Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2018-48-RC3, 2018

Earth Surface Dynamics Discussions

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

G. Balco (Referee)

balcs@bgc.org

Received and published: 21 August 2018

This is just to clarify the comment in the Scherler review, at the top of page C2:

"That basically means that we assume that all particles approaching the Earth's surface follow trajectories that are normal to the geoid."

As this is written, it sounds incorrect – in the DiBiase paper, as in other work, the cosmic-ray flux is assumed to be distributed around the upper hemisphere such that the intensity is proportional to the cosine of the zenith angle taken to a power. So it is

true that the intensity (particles per time, per area normal to the particle direction, per unit solid angle) of cosmic-ray particles from the vertical direction (e.g., "normal to the geoid") is higher than the intensity of particles arriving from lower angles. But incident particles arrive from all directions in the upper hemisphere.

More generally, let me try to clarify the frame-of-reference issue a bit more. The important thing is that there are two parts to the calculation: computing surface and subsurface production rates, and then using that information to relate erosion rates to surface nuclide concentrations. Obviously, the production rate at a particular surface or subsurface location is the same no matter whether the reference frame is vertical or slope-normal. The reference frame only becomes important when it is necessary to compute the relation between erosion rate and surface nuclide concentration, because you need to define the direction in which erosion is taking place and therefore in which you are integrating production rates. A vertical reference frame, of course, is nearly always used in erosion rate applications because in this reference frame, each pixel has the same area, so it is not necessary to consider different pixel areas in averaging the nuclide concentration from a group of pixels with different slopes. A slope-normal reference frame, as far as I am aware, has only been used in a few papers (like the Ward and Anderson example) that are mostly concerned with cliff retreat rates, because if the cliff is vertical and the reference frame is vertical, then cliff retreat is effectively mixing subsurface and surface sediment, which would violate basic assumptions of watershed erosion-rate calculations. Also, as shown by Masarik, there are other effects besides shielding that are important in computing production rates under near-vertical surfaces, so the exponential approximation doesn't really work very well anyway.

The present paper chooses the vertical reference frame, which is likely most appropriate anyway because, as Scherler notes, most watersheds do not have vertical cliffs, so the fact that cliff retreat violates the usual assumptions of erosion-rate calculations is not relevant. It is true that the attenuation length computed in a vertical direction underneath a dipping surface is totally different from the attenuation length computed normal to the surface. This is confusing, because the same symbols are used in various papers for both things, so it is necessary to be clear how the attenuation length is defined, and I agree that this could be pointed out more often in the paper.

In the context of computing an erosion rate, however, the difference between the slope-normal attenuation length and the vertical attenuation length is just the same as the difference between the slope-normal erosion rate and the vertical erosion rate, so if we consider the basic relation $N = P\Lambda/\epsilon$, then (given several assumptions) changing to a slope-normal erosion rate and slope-normal Λ doesn't affect P, but makes both Λ and ϵ smaller by a factor of the cosine of the angle, so the nuclide concentration is unchanged.

This also highlights why cliffs are trouble, because as the slope approaches vertical, the slope-normal erosion rate approaches zero, which is probably not what you want.

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