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Interactive comment on "Ionospheric total electron content anomaly possibly associated with the April 4, 2010 Mw7.2 Mexico earthquake" *by* Jing Liu et al.

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1. The paper of Liu et al. creates very strange impression starting from the item selected and finishing by used methodology of data processing. So, let's start from the very beginning. Why in year 2020 was selected earthquake which took place 10 years ago and which was studies by other scientists: Mustafa Ulukavak Mualla Yalcinkaya (2017) Precursor analysis of ionospheric GPSTEC variations before the 2010 M7.2 Baja California earthquake, Geomatics, Natural Hazards and Risk, 8:2, 295-308, DOI: 10.1080/19475705.2016.1208684 Y. B. Yao, P. Chen, S. Zhang, J. J. Chen, F. Yan, and W. F. Peng, Analysis of preearthquake ionospheric anomalies before the global

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M = 7.0+ earthquakes in 2010. Actually, the case studies can be accepted now if something exclusive was detected or some original technology was applied. So let us consider what kind technologies of data processing and methodology of precursor identification were applied.

A: There are two reasons that we selected 2010 Mw7.2 Mexico earthquake to carry out this study. Firstly, in Fig. 1, it shows that there are more MIT TEC data in the North America region that makes it possible to determine unambiguously the potential earth quake signal in TEC and its regional distribution. Secondly, the seismo-ionospheric disturbances are likely related to the depth and magnitude of the earthquake (Le et al., 2011; Liu et al., 2014), therefore, the shallowest ones with M$\geq$7.0 (shown in Table of Fig. 2) are selected in most studies (from 2000 to 2017). The 2010 Mw7.2 Mexico earthquake is thus a very suitable one for our study.

For the same earthquake event, new datasets and new analysis methods can be employed to obtain new results or insight. We believe that our paper is totally different from the early paper of Ulukavak Yalcinkaya (2017) in dataset (although both used TEC), analysis method, and results. In fact, a thorough examination of an event using different datasets and methods produce a more complete description of the events and gain new physical insight. Taking 2011 Tohoku-Oki Mw 9.0 earthquake as an example, many researchers have studied the seismo-ionospheric anomalies since its occurrence (Heki, 2011; Iwata and Umeno, 2016; Oyama et al., 2019). Specifically, Ulukavak and Yalcinkaya (2017) applied the time series method to analyze the original data of GPS TEC, while in our study, we use a new decomposition and nonlinear fitting method to extract possible ionospheric anomalies related to earthquakes. We obtain TEC residuals by removing the known and identified oscillations in the ionosphere TEC data. Since earthquakes are mostly single occurrence events at particular locations and times, these TEC residuals can manifest earthquake effects in the ionosphere better. Therefore, our method is completely different from that in Ulukavak and Yalcinkaya. Furthermore, we used physics-based whole atmosphere model simulations to demon-

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strate that the anomaly seen in TEC data is unlikely originated from lower atmospheric wave perturbations, which is definitely new and not in their paper either. We will cite this paper in the revised text and describe the differences between their method/results and ours.

2. The only unique in the paper is the use of MIT TEC maps. Authors consider these maps probably as advantage because of “The advantage of MIT TEC is that it is strictly data driven with no underlying models that smooth out the real gradients in the TEC” in addition the maps have the higher temporal (5 min) and spatial (1ïC′ ËĞrx1ïC′ ËĞr) resolution in comparison with GIM TEC maps (IONEX). And here immediately some comments appear. Use of such kind of maps is possible if you have the distance between GPS receivers of order 100 km or less between them, so for such areas as oceans or Africa for example, such maps are not applicable. The linear regression without models is possible only if you have uniform distribution of receivers, otherwise you should use some interpolation procedures as Kriging, for example. So, the advantage of MIT TEC maps seems questionable.

A: The advantage of our research is not only the data source, but also the analysis method. The TEC residuals are applied to extract anomalies associated with earthquakes by using a new decomposition and nonlinear fitting method, which is described in detail in the manuscript.

It is true that there are almost no data in the oceans and Africa, as shown in the Fig.1. The vertical TEC data of the map are obtained from slant TEC data, hence the distance between two GPS receivers may be a little farther than 100 km. In the North America, the GPS stations are sufficiently dense to obtain high spatial resolution maps, which is also the main reason that we selected 2010 Mw7.2 Mexico earthquake to do this analysis. Furthermore, as shown in Fig. 3 this earthquake occurred on the land and we have sufficient data to carry out our analysis.

3. My most concern is the use by authors the 24-hours averaging. This procedure could

compared with calculating the average temperature of patients through the whole hospital. Ionospheric anomalies before earthquakes are transient phenomena and don't last through the whole day, So the average daily TEC is senseless. Such procedure may be applied probably with long lasting increase of F10.7 index, ore strong geomagnetic storm lasting several days, but not for ionospheric precursor's detection. Instead of use the mentioned by authors high temporal resolution of MIT TEC maps, they average them. In conclusion, I consider the obtained results questionable with application of not adequate technology of the precursor's identification and I'm forced do not recommend this paper for publication.

A: In this study, the TEC residuals are applied to extract anomalies possibly associated with the earthquake by using a new decomposition and nonlinear fitting method. The high temporal resolution data is useful for the fitting method and, in fact, is used in our study. In other words, we use both high temporal resolution data and daily average in our paper, as explained below. The more the data, the better the fitting results.

At the beginning, the time series of TEC residual (extracted by the analysis method), as exhibited in Fig. 2 of the manuscript, is not averaged. Under the quiet geomagnetic activity conditions, the TEC value exceeded the threshold just on March 25, and this anomaly lasted for almost the whole day. Liu et al. (2011) found that the anomalous enhancement before 2010 M7 Haiti earthquake was lasting for about 31 hours. Next, in order to see the distribution of the anomalies, the TEC map is analyzed using the mean value of the 24-hour data for each day. It is seen that the TEC depletion on March 25 is not just in the epicenter but also in the surrounding area (Fig. 3 of the manuscript). Then, by analyzing the data in a long period of time and SD-WACCM-X simulations, we conclude that the TEC anomaly on March 25 cannot be explained by lower atmosphere waves or geomagnetic activity forcing. Therefore, we suggest the unique TEC depletion on March 25 is potentially related to the Mw7.2 Mexico earthquake occurred on April 4, 2010. Therefore, we did consider the time variation of the TEC, not just daily mean. The daily mean used is purely for the illustration of spatial distribution and we cannot show

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a large amount of data with 5-minute cadence in the paper for the whole period. We will make this point clear in the next revised text. We apply our analysis method to extract the TEC disturbances and demonstrate that the TEC anomaly is possibly related to the Mexico earthquake. Therefore, our analysis method is new and the results of our study are important for the seismo-ionospheric research.

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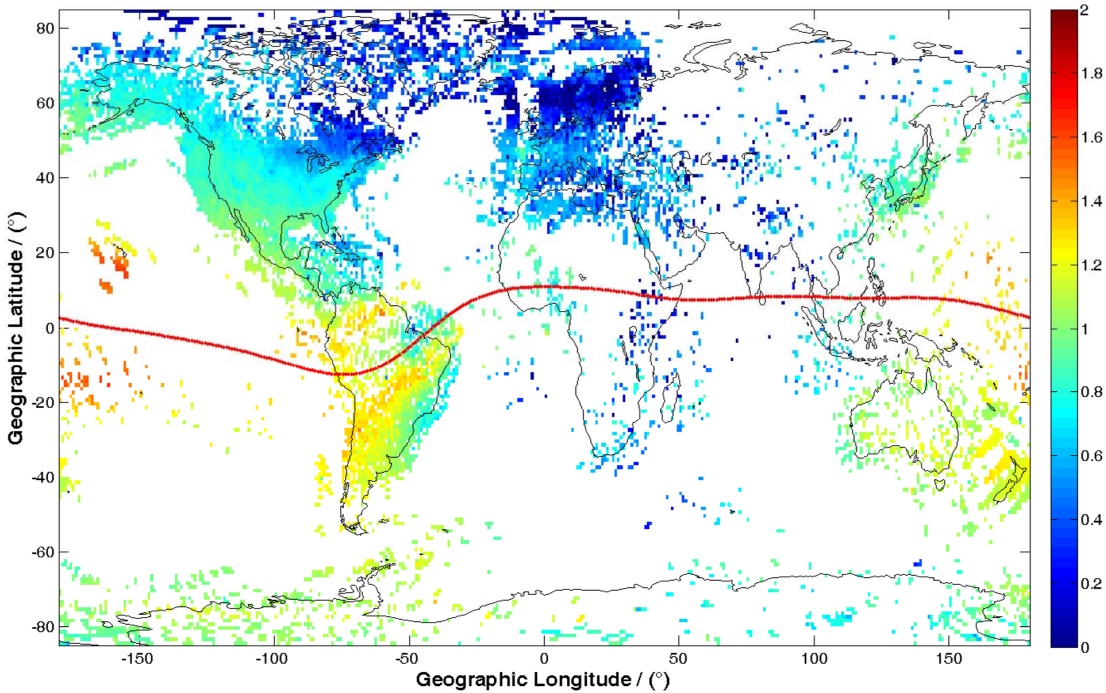

Fig. 1. The distribution map of MIT TEC data

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The list of $M \geqslant 7.0$ earthquakes from 2000 to 2017

Time	Latitude	Longitude	Depth (km)	Magnitude
2014-04-18T14:27:24.920Z	17.397	-100.972	24	7.2
2012-11-07T16:35:46.930Z	13.988	-91.895	24	7.4
2012-08-27T04:37:19.430Z	12.139	-88.59	28	7.3
2012-04-12T07:15:48.500Z	28.696	-113.104	13	7.0
2012-03-20T18:02:47.440Z	16.493	-98.231	20	7.4
2010-04-04T22:40:42.360Z	32.28617	-115.295	9.987	7.2
2010-01-12T21:53:10.060Z	18.443	-72.571	13	7.0
2009-05-28T08:24:46.560Z	16.731	-86.217	19	7.3
2005-06-15T02:50:54.190Z	41.292	-125.953	16	7.2
2003-01-22T02:06:34.610Z	18.77	-104.104	24	7.6

Fig. 2. The list of $M \geq 7.0$ earthquakes from 2000 to 2017

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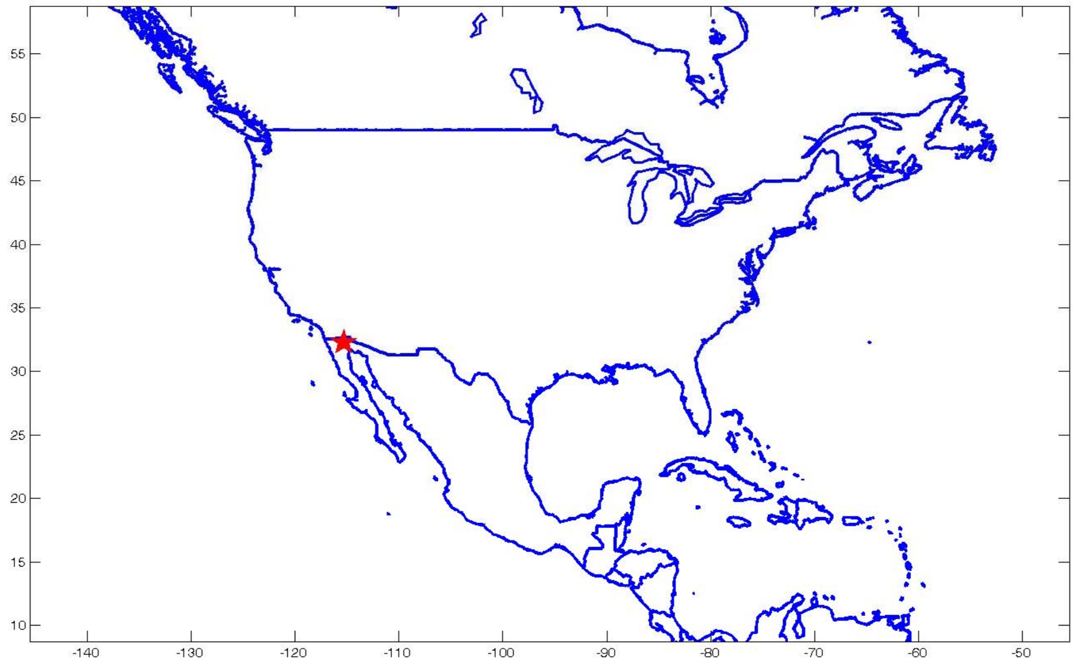

Fig. 3. The location of 2010 Mw7.2 Mexico earthquake

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