

Comparative assessment of measures of surface roughness

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Introduction

- “Roughness” has been used to determine:
 - landslide age relationships¹
 - topography as a component in species habitation²
 - impact upon basal sliding of a glacier³
- This project reviewed and compared primary methods for calculating surface roughness

Surface Roughness

- Intuitive notion of “rough” and “smooth”
- Remotely sensed input parameters:
 - EMR
 - derived elevation
- Surface roughness:
 - variability of elevation
 - at a given scale



Some methods

Contour

based

Vector

Orientation

Fourier

Analysis

Geostatistics

Area Ratio

Deviation of

Values

Fractal

Dimension

Image

Analysis

Input and Outputs

- Data inputs can be:
 - Global (2D): DEMs, images
 - Local (1D): elevation profile
- Outputs can therefore be:
 - 2D roughness “maps”
 - summary statistics

Area Ratio (aka rugosity)

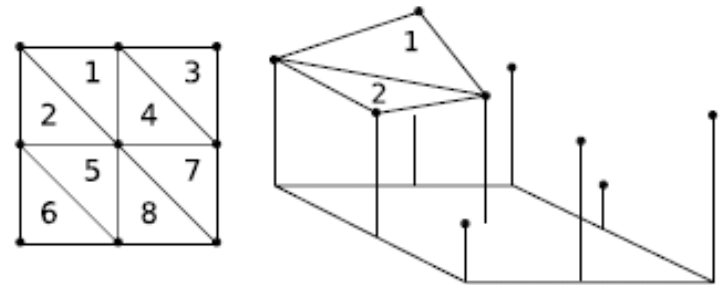
- Calculates the ratio of *surface* to *plan* area

$$R = \frac{A_r}{A_g}$$

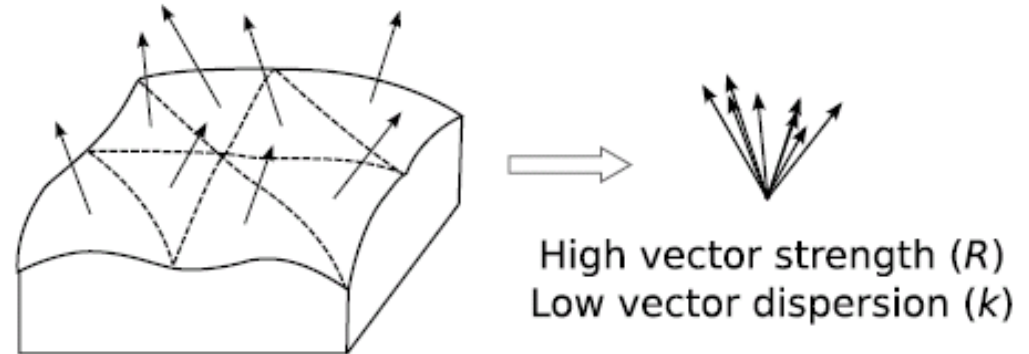
- Two end members:
 - **Flat**: values trend to 1.
 - **Irregular**: as real area increases, trends to infinity

Vector Orientation

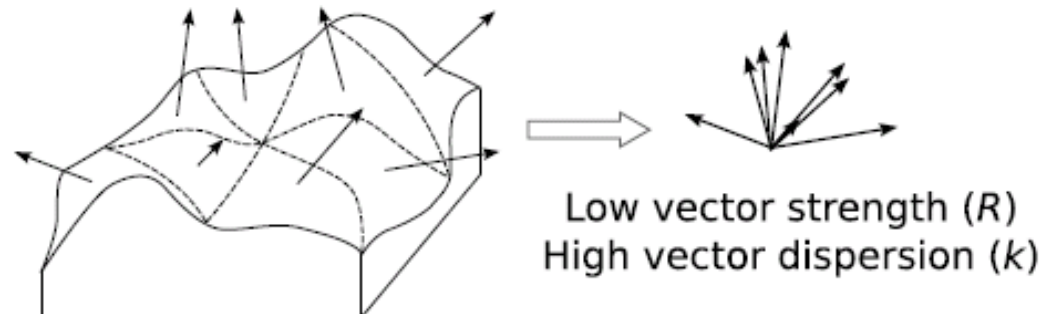
Elevation readings:



Smooth terrain:



Rough terrain:

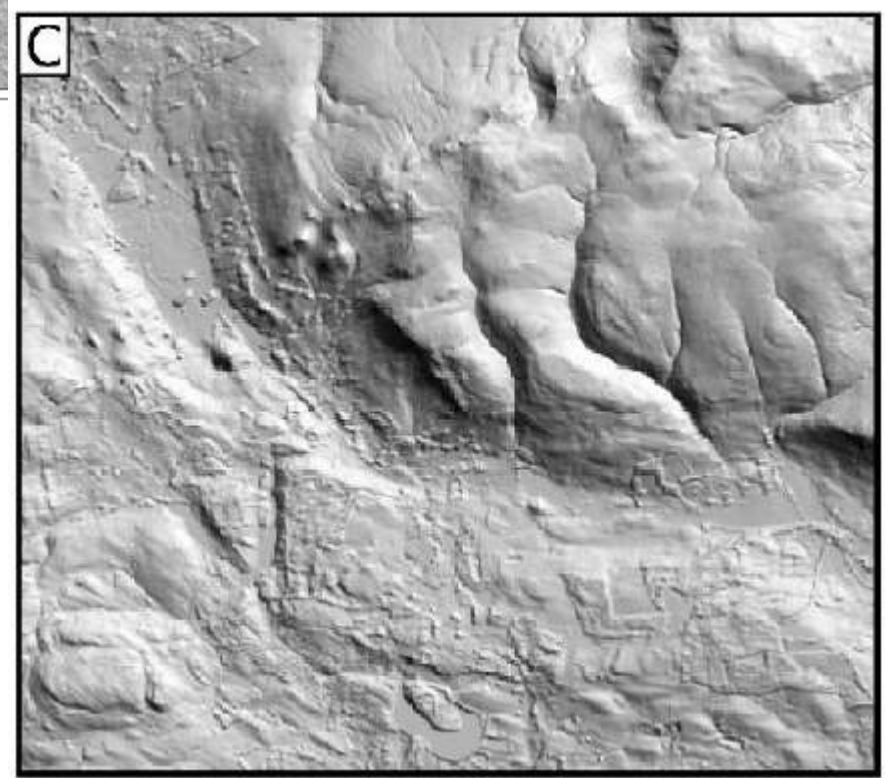
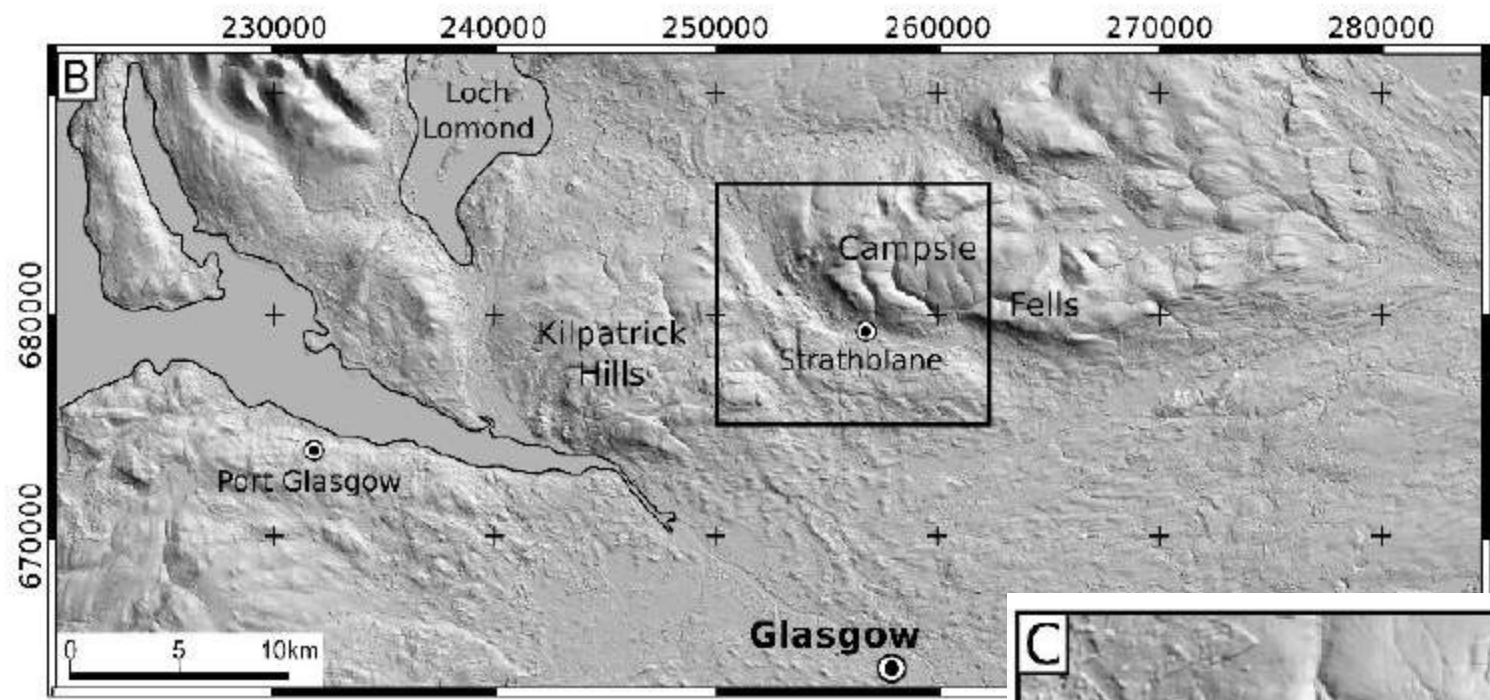


Standard Deviation of Elevation

- Measures the *variability* of elevation values:
 - Standard deviation of values within a window (or kernel)
 - Deviation from a best fit plane

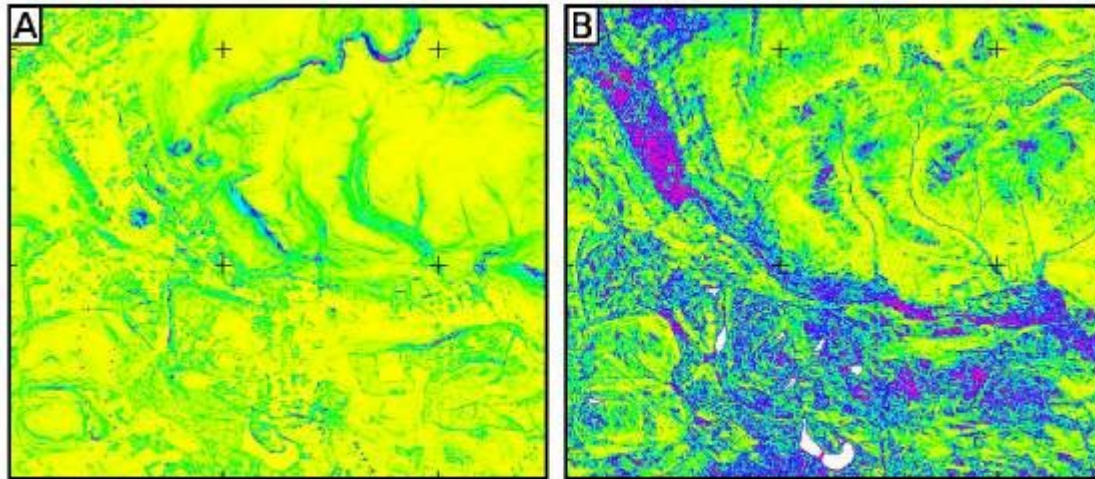
Methodology

- Comparison of 3 methods
 - at different scales
 - at different DEM resolutions
- Input DEM
 - NextMap Great Britain
- Study Areas
 - Midland Valley, Scotland



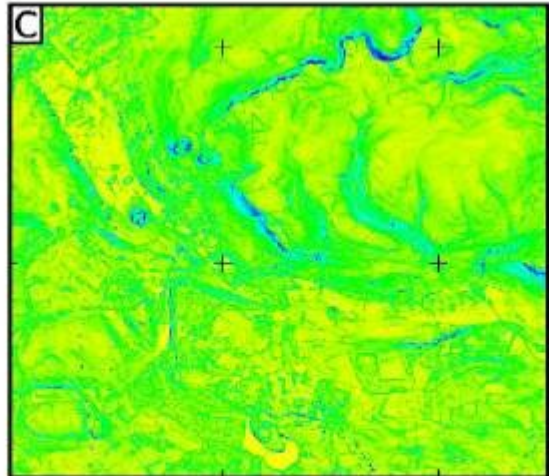
Methodology

- Input Resolutions:
 - 5m, 10m, 25m, 50m, 100m
 - DEMs were averaged (mean) from the original
- Input scale:
 - scale changed through kernel size
 - 3x3,5x5,7x7,9x9,11x11,13x13,15x15,17x17,19x19,21x21,31x31,51x51
- 180 model runs!



area ratio
1.0 1.1 1.2 1.3 1.4 1.5

vector dispersion (1/k)
0.0 0.25 0.5 0.75 1.0



standard deviation of elevation
0 5 10 15 (±m)

Area Ratio

- Uniform steep slopes = high roughness
 - yet they are smooth inclined surfaces
- Broad pattern does *not* change across scales and resolutions
 - generally scale independent
 - coarse DEMs should give the same result

Vector Dispersion

- Sensitive to local roughness variations
- Uniform (smooth) slopes have *low* dispersion
- Aggradation of areal extent of roughness at
 - coarser resolution
 - larger window size
- Scale dependent
 - doesn't identify regional roughness features
 - potentially useful for DEM “surface clutter” removal

Standard Deviation of Elevation

- Increase in roughness as resolution/window size increase
- Identifies regional relief
- Simple calculation

Conclusions

- Vector dispersion suited to
 - identification of local roughness
 - identification of uniform slopes
 - performs poorly at large scales/window sizes
- Area Ratio scale invariant
 - ideal for application with coarse resolution data
 - cannot differentiate multi-scale roughness
- SDE best overall method
 - identifies multi-scale roughness
 - identifies regional relief
 - simple

References

- ¹McKean, J., Roering, J., 2004. Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry. *Geomorphology* 57, 331-351.
- ²Riley, S. J., DeGloria, S. D., Elliot, R., 1999. A terrain ruggedness index that quantifies topographic heterogeneity. *Intermountain Journal of Sciences* 5 (1-4), 23-27.
- ³Hubbard, B., Siegert, M. J., McCarroll, D., 2000. Spectral roughness of glaciated bedrock geomorphic surfaces: implications for glacier sliding. *Journal of Geophysical Research* 165(B9), 21,295-21,303.

GRASS:

<http://grass.itc.it/>

Roughness Scripts:

http://grass.gdf-hannover.de/wiki/GRASS_AddOns