

QUANTITATIVE ANALYSIS OF GEOMORPHIC PROCESSES USING SATELLITE IMAGE DATA AT DIFFERENT SCALES

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Summary

Aerial and satellite images and photographs of the Earth and satellite images of other planets and moons in our solar system are a rich new source of information about the landforms on these planetary bodies. The availability of this material has triggered a renewed scientific interest in regional and global geomorphic investigations and comparative studies of landforms on different planets and moons.

In addition to Landsat images, Large Format Camera (LFC) photographs, and other types of satellite imagery, such as satellite imaging radar (SIR) images, side-scan sonar (SSS) images of the seafloor are also providing new data about the geomorphic, structural, and tectonic character of the 75 percent of the Earth's surface obscured from satellite (or aerial) view. Comprehensive knowledge about the geomorphology of landforms on the seafloor is vitally important for comparative planetologic studies. In the near future, the Venus Radar Mapper (VRM) system will provide important image and other data about the geomorphic, structural, and tectonic character of Venus. Side-looking airborne radar (SLAR) images, SIR images, and SSS images of our own planet will be important in the analysis of the VRM images. Viking Orbiter images of Mars and Voyager images of Jupiter's Galilean moons and the moons of Saturn have provided unexpected information about active and dormant geomorphic processes that have shaped or are still shaping these planetary surfaces.

When aerial and satellite photographs and images are used in the quantitative analysis of geomorphic processes, either through direct observation of active processes or by analysis of landforms resulting from inferred active or dormant processes, a number of limitations in the use of such data must be considered. Active geomorphic processes work at different scales and rates. Therefore, the capability of imaging an active or dormant process depends primarily on the scale of the process and the spatial-resolution characteristic of the imaging system. Scale is an important factor in recording continuous and discontinuous active geomorphic processes, because what is not recorded will not be considered or even suspected in the analysis of orbital images. If the geomorphic process or landform change caused by the process is less than 200 m in x-y dimension, then it will not be recorded. Although the scale factor is critical, in the recording of discontinuous active geomorphic processes, the repeat interval of orbital-image acquisition of a planetary surface also is a consideration in order to capture a recurring short-lived geomorphic process or to record changes caused by either a continuous or a discontinuous geomorphic process.

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The experience with Landsat multispectral scanner (MSS) images of our own planet is instructive. For many types of landforms, Landsat MSS images have inadequate spatial resolution to be able to record them. In other words, a particular geomorphic process or the change caused by the process must reach a certain size threshold before it can be recorded by an imaging system. Also, the maximum repeat interval of Landsat 1, 2, and 3 for any given area was 18 days, 16 days for Landsat 4 and 5. Because of cloud cover the actual repeat interval is often considerably longer, several months or even years in some terrestrial locations. Few volcanic eruptions among many, for example, have been recorded by Landsat since 1972. The NOAA satellite, with its 12-hour repeat interval, albeit at lower resolution, has been far more successful in recording volcanic eruptions.

Analysis of Landsat MSS images (79-m picture element or pixel), Landsat RBV or TM images (30-m pixel), and the space shuttle LFC photographs (10 m per line pair) indicates that the LFC photograph probably has spatial resolution adequate for most regional quantitative studies of landforms and for comparative global studies of various types and classes of landforms. Landsat MSS images are an important source of image data for similar studies, but the scale of the landforms being analyzed must be 20 times larger than those discernible on LFC photographs: 200-m minimum dimensions (x,y) for the MSS image versus 10-m minimum dimensions (x,y, and z) for the LFC photograph. This means that all classes of landforms that have x and y dimensions less than 200 m will not be discernible on MSS images.

Landsat MSS images can best be used in quantitative studies of large-scale geomorphic processes, or in the changes produced by such processes, in a time-lapse manner. The changes recorded on an image may be the result of indirect influence rather than the direct influence of a specific geomorphic process or processes. Even the effects of very subtle geomorphic processes, such as small-scale stream captures, tectonic changes, land subsidence caused by groundwater withdrawals, etc., especially when reinforced by regional variations in climate, may produce local or regional changes in vegetative cover and drainage patterns. Successful quantitative geomorphic studies with Landsat MSS images completed so far include: changes in fluvial landforms caused by major floods, measurement of glacier advance (including surging glaciers) or recession, measurement of average velocity of outlet glaciers from two or more images, delineation of coastal changes caused by the passage of severe storms, areal measurements of new lava flows and tephra falls.

The scale factor is so critical in regional or global quantitative geomorphic studies that an important first step for geomorphologists is to obtain complete image data sets of all land areas of the Earth at the largest scale feasible with existing technology. This has now been nearly achieved with Landsat MSS images (79-m pixel size or about 200 m equivalent spatial resolution). This existing Landsat image data set allows geomorphologists to conduct comparative global studies for the first time, some of which were enumerated in the preceding paragraph. The next step is to acquire a Landsat TM image data set of the land areas of the Earth. The 30-m pixel of the TM image (or about 75 m equivalent spatial resolution) lowers the threshold of detectability and, therefore makes many more landforms of the Earth's land areas available for geomorphic analysis.

Another image data set of considerable value to regional geomorphologic studies, especially in regions of persistent cloud cover and low relief, is the SIR imagery acquired during two space shuttle missions. Satellite radar images of the Earth's surface are also important to have for comparative planetologic studies of Venus. The Earth's volcanic regions should have a special priority in the continuing program to acquire SIR images of our planet.

The newly available LFC photographs, all in stereo and some with a spatial resolution of 8 m per line pair (equivalent to a digital imaging system with 3-m pixels), represent a quantum leap in satellite imagery available for scientific analysis. The stereophotogrammetric characteristics of the LFC photograph would essentially open all the land areas of the world for quantitative geomorphic analysis, if complete coverage existed, and open a "golden age" for regional and global geomorphic studies of our planet.