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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Atmospheric and ionospheric coupling phenomena related to large earthquakes" *by* M. Parrot et al.

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We thank the referee for his comments. Answers are given below separated by ——. Corrections in the revised version of the paper are in red (see the supplement).

The manuscript submitted by Parrot et al. addresses an important topic, and clearly is the result of a lot of work, analyzing a broad range of different data. It is hard for me to evaluate it since it is outside my main fields of interests, but I believe that some criticism can be made without addressing the technical details. In general, it seems to me that this study suffers from a lack of statistics-based quantification of the "significance" of the "anomalies" that are discussed. In some cases, I frankly do not see anything anomalous in graphs that the authors claim to show significant changes in some observables. This is the case, for example, of Figs. 2 and 3 and other analogous plots. In

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some other figures, differences can be seen visually, but there is nothing indicating that they should be considered "significant"–at least for a non-specialist as I am. ———————————————— ANSWER: Sorry for the confusion. This is because that we try to keep the paper concise, and simply refer "for more details see Liu et al. (2011)" in the manuscript. In fact, the "anomaly" and "significance" are rigorously defined. Regarding Fig. 2 and its analogous plots, we have following criteria. To detect anomalous signals of the GPS TEC variations, a quartile-based process is performed. At each time point, we compute the median M of every successive 15-day of the GPS TEC as well as find the deviation between the observed one on the 16th day and the computed median M. To provide the information about the deviation, we also calculate the first (or lower) and the third (or upper) quartiles, denoted by LQ and UQ, respectively. Note that assuming a normal distribution with mean m and standard deviation σ for the GPS TEC, the expected values of LQ and UQ should be m-0.67σ and m+0.67σ, respectively [Klotz and Johnson, 1983]. To have a stringent criterion, we set the lower bound, LB = M $-$ 1.5(M $-$ LQ) and upper bound, UB = M + 1.5(UQ $-$ M). Therefore, the probability of a new GPS TEC in the interval (LB, UB) is approximately 68%. The median together with the associated LB and UB then provide references for the GPS TEC variations on the 16th day. When an observed GPS TEC on the 16th day is not in the associated (LB, UB), we declare an upper (increase) or lower (decrease) abnormal GPS TEC signal. Since the GPS TEC time resolution is 2-hour, there are 12 data points per day. If more than one third (4/12) of the upper or lower abnormal signals successively appear in one day, and the observed GPS TEC is greater or smaller than the associated UB or LB, we then consider the upper or lower anomalous (positive or negative precursor) day being detected. The probability of having a daily anomaly by observing four or more signals (negative or positive) is about 0.22, that of the successively appearing anomalies should be even less. Regarding Fig. 3 and its analogous plots, the top and lower panels are the GIM TEC and associated variation normalized by the standard deviation, respectively. The anomalies and statistical significance are defined by the associated "the standard deviation". Note that the anomalies and the significance in

Figs. 2 and 3 and their analogous plots are rigorously defined by the median and mean bases, respectively.

Regarding the fact that the paper can be read by scientists not really aware of our previous works we have decided to introduce in the paper a large part of the text written above for easiness. ———————————— Take for example Fig. 4: we are shown three curves, each recorded on a different day. We are told that one curve represents "undisturbed conditions", and the other two, recorded on two consecutive days, are characterized by an "anomaly". But why should we call it an "anomaly"? What are the typical differences between observations of this kind that are made in the absence of large seismic events? Or does the "GPS TEC" indeed follow precisely the green curve on any day except for 4 and 5 days before the earthquake in question? ———————————— ANSWER: One of the most spectacular features in the ionosphere is equatorial ionization anomaly (EIA). The EIA is characterized by two enhanced plasma (or electron density, TEC, etc.) crests at low latitudes straddling the magnetic equator with the electron density depleted on the magnetic equator. It is the region that yields the greatest electron density in globe. The EIA is produced by the equatorial plasma fountain, which lifts the plasma from magnetic equator to higher altitudes and then it diffuses down along magnetic field lines to higher latitudes creating two ionization crests on both sides of the magnetic equator (Namba and Maeda, 1939; Appleton, 1946; Duncan, 1960; Hanson and Moffett, 1966; Anderson, 1973; Balan and Bailey, 1995; Rishbeth, 2000; Lin et al., 2007). Thus, the EIA is a daily normal feature (for example, red and pink curves in Figs 4 and 8), which reveals that two GPS TEC enhancements (peaks) at low latitudes straddling the magnetic equator with the depletion on the magnetic equator. By contract, green curves in Figs. 4 and 8 show no peaks at low latitudes, which means the EIA disappearing.

Namba, S., and K.-I. Maeda (1939), Radio Wave Propagation, 86 pp., Corona, Tokyo. Appleton, E. V. (1946), Two anomalies in the ionosphere, Nature, 157, 691. Duncan, R. A. (1960), The equatorial F region of the ionosphere, J. Atmos. Terr. Phys., 18,

89 – 100. Hanson, W. B., and R. J. Moffett (1966), Ionization transport effects in the equatorial F region, J. Geophys. Res., 71(23), 5559 – 5572. Anderson, D. N. (1973), A theoretical study of the ionospheric F-region equatorial anomaly. I: Theory, Planet. Space Sci., 21, 409 – 419. Balan, N., and G. J. Bailey (1995), Equatorial plasma fountain and its effects: Possibility of an additional layer, J. Geophys. Res., 100(A11), 21,421 – 21,432. Rishbeth, H. (2000), The equatorial F-layer: Progress and puzzles, Ann. Geophys., 18, 730 – 739. Lin, C. H., J. Y. Liu, T. W. Fang, P. Y. Chang, H. F. Tsai, C. H. Chen, and C. C. Hsiao, Motions of the equatorial ionization anomaly crests imaged by FORMOSAT-3/COSMIC, Geophys. Res. Lett., 34 , L19101, 10.1029/2007GL030741, 2007.

A part of the text above is now in the paper. ———————————————————— Another example is, to me, Fig. 16, where we are shown the behaviour of electron density during a month and a half, around the time of a seismic event. The curve shows a peak about a month before the event, but how does it look like over the rest of the year? and how do similar data look like in other areas, in the absence of seismic events? I am not saying that there is no relationship between this observable and the seismic event, but, rather, that this curve and the authors' discussion of it are not a convincing indication of such a relationship. Somewhat more convincing, or at least more suggestive, are Figs. 17 and 25. In both cases, "outgoing longwave radiation" is shown over one entire year, and the largest peak in its "anomalies" happens shortly before the large earthquake under consideration. I, however, did not understand what the authors mean by "average", "daily values" and "anomalies", i.e. what the difference between the three curves shown in these figures is. As a result, I do not really know what to make of these figures. Also, the red curves show many other peaks: is there a statistically significant correlation between these and seismicity? ——————————————— ANSWER: Concerning Figure 16, an introduction is now done about the fact that previous statistical analyses have shown a variation of the electron density before EQs. Figure 16 is just related to the event studied in the paper. ———————————————- Finally, the paper is written in clear English, but contains many typos ("witch" for "which", "reviled" for "revealed") and some non-quite-English phrasing. The Figures are small and hard to read, at least in the pdf file I have downloaded. Often colorscales and axis labels are given withouth specifying the units of measurement. All this does not help the reader. ———————————————————— ANSWER: We have corrected some errors. ———————————————————— In summary, I think that this is an interesting paper, but needs at least a very thorough revision. I am not quite sure what the benefit of such a contribution would be in the absence of a quantiative (statistics?) evaluation of the "significance" of the observed anomalies. To be honest, I am hesitating between recommending rejection and major revision, and I am opting for the latter on account of my lack of specific competence in this field.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2016-172/nhess-2016-172-AC1-supplement.pdf

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