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Geophysical Variations During the Total Solar Eclipse in 2006 in Turkey

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Abstract: It has been observed that some geophysical parameters could be changed during a solar eclipse. We have therefore measured gravity and magnetic fields during solar eclipses. We also measured the gravity field during the previous eclipse on the 11th of August, 1999. Gravity measurements on the 29th of March, 2006 are compared with previous gravity measurements at the same location during the eclipse on the 11th of August, 1999. Both showed the same behaviour during the eclipses. Gravity measurements showed fluctuations during both eclipses. A decrease in the intensity of the magnetic field was observed. Low-pass filtered magnetic data show peculiarity during the eclipse which can be correlated with the fluctuations in the gravity fields.

Key Words: total solar eclipse, gravity measurements, magnetic measurements, power spectrum, low pass filtering

Türkiye'de 2006 Yılı Tam Güneş Tutulması Sırasında Gözlenen Jeofizik Değişimler

Özet: Güneş tutulması sırasında değişen jeofizik parametrelerin bazıları gözlenmiştir. Gerçekte güneş tutulmaları sırasında gravite ve manyetik alanları ölçtük. Ayrıca 11 Ağustos 1999 tarihinde bir önceki güneş tutulması sırasında gravite alanını ölçmüştük. 29 Mart 2006 tarihinde yapılan gravite ölçümleri, aynı noktada 11 Ağustos 1999 tarihindeki önceki gravite ölçümleriyle karşılaştırılmıştır. Her iki ölçü de tutulma sırasında aynı davranışı sergilemiştir. Gravite ölçüleri, her iki tutulma sırasında dalgalanmalar göstermiştir. Manyetik alan şiddetindeyse bir azalma gözlenmiştir. Alçak geçişli filtre uygulanmış manyetik veri, tutulma sırasında gravite alanlarında meydana gelen dalgalanmalarla ilişkilendirilebilen bir özellik göstermiştir.

Anahtar Sözcükler: güneş tutulması, gravite ölçümleri, manyetik ölçümler, güç spektrumu, alçak geçişli süzgeçleme

Introduction

A total solar eclipse occurred on the 29th of March, 2006 within a narrow corridor in the northern hemisphere starting near the equator in the Atlantic ocean, crossing central and northern Africa, going across the Mediterranean sea to Turkey and terminating at sunset in Mongolia (Figure 1a, b). The previous total solar eclipse occurred in central Europe, the Middle East, and India on the 11th of August, 1999. Malin *et al.* (1999) observed changes in the declination angle of the geomagnetic field at the different observatories in Europe during the previous eclipse. However, Korte *et al.* (2001) reported that there was no eclipse-related magnetic variation observed from various parts of Europe. However, they found a magnetically quiet period with magnetic activity index Kp= 1 around the solar eclipse time (±6 hours). Ionospheric measurements showed a decrease of electron density during the eclipse. Hvozdara and Prigancova (2002) studied the

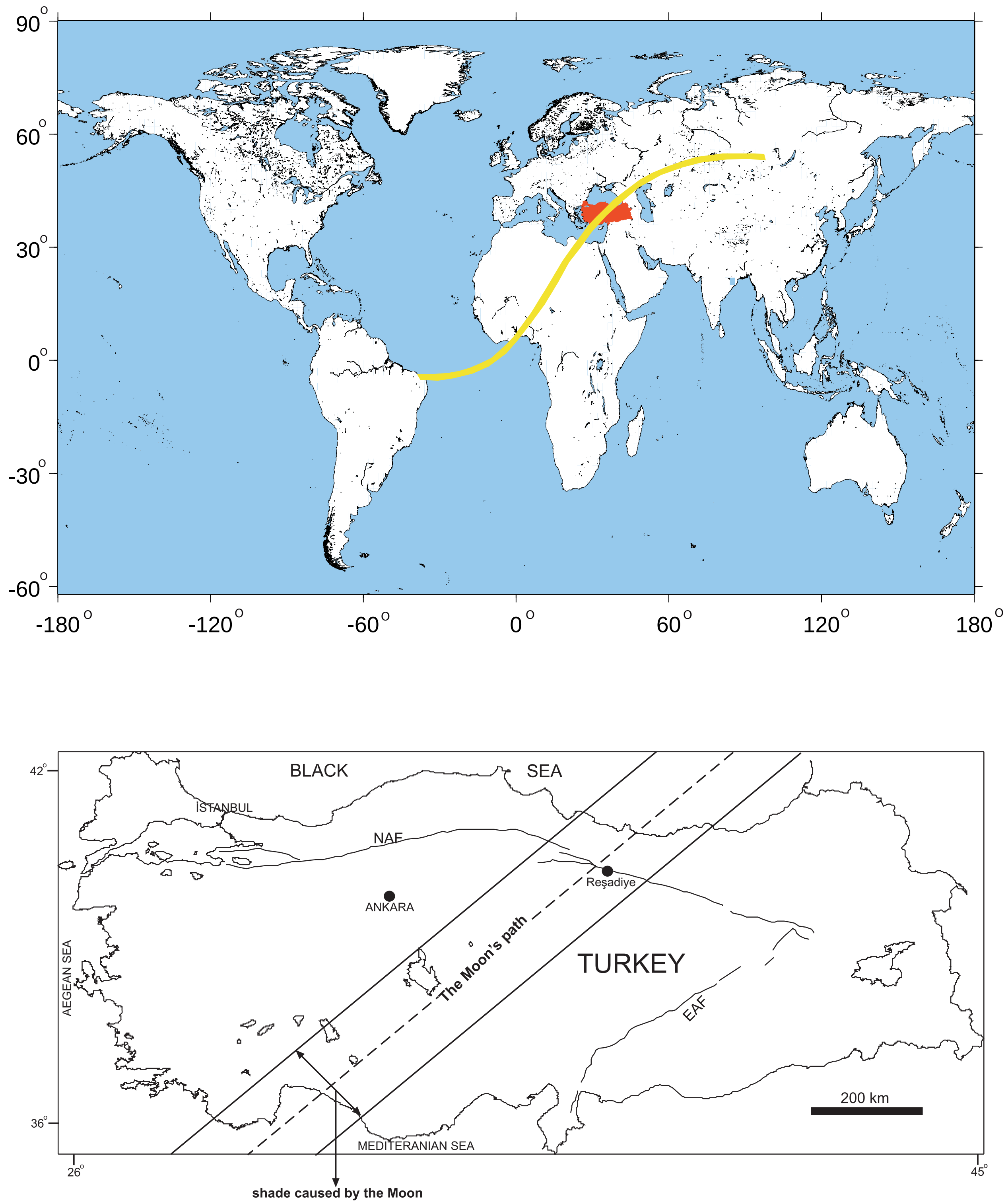

Figure 1. **(a)** The path of the total solar eclipse on the earth, **(b)** the corridor in Turkey of the total solar eclipse on the 29th of March, 2006.

ionospheric and geomagnetic observations during the eclipse to determine eclipse-induced effects. According to their study, a mathematical model based on the Ashour-Chapman model showed a decrease of the ionospheric total electron content in the region of the totality belt. They explained that the geomagnetic disturbances were quantitatively dependent on the position of both the quasicircular spot of the ionospheric conductivity decrease and the given geomagnetic observatory location.

Bencze *et al*. (2007) correlated geomagnetic pulsations and interplanetary medium effects during the solar eclipse on 11th of August, 1999 and found in the interplanetary medium no indication any extraordinary event in pulsation activity. They found that the reason for electron density decreasing as a both horizontally and vertically widespread ionospheric effect was explained by a change of the polarisation angle of about ten degrees in the local field line resonance band. The solar eclipse effect was identified as a dramatic clockwise rotation of the polarisation ellipse of Pc3, Pc4 and Pc5 pulsations.

Wang *et al.* (2000) obtained anomalous gravity data in their gravimetric experiments during the 1997 total solar eclipse in China. This could be evidence for the eclipsing Moon shielding the Sun's gravity. They also suggested that the anomalies might indicate some new property of gravitation. Gravity measurements were carried out during the 9th of March, 1997 total solar eclipse in Mohe region in Northeast China by using a high-precision LaCoste-Romberg gravimeter. The gravity variations were digitally recorded during the total solar eclipse so as to investigate possibly anomalous solar and lunar gravitational pulls on the Earth. There were two 'gravity anomaly valleys' with near symmetrical decreases of about 6–7 μgal at the first and last contacts. This anomaly phenomenon was observed and reported for the first time in the literature (Xin & Qian 2002). Unnikrishnan *et al*. (2002) showed that gravity anomaly observed by Wang *et al.* (2000) during the total solar eclipse is not gravitational shielding and argued that it does not indicate any new property of gravitation. They suggested two models that can reproduce the main data features in Wang *et al.* (2000). They analyzed Wang *et al.* (2000)'s data collected for about a week and obtained a significant new lower bound of $h < 2 \times 10{-}17$ cm^2/g, two orders better than the existing limits from any terrestrial experiment, on the Majorana (1920) gravitational shielding parameter 'h'. Yang & Wang (2002) estimated a new gravitational shielding parameter constraint as $h \leq 6 \times 10{-}18\ cm^2\ g^{-1}$ on Majorana by using the same method.

Flandern & Yang (2003) measured gravitational effect using a very accurate Foucault-type pendulum during the 1997 eclipse and found an acceleration of gravity decrease on the Earth during the solar eclipse.

During the eclipse the ionisation decreases and conditions in the shadow zone are similar to those during the night. After the eclipse it returns to its former value (Streštík 2001).

Geophysical Observations

During the eclipse two different geophysical parameters were observed at two different station locations. Magnetic measurements were carried out at the recreation field of Ankara University (39°56'15'' N; 32°49'46'' E, elevation: 853 m). Gravity measurements were also carried out in F Block, room 313, close the recreation field mentioned above. Gravity measurements were also done during the total eclipse on the 11th of August, 1999 (Table 1).

Gravity Measurements

Gravity measurements were carried out by using a Worden-Master gravimeter. Three measurements were made at every sampling and these were averaged to a single value. Gravity variations were normal until a couple of hours before the total eclipse. Thereafter fluctuations were observed during total eclipses on the 11th of August, 1999 and 29th of March, 2006. The gravity readings were converted to mGal by multiplying them with the dial constant of the gravimeter (Figure 2a, b).

Magnetic Measurements

Magnetic measurements were carried out by a SCINTREX (SM-4) magnetometer with a Caesium vapour sensor. 5 measurements per second were

Table 1. Gravity measurements data from the total solar eclipses on 11th of August, 1999 and 29th of March, 2006.

1999		2006	
Time (LT-Ankara)	Gravity (mGal)	Time (LT-Ankara)	Gravity (mGal)
09:20:00	105.680	09:45:00	96.24
09:50:00	105.661	10:02:00	96.23
10:10:00	105.642	10:41:00	96.19
10:50:00	105.593	10:51:00	96.17
11:15:00	105.574	11:39:00	96.16
11:35:00	105.574	12:28:00	96.16
11:52:00	105.574	12:40:00	96.16
12:19:00	105.574	13:10:00	96.16
12:38:00	105.574	13:27:00	96.16
12:57:00	105.603	13:33:00	96.18
13:06:00	105.584	13:47:00	96.16
13:13:00	105.593	13:50:00	96.19
13:28:00	105.622	14:09:00	96.19
13:45:00	105.622	14:14:00	96.21
13:58:00	105.642	14:17:00	96.21
14:21:00	105.632	14:30:00	96.22
14:24:58	105.700	15:13:00	96.3
14:25:00	105.680	16:15:00	96.31
14:43:00	105.700	16:34:00	96.39
15:00:00	105.690	16:43:00	96.34
15:19:00	105.748	16:50:00	96.37
15:30:00	105.758		
15:51:00	105.777		
16:10:00	105.787		
16:25:00	105.825		
16:45:00	105.845		
17:06:00	105.854		
17:16:00	105.874		
17:26:00	105.903		
17:35:00	105.903		
17:46:00	105.91		

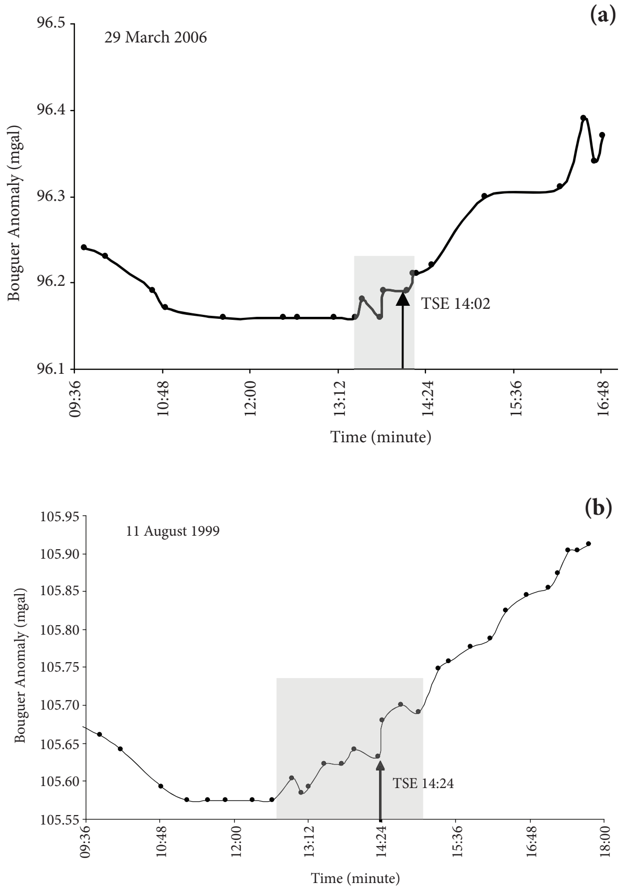

Figure 2. **(a)** Gravity measurements during the 29th of March, 2006 eclipse (the solar image was 96.7% covered by the Moon), **(b)** Gravity measurements on the 11th of August, 1999 (the solar image was 96.7% covered by the Moon). The shaded zone shows the fluctuations during the eclipse. Time zone is local (Ankara). TSE: Total Solar Eclipse

automatically taken and the readings were recorded to the instrument memory. One average value of 5 magnetic measurements per second was calculated using a routine arithmetic averaging method. A decrease of the intensity of the magnetic field was observed during the eclipse. This situation can be better observed by fitting a 6 degree polynomial line to the magnetic anomaly in Figure 3. The reason for change in the declination angle (D) was explained by Malin *et al*. (2000). In order to remove the noise and the high-frequencies from the magnetic measurements, the data set shown in Figure 3 was low-pass filtered using a cut-off frequency of 0.0016 km^{-1}, obtained from the power spectrum method. The power spectrum graphic is shown in Figure 4. The low-pass filtered magnetic data is presented in Figure 5. In this graphic, the general characteristics of the magnetic data during the eclipse changed in amplitude and shape. This abnormal region is annotated by a perpendicular shade. Time of the eclipse is shown by a line.

Conclusions

We also took gravity and magnetic measurements with the available instruments at different locations. These measurements are as follows:

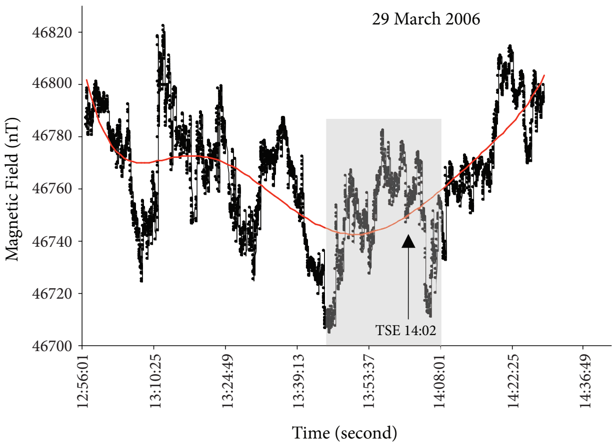

Figure 3. Magnetic measurements in Ankara, Turkey. The red line shows a six degree polynomial fit to the magnetic measurements. The shaded zone shows the fluctuations during the eclipse. Time zone is local (Ankara). TSE– Total Solar Eclipse

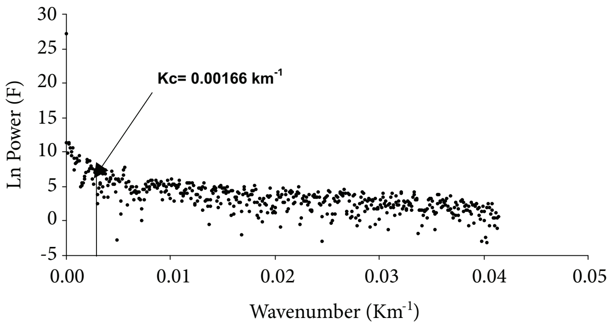

Figure 4. Power spectrum graphic of magnetic data. The arrow shows the cut-off wavenumber of 0.00166 km^{-1}. The vertical axis is the logarithm of the power. The horizontal axis is the wavenumber.

(i) Gravity measurements were taken during the 11th of August, 1999 and 29th of March, 2006 eclipses in Ankara.

(ii) Magnetic measurements were taken only during the 29th of March, 2006 eclipse in the recreation field of the Ankara University.

Fluctuations observed during total eclipses on the 11th of August, 1999 and 29th of March, 2006 could be explained as the shielding effect of the Moon. The Sun's and Earth's gravity pull in opposite directions. Hence, the different positions of the Moon caused mass movement of the atmosphere. This effect

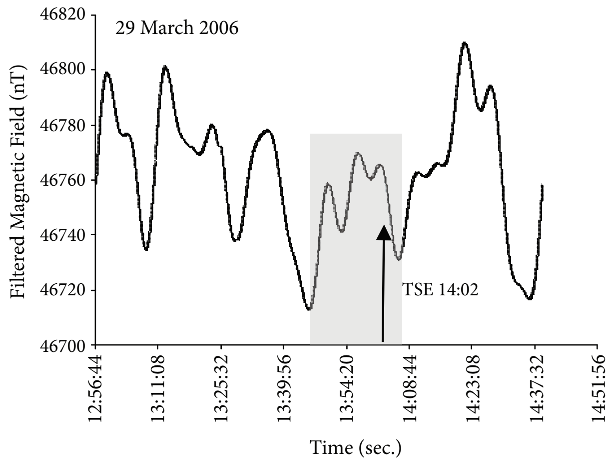

Figure 5. Low-pass filtered magnetic data. Time zone is local (Ankara). The abnormal region is annotated by the shaded zone. TSE– Total Solar Eclipse.

fluctuated the gravity that we observed during eclipses.

The ionisation in the E-layer decreased to 65% of its normal value (van Zandt *et al.* 1960). Due to changing ionisation conditions during the day, the intensity of Earth's magnetic field showed abnormality during the eclipse. Ionospheric measurements showed a decrease of electron density during the eclipse on 11th of August, 1999 (Korte *et al.* 2001; Hvozdara & Prigancova 2002). The reason for electron density decrease as both a horizontally and vertically widespread ionospheric effect was explained by a change of the polarisation angle by about ten degrees in the local field line resonance band by Bencze *et al.* (2007) during the total solar eclipse in 1999.

The magnetic data are available digitally on a hard disk. Send a blank CD or DVD to the authors if you request the data.

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