GEOLOGIC REMOTE SENSING IN THE THERMAL INFRARED

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ABSTRACT

Remote sensing of emitted radiance from the Earth's surface in the thermal infrared region (8 to 13 μm) is useful for geologic studies including lithology and soil and mineral mapping. Since 1982, new air borne, field portable and spaceborne instruments have been demonstrating the advantages of multispectral measurements in this region for geologic applications. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), presently being built in Japan, is the newest of the spaceborne multispectral instruments. ASTER, which has fourteen channels in the visible out through the thermal infrared, will be flown aboard NASA'S EOS AM1 platform in 1998. Other multispectral instruments, including PRISM, JRSIII and Sacagawea are projected to be built and flown after ASTER. The advent of these sensors is expected to result in a demand for more high spatial-resolution multispectral thermal infrared data.

INTRODUCTION

The feasibility of using multispectral thermal infrared remote sensing for geologic applications has been recognized by a number of users, but advancement has been limited by lack of sensors. The use of the visible and near infrared (VNIR) and shortwave infrared (SWIR) spectral data made a tremendous leap forward with the advent of the Landsat satellite sensors (MSS, TM). We anticipate a similar phenomenon when orbital multispectral thermal infrared data becomes generally available with the launch of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) in 1998. The ASTER instrument will be the first spaceborne multispectral thermal infrared instrument with spatial and spectral resolution adequate for geologic applications. From thermal data one can derive both surface temperature and surface spectral emissivity. The primary application of the emissivity is for surface lithologic mapping. The temperature data can be used both for studies of thermal inertia of surface materials, and for studies of thermal processes related to volcanism and hydrology.

THEORETICAL BACKGROUND

At terrestrial temperatures, the thermal infrared spectral radiance emitted by the surface is at a maximum around 10 to 11 μm, dropping off sharply to the shorter and longer wavelengths. The best atmospheric window lies between about 8 and 13 μm with another window between 3 and 5 μm. Interpretation of data from the 3 to 5 μm region is complicated by overlap with reflected solar radiation which, although dropping rapidly in intensity with increasing wavelength, makes a large contribution during the day. Thus, the 8 to 13 μm region is the best thermal infrared spectral region to use and has received most attention to date. This is also a spectral region containing diagnostic spectral information for many minerals, including the silicates which make up the great majority of continental surface rocks.

Spectral features of minerals in the thermal infrared region are the result of vibrational molecular motions. The location, strength and form of these features vary systematically with composition and crystal structure. The most intense band in the spectra of all silicates (the reststrahlen effect) occurs between 8 and 1[illegible] μm. Typically, this spectral feature shifts to shorter wavelengths as the bond strength within the lattice increases (Hunt, 1980; Lyon, 1965). The carbonates, sulfates, phosphates, and hydroxides are other important mineral groups that have spectral features in the thermal infrared (Hunt and Salisbury, 1974, 1975, 1976).

The range of minerals found in soils is usually quite limited, particularly with older, more developed soils, in which iron oxides, quartz and clays almost always dominate, except in arid climates where carbonates may be important. The relative amounts of these minerals should vary systematically, depending on climate and the composition of the parent rock. Using remote sensing, these minerals can all be detected and identified, based on their spectral properties. Iron oxides produce absorption features in the VNIR, clays and carbonates in the SWIR, while quartz has characteristic features only in the thermal infrared ([illegible]). Thus, remote soil mapping, like geologic mapping, will be enhanced by combining VNIR, SWIR production of digital elevation models, (2) a six-channel shortwave infrared radiometer (SWIR), and (3) a five-channel thermal infrared radiometer (TIR). All three radiometers can be operated independently and all are individually pointable. The instrument features high spatial and radiometric resolution. The nadir-viewing swath width is 60 km. With its pointing capability, ASTER is capable of viewing any point on Earth every 16 days. Because of its polar orbit, it can view any point above 45° every 7-9 days and any point above 69° every 3-4 days. It takes 48 days to provide full surface coverage.

The ASTER characteristics are given in Table 1.

Table 1 ASTER

Radiometer	Spectral range	Data rate	Radiometric resolution	Spatial resolution
VNIR	Nadir bands 0.52-0.60 µ 0.63-0.69 µ 0.70-0.86 µ Stereoscopic band 0.76-0.86 µ	62 Mbps	<0.5%	15 m
SWIR	6 bands 1.6-1.7 µ 2.145-2.185 µ 2.185-2.225 µ 2.235-2.285 µ 2.295-2.365 µ 2.360-2.430 µ	23 Mbps	<0.5%-1.3%	30 m
TIR	5 bands 8.125-8.475 µ 8.475-8.825 µ 8.925-9.275 µ 10.25-10.95 µ 10.95-11.65 µ	4.1 Mbps	<3K	90 m

Instrument and spacecraft resources are allocated to support an 8% average duty cycle. ASTER data will be acquired and processed according to specific user requirements identifying acquisition time, gain, wavelength region and data product. For daytime observations, the user may request that any or all of the three subsystems be operated. For nighttime observations, typically only the TIR subsystem will be employed, but it is possible to request both TIR and SWIR at night for hot volcanic targets. Current plans are that all EOS investigators, and other scientists approved by NASA or MITI will be allowed to submit requests for data acquisition over their targets. Additionally, the ASTER Science Team, working with the IDS Teams, will define targets such as active volcanoes, which should be monitored routinely, and a one-time global land surface map will be created over the six-year life of the mission. Data, once acquired, will be available to all investigators.

SUMMARY

The next decade should prove to be an exciting one for geologists using thermal infrared remote sensing. Just as Landsat developed a large user community in the 1970s when multispectral VNIR data became available over users' areas of interest, we anticipate that the advent of the sensors discussed here will develop a demand for high-spatial-resolution multispectral, thermal infrared data. It is important that the technology be developed to allow continued improvement in these types of instruments.

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