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Ionospheric evidence of the May 1960 earthquake over Concepción?

A. J. Foppiano[1*], E. M. Ovalle[1], K. Bataille[1] and M. Stepanova[2]
[1]*Universidad de Concepción, Concepción, Chile*
[2]*Universidad de Santiago de Chile, Santiago, Chile*

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Resumen

Por muchos años se ha estudiado la relación entre actividad sísmica y cambios ionosféricos asociados. En particular, se ha considerado como una meta específica la posibilidad de identificar precursores ionosféricos por su eventual valioso uso práctico. En este artículo se analiza primero las observaciones de la foF2 hechas sobre Concepción (36.8°S; 73.0°W), antes de los dos grandes terremotos de Chile del 21 y 22 de mayo de 1960, usando el mismo procedimiento de Chuo *et al*. (2002) para el terremoto de Taiwan de septiembre de 1999. Luego, se muestra el resultado de analizar los valores de la foF2 de dos maneras diferentes, esto es, usando variaciones diarias de referencia calculadas directamente para días geomagnéticamente quietos, y usando un modelo de las dependencias conocidas de la foF2 con la actividad solar y geomagnética para Concepción (Arriagada y Foppiano, 1999). Se muestra que las conclusiones sobre precursores ionosféricos dependen del análisis de los valores observados de la foF2 que se use.

Palabras clave: foF2, ionosfera, precursores ionosféricos, Chile.

Abstract

For many years relations between seismic activity and associated ionospheric changes have been studied. Particularly, the possibility to identify ionospheric precursors of large earthquakes has been regarded as a specific goal for eventual obvious very valuable practical use. This paper first analyses foF2 observations over Concepción (36.8°S; 73.0°W) prior to the two very large Chile earthquakes of 21 and 22 May 1960, using the same procedure of Chuo *et al*. (2002) for the September 1999 Taiwan earthquake. Then it reports results from processing foF2 values in two different ways, namely, using direct estimations of reference geomagnetic quiet-day diurnal variation of foF2 and using an empirical model that filters known dependencies of foF2 on solar and geomagnetic activities for Concepción (Arriagada and Foppiano, 1999). It is shown that different analyses of observed foF2 values lead to different conclusions regarding possible ionospheric precursors.

Key words: foF2, ionosphere, earthquake precursor, Chile.

Introduction

For over the last half a century many attempts have been made to identify ionospheric precursors of strong earthquakes, and in most cases, some ionospheric variability relative to a sort of reference, observed for hours to days before the earthquake is suggested as an ionospheric precursor (for a review see Pulinets and Boyarchuk, 2004). Moreover, there are also studies which put forward likely mechanisms to justify the association between observed precursor ionospheric variability and seismic activity occurring before strong earthquakes (e.g. Pulinets *et al*., 2003; Sorokin *et al*., 2003; Sukov *et al*., 2003). However, even today the possibility to identify ionospheric precursors is somewhat controversial (e.g. Rishbeth, 2006; Pulinets, 2007). One of the key points is whether it is possible to screen solar, geomagnetic and even tropospheric variability (Mendillo *et al*., 2002) from the observed ionospheric variability so as to identify likely precursor ionospheric signatures. Obviously, the eventual confirmation of the existence of ionospheric precursors and the development of techniques to use them would have a very valuable practical use. The purpose of this paper is only to show that different analyses of observed values of a given ionospheric characteristic may lead to different conclusions regarding possible ionospheric precursors.

Data analisis

This paper analyses values of the F-region maximum electron concentration (as measured by F-region critical frequency, foF2) observed every 15 minutes at Concepción (36.8°S; 73.0°W), during every day in May 1960, prior and after the two very large earthquakes of 21 and 22 May 1960. The earthquakes (Mw = 9.5 and 9.3 respectively) are thrust events occurring at a well defined subduction zones, where the Nazca plate subducts at a rate of 80 mm/yr underneath the South American plate (Barrientos and Ward 1990). Most of the fault plane reaches the surface beneath the ocean at several km depth. To determine whether the observed values show any signature which

could be interpreted as ionospheric earthquake precursor reference diurnal variations are first derived and then observed values are compared with this reference. Three different ways to derive diurnal references are used.

15-day running means reference

The same statistical procedure used by Chuo *et al.* (2002) in the case of the Chi-Chi earthquake is first used. In this case, reference diurnal variations of foF2 are determined using running mean value for last 15 days for a given local time, plus and minus the standard deviation. Comparison of observed foF2 and references for some days before and after both earthquakes are shown in Fig. 1.

Geomagnetic quiet-day reference

Reference diurnal variation of foF2 using values for geomagnetic quiet days of May 1960 (4, 18, 19 and 20) plus 3 point smoothing are the derived. Comparison of observed foF2 and reference are shown in Fig. 2, top panel.

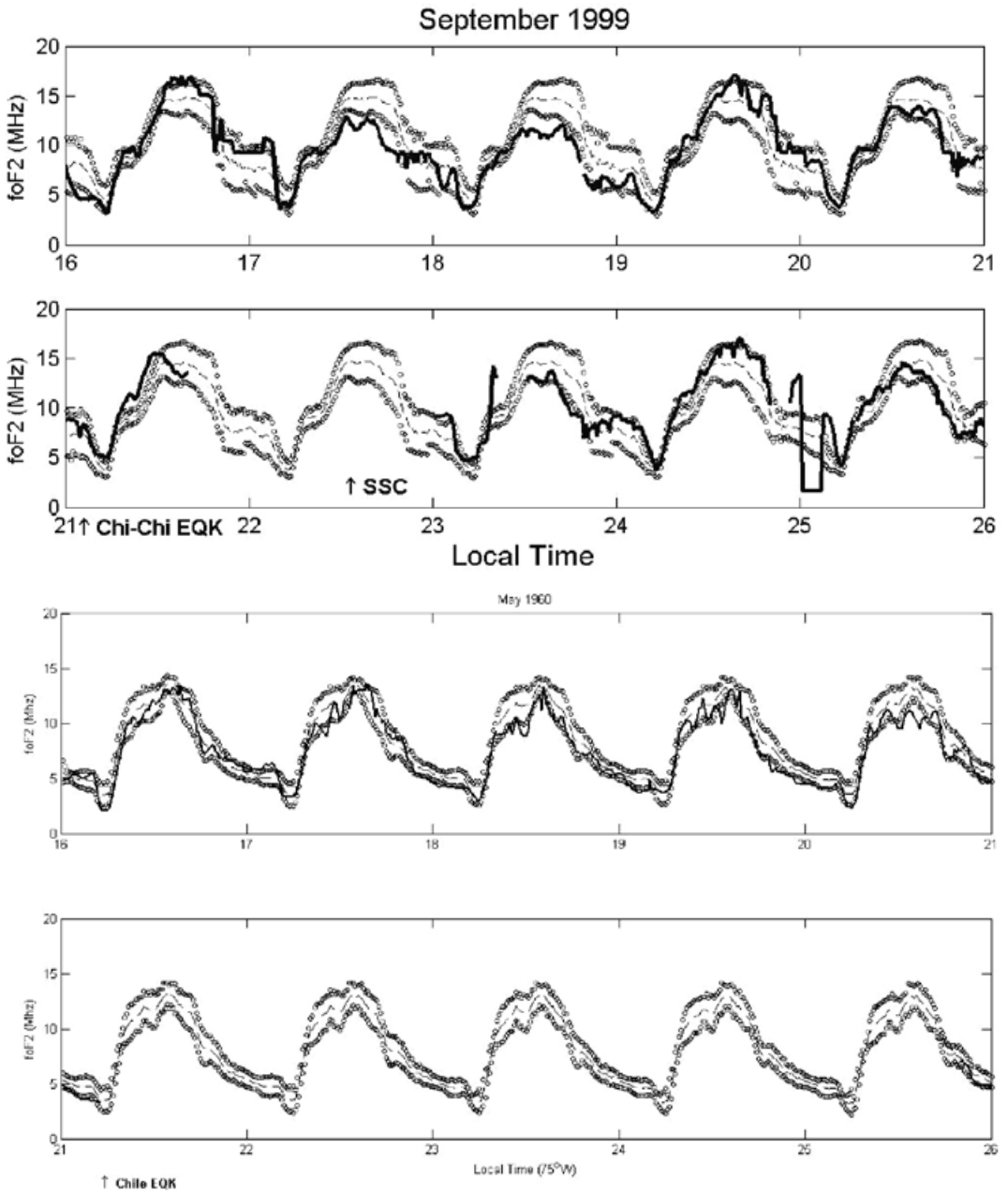

Fig. 1. Running mean foF2 for previous 15 days (dashed line), plus (open circles-upper line) and minus (open circles-low line) the standard deviation, and observed foF2 (full line). Taiwan earthquake (top panel). Concepción earthquake (bottom panel).

Solar and geomagnetic dependencies reference

Finally, references are derived by using results from a previous analysis of the observed dependencies of foF2 on F10.7 and on Ap for the interval March 1958 to 31 October 1968 (procedure of Wreen *et al*, 1987, used by Arriagada y Foppiano, 1999). In this case, hourly values were binned according to four levels of F10.7 and five levels of three-hourly Ap index. Empirical dependencies of foF2 on F10.7 and on Ap are then determined. This leads to the calculation of a reference foF2 for every hour of the interval which incorporates solar activity fluctuations on a daily scale and geomagnetic activity on a three hourly scale. The reference diurnal variations are determined as the maximum and minimum values for a given hour using values for all days of May. Comparison of observed foF2 and reference are shown in Fig. 2, bottom panel.

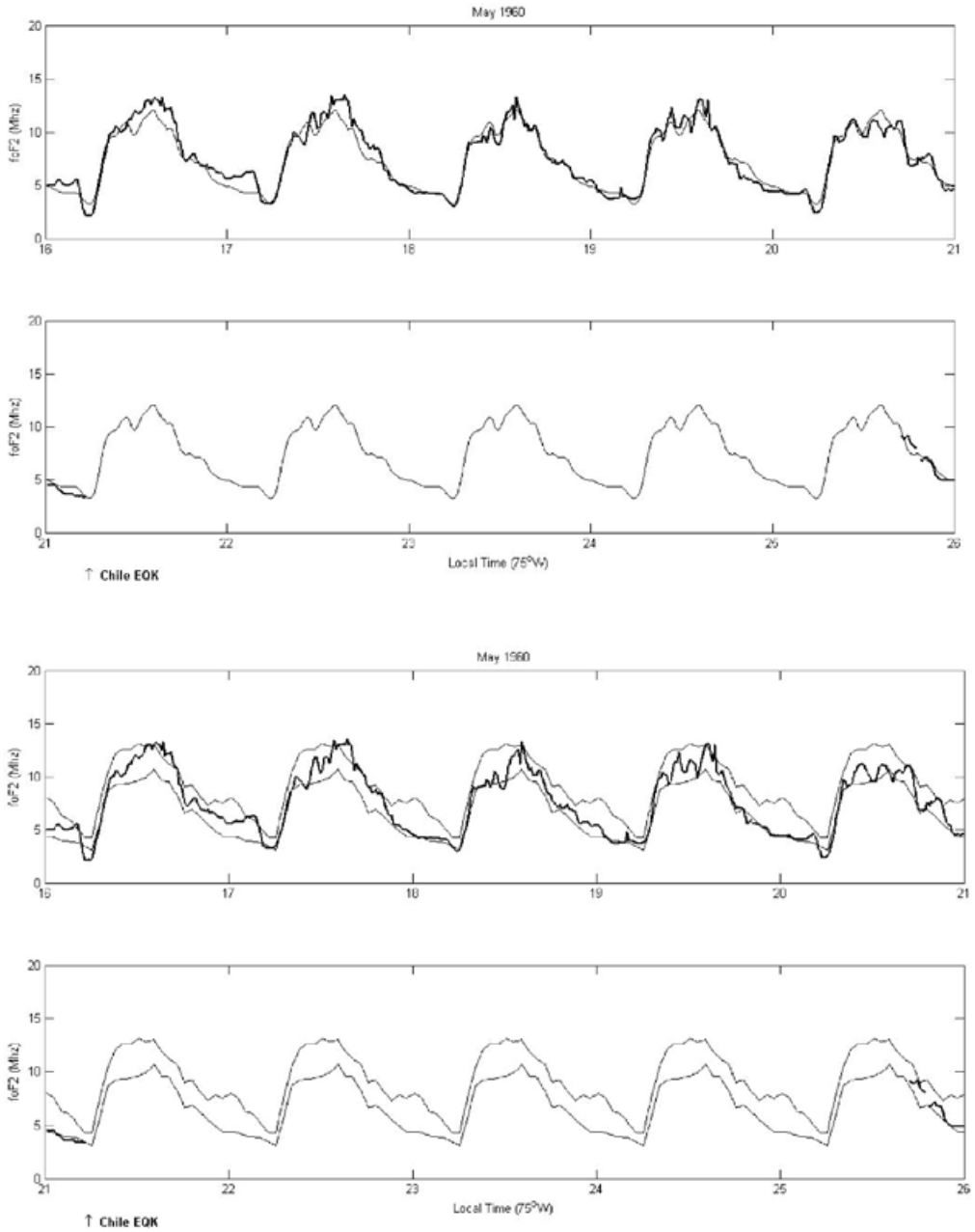

Fig. 2. Top panel. Reference foF2 for geomagnetic quiet days of May 1960 (4, 18, 19 and 20) plus 3 point smoothing (thin line) and observed foF2 (thick line). Bottom panel. Reference foF2 incorporating solar activity fluctuations on a daily scale and geomagnetic activity on a three hourly scale – see text. Upper and lower limits for each day (thin line) and observed foF2 (thick line).

Results

Fig. 1 indicates that foF2 values for 20 May are at and slightly below the running mean minus the standard deviation for a few hours. This could be interpreted as the ionospheric precursor suggested by Chuo *et al*. (2002) for days 17 and 18 September in the case of the Chi-Chi earthquake as shown also in Fig. 1 (copy supplied by Yu-Jung Chuo, private communication). The same could be said from Fig. 2, top panel. However, in this case no indication of the variability above or below the reference can be given. The variability can be assessed from Fig. 2, bottom panel. Here, foF2 values for day 20 are well within the expected variability which takes into account known dependencies of foF2 on solar (daily) and geomagnetic (three hourly) activities.

The rather regular oscillation of Concepción foF2 with a period of about 3 hours observed during several hours around noon on day 20 are most likely associated to travelling ionospheric disturbances. Furthermore, a very large change in surface pressure observed between 17 and 20 May, associated to the passing of deep synoptic scale low, should be also considered.

Conclusions

The different statistical analyses used for the same ionospheric characteristic, foF2, lead to different conclusions as regards the identification of precursors for the Chile May 1960 earthquakes.

Although the Taiwan and Chile earthquakes considered here are different in some respects (depth, fault plane intersection with surface), this should be of no concern. For earthquakes differences, contingency tables should be used as suggested by Rishbeth (2006).

Recent analyses of foF2 observed in Bombay for several earthquakes in Asia (Babas *et al*., 2007) shows that foF2 increases and decreases prior to earthquakes in about the same number of cases.

Acknowledgements

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A. J. Foppiano[1*], E. M. Ovalle[1], K. Bataille[1] and M. Stepanova[2]
1Universidad de Concepción, Casilla 160-C, Concepción, Chile
2Universidad de Santiago de Chile, Casilla 307, Santiago, Chile
E-mail:
**Corresponding author: foppiano@udec.cl*