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Interactive comment on "Dynamic processes in the magnetic field and in the ionosphere during the 30 August–2 September, 2019 geospace storm" *by* Yiyang Luo et al.

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Dear Anonymous Referee #2,

Thank you very much for a comprehensive study of the text and your valuable recommendations.

With regard to your comments, we can reply the following.

Anonymous Referee #2 Comment #1: The paper by Luo et al. investigated the storm energy input and ionospheric storm effects during a storm event. They estimated the energy, power, magnetic ïňĄeld variation, F-region density decrease, E-region lifting,

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and density modulation. They interpreted that the density modulation is cause by atmospheric gravity waves.

Authors' response to Anonymous Referee #2 Comment #1: Indeed, the paper deals with a storm event.

Anonymous Referee #2 Comment #2: The paper presents interesting data but gives very little data interpretation. It is difïňĄcult for readers to ïňĄnd out what physical mechanisms contributed to create the ionospheric storm. Please extend the discussion of the key observation results of the ionospheric storm. The storm energy and magnetic ïňĄeld variation have already been studied in earlier works and I don't think that the present paper gives any new aspects of them. I suggest to remove them from the conclusion and focus on the ïňĄndings on the ionospheric storm.

Authors' response to Anonymous Referee #2 Comment #2: The information on the magnetic storm and its energy should not be removed from the paper for the following reasons. (1) In accordance with the aim of the study, the analysis has been undertaken of the dynamical processes that occurred in the course of the geospace storm, which is comprised of the magnetic, ionospheric, atmospheric, and electrical storms. (2) The magnetic storm in question was not yet described by anybody except for the authors of this paper. (3) Any two magnetic storms are not identical, and the estimation of the basic parameters of each new storm will ever remain a problem of current importance. For example, the basic parameters of every new earthquake, are also described for exactly the same reason. (See also the (4th) point in Authors' response to Anonymous Referee #2 Comment #3)

Anonymous Referee #2 Comment #3: Line 15-23 Basic properties of storms (energy, power, duration and magnetic ïňĄeld variations) are already documented more in details in existing papers (e.g., Gonzalez et al., 1994, Knipp et al., 1998, Feldstein et al., 2003). I don't think these are not unique features. These sentences should be removed and the abstract should focus on the ionospheric storm part.

5Authors' response to Anonymous Referee #2 Comment #3: Gonzalez et al. (1994) made an excellent review summarizing information on geomagnetic storms up to the early 1990s. From that time on, significant progress in understanding geomagnetic storms has been made. The authors have used a relation from the paper by Gonzalez et al. (1994) for estimating the magnetic storm energy and the power (see Section 7.1 Geomagnetic field effects, Line 404). Knipp and Emery (1998) described in detail the processes accompanying the November 2–11, 1993 geomagnetic storm. Feldstein et al. (2003) analyzed in detail the energy of the processes acting in the magnetosphere during two particular storms. In the Introduction, the following text has been added (Line 63–66):

In particular, Gonzalez et al. (1994) made an excellent review summarizing information on geomagnetic storms up to the early 1990s. Knipp and Emery (1998) described in detail the processes accompanying the November 2–11, 1993 geomagnetic storm. Feldstein et al. (2003) analyzed in detail the energy of the processes acting in the magnetosphere during two particular storms. In the Reference list, the following two references has been added: Feldstein, Y.I., Dremukhina, L.A., Levitin, A.E., Mall, U., Alexeev, I.I., and Kalegaev, V.V.: Energetics of the magnetosphere during the magnetic storm, J. Atmos. Terr. Phys., 65 (4), 429–446, ISSN 1364-6826, https://doi.org/10.1016/S1364-6826(02)00339-5, 2003.

Knipp, D.J. and Emery, B.A.: A report on the community study of the early November 1993 geomagnetic storm, Advances in Space Research, 22 (1), 41-54, , DOI: 10.1016/S0273-1177(97)01098-3,1998.

Since energy characteristics for various geomagnetic storms vary by orders of magnitude, the estimates of these characteristics should be made for each new storm. We have estimated the energy characteristics of the geospace storm, as well as of its constituent parts viz the magnetic storm and the ionospheric storm. (4) The energy estimates of geospace and magnetic storms, and the ionospheric storm index permitted us to establish the non-trivial fact that a weak geospace storm acted to give rise to a moderate magnetic storm and to a strong ionospheric storm. The establishment of this fact were impossible without the quantitative estimates. This fact has been described in the paragraph that has been added to the text at the end of Section 7.3.1 (Ionogram Parameter Disturbances): The estimate of the ionospheric storm index and of the energy of the geospace and magnetic storms have allowed us to establish that a weak geospace storm acted to give rise to a moderate magnetic storm and to a strong ionospheric storm, which is not as trivial as may be supposed. The establishment of this fact were impossible without the quantitative estimates.

Anonymous Referee #2 Comment #4: For the same reason, the title of the paper is not very informative. I suggest to remove the magnetic ïňĄeld and instead specify what dynamic processes are the major ïňĄnding of this paper.

Authors' response to Anonymous Referee #2 Comment #4: It does not seem to us that the paper title is not very informative. The paper deals with the manifestations of the magnetic and ionospheric storms that are integral parts of the geospace storm. The manifestations of the atmospheric and electrical storms are observed in the indirect features: (1) in quasi-periodic variations in the Doppler shift of frequency under the action of atmospheric gravity waves, and (2) in the vertical plasma drifts in the ionosphere under the action of the enhanced zonal electric field.

Anonymous Referee #2 Comment #5: The paper uses the network of radio wave observations but does not discuss how the ionospheric storm effects vary in latitude or longitude. What spatial dependence of the ionospheric storm effects do the authors see? Are those localized in speciïňĄc areas or do they propagate in any direction? Such information will be useful to interpret the mechanism of the ionospheric storm.

Authors' response to Anonymous Referee #2 Comment #5: This storm, as any other storm, was global in nature. At least it occupied all area of the People's Republic of China. The global character of the storm is also supported by the magnetic measurements at the City of Kharkiv, Ukraine, and by the state of the ionosphere as inferred

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from the ionosonde data at the City of Moscow, the Russian Federation, and at the City of Wakkanai, Japan. The investigation of longitudinal and latitudinal dependences was not a purpose of the paper (see line 12–15). Such an investigation requires measurements different from those used in this study.

Anonymous Referee #2 Comment #6: What is the cause of the negative ionospheric storm? Is the F-region density decrease created by vertical motion of the ionosphere, horizontal motion, or change in thermospheric composition?

Authors' response to Anonymous Referee #2 Comment #6: The authors have not intended to discuss mechanisms for the negative storm (see line 12–15). The subject of this study is the influence of the ionospheric storm on the characteristics of HF radio waves propagating over the area of the People's Republic of China. As a whole, the mechanisms for negative ionospheric storms are well known (e.g., see Section 11.16, Ionospheric storms, in the textbook of R.W. Schunk and A. F. Nagy Ionospheres: Physics, plasma physics, and Chemistry, Cambridge University Press, 2009, ISBN-13 978-0-521-87706-0). They include an enhancement in the wind speed, traveling atmospheric disturbances propagating equatorward [Prölss G. W. On explaining the local time variation of ionospheric storm effects, Ann. Geophys. 1993. Vol. 11. pages 1–9; Prölss G. W. Common Origin of Positive Ionospheric Storms at Middle Latitudes and the Geomagnetic Activity Effect at Low Latitudes, J. Geophys. Res. 1993. Vol. 98, No. A4. pages 5981−5991], composition changes in the thermosphere, and an increase from ∼0.1âĂŤ0.3 mV/m to 5âĂŤ10 mV/m in an eastward zonal electric field arising during an electrical storm (see, Section 1, Introduction) that acts to decrease the electron density and to increase F2-layer virtual height.

In the paper, the following text is added (at the end of Section 7.3.1 (Ionogram Parameter Disturbances)): As a whole, the mechanisms for negative ionospheric storms are well known. They include an enhancement in the wind speed, traveling atmospheric disturbances propagating equatorward (Prölss, 1993a, b), composition changes in the thermosphere, and an increase from ∼0.1âĂŤ0.3 mV/m to 5âĂŤ10 mV/m in an eastward zonal electric field arising during an electrical storm (see, Section 1, Introduction) that acts to decrease the electron density and to increase F2-layer virtual height.

In the Reference list, the following two references has been added: Prölss, G. W.: On explaining the local time variation of ionospheric storm effects, Ann. Geophys., 11 (1), 1–9, 1993.

Prölss, G. W.: Common Origin of Positive Ionospheric Storms at Middle Latitudes and the Geomagnetic Activity Effect at Low Latitudes, J. Geophys. Res., 98 (A4), 5981−5991, https://doi.org/10.1029/92JA02777, 1993.

Anonymous Referee #2 Comment #7: What is the interpretation of the driver of the increased height of the reïňĆection from 150 to 300 km? Is it because of the penetration electric ïňĄeld?

Authors' response to Anonymous Referee #2 Comment #7: Regarding the increased height of the reïňĆection from 150 to 300 km, such a large increase was observed one time at 14:00 UT on August 31, 2019, when a few reasons had been added together. First, the rearrangement of the evening ionosphere into the night ionosphere had been completed, which was accompanied by a decrease in the electron density and an increase in the height of reflection. Second, due to the processes referred to above, the negative ionospheric storm ensued. Third, a large negative half-wave of the quasi-periodic disturbance had arrived, which was observed along all radio wave propagation paths from about 12:00 UT to 16:00 UT. Variations in the height of reflection that occurred over other time intervals were observed to occur within the 30âĂŤ50 km limits. In the text of the paper, this information has been added to the paper as follows. Regarding the mechanism for an increase in the height of reïňĆection from 150 km to 300 km, such a large increase was observed at one time, 14:00 UT on August 31, 2019, when a few causes merged together. First, the rearrangement of the evening ionosphere into the night ionosphere had been completed, which was accompanied by a decrease in the electron density and an increase in the height of reflection. Second, due to the processes referred to above, the negative ionospheric storm ensued. Third, a large negative half-wave of the quasi-periodic disturbance had arrived, which was observed along all radio wave propagation paths from about 12:00 UT to 16:00 UT. Variations in the height of reflection that occurred over other time intervals were observed to occur within the 30âĂŤ50 km limits.

Anonymous Referee #2 Comment #8: Have the authors looked at the total electron content data from GNSS receivers for this storm? The total electron content covers much wider areas and could be useful to show how the distribution of the ionosphere density changed and what density structure gave the negative storm.

Authors' response to Anonymous Referee #2 Comment #8: The authors did not studied variations in the total electron content. Such an investigation could be the subject of a separate paper. It has not been a purpose of this paper (see line 12–15).

Anonymous Referee #2 Comment #9: The authors suggest that the quasi-periodic variations are caused by atmospheric gravity waves generated in the auroral oval. In the radio wave data, do you see that the quasi-periodic variations propagate from higher to lower latitudes? If the equatorward propagation is seen, it could be a supportive evidence of the auroral source.

Authors' response to Anonymous Referee #2 Comment #9: It is well known that geospace storms are accompanied by the generation of atmospheric gravity waves in the auroral zone [R.W. Schunk and A. F. Nagy Ionospheres: Physics, plasma physics, and Chemistry, Cambridge University Press, 2009 (ISBN-13 978-0-521-87706-0)]. In the paper, as an example, three references are made (Hajkowicz, 1991; Lei et al., 2008; Lyons et al., 2019). We have tried to find a confirmation of this fact in our measurements. For example, the minimum magnitude of the Doppler shift of frequency along the Ulaanbaatar to Harbin (7,260 kHz) propagation path is observed to occur at approximately 12:47 UT, and along the Beijing to Harbin (6,175 kHz) propagation path at 13:00 UT. Taking into account the distance of 400 km between the propagation path midpoints in the equatorward direction yields the equatorward speed of 510 m/s. Such speeds and periods of tens of minutes are inherent in atmospheric gravity waves. In the text of the paper, this information has been added to the paper as follows. We have tried to find a confirmation of this fact in our measurements. For example, the minimum magnitude of the Doppler shift of frequency along the Ulaanbaatar to Harbin (7,260 kHz) propagation path is observed to occur at approximately 12:47 UT, and along the Beijing to Harbin (6,175 kHz) propagation path at 13:00 UT. Taking into account the distance of 400 km between the propagation path midpoints in the equatorward direction yields the equatorward speed of 510 m/s. Such speeds and periods of tens of minutes are inherent in atmospheric gravity waves.

The authors have tried to give answers to all Referee #2's comments. Sincerely, Authors.

Please also note the supplement to this comment:
https://angeo.copernicus.org/preprints/angeo-2020-57/angeo-2020-57-AC2-supplement.pdf

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