The influence of radiative forcing on permafrost temperatures in Arctic rock walls

Juditha Schmidt[1], Sebastian Westermann[1], Bernd Etzelmüller[1], Florence Magnin[2]

[1]Department of Geosciences, University of Oslo, Norway

[2]CNRS, EDYTEM Laboratory, Bd de la Mer Caspienne, 73376 Le Bourget de Lac, France

Introduction

Climate change has a strong impact on periglacial regions and intensifies the degradation of mountain permafrost[2]. Radiative forcing is a crucial factor for solving the energy surface balance. It can differ significantly in intensity over time, latitudinal positions and exposures of frozen rock slopes.

In this project, we suggest improving the parametrization of the radiative forcing in the thermal model CryoGrid for simulations of the local thermal regime.

Surface temperature records

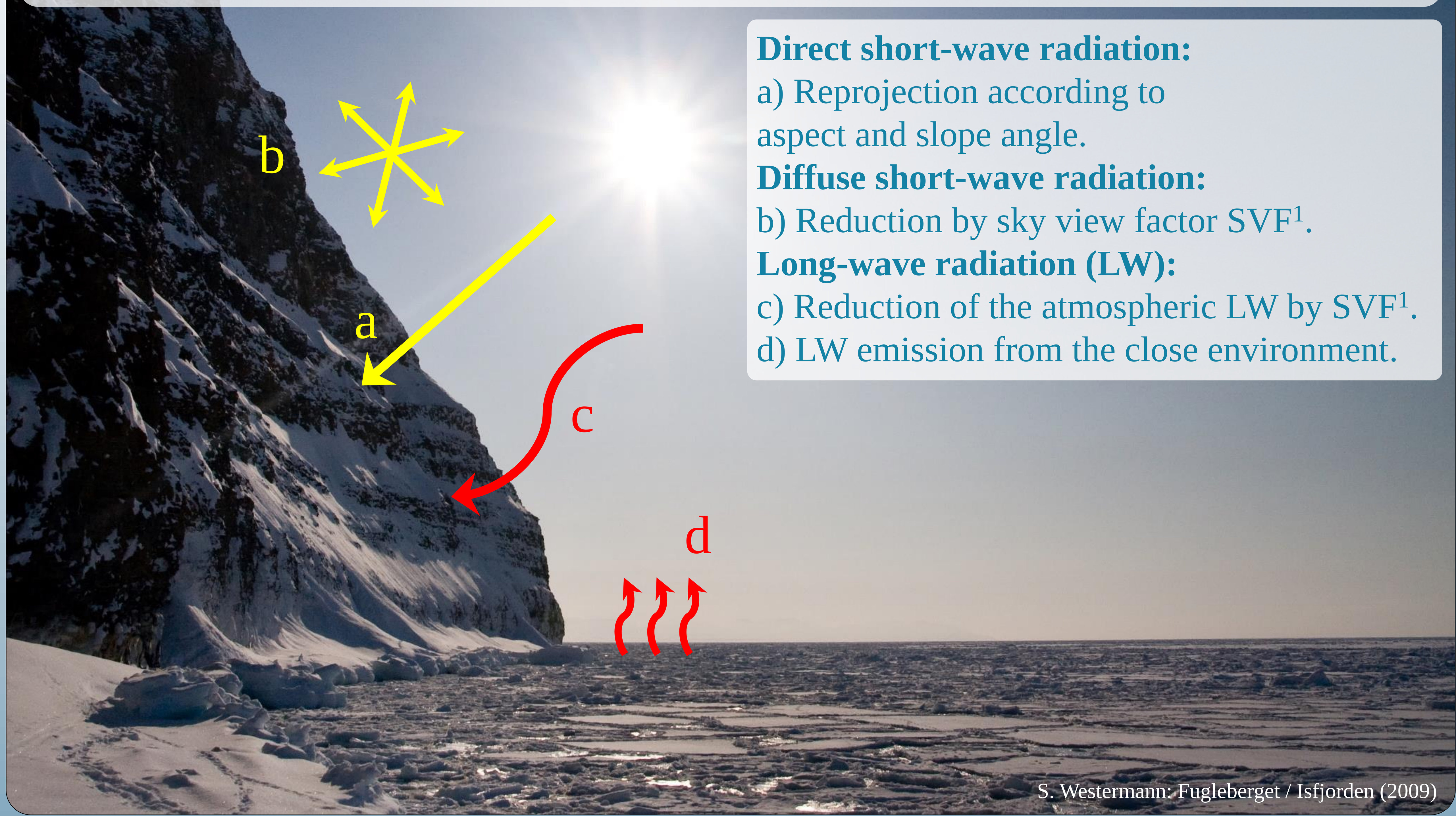
- 37 loggers are located in positions between Southern Norway to Svalbard[3]
  → analysis of dependency on latitude and aspect.
- 8 loggers are located in Ny Ålesund (Svalbard) in coastal and non-coastal cliffs (fig. 1)
  → analysis of the influence of seawater.

Figure 1: Locations of the installed loggers at non-coastal rock walls (blue), at coastal cliffs (red) and at cliffs the bay (green).
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USGS, AeroGRID, IGN, and the GIS User Community.

CryoGrid: radiative forcing on steep rock walls

CryoGrid is a thermal model designed for permafrost applications[4].
The following modifications were implemented for inclined planes:

Direct short-wave radiation:
a) Reprojection according to aspect and slope angle.
Diffuse short-wave radiation:
b) Reduction by sky view factor SVF[1].
Long-wave radiation (LW):
c) Reduction of the atmospheric LW by SVF[1].
d) LW emission from the close environment.



S. Westermann: Fugleberget / Isfjorden (2009)

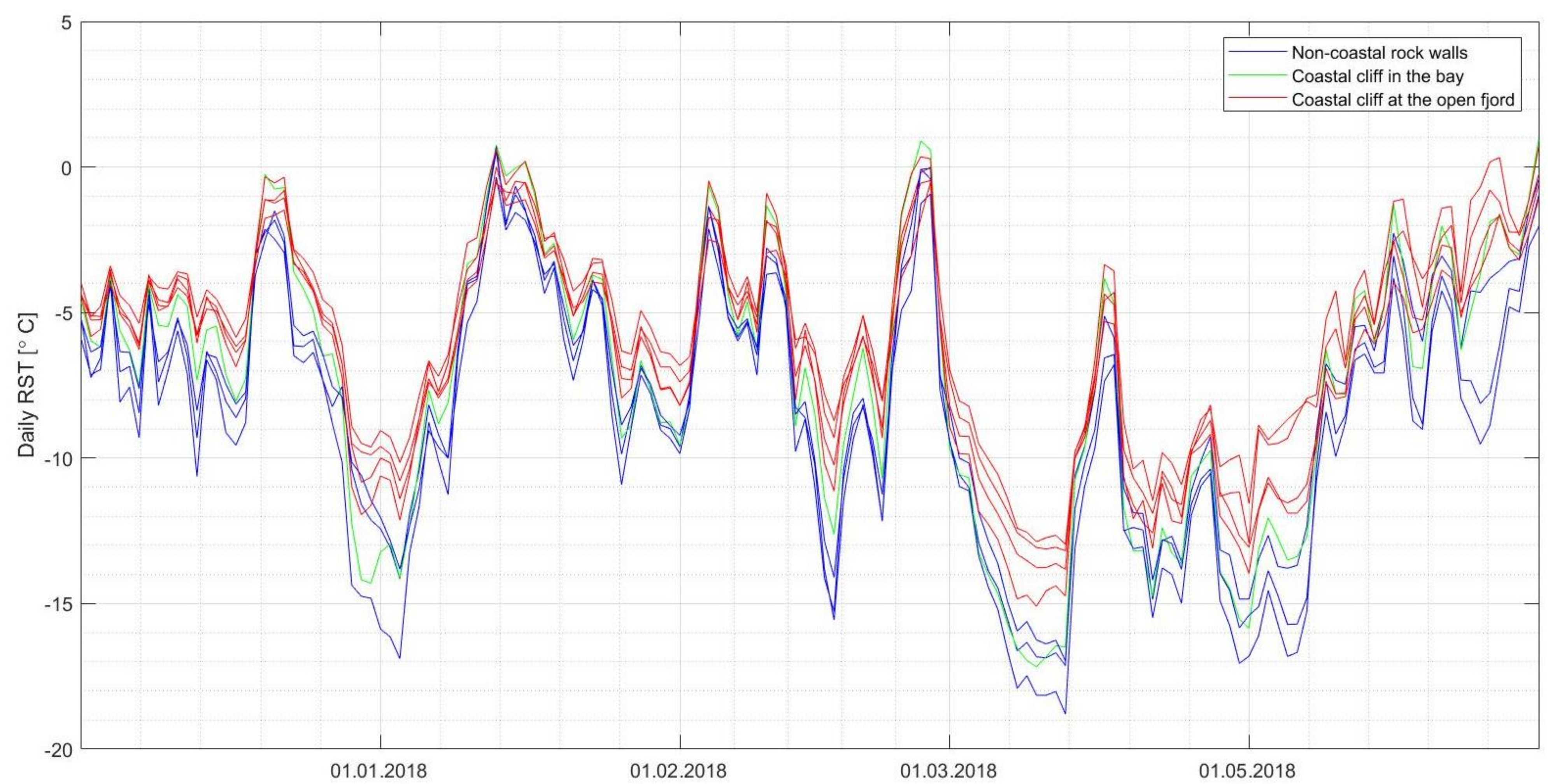


Figure 2: Measured daily rock surface temperature (RST) in Ny Ålesund / Svalbard from 12/2017 to 04/2018.

Key findings in Ny Ålesund

1. The continuous **heat emission of seawater** by LW and **higher air temperatures** at the coast result in increased RST at coastal cliffs (fig. 2, tab. 1).
2. A temporarily frozen bay leads to **colder RST during the presence of an ice layer** by blocking the heat emission of the seawater (fig 2).
3. Model results predict an **increase in RST at the cliff as a consequence of sea ice loss** in Kongsfjorden.

The analysis of different latitudes is currently in progress and statements are expected in summer 2020.

Location	Site	RST (Winter 2018)	Mean RST (Winter 2018)
RW05		-8.2	
RW06	Canyon	-8.7	-8.7
RW07		-9.1	
RW08	Bay	-7.7	-7.7
RW09		-6.9	
RW10	Cliff	-6.9	-6.5
RW11		-6.4	
RW12		-6.0	

Table 1: Measured monthly rock surface temperature (RST) in Ny Ålesund in winter season 2018 (January – April).

References

[1]Fiddes, J. & Gruber, S. (2014): TopoSCALE v.1.0: downscaling gridded climate data in complex terrain. – Geoscientific Model Development, 7: 387 – 405.

[2]IPCC (2019): IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. [Pörtner, H.-O., Roberts, D. C., Masson-Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Nicolai, M., Okern, A., Petzold, J., Rama, B. & Weyer, N. (eds.)]. In Press.

[3]Magnin, F., Etzelmüller, B., Westermann, S., Isaksen, K., Hilger, P. & Hermanns, R. H. (2019): Permafrost distribution in steep rock slopes in Norway: measurements, statistical modelling and implications for geomorphological processes. – Earth Surface Dynamics, 7: 1019 – 1040.

[4]Westermann, S., Langer, M., Boike, J. Heikenfeld, M., Peter, M., Etzelmüller, B. & Krinner, G. (2016): Simulating the thermal regime and thaw processes of ice rich permafrost ground with the land-surface model CryoGrid 3. – Geoscientific Model Development, 9: 523 – 546.