REMOTE SENSING (SATELLITE) SYSTEM TECHNOLOGIES

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Summary

Satellite remote sensing technology has revolutionized global change and environmental monitoring research by exponentially expanding our knowledge of the terrestrial environment. The technology provides environmental scientists with quantities of quality information and data that could not be obtained by any other data-gathering methods. The argument for satellite remote sensing technology includes the fact that it collects data in a timely, cheaper, and more efficient way than conventional *in situ* approaches and satellite data are readily and uniquely suitable to automated analysis in microcomputers. The synergy of advances in both satellite remote sensing and computer technologies, certainly, controls our present approach to environmental research and will, most probably, continue to shape our environmental research direction and agenda in the future.

However, many policy makers, resource managers, and environmental practitioners who use remote sensing data are not very familiar with important remote sensing concepts including the limitations of satellite data and the art and science of an actual remote sensing application process. This paper discusses the importance and value of satellite remote sensing technology, but points out that the technology is not a “know it all, do it all” solution for all the environmental challenges facing humankind. It highlights some limitations and drawbacks of satellite data that practitioners and policy makers should be aware of in order to view the technology in proper perspective.

For instance, many variables that are pertinent to environmental research cannot be remotely sensed from space. Also, satellite sensors estimate most environmental variables only indirectly and quasiquantitatively, and the processes of interpreting and converting remote sensing signals to actual parameter values are often fraught with significant errors. Again, a proper analysis of most satellite imagery requires the use of “ground truth” or reference data from a nonremote sensing source for “calibration” (developing training areas) and “validation” (accuracy assessment) of remotely sensed data product.

Hence, although satellite systems have unprecedented and unparalleled capabilities to gather valuable information, the utility of many remotely sensed data and the success of most environmental investigations, may still rest significantly on the availability of quality data from nonremote sensing sources.

1. Introduction

Since the dawn of civilization, scientists have been keenly interested and actively engaged in observing, evaluating, and measuring the conditions of the earth environments and resources, and the processes and degrees of natural and human-induced changes in them. This is because Earth’s physical environment and resources undergo certain, inevitable, and virtually constant changes that often seriously affect or even threaten the well-being or existence of humans. Scientists have developed and employed various methods for obtaining information or data about the changing environment, but nothing has been as revolutionary to environmental monitoring studies as remote sensing technologies. Remote sensing technologies enable scientists to obtain information about a material object, conditions of a geographic space, or an environmental phenomenon, through a sensing device that is distant or far away from the object, area, or phenomenon under investigation.

Remote sensing data can be acquired by airborne devices such as aircraft and balloons, but this paper focuses on space-borne or satellite remote sensing technology. There are presently over two dozen space-based satellites with sensors that scan Earth's surface and send back image data containing varying degrees of detailed information about Earth's biophysical environments.

The specifications for the data from these satellite sensors are driven by national and global environmental agenda and major international and interagency environmental programs such as the Global Climate Observing Systems (GCOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS), the World Climate Research Program (WCRP), and the International Geosphere-Biosphere Program (IGBP). Also, environmental questions at regional to global scales are defined or refined in the light of the capabilities of the modern technology of satellite remote sensing.

Satellite remote sensing systems are useful for collecting information on environmental variables such as climatic and atmospheric radiation and chemistry, ocean dynamics and productivity properties, geographic and topographic locations, and land-biosphere characteristics.

Specific information derivable from satellite remote sensing include land use and land cover (including urban infrastructure and vegetation types), land surface temperature, soils, soil moisture, vegetation stress, chlorophyll concentration and plant biomass, sea surface temperature, bathymetry, and ocean biochemistry, color and surface characteristics, atmospheric temperature, humidity, wind speed, precipitation, cloud and aerosol properties; volcanic effects, and snow, sea, and polar ice distribution and thickness, etc.

Several publications in the bibliography show names and characteristics of selected satellite remote sensors that may be used to derive each of these bio-geophysical variables. However, satellite sensors estimate most of these variables only indirectly and quasiquantitatively, and the processes of interpreting and converting remote sensing signals to actual parameter values are potentially fraught with significant errors.

The objectives of this paper are to present a brief and practitioner's review of satellite remote sensing technologies and to discuss why satellite sensors are fast becoming the *de facto* technology for most global change and environmental monitoring programs. The paper also examines the limitations of the satellite remote sensors and discusses some preliminary considerations in determining if an environmental project should involve the analysis of satellite data, and how to choose between basic types of remote sensing image data. The bibliography provides Internet sites for information on available commercial satellite systems, their basic characteristics, and sources of both raw satellite imagery and important remote sensing derived dataset. The remote sensing technology and market are changing continually, and the dynamic nature of the Internet makes it a more suitable source of this type of information.

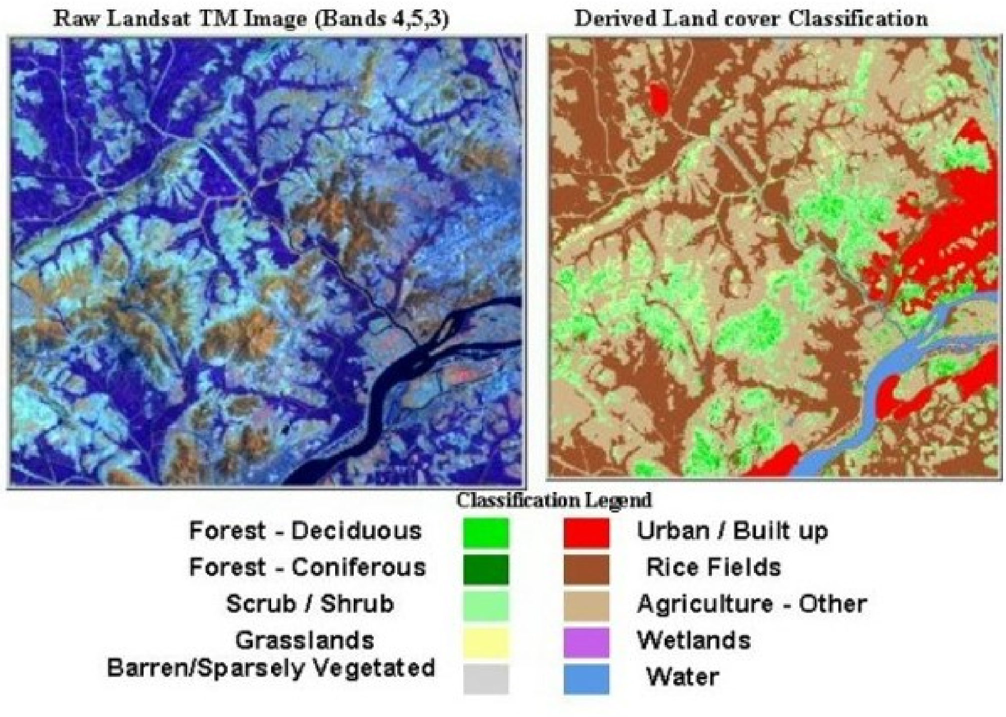

Figure 1. An example of a satellite image before and after a land cover classification analysis

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Business Image Group and SPOT Image Corporation. (1998). *Satellite Imagery: An Objective Guide*, 30 pp. [This small booklet is quick and easy-to-read source of knowledge on satellite remote sensing systems, imagery, terminology, and how to select image products for specific applications.]

Canadian Center for Remote Sensing. http://www.ccrs.nrcan.gc.ca/ccrs/homepg.pl?e [This is a comprehensive website on satellite remote sensing. The site contains excellent educational materials and information on satellites and sensors, satellite imagery, remote sensing glossary, and links to other important sites.]

CEOS (Committee on Earth Observation Satellites). (1992). *The Relevance of Satellite Missions to the Study of the Global Environment*. London, UK: Committee on Earth Observation Satellites, British National Space Center. [Contains excellent discussion on the importance of satellite remote sensing to global environmental research agenda.]

Earth Satellite Corporation. Website. http://www.earthsat.com [Earth Satellite Corporation is the industry's leader in the utilization of all forms of satellite imagery for environmental analyses, mineral and hydrogeological explorations, agricultural weather forecast and yield estimation, disaster response serves, land use/land cover mapping and change analysis. This site provides great examples of real applications of satellite remote sensing technology.]

Environmental Remote Sensing Center (ERSC) at the University of Wisconsin-Madison. Website. http://www.ersc.wisc.edu/ersc/Resources/EOSF.html [This site contains a tabular listing of current and proposed satellite systems, their important characteristics such as their spatial and spectral resolutions, launch dates, hosts, etc., and links to the Websites of their vendors.]

Giles F. and Curran P., eds. (1994). *Environmental Remote Sensing From Regional to Global Scales*. New York: John Wiley & Sons. [This book contains 14 papers on applications of remote sensing at regional to global scale, and illustrates the important role satellite remote sensing can play in the provision of data and information on the environment at regional to global scales.]

Jensen J. R. (2000). *Remote Sensing of the Environment: An Earth Resource Perspective*. Prentice Hall. [This is a recent and readable basic text on remote sensing with information on most existing remote sensing systems. This is an excellent resource for both beginning and experienced remote sensing practitioners.]

Biographical Sketches

Dr. Okoye is a Senior Applications Scientist in the Division of Environmental Remote Sensing and GIS Services, of Earth Satellite Corporation Interpretation, Rockville, Maryland, USA. Earth Satellite Corporation is an international remote sensing and GIS consulting firm specializing in environmental and geophysical mapping and analyses. Dr. Okoye holds a B.Sc. in Soil Science from the University of Ibadan, Nigeria, an MS degree in Soil/Environmental Science and Geography from Oklahoma State University, USA, and a PhD in Natural Resources from the University of New Hampshire, USA. Dr. Okoye's graduate education and employment interests have focused on the applications of remote sensing, GIS, and related computer-based technologies. Prior to joining Earth Satellite in 1998, Dr. Okoye taught undergraduate/graduate courses in soil science, remote sensing and GIS, applied statistics, and Earth-environmental science, at three US universities.

Dr. Koeln is a Senior Vice President and Chief Scientist in Earth Satellite Corporation, and the Director of the company's Division of Environmental Remote Sensing and GIS Services. Dr. Koeln's degrees are in natural resources management, with specialization in the application of remote sensing and geographic information systems (GIS). Dr. Koeln joined Earth Satellite Corporation in October 1992 and has participated in the numerous projects involving the development and applications of remote sensing and GIS technologies for land use/land cover mapping, environmental monitoring, wetland delineation and mapping, agricultural yield estimation, forest inventory and natural resources evaluation, geologic and mineral explorations, as well as technical training in remote sensing, GIS and database development and management. Prior to joining EarthSat, Dr. Koeln was the Director of the Habitat Inventory and Evaluation program for Ducks Unlimited, Inc., USA. In this position, he initiated and managed one of the first and most successful programs that used satellite data to inventory and monitor wetlands and waterfowl habitat. Dr. Koeln was an assistant professor at the University of Missouri-Columbia, where he taught geography and planning, advanced cartography, and GIS. Dr. Koeln has held numerous workshops and short courses on remote sensing and GIS. Dr. Koeln's BS, MS, and PhD are all in wildlife management, focusing on computer mapping system and the use of GIS.