ATINER's Conference Paper Proceedings Series
GEL2018-0081
Athens, 27 August 2018

The Geothermal Fields Monitoring

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ATINER's Conference Paper Proceedings Series
COM2018-0081
Athens, 27 August 2018
ISSN: 2529-167X

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ABSTRACT

The concept of energy and the energy resources sustainability have been one of the most important subjects and problems of the world from past to present. Depletion of the energy resources rapidly, using the non-renewable resources such as petroleum, coil and nuclear energy unconsciously and the effect of the pollutions that these resources give to environment and atmosphere are directed the human beings to use renewable energy sources. The geothermal energy, which is one of the most important renewable resources, is used in lots of fields such as electric production, medicine, tourism, agriculture, industry. The mass changes which is very significant subject for the terms of the earth sciences, can occur with the effect of water potential in geothermal fields. In particular, the reinjection in the geothermal plants can be caused the important subsurface changes in the geothermal basin. Microgravity and GNSS methods are used for monitoring these changes in the geothermal basins. The vertical mass movements can be determined with the help of time-dependent microgravity measurements. Besides, while the isostatic state of these vertical movements, also the horizontal deformation can be calculated by using GNSS measurements. In the scope of this study, the monitoring of the geothermal basins by using microgravity and GNSS methods is examined in general and additionally, the samples realized in Izmir city and Western Turkey are presented.

Keywords: Geothermal monitoring, gravity, GNSS.

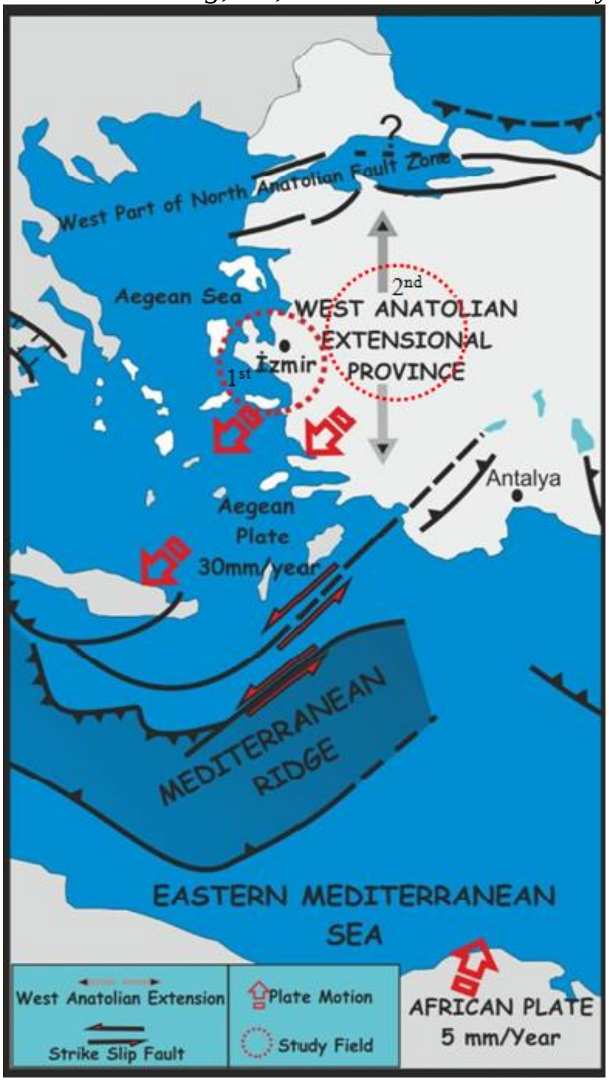
Introduction

From past to recent days, the energy and sustainability of the energy resources is one of the most significant subjects and problems of our era. The geothermal energy as the most important renewable resource is used in lots of different fields from tourism to industry.

The mass changes which is very significant subject for the terms of the earth sciences, can occur with the effect of water potential in geothermal fields. In particular, the reinjection in the geothermal plants can be caused the important subsurface changes in the geothermal basin. Microgravity and GPS methods are used for monitoring these changes in the geothermal basins (Andres and Pedersen, 1993; Hunt, 1995; Sugihara and Ishido, 2008). The vertical mass movements can be determined with the help of time-dependent microgravity measurements. Besides, while the isostatic state of these vertical movements, also the horizontal deformation can be calculated by using GPS measurements. Gravity and GPS velocity changes for various periods can be measured as network. Therefore it can be monitored the changes on the gravity and deformation values with depends on years.

In this study, we used gravity and GPS methods in Western Anatolia (Figure 1). Western Anatolia is one of the most active continental zones and deforming under the effect of extensional forces. The main tectonic structures of Western Anatolia are E–W trending grabens and the active normal faults and additionally, the NNE-trending basins (Taymaz and Price, 1992; Yılmaz et al., 2000; Bozkurt, 2001). As a result we discussed two data set relations for known and potential geothermal fields for study area.

Figure 1. *This Figure Shows that the Main Tectonic Framework of the Western Anatolia and its Surroundings (Modified from Çırmık et al., 2017). 1st; İzmir and Surrounding, 2nd; Western Anatolian Study Area*



Applications

In this study, we used Trimble RTK 5700 for GPS measuring and Scintrex gravimetry CG-5 for microgravity observations network for field measurements (Figure 1). The processing strategy which is given at Table 1 is used in the GPS processing.

Figure 2. *The Equipment used in this Study*

Table 1. *GPS Data Processing Strategy*

Data Interval	30 sec.
Cut Off Elevation	10 degree
Day Of Year	183-190
Orbit	IGS final orbit and ERP
Antenna Phase Center Variation	Elevation dependent weigthing model (PCV-antmod.dat)
Troposphere Parameters	VMF (Vienna Mapping Function) model. Zenith parameters were estimated for every 2 hours.
IGS Stations	12 IGS Stations (ANKR, WTZR, ISTA, NICO, ZECK,GLSV, MIKL, NSSP, TUBI, PENC, MATE, BUCU.)
Receiver Clock Syncronisation	Receiver clock unknowns were estimated for each epoch.
Phase Ambiguity Resolution method	WL (Wide Lane) and NL (Narrow Lane)
Correlation	Full correlation between observations and unknowns.
Final Coordinate Estimation	Daily solutions were combined using GLOBK.

To investigate the relation between GPS (X; Equation 1) and microgravity data (Y; Equation 1) we calculated the correlation coefficients (*r*) between two data sets. If the r values are zero, it means that there is not any relationship between two data sets. If *r* values are close to -1 or -1, it means that there is an inverse relationship between two data sets.

Formula of the correlation coefficient is given in Equation 1.

$$r = \frac{\sum x_i y_i}{\sqrt{\sum x_i^2 \sum y_i^2}} = \frac{\sum\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{\sqrt{\sum\left(X_i - \bar{X}\right)^2 \sum\left(Y_i - \bar{Y}\right)^2}} \quad (1)$$

Conclusions

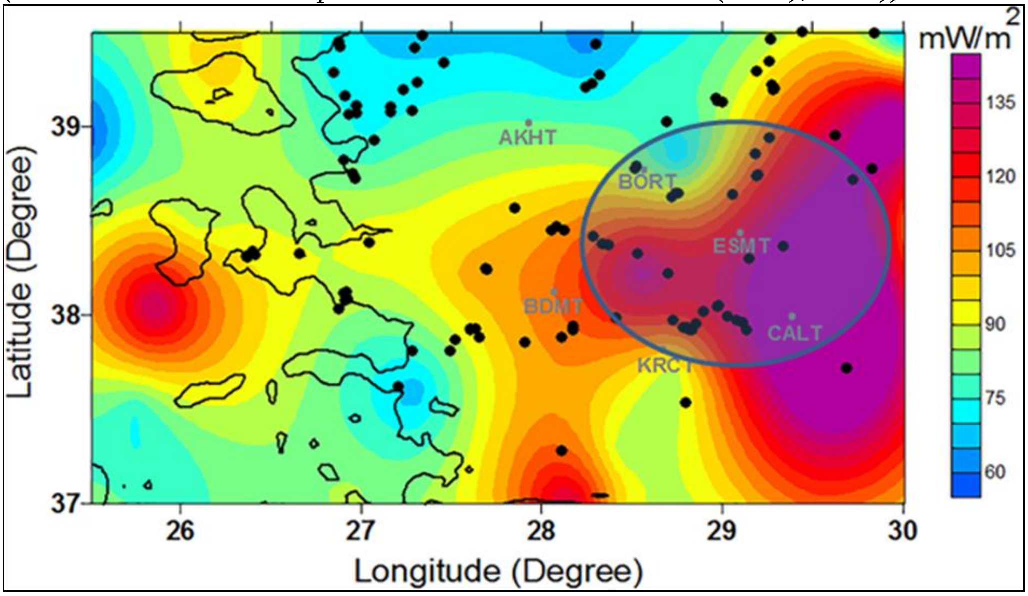
For the isostatic balance gravity and GPS Up values should show increased gravity value in response to decreased vertical changes or decreased microgravity value in response to increased vertical changes. This may be possibly considered as uncompensation in load distribution arising from mass loss occurring subsurface due to the effects of geothermal environment, subsurface water, or seismic activity (Pamukçu et al., 2014; Çırmık et al., 2016). If there is an isostaic balance, the *r* values must be close to -1 or -1. Therefore, if there is not any isostaic balance, the *r* values must be close to +1 or +1. According to this acceptance some stations in İzmir were not working in a manner suitable for isostatic balance. Because *r* values of these stations are close to +1. This may be possibly considered as imbalance in load distribution caused by subsurface mass loss due to geothermal environment, subsurface water or seismic activity for these points (Pamukçu et al., 2014). Red circles are known geothermal areas in Izmir in Figure 3 are consistent with the GPS and microgravity stations 1, 2, 3 (Figure 3) with red point.

Figure 3. *The View of GPS Stations which Locate Izmir and its Surroundings. Red Points Represent GPS Stations and Red Circles Represent Known Geothermal Sources. This Figure was created by using Google Earth Pro,* 2018 (http://www.google.com/earth/download/ge/)

The same applications were applied to the GPS and microgravity data of Western anatolia and the geothermal structure of the study area were examşned with the help relationship between GPS and microgravşty data (Figure 4). The values of r are positive for BORT, CALT and ESMT and there are positive relationships between two data sets. Because r values of these stations are close to +1. This may be possibly considered as imbalance in load distribution caused by subsurface mass loss due to geothermal environment, subsurface water or seismic activity for these points (Pamukçu et al., 2014). If these results are evaluated with the heat flow map of the study area, positive r values are consist with the high heat flow value regions as seen as blue circle in the heat flow map.

As a result, ıf the correlation coefficient between the GPS and microgravity data are +1 (r = +1), these locations are not working in a manner suitable for isostatic balance. Therefore according to our studies, it can be said that this type of regions can include a geothermal source.

Figure 4. *The View of Heat Flow of Western Anatolia and its Coherence with the Approach of Relationship Coefficient between Gravity and GPS Data of Western Anatolia. (Heat Flow Map of Western Anatolia, Turkey (Modified from Çırmık et al., 2016). Black Points Represent the Geothermal Sources (Mineral Research & Exploration General Directorate (MTA), 2005)).*



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