Response to Reviewer 1: https://doi.org/10.5194/essd-2022-303-RC1

We thank the reviewers for their time and attention. Responses are inline below.

In this paper, the authors describe a new experimental framework, still in development, based on the crowdsourcing paradigm for the measurement of ionospheric phenomena using radio waves. The authors focus on describing the data produced by this system and not much on the physics. Nevertheless, they outline some possible scientific questions that can be addressed as this experimental framework continues evolving.

Before going into the specific comments, I want to point out two general issues I see with the paper's current approach.

First, I found it challenging to infer the paper's primary goal. It was not explicit in either the abstract or the introduction.
We have added this sentence to the abstract: *"The primary goal of this paper is to explain the types of measurements this instrument can make and some of its use cases, demonstrating its role as the building block for a large-scale ionospheric and HF propagation measurement network which complements existing professional networks.."*

Second, the authors might be underestimating the potential impact of this work. As I see it, this is the first step in building a system to systematically assess the accuracy of the bottom-side estimates from almost all ionospheric models. These measurements can be compared to the oblique paths obtained with each ionospheric simulation if coupled with accurate ray-tracing solvers. If the authors agree that this is a viable application, they should mention it in the paper.
We have added this to our abstract and Future Work sections. The suggestion is greatly appreciated.

In the abstract: *"These data may be used to supplement observations made with other geospace instruments in event-based analyses, e.g., traveling ionospheric disturbances and solar flares, <u>and to assess the accuracy of the bottom-side estimates of ionospheric models by comparing the oblique paths obtained by ionospheric ray-tracers with those obtained by these receivers.</u>"*

In Future Work (Sect. 7): *"By making these data permanently accessible to professional and citizen scientists, and by continuing data collection with a growing network of stations through Cycle 25 and beyond (MacDonald et al., 2022), we hope to produce a record of short-term events and seasonal variability which will inform future studies of solar flare responses, MSTIDs and other phenomena, and <u>which will form a benchmark for the validation of simulated Doppler shift in ionospheric models.</u>"*

The following is a list of specific comments. I will use "l." to refer

to "line."

l.1: It is unclear what you mean by "atmospheric coupling." If it is being used as an umbrella term for neutral atmosphere, solar activity, particle precipitation, etc., it might be better to say "ionospheric variability."
The phrase “due to atmospheric coupling” has been removed. The sentence now reads *“Ionospheric variability produces measurable effects in Doppler shift of HF (high frequency, 3-30 MHz) skywave signals.“*

l.12: My understanding is that Doppler shifts can be caused not only by changes in ionospheric height. I do not think you have to make this assumption, but if you want to focus on height, you should be very specific about this being an essential assumption of the paper.
We have edited the introduction to remove this assumption. The beginning of the introduction now reads, *“HF (high frequency, 3-30 MHz) Doppler sounding is an established means of observing the bottomside ionosphere. Its principle of operation is straightforward: a shift in signal path length effects a corresponding Doppler shift. This information may be integrated with other ionospheric measurements to examine ionospheric variability resulting from geophysical events.“*

l.23: Considering that one of the main contributions of this experimental framework is the role of citizen science, you should elaborate further on what it is and its advantages and limitations for this work.
We have added an additional section (Section 5.3) providing context for this work in the landscape of citizen science. This topic is also addressed in the feedback to Reviewer 2.

l.32: "Long-term ionospheric trends" is a whole area of research studying time series, often covering several solar cycles. Maybe you can use "seasonal variability."
This change has been implemented. We have also replaced “long-term” with “seasonal,” “multiyear,” etc. elsewhere in the paper.

l.45: AGWs are ubiquitous and are not restricted to the mechanisms you listed.
We have edited this sentence for clarification: *“[AGWs] are associated with terrestrial weather patterns and may be caused by events such as tornadoes (Nishioka et al., 2013), tsunamis (Galvan et al., 2011; Huba et al., 2015), or high latitude sources (Grocott et al., 2013; Frissell et al., 2016).”*

Figure 1: Should elaborate on what multi hops and Pederson modes are.
The caption now reads: *“A simplified illustration of the relationship between rate of change in ionospheric layer height and received frequency shift. Precision frequency standards are required at both beacon and receiver in order to make an effective comparison. Frequency variation is generally on the order of ± 1 Hz. Multihop propagation (multiple reflections between ionosphere and ground), Pedersen modes (internal ionospheric reflections), asymmetric paths, and other factors impacting path length are not shown. Reproduced from Collins et al. (2022).“*

I.57: Consider using a simple algebraic expression to illustrate the dependency between phase, wavelength, and local ionospheric parameters.
We have added an equation from Chum et al (2018):

The Doppler shift f_D in a received signal may be expressed as the time derivative of the phase path of the radio signal. After Chum et al. (2018):

$$f_\mathrm{D} = -2 \cdot \frac{f}{c}\frac{\mathrm{d}}{\mathrm{d}t}\left(\int_0^{z_R} n \cdot \mathrm{d}r\right) = -2 \cdot \frac{f}{c}\int_0^{z_R} \frac{\partial n}{\partial N} \cdot \frac{\partial N}{\partial t} \cdot \mathrm{d}r, \tag{1}$$

where c is the speed of light, n is the real part of refractive index for electromagnetic waves, N is the electron (plasma) density, and z_R is the height of reflection. This methodology is well-established in the scientific literature (Breit and Tuve, 1925; Davies et al., 1962; Jacobs and Watanabe, 1966).

I.77: What does "cleaning" imply?
No actual changes to the data are made at this point in the process. Rather, the filenames and sizes are given a cursory review which takes only a few minutes. This sentence has been rephrased for clarification: *"Test files, corrupted files and spurious uploads are eliminated, and the data are consolidated into a single .zip file, which is posted to the data repository (…)."* The graphical abstract has also been amended to use the phrase "Data are manually checked" and "Cleaned data storage" has been redesignated "Temporary data storage."

Figure 3: The image is too big, considering the information it is displaying. I suggest making it smaller or just listing these files' information.
The file has been included as an appendix instead.

I.118: Instead of displaying the frequency response of the Butterworth filter, you should limit it to summarize its features. The details shown in Figures 7 and 10 are unnecessary for the explanations presented.
This change has been implemented.

I.124: Instead of "line of pixels from bottom to top," you might want to use "columns."
This change has been implemented: *"Each day is represented by a column of pixels, with corresponding solar mean time lined up across the plots horizontally and time's arrow running from bottom to top."*

I127: You should elaborate on the mechanism responsible for this seasonal movement considering this is one of the main outputs of the measurements.
This topic is also addressed in feedback to Reviewer 2. We have added a plot of computed sunrise/sunset times in order to reinforce the connection between the trends shown in the time/date/parameter plots and the changing length of day as the seasons progress. We have also added exposition in Section 4.2: *"As illustrated in Figure 1, electron density in the ionosphere increases during the day as a result of photoionization and decreases at night due to recombination (Davies, 1990), producing a recognizable trend in Doppler plots. Confirming*

this diel variation (i.e., checking for a sunrise peak) is recommended by Gibbons et al. (2022) as a benchmark for an operator to ensure that the trends observed in their station's data are geophysical in nature."

Figure 6: Give more details on the location of the sunrise peak.
We have added an annotation in the new version of the figure. We also reduced the range of the y axis and used a smaller marker size to make the peak more evident.
To address feedback from Reviewer 2 regarding validation, we changed the date being plotted in this example from 1 October 2019 to 28 October 2021, because it shows the Doppler flash discussed elsewhere in the paper in addition to a good sunrise peak.

Figures 8 and 10: What are the sources of variability in Doppler shift and power? Is it just experimental uncertainty, or are there other ionospheric mechanisms involved?
This topic has also been addressed in feedback to Reviewer 2. We have added a section on measurement uncertainty. There are of course many ionospheric mechanisms at play, but quantifying the contributions of these mechanisms goes beyond the scope of this paper and is a subject for future work.

Figure 9: The caption needs more details. Using a smaller marker size would facilitate visualization.
More detail has been added to this caption: "Observations of the 10 MHz WWV signal (Ft. Collins, CO) received by a Grape receiver located near Cleveland, OH on 7 April 2021 from 02-22 UT. (Top) Time series of received 10 MHz Doppler shifts. Blue dots show raw observations; orange trace shows data filtered with a 15-60 min digital bandpass Butterworth filter. (Bottom) Spectrogram showing power spectral density of the filtered data from the top panel. The oscillations and enhanced PSD in the 15-60 min band observed between ∼0330 to ∼1200 UT is consistent with signatures of medium scale traveling ionospheric disturbances."

A smaller marker size has also been used here, as well as in the revised version of the one-day plot above it.

l.149: There might be better choices for a time series with such a finite perturbation than a band-pass filter. Have you considered calculating the high-frequency oscillation from the difference between the original time series and its smoothed form?
We chose the filter used here particularly for looking at MSTIDs, which are generally defined to have periods on the order of 15 to 60 minutes. The same filter has been used by the authors before for this purpose (cf. 10.1002/2014JA019870, 10.1002/2015JA022168). The raw data is archived, so end users may apply other filters as needed for their phenomena of interest.

Figure B1: The colormap is different from Figure 9.
We chose to include a discussion of colormap options as an appendix. Figure B1 is intended to be analogous to the time-date parameter plot (Figure 8 in original draft).