MOUNTAIN RESEARCH INITIATIVE
20TH ANNIVERSARY LECTURE SERIES

Toward a definition of Essential Mountain Climate Variables

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29th September 2021

20 Years of Our Changing Mountains

www.mountainresearchinitiative.org

Personal introduction

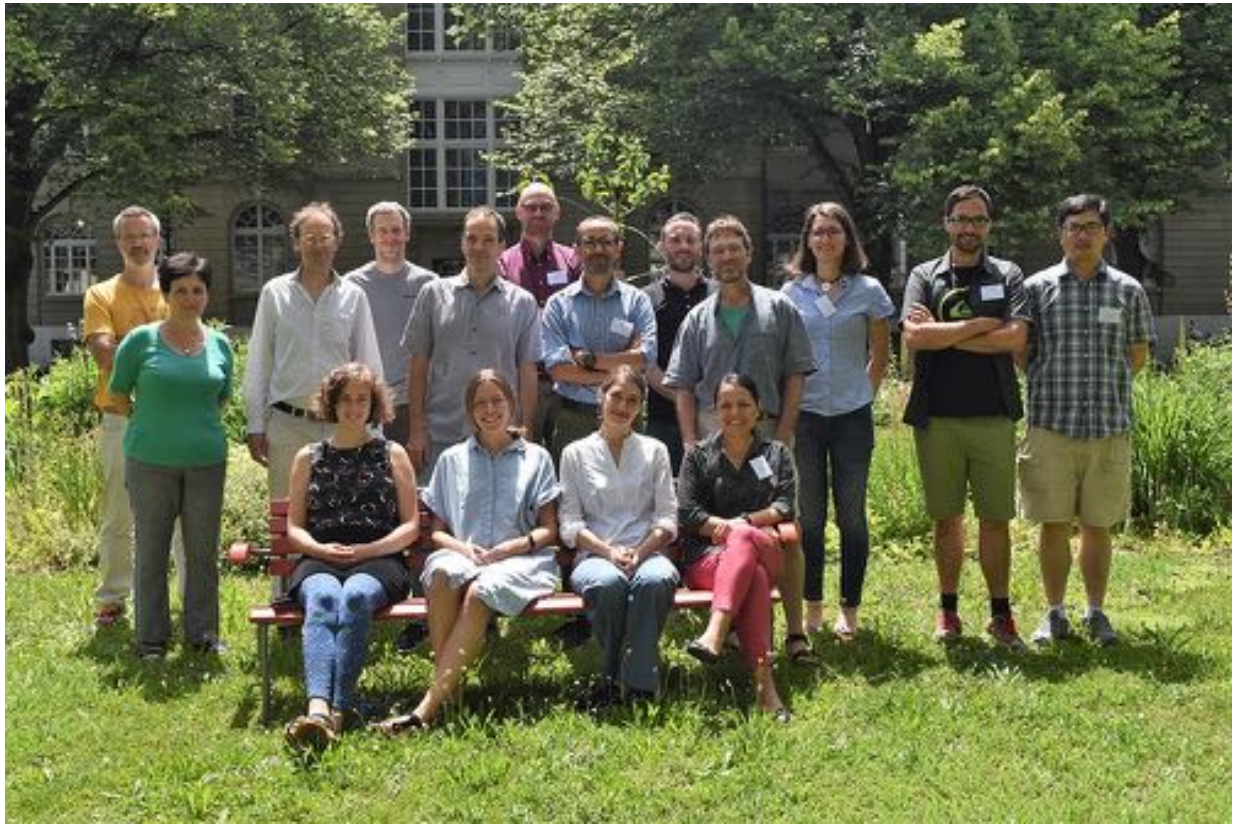
"An interdisciplinary but hydrologically-focused environmental scientist"

- 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)

Acknowledgements

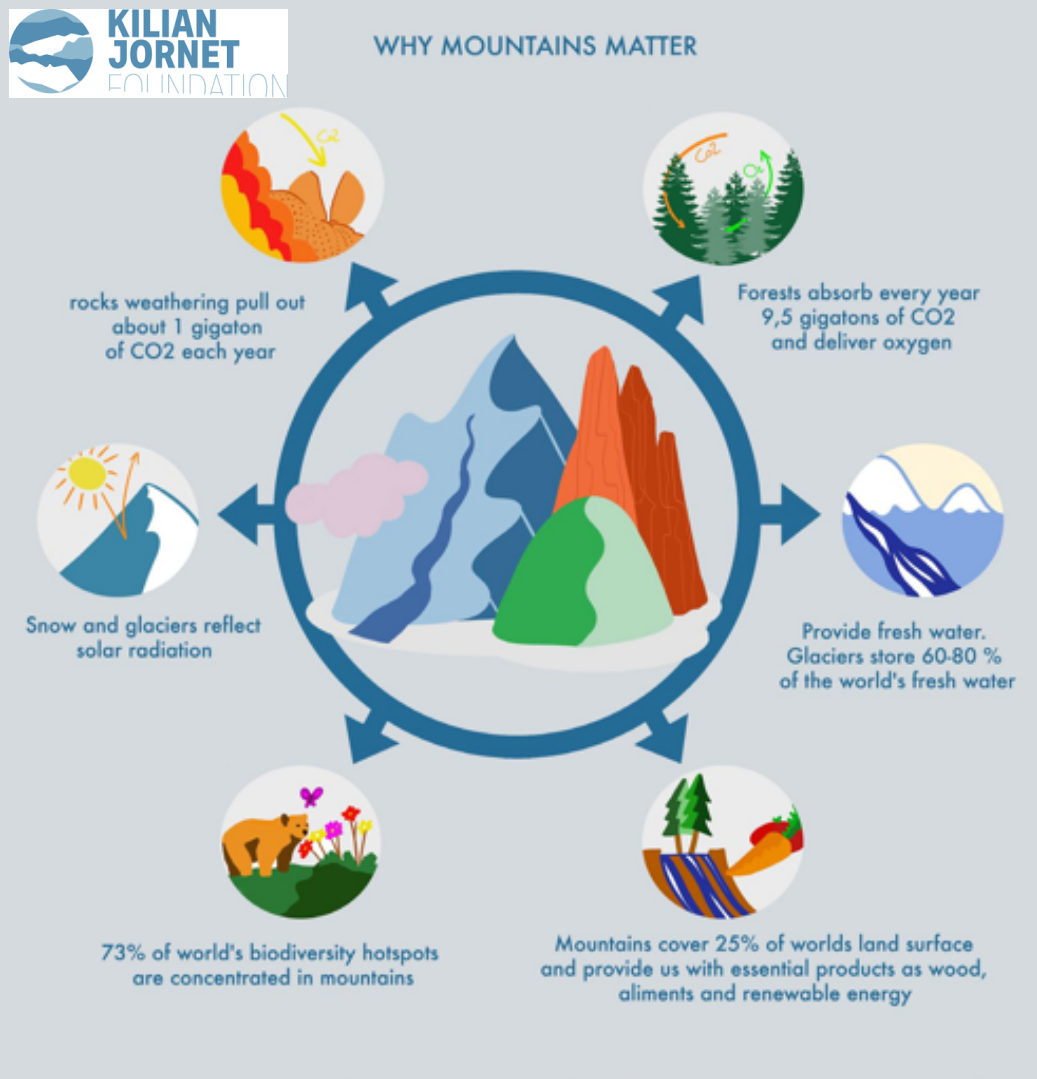
Elisa Palazzi, Nicolas Pepin, Paolo Cristofanelli, Richard Essery, Sven Kotlarski, Gregory Giuliani, Yaniss Guigoz, Aino Kulonen, David Pritchard, Xiaofeng Li, Hayley Fowler, Christophe Randin, Maria Shahgedanova, Martin Steinbacher, Marc Zebisch & Carolina Adler



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

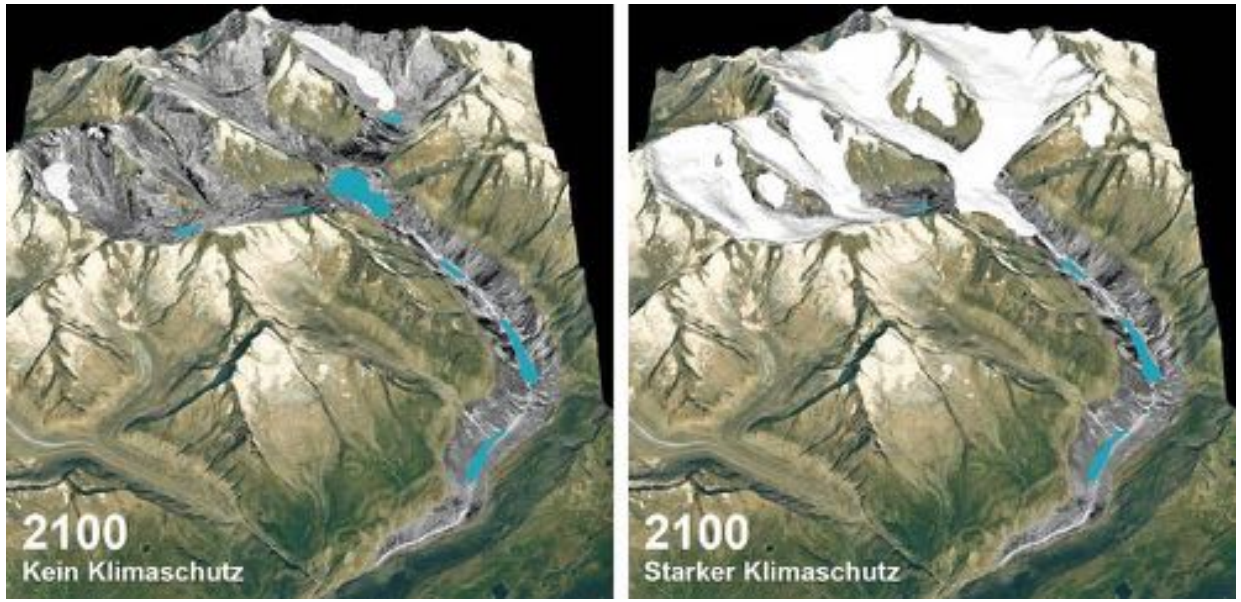
Importance of mountain globally



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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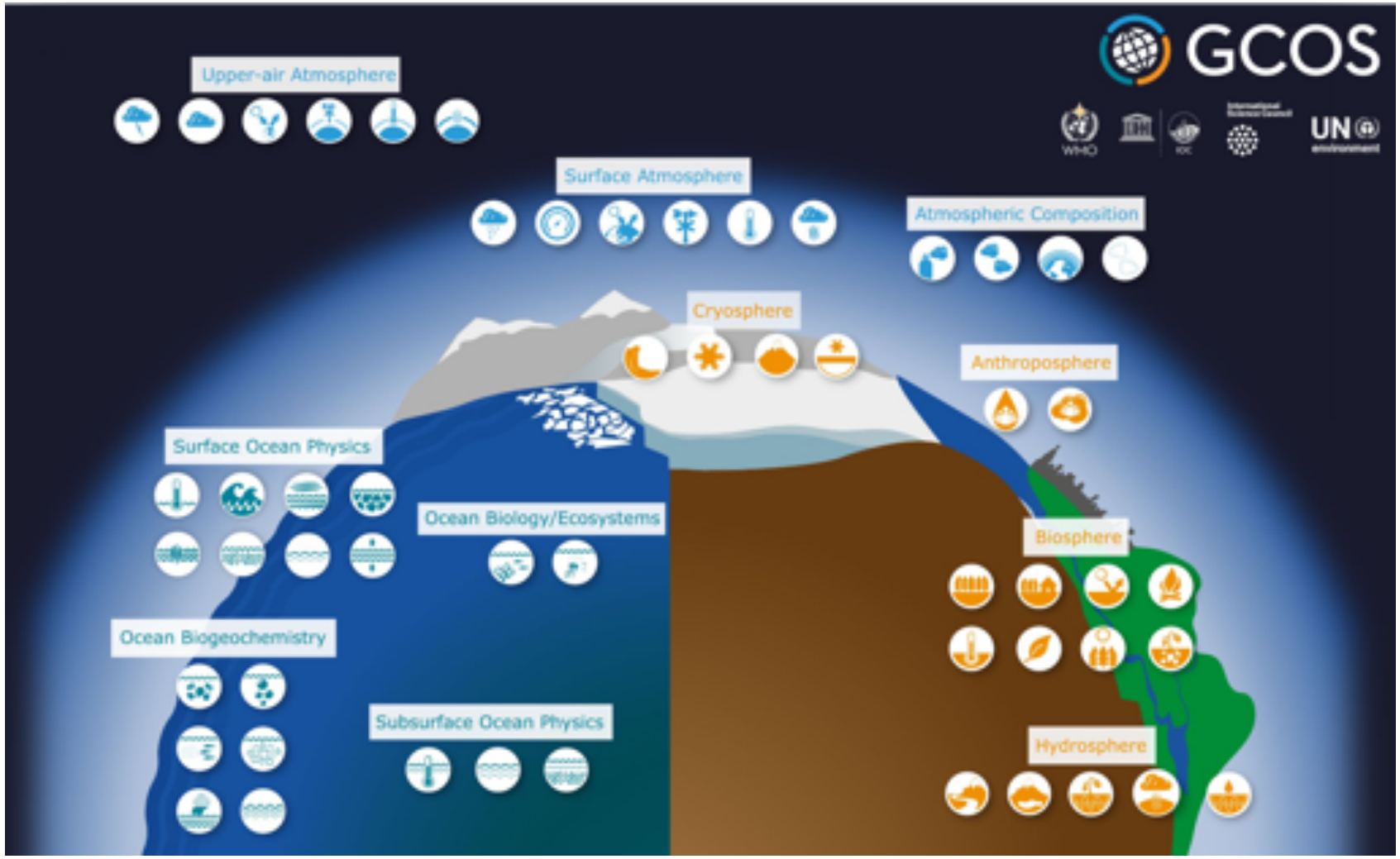
Essential Climate Variables (ECVs)



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

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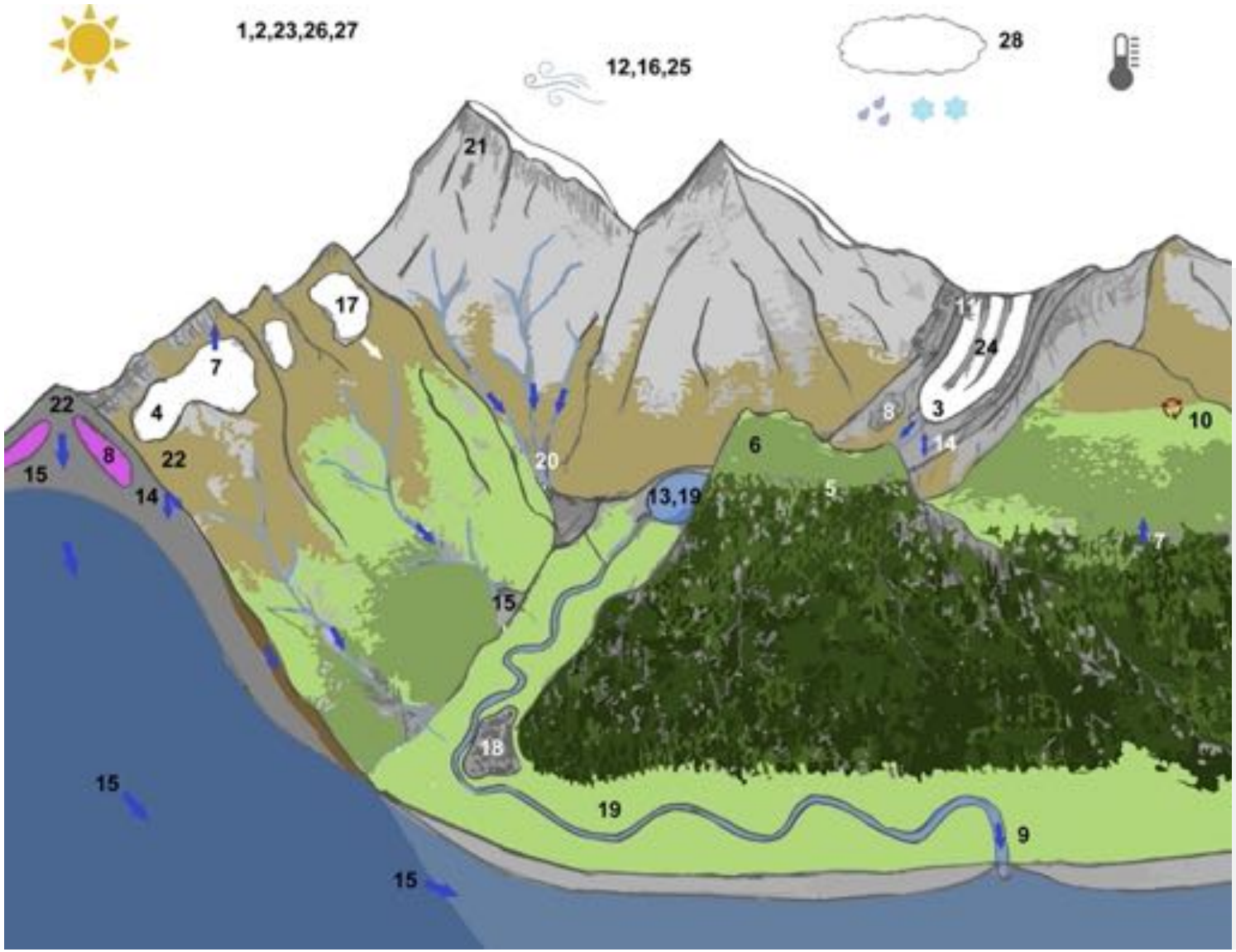
Observing Mountain Environments

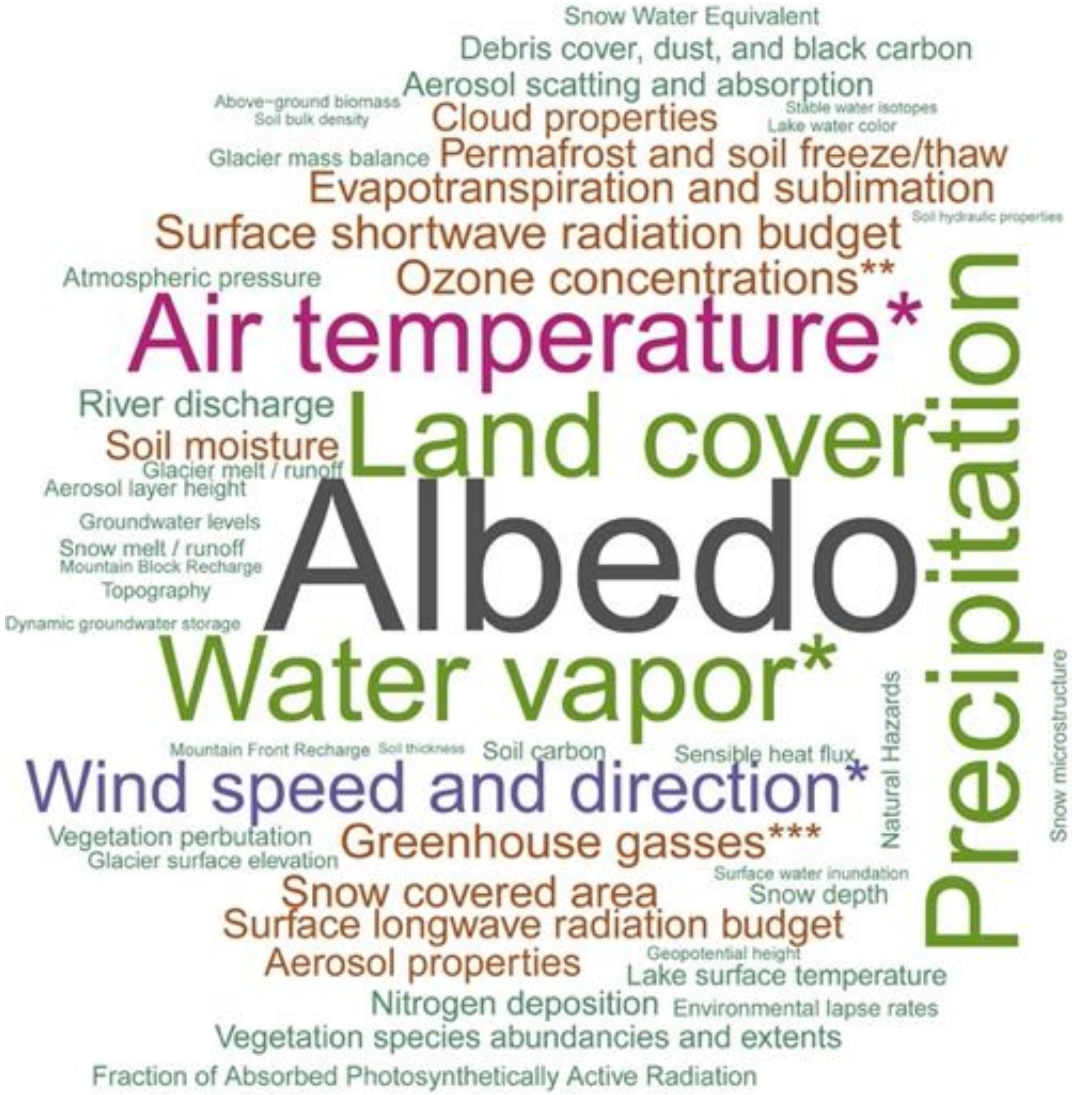
Generic integrated mountain environmental system



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

Principal sphere(s)	EMCVs
Biosphere and hydrosphere	evapotranspiration
Atmosphere	nitrogen deposition
Biosphere	vegetation species abundances and extents
Atmosphere	*in situ* ozone concentration
Biosphere	geomorphological or avalanche perturbation of vegetation (spatial extents)
Cryosphere	glacier debris cover (extent and thickness) and dust deposition on snow and ice
Atmosphere	*in situ* aerosol absorption
Atmosphere	*in situ* aerosol scattering
Atmosphere	near-surface air-temperature lapse rates and orographic precipitation gradients
Biosphere	forest extent
Cryosphere	snow microstructure
Atmosphere and cryosphere	black carbon deposition
Atmosphere	geopotential height
All	upward longwave radiation flux
All	upward shortwave radiation flux
All	natural hazard maps
All	spatially distributed topographic data
Hydrosphere	mountain front recharge
Hydrosphere	mountain block recharge
Hydrosphere	glacier melt (also known as runoff)
Hydrosphere	snow melt (also known as runoff)
Hydrosphere	stable isotopic composition of water (snow, rain, glacier ice, surface, and groundwaters)
All	past natural hazard event extents and intensities
Hydrosphere	dynamic groundwater storage
Hydrosphere	soil hydraulic properties
Hydrosphere and biosphere	soil thickness

- **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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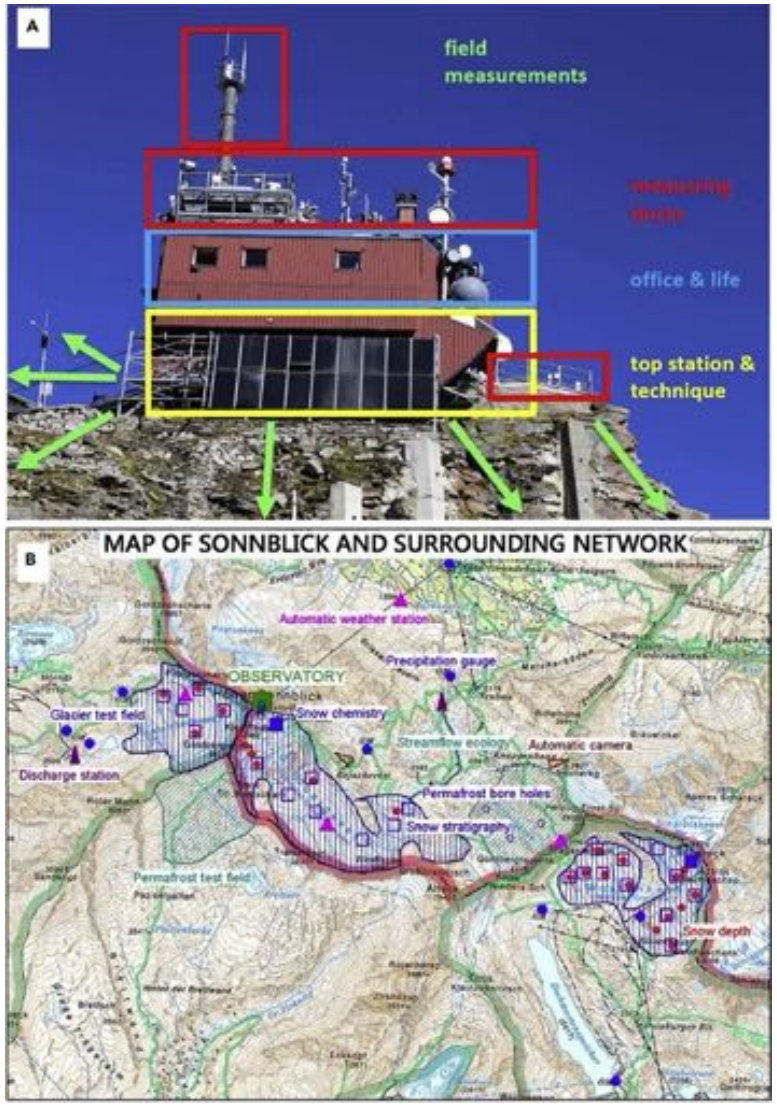
Install new & expand existing “Mountain Observatories”



https://www.sonnblick.net/en/

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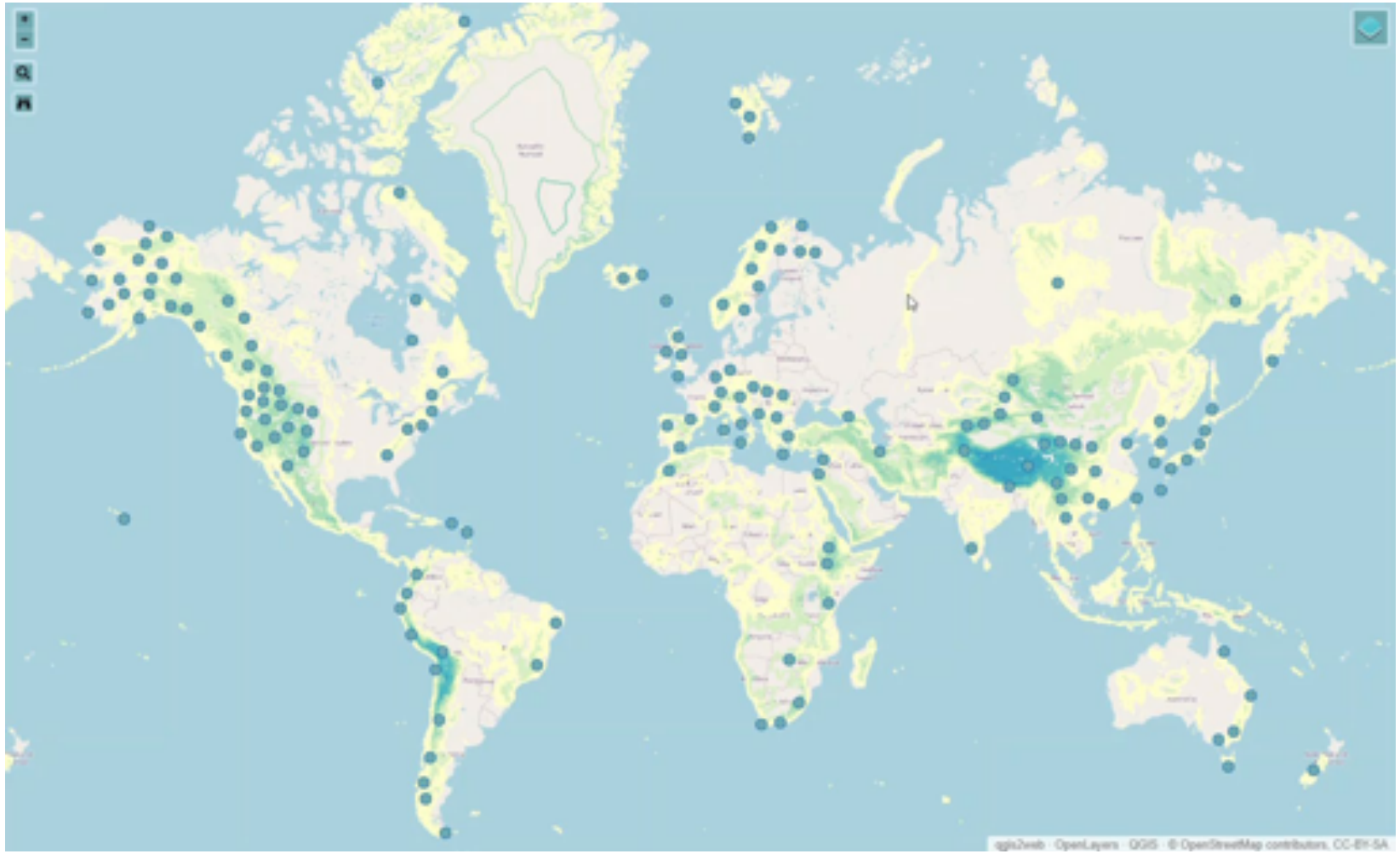
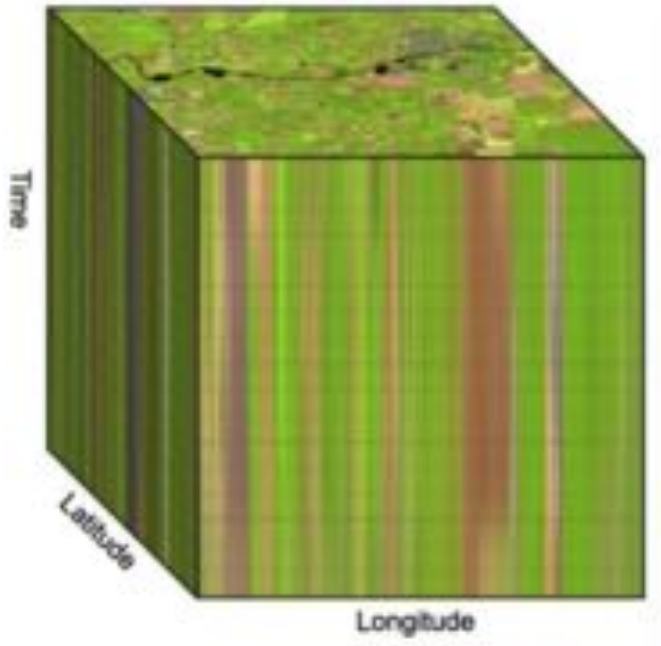
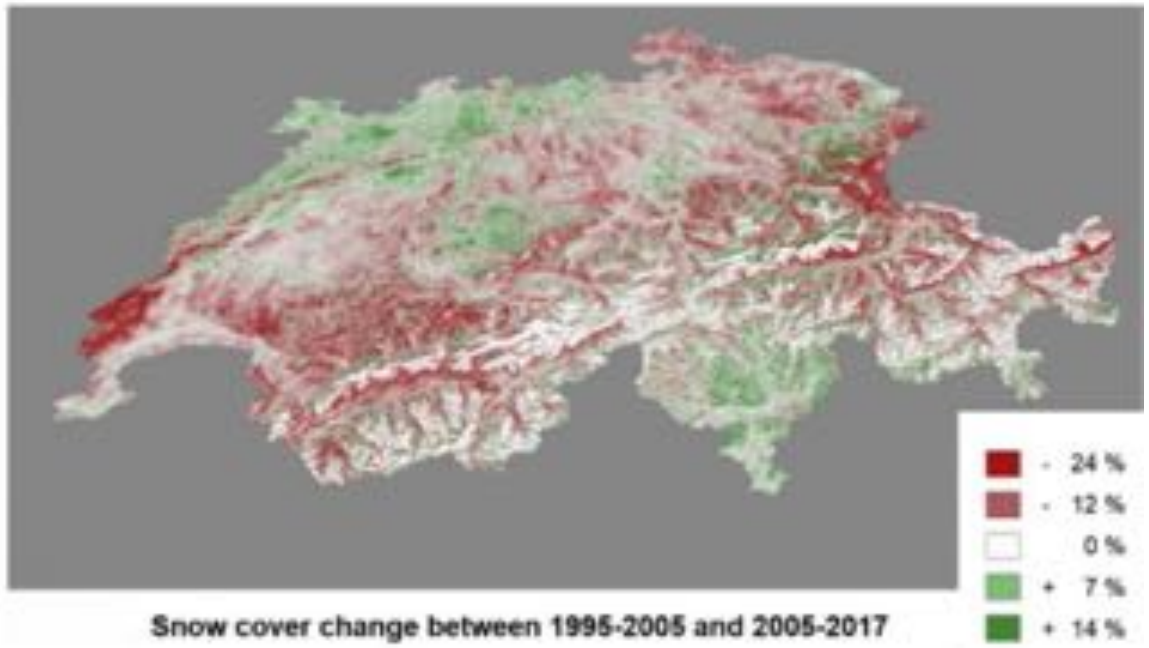


https://www.geomountains.org/resources-open-surveys/resources-surveys/inventory-of-in-situ-observational-infrastructure; see also Shahgedanova et al. (2021)

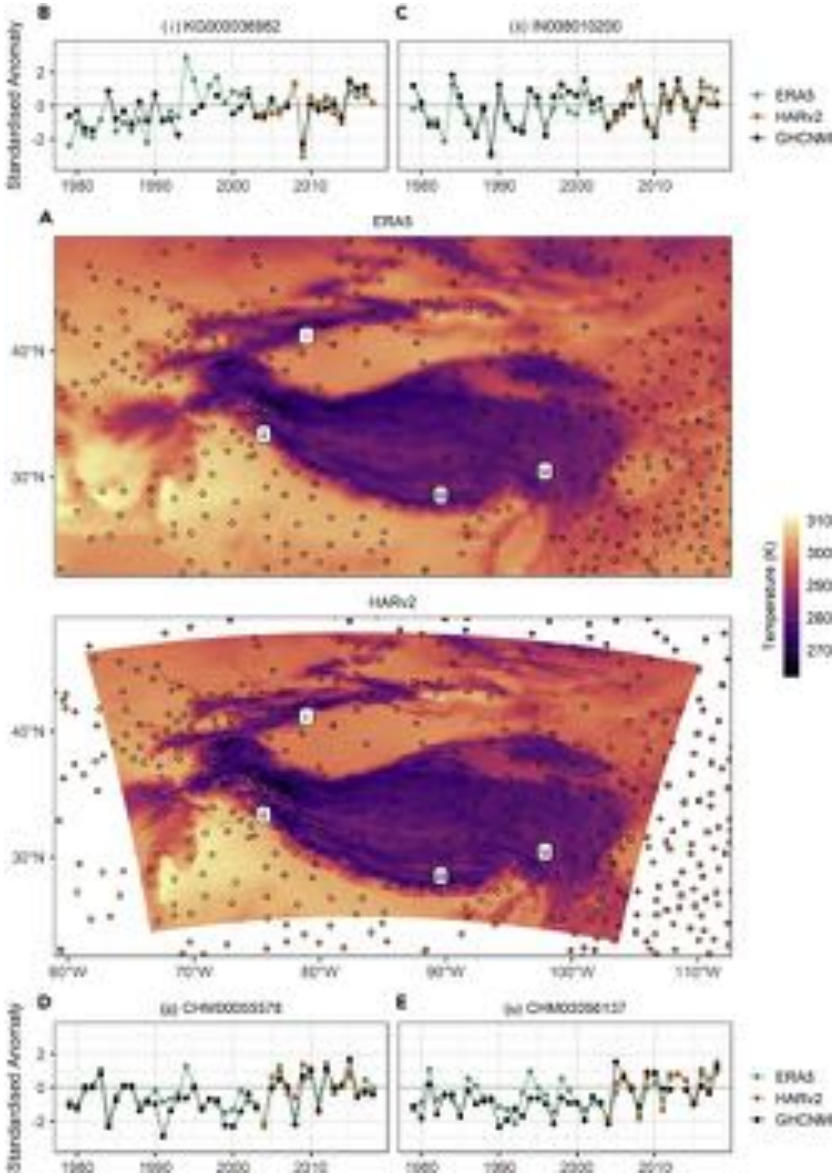
Exploit the latest remotely-sensed data





Dhu et al. (2021)

Exploit the latest climate models



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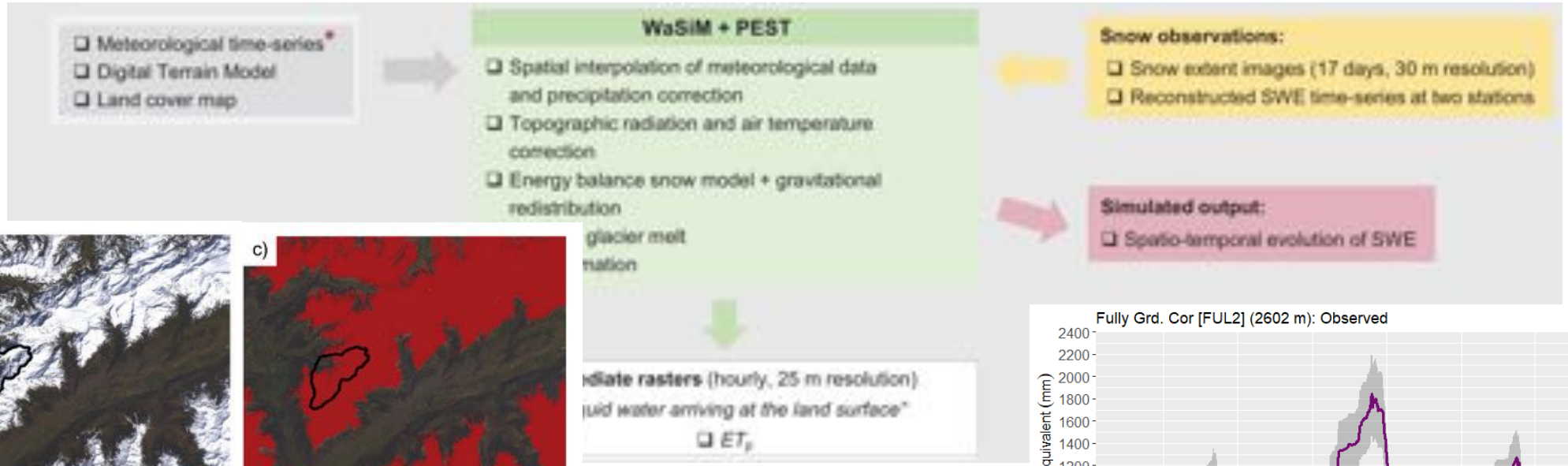
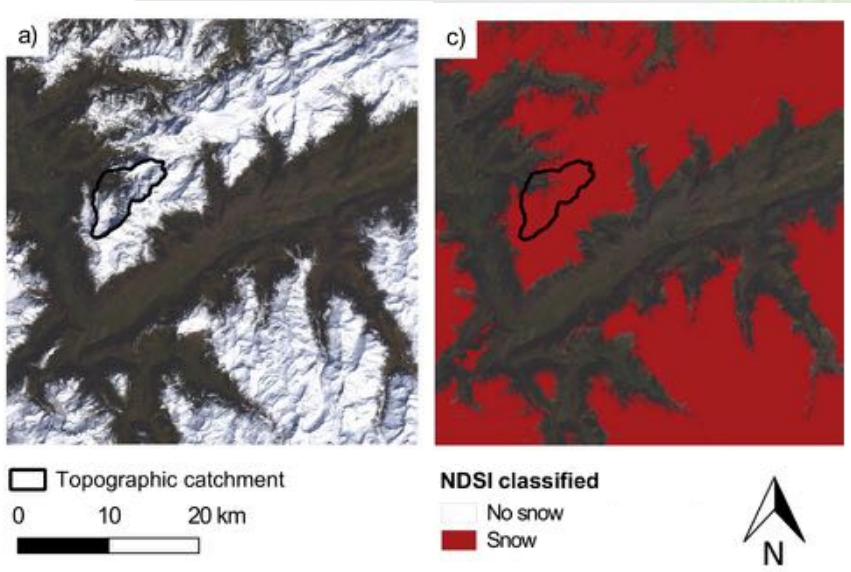
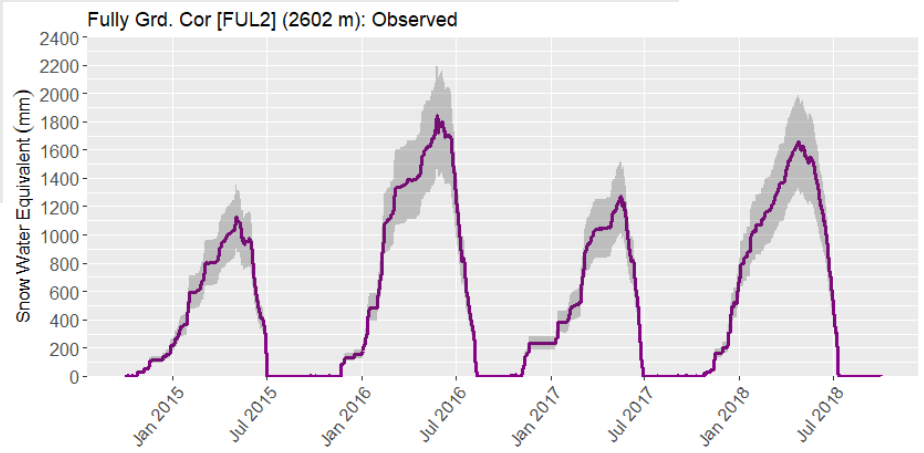
Exploit the latest climate models

Integrate in situ and remotely sensed data with advanced numerical models

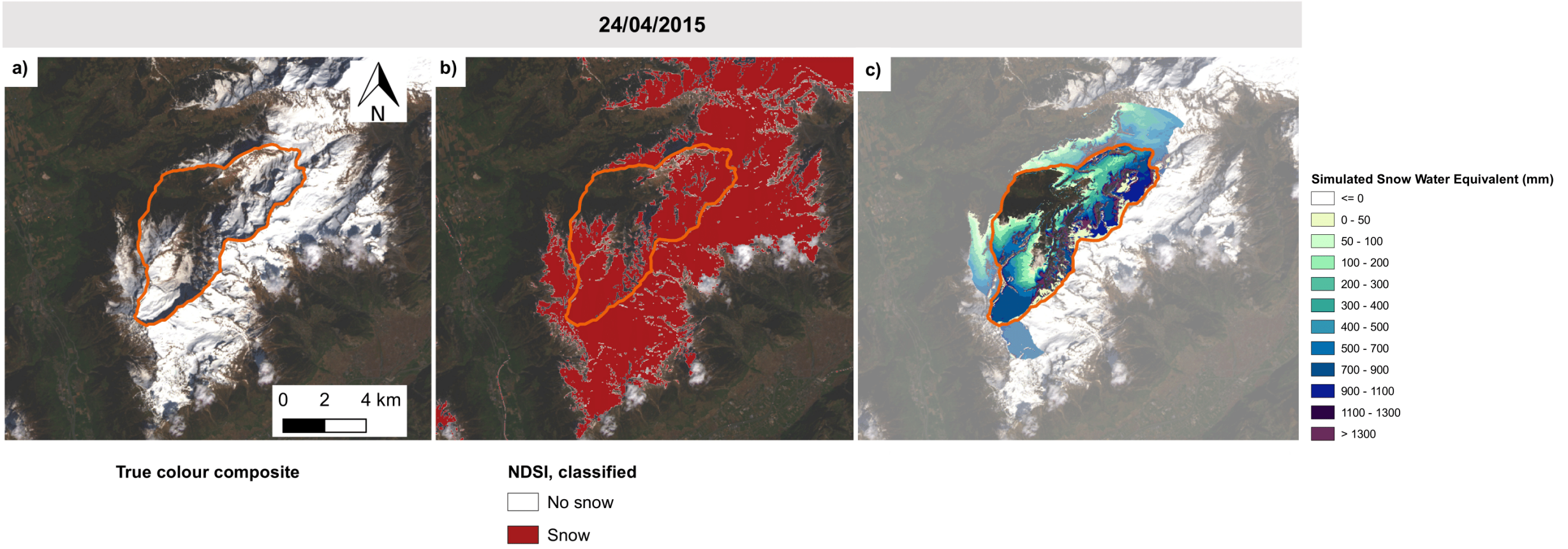






Thornton et al. (2021)

Integrate in situ and remotely sensed data with advanced numerical models



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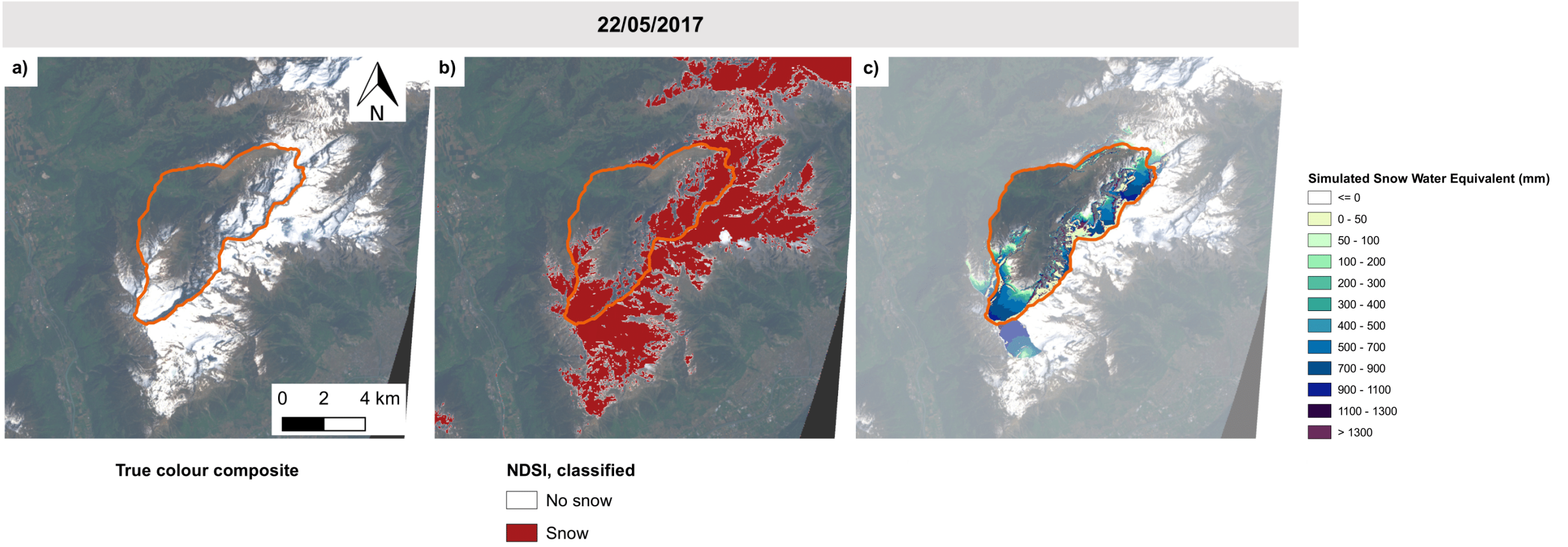

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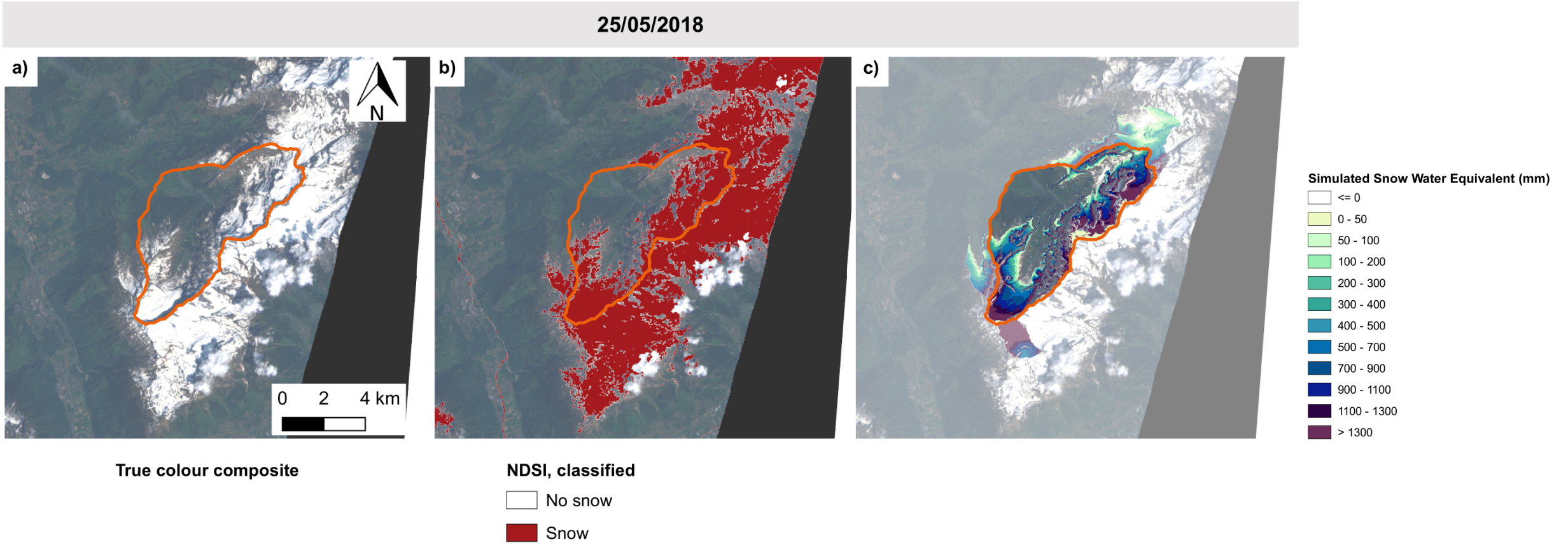

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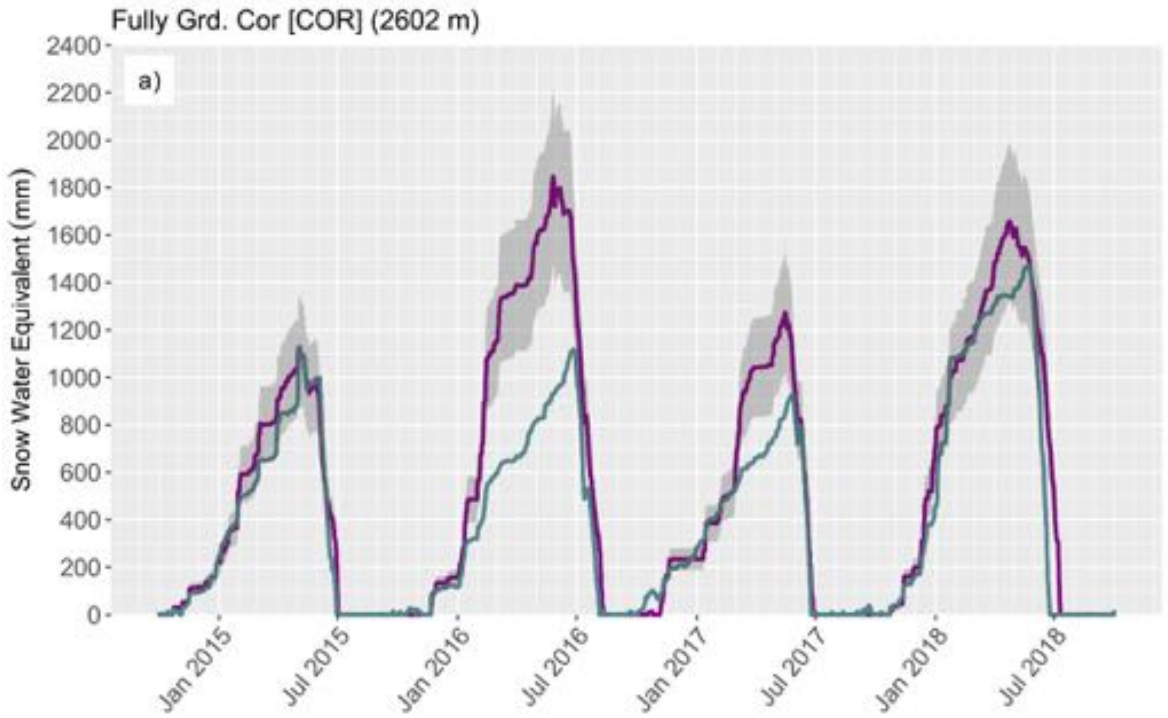
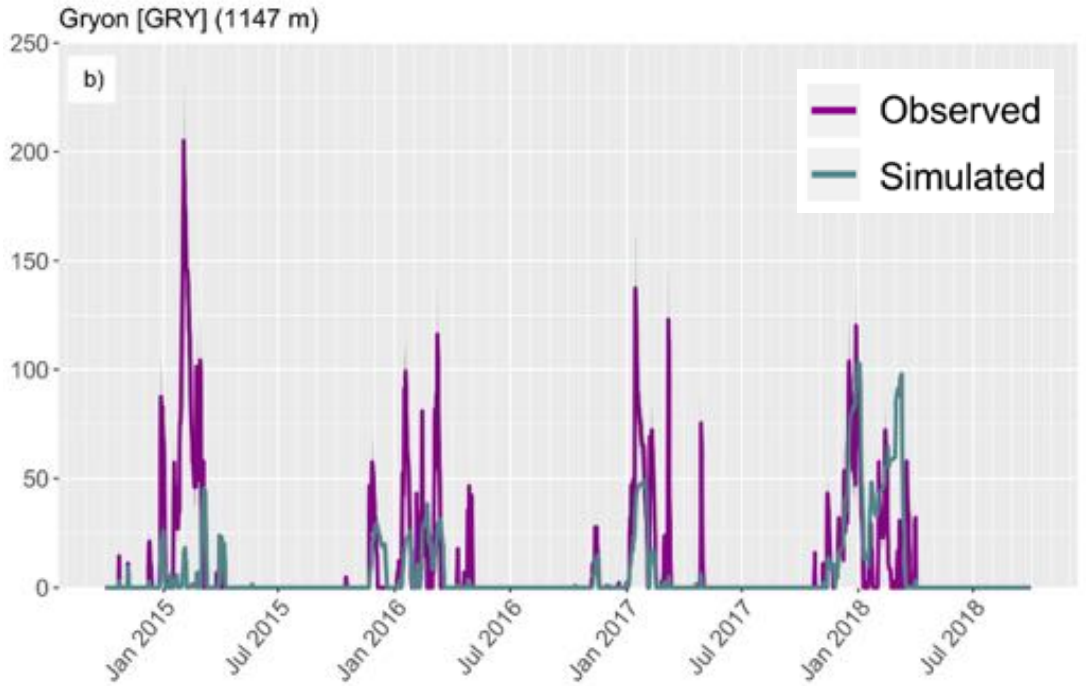
High elevation site:



Low elevation site:



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Thornton et al. (2021)

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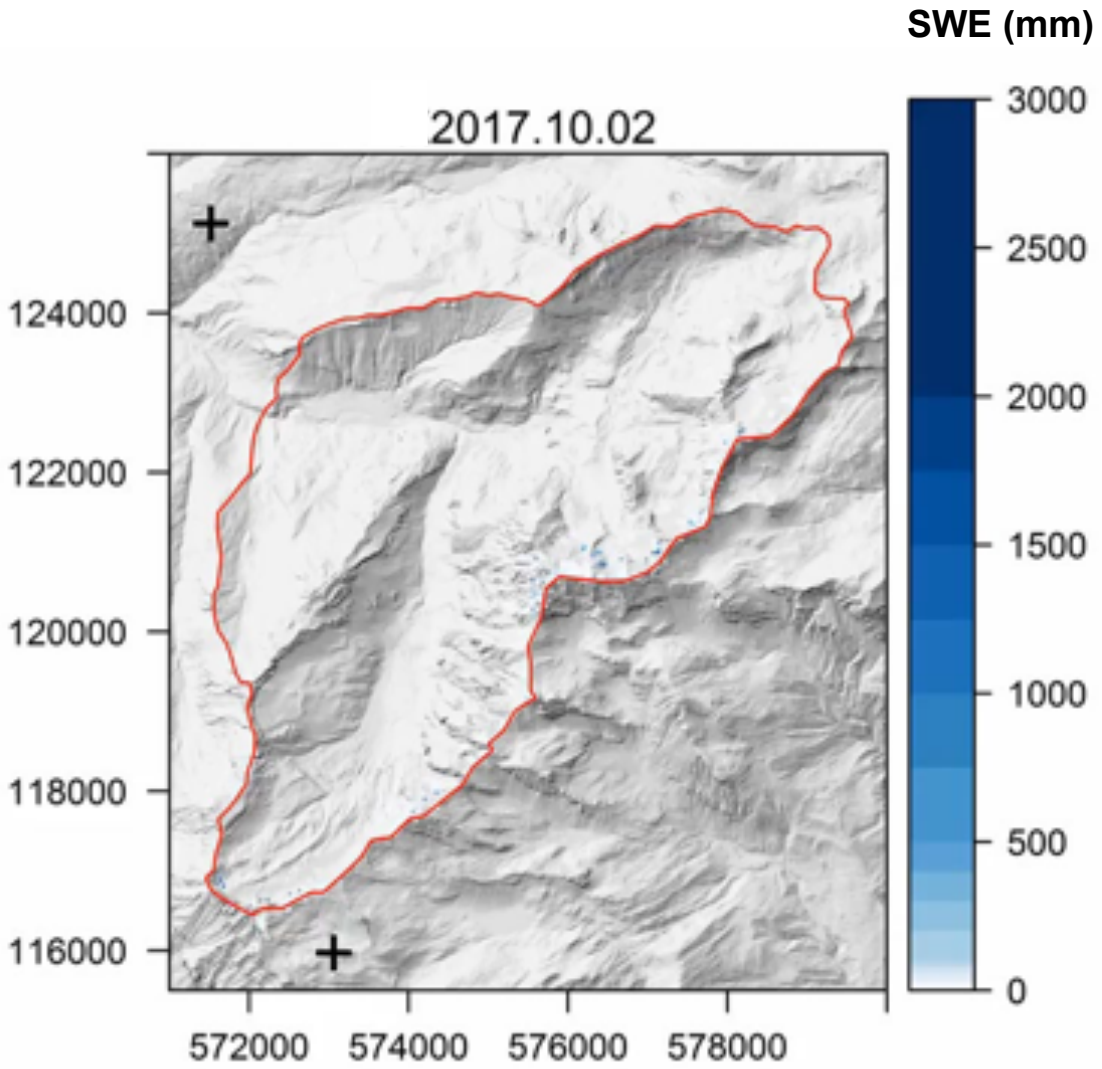

+ In situ station

Thornton et al. (2021)

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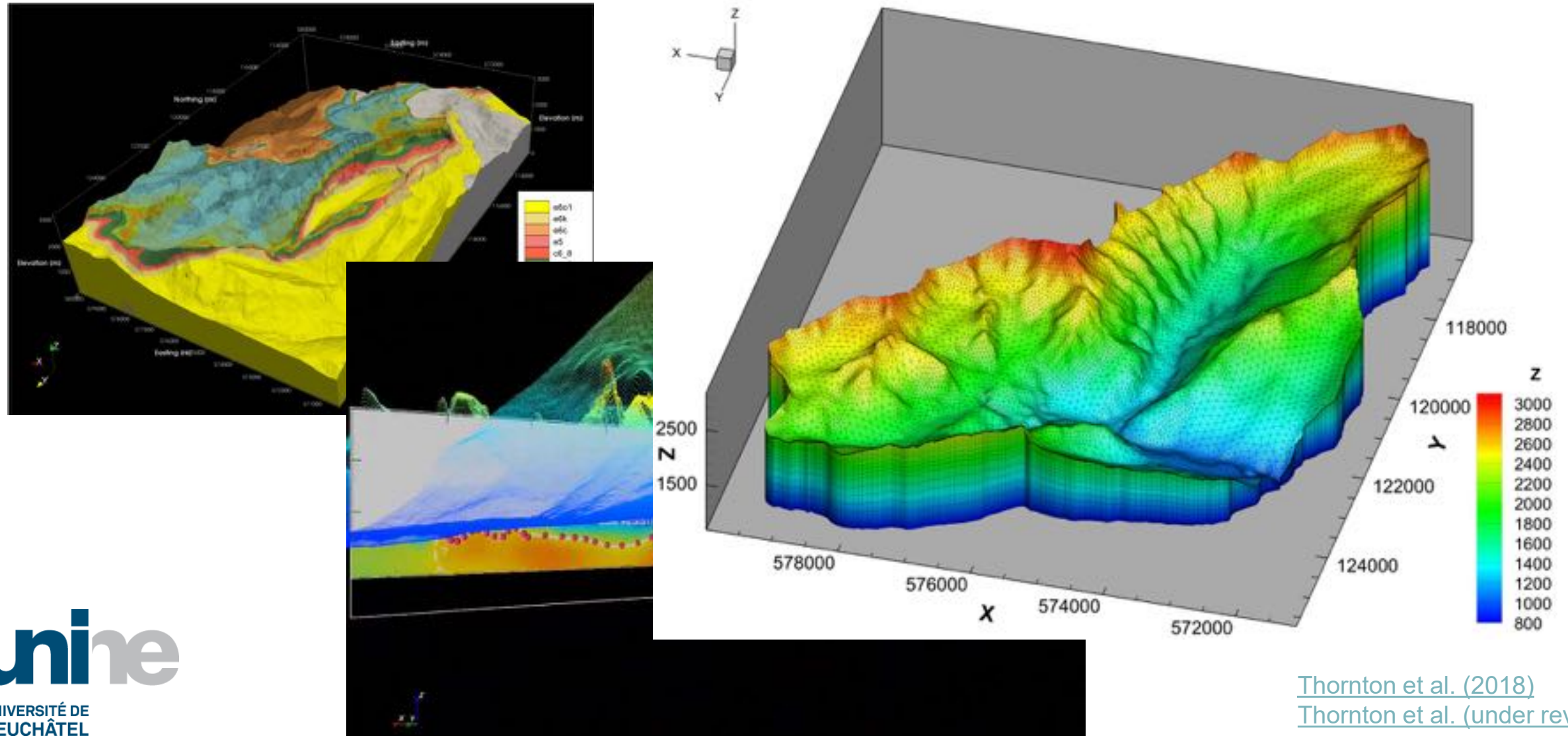
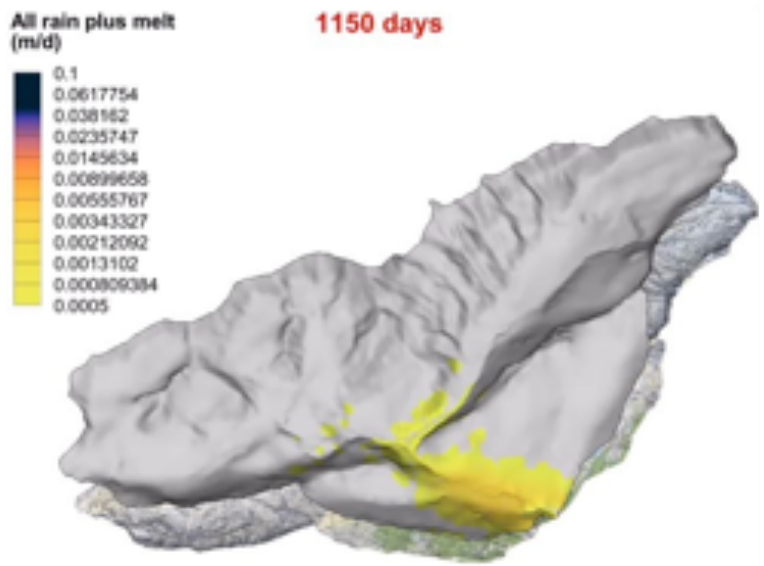
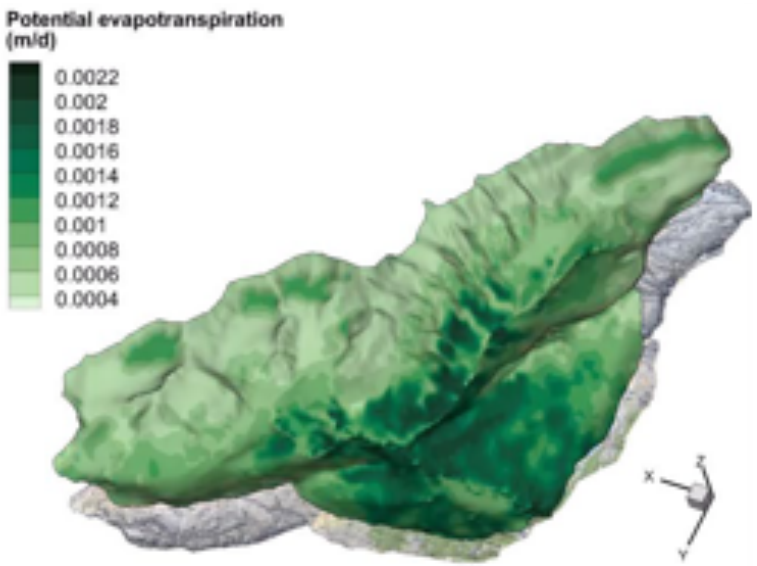
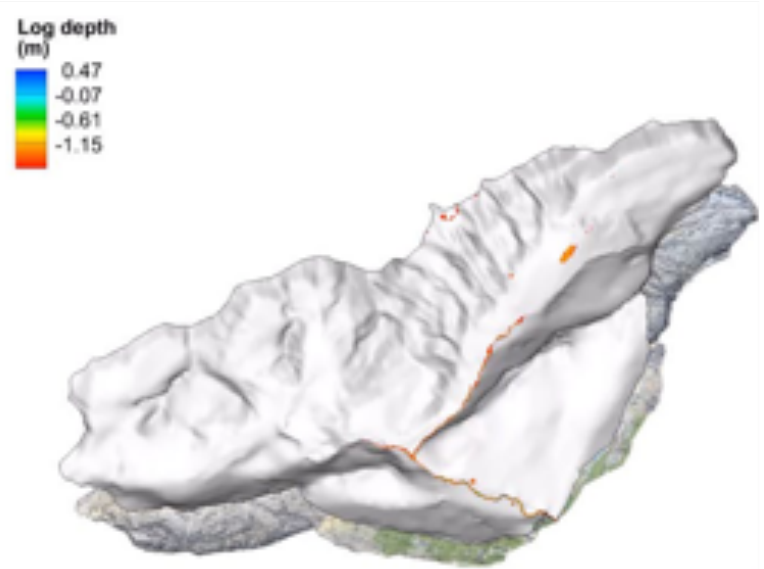
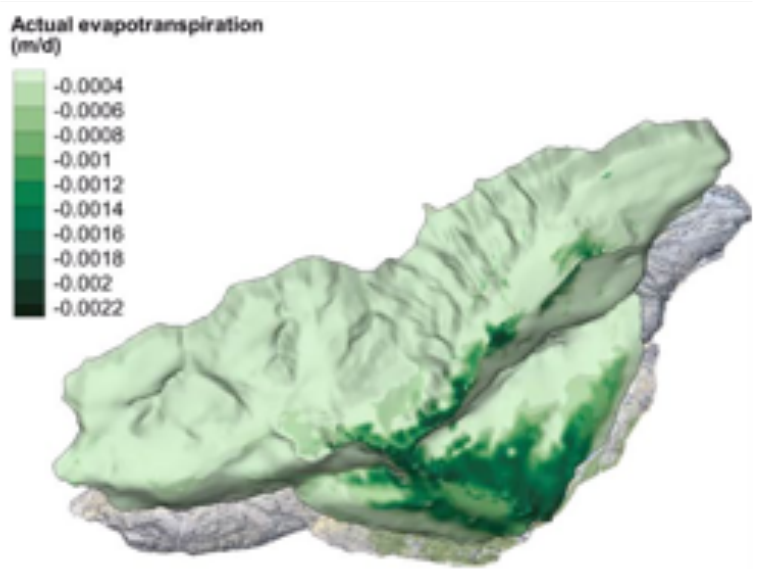


Thornton et al. (2018)
Thornton et al. (under review)

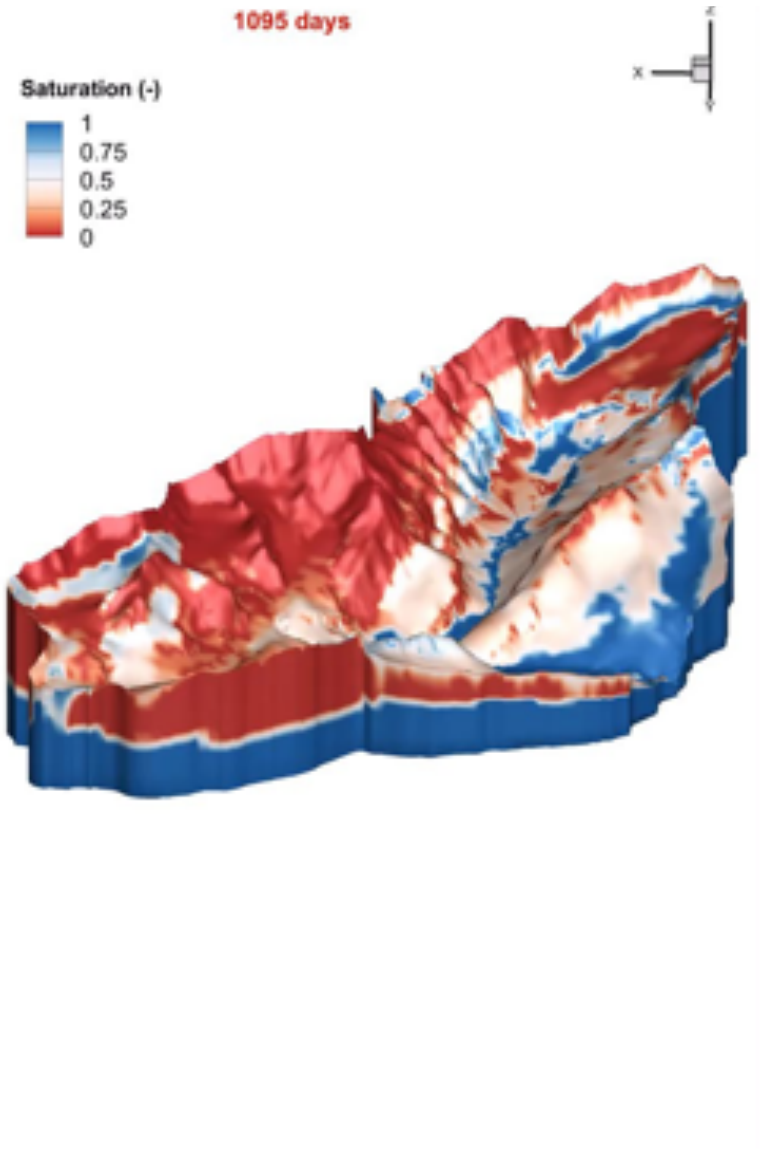


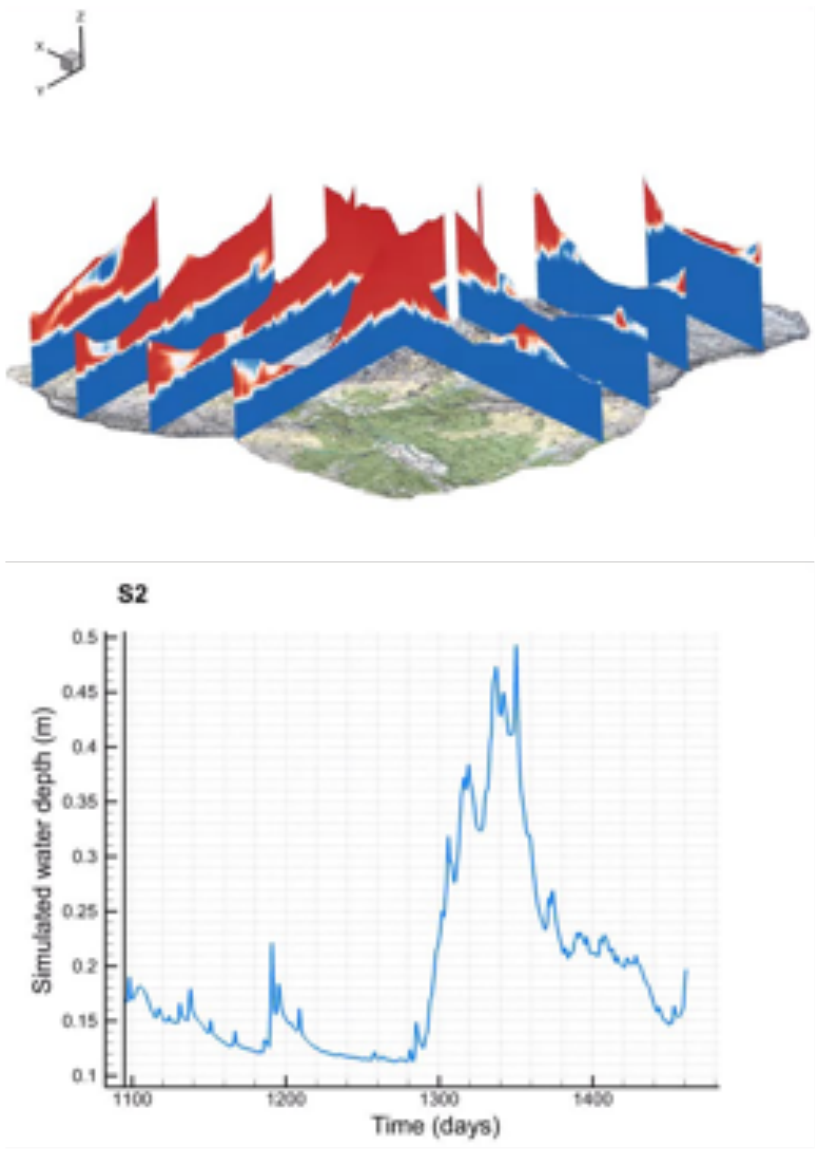






Thornton et al. (under review)





Thornton et al. (under review)

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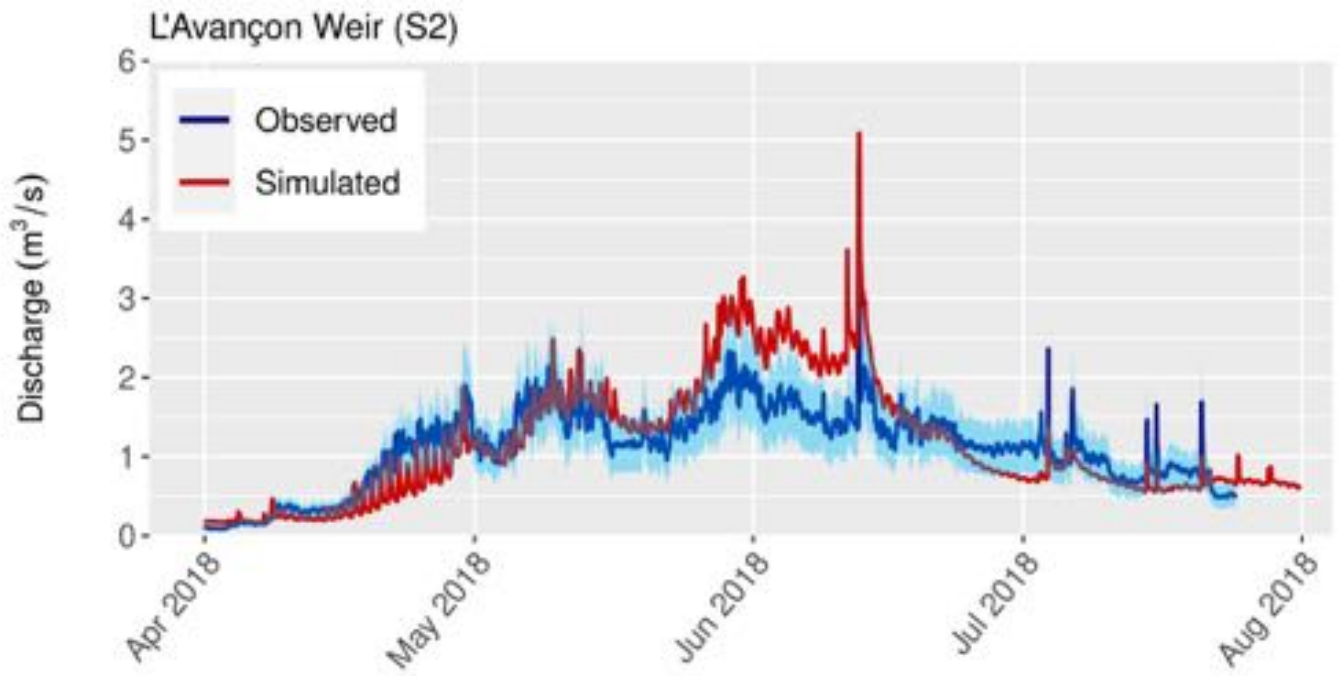

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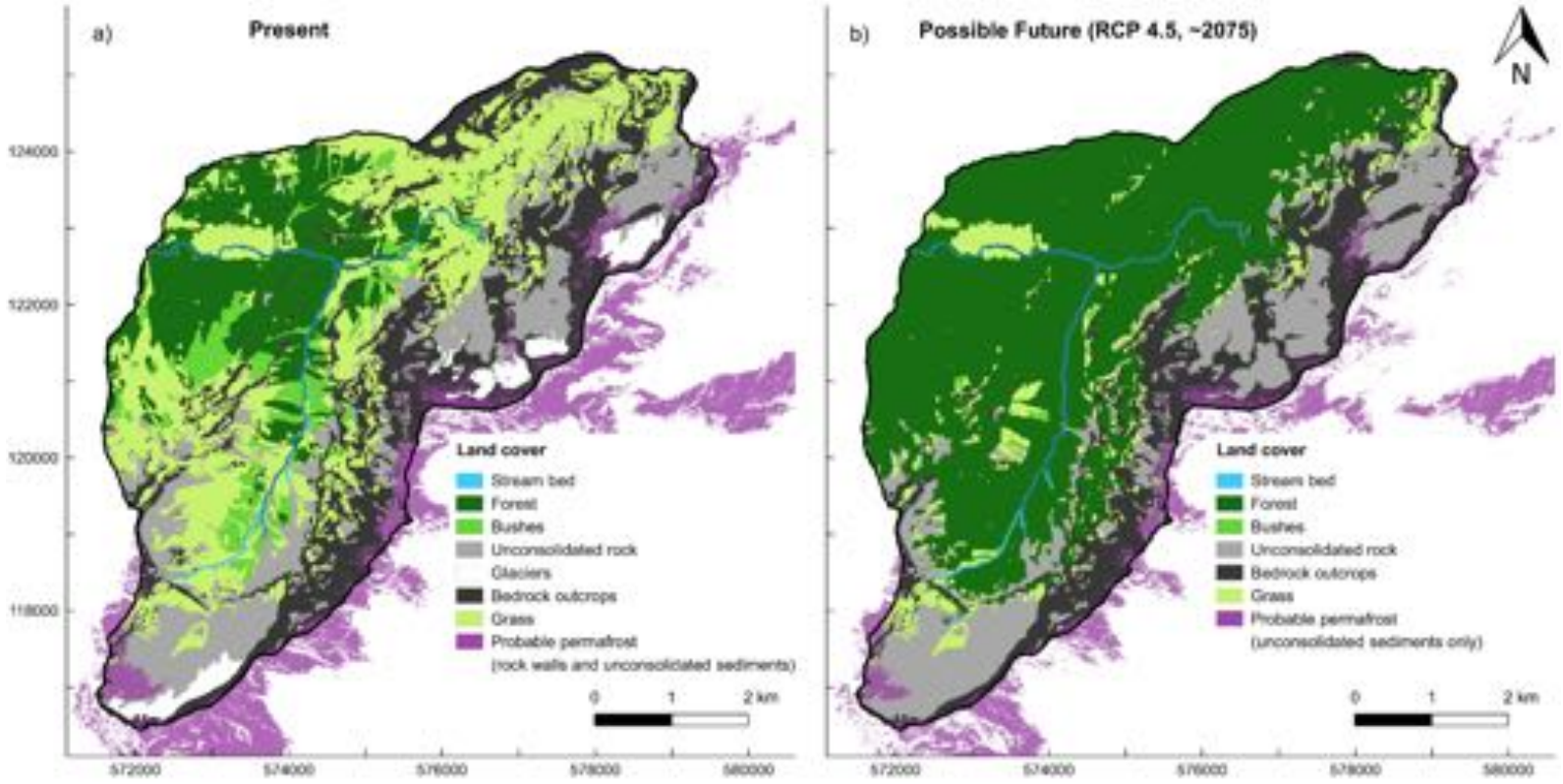

Vegetation modelling: D. Scherrer

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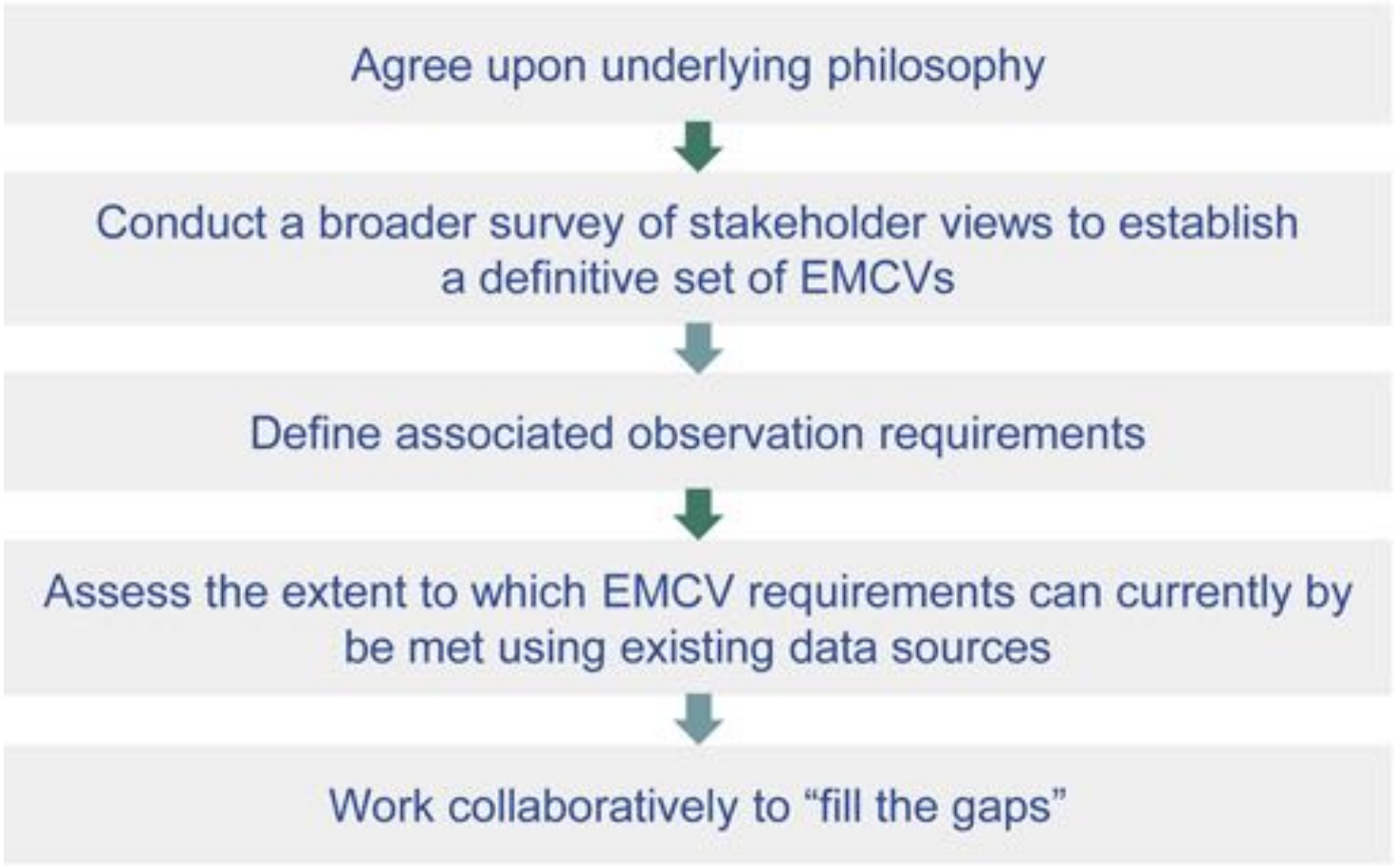
Roadmap:


Agree upon underlying philosophy
Conduct a broader survey of stakeholder views to establish a definitive set of EMCVs
Define associated observation requirements
Assess the extent to which EMCV requirements can currently by be met using existing data sources
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

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