Re-scaling Terrain Variables

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1. Introduction

Most environmental modelling takes place within the toposequence. Conventionally, the terrain variables for these purposes have been derived from digital elevation models (DEMs) produced from large scale topographic maps (e.g. 1:25,000 (approx 30 meters)) or topographic data at that scale. Coverage in Australia of this scale DEM is very limited. However, global and continental coverage of DEMs is becoming available at coarser scale. The most important data set is derived from radar images from the NASA Space Shuttle which were processed to give a 3 arc second (approximately 90 meters, **SRTM-3**) for non- US landmasses. Whilst this is not at a scale appropriate to analysis of relationships within the toposequence, it does have the advantage of being readily available over broad areas.

Work by Gallant (1997; Gallant & Hutchinson, 1997) on the scaling behaviour of topography found that the manner in which geomorphic parameters like slope and contributing area change with scale is not irregular, but systematic, suggesting that an appropriate mathematical characterization is possible, capturing whatever lies behind the regularity. The prospect of being able to re-scale coarse DEM derivatives to resemble finer DEM derivatives is extremely significant both operationally and financially.

Considerable work has been done in China to develop strategies for modifying coarse DEM slope to produce useable data for finer scale erosion modelling. Attempts have been made to develop an alternative, or substitute, parameter, for slope e.g. elevation difference (***ED***) in specified spatial extent (Liu, 2001). Another strategy by Tang et al, (2001; 2004: Tang, 2001: Chen, 2004) attempted to transform coarser resolution slopes to finer resolution slopes by analyzing the histogram of slope and constructing a transform table. However they found it difficult to define a relationship between ***ED*** and slope, because the transform table does not capture the spatial pattern of slopes effectively. Yang, in concert with Chinese colleagues and CSIRO researchers McVicar, Van Niel T., and Jupp (Yang et al, 2005; 2006a, 2006b, 2006c), built a transformation function by matching the histogram of the coarse DEM to that of a fine DEM sample. The DEM produced by applying this to the coarse DEM has the slope histogram and partial surface pattern of the finer resolution DEMs (training area). It appears to depict the land surface more accurately than the original.

Although the approach described by Yang et al, (2006) is the most promising, it is far from operational, nor has it been checked for error or applicability to other geomorphic variables. Yang et al, (2006) identified a range of issues which need further investigation. Importantly, many of the Chinese studies have focused on trying to convert slope from 1:250,000 to 1:100,000 scale while we believe the important conversion for terrain derivatives in hydrological analyses is from 1:100,000 to 1:25,000 (roughly from ~3-second to <1-second). The aim of this project is to build on the work described by Yang et al, (2006c).

2. Analysis

Our previous work (Laffan & Lees, 2004) indicates that quantitative landscape descriptor histograms are spatially non-stationary. We believe that it is possible to automatically identify geomorphic terrains within which histograms are stationary, and between which they vary. The available DEMs are at scales which can support this sort data segmentation. However, in this preliminary analysis, we used the existing 1:25,000 Kioloa Geology data from the Pathfinder site (Lees, 1999) to automatically segment the DEM data.

The DEM was developed by digitising elevation contours (10 m interval), streamlines and spot heights from 1:25 000 scale topographic maps of the region then interpolating the data using LDW. The resolution is 30 meters (~ 1 second). This DEM is useful because it covers a very diverse range of topographies. Van Neil et al., (2004) determined that the level of error in the Kioloa DEM was comparable to DEM error levels found in USGS and British Ordnance Survey high-resolution DEMs. A 15 x 15 km subset of the reference DEM was progressively degraded in stages to provide 1, 3, 5, 9 and 18 second datasets.

We used a straightforward back-propagation network and sampled three datasets to provide the learning sample. These were the slope derived from the original, 30m resolution DEM, slope derived from the generalized 90m resolution DEM, and geology. Sampling was random and generated a 2,000 point representative sample. We then used the network and the 90m DEM and Geology to predictively map slope as though we were using a 30m DEM.

3. Results

The results were encouraging. The original error between the slopes produced by the 30m and 90m DEMs (fig 1) was considerably reduced (fig 2). It was not eliminated however.

The areas of maximum error were reduced by about 70%, in mid-range slopes they were reduced by about 85%. The area and amount of reduction was not evenly distributed with the slope difference on the volcanic rock being reduced least. An analysis of these results suggests that, because steep slopes are rare here, the representative sample had under sampled them. Similarly, the areas of volcanic rock are quite limited and it appears that they too were under sampled. At the time of writing, we had not tested the impact of an unbiased sample but expect the results to improve the performance of the prediction.

If we can reconstruct comparatively fine scale slope values from coarser DEMs with only a local sample of the fine scale DEM, and it appears that we can, then it might be possible to reconstruct other terrain variables such as aspect, plan curvature and slope curvature, and derivatives such as position on slope and net solar radiation. Clearly, this would be an important step forward in cutting costs of providing suitable data for modelling, but much more analysis and testing remains to be done.

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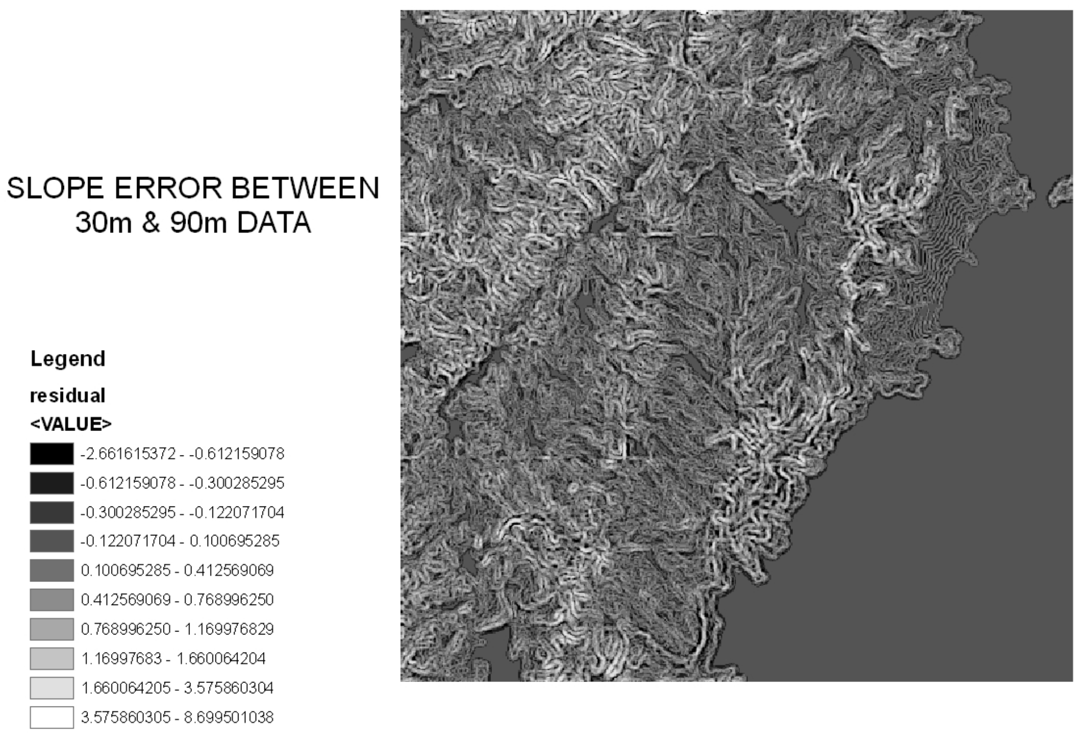

Figure 1. The differences in slopes calculated from a 30m and 90m DEM.

Figure 2. The predicted slope compared with the actual slope from the 30m DEM.

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