Interactive comment on “Kinematic observations of the mountain cryosphere using in-situ GNSS instruments” by Alessandro Cicoira et al.

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General response:

We thank the two reviewers for their positive and constructive comments. Thanks to their comments, we have substantially re-structured and re-written the manuscript, designed, and updated most of the figures and updated some of the (meta-) data.

In this review, we provide a detailed answer to both reviewers regarding:

- Their major comments
- Some of their minor comments, for which discussion was needed

Please, note that in the track-changes version of the article there might be some mistakes due to the large amount of text that has changed. Especially the tables showed errors during compilation. Please, use the updated manuscript as a reference. The other minor comments, which did not require extensive explanations, are directly amended in the new version of the manuscript.

Reviewer #1:

Detailed answer to the major comments of reviewer #1:

I strongly recommend checking the document for correct spelling and wording. English is not my mother tongue, but I believe that I can read technical text that covers my field of expertise. Many passages in the text were characterized by extremely long sentences, some of them were not well-structured. I tried to make improvements (see the PDF-document), but at times I found the sentences not conclusive. I recommend shortening complicated sentences by splitting them in several parts. In the end, the final document should maybe be checked by a native speaker. That should improve the text significantly.

As suggested by reviewer #1, we have checked the manuscript for spelling and wording. In particular, we have followed the suggestion to shorten some sentences and being more careful with technical language. In fact, we have restructured the entire manuscript and rewritten substantial parts, with the aim of shortening and focusing it and making it clearer for all the readers.

I would change the title of your paper since I have a different understanding concerning “kinematic observations”. From my point of view, kinematic GNSS observations are best described by a rover/platform that is moving. Therefore, you have to determine a new position for every epoch. Looking at your figure B1 it clearly indicates that you have used the tool “rtkpost” for processing the double difference observations in a “static” mode. That means you assume a stationary position during the observation period. The control points are stationary on a daily basis but move over the years. Therefore, reconsider the title of your paper.

We have updated the title to: “In-situ observations of the Swiss periglacial environment using GNSS instruments”. The issue with the usage of the term "kinematic" is originates in the multidisciplinary nature of this work. In geosciences and in general in mechanics, the term "kinematic" refers to the study of the motion of an object. We understand that in geodesy this has a different technical meaning. Operating at the boundary between different fields, we tried to make sure that the reader can discern between the use of the term in the two fields.

All the minor comments directly embedded in the manuscript are implemented (or rejected) without discussion, as also suggested by the reviewers.

In the following, we provide an answer to the minor comments of reviewer#1 that require some discussion:

You are using the term “double differential GNSS processing” all over your paper. I am used to the terms “differential GPS [GNSS]” or "double difference processing". The typical observable processed in GNSS data analysis is the double difference. My background is geodesy, and we always talk about "double difference processing". Please consider changing the term “double differential processing”.

We have amended all the text for the incorrect use of "double differencing processing" to “double difference processing” as per the recommendation.

Often you use the term “raw observations”. This needs clarification in your document. I suppose that you mean with “raw GNSS observations” the availability of carrier phase data. The geodetic GNSS community considers raw observations as the data provided by the receiver. In your case, these are ubx-files. Those are converted to RINEX (Receiver INdependent EXchange format) to be processed with different software packages. Check your document for the use of “raw observations” and explain it. It is also very important that you mention the availability of the phase observation, which are required for precise relative positioning.

We have clarified the use of the term "raw observations", which is referred to the RINEX files. All the relevant details are provided in the section “Primary data products”. All RINEX files as was described in the original manuscript contain carrier phase measurements, pseudo-range values as well as Doppler shift and raw signal strength data. The wording has been clarified.

At one place you write about the RINEX-2 specific abbreviation for the code, phase, Doppler and signal-to-noise observations without explaining it: “These contain C1 and L1 as well as C1, L1, D1, S1, P2, L2, D2, and S2 observables of the L1 and L1/L2 GNSS.”. Please add the necessary information.

The wording has been clarified.

Please write a few more sentences concerning RTKLIB. It consists of a number of tools and from what I have seen you have used “convbin” and “rtkpost”. Describe these two programs and their purpose shortly. Did you test other tools as well? RTKLIB has so far only been maintained by one person and new versions have not been published very often recently. Therefore, RTKLIB´s future may be uncertain and one has to switch to other programs.

As stated in the manuscript we are using two tools for post-processing: Bernese and rtklib. As Bernese requires a license and extensive user know-how to operate we are not giving details in this paper but include the data produced in the dataset. We concentrate on an open-source and accessible solution here. A detailed comparison of tools and their capabilities is out of the scope of this data paper.

It is correct that rtklib is more or less a one-man-show by the author. However it is well maintained with regular updates and there exist multiple well maintained forks. We actually mention the option to also download rtklibexplorer which is one of these forks. The last code update on github for this package has been done a few days ago. Therefore we are of the opinion that this is an actively managed tool. By giving detailed descriptions and also our script package to drive the post-processing the reader should be readily possible to also adapt the processing to another tools should this be desired.

The description of the rtklib script package has been refined and augmented.

You are using the term SLURM without explaining it. What is the advantage or purpose of SLURM in this context? Did you analyse the data with a linux version of rtkpost?

Slurm is an open source, fault-tolerant, and highly scalable cluster management and job scheduling system for large and small compute clusters. A comment about the processing platform (linux x86) has been added.

While looking at your RINEX data I noticed that many of them are provided in RINEX-3.04. In your paper you mention only RINEX-2. Please add information on RINEX-3. After uncompressing the data I was wondering that they are not compressed with the Hatanaka-compression. You are providing a very large amount of data. Using a zip-compression we are talking about 100 Gigabyte of RINEX data. In table 6 of your document you state that entire size of the RINEX data is 297 Gbyte. Therefore the zip-compression reduces the data to 30% of its original size. Using first Hatanaka-compression and then zip-compression would allow to reduce the data to nearly 10-15% of its original size, which is significantly smaller than the provided data. Scripts like RNX2CRZ or CRZ2RNX [Hatanaka, Y. (2008): A Compression Format and Tools for GNSS Observation Data, Bulletin of the Geographical Survey Institute, 55, 21-30, available at http://www.gsi.go.jp/ENGLISH/Bulletin55.html] can easily compress and decompress the data. It is a standard used in the GNSS community. This will save resources at Pangea.

All data are now RINEX-2.11 files. The mix of formats was due to the different origin of some of the geodetic reference data files. Also all files have now been compressed per your suggestion. A short description was added to the text.

You are providing three files with meta-data for different areas. Within these files the information given for the GPS receivers is only “GPS Logger”, but not that it is a u-blox LEA-6T receiver. Also the antenna type is missing. The given coordinates of the sites are without information on the type, reference frame or projection. Please add these items.

We have re-structured the manuscript and now all the information about the logger and the antenna types are given in Section 2 (Instrumentation technology and data management) and in Section 4 (Primary data products). The metadata excels have been included for the sake of completeness of the dataset containing much more data and sensor locations than documented in this paper, e.g. all field interventions. These are the original metadata files that have grown over many years of multiple projects.We feel it is nice for the users of this data to have access to this data but of course these can be removed easily if you see it as a complication.

While looking at your RINEX data I tested the Hatanaka compression and run into a problem. Obviously, the raw data translator “convbin” did not provide standard RINEX. In a next step I used “gfzrnx” (GFZRNX - RINEX GNSS Data Conversion and Manipulation Toolbox supplied by the GFZ) that was able to read the data and convert them into standard RINEX. Then it was possible to compress the RINEX by the tool “RNX2CRZ” applying the Hatanaka-compression and a zip-compression.

This was a bug relative to the version used. In the current newest version of RNX2CRZ/CRX2RNX it is all working out fine now.

I also realized that the metadata are not provided in most of the RINEX headers. Information on the used receiver, antenna, approximated position and antenna height is missing. Please be aware that some software packages require this information. This information is not always mandatory, but some users applying different software tools to this GNSS observations may be forced to preprocess the data accordingly. It would be good style to add this missing information, because then it complies with the RINEX standard and also ensures the use of the data in the future. I realize that it is extra work. But I believe that with suitable scripts this is less effort than one might think at first.

The receiver and antenna type have been included into the RINEX files. As for the antenna height this cannot be included as suggested. It is often unclear what the true zero in z-axis is at a GNSS sensor location as has been described and also since most sensors exhibit rather strong motion, this value will change over time and therefore no sensible value could be included in the RINEX file headers.

Reviewer #2:

Detailed answer to the major comments of reviewer #2:

The landforms that are instrumented must be clearly defined from the start and for each location, for the dataset to become useful for future users. The title is fuzzy: Mountain cryosphere is a very wide domain, it could theoretically include snow, glaciers, ice on lakes, etc. If you mean permafrost, just say it so. If many sites are not in permafrost zone (which is btw fuzzy in the paper): 'periglacial landforms' / 'slope movements' / 'gravitational landforms' could be used. A list of elements is provided at l.37-38 and l.59, but it lacks clarity: What is the difference between a rockfall site and a single unstable block? Or between a large rockfall site and a landslide? What do you mean by 'fractures' (l.59): it does not fit in a list of landform types I think. In general, I would suggest that you simplify by using 'rock glaciers' and 'unstable rock slopes' (all along the manuscript, also in Section 6). The terminology must also be briefly defined in the introduction to understand what we are speaking about. In tables 3 and 4, please add a column documenting the landform type / context. If not, potential future users will have a hard time to use the data in a meaningful way. Section 6 provides a rough number / landform types (except for landslides, l.452), but it is really hard to have an overview of what is documented and where. Maybe additional regional maps with sites categorized by landform types could help?

We welcome the suggestion of the reviewer and try to improve the manuscript in this direction as much as possible. The variety of all landforms has been reduced to three categories only: rock glaciers, landslides and steep rock walls. Furthermore, we have put some effort in an attempt to give a short but detailed overview of all the different mass movements that have been investigated, which is now Section 3 (Field sites) of the new manuscript. A new map (Fig. 2) has been added to the manuscript, including more graphical information. A division of the measurement points is not possible at this level, but this should be clear from the text. The newly adopted terminology complies with the Varnes-Hungr classification. Finally, in the Appendix A, the landforms are described and a kml file with all locations has been included as supplementary material.

The relevance description could also be improved. There are numerous vague statements regarding the link with climate (l.148-151, l.494-497) and mixing hazard assessment & risk mitigation (l.79, l.153-154) (see also comments in pdf).

We welcome this comment, and we understand that some statements were vague and hard to follow for the reader. We have re-structured the manuscript and now the project history, the evolution of the measurement network and the relevance of the observations are clearly discussed after the results.

GNSS and GPS terminology, as well as the references to the different generations of sensors are used in an inconsistent way all along, without actually explaining the differences (e.g. l.106, l.185, fig.6 caption, tables 3-4: L1/L2-GNSS vs L1-GPS). In general, it looks like the authors assume that the technology is an obvious background knowledge for all readers. As a result, some theoretical explanations are just spread in the manuscript without clear references and explanations (e.g. in 3.1, 3.4, 3.7). What we mean by data expressiveness (l.152, l.193) is not explained. Explanations regarding the sampling, the schedule, the granularity are really unclear (l.273-279) (probably party due to English). I think one solution would be to have a section early enough in the manuscript that briefly explains the main theoretical elements for nonexperts (as a method section in a traditional article structure). The expected/estimated accuracy of the GNSS data is never explained (n.a. in Table 2). Instead, there are very vague words/statements such as 'very small displacements' (l.78), 'high accuracy' (l.304), 'highest fidelity' (l.487), etc. The quality measure 'ratio of fixed ambiguity' is never explained (l.309, Table 5). Some limitations of the method are presented (for ex. Section 3.7) and solutions to mitigate them introduced (for ex. Section 5.2) but it is scattered in the paper. I would suggest adding a section on limitations/uncertainties that regroup all these elements.

We welcome the comment of the reviewer. We can trace it back to two main issues. On the one hand, there were some inconsistencies in the manuscript, which have been amended. On the other hand, the structure of the paper had to be improved. For this reason, we completely re-structured the manuscript, including a second section about the sensors (methods), a section about the field sites and sampling strategy. This also answers the next comment.

The structure is not traditional, and it makes it hard to follow. There are also many subsections and I must admit I got a bit lost along the way. So here is a suggestion (there are surely other alternatives - it is just an example, a way to illustrate my thought):

Introduction: The current intro is quite fuzzy. It could go directly to the point, explain the project background and relevance.

Methodology/Technology: Technical knowledge on the sensors, explanations of the main terminology and the different generations of integrated system.

Data/Products: 3.1. Site description (that should include information about which landform is documented), 3.2. Primary data, 3.3. Derived products.

Limitations/Uncertainties: The problem of tilting / site challenges (current 3.7) could come here. It also should include an accuracy estimation and explanation of the quality measures.

Applications: Here come the examples of previous exploitation as in the current Section 6, but maybe reorganized as 5.1 rock glaciers / 5.2. unstable rock slopes?

We welcome the suggestion of the reviewer and implement it as far as possible, see also the previous answer. We have improved the clarity of the text by modifying its structure, introducing more carefully technical terms and abbreviations.

The figures could also benefit from some work to be more readable / useful. For example:

Figure 2: hard to see what we are looking at without help (delineated landform, arrow to point out the described elements).

Figure 5: the third plot is dominated by the extreme increase of LS05, such as we don't see anything for the others. Two scales maybe?

Figure 6: without explanation, this figure is not very informative to be honest...

Figure 7: missing unit on y-axis and unclear legend of colors.

Figure 10: a zoom on one local cluster would help to read it.

Figure 14: it includes many elements that are never explained in the paper. I would suggest simplifying it (or explain it better in the text and/or in the figure caption).

Figure 15: where is the blue line (raw data)?

Some improvement was possible in the figures, so we updated and re-ordered most of them and moved a few to the appendix. The text and the figure should be much clearer now.

More detailed comments in the attached pdf.

These comments have been addressed directly in the new version of the manuscript.