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The 2020-2022 surface energy balance of rock glacier Murtèl: the role of rain and snow

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1 Setting

- Setting: Active rock glacier Murtèl located in the Engadine high valley, eastern Swiss Alps (Fig. 1). A rock glacier with a furrow-and-ridge topography, 2–5 m thick coarse & porous debris mantle.
- Aim: Determination of the surface energy balance, in particular the **turbulent fluxes, on the bouldery surface of the ventilated debris mantle**.
- Sensors: PERMOS automatic weather station, PERMA-XT pylon, instrumented cavity (Figs. 2, 3).

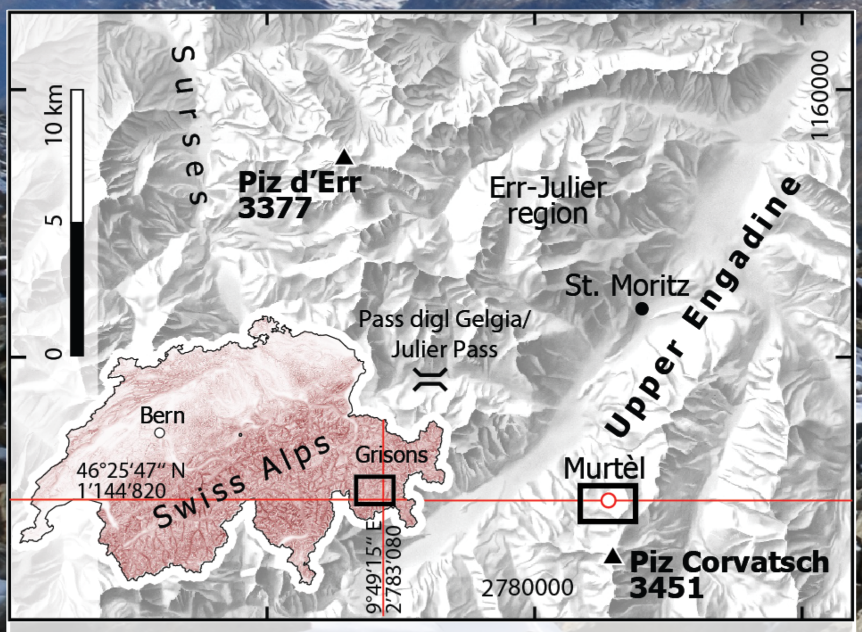

Fig. 1: Location of the rock glacier Murtèl in the Upper Engadine high valley and within Switzerland.

Fig. 2: The above-surface automatic weather station: meteo pylon with a CSAT sonic anemometer, a sonic ranger for snow height, hygrometer and pluviometer.

Challenges

- Big blocks, rough terrain
- Partial, seasonal snow cover
- Permeable **ventilated debris mantle**: air circulation extends into the ground - no clear surface!

> *Subsurface and surface fluxes are linked*

Approach

- Test different approaches: Bowen flux partitioning, bulk aerodynamic parametrization, eddy-covariance method.

Fig. 3: The below-ground sensor array in a natural cavity, down to 3 m depth, located on a rock-glacier ridge. Installed sensors include:

- wind speed sensors (Figs. 4, 5)
- thermistors and hygrometers (Fig. 6)

Field view of the coarse debris surface, the meteo pylon and the access to the instrumented cavity. Photograph taken on Oct 11, 2021.

2 Subsurface air circulation modes

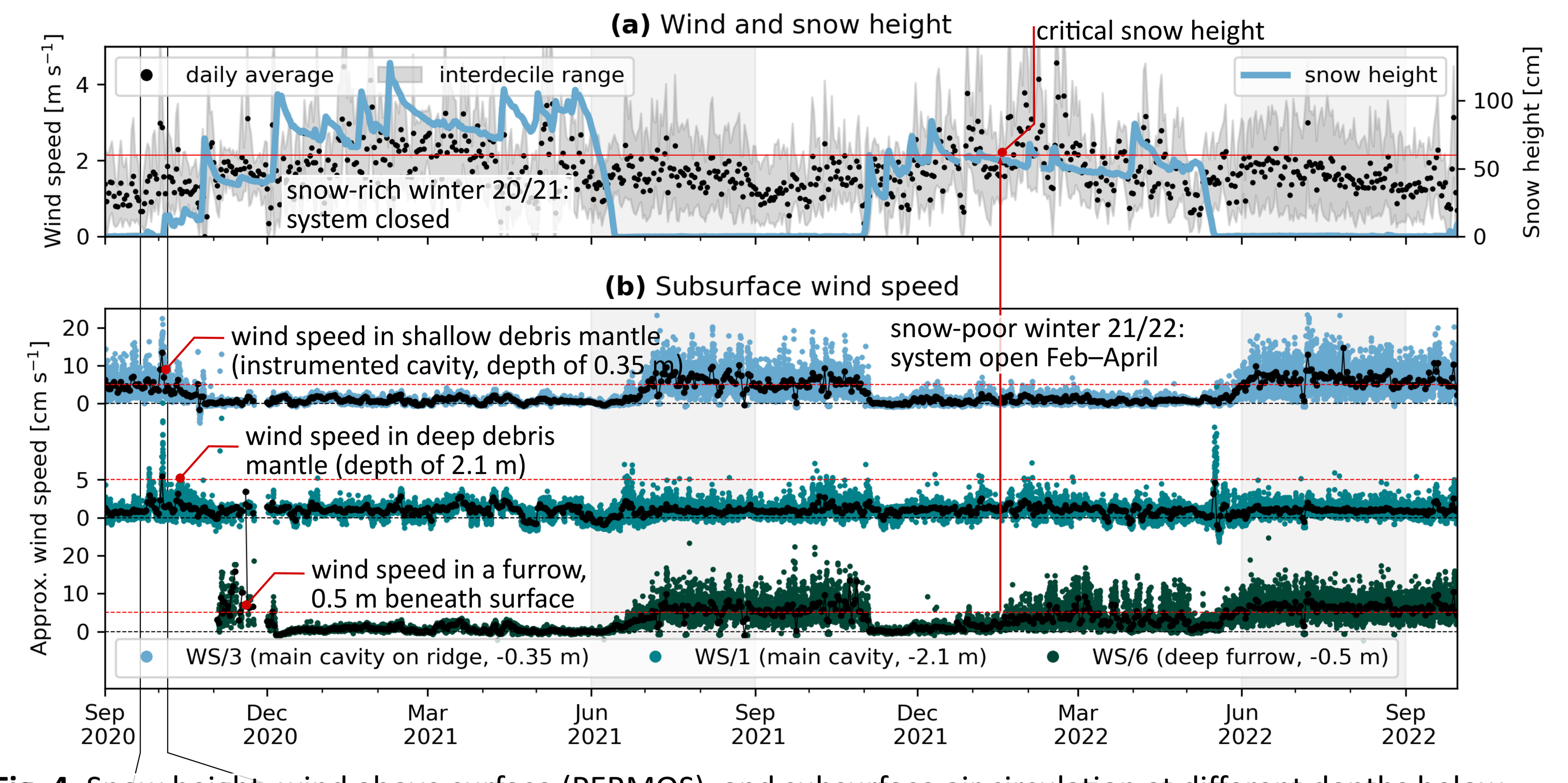

Fig. 4: Snow height, wind above surface (PERMOS), and subsurface air circulation at different depths below ground surface.

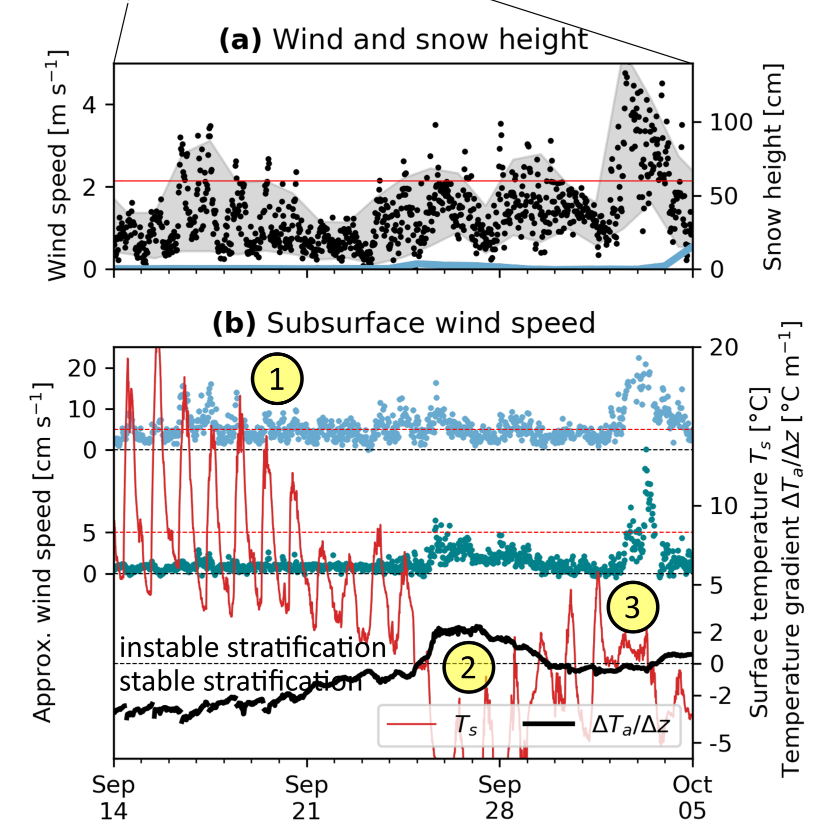

Fig. 5: Zoom-in to the autumnal cooling in 2020 with the different air circulation modes in the debris mantle.

- Wind speed sensors are distributed in the debris mantle at different depths (Fig. 4).
- Roughly 60 cm of snow necesssary to shut off the air circulation.

> **Snow** modulates the strength of the subsurface air circulation.

> Different **circulation patterns** according to the surface weather and ground thermal regime:

1. Strong diurnal surface heating with **shallow air circulation**: characteristic for summer days (Fig. 6). No circulation in deep cavity despite strong winds due to stable air stratification.
2. Rapid surface cooling and destabilization of air column: **buoyancy-driven circulation**.
3. Vigorous mechanical mixing of isothermal air column by strong winds: **wind-forced circulation**.

3 Moisture and heat fluxes

The turbulent fluxes are determined by the **gradients of temperature and specific humidity** between atmosphere and surface. The summertime fluxes are directed into the atmosphere.

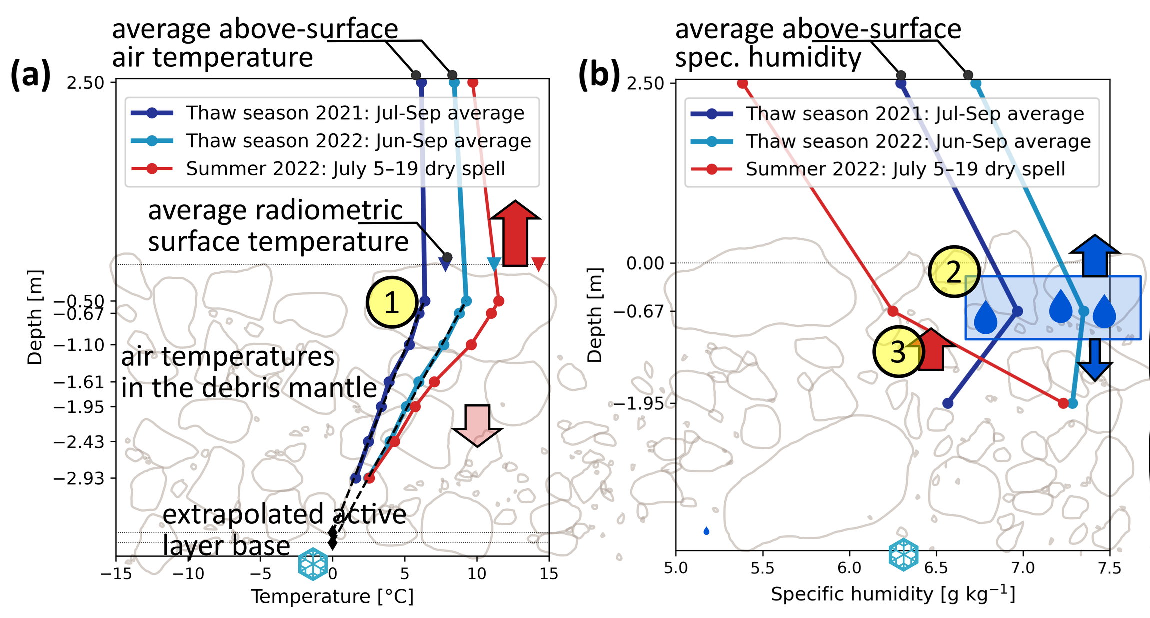

Fig. 6: **(a)** Averaged vertical temperature and **(b)** specific humidity profile during the thaw seasons 2021 (wet-cool summer) and 2022 (dry-hot).

1. Heat export into atmosphere; turbulent downwards transport impeded by stable stratification.
2. Moisture export from a shallow, rain-fed moisture reservoir helps cooling the debris.
3. During dry spells: Moisture supplied from ground ice.

4 First results & outlook: Bowen, bulk and eddy fluxes

Timing and flux direction match. **Next steps**: Reduce discrepancies in magnitude by better assessing the influence of the snow cover and the links between "surface" temperature and moisture.

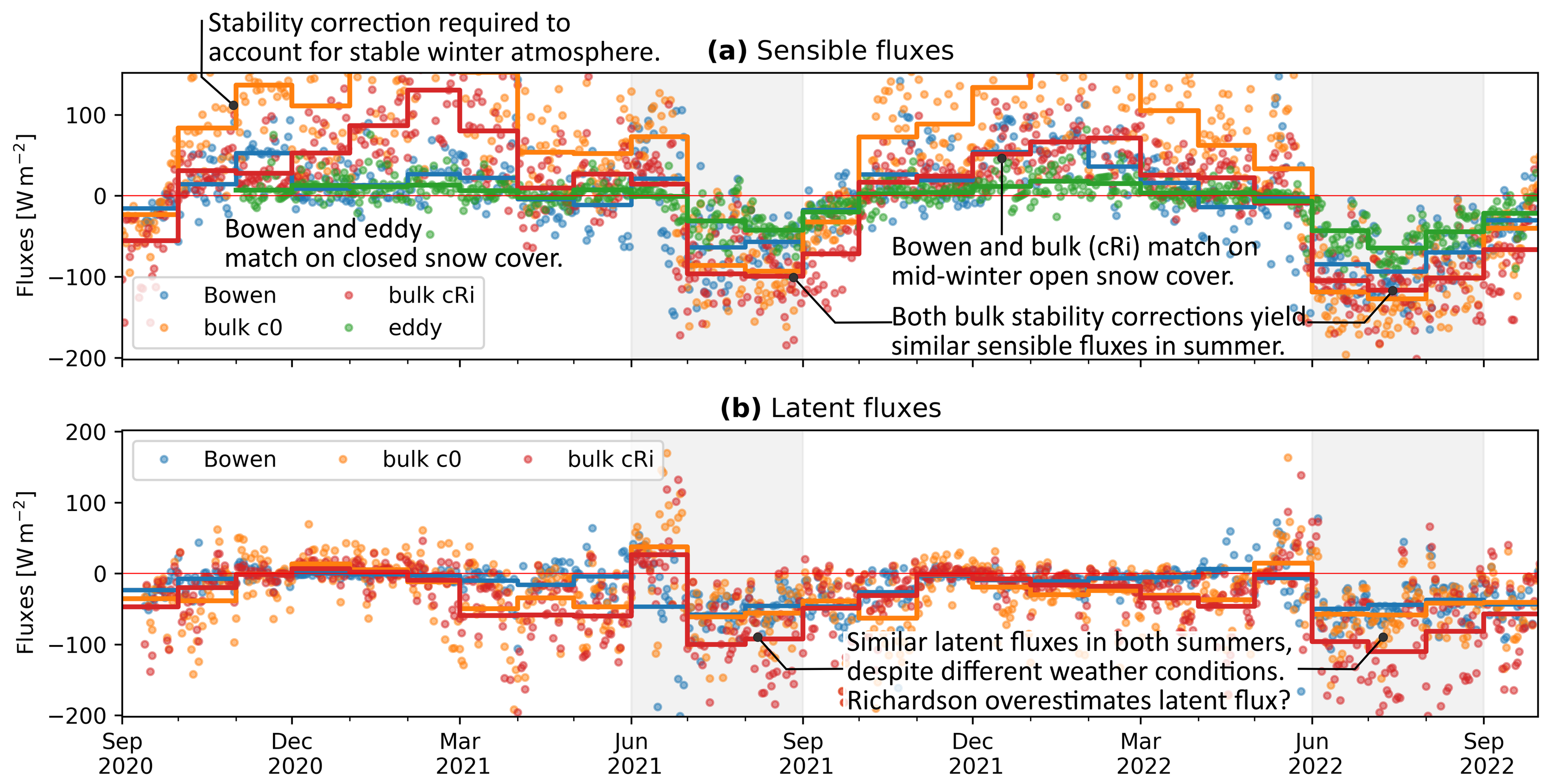

Fig. 7: First results of the **(a)** sensible and **(b)** latent turbulent fluxes; daily (dots) and monthly (bar) averages from 30-minute values. Sign convention: positive flux is towards the surface (gain). Bulk fluxes without stability correction ('c0') and with the Richardson stability correction ('cRi'). Calculation procedure in [1].

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Feb 3, 2023

References

[1] Hoelzle et al. (2022) ESSD (10.5194/essd-14-1531-2022)