LTER Network Office Remote Sensing, GIS and Technological Coordination Background

John Vande Castle, 2/96 - last edited 8/2008

Introduction

The LTER Network Office (LNO) installed Geographic Information System (GIS) technology in support of Network level research at the same time that individual LTER sites were funded through technological improvement supplements for electronic networking, Geographic Information System, and remote sensing image processing technology. Support for the LTER Network follows guidelines outlined in early technology development reports. LNO has integrated this activity within the framework of the LTER Network Information System (NIS) and continues to update access to data and information as the NIS evovles.. The goal of the work is to assist the research of the sites by facilitating technical aspects of GIS/RS data and tools. The aim is to cover aspects of GIS/RS that is useful to the LTER Network as a common group, more than aiding any individual site research program - although this type of assistance is given when needed. This report is meant to be a short example of information for reference and review. It is not a comprehensive list of all ongoing activities at LNO, but presents a few key examples of some of the Network level service and research support provided by LNO.

The focus for remote sensing and GIS activities at LNO is for data acquisition and the cross-site, large-scale collaborations which are afforded by these data. More important is a focus for linking the technically oriented scientists specializing in these data with other ecological researchers. GIS information at the national and global scale is highly specialized and complex. Recognition of this requires a need to create ties with key leaders of remote sensing and GIS activities in national, and more recently international programs. Such links have been made to both commercial and government programs, in particular to various programs within NASA, the USGS - in particular Oak Ridge National Laboratories (Oak Ridge DAAC), the EROS Data Center, programs at NOAA, and to commercial providers of remote sensing and GIS data. In addition, close contacts with lead software vendors for tools used in remote sensing and GIS work, have been established in both the commercial and public sector. LNO has acquired beta versions of major software (Arc/INFO, ERDAS, ENVI, etc.) and has worked closely with the companies - providing feedback on the utility of the software for large-scale ecological research. The variety and amount of GIS data in use by LNO has made extensive use of the various software tools. Communication and assistance with LTER site personnel has also been a key role of the work at LNO - assisting with data access (those archived here at LNO, as well as where to locate other data), data distribution, data archive, and access to software.

NASA Linkages

Early work with NASA has been a very fruitful collaborative research effort for LTER Network as a whole, as well as individual site programs. More complete information can be found on the "LTER/NASA page". Rather than being just an exercise in data

access, this work is a true collaboration, with NASA viewing the LTER Network as an important link for their research programs with the LTER Network benefiting from the expertise of NASA scientists. More important to the data access has been linking various levels of expertise within the NASA programs with LTER science. An example of this is within the sun photometer activity (described later) where the technical and scientific expertise of NASA has provided a springboard for important satellite data correction information, and in exchange, an important link by NASA to LTER researchers on the ground. Individual site programs have acquired specialized aircraft and satellite data ranging from digital high resolution AVIRIS to experimental MODIS simulator data. Future work is planned to encourage collaboration of these more experimental datasets. For the present, collaborations with more operational data sources such as Landsat-TM and NOAA-AVHRR data are underway between NASA-EOS and LTER. All LTER sites were included in work with the NASA global change program. In part of this work, NASA paid for, and provided full Landsat-TM scenes for all of the LTER sites, with most sites receiving multiple scenes during 1992 and1993. More recently additional dataset during 1993, and 1995 have been acquired with atmospheric correction of Landsat-TM data as part of a NASA grant (Vande Castle and Vermote). Most sites are also included in the NASA Pathfinder programs, where historic and present Landsat and AVHRR data are acquired for comparison with ground based measurements. Interactions with the NASA ORNL DAAC has resulted in the inclusion of all LTER sites for extraction of MODIS time series datasets, and coordination with the NASA/MSFC has resulted in the inlcusion of targeted photography for LTER sites in the operational science plan of the International Space Station. These activities with NASA are expected to continue and expand.

Data Acquisition

Regular acquisition of data from the Thematic Mapper (TM) sensor system of the Landsat series of satellites was seen as an important source of unbiased, systematic, and comparable data for use by the LTER sites. This need was documented in past technology reports known within the LTER Program as the Shugart report and the Gosz report. Information regarding this and past recomedations for remote sensing and GIS for LTER sites can be found in the initial document for the "Minimum Standard Installation" know as the **MSI**. This need was explored further in an LTER funded workshop lead by John Aber resulting in the initial acquisition plans. Since the data were originally expensive, proprietary, and difficult to acquire, LNO started an initial acquisition of these data for each site in 1991. The details of the acquisition were presented at meetings and published in proceedings volumes for reference (ERDAS users group - Atlanta, 1991; GIS/LIS, 1991). At that time special license was arranged to enable all LTER Landsat data be used by any LTER site. This was a large change in EOSAT policy, and lead to further changes in data licenses by other groups (such as state-wide TM purchases by USGS "GAP" researchers). The data acquired were screened for cloud cover (almost 50% of scenes deemed acceptable by EOSAT were returned for reacquisition), sent to the individual sites, and placed online via optical disk of the LTERnet information server (this has since been moved to an external mass storage system described later). High resolution SPOT-HRV data have been acquired for most sites in 1991 with similar license arrangements as those for

the EOSAT TM data. These data provide panchromatic 10m resolution data - a substantial improvement over 30m TM data. Again these data were distributed to the sites and placed online. The LTER remote sensing archive originating from the initial Landsat and SPOT data acquisition for all LTER sites in 1991 and continued with data acquisition for research projects at the LTER sites the LNO. From a series of efforts by LNO with NASA headquarters, research collaborations, particulary with the NASA AERONET project, and with atmospheric corrections projects lead to use of a large number of Landsat and other remote sensing data. Full Landsat-TM scenes (primarily 1992 and 1993) were acquired for all of the LTER sites, some providing multi-temporal data which was extremely important for future seasonal change and cross-site comparative research. All of these data were distributed to the sites, documented, and placed into on-line mass storage at LNO. With the changes in licensing of Landsat data, the data can now be shared without restricition, unlike other forms of data such as SPOT or IKONOS data. The continues to be recommendations from LTER committees and groups for regular acquisisition of Landsat data for LTER sites. After the data distribution of these data was transferred to the Eros Data Center NASA DAAC, these data become somewhat affordable. However, even with the reduced cost of only about $500/scene, it still meant a total cost of over $50,000 to do this for all sites, assuming about 4 usable scenes on average for all 26 LTER sites.With the more recent change in distribution policy where Landsat data can be downloaded without charge, it is time to revisit the recomendations to acquire Landsat data for all LTER sites. This will be an issue for the LTER Network Information System Advisory Committee (NISAC) to consider now that the LTER Technology Committee has been disbanded. The Committee should consider if it is usefull to organized a single collective repository of Landsat data for all LTER sites, with the conisderation that all of these data can be acquired by the individual sites. An advantage here is that the data could be used more easily for collaborative research within the framework of the LTER Decadal Plan. If this were thought to be important, LNO would require resources to search, download and store these data locally, and integrate the data withing the framework of the LTER Network Information System.

AVHRR (Advanced Very High Resolution Radiometer) data come in many forms since these data are from a public domain, operational satellite program covering the earth more than once/day. Most useful for LTER research are those data ingested and processed by USGS/EDC in Sioux Falls, SD. A number of single pass satellite images have been acquired for comparison with other data, but the operational processing of the raw data into 1km vegetation index data (NDVI) has been relatively simple to acquire. Since 1990, these data have been ordered on CDROM, sent to the sites, and preserved offline at LNO. Ancillary data comprise most of the CDROM information. The actual NDVI data are relatively small (2-3gb total), and these data have been subset from all CDROMs and placed online. A few AVHRR datasets have been acquired from NOAA (LUQ for instance is only contained in the NOAA data acquisitions), and future plans may involve use of these data for sites outside of the US continent. With the advent of MODIS data, more recent AVHRR data haven't been acquired. The LTER NISAC committee should also consider the options involved in

acquiring AVHRR as well as MODIS data for LTER sites.

Research Support

One large task at LNO is to provide general information regarding remote sensing and GIS research questions. This is primarily a consulting task, but is also a large part of the on-going data acquisition, data access, and research work at the sites as well as here at LNO. In 1992, LNO supported the sabbatical research of Dr. John Magnuson from NTL-LTER. This research involved an extremely intensive research task to process and classify full Landsat-TM scenes for regional comparison of the sites. The initial work generated over 6gb of processed data. Since his sabbatical, this collaboration has been maintained, and much of the data reprocessed to take advantage of the tools in more recent software. For instance, a serious limitation to this research was the need to convert all model output to 8 bit data. The newer NDVI calculations (numbers ranging from -1.0 to +1.0) can be easily stored unchanged as floating point numbers, eliminating a number of serious processing limitations. All of the reprocessed data are kept in mass storage - an additional 9gb of data.

GIS Data Archive

Most GIS data archived at LNO are stored in the original format supplied by vendors or archive centers. The LNO GIS data archive serves a number of purposes. It is a repository for data that is referenced in published research (see bibliography below). Another important purpose is to simply presearch the data that has been acquired for historical purposes. Following the data policy of “non throw away” data for LTER, these data are maintained in an online archive and are frequently accessed for student and research use. The LTER remote sensing data and the various projects they originated from have been used extensively for various LTER site landcover assessments and experiments and have resulted in a variety of publications from both LTER, NASA and other researchers (Vande Castle, 1995, 1996,1998, 2003, Asner and Heidebrecht, 2002, Pennington et al., 2002, Riera et al. 1998, Quadrari and and Vermote, 1999, Thomlinson et al. 1999, Olson et al., 1999, Vande Castle and Vermote, 1996). The archive maintained at LNO has been an important source for intersite research as well as a known location of these data for the sites. LNO receives regular requests for data as well as replacement copies of the data from individual LTER sites.The purpose of this is to maintain the original data format until a truely universal data format is accepted by researchers and GIS software vendors. Original data supplied in tape format (i.e. 6250BPI reels) have been read to disk and with a backup version on 8mm tape. All data are currently stored on-line in a distriburted RAID system and made available through the LTER public webpages for GIS/Remote Sensing data. Backup for the data follow standard LNO data backup policies for all of its servers.

Documentation and WWW:

Documentation of the GIS data has been an on-going and time intensive effort due to the large amount and variety of data archived. For example, the current data archive is in the range of 1Tb - most of it imported, viewed, and used in metadata generation. For the remote sensing image archive, all raw documentation data, (generally tape

header files) have been stored with the imported scene data. This information has also been translated to so it can be viewd directly on the Web. All Landsat-TM and SPOT image have been subset and stored as .gif files, to use as browse images for reference. The combination of this information - image file, .gif browse image, raw header file, and translated html documents comprise information for the metadata currently used to document the remote sensing data archive. Actual data access is restricted by access permission on the LTERnet information server by conventional computer security procuedures. Primarily this means that complete access to **information** is available though anonymous ftp, WWW services. **Actual data** access to maintain license restriction where they exist are controlled by access permission where needed on the file server and mass storage archive. All data are stored on the LTER server in the directory/folder /archive, and stored within that folder by site acronym. All of these data are made available on the LTER GIS/Remote Sensing web page.

The important understanding of the long-term implications of this data storage is well noted at LNO. These formats will change over time, but the need for a common archive format now, is required simply because it is not practical to attempt a data archive in the many formats that are present for these data. This "active" archive is expected to change with time, and if a common data format for storage of these data becomes a true standard, these data will be translated. Currently all LTER remtoe sensing data maintianed by LNO is documented both within the LTER Technoloyg pages as well as by Ecological Metadata Language (EML) documentation. The data are registered in the LTER Metacat system and are searchable within online LTER search mechanisms.

Sun Photometer Activity

One of the more recent efforts related to satellite image data is a link to state of the art solar calibration work with scientists at NASA-Goddard. An LTER/EOS workshop at SEV-LTER identified data calibration as a major limitation to future use of satellite data. Instruments known as sun photometers are able to take measurements to estimate the exact amount of light energy present at the earth's surface at any time. These automated instruments collect solar information every 15 minutes and transmit this information via satellite to NASA-Goddard for processing. The processed data are mirrored (as well as the "demonstrat" processing software) on the LTERnet system. The raw data are accessed by graphical interface on the AERONET web page maintained by NASA. These data are used to estimate particulate and water vapor constituents in the atmosphere (the two primary sources of optical interference). This information is then used to estimate the exact energy levels reaching the earth, which can then be converted to fit the wavelength and bandwidth of the various satellite sensor systems. This final "product" is shown in figure 4. Since the initial Sunphotometer work, NASA has expaned this to a large "AERONET" program. The Sunphotometer project also initiated a small "atmospheric correction" project to produce atmosphericly corrected Landsat-TM data. These additional datasets are maintained on-line, and the final modified TM data are available in the public domain.

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