Coverage of in situ climatological observations in the world's mountains

James Thornton, Nicolas Pepin, Maria Shahgedanova, and Carolina Adler

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MOUNTAIN RESEARCH INITIATIVE

UNIVERSITY OF PORTSMOUTH

University of Reading

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Motivation

- **In situ** climatological observations have **many key applications** in all settings
- *"Monitoring networks are insufficient at high elevations"*; *"the density of stations decreases with elevation"*
- [Change detection and attribution efforts are inhibited…]

these climate-related changes (Section 2.2.1), due to limited spatial density and/or temporal extent of observation records at high elevations. For example, trends in total or solid precipitation at high

These observational knowledge gaps currently impede efforts to quantify trends, and to calibrate and evaluate models that simulate the past and future evolution of the cryosphere and its impacts.

(Hock et al., 2019)

- However, there have been **no concerted effort to assess patterns of mountain in situ climatological data coverage** on a **consistent and global basis**

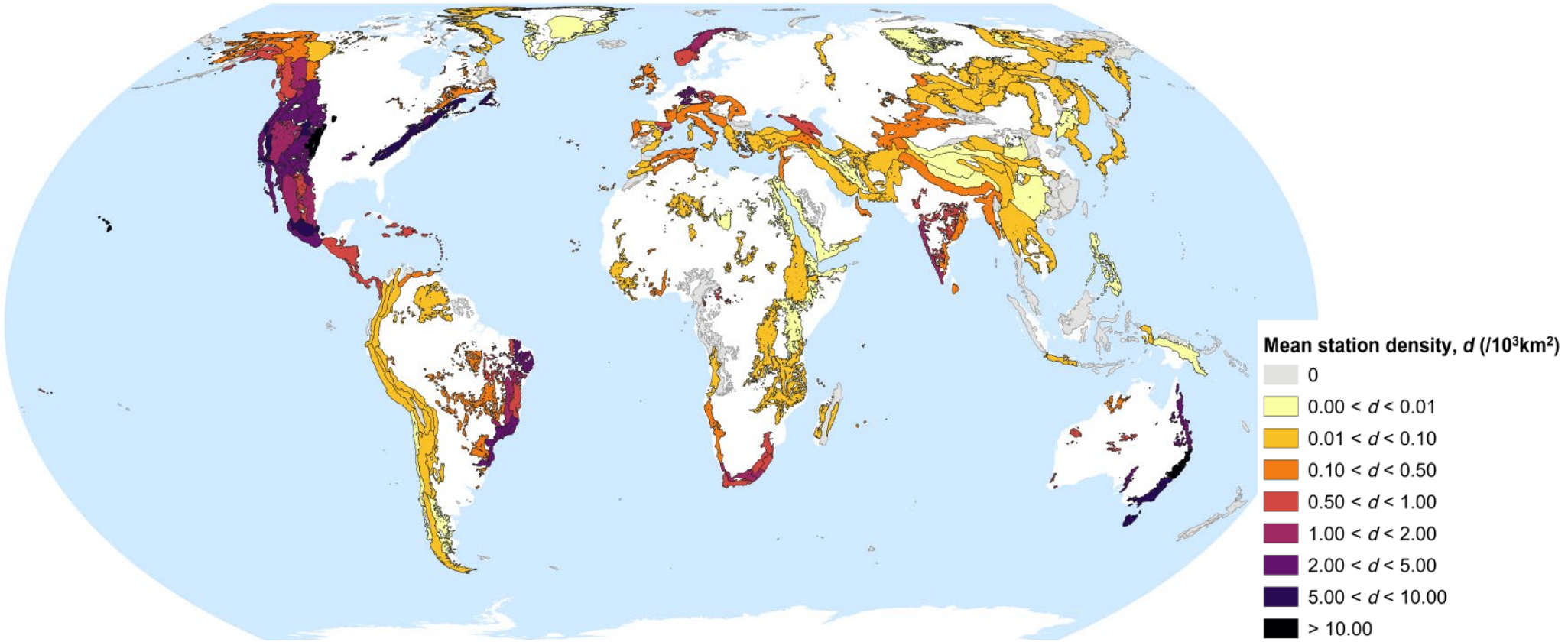
Objectives & Data

- To quantify patterns of in situ climatological station record coverage with respect to:
  - **Space**, **time**, and **elevation** (absolute coverage)
  - Three key variables; **air temperature**, **precipitation**, and **snow depth**
  - Across **292 named global mountain regions** (Snethlage et al., 2022)
  - Station inventory: **Global Historical Climatological Network-Daily** (GHCNd) (Menne et al., 2012)

- Also introduce additional datasets to assess **coverage metrics relative to other potential covariates**:
  - **Water Tower Index (WTI)** (Immerzeel et al., 2020)
  - **Population** (Pesaresi et al., 2019) and **GDP** (Kummu et al., 2018) of **corresponding downstream river catchments** (GRDC, 2020)

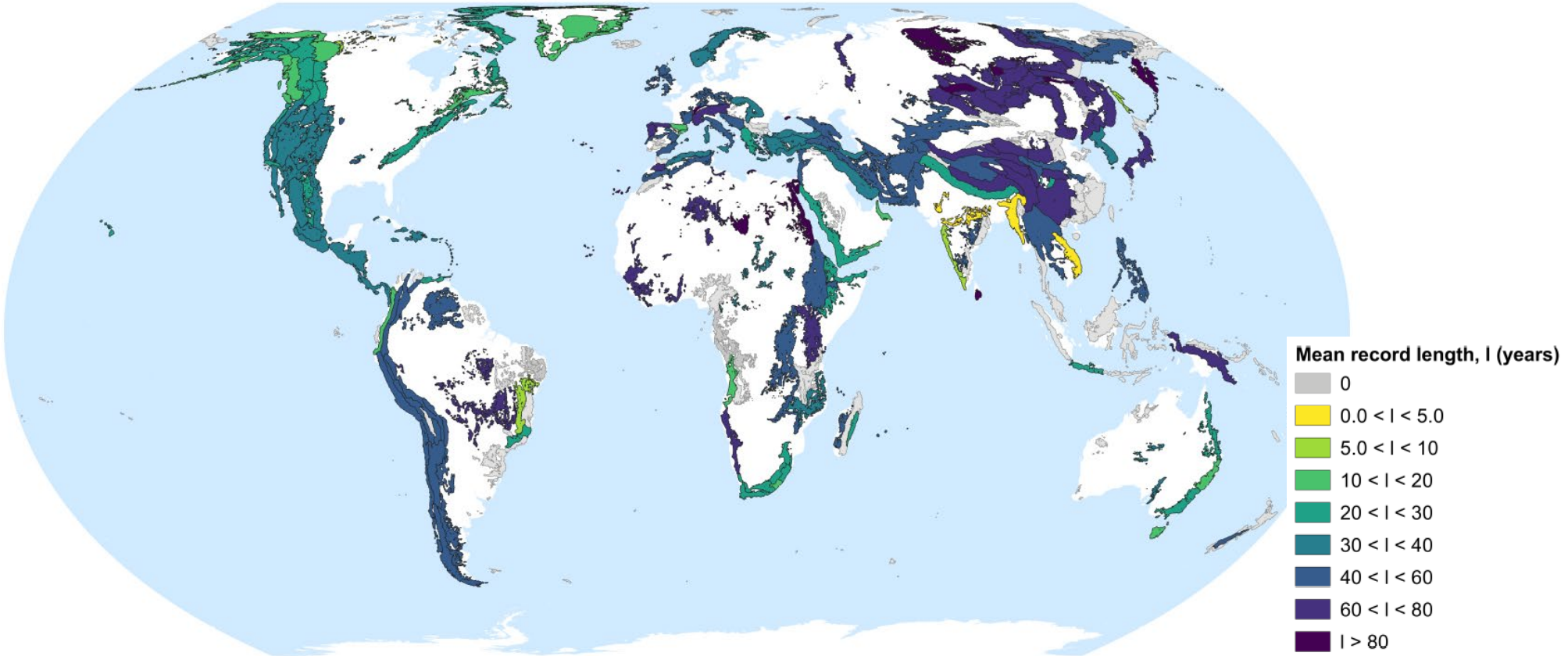
Selected results: spatial density

- **Mean spatial density** by mountain range, irrespective of record length, for **precipitation**:

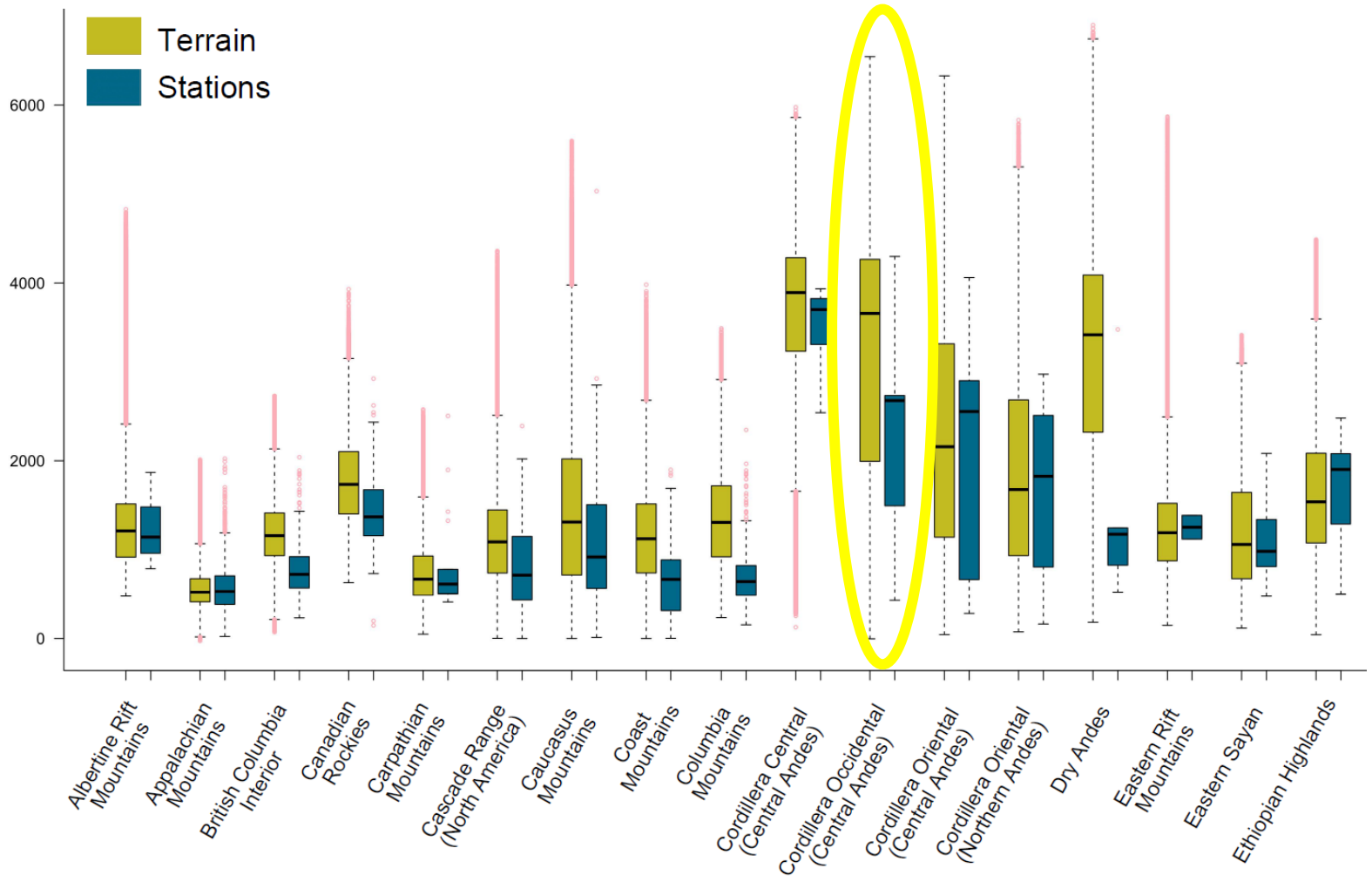


Selected results: record length

- **Mean record length** by mountain range for **air temperature** (daily max):

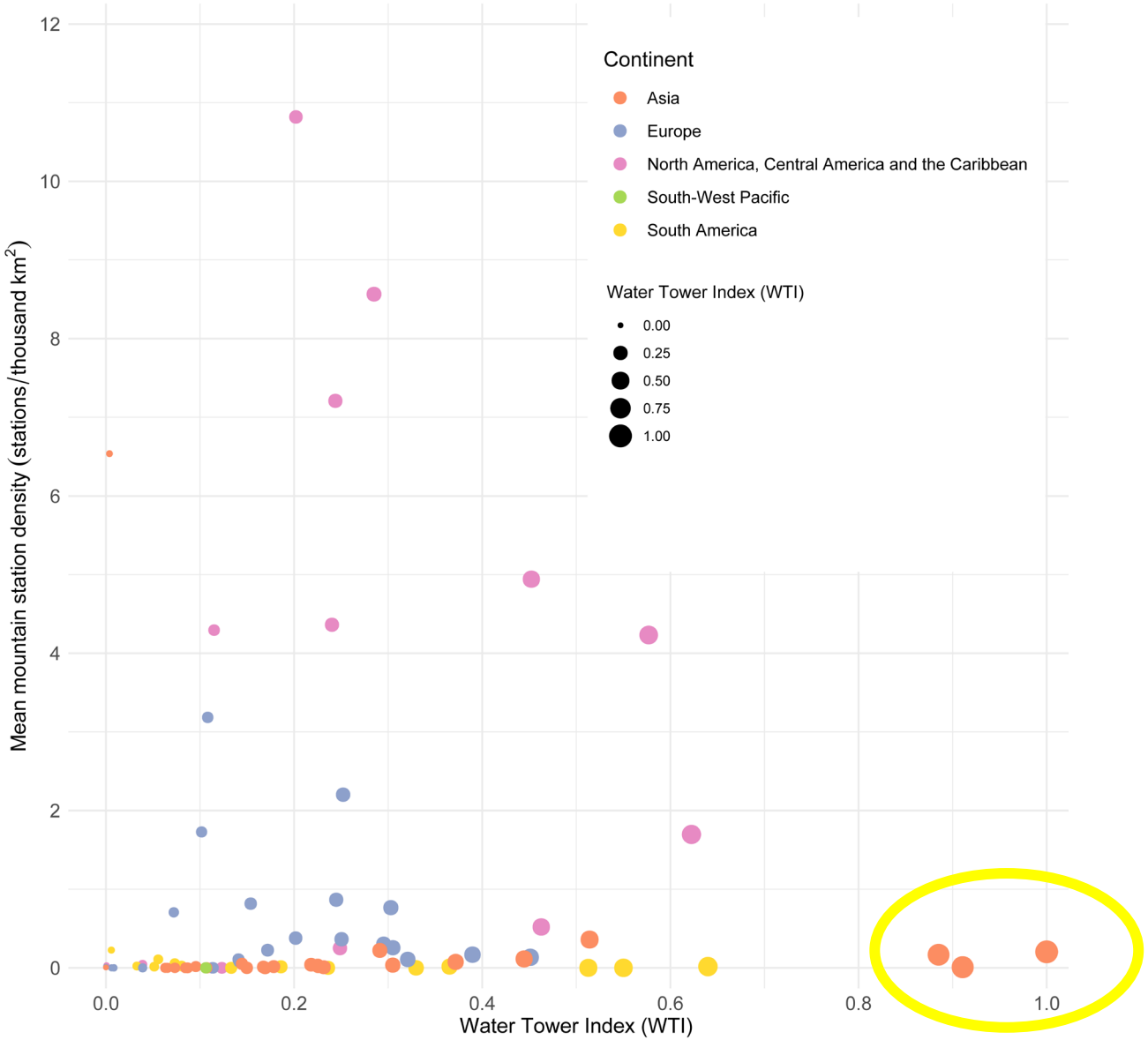


Selected results: elevational coverage



- **Elevational distribution** of **several mountain ranges** seems to be **severely under-sampled**, e.g. *Caucasus Mountains, Cordillera Occidental (Central Andes), Dry Andes, Mongolian Altai, Himalaya, Hindu Kush, Pamir Mountains*, and *Tian Shan*

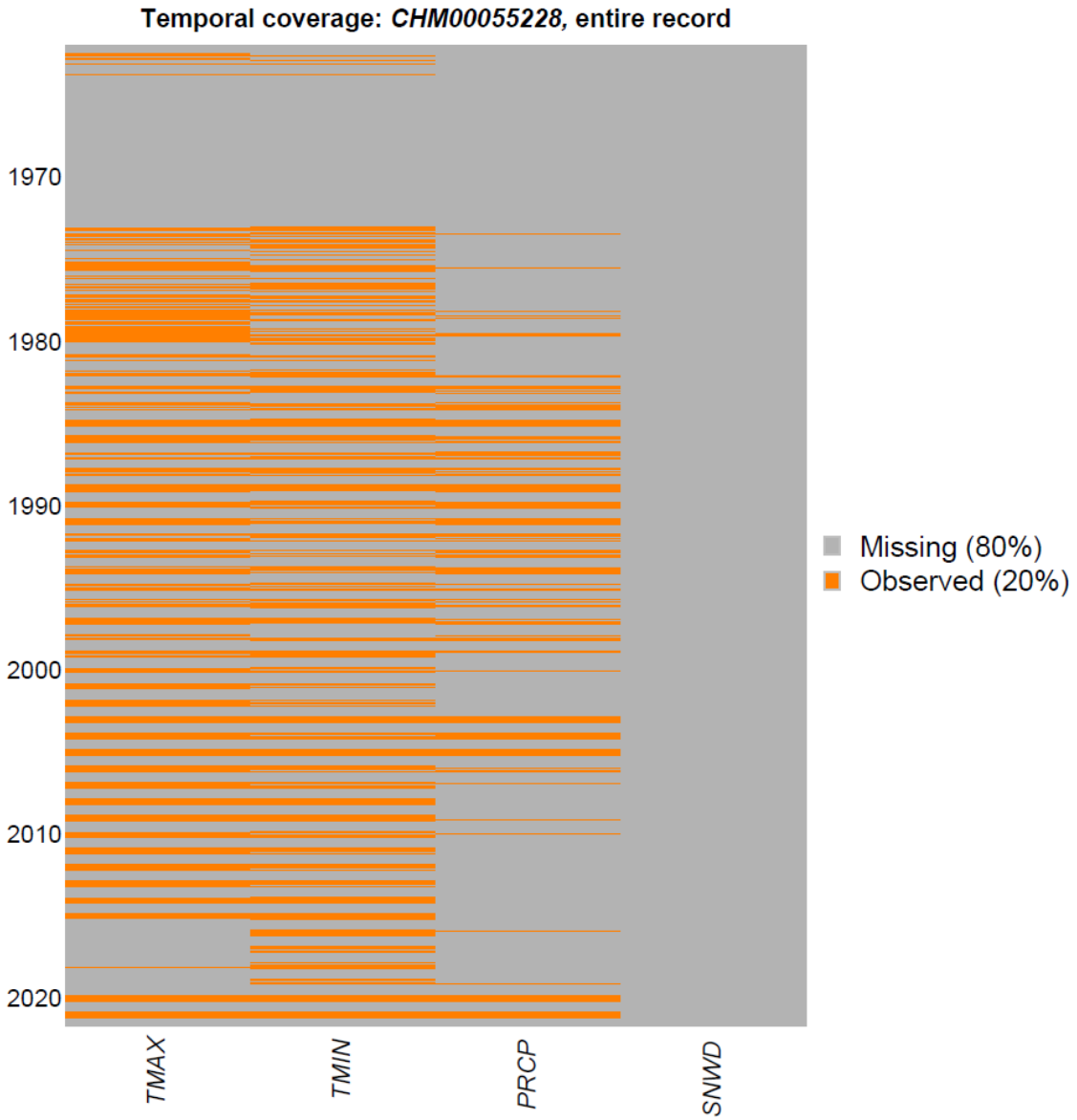
Water Tower Index vs. mean station density*



*Mean station density per Water Tower Unit (WTU); See Immerzeel et al. (2020) for further details

Detailed temporal coverage and quality information

- **R script** provided in online Supplementary Material
- Works on **any GHCNd station** (potentially useful beyond mountains)
- E.g. temporal coverage, all variables at a given station (right)



Conclusions

- Spatial patterns of mountain data coverage are **highly uneven**
- Station densities in several **"Water Tower Units"** that were previously identified as having **great hydrological importance to society** are **especially low**
- Some mountainous regions whose **elevational distribution** is **severely undersampled by GHCNd stations** could be identified
- Mountain **station density** is only **weakly related** to the **human population** or **economic output** of the **corresponding downstream catchments**

Such insights may assist **national**, **regional**, and **international organisations to** make more **informed decisions** around in situ climatological monitoring network **investment / maintenance / optimisation** in mountains

Limitations and Outlook

- A key caveat is that not all stations are included in inventories such as GHCNd
  - Operational stations > responsible agencies should endeavour to integrate their stations
  - Research-oriented stations > the GEO Mountain In Situ Inventory can provide a home

Limitations and Outlook

https://www.geomountains.org/resources/resources-surveys/inventory-of-in-situ-observational-infrastructure

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- The ultimate goal is to conduct much **more extensive** and **interdisciplinary** data coverage analyses

Many thanks!

Thornton, J. M., Pepin, N., Shahgedanova, M., & Adler, C. (2022). Coverage of in situ climatological observations in the world's mountains. *Frontiers in Climate*, *4*. https://doi.org/10.3389/fclim.2022.814181

james.thornton@unibe.ch