Remotely Acquired Data and Information in GIScience

UCGIS Research Initiative

I. Introduction

Since the original UCGIS research themes were developed, the science and technology of remotely acquired data and information has undergone a revolution in the number and type of sensors, data availability, potential applications, and governmental and commercialization activities. There has been a massive increase in our ability to acquire radiometrically sensitive, geospatially-referenced sensor data from aircraft, satellite and undersea instrument platforms. Furthermore, new innovations in sensor systems are being developed to exploit various types of acoustic and electromagnetic (EM) data, including interferometric radar, infrared detector arrays, thermal, LIDAR (LIght Detection And Ranging), and other laser illumination techniques. Many new sensors are being developed that acquire EM data in novel ways, such as the acquisition of hundreds of narrow band spectra, termed hyperspectral remote sensing.

The range of use of remotely acquired data is changing as well. In the past, most research efforts were on terrestrial landscapes, but the structure and composition of the atmosphere and hydrosphere of the earth are being recognized as increasingly important to the quality of life and survival of humans. The submerged portions of our planet (71% of the Earth's total surface) are the focus of recent development of sophisticated sensors for ocean data collection and management. These sensors hold tremendous potential for mapping and interpreting the ocean environment in unprecedented detail.

The use of remotely acquired data is entering the everyday life of the typical person. Weather radar, on-board automobile navigation, recreational wayfinding and many other citizen uses depend on advancements in remotely acquired data and information. The new frontiers in sensors, modes of data acquisition and domains of investigation require research into these new and, in some cases, radical conceptual approaches to remote sensing.

Since 1997-1998, when the original themes were developed, the science and technology of remote sensing and data acquisition has undergone major changes. None of the original UCGIS themes address this expansive, dynamic nature of the remote sensing field. While the existing research theme, "Spatial Data Acquisition and Integration" touches on data acquisition, it is primarily focused on data integration issues. It does not adequately address research required for utilizing and integrating remotely acquired sensory data in a GIScience environment, especially those data that will be acquired by the new generation of sensors. The proposed theme, "Remotely Acquired Data and Information in GIScience," warrants inclusion in the UCGIS research agenda as a separate initiative for several reasons.

The original theme, "Spatial Data Acquisition and Integration," was very broad and diffuse in its scope. The scope ranges from data standards to map conflation to use of census data. Quotes from the original theme paper "High Priority Activities," indicate this breadth, and lack of connection to the proposed theme.

> "High Priority Activities.
> -TIGER database enhancements and adjustments via conflation of other spatial datasets;
> -horizontal integration of diverse resources at different scales (e.g., edge matching)
> -construction of a common U.S./Mexico spatial database that includes aerial photos;
> -construction of an interstate environmental database;
> -development of relative measures of database quality based on positional differences;
> -analysis of content differences of spatial databases."

While these are very important areas of research for the nation, the proposed research theme will focus on remotely-sensed phenomena, the measurement of these phenomena, integration of these sensory data into information, and expansion of the array of analytical products that can be derived from this information.

A more directed focus will foster our internal UCGIS research coordination efforts, while improving the comprehension of UCGIS capabilities by the outside community. UCGIS desires to have a role in science and technology policy for the nation. The proposed theme aligns very well with the recent initiatives in the major GIscience and policy communities in the U.S. For example, the declassification and resultant adaptation of military remote sensing assets to the civilian community, the Open Skies Policy, new, large governmental and private sector programs in remote sensing beyond the Landsat program, and the efforts in global environmental change detection and monitoring could and should involve

focused UCGIS participation.

These initiatives are a large portion of the future GIScience programs of the U.S. Congress, National Aeronautical and Space Administration (NASA), the National Imagery and Mapping Agency (NIMA) the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Transportation (USDOT), and the National Science Foundation (NSF). UCGIS can utilize this proposed theme to better focus our intellectual resources, and to provide credibility to our efforts in assisting these agencies and the private sector in addressing the use of remote sensing in these new research programs.

II. Objectives

The following objectives represent research arenas for UCGIS researchers defined using perspectives related to scientific merit, funding potential and national policy implications.

1) Encourage UCGIS research into the methods by which advances in sensor systems, data sources and analysis procedures can be utilized with the other capabilities of geographic information science: GPS, measuring systems, visualization, data mining, real-time GIS and other geospatial scientific advancements.

2) Develop a UCGIS-based research capacity as an unbiased evaluator of new sensor technologies and comparative data analyses.

3) Provide a structure for UCGIS members to increase their involvement in research associated with new sensors, digital sensor calibration and sensor data systems.

4) Encourage the increased use of remote sensing to study our land, oceans, lakes, rivers and the atmosphere of the Earth**.**

5) Foster the conversion of military remote sensing assets to civilian uses in the environmental, agricultural, natural hazards and other domains.

6) Investigate methods of using one or more existing data sources of modern ancillary geospatial data. to leverage with the massive amounts of historical remote sensing data for research on global environmental change.

III. The UCGIS Approach

The UCGIS was formed to focus university interdisciplinary research and educational efforts on major national issues of GIScience. The basic and applied research activities necessary to meet the above objectives mesh well with the founding rationale for the UCGIS. In fact, the UCGIS ability to pool interdisciplinary talent is essential to meeting the objectives, which will foster the efficient and valid utilization of remote sensing data in the integrated GIScience enterprise.

Additionally, the involvement of the UCGIS, as an innovative and credible organization, is important to elevate the new era in remote sensing as an increasingly important component of GIScience. In the last 40 years, science and technologies that allowed travel to outer space, have provided the satellite systems and massive computer capabilities that allow us to better study and understand the earth through remote sensing. In the past, university researchers in remote sensing and GIScience were forced to spend most of their resources dealing with hardware, data acquisition and data storage issues. Recent advancements in these areas, linked to lower costs, now allows multidisciplinary teams of university-based researchers to share capabilities to address fundamental science questions and their associated applications.

In the 1998 National Research Council publication, *People and Pixels: Linking Remote Sensing and Social Science*, social scientists Ronald Rindfuss and Paul Stern cite 1) building a community of scholars, 2) training future scholars and 3) providing the necessary data as the critical institutional needs for linking remote sensing and social science to address important scientific and public policy questions (Liverman, 1998). The proposed research theme will contribute to meeting these needs through collaborative research between various disciplines. The UCGIS is the natural home and should be the advocate of this research.

IV. Importance of the Emerging Theme to National Research Needs/Benefits

Recent interrelated, fundamental changes in remote sensing policy, basic science, technology transfer and the private-public mixture of investment and control in remote sensing represents a nexus of activities that has heightened the importance of remote sensing to the national research and economic agendas. This proposed theme is a means for UCGIS to directly convey that we recognize these changes, and are attempting to address them as they relate to national research needs and benefits. These recent changes include:

1) The governmental controls on the spatial and spectral resolution of sensors and data have been relaxed. Until recently, the U.S. remote sensing community was constrained to broad spectral band sensors and a spatial resolution of 30 meters. Foreign competition and a changing view of the future have resulted in the easing of constraints on the spatial and spectral resolution for the U.S. In addition, it is likely that even more classified remotely acquired data and information will be released for public use for economic development, global environmental research, and other scientific purposes. The proposed research theme will place the UCGIS in the forefront of policy and application as these changes continue to occur in the future.

2) There has been a leap in the scientific development and technology transfer of usable sensor systems producing reliable, cost effective data. The newest developments have occurred in high spatial resolution satellite data in the visible and near infrared spectrum, radar and interferometric radar, hyperspectral and laser illumination sensors (LIDAR). In the oceans, new remotely-operated vehicles (ROVs), carry out mapping tasks at unprecedented m- to cm-scales, both on the ocean floor and in the water column. University investigators analyzed Landsat data in every conceivable manner for years. Suddenly, we are confronted with new possibilities in remotely acquired data and information to support both basic and applied science never before available to the university community.

3) The last few years has seen a major growth in the private sector commercialization of remote sensors, data and information products. The impact of commercialization is taking esoteric science and moving it to the public consumer level. This has led to increased availability and reduced cost, which is a great opportunity for university-based science. Also, the commercial entities are in dire need of university research in sensor calibration, algorithms for analysis, and enhanced applications to bolster their link to the expanding markets for imagery products.

4) The NASA, Department of Defense (DoD), NOAA, the U.S. Department of Transportation (USDOT) and the U.S. Geological Survey (USGS) are major GIS agencies in the U.S. government. While they have major initiatives in many areas, the leading GIS-related ones are in new sensor systems, space-based sensors, imagery analysis and supplying of remotely-acquired data for geographic information systems.

The rapid growth and changing nature of remote sensing has prompted NASA, in collaboration with the American Society for Photogrammetry and Remote Sensing (ASPRS), to undertake a ten year dynamic forecast project for the commercial, academic and governmental sectors. NASA's newest satellite systems include the Terra and EO-1 satellites. Sensors on Terra include the MODIS (a 36-channel instrument at a 250-m, 500-m or 1000-m resolution), and ASTER (a visible and thermal channel instrument at 15- and 30-m resolutions). The EO-1 satellite, which was recently launched, includes the Hyperion, which is a hyperspectral scanner (220 bands at 30-m resolution). In cooperation with NASA, the USDOT is supporting a major new program for university research in the application of remote sensing to transportation infrastructure, transportation flow, safety and disaster assessment and the environment (see http://www.cfm.ohio-state.edu/info/ncrst.html).

NOAA, via its High Performance Computing and Communications initiative has been funding projects that incorporate satellite AVHRR and ocean color imagery, color aerial photographs, and LIDAR imagery into GIS and digital libraries.(see http://www.hpcc.noaa.gov/digital.html).

Also for the oceans, the USGS has recently invested in several new systems for characterizing the US continental shelf. These include acoustic sidescan-sonar imaging and multibeam swath-imaging systems that produce both sidescan sonar and bathymetric data (see p://walrus.wr.usgs.gov/infotech/).

The Department of Defense lists laser, infrared, radar, and acoustic sensors as militarily critical remote sensing technologies for spaceborne and airborne sensing of terrestrial, atmospheric and ocean environments (see www.dtic.mil/mctl), The Shuttle Radar Topographic Mission (SRTM) for the acquisition of interferometric radar data and the Navy's Warfighter hyperspectral satellite are on-going programs that will support both military and civilian science.

5) The last major change is the recognition of the broader potential for remote sensing in the atmospheric and oceanographic domains. This trend has been stimulated by the recognition that the oceans and atmosphere are critical components in the analysis of global environmental change. In addition to acoustic sensing, investigation of thermal and microwave sensors for sea level measurement, wave (wind) speed and direction, and surface temperatures are areas of needed research for global weather, climate change and biological resources management. Shallow water chemical and biological analysis can utilize hyperspectral sensor data for biological productivity and pollution studies.

These changes in the posture of remote sensing science and policy frame a major component of the national needs and benefits in the GIScience area. It is imperative that the UCGIS coordinate with its members universities and the ASPRS a response to these changes in the national research and policy agendas.

V. Priority Research Areas

Short Term (2-3 years)

1) Fundamental research in the spectral signatures provided in imaging spectroscopy from airborne and satellite platforms. Hyperspectral data provide new opportunities for study of the earth. Signatures of actual earth surface materials differ from laboratory-derived spectra of these materials, which vary from airborne and satellite imagery data.

amounts of data collected can be effectively reduced and transformed to information using these systems, thereby, eliminating the need for real time raw data transmission to processing stations. Approaches include expert systems, artificial neural networks, and agent-based information extraction strategies. The applications include satellite and aircraft on-board feature detection and image classification, hyperspectral signature extraction, and DEM creation from LIDAR and IFSAR data acquisition. In the ocean, these systems would improve classification of sea-surface reflected sonar pulses, extraction of surface wave slopes from polarimetric synthetic aperture radar images, and mapping of mesoscale wind fields using RADARSAT-1 ScanSAR images.

Long Term (10 years and beyond)

1) Research in analysis of time series information from remote sensing data. Most current GISs have only rudimentary support for time series analysis, a weakness still rooted in imperfect conceptual understandings of temporal data and, more specifically, of the spatial dynamics of many terrestrial, atmospheric, marine and coastal environments (Wright and Bartlett, 1999). The greatest problem facing all means of change detection and analysis is simply the lack of consistent, and often continuous, data over long time spans. Temporally formatted remote sensing products can form the basis for research into this problem that can have a major impact on understanding earth processes and patterns through time and space.

VI. Example Research Projects / Showcase Demonstrations

1) The Virtual Research Vessel. In 1999, NSF created a new Information Technology Research (ITR) initiative. ITR was established in direct response to the call for increased federal investment to maintain America's leadership in information technology, particularly information storage and retrieval (included remotely-sensed data and information), scalable networks and connectivity, and studies of the impact of information technology on society.

A team of researchers in the Pacific Northwest (University of Oregon, Oregon State University, and Evergreen State College, Washington) will use recent ITR funding over a 3-5 year period to develop a computational infrastructure to support data sharing, tool composition, and model coupling for the use of large scale, interdisciplinary data archives. A key aspect will be the support of data sharing by the merging of remote sensing-GIS, database management systems, and electronic notebooks. This integrated data infrastructure will be employed to build a domain-specific environment called the Virtual Research Vessel (VRV), which will facilitate the use of acoustic sonar maps and imagery, visual imagery from towed camera systems and submersibles, and numerical models from the East Pacific Rise seafloor-spreading center.

2) Urban Remote Sensing. In general our understanding of urban theory, structure and process is insufficient to explain and predict how urban change will be manifested in land use patterns and environmental alterations in urban and suburban areas. As cities continue to grow at unprecedented rates, understanding the relationship between changes to land cover, local climate, transportation systems becomes increasingly more important. For cities located in developing areas of the world, there is virtually no geographic data system infrastructure to provide essential information on transportation, 3-D urban structure, land use and surface materials. To help compensate for this deficiency, this demonstration project would serve to investigate the use of a remotely sensed information systems approach to delineate, measure and characterize selected urban areas. The project would integrate satellite and airborne LIDAR, interferometric radar and hyperspectral sensor systems within a geographic information systems framework. Valid data and models for land use change, non-point source pollution modeling, flood hazard and emergency response to disasters could be developed for these cities in the developing world.

3) MODIS Resources Analysis. The MODIS Proto-Flight Model (Moderate Resolution Imaging Spectroradiometer) is the key instrument aboard the Terra (EOS AM-1) satellite launched on December 18, 1999. The MODIS Instrument views the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands. This repetitive hyperspectral coverage of the earth's surface at moderate spatial resolution (250m-1km) is well suited for monitoring the earth's oceans, atmosphere and land resources. This project would select several large regional sites worldwide and monitor the change in these sites over time. Several investigators affiliated with UCGIS presently maintain surface databases on land and ocean study sites that could be used for scientific research to investigate the potential for hyperspectral data in resources management.

VII. Conclusions

The remote sensing area is an increasingly significant portion of GIScience. The authors firmly believe that the proposed research theme fulfills an important need within the UCGIS research agenda. The proposed theme is a credible addition to the UCGIS research agenda on scientific merit alone. However, given the trends in the governmental and commercial sectors, the need to establish the UCGIS as a leader in remote sensing research has important implications to the prominence of the UCGIS in the funding and policy areas. It is critical for the UCGIS to respond to the recent changes in remote sensing and allied areas by creation of this theme as a new and separate research initiative.

Authors/Sponsors

Carolyn Merry, Ohio State University
Dawn Wright, Oregon State University
Elizabeth Wentz and Sharolyn Anderson, Arizona State University
Amy Budge, ASPRS- University of New Mexico
George Hepner, ASPRS- University of Utah

VIII. Bibliography

Detrick, R., and Humphris, S., (1994). Exploration of Global Oceanic Ridge System Unfolds. *Eos, Transactions of the American Geophysical Union*, 75: 25-26.

Garver, S., Siegel, D. and Mitchell, B. (1994). Variability in Near Surface Particulate Absorption Spectra: What Can a Satellite Ocean Color Imager See? *Limnology and Oceanography*, 39: 1349-1367.

Goetz, A.F. et al. 1985. "Imaging Spectrometry for Earth Remote Sensing,"*Science*228:1147-1153.

Hepner, G.F., B. Houshmand, I. Kolikov and N. Bryant, "Investigation of the Integration of AVIRIS and IFSAR for Urban Analysis," Photogrammetric Engineering and Remote Sensing, 64-8 (August, 1998), pp. 813-820.

Houshmand, B.,1996. "A Geometrical Optics Model for Interferometric Synthetic Aperture Radar Height Measurements For Urban Areas, URSI Proceeding.

Kracker, L. (1999). The Geography of Fish: The Use of Remote Sensing and Spatial Analysis Tools in Fisheries Research. *The Professional Geographer*, 51(3):440-450.

Liverman, D. E. Moran, R. Rindfuss and P. Stern, eds. 1998. People and Pixels; Linking Remote Sensing to Social Science. National Academy Press; Washington, DC.

Lubin, D., Ricchiazzi, P., Gautier, C. and Whritner, R. (1994). A Method for Mapping Antarctic Surface UV Radiation Using Multispectral Satellite Imagery in C. Weiler and P. Penhale (eds.), *UV Radiation and Biological Research in Antarctica*, 62. Washington, D. C.: American Geophysical Union, 53-81.

Marine Technology Society and IEEE Oceanic Engineering Society (2000). Proceedings of Oceans 2000: MTS/IEEE, Providence, Rhode Island.

National Research Council (1988). *The Mid-Ocean Ridge: A Dynamic Global System*. Washington, D. C.: National Academy Press.

Psuty, N.P., Steinberg, P., and Wright, D.J. (in press), Coastal and marine geography, in Gaile, G.L. and Willmott, C.J. (Eds.) *Geography in America at the Dawn of the 21st Century*, New York: Oxford University Press.

Ricchiazzi, P. and Gautier, C. (1998). Investigation of the Effect of Surface Heterogeneity and Topography on the Radiation Environment of Palmer Station, Antarctica, with a Hybrid 3-D Radiative Transfer Model. *Journal of Geophysical Research*, 103: 6161-6176.

Schweizer, D., and Gautier, C. (1997). Ocean Expeditions: El Niño, in *6th Symposium on Education, American Meteorological Society*. Long Beach, California: American Meteorological Society, 1-10.

Siegel, D., and Michaels, A., (1996). On Non-chlorophyll Light Attenuation in the Open Ocean: Implications for Biogeochemistry and Remote Sensing. *Deep-Sea Research*, 43: 321-345.

Smith, R., Baker, K., Byers, M. and Stammerjohn, S. (1998). Primary Productivity of the Palmer Long Term Ecological Research Area and the Southern Ocean. *Journal of Marine Systems*, 17: 245-259.

Stammerjohn, S., and Smith, R. (1996). Spatial and Temporal Variability of Western Antarctic Peninsula Sea Ice Coverage, in R. Ross, E. Hofmann, and L. Quetin (eds.), *Foundations for Ecological Research West of the Antarctic Peninsula*. Washington, D. C.: American Geophysical Union, 70: 81-104.

Vallega, A. (1999). Ocean Geography Vis-à-vis Global Change and Sustainable Development, *The Professional Geographer*, 51(3): 400-413.

Washburn, L., Emery, B. and Paduan, J. (1998). Preliminary Results from an Array of HF Radars for Mapping Surface Currents in the Santa Barbara Channel, *Eos, Transactions of the American Geophysical Union*, 79: F393.

Wright, D.J. (1999) Getting to the Bottom of it: Tools, Techniques, and Discoveries of Deep Ocean Geography. *The Professional Geographer*, 51(3): 426-439.

Wright, D.J. and Bartlett, D.J. (eds.) (1999) Marine and Coastal Geographical Information Systems. London: Taylor & Francis.