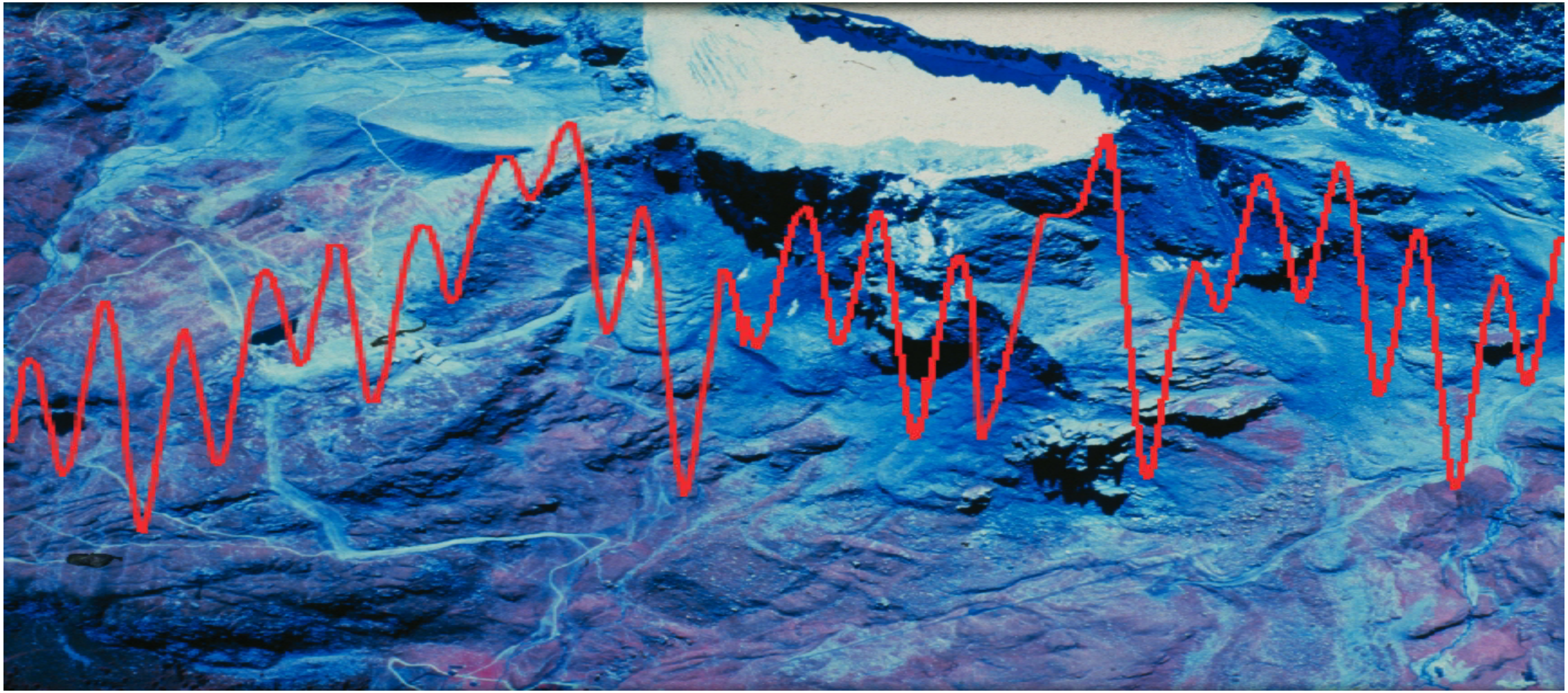
EGU, 05.May 2020

Long-term meteorological and energy balance measurements at three different mountain permafrost sites in the Swiss Alps



Martin Hoelzle, Christian Hauck, Jeannette Noetzli, Cécile Pellet, Martin Scherler, University of Fribourg, SLF

Objectives

1) present a long-term dataset of carefully controlled, corrected and partially gap filled meteorological measurements at three different mountain permafrost sites and make this dataset available within different national and international databases

2) quantify the energy fluxes at the surface of three different permafrost occurrences using the long-term dataset

3) record and explain patterns of variation in surface layer meteorology for the different surfaces and compare them.

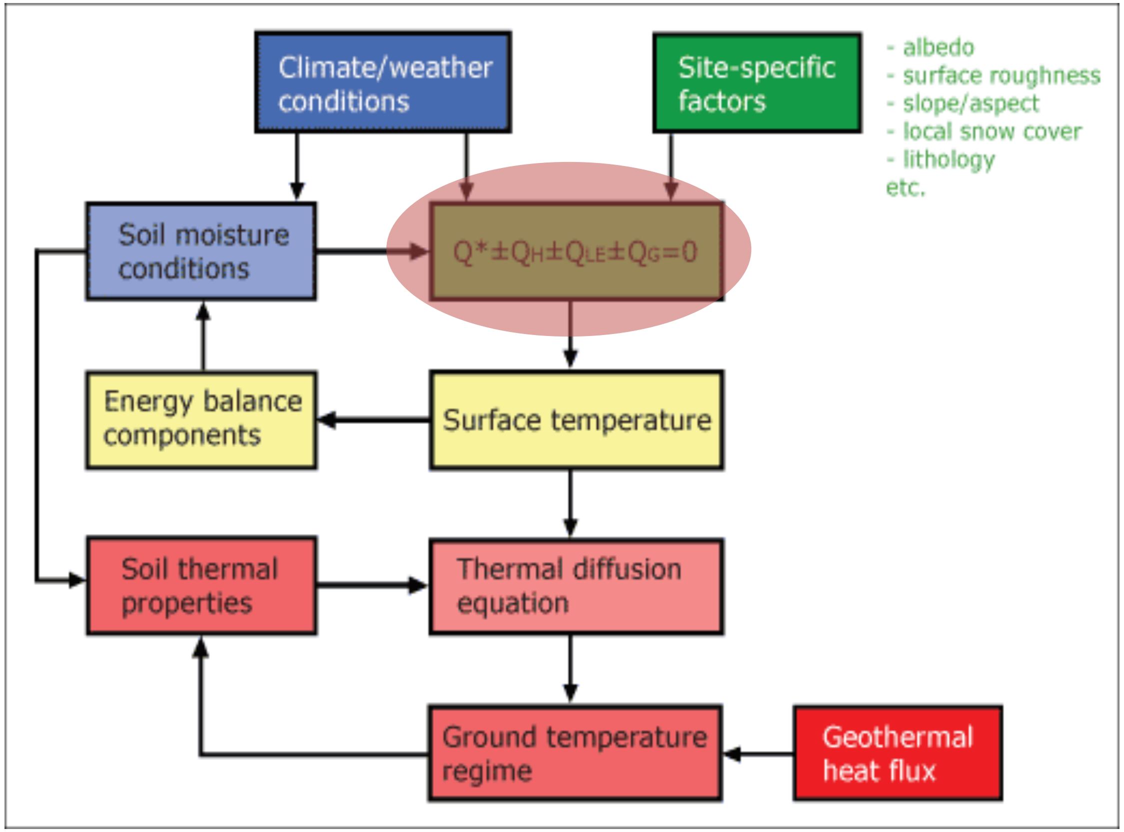
These objectives are important for the development of physically based energy balance models for permafrost environments and to evaluate their sensitivity to climatic warming

Background

Why are these energy fluxes important?

Temperatures, we usually measure within the permafrost are the result of all energy fluxes at the surface as well as in the ground

Therefore, understanding and quantifying these fluxes are necessary to improve process understanding and the development of process-based models!



Williams and Smith 1989

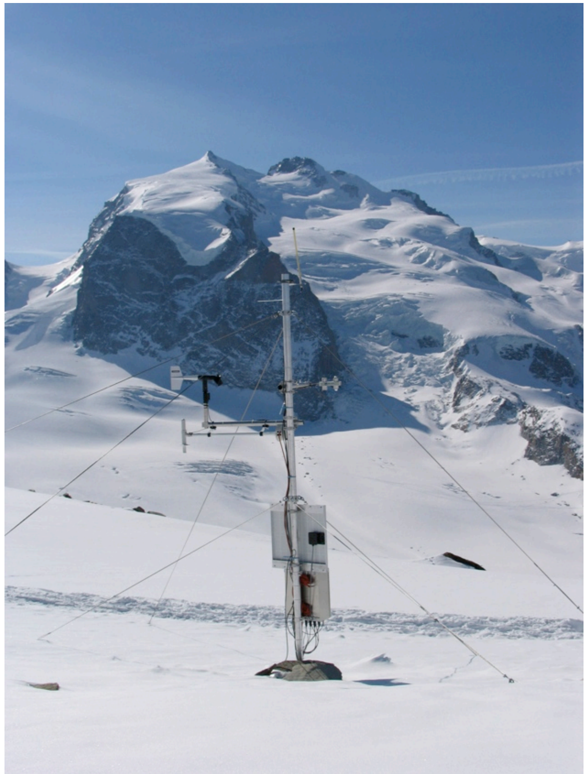
Investigation sites

Schilthorn

Altitude: 2970 m a.s.l.
Measurement Period: 1999-2019

Murtèl-Corvatsch

Altitude: 2700 m a.s.l.
Measurement Period: 1997-2019



Stockhorn

Altitude: 3410 m a.s.l.
Measurement Period: 2002-2019

Measurements

Variables	Sensor (Company)	Type of Sensor	Range	Accuracy by manufacturer	Station
	Logger (CR10X), CR1000 (Campbell)				Murtèl-Corvatsch Schilthorn Stockhorn
Radiation (short- and longwave)	Netradiometer CNR1,4 (Kipp&Zonen)	Pyranometer CM3 Pyrgeometer CG3 PT-100 T-sensor	0.3 – 3 μm 5 – 50 μm	± 10% for daily total ± 10% for daily total ± 10% for daily total	Murtèl-Corvatsch Schilthorn Stockhorn
Air temperature Air humidity	MP-100A Ventilated (Rotronic)	RTD PT-100 C94 hygrometer	-40 – 60° C 0 – 100 % rh	± 10% ± 2%	Murtèl-Corvatsch Schilthorn Stockhorn
Wind speed Wind direction	Model 05103 – 5 (Young)	Potentiometer	0 – 60 m s^{-1} 0 – 355°	± 0.3 m s^{-1} ± 3°	Murtèl-Corvatsch Schilthorn Stockhorn
Snow height	SR50 (Campbell)	Ultrasonic electrostatic transducer	0.5 – 10 m	±0.01 m	Murtèl-Corvatsch Schilthorn Stockhorn
Surface temperature	Infrared thermometer	Irt/c.5	-35 – 60° C	± 1.5° C	Murtèl-Corvatsch
Borehole temperature	YSI 44006 (Yellow Springs Instruments) UUB 31J1 (Fenwal)	NTC-thermistors	-10 – 40° C	±0.02° C	Murtèl-Corvatsch Schilthorn Stockhorn

Data processing

Several meteorological datasets have been prepared for this study, which are classified into three levels:

- **Level 0 is the collected set of raw data, mainly obtained directly from the logger (wherever the data was still available). This data is not treated at all and large part of this data set may contain errors**

- **Level 1 data consist of corrected and partly gap-filled data**

- **Level 2 data contain the finalized dataset, including additional data processing steps such as correction of shortwave incoming radiation due to snow covered sensors. It is recommended to use level 2 data for modelling studies**

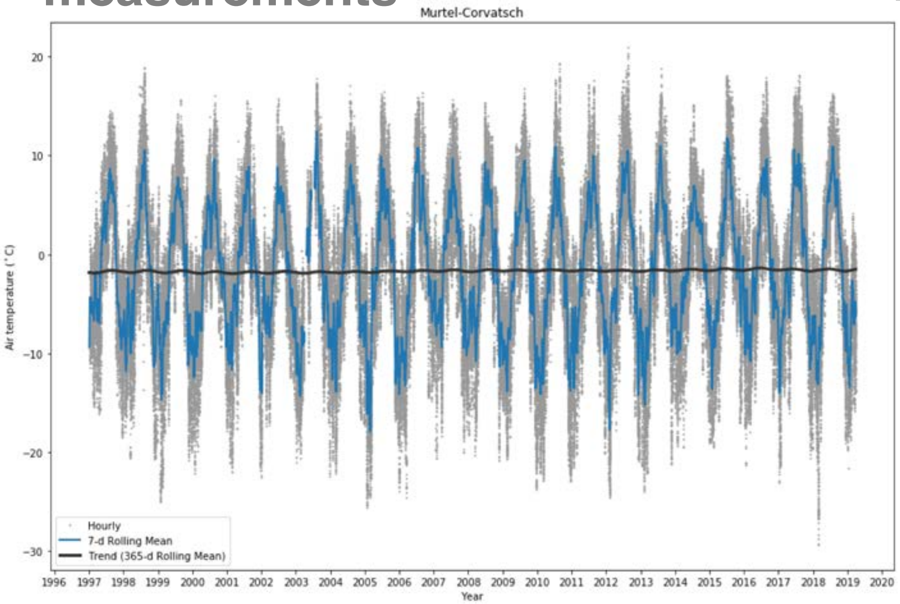
Results: Meteorological Measurements

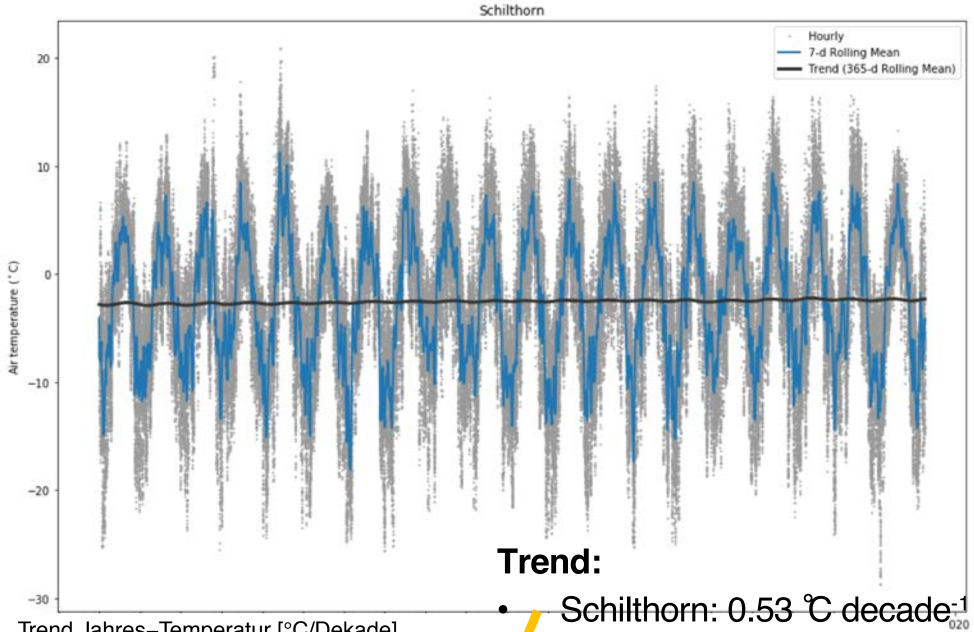
Mean values and standard deviation for the different climate variables and the corresponding time period of measurements calculated based on the mean monthly values

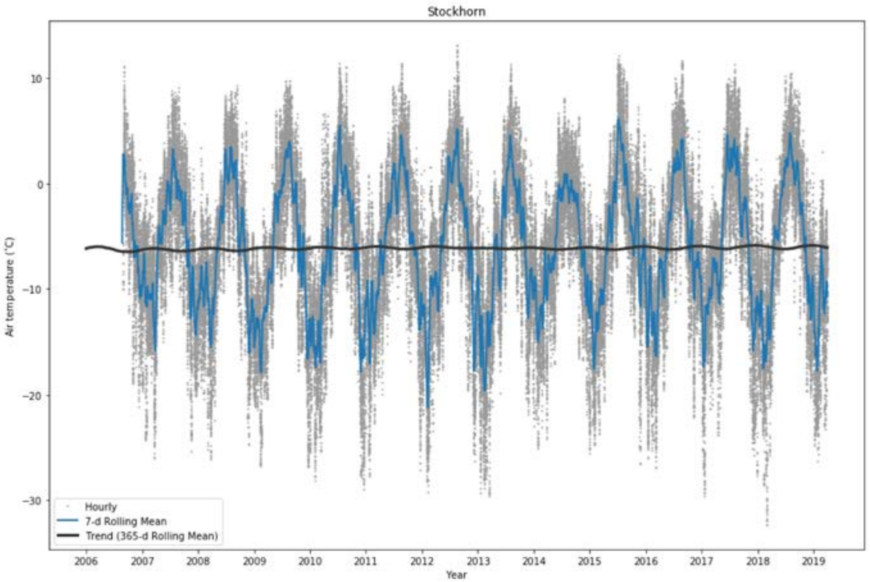
	Mean air temperature (°C)	Mean relative humidity (%)	Mean wind speed (ms^{-1})	
Stockhorn	-5.99±5.27	73.15±5.49	2.08±0.38	
Schilthorn	-2.48±5.12	72.33±6.34	1.96±0.32	
Murtèl–Corvatsch	-1.66±5.86	71.17±4.95	1.70±0.26	
	Shortwave incoming radiation (Wm^{-2})	Shortwave outgoing radiation (Wm^{-2})	Longwave incoming radiation (Wm^{-2})	Longwave outgoing radiation (Wm^{-2})
Stockhorn	224.50±69.80	-131.12±62.88	213.01±24.04	-285.41±35.72
Schilthorn	155.20±86.30	-76.48±51.86	254.19±28.87	-294.78±34.03
Murtèl–Corvatsch	147.43±86.42	-69.83±55.20	253.55±25.31	-299.45±37.19
	Mean snow height (m)	Mean ground temperature (°C)	Mean ground temperature (°C)	
Stockhorn	0.32±0.26	-0.33±5.24 (0.3m)	-0.21±4.41 (0.8m)	
Schilthorn	0.83±0.60	0.03±2.28 (0.2m)	0.11±1.99 (0.4m) height	
Murtèl–Corvatsch	0.50±0.40	0.05±4.48 (0.5 m)	-0.27±3.24 (1.5 m)	

Results: Meteorological measurements

Air temperatures and trends for the three stations Murtèl, Schilthorn and Stockhorn.

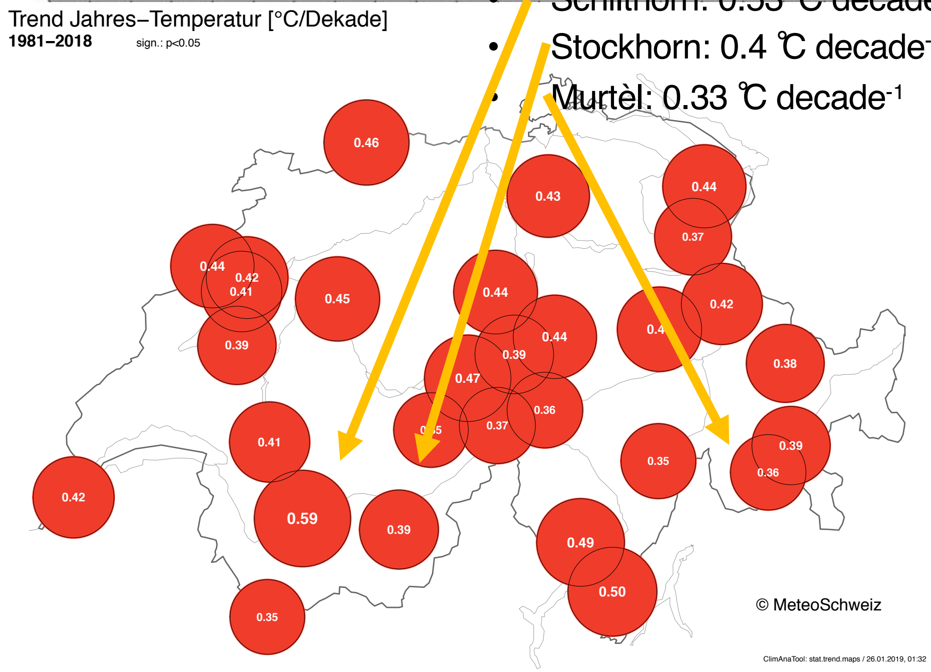






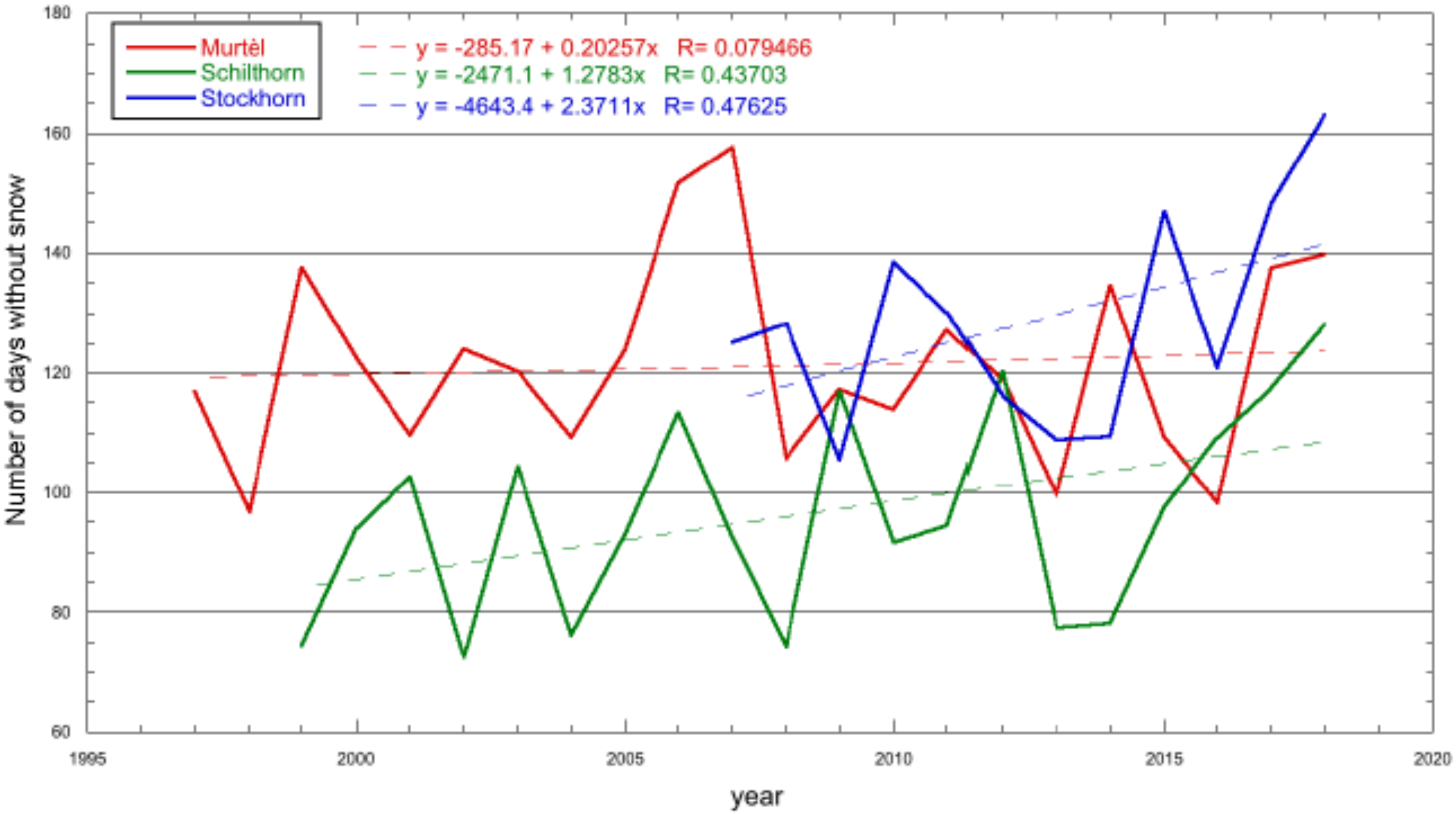
Trend:

- Schilthorn: 0.53 °C decade^{-1}
- Stockhorn: 0.4 °C decade^{-1}
- Murtèl: 0.33 °C decade^{-1}



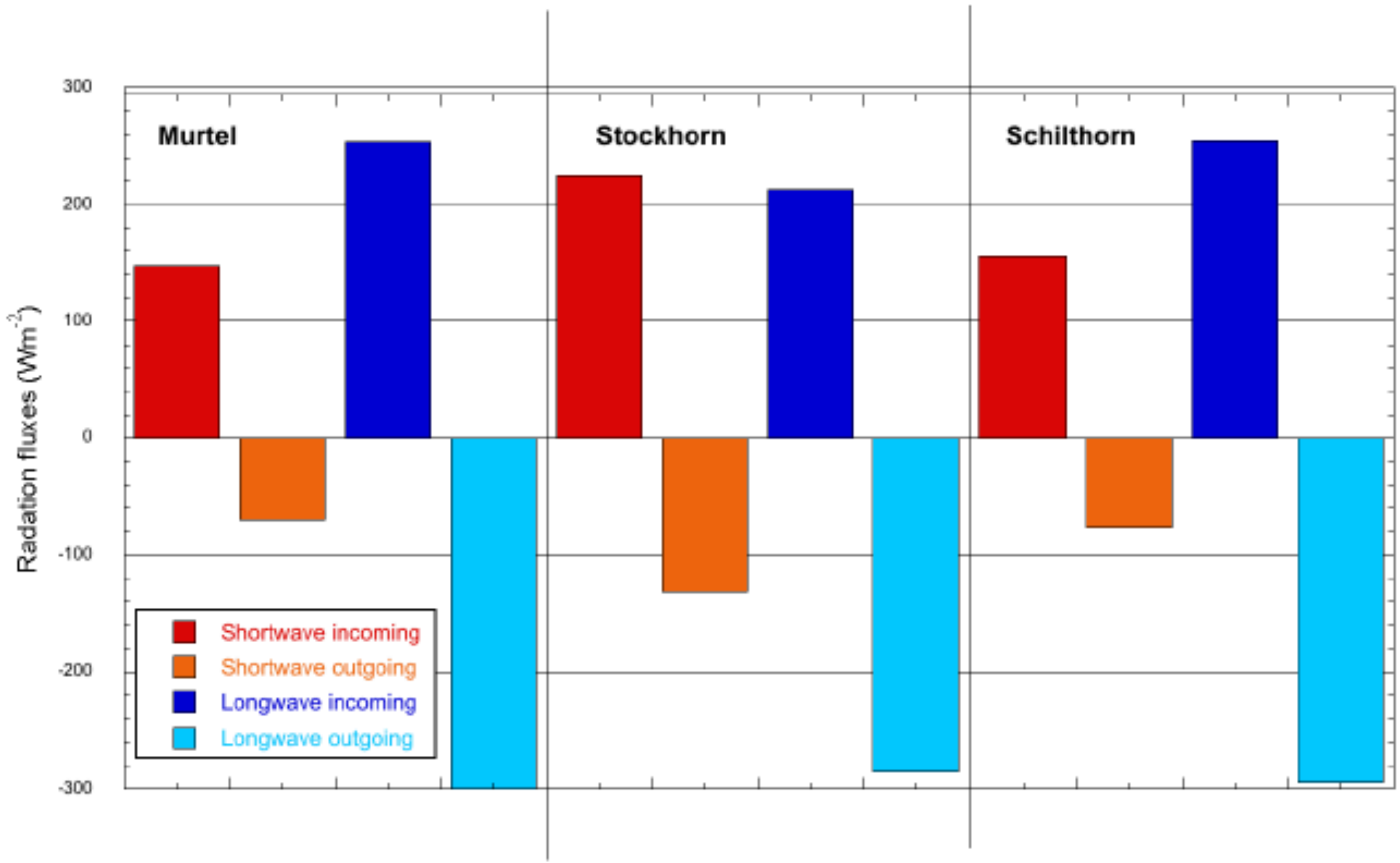
Trends fit with the ones determined by MeteoSwiss

Number of days without snow for the three stations Murtèl, Schilthorn and Stockhorn.

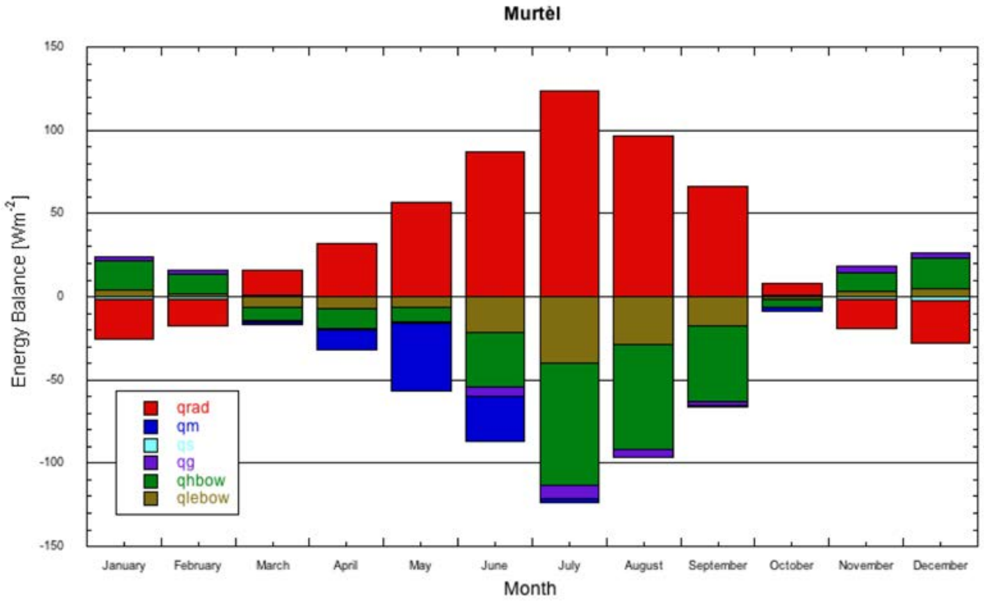


General reduction of snow covered days is observed at all three stations

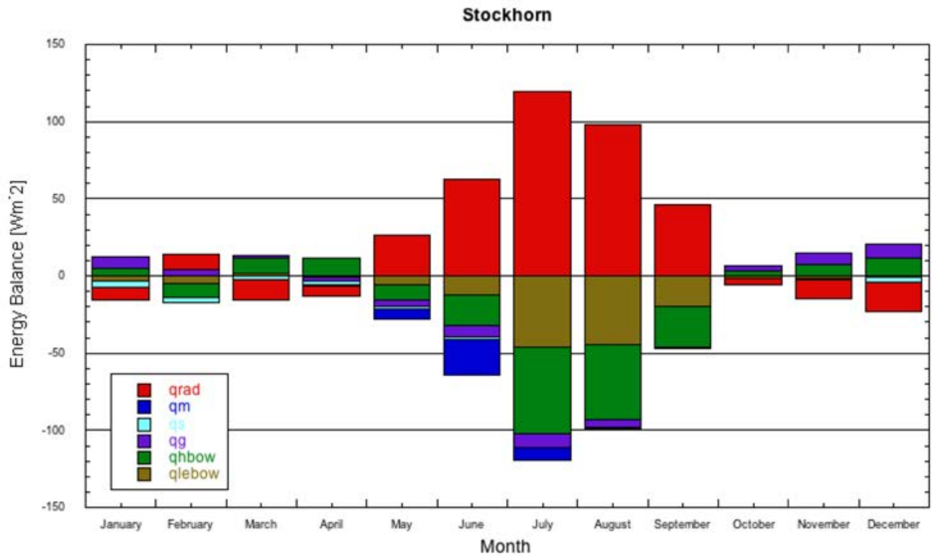
All radiation components for all three stations averaged for the whole observation periods.



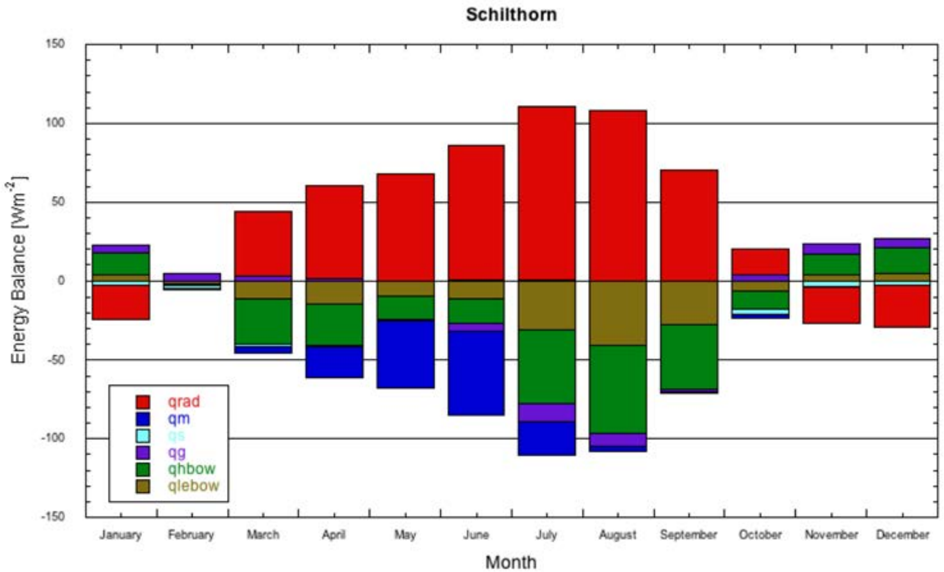
Energy balance components of the Schilthorn, Murtèl and Stockhorn stations averaged for each month of the whole observation periods



1997-2019

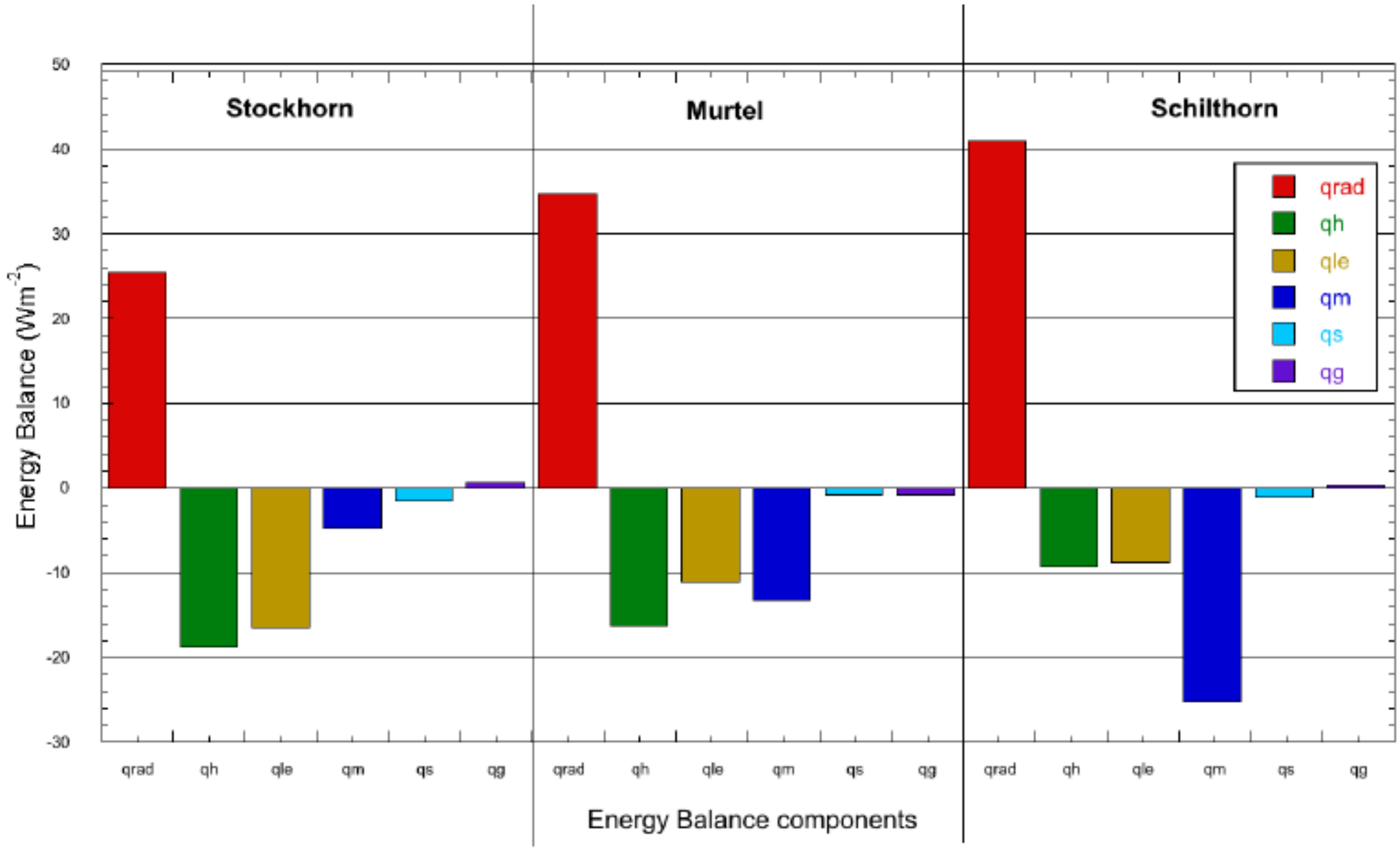


2006-2019

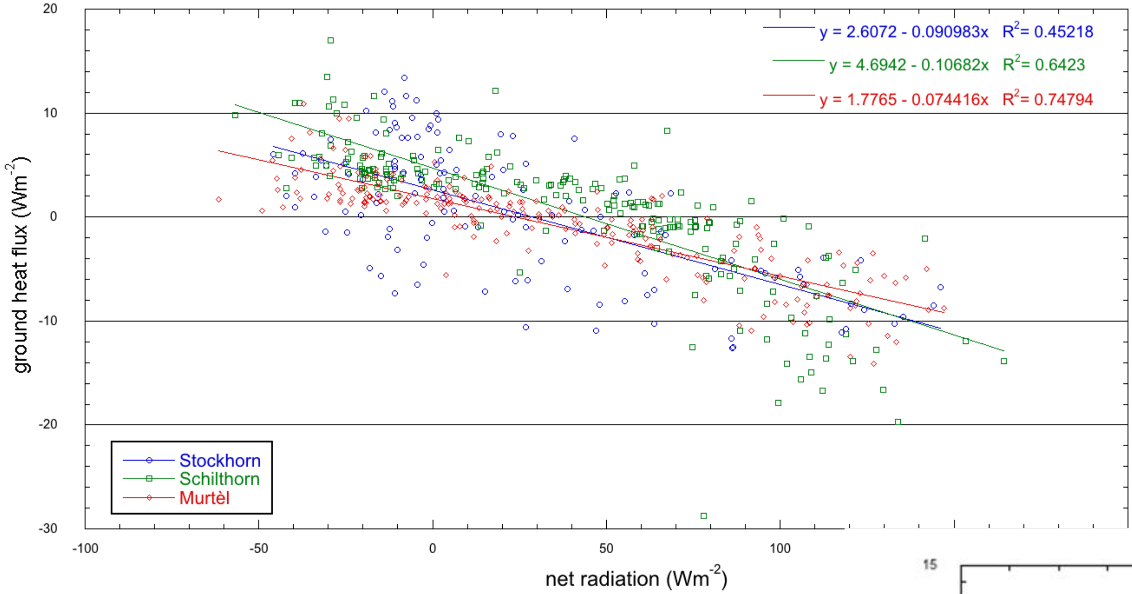


1999-2019

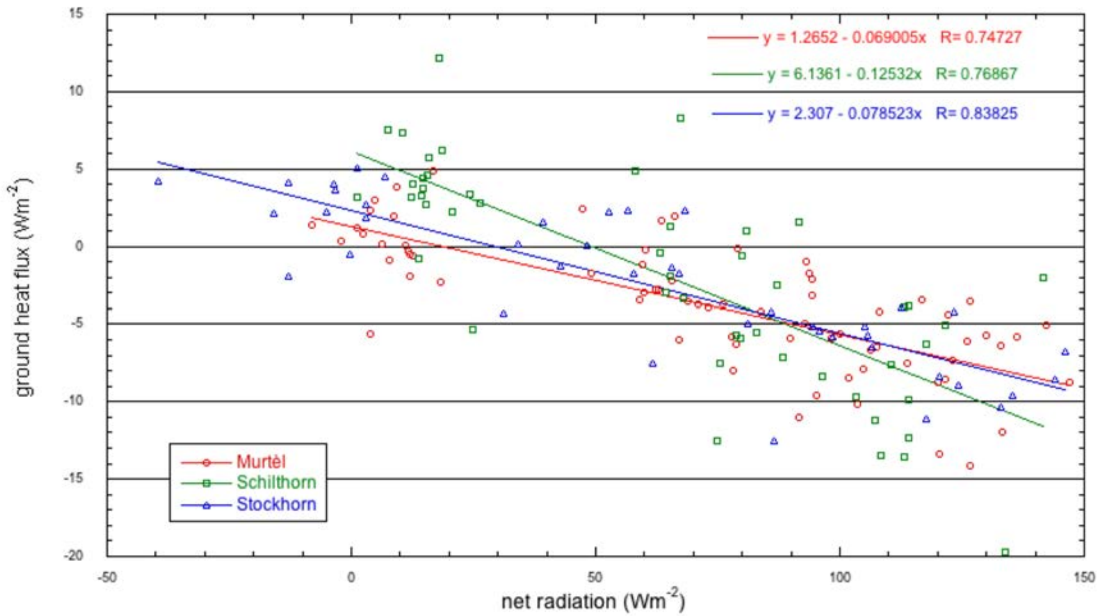
Mean energy balance components for the stations Murtèl, Schilthorn and Stockhorn for the whole observation period



Relation between net radiation and ground heat flux for the stations Murtèl, Schilthorn and Stockhorn (monthly resolution)



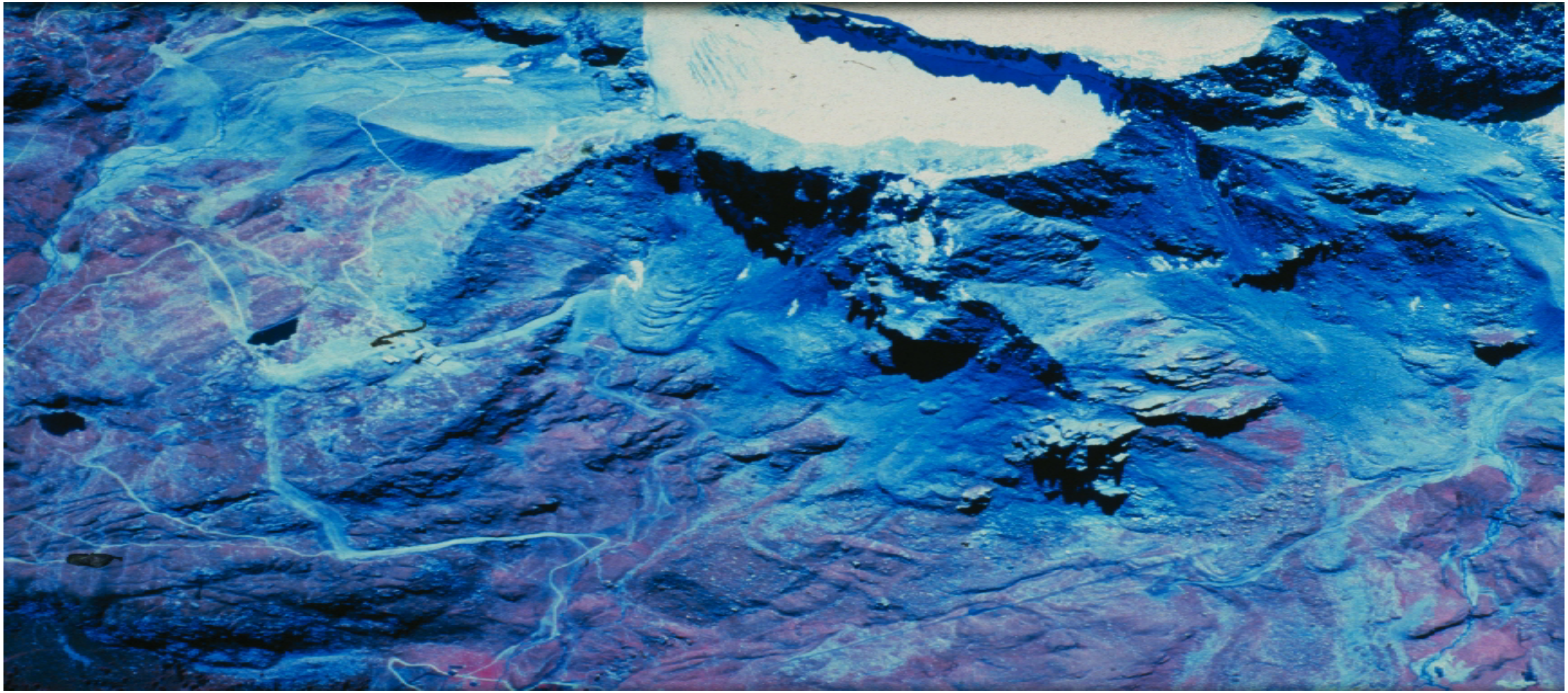
All month



Only summer month

Conclusions

- Long-term meteorological time series at three PERMOS station could be established
- The energy balance at the three permafrost sites within the PERMOS network of Switzerland could be determined serving as important validation and calibration data for further studies
- Many data gaps exists and data processing was very laborious
- Further analysis will allow improvements of local process studies at these sites as well as improved process-based model approaches can be developed



Thanks for your attention