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Sensitivities of an EB model for a debris covered glacier

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Background and Field Site

Although a number of energy balance studies have been performed on debris covered glaciers in the Alps [*Reid and Brock, 2010*] as well as in the Himalaya [*Rounce et al. 2015*], there are still significant shortcomings in understanding processes in the surface boundary layer as well as the energy transport through the debris layer. Additionally field data is still scarce as measurements on the debris surface are difficult and with a heterogeneous debris surface spatial variability is likely important.

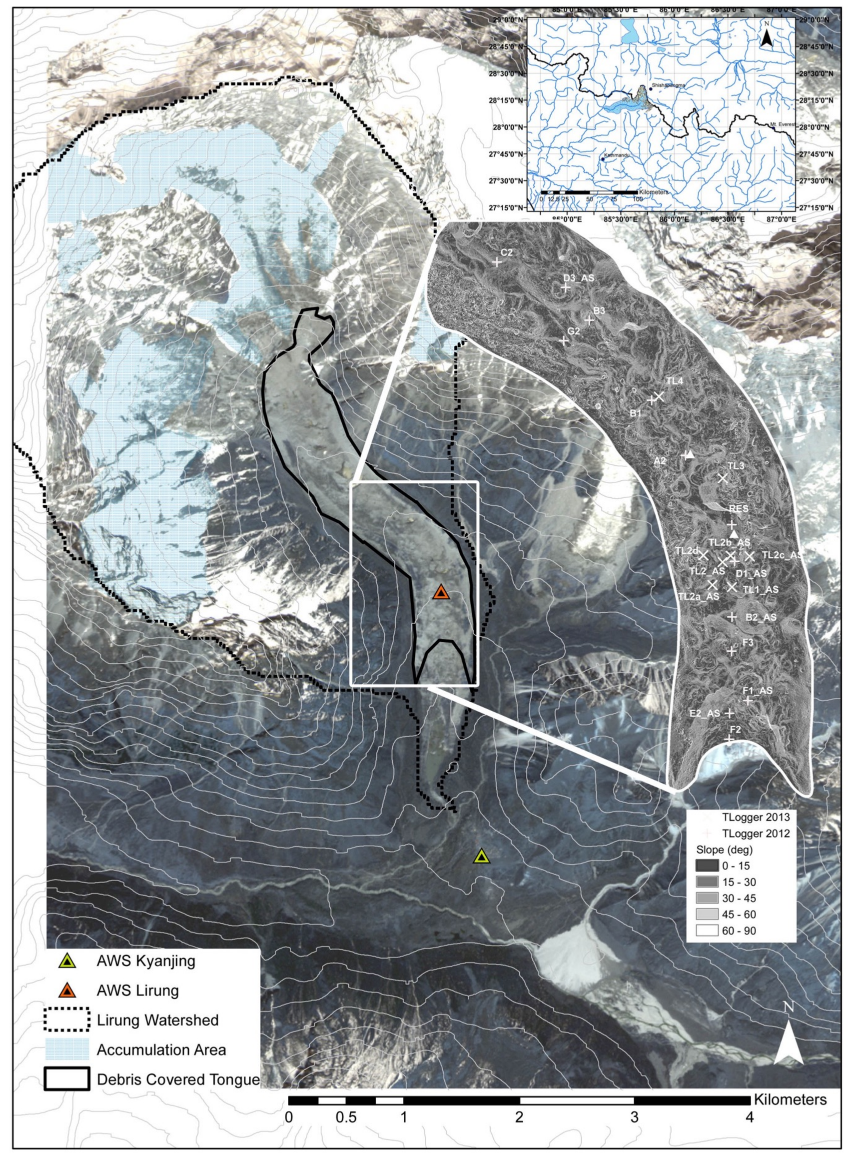

Figure 1: An overview of Lirung glacier showing the AWS location as well as the TLogger positions with stakes associated.

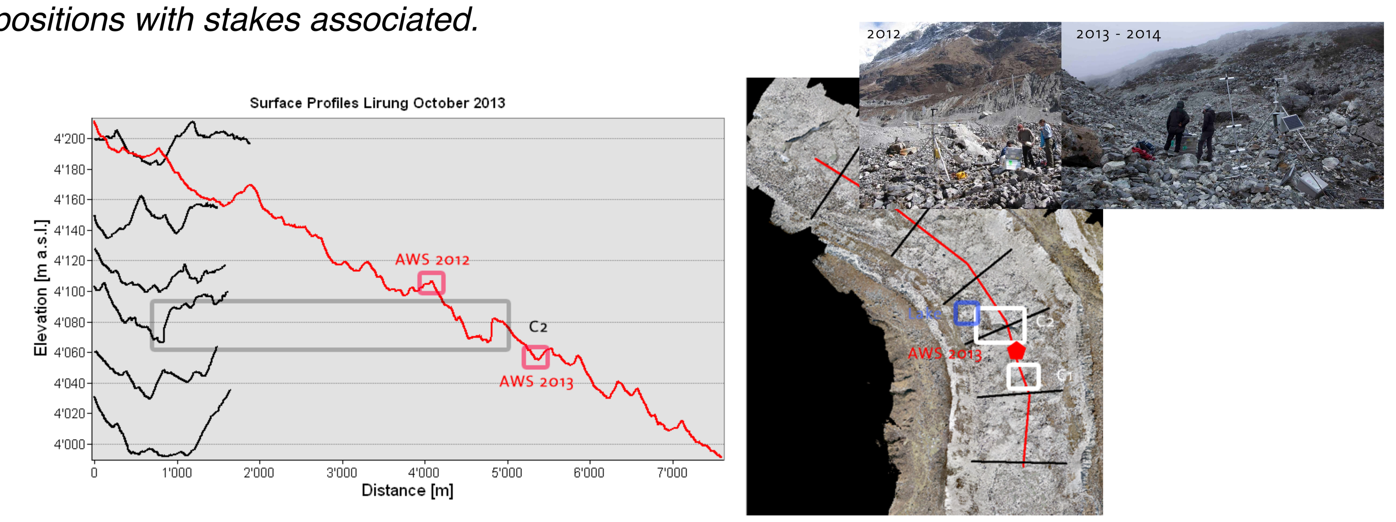

Figure 2: Crosssections through the tongue of the Lirung glacier showing the locations of the AWS. The heterogeneity of the surface is apparent.

We have collected meteorological data on the tongue of Lirung Glacier in the Langtang catchment between 2012 and 2014, generally from May until October and once during the winter months. The catchment is located 60 km north of Kathmandu. The debris covered tongue extends from ca 4000 m asl. to 4400 m asl. and is disconnected from the accumulation zone on the surrounding head walls [*Ragettli et al. 2015*].

Motivations, Methods and Challenges

An established EB model [*Reid and Brock, 2010*] is slightly adapted for the monsoon climate which has strong differences between the wet and dry seasons. Additionally a Monte Carlo sensitivity analysis was integrated.

It was found that

(a) essential **input data** is **variable in space, between seasons and between years**

(b) the uncertainties from the stake measurements are large as debris movement tilts stakes

We attempt to show here the variability of some of this input data and how that affects model outputs.

Field Data

We measured shortwave radiation, air and surface temperature as well as relative humidity and wind speeds and directions at the AWS. The AWS in 2012 was placed on top of a mound, while in 2013 and 2014 it was in a depression (*Figure 2*). Additionally air and surface temperature was measured at different TLoggers (*Figure 1 and 2*).

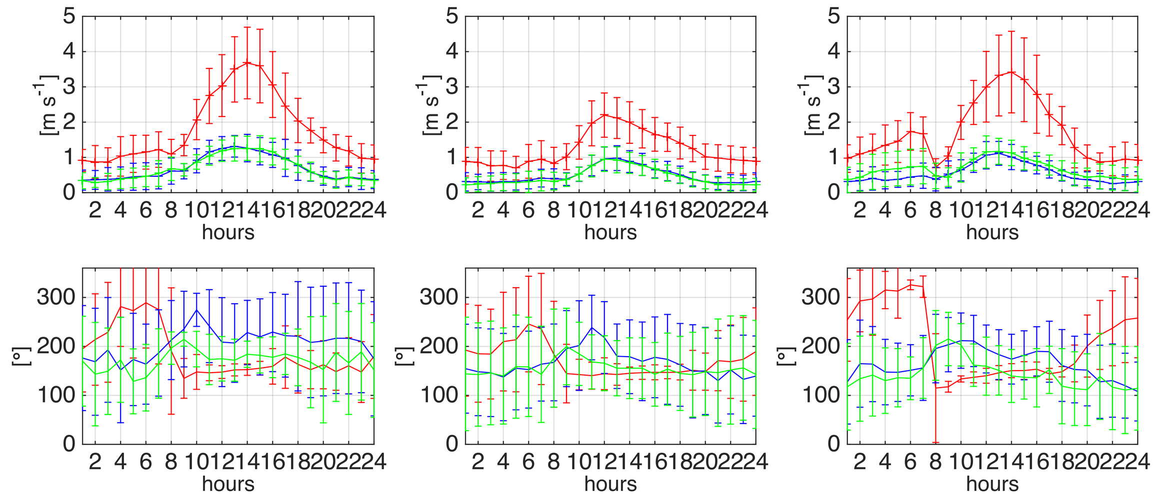

Figure 4: Wind speed (top) and direction (bottom) in 2012 (red), 2013 (blue) and 2014 (green).

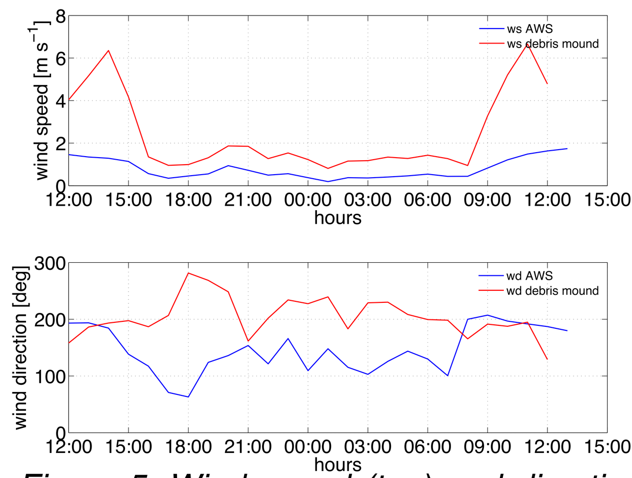

Figure 5: Wind speed (top) and direction (bottom) measured at two locations 100 m apart on a debris mound and in a depression.

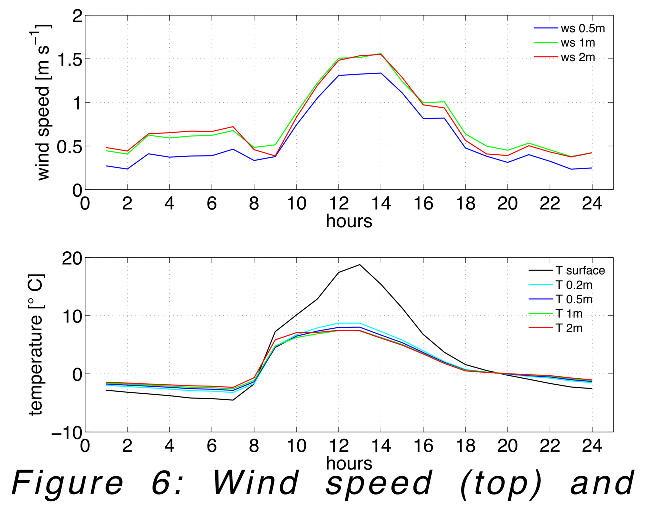

Figure 6: Wind speed (top) and temperature both from 2 m towers placed next to the AWS for two weeks.

The most variable data is likely wind as well as surface temperature data [Steiner and Pellicciotti, 2016]. This has consequences for the SBL and subsequently the suitability of turbulent fluxes (Figure 4 - 7). Additionally debris thermal conductivity values have varied between 0.5 and 6 between the years and seasons and there was no clear indication of when which value would be applicable. We also show that albedo varies strongly over the season and during the day even just for one location (*Figure 8*).

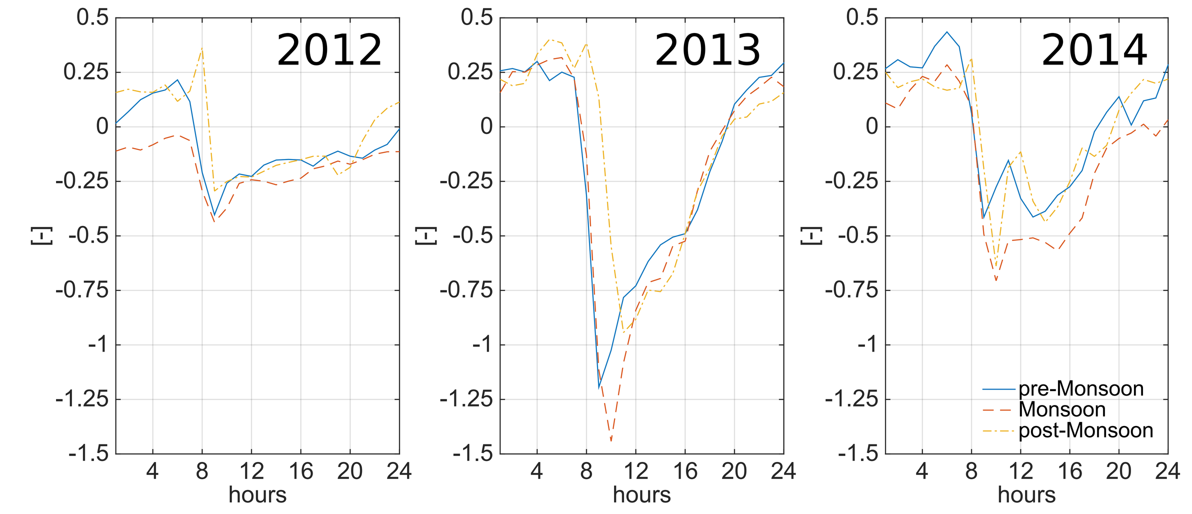

Figure 7: Richardson Number derived from TLogger data and wind measurements for all three years.

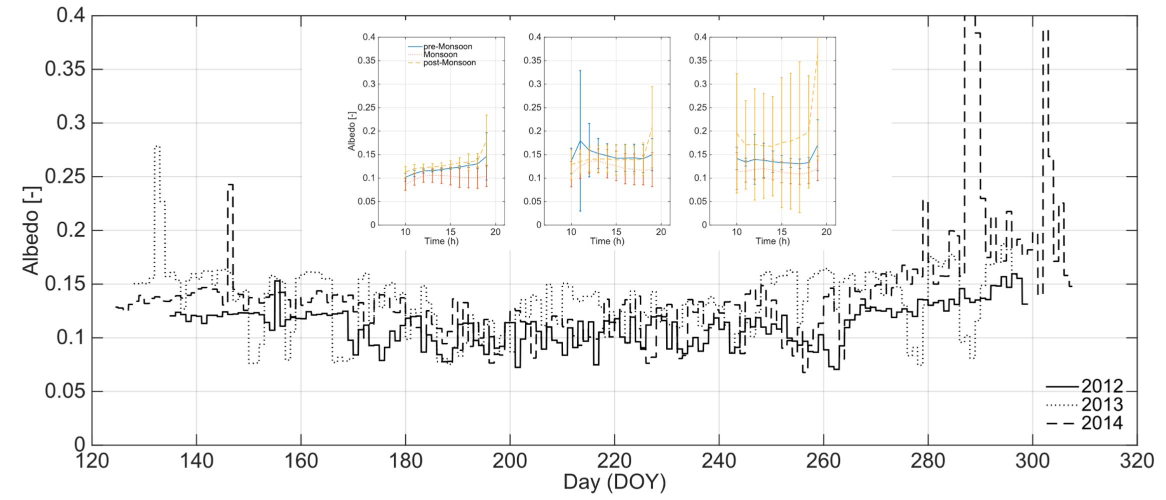

Figure 8: Annual albedo as well as diurnal cycles (inset) at the location of the AWS

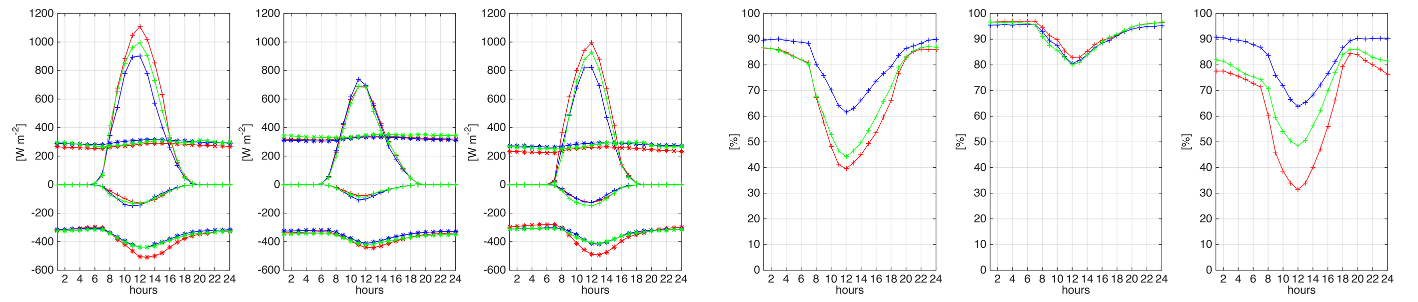

Figure 9: Shortwave radiation (left) and relative humidity (right). The data is stable for the earlier and the model relatively insensitive to differences in the latter. (red: 2012, blue: 2013, green: 2014)

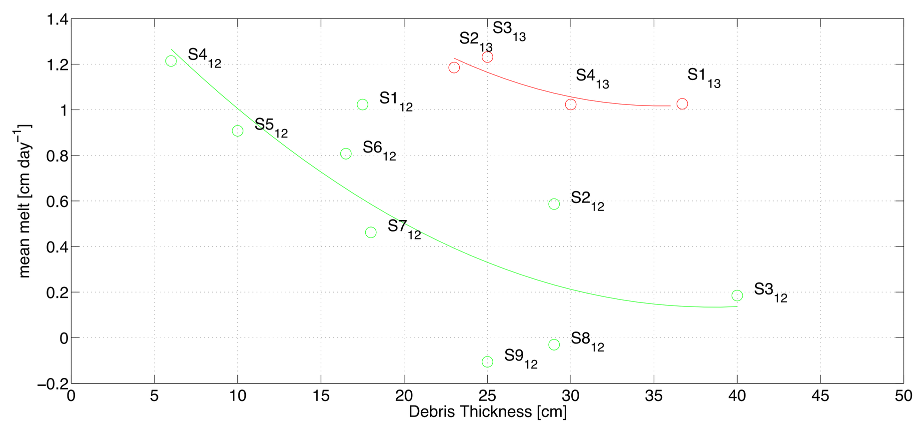

Figure 10: Stake Measurement Data from two seasons compared to debris thickness.

Results

Below we show model runs with conductivity values ranged between 1.4 and 1.7 for the wet and 0.94 and 1.14 for the dry season based on Literature [Nicholson and Benn, 2006/2012] and own thermistor data.

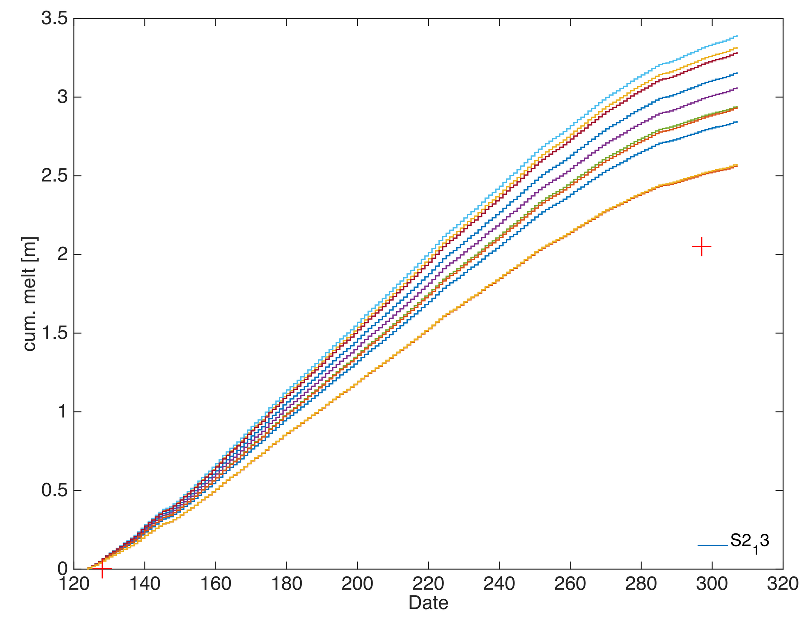

Figure 11: Variability of modelled melt only by varying k_d. The stars mark stake measurements. The stake is located next to the AWS.

Conclusion

- we need to get a better understanding of debris thermal conductivity under local conditions also considering water content
- we need to understand the variability of turbulent fluxes
- using high-res DEM (photogrammetry, UAV) a distributed surface roughness could be implemented
- variability of albedo in space could be derived from satellite imagery

Selected Literature

Reid TD, Brock BW. An energy-balance model for debris-covered glaciers including heat conduction through the debris layer. J Glaciol 2010;56(199):903–16. http://dx.doi.org/10.3189/002214310794457218.

Rounce DR, Quincey DJ and McKinney DC (2015) Debris-covered glacier energy balance model for ImjaLhotse Shar Glacier in the Everest region of Nepal. The Cryosphere, 9 , 1{16, ISSN 1994-0440 (doi: 10.5194/tc-9-1-2015)

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