Snow ripening processes in marginal Australian snowpacks

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AMRF
AUSTRALIAN MOUNTAIN RESEARCH FACILITY

UNIVERSITY OF CANBERRA

Australian National University

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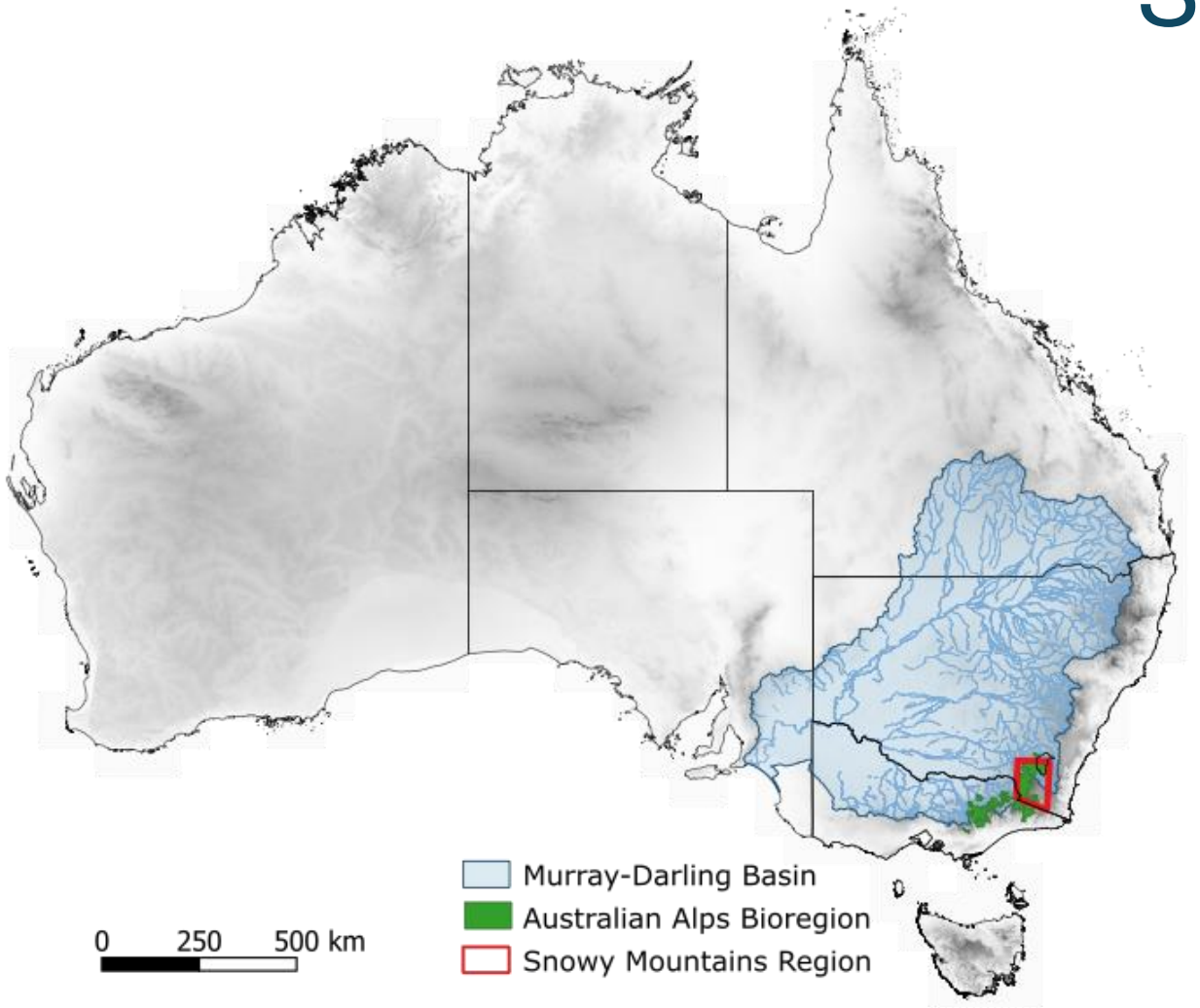
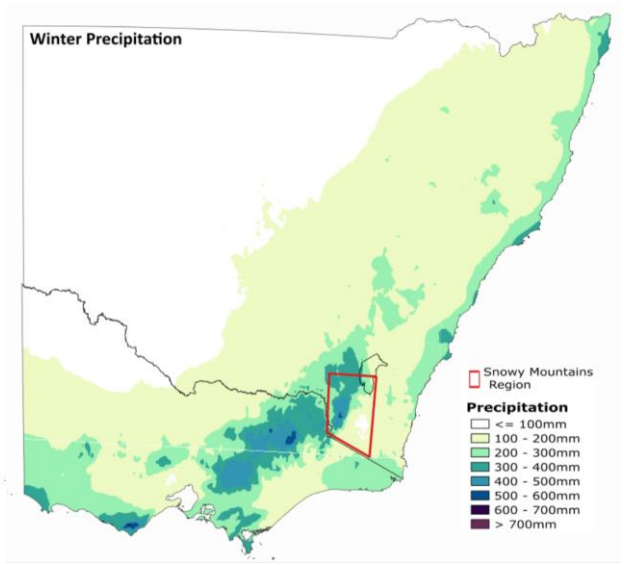
Snow-affected Australia

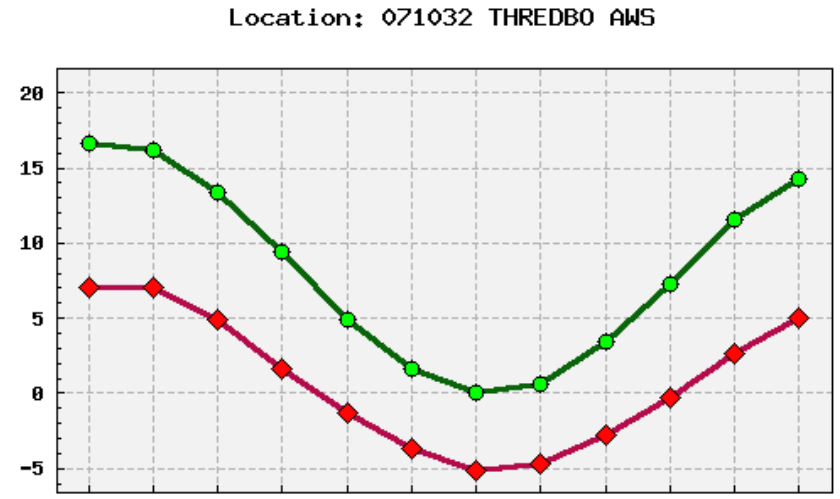


- South-eastern Australia & Tasmania
- 35-42 degrees latitude
- Highest peaks ~ 2200 m
- Snowpack above 1400 m
- Significant water supplies to semi-arid inland catchments

[1] Morrison, C., Pickering, C., 2012. Climate Change Adaptation in the Australian Alps: Impacts, Strategies, Limits and Management. National Climate Change Adaptation Research Facility, Gold Coast.
[2] Australian Bureau of Statistics, 2008. Water and the Murray–Darling Basin – A statistical profile, 2000-01 to 2005-06. Canberra, Australia.
[3] Eggleton, R.A., 2020. On the Snowy Mountains granites. Australian Journal of Earth Sciences 67, 331–338. https://doi.org/10.1080/08120099.2020.1671491

Regional Climate

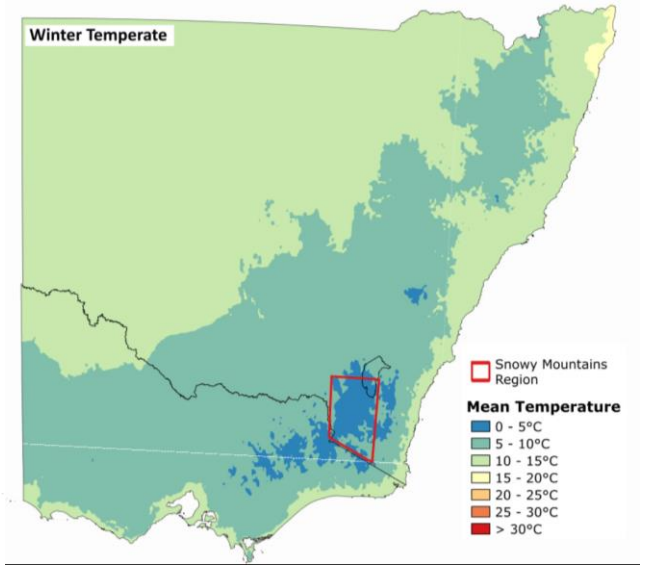


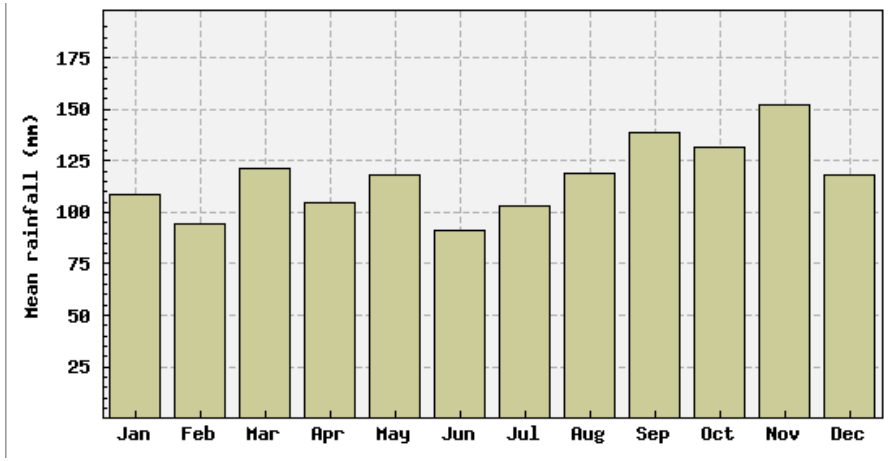


Temperatures

Winter temperatures close to 0°C

Precipitation form highly vulnerable to temperature changes





Precipitation

Frequent

- ~109 days of >1mm per year

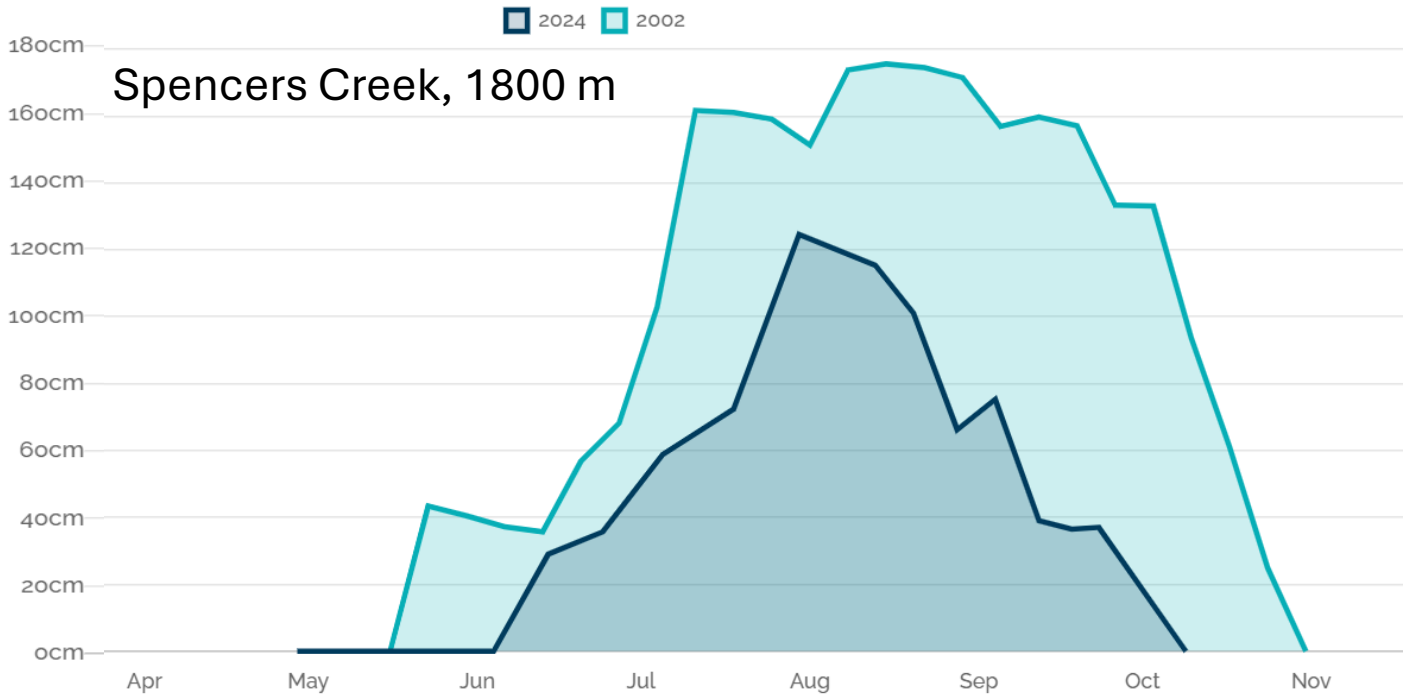
(~61 days of >5mm per year)

Snow events at any time of year

Bureau of Meteorology. (2024). Gridded Climate Data. Bureau of Meteorology. http://www.bom.gov.au/climate/averages/climatology/gridded-data-info/gridded-climate-data.shtml

Mid-latitude marginal snowpack

- Short-duration seasonal snow cover
- Variable & event-driven
  - Often 2-3 large snowfalls per season

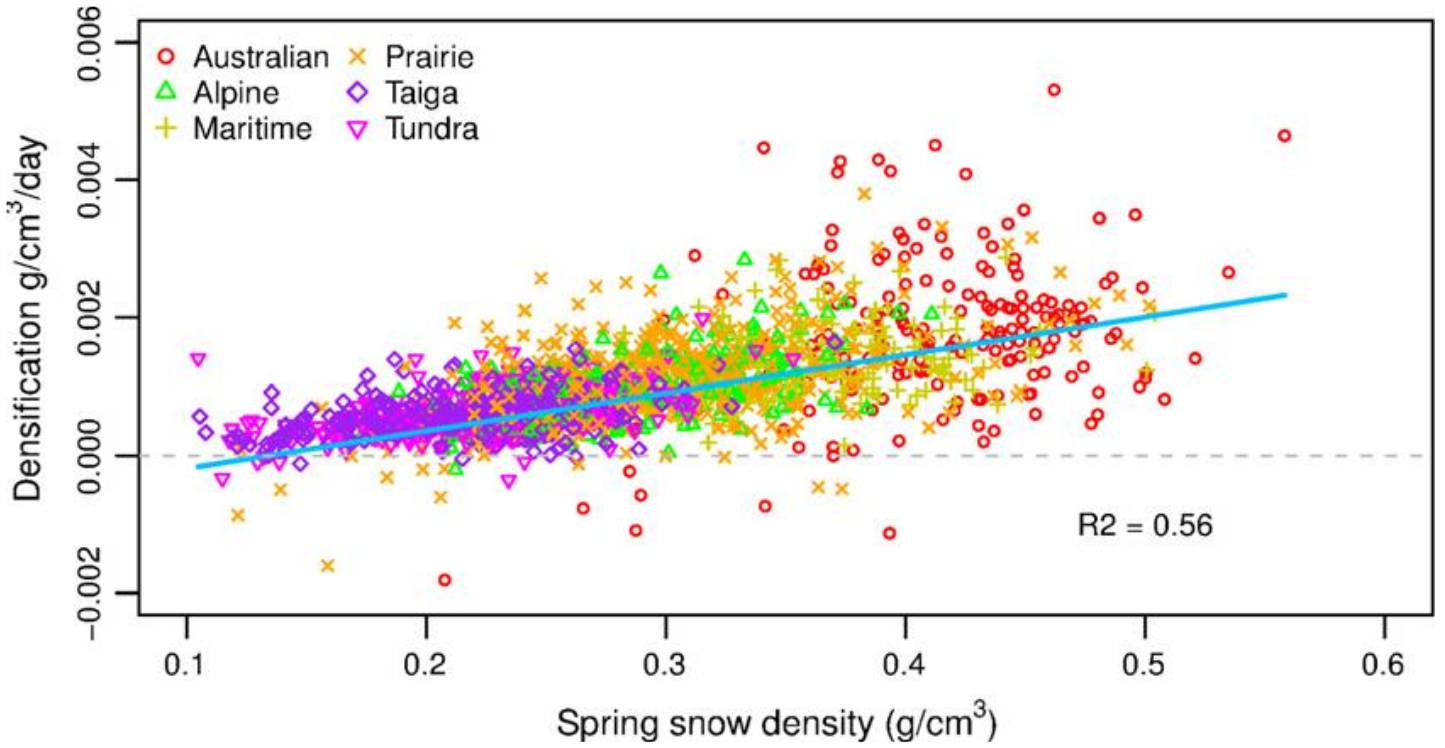


[1] Bilish, S.P., McGowan, H.A., Callow, J.N., 2018. Energy balance and snowmelt drivers of a marginal subalpine snowpack. Hydrological Processes 32, 3837–3851. https://doi.org/10.1002/hyp.13293
[2] Bormann, K., 2013. Snowpack Characteristics and Modelling in the Marginal Snowfields of Southeast Australia (PhD Thesis). School of Biological, Earth & Environmental Sciences. The University of New South Wales, Sydney, Australia.

Mid-latitude marginal snowpack

- Significant windblown drift
- Isothermal?
- Rain on snow common

- High snow densities
  - 0.41 g/cm^3 mean in spring



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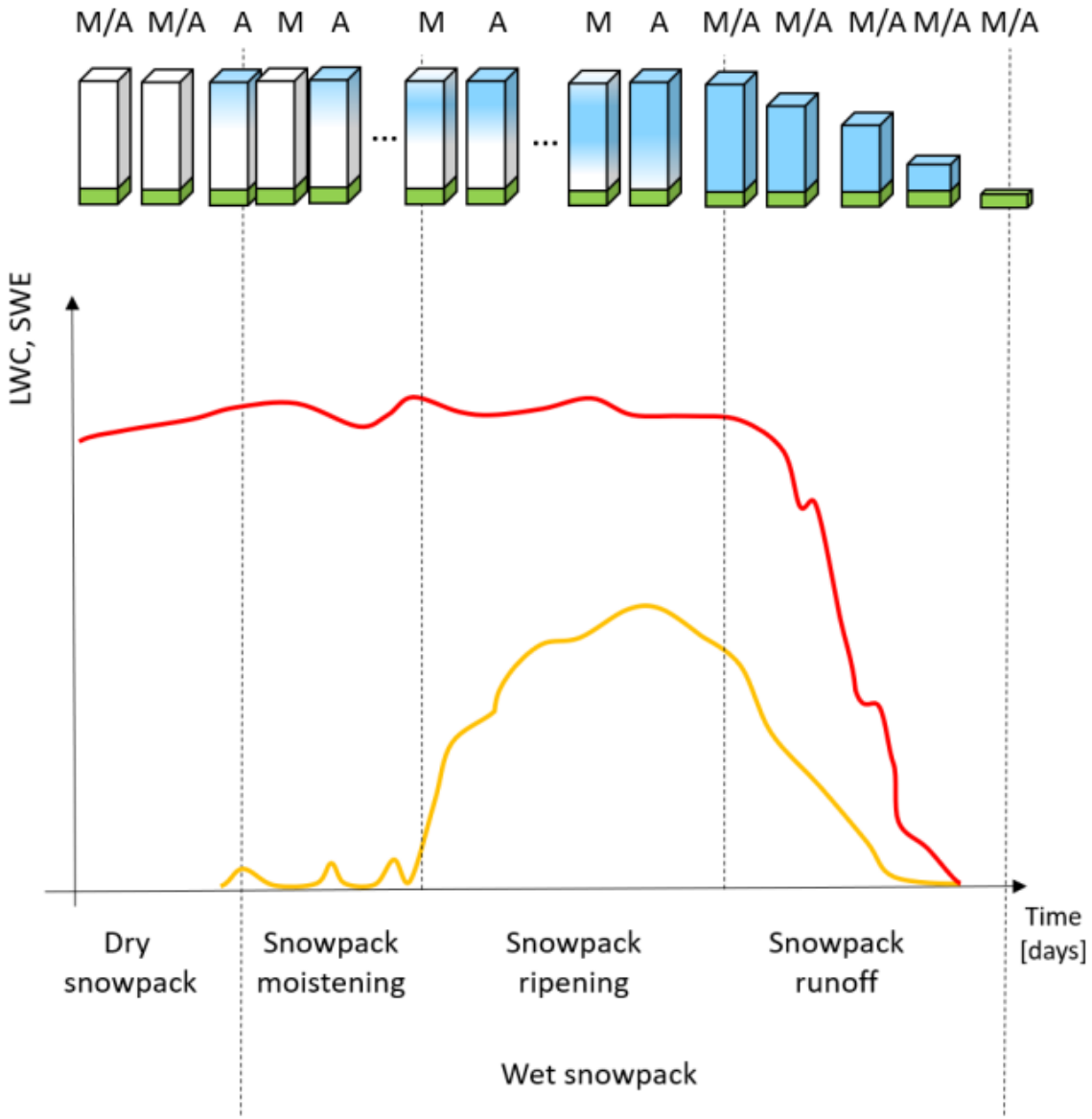
What factors contribute to Snowpack ripening?

- warming of the snow to melting temperature
- grain growth and rounding
- ice-layer formation
- densification
- capillary retention of liquid water
- creation of a flow network



Kattleman and Dozier, 1999

Marin et al, 2020

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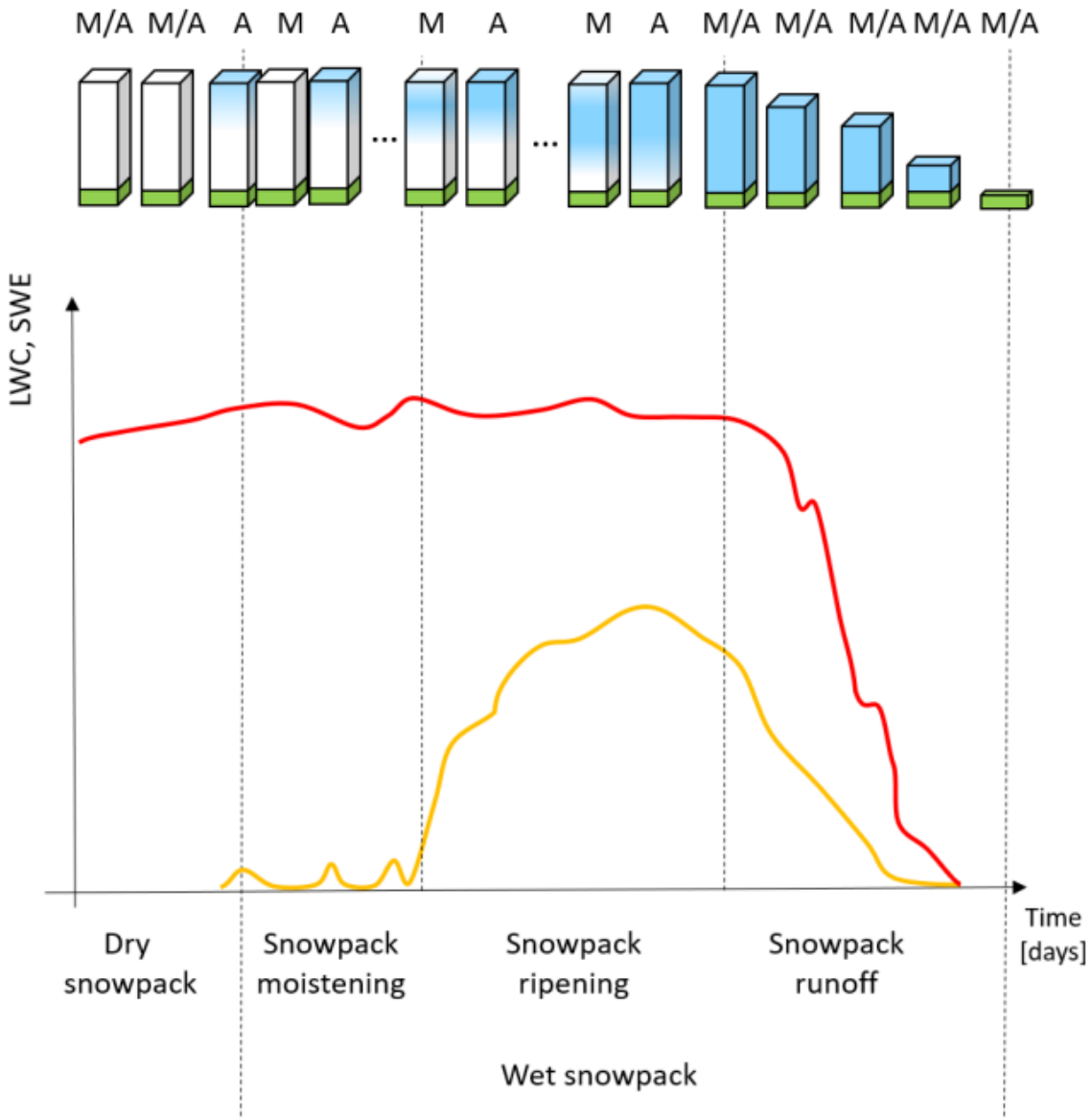

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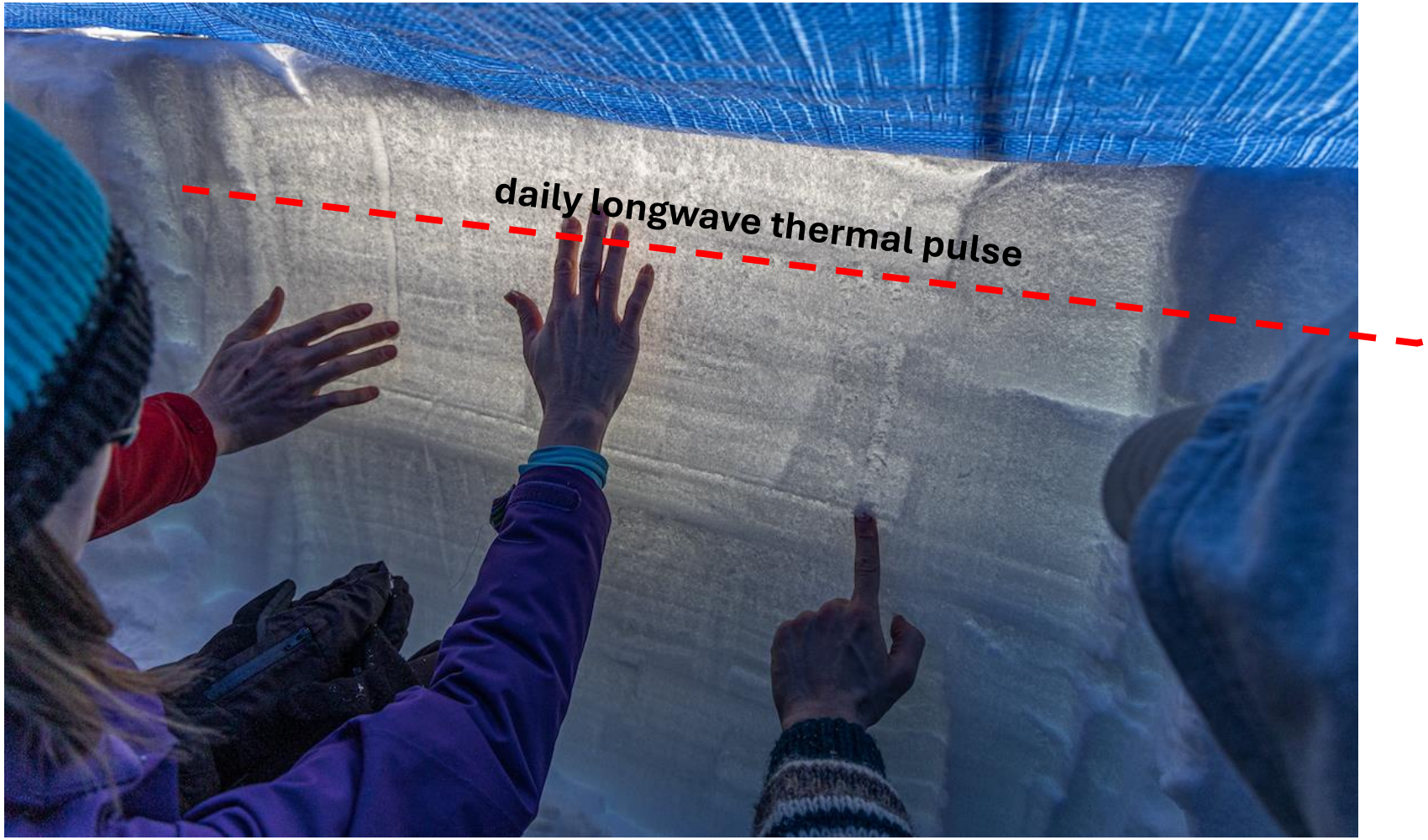
Pilot study: does significant shortwave radiation propagate to below daily freeze depth?



https://www.agci.org/blog

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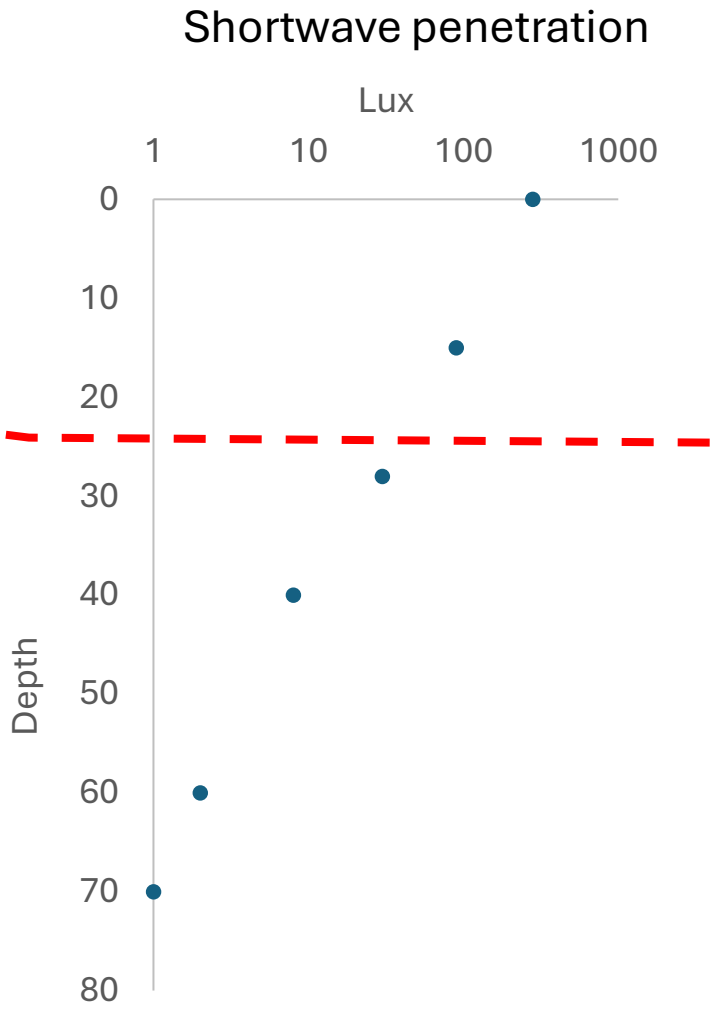


https://www.agci.org/blog

After Green and Osbourne, 2012

Test shortwave propagation experiment

- Hobo light/temperature sensors: June-Sept 2024
- Snow thickness (daily)
- Periodic logs (after Fierz, 2009)
  - Grainsize/shape
  - Density
  - Liquid water content
- Distributed observations
  - snow thickness (UAV)
  - Snow structure
  - Liquid water content

Subalpine: Aqueduct, ~ 1600 m

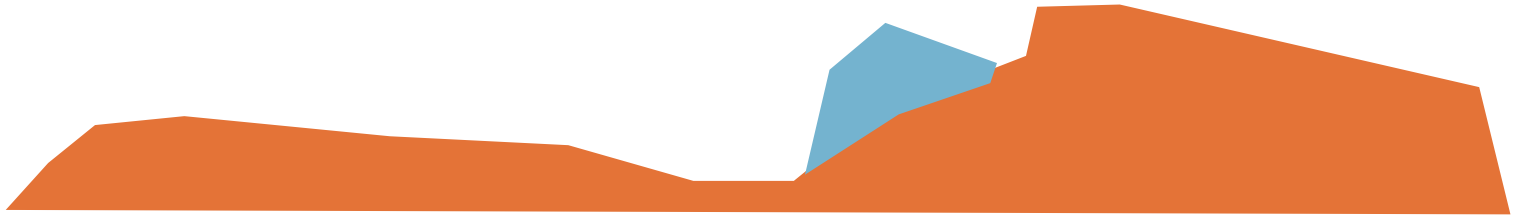
Alpine: Cruiser, ~ 2000 m

Snowpack thermal regime

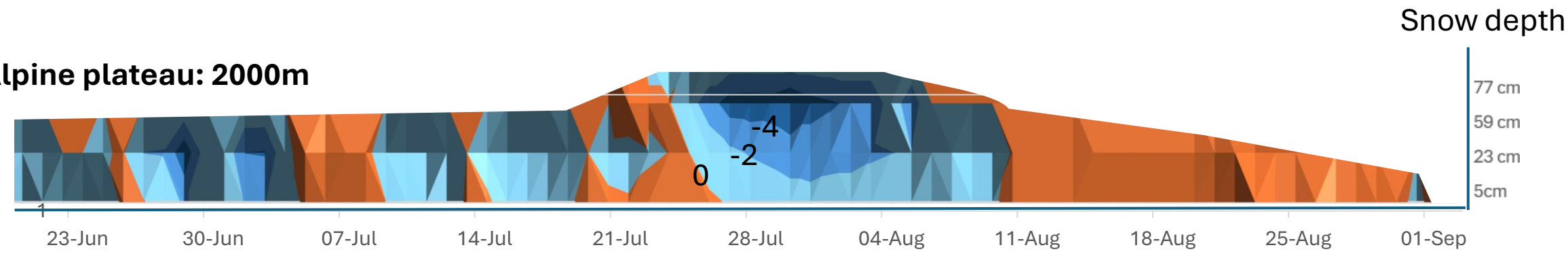
midday temperatures (ºC)

Subalpine: 1600 m

Treeline: 1800 m (2019)
Schwartz et al. 2021



Alpine plateau: 2000m



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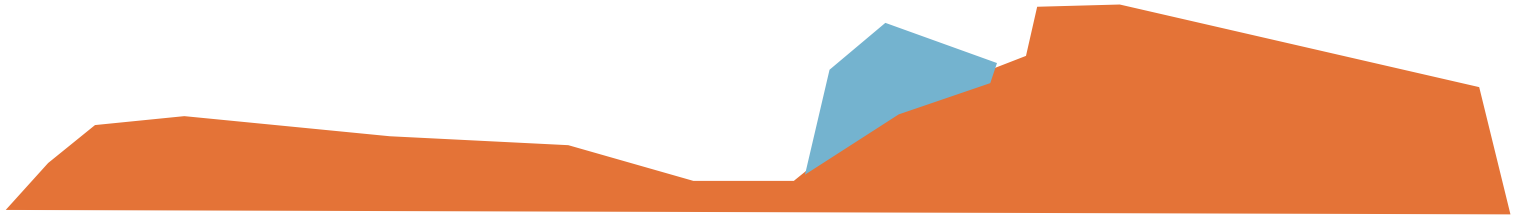

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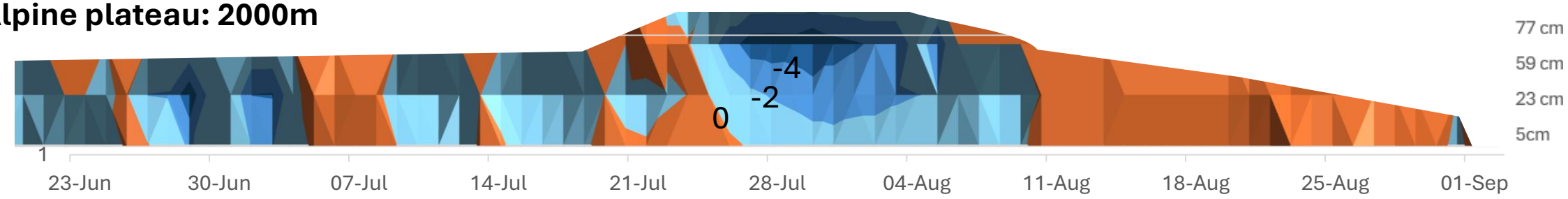
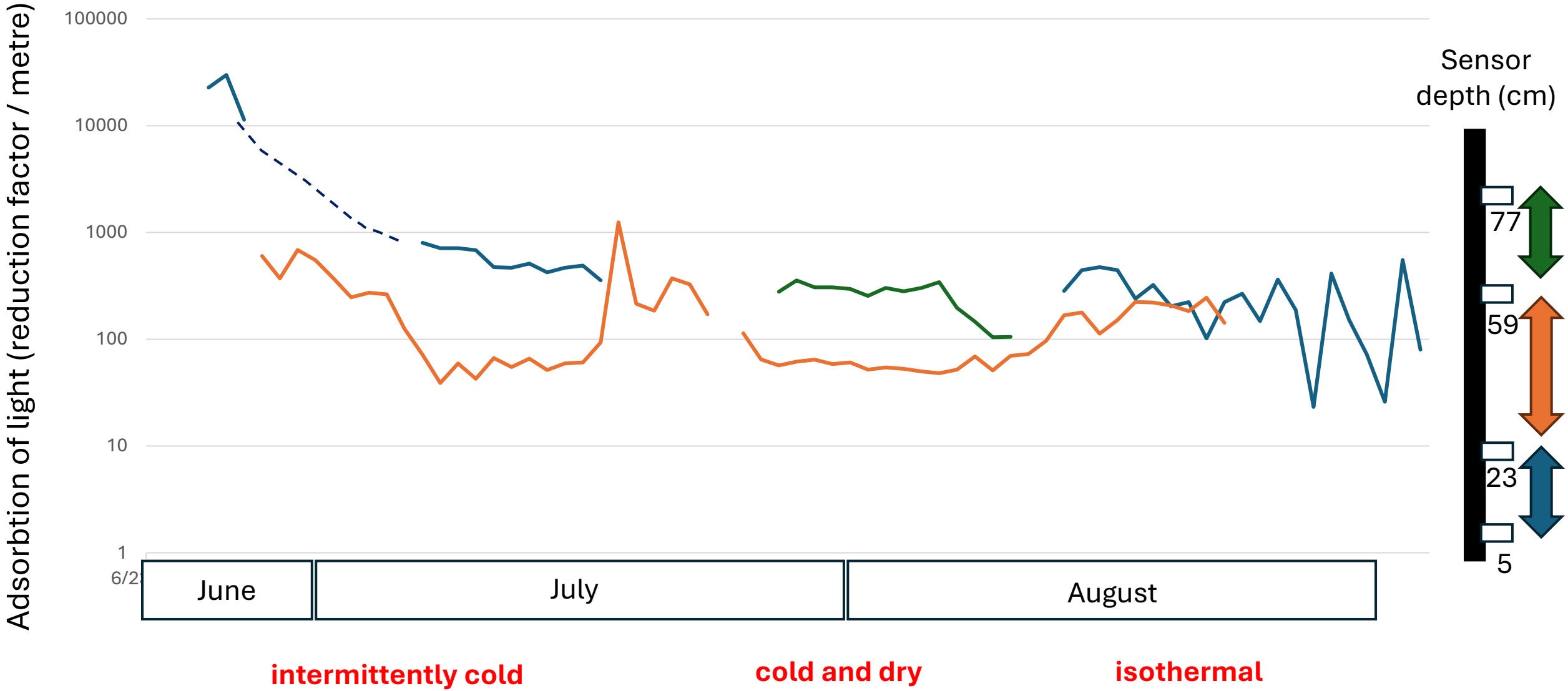
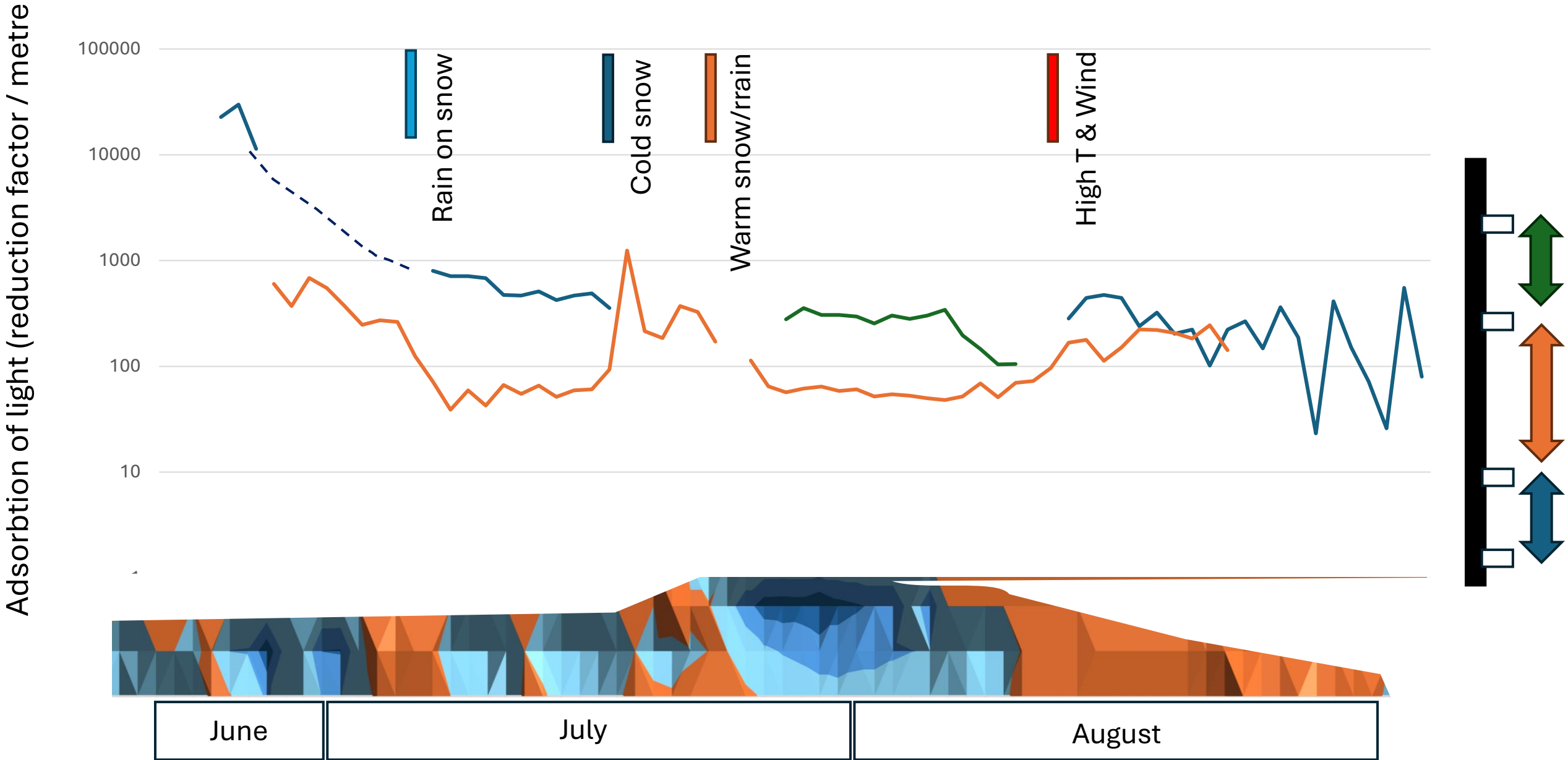


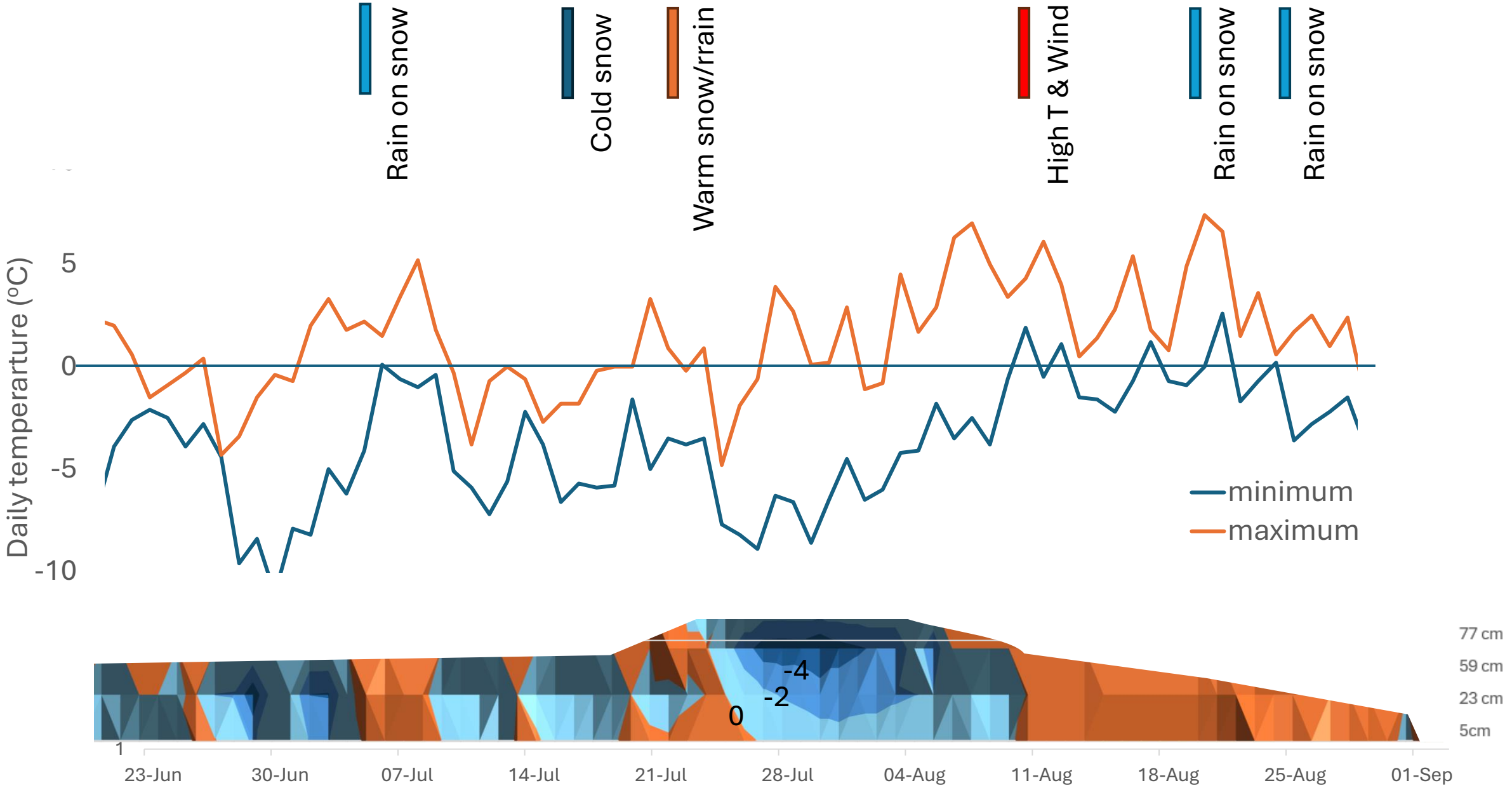
intermittently cold **cold and dry** **isothermal**

Alpine plateau: shortwave propagation



Alpine plateau: shortwave propagation



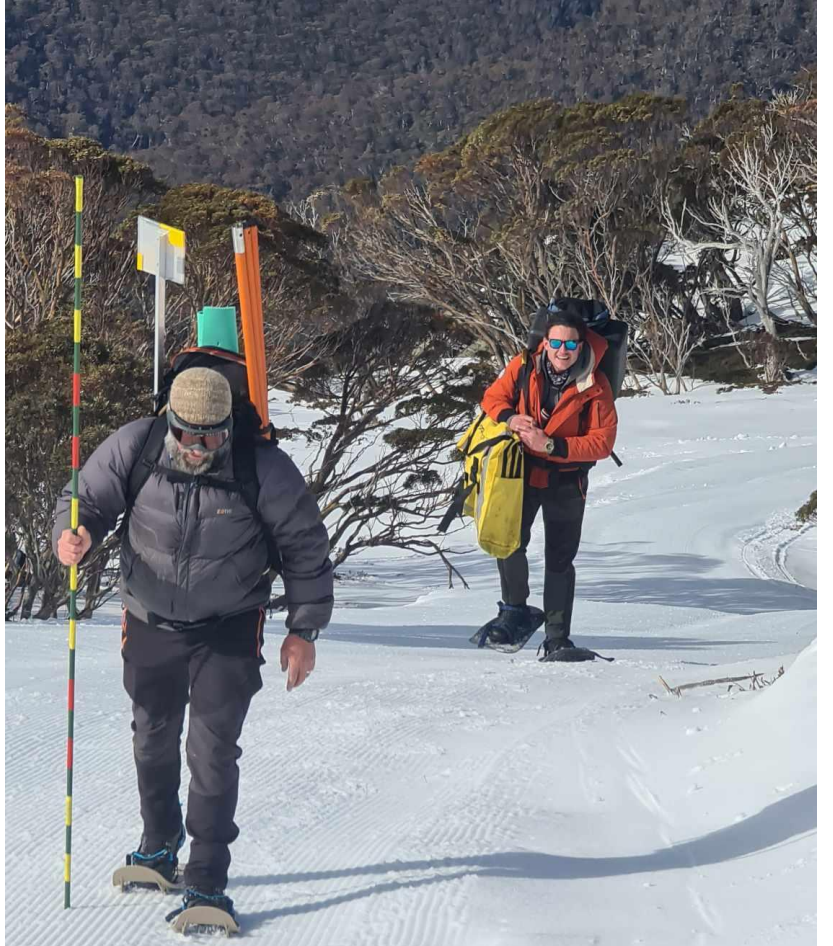

Rain on snow
Cold snow
Warm snow/rrain
High T & Wind
Rain on snow
Rain on snow
Daily temperarture (°C)
5
0
-5
-10
minimum
maximum
77 cm
59 cm
23 cm
5cm
-4
-2
0
1
23-Jun
30-Jun
07-Jul
14-Jul
21-Jul
28-Jul
04-Aug
11-Aug
18-Aug
25-Aug
01-Sep
Intermittently cold snow
Cold snow
Isothermal melting snow

Conclusions

- Up to 30% of shortwave radiation propagates to below daily freeze depth
- Strong elevation gradient in snowpack thermal character
  - Good site for observations at a threshold

Future plans

- Higher density of optical & temperature sensors
- instrumental monitoring of snow liquid water content
- Other ideas?

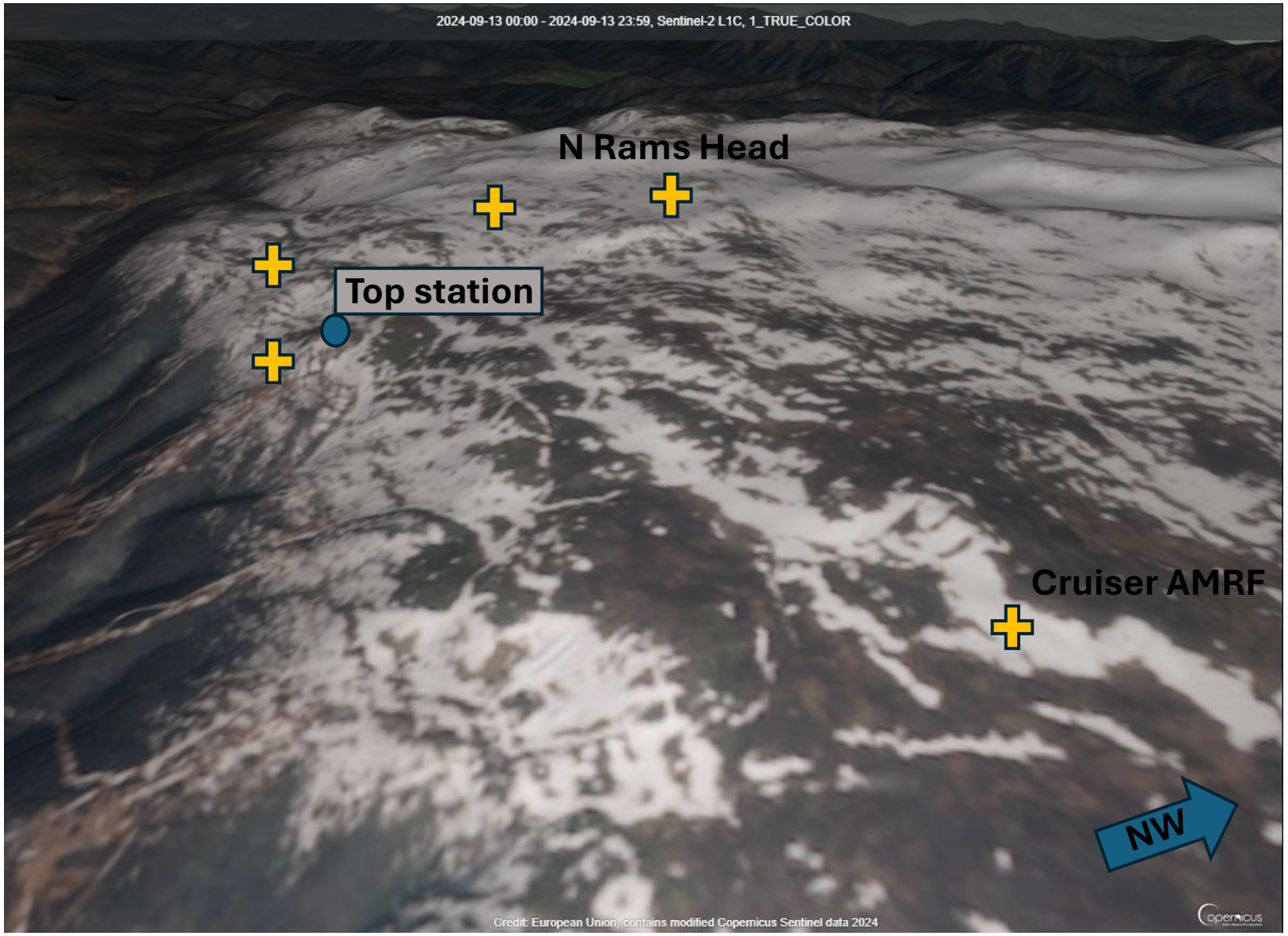


Thanks to the many volunteers and contributors:
AMRF for sites & data
Gus & Max at UC
Craig Sheppard (MSC)
Shane Billish & Sander van Tol

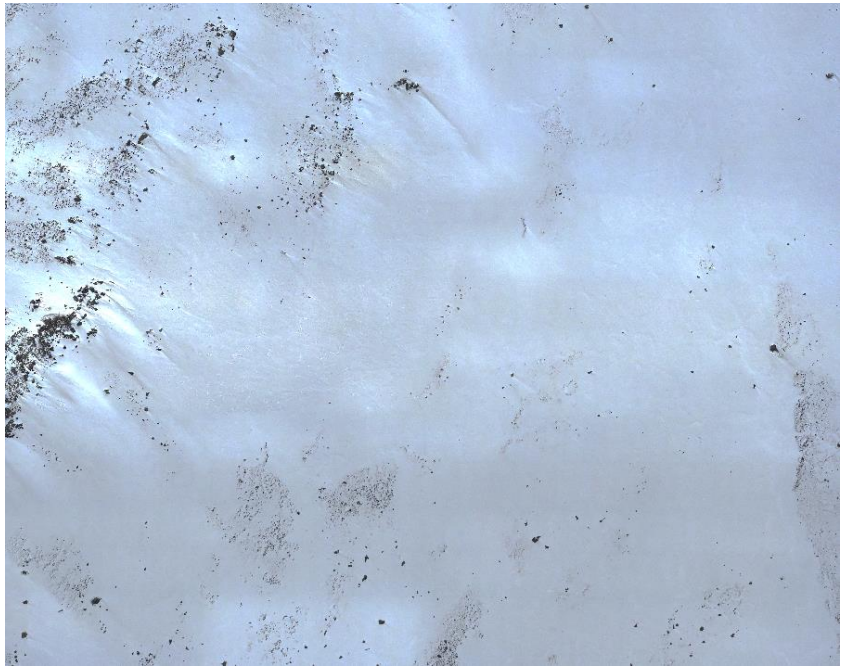
Melt season elevation snapshot (12 Sept 2024)

Elevation	Liquid water	density
2130	1-3%	0.35
2070	2-4%	0.4
2000	3-5%	0.6
1850	5-8%	0.65

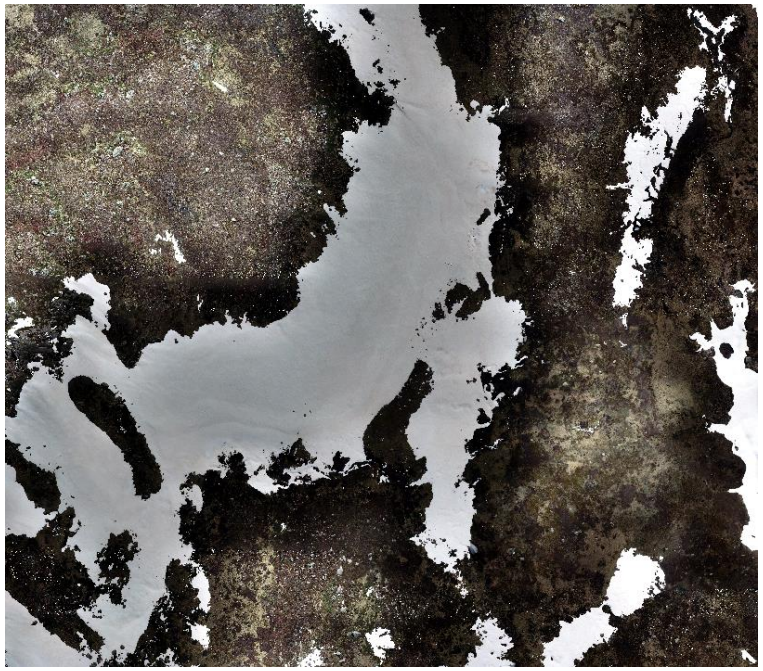
Thredbo



UAV based elevation and GPR

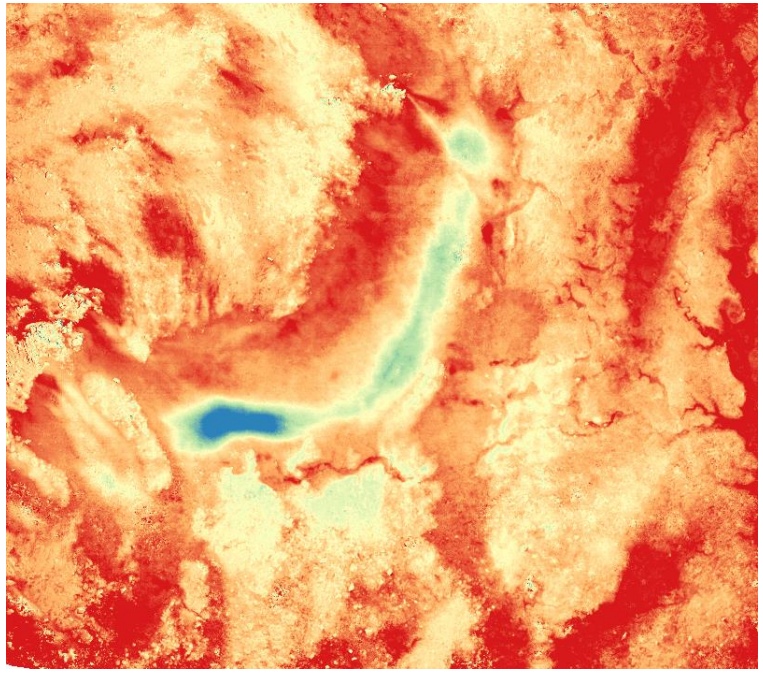


23 August



13 September

Snow loss (Red = 1m, Blue = -1m)



23 Aug – 13 Sept

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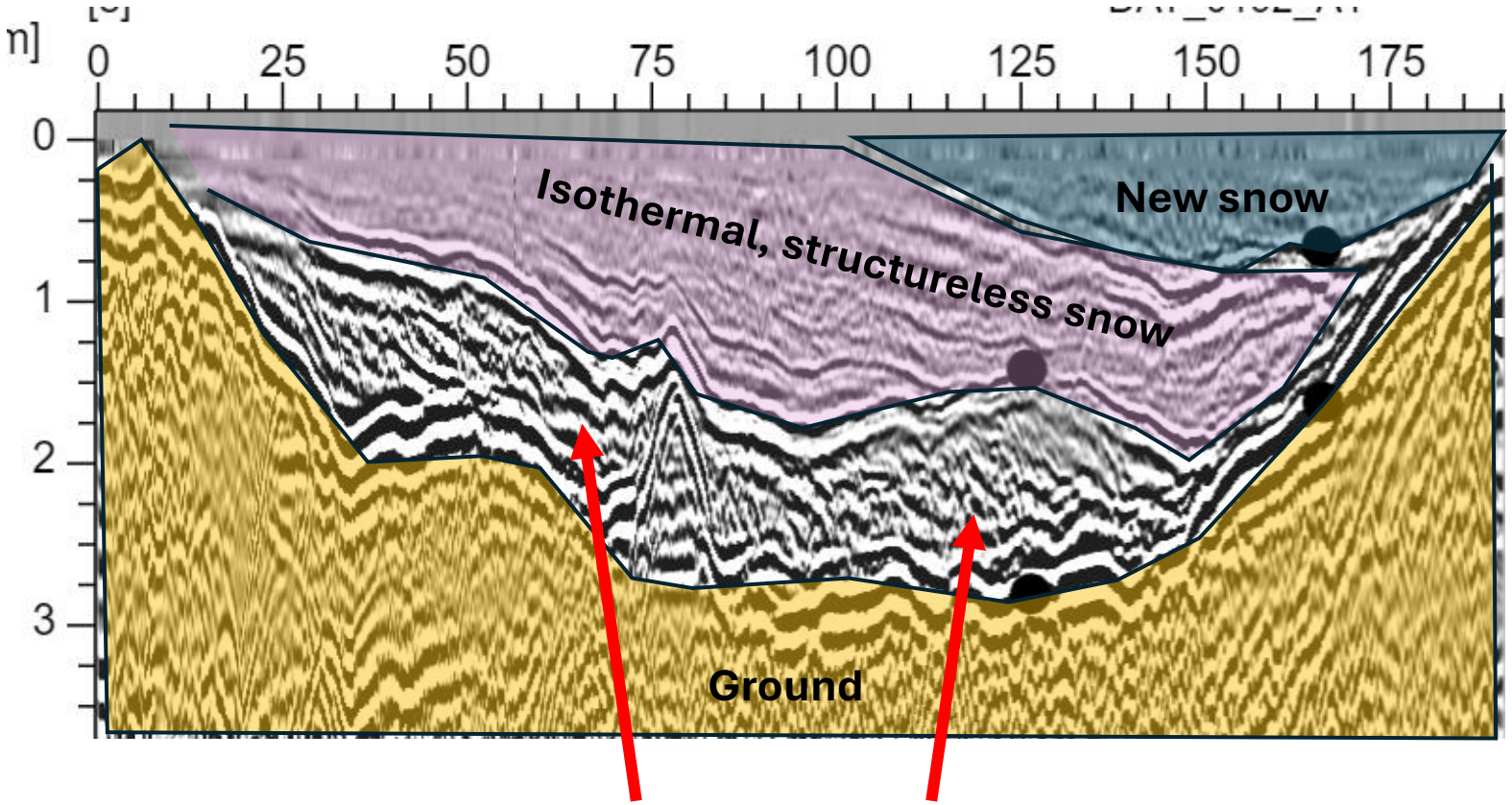
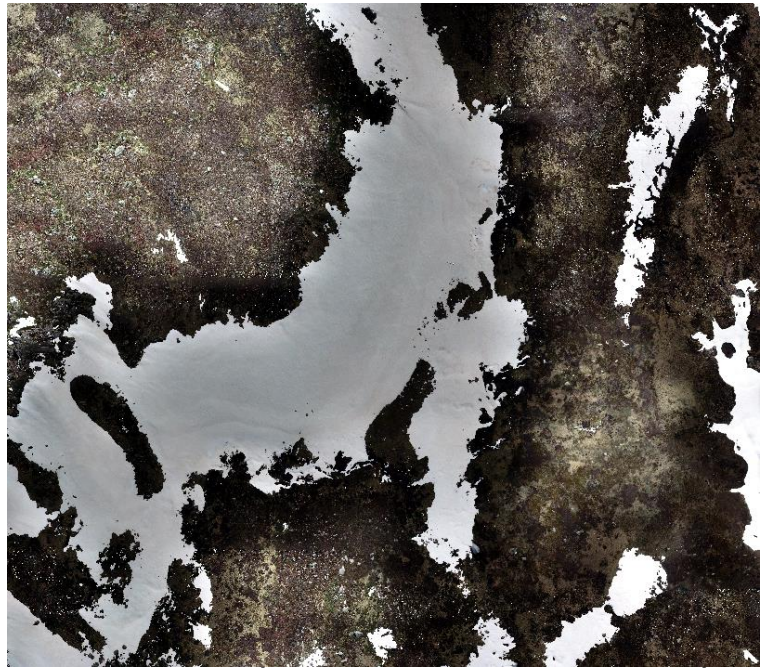
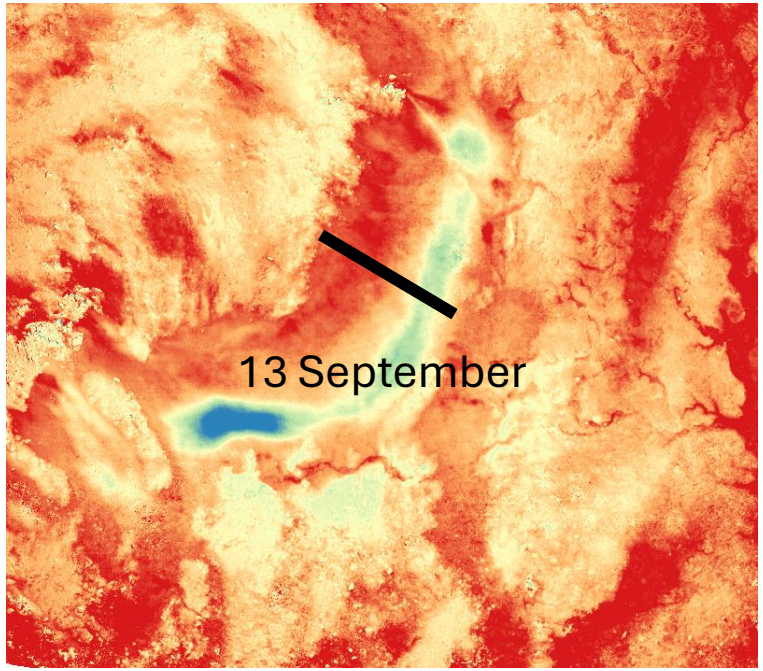


Old highly structured snow & flow fingers?





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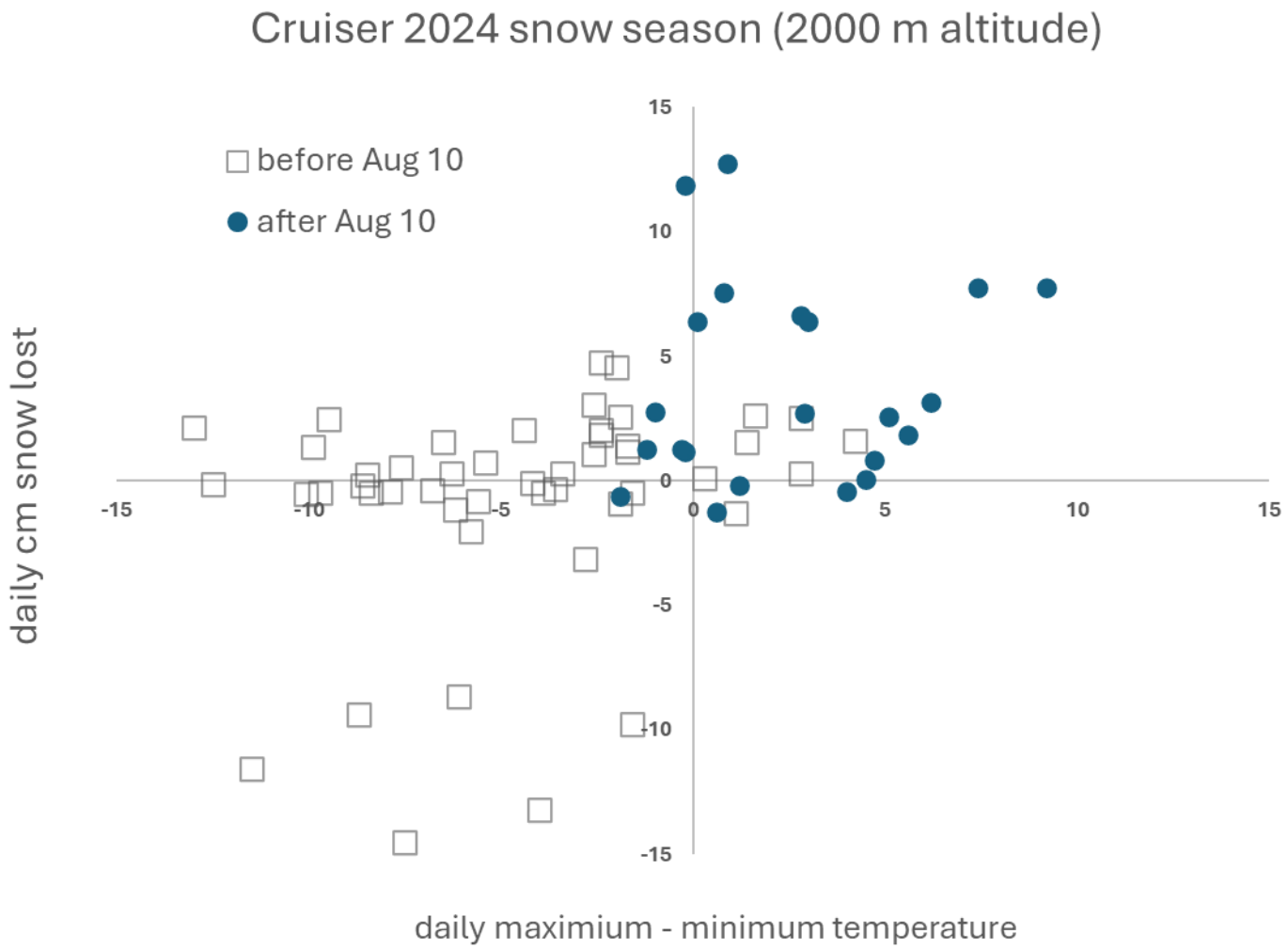
Snowmelt vs air temperature