USGS
science for a changing world

EROS

National Center for Earth Resources Observation and Science

2004 Annual Report

U.S. Department of the Interior
U.S. Geological Survey

National Center for Earth Resources Observation and Science

Strategic Plan 2005-2010

Vision

EROS is the world's leader in monitoring and assessing the Earth's landscape.

Mission

EROS resources are dedicated to greater understanding of the Earth's land resources through excellence in science, data management, infrastructure, and facilities devoted to evaluation and assessment of land changes and their impact on our society. Key elements of this mission include:

- **Earth Observation:** Observe the Earth at all scales to ensure availability of historical and current observations.
- **Terrestrial Monitoring:** Characterize and quantify land surface status and trends to provide a framework for studies at local to global scales.
- **Vulnerability Assessment:** Study impacts of population, environment, and economy to assess vulnerability to changes in climate, water, carbon cycle, ecosystems, invasive species, and other societal concerns.
- **Emergency Response:** Apply remote sensing technology and geospatial information to enhance the scientific basis for risk assessment and emergency response related to natural and human-induced hazards.
- **Data and Information Management:** Preserve remote sensing and geospatial data and information and provide timely and ready access for a broad range of users and applications.
- **Training and Assistance:** Promote the use of remote sensing technology by government, academia, private sector cooperators, state and local institutions, the international community, and customers through training and assistance to our partners.

To accomplish our mission, EROS will acquire, develop, evaluate, and apply information technology, advanced systems and tools for processing and disseminating remote sensing data and information in partnership with U.S. Geological Survey (USGS) disciplines, other Department of the Interior (DOI) bureaus, other government agencies, international scientists, academia, and industry.

About the Cover

The Lewis and Clark Expedition was the first of many government surveys of natural resources in the American West. The U.S. Geological Survey (USGS) was established on March 3, 1879 in response to a report from the National Academy of Sciences, which had been asked by the Congress in 1878 to provide a plan for surveying and mapping the Territories of the United States that would secure the best possible results at the least possible cost. The USGS continues to serve the nation as an independent fact-finding agency that provides scientific understanding about natural-resource conditions, issues, and problems. Because of its origin in natural resource surveys and the similarity of the USGS mission to Thomas Jefferson's charge to Meriwether Lewis, the USGS can be seen as the organizational successor to Lewis and Clark.

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Part 1: INTRODUCTION

Executive Summary

This report provides a brief overview of the scientific achievements at the U.S. Geological Survey (USGS) National Center for Earth Resources Observation and Science (EROS) during fiscal year (FY) 2004. It is not intended to be a presentation of every project or every milestone achieved during the fiscal year, but rather a representation of the range and scope of science being accomplished at EROS. The report also does not attempt to reproduce material from the myriad of scientific papers created as a result of the research done at EROS; Web links are provided in the report for that purpose.

In keeping with our national mission of providing world-class Earth resources observation and science, we have divided the report into three major categories: Remote Sensing Achievements, reflecting our original mission to receive and interpret data from Earth-observation satellites; Land Science Achievements, which report the practical applications of the data received, stored, and studied at EROS; and Information Science Achievements, a commentary on the constantly-evolving methods of digital distribution and utilization achieved by EROS scientists across a wide spectrum of customers, government partners, and constituent organizations.

In addition, we have here reported on the ongoing success of our Native American Initiative, forging partnerships and land science programs with tribal governments and Indian communities across America.

We welcome comments and follow-up questions on any aspect of this Annual Report and invite any of our customers or partners to contact us at their convenience.

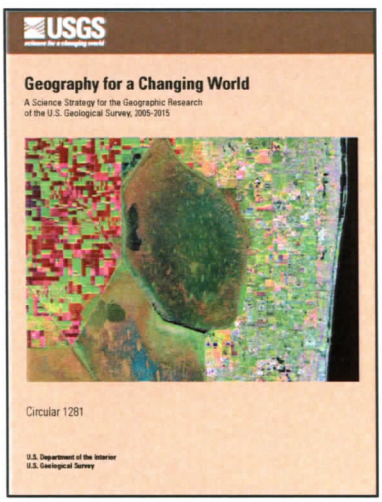
U.S. Geological Survey: Science for a Changing World

Excellence in Science, Responsiveness to World Needs

The National Center for Earth Resources Observation and Science (EROS) is a U.S. Geological Survey (USGS) facility. USGS was established by Congress in 1879. The USGS provides geologic, topographic, biologic, and hydrologic information to the nation. In the modern era, the USGS has emerged as a leading force in the use of digital technology, applied to solutions to scientific challenges in the United States and around the globe.

The USGS coordinates its efforts with more than 2,000 agencies at the federal, state, county, and municipal levels, along with other nations and international organizations. USGS headquarters are in Reston, Va., with regional centers in Menlo Park, Calif.; Denver, Colo.; and Reston. USGS field offices are located in all fifty states, the Commonwealth of Puerto Rico, and the Trust Territories of the Pacific. To learn more about USGS services and programs on the World Wide Web, go to www.usgs.gov.

In national science facilities such as EROS, the USGS is creating a new generation of practical knowledge that is being applied to solve global challenges, such as world hunger, disaster response, land use changes, volcanic and seismic prediction, and forest management and fire control. Working with other governmental agencies, the USGS is making America a better and safer place to live.



Geography for a Changing World: A Science Strategy for the Geographic Research of the U.S. Geological Survey, 2005-2015 documents the long-term vision, mission, and goals of the UGSG Geography Discipline. The goals and actions presented in the plan are consistent with national science priorities and the Department of Interior and USGS missions, take advantage of existing expertise, and lead to the strengthening of critical geographic research capacities that do not exist in other USGS disciplines.

A New Charter for the National Center for EROS

On August 17, 2004, the Director of the U.S. Geological Survey (USGS) announced the decision to establish the EROS Data Center as a "national capability" of the USGS. The EROS Data Center is a national data reception, processing, archiving, distribution, and research facility for remotely sensed data and other forms of geographic information. It holds the world's largest collection of civilian remotely sensed data covering the Earth's land surface, archiving millions of satellite images and aerial photographs. This archive, collocated with its attendant engineering and scientific expertise, provides a unique capability for developing and promoting science applications of remotely sensed data to identify, monitor, and understand changes on the landscape and across the interface between nature and society. Formerly the Earth Resources Observation Systems Data Center, the Center will rededicate its resources and capabilities to become the National Center for Earth Resources Observation and Science (EROS).

As a national capability, EROS will focus on the development and implementation of remote-sensing-based terrestrial monitoring capabilities to address national and international science and land management issues of concern to the U.S. Department of the Interior (DOI), other federal agencies, and the public-at-large. EROS will bring to bear its unique combination of existing capabilities and expertise in geographic information sciences, remote sensing technology, data acquisition, systems engineering, information access and management, and archive preservation. Through its diverse multidisciplinary science staff, EROS will provide an effective and

The National Center for Earth Resources Observation and Science (EROS).

critical link between remote sensing tools and techniques and interdisciplinary science needs. EROS will also assume an important role in establishing national priorities for existing and proposed land remote sensing systems based on the terrestrial monitoring requirements of the USGS and other bureaus within the DOI. EROS will leverage its existing infrastructure to access, archive, process, and distribute national and global remotely sensed data, and will work with the USGS Geospatial Information Office and external partners to implement key information technology and data management capabilities.

As a national capability, EROS will work directly with USGS national programs and the associated USGS science disciplines to develop and enhance the terrestrial monitoring capabilities of the USGS via land remote sensing systems, data streams, allied technologies, and partners. EROS will work to expand and enhance the beneficial use of remotely sensed data as tools of Earth and biological science by providing scientists and managers with a variety of remote sensing education and training resources and opportunities. EROS will work with USGS regional executives to ensure that regional monitoring requirements take advantage of existing, cost-effective, remote-sensing-based systems, whenever and wherever appropriate, as well as to ensure that those requirements are considered in the design, development, and exploitation of new systems. EROS will also work to ensure that resultant regional monitoring capabilities are designed to enable integrated science across regions and at national scales. EROS will continue to leverage reimbursable collaborations and external partnerships that advance and facilitate development and implementation of new USGS mission-relevant, remote-sensing-based monitoring capabilities.

The National Center for EROS: A New Mission

As the world's largest—and fastest growing—archive of remotely sensed images of Earth, the National Center for Earth Resources Observation and Science (EROS) has a mission and a vision to make that archive a vital element in the understanding and intelligent use of our global resources. Through the work of hundreds of scientists at EROS, and thousands more employing EROS data and images around the world, we are moving closer to an understanding of the forces of nature.

As a national science resource, EROS will continue to support and enhance the work of government agencies, scientific research organizations, international efforts, and private sector customers by improving access to accurate, timely, and effective land information. Through its partnership with National Aeronautic and Space Administration (NASA), EROS is employing cutting-edge technology to analyze, catalog, and interpret the terrestrial changes and challenges we face today.

Excellence is our goal; innovation is our watchword; and service is our mission in fulfilling the role that the U.S. Geological Survey (USGS) has entrusted to us. Through the pages of this report, you will discover that EROS scientists are vital partners in the global research that is defining and creating a new understanding of our home planet.

Part II: Fiscal Year 2004 in Review

Land Science Achievements

Gulf of Mexico Estuaries: Tampa Bay Integrated Science Study

Initial urban growth model analyses indicate the impact of urbanization has negatively affected the extent and distribution of sea grasses in the Tampa Bay, Fla., estuary. Urbanization is also modifying the regional climate through the formation of heat islands and changes in precipitation patterns. Vulnerability assessments of population and construction on the mix of natural and man-made hazards characterizing the Tampa Bay watershed are continuing with the acquisition of information on historic land use, landfills, sinkholes, and storm drains and outflow points around the bay. Present and predicted urbanization, together with selected socioeconomic variables of the population, are included in the study. A new 10-meter (m) topographic-bathymetric seamless digital elevation model is being created for the watershed (fig. 1). For more information, contact Michael Crane, USGS EROS, 605-594-6041, mpcrane@usgs.gov.

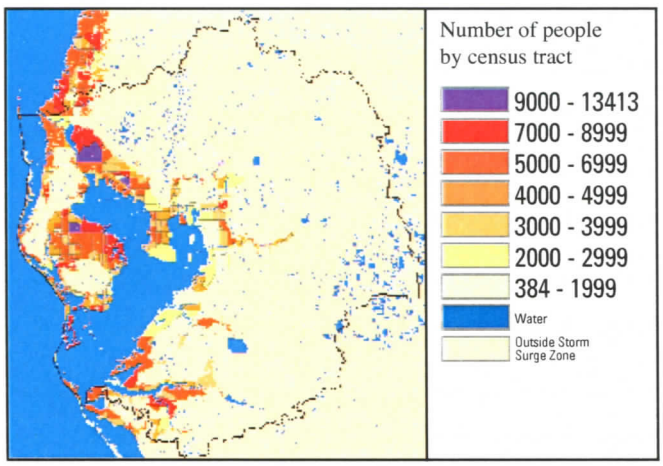


Figure 1. Population of the Tampa Bay, Fla., watershed residing in the maximum hurricane storm surge zone (Census 2000).

The National Land Cover Database

The National Land Cover Database project compiles various types of land cover information across all 50 states and Puerto Rico, using a partnership of eight federal agencies and private outsourcers with the U.S. Geological Survey (USGS) as lead. This database captures type of land cover (fig. 2), proportion of urban development, percentage of impervious surface (fig. 3), and proportion of trees (fig. 4) for every 1-acre and larger patch across the United States. This information is used in a tremendous variety of applications among federal, state, and private organizations for programs as diverse as pesticide management, fire risk modeling, watershed runoff modeling, wildlife habitat characterization, and economic development.

By the end of fiscal year (FY) 2004, 15 percent of Alaska had been completed, and 42 percent of the continental United States. Current FY 2005 plans include completing 35 percent of Alaska, and up to 75 percent of the continental United States, with FY 2006 plans including the completion of 55 percent of Alaska and 95 percent of the continental United States. For more information, contact Collin Homer, SAIC at USGS EROS, 605-594-2714, homer@usgs.gov.

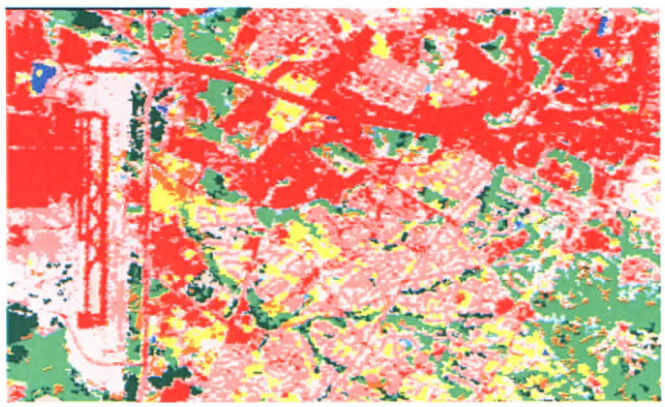


Figure 2. Land cover.

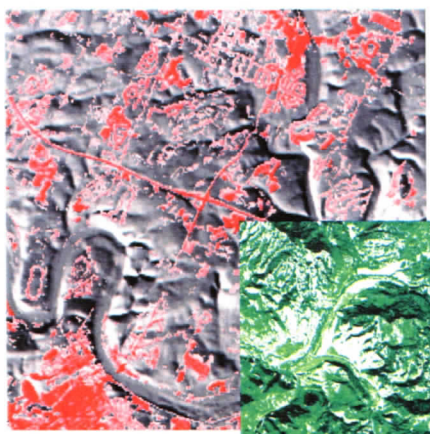


Figure 3. Percentage of imperviousness.

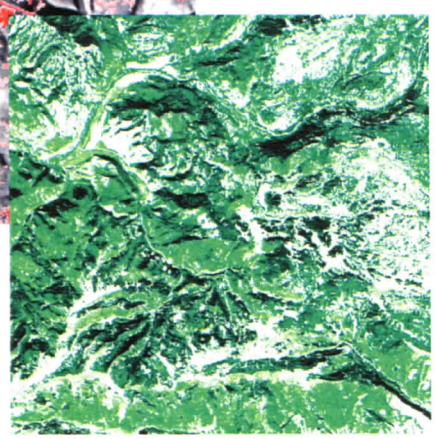


Figure 4. Percentage of tree canopy.

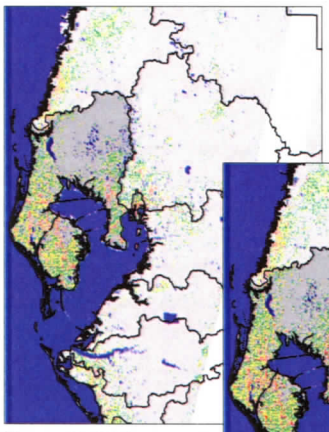


Figure 5. 1991.

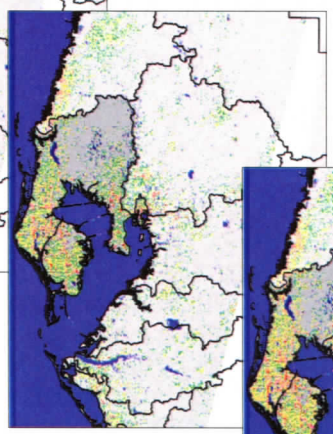


Figure 6. 1995.

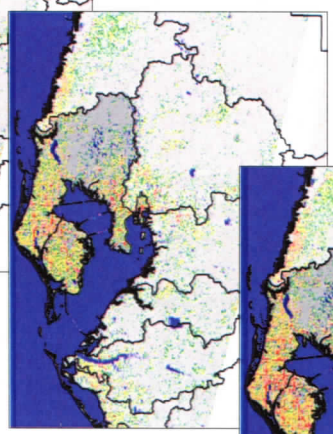


Figure 7. 2000.

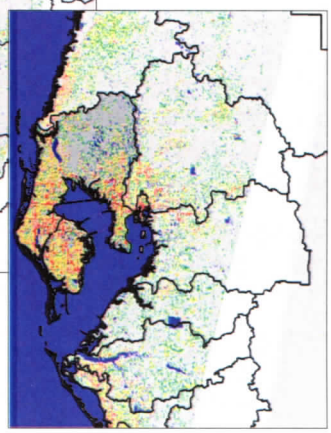


Figure 8. 2002.

Imperviousness change has been determined for the Tampa Bay, Fla., watershed for four dates from 1991 to 2002 using multi-temporal Landsat satellite data together with digital orthophotography (fig. 5-8). Within the Anclote River Basin, highlighted in darker gray, medium to high imperviousness increased about 100 percent during this timeframe (fig. 9).

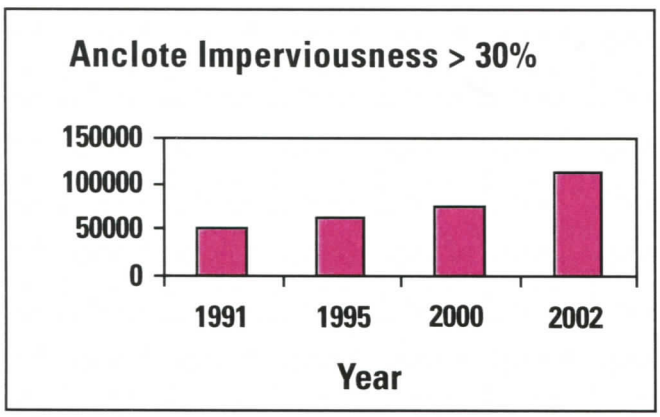


Figure 9. Anclote River Basin imperviousness.

These mapping results have been used in a modified version of the SLEUTH model to predict growth of imperviousness to 2025. The results of this modeling effort were presented at the American Society for Photogrammetry and Remote Sensing (ASPRS) 2004 Fall Conference in "Modeling increasing imperviousness in the Tampa Bay watershed." Future work associated with the Modeling Imperviousness task will focus on the Las Vegas, Nev., region. This phase of the project will evaluate Hyperion, Advanced Land Imager (ALI), Advanced Spaceborne Thermal and Reflection Radiometer (ASTER), IKONOS, and Digital Globe remote sensing data for mapping imperviousness.

In addition, the Military Imperviousness project has completed mapping of urban growth for the environs of Fort Bragg, N.C., for 1992 and 2002. The changes have been analyzed and will be documented in a report and poster that also includes imperviousness results for Fort Benning, Ga. For more information, contact Michael Crane, USGS EROS, 605-594-6041, mpcrane@usgs.gov.

Research on Amphibian-Landscape Relationships

In response to concerns about amphibian declines, research is being conducted to better understand how amphibians interact with the environment. The Geographic Analysis and Monitoring (GAM) Program's focus on landscape change and the Wildlife Program's interest in determining the status of U.S. amphibians have fostered an interdisciplinary approach that merges remote sensing of land characteristics with field and laboratory measurements of amphibian biophysical response to environmental conditions (fig. 10). In FY 2004, scientists from the USGS Geography and Biology disciplines, working with university researchers and Yellowstone National Park managers, applied this approach to determine ways in which different amphibian species use Yellowstone's landscape. Much of the environmental data used in this research has been compiled for national coverage and is available to scientists through an interactive Web application (http://gisdata.usgs.net/website/armi/). For further information, contact Alisa Gallant, USGS EROS, 605-594-2696, gallant@usgs.gov.

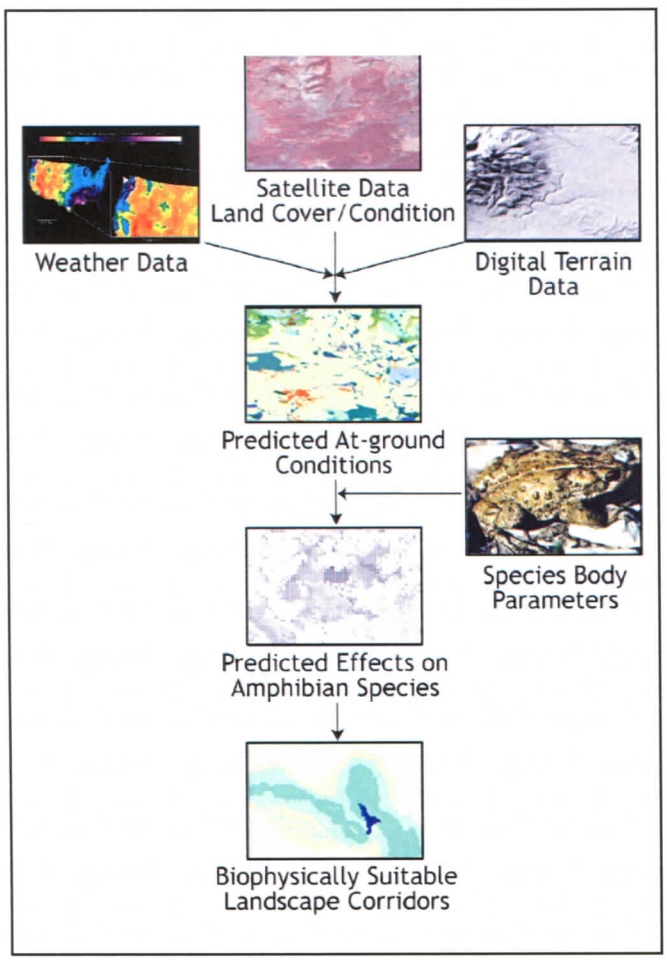


Figure 10. Satellite data are merged with terrain and weather data to predict at-surface conditions and effects on amphibians. This is coupled with information on amphibian behavior to determine the parts of the landscape most suitable for amphibian use.

Land Remote Sensing Applications

Geologic Applications of Remote Sensing Technology

Scientists at the National Center for EROS are developing and improving remote sensing techniques for terrain deformation mapping and investigating the use of multi-temporal Synthetic Aperture Radar (SAR) imagery over land cover types such as coastal wetlands. These areas have proven difficult to map with electro-optical methods. Scientists are improving numerical modeling techniques to better understand the mechanisms driving tectonic, hydrologic, and volcanic processes based on SAR and Interferometric Synthetic Aperture Radar (InSAR) data. They are making progress in the refinement of Interferometric Point Target Analysis (IPTA) techniques that offer the potential to monitor movement of man-made structures with an accuracy of a few millimeters. This order of accuracy enables them to monitor hazardous areas such as seismically active faults, areas of subsidence, slope instability, volcanic deformation, and building stability.

Other work involves investigating the polarimetric and interferometric characteristics of SAR imagery for determining land cover classes, performing flood assessments, and measuring soil moisture. Scientists are evaluating new and future SAR systems in terms of the systems' capabilities for supplementing existing land cover mapping technologies, classifying wetland resources, mapping surface hydrology variables, and as a tool for mapping wildfires during conditions that hinder the use of optical imagery. In addition, scientists can now combine information from multispectral Landsat-7 data with SAR images to map lava flows of active volcanoes (fig. 11 and 12).

New Orleans Subsidence

This project investigates the utility of radar interferometry for characterizing land subsidence in coastal Louisiana, an area of vast wetlands. In-situ measurement of water level over these wetlands is cost prohibitive, which explains the lack of stage-recording instruments throughout the region. As a consequence, it has been difficult to measure changes in the water level and water storage capacity of these wetlands, leading to questionable results from hydrologic models.

In the course of processing C-band European Remote Sensing (ERS)-1 and ERS-2 Satellite SAR images for this project, it was unexpectedly discovered that InSAR images were sharp enough to allow measurement of changes in water level over swamp forests composed of moderately dense trees with a medium-low canopy closure in southeastern Louisiana. The study area consists of sugar-cane, field-sand swamp

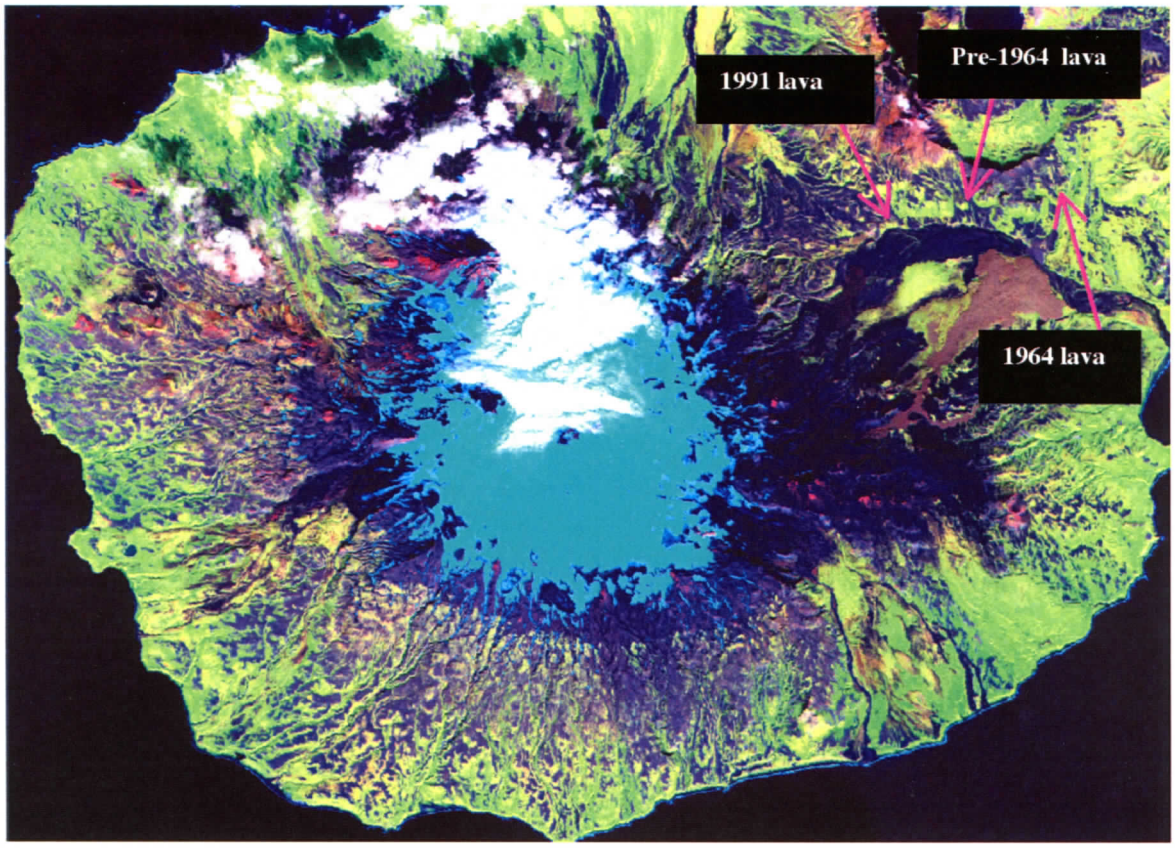


Figure 11. A September 16, 2000, Landsat-7 Enhanced Thematic Mapper Plus (ETM+) image of Westdahl Volcano, Alaska, with three distinct lava flows visible.

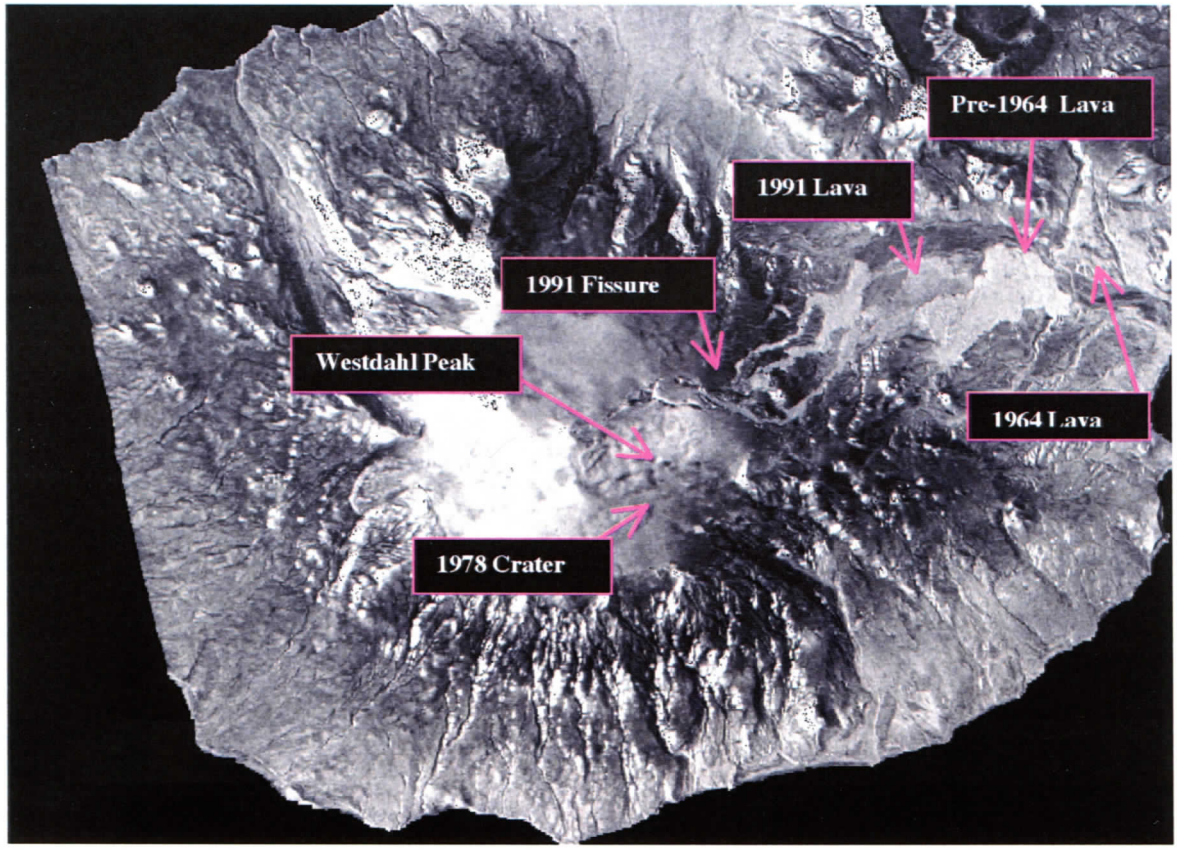


Figure 12. Compare the content of this January 1992 SAR image of Westdahl Volcano, Alaska, to the Landsat-7 image in Figure 11.

forests. The forests are of moderately dense trees ranging from 10 to 25 m in height with a medium-low canopy closure. The interferogram in figure 13 was generated from two C-band SAR images acquired on January 5 and March 16, 1997, with a temporal separation of 70 days and a perpendicular baseline of 70 m. A full cycle of colors (called a fringe), ranging from red, yellow, green, blue to purple, represents a 2.8-centimeter (cm) change in range distance (from the satellite to the ground) or a 3.1-cm vertical displacement. Areas of coherence loss occurred primarily over non-flooded forests, and these areas are uncolored.

The results of this research demonstrate that (1) moderately dense swamp forests with a medium-low canopy closure permit double-bounce returns for C-band radar, and (2) C-band InSAR images can measure change in water levels beneath moderately dense tree

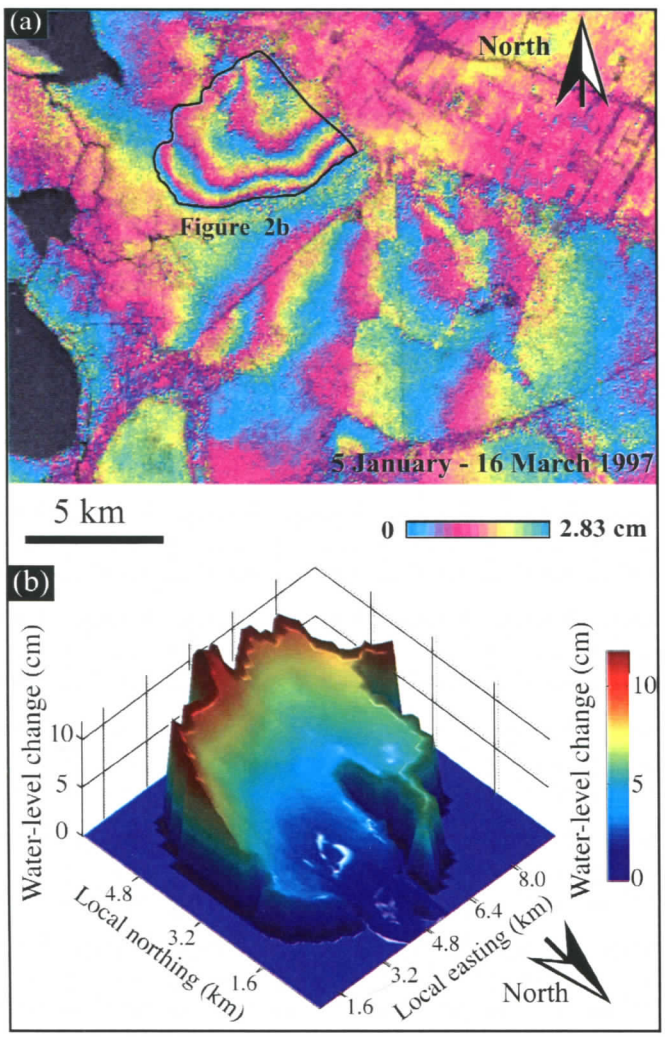


Figure 13 (a) and (b). C-band (wavelength of 5.7 cm) interferogram (a) showing changes in water level over swamp forests between Jan. 5 and Mar. 16, 1997. The interferogram was produced from radar images from the ERS-2 satellite. The interferometric phase image is draped over the radar intensity image. Each fringe (full-color cycle) represents a 3.1-cm change in water level. Areas that lack interferometric coherence are uncolored. A 3-dimensional perspective view (b) portrays the changes in water level for the area outlined in (a).

cover at a greater vertical accuracy than L-band SAR due to it's shorter wavelength. For more information, contact Zhong Lu, SAIC at USGS EROS, 605-594-6063, lu@usgs.gov.

Terrestrial Deformation and Stress Analysis

The following accomplishments are a direct result of Deformation and Stress activity:

- 7 peer-reviewed publications (published or submitted)
- 7 conference presentations (delivered or submitted)
- 6 peer reviews for proposals or journal manuscripts
- 4 outreach presentations to local community schools
- 4 briefings
- 1 Web-based visualization movie
- 1 proposal submitted to the National Aeronautic and Space Administration (NASA) Mars Data Analysis Program ($306,000)

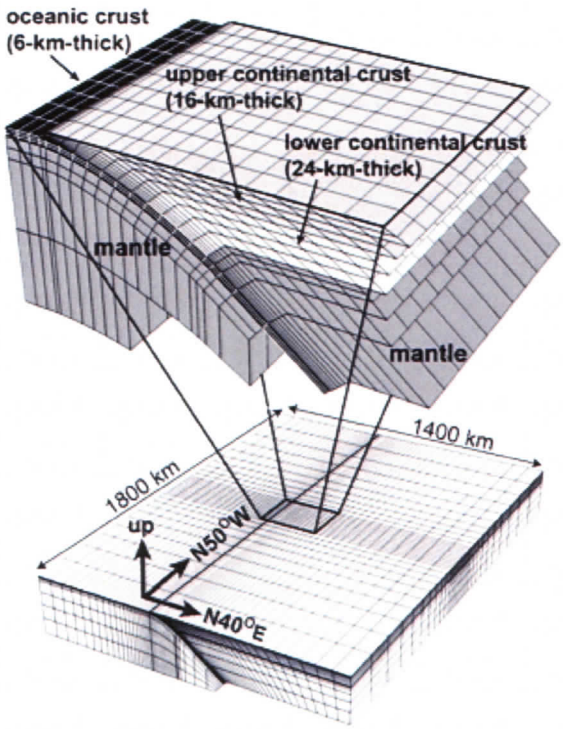
Masterlark, T., 2003, Finite element model predictions of static deformation from dislocation sources in a subduction zone: Sensitivities to homogeneous, isotropic, Poisson-solid, and half-space assumptions: *J. Geophys. Res.*, 108(B11), 2540, doi:10.1029/2002JB002296.

This publication demonstrates how innovational numerical modeling methods can improve our understanding of the occurrence and effects of large earthquakes. Precise Global Positioning System (GPS) data reveal the time-dependent surface deformation caused by the 1995 M=8 earthquake along the Middle America Trench near west-central Mexico. Inverse methods, based on advanced finite element models, allow us to understand the source of the observed deformation. Furthermore, the finite element models accurately predict an earthquake-triggering event that followed the M=8 earthquake. This publication challenges the standard and oversimplified earthquake deformation and stress models and offers more reliable alternatives. To date, the models presented in this publication are the most realistic representations of earthquake deformation in a subduction zone (fig. 14).

Masterlark, T., and Z. Lu, 2004, Transient volcano deformation sources imaged with interferometric synthetic aperture radar: Application to Seguam Island, Alaska: *J. Geophys. Res.*, 109, B01401, doi:10.1029/2003JB002568.

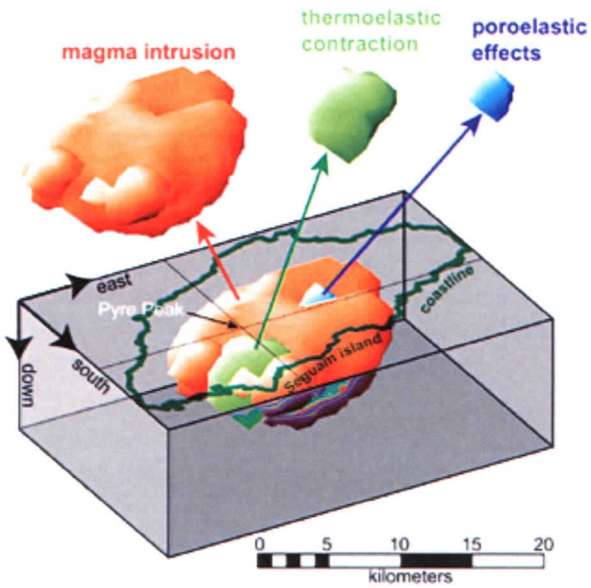
InSAR is a remote sensing technology capable of mapping deformation of the Earth's surface. Thirty InSAR images of Seguam Island, Alaska, an Aleutian

Figure 14. Finite element model.



The subduction zone of the Middle America Trench

Figure 15. Seguam Island, Alaska.



Deformation sourcces within Seguam Island, Alaska

Arc volcano, document time-dependent deformation from 1992 to 2000. The InSAR data alone are interesting, but little more than curiosities if we cannot identify the causes or sources of the deformation signals. Models provide the linkage between the deformation (what we can directly observe) and the deformation source (what we cannot directly observe). This publication uses innovational numerical models to characterize the inaccessible interior processes of the volcano that cause the observed deformation. Results of the publication suggest the InSAR data can be accounted for by separate, but interlinked, processes including magma intrusion, thermoelastic contraction, and poroelastic effects (fig. 15).

Human Health Applications

Clean Water and Agricultural Landscapes

Clean water is essential to sustaining environmental and human health. The Federal Clean Water Act requires that all states meet strict water quality standards. To meet these standards, individual states must identify, monitor, and control pollutants that impact water quality. During FY 2004, EROS collaborated with the South Dakota Department of Environment and Natural Resources (SD-DENR) and the East Dakota Water Development District (EDWDD) to

Figure 16. Landsat image.

Figure 17. Crop map.

develop crop-specific maps using Landsat satellite imagery for South Dakota water quality initiatives. Geographical Information Systems (GIS) are used to model the relationship between pollutants, such as fertilizers and pesticides, and water quality. Spatial information on crop types is essential to determine where specific agricultural chemicals are applied across the landscape. Nearly 100 satellite images were required to develop crop maps for 2000 and 2001 for South Dakota (fig. 16 and 17). An advanced object-oriented, knowledge-based approach was developed to automate much of the processing, considerably reducing the time and cost of this effort. For more information, contact Susan Maxwell, SAIC at USGS EROS, 605-594-6008, maxwell@usgs.gov.

Initiatives and Support

Habitat Analysis for Sage Grouse Protection

The USGS EROS is participating on a project that involves scientists from the University of Montana, Wyoming State Game and Fish Department, Montana State Department of Fish, Wildlife and Parks, Wyoming and Montana Bureau of Land Management (BLM), plus several private industry partners. The focus of the project is conservation planning for sage grouse in the Powder River Basin of southeast Montana and northeast Wyoming. The vision is to develop planning tools that provide land managers with the information necessary to provide the National Environmental Policy Act (NEPA) with information on sage grouse habitat and populations and ways to mitigate the effects of coal bed methane (CBM) extraction. This project tests actual CBM impacts and current BLM protective measures to enable better protection of sage grouse and their habitat facing CBM development. Detailed sage grouse habitat and population data are being linked with landscape scale vegetation/habitat maps derived from satellite imagery and aerial photography to create planning maps that prioritize landscapes for sage grouse conservation in the Powder River Basin. Linking bird-habitat relationships with spatial data will provide planners with the maps they need to expedite methane recovery from onshore federal lands while assuring effective environmental protection through research, development, and technology transfer.

USGS participation focuses on the use of remote sensing data to map sagebrush/grass habitats and CBM infrastructure in the Powder River Basin. Intensive field sampling was conducted in Wyoming and Montana during which canopy cover measurements were made in sagebrush/grass ecosystems. Land cover and canopy cover field sampling data were also obtained from the Wyoming Game and Fish Department (WGFD) and integrated with other data collected by the project.

Figures 18 and 19 are images of a portion of the Powder River Basin about 3 miles northwest of Gillette, Wyo. They illustrate the dramatic impact that CBM extraction is having on the region's habitat for sage grouse. Each image covers an area of 2.2 miles east-west and 1.9 miles north-south.

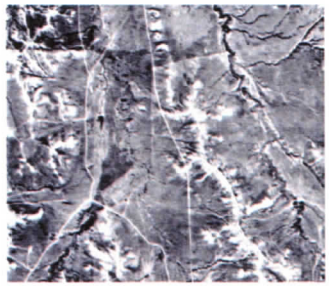


Figure 18. Black-and-white Digital Orthophoto Quarter Quadrangle (DOQQ), 1994.

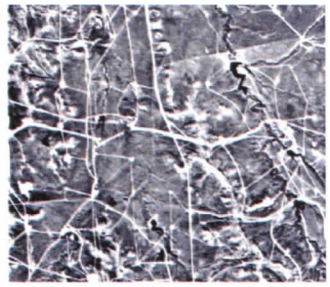


Figure 19. Red band of National Aerial Photography Program (NAPP) color infrared photo, 2001.

Biological Applications

Phenology and Drought Monitoring

Regular, repeatable Earth observations from satellites provide a strong, objective basis for terrestrial monitoring. By analyzing time-series greenness data derived from the National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) and NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) satellite-based sensors, we can identify patterns of changing vegetation conditions and research their causes. In this research, we analyze vegetation dynamics phenology for regional trends toward shorter or longer growing seasons, increasing or decreasing production, and earlier or later growing seasons.

Results indicate increasing growing season length (and corresponding increasing production) in the Great Lakes area, while there is decreasing production in the Desert Southwest. Ongoing research is designed to explain the driving forces of the phenological changes as a result of natural climatic cycles (e.g., El Niño-related fluctuations), longer term shifts in climate related to greenhouse gas buildup in the Earth's atmosphere, or because of the climatic influences of land use and land cover change.

In a cooperative project with the National Drought Mitigation Center at the University of Nebraska-Lincoln, we have developed techniques to incorporate satellite-derived phenological information with additional geographic information on soils, irrigation, land cover, and daily weather to develop a Vegetation Drought Response Index (VegDRI) for the northern Great Plains (fig. 20). This product identifies levels of drought severity during the growing season and is

updated on a biweekly basis. Research for FY 2005 involves continuing to populate the satellite-derived phenology and drought monitoring database, expanding drought monitoring to encompass the western United States, and continuing our research to identify and quantify the driving forces of terrestrial climate change. For further information, contact Brad Reed, USGS EROS, 605-594-6012, reed@usgs.gov, or Jesslyn Brown, USGS EROS, 605-594-6003, jfbrown@usgs.gov.

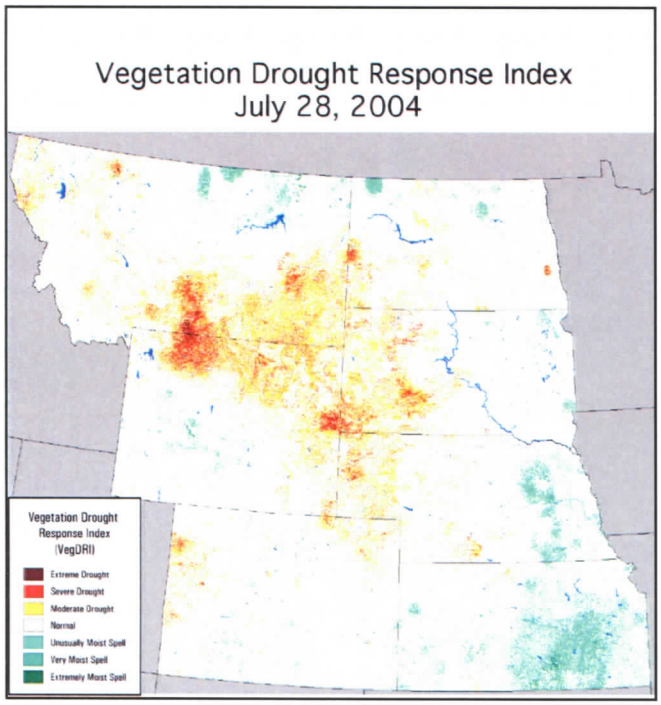


Figure 20. Vegetation Drought Response Index, July 28, 2004.

Land Cover Trends

Consequences of Land Cover Change

Research findings suggest that the conversion of natural wetlands to agriculture may increase the incidence and severity of damaging freezes in south Florida. Agricultural production in former wetlands areas now includes extensive cultivation of winter season vegetable, citrus, and sugar cane crops, but in spite of this shift southward, crops are still prone to damaging winter "radiation freezes," which occur on calm, clear nights with nocturnal cooling.

As part of ongoing research to study the consequences of land cover change on surface weather and climate variability, the USGS and Colorado State University (CSU) used regional climate modeling with historical land cover change datasets to investigate the potential link between land use change and damaging radiation freeze events in south Florida. Land cover change in south Florida over the past 100 years is illustrated in figure 21, upper panels. The figure shows USGS reconstructed pre-1900 natural vegetation versus current land use derived by the USGS from early 1990s Landsat data. The CSU model suggested that current land use of the 1990s is associated with a tendency for lower minimum temperatures with longer critical freeze duration as compared to the pre-1900 natural vegetation (fig. 21, lower panels). In addition to this winter season study, the USGS and CSU conducted a warm season study and published a paper in *Monthly Weather Review* describing the potential consequences of land cover change on the summer season weather variability in south Florida.

The USGS has also focused on the reconstruction of land cover data for the eastern United States to investigate the consequences of historical land cover change. The south Florida research has demonstrated the importance of coupled models to quantify the potential effects of land cover change. Furthermore, this joint USGS and CSU research has demonstrated the utility of the Landsat-derived National Land Cover Dataset (NLCD) as an important resource for regional coupled modeling studies. For further information, contact Louis Steyaert, USGS EROS, 301-614-6675, steyaert@usgs.gov.

Early Warning and Environmental Monitoring

Flood Monitoring in Africa

The Famine Early Warning Systems Network (FEWS NET) created regionally based flood-monitoring systems in southern and East Africa. In southern Africa, the water agency for southern Mozambique models stream flow conditions and monitors flood potential based on techniques developed by the USGS FEWS NET and transfers the data to local Mozambique institutions. Lessons learned in southern Africa have been used in East Africa, where the Regional Center for Mapping of Resources for Development (RCMRD), in conjunction with the regional FEWS NET office, is responsible for flood monitoring for the Greater Horn of Africa region (fig. 22). Flood monitoring data are developed at RCMRD and posted to the USGS FEWS NET website. The regional-based flood monitoring systems allow quicker responses to decision makers in both the United States and Africa. For more information on the USGS FEWS NET project, see:

- http://edcintl.cr.usgs.gov/fewsnet.html
- http://edcintl.cr.usgs.gov/adds
- http://edcintl.cr.usgs.gov/afghan
- http://edcintl.cr.usgs.gov/centralamerica
- http://edcintl.cr.usgs.gov/haiti

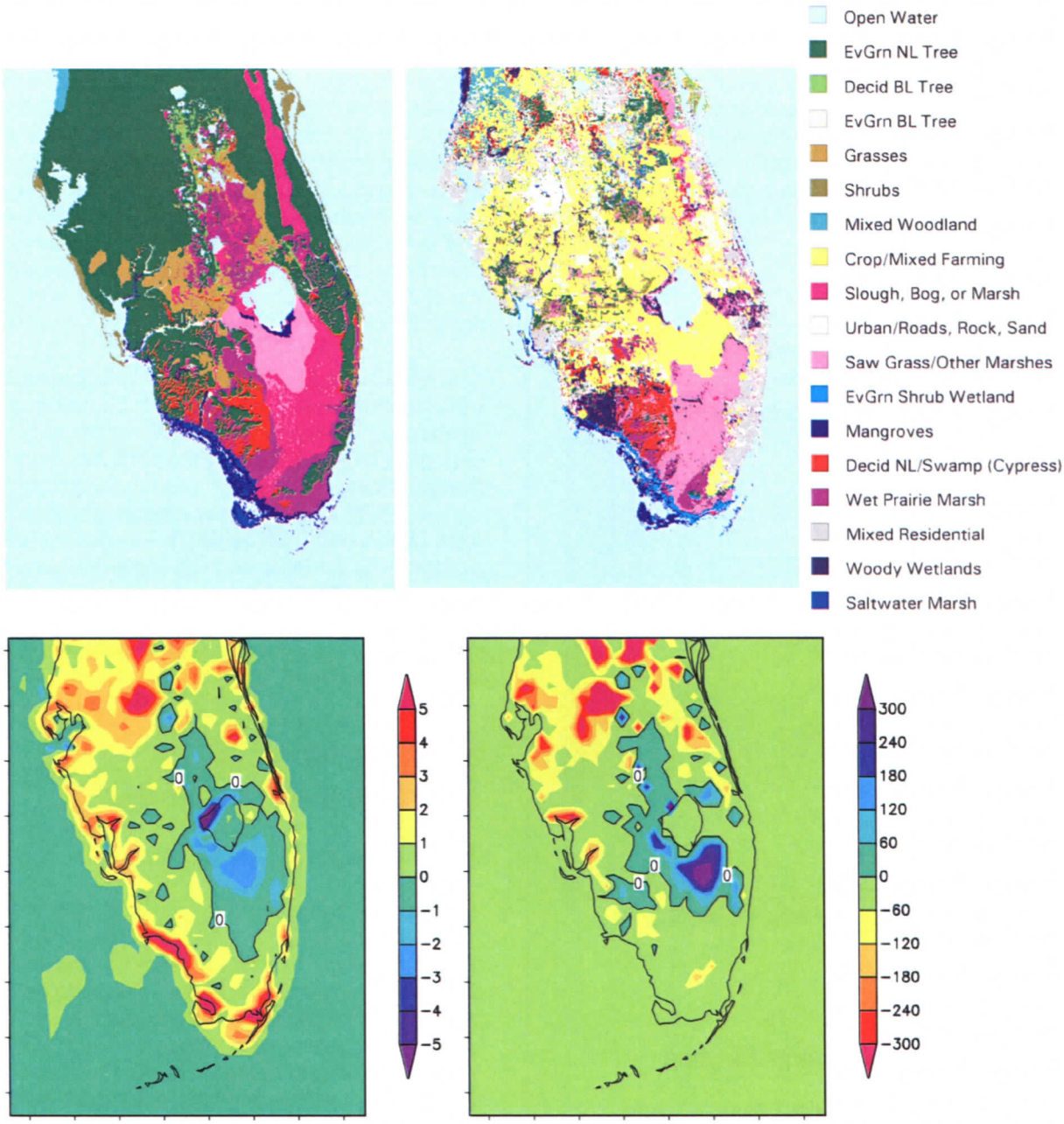


Figure 21. Pre-1900 natural vegetation and current land use derived from Landsat scenes (upper-left and upper-right panels). Model-simulated minimum temperature results showing the minimum temperature difference (current land use minus natural vegetation; lower-left panel) and difference in the duration of freeze event in minutes (current land use minus natural vegetation; lower-right panel). Source: Marshall, C.H., R.A. Pielke, Sr., and L.T. Steyaert, 2003, Crop freezes and land-use change in Florida: *Nature,* 426, 29-30.

- http://gisdata.usgs.net/sa_floods/aspmap/
- http://gisdata.usgs.net/gh_floods/ghamap/

or contact James Verdin, USGS EROS, 605-594-6018, verdin@usgs.gov.

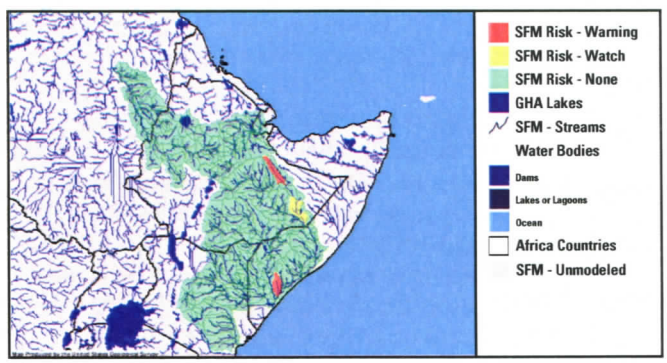


Figure 22. Greater Horn of Africa Flood Monitoring website (Oct. 29, 2004).

Domestic and International Drought and Flood Modeling and Monitoring

A spatially distributed Standardized Precipitation Index (SPI) has been implemented for U.S. drought monitoring. Techniques developed and applied for drought monitoring in Africa for the U.S. Agency for International Development (USAID)-funded FEWS NET project were modified to provide national coverage of the SPI for the United States. The SPI is a popular drought indicator that quantifies precipitation deficit for multiple timescales, in this case for 1-, 2-, 3-, 6-, 9-, 12-, 24-, and 36-month time steps. SPI provides higher spatial resolution than other drought indicators that are based on climate or political (e.g., county or district) divisions. The result for drought monitoring is that the identification and impact of drought can be mapped with greater specificity (fig. 23).

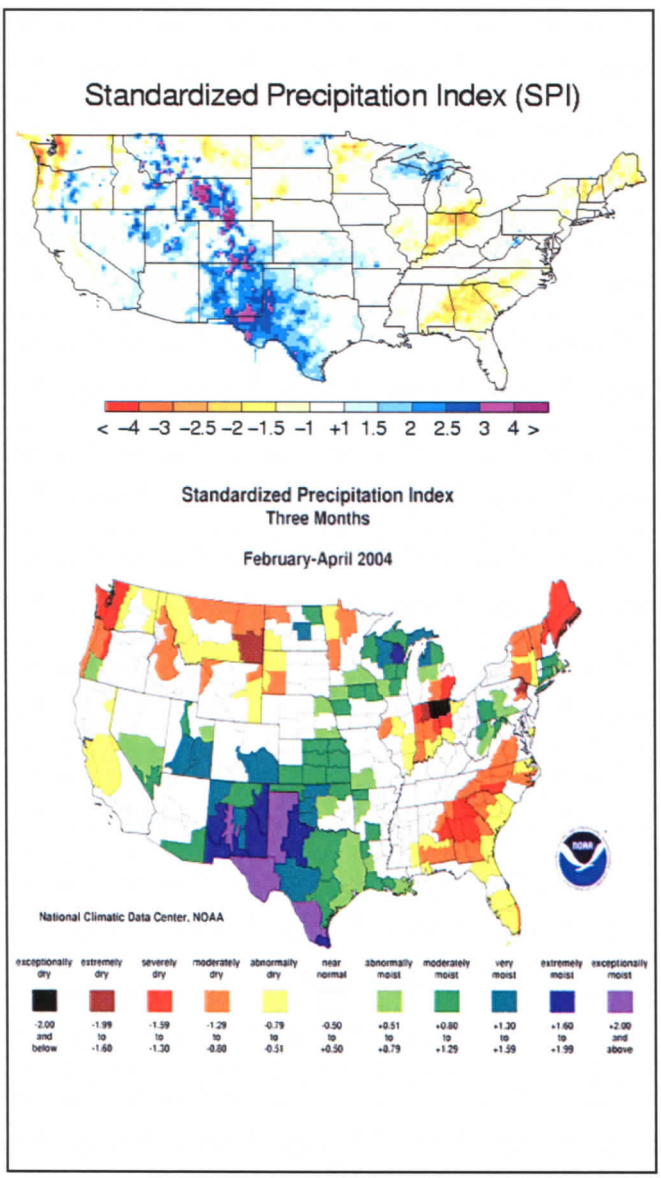


Figure 23. Drought monitor products for the continental United States: 3-month Standardized Precipitation Index (Feb.-Apr. 2004).

Topographic Science

Watershed-Based Analysis

Watershed-based analysis focused on tool development and representative applications that leverage the USGS Elevation Derivatives for National Applications (EDNA) database (http://edna.usgs.gov/). Several national images were added to the EDNA interactive map service to provide visual comparisons and spatial reference for data layers. The flow-accumulated variable procedures were applied to several watershed-based analysis scenarios in the land cover thematic area. Specifically, an analysis was performed to relate the National Agricultural Statistics Service's multi-year land cover data to point samples from the Environmental Protection Agency's (EPA) Storage and Retrieval System (http://www.epa.gov/STORET/) and the USGS National Water Information System water quality databases (http://waterdata.usgs.gov/nwis/). Also, the USGS National Land Cover Database (http://landcover.usgs.gov/nationallandcover.asp) land cover for the Chesapeake Bay watershed was flow-accumulated to demonstrate how this type of analysis can zero in on areas of greatest land cover change within a watershed. For more information, contact Sue Greenlee, USGS EROS, 605-594-6011, sgreenlee@usgs.gov.

Department of Energy's Idaho National Engineering Laboratory Water Energy Resources Study

EROS scientists, working with the Department of Energy's Idaho National Engineering and Environmental Laboratory (INEEL), completed an analytical assessment of water energy resources in the 20 hydrologic regions of the United States. Using the EDNA dataset as a base, estimates of hydraulic stream flows were developed for every reach segment in the United States. Stream segments excluded from development and those representing currently developed hydropower were accounted for to produce an estimate of the theoretical power potential available for development. For more information, contact Susan Greenlee, USGS EROS, 605-594-6011, sgreenlee@usgs.gov. A report detailing the results of this work is available at the INEEL website: http://hydropower.inel.gov/resourceassessment/pdfs/03-11111.pdf.

National Elevation Dataset Updates

One of the best-known products from the Topographic Science group is the National Elevation Dataset (NED). The data is complete and is available to the public using a Web interface at: http://ned.usgs.gov/.

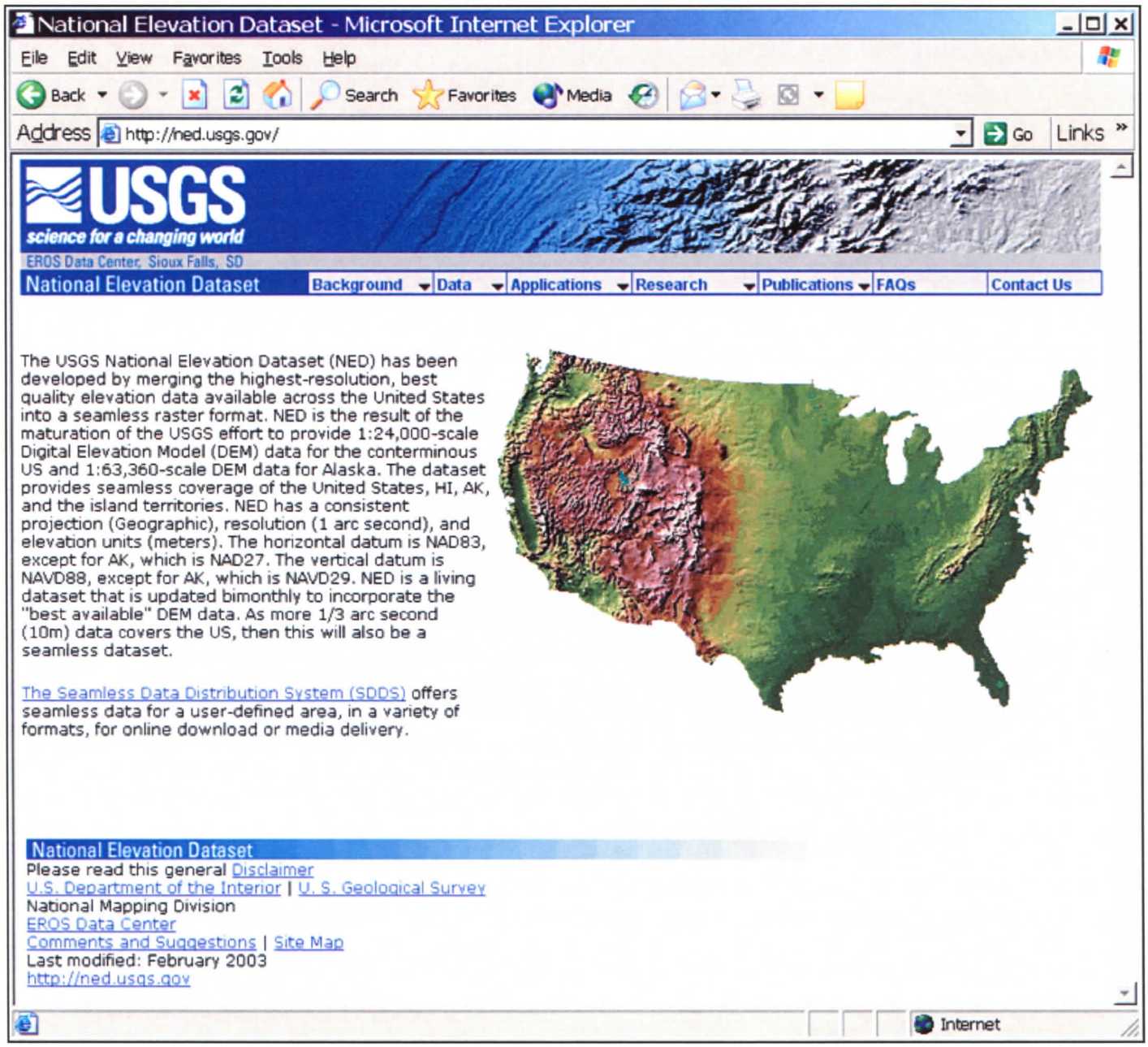


Figure 24. Web interface for the distribution of NED in its new version in 2004.

The website has been reworked (fig. 24).
The project requires regularly scheduled updates every two months in its 1-arc-second and 1/3-arc-second, which were successfully completed as scheduled. The requirements of the project also include the distribution of Release Notes, which were successfully completed and distributed as well in 2004. Project scientists provided input and solutions to problems and errors with the dataset in regularly scheduled teleconferences. For example, a problem with incorrect data at the edges was discussed and corrected through these teleconferences.

In order to keep the project tools current with newer technologies, scientists at EROS took on the task of converting scripts in Arc Macro Language (AML) into Visual Basic for Applications (VBA), which was necessary for the continued success of this task.
One of the important factors in NED is to include more modern, reliable, and precise elevation data such as Light Detection and Ranging (LiDAR). A LiDAR dataset from North Carolina was successfully incorporated into NED during 2004. Finally, all available 10-m Digital Elevation Model (DEM) data pieces were incorporated into 1/3-arc-second NED this year. This achievement is a significant milestone because it enhances the quality of the product provided to the public.

High-Resolution Elevation Data Integration

An important component of NED is the integration of high-resolution elevation data. This year, the team completed production and release of the first two NED layers derived from non-standard (non-USGS) source elevation data: 1/9-arc-second NED for the Puget Sound region and 1/3-arc-second NED for a portion of North Carolina, both derived from LiDAR.

As part of necessary NED research, EROS scientists are analyzing LiDAR data of Harris County, Tex., and photogrammetric data of Mississippi River Basin floodplains (Scientific Assessment and Strategy Team (SAST) data). Continuing our commitment to quality and use of newer, high-quality elevation data such as LiDAR, EROS staff have initiated processing for NED integration of two collections of LiDAR data over the Brownsville, Tex., area. Similarly, team members processed and evaluated a photogrammetric dataset of Birmingham, Ala., for possible inclusion in NED. Also completed was the integration of non-standard 10-m DEMs produced by the state of Ohio from 1:24,000 hypsography; this new source provides a significant upgrade to the NED over Ohio (both 1-arc-second and 1/3-arc-second).

The NED team communicated with our colleagues in science through conferences such as the American Society for Photogrammetry and Remote Sensing (ASPRS)- Management Association for Private Photogrammetric Surveyors (MAPPS) Terrain Data Conference in Charleston, S.C., where we presented "Integration of High-Resolution, High-Accuracy Elevation Data into *The National Map*."

National Elevation Data Research

Research is necessary to keep NED current with trends and new technologies. The NED team gave a presentation on USGS LiDAR research and results at a workshop in North Carolina for state and local decision makers and university users. EROS staff also participated in the National Digital Elevation Program (NDEP) Steering Committee meetings held in January and June and presented a poster on wavelet compression techniques for floating point DEMs at the ASPRS/MAPPS Terrain Data Conference in Charleston, S.C. Other events included the USGS GIS workshop in March, the ESRI User Conference in San Diego, Calif. (with inclusion in the proceedings of "The Effects of Wavelet Compression on Digital Elevation Models"), and the presentation of "Voxels as a Representation of Multiple-Return LiDAR Data" at the ASPRS annual meeting in May in Denver, Colo.

To make data storage more efficient for NED, our team investigated data compression techniques, such as wavelet compression, which we applied to floating-point DEMs, yielding useable results at compression ratios of up to 20:1. As part of the integration of LiDAR elevation data, our team members began researching the most efficient way to load 380 million LiDAR points into ArcSDE; in addition, the NED team worked with EROS Web Mapping personnel on development of prototype data extraction and distribution for LiDAR point clouds.

On the same LiDAR elevation data research track, scientists at EROS delivered nine quads of bare Earth LiDAR data and one-quarter quad of high-resolution data for Lincoln, Nebr. Our team members also worked with the Natural Resources Conservation Service (NRCS) and the state of Texas to develop a plan for acquisition of LiDAR data over a coastal watershed near Corpus Christi, Tex. Another application of LiDAR data is the processing and analysis of post-fire LiDAR data for the Hayman, Colo., area; the analysis includes change detection for erosion/sedimentation through comparison with pre-fire LiDAR data. Because LiDAR data require better and more sophisticated software tools, scientists in our team participated with several other USGS staff in training courses on use of Terrascan software for LiDAR processing. Additionally, we consulted with technical staff at NGRAIN, the developers of volume visualization (voxel) software on the use of their products for topographic LiDAR research. The company visited EROS and discussed partnerships to benefit ongoing research initiatives.

The team has designed and produced NED shaded-relief color graphics of 34 states, available for download and sale to the public.

As an example of publications and reports from the NED team, EROS scientists edited and released version 1.0 of NDEP "Guidelines for Digital Elevation Data." On behalf of NDEP, comments were provided to the ASPRS LiDAR Committee on proposed guidelines for testing and reporting vertical accuracy of LiDAR-derived elevation data. A draft of an open-file report on the Lincoln LiDAR project was also created, with the manuscript now in the USGS review and approval cycle.

Coastal Mapping Data Integration

One important aspect of expanding NED is the incorporation of other data sources, including information about the seafloor close to the coastlines of the continental United States. As part of this task, our scientists compiled all of NOAA's Geophysical Data System (GEODAS) bathymetric points into a single ArcSDE layer, 71,000,000 points resulting in a 10-gigabyte (GB) dataset. Our scientists met with NOAA and USGS staff on increasing collaboration

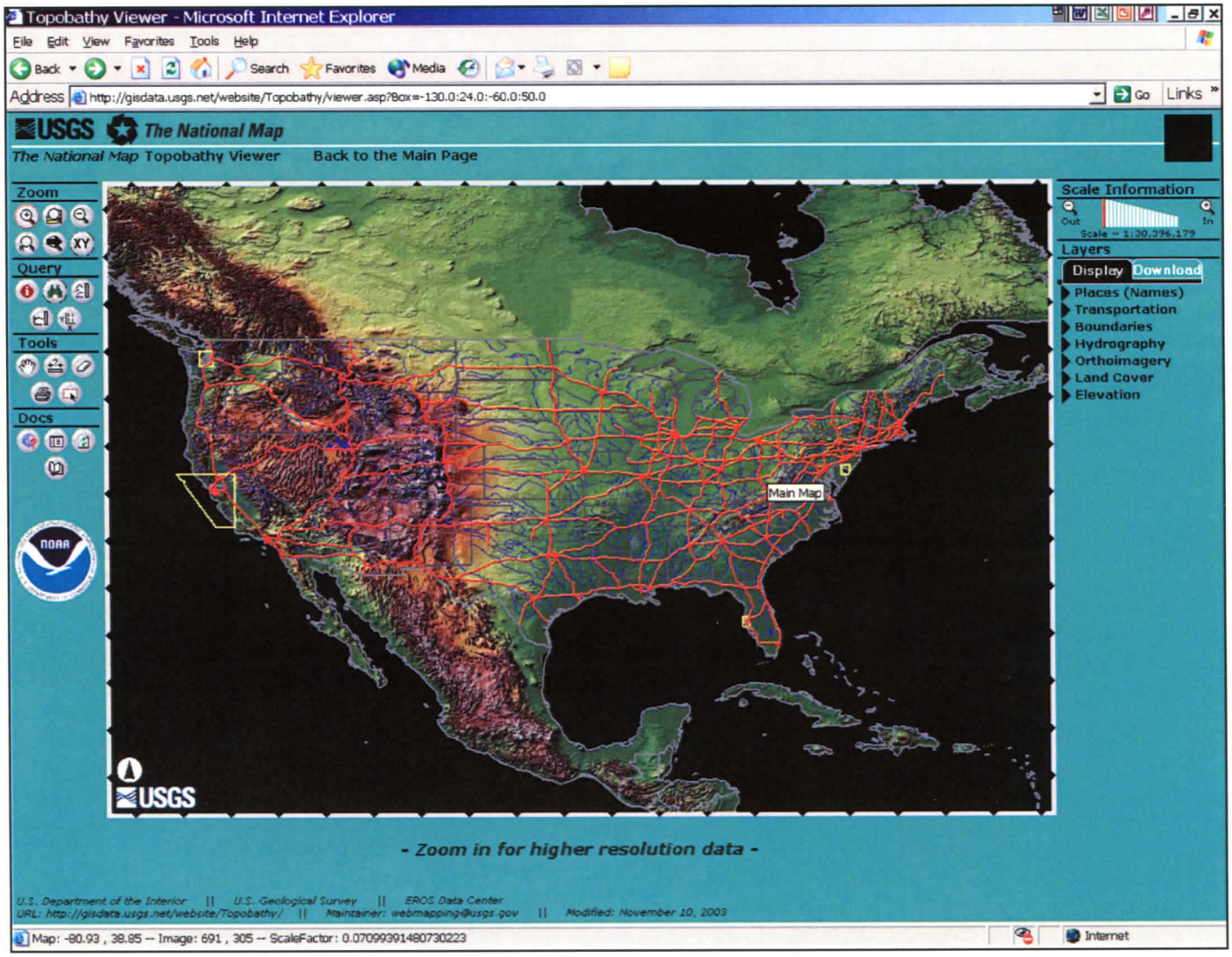


Figure 25. The topo/bathy viewer website, an ArcIMS-enabled website prepared in conjunction with the Web Mapping group.

on coastal data integration, reflecting related ongoing collaborations each agency has with the U.S. Army Corps of Engineers (USACE) and the Federal Emergency Management Agency (FEMA). Also, team members participated in a NOAA-USGS-FEMA interagency workshop on impacts of the Hurricane Isabel storm surge in Chesapeake Bay.

As part of this research, we conducted an investigation to determine the best way to export a geo-referenced color Tagged Image File Format (TIFF) image from an ArcMap layout. NED documented workflow and settings needed to obtain an image with a cell size that is almost identical to the input image. A geo-referenced TIFF image is required for each study site for use on the topo/bathy viewer. Also, research was begun to determine a better method for prioritizing which bathymetric surveys should be selected to form a "best-available" topographic/bathymetric merged dataset.

The Topographic Science group has a well-designed and active website for presentation and delivery of some of its results. In conjunction with the Web Mapping team, our scientists provide the Tampa Bay and Delaware Bay topo/bathy merged data and ancillary layers, which are made publicly available via the topo/bathy ArcIMS-enabled website at http://gisdata.usgs.net/website/Topobathy/. A sample screenshot is presented in figure 25.

EROS elevation scientists presented "Integration of Coastal Topographic and Bathymetric Data: Status of Ongoing USGS-NOAA Efforts to Develop Seamless Elevation Models for the Land-Water Interface" at the ASPRS-MAPPS Terrain Data conference in Charleston, S.C. Also, some of our team members were invited to participate in an NOAA-sponsored workshop on the environmental effects of sea-level rise in North Carolina, which will result in a topo/bathy product, including the North Carolina LiDAR data, to be produced for a portion of the Outer Banks and Pamlico Sound.

As part of the data processed in this activity, the group merged topo/bathy datasets for Puget Sound and California (including San Francisco Bay) and made them available on the topo/bathy viewer and download site. Processing was initiated on the New York (Long Island) merge, including SHOALS bathymetric LiDAR data. Members of the team also initiated reprocessing of the Louisiana merge, integrating newly available topographic LiDAR data.

Significant Topographic Surface Change: A Nationwide Assessment

Partially funded by the GAM Program as the Topographic Status and Trends task, our team completed accuracy assessments of national coverage of 1-arc-second NED and Shuttle Radar Topography Mission (SRTM) datasets based on a comparison with more than 13,000 GPS benchmark points from the National Geodetic Survey. Team members completed data processing for calculation of elevation differences between NED and SRTM national datasets, and refined and implemented a topographic change detection procedure based on vertical accuracy of the elevation datasets and national land cover.

Presentations given by team members at several forums and meetings were a vital aspect of this project. "A Nationwide Inventory and Assessment of 20th Century Topographic Surface Change" was presented at the Association of American Geographers (AAG) Centennial Meeting, March 14-19, 2004, in Philadelphia, Pa. "Use of Broad Area, Multi-Temporal Elevation Datasets to Detect and Assess Areas of Significant Topographic Surface Change" was successfully presented at the ASPRS/MAPPS Conference on Terrain Data: Applications and Visualization – Making the Connection, October 26-30, 2003, in Charleston, S.C. "Use of LiDAR and IFSAR-Derived Elevation Data to Detect and Assess Significant Topographic Surface Changes" was presented by our scientists at the International Society for Photogrammetry and Remote Sensing (ISPRS) Joint Workshop of ISPRS WG I/3 and WG II/2 – Three Dimensional Mapping from InSAR and LiDAR, June 17-19, 2003, in Portland, Oreg.

Perennial/Intermittent Stream Classification for *The National Map*

Perennial/intermittent stream classification receives national attention not only for its implications for mapping and research but also for its potential legal implications. As a result of the acquisition of high-resolution LiDAR from North Carolina, our scientists formed a collaborative partnership with the USGS office in Raleigh, N.C., for data exchange. High-quality data streams were produced, which compared well with existing cartographic data. The result can be seen in figure 26. The partnership included the acquisition of more remotely sensed data, enabling the team to process soil data information for the Upper Neuse River from the USGS office in Raleigh. With data that is freely available, our team delineated watersheds for 1,553 of the 1,703 Hydro-Climatic Data Network (HCDN) gauging stations. Historical flow records were analyzed for zero flow events for identifying gauging stations on intermittent streams. The watersheds were used for analysis and development of basin characteristics that can be related to the flow characteristics.

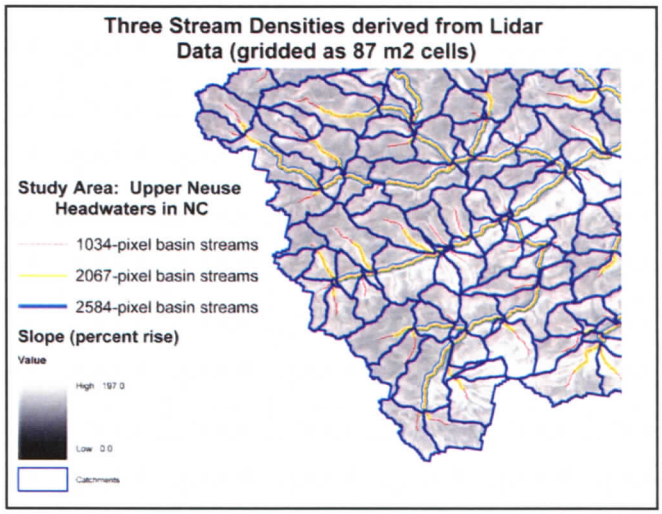


Figure 26. LiDAR elevation with synthetic streams at three different thresholds and catchments in blue. Done as part of the perennial/intermittent prospectus work.

Our work included collaboration with educational institutions such as North Carolina State University (NCSU) and South Dakota State University. These collaborative efforts included hosting a meeting with a group of students and faculty from NCSU to discuss goals and issues related to stream classification strategies, using GIS and remotely sensed information. Another meeting initiated work on suitable areas in South Dakota to implement strategies and methods of stream classification. Preparing for future work, team members represented EROS in a preliminary collaboration with the Consortium of Universities for the Advancement of Hydrological Science (CUAHSI) to extend access to the EDNA data layers to member universities. This partnership will create a scientific dialogue for valuable feedback on EDNA.

At the ESRI International User Conference, team members presented "Stream Classification Strategies using GIS." At the same conference, the group presented a poster on results worked in the Upper Neuse River Basin in North Carolina. EROS scientists prepared a presentation for the 2004 Joint Agency Commercial Imagery Evaluation (JACIE) High Spatial Resolution Commercial Imagery Work-

shop held in November at the USGS National Center in Reston, Va., involving the use of Orbview 4-m resolution spectral images to study stream placement and sinuosity in the Big Sioux watershed. As part of the work with the state of North Carolina, our team members attended a LiDAR seminar at the North Carolina LiDAR User's Workshop in Raleigh.

Innovative Approaches to Analysis of High-Resolution LiDAR Data for *The National Map*

EROS scientists conducted research on "bare earth" processed LiDAR data collected for a 9-quad area surrounding Lincoln, Nebr., successfully using new tools. EROS is continuing to use this data to improve three-dimensional (3-D) visualization and "virtual city" modeling. Also, as part of this activity, team members' automated feature extraction research has demonstrated the potential for using full-return LiDAR point data to create building footprints for the Lincoln area. To ensure good communication in the scientific community, EROS scientists prepared a comprehensive open-file report detailing tools and methodologies titled "Lincoln LiDAR: From Ideas to Information," which is in the editing/review process. For more information, contact Jason Stoker, SAIC at USGS EROS, 605-594-2579, jstoker@usgs.gov.

Fire Danger Monitoring

Monitoring fire danger or the potential for wildfire is the effort of federal, state, and local fire managers. At the national level, daily satellite observations are compiled to monitor status of the vegetation condition. The satellite observations allow direct spatial observation of vegetation condition and change over time. The GAM Program's focus on landscape monitoring and fire science has fostered an interagency approach that integrates remote sensing-based monitoring of vegetation condition with weather information and other model results to predict fire danger conditions.

In FY 2004, scientists from the USGS Geography discipline, working with researchers from the U.S. Forest Service (USFS), refined the 16-year time series of satellite observations using advanced processing techniques to improve the sensitivity of the vegetation condition information. In FY 2005, the research will include the adoption of new satellite technology that will enhance the capability to measure changes in vegetation condition and to improve the capability to predict fire danger (fig. 27). Much of the fire danger information used in this research has been compiled for national coverage and has been made available to USGS scientists and cooperating organizations through an interactive Web application (http://gisdata.usgs.net/website/IVM) to promote

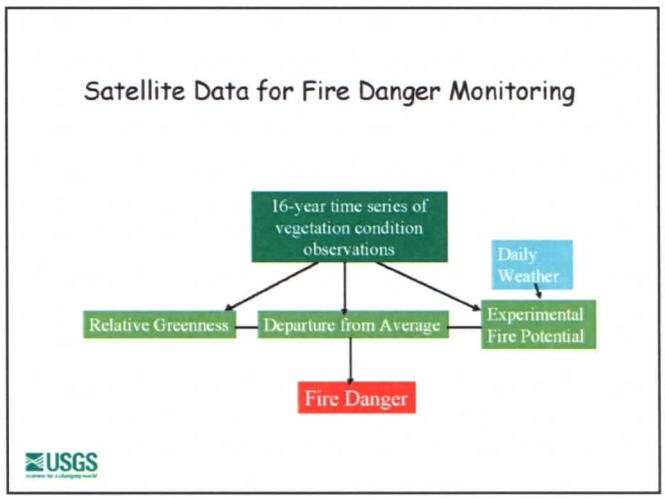


Figure 27. Satellite data for fire danger monitoring.

further interdisciplinary work. For further information, contact Jeff Eidenshink, USGS EROS, 605-594-6028, eidenshink@usgs.gov.

Joint Fire Science

A strong component using LiDAR data has been applied to fire science activities. EROS scientists collected post-fire LiDAR in an area inside the Hayman, Colo., fire. LiDAR was used to identify significant topographic and biomass change caused by the fire and post-fire erosion near Cheesman Lake, Colo. Post-fire data corresponds with LiDAR data that was collected prior to the Hayman fire, and preliminary analysis has yielded good results on detecting statistically significant erosion and sedimentation change from pre-fire to one year after the Hayman fire. For more information, contact Jason Stoker, SAIC at USGS EROS, 605-594-2579, jstoker@usgs.gov.

Remote Sensing and Modeling Carbon Fluxes

An important goal of both the North American Carbon Program and the Terrestrial and Atmospheric Carbon Observation Initiative is to scale localized carbon dynamics to the regional scale in order to identify carbon sinks and sources. A better understanding of regional carbon dynamics is needed to quantify and understand regional and global carbon budgets. Understanding the causal factors of sinks and sources is important for monitoring these ecosystems and making predictions of future ecosystem responses to climate change. This will improve and refine current global mapping products (MODIS and SPOT VEGETATION) on rangeland systems.

Detailed localized movements of carbon dioxide (CO_2) into and out of the atmosphere at the land sur-

face are achieved by Ameriflux, Agriflux, and other researchers' flux towers. Flux tower detailed measurements of net ecosystem exchange are converted with complex light curve equations into carbon fluxes associated with gross primary production and ecosystem respiration and scaled to the ecoregions using remotely sensed data and other spatial environmental data. This allows the mapping of temporal dynamics of rangeland carbon fluxes in Central Asia (http://edc.usgs.gov/carbon_cycle/FluxesResearchActivities.html), the Sagebrush Steppe (United States), and the Northern Great Plains (United States) (fig. 28). This approach will be expanded to the Central Great Plains, Tallgrass, and Southwestern Shrublands, allowing an overall synthesis of rangeland carbon dynamics and environmental drivers by FY 2006. Plans have been made to augment long-term Northern Great Plains flux towers and apply this approach to cropland fluxes as well. For further information, contact Bruce Wylie, USGS EROS, 605-594-6078, wylie@usgs.gov.

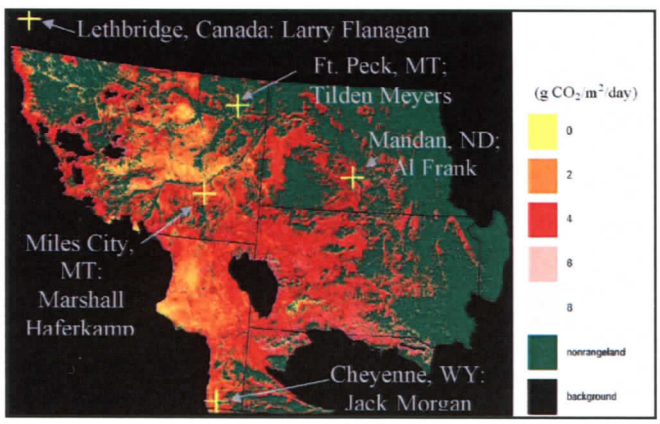


Figure 28. Growing season gross primary production CO_2 fluxes averaged for 1999-2001 growing seasons and flux tower locations in the Northern Great Plains, U.S.

Status and Trends of Carbon Stock in the Conterminous United States

CO_2 in the atmosphere plays an important role in regulating the climate of Earth. The continuing increase of atmospheric CO_2 concentration has the potential to significantly alter our living environment and affect the economy at regional to global levels. However, the magnitude, spatial patterns, mechanisms, and uncertainty of contemporary U.S. carbon sources and sinks of CO_2 exchange with the atmosphere are not well understood. We have estimated contemporary (1973-2000) carbon dynamics with measures of uncertainty in the terrestrial biosphere of the conterminous United States using the spatially explicit General Ensemble Biogeochemical Modeling System (GEMS), and quantified the dynamic exchange of CO_2 between the land and the atmosphere under the impacts of land use change activities and climate variability and change.

For the first time, dynamic land cover change information derived from Landsat imagery is being used for assessing carbon storage change for the continental United States (fig. 29). This study takes advantage of many kinds of existing national benchmark databases including estimates of net primary productivity from MODIS, grain yield, and cropping practices from the U.S. Department of Agriculture, and forest properties from the Forest Service's Forest Inventory and Analysis database. In FY 2004, scientists from the USGS Geography discipline refined the modeling techniques and applied them to several ecoregions in the nation. Preliminary results at the ecoregion level indicate that the United States has been a significant carbon sink since 1973. However, the carbon sink strength decreased from 1973 to 2000. Climate variability and change was the predominant factor defining the inter-annual variability of the carbon sink strength. Ignoring the dynamic land use change information could lead to significant overestimation of the carbon sink strength.

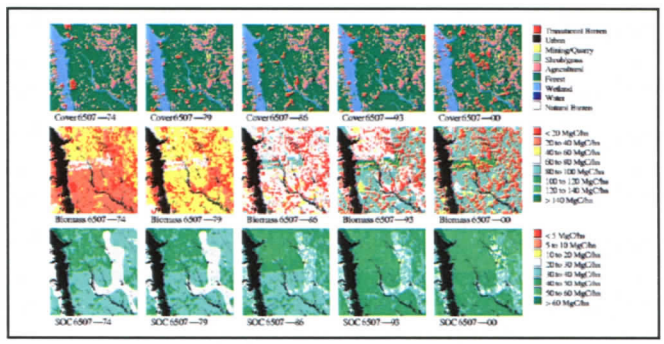


Figure 29. The spatial and temporal dimensions of changes of land cover and carbon stock in biomass and soil in 1974, 1979, 1986, 1990, and 2000 in a 20- by 20-kilometer (km) area.

Future studies will quantify the effects of fire, grazing, and other natural disturbances and human activities on the status and trends of carbon stocks and fluxes. The results generated from this project will advance our understanding of the spatial and temporal dimensions of the contemporary U.S. carbon sources and sinks and the underlying mechanisms that determine these dimensions, and will provide a solid scientific basis for societal decisions about CO_2 management and the carbon cycle at regional and national scales. For further information, contact Shuguang (Leo) Liu, USGS EROS, 605-594-6168, sliu@usgs.gov.

Carbon Stocks on DOI Lands

Agencies of the federal government manage large areas of land, and the condition of these lands can

influence the exchange of CO_2 and other greenhouse gases between biomass, soil, and the atmosphere. Understanding these processes is important for projecting future responses of ecological systems to climate change. In FY 2004, a study was completed showing large portions of the nation's soil organic carbon located in high latitudes on lands managed by the Department of the Interior (DOI) (fig. 30). A set of 523 soil profiles in Alaska was evaluated to begin establishing a baseline for monitoring future changes in soil carbon.

The capabilities of satellite radar for remote sensing of soil moisture were investigated, with consideration of moisture and temperature as controls on the decomposition rate of soil organic carbon. In FY 2005, a monitoring system will be designed for soil carbon with sample locations based on the magnitude of carbon stocks, carbon fluxes, and the potential for carbon sequestration. The monitoring will be essential for evaluating programs for carbon sequestration and for assessing the potential for unintended feedbacks in which climate change may influence the carbon flux rates. Also, the interaction of land use and land cover change with soil characteristics such as soil carbon and agricultural potential will be investigated, especially for the eastern United States. The research will lead to greater understanding of the geographical nature of the interactions between human and natural systems. For further information, contact Norman Bliss, USGS EROS, 605-594-6034, bliss@usgs.gov.

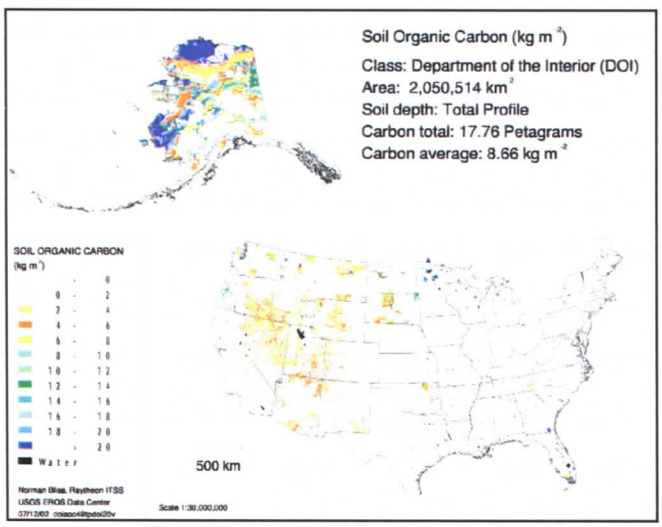


Figure 30. The DOI has 22% of the nation's land area, and 22% of the soil organic carbon (SOC), but 74% of that SOC is in Alaska.

Carbon in Africa and the United States

With support from USAID, a project was undertaken to study the carbon cycle in the Sahel and to recommend strategic management interventions to enhance soil fertility, encourage sustainable agriculture, and improve carbon sequestration. The modeling and climate change components were supported by the Earth Surface Dynamics program, and research was done by an alliance of American and African scientists along with national experts from Senegal institutions. Extensive land cover interpretation with Corona, Landsat, and airborne imagery documented changes in land cover over a 35-year period. When combined with field data, an extensive loss of biomass carbon was established (fig. 31). This loss was due to selective thinning and loss of biodiversity among tree species.

A biogeochemical model, GEMS, was developed to simulate the carbon and nitrogen dynamics across large areas and at high resolution. This model was refined in the southern woodland of Senegal and documented the impact of land conversion to agriculture. The output of 2xCO2 climate change for the area was used to drive the simulation modeling until 2100. Increased temperature and evapotranspiration resulted in a small reduction in soil and biomass carbon but large reductions in grain yields, suggesting that the potential impact of climate change on food security is high, and the region is highly vulnerable. Recommendations concerning agricultural policies, farm credit, and donor practices were provided.

The project produced research papers that were published in a Special Issue of the *Journal of Arid Environments,* Vol. 59 (3), *Land Cover, Biomass, and Soil Carbon Trends in Senegal:* Management Options and Climate Sensitivity. This work also contributed toward a bilateral agreement between Italy and the United States for future cooperation in land cover, carbon cycling, and information systems development in Africa. Invited presentations contributed to the Department of State's workshop on "Science Contributions to Foreign Policy." Prototype work in Senegal will continue in FY 2005 with the initiation of general capacity building throughout the Sahel and detailed project work in Mali, Niger, Burkina Faso, and Ghana. Collaborative projects are underway with Italian and Food and Agriculture Organization (FAO) counterparts. The modeling approach is being refined and will be used to assess management and climate impact on carbon cycling for the Land Cover Trends project in the United States. Research in FY 2006 will result in Sahel-wide assessments and applications in the United States. For more information, see http://edcintl.cr.usgs.gov/carbonsequestration.html or http://edc.usgs.gov/carbon_cycle/, or contact Larry L. Tieszen, USGS EROS, 605-594-6056. Tieszen@usgs.gov.

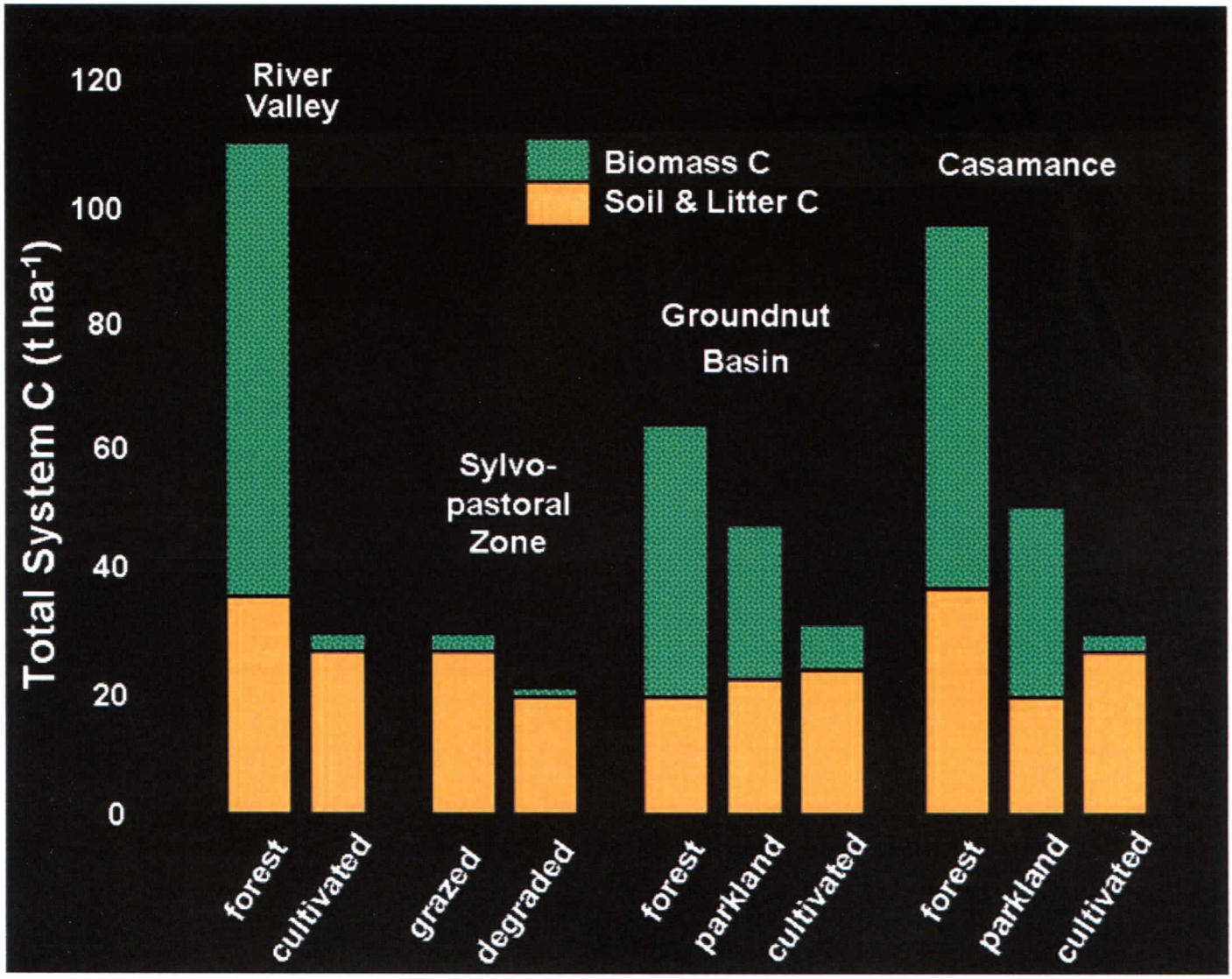


Figure 31. Land cover and sustainable development.

Predicting the Potential Distribution of Invasive Species

In order to prevent invasive alien species of vegetation from becoming established or spreading into new areas and causing environmental and economic harm, experts have called for predictions that will allow identification of the species, vectors, and geographic areas at risk for invasion. EROS is collaborating with other USGS centers, the University of Wisconsin-Madison, and the Chinese government to provide information for the mutual benefit of the United States and China, the major sources of mutually invasive species. During FY 2004, EROS scientists used state-of-the-art remote sensing and GIS data, statistical models, and machine learning tools to explain and predict the potential distributions of such harmful biotic invaders as Chinese tallow, Asian bittersweet, and tree-of-heaven (fig. 32). This work was presented to scientific and management experts

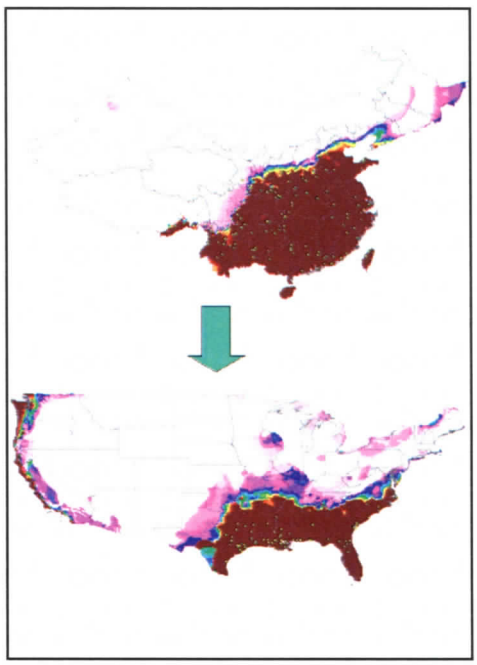


Figure 32. Models of the distribution of Chinese tallow in its native Chinese range (above) and its current invasion of the United States (below). Yellow points represent specimen locations, and the color scale depicts confidence in the predictions with brown indicating the most confidence.

at international conferences in China and the United States. During FY 2005, scientists will incorporate more geographic species information from China, refine the quality of their models, and expand modeling efforts to other species. This information will ultimately help scientists and managers understand the risks posed by different species and their potential to spread to new areas. For more information, contact Thomas Albright, SAIC at USGS EROS, 608-265-6427, talbrigh@usgs.gov.

GeoCafe: Geoinformation Tools in Support of Coffee Production and Marketing

The recent international decline in coffee prices has adversely impacted the social and economic conditions of countless small coffee farmers in Central America and the Caribbean. Working under the framework of the USAID-funded Quality Coffee Program, EROS is assisting coffee sectors in the Dominican Republic, Costa Rica, and Guatemala. The project seeks to use geoinformation tools to assist coffee marketing, sourcing, certification, and environmental monitoring with the objective of increasing the prices of specialty coffees and improving socio-economic conditions for coffee producers. The GeoCafe project focuses on the development of Internet Map Servers (IMS), GIS applications, and spatial datasets to assist coffee buyers and national coffee sectors in better understanding how and where coffee is produced, how it moves through the commercial chain, and the socio-economic and environmental impacts of its commerce (fig. 33). If successful, this approach could be implemented in other coffee-producing countries, as well as for other crops.

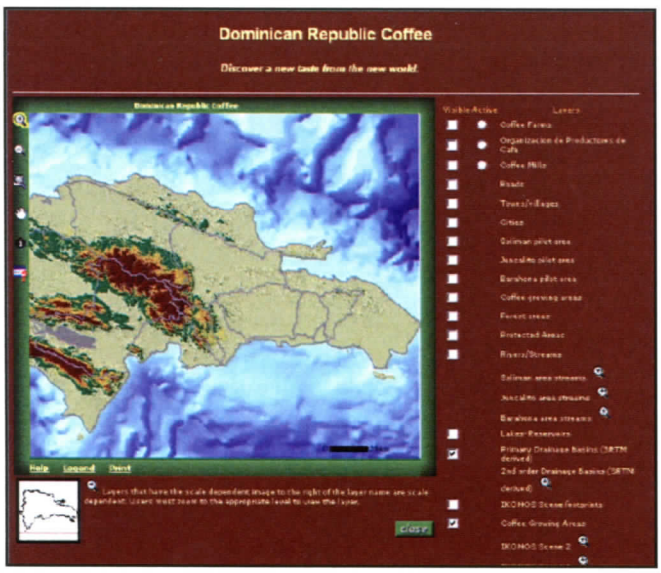


Figure 33. The GeoCafe project.

The IMS coffee applications so far developed can be viewed at:

- http://www.dominicancoffee.com (Coffee Map section)
- http://sigicafe.icafe.go.cr/Sig_icafe.htm
- http://gis.anacafe.org/website/guatemala/viewer.htm

For more information, contact Eric van Praag, vanpraag@usgs.gov, or Larry Tieszen, tieszen@usgs.gov, USGS EROS, 605-594-6056.

West Africa Land Use

USGS EROS scientists are implementing a cooperative project with West Africa's Regional AGRHYMET Program to identify land use and land cover trends within ecological regions in 15 countries covering most of West Africa. The effort combines the use of historical and current satellite image data, existing published studies, supporting ground and aerial information on biophysical resources, and socioeconomic data. EROS provided complete coverage of Corona satellite photography, Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), and Landsat ETM+ imagery to most of the countries of West Africa. The images record land resource conditions in 1965, 1972, 1985, and 2000, respectively. Teams of West African scientists from government agencies in each country are conducting the time-series analysis with technical support from AGRHYMET and EROS.

In the past year, EROS led two workshops at the AGRHYMET Center in Niger, the first to help national teams analyze land cover trends among many of West Africa's coastal countries, and the second to validate those trends and to prepare final reports.

Some ecoregions exhibited stability and land use permanency, while others showed dramatic change as agriculture expands into natural vegetation. The most troublesome finding was the continued decline of dense forest. Some countries, Togo and Benin, for example, have lost nearly all of their dense forest. Others, notably Guinea and Ghana, still have large tracts of forest, but they are coming under great pressure from logging and agriculture. Results from this work will be presented to policy makers in the respective countries. For more information, contact Gray Tappan, SAIC at USGS EROS, 605-594-6037, tappan@usgs.gov.

International Spatial Data Infrastructure

Environmental Management and Information Systems

Through the Environmental Management and Information Systems (EMIS) project, funded mainly by USAID and supported by the USGS Geographic Analysis and Monitoring (GAM) Program and Land Remote Sensing (LRS) Program, spatial data infrastructures were established in Africa. Direct activity with the Global Spatial Data Infrastructure (GSDI) was used, along with the distribution of geospatial datasets and applications for natural resource management. A monthly newsletter, *SDI-Africa*, was prepared and distributed broadly to facilitate networking among specialists from the international community and Africa. The successful newsletter was replicated for Asia and for Latin America (*SDI-LAC*) by request following a major workshop in Central America.

The GeoCover distribution provided source data for land cover change projects in Nairobi, conducted by national experts, resulting in a request for Corona data. Internet map server systems were implemented in Africa, and an Africa Clearinghouse for Spatial Data was implemented. The obstacles posed by inadequate bandwidth for the AGRHYMET Regional Center in Niamey, Niger, were overcome with assistance from the Department of State, and the center now has better digital communication and data delivery. Support for Committee on Earth Observation Satellites (CEOS) training activities provided source GeoCover data to each of three regional remote sensing centers in Africa and substantial training in applications. In addition, integrated plans were developed among the three centers for greater contributions to help their constituent countries, with expertise provided by EROS.

Activities in FY 2005 will focus on carbon and global change projects in sub-Saharan Africa. The goal will be to increase remote sensing at the regional centers. FY 2006 will continue implementation of data delivery systems with an emphasis on SRTM data applications and hydrological modeling and national syntheses of natural resources and carbon in the Sahel and West Africa. For further information, see http://edcintl.cr.usgs.gov/dataportal.html or http://www.geoafrica.net/, or contact Larry L. Tieszen, USGS EROS, 605-594-6056, Tieszen@usgs.gov.

MesoAmerican and Caribbean Geospatial Alliance

The MesoAmerican and Caribbean Geospatial Alliance (MACGA), funded mainly by USAID through its Global Development Alliance program and supported by USGS GAM, created spatial data infrastructures in Central America and the Caribbean. The project brought together direct activity with the GSDI, the donation of software and hardware, expert training, the distribution of valuable geospatial datasets, project integration, and applications for disaster planning and natural resource management. MACGA created an alliance of donors, projects, national agencies, and non-governmental organizations (NGO) that delivered more than $2 million in services and materials to Central America and the Caribbean. Agriculture, environmental, and mapping representatives from each Central American country attended a workshop in Panama for extensive training in software and source data applications. The MACGA project in the Caribbean was supported by the Organization of American States (OAS), which convened a conference of ministers from each country to discuss the value of national Spatial Data Infrastructures and to support a training workshop held in Trinidad. A project to study bioinformatics is being largely funded by the World Bank and is an implementation phase for a Global Environment Facility (GEF) project in the region. In FY 2005, SRTM 30-m data secured by EROS from the National Geospatial-Intelligence Agency (NGA) will be used to provide products for implementation in Caribbean and Central American countries. FY 2006 will continue implementation of data delivery systems with an emphasis on SRTM data applications and hydrological modeling and disaster planning. For further information on Central America or the Caribbean see http://edcintl.cr.usgs.gov/macga/index.php, or contact Larry L. Tieszen, USGS EROS, 605-594-6056, Tieszen@usgs.gov.

Web Mapping Support of Integrated Science

In FY 2004, the Web Mapping team supported 14 integrated science projects that included:

1. Amphibian Research and Monitoring Initiative (ARMI) Web-enabled Applications
2. Drought Monitoring (fig. 34, 35, 36, and 37)
3. EDNA Watershed Based Analysis
4. FEWS NET
5. High Resolution Elevation Data Integration
6. Land Cover Trends

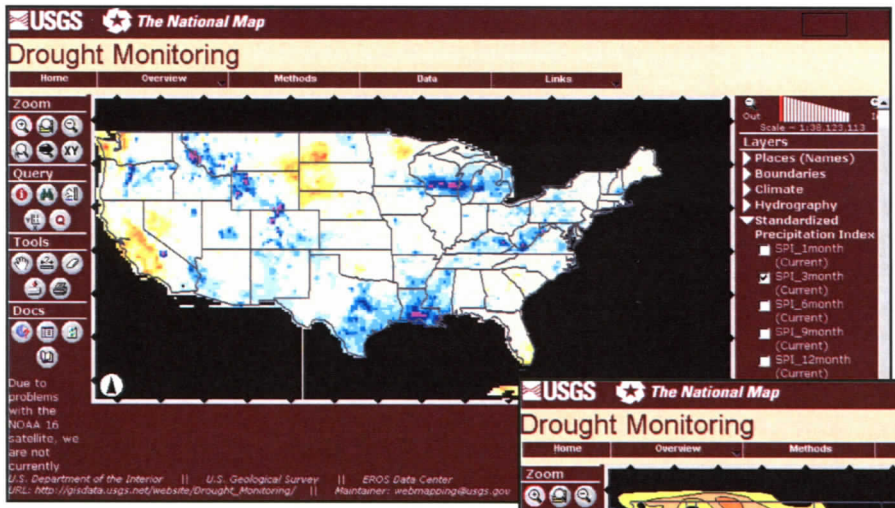


Figure 34. Standard Precipitation Index, 3 Month (Current) (http://*gisdata.usgs.net/website/Drought_Monitoring*).

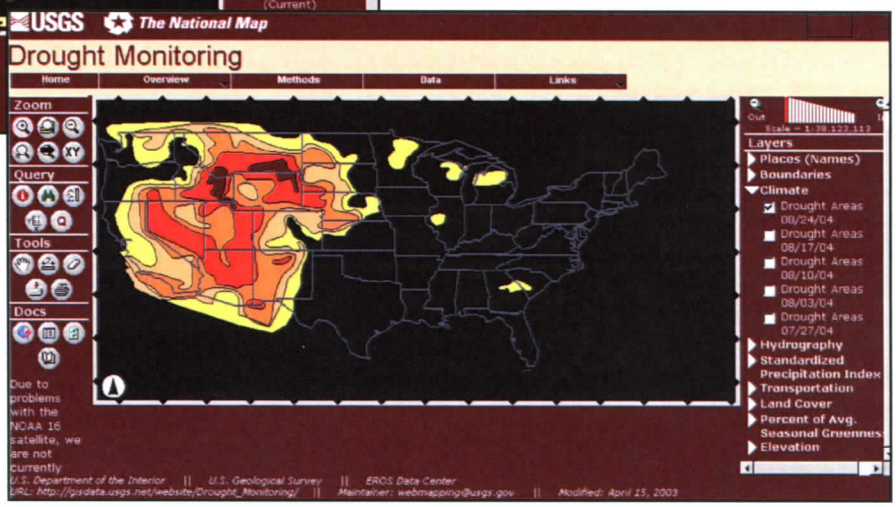


Figure 35. Drought Areas, Aug. 24, 2004.

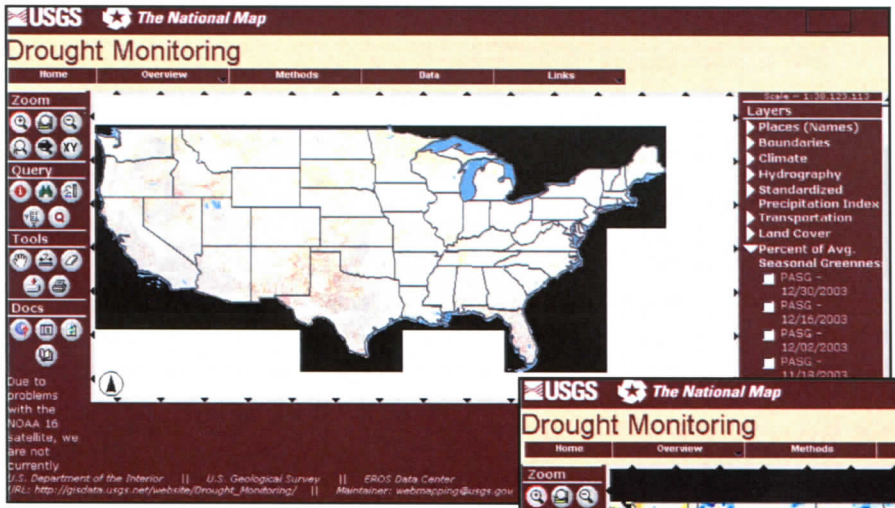


Figure 36. Drought Monitoring interactive page, featuring Percent of Average Seasonal Greenness.

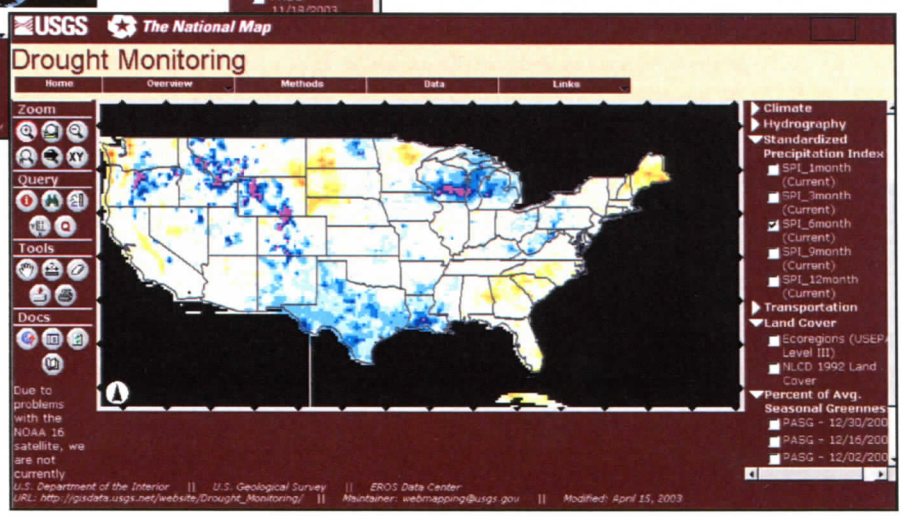


Figure 37. Standard Precipitation Index, 6 Month (Current).

Information Science Achievements

National Synthesis

Overview

National Synthesis is the assembly of geospatial data from multiple sources and locations to produce maps, images, and Web geoprocessing services to solve problems and answer scientific questions.

The National Map is intended to provide the best and most consistent geospatial data from a wide range of producers, using timely maintenance techniques and efficient data serving mechanisms. The project requires cooperation and consensus from many partners, the establishment of standards for quality and consistency, and the promotion of open standards for data. The USGS EROS has provided direct support to several state, county, and city entities, as well as the National Geospatial-Intelligence Agency (NGA). The map in figure 38 highlights the areas we actively supported in 2004.

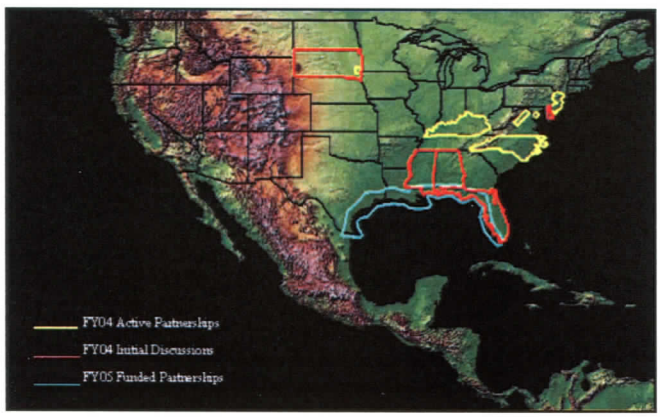


Figure 38. Areas actively supported by EROS in 2004.

New Jersey Partnership

In New Jersey, about 900 gigabytes (GB) of high-resolution orthoimagery has been loaded for the state. Through an Innovative Partnership Agreement (IPA), the U.S. Geological Survey (USGS) agreed to host and deliver this data to the public (http://seamless.usgs.gov).

In assisting New Jersey, the EROS Web Mapping team helped the state with data loading advice and training, system design criteria, and a website highlighting the state (http://gisdata.usgs.net/website/NewJersey/) (fig. 39).

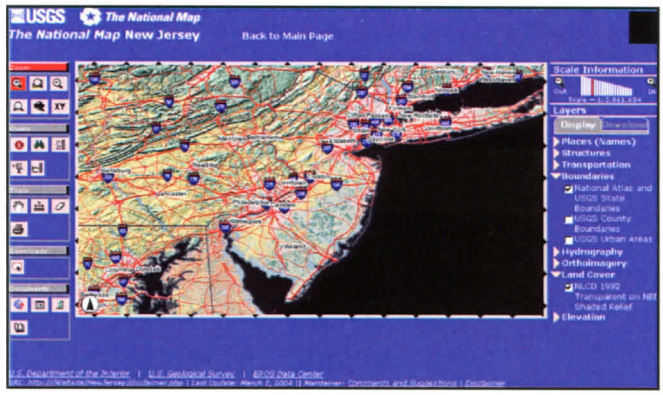


Figure 39. New Jersey, interactive viewer.

North Carolina Partnership

The best example of the principle of National Synthesis is the cooperative work of EROS and the state and counties of North Carolina (http://gisdata.usgs.net/website/NC_OneMap/) (fig. 40).

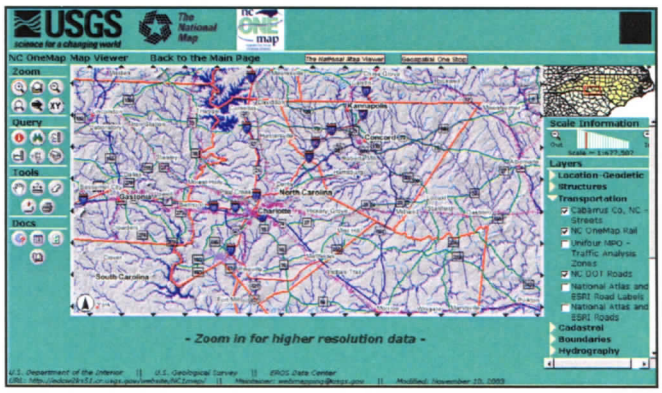


Figure 40. North Carolina OneMap.

From our initial work with Mecklenburg County, N.C., last year, our support role has increased to 31 counties, 18 cities, 3 federal agencies, and 4 other organizations. *The National Map* supported North Carolina (NC) OneMap partners with technical help from EROS staff.

EROS is co-hosting county data including cadastral, transportation, orthoimagery, and other local data. Technical expertise for the NC OneMap was provided to implement an Open Geospatial Consortium (OGC) specification for Web Map Services (WMS) interactive viewer. This enabled the state to access its own local data on individual servers and also access *The National Map* framework layers hosted at EROS (fig. 41). EROS staff worked in conjunction with the state to produce Web geoprocessing services for increased functionality of the NC OneMap interactive viewer.

EROS worked with North Carolina to deliver data via Extract or Download from North Carolina or

EROS data (fig. 42). Data can either come from EROS, the state, or the city.

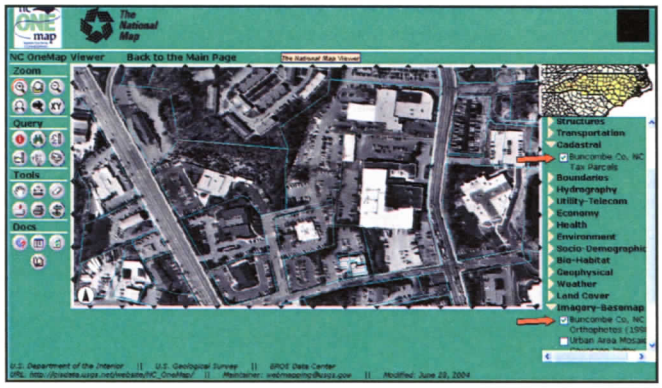


Figure 41. County data accessed through NC OneMap and *The National Map* framework.

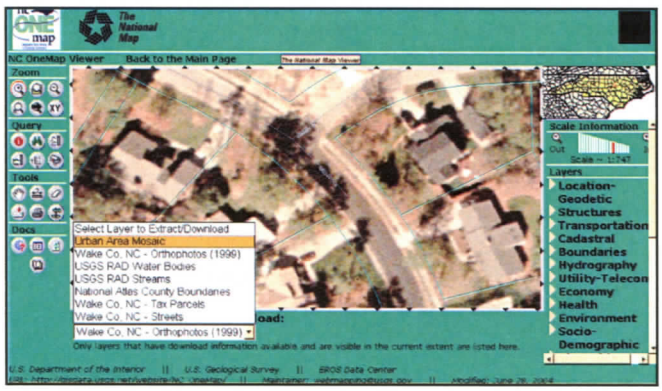


Figure 42. Data delivered via Extract/Download.

Other Partnerships

EROS has worked with other states and cities to create interactive viewers to highlight special interest datasets like the Kentucky Landscape Snapshot Viewer. In conjunction with the state, EROS created and hosts the new National Landcover Dataset 2001 and high-resolution orthoimagery (http://gisdata.usgs.net/website/Kentucky).

EROS, with the City of Sioux Falls, S. Dak., expanded an existing Memorandum of Understanding to mirror the city's data and to provide access to data for *The National Map* (http://gisdata.usgs.gov/website/Map_Studio/).

National Geospatial-Intelligence Agency (NGA) Support

The Internet Access and Distribution Development team supported the delivery of urban area high-resolution orthoimagery to NGA. The team provided quality assurance/quality control data prior to delivery to NGA and the Seamless Data Delivery System. The exact level of effort was adjusted through the year, based on the degree of non-standardized datasets acquired from multiple sources. We built an automatic reprojection and rechipping system to ensure that NGA received a consistent product. We also worked with NGA to develop table space transfers of high-resolution orthoimagery, saving NGA several staff-years in data loading time.

Urban Areas

Urban areas loaded to the Spatial Database Engine (SDE) and accessible via the orthoimagery viewer include: Fort Wayne, Ind.; Houston, Tex.; Louisville, Ky.; Montgomery, Ala.; Riverside-San Bernardino, Calif.; San Diego, Calif.; San Francisco, Calif.; Los Angeles-Glendale, Calif.; Baltimore, Md.; Jacksonville, Fla.; New Jersey; Philadelphia, Pa.; Columbus, Ohio; New Orleans, La.; Worcester, Mass.; Huntsville, Ala.; Minneapolis, Minn.; Nashville, Tenn.; Chattanooga, Tenn.; Carson City, Nev.; Cleveland, Ohio; Savannah, Ga.; South Dakota DOQQs; Bismarck, N. Dak.; Reno, Nev.; Salt Lake City, Utah; Harrisburg, Pa.; Phoenix, Ariz.; Cincinnati, Ohio; Miami, Fla.; Boston, Mass.; Central Massachusetts; Western Quarter Massachusetts; Kansas City, Mo. (Johnson County); Cleveland, Ohio (Cuyahoga County); Allentown, Pa.; Sacramento, Calif.; Cleveland, Ohio (Lake County, black and white); Cleveland, Ohio (Lake County, color); DOQQs east of –84 degrees New Jersey.

Information Access and Distribution Development

Overview

The Information Access and Distribution Development (IADD) Project manages and distributes seamless data from the EROS Seamless Server and its ESRI mirror site serving in support of *The National Map*, Geospatial One Stop, The Geography Network, NGA, and the Department of Homeland Security (DHS)/Federal Emergency Management Agency (FEMA). It supports map, data, and Web services as well as custom applications (http://gisdata.usgs.gov/).

Currently hosting approximately 21 terabytes (TB) of data and growing, the Seamless Server provides access to the national framework theme datasets, science data, and partner data for *The National Map* (fig. 43). The system is flexible and scalable, which enables EROS to provide different levels of service to different customers, both with online services and custom media deliveries. The Department of the Interior's (DOI) security (C&A) requirements were

Figure 43. Access to the Seamless Server.

satisfied with a mirror system at ESRI that will take over the functions of the Seamless Server through an automatically switched failover scenario when the Seamless Server is offline. Operational backups for the Seamless Server are being stored at an offsite vault location, and all data will be archived at EROS for long-term preservation.

The New Seamless Data Distribution Interface

In addition to its central role in serving *The National Map*, this project offers new and innovative techniques for leveraging data holdings on the Seamless Server in support of other activities (http://gisdata.usgs.net/Website/Seamless/) (fig. 44-45).

Figure 44. New Seamless Data Distribution System entry (http://gisdata.usgs.net/Website/Seamless/).

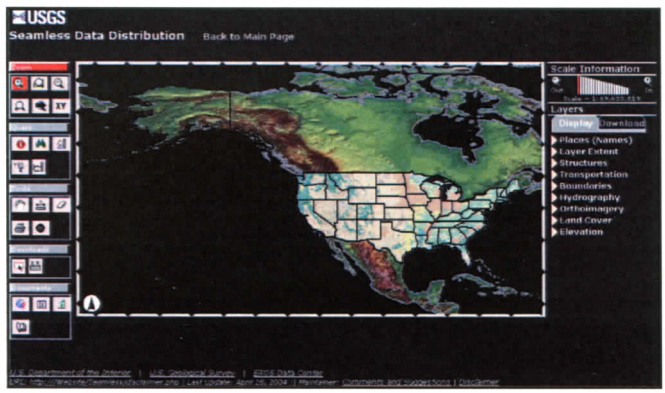


Figure 45. New Seamless Data Distribution System.

Restoration of Data from Lossy Compression

In fiscal year (FY) 2004, USGS funded Restoration of Data from Lossy Compression, a joint research project between EROS and the Mid-Continent Mapping Center (MCMC), with a planned duration of three years. During FY 2004, the project developed algorithms to determine if an image had been previously compressed, and if so, to determine the compression parameters that were used. This repeatable

approach to restoration produces encouraging results for very small images, but its runtime is prohibitive for larger imagery.

The National Map Print Applications Project

A Landsat Thematic Mapper (TM) mosaic and shaded relief map of the conterminous United States was assembled, clipped, masked, and delivered to the National Atlas. Elevation was extracted from the National Elevation Dataset (NED). The Landsat data came from the TM imagery used as the basis for the 1992 National Land Cover Dataset. Staff at EROS and Eastern Region Geography assembled data mosaics and combined the TM imagery with shaded relief at 200-meter (m) resolution.

The combined TM/shaded relief image was used to generate three products:

1. A 20-foot outdoor banner that was displayed at the USGS 125th anniversary open house in Reston, Va. (fig. 46)
2. A plottable map product in National Atlas format at 1:2,000,000 scale (about 8 by 5 feet)
3. A Red-Green-Blue (RGB) version of the image, formatted for the National Atlas Web-based mapmaker (http://nationalatlas.gov)

Figure 46. Outdoor banner on display at the USGS 125th anniversary open house.

This dataset represents a step in the evolution of the National Atlas toward larger scale data and better resolution imagery, in accord with the National Atlas's role as "the small scale implementation of *The National Map*." Future work will bring additional datasets, such as land cover and greenness data, into the National Atlas as well as develop 100-m versions of elevation and Landsat TM data mosaics. Incorporating such data into the National Atlas makes them viewable by the public in the National Atlas mapmaker and makes them available for download by geographic professionals for use in Geographic Information Systems (GIS) applications.

Information Technology Research Project

Visualization Research Task: OptIPuter

The Information Technology Research project at USGS EROS became a Federal Affiliate Partner in the National Science Foundation (NSF)-sponsored OptIPuter research project (www.optiputer.net). The OptIPuter is named for its use of Optical networking, Internet Protocol, computer storage, processing, and visualization technologies. The OptIPuter functions in an envisioned infrastructure that will tightly couple computational resources over parallel optical networks using the Internet Protocol (IP) communications mechanism. The USGS is providing real-world data and science requirements to the project and in-kind staff contributions. As a result of this partnership, EROS has received ultra-high resolution display technology. The technology developed by this high-speed networking research project will be required for researchers, scientists, and emergency managers to interactively visualize and analyze large-scale datasets and will be deployed at EROS during the five years of the project.

Figure 47. Chip Groat and other members of the USGS Science Planning team appear with the GeoWall² system.

USGS Director Chip Groat and other members of the USGS Science Planning team are shown in figure 47 with the newly installed GeoWall² system, which is displaying 1-foot resolution aerial photography of the Mall in Washington, D.C.

This system was designed to be portable, and was therefore available for use by the OptIPuter project for a booth at the 2003 Supercomputing Conference in November to showcase USGS satellite imagery (fig.48).

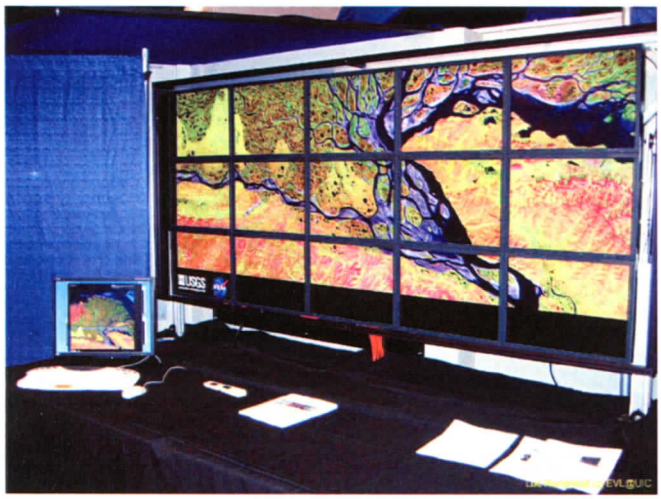


Figure 48. Supercomputing Conference booth.

EROS was invited to participate at U.S. Senator Tom Daschle's 2004 South Dakota Technology Summit in Sioux Falls, S. Dak., and highlight the GeoWall[2] technology, which is capable of simultaneously displaying 2 GB of satellite image pixels covering the entire state of South Dakota.

EROS staff also co-authored, with colleagues from the University of Chicago-Illinois (UIC), a presentation ("From CAVES to Collaborative Visualization and Desktop Analysis Challenges in Ultra-High Resolution Visualization and Collaboration") for the U.S. Display Consortium Conference and a paper ("JuxtaView – A Tool for Interactive Visualization of Large Imagery on Scalable Tiled Displays") presented at the Cluster Computing 2004 Conference.

Visualization Research Task: GeoWall Consortium

Staff from EROS became founding members of the GeoWall Consortium (www.GeoWall.org), leading the development of low-cost, three-dimensional (3-D) virtual reality capabilities in a spirit of open source software, data, and information. EROS staff worked with Consortium members from the University of Minnesota on development of a 3-D dataset covering the entire Earth and ocean floor surface. This visualization, "Three-Dimensional Anaglyph of the Earth," was submitted for consideration in *ESRI Map Book, Volume 19, GIS—The Language of Geography* (fig. 49). This yearly publication celebrates achievements in GIS and explains how GIS helps to solve many of the world's problems. This visualization, which was one of 116 accepted from thousands of entries, was also chosen for the cover of the publication.

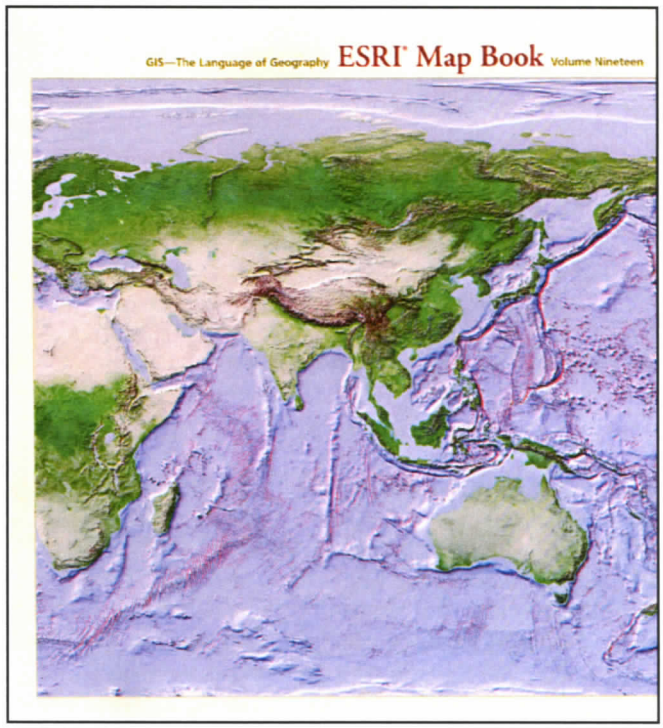


Figure 49. *ESRI Map Book* cover.

EROS staff also authored an article in *ArcNews* magazine, "Virtual Reality Meets GIS: 3D on the Wall." This article introduces affordable 3-D stereo display technology to the mass GIS marketplace. A corresponding article, published in *ArcUser* magazine, was titled "Affordable System for Viewing Spatial Data in Stereo." This article briefly describes the ESRI and USGS collaboration on the new stereo capabilities of ArcGIS version 9.0, and outlines the steps for setting up a low-cost, 3-D stereo display system.

As a result of collaboration with the GeoWall Consortium and ESRI in development of 3-D visualization technology, EROS was invited to help represent the USGS and showcase GeoWall technology in a DOI Special Exhibit at the ESRI User conference. An example of the data displayed at the conference is shown in figure 50.

Non-Linear Digital Video Editing

EROS staff converted a time series of historical Landsat imagery to reflectance and produced digital movie animations of growing season land cover change on Bureau of Indian Affairs lands. Landsat Enhanced Thematic Mapper Plus (ETM+) im-

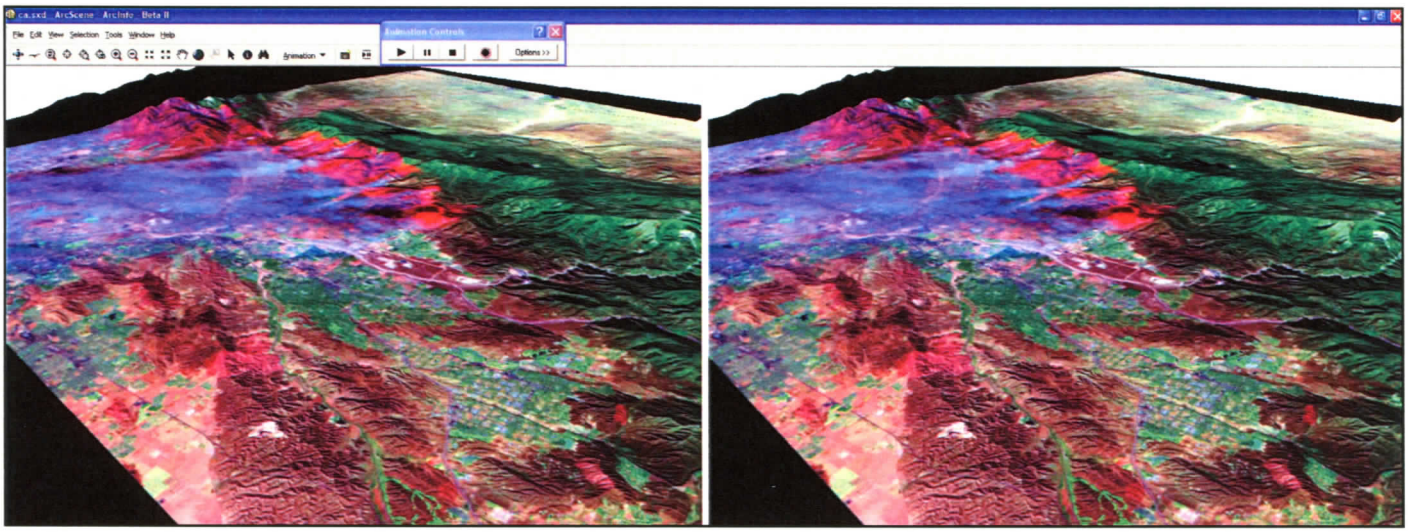


Figure 50. ArcGIS 3-D Analyst displays NASA's ASTER satellite imagery of the San Bernardino, Calif., wildfire of 2003 in stereo.

ages are used in a seasonal time sequence over the Rosebud Sioux Reservation in South Dakota. This video stream will be incorporated into a DVD-based presentation, allowing users with standard (and ultimately high) definition televisions, with consumer grade DVD players, to observe land surface changes over a growing season and optionally overlay other graphic information such as climate variables, land cover, and topographic variables using standard DVD player controls.

Hand-Held Applications

EROS scientists developed java interface software (fig. 51) for database interaction with hand-held computer devices (fig. 52) for entry of field data measurements and subsequent automated download and database population. Image and map images were integrated into hand-held applications software.

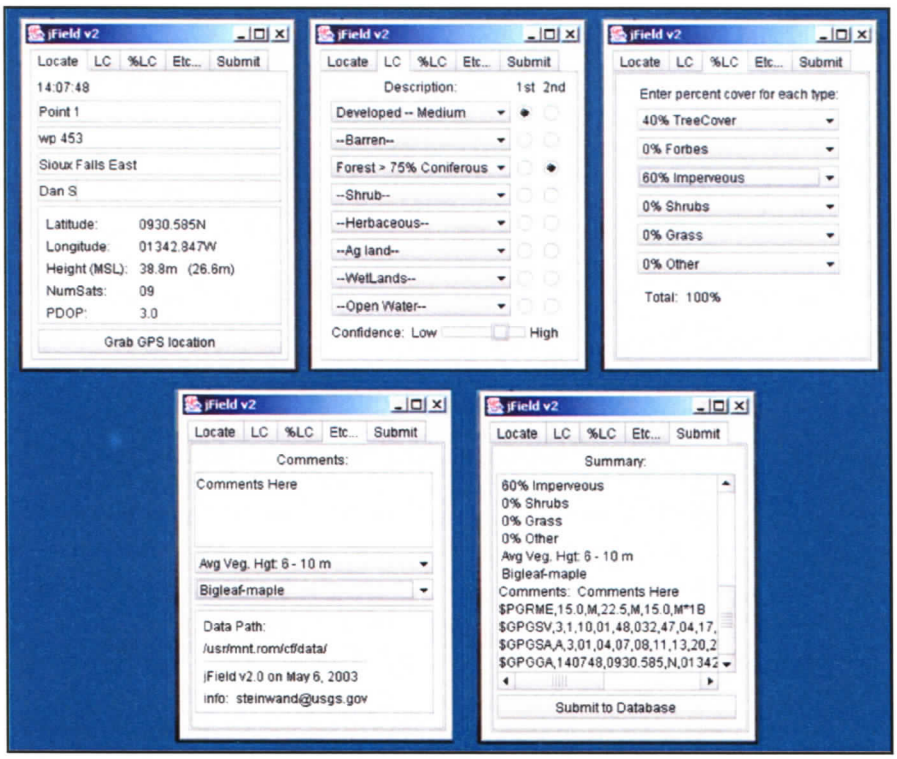


Figure 51. Java interface software for database interaction with hand-held devices.

Figure 52. Example of a hand-held computer device.

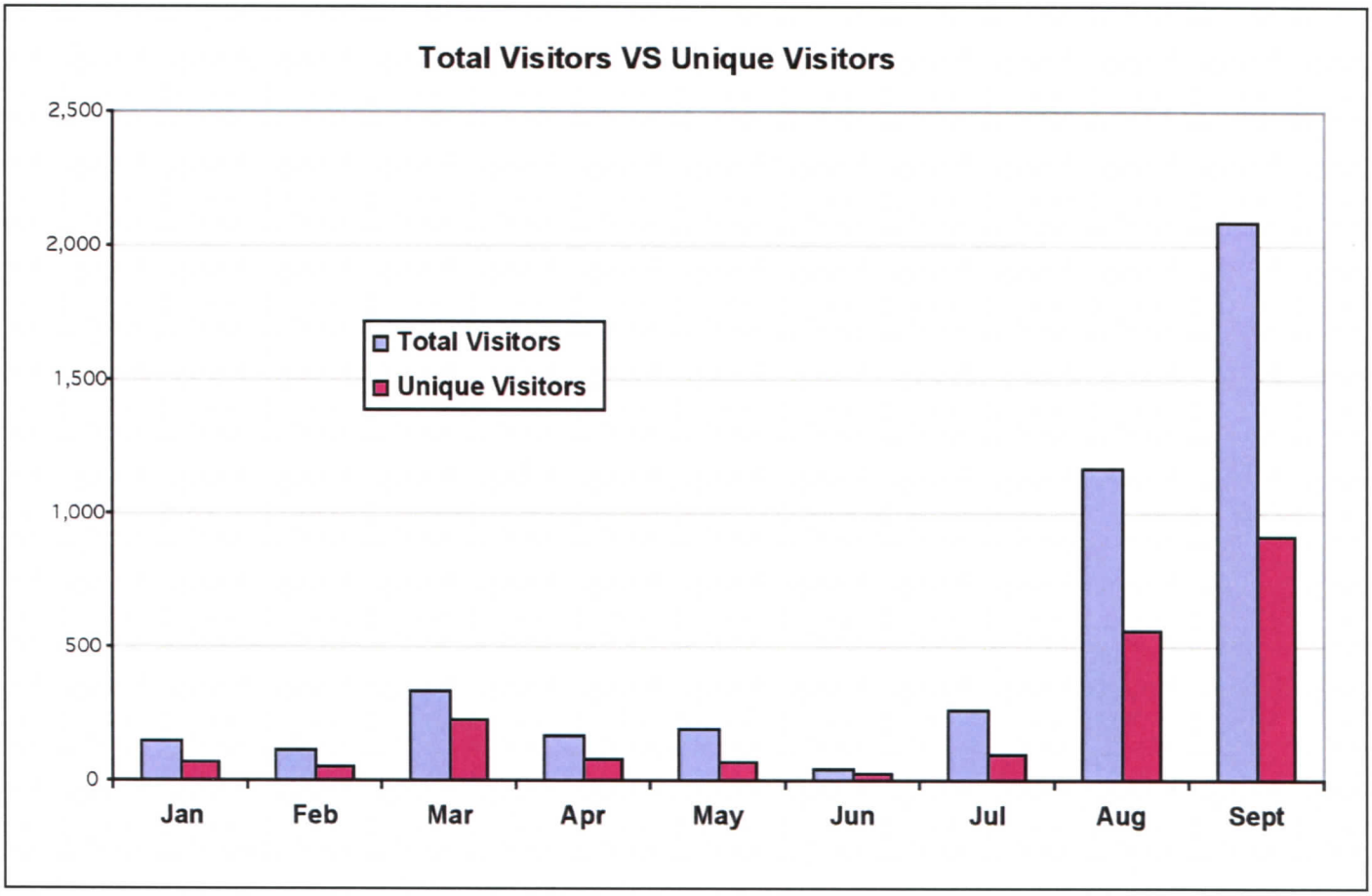


Figure 53. HDDS usage increase after Hurricane Charley.

Emergency Response Coordination

The USGS provided support and coordination activities for federal, state, and local agencies during Hurricanes Isabel, Charley, Frances, Ivan, and Jeanne. FEMA was supported with aerial imagery, radar imagery, and value-added products and various optical satellite data collections. *The National Map's* Hazards Data Distribution System (HDDS) supported the data viewing and delivery tool. In the last two months of FY 2004 (August/September), we loaded more than 1 terabyte (TB) of data to the file transfer protocol (ftp) site and viewer to support hurricane activity. Figure 53 shows HDDS usage increase after Hurricane Charley hit on August 13, 2004.

We also provided support for fires in California and Alaska, floods in Washington state, typhoon Lupit in the Federated States of Micronesia, the earthquake in Bam, Iran, and the train wreck/chemical spill in Neyshabur, Iran. Staff provided support and technical assistance to the Transportation Security Administration (TSA) at Midway Airport in Chicago, Ill., the Secret Service for a Presidential visit to Kansas, the TSA and Federal Bureau of Investigation (FBI) in South Dakota for airport coverage, the Border Patrol Field Intelligence, the U.S. Attorney/Hammond, Ill., the New York State Office of Cybersecurity, the DHS Inspector General's Field Office, the NGA, the Central Intelligence Agency (CIA), the DOI, the U.S. Agency for International Development (USAID)/ Office of U.S. Foreign Disaster Assistance (OFDA), the U.S. Army Topographic Engineering Center (TEC), U.S. Marine Corps Intelligence, the National Reconnaissance Office (NRO), the State Department, the Department of Veterans Affairs, and the Department of Agriculture. Examples of viewable images on *The National Map* are shown in figures 54-56.

EROS staff published an article in the Sept./Oct. 2004 issue of *Earth Imaging Journal*. They also made presentations at the ESRI Federal User Conference, American Geophysical Union (AGU) Fall Meeting, American Society for Photogrammetry and Remote Sensing (ASPRS) Annual Conference, the National Resource Disaster Assessment Workshop, United Nations meeting on the Use of Space Technology for Disaster Management, and the ESRI annual meeting.

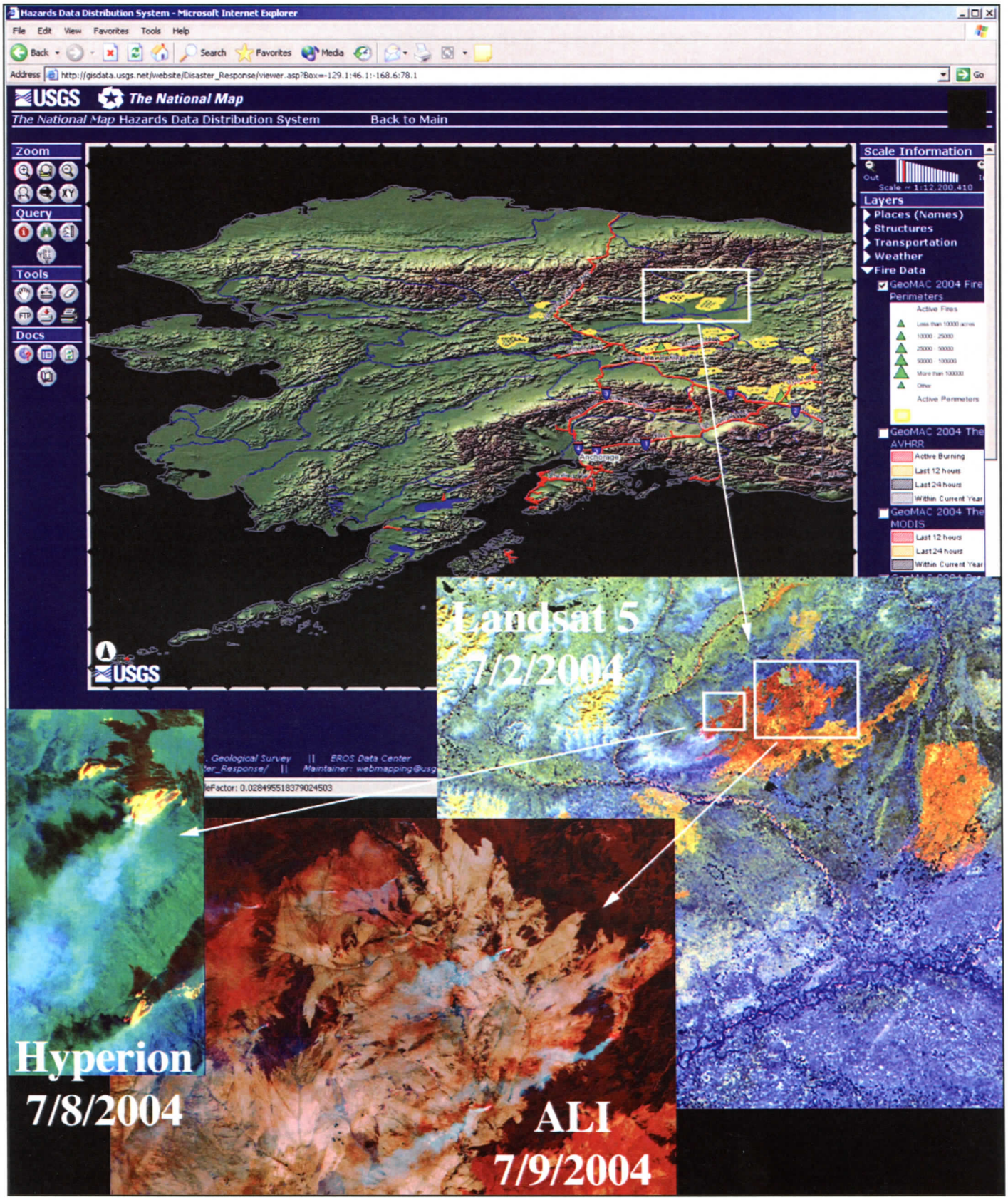


Figure 54. A view of *The National Map's* Hazards Data Distribution System shows the state of Alaska with Alaska State Department of Transportation (DOT) highways, the Geomac fire boundaries, USGS shaded relief, and National Atlas water bodies and streams. This graphic also illustrates the use of multiple satellite platforms for frequent coverage of events. The Landsat data is from July 2, 2004; the Hyperion data is from July 8, 2004; and the ALI data is from July 9, 2004.

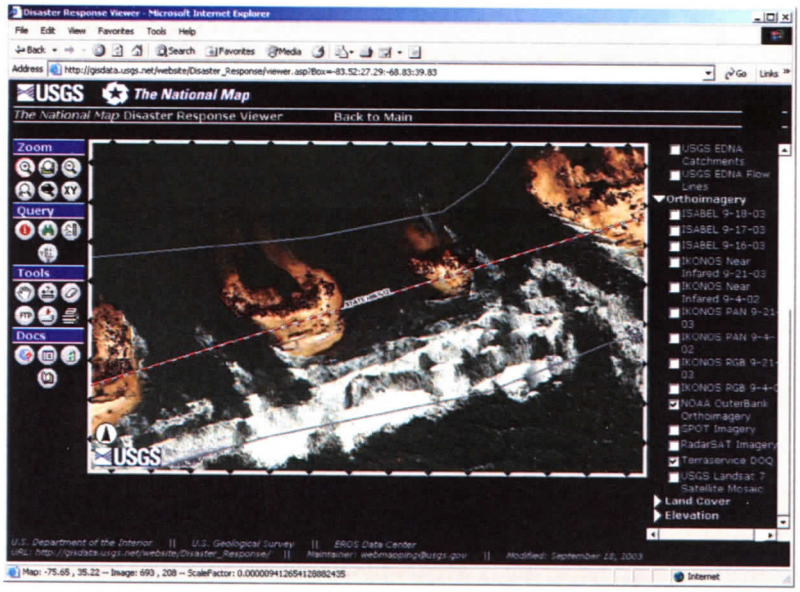
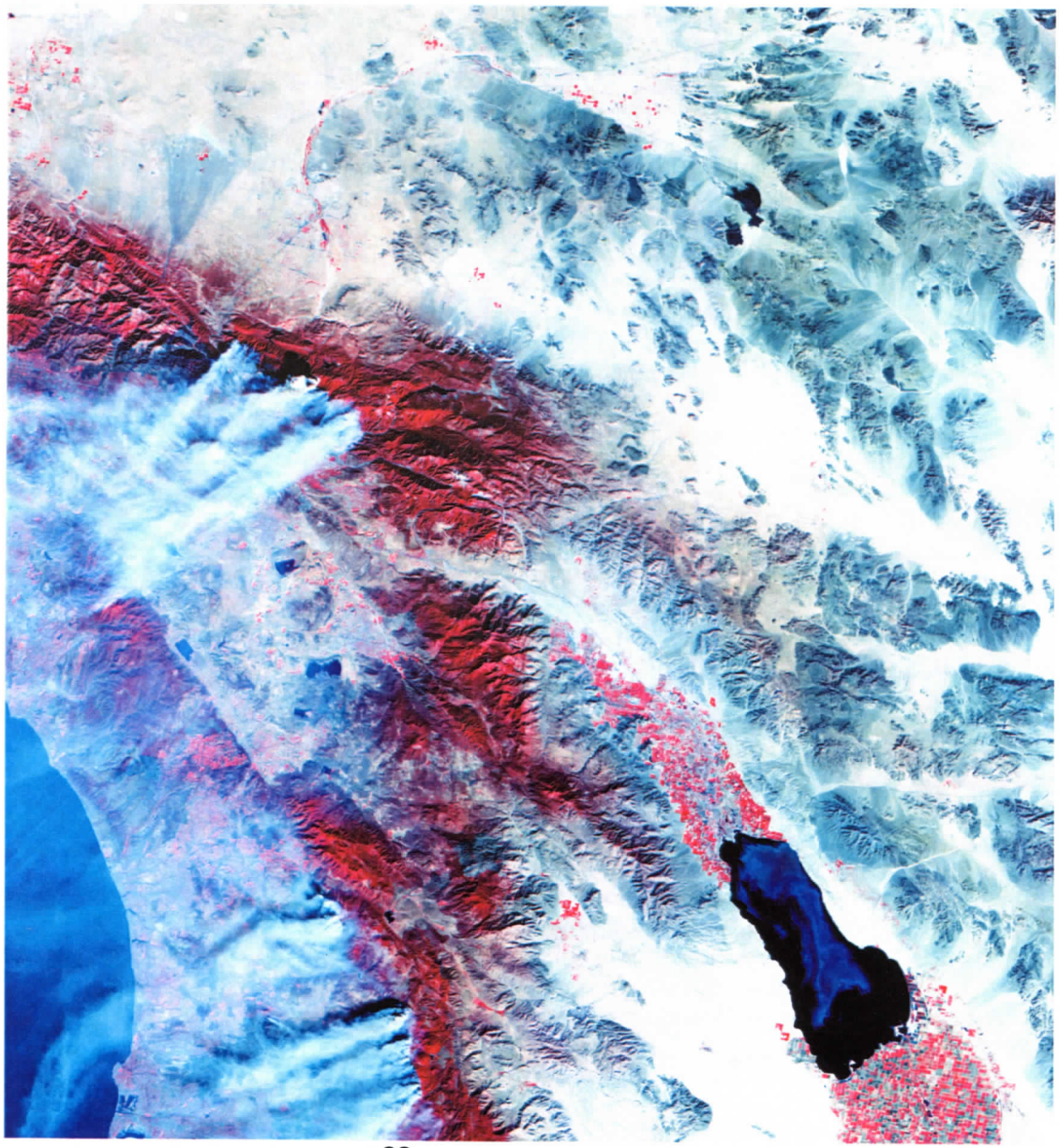


Figure 55. This graphic view from HDDS of post-Isabel high-resolution orthoimagery overlaid with the North Carolina State DOT roads shows the breach by Cape Hatteras, N.C., caused by Hurricane Isabel.

Figure 56. This image of the California fires was supplied by Surrey Satellite Technology from the Disaster Monitoring Constellation. The smoke from the fires is white. The footprint from this satellite is approximately 600 kilometers (km) square, compared to Landsat at 185 km.



Remote Sensing Achievements

AmericaView Program

The mission of the USGS AmericaView Program is to advance the availability, timely distribution, and widespread use of remote sensing data and technology through education, research, outreach, and sustainable technology transfer to public and private sectors.

The AmericaView Program began as a pilot program in 1998 set up by the USGS and a group of Ohio universities. The goal of the OhioView (http://www.ohioview.org/) pilot was to overcome the cost and data access problems historically faced by the research community interested in using remote sensing data. Under the original pilot, the state of Ohio purchased and received all of the Landsat 7 (http://landsat.usgs.gov/) images acquired over Ohio within 36 hours of the time the data were collected at the USGS-operated receiving station. In turn, through an in-state consortium of research universities and computer facilities, the data were made publicly available though digital library facilities in Ohio. Thus, researchers, educators, students, land managers, and the general public now have local access to this data at no cost and with no restrictions on further use. In 2000, based on the success of the OhioView pilot, the USGS began implementing the AmericaView program nationwide. The USGS has entered into an agreement with the national consortium, AmericaView, Inc. (http://www.americaview.org/), as a partner in accomplishing this mission. The AmericaView Program is administered under the USGS Land Remote Sensing (LRS) Program (http://remotesensing.usgs.gov/). USGS infrastructure activities for this effort are carried out at the National Center for Earth Resource Observation and Science (EROS) in Sioux Falls, S. Dak.

In fiscal year (FY) 2004, the AmericaView project continued to successfully operate and maintain the Moderate Resolution Imaging Spectroradiometer (MODIS) direct broadcast capability. MODIS data are available for download by registered users within three hours of acquisition from the satellite (http://edc.usgs.gov/modisdata/). There are currently 130 registered users for this site. In addition, time-composited products, vegetative indices, and conterminous U.S. mosaics are also available. In particular, a rolling 7-day Normalized Difference Vegetative Index (NDVI) for the conterminous United States is processed nightly and sent to the USGS Seamless Server (http://seamless.usgs.gov) where it is made available as a layer for *The National Map*. The USGS Global Visualization team completed the development work needed to include additional Landsat-related and Earth Observing-1 (EO-1) data collections in the system. These data collections give researchers visual access to a broader set of the Landsat satellite data than was previously available. In particular, the addition of the Landsat orthorectified datasets is significant as it marks a contribution by the LRS Program to the data available for *The National Map* (http://glovis.usgs.gov).

AmericaView, Inc. and the USGS LRS Program hosted a Congressional reception in FY 2004. The reception was held in the Rayburn House Office Building in Washington, D.C., and included exhibits featuring applications of remote sensing in each of the member states. AmericaView, Inc. also presented an award to Ohio Congressman Ralph Regula in recognition of his support for AmericaView.

AmericaView, Inc. advertised a call for proposals for new affiliate membership in May 2004. Following the evaluation of these proposals by the membership committee, the full membership voted to extend membership in AmericaView, Inc. to the following state consortiums: California, Hawaii, Kentucky, Louisiana, and North Dakota. This increased total membership in AmericaView, Inc. to twenty states, with fourteen full members and six affiliate members (fig. 57).

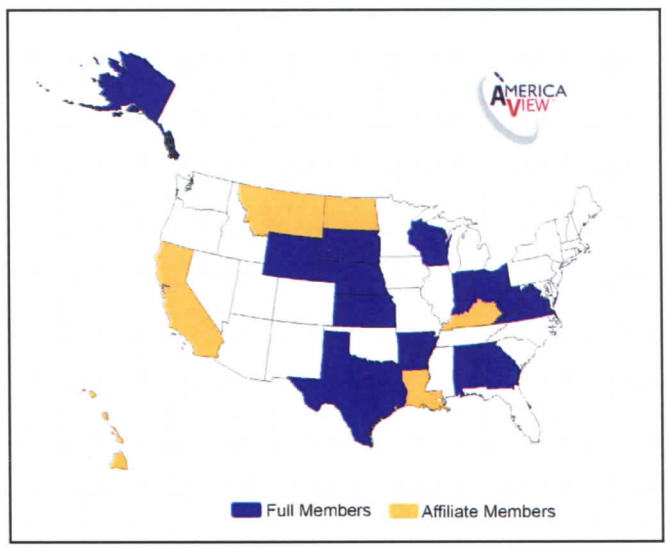


Figure 57. AmericaView, Inc. membership status.

The AmericaView, Inc. annual conference was held September 20-22, 2004, at EROS, with the theme "National and State Partnerships to Enable Remote Sensing Education, Training, and Applications." Workshop topics included Introduction to ArcGIS 9.0, Adapting GloVis for State Use, Introduction to LiDAR, DigitalGlobe and QuickBird's Imagery for Use in Government and Commercial Applications,

Introduction to eCognition Software and Status Reports on USGS EO-1 and Landsat 7 Missions. There were 68 participants from 20 states for the 2-day conference, representing several state and local government organizations as well as research faculty and graduate students from nearly 30 universities.

Commercial Remote Sensing

Commercial Remote Sensing (CRS) is a new, rapidly evolving project initiated at the USGS in response to the President's U.S. Commercial Remote Sensing Space Policy (CRSSP). In FY 2004, EROS participation in this activity was divided into two commercial remote sensing projects: CRSSP Implementation Project (CIP) and CRS Characterization, Calibration, Verification, and Validation (C2V2) project.

In FY 2004, CIP made significant progress in the implementation of the CRSSP policy. Collection, analysis, and reporting were completed on the civil agency short-term data requirements. A paper was also presented on these requirements at the fall American Society for Photogrammetry and Remote Sensing (ASPRS) Technical Conference in Kansas City, Mo. In addition, the requirements were used to determine three primary focus areas for civil agency data needs.

Significant progress has also been made in developing a relationship with the National Geospatial-Intelligence Agency (NGA). The CIP has obtained access to NGA's new unclassified customer interface and has ordered and received data, which has been distributed to approved civil agencies.

The CIP hosted an Interagency Working Group (IWG) meeting at EROS in July with attendees from the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the NGA, the Department of Homeland Security (DHS), and other agencies from the Department of the Interior (DOI). Topics included a demonstration of USGS systems and CRSSP infrastructure, a brainstorming session on areas of collaboration, and a review of the Commercial Remote Sensing Data Contracts established at the USGS Mid-Continent Mapping Center (MCMC). NGA also gave a system architecture presentation.

The USGS CRS C2V2 project is responsible for the calibration and validation of satellite data, national aerial mapping sensors, and validation of product types to ensure quality image-derived products. To meet these responsibilities, the C2V2 team provides system characterization and product validation in the laboratory and in the field for both satellite and aerial sensors.

The USGS has a mission to provide basic cartographic information for the United States. Primary sources for these data are airborne film mapping cameras. Since 1973, the USGS Optical Science Laboratory at EROS has been responsible for calibrating these cameras for the aerial mapping community. Over the years, the lab has been recognized nationally for providing this essential service. During FY 2004, the USGS lab calibrated more than 115 cameras.

Figure 58. The new Digital Camera Calibration Lab established at EROS.

In FY 2003, the C2V2 project established a Digital Camera Calibration Laboratory to research the digital imaging technologies that are replacing film-based systems. The lab is equipped with a target cage, hardware, and software to calibrate small- to medium-format digital cameras (fig. 58). The C2V2 project also developed an in-situ calibration test range and associated software to evaluate the combined platform-camera system end-to-end. The range covers a 4-by 4-mile square surrounding EROS, incorporating 150 precision calibration points (fig. 59). Each point has been surveyed for latitude, longitude, and elevation and uses advanced instrumentation capabilities to support characterization. This information is currently being used to research new camera calibration procedures and methodologies to support digital sensor policy and standards development. The C2V2 project also uses a Reimbursable Interagency Agreement with NASA's Stennis Space Center to help characterize large-format digital cameras being used to obtain commercial remote sensing data through contract purchases. Ohio State University and South Dakota State University are working with the USGS on the development of in-situ test ranges and testing of image assessment software. The research experience gained by the USGS through this project will be used to support the establishment of a USGS-chaired Interagency Digital Imagery committee that will be established in FY 2005.

Figure 59. Example of EROS range points for aerial and satellite calibration and validation.

The USGS has been working with NASA, NGA, industry, and academia to validate and characterize commercial remote sensing space data products since 2000 through the Joint Agency Commercial Imagery Evaluation (JACIE) team. The results of these tests, designed and documented by the JACIE team, ensure that the data meet the specialized needs of a range of government applications. Test results have also proven to be highly useful to satellite vendors who use the results of these assessments to improve their products and services. Findings are presented annually at the High Spatial Resolution Commercial Imagery Workshop. The fourth annual workshop was held in November 2004 at USGS headquarters in Reston, Va. The workshop featured results from analysis of Space Imaging, DigitalGlobe, and ORBIMAGE satellite imagery.

In December 2003, the USGS sponsored the International Workshop on Radiometric and Geometric Calibration in Gulfport, Miss., in conjunction with NASA, the International Society for Photogrammetry and Remote Sensing Commission I/Working Group 2 (ISPRS I/WG2), and the Committee on Earth Observation Satellites Working Group on Calibration and Validation (CEOS/WGCV). The results from the workshop were documented in a publication, *Post-Launch Calibration of Satellite Sensors*, which was provided to the calibration-validation community.

A successful 2-day USGS calibration-validation working group meeting was held at EROS in March 2004. Fourteen members from the Geography discipline participated, including representation from USGS Headquarters and all Science Centers. The purpose of this meeting was to define strategic requirements for digital sensor characterization and calibration, and digital image product verification and validation. The group was successful in defining USGS FY 2005 requirements and laying out a strategic plan for the future.

In June 2004, EROS hosted the CEOS/WGCV 22nd Plenary Meeting, which allowed the USGS to highlight its calibration and validation activities to CEOS/WGCV members, who represent an important cross-section of the international remote sensing community. Attendees focused their attention on two major areas: the assessment and recommendation of current techniques and standards for pre- and post-launch characterizations and calibration and the techniques for validation of geophysical parameters derived from Earth observation satellite systems.

The USGS has established joint agency agreements with NOAA and the USDA to become part of seven different instrumentation networks, locating in-situ observation nodes at or near the EROS campus. These networks, established in 2003, continued to support earth science data calibration and validation under the C2V2 project in 2004. Data collected includes high-precision Global Positioning System (GPS) reference data, complete meteorological microclimate data, soil temperature and moisture data, surface solar radiation data, and carbon flux measurements.

The recently established USGS instrumentation network site at EROS includes:

1. NOAA National Ocean Service National Geodetic Survey's Continuously Operating Reference Station Network
2. NOAA Forecast Systems Laboratory's GPS Surface Observation System Network
3. USDA Natural Resources Conservation Service's Soil Climate Analysis Network
4. NOAA Surface Radiation Research Branch's Surface Radiation Budget Network
5. NOAA National Climatic Data Center's Climate Reference Network

6. USGS carbon flux tower supporting NOAA and USDA networks, such as Ameriflux and Fluxnet
7. USGS Cimel instruments supporting the NASA AERONET network

The C2V2 project also provides support for instruments and vicarious calibration tools required to calibrate/validate commercial remote sensing data in the field.

Land Processes DAAC

The Land Processes (LP) Distributed Active Archive Center (DAAC) was established as part of NASA's Earth Observing System Data and Information System (EOSDIS) initiative to process, archive, and distribute land-related data collected by earth Observing System (EOS) sensors, thereby promoting the interdisciplinary study and understanding of the integrated Earth system. The LP DAAC role subsequently was expanded to include processing and distribution responsibilities related to Landsat 7 data.

The LP DAAC recently went operational with the NASA EOS Data Clearinghouse, making data available to USGS scientists, users, and Earth science client developers through a new NASA capability. It also made all of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and MODIS data available through the USGS Global Visualization viewer. Collaboration with the Seamless Data Distribution project has led to the development of mosaics of Terra/MODIS 16-day, 1-kilometer (km) vegetation indices for the conterminous United States, available as part of *The National Map* through the Seamless Data Distribution system. This initial phase makes the Terra/MODIS vegetation indices accessible using Open GIS Consortium (OGC) compliant Web Mapping Services (WMS) using the seamless data viewer.

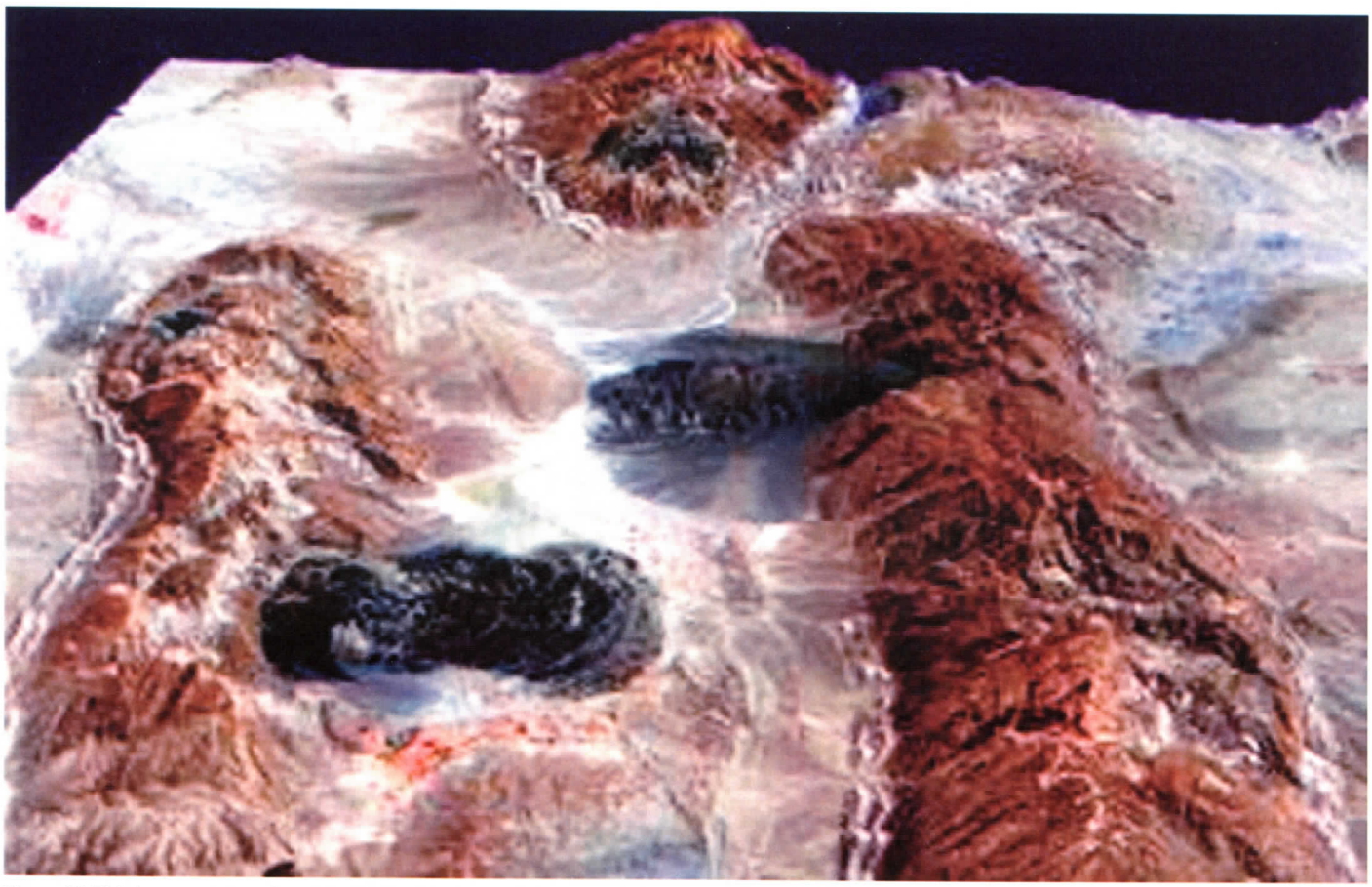


Figure 60. This image was produced by NASA/GSFC/METI/ERSDAC/JAROS and the U.S./Japan ASTER Science team. The diapirs, or salt plugs, in the image are a few of more than 200 similar features scattered about the Zagros Mountains in southern Iran. This region of folded rocks is the result of a collision between the Asian landmass and the Arabian platform. The deeper underlying deposits of salt have been reformed into ascending fluid-like, plastic plumes. In some places these plumes have pushed through the overlying rock units, like toothpaste extruding from a tube, and are now visible as darkish irregular patches. Gravity has caused the salt to flow into adjacent valleys; the resulting tongue-shaped bodies, more than 5 km long, resemble glaciers, with arcuate ridges separated by crevasse-like gullies and with steep sides and fronts. The darker tones are due to clay brought up with the salt, as well as the probable accumulation of airborne dust. This ASTER perspective view was created by draping a band 3-2-1 (RGB) image over an ASTER-derived Digital Elevation Model (DEM) (2x vertical exaggeration), and was acquired on Aug. 10, 2001.

The LP DAAC at EROS continues to ingest, archive, and distribute massive amounts of earth science data. In FY 2004, the LP DAAC handled more than 5.6 million products or 472 terabytes (TB) of data; in one quarter, almost 150 TB of data from NASA satellites through Japan and NASA's Goddard Space Flight Center were ingested, with a record of 2.5 TB in one, 24-hour period. Over the course of a year, the LP DAAC distributed approximately 2.4 million products or more than 270 TB of data (including only Enhanced Thematic Mapper Plus (ETM+), ASTER, and MODIS scenes, and not including Web views or browse downloads).

Despite the heavy workload of maintaining computer systems and data to meet these extraordinary demands, those systems continued to be available to users almost full time. March 2004 was the first month with no unscheduled downtime. Users seem to appreciate that; not only are orders steadily increasing, but the number of people who visit the website is climbing, too. More than 30,000 unique users visited the website at least once in the quarter.

The LP DAAC held a number of workshops and poster sessions to teach users how to use ASTER and MODIS data (fig. 60). For example, the LP DAAC held an ASTER and MODIS Data for Land Process Studies workshop at EROS. Fifteen individuals attended from the Bureau of Reclamation, Bureau of Land Management, Bureau of Indian Affairs, and NASA ITD.

Landsat Update

The Landsat Project is a joint initiative of the USGS and NASA to gather Earth resource data using a series of satellites. NASA was responsible for developing and launching the spacecrafts and the ground systems, while the USGS is responsible for flight operations, maintenance, and management of all ground data reception, processing, archiving, product generation, and distribution.

The primary objective of the Landsat Project is to ensure a collection of consistently calibrated Earth imagery. Landsat's global survey mission is to establish and execute a data acquisition strategy that ensures repetitive acquisition of observations over the Earth's land mass, coastal boundaries, and coral reefs, and to ensure that the data acquired are of maximum utility in supporting the scientific objectives of monitoring changes in the Earth's land surface and associated environment.

The Landsat project released a new product for Landsat 7 ETM+ data captured after the Scan Line Corrector (SLC) anomaly. This new product uses Landsat 7 data collected before the anomaly to fill the missing areas due to the non-functional SLC. Two scenes are geometrically registered, and a histogram-matching technique is applied to the pixels that provide the best-expected radiance values for the missing data (fig. 61). This product will increase the utility of Landsat 7 data affected by the anomaly.

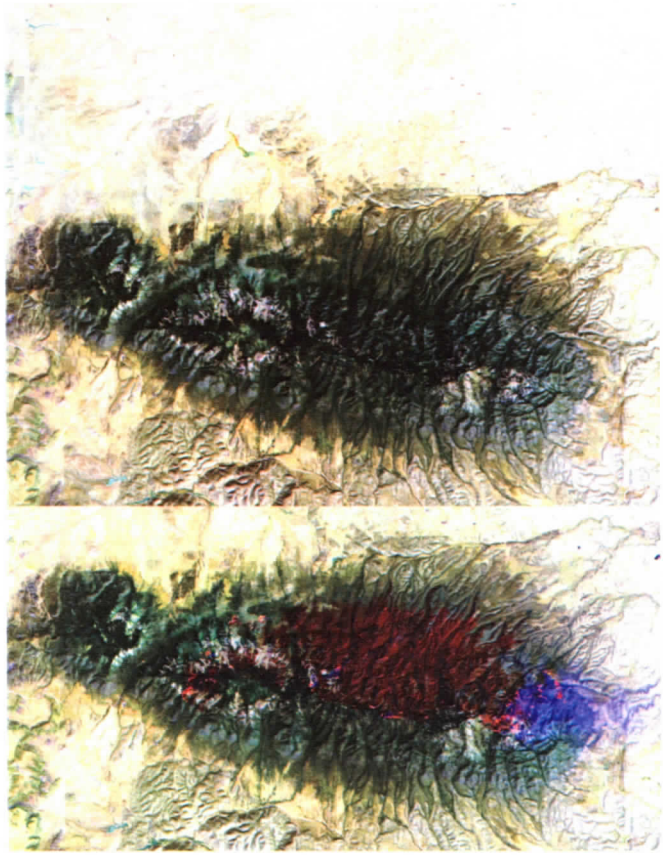


Figure 61. These images show Landsat 7 ETM+ data over New Mexico's El Capitan Mountains acquired May 11, 2003 (top), and May 29, 2004 (bottom). The lower image, a gap-filled product, shows the 2004 Peppin fire that burned more than 64,000 acres.

Landsat data continue to be useful for evaluating land cover events. A number of fires broke out in Alaska in 2004 (fig. 62). Landsat data were used to monitor the extent, burn rate, and effects of more than 70 individual fires in the state.

EROS scientists investigated the utility of the gap-filled imagery for various mapping applications. Preliminary results show that gap-filled imagery is well suited for burn severity, geological, and impervious surface mapping. Investigation into promising techniques for other applications continues.

The USGS is currently in final testing for the next major product enhancement of Landsat 7 ETM+ data captured after the SLC anomaly. This new product will allow users to select and prioritize SLC-off scenes for generation of a final "gap-free" image. The user may now select from zero to four SLC-off scenes, in addition to an optional SLC-on scene, to create the final data merged product.

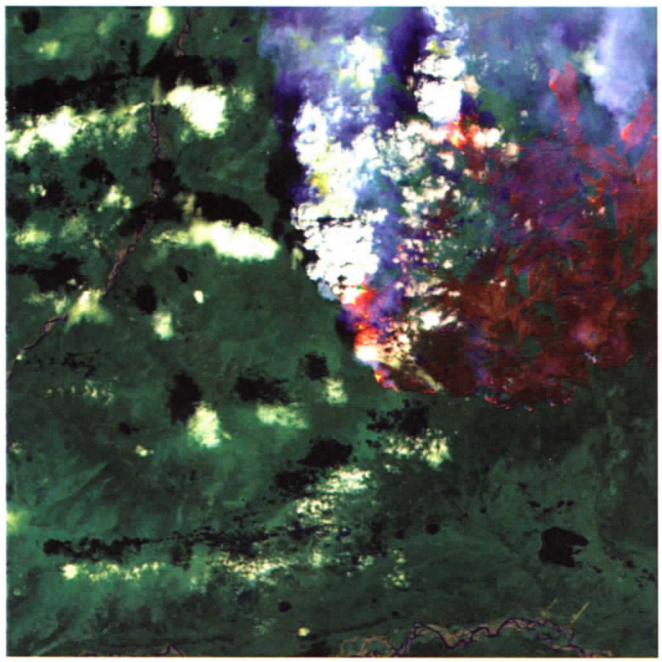


Figure 62. Landsat 5 image of the Pingo fire in Alaska, acquired in June 2004.

The technique used to generate the new product is similar to the previous gap-filled product and employs a histogram-matching approach. The major advantage of this new product is improved temporal resolution within the final image. The initial gap-filled product was limited to using data that had been collected prior to the SLC anomaly (one or more years previous) to fill the gaps of the target scene. This newer product allows the use of scenes from consecutive passes to fill the gaps of the target scene (fig. 63).

The new SLC-off to SLC-off merged product requires reprocessing of post-anomaly data to provide metadata pertaining to the gap locations in each scene. Reprocessing began in October 2004 with a later announcement of the new product (http://landsat7.usgs.gov).

The cooperative agreement between EROS and South Dakota State University (SDSU) enables cooperative research, technical support, and operational functions between the SDSU Electrical Engineering Department's Image Processing Laboratory and the Landsat project. This agreement also provides the USGS and SDSU a unique opportunity to enhance the calibration of USGS Landsat data and to further SDSU's satellite image data calibration research and education activities. The overall goal of this cooperative agreement is to use SDSU's unique skills in Landsat calibration to develop and operate a Multispectral Scanner (MSS) and Thematic Mapper (TM) calibration system for Landsats 1, 2, 3, 4, and 5.

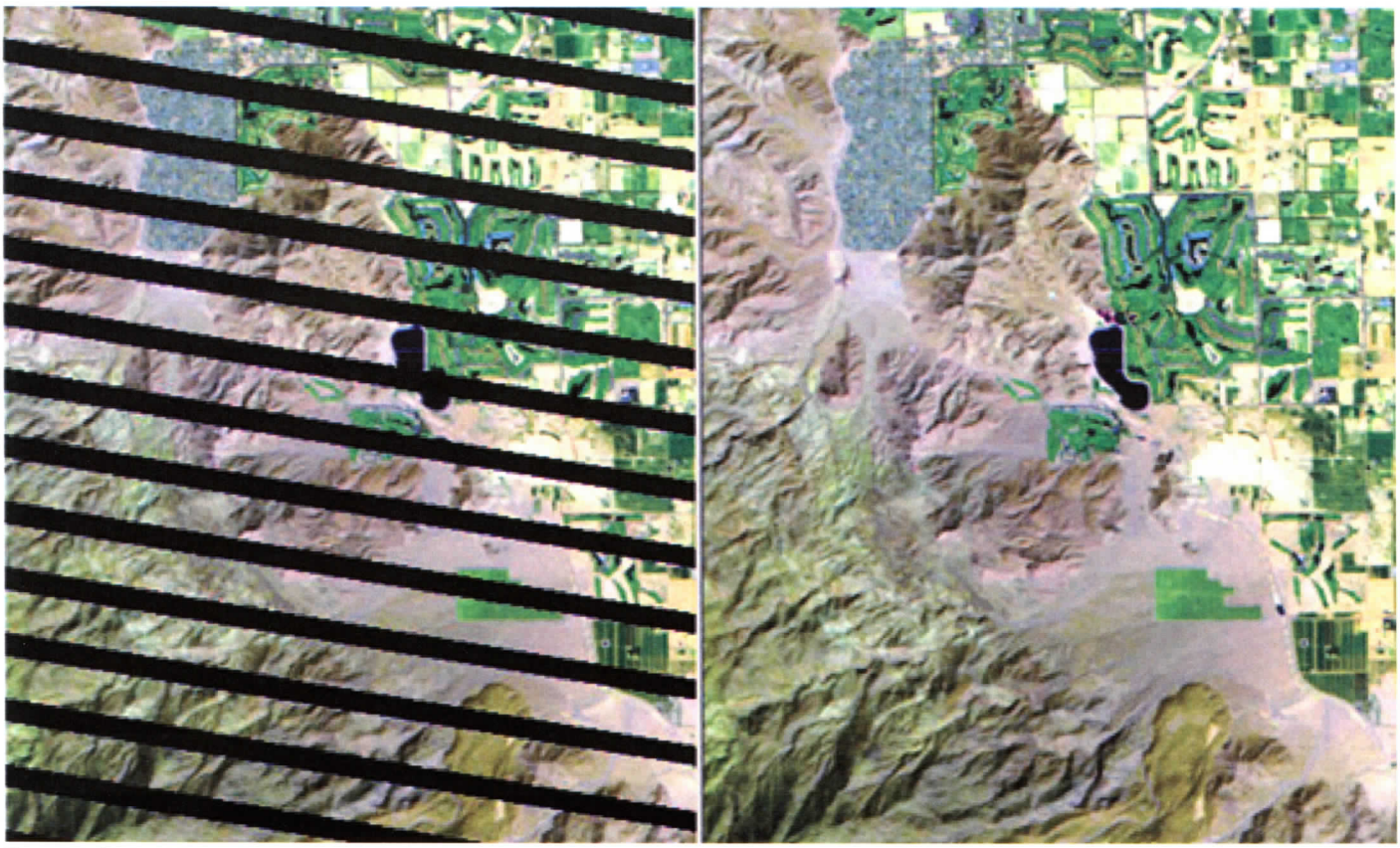


Figure 63. On the left is an image subset of a Landsat 7 ETM+ SLC-off scene acquired on Sept. 17, 2003 (Salton Sea, Calif.). On the right is an image subset of the same SLC-off scene after using image data from a separate SLC-off scene acquired on Sept. 1, 2003.

Because of this agreement, the Landsat user community will benefit from the improved radiometric and geometric calibrations on more than 30 years of Landsat data.

The Landsat project completed major releases of the Data Capture System (DCS) and the Landsat Processing System (LPS). These major releases are significant in that they transitioned these systems from obsolete Silicon Graphics hardware to high-end computers running Linux. In addition to this major platform change, these releases also incorporated the new Storage Area Network (SAN) drives, providing shared storage for multiple systems in the Landsat operations workflow. With the new Linux systems and the SAN now in place, capture and initial processing time of Landsat 7 data will greatly improve. Initial testing shows an improvement of approximately 40 percent. With the old systems, data generally took at least several hours to capture, process, and make available to customers. Now, data are nominally available in less than one hour. In addition to performance improvements, these changes reduce the long-term operating costs for these systems. The Landsat Product Generation System (LPGS) and the Image Assessment System (IAS) process Landsat 7 data for customers and for calibrating the ETM+ instrument onboard Landsat 7. NASA originally developed the software on Silicon Graphics computer systems. Due to obsolescence and increasing maintenance costs, the Landsat project also transitioned these systems to Linux, Intel-based servers. The new configuration allows the Landsat project to easily increase capacity without major investments in large, single-vendor hardware.

The historical Landsat data archive, dating back to 1972, largely exists on aging analog tape media retrieved and handled manually for product requests. The Landsat Archive Conversion System (LACS), which began operation in June 2004, will convert these data into an automated near-line silo (fig. 64). Additionally, LACS significantly automated the processes of collecting new Landsat 5 data from the satellite and placing those data in the archive. This process previously took approximately 24 hours from the time of data collection until it became available for customers to order. With LACS, this process takes only 3 hours.

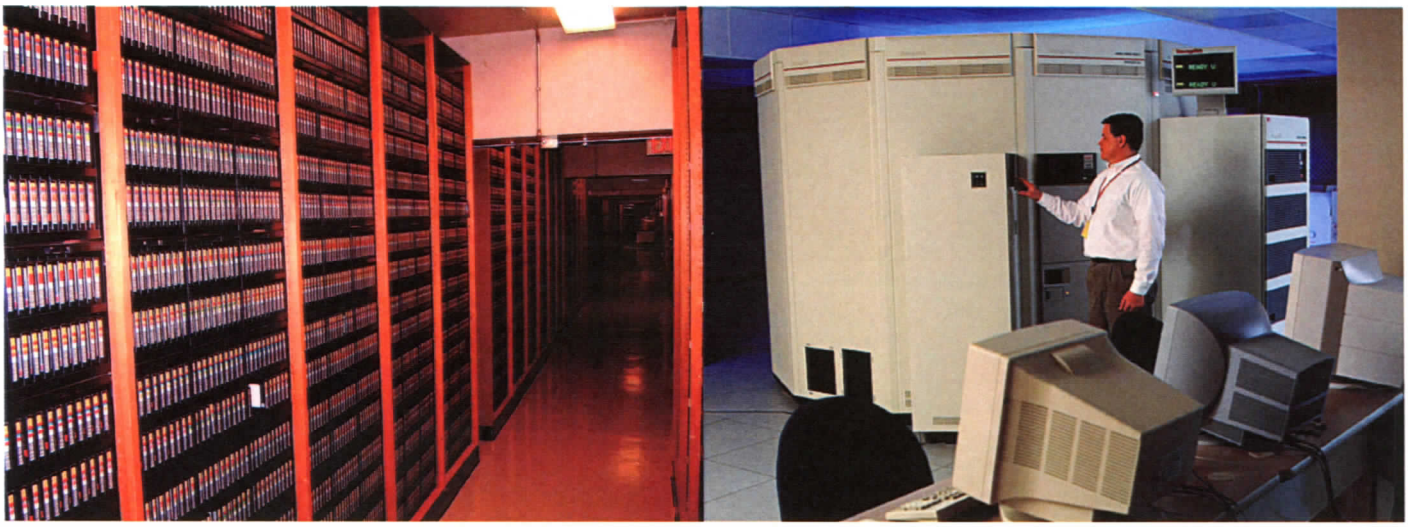


Figure 64. Historic data archive (left) and automated silo storage (right) located at EROS.

The Landsat project held its yearly Landsat Ground Station Operators Working Group (LGSOWG) meeting in Japan, October 13-17, 2003. More than 50 people, representing, 15 countries attended the 32nd LGSOWG meeting. Of critical importance at this session were discussions related to the Landsat 7 SLC failure. With the anomaly investigation completed, the meeting focused on results of the investigation and attempted recovery, continued operations of the satellite, and necessary processing of the data.

Remote Sensing Data Management

The Remote Sensing Data Management project has the responsibility to preserve, provide access to, and distribute products from the Long Term Archive (LTA) of aerial and satellite data in EROS archives and the National Satellite Land Remote Sensing Data Archive (NSLRSDA) to a worldwide community of federal and scientific users. Currently, the archive consists of more than 107,000 rolls of aerial and satellite imagery containing in excess of 13 million frames. It also includes a digital inventory of more than 1,300,000 scenes on 25,000 magnetic tapes, totaling nearly 500 TB. EROS is a world leader in archiving remotely sensed data and providing those

data to users quickly, affordably, and in the most accessible format.

The archive holdings are used for environmental research, homeland security, land management, natural hazard analysis, and natural resource management and development, with applications that extend beyond America's borders. The worldwide community of users includes personnel in federal, state, and local governments, researchers at academic institutions, and private enterprise.

Congress directed the DOI to establish a permanent government archive containing satellite remote sensing data of the Earth's land surface and to make them available for study. This collection, formally known as the NSLRSDA, is managed and maintained at EROS.

Since the early 1970s, the USGS has offered a variety of photographic products (both print and film); however, for the last few years there has been a decline in customer demand for these types of products. Therefore, with production expenses continuing to increase and the user community transitioning to digital data and products, the USGS discontinued offering photographic products on September 3, 2004, and began offering a new digitized product on October 1, 2004. This new digitized product is medium-resolution, created using a camera system with an output file size of approximately 15 megabytes (MB) from a black-and-white photograph, and 45 MB from a color photograph (fig. 65). Both products will be provided in a Tagged Image File Format (TIFF). This digitized product will also be used to generate a digital browser to improve access to the USGS historical aerial photographic archive. EROS has in its possession thousands of rolls of film containing several million frames of historical aerial and satellite photographs dating back to the 1930s gathered from various federal agencies. The largest part of this archive consists of original film acquired in support of the USGS 1:24,000 topographic quadrangle map series, taken from the 1940s through the 1970s. Most of this photography is reasonably large-scale to support the production of the quadrangle maps (http://edc.usgs.gov/products/aerial/medresdig.html).

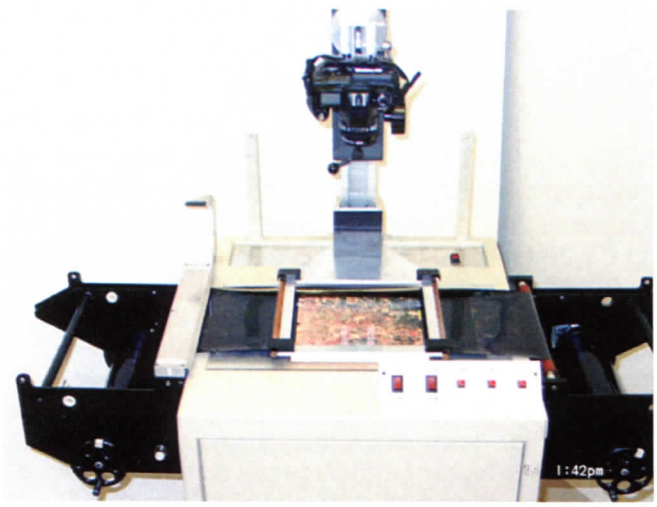


Figure 65. Camera system.

Figure 66. Leica Geosystems DSW600 Digital Scanning Workstation.

The USGS has begun to offer a high-resolution, digitally scanned product. The high-resolution files are photogrammetric quality and are created at approximately 1,200 dots per inch (dpi) with an output file size of approximately 120 MB for black-and-white images and 360 MB for color images and are stored in a TIFF format. The high-resolution files are produced on either a Zeiss SCAI Precision Scanner, using a PHODIS Photogrammetric Image Processing System, or a Leica Geosystems DSW600 Digital Scanning Workstation (fig. 66).

Accessing "Earth as Art"

"Earth as Art" images are now available through the EROS website at no cost if the data are downloaded electronically. Through the first quarter of the fiscal year, more than 5,500 "Earth as Art" files have been provided to the user community at no cost. Access to these 83 images can be obtained by logging on to EROS Image Gallery at http://edc2.usgs.gov/ImageGallery. In FY 2004, several state mosaics were created using the Landsat ETM+ Orthorectified Pan sharpened data. They included North Dakota, South Dakota, Ohio, Wyoming, California, Nebraska, and Kansas (http://edc2.usgs.gov/imagegallery).

The Shuttle Radar Topography Mission (SRTM) successfully collected Interferometric Synthetic Aperture Radar (IFSAR) data over 80 percent of the landmass of Earth between lat 60°N and 56°S in February 2000. The mission was co-sponsored by NASA and NGA. All of the "Research" grade data has been delivered to the USGS and are available to customers

through a file transfer protocol (ftp) server. In addition, most of the "Finished" data have been received from NGA and are available over the Internet at http://edc.usgs.gov/products/elevation/srtmbil.html.

Remote Sensing and Volcanic Activity

Mount St. Helens (Washington) is a prime example of how Earth's topographic form can greatly change within our lifetimes. Prior to 1980, Mount St. Helens had a shape roughly similar to other Cascade peaks, a tall, bold, irregular conic form that rose to 2,950 meters (m) or 9,677 feet. However, the explosive eruption of May 18, 1980, caused the upper 400 m or 1,300 feet of the mountain to collapse, slide, and spread northward, covering much of the adjacent terrain, leaving a crater atop the greatly shortened mountain (fig. 67). Eruptions at Mount St. Helens subsided in 1986, but renewed volcanic activity here and at other Cascade volcanoes is inevitable. For this view, a nearly cloud-free Landsat 5 image, acquired on September 28, 2004, was draped over elevation data from the SRTM mission and shading derived from the SRTM data was added to enhance the topographic expression.

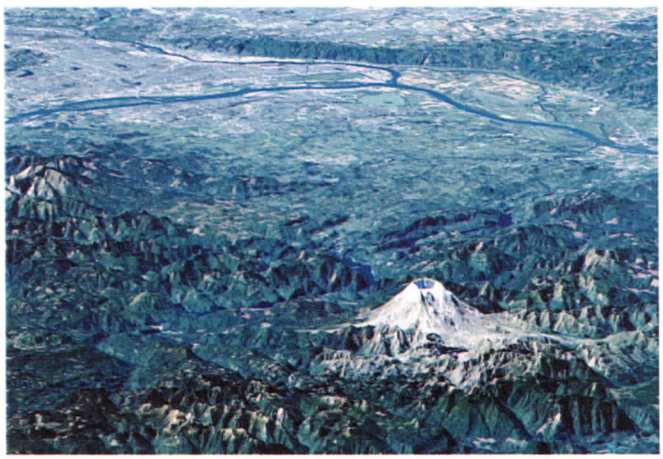


Figure 67. Perspective of Mount St. Helens, Wash., combining Landsat with SRTM data.

Early in FY 2004, the NOAA 16 satellite began experiencing a serious scan motor mechanical problem indicative of end-of-life. To ensure data continuity to USGS scientists and customers, greenness mapping was successfully transitioned to the NOAA 17 satellite on April 28, 2004. Consequently, acquisition of NOAA 16 Advanced Very High Resolution Radiometer (AVHRR) data was terminated on May 1, 2004. NOAA 17 AVHRR data continues to be acquired and archived in support of scientific applications, such as agricultural assessment, fire science research, fire burn mapping, and land cover mapping. Generation and distribution of 7- and 14-day greenness composite image maps of the conterminous United States and Alaska are being provided to cooperators and customers (fig. 68).

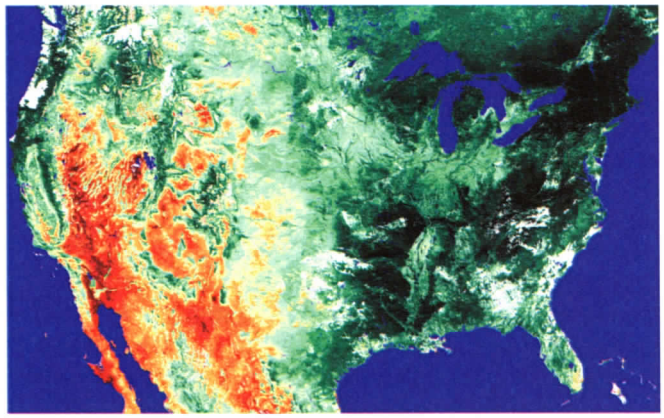


Figure 68. Example of AVHRR greenness map of conterminous United States.

Clean Water and Agricultural Landscapes

To meet Federal Clean Water Act standards, individual states must identify, monitor, and control pollutants that impact water quality. During FY 2004, the USGS collaborated with the South Dakota Department of Environment and Natural Resources and the East Dakota Water Development District to develop crop-specific maps using Landsat satellite imagery to support South Dakota water quality initiatives. Geographic Information Systems (GIS) are used to model the relationship between pollutants, such as fertilizers and pesticides, and water quality. Spatial information on crop types is essential to determine where specific agricultural chemicals are applied across the landscape. Nearly 100 satellite images were required to develop crop maps for 2000 and 2001 for the state of South Dakota. An advanced object-oriented, knowledge-based approach was developed to automate much of the processing, considerably reducing the time and cost of this effort.

Landsat Data Continuity Mission

While NASA, the NOAA, and the USGS collectively prepared a joint mission description endorsed by the Office of Science and Technology Policy (OSTP) late in FY 2004, the USGS team defined a ground system configuration compatible with the mission. Toward that end, the USGS prepared an operations concept document that configured the USGS as the sole agency responsible for Landsat Data Continuity Mission (LDCM) data acquisition, archiving, and distribution. A set of high-level requirements was compiled, and from that, a 7-year ground system development budget was prepared for USGS and NASA review.

The requirements were iterated with NASA, in support of its development of an Operational Land Imager (OLI) instrument specification. The OLI is the proposed continuity imager for Landsat 7 ETM+, with spectral and spatial characteristics consistent with ETM+ but with technology and performance parameters similar to an experimental NASA imager currently being flown on NASA's EO-1 satellite, the Advanced Land Imager (ALI). The USGS team played an integral role in the specification of OLI requirements, which NASA released in late summer for comment by industry and the Landsat user community.

The USGS formed a unique partnership this year with NASA in which technical staff from the two agencies collaborated on the development of a prototype image calibration and validation (cal/val) system, called the Advanced Land Imager Analysis System (ALIAS). The cal/val system was based on the Landsat 7 Image Assessment System (IAS), an operational component of the Landsat 7 ground system. The ALIAS prototype was based on IAS architecture, with new radiometric and geometric algorithms tailored to the ALI instrument. The use of ALI data is key to the prototype, because unlike ETM+, which has 136 detectors, the OLI instrument will have 70,000. Of necessity, radiometric calibration of OLI will be entirely different from that used with ETM+, and data from the ALI instrument is ideal in simulating OLI data because the ALI uses a similar imaging technique, except that 15,000 detectors are used instead of 70,000.

The initial phase of the ALIAS prototype was very successful. ALI algorithms were documented and system software based on the algorithms was integrated into a system that will be used in a subsequent phase to test proposed analytical methods. NASA benefited from the prototype because the system may be used to evaluate test data derived during OLI fabrication, and the USGS benefited because system and database architectures were prototyped for subsequent integration into a complete LDCM ground system beginning in FY 2005. Over the 7-year life of the LDCM mission, the calibration database will grow to 5 TB.

The analytical tools and methodologies being prototyped through ALIAS are also applicable and transportable to other fixed-array sensors such as those used in other space assets—the Indian Remote Sensing ResourceSat-1, and the European Space Agency SPOT-5, for example.

Earth Observing-1 Extended Mission

Three years ago, the USGS formed a partnership with NASA under which the USGS conducted ground systems processing and product distribution of data acquired by EO-1, while NASA conducted flight operations (flying the satellite and scheduling imaging). The partnership has worked exceptionally well. User fees and data sales have funded the annual costs of scheduling, acquiring, and processing EO-1 data.

Because the EO-1 satellite has both a multispectral and a hyperspectral imager, USGS participation in the EO-1 Extended Mission has made possible Department of Defense (DOD) and intelligence community research into hyperspectral image analysis techniques. The Hyperion imager on board EO-1 is the only space-based hyperspectral instrument in existence. The research directly supports America's homeland security efforts.

The USGS leveraged its substantial expertise in orthographic rectification of space-based imagery to develop a geodetically corrected ALI product suitable for direct incorporation into GIS analysis packages. Development on the new product occurred this year, with product availability planned for early FY 2005. The product is eagerly sought by the U.S. Forest Service and other agencies for after-fire mitigation and restoration activities. With SLC artifacts present in current ETM+ products, a GIS-ready ALI product is useful for some limited-area remote sensing applications that are incompatible with ETM+ SLC-off products.

The USGS satellite ground terminal at EROS allows selected ALI and Hyperion scenes to be downlinked to the USGS. The direct downlink to a USGS ground terminal, instead of to one of NASA's polar ground terminals, makes rapid turnaround of data possible. Instead of 3- to 7-day availability, USGS capability allows newly acquired data to be distributed to high-priority customers in as little as 12 hours.

Another contribution USGS technical staff made to the ground system was the implementation of data capture directly to computer disk. Previously, the data were recorded on specialized telemetry recorders that were not reliable and were costly to maintain. The direct-to-disk capability implemented this year allowed data to be reliably and immediately processed and archived. As a consequence, operational costs associated with staff and maintenance were lowered.
All systems on board EO-1 are operating nominally four years after launch, and ALI data have been calibrated with concurrent ETM+ data. The improved data products to be available in FY 2005 are limited in sensor coverage and are not directly readable by Landsat 7 ETM+ input software, but for some applications, ALI data are of equal or higher quality to ETM+. After four years of daily image acquisition, the USGS archive of EO-1 data totals 14,000 scenes of both ALI and Hyperion data (fig. 69 and 70). The examples show the scale and 30-meter (m) ground

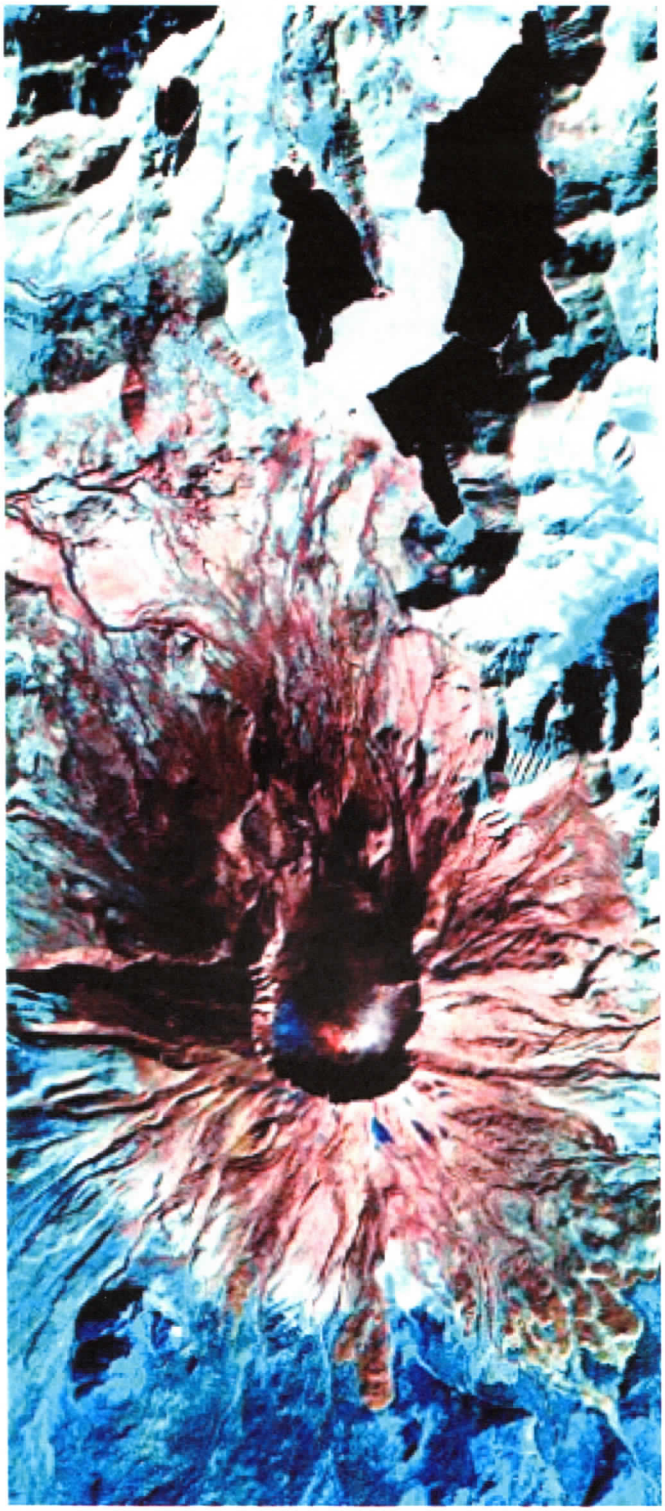


Figure 69. Mount St. Helens, Wash., Hyperion image.

resolution of scenes acquired with the multispectral ALI and hyperspectral Hyperion instruments.

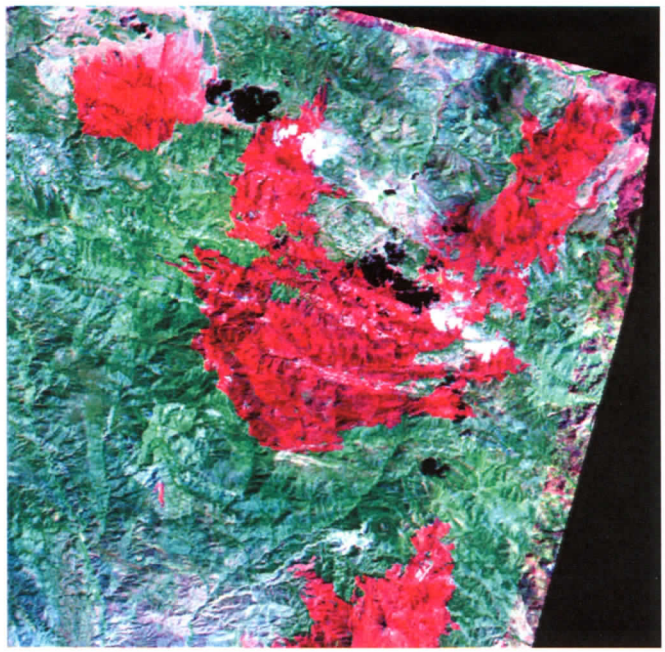


Figure 70. ALI subset of Hawkins fire,Enterprise, Utah.

Committee on Earth Observation Satellites (CEOS)

The USGS chairs the Committee on Earth Observation Satellites (CEOS) Working Group on Information Systems and Services. This role includes providing a working group chair report to the CEOS Plenary meeting, which was held May 16-20, 2004, in Tromso, Norway. Plenary representatives are typically the heads of civil agencies and international organizations involved in satellite remote sensing. In addition to the reporting requirement, the Plenary provides guidance to working groups for the upcoming year. For further information, contact John Faundeen, 605-594-6092)

Native American Initiative Achievements

Central Region Integrated Science Partnerships: A Native View Prototype

Figure 71. Geneva Chong, USGS Fort Collins Science Center, demonstrates field data collection methods using hand-held devices to Sarah Wolfe of Sinte Gleska University. USGS invasive plant species mapping techniques find utility in ethnobotany studies on the Rosebud Sioux Indian Reservation.

The U.S. Geological Survey's (USGS) Geography, Water, and Biology disciplines are partnering with Sinte Gleska University (SGU) in Mission, S. Dak., to establish proof-of-concept projects on the Rosebud Sioux Indian Reservation (South Dakota) as models to share USGS earth science information and technology with tribal colleges and universities (TCU). Geography discipline scientists helped to open the Geospatial Applications Center at SGU, including a 9-workstation instructional Geographical Information Systems (GIS) lab. Along with the lab opening, the USGS and SGU teamed with the Rosebud Sioux Tribe (RST) to develop pilot projects demonstrating the use of USGS resources for tribal resource management. Water discipline scientists from the South Dakota District Office in Rapid City, S. Dak., leveraged a long-standing relationship with RST to develop a "hydrological information partnership" between the USGS, RST, and SGU. A workshop was held on the use of National Water Information System's online resources for applications such as water quality studies.

Biology discipline scientists from the Fort Collins Science Center demonstrated field data collection methods used to map invasive plant species at the nearby LaCreek Wildlife Refuge (South Dakota) for use in ethnobotany research conducted by the Lakota Studies Department at SGU (fig. 71). Preliminary results from this study, titled "Traditions through Technology," were presented in a poster session at the 2004 ESRI User Conference. Each discipline area provided guidance to SGU staff and faculty on the development of proposals to fund the continuation and expansion of these pilot projects. The Sinte Gleska effort will serve as a template for USGS scientists to work with TCUs through NativeView, a consortium founded to develop geospatial technologies at TCUs for managing natural, cultural, and economic resources on tribal lands. For further information, contact Gene Napier, USGS EROS, 605-594-6088, enapier@usgs.gov.

NativeView Charter Ratified at San Diego Tribal Council Forum

In the summer of 2004, representatives from 24 tribal colleges from across the United States met at the International User ESRI Conference in San Diego, Calif., to approve the Charter for NativeView. NativeView is a USGS endorsed and supported geospatial education initiative whose goals are to integrate earth science technologies for the benefit of education, agriculture, resource management, and economic development for tribal colleges and their communities. The Tribal Council Forum also served as an opportunity for tribal colleges, tribes, and government agencies to highlight applications of related work being done for and on Indian lands. Fiscal year (FY) 2005 will provide new challenges and opportunities for getting the word out to other Native American constituencies, generating funding, and implementing collaborative programs among tribal colleges, Native American communities, and the federal government. Another Tribal College Forum was held in December 2004, at the Southwestern Indian Polytechnic Institute (SIPI) in Albuquerque, N. Mex.

United Sioux Tribes Development Corporation – USGS MOU

In September 2004, the United Sioux Tribes Development Corporation (USTDC), representing 11 Lakota, Dakota, Nakota (Sioux) Northern Great Plains tribes, completed a Memorandum of Understanding (MOU) with the USGS. The MOU establishes the framework for collaboration in the areas of GIS, Information Technology (IT), and natural science research and training in areas that relate to Native American capacity building as well as contribution to national initiatives such as *The National Map* and NativeView. There are high expectations for FY 2005 and FY 2006 to leverage this MOU for USTDC-USGS collaborations on a variety of initiatives aimed at maximizing Native American contributions in areas of mutual interest.

Alliance of Tribal Tourism Advocates – USGS MOU

In September 2004, the Alliance of Tribal Tourism Advocates (ATTA) of Lower Brule, S. Dak., an organization representing Native American tribes of the Northern Great Plains, and the USGS entered into an MOU that creates the framework for promoting and developing land use planning directed toward building sustainable tribal communities and increasing learning opportunities in the areas of community mapping, resource preservation, and community capacity building by creating a more productive tribal workforce and by preserving indigenous knowledge and oral traditions of tribal nations. The ATTA-USGS MOU enabled close teamwork in promotion of the Northern Great Plains 2004 Lewis and Clark Commemorative activities.

Sinte Gleska University – USGS EROS Human Resources Initiative

Under a USGS-sponsored internship program to promote science and GIS technology, three Sinte Gleska University Native American undergraduate students are participating in learning opportunities and training under the mentorship of EROS scientists and GIS professionals. In addition, students are contributing to real-world collaborative projects such as the NASA-SGU-USGS REASoN CAN, "Using Geospatial Information to Enhance Tribal Rangeland Management Through Education and Understanding," and the USGS Central Region Integrated Science Program (CRISP). Growth of the Human Resources Initiative (HRI) program is anticipated in FY 2005 with four students and one SGU faculty professional participating in initiatives and advancing learning. FY 2006 programs will be aimed at creating opportunities for Sinte Gleska University student education and career growth. For further information contact Gene Napier, USGS EROS, 605-594-6088.

Communications and Outreach Achievements

Communications and Outreach Advisory Team (COAT)

In FY2004, EROS chartered the Communications and Outreach Advisory Team (COAT) as a group of creative people who work together to brainstorm, formulate, and help implement technical, scientific, and professional outreach projects on behalf of the Center. Ultimately, COAT will endeavor to create excitement and enthusiasm for our science among the lay public, the science community, our colleagues in government and the private sector, and potential sponsors of our work. Together this team targets important, timely, and interesting areas of EROS outreach focus; chooses effective media, venues, and events through which to present and publicize these focus projects; and assists in planning and prioritizing the work to accomplish our outreach goals. For further information, contact Tom Holm, 605-594-6127.

EROS Exhibit Traces Lewis and Clark Expedition Using Landsat Images

With its federally authorized role for science and geography, the Lewis and Clark expedition of 1804–1806 was, in many ways, a forerunner of the U.S. Geological Survey. In recognition of the 200th anniversary of this journey, USGS EROS assembled a collection of satellite images tracing the route Lewis and Clark took from St. Louis, Missouri, to the Pacific Coast.

The exhibit, titled "The Voyage of Discovery Continues: Another View of the Journey of Lewis and Clark," was on display at the Washington Pavilion of Arts and Science Visual Arts Center in Sioux Falls, South Dakota, from March 12 to June 6, 2004. It featured a digitally produced shaded relief map that provides an overview of the expedition route and gives a much more detailed look at the same area mapped manually by William Clark.

The map was created using digital elevation model (DEM) data from The National Map and gives a sense of the vast and increasingly rugged terrain Lewis and Clark encountered on their journey. Twenty-two satellite images highlight historic points along the trail. These images were acquired by the Landsat-7 satellite.

Hundreds of people commented on the exhibit, including Washington Pavilion staff. The favorable reaction generated positive, educational news segments on both television and radio. The use of satellite imagery in the exhibit reinforced public recognition of the unique role that EROS has in providing Earth observation data and geographic analysis for the Nation.

Part III: Conclusion

A Final Word

The National Center for Earth Resources Observation and Science (EROS) is keenly aware of our mandate to serve the national need for accurate, timely, and innovative information about the planet on which we live. Our goal is to serve a growing customer base with earth science products that set a new standard, while serving the U.S. Geological Survey and other federal agencies with the information vital to protecting, preserving, and maintaining our nation's resources and quality of life.

Communication with our expanding constituent and customer base is vital to the success of our programs, and we encourage your feedback. Please let us know how well we are meeting your needs and share your suggestions for improvement with us directly.

To communicate with us, or for more information about EROS, contact the Customer Services office at:

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