SURVEYING EARTH RESOURCES BY REMOTE SENSING FROM SATELLITES

J. OTTERMAN*, P. D. LOWMAN**, and V. V. SALOMONSON**
Goddard Space Flight Center, NASA, Greenbelt, Md. 20771, U.S.A.

Abstract. This paper reviews the techniques and recent results of orbital remote sensing, with emphasis on Landsat and Skylab imagery. Landsat (formerly ERTS) uses electronic sensors (scanners and television) for repetitive observations with moderate ground resolution. The Skylab flights used a wider range of electro-optical sensors and returned film cameras with moderate and high ground resolution. Data from these programs have been used successfully in many fields. For mineral resources, satellite observations have proven valuable in geologic mapping and in exploration for metal, oil, and gas deposits, generally as a guide for other (conventional) techniques. Water resource monitoring with satellite data has included hydrologic mapping, soil moisture studies, and snow surveys. Marine resources have been studied, with applications in the fishing industry and in ocean transportation. Agricultural applications, benefiting from the repetitive coverage possible with satellites, have been especially promising. Crop inventories are being conducted, as well as inventories of timber and rangeland. Overgrazing has been monitored in several areas. Finally, environmental quality has also proven susceptible to orbital remote sensing; several types of water pollution have been successfully monitored. The effects of mining and other activities on the land can also be studied. The future of orbital remote sensing in global monitoring of the Earth's resources seems assured. However, efforts to extend spectral range, increase resolution, and solve cloud-cover problems must be continued. Broad applications of computer analysis techniques are vital to handle the immense amount of information produced by satellite sensors.

1. Introduction

What is remote sensing? Photography and photointerpretation have existed for over a hundred years, but remote sensing, as an identified discipline or activity, has existed for no more than one decade. In view of the fact that photographic techniques are still the backbone of remote sensing, one may ask what makes remote sensing a new field and a new profession.

Different workers might answer this question in various ways, stressing one of the following points and possibly omitting the others. Most researchers, however, probably would agree that remote sensing differs from the conventional photography on these counts:

(a) In remote sensing, techniques are used which may involve the use of wavelengths selected from broad regions of the electromagnetic spectrum, extending over a range of more than $10^5$ in wavelengths. Selection of a proper operating wavelength is tailored to the phenomena studied and to the observational requirements. The operation may be based on reflectance, polarization, emissivity, or transmissivity. Temporal variations in those characteristics are also utilized.

(b) New instruments, both passive and active, are operating which, in particular,
are quite different from conventional cameras. The instrument selection is based on radiometric fidelity, spatial resolution, spectral resolution, and the suitability of the data to the processing requirements, as well as reliability, weight, and cost.

(c) New platforms, such as high flying aircraft and satellites in low, Earth orbit (≈ 1000 km) or in geostationary orbit (36000 km) are commonly used. It is really the combination of the new instruments which operate in new regions of the spectrum and these new platforms that has opened the vistas of remote sensing.

(d) Very large amounts of information are typically produced. These may come from a special aircraft involved in a multi-year program of data collection from instruments, on a large number of stratospheric balloons that circle the globe, or on a satellite that operates for several years. In any case, the deluge of data can be overwhelming.

(e) Coupled with this deluge of data, and with the mathematical complexity of some data reduction methods, such as atmospheric inversion techniques, the high speed digital computer plays a highly significant role in this new profession. Without computer processing some remote sensing missions would be pointless and, indeed, a plan for computer processing should be incorporated in the design studies of a remote sensing mission.

In what follows we restrict the discussion to the imaging techniques of remote sensing. Spectroscopic techniques, primarily oriented toward atmospheric studies, but which also have applications in surface studies, are not discussed.

2. Techniques of Observation

2.1. Earth Observation from Satellites

The recognized advantages of imaging the Earth from satellites are: first, the capability of synoptically viewing a large area, practically in a vertical view, under essentially the same illumination conditions and sensor operating conditions, and second, the capability of repetitive coverage of the area at fixed intervals of time and at the same time of day.

The synoptic viewing is an important advantage both for the standard photointerpretation and for the computer processing of the imagery. To a photointerpreter who searches for some simple geometric features, a mosaic of photographs taken at somewhat different times would tend to introduce some spurious features and mask the actual features. In computer processing, the change of general illumination level by itself is a minor problem, but the spectral distribution of illumination and the spectral signatures (i.e., reflectances in the various spectral bands) can change with a change in the solar elevation angle and the time of day. This would make such computer processing from a mosaic quite difficult, and probably impracticable.

Two distinct kinds of satellite orbits are in use for Earth observations: (1) low orbits, with altitudes ranging from 250 km to 1200 km with a period of about 90 to 110 min, and (2) geostationary orbits with a period equal to the sidereal rotation