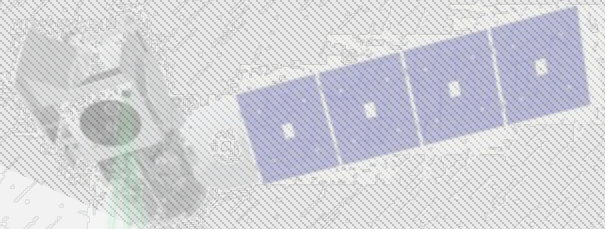


Unlocking the Secrets of Snow Depth

A Study of Satellite Altimetry and High-Precision Digital Elevation Models

Zhihao LIU
Master student of Geoscience

Supervisor | Andreas Max Kääb, Désirée Treichler
Projects | SNOWDEPTH: Global snow depths from spaceborne remote sensing for permafrost, high-elevation precipitation, and climate reanalyzes

The Research Council of Norway

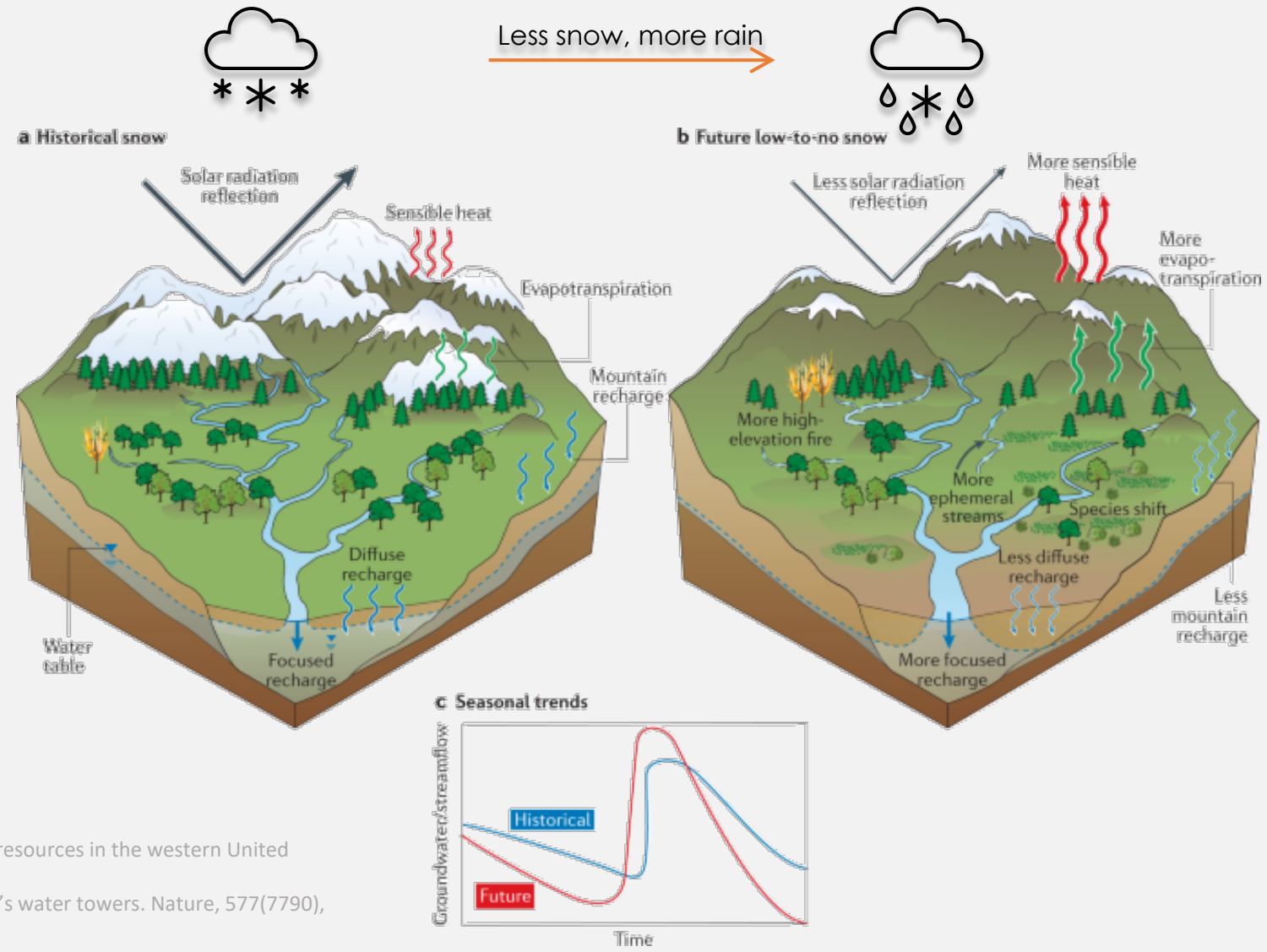
Challenges | Secrets | Our Works | Future works | Summary

Imaging a world with less snow…

A low-to-no-snow future for 'water tower' (Immerzeel et al., 2020; Siirila-Woodburn et al., 2021):

- Solar radiation reflection ↷
- Glacier mass balance ↷
- Water resource ↷
- Stream-flow dynamic ↑
- Snow drought & Wild-fire ↑
- Hydropower ↷
- Vegetation ↷
- …

- Cross-country skiing ↷

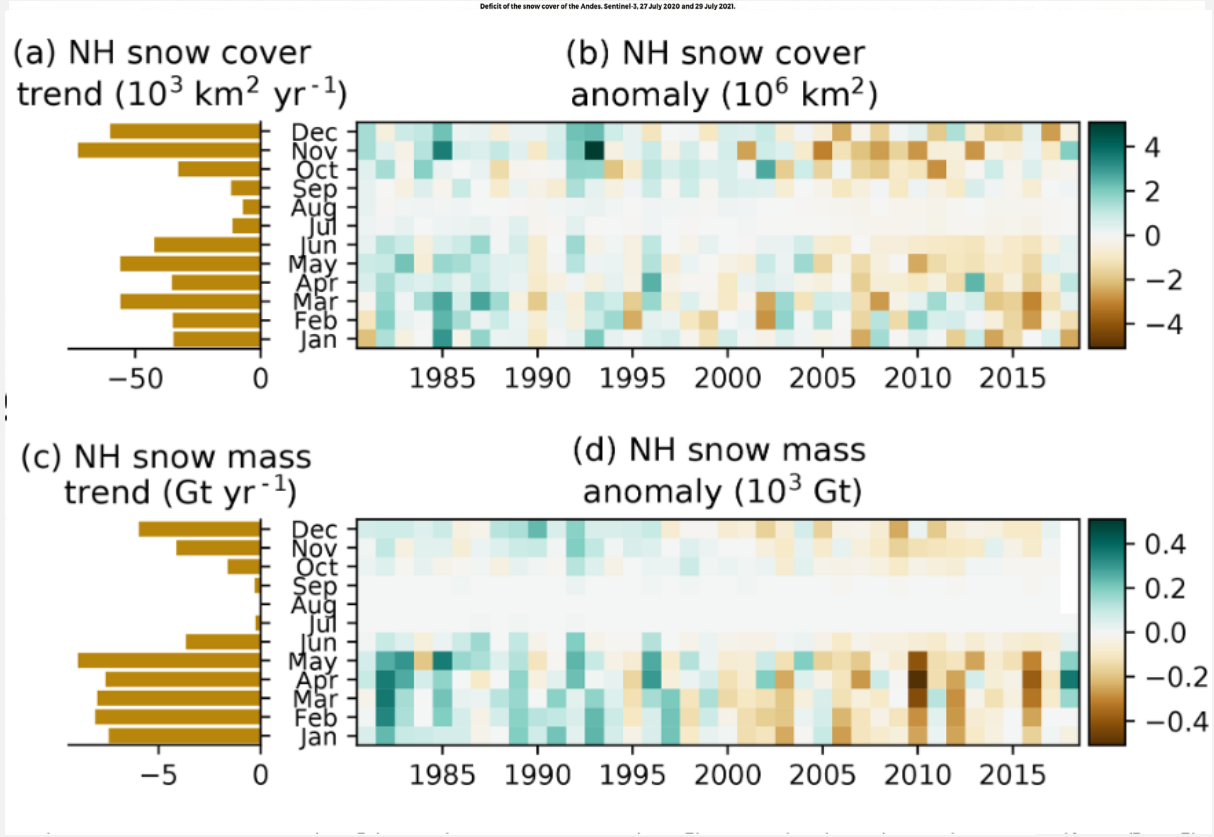


Siirila-Woodburn, *et al.* A low-to-no snow future and its impacts on water resources in the western United States. *Nat Rev Earth Environ* **2**, 800–819 (2021).

Immerzeel, W. W., *et al.* (2020). Importance and vulnerability of the world's water towers. Nature, 577(7790), 364–369.

Secrets | Our Works | Future works | Summary

The variability of snow covers the secrets



Snow cover is the most variable land surface condition spatially and temporally (Henderson et al., 2018), it varies by:

- Season + Local climate + La Niña/El Niño Oscillation…
- Topography
- Wind redistribution,
- Vegetation, Interception
- Sublimation
- Albedo, Solar radiation

…

Snow mass (depth) is more challenging to monitor than extent (Bormann et al., 2018). Snow mass products vary as much as 50% (Mudryk et al., 2015)

Bormann, K. J., Brown, R. D., Derksen, C., & Painter, T. H. (2018). Estimating snow-cover trends from space. Nature Climate Change, 8(11), 924–928.

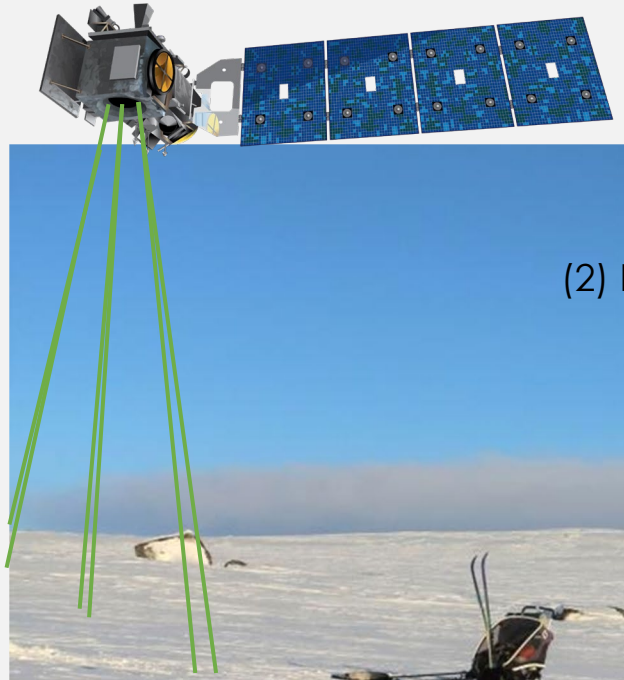
Mudryk, L. R., Derksen, C., Kushner, P. J., & Brown, R. (2015). Characterization of Northern Hemisphere Snow Water Equivalent Datasets, 1981–2010. Journal of Climate, 28(20), 8037–8051.

Henderson, G. R., Peings, Y., Furtado, J. C., & Kushner, P. J. (2018). Snow–atmosphere coupling in the Northern Hemisphere. Nature Climate Change, 8(11), 954–963.

Our Works | Future works | Summary

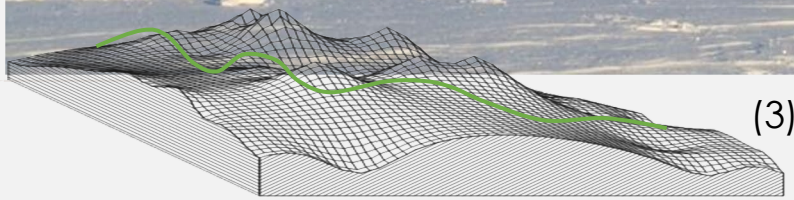
Deriving snow depth from satellite altimetry and high-precision DEMs

(1) ICESat-2 – Snow-on measurements

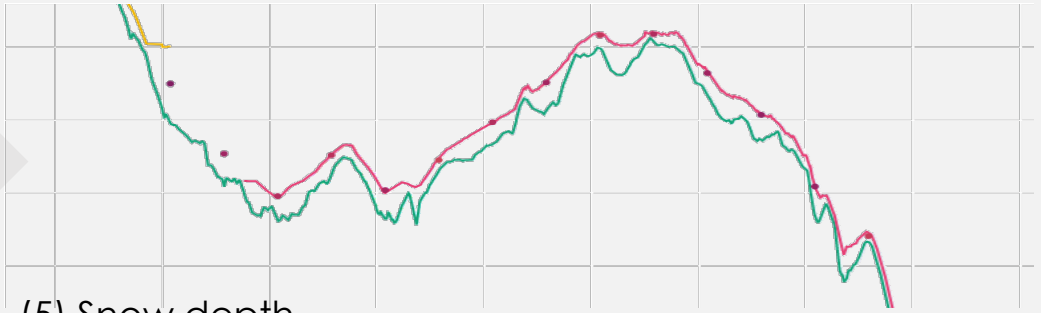


(2) Field trip - validation

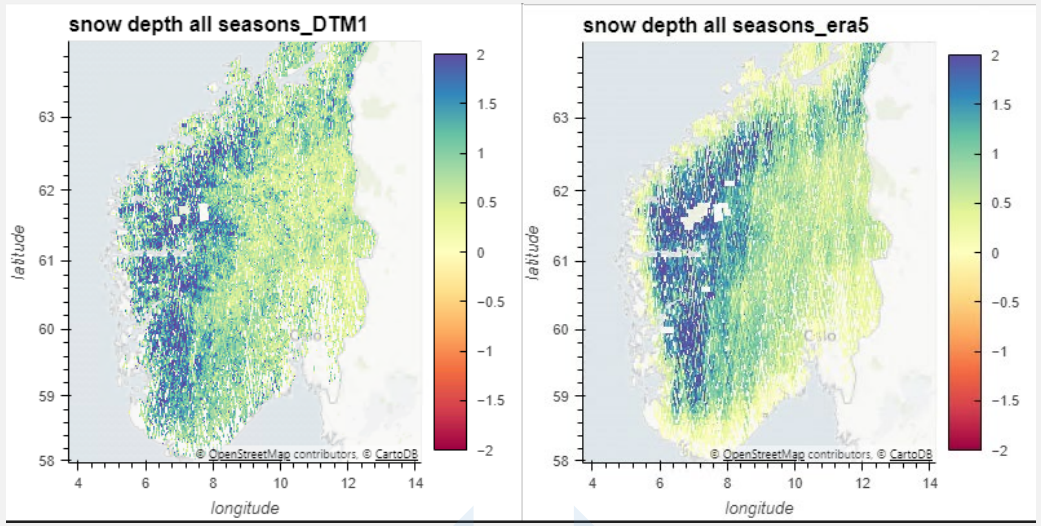
(3) Snow-off DEM



(4) Differencing DEMs



(5) Snow depth



Our results

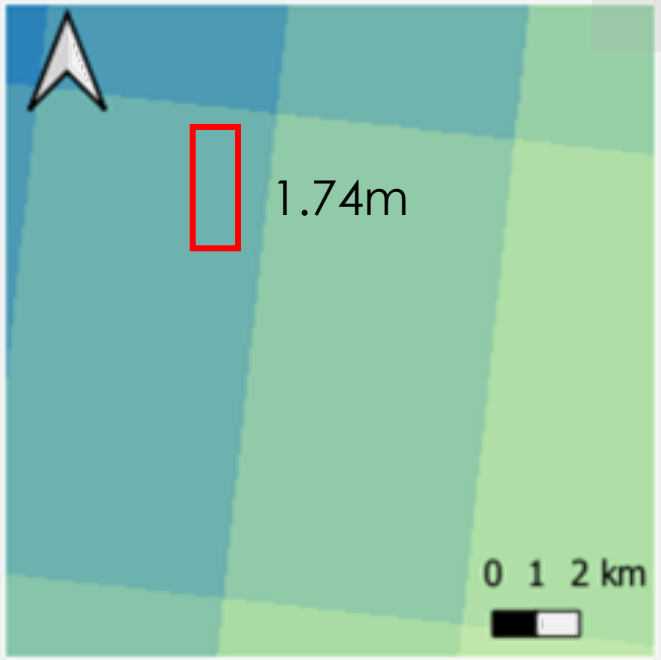
ERA5: overestimate

Future Works | Summary

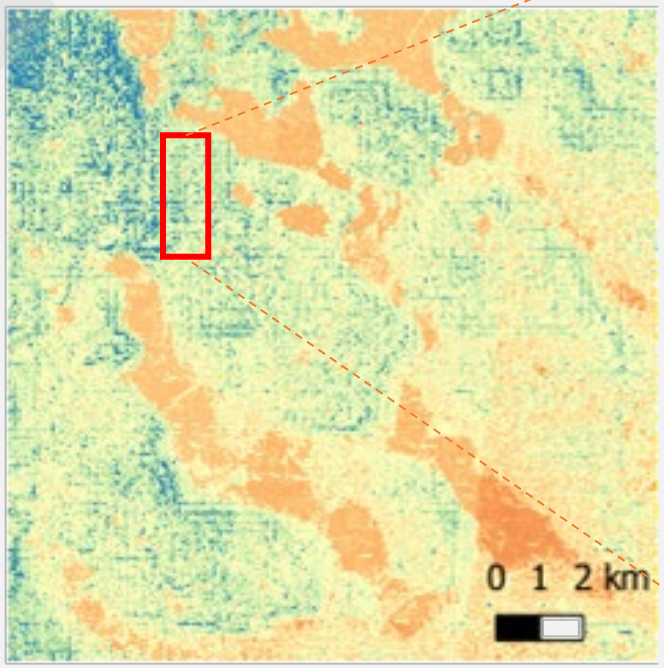
Challenges: Sub-grid distribution, DEM uncertainties

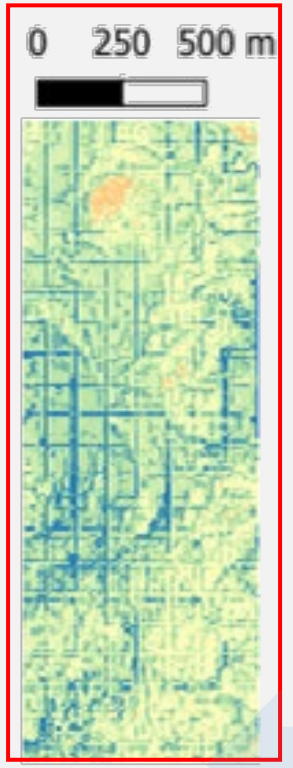
Input ICESat-2 measurements
Xgboost regression

ERA5



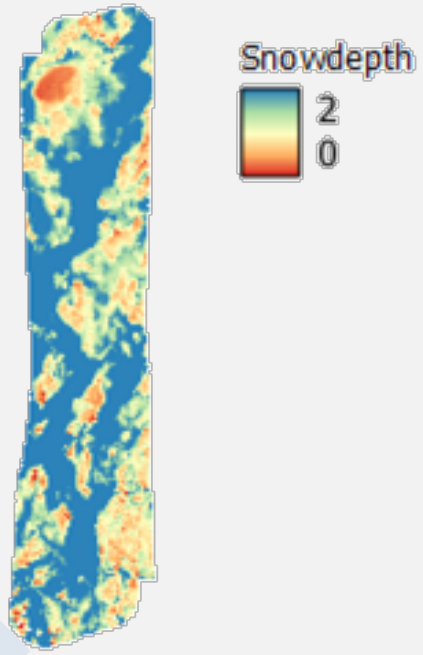
Subgrid snowdepth





Mean = 1.38m

LiDAR Validation



Mean = 1.32m

Source: Field trip to Hardangervidda,
Date: 2022-03-05

Summary

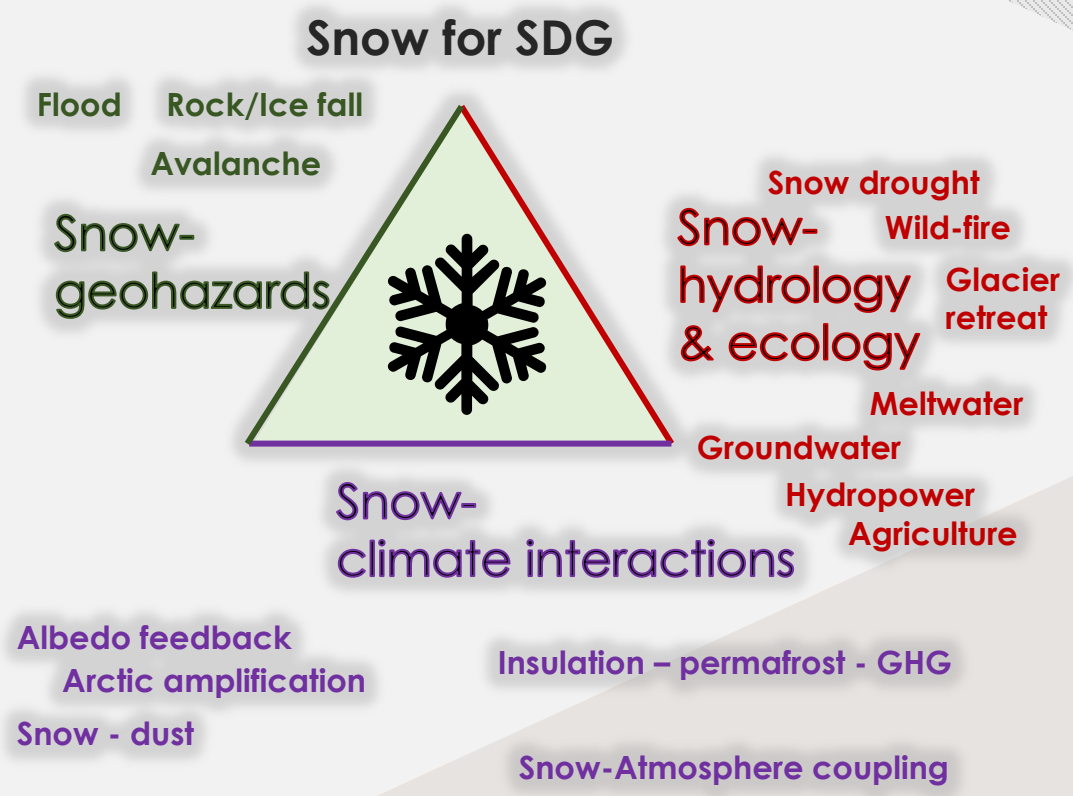
Snow matters!

Scientific secrets by snow:

How much water is in the mountain snowpack?

The chain reactions and interactions, such as:

- snow and atmospheric (Henderson et al., 2018)
- Snow and permafrost degradation



Scientific facts about snow:

47% of North hemisphere land covered by snow in Winter, but 3% in summer. (Estilow et al., 2015)

1.9 billion people rely on meltwater (Immerzeel et al., 2020)

In the Alps, snow cover duration decreased 5.6% per decade, resulting in a loss of 36 days of winter (Carrer et al., 2023)

Snowstorm on Mars (Spiga et al., 2017)

Henderson, G. R., Peings, Y., Furtado, J. C., & Kushner, P. J. (2018). Snow–atmosphere coupling in the Northern Hemisphere. Nature Climate Change, 8(11), 954–963.
Immerzeel, W. W., Lutz, A. F., Andrade, et al,. (2020). Importance and vulnerability of the world's water towers. Nature, 577(7790), 364–369.
Estilow, T. W., Young, A. H., & Robinson, D. A. (2015). A long-term Northern Hemisphere snow cover extent data record for climate studies and monitoring. Earth System Science Data, 7(1), 137–142.
Carrer, M., Dibona, R., Prendin, A. L., & Brunetti, M. (2023). Recent waning snowpack in the Alps is unprecedented in the last six centuries. Nature Climate Change, 1–6.