Faculty of Geosciences
Physical Geography

Resolving the impact of surface properties of a debris covered glacier on the energy balance using large eddy simulations.

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Introduction

Debris-covered glaciers account for 18% of the total glacier ice volume in High Mountain Asia, however the exact melt processes of these glaciers are still unknown and their total contribution to the total glacier melt remains uncertain. Debris influences the surface energy balance and therefore glacier melt by influencing the thermal properties (e.g. albedo, thermal conductivity) of the glacier surface. In this study, the impact of topography, surface temperature and moisture of debris on the spatial distribution of small-scale meteorological variables, such as the turbulent fluxes, wind fields, moisture and temperature for a debris-covered glacier and finally the conductive heat flux into the debris is investigated.

Methodology

We simulated a debris-covered glacier (Lirung glacier, Nepal) at a high-resolution of 1 meter with the microHH model (Van Heerwaarden, 2017) with boundary conditions retrieved from an automatic weather station (temperature, wind and specific humidity) and UAV flights (digital elevation model and surface temperature), and is validated with eddy covariance data.

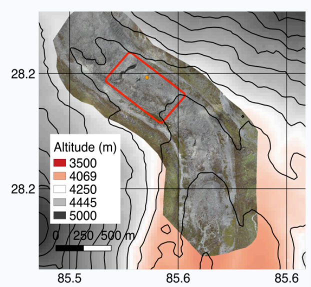

Figure 1: Lirung glacier with the microHH domain (red contour) and location of the AWS (orange point).

Input fields

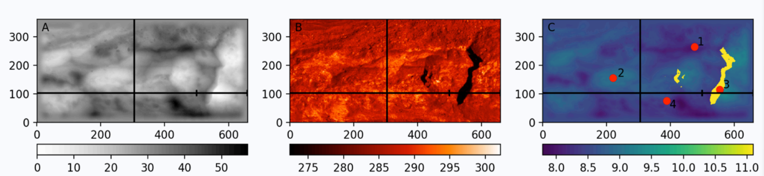

__Figure 2__: Boundary conditions used in microHH: the DEM (A), surface temperature (B) and surface specific humidity (C). The vertical cross section used for the ice cliff is x=500-660, y=102. Red points indicate the locations used in Figure 4 (1=dry debris, 2=wet debris, 3=ice cliff and 4=AWS).

Experiments

__Table 1:__ Overview of experiments. If a value is given, this means the surface is homogeneously forced with that value. For the DEM and surface temperature spatially variable measured values are available and this is indicated with __Real__. A DEM of 0 indicates no topography input is used and the surface is flat and homogeneous. A specific humidity of 8.6 g/kg and surface temperature of 313.3K are the averages of the measured spatial fields.

EXP	Description	DEM	T_s	q_s
HOM_{flat}	Homogeneous glacier	0	313.3K	8.6 g/kg
HOM_{DEM}	Topography effects	Real	313.3K	8.6 g/kg
HET_T	T_s effects 'normal'	Real	Real	8.6 g/kg
HET_q	q_s spatial effects	Real	313.3K	Spatially 85-70%
REAL	'Reality'	Real	Real	Spatially 85-70%

Results

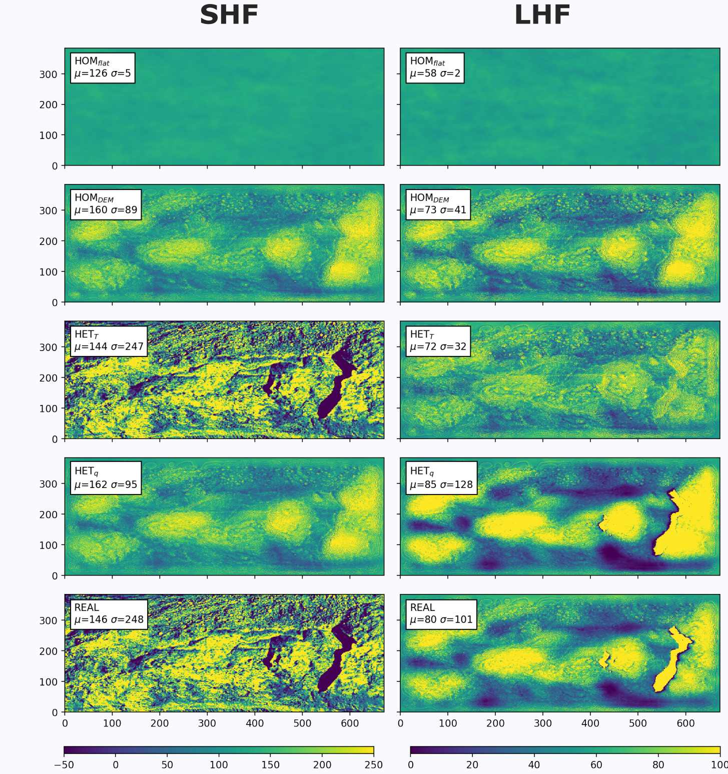

__Figure 3__: 2D plots of average variables sensible heat flux (SHF, left panels) and latent heat flux (LHF, right panels) at the surface for each experiment.

Cross sections

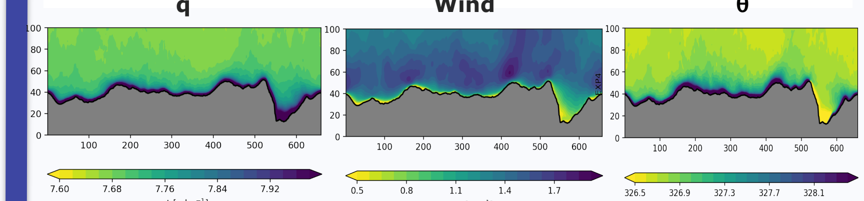

__Figure 4__: Vertical cross sections of specific humidity, wind and potential temperature for the REAL experiment.

Conductive heat flux

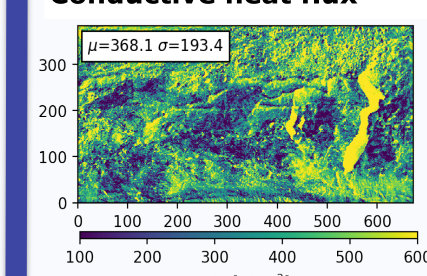

__Figure 5:__ The conductive heat flux for experiment REAL.

- Topography is key driver of turbulence
- Heterogeneous surface boundary controls melt and energy availability for supra-glacial features.
- If the homogeneous surface input is representative for domain this gives good average results.
- Conductive heat flux at ice cliff is aproximately 2 times higher than at debris and is mainly driven by the SHF.

Spatial analysis

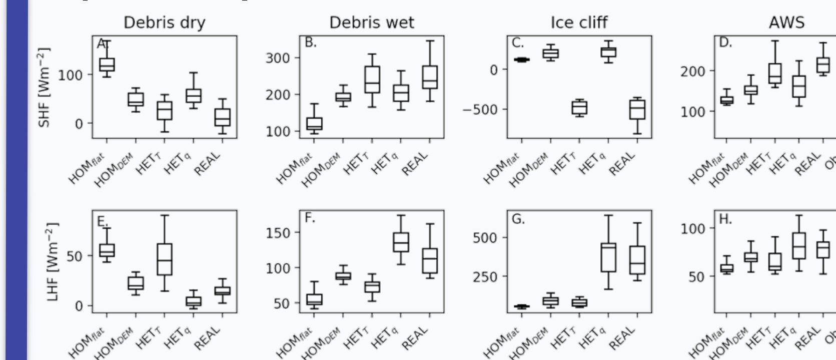

__Figure 6:__ The possible outcomes at 11:00 LC for the sensible and latent heat flux for four different locations, indicated in Figure 2.

Ice cliff

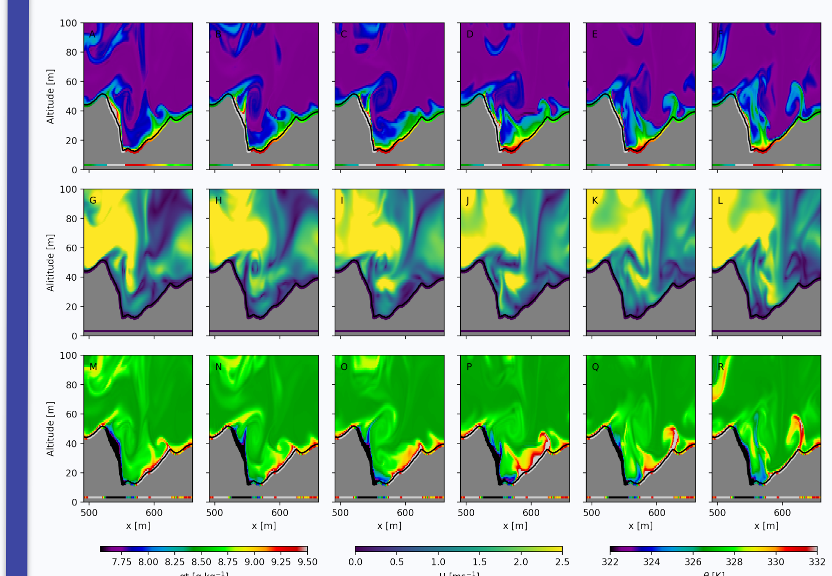

__Figure 7__: Vertical cross sections through the ice cliff at time steps t=657 till 707s (10s interval).

Conclusions

- Surface temperature drives SHF, specific moisture drives LHF.
- Homogeneous input boundary conditions are ok but variation in resulting SEB is cause of ice melt variability.
- Local melt hot spots are possibly initiated by irregularities in the topography.
- Turbulent fluxes and local heat advection contribute besides radiation to accelerated melt at ice cliffs.

References:
Heerwaarden, Chiel C Van, Bart J H Van Stratum, Thijs Heus, Jeremy A Gibbs, and Evgeni Fedorovich. 2017. "MicroHH 1 . 0 : A Computational Fluid Dynamics Code for Direct Numerical Simulation and Large-Eddy Simulation of Atmospheric Boundary Layer Flows," 3145–65.