Surface Roughness Scaling Trends

K. Arrell, S. Carver

School of Geography, University of Leeds, LS2 9JT
Tel. (+44) 0113 3433343 Fax (+44) 0113 3433308
Email k.arrell@leeds.ac.uk

1. Introduction

Greater accuracy and higher resolution terrain data from direct measurements (for example SAR/LiDAR/TLS) have created a wide range of opportunities for detailed landscape analyses previously hampered by a lack of suitable data. Further, the increasing size and volume of these datasets necessitate quantitative data generalisations and metadata that can inform process studies, for example drainage density and relative relief. A number of studies have attempted to extract geomorphically significant measures from digital elevation data (Pellegrini, 1995; Wood, 1996; Burrough, et al., 2000; Arrell et al., 2007), these have largely attempted to characterise landscape elements and thus infer geomorphic process. Attempts to characterise or classify landscapes holistically still remain under developed and would provide useful metrics for digital elevation data analysis and geomorphological applications for example landscape evolution modelling. This paper looks at the development of measures of surface roughness as a multi-scale index for characterising landscape types.

We propose that the methods outlined here can provide landscape characterisations that reflect surface geomorphology, differentiating between surface types e.g. fluvial vs. glacial, erosional vs. depositional, soft vs. hard geology, when these landscape types exhibit different surface roughness scaling trends. We propose that scaling roughness trends will provide meaningful measures where local variability in surface properties governs the convergence and divergence of mass and energy which form critical controls on surface processes.

2. Study Area

2 m LiDAR data for the upper Wharfe Yorkshire, the Aire valley, and Cley-next-to-the-Sea and 5 m NEXTMap data for parts of the Cairngorms were used as test datasets. These varied landscapes were selected to assess the robustness of the outlined technique to differentiate between landscapes of differing characteristics and roughness. Further multi-resolution analyses were performed for the Wharfe using 2, 10, 50 and 75 m data. These data are all from proprietary sources, including both direct measurement and interpolated DEMs. There are summarised in Table 1.

Resolution	Type	Source		
2 m	Direct measurement	EA LiDAR		
10 m	Interpolation from1:10k map data	Ordnance	Survey	Landform
		Profile™		
50 m	Interpolation from 1:50k map data	Ordnance	Survey	Landform
		Panorama™		
75 m	Direct measurement	NASA SRTM		

Table 1. DEM data sources.

3. Methods

A number of different measures of surface roughness were used to assess their ability to differentiate between landscape types. Roughness was measured as the standard deviation of each elevation, slope, the sine of aspect and finally curvature, comprising four different measures. These roughness indices are characterising the topography in different ways and consequently are therefore quantifying different surface features and trends. Here roughness is used as tool for differentiating between landscape types; the roughness data themselves do not form the primary focus of the study. Indeed any geomorphometric measure could be used, and the suitability of different measures will be the focus of future studies.

Surface roughness was measured within increasing kernel windows from 3x3 cells upward and stored per pixel for each different kernel size. The average roughness within the raster for each kernel resolution was calculated and plotted against kernel window size to look at local, focal and global trends in surface roughness. The confidence with which the average roughness value can account for the variability within the data will be explored in future work. This process was repeated with each of the four quantifications of surface roughness.

Data for each study area were plotted and used to characterise trends for landscape types. A theoretical representation is shown in Figure 1, where landscape types can be defined by their scaling trends. These may reflect key landforms or constituent landscape elements present at specific scales. Optimal landscape differentiation and hence classification will occur where surface roughness is different for different landscape types at the same kernel size and where surface roughness changes for the same landscape type at different kernel sizes.
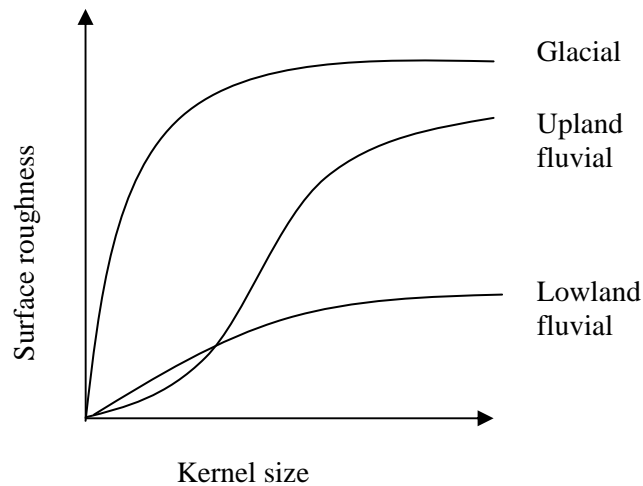

Figure 1. Schematic of plotted landscape types.

4. Results and Discussion

Initial results show that different landscapes exhibit different roughness scaling trends (Figure 2). The results show that indicative roughness trends for different landscapes exist through analysis of absolute magnitudes of, and scaling trends in, surface roughness.
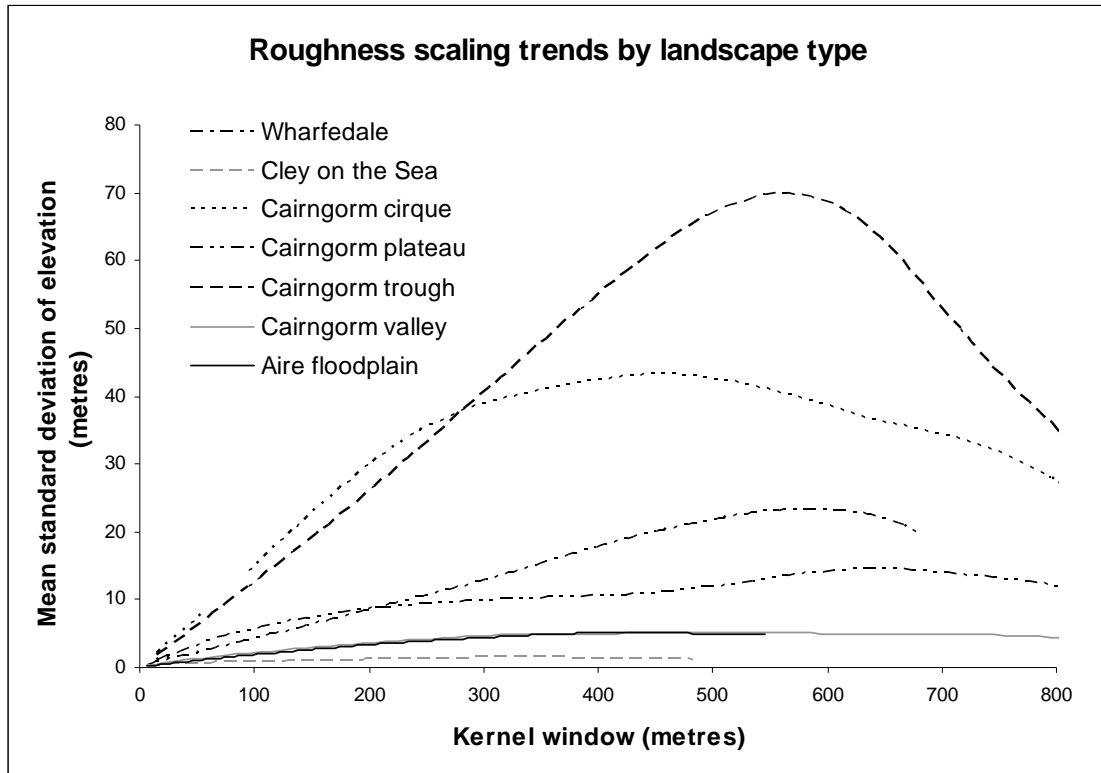
Figure 2. Measured roughness scaling trends.

Coastal and glacial valley floor landscapes exhibit a nominal scaling trend where surface roughness remains largely constant with kernel window size. Glacial landscapes, namely cirques and troughs exhibit a very different pattern, where surface roughness increases rapidly initially as cirque and valley walls are encountered. Both landscapes exhibit a marked inflection point in surface roughness after which elevations become increasingly less rough (more similar). These inflection points are felt to reflect landform spacing and frequency. This is supported by an average valley floor width of ~ 600 metres within the Cairngorm trough dataset. The Cairngorm plateau results suggest the possibility of two distinctive components which may represent palaeosurfaces.

Experiments were repeated with three other surface roughness measures which show similar trends but indicate different sensitivities to surface roughness scaling (Figure 3). Although these in part reflect differing units the gradient of the inflection point and the scaling relationships vary, these results are currently being investigated further.
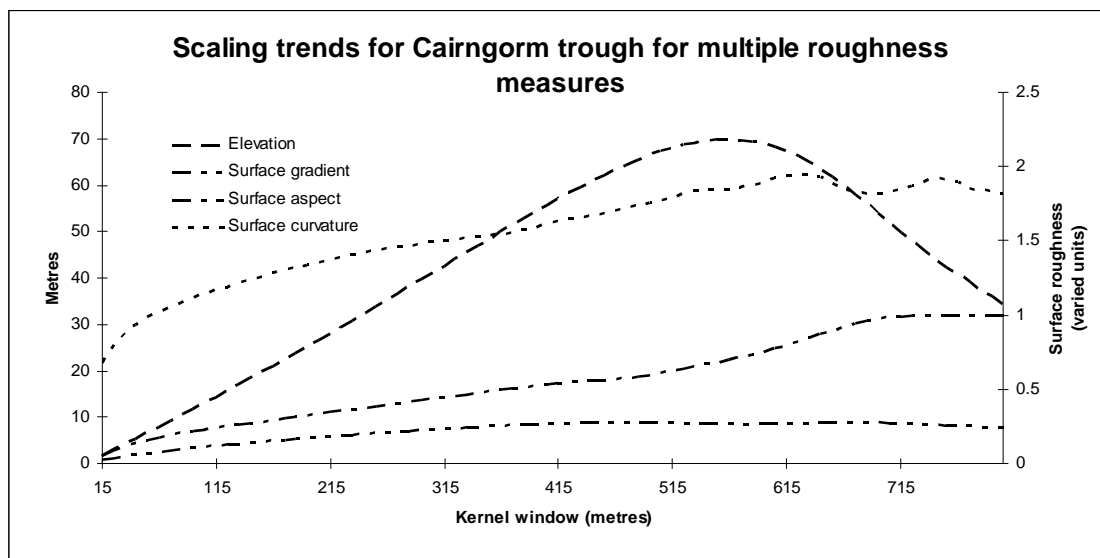
Figure 3. Multiple roughness measures.

Experiments were also undertaken with differing resolution data for the Wharfedale study area, these showed that trends were stable at multiple resolutions, where the point of inflection and scaling trends held for a landscape type using different resolution data.

The method proposes the identification of key or indicative kernel sizes for different landscape types defined by the scale of key landforms (for example valleys, slopes, cliffs). Initial results indicate that this methodology can also identify and extract geomorphologically meaningful data, for example cirque and valley spacing. A measure of the robustness of this technique to classify landscape types and the ability of different roughness measures to differentiate between different landscape types will be assessed by testing the resulting classifications on a range of "unseen" terrain models.

References

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