Response to Reviewer 2

General comments:

I had the chance to review the paper 'Early warning system for ice collapses and river blockages in the Sedongpu Valley, southeastern Tibetan Plateau'. The paper analyses the performance of a three sets early warning system in Sedongpu valley to detect ice rock collapse and alert the communities. Such an analysis is very useful for the emergency and scientific community and while the novelty of the approach is moderate, I recommend this paper for NHESS with major revisions.

Overall, the paper is very interesting, and the data well presented. The strengths of this paper are the EWSs setups which fed the paper and made the analysis relevant. The efficiency of EWS 1, 2 and 3 data is well described. Evidence on the waveform characteristics of a flow is very informative as well as the dilution of the flow when rocks and ice are mixed. The charts are clear, although I have made some suggestions below. While this paper will find readers from the scientific and the emergency stakeholders, I would recommend to further improve the scientific analysis and take full advantage of this EWSs' network. The EWSs network introduced here offer a great source of dataset which could be further exploited in this paper. Particularly, EWS1 meteorological records should have been analysed to understand the role of weather parameters on ice-rock detachment (Temperature? Precipitation? Radiation?). EWS1 was established in May 2022, therefore it would be very useful to look at the data records prior to Ice-rock collapses and river blockage on 14 May 2022 and to the repeated ice-rock collapses on 11 August 2022. If there are any anomalies prior to the events, those must be mentioned in the paper to better understand the weather conditions which trigger such hazards. This is the main, if not the only, gap of this paper. Please, see some of my comments in details below.

Reply: Thank you for your positive assessment of our work and your constructive comments, which will help us to improve the paper considerably. Following your suggestion, we have re-examined the meteorological data to analyze the relationship between the occurrence of ice-rock collapses and the possible weather conditions that could trigger the hazards in the Sedongpu valley. The following new Figure 8 shows the occurrence of ice-rock collapse and the time series of meteorological factors such as air temperature, precipitation, wind speed and incoming shortwave radiation. Table S1 also lists the detailed values of meteorological factors during the occurrence of ice-rock collapse in 2022.

Both Figure 8 and Table S1 show that the ice-rock collapses could occur under different meteorological combinations. For example, the weather condition of ice-rock collapse on 14 May 2022 was characterized by relative colder (8.3 ^{o}C), heavy rainfall (22.6 mm), weaker wind speed (0.3 m/s) and lower solar radiation (83.9 W/m^2). In contrast, the weather condition of ice-rock collapse on 11 August 2022 was warmer (15.4 ^{o}C), less precipitation (0.4 mm), moderate wind speed (0.7 m/s) and sunny weather (321.1 W/m^2). In addition, Figure 8 also showed no clear anomalies prior to the ice-rock events (e.g. the extreme high air temperature or heavy rainfall). This suggests that there were no immediate meteorological triggers for the ice-rock collapses and the associated debris flows in 2022 at the Sedongpu Valley. The main triggers of ice-rock collapse are worth investigating from the instability of temperate glaciers, rock properties and associated freeze-thaw weathering, pre-event seismic activity, the cumulative role of climate change and other possible factors. It is unfortunate, however, that there are few data in the high-altitude collapse regimes in the Sedongpu Valley to clarify this important issue.

Following the review comments, we have added the following Figure 8 in Section 5.1 (Table S1 in the Supplement) to discuss the possibility between the occurrence of ice-rock collapse and weather conditions. Such figure is helpful for the reader to understand the meteorological conditions in the Sedongpu valley and to answer the possible confusion about the relationship between extreme weather conditions and ice-rock collapses.

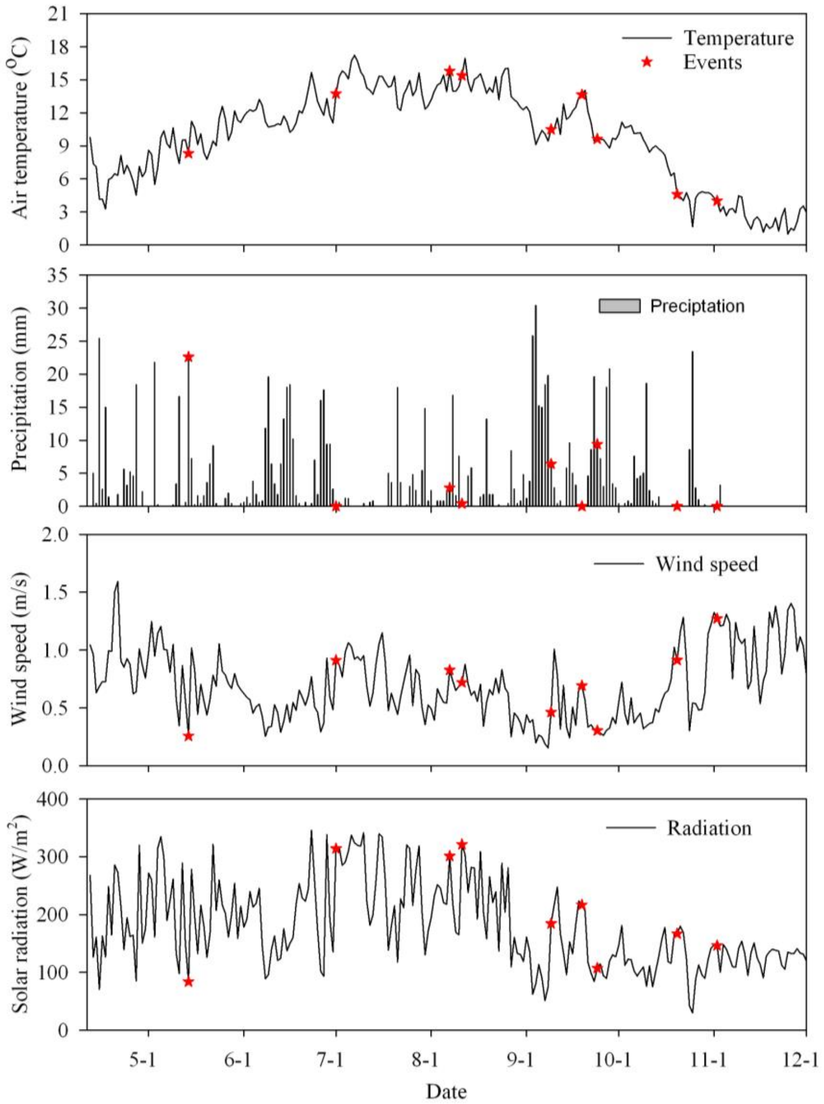

Figure 8: The occurrence of repeated ice-rock collapses (red stars) and the time-series of meteorological factors including air temperature(a), rainfall(b), wind speed(c) from EWS1 and incoming shortwave radiation from EWS3(d).

Table S1. The daily mean values of meteorological factors during the occurrence of ice-rock collapses in 2022

Collapse Time	Air temperature (°C)	Rainfall (mm)	Wind speed (m/s)	Solar radiation (W/m^2)
2022/5/14	8.3	22.6	0.3	83.9
2022/7/1	13.7	0.0	0.9	314.0
2022/8/7	15.8	2.8	0.8	301.0
2022/8/11	15.4	0.4	0.7	321.1
2022/9/9	10.5	6.4	0.5	184.3
2022/9/19	13.6	0.0	0.7	216.6
2022/9/24	9.6	9.4	0.3	107.3
2022/10/20	4.6	0.0	0.9	166.8
2022/11/2	4.0	0.0	1.3	146.4

Scientific Significance: Fair. All statements are supported by clear evidence which contributes to the understanding of these natural hazards. However, weather parameters should be further exploited to explain the weather conditions of such hazards in Sedongpu.

Reply: As the reply in above, we will add the relevant Figure 8 and the Table S1 in the revised manuscript to discuss the linkage between the occurrence of ice-rock collapses and the abnormal weather condition in the Sedongpu valley.

Scientific Quality: Good. The paper is based on exclusive observations of two remote rivers. Some references could be added to the paper to better place this paper in a global context.

Reply: We will add the following references in the revised manuscript.

Massey, C. I., Manville, V., Hancox, G. H., Keys, H. J., Lawrence, C., and McSaveney, M.: Out-burst flood (lahar) triggered by retrogressive landsliding, 18 March 2007 at Mt Ruapehu, New Zealand—a successful early warning, Landslides, 7, 303-315, 2010.

Haemmig, C., Huss, M., Keusen, H., Hess, J., Wegmüller, U., Ao, Z., and Kulubayi, W.: Hazard assessment of glacial lake outburst floods from Kyagar glacier, Karakoram mountains, China, Annals of Glaciology, 55, 34-44, 2014.

Tiwari, A., Sain, K., Kumar, A., Tiwari, J., Paul, A., Kumar, N., Haldar, C., Kumar, S., and Pandey, C. P.: Potential seismic precursors and surficial dynamics of a deadly Himalayan disaster: an early warning approach, Scientific reports, 12, 3733, 2022.

Stähli, M., Sättele, M., Huggel, C., McArdell, B. W., Lehmann, P., Van Herwijnen, A., Berne, A., Schleiss, M., Ferrari, A., Kos, A., Or, D., and Springman, S. M.: Monitoring and prediction in early warning systems for rapid mass movements, Natural Hazards and Earth System Sciences, 15, 905–917, 2015.

Cook, K. L., Rekapalli, R., Dietze, M., Pilz, M., Cesca, S., Rao, N. P., Srinagesh, D., Paul, H., Metz, M., and Mandal, P.: Detection and potential early warning of catastrophic flow events with regional seismic networks, Science, 374, 87-92, 2021.

Presentation Quality: Good. The data are well described and clear. Again, the weather conditions of these hazards are too concise here and should be further explained.

Reply: As the reply in above, we will add the relevant Figure 8, Table S1 in the revised manuscript to discuss the linkage between the occurrence of ice-rock collapses and the abnormal weather condition in the Sedongpu valley.

Line 27: can you provide a figure of the ‘rate of air temperature warming’?

Reply: We will add the warming rate of 0.42 °C per decade, which was reported by Yao et al (2022) and the relevant referenced papers.

Line 46: ‘Given the short duration of glacier collapse, it is difficult to provide timely warnings of glacier catastrophes and assess their impacts’, add ‘using remote sensing only’ at the end of this sentence, to emphasize your point about remote sensing’s limitations.

Reply: Following your suggestion, we will add it.

Line 49-51: provide more explanations about the difficulties faced with those EWSs. The reader needs to understand the limitations of EWSs, and how you are going to address these issues in your paper.

Reply: We completely agree with your comments. In the revised manuscript, we will add one sentence to address the difficulties faced with the ground-based EWS in the mountainous regimes. The following sentence will be added in the paper.

“*In reality, the installation and maintenance of EWS in sparsely populated regions generally faces many difficulties such as the instrument transport and logistics in high altitude mountainous areas, the harsh extreme weather conditions, the power supply and data transmission in cloudy and rugged regions, the reliability and compatibility of different sensors, the sustainable funding.*”

In the objective paragraph line 52 to 59, I would suggest being more specific on your objective, rather than mentioning the EWS only. For instance, on what real-time physical measurements the real-time warnings signals are based. Water level and other parameters such as soil moisture or precipitation? We find information about this only in caption of Figure 1.

Reply: Thanks for pointing out this issue. In the revised manuscript, we will re-organize the objective to address the performance of different signals for warning the occurrence and process of different types of ice-rock collapses.

"The aim of this study is to introduce the structure of three EWSs installed near/inside the Sedongpu Valley, to analyse the performance of different monitoring signals (e.g. water level, geophone waveform, meteorological variables, optical/thermal images) on warning the occurrence and process of different types of ice-rock collapses (ice-rock mixed or rock-dominated events) and finally discuss the possible monitoring priority and challenge for ice-rock disasters in other mountain regions on the Tibetan Plateau."

How your EWS is more transferrable to other regions than other EWS, as stated line 58-59. We need to have a clue of the real novelty of your approach at this point of the paper. All EWS use real-time signals.

Reply: Thank for this comment. You are right, all EWS use the real-time signals. In the revised manuscript, the pioneering work will be not mentioned any more. In the Section 5.3, one paragraph will be added to address the challenges of our EWS and other EWS.

Line 57: 'different types of ice-rock collapse', define them here in few words.

Reply: we will list two types of ice-rock collapse in the revised manuscript as "*ice-rock mixed or rock-dominated events*"

Line 54: I would, conventionally, keep 'Second Tibetan Plateau Scientific Expedition and Research Program' mentioned line 54 to the acknowledgement section.

Reply: Following your suggestion, we will move it to the acknowledgement section.

Line 67: "There were two peaks over 7000 m above sea level (m asl): Mt. Namcha Barwa (7782 m asl) and Mt.Gyala Peri (7294 m asl)." Please change 'were' into 'are', those peaks still exist.

Reply: Following your suggestion, we will revise it in the revised manuscript.

Line 70: when the summer monsoon is mentioned, I suggest to provide the annual precipitation mean of Sedongpu Valley, and its seasonal distribution (% per season). Moreover, it would be useful to know the share of liquid and solid precipitation. Heavy precipitation, and therefore saturated soil moisture can have an impact on ice-rock collapses.

Reply: Following the reviewer's suggestion, we provide the annual precipitation and seasonal distribution of Medog station in which is about 60km from the Sedongpu valley in the revised manuscript. In addition, there are less information on the solid and liquid precipitation in both stations and AWS in the Sedongpu valley. However, we provide both precipitation and air temperature variation in the Sedongpu Valley during the period from April to December. From the Figure 8, the mean daily air temperature was generally higher than zero degree. Therefore, we assumed that most of precipitation fall as rainfall at the elevation of 3300m near EWS1.

Section 3 on the history of ice rocks collapses is very informative and interesting. I suggest however to move it to the study area section (section 2) as it is not part of the EWS' results but rather a review of previous studies on this region. Moreover, information about the consequences (or even the absence of severe destructions) of the cited debris flows on villages in the lower part are needed here, in order to better understand the challenges of this valley. What happened to the villages downstream or the bridge of Gyala after the 22 October 2017 for example, once the water was released?

Reply: Both reviewers have pointed out this issue. In the revised manuscript, we will move it to the study area section. The title of Section 2 will be changed as "Study region and historical ice-rock collapses". And following your suggestion, we will add some text to address the consequences of river blockages in the revised manuscript.

For the 2018 and 2021 blockage, we will add "*This event blocking the Yarlung Tsangpo River for ~60 h and the river level increased about 75m above the original level, which damaged two upstream bridges and inundated dozens kilometres of roads and power supply facilities and forced the evacuation of at least 6000 local resident (Chen et al., 2020). The blocked dam was overtopped on 19 October, with the peak breaching flow as large as 32000 m3 and damaged the downstream hydropower station. On 22 March 2021, massive ice-rock collapses totaling 50 Mm^3 occurred in the Sedongpu Valley, producing a mobile debris flow that temporarily blocked the Yarlung Tsangpo River, leading to the inundation of road to Gyala village (Zhao et al., 2022)*"

For the Zelongnong valley, we will add "*The glacier collapse in 1950 engulfed the village of Zhibai and thus leading to 97 villager death. In 2020, a total of 1.14 Mm3 of ice-debris mixture produced a high-speed debris flow and partially blocked the Yarlung Tsangpo River and damaged the Zhibai Bridge (Peng et al., 2022).*"

Line 115: 'Since 2019, the EWSs have been built around the Sedongpu Valley.' '*Along'* the valley would better depict the distribution of EWSs based on Fig 1.

Reply: Done

Line 136-137: it would be helpful for the reader to have a brief explanation about the recurrent timing of the small-scale collapses at midnight. Is it due to accumulated solar energy during the day, frost-thaw, or any other factor?

Reply: During the installation of EWS1 in April 2022, we observed several small snow-ice collapses during the day. It is a pity, however, that the monitoring system, including the geophone, was not completed. At midnight the geophone system was running continuously and fortunately several collapses occurred and were clearly reflected in the geophone waveform. Therefore, due to the large amount of useless waveform data and the limited capability of satellite transmission, if any XYZ vector was greater than three (the maximum amplitude of the collapse in the midnight), the 200 seconds of waveform data before and after the threshold were automatically transmitted to the server. We will add the relevant description in the revised manuscript.

I suppose the meteorological parameters were recorded on an hourly basis. Please precise it in the text.

Reply: Meteorological parameters were stored at 30 min. In the revised manuscript, we will add this information.

Line 184: what sensor was used and what resolution?

Reply: we will add the details of sensor e.g. pixels for thermal/optical and resolution of water level sensor in the revised manuscript.

Figure 3a, 5a, precise the units of the amplitude.

Reply: The units of the amplitude (V/m/s) have added in the revised manuscript.

Line 212-213: 'which agrees well with the delay between the observed ice collapse in October 2019 and its delayed debris flow (Zhao et al., 2022)', please provide a value (hours) of the time of response between the collapse and the actual water level rise on that day.

Reply: According to the geophone and water level records, the time of rive blockage by the debris-flow was about 20-21 hours later than the first collapse. We will add this information in the revised manuscript.

Figure 5b, the photo is not visible and deserves a better resolution. I suggest increasing its size below Fig5.

Reply: Following your suggestion, the photo was enlarged and the photo before the occurrence of debris flow was also provided to highlight the fresh debris flow.

Line 226: 'EMS1', EWS1?

Reply: We have changed it as EWS1.

In Figure 8 (very informative), it would be better to have the same amplitude axis to better visualize the difference between collapse and seismic waveforms.

Reply: Following your suggestion, we have unified the amplitude of both X (a total of 20 mins) and Y (ranging from -40 to +40 for ice-rock collapse and -80 to +80 for earthquake) axis to show the difference between ice/rock collapse and seismic waveforms in the duration and waveform morphology. Please see the revised Figure as followings:

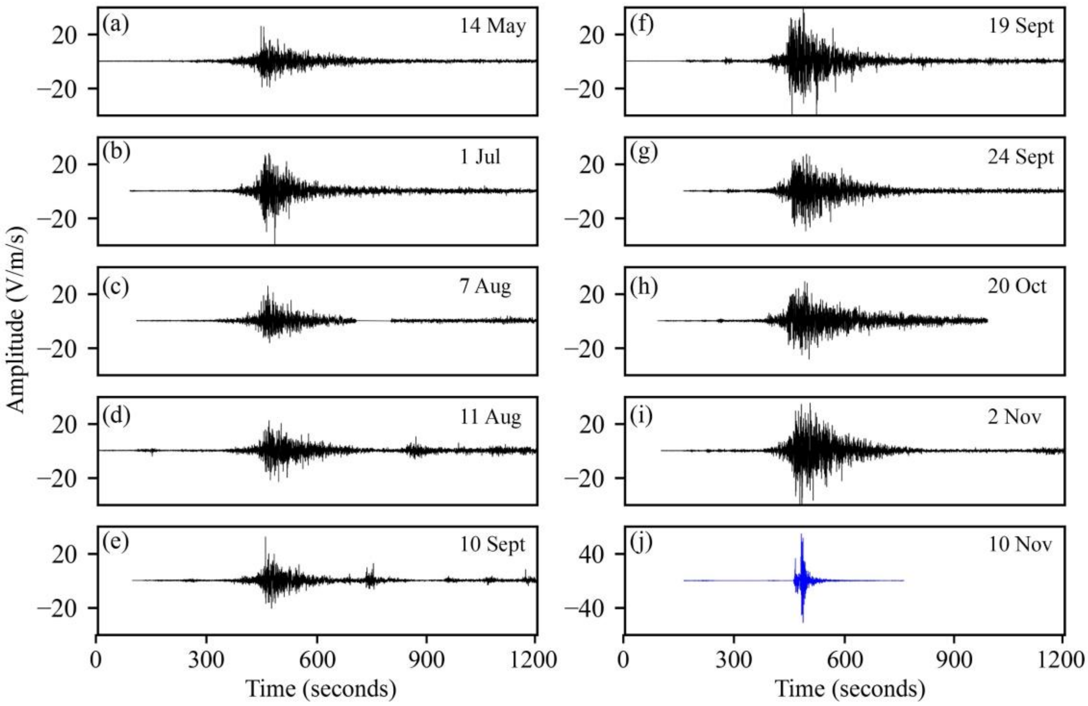

Figure 7: Comparison of the waveforms generated by a series of rock collapses occurred on 14 May (a), 1 July (b), 7 August (c), 11 August (d), 10 September (e), 19 September (f), 24 September (g), 20 October (h), 2 November (i) and the seismic waveforms generated by the earthquake on 10 November 2022 (j). Note the different y-axis limits.

In Figure 8, add the Hugonnet and Millan references in the caption.

Reply: We did it.

In the discussion, you may want to go through Tiwari et al., 2022 and compare your approaches using amplitudes. (Potential seismic precursors and surficial dynamics of a deadly Himalayan disaster: an early warning; https://doi.org/10.1038/s41598-022-07491-y). It's worth adding this reference in the discussion section. See also Cook et al., 2021: 'Detection and potential early warning of catastrophic flow events with regional seismic networks', DOI: 10.1126/science.abj122

Reply: Thank you very much for this comment. We have cited these two important references in the revised manuscript. Detailed retrospective analysis of the waveform showed that some possible precursors were present before the collapses. However, regarding the possible noise is concerned, there is no solid evidence that such signals could be used as the pre-warning way. In section 5.3, we will discuss the challenges and priority of seismic warning and more relevant references will be cited in the revised manuscript.