Quantitative Analysis of Topographic Signatures for Geomorphic Applications

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Topographic information is required for many Earth Science investigations. For example, topography is an important element in regional and global geomorphic studies because it reflects the interplay between the climate-driven processes of erosion and the tectonic processes of uplift. Topographic information can also be used to investigate hillslope development and to determine soil thickness, potential for erosion or accumulation, and the rate of incision of drainage networks. In addition, it may be possible to identify the types of terrains that are susceptible to landslides based on their topographic signatures. Topographic information is also required to correct for solar illumination effects and geometric distortions in remote sensing data. Slope and aspect information is required for accurate estimates of solar radiation and snow-melt; and models of evapotranspiration, and mass and energy exchange with the atmosphere.

For regional and local-scale investigations, high-resolution digital elevation models (DEMs) can be used for terrain analysis. DEMs can be produced from airborne or orbital stereophotos or by digitizing previously produced topographic maps. More recently spaceborne synthetic aperture radar (SAR) interferometry data have been shown to yield accurate DEMs, thereby opening the possibility for generation of globally consistent data base. For example, the European Space Agency's ERS satellites have produced a large number of DEMs, the Japanese JERS-1 and Canada's Radarsat have demonstrated their capabilities for producing digital topographic data, and in 1994 SIR-C/X-SAR collected over a million square kilometers of repeat-pass SAR interferometry data. The SIR-C/X-SAR hardware will now be modified by adding a 60 m boom for single-pass interferometry and will be flown in the 1998-2000 timeframe to generate a global topographic data base. This mission will provide an unprecedented digital topographic map of the world equator-ward of 60 degrees latitude, which will serve as the reference data for future higher resolution topographic and topographic change studies. In a single 11 day Shuttle flight a digital topographic map of 80% of Earth's land surface will be produced with data points spaced every 30 meters and with 8 meter relative vertical accuracy.

A number of techniques have been developed to analyze digital topographic data, including Fourier texture analysis. A Fourier transform of the topography of an area allows the spatial frequency content of the topography to be analyzed. Band-pass filtering of the transform produces images representing the amplitude of different spatial wavelengths. These are then used in a multi-band classification to map units based on their spatial frequency content. Results using a radar image instead of digital topography showed good correspondence to a geologic map, however brightness variations in the image unrelated to topography caused errors. An additional benefit to the use of Fourier band-pass images for the classification is that the textural signatures of the units are quantitative measures of the spatial characteristics of the units that may be used to map similar units in similar environments. In this paper we present several examples of topographic analyses from data derived from a variety of sources.

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