RESPONSE TO REFEREE #2 COMMENTS

RC3: 'Comment on angeo-2023-37', Anonymous Referee #2, 08 Apr 2024 reply
This paper examines and classifies the variability of noise occurrence in the ISR ion velocities data. This is useful work that is potentially worth publishing. However, the present version needs a major revision because of rather poor structuring and lack of necessary information mainly related to the introduction and discussion.

Thank you for the positive comments on the importance of this study and for providing valuable recommendations on how to improve the paper as well as clarify confusing text. Please find responses to the points raised below. The responses made to the points raised by the reviewer are written in italics. Those coloured in red are the new input.

Comments.

Ll. 39-40. "The main focus of this paper ..." This basic statement does not seem to adequately reflect what is actually being done. First, the statistical occurrence of noise is studied, rather than noise in terms of its inherent properties. Secondly, not only seasonal variability is presented, but also the dependence on LT. Please formulate your goal more precisely.

The main focus of this paper is the analysis of the statistical occurrence of noise associated with different classes of ionospheric upflow, local time (LT) dependence, as well as seasonal variability of the noise during ESR observations of upwelling ions at solar minimum of 2007 – 2008 shown in Figure 1

It is also not clear how the present study is placed into context. The sentence preceding "the main focus", with reference to earlier work by Wannberg et al. (1997), lists possible sources of the noise occurrence. And after this, a reader may expect a brief overview of what has been done (or not done) in the past to evaluate the noise and what remains unexplored. More references and explanations are needed here. Otherwise, the purpose of this study does not seem sufficiently justified.

Although the ESR facility like other IS radars is built with high gain and low noise performance owing to its transmitted power (up to a maximum of 1.0 MW), antenna sensitivity (42 m *diameter) and high latitude location $(78^{\circ}09'11''N)$, there are noise from other sources such as the signal-to-noise ratio (SNR) that varies inversely as the square of the distance from the receiver to the target $(i.e., S \propto R^{-2})$, noise associated with clutter in altitude up to 140 km (Wannberg et al., 1997) and the electromagnetic noise at the background. Lehtinen (1989) and Vierinen et al., (2008) have suggested that the accuracy of the autocorrelation function in radar backscatter is limited as a result of disturbances from noise. David et al. (2018) worked on the technique to filter the real data from noise, but no statistical analysis to quantify the level of noise was carried out. Li et al. (2020) in their attempt to simulate the SNR of a proposed ISR (phased array radar) and compared with an equivalent parabolic dish radar, showed theoretically through their findings that the SNR from the phased array radar is weaker compared to that of the equivalent parabolic dish, whereas the analysis of noise and its error were left for future work.*

In order to avoid radar data that are susceptible to clutter as a result of mountainous topography of Svalbard (David et al., 2018), the data analysed in this work were observed by the EISCAT Svalbard Radar (ESR) 42 m dish between the altitude range of 100 and 470 km (where noise associated to clutter and background electromagnetic effect have been filtered) with a time resolution of 1 minute. As such, the focus of this paper is the analysis of the statistical occurrence of noise associated with different classes of ionospheric upflow, local time (LT) dependence, as well as seasonal variability of the noise during ESR observations of upwelling ions at solar minimum of 2007 – 2008 shown in Figure 1.

Such statistical studies have potential application in the improvement of the EISCAT instrumentation. For example, in the development of the upgrade of the existing EISCAT radars, the EISCAT 3D. This is because, for example, noise from sources such as the signal-to-noise ratio influence the temporal resolution of the EISCAT 3D radar measurements (Stamm et al., 2021). The EISCAT 3D radar relies on a high-power and phased array system can produce three-dimensional imaging of the upper atmospheric structures and processes in high resolution (McCrea et al., 2015). With such high-resolution imaging capabilities of the EISCAT 3D radar data, they can enhance research in, for instance, ionospheric electron densities and ion flow velocities. Thus, the present study can contribute to the development of the recent EISCAT 3D radar.

The statement that noise is associated with non-physical velocities (ll. 43-44) hardly needs so many references. And they all seem rather formal, since the papers mentioned are actually in-depth studies of various aspects of radar observations, naturally using only physically meaningful values.

The number of references has been reduced. The statement now reads:

Noise or rejected data in this study refers to ISR data with very high values of unphysical velocities above 10 km s^{-1} unintentionally obtained during incoherent scatter analysis (Jones et al., 1988; Blelly et al., 1996; David et al., 2018).

To avoid confusion and ambiguity, it would be much better to make the introduction as a separate section and add more relevant information there. The next section should be Instrumentation & data. The classification of fluxes should certainly be moved to this second section.

The Introduction has been made a separate section, likewise Instrumentation. More relevant information has been added to the introduction as indicated in the preceding page.

Instrumentation and Data

The primary data used for this work is sourced from EISCAT Svalbard radar (ESR) during the international polar year (IPY) campaign in 2007.

- *The ESR is a fixed and field-aligned 42m dish.*
- *Basic ionospheric parameters measured by the ESR are the electron density, electron and ion temperature and, the ion velocity which are respectively abbreviated as:* n_e, T_e, T_i, *and* v_i
- *About 300 days observation of 312,444 field-aligned profiles was made*
- *The observation occurs during a deep solar minimum as shown in Figure 1*

The ESR observations of upwelling ions at solar minimum of 2007 – 2008 shown in Figure 1, indicates that the maximum daily total sunspot number is 66.0 in 2007 and 60.0 in 2008. Likewise, the maximum daily F10.7 radio flux over the same period as shown in Figure 1 is 93.9 and 88.6 in 2007 and 2008 respectively. Noise or rejected data in this study refers to ISR data with very high values of unphysical velocities above 10 km s^{-1} *unintentionally obtained during incoherent scatter analysis (Jones et al., 1988; Blelly et al., 1996; David et al., 2018). The classes of flux (*$\geq 7.5 \times 10^{13} m^{-2} s^{-1}$*; Wahlund & Opgenoorth, 1989) in this study and the filtering methodology follow the work by David et al. (2018), where upflows are categorised as follows:*

Low-flux upflow: $1.0 \times 10^{13}\ m^{-2}\ s^{-1} \leq f_{ion} < 2.5 \times 10^{13}\ m^{-2} s^{-1}$

Medium-flux upflow: $2.5 \times 10^{13}\ m^{-2}\ s^{-1} \leq f_{ion} < 7.5 \times 10^{13}\ m^{-2} s^{-1}$

High-flux upflow: $f_{ion} \geq 7.5 \times 10^{13} m^{-2} s^{-1}$

Although section 2 is titled Results and Discussion, this reviewer did not find any discussion. Only the two last sentences can be considered somewhat related to the discussion. And it is too few. The discussion should be expanded, or the word "discussion" should be removed from the title. The results without discussion seem not a good idea though, especially if the introduction is too brief. There can be different ways to have an interesting discussion, e.g. implementation of the results obtained (for EISCAT 3-D?), their physical meaning, comparison with previous results.

The statement below has been added to the discussion.

In the light of the above, the proposed phased array ISR, named Sanya ISR should take into cognisance, an ISR that in practice, will have a better SNR by ensuring the best input radar system constants, effectual scattering volume, and spatial variability terms in space, as stated in the work of Li et al. (2020). The results of this work could also be integrated in the buildup of the EISCAT 3D to allow for comparison in the SNR of the Scandinavian Arctic infrastructure and the Sanya ISR, which is proposed to be the first multistatic ISR in a low latitude region.

Reply
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New references

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