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Interactive comment

Interactive comment on "A global high-resolution map of debris on glaciers derived from multi-temporal ASTER images" *by* Orie Sasaki et al.

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The debris thickness mapping effort on a global scale is a commendable and important area of research that will help understand the debris' influence on glacier melt in response future climate projections. There are many interesting aspects of this paper and one important contribution is determining the areal extent of debris cover throughout the world. This in itself is important. However, I believe the thermal resistance estimates need to be treated with tremendous caution as they appear to be orders of magnitude smaller than those that one would expect. This severe underestimation is likely due to the methodology used in this study, which will be discussed in more detail below.

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Regarding the validity of the thermal resistance estimations, this study uses thermal resistances from Suzuki et al. (2007), Mihalcea et al. (2008), Zhang et al. (2011), and Fujita and Sakai (2014). Figure 3 shows a thermal resistance map of Baltoro Glacier, which the authors state was in close agreement with Mihalcea et al. (2008). However, if one assumes a thermal conductivity of 1 W m-1 K-1 (a reasonable value for the area), the terminus of Baltoro Glacier has a thermal resistance of ~0.05 m2 K W-1, which is a debris thickness of ~ 0.05 m. This is 1-2 orders of magnitude smaller than the debris thickness maps derived by Mihalcea et al. (2008) at the terminus, which ranged from 0.5 – 3 m. It is important to note that while these thermal resistances are severely underestimated, the trends in the spatial distribution of the thermal resistance (higher values toward the terminus that thin upglacier) agree well. This agreement of spatial trends, despite severely underestimating the actual values of thermal resistance, was noted by Rounce and McKinney (2014). This is likely a product of the model simply reflecting trends related to the surface temperature over the debris as one would expect.

The good agreement between this study and the thermal resistances derived from Suzuki et al. (2007), Zhang et al. (2011), and Fujita and Sakai (2014) is likely due to these models using the same methods and assumptions; however, those studies also appear to severely underestimate the thermal resistance as well. Suzuki et al. (2007) show thermal resistances for the Everest region (Figure 6 in that study) that have maximum values of ~ 0.03 m2 K W-1 (or a maximum debris thickness of 0.03 m), which severely underestimate debris thickness measurements in the Everest region from Ngozumpa Glacier (Nicholson and Benn, 2012) and Imja-Lhotse Shar Glacier (Rounce and McKinney, 2014) that commonly exceed 0.30 m and even exceed 1 m as well. As previously mentioned, Zhang et al. (2011) and Fujita and Sakai (2014) make the same assumptions as Suzuki et al. (2007), which is why they also derived thermal resistances on the order of 0.03 m2 K W-1 (approximate debris thickness of 0.03 m), which are orders of magnitudes lower than those measured in the field in the Himalaya.

These thermal resistances are likely severely underestimated due to the assumptions

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made in the methods. The first major assumption that influences these results is assuming that the sensible heat flux is negligible. On the contrary, the sensible heat fluxes are quite significant and can range from 100-400 W m-2 (e.g. Reid and Brock, 2010; Rounce et al., 2015). If one examines Equation 4, including the sensible heat flux would reduce the denominator, which would in turn increase the derived thermal resistance. This increase is often quite substantial. The second major assumption is that the temperature profile in the debris is linear. Debris temperature measurements have shown that at the time that the satellite images are acquired (early morning in the Himalaya), the temperature profiles are actually highly nonlinear, which can cause the thermal resistance to be underestimated by a factor of 2-3 (Rounce and McKinney, 2014). These two major assumptions both cause the thermal resistance to be severely underestimated.

I do want to express my support of this work as I believe mapping the thermal resistance (or debris thickness) of all glaciers would be a valuable contribution to the current state of knowledge; however, the severity of these underestimations is alarming and should be addressed.

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