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Advances in Space Research xxx (2016) xxx–xxx

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

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Atmospheric electric field variations and lower ionosphere disturbance during the total solar eclipse of 2010 July 11

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Received 2 June 2015; received in revised form 29 January 2016; accepted 30 January 2016

Abstract

In this paper, we study the variations of atmospheric electric field during the total solar eclipse (TSE) of July 11, 2010, at Complejo Astronómico El Leoncito (CASLEO). These variations observed with two identical sensors separated by 0.4 km, show a significant increase (~55 V/m) when compared with averaged values measured during previous and subsequent fair weather days. Furthermore, identical changes are detected on the measured phases of Very Low Frequency waves received at CASLEO. The latter suggests a possible connection between the lower ionosphere and the lower atmosphere during the period of the eclipse.

Keywords: Atmospheric electric field; Fair-weather; Total solar eclipse; Very Low Frequency waves

1. Introduction

The atmospheric electric field persists in fair weather[1] regions mainly due to thunderstorms occurring at remote locations. This is part of the current knowledge of the global atmospheric electric circuit (GAEC). In short, the GAEC relates the charge separation in regions of disturbed weather to electrical current flowing in fair weather regions. Recent advances on study of the GAEC are reviewed in Williams and Mareev (2014).

The atmospheric electric field in fair weather regions is affected by several phenomena, such as for example, solar and seismic activities (see references in Tacza et al., 2014). Investigations of the effects of solar eclipses on the atmospheric electric field have also been reported for a long time. Previous studies showed an increase of the atmospheric electric field (Anderson and Dolezalek, 1972; Dhanorkar et al., 1989; De et al., 2009), while other reports mention a decrease (Jones and Giesecke, 1944; Markson and Kamra, 1971; Kamra and Varshneya, 1967; Retalis, 1981; Kamra et al., 1982; Manohar et al., 1995; Babakhanov et al., 2013; De et al., 2013; Kumar et al., 2013). Finally, few studies do report no change at all (Freier, 1960). Inconsistency of the effects of a solar eclipse on atmospheric electricity may occur because of different instrumentations and local meteorological conditions during observations (Babakhanov et al., 2013).

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[1] Fair weather conditions are those in which no local electrification processes are occurring, without appreciable convective cloud extent (Harrison, 2013).

http://dx.doi.org/10.1016/j.asr.2016.01.021
0273-1177/

Please cite this article in press as: Tacza, J.C., et al. Atmospheric electric field variations and lower ionosphere disturbance during the total solar eclipse of 2010 July 11. Adv. Space Res. (2016), http://dx.doi.org/10.1016/j.asr.2016.01.021

Two factors have been proposed to explain the effect of the eclipse on atmospheric electrical parameters. These are, changes in upper atmosphere processes (e.g. Koenigsfeld, 1953; Dhanorkar et al., 1989; De et al., 2009; Kumar et al., 2013; Babakhanov et al., 2013) or changes in atmospheric boundary layer processes close to ground surface (e.g. Jones and Giesecke, 1944; Gish, 1944; Anderson, 1972; Anderson and Dolezalek, 1972; Kamra et al., 1982).

With respect to processes in the upper atmosphere, Koenigsfeld (1953) suggests that variations in the amount and height of ozone influence the amount of ultraviolet radiation absorbed and reduce the electrical conductivity of the atmosphere. In addition, the author mentions that the ionization of ice crystals by ultraviolet photons should result in change of the electrical conductivity. De et al. (2009) suggest that the removal of electrons from the lower ionosphere due to recombination during the solar eclipse may give rise to an increase in the electrical field.

With respect to changes in atmospheric boundary layer, Anderson and Dolezalek (1972) propose a mechanism to determine the variation of the electric field intensity. The attenuation of solar radiation due to an eclipse causes a reduction in the turbulent activity (or eddies) starting at the lowest levels of the atmosphere and propagating upward. After a series of processes, a downward convection current of heavy positive ions is established. The latter, causes a reduction in electrical conductivity and therefore produces an increase in the atmospheric electric field. Jones and Giesecke (1944) also proposed a similar mechanism.

In this paper, we study the variations of atmospheric electric field during the total solar eclipse (TSE) on July 11, 2010 at Complejo Astronómico El Leoncito (CASLEO), Argentina (Lat. 31.798°S, Long. 69.295°W, Altitude: 2550 masl). Section 2 presents the instrumentation and data treatment. In Section 3 we present our results by comparing the effects of the TSE on both electric field records, and VLF phase measurements. Section 4 is devoted to the discussion of our findings, and in Section 5 we give our concluding remarks.

2. Instrumentation

Continuous measurements of atmospheric electric field are being recorded with two sensors located in CASLEO (CAS1 and CAS2), ~0.4 km apart. Each sensor consists of a commercially manufactured (Boltek Corporation EFM100-1000120-050205) electric field mill (EFM) and is part of a network of electric field sensors installed in South America. The dynamic range of the EFM is ±20 kV/m and the response time 0.1 s. The principle of EFM operation is based on the fundamental laws of electromagnetism. When a conducting plate is exposed to an electric field, a charge is induced proportional to the electric field and the area of the plate (Tacza, 2015). Electric field measurements are recorded with a time resolution of 0.5 s, and afterwards integrated using 30 min averages for the analysis reported here. The electric field intensities are previously corrected to account for the height of the local instrument (sensor) mounting. This is because the latter results in overestimated readings (Tacza et al., 2014).

The database of VLF signals is provided by the South American VLF Network (SAVNET) (Raulin et al., 2009). In this work we use the VLF propagation path between transmitter (NPM; Hawaii; $f = 21.4$ kHz) and the receiver CAS (CASLEO). The transmitted wave propagates within the Earth-Ionosphere waveguide to the receiver CAS. Phase and amplitude of the VLF wave are recorded with 1 s time resolution. This allows remote monitoring of the D-region height at ~70 km during quiet conditions.

3. Observations

The path of the TSE on July 11, 2010 over the Earth's surface is illustrated in Fig. 1. The trajectory of the umbra and penumbra are represented by a sequence of filled circles and by solid lines, respectively. The TSE has is first contact on the Earth's surface at 17:10 UT and ended at 21:58 UT. The percentage of maximum obscurity over CASLEO was of 41.73%. The end of the eclipse coincides with the sunset in CASLEO (21:50 UT). The local circumstances of the eclipse were obtained from http://xjubier.free.fr/en/site_pages/SolarEclipseCalculator.html.

Our definition of fair weather is not related to meteorological variables, since there is not a weather station at the same EFM location. However, there is a meteorological station 1.5 km away. This station recorded averaged values of $T = 8°$ and humidity <15%, for the time period during

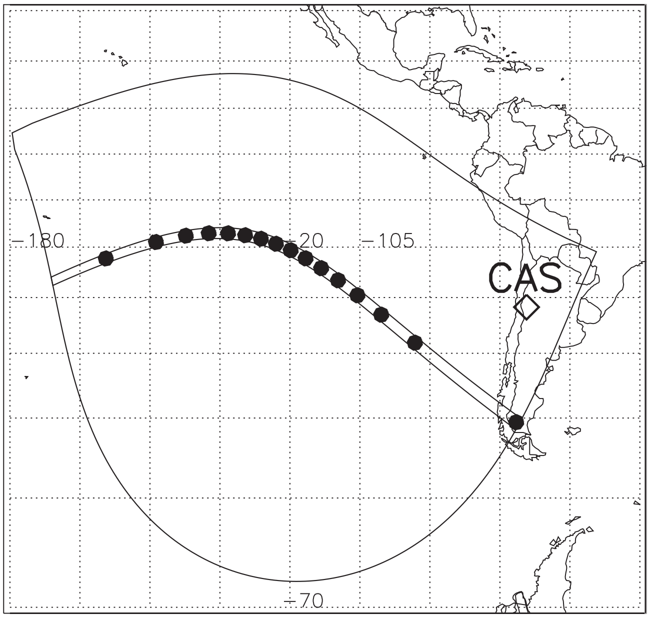

Fig. 1. The propagation path of the eclipse on July 11, 2010 on the Earth's surface, showing the trajectory of the umbra (sequence-filled circles) and penumbra (solid lines). Additionally, CAS indicates the location of the sensors (CAS, black diamond).

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