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Interactive comment on "Strong influence of solar X-ray flares on low-frequency electromagnetic signals in middle latitudes" *by* Alexandr Rozhnoi et al.

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We thank the Referee for his valuable comments which have been carefully taken into account in our revision. Below we provide answers to the specific queries raised by the Referee.

Several major comments are suggested as follows: 1. In section abstract. Line 6 in page 1: "It" was found that:

Done

2. In section 1. Line 7 in page 2: Recently, Li et al. (2019) studied the ionospheric

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response to solar flares based on medium frequency (MF) radar, and found that the electron density (Ne) and effective reflection height (H) had profound responses to solar flares. Liu et al. (2018) investigated the ionospheric D layer height fluctuations, during the solar flares, by analysing the VLF/LF waveforms emitted by lightning. It was found that the short-time fluctuations of D-layer height are linearly correlated to the flux density of solar radiations.

The information and references have been added to the paper.

3. In section 2, page 5: What is sampling rate of your VLF receiver? Is the receiver able to continuously record waveforms? The manuscript needs to do a better job of introducing your data.

Thank you for this remark. The information about our receivers has been added in Introduction.

4. In section 2. Line 8-12 in page 5: “The study of ionosphere: : :with navigation”. This paragraph seems to introduce the importance of investigating the ionospheric, so it is not suitable for the position in this section. It should be moved into the introduction.

Done

5. In section 2, page 6: State the reason why the amplitude anomaly for the path GBZ-BIR is negative shown in Figure 5.

It is well known fact that sometimes during solar X-ray flares the phases/amplitude of VLF/LF signals reflected from the ionosphere shows an opposite behavior, the so-called phase/amplitude antinomy (see e.g. Giovanni E. Perona, LF and VLF phase antinomies during solar X-ray flares, Radio Science, 10 (4), 435–444, 1975). Author has analysed two years of data and explains such behavior in terms of changes in the phase of the ionospheric reflection coefficient. We observed antinomy (or even more complicated behavior) of phase/amplitude anomalies during solar X-ray flares on very short paths where VLF signal propagation is structured with many propagating

modes, each of which has its own phase and amplitude, and the signal at any given location is the sum of those modes, unlike signal which propagates on long distances (far-field zone) where the only one mode is the principal. The distance between the GBZ transmitter and receiver at the Birr is only 350 km. It is near-field zone and in such short distance we can expect any behavior of the phase/amplitude of signal.

6. In section 2, page 6: Need to briefly mention how the effective reflection heights are calculated by the VLF/LF signals in manuscripts.

We added the formula.

7. In section 2.1, page 7: “Maxima for both X-ray and LF spectra are in the interval of 2-16 min”. It seems that interval between X-ray flares and LF spectra has correlation with the class of X-ray. Discuss it in this section.

We cannot discuss this fact because we calculated spectra only for class X of X-ray.

8. In section 2.2, page 8: “Response of the D region of the ionosphere to weak X-ray fluctuations during the recovery phase”. What is “weak”? Be more specific.

Done

9. In section 2.2, page 8. Need to discuss with previous work.

Done

10. In section 1, page 1. The effective reflection height would be different retrieved by different frequency signals. The Transmitter frequency varies from 19.5 kHz to 45.9 kHz shown in Table 1. It would be useful to compare the reflection height retrieved by different frequency signals.

Yes, such analysis would be interesting. However, for the reliability of result we need to have a transmitter which transmits several signals of different frequencies and these signals should propagate along the same path. In our case we have different transmitters which transmit signals propagating in different directions along path with different

length. Therefore the comparison would be incorrect.

Li N, Lei J, Luan X, et al. Responses of the D region ionosphere to solar flares revealed by MF radar measurements[J]. Journal of Atmospheric and Solar-Terrestrial Physics, 2019, 182: 211-216. Liu, F. F., Qin, Z. L., Zhu, B. Y., Ma, M., Chen, M., & Shen, P. (2018). Observations of ionospheric D layer fluctuations during sunrise and sunset by using time domain waveforms of lightning narrow bipolar events. Chinese Journal of Geophysics, 61 (2), 484 – 493. https://doi.org/10.6038 /cjg2018K0658.

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2019-53/angeo-2019-53-AC1-supplement.pdf

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