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The First Documented Space Weather Event That Perturbed the Communication Networks in Iberia

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Abstract In this work, we review the first space weather event that affected significantly a number of communication networks in the Iberian Peninsula (Southwest of Europe). The event took place on 31 October 1903, during the ascending phase of solar cycle 14 (the lowest since the Dalton Minimum). We describe the widespread problems that occurred in the telegraph communication network in two midlatitude countries (Portugal and Spain), that was practically interrupted from 09 h30 to 21 h00 UT. Different impacts on the telegraphic communication are described and shown to be dependent on the large-scale orientation of the wires. In order to put these results into a wider context we provide measurements of the concurrent geomagnetic field that are available from the observatories of Coimbra (Portugal) and San Fernando (Spain). The measurements confirm the simultaneous occurrence of large geomagnetic disturbances. In particular, the magnetograms recorded in Coimbra show a clear and large amplitude storm sudden commencement around 05 h30. The main phase, with a *H* (horizontal component of geomagnetic field) maximum range of ~500 nT, started approximately 1 h later and lasted for almost 10 h, suggesting that the interplanetary magnetic field was strongly southward for long time.

Introduction

The effects of geomagnetic storms on the technological systems have been recognized almost as early as the installation of the primitive telegraph networks in the midnineteenth century. Since then, several historical geomagnetic storms have been reported and studied considering the impact that they caused in the communication networks over different regions of the world at different latitudes [e.g., *Silverman*, 2006; *Vaquero et al*., 2008; *Ribeiro et al*., 2011; *Lakhina and Tsurutani*, 2016]. Here we review the first documented space weather event—the geomagnetic storm of 31 October 1903—that affected significantly a number of communication networks in midlatitude Iberian countries, i.e., Portugal and Spain (Figure 1). However, it is worth noting this was not a regional phenomenon [e.g., *Bauer*, 1904; *Chaves*, 1904; *Okada*, 1904; *Rudzki*, 1904] as this storm had a strong impact on technological systems in various parts of the world. On its edition of 1 November 1903 the *Chicago Daily* newspaper stated that the telegraph communications between France and other European countries and America were virtually disrupted all day, and the conditions resulting from the disturbances were the worst known since the installation of telegraphs (the text is reproduced in http://www.solarstorms.org/SRefStorms.html).

To the best of our knowledge, this was the first time that the effects of a geomagnetic storm on the Iberian telegraph network were matter of report. Published on Nature's section *Letters to the Editor* (12 November 1903) by Augusto Arcimis (1844–1910), Director of *Instituto Central Meteorológico* (Madrid, Spain), this short account refers that Iberian telegraph communications were perturbed almost uninterrupted from the morning of 31 October 1903 until the first hours of 1 November. These perturbations were caused by geomagnetically induced currents (GIC) flowing in the telegraphic lines. GIC are often described as an almost direct (or continuous) current, although the frequency variation is governed by the time variation of the electric field, which in turn is governed by the external magnetic field variations associated with geomagnetic storms. The effects of GIC on the old telegraphic wires (or on other modern communication cables and power grids) are mainly dependent of (1) geomagnetic latitude, (2) magnitude and time-varying behavior (d*B*/d*t*) of geomagnetic storms, (3) regional geology (resistivity ground patterns), and (4) grid characteristics (physical or electrical properties and spatial orientation) [e.g., *Viljanen et al*., 2014].

Telegraph Network Disturbances

Despite the storm's main phase had begun in the early morning (~06 h30 UT; see brief discussion of magnetic data ahead), the first sign of the telegraph perturbation was observed only around 09 h30 in the form of

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Figure 1. Map of Iberian Peninsula showing the main cities (and telegraph stations) referred by *Arcimis* [1903] on its report about the impacts of the space weather event of 31 October 1903; we have represented some of the main telegraphic lines with simplified straight lines where red (green) branches refer to more (less) affected lines (see text). Also shown are the cities of Coimbra and San Fernando where the Portuguese and Spanish magnetic observatories were installed, respectively (depicted by encircled stars).

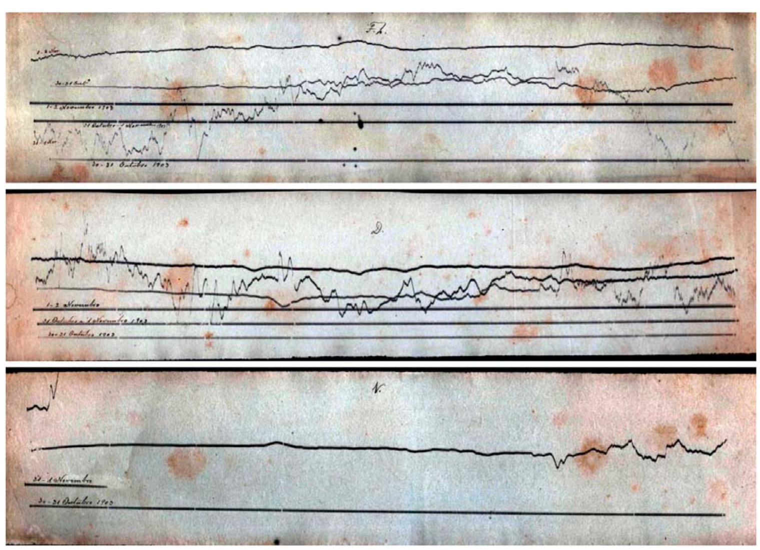

Figure 2. Coimbra (COI) original magnetograms of (top) *H* (geomagnetic horizontal component), (middle) *D* (geomagnetic declination), and (bottom) *Z* (geomagnetic vertical component) for the days around the storm of 31 October 1903 (30 October to 2 November). Recorded on photosensitive paper with a normal running speed of ~15.5 mm/h by the Adie magnetographs, the recording papers used to be replaced daily at noon (scales values: $H = 7.7$ nT/mm, $D = 1.13'$/mm, and $Z = 6.7$ nT/mm). COI geomagnetic coordinates (1900): 44.9°N, 69.9°E.

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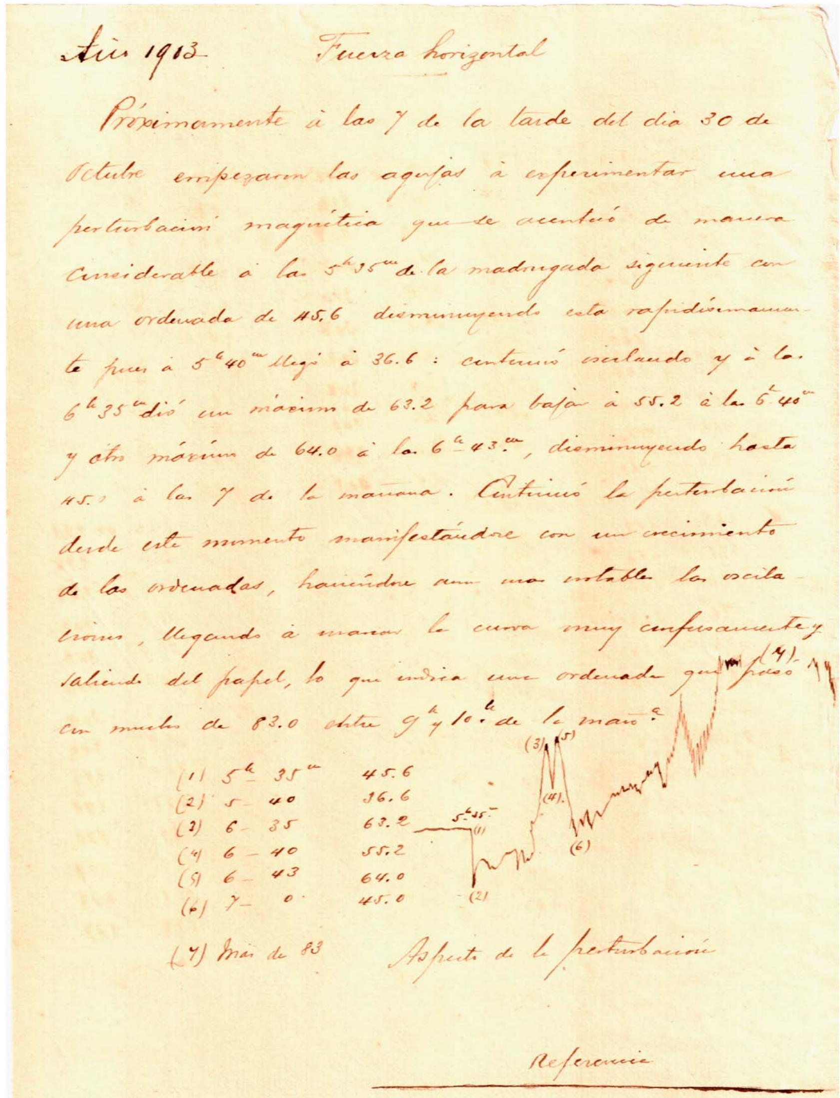
Año 1903 Fuerza horizontal

Próximamente á las 7 de la tarde del dia 30 de Octubre empezaron las agujas á experimentar una perturbación magnética que se acentuó de manera considerable á las 5h 35m de la madrugada siguiente con una ordenada de 45.6 disminuyendo esta rapidísimamente pues á 5h 40m llegó á 36.6: continuó oscilando y á las 6h 35m dió un máximo de 63.2 para bajar á 55.2 á las 6h 40m y otro máximo de 64.0 á las 6h 43m, disminuyendo hasta 45.0 á las 7 de la mañana. Continuó la perturbación desde este momento manifestándose con un crecimiento de las ordenadas, haciéndose aun más notables las oscilaciones, llegando á marcar la curva muy confusamente y saliendo del papel, lo que indica una ordenada que pasó (7) con mucho de 83.0 entre 9h y 10h de la mañana.

(1)	5h 35m	45.6
(2)	5 – 40	36.6
(3)	6 – 35	63.2
(4)	6 – 40	55.2
(5)	6 – 43	64.0
(6)	7 – 0	45.0

(7) Más de 83

Figure 3. Handwritten notes on the early stages of the storm of 31 October 1903 from the SFS observatory (geomagnetic coordinates, 1900: 40.8°N, 70.9°E). Translation from Spanish into English: "Horizontal Force—Near 19 h00 on 30 October (1903), the needles began to experience a magnetic disturbance, which increased substantially by the next morning at 5 h35, when it reached an amplitude value of 45.6 (arbitrary units); having however decreased rapidly to 36.6 at 5 h40; having kept its oscillating movement, it reached a maximum of 63.2 at 6 h35, to lower again to 55.2 at 6 h40, and a new high of 64.0 at 6 h43, then decreasing to 45.0 by 7 h00. From this point, the magnetic disturbance continued to show increasing values, and the most notable fluctuations, making the curve's registration difficult and confusing, which ended by leaving the paper (out of scale), indicating a value that surpassed clearly 83.0 between 9 h and 10 h in the morning."

continuous currents along practically all the lines that start from the Madrid's central station (Figure 1). The maximum intensity of telegraph disturbances occurred between 12 h30 and 15 h00 (roughly corresponding to the period of larger deviations of magnetic needles during the storm's main phase). Nonetheless, during the first hours of the evening and even late at night (already during the storm's recovery phase) the continuous currents were still recorded for periods of several minutes in some of the wires (i.e., Vigo, Bilbao). Moreover, the disturbances were felt differently across the telegraphic network and diverse impacts were described and shown to be dependent on the large-scale orientation of the wires: with the N-S running lines being the most affected. In fact, even for the same region, lines of same length but running approximately E-W, e.g., Málaga to Almería, did not show any effects or critical disturbances, while the nearby S-N oriented line from Málaga to Granada, the perturbation noticed was much stronger (Figure 1).

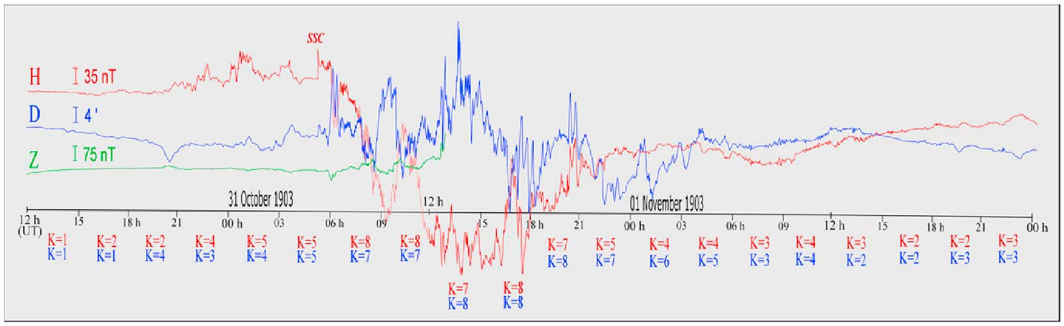

Figure 4. Magnetic variations digitized from the original magnetograms recorded in Coimbra during the great storm of 31 October 1903 and the 3-hourly local geomagnetic *K* indices (hand scaled) for *H* and *D*.

Besides the reported perturbations observed on the continental telegraphic lines, serious problems were also reported for various submarine cables and in the words of *Arcimis* [1903]: "*At 3 h. 20 m* [1 November] *the cable from Cádiz to Tenerife in the Canary Islands remained perturbed so strongly that the clerks made the contact with the earth to avoid the discharges*". Also of noteworthy is the reference made by *Arcimis* [1903] to the disturbances observed on the equatorial submarine cable connecting Senegal (18.4°N, Geomag. Lat. to 1900) to the Noronha Island (0.34°N, Geomag. Lat. to 1900, close to Brazil northeastern coast), which confirms the storm's severity.

Regional Geomagnetic Data

In order to put the reported disturbances into a regional geomagnetic context we provide measurements of the concurrent geomagnetic field that are available from the Iberian observatories. In the early twentieth century there were two operating geomagnetic observatories in the Iberian Peninsula (Figure 1): Coimbra (Portugal) and San Fernando (Spain). The magnetic observatory of Coimbra (COI; 40.2°N, 351.6°E) was installed in 1864, while San Fernando (SFS; 36.5°N, 353.8°E) was mounted about two decades later (1887). By the year of 1903, both observatories were still equipped with the same set of instruments of absolute observation and continuous recording. However, as magnetographs of both observatories were possibly operating with different scales, it was only possible to recover the original records from COI (Figure 2); in SFS the magnetic record went off-scale. Nevertheless, the handwritten notes on the early stages of the storm were also found (Figure 3).

The COI magnetograms (Figure 4) show that the storm was preceded by a bay-like disturbance on D and a small increase of *H* accompanied by fast oscillations around 20 h30 on 30 October. The main shock occurred ~10 h later, when around 05 h30 (31 October) a strong storm sudden commencement (SSC) was recorded; the large amplitude (~70 nT) of this rapid movement for *H* makes this SSC one of the strongest ever recorded in Coimbra. The storm's main phase, with a *H* maximum range of ~500 nT, started approximately 1 h later and lasted for almost 10 h, suggesting that the interplanetary magnetic field was strongly southward for long time.

Concluding Remarks

Unlike most other great geomagnetic storms that tend to occur around the solar maximum (or during the declining phase), the storm of 31 October 1903 occurred very shortly after the beginning of solar cycle 14 (the lowest since the *Dalton Minimum*). In addition, the years around solar minimum (1901–1902) were characterized by one of the lowest levels of geomagnetic activity (as recorded by the *aa indices*) since 1868 [*Hathaway*, 2015]. Nonetheless, it was under this period of faint solar activity that the severe geomagnetic storm of 31 October 1903 was produced, emphasizing that significant space weather activity can occur during any cycle and at any time within the cycle [*Bell et al.*, 1997; *Le et al.*, 2013].

This short memory also shows that under certain geomagnetic conditions large GIC can occur in southern European countries. Besides its overall large intensity (ΔH ~500 nT), the storm of 31 October 1903 was characterized by rapid and extreme magnetic fluctuations (strong dB/dt) over a long period of time (resulting in an exceptional long sequence of very high *K* indices, Figure 4), which most likely contributed to the induced currents and the observed prolonged disturbances in the midlatitude Iberian countries.

In this context, this assessment aims to emphasize that the study of historic space weather events (such as the 31 October 1903) is of utmost importance to evaluate the likelihood of occurrence of similar events in the future and in this way to obtain added understanding of the inherent risks.

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References

Arcimis, A. (1903), Telegraphic disturbances in Spain on October 31, *Nature*, *69*(1776), 29, doi:10.1038/069029b0.

Bauer, L. A. (1904), Magnetic storm of October 31-November 1, 1903, recorded at the coast and geodetic survey magnetic observatories, *Terr. Magn. Atmos. Electr.*, *9*(1), 25–27, doi:10.1029/TE009i001p00025.

Bell, J. T., M. S. Gussenhoven, and E. G. Mullen (1997), Super storms, *J. Geophys. Res.*, *102*(A7), 14,189–14,198, doi:10.1029/96JA03759.

Chaves, F. A. (1904), Record of the great magnetic storm of October 31, 1903, at Ponta Delgada, Azores, *Terr. Magn. Atmos. Electr.*, *9*(1), 29–33, doi:10.1029/TE009i001p00029-02.

Hathaway, D. H. (2015), The solar cycle, *Living Rev. Solar Phys.*, *12*, 4, doi:10.1007/lrsp-2015-4.

Lakhina, G. S., and B. T. Tsurutani (2016), Geomagnetic storms: Historical perspective to modern view, *Geosci. Lett.*, *3*, 5, doi:10.1186/s40562-016-0037-4.

Le, G.-M., Z.-Y. Cai, H.-N. Wang, Z.-Q. Yin, and P. Li (2013), Solar cycle distribution of major geomagnetic storms, *Res. Astron. Astrophys.*, *13*, 739–748, doi:10.1088/1674-4527/13/6/013.

Okada, T. (1904), Magnetic storm of October 31-November 1, 1903, in Japan, *Terr. Magn. Atmos. Electr.*, *9*(1), 33, doi:10.1029/TE009i001p00033.

Ribeiro, P., J. M. Vaquero, and R. M. Trigo (2011), Geomagnetic records of Carrington's storm from Guatemala, *J. Atmos. Sol. Terr. Phys.*, *73*, 308–315, doi:10.1016/j.jastp.2009.12.017.

Rudzki, M. P. (1904), La grande perturbation magnétique du 31/x/1903 á Cracoire, *Terr. Magn. Atmos. Electr.*, *9*(1), 28, doi:10.1029/TE009i001p00028.

Silverman, S. M. (2006), Comparison of the aurora of September 1/2, 1859 with other great auroras, *Adv. Space Res.*, *38*, 136–144, doi:10.1016/j.asr.2005.03.157.

Vaquero, J. M., M. A. Valente, R. M. Trigo, P. Ribeiro, and M. C. Gallego (2008), The 1870 space weather event: Geomagnetic and auroral records, *J. Geophys. Res.*, *113*, A08230, doi:10.1029/2007JA012943.

Viljanen, A., R. Pirjola, E. Prácser, J. Katkalov, and M. Wik (2014), Geomagnetically induced currents in Europe, *J. Space Weather Space Clim.*, *4*, A09, doi:10.1051/swsc/2014006.

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