Comparative assessment of measures of surface roughness

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Introduction

- “Roughness” has been used to determine:
  - landslide age relationships[1]
  - topography as a component in species habitation[2]
  - impact upon basal sliding of a glacier[3]
- 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

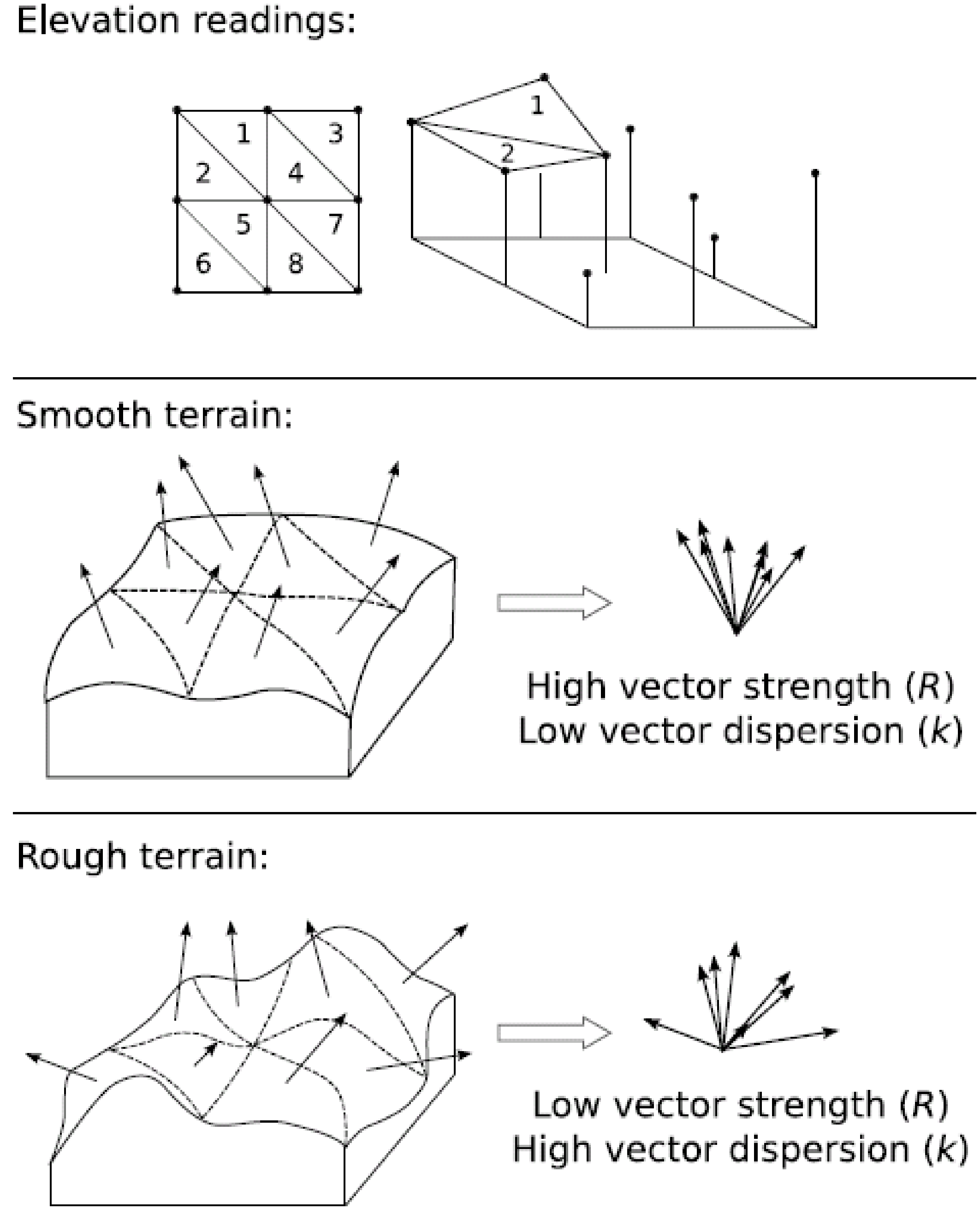
Area Ratio (aka rugosity)

- 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

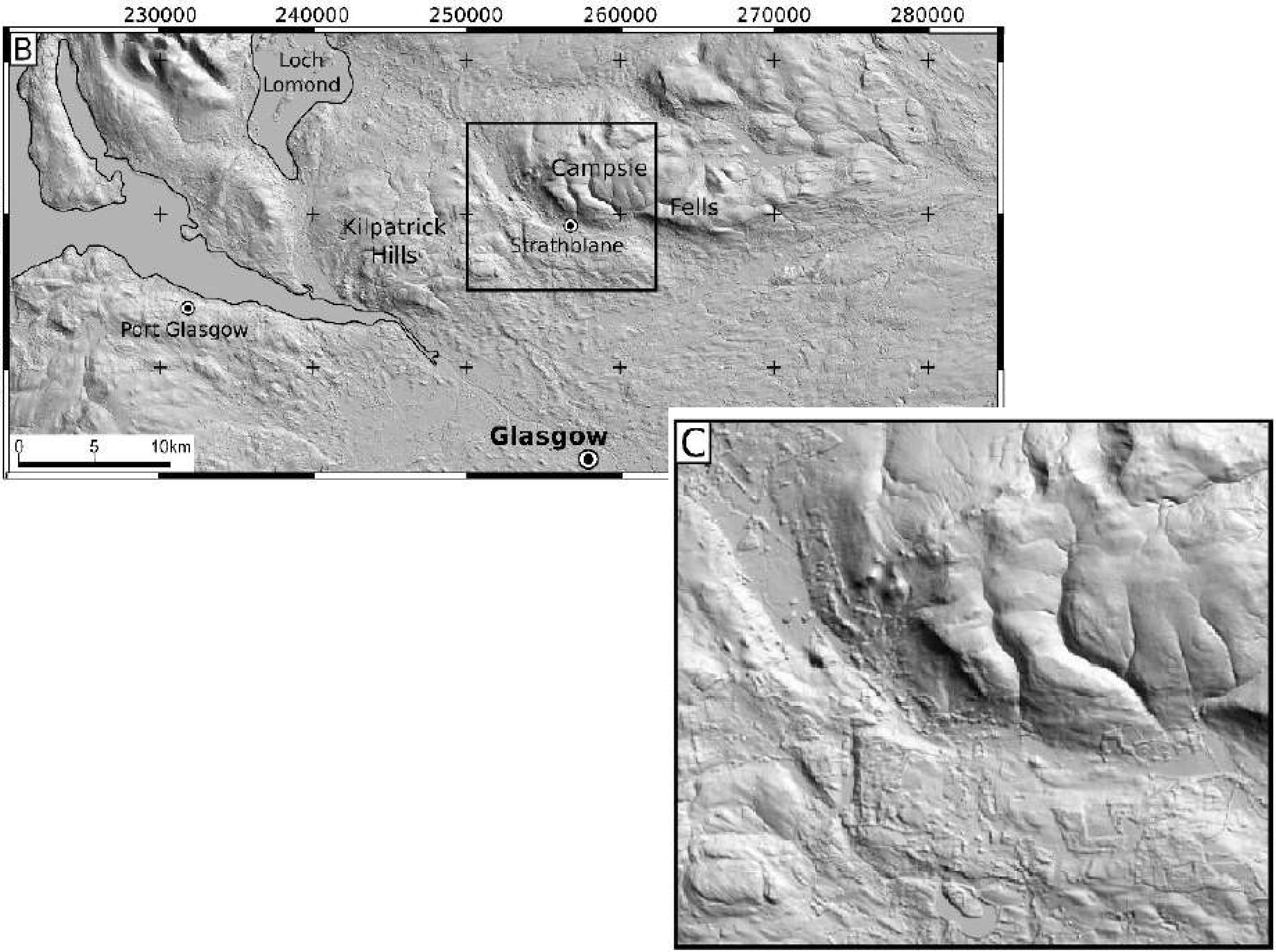


Standard Deviation of Elevation

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

Methodology

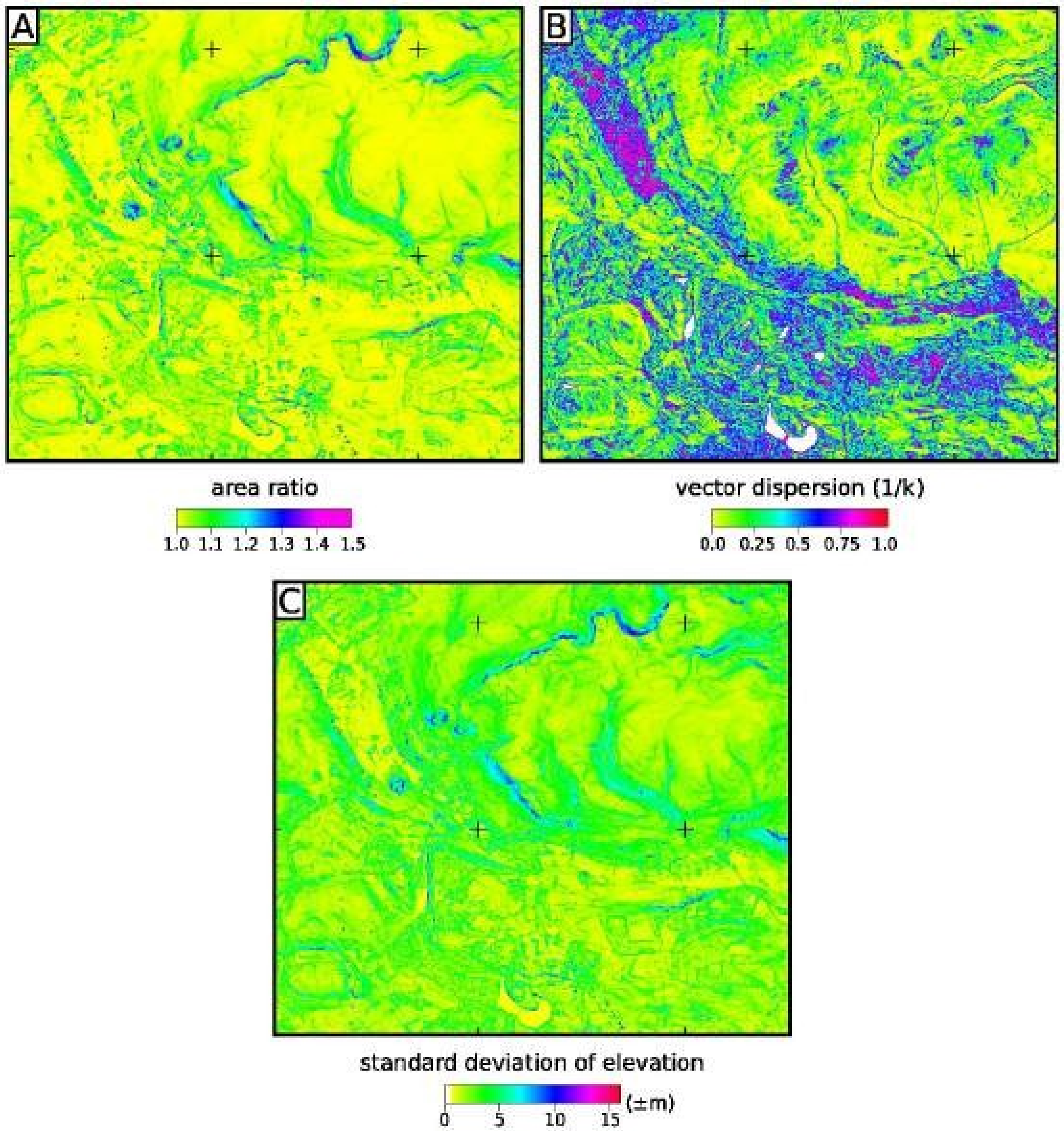
- Comparison of 3 methods
  - at different scales
  - at different DEM resolutions
- Input DEM
  - NextMap Great Britain
- Study Areas
  - Midland Valley, Scotland



B
230000
240000
250000
260000
270000
280000
680000
670000
Loch Lomond
Campsie
Fells
Kilpatrick Hills
Strathblane
Port Glasgow
Glasgow
0
5
10km
C

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!


A
B
C
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

[1]McKean, J., Roering, J., 2004. Objective landslide detection and surface morphology mapping using high-resolution airborne laser altimetry. Geomorphology 57, 331-351.

[2]Riley, 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.

[3]Hubbard, B., Siegert, M. J., McCarroll, D., 2000. Spectral roughness of glaciated bedrock geomorphoric 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