Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2018-48-AC1, 2018

Earth Surface Dynamics Discussions Open Access EGU

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Interactive comment

Interactive comment on "Short Communication: Increasing vertical attenuation length of cosmogenic nuclide production on steep slopes negates topographic shielding corrections for catchment erosion rates" *by* R. A. DiBiase

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Received and published: 20 July 2018

I thank Reviewer 1 for highlighting a few confusing geometrical complications to treating cosmogenic nuclide production on sloped surfaces, which emerge from differences in choice of coordinate system/frame of reference used by prior studies. I will work to clarify these points in the revised manuscript, but post responses to them now for discussion:

Reviewer #1 Comment 1: *"Gosse and Phillips (2001) noted on pg 1521 that increasing effective attenuation length due to increased surface slope is exactly offset by foreshortening. Is that not also the case here?"*

Response: As noted by Dunne et al. (1999), the competing factors described by Gosse and Phillips (2001) of changing effective attenuation length and foreshortening are already accounted for in the formulation of Equation 1 in the present manuscript (Equation 11 of Dunne et al., 1999). Specifically, these geometrical effects fall out by framing the problem using the mass attenuation length for collimated radiation, λ, and directly determining the mass length, d, along a ray path from the surface to a given position (x, z) in the subsurface. The consequence of this explicit treatment of exponential attenuation in the ray path direction is nicely shown by Figure 5 and Equations 16 and 17 of Dunne et al., highlighting the difference between λ and the more commonly used attenuation length, Λ.

Reviewer #1 Comment 2: *"It is counterintuitive that the effective shielding factor can be greater than 1. In this model, this is due to the large increase in vertical attenuation length. Previous authors have noted that attenuation path length decreases on sloped surfaces due to increasingly oblique incidence angles reducing the intensity. This discrepancy should be addressed. On a similar topic, it is not clear is how production rates were dealt with here. For a give incoming flux, increasing the attenuation path length must decrease the near surface production rate as it implies fewer collisions per mass length. The implication is that as normalized effective attenuation length increases, the normalized effective surface production rate must decrease. This would offset the effect of increasing attenuation length (requiring a topographic shielding correction again). This could be treated as equivalent to foreshortening."*

Response: Similar to the above response to point 1, the effects of changing attenuation path length and foreshortening are already accounted for in the model. The counterintuitive result of shielding factors greater than 1 emerges entirely because of treating the problem in the vertical direction rather than normal to the surface – the cosine correction from slope-normal to vertical frame of reference quickly overcomes the shielding effect for sloped surfaces.

Reviewer #1 Comment 3: *"There is an important potential talking point here on how erosion/denudation is defined in cosmogenic nuclide studies. Both lowering rates (i.e. m My-1) and mass loss rates (i.e. t km-2 yr-1) tend to be based on 2D areas. This is in line with the definition of attenuation length presented here. However, it is not clear that this is the appropriate definition (of either erosion or attenuation) for the real world. A broader discussion around the implications of setting the attenuation path length to the vertical could be quite useful since previous authors rotate the coordinate system to determine attenuation path length perpendicular to the surface. The vertical definition makes sense since we tend to perform shielding calculations on a DEM and often define erosion as a lowering rate. However, it seems unlikely that an* $80°$ *slope would be eroding vertically. In this case, using a vertical attenuation path length would result in an artificial increase in production rate (i.e. it would appear as less shielding, as found here). The 'true' surface area in this case is also probably the 3D surface area and erosion would be spread across a larger area (essentially the foreshortening argument applied to erosion). I recognise that this is a bit circular, but it highlights the need for a clearer explanation around coordinate definitions."*

Response: Aside from the fact that the standard reporting of erosion rates is done in the vertical frame of reference, there is a grid-scale-dependence issue that arises when trying to quantify 3D area that is a significant limitation (e.g., Norton and Vanacker, 2009). This opens up a whole host of new challenges, and so treating the topographic shielding (and reporting of erosion rates) is best done in the vertical. Of course, this is not to say that surface process models might not be better cast in terms of horizontal retreat or surface-normal displacement. Rather, the conversion should be done in comparison with model predictions, and not at the stage of reporting mass flux out of catchments or catchment-mean lowering rates. As I mention in the manuscript, the larger issue with very steep catchments is that the assumptions of steady lowering are more likely to be violated due to stochastic mass wasting processes.

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