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Monitoring of the Telluric Currents Originated by Solar Related Atmospheric Events in Northwestern Turkey

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Abstract. Telluric currents have a number of origins caused by naturel events such as electrochemistry activities, atmospheric electricity, ionospheric conditions, solar activity and geomagnetism. Telluric currents circulate continuously in the upper regions of the earth's crust. Between 21 and 27 August 1991, ground based observations of the telluric currents were made at Boyalı, Kastamonu (northwestern Turkey). During the continuous monitoring, the telluric (originated by Pc geomagnetic pulsations) and the other currents are simultaneously recorded chart paper. It is readily apparent that the persistent variations and the micropulsations have different patterns caused by high atmospheric electricity due to local lightning, and by the geomagnetic field of the Earth. Additional examples from different sites recorded using a magneto-telluric measuring system are given.

1. Introduction

It is well known that the magnetosphere-ionosphere system and interaction is strongly governed by the activity of the Sun (Hargreaves 1992). The study of upper atmosphere and magnetosphere phenomena by means of geomagnetic field observations plays an important role in the understanding of the Earth's electromagnetic environment (Russell 1986; Engebretson et al. 1995). The alternating electromagnetic field of the earth that has a regional nature that is intimately related to phenomena on the Sun and in the ionosphere (Figure 1).

The Earth's electromagnetic field is closely related to terrestrial and extraterrestrial phenomena. The electromagnetic field apparently arises as a result of current systems set up mechanically in the ionosphere. These electromagnetic waves are noted at the Earth's surface as variations in the geomagnetic field and the telluric current field. The electric part of such a field is known as the telluric current field. Their presence can be detected by measurements made with two grounded electrodes. They are associated with the general electromagnetic character of the Earth in response to solar activity. The existence of geomagnetic changes might be ascribed to two different effects related to piezo-magnetism and electrofiltration.

In tectonically active areas, water flows cause interstitial pressure gradients that can generate electro-filtration currents causing magnetic anomalies (Mizutani et al. 1976; Fitterman 1979) and consequently these two sources of magnetic

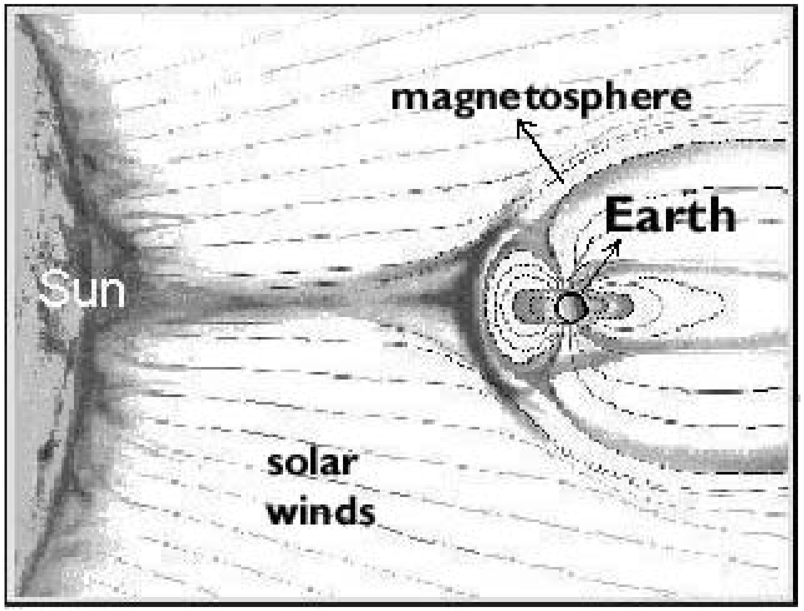


Figure 1. Micropulsations of 0.2 sec to 10 h period are also caused by interaction between the solar wind and magnetosphere.

anomalous variations may co-exist. In this paper, the observations of the telluric currents using the ground based monitoring system is made to obtain several evidences associated with atmospheric and magnetospheric electricity.

2. Micropulsations and telluric currents

2.1. Micropulsations originated by solar winds

In Figure 2 typical diurnal amplitude spectrum of the short-period variation in the geomagnetic field, indicating the peaks, is shown. Micropulsations of 0.2 sec to 10 h period are also caused by interaction between the solar wind and the magnetosphere. Here Pc1=0.2-5 sec, Pc2=5-10 sec, Pc3=10-45 sec, Pc5=150-600 sec and Pc6>600 sec.

The diurnal variation is believed to be caused by the interaction of the conducting ionospheric layers of the upper atmosphere with the main magnetic field. This is mainly produced by two large loops in the ionosphere at about 100 km height on the side of the Earth which faces the Sun. The most conspicuous short-period variation is the diurnal variation. If a record covering a period of many days is subjected to spectral analysis, it is found that the dominant period is one day and that there are conspicuous harmonics of period 12 h and 8 h. A period of 27-day and its harmonics which may be related to tides caused by Moon's orbital motion. Within a series of Micropulsations, the amplitude rapidly increases and then rapidly decreases again. The period of the pulses contained within a group in most cases falls in the spectrum 40 to 80 seconds. It is readily apparent that the persistent variations and the Micropulsations

Table 1. Users of ionospheric forecasts

Customer	Day or Night Effects	Type or Activity Producing Effects
Civilian satellite communication	night	magnetic storms
Communication (VHF)	day	solar radio emissions
Commercial aviation polar cap	day & night	PCA, magnetic storms
Commercial aviation navigation (VLF)	day & night	PCA, magnetic storms
Electric power companies	day & night	magnetic storms
Long line telephone communication	day & night	magnetic storms
High altitude polar flights	day & night	solar proton events
Radiation hazards	day & night	solar proton events
Civilian HF communication	day & night	X-ray emis., UV emis.
Geophysical exploration	day	magnetic storms
Scientific satellite studies	day & night	solar flares, magnetic storms
Solar constant measurements	day & night	X-ray emis. UV emis., solar ev.
Scientific rocket studies	day & night	solar flares
Studies on magnetosphere	day & night	magnetic storms
International community	day & night	All
Scientific ground studies	day & night	solar flares, magnetic storms
Magnetosphere, ionosphere, upp. atmosphere	day & night	solar emission
Seismological and geomagnetic	day & night	X-ray emis. UV emis.

have different diurnal patterns. The high-frequency components are of large amplitude only in regions where the air is highly ionized. A variation of 11-year period is associated with the sunspot cycle. Solar activity and magnetic storms caused by abnormal variations of the Micropulsations generally affect telephone, satellite and radio communications (Table 1). Magnetic storms are caused by large and sudden increases in the energy density of the solar wind. This distorts the magnetosphere and causes injection of high energy particles into it.

2.2. Telluric currents

We shall consider that the source of micropulsations in telluric (Earth) currents as having their origin in electric or magnetic dipoles in the ionosphere. The

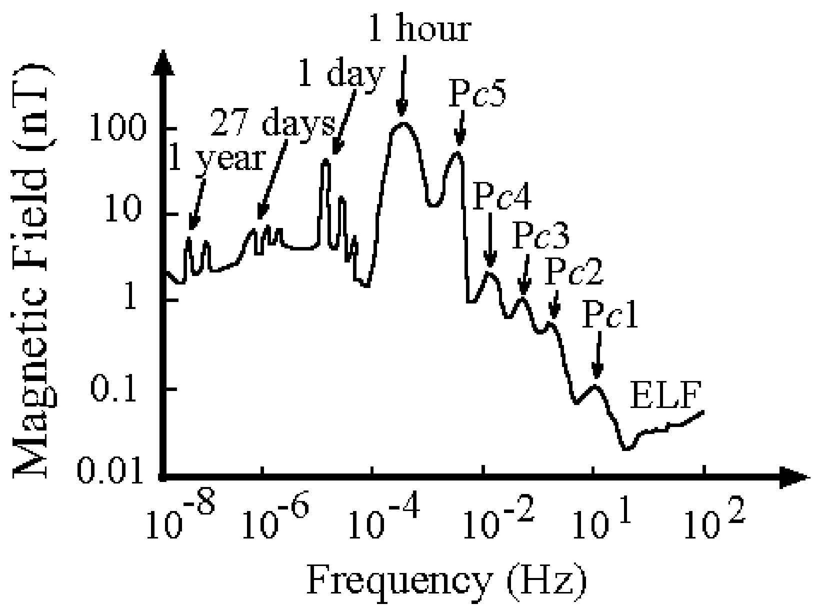


Figure 2. The amplitude spectrum of the geomagnetic fields. Pc1, etc., refer to micropulsations.

geographic distribution of telluric currents over the Earth's surface, therefore, has a yearly variation in their amplitude. Electromagnetic waves radiated from the above sources are refracted at the earth's surface and travel through the surface layers as plane waves, attenuated with depth below the surface. This description is reasonably true if:

1. The earth has a much lower resistivity than the air;
2. The current sources are located at a considerable distance from the earth's surface;
3. The area in which telluric currents are being measured is relatively small.

The already various pattern of the telluric records (tellurograms) are shown in Figure 3.

3. Telluric monitoring in northwestern Anatolia

Based on the ionospheric observations at Istanbul (Turkey) in 1968, electromagnetic radio waves distorted by solar activity are investigated (Agopyan 1995). The F-region within the ionosphere is mostly affected by magnetic storms which are caused by large and sudden increases in the energy density of the solar wind.

Between 21 and 27 August 1991, ground based observations of the telluric currents were made at Boyalı, Kastamonu. The Boyalı area is located at 41.3N, 34.15E on the region of Çangal metaophiolite geological units. The micropulsations (i.e. telluric currents caused by them) measuring system is located in a quiet place approximately 10 km outside the town of Taşköprü, Kastamonu.

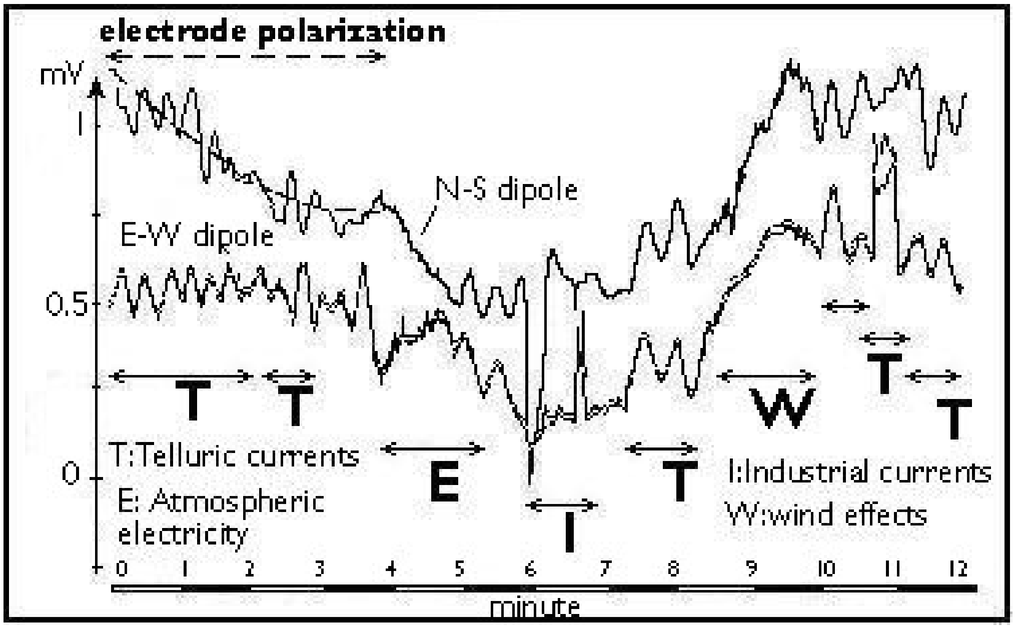
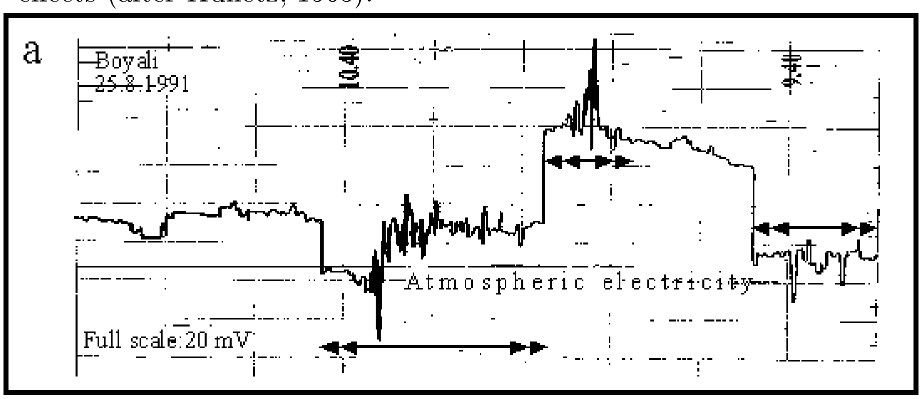


Figure 3. The possible general shape of a telurogram showing various effects (after Kunetz, 1965).



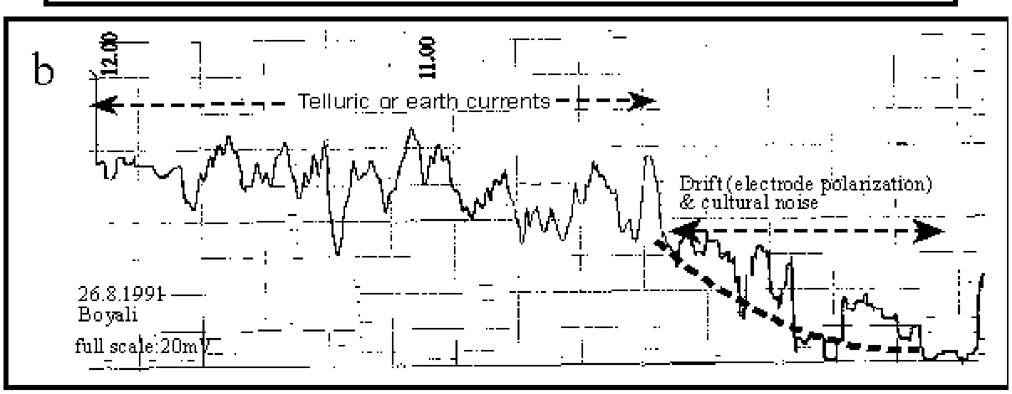


Figure 4. Some records of Tellurograms from Boyalı.

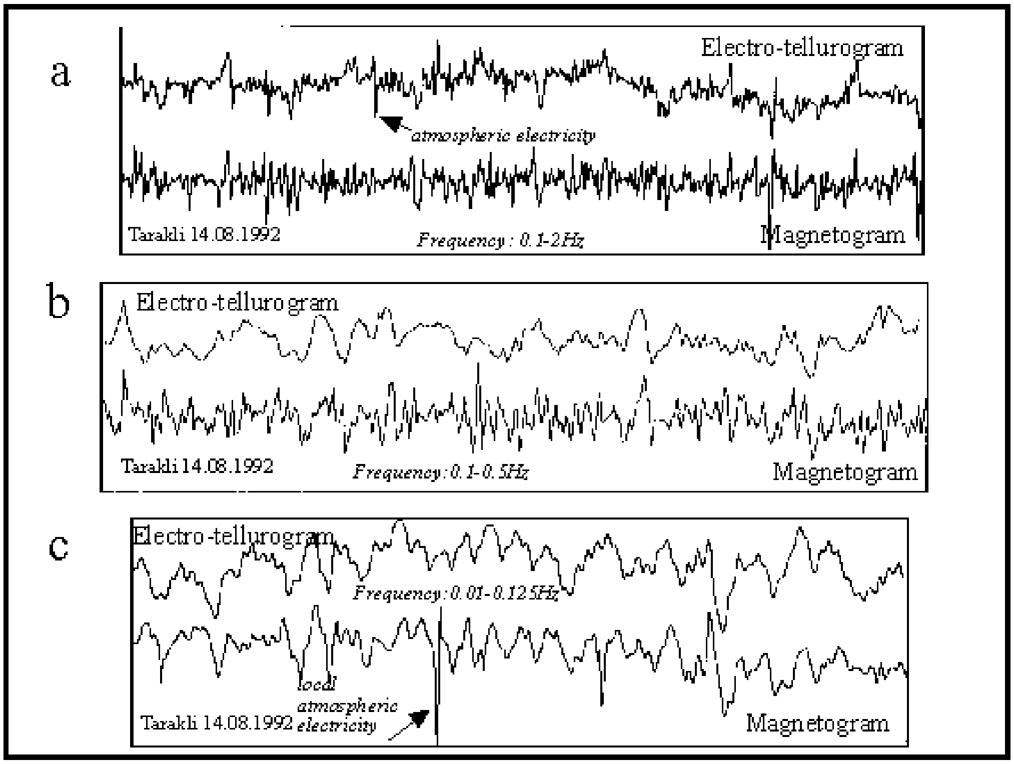


Figure 5. Electro-tellurograms and magnetograms recorded at Tarakli site.

This station is located in the area with the lowest noise level. A telluric monitoring station (Corry et al. 1983) using an electric dipole of 100 m length with north-south direction is constructed here. Two grounded electrodes of the $Cu - CuSO_4$ non-polarising type, are used for the electric dipole. Differences in potential due to polarisation are thereby reduced to a few millivolts and, chiefly, they are kept fairly constant with time.

During the continuous monitoring, the telluric and other currents are simultaneously recorded on a strip chart, moved at a rate of 2 cm per minute. The records in Figure 3 show that telluric field variations are roughly periodic with an average period of a few dozen seconds. Field distortion due to natural or artificial causes (industrial currents in particular) makes it more difficult to compare with the pattern of records in Figure 4.

4. Analysis of the tellurograms and conclusions

Telluric currents have a number of origins: some are related to industrial activities, others are due to natural causes but of a more or less local nature: electrochemistry, atmospheric electricity, etc. Other currents at least, telluric currents proper, assume the nature of general phenomena extending over considerable portions of the globe area. Sometimes electric (interference) fields appear

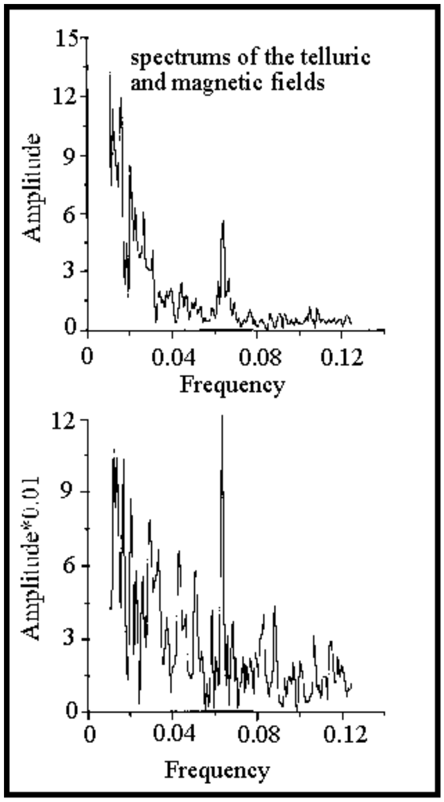


Figure 6. Fourier spectrum of the electro-tellurogram and magnetogram in Figure 5.

having frequencies similar to those of the telluric current field that distort the phenomenon (Figure 3). Typical sources of these interference are:

(i) Industrial Interference: In recording sites near industrial cities or electric railways, industrial currents cause sudden irregular changes which can be easily recognised on the tellurograms (Figure 4b). Inductive Interference: If the measurements are made near telephone or electric transmission lines, interference signals at 5 to 50 cyc/sec are induced in the measuring circuits.

(ii) Noise due to the wind: In windy weather, interference with an amplitude from 0.2 to 0.4 mV, and with periods from 1.5 to 2 sec, are introduced in tellurograms. These voltages are due to the electromotive forces induced by the magnetic field or the earth in wind-blown wires.

Only the alternating electromagnetic field of the Earth, that has a regional nature and is intimately related to the phenomena on the Sun and in the ionosphere, is considered in this study. The electro-tellurograms and magnetograms simultaneously recorded at Taraklısite using a magneto-telluric system are shown in Figure 5. These records show that telluric field variations originated by Pc geomagnetic pulsations are roughly periodic with an average period of a few dozen seconds and an amplitude about several tens of millivolts. Some field distortions due to atmospheric electricity are indicated in the records. These records are obtained for different frequency bands that are related to the types of Pc micropulsations. The results obtained for the highest frequency bands (Pc1-Pc3a) reveal a significant weekly modulation of the power.

The spectral analysis results of the records in Figure 5 are shown in Figure 6. From this figure it can easily be seen that the electro-telluric and magnetic field variations are generally coherent over the frequency range 0.01-0.125 Hz. This pattern indicates an induction in the earth's crust caused (unless incohorent) by an external electromagnetic field. In this paper we have shown that significant changes in the local magnetic and electric field are observed. The results are easily explainable and several factors may be considered responsible.

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