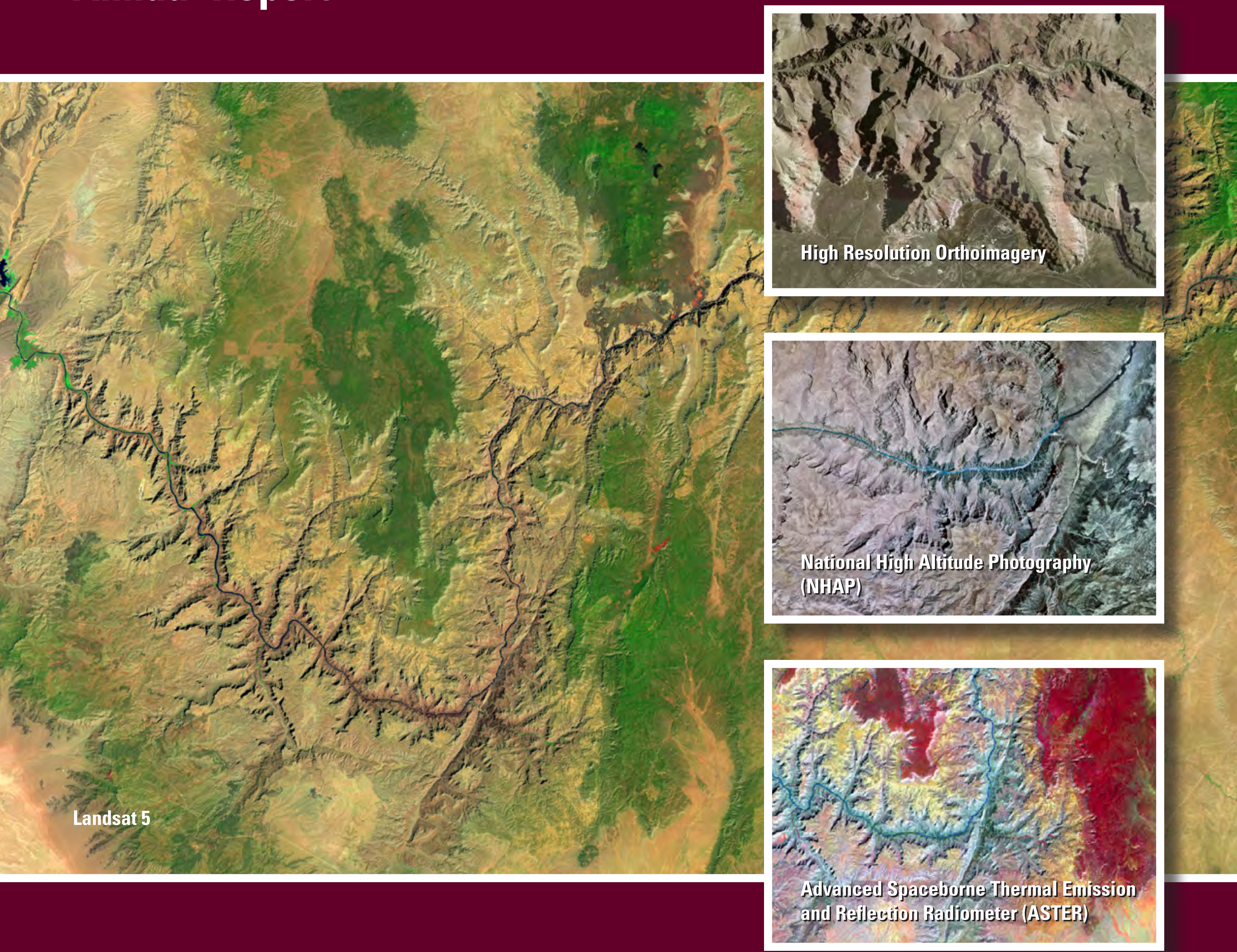
U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center—Fiscal Year 2009 Annual Report



Open-File Report 2010–1060

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

Cover: Carved out by the Colorado River, the Grand Canyon in Arizona is one of the most spectacular gorges in the world. Capturing the grandeur of the canyon, the four images on the cover bring the Grand Canyon to life. The background image was acquired by the Landsat 5 satellite. It was the one millionth Landsat scene downloaded from the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center since October 2008, when the Landsat archive was opened to user access at no charge. Since then, the USGS has implemented free, web-based access to all data archives at EROS, resulting in users downloading more than 1,000 terabytes of data. Some of the more popular data downloads included aerial imagery such as the High Resolution Orthoimagery (top inset), National High Altitude Aerial Photography (NHAP) (middle inset), other satellite imagery such as Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (bottom inset), and elevation data. The USGS is putting land imaging data literally at the public's fingertips, allowing the rich archive to be shared with more people than ever before. By enabling science and operational applications and providing land imaging data to anyone, anywhere, anytime, at no cost, we have essentially created a land remote sensing "archive without walls."

U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center—Fiscal Year 2009 Annual Report

Compiled by Janice S. Nelson

Open-File Report 2010–1060

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Nelson, J.S. comp., 2010, U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center—Fiscal year 2009 annual report: U.S. Geological Survey Open-File Report 2010–1060, 83 p.

Contents

Figures

Table

Acronyms

AAG	Association of American Geographers
AFO	Alaska Field Office
AGCHO	Afghanistan Geodesy and Cartography Head Office
AGRHYMET	Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center
AGU	American Geophysical Union
ANACAFE	Guatemala's National Coffee Association
ARRA	American Reinvestment and Recovery Act
ARTS	ASRC Research and Technology Solutions
ASDI	Afghanistan Spatial Data Infrastructure
ASPRS	American Society of Photogrammetry and Remote Sensing
ASRC	Arctic Slope Regional Corporation
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advanced Wide Field Sensor
BAER	Burned Area Emergency Response
BLM	Bureau of Land Management
C&A	Certification and Accreditation
C&O	Communications and Outreach
CBERS	China-Brazil Earth Resources Satellite
CCRS	Canada Centre for Remote Sensing
CEOS	Committee on Earth Observing Satellites
CILSS	Inter-Governmental Authority on Combating Drought in the Sahel
CO_2	Carbon Dioxide
CONUS	Continental United States (refers to contiguous 48 states)
CPIC	Capital Planning and Investment Control
DBS	Direct Broadcast System
DEM	Digital Elevation Model
DOI	Department of the Interior
DPAS	Data Processing and Archive System
DSS	Decision Support System
ECHO	Earth Observing System (EOS) Clearinghouse
eMODIS	"enhanced" MODIS
EO	Earth Observation
EO-1	Earth Observing Mission 1

EOS	Earth Observing System
EROS	Earth Resources Observation and Science
ESDIS	Earth Science Data and Information System
ESRI	Environmental Systems Research Institute
ETM	Enhanced Thematic Mapper
EVM	Earned Value Management
FAS	Foreign Agricultural Service
FEWS	Famine Early Warning System
FIREHARM	FIRE Hazard and Risk Model
FPI	Fire Potential Index
FY	Fiscal Year
GAM	Geographic Analysis and Monitoring
GDEM	Global Digital Elevation Model
GEO	Global Earth Observation
GEOSS	Global Earth Observation System of Systems
GeoTIFF	Georeferenced information embedded in a Tagged Image File Format (TIFF)
GIS	Geographic Information System
GISTDA	Geo-Informatics and Space Technology Development Agency
GloVis	Global Visualization Viewer
GLS	Global Land Survey
GOFC/GOLD	Global Observation of Forest Cover/Global Observation of Landscape Dynamics
GOS	Geospatial One Stop
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GS	Ground System
HDF	Hierarchical Data Format
HHS	Health and Human Services
HydroSHEDS	global Hydro logical data and maps based on Shuttle Elevation Derivatives at multiple Scales
IADIWG	Inter-Agency Digital Imagery Working Group
iGETT	Integrated Geospatial Education and Technology Training
IKONOS	Commercial Earth Observation Satellite; derived its name from the Greek term *eikōn* for image
INL	Idaho National Laboratories
INPE	Instituto Nacional de Pesquisas Espaciais

InSAR	Interferometric Synthetic Aperture Radar
IPDS	Information Product Data System
IRS	Indian Remote Sensing
IT	Information Technology
IVM	Integrated Vegetation Mapping
JACIE	Joint Agency Civil Imagery Evaluation
LAI	Leaf Area Index
LANDFIRE	Landscape Fire and Resource Management PlanningTools Project
LANDSUM	LANDscape SUccession Model
LDCM	Landsat Data Continuity Mission
Lidar	Light Detection and Ranging
LIMA	Landsat Image Mosaic of Antarctica
LP DAAC	Land Processes Distributed Active Archive Center
LRS	Land Remote Sensing
LSI	Land Surface Imaging
LST	Landsat Science Team
LST	Land Surface Temperature
LTA	Long Term Archive
METI	Ministry of Economy, Trade, and Industry
MODIS	Moderate Resolution Imaging Spectroradiometer
MOPEX	Model Parameter Estimation Experiment
MOU	Memorandum of Understanding
MRLC	Multi-Resolution Land Characterization
MRTWeb	MODIS Reprojection Tool (MRT) Web
MSS	Multispectral Scanner
MTBS	Monitoring Trends in Burn Severity
NAFTA	North American Free Trade Agreement
NAIP	National Agriculture Imagery Program
NALC	North American Landscape Characterization
NAPP	National Aerial Photography Program
NARA	National Archives and Records Administration
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service
NCA	North Central Geographic Area
NDMC	National Drought Mitigation Center

NDVI	Normalized Difference Vegetation Index
NED	National Elevation Dataset
NESDIS	National Environmental Satellite, Data, and Information Service
NGA	National Geospatial-Intelligence Agency
NGP	National Geospatial Program
NHAP	National High Altitude Aerial Photography
NHD	National Hydrography Dataset
NHO	National Health Observances
NLAPS	National Landsat Archive Production System
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPWRC	Northern Prairie Wildlife Research Center
NREL	National Renewable Energy Laboratory
NSTA	National Science Teacher Association
OGC	Open Geospatial Consortium
OSL	Optical Science Laboratory
PE&RS	Photogrammetric Engineering and Remote Sensing
PMT	Project Management Team
QA	Quality Assurance
QA4EO	Quality Assurance for Earth Observation
ROSES	Research Opportunities in Space and Earth Sciences
RREX	Renewable energy Resource EXplorer
RSS	Rich Site Summary
RST	Remote Sensing Technologies
SAIC	Science Applications International Corporation
SCAR	Scientific Committee on Antarctic Research
SGT	Stinger Ghaffarian Technologies
SIR-C	Shuttle Imaging Radar-C
SNC	Southern Nevada Complex
SPOT	Systeme pour l'Observation de la Terre (France)
SRTM	Shuttle Radar Topography Mission
SSC	Service Status Checker
SWERA	Solar and Wind Energy Resource Assessment
TCU	Tribal Colleges and Universities
TIN	Time Integrated NDVI

TIRS	Thermal Infrared Scanner
TM	Thematic Mapper
UK-DMC-2	United Kingdom-Disaster Monitoring Constellation-2
UNEP	United Nations Environment Programme
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VegDRI	Vegetation Drought Response Index
VI	Vegetation Index
VIIRS	Visible Infrared Imager Radiometer Suite
WGEdu	Working Group on Education
WGISS	Working Group on Information Systems and Services
WGVC	Working Group for Calibration and Validation
WIST	Warehouse Inventory Search Tool
WMS	Web Mapping Services
wRLCM	web Rapid Land Cover Mapper
YRB	Yukon River Basin

U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center—Fiscal Year 2009 Annual Report

Compiled by Janice S. Nelson

Introduction

The Earth Resources Observation and Science (EROS) Center is a U.S. Geological Survey (USGS) facility focused on providing science and imagery to better understand our Earth. As part of the USGS Geography Discipline, EROS contributes to the Land Remote Sensing (LRS) Program, the Geographic Analysis and Monitoring (GAM) Program, and the National Geospatial Program (NGP), as well as our Federal partners and cooperators. The work of the Center is shaped by the Earth sciences, the missions of our stakeholders, and implemented through strong program and project management and application of state-of-the-art information technologies. Fundamentally, EROS contributes to the understanding of a changing Earth through "research to operations" activities that include developing, implementing, and operating remote sensing based terrestrial monitoring capabilities needed to address interdisciplinary science and applications objectives at all levels—both nationally and internationally.

The Center's programs and projects continually strive to meet and/or exceed the changing needs of the USGS, the Department of the Interior, our Nation, and international constituents. The Center's multidisciplinary staff uses their unique expertise in remote sensing science and technologies to conduct basic and applied research, data acquisition, systems engineering, information access and management, and archive preservation to address the Nation's most critical needs. Of particular note is the role of EROS as the primary provider of Landsat data, the longest comprehensive global land Earth observation record ever collected.

This report is intended to provide an overview of the scientific and engineering achievements and illustrate the range and scope of the activities and accomplishments at EROS throughout fiscal year (FY) 2009. Additional information concerning the scientific, engineering, and operational achievements can be obtained from the scientific papers and other documents published by EROS staff.

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. To communicate with us, or for more information about EROS, contact: Communications and Outreach, USGS EROS Center, 47914 252nd Street, Sioux Falls, South Dakota 57198, *jsnelson@usgs.gov, http://eros.usgs.gov/.*

Fiscal Year 2009 in Review

Science and Applications Activities

The Center's science and applications activities include multidisciplinary Earth science research, remote sensing applications development, and generation of associated products such as oral presentations, publications, workshops, databases, and websites. Science and applications activities are aligned with the USGS strategic science goals and priorities set by the USGS Geography Discipline.

Disciplines and skills represented in science activities at EROS include geography, cartography, geology, soil science, hydrology, biology, forestry, ecology, geochemistry, computer science, applied physics and remote sensing, mathematics, and statistics.

Science partners and collaborators include the USGS Geography Discipline's regional science centers, other USGS science disciplines and offices and their associated bureau programs, other bureaus and agencies within the U.S. Department of the Interior (DOI), bureaus and agencies in other departments of the Federal Government, State agencies, tribal governments and universities, non-Government agencies, academic institutions, and international organizations.

The Center's research and applications activities are conducted via five teams and take full advantage of the Center's extensive national and global archive of remotely-sensed data. On the following pages, the science and applications teams' primary objectives are highlighted followed by key accomplishments of each.

Early Warning, Environmental Monitoring, and Hazards Management

The Early Warning, Environmental Monitoring, and Hazards Mitigation Team conducts research on and implements new approaches for monitoring environmental hazards and mitigating their impact through creative applications of geographic analysis and modeling of Earth processes. Key accomplishments are given in the following sections.

Remote Sensing Harvest Estimates for Afghanistan and Zimbabwe

In Afghanistan and Zimbabwe, years of political upheaval and drought have contributed to the prospects of widespread hunger. A well below normal 2008 spring snow pack and inadequate water supply for irrigation in Afghanistan threatened the country's wheat harvest. Knowledge of crop production and distribution lagged by many months, threatening serious hardship for many people. In Zimbabwe, in February 2009, an estimated 7 million people faced serious food shortages, many surviving on just one meal per day. Zimbabwe's once-thriving agricultural production had fallen by more than one-half, and political upheaval and drought contributed to the prospect of widespread hunger. The unraveling of the agricultural system also made it difficult to get good estimates of crop production.

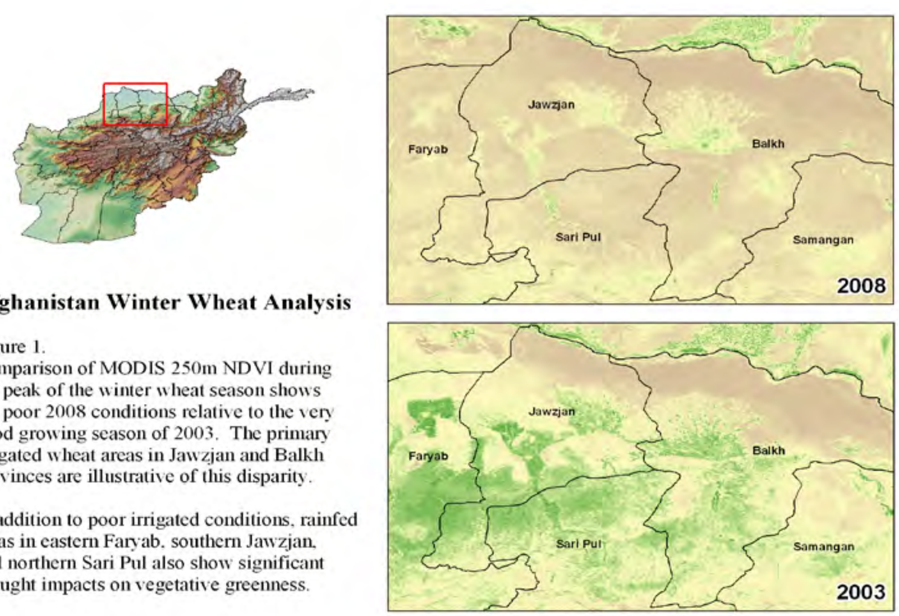
Political disruption and security concerns made timely on-the-ground surveys of agricultural production difficult and dangerous in both countries. But clear and early answers were needed by organizations poised to send famine-mitigating food aid. Could satellite observations provide the basis for non-political, objective, and reproducible crop production estimates?

In both cases, the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, with its high-resolution daily data, was a resource well-suited to monitoring national scale crop growing conditions (fig. 1). Spaceborne sensors like MODIS can measure the energy reflected from vegetation, resulting in measures of plant vigor such as the Normalized Difference Vegetation Index (NDVI). The USGS's Famine Early Warning Systems Network team was able to use historically observed strong relations between NDVI and crop production to develop MODIS-based crop production estimates well before conventional statistics became available. In Afghanistan, this meant that anecdotal reports of widespread crop failure could be substantiated. In Zimbabwe, remote sensing analysis showed improved crop production over the previous year, with the number of food shortages and people with insecure food sources falling to a relatively low number, compared to recent history. In both cases, strategic decisions for food aid programs could be made in a timely fashion, helping to keep costs down and increase effectiveness in staving off widespread hunger. For further information, contact James Verdin, USGS EROS, *verdin@usgs.gov.*

USGS in Indian Country—Native American Activities Program

The USGS Native American Tribal Liaison Team represents each USGS region and geographic area, scientific discipline, and the Office of Equal Opportunity, and the Bureau as a whole. The Liaison Team continues building new partnerships and strengthening current partnerships with other Federal agencies, universities, and numerous tribes throughout the United States.

The USGS North Central Regional Executive has identified support for USGS Native American programs as an



Afghanistan Winter Wheat Analysis

Figure 1.
Comparison of MODIS 250m NDVI during the peak of the winter wheat season shows the poor 2008 conditions relative to the very good growing season of 2003. The primary irrigated wheat areas in Jawzjan and Balkh provinces are illustrative of this disparity.

In addition to poor irrigated conditions, rainfed areas in eastern Faryab, southern Jawzjan, and northern Sari Pul also show significant drought impacts on vegetative greenness.

important science priority. The North Central Geographic Area (NCA) includes more than 40 Indian reservations and associated tribal lands that have significant scientific and educational needs as well as large land ownership. DOI has significant Trust responsibilities for Native American tribes, and as the science arm of the Department, the USGS is a critical partner for these responsibilities. The Native American Liaison from NCA is stationed at EROS and also serves as the USGS Geography Discipline Liaison.

Ongoing USGS programmatic activities include educational and technical support; mentoring; development and coordination of formal agreements with tribal colleges, tribal governments, and the Bureau of Indian Affairs; collation of annual USGS activities with Native Americans; serving on tribal boards; helping to organize meetings, workshops, and the annual Tribal College Forum; training in the use of geospatial technologies; and identifying possible program opportunities for USGS. Activities also include internship programs, which in 2009 resulted in 6 students being chosen for the Student Interns in Support of Native American Relations Program, with an additional 7 given USGS Global Change Program Student Internships.

EROS has participated in a number of regional workshops, examples of which include five community mapping workshops (fig. 2) and an Introduction to Remote Sensing workshop for the four tribes in Eastern Montana, as part of the Environmental Protection Agency funded Montana Indian Country Care Program. Under that same funding, EROS presented a 2-day workshop on water quality sampling and analysis hosted by the Northern Cheyenne Tribe and Rocky Mountain College.

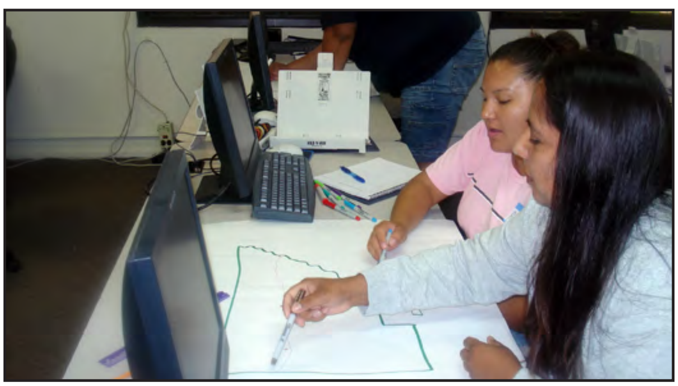


Figure 2. A community mapping workshop held at the Northern Cheyenne's Chief Dull Knife College.

The Liaison has submitted several proposals for additional funding to enhance the NCA and Geography Discipline programs. An example of a successful submission is one in which the North Dakota Association of Tribal Colleges, in partnership with USGS EROS and the National Center for Atmospheric Research and University Corporation for Atmospheric Research, has been awarded a National Aeronautics and Space Administration (NASA) Global Climate Change Education grant for its "Tribal Colleges Climate Change Education Initiative." The project proposes to utilize NASA and other technologies and resources to establish a climate change education initiative among its six-member Tribal Colleges and Universities (TCUs). The goals of this 3-year project are to enhance the TCUs capacity to educate their constituents on the science of climate change, and to identify vulnerabilities and mitigation strategies specific to Indian Country. The target audience consists of Tribal College faculty and students and Tribal leaders at the TCUs and tribal governance levels. For further information, contact Eric Wood, USGS EROS, *woodec@usgs.gov*.

The Maps of Afghanistan—Afghanistan Geospatial

The Afghanistan Geospatial Program is one component of the USGS Projects associated with the U.S. Agency for International Development (USAID) funded reconstruction effort in Afghanistan. Within the Program, EROS has taken the lead on data archiving, visualization, and dissemination through the USGS Afghanistan Project website (fig. 3; *http://Afghanistan.cr.usgs.gov*).

Along with the USGS interest in Global Spatial Data Infrastructure and its related domestic thrust through the Federal Geographic Data Committee, EROS has led the international effort in Afghanistan to develop the Afghanistan Spatial Data Infrastructure (ASDI). As a result, there have been two national conferences (fig. 4), a Presidential decree supporting ASDI, and a program office established at the Afghanistan Geodesy and Cartography Head Office (AGCHO), the national mapping agency. AGCHO is now finishing a national data inventory as one of its primary ASDI tasks.

In an effort to further strengthen AGCHO, USGS, through funding from the National Geospatial-Intelligence Agency (NGA), is coordinating advanced training for AGCHO technical staff in various aspects of remote sensing and image processing. That training will be conducted in Kabul, Nepal, and in the United States at USGS. For further information, contact Eric Wood, USGS EROS, *woodec@usgs.gov*.

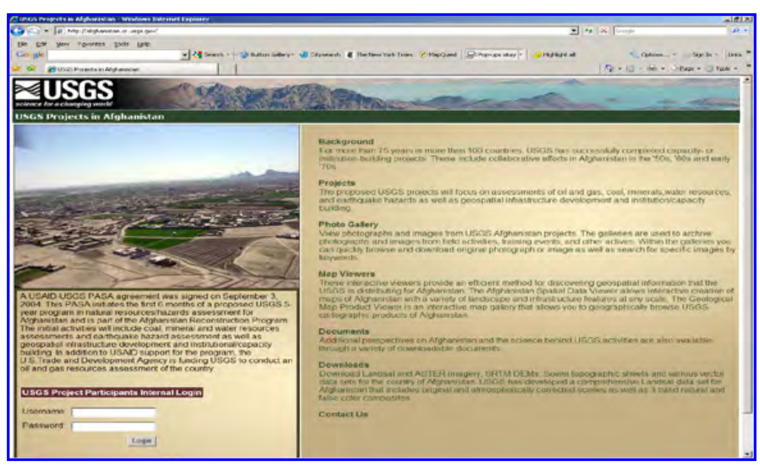


Figure 3. USGS Afghanistan project website.

Figure 4. Second ASDI National Conference.

Decision Support for Renewable Energy Solar and Wind Energy Resource Assessment

In the face of global climate change and what are perceived as finite energy resources, there is an unquestionable need for the development of additional renewable energy sources. Through World Bank's Global Environment Facility funding, the United Nations Environment Programme (UNEP) created the Solar and Wind Energy Resource Assessment (SWERA) project to address these needs.

SWERA's core activity is to generate and provide high quality, renewable energy data and resource maps, offering a variety of products and services. SWERA provides all countries with basic solar and wind data from a variety of international agencies including the Danish Risø National Laboratory, the U.S. National Renewable Energy Laboratory (NREL), the State University of New York, the Brazilian Space Agency, and the German Space Agency. Although the focus continues to be on solar and wind energy resources, resource information in sources such as micro-hydro, biomass, and geothermal will be included, where possible.

The North American UNEP Global Resource Information Database office located at USGS EROS in Sioux Falls, South Dakota, has been the host of the project website and archive. More importantly, with additional funding from NASA's Research Opportunities in Space and Earth Sciences (ROSES), UNEP has developed the website into a fully functioning Decision Support System (DSS). The DSS includes services for downloading original datasets from the archive as well as tools for viewing the spatially explicit datasets through an interactive viewer (fig. 5). Examples of those tools include:

- Renewable energy Resource EXplorer—RREX (UNEP). An on-line geographic information system (GIS) tool for viewing renewable resource data. Through this interactive system (fig. 6), users can view several renewable resource datasets available through SWERA.
- GeoSpatial Toolkit (NREL). A stand-alone interactive application that can be used for decision making and policy analysis in addition to planning for future renewable energy projects.
- Homer (NREL). A computer model that simplifies the task of evaluating design options for off-grid and grid-connected power systems for remote, stand-alone, and distributed generation applications.
- RetScreen Clean Energy Project Analysis Software (Natural Resources Canada). A unique decision support tool developed with the contribution of numerous experts from Government, industry, and academia.

SWERA products include spatial Geographic Information System (GIS) readable data and maps and temporal products that can be used in analytical tools, written summaries for decision makers, and brochures, reports and other print and web-based materials that describe these products. SWERA services include feasibility analysis, training services, contact/expert databases and referral services, and integrated analysis

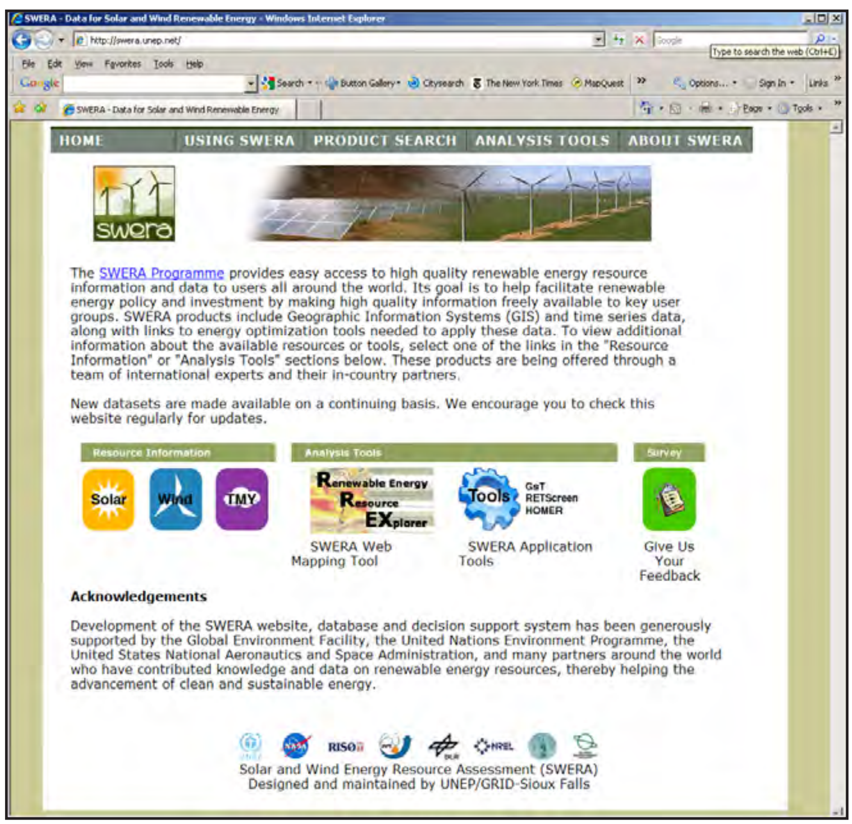


Figure 5. SWERA Decision Support System (*http://swera.unep.net*).

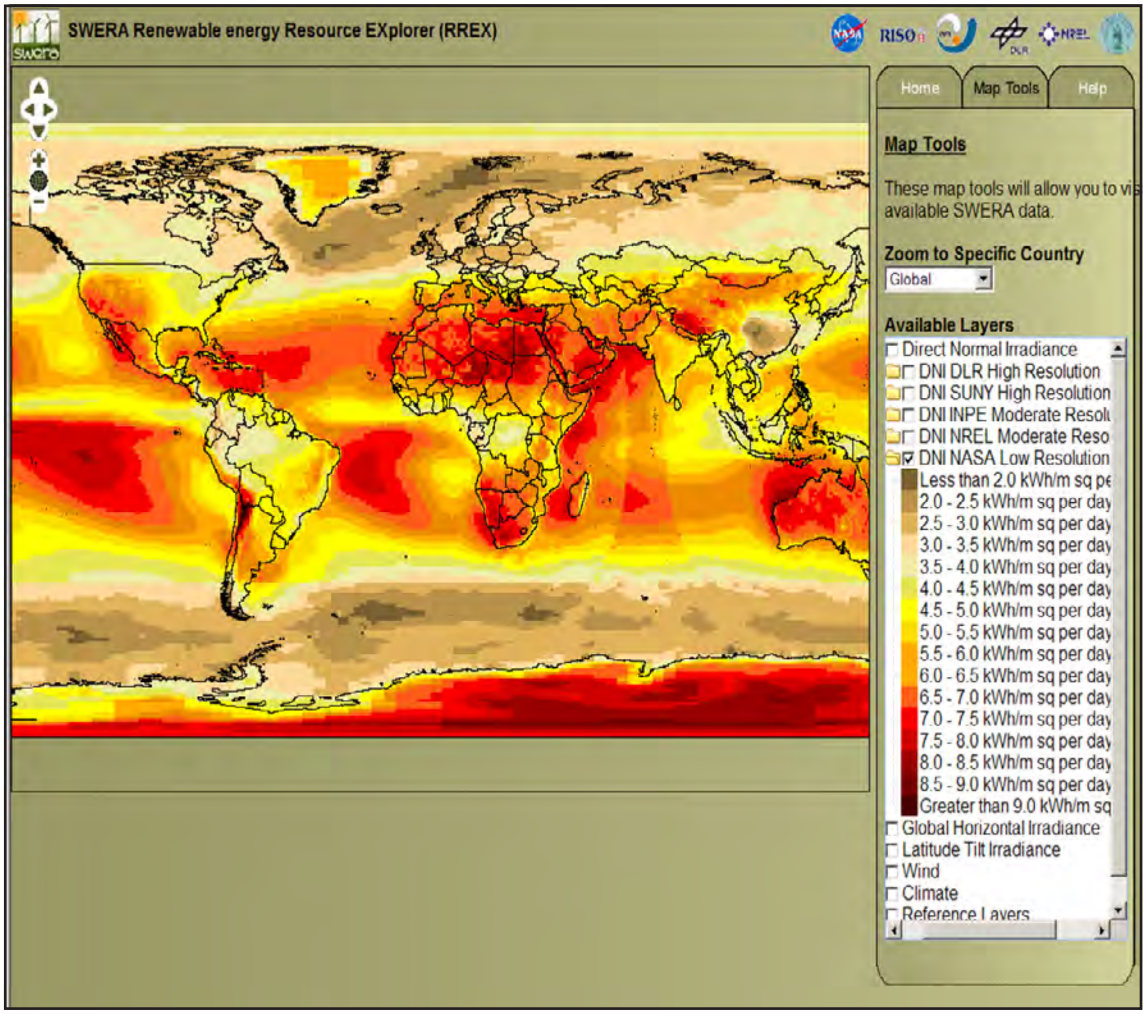


Figure 6. The Renewable Energy Resource Explorer (RREX) tool developed by UNEP.

of renewable energy resource options for countries. In the near future, the DSS also will include the datasets developed as part of a micro-hydro pilot project also initiated with the NASA ROSES funding. For further information, contact Eric Wood, USGS EROS, *woodec@usgs.gov*.

Pinpointing Drought from Coast to Coast

The Vegetation Drought Response Index, known to specialists as VegDRI, is a computer modeling and monitoring method providing continuous drought information over large regions and supplies finer spatial detail than other commonly-used drought indicators. In 2009, the index became available at 2-week intervals across the conterminous United States.

VegDRI integrates time-series observations of vegetation with climate, land cover-land use type, ecological setting, and soil characteristics to show drought's effect on vegetation at a 1-kilometer resolution. The massive remote sensing archives at the USGS EROS supply historical satellite data from the last 20 years that are critical in establishing a sound comparison to normal conditions established over a longer historical period.

Research on VegDRI began in 2002 when scientists from the USGS EROS and the University of Nebraska–Lincoln began developing a drought monitoring tool with initial funding from the USGS. Scientists from the National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln worked closely with Jesslyn Brown and staff at USGS EROS, with additional sponsorship from the U.S. Department of Agriculture's (USDA's) Risk Management Agency.

In 2006, the team began to convert VegDRI from a research activity to regular map production. After starting with a seven-state region in the Great Plains, they reached a VegDRI milestone on May 4, 2009, with coverage of the entire conterminous United States at 2-week intervals.

Several websites offer public access to VegDRI maps and statistics:

- EROS Drought Monitoring Map Service (fig. 7) at *http://gisdata.usgs.gov/website/Drought_Monitoring/viewer.php*
- NDMC VegDRI Website at *http://www.drought.unl.edu/vegdri/VegDRI_Main.htm*

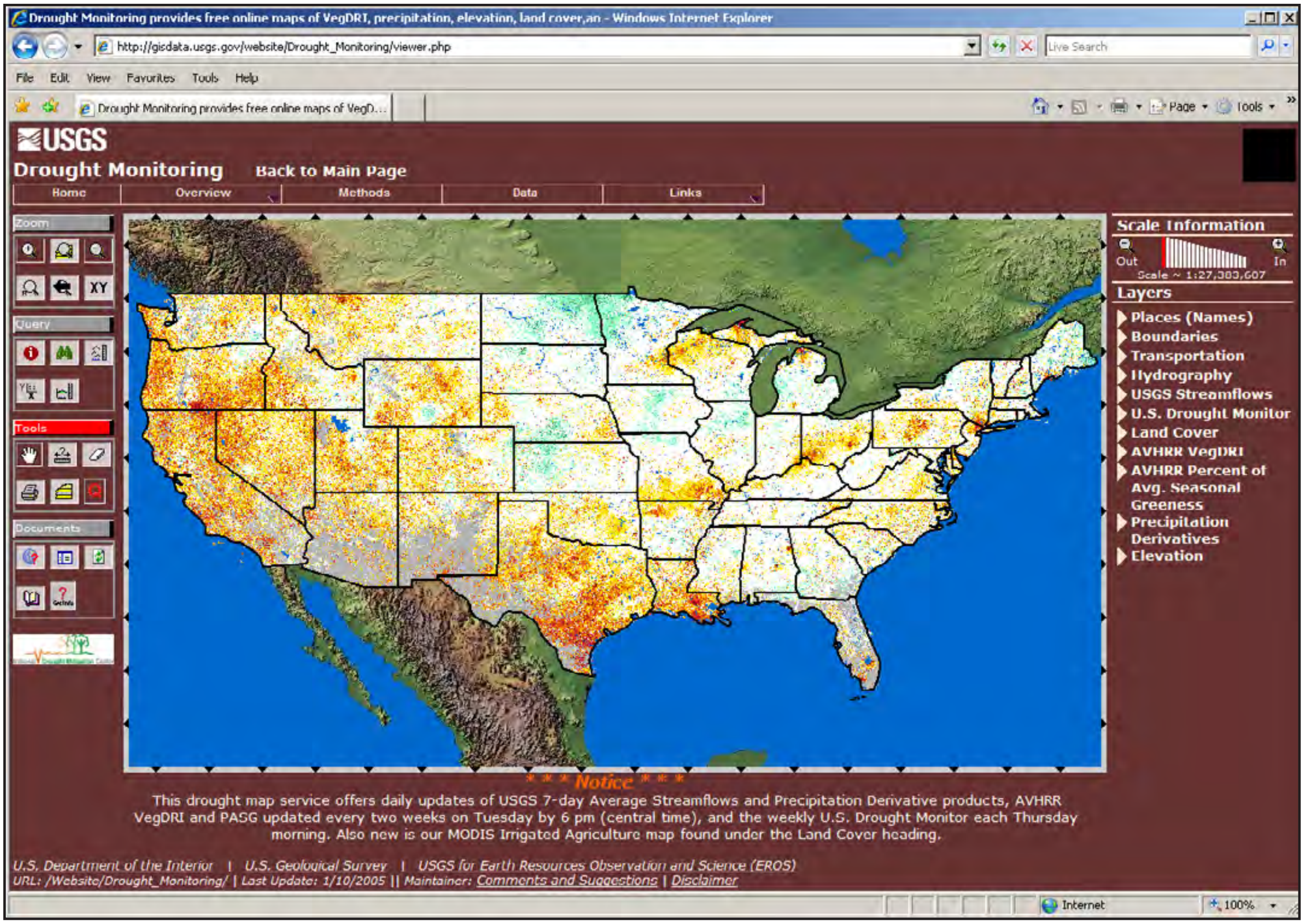


Figure 7. Drought monitoring map service website.

- U.S. Drought Portal at *http://drought.gov*

For further information, contact Jesslyn Brown, USGS EROS, *jfbrown@usgs.gov*.

Satellite Data on Nature's Cycles

USGS EROS made its long-term historical remote sensing data and graphics about biological life-cycle events available to the public at no charge on the web in June 2009. Orbiting hundreds of miles above the Earth, remote sensing satellites monitor plant and animal life cycle events that occur at certain times of the year, such as plant leafing and flowering or bird migrations. The scientific term for the study of these recurring life cycle events is *phenology*. Many phenological events are sensitive to climatic variation and change, and observing these events—for example, noting when certain plant species flower (such as lilacs) compared to a long-term norm—can help scientists understand environmental trends so society can better adapt to climate change.

Dating back to 1989, the USGS historical phenology datasets provide a widely accessible and impartial record (at 1-kilometer resolution) of the time of year that measurable cyclic events in nature have occurred over the conterminous United States. These graphics and image data for the conterminous United States (fig. 8) can be accessed online at *http://phenology.cr.usgs.gov/get_data.php*. These data are acquired from satellites and then compiled and maintained at EROS.

Satellite data provide a unique perspective of the planet and allow for regular, even daily, monitoring of the entire global land surface. Furthermore, data collection by satellite sensors can be standardized, making the data reliably objective. Remote sensing phenology can reveal broad-scale phenological trends that would be difficult, if not impossible, to detect from the ground. The remote sensing phenological website provides data and graphics that complement and reinforce human observations of similar natural events on the ground. For further information, contact Jesslyn Brown, USGS EROS, *jfbrown@usgs.gov*.

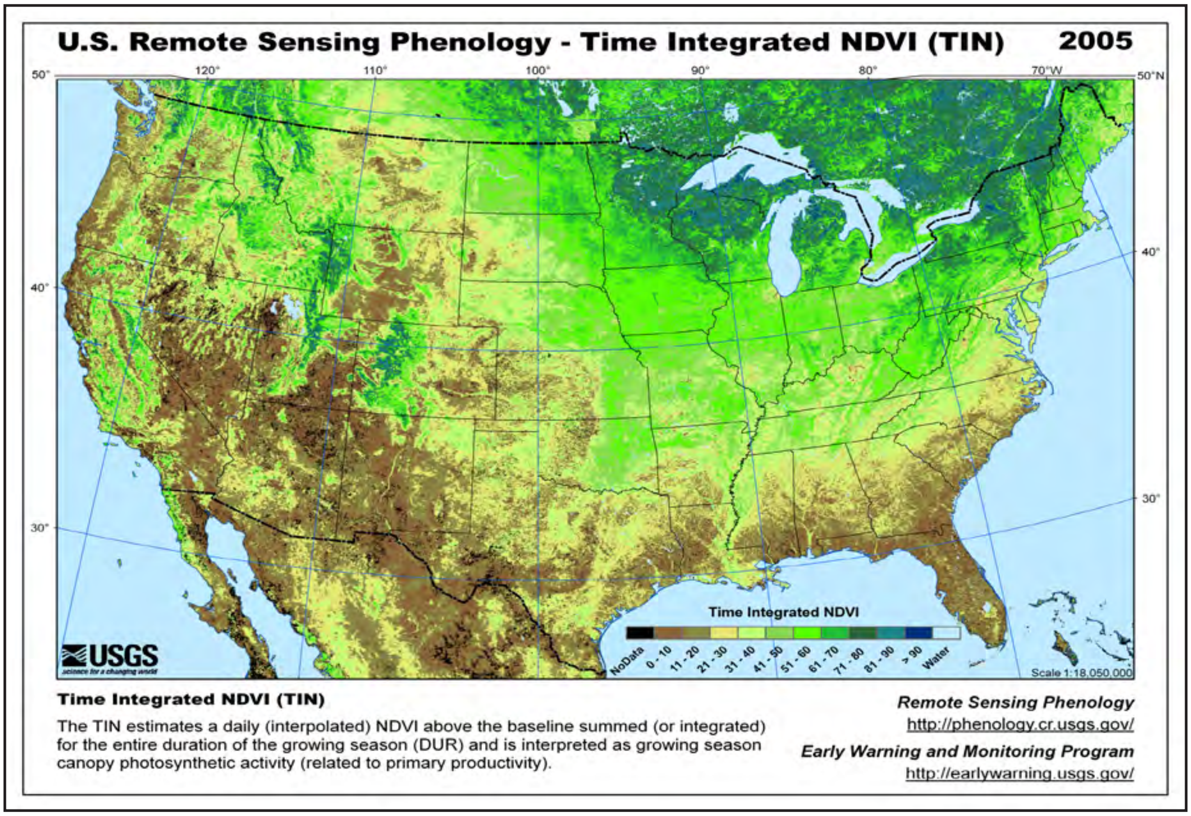


Figure 8. The Time Integrated NDVI estimates a daily (interpolated) NDVI above the baseline summed (or integrated) for the entire duration of the growing season and is interpreted as growing season canopy photosynthetic activity (related to primary productivity).

Low-Head Hydropower Assessment of Brazil

Working with the USGS' Water Science Center (Maryland) and the Idaho National Laboratories (INL), a low-head hydropower assessment for all of Brazil is nearing completion. Estimates of mean annual streamflow were derived from equations developed by Brazilian and USGS scientists. These flow estimates, coupled with the topographic information derived from the global hydrological data and maps (fig. 9) based on Shuttle Elevation Derivatives at multiple Scales (HydroSHEDS) digital elevation model (DEM), provided estimates of hydropower for more than 1.6 million stream reaches. The data are now being analyzed by scientists at INL to provide an estimate of the developable hydropower for Brazil. The results will be made available via published reports, as well as through a Virtual Hydropower Prospector, similar to the one developed for the United States hydropower assessment completed in 2004 (*http://hydropower.inel.gov/prospector/r_selector.shtml*). For further information, contact Kristine Verdin, USGS EROS, *kverdin@usgs.gov*.

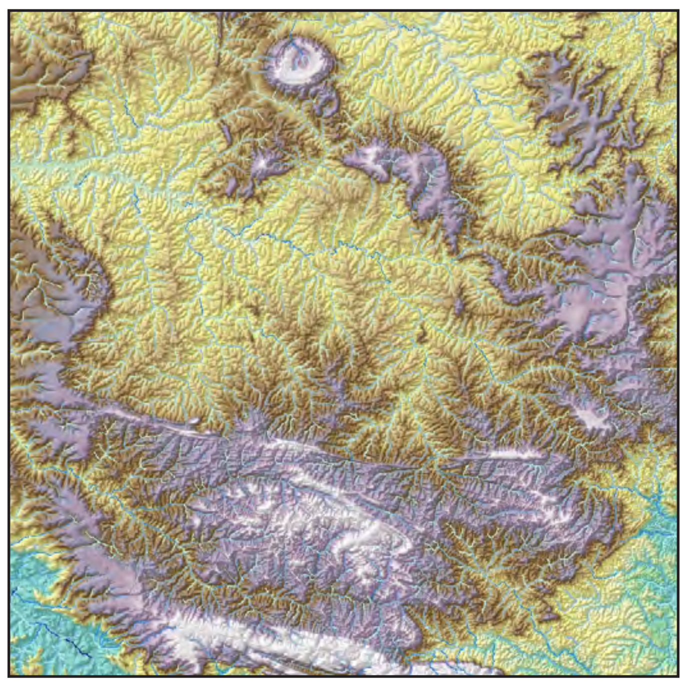


Figure 9. Image depicts a portion of the Brazilian stream network derived from the HydroSHEDS dataset. Gradations in stream color from light blue to dark blue indicate increasing small-head hydropower potential. The hydropower potential will be evaluated for feasibility of development in the next phase of the project.

Radar Applications Development

This project focuses on the development of state-of-the-art radar and interferometric synthetic aperture radar (InSAR) technologies and the transfer of satellite radar remote sensing into bureau-wide applications. Project members have strived to actively collaborate with bureau scientists on monitoring natural and man-made hazards (volcano, earthquake, landslide, land subsidence, and mining) and imaging landscape characteristics (wetland and flood mapping, snow, ice, glacier and soil moisture mapping, and vegetation height and biomass retrieval). Project activities provide fundamental research and technologies on mapping and monitoring the Nation's ecosystem function, water availability, natural hazards, and climate changes, topics addressed in Circular 1309, "Facing Tomorrow's Challenges—U.S. Geological Survey Science in the Decade 2007–2017." Project scientists have authored/co-authored about 14 journal manuscripts on volcano deformation monitoring, wetland mapping, radar polarimetry technique development, radar remote sensing of natural hazards (fig. 10), mining investigation, land subsidence mapping, and earthquake studies. Staff members have conducted radar/InSAR training courses and Webex trainings, given support and guidance to USGS (and other Federal agencies) scientists on exploring radar/InSAR technologies, and provided support to LRS Headquarter staff on radar-related activities. For further information, contact Zhong Lu, USGS EROS, *lu@usgs.gov*.

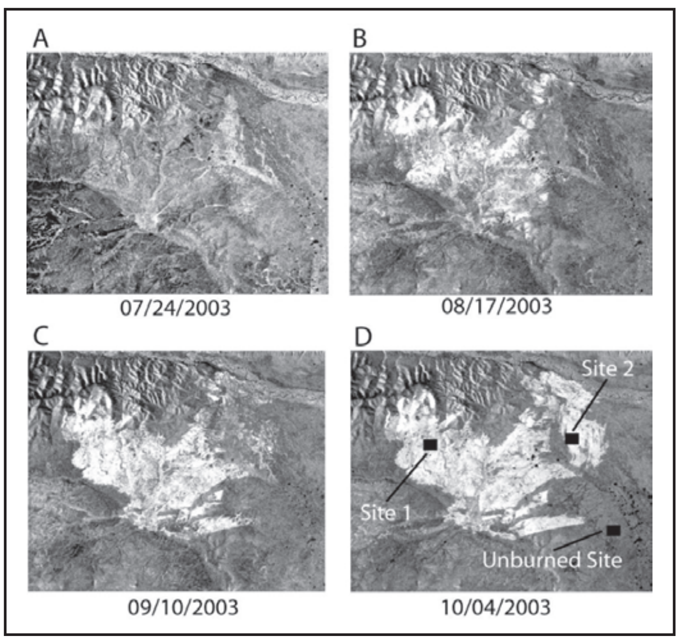


Figure 10. Multi-temporal radar images were used to map the progression and extent of a 2003 boreal wildfire in the Yukon Flats National Wildlife Refuge, Alaska, during conditions of near-persistent cloud cover.

Fire Science

The Fire Science Team conducts, applies, leads, and advances fire science by supporting the U.S. Department of the Interior, other land-management agencies, and their fire management programs with scientifically credible, timely, reliable, and nationally consistent data, and constructive collaboration with other partners. Key accomplishments are given in the following sections.

Operational Wildland Fire Danger Forecasting and Analysis

The USGS EROS Wildland Fire Science Team produces daily and weekly updates of wildland fire danger conditions in the conterminous United States (fig. 11). These forecasts integrate weekly vegetation condition data derived from 1-kilometer Advanced Very High Resolution Radiometer (AVHRR) data, daily updates of 7-day weather forecasts from the National Digital Forecast Data from National Oceanic and Atmospheric Administration (NOAA), and statistical probability of wildland fire based on historical fire occurrence data (fig. 12) with the fire occurrence data characterized by Geographic Area Coordination Center. The information is presented in several forums and formats. Two web mapping services provide access to the data; *http://firedanger.cr.usgs.gov*, *http://ivm.cr.usgs.gov/viewer*. Static maps and background information are available from *http://www.wfas.net/*. For further information, contact Robert Klaver, USGS EROS, *bklaver@usgs.gov*.

The LANDFIRE Program: Consistent and Comprehensive National Vegetation and Wildland Fuel Mapping

LANDFIRE, also known as the Landscape Fire and Resource Management Planning Tools Project, is a 5-year, multi-partner project producing consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States. It is a shared project between the wildland fire management programs of the USDA and DOI. The project has four components: (1) LANDFIRE Prototype, (2) LANDFIRE Rapid Assessment, (3) LANDFIRE National, and (4) Training/Technology Transfer.

All vegetation mapping (fig. 13), remote sensing of landscape change, web services, and data distribution for the LANDFIRE program occur at USGS EROS. On July 15, 2009, mapping teams completed vegetation data products for all 50 United States.

After 2009, the LANDFIRE program enters its operations and maintenance phase with administrative responsibility shifting to USGS EROS. Currently (2009), the LANDFIRE staff is preparing an implementation plan with specific information for the continuing implementation of LANDFIRE by

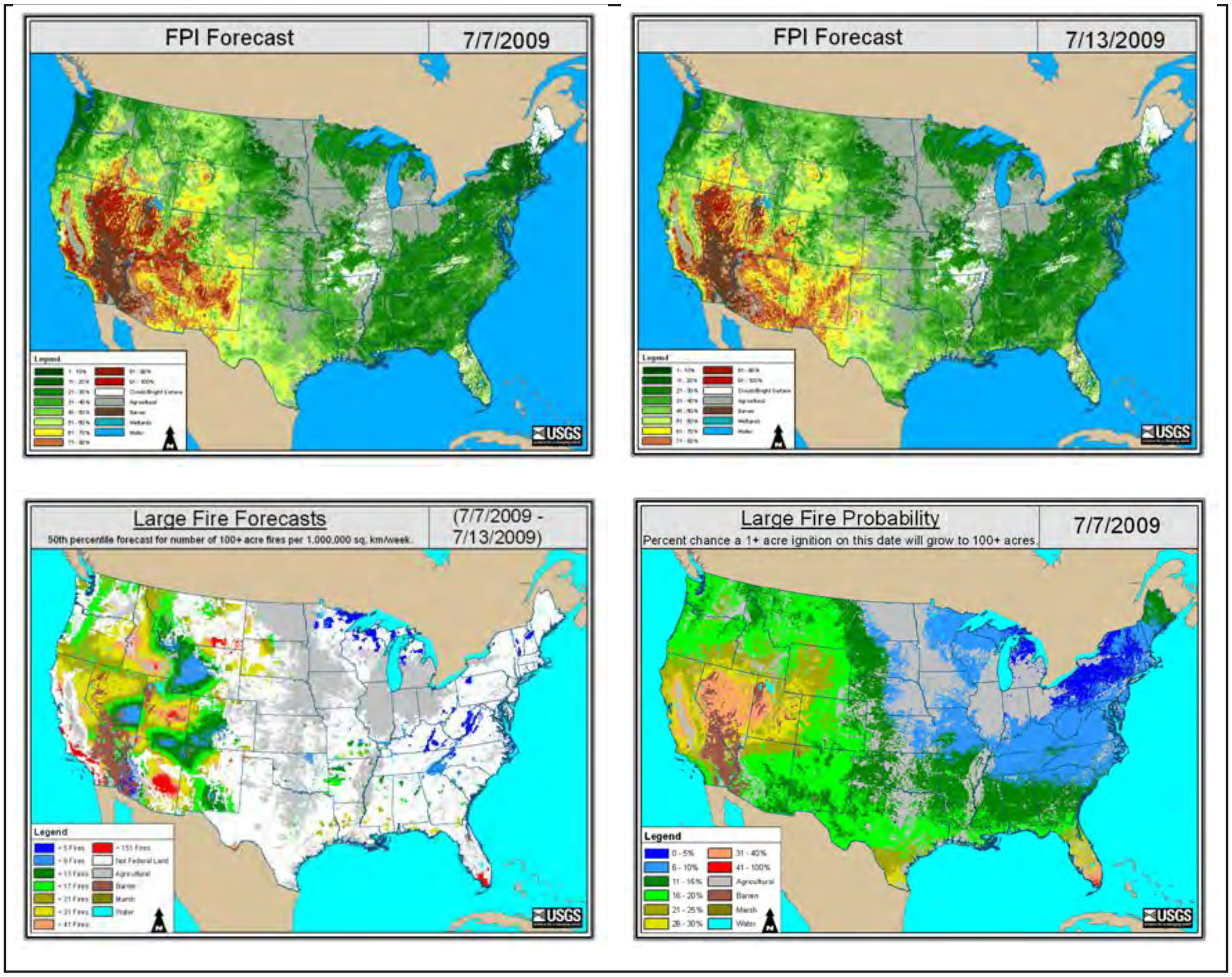


Figure 11. Fire Potential Index (FPI) maps show the likelihood of large fires occurring during a given week.

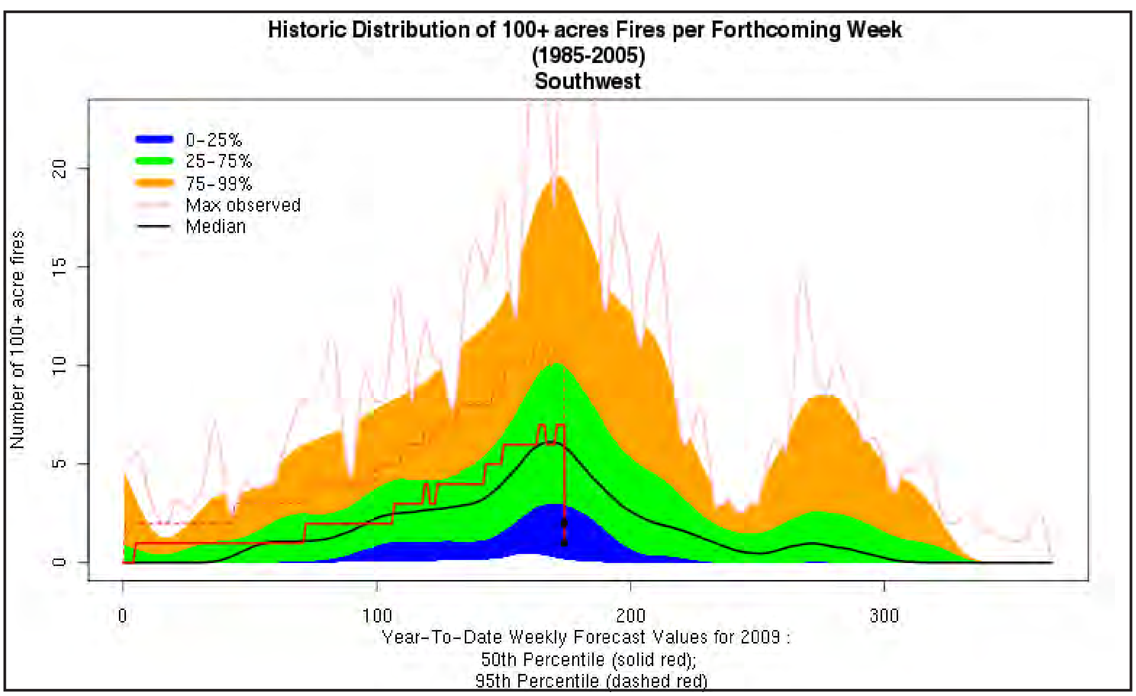


Figure 12. Historical data of fire distribution for a region helps forecast when large fires are likely to occur.

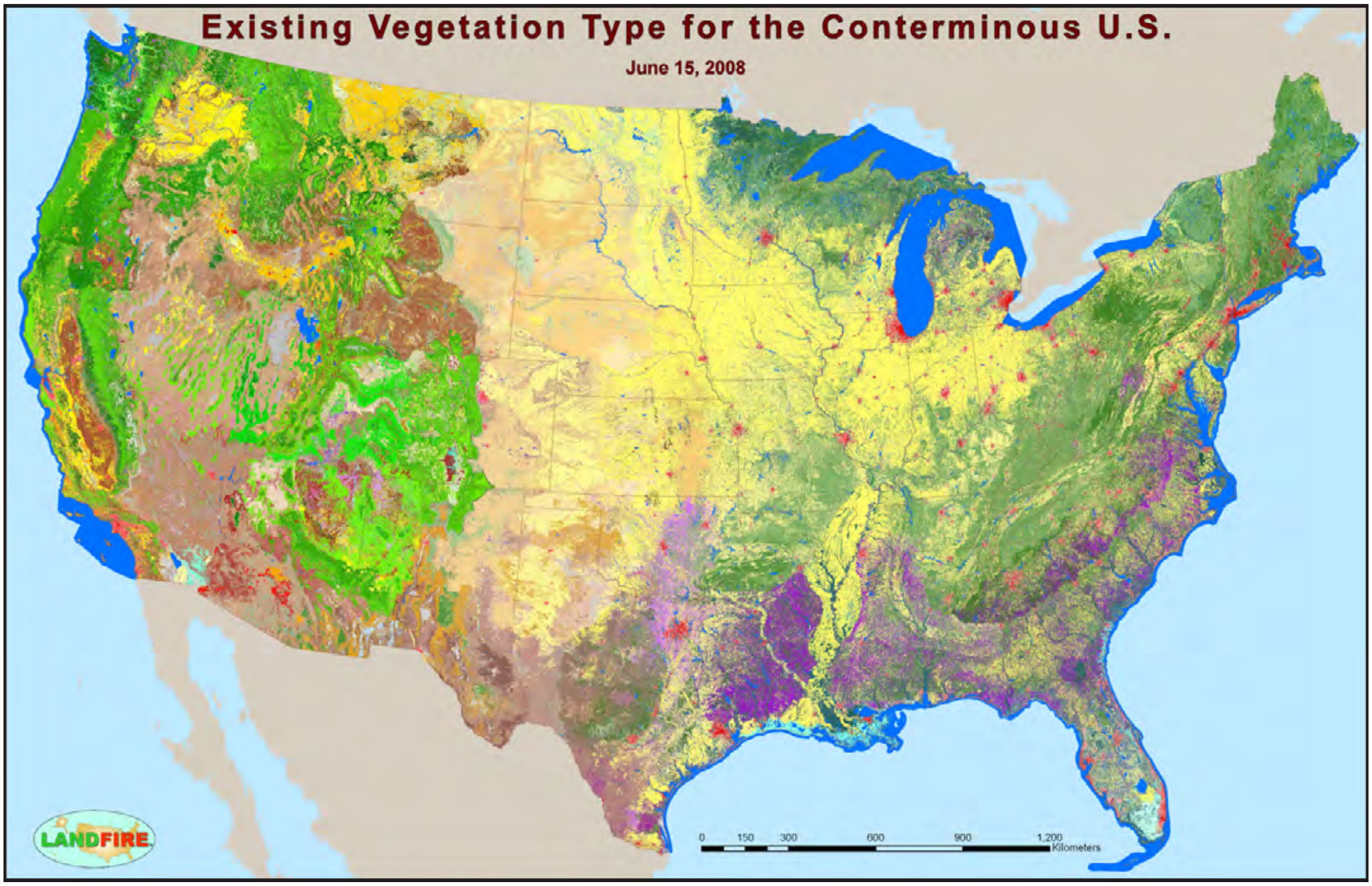


Figure 13. The Existing Vegetation Type data layer for the conterminous United States representing the vegetation currently present at a given location. These map units are derived from the NatureServe's Ecological Systems classification. There are nearly 465 different classes for the conterminous United States.

the USGS. For further information, contact Matthew Rollins, USGS EROS, *mrollins@usgs.gov*.

Distribution of LANDFIRE and MTBS Data Products for National Wildland Fire and Land Management Applications

A variety of fire science projects are being conducted by the USGS in collaboration with wildland fire and land management agencies. Integration of the Landsat archive, other remotely sensed data, and geospatial technologies provide valuable information and tools for monitoring vegetation and wildland fire patterns at national-to-local levels. The Landscape Fire and Resource Management Planning Tools Project (LANDFIRE) and the Monitoring Trends in Burn Severity (MTBS) project are examples of USGS programs developing data products at moderate spatial resolutions for all 50 United States.

For more than 5 years, the USGS EROS has been tasked to provide for distribution, technology transfer, user-support, versioning, archiving, and documentation of data products from these national programs.

The LANDFIRE project produces consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States. LANDFIRE data products include layers of vegetation composition and structure, surface and canopy fuel characteristics, and historical fire regimes (fig. 14).

The MTBS project is underway to produce a fire atlas of all United States' fires occurring from 1983 through 2010. Wildland burn severity data are being used to monitor landscape recovery and long-term effects of wildland fire (fig. 15). These data are an important partner with LANDFIRE, as MTBS documents disturbances caused by fire and this information is used to update LANDFIRE data layers. Nearly 7,000 fires have been mapped and staged on the MTBS distribution website to date (2009).

Data products from LANDFIRE and MTBS appear to be reaching the customers as is illustrated in figure 16 by the increasing trend with the number of visitors visiting these websites. USGS EROS scientists are in constant contact with program partners and end users in order to improve and maintain the quality of data products and to maintain and continue to evolve the quality of data distribution. For further information, contact Donald Ohlen, USGS EROS, *ohlen@usgs.gov*.

Figure 14. LANDFIRE data are all available for download from the LANDFIRE National Map website at *http://landfire.cr.usgs.gov/viewer/*.

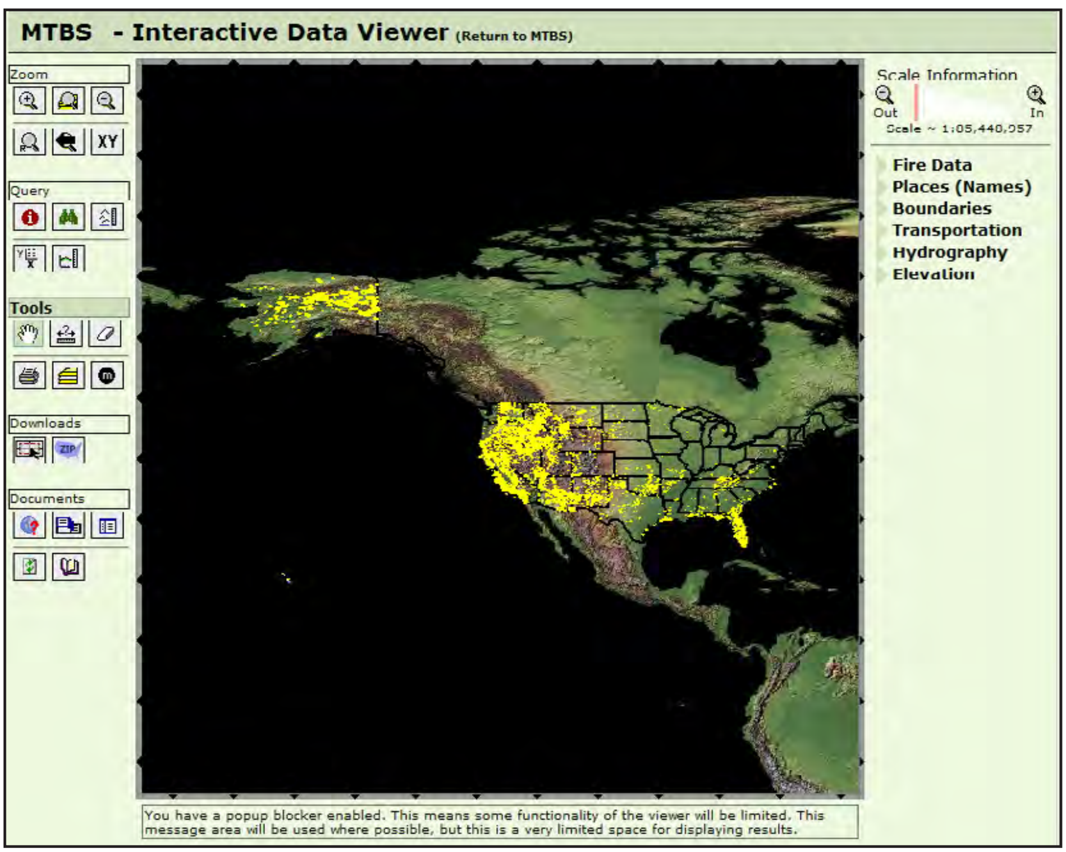


Figure 15. The Monitoring Trends in Burn Severity data are available at *http://mtbs.cr.usgs.gov/viewer/viewer.htm*.

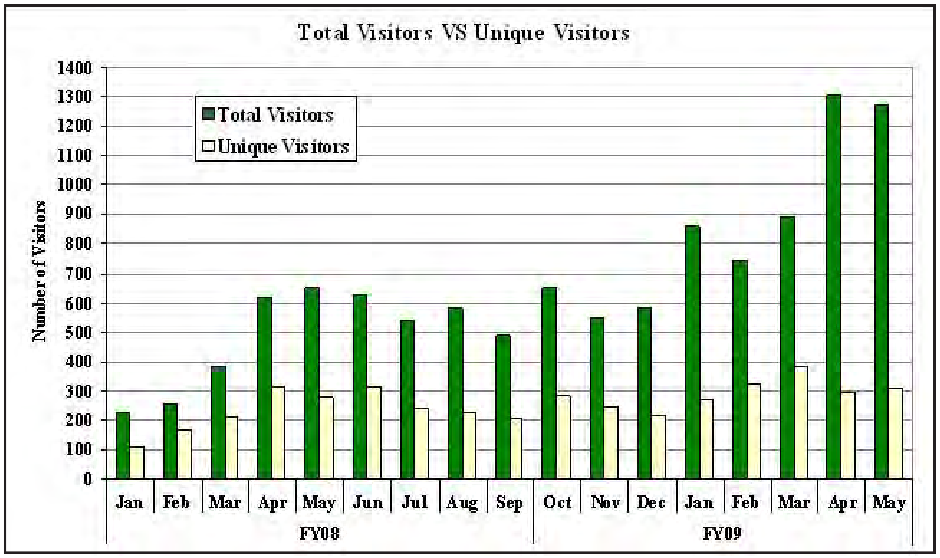


Figure 16. Increasing number of visitors to the LANDFIRE and MTBS websites.

Developing Satellite-Based Fire History Maps from 1984 through 2008

Using images from the Landsat data archive, the MTBS project at the USGS EROS, and in collaboration with the U.S. Forest Service (USFS), has generated and provided access to burn severity assessments for thousands of fires from 1984 to 2007 (fig. 17). In FY 2009, all large historical fires were assessed for the Southeastern United States, as well as those that occurred in 2007 across all 50 United States. Additionally, the MTBS project began providing support to the LANDFIRE Refresh effort where burn severity assessments for smaller fires are provided directly to the LANDFIRE project to support the updating of data products. Burn severity data are used to monitor vegetation recovery and analyze long-term fire effects. These facilitate assessment of ecological or socio-economic factors that are affected by wildland fire. These data are used to study the effectiveness of management practices implemented in response to the National Fire Plan and the Healthy Forest Restoration Act.

To support the ongoing MTBS and the Multi-Resolution Land Characterization (MRLC) Consortium projects, a suite of image processing software was developed to convert Landsat scenes generated by the Level-1 Product Generation System into the standard products used by MTBS and MRLC: Top of atmosphere reflectance, Normalized Burn Ratio, Tassel Cap, and Temperature, all in a common map projection. This software enables these projects to continue to add hundreds of new scenes to the MRLC image archive each year, and now totals more than 10,000 images from 1984 to present (fig. 18). For further information, contact Stephen Howard, USGS EROS, *smhoward@usgs.gov*.

Hayman pre-fire. **Hayman post-fire.** **Hayman burn severity.**

Figure 17. These Landsat images show the Hayman fire, which burned more than 135,000 acres near Denver, Colorado, in 2002. Analyzing the change between the pre-fire image and post-fire image allows land managers to identify the most severely affected areas (red) and concentrate their erosion mitigation and landscape rehabilitation efforts in those areas.

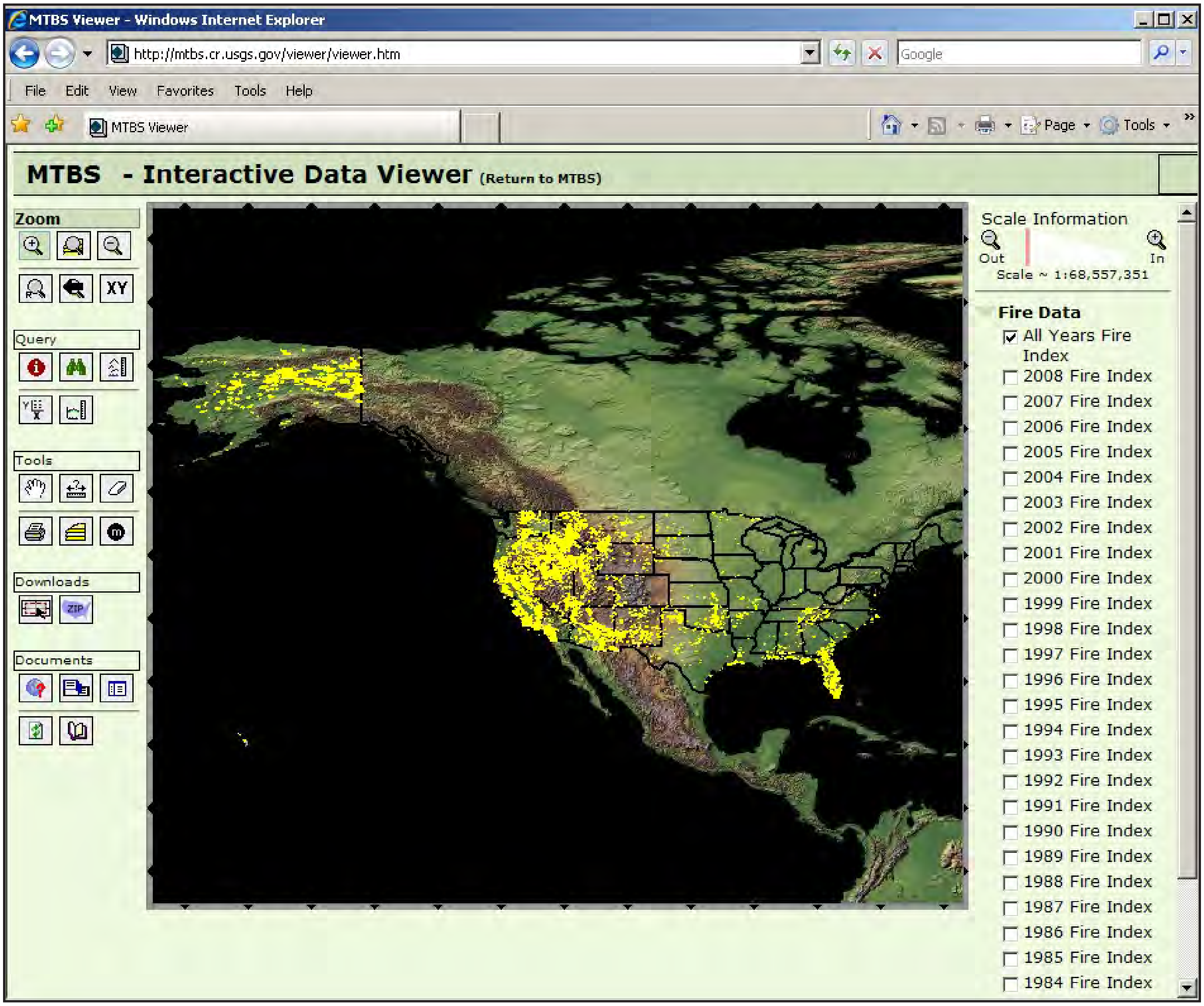


Figure 18. Each yellow dot represents a single fire of more than 7,000 currently (2009) available via the MTBS data distribution system. Users may download single or multiple fires. Each fire dataset contains the burn severity assessment, the pre- and post-fire images used to create the assessment, a fire perimeter, and an accounting of the types of vegetation burned. MTBS Interactive Data Viewer is available at *http://mtbs.cr.usgs.gov/viewer/viewer.htm*.

Automated Landsat Scene Selection for Temporal Analysis

The USGS EROS is now in an era of freely available data from the Landsat sensors. At the same time, remote sensing and Earth science communities increasingly are focused on the effects of a changing planet. The Landsat archive, with imagery of the Earth dating back to 1972, contains a valuable record of land surface change through time, but it is organized in a manner that is as dated as the archive is old, based on a single scene, path/row indexing system that makes little sense to those not familiar with the orbital characteristics of the satellite. Current (2009) scene-selection interfaces to the archive provide a good lookup of scenes from a time and location point-of-view, but little has been done to enable search and scene selection based on the spectral characteristics of the individual scenes. The search and selection of Landsat imagery is still a time-consuming manual process; there are no automated tools to aid the user in finding scenes of interest. Development of automated processes for scene selection and data stack (25-year time series of images from the same geographic area) are necessary for successful wildland fire and terrestrial monitoring.

We are focused on two techniques to enable search of the Landsat archive: (1) a high resolution browse image that fully represents the spectral content of the original image; and (2) a self-organizing, time-series based data structure that records image disturbance through time (fig. 19). This research, initiated in FY 2009, has demonstrated that advanced techniques used in text-based document searching have application for data mining of remotely sensed image archives. For further information, contact Daniel Steinwand, USGS EROS, *steinwand@usgs.gov*.

Figure 19. An automated process uses a time series of images (lower part of image) and identifies change over time. In this example, a burn has been identified and is shown in the enlarged image.

Parallel Computing in Support of National Wildland Fire Severity Modeling

The LANDFIRE Modeling project supports computationally intensive numerical models used in the Wildland Fire Science Team at USGS EROS. Work performed in this project includes the operation and maintenance of five Beowulf Cluster computers with 200 processors, as well as the parallel implementation of models that simulate landscape scale wildland fire behavior and effects. During the chartered production of LANDFIRE data, these computational resources were used on a continuous basis. LANDFIRE production included implementation of three computationally-intensive modeling tasks—WxBGC, LANDscape SUccession Model (LANDSUM), and a decision-tree model applier. Scientists at the USDA Forest Service's Fire Sciences Lab in Missoula, Montana, developed serial versions of the WxBGC and LANDSUM for national applications.

The objective of the WxBGC model is to create weather and ecosystem variables for predictive landscape mapping by combining the weather simulation ability of the WxFIRE model with a gridded, 18-year database of daily weather measurements (Daymet; *www.daymet.org*) and the Biome-BGC ecosystem process model to produce 84 biophysical variables for two plant functional types.

LANDSUM simulates the effects wildland fire has had on natural, unmanaged landscapes during 10,000 years. The objective of the implementation of this model by the USGS EROS is to provide ranges and variations of historical landscape dynamics to provide a reference for current (2009) landscapes. Inputs to this model are derived from LANDFIRE data layers including Landcover, Landsat imagery, Elevation, and the biophysical gradients derived from the WxBGC model. The LANDSUM model also is computationally intensive; typical model runs utilized from 64 to 96 processors and would run for a week for each of the 68 LANDFIRE mapping zones.

The LANDFIRE project uses classification and regression trees to derive potential and existing vegetation data products. Because national data volumes are great and this classification is done at the 30-meter pixel level, these models were implemented as a parallel process, reducing the runtime by two orders of magnitude. This dramatically increased the time scientists dedicated to control the quality of vegetation data products given the overall aggressive schedule of the national program.

Currently (2009), the USGS EROS Wildland Fire Science Team is collaborating with the Fire Modeling Institute from the Missoula Fire Sciences Laboratory to implement the wildland Fire Hazard and Risk Model (FIREHARM) in a parallel computing environment (fig. 20). Still in a research mode, FIREHARM maps fire hazard and fire risk over an area, again using the 18 years of gridded Daymet daily weather data, which is used to simulate fuel moistures and compute fire variables. Additional collaboration (post-FY 2009) includes the implementation of a national model predicting wildfire severity under ranges of land use and climate change scenarios. For further information, contact Daniel Steinwand, USGS EROS, *steinwand@usgs.gov*.

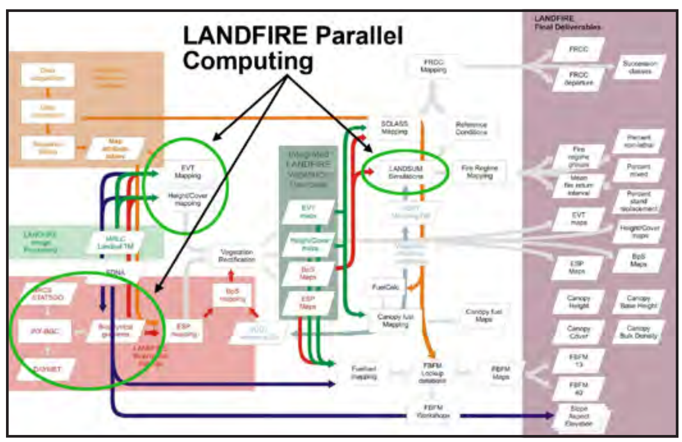


Figure 20. Flow of the LANDFIRE production process. The green circles indicate where parallel computing was used.

Operational Support of Burned Area Emergency Response Teams

The USGS EROS provides DOI Burned Area Emergency Response (BAER) teams with rapid response wildfire burn severity mapping in support of their efforts to minimize potential post-fire hazards such as downstream flooding, landslides/debris flows, and soil erosion. In FY 2009, the USGS mapped more than 23 fires, representing more than 800,000 burned acres, at the request of DOI BAER teams. In the spring of 2009, the USGS assisted DOI BAER teams sent to Australia by mapping more than 700,000 acres of burned land in Victoria province. International burn severity mapping assistance also was provided to National Park Service BAER staff working to assist local fire managers with two wildfires impacting national parks in the Democratic Republic of Georgia.

To be useful to BAER teams, burn severity data must be delivered within a few days after fire containment. Landsat 5 and 7 are the primary sources of satellite imagery used for burn severity assessments (fig. 21). The USGS also provides Landsat imagery to the U.S. Forest Service (USFS) for similar burn severity mapping activities on USFS land. For further information, contact Randy McKinley, USGS EROS, *rmckinley@usgs.gov*.

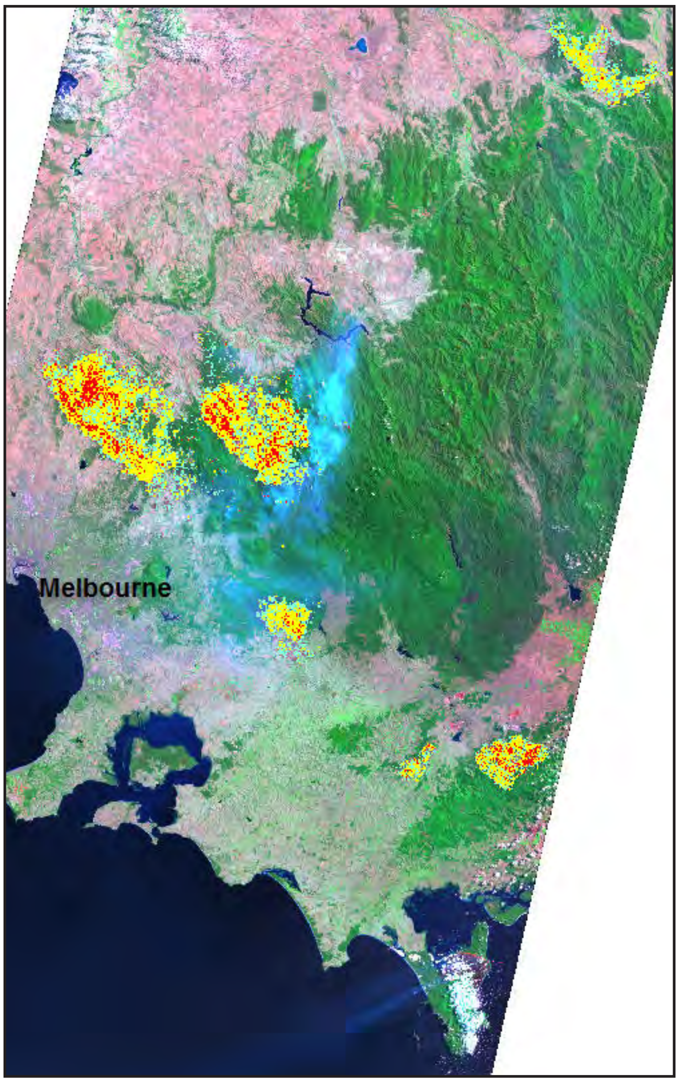


Figure 21. Satellite-derived soil burn severity classes over a Landsat false-color composite image (Bands 7,4,3) for a part of Victoria province near Melbourne, Australia. Soil burn severity was generated for 2009 wildfires where light blue equals low severity, yellow equals moderate severity, and red equals high severity.

Detailed Historical Mapping of Fire Severity and Intensity Using Remote Sensing and Field Referenced Data

In 2009, USGS EROS wildland fire science is completing a 3-year monitoring project for the 2005 Southern Nevada Complex (SNC) wildfire using remote sensing techniques. This collaborative effort with the Bureau of Land Management (BLM) Ely District Office specifically is examining extensive seeding treatments implemented within a large burn area (700,000 acres) during the winter of 2005/2006. The USGS EROS developed a 3-year time series of Landsat imagery to enable the monitoring of greenness and other indicators of vegetation recovery/establishment, assessments of burn severity, the selection of post-fire seeding locations, assessments of seeding effectiveness, mapping the occurrence of invasive annual and perennial plants, and other applications potentially relevant to the management of lands impacted by the SNC. USGS Biological Resources Division staff collected 3 years of extensive field data to support traditional monitoring assessments and to assist with the USGS EROS remote sensing analysis.

The multi-temporal Landsat satellite image database (fig. 22) developed for the SNC allows for the analysis of satellite image data or derived indices at varying time intervals from immediate pre-fire 2005 (May 2005) to more than 3 years post-fire 2008 (September 2008). Satellite image vegetation indices or individual spectral band values have been extracted at field macroplot/sampling point coordinates, by paired 40 acre (seeded and non-seeded) plot polygons, and other user-defined geographic areas (grazing allotments). Extracted image values, along with field data parameters, are being analyzed for 1,173 macroplot locations. Statistical analyses are examining relations between remotely sensed data and field data. Final results are expected in FY 2009. This collaborative USGS BLM project is expected to result in a better understanding of effectiveness of treatments and effects of fires in Mojave Desert ecosystems. For further information, contact Randy McKinley, USGS EROS, *rmckinley@usgs.gov*.

Land Characterization and Trends

The Land Characterization and Trends Team develops solutions for characterizing land cover at multiple temporal and spatial scales that enable subsequent analysis, monitoring, forecasting, and reporting of land cover processes. Key accomplishments are given in the following sections.

National Assessment of Land Use and Land Cover Change

The Land Cover Trends project completed the analysis of contemporary land use and land cover change in the remaining 11 ecoregions needed to complete the Western United States

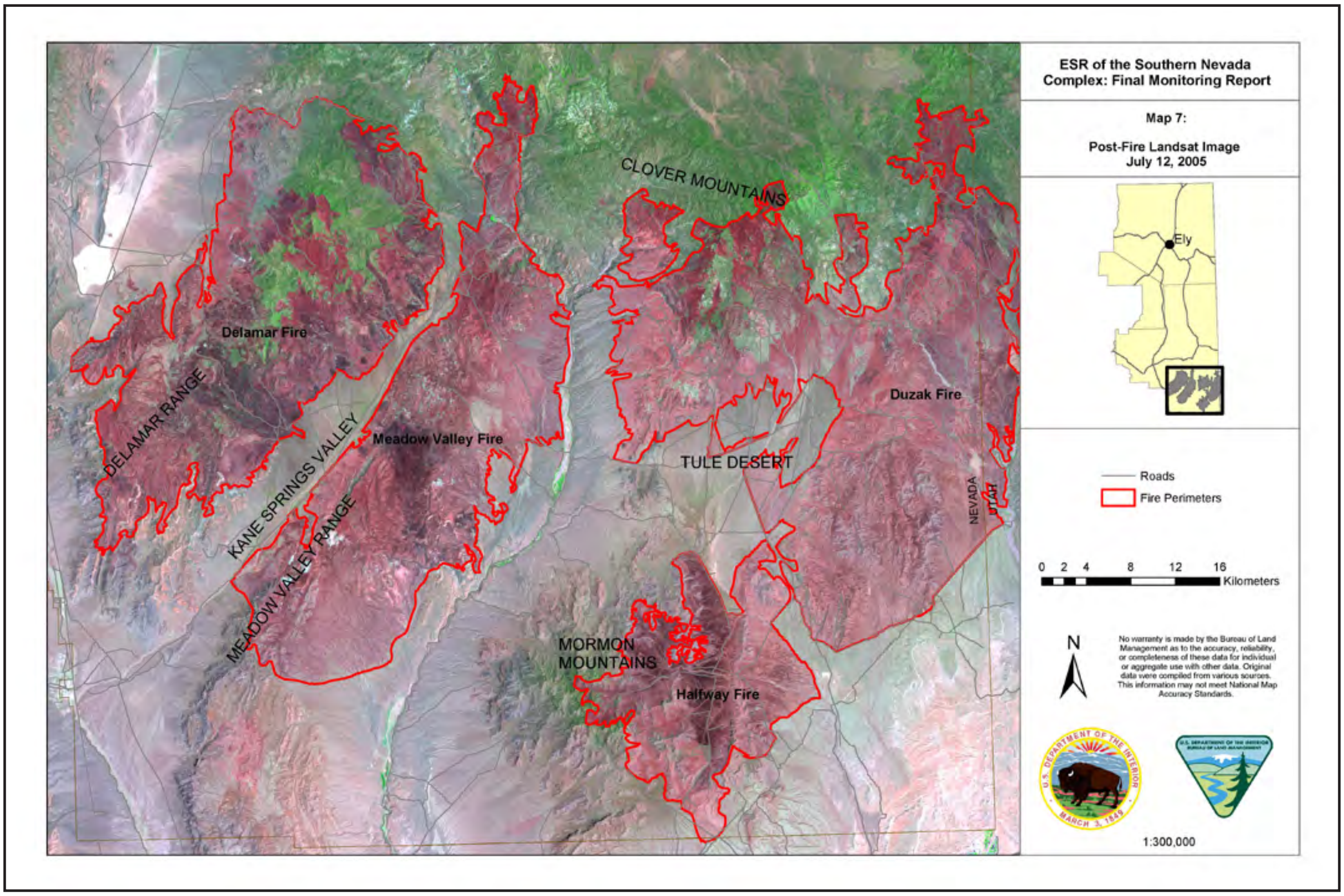


Figure 22. A July 2005 Landsat image showing the extent of the Southern Nevada Complex burned area (700,000 acres).

part of the land cover trends national assessment. USGS scientists completed manual interpretation of historical land use and land cover in 332 sample blocks. The national assessment now has 71 of 84 ecoregions completed (85 percent of the country done). Each 10-kilometer by 10-kilometer sample block required the mapping of land cover on five different dates using Landsat multispectral data. Using the project's methodology, each interpreter creates an initial baseline land cover image map followed by forward and backward classifications of any land cover changes evident in the Landsat images for each core date. Field data collection was conducted for the 11 ecoregions that will be analyzed next year. Field crews visited each ecoregion and collected geo-referenced field photographs and descriptions of the land use and land cover in all sample blocks. Any indicators of potential drivers of change also were documented in the field notes. Fifteen ecoregion datasets were added to the Land Cover Trends website (*http://landcovertrends.usgs.gov/*), making 64 datasets available to the public. This complex, long-term project provides the first comprehensive analysis of national land cover change ever conducted, and has the ambitious goal of establishing the extent, nature, and causes of change to the Nation's land surface (fig. 23). Scheduled to complete the initial 30-year assessment in 2010, the project is intended to provide a foundation for predicting the impacts of land change, as well as modeling future land changes. For further information, contact William Acevedo, USGS EROS, *wacevedo@usgs.gov*.

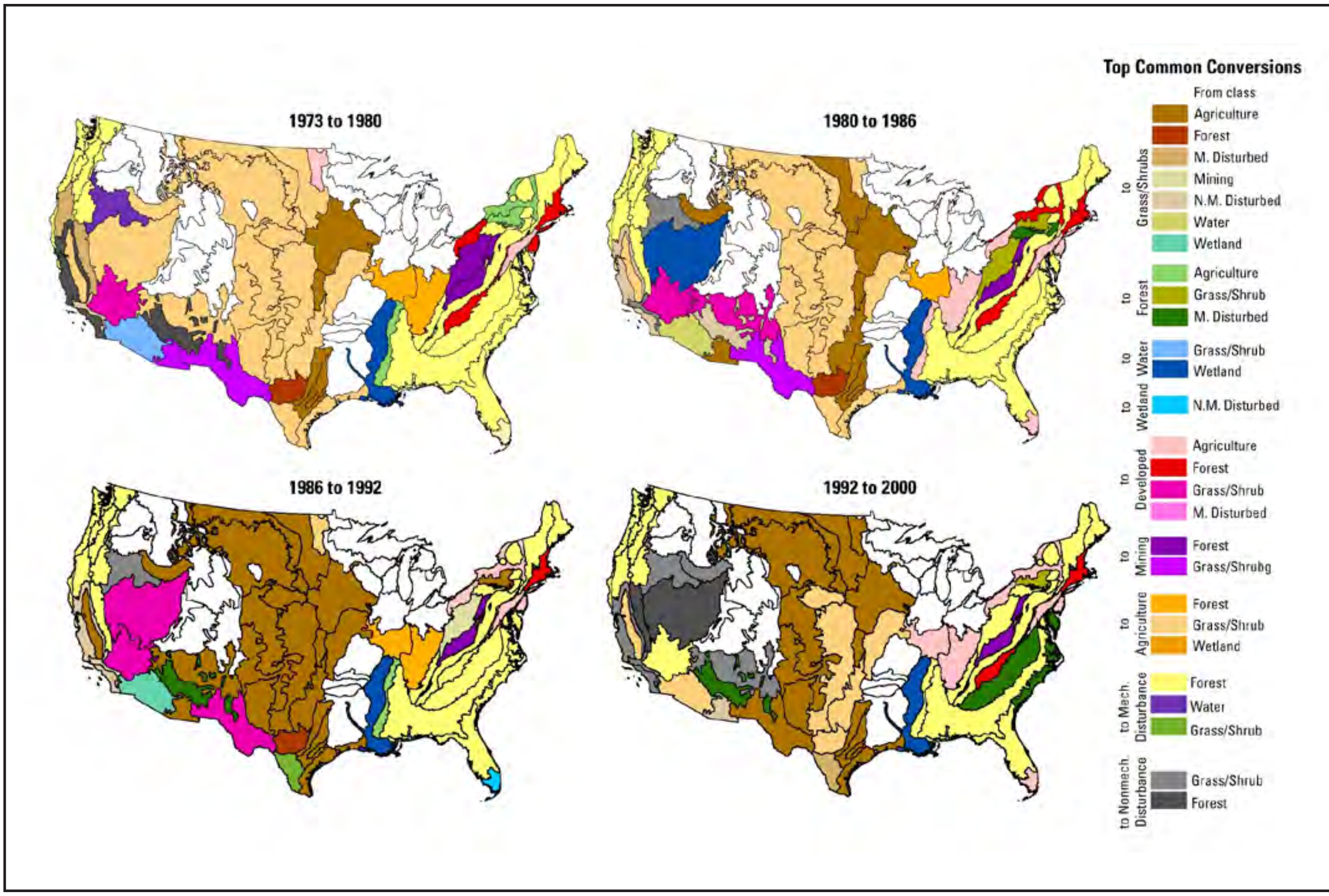


Figure 23. Most common conversions, during each of four time periods, for ecoregions of the conterminous United States, as measured by the USGS Land Cover Trends project. Primary land cover conversions vary geographically and temporally, with each ecoregion characterized by unique rates, spatial patterns, and temporal patterns of change.

Land Cover Status and Trends Report

USGS scientists conducted the statistical analysis, literature review, and editing necessary to prepare 25 ecoregion summary manuscripts for publication. These manuscripts provide a brief overview of the statistical results and major stories of change present in each ecoregion. These summaries are being assembled and will be published for each major United States region (for example, the Eastern United States, Great Plains, Western United States, and Midwest/Gulf Coast). The national assessment report now has 57 ecoregion summaries in various stages of review and approval for publication. A regional overview synthesis paper for the Great Plains land cover change report was prepared this fiscal year (2009) and currently is in final review (fig. 24). The Eastern United States and Great Plains reports should be published by the end of 2009. The Western United States report (fig. 24) will be out in 2010; the Midwest report is planned for the following year. For further information, contact William Acevedo, USGS EROS, *wacevedo@usgs.gov*.

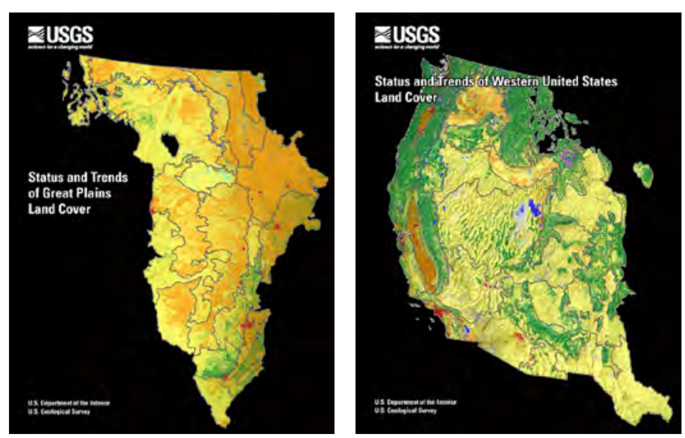


Figure 24. Covers proposed for the Great Plains and Western United States land cover status and trends reports currently (2009) being prepared for publication following the completion of individual ecoregion assessments of contemporary land use and land cover change.

Production of the 2006 National Land Cover Database

The National Land Cover Database (NLCD) provides consistent public domain information on the Nation's current and historical land cover characteristics that are applicable at national, regional, and local scales (fig. 25). Much of this work is accomplished through partnerships with Federal, State, and local Government agencies, private industry, and non-Governmental organizations. NLCD represents three major land cover data releases including a 1992 conterminous United States land cover dataset containing 1-thematic layer of land cover (NLCD, 1992); an updated 50 United States/Puerto Rico land cover database with 3-thematic layers including land cover, percent imperviousness, and percent tree canopy (NLCD, 2001); and an NLCD 1992/2001 retrofit land cover change product that is designed to identify land cover change between the two eras (NLCD, 1992/2001 Retrofit Land Cover Change Product). These comprehensive sets of scientifically credible land cover data layers are used to support thousands of applications in land management, environmental studies, modeling, and policy decisions by organizations using NLCD products. All NLCD products are Web enabled for download at the MRLC website at *http://www.mrlc.gov*.

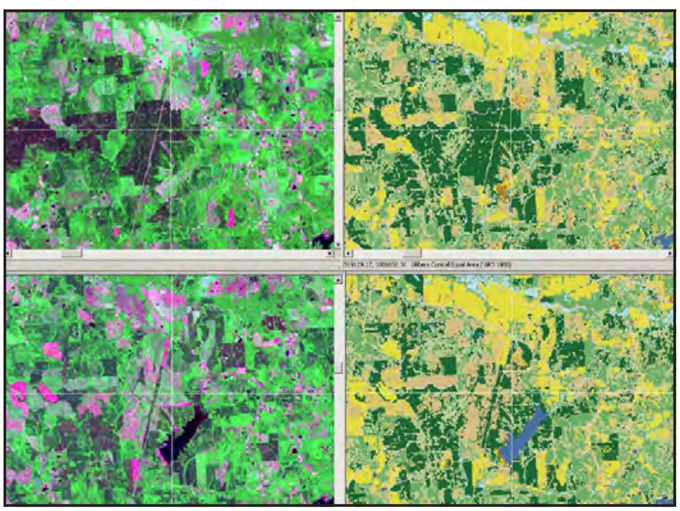


Figure 25. Example of NLCD 2006 and NLCD 2001 land cover change in Mississippi.

In FY 2009, full scale production of NLCD 2006 (updated land cover for the nominal year of 2006) was initiated. NLCD 2006 included updating 2001 land cover and percent imperviousness to the year 2006, as well as detailing the type and amount of land cover and imperviousness change between 2001 and 2006. During FY 2009, 40 percent of the conterminous United States was completed. For further information, contact Collin Homer, USGS EROS, *homer@usgs.gov*.

Developing a Multi-Scale Remote Sensing Monitoring System in Wyoming

Sagebrush ecosystems in North America have experienced dramatic elimination and degradation since European settlement, with new ways needed to characterize and monitor these systems.

A new remote sensing monitoring framework that modeled detailed products with statistically validated estimates of accuracy over sagebrush habitats was completed in FY 2009 for the state of Wyoming. This research employed a combination of new tools, including (1) modeling the sagebrush ecosystem as a series of eight independent continuous field components that can be combined and customized by any user at multiple spatial scales; (2) synergizing the collection of ground-measured plot data with 2.4-meter imagery image acquisition; (3) successful modeling of ground-measured plot data on 2.4-meter imagery to enable large area extrapolation on courser imagery; (4) acquiring multiple seasons (spring, summer, and fall) of an additional two spatial scales of imagery (30 meter and 56 meter) for optimal large-area modeling; (5) using regression tree classification technology that optimizes data mining of multiple image dates, ratios, and bands with ancillary data to extrapolate ground training data to support models; and (6) employing rigorous accuracy assessment of model predictions to enable users to understand the inherent uncertainties.

Eight rangeland components (four primary targets and four secondary targets) were modeled as continuous field predictions including percent bare ground, percent herbaceousness, percent shrub, percent litter, percent sagebrush (*Artemisia* spp.), percent big sagebrush (*Artemisia tridentata*), percent Wyoming sagebrush (*Artemisia tridentata wyomingensis*), and shrub height (centimeters).

Model predictions (fig. 26) were evaluated using an independent accuracy assessment, with the average root mean square error (RMSE) value for seven canopy components (excluding shrub height) for 2.4-meter QuickBird at 6.03, 30-meter Landsat at 8.72, and 56-meter Advanced Wide Field Sensor (AWiFS) at 9.09. These results offer significant improvement in sagebrush ecosystem quantification from remote sensing, and offer critical baseline information for a variety of potential habitat applications now capable of being quantitatively monitored into the future. For further information, contact Collin Homer, USGS EROS, *homer@usgs.gov*.

Landscape Dynamics and Global Change

The Landscape Dynamics and Global Change Team integrates remote sensing resources with simulation models of natural and managed ecosystems to understand environmental change across landscape units, ecological systems, and multi-temporal/spatial scales in support of a sustainable Earth. Key accomplishments are given in the following sections.

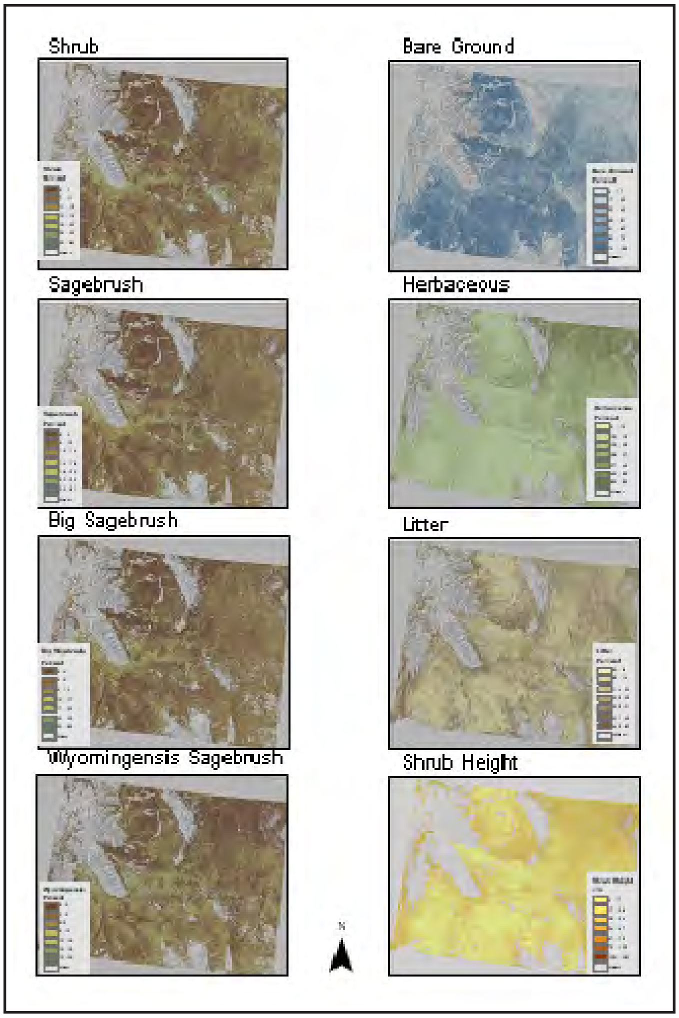


Figure 26. Wyoming state-wide predictions across all eight components from combined Landsat and AWiFS predictions.

The Buzz About Important Ecosystem Services in the Northern Plains

Honey bees account for 80 percent of all insect pollination of plants globally. In the United States, agricultural crops worth more than $15 billion annually rely on the pollination services of honey bees. Transporting bees around the country to pollinate crops exposes them to multiple stressors, including pesticides, limited diets, diseases or parasites, and the stress of the long-distance move. There is evidence that bees having good nutritional health before being shipped around the country will be more resistant to disease and stressors. The Northern Plains region of the United States provides important landscapes for maintaining honey bee colonies before they are needed for pollination of crops elsewhere in the country (fig. 27). Long summer days and grasslands rich in flowering species supply the ideal mix of pollen and nectar sources required by bees for healthy nutrition and for honey production. The USGS is working in partnership with the USDA, the University of Minnesota, the USFS, and the beekeeping industry to test effects on bee health and honey production from different land cover configurations around hives. An approach to classify landscape suitability for honey bees has been developed, and the results will be used to estimate potential effects from climate change and economic incentive programs that encourage land use change on the Northern Plains to sustain sufficient numbers of honey bee colonies for pollination services needed nationally. For further information, contact Alisa Gallant, USGS EROS, *gallant@usgs.gov*.

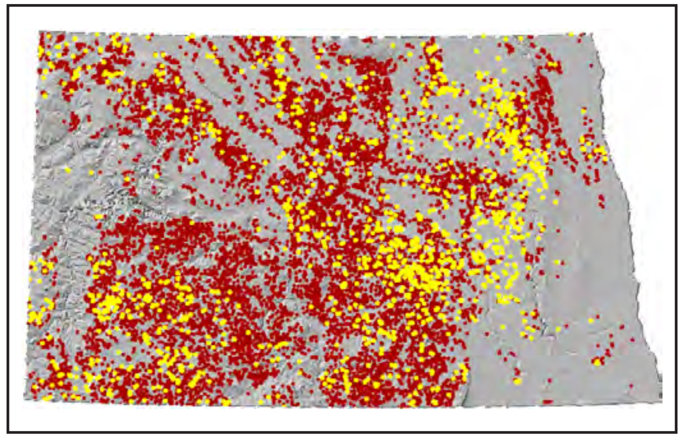


Figure 27. The red and yellow dots in this image depict locations in North Dakota that met landscape criteria to support 100 honey bee colonies in 2002, given the distribution of crop types and assuming the local grasslands had sufficient flowering species for bees. The yellow dots show the locations that benefitted from lands in the Conservation Reserve Program. Because the crop types grown in eastern North Dakota typically are not beneficial to honey bees, the map highlights the importance of the conservation program for maintaining bees in that part of the state.

MODIS and Dynamic Monitoring in the Yukon River Basin

Climate change effects are being expressed in high northern latitudes more dramatically than other parts of the globe. Understanding how climate change will impact permafrost, carbon dynamics, and watershed hydrology will help scientists predict future ecosystem responses. Cooperation with the Canada Centre for Remote Sensing (CCRS) allows us to collaborate, secure Canadian imagery, and examine the entire Yukon River Basin (YRB). Models and maps of boreal forest growing season NDVI, a surrogate for ecosystem productivity, are produced from interpolated weather and site potential using MODIS NDVI at a resolution of 250 meters (CCRS MODIS and eMODIS products). Expected productivity maps are then compared to actual productivity maps to identify anomalous areas, or areas which are more or less productive than expected during any given year's weather conditions. This approach accounts for interannual variations associated with weather to reveal effects caused by insect infestation, fires, changed drainage patterns, and permafrost degradation, all of which are of increasing concern as warming continues. Anomalous areas that are persistent over multiple years are mapped and can be used by modelers to account for disturbances in boreal forests of the YRB (fig. 28). For further information, contact Bruce Wylie, USGS EROS, *wylie@usgs.gov*.

Ecosystem Performance Supports Bureau of Land Management Objectives

The BLM is responsible for the sustainable management of large tracts of Federal land, typically in moisture-limited areas. Limited numbers of BLM district personnel are responsible for assessing and managing these areas with increasing concerns for water quality, endangered species, wildlife, and domestic grazing in areas with variable forage production dependent on weather conditions. Models and maps are produced that estimate vegetation productivity, for which the eMODIS NDVI, at a resolution of 250 meters, serves as a proxy. Significant differences between a year's expected productivity based on weather conditions and actual productivity identify areas that are either more or less productive than expected. Degraded sites and heavily grazed pastures are related to areas less productive than expected, whereas good condition rangelands and lightly grazed pastures appear normal or more productive than expected. Annual maps of productivity anomalies are produced, and areas that are anomalous for multiple years are identified. Productivity anomalies have been related to percent bare ground (an indicator of a degraded rangeland) and grazing pressures. Productivity anomalies also monitor rangeland fire recovery, for example, following the Murphy Complex Fire in southern Idaho. Productivity anomalies are being developed for the Owyhee Uplands, a sagebrush dominated rangeland system in Idaho, Nevada, and Oregon, and the Upper Colorado Basin, a shrub and Pinyon-Juniper rangeland system (fig. 29). This monitoring system will assist BLM district personnel optimize field visits and provide a model for a national consistent monitoring approach for BLM headquarters. For further information, contact Bruce Wylie, USGS EROS, *wylie@usgs.gov*.

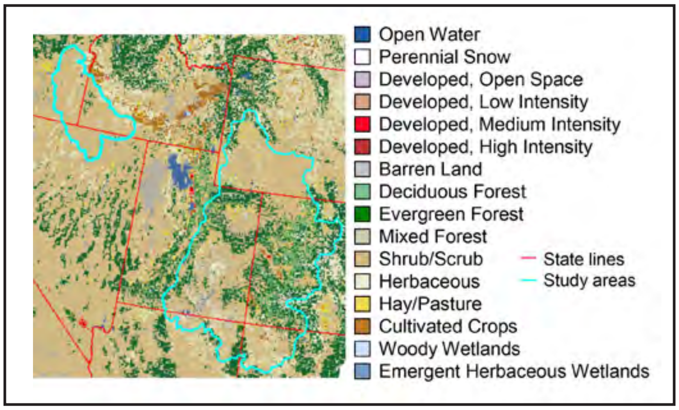


Figure 29. Bureau of Land Management areas of interest for rangeland ecosystem performance anomalies and drought monitoring; the Owyhee uplands study area is on the left and the Upper Colorado River Basin study area is on the right.

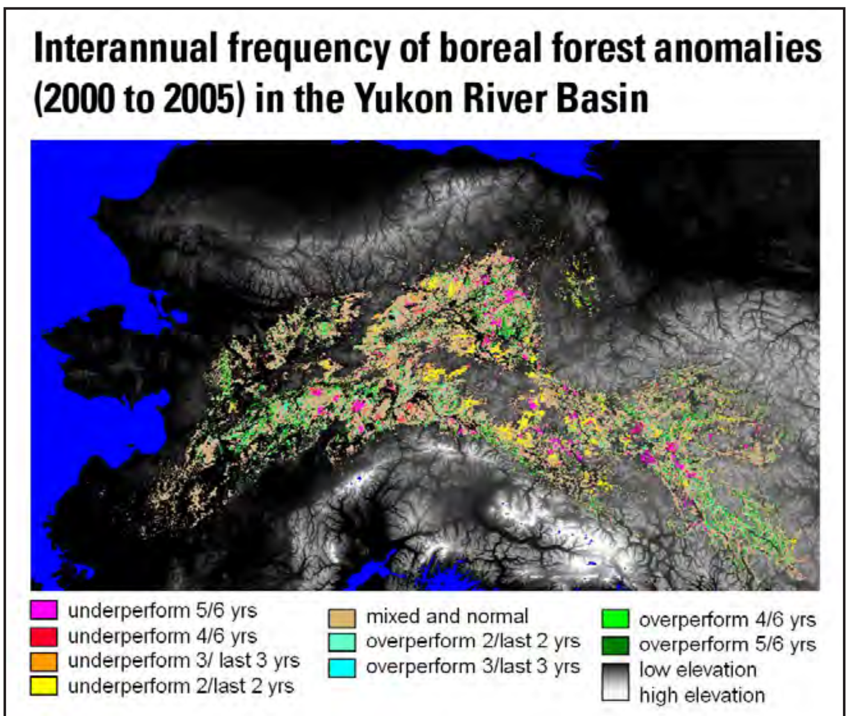


Figure 28. Interannual frequency of boreal forest anomalies (2000 to 2005) in the Yukon River Basin.

eMODIS: A New and Valuable Product for Alaskan Environmental Monitoring

Satellite remote sensing provides invaluable information for monitoring climate change in the high latitudes and remote regions of Alaska. This is especially important because these areas show warming twice that of the conterminous United States. The soils and permafrost contain large carbon stores, and the deteriorating permafrost affects human subsistence patterns, and may lead to positive feedback as old carbon is released into the atmosphere. Satellite observations of the land surface characteristics over Alaska are vitally important because of the vastness and remoteness of the region. The MODIS sensor, as one of the principal instruments on board the NASA Earth Observing System (EOS) satellites, provides high temporal resolution images, which prove useful for monitoring these important environmental changes in

Alaska; however, distortions and other quality concerns in high latitude regions have been problematic and limited the utility of standard products. eMODIS overcomes some of these limitations.

Recently (2009), the USGS EROS Center produced and evaluated an “eMODIS” dataset for the conterminous United States and Alaska that has significantly improved image quality over the standard MODIS data, but retains the original spectral characteristics. Figure 30 shows an example of rivers and streams in the 250-meter resolution eMODIS and Standard MODIS NDVI images compared with a 15-meter NDVI image. Although both MODIS maps capture the primary features of the bigger rivers, the water body boundaries are more distinct and smoother in the eMODIS image than the standard MODIS NDVI image, in which water bodies reveal “stair stepped edges.” For the small rivers and streams, linear features are generally continuous in the eMODIS images, but they are noticeably discontinuous in the standard MODIS image. Because Alaska and other high latitude areas will be playing increasingly important roles in global warming investigations, eMODIS will be a new and valuable dataset for Alaskan environmental and ecological monitoring. For further information, contact Bruce Wylie, USGS EROS, *wylie@usgs.gov*.

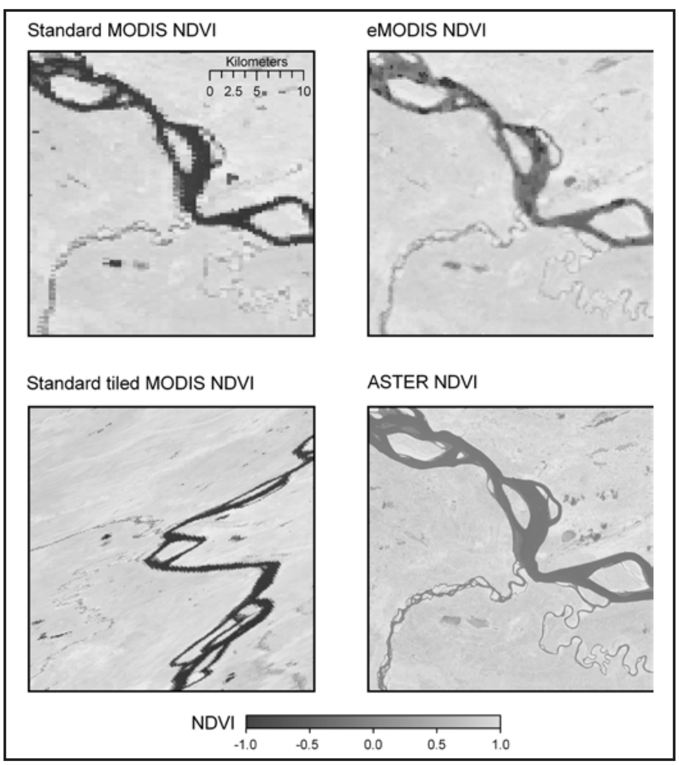


Figure 30. Water body boundaries and small rivers and streams are more distinct in the eMODIS image and ASTER NDVI image than the standard MODIS NDVI product.

Carbon Fluxes Respond Dynamically to Climate in the Northern Great Plains

The grassland ecosystems in the United States’ Great Plains are the primary resources for livestock production in North America and are important contributors for climate regulation and global carbon balance. They encompass broad climate gradients of temperature and moisture and include native tallgrass, mixedgrass, and shortgrass systems, grazing lands, and conversions to productive and intensive agricultural use. Understanding carbon budget in the Northern Great Plains grasslands under various climatic conditions, especially drought, requires adequate knowledge of interannual variation in ecosystem carbon exchange with the atmosphere.

The AmeriFlux and Agriflux networks provide continuous observations of ecosystem exchange of carbon. However, these flux measurements represent only the carbon fluxes at the scale of the tower footprint. There have been no detailed long-term estimations or studies investigating the interannual variability in carbon exchange across the entire Northern Great Plains. The scientists at the USGS EROS have developed a remote sensing-driven model that integrated the flux tower data with remote sensing data to estimate carbon exchange. Annual totals of gross primary production and net ecosystem exchange were modeled and mapped to characterize the temporal dynamics and geographic patterns of sink/source activity in the region (fig. 31).

These estimates and the quantitative analysis of carbon fluxes provide insights into how the grassland ecosystem will respond to future climate under a variety of environmental conditions and what systems are sustainable and offer net carbon sinks. Additionally, this research also will provide a valuable source of data for atmospheric modelers and will facilitate the synthesis and integration necessary to meet the goals of the Mid-Continent Intensive Areas of the North American Carbon Program.

This study shows that the Northern Great Plains grassland ecosystem was a weak source for atmospheric carbon during 2000–2006, which included 3 drought affected years. Drought has a strong effect on the carbon budget and has the potential to alter long-term carbon balances over the Northern Great Plains grasslands, especially in the Western High Plains and the Northwestern Great Plains. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

The Rapid Land Cover Mapper: Now on the Web

Mapping land use and land cover over large areas and through time has always presented major challenges. There are two contrasting approaches to land use and land cover mapping: automated/semi-automated classifications and manual photo interpretation. The first approach is fast and efficient in classifying large areas, but it is problematic when comparing two or more time periods. The photo interpretation method produces good results for time-series mapping, but it

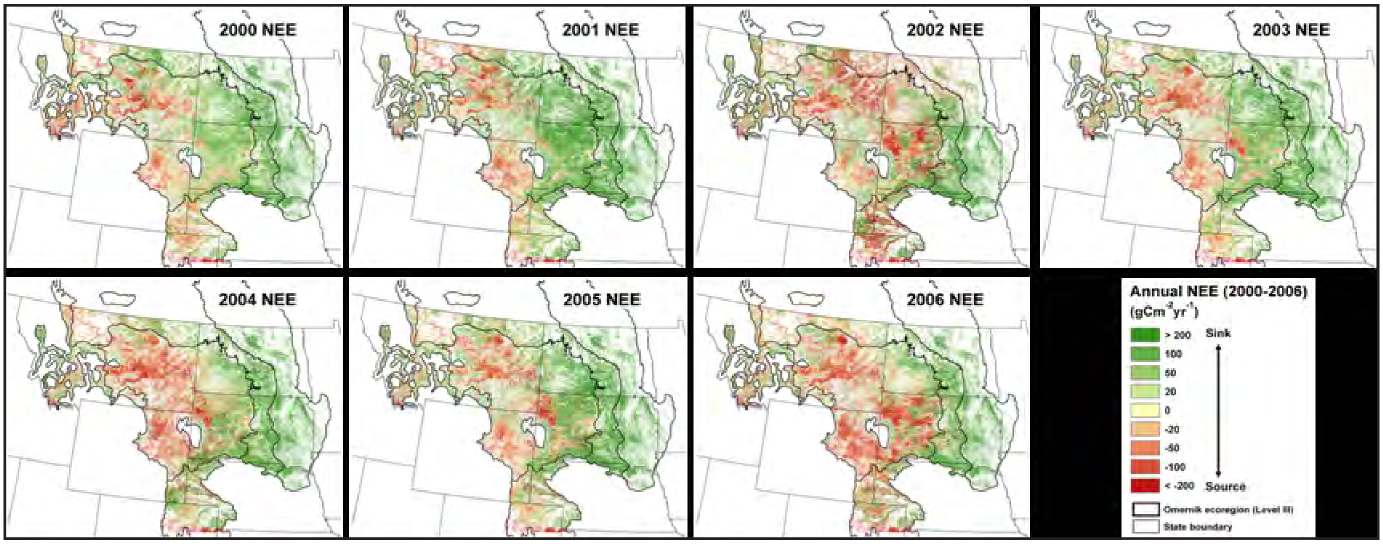


Figure 31. Spatial distribution of grassland annual net ecosystem exchange.

is labor intensive for large areas. In 2006, the USGS released the Rapid Land Cover Mapper (RLCM) (*http://lca.usgs.gov/lca/rlcm*) tool to address these challenges (fig. 32). Stemming from its success, the USGS GAM Program has developed an online version that extends its functionality to the Internet, making it freely available to the global community. This Web Rapid Land Cover Mapper (wRLCM) tool uses the same standard photo interpretation techniques as the RLCM, but uses web mapping services (WMS) to distribute global image datasets. The first WMS used in the wRLCM is NASA 2000 global Landsat mosaic. Alternatively, instead of a WMS, users can upload their own images for interpretation. wRLCM also includes the ability to collaborate with colleagues on the same project. Once they have completed the classification for their defined area, they can download the result in standard GIS file formats. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

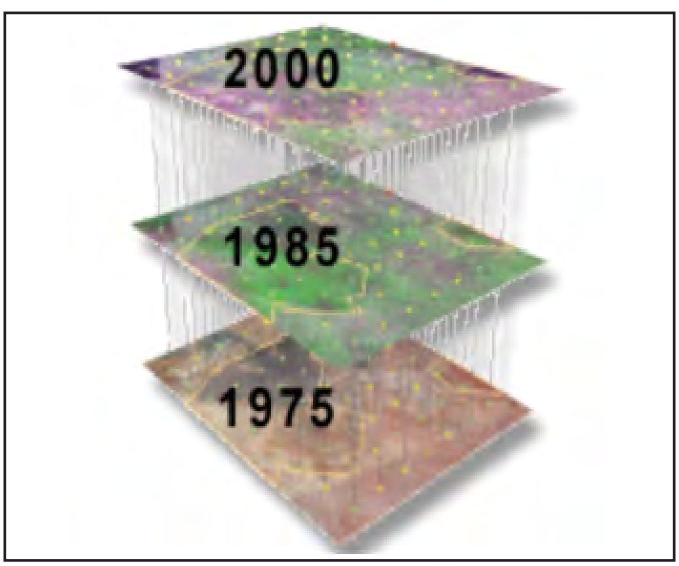


Figure 32. RLCM land use and land cover time-series interpretation.

Characterizing Land Cover Change in West Africa's Sahel

EROS scientists and their counterparts in West African countries recently (2009) completed a major effort to use Landsat imagery to map the land use and land cover of much of West Africa for 1975 and 2000 (fig. 33). This was the culmination of a project carried out collaboratively with the Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center in Niger, and partners from 12 participating countries, with support from the U.S. Agency for International Development. Environmental scientists from each country were trained in the analysis, mapping, and monitoring of trends in land resources using a wealth of Landsat imagery spanning nearly 30 years; the mapping was done on a national level. To map this vast region efficiently and with time, EROS scientists developed a special tool called the Rapid Land Cover Mapper. It is a vector-raster hybrid approach that lends itself to time-series land use and land cover mapping. The new results are providing West African land managers with a better understanding of the land use/land cover patterns and trends in each country. The information is being used by the Inter-Governmental Authority on Combating Drought in the Sahel (CILSS), particularly in their food security and natural resource management programs. For further information, contact Gray Tappan, USGS EROS, *tappan@usgs.gov*.

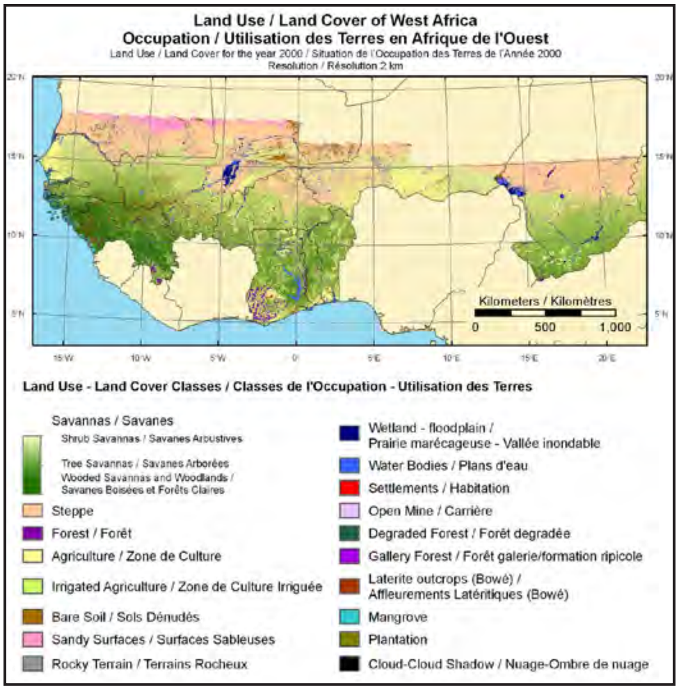


Figure 33. Land use and land cover map of the 12-country region in West Africa for the year 2000.

Monitoring Biodiverse Forests and Other Hotspots in the High Rainfall Countries of West Africa

The remaining forests and woodlands in the high rainfall countries of Guinea, Sierra Leone, and Liberia play a critical role in preserving hotspots of biodiversity in the region, as well as providing crucial ecological goods and services. Maintaining forest cover in Guinea, for example, is critical because the Guinean highlands are the "water tower" of West Africa, spawning many of the region's major rivers; however, many of the forest reserves have become so degraded that they no longer resemble a forest. In recent decades, West Africans have become keenly aware of the degradation of the forests, owing to population pressure, slash and burn agriculture, uncontrolled burning, and clandestine exploitation of timber and firewood. Despite this, there is an increased sense of optimism that forest resources—at least in some areas—actually have improved, and that local communities now have the right to manage them sustainably.

Recently (2009) the USAID requested the assistance of USGS EROS to map and monitor the remaining biodiverse forest hotspots across the three countries, as well as land cover in trans-boundary areas where project partners are working on chimpanzee habitat conservation, planning for increased protected area networks, establishing wildlife migration corridors, and promoting forest management with local communities. Using recent Landsat and ASTER imagery, EROS scientists have completed a detailed map of remaining dense forest patches in Sierra Leone and southern Guinea. Against a backdrop of environmental degradation, EROS scientists also were able to document local successes within four national forests where USAID and its partners have been promoting "forest co-management," an innovative approach to forest conservation that provides local communities with increased authority to use and safeguard forest resources.

Review of 45 years of time-series imagery turned up positive results—national forests that have benefitted from forest management practices are denser and their overall integrity is better than it was 40 years ago (fig. 34). The results show the positive effects of many years of USAID and national forest service investment in forest management in Guinea. For further information, contact Gray Tappan, USGS EROS, *tappan@usgs.gov*.

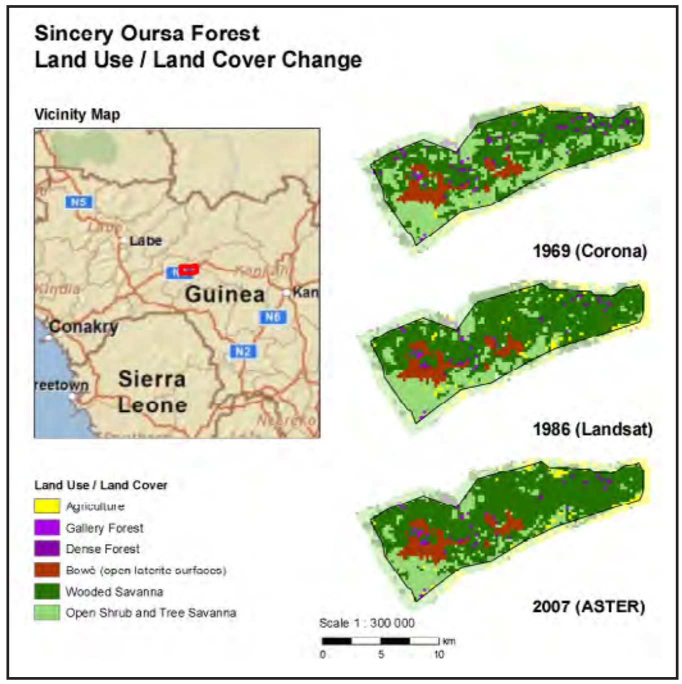


Figure 34. Land cover map of the Sincery Oursa National Forest in Guinea shows that management practices can improve the condition of forests.

Assessing Human Effects on Critical Environments in Senegal

USGS scientists have initiated a new activity that provides a unique opportunity to build upon more than 20 years of environmental monitoring work in Senegal (fig. 35). They have teamed up with Senegal's Center for Ecological Monitoring to track rapid changes in land resources in areas of high biodiversity, and in critical habitats at risk from gold mining and other pressures. The United States-Senegalese team also will work with local communities in Senegal's last remaining wilderness areas to help formulate community forest management plans that help them obtain increased income from forest products while sustaining forest resources for the long term. This 3-year effort will promote awareness among national policy makers on the effects of major human activities, especially mining and forest harvesting within the country's remaining areas of wilderness. For further information, contact Gray Tappan, USGS EROS, *tappan@usgs.gov*.

Figure 35. This aerial view shows the landscape diversity in Niokolo Koba National Park, Senegal. The biologically diverse habitats include riparian woodlands along the Gambia River, grassland and wooded savanna uplands, and a seasonal wetland. The park preserves some of the last undisturbed wildlands typical of the Sudanian Zone Ecosystem. USGS scientists are mapping the natural resources of this park in support of wildlife conservation efforts.

Lakes Along the Yukon River, Alaska, Dramatically Increase after Flood

Heavy snow fell across most of the state of Alaska during the 2008/2009 winter season and was followed by rapidly warming temperatures in late April. The dramatic increase in temperatures melted the snowpack, leading to flooding and ice jams along the Yukon River. Several villages along the river and its tributaries were damaged by the flood waters and the extraordinarily large pieces of ice carried downstream. The damage to homes and business, as well as long-established forests near the rivers, was severe. Landsat Thematic Mapper (TM) imagery acquired days after the event provided a means for assessing the location and severity of the flooding. Surface water levels identified from Landsat 1 year before the flood (May 10, 2008) were compared to surface water levels after the flood (May 13, 2009) (fig. 36). A dramatic increase was seen in the Yukon River discharge and in many lakes along the river. The changes in lake surface water area varied from large increases (+100 percent) near the river to slight decreases in lakes further from the river. Scientists speculate that the varying degrees of change in lake sizes are a result of differences in surface flows, sub-surface flows, permafrost, and the geological structure of the underlying materials. As the water recedes, additional imagery will provide new information regarding lake behavior in the YRB. For further information, contact Jennifer Rover, USGS EROS, *jrover@usgs.gov*.

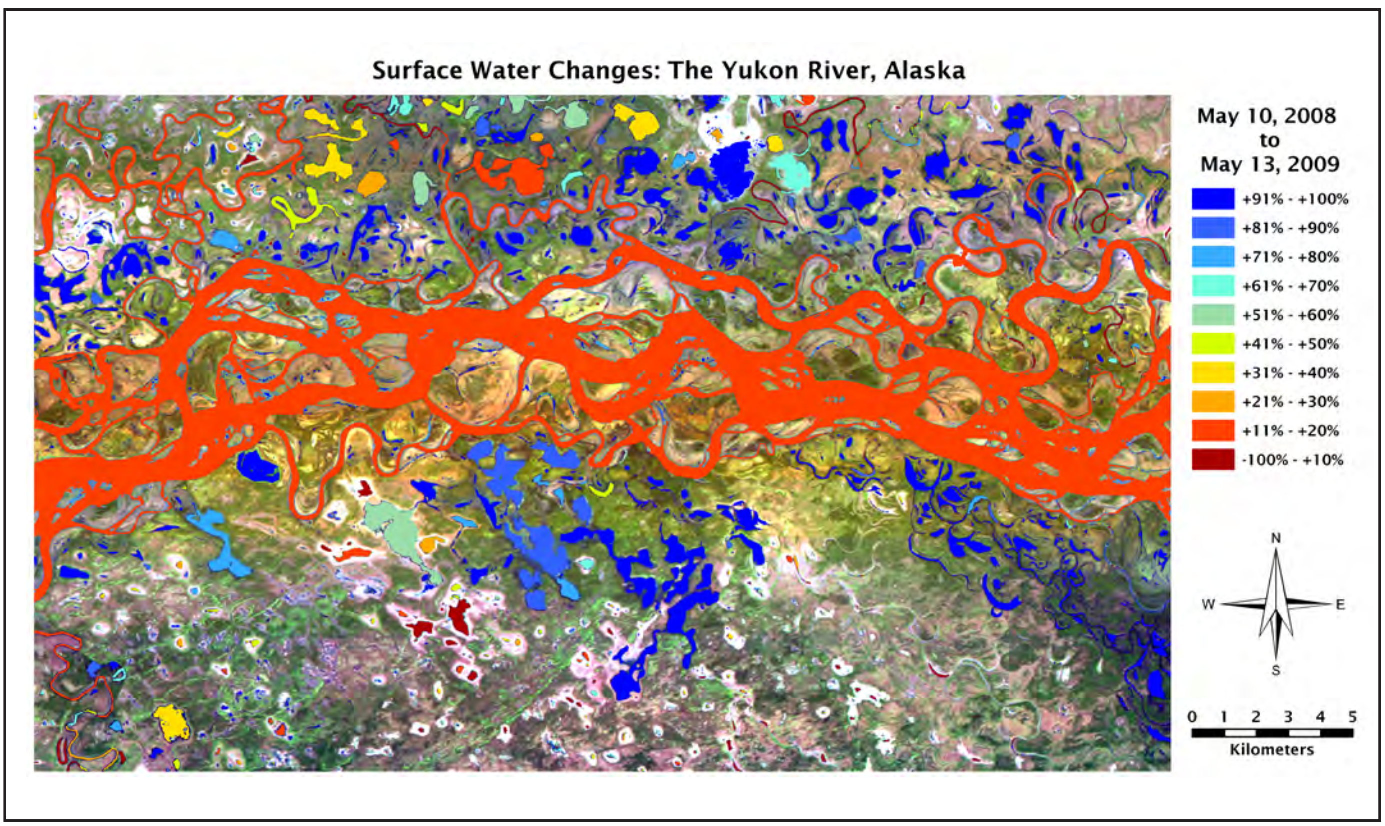


Figure 36. Surface water changes: The Yukon River, Alaska.

New Technique for Mapping Small Water Bodies

Slight changes in the amount of surface water in lakes and small wetlands can be of great ecological significance. These changes are difficult to quantify for large areas and at seasonal or yearly intervals. In the past, monitoring of large, remote areas has proved difficult with moderate resolution remotely sensed imagery such as Landsat TM because the methods required field training sites or high resolution images from the same time period. To avoid these limitations, a new technique was developed that is capable of collecting training information from the Landsat image itself (self-trained) to map small water features and changes in lake boundaries in the YRB, Alaska, which are less than the pixel resolution of Landsat (30 meter) (fig. 37). It has been determined that the new method performs as well or better than other established methods. For further information, contact Jennifer Rover, USGS EROS, *jrover@usgs.gov*.

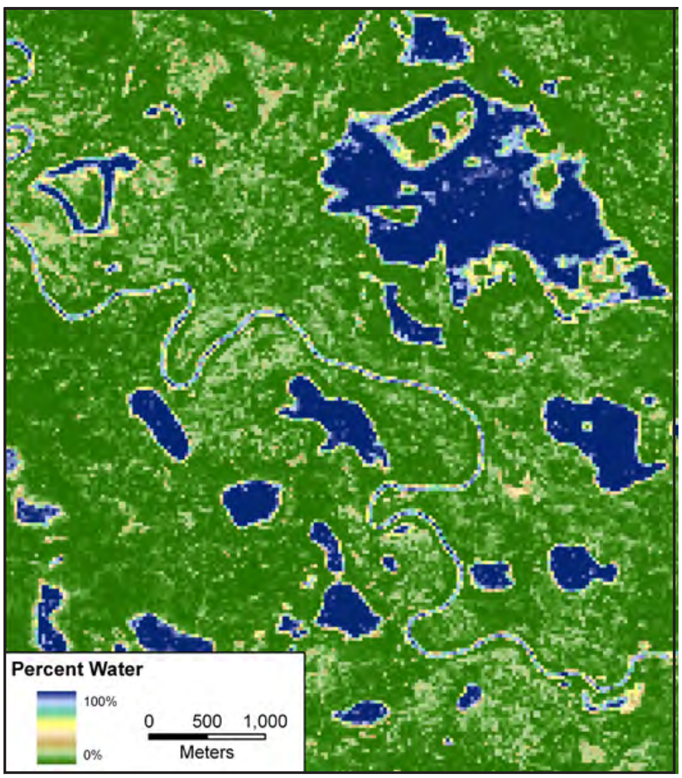


Figure 37. Example of percent surface water area estimated for each pixel in a Landsat 30-meter resolution scene.

Landsat Data Monitors Mangrove Forests Around the World

This research is the first application of multi-temporal Landsat data to assess and monitor mangrove forest dynamics of the world from 1990 to 2005. Recently available Global Land Survey (GLS) data from 1990, 2000, and 2005, are used, with state-of-the-art image processing and geo-spatial modeling tools to better characterize mangrove forest attributes and dynamics (fig. 38). The initial global documentation of the extent and characteristics of mangrove forests will be followed by change analyses and detailed assessments of environmental and socio-economic consequences of mangrove deforestation.

This global assessment and mapping of mangroves have just been completed in 2009. The refined methodology allows scientists to use large volumes of data to produce products now being field validated for quality assurance of the regional and global mosaic. The change analysis using GLS 1990 and 2005 data is underway, as are assessments of roles in coastal protection, marine ecosystem services, and carbon sequestration. Responses to climate change are being evaluated as adaptation strategies are being formulated for an anticipated substantial sea level rise during this century. Capacity building, integration, and collaboration are underway with host countries, the U.S. Virgin Islands, international organizations, and universities. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

Remote Sensing Aids Protection of Endemic Mammals in the Americas

In recent decades, increasing land use and land cover change and accelerating rates of biodiversity loss across North America have been observed, resulting in important ecosystem and societal consequences. Yet, the understanding of the characteristics and dynamics of biodiversity resources of the region is limited. Innovative research has been conducted to advance scientific knowledge and understanding of biodiversity resources and their dynamics by integrating remote sensing, GIS, and ecological and climate change models. This research builds on strengths, capabilities, and resources available at the USGS EROS Center.

Satellite data from various sensors supported the analysis that has identified priority areas for conservation in Central America. This demarcation begins to define ecosystem requirements that likely will be disrupted as climate change alters species distributions and results in new habitats. This has the potential to define new distribution areas for various ecosystems as climate change progresses and supports adaptive management plans (fig. 39). This research also integrates the work of scientists from Mexico and Canada for land cover of North America based on 7 bands of MODIS 250-meter data. This will lead to change analysis protocols suitable for Canada, Mexico, and the United States, especially important as climate change continues. The way that humans and invasive species are spreading throughout the conterminous United States also is explored. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

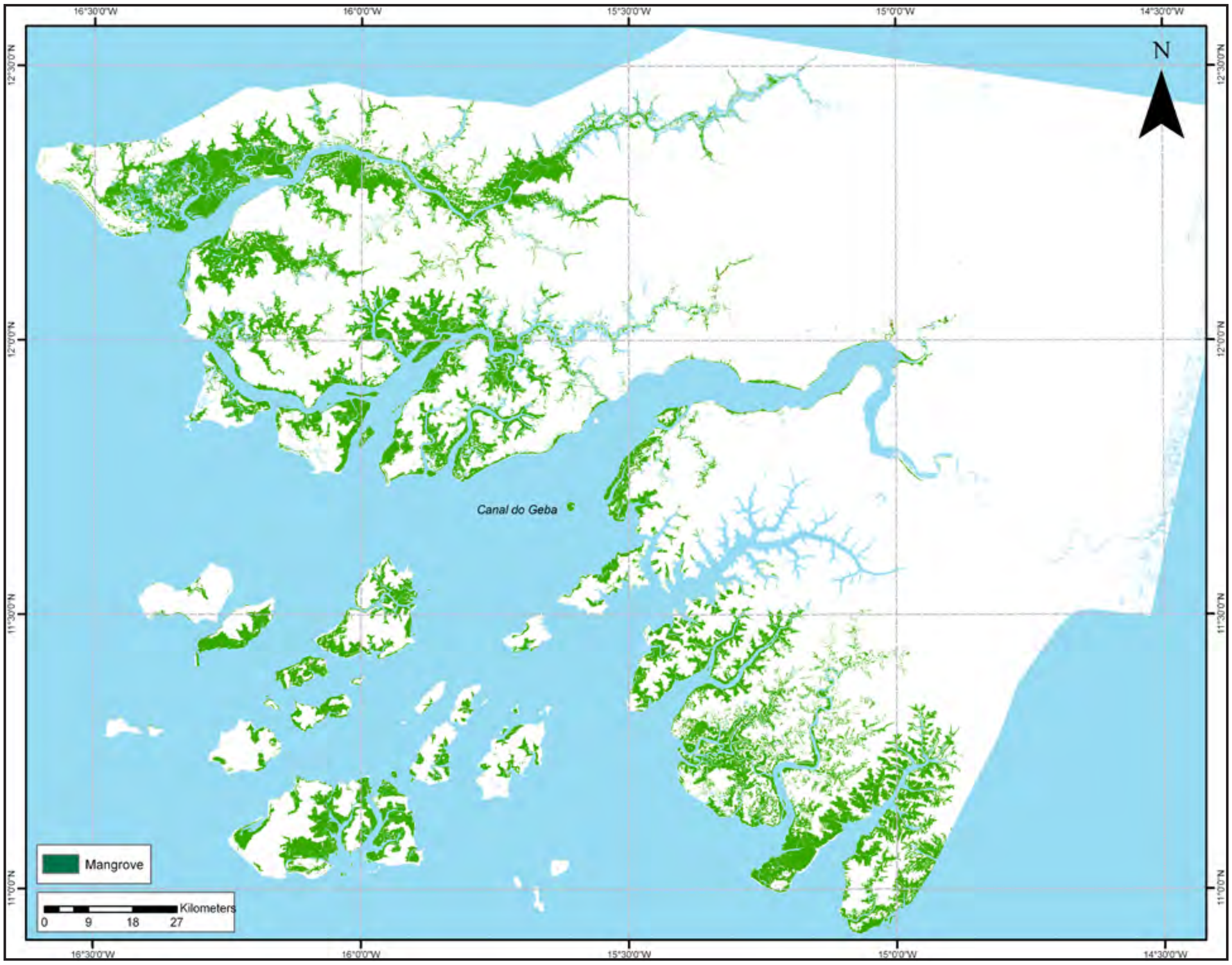


Figure 38. Example of a mangrove cover map showing the extent of mangrove forests in Guinea Bissau in 2000.

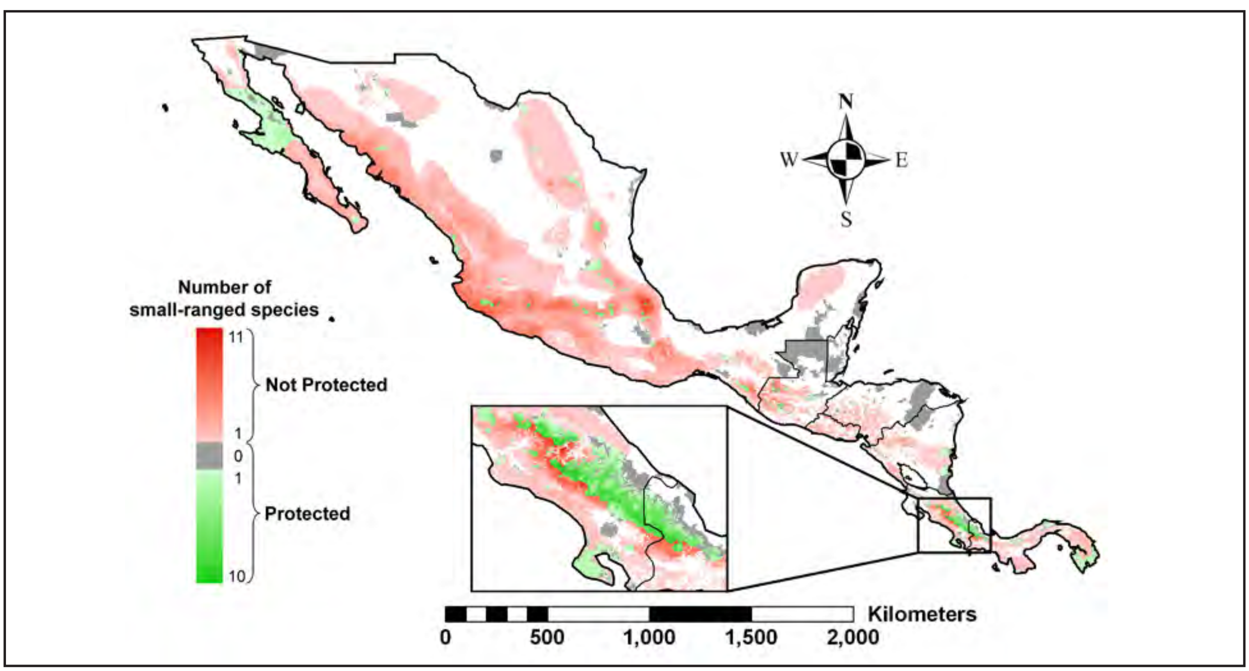


Figure 39. The extent of protected and non-protected small-ranged species, data that support the study of how land use and land cover change affect species distribution.

Innovative Tool Allows South Americans to Securely Request Geospatial Products from Restricted Data

When NASA and NGA released the Shuttle Radar Topography Mission (SRTM) 90-meter global DEM free to the public in 2003, the geospatial communities saw a paradigm shift in global elevation modeling. This shift primarily was because of the increase in spatial resolution from 1,000 to 90 meter for most of the globe. For South America, this was a tremendous boost for its countries, since most of their elevation datasets were of much coarser resolution. Since that time, South American countries have used this information extensively.

This year, the USGS cooperated with the Andean Development Bank and the Pan-American Institute of Geography and History to release a tool to enhance this information. Designed and implemented at the USGS EROS, this tool allows these countries to securely access SRTM's full 30-meter resolution DEM over the Internet to produce elevation-derived products (fig. 40). These higher resolution products will allow them to extract more detailed information to better aid them in natural disaster prevention and mitigation, natural-resource management, and local and international infrastructure development. In conjunction with the development of the tool, EROS hosted a technical workshop in June 2009 where 20 representatives from the Americas were taught how to use it. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

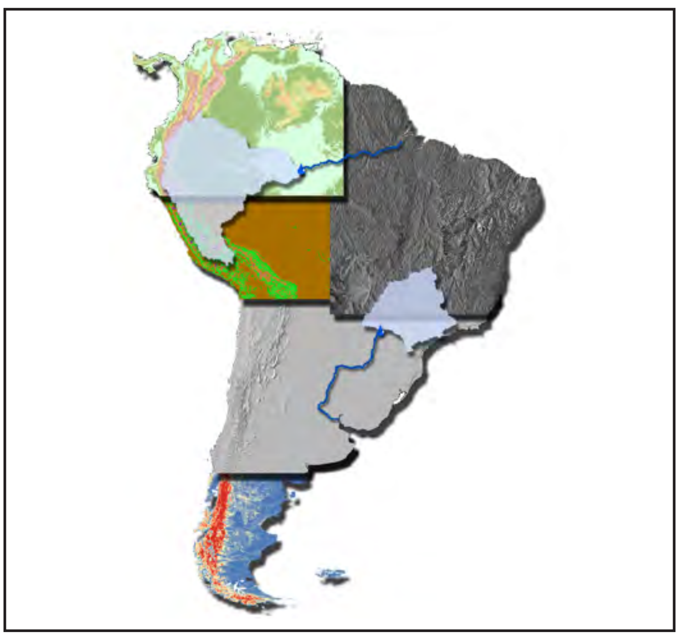


Figure 40. Examples of derivative elevation products that now are available and used extensively by South American countries.

Large Soil Carbon Stocks in Alaska are Vulnerable to Warming

New maps of soil carbon have been developed for Alaska (fig. 41), showing that about 50 billion metric tons of carbon are present in the State's soils, with large stocks present in permafrost areas. The new maps show a higher amount than previous estimates because more current data are used. The high rate of warming in permafrost areas is resulting in permafrost degradation and may cause some of this carbon to be released to the atmosphere as carbon dioxide or methane, greenhouse gases that could provide positive feedback to climate change. The rates at which this may happen are difficult to estimate and the subject of ongoing and proposed studies. If the rates of release become large, these soils will contribute to greenhouse gases in the atmosphere at higher rates than are included in some global models. Such releases cannot be effectively stopped if they are started, because the processes are not subject to changes in management or short-term policy. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

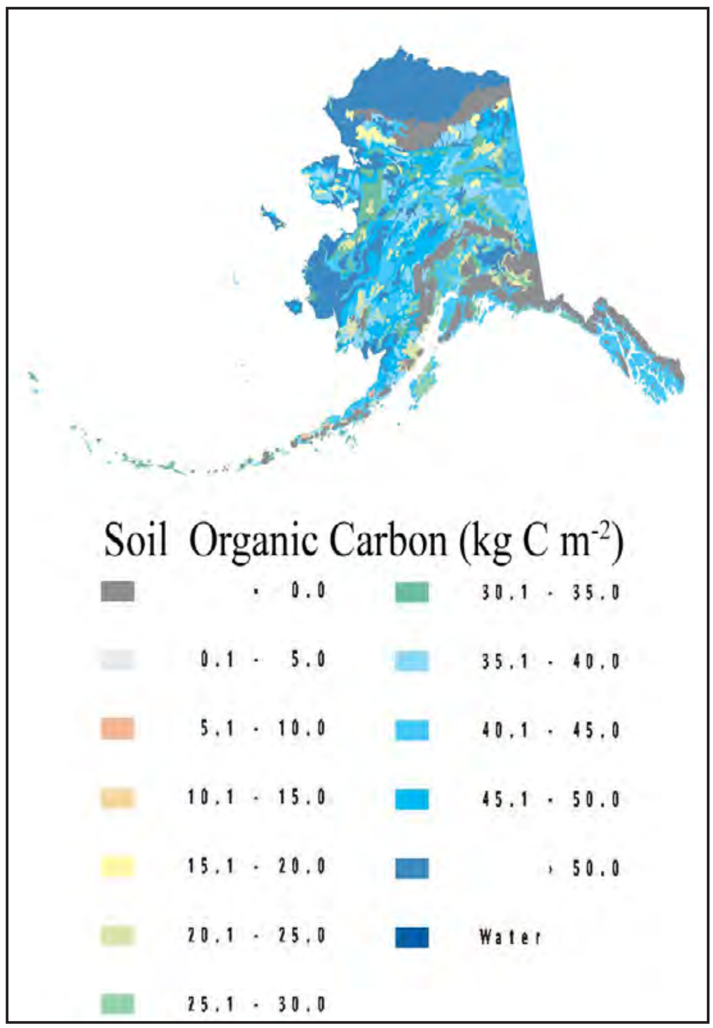


Figure 41. New map of soil carbon developed for Alaska. Dark blue areas have high soil organic carbon.

Monitoring Geospatial Web Services for GOS and GEOSS—The Service Status Checker

A new application developed by the USGS, the Service Status Checker (SSC), provides for the testing and monitoring for geospatial web services including the Open Geospatial Consortium specifications. Catalog systems such as Geospatial One-Stop (GOS) and the Global Earth Observation System of Systems (GEOSS) are utilizing the SSC system by calling the web service to provide a score for all services returned in their respective search results (fig. 42). The system tests and scores each service based upon its speed and reliability. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

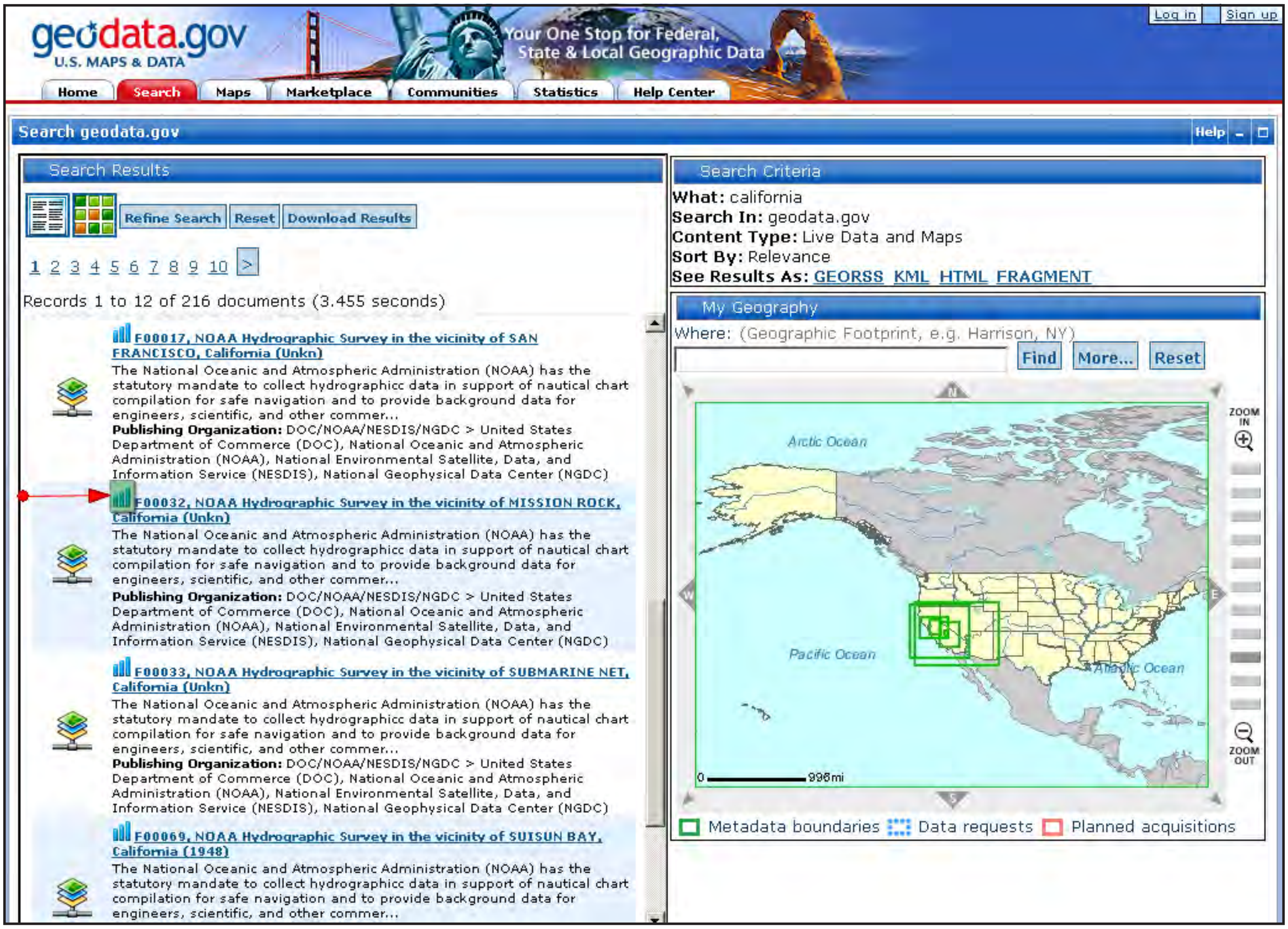


Figure 42. GOS search results display an icon (similar to a cell phone strength icon) next to its search results for live services. This icon indicates the speed and reliability of each live service and is obtained from the service status checker web service.

Specialty Coffee, Ecotourism, and Google

The USGS, in cooperation with USAID, has worked closely with Guatemala's National Coffee Association, ANACAFE, to create the tools and knowledge necessary to create an on-line knowledge and information tool to support coffee production, certification, marketing, and sustainable capacity development for Guatemala (fig. 43).

The USGS provided technical support and capacity transference in developing a set of foundation tools, such as web services and spatial maps from Google Maps and Google Earth, that can be used to provide access to a rich variety of information on coffee farms, cooperatives, mills, roasters, and associated spatial data. The system will provide assurance of conservation practices and environmental management used within the Guatemala coffee growing regions. The application is geared mainly at international coffee buyers interested in Guatemalan coffee to make the experience of searching and research for coffee an enjoyable and informative process. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

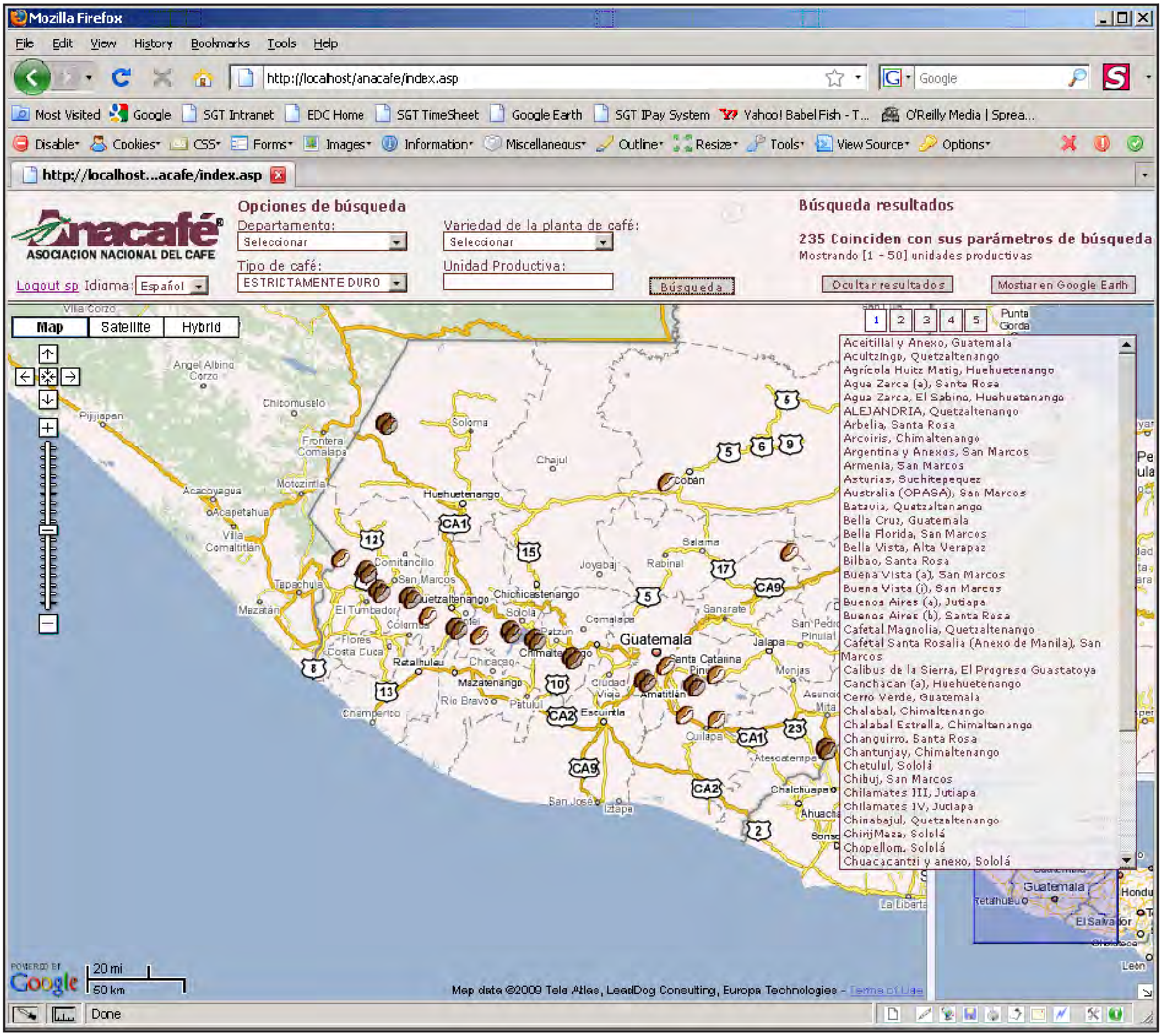


Figure 43. A sample application shows a user's coffee search and displays the results on a map of Guatemala.

How to Improve Food Security and Sequester Carbon in West Africa

Deforestation for agriculture, along with inadequate nutrients added to cultivated lands during the 20th century, have led to substantial carbon loss from many terrestrial ecosystems in African countries. That carbon loss not only contributes to climate warming, but also jeopardizes the agricultural sustainability and food security there. With the Carbon Fluxes and Land Use in West Africa project, the USGS is working on promoting economically viable natural resource management and agricultural practices that help sustain soil fertility and enhance soil carbon sequestration across West Africa. To pursue this objective, the carbon dynamics in the soil and vegetation were quantified using time-series data about land use and land cover change, historical climate variation, soil variability, and land management practices to drive a biogeochemical model.

The simulation results were validated using field observations made from representative research sites. The potential for climate mitigation through carbon sequestration within specific ecosystems was evaluated, and the responses of individual ecosystems to the projected climate change and land management scenarios in the future were predicted. Model simulations for three research sites in Ghana (fig. 44) show a significant reduction in ecosystem carbon and soil carbon stocks during the 20th century. Simulations also show that the low nitrogen fertilization rate has been the primary constraint on crop production and soil carbon accumulation. An increase in nitrogen fertilization would be a critical adaptive measure to improve food security and agricultural sustainability in Ghana during the 21st century. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

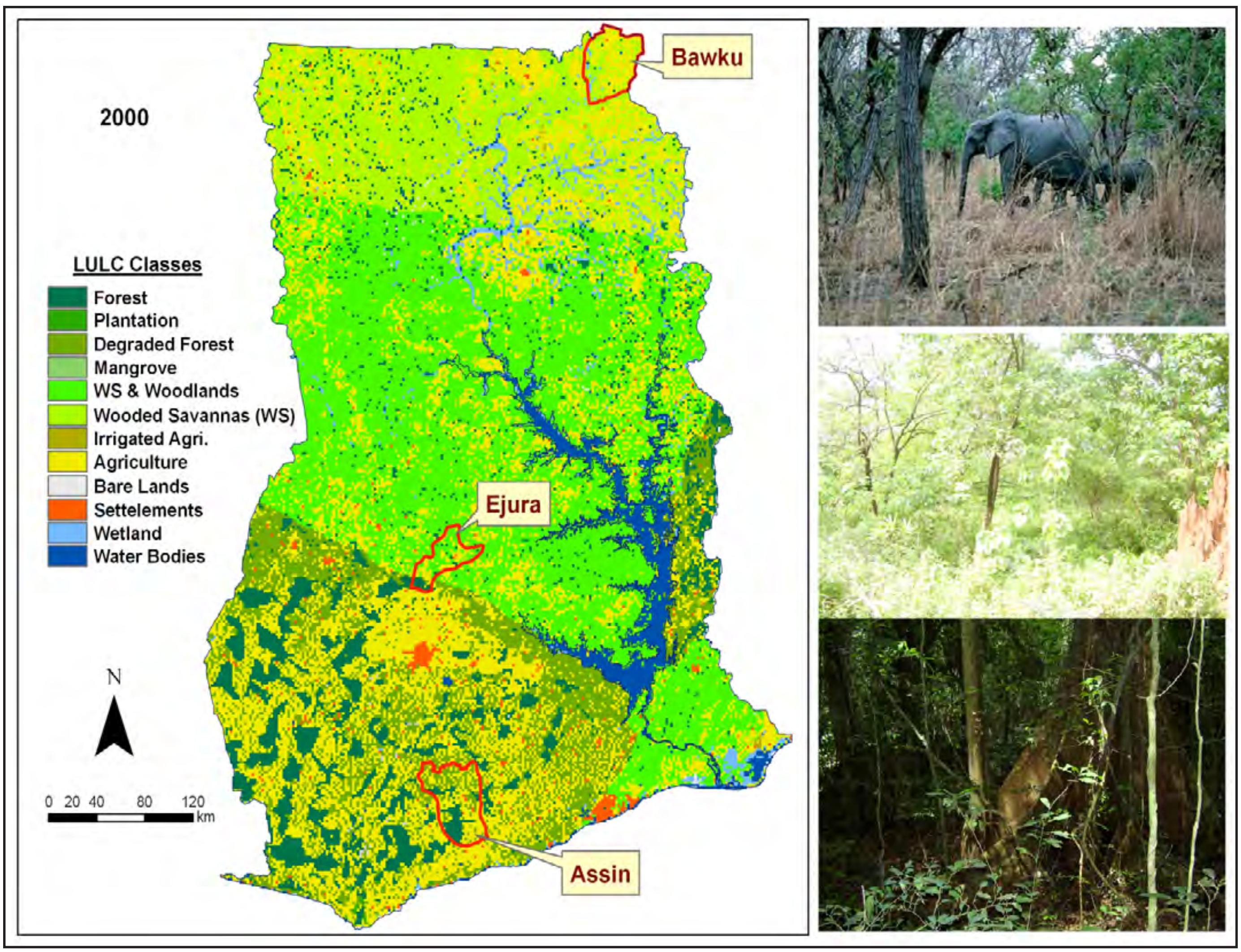


Figure 44. Land cover map of Ghana showing the locations of three study areas where soil carbon stocks were simulated.

Where Should the Cattle Graze?

Almost one-third of the United States land area is managed by DOI. Government land management practices can have a large effect on carbon sequestration and climate change mitigation efforts. Because Federal land meets about 10 percent of the feed requirements of livestock in the United States, different range management strategies could be considered to help sequester carbon. Unfortunately, no systematic research has been done on the ecosystem carbon status and trends; as a result, a good understanding of the national carbon trends and carbon sequestration potential is not available. As a case study, the Green River Basin in Wyoming, covering 43,786 km^2 and dominated by sagebrush and native grass, was selected to investigate impacts of range management and climate change on ecosystem carbon dynamics using a model called the General Ensemble Biogeochemical Modeling System (fig. 45).

Model simulations reveal the uncertainty of biomass production. Results show that grazing had a larger effect on the sagebrush system than on the grass system from 1970s through 2000, and that overgrazing could turn both systems to carbon sources. Precipitation is projected to decrease in this area in the future, which could change all systems from carbon balanced to carbon sources. One strategy to enhance soil carbon sequestration is to convert sagebrush to grassland; however, it was determined that this would work only in the first 6 to 7 years, then likely lead to losses of ecosystem carbon in the long term. These results will help policy makers make adaptive management strategy decisions on this kind of land to maintain its sustainability. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

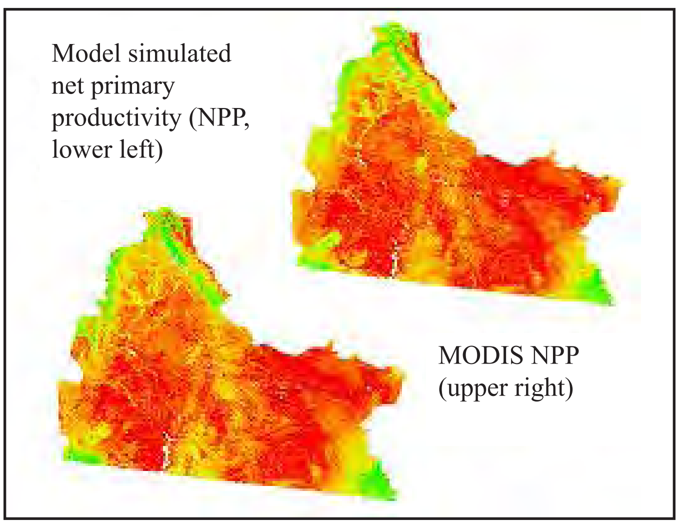


Figure 45. Model simulations in the Green River Basin, Wyoming, show net primary productivity. The colors from red to green represent the level of net primary productivity from lower to higher.

Learning About Carbon Sequestration from a Military Base

Land use activities greatly affect the regional land-atmosphere exchange of carbon. Military installations generally have substantially different land management strategies from surrounding areas, and the carbon consequences rarely have been quantified and assessed. A project at the USGS EROS Center is changing that. To evaluate the environmental consequences of military ground training and other land use activities, a model called the General Ensemble biogeochemical Modeling System was used to simulate ecosystem carbon dynamics at Fort Benning, a military training base in Georgia, from 1992 to 2050 (fig. 46).

Results indicate that the military installation sequestered more carbon than surrounding areas at present (76.7 versus 18.5 g C m-2 yr-1 from 1992 to 2007) and in the future (75.7 versus 25.6 g C m-2 yr-2 from 2008 to 2050). Fort Benning has relatively stable land cover composition with time, whereas its surrounding areas exhibit rapid urban development at the expense of forest and cropland. This carbon source and sink result, as an ecological indicator of ecosystem performance, can be used by military land managers for decision making. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

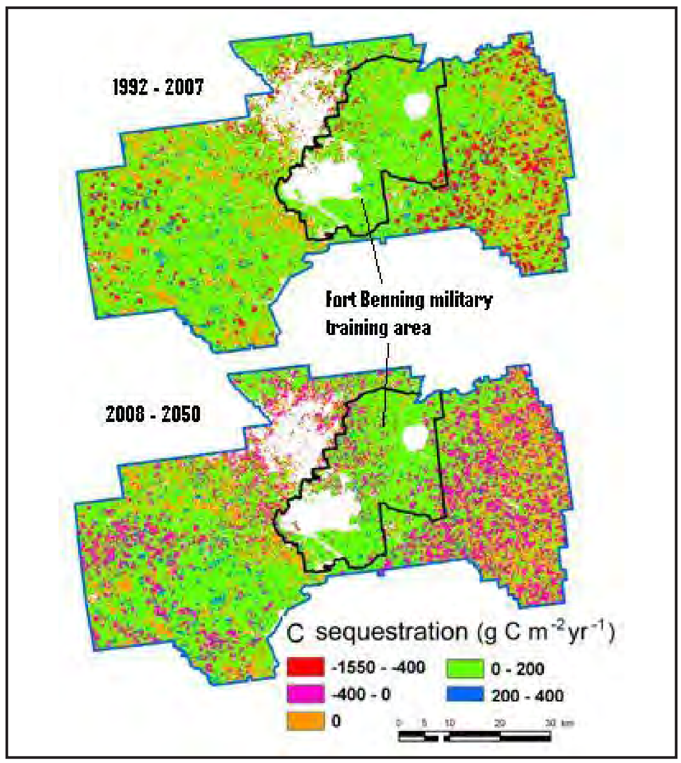


Figure 46. Carbon sequestration simulations for the Fort Benning military base in Georgia show regional carbon flux. Positive values indicate carbon sink and negative values indicate carbon source.

Is Iowa a Carbon Source or Sink?

The goal of the United States Carbon Trends Project is to quantify patterns of carbon sources and sinks in the conterminous United States from the early 1970s to 2000s. The information can help identify the primary factors that control the ecosystem carbon dynamics and balance based on validated model simulation results.

Iowa was focused on to evaluate the effects of changes in cropping systems and management practices (tillage and residue management options, drainage, and irrigation) on the carbon balance from 1972 to 2007 using the General Ensemble biogeochemical Modeling System developed at the USGS EROS. It was determined that the installation of a massive drainage system in Iowa enhanced carbon release from deep soil layers, generally making Iowa a carbon source. Management practices (conservation tillage since the mid-1980s) have slowed the total release of soil carbon from the ecosystems but could not reverse the general trend of net carbon release in the region as illustrated by figure 47, which shows the difference in carbon stocks stored in the top 100 cm of soil between 1972 and 2007. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

Prairie Potholes, Climate Change, and Greenhouse Gas Emissions

The USGS EROS Center has been collaborating with the USGS Northern Prairie Wildlife Research Center (NPWRC) to evaluate greenhouse gas emissions in the Prairie Pothole Region (fig. 48). Satellite data and field observations provided by the NPWRC were used to model the rate of soil carbon dioxide (CO_2) release and its annual and seasonal variability. Our simulations indicate that:

- Seasonal dynamics of predicted soil respiration agreed well with field measurements of soil CO_2 emissions;
- Any changes in soil CO_2 emission during the growing season mainly are controlled by changes in soil temperature and vegetation growth stage; and
- Any changes in soil CO_2 emission from different locations within the study area are dominated by soil moisture content and vegetation type.

This pilot study will contribute to the development of the national greenhouse gas emission monitoring system for all Prairie Pothole areas of the United States. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

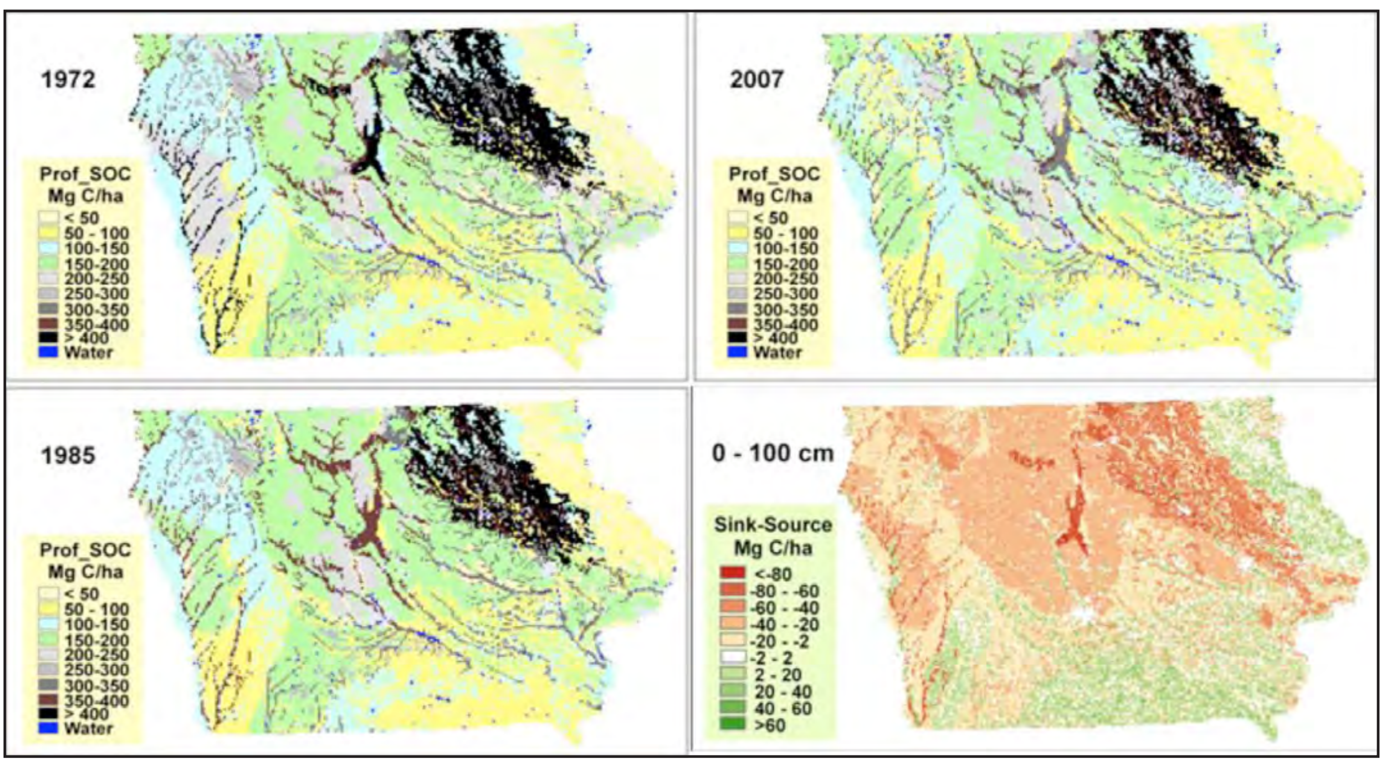


Figure 47. Carbon trend maps showing the soil carbon balance in Iowa. In the lower right graphic, the red colors mean more soil carbon loss and a larger carbon source to the atmosphere.

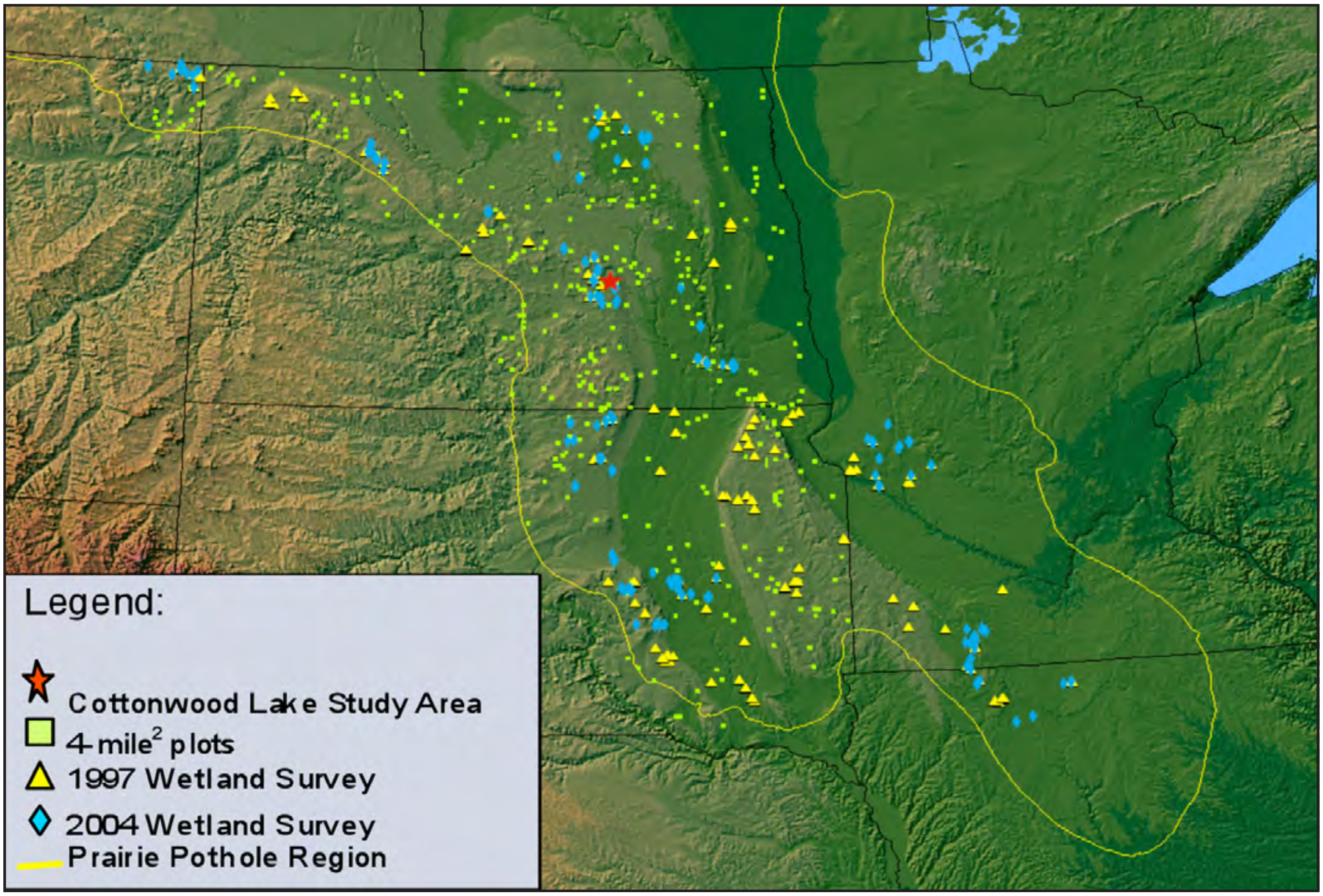


Figure 48. The Prairie Pothole Region extent and location of the study area and filed observation sites for the pilot study collaboration with the USGS Northern Prairie Wildlife Research Center.

Monitoring Climate Change in the Yukon River Basin

The Yukon River Basin (YRB) in interior Alaska, like other high latitude areas, has experienced pronounced warming and increased wildfire disturbances. The ecosystems within the YRB are vulnerable to the effects of climate warming because most of it contains permafrost that likely degrades with climate warming. These ecosystems have high carbon densities and can accelerate climate change because degraded permafrost releases carbon into the atmosphere. To evaluate the vulnerability of boreal ecosystems, the greenness index was used as one of the indicators of how these ecosystems respond to climate warming and wildfire disturbances. Our analysis of data derived from satellite imagery (NDVI) from 2000 through 2006 shows that the growing season started earlier, and the annual average and maximum vegetation index within burned areas changed dramatically before and after fires (fig. 49).

This information will be further used for model simulations of ecosystem energy, water, and greenhouse gas fluxes to predict effects of climate warming and other land surface disturbances on ecosystem services for the entire YRB. For further information, contact Larry Tieszen, USGS EROS, *tieszen@usgs.gov*.

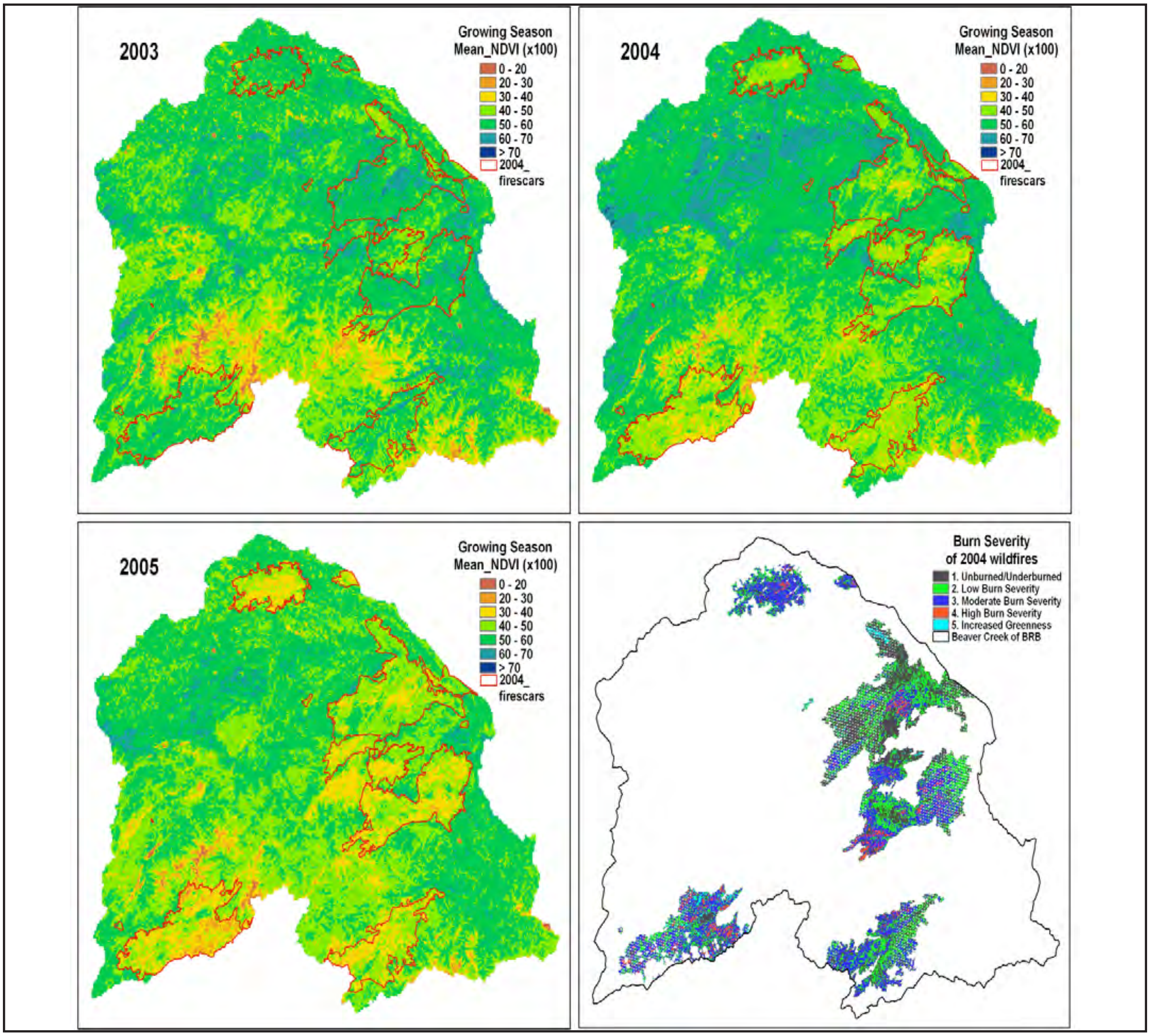


Figure 49. Graphs displayed here show a case study area, Beaver Creek of the Yukon River Basin, where wildfires caused a lower vegetation index.

Topographic Science

The Topographic Science, Elevation, and Light Detection and Ranging (Lidar) Team establishes partnerships and conducts research, technique development, dataset development, and applications focused on the study of the topographic land surface. Key accomplishments are given in the following sections.

National Atlas Support for Global Map

The National Atlas of the United States is a collaborative effort among Federal producers of geospatial data to make information about America's geography easier to find, obtain, and use by the Nation's citizens. The USGS leads the effort to maintain cartographic frameworks that are crucial to integrating data from contributing organizations. Consistent with this mission, the National Atlas is participating in Global Map, a world-wide effort by national mapping organizations to produce a consistent set of cartographic frameworks. The National Atlas has worked to produce framework datasets at 1:1,000,000 scale for data integration and product generation, and these datasets will be submitted for inclusion in Global Map.

In FY 2009, staff at the USGS Texas Water Science Center developed a semi-automated technique to derive 1:1,000,000-scale streamlines from 1:100,000-scale National Hydrography Dataset (NHD). Guided by 1:2,000,000-scale National Atlas data, scanned International Map of the World sheets, and other existing maps, the Texas Water Science Center team took advantage of NHD's network connectivity to select and generalize a stream network from the larger scale NHD data (fig. 50).

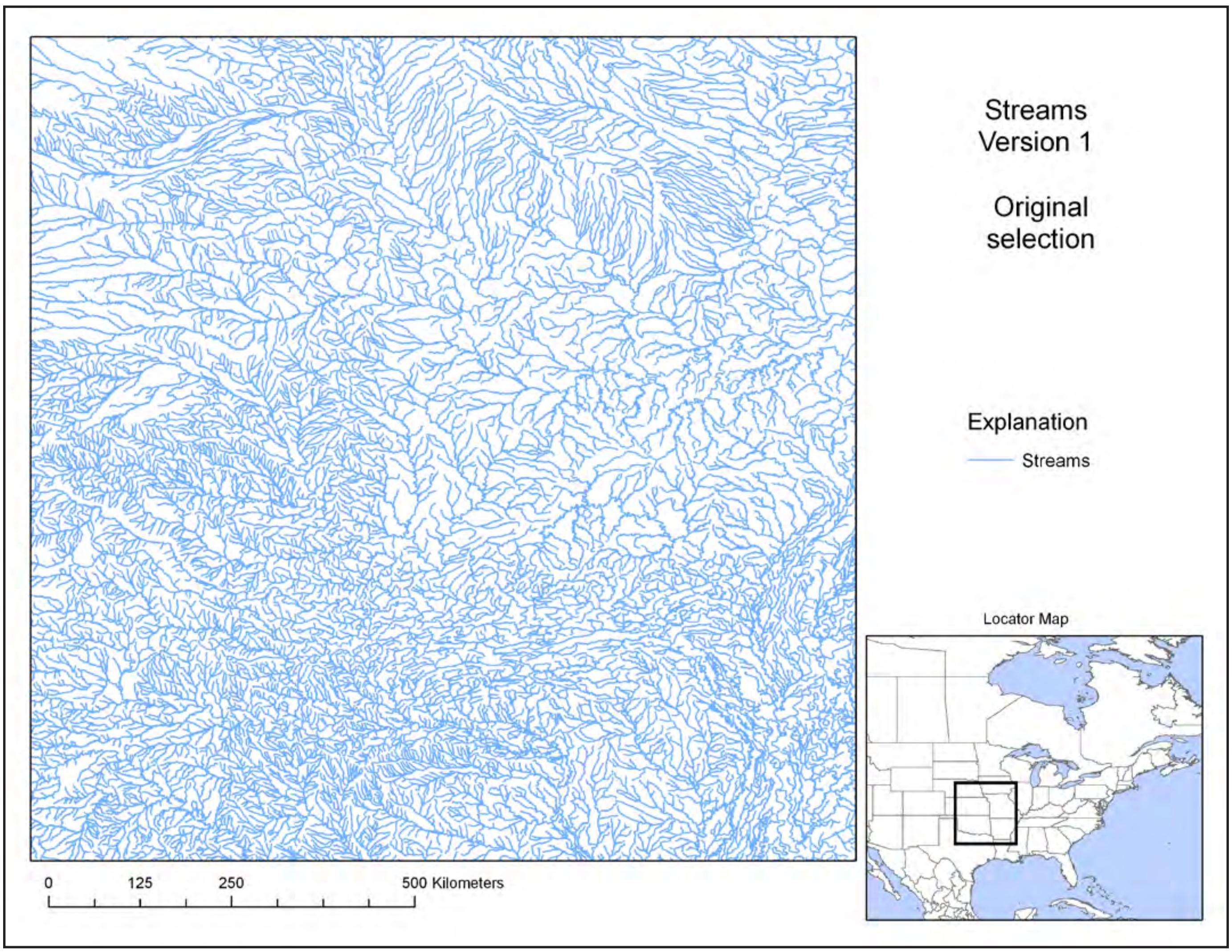


Figure 50. 1:1,000,000-scale streams before editing.

To lessen stream density differences at quadrangle boundaries, staff applied a 2-step thinning process. Step 1 was an automated density equalization routine; step 2 was a manual edit. As applied to the conterminous United States, the result was a stream network in which the discontinuities have been much reduced (fig. 51).

This dataset was then clipped to a new 1:1,000,000-scale coastline dataset (also developed by the National Atlas in FY 2009). Streamlines that extended beyond the coast were clipped, and streamlines that did not make it to the coast were extended to reach the coast to establish a defined coastline. For further information, contact John Hutchinson, USGS EROS, *hutch@usgs.gov*.

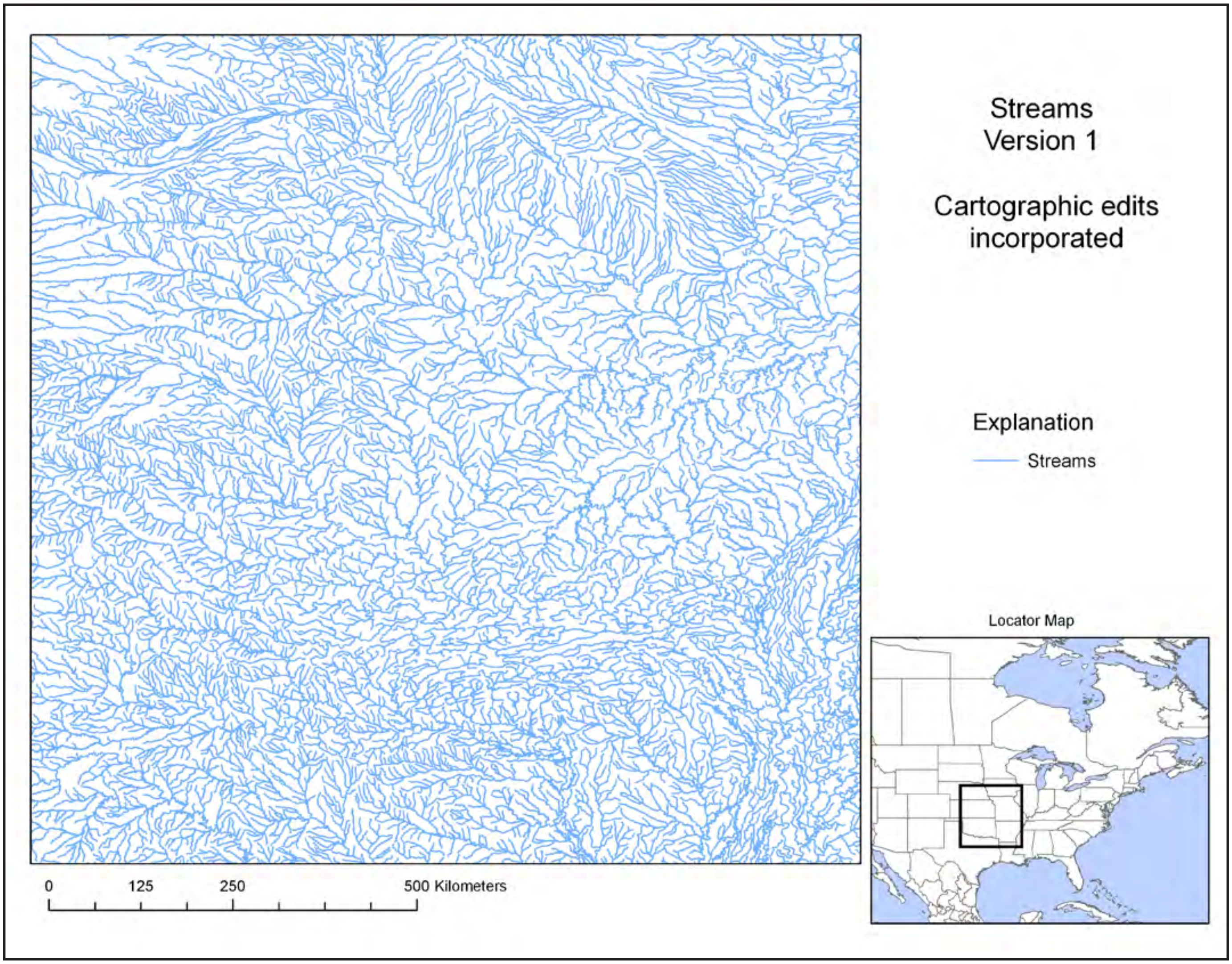


Figure 51. 1:1,000,000-scale streams after editing.

Lidar Science at USGS Covered on Prestigious Trade Journal

Lidar (light detection and ranging) is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. There has been increasing demand for research utilizing all information generated from lidar remote sensing data and not just bare earth digital elevation models (DEMs).

Lidar research and development activities at EROS were featured on the cover of Photogrammetric Engineering and Remote Sensing (PE&RS); first in September 2008 and again in January 2009 (fig. 52). The January 2009 cover, which detailed a fusion of three-dimensional lidar and imagery using traditional and novel methods, was accompanied by the February 2009 PE&RS highlight article entitled "Volumetric visualization of multiple-return LIDAR data—using voxels."

This article highlighted a revolutionary new approach for representing lidar data—using volumetric elements, or voxels, as the way to represent lidar data in three dimensions. By converting lidar data to a voxel matrix structure, users have the potential to model ecological processes in three dimensions, such as modeling surface and subsurface water movements, and fire and smoke behavior. Vegetation and urban areas may be visualized and modeled more effectively and realistically in the future using this approach. For further information, contact Jason Stoker, USGS EROS, *jstoker@usgs.gov*.

Figure 52. Lidar featured on PE&RS covers depicting Falls Park in Sioux Falls and the EROS Center: September 2008 (on the left); January 2009 (on the right).

Comparison of Surface Flow Features from Lidar-Derived Digital Elevation Models

The USGS has begun creating a valuable remote sensing product by incorporating DEMs derived from lidar into the NED, the elevation layer of "*The National Map*." High-resolution lidar-derived DEMs provide the accuracy needed to systematically quantify and fully integrate surface flow including flow direction, flow accumulation, sinks, slope, and a dense drainage network. In 2008, 1-meter resolution lidar data were acquired in Minnehaha County, South Dakota. The acquisition was a collaborative effort between Minnehaha County, the city of Sioux Falls, and the USGS EROS. With the newly acquired lidar data, USGS scientists generated high-resolution DEMs and surface flow features.

A USGS Scientific Investigations Report (fig. 53) entitled "Comparison of Surface Flow Features from Lidar-Derived Digital Elevation Models with Historical Elevation and Hydrography Data; an Analysis Performed in Minnehaha County, South Dakota," was published at *http://pubs.usgs.gov/sir/2009/5065/*. The authors, Sandra Poppenga, Bruce Worstell, Jason Stoker, and Susan Greenlee compared lidar-derived surface flow features in Minnehaha County to 30- and 10-meter elevation data previously incorporated in the NED and ancillary hydrography datasets. Surface flow features generated from lidar-derived DEMs are integrated consistently with elevation and are important in understanding surface-water movement to better detect surface-water runoff, flood inundation, and erosion. Many topographic and hydrologic applications will benefit from the increased availability of accurate, high-quality, and high-resolution surface-water data. The remotely sensed data provide topographic information and data integration capabilities needed for meeting current (2009) and future human and environmental needs. For further information, contact Sandra Poppenga, USGS EROS, *spoppenga@usgs.gov*.

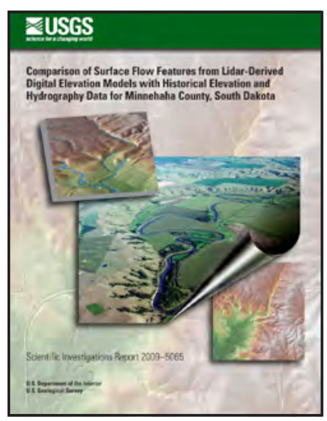


Figure 53. Cover of Scientific Investigations Report 2009–5065 "Comparison of Surface Flow Features from Lidar-Derived Digital Elevation Models with Historical Elevation and Hydrography Data; an Analysis Performed in Minnehaha County, South Dakota."

The National Elevation Dataset: Growth, Improvement, and Preparation

The National Elevation Dataset (NED) serves as the elevation layer of *The National Map*, and provides basic elevation information for Earth science studies and mapping applications in the United States. Scientists and resource managers use NED data for global change research, hydrologic modeling, resource monitoring, mapping and visualization, and many other applications. Growth, improvement, and preparation of the Dataset layers have been the accomplishments for 2009.

The NED 1/9-arc-second layer now covers 273,595 square miles and has crossed a milestone as many data areas now overlap each other. This adds a new layer of complexity for processing and evaluating the datasets. Not only is it necessary to edge-match and merge many of the datasets, it now also is necessary to develop a decision tree for determining the best available datasets. The NED 1- and 1/3-arc-second data previously used made this task relatively straightforward; however, with new technology, high-resolution datasets are being reacquired with varying processing levels, making the decision difficult. There also is a need to provide not only the best available data, as NED has in the past, but also multiple datasets for the same area in a separate collection.

The 2,570 quadrangles were updated in the NED 1- and 1/3-arc-second data layers, supporting the effort to have source data at 10 meter or finer resolution over the continental United States (fig. 54). Another major accomplishment was the international collaboration between USGS and Mexico's National Institute of Statistics and Geography (INEGI), which enlarged the NED 1-arc-second elevation dataset footprint to include the entire country of Mexico. This was done at little expense, and it was mutually beneficial to us and our international neighbor, providing our customers with an additional resource.

The NED Team continuously investigates new and better ways to provide the nation with the best available digital elevation data. The original NED paradigm was developed for a relatively small NED 1-arc-second data layer. The NED 1/9-arc-second layer currently is straining the capabilities of ArcSDE, the primary database. As a possible solution, ESRI Image Server technology was investigated in FY 2009; however, the current Image Server software needs further research and enhancements to fully support the 32-bit float data type required for elevation data and native storage in geographic coordinates required for seamless national coverage. Elevation Project personnel have documented and submitted several critical problems to ESRI. If these can be resolved, then Image Server technology can be reevaluated for NED use.

Preparations are under way for the large influx of lidar data anticipated in FY 2010–2011 because of American Recovery and Reinvestment Act (ARRA) and partnership funding for lidar-based and other new high resolution elevation datasets. To accommodate the increased data throughput, the Elevation Project has developed and tested a new information technology (IT) architecture and process to streamline

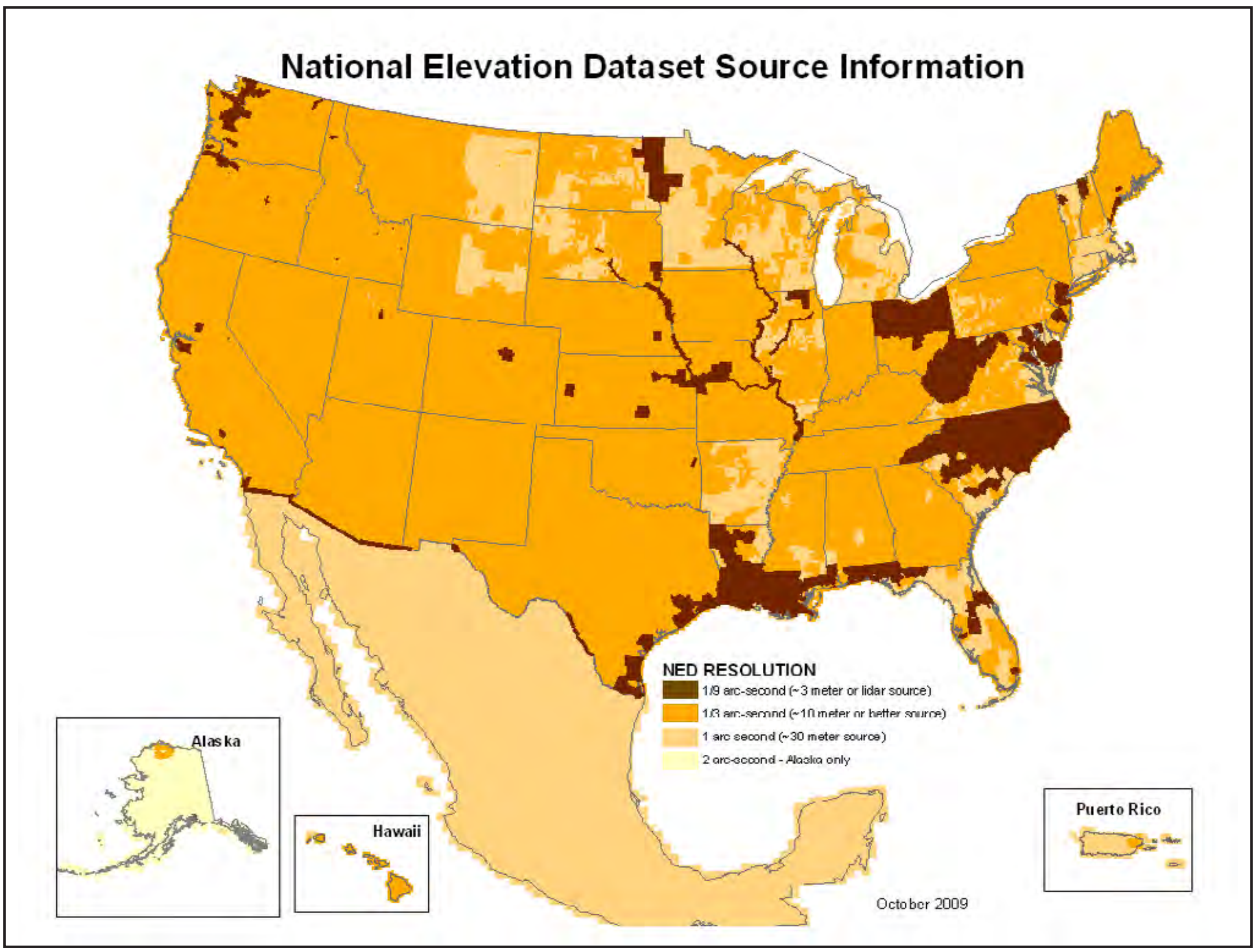


Figure 54. The image depicts the resolution of the source data used in the NED layers.

NED integration, moving from a workstation/external hard drive paradigm to a server-based model utilizing central storage. The architecture and hardware procurement has been reviewed and approved by the National Geospatial Program (NGP) IT Technical Review Board and the internal EROS IT Configuration Management Board. This activity also has been key in the NGP-wide process refinement investigation being conducted by the Business Process Re-engineering efforts.

NED personnel also have been working to assist in standardizing lidar acquisitions by developing a USGS lidar specification. This document has been through multiple iterations, combining input from a wide audience of USGS staff, industry providers, and users. In addition, the NED Fact Sheet and Frequently Asked Questions were revised, reviewed, and published to assist customer support activities. For further information, contact Gayla Evans, USGS EROS, *gevans@usgs.gov*.

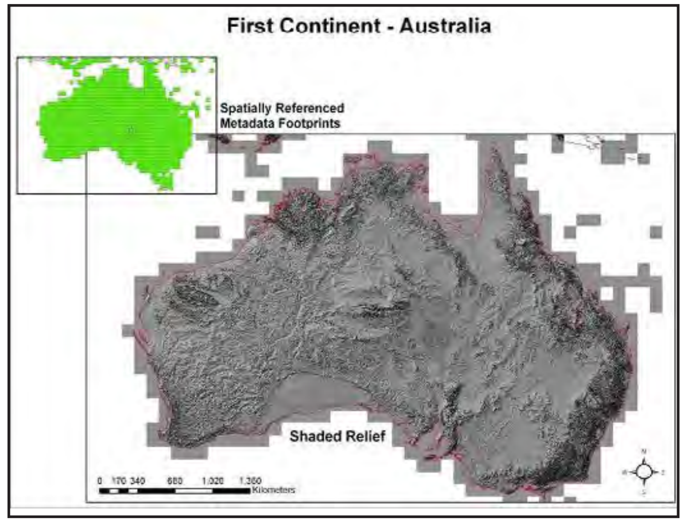


Figure 55. Australia digital elevation model—shaded relief.

The Global Elevation Replacement Project

The goal of this activity is to develop a fully global medium scale elevation model to replace and enhance GTOPO30. GTOPO30, completed in late 1996, is a global DEM with a horizontal grid spacing of 30 arc-seconds (approximately 1 kilometer). More information on GTOPO30 data is available at *http://topotools.cr.usgs.gov/*.

This new dataset will be useful in many hydrological, climatological, and geomorphological applications at the regional and global scales. The new model is being generated at three separate resolutions (horizontal post spacings) of 30 arc-seconds (1 kilometer), 15 arc-seconds (500 meter), and 7.5 arc-seconds (250 meter) from the best available higher resolution data sources. The primary data source for this project is the void-filled 1 arc-second Shuttle Radar Topography Mission (SRTM) dataset. In addition to providing a multi-resolution data structure, seven new products also are being generated at each resolution (7.5, 15, and 30 arc-seconds). The following elevation products are being produced: minimum, maximum, mean, median, standard deviation, systematic subsample, and breakline emphasis. Detailed spatially referenced metadata are being produced for all the datasets that constitute the global elevation model.

Project accomplishments in FY 2009 included the completion of the Australia (fig. 55) and South America (fig. 56) continental datasets with products delivered to the funding organization, National Geospatial-Intelligence Agency (NGA), for final acceptance. Furthermore, void-filling and generalization of the 1arc-second SRTM has been completed for Africa. Currently for Eurasia, 4,482 out of 5,259 1-degree tiles of 1 arc-second SRTM void-filled data have been processed through the global generalization workflow. At present for North America, 1,082 out of 2,356 1-degree tiles of 1 arc-second SRTM void-filled data have been processed. Project status reports are delivered to NGA monthly. For further information, contact Jeffrey Danielson, USGS EROS, *daniels@usgs.gov*.

Figure 56. South America digital elevation model—shaded relief.

Improved Mapping of Sea-Level Rise Impact Zones

The importance of sea-level rise in shaping coastal landscapes is well recognized within the Earth science community, but as with many natural hazards, communicating the risks associated with sea-level rise remains a challenge. This project uses high quality elevation data to identify and delineate lands that are vulnerable to inundation from sea-level rise in the next century. The analysis includes a rigorous treatment of the uncertainty of the elevation data and its effects on the delineations of potential inundation zones. Project accomplishments in FY 2009 include a chapter titled "Coastal Elevations" in the interagency U.S. Climate Change Science Program's report "Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region" (fig. 57). For further information, contact Dean Gesch, USGS EROS, *gesch@usgs.gov*.

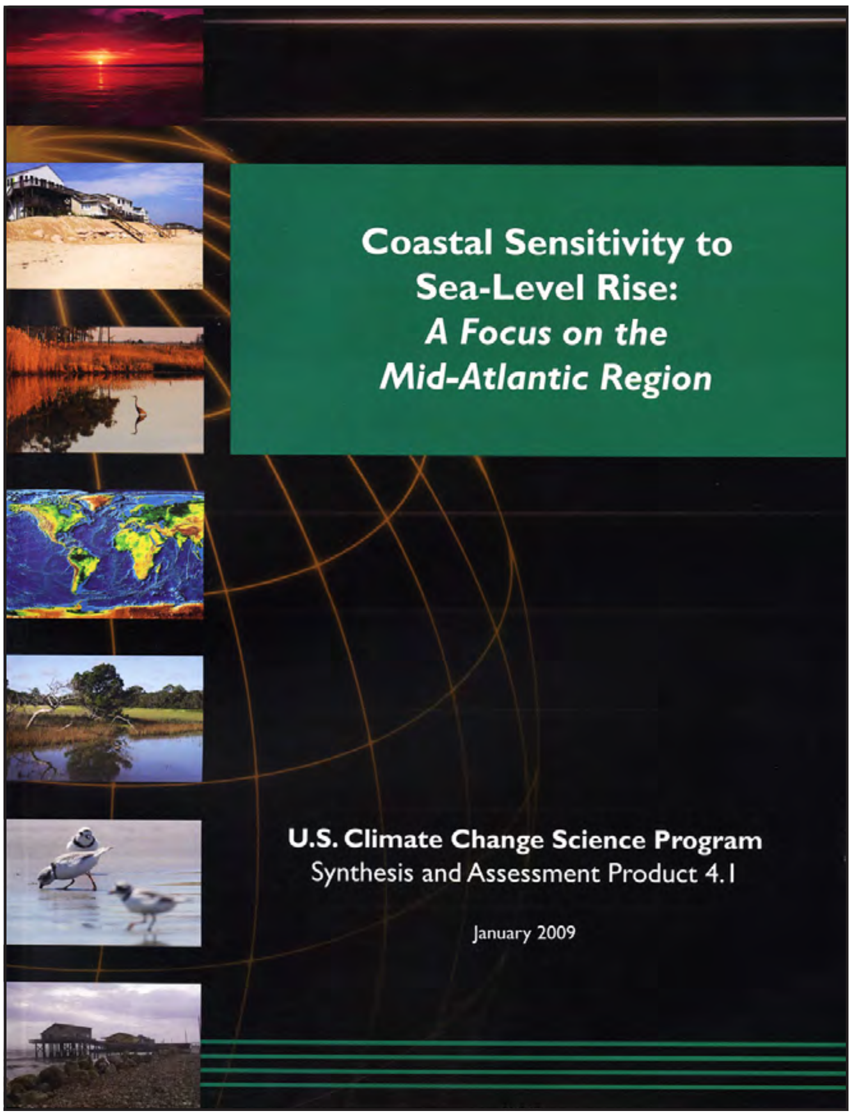


Figure 57. Results reported in a Journal of Coastal Research paper and in the Climate Change Science Program report were included in the recent National Research Council report titled "Mapping the Zone: Improving Flood Map Accuracy."

Remote Sensing Activities

The USGS EROS Center's remote sensing activities are framed around excellence in science, data management, infrastructure, and facilities devoted to evaluation and assessment of land changes and their impact on society. Core to the EROS mission is the continuity of remote sensing of the Earth's land surfaces at all scales to ensure availability of historical and current observations. Although EROS is perhaps best known as the USGS receiving station for Landsat satellite images, data from many other satellites and other remote sensing platforms also are archived and distributed by EROS. Receiving, calibrating and validating, processing, archiving, and distributing these data are primary tasks performed at EROS. In addition, EROS is defining requirements and specifications for future instruments, developing and implementing ground systems for future Earth observing missions, and developing national and international partnerships.

Landsat Program

The Landsat Program is a joint effort of the USGS and NASA to gather Earth resource data using a series of land observing satellites. Whereas NASA's role is the development and launch of Earth observing instruments and spacecrafts, the USGS is responsible for flight operations, maintenance, and management of all ground data reception, processing, archiving, product generation, and distribution. A primary objective of the Landsat Program is to ensure a collection of consistently calibrated Earth imagery.

Today, the Landsat Project at EROS manages two active satellites—Landsat 5 and Landsat 7—and the entire historic archive of data collected since 1972—more than 2.4 million images. In FY 2009, a change in data policy (no charge, web enabled data) transformed the distribution of Landsat data for scientists and operational users worldwide; and as a result, more than 1.1 million Landsat images were delivered to customers! In FY 2009, the Landsat Project also reached milestones with both satellites. Landsat 5 celebrated 25 years in orbit, and Landsat 7 reached 10 years in orbit. With the respective design life of 3 years and 5 years, both of these satellites continue to provide essential data to scientists well beyond their expected lifespan. The Landsat team continually is working to extend the longevity of the satellites in orbit, enhance Landsat data quality, improve systems at EROS used to archive, process, and access Landsat data, and is leading the design and development of the ground system for the Landsat Data Continuity Mission.

Beaufort County, North Carolina
Modeling Flood Inundation: Sea-Level Rises 1 meter
Explanation: Darker blue tint: Inundated land if sea level rose 1 meter
Lighter blue tint: Area of uncertain inundation if sea level rose 1 meter

Figure 58. Calculated using 30-meter DEM.

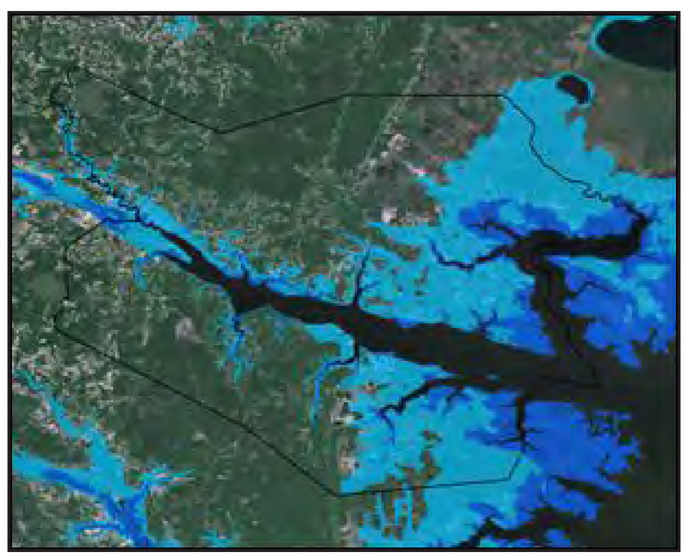


Figure 59. Calculated using 3-meter lidar data.

Landsat 5 Celebrates 25 Years in Orbit—8 Times Longer than Expected!

Outliving its expected 3-year lifespan by more than 22 years, on March 1, 2009, Landsat 5 completed a busy quarter-century of collecting information about and observations of the planet Earth's land mass and is still functioning. It has proven to be a remarkable workhorse for global Earth observations. The catalog of more than 700,000 Landsat 5 images is a 'photo album' of major landscape scale events and changes in the Earth's history of the past 25 years (fig. 60).

"The success of Landsat is a tribute to the engineering and dedication by the men and women in the Landsat Program. . ." said Dr. Bruce Quirk, manager of the USGS's Land Remote Sensing Program, the oversight program for the Landsat mission. "The global science community has come to rely on Landsat 5 data for studies of anthropogenic and natural changes to the Earth's surface."

Landsat 5 was launched on March 1, 1984, at Vandenberg Air Force Base in California. Construction and launch was the responsibility of NASA. Operation of the satellite and distribution of the data is the responsibility of the USGS. It was designed to provide data compatible with the previous Landsat satellites, a series of spacecraft begun in 1972. Landsat 5 was constructed with extra fuel systems so it could be brought down to a lower orbit for potential repair by the Space Shuttle vehicles. Although engineering issues made that option unrealistic, part of the success of the Landsat 5 longevity is based on that extra fuel reserve. The fuel has been used to stabilize the orbit well past normal design life.

"When anthropogenic and natural events occur, Landsat 5 has recorded them..." said Kristi Kline, Landsat program manager at the USGS' EROS Center in Sioux Falls, South Dakota. From Chernobyl, the drying of Asia's Aral Sea, Red River flooding in North Dakota, and the effects of Hurricane Katrina, Landsat 5 was collecting observations and data that scientists, emergency response leaders, and Government officials have found invaluable.

Even though Landsat 5 has had a normal collection of problems for an orbiting satellite over the years, mostly dealing with the electrical circuits affecting the sensor, engineers are predicting Landsat 5 may continue to operate until 2012 when its successor, the Landsat Data Continuity Mission, is launched. In the meantime, every 99 minutes this 'workhorse' of a satellite makes another of its 130,000+ revolutions around the planet, observing and relaying data about the ever changing surface of the planet. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

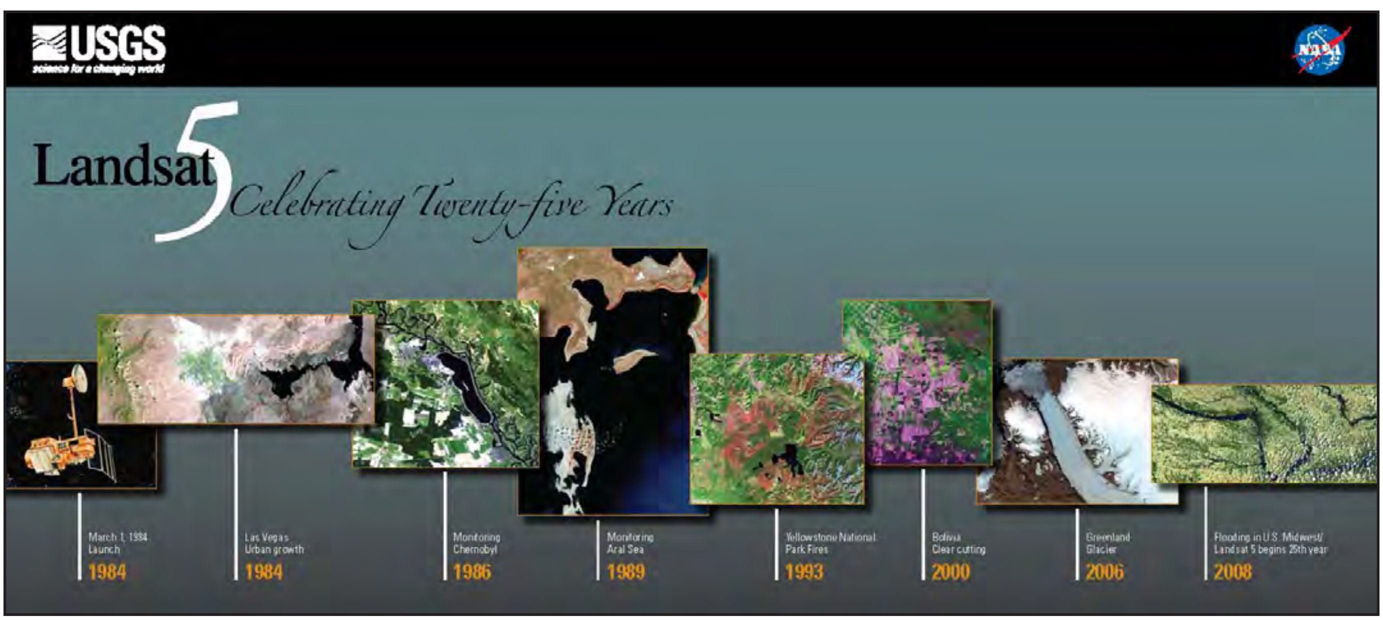


Figure 60. Landsat 5 celebrating 25 years.

Landsat Delivers More Than 1 Million Images!

> "The opening of the Landsat archive to free, web-based access is like giving a library card for the world's best library of Earth conditions to everyone in the world."—Adam Gerrand, Food and Agriculture Organization of the United Nations

Since October 2008, 1 million Landsat scenes have been downloaded at no charge from the USGS by users from around the world (fig. 61) . This 1 million scene distribution represents a $500 million USGS contribution to the global user community.

Figure 61. Data delivery increases into FY 2009.

Landsat 1 was launched on July 23, 1972. Subsequent Landsat missions continually have acquired data from around the globe. Scientists, educators, and the public have used these data for a wide-ranging array of activities from disaster relief efforts to setting cell phone towers.

The USGS previously charged nominal fees for Landsat data, but this proved to be a barrier to the use of the 37-year archive of more than 2.4 million images. A recent USGS policy change enabled Landsat data to be distributed at no charge via the internet. Before the policy change, the highest year of distribution was in FY 2001, when approximately 25,000 scenes were delivered. New web-based technology has made Earth observation data easily accessible to all interested people. Free Landsat data will enable richer and more complex research, as well as further encourage new communities to explore uses for these data.

More Landsat data have been processed and distributed this year than in the history of the Landsat mission combined. Particularly exciting is that the oldest data in the archive, from more than 30 years ago, are being downloaded at unprecedented levels.

Each Landsat image covers more than 12,000 square miles. There are approximately 57.5 million square miles of land mass on Earth. One million Landsat scenes represent more than 12 billion square miles, which would cover the Earth's landmasses 212 times! For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

Global Land Survey 2005: The First-Ever Global Dataset Built with Data from Multiple Sensors

The USGS and NASA collaborated on the creation of several global land datasets derived from Landsat images: one from the 1970s, and one each from circa 1990 and 2000. Each global dataset was created from the primary Landsat sensor in use at the time: Multispectral Scanner (MSS) in the 1970s, Thematic Mapper (TM) in 1990, and Enhanced Thematic Mapper Plus (ETM+) in 2000.

To extend this multi-decadal Landsat data collection, NASA and the USGS again partnered to develop the Global Land Survey 2005 (GLS 2005), a new global land dataset with core acquisition dates from 2005–2006. The data consist of Landsat TM and ETM+ and Earth Observer 1 (EO-1) data, making GLS 2005 the first-ever global dataset built with data from multiple sensors (fig. 62). The entire dataset is nearing completion with more than 95 percent currently (2009) available for free download. Plans to collaborate on the GLS 2010 are in the works and expected to begin in late 2009.

Although Landsat 7 ETM+ data can be acquired around the globe, stored on the spacecraft, and downlinked at USGS EROS, Landsat 5 TM data must be downlinked in real time to a local ground station, and cannot be stored for downlink at USGS EROS. To obtain Landsat 5 TM images for areas outside the United States, the USGS negotiated agreements with international ground stations to downlink and send data to USGS EROS. These agreements made thousands of additional Landsat 5 TM scenes available for GLS 2005 consideration.

The USGS Landsat Ground Station archives nearly 100,000 new Landsat 7 ETM+ images every year. These images are a record of nearly all of the land area on Earth. ETM+ scenes have a 22 percent data loss because of the Scan-Line Corrector failure in 2003. This requires combining two ETM+ scenes for each path/row to have complete, or near-complete, coverage.

Data recorded in 2004 and 2007 will be used as needed to fill areas of low image quality or excessive cloud cover. The EO-1 instrument completed global coverage by collecting image data of small remote islands. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

Landsat Satellites Overcome Technical Problems

The Landsat Project at EROS currently (2009) manages operations for two satellites, Landsat 5 and Landsat 7. Given the age of these missions, 25 and 10 years respectively, technical problems commonly are encountered. In FY 2009, the flight operations teams maintained the missions and improved capability of the aging satellites.

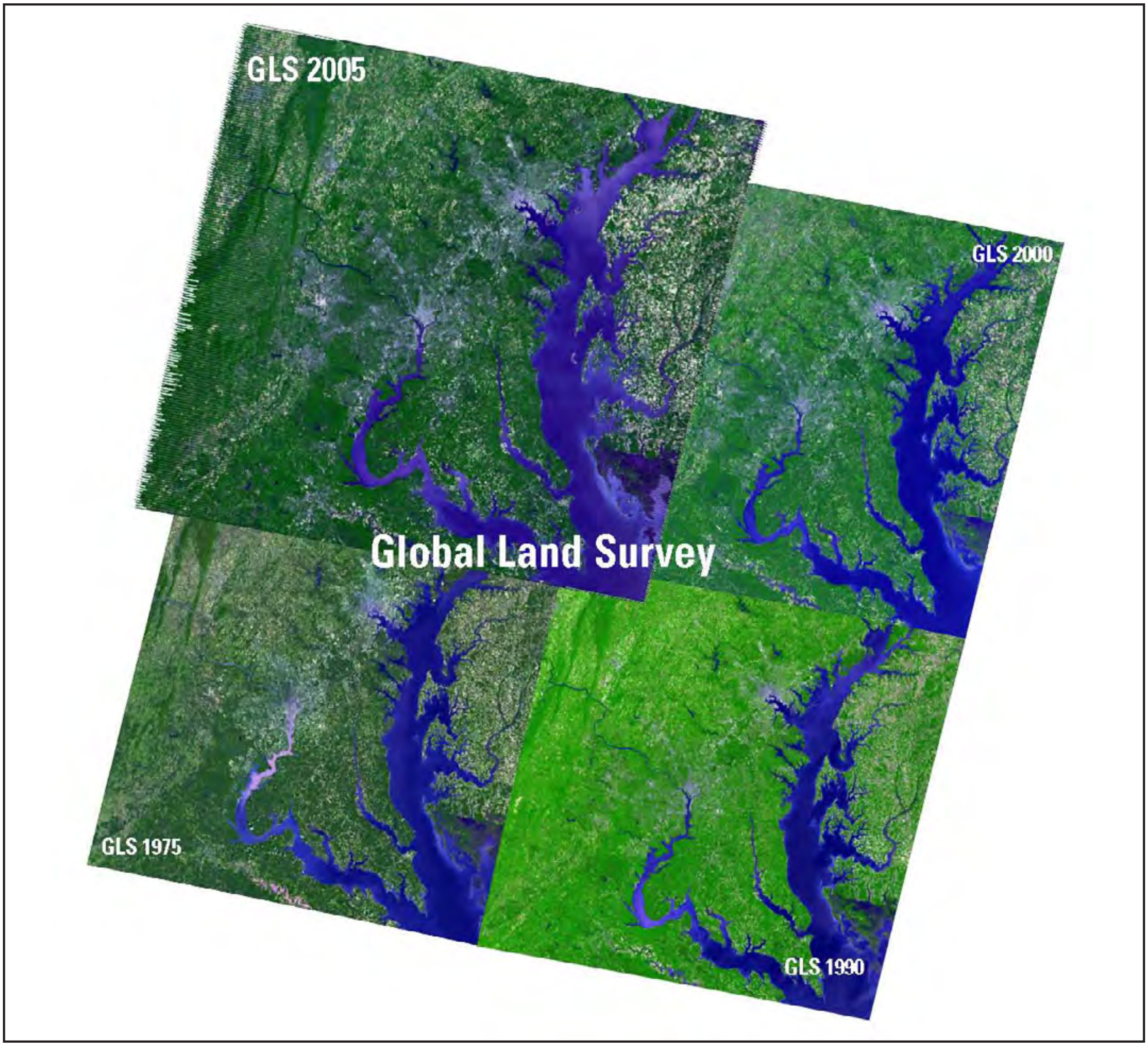


Figure 62. Global Land Survey 2005 completed.

Both missions successfully completed delta-inclination maneuvers. These maneuvers take considerable planning and execution. Changing the satellite inclination, or change of orientation of the orbital plane, requires significant propellant usage. These maneuvers are essential to maintain the proper orbit of the spacecraft in reference to the Earth.

Because of previous problems with one of the Landsat 5 batteries used to maintain power on the spacecraft, power limitations was causing decreased data coverage to several ground stations. In FY 2009, the flight operations team successfully changed operations procedures to maintain battery power that allowed for increased data coverage. More than 3,600 images were added to the schedule, allowing for greater global coverage.

Landsat 5 experienced an anomaly in the early morning hours of August 13, 2009. The attitude anomaly was characterized by extreme gyro rates. The spacecraft proceeded to tumble out of control for some time until the flight operations team was able to stabilize the satellite attitude (positioning). Power to the batteries reached a critical state before spacecraft stabilization, and imaging was suspended for approximately 36 hours. Since the anomaly, the team changed one of the primary gyroscopes that could have contributed to the issue. Additionally, the team initiated additional telemetry contacts with the spacecraft to help monitor the on-board systems, and staffed the mission operations center to 24 hours per day. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

Landsat Archive at EROS Increases by Almost 180,000 Images

In FY 2009, the Landsat Ground Station collected nearly 180,000 new Landsat images into the archive at EROS. More than 74,000 of these images were collected with antennas at EROS with a nearly perfect capture success rate. Only 4 images were lost because of operator error or technical issues resulting in a capture success rate of 99.99 percent!

The Landsat 7 satellite is capable of collecting data globally through the use of an on-board data recorder (fig. 63). Landsat 5, launched in 1984, did not include this newer technology. To collect data globally, ground stations must exist in the area of interest. In FY 2009, the Landsat Project collected Landsat 5 data through several campaign ground stations. Through an on-going partnership with USGS EROS, NOAA/National Environmental Satellite, Data, and Information Service (NESDIS) Fairbanks Command and Data Acquisition Station, and University of Alaska Geographic Information Network of Alaska, more than 6,000 Landsat 5 images were added to the USGS archive and made available to users. More than 23,600 additional images were collected at other campaign stations around the world and added to the archive.

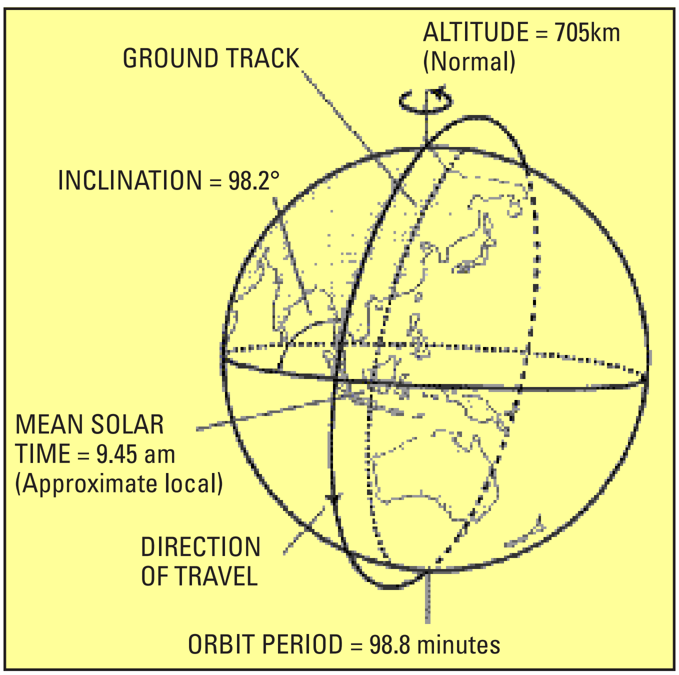


Figure 63. Diagram of Landsat 7 satellite orbit.

The Landsat Project initiated an effort to retrieve previously unavailable Landsat 1-3 MSS data. During an archive transcription of data several years ago, missing satellite information data tapes required for processing data resulted in "orphan" MSS images (fig. 64). These images include the actual pixels of data recorded by the instrument, but not the spacecraft telemetry that feeds the processing system geometric information and other metadata necessary for processing. More than100,000 MSS images not in the Landsat archive could potentially be rescued as part of this effort. Development of processes and software currently (2009) is underway that will recreate the missing satellite information necessary for archive and processing of the missing MSS data. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

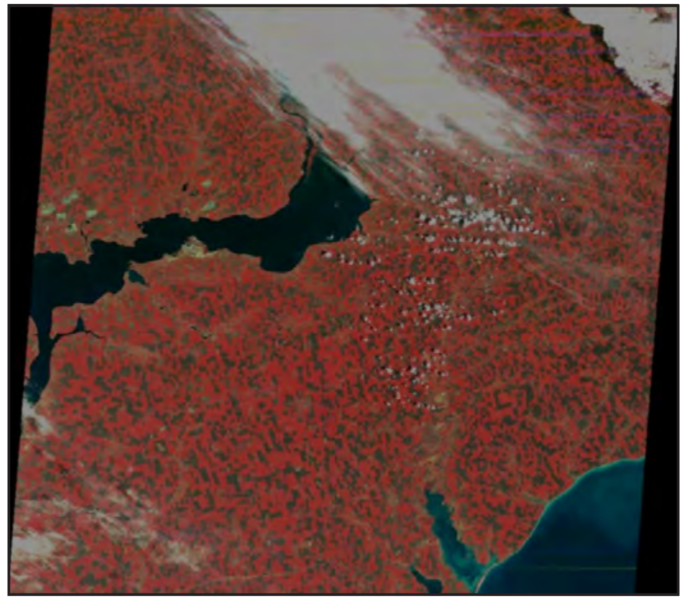


Figure 64. Example of "orphan" MSS image over the Ukraine rescued during testing.

Landsat Improves Data Quality

The Landsat series began with the first satellite launched in 1972. Since that time, technology radically has changed for the satellite and instruments as well as information technology used to store, process, and distribute data. During the 35+ year history of the Landsat Program, these technology changes have resulted in disparate data products from the various satellites. In FY 2009, the Landsat Project at EROS has made improvements that help bring the older data up to more current (2009) standards. New product algorithms and calibration techniques are in place for much of the archive. The Landsat team began migration of the oldest data algorithms to a newer processing system. Additionally, improvement to data quality and calibration are underway for much of the older data in the archive.

With the new processing system, older data that require significant operator intervention to create geometrically accurate products will be processed automatically. A refined approach to orthorectification (correct for geometric and terrain displacement) using a Gaussian pyramid, a hierarchical image matching approach will automate the process and improve geometric accuracy (fig. 65). Currently (2009), the Landsat team has proven this method with prototype algorithms that are able to correct test images with geometric displacement of up to 12 kilometers. In addition to the geometric algorithm changes, improvements to the radiometric calibration also are incorporated in the upcoming migration. Users will see these improvements in FY 2010. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

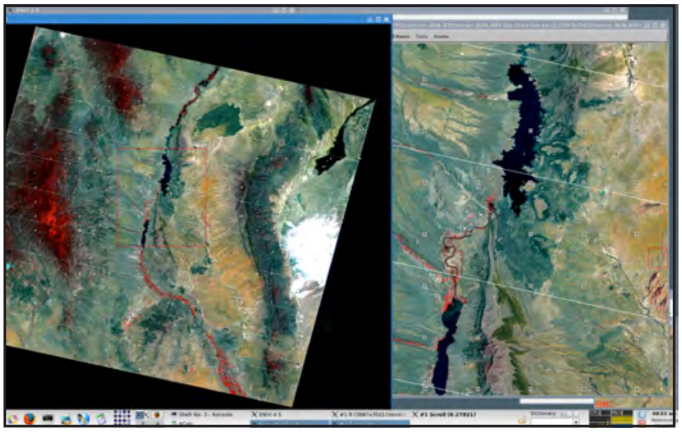


Figure 65. Example of improved orthorectification.

New Missions

The USGS and the EROS Center continually are seeking opportunities to collaborate in the development and operations of Earth observing remote sensing missions to satisfy the needs of the Nation's land imaging data requirements. The New Missions activities facilitate the communication and definition of USGS LRS Program requirements to the EROS Center. These activities are focused on developing partnerships to collect, archive, process, and distribute remotely sensed data in response to the evolving needs of scientific research, operational applications, decision makers, and educators. Towards these ends, teams are established to develop project plans, define and document requirements, perform systems engineering analysis, and implement technical solutions.

Landsat Data Continuity Mission

The Landsat Data Continuity Mission (LDCM) is the development phase for the next Landsat mission (Landsat 8). In FY 2009, the LDCM project has been busy responding to the challenges of new and evolving mission requirements; in particular, the potential of adding a Thermal Infrared Scanner (TIRS) to the mission manifest. Although the addition of TIRS is not yet officially funded, NASA is proceeding with instrument development to mitigate risk to the LDCM project schedule. The original launch date of July 2011 has moved to December 2012 to satisfy NASA's criteria for a 70 percent probability meeting schedule and staying within budget.

The USGS and NASA have been refining requirements for the LDCM ground system and have undertaken a reanalysis of its architecture to ensure that an optimal design is achieved (fig. 66). An important goal is to assure that the technical approach to its development is modular and extensible—in other words, it can be expanded easily to support additional Landsat missions. This revised approach to the LDCM is based on a synthesis with existing Landsat ground system capabilities, thereby resulting in lower costs for development as well as operations and maintenance.

As the technical approach to the LDCM ground system development matures, the project has achieved completion of numerous mission and project milestones. Many of these are associated with major systems requirements and engineering design reviews to ensure that the necessary functional capabilities and systems performance criteria are achieved. For further information, contact David Hair, USGS EROS, *hair@usgs.gov*.

LDCM Ground System Preliminary Design Review

The LDCM Project achieved a major milestone in September 2009 through the successful completion of the Preliminary Design Review for the entire Ground System (fig. 67) as well as for the Data Processing and Archive System (DPAS). The DPAS contains all of the major subsystems involved with storage and archive, science data processing, and distribution of Operational Land Imager and Thermal Infrared Sensor data products. No requests for action were issued by the review panel. These reviews were followed a month later by the successful completion of another major Mission milestone, the Non-Advocate Review. For further information, contact David Hair, USGS EROS, *hair@usgs.gov*.

Landsat Science Team Mid-Term Review

The Landsat Science Team (LST) is a group of 18 scientists that were selected by the USGS through an open competition solicitation to provide technical and scientific input to the USGS and NASA in support of Landsats 1–7 and the LDCM, which will become Landsat 8 after successful commissioning. The LST is completing its third year out of a 5-year contract, and the team has sustained a regular schedule of meetings every January and June since its inception in FY 2007.

In January 2009, the team meeting was hosted by the USFS in Fort Collins, Colorado. During this meeting, the Deputy Director of the Western States Water Council presented an overview of the water information needs and strategies of the western states, in which the importance of Landsat TIRS data was highlighted. These applications have stimulated increased awareness in Congress of the importance of TIRS data for water management and monitoring water consumption for irrigation, and consequently have built strong advocacy and support for the deployment of a TIRS instrument on the LDCM.

The June 2009 team meeting was hosted by the Rochester Institute of Technology in Rochester, New York. A representative from the European Space Agency presented an overview

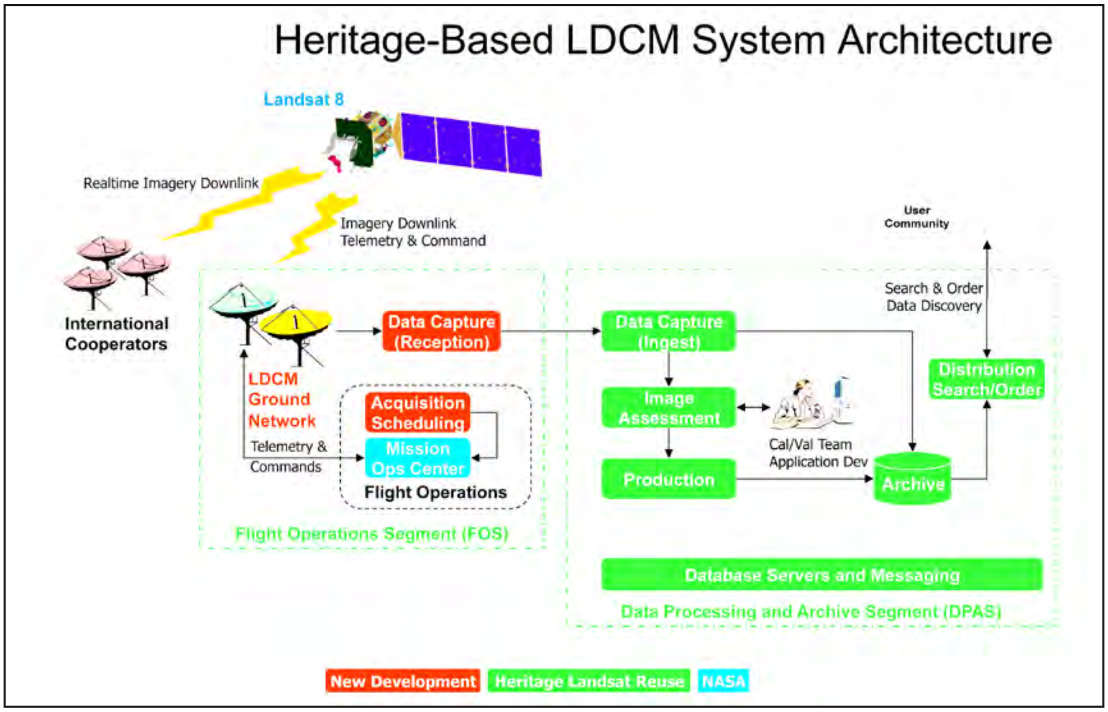


Figure 66. Illustrates the amount of the current (2009) Landsat data processing that is being re-used or built upon for the LDCM.

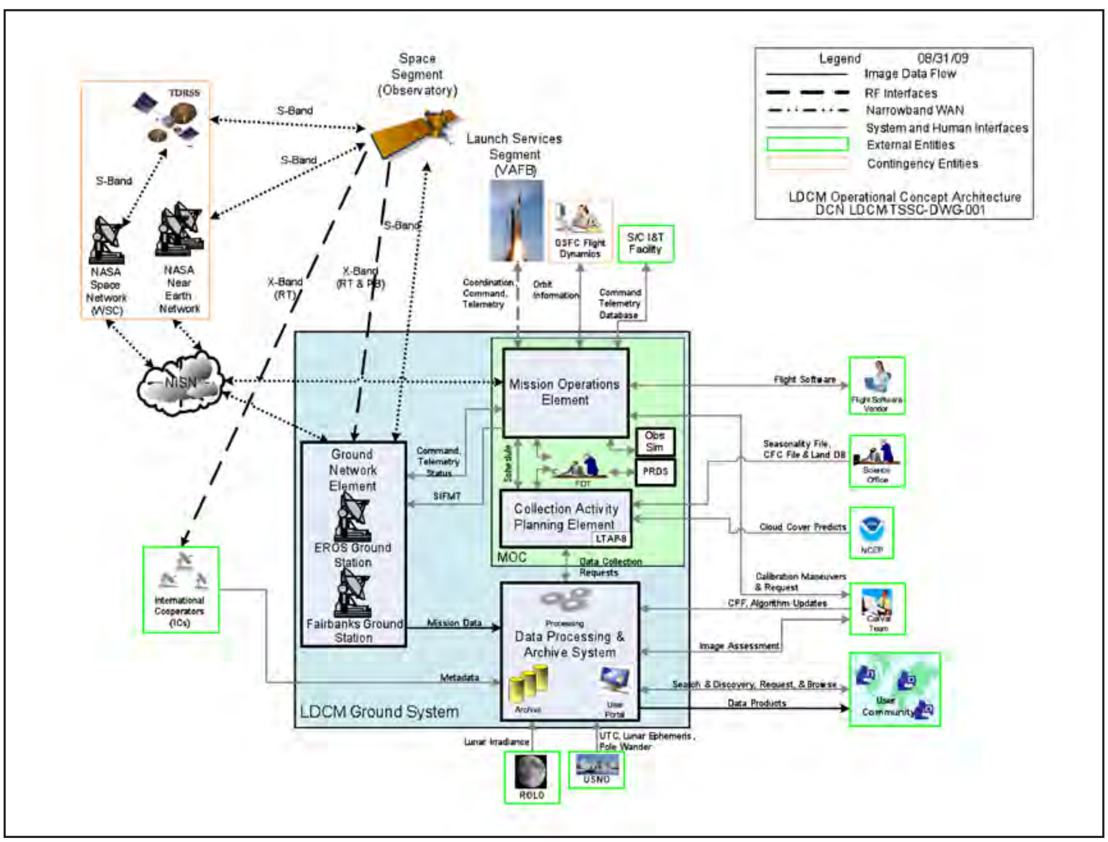


Figure 67. High-level architectural diagram of the LDCM Ground System.

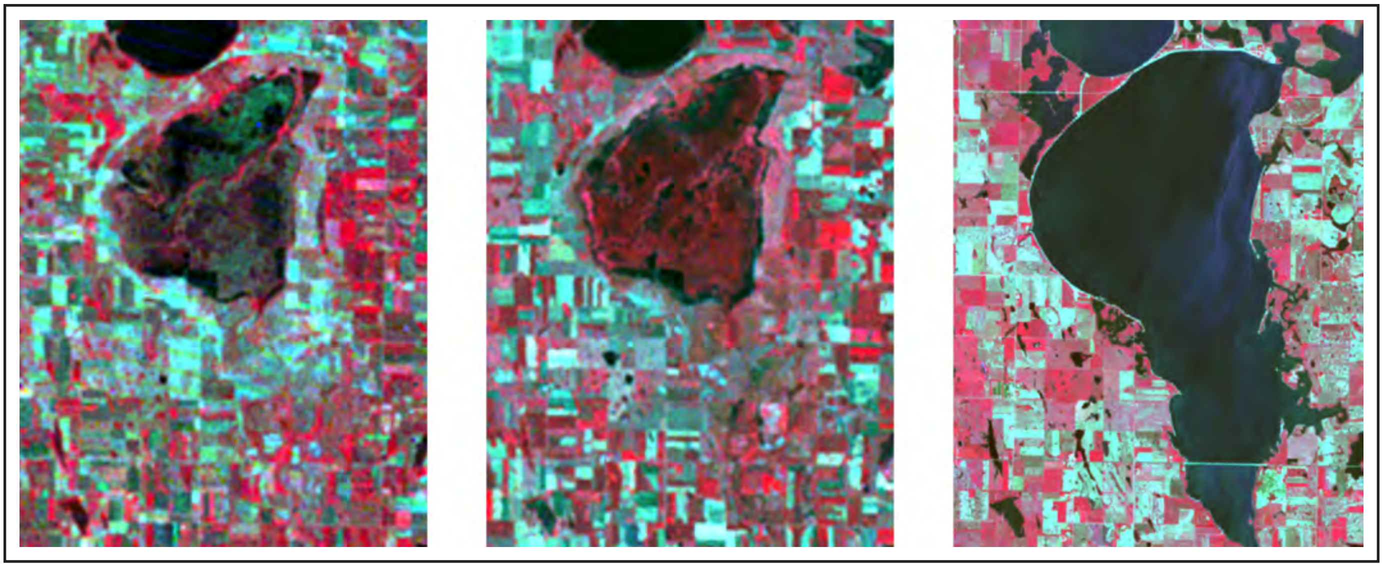


Figure 68. Landsat MSS images of Lake Thompson, South Dakota, showing the impacts of climate variability, July 5, 1973 (left); Landsat TM image, August 13, 1984 (center); Landsat ETM+ image, June 30, 2000 (right).

of the Sentinel-2 mission that is under development to support the European Union's program of Global Monitoring for Environment and Security. This briefing and other presentations highlighted the needs and importance of synergistic land remote sensing satellite capabilities to provide the necessary frequency of repeat coverage and long term continuity of observations in support of numerous environmental monitoring requirements.

The LST convened special sessions at the Pecora 16 Conference in Denver, the American Geophysical Union (AGU) Fall Meeting in San Francisco, and the American Society of Photogrammetry and Remote Sensing (ASPRS) Annual Meeting in Baltimore, to highlight progress on the development of the LDCM, and the benefits to the research and applications communities from opening the Landsat archives through no cost web-enabled data distribution. The team has been active in advocating the need to initiate planning for Landsat 9 to ensure a sustained minimum 8-day repeat coverage of global Landsat data. This is crucial if the United States Government is to achieve major science objectives such as those articulated by the U.S. Global Change Research Program:

> "One of the great challenges is how to relate human incentives, behavior and action at particular localities to land cover change at broader (e.g., regional) geographic regions. The fine spatial resolution of Landsat images along with its global geographic extent provides the necessary data for making this linkage." (Climate Change Science Program, 2003)

For further information, contact David Hair, USGS EROS, *hair@usgs.gov*.

Landsat Data Gap Readiness Plan

The USGS EROS Center developed a comprehensive Landsat Data Gap Readiness Plan that outlines the needed steps to "ready EROS and USGS contracts" so that the USGS can immediately implement a data gap solution following the demise of Landsat 5 and 7. The plan outlines the necessary steps to be ready for the start of a data gap, including a set of options and capabilities to acquire Landsat-like data from 1 or more candidate data sources to mitigate a potential gap. Specific data access terms and conditions have been documented with five potential data providers, including the internal USGS EROS impacts for implementing any of these solutions pending a loss of Landsat 5 and 7. Five candidate data sources were identified and evaluated, per recommendations of the Landsat Data Gap Study Team and other considerations of the USGS. They were: (1) SPOT-4 and SPOT-5 sensors, (2) IRS Satellite RESOURCESAT-1 AWiFS, (3) CBERS 2-B, (4) RapidEye Imaging constellation, and (5) UK-DMC-2 satellite. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

Earned Value Management—Performance Reporting for LDCM

The LDCM Project is an Exhibit 300 Development Project, which has a Capital Planning and Investment Control (CPIC) reporting requirement. The Project Management Team (PMT) was tasked to provide Earned Value Management (EVM), Monthly Performance Reporting, to the LDCM Proj-

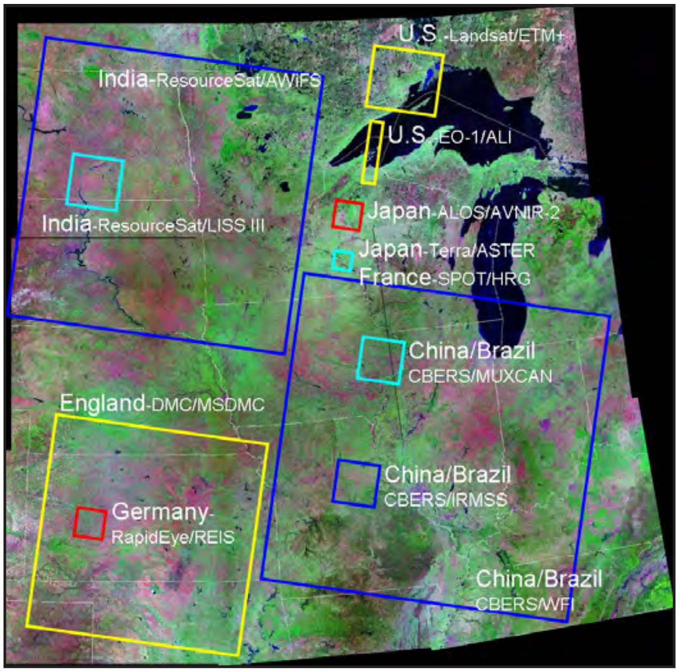


Figure 69. Comparison of satellite scene-based coverage plots.

ect in FY 2007, and has continued this service throughout FY 2009. The PMT compiled and provided those metrics to the USGS Geography Discipline; those reports are then supplied to the CPIC Office. The PMT provided data to eCPIC, which is the Exhibit 300 reporting tool, on behalf of the LDCM Project and worked closely with the CPIC Office on updates to eCPIC.

The PMT provided all the budget formulation input and updates that were used for BASIS+ updates. The PMT worked closely with the LDCM Project Manager to stay appraised of day-to-day planning and changes to the project baseline. The PMT tracked the spend plan for the LDCM Project to ensure the project tracked to the planned baseline, which in turn was key to good EVM reporting throughout FY 2009. For further information, contact Connie Hamann, USGS EROS, *chamann@usgs.gov*.

Data Management and Distribution

The USGS EROS Center manages a variety of data collections acquired from a wide array of current and historical sources, and distributes them to a broad range of global and niche user communities in science, applications, and operations. Data sources range from active satellite missions that are operated by EROS and others, historical aerial and satellite sources, as well as information about elevation, land cover, and other aspects of the Earth's land surfaces and data that are maintained in EROS' archives. The archives include film and digital systems developed commercially, in-house, and by and with other collaborators such as NASA. Access to the data is via a number of web-enabled user interfaces tailored to the collaborators' and users' needs, from simple websites to fully featured data discovery tools. In addition to managing the data as bits, EROS maintains the data via a data calibration and validation function, as well as science-based collection appraisals, and working with NASA and academia to ensure the integrity and value of the data. EROS uses this broad range of capabilities in collaboration with a number of partners to more effectively meet USGS strategic objectives.

Orthoimagery—A Bird's Eye View

Digital aerial photographs of at least 1-meter pixel resolution make up the orthoimagery component of *The National Map* (fig. 70). The standard product is natural color or color-infrared as GeoTIFFs [Georeferenced information embedded in a Tagged Image File Format (TIFF)] with accompanying Federal Geographic Data Committee metadata. The original purpose, in partnership with the NGA, of the orthoimagery program was to collect imagery over densely populated urban areas for homeland security and emergency operation purposes. As the program has increased during the last 7 years, the scope has changed to become the primary mechanism available for Federal, state, and local governments and organizations for partnering to collect high-resolution imagery. The expansion also has included partnering with the Farm Service Agency for leaf-on National Agriculture Imagery Program (NAIP). This imagery is the key component to new generation of USGS topographic maps (*http://nationalmap.gov/digital_map*).

Dissemination of the orthoimagery acquired by USGS through contracts, agreements with other Federal, state, tribal, or regional organizations, or direct purchases from private industry data vendors, are available through *The National Map* Seamless Data Distribution Service (*http://seamless.usgs.gov*). The USGS internet site provides viewing, WMS, and downloading at no charge. In FY 2009, more than 390 terabytes were distributed at no charge via the web. Any data acquired through the above mechanism becomes part of the USGS data holdings for long-term archiving, in addition to the distribution. The total amount of online data distributed is 100 terabytes. The orthoimagery data holdings available for distribution, via WMS and online download, is 286 terabytes.

Sources of Orthoimagery information include:

- *The National Map*—Orthoimagery fact sheet (*http://pubs.usgs.gov/fs/2009/3055/*).
- *The National Map* (*http://nationalmap.usgs.gov*).
- *The National Map* Seamless Data Distribution Service (*http://seamless.usgs.gov*).

For further information, contact S. Jean Paulson, USGS EROS, *paulson@usgs.gov*.

Figure 70. Falls Park on the Big Sioux River, Sioux Falls, South Dakota (source imagery is Minnehaha County, South Dakota, April 2008).

All-Digital, All-Free, All-Internet Data Distribution

The USGS archive is a comprehensive, long-term, and impartial record of our planet's changing land surface that contains aerial photographs dating from the 1940s and satellite images over every part of the Earth's surface starting in the 1960s and continuing to the present (2009) and on into the future.

During the past several years, the EROS Long Term Archive (LTA) project has been readying its data, systems, and processes to make all remote sensing data within its archives electronically accessible to customers at no charge over the Internet.

As of October 1, 2009, nearly 8,000,000 aerial and satellite image files were transitioned to an all-digital, all-free, all-Internet data distribution to the public using two USGS archive access systems:

- EarthExplorer (fig. 71)—*http://earthexplorer.usgs.gov*
- Global Visualization—*http://glovis.usgs.gov*

Included within this significant accomplishment was Web enabling the extensive collections of medium resolution digitized aerial photography dating back to 1939. Begun in October 2004, with the goal to improve access to the aerial film archive, the LTA has digitized more than 6.4 million frames of aerial film creating medium resolution digital imagery (400 dots per inch) and browse for all of the USGS mapping pho-

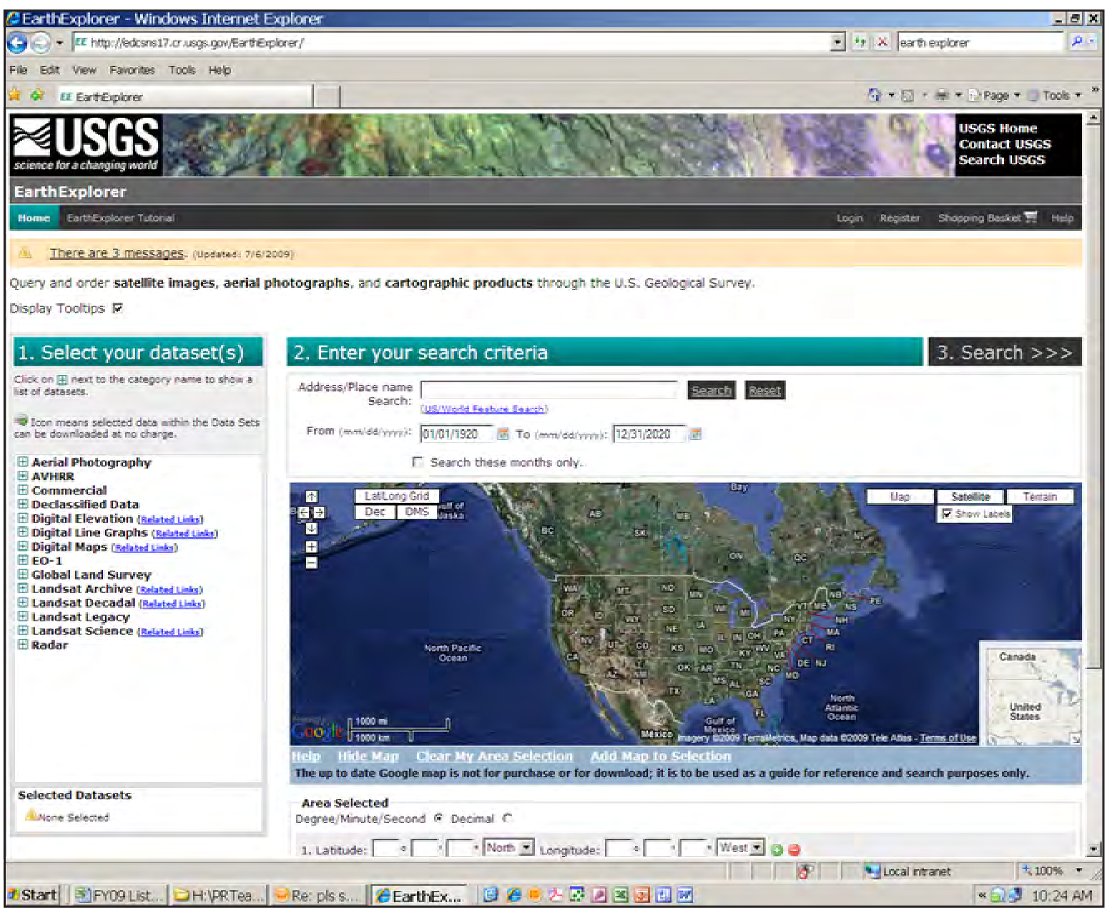


Figure 71. Earth Explorer—A complete search and order tool for aerial photos, elevation data, and satellite products distributed by the USGS.

tography. Additional medium resolution imagery will be made available as work progresses to create and link geo-retrievable coordinate information to the digitized photography. Thus far, single frame coordinates have been generated for more than 1,500,000 older aerial images permitting easier access to these important images. Using historical photography with current imagery is a powerful tool in understanding natural- and man-induced changes to our land surface. For further information, contact Wayne Miller, USGS EROS, *wamiller@usgs.gov*.

MODIS Data for Operational Land Imaging

The Moderate Resolution Imaging Spectroradiometer (MODIS) instrument monitors terrestrial processes globally, and is the source of products that have undergone extensive peer review and validation. These products are a critical source for Earth Science Data Records linking historical Advanced Very High Resolution Radiometer (AVHRR) products to those from the upcoming Visible Infrared Imager Radiometer Suite (VIIRS) system; however, they aren't well-suited for many operational agencies. For near real time applications such as drought monitoring, product latency (4 to 14 days) is a severe limitation. The 16-day compositing period of products such as vegetation indices (VI) doesn't align with these agencies' reporting requirements. Finally, these agencies require map projections other than the standard one, resulting in information loss because of re-projection.

The eMODIS prototype addresses the needs of operational users by providing customized products in a timely fashion. The product suite consists of near real time, 7- and 14-day VI composites over the Continental United States (CONUS), as well as more precise historical composites that were extended to include Alaska for the Yukon River Basin project. These products have generated considerable interest by several groups wanting to monitor the entire North American and African continents, as well as the Caribbean islands. Also, there is growing demand for land surface temperature and surface radiation products (table 1).

LRS initially funded eMODIS in FY 2007, as a replacement capability for the MODIS direct broadcast system (DBS) for CONUS drought monitoring applications that had depended on the DBS for input. The new system utilized the NOAA "bent pipe" to acquire expedited, low-level MODIS data to drive VI product generation at 7-day intervals. Subsequently, parallel products were produced from non-expedited, higher-accuracy NASA data streams to produce historical products for the long-term record. USDA/National Agricultural Statistics Service (NASS) funded a third CONUS data stream to produce historical records on 14-day intervals, and another stream was added to produce VI composites for the YRB. Because of increasing demand for eMODIS products, LRS funding requests were made in FYs 2008 and 2009, to stabilize the prototype into an operational system.

In FY 2009, all near real time and forward production is on schedule for completion. The 7-day Terra CONUS produc-

Table 1. Current and potential clients for "enhanced" MODIS (eMODIS).

Current and Potential Clients for eMODIS			
Agency	**Products**	**Geographic Focus**	**Application**
USGS/YRB	LST, NDVI, Swath Reflectance	Yukon River Basin	Carbon mapping/ecosystem services
USGS/NAFTA	NDVI, Swath Reflectance	North America	Land process change
USGS/Amphibians	LST, NDVI, Swath Reflectance	North America	Habitat mapping
DOI/BLM	NDVI, Swath Reflectance	CONUS	Land management
Idaho State Univ.	NDVI, Swath Reflectance	CONUS	Natural resources
NDMC	NDVI, Swath Reflectance	CONUS	Drought monitoring
NASA/Stennis	LST, NDVI, Swath Reflectance	Global	Land process monitoring
USAID/FEWS	LST, NDVI, Swath Reflectance	Caribbean/C. America/ Africa	Food security
USGS/Hydro	LST	CONUS	Surface energy balance
USGS/VegDRI	NDVI, Swath Reflectance	CONUS	Drought monitoring
USDA/NASS	NDVI, Swath Reflectance	CONUS	Agricultural statistics
USGS/YRB	LST, NDVI, Swath Reflectance	Yukon River Basin	Ecosystem services
Univ. of N. Iowa	NDVI, Swath Reflectance	CONUS	Land process change
USDA/LAI	LST, LAI	CONUS	Hydrological modeling
USDA/FAS	LST, NDVI, Swath Reflectance	Global	International crop mapping
HHS/NHO	LST	CONUS, Africa	Human health
USGS/AFO	NDVI, Swath Reflectance	Alaska	Land process change

tion continues with emergency funding from the "Carbon Fluxes in the Great Plains" activity (from GAM), whereas the 14-day Terra CONUS back-processing for USDA/NASS temporarily has been discontinued. The data have been web-enabled through standard File Transfer Protocol, and back-up procedures for historical products were implemented. A paper was submitted to ASPRS 2009, and the USGS Open File Report is in review. Links to eMODIS were added to the Land Measurements Portal (*http://landportal.gsfc.nasa.gov/*), to the USGS Land Cover Applications and Global Change website (*http://lca.usgs.gov/lca/projects.php?id=2*), and to the USGS Alaska Science Portal (*http://alaska.usgs.gov/portal/*).

Fiscal year 2010 will be critical to aligning the capabilities of eMODIS to increasing demands, requiring a transition from prototype to an operational system. From an operational land imaging perspective, the eMODIS system places the USGS in a strong position as a source of synoptic observations from legacy (AVHRR), current (MODIS) and future (VIIRS) systems. The LRS program, along with other USGS (YRB, Ecosystem Performance) and external (USDA/NASS) partners have provided generous support in the development of the current (2009) prototype. However, significant investment in an adaptable, operational system now is required to capitalize on these opportunities while they still exist, and the experience gained from the prototype is still fresh. For further information, contact David Meyer, USGS EROS, *dmeyer@usgs.gov*.

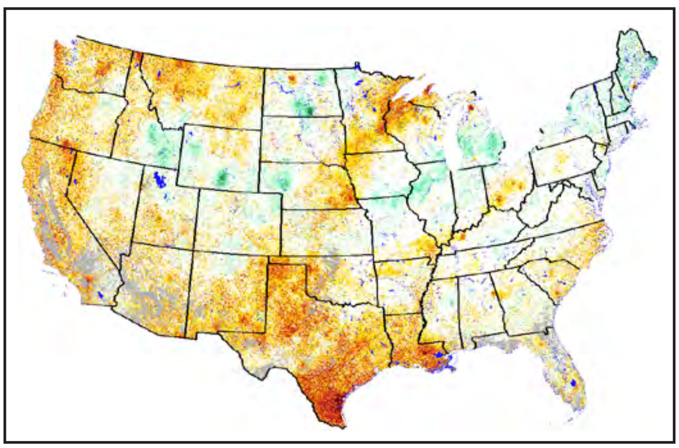


Figure 72. VegDRI application of eMODIS data: drought conditions over the Conterminous United States for the week ending July 12, 2009, generated on July 13, 2009. Shades of green represent areas that are more moist than average; yellows and oranges represent drought-affected areas.

MRTWeb: Enhanced MODIS Data Discovery and Delivery Services from the LP DAAC

Historically, the Land Processes Distributed Active Archive Center (LP DAAC) has distributed MODIS land product tiles in the standard 10 x 10 degree extent, Sinusoidal projection, and Hierarchical Data Format (HDF)-EOS format. User feedback-based requirements helped define the MODIS Reprojection Tool (MRT) Web (MRTWeb) interface, which was developed to provide enhanced, web-based discovery and delivery services for MODIS land product tiles archived at the LP DAAC.

The LP DAAC has developed enhanced MODIS data discovery and delivery services by combining the familiar search, visualization, and selection capabilities of the USGS Global Visualization Viewer (GloVis) and the mosaicking, spatial subsetting, band subsetting, reprojection, resampling, and reformatting functions of the MRT.

The MRTWeb interface (fig. 73) combines and modifies the pre-existing GloVis and MRT layouts into 3 main tabs: Selection, Process, and Download, which allow the user to perform the following functions:

- Find/Visualize/Select tiles of interest.
- Choose bands or layers (Science Datasets in HDF terminology) of interest.
- Mosaic multiple adjacent tiles from same date (and subset to an area of interest if desired).
- Subset an area of interest from multiple dates of the same tile (time series extraction).
- Set projection (currently limited to Albers Equal Area, Geographic, Lambert Azimuthal, Polar Stereographic, Sinusoidal, and Universal Transverse Mercator).
- Set resampling (currently limited to Nearest Neighbor, with native, 250-, 500-, and 1,000-meter griddings).
- Choose output format (currently limited to HDF-EOS, GeoTIFF, and Raw Binary).
- Submit processing job(s) to LP DAAC.
- Monitor progress of processing job(s).
- Download customized MODIS datasets and processing logs.
- Exit the interface, and login later to check job status and/or download datasets.

The MRTWeb target audience includes intermediate to expert users of MODIS land data. Knowledge of MODIS land product characteristics and general image processing techniques is assumed. For further information, contact Tom Sohre, USGS EROS, *tsohre@usgs.gov*.

LP DAAC Distributes Most Complete Topographic Map of Earth

On June 29, NASA and the Ministry of Economy, Trade, and Industry (METI) of Japan, jointly announced the release of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) product (fig. 74). News of the "Most Complete

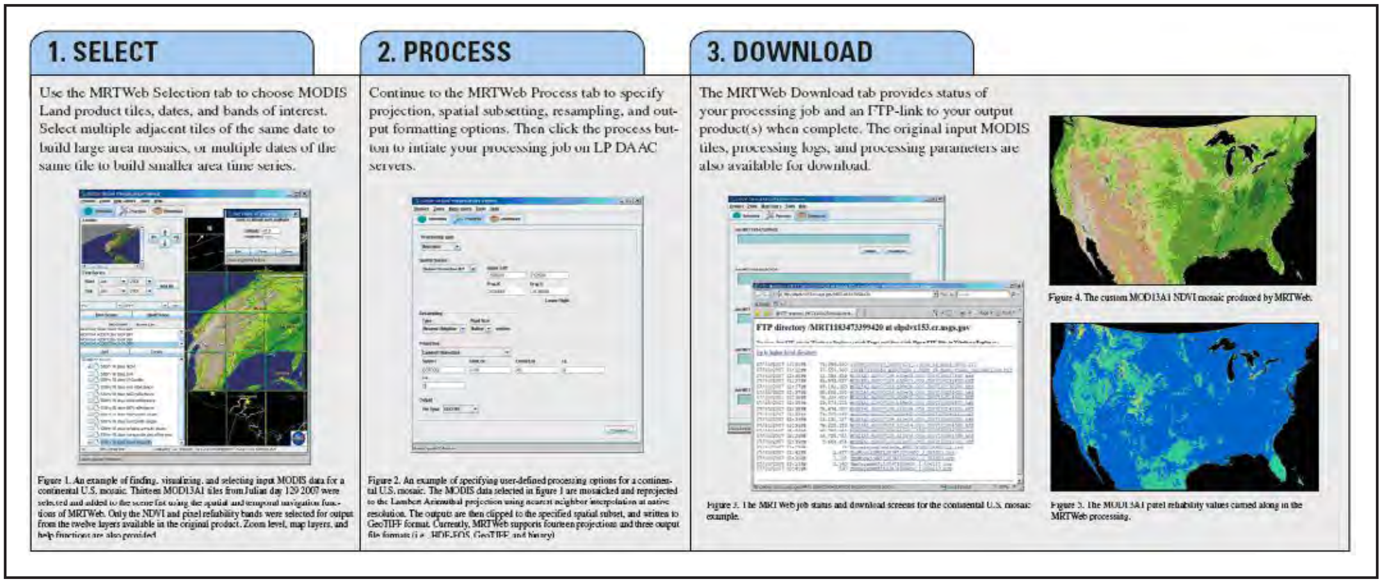


Figure 73. Sample MRTWeb user interface.

Topographic Map of the Earth" spread quickly to a number of news sites including CNN and during the first week, the LP DAAC website was host to more than 41,000 visitors interested in the product. Within the first 10 days of distribution, the LP DAAC at EROS distributed more than 500,000 ASTER GDEM tiles to the user community.

The new global digital elevation model of Earth was created from nearly 1.3 million individual stereo-pair images collected by the Japanese ASTER instrument aboard Terra. NASA and METI developed the dataset. It is available online to users everywhere at no cost.

"This is the most complete, consistent global digital elevation data yet made available to the world," said Woody Turner, ASTER program scientist at NASA Headquarters in Washington, D.C. "This unique global set of data will serve users and researchers from a wide array of disciplines that need elevation and terrain information."

Previously, the most complete topographic set of data publicly available was from NASA's SRTM. That mission mapped 80 percent of the Earth's landmass, between 60 degrees north latitude and 57 degrees south. The new ASTER data expands coverage to 99 percent, from 83 degrees north latitude and 83 degrees south. Each elevation measurement point in the new data is 98 feet apart.

NASA, METI, and the USGS validated the data, with support from the NGA and other collaborators. The data will be distributed by NASA's LP DAAC at the USGS's EROS Center in Sioux Falls, South Dakota, and by METI's Earth Remote Sensing Data Analysis Center in Tokyo, Japan.

The data were contributed to the ASTER topographic data to the Group on Earth Observations, an international partnership headquartered at the World Meteorological Organization in Geneva, Switzerland, for use in its GEOSS. For further information, contact Tom Sohre, USGS EROS, *tsohre@usgs.gov*.

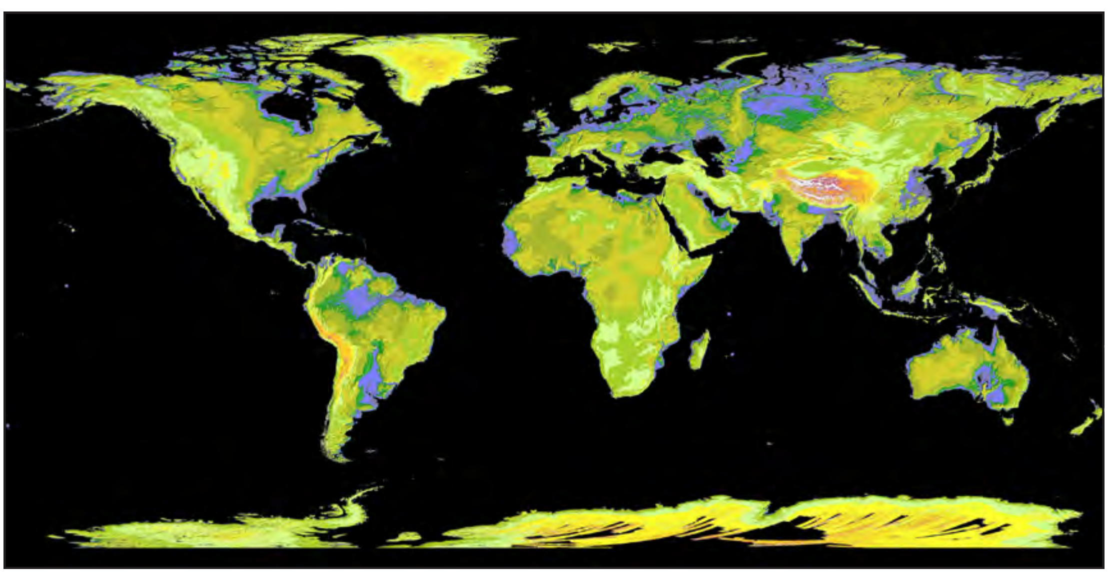


Figure 74. ASTER global digital elevation model visualization.

LP DAAC Implements New Website

In December 2008, the LP DAAC implemented a new website (fig. 75). The new website was an opportunity to increase LP DAAC visibility, improve communications with our user community, and present LP DAAC data and services in an improved format. The focus was on product information, data accession, and product tools—the three activities that customers have repeatedly indicated are the most important to them. They are now prominently featured at the top of every page on the site. Additional features include search capability across the website and Rich Site Summary (RSS) feeds. Technically, the new Website is built around a content management system that allows for LP DAAC content owners to have more direct responsibility for the Website content. The system is implemented on virtual servers that allows for rapid horizontal scaling to meet user demand. As an example, LP DAAC traffic normally can be handled by a single server, but when the ASTER Global DEM was released in June 2009, the user demand was so great that traffic needed to be load-balanced across four servers.

Figure 75. New LP DAAC website.

As the LP DAAC developed the new Website, the customer survey feedback was utilized, as well as input from our user working group. The Website was developed using an iterative approach and the design seen today reflects the input of our real-life users. For further information, contact Tom Sohre, USGS EROS, *tsohre@usgs.gov*.

Landsat Web Enabled Products Available Through NASA ECHO

The NASA-developed Earth Observing System (EOS) Clearinghouse (ECHO) is a spatial and temporal metadata registry that enables the science community to more easily use and exchange NASA's data and services. Currently (2009), ECHO contains metadata for more than 2,726 data collections comprising 87 million individual data granules and 34 million browse images. ECHO stores metadata from a variety of science disciplines and domains, including Climate Variability and Change, Carbon Cycle and Ecosystems, Earth Surface and Interior, Atmospheric Composition, Weather, and Water and Energy Cycle. ECHO also has a services registry for community-developed search services and data services.

To help science communities that need data from multiple organizations and multiple disciplines, ECHO allows users to more efficiently search and access data and services and increases the potential for interoperability with new tools and services. The value of these resources increases as the potential to exchange and interoperate increases. Although ECHO's main objective is to enable broader use of NASA's data, ECHO has been working with other organizations to provide their Earth science metadata alongside NASA's for users to search and access as well.

In 2008, the LP DAAC User Working Group recommended that the LP DAAC enable the capability, in collaboration with the NASA Earth Science Data and Information System (ESDIS) and the USGS, to perform cross-dataset search/order of Landsat data in addition to the standard EOS datasets. The LP DAAC worked with the NASA ESDIS to place Landsat metadata in ECHO. Beginning February 11, 2009, Landsat 7 ETM+, Landsat 1–5 MSS, and Landsat 4–5 TM standard data products are available through the NASA Warehouse Inventory Search Tool (WIST) (fig. 76).

Electronic access to the USGS Landsat archive, enabling users to download standard format scenes at no charge, has been an amazing success. The LP DAAC, in cooperation with

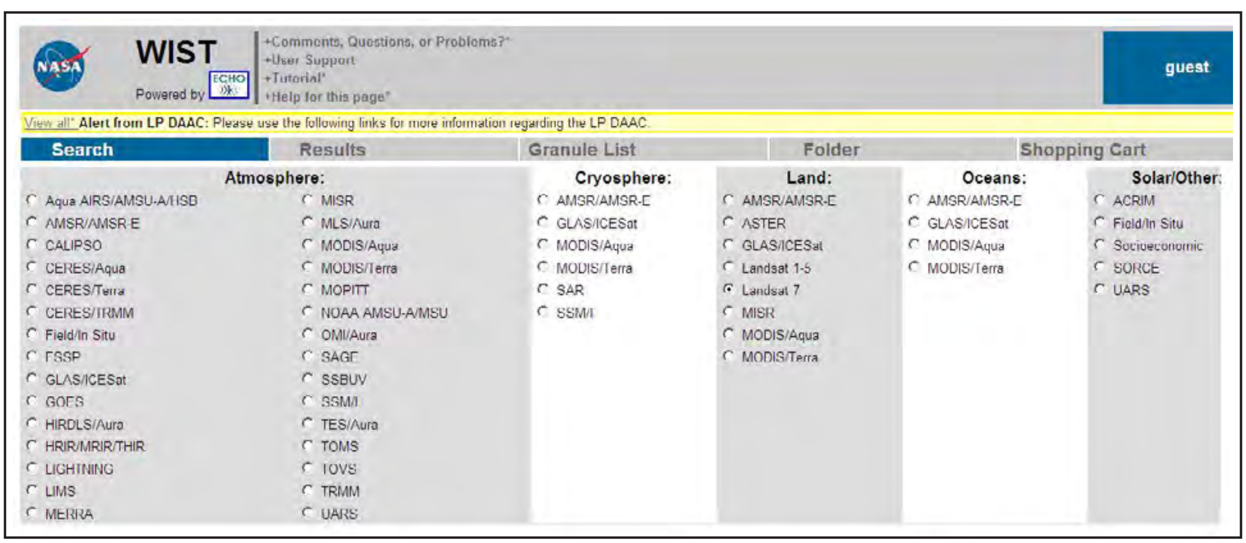


Figure 76. NASA Warehouse Inventory Search Tool (WIST).

the NASA ESDIS, are excited to further enhance user access to the Landsat archive by enabling search of this valuable dataset through ECHO/WIST. For further information, contact Tom Sohre, USGS EROS, *tsohre@usgs.gov*.

Scientific Records Appraisals

All collections offered to or maintained at EROS are reviewed through the EROS scientific records appraisal process. This process is used to ensure that EROS maintains collections aligning to the mission, allowing the best service for the land remote sensing research community. Appraisal involves the process of determining if materials have sufficient value to be accessioned into a repository, including the process of determining the length of time records should be retained, based on legal requirements and on their current and potential usefulness, and determining the market value of an item (monetary appraisal).

Fifteen reviews of science collections were completed ensuring that the records that align to our mission and legal responsibilities are preserved and made accessible. The collections (program) included:

- Digital Raster Graphics (NGP)
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (LRS)
- Digital Orthophoto Quad County (NGP)
- Système Pour l'Observation de la Terre (LRS)
- Slant Range Radar (LRS)
- Digital Elevation Model Tiles (NGP)
- Skylab (LRS)
- Side Looking Airborne Radar (LRS)
- Paper Maps and Imagery (EROS)
- Digital Orthophoto Quad (NGP)
- Arc Digitized Raster Graphics (EROS)
- Moderate Resolution Imaging Spectroradiometer (LRS)
- Control Image Base (EROS)
- TriDecadel (LRS)
- For Official Use only Digital Orthophoto Quads (EROS)

The online tool developed as part of the scientific records appraisal process was reviewed internally and by a USGS employee in Fort Collins, Colorado. The result was a significant revision that was released for public use in June 2009. The new tool is located at *http://eros.usgs.gov/government/ratool/*. For further information, contact John Faundeen, USGS EROS, *faundeen@usgs.gov*.

Off-Site Archiving

Building upon the success of FY 2008, when a contract was negotiated with the National Archives and Records Administration (NARA) for off-site archiving at their Kansas City underground facility (fig. 77), using the contract was expanded to include Landsat and the Long-Term Archive Projects. It is estimated that nearly 1 petabyte of electronic records will be protected at this off-site facility by the end of calendar year 2009, thereby safe-guarding our Nation's observational records in case of a natural or manmade tragedy. For further information, contact John Faundeen, USGS EROS, *faundeen@usgs.gov*.

Figure 77. NARA mine entrance at Lee's Summit, Kansas City, Missouri.

USGS Records Management Expertise

Representing the USGS leadership role in scientific records management included publishing and presenting a paper entitled "A Selection and Archiving Strategy for Science Records," for The Society for Imaging Science and Technology's Archiving 2009 Conference. A presentation also was made at the ASPRS Annual Conference. The presentation was titled "Records Management Best Practices: Archiving Done Right."

Participation was requested by the European Union's Digital Library initiative. The 18-month involvement is centered upon a policy working group that involves representation from Canada, New Zealand, Germany, the United Kingdom, and the Massachusetts Institute of Technology. The first meeting was held in Pisa, Italy, in July 2009.

To continue records management expertise development, a Society of American Archivists workshop entitled

"Advanced Appraisal for Archivists," was held at a NARA facility and attended. New thoughts and techniques related to appraising records were learned.

Basic records management training was provided at the USGS Upper Midwest Environmental Sciences Center in LaCrosse, Wisconsin. Four administrative and 18 science staff received the training.

USGS EROS was noted in a Society of American Archivists Newsletter for our Scientific Records Appraisal Process and our archive media trade studies. See *http://www.archivists.org/saagroups/acq-app/newsletter.asp* for the reference.

A science records workshop was provided to the EROS Science Division. Topics included: EROS Scientific Records Appraisal Process, disposition of records, preservation of records, and a lifecycle of science records concept. Open discussion followed the presentation with 21 scientists participating.

A team participated in a NARA telecon to discuss guidance NARA could provide to science agencies related to data preservation and access. Several ideas were provided to NARA, and additional support is anticipated.

USGS EROS received recognition by NOAA in their agency-wide "Procedure for Scientific Records Appraisal and Archival Approval: Guide for Data Managers." The USGS work in developing a scientific records appraisal process was specifically referred to.

A team reviewed and provided comments on the FY 2010 Records Management training section of the annual required DOI training program. For further information, contact John Faundeen, USGS EROS, *faundeen@usgs.gov*.

USGS Data Rescue Initiative

Since 2006, the USGS Records Management Program has supported a data rescue project that provides grants to science projects having legacy preservation and access challenges related to USGS science records. EROS was the impetus behind establishing the initiative and annually supports the online application form, the compilation of bureau requests, and the final disbursement of funds. During FY 2009, USGS science projects received $89,000; the total since 2006 is $244,000. An example includes the data rescue of the records from the Scientific Assessment and Strategy Team as established by the White House in 1993 in response to the Upper Mississippi flooding.

The NGP Office requested assistance in developing a FY 2011 budget initiative directed at rescuing USGS science data at risk of loss. Several strategy pieces were compiled and forwarded as part of an intensive effort. For further information, contact John Faundeen, USGS EROS, *faundeen@usgs.gov*.

Consolidated Archive and Distribution Data Report: A Monthly "Consolidated Report" for All Data Managed and Distributed at EROS

Working with input from projects, EROS prepared a report template to be used by the projects for inputting their respective data. The template has been reviewed by the projects and the USGS LRS Program. The report gives statistics in terabytes distributed and data managed in FY 2009.

Monthly and cumulative totals distributed and managed for all projects are shown in figures 78–81. Data distributed and managed are shown in figures 82–91 for the following groupings:

- Landsat (figs. 82 and 83)
- LP DAAC (figs. 84 and 85)
- Other Satellite (figs. 86 and 87)
- Non-Satellite (figs. 88 and 89)
- Seamless (figs. 90 and 91) including Orthoimagery, Elevation, Land Cover, and Other

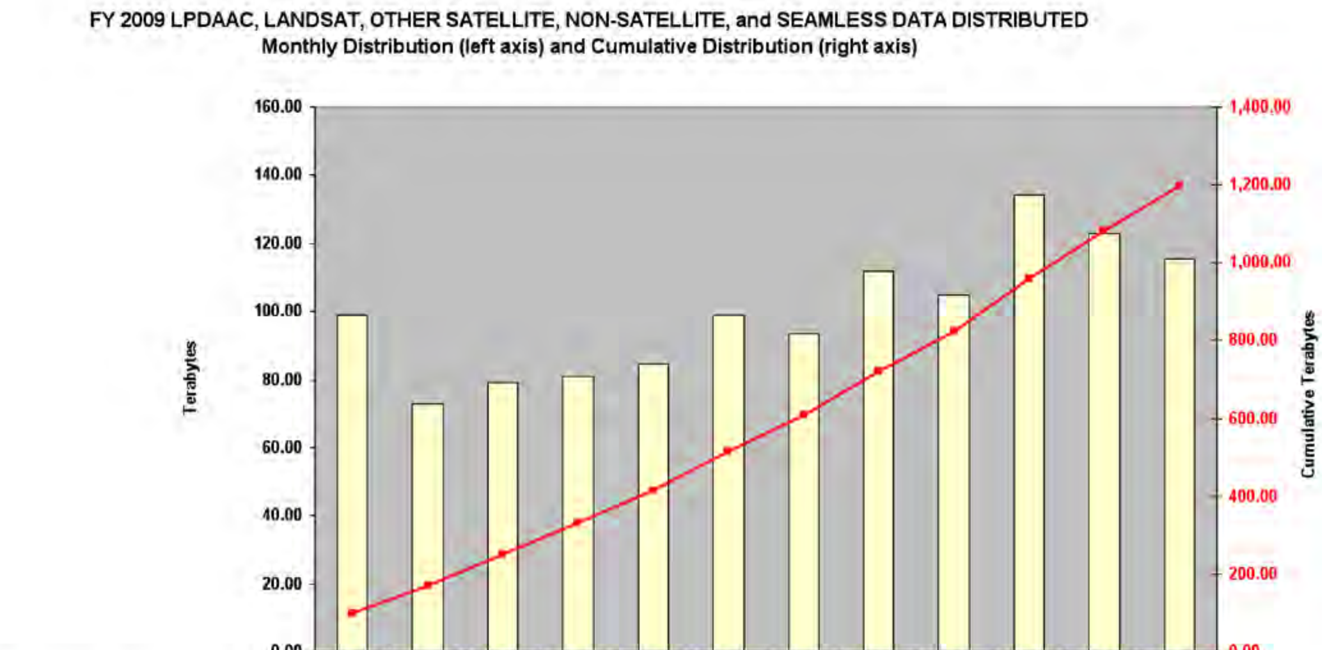
For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

Calibration and Validation

Remotely sensed data are a valuable tool in the management, study, and monitoring of the Earth's surface. The usability and reliability of these data for users and decision makers depends on the accuracy with which these data represent the surface of the Earth and the processes underway on it. The USGS, as a critical provider, as well as user of remotely sensed data, products, and services places a critical reliance on the accuracy of these data and understanding the capabilities and limitations of the data because of the technologies used to generate these data. Other agencies as well as the broad user community in the United States and around the world rely on the USGS to provide assessment of these data. The value of remote sensing data is assessed according to its accuracy and ability to assess change required to address societal needs.

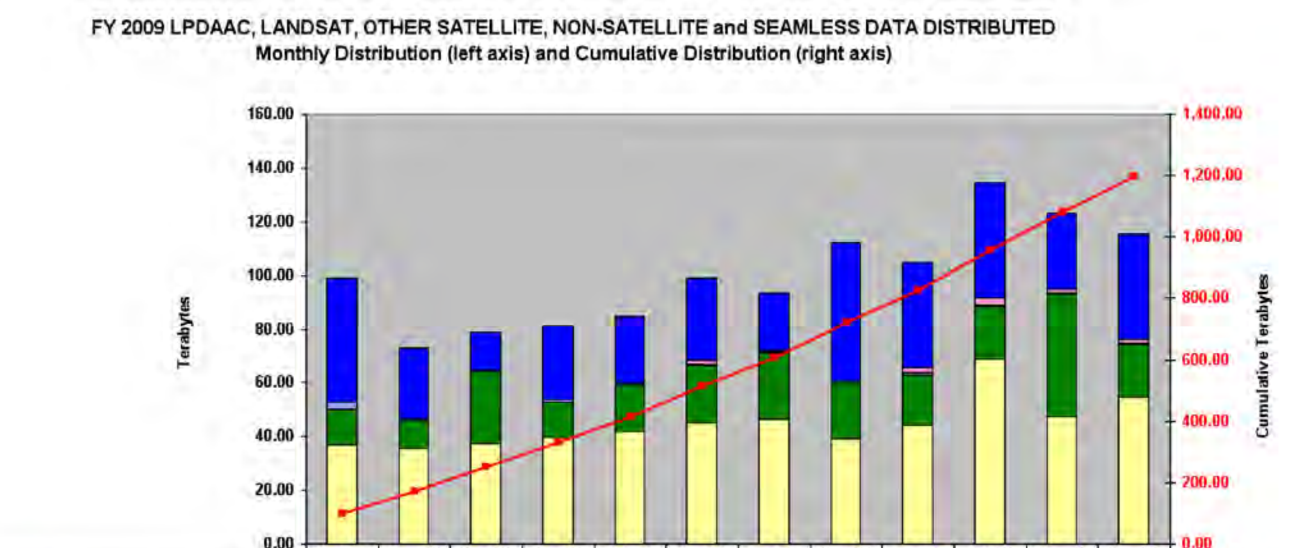
Satellite Data Characterization and Joint Agency Civil Imagery Evaluation

The USGS Remote Sensing Technologies (RST) Project continued its research into the quality and usability of remotely sensed data from satellite and airborne platforms, whether public or private, United States or foreign. During the year satellite data evaluated by RST Project staff included



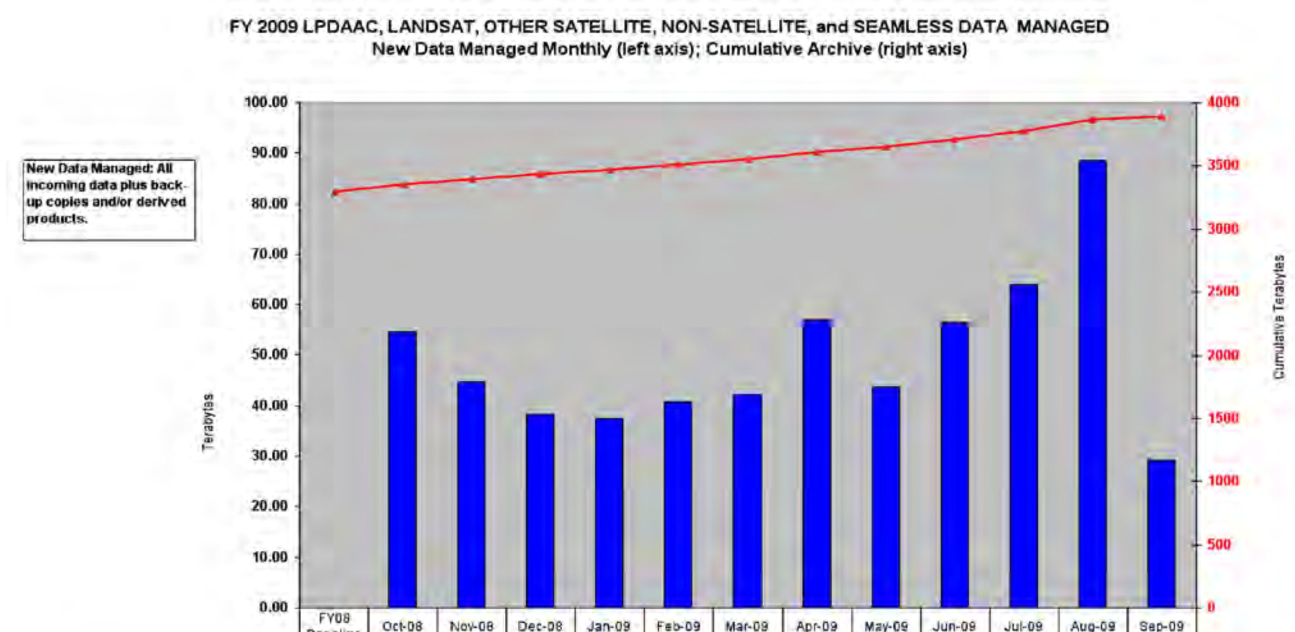
	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
All Data Distributed - Monthly	99	73	79	81	85	99	93	112	105	134	123	116
Cumulative Terabytes Distributed	99	171	251	332	416	515	608	720	825	959	1082	1198

Figure 78. FY 2009 LP DAAC, Landsat, other satellite, non-satellite, and Seamless data distributed.



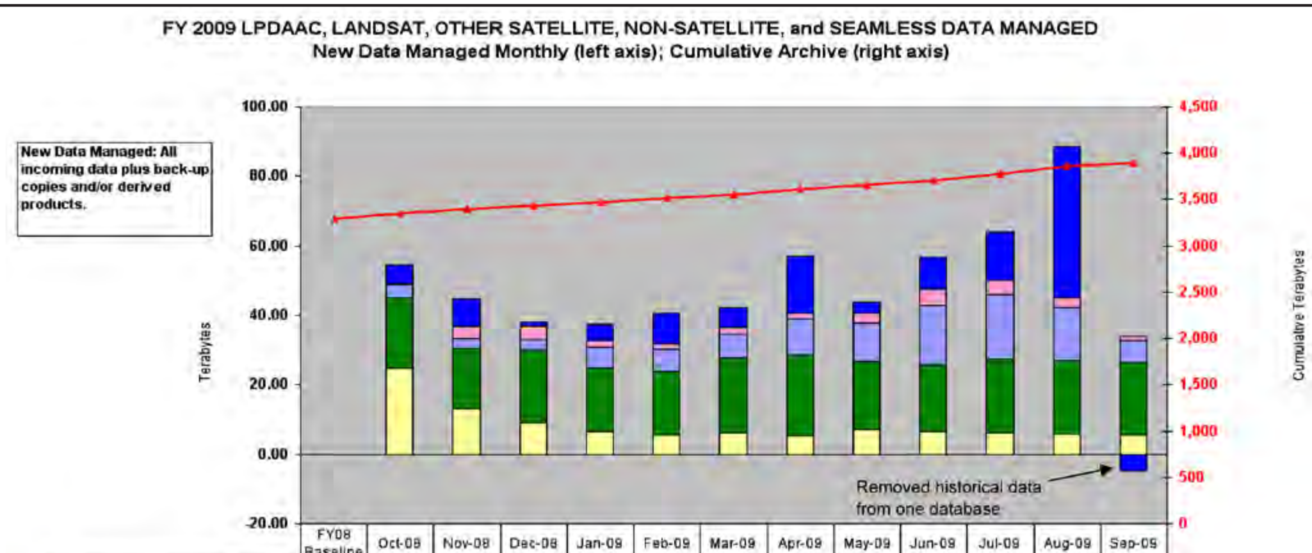
	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09	FY09 Totals
Seamless	45.92	26.15	14.33	27.18	25.00	30.43	21.41	51.11	39.23	42.87	28.29	39.21	391 TB
Other Satellite	0.08	0.13	0.08	0.24	0.21	1.17	0.24	0.12	1.62	2.44	1.06	1.43	9 TB
Non-Satellite	2.84	0.45	0.34	0.53	0.31	0.53	0.54	0.43	0.70	0.82	0.76	0.59	9 TB
Landsat	13.08	10.20	26.99	13.50	17.15	21.39	24.47	20.86	19.13	19.31	45.70	19.68	251 TB
LPDAAC	36.86	35.78	37.33	39.59	41.94	45.27	46.60	39.40	44.00	68.90	47.20	54.60	538 TB
Cumulative Terabytes Distributed	99	171	251	332	416	515	608	720	825	959	1082	1198	1198 TB

Figure 79. FY 2009 LP DAAC, Landsat, other satellite, non-satellite, and Seamless data distributed.



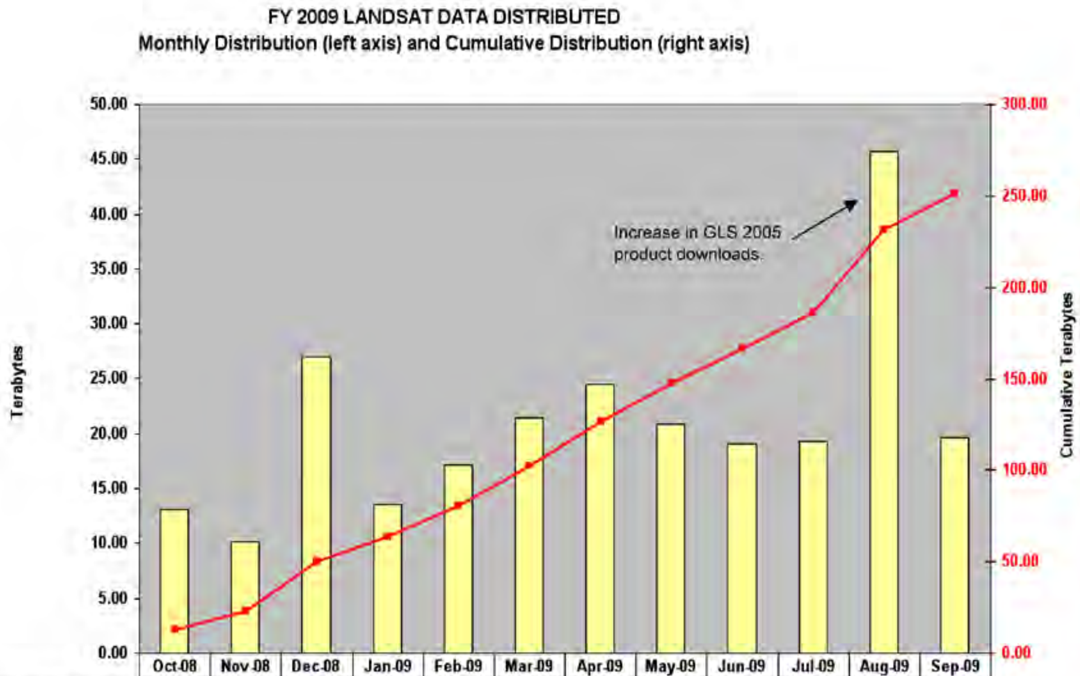
	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
All Data Collected - Monthly		53.29	31.1	24.79	20.26	26.46	24.24	19.73	22.27	30.39	25.06	19.86	15.98
All Data Managed - Monthly		54.65	44.81	39.24	37.41	40.72	42.19	57.16	43.78	56.6	63.95	88.56	29.24
Cumulative Terabytes Managed	3296.31	3350.96	3395.77	3434.01	3471.42	3512.14	3554.33	3611.49	3655.27	3711.67	3775.82	3864.38	3893.62

Figure 80. FY 2009 LP DAAC, Landsat, other satellite, non-satellite, and Seamless data managed.



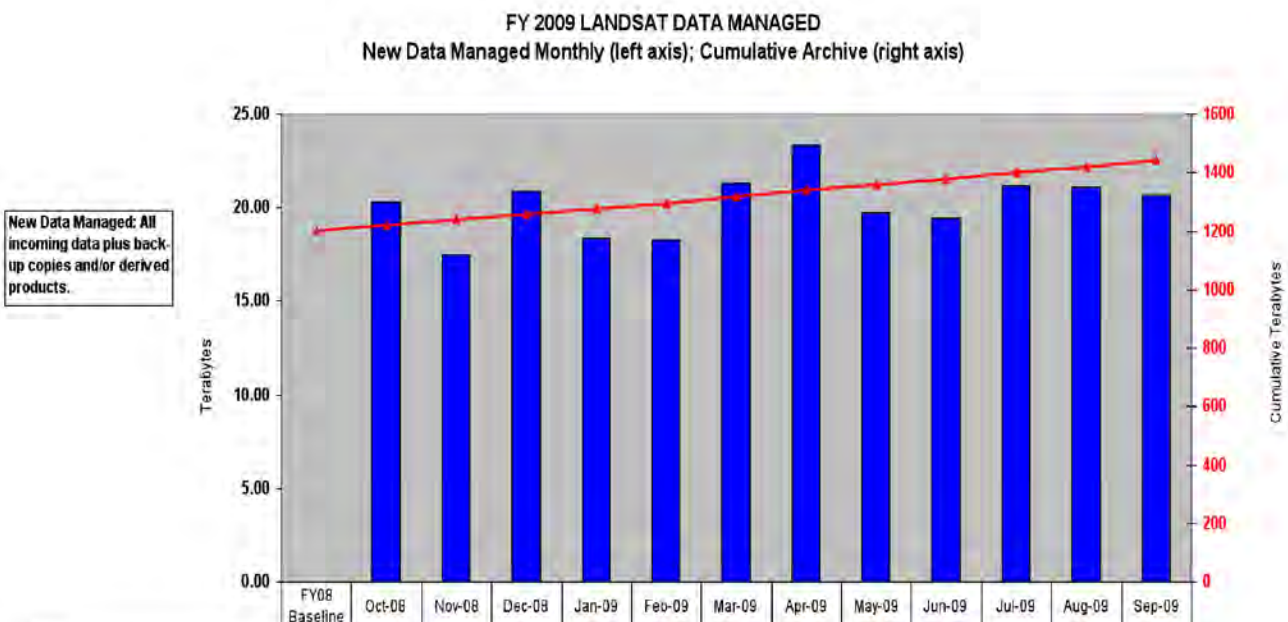
	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
All Data Collected - Monthly		53	31	25	20	26	24	20	22	30	25	20	16
Seamless Managed Monthly		5.57	8.11	1.45	4.75	8.79	5.82	16.54	3.22	9.02	13.99	43.47	-4.81
Other Satellite Managed Monthly		0.29	3.29	3.84	1.67	1.64	1.61	1.65	2.67	4.62	4.06	2.82	1.36
Non-Satellite Managed Monthly		3.73	2.90	2.99	6.01	6.39	7.08	10.24	11.07	17.03	18.60	15.37	6.39
Landsat Managed Monthly		20.30	17.49	20.86	18.38	18.31	21.34	23.33	19.72	19.43	21.20	21.10	20.70
LPDAAC Managed Monthly		24.76	13.02	9.10	6.60	5.59	6.34	5.40	7.10	6.50	6.10	5.80	5.60
Cumulative Terabytes Managed	3,296	3,351	3,396	3,434	3,471	3,512	3,554	3,611	3,655	3,712	3,776	3,864	3,894

Figure 81. FY 2009 LP DAAC, Landsat, other satellite, non-satellite, and Seamless data managed.



	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Landsat Data Distributed Monthly	13.08	10.20	26.99	13.50	17.15	21.39	24.47	20.86	19.13	19.31	45.70	19.68
Cumulative Terabytes Distributed	13	23	50	64	81	102	127	148	167	186	232	251

Figure 82. FY 2009 Landsat data distributed.



	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Landsat Data Collected Monthly		4.94	5.11	4.83	4.89	4.46	5.07	4.9	4.84	4.63	4.8	4.55	4.71
Landsat Data Managed - Monthly		20.3	17.49	20.86	18.38	18.31	21.34	23.33	19.72	19.43	21.2	21.1	20.7
Cumulative Terabytes Managed	1200.35	1220.65	1238.14	1259	1277.38	1295.69	1317.03	1340.36	1360.08	1379.51	1400.71	1421.81	1442.51

Figure 83. FY 2009 Landsat data managed.

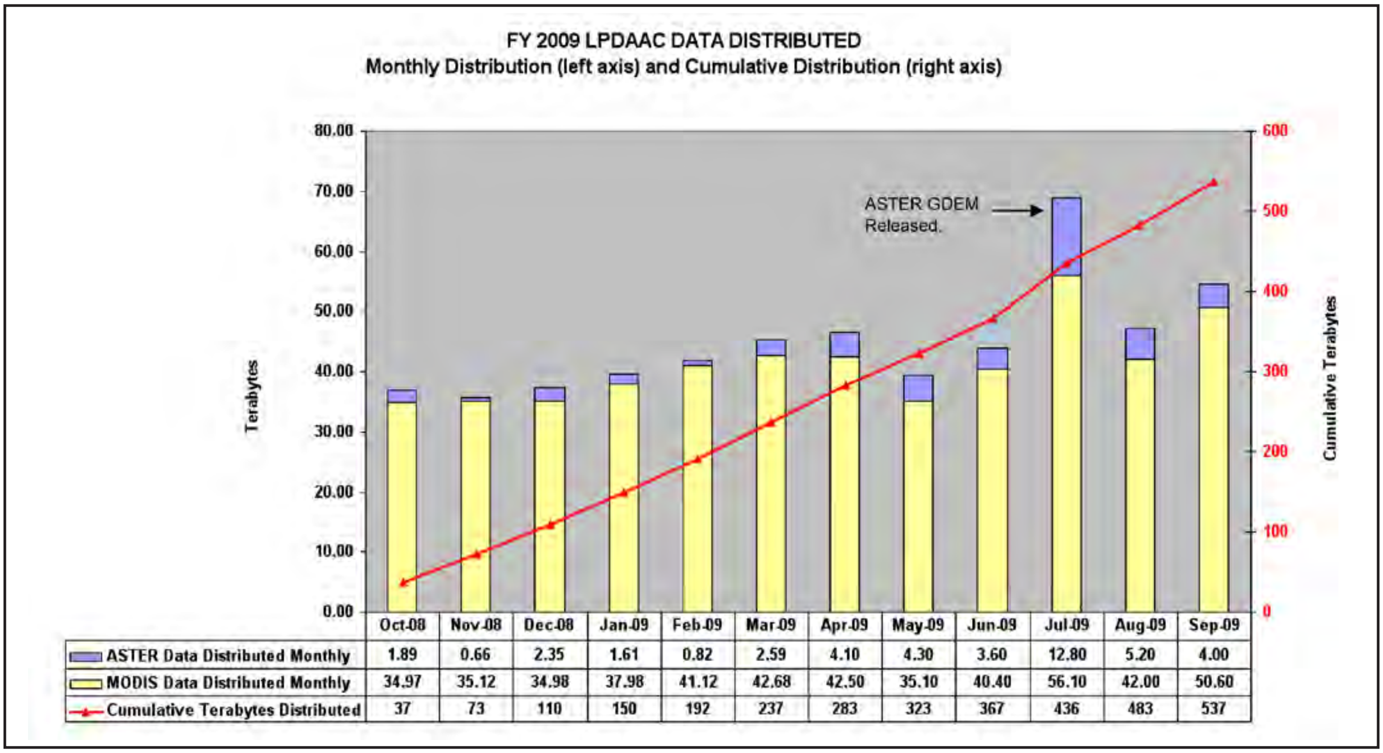


Figure 84. FY 2009 LP DAAC data distributed.

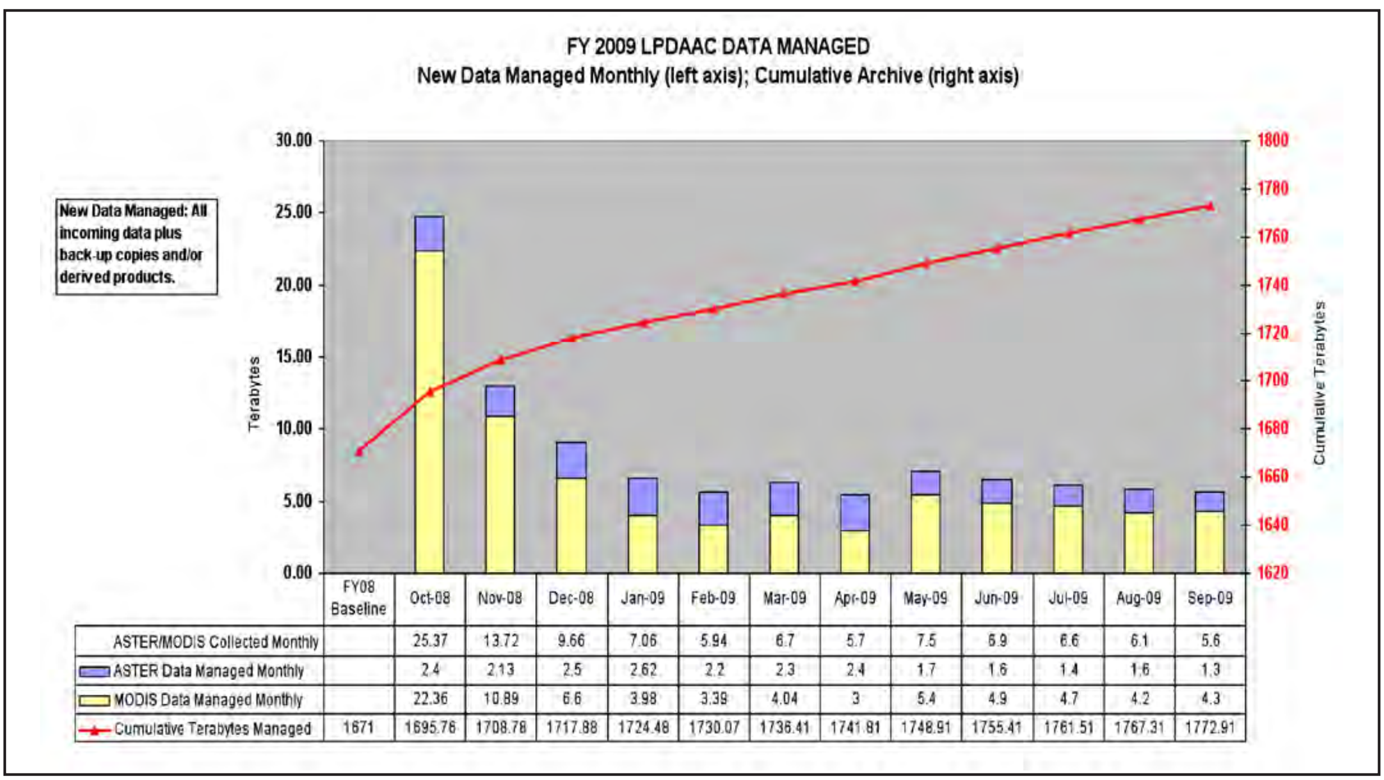
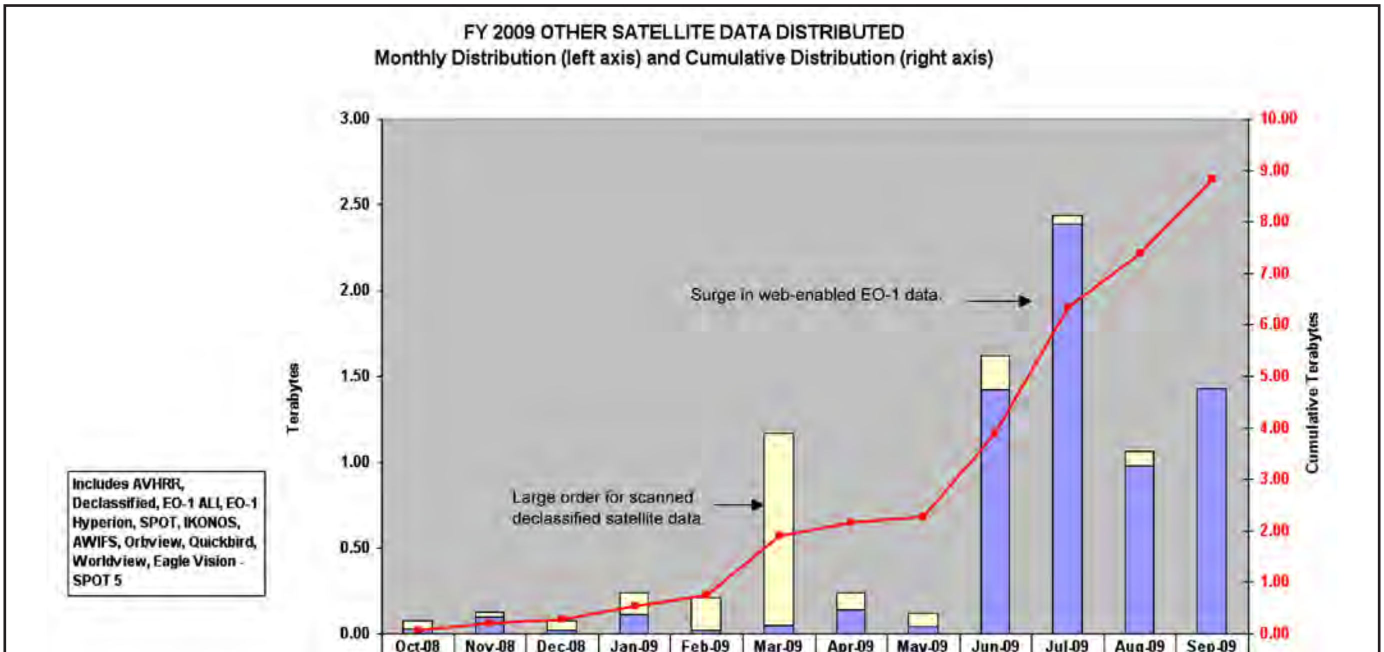
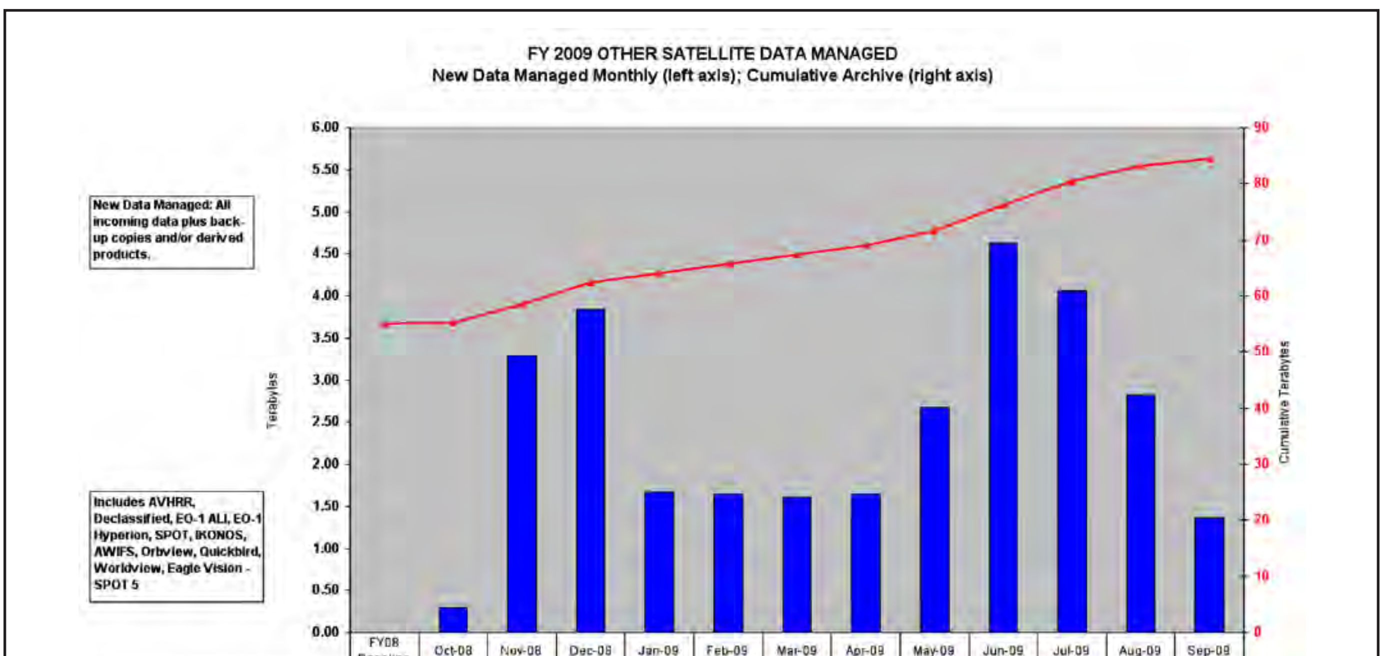


Figure 85. FY 2009 LP DAAC data managed.



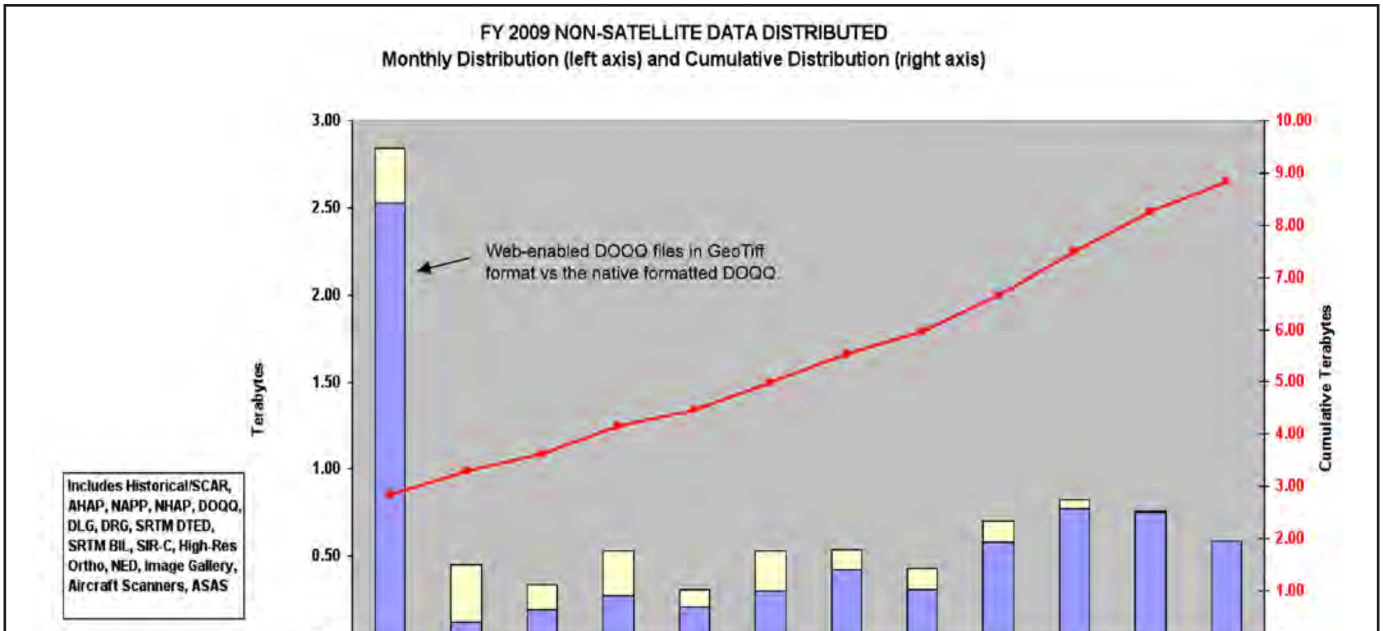
	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Other Satellite Data Sales	0.05	0.03	0.06	0.13	0.19	1.12	0.10	0.08	0.20	0.05	0.08	0.00
Other Satellite Data Web-Enabled	0.03	0.10	0.02	0.11	0.02	0.05	0.14	0.04	1.42	2.39	0.98	1.43
Cumulative Terabytes Distributed	0.08	0.21	0.29	0.53	0.74	1.91	2.15	2.27	3.89	6.33	7.39	8.82

Figure 86. FY 2009 other satellite data distributed.



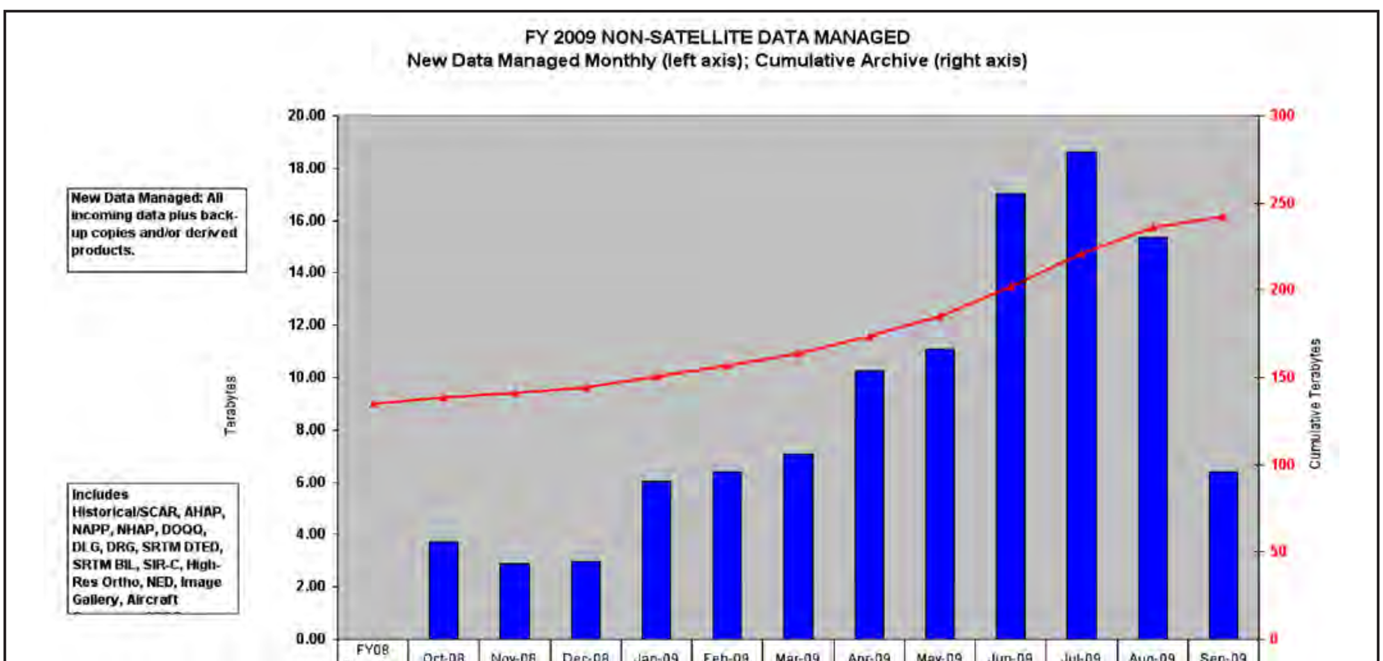
	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Other Sat. Data Collected Monthly		1.66	3.77	4.54	2.66	1.29	1.98	1.64	2.68	4.65	4.04	2.85	1.39
Other Sat. Data Managed Monthly		0.29	3.29	3.84	1.67	1.64	1.61	1.65	2.67	4.62	4.06	2.82	1.36
Cumulative Terabytes Managed	55	55.29	58.58	62.42	64.09	65.73	67.34	68.99	71.66	76.28	80.34	83.16	84.52

Figure 87. FY 2009 other satellite data managed.



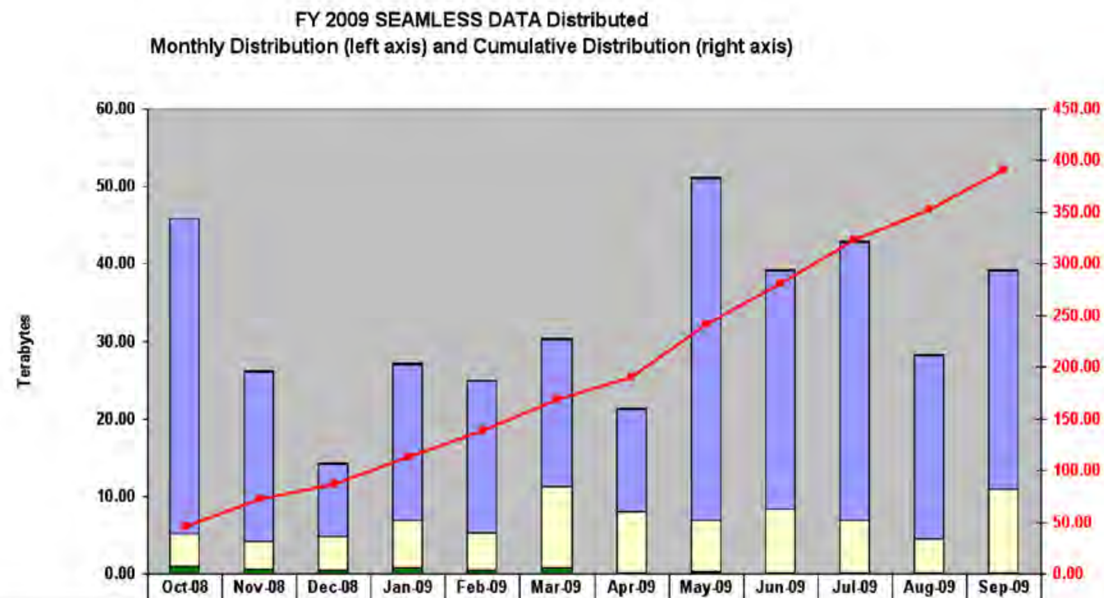
	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Non-Satellite Data Sales	0.31	0.33	0.15	0.26	0.10	0.23	0.12	0.12	0.12	0.05	0.01	0.00
Non-Satellite Data Web-Enabled	2.53	0.12	0.19	0.27	0.21	0.30	0.42	0.31	0.58	0.77	0.75	0.59
Cumulative Terabytes Distributed	2.84	3.29	3.63	4.16	4.47	5.00	5.54	5.97	6.67	7.49	8.25	8.84

Figure 88. FY 2009 non-satellite data distributed.



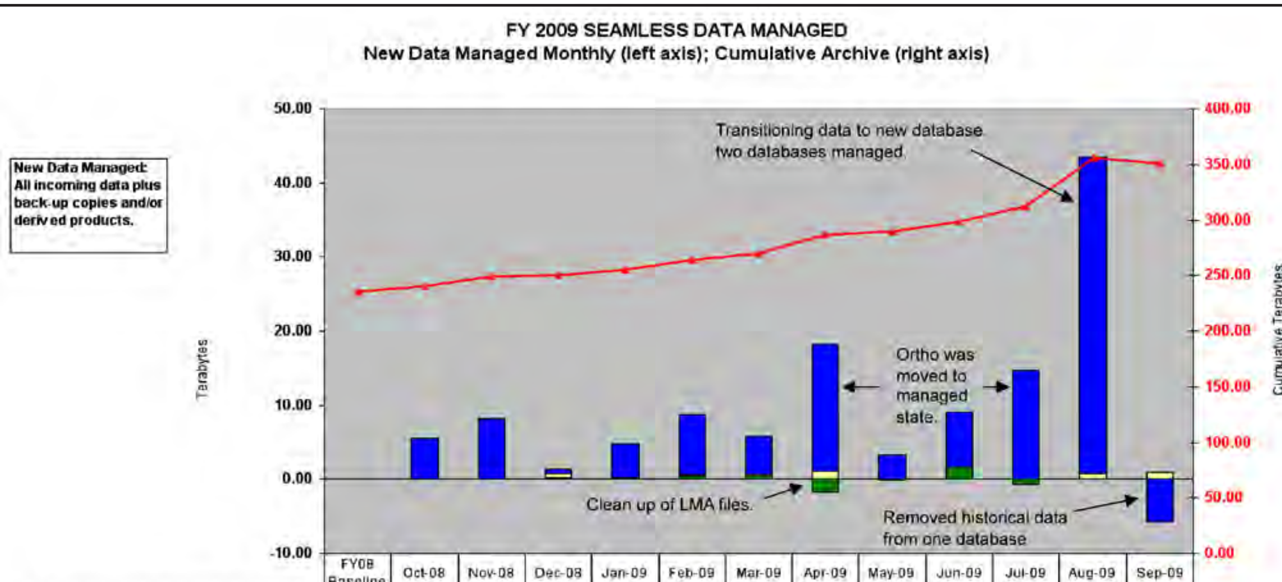
	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Non-Sat. Data Collected Monthly		12.02	5.96	3.24	3.26	10.46	5.05	4.47	4.1	5.63	2.92	1.5	1.17
Non-Sat. Data Managed Monthly		3.73	2.9	2.99	6.01	6.39	7.08	10.24	11.07	17.03	18.6	15.37	6.39
Cumulative Terabytes Managed	134.77	138.5	141.4	144.39	150.4	156.79	163.87	174.11	185.18	202.21	220.81	236.18	242.57

Figure 89. FY 2009 Seamless data managed.



	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Land Cover	0.12	0.08	0.12	0.18	0.12	0.19	0.16	0.16	0.13	0.11	0.12	0.16
Orthoimagery	40.73	21.96	9.37	20.10	19.55	18.97	13.20	44.02	30.68	35.91	23.63	28.10
Elevation	4.11	3.44	4.29	6.15	4.82	10.40	7.87	6.56	8.31	6.65	4.40	10.82
Other	0.96	0.67	0.55	0.75	0.51	0.87	0.18	0.37	0.11	0.20	0.14	0.13
Cumulative Terabytes Distributed	46	72	86	114	139	169	190	242	281	324	352	391

Figure 90. FY 2009 Seamless data distributed.



	FY08 Baseline	Oct-08	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09	Jun-09	Jul-09	Aug-09	Sep-09
Seamless Data Collected Monthly		9.30	2.54	2.52	2.39	4.31	5.44	3.02	3.15	8.58	6.70	4.86	3.11
Land Cover Data Managed Monthly									-0.01				
Orthoimagery Data Managed Monthly		5.49	8.11	0.64	4.50	8.08	5.22	17.09	3.31	7.31	14.65	42.69	-5.73
Elevation Data Managed Monthly		0.08		0.64		0.19		1.12	-0.02	0.01		0.78	0.92
Other Data Managed Monthly				0.17	0.25	0.52	0.60	-1.67	-0.06	1.70	-0.66		
Cumulative Terabytes Managed	235	241	249	250	255	264	270	286	289	298	312	356	351

Figure 91. FY 2009 Seamless data managed.

WorldView-1 (United States), GeoEye-1 (United States), the 5-satellite RapidEye constellation (Germany), multiple DMC satellites (United Kingdom), ResourceSat-1 (India), CBERS-2B (Brazil), SPOT 4 and SPOT 5 (France), along with numerous aerial imagery platforms including digital imaging systems and lidar datasets, as well as new technology assessments.

RST Project staff also assisted the New Missions/Landsat Data Gap study effort during the year and provided data quality assessments from the above systems for consideration in the Data Gap Study report and system assessment and accuracy reports. This effort included a direct downlink test for the CBERS-2B satellite.

The results of USGS assessments were presented at this year's Joint Agency Civil Imagery Evaluation (JACIE) conference. The JACIE group is led by the USGS RST Project and consists of agency representatives from the USGS, NGA, USDA, and NASA. The group hosts an annual workshop to present the results of their assessments of the growing body of remotely sensed data available for use.

This year's 3-day workshop was held in Fairfax, Virginia, (fig. 92) with more than 150 attendees. On the first day of the workshop presentations were given by experts from the USGS, NASA, NOAA, USDA, and NGA who jointly provided a Land Imaging Panel Discussion. Presentations were made by two United States satellite operator firms and six foreign satellite operators, as well as several makers of aerial sensors and dozens of users of remote sensing data. For further information, contact Greg Stensaas, USGS EROS, *stensaas@usgs.gov*, or visit *http://calval.cr.usgs.gov/*.

Figure 92. JACIE Conference, Fairfax, Virginia.

USGS Quality Assurance Plan for Digital Aerial Imagery

The USGS is leading an effort to establish a Quality Assurance (QA) framework for digital aerial imaging and mapping for the nation. Responding to requests and recommendations from the ASPRS, the USGS has established a four-part plan covering: (1) how to properly specify digital aerial imaging work, (2) certification of aerial sensors for use in aerial mapping, (3) certification of aerial data providers, and (4) quality assessment methods of the final product to ensure that it meets specifications.

To address parts one and four, the RST Project is developing a web-based tool to assist with the specification and assessment parts of the plan. This tool (fig. 93), known as the "Spec & Check Tool," is being developed at EROS with strong support from NGP staff in Rolla and Denver, with advice from industry and USGS State Liaisons.

Part 2, sensor type certification, is accelerating with seven sensors from four manufacturers currently (2009) certified. An additional three sensors are in the process of certification at the time of this report, and several other firms are in the preliminary stages to begin certification or have expressed interest in it.

Data provider certification (Part 3) has started progressing with the development of the first USGS aerial range for assessing aerial data products. This range, built around the city of Sioux Falls and the two surrounding counties, has control imagery of 12-inch, 6-inch, and 3-inch resolution (fig. 94). This range, at 54 kilometers by 85 kilometers, also is large enough to use in the assessment of higher-resolution satellite imagery.

This four-part QA plan has been developed in consultation with industry, academia, and the Inter-Agency Digital Imagery Working Group (IADIWG). The IADIWG, a group of 14 Federal agencies that use aerial imagery, was formed by the RST Project to ensure that the talents and interests of other Federal agencies were addressed by the USGS QA Plan. The RST Project also has been working closely with international groups involved with exploring digital sensor technologies and establishing standards for their countries and regions. The Project has enjoyed a close and cordial relationship with the European Spatial Data Research group "EuroSDR" and is working with them to harmonize efforts between Europe and the United States.

To accomplish these things and more, it is crucial that the USGS engage in research study of these rapidly advancing technologies to maintain the USGS reputation for technical excellence in support of the aerial imaging community.

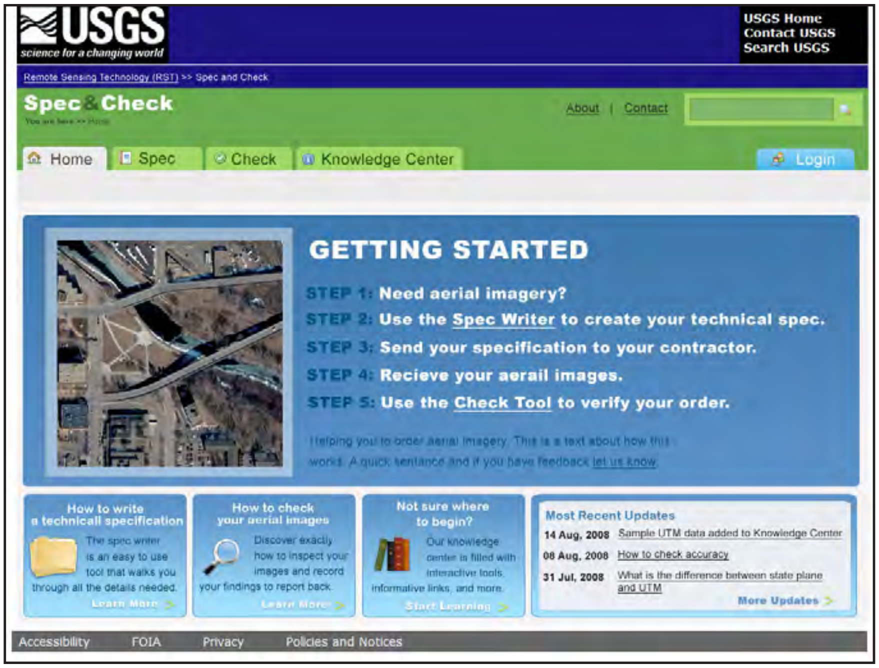


Figure 93. “Spec & Check” tool for aerial imagery quality assurance plan.

The RST Project maintains the Optical Science Lab at USGS Headquarters in Reston, Virginia, for the calibration of aerial film cameras and also has established a digital camera calibration lab at EROS to research the capabilities of new digital systems. Research at EROS has resulted in new calibration methods that will allow easier and more reliable calibration by aerial data providers and higher quality of data for users. For further information, contact Greg Stensaas, USGS EROS, *stensaas@usgs.gov*, or visit *http://calval.cr.usgs.gov/*.

Committee on Earth Observation Satellites and Quality Assurance for Earth Observation

The USGS RST Project has continued its long involvement with the Working Group for Calibration and Validation (WGCV) of the Committee on Earth Observing Satellites (CEOS). This year, Greg Stensaas, RST Project Chief, was elected to vice-chair of the WGCV and will advance to become chair in 2011.

The RST Project continues to support and coordinate CEOS WGCV efforts in order to maximize the effect of work already underway within the USGS and to harmonize USGS efforts with others around the world.

The WGCV group within CEOS exists to share calibration and validation ideas, methods, and results among the various WGCV members with the goal of improving the calibration, quality, and interoperability of data from the various spaceborne sensors operated by the members.

The Quality Assurance for Earth Observation (QA4EO) framework effort launched this year has been supported and promoted by the CEOS WGCV. This is an effort to advance the ability to use data products and knowledge from all Earth observing satellites to address key societal benefit areas. The QA4EO framework, partially written by RST Project staff, has been approved by the CEOS plenary and met with wide acceptance worldwide. This will continue to be refined and promoted further in the coming year. This important framework will provide a solid benefit to all operators of Earth observing satellites and greater benefit to all users of remote sensing data products and knowledge. As part of this framework, the RST Project used the Land Cover and Land Use Change Program cross-calibration of Landsat-class sensors for long-term monitoring of land surface processes and provided a component supporting CEOS QA4EO, such as the worldwide test site catalog and the coincident imaging tool. For further information, contact Greg Stensaas, USGS EROS,*stensaas@usgs.gov*, or visit *http://calval.cr.usgs.gov/*.

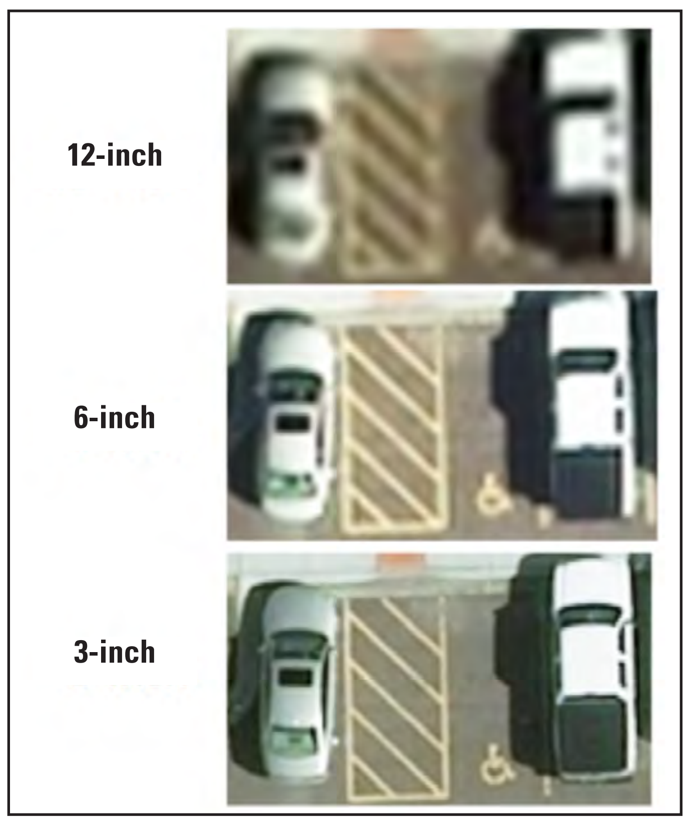


Figure 94. Example of 12-inch, 6-inch, and 3-inch resolution images.

Optical Science Laboratory Film Camera Calibration

The USGS Optical Science Laboratory (OSL) has been responsible for providing calibration services for the airborne film mapping industry since 1973, and is considered to be the only certified analog film camera calibration capability in the United States. This work is considered critical to the national survey and must be continued by the USGS into the foreseeable future.

The photographic multi-collimator calibration process used in the OSL for determining lens and camera coefficients relies on emulsion coated glass calibration plates. The OSL completed its annual 2-week recalibration of the multi-collimator assembly that is used to calibrate aerial film cameras from across the country and around the world. This annual calibration is performed to ensure that the USGS lab is able to continue providing the highest accuracy calibrations for the aerial mapping community.

There has been a marked increase in requests from public and private sector entities in foreign countries for USGS camera calibration services (fig. 95). Currently (2009), inquiries are being fielded from Germany, South Africa, Bolivia, Columbia, Morocco, Canada, and Kenya. This increase in requests primarily is because of the closing of the other analog calibration laboratories, and the discontinued calibration capabilities by manufacturer factory locations, such as Zeiss and Wild. For further information, contact Greg Stensaas, USGS EROS, *stensaas@usgs.gov*, or visit *http://calval.cr.usgs.gov/*.

Coordination and Collaboration

As the USGS endeavors to provide overall leadership for land imaging, both nationally and internationally, the USGS must continue to enhance leadership visibility, improve communications between and among the Federal and non-Federal sectors regarding remote sensing observations of the Earth, and promote excellence in remote sensing for understanding the Earth's land environment through education and training. A large part of the efforts to achieve these objectives will be accomplished through continued activities with CEOS plenary support and CEOS' standing working groups on calibration and validation, on information systems and services, and on education and training. The USGS also has the lead role in development of a prototype for the "Land Surface Imaging (LSI) Virtual Constellation"—a CEOS GEOSS initiative (see web portal at *http://wgiss.ceos.org/lsip/*). The USGS continues to serve as the lead U.S. agency to the International Charter "Space and Major Disasters." Finally, EROS will continue to develop and offer a variety of ongoing education and train-

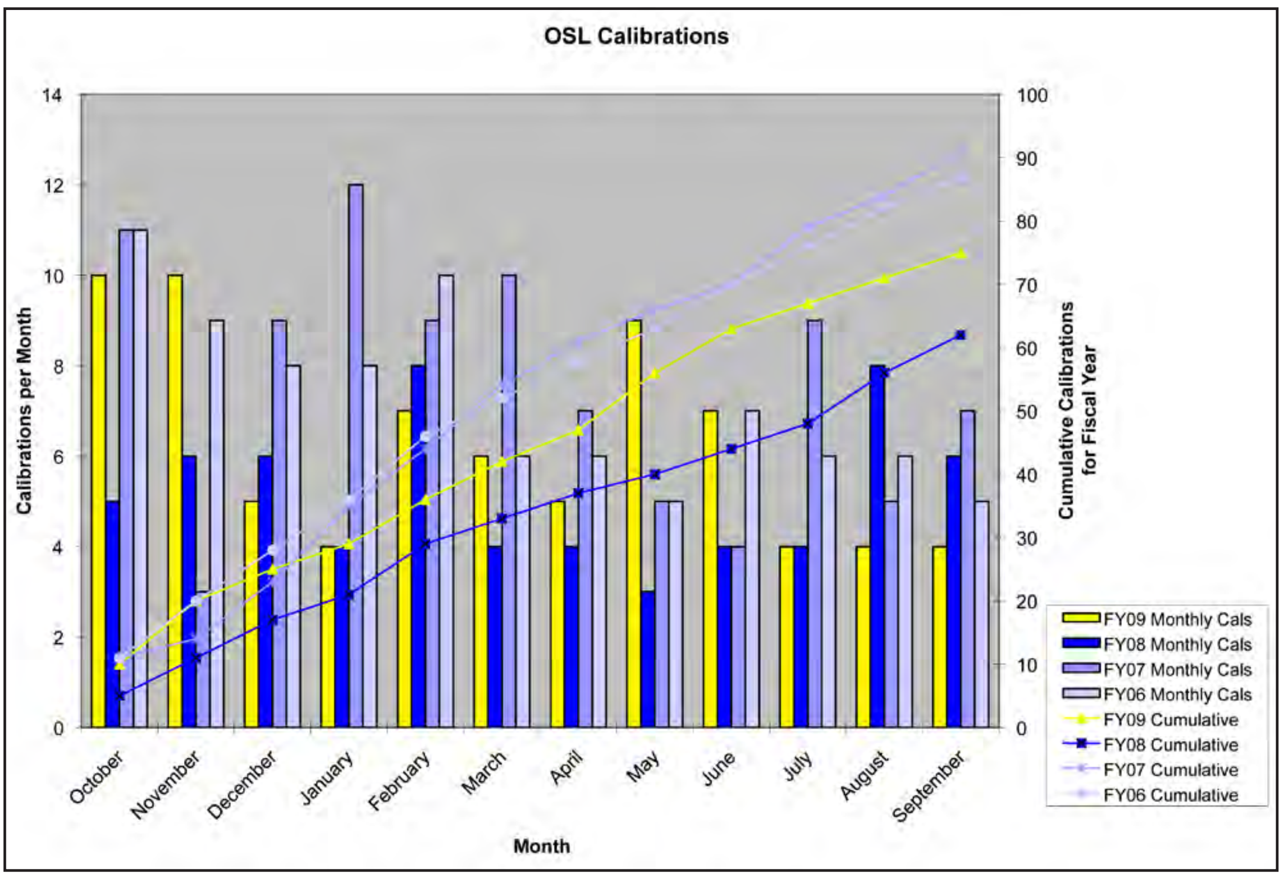


Figure 95. The number of film mapping cameras calibrated at the Laboratory during the last 4 years, and the 18 percent increase in calibrations in FY 2009 (73) from calibrations performed in FY 2008 (62).

ing that together provide remotely sensed data users, and especially potential users, with opportunities to become more informed and educated about all aspects of the science and technology of land remote sensing.

Volcanoes, Earthquakes, and Floods—The International Charter Responds to Disasters

The USGS continues to serve as the lead U.S. agency to the International Charter "Space and Major Disasters." The International Charter aims to provide a unified system of space data acquisition and delivery to those affected by natural or man-made disasters. Each of the 10-member agencies has committed resources to support the provisions of the Charter, and thus is helping to mitigate the effects of disasters on human life and property. As of July 1, 2009, the Charter had responded to 28 events, including 18 floods, 1 landslide, 3 hurricanes, 3 earthquakes, and 3 volcanoes. The USGS submitted 6 of the 28 activations, including an earthquake in Pakistan, floods in Washington, Indiana, and North Dakota (fig. 96), fires in Australia, and an earthquake/volcano in Saudi Arabia.

The USGS provided support for the procedural training of the Nigerian authorized users in Abuja, Nigeria. An authorized user is an "Aassociated body," which may be an institution or service responsible for rescue and civil protection, who has the authority to request an activation of the Charter. The USGS also provided training on procedures for project managers in Denver, Colorado. The project manager interacts with the authorized user on all the data and information requirements and with other parties for any required delivery of value-added products and information. The project manager training provides local emergency management agencies information on Charter procedures for obtaining disaster response support. For further information, contact Brenda Jones, USGS EROS, *bkjones@usgs.gov*.

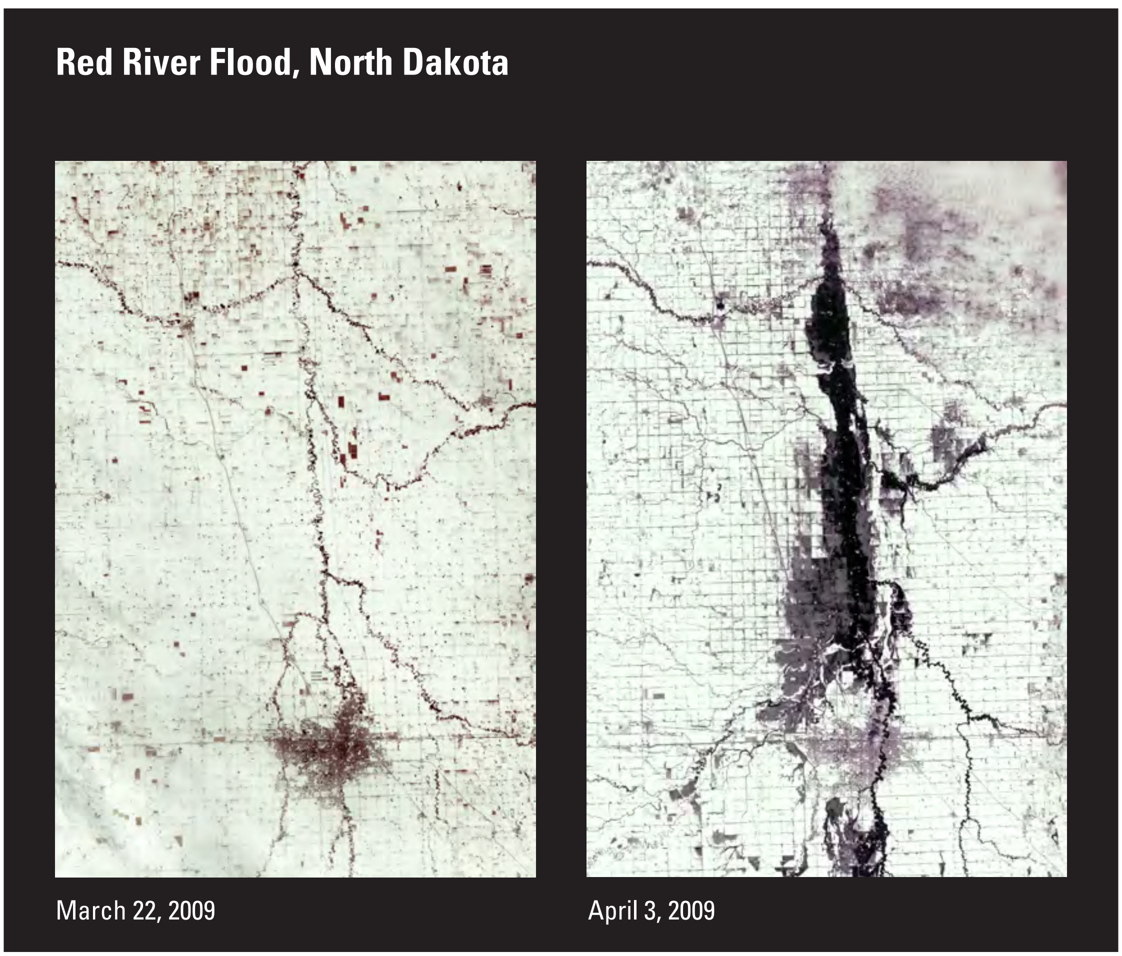


Figure 96. Red River Flood, North Dakota. Landsat pre-and post-event comparison.

Landsat Project Helps Prepare the Geospatial Workforce through iGETT

The Integrated Geospatial Education and Technology Training (iGETT) project is a National Science Foundation Advanced Technological Education Program grant whose focus is to help community and tribal colleges integrate remote sensing and Global Positioning System (GPS) into existing GIS courses and programs. iGETT is a collaboration between the National Council for Geographic Education, the NASA Goddard Landsat Project Science Office, Environmental Systems Research Institute (ESRI), Dell Mar Community College, and the USGS. Ron Beck, USGS LRS Program, was instrumental in the USGS involvement in the initiation of the original grant.

Each participant is committed to 2 years of activities that include workshops, tutorials, and individualized assistance. Forty instructors from around the nation have been exposed to remote sensing and GPS technologies. Participants are expected to create 2-week learning units for use in the classroom. Landsat data play a critical role in the training and learning-unit development, particularly since the opening of the Landsat archive for free (data cost was previously a barrier to these educators).

The USGS plays a key role in iGETT. USGS EROS scientists have given lectures on Landsat applications to demonstrate remote sensing capabilities. Other EROS staff have given tutorials and advice about how to acquire and order Landsat, ASTER, and MODIS data. The Landsat Project's Rachel Headley (fig. 97) also has a role in the overall maturation of the iGETT grant, preparing and giving lectures on specific workshop topics, technical review of participant's learning units, and general support of participants throughout their 2-year commitment.

The final workshop was held in June 2009, and the feedback from the participants made it clear that iGETT had accomplished what it had been developed to achieve. Here is an excerpt from the final workshop survey:

> "iGETT is one of the best programs I've been involved with. I believe iGETT is accomplishing its goals—increasing the RS trained workforce by training college faculty. iGETT staff are super, & helpful, & fun to work with, which makes the program appealing & effective. I feel lucky to receive this quality of training. I started with a very basic knowledge of Remote Sensing (some aerial photography, no space-based). After completing iGETT I feel confident enough to design & instruct a college-level RS course. This would not have been possible without the iGETT program & staff."

Participants continue to work on marketing their geospatial courses and programs within and without their respective campuses. Planning for iGETT-2 is underway, where participants will continue to develop advanced geospatial skills and pass on what they have learned to new groups of 2-year instructors. For further information, contact Kristi Kline, USGS EROS, *kkline@usgs.gov*.

Figure 97. Rachel Headley (left), USGS, and Laura Rocchio (right), Science Systems and Applications, Inc. at the NASA Goddard Landsat Project Science Office, assist Dawn White (center), Lac Courte Oreilles Ojibwa Community College, in mapping wild rice near her college in Wisconsin.

Facilitating Access to Landsat Data for Developing Countries: Creating Archives Without Walls

A USGS policy change has enabled Landsat satellite data to be distributed via the internet to users all over the world, at no cost. The USGS is allowing all people to discover, use, and learn from these observations by creating "archives without walls." Developing countries are taking advantage of the data made available through the opening of the Landsat archive, and are doing so with the support of the international panel for Global Observation of Forest Cover/Global Observation of Landscape Dynamics (GOFC/GOLD). As a result, a regional network data workshop was held at the USGS EROS Center April 23 through May 5, 2009. The workshop was attended by seven regional representatives (six from Africa and one from Russia). The workshop was geared toward providing developing nation experts with training on how to access, manage, and apply data from USGS EROS archives. The seven attendees are involved in various aspects of remote sensing applications, particularly land cover and fire activities, but are restricted in their use of Landsat and other data because of cost (historically) and Internet limitations. With free Landsat data, there is a new opportunity for expanding applications. Specific goals achieved included: (1) disseminate Landsat data to the international science community in regions where currently available distribution methods are not effective, (2) compile regional and in-country datasets relevant to land cover and fire observations and make them freely available to the international community, and (3) engage regional science expertise in the global dataset development, evaluation, and validation. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

Figure 98. Moscow, Russia, from Landsat 7 on October 6, 1999.

Enhanced Data Access to Mid-Resolution Optical Satellite Data

The CEOS Land Surface Imaging (LSI) Constellation Portal for Mid-Resolution Optical LSI Satellite Information (fig. 99) was released in early FY 2009, allowing users to access data acquired by mid-resolution (10 to 100 meter), optical land surface imaging satellite systems operated by CEOS member agencies. The LSI Constellation seeks to promote the efficient, effective, and comprehensive collection, distribution, and application of space-acquired image data of the global land surface, especially to meet societal needs of the global population, such as those that comprise the nine societal benefit areas of GEOSS. The CEOS LSI Portal is accessible at *http://wgiss.ceos.org/lsip/*. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

Figure 99. CEOS LSI Constellation Portal for mid-resolution optical LSI satellite information.

USGS Supports CEOS Working Group on Calibration and Validation

The CEOS Working Group on Calibration and Validation (WGCV) 30th Plenary Meeting was held jointly with the QA4EO framework implementation group meeting at Ilhabela, São Paulo, Brazil, May 25–30, 2009. The meeting was hosted under the auspices of Instituto Nacional de Pesquisas Espaciais (INPE). The purpose of the WGCV meeting was to discuss and ensure long-term confidence in the accuracy and quality of Earth observation (EO) data and products. The WGCV provides a forum for calibration and validation information exchange, coordination, and cooperative activities.

The main goals of the meeting were to present and exchange experiences and knowledge from various agencies/countries and learn about the “best practices” work on inter-comparing large scale EO sensor data at different product levels. The WGCV and QA4EO meetings provided an integrated CEOS technical forum to support Global Earth Observation (GEO) objectives in data quality and availability, and to contribute to the CEOS Implementation Plan for the GEO space segment. It was a successful meeting, and the attendees were impressed by the discussion, presentations, and overall organization. The WGCV-30 agenda, meeting details, seed documents, and minutes from the meeting are posted on the WGCV website at *http://wgcv.ceos.org/documentation/wgcv30.htm*. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

USGS Supports CEOS Working Group on Education: Third Jay Feuquay Memorial Workshop

USGS helped organize and participated in the CEOS Working Group on Education (WGEdu), training, and capacity building remote sensing workshop “Remote Sensing for Disaster Management in Southeastern Asia,” hosted by the Geo-Informatics and Space Technology Development Agency (GISTDA) of Thailand and held February 2009 in Bangkok (fig. 101). The 3-day workshop was attended by more than 30 remote sensing practitioners and educators from 8 Southeastern Asian countries, who were welcomed on the opening day by CEOS Chair Dr. Darasri Dowreang, Deputy Direc-

Figure 100. Catalog of worldwide test sites: *http://calval.cr.usgs.gov/sites_catalog_map.php*.

tor of GISTDA, and by WGEdu Chair, Gordon Bridge from EUMETSAT (European Organization for the Exploitation of Meteorological Satellites). The workshop was the third WGEdu remote sensing workshop held in memory of former USGS LRS Program Coordinator, Jay Feuquay, and enabled by funding support from the USGS. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

USGS Supports CEOS Working Group on Information Systems and Services

Working Group on Information Systems and Services (WGISS) meetings are held twice a year and hosted by CEOS member agencies. WGISS-27 was hosted by CNES (Centre National d'Études Spatiales) in Toulouse, France, May 11–15, 2009 (fig. 102).

WGISS meetings are structured at two levels. There is a plenary level part to the agenda and there are dedicated subgroup parts, which further divided into various special interest groups and projects. The USGS leads and participates in a number of interest groups and projects: (1) Web services interest group—the primary purpose of the Web services interest group is to share experiences and lessons learned among members regarding the application of the Open Geospatial Consortium standard and other standard and non-standard Web services interfaces to enhance the interoperability of their online information systems and services; (2) LSI interest group and lead of the LSI Constellation Portal Project—the purpose of the LSI interest group is to explore and pursue areas and activities where WGISS can support and assist the international LSI user community with information and access to land imaging satellite data; and (3) WGISS Plenary Sessions—the group reviewed the status of various GEO tasks being supported or led by WGISS. Particular attention was given to two areas: collaboration with the WGCV on a data-quality task, and formation of a new WGISS project team to support the GEO data, metadata, and products harmonization task in GEO. The USGS is participating in both efforts. For further information, contact Lyndon Oleson, USGS EROS, *oleson@usgs.gov*.

Figure 101. The third Jay Feuquay Memorial Workshop—Bangkok, Thailand, February 2009.

Figure 102. Participants in WGISS-27 in Toulouse, France, May 2009.

Pecora 17 Conference a Huge Success

The 17th William T. Pecora Memorial Remote Sensing Symposium held in Denver, Colorado, November 16–20, 2008, was a huge success. The Pecora Conference series was established by the USGS and NASA in the 1970s as a means of sharing ideas and experiences resulting from the use of remotely sensed data. With an eye toward the future, the theme of Pecora 17 was “Future of Land Imaging…Going Operational” (fig. 103).

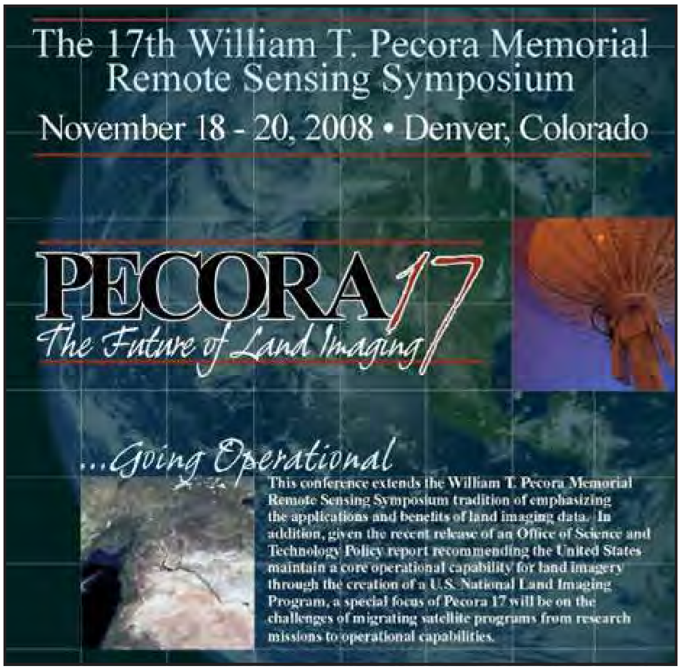


Figure 103. Theme of Pecora 17 “The Future of Land Imaging… Going Operational.”

The conference offered a program on applications of satellite and other remotely sensed data to study, monitor, and manage the Earth’s land surface, as well as technologies to improve satellite data analyses, quality, access, and preservation. The keynote address by Dr. Berrien Moore, Executive Director, Climate Central, Inc., highlighted the enormous challenge we face with Global Climate Change and the role of Earth observations. He emphasized the science—and while we all talk so proudly about the data, as we should, it is the science and operational applications that makes the data relevant. Dr. Gene Whitney highlighted the challenges of moving a new program (securing funding) through the “chain of persuasion” in Washington D.C. Kass Green did a nice job of putting a ribbon around Berrien and Gene’s talks by firmly stating that an “Operational Land Imaging Program” is needed, and that all of us must be an integral part of our future.

Our past Pecora Award recipients reminded us of past successes and at times an uncertain and shaking past, yet we have persevered. Then we heard from international speakers focusing on use, availability, and applications of current Radar and Multi-Spectral Imagery. The meeting closed with a look at “Entering a New Landsat Era—the Future is Now.” With the new Landsat data policy (no cost access to data), we are enabling science and operational applications in ways that have not even been imagined yet. Today, Landsat data can be used to match our application versus what we can afford to buy.

In addition, we heard more than 120 technical presentations that clearly illustrate that we, as a key segment of the remote sensing community, are ready for an Operational Land Imaging Program. It was highlighted that we have so much work to do to make “The Future of Land Imaging Operational;” however, with everything presented at Pecora, everything we already have and are doing today, the lessons we have learned from our past, and what we will have tomorrow—our future is bright. For further information, contact Thomas Holm, USGS EROS, *holm@usgs.gov*.

United Nations Environment Programme

The North American node of UNEP is located at the USGS EROS Center and is a leader in the use of information technology tools such as remote sensing, GIS, and Web mapping to investigate relations between human populations and the environment around the world. Expert knowledge of staff and visiting scientists is applied to information created with these tools to provide policy makers, especially in developing countries, with a scientific basis for making decisions. Patterned after the hugely successful “Africa: Atlas of Our Changing Environment,” two country-focused publications—”Kenya: Atlas of Our Changing Environment” and “Uganda: Atlas of Our Changing Environment”—have been produced in 2009 (fig. 104) and a third atlas focused on Arab countries is underway. These publications seek to safeguard each country’s environment and inspire decision makers to positive action.

In addition to the dissemination of these products as printed media, many other state-of-the-art internet technologies are being used to make this complex information available to decision-makers in a timely and understandable manner. UNEP also is working with Google Earth as a dissemination outlet.

UNEP has played an aggressive role in facilitating the flow of developing country data to the North American scientific community and vice versa. For example, UNEP is participating in the development of the Global Environmental Alert Service and will disseminate environmental early warning information including fire (University of Maryland’s Web Fire Mapper), flood (Dartmouth Flood Observatory), seismic (USGS Earthquake Hazards Program), cyclone (NOAA National Weather Service), and environmental change (USGS and other Earth observations). For further information, contact Michael Crane, USGS EROS, *mpcrane@usgs.gov*.

Figure 104. The covers of the two country-focused publications—"Kenya: Atlas of Our Changing Environment" and "Uganda: Atlas of Our Changing Environment"—produced in FY 2009.

Center Support Activities

Center support at the USGS EROS provides a wide range of services for numerous and highly complex science, engineering, and operational projects, diverse contracts, intricate partner and customer relationships, and national and international activities. Center support functions are located within the internal organizational units of the Center Director's Office, Administrative Services Branch, Data Management Branch, and the Project Management Team. The FY 2009 accomplishments highlighted below include achievements related to communication and outreach, American Reinvestment and Recovery Act efforts, financial customer service, information technology (IT) security, contract management, and performance reporting.

EROS Communications and Outreach

The Communications and Outreach (C&O) Project at the USGS EROS Center had numerous accomplishments through FY 2009. From developing the Landsat 5 Celebration products to releasing the redesigned EROS external website, C&O worked diligently to present, promote, and highlight USGS science and remote sensing research, both locally and nationally.

EROS C&O started the fiscal year by designing a family of products to commemorate the remarkable longevity of Landsat 5. The products included a three-sided island display, a poster, and a brochure honoring 25 years of Landsat 5. These products were introduced at the Pecora 17 Conference in Denver, Colorado (fig. 105), and subsequently were displayed at the USGS National Center in Reston, Virginia. Along with the roll-out of the Landsat 5 Celebration exhibit, C&O produced two 20-foot exhibit backdrops highlighting Landsat and LDCM—Past, Present, and Future, focusing on web-enabled imagery.

Figure 105. The tri-wall display featuring the 25th Anniversary of Landsat 5 made its debut at Pecora 17 in Denver, Colorado, November 2008. Visitors enjoyed the three-sided display and were impressed with the imagery, the information, and the artistic design.

C&O coordinated EROS staff participation in four Bureau sponsored conferences around the Nation—the AGU Fall Meeting, the Association of American Geographers (AAG) Annual Meeting, the ESRI International User Conference, and the National Science Teacher Association (NSTA) National Conference. EROS support included designing exhibit backdrops, staffing; supplying handouts that highlight EROS science and activities; and individual demonstrations to participants on how to search for and download web-enabled imagery through EarthExplorer and GloVis.

Closer to home, C&O staff developed graphics providing a consistent theme for use on EROS products, such as the Who We Are and What We Do Fact Sheet (FS 2008–3055), postcards, rack cards, trading cards, and a pocket folder (fig. 106). New products developed in 2009 include oversized puzzles for use in classroom activities featuring imagery from the Earth As Art collections, the state mosaics, change over time imagery, and trading cards of all 50 United States mosaics.

Figure 106. The C&O team created a consistent theme for outreach products.

On October 1, 2008, the USGS mandated Bureau-wide use of the Information Product Data System (IPDS). IPDS was developed to track, monitor, and manage information products as they progress through the planning, review, approval, and production processes. The C&O Publications Support Team did an exemplary job training and assisting authors in using this new system.

The EROS Librarian took on the huge task of developing a digital archive of all USGS EROS publications; to date there are links to 960 full text records in the database. She also implemented installation of EndNote, a reference management software that replaced Pro-Cite.

Last, but certainly not least, C&O launched the updated and redesigned EROS website (fig. 107). It has a new look and feel, as well as additional features designed to improve the user experience by featuring improved navigation and quicker access to information. For further information, contact Janice Nelson, USGS EROS, *jsnelson@usgs.gov*.

The American Reinvestment and Recovery Act Effort at the USGS EROS

The USGS EROS Center has eight projects of varied scope and with robust funding needs, from security checkpoint replacement to roofing to environmental controls and systems, which all are directly related to maintenance and operations of the facilities that will utilize the funding provided to the USGS by the American Reinvestment and Recovery Act (ARRA).

The EROS ARRA projects have been the result of prior-year foresight in planning. Most recently, with further refinement and work with those responsible within the USGS for the ARRA effort, the EROS projects have been noted for their need and were accorded priority among the projects across the USGS. These projects will serve to enhance and maintain the integrity of the facility for years to come. For further information, contact Bruce Potter, USGS EROS, *potter@usgs.gov*.

Financial Services Renewed Focus on Customer Service

The Finance Team of the Administrative Services Branch increased efforts to provide timely customer support to EROS project managers. This required a redefinition of local service levels while still meeting our Headquarters requirements. The Finance Team restructured staff into project specific teams to provide customized support and increase communication in the delivery of our services.

A Financial Services Customer Survey was sent to all EROS project managers to solicit their feedback on the quality of service they receive and suggestions for improvement. The survey also was given to finance staff to get their view of how well the Team supports these customers. Lots of good information was received, and the Finance Team is actively working to improve service based on this feedback. For further information, contact Shar Van Beek, USGS EROS, *vanbeek@usgs.gov*.

IT Security Certification and Accreditation

A most significant accomplishment of the Enterprise and Information Technology Project was the successful completion of the IT Security Certification and Accreditation (C&A) process, focusing on all USGS Science and Support Systems. These assets represent most of the USGS computing environment and include all desktops/laptops/servers and local-area networks, as well as non-major mission support systems and applications geographically dispersed across the organization under local control.

According to the Federal Information Security Management Act, the USGS is required to have all IT systems complete the C&A process every 3 years. In 2006, the USGS successfully certified and accredited all major IT investments.

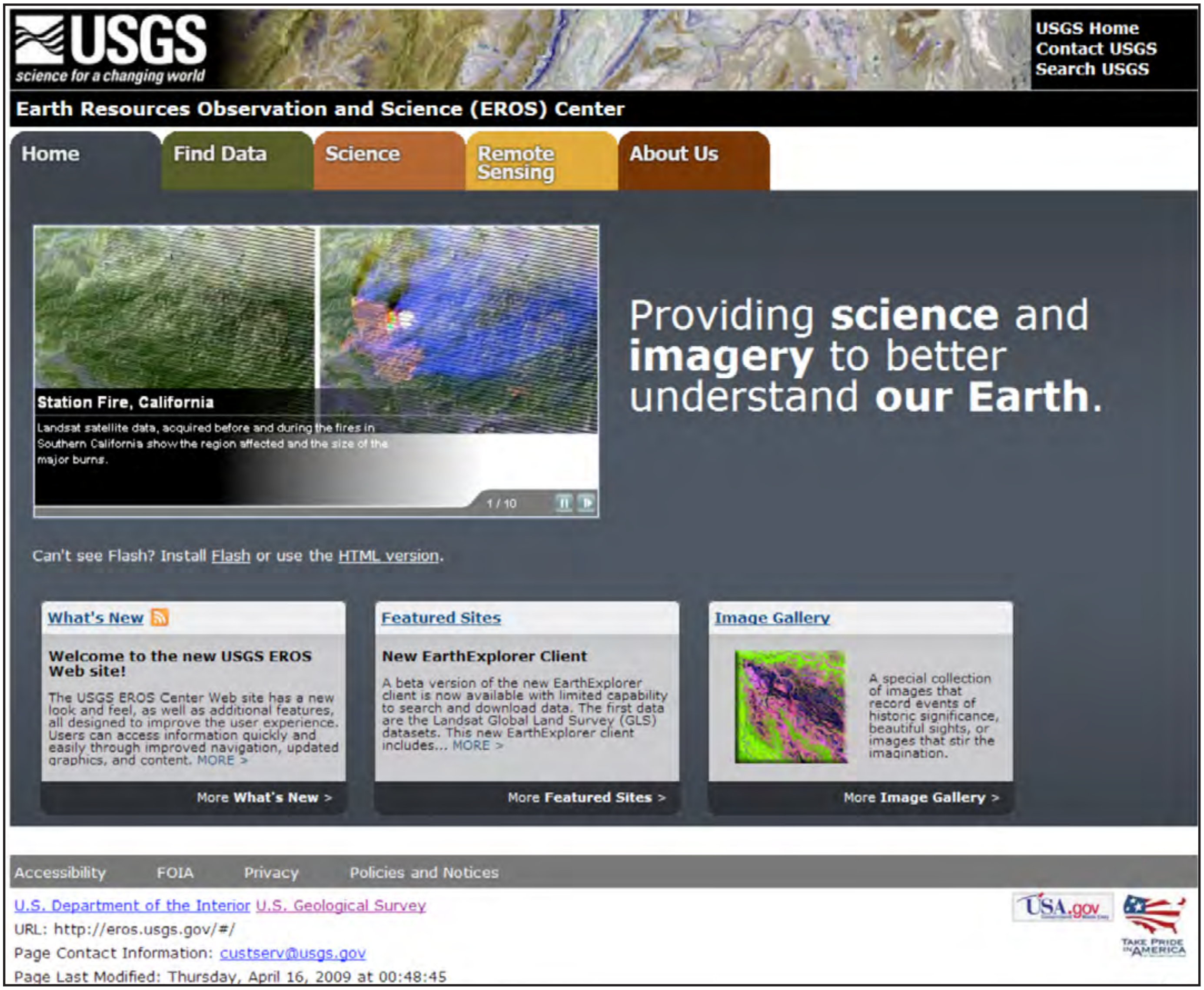


Figure 107. Home page of the recently released EROS external website.

The full C&A process was again required and completed by the USGS in 2009. This year, as the C&A process was completed, the Centers and USGS Headquarters collaborated to make the process easier. USGS Headquarters developed high level responses to the various requirements, whereas each Center focused on specifics unique to the respective Center and its IT environment.

The C&A process consisted of a series of five tasks that were required to be completed. These steps included the development of a thorough IT security threat list, development of a comprehensive contingency plan responsive to those identified threats, completion of the Federal Information Processing Standard 199 information categorization of all assets within the Center, compilation of a complete inventory of Center systems comprising the C&A asset, and, finally, assimilation of responses to the 800-53 IT controls self assessment document indicating compliance with DOI and USGS IT security regulations and directives. For further information, contact David Ochsner, USGS EROS, *ochsner@usgs.gov*.

Contract Management

A combined Government and contractor work environment has proven to be successful for more than 35 years at EROS. This partnership combines Government and industry strengths and ensures workforce flexibility. The Government employees oversee the work of the Center. Today at EROS, approximately 130 Government employees comprise 22 percent of the workforce. USGS contractors comprise the balance of the workforce. The following contractors currently support the EROS mission:

- Earth science, computer science, satellite system engineering, and other professional and technical support services are provided by Stinger Ghaffarian

Technologies (SGT), Arctic Slope Regional Corporation (ASRC) Research and Technology Solutions (ARTS), Science Applications International Corporation (SAIC), and Aerospace.

- Landsat 5 and 7 Mission Operations are provided by Honeywell.
- Facility operation and maintenance are provided by DCT, Inc.
- Physical security is provided by ATA Services, Inc.
- Custodial services are provided by Pleasant Valley Cleaning.
- Convention and meeting planning services are provided by Augustana College.

For further information, contact Joy Hood, USGS EROS, *jhood@usgs.gov*.

Performance Management and Reporting—How Does It Affect Me?

As a result of the Government Performance and Results Act (GPRA) and other mandates, there are a growing number of performance reporting and management requirements that are being imposed on Federal agencies. In addition to GPRA, there are Program Asssessment and Rating Tool reporting; Activity Based Costing reporting; Internal Control Plan reporting; Science Center annual, quarter, and monthly reporting; and others. All of these are directed toward holding ourselves accountable for results that improve taxpayer benefits. Performance management and reporting are forward-looking processes for establishing plans, setting goals, and regularly checking progress toward achieving those plans and goals.

During FY 2009, the Project Management Team (PMT) supported Center management and project teams in a number of specific efforts aimed at promoting consistency and uniformity in performance management and reporting practices. At the same time, the PMT investigated and recommended options to better coordinate responses to the various requirements. For further information, contact Becky Foster, USGS EROS, *foster@usgs.gov*.

Selected Research and Technical Publications

The work cited was published in FY 2009. Online addresses are provided, where available. If a problem or an error is experienced while attempting to access an address, you may need to copy and paste that address into your Web browser for access.

Journal Articles

Beighley, R.E., Eggert, K.G., Dunne, T., He, Y., Gummadi, V., and Verdin, K.L., 2009, Simulating hydrologic and hydraulic processes throughout the Amazon River Basin: Hydrological Processes, v. 23, no. 8, p. 1,221–1,235. (Available online at *http://dx.doi.org/10.1002/hyp.7252*).

Bindschadler, R., Vornberger, P., Fleming, A., Fox, A., Mullins, J.L., Binnie, D.R., Paulsen, S.J., Granneman, B.J., and Gorodetzky, D., 2008, The Landsat Image Mosaic of Antarctica: Remote Sensing of Environment, v. 112, no. 12, p. 4,214–4,226. (Available online at *http://dx.doi.org/10.1016/j.rse.2008.07.006*).

Chander, G., and Groeneveld, D.P., 2009, Intra-annual NDVI validation of the Landsat 5 TM radiometric calibration: International Journal of Remote Sensing, v. 30, no. 6, p. 1,621–1,628. (Available online at *http://www.informaworld.com/10.1080/01431160802524545*).

Chander, G., Markham, B.L., and Helder, D.L., 2009, Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors: Remote Sensing of Environment, v. 113, no. 5, p. 893–903. (Available online at *http://dx.doi.org/10.1016/j.rse.2009.01.007*).

Chander, G., Saunier, S., Choate, M.J., and Scaramuzza, P.L., 2009, SSTL UK-DMC SLIM-6 Data Quality Assessment: IEEE Transactions on Geoscience and Remote Sensing, v. 47, no. 7, p. 2,380–2,391. (Available online at *http://dx.doi.org/10.1109/TGRS.2009.2013206*).

Chen, M., Liu, S., Tieszen, L.L., and Hollinger, D.Y., 2008, An improved state-parameter analysis of ecosystem models using data assimilation: Ecological Modelling, v. 219, no. 3–4, p. 317–326. (Available online at *http://dx.doi.org/10.1016/j.ecolmodel.2008.07.013*).

Cheung, W.H., Senay, G.B., and Singh, A., 2008, Trends and spatial distribution of annual and seasonal rainfall in Ethiopia: International Journal of Climatology, v. 28, no. 13, p. 1,723–1,734. (Available online at *http://dx.doi.org/10.1002/joc.1623*).

Funk, C.C., and Brown, M., 2009, Declining global per capita agricultural production and warming oceans threaten food security: Food Security, v. 1, no. 3, p. 271–289. (Available online at *http://dx.doi.org/10.1007/s12571-009-0026-y*).

Funk, C.C., and Budde, M.E., 2009, Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe: Remote Sensing of Environment, v. 113, no. 1, p. 115–125. (Available online at *http://dx.doi.org/10.1016/j.rse.2008.08.015*).

Gallant, A.L., 2009, What you should know about land-cover data: Journal of Wildlife Management, v. 73, no. 5, p. 796–

805. (Available online at *http://dx.doi.org/10.2193/2007-509*).

Gu, Y., Hunt, E., Wardlow, B., Basara, J.B., Brown, J.F., and Verdin, J.P., 2008, Evaluation of MODIS NDVI and NDWI for vegetation drought monitoring using Oklahoma Mesonet soil moisture data: Geophysical Research Letters, v. 35, no. L22401. (Available online at *http://dx.doi.org/10.1029/2008GL035772*).

Helder, D.L., Markham, B.L., Thome, K.J., Barsi, J.A., Chander, G., and Malla, R., 2008, Updated radiometric calibration for the Landsat-5 thematic mapper reflective bands: IEEE Transactions on Geoscience and Remote Sensing, v. 46, no. 10, p. 3,309–3,325. (Available online at *http://dx.doi.org/10.1109/TGRS.2008.920966*).

Herman-Brunson, K.M., Jenson, K.C., Kaczor, N.W., Swanson, C.C., and Klaver, R.W., 2009, Nesting ecology of greater sage-grouse Centrocercus urophasianus at the eastern edge of their historic distribution: Wildlife Biology, v. 15, no. 3, p. 237–246.

Huang, C., Goward, S.N., Masek, J.G., Gao, F., Vermote, E.F., Thomas, N., Schleeweis, K., Kennedy, R.E., Zhu, Z., Eidenshink, J.C., and Townshend, J.R.G., 2009, Development of time series stacks of Landsat images for reconstructing forest disturbance history: International Journal of Digital Earth, v. 2, no. 3, p. 195–218, available only online at *http://dx.doi.org/10.1080/17538940902801614*.

Huang, C., Goward, S.N., Schleeweis, K., Thomas, N., Masek, J.G., and Zhu, Z., 2009, Dynamics of national forests assessed using the Landsat record–case studies in eastern United States: Remote Sensing of Environment, v. 113, no. 7, p. 1,430–1,442. (Available online at *http://dx.doi.org/10.1016/j.rse.2008.06.016*).

Jacques, C.N., Jenks, J.A., and Klaver, R.W., 2009, Seasonal movements and home-range use by female pronghorns in sagebrush-steppe communities of western South Dakota: Journal of Mammalogy, v. 90, no. 2, p. 433–441. (Available online at *http://dx.doi.org/10.1644/07-MAMM-A-395.1*).

Jiang, L., Liao, M., Lin, H., and Yang, L., 2009, Synergistic use of optical and InSAR data for urban impervious surface mapping–a case study in Hong Kong: International Journal of Remote Sensing, v. 30, no. 11, p. 2,781–2,796. (Available online at *http://dx.doi.org/10.1080/01431160802555838*).

Karstensen, K.A., and Loveland, T.R., 2009, Monitoring land use on military installations: The Military Engineer, v. 101, no. 657, p. 47–48. (Available online at *http://themilitaryengineer.com/TME/TMEpastissuespage.htm*).

Kwoun, O., and Lu, Z., 2009, Multi-temporal RADARSAT-1 and ERS backscattering signatures of coastal wetlands in southeastern Louisiana: Photogrammetric Engineering & Remote Sensing, v. 75, no. 5, p. 607–617. (Available online at *http://www.asprs.org/publications/pers/*).

Larocque, G.R., Bhatti, J.S., Liu, J., Ascough II, J.C., Luckai, N., and Gordon, A.M., 2008, The importance of uncertainty and sensitivity analyses in process-based models of carbon and nitrogen cycling in terrestrial ecosystems with particular emphasis on forest ecosystems: Selected papers from a workshop organized by the International Society for Ecological Modelling (ISEM) at the third biennial meeting of the International Environmental Modelling and Software Society (IEMSS) in Burlington, Vermont, USA, August 9–13, 2006: Ecological Modelling, v. 219, no. 3–4, p. 261–263. (Available online at *http://dx.doi.org/10.1016/j.ecolmodel.2008.07.010*).

Li, M., Huang, C., Zhu, Z., Shi, H., Lu, H., and Peng, S., 2009, Assessing rates of forest change and fragmentation in Alabama, USA, using the vegetation change tracker model: Forest Ecology and Management, v. 257, no. 6, p. 1,480–1,488. (Available online at *http://dx.doi.org/10.1016/j.foreco.2008.12.023*).

Liu, J., Liu, S., Loveland, T.R., and Tieszen, L.L., 2008, Integrating remotely sensed land cover observations and a biogeochemical model for estimating forest ecosystem carbon dynamics: Ecological Modelling, v. 219, no. 3–4, p. 361–372. (Available online at *http://dx.doi.org/10.1016/j.ecolmodel.2008.04.019*).

Liu, S., Anderson, P., Zhou, G., Kauffman, B., Hughes, F., Schimel, D., Watson, V., and Tosi, J., 2008, Resolving model parameter values from carbon and nitrogen stock measurements in a wide range of tropical mature forests using nonlinear inversion and regression trees: Ecological Modelling, v. 219, no. 3–4, p. 327–341. (Available online at *http://dx.doi.org/10.1016/j.ecolmodel.2008.07.025*).

Pielke Sr., R.A., Davey, C.A., Niyogi, D., Fall, S., Steinweg-Woods, J., Hubbard, K., Lin, X., Cai, M., Lim, Y.K., Li, H., Nielsen-Gammon, J., Gallo, K.P., Hale, R., Mahmood, R., Foster, S., McNider, R.T., and Blanken, P., 2009, Reply to comment by David E. Parker et al. on "Unresolved issues with the assessment of multidecadal global land surface temperature trends": Journal of Geophysical Research D–Atmospheres, v. 114, no. D05105. (Available online at *http://dx.doi.org/10.1029/2008JD010938*).

Preisler, H.K., Burgan, R.E., Eidenshink, J.C., Klaver, J.M., and Klaver, R.W., 2009, Forecasting distributions of large federal-lands fires utilizing satellite and gridded weather information: International Journal of Wildland Fire, v. 18, no. 5, p. 508–516. (Available online at *http://dx.doi.org/10.1071/WF08032*).

Ramsey III, E., Werle, D., Lu, Z., Rangoonwala, A., and Suzuoki, Y., 2009, A case of timely satellite image acquisitions in support of coastal emergency environmental response management: Journal of Coastal Research, v. 25, no. 5, p. 1,168–1,172. (Available online at *http://dx.doi.org/10.2112/JCOASTRES-D-09-00012.1*).

Reed, B.C., Budde, M.E., Spencer, P., and Miller, A.E., 2009, Integration of MODIS-derived metrics to assess interannual variability in snowpack, lake ice, and NDVI in southwest Alaska: Remote Sensing of Environment , v. 113, no. 7, p. 1,443–1,452. (Available online at *http://dx.doi.org/10.1016/j.rse.2008.07.020*).

Reeves, M.C., Ryan, K.C., Rollins, M.G., and Thompson, T.G., 2009, Spatial fuel data products of the LANDFIRE Project: International Journal of Wildland Fire, v. 18, no. 3, p. 250–267. (Available online at *http://dx.doi.org/10.1071/WF08086*).

Rollins, M.G., 2009, LANDFIRE: a nationally consistent vegetation, wildland fire, and fuel assessment: International Journal of Wildland Fire, v. 18, no. 3, p. 235–249. (Available online at *http://dx.doi.org/10.1071/WF08088*).

Senay, G.B., 2008, Modeling landscape evapotranspiration by integrating land surface phenology and a water balance algorithm: Algorithms, v. 1, no. 2, p. 52–68, available only online at *http://dx.doi.org/10.3390/a1020052*.

Sohl, T.L., and Sayler, K.L., 2008, Using the FORE-SCE model to project land-cover change in the southeastern United States: Ecological Modelling, v. 219, no. 1–2, p. 49–65. (Available online at *http://dx.doi.org/10.1016/j.ecolmodel.2008.08.003*).

Stoker, J.M., 2009, Volumetric visualization of multiple-return LIDAR data–using voxels: Photogrammetric Engineering & Remote Sensing, v. 75, no. 2, p. 109–112. (Available online at *http://www.asprs.org/publications/pers/2009journal/february/highlight2.pdf*).

Strack, J.E., Pielke Sr., R.A., Steyaert, L.T., and Knox, R.G., 2008, Sensitivity of June near-surface temperatures and precipitation in the eastern United States to historical land cover changes since European settlement: Water Resources Research, v. 44, no. W11401. (Available online at *http://dx.doi.org/10.1029/2007WR006546*).

Svancara, L.K., Scott, J.M., Loveland, T.R., and Pidgorna, A.B., 2009, Assessing the landscape context and conversion risk of protected areas using satellite data products: Remote Sensing of Environment, v. 113, no. 7, p. 1,357–1,369. (Available online at *http://dx.doi.org/10.1016/j.rse.2008.11.015*).

Tadesse, T., Haile, M., Senay, G.B., Wardlow, B.D., and Knutson, C.L., 2008, The need for integration of drought monitoring tools for proactive food security management in sub-Saharan Africa: Natural Resources Forum, v. 32, no. 4, p. 265–279. (Available online at *http://dx.doi.org/10.1111/j.1477-8947.2008.00211.x*).

Tan, Z., Liu, S., Tieszen, L.L., and Tachie-Obeng, E., 2009, Simulated dynamics of carbon stocks driven by changes in land use, management and climate in a tropical moist ecosystem of Ghana: Agriculture, Ecosystems & Environment, v. 130, no. 3–4, p. 171–176. (Available online at *http://dx.doi.org/10.1016/j.agee.2009.01.004*).

Tan, Z., Tieszen, L.L., Tachie-Obeng, E., Liu, S., and Dieye, A.M., 2009, Historical and simulated ecosystem carbon dynamics in Ghana–land use, management, and climate: Biogeosciences, v. 6, no. 1, available only online at *http://www.biogeosciences.net/*.

Verdin, K.L., and Worstell, B.B., 2008, A fully distributed implementation of mean annual streamflow regional regression equations: Journal of the American Water Resources Association, v. 44, no. 6, p. 1,537–1,547. (Available online at *http://dx.doi.org/10.1111/j.1752-1688.2008.00258.x*).

Vogelmann, J.E., Tolk, B.L., and Zhu, Z., 2009, Monitoring forest changes in the southwestern United States using multitemporal Landsat data: Remote Sensing of Environment, v. 113, no. 8, p. 1,739–1,748. (Available online at *http://dx.doi.org/10.1016/j.rse.2009.04.014*).

Weng, Y.L., Gong, P., and Zhu, Z.-L., 2008, Reflectance spectroscopy for the assessment of soil salt content in soils of the Yellow River Delta of China: International Journal of Remote Sensing, v. 29, no. 19, p. 5,511–5,531. (Available online at *http://dx.doi.org/10.1080/01431160801930248*).

Wickham, J.D., Riitters, K.H., Wade, T.G., and Homer, C.G., 2008, Temporal change in fragmentation of continental US forests: Landscape Ecology, v. 23, no. 8, p. 891–898. (Available online at *http://dx.doi.org/10.1007/s10980-008-9258-z*).

Wimberly, M.C., Cochrane, M.A., Baer, A.D., and Pabst, K., 2009, Assessing fuel treatment effectiveness using satellite imagery and spatial statistics: Ecological Applications, v. 19, no. 6, p. 1,377–1,384. (Available online at *http://dx.doi.org/10.1890/08-1685.1*).

Xian, G., Homer, C.G., and Fry, J.A., 2009, Updating the 2001 National Land Cover Database land cover classification to 2006 by using Landsat imagery change detection methods: Remote Sensing of Environment, v. 113, no. 6, p. 1,133–1,147. (Available online at *http://dx.doi.org/10.1016/j.rse.2009.02.004*).

Yang, L., Jiang, L., Lin, H., and Liao, M., 2009, Quantifying sub-pixel urban impervious surface through fusion of optical and InSAR imagery: GIScience & Remote Sensing, v. 46, no. 2, p. 161–171. (Available online at *http://dx.doi.org/10.2747/1548-1603.46.2.161*).

Zhao, S., Liu, S., Li, Z., and Sohl, T.L., 2009, Ignoring detailed fast-changing dynamics of land use overestimates regional terrestrial carbon sequestration: Biogeosciences,

v. 6, no. 8, p. 1,647–1,654, available only online at *http://www.biogeosciences.net/6/1647/2009/*.

Zhou, G., Guan, L., Wei, X., Tang, X., Liu, S., Liu, J., Zhang, D., and Yan, J., 2008, Factors influencing leaf litter decomposition–an intersite decomposition experiment across China: Plant and Soil, v. 311, no. 1–2, p. 61–72. (Available online at *http://dx.doi.org/10.1007/s11104-008-9658-5*).

Larocque, G.R., Bhatti, J.S., Liu, J., Ascough II, J.C., Luckai, N., and Gordon, A.M., eds., 2008, Ecological Modelling, v. 219, no. 3–4. (Available online at *http://www.sciencedirect.com*).

Books

United Nations Environment Programme, 2009, Kenya–atlas of our changing environment: Nairobi, Kenya, United Nations Environment Programme, 374 p. (Available online at *http://www.unep.org/dewa/africa/kenyaatlas/*).

Book Chapters

Alexandrov, G.A., Chan, D., Chen, M., Gurney, K., Higuchi, K., Ito, A., Jones, C.D., Komarov, A., Mabuchi, K., Matross, D.M., Veroustraete, F., and Verstraeten, W.W., 2008, Model-data fusion in studies of the terrestrial carbon sink, chap. 19 *in* Jakeman, A.J., Voinov, A.A., Rizzoli, A.E., and Chen, S.H., eds., Environmental modelling, software and decision support, 3: Oxford, Elsevier Science, p. 329–344. (Available online at *http://dx.doi.org/10.1016/S1574-101X(08)00619-4*).

Brown, J.F., Maxwell, S.K., and Pervez, S., 2009, Mapping irrigated lands across the United States using MODIS satellite imagery, chap. 6 *in* Thenkabail, P., Lyon, G.J., Biradar, C.M., and Turral, H., eds., Remote Sensing of Global Croplands for Food Security: Boca Raton, FL, Taylor & Francis, p. 177–198.

Davis, B.N., and Maddox, B.G., 2009, Real-time visualization techniques, chap. 44 *in* Madden, M., ed., Manual of GIS: Bethesda, MD, American Association of Photogrammetry and Remote Sensing, p. 871–883.

Gesch, D.B., Gutierrez, B.T., and Gill, S.K., 2009, Coastal elevations, chap. 2 *in* Titus, J.G., Anderson, K.E., Cahoon, D.R., Gesch, D.B., Gill, S.K., Gutierrez, B.T., Thieler, E.R., and Williams, S.J., ld. auths., Coastal sensitivity to sea level rise–a focus on the Mid-Atlantic Region: A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, U.S. Environmental Protection Agency, Synthesis and Assessment Product 4.1, p. 25–42. (Available online at *http://www.climatescience.gov/Library/sap/sap4-1/final-report/sap4-1-final-report-all.pdf*).

Giri, C.P., Reed, B.C., Hastings, D., and Tateishi, R., 2009, Status and future of global databases, chap. 13 *in* Madden, M., ed., Manual of GIS: Bethesda, MD, American Association of Photogrammetry and Remote Sensing, p. 113–137.

Larocque, G.R., Bhatti, J.S., Gordon, A.M., Luckai, N., Wattenbach, M., Liu, J., Peng, C., Arp, P.A., Liu, S., Zhang, C.F., Komarov, A., Grabarnik, P., Sun, J., and White, T., 2008, Uncertainty and sensitivity issues in process-based models of carbon and nitrogen cycles in terrestrial ecosystems, chap. 18 *in* Jakeman, A.J., Voinov, A.A., Rizzoli, A.E., and Chen, S.H., eds., Environmental modelling, software and decision support, 3: Oxford, Elsevier Science, p. 307–327. (Available online at *http://dx.doi.org/10.1016/S1574-101X(08)00618-2*).

Senay, G.B., Budde, M.E., Verdin, J.P., and Rowland, J.D., 2009, Estimating actual evapotranspiration from irrigated fields using a simplified surface energy balance approach, chap. 13 *in* Thenkabail, P., Lyon, G.J., Biradar, C.M., and Turral, H., eds., Remote Sensing of Global Croplands for Food Security: Boca Raton, FL, Taylor & Francis, p. 317–330.

Vogelmann, J.E., Ohlen, D.O., Zhu, Z., Howard, S.M., and Rollins, M.G., 2009, The role of remote sensing and GIS for wildland fire hazard assessment, chap. 35 *in* Madden, M., ed., Manual of GIS: Bethesda, MD, American Association of Photogrammetry and Remote Sensing, p. 677–698.

Reports

USGS Fact Sheets

U.S. Geological Survey, 2008, Opening the Landsat archive: U.S. Geological Survey Fact Sheet 2008–3091, 1 p. (Available online at *http://pubs.er.usgs.gov/usgspubs/fs/fs20083091*).

U.S. Geological Survey, 2009, Shuttle Radar Topography Mission (SRTM): U.S. Geological Survey Fact Sheet 2009–3087, 2 p. (Available online at *http://pubs.er.usgs.gov/usgspubs/fs/fs20093087*).

USGS General Information Products

U.S. Geological Survey, 2008, EarthNow!: U.S. Geological Survey General Information Product 81, 2 p. (Available online at *http://pubs.er.usgs.gov/usgspubs/gip/gip81*).

U.S. Geological Survey, 2008, See your state from space: U.S. Geological Survey General Information Product 82, 2 p.

(Available online at *http://pubs.er.usgs.gov/usgspubs/gip/gip82*).

U.S. Geological Survey, 2009, Earth Resources Observation and Science (EROS) Center popular Websites: U.S. Geological Survey General Information Product 84, 1 p. (Available online at *http://pubs.er.usgs.gov/usgspubs/gip/gip84*).

USGS Open-File Reports

Fry, J.A., Coan, M.J., Homer, C.G., Meyer, D.K., and Wickham, J.D., 2009, Completion of the National Land Cover Database (NLCD) 1992–2001 land cover change retrofit product, U.S. Geological Survey Open-File Report 2008–1379, 19 p., available only online at *http://pubs.er.usgs.gov/usgspubs/ofr/ofr20081379*.

USGS Scientific Investigations Reports

Artan, G.A., Smith, J.L., and Verdin, J.P., 2009, Monitoring snow water status with a distributed snowmelt model, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 1, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Bliss, N.B., 2009, A new method of multiscale topographic analysis–extracting landforms, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 3, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Chen, M., Liu, S., and Tieszen, L.L., 2009, Mutually interactive state-parameter estimation of a carbon cycle model using a smoothed ensemble kalman filter, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 7–8, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Li, Z. and Tan, Z., 2009, Regional modeling of carbon dynamics change in the Green River Basin, Wyoming, based on remotely sensed data, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 28–29, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Liu, S., Li, Z., Loveland, T.R., and Tieszen, L.L., 2009, Modeling terrestrial carbon dynamics in the eastern United States, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 29, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Liu, S., Rover, J.A., Zhang, L., Wylie, B.K., Ji, L., and Bliss, N.B., 2009, De-trending for climatic variations to reveal stressed ecosystems, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 33, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Polloni, C., Pantea, M., Kelly, M., and Davis, B.N., 2009, Animation and publication of three-dimensional and four-dimensional physical models, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 11, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Poppenga, S.K., Worstell, B.B., Stoker, J.M., and Greenlee, S.K., 2009, Comparison of surface flow features from lidar-derived digital elevation models with historical elevation and hydrography data for Minnehaha County, South Dakota: U.S. Geological Survey Scientific Investigations Report 2009–5065, 24 p. (Available online at *http://pubs.usgs.gov/sir/2009/5065/*).

Queija, V.R., Worstell, B.B., and Greenlee, S.K., 2009, Elevation derivatives for modeling post-wildfire debris flows, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 33, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Senay, G.B., Budde, M.E., and Verdin, J.P., 2009, Landscape evapotranspiration estimation using a simplified surface energy balance approach for watershed water-balance modeling, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 35, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Sohl, T.L. and Sayler, K.L., 2009, An integrated modeling approach for analyzing the effects of an expanding biomass-for-biofuel economy in the northern Great Plains, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 34, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Sundquist, E.T., Ackerman, K., Stallard, R.F., and Bliss, N.B., 2009, Modeling the historical influence of soil and water management on sediment and carbon budgets in the United States, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–

Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 37–38, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Tan, Z., Tieszen, L.L., and Tachie-Obeng, E., 2009, Ecosystem carbon budgets and crop yields in a tropical savanna ecosystem as related to changes in climate and management, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 39–40, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Zhang, L., Wylie, B.K., Ji, L., Gilmanov, T., and Tieszen, L.L., 2009, Empirically modeling carbon fluxes in the northern Great Plains grasslands, *in* Brady, S.R., ed., Proceedings of the Second All-USGS Modeling Conference, February 11–14, 2008–Painting the big picture: U.S. Geological Survey Scientific Investigations Report 2009–5013, p. 48, available only online at *http://pubs.usgs.gov/sir/2009/5013/*.

Conference Proceedings

Chen, X., and Ohlen, D.O., 2009, Use of multi-temporal Landsat images to monitor forest disturbance (1987–2007) in the Black Hills of South Dakota, *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 3–10.

Faundeen, J.L., 2009, A selection and archiving strategy for science records, *in* Archiving 2009, Crystal City, VA, May 4, 2009–May 7, 2009, Proceedings: The Society for Imaging Science and Technology. (Available online at *http://www.imaging.org/ist/store/physpub.cfm?seriesid=28&pubid=910*).

Jenkerson, C.B., and Schmidt, G., 2008, eMODIS product access for large scale monitoring, *in* The future of land imaging . . . going operational, William T. Pecora Memorial Symposium on Remote Sensing, 17th, Denver, CO, Nov. 16, 2008–Nov. 20, 2008, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing, p. 19. (Available online at *http://www.asprs.org/publications/proceedings/pecora17/pecora17_proceedings/0019.pdf*).

Jenkerson, C.B., and Schmidt, G., 2009, eMODIS Alaska, *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing. (Available online at *http://landportal.gsfc.nasa.gov/Documents/eMODIS_readme_Alaska_121108.doc*).

Nelson, K., and Peterson, B., 2009, Labeling landscape changes through automated disturbance vector matching, *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 34–39.

Peterson, B., and Nelson, K., 2009, Vegetation change detection and quantification–linking Landsat imagery and LIDAR data, *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 59–65.

Wylie, B.K., Rover, J.A., Murnaghan, K., Tieszen, L.L., and Brisco, B., 2009, Ecosystem modeling based upon remote sensing, site potential, and weather to monitor vegetation responses to climate, management, and disturbances, *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 184-191.

Xian, G., and Homer, C.G., 2009, Identifying 5 years of land cover change across the nation–updating NLCD 2001 to 2006 through image change detection, *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 78–85.

Conference Abstracts

Agarwal, D., Amiro, B., Anderson, R., Arain, A., M., Baker, I., Baldocchi, D., Barr, A., Black, A., Boden, T., Bolstad, P., Burns, S., Campbell, S., Chen, G., Chen, J., Ciais, P., Cook, B., Cook, D., Curtis, P., Davis, K., J., Delgrosso, S., Dietze, M., Dimitrov, D., Dragoni, D., Epstein, H., Falk, M., Fischer, M., Flanagan, L., Goldstein, A., Goulden, M., Grant, R., F., Gu, L., Hanan, N., Hawthorne, I., Hilton, T., Hoffman, F., Hollinger, D., Hudiburg, T., Ishizawa, M., Izaurralde, C., Nichols, J., Kelly, R., King, T., Kucharik, C., Lafleur, P., Law, B., Li, Z., Liu, S., Liu, M., Lokupitiya, E., Luo, Y., Margolis, H., Matamala, R., McCaughey, H., Meyers, T., Monson, R., Munger, B., Oechel, W., Oren, R., Parton, W., Pattey, E., Peng, C., Peylin, P., Piao, S., Post, M., Poulter, B., Price, D., Raczka, B., Ricciuto, D., Richardson, A., Riley, W., J., Ryan, M., Sahoo, A., Saliendra, N., Schaaf, C., Schaefer, K., Schuh, A., Sprintsin, M., Stoy, P., Thornton, P., Tian, H., Tonitto, C., Torn, M., van Ingen, C., Vargas, R., Verbeeck, H., Verma, S., Viovy, N., Wang, W., Weng, E., Williams, C., Xu, X., Yang, B., Yuan, W., Zha, T., and Zhou, X., 2009, Site-level synthesis of modeled and measured carbon water and energy fluxes across North America–evaluation of model and measurement uncertainty [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 16–18. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Benson, M., 2009, Joint Agency Commercial Imagery Evaluation (JACIE) [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Brown, J.F., and Wardlow, B.D., 2008, Improving decision support for drought using new geospatial models and online tools [abs.], *in* Using science for decision making in dynamic systems, ACES–A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 17. available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Chander, G., 2009, Catalog of worldwide test sites [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Chen, M., Liu, S., Tieszen, L.L., Yuan, W., Liu, H., and Randerson, J., 2008, An improved state-parameter estimation of forest carbon dynamics in a boreal forest ecosystem of interior Alaska using data assimilation [abs.], *in* Fall Meeting, San Francisco, CA, Dec. 15, 2008–Dec. 19, 2008, Eos Transactions, Suppl., v. 89, no. 53: Washington, D.C., American Geophysical Union, p. B33A–0401. (Available online at *http://www.agu.org/meetings/fm08/waisfm08.html*).

Christopherson, J., 2009, USGS QA plan for digital aerial imagery [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Faundeen, J.L., 2009, Records management best practices–archiving done right [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Fosnight, E.A., Wylie, B.K., and Rover, J.A., 2008, Compare and contrast performance anomalies in the boreal forests and Arctic tundra of Alaska [abs.], *in* Fall Meeting, San Francisco, CA, Dec. 15, 2008–Dec. 19, 2008, Eos Transactions, Suppl., v. 89, no. 53: Washington, D.C., American Geophysical Union, p. C31E–0551. (Available online at *http://www.agu.org/meetings/fm08/waisfm08.html*).

Gallant, A.L., Euliss Jr., N.H., Spivak, M., Miller, J., and Browning, Z., 2008, Estimating landscape suitability for pollinators—the importance of landscape configuration for honey bees [abs.], *in* Using science for decision making in dynamic systems, ACES–A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 52, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Gallant, A.L., Liu, S., Polasky, S., and Sohl, T.L., 2008, Integrated assessment of climate change and biofuels production on ecosystem services and sustainability [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 53, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Gilmanov, T.G., Tieszen, L.L., Wylie, B.K., Zhang, L., Baker, J.M., Bernacchi, C.J., Billesbach, D.P., Bradford, J.A., Cook, D.R., Coulter, R.L., Detwiler, A.G., Dugas, W.A., Flanagan, L.B., Frank, A.B., Griffis, T.J., Haferkamp, M.R., Ham, J.M., Heilman, J.L., Heuer, M.W., Hollinger, S.E., Matamala, R., Meyers, T.P., Mielnick, P.C., Morgan, J.A., Owensby, C.E., Prueger, J.H., Sims, P.L., and Torn, M.S., 2009, CO_2 exchange and budget of natural and agricultural ecosystems across the Great Plains of North America—integration of flux tower data [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 75. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Giri, C., Zhu, Z., Singh, A., and Tieszen, L.L., 2009, Mangrove forest distributions and dynamics of the world (1990–2005) [abs.], *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 213–215.

Giri, C.P., Zhu, Z., Reed, B.C., Gillette, S., Singh, A., and Tieszen, L.L., 2008, Mangrove forest distributions and dynamics (1975–2005) in the tsunami-impacted region of Asia [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 55, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Huang, C., Li, A., Shi, H., Vogelmann, J.E., Zhu, Z., Toney, C., Thomas, N., Goward, S.N., and Masek, J.G., 2009, Forest dynamics in southeastern United States assessed using time series stacks of Landsat observations [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Jenkerson, C.B., 2009, eMODIS overview [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings:

Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Li, Z., Liu, S., and Gleason, R., 2009, Modeling CO_2 emissions in Prairie Pothole region using DNDC model and remotely sensed data [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 44–45. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Liu, S., Euliss Jr., N.H., Li, Z., Feng, M., Mushet, D., Gleason, R., Gallant, A.L., Rover, J.A., Wylie, B.K., Yuan, W., and Kermes, K., 2008, Integrated monitoring and forecasting of ecosystem services in the Prairie Pothole region of the United States [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 96, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Liu, S., Li, Z., Gallant, A.L., Tan, Z., and Zhao, S., 2008, On-site consequences of biomass production for bioenergy–spatially explicit monitoring, forecast, and optimization [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 97, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Liu, S., Tan, Z., Li, Z., Zhao, S., and Yuan, W., 2009, Is Iowa currently a carbon sink? GEMS simulated changes in ecosystem carbon stocks and fluxes from 1972 to 2007 [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 67. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Ricciuto, D.M., Davis, K.J., Desai, A.R., Fox, A.M., Dietze, M.C., Liu, S., Luo, Y.Q., Richardson, A.D., Schaefer, K., and Williams, M., 2009, Improving carbon flux predictions in North America from the bottom up–the current state of eddy covariance based model-data fusion [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 72. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Rover, J.A., Wylie, B.K., and Ji, L., 2009, Estimating percent surface-water area using intermediate resolution satellite imagery [abs.], in Managing water resources and development in a changing climate, Spring Specialty Conference, Anchorage, AK, May 4, 2009–May 6, 2009, Poster Session Abstracts: American Water Resources Association, p. 12. (Available online at *http://www.awra.org/meetings/Anchorage2009/posters.html*).

Rover, J.A., Wylie, B.K., Ji, L., Wright, C.K., and Gallant, A.L., 2008, Using remote sensing to estimate ecosystem services in the Prairie Pothole region [abs.], *in* Using science for decision making in dynamic systems, ACES–A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 144, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Sadinski, W., Roth, M., and Gallant, A.L., 2008, Our growing need to understand relationships between human activities, global change, and ecosystem services [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 147, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Steinwand, D.R., 2009, Landsat Change Mining–using Multi-Temporal Data Mining techniques to assist in the selection of imagery from the Landsat Archive [abs.], *in* Civco, D.L., ed., International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, 5th, Groton, CT, July 28, 2009–July 30, 2009, Conference Proceedings: University of Connecticut, p. 31–33.

Stensaas, G., 2009, CEOS WGCV QA4EO "operational guidelines, a quality assurance framework for Earth observation" [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Stoker, J.M., 2009, Summary of the 2nd National Lidar Strategy Meeting [abs.], *in* Reflection of the past, vision for the future, Annual Conference, Baltimore, MD, Mar. 9, 2009–Mar. 13, 2009, Proceedings: Bethesda, MD, American Society for Photogrammetry and Remote Sensing.

Tao, B., Liu, S., and Tan, Z., 2009, Temperature responses of soil carbon dynamics and its implication for regional carbon balance in Yukon River Basin, Alaska [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 49. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Taylor, J.L., 2008, Ecosystem services and land use in the Nebraska Sandhills ecoregion [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 161, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Wylie, B.K., Murnaghan, K., Zhang, L., Rover, J.A., Ji, L., and Brisco, B., 2008, Satellite-based monitoring of climate effects and disturbances in the boreal forests of the Yukon River Basin [abs.], *in* Park science in the Arctic, 2008 Alaska Park Science Symposium in Conjunction with Beringia Days 2008 International Conference, Fairbanks, AK, Oct. 14, 2008–Oct. 16, 2008, Poster Abstracts: U.S. National Park Service, available online at *http://nps.arcus.org/meetings/2008/abstracts.html*.

Wylie, B.K., Rover, J.A., and Fosnight, E.A., 2008, Performance anomalies are a relative measure of ecosystem services [abs.], *in* Using science for decision making in dynamic systems, ACES—A Conference on Ecosystem Services, Naples, FL, Dec. 8, 2008–Dec. 11, 2008, Conference Abstract Book: U.S. Geological Survey, p. 177, available online at *http://conference.ifas.ufl.edu/ACES/index.html*.

Xiao, J., Davis, K.J., Zhou, X., Zhou, T., Luo, Y., Beer, C., Bond-Lamberty, B., Desai, A., Jung, M., Law, B.E., Liu, S., Post, W.M., Reichstein, M., Ricciuto, D., Tomelleri, E., Turner, D., Wofsy, S.C., Wylie, B.K., Xiao, X., Yang, F., Zhang, L., and Zhao, M., 2009, Regional to continental upscaling of AmeriFlux data for carbon cycle studies–progress, challenges, and new directions [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 18. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Yuan, W., and Liu, S., 2009, Estimation of evapotranspiration (ET) and gross primary production (GPP) over North America [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 81. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Zhao, S., Liu, S., Li, Z., and Sohl, T.L., 2009, Impacts of future scenarios of land cover and climate change on ecosystem carbon sequestration in the southeastern United States [abs.], *in* NACP All-Investigators Meeting, 2nd, San Diego, CA, Feb. 17, 2009–Feb. 20, 2009, Abstract Book: North American Carbon Program, p. 70. (Available online at *http://www.nacarbon.org/cgi-bin/meeting_2009/mtg2009_ab_search.pl*).

Conclusion

In FY 2009, the EROS Director focused on modernizing the Center's strategic plan for the next 3 to 5 years. The first step was to revive the strategic planning process, and formulate a strategic planning team. The planning team consisted of individuals from throughout EROS who represented the breadth of EROS activity and a perspective that would recognize the capability of our staff and the potential for the future. The team interviewed numerous EROS employees and customer organizations. As a result of these interviews, the team identified the following four goals for EROS to pursue in the future:

- Understand the Nation's remote sensing requirements;
- Expand our multi-mission capabilities so that those requirements can be addressed;
- Develop a terrestrial monitoring system that provides the data, services, and assessments needed to understand and manage environmental change; and
- Maintain a strong remote sensing science, applications, and development program that addresses the Nation's most pressing needs.

EROS plans to work with USGS Geography leadership and the network of USGS Geography Science Centers to achieve these goals.

Communication with our expanding constituent and customer base is vital to the success of our programs and projects, 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:

Communications and Outreach
USGS EROS Center
47914 252nd Street
Sioux Falls, South Dakota 57198
jsnelson@usgs.gov
http://eros.usgs.gov/

Publishing support provided by:
Rolla Publishing Service Center

For more information concerning this publication, contact:
U.S. Geological Survey Earth Resources Observation and Science
(EROS) Center
47914 252nd Street
Sioux Falls, South Dakota 57198
(605) 594-6151

Or visit the EROS Center Web site at:
World Wide Web: *http://eros.usgs.gov/*

USGS

Nelson (compiler)—**U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center—Fiscal Year 2009 Annual Report**—Open-File Report 2010–1060