RC1: 'Comment on egusphere-2022-1089', Anonymous Referee #1, 03 Jan 2023

The paper contains a lot of valuable and high-quality science, which is suitable for publication. I enjoyed reading the material and found the subject matter very interesting. The paper, however, currently contains grammar errors, lacks proper citations, and several figures/captions are missing information. There is currently no mention or analysis of the reliability of the results- (no statistical significance or error analysis associated with the final results). Therefore, I recommend that the manuscript is revised before acceptance. I have made several additional notes as examples of some of the suggested edits in the attached PDF document. Overall, great paper.

Answer:

First of all, thank you for your valuable comments and corrections. We have applied the suggestions you did in the attached PDF and updated the missing information you mention. Following yours and other comments, the next version of the paper will provide a better analysis of the reliability of the results.

RC2: 'Comment on egusphere-2022-1089', Anonymous Referee #2, 06 Feb 2023:
The manuscript studies three methods for detecting seismic ionospheric disturbances and obtains some results. However, the manuscript lacks highlights, and the results and related discussions are not good.

1. There are few explanations related to S4. How to use GNSS or GNSS-RO to obtain S4? What is the specific response relationship between S4 and earthquake? None of the above issues were explained clearly.

2. The S4 results obtained by GNSS-RO have obvious anomalies before and after the earthquake. Are these anomalies caused by the earthquake or other reasons? Geomagnetic activity? Solar activity? In addition, do the results obtained by the other two methods also consider the causes of geomagnetic activity and solar activity? Relevant data are not analyzed in this paper.

3. What is the correlation coefficient R between the two variables? The correlation coefficient R is less than 0.1.The correlation is too weak and has no practical significance.

4. There is too little analysis of the results obtained by each method. It seems that it only describes the results without analyzing the physical mechanism behind them.

For the above reasons, I propose to reject this manuscript.

Answer for RC2: 'Comment on egusphere-2022-1089', Anonymous Referee #2, 06 Feb 2023

First of all, thank you for your detailed comments and suggestions. We detail our response and the changes performed in the following bullets:

1. In the case of GNSS-RO, S_4 is a parameter provided directly from Spire and Cosmic databases without any processing by our side except for the temporal and geographic matching. For the GNSS ground stations, we have extended the description of the method applied in the following version of the manuscript and cited the related bibliography [1-3].
The specific response of ionospheric scintillation (measured using the S_4 parameter) associated to earthquake activity is under study, and one of the goals of this work is to analyze the performance of S_4 as a possible earthquake indicator using 3 different techniques (GNSS ground stations, GNSS-R and GNSS-RO) linked to the very same event.

2. You are right that the S_4 anomalies can also be due to geomagnetic or solar activity. We have already performed a deeper analysis correlating S_4 with geomagnetic and solar activity, and we can say that for most cases, the correlation is smaller than that from earthquakes. Figure 1 shows the correlation already obtained in the manuscript, which contrasts with the two new correlations calculated for the planetary index (Figure 2), and the solar flux F10.7 (Figure 3). It is clear that GNSS-RO shows larger peaks of correlation with EQ than for Kp or F10.7, and that they appear mostly before the EQ occurrence. Also, GNSS-R peaks are a bit larger than the ones on the correlation with Kp. We will extend this analysis and its results in the following version of the manuscript.

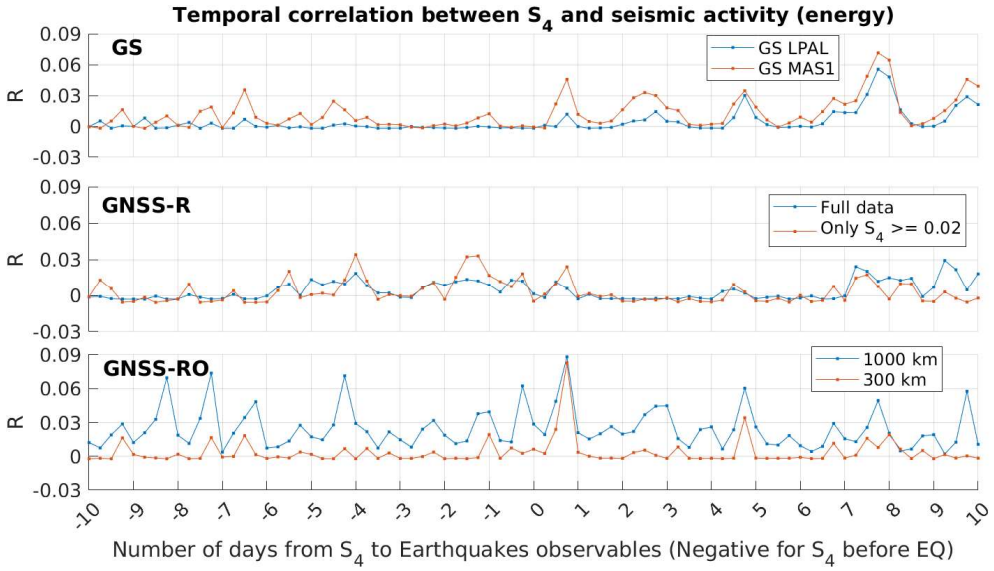

Figure 1. Temporal correlation of seismic activity with ionospheric scintillation. This is the same figure as shown in the first version of the manuscript.

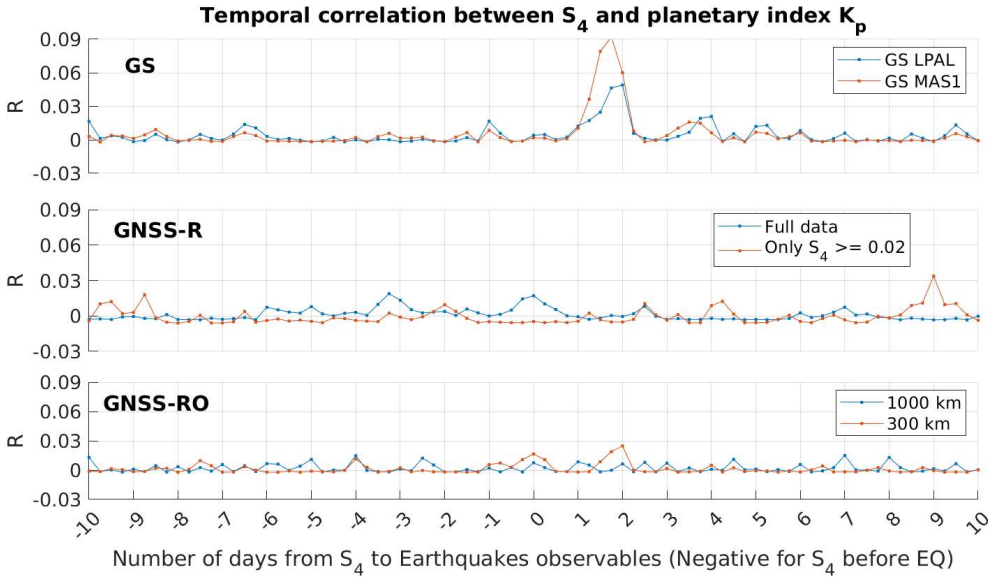

Figure 2. Temporal correlation of the planetary index with the ionospheric scintillation, showing a peak of a similar height than the ones for the seismic activity in the ground stations correlation. GNSS-R and GNSS-RO shoes very small or negligible correlations.

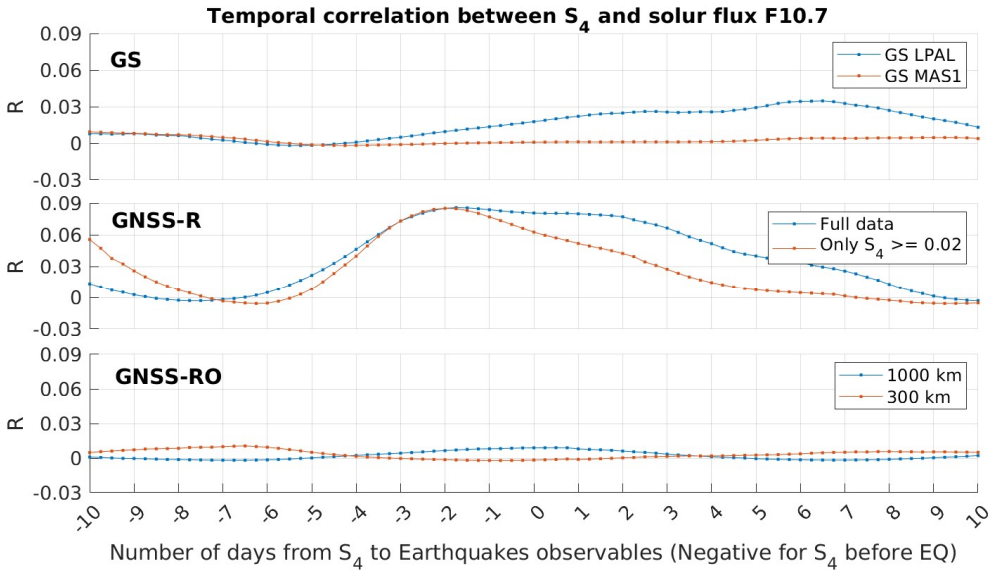

Figure 3. Temporal correlation of the solar flux F10.7 with the ionospheric scintillation. GNSS-R is showing a wide peak with a maximum of 0.09 correlation in the central days. Both GNSS-RO and GS are almost non-correlated for most of the time.

3. The correlation coefficient (R) is the linear regression when plotting points of EQ energy vs. S_4; further explanation will be included in the following paper's version. Yes, the correlation is small in this case, but so are the magnitudes of the earthquakes. Consequently, we will update the conclusions to remark that with the current event and its low magnitude, the correlation is almost undetectable for a practical use. As it has been said, the study's novelty is to use the three techniques in the same event.

4. This study aims to analyze the correlation between seismic activity and ionospheric scintillation, not the physical mechanism behind it, which is the matter of other works already cited in the bibliography, notably the link between the non-static electric field generated by the pressure between tectonic plates and the ionosphere.

[1] Juan JM, Aragon-Angel A, Sanz J, González-Casado G, Rovira-Garcia A (2017) "A method for scintillation characterization using geodetic receivers operating at 1 Hz" Journal of Geodesy

91(11):1383–1397. DOI 10.1007/s00190-017-1031-0

[2] Rovira-Garcia A, González-Casado G, Juan JM, Sanz J, Orús R (2020) "Climatology of High and Low Latitude Scintillation in the Last Solar Cycle by Means of the Geodetic Detrending Technique. Proceedings of the 2020 International Technical Meeting of The Institute of Navigation, San Diego, California, January 2020, pp. 920-933. DOI 10.33012/2020.17187.

[3] Juan JM, Sanz J, González-Casado G, Rovira-Garcia A, Camps A, Riba J, Barbosa J, Blanch E, Altadill D, Orus R (2018) "Feasibility of precise navigation in high and low latitude regions under scintillation conditions" Journal of Space Weather Space Climate 8:A05:1-11. DOI 10.1051/swsc/2017047