Ann. Geophys. Discuss., referee comment RC1 https://doi.org/10.5194/angeo-2022-24-RC1 , 2022

Comment on angeo-2022-24
Anonymous Referee #1

Referee comment on "Ionospheric Effects over the People's Republic of China from the Super-Powerful Tropospheric Western Pacific Phenomenon of September–October 2018: Results from Oblique Sounding" by Leonid Chernogor et al., Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2022-24-RC1 , 2022

Reply to Anonymous Referee #1

Dear Anonymous Referee #1,

Thank you very much for your valuable comments that have helped the Authors greatly improve the draft of their paper.

Your comments are placed together with the Authors' answers (marked in yellow), and the changes made in the text of the manuscript, are also marked in yellow.

Authors.

Review report on the Manuscript: "Ionospheric Effects over the People's Republic of China from the Super-Powerful Tropospheric Western Pacific Phenomenon of September–October 2018: Results from Oblique Sounding"

(A) General Comments :

The authors deserve merit for putting up efforts in analyzing and presenting Doppler spectra of the signals recorded over eight propagation paths for identifying typhoon-induced effects at the ionospheric height, a subject of importance in understanding lower-upper atmosphere coupling dynamics. The prime data in the analyses are oblique incidence signal reception quality in the frequency range 6.015 MHz – 9.75 MHz at Hibon China from the transmitters located in Japan, South Korea, and China.

However, the work requires clarification on some vital issues and needs supporting parameters to justify the final conclusion of the work which goes as "the periodic components of 20 min to 120 min at the ionospheric heights as reflected in the received signals are the effects of the superpowerful typhoon of September – October 2018". The authors need to provide the required inputs and clarifications for assessing the fulfillment of the aims of the work and to judge the scientific merit of the paper.

The paper thus requires major revision to make it suitable for publication in the esteemed Journal. A few suggestions and recommendations are put forward for possible implementation in the revised MS :

(i) Going through the Doppler spectra (Figure Nos. 6 to 13) presented separately for the different paths covering the period from September 29 to October 6, it is, however, observed that as claimed in the MS the components within 20 mins to 120 mins, are not visible (except the latter component in some cases) and apparently indistinguishable. These components must be well displayed along with their respective power because these are the basic parameters leading to the conclusion of the work. The results of observations also need to be coherent and clear which are somewhat missing and thus difficult to keep track of the records imprinted by the Typhoon (if any) on different propagation paths, to make a constructive comment.

Dear Anonymous Referee #1, Thank you very much for this comment.

The ionosphere is rarely quiet. Aperiodic and quasi-periodic perturbations systematically arise in it. Figures 6–13 show enhancements in variations in the Doppler spectra, and in particular, an increase in the fluctuations in the main ray. These fluctuations were almost always quasi-periodic, with the number of periods ranging from one to 4–5. The amplitude changed from 0.05 Hz to ~ 0.5, with larger periods corresponding to larger Doppler shifts. Basic information on the quasi-periodic perturbations (wave disturbances) is presented in Table 4. Certainly, the processes with periods from ~20 min to 120 min occurred.

The authors have constructed Table 4 showing the main parameters of the wave disturbances in October 2018.

Table 4
Basic parameters of wave disturbances in October 2018

Radio-wave propagation path	Date			
	October 01	October 02	October 05	October 06
Hwaseong to Harbin	T = 120; 24 min f_{Da} = 0.4; 0.1 Hz	T = 120; 24 min f_{Da} = 0.25; 0.1 Hz	T = 100–110; 15 min f_{Da} = 0.1–0.2; 0.05 Hz	T = 120; 20 min f_{Da} = 0.3; 0.05 Hz
Chiba/Nagara to Harbin	T = 60–80 min f_{Da} = 0.4 Hz	T = 20–30 min f_{Da} = 0.2–0.3 Hz	T = 30–40 min f_{Da} = 0.3 Hz	T = 100 min f_{Da} = 0.3 Hz
Hailar/Nanmen to Harbin	T = 80; 15 min f_{Da} = 0.4; 0.05 Hz	T = 40–50 min f_{Da} = 0.2–0.3 Hz	T = 40; 20 min f_{Da} = 0.2–0.3 Hz	T = 40–60 min f_{Da} = 0.1–0.2 Hz
Beijing to Harbin	T = 30–40; 20–24 min f_{Da} = 0.2; 0.1 Hz	T = 60; 20–25 min f_{Da} = 0.2; 0.1 Hz	T = 40–60; 20 min f_{Da} = 0.2; 0.05 Hz	T = 80; 20–30 min f_{Da} = 0.2 Hz
Goyang to Harbin	T = 120; 30–40 min f_{Da} = 0.3; 0.1 Hz	T = 40–60; 30 min f_{Da} = 0.2; 0.1 Hz	T = 80–90 min f_{Da} = 0.2 Hz	T = 100–120; 20 min f_{Da} = 0.4; 0.1 Hz
Shijiazhuang to Harbin	T = 120min f_{Da} = 0.3 Hz	T = 60 min f_{Da} = 0.3 Hz	T = 120 min f_{Da} = 0.3 Hz	T = 120 min f_{Da} = 0.1 Hz
Hohhot to Harbin	–	T = 120; 40–50 min f_{Da} = 0.2–0.3 Hz	–	–
Yamata to Harbin	T = 65–80 min f_{Da} = 0.3–0.4 Hz	T = 80 min f_{Da} = 0.2 Hz	T = 40; 25–30 min f_{Da} = 0.2; 0.1 Hz	T = 70 min f_{Da} = 0.2 Hz

Regarding the comment that “The results of observations also need to be coherent and **clear** which are somewhat missing and thus difficult to keep track of the records imprinted by the Typhoon (**if any**) on different propagation paths, to make a constructive comment”, we use the following general methodology for revealing perturbations arising from any powerful source of energy:

(1) perturbations **from any powerful source releasing energy** are in principle **not distinguishable with each other**; (2) **any powerful source** can be associated **with any changes in the character of the signal** (Doppler shift, Doppler spectrum, the number of rays, discrete spectrum broadening, changes in the signal amplitude, etc.); (3) **intercomparisons** of radio wave characteristics observed **prior to and after** the release of energy must be made; (4) **intercomparisons** of the behavior of the radio wave characteristics observed on the day when the event occurred and on the **reference days** must be made. **Any differences may be due to** the release of energy; (5) the magnitudes of the **speeds of propagation** of disturbances must have a physical significance and correspond to the known types of waves (seismic, atmospheric gravity waves, infrasound, magnetohydrodynamic); (6) the data acquired over a large (10–14) number of propagation paths **must be consistent with each other**.

In the manuscript, this methodology is placed at the end of the section “5 Instrumentation and techniques”.

(ii) To strengthen the conclusion, it is also recommended that Doppler spectra for the period not influenced by the Typhoon may be presented along with the observations from September 29 to October 6, which cover the growth and landfall days of the typhoon.
Dear Anonymous Referee #1, Thank you very much for this comment.
Now, we have increased the number of reference days (September 27 and 28, 2018 and October 7 and 8, 2018) shown in Figures 6–13. They really strengthen the conclusion that the Doppler spectra observed on October 1, 2, 5, and 6, 2018, differ from those observed on the reference days, testifying to the effects from the typhoon.

(iii) Further, to establish the growth of such periodic structures at the ionospheric height by the typhoon-induced wave -dynamics at the lower atmosphere, supporting evidence is necessary. It is thus suggested that the authors present profiles of any lower atmospheric/near-earth parameter during the period and around the locations covered by the study, to identify the features present therein with the wave components provided by their Doppler analysis.
Dear Anonymous Referee #1, Thank you very much for this comment.
The authors do not have “profiles of any lower atmospheric/near-earth parameter”. Moreover, the transport of the typhoon-induced wave dynamics at the lower atmosphere to ionospheric heights involves a chain of non-linear processes preventing a simple identification of the features present in the troposphere with the wave components provided by their Doppler analysis. First, a typhoon is accompanied by strong neutral air turbulence, which leads to the generation of acoustic–atmospheric gravity waves over a wide range of frequencies (Drobyazko and Krasil’nikov, 1975). Second, these waves propagate to the upper atmosphere, partially dissipating their energy for heating the neutral air and launching secondary gravity waves in wave breaking regions (see, e.g., Vadas et al., 2003; Vadas and Crowley, 2010). Third, the latter waves in the atmosphere modulate the electron density [Schunk & Nagy, 2009], tracing neutral air turbulence, and act to generate plasma turbulence. Fourth, as a result, the Doppler spectra and the

Doppler shifts are observed to exhibit regular (quasiperiodic) and chaotic variations [Matthew, 1998].

Drobyazko, I. N., & Krasil'nikov, V. N. (1985). Generation of acoustic-gravity waves by atmospheric turbulence. *Radiophysics and Quantum Electronics, 28*(11), 946-952. https://doi.org/10.1007/bf01040717

Vadas, S. L., Fritts, D. C., & Alexander, M. J. (2003), Mechanism for the Generation of Secondary Waves in Wave Breaking Regions. *Journal of the Atmospheric Sciences*, 60 (1), 194–214.

Vadas, S. L., & Crowley, G. (2010). Sources of the traveling ionospheric disturbances observed by the ionospheric TIDDBIT sounder near Wallops Island on 30 October 2007. J. Geophys. Res., 115, A07324, doi:10.1029/2009JA015053.

Schunk and A. F. Nagy, Ionospheres: Physics, plasma physics, and Chemistry, Cambridge University Press, 2009 (ISBN-13 978-0-521-87706-0:

Matthew J. Angling, Paul S. Cannon, Nigel C. Davies, Tricia J. Willink, Vivianne Jodalen, and Bengt Lundborg, Measurements of Doppler and multipath spread on oblique high-latitude HF paths and their use in characterizing data modem performance, Radio Science, Volume 33, Number 1, Pages 97-107, January-February 1998. Paper number 97RS02206. 0048-6604/98/97RS-02206

(iv)The authors no doubt have tried to associate density fluctuation (ionosphere) with the formation of waves but need justification for their approach as the considered paths are of varied propagation statuses and positions. It is important also to provide physics and system dynamics associated with density modulations leading to the formation of waves. The scientific explanation is missing.

Dear Anonymous Referee #1, Thank you very much for this comment. Use has been made of radio wave paths with various orientations and distances from the typhoon, which permitted the identification of the ionospheric effects associated with the typhoon. Indeed, certain effects were observed along the nearest radiowave propagation paths, while such effects were absent along the most distant ones (Hohhot to Harbin) from the typhoon. This is the best proof of the influence of the typhoon.

Regarding the physics and system dynamics associated with density modulations leading to the formation of waves, it is presented in textbooks on the ionosphere (see, e.g., Schunk and A. F. Nagy, Ionospheres: Physics, plasma physics, and Chemistry, Cambridge University Press, 2009 (ISBN-13 978-0-521-87706-0:), and therefore such an explanation is not being considered suitable for publication in the esteemed Journal.

(v)The abstract, the basic key to the contents of the paper is not well spelled out and needs to be rewritten with clear objectives and approaches.

Dear Anonymous Referee #1, Thank you very much for this comment.

The scientific objectives of the study are to reveal the possible perturbations caused by typhoon Kong–Rey action, and to estimate the possible wave parameters of the ionosphere and radio signals. The abstract has been updated, and it is as follows:

Abstract.
Doppler measurements at oblique propagation paths from the City of Harbin, People's Republique of China (PRC), to ten HF radio broadcast stations in the PRC, Japan, Mongolia, and the Republic of Korea captured the response in the ionosphere to the super typhoon Kong-Rey action from September 30, 2018, to October 6, 2018. The Harbin Engineering University coherent software defined radio system accumulates the database containing the complex amplitudes of the radio signals acquired along 14 propagation paths since 2018. The complex amplitudes are used for calculating the temporal dependences of the Doppler spectra and signal amplitudes, and the Doppler spectra are used to plot the Doppler shift as a function of time, $f_D(t)$, for all rays. The scientific objectives of this study are to reveal the possible perturbations caused by the action of typhoon Kong-Rey, and to estimate the magnitudes of wave parameters of the ionospheric plasma and radio signals. The amplitudes, f_{Da}, of the Doppler shift variations were observed to noticeably increase (factor of ~2–3) on October 1–2 and 5–6, 2018, while the 20–120 min periods, T, of the Doppler shift variations suggest that the wavelike disturbances in the ionosphere are caused by atmospheric gravity waves. The periods and amplitudes of quasi-sinusoidal variations in the Doppler shift, which have been determined for all propagation paths, may be used to estimate the amplitudes, δ_{Na}, of quasi-sinusoidal variations in the electron density. Thus, $T \approx 20$ min and $f_{Da} \approx 0.1$ Hz yield $\delta_{Na} \approx 0.4\%$, whereas $T \approx 30$ min and $f_{Da} \approx 0.2$ Hz give $\delta_{Na} \approx 1.2\%$. If $T \approx 60$ min and $f_{Da} \approx 0.5$ Hz, then $\delta_{Na} \approx 6\%$. The periods T are found to change within the 15–120 min limits, and the Doppler shift amplitudes, f_{Da}, show variability within the 0.05–0.4 Hz limits.

(vi) Discussions and Conclusions are to be modified accordingly.
Dear Anonymous Referee #1, Thank you very much for this comment.
The discussion and conclusions have been modified accordingly.

(vii) There are scopes for improvement in sentence construction and also in clarity.
(vii) We have made the improvements.

(B) Other comments :

(i) Line number 20 -25: The authors' statement that "typhoon-induced effects are clear near the midpoint of communication path". This needs clarification when several propagation paths covering SE, S, and NW directions are taken for their study and the mid-point of one propagation path varies from the other. From Figure 1(a) and Figure 5 one can see that the Typhoon trajectory and mid-point of the communication link may come nearer only from October 4 that too in the Harbin –Yomotta, Harbin- Chiba, Harbin-Goyang and Harbin-Hwasenong paths. These points may be cleared and looked into while explaining their observational results.

Dear Anonymous Referee #1, Thank you very much for this comment.
Regarding the midpoints, the movement of the midpoints makes the main contribution to the Doppler shift observed at oblique incidence (see, e.g., Davies,

K. Ionospheric radio. Peter Peregrinus Ltd., 2008. ISBN (13 digit) 978-0-86341-186-1, 1989).

The time when the effects are observed is more important than the place where the typhoon is located. If the typhoon approached on October 04, then the response to the typhoon might be naturally expected to occur on October 05 and 06.

(ii) Concerning (i) above, it is observed that wave components of 20 mins to 120 mins as claimed as Typhoon–induced effects are not visible, except for the Chiba-Herban link Doppler spectra which provide relatively clear components of 2/3 hrs (Figure 7). But those signatures appeared even on September 29 -30, and also on October 6 (also identified by the authors). It is not understood why on September 29 relatively clean wave structure is seen (Figure 7) when it was in a tropical storm category and only on September 30, the storm attained Typhoon status. Further, the Kong Rey then weakened to category 3 on October 3 and degraded to a tropical storm on October 4, and made landfall on early October 6. Therefore it seems that the superpowerful typhoon effect may not be seen by the authors from October 4 as Kong-Rey penetrated the Chinese mainland, at 18:00hrs on October 3. The authors are suggested to look into their statement and discussion in this background and to provide Doppler spectra for days free from typhoons for clearing the issue.

Dear Anonymous Referee #1, Thank you very much for this comment.

This is not entirely true. Quasi-periodic perturbations are observed along all propagation paths except for the Hohhot to Harbin propagation path. The quasi-periodic perturbations in Figure 7 are just more clearly evident. Rather, such structures arise on October 1 and 2, 2018, as well as on October 5 and 6, 2018.

The authors have constructed Table 4 showing the main parameters of the wave disturbances in October 2018.

Table 4

Basic parameters of wave disturbances in October 2018

Radio-wave propagation path	Date			
	October 01	October 02	October 05	October 06
Hwaseong to Harbin	T = 120; 24 min f_{Da} = 0.4; 0.1 Hz	T = 120; 24 min f_{Da} = 0.25; 0.1 Hz	T = 100–110; 15 min f_{Da} = 0.1–0.2; 0.05 Hz	T = 120; 20 min f_{Da} = 0.3; 0.05 Hz
Chiba/Nagara to Harbin	T = 60–80 min f_{Da} = 0.4 Hz	T = 20–30 min f_{Da} = 0.2–0.3 Hz	T = 30–40 min f_{Da} = 0.3 Hz	T = 100 min f_{Da} = 0.3 Hz
Hailar/Nanmen to Harbin	T = 80; 15 min f_{Da} = 0.4; 0.05 Hz	T = 40–50 min f_{Da} = 0.2–0.3 Hz	T = 40; 20 min f_{Da} = 0.2–0.3 Hz	T = 40–60 min f_{Da} = 0.1–0.2 Hz
Beijing to Harbin	T = 30–40; 20–24 min f_{Da} = 0.2; 0.1 Hz	T = 60; 20–25 min f_{Da} = 0.2; 0.1 Hz	T = 40–60; 20 min f_{Da} = 0.2; 0.05 Hz	T = 80; 20–30 min f_{Da} = 0.2 Hz
Goyang to Harbin	T = 120; 30–40 min f_{Da} = 0.3; 0.1 Hz	T = 40–60; 30 min f_{Da} = 0.2; 0.1 Hz	T = 80–90 min f_{Da} = 0.2 Hz	T = 100–120; 20 min f_{Da} = 0.4; 0.1 Hz
Shijiazhuang to	T = 120min	T = 60 min	T = 120 min	T = 120 min

Harbin	f_{Da} = 0.3 Hz	f_{Da} = 0.3 Hz	f_{Da} = 0.3 Hz	f_{Da} = 0.1 Hz
Hohhot to Harbin	–	T = 120; 40–50 min f_{Da} = 0.2–0.3 Hz	–	–
Yamata to Harbin	T = 65–80 min f_{Da} = 0.3–0.4 Hz	T = 80 min f_{Da} = 0.2 Hz	T = 40; 25–30 min f_{Da} = 0.2; 0.1 Hz	T = 70 min f_{Da} = 0.2 Hz

The authors also point out that although the typhoon somewhat weakened on October 3 and 4, 2018, it achieved the closest distance to the propagation paths. Therefore, the ionospheric effects from the typhoon were again observed on October 5 and 6, 2018.

(iii) As the observations are in the oblique mode, the tropospheric effect cannot be ignored, when the contribution varies with the looking angle of the signals from the transmitter. It is suggested that the authors analyze tropospheric/near surface parameters along the path of propagation (or around) and look for (if detected) supporting inputs to justify the authors' conclusion (already suggested above).
Dear Anonymous Referee #1, Thank you very much for this comment.
The tropospheric effects cannot arise at 5–10 MHz frequencies, because the non-conducting atmosphere below the ionosphere is treated as free space, with refractive index unity, in the HF frequency range (see, e.g., Budden, K. G., The propagation of radio waves: The theory of radio waves of low power in the ionosphere and magnetosphere, Cambridge University Press, 1988).

(iv) The Wakkanai ionogram may also be examined for such waves. The relevance of figures 3 and 4 are to be clearly spelled out and may be brought into the discussion while explaining the observed Spectral components. The only points of reference of these figures in the MS perhaps are in terms of diurnal variations in layer reflection height and critical frequency status during the period of study.
Dear Anonymous Referee #1, Thank you very much for this comment.
We would also like the Wakkanai ionosonde to provide us with ionograms updated every minute. However, Figures 3 and 4 show ionogram measurements acquired with an update rate of one ionogram per 1 hour. Thus, these ionograms cannot give information on the ~20–120-min period wave processes. Nevertheless, they are used for analyzing the state of space weather in Section *4 Analysis of the State of the Ionosphere*.

(C) Additional Comments :

(i) Caption of the MS :

The caption may be more appropriate as “Effects of Super-Powerful Tropospheric Western Pacific Phenomenon of September–October 2018 on ionosphere over china: Results from Oblique Sounding”.
Dear Anonymous Referee #1, Thank you very much for this comment.
We have changed the title of this paper.

(ii) Abstract :

The abstract is not well spelled out and needs to be rewritten with clear objectives and approaches. It is necessary to mention what ionospheric parameters the authors are monitoring, and of signal sources.

Dear Anonymous Referee #1, Thank you very much for this comment.

We have rewritten the abstract as follows.

Abstract.

Doppler measurements at oblique propagation paths from the City of Harbin, People's Republique of China (PRC), to ten HF radio broadcast stations in the PRC, Japan, Mongolia, and the Republic of Korea captured the response in the ionosphere to the super typhoon Kong-Rey action from September 30, 2018, to October 6, 2018. The Harbin Engineering University coherent software defined radio system accumulates the database containing the complex amplitudes of the radio signals acquired along 14 propagation paths since 2018. The complex amplitudes are used for calculating the temporal dependences of the Doppler spectra and signal amplitudes, and the Doppler spectra are used to plot the Doppler shift as a function of time, $f_D(t)$, for all rays. The scientific objectives of this study are to reveal the possible perturbations caused by the action of typhoon Kong-Rey, and to estimate the magnitudes of wave parameters of the ionospheric plasma and radio signals. The amplitudes, f_{Da}, of the Doppler shift variations were observed to noticeably increase (factor of ~2–3) on October 1–2 and 5–6, 2018, while the 20–120 min periods, T, of the Doppler shift variations suggest that the wavelike disturbances in the ionosphere are caused by atmospheric gravity waves. The periods and amplitudes of quasi-sinusoidal variations in the Doppler shift, which have been determined for all propagation paths, may be used to estimate the amplitudes, δ_{Na}, of quasi-sinusoidal variations in the electron density. Thus, $T \approx 20$ min and $f_{Da} \approx 0.1$ Hz yield $\delta_{Na} \approx 0.4\%$, whereas $T \approx 30$ min and $f_{Da} \approx 0.2$ Hz give $\delta_{Na} \approx 1.2\%$. If $T \approx 60$ min and $f_{Da} \approx 0.5$ Hz, then $\delta_{Na} \approx 6\%$. The periods T are found to change within the 15–120 min limits, and the Doppler shift amplitudes, f_{Da}, show variability within the 0.05–0.4 Hz limits.

A few examples :

"The ionospheric response to the super typhoon action was clearly observed to occur both on October 1–2, 2018 (when the typhoon was 2,800–3,300 km from the propagation path midpoints ..." (As already identified in other comments (i) above)

Similarly: " … on October 5–6, 2018 when the typhoon was 1,000–1,500 km from the midpoints and its energy decreased by a factor of about 4."

And also " The ionospheric effects are more pronounced along the nearest propagation paths, whereas no effect was detected along the propagation path at the farthest distance from the typhoon ".

These are vague and unspecified sentences carrying no meaning if not mentioned the receive mode and propagation paths of signals.

Dear Anonymous Referee #1, Thank you very much for these comments. The seeming vagueness is rooted in the general methodology of revealing the effects that are due to any powerful source of energy above. For convenience, it is copied below:

To reveal perturbations arising from any powerful source of energy, the following general methodology is invoked: (1) perturbations from any powerful source releasing energy are in principle not distinguishable with each other; (2) any powerful source can be associated with any changes in the character of the signal (Doppler shift, Doppler spectrum, the number of rays, discrete spectrum broadening, changes in the signal amplitude, etc.); (3) intercomparisons of radio wave characteristics observed prior to and after the release of energy must be made; (4) intercomparisons of the behavior of the radio wave characteristics observed on the day when the event occurred and on the reference days must be made. Any differences may be due to the release of energy; (5) the magnitudes of the speeds of propagation of disturbances must have a physical significance and correspond to the known types of waves (seismic, atmospheric gravity waves, infrasound, magnetohydrodynamic); (6) the data acquired over a large (10–14) number of propagation paths must be consistent with each other.

(iii) Introduction and Discussion :

In the introduction, the authors introduce relevant references on the need of understanding typhoon-induced effects by coupling dynamics between ocean-lower and upper atmosphere through gravity waves, water vapor condensation, and severe thunderstorms (to name a few).

The authors have not brought up these parameters and issues either in the analysis or in the discussion. The introduction and discussion aspects should bear relevance.
Dear Anonymous Referee #1, Thank you very much for this comment.

Indeed, the introduction strives to depict an entire broad research effort among scientists from around the world aimed at acquiring a deep understanding of the physical processes that drive the ocean–atmosphere–ionosphere–magnetosphere system. Also, a broad spectrum of instruments to investigate these processes is mentioned.

The scope of the last paragraph in the introduction narrows to the scientific objectives achievable with the instrument the authors have created. The paragraph is as follows:

The scientific objectives of this study is to reveal the processes that the typhoon–dusk terminator coupling brings into play, to derive specifications of wave periods and amplitudes of perturbations in the in the electron density, and to estimate the space scales of the perturbations launched by the super typhoon Kong-Rey event of September–October 2018 into the ionosphere over the People's Republic of China (PRC).The observations were made using the Harbin Engineering University, PRC, multifrequency multiple path coherent software defined radio system for probing the ionosphere at oblique incidence.

(iv) Figures :

Figure 2: Here Space weather knowledge is no doubt relevant. These plots however may be omitted and Kp, Dst magnitude statement may be enough to support the status of the days.
Dear Anonymous Referee #1, Thank you very much for this comment.
The authors consider the presented in the MS analysis of the state of space weather to be important and its reduction to be inappropriate.

Figures 3 and 4: The relevance of the content of the figures to be placed in the MS where appropriate (already identified above).
Dear Anonymous Referee #1, Thank you very much for this comment. The relevance of the data in Figures 3 and 4 have already been already identified above as follows.

Figures 3 and 4 show ionogram measurements acquired with an update rate of one ionogram per 1 hour. Therefore, these ionograms cannot provide information on the ~20–120-min period wave processes. Nevertheless, they are used for analyzing the state of space weather in Section *4 Analysis of the State of the Ionosphere*.

Figure 4: Check for the y-axis

Virtual height E is to be replaced with Es.
Dear Anonymous Referee #1, Thank you very much for this comment.
In Figure 4, both E and Es virtual heights are presented.

(v) Clarity of sentence suggested (examples):

(a) Line 170: "…Main ray and few rays "

Dear Anonymous Referee #1, Thank you very much for this comment. Indeed, this phrase sounds stupid. The phrase is altered as follows: all rays under analysis

(b) Line 225-230:: " L 1.5 Hz, broadening±he Doppler spectra exhibit significant, up to and such a diffuseness that the main ray is practically not distinguishable"

Dear Anonymous Referee #1, Thank you very much for this comment. This misprint has been corrected as follows:
the Doppler spectra exhibit significant, up to ±1.5 Hz, broadening and such a diffuseness that the main ray is practically not distinguishable.

(vi) Reconstruction of sentence necessary (examples)

(a) Line No 320: "The frequency of this radio wave became greater than the maximum usable frequency and the radio wave penetrated the ionosphere during the second half of the nights. Consequently, the observation of became impossible".

Dear Anonymous Referee #1, Thank you very much for this comment.
The sentences have been reconstructed as follows:
The frequency of this radio wave became greater than the maximum usable frequency and the radio wave penetrated the ionosphere during the second half of all nights (see Figure 12). The received signal was absent, and the observation of the ionospheric dynamics became impossible.

(b) line No 325: "During the night of September 30, 2018, the reflection of radio waves took place from the sporadic E layer, resulting in fD(t) » 0 Hz. During October 1, 2018, nighttime, the Doppler shift fD(t) » 0 Hz) as well. During the course of the October 2. 2018, night, the Doppler shift was observed to change from –0.3 Hz to 0.3 Hz, the signal amplitude was observed to exhibit considerable variability, up to 20 dBV, In the course of the October 3–6, 2018 nights, the measurements were ineffective, whereas fD(t) » 0 Hz at daytime."

Note also the highlighted segments.

Dear Anonymous Referee #1, Thank you very much for this comment.
We have re-written line No 325 as follows:

On the UT night of September 30, 2018, the reflection of radio waves took place from the sporadic *E* layer, resulting in $f_D(t) \approx 0$ Hz, and during the UT night of October 1, 2018, the Doppler shift $f_D(t) \approx 0$ Hz as well. On the UT night of October 2, 2018, the Doppler shift showed changes from –0.3 Hz to 0.3 Hz, while the signal amplitude exhibited considerable variability, up to 20 dBV. During the UT nights of October 3–6, 2018, the measurements were ineffective, whereas $f_D(t) \approx 0$ Hz at daytime.

Final Comment

The paper needs major revision in light of the above suggestions and comments, before being considered suitable for publication.

Please also note the supplement to this comment:
https://angeo.copernicus.org/preprints/angeo-2022-24/angeo-2022-24-RC1-supplement. pdf

Dear Anonymous Referee #1, Thank you very much for this comment. Your suggestions and comments have helped the Authors to significantly improve the manuscript.

Sincerely,
Authors.