Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2019-56-RC1, 2019

ESurfD

Interactive comment

Interactive comment on "The role of frost cracking in local denudation of steep Alpine headwalls over millennia (Mt. Eiger, Switzerland)" *by* David Mair et al.

Anonymous Referee #1

Received and published: 21 November 2019

The paper "The role of frost cracking in local denudation of steep Alpine headwalls over millennia (Mt. Eiger, Switzerland)" by Mair et al. presents one new and four already published denudation rates derived from cosmogenic nuclide concentrations in the Eiger rockwall. The authors reconstruct temperature conditions at the sampling location and use a state-of-the-art frost cracking model to simulate frost cracking intensities (FCI). Resulting FCIs are compared to denudation rates and show that low FCIs correspond to low denudation rates, which suggest that denudation is primarily controlled by frost weathering due to ice segregation. This study provides interesting insighst and is from my point of view the first study that compares in-situ cosmogenic nuclide denudation rates with frost cracking model results. However, the manuscript is

1) poorly structured, 2) denudation rates are derived from a single 10Be sample, 3) input data of frost cracking modelling is insufficiently introduced and 4) the frost cracking model as well as used parameters are insufficiently described. In addition, there are 5) scale issues between current FCI and long-term denudation rates that integrate much longer time scales than modelled FCI. 6) Data is primarily discussed focusing on frost cracking without addressing other potential factors such as permafrost degradation and paraglacial processes, which could also be responsible for the observed spatial pattern of denudation rates. This study could be suited for publication after major revision.

1) The manuscript is poorly structured. The authors use a range of unclear terms such as headwall, flank, side, footwall, foothill that make it difficult to understand the text. The introduction section lacks of clear objectives or aims of the study. This section is mixed with results. The glacial history of the Eiger is missing in the study site section, however, glacial history is necessary to understand the maximum age of CN samples and the time scales that are integrated in the denudation rates. The method section is incomplete and lacks of conducted geotechnical measurements. The reconstructed temperature time series is difficult to understand and used input parameters are insufficiently introduced. 2) This paper uses five denudation rates, one derived from a new 10Be measurement (EW-1) and four already published in a previous study (Mair et al., 2019). The one measurement, the method and the results are described in very detail, however, the resulting denudation rate is very similar to already published EW-2, which is only located 41 m above EW-1. Rock temperature is adapted by altitudinal temperature lapse rates and the close altitudinal location of EW-1 and EW-2 results in the use of the same frost cracking model. The title and the objectives suggest that frost cracking is the main topic of this paper, however, more than half of the length of this paper focuses on one 10Be sample that at the end produce similar results that the previous study. I recommend to omit this sample and the cosmogenic nuclide technique from the method and result sections and just use your published data from Mair et al. (2019) for your analysis of frost cracking results. This would significantly reduce the manuscript length and the author can address comments 3 and 4 in more detail.

3) The authors reconstructed a rock temperature series based on rock temperature logger data by Gruber et al. (2004) and PERMOS data from the years 2001-2014. The authors should produce a figure showing the original data and the generated time series they use as input data. They use only 7 complete years from the data to generate the time series for their sample locations. Which years are used are unknown and it remains unknown how representative the time series is. The rock temperature data could be compared to a longer air temperature time series. There will be a thermal offset, however, this offset should be similar for all the years. Furthermore, the authors shift the temperature data to back to LIA and Medieval climatic optimum based on published temperature offsets. This can be suited for EW-3 and EM-samples, however, EW-2 is exposed to atmospheric conditions more than 1.73 ± 0.26 ky (Mair et al., 2019). Differences in temperatures between logger locations are explained by an insolation model and there is no information how this model is derived in the entire manuscript.

4) The authors used the frost cracking model by Andersen et al, 2015. They use a rock porosity of 2 % and provide no basis why they use this value. The model requires more than 15 more variables such as flow restrictions, conductivities, heat capacities and so on that are not introduced in the method section. Therefore, it is impossible to understand the model set up. There are different limestones at Eiger, which could results in differences of variables such as conductivities of rock. Different conductivities can result in different model results. The authors should test the sensitivity of their model in terms of their chosen input parameters. In addition, they use a fixed frost cracking window (FCW) of -8 to -3°C. Andersen et al. (2015) already demonstrated the consequences of different FCWs in their study and the authors should address this in the discussion. FCWs are lithology and strength dependent which is currently reflected by the model by Rempel et al. (2016) and the lab study by Draebing and Krautblatter (2019). In addition, the model assumes water availability in rock when temperatures are above 0°C. The length of rock the water needs to travel to the freezing front is penalized following Anderson et al. (2013). The authors should discuss the penalization thus water flow can be increased by fractures and therefore increase

the FCI. The assumption of water availability decreases frost cracking in permafrost, which is the major argument of the authors for the difference in the denudation rates between North and South and upper and lower locations. However, this assumption is contrary to the findings of Murton et al. (2006) that find higher frost cracking in permafrost due to water release of the active layer during thawing and refreezing of water at the permafrost table. Physical frost cracking models by Walder and Hallet (1985) and Rempel et al. (2016) would show contrary results thus these models integrate mechanical parameters such as ice pressure and rock strength. The authors should be more careful in their discussion and discuss the influence of model assumptions on their results. Draebing, D., & Krautblatter, M. (2019). The Efficacy of Frost Weathering Processes in Alpine Rockwalls. Geophysical Research Letters, 46(12), 6516-6524. doi:10.1029/2019gl081981 Rempel, A. W., Marshall, J. A., & Roering, J. J. (2016). Modeling relative frost weathering rates at geomorphic scales. Earth and Planetary Science Letters, 453, 87-95. doi:10.1016/j.epsl.2016.08.019

5-6) The denudation rates reflect different time scales ranging from 0.29 $\pm$ 0.05 to 1.73 $\pm$ 0.26 ky (Mair et al., 2019). These are quite large differences where climatic conditions and therefore frost cracking will change. The scaling issue is not addressed at all by the authors. Other studies observed a paraglacial adjustment of rockwalls and increased denudation rates directly after deglaciation or with a response time up to millennia after deglaciation (Grämiger et al., 2017). Different glacial history between North and South rockwall could result in differential paraglacial adjustment between North and South rockwall and different denudation rates. The authors also use the APIM model to analyze the effect of permafrost. The APIM models permafrost on a regional scale of the European Alps and logger data used by the authors in this study demonstrate that the APIM model fails to model permafrost distribution on the South rockwall. Model results from APIM cannot be used on smaller scale and the use is contradictive to the logger data due to scale issues. In addition the APIM suggest a current permafrost distribution (for a period around 2012) due to the used data input (logger data and rock glacier inventories) and provide no insights into past permafrost distribution. In summary, the authors focus too much on frost weathering, discuss a bit thermal stresses and permafrost, however, completely ignore alternative explanation of the observed denudation rates. McColl and Draebing (2019) recently reviewed rock slope adjustment and describe how paraglacial processes, permafrost and weathering processes jointly influence rock slope stability. Therefore, I recommend to discuss the denudation rates more openly and not only focused on frost weathering.

Grämiger, L. M., Moore, J. R., Gischig, V. S., Ivy-Ochs, S., & Loew, S. (2017). Beyond debuttressing: Mechanics of paraglacial rock slope damage during repeat glacial cycles. Journal of Geophysical Research: Earth Surface, 122(4), 1004-1036. doi:10.1002/2016JF003967 McColl, S. T., & Draebing, D. (2019). Rock slope instability in the proglacial zone: State of the Art. In T. Heckmann & D. Morche (Eds.), Geomorphology of proglacial systems - Landform and sediment dynamics in recently deglaciated alpine landscapes (pp. 119-141). Heidelberg: Springer.

See also attached pdf for detailed comments.

Please also note the supplement to this comment:
https://www.earth-surf-dynam-discuss.net/esurf-2019-56/esurf-2019-56-RC1-supplement.pdf

---

Interactive comment on Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2019-56, 2019.