Moroccan geothermal potential and the possibilities of using geothermal energy.

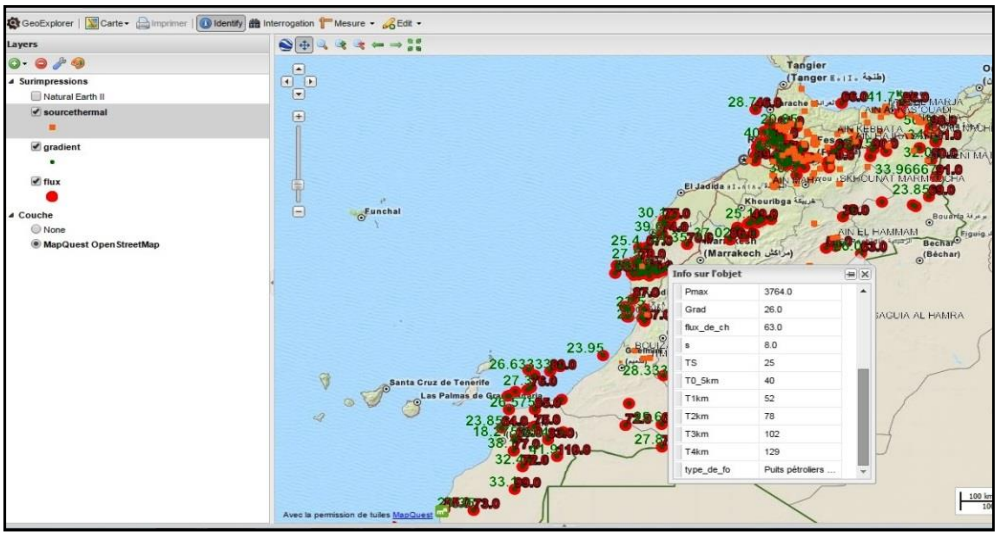

Figure 11: Geo-portal of the values of terrestrial heat flow, geothermic gradient and thermal springs in Morocco

3.2 Discussions

It is possible to identify the potential geothermal sites by an analysis of the relationship between the geothermal systems and their environment, defined by geological and geophysical characteristics. Within this framework, the relationship between the geothermal events and geological and geophysical information

publicly available (seismicity, lineaments, gravity and magnetic anomaly) is evaluated by means of data modeled in a GIS environment.
Resulting maps Figure. 12 and 13 of the model of the multiple linear regression of the northern and southern provinces of Morocco shows that the areas having a significant geothermic flow generally correspond to Eastern Rif and to the grounds of the Paleozoic base of the Meseta region field where the alpine tectonic phases were not relevant (tabular méso-cenozoic cover).

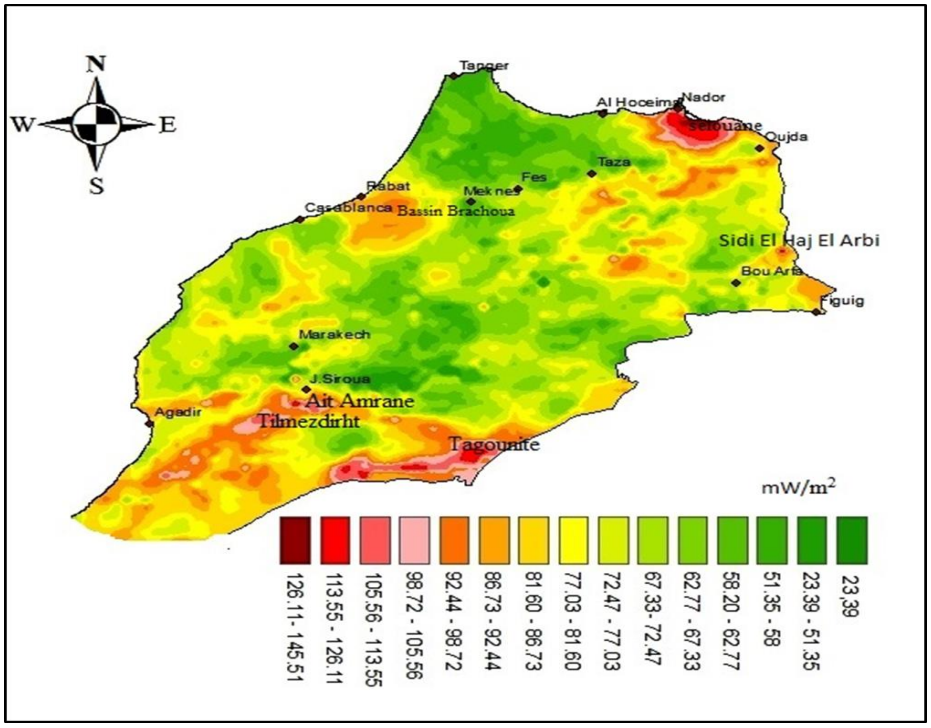

Figure 12: The map resulting from the model of multiple regression of prospective geothermal areas of northern provinces in Morocco

Elsewhere, the Atlas mountain range, the High Paleozoic Atlas (alpine orogeny) does not show any significant thermal signature. However, at the Anti-Atlas and the extreme south of Morocco, it is possibly to note the presence of zones with an important geothermal anomaly.

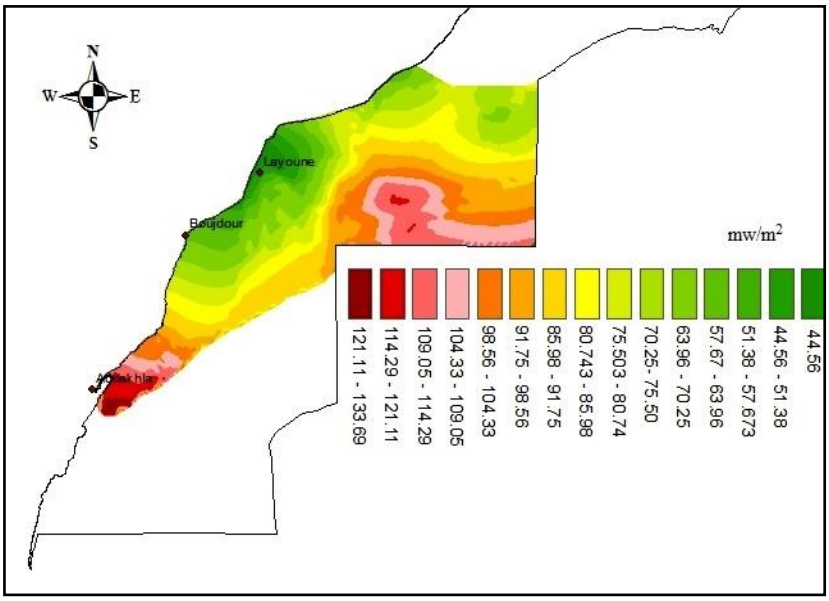

Figure 13: The resulting map of the model of multiple regression of prospective geothermal areas in the Southern provinces of Morocco

Conclusion

In this study, a mapping of prospective geothermal areas in Morocco was performed through compiling geothermal, volcanic, fracturing, density, magnetic and seismic data. This work was carried out via the identification, collection, processing and spatialization of various collected from numerous studies conducted on Moroccan territory. The geothermal gradient and heat flow data measured in oil, mining and hydrogeological boreholes, and the physical and chemical characteristics of the thermal springs have been compiled using a GIS platform, in the form of accessible geo-portal and a geo-catalog for the users. The implemented Moroccan spatial data infrastructure on prospective geothermal areas should make possible different scale mapping and online visualization of spatial database. The analysis of the resulting map, achieved according to the model, shows that the most important geothermal anomaly is observed in the north-eastern Rif. This result agrees with the map of potential geothermal zones of North-Eastern Morocco [24]. An important anomaly exceeding 120 mW/m2 was also observed in some areas of the Anti-Atlas. An important geothermal interest also appears in the basin of Tindouf and in the regions of Semara and Dakhla. The obtained results should guide the programs of geothermal exploration in Morocco.

Acknowledgements-This work was completed within the framework of L3GIE laboratory of the Mohammedia School of Engineers (EMI).Special thanks to Pr. Lahcen Bahi (EMI)for his valuable comments and supervision.

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