Toward a definition of Essential Mountain Climate Variables

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Personal introduction

“An interdisciplinary but hydrologically-focused environmental scientist”

Fieldwork and numerical modelling

- Coordinator of GEO Mountains, MRI
- PhD in Hydrogeology, Université de Neuchâtel (2020)
- Previous work in insurance industry (UK) on natural catastrophe risk modelling (floods, windstorms)
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Outline

1. The challenge / motivation

2. Our proposed solution

3. Emerging and future prospects for better measuring / exploiting / deriving climate-related data in mountains

4. Next steps

5. Conclusions & Q&A, discussion, & survey
Importance of mountain globally

See also e.g.
Grêt-Regamey and Weibel (2020)
Viviroli et al. (2020)
Immerzeel et al. (2020)
The need for climatic and climate-related observations in mountains

• Monitor ongoing changes in external conditions and system responses

• Developed improved conceptual understanding of the processes/mechanisms involved

• Generate more reliable, local-scale impact projections as a basis for environmental management, risk mitigation, and climate change adaptation

Huss (2021)
General challenges

- High degree of system complexity
- Challenging conditions for the installation and of in situ infrastructure
  - Limited spatial representativeness of in situ measurements
  - Sometimes low reliability (e.g. precipitation)
- Advancements in remote sensing are not a panacea; shadows, clouds, GPS signal for drones, radar shadowing, some important variables simply cannot be measured remotely
Consequences

- **Quantity and informativeness** of climate and climate-dependent environmental and ecological observations is **often lower in mountains than elsewhere**

- **Heterogenous “data landscape”** globally: lack of data consistency, inter-comparability and interoperability

- Moreover, **interdisciplinary consensus** regarding **which variables** should be considered **observation priorities**, and **how they should be measured**, remains lacking
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Essential Climate Variables (ECVs)

https://gcos.wmo.int/en/essential-climate-variables/about
Essential Mountain Climate Variables (EMCVs)

“Physical, chemical or biological variables that either currently do, or potentially could, significantly contribute to the characterization of Earth's mountainous environmental systems, especially under climatic change.”

- Maintain GCOS’s broad definition of “climate”

- But more inclusive in certain ways; in situ data, measurement feasibility, empericalism

- Parsimony vs. utility?
Identifying important mountain components and processes of mountain systems
Generic integrated mountain environmental system

1) Increasing atmospheric greenhouse gas concentrations
2) Shifts in the radiative forcing, air temperature, and precipitation
3) Increasingly negative glacier mass balance or glacial retreat
4) Changing snow properties and dynamics
5) Rising treelines
6) Increased species richness or biomass on mountain summits
7) Changing evapotranspiration and sublimation dynamics
8) Permafrost and rock glacier thaw
9) Changing streamflow dynamics
10) Accelerated nutrient cycling
11) Changes in glacier debris cover
12) Changes in the atmospheric transport and deposition
13) Changing lake water temperatures and ecology
14) Changing hydrological partitioning at the land surface
15) Changing groundwater recharge, storage, flow, and discharge dynamics
16) Changing redistribution of snow by wind
17) etc, etc……
Consensus ranking of associated variables
Results – All variables
Results – New / “mountain-unique” variables

- **More specific** (e.g. ET vs. sublimation, snow microstructure, glacier debris cover, vegetation disturbance extents, dynamic GW storage, species abundancies)

- Some **derived**, e.g. temperature lapse rates

- Generally measured **in situ** (overlooked by GCOS?)

- Importance of **topographic characterisation**

- Emphasis on **extremes / natural hazards**

- Some may have **broader global relevance** > potential to become ECVs in future (e.g. aerosol deposition on cryosphere, including at the poles)?
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Install new & expand existing “Mountain Observatories”
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https://www.geomountains.org/resources-open-surveys/resources-surveys/inventory-of-in-situ-observational-infrastructure; see also Shahgedanova et al. (2021)
Exploit the latest remotely-sensed data

Dhu et al. (2021)
Exploit the latest climate models
Exploit the latest climate models

MeteoSwiss
Integrate in situ and remotely sensed data with advanced numerical models
Integrate in situ and remotely sensed data with advanced numerical models

24/04/2015

True colour composite

NDSI, classified

Simulated Snow Water Equivalent (mm)
- ≤ 0
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 700
- 700 - 900
- 900 - 1100
- 1100 - 1300
- > 1300

Thornton et al. (2021)
Integrate in situ and remotely sensed data with advanced numerical models

Thornton et al. (2021)
Integrate in situ and remotely sensed data with advanced numerical models

25/05/2018

True colour composite

NDSI, classified

- No snow
- Snow

Simulated Snow Water Equivalent (mm)

- <= 0
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 300
- 300 - 400
- 400 - 500
- 500 - 700
- 700 - 900
- 900 - 1100
- 1100 - 1300
- > 1300

Thornton et al. (2021)
Integrate in situ and remotely sensed data with advanced numerical models

High elevation site: Low elevation site:
Integrate in situ and remotely sensed data with advanced numerical models

Thornton et al. (2021)
Integrate in situ and remotely sensed data with advanced numerical models
Thornton et al. (under review)
Integrate in situ and remotely sensed data with advanced numerical models
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Vegetation modelling: D. Scherrer
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Roadmap:

1. Agree upon underlying philosophy
2. Conduct a broader survey of stakeholder views to establish a definitive set of EMCVs
3. Define associated observation requirements
4. Assess the extent to which EMCV requirements can currently be met using existing data sources
5. Work collaboratively to “fill the gaps”
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Conclusions

• We propose the concept of EMCVs as a framework that could contribute to the availability of more standardized and interoperable climate-related data across the world's mountains.

• A preliminary interdisciplinary ranking has been developed, but further and wider debate, discussion, and refinement are required, especially around *minimum* observational requirements.

• The intelligent combination of models and a broad range of observational data offers many possibilities to meet societal needs for information on mountain climate change impacts.
Q&A, discussion & survey

Please follow this link to access the survey

www.geomountains.org
Thank you for your attention

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20 Years of Our Changing Mountains
www.mountainresearchinitiative.org