GEO Mountains Workshop: Interdisciplinary Monitoring, Data, and Capacity Sharing across East Africa

University of Rwanda, Kigali, Rwanda

27 October 2023

Final Report (for Dissemination)

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Organised and supported by:

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Contents

1. Introduction & Workshop Aims

The workshop was part of a series of regional engagements undertaken in 2023-24 by the Mountain Research Initiative (MRI) in its role co-leading the Global Network on Observation and Information in Mountain Environments (GEO Mountains) under the Adaptation at Altitude programme (A@A). The workshop in East Africa took place on Friday 27 October 2023, and was convened by multiple partner organisations that included the Albertine Rift Conservation Society (ARCOS), the University of York (UK), and the World Meteorological Organization (WMO).

The workshop was hosted by the Center of Excellence in Biodiversity & Natural Resource Management at the University of Rwanda, Kigali, Rwanda. The workshop coincided with the World Climate Research Programme (WCRP) Open Science Conference 2023 which was also held at the same the venue and was designated as an official side event of the conference programme.

The workshop sought to bring together data providers and users from a range of disciplines whose work centres on mountains across the East Africa region. More specifically, through a series of short, invited presentation and group discussion activities, the workshop sought to:

1. Establish the current status of monitoring and associated data availability from multiple disciplines and countries / sub-regions, including the identification of best practices;
2. Explore opportunities to enhance capacity sharing in relation to mountain monitoring and associated data availability;
3. Identify potentially high-impact projects that could be conducted collaboratively by integrating observations from different disciplines, sub-regions, and methods represented by the participants, and;
4. Provide opportunities to network and establish personal connections and specific collaborations.

This report presents the workshop proceedings and summarises the key points, outcomes, and recommendations that arose from the discussions.

The workshop was attended by representatives of environmental monitoring national agencies, researchers, and local institutions. In total, 32 participants attended the workshop, of whom 30 attended in person and 3 online. Participants came from across the region, including Rwanda, Uganda, Kenya, the Democratic Republic of Congo, Tanzania, and Ethiopia, plus international guests, invited speakers, and participants from outside the East Africa region including from Zimbabwe, South Africa, the Netherlands, United States of America, China, Norway, Switzerland, and the United Kingdom. For the full list of attendees, see Annex 2.

2. Previous Workshop & Consultation: Southern Africa, 2022

The workshop was partially built upon a session organised by GEO Mountains that was held at the Southern African Mountain Conference (SAMC) on 15 March 2022; whilst the focus on this occasion was more explicitly on the mountains of East Africa, one of the focal regions of A@A, in the spirit of inter-regional exchange, there was still some representation from southern Africa (Dr. Johan van Tol).

For reference, the main conclusions from the presentations and the consultation exercise that accompanied the SAMC 2022 can be accessed here [1]. At the SAMC session, a series of invited presentations were given. The main points communicated by those presentations include the following:

- Climate change projections for southern Africa show a strong likelihood of drying and warming. These will have impact on droughts and fire risk, mountain top species and the African cryosphere.
- The South African Environmental Observation Network (SAEON)'s new Data Portal [2] and associated infrastructure was presented, which provides a means by which mountain datasets from across the entire continent can be shared according to the FAIR principles (Findable, Accessible, Interoperable, and Reusable)
- Financial resources and lack of awareness at policy and legislative levels regarding the importance of mountains were identified, *inter alia*, as key barriers to improving the coverage of systematic observations in Kenya's mountain regions.

Regarding the subsequent consultation exercise, it should be highlighted that most participants came from either South Africa or Lesotho. Still, several main outcomes helped to frame the engagement in East Africa, including the following:

- Respondents relied upon a diverse range of approaches for discovering datasets, including "reading journals and technical reports", "word of mouth / from colleagues", and and "via web-searches". In contrast, "searching geospatial catalogues" was the primary means of data discovery for only a small proportion of respondents;
- Interestingly, a majority of respondents indicated that they would consider sometimes paying licence fees to access important datasets
- A combined proportion of half of the respondents indicated that they frequently or sometimes experience difficulties discovering, accessing, or using data necessary for their jobs / roles, and no respondents reported that they never experience such difficulties;
- Land use intensities, reliable long-term homogenous meteorological and hydrological datasets at high elevations, monetary ecosystem service value estimates, socio-economic data (e.g. unemployment rates and incomes), and information on mountain development policies were some of the specific datasets / sources of information that are currently lacking;
- A clear majority of respondents indicated that addressing the most critical data gaps would either greatly or somewhat improve the efficiency and impact of their work;
- A clear majority of respondents likewise stated that they make their own data freely available to others for research / non-commercial purposes, and this is largely achieved via institutional or external repositories. Other data (and code) sharing options mentioned included providing it in form of Supplementary Material to a scientific article, or posting it on GitHub;
- The primary motivation cited for sharing data was altruistic, i.e. as a service to the community, though some respondents indicated that they are mandated by their institutions to share data;
- "Making the actual measurements" (including data processing) and "generating informative metadata" were identified as the most problematic steps for data providers across the data lifecycle. "Finding a suitable repository", "selecting an appropriate licencing option", and "funding" were all reported to be lesser concerns;
- "Limited time / funding", "limited technical capacity" and "(inter-) institutional competition" were all identified as being amongst the more significant barriers to more routine or

extensive data sharing. In addition, a few respondents mentioned the perceived lack of incentive of not all journals / funding agencies requiring data sharing at present.

- As in other regions, Open Data and Open Science were deemed to be "extremely important" or "somewhat important" by a remarkably high combined proportion of respondents;
- Many respondents indicated that they have shared research materials (e.g. code, data) associated with at their research projects or papers in the last five years;
- The increasing prominence of data journals (in which "data descriptor" papers are presented) was viewed extremely positively;
- The following strategies were identified by respondents as having the most potential to improve the availability and usability of climate and climate impact-related data in the region's mountains: "extending in situ observations and establishing so-called Mountain Observatories", "combining situ data, remotely-sensed data, and numerical models to generate spatio-temporally complete datasets that are informed to the greatest extent possible by all available observations", and "exploiting the latest climate models for both historical reanalyses and future predictions";
- Responses to a question regarding the importance of various possible functionality of (an) online data portal(s) were fairly evenly split, with "straightforward links to download the data" and "efficient filtering of data entries by (sub-)region / discipline receiving the highest response proportions;
- Respondents' agreement with the statement that "the large number of different geospatial data portals complicates the discovery of relevant datasets" was neutral-to-moderate, and
- A dedicated regional data inventory or portal was deemed fairly important by respondents.

These findings from the engagement in southern Africa can be considered something of a point of departure for the East Africa workshop, or at least help further contextualise the outcomes (for example in terms of similarities and differences between the regions).

3. Workshop Programme & Key Points

In this section, the workshop programme is presented and the subsequent discussions held are summarised. The workshop was facilitated in a hybrid mode, with the possibility of online participation. For further details on the presentations, please see the slides which are available via the link given in Annex 1.

9:00 – 09:10: Welcome – **Dr. Carolina Adler** (MRI; virtual) and **Prof. Beth Kaplin** (University of Rwanda)

Dr. Adler and Prof. Kaplin welcomed the participants to the workshop and to the University of Rwanda.

9:10 – 09:30: Workshop Objectives, Participants' Expectations & Overview of GEO Mountains – **Dr. James Thornton** (MRI)

Dr. Thornton began by thanking all co-organisers and introduced the workshop's aims from the perspective of GEO Mountains. He proceeded to invite all participants to share their own expectations of the workshop, as well as any initial general ideas or thoughts concerning the topic (see Annex 3). An overview of GEO Mountains' recent activities and

areas of work was provided, and all participants were given the opportunity to briefly introduce themselves and their main activities.

09:30 – 10:45: Flash Talks Session #1.

In advance of the workshop, each invited speaker was asked to focus their presentation by reflecting on the following question: "***Based on your knowledge, experiences, and activities conducted in the region, what solution(s) are you aware of or have explored / implemented to address common challenges encountered in monitoring / observing Africa's mountain systems?***"

The first session of flash talks began with a general initial presentation by Dr. Muganga on behalf of ARCOS. Thereafter, a series of presentations focusing mainly on meteorology / climatology and hydrology were given. Following the presentations, some time was assigned for questions and answers.

- *African Mountains: Overview, Challenges, and ARCOS' interventions* – **Dr. George Muganga** (Albertine Rift Conservation Society; ARCOS)

- *The Trans-African Hydro-Meteorological Observatory* (TAHMO)*: Ten years of challenges and successes* – **Prof. Nick van de Giesen** (Delft University of Technology & TAHMO)

- *Supporting Ecosystem Conservation in Kenya's Mountain regions through Meteorological Data Rescue and Digitization ("SECoMet")* – **Dr. Joyce Kimutai** (Kenya Meteorological Department)

- *Alpine Wetland Degradation in the Maloti-Drakensberg Mountains: Theories, Perceptions and the Need for Baseline Research* – **Prof. Johan van Tol** (Afromontane Research Unit, University of the Free State)

- *Groundwater Monitoring in the Kenya Rift* – **Dr. Lydia Olaka** (The Technical University of Kenya)

10:45 – 11:15: BREAK

11:15 – 12:30: Flash Talks Session #2

The second set of flash talks placed greater emphasis on alternative sources of climate data (Dr. Cuni-Sanchez), as well as ecological and biodiversity data from across the region. Flash talks were designed as short inputs of 5 minutes each.

- *The Importance of Local Perceptions on Climate Change* – **Dr. Aida Cuni-Sanchez** (Norwegian University of Life Sciences)

- *Past and Present Challenges for the Eastern Arc Mountains of Tanzania and Future Opportunities* – **Prof. Rob Marchant** (University of York)

- *Ecological Observations in Two Mountain Regions in Tropical East Africa: Key Challenges and Opportunities* – **Dr. Fredrick Ssali** (formerly of the Institute of Tropical Forest Conservation & GLORIA)

- *Monitoring Landscape Changes around Mt. Kenya with Concurrent Invasive Species Mapping using Remote Sensing and Machine Learning Approaches* – **Dr. Edward Ouko**, (Regional Centre for Mapping of Resources for Development; RCMRD)

- *Monitoring Mountain Ecosystems using Geospatial Analysis* – **Waswa Rose Malot** (AfriGEO & Regional Centre for Mapping of Resources for Development; RCMRD)

- *Making Biodiversity Data Available* – **Prof. Beth Kaplin** (Center of Excellence in Biodiversity & Natural Resource Management, University of Rwanda)

- *"Mountains Adapt" Solutions*: Underlying Data and Information from East Africa **– Janvier Hitimana** & **Yvonne Bigengimana** (Albertine Rift Conservation Society; ARCOS)

12:30 – 13:45: GROUP PHOTO & LUNCH

13:45 – 14:45: Discussion on opportunities for enhanced cross-disciplinary and cross-sector exchange of data and capacities and the involvement of students & Early Career Researchers (ECRs) in mountain monitoring activities (**All; Led by Prof. Rob Marchant**)

Participants were randomly divided into three small groups. Each group was invited to appoint a Rapporteur and then independently discuss a common set of (somewhat inter-related) questions. Following this, all participants reconvened for a reporting session in Plenary. The specific questions posed were as follows:

1. What are the current monitoring strengths / capacities in the region? In which regards is the mountain data situation already good?

2. What are the major data / knowledge gaps? What are the main opportunities to enhance monitoring (e.g. extend thematic scope at existing sites, employ multi-method approaches, extend spatial or elevational coverage)?

3. What are the barriers to enhanced free and open exchange of data and information from multiple different disciplines in the region, plus possible solutions?

4. How can the exchange of data and knowledge / capacities between the research and operational monitoring communities be enhanced?

5. What further opportunities exist for embedding student research projects / field courses in existing monitoring sites?

Below, the main responses are summarized by each group:

Group 1 (Rapporteur: Robert Marchant):

- An identified strength is the network working on issues related to carbon stock quantification in African mountains (e.g. Aida Cuni Sanchez, Angela Galago-Sala and colleagues), which has begun to yield important results. A good diversity of associated variables are measured, used, and exchanged, and efforts are made to explicitly incorporate traditional or local knowledge.

- Group 1 also discussed more broadly the standardization of data, and the need for completeness and transparency of metadata (including e.g. measurement units) to allow use or increase ease of use;
- The notion of a minimum set of variables that should be measured and standardized across regions (which could be considered "Essential Variables" or "Essential Mountain Variables" was also deemed to be potentially useful.
- Promising development in technology and mobile access were also identified. The group discussed applications to which mobile and other technologies could contribute, notably citizen science / "crowd sourcing" initiatives. The group also noted the increased availability of data thanks to open access initiatives.
- One of the outstanding challenges concerns metadata, and in particular the importance of the variables being precisely described / defined. Another challenge (which was also identified as a strength to some extent) is the increase in the numbers and types of sensors that has been observed, which implies a strong need for strong technical capacities to make use of the associated data.
- The fundamental value of data was highlighted, and the group suggested that better connecting the monitoring community with regional databases and hence data users could lead to important advancements.
- Several related ideas emerged from the group's discussion, such as organizing a half-day workshop on knowledge sharing with communities (public). This would be the opportunity to connect and engage with users of data / associated knowledge and to understand their needs. Engaging more with youth groups was a suggestion along similar lines.

Group 2: (Rapporteur: Fredrick Ssali):

- The group identified several areas of strength, including good and improving manpower, skills, and technical competencies. Active institutions (governmental and non-governmental) and the existence of standardised monitoring protocols (such as the Global Observation Research Initiative in Alpine Environments; GLORIA) [3] have also contributed greatly to the current situation. Satellite data are readily accessible, and there are now some resources available (including funding, datasets, and associated tools / software). According to the group, all these areas have potential for further strengthening, however;
- The major data/ knowledge gaps identified were: i) in relation to understudied species (reptile, amphibians, cryptograms, lichens), for which there is a clear need for specialists to work on emerging areas, ii) a lack of in situ climate observations, iii) and extremely limited standardised data on human and cultural aspects, which are crucial to effectively develop solutions to adapt to challenges posed by climate change.
- There is likewise currently a lack of "overview" of existing knowledge and exchange on what others (in other regions, at other institutions, or working in other sectors) are doing, and this impedes progress towards more integrative research approaches, although the current workshop and the GEO Mountains' inventories have the potential to improve this situation.
- The cost of mountain research (including not only station installation but also maintenance, data management through challenges of access etc.) is sometimes prohibitive and identified as a major challenge. To address this, there is a need to develop models for more equitable sharing of monitoring costs / risks (with ultimate data users) be developed / implemented?
- Several possible solutions to some of these challenges were explored by the group, including developing more formal networks at regional level, improving the communication between researchers and institutions (e.g. a local newsletter or WhatsApp group, with the latter in particular being deemed highly effective in the region), seeking funding for joint proposals, and developing data sharing frameworks, agreements, or Memoranda of Understanding; all

such activities could somewhat reduce the perceived current "fragmentation" or isolation of the community according to specific research field and/or country. The possibility of a dedicated East Africa workshop or session at the Southern African Mountain Conference 2025 could be explored as a next step.

- Finally, three main steps needed to improve data and knowledge availability and usability were proposed: i) define metadata following established frameworks / methodologies, ii) engaging in participatory project planning and co-design to improve involvement and communication both within and beyond the scientific community, and iii) working to digitise observational data that currently only exists in analogue forms ("data rescue", including of paper-based climatological data).

Group 3: (Rapporteur: Humphrey Maganga):

- The ground identified the following monitoring strengths: i) the availability of spatio-temporally complete environmental data (e.g. the Climate Hazards Group InfraRed Precipitation with Station data; CHIRPS) [4] , ii) the existence of some good policies and governance structures, iii) effective international collaboration / twinning programmers, for example between the Kenya Meteorological Department and MeteoSwiss (who are currently collaborating on a project under the GEO Mountains Small Grants Scheme 2023), and iv) available data sharing infrastructures.
- The major gaps identified included a lack of high-resolution soil data across the region (but see Africa Soil Information Service), a lack of political will to routinely share data collected by some government agencies, and some limitations in terms of technical skills (e.g. data processing).
- Similarly to Group 2, developing data sharing protocols and standards was identified as a potential solution, as was making efforts to improve levels of trust and communication between organisations (across different levels).
- Good opportunities could be made for students and Early Career Researchers though enhanced collaboration between different research groups / institutions, including between the research and operational sectors, building upon existing personal relationships.

From the above summaries, while many common challenges clearly emerged (especially the need for enhanced data exchange and communication), different research fields equally have some specific / unique challenges.

14:45 – 15:45:

- Demonstration of a workflow to compare in situ and gridded climate data in East Africa's mountains (**Led by Dr. James Thornton)**

  Dr. Thornton explained that due to the limited coverage of in situ climatological observations across the regions (often rather coarse), great reliance is placed on gridded climate data products. Thanks to platforms such as Google Earth Engine (GEE) [5], accessing and integrating these large datasets into scientific workflows has never been more straightforward.

  Yet is crucial that users of these products have as good an appreciation of possible of their accuracy, uncertainty, and general utility, in particular for mountains (for instance whether performance in comparison to some benchmark data decreases with increasing

elevation, or the extent to which other notable spatial patterns in quality / performance are discernable). Thanks to the efforts of multiple initiatives and institutions represented at this workshop, plus others (e.g. TAHMO, the Kenya Meteorological Department, data compiled under the Global Historical Climatological Network (GHCN) [6], research-oriented monitoring on Mt. Kilimanjaro and elsewhere), an increasing amount of in situ ("ground truth") climate data are available, but are distributed across many "nodes" and are somewhat heterogenous in terms of format or accessibility.

The potential could therefore exist to "pool" this in situ data and use it as reference data to conduct a rather comprehensive assessment and intercomparison of various available gridded data products. Whilst several similar papers have already been presented, do our best knowledge none have integrated in situ data for such a diverse set of sources, considered multiple EMCVs and / or focused specifically on mountain regions (including elevational dependencies / patterns). This idea could therefore represent one possible joint project that could emerge from the workshop.

The preliminary workflow presented by Dr. Thornton was based on a GEE script which efficiently extracted daily precipitation data from two alternative products from pixels within which climate stations (from multiple networks) are located. The results of the gridded dataset comparison for a four-day period during which intense, flood-inducing precipitation occurred demonstrated that whilst there is some correlation between the respective pixel values, a great deal of scatter (i.e. disagreement) was also apparent.

If a group of participants decides to work on this (or submit a proposal to obtain dedicated funding for such a project), the next steps would be i) to agree a standard format in which all in situ time-series should be prepared / converted (including treatment of gaps), ii) develop and apply a standardised workflow (e.g. in the form of a Jupyter notebook; [7]), and iii) compile and write up the results. If desired, climate change perception data, obtained via community surveys, or other information combined via citizen science (e.g. using mobile apps) could also be introduced.

Some participants expressed interest in having further discussions regarding such a project.

15:45 – 16:15: BREAK

16:15 – 17:15: Final discussion

- Discussion of possible next steps on climate data comparison & identification of other potentially high-impact projects that could be conducted collaboratively using existing data and information **(All)**

  This final discussion, which was held directly in plenary, was oriented around the following questions posed to participants:

  1. What can we do or develop to improve the offering / possibilities for students and ECRs, for instance in terms of training / capacity sharing courses, workshops on the writing and peer-review processes, etc.)?

2. What other potential collaborative, interdisciplinary projects could be developed by combining some of the datasets that have been presented today?
3. What are the key questions (scientific, practical, or policy-related) that we need to address to deliver relevant information for environmental management, sustainable development, and climate change adaptation, but have not or cannot yet?

In response to these questions, the following key points were raised by participants:

- To improve the capacities of the next generation of mountain scientists, it was suggested to arrange a dedicated residential field school (similar to the summer schools organized by the UN Food and Agriculture Organisation (FAO), e.g. the International Programme on Research and Training on Sustainable Management of Mountain Areas (IPROMO; [8]) and GROW [9], but focused specifically on the context and challenges of (East) African mountains (and especially data-related aspects). In such a workshop, participants would also be directed to relevant data and tools and shown how they might be used. An important challenge would be to identify prospective funders and eventually secure the funds necessary. There could be potential for various interested organisations / networks to co-finance such a course.
- Participants suggested that similar projects are successful in some regions, but less so in others. Variability in capacities was hypothesised as a reason for this. Related to that, participants emphasised the need to fully involve local communities (including during the project design phase), and to develop citizen involvement in monitoring and associated activities wherever feasible. For example, assisted by modern mobile technology, engagements could explore how communities relate to mountain ecosystems and how their experiences of any trends relate to those present in observational data.
- Efforts to communicate past "success stories" could be redoubled; for instance, many ecosystem restoration efforts remain unevaluated in quantitative terms. In this sense, there should be a constant cycle of monitoring, first to provide support for the design of climate change adaptation and risk mitigation solutions, but then to also evaluate their effectiveness. Related to this, the organisers highlighted the existence of the Adaptation@Altitude Solutions Portal [10], which provides a set of examples of actual mountain climate change adaptation interventions which could inspire or be modified to inform new interventions in similar settings elsewhere.
- Communication efforts should also entail better connecting scientists (and more specifically the scientific data and knowledge they generate) with policy- and other decision-makers. For example, some participants suggested policy briefs could be more routinely developed from scientific papers and shared with the relevant stakeholders (including national-level decision makers); see e.g. weADAPT. However, other participants emphasised the need for communication activities to be creative and innovative in if they are to gain traction, with traditional policy briefs for instance perhaps not being the most conducive format. Rather, it was suggested that engaging with communities / research users from the start and in the methods (such as the KESHO framework [11]) is paying dividends;
- Participants responded positively to the concept of further refining a set of Essential Mountain Climate Variables (EMCVs; Thornton et al., 2021 [12]), including their associated minimum observation requirements (resolution, frequency, etc.) to be useful for general applications in mountains, and expressed the need for better standardised data more generally.
- Participants suggested there could be scope for a paper which provides a basic overview of the availability of various datasets (similarly to that published by Condom et al. (2020)

for the Andes; 13]), potentially vis à vis “what we want / need” (captured for instance in the existing list of EMCVs. One participant suggested that to narrow the scope, this effort could focus specifically on data for decision making, including how best communities of practice can help fill these gaps going forward.

- The importance of links between climate, biodiversity, and human health also emerged. Although few of the participants themselves were working directly on health-related topics, this is clearly a key nexus given ongoing climate change and human population growth across many African mountain regions. Given the climatic and biodiversity collected by / available to the group, additional collaboration with scientists working in the health field could lead to the development of very useful projects.
- Another participant raised the topic of ecosystem services. Although the important ecosystem services in East African mountains are fairly well understood qualitatively, they are less well understood on a seasonal basis, and quantitatively. This situation is problematic in case one must make difficult trade-offs between individual ecosystem services (e.g. reforestation schemes to enhance carbon storage, but which could exacerbate water shortages during droughts due to enhanced evapotranspiration). The participant suggested compiling a list of relevant ecosystem services by season, identifying which are common across the entire region and those which are more geographically limited, and assessing the extent to which climate change is expected to affect each of them. The project could be extended to conduct “ecosystem (service) accounting” where possible. Although a desk-based review / synthesis type activity, some funding may be needed to support colleagues’ time to prepare such an article.

Finally, in closing, the organisers compiled inputs from participants and identified some common or prominent themes amongst the ideas and expectations that the participants had shared at the outset and made some last reflections on the key discussion outcomes (see the “Ideas” & “Expectations” Boards, which participants were invited to post their reflections on following the opening segment of the workshop).

4. Conclusions & Next Steps

In the morning, participants heard about various current projects underway in the region, associated data-related challenges and potential solutions. The first discussion of the afternoon allowed participants to engage in detailed small-group discussions and provide additional examples of good data and monitoring practices, challenges, possible reasons for those challenges, and potential solutions. Recurrent example of good practice included the availability of global scale gridded data, the existence of good policies and governance, the access to technology (through mobile phones for example) and the capacities of people in the region. Data gaps included some biodiversity data, in situ climate data, soil data, and societal / cultural data. Data accessibility, standardization, and metadata traceability / clarity were also raised by some participants as outstanding challenges.

Promising solutions to many of these challenges including the development of standard protocols for data collection and sharing, exchanging more data, and improving communication and networking at both regional and international levels between various institutions and other stakeholders (including local communities and national agencies). Indeed, the need for greater involvement of local communities with a view to delivering better project relevance, implementation, and sustainability was a strong theme throughout the discussions. There was also keen interest in better exploiting the potential offered by citizen science approaches, especially considering ever-improving technological capabilities and mobile internet coverage.

Regarding the second discussion, which focused more on capacity budling, a dedicated field or residential school for young researchers emerged as a clear priority of the participants. Challenges some participants reported experiencing with the peer-review process could potentially be addressed by targeted writing workshops.

A limitation of the workshop was that there was virtually no time for a thorough discussion of socio-economic data availability and use, despite societal / anthropogenic processes playing a major role in African mountain systems under ongoing global change. An associated recommendation would be to conduct a longer regional workshop (e.g. 3 days) during the Phase 2 of A@A (2024–2027).

Nevertheless, at least three specific potential collaborative follow-up projects have been identified: i) a mountain-focused climate data intercomparison project, involving GEE and in various in situ observations, ii) a synthesis or review of available multi-disciplinary data available for in the region, major gaps, and recommendations for future data collection activities (*sensu* Condom et al. (2020), and iii) a review synthesis on ecosystem services in East Africa's mountain and their value, potentially involving health-related aspects.

In closing, the organisers warmly thanked:

- ARCOS, for the two flash talks they contributed and the excellent logistical support they provided (which included organising the travel and accommodation of all non-local participants);
- Prof. Kaplin and her group members, especially Gloria Kamwezi and Diane Umutoni, for hosting us at the University of Rwanda (including the room reservation and organising the lunch);
- Prof. Marchant for playing a key role in the design of the workshop and assisting with facilitation on the day itself;
- All invited speakers for their inputs; and
- All participants for sharing their time and expertise so freely.

Before departing, the organisers invited all participants to complete a short feedback survey (see Annex 5).

Author and note taker(s): Alex Massot, supported by Rob Marchant and James Thornton.

Annex 1. Link to Presentations

All presentations given during the workshop, along with a selection of photographs, are publicly accessible from this online repository.

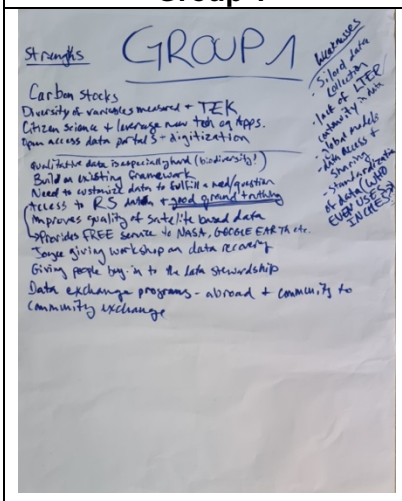
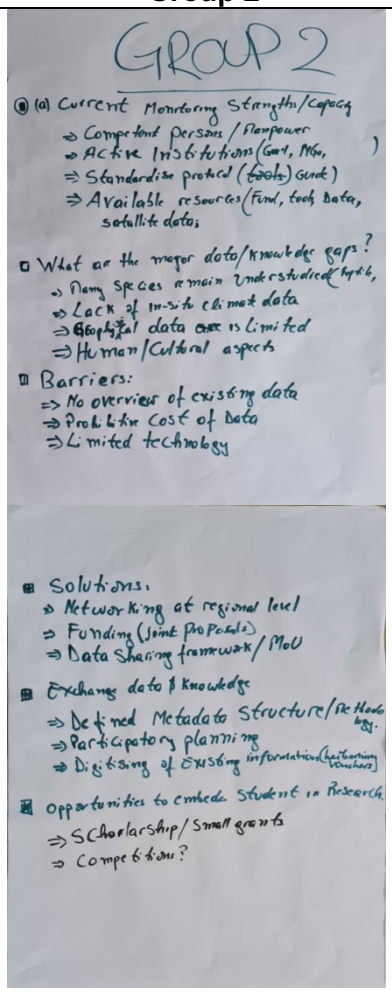
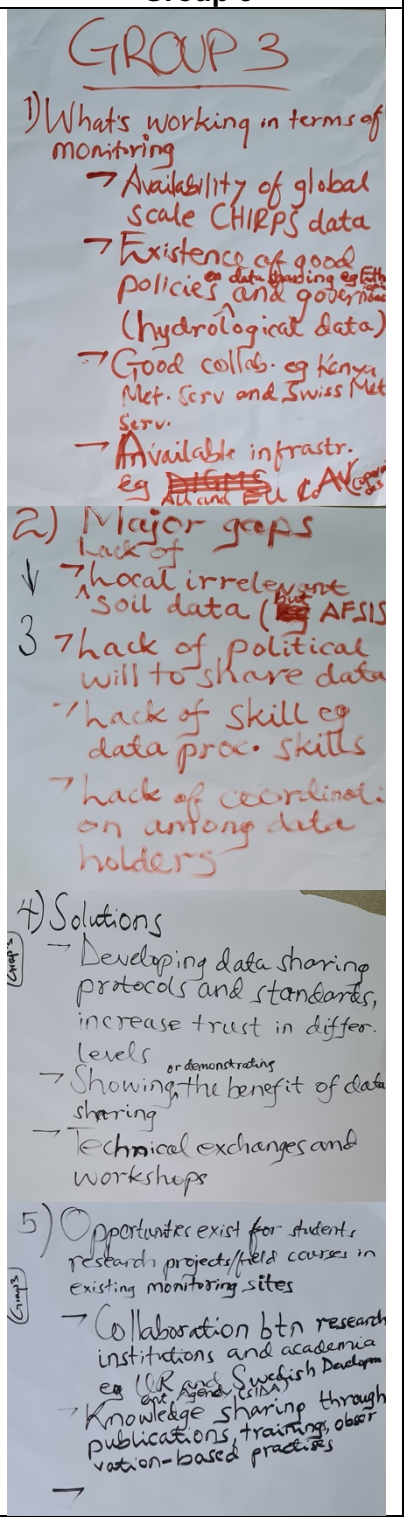
Annex 2. Lists of Attendees

The full list of workshop attendees is provided below. Please also note that it is possible that other participants not listed above joined the meeting online.

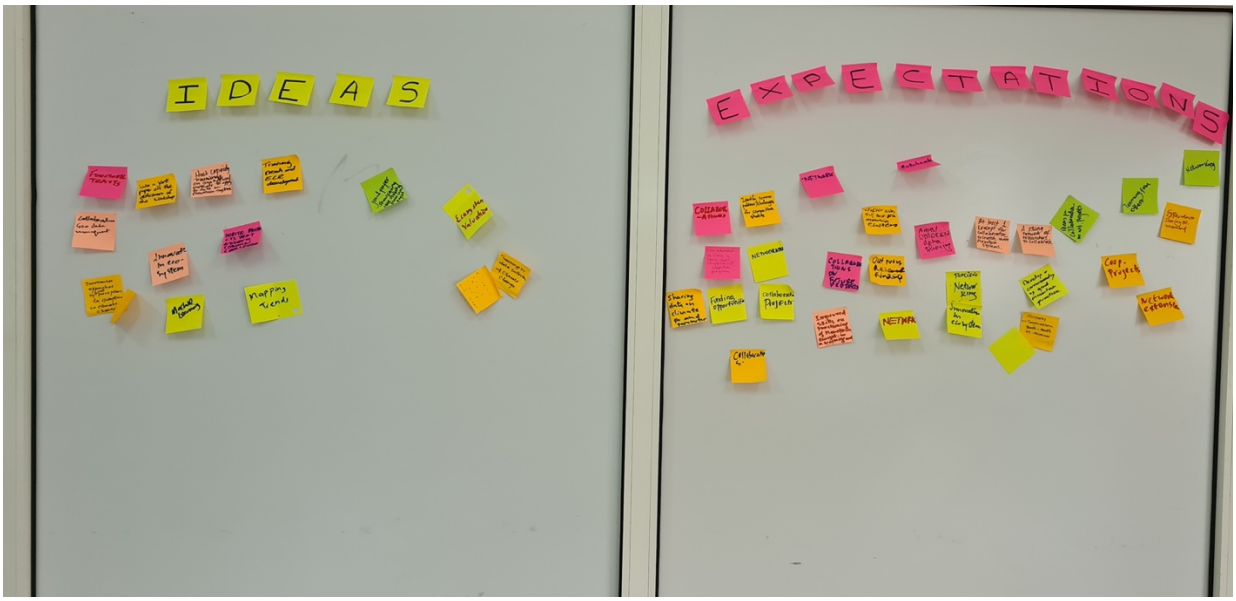
First Name	Last Name	Affiliation	Country
Alexandrine	Massot	MRI	Switzerland
James	Thornton	MRI	Switzerland
George	Muganga	ARCOS	Uganda
Yvonne	Bigengimana	ARCOS	Rwanda
Beth	Kaplin	University of Rwanda	Rwanda
Robert	Marchant	University of York	United Kingdom
Fredrick	Ssali	Institute of Tropical Forest Conservation	Uganda
Johan	van Tol	University of the Free State	South Africa
Joyce	Kimutai	Kenya Meteorological Department	Kenya
Nick	van de Giesen	Delft University of Technology	Netherlands
Rose	Waswa	RCMRD/AfriGEO	Kenya
Lydia	Olaka	The Technical University of Kenya	Kenya
Fabien Idrissa	Nkurunziza	University of Rwanda	Rwanda
Joshua	Talib	UK Centre for Ecology and Hydrology	United Kingdom
Aloysie	Manishimwe	University of Rwanda	Rwanda
Ghislain	Kabumba Rubega	Université Officielle de Bukavu	Democratic Republic of Congo
Edward	Ouko	RCMRD	Kenya
Janvier	Hitimana	Albertine Rift Conservation Society (ARCOS)	Rwanda
Emanuel	Martin	College of African Wildlife Management, Mweka	Tanzania
Abreham	Aneseyee	Wolkite University	Ethiopia
Humphrey	Maganga	Arrupe Jesuit University	Zimbabwe
Meghan	Taylor	University of Massachusetts, Amherst	USA
Christian	Mukama	ARCOS	Rwanda
Aimable	Hategekiman	ARCOS	Rwanda
Xianhong	Meng	Northwest Institution of Eco Environment, CAS	China
Nimgsham	Deng	Northwest Institution of Eco Environment, CAS	China

Gerard	Imani	Université Officielle de Bukavu	Democratic Republic of Congo
Pacifique	Niyobuhungiro	ECO Great Volunteers	Rwanda
Olive	Byukusenge	Rwanda Managment Authority	Rwanda
Martin	Steinbacher	Empa	Switzerland
Aida	Cuni-Sanchez	Norwegian University of Life Sciences	Norway
Nereyda	Cruz		

Annex 3. Group Discussion Outcomes

Group 1	Group 2	Group 3
		

Outcomes of the group discussions (Photo: © Alexandrine Massot / MRI).



"Ideas" & "Expectations" Boards, which participants were invited to post their reflections on following the opening segment of the workshop (Photo: © Alexandrine Massot / MRI).

The responses are transcribed below:

Ideas:

- Mapping spatio-temporal trends in mountain system components
- Write a joint paper showcasing case successful case studies
- Conduct work on ecosystem valuation
- Collect data regarding climate change
- Meet training needs and ECR development
- Host capacity training on analytical methods to apply to mountain system
- Write a joint paper on the outcomes of the workshop
- Collaborative geospatial data management
- Apply innovative approaches in relation to climate change adaptation
- Exploit the Machine Learning approaches
- Write project proposals that address common challenges

Expectations:

- Establish collaborations / collaborative projects
- Networking / Establish a strong network of researchers
- Identify common problems/challenges for comparative studies
- Sharing data on climate and other mountain system components
- Identify and pursue possible funding opportunities
- Listen and learn about the Adaptation@Altitude programme
- Develop improved skills regarding the functioning of mountain ecosystem in a warming world
- Access/unlock data sharing
- Develop at least one concept for collaborative research across mountain systems

- Develop a community of good mountain practice
- Enhance North-South cooperation in science

Annex 4. Photographs

Some of the photographs taken during the workshop are reproduced below:

Participants during the workshop (Photo: © Alexandrine Massot / MRI).

Participants discussing with one another during lunch break (Photo: © Alexandrine Massot / MRI).

Small group discussions during the afternoon session (Photo: © Alexandrine Massot / MRI).

Dr. Lydia Olaka (Technical University of Kenya) presenting (Photo: © Alexandrine Massot / MRI).

Prof. Rob Marchant (University of York & MRI Science Leadership Council) presenting (Photo: © Alexandrine Massot / MRI).

Ms. Waswa Rose Malo (AfriGEO & RCMRD) presenting (Photo: © Alexandrine Massot / MRI).

Annex 5. Bibliography / Links

1. GEO Mountains (2022). Long-Term Monitoring Activities and Associated Data Availability for Climate Change-Related Applications Across Africa's Mountains: https://www.geomountains.org/news-page-all/138-geo-mountains/2849-long-term-monitoring-activities-and-associated-data-availability-for-climate-change-related-applications-across-africa-s-mountains
2. SAEON Data Portal: https://catalogue.saeon.ac.za/
3. Global Observation Research Initiative in Alpine Environments (GLORIA): https://www.gloria.ac.at/home
4. Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS): https://www.chc.ucsb.edu/data/chirps
5. Google Earth Engine (GEE): https://earthengine.google.com/

6. Global Historical Climatological Network (GHCN): https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily
7. Jupyter Notebooks: https://jupyter.org/
8. International Programme on Research and Training on Sustainable Management of Mountain Areas (IPROMO): https://www.fao.org/mountain-partnership/our-work/capacitydevelopment/ipromo/course-2023/en/
9. GROW: https://www.fao.org/mountain-partnership/our-work/capacitydevelopment/summer-school-grow-agrobiodiversity-in-a-changing-climate/2023/en/
10. Adaptation at Altitude Solutions Portal: https://adaptationataltitude.org/solutions-portal
11. The KESHO framework: http://www.real-project.eu/the-kesho-framework/
12. Thornton, J. M., Palazzi, E., Pepin, N. C., Cristofanelli, P., Essery, R., Kotlarski, S., ... & Adler, C. (2021). Toward a definition of essential mountain climate variables. One Earth, 4(6), 805-827.
13. Condom, T., Martínez, R., Pabón, J. D., Costa, F., Pineda, L., Nieto, J. J., ... & Villacis, M. (2020). Climatological and hydrological observations for the South American Andes: in situ stations, satellite, and reanalysis data sets. Frontiers in Earth Science, 8, 92.

Annex 6. Feedback Survey

East Africa Workshop

27 October 2023

How did you attend the workshop?

- ◯ In person
- ◯ Online

a) On a scale from 1 (poor) to 5 (excellent), please rate the overall quality and relevance of the workshop content (i.e., was it comprehensive and/or informative?): *

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

b) On a scale from 1 (poor) to 5 (excellent), please rate the format and facilitation of the workshop (i.e., organization, interaction, tools, tasks, duration etc): *

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

c) If you have any comments to qualify your rating, or suggestions for improvement with regards to content and/or facilitation of the workshop, please use the space below:

e) If you have any other general comments or suggestions for future events, please feel free to use the space below to provide your response.

Type here...

Submit

Print your responses