Maximum Adirectional Slope for Terrain Analysis

The maximum adirectional slope algorithm (see Masarotto et al., '*Planetary Terrain Analysis for Robotic Missions*') quantifies the steepest slope in any direction from every point in a DEM. It is calculated at a distance, referred to as the baseline. The minimum baseline at which adirectional slope may be calculated is inherently limited by the lateral resolution of the DEM (for HiRISE DEMs this is typically 1 metre).

At short baselines, small but steep topographic features dominate the slope abundance, such as boulders, crater rims and other sources of short-scale surface roughness represented by the DEM. As the baseline increases, small features become less important compared to larger elevation differences, which could be caused by geomorphic features on decameter (e.g. aeolian ripples, rocky outcrop), 100-meter (e.g. dunes, cliffs, craters) and multi-km scales (e.g. valleys, volcanoes). The diminishing influence of small-scale features with increasing baseline is observed in maximum adirectional slope maps (Figure 1) of a study area represented by a subframe of a HiRISE DEM (Figure 3, left panel).

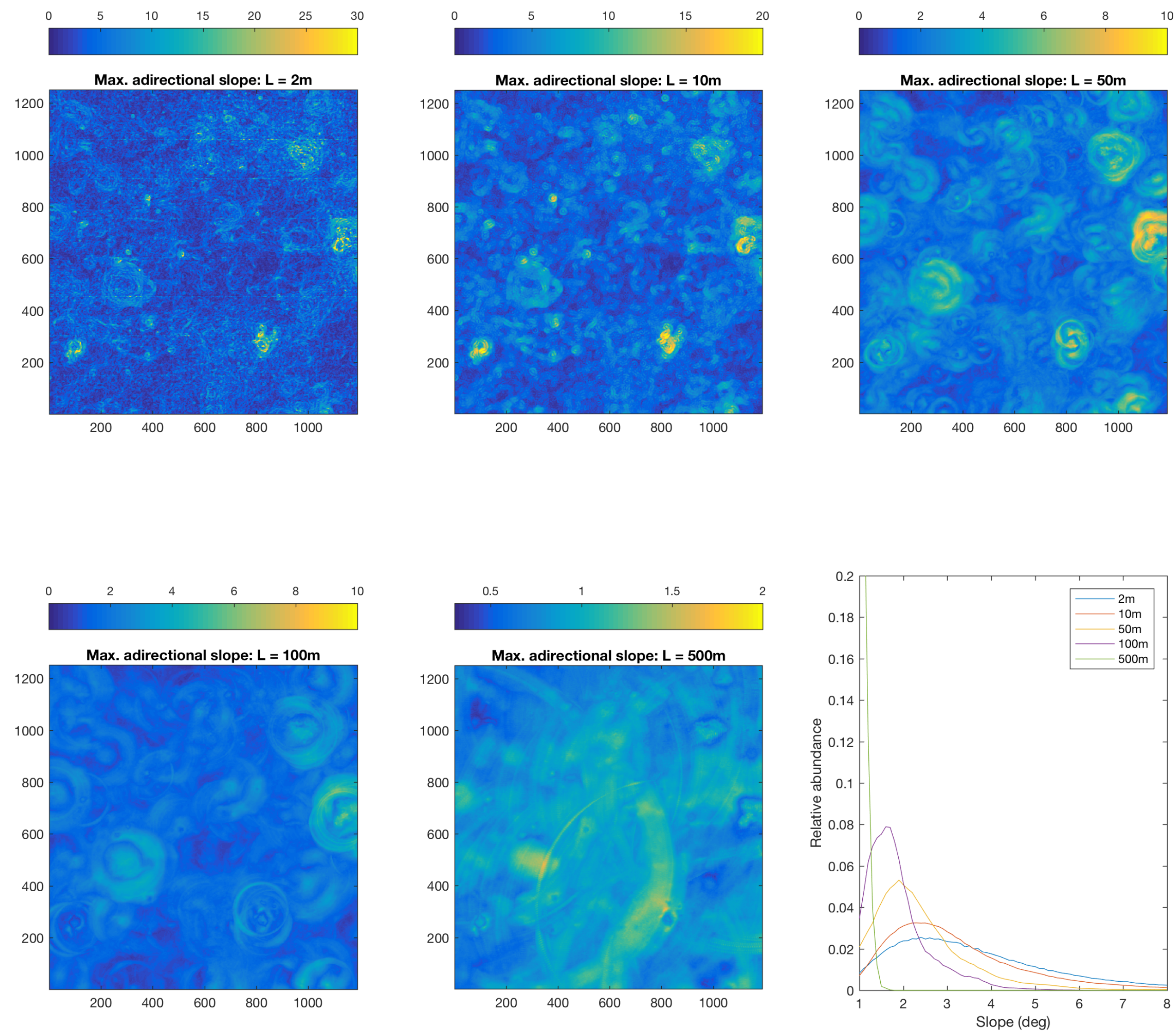

Figure 1: Maximum adirectional slope maps of a study area represented by a subframe of a HiRISE DEM (ExoOxiaPlanum_2).

Note that the curvilinear features are not an artifact, but a natural result of the way the maximum adirectional slope algorithm interacts with topographic features.

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Consider standing on the rim of a 100m crater: If the surrounding terrain is flat, then maximum slope in any direction is that to the center of the crater. This is true for any point on the crater rim and consequently a 50m baseline slope map would show a high slope values on the top of the rim. This is also true for the point at the center of the crater. The chances of the crater being equal to the baseline are slim, but a small number of cases where this occurs are visible in Figure 1 (top right panel).

Now consider being on the side of a large slope. The maximum elevation change to any point at a baseline L, is that to the bottom of the slope, or to the top. However, if L is larger than the distance to the top or the base of the slope, then the maximum slope measured in the middle is less than that at the top or the bottom. In this case (Figure 2), the topographic feature would be represented in a maximum adirectional slope map, calculated at baseline L, as an area of low slope running along strike, surrounded by two parallel areas of high slope. The effect of this interaction between the algorithm and real-world topographies leads to the textures we observe in maximum adirectional slope maps.

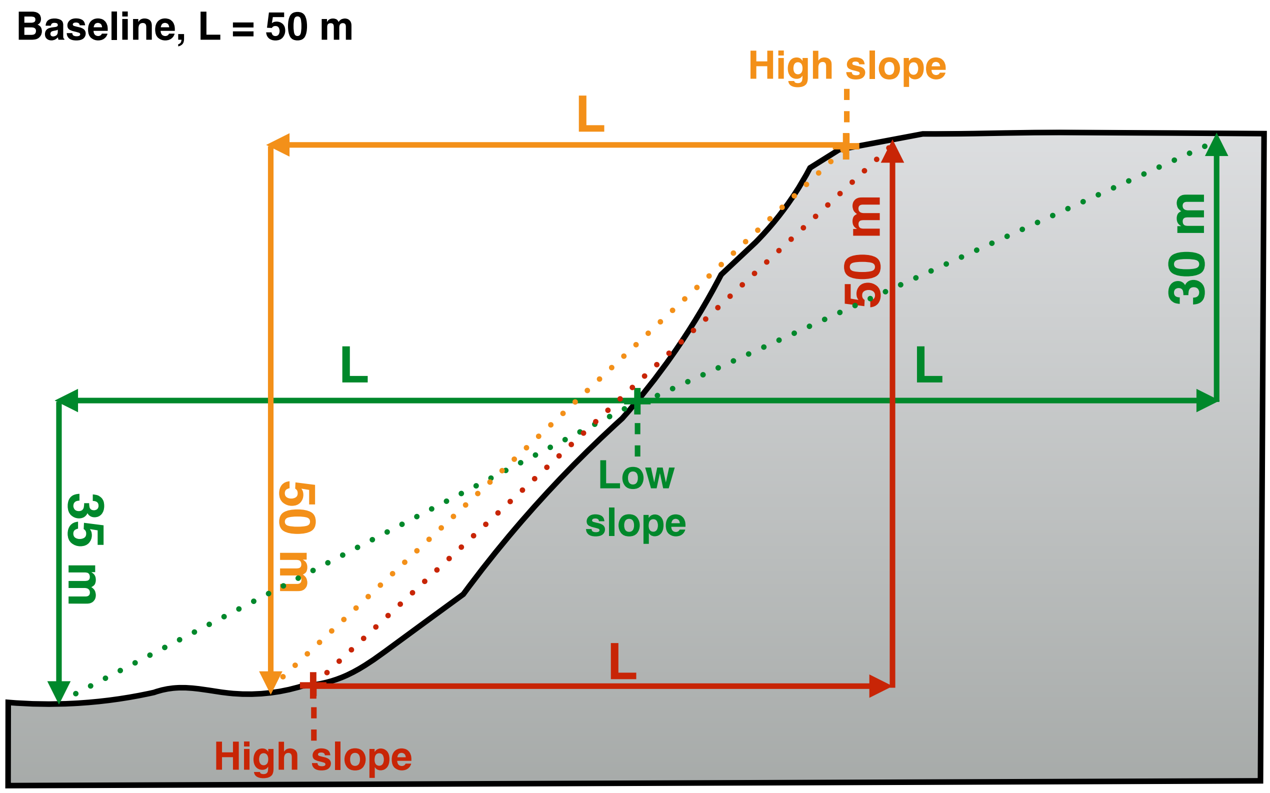

Figure 2: Schematic of maximum adirectional slope calculated at baseline L, on, and either side of, a topographic feature of similar lateral size to L. Counter-intuitively, the largest adirectional slopes at baseline of 50m are measured at the base and summit of the feature, and not on the face. Were the baseline to be just a few metres the steepest adirectional slopes would be on the face. This effect applied to real-world topography can produce curious textures in slope maps because curvilinear features run parallel to slopes.

The progressive change in the distribution of slopes as a function of baseline can be illustrated by calculating slope maps over a range of baselines and successively calculating histograms of the slope population. The resulting 2D histogram is similar to a power spectrum, and offers a quantitative way of combining slope distributions measured at discrete baselines (e. g. Figure 1, lower right panel) so that slopes according to DEMs from different areas may be inter-compared.

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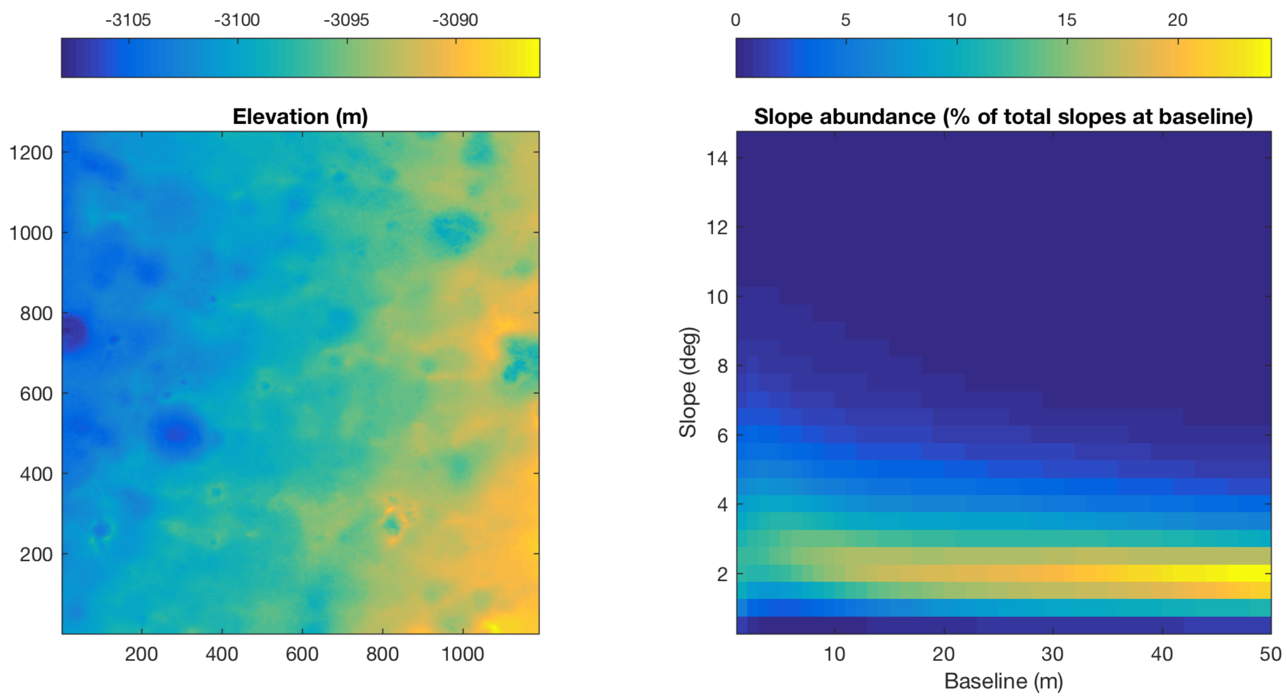

Figure 3: Left – Portion of HiRISE DEM ExoOxiaPlanum_2. Right – 2D histogram showing the distribution (in %) of the slopes at each baseline.

For the chosen study area it is noted in particular that there is a dominant long-baseline slope across the region, increasing left to right. This manifests as a peak in relative abundance of slopes around 2° that becomes increasingly dominant at baselines $\gtrsim$ 30 to 40m.