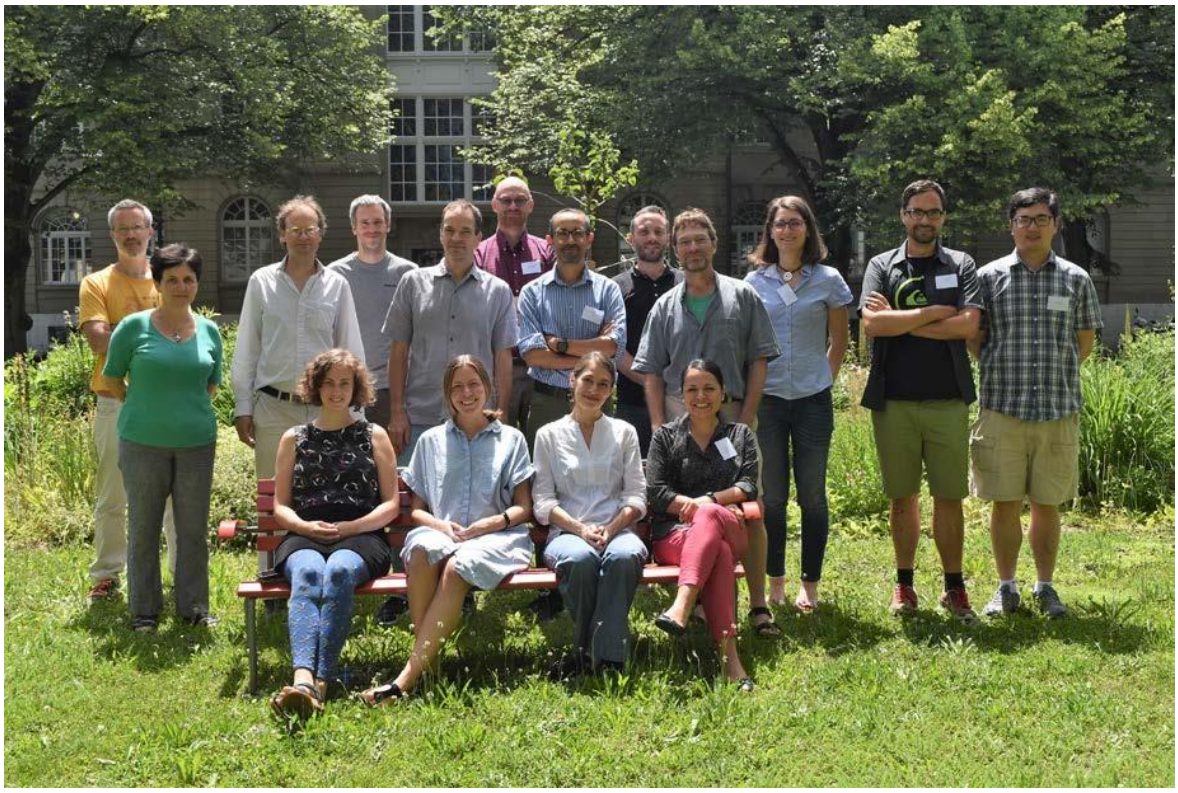
GEO GNOME
OBSERVING MOUNTAIN ENVIRONMENTS

Workshop Report

GEO-GNOME Workshop
"Essential Climate Variables for Observations in Mountains"

24-26 June 2019
UniS Building, Rooms A019, A024 and A027, University of Bern I Bern, Switzerland



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Summary

At the GEO-GNOME Status and Scoping Workshop held in Bern in May 2018[1] , key objectives and tasks listed on its work plan 2017-2019 were revised (see also Adler et al, 2018[2]). The importance of climate as one key driver of environmental change in mountains, with relevant consequences for social-ecological systems, was reiterated. Given already existing initiatives on essential climate variables from observations and modelling, an opportunity was identified to focus attention on mountain-specific needs of key variables allowing from understanding and tracking changes in mountains and their consequences. A transect network of in-situ climate data over elevation gradients (Unified High Elevation Observing Platform, UHOP[3]), together with consistent time series of EO (satellite) data, was suggested as a means to address key observational data gaps and to improve our understanding of processes of elevation-dependent warming (EDW) and elevation-dependent climate change (EDCC) in mountains, and support a systematic strategy for identifying and collecting new observation data.

Essential Climate Variables (ECVs) relevant for mountains were identified as a first starting point. They include "pure climate" variables like temperature, precipitation, snow, radiation, wind, etc., as well as other important variables/drivers such as land-cover. With the support from the European Space Agency (ESA), Future Earth (FE), and the Mountain Research Initiative (MRI), the 2019 GEO-GNOME workshop aimed at identifying and selecting ECVs required in high elevation contexts for the monitoring and better understanding of 'mountain climate change', including considerations for integration between in-situ measurements, EO satellite data and modelling. The WMO/GCOS existing catalogue of ECVs was used as initial basis for compiling our list of essential mountain variables. The possibility to use ESA's existing datasets on ECVs within its Climate Change Initiative (CCI) program was also considered.

The key output and outcome of this workshop is a list of ECVs required to observe the processes of elevation-dependent climate change in mountains. In addition, a data collection protocol with identified existing data-sources and criteria for required data quality (particularly the spatial and temporal resolution required) for selected key processes was produced. There are huge observational and information gaps in mountain environments and agreeing on joint protocols and data resolution needed for each relevant process would allow filling these gaps.

Collecting data on other environmental processes in addition and in relation to strictly climate-related processes will strengthen GEO-GNOME's ability to identify relevant data and information that meet the needs of management, policy and scientific research. Making this data discoverable and accessible via suitable data portals, such as the GEO-GNOME Global Earth Observation System of Systems (GEO-GNOME GEOSS, under development), will further facilitate data use and research collaborations.

[1] See http://www.mountainresearchinitiative.org/index.php/news-page-all/350-geo-gnome-status-and-scoping-workshop-bridging-datagaps-in-mountain-environments

[2] See Adler et al (2018) - https://doi.org/10.1659/MRD-JOURNAL-D-8-00065.1

[3] See http://www.mountainresearchinitiative.org/index.php/activities/projects/geo-gnome

Key objectives of the workshop

1. Identify relevant physical processes which can lead to elevation dependent mountain climate change;
2. Identify EVs (essential variables) which are required to monitor and understand such processes and their consequences, i.e. relevant ECVs;
3. Discuss selected ECVs in the context of surface and in-situ observations (e.g. UHOPs), other EO (e.g. satellite) and numerical model simulations, and how information from these different sources can be combined or integrated to gain the most relevant information to improve understanding of key processes and prediction capacity for mountain climate change.

Part 1: Identifying ECVs for observations in mountains

To set the context for the goals of the workshop, the first day provided an opportunity to reflect on processes specific for mountain environmental systems and on the concept of ECVs with diverse input from the participants. Nick Pepin (University of Portsmouth) started by offering an overview of the processes leading to Elevation-Dependent Warming and to the need to identify key variables required to understand them and their feedbacks, providing examples based on observations and models. Richard Essery (University of Edinburgh) expanded the discussion into the processes related to changing snow and ice in mountain systems. Christophe Randin (University of Lausanne) presented ecological changes and migrating ecotones and how these feed into other processes in the mountain environments. Xiaofeng Li (Newcastle University) presented research studies focusing on hydrological processes in mountains. Paolo Cristofanelli (CNR) expanded on changes in atmospheric composition and related transport processes in high-altitude regions. Finally, Yaniss Guigoz and Gregory Giuliani (University of Geneva) talked about their current work on Essential Variables at national and regional scales showing applications on the use of Data cubes.

Selecting key processes and identifying related ECVs was conducted as an exercise where the participants were divided into four thematic break-out groups: Cryosphere, Hydrosphere, Anthroposphere and Biosphere following the Global Climate Observing System (GCOS) [4] division of processes and ECVs. Participants of each group discussed the key processes in the given “sphere” in mountain context and specifically keeping in mind Elevation-Dependent Climate Change. Based on the GCOS list of global ECVs, the groups then identified and agreed on importance of the variables essential to understand change in these process areas (Picture 1).

The resulting table of essential climate variables for mountain environments lists over 100 specific ECV products, which can be categorised under 45 ECVs (following the GCOS system). All these named ECV products are relevant for monitoring and understanding of at least one key mountain process. Land surface temperature, precipitation, albedo, snow cover, wind and water vapor were the ECVs that ranked most important for mountain processes across spheres. The existing GCOS list of global ECVs covers most of the selected variables but in-depth understanding of mountain specific processes requires also inclusion of new variables. Preliminary comparison with the ESA cci datasets, shows that for 39 of the considered ECV products some data is already available through the cci initiative. Further consideration of the data criteria (including required spatial and temporal scales) for each selected ECV is needed for a proper gap analyses for mountain specific data needs.

Picture 1. Left: An example of a poster filled by Anthroposphere Group with colored dots presenting the rated importance of an ECV (columns) for a specific process (rows). Right: Ecosphere Group discussing the rating of ECVs.

[4] See https://gcos.wmo.int/en/essential-climate-variables

Part 2: Considering data collection protocols for remote sensing, in-situ observations and modelling for ECVs of key processes

Input talks of the second workshop day expanded the topic from mountain processes and ECVs into data collection protocols and frameworks in mountain environments. Maria Shahgedanova (University of Reading) presented the status of the MRI Mountain Observatories Working Group, which is working on building a global network of observatories with shared protocols for in-situ-measurements covering fields from meteorology to social-ecological systems. Nick Pepin (University of Portsmouth) continued discussing the next steps from Elevation-Dependent Warming to understanding Elevation Dependent Climate Change and the potential of a transect network of in-situ climate data over elevation gradients (Unified High Elevation Observing Platform, UHOP[5]). Elisa Palazzi (ISAC-CNR) gave an overlook on how climate change in mountains regions is seen by global and regional models, stressing the need to use a modelling chain and to reduce uncertainties. Marc Zebisch (EURAC) continued to Earth Observations and their use in mountain areas. Finally, Sven Kotlarski (MeteoSwiss) discussed the role of mountain observations/models for climate services.

ECVs have been introduced by GCOS to characterize the climate system and its changes at global scale and are not specifically designed to investigate processes at the spatial scales required in mountain context. Hence, agreeing on data collection protocols for the selected essential climate variables in mountain regions is needed. The participants continued working in two groups, one focusing on cryosphere-hydrosphere and the second one on anthroposphere-ecosphere, considering best possible ways to collect data for pre-selected key processes and corresponding ECVs identified in the first group exercise. Possibilities to use data from in-situ observations, earth observations and/or modelling sources or integrating between them was considered separately for each ECV identified for a process. Further on, adequate spatial and temporal resolution for each data source were defined to feed into a standard protocol for data collection in mountain environments.

Part 3: Excursion to Jungfraujoch Research Station

Following the invitation from the President of the Research Station, Silvio Decurtins, participants of the workshop had a chance to visit the Junfraujoch Research station after the official end of the workshop programme. During the excursion participants were accompanied by Prof Decurtins himself, who gave a short presentation on the history and infrastructure of the station and guided the group through the different sectors and laboratories of the station (Picture 2). One of the custodians of the station, Ruedi Käser, introduced the group to his daily work and life at the station with insights to daily weather observations. Atmospheric scientist Ginette Roland gave a fascinating presentation on the key findings in atmospheric and radiation sciences made at the Jungfraujoch during the past decades.

The research station was inaugurated in 1931 and is owned by the International Foundation High Altitude Research Stations Jungfraujoch and Gornergrat (HFSJG). The station is located at the elevation of 3’466 meters above the sea level in the Bernese highlands and marks a key infrastructure in interdisciplinary climate and environmental research and among mountain observatories. In around 50 projects, the station measures over 100 different variables, collecting data for several international observation networks. Research topics vary from meteorology and monitoring of radiation balance and atmosphere to glaciology and medical research. Jungfraujoch Research Station welcomes new initiatives and collaborations. For further information on the research station and contacts, please refer to the homepage of the station (https://www.hfsjg.ch/en/home/).

[5] See http://www.mountainresearchinitiative.org/index.php/activities/projects/geo-gnome

Picture 2. Left: Participants of the excursion at Jungfraujoch with staff members of the station. Right: Ginette Roland works at the Jungfraujoch since 1950's.

Key outcomes and outputs of the workshop

The first key outcome of the workshop is the nomination of key processes of elevation-dependent climate change in mountains and selection and rating of ECVs required to observe and monitor these processes. The second key outcome is the consideration of data sources and criteria for data quality (spatial and temporal resolution) for the selected key processes.

Planned actions

1. A peer-reviewed publication presenting the selection of mountain specific ECVs is envisaged.
2. Possibilities to expand the data collection protocol from the selected key processes to further mountain processes will be studied. Including other research communities in the discussions is envisaged as this would allow expanding from the general recommendations to protocols which can be adjusted for different regions and scales.
3. Encouraged by the experiences and results of this workshop, the work on mountain specific essential variables will continue and a workshop to identify Essential Biodiversity and Societal Variables in mountain context in foreseen for February 2020.

Key follow-up events

- GEO-GNOME side-event at the International Mountain Conference | Innsbruck, Austria |September 2019
- GEO Week 2019 - Ministerial summit | Canberra, Australia | 4-11 November 2019
- GEO-GNOME Workshop: Essential Mountain Biodiversity and Societal Variables | Zürich, Switzerland | 21-22 February 2020
- GEO-GNOME Essential Mountain Variables Session at World Biodiversity Forum | Davos, Switzerland | February 2020
- GEO-GNOME UHOP Workshop | (time and place tbc)

We take this opportunity to thank all participants of this workshop for your active participation and engagement and for sharing your valuable time. We also thank Prof Decurtins and the staff of the Research Stations for welcoming us at Jungfraujoch.

Carolina and Elisa
27 September 2019

Annex 1: Participants list

Name	Affiliation	Country
Adler Carolina	MRI	Switzerland
Cremonese Edoardo	Environmental Protection Agency of Aosta Valley, Climate Change unit	Italy
Cristofanelli Paolo	National Research Council (CNR)	Italia
Essery Richard	University of Edinburgh	UK
Giuliani Gregory	University of Geneva	Switzerland
Goss-Durant Grace	MRI	Switzerland
Guigoz Yaniss	University of Geneva	Switzerland
Kotlarski Sven	MeteoSwiss	Switzerland
Kulonen Aino	MRI	Switzerland
Li Xiaofeng	Newcastle University	UK
Palazzi Elisa	Institute of Atmospheric Sciences and Climate (ISAC), National Research Council (CNR)	Italy
Pepin Nick	University of Portsmouth	UK
Randin Christophe	University of Lausanne	Switzerland
Haver Marilen	Toulouse INP	France
Seidler Reinmar	University of Massachusetts Boston	United States
Shahgedanova Maria	University of Reading	UK
Steinbacher Martin	EMPA	Switzerland
Terzago Silvia	Institute of Atmospheric Sciences and Climate (ISAC), National Research Council (CNR)	Italy
Zebisch Marc	Eurac Research	Italy

Annex 2: Workshop Program

Monday 24 June	Tuesday 25 June
Plenary - Room A 027 **09:00 Welcome coffee (UniS foyer)** **09:30 Welcome and introductions** *Carolina Adler (MRI) & Elisa Palazzi (ISAC-CNR)* **09:45 Key processes in Elevation-Dependent Climate Change** Invited talk (30' talk and 15' discussion) 1. EDW context and the identification of processes – research developments within the last 4 years *Nick Pepin, University of Portsmouth*	**Plenary - Room A 027** **09:00 Recap Day 1 and plan for Day 2** **09:15 Definition and Scoring of ECVs** Group Discussion of ECVs identified for each process area from Day 1.
10:30 Coffee break	**10:30 Coffee break**
Plenary - Room A 027 **11:00 Key processes in mountain contexts (invited talks)** (15' each and 5' discussion) 2. Changing Snow and Ice, Glaciers and Permafrost in Mountain Systems – *Richard Essery, University of Edinburgh* 3. Ecological Changes in the Mountain Environment and Migrating Ecotones – *Christophe Randin, University of Lausanne* 4. Increased Cycling of Moisture in Mountain Systems– *Xiaofeng Li, Newcastle University* 5. Changes in Atmospheric Composition in High Altitude Regions – *Paolo Cristofanelli, CNR*	**Plenary - Room A 027** **11:00 Invited talks continue** 7. MRI Mountain Observatories Working Group – *Maria Shahgedanova, University of Reading (15')* 8. Climate change in mountain regions seen by field observations, earth observations and global and regional models – *Sven Kotlarski, Meteo Swiss; Elisa Palazzi; and Marc Zebisch, EURAC* **11:35 Orientation to break out groups** *Elisa Palazzi & Nick Pepin* **Rooms A019, A024 and A027** **11:45 Break out groups** Working groups will discuss how ECVs could be operationalised in ***1)*** *Field Observations;* ***2)*** *EO data;* ***3)*** *Models*
12:30 Lunch	**12:30 Lunch**
Plenary - Room A 027 **13:30 Considerations for essential variables in the mountain context** (15' and 5'discussion) 6. Insights in Essential Variables at national and regional scales - *Yaniss Guigoz and Gregory Giuliani, University of Geneva* **13:50 Orientation to break out groups** *Elisa Palazzi & Nick Pepin* **Rooms A019, A024 and A027** **14:00 Break out Groups** Identifying ECVs essential in the mountain context to understand change in process areas corresponding roughly to earlier talks *1) Mountain Cryosphere* *2) Moisture/Precipitation/Cloud Linkages* *3) Atmospheric composition and transport processes* *4) Ecological Zonation*	**Rooms A019, A024 and A027** **13:30 Break out Groups** Work continues in break out groups
15:45 Coffee break	**15:45 Coffee break**
Rooms A019, A024 and A027 **16:15 Break out Groups continue** Participants may change groups **Plenary - Room A 027** **17:15 Plenary** Summing up day 1 - groups present list of ECVs for their processes. **17:30 Close Day 1**	**Plenary - Room A 027** **16:15 Wrap up Day 2** Groups present their outcomes - lists of associated protocols for each ECV - Discussion **Final words and next steps** Carolina Adler & Elisa Palazzi
18:30 Workshop dinner in Restaurant Beaulieu	**17:30 Close Day 2 and end of workshop**

Wednesday 26 June

EXCURSION - Jungfraujoch High Altitude Research Station, Bernese Alps

07:45 Meeting at Bern Railway Station Meeting Point

Departure at 8:04 - Arrival at Jungfraujoch at 11:05

11:05 Welcome coffee

11:30 Introduction and tour through the Jungfraujoch Research Station

Prof. Silvio Decurtins
President of the Board of the Foundation of the High Altitude Research Station Jungfaujoch – Gornergart (HFSJG)

12:15 Lunch
Self-service Restaurant (at own cost)

13:15 Tour through the Sphinx-Observatory

Prof. Silvio Decurtins
President of the Board of the Foundation (HFSJG)

14:15 Touristic tour

Alpine Sensation, Ice Palace, Plateau, and glacier

15:30 Coffee break
Self-service Restaurant

16:00 Meeting point at the train station

Departure at 16:13 - Arrival in Bern at 19:24