Mountain Research Initiative (MRI) AGU 2019 splinter meeting

"Synthesis Workshop on Future Mountain Climate Change - From Elevation-Dependent Warming (EDW) to Elevation-Dependent Climate Change (EDCC)"

Workshop Report

24 April 2020

Wednesday 11 December 2019 I 09:00-12:30
600 Mason Street, San Francisco, USA

Organisers: Nick Pepin (University of Portsmouth, MRI Elevation-Dependent Warming WG), Aino Kulonen (MRI), Mathias Vuille (University at Albany) and Connie Millar (USDA Forest Service)

Background

During the AGU Fall Meeting 2019, a workshop held on 11 December 2019 reconvened the EDW Working Group collective and new interested participants to continue and expand the work of the Working Group. Since the 2015 workshop on EDW, the results of which were published in Nature Climate Change, there has been much more research on how present and future temperature trends may be elevation-dependent. Increasingly it is recognized that temperature changes do not act in isolation but are influenced by other variables and mechanisms. However there has been less detailed consideration of other climate variables such as snow cover, precipitation, humidity and cloud patterns. During EGU General Assembly in Vienna in May 2019, theoretical aspects of other elevation dependent climate change processes were discussed at the relevant session on *Mountain climatology and meteorology* (Session AS4.47/CR1.13/HS11.22/CL4.30), and at the MRI Synthesis Workshop on mountain meteorology and climatology, which took place at the University of Vienna that same week (see EGU 2019 and workshop outcomes reported here). A peer-reviewed paper is currently under development as a result of this earlier workshop in 2019.

The AGU workshop broadened the perspective from Elevation-Dependent Warming to Elevation-Dependent Climate Change and considered i) the theoretical perspective behind expected changes in elevation profiles of variables other than temperature, and ii) what observations need to be developed to capture these expected changes (i.e. future practice). This workshop was linked to the AGU Fall Meeting 2019 sessions "*Mountain Weather and Climate in a Warmer World I and II*". The key outcome

of the workshop was the identification of climate processes that could be considered to be further studied for their elevation-dependent patterns. A second important finding was the notion that to answer complicated questions on elevation-dependent climate change merging together two levels of global observation systems (high and lower quality) would be the way forward. To enable process creation and adoption of unified standards are a key requirement that could be addressed in follow up activities of the renamed EDCC Working Group.

Key objectives of the workshop

1) To explore the physical theories behind elevation-dependent climate change and how various climate processes interact to create distinct elevation profiles in temperature, precipitation, snow cover, humidity, cloud cover, radiation fluxes etc.;
2) To consider a peer-reviewed publication (possible follow-up from the NCC Paper of 2015 and paper under development from the EGU 2019 Workshop[1]) presenting theoretical perspectives behind elevation-dependent climate change and observational data needs to capture these changes;
3) To connect and enhance collaboration among scientists involved in the mountain meteorology and climatology research communities, including collaboration and activity among the MRI EDW Working Group with whom other research prospects and/or collaboration activities could be identified; and
4) Foster connection through exchange and networking.

Part 1: Processes of Elevation-Dependent Climate Change

The workshop started with welcoming words by Aino Kulonen from the MRI, followed by a presentation from Nick Pepin "From Elevation-Dependent Warming to Elevation-Dependent Climate Change".

An exercise in break-out groups allowed the participants to discuss the processes other than temperature that result in elevation-dependent patterns of mountain climate. The groups were asked to discuss 1) how do changes in each set of processes influence elevation patterns in variables other than temperature (e.g. clouds, precipitation (orographic gradient), radiation fluxes, wind shear); and 2) the interactions between sets of processes.

A variety of processes, especially focusing on hydrology, were presented and discussed and the organisers had a chance to add and elaborate their ideas online after the workshop. The organisers will observe possibilities to elaborate the outcomes into a peer-reviewed publication on Elevation-Dependent Climate Change.

Part 2: Protocols for high-elevation climate observations

To open the second part of the workshop Nick Pepin gave a presentation on "Protocols for Mountain Observations and Modelling", with an overview of the current monitoring systems in mountains. This highlighted the lack of stations in the highest elevations and presented the concept of the Unified High-elevation Observing Platform (UHOP). The observation needs were summarised in four points: 1) need to cover an elevational range (ridgeline) – possibly two ridges joining together to form a transect across a mountain range; 2) need for at least 2 AWS as anchor stations, including radiation balance terms and precipitation monitoring; 3) Need for greater number of float stations to build up an extensive geographical network; and 4) need for international collaboration and data sharing.

[1] See more on the workshop: https://mountainresearchinitiative.org/news-page-all/129-mri-news/2299-making-connections-at-the-egu-general-assembly-2019

The following discussion started on the need for standardised measurements to calibrate against other data sources and the participants agreed on need to connect ground data with remote sensing and modelling initiatives. The need for and possibilities to develop a global standard for stations that can collect highest quality observations was stressed. High-quality WMO-approved transects with the highest quality of instrumentation (e.g. aspirated sensors) were suggested as a good reference with a need to identify further such networks.

Another key topic identified in the discussion was the need to consider how to include existing networks which have been monitoring elevation gradients and topo-climate for a long time but might fall below the "highest" quality standards. It was agreed that two levels of data might be needed because the suggested high-quality data over transects might not be achievable outside parts of the northern hemisphere. A limited number of high-quality stations such as UHOP could be linked to remote sensing data (e.g. soil moisture, surface temperature) and to lower quality global data networks through calibrations. New stations should be located to support the network and fill gaps. For decisions on where to locate new sensors, existing resources from ground, remote sensing and modelling could be used.

It was summarised that we need to think about merging together two levels of global observation systems (ultra high- and low/medium quality), perhaps through remote sensing data and for this process unified standards are needed. A number of local, regional and global networks are keen on being involved in a broader global high-elevation climate monitoring network. To include them in the system, we need high-level metadata (uncertainty on methods and how this uncertainty has been quantified), to understand how to use the data and what the limitations are. A technical workshop to bring together experts from different observation networks to define standards for metadata and calibration was identified as a potential follow-up activity. Establishing an inventory of existing data sources and identifying gaps in the existing data were identified as an important starting point and something GEO-GNOME will be working on later this year.

Key outcomes of the workshop

The key outcome of the workshop was the identification of climate processes that have elevation-dependent patterns and require further exploration. A second important finding was that to answer complicated questions on elevation-dependent climate change merging together two levels of global observation systems (high- and low quality) would be the best way forward. For this process unified standards are a key requirement that could be addressed in follow up activities of the EDW Working Group.

Planned actions

1) A peer-reviewed publication on Elevation-Dependent Climate Change based on the workshop outcomes
2) A follow up workshop to define standards and protocols for collecting metadata for a global database of existing observational networks (tbc)

The organisers would like to thank all participants for their engaged participation and valuable input in the discussions and look forward to further collaborations!

Nick and Aino
24 April 2020

APPENDIX I: LIST OF WORKSHOP PARTICIPANTS
APPENDIX II: DRAFT PROGRAMME

List of workshop participants

	Last Name	First Name	Remote part.	Representing institution
1	Apple	Martha		Montana Technological University
2	Bradley	Ray		University of Massachusetts
3	Carroll	Rosemary		Desert Research Institute
4	Csank	Adam		University of Nevada-Reno
5	Deneen	Peter		GlacierHub
6	Feldman	Daniel		Lawrence Berkeley National Laboratory
7	Flint	Alan		USGS
8	Flint	Lorrie		USGS
9	Gleason	Kelly		Portland State University
10	Harpold	Adrian		University of Nevada, Reno
11	Hik	David	X	Simon Fraser University
12	Johnson	Brittany	X	University of Washington
13	Knowles	John		University of Colorado Institute of Arctic and Alpine Research (INSTAAR)
14	Kulonen	Aino		Mountain Research Initiative
15	Lebel	Thierry		University of Grenoble
16	Lopez Moreno	Juan Ignacio		Spanish Research Council
17	Luce	Charles		US Forest Service
18	Lundquist	Jessica		University of Washington
19	Mark	Bryan		The Ohio State University
20	Marshall	Adrienne		University of Idaho
21	Millar	Connie		USDA Forest Service, Pacific Southwest Research Station
22	Miller	Jim		Rutgers University
23	Minder	Justin		University at Albany
24	Osenga	Elise		Aspen Global Change Institute
25	Ning	Liang		Nanjing Normal University & University of Massachusetts Amherst
26	Pepin	Nick		University of Portsmouth
27	Rhoades	Alan		Lawrence Berkeley National Laboratory
28	Rudisill	William		Boise State University
29	Scuderi	Louis		University of New Mexico
30	Segura	Hans Mikhail		IRD-IGE-UGA
31	Shafer	Sarah		USGS

	Last Name	First Name	Remote part.	Representing institution
32	Smithers	Brian		Montana State University
33	Sproles	Eric		Department of Earth Sciences - Montana State University
34	Strachan	Scotty		Nevada Climate-ecohydrology Assessment Network, Reno
35	Vuille	Mathias		University at Albany
36	Williamson	Scott	X	University of Ottawa
37	Zimmer	Anaïs		University of Texas at Austin

Workshop draft programme

Wednesday 11 December 2019	
09:00 - 09:40	**Welcome and orientation (5 min)** *Aino Kulonen (MRI)* **Introduction to Elevation-Dependent Climate Change (30 min)** *Nick Pepin (University of Portsmouth)* **Paper objectives and proposal for structure scope (5 min)** *Nick Pepin & Aino Kulonen*
09:40 - 10.15	**Discussions in break out groups (35 min)** Consideration of theories which could explain elevation-dependent profiles of change in climate variables other than temperature (e.g. precipitation, snow, clouds etc) *All*
10:15 - 10:45	**Coffee break**
10:45 - 11:15	**Presentations and discussion on results of break out groups (15 min)** *All* **Introduction to Unified High-Elevation Observing Platforms (UHOPs)[2] (15 min)** *Nick Pepin*
11:15 - 11:50	**Discussions in break out groups (35 min)** Observations and protocols for considered variables *All*
11:50 - 12:30	**Presentations and discussion on results of break out groups (20 min)** *All* **Paper development (10 min)** Timelines, tasks & responsibilities, journals to consider *Nick and Aino* **Final words and next steps (10 min)** *Nick and Aino*
12:30	**Close of Workshop**

2 http://www.mountainresearchinitiative.org/images/Projects/GEO_GNOME/UHOP-Print-update-April2019.pdf