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Use of Spaceborne Imaging Radar in Regional Geomorphic Studies

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In the past two decades, the use of both photographic and non-photographic remote sensing from satellite platforms has provided a unique capability for the observation and study of earth and planetary surfaces. A wide range of imaging sensors that operate in different portions of the electromagnetic spectrum have yielded images of large areas that formerly were unknown, or that had not previously been observed at a simultaneous instant in time. In addition, remote sensors equipped with multispectral or multiband capabilities are capable of taking data at different wavelengths simultaneously. Notable examples include the Landsat series of multispectral scanners, thematic mappers, and return beam vidicons.

Landsat images of the earth have found wide application in regional reconnaissance mapping programs. They serve especially well in mapping remote inaccessible terrains, in areas where conventional aerial photographs and topographic maps are not available. However, the quality of Landsat images, and of all images or photographs that are acquired at optical and infrared wavelengths, depends on solar illumination conditions. The utility of such images is limited in areas that are cloud covered.

Large areas of the earth are perennially cloud covered, particularly in the humid intertropical belt and in polar regions. As exploratory and exploitive activities are extended further into such regions, there is an increasing need to understand the geomorphic processes that are peculiar to the respective environments, and to assess the impact of cultural activities on these processes. The task of observing and evaluating the geomorphic processes that operate over large areas is facilitated with the utilization of spaceborne images.

Microwave radar energy is capable of penetrating cloud cover, and synthetic-aperture radar (SAR) systems are active sensors that provide their own illumination. Thus, SAR sensors can be effectively operated independently of weather conditions or time-of-day, and they are well suited to the acquisition of images over cloud-covered terrains.

Brightness levels on a radar image are representations of surface backscatter. They are determined by the interaction of surface physical properties with imaging parameters, notably including incidence angle, polarization and wavelength. For any given set of imaging parameters, the backscatter is mostly a function of surface slope and surface roughness at the scale of the radar wavelength. The sensitivity of the backscatter to topography is very high. A change in slope of a few degrees can change the radar backscatter by a factor of 2 or more at incidence angles below 30°. At larger incidence angles, the backscattered energy is proportional mostly to surface roughness. Thus, SAR images are most useful in studying patterns and features that are expressed as changes in slope or roughness. For this reason, airborne SAR images have been successfully used in geomorphic and structural mapping.

Airborne radar images have been acquired for geological exploration and for inventorying natural resources by exploration companies and government agencies, notably in extensively cloud-covered tropical regions such as Brazil, Venezuela, Panama, Nigeria, Togo, etc. Airborne radar images are acquired in the form of narrow linear swaths, with a wide range of incidence angles across the swath. Large-area coverage is obtained by mosaicing adjacent image swaths.

The Seasat SAR (1978), Shuttle Imaging Radar SIR-A (1981), and SIR-B (1984) experiments have successfully demonstrated that spaceborne SAR's provide high-resolution coverage of land and ocean surfaces. The spaceborne SAR's have the capability to acquire large-area coverage across a wide swath through a small range of incidence angles. Both Seasat SAR and SIR-A operated at a single frequency (L-band, 23.5 cm wavelength), single polarization (HH), and fixed incdence angles (20 for Seasat SAR; 50 for SIR-A). Interpretations of Seasat SAR and SIR-A images for geologic mapping purposes have demonstrated that the images contain a predominance of useful geomorphic information (see references for examples). Distinctive terrain textures are highlighted on the images and serve to discriminate broad lithologic associations. The SAR's enhance subtle topographic features to provide important geomorphic and structural data. The potential exists for future operational SAR systems to monitor dynamic geomorphic processes, such as shoreline erosion, delta formation, stream channel flooding, glacier movement, etc.

During the present decade, the main thrust of spaceborne radar research is to understand the basic properties of surface features that relate to the radar illumination geometry (incidence angle), polarization and radar signal frequency (wavelength). SIR-B was equipped with a stepwise movable antenna to provide multiple incidence capability. Multiple incidence coverage yields a capability for radar stereo measurement and topographic mapping. The role of SIR-C (1988) is to provide unique information about surficial units and processes that can be obtained through its multipolarization and multifrequency capabilities. Existing and future spaceborne imaging radar data sets will provide an excellent tool for application to regional geomorphic studies.

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