U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center – Fiscal Year 2014 Accomplishment Report

Compiled by Becky A. Foster

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Acronyms

3D	Three Dimensional
3DEP	3D Elevation Program
AGB	Above Ground Biomass
AGRHYMET	Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center
API	Application Program Interface
ASPRS	American Society for Photogrammetry and Remote Sensing
AST	Architecture Science Team
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
BAER	Burned Area Emergency Response
BDA	Bulk Download
C	Carbon
C&O	Communications and Outreach
CAF	Development Bank of Latin America (previously Corporación Andina de Fomento, while maintaining the original CAF acronym)
CDL	Crop Data Layer
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CFlux	Carbon Flux
CHIRPS	Climate Hazard group Infrared Precipitation with Stations
CHISLIC	Creating Hybrid Structure from LANDFIRE/Lidar Combinations
CILSS	Inter-State Committee on Drought Control in the Sahel
CIO	Chief Information Officer
CLU	Climate and Land Use Change (CLU) Mission Area
CMGP	Coastal Maine and Geology Program
CO_2	Carbon Dioxide
CoNED	Coastal National Elevation Database
CSV	Comma Separated Value. File format used to exchange data between disparate applications.
DAAC	Distributed Active Archive Center
DAAC2Disk	LP DAAC to Disk HTTP Download (DAAC2Disk) Manager
DAT	Damage Assessment Toolkit
DEM	Digital Elevation Model
DFO	Dartmouth Flood Observatory
DMCii	DMC International Imaging
DMZ	Demilitarized Zone
DOI	Department of the Interior
DSB	Data Services Branch
e.g.	For example
ECHO	EOS Clearing House
ECS	ESDIS Core System
ECV	Essential Climate Variables
EDCM	Erosion Deposition Carbon Model
EF	Enhanced Fujita

EMT+	Enhanced Thematic Mapper +
eNEP	Ecological-based Net Ecosystem Production
EORES	Earth Observation Requirements Evaluation System
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EPA	Environmental Protection Agency
ERC	Energy Release Component
EROS	Earth Resources Observation and Science (EROS) Center
ESD	Earth Science Division
ESDIS	Earth Science Data and Information System
ESDR	Earth Science Data Record
ESRI	Environmental Sciences Research Institute
ET	Evapotranspiration
FEMA	Federal Emergency Management Agency
FEWS	Famine Early Warning Systems
FEWS NET	FEWS Network
FGDC	Federal Geographic Data Committee
FL	Flame Length
FME	Flexible Modeling Environment
FTP	File Transfer Protocol
FY	Fiscal Year
GEMS	General Ensemble biogeochemical Modeling System
GeoTIFF	Georeferenced Tagged Image File Format
GFCC	Global Forest Cover Change
GIS	Geographic Information System
GPCC	Global Precipitation Climate Centre
GPP	Gross Primary Production
GPS	Global Position System
GRID	Global Resource Information Database
HAG	Height Above Ground
HDDS	Hazards Data Distribution System
HTTP	Hypertext Transfer Protocol
HURDAT	Hurricane Database
HVAC	Heating, Ventilating, and Air Conditioning
IA	Information Assurance
IBM	International Business Machines (IBM) Corporation
IC	International Cooperator
i.e.	That is
IEM	IBM Endpoint Manager
IKONOS	Commercial earth observation satellite that derived its name from the Greek term *eikōn* for image.
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
JACIE	Joint Agency Civil/Commercial Imagery Evaluation
JPG	Joint Photographic Experts Group (or JPEG)
km	Kilometer

KML	Keyhole Markup Language. An XML based file that expresses geographic annotation and visualization for earth viewing software such as Google Earth.
L1T	Level-One Terrain-Corrected
LAC	
LANDFIRE	Landscape Fire and Resource Management Planning Tools
LCMAP	Land Change Monitoring, Assessment, and Projection
LDCM	Landsat Data Continuity Mission
Lidar	Light Detection and Ranging
LP DAAC	Land Processes Distributed Active Archive Center
LRS	Land Remote Sensing
LSDS	Land Satellites Data System
LSRD	LSDS Science Research and Development
LTA	Long Term Archive
LTWG	Landsat Technical Working Group
LULC	Land Use Land Cover
m	Meter
M2M	Machine-to-Machine
MEaSUREs	Making Earth Systems Data Records for Use in Research Environments
MEM	Ministry of Energy and Mines
MIICA	Multiple Indices Integrated Change Analysis
MODIS	Moderate Resolution Imaging Spectroradiometer
MRLC	Multi-Resolution Land Characterization
MTBS	Monitoring Trends in Burn Severity
NARA	National Archive and Records Administration
NASA	National Aeronautics and Space Administration
NBR	Normalized Burned Ratio
NDVI	Normalized Difference Vegetation Index
NEXRAD	Next Generation Weather Radar
NGA	National Geospatial-Intelligence Agency
NGP	National Geospatial Program
NLCA	National Land Change Assessment
NLCD	National Land Cover Database
NLIR	National Land Imaging Requirements
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Production
NRCS	Natural Resources and Conservation Service
NSLRSDA	National Satellite Land Remote Sensing Data Archive
NTNC	Northern Tier Networking Consortium
NWS	National Weather Service
OLI	Operational Land Imager
OMB	Office of Management and Budget
OSB	Observation Systems Branch
OSTP	Office of Science and Technology Policy
PECAN	Plains Elevated Convection At Night

PHP	Hypertext Preprocessor
RCA-EO	Requirements Capabilities and Analysis for Earth Observation
RMSE	Root Mean Square Error
RSAC	Remote Sensing Applications Center
RST	Remote Sensing Technologies
SCE	Shuffled Complex Evolution
SHP	Shapefile; is a data format for GIS software.
SIR	Surveys, Investigations, and Research
SLC	Scan Line Corrector
SLI	Sustainable Land Imaging
SOAP	Simple Object Access Protocol
SOC	Soil Organic Carbon
SOMA	Scanning Orders Maintenance Application
SPoRT	Short-term Prediction Research and Transition Center
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
TBDEM	Topobathymetric Digital Elevation Model
TEP-A	Tillage Erosion Prediction Aid
TgC	Teragrams of Carbon
TIFF	Tagged Image File Format
TIR	Thermal Infrared
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TOA	Top of Atmosphere
TV	Television
UNEP	United Nations Environment Programme
UNITAR	United Nations Institute for Training and Research
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOSAT	United Nations Operational Satellite Applications Programme
URL	Uniform Resource Locator
USAID	U.S. Agency for International Development
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USPED	Unit Stream Power-based Erosion and Deposition
UTC	Coordinated Universal Time
VIP	Vegetation Index and Phenology
WaterSMART	Water for Sustainable Management of America's Resources for Tomorrow
WELD	Web Enabled Landsat Data
WGCapD	Working Group on Capacity Building and Data Democracy
XML	Extensible Markup Language. A textual data format that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center – Fiscal Year 2014 Accomplishment Report

Compiled by Becky A. Foster

Purpose

This desk reference provides an overview of the USGS EROS Center achievements throughout fiscal year (FY) 2014. It also illustrates the range and scope of the projects and activities performed. Scientific papers and other documents published by the scientists, engineers, and information professionals affiliated with EROS provide additional information (see Appendix A).

Communication with our expanding constituent, customer, and user base is vital to achieving the EROS mission and the success of our projects and activities. To communicate with us or for more information about EROS, contact Thomas Holm holm@usgs.gov or Janice Nelson jsnelson@usgs.gov, Policy and Communications Office, USGS EROS Center, 47914 252nd Street, Sioux Falls, South Dakota 57198, http://eros.usgs.gov/.

Executive Summary

The USGS EROS Center mission – *"contributing to the understanding of a changing Earth"* – as illustrated by this report, is accomplished through a wide variety of land change science data and information activities. These activities include researching, developing, implementing, operating, and applying remote sensing based land change monitoring, assessment, and projection capabilities. Together our activities and capabilities are critical to addressing science and applications objectives at all levels within the Department of the Interior (DOI), USGS, across the Federal government, and around the world. Fundamental to our mission is the sustained collection and archiving of data about the earth's land surfaces ensuring a visual and digital record of global features and environmental change accessible to anyone, anywhere, anytime, at no cost.

As in the past, Center-wide priorities were established for 2014 to focus our work to provide land change science data, information, and knowledge to our expanding constituent, customer, and user base. During the year, we made great strides in addressing our priorities. The following synopses highlight several 2014 priority achievements focused on our view of EROS future. For more detail, please refer to the write-up for each and the complete set of accomplishments in this report.

Support Completion of Sustainable Land Imaging (SLI) Architecture Study
The National Aeronautics and Space Administration (NASA) led, with USGS support, the design of a system architecture for a sustainable, realistic, and affordable program to provide future land imaging data compatible with the existing Landsat data record. The activities were focused on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system to achieve National objectives. Specifically, the NASA/USGS Architecture Science Team (AST) defined a system for delivering sustainable global land imaging multispectral and thermal infrared data and resulting information for approximately a 20-year period starting in 2018. In August, the AST delivered its final report to NASA and supported on-going efforts by DOI/USGS headquarters and NASA headquarters to communicate findings, observations, and recommendations to the Executive Office of the President and the Office of Management and Budget. A decision from the Administration on the near-term mission component is expected in FY 2015.

Implement a Remote Sensing Systems Information Capability
EROS led an effort called the Requirements Capabilities and Analysis for Earth Observation, or RCA-EO. The goal of RCA-EO is to determine, in a consistent, unbiased, and system agnostic way, what users require in terms of earth observation data and how to best meet those needs. To help realize this goal, USGS collaborated with the National Atmospheric and Oceanic Administration (NOAA) to develop a state-of-the-art Earth Observation Requirements Evaluation System (EORES). EORES is the heart of RCA-EO as an open-source, web-based suite of tools and databases populated with information about earth observation user requirements as well as current and planned earth observation capabilities. This high visibility cross-agency collaboration is definitely a first with EROS as an integral partner.

Bring Initial Set of Essential Climate Variables to an Operational State
The Land Remote Sensing (LRS) Program is sponsoring the development of Landsat science information products, referred to as essential climate variables (ECVs). These information products provide readily usable research and applications by taking some of the data processing burden off of the end user. In this particular case, a “burned area” product is being generated as a proxy for fire disturbance, which is an important parameter used for modeling ecosystem dynamics and biogeochemical cycling. EROS is systematically generating the burned area ECV extending back through the historical archive of Landsat thematic mapper (TM) and enhanced thematic mapper + (EMT+) data. We are also moving forward with the Landsat 8 Operational Land Imager (OLI) data to provide a valuable source of information relating to landscape disturbance at National to local scales.

Land Change Monitoring, Assessment, and Projection
EROS began the development of a Center-wide strategy for exploiting the Landsat archive in a way that will move EROS science toward what is being called Land Change Monitoring, Assessment, and Projection (LCMAP). The essence of LCMAP is to provide “analysis-ready” data to help users hit the ground running for both research and

applications. LCMAP feeds a new Center capability for continuous monitoring that, in turn, enables publishing annual reports on land change and supporting agile and timely responses to needs for short-term topical assessments. Instead of simply providing access to data, we are aspiring to become the 'go to' Center for land change assessments and products, allowing access to the information in a variety of ways. Under LCMAP, EROS will transition from not only being a source of Landsat scenes to being a source of land change information and knowledge. The key to realizing this vision is to make the full historical record of clear observations easily accessible for every pixel, so each new Landsat overpass compares current and historical pixel characteristics.

Implement a Center-wide Process for Planning and Prioritizing our Work
Good project management is all about "doing projects right," and EROS has a very successful project management track record. In 2014, EROS worked to improve the Center's ability to plan and prioritize its work by using portfolio management concepts and processes, as well as basic management tools, to plan and prioritize from a Center perspective. This includes documenting and using EROS vision, goals, objectives, priorities, roles and responsibilities, and metrics. Using this common set of information, EROS is better equipped to communicate, coordinate, prioritize, and make decisions regarding current and potential work. As a result, EROS will focus on selecting and "doing the right projects" to better achieve the EROS mission.

Dr. Frank P. Kelly
Director, Earth Resources Observation and Science (EROS) Center
Space Policy Advisor

Fiscal Year 2014 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 Climate and Land Use Change (CLU) Mission Area.

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 CLU Programs and other USGS mission areas and their associated programs, other bureaus and agencies within 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 EROS research and applications activities take full advantage of the Center's extensive national and global archive of remotely sensed data.

Fire Science

The Fire Science Team conducts, applies, leads, and advances fire science by supporting the DOI, 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.

Fires Mapped by Monitoring Trends in Burn Severity Project Approaches 20,000

The Monitoring Trends in Burn Severity (MTBS) project is a collaborative effort between the U.S. Forest Service (USFS) Remote Sensing Applications Center (RSAC) and the USGS EROS. In 2006, the Wildland Fire Leadership Council tasked MTBS to assess burn severity for all known large fires that have occurred on any land ownership in the United States since 1984. This information helps identify the trends and impact of fire in the United States and is used to support other fire-related programs like LANDFIRE, the Landscape Fire and Resource Management Planning Tools program.

Landsat data from the archive at USGS EROS is being analyzed to accomplish this task. The Normalized Burn Ratio (NBR) is computed for Landsat scenes acquired before and after the fire. The differenced NBR (prefire NBR minus postfire NBR) is assessed to evaluate the level or severity of the fire-caused change to the vegetation. On October 1, 2014, RSAC released 563 fire assessments to the MTBS.gov website. This included 406 fires from 2013 from across the United States and 157 historical fires from Texas. This release brings the total to 18,497 fires that have been mapped across the United States and Puerto Rico (fig. 1). The release scheduled for spring 2015 will include over 1,800 historical U.S. Fish and Wildlife Service fires mapped by the USGS EROS over the past 2 years.

The MTBS project provides a basis for local, regional and national assessment of fire and its short- and long-term impacts upon the landscape. For further information, contact Stephen Howard, USGS EROS, smhoward@usgs.gov.

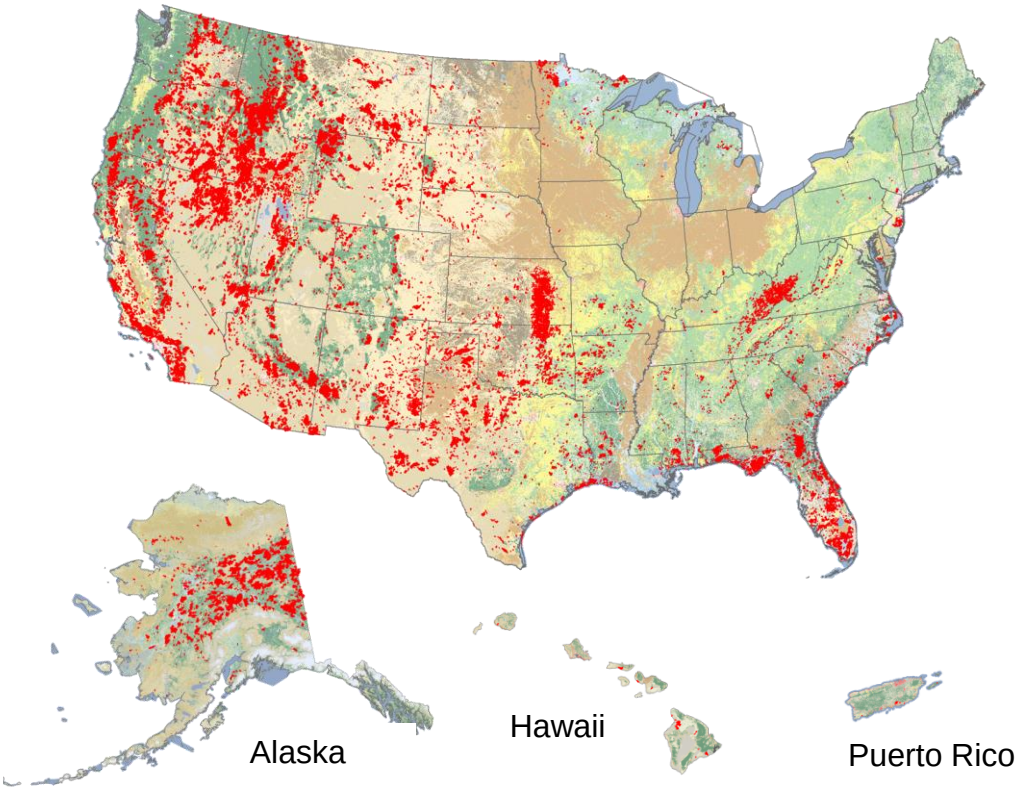


Figure 1. The red areas in the image represent the almost 18,500 large fires mapped by the Monitoring Trends in Burn Severity project as of October 1, 2014.

Historical Fire Atlases Created for Over 50 Wildlife Refuges

The USGS EROS and the U.S. Fish and Wildlife Service recently signed a 2-year agreement to compile Landsat-based fire atlases for 51 National Wildlife Refuges and 7 Wildlife Management Districts. The fire atlases will provide refuge managers a deeper insight into the short- and longer-term impacts of fire and other land cover change on the refuges.

Using historical fire records that indicate the date and location of a fire, the USGS Landsat archive will be automatically queried to identify and order corresponding Landsat imagery that is likely to show the fire. A specialized algorithm will scan the Landsat imagery for fire scars. Once a fire scar is identified, the burned area "perimeter" will be automatically delineated and added to a refuge-based spatial dataset that will also contain the Landsat imagery and derivative products including the Normalized Burn Ratio and Normalized Difference Vegetation Index.

At this writing, the first 4 refuges of Hanford/Saddle Mountain, Columbia, McNary, and Umatilla are being evaluated. These refuges are located along the Columbia River in

south-central Washington (fig. 2). A total of 4,333 unique Landsat scenes from 1984 to 2014 were processed to create 5,072 individual subsets centered on the refuges. There are 1,613 subsets for Hanford/Saddle Mountain and Columbia, 1,728 for McNary, and 1,731 for Umatilla. All subsets have been scanned to create a burned/not burned classification which will be used to create the fire perimeters for the fire atlases. For further information, contact Stephen Howard, USGS EROS, smhoward@usgs.gov.

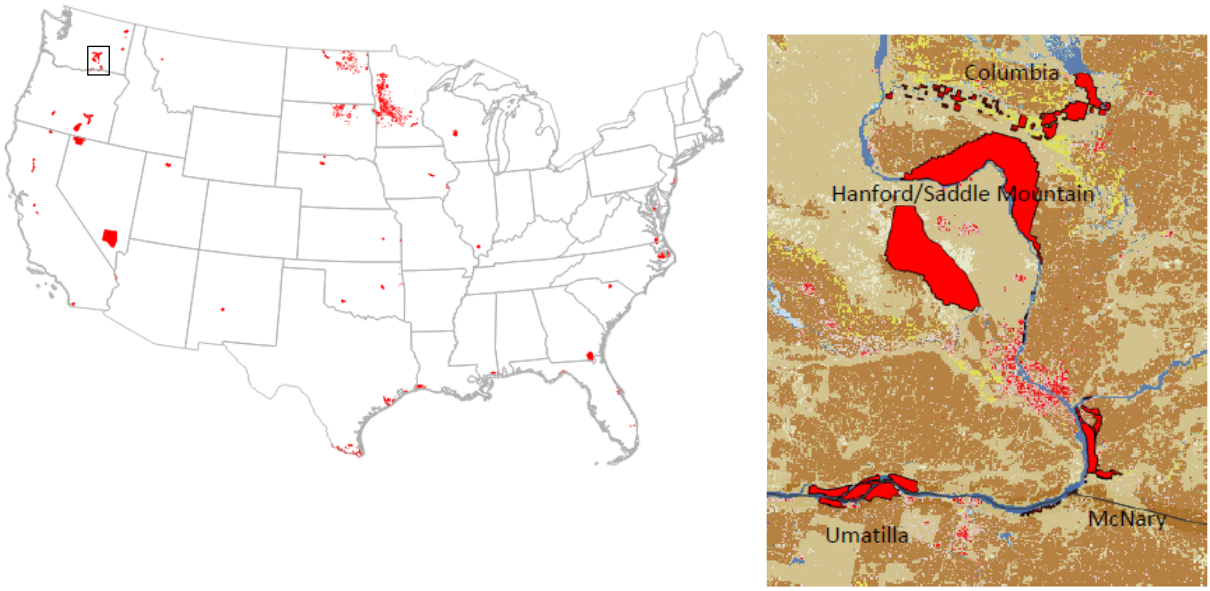


Figure 2. The red areas in the image (on the left) represent the locations of over 50 refuges in the continental United States. Note many smaller refuges in the central United States, Florida, and along Gulf and east coasts. The enlargement (on the right) shows the first group of refuges, indicated by the red areas, to be mapped located in Washington and Oregon. Background: National Land Cover Dataset.

Enhanced Wildland Fire Management Decision Support Using Lidar-Infused LANDFIRE Data

The USGS, USFS, and the University of Montana are working together to build an application that will enable the automatic integration of light detection and ranging (lidar) data into the LANDFIRE product suite. This work has been funded through the NASA Applications Program, initially for a 1-year prototype. With the successful completion of the 1-year prototype effort, the team was awarded 3 more years of funding to continue to develop the application's platform and functionality. The application, called Creating Hybrid Structure from LANDFIRE/Lidar Combinations (CHISLIC), allows anyone to take available lidar data and use it to build canopy height, canopy cover, and canopy base height layers. The application is targeted toward those with little or no experience working with lidar data, or even other remote sensing datasets. This application was developed in recognition of the fact that although lidar data sets are being collected over more and more areas they are still being underutilized in the fire science arena where

they are especially suited for mapping the three-dimensional (3D) structure of vegetation, which is an important driver of fire behavior.

LANDFIRE provides nationally continuous data using consistent methodologies, which are used to support national and regional strategic planning. However, these landscape-scale data are not ideal for developing local strategies and tactics. This places considerable demand on local units to develop data suitable for their local needs. In particular, information related to the 3D arrangement of material within vegetation canopies is not well represented in LANDFIRE maps at the local scale. This is, in part, driven by LANDFIRE's reliance on Landsat imagery as the sole remote sensing data input for mapping; such imagery does not directly capture the vertical distribution of canopy elements. CHISLIC will help address this data-use gap by allowing local units to develop geospatial layers of vegetation structure metrics from lidar data and merge these with existing LANDFIRE data products.

Through CHISLIC, detailed vegetation structure information derived from lidar can be integrated with the LANDFIRE product suite to generate locally enhanced vegetation structure and fuels maps. Lidar data are not yet incorporated into LANDFIRE production because they are not consistently available across the United States. The potential impact of integrating lidar-derived structure with LANDFIRE can be seen in figure 3.

In May of 2014, at the Large Wildland Fire Conference, held in Missoula, Montana, a workshop was held that provided an overview of lidar-based vegetation structure mapping, LANDFIRE, and the CHISLIC application. The workshop was well attended by fire scientists from various agencies and the information and demonstrations provided were well-received. The feedback that the CHISLIC team received will be incorporated into future development of the application. Continued input from potential end-users of CHISLIC will be sought out during the next 3 years of development to ensure optimal functionality and utility. For further information, contact Kurtis Nelson, USGS EROS, knelson@usgs.gov.

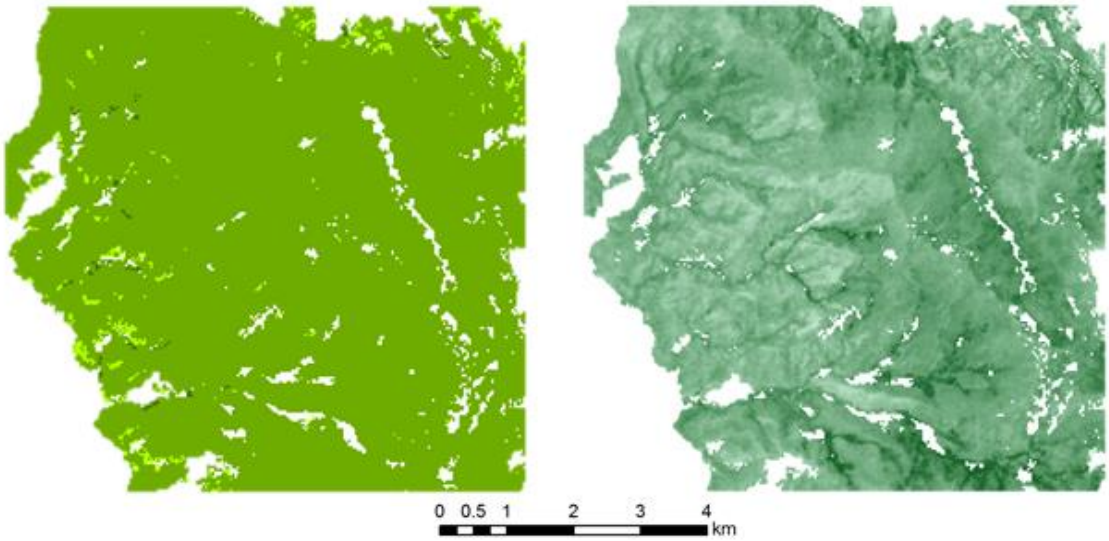


Figure 3. Canopy height products from LANDFIRE (left) and Creating Hybrid Structure from LANDFIRE/Lidar Combinations (CHISLIC) (right). Because of the source of the input data for the LANDFIRE canopy height product, the legend needs to be binned. The CHISLIC canopy height product, mapping of continuous variable, better represents the heterogeneity of canopy height across this landscape in Grand County, Colorado.

LANDFIRE Completes 2010 Update, Rolling Ahead on 2012 Update

LANDFIRE, the Landscape Fire and Resource Management Planning Tools program, is a vegetation, fire, and fuel characteristic mapping program jointly managed by the U.S. Department of Agriculture USFS and the DOI. LANDFIRE represents the first, and only, complete, nationally consistent collection of resources with an ecological foundation that can be used across multiple disciplines. LANDFIRE provides landscape-scale, cross-boundary, geospatial products to support fire and land management planning activities. LANDFIRE data products are primarily designed and developed to facilitate national and regional strategic planning; however, LANDFIRE's spatially comprehensive data set can also be adapted to support a variety of local management applications when other data sets are not available.

The LANDFIRE suite of spatial products includes more than 25 vegetation, fire, fuel, and topography datasets describing existing vegetation composition and structure, potential vegetation, and surface and canopy fuel characteristics across the Nation. Data products are created at a 30-meter spatial resolution and are developed using geo-referenced field plot data, satellite imagery, and simulation models.

LANDFIRE is continuously improving and updating its product offerings to increase their appropriate use. These updates generally address changes in vegetation across the

landscape, such as those resulting from wildland fire, fuel and vegetation treatments, or management. In addition, where data are available, changes from insects and disease, storm damage, invasive plants, and other natural or anthropogenic events are incorporated. In 2014, LANDFIRE completed its most recent update – LF2010. LF2010 represents the most current comprehensive database of vegetation and wildland fuel information for the entire United States. Multiple earth observing datasets were instrumental in the creation of new maps, improvement of previous products, and subsequent update of the products. Highlights of LF2010 include: (1) Improved Events Implementation – improvements were made to the LF2010 events database to refine the data for disturbance mapping by identifying and deleting very small event polygons to reduce false changes to the landscape; (2) Multiple Indices Integrated Change Analysis (MIICA) – MIICA was implemented to better detect changes in forest and non-forest ecosystems from satellite imagery; and (3) Expanded Extent: Insular Areas – LANDFIRE mapping was extended for the first time to American Samoa, Northern Mariana Islands, Guam, Federated States of Micronesia, Palau, Marshall Islands, Puerto Rico, and the U.S. Virgin Islands.

Work is also well underway on the latest update project – LF2012. The objective for LF2012 is to provide for currency of landscape conditions by both utilizing remote sensing data and applying available disturbance information for calendar years 2011 and 2012. A primary improvement implemented in LF2012 will be a new compositing and tiling approach when using Landsat 7 Scan Line Corrector (SLC)-Off data. This approach will allow multiple scenes to be combined to fill SLC-Off gaps, cloudy, or shadowed areas in the change detection products. These methods will provide higher quality data and more efficient processing by reducing time spent on anomaly investigations on these change detection outputs. LF2012 reached a critical milestone in September 2014 by delivering the first half of all conterminous United States products. Figure 4 illustrates, using map zones, the current availability of LF2010 data (in olive) and LF2012 data (in yellow).

LANDFIRE continued its association with many key partners and stakeholders in 2014. LANDFIRE principal partners are the Rocky Mountain Research Station (USFS), the USGS EROS (DOI), and The Nature Conservancy. LANDFIRE program partners include the USGS National Gap Analysis Program, the Multi-Resolution Land Characteristics Consortium (MRLC), the National Land Cover Database (NLCD), the USFS Forest Inventory and Analysis program, and the National Agricultural Statistics Service.

In 2015, LANDIRE will focus on planning for two key production efforts: (1) an update project (LF2014) to apply disturbance and succession updates to the vegetation and fuel data and bring the current base data to circa 2014 and (2) a comprehensive, multi-year remap project (LF2015) to produce a completely new edition of the LANDFIRE product suite by using the most current data sources, methods, protocols, and technology without the constraints associated by updating a legacy edition dataset. For further information, contact Stephen Zahn, USGS EROS, sgzahn@usgs.gov.

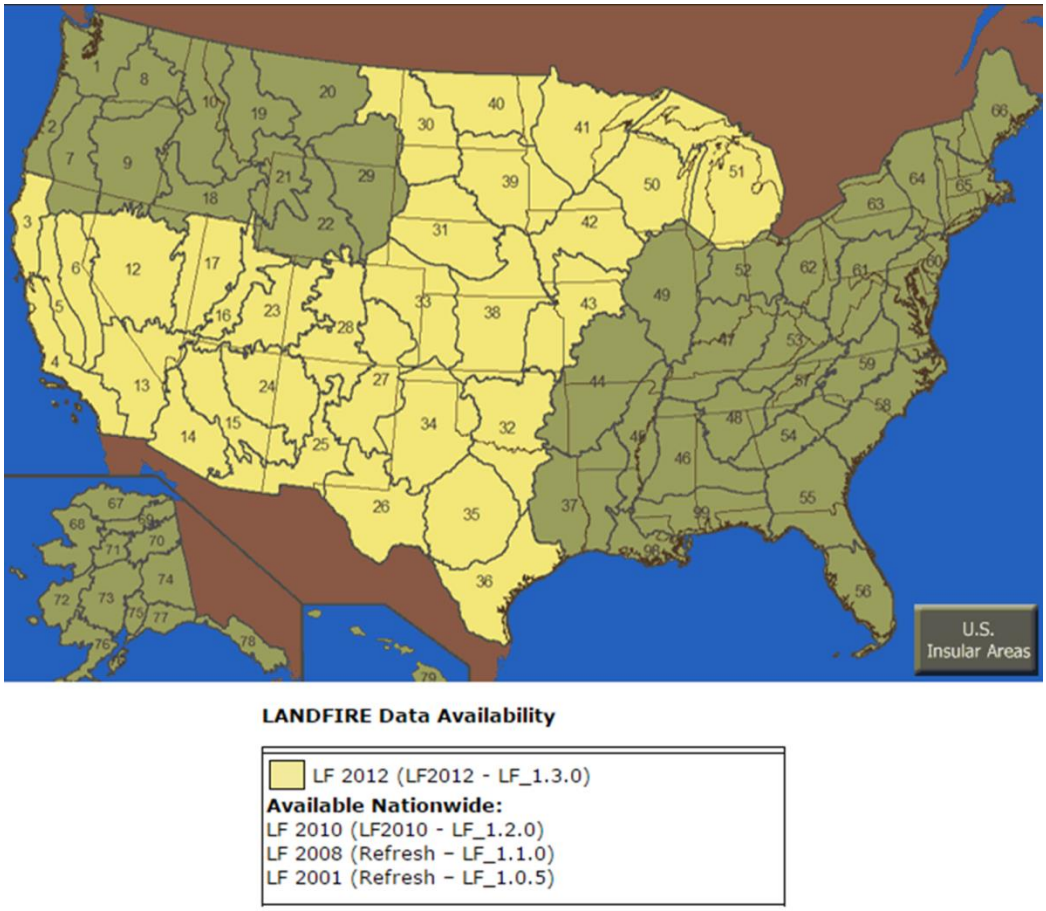


Figure 4. Current availability of LANDFIRE data showing nationwide access to LF2010 (in olive) and available products from LF2012 (in yellow).

Remote Sensing Support for Interior's Burned Area Emergency Response Teams

Since 2001, USGS EROS fire science staff have worked jointly with USFS RSAC staff to map significant wildfires on DOI and USFS managed lands and to satisfy soil burn severity and other mapping requirements of Burned Area Emergency Response (BAER) teams. EROS receives national level funding from DOI fire management programs to support this ongoing activity.

EROS rapidly processes Landsat and other satellite imagery enabling the timely delivery of both DOI and USFS map products (fig. 5), generally in less than 2 days after image acquisition. In 2013, and continuing in 2014, the availability of the new Landsat 8 satellite greatly enhanced USGS capability to respond to the needs of fire rehabilitation managers in a timely manner. Historically, 9 to 10 years ago, BAER soil burn severity mapping was done by manually sketch mapping severity patterns on topographic maps, perhaps with the aid of a digitized fire perimeter. Today, burn severity mapping is accomplished using digital image data processing techniques to analyze pre- and post-fire satellite imagery. The analysis of satellite imagery has replaced manual methods,

except in the very few cases where timely high quality imagery is not available due to excessive clouds, smoke, or active fire issues.

This was a demanding year for BAER burn mapping support. The 2.3-million acres mapped in 2014 was less than the average acres mapped annually since 2001. However, the 107 fires mapped exceeded the annual average number of fires mapped since 2001. In total, 2001 through 2014, USGS EROS and USFS RSAC have mapped over 1,436 wildfires representing over 42-million burned acres in support of BAER and other local DOI and USFS land managers. Additionally, USGS EROS and USFS RSAC have provided support for U.S. BAER teams deployed to international wildfire events including Chile in 2012 and Australia, Greece, and the Democratic Republic of Georgia in 2009. For further information, contact Randy McKinley, USGS EROS, rmckinley@usgs.gov.

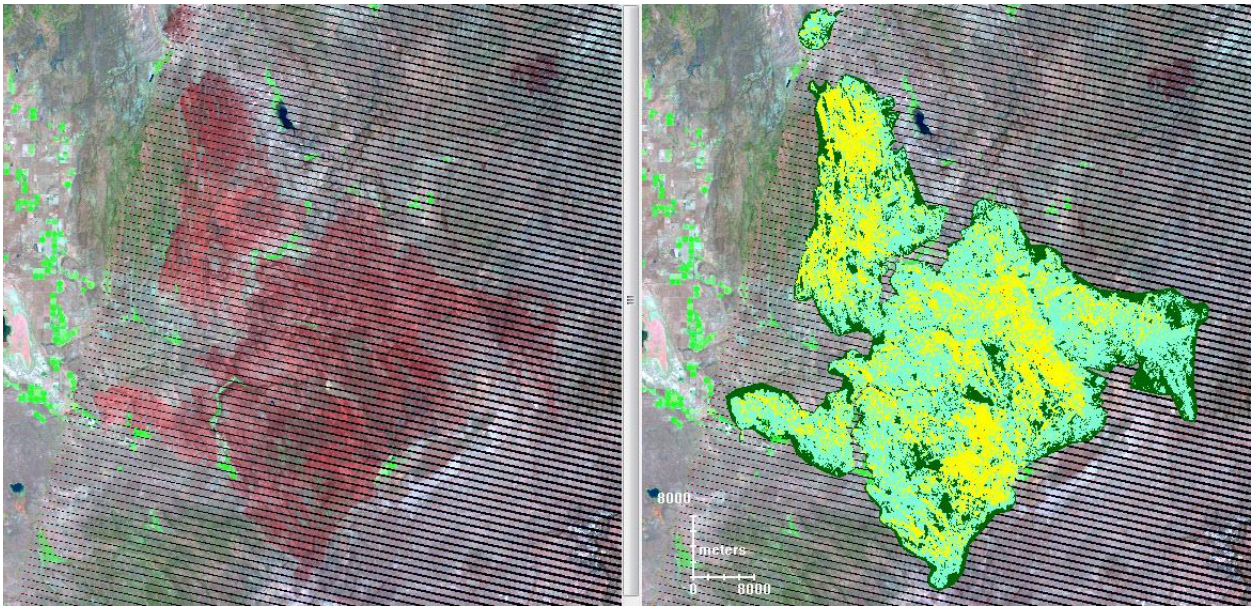


Figure 5. Burned Area Emergency Response map products, Landsat 7 image (left) and soil burn severity map (right), for the Buzzard Complex fire located near Burns, Oregon. This was one of the largest fires mapped in 2014, impacting almost 400,000 acres. The fire was mapped after containment to provide local fire rehabilitation managers with timely soil burn severity information. Landsat 7 scan line corrector anomalies were minimized in the burn severity map using spatial filtering techniques. Within the severity map dark green is non-burn, light blue is low severity, yellow is moderate severity, and red is high severity (little high severity within this fire).

Improving National Shrub and Grass Fuel Maps for Fire Risk Assessments

Shrub and grassland ecosystems in the western United States are especially prone to fire events, yet available data for assessing fire risk in these areas are inadequate. The reasons for the difficulties in being able to effectively characterize shrub and grasslands

for fire applications are varied and many, but part of the problem revolves around the high degree of intra- and inter-annual variability in fuel characteristics in these areas, necessitating higher level understanding of the dynamics of these systems. It is clear that we need to develop better understanding of the conditions that lead to wildland fire in shrub and grasslands. This information is of special importance to projects such as the LANDFIRE project, which has the goal of providing fire managers with nationally consistent and detailed spatial information about vegetation and fuel structure.

Through the support of the NASA Applied Sciences Program, we embarked on an assessment to derive better fuel characterizations in western United States shrub and grassland ecosystems. Our primary objectives of the first phase of the project included: (1) improve upon shrub and grassland mapping for fire applications, (2) develop intra-seasonal (e.g., monthly) fuel data sets in shrub and grassland areas using a combination of Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) data, and (3) determine if improvements in shrub and grassland data layers will alter and improve fire behavior model results.

While our long-term goals are to expand our assessments to include all of the western United States, our initial focus was on an area in and adjacent to the Owyhee Basin of Idaho, Nevada, and Oregon. This area is the site of many large and frequent shrub and grassland fires. The shrubland areas are dominated by sagebrush (*Artemisia* spp), and the grassland areas have a substantial amount of cheatgrass (*Bromus tectorum*) associated with them. Many fires occurred within the study area from 1984 to present; and most, but not all, were in the shrub and grassland areas. We consider years 1985, 1996, 2005, 2006, 2007 and 2010 to be “high fire years,” when at least 1,500 km^2 burned within the study area.

As depicted in figure 6, the shrub and grassland areas of the region are characterized by high levels of biomass variability detectable through time-series data analyses from MODIS. Those areas that have burned recently tend to have higher levels of biomass than those that have not. Understanding these patterns helps the fire management community to recognize which areas have high likelihood of burning in the future, thus enabling them to anticipate and plan accordingly.

Custom fire behavior fuel models for grasslands and shrubland were created to evaluate the impacts of surface fuel changes on fire behaviors. We compared results with those of existing static fuels data, which did not take into account intra- and inter-annual fuel variability. Then, we calculated two indices commonly used for fire management decisions: the Energy Release Component (ERC) and the Flame Length (FL). Fire behavior indices and simulated burned area showed differences with fuel load estimates in different years. For instance, ERC and FL were predicted to be substantially greater in years with high fuel loads (2005 and 2007) than years with low fuel loads (2008) in both grass and shrub vegetation types.

Given the results from our first set of investigations, we are now initiating the second phase of the study. This includes: (1) expansion of our work to other western United

States shrub and grassland areas; (2) expanding our collaboration with external partners, including the MRLC consortium and the Bureau of Land Management; and (3) transitioning the process into operations through interactions with LANDFIRE. For further information, contact James Vogelmann, USGS EROS, vogel@usgs.gov.

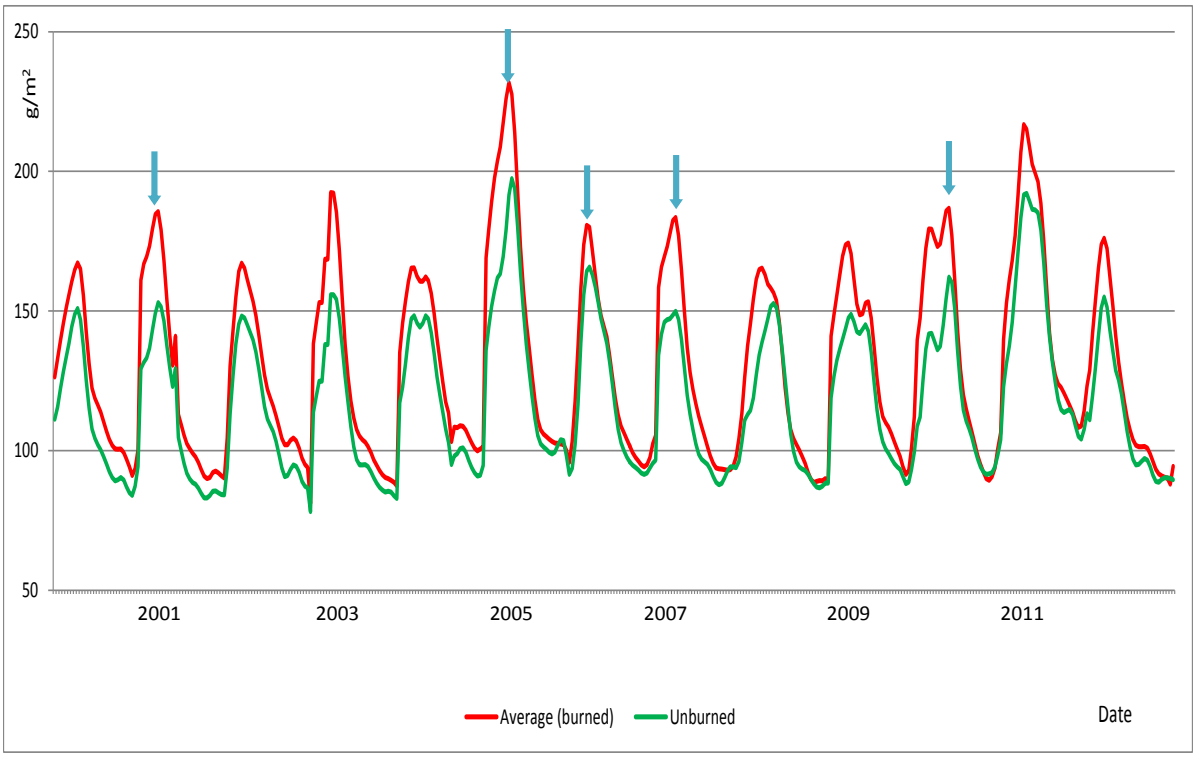


Figure 6. Seasonal live biomass profile for shrublands in the study region. Red indicates live biomass for sagebrush sites that burned at least once between 1984 and 2010, according to the Monitoring Trends in Burn Severity project. Green indicates sites that did not burn during the time period. Blue arrows indicate high fire years. Note the high levels of variability in biomass for these grass and shrub-dominated areas from year to year, and that sites that burned at least once over the time period are consistently higher than sites that did not burn over the same time frame. This information is useful for predicting the areas most likely to burn in the future.

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.

Land Change Monitoring, Assessment, and Projection

The USGS EROS Land Change Monitoring, Assessment, and Projection (LCMAP) initiative centers on structured, operational, ongoing, and timely collection and delivery of accurate and relevant data, information, and knowledge on land use, cover, and condition. LCMAP has the following overarching objectives that support a wide array of science questions: (1) provide documentation and understanding of historical land change and contemporary land change as it occurs; (2) explain how past, present, and future land change affects society, natural systems, and the functioning of the planet at local to global scales; (3) alert relevant stakeholders to important or emerging land-change events in their jurisdictions; and (4) support others in the use of land-change data, information, and science results.

LCMAP has its roots in a decade of science planning at the USGS and EROS. For example, the USGS 10-year strategy *"Facing Tomorrow's Challenges"* repeatedly calls for information on land cover and land change to meet information needs across the Bureau's strategic science directions. In FY 2014, EROS rolled out a roadmap to achieve this vision for science. The centerpiece of LCMAP is a continuous land-change monitoring capability that is supported by analysis-ready Landsat data and that feeds an agile capacity to provide timely assessments for decision makers (fig. 7). LCMAP initially will be implemented for the conterminous United States and subsequently expanded to provide global coverage. Integral to LCMAP is improved provisioning of data, information, and knowledge services for users at large. This requires developing and implementing new ways to efficiently store and process Landsat time-series data, as well as enabling users to extract desired information without having to move large volumes of data.

LCMAP is a large undertaking that can be fully realized only through participation and partnerships within and external to the USGS. Initial support for LCMAP has come through the USGS Land Remote Sensing Program, Land Change Science Program, and LandCarbon Project. Key scientific and technical input has been provided by the Landsat Science Team, USFS Land Change Monitoring Systems Team, Boston University, South Dakota State University-Environmental Sciences and Forestry, State University of New York, and Western Kentucky University; but, the list of partners is expected to expand as LCMAP matures. For further information contact Alisa Gallant, USGS EROS, gallant@usgs.gov.

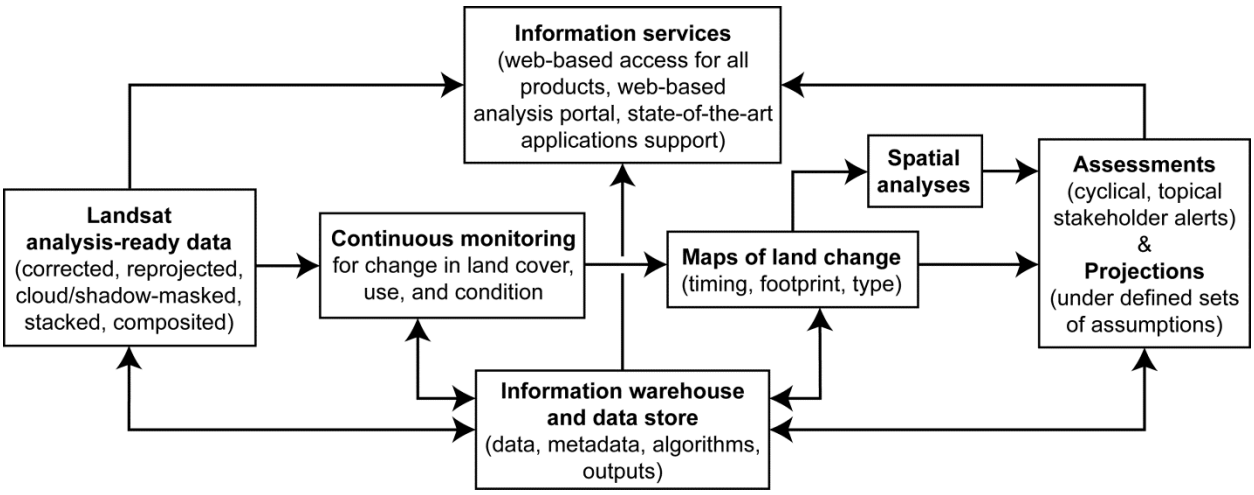


Figure 7. Conceptual schematic of the main, integrated components of the Land Change Monitoring, Assessment and Projection initiative.

National Land Cover Database 2011

The USGS, working in partnership with the interagency MRLC Consortium, has completed the production of the NLCD 2011 for the conterminous United States. The NLCD serves as the definitive Landsat-based, 30-meter pixel resolution, land cover database for the Nation. NLCD 2011 products derived from nominal 2011 Landsat data depict 16 classes of land cover, define the degree of surface imperviousness in urban areas, and quantify the amount of tree canopy cover.

NLCD 2011 innovations include integration with previous NLCD versions to provide a 10-year land cover change story for our nation at 5-year intervals, a quicker production time over previous efforts, more comprehensive change and image analysis resulting in more accurate products, a more comprehensive update of the imperviousness product resulting in more accurate products for each era in the last 10 years, and the first-ever change analysis of Alaska. Later this year, NLCD 2011 will be released for Alaska, quantifying land cover change over the state between 2001-2011.

Overall, NLCD remains a significantly evolving and important database to a wide range of users, making it essential to thousands of applications. It is used to inform a variety of investigations, from monitoring forests to modeling water runoff in urban areas. For example, figure 8 illustrates a typical land cover change pattern in an area where forest harvest is the dominant source of change. For more information on NLCD and to obtain NLCD data, visit http://www.mrlc.gov/ or contact Collin Homer, USGS EROS, homer@usgs.gov.

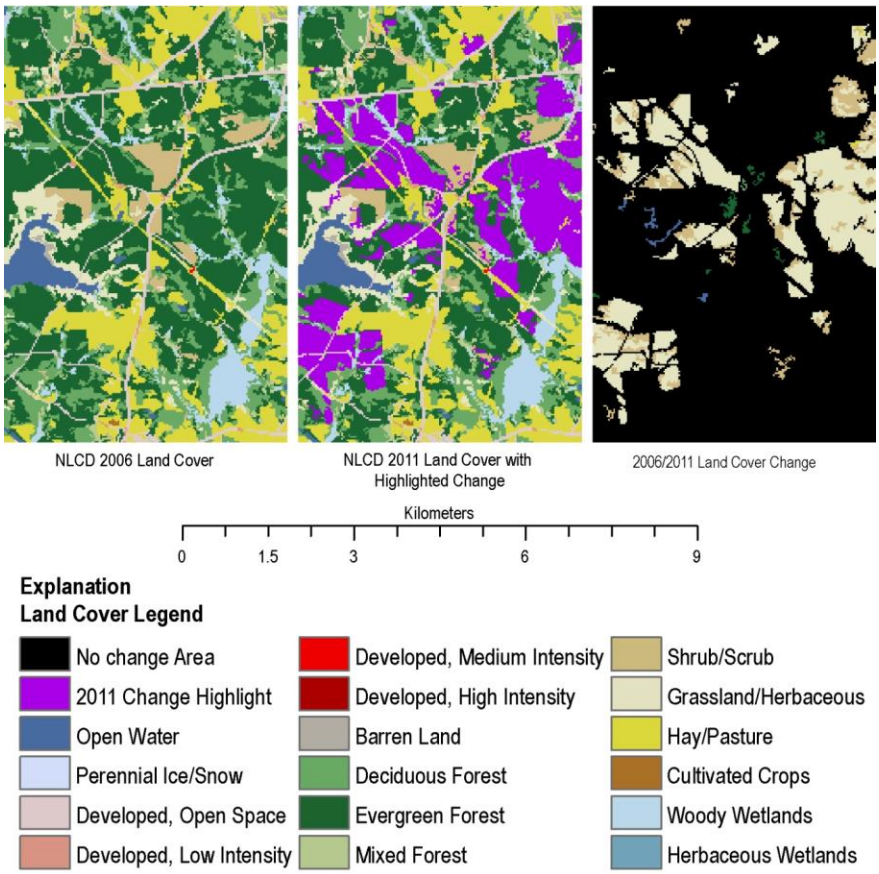


Figure 8. An example of land cover change in Pike County, Georgia (Landsat Path 19, Row 37). In the area shown, a majority of the change is from coniferous forest in 2006 to grass or shrub in 2011 – a typical land cover change in areas where forest has been harvested.

Setting the Stage for Multi-Scale Land Use and Land Cover Change Knowledge

The USGS National Land Change Assessment (NLCA) project (Principal Investigator, Mark Drummond of the Geosciences and Environmental Change Science Center) provides national and regional assessments of United States land use and land cover (LULC) change and their driving forces. Roger Auch is the main USGS EROS researcher of the NLCA project and was the lead or co-author of three publications that neared completion during FY 2014. These include a regional study of the continuing land use evolution of the Southern Piedmont in the Southeast United States, the methodology of the NLCA project to conduct conterminous United States and regional scale general United States land change assessments as well as a 2001-2006 assessment of the Southeastern Coastal Plains Level III and IV ecoregions, and finally the remaining volumes of USGS Professional Paper 1794 (a legacy publication of the USGS Land Cover Trends project). The common link among these publications is the use of Landsat derived land change data for the basis of the change analysis.

Regional LULC Change Publication #1 – *The untold geographic story of the leading land cover and land use changes in the Southern Piedmont.*

Roger Auch, academic colleague Darrell Napton, and fellow USGS scientists Kristi Sayler, Mark Drummond, Steve Kambly, and Dan Sorenson describe contemporary land change in the Piedmont ecoregion of the Southeast United States and tell how both it is different than that of much of the 20th Century and how the leading land cover change (cyclic forestry) has been largely missed in the geographic literature that has concentrated on agricultural decline and then urbanization in the region. The manuscript has been submitted to the *Southeastern Geographer* journal. The article also stresses the differences between land cover and land use change. Cyclic forestry is the largest changer of land cover in the ecoregion but is generally not a change in land use. Urbanization was the largest land use change in the ecoregion during the study period but was much smaller in total extent than forestry land use. The manuscript also states that an important fraction of the region's forest land cover (intensely used pine plantations) is actually a recent human construct (see figures 9 and 10 as examples from this manuscript).

Regional LULC Change Publication #2 – *Recent land change in the Southeastern Coastal Plains ecoregions and the NLCA's methodology to produce decadal land change assessments at regional and national scales.*

USGS scientists Mark Drummond, Mike Stier, Roger Auch, Glenn Griffith, David Hester, William Acevedo (Land Change Data Collection and Monitoring project), Chris Soulard, and USGS contract scientist Janis Taylor (SGT) detail the NLCA project's methods to create regional and national assessments of recent land use and land cover change for the 2001-2011 (in this case just 2001-2006) era by using multiple datasets to complement each other as well as indicating areas where manual visual inspection may be needed to settle classification conflicts. The manuscript will be submitted soon to either *Regional Environmental Change* or *Journal of Environmental Management*. The article also discusses the main processes of land change in the Southeastern Coastal Plains ecoregions, a high changing region that is home to a complex suite of land uses. These processes include replacement, reoccurrence, and recovery. Replacement land changes include urbanization and the conversions of more natural land covers to semi-permanent land uses such as agriculture and forestry. Reoccurrence changes in this region are found primarily in cyclic forestry and wild fires whereas recovery can be changes such as from agriculture back to more natural forests or wetlands. In the Southeastern Coastal Plains ecoregions, the leading types of changes were reoccurrence, followed by replacement with recovery affecting the smallest amount of land (see fig. 11 and 12a-d as examples from this manuscript).

Regional LULC Change Publications #3 – *The finishing of the Land Cover Trends project's "Status and Trends" USGS Professional Paper 1794 (the final three volumes).*

USGS Professional Paper 1794 is a highly detailed national assessment of the former Land Cover Trends project that is presented in multiple scales of 84 Level III U.S. Environmental Protection Agency (EPA) (1999) ecoregions and four larger sub-regions of the conterminous United States. The first volume of the professional paper (1794-A), *Status and Trends of Land Change in the Western United States – 1973 to 2000*, was published in December 2012. USGS EROS scientists William Acevedo (Land Change Data Collection and Monitoring project), Roger Auch, Kristi Sayler (Land Change Data Collection and Monitoring project, USGS EROS contractor scientist Janis Taylor (SGT), and former USGS EROS scientist Krista Karstensen spent a considerable time in FY 2014 editing the three remaining volumes of Professional Paper 1794 as they worked with the Menlo Park Science Publishing Network group (who had published Volume A) to finalize publication. Janis Taylor and William Acevedo were the editors for the Great Plains volume which is in the last phase of production and will most likely be released in the first quarter of FY 2015 followed by Auch's and Karstensen's edited Midwest-South Central United States volume, and finishing with Sayler's edited Eastern United States volume. Each of these volumes will run between 150 to 200 pages in length, finishing the most comprehensive USGS led analysis of United States land cover and land use ever undertaken (see fig. 13 as an example from this publication).

For further information, contact Roger Auch, USGS EROS, auch@usgs.gov.

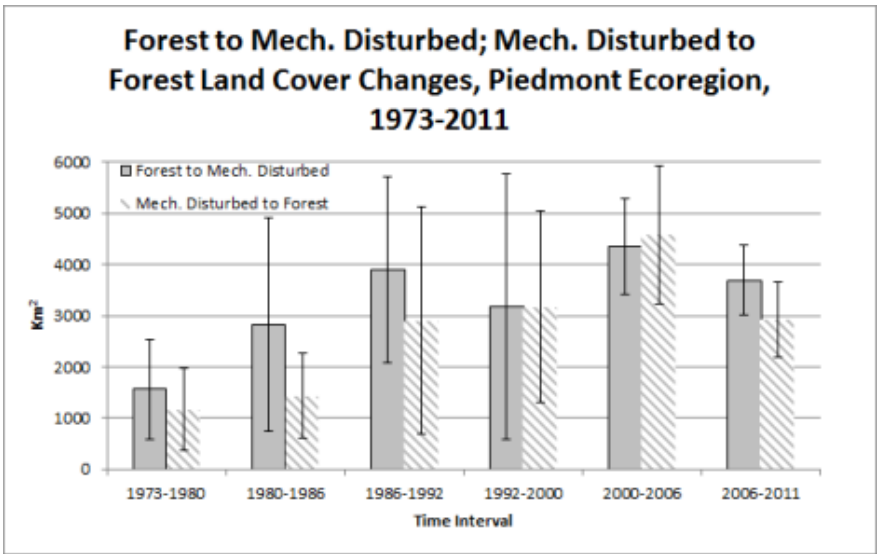


Figure 9. Estimated area of forest to mechanically disturbed and its reciprocal, 1973-2011.

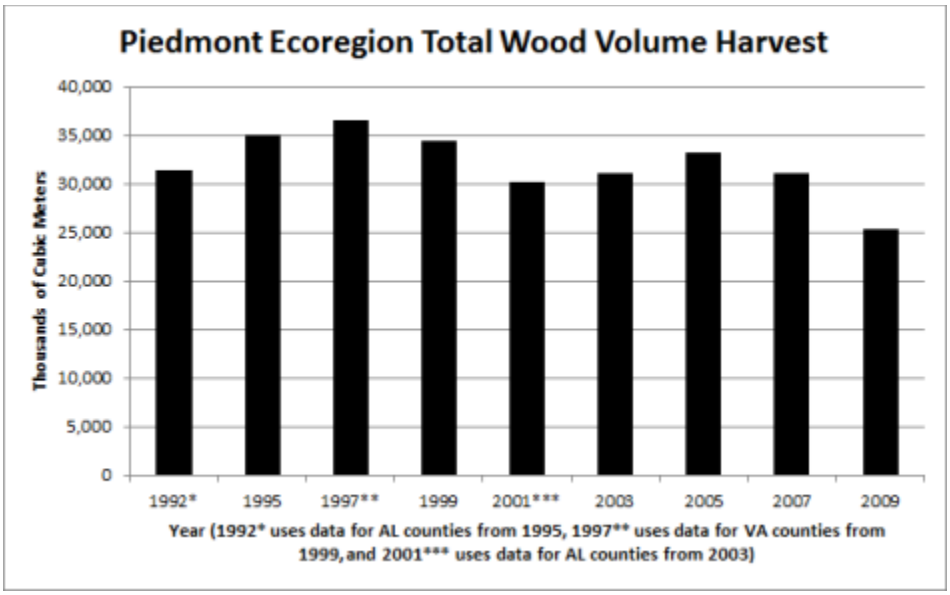


Figure 10. Total wood production for the Piedmont ecoregion 1992-2009 in thousands of cubic meters.

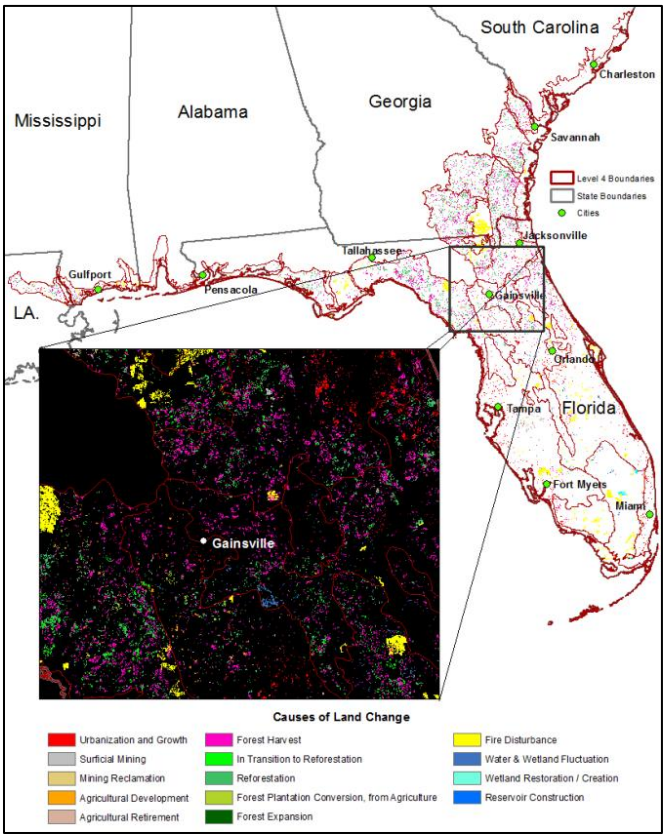
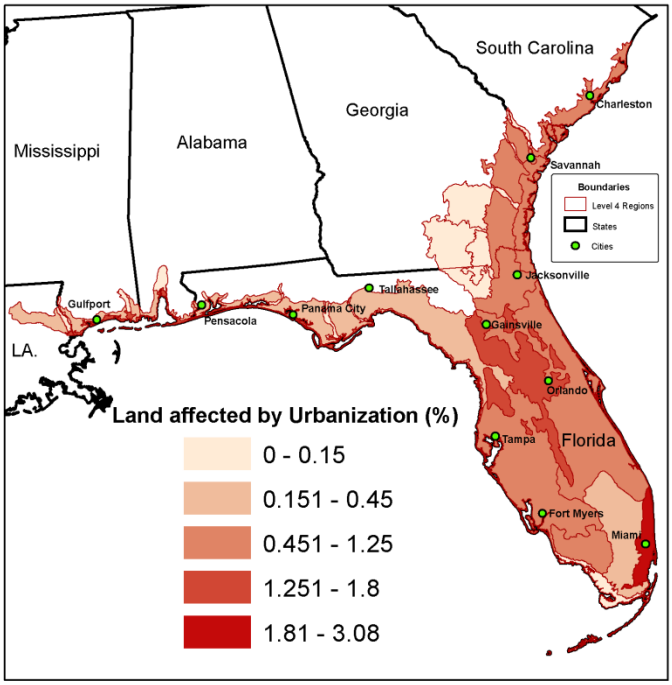


Figure 11. The main types of spatially-specific causes of landscape change in the Southeastern Coastal Plains between 2001 and 2006.



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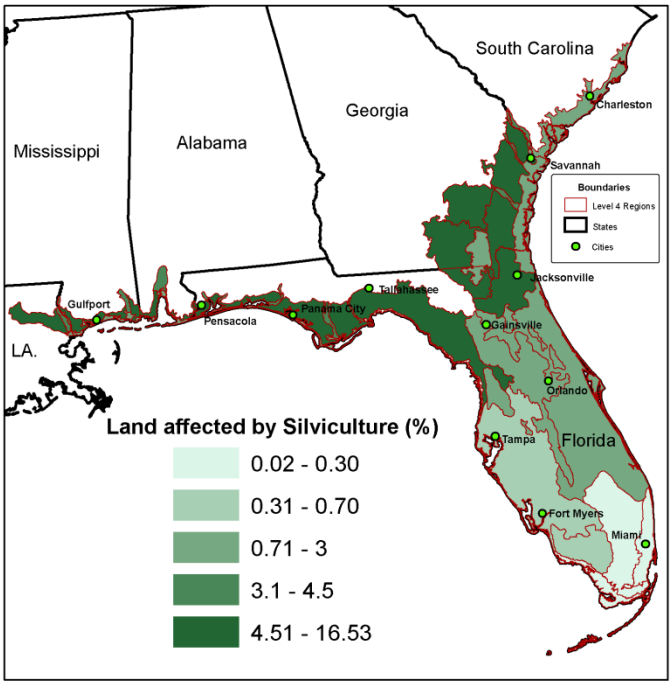
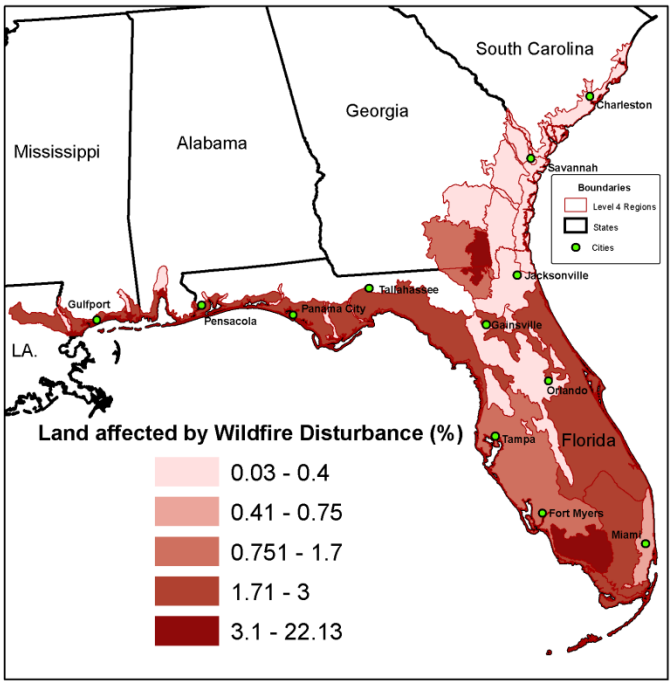


12b

Figures 12a and 12b. Variability of four landscape change processes across the Environmental Protection Agency's level 4 ecoregions, (12a) urbanization, (12b) total forest harvest/regrowth activity.



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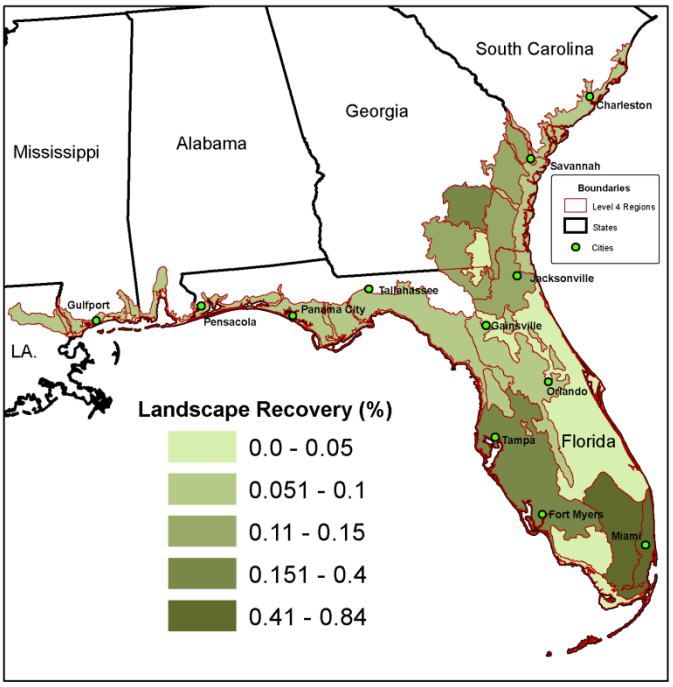

12d

Figures 12c and 12d. Variability of four landscape change processes across the Environmental Protection Agency's level 4 ecoregions, (12c) fire disturbance, (12d) landscape recovery.

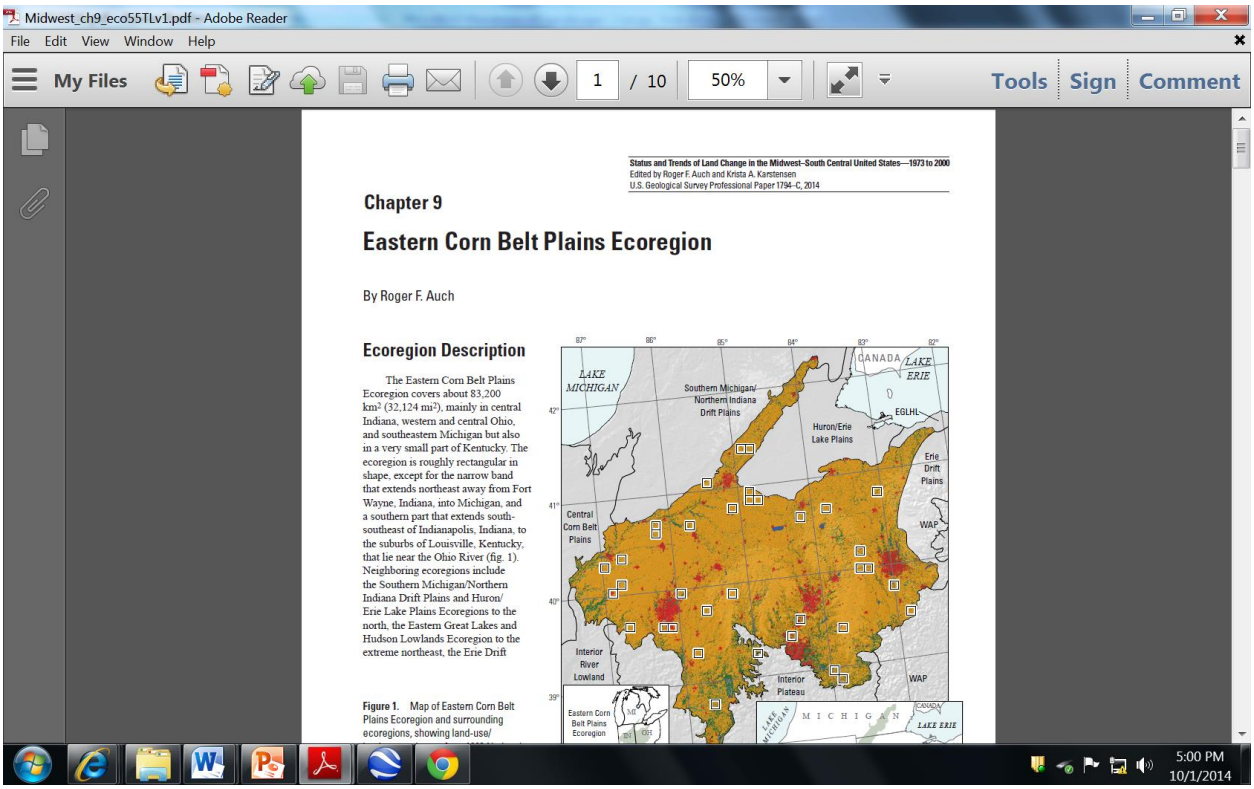

Figure 13. A screen capture of the beginning of a typical ecoregion chapter layout from USGS Professional Paper 1794 (in this case from 1794-C, *Status and Trends of Land Change in the Midwest-South Central United States – 1973 to 2000*).

Changes in World's Forests Portrayed in High-Definition Landsat Satellite Data

A new study based on earth-observing satellite data comprehensively describes changes in the world's forests from the beginning of this century. Published in the journal *Science*, this unparalleled survey of global forests tracked forest loss and gain at the spatial granularity of an area covered by a baseball diamond (30-meter resolution).

Led by University of Maryland and assisted by USGS, a team of scientists analyzed data from the Landsat 7 satellite to map changes in forests from 2000-2012 around the world at local to global scales. The uniform data from 654,178 scenes taken by Landsat 7 ensured a consistent global perspective across time, national boundaries, and regional ecosystems (fig. 14).

Tracking changes in the world's forests is critical because forests have direct impacts on local and national economies, on climate and local weather, and on wildlife and clean water. This fresh view of recent changes in the world's forests is thorough, objective, visually compelling, and vitally important.

Overall, the study found that from 2000-2012 global forests experienced a loss of 888,000 square miles (2.3-million square kilometers), roughly the land area of the United States east of the Mississippi River. During the study period, global forests also gained an area of 309,000 square miles (800,000-square kilometers), approximately the combined land area of Texas and Louisiana.

The global survey found that Russia experienced the most forest loss overall (in absolute numbers) over the study period. Brazil was the nation with the second highest level of forest loss; but other countries, including Malaysia, Cambodia, Cote d'Ivoire, Tanzania, Argentina and Paraguay, experienced a greater proportional loss of forest cover. Indonesia exhibited the largest increase in forest loss; its losses on an annual basis during 2011-2012 were twice what they were during 2000-2003.

The research team included scientists from the University of Maryland, USGS, Google, the State University of New York, Woods Hole Research Center, and South Dakota State University. The collaborative study is published in the November 15, 2013, issue of the journal *Science.* For further information, contact Thomas Loveland, USGS EROS, loveland@usgs.gov.

Learn More

- "High-resolution global maps of 21st-Century forest cover change," *Science*, November 15, 2013.
- Forest cover maps in Google Earth Engine
- Global Forest Change animation videos

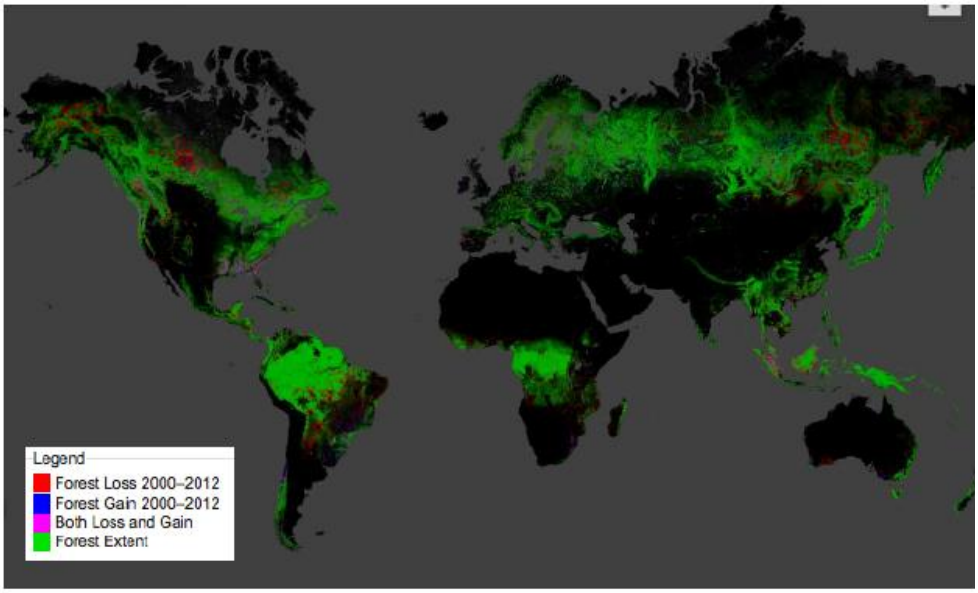

Figure 14. Results from time-series analysis of 654,178 Landsat 7 images characterizing forest extent (green tones) and change (red – forest loss, blue – forest gain, and purple – both loss and gain), 2000-2012.

Harmonized Land Use and Land Cover Datasets Improve Understanding of U.S. Land Change

USGS scientists, supported by the Climate and Land Use Change Research and Development Program, developed a prototype 2001 land use and land cover dataset by harmonizing existing multi-temporal land use and land cover datasets. The methodology relies on the principal of convergence of evidence to reclassify areas mapped by multiple national-scale LULC datasets. Datasets are combined through a pixel-based data fusion process that determines the most likely pixel classification based on input dataset agreement. This process allows for classification errors in some of the input datasets. The work is necessary because a wide range of national-scale LULC classification efforts exist, yet major differences between these data arise because of different methodologies, class definitions, and mapping objectives.

The current methodology used over 20 national LULC datasets that were readily available from various archives. The datasets ranged in vintage from 1992 to 2011. The harmonization process (fig. 15) begins by identifying pixels that are persistent land cover and do not change over the 20-year harmonization period. Based on previous USGS research, the amount of persistent cover should be approximately 90 percent of the conterminous United States land surface between 1992 and 2011. Any differences from this amount are due to errors in input classifications. In developing the prototype, only 54 percent of 30-meter raster cells had 100 percent agreement between input datasets. This number increased to 82 percent when some datasets were allowed to disagree but each cell still had a clear majority of the input datasets in agreement. Persistent cover increased to 90 percent of the land surface when cells were assigned a cover type even though the input datasets was evenly split between two classes. These cells tended to correspond to vegetation cover types that were spectrally similar. The remaining 10 percent of the land surface were cells that experienced a change in land cover and cells that had significant disagreement between datasets and could not be classified based on input datasets alone. These cells tended to correspond to areas that are difficult to map because they correspond to mixed spectral responses and transition zones between biomes.

The resulting dataset looks very good from a qualitative perspective. Artificial boundaries and other processing artifacts in the input data are minimized by harmonization. The addition of three disturbance classes (forest harvesting, wildland fire, and surface mining) also improve detail for land change analysis. An accuracy assessment is underway to provide a more quantitative measure on the quality of the resulting land change statistics. Land change harmonization seeks to provide LULC data that leverages the best elements of readily-available data to improve LULC change monitoring across the conterminous United States.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, environmental modeling, and GIS technologies to support land change science. For further information, contact William Acevedo, USGS EROS, wacevedo@usgs.gov.

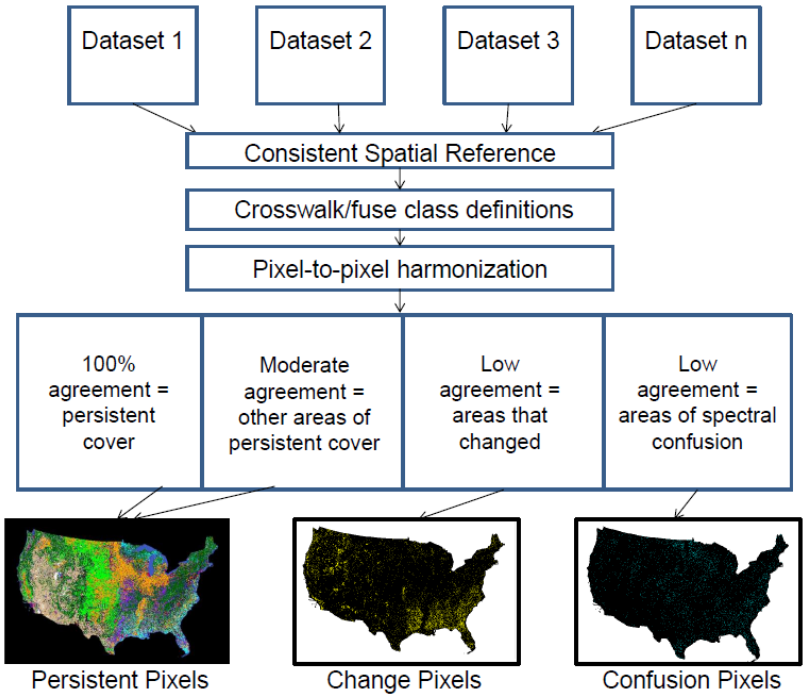

Figure 15. Conceptual diagram of the harmonization process.

Land Use and Land Cover Database Developed for Use in Validation and Regional Assessment

USGS scientists, supported by the Climate and Land Use Change Research and Development Program, developed a database of 2006 and 2011 land use and land cover information for selected 100-km2 sample blocks within 29 EPA Level 3 ecoregions across the conterminous United States. The data is critical for validation of LULC datasets being developed from remotely sensed data sources.

The LULC of the United States is constantly changing: forests are clear-cut; urban growth and development replace agricultural land; wildland fires convert shrubland to grassland; and flooding causes changes to riparian vegetation. These changes are starting to be monitored by a variety of national-scale LULC change datasets that are becoming quite common, yet these datasets provide an incomplete story of change or contain questionable land change statistics. In order to use these datasets appropriately, the overall quality, accuracy, or precision of LULC products needs be validated by comparing results from independent approaches.

LULC data for the 2001-2006 and 2006-2011 time periods was manually collected using the same sample block classification procedures as the USGS Land Cover Trends project. Ecoregion specific alterations in the sampling density were made to expedite the completion of manual block interpretations. A 30-meter pixel resolution for the land

cover classifications was instead used to remain consistent with Landsat derived data. The Landsat data used was again from the NLCD collection of images. The methodology was to start with the 2000 date from the previous assessment and make any needed corrections before completing the next two dates of 2006 and 2011. The 2000 land cover was copied and any changes seen in the 2006 Landsat images were digitized into a new 2006 land cover image. Similarly, the 2011 land cover image was created to maintain consistency. Figure 16 shows an example sample block with the expanded classification.

Results from this study include ecoregion based statistical estimates of the amount of LULC change per time period, the most common types of conversions, rates of change, and percent composition. Overall estimated amount of change per ecoregion from 2001 to 2011 ranged from a low of 370 km2 in the Northern Basin and Range Ecoregion to a high of 78,782 km2 in the Southeastern Plains Ecoregion. The Southeastern Plains Ecoregion continues to encompass the most intense forest harvesting and regrowth in the country.

The database created using manual interpretation procedures yields the highest map accuracies possible because it eliminates errors that may arise between independently created LULC products for two dates and then differencing them in a subsequent change analysis. Classification errors are greatly reduced because only manually identified, delineated, and coded LULC changes are delineated during data collection. Manually collected LULC statistics provide a valuable resource that may be used to validate other land change products or used alone to conduct regional land change assessments.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, environmental modeling, and GIS technologies to support research objectives of the USGS Climate and Land Use Change Research and Development Program. For further information, contact William Acevedo, USGS EROS, wacevedo@usgs.gov.

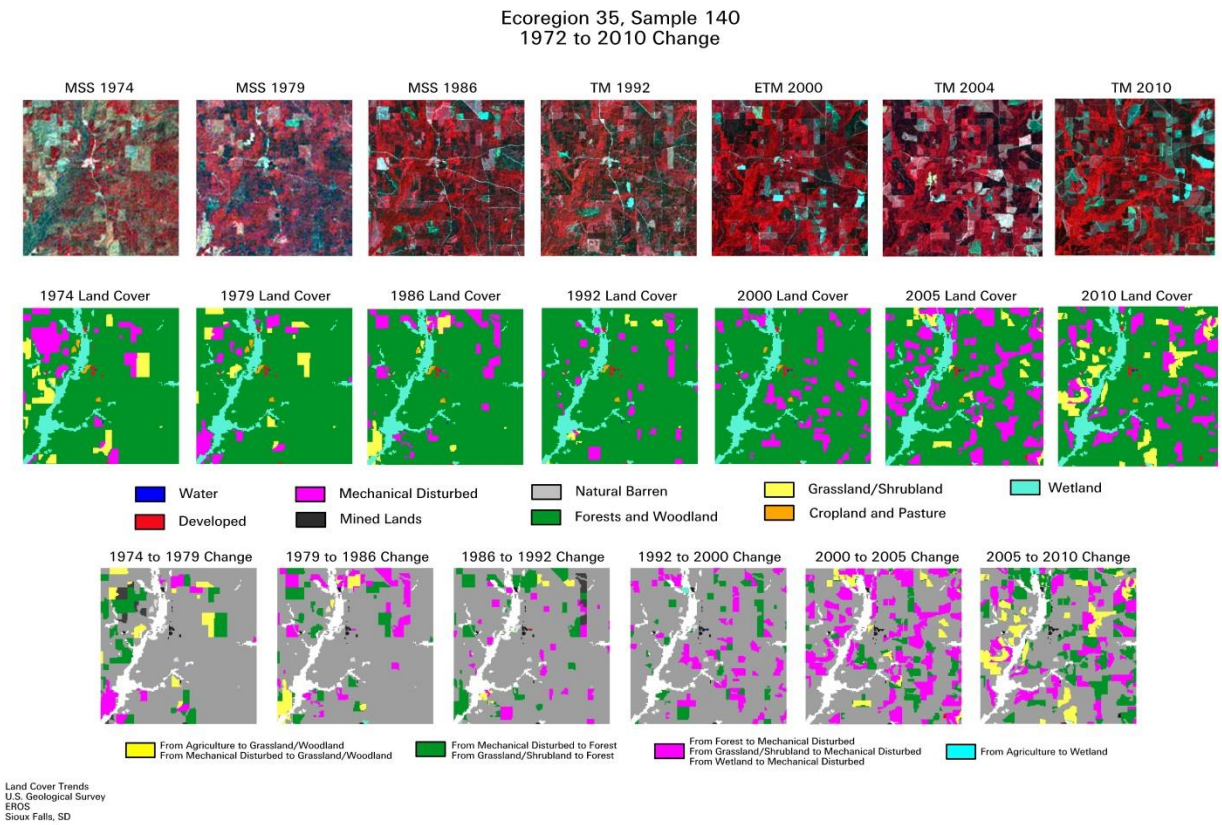

Figure 16. An example of the 2006 and 2011 land use and land cover data collected for a sample block in ecoregion 35 (South Central Plains). The top row shows the source Landsat data, the middle row shows the land use and land cover that was manually collected, and the bottom row shows the land use and land cover change in each respective time period.

Mangrove Reemergence in the Northernmost Range Limit of Eastern Florida

Mangrove forests are distributed mainly in the tropical and sub-tropical regions of the world. In response to global warming the forests are expected to migrate to higher latitudes. Poleward expansion of mangrove have been observed and reported in various parts of the world in the last two to three decades.

In eastern Florida of the United States, recent studies analyzed Landsat satellite data acquired since 1984 and concluded that mangrove is expanding beyond their geographic range due to climate change. However, these studies that used less than 30 years of earth observation satellite data raised an important research question about the time frame to study poleward expansion of mangroves. The use of 30 years of earth observation satellite data is impressive; but in terms of an ecological time scale to study, the mangrove's geographic range expansion this observation period may be inadequate or too short.

To test this hypothesis, we analyzed Landsat satellite data of eastern Florida from 1983 to 2014. The historical archive of Landsat data available free of charge provided an opportunity to examine dense time-series data with longer time period.

In eastern Florida, winter freeze has been considered as the limiting factor for their northern latitudinal limits (approximately 300 N). Due to the presence or absence of winter freeze, the interplay between mangroves and saltmarshes has been witnessed since the 1950s. Severe winter freeze kills mangroves and the area is replaced by salt marshes. Following relatively milder winter, mangrove reclaim the area replacing salt marshes. In 1983, a severe winter freeze, a 100-years event, killed more than 90 percent of mangrove forests in eastern Florida. After several years of milder winters after 1983, mangrove reemerged. The severity and extent of damage or reemergence was not uniform throughout the eastern Florida. As expected, the damage decreased towards the lower latitudes, and reemergence of mangroves was higher in northern limits. This interplay has important implications for ecological structure and functioning of coastal ecosystems.

Our analysis revealed that mangrove in eastern Florida is not expanding beyond their geographic range but reemerging after the winter freeze of 1983 (fig. 17). Analysis of satellite data from 1984 to present provides a false impression of poleward expansion of mangroves. In a similar study, researchers from the USGS EROS Center found that the severe winter freeze of 1983 killed 90 percent of mangroves in Louisiana. Similar to Florida's mangrove areas, Louisiana's mangrove area started to increase after the extreme freeze; however, it has not reached the 1983 extent (fig. 18). Both of these forests were also impacted by freezes in 1989 and 2009. This study suggests that 30 years is not enough to study mangrove's geographic range expansion due to climate change, longer time frame, possibly 100 years of observation may be needed.

The USGS EROS Center located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, environmental modeling, and GIS technologies to support mangrove mapping and monitoring of the world. For further information, please contact Chandra Giri, USGS EROS, cgiri@usgs.gov.

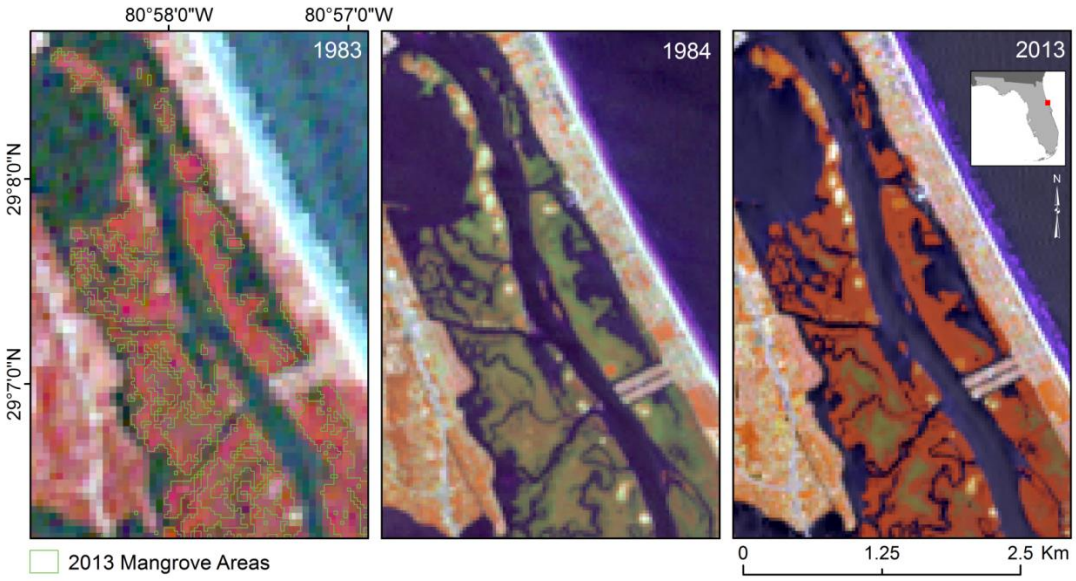

Figure 17. Bright red pixels in the 1983 Landsat Thematic Mapper image (left shows similar mangrove extent as 2013). A severe winter freeze in late December of 1983 severely damaged mangrove areas in the northern limit of eastern Florida; damage to mangrove areas is visible in the 1984 Landsat 5 image (center). The mangrove area recovered in the northern range from 1984 to 2013, and reemerging mangrove areas appear bright orange in the 2013 Landsat 8 image (right).

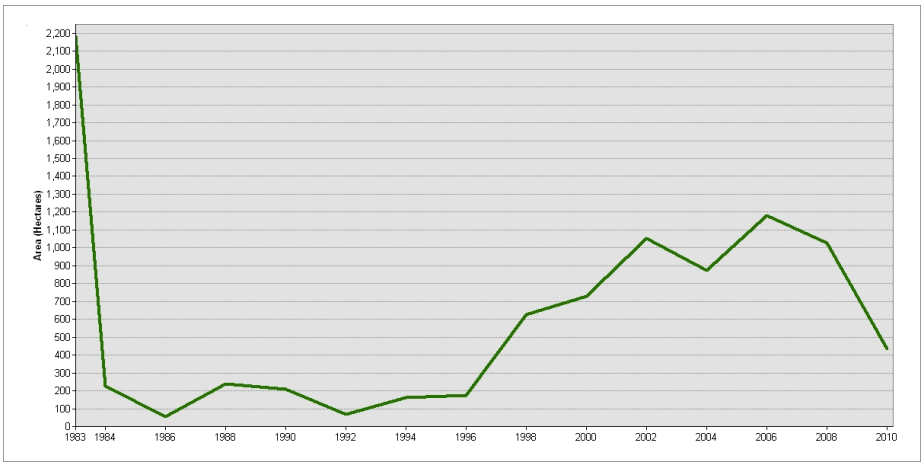

Figure 18. Mangrove forest area of Louisiana from 1983 to 2010 derived from 30-meter Landsat data. Mangrove in Louisiana is reemerging after the severe winter freeze of 1983 followed by milder winter freeze of 1989 and 2009.

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 multitemporal/spatial scales in support of a sustainable earth. Key accomplishments are given in the following sections.

Three Years of Conterminous United States Burned Area Essential Climate Variable Products

The Land Remote Sensing Program is sponsoring the development of Landsat science information products, referred to as essential climate variables (ECVs), that are designed to be more readily used in research and applications by taking some of the data processing burden off of the end user. In this particular case, a "burned area" product is being generated that is a proxy for fire disturbance, which is an important parameter used for modeling ecosystem dynamics and biogeochemical cycling.

The burned area ECV is generated using a statistical model referred to as a "boosted regression tree" that is based on a national scale sampling scheme from which training statistics are compiled. Five distinct regression tree models were developed in order to capture ecosystem specific characteristics and variability. The regression tree models are applied on a scene-by-scene basis for each Landsat TM and ETM+ scene in the archive for the years 2011-2013, from which an annual summary of burned area is compiled and then mosaicked into a single seamless product covering the conterminous United States for a given year (fig. 19).

In the course of developing and verifying the algorithm for the burned area ECV product, all available scenes over the conterminous United States for years 2011-2013 were processed to generate single date and annual summary burned area products. These products were provided to the LANDFIRE and MTBS projects for comparison and evaluation with similar products generated by the respective projects. The primary distinction of the burned area ECV is that it is generated for every available image and there is no minimum threshold for the size of the burned area to be mapped.

The burned area ECV products compare favorably with results from the methodologies implemented by the LANDFIRE and MTBS projects, and therefore may serve to complement and augment the information generated by those projects. The systematic generation of the burned area ECV extending back through the historical archive of Landsat TM and ETM+ data, and moving forward with the Landsat 8 OLI data, will provide a valuable source of information relating to landscape disturbance at national to local scales. For further information, contact John Dwyer, USGS EROS, dwyer@usgs.gov.

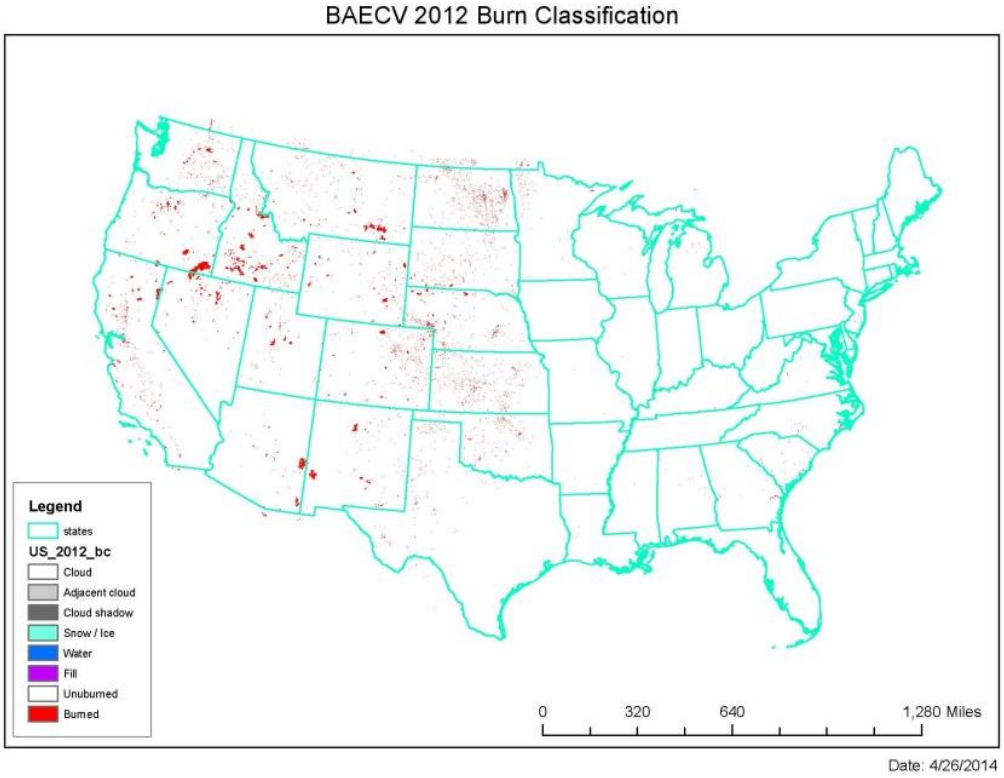

Figure 19. This map shows the annual summary of burned area extent for the year 2012 for the conterminous United States as defined by the burned area essential climate variables product.

Detecting and Monitoring Tropical Forest Degradation in Vietnam

According to the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in developing countries, it is important to establish a national forest monitoring system using remote sensing and ground-based approaches for conducting carbon inventory and assessments of forest degradation. Landsat TM and ETM+ data have been systematically acquired for many portions of the globe since the launch of Landsat 5 in 1984, and now that the data are available at no cost via the Internet, the use of Landsat data for global monitoring applications is expanding. With the recent launch of Landsat 8, the acquisition of high quality 30-meter resolution data continues with some notable improvements. Landsat time-series data are particularly powerful for assessing status and trends throughout a wide range of terrestrial ecosystems, and the purpose of this project is to explore the use of Landsat time-series data for mapping and monitoring forest degradation in Vietnam.

We are focusing our work on the Lam Dong Province, which is located towards the southern part of Vietnam in the Central Highlands. This province has many noteworthy

features, including extensive regions of coffee, cashew, and *Acacia* plantations, as well as several reasonably undisturbed and protected forest regions within the Vietnamese National Park system. During the summer of 2014, and in association with our Vietnamese partners, we conducted an extensive field trip to familiarize ourselves with the types of landscape changes taking place throughout the Lam Dong province. This insight enables us to better interpret the Landsat imagery with which we are working. Ultimately this will facilitate the determination of the best approaches for using Landsat time-series data for assessing change throughout the region.

Analyses of Landsat time-series data from 2000-2014 indicate that many of the areas within the Lam Dong province have experienced significant change, with some areas showing evidence of increasing forest, other areas showing decreasing forest, and others showing no change in condition (fig. 20). The areas with the greatest level of changes are associated with agroforestry regions (e.g., coffee growing, cashew production) that are located outside of the protected reserves. The reserves themselves appear to be very stable over the time period, implying that protection status is having the desired effect on conserving these areas.

As part of the SilvaCarbon mandate, it is important that Vietnamese researchers and managers develop the appropriate set of skills such that they can monitor and manage their own forests. Thus, there is a strong need to transition the approaches that we develop from this project to the individual scientists and practitioners residing within Vietnam. During 2015, we are planning on hosting two Vietnamese scientists, which will help ensure that information flow will be efficient, and help to facilitate the transfer of technical processes and insight towards the development of a national forest monitoring program for Vietnam. For further information, contact James Vogelmann, USGS EROS, vogel@usgs.gov.

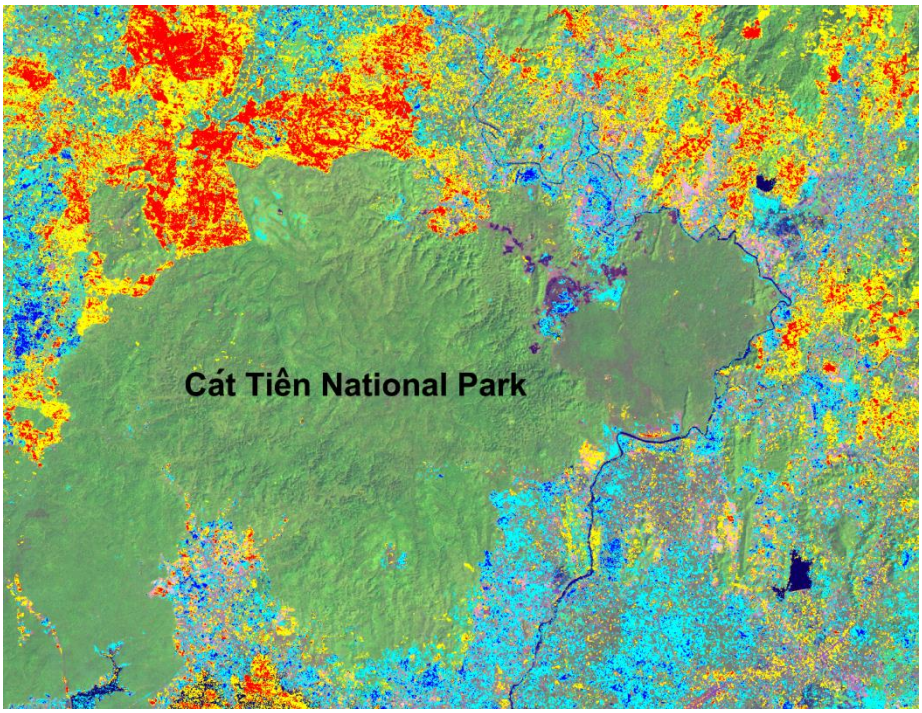

Figure 20. Areas of forest change from 2000 through 2014 superimposed on a 2014 Landsat 8 image. Most of the green represents non-changing forest. Areas of red and yellow indicate where forest losses have occurred; whereas, areas of turquoise and blue indicate where forest gains have occurred. Most of the changes have occurred outside of protected areas (e.g., Cat Tien National Park), where extensive agroforestry activities are taking place.

Distribution of Near-Surface Permafrost in Alaska: Estimates of Present and Future Conditions

High-latitude regions are experiencing rapid and extensive changes in ecosystem composition and function as the result of climate change. Increasing air temperatures have led to widespread thawing and degradation of permafrost, which in turn has affected ecosystems, socioeconomics, and the carbon cycle of high latitudes. Despite permafrost's profound influence on earth systems, relatively little has been done to quantify permafrost distributions and dynamics across extremely large areas and in great detail. Subsequently, additional data and approaches are needed to properly observe and monitor permafrost, as called for by experts in a recent National Research Council report (National Research Council, 2014). In response to this call and in support of the USGS LandCarbon project, USGS scientists, in partnership with Federal and Local agencies, developed an approach to produce the first high-resolution (30-meter pixel) maps of near-surface (within 1 meter) permafrost properties in Alaska (fig. 21).

This empirical modeling approach was used to statistically and spatially extend permafrost field observations using remotely sensed imagery, climatic data, and thematic maps of a wide range of surface and subsurface biophysical characteristics. Accurately calibrated models were then used to quantify changes in permafrost distributions under varying future climate scenarios assuming no other changes in biophysical factors. Model results indicate that near-surface permafrost presently underlays 38 percent of the land surface in Alaska. Projected increases in mean annual temperatures and precipitation are likely to have a profound effect on permafrost distributions. According to model simulations, near-surface permafrost areal extents were estimated to decline with a range of 16 to 24 percent during the 21st Century. Simulations suggest that the central region of Alaska is more vulnerable to permafrost degradation than more northerly regions and that lowland ecosystems were more resilient to permafrost degradation than upland ecosystems.

Partners involved in this study include the USGS, Alaska Ecoscience, Fish and Wildlife Service, Alaska Climate Science Center, University of Alaska Fairbanks, and the Department of Agriculture. The USGS EROS Center provides scientific analyses based on remote sensing and GIS technologies, field monitoring, and environmental modeling to support comprehensive terrestrial and aquatic LandCarbon assessments.

This mapping effort represents the first attempt to quantitatively map baseline and potential future distributions of near-surface permafrost in Alaska and is important for land use planning, environmental assessments, and a wide array of geophysical studies. Future studies are needed to better understand the resiliency and vulnerability of permafrost from climate and disturbance factors. For more information, contact Bruce Wylie, USGS EROS, wylie@usgs.gov.

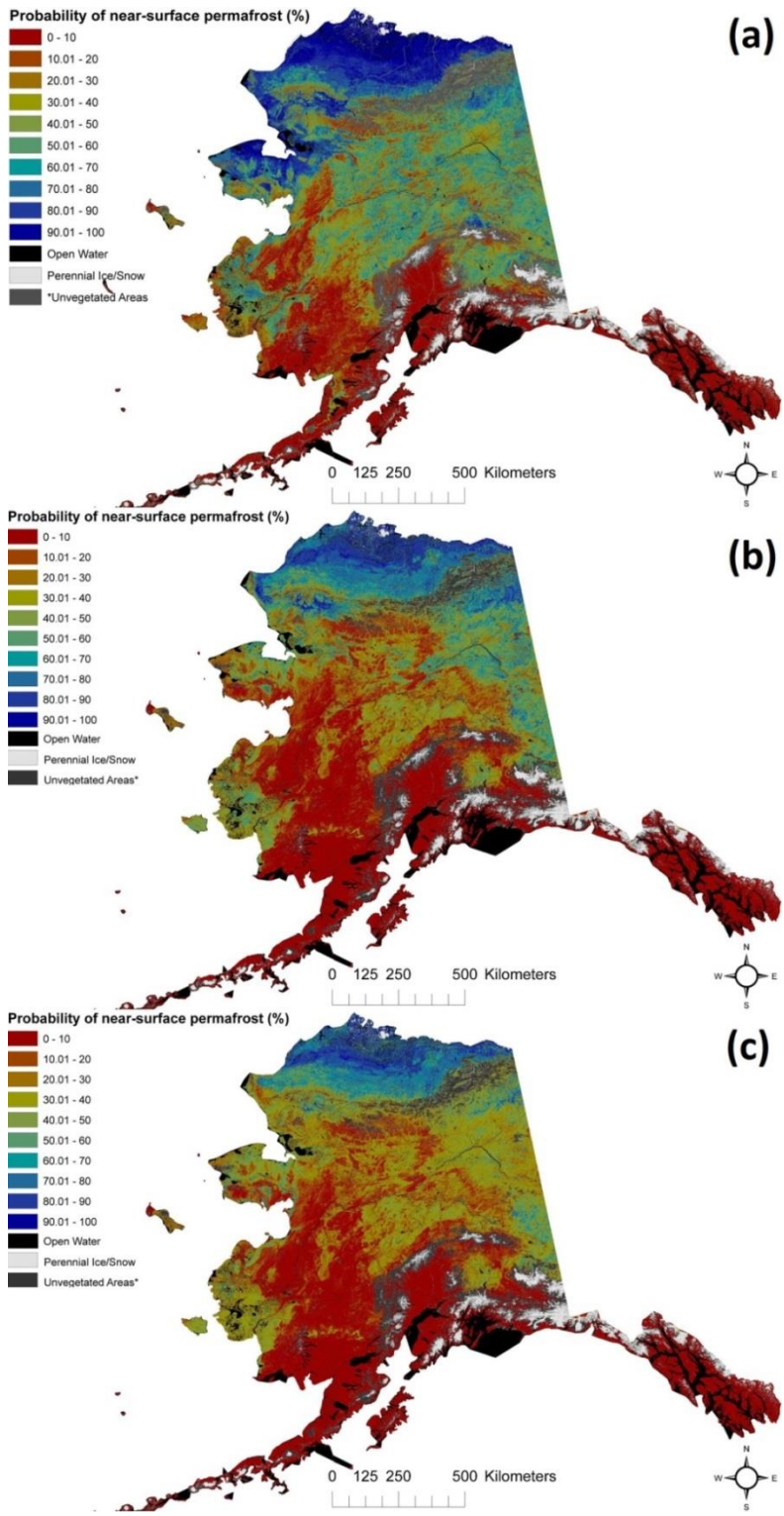

Figure 21. Probabilistic projections of near-surface (within 1 meter) permafrost extents using downscaled climate forcing data from generalized circulation model composites with A1B emission scenario for the 21st Century for years (a) 2010, (b) 2050, and (c) 2099.

Reference

National Research Council, 2014, Opportunities to use remote sensing in understanding permafrost and related ecological characteristics – Report of a workshop: Washington, D.C., The National Academies Press, 84 p., at http://www.nap.edu/openbook.php?record_id=18711.

Flux-Based Carbon Sinks and Sources of Grassland and Cropland of the U.S. Great Plains

In this study, scientists have developed two ecological-based net ecosystem production (eNEP) regression tree models capable of up scaling carbon flux (CFlux) measurements, collected at 28 point-based flux tower locations, to most grassland and cropland areas of the U.S. Great Plains. The models developed in this study yielded weekly cropland and grassland eNEP maps of the U.S. Great Plains at a 250-meter resolution for 2000-2008. Furthermore, the grassland and cropland results were statistically analyzed in a spatial and temporal comparative investigation. Results and analysis of this study presented CFlux characteristics of a vegetation type with minimal management (grassland) compared to that of a highly managed vegetation type (cropland).

Twenty-eight flux towers were incorporated into two databases for regression tree model development with 15 towers driving the grassland CFlux mapping model and 13 towers used to determine the cropland CFlux mapping model. Model training was completed by spatially and temporally linking the supporting flux tower records with applicable remote sensing data, weather metrics, and other biophysical inputs. The fully developed models were applied on weekly repetitions using the applicable input data to create weekly eNEP maps for grassland and cropland of the U.S. Great Plains. Finally, the cropland and grassland eNEP maps were analyzed and statistically compared using various temporal and spatial units.

The results of this study were a combination of map products (fig. 22) and statistical analyses (fig. 23). The weekly CFlux maps were further combined and summarized into weekly averages, seasonal averages, and annual averages for big picture analyses. An interannual variability assessment was performed, and the two different land cover types were considered in a statistical comparative analysis that revealed how each performed through time and space.

The modeling methodology used in this study exhibited the capability for upscaling eNEP measurements made by flux tower principal investigators aligned with Ameriflux, Fluxnet, Agriflux, the North American Carbon Program and independent researchers and provide a synoptic regional level CFlux synthesis. These results can focus localized and seasonal optimal carbon-based management approaches to help control rising atmospheric greenhouse gases linked to climate change. There is also work in

progress on creating a version of the model that performs upscaling to the full conterminous United States. For more information, contact Bruce, Wylie, USGS EROS, wylie@usgs.gov.

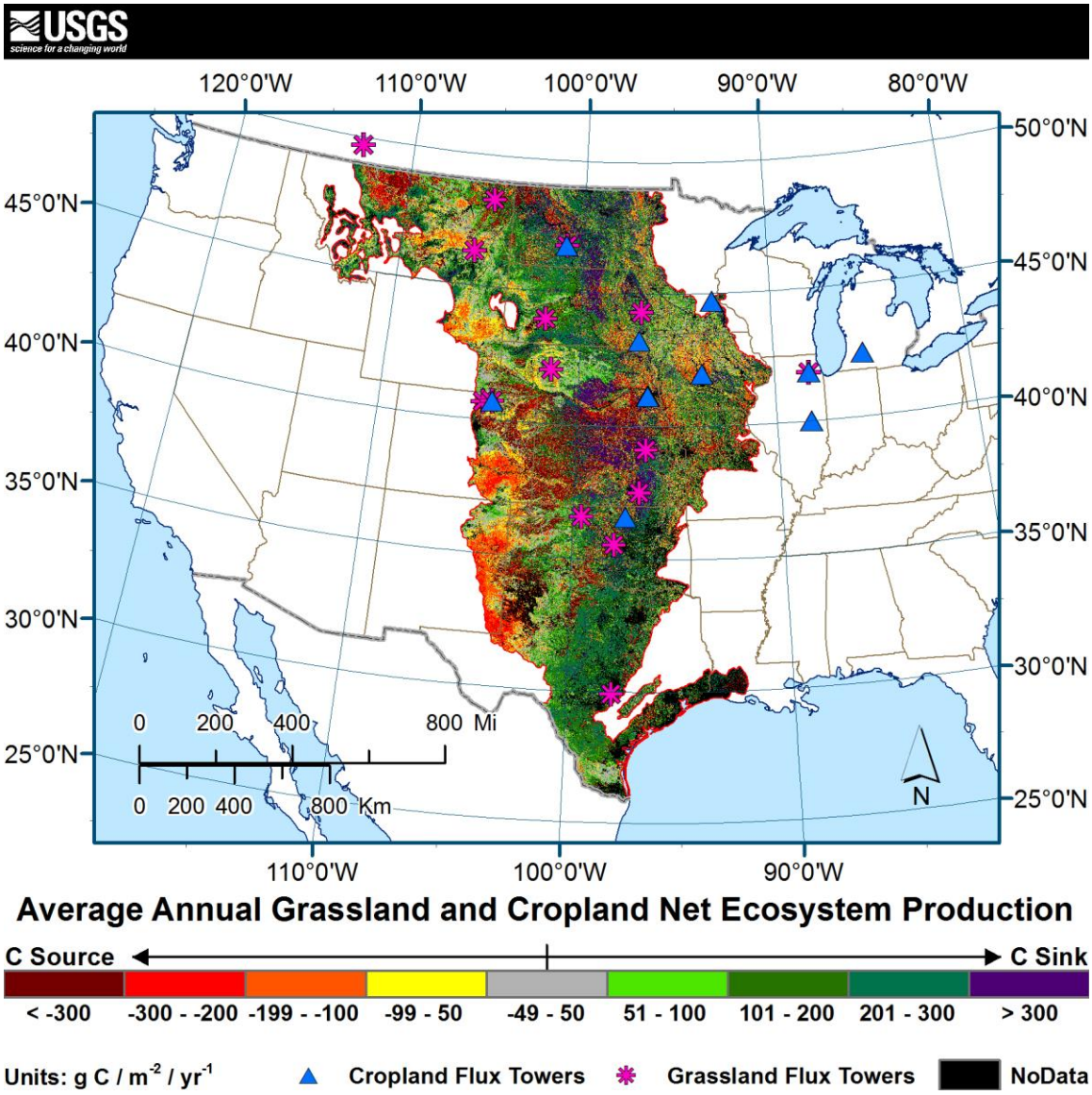

Figure 22. Average annual ecological-based net ecosystem production (eNEP) map (2000-2008) of the U.S. Great Plains. According to this map result, the spatial mean of cropland eNEP for the entire U.S. Great Plains was calculated to be -118.89 g of $C/m^{-2}/year^{-1}$, and the spatial mean of grassland eNEP was calculated to be 125.64 g of $C/m^{-2}/year^{-1}$.

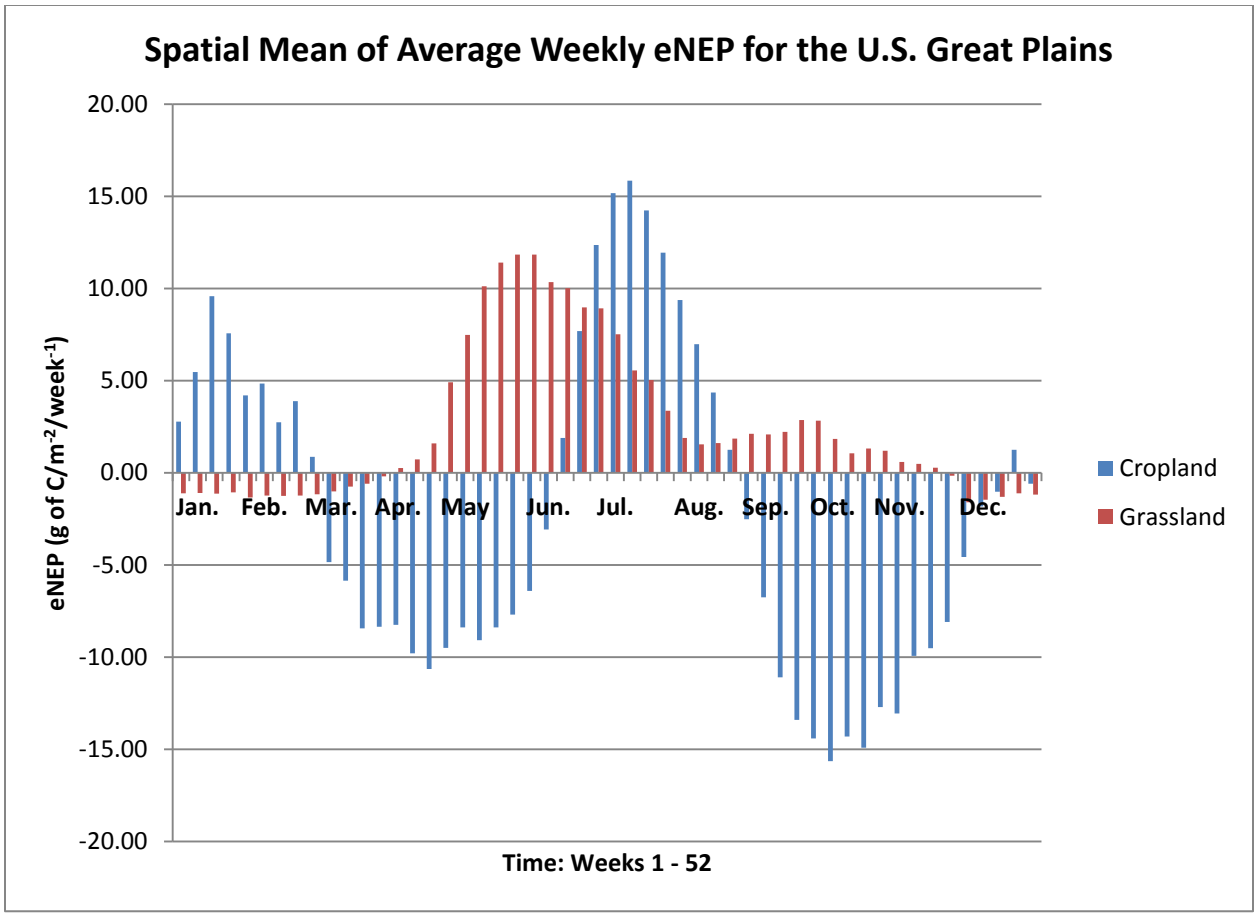

Figure 23. Spatial mean of average weekly ecological-based net ecosystem production for the entire U.S. Great Plains. The weekly iterations of this chart show how cropland and grassland compare and contrast during the course of a typical year. The positive values on the vertical axis indicate a carbon (C) sink (i.e., C taken out of the atmosphere), and the negative values indicate a C source (i.e., C released into the atmosphere).

How Land Cover Change Can Affect Honey Bee Pollination Services

The United States is the world's most active market for pollination services by honey bees, and the Northern Great Plains provide the majority of bee colonies used to meet the Nation's annual pollination needs. Legislation requiring increased production of biofuel crops, increasing commodity prices for crops of little nutritional value for bees in the Northern Great Plains, and reductions in government programs aimed at promoting land conservation have converged to alter the regional landscape in ways that challenge beekeepers to provide adequate numbers of hives for pollination services in California and elsewhere in the United States. In June 2014, the White House issued a Presidential Memorandum to create a Federal strategy to promote the health of honey bees and other pollinators. Section 3 of the memorandum focuses on increasing and

improving pollinator habitat. This signals a strong need to monitor land change from the perspective of habitat suitability for honey bees and other pollinators.

We developed a spatially explicit model that identifies sites with the potential to support large apiaries based on land cover requirements for honey bees within foraging distance from hives. The model can be used to assess large-area landscape suitability for apiaries in the Northern Plains under different scenarios of change, such as to consider influences from national policies and programs and/or other land change incentives. We identified local landscape criteria for honey bees based on industry standards professional beekeepers use to place hives in the Northern Great Plains. These criteria considered acreages of land cover types that provide valued floral sources of pollen and nectar throughout the growing season. We applied our model to locate places in the North Dakota landscape that met the land cover criteria using historical land cover data as well as land cover tuned to fit a scenario under recent drivers of land use change.

Our current wall-to-wall land cover and land change products lack adequate levels of mapping accuracy to monitor change at a scale appropriate for managing honey bees. Rather, our products are more effective as foundations for developing scenarios of change to analyze outcomes for pollinators from different drivers of land change (fig. 24). A new paradigm for monitoring land cover change that is under testing by EROS (through the Land Change Monitoring, Assessment, and Projection initiative) may help USGS realize the level of mapping accuracy required to monitor changes in land cover patterns at a scale appropriate for honey bees. For further information contact Alisa Gallant, USGS-EROS, gallant@usgs.gov.

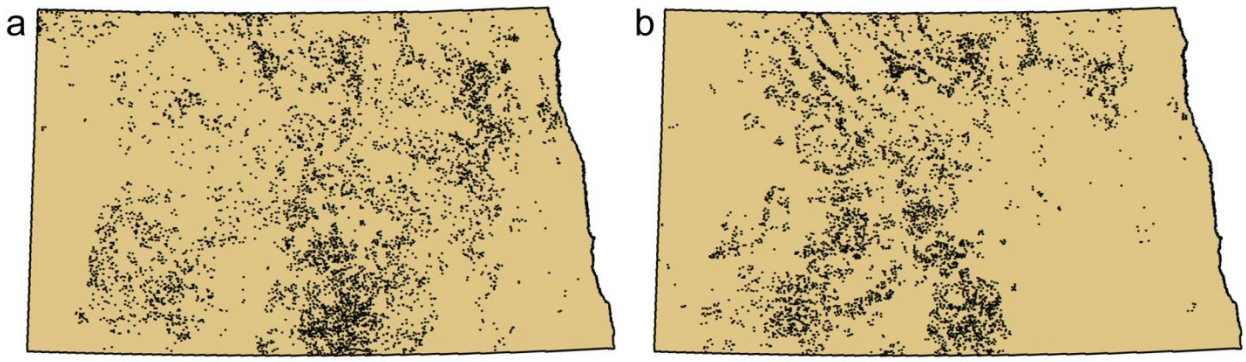

Figure 24. The distribution of locations (1 dot = 1 apiary location) in North Dakota meeting criteria to support large apiaries in 2002, a period with high land enrollment in the Conservation Reserve Program (a); versus in 2010, a period following landowner influence from high commodity prices and incentives to expand production of biofuel crops (b).

Hurricanes, Mosses, and the Carbon Cycle

Carbon cycle research is one of the main research activities in the U.S. Global Change Research Program and one of the key strategic research directions of the USGS. In FY 2014, scientists at the USGS EROS Center researched disturbance impacts to the carbon cycle from the aspects of hurricanes and of mosses.

Hurricanes cause severe impacts on forest ecosystems in the United States. These events can significantly alter the carbon biogeochemical cycle at local to regional scales. Scientists at the EROS Center have selected all tropical storms and more severe events that made United States landfall between 1900 and 2011 (fig. 25) and used hurricane best track database, a meteorological model (HURRECON), National Land Cover Database, U.S. Department of Agriculture's Forest Service biomass dataset, and pre- and post-MODIS data to quantify individual event and annual biomass mortality.

The average annual loss of above ground biomass (AGB) for the studied time period was 18.2 TgC (the range was between 12.7 and 23.5 TgC). The most destructive year in terms of AGB was 1954 with 68.37 TgC followed by 1960 and 1969 with 65.95 TgC and 63.76 TgC, respectively. Individually, Hurricane Camille in 1969 caused largest destruction of AGB with 59.49 TgC while passing through Louisiana and Mississippi. The other two most destructive hurricane events were Donna in 1960 and Hazel in 1954 with 51.48 TgC and 47.39 TgC, respectively. Spatially, the Gulf coast (coastal region of Louisiana, Mississippi, Alabama, and North Western Florida) and the mid-Atlantic coast (Virginia and North Carolina coastal areas), lost higher biomass on average per square meter over the studied time period (fig. 26). The 1925-1950 time period had lower AGB mortality rate compared to 1900-25, 1950-75, 1975-00, and 2000-11 time periods (fig. 26). More detailed information on this topic can be found in Dahal and others, 2014.

Differentiating moss from higher plants is critical in studying the carbon cycle of the boreal biome, otherwise known as swampy, moist forest in the northern high latitudes. Vegetation gross primary production (GPP) is one of the major components controlling land-atmosphere CO_2 exchange. A small error in simulating vegetation production can substantially alter the magnitude of the estimated global carbon balance. Moss, one of the major groups of bryophytes, is a ubiquitous and dominant component of ground-level vegetation in the boreal biome. Moss is typically among the first ground layer species to become established after disturbance. The satellite-derived normalized difference vegetation index (NDVI), which is used for estimating GPP, often includes contributions from both mosses and vascular plants in boreal ecosystems. For the same NDVI, moss can generate only about one third of the GPP that vascular plants can because of its much lower photosynthetic capacity. However, the difference in photosynthetic capacity between these two plant functional types has never been explicitly included when estimating regional GPP in the boreal region. Using eddy covariance measurements and modeling techniques, scientists show that ignoring the difference may lead to a substantial overestimation of GPP. The magnitude of this

overestimation could have important implications on whether the boreal biome is a carbon source or sink. Moss abundance, associated with ecosystem disturbances, needs to be mapped and incorporated into GPP estimates in order to adequately assess the role of the boreal region in the global carbon cycle. The results on this topic are published in *Nature Communications* (Yuan and others, 2013).

For further information on these topics, contact Shuguang Liu, USGS EROS, sliu@usgs.gov.

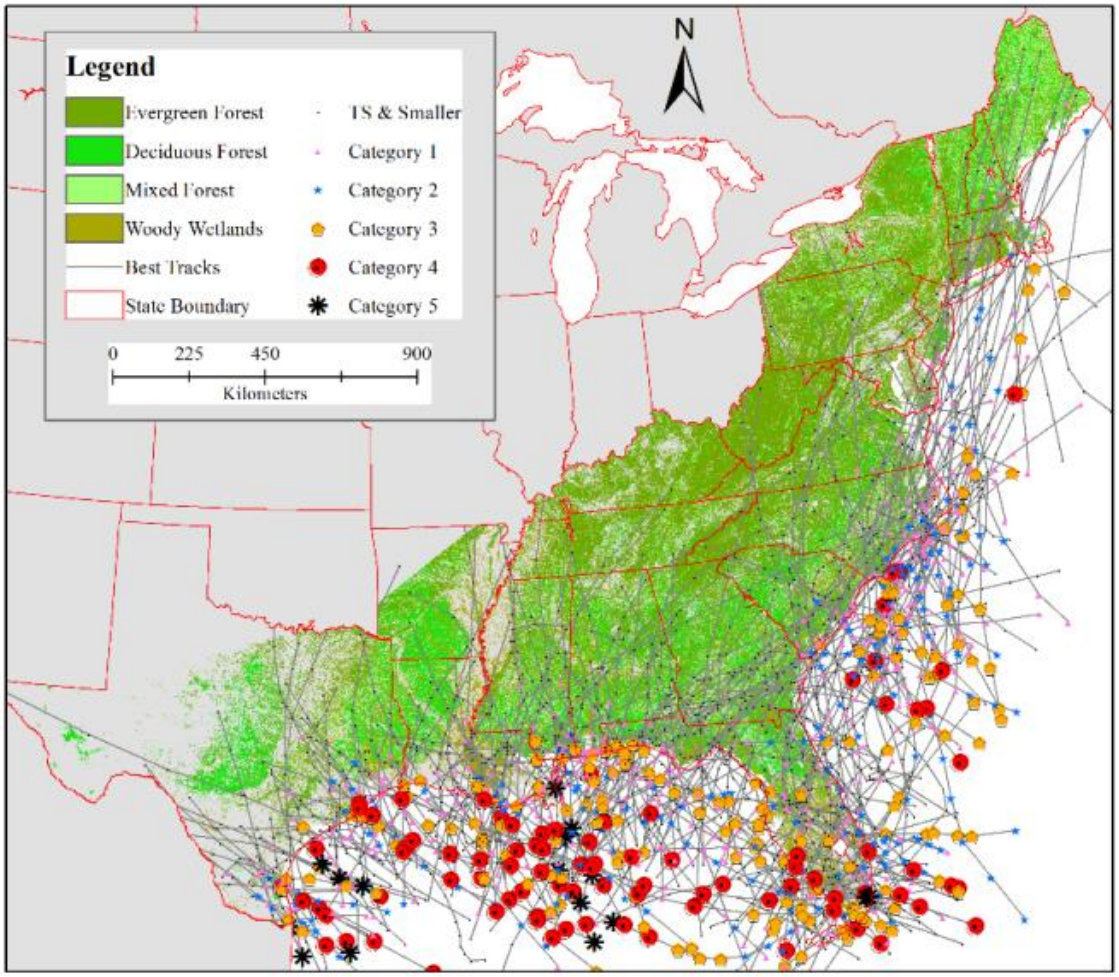

Figure 25. Forest areas were derived from National Land Cover Database 2001. Hurricane best-tracks and category data were from The North Atlantic hurricane database, or HURDAT, for 1900-2011. Categories were based on the Saffir-Simpson scale and TS stands for tropical storm. Best-tracks were cut off after they decreased below a sustained weed speed of 18 mile per hour over land.

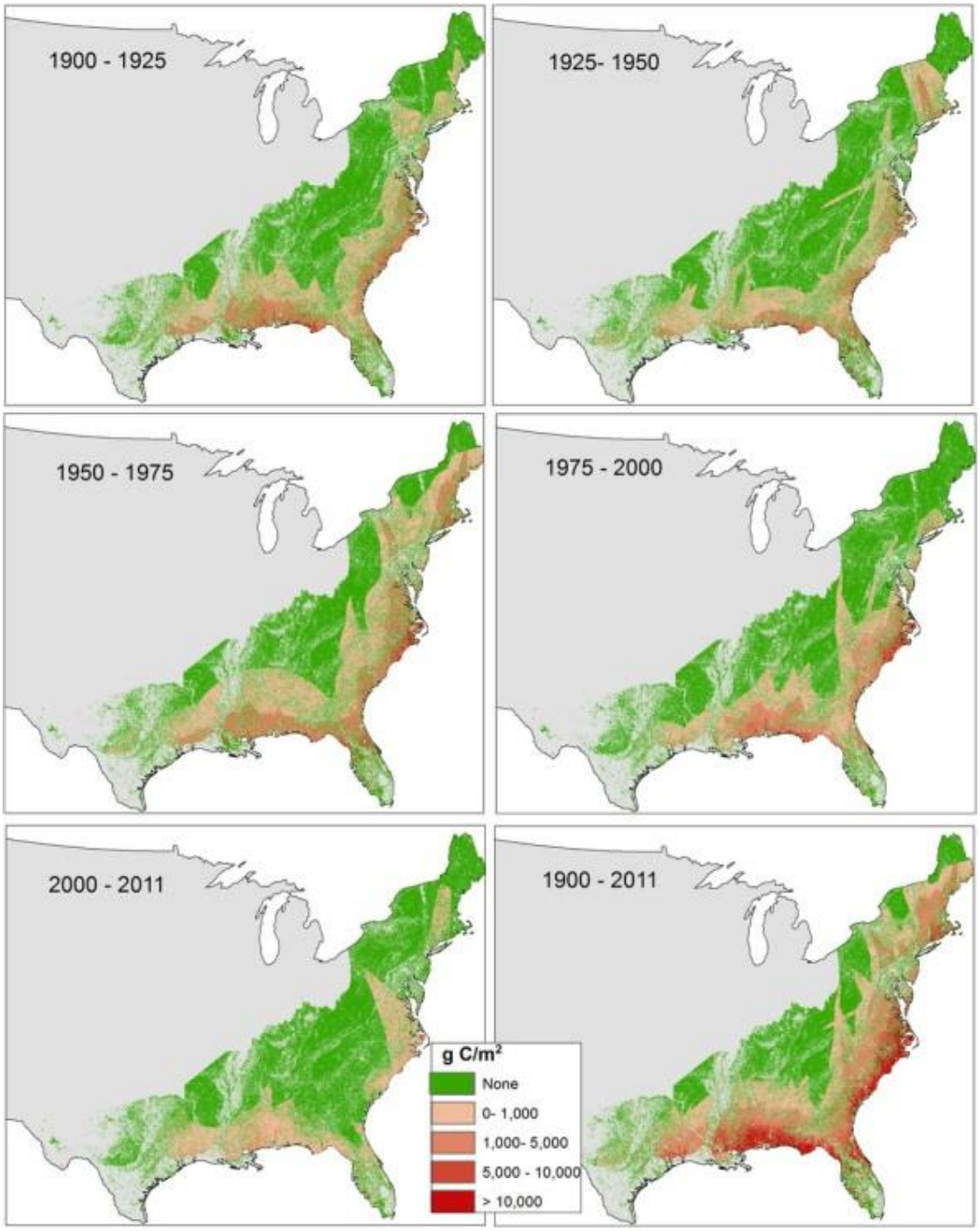

Figure 26. Long-term average biomass mortality from hurricane events for the conterminous United States over different time periods.

Modeling Capacity Development and Applications to Carbon Cycle

Carbon cycle research is one of the main research activities in the U.S. Global Change Research Program and one of the key strategic research directions of the USGS. Developing robust modeling systems with data assimilation capacity is critical to quantify and understand carbon dynamics over large areas.

In FY 2014, scientists at the USGS EROS Center developed a generic automatic calibration (auto-calibration) package for a well-established biogeochemical model – the General Ensemble Biogeochemical Modeling System (GEMS)-Erosion Deposition Carbon Model (EDCM) – using data assimilation technique: the Shuffled Complex Evolution (SCE) algorithm and a model-inversion R package – Flexible Modeling Environment (FME). The new functionality can support multi-parameter and multi-objective auto-calibration of GEMS-EDCM. Figure 27 shows the operational flowchart of the developed auto-calibration package for ecological modeling.

EROS scientists successfully applied the GEMS-EDCM with this auto-calibration package for a single crop pixel with a corn wheat rotation and a large ecological region (Level II) – Central United States Plains. The county-based scatter plots shown in figure 28 demonstrates the model performance in net primary production (NPP) simulation for non-crop land covers (forest, grass/shrub, and wetland pixels) and grain yield simulation for crops (corn, wheat, and soybean). The case studies and evaluation results indicate that the developed package works satisfactorily by implementing calibration and validation with readily available survey data (grain yield) and remote sensing data (NPP) especially at regional and national levels.

Another study in FY 2014 focused on modeling soil and soil organic carbon movement on the agricultural landscape. Increases of global demand for agricultural production and global warming affect fragile lands. Cultivated lands in the United States Midwest have been affected by soil erosion and deposition, causing soil organic carbon (SOC) redistribution in the landscape and other environmental agricultural problems. The importance of SOC redistribution on soil productivity and crop yield is still uncertain. The main objective of this study was to evaluate a soil modeling framework and to estimate and understand soil and SOC redistribution caused by water and tillage in two agricultural fields in Iowa of the Midwest United States where corn-soybean rotation and different tillage systems have been applied since 1957.

In this study, a GIS model framework, which includes the Unit Stream Power-based Erosion and Deposition (USPED) and the Tillage Erosion Prediction Aid (TEP-A) models, was evaluated for different digital elevation model (DEM) spatial resolutions (10-m, 24-m, 30-m, and 56-m) and topographic exponents for rill and sheet erosion from water (m =1.0–1.6 and n =1.0–1.3) using soil redistribution rates from ^{137}Cs measurements.

The results showed that the aggregated 24 m DEM, m = 1.4 and n = 1.0 for rill erosion, and m = 1.0 and n = 1.0 for sheet erosion, provided the best fit with the observation

(^{137}Cs) data at both sites. Moreover, estimated average SOC redistributions were 1.3 ± 9.8 g C m^{-2} y^{-1} and 3.6 ± 14.3 g C m^{-2} yr^{-1} respectively at these two sites. Spatial distribution patterns showed SOC loss (negative values) in the eroded areas and SOC gain (positive value) in the deposition areas (fig. 29). The results showed where carbon loss and gain occurred because of soil erosion and deposition from water and tillage erosion.

This study demonstrated the importance of the spatial resolution and the topographic exponents to estimate and map soil redistribution and the SOC dynamics throughout the landscape, helping to identify places where erosion and deposition from water and tillage are occurring at high rates. Improving predictions about soil erosion and deposition in agricultural landscapes and assessing their impacts on soil carbon redistribution and dynamics may help to understand where and why soil and SOC redistribution is happening. This may lead to better management to control erosion in the future and better assessments of the impact of erosion and deposition on C loss and sequestration at local or regional scales through SOC redistribution. The research results from this study were published in the journal *Geoderma* (2014).

In yet another study, scientists set out to evaluate baseline ecosystem carbon stocks and future changes using three climate change projections and three global change scenarios. The Federal lands across the conterminous United States account for 23.5 percent of the conterminous United States terrestrial area, but have received no systematic studies on their ecosystem carbon dynamics and contribution to the national carbon budgets. Based on the national assessment of biological carbon sequestration potentials, mandated by the Energy Independence and Security Act of 2007, we evaluated baseline (around 2005) ecosystem carbon stocks and future changes under three climate change projections and three IPCC (Intergovernmental Panel on Climate Change) global change scenarios (A1B, A2, and B1). The average total ecosystem carbon stock was estimated as 11,613 TgC in 2005 and projected to be 13,965 TgC in 2050, ranging from 13,766 TgC under A1B, 13,811 TgC under A2, to 14,017 TgC under B1, or representing an average increase of 19.4 percent from the baseline (2005) (fig. 30). The estimates of the ecosystem carbon stocks for either baseline or future projection were highly variable among multiple model runs, global change scenarios, particularly among land use and land cover scenarios. The baseline ecosystem carbon density of forests, grasslands, and shrublands (three major ecosystems) were 128, 27, and 19 kg C ha^{-1}, respectively. Forests and grassland were predicted to act as carbon sinks and shrublands as a source in the future. The Federal lands could contribute about 14 percent to the national terrestrial ecosystem carbon budget. The carbon sequestration potential in the future depends not only on the footprint of individual ecosystems, but also on the agency's missions-oriented land use and management. More field observations and modeling studies are required to evaluate the actual differences in ecosystem carbon budgets and carbon sequestration potential between Federal lands and their neighbored non-Federal lands.

For further information on these topics, contact Shuguang Liu, USGS EROS, sliu@usgs.gov.

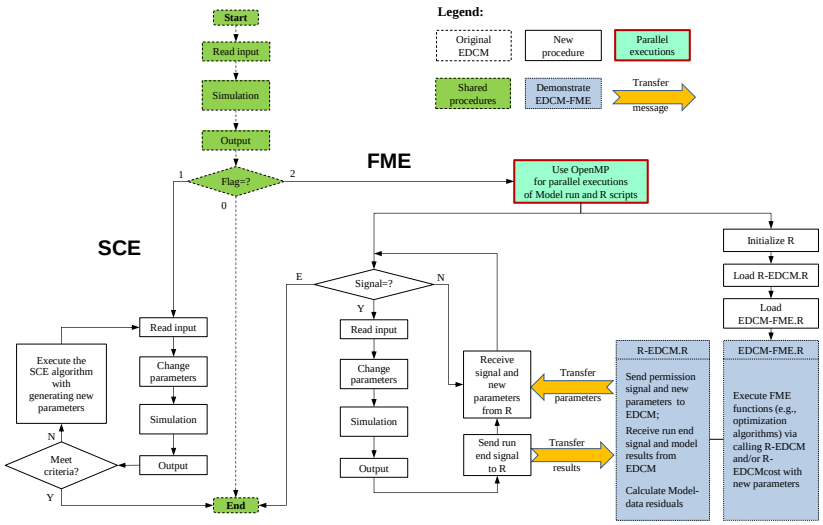

Figure 27. The operational flowchart of the auto-calibration package for Erosion Deposition Carbon Model (EDCM) with three options: original EDCM, EDCM-Shuffled Complex Evolution (SCE) and EDCM- Flexible Modeling Environment (FME). EDCM-FME requires two R script files (R-EDCM.R, comprised of two R functions: R-EDCM and R-EDCMcost, and EDCM-FME.R, which contains the major FME functions) (adapted from Wu and Liu, 2012).

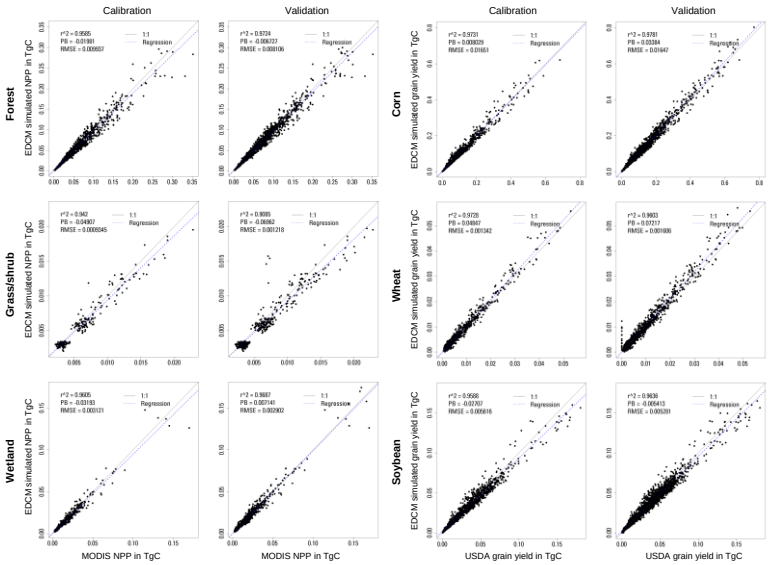

Figure 28. Scatter plots of county-based annual total net primary production (NPP) of Moderate Resolution Imaging Spectrometer and Erosion Deposition Carbon Model (EDCM) for forest, grass/shrub, and wetland (left two columns) and grain yield of the U.S. Department of Agriculture and EDCM for corn, wheat, and soybean (right two columns) during the regional calibration (2001–2005) and validation (2006–2010) periods. One data point represents the annual total NPP or grain yield in TgC (=10^{12} gC) for a county.

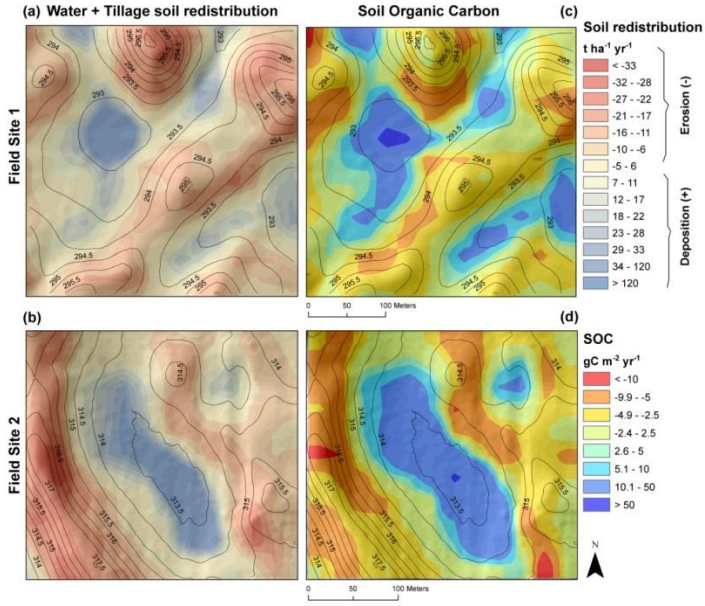

Figure 29. Simulated soil (a and b) and soil organic carbon (c and d) redistribution from water and tillage on two landscapes.

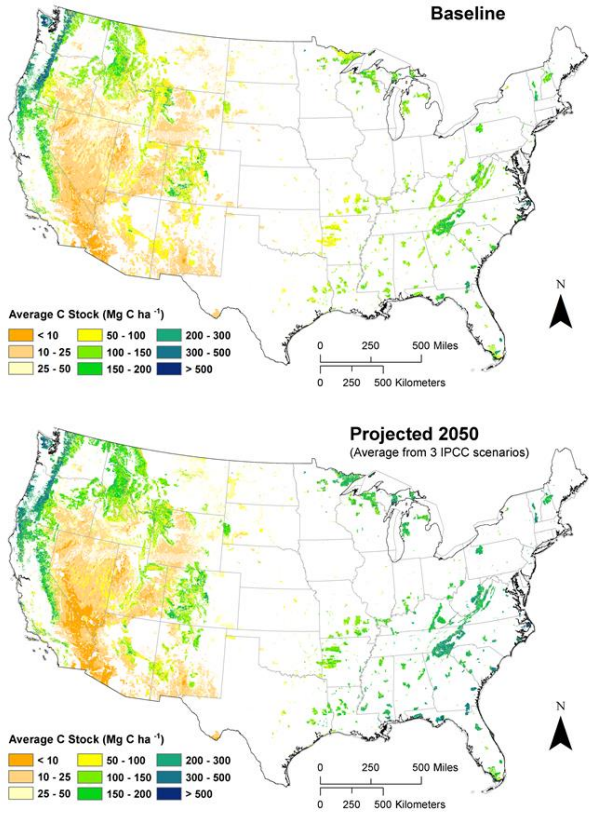

Figure 30. Spatial distribution of ecosystem carbon stocks in the conterminous United States federal lands for the baseline (2005) and the projection as of 2050, respectively.

Size Distribution of Lakes and Ponds in Alaska and Effects of Mapping Scale

Lakes and ponds are important aspects of most ecosystems. Not only do they provide water resources for human use, they play important roles in global biogeochemical cycles. Much of the geographic data available for lakes and ponds are published at scales that omit small bodies and map only the larger lakes. For example, Alaska, the largest state in the Nation, is also very geographic data poor due to the physical size of the state and the difficulty accessing large remote areas. Currently, the mapping inventories of Alaska's lakes and ponds are available only at a moderate or coarse resolution. This lack of information requires scientist to estimate the impact of small lakes and ponds based on distribution models rather than with actual data.

Research has noted that small lakes and ponds in lake-rich northern permafrost regions (fig. 31) can account for over 70 percent of net CO_2 emissions. To assess the impact of using moderate resolution data to estimate water surface area, we compared available map products to lake and pond area calculated from high-resolution satellite data. We found that methods used to develop the geographic data products and scale impact data accuracy. The results provide information for scientists to consider when attempting to reduce error in estimating small lake and pond area from currently available datasets. For further information, contact Jennifer Rover, USGS EROS, jrover@usgs.gov.

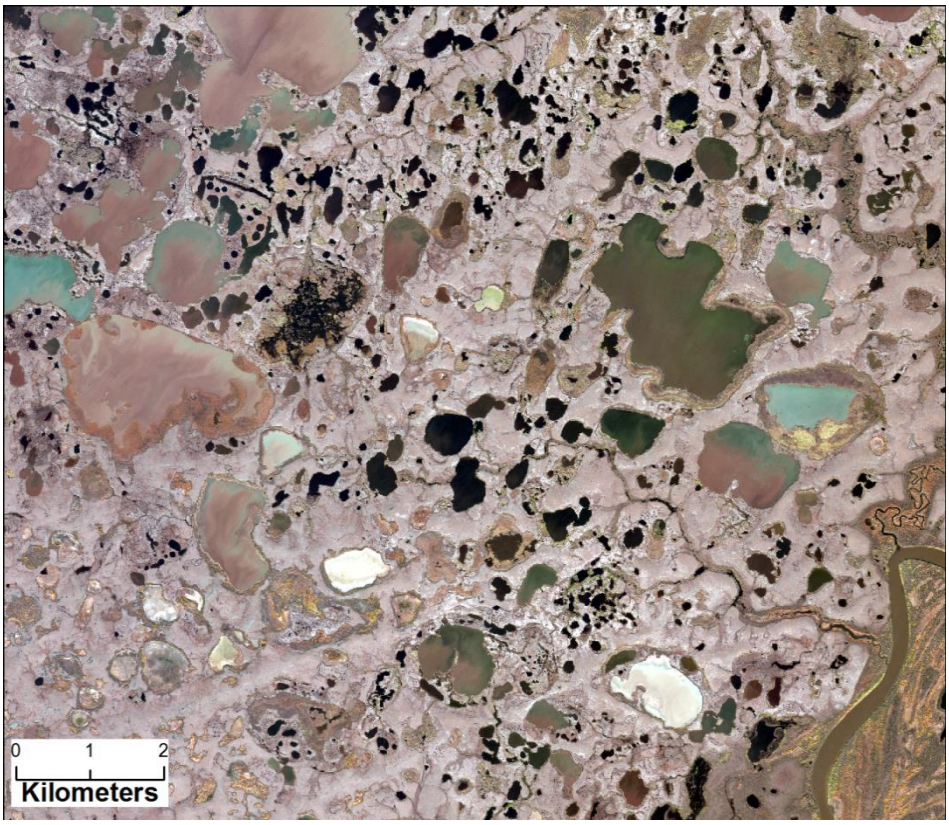

Figure 31. An example of a northern latitude lake-rich landscape.

Mapping Great Plains Playa Habitat

Many of the wetlands located in the Great Plains of the United States are playas. A playa is a shallow wetland that is sometimes full of water from precipitation, but at other times, is completely dry. This irregular hydroperiod promotes diversity within the playa and the surrounding prairie. Playas are often recognized as a unique habitat, and they provide resources for migrating birds, including the Sandhill Crane. Playas also supply water for irrigation and provide a recharge source for the Ogallala Aquifer. Unfortunately, the aquifer water levels continue to decline as irrigated agriculture and human usage exceeds the recharge rate.

Data from space-based sensors provide coverage of the Great Plains during both dry and wet weather. This data, from Landsat, provides snapshots of the playas at different times, under different types of conditions. This provides a robust inventory of playas and their hydroperiods, indicating habitat and groundwater recharge availability. In the near future, the USGS and Fish and Wildlife Service will model playa habitat by including climate and bird migration data. This project is supported by multiple Federal, State, and nonprofit agencies who will use the data to manage playa-related resources. For further information, contact Jennifer Rover, USGS EROS, jrover@usgs.gov.

Topographic Science, Lidar, and Elevation

The Topographic Science, Elevation, and 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.

Coastal National Elevation Database: Sandy-CoNED and the Northern Gulf Coast

Quantitative high-resolution coastal elevation information is required to build integrated topobathymetric elevation models, inventory wetland and agricultural land resources, and to identify flood, hurricane, and sea-level rise inundation hazard zones. Many applications of geospatial data in coastal environments require detailed knowledge of near-shore topography and bathymetry as physical processes in the coastal environments are controlled by the geomorphology of both “over-the-land” topography and “underwater” bathymetry. Light detection and ranging (lidar) enables the rapid collection of very accurate elevation data over large areas, and during the last decade, airborne laser altimetry has been widely applied to map coastal geomorphology, leading to improved knowledge of coastal geomorphic processes.

The Coastal National Elevation Database (CoNED) applications project, supported by the USGS Coastal Marine and Geology Program (CMGP), is arranged to construct high-resolution integrated topobathymetric elevation models from disparate lidar and acoustic bathymetric datasets aligned both vertically and horizontally to common

reference systems. Topobathymetric digital elevation models (TBDEMs) are merged renderings of both topography (land elevation) and bathymetry (water depth). Topobathymetric models provide a required seamless elevation product for several science application studies such as shoreline delineation, coastal inundation mapping, sediment-transport, sea-level rise, storm surge models, tsunami impact assessment, and also to analyze the impact of various climate change scenarios on coastal regions.

Hurricane Sandy severely impacted the New Jersey coast, altering the topography and ecosystems of this heavily populated region. In response to Super Storm Sandy, the USGS is developing high-resolution 3-D topobathymetric models from Cape Cod, Massachusetts, to the Outer Banks in North Carolina. A 1-meter TBDEM (version-1) was developed for the Barnegat Bay estuary and adjacent coastline in New Jersey that integrated dozens of high-resolution lidar and bathymetric surveys acquired by numerous sources (fig. 32). The Barnegat Bay estuary is a small briny extension of the Atlantic Ocean with several small rivers, including the Toms River and Metedeconk River draining into the bay. The estuary is separated from the Atlantic Ocean by a long barrier peninsula and Long Beach Island. This model of New Jersey/Delaware will be updated (version-2) in FY 2015 with new post-Sandy lidar and bathymetry data.

A 1/9th arc-second (approximately 3-meter) TBDEM was also developed for the Northern Gulf Coast, extending from the Florida/Alabama border on the east to the Louisiana/Texas border on the west (fig. 33). Coastal Louisiana is experiencing the highest rates of wetland loss in the United States, resulting in the disappearance of 1,880 square miles of land since the 1930s (State of Louisiana, 2012). Land loss in Louisiana is caused by both human activities and natural factors, from the unintended consequences of coastal engineering projects that provide flood protection to communities, to natural phenomena such as sea-level rise and storm surge. The new and improved integrated elevation model derived from over 400 different lidar and bathymetric sources will help agencies in the region model the risk and impacts of flood and storm surge events.

In support of Hurricane Sandy, the CoNED project in FY 2015 plans to release a 1-meter TBDEM for the New England, Chesapeake Bay, and North Carolina sub-regions. In addition, existing high-resolution topobathy models in Southern California and San Francisco Bay will be extended in FY 2015 further offshore and inland based on the availability of new lidar and bathymetric data. Using lidar, research in FY 2015 will be conducted to map wetland shoreline to derive wetland status metrics, to measure sea cliff erosion, and to hydrologically-enforce channels in topobathymetric models. For further information, contact Jeffrey Danielson, USGS EROS, daniels@usgs.gov.

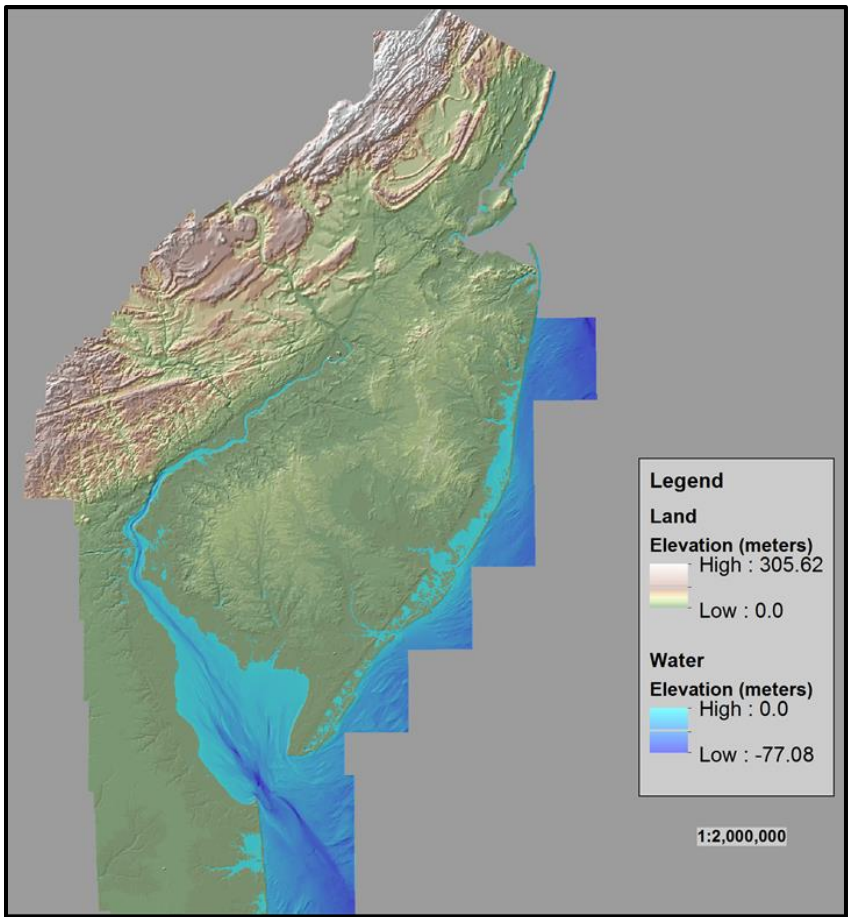

Figure 32. Sandy Coastal National Elevation Database – New Jersey/Delaware region (version-1) 1-meter integrated topobathymetric model (2014).

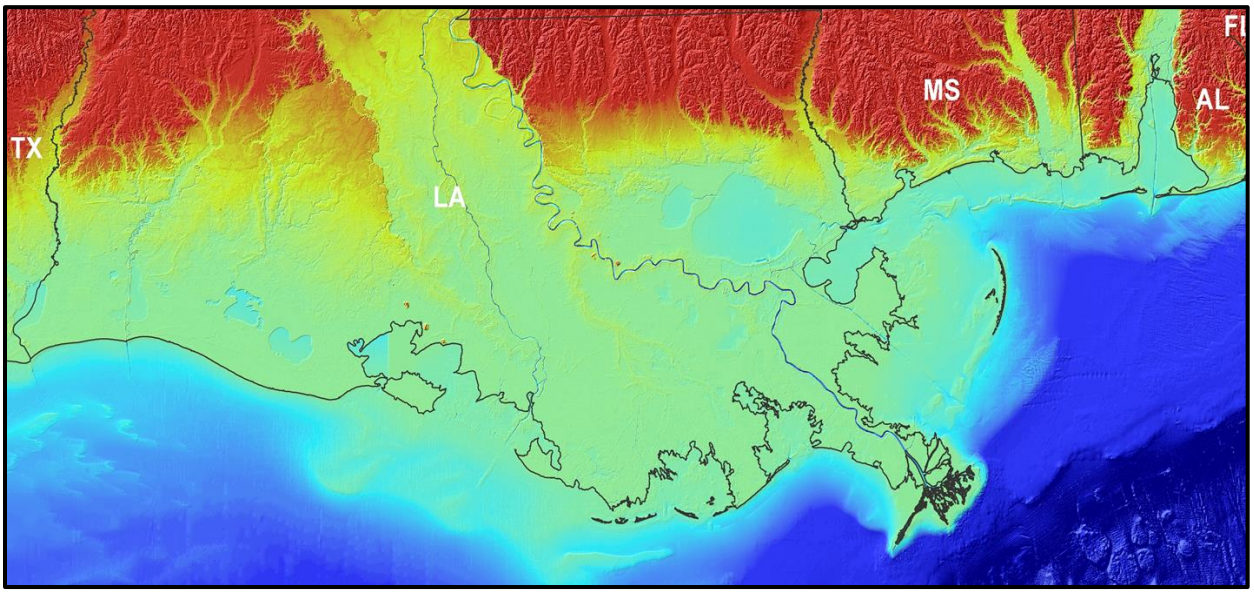

Figure 33. Northern gulf coast 3-meter integrated topobathymetric model (2014).

USGS Investigates Height Above Ground Models from Lidar Point Cloud Data

USGS scientists, with funding from the LRS Program, have begun research into the development and applications of Height Above Ground (HAG) models derived from lidar point cloud data. HAG models support numerous critical environment analyses including fire science, biomass, forestry, habitat and environmental studies, agriculture health and yields, weather, and other natural hazards (fig. 34). Although the topical applications of HAG models are known, such models are not widely available, rarely extend beyond individual collections, and usually require substantial effort to develop for each study. With the advance of the 3D Elevation Program (3DEP), methods are needed to manage and exploit lidar data over broad areas and across multiple collections if the value of the lidar point cloud is to be fully realized.

Using existing lidar data collected under common specifications, semi-automated routines were developed to produce consistent analysis-ready HAG output products. These routines utilize off-the-shelf software common within the lidar industry, enabling rapid prototyping and community accessibility.

Even when collected and delivered using a common specification and file format, processing and handling of lidar data varies widely across vendors. Irregularities in data file content and structure were widespread and proved significant in both cross-project analysis and within individual collections. Similarly, the various software packages have different tolerances for these errors; data accepted and processed through one application might fail at a later step. Many projects unexpectedly required substantial pre-processing and standardization to make the source data usable in an automated process.

In practice, variations in lidar point density within and across projects had an unforeseen influence on HAG calculations (fig.35). This effect was mitigated, though not eliminated, through adjustments to data structure and processing algorithms; further research into a more robust normalization process is needed.

In addition, the HAG project is supporting the Center for Severe Weather Research by providing HAG and First Reflective Surface models for use in their Plains Elevated Convection At Night (PECAN) study (fig. 36). The PECAN study will increase understanding of dangerous nocturnal convective storms, allowing earlier and more accurate prediction to reduce damage, injury, and loss of life. PECAN receives additional support from the National Science Foundation, NOAA, NASA, and the Environmental Science Research Institute (ESRI).

In spite of the unexpected extra effort required to prepare the data, HAG models were produced and are now available for 68 projects, totaling approximately 66,000 square miles (fig. 37). Research and development of HAG and related models is continuing through FY 2015.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, environmental modeling, and GIS technologies to support 3DEP development and implementation activities. For further information, contact Karl Heidemann, USGS EROS, kheidemann@usgs.gov.

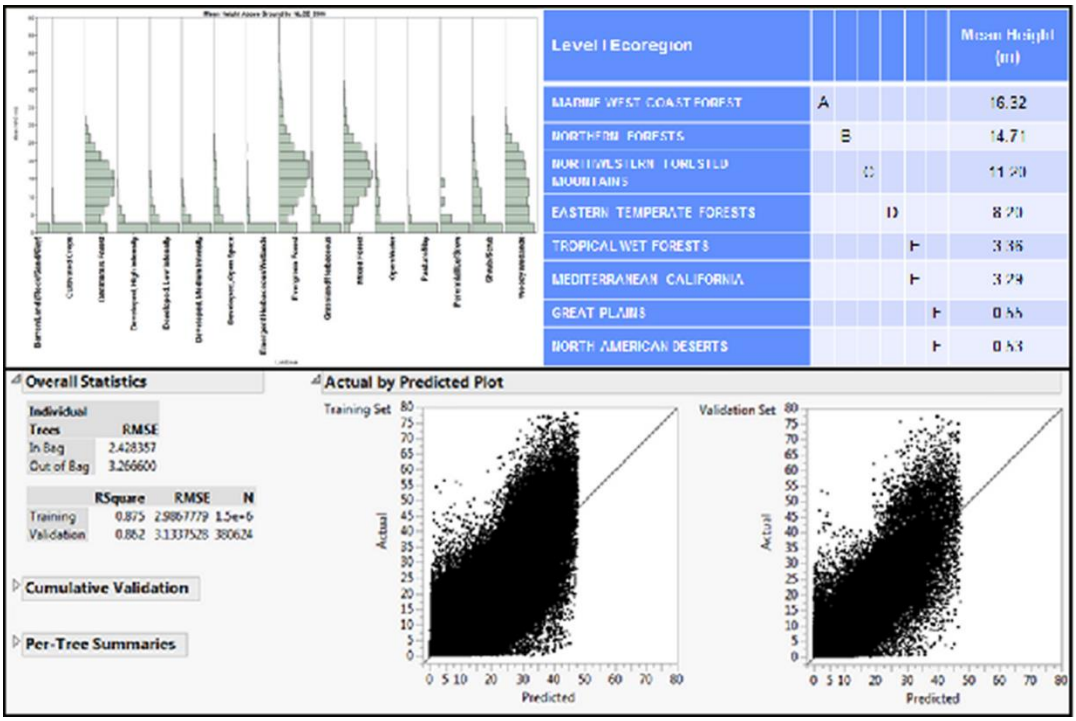

Figure 34. Examples of descriptive vegetation metrics and characterizations derived from lidar point cloud data and height above ground models.

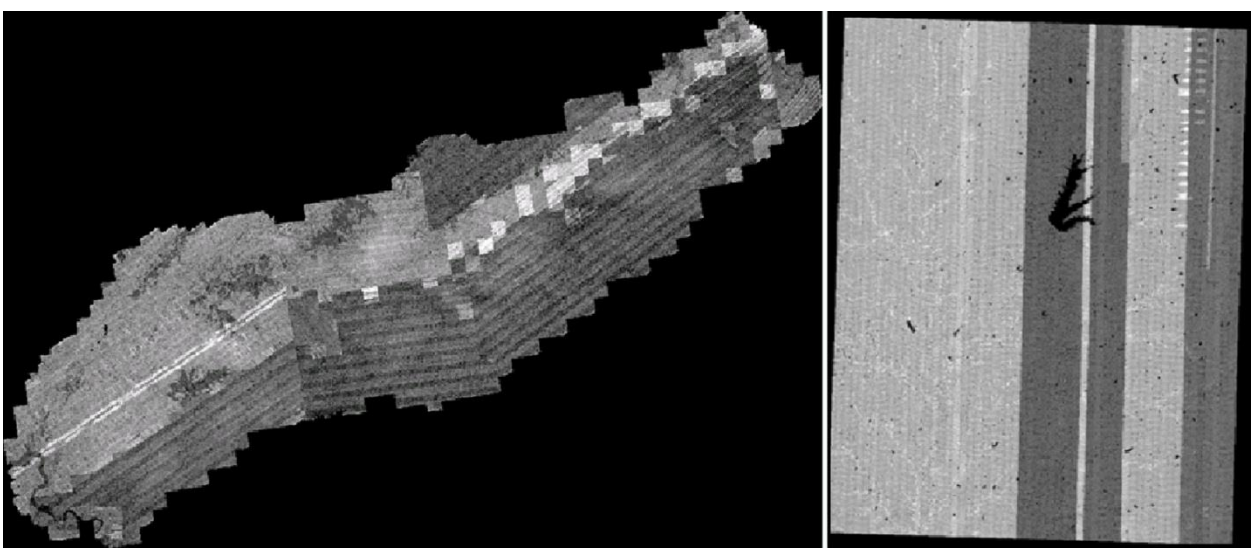

Figure 35. Examples of irregular variations of lidar point density within individual collection projects.

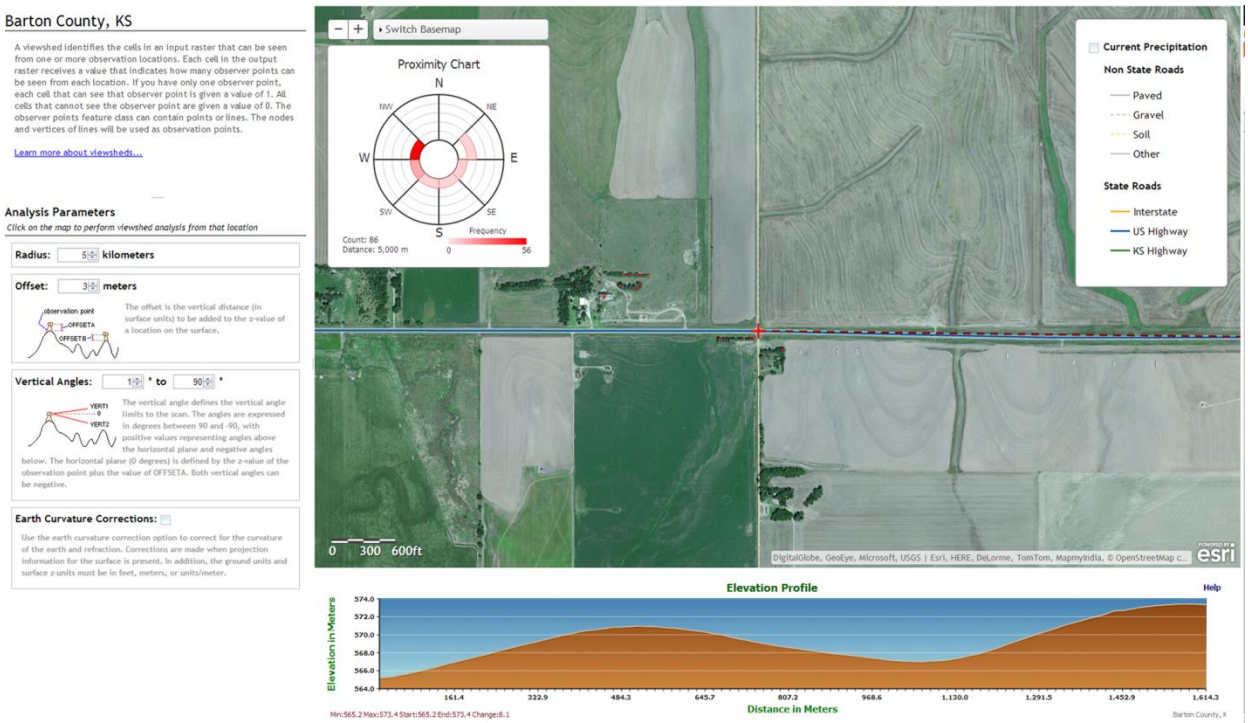

Figure 36. First reflective surface and viewshed analysis for the Plains Elevated Convection At Night study.

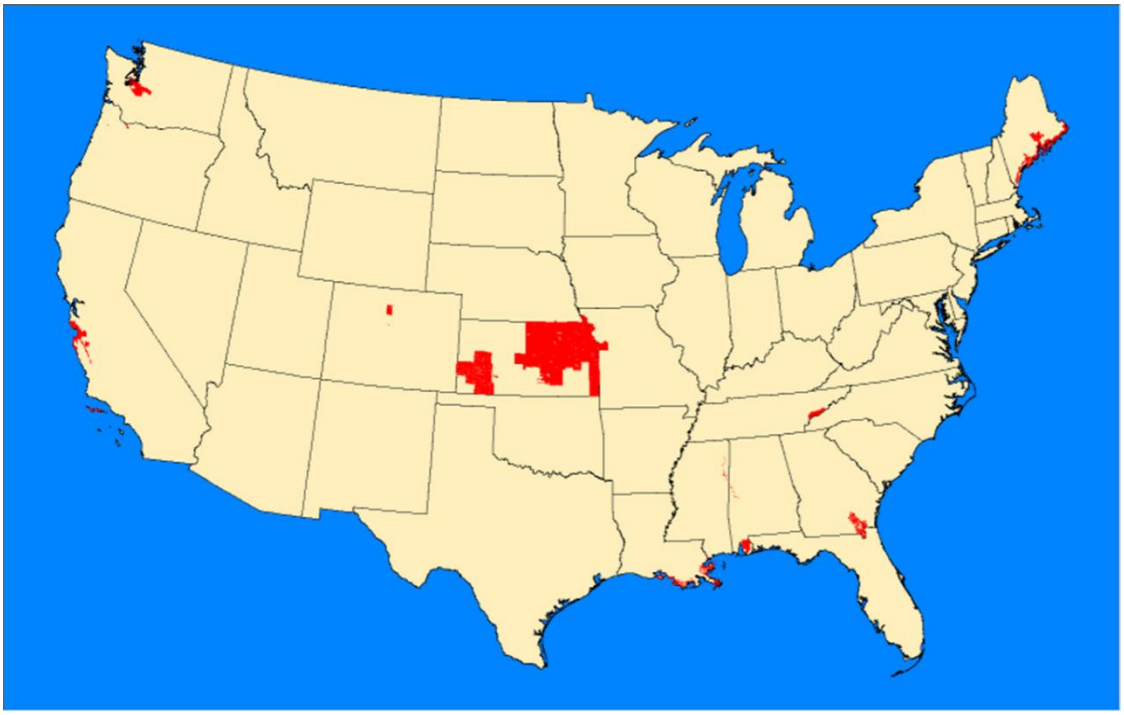

Figure 37. Areas for which lidar-derived height above ground products were produced in FY 2014.

New Million-Scale Datasets from the National Atlas of the United States®

The National Atlas of the United States® produced maps, datasets, and geographic information at regional and national scales for use by government agencies, mapping professionals, and the public. The project was funded by the USGS National Geospatial Program (NGP) under Core Science Systems and was managed by Jay Donnelly. As part of close-out activities in FY 2014, the National Atlas continued to work on 1:1,000,000-scale datasets, representing the USGS's first original compilation in many years of a comprehensive, multi-layered, national-coverage base dataset.

Two accomplishments are highlighted from the body of work performed in support of million-scale dataset development by the National Atlas project at EROS in FY 2014:

1. Populated places (cities, towns, etc.) are a critical part of million-scale base mapping. National Atlas staff at EROS completed cartographic review of 41,103 million-scale populated places in FY 2014, and that dataset has been released as part of *The National Map S*mall-Scale collection.

2. Federal and tribal lands is the final million-scale National Atlas dataset in development. National Atlas staff at EROS completed cartographic review of the eastern United States (fig. 38); staff in Reston completed the western United States and Alaska. This dataset is scheduled for release by the end of calendar year 2014 as part of *The National Map* Small-Scale collection.

The National Atlas has been rebranded as *The National Map* - Small Scale. Legacy datasets, web mapping services, selected dynamic maps, and hundreds of printable maps are accessible under the new name at (http://nationalmap.gov/small_scale/). For further information, contact John Hutchinson, USGS EROS, hutch@usgs.gov.

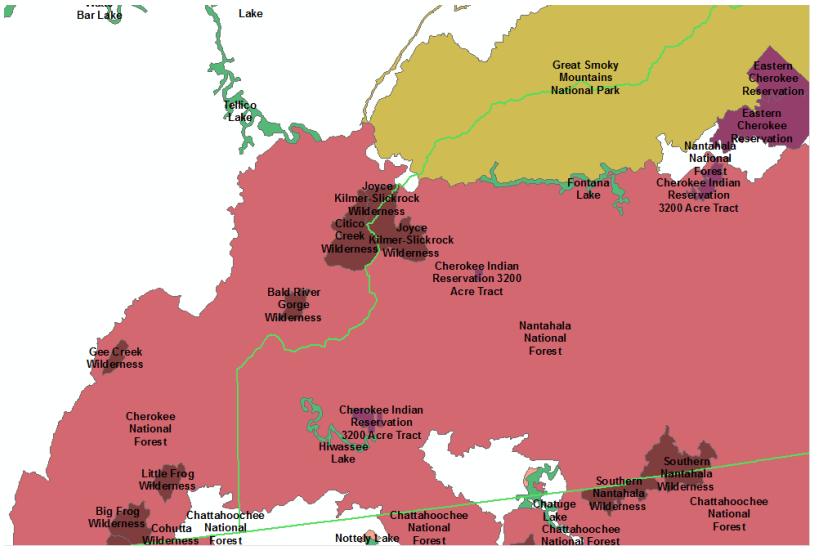

Figure 38. This illustration shows a section of the million-scale Federal and tribal lands dataset in the North Carolina – South Carolina – Tennessee border region.

Early Warning and Environmental Monitoring

The Early Warning and Environmental Monitoring 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.

Enhanced Elevation Data to Sharpen Global Focus on Climate Issues

Elevation is a fundamental quality in nature. The height of the land determines where water will flow. It can influence what the average local temperature will be. The height of the land in relation to the height of the water determines where there will be coasts or riverbanks, marshes or islands, saltwater or freshwater. Terrain elevation, in combination with other factors, helps determine where species of plants will grow and where species of animals will thrive.

In Africa, accurate elevation (topographic) data are vital for pursuing a variety of climate-related studies that include modeling predicted wildlife habitat change; promoting public health in the form of warning systems for geography and climate-related diseases (e.g., malaria, dengue fever, Rift Valley fever); and monitoring sea level rise in critical deltas and population centers, to name just a few of many possible applications of elevation data.

On September 23, 2014, NASA, the National Geospatial-Intelligence Agency (NGA), and the USGS released more detailed elevation data across most of the African continent from the Shuttle Radar Topography Mission (SRTM). Figure 39 illustrates SRTM elevation data in the Niger River Delta, Nigeria.

The datasets were released following the President's commitment at the United Nations to provide assistance for global efforts to combat climate change. Enhanced SRTM elevation datasets covering remaining continents and regions will be made available within 1 year. These SRTM-derived data, which have been extensively reviewed by relevant government agencies and deemed suitable for public release, are being made available via a user-friendly interface on the USGS's Earth Explorer website. For further information, contact Eric Wood, USGS EROS, woodec@usgs.gov.

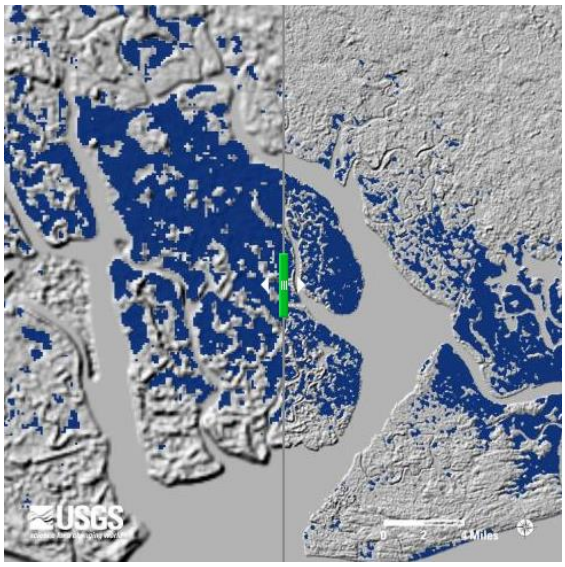

Figure 39. Shuttle Radar Topography Mission elevation data in Niger River Delta, Nigeria. Left, 90-meter resolution; right, enhanced 30-meter resolution.

Capacity Building in Africa – Completion of Image Processing Toolkit and Africa Mountains Atlas

USGS scientists, in partnership with the United Nations Environment Programme (UNEP) and other global partners and stakeholders, conduct environment assessments of developing parts of the world using remote sensing and other geospatial datasets, with the goal of connecting local changes to global audiences by keeping governments, policy makers, and civil society informed about the state of the environment.

UNEP/Global Resource Information Database (GRID) has developed a manual that provides GIS and remote sensing practitioners with a step-by-step guide to communicating the scientific findings of time-series satellite imaging studies to a wide audience. It is based on lessons learned by the UNEP/GRID Sioux Falls office located at the USGS EROS Center, in helping to develop *Atlases of Our Changing Environment* series. The Africa Mountains Atlas, the continental atlas featuring Africa's mountain ranges and describing the changes these mountain ecosystems have undergone or are currently experiencing, through 64 maps and 73 compelling satellite images, text, and other graphics, is the most recent publication in this series.

Satellite images, like Landsat over the past 40 years, maps, ground photos, and interpretative text and narratives providing context combine to convey clear, compelling and often startling scientific evidence of the huge changes occurring at specific places on the planet to non-technical audiences. These images make the scientific evidence compelling enough to stimulate sound environmental policy-making. The manual will be useful in learning how to effectively use change-pair images to accurately reflect

modification on the ground. The Africa Mountains Atlas, scheduled to be released in January 2015, was completed using methods and technologies outlined in the manual.

Capacity building is central to the work of UNEP. UNEP's capacity building programme supports regional capacity building in assessing global environmental trends and conditions, developing international or national legal instruments for environmental management, and encouraging new partnerships and mind-sets within civil society and the private sector. It aims to further develop the capacity of people and institutions in the region to undertake, participate, and provide training in integrated environmental assessment. As part of UNEP's capacity building effort, a tool kit for producing atlases of environmental change titled **Atlas of Our Changing Environment – A Manual** has been developed by UNEP/GRID Sioux Falls, which provides a step-by-step guide for analyzing and packaging time-series satellite imagery, mainly Landsat, for understanding and organizing environmental knowledge (fig. 40).

UNEP/GRID Sioux Falls, in partnership with USGS, UNEP's Regional Office of Africa, and other stakeholders in the region, collaborated to advance an agenda for action on sustainable mountain development by producing an atlas of environmental change. Admired and protected for their beauty, mountains are vital to Africa's 1.1-billion people because of their ecosystem goods and services. Africa's mountains are water towers, providing water for domestic, industrial, irrigation and hydropower uses. They are also the breadbaskets for highland and lowland communities. They are sites of food production, forest products, minerals, tourism, sacred places, wildlife habitat, and biodiversity conservation, among many other important assets.

The **Africa Mountains Atlas** highlights challenges and opportunities faced by Africa's mountain populations. It addresses environmental issues to ensure future sustainable development in the region. The publication provides a framework to set and guide the mountain agenda for Africa, by addressing the lack of enabling institutional, policy, and legal frameworks to guide mountain development, which is a major hurdle to achieving sustainable development in mountain areas at national, sub-regional, and regional levels. In 300 pages, the Africa Mountains Atlas defines Africa's challenges and presents the associated opportunities that can be seized to prevent unsustainable development of Africa's mountain ecosystems (fig. 41).

UNEP/GRID Sioux Falls partners include USGS, The African Ministerial Conference on the Environment, Norwegian Ministry of Foreign Affairs, Centre for Development and Environment – Bern, The National Environment Management Authority – Uganda, the Austrian Development Cooperation, the Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety – Germany, the University of Natural Resources and Life Sciences – Vienna, Swiss Agency for Development and Cooperation, and the Albertine Rift Conservation Society Network, who have contributed to UNEP/GRID activities in 2014.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides operational

and technological support to UNEP/GRID activities since its inception in 1991. For further information, contact James Rowland, USGS EROS, rowland@usgs.gov.

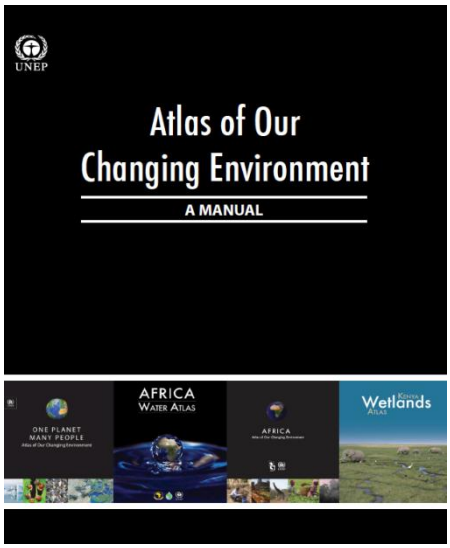

Figure 40. Cover page of Atlas manual, a capacity building tool kit for the production atlases.

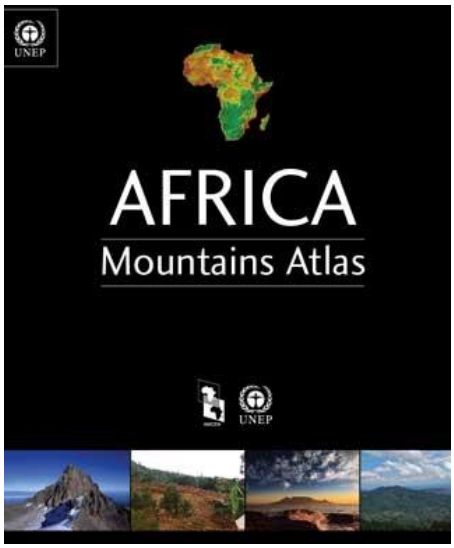

Figure 41. Cover page of Africa Mountains Atlas, scheduled to be released in January 2015.

USGS Science Predicts and Monitors Drought with a New Environmental Climate Record

USGS scientists, in partnership with the U.S. Agency for International Development (USAID) and other Federal agencies, have developed a new satellite-based precipitation dataset, and integrated these earth observations with climate forecasts to monitor and predict drought in food insecure areas such as East Africa.

In 2008, 2009, 2011, and 2012, eastern East Africa experienced severe droughts that led to severe food crises and even famine in Somalia in 2011. Since 2011, the USAID-funded Famine Early Warning Systems Network (FEWS NET) has developed improved rainfall monitoring and climate modeling tools. In 2014, this new system performed very well, providing increasingly precise forewarning of another crippling drought.

Remote sensing from space allows USGS scientists to track rainfall and sea surface temperatures from space. These data, and derived information, can be combined to monitor water deficits and predict future drought, providing humanitarian aid agencies time to prepare effective responses.

In January 2014, USGS research was used to link very warm western Pacific Ocean sea surface temperatures with an increased chance of spring drought over eastern East Africa. This forecast system, based on the difference between sea surface temperatures (SSTs) in the equatorial West Pacific and Central Pacific, can predict

most of the recent extreme droughts (1999, 2000, 2008, 2009, 2011, and 2014). In figure 42, negative correlations with the western Pacific SSTs indicate that warmer SSTs often precede dry years for East Africa. In the Central Pacific, the opposite holds; warmer SSTs decrease the chance of drought over East Africa. Figure 42c shows that the difference between western and central Pacific SSTs in January can be used to predict standardized East Africa rainfall (x- and y-axes in units of standardized deviations). During the spring of 2014, this forecast system helped USAID prepare for potential food insecurity when April and May rains were very poor.

A new satellite-based 1981-present environmental record (CHIRPS, for Climate Hazards InfraRed Precipitation with Stations) was also used for the first time in 2014 to quantify the poor performance of seasonal rainfall. This new rainfall record combines rain gauge observations with satellite data (cloud top temperature) to place recent rainfall deficits in historic context. In 2014, data from this remote sensing system was used to quickly relate the poor April-May rainfall to the historic context (fig. 43). By mid-June, we knew that there had been a severe drought, and the tendency toward severe dryness was evident considerably earlier.

Sponsored by the USAID Office of Food for Peace, FEWS NET identifies critical instances when, and where, food aid is required by the most food insecure populations of the developing world, populations whose livelihoods are tied to subsistence rainfed agriculture and pastoralism. Climate forecasts developed by FEWS NET scientists supply forward-looking food security assessments based on expected agricultural outcomes for the season ahead. Since ground station networks are sparse in developing countries, FEWS NET has a tradition (since the late 1980s) of reliance upon satellite remote sensing of vegetation and rainfall.

While food security conditions in 2014 did not blossom into a full-blown emergency (as in 2011), the extreme climate and weather conditions of 2014 provided an excellent chance to test our early warning system. Both the forecast and monitoring components performed well, and given a future food crisis development in East Africa, we will be better prepared to prevent famine.

The USGS EROS Center provides scientific analyses based on remote sensing, environmental modeling, and GIS technologies to support FEWS NET activities throughout the world. For further information, contact Christopher Funk, USGS EROS, cfunk@usgs.gov.

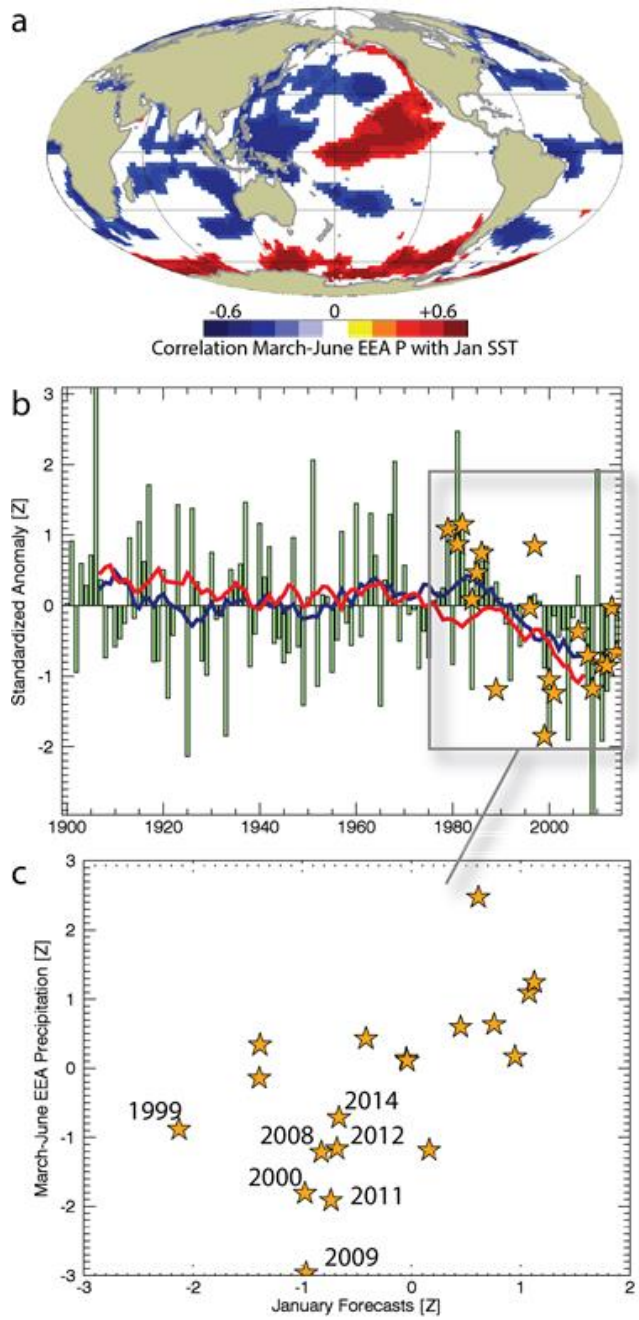

Figure 42. How we predicted the 2014 drought. **a**. Correlations between March-June eastern East Africa (EEA) precipitation and the preceding January sea surface temperatures. **b**. Long time series of EEA precipitation together with forecast precipitation (stars). **c**. Scatterplot of January forecasts and observed March-June EEA precipitation.

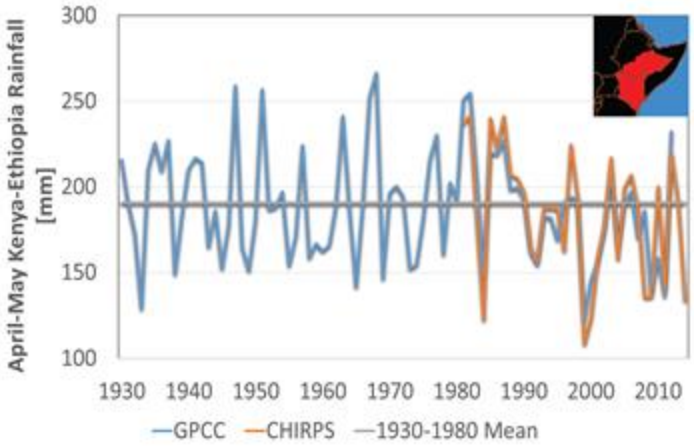

Figure 43. How we placed the 2014 drought in historic context. April-May CHIRPS rainfall estimates for southern Ethiopia and Kenya can be quickly readily compared to long latency products like the Global Precipitation Climate Centre.

Land Use Maps Characterize Rapid Changes in West Africa's Human and Natural Landscapes

Newly completed land use and land cover maps – the culmination of a large collaborative effort – tell a story of rapid change in West Africa's natural and human landscapes from 1975 to 2013. These maps provide a new tool for decision-makers facing the challenge of balancing the need to preserve natural ecosystems with the need to grow more food, against the background of climate change.

West African leaders and decision-makers, faced with balancing environmental protection against producing food for a growing population, now have a new and unique tool for better understanding the region's natural and human landscapes. A set of multi-period maps of the LULC accurately depict the landscapes of 1975, 2000, and 2013, documenting the growing human footprint. The regional map is a seamless collage constructed from the country maps – each one telling a complex story of stability and change. The maps represent the culmination of a large collaborative effort between environmental scientists from the USGS, the Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center, and national counterparts from 17 West African countries. To achieve this, we tapped into the 42-year record of Landsat satellite imagery. The regional map is nearly complete – we are still working to complete the gaps represented by Liberia, Sierra Leone, and Nigeria. Figure 44 presents the 2013 LULC map of West Africa.

Earth is a dynamic planet, with natural climate and environmental conditions in constant flux. However, the pace, magnitude, and spatial extent of change to the earth's surface in the last several decades are unprecedented and carry the dramatic imprints of human activity. These accelerated changes in land cover (biophysical attributes of the land surface, such as forest or savanna) and land use (human use of the land surface, such

as agriculture) began to raise concerns in the global community with the growing realization that they affect key aspects of earth system functioning such as ecosystem services (i.e., the ability of the earth's resources to support human needs). Land cover and land use changes are also known to contribute to the vulnerability of places to climatic, economic, or socio-political perturbations. West Africa faces particular challenging factors contributing to its rapid LULC change, among others, the challenge of absorbing the highest percentage increase in population of any world region. In 2010, the 17 countries included in this project counted a total population of almost 317 million, representing an over 4.3-fold increase since 1950 (73 million). The continuing growth in population and consumption poses a major challenge for achieving and maintaining food security, without further diminishing the natural resources that allow West African societies to sustain food production into the future.

Fifteen years ago, regional West African organizations like CILSS (Inter-State Committee on Drought Control in the Sahel) identified a critical need to map and monitor LULC, but producing accurate multi-period maps is technically challenging. Unlike previous attempts by other regional and global programs to map LULC using computer-based classification techniques, we use an expert-based visual analysis approach that incorporates the many dimensions of information inherent in remotely-sensed imagery, coupled with field observations, aerial photography, and verification using high resolution satellite images. West Africa's croplands, for example, are particularly difficult to map using computer-based image classification techniques. The visual mapping approach sidesteps many of the difficulties that mappers face using semi-automated techniques. Mapping complexity is compounded by the call for multi-period maps that characterize LULC dynamics. To do this, we developed a special mapping tool (Rapid Land Cover Mapper) that is designed specifically for accurate multi-period mapping – to produce both maps and trends statistics.

The West Africa LULC maps are giving us an unprecedented view of change – and a narrative that we are already sharing with decision-makers across the region through a series of national workshops. While we cannot do justice here to what the multi-period maps show, we can point out a few highlights. In Senegal, we see the extension of its agricultural "Peanut Basin" into its central and southern woodlands. In Guinea and Côte d'Ivoire, we see how little is left of the forest ecosystem. In Ghana, Togo, and Benin, we see rapid expansion of agriculture in all regions. Among the three, only Ghana maintains significant tracts of dense forest. In southern Mali, we see the fragmentation of its ecosystems by cultivation, while its Sahelian landscapes remain more stable. Perhaps the most dramatic change in West Africa is seen in Burkina Faso. In comparing its landscapes in 1975 and 2013 (fig. 45), we see the loss of its biodiverse savannas, woodlands, and gallery forests to agriculture. Only its scattered protected areas are spared from the tide of human activity. Niger presents a picture of relative stability, where we have documented major successes in regreening across Niger's farmlands. Chad stands out as the one country that still maintains vast areas of wilderness, though the winds of change have begun to blow there too.

These LULC maps are providing West Africa's decision-makers with a much clearer picture of change – its patterns, magnitudes, and driving factors. Land use information is key for understanding and potentially solving sustainability problems such as climate change, increasing demand for food, accelerating urbanization, and changes in the functioning of ecosystems and the services they provide. Completing these maps and providing them to decision-makers is a major accomplishment. For further information, contact Gray Tappan, USGS EROS, tappan@usgs.gov.

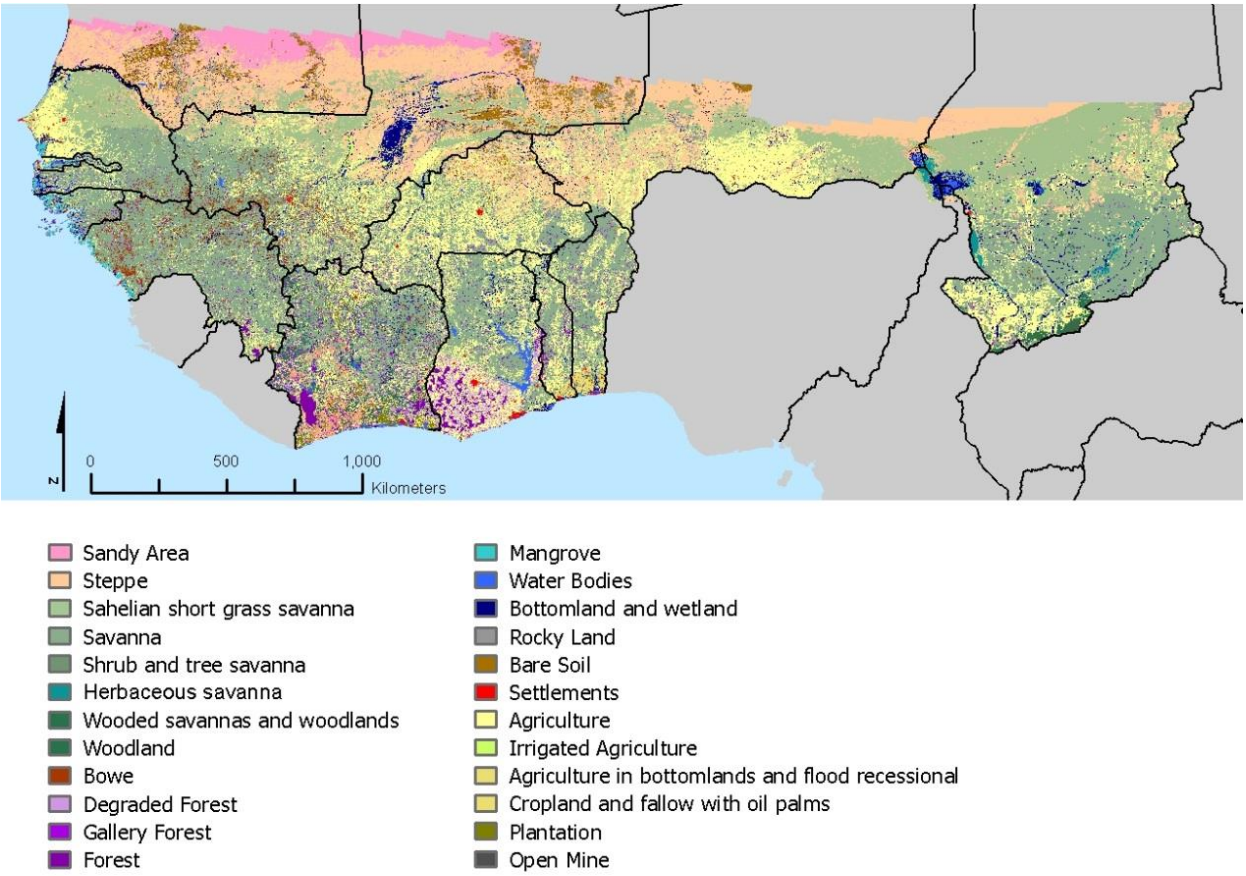

Figure 44. West Africa Land Use and Land Cover in 2013. This map provides a near-complete depiction of the region's natural and human landscapes. It is the third in a multi-period map series that allows us to compare landscapes between 1975, 2000, and 2013, and to derive change statistics.

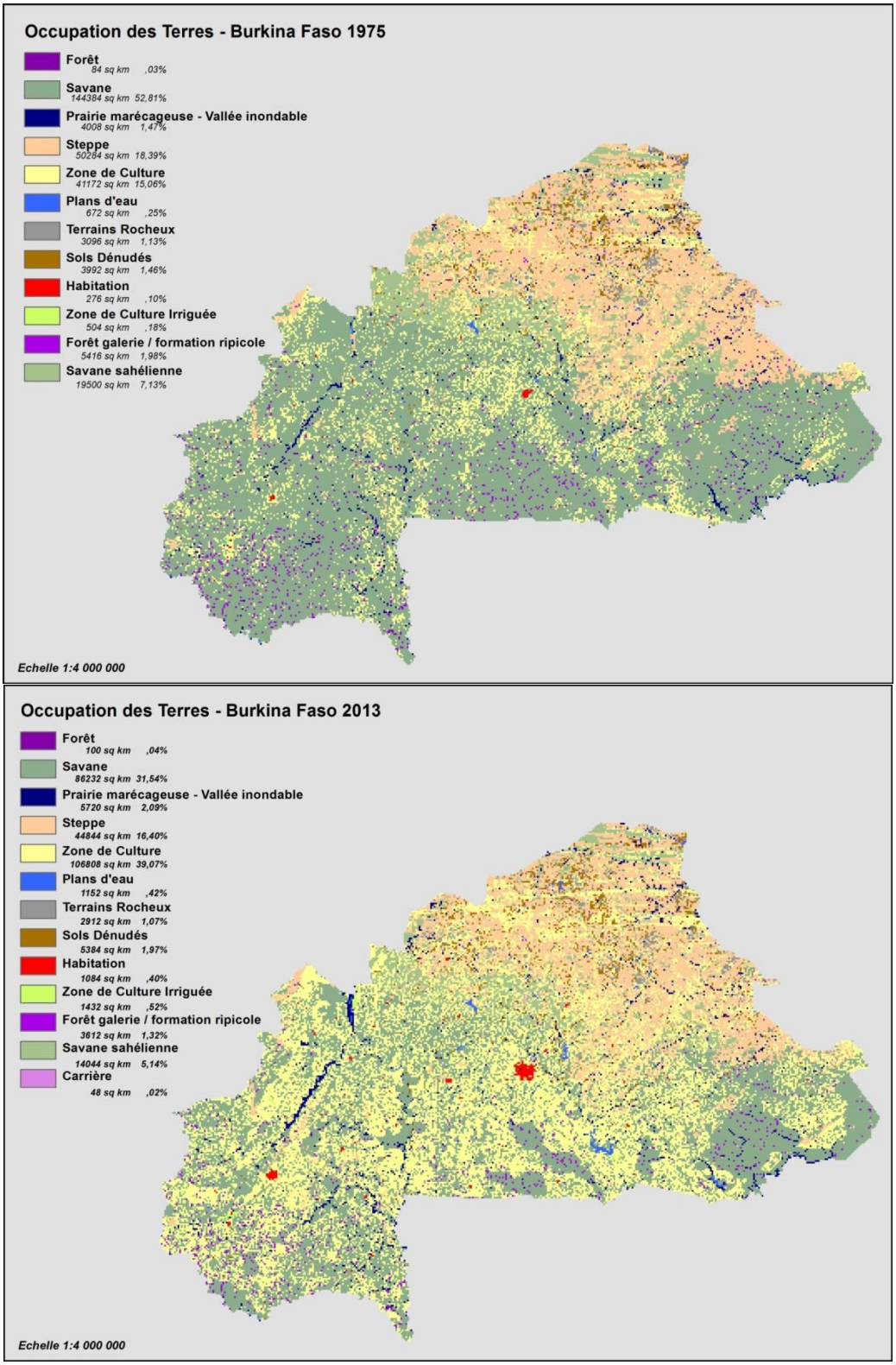

Figure 45. Burkina Faso Land Use and Land Cover in 1975 (top) and in 2013 (bottom). Note the extensive loss of the country's savannas and gallery forests as agriculture land (yellow) expands into nearly all regions.

GeoSUR – Building Geospatial Capacity Beyond the Foundation

The USGS and Development Bank of Latin America (CAF) officially began their partnership in 2007 under the sponsorship of the GeoSUR Program (http://geosur.info/), a CAF initiative to promote the discovery and distribution of geospatial information to scientists, developers, and government agencies in Latin America and the Caribbean (LAC). To facilitate this program, CAF solicited USGS support, drawing on EROS experience with geospatial data management, digital distribution, and hydrologic modeling. The program takes a multifaceted approach to data discovery and distribution. The primary facets are provision of a portal to discover geospatial data, online mapping services to streamline visualization, and web processing services to elevate regional geospatial capacity. Additionally, this collaboration provides workshops and technical support to collaborating agencies. With continual economic growth in the LAC region over the last several years, countries are recognizing that their energy infrastructure requires improvements. Since 2010, USGS has collaborated with CAF on conducting hydropower assessments for the State of Sao Paulo, Brazil (http://pubs.usgs.gov/of/2014/1206/), Peru, and recently Bolivia.

The GeoSUR Program distributes data and information through web services hosted at USGS EROS, leveraging technology of both commercial and open source software. When the program began in 2007, EROS was a logical location to manage such an operation. At that time, web mapping and data distribution were in early development, and EROS was at the forefront of the technology. Although the technology has matured, EROS still provides the best match to meet the demands of GeoSUR and its partners.

During the past year, USGS has continued to support the program's primary objective of providing policy-makers and the public access to the most comprehensive geospatial information for planning, environmental conservation, climate change adaptations, and other developmental needs. This year GeoSUR has introduced a dynamic flood monitoring tool in collaboration with the Dartmouth Flood Observatory (DFO) (http://floodobservatory.colorado.edu/), which allows users to view flooding events from the past 2 weeks and the prior year. GeoSUR plans to continue collaboration with EROS and DFO to provide LAC with current flooding events and a comprehensive historical archive. During this past year, USGS EROS also collaborated with CAF and Peru's Ministry of Energy and Mines (MEM), releasing a hydropower assessment and contour extraction tool for MEM on the GeoSUR Topographic Processing Service platform. This tool allows MEM and their consultants to conduct a preliminary hydropower assessment for selected regions of Peru. This tool was introduced in May 2014 during a 3-day training session in Lima, Peru, that concluded the USGS hydropower support. For further information, contact W. Matthew Cushing, USGS EROS, mcushing@usgs.gov.

Landsat 8 Based Mapping of Basin-Wide Evapotranspiration for the Colorado River Basin

Since 2010, the USGS has developed and begun implementation of the WaterSMART (Sustain and Manage America's Resources for Tomorrow) Use and Availability Assessment program, known as the National Water Census. The WaterSMART initiative has enabled both the USGS and the U.S. Bureau of Reclamation (USBR) to invest in new efforts to address the water resources challenges facing the Nation.

Increasing population, decreasing streamflows, and the uncertain effects of a changing climate urge a better understanding of water use and water availability in the Colorado River Basin. Estimation of current consumption and historical trends in water use, and projection into the future, will help define the extent of water supply and demand imbalances. Evapotranspiration (ET) from irrigated crops and native vegetation is a significant component of the water budget in the Western United States and an essential piece of information within management strategies.

Remote sensing capabilities using 100-meter Landsat 8 thermal data provide an unprecedented view of withdrawal trends in the Colorado River Basin and enable scientists to produce quick, reliable, and useful ET estimations at various time scales with high spatial accuracy for use in regional water management decisions.

Better understanding of ET processes in the varied landscapes of the Colorado River Basin is supported by improved estimation methods that utilize enhanced characteristics of the Landsat 8 satellite and its thermal capabilities. Derivative products from this effort demonstrate interpretative analyses at multiple spatial and temporal scales to develop information across the entire basin (fig. 46 and fig. 47).

By renewing efforts on quantification of water use, the USGS will be better able to describe how humans move, use, consume, and dispose of the water they withdraw, divert, or impound and then integrate that information with our understanding of natural flows in the environment.

This remote sensing application demonstrates the vitality and creative strategies involved in improving water conservation and helping water-resource managers make sound decisions about water use. Landsat 8 based ET mapping of the Colorado River Basin supports the WaterSMART program activities and demonstrates cost-effective technologies for the collection and analysis of water use data at a national scale.

USGS EROS shares these products with USGS Water Science Centers that are responsible for compiling nationwide water use data every 5 years. Furthermore, researchers at USBR are interested in evaluating the usefulness of the product in relation to existing and other new methods. Recently, USGS EROS was invited to participate in a multi-model evaluation of satellite-based ET for USBR for the Upper Colorado River Basin for FY 2015. Similarly, the DOI North Central Climate Science

Center is using these products for investigating the relationships between ET-based wetland dynamics and bird habitat.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing and agro-hydrologic modeling. For further information, contact Gabriel Senay, USGS EROS, senay@usgs.gov.

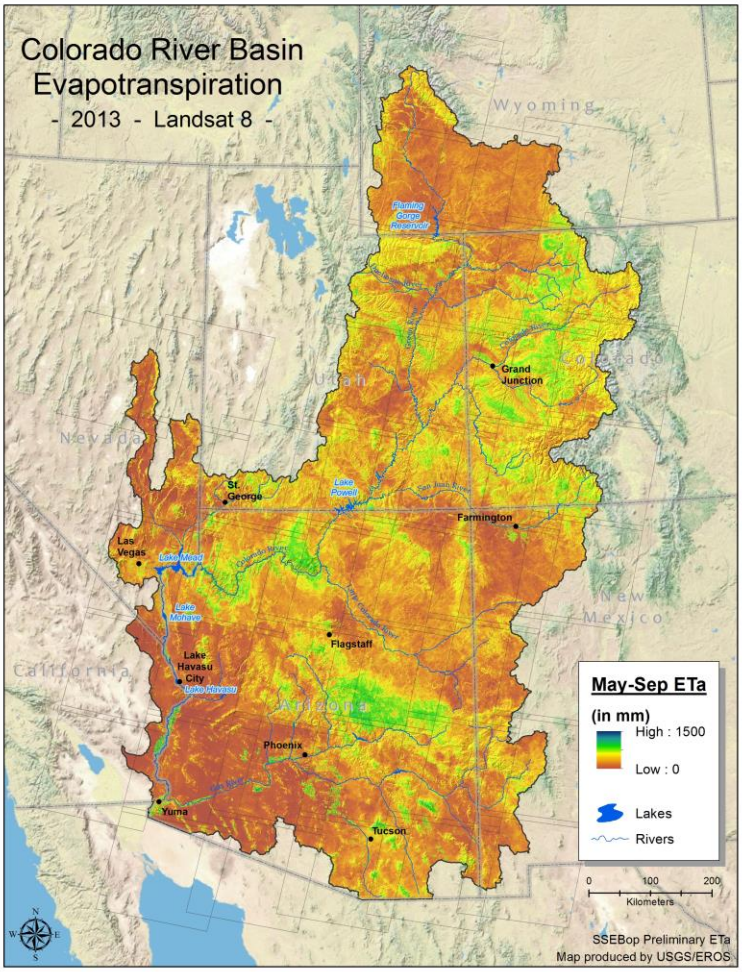

Figure 46. Spatial variability of 2013 seasonal (May to September) evapotranspiration for the entire Colorado River Basin using 100-meter resolution Landsat 8 thermal data.

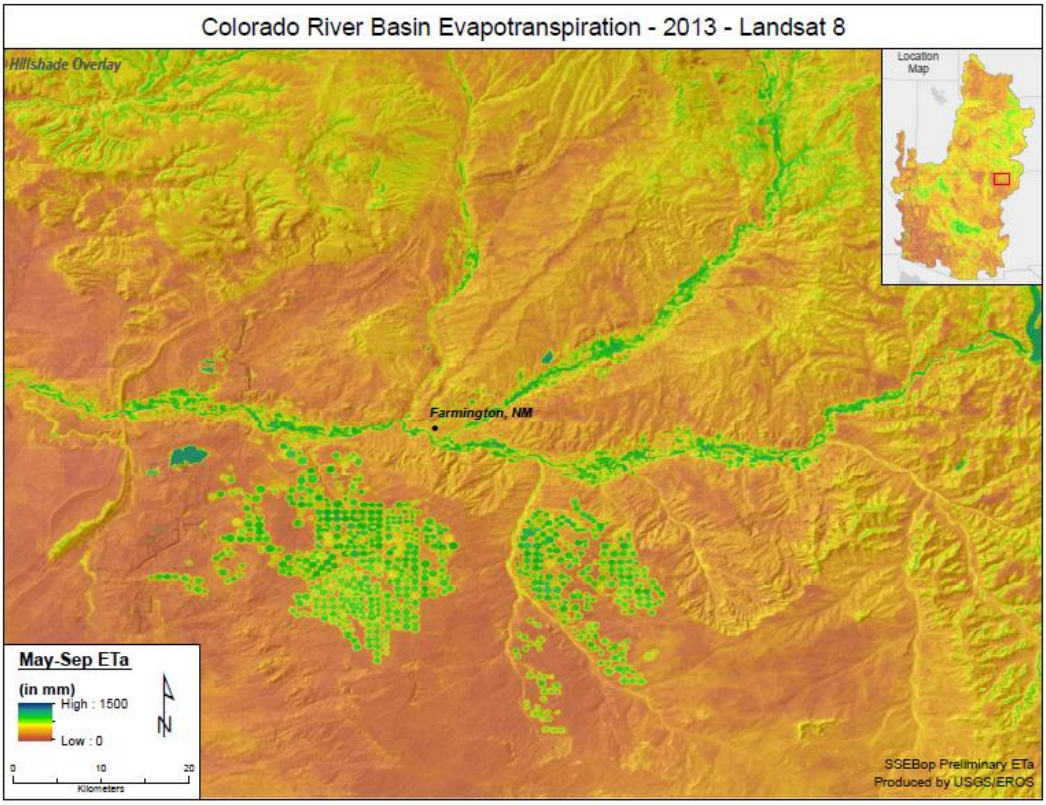

Figure 47. Spatial detail of seasonal evapotranspiration that can be achieved using Landsat 8 data in the area of Farmington, New Mexico. The method not only captures evapotranspiration in irrigated fields but also along river corridors and mountainous landscapes.

Primary Climate Drivers of Aspen Phenology

Phenology is the study of biological life cycle events and how they are affected by climate and environmental factors. Since phenology cycles like the start and end of the growing season are sensitive to climate variation, land surface phenology data provide baseline information on vegetation variability and trends and the impacts of climate on ecosystems at multiple scales.

Trembling aspen (*Populus tremuloides* Michx.) is an overstory deciduous tree species and occurs over wide expanses of North America, making it a favorable candidate for broad study of phenology and climate relationships. Aspen communities provide numerous ecosystem services, such as high primary productivity, biodiversity, and soil moisture retention. However, there is concern that aspen-dominated systems are experiencing declines in the western United States due to recent climate-induced drought conditions.

The phenology of aspen woodlands is sensitive to weather and climate variables such as temperature and precipitation (in the form of snow or rain). In a study for southwestern Colorado, Meier, Brown, Evelsizer, and Vogelmann (2015) found that the relationship between the start of the growing season (shown in figure 48) and spring snow water equivalent was strong and significant ($R^2 = 0.84$, $p<0.001$). They also determined that the end of the growing season was positively correlated with minimum fall temperature and negatively correlated with fall precipitation. Expanding this research across aspen in the western United States is in the initial phase.

Annual national phenology indicators used in this study (found at http://phenology.cr.usgs.gov/) were calculated from satellite remote sensing. Nine phenological indictors at various spatial resolutions (250 m^2 and 1000 m^2) are accessible online, including measures for the timing of the beginning and end of the growing season. Users have applied these data to model the growth of noxious weeds, map annual crops, assess forage production, and understand wildfire potential (Boyte, Wylie, Major, and Brown, in press; Gu, Wylie, Boyte, and Phuyal, 2014; Howard and Wylie, 2014; Tan and others, 2013). For further information, contact Jesslyn Brown, USGS EROS, jfbrown@usgs.gov.

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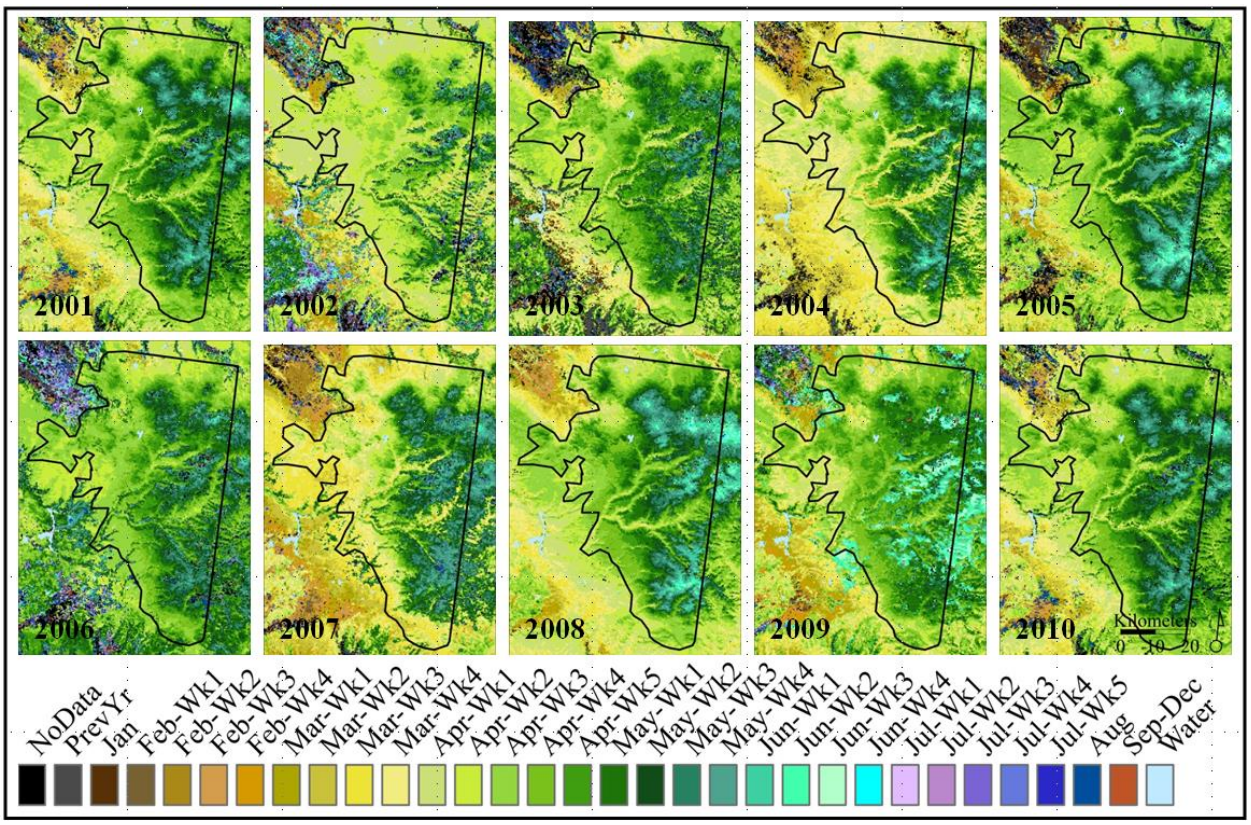


Figure 48. Annual maps of the start of the growing season from 2001 to 2010 for southeastern Colorado estimated from remote sensing (Moderate Resolution Imaging Spectroradiometer). In 2002 and 2007, drought appears to have advanced the start of the season compared to other years. In contrast, 2005 and 2008 show later starts to the growing season associated with relatively higher spring snow water equivalent.

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. The Landsat Project at EROS manages two active satellites – Landsat 7 and Landsat 8 – and the entire historic archive of data collected since 1972. Key accomplishments are given in the following sections.

A Landsat 8 Yearbook: Earth Images for Everyone

On February 11, 2014, Landsat 8 had been on the job for a year, and May 30, 2014, marked the one-year anniversary of when NASA transferred ownership and operation of the satellite to the USGS. Landsat 8 is the latest in the Landsat series of remote-sensing satellites that have provided a continuous record of change (fig. 49) across earth's land surfaces since 1972.

Scientists, land management professionals, and space enthusiasts already know that Landsat 8 is stocked with a 10-year supply of fuel, that it carries two highly sensitive observation instruments operating more precisely than before, and that the USGS now operates Landsat 8 along with older sister Landsat 7. With two Landsat satellites on orbit, the USGS can provide data every 8 days for any spot on the earth's land masses, supporting water managers, agricultural commodities markets, and scientists around the globe.

To mark an extremely successful first year of space operation for Landsat 8, the scientists and imagery experts at the USGS EROS Center selected 10 sets of images that demonstrate the broad range of changes on the land that Landsat 8 has observed in its first year and compiled them in a special collection – the Landsat 8 Yearbook.

The Landsat 8 Yearbook features "before" and "after" sets of images that you can manipulate with a digital slider bar to see change over time. Some of the images also show the enhanced technical capabilities of the Landsat 8 spacecraft. For further information, contact James Lacasse, USGS EROS, jmlacasse@usgs.gov.

Figure 49. The volcanic blast from Mount St. Helens on May 18, 1980, devastated nearly 400 km2 (150-square miles) of forest within a few minutes. The 2013 image shows that much of the forest in the area has recovered. A small section on the northern slope of the volcano is still dominated by ash. Left: Landsat 2 from August 19, 1980. Right: Landsat 8 from August 20, 2013.

Space Veteran Landsat 7 Marks 15 Years of Observing Earth

Launched on April 15, 1999, the Landsat 7 satellite has now been observing earth from outer space for 15 years. The Landsat program is a decades-long NASA and USGS partnership that has provided a continuous, unbiased record of change across the earth's land surface since 1972.

Landsat 7 provides a worldwide audience with objective views, both current and historical, of events and trends across the global landscape. Landsat data can be used to detect and monitor urban growth, forestry practices, the extent of floods, wildfire burn acreage, major natural or human-caused disasters, and many other important changes in land-surface conditions (fig. 50).

Landsat 7's remarkable longevity has been vital to the majority of Landsat data users who require frequent imaging of specific areas for land and resource management. For example, water resource managers in western U.S. states need Landsat's unique combination of thermal and vegetation condition readings at field scale to estimate water use more efficiently for crop irrigation – typically the major source of water consumption in these arid regions.

Barring the failure of any key spacecraft component, the remaining fuel on Landsat 7 is expected to permit imaging operations through 2017. NASA and the USGS are working together on a plan to ensure long-term continuity of land imaging operations while addressing the near-term need to replace Landsat 7. For further information, contact James Lacasse, USGS EROS, jmlacasse@usgs.gov.

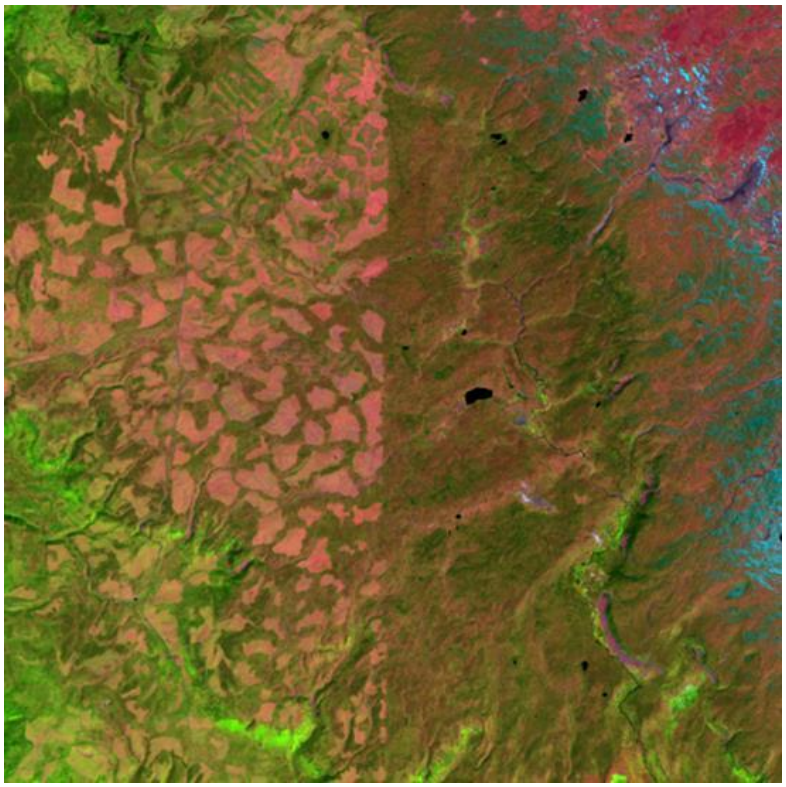


Figure 50. The boundary between Yellowstone National Park (right) and Targhee National Forest (left) is clearly seen in this Landsat 7 image. Clearcuts are evident on the left (west) side of the boundary. Landsat 7; July 13, 1999.

Land Satellites Data System Recommended as Example of Successful Investment

The Land Satellites Data System (LSDS) Information Technology (IT) Investment was rebaselined in 2010 as a consolidation of the Landsat IT Investment and the Landsat Data Continuity Mission (LDCM) IT Investment. LSDS is currently one of 224 IT Investments within the DOI and is one of six “major” investments within USGS.

The Clinger-Cohen Act of 1996 places responsibility for managing investments with the heads of agencies and establishes chief information officers (CIO) to advice and assist agency heads in carrying out this responsibility. Additionally, this law requires the Office of Management and Budget (OMB) to establish processes to analyze, track, and evaluate the risks and results of major capital investments in information systems made by Federal agencies and report to Congress on the net program performance benefits achieved as a result of these investments.

OMB uses several data collection mechanisms to oversee Federal IT spending. Specifically, OMB requires agencies to provide information related to their IT investments, including agency IT investment portfolios (called exhibit 53s) and capital asset plans and business cases (called exhibit 300s). The purpose of the exhibit 53 is

to identify all IT investments – both major and nonmajor – and their associated costs. The purpose of the exhibit 300s is to provide a business case for each major IT investment and allow OMB to monitor IT investments once they are funded. Agencies are required to provide information on each major investment's cost, schedule, and performance.

All major IT Investments are regularly evaluated by the agency CIO and rated using a set of pre-established criteria including risk management, requirements management, stakeholder involvement, contractor oversight, historical performance, adherence to cost and schedule plans, and management oversight. The evaluation reflects the CIO's assessment of the risk and the investment's ability to accomplish its goals. In FY 2014, LSDS was rated a "4" (out of 5) which is the highest rating provided to any investment within the USGS (and DOI).

In June, the DOI recommended the LSDS IT Investment to OMB as an example of a successful investment. As part of the recommendation, the LSDS IT Investment was assessed in the following areas: investment goals and targeted outcomes from the business case including alignment with the agency strategic plan, customer centricity including how requirements address/understand the different audience types and how feedback is captured, governance, time to market including delivery of functionality on-time/within budget, security, and system results including how performance metrics are published and measured against established benchmarks.

LSDS continues to exemplify the Federal CIO's guidance to innovate, deliver and protect by providing a unique, global, long-term archive of the earth's land surface with enhanced delivery through various channels while continuing to protect and preserve the Landsat Global Archive. The consistency of Landsat data acquired through the years allows for direct comparison of current specific site images with those taken months, years, or decades earlier (fig. 51). This comparison process can reveal land cover changes that occur slowly and subtly, or quickly and devastatingly. The richness of the archive, combined with a no cost data policy, allows users to exploit time series of data over extensive geographic areas to establish long-term trends and monitor the rates and characteristics of land surface change.

Since 2008 when Landsat data were made free to the global user community, the distribution of Landsat has grown significantly each year. The change to free data has sparked a clear revolution that has led to the major growth in Landsat applications with increased societal benefits associated with them, and significant changes in the way Landsat data are used. Today's Landsat applications are more technically sophisticated and cover larger geographic areas and span longer periods of time. Because the way users access and analyze Landsat data is rapidly changing, LSDS is continuously exploring new access and product paradigms that will further expand the impact of Landsat. The USGS Open-File Report 2013-1269, "Users, Uses, and Value of Landsat Satellite Imagery – Results from the 2012 Survey of Users," provides information regarding the use and value of Landsat imagery delivered by LSDS.

In the 2013 report, “Landsat and Beyond: Sustaining and Enhancing the Nation's Land Imaging Program,” the National Research Council’s Committee on Implementation of a Sustained Land Imaging Program noted that the economic, intrinsic, and scientific benefits to the United States of Landsat imagery far exceed the investment in the system. In July 2014, the National Science and Technology Council released the “National Plan for Civil Earth Observations.” This plan prioritizes 145 high-impact observation systems from 362 systems assessed across the United States, and places Landsat as the overall #3 system with respect to 12 societal benefit areas. For further information, contact Tom Sohre, USGS EROS, tsohre@usgs.gov.

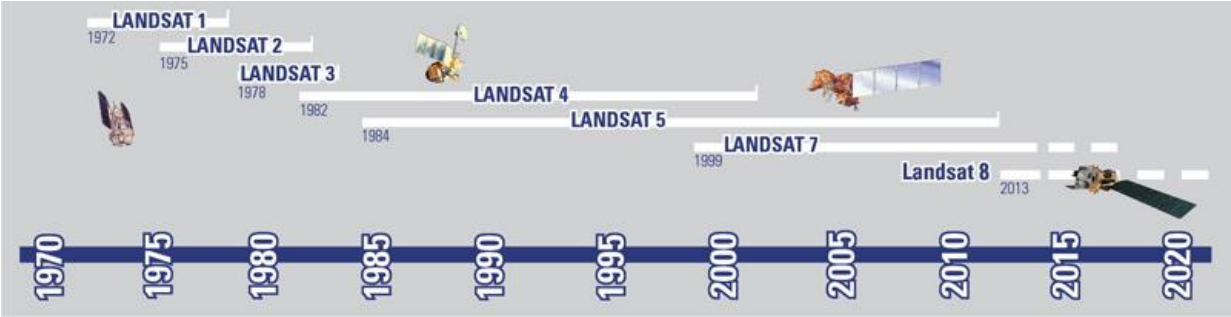


Figure 51. Landsat satellites have been collecting imagery of the earth’s surface since 1972, creating a historical archive that is unmatched. The millions of scenes held in the U.S. Geological Survey archives provide useful science to all users worldwide.

Increasing Landsat Daily Imaging Rate

The Landsat mission strives to create a systematic and objective environmental record of the earth’s surface guided by a long-term acquisition plan. As a result, Landsat 8 and Landsat 7 are being managed in a novel way, with the newer satellite being used to extend the capabilities – and lifespan – of the older one. In early 2014, Landsat 7 went to a continental landmass acquisition strategy. Capturing images of islands, for example, was very inefficient due to Landsat 7 scheduling constraints. The responsibility for capturing images of islands has been turned over to Landsat 8, with its much more sensitive sensor. The change helps to conserve the resources of Landsat 7 while still meeting our science goals.

This change has also resulted in more data than anticipated being acquired by both satellites. Freed from routine acquisition of island images – as well as those of water, Antarctica, and night scenes – Landsat 7’s output has increased from 375 to approximately 430 scenes per day while at the same time prolonging the life of the Enhanced Thematic Mapper + (ETM+). The acquisition of longer intervals will reduce wear on the instrument and increase the likelihood of Landsat 7 and 8 continuing the 8-day repeat cycle into early 2018.

Landsat 8 is also collecting more than its anticipated 400 scenes per day. Initially an average of 550 images per day were collected when operations began on May 30,

2013. During the 2014 Northern Hemisphere growing season, the collection rate was incrementally increased to optimize Landsat 8's science data collection. Based on results of increased data collection, the daily rate was set to 725 images per day. An example of the change in Landsat 8 global collects can be seen in figure 52.

With the addition of the Landsat 8 mission and managing Landsat data collection in a more integrated fashion, the Landsat user community is now being provided with improved global coverage. For further information, contact Jim Lacasse, USGS EROS, jmlacasse@usgs.gov.

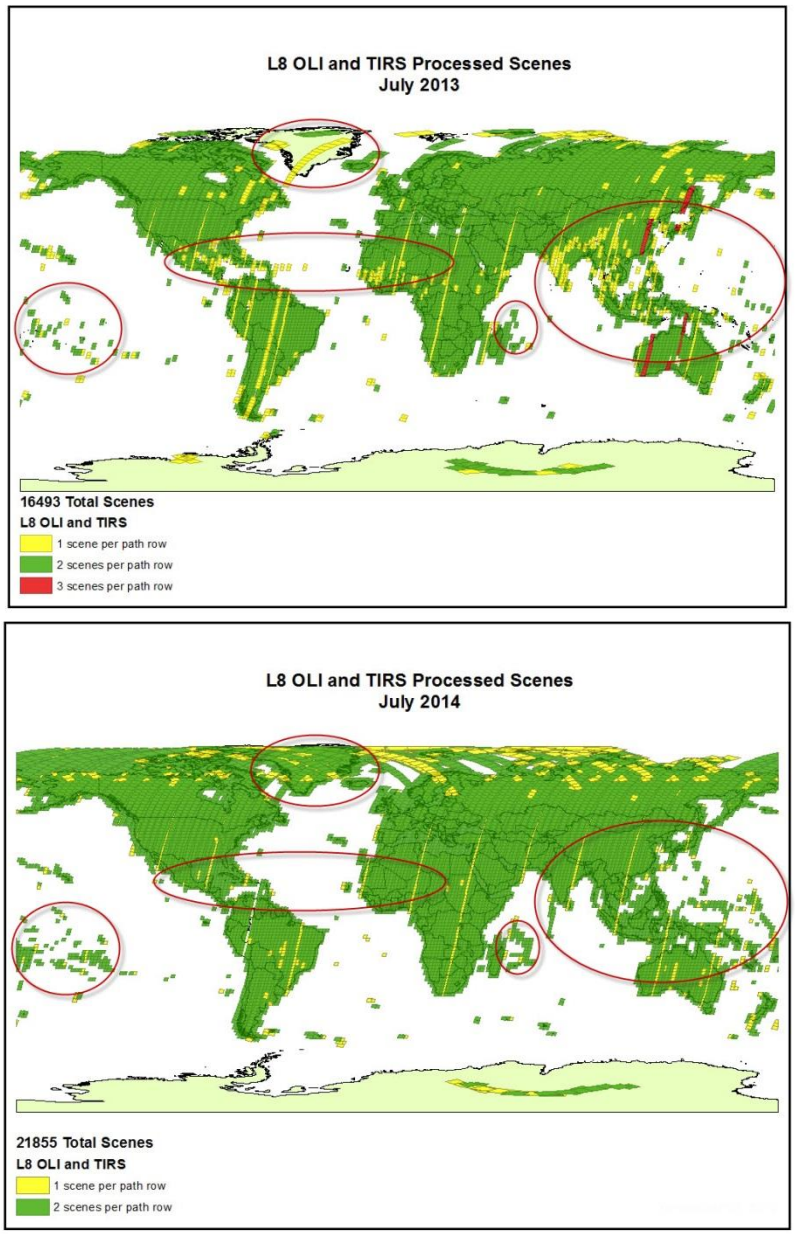


Figure 52. Comparison of global plots of Landsat 8 acquisitions: July 2013 and July 2014. These graphs show an increase of over 5,000 scenes collected.

Cooperative Agreements Established for Landsat Vicarious Calibration

The vicarious calibration activities involve the use of field-based measurements to independently validate the calibration of the Landsat solar reflective (visible, near-infrared, shortwave infrared) and thermal emissive (thermal infrared) bands. This work is performed in collaboration with researchers from the University of Arizona, the Rochester Institute of Technology, South Dakota State University, and the Jet Propulsion Laboratory at the California Institute of Technology. These studies provide an independent means of validating the calibration of the Landsat sensors which is crucial for monitoring and characterizing changes to the state and condition of the landscape.

Vicarious calibration of the solar reflective bands involves collecting field spectroradiometer measurements of spectrally stable targets, such as desert playas, coincident with a satellite overpass and then using radiative transfer models to translate the ground-based radiances to the equivalent of those measured by the satellite sensors after transmission through the atmosphere. For the thermal infrared (TIR) data, buoy measurements of surface water temperature are converted to spectral radiances and then processed through radiative transfer models for conversion to top of atmosphere (TOA) radiances. The in situ TOA radiances are then compared with the corresponding satellite radiances to quantify the differences and to determine uncertainties associated with the radiances measured by the satellite sensors (fig. 53).

The validation of the Landsat instrument calibration is important for scientific research and applications that require the construction of long-term data records for monitoring and characterizing land surface change. The stability of the calibration and the quantification of the uncertainties are needed for the retrieval of geophysical parameters such as surface reflectance and surface temperature.

The Landsat user community depends on the sustained calibration of the instruments during inflight operations in order to satisfy a broad range of applications, and numerous other earth observing satellites use the Landsat instruments as reference standards for radiometric calibration. For further information, contact John Dwyer, USGS EROS, dwyer@usgs.gov.

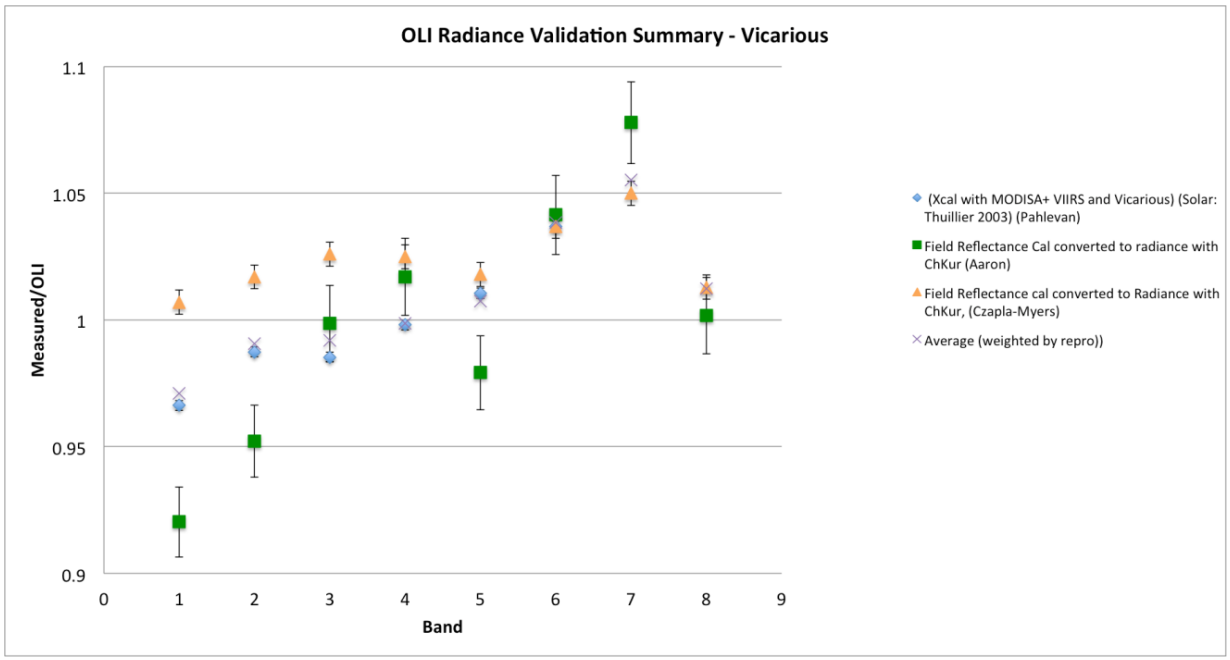


Figure 53. This plot shows the ratio of field-based radiance measurements with at-sensor radiances measured by the Operational Land Imager (OLI) instrument on Landsat 8. The difference symbols represent measurements by different investigators at different sites. A ratio value of 1.0 means that the field and at-sensor radiances are identical.

International Cooperator Network: Growth of Landsat International Partnerships

The Landsat International Cooperator (IC) Network is rapidly growing to meet the increasing demands of the global Landsat user community. Since the February 11, 2013, launch of Landsat 8, 38 organizations from 36 countries representing 47 ground stations from around the world have shown interest in becoming part of the Landsat IC Network. Figure 54 depicts the potential Landsat 8 international ground stations, which have shown interest in participating in the Landsat 8 mission as an IC.

Of these potential International Cooperators, to-date 13 organizations have a signed agreement to be part of the Landsat IC Network. Table 1 lists the organizations representing 23 possible ground stations.

Once a ground station is technically prepared to receive the Landsat downlink for direct reception, the USGS conducts a rigorous 14-step certification process. At this time, 7 Landsat 7 and 14 Landsat 8 international ground stations have been certified and are actively receiving Landsat images with several more in process. Figure 55 shows the active Landsat international ground stations.

On June 9-13, 2014, the Landsat ICs participated in the 23rd Landsat Technical Working Group (LTWG #23) meeting held in Saskatoon, Saskatchewan, Canada. Participants

from 21 countries, including members of the USGS and NASA Landsat teams, represented 35 United States and international organizations and discussed a wide range of Landsat ground station topics. A photograph of the LTWG #23 participants is shown in figure 56. Special guest, His Worship Donald J. Atchison, Mayor of Saskatoon, welcomed the attendees and provided an overview of his beautiful city.

The Landsat IC Network has been enhanced over the years to provide not only basic data downlink services, but it also provides numerous key strategic international partnership benefits to the USGS, including:

- local and regional expertise for the global Landsat community;
- historical and ongoing global data collection, as well as backup capabilities;
- vital international charter and other emergency response support;
- critical spacecraft anomaly investigation and recovery operations; and
- an expansion of available scientific and technical resources/capabilities.

For further information, contact Steve Labahn, USGS EROS, labahn@usgs.gov.

Table 1. International cooperators with a signed Landsat 8 international cooperator agreement.

Signed (23 ground stations):				
1.		Australia (GA)	ASA, DWA, HOA	15 June 2012
2.		Europe (ESA)	KIS, MLK, MTI, MPS, NSG	22 August 2012
3.		China (RADI)	BJC, KHC	20 October 2012
4.		Indonesia (LAPAN)	DKI, RPI	2 November 2012
5.		Gabon (AGEOS)	LBG	11 February 2013
6.		Argentina (CONAE)	COA	15 February 2013
7.		Canada (CCMEO)	PAC	22 March 2013
8.		Norway (NSC / KSAT)	SGS	22 March 2013
9.		Saudi Arabia (KACST)	RSA	27 April 2013
10.		Thailand (GISTDA)	BKT, SRT	29 April 2013
11.		South Africa (SANSA)	JSA	29 May 2013
12.		Japan (AIST)	KUJ	21 November 2013
13.		Brazil (INPE)	CUB	21 October 2014

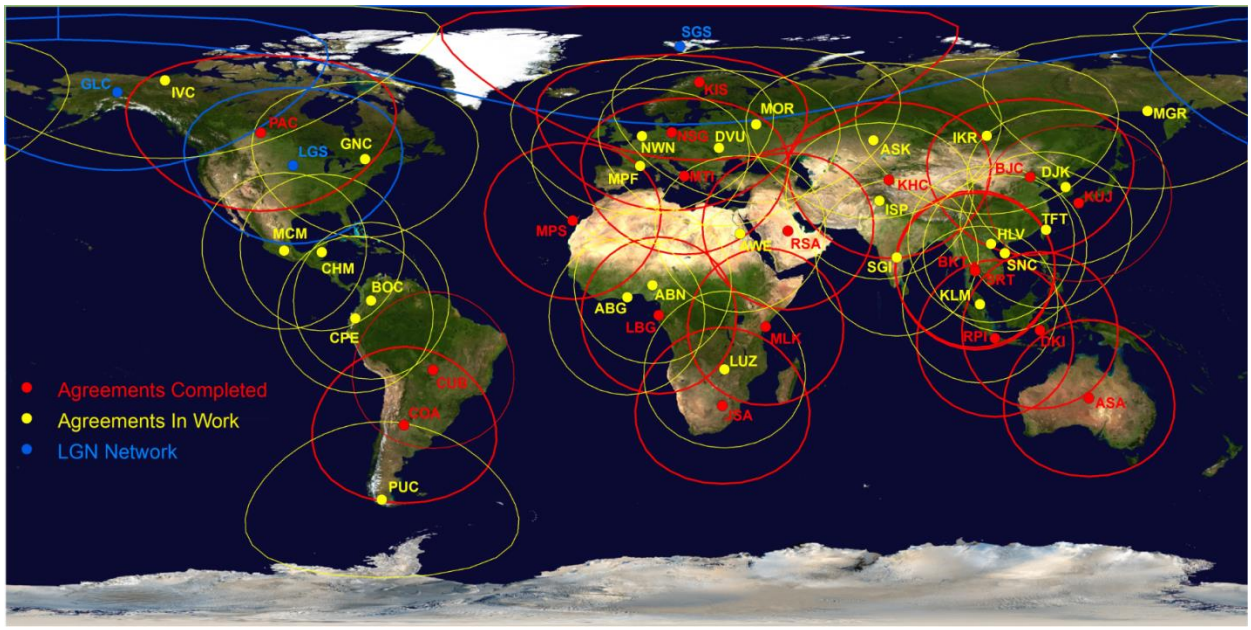


Figure 54. Potential Landsat 8 international ground stations.

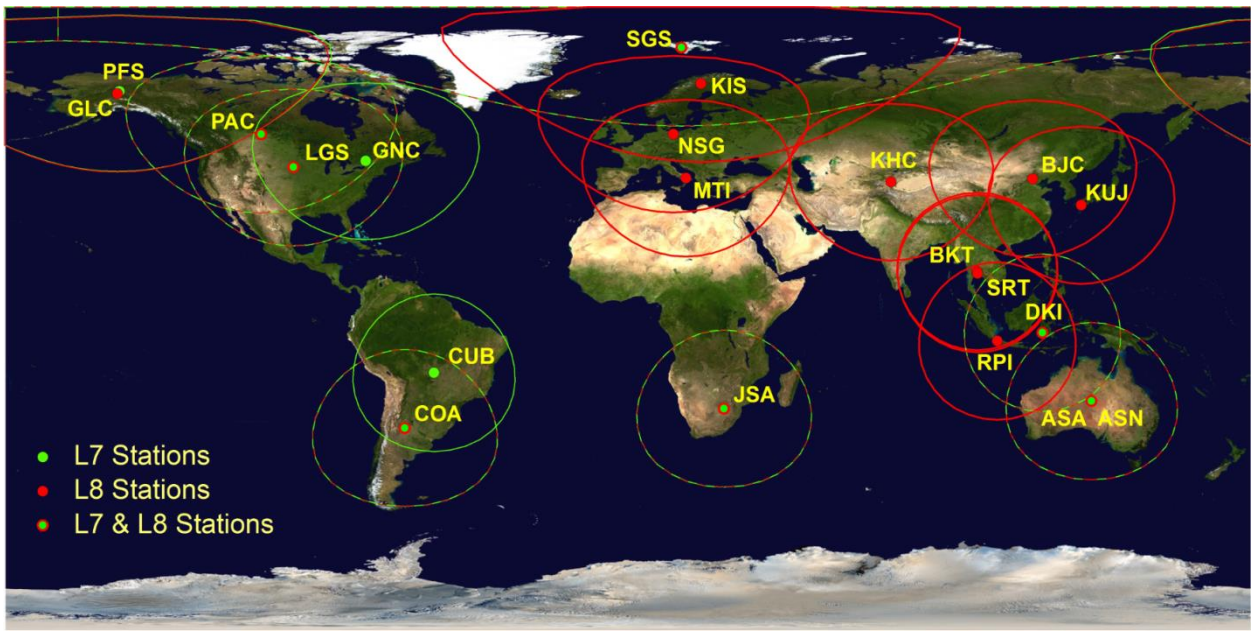


Figure 55. Active Landsat international ground stations.

Figure 56. Participants in the 23rd Landsat Technical Working Group meeting held in Saskatoon, Saskatchewan, Canada on June 9-13, 2014.

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 Land Remote Sensing 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. Key accomplishments are given in the following sections.

Sustainable Land Imaging Architecture Study Team

For more than 40 years, multispectral image data obtained from the Landsat series of satellites, first launched in 1972, have provided the longest continuous record of

changes in earth's surface as seen from space. Landsat is the only satellite system to date that is designed and operated to repeatedly observe the global land surface at moderate resolution. The most recent satellite in this series, Landsat 8, was launched in February 2013. The establishment of this latest data stream in the Landsat series triggered an initiative to take stock of this successful satellite series, and plan for its future evolution.

The FY 2014 President's budget called for "*Near-term activities led by NASA, in cooperation with USGS, will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Evaluations and design activities will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships."* In response, the NASA Earth Science Division (ESD), in cooperation with the USGS, established the Sustainable Land Imaging (SLI) Architecture Study Team (AST) to conduct a comprehensive study during FY 2014. The AST activities were focused on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Specifically, the AST defined a system for delivering sustainable global land imaging multispectral and thermal infrared information for approximately a 20-year period starting in 2018.

The AST was formed cooperatively by NASA and USGS, drawing on expertise from field centers within both agencies as well as from other independent organizations. Four members of the EROS Center participated in the SLI AST and represented the interests of the science and user communities as well as the DOI and the USGS. USGS AST members were Jim Nelson, John Dwyer, Doug Daniels, and Jason Williams.

The AST applied three basic tenets to guide its overall architecture study:

- Sustainability: The land imaging program should provide the *data products* for the long haul, without extraordinary infusions of funds, within the budget guidance provided.
- Continuity: The land imaging program should continue the long term Landsat data record. This does not necessarily mean the imagery per se, but the *usable products* that define the utility of the data record.
- Reliability: The land imaging program should be robust and *not susceptible to single point failures*. The loss of a single satellite or instrument on orbit should not cripple the program or significantly impact users.

In order to address such a wide-ranging charge, the AST established a comprehensive study methodology to sufficiently meet the goals, objectives, and constraints of the team's charter (fig. 57).

Specifically, the AST assessed minimum requirements and desired performance enhancements identified by the user and science community to define the target set of

capabilities to achieve by the "end state" of the AST study period (e.g., approximately 2038). Based on feedback from the Landsat Science Team, input from the USGS National Land Imaging Requirements (NLIR) Moderate Resolution Pilot Project (http://pubs.usgs.gov/of/2014/1107/), and the programmatic charge to maintain Landsat continuity, the AST observed a strong community desire for enhanced, ongoing multispectral data with increased temporal coverage (global revisit).

The AST then defined the characteristics for conceptual land imaging architectures and created a comprehensive candidate architecture taxonomy of over 500 combinations of technical and business model implementation options. From this point, the AST adopted a three-phase screening process to enable initial assessment of representative classes of architectures followed by more detailed assessments of down-selected subsets. In Phase 1, architecture assessments included technology readiness, constraints associated with technical performance and budget, and average availability. In Phase 2, architectures were evaluated against a set of metrics and a relative risk assessment was performed. Finally, in Phase 3, the near-term missions of the remaining architectures were further vetted in terms of technical, cost, and schedule analysis, and detailed risk assessment. In addition, the AST formulated a roadmap to map the remaining near-term mission concepts to the desired mid-term and end-state capabilities.

Thorough architecture analyses led to the identification of the most promising near-term mission concepts, and analysis of the needs and desires of the user community enabled the AST to reach conclusions regarding the desired performance of the architecture end state by 2038. Finally, the near-term mission concepts were then mapped to the desired architecture end state, generating candidate 20-year SLI roadmaps.

The AST study resulted in identification of four near-term mission options. These included three full spectrum missions and a Thermal Infrared (TIR)-only mission performed in partnership with the European Space Agency's Sentinel-2.

In August 2014, the AST delivered its Final Report to NASA ESD and supported on-going efforts by DOI/USGS headquarters and NASA headquarters to communicate SLI findings, observations, and recommendations to the Executive Office of the President and the Office of Management and Budget. A decision from the Administration on the near-term mission component is expected in FY 2015. For further information, contact Jim Nelson, USGS EROS, jnelson@usgs.gov.

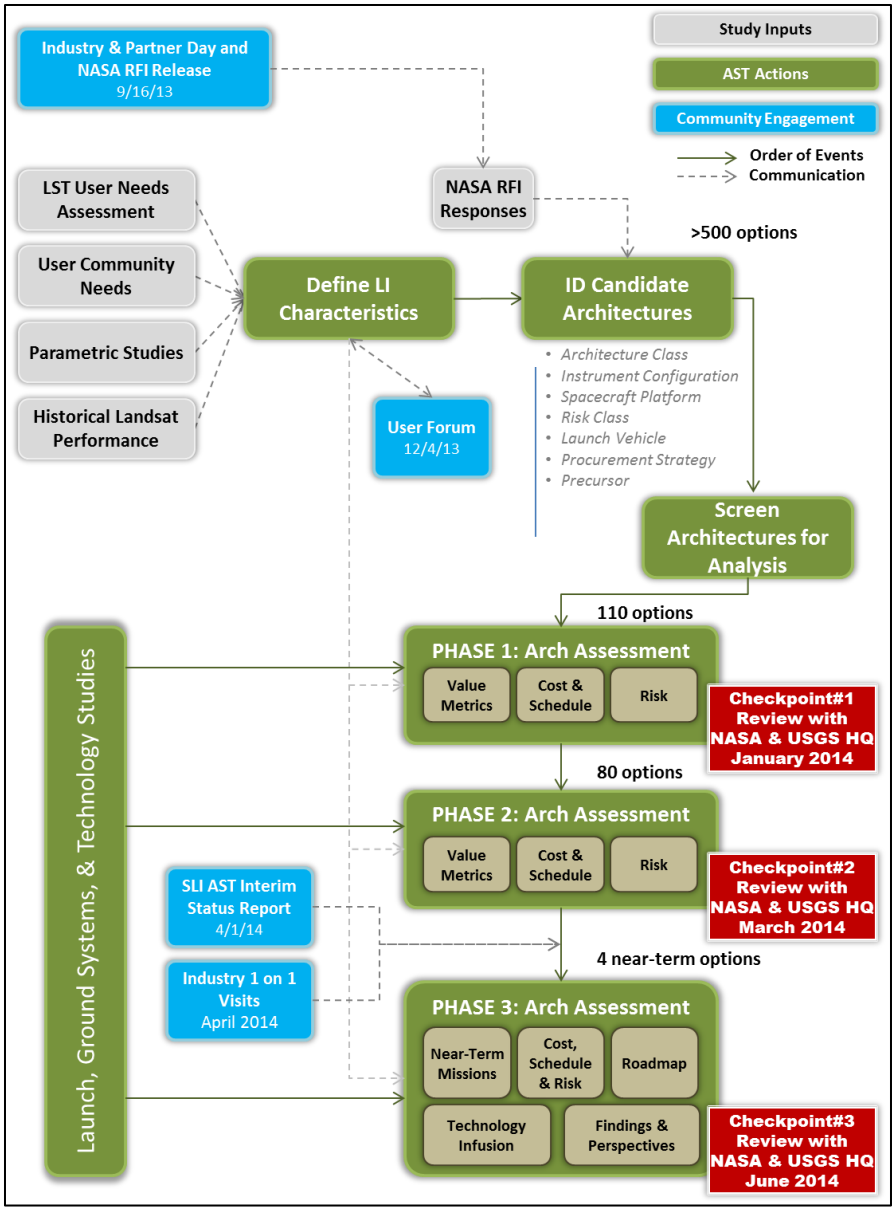


Figure 57. Image of methodology used by the Sustainable Land Imaging Architecture Study Team.

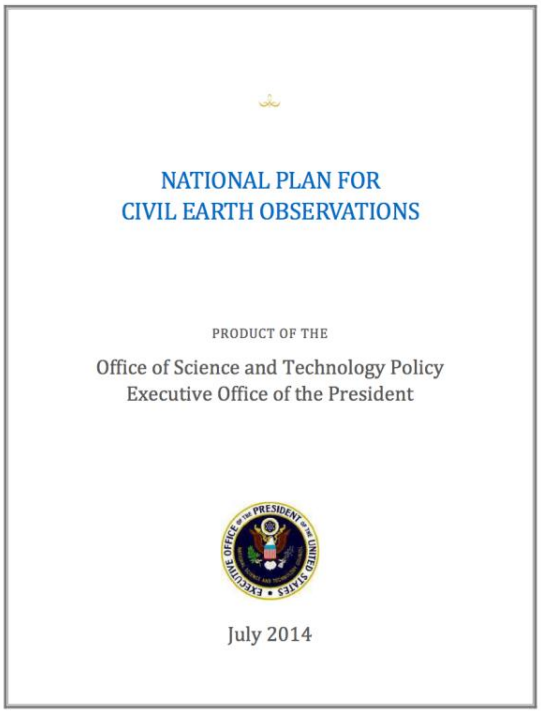
Observing Earth Today and Tomorrow: A National Plan

As the Nation's earth observation capacity has grown, so has the complexity and challenge of assuring its most effective use. In 2010, Congress charged the Director of the Office of Science and Technology Policy (OSTP) with establishing a mechanism to ensure greater coordination among the 11 departments and agencies of the Federal government that are funded to conduct earth observation programs.

In response, OSTP released a National Plan for Civil Earth Observations in July 2014 that aims to maximize the value of earth observation data collected by Federal agencies. The Plan (fig. 58) is a blueprint for future Federal investments and strategic partnerships in earth observing systems. It lays out Federal priorities and supporting actions to manage earth observation systems through periodic assessments, interagency planning, and international collaboration.

The Plan includes a list of 145 high-impact earth observation systems. The top 15 systems form a select top tier and are ranked in order of importance, according to carefully identified priorities. USGS systems make up 3 of the top 15.

First on the prioritized list is the Global Position System (GPS). In second place is the national weather radar network, Next Generation Weather Radar (NEXRAD). The USGS-related programs that follow are Landsat (ranked 3rd), airborne lidar mapping (8th), and the USGS stream gage network (13th). For further information, contact Greg Stensaas, USGS EROS, stensaas@usgs.gov.


NATIONAL PLAN FOR
CIVIL EARTH OBSERVATIONS

PRODUCT OF THE

Office of Science and Technology Policy
Executive Office of the President

July 2014

Figure 58. National Plan for Civil Earth Observations, July 2014.

Requirements, Capabilities, and Analysis for Earth Observation: Assessment II

The United States invests billions of dollars each year in earth observing systems that help protect lives and property, preserve natural resources, and expand our understanding of the earth. United States earth observation efforts are distributed among more than 100 programs under the purview of Federal agencies and non-

Federal entities that both produce and use these data. Technology available to support these programs is constantly and rapidly evolving, and with rapid growth comes numerous and diverse earth observing systems in land, water, atmosphere, and space. As an earth observation user, how can you be sure your requirements will be considered as the Nation develops new earth observation systems and technologies? The USGS Requirements Capabilities and Analysis for Earth Observations (RCA-EO) activities have been established to meet this challenge. This USGS effort will document requirements to inform the development of improved future earth observation systems. It will also match user requirements to systems, to help decision makers and scientists identify the best solutions to meet society's needs.

The USGS is taking a different approach to user requirements by eliciting and fully documenting stakeholders' needs in a unified framework. These user requirements are maintained in one place, enabling an integrated perspective and providing the capability to analyze them against current and future solutions. This capability will strengthen our case for sustaining important observations and for establishing new systems and priorities. We work directly with the experts – who are using the data – to identify, document, and prioritize user requirements to meet their needs. By maintaining verified and validated user requirements in a centralized web enabled application, we can use them again and again in different analyses, enabling us to effectively match requirements to prospective earth observation solutions across a broad perspective instead of an individual system view.

The USGS Earth Observation Requirements Evaluation System (EORES) will provide the first-ever capability to view earth observing user needs and systems capabilities together. As well, it will provide an assessed value of the contributions of systems to the user, and allow a vision for the future informed by comprehensive and enduring user requirements. Integrating these user requirements into our decision processes will help us better serve our stakeholder community and exercise good stewardship of the taxpayer's investments in earth observing systems through data-driven decisions on programs and budgets.

The first Earth Observations Assessment, performed in 2012, changed the way earth observing systems are viewed at the Office of Science and Technology Policy. It provided OSTP the first integrated look at earth observing systems, informing the development of The National Plan for Civil Earth Observations that presents a new framework for constructing a balanced portfolio of these systems. The National strategy for civil earth observations is designed to maximize interagency coordination, increase efficiency and efficacy of future earth observation efforts, and promote environmental and economic sustainability. This same methodology, with improvements, is being used by the USGS for Earth Observation Assessment II.

We are engaging hundreds of scientists, managers, to address this highly complex earth observations landscape. To document the value currently delivered, we use a value tree framework to link the earth observations to the benefit they provide. The value tree can be described in three parts (fig. 59). First, we define stakeholder

interests and what users are trying to accomplish – the top of the value tree. Second, we identify and assess the products, services, and models that deliver the value of the earth observations. And third, we identify and assess the specific earth observations and measures that form the foundation of this value – the base of the value tree. Multiple value trees can then be modeled within a single, integrated framework from which user requirements are developed, maintained, and analyzed to inform decision-making.

For an event like Hurricane Sandy, a broad suite of observations are needed. Sensors deployed on satellites, aircraft, and in-situ provide data that can be combined to model the impacts and help us create a vision of a more resilient and sustainable future. Having a comprehensive view and understanding of earth observing requirements needed to support our hazards mission helps us to see, and show others, the integrated suite of earth observing systems that provide critical information needed to do our work.

We are committed to reaching out and working with our user community to capture user needs. Together with our Federal partners, we are assembling this comprehensive "Big-Picture" view of the Nation's earth observing enterprise and assessing the relative value to our stakeholders. This unprecedented view of the requirements and capabilities will support the analysis needed to lay out the vision for tomorrow. With this new capability, we will be able to see earth observation user requirements across multiple disciplines, potentially opening new avenues for interagency collaboration in one of our primary missions of understanding how change in land use, cover, and condition affect people and nature.

Vision and strategic planning are very important to the USGS. Understanding our user community's needs and capturing their enduring user requirements is a critical step toward developing our way forward. We look forward to building this collaborative, integrated capability. Using innovative processes and tools for data driven decision-making, the USGS will gain key insights into the formulation of what future systems and technologies will best serve the earth observation users' needs. For further information, contact Gregory Stensaas, USGS EROS, stensaas@usgs.gov.

More information:

RCA-EO website and vision videos: http://remotesensing.usgs.gov/rca-eo

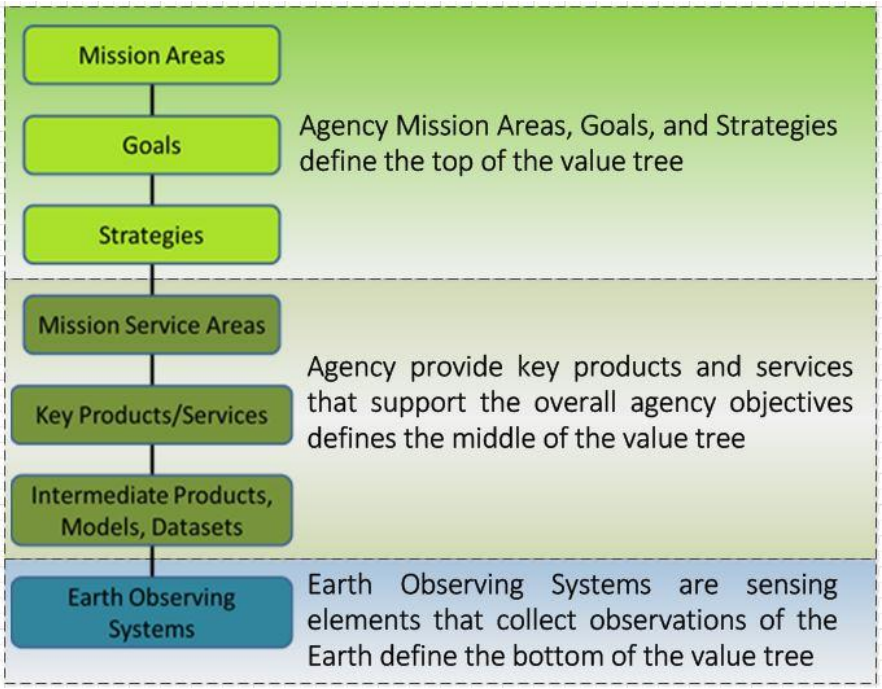


Figure 59. Three-part understanding of a value tree.

Thirteenth Joint Agency Commercial Imagery Evaluation Workshop

The USGS Remote Sensing Technologies (RST) project as the lead for the Joint Agency Commercial Imagery Evaluation (JACIE) team with NASA, NOAA, and U.S. Department of Agriculture (USDA) to sponsor the 13th JACIE workshop. The JACIE series of workshops began in 2001, following the launch of IKONOS, the first truly commercial imaging satellite. As a joint effort of U.S. Federal agencies and commercial partners to learn and understand the quality and capability of new commercial remotely sensed data and applications. The JACIE workshop has grown to include not only the growing number of commercial satellites, but also government (civil) satellites, as well as, airborne and other remote sensing instruments, such as lidar and radar.

This year, for the first time, the JACIE workshop was co-located with the American Society for Photogrammetry and Remote Sensing (ASPRS) Annual Conference in Louisville, Kentucky. This co-location was done in an effort to help promote the closely-aligned goals of both events, share resources and organizing efforts, and improve efficiencies. This has resulted in cost savings not only in organizing the workshop but also in reducing travel expenses for those who normally traveled to both events separately in years past.

Several EROS leaders highlighted the USGS presence at the co-located JACIE-ASPRS event. Dr. Frank P. Kelly (fig. 60), EROS Director and Space Policy Advisor for the USGS, was a keynote speaker at a joint plenary session along with the Disaster

Monitoring Constellation International Imaging (DMCii) Managing Director David Hodgson**.** Ms. Jennifer Lacey (fig. 61), EROS Observing System Branch Chief, represented the USGS EROS as part of the popular JACIE "Agency Speakers" section where leaders of each sponsoring agency along with the JACIE keynote speakers spoke and answered questions from the workshop audience, as part of a panel session.

Technical presentations at JACIE 2014 featured a broad cross-section of some of the exciting advances being made in earth observation and remote sensing. Presentations from EROS staff on the exceptional quality of Landsat 8 data was well received by all. Several companies such as Planet Labs and Google/Skybox with recently-launched or soon-to-launch satellites were able to give presentations on the data that they are collecting or soon to receive.

Interestingly, although five different satellite-operating government agencies from the United States and abroad were present, they were outnumbered by commercial companies operating or planning their own satellites. This illustrated to JACIE team and ASPRS attendees how the traditional government role in earth observation is being augmented by new commercial players. JACIE 2014 workshop illustrated that, through the exciting activities underway on both the government and commercial sectors, the future of earth observation will be bright indeed.

The RST team is currently in the planning stages for JACIE 2015, to be again co-located with the ASPRS Annual Conference in Tampa, Florida, May 5-7. For more information on JACIE and workshop proceedings, visit http://calval.cr.usgs.gov/jacie/. For further information, contact Gregory Stensaas, USGS EROS, stensaas@usgs.gov.

Figure 60. Dr. Frank Kelly, U.S. Geological Survey; and Dr. Stephen Volz, the new head of the National Oceanic and Atmospheric Administration's Satellite and Information Service, formerly the Associate Director for Flight Programs, National Aeronautics and Space Administration's Earth Science Division; at the Joint Agency Commercial Imagery Evaluation panel session.

Figure 61. Ms. Jennifer Lacey, representing the U.S. Geological Survey along with Glenn Bethel, U.S. Department of Agriculture, and David Hodgson, DMCii, at the Joint Agency Commercial Imagery Evaluation Workshop 2014.

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 the 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. Key accomplishments are given in the following sections.

MEaSUREs: Making Earth Systems Data Records for Use in Research Environments

The Land Processes Distributed Active Archive Center (LP DAAC), located at the USGS EROS Center, archives and distributes NASA Earth Observing System data products. Historically, these products have been derived solely from individual instruments, such as the Advanced Spaceborne Thermal Emissions and Reflection Radiometer (ASTER) and Moderate Resolution Spectroradiometer (MODIS).

Increasingly, however, earth scientists rely on compilations of earth science data records (ESDRs) that are unified across different measurement platforms, and coherent both geographically and through time. Consistent with an emphasis on "measurements, not missions," NASA has been soliciting the development of ESDRs through the Making Earth Systems Data Records for Use in Research Environments (MEaSUREs) program, creating consistent records, often through the integration of information from many sources. Requests for proposals occurred in 2006 and 2012. Selected ESDRs related to land processes are assigned to the LP DAAC for ultimate archive and distribution.

The land-process ESDRs from the 2006 solicitation are either currently in distribution, or will be in distribution by the fall of 2015. These include the currently released Web-Enabled Landsat Data (WELD) and Shuttle Radar Topographic Mission "Plus" (SRTM+) records, along with the soon-to-be-released Vegetation Index and Phenology (VIP) and Global Forest Cover Change (GFCC) records. Information about these products can be found on the LP DAAC website at https://lpdaac.usgs.gov/products/measures_products_table.

The WELD was derived from Landsat ETM+ data to create consistently gridded 30-meter radiance, reflectance and temperature records, composited to uniform time intervals (weekly, monthly, yearly). The WELD record runs from 2002-2012 for the conterminous United States and Alaska, and is organized as 5,000 by 5,000-pixel tiles in a manner similar to MODIS. The WELD record provides an alternative to scene-based analysis of Landsat data, and has been used in a number of earth science studies, including land cover classification and the mapping of permafrost and wildlife habitats. Figures 62 and 63 illustrate the extraction of crop information from WELD imagery. Figure 62 illustrates WELD tile subsets of four weekly WELD products over an agricultural region of Texas, while figure 63 illustrates the results of a crop data layer extraction from a nearby area compared against *(Yan, Lin and Roy, David, P., 2014, Automated crop field extraction from multi-temporal Web Enabled Landsat Data: Remote Sensing of the Environment v.144, p. 42-64; http://dx.doi.org/10.1016/j.rse.2014.01.006)*. The principle investigator for the WELD project is David Roy from South Dakota State University.

The SRTM+ was derived from interferometric synthetic aperture radar data acquired from the Space Shuttle in 2000, between 60 degrees north latitude to 56 degrees south. While providing the first globally consistent elevation model, earlier versions of the SRTM included a large number of data gaps due to observational and processing artifacts. The SRTM+ fills these gaps with data from other sources, including the ASTER Global Digital Elevation Model, the USGS National Elevation Dataset, and the Global Multi-resolution Terrain Elevation data 2010. The principle investigator for the SRTM+ project is Mike Kobrick from the California Institute of Technology's Jet Propulsion Laboratory.

The NASA SRTM+ record has a lineage that differentiates it from the void-filled SRTM data set developed by the National Geospatial Intelligence Agency. Like the NGA data

set, it is a 3 arc-second gridded global product, with 1 arc-second data publically available over the United States. Also like the NGA SRTM, there is a global 1 arc-second data set that is subject to rules of limited distribution. Recently, the NGA relaxed its distribution policy on the finer resolution global product, and will release it through the USGS on a phased basis. Through an agreement between NASA and NGA, the LP DAAC will release SRTM+ 1 arc-second global data according to the same phased release schedule as the NGA data.

The other two records, VIP and GFCC, are in their final stages of production and should be available by the fall of 2015. Both products are multi-source: VIP develops global vegetation and phenology records from the Advanced Very High Resolution Radiometer (AVHRR) and MODIS instruments, while GFCC looks at forest cover change with Landsat and MODIS data. In addition to the 2006 MEaSUREs products, the LP DAAC will be receiving five product suites selected from the 2012 solicitation. These include global vegetation continuous fields over the combined MODIS and AVHRR histories, a improved global elevation model derived from completely reprocessed SRTM interferograms, a global version of WELD produce suite, a global 30-meter agriculture crop data base, and a unified, coherent global temperature and emissivity database.

The LP DAAC is located at the USGS EROS Center in Sioux Falls, South Dakota, and is operated by the USGS with NASA funding (https://lpdaac.usgs.gov). For further information, contact David Meyer, USGS EROS, dmeyer@usgs.gov.

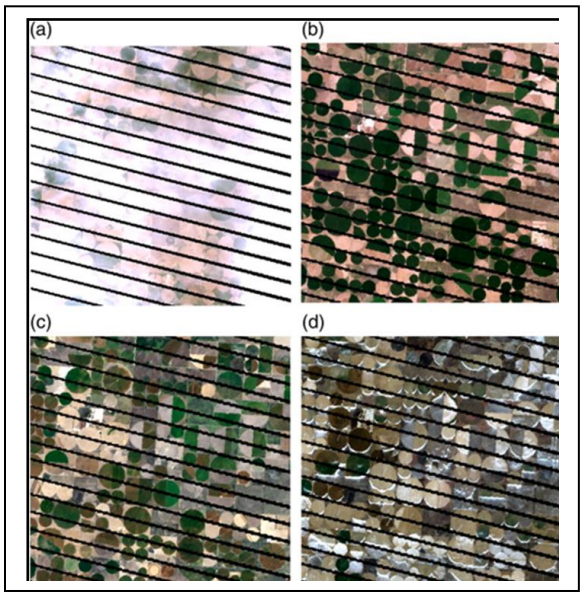


Figure 62. Weekly Web-Enabled Landsat Data subsets (Northern High Plains, Texas) showing true color, at-sensor reflectance for four weeks in 2007, (a) week 13 day 87 (Spring), (b) week 29 day 199 (Summer), (c) week 38 day 263 (Autumn), and (d) week 52 day 359 (Winter).

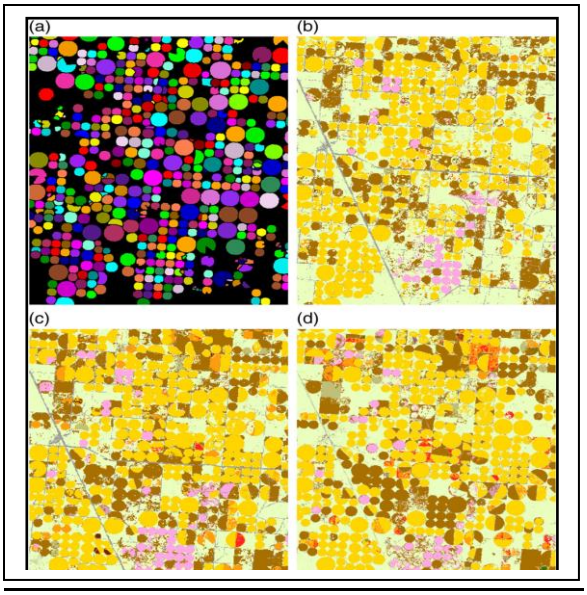


Figure 63. Crop data layer (CDL) classification results near Hartley, Texas, (a) crop field extraction results derived from five years of weekly Web-Enabled Landsat Data products; included for comparison are (b) 2008 30-meter CDL classification product from the National Agricultural Statistics Service, (c) 2009 CDL, and (d) 2010 CDL.

Land Processes Project Migration to Postgre Database

NASA's Land Processes Distributed Active Archive Center (LP DAAC) located at the USGS EROS Center utilizes NASA's Earth Observing System Data and Information System (EOSDIS) Core System (ECS). Until recently the ECS used Sybase as the primary underlying database. ESDIS was paying in excess of $1 million per year to support Sybase across all of its DAACs. A decision was made to evaluate an open source solution for its database needs, and PostgreSQL was selected.

ECS Release 8.2 completed in FY 2014 contained the scope to implement PostgreSQL across the three ECS DAACs. Replacing a database is always a significant system change. But since the completion of the migration, the expected cost savings have been realized. Also the project's initial expectations of performance changes were simply that there would be no noticeable degradation; but in reality, there was a significant improvement in the performance of database calls. As a consequence of the successful transition of Sybase to PostgreSQL, the LP DAAC plans to also migrate other commercial databases to PostgreSQL in the coming fiscal year along with other projects within EROS. For further information, contact Christopher Torbert, USGS EROS, ctorbert@usgs.gov.

DAAC2Disk: New Tool for Downloading Large Amounts of Land Processes Data

The LP DAAC has a number of large users who prefer to down load significant amounts of data at one time. To enable large downloads, the LP DAAC developed the LP DAAC to Disk HTTP Download (DAAC2Disk) Manager, which makes this very easy.

Download tools/scripts existed for FTP (File Transfer Protocol), but with additional Government restrictions and a push to migrate to HTTP (Hypertext Transfer Protocol), the need for a new capability existed. Staff at the LP DAAC suggested we develop this service and implement it for our large download users. This tool took a month to develop and is designed to be reused by other DAACs, large users, or partners.

The DAAC2Disk Manager is available as a web-based version (fig. 64), as well as script-based version for Windows, Macintosh, and Linux/Unix (fig. 65). Each version has three different modes of operation; searching via input parameters, providing an input file, and an order URL (Uniform Resource Locator) option. The search via input parameters allows users to search the NASA's Earth Science Data and Information System (ESDIS) Earth Observing System (EOS) Clearing House (ECHO) metadata catalog with a data set shortname, version identifier, acquisition date range, and geographic search parameters. Note: this search feature only works for data sets that have online access URLs provided in the ECHO metadata catalog.

Since the release of the DAAC2Disk Manager, the LP DAAC User Services has seen fewer complaints on the HTTP protocol. Users who are unaware of the new service have been directed to the DAAC2Disk and have had a positive experience. Use of the DAAC2Disk website has grown since the release in July 2014 (fig. 66).

The Download Manager is satisfying users who are new to HTTP, as well as those looking for an efficient way to download bulk data. A recurring issue is with the available datasets. Users can be somewhat confused as to which datasets are downloadable from other DAACs/data centers.

In an effort to reach out to additional users, the LP DAAC is conducting a webinar in December 2014 and providing a NASA in-booth demonstration at the 2014 American Geophysical Union conference in December 2014.

The DAAC2Disk service is an efficient and helpful capability that the LP DAAC has developed and enabled for its users and partners to gain access to ESDIS data via HTTP protocol going forward. For further information, contact Chris Doescher, USGS EROS, cdoesch@usgs.gov.

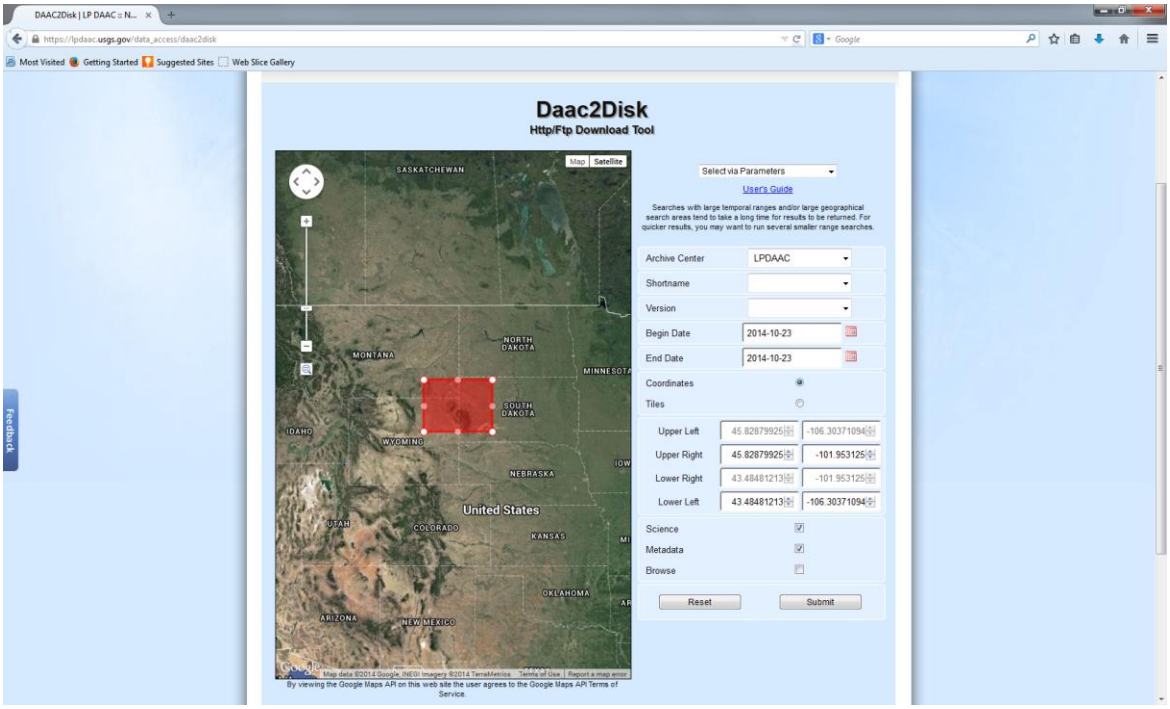


Figure 64. Screen shot of the DAAC2Disk web tool.

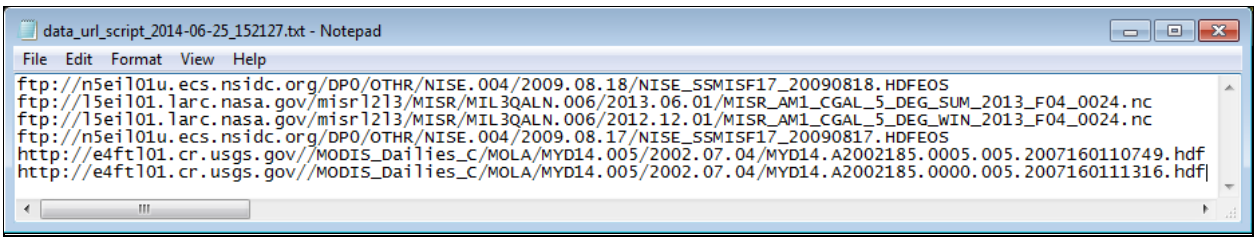


Figure 65. A screen shot showing the DAAC2Disk script.

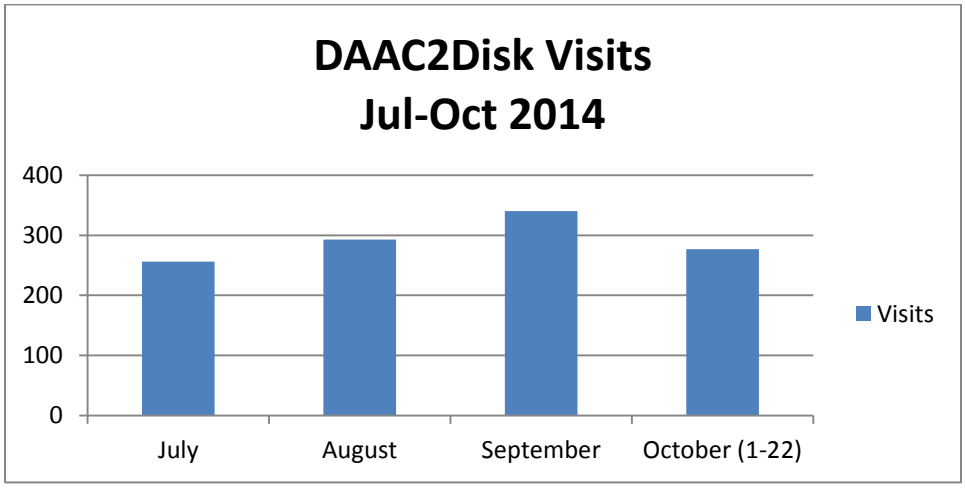


Figure 66. A bar chart illustrating the growth in use of the DAAC2Disk web tool.

Vinegar Syndrome

The Long Term Archive (LTA) completed its work in scanning USGS Vinegar Syndrome aerial film. At risk were over 2.4-million USGS aerial photos acquired from 1937 through 1972. Vinegar syndrome destroys the acetate film, causing it to bubble and warp (fig. 67). This chemical degradation process separates the emulsion from the acetate base and emits a vinegar-like odor, hence the name “vinegar syndrome.”

Options to deal with this problem included (1) duplicate every acetate roll onto mylar film, (2) freeze the old film rolls to stop the deterioration process, or (3) scan the rolls to make a digital copy of each frame. Options 1 and 2 were not feasible due to EROS funding and facility limitations. Therefore, the LTA moved ahead with its plan to scan the vinegar rolls at 25 micron through the Phoenix V systems and ship the completed rolls to the National Archive and Records Administration (NARA) for cold storage. The resulting digital imagery lives on at EROS for no-cost user access through EarthExplorer, and the original media is shipped to NARA for cold storage preservation. Over 11,000 vinegar syndrome rolls have been shipped since 2012.

The LTA celebrated the milestone of having completed the scanning of all vinegar-syndrome-afflicted rolls of USGS aerial projects in August 2014.

A considerable number of non-USGS vinegar-syndrome film rolls remain to be scanned, and the LTA film scanning effort continues, but the scent of vinegar has been largely replaced by the smell of success in resolving a major threat to the USGS aerial archive. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

Figure 67. These images show film without vinegar syndrome (left), one with vinegar syndrome (center), and the chemical sieves that were used to slow down the chemical degradation (right).

Release of Shuttle Radar Topography Mission Global 1 Arc-Second Data Set

The Shuttle Radar Topography Mission (SRTM) was flown aboard the space shuttle Endeavour from February 11-22, 2000. NASA and NGA participated in an international project to acquire radar data which were used to create the first near-global set of land elevations at 1-arc-second (approximately 30-meter) resolution. This data set is available to the public via a user-friendly interface on the USGS EarthExplorer website.

Specially modified radar antennas aboard the Endeavour were used to collect interferometric radar, which compared two radar images or signals taken at slightly different angles. This mission used single-pass interferometry, which acquired two signals at the same time by using two different radar antennas. An antenna located on board the space shuttle collected one data set and the other data set was collected by an antenna located at the end of a 60-meter mast that extended from the shuttle. Differences between the two signals allowed for the calculation of surface elevation.

Until now, SRTM elevation data for the global community were available only at 3-arc-second (approximately 90-meter) resolution. The data acquisition was spaced at intervals of 1 arc-second; however, the initial data release for regions outside the United States were resampled at a less-detailed resolution for open distribution. Newly processed 1 arc-second elevation data for the African continent were released by NASA, NGA, and USGS on September 23, 2014, that allow scientists to view their area of interest with greater detail than they could previously (fig. 68). The remainder of the higher-resolution global data will be released in phases over the next 12 months.

NASA, NGA, and USGS have committed to open international sharing of SRTM 1 arc-second global data to better understand the impacts of severe environmental changes such as drought, glacial retreat, flooding, landslides, coastal storm surges, agricultural stresses, and challenges concerning public health. The USGS EarthExplorer (http://earthexplorer.usgs.gov/) can be used to search, preview, and download this newly released topographic database. Users may check the coverage map in EarthExplorer to verify if data are available for their area of interest. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

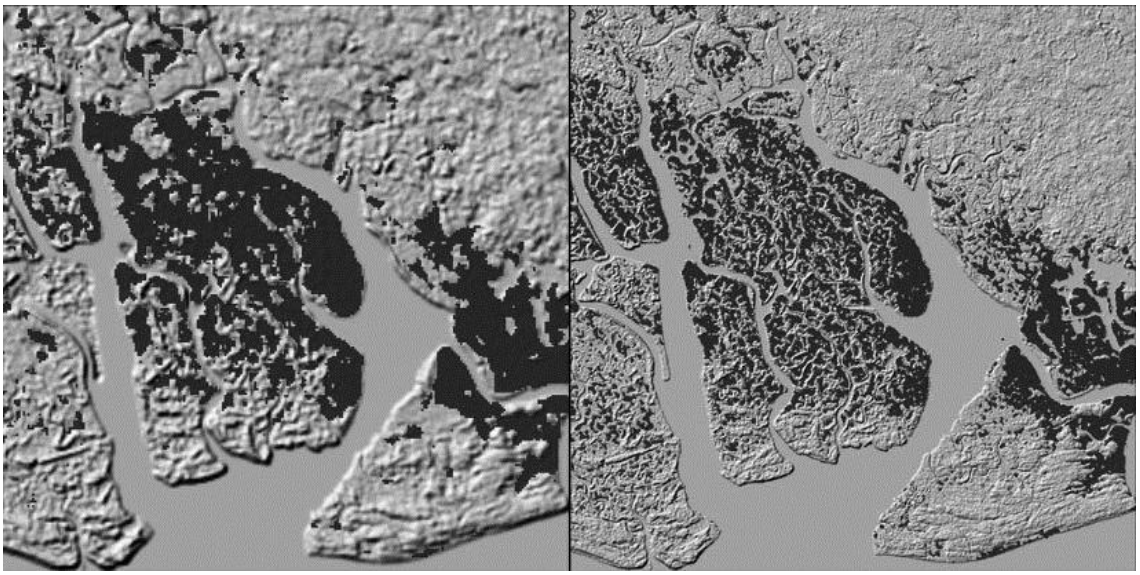


Figure 68. These images showcase the differences in the level of detail between the 3-arc-second and 1-arc-second resolution Shuttle Radar Topography Mission data of the Niger River Delta in western Africa.

“HDDS Explorer” Release

The USGS EarthExplorer (http://earthexplorer.usgs.gov) interface has been redesigned to support new functionality required for query, visualization, and distribution of Landsat 8 and other remote sensing datasets as well. This enhanced flexibility and systems engineering framework of EarthExplorer fits well for providing multiple features that markedly advance the support of Emergency Operations.

The EarthExplorer flexible engineering framework allowed for the design and development of Hazards Data Distribution System (HDDS) Explorer (http://hddsexplorer.usgs.gov/). The same features provided by EarthExplorer are made available through the HDDS Explorer interface. The Google Map Application Program Interface (API) provides a rich map interface to improve the user’s ability to search for data. The events tab displays all the events by year to allow users to choose the emergency response event they are supporting. Search criteria include the Google Map interface, Address/Place name, Features, Predefined areas, and the ability to upload shapefiles or Keyhole Markup Language (KML) files to define an area-of-interest. Through the HDDS Explorer results (fig. 69), users can display footprints, browse, view metadata on each scene, download the scene directly, or submit a bulk order request for multiple scenes.

The user registration allows users to save search criteria to be used for future reference. The user registration also provides the flexibility for managing licensed data received from another organization that requires specific licensing agreements for distribution. Standing request services (fig. 70) provide the capability for saving search criteria to a standing request. The standing request searches the inventory for new data that fulfills the first responders area of interest and date/time requirements. Users are then automatically notified when the data are available for download. The standing request feature immediately provides disaster responders with data based on their area of interest to support the event.

The release of the HDDS Explorer provides a consistent look and feel for users familiar with the EarthExplorer interface. The tool set provided by HDDS Explorer, advances the capabilities for first responders requiring access to data in support of emergency operations. The HDDS Explorer provides a single, consolidated interface and distribution system for access to all available USGS-hosted datasets related to an emergency event. The additional features such as standing request notification, ability to export all results in a variety of standardized metadata results formats (CSV, KML, SHP, XML, FGDC), and the ability to view all supported events provides first responders with enhanced capabilities in supporting national and international disasters. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

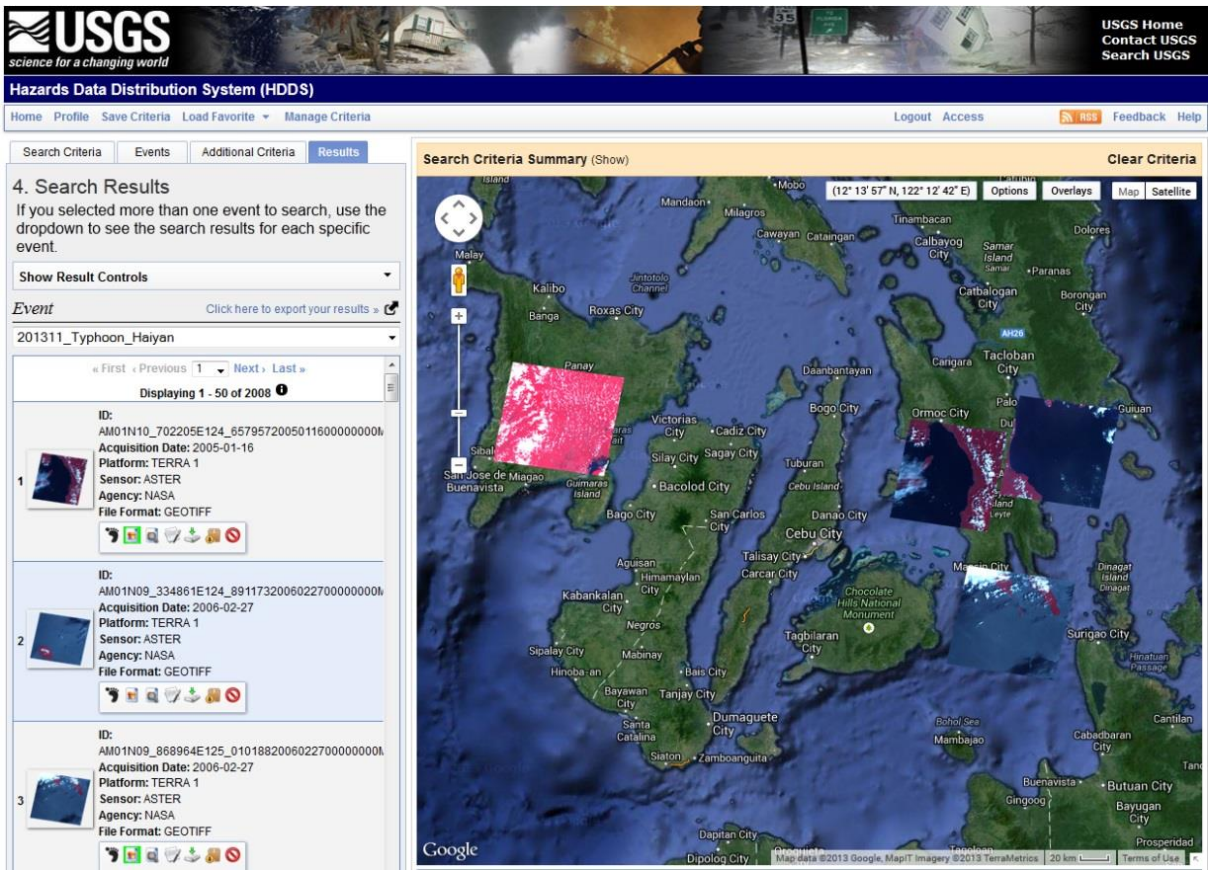


Figure 69. Hazards Data Distribution System Explorer Search Results.

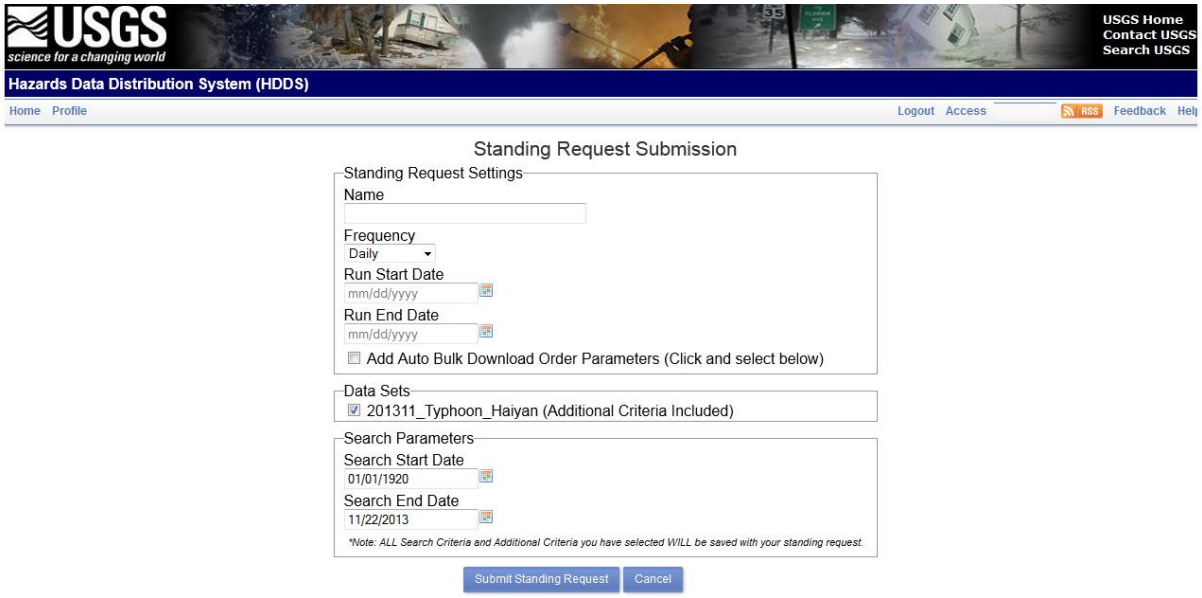


Figure 70. Standing request functionality in Hazards Data Distribution System Explorer.

Scanning Orders Maintenance Application

The EROS digital scanning laboratory provides high resolution scanned digital files from the historical aerial and satellite archive. Customers request products for scanning through EarthExplorer for $30.00 per frame. The scan request is put into a hold status until payment is received. In FY 2014, the USGS Store in Denver, Colorado, managed the payment for scanned orders. The interface for managing the scanned orders was a spreadsheet that was sent back and forth between EROS and the USGS Store. This process proved to be time consuming and error prone.

The Long Term Archive project developed the Scanning Orders Maintenance Application (SOMA) system to provide a paperless interface for the management of scanned orders between EROS and the USGS Store. The LTA software and LTA operations staff designed and developed the SOMA web interface. The SOMA provides information on the orders, status information on the order, and tracking of the scanned product throughout the entire process, as shown in figure 71.

To facilitate a paperless environment, the web application was tested on an Apple iPad. The iPad was integrated with a blue-tooth scanner to track film canisters through the scanning process from the film archive to the scanner and back to the film archive. Using iPad mobile wireless technology, SOMA represents a significant productivity improvement while moving EROS operations to a paperless work flow controlled environment. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

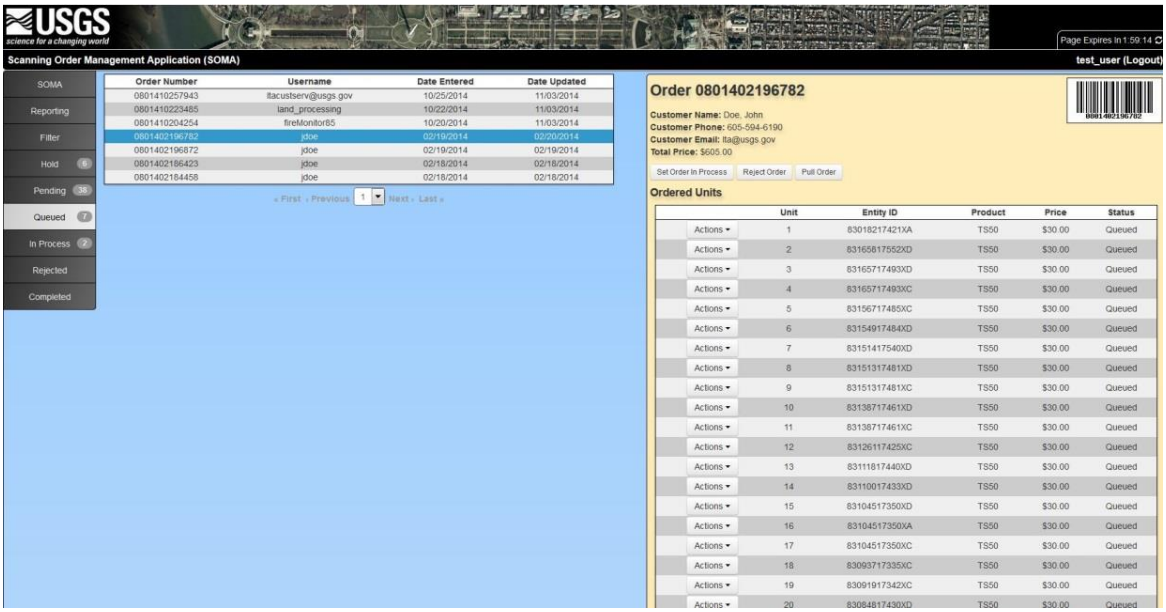


Figure 71. Scanning Order Maintenance Application system web interface.

EarthExplorer Machine-to-Machine Interface

The USGS EarthExplorer (http://earthexplorer.usgs.gov) provides online search, browse display, metadata export, and data download for earth science data from the archives of the USGS. EarthExplorer provides an enhanced user interface using state-of-the art JavaScript libraries, Hypertext Preprocessor (PHP), and the advanced Oracle spatial engine. Currently, EarthExplorer provides access to over 300 datasets ranging from Landsat 1-8, declassified, aerial, SRTM, lidar, and NASA LPDAAC collections.

The Bulk Download (BDA) tool allows users to download data identified from the EarthExplorer system. While this has proven to be very popular, the BDA requires user interaction with the BDA to run and download data. Because of this limitation, users have requested an applications programming interface to search, request, and download data directly to their system.

The EarthExplorer software team extended the services available from EarthExplorer through the Machine-to-Machine (M2M) interface (fig. 72). The purpose of this inventory service is to provide access to publicly available data within the Long Term Archive via web services. The M2M services extend the capabilities access to data through the API developed by the LTA team. Once the API is setup on the users system, the API can be setup as a automated script to search and download data from the USGS archive. This service allows for basic data searching, metadata retrieval, and download of data. The services are based on a SOAP, the Simple Object Access Protocol, based interface using PHP Zend Framework to create the services. Users using the interface must be a registered user to use the services and to allow the USGS to collect user demographics on how the data is used.

The EarthExplorer Machine-to-Machine interface has proven to be very successful. Over 40 users are currently using the interface. Downloads of data have increased monthly, with more users requesting access to the service. The service provides another method for users to access the vast archive of USGS data (fig. 73). For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

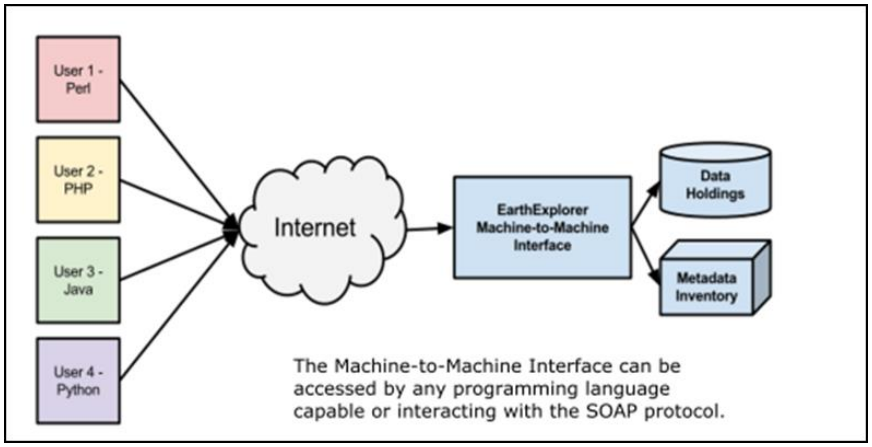


Figure 72. Machine-to-machine interface.

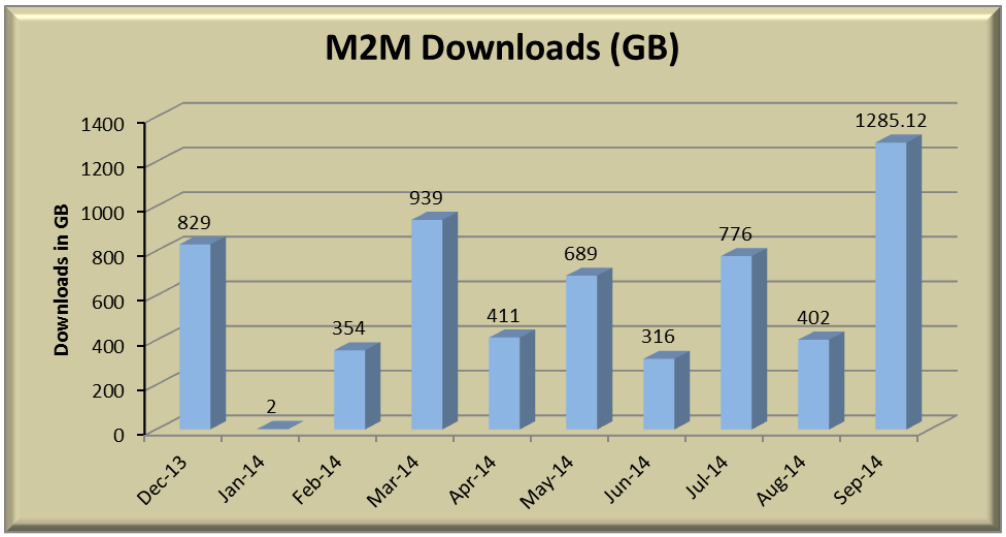


Figure 73. Machine-to-machine metrics.

Landsat Transition

The EROS Center is a USGS facility with a national and international mission. The USGS Landsat Project is responsible for two active satellite systems (Landsat 7 and Landsat 8) and data from previous missions (Landsat 1-5). This responsibility includes daily management and long term sustainment of all operations, maintenance, and engineering for the Landsat 7 and Landsat 8 spacecraft systems, flight operations located in Maryland, and Landsat ground station operations, located at the USGS EROS in Sioux Falls, South Dakota. The operations and maintenance activities of the ground segment at USGS EROS includes the data capture and processing, systems for data archival, data discovery, data ordering, product generation, quality control, product distribution, calibration/validation, and customer support.

The Long Term Archive project at EROS is responsible for the long-term data and archive management of aerial and satellite data in the USGS EROS archives to include operations, systems engineering and software development of systems to access, manage, preserve, and distribute archived remotely sensed data.

The USGS EROS management agreed to look at the management, operations, and infrastructure of the Landsat activities to determine a cost effective architecture to support the long-term vision of the USGS and EROS. Staff from the Observation Systems Branch (OSB) and Data Service Branch (DSB) had a kickoff meeting in September 2013 to begin initial discussions, evaluate roles and responsibilities, and review overall architecture. This resulted in the overall high-level diagram (fig. 74) depicting the roles/responsibilities and break out of functionality between the two organizations. The two organizations continued discussions on key areas of operations

and functional responsibility, and agreed to the overall architecture and organization break out.

The DSB staffs have worked closely with the OSB staff transitioning Landsat archive and distribution responsibility to DSB (fig. 74). The Landsat archive and distribution maintenance contracts and overall operations of the systems have been transferred seamlessly to DSB. The operations of the Searchable Inventory Database and USGS Inventory Server databases continue to be operated seamlessly with EarthExplorer. The next major area for transitioning is to transfer distribution of Landsat Level-One Terrain-Corrected (L1T) data distribution to the DSB tiered disk cache architecture. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

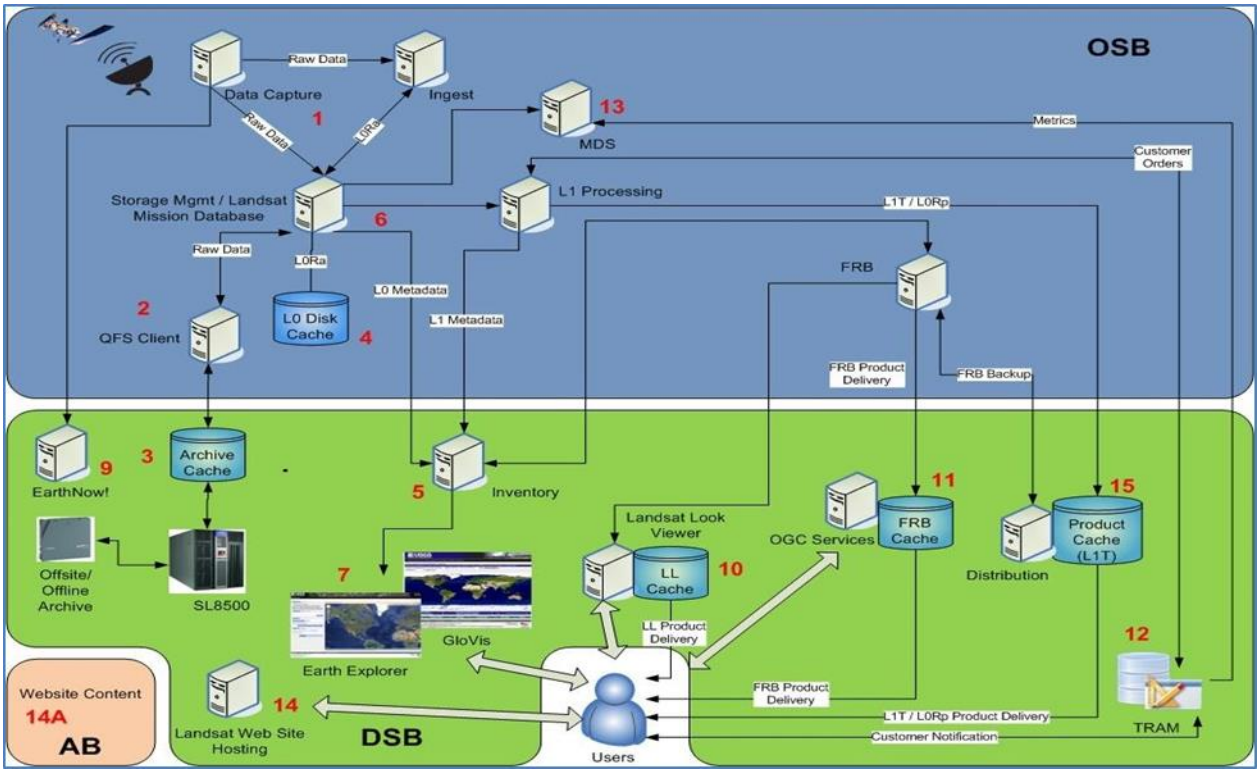


Figure 74. Observation Systems Branch and Data Service Branch Architecture.

Natural Resources and Conservation Service Data Access

The Long Term Archive project worked with the USDA's Natural Resources and Conservation Service (NRCS) office in Huron, South Dakota, to web enable 488,575 color scans that NRCS produced from their 35-millimeter aerial photography slides.

The photography was acquired from 1979 to 2002 over 33 counties of eastern South Dakota and was originally used for cropland compliance and monitoring. The LTA used the unique Township/Range/Section/Date file names, JPG, and TIFF imagery provided

by NRCS Huron to create EarthExplorer metadata that included center points, corner points, browse, and complete dates of acquisitions to web-enable the collection for no cost data downloads on July 17, 2014. Figure 75 provides examples of the NRCS files for the USGS EROS township, range, and section. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

Figure 75. Natural Resources and Conservation Service files for the USGS EROS township, range, and section (July 1979 on the left and July 2002 on the right).

Spatial Data Warehouse Migrates to Newer Technology

The USGS Spatial Data Warehouse project provides high-resolution orthoimagery, National Agriculture Imagery Program, and National Land Cover Database data and web mapping services to *The National Map*, as well as the general public and partner stakeholders, such as NGA and FEMA (Federal Emergency Management Agency). The migration data and systems from ESRI ArcGIS 9.3 to ArcGIS 10.2.2 allows the web mapping services to be created utilizing Mosaic Dataset technology, instead of Image Server technology. The new technology provides a more efficient means of creating and delivering web mapping services.

The migration to newer technology allowed the release of 762 updated areas to be added to the High Resolution Orthoimagery web mapping service. The update servers added approximately 25 percent or 600,000 square miles to the available coverage area (fig. 76). The new technology utilizing the Mosaic Dataset allowed for modifying system architecture. The Mosaic Dataset needs less servers to deliver web mapping services, thus eliminating six servers. With the update, orthoimagery was removed from the legacy system that used Spatial Data Engine and Oracle. End result of the data being removed was excessing three servers, consolidating remaining data, and excessing older storage disks.

The update made available more coverage area for high-resolution orthoimagery, which benefits *The National Map*, general public, and other partners. The use of the Mosaic Dataset reduced the operations and maintenance cost by shrinking the architecture footprint. For further information, contact Chris Rusanowski, USGS EROS, crusanow@usgs.gov.

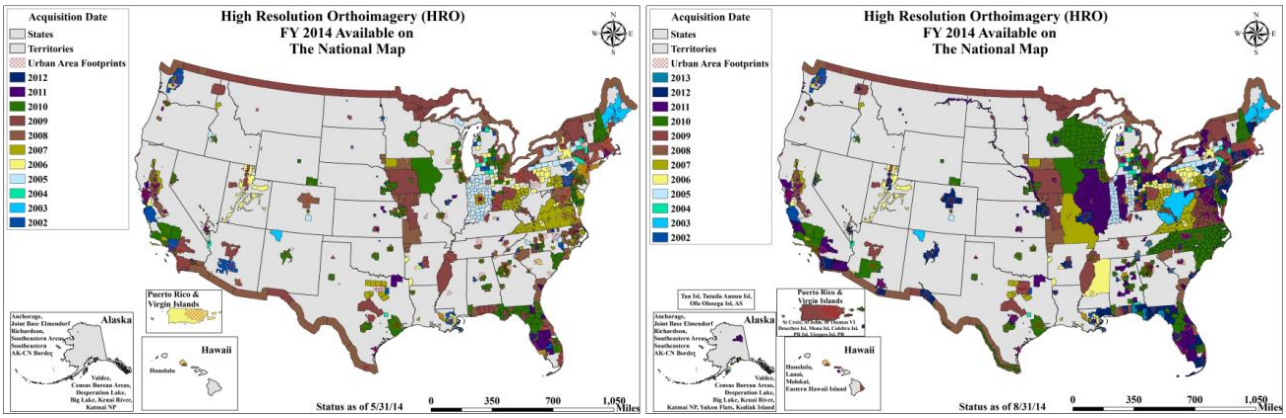


Figure 76. A map showing the additional orthoimagery coverage now available.

Completion of the Google Analytics Template

In an effort to standardize the reporting of web-based metrics for the USGS Land Remote Sensing Program, a template was developed to be utilized through the current Google Analytics capability.

Multiple developers throughout the LRS Program met and discussed the requirements for web-based metrics and statistical reports. The team analyzed the information to provide the best snapshot for managers regarding how their projects are being accessed. Once a set of statistics were decided upon, it was presented to EROS LRS-funded managers and the headquarter's LRS lead. After an initial question and answer period, some adjustments to the final set of analysis statistics were completed. A Google Analytics Manager template was created and presented to LRS management in Reston, Virginia. The template was approved. Four training sessions were held to provide all LRS projects information on how to add Google Analytics to their website(s). Additional USGS WebEx sessions were held to demonstrate the benefits of Google Analytics and how to interpret and customize reports.

The result of the standardization of the Manager template include a common Google Analytics configuration as well as a common reporting format (fig. 77).

Google Analytics provides up-to-date summaries of the web metrics for the owners of the LRS websites. The new template is now in use across multiple projects, which ensures all LRS-funded managers have consistent reporting. For further information, contact Chris Rusanowski, USGS EROS, crusanow@usgs.gov.

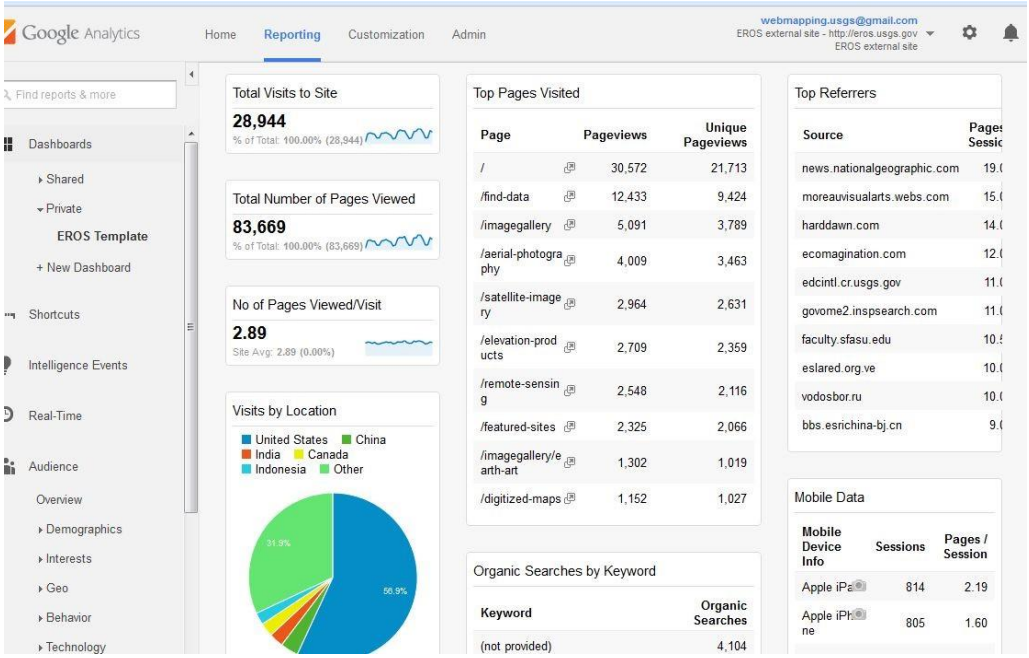


Figure 77. A screenshot showing the final Google Analytics reporting format for an active LRS website.

Converted Static International Ground Station Map to Interactive Map

The International Partnership program requested an overhaul of the existing International Ground Station page which included implementation of an interactive map displaying ground station locations.

Landsat Missions website team members discussed interactive map requirements with International Cooperator management and technical support staff. The team analyzed requirements and proposed a design based on the use of ArcGIS Application Program Interface for JavaScript for the map viewer and the Bootstrap framework for page design. Once the page was created and the API added, acquisition circles were generated from ground station coordinates and a fixed distance from the center point. Several ArcGIS map layers, with varying projections, were tested to find the best projection for proper display of acquisition circles; this was particularly problematic for ground stations located near the poles. Information windows, which display upon a mouse click, were added, then populated with information for each ground station. Additional page features included station availability tables and a KML file for each station for display within Google Earth and other map viewers supporting KML.

The finished product resulted in a rich and highly interactive webpage showcasing the International Ground Station network system.

The new interactive map (fig. 77) shows the coverage of all the Landsat ground stations in a way that allows all users to more accurately spatially correlate station capabilities. For further information, contact Chris Rusanowski, USGS EROS, crusanow@usgs.gov.

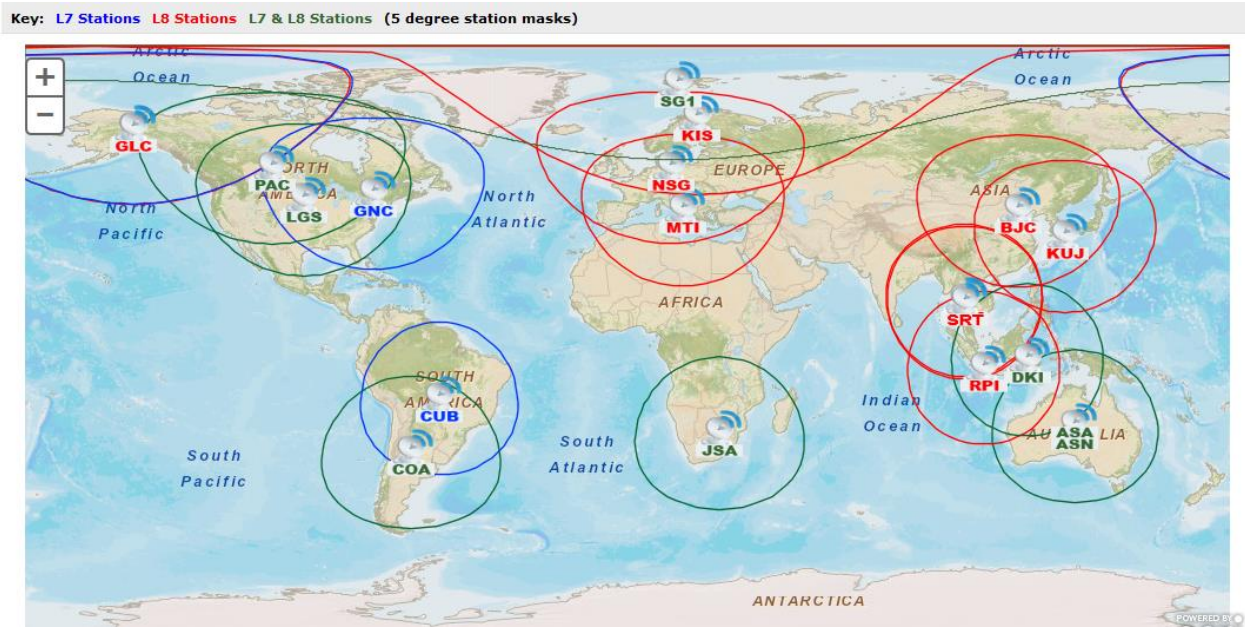


Figure 78. An interactive map displaying the Landsat ground stations.

National Satellite Land Remote Sensing Data Archive

The National Satellite Land Remote Sensing Data Archive (NSLRSDA) resides at the USGS EROS Center. Through the Land Remote Sensing Policy Act of 1992, the U.S. Congress directed DOI to establish a permanent Government archive containing satellite remote sensing data of the earth's land surface and to make the data easily accessible and readily available. This unique DOI USGS archive provides a comprehensive, permanent, and impartial observational record of the planet's land surface obtained throughout more than five decades of satellite remote sensing.

NSLRSDA contains film and digital records from the 1960s to the present day. NSLRSDA collections, as shown in table 2, provide unique observations of our Nation or the globe from different periods of time, through various cameras or sensors, and at ground resolutions ranging from less than 1 to 1,000 meters. For further information, contact John Faundeen, USGS EROS, faundeen@usgs.gov.

Table 2. Highlights of current collections in the National Satellite Land Remote Sensing Data Archive.

Collection name	Time span	Ground resolution[1]
Declassification I	1960–1972	2–153 meters
Declassification II	1963–1980	0.6–10 meters
Large Format Camera	1984	10–15 meters
Landsat Multispectral Scanner	1972–1992	80 meters
Landsat Thematic Mapper	1982–2012	30 meters
Landsat Enhanced Thematic Mapper Plus	1999–still operating	15 or 30 meters
Landsat Operational Land Imager	2013–still operating	15 or 30 meters
Landsat Thermal Infrared Sensor	2013–Still operating	100 meters
Landsat Orthoimagery	1972–2003	15–80 meters
Global Land Surveys	1972–2011	15–80 meters
Systeme Pour l'Observation de la Terre	1986–1998	10 or 20 meters
Advanced Very High Resolution Radiometer	1980–still operating	1,000 meters
Shuttle Radar Topography Mission	2002	30 meters
GeoEye OrbView–3	2003–2007	1 or 4 meters

[1] One meter is approximately 39.4 inches.

Consolidated Report: Data Distributed and Managed, and Products Distributed

The USGS EROS has a prepared report template used by the EROS projects for inputting their respective data distributed and managed, and products distributed. The volume of data managed and distributed, reviewed by the projects and the USGS LRS Program, gives statistics in terabytes over a 24-month period (i.e., FY 2013-2014). The volume of products distributed, reviewed by the projects and the USGS LRS Program, gives statistics in thousands over a 12-month period (i.e., FY 2014).

The data distributed and managed is illustrated in figures 79-92, followed by the products distributed in figures 93-99. For further information, contact John Faundeen, USGS EROS, faundeen@usgs.gov.

Data Distributed and Managed

Data distributed and managed for all projects, showing both monthly and cumulative, is shown in figures 79-82. Data distributed and managed for the following groupings are shown in figures 83-92:

- Landsat (fig. 83 and 84)
- LP DAAC (fig. 85 and 86)
- Other Satellite (fig. 87 and 88)
- Non-Satellite (fig. 89 and 90)
- Geospatial (fig. 91 and 92) including Land Cover, Orthoimagery, Elevation, and Other

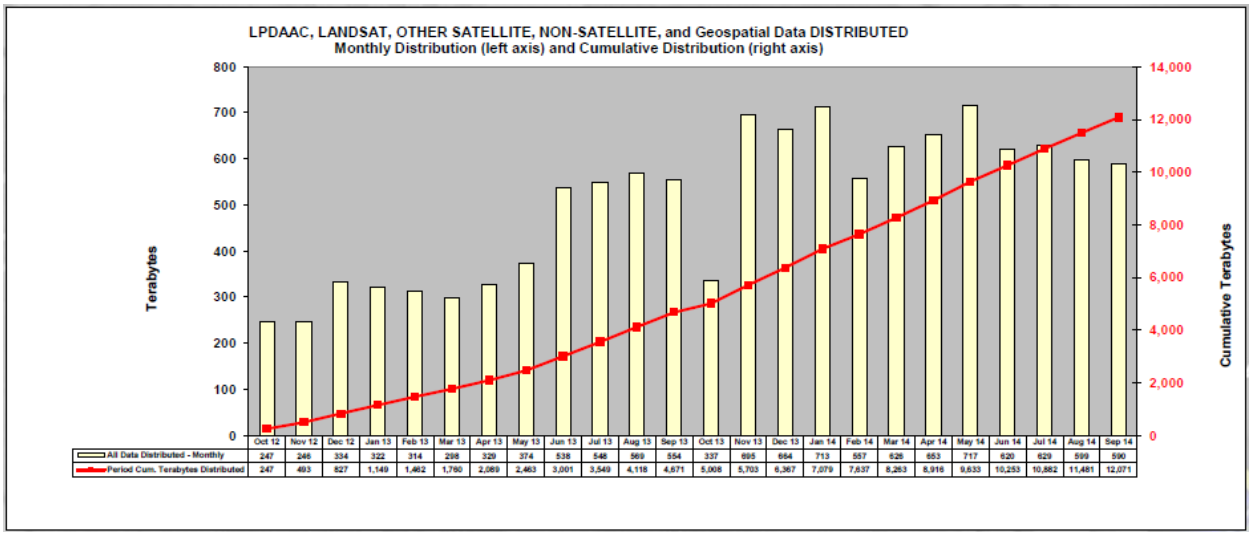


Figure 79. FY 2013-2014 of all projects combined. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.

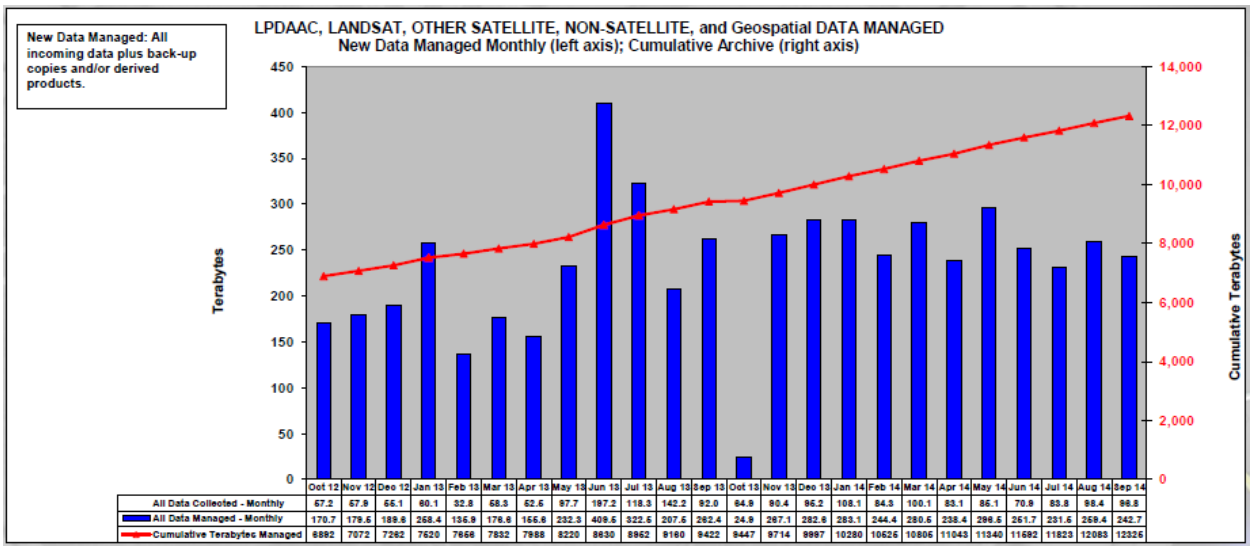


Figure 80. FY 2013-2014 of all projects combined. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.

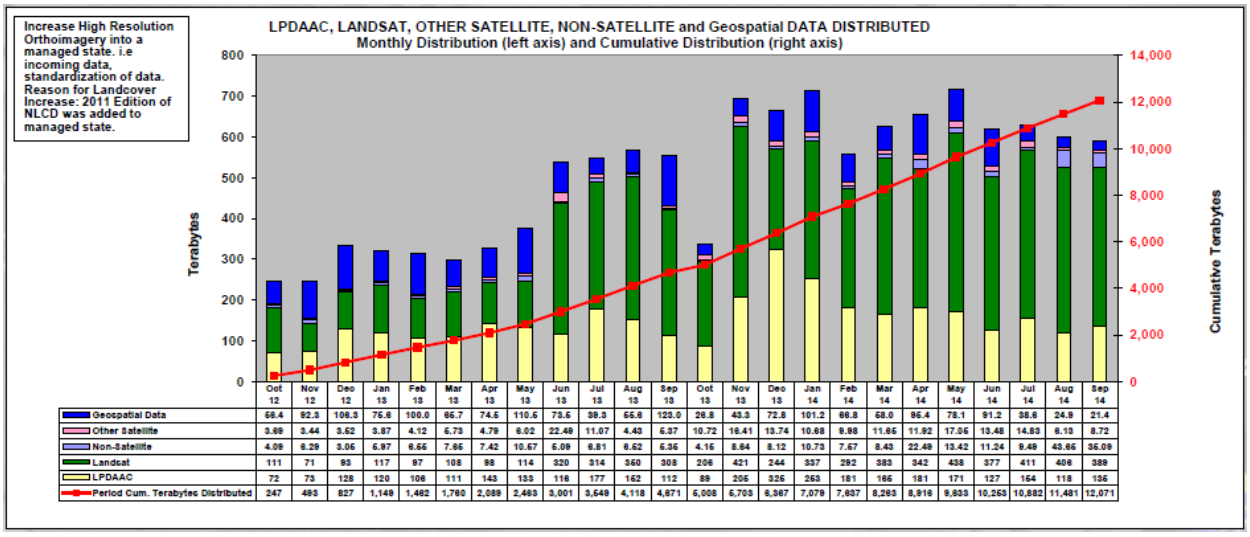
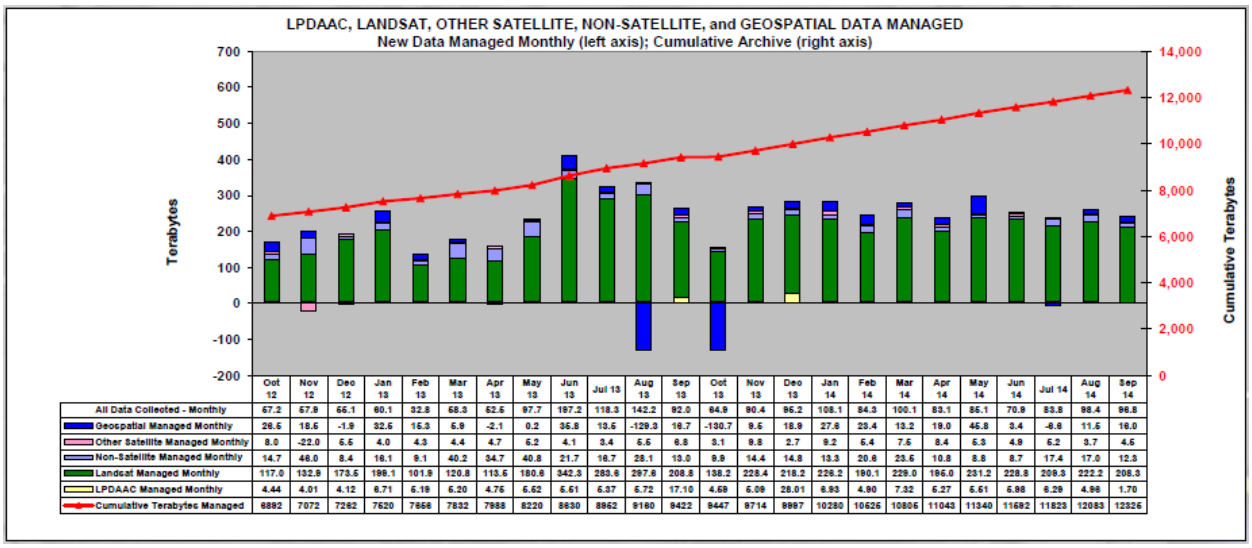
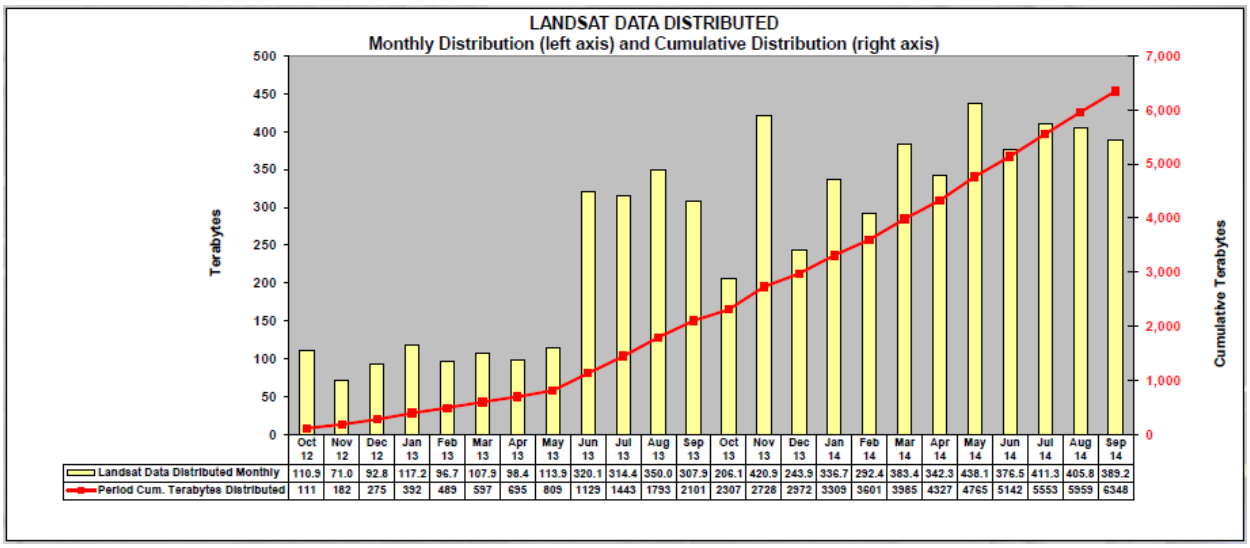


Figure 81. FY 2013-2014 of all projects with detail. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
All Data Collected - Monthly	67.2	67.9	66.1	80.1	32.8	58.3	52.5	87.7	197.2	118.3	142.2	92.0	64.9	90.4	96.2	108.1	84.3	100.1	83.1	85.1	70.9	83.8	98.4	96.8
Geospatial Managed Monthly	26.5	18.6	-1.9	32.6	15.3	5.9	-2.1	0.2	35.8	13.5	-129.3	16.7	-130.7	9.5	18.9	27.8	23.4	13.2	19.0	46.8	3.4	-8.8	11.5	16.0
Other Satellite Managed Monthly	8.0	-22.0	5.5	4.0	4.3	4.4	4.7	5.2	4.1	3.4	5.5	6.8	3.1	9.8	2.7	9.2	5.4	7.5	8.4	5.3	4.9	5.2	3.7	4.5
Non-Satellite Managed Monthly	14.7	46.0	8.4	16.1	9.1	40.2	34.7	40.8	21.7	16.7	28.1	13.0	8.9	14.4	14.8	13.3	20.6	23.5	10.8	8.8	8.7	17.4	17.0	12.3
Landsat Managed Monthly	117.0	132.9	173.5	198.1	101.9	120.8	113.5	180.8	342.3	283.6	297.6	208.8	158.2	228.4	218.2	226.2	190.1	229.0	196.0	231.2	228.8	209.3	222.2	208.3
LPDAAC Managed Monthly	4.44	4.01	4.12	8.71	6.19	5.20	4.76	5.62	5.61	5.37	5.72	17.10	4.59	5.09	28.01	6.93	4.90	7.32	5.27	5.51	5.98	6.29	4.96	1.70
Cumulative Terabytes Managed	6892	7072	7262	7520	7656	7832	7988	8220	8830	8962	9160	9422	9447	9714	9997	10280	10526	10806	11043	11340	11692	11823	12083	12326

Figure 82. FY 2013-2014 all projects with detail. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Landsat Data Distributed Monthly	110.9	71.0	92.8	117.2	96.7	107.9	98.4	113.9	320.1	314.4	350.0	307.9	206.1	420.9	243.9	336.7	292.4	383.4	342.3	438.1	376.5	411.3	405.8	385.2
Period Cum. Terabytes Distributed	111	182	275	392	489	597	695	809	1129	1443	1793	2101	2307	2728	2972	3309	3601	3985	4327	4765	5142	5553	5959	6348

Figure 83. FY 2013-2014. A 24-month volume of Landsat data distributed.

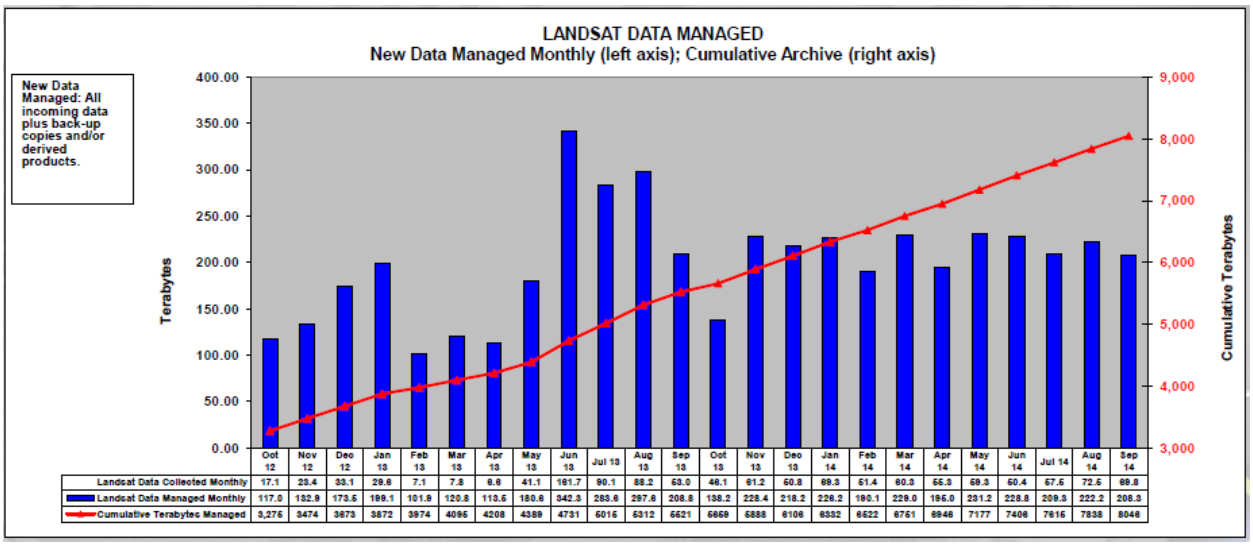


Figure 84. FY 2013-2014. A 24-month volume of Landsat data managed.

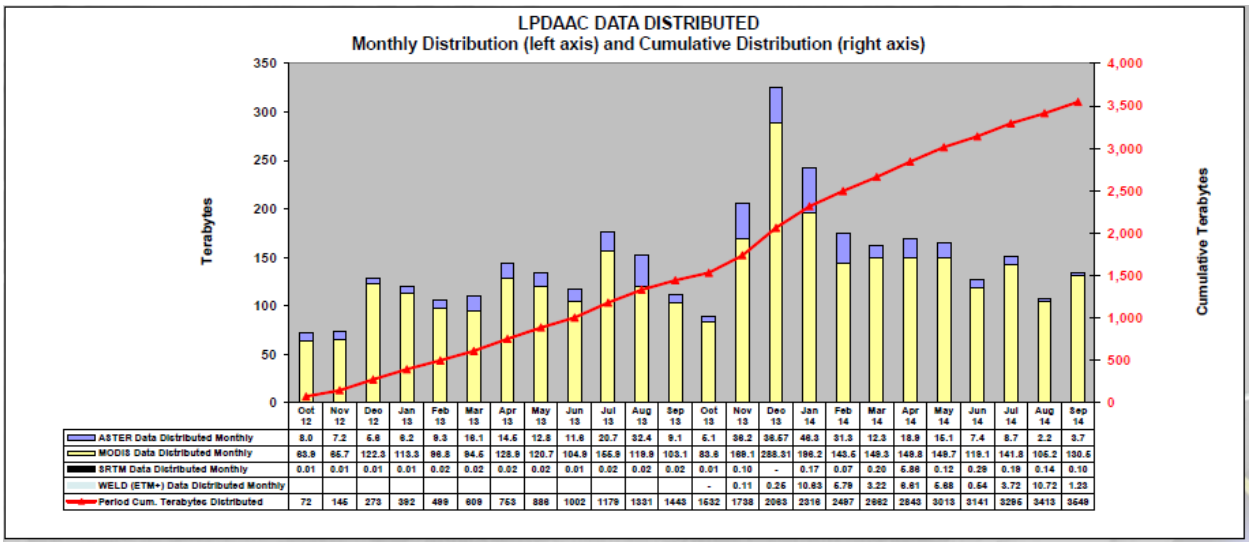
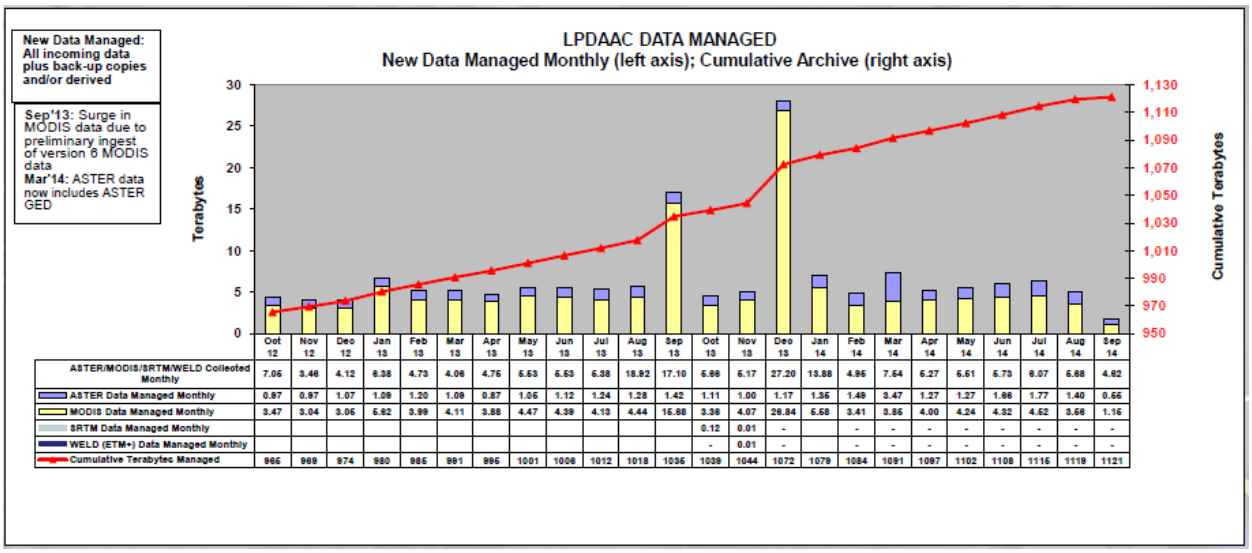
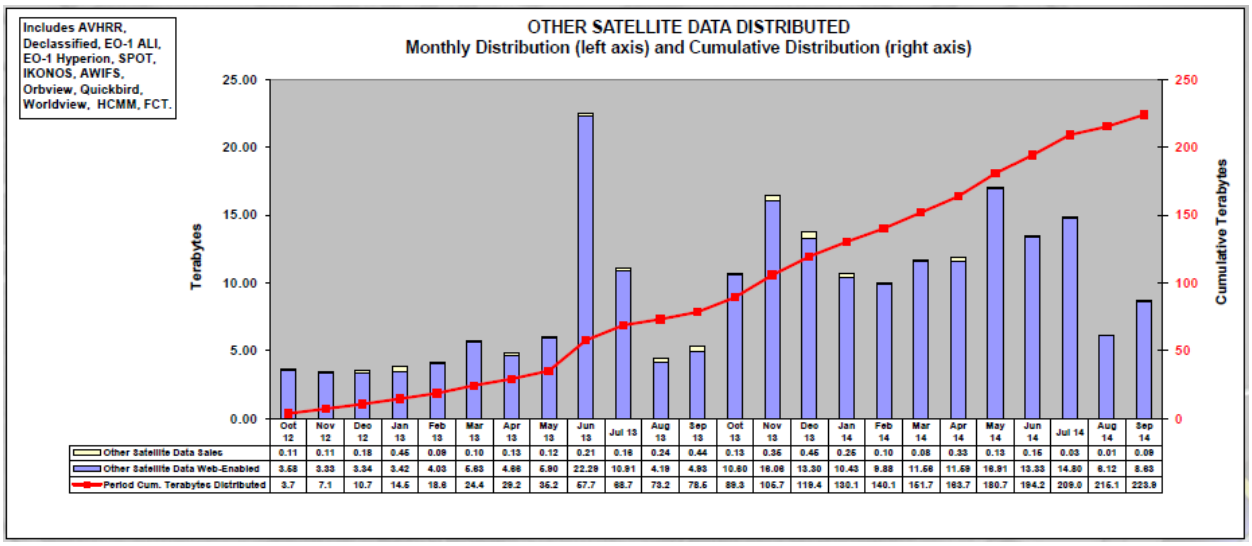


Figure 85. FY 2013-2014. A 24-month volume of Land Processes Distributed Active Archive Center data distributed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
ASTER/MODIS/SRTM/WELD Collected Monthly	7.06	3.46	4.12	6.38	4.73	4.06	4.76	5.53	5.53	5.38	18.92	17.10	5.66	5.17	27.20	13.88	4.96	7.64	5.27	5.51	5.73	6.07	5.68	4.62
ASTER Data Managed Monthly	0.97	0.97	1.07	1.09	1.20	1.09	0.87	1.06	1.12	1.24	1.28	1.42	1.11	1.00	1.17	1.36	1.49	3.47	1.27	1.27	1.88	1.77	1.40	0.66
MODIS Data Managed Monthly	3.47	3.04	3.06	5.82	3.98	4.11	3.88	4.47	4.39	4.13	4.44	15.68	3.38	4.07	26.84	5.58	3.41	3.86	4.00	4.24	4.32	4.52	3.58	1.16
SRTM Data Managed Monthly													0.12	0.01	-		-	-	-	-	-	-	-	-
WELD (ETM+) Data Managed Monthly													-	0.01	-		-	-	-	-	-	-	-	-
Cumulative Terabytes Managed	966	969	974	980	985	991	995	1001	1006	1012	1018	1036	1039	1044	1072	1079	1084	1091	1097	1102	1108	1116	1119	1121

Figure 86. FY 2013-2014. A 24-month volume of Land Processes Distributed Active Archive Center data managed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Other Satellite Data Sales	0.11	0.11	0.18	0.45	0.09	0.10	0.13	0.12	0.21	0.16	0.24	0.44	0.13	0.35	0.46	0.25	0.10	0.08	0.33	0.13	0.16	0.03	0.01	0.09
Other Satellite Data Web-Enabled	3.58	3.33	3.34	3.42	4.03	5.63	4.86	5.90	22.29	10.91	4.19	4.93	10.80	16.06	13.30	10.43	9.88	11.56	11.59	16.91	13.33	14.80	6.12	8.63
Period Cum. Terabytes Distributed	3.7	7.1	10.7	14.5	18.6	24.4	29.2	35.2	57.7	68.7	73.2	78.6	89.3	105.7	119.4	130.1	140.1	151.7	163.7	180.7	194.2	209.0	215.1	223.9

Figure 87. FY 2013-2014. A 24-month volume of other satellite data distributed.

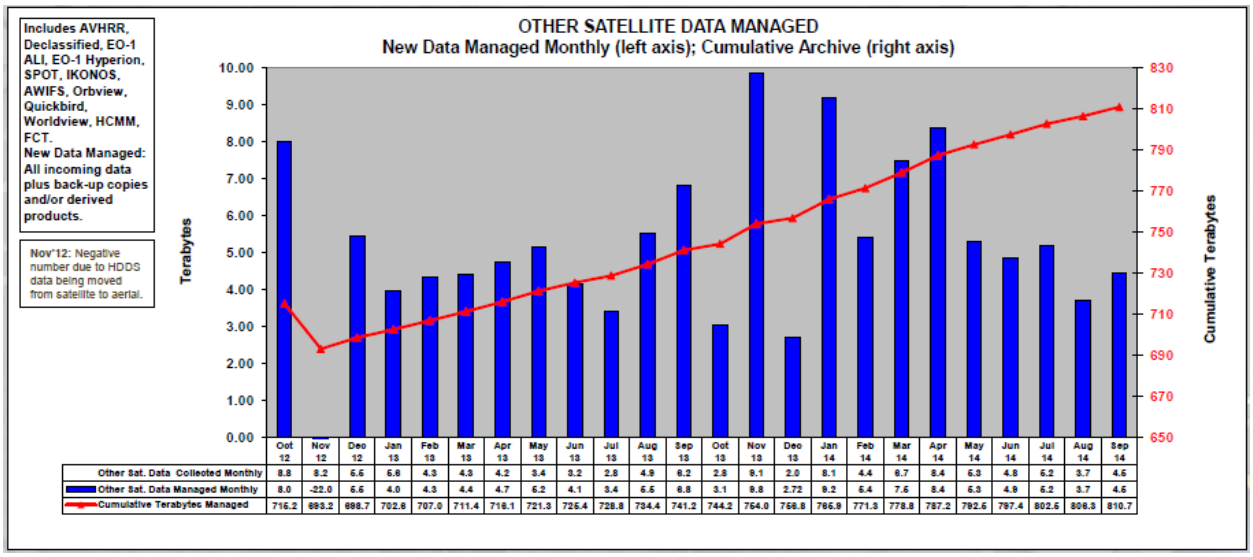


Figure 88. FY 2013-2014. A 24-month volume of other satellite data managed.

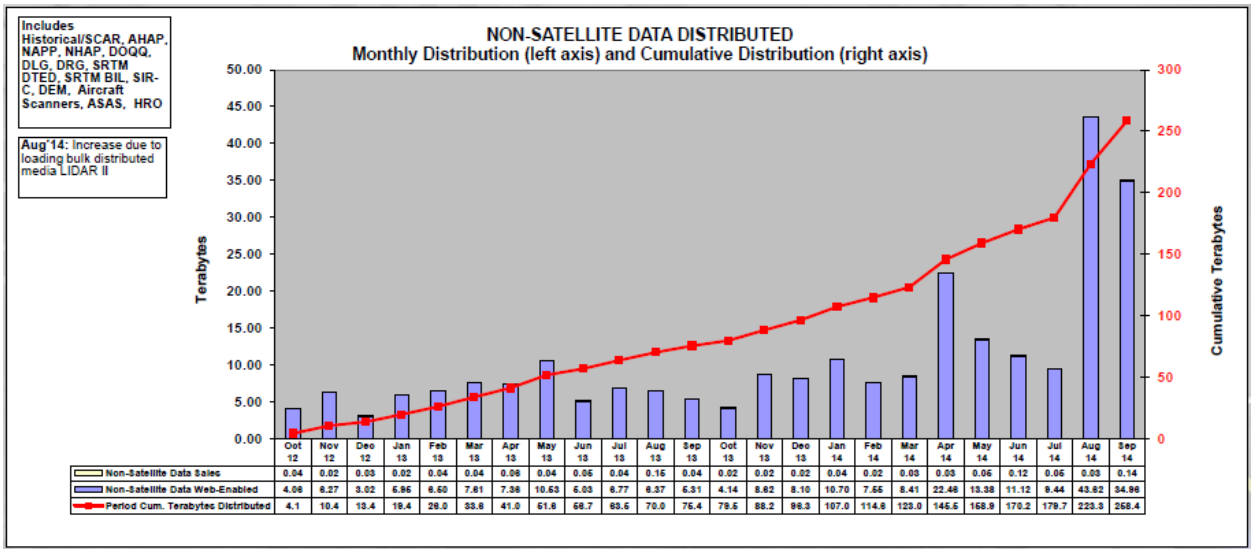


Figure 89. FY 2013-2014. A 24-month volume of non-satellite data distributed.

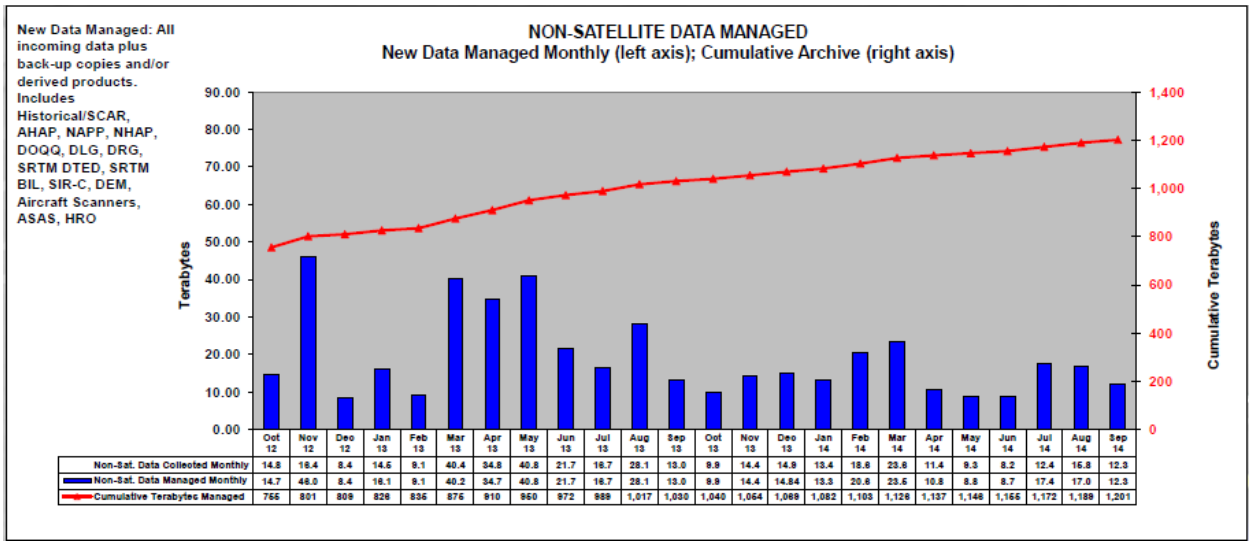


Figure 90. FY 2013-2014. A 24-month volume of non-satellite data managed.

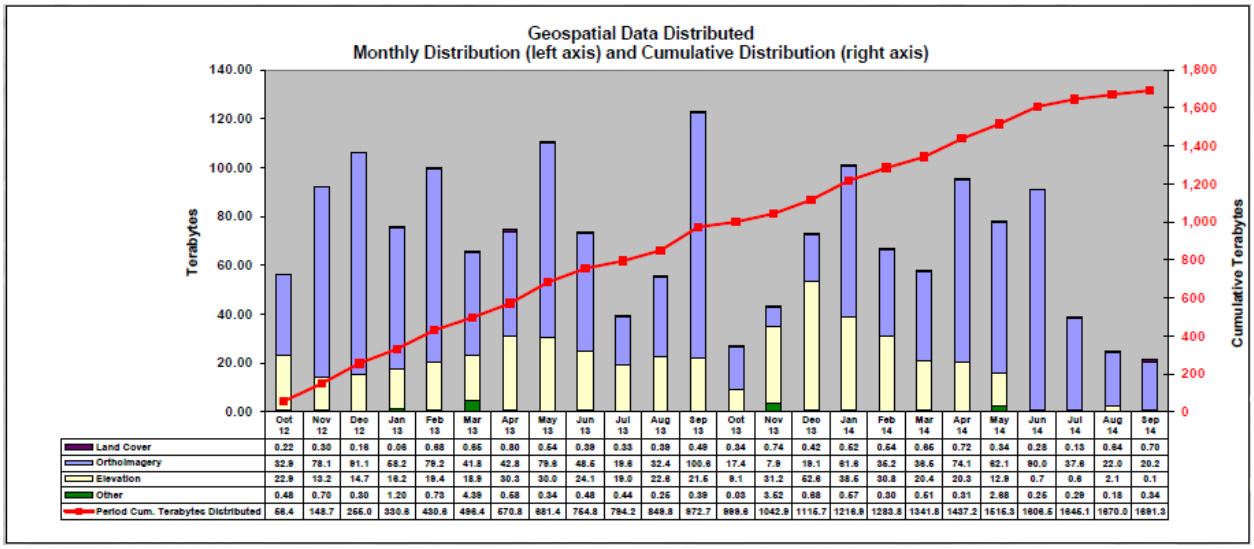
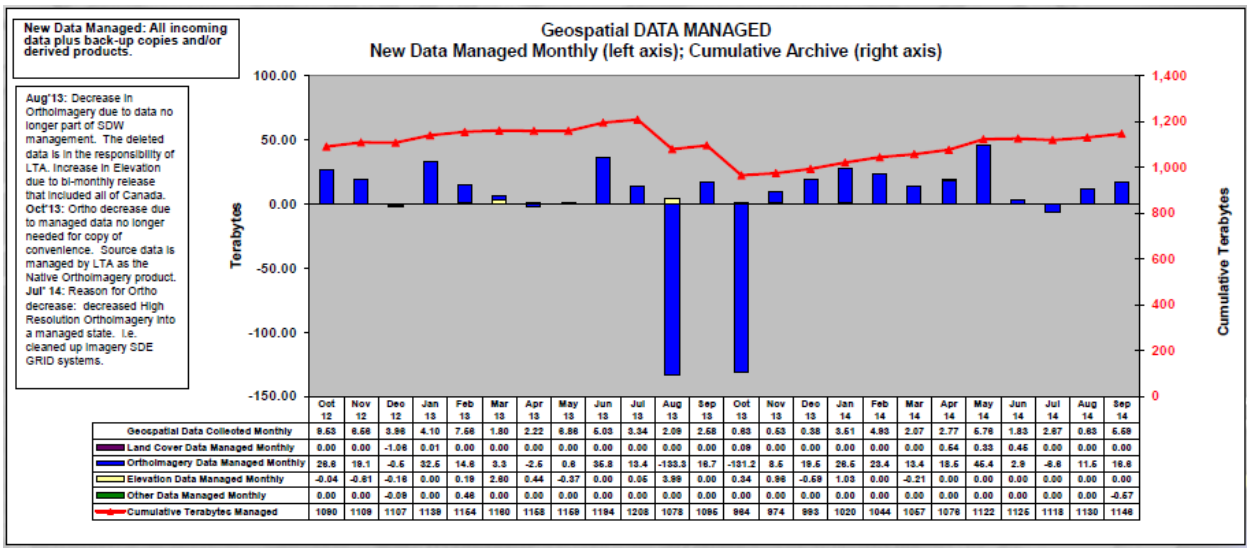


Figure 91. FY 2013-2014. A 24-month volume of geospatial data distributed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Geospatial Data Collected Monthly	9.53	8.58	3.96	4.10	7.68	1.80	2.22	8.86	6.03	3.34	2.09	2.68	0.83	0.63	0.38	3.51	4.93	2.07	2.77	5.76	1.83	2.87	0.83	5.59
Land Cover Data Managed Monthly	0.00	0.00	-1.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.54	0.33	0.45	0.00	0.00	0.00
Orthoimagery Data Managed Monthly	28.8	19.1	-0.5	32.5	14.8	3.3	-2.5	0.8	36.8	13.4	-133.3	16.7	-131.2	8.5	19.5	28.5	23.4	13.4	18.5	45.4	2.9	-8.8	11.5	16.8
Elevation Data Managed Monthly	-0.04	-0.81	-0.18	0.00	0.19	2.80	0.44	-0.37	0.00	0.05	3.99	0.00	0.34	0.98	-0.59	1.03	0.00	-0.21	0.00	0.00	0.00	0.00	0.00	0.00
Other Data Managed Monthly	0.00	0.00	-0.09	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.57
Cumulative Terabytes Managed	1090	1109	1107	1139	1164	1160	1158	1159	1194	1208	1078	1095	964	974	993	1020	1044	1057	1076	1122	1126	1118	1130	1148

Figure 92. FY 2013-2014. A 24-month volume of geospatial data managed.

<u>Products Distributed</u>

Products distributed for all projects, showing both monthly and cumulative, is shown in figures 93-94. Products distributed for the following groupings are shown in figures 95-99:

- Landsat (fig. 95)
- LP DAAC (fig. 96)
- Other Satellite (fig. 97)
- Non-Satellite (fig. 98)
- Geospatial (fig. 99) including Land Cover, Orthoimagery, Elevation, and Other

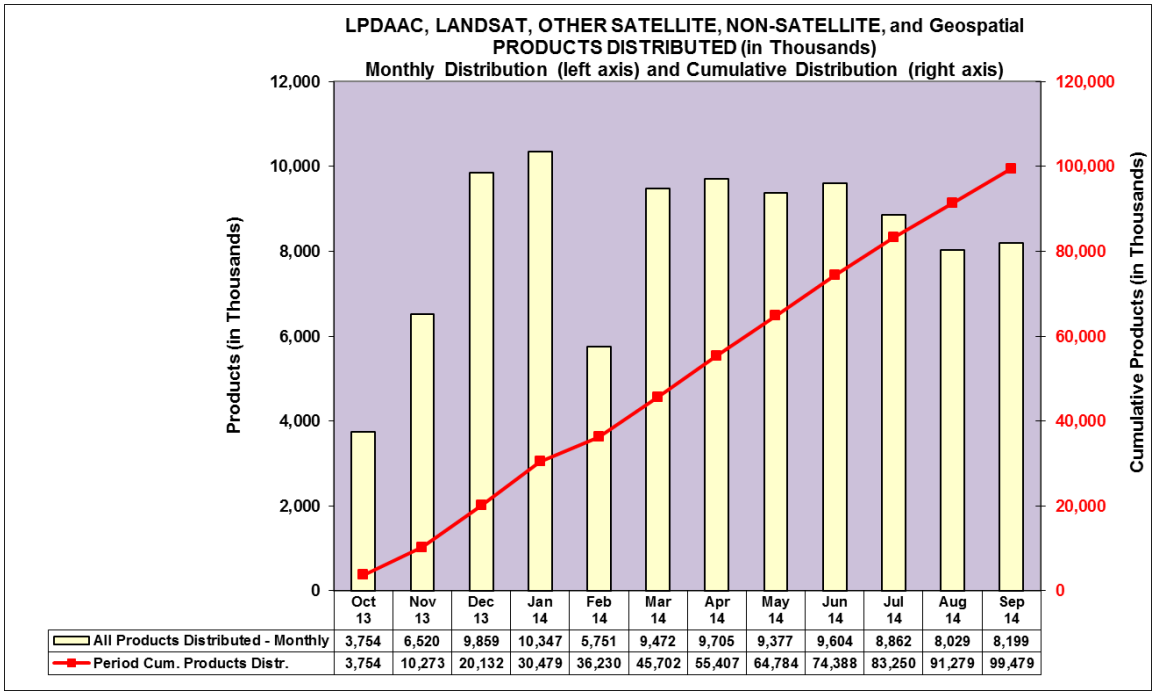


Figure 93. FY 2014 all projects combined. A 12-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial products distributed.

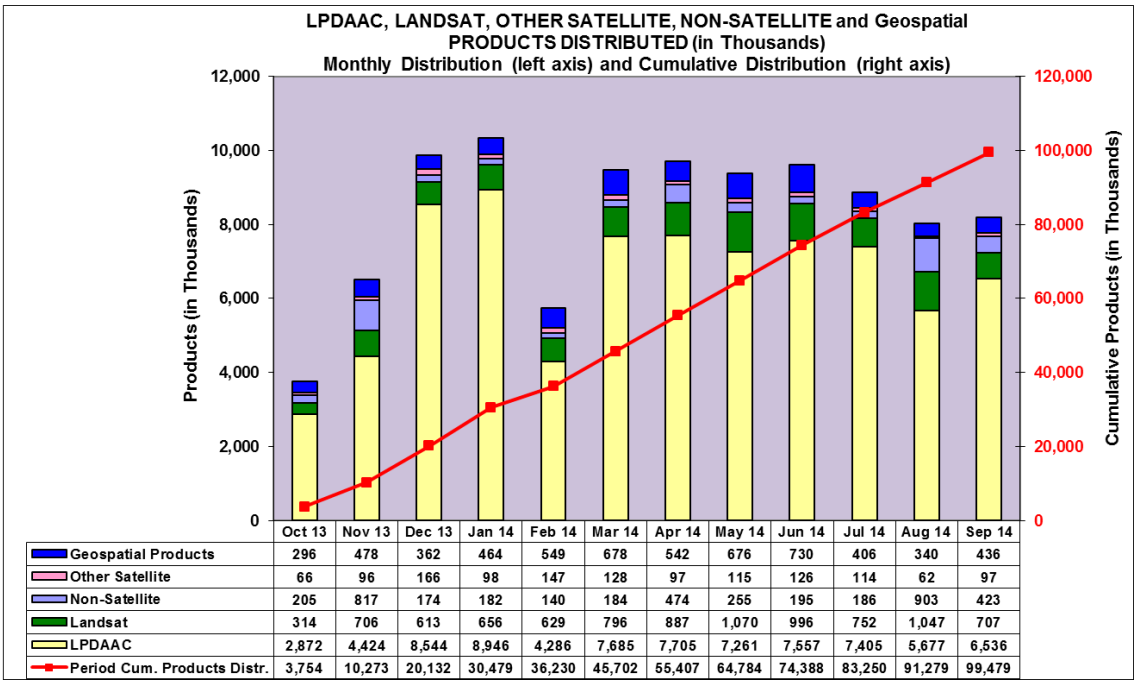
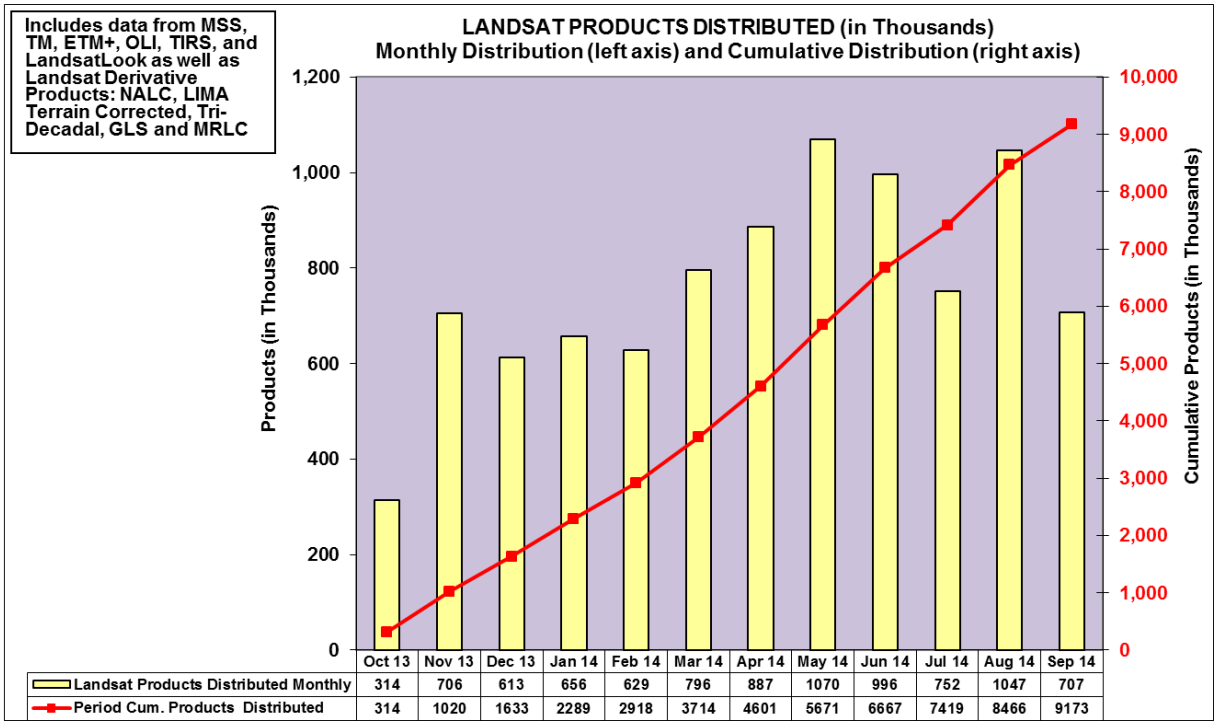
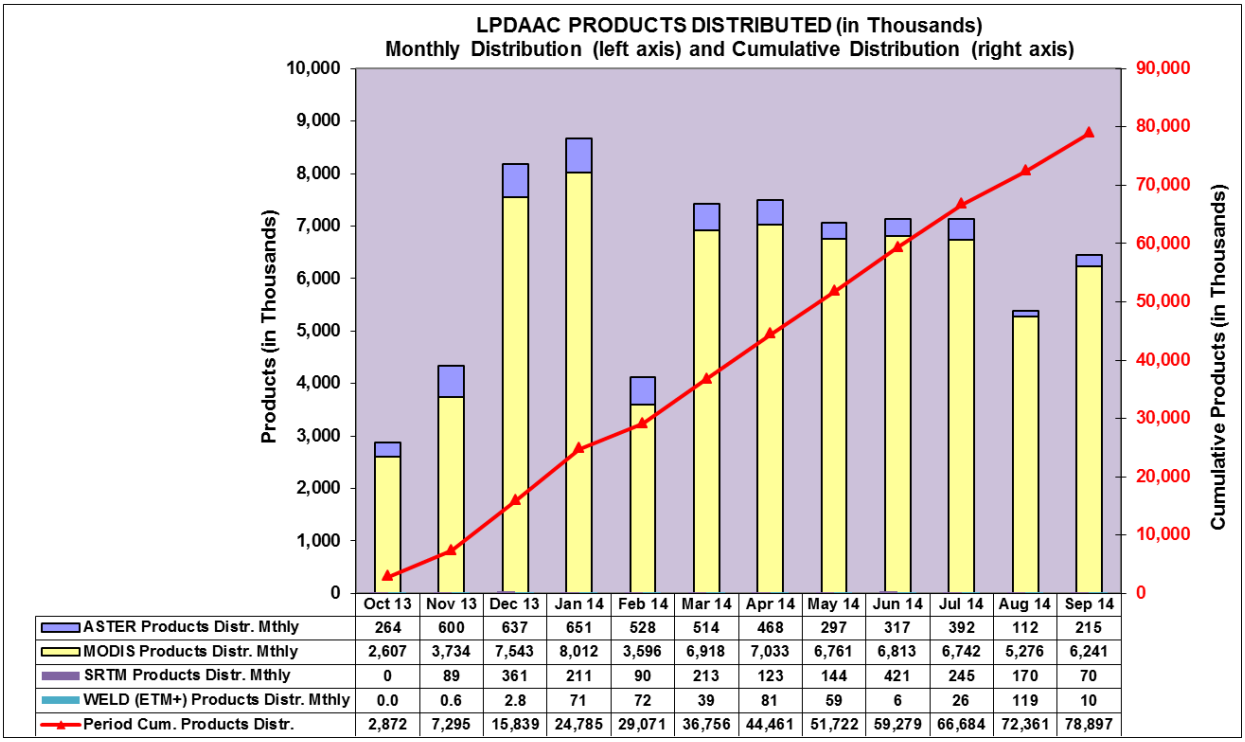


Figure 94. FY 2014 all projects with detail. A 12-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial products distributed.



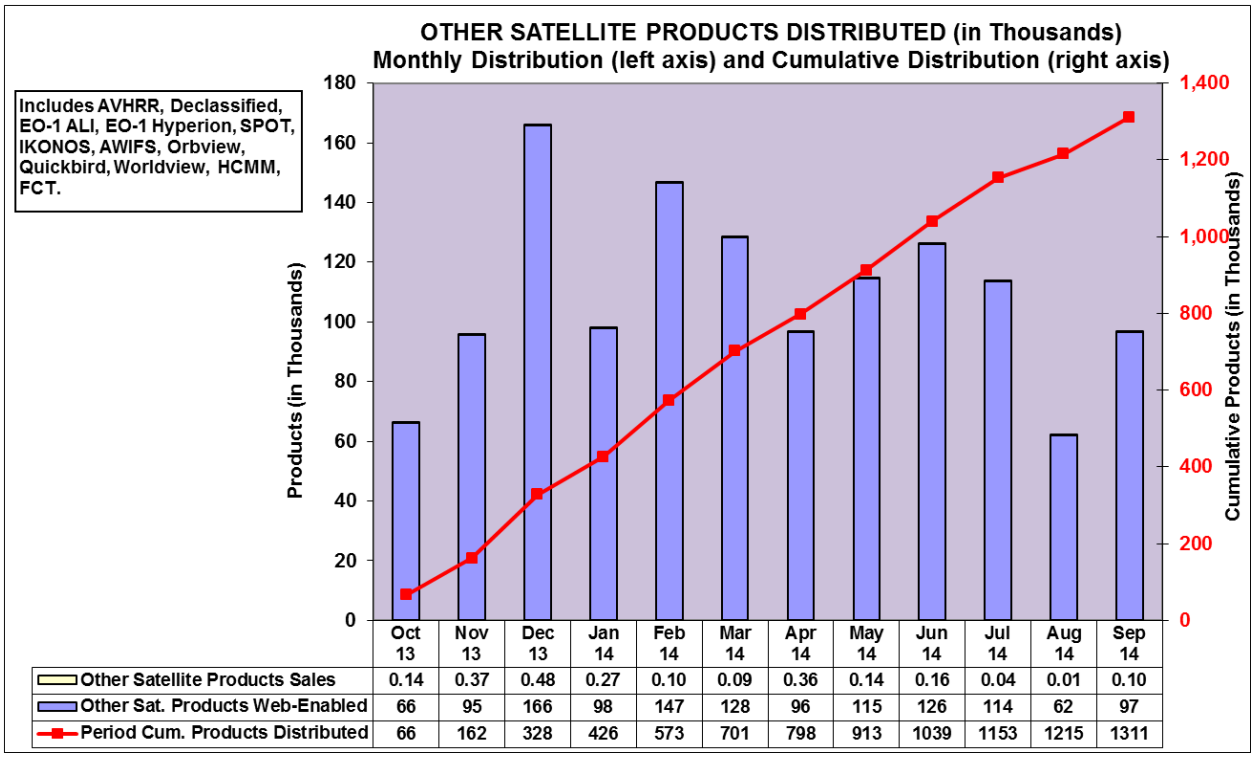
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Landsat Products Distributed Monthly	314	706	613	656	629	796	887	1070	996	752	1047	707
Period Cum. Products Distributed	314	1020	1633	2289	2918	3714	4601	5671	6667	7419	8466	9173

Figure 95. FY 2014. A 12-month volume of Landsat products distributed.



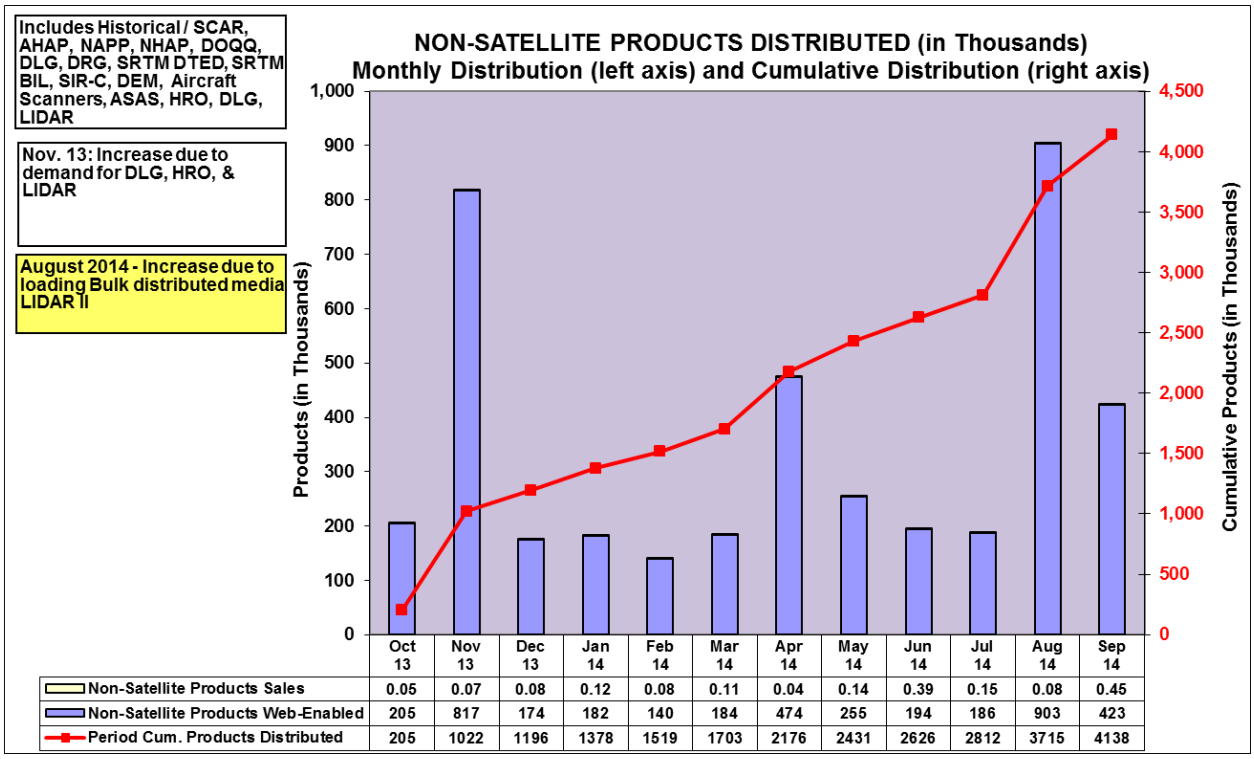
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
ASTER Products Distr. Mthly	264	600	637	651	528	514	468	297	317	392	112	215
MODIS Products Distr. Mthly	2,607	3,734	7,543	8,012	3,596	6,918	7,033	6,761	6,813	6,742	5,276	6,241
SRTM Products Distr. Mthly	0	89	361	211	90	213	123	144	421	245	170	70
WELD (ETM+) Products Distr. Mthly	0.0	0.6	2.8	71	72	39	81	59	6	26	119	10
Period Cum. Products Distr.	2,872	7,295	15,839	24,785	29,071	36,756	44,461	51,722	59,279	66,684	72,361	78,897

Figure 96. FY 2014. A 12-month volume of Land Processes Distributed Active Archive Center products distributed.



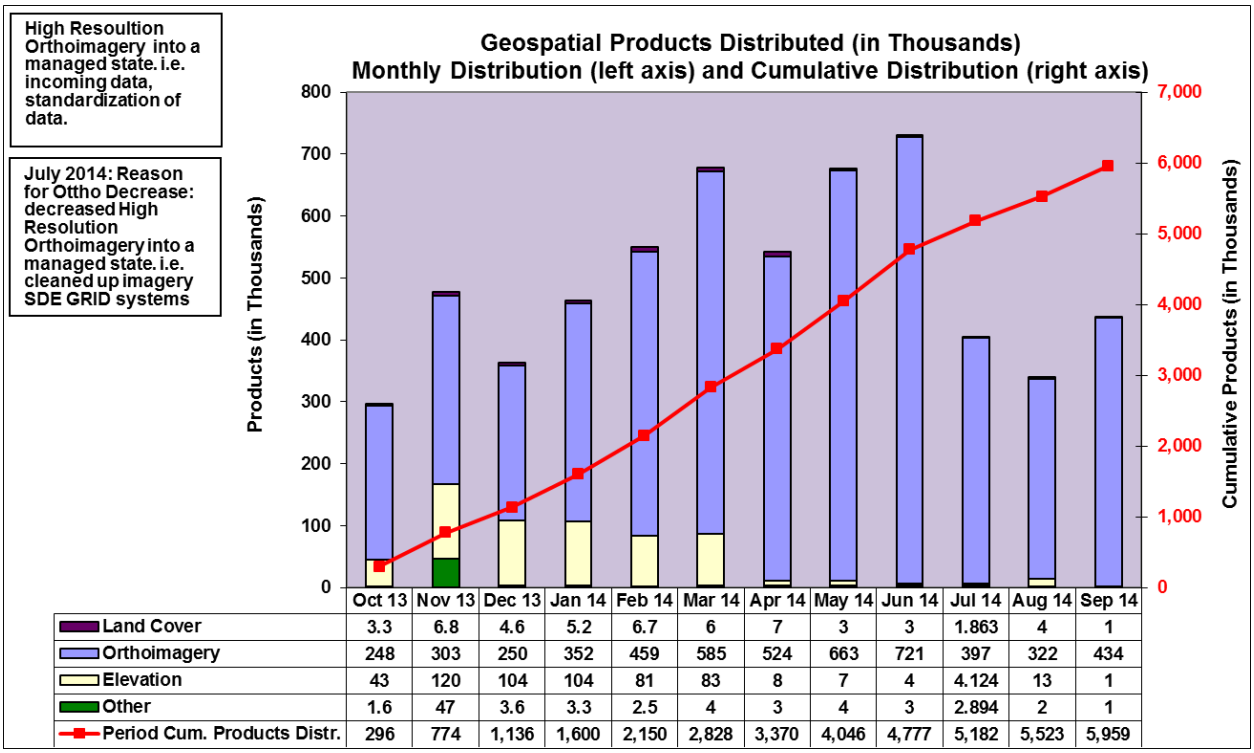
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Other Satellite Products Sales	0.14	0.37	0.48	0.27	0.10	0.09	0.36	0.14	0.16	0.04	0.01	0.10
Other Sat. Products Web-Enabled	66	95	166	98	147	128	96	115	126	114	62	97
Period Cum. Products Distributed	66	162	328	426	573	701	798	913	1039	1153	1215	1311

Figure 97. FY 2014. A 12-month volume of other satellite products distributed.



	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Non-Satellite Products Sales	0.05	0.07	0.08	0.12	0.08	0.11	0.04	0.14	0.39	0.15	0.08	0.45
Non-Satellite Products Web-Enabled	205	817	174	182	140	184	474	255	194	186	903	423
Period Cum. Products Distributed	205	1022	1196	1378	1519	1703	2176	2431	2626	2812	3715	4138

Figure 98. FY 2014. A 12-month volume of non-satellite products distributed.



	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Land Cover	3.3	6.8	4.6	5.2	6.7	6	7	3	3	1.863	4	1
Orthoimagery	248	303	250	352	459	585	524	663	721	397	322	434
Elevation	43	120	104	104	81	83	8	7	4	4.124	13	1
Other	1.6	47	3.6	3.3	2.5	4	3	4	3	2.894	2	1
Period Cum. Products Distr.	296	774	1,136	1,600	2,150	2,828	3,370	4,046	4,777	5,182	5,523	5,959

Figure 99. FY 2014. A 12-month volume of geospatial products distributed.

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. The USGS continues to serve as the lead United States agency to the International Charter "Space and Major Disasters." EROS will continue to develop and offer a variety of ongoing education and training 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. Key accomplishments are given in the following sections.

Search for the Missing Malaysian Airliner

In 1999, an international consortium of space agencies conceived and approved a mechanism to provide satellite information in support of worldwide disaster relief. This group came to be known as the "International Charter Space and Major Disasters" and has become an important resource for the use of satellite data to provide support for response to natural and man-made disasters. As of 2014, the Charter has been

activated more than 400 times in response to natural disasters such as earthquakes, landslides, volcanic eruptions, floods, hurricanes, and fires and technological disasters such as oil spills. In March 2014, the Charter was activated for the first time to try and help responders locate a missing airliner.

Malaysia Airlines Flight MH370 disappeared from radar on March 7, 2014. The jet was carrying 239 people (12 crew and 227 passengers) and has yet to be found despite a multi-national search. The aircraft departed from Kuala Lumpur at 16:41 UTC (Coordinated Universal Time) and was scheduled to arrive in Beijing at 22:30, but Vietnamese air traffic controllers lost contact with the aircraft at 01:30 local time.

An international search for the aircraft began in the South China Sea, the last known location of the jet, but 4 days later no sign of the aircraft had been found. The search area was then expanded to the Malacca Strait, on the western coast of Malaysia. The Charter was activated on March 11 by the China Meterological Administration to provide support for the Chinese search efforts, as many Chinese citizens were aboard the flight. On March 15, the search shifted to the Indian Ocean.

There has been much speculation regarding the fate of the aircraft. No debris has been found; and though several oil slicks have been investigated (fig. 100), it was determined that they were not from the aircraft. No distress signals have been received from the plane, and it remains unknown what happened. Naval vessels and aircraft from at least ten different countries have participated in the search. Satellite imagery has been employed to search for any evidence of the plane, both before and after it disappeared. China used ten of its satellites to image the search area. DigitalGlobe started a crowdsourcing campaign in which over two-million volunteers have studied DigitalGlobe images of the area, looking for possible debris or other signs of the aircraft. USGS provided over 4,000 images on the Hazards Data Distribution System covering several areas to try and help locate the airliner (fig. 101).

The latest reports indicate that the plane turned back after take-off and passed over Malaysia and then headed toward the Indian Ocean. Evidence suggests the plane flew for several hours after communication with air traffic controllers was lost. As of October 31, 2014, the search remains ongoing. For further information on this Charter activation, contact Brenda Jones, USGS EROS, bkjones@usgs.gov.

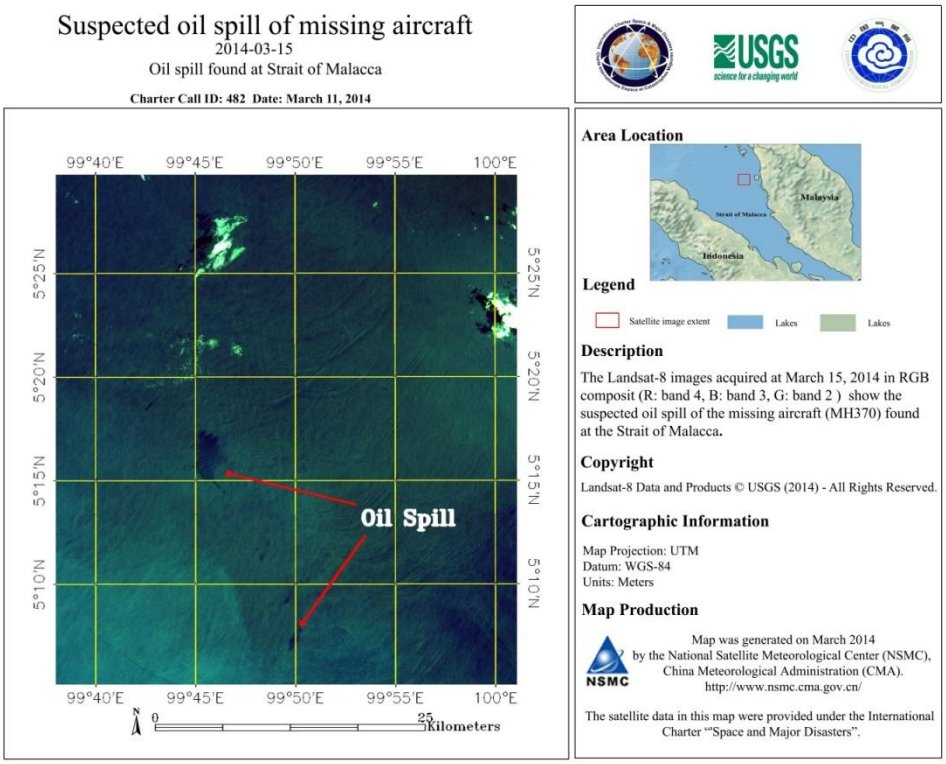


Figure 100. Landsat 8 image showing suspected oil spill of the missing aircraft in the Strait of Malacca.

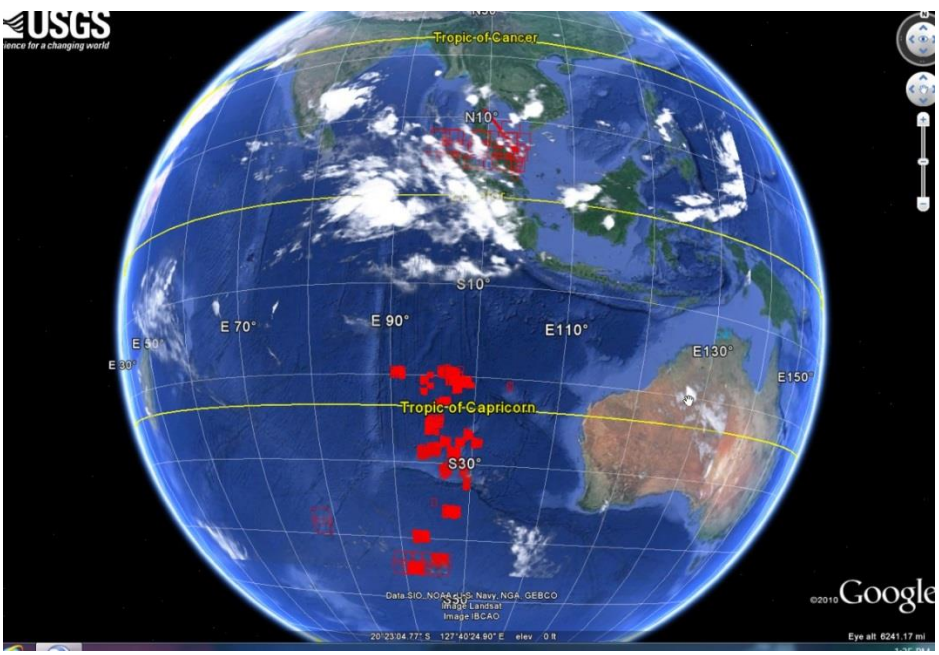


Figure 101. Footprints of the over 4000 images available on the Hazards Data Distribution System.

International Charter Support for Typhoon Haiyan

As part of the USGS responsibilities for providing hazard and risk assessment and monitoring, the USGS also provides geospatial information to support emergency response operations for floods, fires, hurricanes, earthquakes and many other natural and man-made disasters. As part of the geospatial response effort, the USGS is a member of the International Charter for Space and Major Disasters (Charter). Through the Charter partnership, along with the Hazards Data Distribution System, USGS strives to provide fast and timely access to many types of remotely sensed and geospatial data products that can be used in emergency response operations.

Super Typhoon Haiyan made landfall over the central Philippines on November 8, 2013, at 04:40, local time. There were over 7,000 fatalities, and it is estimated that over 16-million people were affected. The category five storm brought winds as strong as 314 kilometers per hour, and analysts believe it may be one of the strongest storms to make landfall in recorded history. Among the worst affected areas were the central islands of Leyte and Samar. The storm left widespread damage in its wake across the Philippine islands, with power lines cut off and roads blocked by fallen debris and trees. Some buildings reportedly collapsed under the strong winds, with wooden houses particularly susceptible to the storm. At the time Haiyan made landfall, the Philippines were still recovering from the 7.3-magnitude earthquake that struck the island of Bohol on October 15, causing further misery to the island nation.

The International Charter was activated by the United Nations Institute for Training and Research (UNITAR) United Nations Operational Satellite Applications Programme (UNOSAT) on behalf of the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) on November 8, 2013, in response to the landfall of Typhoon Haiyan. The USGS nominated Richard Nezlek from the Pacific Disaster Center as the project manager for the activation. He was responsible for coordination of image collections, product creation, and data distribution for the Charter activation. On November 15, Digital Globe and the National Geospatial Intelligence Agency announced that all of the commercial imagery for the event would be made available as public domain for 30 days. This had a huge impact on the number of users that had access to the imagery. Some of the end users that downloaded the imagery from the HDDS included:

- Governments of Philippines, United Kingdom, Australia, Japan, France, Germany, Russia, Taiwan, European Commission
- U.S. government agencies including the Agency for International Development, Geological Survey, Federal Emergency Management Agency, National Aeronautics and Space Administration, National Oceanic and Atmospheric Agency, National Geospatial-Intelligence Agency, Army Corps of Engineers, Department of Agriculture, Center for Disease Control, Pacific Disaster Center, Navy, Army, Marines, National Park Service
- United Nations/UNOSAT, Food and Agriculture Organization
- World Bank
- Red Cross

- Humanitarian OpenStreetMap
- Private Business
- General Public
- Academia

During the response period, there were 1,852 images/tiles loaded to HDDS, and in the same period, over 21,000 files were downloaded. One of the products provided from analysis of the imagery were damage assessments as shown in figure 102. For further information on this Charter activation, contact Brenda Jones, bkjones@usgs.gov.

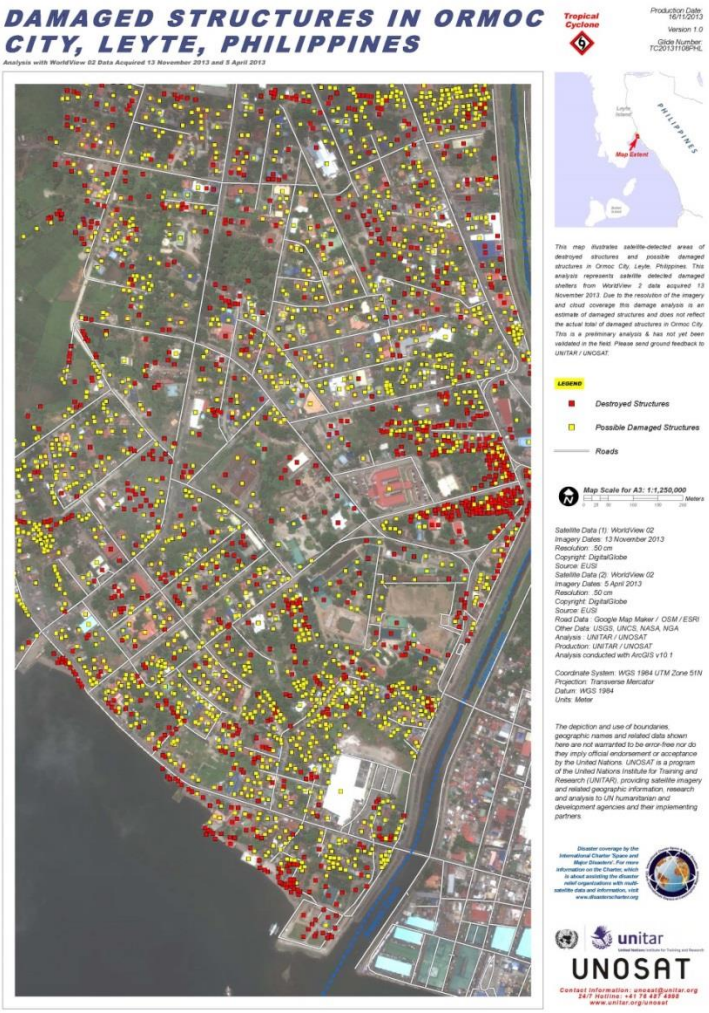


Figure 102. Damaged structures in Ormoc City, Leyte, Philippines.

Fire Support

Responding to catastrophic natural disasters requires information. When the flow of information on the ground is interrupted by crises such as earthquakes, landslides, volcanoes, fires, and floods, satellite imagery and aerial photographs become

invaluable tools in revealing post-disaster conditions and in aiding disaster response and recovery efforts. USGS is a global clearinghouse for remotely sensed disaster imagery.

USGS Emergency Operations provided remote sensing and geospatial product support for 75 domestic and international disaster events in FY 2014. Of those 75 events, 18 were in support of 44 individual fires. Fire support was requested by various State and Federal agencies including California, Oregon, Washington, Nebraska, New Mexico, Arizona, and Alaska, U.S. Forest Service, Bureau of Land Management, U.S. Geological Survey, National Park Service, National Guard Bureau, Department of Interior, Department of Agriculture, U.S Army, and U.S Air Force and the governments of Australia, India, Chile, and the Dominican Republic.

USGS Emergency Operations has also worked closely with the Forest Service this year to post over 31,000 base topographic maps covering the states of Arizona, California, Colorado, Idaho, Kansas, Montana, North Dakota, Nebraska, New Mexico, Nevada, Oregon, South Dakota, Utah, Washington, and Wyoming. These map products are the USGS Topos, which have been published since 2010 as GeoPDFs, converted to GeoTIFF format. They do not have collars, forest tint, imagery or hillshading. They provide just the data layers needed to support the USFS GIS staff for all hazards (fig. 103). They are available for download on the Hazards Data Distribution System.

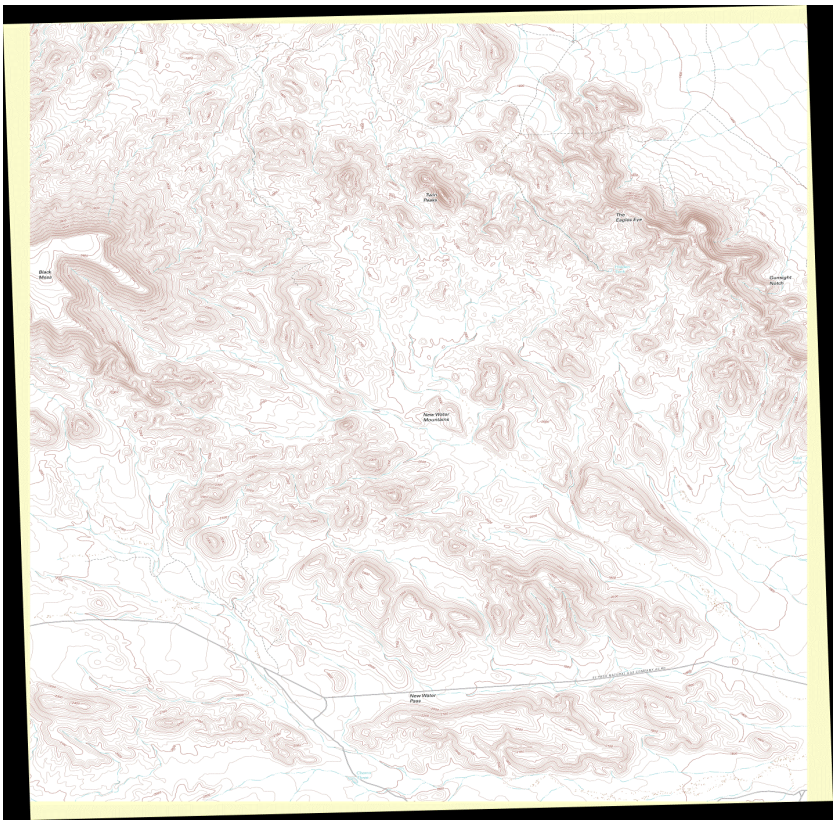


Figure 103. Forest Service base map of the New Water Mountains Quad in Arizona.

Emergency Operations Expands Support for Tornado Response

As part of its mission to provide remotely sensed imagery for emergency and hazard response, USGS Emergency Operations continued to expand on previous support for domestic tornado response. There were nine new tornado events added to the Hazards Data Distribution System (HDDS), many of which included multiple tornado incidents. A total of over 4,000 satellite and aerial images were loaded for tornado response, supporting tornadoes and tornado swarms across numerous states, including Mississippi, Arkansas, Louisiana, Alabama, Iowa, Nebraska, Iowa, Wisconsin, and South Dakota. The imagery was collected in response to requests from the NOAA National Weather Service (NWS), in support of their tornado response activities. Additional end users included other Federal agencies such as the Department of Homeland Security/FEMA, Department of Agriculture, National Park Service, Northern Command (NORTHCOM), National Guard Bureau, along with State and local emergency managers.

Only a few years ago, USGS EROS did not support tornado events. However, this has been changing in recent years as end users are becoming aware of the value of satellite imagery for tornado response and damage assessment. Over the past few years, the USGS HDDS has supported an increasing number of tornado events, including some of the nationally prominent events such as Joplin, Missouri, and Moore, Oklahoma. However, along with these major events affecting concentrated population centers, there are many less-publicized tornado incidents that occur every year. Even though less prominent, these tornadoes still create local impacts on smaller communities, and rapid damage assessments can sometimes be difficult. This is also true when tornadoes have formed as part of a widespread “swarm,” or if the tornadoes have occurred in hilly, forested, or otherwise inaccessible or remote regions. For these types of conditions, creation of a damage assessment map based on ground observations alone can be very difficult, costly, and time-consuming.

The imagery delivered through USGS HDDS can provide a valuable synoptic insight that allows rapid damage assessments and high-quality precision mapping of the tornado path, including the assignment and validation of the Enhanced Fujita (EF) ratings and EF contours for a given tornado path. This information is important for responders and many other end users to understand where the greatest damage has occurred and what infrastructure may be affected. Figure 104 shows an example image of the dual tornado tracks from a “twin tornado” that moved through Pilger, Nebraska, on June 16, 2014. This image clearly shows the path and later convergence of the two separate tornado tracks. This type of image-based observation was used by responders to identify potential areas of destruction and create damage maps that would have been very difficult to generate from ground-based observations alone.

In FY 2014, EROS continued to build on its earlier relationship with the NWS by continuing to engage with users from the NWS community along with representatives from NASA Short-term Prediction Research and Transition Center (SPoRT) facility to support the development and further enhancements of a NWS Damage Assessment

Toolkit (DAT). The DAT is an interactive tool being developed by NASA SPoRT that will integrate satellite- and ground-based observations for rapid mapping of tornado damage. As part of this activity, USGS has been assisting NWS and NASA in their efforts to establish a more automated ("hands off") set of workflows for transmitting image requests and pulling image deliveries from HDDS. For further information, contact Rynn Lamb, USGS EROS, lamb@usgs.gov

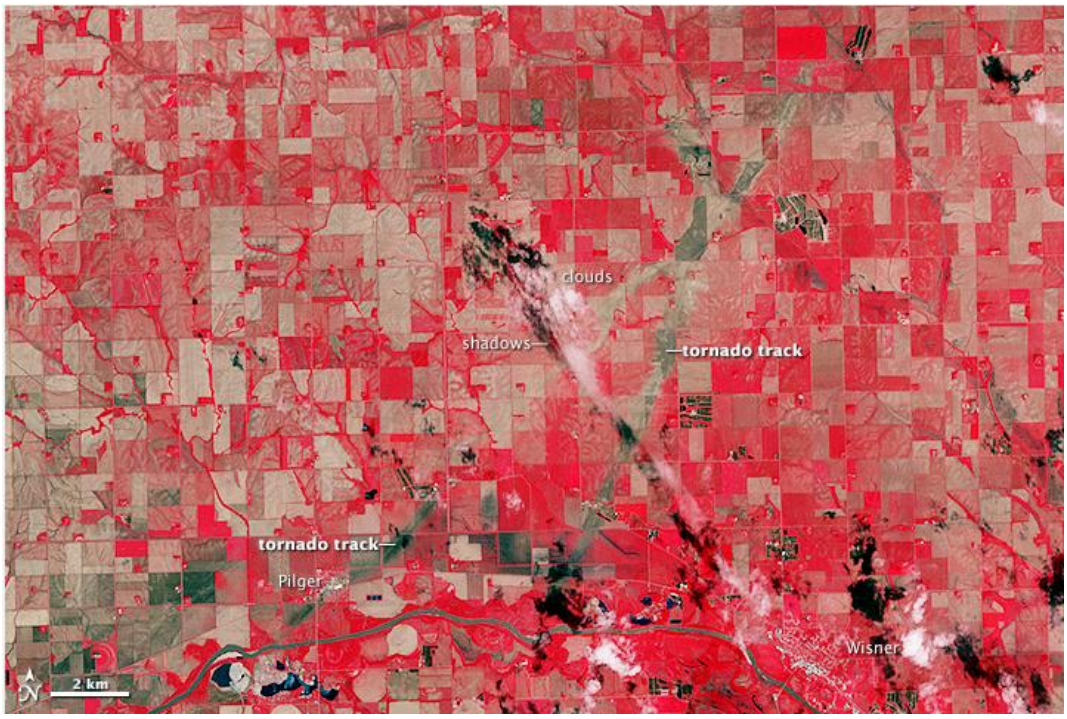


Figure 104. False-color satellite image showing dual tornado tracks from the "twin tornado" that occurred on June 16, 2014, near Pilger, Nebraska. This image was acquired on June 21, 2014, by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument onboard the National Aeronautics and Space Administration (NASA) Terra satellite. (Hazards Data Distribution System Event Identification: 201406_Tornadoes_Midwest).

Center Support Activities

Center support activities 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. Key accomplishments are given in the following sections.

This Just In – An Entirely New EROS Center Information Technology Team

EROS has a new Center Information Technology Team (CITT) supporting the core IT infrastructure of the Center. This group of experts was brought together from diverse backgrounds. They will bring a fresh look at how IT service is accomplished at EROS. The team is comprised of Ken Klinner (CITT Supervisor), Philip Egeberg (EROS Information Security), Mia Call Lee (Networking Engineer), and Nylis "Gene" Renschler (Desktop Services).

Ken Klinner is the new CITT supervisor. He comes to EROS from Germany where he served as a Defense Civilian Intelligence Personnel employee. Ken has an extensive background in IT Program Management, Enterprise Architecture, Data Center Consolidation, and Knowledge Management. He has both government and private sector experience in each of these areas. He brings a strategic planning and process-oriented focused methodology to the Center.

The new Information Assurance (IA) Security Officer for EROS is Philip Egeberg. Philip comes from right here in sunny South Dakota, and brings private sector IA experience to the Center. He has worked in a variety of corporations, and is an expert in information security, auditing, penetration testing, and social engineering. Philip brings to the table a risk management strategy that will protect and enhance the mission of EROS.

Mia Calla Lee comes to EROS from Virginia where she worked with the Navy as the department head in networking security for the Unified Atlantic Regional Network Operations Center. Mia Calla is an outstanding engineer bringing to the table a strong and diverse background in network engineering, security, and project management.

Gene Renschler recently retired from the U.S. Army and comes to the Center from the state of Washington. Gene has broad experience in IT customer service. He brings to EROS expertise across the IT spectrum to include networking, call center management, systems administration and programming.

The new CITT team is poised to provide exceptional support to the EROS science and data center missions. The team is service oriented, customer focused, and are bringing a process oriented IT structure to the Center thereby enhancing its capabilities. For further information, contact Kenneth Klinner, USGS EROS, kklinner@usgs.gov.

Northern Tier Networking Consortium, Increased Bandwidth, and Improved Network Resilience

The Center Information Technology Team is working to improve EROS capabilities in order to better support its science mission requirements. One of the ways CITT has improved capability is by instituting a more robust network infrastructure.

In response to growing bandwidth and infrastructure requirements (e.g., Sentinel 2 ingest), CITT has worked with the Northern Tier Networking Consortium (NTNC) to augment the current network path to the Chicago aggregation point. This augmentation does two things. First, the additional connection significantly increases the bandwidth throughput so that EROS is poised to meet additional science mission requirements. The internet route being augmented ingests and distributes the highest volume of data for the entire Center. Second, this additional route establishes a secondary backup path for this very important connection. At this time, EROS has obtained a NTNC provisioned 2.5G shared connection (fig. 105). CITT is working on improving this connection by increasing the throughput to a dedicated 10G connection.

The NTNC network brings to EROS a robust network connection using an interconnected fiber backbone that reaches across the northern tier of the United States. This fiber backbone is used to interconnect research scientists and academia members from Chicago, Illinois, to Seattle, Washington (fig. 106). The connection gives EROS a low cost solution capable of connecting at many national and international aggregation points. The additional infrastructure will greatly benefit all of the projects and organizations hosted at EROS. For further information, contact Mia Calla Lee, USGS EROS, mdlee@usgs.gov.

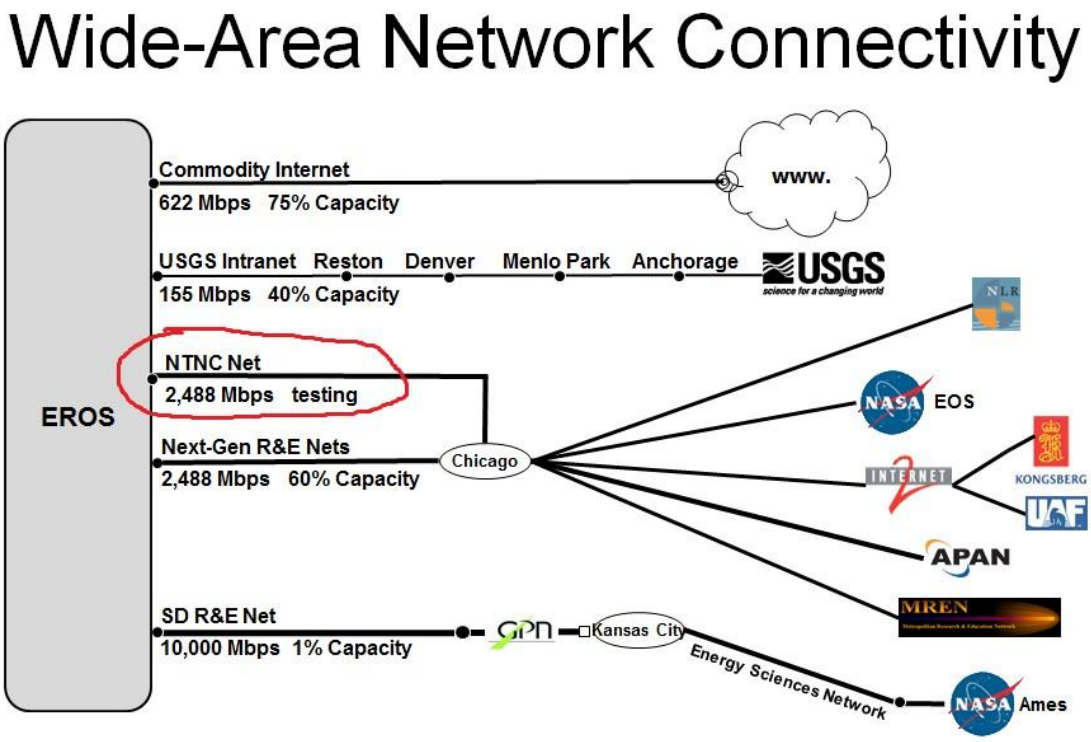


Figure 105. EROS wide-area network connectivity.

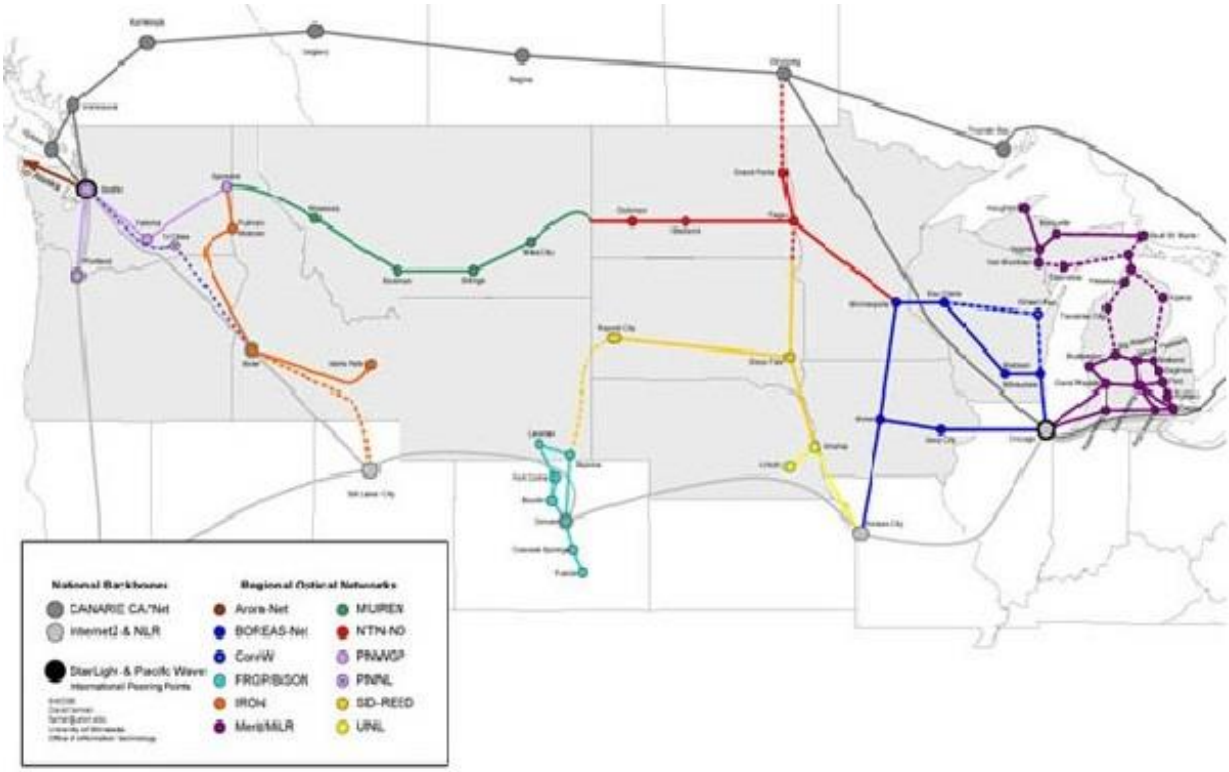


Figure 106. Northern Tier Networking Consortium connectivity.

EROS Information Technology Security Tunes Up

CITT Information Assurance has been working to fine tune the EROS environment through a robust risk management initiative. The initiative has focused on process improvement, quick response to vulnerability identification and remediation, and automating the process to identify and mitigate risks.

It has been a busy past few months in the security world. New critical vulnerabilities that used to appear once every couple months now seem to raise their ugly head several times a month. With that said, we do need to celebrate the teams within EROS that hit these head on and share their accomplishments and hard work.

One good example is the recent “Bash” or “Shellshock.” In only 3 working days, 100 percent of the DMZ systems were remediated. End user services recently patched 503 end user systems in 8 working days to remediate the “Sandstorm” vulnerability. The EROS teams replaced and rebuilt all the public facing Drupal servers in little over 3 working days. None of these are were easy tasks. Table 3 illustrates the work competition on the Bash vulnerability.

In the background, the Information Security Team (Working Group) has made improvements to our vulnerability processes and procedures. These improvements included creating dashboards, new reporting, giving near real-time access to our system

administrators for their respective systems, and automating processes for remediation. These efforts have saved approximately 24 hours of work per month by moving away from manually manipulating vulnerability information in spreadsheets to utilizing the full extent of our Nessus vulnerability management tool.

The IBM Endpoint Manager tool (also known as, IEM) has also become a tool of choice in combatting vulnerabilities. When attacking the recent Bash and Sandstorm vulnerabilities, this was the tool of choice for reporting and remediation efforts. Table 3 is one example of how EROS used IEM to monitor and manage the progress of our remediation efforts using the IEM tool.

We have also seen a significant reduction in critical and high vulnerabilities across the Center and specifically on our external facing systems. The work over the past few months is evident in the sharp decline in critical and high vulnerabilities on external systems. Figure 107 illustrates the hard work and dedication to reducing risk at EROS on external systems.

Other efficiencies include the use of electronic forms with built-in process flows for various security requests. SharePoint has been used to create automated Information Security Exception Request forms and Two Factor Authentication Waiver Request forms instead of manual methods to speed up the approval process. The Security team is also currently working on creating patch management procedures and processes to help define, manage, report, and respond to critical vulnerabilities in a consistent and predictable manner. And there is more to come. For further information, contact Philip Egeberg, USGS EROS, pegeberg@usgs.gov.

Table 3. Work completed on the Bash vulnerability.

Date	9/29/2014	% Fixed	9/30/2014	% Fixed	10/1/2014	% Fixed	10/2/2014	% Fixed	10/3/2014	% Fixed
EROS DMZ Vulnerable	24		15		0		0		0	
EROS DMZ Not Vulnerable	43		52		67		67		67	
EROS Total DMZ Systems	67	64.18%	67	77.61%	67	100.00%	67	100.00%	67	100.00%
Internal Vulnerable	236		80		17		7		6	
Internal Not Vulnerable	98		255		321		330		336	
Total Internal Systems	334	29.34%	335	76.12%	338	94.97%	337	97.92%	342	98.25%
EROS Total Systems Affected	401	35.16%	402	76.37%	405	95.80%	404	98.27%	409	98.53%

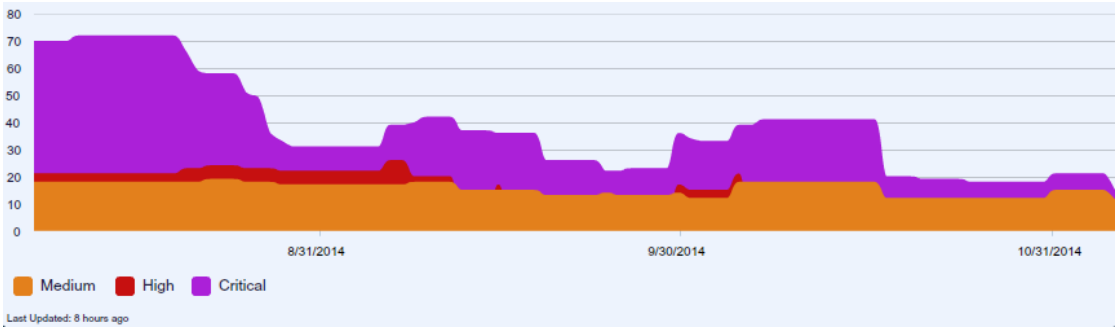


Figure 107. Graphic of risk reduced at EROS on external systems in a 3-month period.

Portfolio Management and Improving Processes

The Coordination and Requirements Office is working to improve EROS's ability to plan and prioritize its work across the Center. EROS is using portfolio management concepts and processes, as well as basic management tools, to plan and prioritize from a Center perspective. This includes documenting and using EROS vision, goals, objectives, priorities, roles and responsibilities, and metrics. Using this common set of information, EROS is better equipped to communicate, coordinate, prioritize, and make decisions regarding current and potential work.

FY 2014 was a year of transition. The EROS annual planning process was used to examine the Center's portfolio of work. This process was expanded from FY 2013 to address not just a couple but all the projects funded with SIR (Surveys, Investigations, and Research) dollars and provide Center priorities to the staff earlier than had been done in the past. A basic set of metrics classifying the work with respect to the EROS vision was defined and generated for discussion (fig. 108). Performance metrics, based on milestones, were discussed and are being tested with the Land Satellites Data System portfolio. Prioritization was explored and is still in discussion. A method of coordinating responses to requests for proposals across the Center was tested and used.

The work so far has provided benefit to our USGS customers through a single coordinated EROS response to calls for statements of intent, rather than multiple responses from projects, and we have received positive feedback on the new approach. The plan for FY 2015 is to include reimbursable-funded projects and extend the annual planning process to address FY 2016-2018 priorities early enough to be able to impact all 3 years. A key lesson learned in FY 2014 was to limit the number of EROS priorities to five or less, to allow focus. We will use the 2 years of metrics to look for trends and judge the worth of the classification metrics. We will be looking at making the process more proactive, and further explore prioritization of our work. For further information, contact Thomas Kalvelage, USGS EROS, kalvelage@usgs.gov.

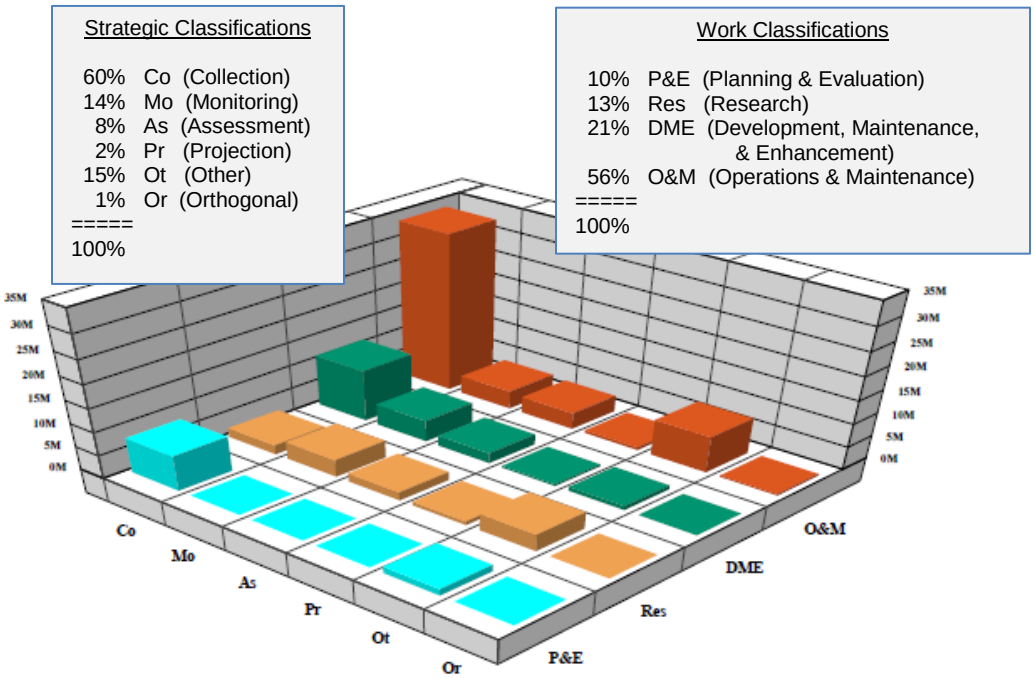


Figure 108. Graph depicts EROS body of work across EROS strategic areas and project life-cycles.

Communicating EROS Science – An Enhanced Communication Strategy

The Communications and Outreach (C&O) project at the USGS EROS Center focuses on innovative ways to engage and inform the science community and the public about the Center's mission, goals, and programs. C&O strives to increase public awareness and understanding of the Center's activities locally, nationally, and globally.

During FY 2014, the team supported USGS headquarters staff in the production of several USGS Top Stories, Science Picks, and Press Releases highlighting EROS products and work. These can be viewed through the USGS homepage Newsroom and Science Features section (see http://www.usgs.gov/).

One of our goals is to bring unified web policy and procedures for all external facing websites at EROS. To do this, we are partnering with EROS Data Services Branch and headquarters LRS Program staff.

Staff collaborated on 45 Image of the Week posters, 18 Views of the News articles, and 9 Featured Sites articles, all accessible through the EROS Homepage (http://eros.usgs.gov/). Mount Tavurver's eruption (fig. 109) illustrates one of our completed Image of the Week posters.

In an effort to enhance the capability for on-line based training and video streaming noon-time seminars, we added state-of-the art audio-visual equipment in the EROS Auditorium. Additionally, working with the USGS Office of Communications and Publishing, we posted several project presentations to the USGS YouTube Channel.

Work on the Earthshots website (http://earthshots.usgs.gov/earthshots/) focused on adding new content. This on-line companion to our printed Change Over Time cards is used in classrooms, presentations, and conferences. Future plans include adding new locations to the website and creating matching trading cards.

A new module was added to the Tracking Change Over Time Lesson Plan. The new module titled "River Flooding" lets students explore the effects of flooding using satellite imagery and is available for download at http://eros.usgs.gov/educational-activities.

Continuing to enhance our digital communication capabilities, we added a new feature to the EROS internal website called *Around the Center*. *Around the Center* has proven to be an effective method of communicating EROS activities and project accomplishments to our staff. We released 15 articles in FY 2014 (see appendix B).

The EROS C&O team assisted headquarters LRS staff in compiling and publishing the 2013 DOI Remote Sensing Report. This report from the DOI Remote Sensing Working Group highlights a sample of DOI remote sensing applications and illustrates the many types of technology, platforms, and specialized sensors employed. C&O assists by developing the website used to gather content from all DOI agencies, facilitating peer reviews, tracking the approvals through the USGS Information Product Data System, and entering final content to the website prior to the public release. To view the reports, visit http://remotesensing.usgs.gov/doireports.php.

We also began a phased plan to design new exhibits for the EROS Visitor Center. The new exhibits will provide an easily understood description of who we are, what we do, and what it means. The plan includes engaging visitors by using story-telling and a wide-range of design aspects, such as graphics, interactive displays, hands-on experiences, and digital technology. Figure 110 is an artist's rendition of the new welcome exhibit that will be in the Visitor Center.

The EROS library supported the Center's science and professional staff by assisting with more than 900 research requests of literature and reference resources. In addition, it delivered 321 bibliographies for authors and fielded 630 questions on references and document access. To provide an easier interface for managing scientific literature, references, and citations, C&O moved from Refman to Refbase as our publication search tool. The addition of this search tool made it possible for EROS projects to add project specific search tools to their websites. With our Librarian's support, Land Cover Applications Remote Sensing, National Land Change Assessment, and the Landsat Science projects have added this capability.

Throughout FY 2014, C&O welcomed over 6,675 visitors and offered more than 290 tours. Outreach staff also gave multiple presentations in the local/regional community and supported exhibit booths locally and nationally.

Other special events supported by C&O involved assisting an Italian film crew, commissioned by Norway's Food and Agriculture Organization Space Data management service to shoot video of EROS and interview scientists about the Landsat archive and the open data policy; hosting a Nitrogen Utilization Workshop; a visit from the Norwegian Space Center; and visitors from Kazakhstan.

For further information, contact Janice Nelson, USGS EROS, jsnelson@usgs.gov.

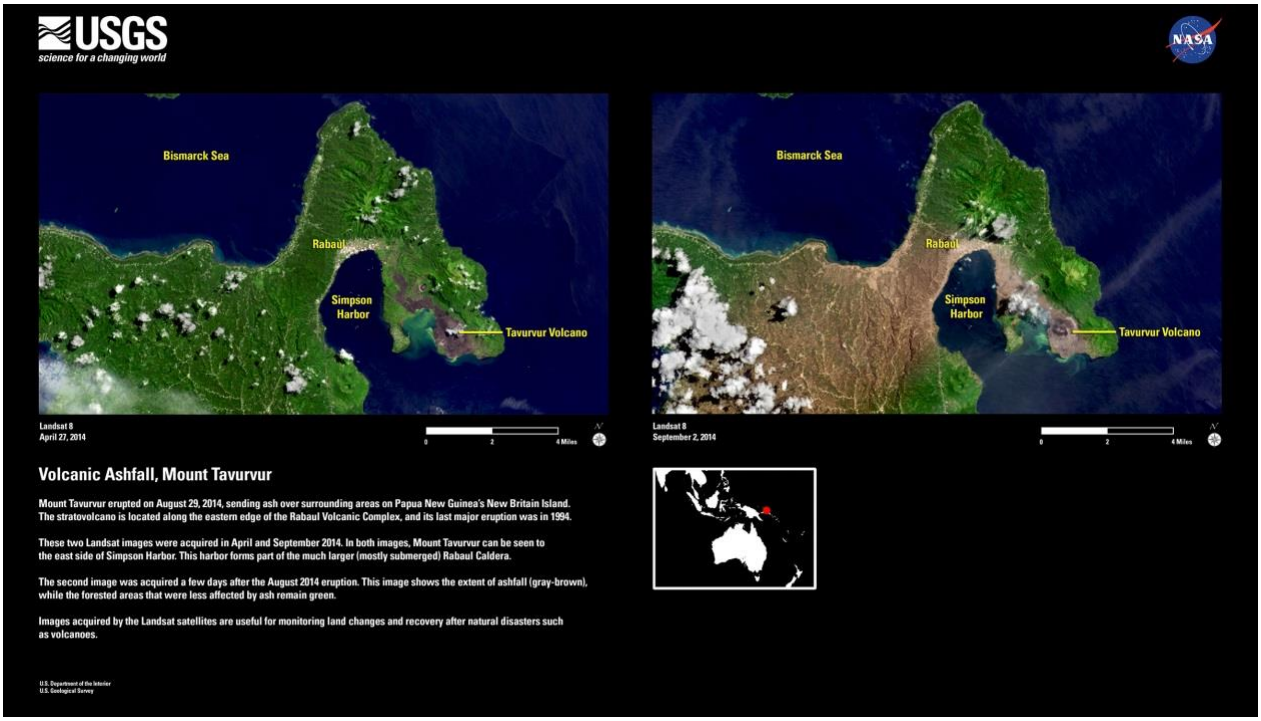


Figure 109. Mount Tavurvur erupted on August 29, 2014, sending ash over surrounding areas on Papua New Guinea's New Britain Island. To view go to: http://eros.usgs.gov/imagegallery/image-week-2#Mt.Tavurvur-images.

Figure 110. Artist's rendering of the welcome exhibit in the Visitor Center, which will include a large format monitor that can eventually be used interactively.

Conclusion

The EROS mission, *contributing to the understanding of a changing Earth*, focused on land change monitoring, assessment, and projection is consistent with the USGS geographic research focus on land change science and with the USGS vision to provide "science for a changing world."

As program planning for 2016-2017 is underway, the accomplishments of 2014 and initiating actions of 2015 are making great strides in achieving our mission goals and priorities while advancing our vision of higher levels of service to the Nation and our planet.

Communication with our expanding constituent, customer, and user base is vital to achieving our mission and the success of our projects and activities. To communicate with us or for more information about EROS, contact Thomas Holm holm@usgs.gov or Janice Nelson jsnelson@usgs.gov, Policy and Communications Office, USGS EROS Center, 47914 252nd Street, Sioux Falls, South Dakota 57198, http://eros.usgs.gov/.

Appendix A. FY 2014 Research and Technical Publications

Executive Summary of Research and Technical Publications

In FY 2014, **92** scientists, engineers, and information professionals from throughout the USGS EROS Center contributed to the Center's extensive publishing record. The complete record for fiscal 2014 totaled **136** publications. The 2014 record includes:

- **63** journal articles (**3** of which were published in a top-ranking journal as measured by Thomas Reuters Impact Factor: *Global Change Biology* and *Remote Sensing of Environment;* **31** of which were published in or have been accepted for publication in a journal ranked in the first quartile (Q1) of at least one of the 2012 Thomson Reuters Journal Impact Factor (JIF) categories). EROS authors have collaborated on journal articles with researchers in **19** different countries (China, Canada, Australia, France, Belgium, Czech Republic, Denmark, Finland, Germany, Italy, Japan, Netherlands, New Caledonia, New Zealand, Puerto Rico, Russian Federation, Sri Lanka, Sweden, Switzerland) and **100+** institutions.
- **19** reports (**17** USGS Series reports and **2** other agency reports)
- **7** book chapters
- **45** conference presentations, including **3** invited conference presentations (full papers, abstracts, posters, and slide presentations) at **6** different conferences
- **2** magazine/newsletter articles

The following **3** bibliographic citations from FY 2014 are provided for those journal articles published in the **2** top-ranking journals. To search all EROS publications, see http://eros.usgs.gov/#/Publications. For further information, contact Janice Nelson, USGS EROS, jsnelson@usgs.gov.

Pervez, M.S., Budde, M.E., and **Rowland, J.D.**, 2014, Mapping irrigated areas in Afghanistan over the past decade using MODIS NDVI: Remote Sensing of Environment, v. 149, p. 155-165, at http://dx.doi.org/10.1016/j.rse.2014.04.008.
Project: Famine Early Warning Systems -- FEWS
***Remote Sensing of Environment* is ranked #1 in the Remote Sensing category and #1 in the Imaging Science & Photographic Technology category.**

Roy, D.P., Wulder, M.A., **Loveland, T.R.**, Woodcock, C.E., Allen, R.G., Anderson, M.C., Helder, D.L., Irons, J.R., Johnson, D.M., Kennedy, R., Scambos, T.A., Schaaf, C.B., Schott, J.R., Sheng, Y., Vermote, E.F., Belward, A.S., Bindschadler, R., Cohen, W.B., Gao, F., Hipple, J.D., Hostert, P., Huntington, J., Justice, C.O., Kilic, A., Kovalskyy, V., Lee, Z.P., Lymburner, L., Masek, J.G., McCorkel, J., Shuai, Y., Trezza, R., **Vogelmann, J.E.**, Wynne, R.H., and Zhu, Z., 2014, Landsat-8—science and product vision for terrestrial global change research: Remote Sensing of Environment, v. 145, p. 154-172, at http://dx.doi.org/10.1016/j.rse.2014.02.001.

***Remote Sensing of Environment* is ranked #1 in the Remote Sensing category and #1 in the Imaging Science & Photographic Technology category.**

Zhao, S., and **Liu, S.**, 2014, Scale criticality in estimating ecosystem carbon dynamics: Global Change Biology, v. 20, no. 7, p. 2240-2251, at http://dx.doi.org/10.1111/gcb.12496.
***Global Change Biology* is ranked #1 in the category Biodiversity Conservation.**

Significant Attention on the Web.

One journal article earned a score in the 99th percentile of all *Science* articles tracked by Altmetric. Altmetric also notes that the article has been mentioned in 53 news stories from 45 outlets; has been tweeted-about more than 1,834 times by individuals in North America, South America, Europe, Asia, Africa, and Australia; and has 615 readers on Mendeley. The article has been downloaded and/or full-text viewed more than 20,000 times from the journal website. The abstract/extract was downloaded 88,800+ times between publication in October of 2013 and the end of December 2013. Thus far in 2014, the abstract/extract has been downloaded nearly 45,400+ times. Finally, the article has been recommended in F1000 Prime.

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., **Loveland, T.R.**, Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., and Townshend, J.R.G., 2013, High-resolution global maps of 21st-Century forest cover change: Science, v. 342, no. 6160, p. 850-853, at http://dx.doi.org/10.1126/science.1244693.

One journal article earned a score in the 94th percentile all *Remote Sensing of Environment* articles tracked by Altmetric. Altmetric also notes that the article has been tweeted-about 17 times across North America, Europe, and Australia. It has 518 downloads on ResearchGate and 113 readers on Mendeley.

Roy, D.P., Wulder, M.A., **Loveland, T.R.**, Woodcock, C.E., Allen, R.G., Anderson, M.C., Helder, D.L., Irons, J.R., Johnson, D.M., Kennedy, R., Scambos, T.A., Schaaf, C.B., Schott, J.R., Sheng, Y., Vermote, E.F., Belward, A.S., Bindschadler, R., Cohen, W.B., Gao, F., Hipple, J.D., Hostert, P., Huntington, J., Justice, C.O., Kilic, A., Kovalskyy, V., Lee, Z.P., Lymburner, L., Masek, J.G., McCorkel, J., Shuai, Y., Trezza, R., **Vogelmann, J.E.**, Wynne, R.H., and Zhu, Z., 2014, Landsat-8—science and product vision for terrestrial global change research: Remote Sensing of Environment, v. 145, p. 154-172, at http://dx.doi.org/10.1016/j.rse.2014.02.001.

One journal article earned a score in the 84th percentile of all *Scientific Reports* articles tracked by Altmetric. Altmetric notes that this article thus far has been tweeted-about

18 times by individuals in North America and Europe; four Facebook users have posted about the article on their public walls; and two individuals have posted about the article on reddit. Finally, the journal website has recorded 1,433 downloads/full-text views of this article.

Zhou, D., **Liu, S., Oeding, J.**, and Zhao, S., 2013, Forest cutting and impacts on carbon in the eastern United States: Scientific Reports, v. 3, article number 3547, at http://dx.doi.org/10.1038/srep03547.

Other Publications with More than 200 Views/Downloads.

Alemu, H., Senay, G.B., Kaptue, A.T., and Kovalskyy, V., 2014, Evapotranspiration variability and its association with vegetation dynamics in the Nile Basin, 2002-2011: Remote Sensing, v. 6, no. 7, p. 5885-5908, at http://dx.doi.org/10.3390/rs6075885.
Downloaded/Full-Text viewed 622 times from the journal website (10/18/14).

Artan, G.A., Verdin, J.P., and **Lietzow, R.W.**, 2013, Large scale snow water equivalent status monitoring—comparison of different snow water products in the upper Colorado Basin: Hydrology and Earth System Sciences, v. 17, no. 12, p. 5127-5139, at http://dx.doi.org/10.5194/hess-17-5127-2013.
Downloaded/Full-Text viewed 538 times from the journal website (10/18/14).

Dahal, D., Liu, S., and **Oeding, J.**, 2014, The carbon cycle and hurricanes in the United States between 1900 and 2011: Scientific Reports, v. 4, article number 5197, at http://dx.doi.org/10.1038/srep05197.
Downloaded/Full-Text viewed 680 times from the journal website (10/18/14).

Deering, C.A., and **Stoker, J.M.**, 2014, Let's agree on the casing of lidar: Lidar Magazine, v. 4, no. 6, p. 48-51, at http://lidarnews.com/emag/2014/vol4no6/index.html.
Downloaded/Full-Text viewed 1,984 times from the journal website (10/18/14).

Gallant, A.L., Euliss Jr., N.H., and Browning, Z., 2014, Mapping large-area landscape suitability for honey bees to assess the influence of land-use change on sustainability of national pollination services: PLoS ONE, v. 9, no. 6, p. 1-14, at http://dx.doi.org/10.1371/journal.pone.0099268.
Downloaded/Full-Text viewed 1,223 times from the journal website (10/18/14).

Gallant, A.L., Kaya, S., White, L., Brisco, B., Roth, M.F., Sadinski, W.J., and **Rover, J.A.**, 2014, Detecting emergence, growth, and senescence of wetland vegetation with polarimetric synthetic aperture radar (SAR) data: Water, v. 6, no. 3, p. 694-722, at http://dx.doi.org/10.3390/w6030694.
Downloaded/Full-Text viewed 588 times from the journal website (10/18/14).

Jones, B.M., **Stoker, J.M.**, Gibbs, A.E., Grosse, G., Romanovsky, V.E., Douglas, T.A., Kinsman, N.E.M., and Richmond, B.M., 2013, Quantifying landscape change in an arctic coastal lowland using repeat airborne LiDAR: Environmental Research Letters, v. 8, no. 4, article number 045025, at http://dx.doi.org/10.1088/1748-9326/8/4/045025.
Downloaded/Full-Text viewed 3,688 times from the journal website (10/18/14).

Singh, R.K., Senay, G.B., Velpuri, N.M., Bohms, S., Scott, R.L., and **Verdin, J.P.**, 2013, Actual evapotranspiration (water use) assessment of the Colorado River Basin at the Landsat resolution using the Operational Simplified Surface Energy Balance Model: Remote Sensing, v. 6, no. 1, p. 233-256, at http://dx.doi.org/10.3390/rs6010233.
Downloaded/Full-Text viewed 944 times from the journal website (10/18/14).

Wickham, J.D., **Homer, C.G., Vogelmann, J.E.**, McKerrow, A., Mueller, R., Herold, N.D., and Coulston, J., 2014, The Multi-Resolution Land Characteristics (MRLC) Consortium—20 years of development and integration of USA national land cover data: Remote Sensing, v. 6, no. 8, p. 7424-7441, at http://dx.doi.org/doi:10.3390/rs6087424.
Downloaded/Full-Text viewed 232 times from the journal website (10/18/14).

Wu, Y., Liu, S., Huang, Z., and Yan, W., 2014, Parameter optimization, sensitivity, and uncertainty analysis of an ecosystem model at a forest flux tower site in the United States: Journal of Advances in Modeling Earth Systems, v. 6, no. 2, p. 405-419, at http://dx.doi.org/10.1002/2013MS000298.
Downloaded/Full-Text viewed 290 times from the journal website (10/18/14).

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Appendix B. Around the Center 2014

Around the Center is a new internal communications feature that began in 2014 and is hosted on the EROS internal website at http://edchome.cr.usgs.gov/around-the-center. Every 2 to 4 weeks, snapshots of timely topics are posted to help the EROS workforce stay up-to-date on Center activities. Topics are published as interviews covering key events, projects and products, new research, policy changes, etc. – items of interest targeting the EROS workforce. The 2014 record of featured topics and staff interviewed is listed below followed by the full article.

Featured Topic	Staff Interviewed
2014 – A New Era for EROS	Frank Kelly
A Global Forest Survey	Thomas Loveland
Good Things Getting Better	Jim Lacasse, Gene Fosnight, Ron Morfitt
NLCD's New Release	Collin Homer
Declass 3 Arrives at EROS	Wayne Miller, Tim Smith
Even Better Together	Greg Stensaas
Beyond the Breakers: CoNED and America's Coasts	Jeff Danielson
Watching Spring Arrive at EROS	Jesslyn Brown, Gretchen Meier
Secrets to Aging Well	Bruce Potter
LP DAAC at EROS	Chris Doescher
Fire Science, An Outstanding Team	Jeff Eidenshink
Landsat CDRs and ECVs	Calli Jenkerson
A Glimpse of Tomorrow	Alisa Gallant
The Sinister Syndrome: A Story of Creativity vs. A Chemical Reaction	Wayne Miller, Tim Smith
Patience Rewarded	Dean Gesch, Wayne Miller
Priorities that Foster Change	Frank Kelly

2014 – A New Era for EROS

January 13, 2014

Frank P Kelly
Director, Earth Resource Observation and Science (EROS) Center
Space Policy Advisor

As we begin 2014, New Year's resolutions are foremost in many of our minds. What can we do better in the coming months? How can we refocus, improve, and grow?

At the All-Hands meeting in December, I reminded you of some of the Center's FY 2013 accomplishments. We even sang a song (attempted to sing a song) to celebrate the long list of successes! At that meeting I invited you to look ahead by introducing a draft of the Center's Strategic Objective Priorities for FY 2014. You can find the finalized memo at 2014 Center-wide Priorities. In a sense, the FY 2014 Priorities are New Year's resolutions. They are designed not to simply ring in a new fiscal year at EROS, but to bring us into a new era.

I envision FY 2014 as a turning point. We already have a new organizational structure in place and are working out the associated roles and responsibilities in executing our vision. We are now on a path for EROS to actively transition to an organization focused on providing land change science, data, and information to the user community. Now that Landsat 8 is up and operating, we are looking at a more expansive mission, while ensuring the longer-term preservation of land remote sensing data and the continuation of the Landsat record and its applications.

Three major goals for the Center, along with their associated objectives and priorities, form the basis of the FY 2014 plan and beyond. Becoming the world's primary source of remotely sensed land images tops the list. EROS already is an unparalleled repository of remotely sensed imagery. The challenge now, I believe, is to lay the foundation for a sustainable, realistic, and affordable program that will provide future land imaging data compatible with the existing Landsat and remotely sensed land data record. Integral to this challenge is coming up with new ways to meet the ever-changing needs of the global user community.

The second long-term goal for EROS is to become an authoritative provider of not just imagery, but also cutting-edge land change science information, especially as it relates to Climate and Land Use Change (CLU) and USGS priorities. Reaching these objective will include creating science information products such as Essential Climate Variables (ECVs) and Climate Data Records (CDRs), developed from near-real-time earth observations along with 3-dimensional products (think lidar) that help us become the authoritative providers of information and knowledge about change over time. In my view, the best thing we can provide is well-calibrated, reliable data and information at global, regional, and local levels – data and information that can help our user community understand the impacts of a changing climate.

The third major goal as we begin this new fiscal year is to have EROS continue to develop our leadership role in understanding the wide-ranging impacts of land use and land cover change. A Land Change Monitoring, Assessment and Prediction (LCMAP) program comprised of an interdisciplinary team is in the making that will use land-change information products to document and explain patterns, processes, and consequences of land change on people and environments.

It is a tall order, but one I see as achievable. My confidence stems from the extraordinary pool of talent at EROS. During my two years at EROS, I have learned

that there are brilliant, dedicated people at the Center, on both the government and contractor sides. Basically, people need to keep doing the jobs at which they excel while keeping our eyes on our vision and our future. Working together, we can make real progress this year and in the years to come.

Welcome to the New Year and the new era!

A Global Forest Survey
January 27, 2014

Thomas Loveland, *Senior Scientist*

Good things take time. The new 30-meter Global Forest Survey is proof.

Back in 2007, EROS scientist Tom Loveland and Matt Hansen (then co-director of South Dakota State University's Geospatial Science Center of Excellence) were brainstorming Landsat applications. "We wanted to do something global with Landsat, Loveland recalled. Seven years later that "something global has come to life in the form of the Global Forest Survey, an interactive database built from more than 650,000 Landsat 7 scenes that reveals extent and change in forest cover worldwide from 2000 to 2012 at a 30-meter resolution. Users can zoom into an area about the size of a baseball diamond anywhere on the planet to see how forests there have changed during the first dozen years of the 21st Century. Try it yourself at http://www.earthenginepartners.appspot.com/science-2013-global-forest.

Several factors helped turn Loveland and Hansen's idea into reality. One was the quality of Landsat 7 data and the Long Term Acquisition Plan, which enabled the systematic collection of cloud-free, global imagery for each of the four seasons. "From 2000 onward, we got incredibly good Landsat coverage, Loveland said.

Then came the policy change that made Landsat images available at no charge. Prior to the change, the price tag for utilizing 650,000+ Landsat scenes would have topped $380 million. "Once the scenes were freely available we saved huge amounts of money, Loveland said. "In addition, the images were available in orthorectified form at that point, which made comparing images over time much easier and more accurate." A third factor was the vast computing power of Google's Earth Engine. With the support of Google's Rebecca Moore and the involvement and financial support from the Gordon and Betty Moore Foundation, data processing that would typically have taken years took

just six months. The result is a unique view of the world's forests that pushes the frontiers of science and conservation. "It's both globally consistent and locally relevant. Because of the 30-meter resolution, users can get down to very specific locations using this product. It's possible to see the impacts of individual decisions as to how forests have been used."

The final factor was Matt Hansen's innovative approach to mapping and monitoring global forest gains and losses. "Matt's long history in global mapping gave him the unique perspective on how to tackle such a massive remote sensing research challenge, said Loveland. "Few people think as progressively as he does."

Loveland, Hansen (now at the University of Maryland) and others on the project expect the Global Forest Survey to get a lot of attention in the climate change community. Forests are landscape features with the single most obvious link to climate change as they have a huge impact on greenhouse gases, especially carbon dioxide. The team also anticipates significant national-level interest in the Survey as a means to document forest extent and change throughout the United States. They believe it will also appeal to many NGOs, including those representing indigenous peoples who have a strong interest in protecting forests on native lands.

With the Global Forest Survey now released, the plan is to create similar products for other types of land cover at global scales. "Eventually, the goal is to be able to detect change of any kind as it is occurring anywhere in the world, and to understand the direction and consequences of that change, said Loveland.

Good things do take time. But at EROS, they are coming faster all the time.

Good Things Getting Better
February 10, 2014

Jim Lacasse, *Landsat Operations and Maintenance Project Manager*
Gene Fosnight, *Landsat Acquisitions Director*
Ron Morfitt, *Landsat 8 Calibration and Validation Lead, Contractor to USGS EROS*

It's hard to believe a year has passed since the launch of Landsat 8. This first anniversary is going to be an exciting, upbeat celebration because the new satellite is meeting, if not exceeding, all expectations. "Landsat 8 is nearly perfect, said Jim Lacasse, Landsat Operations and Maintenance Project Manager. "We're getting really high quality data."

There is, however, a bit of tweaking going on as Landsat calibration and instrument teams work to correct a few small issues. Landsat 8's Operational Land Imager (OLI), for example, is composed of tens of thousands of very sensitive detectors-so sensitive that tiny discrepancies are evident in Landsat 8 images of dark, uniform areas such as large expanses of water. The calibration team has made an overall improvement to the radiometry (color fidelity) of the OLI sensor's bands to resolve this problem.

The satellite's Thermal Infrared Sensor (TIRS) acquires two infrared bands. Both are being affected, to different degrees, by a stray light problem. "Light from outside the area we are looking at is getting into the telescope-it's being reflected from something in the sensor itself-which is causing 'ghosting' in the images, said Ron Morfitt, Landsat 8 Calibration and Validation Lead. "To fix the problem, the calibration and instrument teams are scanning the moon, which is a very bright object with a very dark background, to try to find out exactly where the stray light is coming from. We'll then build a filter to remove the ghosts from the images, Morfitt added. "It is a very novel solution."

Landsat 8 and Landsat 7 are also being managed in a novel way, with the newer satellite being used to extend the capabilities-and lifespan-of the older one. "Landsat 7 recently went to a continental landmass acquisition strategy, said Lacasse. "Capturing images of islands, for example, was very inefficient due to Landsat 7 scheduling constraints. The responsibility for capturing images of islands has been turned over to Landsat 8, with its much more sensitive sensor. The change helps to conserve the resources of Landsat 7 while still meeting our science goals."

This change has also resulted in more data than anticipated being acquired by both satellites. Freed from routine acquisition of island images – as well as those of water, Antarctica, and night scenes – Landsat 7's output has increased from 375 to 438 scenes per day while at the same time prolonging the life of the ETM+. Landsat 8 is also collecting more than its anticipated 400 scenes per day. "We are currently scheduling 550 images per day, said Gene Fosnight, Landsat Acquisitions Director. "Landsat 8's new bands and increased sensitivity make it particularly useful for dark objects like water and bright objects like snow and ice. We are acquiring those types of images at a higher rate than ever before. Landsat 8 is also cautiously beginning night imaging campaigns of active volcanoes."

More data. Better data. It's definitely something to celebrate.

NLCD's New Release
February 24, 2014

Collin Homer, *Land Characterization Project Manager*

In our tech-savvy world, we hear about new releases all the time. Software updates, next-generation apps, and operating system upgrades are so common that the "latest and greatest starts to feel routine. But coming next month is a new release that is truly a milestone, and one you don't want to miss: NLCD 2011.

NLCD 2011 is the most up-to-date and extensive iteration of the National Land Cover Database, the definitive Landsat-based, 30-meter resolution land cover database for the Nation. If you've spent any time at all at EROS, you've heard about NLCD. NLCD products are created through the collaborative efforts of the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of eleven Federal agencies led by the U.S. Geological Survey. People use the NLCD database for thousands of applications ranging from ecosystem status and spatial patterns of biodiversity to indications of climate change and best practices in land management. March 31, 2014 is the targeted release date for the latest version of this premiere land cover database. And a lot of people can hardly wait.

"Users are really anxious to get their hands on the data, said Collin Homer, EROS' Land Characterization Project Manager and the director of the NLCD 2011 effort. "And we don't think they'll be disappointed."

What's new with NLCD 2011? The data in NLCD 2011 are completely integrated with those of previous versions. Fourteen product suites now harmonize and integrate land cover change across the conterminous United States through 2001, 2006, and 2011. For example, the database's imperviousness product has gone through considerable fine-tuning and hand-editing to make sure urban change is captured in each of the proper eras. Land cover data for Alaska will also take a significant leap forward this year, with new data sources revealing more details of land cover change in the state over the last 10 years, especially from fire disturbance and ice change.

Overall, NLCD 2011 is a significantly evolving tool for change detection. "Over time, NLCD has improved the ability to detect land cover change more accurately, said Homer. "With this version of the database, we are now picking up more subtle patterns of change such as forest re-growth or urban densification."

Homer credits the success of NLCD to the continuing collaborative spirit of the agencies that make up the MRLC. The U.S. Forest Service, for example, produced the Tree Canopy Cover product for NLCD 2011 for the first time. Homer has particularly high praise for the role played by the EROS NLCD team. "EROS has a critical mass of talent and expertise that is hard to find, a combination of talented scientists, engineers, and production infrastructure that enable us to undertake large-scale efforts like NLCD 2011."

Look for announcements about the NLCD 2011 release on the EROS, MRLC, and NLCD websites and twitter feeds. "Land cover is important to lots of folks, Homer says, "and more and more users keep discovering that."

Wait until they discover NLCD 2011.

Declass 3 Arrives at EROS
March 10, 2014

Wayne Miller, *Long Term Archive Project Manager*
Tim Smith, *Long Term Archive Data Management Lead, Contractor to USGS EROS*

One subzero day back in January, a truckload of securely wrapped boxes arrived at the EROS dock. They were taken down into the basement and placed under lock and key. The boxes contained rolls of film that represent the EROS Long Term Archive (LTA) project's latest acquisition of declassified photoreconnaissance satellite imagery. "We're taking the next step in securing the availability of declassified satellite imagery by providing archive support to 1550 rolls of Declass-3 imagery previously maintained at USGS/Reston, said LTA Project Manager Wayne Miller.

Declass 3 is the last of three satellite data sets that were declassified under Executive Order 12951, signed by President Clinton in 1995. Declass 3 consists of film taken by photoreconnaissance satellites that operated between 1971 and 1986. The LTA's recent acquisition represents roughly ten percent of the 15,000 rolls of declassified KH-9 film that were transferred in 2013 from the National Geospatial Intelligence Agency (NGA) to the National Archives and Records Administration (NARA).

This portion of Declass 3 will ultimately join the Declass 1 and 2 collections, which came to EROS in 1996 and 2002, respectively. First, though, there's considerable work to be done. "The film rolls need to be edited before they are released to the public and permanently archived alongside the 22,374 rolls of Declass 1 and 2 imagery, Miller explained. The editing, or redacting, process involves removing images that are still

potentially sensitive. Once redacting is complete, data on the analog film are converted into digital format, complete with metadata. “The LTA Declass-3 effort will take months, but it sets the stage for continued dialog with the NGA and NARA to recognize EROS as a partner in promoting access to the Nation’s declassified satellite imagery. The Declass 1, 2, and 3 collections involve global coverage from 1960 through 1985 that includes over three million original scenes, Miller added.

Digitized, declassified satellite images archived at EROS are accessible through EarthExplorer. They are available as on-demand scans for just $30 per scene. Once a particular scene has been scanned, however, subsequent downloads of that scan are available at no cost. To date, roughly 17,500 no-cost Declass 1 and 2 scenes have been downloaded by users worldwide. As Declass 3 images are added to EarthExplorer, the demand is expected to increase. “Declass 3 is pre-Thematic Mapper data and the resolution is great, said Tim Smith, LTA Data Management Lead. “It’s international coverage that predates Landsat by up to 10 years, so it gives scientists a valuable baseline for land change and other types of studies.”

Even Better Together
March 24, 2014

Greg Stensaas, *USGS Remote Sensing Technologies Project Manager and JACIE Co-Chair*

Pooling talent and technology is nearly always a recipe for success. That’s why expectations are high this week when, for the first time, the annual Joint Agency Commercial Imagery Evaluation (JACIE) workshop will be held in conjunction with the 2014 American Society for Photogrammetry and Remote Sensing (ASPRS) annual conference, which runs March 23-27 in Louisville, Kentucky.

"Holding JACIE in conjunction with ASPRS is a sound strategy, said Greg Stensaas, USGS Remote Sensing Technologies Project Manager and JACIE Co-Chair. “It will provide government and industry technical experts with a common forum to discuss how to improve the quality of remote sensing systems and data to better support a wide variety of relevant applications. Using ASPRS as a door to the remote sensing arena also will allow the remote sensing system characterization and associated data quality and application information published only via the JACIE workshop to be viewed and used by a wider science community.

JACIE is a unique interagency team of scientists and engineers from USGS, NASA, NOAA, and USDA who work together to evaluate and enhance remote sensing data for commercial and government use. That is a multi-faceted task, one that includes geospatial and radiometric calibration, data accuracy and resolution assessment, and understanding the applicability of remotely sensed information to specific topics of interest in both government and industry. Each of the JACIE agencies brings a unique set of resources and strengths to the table.

For the past 14 years, JACIE has held its own annual workshops. However, since the goals of JACIE and ASPRS complement each other so well-and because many scientists and engineers in the field of remote sensing typically attend both conferences-bringing the two events together made perfect sense. As both events focus on issues relevant to USGS' Climate and Land Use mission area and its Land Remote Sensing Program, it's also fitting that EROS Director Frank Kelly will give the keynote address on the opening day of the JACIE workshop, which runs March 26-28. A few highlights of the ASPRS conference and JACIE workshop will include USGS-supported special sessions "Government Agency Views on Remote Sensing and Data Quality," Determining the Future of Land Imaging, and "Developing Standards for Lidar Data Quality. USGS will also lead a special joint ASPRS/JACIE session on Landsat 8 capabilities and data quality.

"One of the most important outcomes we'll enjoy as a result of bringing ASPRS and JACIE together will be having so many technical experts together in one place, Stensaas explained. "I anticipate dynamic discussions and unparalleled opportunities for networking, exchanging ideas, planning, and targeting future remote sensing activities."

Beyond the Breakers: CoNED and America's Coasts
April 08, 2014

Jeff Danielson, *Task Lead for CoNED*

If you've ever stood at the shore and looked out to sea, you know that what lies beyond the land is hidden beneath the ocean's surface. Yet the shape of the ocean floor along coastlines strongly influences how seawater behaves, whether it's surging inland during storms or creeping slowly higher as a result of sea-level rise.

Since 2011 topographic scientists at EROS, in collaboration with researchers at other federal and state agencies, have been using the most recent and accurate lidar and bathymetry (water depth) datasets available to develop the Coastal National Elevation Dataset, or CoNED for short. CoNED is a digital elevation model (DEM) of coastal areas in the continental United States, one that integrates high-resolution elevation measurements of coastal lands with near-shore bathymetry. The result is a collection of topobathymetric DEMs that reveal coastline elevation features in unprecedented detail. “You need accurate, high-resolution elevation data when working with coastal elevation because so much depends on elevation when it comes to coastal hydrology, said Jeff Danielson, EROS Task Lead for CoNED.

CoNED’s long-range goal is to develop a suite of regional high-resolution DEMs for America's entire coastline. A major focus at the moment, however, is on the highly dynamic Louisiana coast, home to North America's most extensive delta system and the site of one of the largest coastal restoration and flood risk reduction efforts in the Nation. Creating the Louisiana CoNED hasn't been easy. Part of the difficulty has been integrating over 400 different data sources, including aerial lidar data, hydrographic surveys, side-scan sonar surveys, and multibeam surveys obtained from NOAA, USGS, the State of Louisiana, the U.S. Army Corps of Engineers, FEMA, and other agencies.

"The challenge to making a model like this is the sheer volume of data involved and dealing with so many different kinds of data, explained Danielson. "What EROS really brings to the table in this project is outstanding geospatial analysis skills. We have people with remarkable technical expertise, not just in working with lidar and other types of data, but in integrating different kinds of data to create a common dataset aligned both vertically and horizontally to common reference systems."

Danielson indicated that the Louisiana CoNED topobathymetric model will have a horizontal ground resolution of 3 meters, and an overall vertical accuracy of better than 80-cm root mean square error (RMSE). The model will be completed in the next several weeks. It will be a huge improvement over current models for the region. "The Louisiana CoNED is really going to help policy and decision makers in that state in mitigating flood hazards because the previous model was dated with little information known about the input sources. This new model will be so much better!"

Watching Spring Arrive at EROS

April 21, 2014

Jess Brown, *Geographer*
Gretchen Meier, *Ecologist, Contractor to USGS EROS*

Temperatures are slowly getting warmer and it looks like our long winter is coming to an end. Volunteers at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center will soon mobilize to monitor and observe the timing of nature's calendar (events like bud burst, flowering, and leaf drop) in conjunction with the USA National Phenology Network. This seasonal activity is led largely through the efforts of Gretchen Meier, who works with Jesslyn Brown on satellite-based studies of phenology. Phenology, or the rhythm of the seasons, is a direct way to observe impacts of climate change on ecosystems. Gretchen, who is an ecologist, has organized and led over 20 volunteers who have consistently documented phenological transitions at four sites established on the EROS grounds. View slideshow here.

In association with the EROS remote sensing phenology program, volunteers are building on a 4-year record of vegetation phenology of 14 species around the EROS campus using a phenology monitoring program called Nature's Notebook (https://www.usanpn.org/natures_notebook). Nature's Notebook (Connecting People with Nature to Benefit Our Changing Planet) relies on "citizen scientists to record plant and animal life-cycle events. Subsequently, these data are shared by the National Phenology Network with anyone interested in studying the phenology of species in their local areas and their response to the environment. These local observations also provide important ground data to scientists who study climate and vegetation interactions.

"Scientists alone cannot collect enough data: They need our help," said Jesslyn Brown, USGS EROS Geographer. "Today, there are more than 6,000 other naturalists across the Nation helping take the pulse of our planet through Nature's Notebook; and it is exciting knowing that EROS and our volunteers are part of connecting people with nature. We rely heavily on our local observers, so please consider becoming a part of the volunteer team. It's easy; there is even a Nature's Notebook phone app."

Conducting Nature's Notebook observations at EROS fills an important gap as phenological observations are less dense in the Great Plains compared to other regions. Phenology indicators reveal important environmental data about the world around us. It is a fundamental science of how organisms adapt to and synchronize with their environments and involves nearly all aspects of life on earth, including the abundance, distribution, and diversity of organisms, ecosystem services, food webs, and the global cycles of water and carbon. Phenological events are sensitive to climate variation; therefore, phenology data provide important baseline information documenting trends in organism ecology and detecting the impacts of climate change on ecosystems at multiple scales.

Later this summer, working with AmericaView and the North Central Climate Science Center, the team will also be establishing a near-surface phenological record collected via a "PhenoCam, an automated time-lapse digital web-enabled camera. The EROS PhenoCam will be a part of an international network (online at http://phenocam.sr.unh.edu/webcam/). Time-series "camera greenness data are

robust to atmospheric noise and useful for validating satellite remote sensing phenological records.

Secrets to Aging Well
May 19, 2014

Bruce Potter, *Facility Manager*

In 1973, Nixon was President, polyester leisure suits were high fashion, and the Sonny and Cher Comedy Hour was all the rage on TV. And, believe it or not, the Karl E. Mundt Federal Building – home to the EROS Center – was built.

The icons of early 1970s politics, fashion, and pop culture faded long ago. Yet the EROS facility seems hardly to have aged at all. The fact that the building looks so remarkably "youthful after more than 40 years is primarily due to the hard work and dedication of a diverse EROS Facilities team. "If we do our jobs well, said Bruce Potter, Facility Manager, "no one really notices us. We're a behind-the-scenes team, but everything we do touches the lives of all EROS staff on a daily basis."

The Facilities team comprises four major contracts. ADC Management Services, Inc. provides around-the-clock physical security and accounts for all property. DCT Inc. is responsible for operations and maintenance of the building's physical structure and grounds. "If it's part of the furnishings, the ceilings, walls, or floors – or what's above, behind, or under them – it's the domain of operations and maintenance, said Potter. Custodial services at EROS are provided by Tech Systems Inc. and a fourth contract, also provided by Tech Systems Inc., covers logistics, including copy center and warehouse operations and mail delivery. "All told, about 60 people work as part of these four major contracts, or roughly ten percent of the EROS community, added Potter.

Like most of us, the Facilities team has what seems like an endless to-do list. But theirs covers everything from landscaping and painting tasks to major overhauls of building structures and systems that may take many months to complete. A prime example is the current HVAC project, an 18-month undertaking to replace and upgrade the heating and air conditioning system throughout the building. But the results will be worth the effort. "When this project is complete, the EROS facility will be much more energy efficient, said Potter. "In fact, it will be well on its way to becoming the first building within USGS to qualify for an Energy Star rating."

In addition to the talents and efforts of the Facilities team, Potter credits long-term planning and success in securing funding for improvements as major reasons why EROS looks so good after all these years. A less tangible factor is also key: the pride the entire EROS staff takes in their workplace. “People here treat the building and the things in it with care. Maybe it has something to do with the strong Midwestern work ethic we have in the upper Great Plains, Potter mused. “Whatever it is, everyone at EROS helps take good care of the place, and that makes our lives easier. It’s a great working environment!”

LP DAAC at EROS

June 06, 2014

Chris Doescher, *Land Processes Distributed Active Archive Center Project Manager*

Question: How is the staff of the Land Processes Distributed Active Archive Center, aka the LP DAAC, like a disc jockey? Both keep disks spinning! The disks being spun in the LP DAAC, however, are not vinyl records but data-packed media within hard drives. The disks are kept spinning continuously for a very good reason: to enable the immediate download of the data they contain. This feature, called zero latency, is unique to the LP DAAC and means that all archived data are instantly available to users. The staff strives to maximize the network bandwidth so that this exceptional data availability will always be there.

Chris Doescher, LP DAAC Project Manager, explains that the LP DAAC’s mission is to ingest, archive, process, and distribute NASA land data and products. LP DAAC is a component of NASA’s Earth Observing System (EOS) Data and Information System (EOSDIS). The DAAC manages data derived from the constellation of EOS sensors, including the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Moderate Resolution Imaging Spectroradiometer (MODIS). ASTER data are rigorously used for volcano and landslide monitoring and earthquake research. The coarser resolution of the Moderate Resolution Imaging is well-suited for fire science and other natural hazards monitoring.

The Earth Science Data and Information System (ESDIS) Project manages the science systems of the EOSDIS. The LP DAAC archive at EROS is one of the largest archives within ESDIS. There are over 40,000 users of LP DAAC data all over the world. That’s about half of all EOSDIS users.

The LP DAAC has been at EROS since 1990. The new part of the building and Computer Room 2, which opened in 1996, were built for the LP DAAC project and other NASA partnership work. NASA focuses on research and development, so they partner with USGS for operational needs. “The partnership complements the strengths of both agencies-the sum is greater than the parts, Doescher added.

The ESDIS constellation of satellites sends data to 12 different DAACs. The land products come here to EROS. The USGS manages remotely sensed land data for the Department of the Interior (DOI), so EROS was the logical fit to house the land processes data. Doescher refers to the data offerings as one-stop shopping. Beyond that, the tools and services provided by the LP DAAC team at EROS can be leveraged across the DOI to assist in managing Federal lands. “At EROS, we know the land product users the best, says Doescher.

Along with ASTER and MODIS, the LP DAAC manages community datasets. These specific products from NASA proposals add depth to the archive. These datasets currently include vegetation and phenology, global forest cover change, and digital elevation data.

Distribution of LP DAAC data continues to grow significantly over time. In FY 2013, the LP DAAC distributed about 1.5 petabytes of data. By May 2014, they had already surpassed that total for FY 2014.

“The datasets that the LP DAAC offers can affect human life every day, says Doescher, commenting on the value the LP DAAC provides not just to EROS but to the world. “The future of the LP DAAC involves discovering new tools and services to make the data available immediately to users wherever they are and however they want the data packaged.”

And keeping all those disks spinning.

Fire Science, An Outstanding Team
June 20, 2014

Jeff Eidenshink, *Fire Science Program Manager*

Here in eastern South Dakota, we're struggling with heavy rains and water-logged soil. Residents of drought-stricken western states, however, are bracing for what is likely to be one of the toughest fire seasons yet. "California, Arizona, New Mexico – those states and others are going to see a lot of fires this year, says Jeff Eidenshink, EROS Fire Science Program Manager. Eidenshink should know – predicting wildfires and documenting their effects has been a major focus of his work at the Center since 1987.

What is fire science? Eidenshink breaks it down into three key areas of research: pre-fire and post-fire applications, and fire decision support. "Pre-fire is fire danger forecasting, Eidenshink explains. "Predicting wildfires is a combination of knowing the weather, historical fire occurrence, and current vegetation conditions. EROS' Fire Science team uses data gleaned from satellite images, weather forecasts, fire history, and ground observations to assess the probability of wildfires at a given location, and posts those predictions weekly on the USGS Fire Danger Forecast website. Post-fire studies involve monitoring and mapping burn severity for emergency response and long-term ecological impacts. Just about everyone at the Center is familiar with the Fire Science team's striking burn severity maps, which are overlaid onto satellite images to reveal the extent and intensity of wildfires on the land's surface.

"Our LANDFIRE program fits in the middle, between predicting fires and documenting their effects, Eidenshink continues. LANDFIRE data products are used for running fire simulations, predicting wildland fire behavior, and determining land treatments. As a fire unfolds, they are critical to fire management initiatives and decision support applications. "Whenever there is a wildland fire somewhere in the continental United States and people are doing GIS work and trying to figure out what's going to happen next, they are using LANDFIRE data, Eidenshink adds.

Over the past few weeks, the Fire Science program has received several major grant awards, a sign that the excellence of its research, products, and services is widely acknowledged. These include three, three-year grants from NASA and a two-year grant from the Fish and Wildlife Service, the latter to create burn severity maps for all the federal wildlife refuges in the lower 48 states. "These awards are an incredible endorsement of the type and quality of work we are doing, Eidenshink comments.
The pride in Eidenshink's voice is unmistakable when he says this, but there's a note of melancholy as well. He's retiring after 33 years at EROS. "Sure, I'll miss it, he says. "But I'm just one member of an outstanding team. I have no doubt my very capable colleagues will solve the problems that I'll never get to. I'm confident that everything here is on the right track."

The fires out West are a reminder of how important the Fire Science research at EROS really is, and just how much of a difference each one of us can make.

Landsat CDRs and ECVs
July 15, 2014

Calli Jenkerson, *Land Satellites Data System Task Lead, Contractor to USGS EROS*

Landscape changes happen all the time, some natural and some caused by people. One of the main objectives of our science at EROS is to monitor those changes and assess the causes and consequences of change. To help detect changes on the landscape, scientists can use USGS Climate Data Records (CDRs). CDRs are long-term consistently processed datasets consisting of geophysical parameters derived from Landsat data. They are a baseline from which indicators of change are built.

The Land Satellites Data System (LSDS) Science Research and Development (LSRD) Project at EROS is responsible for creating these higher level data products.

A fair amount of processing is needed before the data are usable. “Landsat is the gold standard of land observation. But the reality is that it’s gold ore. It has to be refined and processed before it’s valuable to scientists, Calli Jenkerson said. “We remove the processing burdens so that scientists can spend more of their time applying the data and discovering the nature of the changes the data reveal.”

The USGS is also creating Essential Climate Variables (ECVs). These products represent specific geophysical and biophysical properties of the land surface. Examples of ECVs that EROS is working on include Global Land Cover, Burned Area Extent, Surface Water Extent, and Snow Covered Area. These ECVs ensure that the archive can be processed consistently.

Specifically, the LSRD team builds algorithms to make consistent science results across the Landsat sensors. Once a baseline, or “normal, is established, scientists can compare that to the changes being seen and characterize the change. They look for the timing of the change, look for patterns, and then project changes that could occur in the future.

The foundation of the historical ECV record is the Landsat Surface Reflectance CDR product derived from Landsats 4 through 7. NASA has just finished coding a surface reflectance product for Landsat 8. Now the LSRD team at EROS is working on translating the code into an open-source language. Not glamorous work, but necessary to make the data useful.

The new product is planned for delivery in December. This product can then be used to extend Landsat time-series research from 1982 into the future, with consistently processed Thematic Mapper, Enhanced Thematic Mapper Plus, and Operational Land Imager surface reflectance input to a variety of higher level products and models useful for identifying land change.

Landsat data hold a great deal of information that can contribute to characterizing, monitoring, and understanding land change. CDRs and ECVs enable the science community to spend more of their time focusing on answering big questions about climate, resource management, and long-term change.

A Glimpse of Tomorrow
August 5, 2014

Alisa Gallant, *Research Physical Scientist*

The EROS of today grew from an idea that a handful of forward-thinking people had back in the late 1960s: acquire images of earth's land resources via satellite and make those images available to the world. For decades, EROS has done just that, and is now known internationally for its archive of freely accessible satellite imagery and other earth observation data. Only slightly less well-known is the work EROS does in land change science, currently undertaken largely in the form of independent projects such as LANDFIRE and the National Land Cover Database.

A change is coming, though, one that's poised to fundamentally transform the EROS Center as we know it.

"This is a vision of EROS that goes beyond individual, independent projects to a more unified EROS focus, says Alisa Gallant, EROS Research Physical Scientist. That vision – currently being fine-tuned by Gallant and a group of fellow EROS staff including Tom Loveland, Jim Vogelmann, Brian Sauer, Dan Steinwand, Dave Hair, and Charlie Trautwein – calls for a new Center-wide strategy for exploiting the Landsat archive in a way that will move EROS science toward what's being called Land Change Monitoring, Assessment, and Projection (LCMAP). The essence of LCMAP is to provide data that are "analysis-ready to help users hit the ground running and to feed a new Center capability for continuous monitoring that, in turn, enables publishing annual reports on land change and supporting agile and timely responses to needs for short-term topical assessments. "Instead of simply providing access to data, we are aspiring to become a

‘go to’ place for land change assessments and products, with the capacity to allow people to access the information in a variety of ways, Gallant adds.

Under LCMAP, EROS will transition from not only being a source of Landsat scenes to being a source of land change information and knowledge. The key to realizing this vision is to make the full historical record of clear observations easily accessible for every pixel, so that with each new Landsat overpass a pixel’s current characteristics can be compared with its historical characteristics.

Gallant stresses that analyzing all clear observations at the pixel level would bring about a paradigm shift in detecting land change. “We’d be continuously monitoring landscape change, rather than periodically assessing snapshots in time, as most of our projects do now. Imagine having a stack of data for each pixel of earth’s land surface, arranged so that you could drill down through time and characterize how that pixel has responded through time since monitoring began. Not only would this new approach help reveal abrupt changes and pinpoint when they occurred in a particular place, but it would be very powerful at revealing slow, gradual changes as well, Gallant says.

The implications of this new approach to land change research at EROS are huge. “Along with other users of these data, we could do a much better job of mapping the timing of change. And we’d have available a level of detail that would help answer questions as to why a particular change might have occurred, or was currently underway, Gallant says. For example, within the LCMAP framework, drivers of change such as alterations in climate or effects from flooding and other temporary disturbances could more easily and quickly be assessed. This framework is going to allow researchers to invest more of their time actually assessing land change rather than generating the datasets needed to assess land change.

Numerous questions need to be answered in regard to exactly how LCMAP might be implemented here at EROS. For starters, how would we handle all the data associated with trillions of pixels being tracked and analyzed through time? Downloading individual Landsat scenes via the internet is one thing; downloading pixel histories for large geographic areas is quite another. The LCMAP group will be exploring ways in which users might be able to access such great volumes of data, and all the various analyses ultimately associated with them, without having to deal with downloads.

“A lot of elements must come together for this new vision to be fully realized, Gallant admits. “We can’t do this by ourselves. We’ll need partners, and some of the research and development might best be done externally. Still, we’re working on it. What’s maybe most important is having the will as a Center to make this happen.”

Expect to hear a lot more about LCMAP in the months to come, as we move toward the EROS of tomorrow. Because if there is any lesson we should glean from the Center’s 40-plus-year history, it is that whatever is required, we will do it.

The Sinister Syndrome: A Story of Creativity vs. A Chemical Reaction
September 4, 2014

Wayne Miller, *Long Term Archive Project Manager*
Tim Smith, *Long Term Archive Data Management Lead, Contractor to USGS EROS*

Sharp, vinegar-like odors are often associated with good things such as dill pickles, sauerkraut, or mustard on a hot dog. In an archive housing several million frames of irreplaceable aerial film, however, a vinegar-like scent is not good at all. In fact, it's a sign of impending disaster. Such a disaster was looming in the EROS archive in the late 1990s, but has been successfully averted in the ensuing years thanks to the talents and determination of the Long Term Archive (LTA) project staff. Here's the scoop:

"Prior to the early 1960s, the film used by USGS and other government agencies for aerial photography had an acetate base, says Wayne Miller, Long Term Archive Project Manager. "It was never meant to be permanent. The reason for the film's limited lifespan was a chemical reaction that takes place between the acetate and moisture in the air. The reaction slowly destroys the film, causing it to bubble and warp. During this sinister degradation process, a telltale vinegar-like odor is emitted, earning it the name "vinegar syndrome."

By the 1990s, the EROS archive contained over 19,000 acetate-based film rolls. In 1999, the staff began testing these rolls for vinegar syndrome by placing chemical test strips inside the film canisters as a means of ranking the rolls in terms of their degree of deterioration. The results, and the telling odor, were disturbing. "The distinct smell of vinegar was an early warning that action needed to be taken quickly, says Tim Smith, Archive & Data Access Task Lead for the LTA. The LTA group had three options to deal with the problem: (1) duplicate every acetate-based roll onto far more stable Mylar-based film; (2) freeze the old film rolls to stop the deterioration process; or 3) scan the rolls to make an accurate digital copy of each one.

Option 1 came with a staggering price tag of over $11 million, so only the film rolls most affected by vinegar syndrome were copied to Mylar before the EROS Photo Lab shut down in 2005. "We were just buying time with those first duped rolls, saving the worst of the worst before they were completely unusable, Miller explains. "We still had to come up with a workable, affordable strategy for salvaging the tens of thousands of rolls that remained at risk. Since EROS didn't have a way to freeze such a huge quantity of film, the only viable solution was to scan them, frame by frame, to create digital copies and then ship the original rolls to the National Archives and Records Administration (NARA), where they could be placed in permanent cold storage. The question was, just how were they going to scan them?

The answer came in the form of the Phoenix IV digitizing system, built with the technical expertise of Max Borchardt, Ryan Longhenry, Mike Austad, Kelvin Tellinghuisen, and other members of the LTA team. From 2004 to 2010, LTA staff used this versatile system to digitize over 6.5 million frames of acetate-based aerial photography. In 2010, the Phoenix IV evolved into the Phoenix V, modified to accept a 25-micron scanning head that made it possible to begin scanning the collection at a higher resolution and produce digital copies with a level of scientific detail that made them, as Miller says, "truly as good as the originals."

The LTA is celebrating the milestone of having completed at the end of August the scanning of all vinegar-syndrome-afflicted film rolls of USGS origin, roughly 2.4 million images of earth's land areas that extend the depth of the EROS archive back to the 1930s. "What I think is so significant about this achievement, says Miller, "is that it was done quietly and efficiently by a group of people striving to mitigate formidable challenges for the long-term preservation of unique material in the archive."

The task isn't complete; a considerable number of non-USGS vinegar-syndrome film rolls remain to be scanned. But at this point, the sour scent of vinegar in the EROS archive has been largely replaced by the sweet smell of success in resolving this threat to an unmatched collection of extraordinary earth observation data.

Patience Rewarded
September 23, 2014

Dean Gesch, *Research Physical Scientist*
Wayne Miller, *Long Term Archive Project Manager*

In February 2000, something quite remarkable took place aboard the Space Shuttle Endeavour. For eleven days, a pair of specially modified radar antennas – one secured in the shuttle's payload bay and another positioned on the end of a 200-foot mast jutting out into space – bounced radio waves off earth, recording the returning echoes as a way of mapping the elevation of its land areas. The undertaking, called the Shuttle Radar Topography Mission (SRTM), acquired elevation data with a 30-meter resolution on a near-global scale, creating an unparalleled topographic snapshot of earth's landmasses. The SRTM dataset became the most complete, high-resolution, digital topographic database of the planet ever produced up to that time.

The National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA) spearheaded the SRTM mission. But USGS also played

a critical role. Even while the mission was still in the planning stage in the late 1990s, NGA and NASA agreed that USGS, and specifically the EROS Center, should be responsible for archiving and distributing SRTM data. “The entire 30-meter SRTM dataset is here in the archive, said Wayne Miller, Long Term Archive Project Manager. “We were chosen to archive and maintain the data from the beginning, and to make it available to users at no cost.”

From the outset, however, there was a caveat concerning that availability. NGA requested that SRTM 30-meter data be released only for the United States and that a modified version, with a less-detailed 90-meter resolution, be produced for the rest of the world’s land areas. “Of course, the lower resolution version wasn’t nearly as useful for projects needing detailed elevation data, explained Dean Gesch, EROS Research Physical Scientist, who along with Miller has been involved with the SRTM project from the start. Other global elevation datasets with higher resolutions soon became available from foreign agencies and for-profit companies, but these were expensive – too expensive for users in many developing countries working on very limited budgets. While no-cost SRTM 90-meter data wasn’t ideal for their needs, it was the only feasible option – until now.

This week, NASA, NGA, and USGS are releasing a newly processed, no-cost global SRTM 30-meter dataset that will become available in phases over the next 12 months. The first phase will consist of 30-meter elevation data for most of the African continent, which EROS staff have staged on EarthExplorer for free and easy access. Phase two will consist of 30-meter data for South America and the Caribbean.

Use of the new SRTM dataset will be enhanced through the efforts of the Working Group on Capacity Building and Data Democracy (WGCapD) within the Committee on Earth Observation Satellites (CEOS). USGS and EROS are key partners in CEOS. “Like the decision to make Landsat freely available throughout the world, the release of a no-cost global SRTM 30-meter dataset will help of a lot of people get closer to solving problems that rely on detailed elevation data, said Eric Wood, EROS Physical Scientist and current WGCapD Chair. “CEOS has been very active in promoting the idea of open access to all geospatial data. In working with NGA, CEOS has agreed that once the new SRTM 30-meter data are released, it will initiate a series of workshops around the world to contribute to that capacity building effort, Wood added.

Having been involved with SRTM for over 15 years, how do Gesch and Miller feel about this latest data release? “I think in some places and for some applications the move from 90-meter to 30-meter data will make a big difference for users, said Gesch. Miller agreed, and described the release as “quietly exciting, both for himself and for EROS. “To be honest, he said, “this is exactly what we were hoping for back in 1998 when SRTM really got started. We just patiently hung in there and did what we could to help make it happen.”

An entire world of data users will soon be very glad they did.

Priorities that Foster Change
October 20, 2014

Frank P Kelly
Director, Earth Resource Observation and Science (EROS) Center
Space Policy Advisor

We all have priorities in our work and private lives: projects to complete, appointments to keep, and households to run. The EROS Center has priorities, too, and Center management formulates these at the beginning of each fiscal year. However, fiscal year priorities are not simply a master "to-do" list, but activities that place extra attention on work that can further EROS toward its mission of contributing to the understanding of a changing Earth. "Fiscal priorities have the potential to bring about significant change in what we'll be doing in the year, or years, to come, says Center Director Dr. Frank Kelly. The priorities for FY 2015 are no exception.

You may recall that Dr. Kelly kicked off these Around the Center articles last January with a piece that focused on FY 2014 priorities. "We had established fourteen priorities for FY 2014and during that time, we've made great strides in addressing most, if not all, of them, Dr. Kelly explains. "For FY 2015, however, we consciously took steps to reduce the number, distilling out four priorities that together form a tightly knit framework for the year ahead and give a more focused view of the Center's future."

A recent memo from the Director's office outlined these four key FY 2015 priorities. They are (1) to implement a remote sensing system information capability; (2) to develop and initiate implementation of a user-focused information services capability; (3) to develop an EROS Land Change Monitoring Assessment and Projection (LCMAP) system; and (4) to execute a Center-wide process for planning, prioritizing, and measuring our work. Dr. Kelly stresses that these four priorities are all closely related, and that LCMAP lies at their core. "LCMAP is really the heart of EROS' future, Kelly explains, "and many of the steps we will take in FY 2015 will support development of the LCMAP system and long-range plans for where we will be going with it."

Alisa Gallant gave an overview of LCMAP in the August 5th Around the Center: A Glimpse of Tomorrow. The essence of LCMAP, as she described it, is to utilize the Landsat archive to its full advantage by providing users with application-ready data and land change assessments and products, while at the same time supporting a new Center capability for continuous land change monitoring. FY 2015 priorities 1, 2, and 4 all support the development of LCMAP to some degree. For example, the first priority – implementing a remote sensing systems information capability – involves EROS becoming the source of the Requirements Capabilities and Analysis for Earth

Observations (RCA-EO) for the Nation, which will identify what the user community most needs from the LCMAP system and how best to get it to them. (Look for more on RCA-EO next month.) Likewise, the second priority – developing a user-focused information services capability – addresses how EROS will transition from a provider of data to a provider of information services and solutions, a capability that will serve as the foundation for a wide variety of land change studies.

"I see the FY 2015 priorities as stepping stones to what we'll be building on for the next two to three years, says Dr. Kelly. "This is no small change we are embarking on at EROS, and these priorities will give us a firm footing from which to forge ahead into 2016, 2017, and beyond."