U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center – Fiscal Year 2015 Accomplishment Report

Compiled by Becky A. Foster

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CONTENTS

Acronyms

3D	Three Dimensional
3DEP	3D Elevation Program
AGRHYMET	Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center
AppEEARS	Application for Extracting and Exploring Analysis-Ready Samples
ASC	Advanced System Center
AST	Architecture Science Team
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AST-L1T	ASTER Level-1 Precision Terrain Corrected Registered At-Sensor Radiance (AST_L1T) product
BAER	Burned Area Emergency Response
BLM	Bureau of Land Management
BNB	Burned/Not Burned
C	Carbon
C3DMM	Centre of Excellence for 3D Mineral Mapping (Western Australian)
C&O	Communications and Outreach
CasaNOSA	NOAA's Observing System Architecture Database
CBA	Cost Benefit Analysis
CCMEO	Canada Centre for Mapping and Earth Observation
CDI	Community for Data Integration
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellites
CITT	Center Information Technology Team
CLU	Climate and Land Use Change (CLU) Mission Area
cm	Centimeter
CMGP	Coastal Maine and Geology Program
CMT	Collection Management Tool
CoNED	Coastal National Elevation Database
COTS	Commercial Off-The-Shelf
CSAS&L	Core Science Analytics, Synthesis, and Libraries
CSIRO	Commonwealth Scientific and Industrial Research Organization
DAAC	Distributed Active Archive Center
DANS	Data Archive and Network services
DEM	Digital Elevation Model
DLR	German Aerospace Center
DMCI	Deferred Maintenance and Capital Improvement
dNBR	differenced NBR
DOI	Department of the Interior
DOS-TEM	Dynamic Organic Soil version of the Terrestrial Ecosystem Model
DSA	Data Seal of Approval
EASI	EROS Architecture Study Implementation
EAST	EROS Architecture Study Team
ECV	Essential Climate Variables
e.g.	for example
eMODIS	expedited MODIS

EMT+	Enhanced Thematic Mapper +
EO	Earth Observation
EORES	Earth Observation Requirements Evaluation System
EOS	Earth Observing System
EPA	Environmental Protection Agency
EROS	Earth Resources Observation and Science (EROS) Center
ESA	European Space Agency
ESPA	EROS Science Processing Architecture
ESRI	Environmental Sciences Research Institute
ET	Evapotranspiration
EUS	End User Services
FEMA	Federal Emergency Management Agency
FEWS	Famine Early Warning Systems
FEWS NET	FEWS Network
FGDC	Federal Geographic Data Committee
FMIS	Fire Management Information System
FMNR	Farmer-Managed Natural Regeneration
FORE-SCE	FOREcasting SCEnarios of land use change (FORE-SCE) model
FPI	Fire Potential Index
FRI	Full-Resolution Composite Image
FTP	File Transfer Protocol
FY	Fiscal Year
g	gram
GA	Geoscience Australia
Gbps	Gigabits per second
GEMS	General Ensemble biogeochemical Modeling System
GEOSS	Global Earth Observation System of Systems
GeoTIFF	Georeferenced Tagged Image File Format
GHG	Greenhouse Gas
GIS	Geographic Information System
GLIMS	Global Land Ice Measurements from Space
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
GPP	Gross Primary Production
h	horizontal
HAG	Height Above Ground
HDDS	Hazards Data Distribution System
HDF	Hierarchical Data Format
HVAC	Heating, Ventilating, and Air Conditioning
IaaS	Infrastructure as a Service
IBM	International Business Machines (IBM) Corporation
IC	International Cooperator
ICPSR	Inter-University Consortium for Political and Social Research
ID	Identification
i.e.	that is
IHAS	In-House Applications as a Service
IMS	Integrated Master Schedule

INPE	Brazilian National Institute for Space Research
ISRO	Indian Space Research Organisation
IT	Information Technology
JIF	Journal Impact Factor
KBDI	Keetch-Byram Drought Index
km	Kilometer
L1T	Level-One Terrain-Corrected
LANDFIRE	Landscape Fire and Resource Management Planning Tools
LBS	Lidar Base Specification
LCMAP	Land Change Monitoring, Assessment, and Projection
LDCM	Landsat Data Continuity Mission
LF	LANDFIRE
LGN	Landsat 8 Ground Network
LGSWOG	Landsat Ground Station Operators Working Group
Lidar	Light Detection and Ranging
LIR	LDCM In Retrospect
LP DAAC	Land Processes Distributed Active Archive Center
LRS	Land Remote Sensing
LST	Land Surface Temperature
LST	Landsat Science Team
LTA	Long Term Archive
LTWG	Landsat Technical Working Group
LULC	Land Use Land Cover
MMT	Million Metric Tons
MODIS	Moderate Resolution Imaging Spectroradiometer
MPI	Max Planck Institute
MRLC	Multi-Resolution Land Characterization
MSFM	Multi-Senor Fire Mapping
MSO	Mexican Spotted Owl
MSS	Multispectral Scanner
MTBS	Monitoring Trends in Burn Severity
NaaS	Network as a Service
NAC	Network Access Control
NARA	National Archive and Records Administration
NASA	National Aeronautics and Space Administration
NAWQA	National Water Quality Assessment
NBR	Normalized Burned Ratio
NCCWSC	National Climate Change and Wildlife Science Center
NDFD	National Digital Forecast Database
NDVI	Normalized Difference Vegetation Index
NEP	Net Ecosystem Production
NGA	National Geospatial-Intelligence Agency
NGP	National Geospatial Program
NHD	National Hydrography Dataset
NLCA	National Land Change Assessment
NLCD	National Land Cover Database

NOAA	National Oceanic and Atmospheric Administration
OLI	Operational Land Imager
OPenDAP	Open-source Project for a Network Data Access Protocol
PaaS	Platform as a Service
PECAN	Plains Elevated Convection At Night
Pg	Petagram
PHP	Hypertext Preprocessor
PREPARED	Policy, Adaptation, Research and Economic Development (USAID climate adaption project)
QA	Quality Assessment
R&D	Research and Development
RCA-EO	Requirements Capabilities and Analysis for Earth Observation
RdNBR	relative dNBR
RE	Respiration
RISE	Resilience in the Sahel Enhanced
RSAC	Remote Sensing Applications Center
SaaS	Software as a Service
SDN	Software-Defined Networking
SDW	Spatial Data Warehouse
SIEM	Security Incident Event Management
SIPS	Standard Imagery Processing System
SLC	Scan Line Corrector
SLI	Sustainable Land Imaging
SSEBop	Operational Simplified Surface Energy Balance (SSEBop) model
START	SysTem for Analysis, Research and Training
TBDEM	Topobathymetric Digital Elevation Model
TIR	Thermal Infrared
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
UAS	Unmanned Aircraft Systems
UK	United Kingdom
UN REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
URL	Uniform Resource Locator
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USDA FS	U.S. Department of Agriculture Forest Service
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
v	Vertical
VIIRS	Visible and Infrared Imaging Radiometer Suite
VNIR/SWIR	Visible-Near/Shortwave Infrared
VTI	Value-Tree Information
WFDSS	Wildland Fire Decision Support System
WHO	World Health Organization

WRS-2	World Reference System 2
WWW	World-Wide Web

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Purpose

This desk reference provides an overview of the USGS EROS Center achievements throughout fiscal year (FY) 2015. 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 EROS mission "*contributing to the understanding of a changing Earth*" is accomplished through science and applications, systems development, information technology, and operations – as illustrated in this report.

The EROS vision is to be:

- The world's primary source and steward of remotely sensed land images of the Earth;
- Authoritative providers of land change science data, information, and knowledge; and
- Leaders in understanding how changes in land use, cover, and condition affect people and nature.

Additionally, these three vision statements serve as the framework for the USGS EROS Center's activities. EROS accomplishments are centered around the use of remotely sensed land data to monitor, assess, and project how changes in land use, land cover, and land condition affect people and nature.

As in the past, Center-wide priorities were established for 2015 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 highlights 2015 priority achievements focused on our view of the EROS future. For more detail, please refer to the write-up for each and the complete set of accomplishments in this report.

Develop an EROS Land Change Monitoring, Assessment, and Projection (LCMAP) System – The strategic intent of the USGS EROS LCMAP initiative is that EROS will provide structured, operational, ongoing, and timely collection and delivery of accurate and relevant data, information, and knowledge on land use, cover, and condition to support a wide array of science questions. This is in direct response to the USGS science strategy for climate and land use change research along with the broader global environmental priorities that span the USGS. A high priority is to move the LCMAP concept into the preliminary analysis, requirements, and design phase for a Center-level system that exploits the Landsat archive to full advantage. During FY 2015, LCMAP made substantial progress towards operational land cover mapping and monitoring (targeted for fall 2017). Progress was made in refining the core algorithm used for continuous monitoring and in testing data structures that better support continuous monitoring. 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.

Implement a Remote Sensing Systems Information Capability – Meeting the needs of the Earth observation data user community has been a priority since the Center's inception over 42 years ago. As EROS moves forward in supporting future Landsat missions and developing a LCMAP system that will provide users with analysis-ready data and land change assessments and products, determining what users need has taken on even greater importance. To that end, the Requirements, Capabilities, and Analysis for Earth Observation, or RCA-EO, has completed significant accomplishments during this last year. For example, the project completed the value-tree information (VTI) elicitation for the USGS (including 27 programs, over 500 subject matter experts, and 345 key products and services); established an operations concept and work flow for analysis, and initial population of the capabilities database; as well as, making excellent progress on the Earth Observation Requirements Evaluation System (EORES) application, which is a tool being developed to support the project. EORES will be a unique resource, a compilation of user requirements and Earth observation capabilities with more depth and detail than anything the Earth observation community has seen before, one that will enable decisionmakers and program managers to plot what users need against what is possible, or potentially possible, in terms of gathering Earth observation data.

Develop and Initiate Implementation of a User-Focused Information Services Capability – As mandated by public law, the USGS is to ensure the long-term preservation, continued population, and timely access to the Nation's land remote sensing data holdings. This data management and access capability serves as a spring board, where by EROS will begin implementation of a user-focused information services capability as a consequence of our data services paradigm shift – moving from a provider of data to a provider of information services and solutions. In FY 2015, the Data Services Branch consolidated user services support activities which included the implementation of a Landsat product control board to better identify product updates, product changes, and user impact and user notification methodologies. Also, user services increased tier 1 and tier 2 support for Landsat customers and initiated the implementation of an application tool for managing and documenting customer interaction. More and more attention will be placed on a cohesive and aggressive strategy for communication, applications services, outreach, and other user and stakeholder support that draws upon shared responsibilities across the Center to being authoritative providers of land change science information and knowledge.

Execute a Center-wide Process for Planning, Prioritizing, and Measuring our Work – EROS continued to improve and evolve processes for planning, selecting, and "doing the right projects" to better focus their efforts on achieving the EROS mission. Key elements of the EROS multi-year annual planning process were documented, and the schedule was updated and refined. From fall 2014 to spring 2015, executive and project managers from around the Center contributed to a series of planning and prioritization efforts. These included a priority-gathering questionnaire; a findings-and-recommendation offsite; a criteria-based, work package prioritization exercise; and project-level peer reviews. Results from these concerted efforts contributed to a targeted set of Center-wide FY 2016 priorities issued May 1, 2015, followed by a coordinated set of proposed FY 2016 work plans and budgets that were submitted to six USGS programs from July-September 2015. FY 2015 culminated with the EROS Director issuing the 2016-2021 EROS Strategic Plan. This Plan sets the direction of EROS leadership and management for the next 5 years, as we move into the future.

Additionally, as we look to 2016 and beyond, it is essential that we continually challenge our future directions in science, research, and applications; technology; products and services; and stewardship. By better understanding and bringing more focus to a set of key directions, strategic actions, and their intent as released at the end of FY 2015 in "Strengthening the Future of EROS, USGS EROS Strategic Plan 2016 to 2021, we will create the opportunities for making our Climate and Land Use (CLU) Mission Area and EROS foundations even stronger as we move into the next decade.

To that end, the 2016-2021 EROS Strategic Plan, combined with a renewed EROS Science Strategy, conveys a targeted and focused set of challenges and opportunities for moving EROS forward and further strengthening our mission of "*contributing to the understanding of a changing Earth.*"

EROS is a world-class Center, with a reputation that is rooted in the Center's long-standing record of science, service, and stewardship as a land remote sensing science and data center. Our foundation is strong, and our opportunities are many.

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

Visions, Revisions, and Revolutions

On September 30, 2015, Director Frank Kelly released the EROS Strategic Plan for 2016-2021. The Plan represents a blueprint for strengthening the future of EROS, or a vision for where we are going.

The Strategic Plan identifies six key areas around which EROS activities will be centered for the next 5 years:

1. Land Change Monitoring, Assessment, and Projection (LCMAP) – *i.e.*, the foundation for land change science at EROS;
2. Sustainable Land Imaging and Ground System Optimization – everything related to Landsat 9 and beyond in the context of Earth observation as it involves EROS;
3. Calibration and Validation – solidifying EROS' position as a global Cal/Val Center of Excellence;
4. EROS Enterprise Architecture – aligning EROS resources to better support its primary activities;
5. Mundt Federal Center Consolidation – expanding opportunities to co-locate key partners with EROS; and
6. Workforce Development – training, retaining, and recruiting an increasingly diverse, skilled, and creative team of employees.

At first glance, what connects and unifies these strategic directions for EROS' efforts in the near future might not seem obvious. In one way or another, however, they all work toward addressing our mission of "*contributing to the understanding of a changing Earth*" and the vision for a future for which that mission fosters: EROS as the world's primary source and steward of remotely sensed land images of the Earth; as an authoritative provider of land change science data, information, and knowledge; and as a leader in understanding how changes in land use, cover, and condition affect people and nature.

The scope and intent of the EROS mission presents overarching and long-term scientific and application challenges throughout the Center. To address these challenges, a new EROS Science Strategy was developed that identified three key science goals. These goals, which form the foundation and topical framework of the Center's science and applications priorities, are:

- improving global land change monitoring through remote sensing research;
- understanding the temporal and geographic dimensions of land change; and
- working to better comprehend the connections between climate and land change and their combined impacts on human and natural systems.

It is also with these science goals in mind that our science and applications agenda has recently undergone a significant revision, and these seven new science focus areas serve as a construct for moving forward:

1. Remote Sensing Research and Development (R&D) for Land Change;
2. Land Change Products – Land Change;
3. Land Change Products – Fire;
4. National and Regional Land Change Assessments;
5. Vegetation, Water, and Climate Dynamics;
6. Coastal Changes and Impacts; and
7. Early Warning for Food Security.

Each of these focus areas will be led by a principal investigator and comprised of both Government and contract staff working together to plan the science and research goals and carry out key objectives. This revision allows for more emphasis on innovation and impact; on creating a collaborative environment that encourages teamwork; and on raising the visibility, both internally and externally, of what is being accomplished at EROS.

If this renewed science agenda sounds revolutionary, it is. In the late 1980s and early 1990s, EROS science transitioned from a series of localized remote sensing and geospatial data applications to the current emphasis on large-area mapping and monitoring. This agenda represents a second revolution, one that is reshaping science at the Center in ways that will enable us to become world-class contributors in the quest to better contribute to the understanding of our changing planet.

Fiscal Year 2015 in Review

Science and Applications Activities

The Center's science and applications activities are primarily focused on land change science. Landsat and land remote sensing is central to our land change science agenda and goals, which are aligned with the DOI and USGS strategic science goals and priorities set by the Climate and Land Use Change (CLU) Mission Area, and our EROS vision. This level of understanding presents challenges to EROS' science and applications that takes full advantage of the Center's extensive national and global archive of remotely sensed data.

As well, our partners and collaborators are important to our science and applications activities and 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.

Global Land Change Monitoring through Remote Sensing Research

As one of the world's largest remote sensing centers, EROS must maintain strong, relevant remote sensing science capabilities. The science focus area primary to supporting this goal is **Remote Sensing Research and Development (R&D) for Land Change**, which is engaged in research that focuses on (1) remote sensing data quality and consistency, (2) algorithms and strategies for characterizing geophysical and biophysical surface properties and dynamics that effect land change, and (3) strategies for validation of environmental and remote sensing based products. 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 an analysis-ready Landsat archive used to feed an agile capacity to provide timely assessments for decisionmakers (fig. 1). During FY 2015, LCMAP made substantial progress towards operational land cover mapping and monitoring (targeted for fall 2017). Progress was made in refining the core algorithm used for continuous monitoring and in testing data structures that better support continuous monitoring. Initially, LCMAP will be implemented for the conterminous United States and subsequently will be 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 will 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, LandCarbon Project, and Climate Research and Development Program. Key scientific and technical input has been provided by the USGS and National Aeronautics and Space Administration (NASA) Landsat Science Team, U.S. Forest Service (USFS) Landscape Change Monitoring Systems Team, Boston University, South Dakota State University, State University of New York – Environmental Sciences and Forestry, and Western Kentucky University. The list of partners is expanding as LCMAP matures. For further information, contact USGS EROS, Alisa Gallant, gallant@usgs.gov.

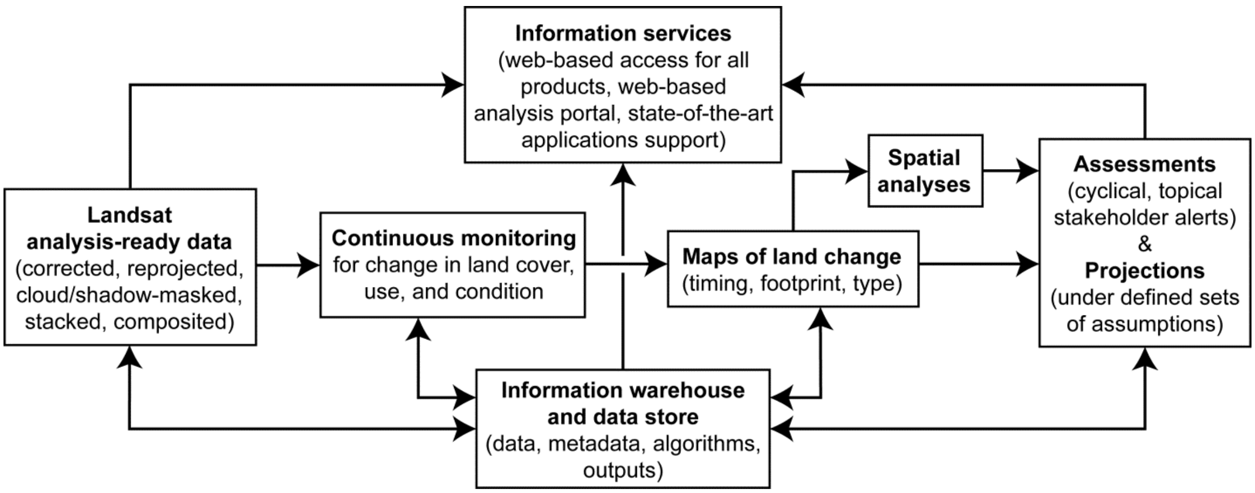


Figure 1. Conceptual schematic of the main, integrated components of the Land Change Monitoring, Assessment, and Projection initiative.

Release of Provisional Climate Data Record and Essential Climate Variable Products

The USGS Land Remote Sensing Program has been supporting the development of Landsat science products, climate data records (CDRs) and essential climate variables (ECVs), derived from historical and current Landsat data acquired by the thematic mapper (TM), enhanced thematic mapper plus (ETM+), and operational land imager (OLI) instruments. The objectives are to provide continuity of observations and measurements to support modeling and decision support for land management, construct long term data records to establish historical trends and enable future projections of landscape state and condition, enable scientific assessments of land surface change, and to remove the burden of processing from the end user. Specific to FY 2015, we have released a provisional Landsat 8 OLI surface reflectance CDR product, and provisional TM/ETM+ burned area and dynamic surface water extent ECV products, as illustrated in figures 2, 3, and 4.

The Landsat 8 OLI surface reflectance algorithm uses a lookup table based on radiative transfer modeling of Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible and Infrared Imaging Radiometer Suite (VIIRS) data, atmospheric water vapor and aerosol concentration derived from Terra MODIS data, and geopotential height calculated from digital elevation model (DEM) data. The burned area product is generated using a boosted regression tree model that was developed from training data extracted from burned areas identified by the Monitoring Trends in Burn Severity (MTBS) project that is applied to Landsat TM and ETM+ data. The dynamic surface water extent product is generated from a series of spectral indices derived from Landsat TM and ETM+ data. The burned area and dynamic surface water extent algorithms also include topographic parameters derived from DEM data to minimize errors of commission from terrain shadows.

The provisional Landsat 8 surface reflectance product has been made publicly available for evaluation and feedback since December 2014. In March 2015, a time series of provisional burned area and dynamic surface water extent products were made available for selected areas for stakeholder evaluation and feedback. Manuscripts describing the science data processing algorithms and methods by which product uncertainties are characterized are currently being written for submission as peer reviewed journal publications. User guides have been written for all products and are available online.

Since the Landsat data policy was modified in 2008 to make the data openly available at no cost, the user community is increasingly accessing the Landsat standard level-1 products as well as the more recent Landsat science products. There has been a growing emphasis on exploiting the temporal richness of the archive and therefore a commensurate need to deliver information, not merely data, to the scientific research and applications community. The development of Landsat science products is directed towards meeting these needs. For further information, contact USGS EROS, John Dwyer, dwyer@usgs.gov.

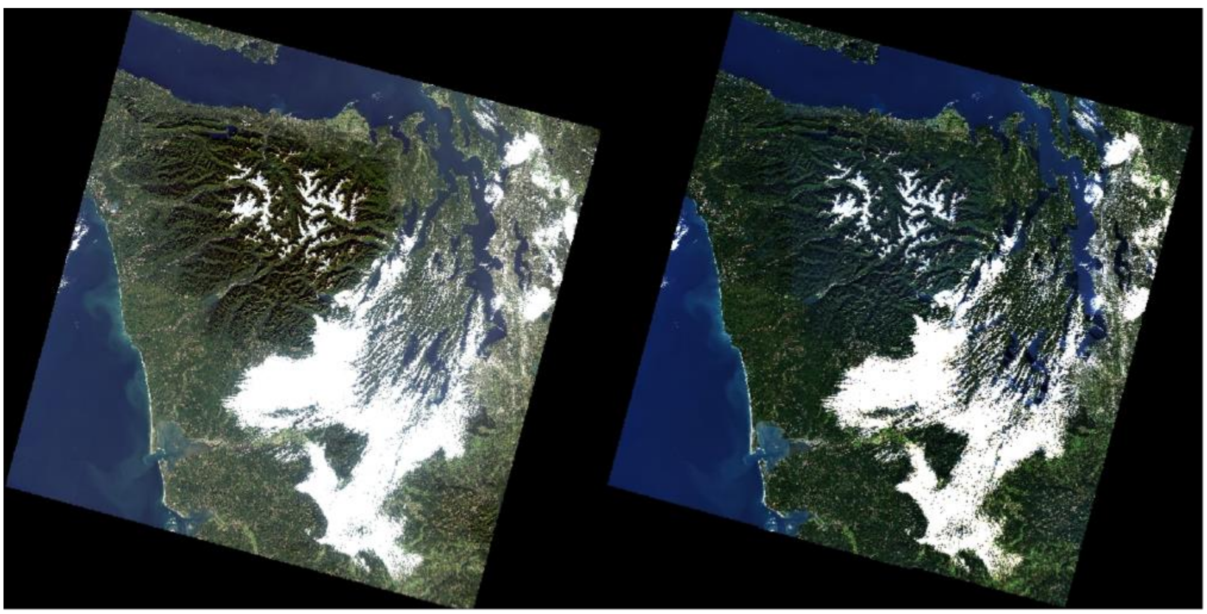


Figure 2. Operational land imager (OLI) surface reflectance. This figure shows OLI top of atmosphere reflectance (left) and atmospherically corrected surface reflectance (right).

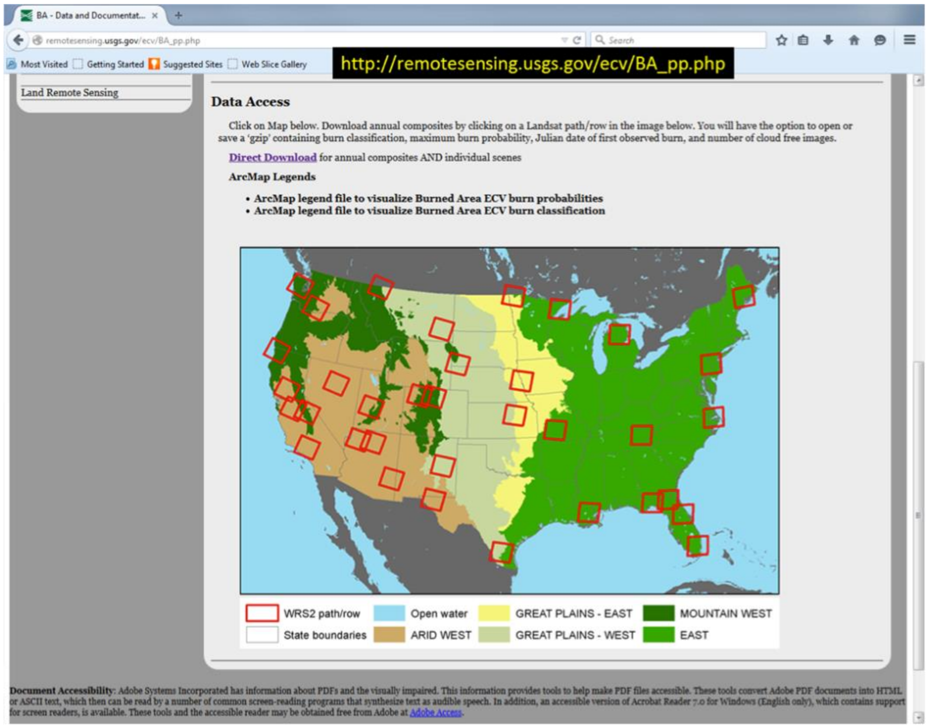


Figure 3. Provisional burned area availability. This map shows the World Reference System 2 (WRS-2) path/row locations for which provisional burned area essential climate variable (ECV) products are available for stakeholder evaluation from http://remotesensing.usgs.gov/ecv/BA_pp.php.

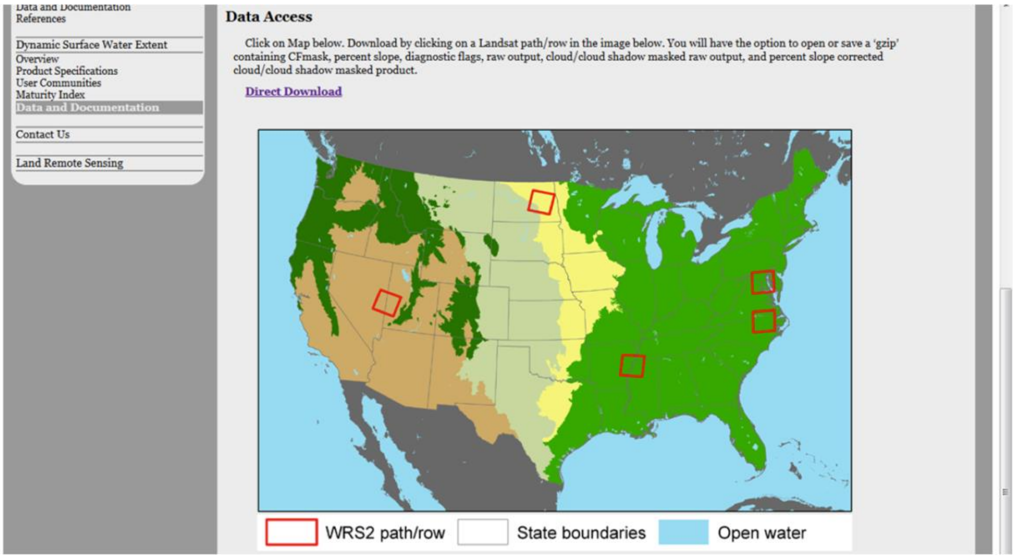


Figure 4. Provisional dynamic surface water extent availability. This map shows the World Reference System 2 (WRS-2) path/row locations for which provisional dynamic surface water extent essential climate variable (ECV) products are available for stakeholder evaluation from http://remotesensing.usgs.gov/ecv/SWE_pp.php.

USGS Continues Lidar Height Above Ground Investigations

With continued funding from the Land Remote Sensing Program, USGS scientists furthered 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. 5). 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.

Previous investigations revealed that, even when using lidar data collected under common specifications and delivery requirements, subtle structural differences between datasets were widespread. These variations significantly complicated the development of automated routines to produce consistent analysis-ready HAG output products. Similarly, it was discovered that the various commercial off-the-shelf (COTS) lidar software packages have different tolerances for such variances. Hence, additional data preparation steps had to be implemented to place all data in a structurally consistent state. This process continues to evolve as new variations continue to be identified.

In practice, variations in lidar point density within and across projects had an unforeseen influence on HAG calculations (fig. 6). This disruptive effect has also been noted by other researchers; further research into a more robust normalization process is needed.

HAG project data 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 (figs. 7 and 8). 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, National Oceanic and Atmospheric Administration (NOAA), NASA, and the Environmental Science Research Institute (ESRI).

USGS Core Science Analytics, Synthesis, and Libraries (CSAS&L) became interested in the HAG products and their utility in assessing biomass, biodiversity, and habitat quality. Using 2011 lidar data and HAG products as a foundation, a team based at the Eastern Geographic Science Center conducted a pilot study in the Great Smokey Mountains National Park (fig. 9). A wide array of ecological and biological metrics were correlated to the lidar and HAG data, sparking interest in a phase two project, with support from the Northern Rocky Mountain Science Center, the Pautuxent Wildlife Research Center, the National Wetlands Research Center, and the National Park Service Inventory and Monitoring Program.

In addition, HAG products came to the attention of John Young in the Ecosystems Mission Area, and were generated for many of the areas impacted by Hurricane Sandy. Pre-hurricane lidar data were processed under the HAG project. The processing tools and transition training were then transferred to the vegetation mapping staff who are presently processing the newer post-hurricane datasets. Collaboration between the HAG team and the Ecosystems scientists continues as the process is refined to meet specific research requirements.

HAG models were produced throughout FY 2015 and are now available for 146 projects (76 produced in FY 2015), totaling approximately 350,000-square kilometers (fig. 10). These projects cover all or part of 543 counties in 41 states, and encompass over 14 terabytes of data and 545-billion points.

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 USGS EROS, Karl Heidemann, kheidemann@usgs.gov.

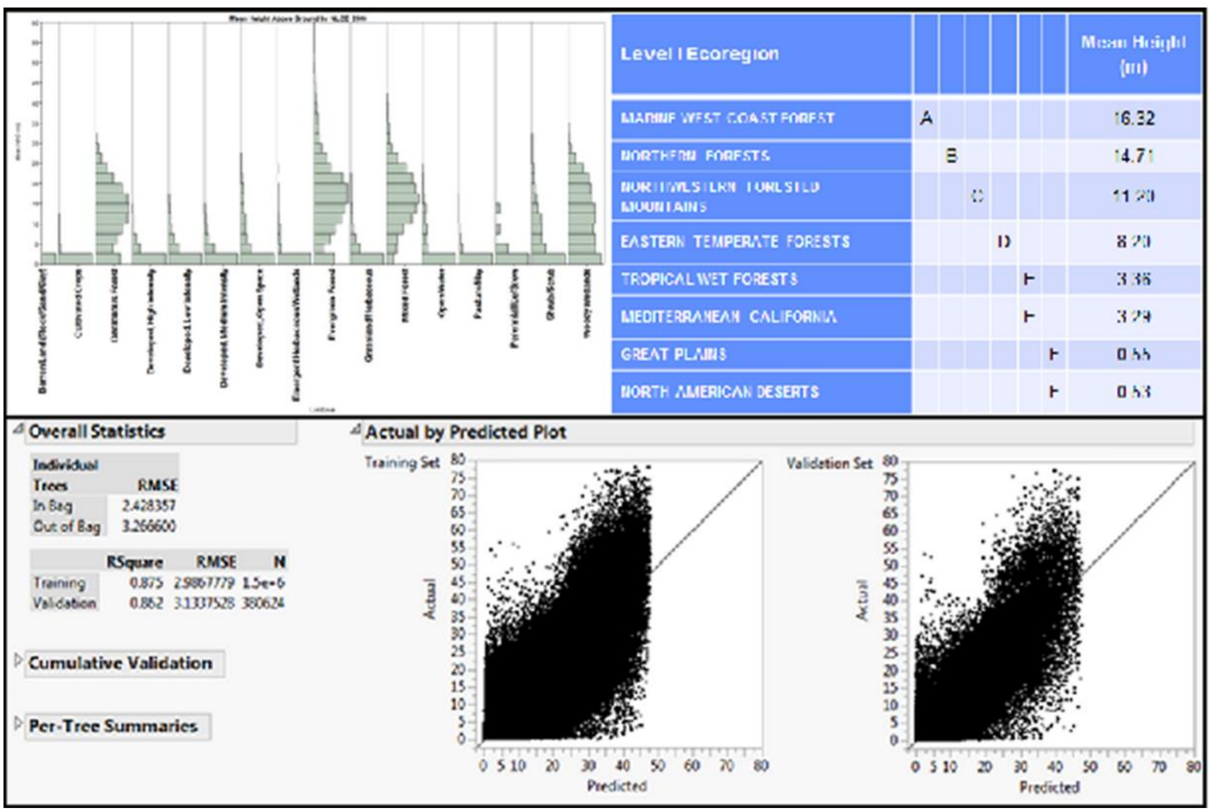


Figure 5. Examples of descriptive vegetation metrics and characterizations derived from lidar point cloud data and height above ground models.

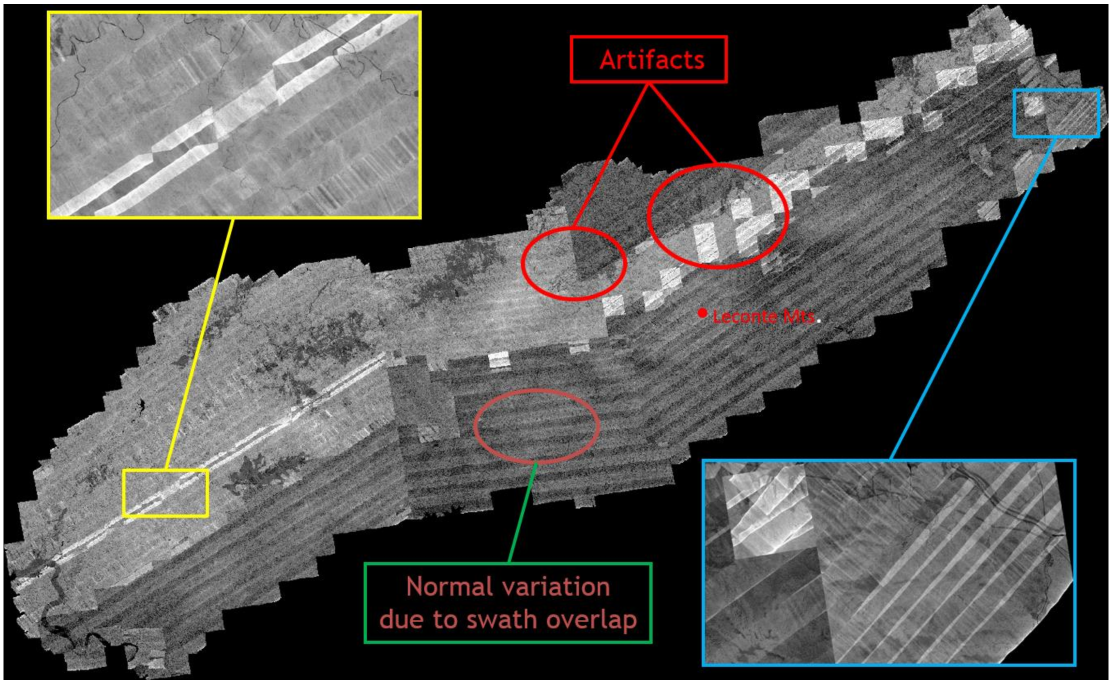


Figure 6. Examples of irregular variations of lidar point density within individual collection projects.

Figure 7. Plains Elevated Convection At Night Mobile Radar systems being supported by height above ground first reflective surface data products.

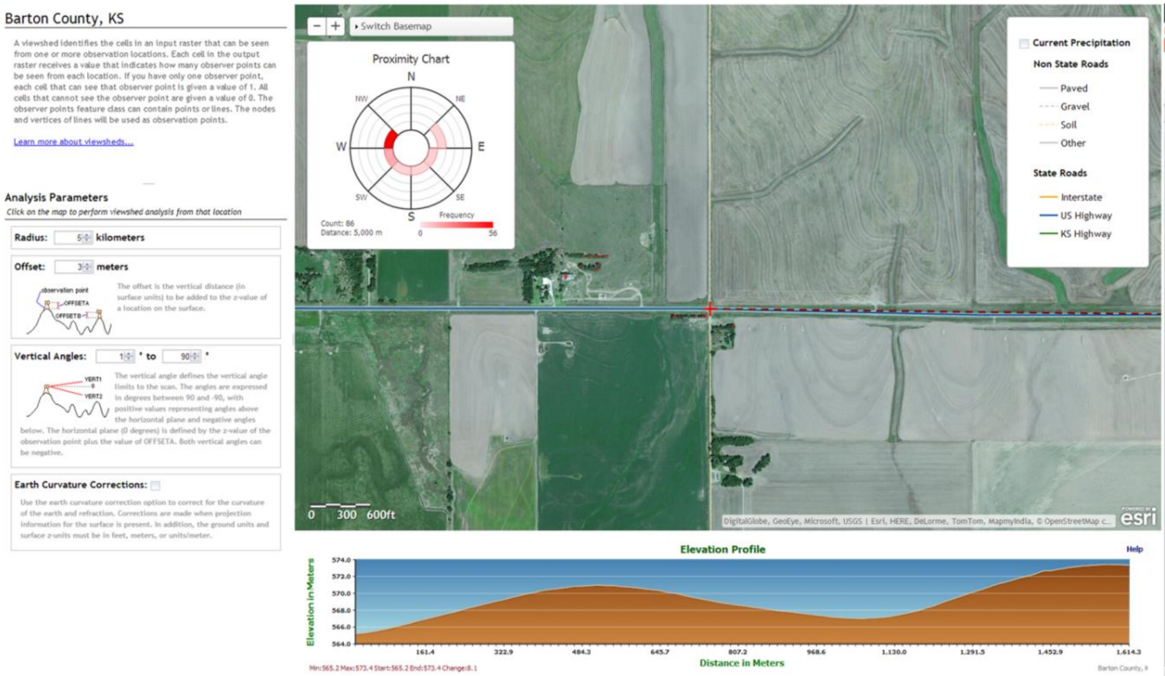


Figure 8. First reflective surface and viewshed analysis for the Plains Elevated Convection At Night study.

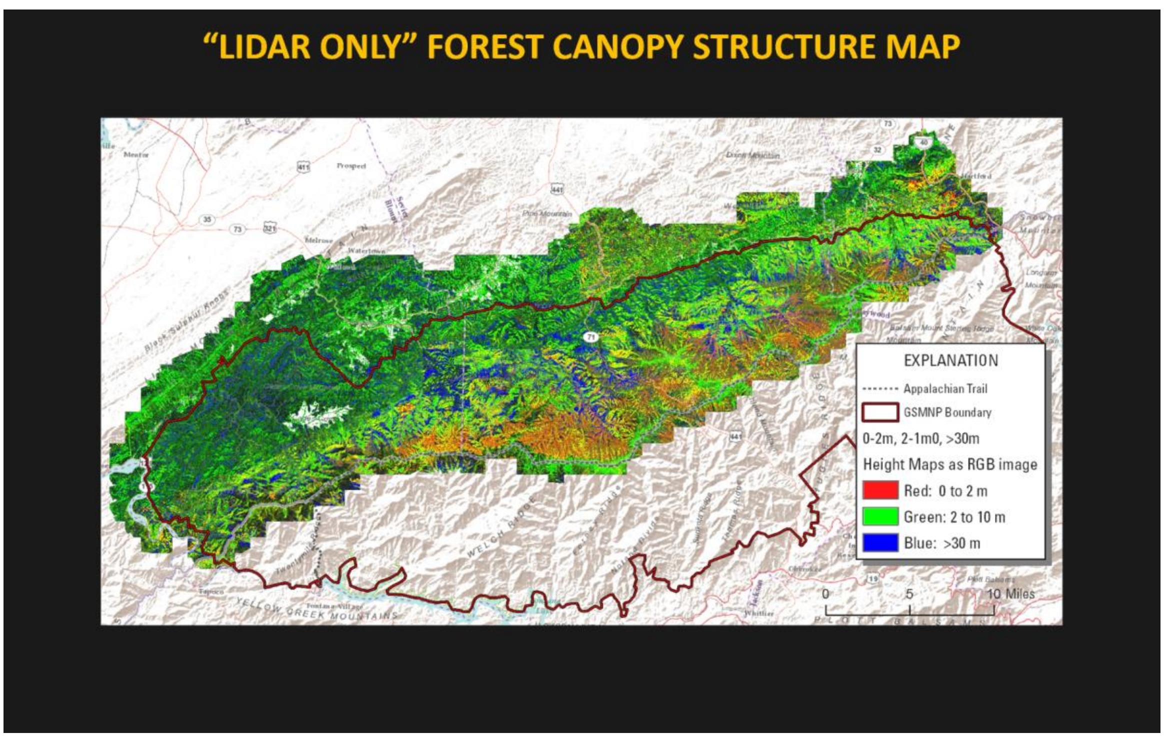


Figure 9. Forest structure map produced by the USGS Core Science Analytics, Synthesis, and Libraries over the Great Smokey Mountains National Park (Tennessee side) using lidar and height above ground products and processes.

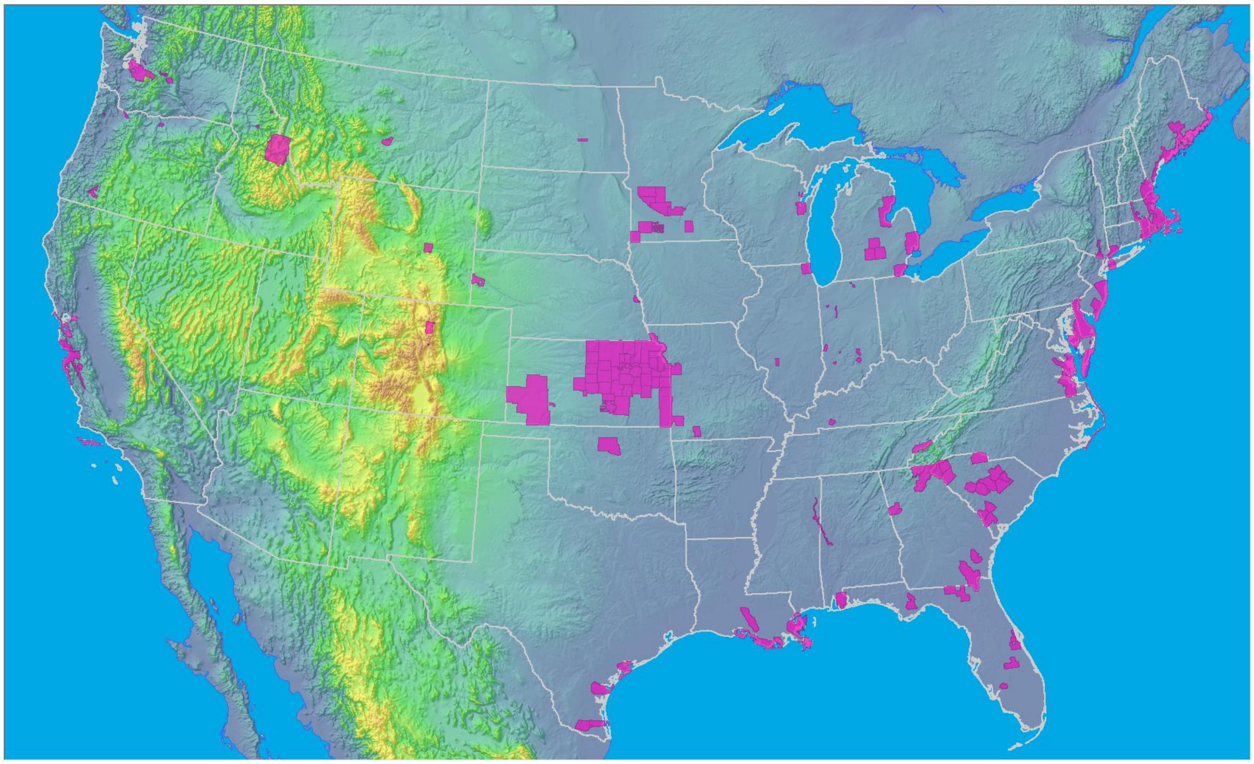


Figure 10. Areas for which lidar-derived height above ground products were completed at the close of FY 2015.

USGS Develops Ele-Hydro Geographic Information System Data Dictionary

Over the last two decades, the geospatial community migrated from building digital elevation models (DEMs) from traditional photogrammetric sources to lidar point cloud data. While lidar offers higher detail and accuracy, its lack of traditional breaklines prevents water bodies from being represented in a lidar DEM with the same character as found in most all traditional DEMs. Responding to widespread requests from users, the USGS began requiring that lidar-based DEMs be "hydro-flattened," a process that modifies the water surfaces to mimic their appearance in a traditional DEM. This is almost always accomplished using 3D breaklines to define the perimeter of each water body. Delivery of these breaklines is now a required deliverable on all USGS supported lidar projects.

The USGS 3D Elevation Program (3DEP) standard product is a topographic DEM. Interest has grown in offering hydrologic, or hydro-enforced, DEMs as well. These can be created from the same data as the standard DEM, with additional breaklines. Also increasing are requests for greater detail in the national hydrography dataset (NHD), inclusion of elevation information in the NHD, and improved alignment of NHD hydrography to the newer lidar-derived 3DEP elevation models.

The coincidence of these needs has presented the USGS with an opportunity to improve data and services for both elevation and hydrography, by having additional breaklines (beyond those required for hydro-flattening) collected by the lidar data producers. These breaklines can then be used to create various types of surface models for 3DEP (figs. 11, 12, and 13), and to expand and update the NHD. As collection would be performed by many different vendors, and potentially other agencies or users, a common geographic information system (GIS) data structure is needed to enable common tools for efficient ingest and processing. Further, care must be taken to ensure that the linework is collected and attributed in such a way that it is natively useful to both the 3DEP and NHD programs.

Working collaboratively with USGS representatives of the NHD, Water Sciences, and 3DEP, an EROS-led team developed a GIS data dictionary that incorporates the existing NHD attribution, adds attribution necessary for elevation processes, and defines attribute domains and topology to meet all stakeholders' requirements (fig. 14). Refined and tested by collecting pilot areas in various terrains, the Ele-Hydro Data Dictionary is being presented for program review in early FY 2016 and is expected to be incorporated in version 2.0 of the USGS National Geospatial Program (NGP) Lidar Base Specification (LBS) later in FY 2016.

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 USGS EROS, Karl Heidemann, kheidemann@usgs.gov.

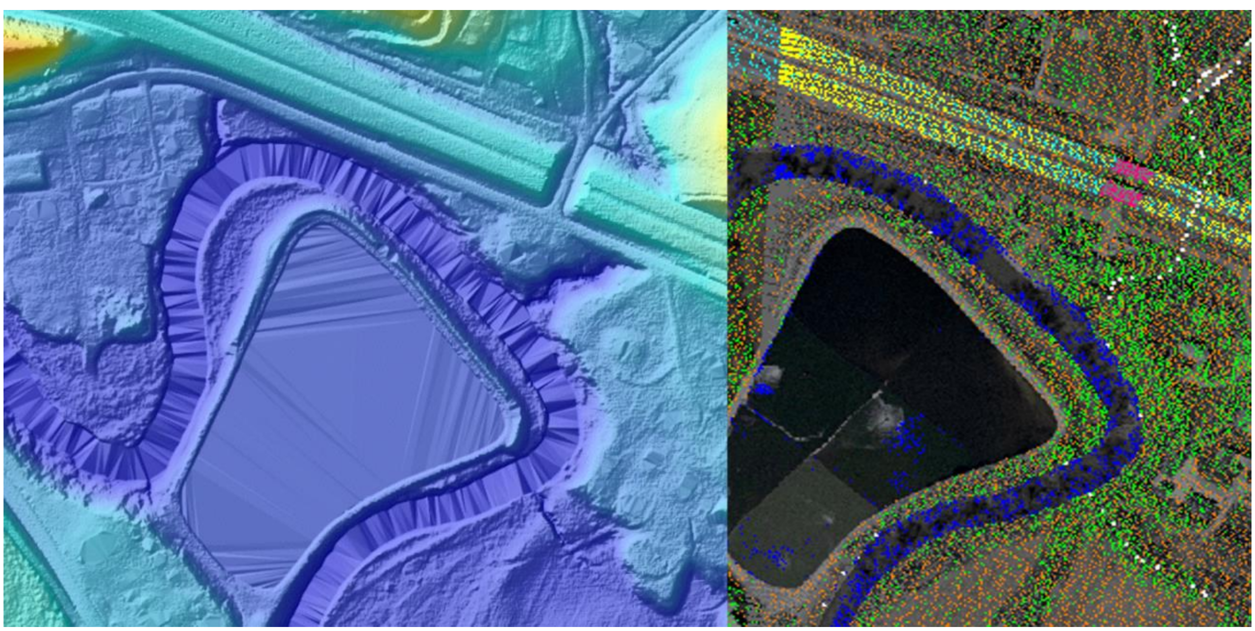


Figure 11. A digital elevation model (DEM) derived solely from lidar points, demonstrating the unwanted artifacts across water surfaces. As-is, this DEM cannot easily be used for either hydrologic modeling or general contour mapping.

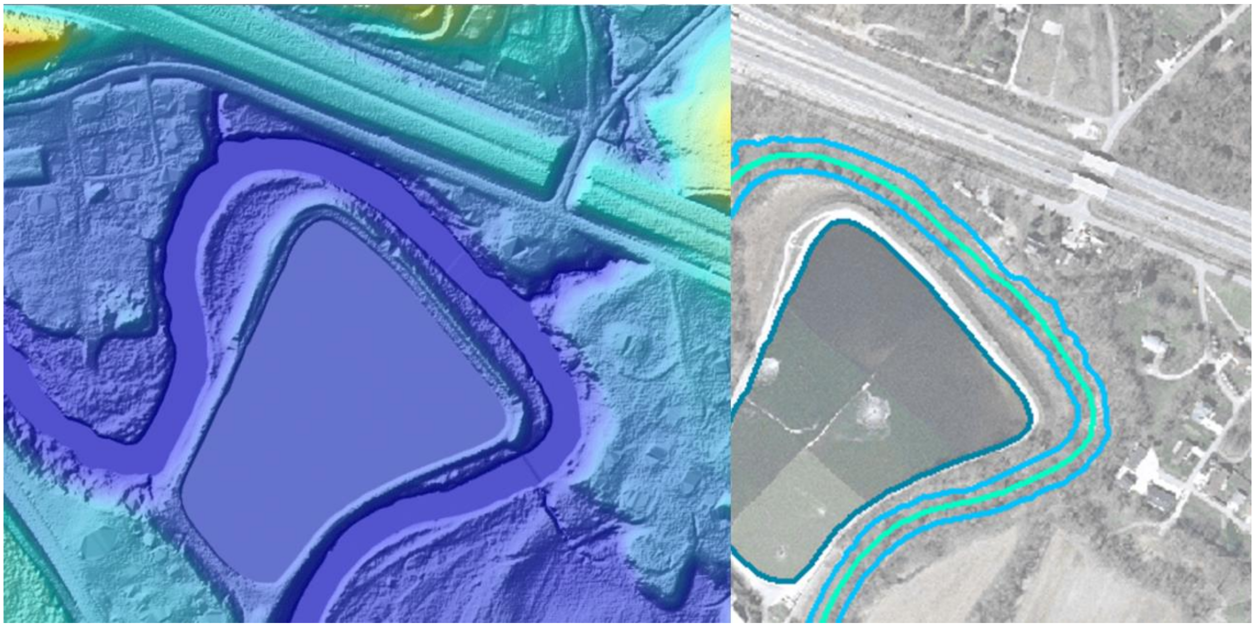


Figure 12. A hydro-flattened digital elevation model (DEM), showing how a more natural water surface is achieved by incorporating minimal breaklines. This is the topological DEM currently maintained by the 3D Elevation Program.

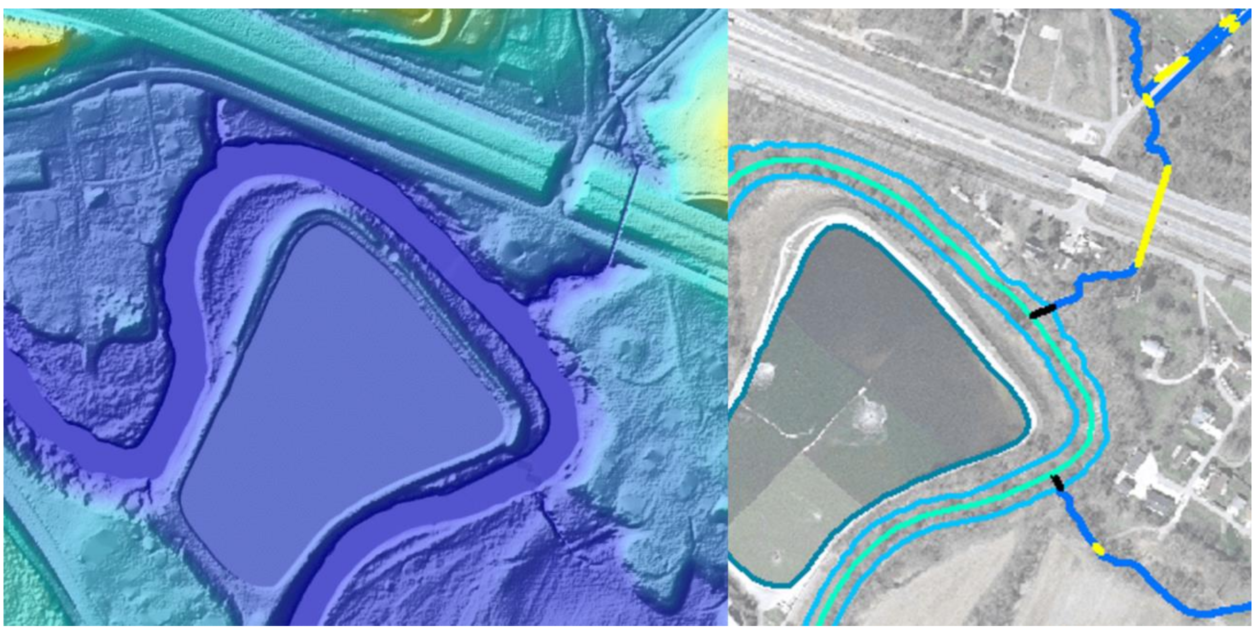


Figure 13. A hydro-enforced digital elevation model (DEM), developed by including additional breaklines to model water flow. Open channels are more cleanly defined, and simply underground structures (culverts) are incorporated into the surface. This hydrologic DEM can be used for surface water modeling not possible with topographic DEMs.

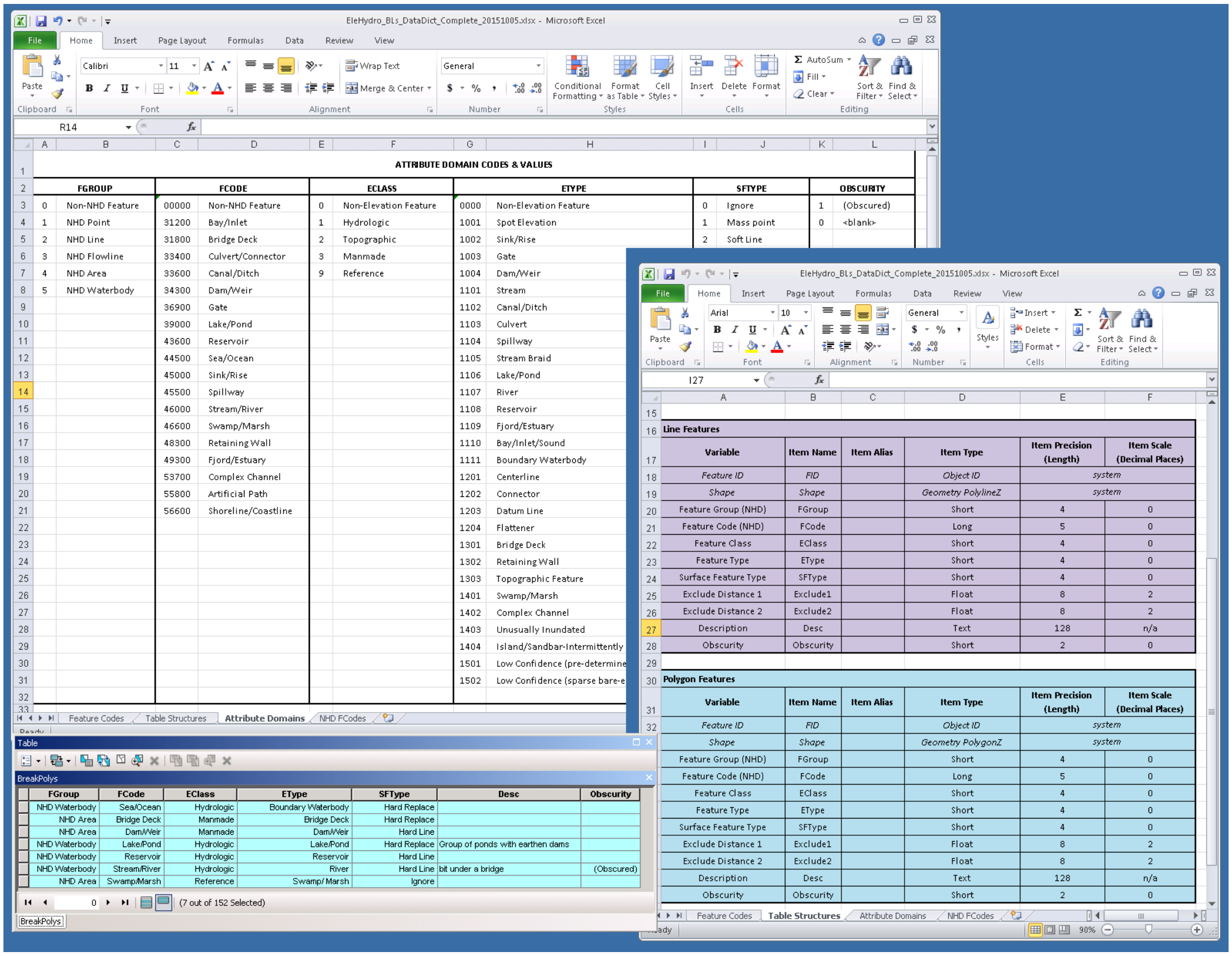


Figure 14. Several tables from the data dictionary detailing attribute domains and table structures, and completed attribute table from the sample test collections.

Analysis of Vietnam Tropical Forest Degradation using Landsat Time Series Data

According to the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (UN REDD) in developing countries, it is important to establish a national forest monitoring system using remote sensing and ground based assessments for conducting carbon inventory and assessments of forest degradation. Landsat data have been systematically acquired for many portions of the Earth since 1972, and are now available at no cost via the Internet. The data from Landsat have proven value for a large array of global monitoring applications. 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 powerful for assessing status and trends throughout a wide range of 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 focused 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 agroforestry, 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 enabled us to better interpret the Landsat imagery from the region.

During 2015, we conducted analyses of Landsat time series data from 2000-2014. These indicate that many of the areas within the Lam Dong Province have experienced significant change, with many areas showing evidence of decreasing forest. Figure 15 illustrates Landsat imagery from 1973-2014 for the area in Vietnam that includes the Cat Tien National Park. The areas with the greatest levels of changes are associated with coffee, cashew, and Acacia plantations, which 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 hosted two Vietnamese scientists during July and August, and provided them with training to help them better develop their own national forest monitoring program for Vietnam. We also participated in workshops arranged in part by the SilvaCarbon project in Bangkok, Thailand, and Ho Chi Minh City, Vietnam, to help facilitate the transfer of technical processes and insight for monitoring forest degradation to scientists and natural resource managers in eastern Asia. For further information, contact USGS EROS, James Vogelmann, vogel@usgs.gov.

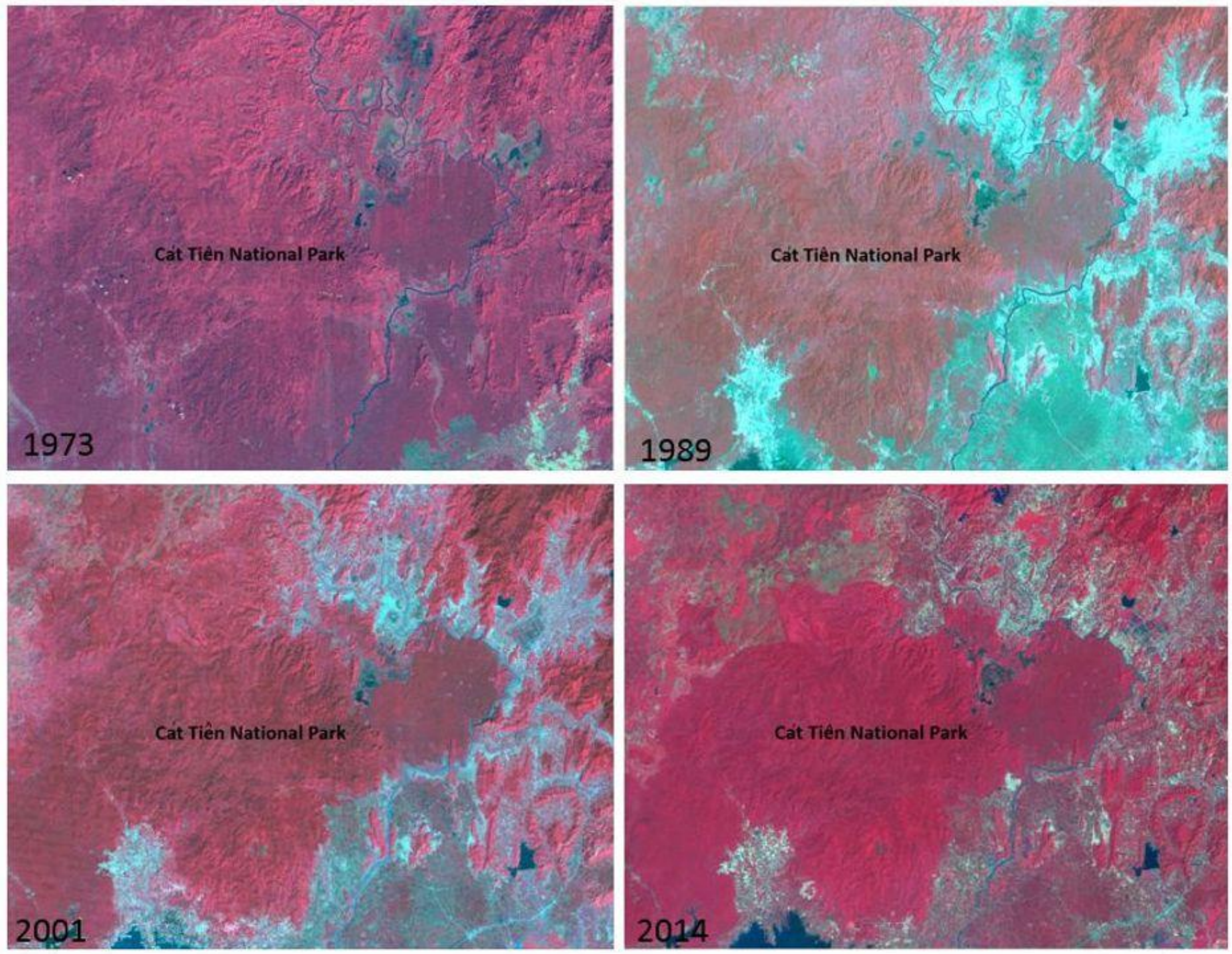


Figure 15. Landsat imagery from 1973-2014 for the area in Vietnam that includes Cat Tien National Park. Most of the red color in these images indicate forest cover. The images indicate that most of the region was forested in 1973. Between 1973 and 1989, substantial deforestation occurred (areas of grey). By 2001 and 2014, many of the areas that had been deforested are plantations of coffee and other woody crops, which have a reddish color in the images. Few of the changes that occurred over the time period occurred inside of Cat Tien National Park, indicating the park is affording protection status to the forests within the park boundaries.

Temporal and Geographic Dimensions of Land Change

This EROS science strategy goal calls for generating the geospatial and statistical data and information, and conducting the analyses that are needed to explain basic land use, land cover, and land condition topics. The primary science focus areas include **Land Change Products – Land Cover**, which concentrates on planning, implementation, and production of the National Land Cover Database and other land cover products. Scientists develop mapping algorithms for generating the consistent and accurate geospatial land cover products for the Nation and or conduct research to analyze the temporal and geographic dimensions of land use and cover change and provide relevant information for land management agencies, resource managers, and decisionmakers; **Land Change Products – Fire**, which focuses on three broad areas related to fire: planning, implementation, production and update of land cover based datasets that characterize vegetation and fire fuels; monitoring fuel conditions and forecasting the probability of fire; and mapping, assessing, and understanding short- and long-term landscape impacts of fire at local, regional, and national scales; **National and Regional Land Change Assessments**, which is engaged in research, analyses, and syntheses of datasets and products derived from remotely sensed imagery and ancillary information to develop assessments of the rates, causes, and consequences of natural and human-induced land change; and **Vegetation, Water, and Climate Dynamics**, which supports improving our understanding of how climate influences and is affected by changes in land cover, use, and condition. Key accomplishments are given in the following sections.

National Land Cover Database 2011 for Alaska

The USGS, working in partnership with the interagency Multi-Resolution Land Characteristics (MRLC) Consortium, completed the production of the National Land Cover Database (NLCD) 2011 for Alaska. 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 19 classes of land cover in Alaska and also define the degree of surface imperviousness in urban areas. Working in partnership with the U.S. Forest Service, a tree canopy product was also completed for coastal Alaska.

New for Alaska NLCD 2011 is the creation of a land cover change product quantifying 10 years of land cover change since 2001 (fig. 16). This innovation integrates NLCD 2001 and 2011 to provide a 10-year land cover change story for the state. The dominant driver of change in the state over the last 10 years has been wildland fire. 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 more information on NLCD and to obtain NLCD data visit http://www.mrlc.gov/, or contact Collin Homer, USGS EROS, homer@usgs.gov.

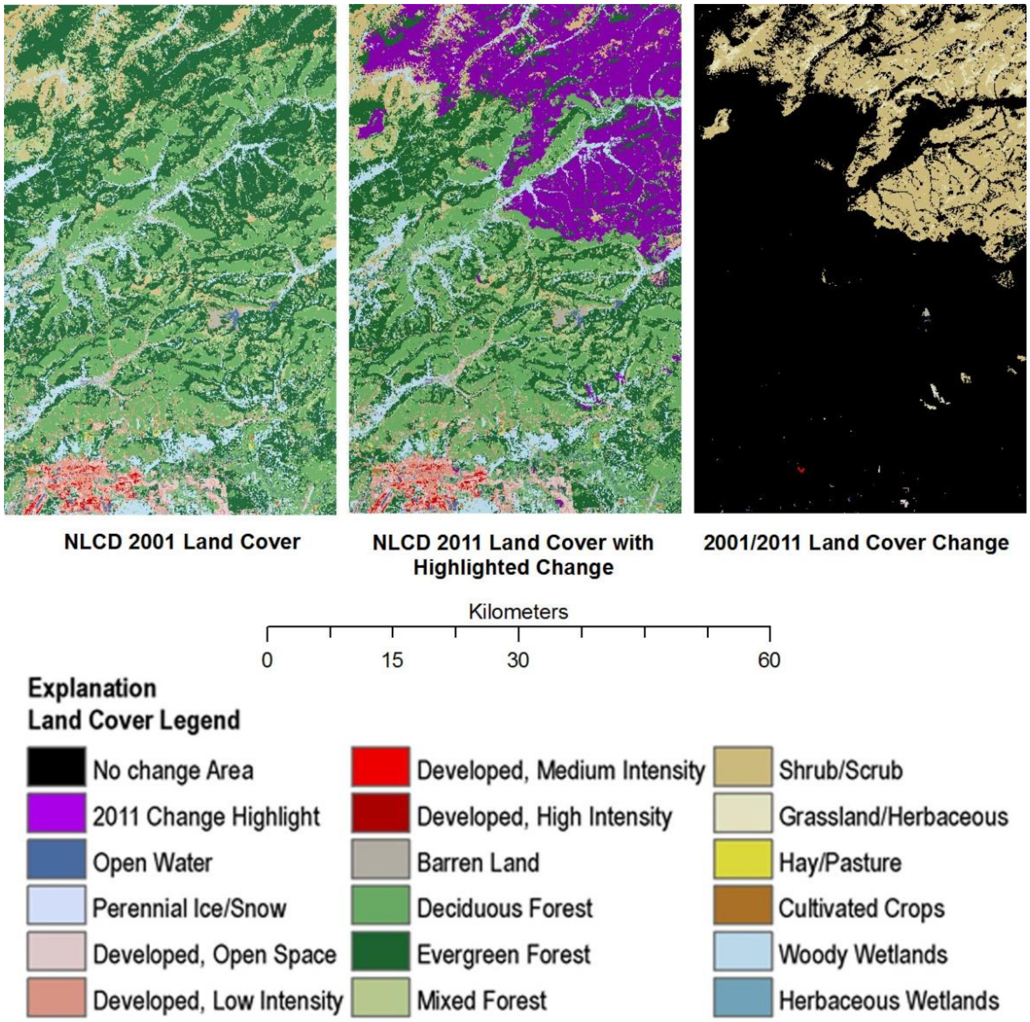


Figure 16. An example of land cover change in the vicinity of Fairbanks, Alaska, from 2001 to 2011. The left panel shows the status of the land cover in 2001 (forests in green, shrublands in brown, wetlands in blue, and urban in red). The middle panel shows the updated land cover in 2011, and the right panel shows areas where change occurred over these 10 years. This change was caused by a wildfire which converted large areas of forests to shrub and grasslands (shades of light brown in the right panel). Approximately a million acres burn across Alaska each year.

Characterization and Monitoring of Shrubland Components in the Western United States

The USGS EROS National Land Cover Database team in collaboration with the Bureau of Land Management (BLM) is producing the most comprehensive remote sensing based quantification of western United States shrublands to date. Nine individual products are being produced that represent primary shrubland components of percent shrub, percent sagebrush, percent big sagebrush, percent herbaceous, percent annual herbaceous, percent litter, percent bare ground, shrub height, and sagebrush height.

This approach relies on three major steps including creating training datasets using field measurements and high resolution satellite imagery at selected sites; extrapolating these training datasets to the landscape level using Landsat 8, and validating the final products with independent field measurements. Product creation has been prioritized to focus on sagebrush ecosystems. Image nominal date 2013 products were developed in 2013 for Southwest Idaho, Southeast Oregon, Northwest Nevada, and Northeast California (fig. 17) with 2014 image date products developed for the Mojave Desert, the Great Basin, western Utah, and southern Idaho this year. In addition, field sampling was completed this year for future products focused on the Sonoran Desert, Wyoming and Montana (fig. 17). For sagebrush ecosystems, research has shown this approach enables more successful monitoring of gradual change and offers opportunities to develop historical 30-year trends of gradual habitat change from climate that can be projected into the future. For further information, contact USGS EROS, Collin Homer, homer@usgs.gov.

Figure 17. Status of U.S. Geological Survey shrub and grass mapping by region. Dates listed in each region represent the nominal year of Landsat 8 imagery used for mapping the region.

LANDFIRE 2012 Update and Drought Based Enhancements; 2014 Projects Rolling Ahead

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 Forest Service (USDA FS) and the U.S. Department of the Interior. 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 dataset can also be adapted to support a variety of local management applications when other datasets 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 all 50 states and United States associated insular areas. 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 also incorporated. In 2015, LANDFIRE completed its most recent update – LF 2012. LF 2012 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. The objective for LF 2012 was to provide for currency of landscape conditions by both utilizing remote sensing data and applying available disturbance information for calendar years 2011 and 2012. The primary highlight of LF 2012 was a new compositing and tiling approach for use with Landsat 7 scan line corrector-off (SLC-off) data. This approach allows multiple scenes to be combined to fill SLC-off gaps, clouds, or shadowed areas in the change detection products. These methods provide higher quality data and more efficient processing by reducing time spent investigating anomalies in these change detection outputs.

In 2015, LANDFIRE also continued planning for its next update release – LF 2014. LF 2014 is expected to focus solely on the fundamental requirements of an update release: vegetation change across the landscape. Data from natural disturbances and vegetation and fuel treatments were processed during the first half of 2015, and product development is expected to start in early FY 2016. LF 2014 will be complete in December 2016.

LANDFIRE also completed a project to provide drought based fuel dynamic methods for the southeast United States. This approximately 2-year innovations project resulted in a process to generate adjusted LANDFIRE surface fuel model layers that are automatically transitioned based on the bi-weekly calculated Keetch-Byram Drought Index (KBDI) within the Wildland Fire Decision Support System (WFDSS). The conversions are based on look-up table values derived by adding additional fuel loading and depth, based on the level of drought expressed by KBDI, and cross-walking subsequent fuel loading values to the LANDFIRE Fire Behavior Fuel Model 40 layer for each of four KBDI drought classifications. The process recently completed testing and was implemented on the WFDSS production system in August 2015.

LANDFIRE continued its association with many key partners and stakeholders in 2015. LANDFIRE principal partners are the USDA FS, the USGS EROS, and The Nature Conservancy. LANDFIRE program partners include the USGS National Gap Analysis Program, the Multi-Resolution Land Characteristics Consortium, the National Land Cover Database, the USDA FS Forest Inventory and Analysis program, and the National Agricultural Statistics Service.

Looking ahead, LANDFIRE will continue plans for a comprehensive mapping effort using new and existing data to create an updated base map data suite representing contemporary conditions, rather than using change detection techniques, look up table transitions, or modeling to represent current conditions. This project is known as LF Remap and will begin a roughly 3-year development effort in late 2016. Hopefully, among the new data sources available for the LF Remap project will include analysis-ready data products from the Land Change Monitoring, Assessment, and Projection program. For further information, contact USGS EROS, Stephen Zahn, sgzahn@usgs.gov.

Fire Potential Forecasting and Fire Mapping at USGS EROS

The Fire Danger Monitoring and Forecasting project assesses the potential for fire occurrence across the country and is one of several fire science activities at EROS. Each day, using weather data from NOAA’s National Digital Forecast Database (NDFD), the current observed and future fuel moisture (6 days into the future) are forecast by the Forest Service’s Missoula Fire Lab. The fuel moisture estimates are downloaded from the Fire Lab by EROS and used in conjunction with satellite observations of vegetation “greenness” condition (the Normalized Difference Vegetation Index, NDVI). Current NDVI observations are compared to historical minimum and maximum NDVI values to estimate the current percentage of dead fuels. The combination of current fuel moisture and percent dead fuels are used to generate the Fire Potential Index (FPI) for each square kilometer of the continental United States. When fuels are dead and dry, the FPI is high. Conversely when fuels are live and moist, FPI is low. Since 2008, these daily and 6-day FPI forecast assessments have been published on the USGS Fire Danger Forecast Web site (http://firedanger.cr.usgs.gov) along with other related products such as current NDVI and NDVI departure from historical average.

Recently, a new product was introduced, the “Expected Number of Large Fires per Predictive Service Area” (fig. 18). Predictive service areas are pre-defined areas of similar fuels, terrain, and weather that are used by the fire management community for planning and forecasting. A study was conducted using historical FPI and fire occurrence data to derive a statistical relationship between the two (Priesler, Eidenshink, Howard, and Burgan, 2014, Proceedings of the Large Wildland Fires Conference, Missoula, Mont., RMRS-P-73, p. 181-187). The new product is the result of the study, and preliminary results using partial data from 2013 indicate a good agreement between observed and forecasted values. A more complete evaluation is planned using all the data from 2008-2014.

Should a fire occur, there are two post-fire assessment programs ready to help land managers determine the best way to mitigate the negative impacts of fire. Both use satellite imagery to evaluate the impacts of fire. The first is the Burned Area Emergency Response (BAER) program that is called upon to immediately respond to the largest and most dangerous fires. The second is the Monitoring Trends in Burn Severity (MTBS) project, which has the mandate to map and assess all fires larger than 500 acres in the east and 1,000 acres in the west. Including prescribed fires, there are easily in excess of 1,000 fires each year that exceed these size criteria.

Rather than assessing a fire immediately after containment, MTBS evaluates fire effects at the next "peak of green." This gives time for effects, such as delayed mortality or recovery, a chance to become apparent. Since 2006, USGS EROS and the U.S. Forest Service's Remote Sensing Applications Center (RSAC) have combined resources to create a database of all large fires that have occurred in the 50 United States since 1984. This has largely been achieved and was possible due to the existence of the Landsat image archive maintained at the USGS EROS Center.

MTBS assessments use Landsat imagery acquired before and after the fire. Using spectral bands 4 and 7, pre- and post-fire Landsat scenes are processed to create normalized burn ratio (NBR) images. The post-fire NBR is subtracted from the pre-fire NBR to create the differenced NBR (dNBR). This image is then visually interpreted by MTBS analysts to create a thematic burn severity map (fig. 19).

Over 20,000 fire assessments have been completed and are available for distribution at http://mtbs.gov/. These assessments can be used at local, regional, and national scales to evaluate the short- and long-term effects of fire and the trends of fire occurrence for the last 30 years.

As mentioned, MTBS has a mandate to map all large fires including prescribed fires, but shrinking budgets have reduced labor resources. More effective collection of prescribed burn records, especially at the state level, have overwhelmed the capacity of the MTBS project to keep up with the mapping requirements using manual procedures. Last year a decision was made to forego the assessment of state-level prescribed burns until more efficient processing and assessment procedures can be put in place. To that end, NASA awarded funding to EROS to investigate ways to streamline the fire assessment process.

The NASA funding is being used by the Multi-Sensor Fire Mapping (MSFM) project to investigate ways to automate many of the manual processes currently used. Fires, to be mapped by the MTBS program, are first identified from Federal and state fire occurrence databases which are fraught with errors of date and or location. Once identified, MTBS analysts use manual methods to search and order appropriate Landsat scenes. The Landsat scenes are pre-processed by the analyst and then reviewed to delineate a perimeter, subset the imagery and estimate thresholds, and create the final products. The MSFM project has developed algorithms that scan Landsat imagery to identify freshly burned areas; these identified areas are automatically delineated to provide an initial perimeter. The spatial extent of the fire perimeters are used to define a subset of pre- and post-fire Landsat scenes which are automatically ordered and pre-processed to create the necessary reflectance and NBR imagery. The analyst then merely picks the appropriate image pair and automated processes create a dNBR and apply default thresholds defined through an analysis of the previously mapped fires in the region. The analyst then confirms the severity product or modifies the thresholds as necessary. It is hoped these processes will improve the efficiency of the MTBS project and allow for more comprehensive and timely fire assessments (fig. 20).

Using the automated methods and procedures initially developed by the MSFM project, USGS EROS is entering the second year of a 2-year project funded by the U.S. Fish and Wildlife Service (USFWS) to compile historical fire atlases for 58 wildlife refuges around the country (fig. 21). Instead of trying to locate and map individual fires widely scattered across the landscape, the USFWS Fire Atlas project is focused on specific refuges and trying to map every fire down to 25 acres in size going back to 1984. The USFWS provided historical fire occurrence information from their Fire Management Information System (FMIS) for all fires from 25 acres up to the minimum MTBS fire size (500 acres in the east, 1,000 acres in the west). Overall there are over 10,000 fire records.

The first step is to order every scene in the Landsat archive that imaged the refuge. Using the known spatial extent of the refuge with a 5-kilometer buffer, an automated script queries the database of all Landsat acquisitions; and each scene that intersects the refuge 5-kilometer buffer is identified and its scene identification (ID) written to a text file. Using the advanced ordering options of the EROS Science Processing Architecture (ESPA) system, the text file of scene IDS is uploaded along with the bounding box coordinates for the refuge. The ESPA system pulls the scenes from the Landsat archive and performs several necessary pre-processing steps normally completed by an analyst: surface reflectance calibration, computation of the NBR and NDVI, generate cloud and shadow masks, and then re-project and subset each derivative product based upon the bounding box coordinates. The result is a complete historical package of Landsat scene subsets and derivative data centered on the refuge.

The next step is to delineate the fires and match a fire scar in the imagery with a fire occurrence record. This is not as simple as it sounds due to location and date errors in the FMIS database. Using MTBS-mapped fires for training, Cubist burned/not burned (BNB) models are developed for each refuge area to spectrally identify pixels. The Cubist BNB algorithm is automatically applied to each image to identify burned pixels by rating each pixel with a BNB value from 1-100. The higher the value the more likely the pixel is burned. A threshold value BNB is automatically derived using a modified OTSU method (Otsu, 1979, IEEE Transactions on Systems, Man, and Cybernetics, v. SMC-9, no. 1, p. 62-66, doi:10.1109/TSMC.1979.4310076) and an interim 0-1 BNB image is created for each scene. Vectors are created to delineate initial fire perimeters. The vectors from consecutive scenes are combined, which creates full perimeters from cloudy or Landsat 7 SLC-off gapped images, or for fires that burn through several acquisitions.

Up to this point, all processing has been automated and now, an analyst visually reviews the composite vectors to make any necessary edits and tries to match the fire scar and perimeter with an FMIS fire record. As mentioned, this can be a challenge due to location errors. Fortunately, many of these errors can be overcome. Most fires in the FMIS are prescribed fires and they are often given the name of a predefined burn unit (e.g., Unit 5) or place name (e.g., Dove's Roost). Using the fire names and a refuge-provided fire burn-unit map or visitor's map, we have been able to resolve many of these errors.

The last step is to package and deliver the final fire atlas which contains the following: fire perimeters; pre, immediate post, and 1-year post-fire surface reflectance images for each fire; NBR for each image; NDVI for each image; cloud, shadow and water mask for each image; yearly peak of green and dNBR images for the refuge; Federal Geographic Data Committee (FGDC)-compliant metadata for each fire; and a meta-database containing the information about each fire, its disposition (mapped or un-mappable), and a link back to the FMIS database record.

Components of the Umatilla Refuge Fire Atlas (along Columbia River in Oregon and Washington) are shown in figure 22. The fire atlases provide refuge managers a comprehensive look at historical fire occurrence and allows them to monitor the results of fire or other management activities since the early 1980s. For further information, contact USGS EROS, Stephen Howard, smhoward@usgs.gov.

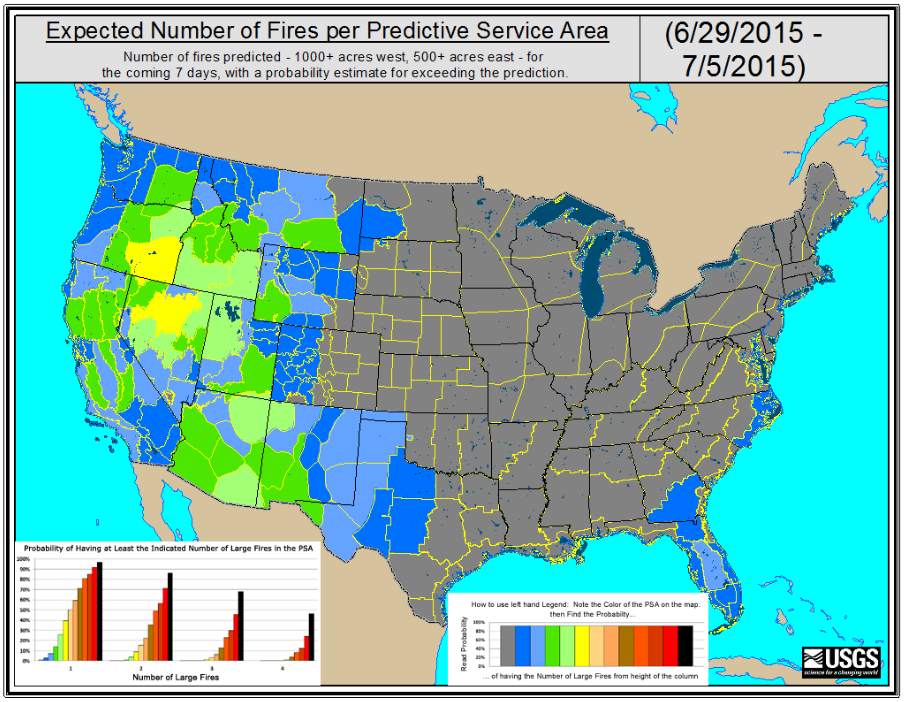


Figure 18. Expected number of large fires per predictive service area. Updated daily at the USGS Fire Danger Forecast Web site (http://firedanger.cr.usgs.gov).

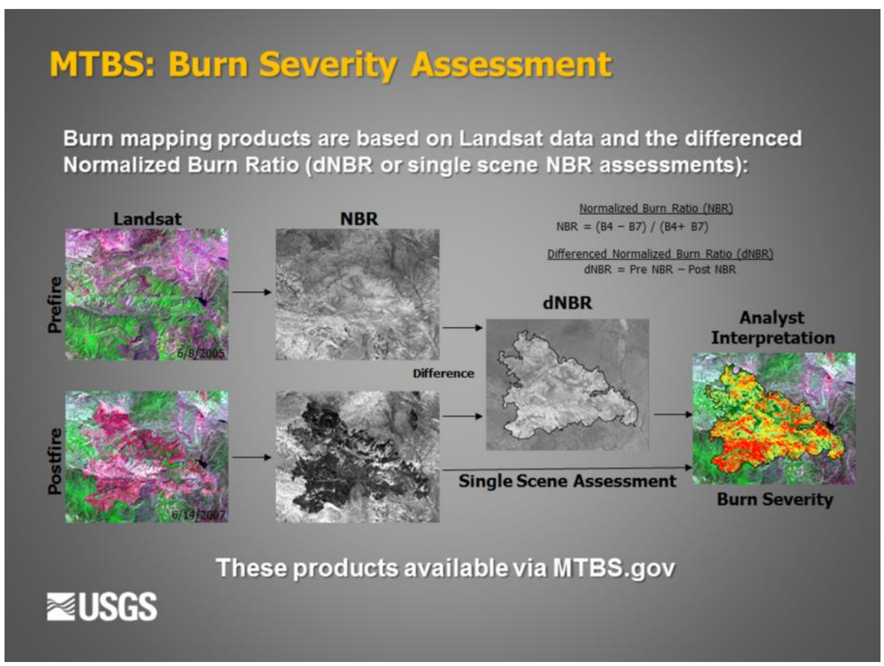


Figure 19. Monitoring Trends in Burn Severity (MTBS) Assessment. Landsat imagery is processed to create normalized burn ratios (NBRs) and a differenced NBR (dNBR), which is color coded to show high, medium, low and unburned areas (red, yellow, light blue, and green, respectively).

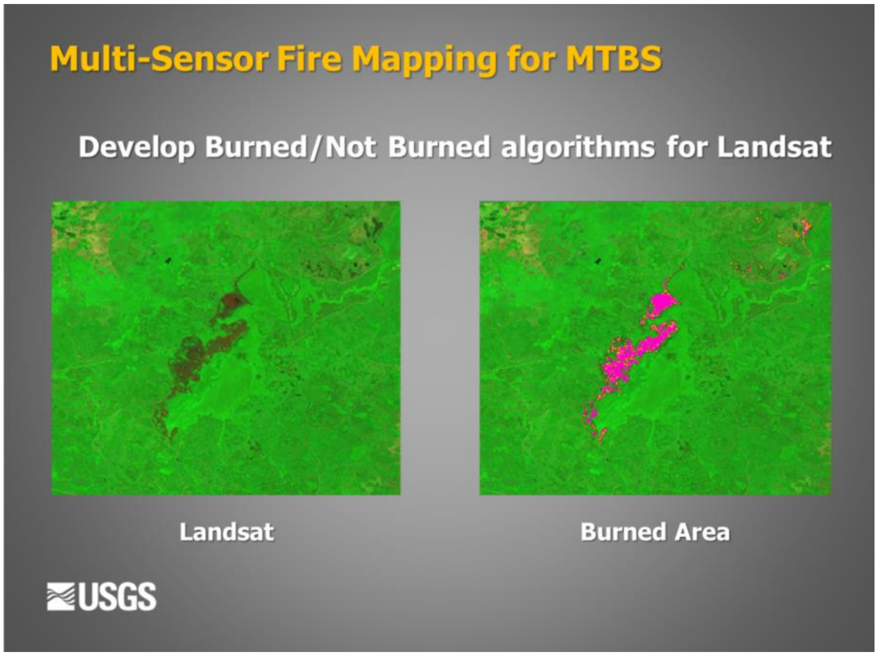


Figure 20. The burned areas of the Landsat scene are color coded by the burned area identification algorithm.

Figure 21. Green represents the refuges and wildlife management districts (in Minnesota and North and South Dakota) for which fire atlases have been completed; those in orange are yet to be completed.

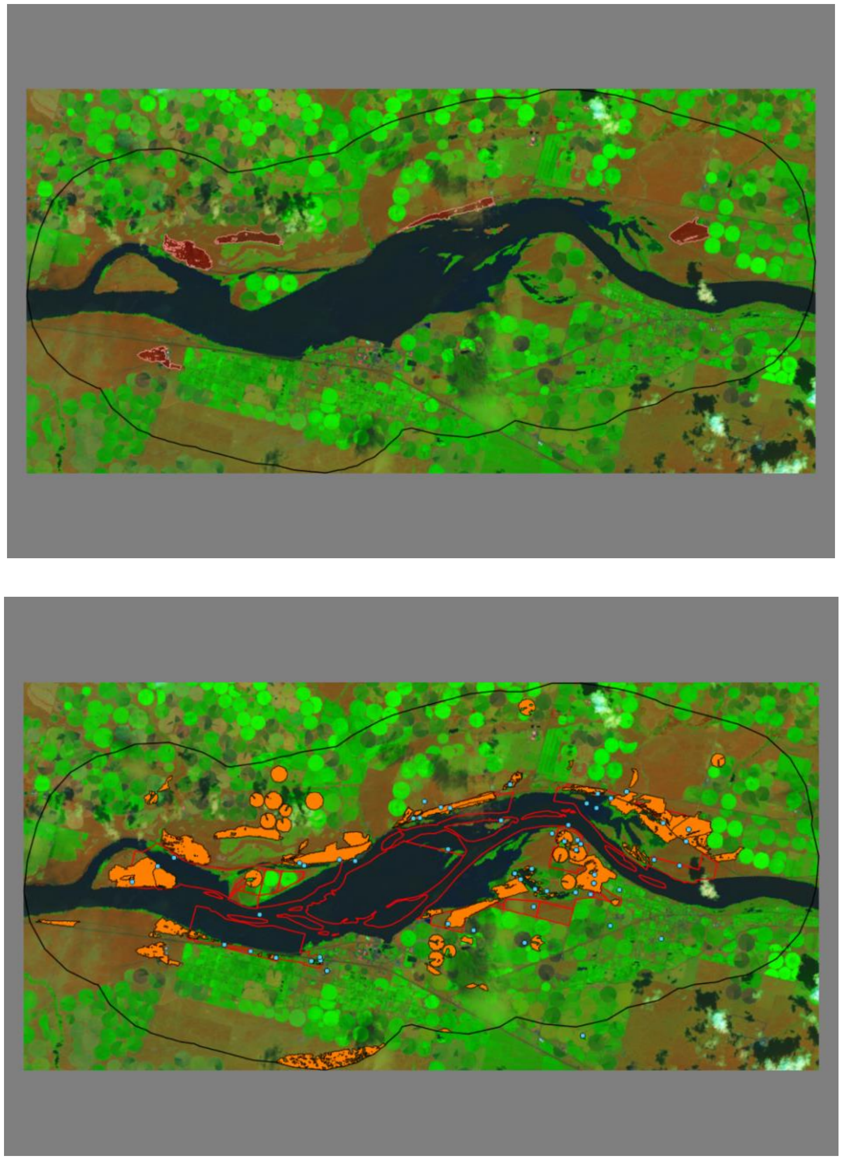


Figure 22. Umatilla Refuge. The top image shows five fire perimeters identified from an image acquired on June 2, 2001. The bottom image shows all the fire perimeters identified (orange polygons) from 1983-2013. The Fire Management Information System recorded fire locations are shown as blue points (note many do not fall on mapped fires). The refuge boundary is shown in red, and the 5-kilometer buffer is black.

Canopy Fuels and Mexican Spotted Owl Habitat Assessments Using Lidar

U.S. Geological Survey scientists, in partnership with staff at Grand Canyon National Park and Kaibab National Forest, have developed geospatial data layers derived from lidar that aid in the delineation of Mexican Spotted Owl (MSO) habitat and the estimation of canopy fuels.

The Fire and Aviation Office at Grand Canyon National Park oversees an active fire program. The Office therefore desires accurate, up-to-date information regarding the distribution and amount of fuels present in the Park. Additionally, the Office needs to account for fire impacts on the Park's resources, especially when implementing fuel treatments such as prescribed fires. For example, the habitat of the threatened MSO coincides with areas ripe for fuel treatment, but must remain untouched to comply with the guidelines of the 2012 Spotted Owl Recovery Plan. The information products developed as part of this project help inform and reconcile the various mandates of the Park.

The Park had acquired lidar data over the North Rim extending into the neighboring Kaibab National Forest. USGS scientists provided the expertise required to process and analyze the data in collaboration with local fire and wildlife ecologists who had extensive knowledge of typical fire behavior and MSO habitat requirements. Vegetation canopy metrics that characterize both fuels and habitat were identified and derived from the lidar data. Canopy height, canopy cover, large tree density, basal area, and canopy complexity metrics were all derived from the lidar dataset to characterize mature forests, ideal habitat for the MSO. Figure 23 shows the lidar derived canopy height map for the entire study area and predicted tree stem locations for an example area. The derived products were delivered to the Park as a set of raster and vector geospatial layers to be used to refine the MSO habitat boundaries and inform upcoming fuel treatment implementation.

Where possible, the derived metrics were compared to field based observations. The Park has conducted several inventory and forest health monitoring surveys and has an extensive network of high quality field data available. For example, the lidar derived height metric was compared to plot level measurements of maximum canopy height to assess the accuracy of the lidar based estimates. The validation of canopy height was particularly important because basal area and large tree density estimates were largely derived from the estimated height.

The set of canopy structure products delivered to the Park, in combination with data layers that they already had available, provided resource managers with the information needed to better map and manage the MSO habitat. This, in turn, allowed wildland fire managers to plan and implement fuels reduction strategies that would reduce the risk of catastrophic wildfire while maintaining the MSO nesting and roosting habitat. For further information, contact USGS EROS, Kurtis Nelson, knelson@usgs.gov.

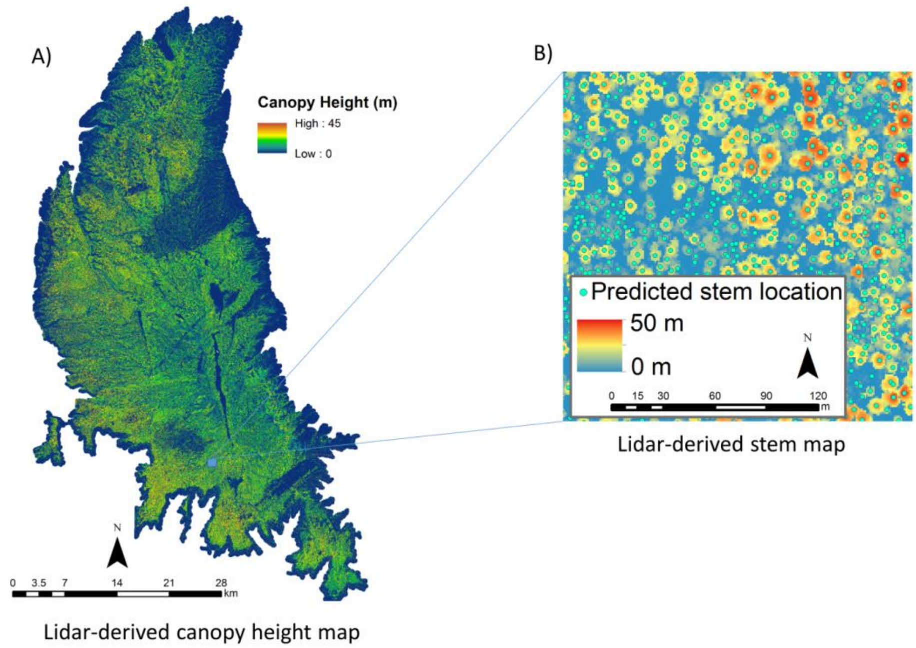


Figure 23. Maximum height-above-ground values were calculated from the lidar data and gridded to 1 meter, as shown in A. Using this gridded product, local maxima (B) are derived and assumed to represent individual tree crowns comprising the canopy.

Monitoring Fire Disturbance

The USGS Landsat series of satellites provide remotely sensed data suitable for mapping wildfire disturbance. However, the sensors onboard the current and historical Landsat satellites vary in terms of the spatial resolution, number of spectral bands, bandwidths, and overall data quality and calibration characteristics. To date, the USGS and others have used Landsat data collected in the Landsat thematic mapper (TM), enhanced thematic mapper plus (ETM+), and operational land imager (OLI) era (1984-present) to map wildfire disturbance. Within the Federal Government, this has been accomplished primarily through the MTBS project and other research projects at the USGS EROS and USFS RSAC. The dNBR and relative dNBR (RdNBR) spectral band ratios and indices have been the basis for most of these wildfire burn area mapping efforts.

Historical fire mapping efforts have essentially ignored the era from the launch of Landsat 1 through Landsat 4 (1972-1983). The data collected during this period by Landsat's multispectral scanner (MSS) sensors is suitable for fire mapping but possesses different spatial resolution and spectral band characteristics than data collected by TM, ETM+, and OLI sensors. This requires that fire mapped during this period be accomplished using different spectral bands and indices. The results from fire mapping during the MSS and TM/ETM+/OLI eras are comparable when considering thematic map products. However, the fire indices from the two eras are not directly comparable; therefore, continuous assessments of burn severity and other variables important to the fire affects research community may not be comparable for the full Landsat time frame. In order to provide a longer time series of fire occurrence and burn severity for the assessment of climate change impacts and burn severity trends, it is necessary to develop a burn severity characterization method that calibrates indexes derived from Landsat MSS and TM/ETM+/OLI data.

Methodologies have been identified that are suitable to detect, map, and monitor fire disturbances in the 1972-1983 time period using Landsat 1-4 MSS data and to then calibrate both MSS results and similar results derived from TM/ETM+/OLI fire data records for the period of 1984-present. Both the MSS and TM/ETM+/OLI results must be adjusted to a common scale to facilitate the comparison of continuous burn severity indices through the full Landsat era. Automated scripts have been written to efficiently calibrate multiple fire mapping datasets across large landscapes. Historical MSS, TM, ETM+ and OLI burn mapping datasets have been acquired or derived for study areas in the Mojave bioregion (fig. 24), selected watersheds in Colorado, and other locations across the country. These Landsat image datasets will be used to test and validate the developed calibration techniques and automated processing capabilities. Perhaps of more critical importance, the effort will also demonstrate the science value of historic wildland fire disturbance mapping and monitoring for the full Landsat era from 1972 to the present. For further information, contact USGS EROS, Randy McKinley, rmckinley@usgs.gov.

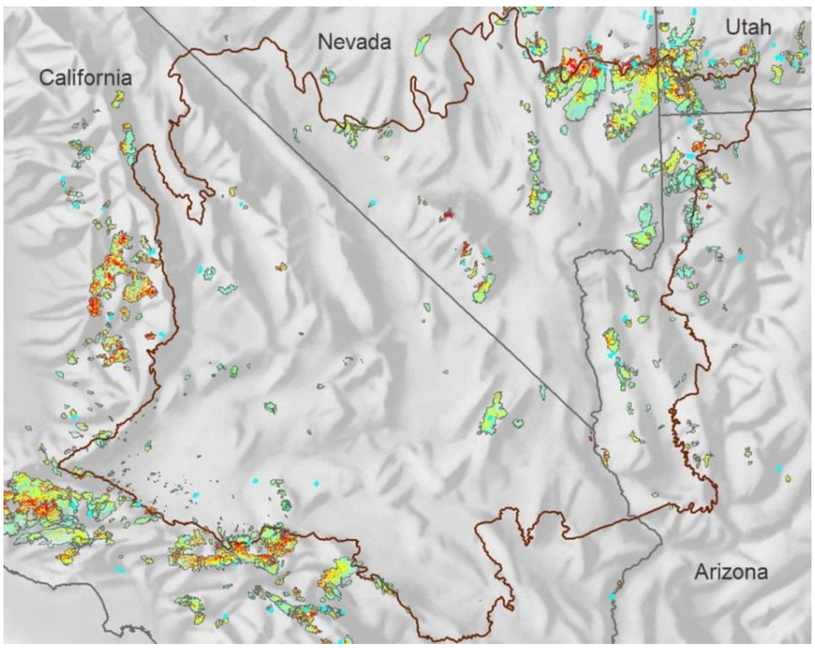


Figure 24. Categorical burn severity for the Mojave bioregion for the period of 1972-2008. Landsat multispectral scanner data were used to generate the 1972-1983 fire location and burn severity information. Within the severity map dark green is non-burn, light blue is low severity, yellow is moderate severity, and red is high severity. The brown line is the Mojave bioregion boundary.

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

Since 2001, USGS EROS fire science staff have worked jointly with U.S. Forest Service (USFS) Remote Sensing Applications Center (RSAC) staff to map significant wildland fires on DOI and USFS managed lands and to satisfy soil burn severity and other remote sensing and mapping requirements of the Burned Area Emergency Response (BAER) teams. USGS 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. 25), generally in less than 2 days after image acquisition. Starting in 2013, and continuing in 2015, the availability of the new Landsat 8 satellite greatly enhanced the USGS capability to respond to the needs of fire rehabilitation managers in a timely manner. Prior to approximately 2001, 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 (fig. 26).

This was a near record year for DOI BAER burn mapping support. EROS staff mapped 2.4-million acres in 2015. The 61+ fires mapped was the second most mapped since 2001. In total, 2001-2015, USGS EROS and USFS RSAC have mapped over 1,600 wildfires representing over 46-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 United States 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 USGS EROS, Randy McKinley, rmckinley@usgs.gov.

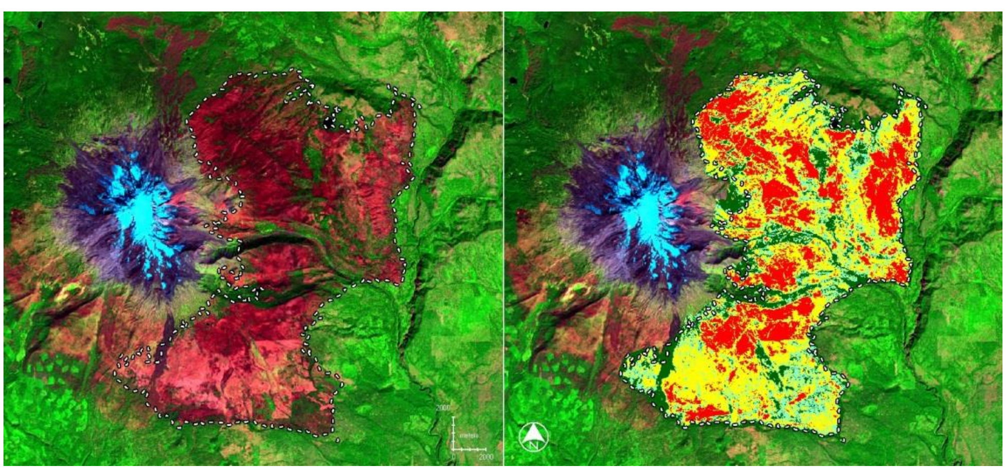


Figure 25. Burned Area Emergency Response map products, Landsat 8 image (left) acquired post fire on September 11, 2015, and soil burn severity map (right), for the

Cougar Creek fire located near Glenwood, Washington. This was a large fire impacting almost 54,000 acres. The fire was mapped after containment to provide local fire rehabilitation managers with timely soil burn severity information. The fire impacted Yakama Nation lands and access to the Gifford Pinchot National Forest and Mount Adams wilderness. A snowcapped Mount Adams is visible in the images with snow a bright blue color. Within the severity map, dark green is non-burn, light blue is low severity, yellow is moderate severity, and red is high severity. The fire's perimeter, as mapped by local fire managers, is shown as a white dashed line.

Figure 26. Landsat 8 image showing the actively burning Cougar Creek, Washington, wildland fire on August 26, 2015. Smoke plumes appear blue in color, and clouds are white. Active fire is bright red. Although an impressive picture, the clouds and shadows, smoke, and active fire make this image unusable for most burn mapping applications.

Shrub and Grass Fuel Maps Using Remotely Sensed Data and Biogeochemical Modeling

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 is related to 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 a 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 the following: (1) improve upon shrub and grassland mapping for fire applications; (2) develop intra-seasonal fuel datasets in shrub and grassland areas using a combination of Landsat and MODIS data; and (3) determine if improvements in shrub and grassland data layers will alter and improve fire behavior model results.

Our current focus is on the Great Basin, which includes portions of Nevada, southern Idaho, and western Utah. This area is the site of many large and frequent shrub and grassland fires (fig. 27). The shrubland areas are dominated by sagebrush (*Artemisia spp*), and the grassland areas have a substantial amount of cheatgrass (*Bromus tectorum*) associated with them. 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.

We are currently developing methods to merge Landsat with MODIS data throughout the region. While we desire the high spatial resolution of Landsat for fire modeling applications, the MODIS sensor provides better temporal frequency data. This high temporal frequency data enables us to understand seasonal dynamics very well, yet at a spatial resolution that is not fine enough for our purposes. Merging of the Landsat and MODIS data will provide the best of both worlds, and will help us to better understand the patterns of green-up and senescence at spatial scales desired by the fire management community. For further information, contact USGS EROS, James Vogelmann, vogel@usgs.gov.

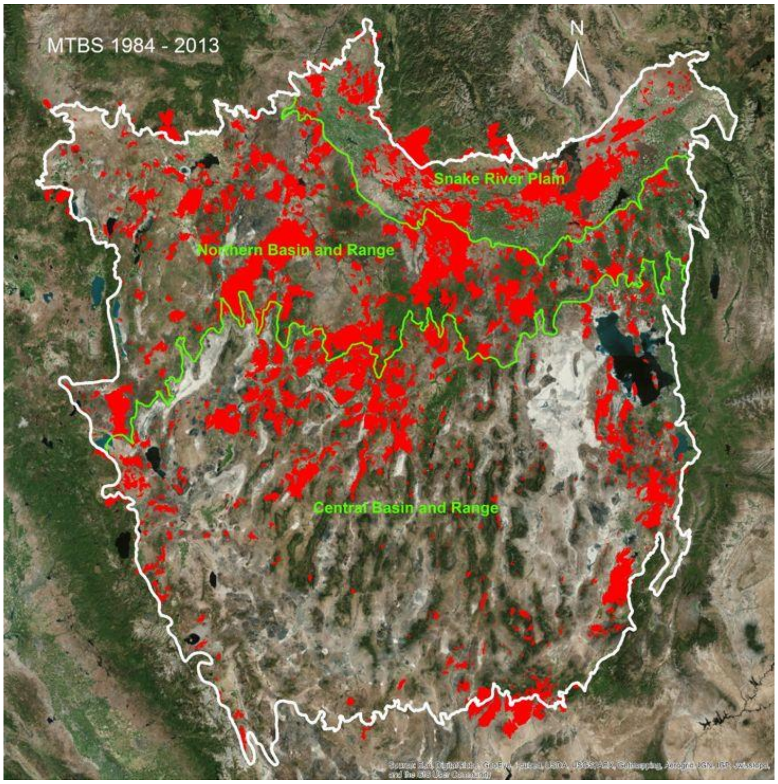


Figure 27. Red indicates areas burned at least once between 1984-2010 within the Great Basin, according to the Monitoring Trends in Burn Severity project. Most of the burned areas are located in shrub and grasslands. The northern portion of the region (especially within the Snake River Plain and the Northern Basin and Range ecoregions), had proportionately more fires than the southern portion of the region. This information is useful for helping predict which areas are most likely to burn in the future.

Regional Land Use and Land Cover Change Knowledge Dissemination and Research

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 change (LULC) and their driving forces. Roger Auch is the main USGS EROS researcher of the NLCA project and was the lead or co-author of two publications that were published in FY 2015 after near completion during FY 2014, one publication almost published, and one additional manuscript nearing completion. 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, two of the remaining volumes of USGS Professional Paper 1794 (a legacy publication of the USGS Land Cover Trends project), and study of crop proportion change in the eastern Northern Plains of the United States and their associated drivers. The common link among these publications, except the eastern Northern Plains work, 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 accepted by the *Southeastern Geographer* journal and will be published in fall of 2015. 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 (i.e., intensely used pine plantations) is actually a recent human construct.

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 (Stinger Ghaffarian Technologies, Inc.) 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 was published in the *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.

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 of 2012. USGS EROS scientists William Acevedo (Land Change Data Collection and Monitoring project), Roger Auch, Kristi Sayler (Land Change Data Collection and Monitoring project), and USGS EROS contractor scientist Janis Taylor (Stinger Ghaffarian Technologies, Inc.) spent considerable time in FY 2015 editing and proofing 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, William Acevedo, Roger Auch, and USGS colleague Mark Drummond were the editors for the Great Plains volume (USGS Professional Paper 1794-B) which was published in early September 2015. Auch's and former EROS scientist Krista Karstensen's edited Midwest-South Central United States volume (USGS Professional Paper 1794-C) which is nearing lay-out form for the entire work and should be publically released still in calendar 2015. Professional Paper 1974-B and C each contain approximately 180 pages and the Sayler and Acevedo edited Volume D, Eastern United States, will most likely be over 200 pages. Together, the four volumes will finish the most comprehensive USGS led analysis of United States land cover and land use ever undertaken.

The new manuscript that neared completion in FY 2015 is an examination of changing crop land use in the eastern Northern Plains of the United States. A group of 42 counties in eastern North Dakota, northeast South Dakota, and western Minnesota were tracked during three 3-year intervals to produce a mean of the proportion of crops planted (as well as harvested hay land) that spanned the early 1980s, middle-to-later 1990s, and 2011-2013. Half of the counties had a majority of their territory in areas of significant increases of precipitation between 1980-2013, and the other half of the counties did not experience significant precipitation change during the study period and were used as a reference set. Wheat was the leading crop during the early 1980s in both sets of counties but had faded to third in the reference counties by the later 1990s and dropped to third place in the significant precipitation group by circa 2012.

Soybeans were the leading crop by area planted in both groups of counties in the study area by circa 2012 with corn in second place in each. An exploration of leading human drivers along with biophysical conditions gave evidence that a synergistic combination of multiple drivers help drive crop land use change in this region. Authorship is Auch, USGS EROS colleagues George Xian and Kristi Sayler, and academic colleague Chris Laingen of the University of Eastern Illinois. The plan is to submit the manuscript to the *Journal of Land Use Science* during the first quarter of FY 2016. For further information, contact USGS EROS, Roger Auch, auch@usgs.gov.

Completion of Historical "Backcast" Modeling to 1938 for Conterminous United States

Land use and land cover (LULC) in the United States has changed dramatically in the last few centuries. With a changing landscape, natural processes have been forever altered, with climate, carbon, hydrology, biodiversity, and other ecosystem services impacted by LULC change. An understanding of historical LULC is needed to assess the past effects of LULC change on ecological and societal processes, and to facilitate the modeling of potential future LULC change to support planning and mitigation efforts.

Multiple contemporary, spatially explicit LULC databases are available for the conterminous United States at moderate spatial and thematic resolutions, including the National Land Cover Database, LANDIRE, and the USGS Land Cover Trends project. However, these data rely on remote sensing data and are unavailable for dates prior to the initiation of Landsat. There are no historical, spatially explicit, consistent LULC databases available for the conterminous United States.

To meet the need for historical LULC data, USGS EROS has used a modeling approach to produce historical LULC maps back to 1938 for the conterminous United States. Historical remote sensing databases were combined with Agricultural Census data, demographic histories, a database of reservoir construction dates, county-level wetland drainage histories, and other historical data to construct historical “demand” back to 1938. Demand essentially provides a prescription for the quantities of historical LULC change at annual time steps at a regional level, with EPA ecoregions serving as the spatial framework. A spatial allocation component within the FOREcasting SCEnarios of land use change (FORE-SCE) model ingests quantitative demand at a regional level, and produces a spatially explicit representation of the prescribed proportions of LULC change.

The resulting product was an annual, spatially explicit LULC database for the conterminous United States from 1938-1992, with 15 distinct LULC classes mapped at a 250-meter resolution (fig. 28). The data were designed to be consistent with existing modeled land cover data from 1992-2100, produced as part of the USGS LandCarbon project. Combined, the two datasets provide truly unique, spatially explicit, annual “snapshots” of LULC conditions across the conterminous United States from 1938-2100, with four alternative future scenarios for the years 2006-2100. No other spatially explicit LULC data exists for the conterminous United States that can match the spatial, thematic, and temporal coverage of these data.

This work was initiated as part of an effort to assess historical LULC change impacts on hydrologic processes, with partial funding received from the National Water Quality Assessment (NAWQA) Program. However, the unique nature of these data makes them suitable to assess the relationship of LULC change with a wide variety of ecological processes. With data now available for both historical and future time periods, researchers can assess historical LULC change processes, determine historical impacts on ecosystem services, and use the future scenarios to determine potential future impacts, facilitating mitigation and planning efforts.

Key funding sources for this work include the USGS Climate and Land Use Programs and the NAWQA Program. The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific expertise in land cover mapping and modeling to complete this work. Land cover modeling results discussed here are available at http://landcover-modeling.cr.usgs.gov. For further information, contact USGS EROS, Terry Sohl, sohl@usgs.gov.

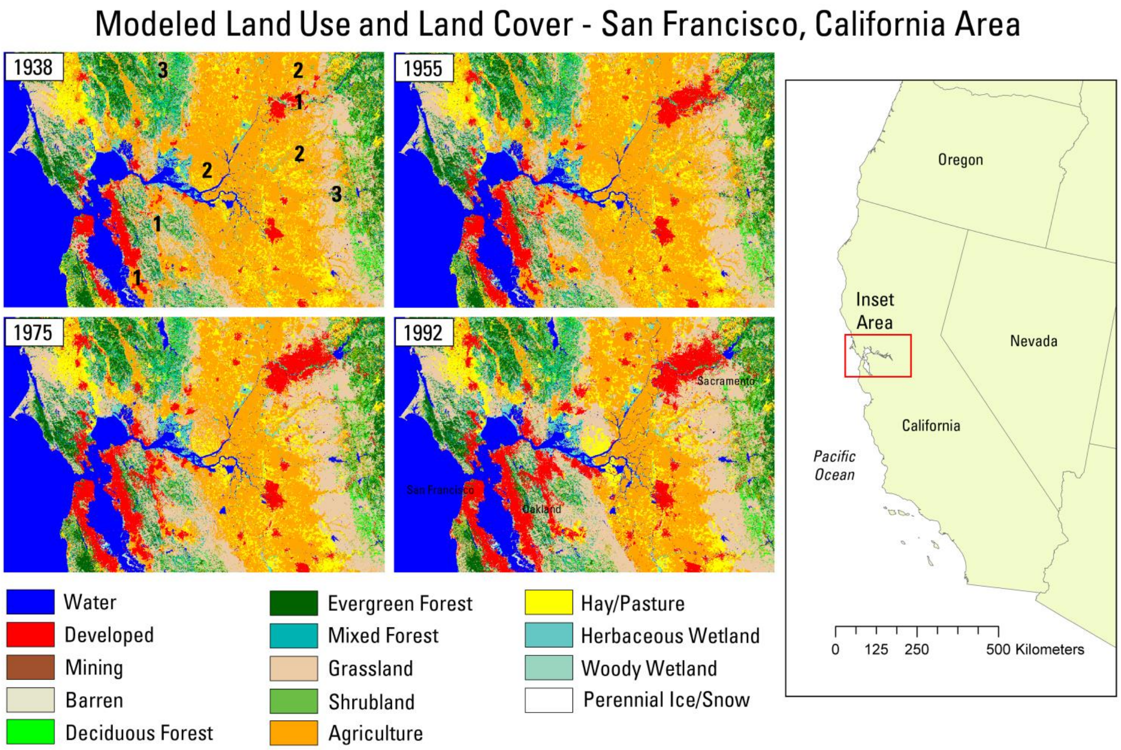


Figure 28. Modeled land use and land cover from 1938-1992 in the San Francisco, California, area.

Alaska Permafrost Mapping with Landsat

Soil carbon and permafrost are important drivers of future greenhouse gas emissions and vegetation communities. Accurately quantifying the magnitudes and spatial distribution of these soil properties is non-trivial because they are below-ground characteristics that are not evident from the surface and their heterogeneous in nature.

As part of the USGS Alaska LandCarbon assessment, EROS scientists in collaboration with other scientists, developed a series of soil carbon and permafrost maps for the state of Alaska. Soil carbon and permafrost parameters from different map products were compared across 23 of Alaska's major ecotypes (unique combinations of ecoregions, upland/lowland classification, and land cover). Average ecotype values from each soil characteristic were then compared to products from the dynamic organic soil version of the terrestrial ecosystem model (DOS-TEM). Agreement between DOS-TEM estimates and best estimates of current conditions built confidence in future predictions made with this model. DOS-TEM estimates fell in the range of mapped product estimates for total organic carbon (31-72 petagram versus 45 petagram), percent of area with near surface permafrost (36-67 percent versus 44 percent), and percent of area with organic or peat soils (6-24 percent versus 18 percent). DOS-TEM was only slightly outside of the observed product range for active layer thickness or maximum thaw depth (76-84 centimeters versus 86 centimeters). The ecotype product means within an ecotype were averaged across map products to produce a multi-product mean for each ecotype. The ecotype mean product values were then used to construct a rank-based index of susceptibility to changing climates based on permafrost vulnerability to degradation, organic layer susceptibility to fire, greenhouse gas emissions, and thawed carbon from permafrost. The susceptibility map (fig. 29) highlights the expected sensitivity of tundra systems in western and arctic ecoregions to changing climates. Interior Alaska also has patches of moderate to high susceptibility.

Information obtained from multiple permafrost and soil carbon map products is useful for validation or as an input into models predicting future carbon emissions, hydrology, and vegetation communities. In addition, ecotypes with high mapping uncertainty or those with significant disparity with process-based model predictions identify areas where further studies or field data may be needed. The soil susceptibility map may also help identify areas in need of model refinement and should be informative for land use managers and agencies. Results from this assessment will soon be released in the Alaska LandCarbon report (Zhu and McGuire, eds., in press, Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of Alaska), which will be followed up by a special issue *Ecological Applications* paper that summarizes primary state factors controlling terrestrial ecosystem properties and processes in Alaska. For further information, contact USGS EROS, Bruce Wylie, wylie@usgs.gov.

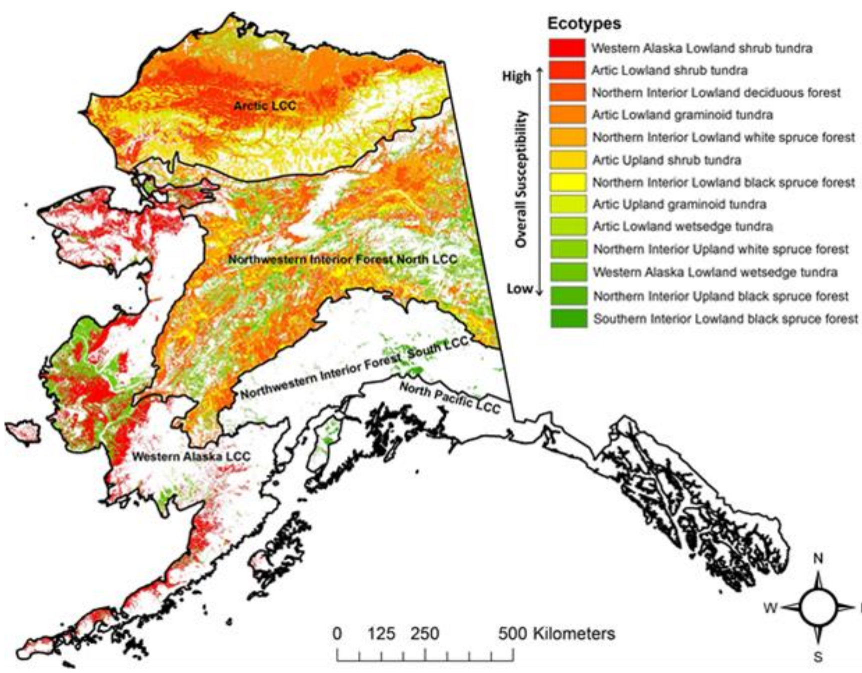


Figure 29. Overall soil susceptibility index (based on greenhouse gas emission, burning, and permafrost thaw) for major Alaska ecotypes. White areas on the map have low susceptibility.

Mapping Highly Erodible Cropland Buffers for Switchgrass Development

Cultivating annual crops in riparian zones or waterway buffers with steep slopes has numerous negative environmental consequences (e.g., soil erosion and water-quality effects of pesticide and fertilizer leakage) and can be environmentally unsustainable. Growing perennial grasses such as switchgrass for biomass (e.g., cellulosic biofuel feedstocks) instead of annual row crops in these high relief waterway buffers can improve local environmental conditions through soil erosion mitigation. Furthermore, this practice can minimize drought and flood impacts, improve wildlife habitat, and serve as carbon sinks.

Providing spatial detailed information on the highly erodible cropland buffers is very important for regional best land management practices, which can reduce negative environmental impacts and retain future sustainability in biomass production. The goal of this study is to identify highly erodible cropland buffers with high switchgrass productivity potential in a pilot study area (eastern Nebraska) that are potentially suitable to convert to switchgrass.

Satellite derived vegetation index, crop masks, and compound topographic index were used in this investigation. Results indicate that around 1,400 km^2 of cropland waterway buffers in eastern Nebraska would be suitable for switchgrass development (fig. 30). The total estimated biomass production "gain" from switchgrass is approximately 1.2-million metric tons for the biofuel potential areas.

Extending this study to the U.S. Great Plains or other geographic regions is planned. Linking switchgrass waterway buffers to hydrologic models by collaborating with hydrological scientists at South Dakota State University to assess water quality and soil erosions is also proposed.

A paper on this research has been published in *Ecological Indicators* (http://www.sciencedirect.com/science/article/pii/S1470160X15003441). For more information contact USGS EROS, Bruce Wylie, wylie@usgs.gov or Yingxin Gu, ygu@usgs.gov.

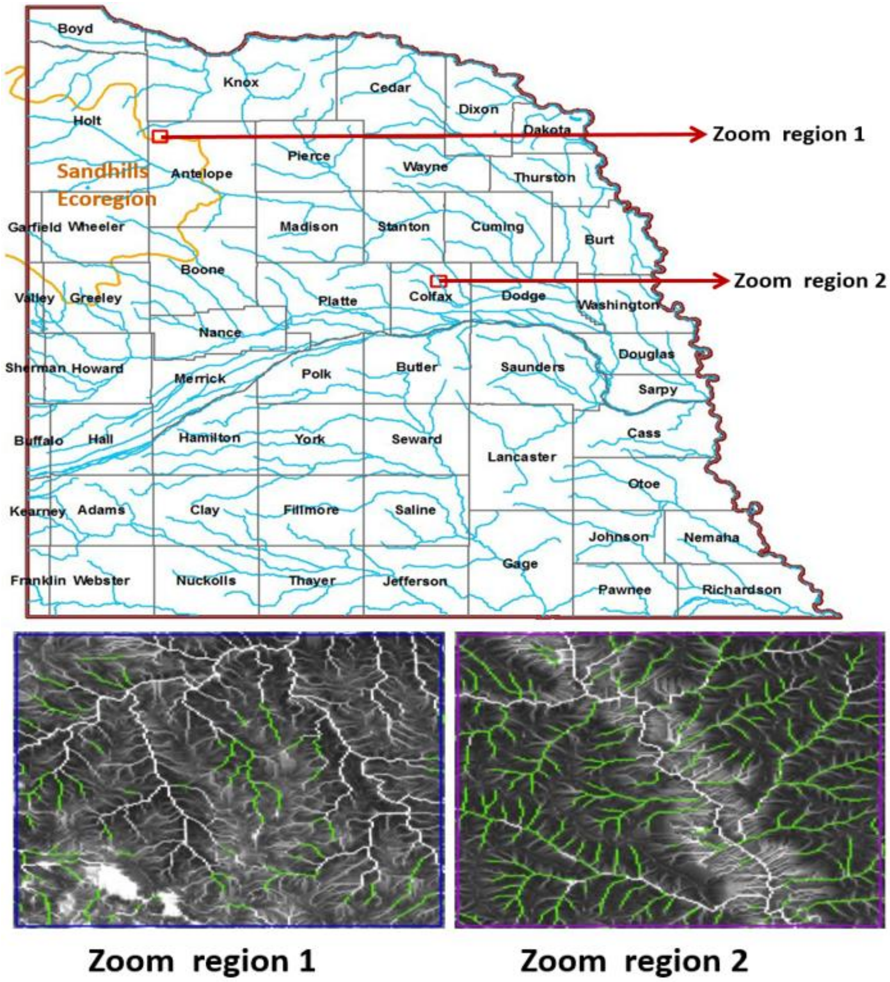


Figure 30. Study area showing county boundaries (gray), streams and rivers (cyan), the Sand Hills ecoregion (orange), and the two zoomed boxes (red). The final biofuel potential areas (green) are illustrated in the two zoom regions.

Expanding Crop Mapping and Carbon Flux Mapping to the Continental United States

Scientists at the USGS EROS Center, funded and supported by the USGS Land Change Science Program, have taken on an effort to expand the spatial extents of the annual crop cover mapping and weekly carbon flux mapping to the continental United States level. This effort will greatly increase the coverage of these two data products from the previously mapped U.S. Great Plains region and provide useful information to land use and land cover researchers and decisionmakers.

Accurate crop cover mapping supports the identification and understanding of annual crop cover dynamics, the associated drivers, and related environmental impacts. The goal of this effort is to develop and implement crop probability models that can accurately map major crops in the continental United States for 2000-2013. Such a dataset would supplement and provide additional temporal and spatial coverage to currently available crop cover datasets, such as the National Agricultural Statistics Service Cropland Data Layers. These products can also feed directly into other modeling applications, such as the carbon fluxes of different land cover types.

The carbon flux modeling effort seeks to identify and quantify terrestrial carbon sinks and sources to help inform land management decisions, improve the understanding of carbon flux drivers, and assess sustainability. The goal of this effort is to develop and implement weekly gross primary production (GPP), weekly respiration (RE), and weekly net ecosystem production (NEP) models that effectively represent carbon dynamics in major cropland and grassland ecosystems of the continental United States for 2000-2013.

The modeling of these two products are derived using similar, data-driven approaches. First, a set of localized training data, that well represents the characteristic that will be modeled (modeled variable), is collected. This set of training data is then spatially and temporally linked to a range of remote sensing imagery, gridded weather data, and other applicable biogeophysical data (input variables) that are selected based on being a potential driver to that which is being modeled. Through this linking, the modeling software (decision and regression trees) “learns” how the modeled variable behaves as a function of the input variables and can make estimations for the modeled variable across the study area.

So far, the crop mapping effort has yielded an annual continental United States crop model and the subsequent 250-meter spatial resolution maps for 2000-2013. These models are currently undergoing a quality control process and are being fine-tuned to maximize mapping accuracy. Figure 31 shows the initial modeled continental United States crop cover map for 2001.

Carbon dynamics modeling of GPP, RE, and NEP is well underway and initial map results have been produced for 2001. These results show the NEP of major cropland, grassland, and sagebrush ecosystems in the continental United States to be a slight carbon source (10.9 grams of Carbon/square meter/day). The map in figure 32 reveals probably locations of C sinks and C sources that occurred in 2001.

Scientists hope this effort will provide data products and supporting scientific analysis and statistics that will serve to inform the land use and land cover scientific community. For further information, please contact USGS EROS, Bruce Wylie, wylie@usgs.gov.

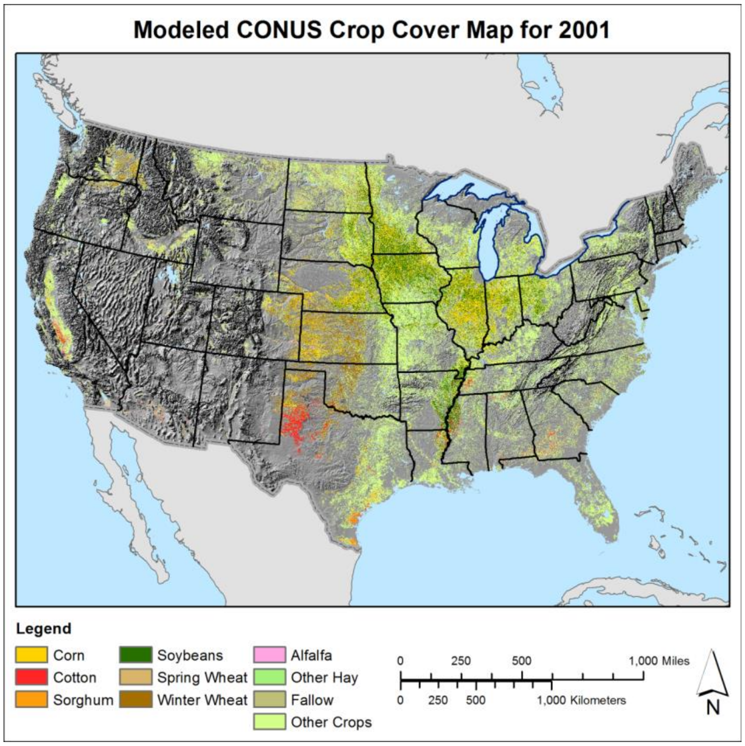


Figure 31. Initial results of modeled annual continental United States crop cover map for 2001.

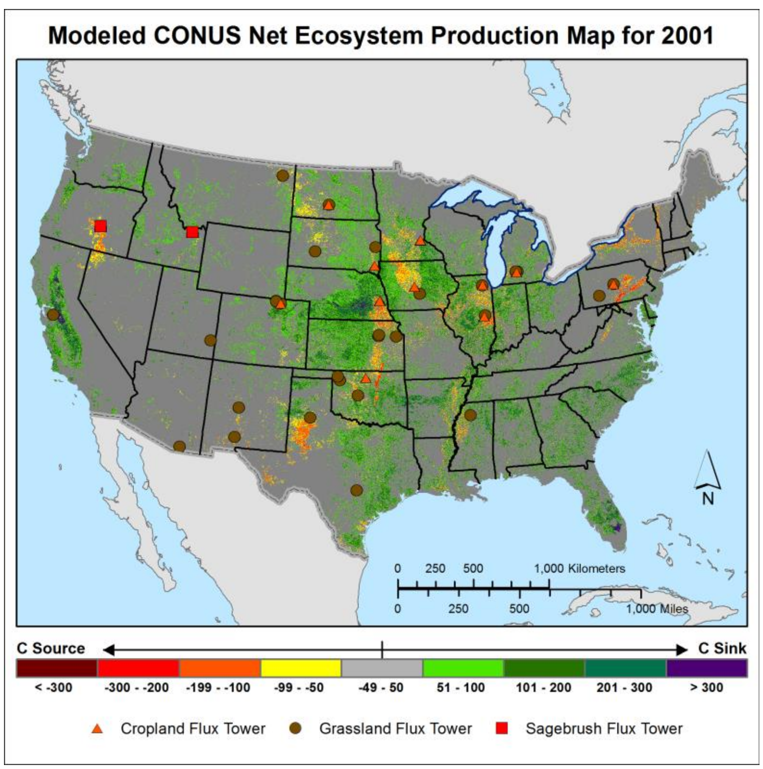


Figure 32. Initial results of the continental United States net ecosystem production map for 2001.

Producing a Near-Real-Time Cheatgrass Percent Cover Map

Cheatgrass is the most problematic invasive plant in the Northern Great Basin, United States, because it substantially helps increase fire frequency, fire size, and fire intensity. During some recent years, acres burned from just one fire in this ecoregion exceeded acres burned from all fires during many years. Fires fragment the sagebrush steppe, lead to severe land and water degradation, and compromise wildlife habitat and grazing acres.

USGS EROS scientists worked with the Bureau of Land Management to develop a time series (2000-2013) of cheatgrass percent cover maps in the Northern Great Basin by integrating remote sensing data with biogeophysical data into an ecological model. Cheatgrass percent cover maps from the recent past allows land managers and scientists to see where, and at what percent cover, cheatgrass existed historically. This information can be useful for evaluating land treatments and understanding fire behavior. However, possibly more useful to land managers and scientists is a cheatgrass percent cover map developed in near-real-time that could be used to highlight a current year's potential fire hotspots and critical habitat losses.

To develop a near-real-time cheatgrass percent cover map, we exploited the flexibility of the ecological model that was used to create the time series. Regression-tree algorithms and parameters defined the previous cheatgrass mapping ecological model, and we applied them to 2015 data with slight modifications to a few of the model's independent variables to expedite data development.

The 2015 near-real-time cheatgrass percent cover map experienced similar results to the overall mean of the 2000-2013 time series. The 2015 cheatgrass percent cover distribution ranged from 0-100, although only about 1 percent of the land area experienced cheatgrass with a cover higher than 60 percent, and 8 percent had no cheatgrass cover (fig. 33). The mean percent cover equaled 9.9 percent, almost 1 percent higher than the 2000-2013 average.

The 2015 dataset and map, as well as the 2000-2013 datasets and maps, are available on the DOI Northwest Climate Science Center Web site for download. As of October 28, 2015, the near-real-time dataset has received 47 reads on ResearchGate since being posted in July 2015. Personnel from the U.S. Forest Service have downloaded the dataset and are using it in the sage-grouse Fire and Invasives Assessment Tool and Wildland Urban Interface projects.

The cheatgrass project partners include the Bureau of Land Management and the Northwest Climate Science Center. We have used funds from both organizations to extend our cheatgrass work, both geographically and conceptually. For more information, contact USGS EROS, Bruce Wylie, wylie@usgs.gov.

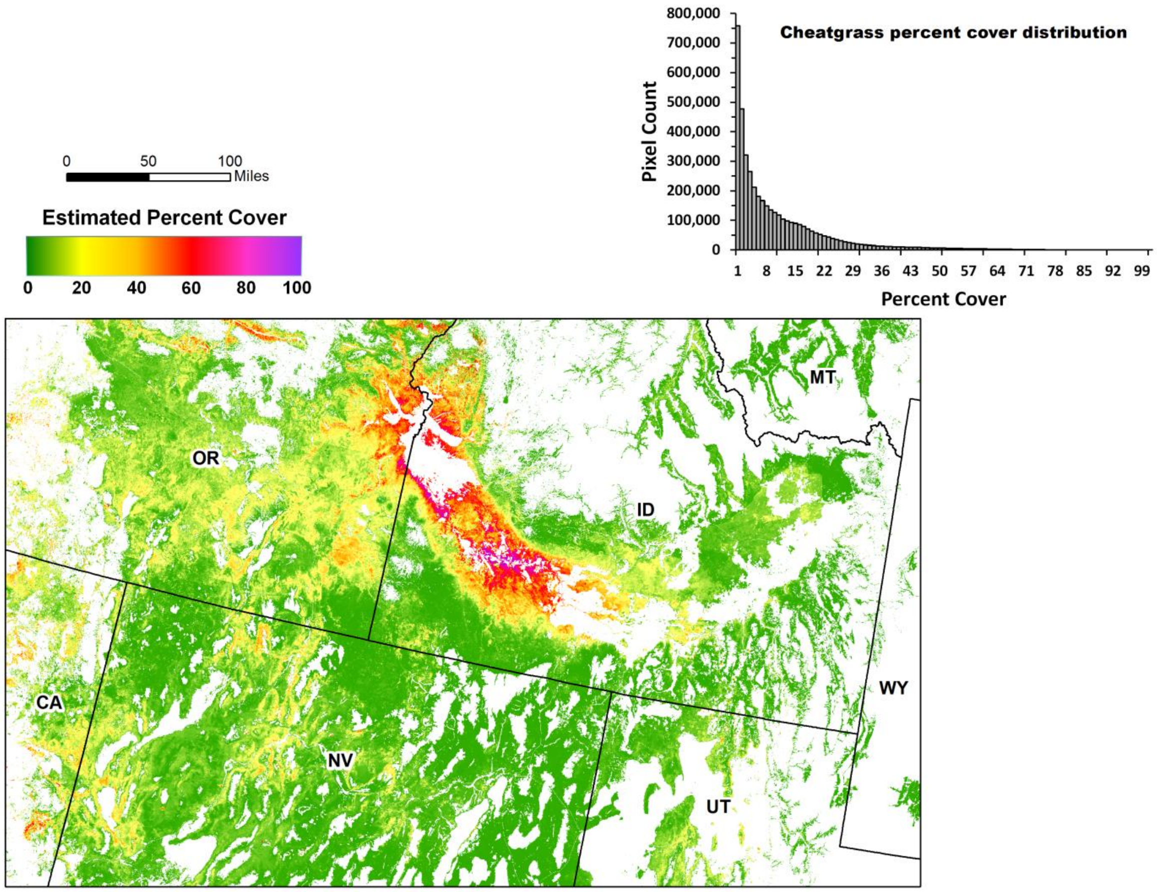


Figure 33. The 2015 near-real-time cheatgrass percent cover map and its distribution. The map was developed using a regression-tree model infused with data from a remote sensing normalized difference vegetation index and biogeophysical data. Map values ranged from 0-100 percent cover with a mean of almost 10 percent. A mask (white) covers areas higher than 2,000-meters elevation or not identified as shrub or grassland/herbaceous.

Carbon Sequestration Potential of Federal Lands in the Conterminous United States

Federal lands, covering about 23.5 percent of the conterminous United States land surface, have been an integral part of United States society and economy throughout history. They were established to help provide and sustain a wide range of ecosystem services including biodiversity preservation, mineral and energy development, recreation, and timber production.

Carbon dynamics on Federal lands is believed to play a major role in the Nation. However, no systematic information about the spatial patterns and temporal changes of carbon stock, and carbon sequestration potentials on Federal lands is available, representing a critical national knowledge gap.

As mandated by the U.S. Congress in the 2007 Energy Independence and Security Act, the USGS has quantified carbon sequestration potentials in the conterminous United States under various land use and climate change scenarios. The current study evaluated contemporary and future ecosystem carbon dynamics in conterminous United States Federal lands under three Intergovernmental Panel on Climate Change Special Report on Emission Scenarios A1B, A2, and B1. The Forecasting Scenarios of Land Use (FORE-SCE) model and the General Ensemble Biogeochemical Modeling System (GEMS) were used to simulate land use change and carbon dynamics, respectively.

It was estimated that conterminous United States Federal lands stored 11,613-million metric tons (MMTs) of carbon circa 2005 and was projected to store 13,965 MMTs of carbon in 2050, an increase of 19.4 percent. The corresponding projected annual carbon sequestration rate (in kilograms of carbon per hectare per year) from 2006-2050 would be carbon sinks (i.e., carbon gains) of 620 and 228 for forests and grasslands, respectively, and a source (i.e., carbon release) of 13 for shrublands. The Federal lands' contribution to the national ecosystem carbon budget could decrease from 23.3 percent in 2005 to 20.8 percent in 2050. The carbon sequestration potential in the future depends not only on the footprint of individual ecosystems but also on each Federal agency's land use and management. The results presented here update our current knowledge about the contemporary ecosystem carbon stock and sequestration potential of Federal lands, which would be useful for Federal agencies to formulate management practices to achieve the national greenhouse gas (GHG) mitigation goal (fig. 34).

The key partners and stakeholders of the project include all Federal agencies, the U.S. Global Change Research Program, and the North American Carbon Program.

The USGS EROS Center, located in Sioux Falls, South Dakota, provided fundamental modeling capabilities on land use change and carbon biogeochemical processes and geospatial analyses for this research. In addition, it provides scientific analyses based on remote sensing, environmental modeling, and geographic information system technologies to support carbon cycle research throughout the world. For further information, contact USGS EROS, Shuguang Liu, sliu@usgs.gov.

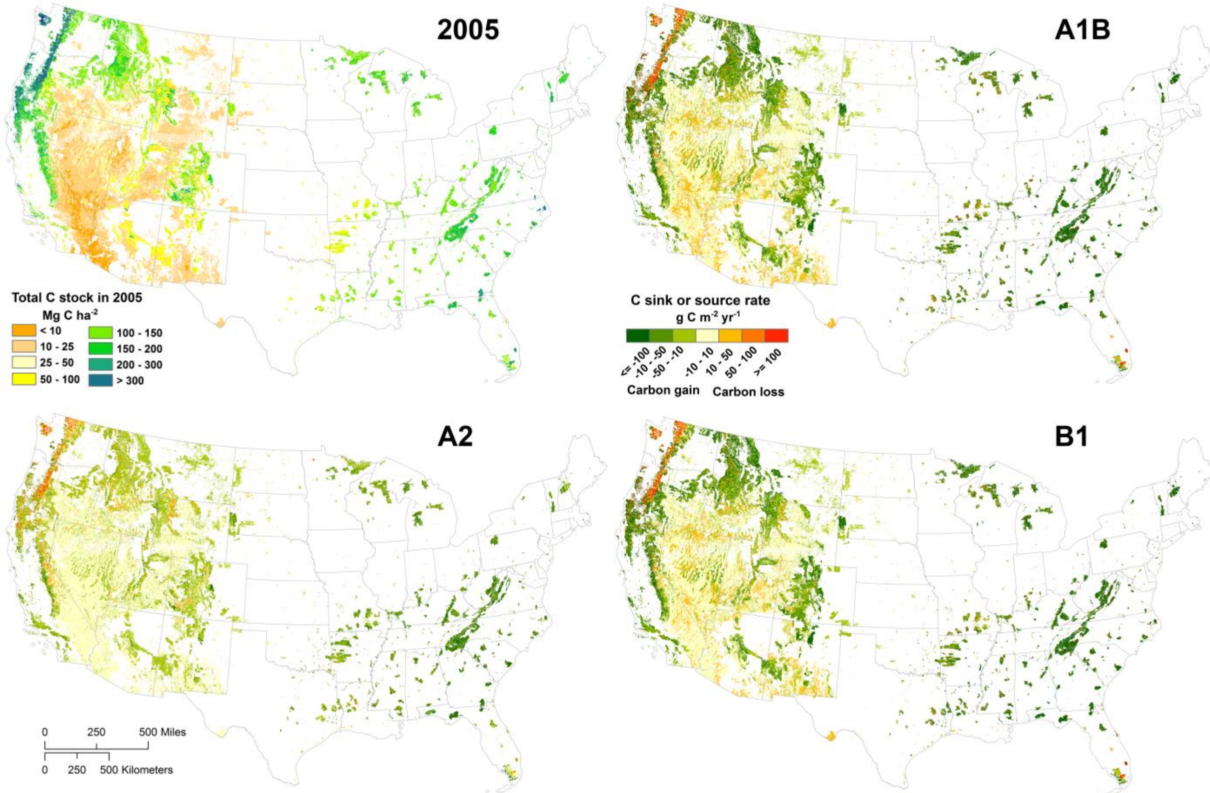


Figure 34. Spatial distribution of the contemporary (circa 2005) ecosystem carbon stock (in vegetation and the top 20-centimeter depth of soil, averaged from three model simulations) in Federal lands across the conterminous United States and its changes from 2006-2050 averaged from seven ensemble model simulations for each Intergovernmental Panel on Climate Change scenarios.

Mapping Land Use and Sustainable Management Practices in West Africa

Land use and land cover (LULC) maps of all 17 countries of West Africa were completed for the years 1975, 2000, and 2013. The maps represent the culmination of a large collaborative effort between environmental scientists from the USGS, the Agriculture-Hydrological-Meteorological (AGRHYMET) Regional Center, and national counterparts. Each country map tells a story of change. Both nationally and regionally, they provide a unique view of unprecedented change in West Africa's natural and human landscapes. The footprint of a rapidly growing population clearly stands out through significant conversions of land cover, and changes in land use. Figure 35 provides an overview of the completed LULC maps of the three periods. At a workshop in March 2015, the project team presented the maps to the heads of land management agencies and other decisionmakers from across West Africa. The maps were widely accepted and seen as a new tool to help address the challenge of balancing the need to preserve natural ecosystems with the need to grow more food, against the background of climate change.

Providing LULC to the user community is a basic data layer and a fundamental indicator of the region's diverse and evolving landscapes. It is considered an essential climate variable by the Global Earth Observation System of Systems (GEOSS). By characterizing LULC change over the past 40 years, users can make land change projections to generate future patterns of LULC that provide insight on ecosystem functioning, carbon dynamics, and other environmental and socioeconomic factors.

An important next step that builds on accurate multi-date LULC maps is to identify, map, and monitor a wide range of land and water management practices that can address land degradation and increase long-term agricultural productivity. The LULC maps of West Africa show a significant decline in the amount of natural vegetation, much of this driven by the expansion of cropland in response to population pressures and declining yields. As natural vegetation becomes scarcer, the ecosystem services provided by this vegetation is also dwindling. Farmers, development practitioners, and scientists have identified a wide range of land and water management practices that can address land degradation, increase long-term agricultural productivity, and strengthen resilience to climate change.

In response to deforestation and declining tree densities, a growing number of farmers in West Africa, particularly in the semi-arid regions, are investing in on-farm trees as a low-cost way to sustainably increase agricultural production and improve food security. Increasing the number of trees on farms can also produce significant volumes of firewood; contribute to farm incomes, provide fodder, edible leaves, and enhance household resilience by providing an alternative source of income.

In order to support of USAID's Resilience in the Sahel Enhanced (RISE) Program, the EROS team is mapping and monitoring land use, tree cover, and soil, water, and vegetation conservation practices across two large RISE project areas in Burkina Faso and Niger. The starting point was to identify current agricultural areas. The completed LULC maps of Niger and Burkina Faso – which accurately show the distribution of cropland area within the RISE areas (fig. 36) – provided the crop mask for this effort. The team then completed a series of thematic maps on conservation practices currently used by farmers. This included a map and an analysis of on-farm tree cover (fig. 37), prepared from high-resolution satellite imagery.

Maintaining and promoting on-farm tree cover is one of the most important practices that farmers can do to transform degraded landscapes – essentially restoring productivity and increasing resilience through the widespread adoption of agroforestry. Agricultural landscapes with on-farm tree cover are the result of a promising agroforestry practice commonly called farmer-managed natural regeneration (FMNR). While the extent and impact of FMNR are quite impressive in Niger, we also see it occurring in large areas of Mali, Burkina Faso, Senegal, Ethiopia, and in parts of eastern and southern Africa.

The multi-date LULC maps are already providing West Africa's decisionmakers with a much clearer picture of change – its patterns, magnitudes, and driving factors. Land use information is key for understanding and facing sustainability problems such as climate change, increasing demand for food, accelerating urbanization, and changes in the functioning of ecosystems and the services they provide. Producing an additional map layer – the land management practices that rural people are using to conserve and protect local soil, water, and vegetation resources – provides powerful, complimentary information to help meet the challenges of promoting sustainable land uses and scaling them up. For further information, contact USGS EROS, Gray Tappan, tappan@usgs.gov.

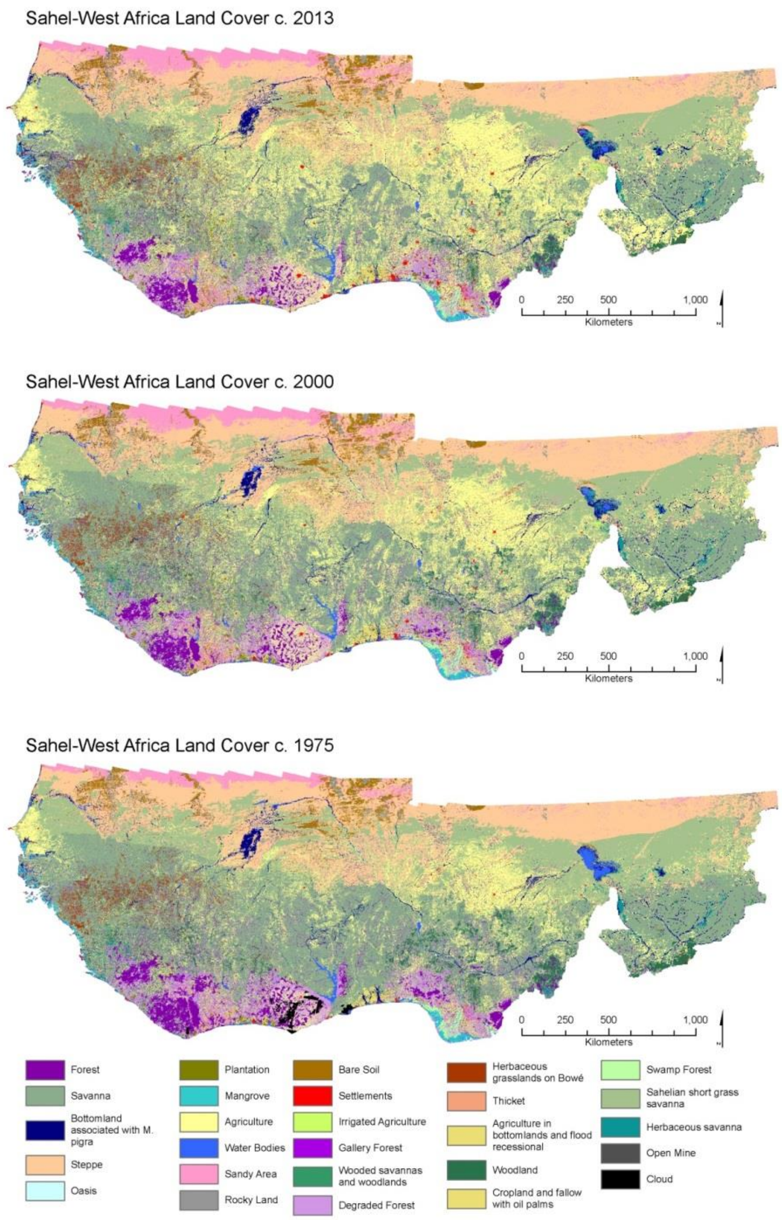


Figure 35. Land use and land cover of West Africa in 1975, 2000, and 2013.

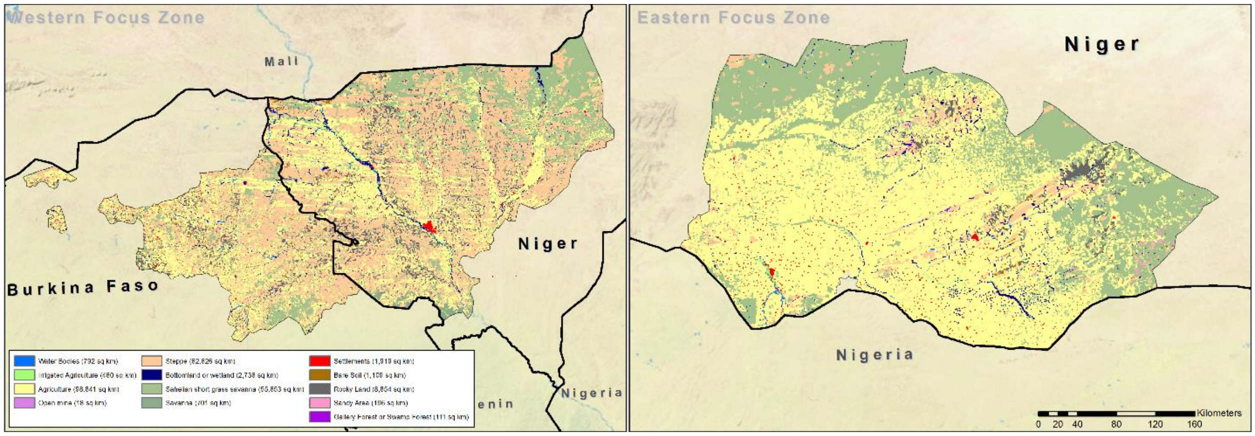


Figure 36. Land use and land cover in 2013 of the Resilience in the Sahel Enhanced Program areas of Burkina Faso and Niger.

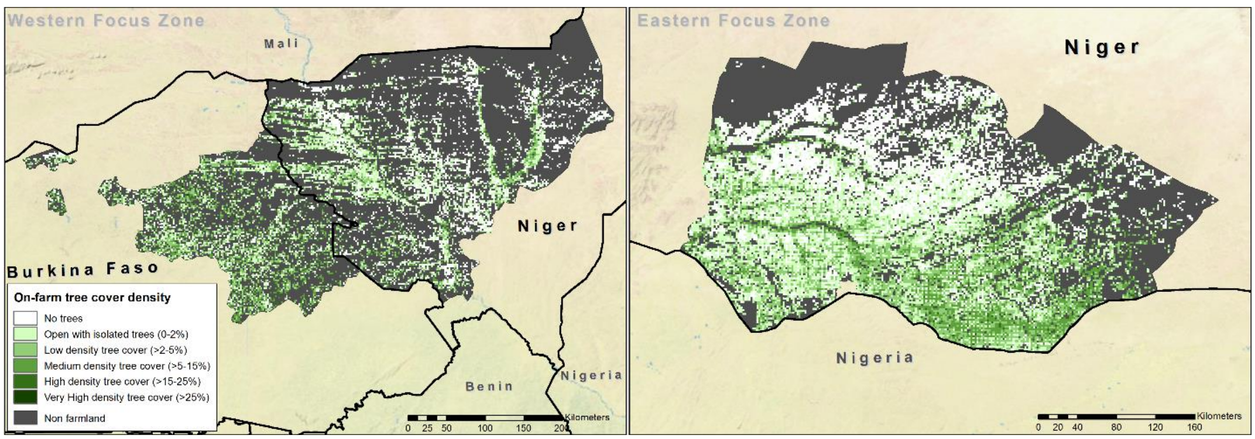


Figure 37. On-farm tree cover in the Resilience in the Sahel Enhanced Program areas of Burkina Faso and Niger.

Application-Ready Expedited MODIS Data for Operational Land Surface Monitoring

Many land monitoring approaches benefit from high temporal frequency image data collected from the moderate resolution imaging spectroradiometer (MODIS) system. Because of near-daily global coverage, MODIS data are especially beneficial to applications that require timely information about vegetation condition related to drought, flooding, or wildfire danger. Rapid satellite data streams in operational applications have clear value for monitoring vegetation, especially when information can be delivered as fast as changing surface conditions. An 'expedited' processing system called 'eMODIS' operated by the EROS Center provides rapid MODIS surface reflectance data to operational applications in less than 24 hours offering tailored, consistently-processed information products that complement standard MODIS products. We assessed eMODIS quality and consistency by comparing to standard MODIS data.

In order to characterize the eMODIS data across a broad range of ground conditions, we selected a large study area covering four contiguous MODIS tiles. This tile selection (h10v04, h11v04, h09v05, h10v05) contains a broad variety of land cover types and also provides coverage over selected carbon flux towers that will be incorporated into future study. The study time period, during March through October, 2003 to 2012, covered 10 years of observations in order to sample a variety of vegetation conditions. Only land data with known high quality were analyzed in a central United States study area. Data were summarized by 150-kilometer zones.

When compared to standard MODIS (MOD/MYD09Q1), the eMODIS normalized difference vegetation index (NDVI) maintained a strong, significant relationship to standard MODIS NDVI, whether from morning (Terra) or afternoon (Aqua) orbits. The statistical results of the study support significant confidence in the operational community needing low latency observations who currently apply the eMODIS data to monitoring applications. Results indicated that the eMODIS source of application-ready monitoring image data has comparable data quality to standard MODIS with a less than 24-hour latency. However, the presence of a few outliers in the study suggest that eMODIS cloud mask and angle selection process should be revisited (fig. 38). A number of users currently ingest the eMODIS data in their applications including: U.S. Agency for International Development, Famine Early Warning System Network, U.S. Department of Agriculture, Foreign Agriculture Service, U.S. Forest Service, Bureau of Land Management, Geographic Information Network of Alaska, National Integrated Drought Information System, and U. S. Drought Monitor. If higher quality data are a higher priority than low latency data, users have the option of working with the standard MODIS products. These data are usually available 5 days after satellite overpass. For further information, contact USGS EROS, Jesslyn Brown, jfbrown@usgs.gov.

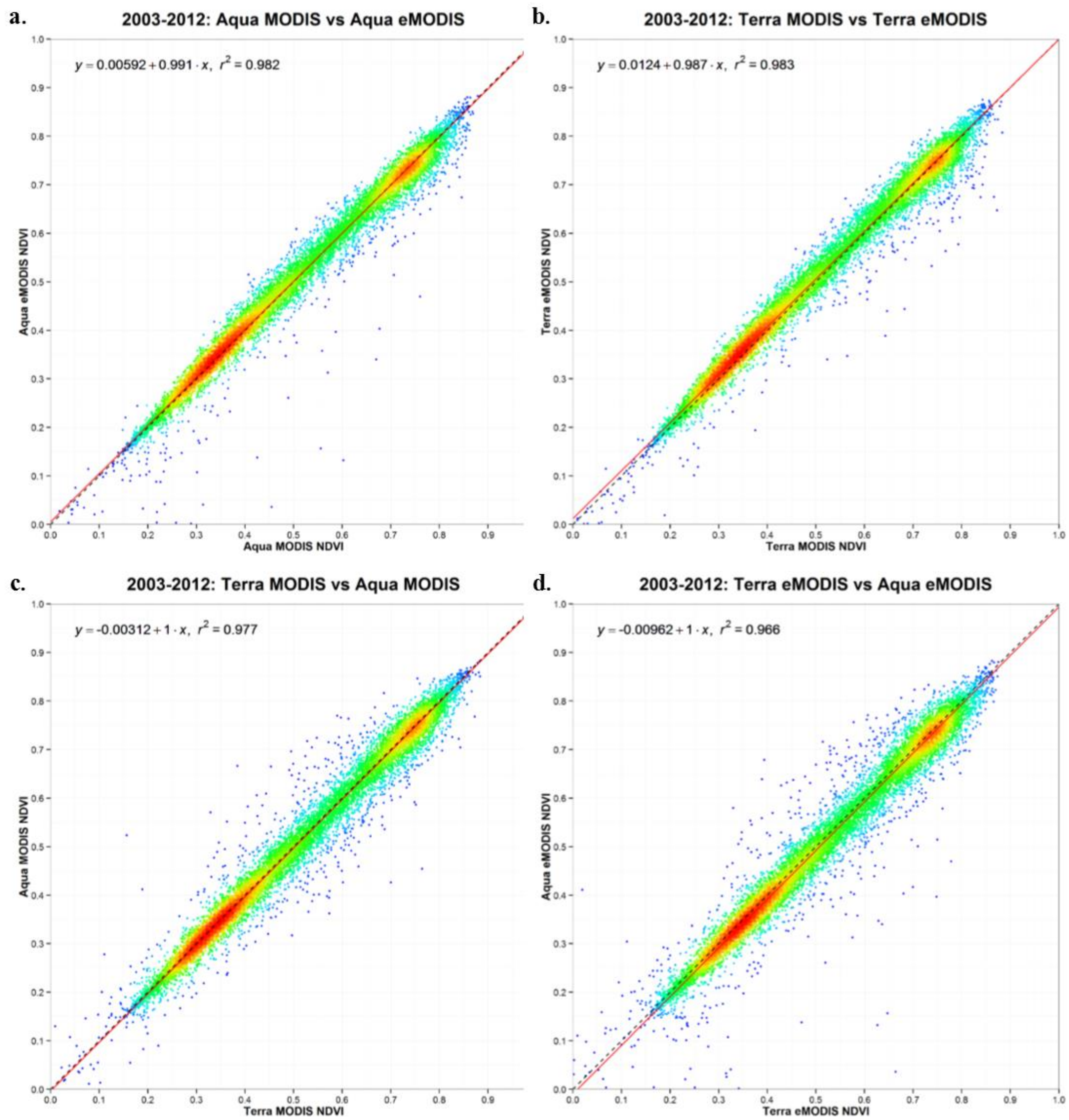


Figure 38. Density normalized difference vegetation index (NDVI) scatter plots, data (*n* = 11,998) for all study zones, 2003-2012; (a) standard Aqua moderate resolution imaging spectroradiometer **(**MODIS) versus Aqua eMODIS, (b) standard Terra MODIS versus Terra expedited MODIS (eMODIS), (c) standard Terra MODIS versus standard Aqua MODIS, (d) Aqua eMODIS versus Terra eMODIS.

Mapping Historical (1984-2014) Evapotranspiration Using the Landsat Archive

Evapotranspiration (ET) from irrigated agriculture is a significant component of the water budget of the western United States and is an essential piece of information for water management decisions. This project uses the Operational Simplified Surface Energy Balance (SSEBop) model to estimate historical evapotranspiration for every scene in the Landsat archive from 1984-2014 and integrate that with precipitation and runoff data to understand historical trends in water balance dynamics. Estimation of the historical change in ET for irrigation over time can inform decisions about water supply and imbalances as well as information about anthropogenic impact on water availability within the last 30 years.

From Landsat, we derived land surface temperature (LST), NDVI, and identified clouds through Fmask (a cloud detecting algorithm). Through process-based ET modeling, cloud detection and data integration of surface temperature, vegetation indices, and air temperature and reference (potential) ET datasets, we created the first ever historical time series ET maps for Palo Verde Irrigation District at the Landsat thermal band resolution (100 meter) to quantify water use at the level of individual agricultural fields (fig. 39). All 880 Landsat scenes over the Palo Verde Irrigation District in California have been processed (figs. 40a and 40b). Actual ET has been estimated to create monthly, seasonal, and annual figures (fig. 41).

A historical analysis of changes in evapotranspiration magnitude and distribution over time in the Southwest region will provide insight on the impact of political, economic, and environmental factors on the use and consumption of natural and managed water flows. Initial results indicate a general increase of LST in more recent years, which is a direct result of a reduction in ET (lack of evaporative cooling) (fig. 42). This historical trend demonstrates how cost-effective remote sensing technology can trace and quantify changes in water consumption over time.

The rich archive of relatively high-resolution Landsat imagery combined with a simplified energy balance model that can estimate evapotranspiration in irrigated fields is not only suitable for scientific investigations of water use, but also provides an advantageous and efficient tool for water management agencies and farmers to understand the spatiotemporal dynamics of water use and make informed decisions about water budgeting.

The results of this project can help establish an objective means of characterizing the impact of drought and anthropogenic water use using remote sensing historical data and demonstrate the capabilities in using data such as Landsat for hydrological applications. Furthermore, this type of historical analysis can impact studies about climate change, changes in agricultural practices, and political/economic developments in the management of water in the southwest United States.

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 USGS EROS, Gabriel Senay, senay@usgs.gov.

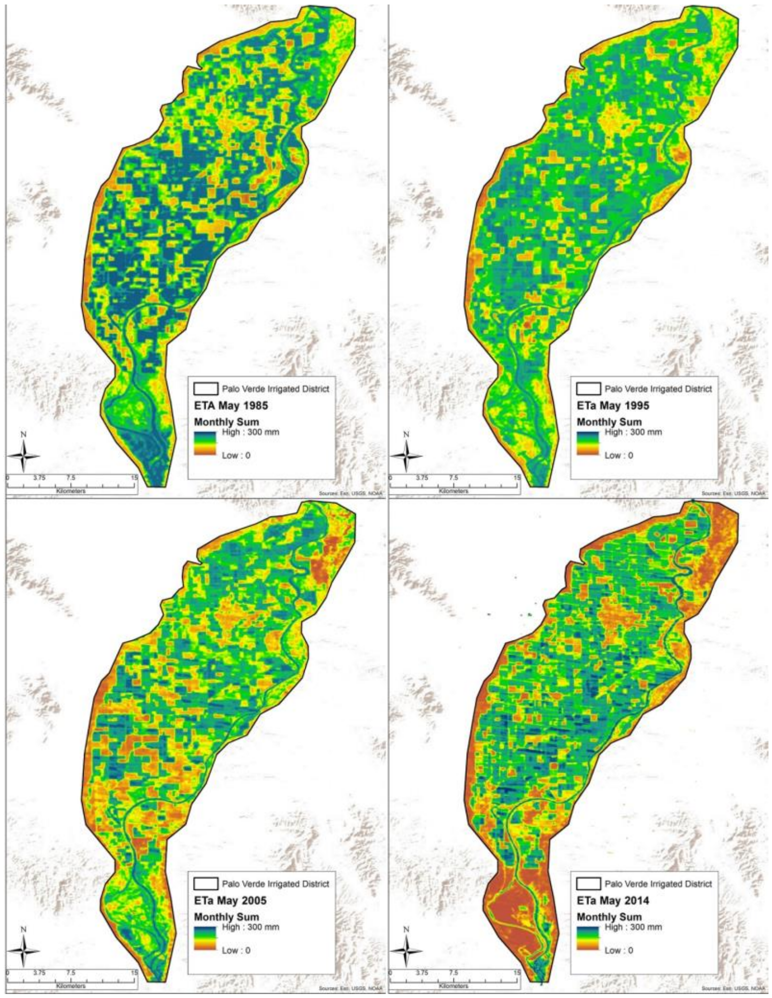


Figure 39. Time series of actual evapotranspiration for the month of May (1985, 1995, 2005, and 2014).

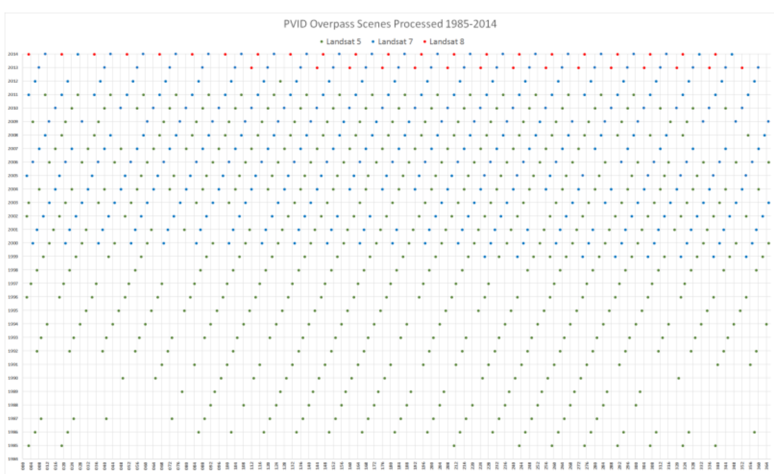


Figure 40a. Summary of overpass scenes processed for the Palo Verde Irrigation District for all three Landsat sensors from 1985-2014.

Scenes Processed	
Landsat 5	512
Landsat 7	331
Landsat 8	37
Total	880

Figure 40b. Summary of the number of scenes processed from each Landsat sensor.

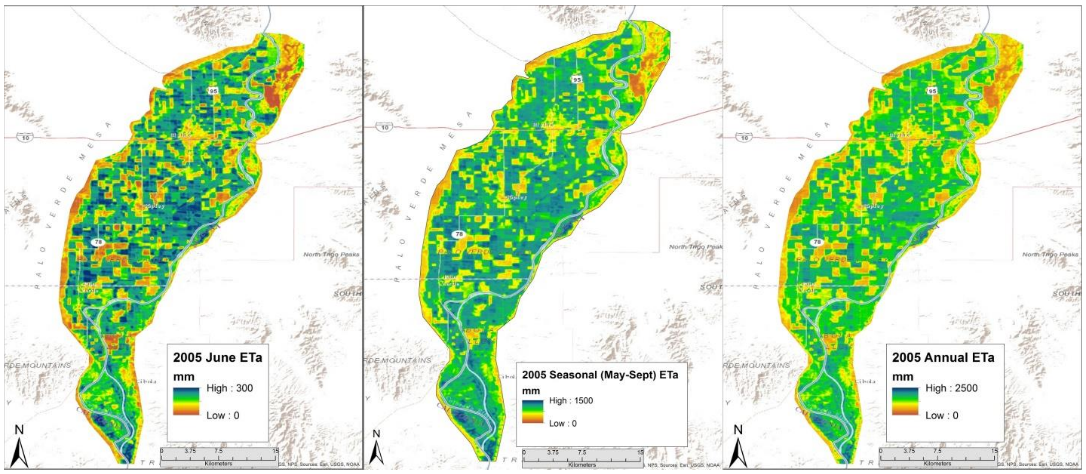


Figure 41. Monthly, seasonal, and annual maps of actual evapotranspiration from year 2005.

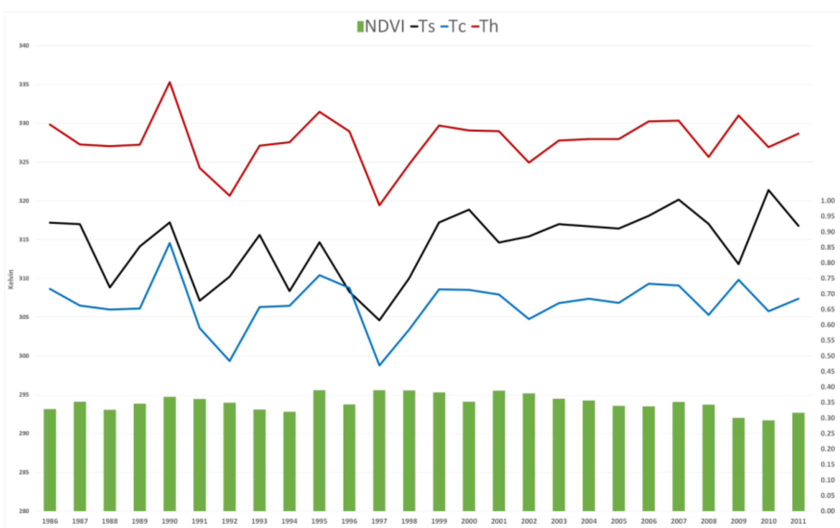


Figure 42. Spatially averaged Ts (satellite-derived surface temperature), Tc (cold/wet limiting temperature derived from air temperature), Th (hot/dry limiting temperature) and normalized difference vegetation index from Landsat 5 June overpass scenes (1986-2011) for Palo Verde Irrigation District.

Climate and Land Change and Their Combined Impacts on Human and Natural Systems

EROS science is committed to research that addresses how land change and climate together affect environmental systems. This requires research that leads to an understanding of the role of land and climate change as both a forcing and a feedback. The science focus areas primary to supporting this goal include **Coastal Changes and Impacts**, which conducts regional and national assessments of the complex interactions between coastal communities and natural landscapes associated with climate change, sea-level rise, and human development. Scientists develop data products and algorithms to carry out integrated, multitemporal, and multiscale research to analyze these interactions and answer questions relevant for land management agencies, resource managers, and decisionmakers; and **Early Warning for Food Security**, which is engaged in research and analyses of climate, remotely sensed land data, and related information to develop and provide operational monitoring and early warning forecasts and assessments of threats to food security, including those associated with climate variability in the near term, and those related to climate change in the longer term. Key accomplishments are given in the following sections.

Coastal National Elevation Database: Sandy-CoNED and Wetland Extent Mapping

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 eastern United States coast, altering the topography, bathymetry, 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 to the Outer Banks in North Carolina. The 1-meter TBDEMs have been developed for the New Jersey/Delaware (fig. 43), Chesapeake Bay (fig. 44), and New England (fig. 45) sub-regions that integrate dozens of high-resolution lidar and bathymetric surveys acquired by numerous sources. The Chesapeake Bay is the largest estuary in the United States and is surrounded by the North American mainland to the west, and the Delmarva Peninsula to the east. This estuary is also an important ecosystem and is home to many diverse species of flora and fauna.

Natural hazards, such as extreme storm events, can impact the spatial distribution of land and water in coastal wetlands and thus change the capacity of the ecosystem to provide services such as water quality enhancement; protection of populated areas from storm surge flooding; and habitat for fish, shellfish, and other wildlife. As part of the USGS Hurricane Sandy synthesis project, pre- and post-Hurricane Sandy remote sensing lidar data are being used to construct wetland extent geospatial products that will enable predictive sediment-transport flow modeling across wetlands in the Forsythe National Wildlife Refuge (fig. 46).

In support of Hurricane Sandy, the CoNED applications project in FY 2016 plans to publish 1-meter TBDEM's for the New England, Chesapeake Bay, and North Carolina sub-regions. In addition, high-resolution 1-meter topobathymetric models will be developed for southern California and Oahu, Hawaii, incorporating new and best available lidar and bathymetric data. Research in FY 2016 will be conducted to further expand mapping wetland extent and measuring sea cliff erosion using lidar, and to derive pseudo-bathymetry using Landsat 8 imagery. For further information, contact USGS EROS, Jeffrey Danielson, daniels@usgs.gov.

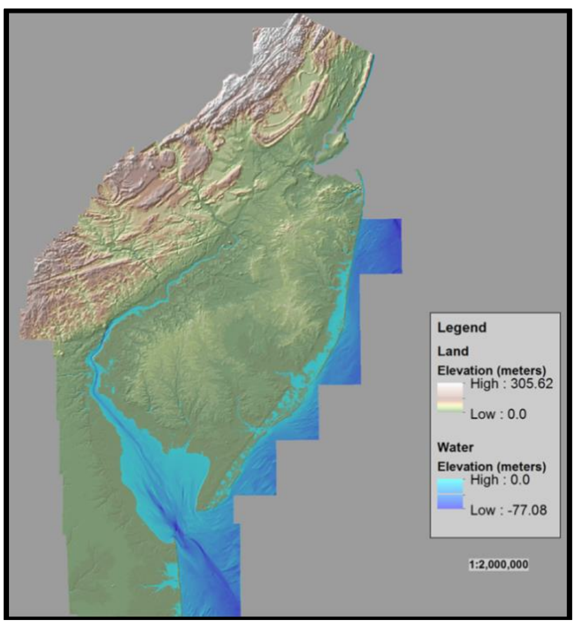


Figure 43. Sandy Coastal National Elevation Database – New Jersey/Delaware sub-region (version-2) 1-meter integrated topobathymetric model (2015).

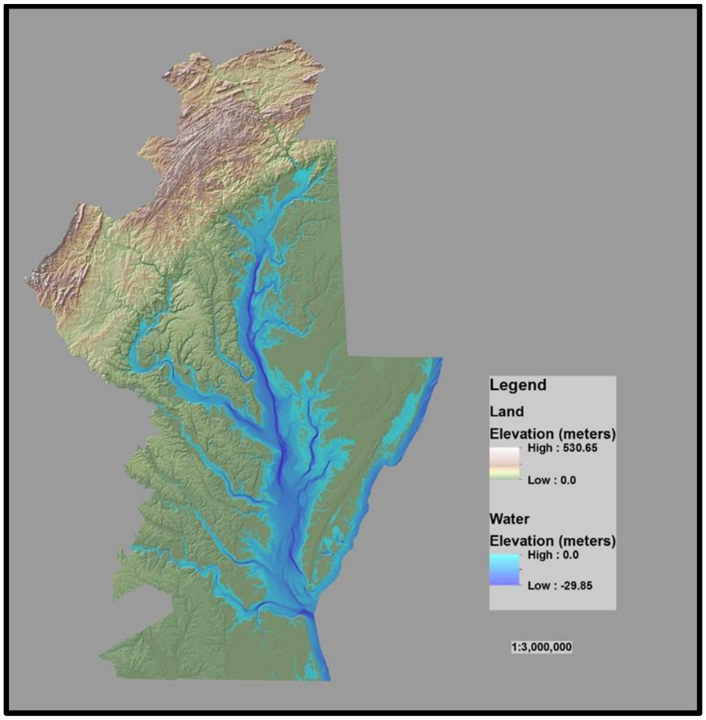


Figure 44. Sandy Coastal National Elevation Database – Chesapeake Bay sub-region 1-meter integrated topobathymetric model (2015).

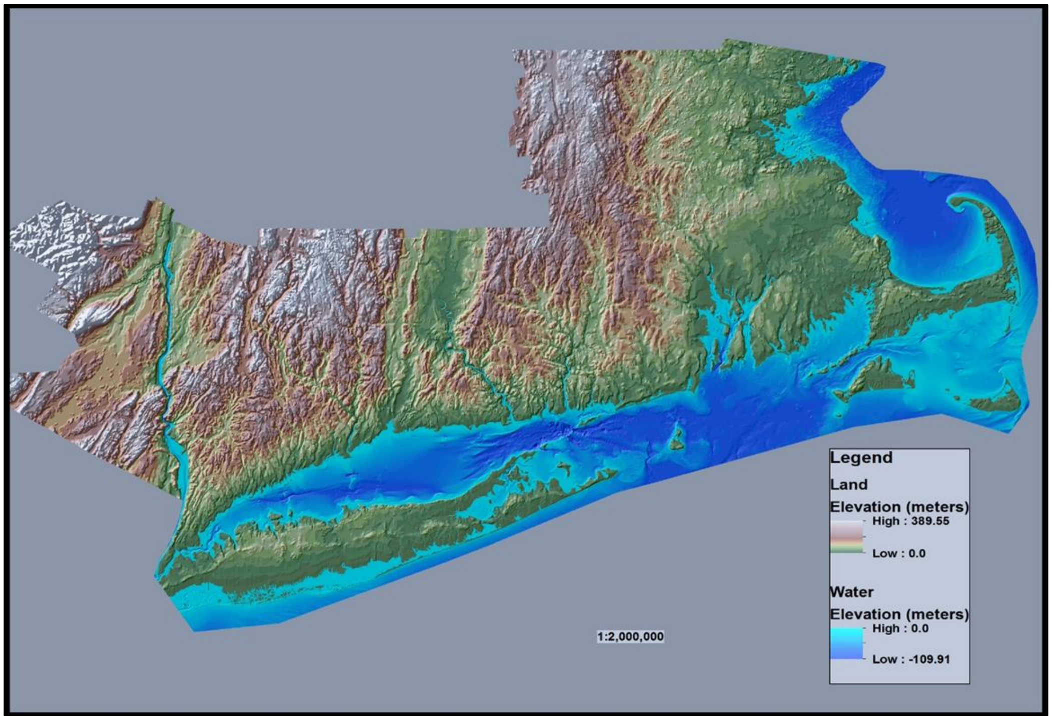


Figure 45. Sandy Coastal National Elevation Database – New England sub-region 1-meter integrated topobathymetric model (2015).

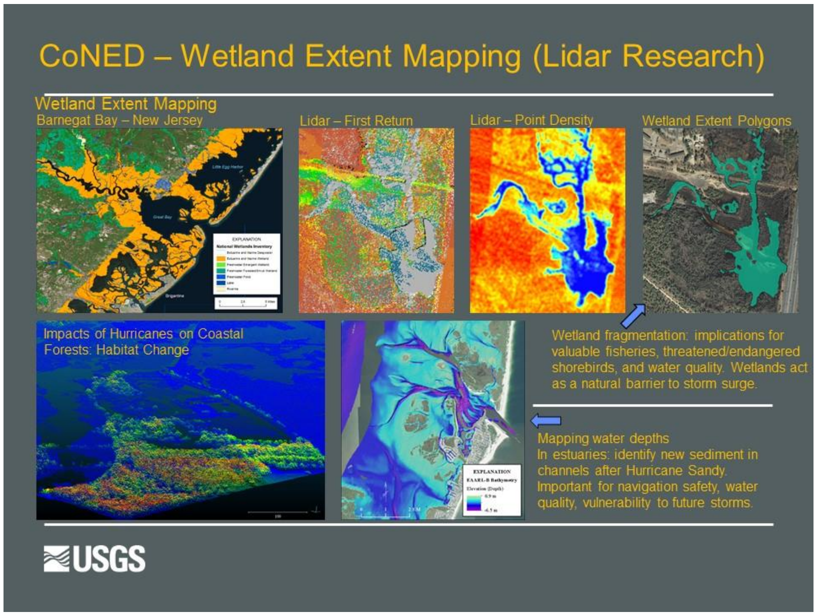


Figure 46. Coastal National Elevation Database – Wetland Extent Mapping Research.

Coastal National Elevation Database: Applications Project Web Site and Viewer

EROS with sponsorship from the USGS Coastal and Marine Geology Program (CMGP) launched a new Web site for the Coastal National Elevation Database (CoNED) applications project. The CoNED Web site (http://topotools.cr.usgs.gov/coned/) features information related to scientific research, new algorithms and methods, and topobathymetric elevation models (fig. 47). The Web site also features links to the CoNED Project Viewer and data download capabilities (fig. 48).

Many applications of geospatial data in coastal environments require detailed knowledge of topobathymetry (fig. 49). Several of these scientific research applications are available on the CoNED Web site including natural hazards impacts on coastal landforms and sea-level rise.

Impacts of Natural Disasters on Coastal Landforms. The USGS CMGP is researching impacts of natural disasters on coastal landforms with the CoNED applications project. CoNED assesses the impacts of various climate change scenarios on coastal regions to understand how catastrophic events impact the restoration, redevelopment, and protection of coastal environments (fig. 50) and the response of the coastal economy to natural disasters. This mission is possible with the use of highly detailed near-shore land (topographic) and water depth (bathymetry) information. This detailed coastal information, often called topobathymetry, is important for numerous scientific applications, such as shoreline delineation, coastal inundation mapping, sediment transport, sea-level rise and storm surge models, and tsunami impact assessments.

Sea-Level Rise. A coastal region that is ecologically important is Mobile Bay, Alabama, the fourth largest estuary in the United States. USGS scientists are assessing sea-level rise in this sensitive ecosystem using a collection of light detection and ranging (lidar) topobathymetric information (fig. 51).

CoNED Applications Project. The USGS CoNED applications project provides important information for a range of applications needed for climate change analysis in sensitive coastal regions including:

- flood hazard mapping and inundation,
- sea-level rise,
- sediment transport,
- storm surge,
- coastal redevelopment planning,
- restoration, redevelopment, and protection,
- cliff metric development and analysis, and
- coastal geomorphology analysis.

Additional information on these scientific applications and publications is available at http://topotools.cr.usgs.gov/coned/ and http://topotools.cr.usgs.gov/coned/publications.php. For additional information, contact USGS EROS, Sandra Poppenga, spoppenga@usgs.gov or Jeffrey Danielson, daniels@usgs.gov.

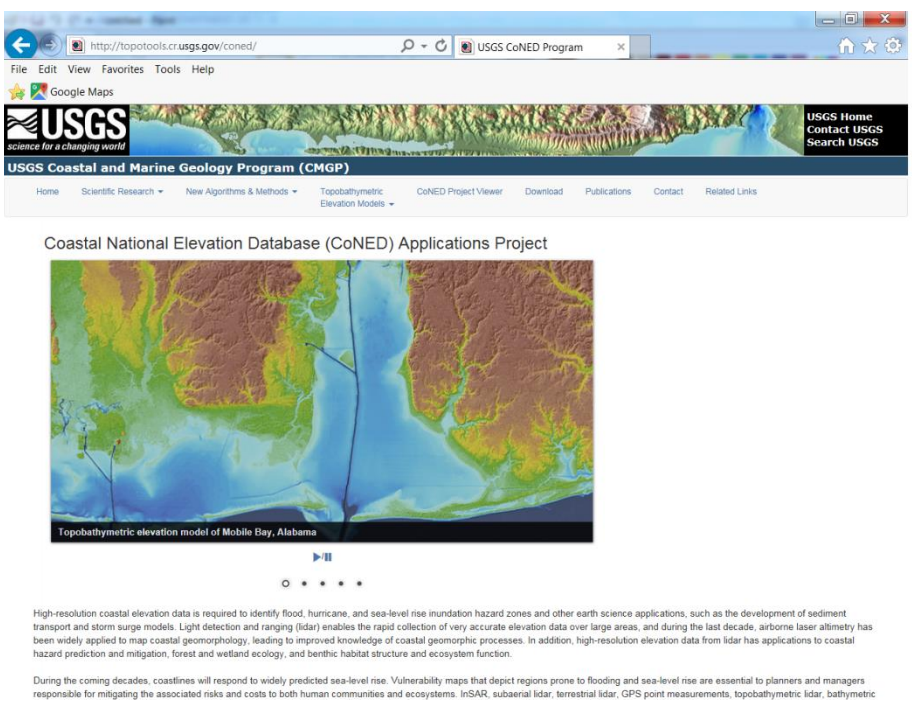


Figure 47. The Coastal National Elevation Database applications project Web site is available at http://topotools.cr.usgs.gov/coned/.

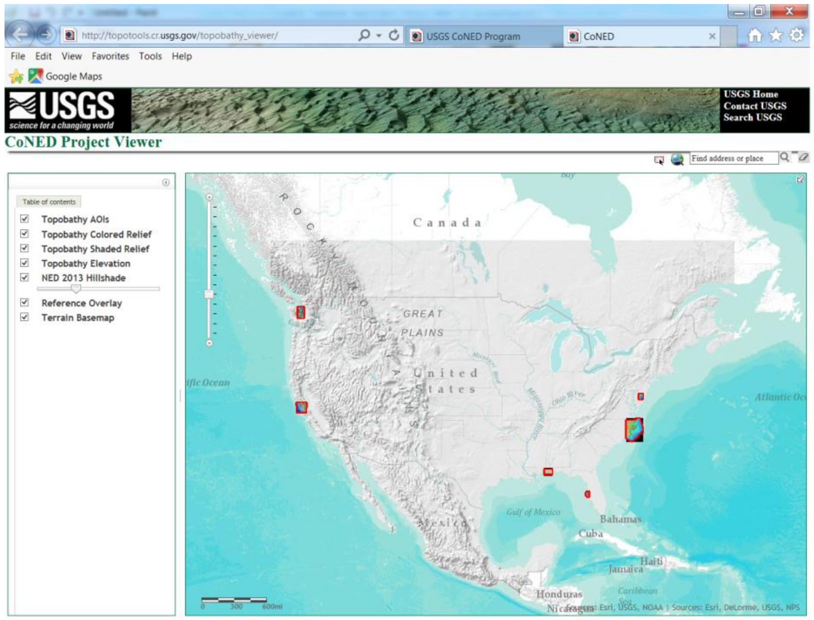


Figure 48. The Coastal National Elevation Database applications project viewer is available at http://topotools.cr.usgs.gov/topobathy_viewer/.

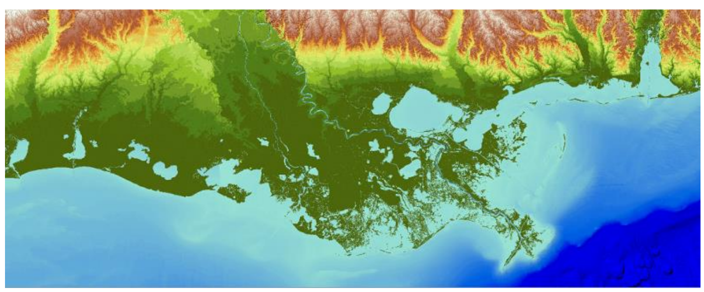


Figure 49. Topobathymetric model of Northern Gulf of Mexico.

Figure 50. House located near Staten Island, New York, beach impacted by Hurricane Sandy flooding.

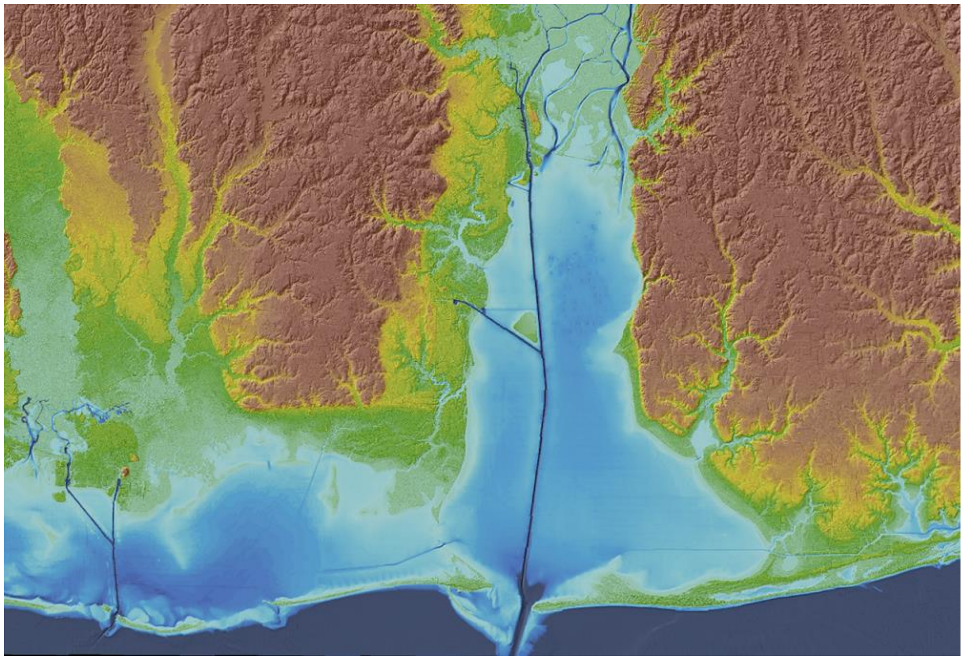


Figure 51. Topobathymetric elevation model of Mobile Bay, Alabama.

Improving African Climate Services with the Centennial Trends Dataset

USGS scientists, in partnership with the U.S. Agency for International Development (USAID) and other Federal agencies, work with African partners to develop improved climate services. These climate services, provided by the national meteorological agencies and other early warning agencies, help identify and mitigate the impacts of droughts and guide 'climate smart' development.

In support of climate services in the Greater Horn of Africa, the USGS Famine Early Warning System (FEWS) Network (FEWS NET) team developed the Centennial Trends rainfall dataset: a 1900-2014 set of monthly gridded 0.1 precipitation observations (fig. 52). This dataset is being used in conjunction with USGS climate analysis tools to help East Africans prepared themselves for future climate extremes.

The Centennial Trends dataset combines a unique high-resolution, satellite-enhanced precipitation climatology with the best available set of rainfall gauge observations using a rigorous geostatistical blending procedure. The station data were compiled in collaboration with scientists at Florida State University.

When combined with the two USGS-developed software tools (i.e., GeoMod and GeoClim), the Centennial Trends dataset allows East African scientists to map, plot, and model very long variations in precipitation and temperature. USGS FEWS NET scientists have performed training sessions on Centennial Trends, GeoClim, and GeoMod in Tanzania, Burundi, Rwanda, Uganda, Ethiopia, and Kenya. African scientists are now using these resources to identify climate change 'hot spots': places where warming and drying interact with high vulnerability, land cover and land use change, and population growth. These efforts, supported by the $35-million USAID Policy, Adaptation, Research and Economic Development (PREPARED) climate adaptation project, are helping these food-insecure countries mainstream climate change adaption. By enhancing the technical capabilities of the national meteorological agencies, USGS science is helping these organizations provide valuable climate services. Assisted by more effective climate services, these countries will be better able to respond to climate extremes and climate change on seasonal and decadal time scales.

FEWS NET partners include USAID, USGS, NASA, NOAA, USDA, and Chemonics International who has been implementing field activities for FEWS NET since 2000.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, environmental modeling, and geographic information system technologies to support FEWS NET activities throughout the world. For further information, contact USGS EROS, Christopher Funk, cfunk@usgs.gov.

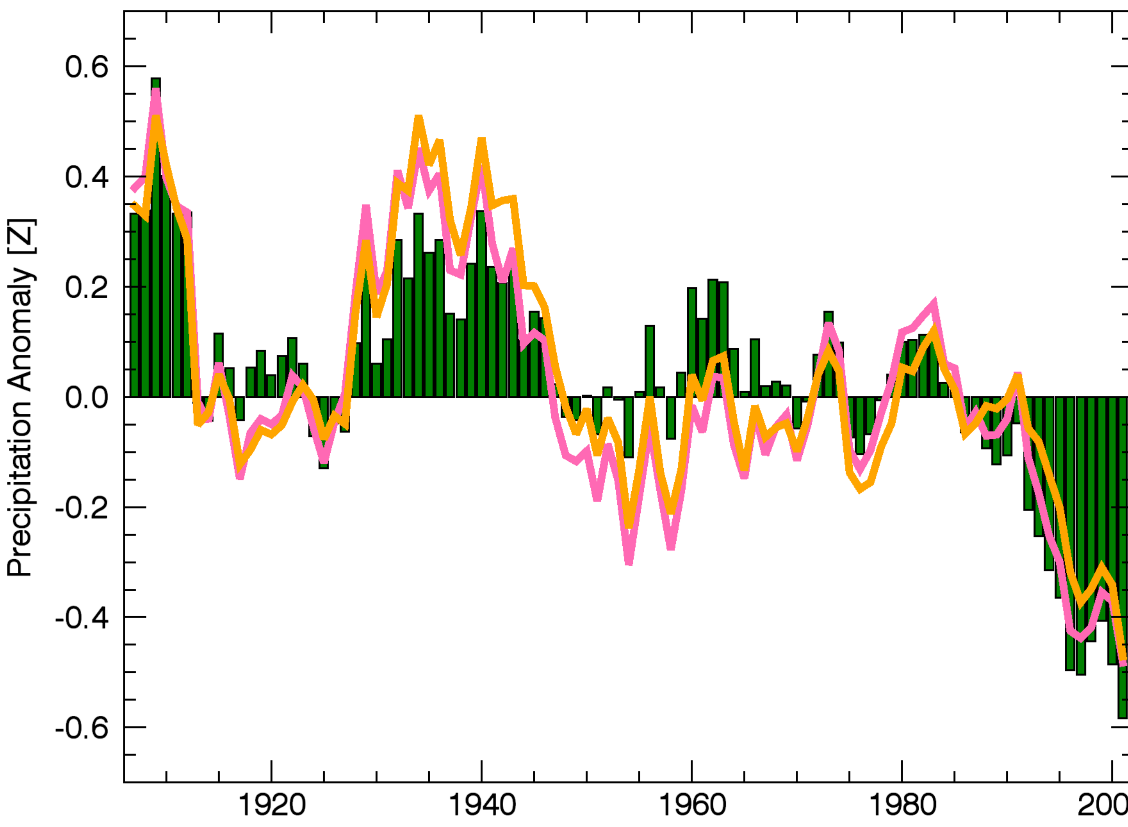


Figure 52. Comparison of Centennial Trends, March-June, Greater Horn of Africa precipitation time series (green bars), Global Precipitation Climatology Center gridded data (orange line), and station observations (pink). All three time series show a very concerning decline in precipitation.

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 Development and Operations

Landsat satellites have continuously acquired multispectral images of the global land surface since the launch of Landsat 1 in 1972. The Landsat Program is a joint effort of the USGS and NASA. The scope of Landsat development and operations activities at the USGS EROS Center includes overall project management and system engineering for successor-mission Landsat ground segment development (i.e., Landsat 9) and on-orbit mission and flight operations (i.e., Landsat 7 and 8), including coordination with NASA for overall mission development and science coordination. Fundamental to the success of these interagency Landsat Program activities is collecting and documenting user requirements in terms of what needs to be observed; seeking technical and scientific input on issues critical to the success of the Landsat program through the Landsat Science Team; and managing the Landsat International Cooperator (IC) Network. Key accomplishments are given in the following sections.

Landsat Data Continuity Mission in Retrospect

The Landsat Data Continuity Mission (LDCM) was a joint development and implementation mission between the National Aeronautics and Space Administration and the Department of the Interior's United States Geological Survey. LDCM was conceived as a follow-on mission to Landsat 7, the next in the highly successful series of Landsat missions that have provided satellite multispectral imagery coverage of the Earth's continental surfaces since 1972. The data from the missions constitutes the longest continuous record of Earth surfaces as seen from space. This mission implementation successfully continues the 40+ years of global data collection and distribution provided by the Landsat series of satellites.

Following transition to on-orbit operations, the integrated NASA and USGS project team pursued an "LDCM In Retrospect (LIR)" activity, where they assessed a broad range of topic areas in order to offer a highly comprehensive and introspective look into key project development and implementation activities. Rather than simply cite a collection of lessons learned for the record, the project opted to conduct a retrospective study, which captured key events and strategic decisions, along with their impacts and associated lessons learned in a narrative form. The intent of the narratives is to tell the "story" around each major key event or strategic decision, which provides valuable content to the reader to aid in its application to different situations. Each narrative also addresses key components of success. In this way, the project provides key messages, themes, and major factors of success for senior decisionmakers, along with detail and context associated with a retrospective assessment of strategic decisions, key events, impacts, and lessons learned for future mission implementers.

Representatives of the entire LDCM team, including current and previous project members from both NASA and USGS Government and industry contractor organizations, participated in this retrospective assessment through a series of open, facilitated discussions. A small team then worked with information provided and subject matter expert authors to craft the retrospective assessment of LDCM. In short, the LIR report represents a thorough retrospective assessment performed by the integrated NASA and USGS project team for the benefit of future NASA and USGS program and project management teams. For more information, contact USGS EROS, Jim Nelson, jnelson@usgs.gov.

USGS Initiates Landsat 9 Development Project

In March 2015, the Land Remote Sensing Program authorized the initiation of the Landsat 9 Development project at EROS based on FY 2015 appropriations and the FY 2016 President's budget. The startup of this effort is concurrent with NASA's establishment of the Landsat 9 project at its Goddard Space Flight Center.

Landsat 9 is a successor mission to Landsat 8. Landsat satellites have continuously acquired multispectral images of the global land surface since the launch of Landsat 1 in 1972. The Landsat data archive constitutes the longest continuous moderate-resolution record of the global land surface as viewed from space. The Landsat 9 mission objective is to extend the ability to detect and quantitatively characterize changes on the global land surface at a scale where natural and human-induced causes of change can be detected and differentiated. The importance of Landsat is reflected in the President's National Space Policy of 2010 and in U.S. Law and Government Policy, Section 6.1.2, of the National Plan for Civil Earth Observations.

Land cover and land use are changing globally at rates unprecedented in human history with profound consequences for weather and climate change, ecosystem function and services, carbon cycling and sequestration, resource management, the national and global economy, human health, and society. Landsat is the only United States satellite system designed and operated to repeatedly observe the global land surface at a moderate scale. The importance of preserving and extending this record of observations is captured in the strategic plans of numerous Earth science and applications programs. These programs, both national and international, have documented the scientific and operational requirements for continuing Landsat observations.

Landsat 9 is being developed and operated through an interagency agreement annex for Landsat 9 established between NASA and DOI USGS. Figure 53 is an illustration of the Landsat 9 logo that depicts the collaboration between NASA and the USGS. The responsibilities for Landsat 9 project implementation are largely divided between mission segment areas: NASA is responsible for the development of the space segment and launch segment; and DOI USGS is responsible for the development of the ground segment. DOI USGS is also responsible for Landsat 9 mission operations after completion of the on-orbit checkout period, including image-data collection, management, and distribution. NASA will serve as the system integrator for the entire Landsat 9 project and lead the mission systems engineering and mission assurance efforts through the on-orbit checkout period. After on-orbit checkout, primary responsibility for the Landsat 9 mission and its operation transfers from NASA to DOI USGS.

The Landsat 9 project scope includes overall project management and system engineering for the ground segment development, including coordination with NASA for overall mission development and science coordination. The ground segment activities consist largely of the evolution of the current Landsat ground system capabilities necessary to support Landsat 9. The USGS project manager at EROS is Jim Nelson. For further information, contact USGS EROS, Jim Nelson, jnelson@usgs.gov.

Figure 53. Landsat 9 logo representing collaboration between NASA and USGS.

Landsat Science Team: Advancing Landsat Science and Applications

The 21 members of the Landsat Science Team (LST) continued to provide technical and scientific input to the USGS and NASA on issues critical to the success of the Landsat program. As recognized national and international leaders in land remote sensing, the Landsat Science Team principal investigators (PIs) contribute to USGS and NASA scientific and technical strategies affecting all Landsat users. Table 1 lists the 2012-2017 Landsat Science Team PIs and their research topics. The team met twice during FY 2015. The first meeting (fig. 54) was held February 3-5, 2015, at the NASA Goddard Space Flight Center in Greenbelt, Maryland; and the second meeting was held July 7-9, 2015, at the USGS EROS Center.

The February Landsat Science Team meeting focused on the recently announced Sustainable Land Imaging (SLI) program, ongoing problems with Landsat 8's Thermal Infrared Sensor (TIRS), and USGS plans for Landsat product improvements. Regarding SLI, the LST members enthusiastically supported the aims of SLI but expressed concern about the potential loss of Landsat data continuity if Landsat 9 is not launched until 2023. Regarding TIRS issues, the team concluded that the TIRS band 11 stray light correction approaches were not sufficiently mature and needed further testing. Finally, the LST applauded USGS Landsat product improvement plans and encouraged the provision of early prototype products for community review and comment. All of the February 2015 meeting presentations are available at https://landsat.usgs.gov/science_LST_feb2015.php.

The July LST meeting focused on science, engineering, and applications investigations of the LST PIs, and on the recent launch of Sentinel-2. Sentinel-2 is part of the European Space Agency's Copernicus Program. Sentinel-2a was successfully launched on June 21, 2015, and will provide moderate resolution imagery that augments Landsat. The LST considers Sentinel-2 as an important opportunity to increase the frequency of observation and to improve global monitoring of changing land use, cover, and condition. The LST also reviewed NASA and USGS plans to make Sentinel-2 data interoperable with Landsat and to distribute the global Sentinel-2 archive from the EROS Center. The science, engineering, and applications presentations highlighted the capabilities of Landsat 8 and emerging applications of Landsat archive data. All of the July 2015 presentations are available at https://landsat.usgs.gov/science_LST_july2015.php. For further information, contact USGS EROS, Thomas Loveland, loveland@usgs.gov.

Table 1. Landsat Science Team principal investigators and their research topics.

Member and Affiliation	Topic Emphasized by Their Research
Dr. Richard Allen University of Idaho	Developing and enhancing Landsat derived evapotranspiration and surface energy balance products.
Dr. Martha Anderson, **Dr. Feng Gao** USDA Agric Research Service	Mapping vegetation phenology, water use, and drought at high spatiotemporal resolution fusing multi-band and multi-platform satellite imagery.
Dr. Alan Belward European Commission Joint Research Center	Understanding the global land use marketplace.
Dr. Warren Cohen USDA Forest Service	Ecological applications of Landsat data in the context of U.S. Forest Service science and operational needs.
Dennis Helder	Landsat data continuity: advanced radiometric

Member and Affiliation	Topic Emphasized by Their Research
South Dakota State University	characterization and product development.
Dr. Jim Hipple USDA Risk Management Agency	Integrating field-level biophysical metrics derived from Landsat science products into a National Agricultural Data Warehouse.
Dr. Patrick Hostert Humboldt University of Berlin	Synergies between future Landsat and European satellite missions for better understanding coupled human-environment systems.
David Johnson USDA National Agricultural Statistical Service	Operational monitoring of United States croplands with Landsat 8.
Dr. Robert Kennedy Boston University	Using time series approaches to improve Landsat's characterization of land surface dynamics.
Dr. Leo Lymburner Geoscience Australia	Multi-temporal analysis of biophysical parameters derived from the Landsat series of satellites.
Dr. Joel McCorkel NASA GSFC	Absolute radiometric and climate variable intercalibration of Earth observing sensors.
Dr. David Roy South Dakota State University	Continuity of the Web Enabled Landsat Data (WELD) product record in the LDCM era.
Dr. Crystal Schaaf Univ of Massachusetts, Boston	North American land surface albedo and nearshore shallow bottom properties from Landsat and MODIS/VIIRS.
Dr. Ted Scambos University of Colorado	Cryospheric applications of the LDCM (Landsat 8).
Dr. John Schott Rochester Inst of Technology	The use of LDCM for the monitoring of fresh and coastal water.
Dr. Yongwei Sheng Univ of Calif, Los Angeles	Developing decadal high-resolution global wake products from LDCM and Landsat.
Dr. Eric Vermote NASA GSFC	Development of Landsat surface reflectance climate data records.
Dr. Christopher Justice University of Maryland	Development of Landsat surface reflectance climate data records.
Dr. Jim Vogelmann USGS EROS	Ecological disturbance monitoring using Landsat time series data.
Dr. Curtis Woodcock Boston University	Better use of the Landsat temporal domain: monitoring land cover type, condition, and change.
Dr. Michael Wulder Canadian Forest Service	Integrating the past, present, and future of Landsat.
Dr. Randolph Wynne Virginia Tech	Making multi-temporal Landsat work.

Figure 54. A group photograph of the Landsat Science Team members and affiliates at the February NASA Goddard Space Flight Center meeting.

Landsat International Cooperator Network: Opening the Door to International Collaboration

Over the years, the Landsat International Cooperator (IC) Network has grown to meet the increasing demands of the global Landsat user community. Since the February 11, 2013, launch of Landsat 8, 39 organizations from 37 countries representing 47 ground stations from around the world have shown interest in becoming part of the Landsat IC Network. Figure 55 depicts the Landsat 8 international ground stations, which have shown interest in participating in the Landsat 8 mission as an International Cooperator.

Of these potential ICs, to date 13 organizations have a signed agreement to be part of the Landsat IC Network. Table 2 lists the organizations representing 22 possible ground stations. Once a ground station is prepared technically to receive the Landsat downlink for direct reception, the USGS conducts a rigorous 14-step certification process. At this time, there are 9 Landsat 7 and 17 Landsat 8 international ground stations that have been certified and are actively receiving Landsat images with several more in process. Figure 56 shows the active Landsat international ground stations.

On November 17-20, 2014, the Landsat ICs participated in the 42nd Landsat Ground Station Operators Working Group (LGSOWG #42) meeting held in Denver, Colorado, in conjunction with the Pecora 19 event. There were 60 participants from 16 countries, including members of the USGS and NASA Landsat teams, represented 26 United States and international organizations to discuss a wide range of Landsat programmatic ground station topics. A photograph of the LGSOWG #42 participants is shown in figure 57.

On June 15-19, 2015, the Landsat ICs participated in the joint 43rd Landsat Ground Station Operators Working Group (LGSOWG #43) and 24th Landsat Technical Working Group (LTWG #24) meeting held in Canberra, Australia. There were 62 participants from 18 countries that represented 28 United States and international organizations to discuss Landsat management and technical ground station topics. Special guest, Australian Minister for Industry and Science, the Honorable Ian Macfarlane, welcomed the attendees and provided an overview of the critical role of remotely sensed Earth observation (EO) data in today's society. Figure 58 is a photograph of the joint LGSOWG #43 and LTWG #24 participants.

Of critical significance for the Landsat IC network this past year was the level of engagement with several key ICs for technical and scientific collaborations. A formal agreement with Geoscience Australia (GA) was signed at the joint LGSOWG #43 and LTWG #24 meeting for more extensive EO collaboration activities. Additionally, similar discussions with the European Space Agency (ESA), the German Aerospace Center (DLR), and the Canada Centre for Mapping and Earth Observation (CCMEO) were well underway. The DLR, GA, and the Brazilian National Institute for Space Research (INPE) were selected to become partners in the optimized Landsat 8 ground network (LGN).

For over 40 years, the USGS and the ICs have collaborated in a variety of scientific and technical areas. Over this time period, the Landsat IC network has been enhanced to provide not only basic data downlink services, but it also provides numerous key strategic international partnership benefits to the USGS including:

- reduction in long-term operational LGN costs,
- expansion of world-wide Landsat data distribution and exploitation,
- local and regional expertise to the global Landsat community,
- historical and ongoing global data collection,
- backup USGS ground station capabilities,
- vital international charter and other emergency response support,
- critical spacecraft anomaly investigation and recovery operations,
- expansion of available scientific and technical resources and capabilities, and
- feedback on and enhancements to ground system processing.

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

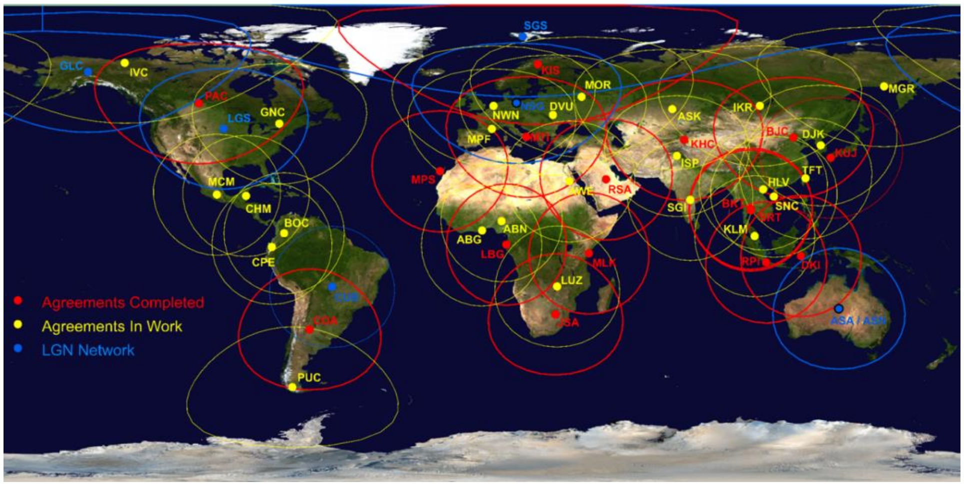


Figure 55. Potential Landsat 8 international ground stations.

Table 2. International cooperators with a signed Landsat 8 agreement.

Signed (22 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

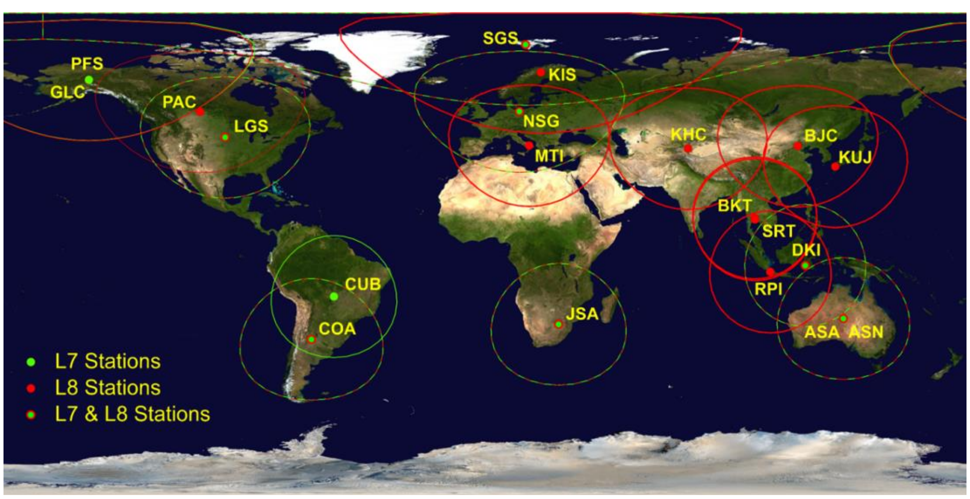


Figure 56. Active Landsat international ground stations.

Figure 57. Participants in the 42nd Landsat Ground Station Operators Working Group meeting held in Denver, Colorado, November 17-20, 2014.

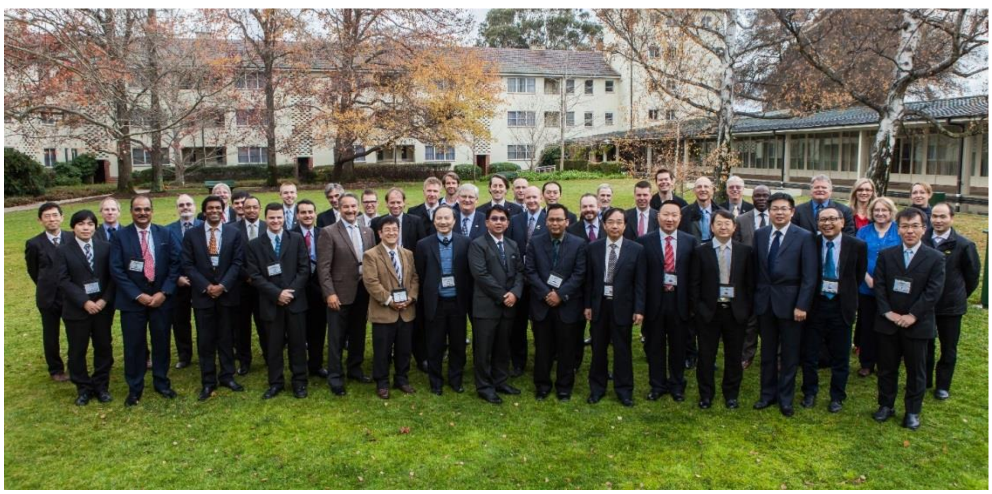


Figure 58. Participants in the joint 43rd Landsat Ground Station Operators Working Group and 24th Landsat Technical Working Group meeting held in Canberra, Australia, June 15-19, 2015.

Landsat Space Operations – Extending Satellite Missions

Operating a vehicle orbiting the Earth at 15,000 miles per hour from the ground located 438 miles below is not your average day job. This is part of the USGS program's responsibilities while daily imaging the Earth via the Landsat satellites. Each mission is designed to endure the extremes of the space environment through robust design including some system redundancies. Landsat 5's distinguished 29-year mission demonstrated not only the benefits of redundant design features but also the value of a skilled and creative flight operations team. Landsat 7 and Landsat 8 are the current missions to continue this challenge of maximizing mission life.

While Landsat 5 was designed for a 3-year mission life, both Landsat 7 (fig. 59) and Landsat 8 (fig. 60) were designed for a minimum 5-year mission life. Landsat 7 recently collected its 2-millionth scene on September 11, 2015, after 16½ years in orbit. By chance Landsat 5 and by design Landsat 8 were each launched with additional fuel, fuel that is required for the spacecraft to maintain a precise orbit for Earth imaging. Landsat 7 is now drawing down its fuel reserve late in the mission; and in 2015, the flight operations team investigated a number of options to optimize fuel use with the goal of maximizing Landsat 7's operational life. On September 29, 2015, Landsat 7 successfully performed its 19th inclination maneuver that positions it to potentially continue its mission into 2020 – over 21 years following its launch.

The Landsat 8 spacecraft was designed for a 5-year design life; however, due to time constraints, its thermal imaging instrument, known as the Thermal Infrared Sensor or TIRS, was designed for 3-year life. Toward the end of 2014, a component of TIRS started exhibiting signs of a problem. While there was no sign of imminent failure in early 2015, the flight operations team initiated an investigation and found the most likely cause could be mitigated by an alternate method of operating the instrument. A team of operators, calibration specialists, and engineers, including USGS, NASA and vendors, was assembled to identify methods to continue acquiring TIRS data and process it to the same data quality specifications while performing calibrations less often then designed. It was through the ingenuity and creative thinking of engineers, scientists, and software developers working together that a solution was found. On orbit tests were performed to verify the feasibility of this method of operation after which the decision was made to switch to the redundant set of electronics. The team choreographed the steps for testing and implementing the alternative method of operation and transitioning to the redundant electronics, which was completed on March 2, 2015. TIRS returned to normal science imaging, and the ground team returned to their normal duties knowing that should a similar problem develop on the redundant side there is a plan to keep TIRS going.

The USGS Landsat team, along with NASA and the spacecraft vendors, continued to meet the challenges of space operations in 2015 and will continue to build on that record in the future. Additional time added to a mission's operation provides more imagery for operational and science applications, a benefit to users and the American taxpayer. For further information, contact USGS EROS, James Lacasse, jmlacasse@usgs.gov.

Figure 59. Landsat 7 artist rendition.

Figure 60. Landsat 8 artist rendition.

Requirements, Capabilities, and Analysis for Earth Observation

The USGS Land Remote Sensing (LRS) Program is partnering with Federal agencies to document user requirements for Earth observation (EO) data and the benefits that these data provide to Federal programs. Requirements, Capabilities, and Analysis for Earth Observation (RCA-EO) was established to help the USGS and other agencies take full advantage of United States and international EO capabilities, and develop requirements-driven, prioritized investment decisions for new EO systems, products, and services. RCA-EO has completed significant accomplishments during this last year within all three focus areas, completing the value-tree information (VTI) elicitation for the USGS (including 27 programs, over 500 subject matter experts, and 345 key products and services), establishing an operations concept and work flow for analysis, and initial population of the capabilities database, as well as making excellent progress on the Earth Observation Requirements Evaluation System (EORES) application which is a tool being developed to support the project.

Requirements. RCA-EO defines requirements in terms of what needs to be observed, rather than in technology terms. For example, users may state a requirement for land surface temperature, land surface topography, or vegetation condition with associated attributes such as where and when it is needed and how accurate it must be. Requirements defined in these terms can be matched against a variety of current or expected spaceborne, aerial, or ground-based EO capabilities. Requirements based on observation needs are typically long-term and can be flexibly remapped to new technologies as they evolve and emerge. This technology-agnostic approach is being developed to reduce the burden of redundant requirements collection efforts, which are often difficult to reuse or reapply.

In the initial stages of the requirements development process, a "value tree" is constructed. In simple terms, a value tree is a hierarchical model that links an organization's goals and objectives to applicable EO data and systems. Using the VTI as context, user requirements are developed by identifying what EO is at the core of a program objective. For example, flood extent is largely a function of land surface topography, so a high-level requirement for a flood mapping objective would be land topography and its attributes. RCA-EO employs experts trained to collect requirements from subject matter experts in the Federal science and user community.

In 2015, the RCA-EO VTI elicitation effort was completed which consists of 345 key products and services across the 27 USGS programs. This data is currently being ingested into the EORES application through a repeatable, validated, semi-automated ingest process (fig. 61). All of the RCA-EO VTI data is scheduled to be ingested by the end of October 2015. As the RCA-EO VTI elicitation completed, the RCA-EO user requirements and EO applications 2016 VTI elicitation began. As EO application 2016 VTI data is elicited, it will be incrementally ingested into the EORES application.

The RCA-EO requirements elicitation process was vetted through a demonstration effort. Through the effort, three representative projects were interviewed and requirements developed. The three elicited projects represented applications on a global, national, and regional scale with similar global change master directories such that follow-on comparison analysis could be completed. Some preliminary results are shown in figures 62 and 63, showing the impact of remote sensing on USGS programs and the usage of Landsat within the USGS.

Capabilities. EO capabilities satisfy requirements. RCA-EO provides a structured database for documenting past, present, and future EO systems and their associated products and services. Information about each capability includes what is observed, where it is observed, how often, and how accurately. This information can be compared to user requirements to determine how well a current or future capability meets user requirements.

The demonstration effort mentioned earlier also supported the collection of information for capabilities. The EO system information was gathered to support comparison analysis with the collected user requirements. Some artifacts that were generated in conjunction with these efforts were a planning topic for the December 2015 technical interchange meeting about the collection, maintenance, and sharing of EO system information across the DOI and NOAA. Key documents that were drafted during the year include a plan documenting the initial approach to the EO requirements maintenance, and a whitepaper documenting the connection between the EO requirements and systems that will inform and shape future analysis efforts.

Analysis. RCA-EO analysis activities are being designed to help guide management decisions by those who manage or develop EO systems, products and services, and to users of these same products and services. From a national perspective, RCA-EO analyses will provide a better understanding of EO systems and their benefits to society, and can inform the development of more responsive and cost-effective EO systems.

The demonstration efforts are beginning to move the analysis team forward in understanding and defining the analysis that will be needed in the future. Two specific areas of interest are a gap analysis between requirements and capabilities, and an impact analysis that relates the capabilities to the overall value to the societal benefit areas. A key document that was drafted during this timeframe was the analysis concept of operations, which outlines the overall analysis strategies and will document additional requirements and workings of the analysis inputs, processing, and outputs. Tools were implemented to track and manage the analysis process, as well as to store the artifacts of ongoing and completed analysis tasks.

In FY 2015, there were a number of requests received by the project to provide background material and analysis to justify various aspects of the Landsat program with respect to emerging systems and technologies. Using the capabilities database and VTI, the analysis team was able to provide comparisons based on facts and data, instead of marketing material. Figure 64 shows an analysis that was done for Landsat 8 as compared to current and emerging systems for evapotranspiration, national land cover data, LANDFIRE, and flooding.

EORES Application. EORES is a relational database system architecture jointly developed by USGS and NOAA to store EO user requirements, VTI, and EO system capabilities and performance information; display, edit, browse, and maintain this information using a graphical user interface; compare requirements to capabilities to identify potential solutions; assess the relative ability of EO systems to support Federal objectives; and inform development of new EO systems through detailed user requirements. EORES will provide interfaces and tools to enter, edit, sort, query, browse, or export any data that are in the architecture or the results of a requirements gap assessment.

From an application development perspective, the VTI area development is complete along with the EO requirements development area. The team continues to develop the EO system functionality with a major release planned for the end for January 2016, which is EORES R3.0.0. EORES R3.0.0 will contain all of the baseline functionality needed to consider the application in an operations and maintenance state, which is a next generation of the NOAA CasaNOSA (NOAA's Observing System Architecture database) tool suite. However, there is a large backlog of work that will propel the

EORES application even further into the automated collection of EO requirements and systems, and VTI data along with enhanced analysis and reporting capabilities.

Vision and strategic planning are very important to the USGS. Understanding our user community 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 decisionmaking, the USGS will gain key insights into the formulation of what future systems and technologies will best serve the EO users' needs. For further information, contact USGS EROS, Gregory Stensaas, stensaas@usgs.gov.

More information:

RCA-EO Overview Video: https://www.youtube.com/watch?t=1&v=rzcP1Bv45ik
RCA-EO Detail Video: https://www.youtube.com/watch?v=3S6mXWhZcBY
RCA-EO Web site: http://remotesensing.usgs.gov/rca-eo/

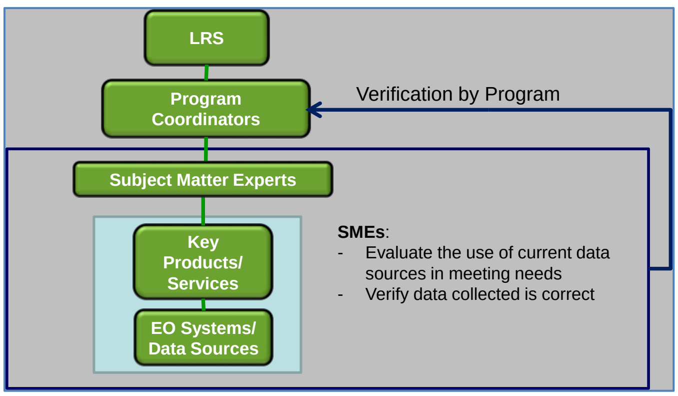


Figure 61. Value-tree elicitation process.

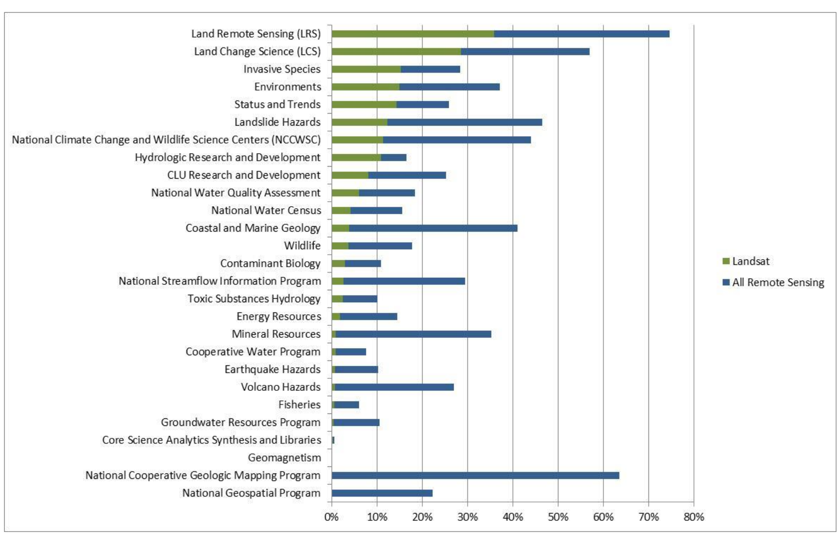


Figure 62. Impact of remote sensing for USGS programs.

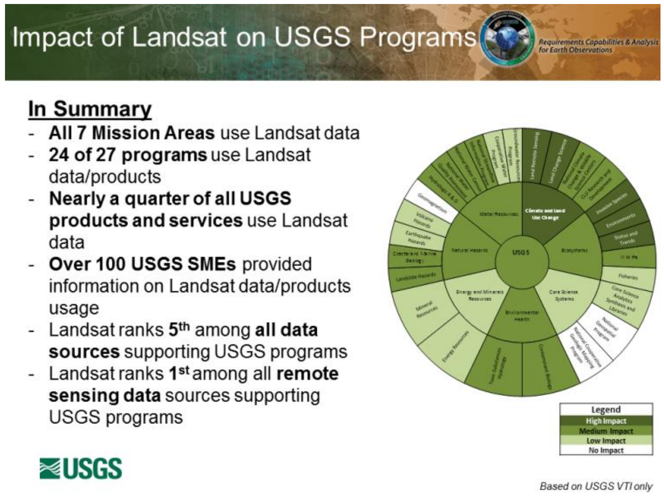


Figure 63. Usage of Landsat by USGS programs.

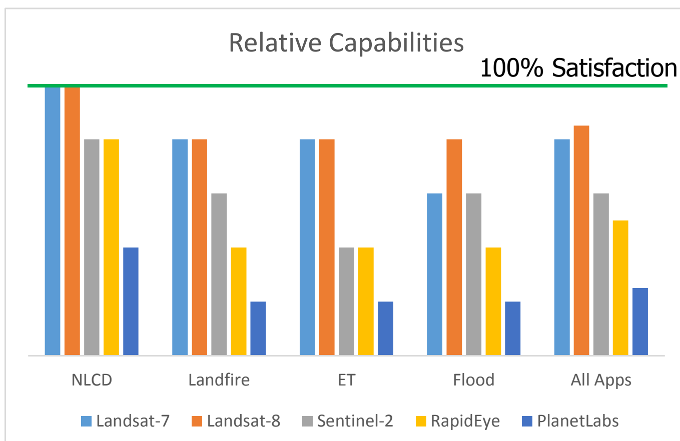


Figure 64. Comparison of Landsat with other systems for selected USGS applications.

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 Web sites 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.

Standard Image Processing System Released

The Spatial Data Warehouse (SDW) has long had a process for ingesting imagery into a standard format and inventory system that allowed for distribution through multiple interfaces. This process had several manual steps, many of which that might change from dataset to dataset. The Standard Imagery Processing System (SIPS) software development set out to standardize the process and allow for upgrades to the underlying technology used.

The overall process was analyzed to produce consistent metadata and standard products using automation wherever possible. The scripts and utilities were bundled into a single system that automates many of the tasks through a single chain of activities. A management console (fig. 65) was built that tracks every dataset and its progress through the process.

The release of the final SIPS allowed for an upgrade of ArcGIS 9.3.1 to 10.1 (and subsequently 10.2.2 to meet security requirements). The new system is faster, and allows more simultaneous processes to occur. This will allow the SDW to continue the processing of orthoimagery to support *The National Map* and still reduce the infrastructure to align with cut backs in funding. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

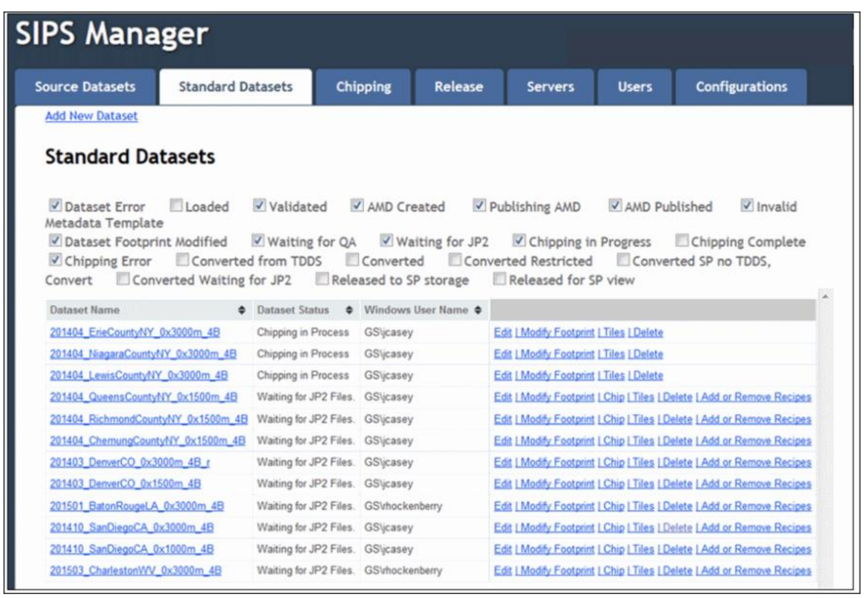


Figure 65. The Standard Imagery Processing System Manager console tracking datasets.

Migration from Windows Server 2003 to 2008/2012

Microsoft recently ended the support for Windows Server 2003. The Spatial Data Warehouse was running servers to support the Federal Emergency Management Agency (FEMA), Land Remote Sensing (LRS) Program, National Geospatial Program (NGP), and National Geospatial-Intelligence Agency (NGA) that had Windows Server 2003 as their operating system. Since the end of support means no new security patches, it was imperative that all these system be upgraded to a newer version of Windows Server. At the start of this effort there were about 60 servers to migrate.

The goal was to migrate to Windows Server 2012 (i.e., newest windows server release), testing each server for compatibility with its existing functionality. This transition (fig. 66) required a team comprised of system administrators, systems engineers, security engineers, and software engineers to create new 2008 or 2012 servers and then migrate a wide range of technologies (e.g., .NET, Java, PHP, etc.) and their higher level services from old servers to new. Windows Server 2012 was the target operating system, but in the event of any incompatibility, then Windows Server 2008 was used.

The coordination and communication maintained by the team allowed the migration to occur with no downtime. During the process, USGS headquarters issued a request to accelerate the transition, which was accomplished.

The transition smoothly moved all servers to the newer operating systems. The underlying infrastructure used for supporting FEMA, LRS, NGP, and NGA will continue to have support from Microsoft. The risks of continuing to support these projects with vulnerable operating systems is greatly reduced. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

Figure 66. Operating system transition.

Creation of New Kiosk Applications for the EROS Lobby

For the 25th anniversary of the Land Processes Distributed Active Archive Center (LP DAAC) at the USGS EROS, the lobby displays were updated. This included the development of new touch screen kiosks.

The Spatial Data Warehouse provided the software development and testing to support the new kiosks, while Media Services provided the content and media. The SDW team coordinated with Media Services to prioritize the order of the kiosks developed as the number of kiosks planned went from two to five, plus a welcome display.

One kiosk focused on Native American records that are used to validate climate history. A second kiosk displayed the global land characterization of forest cover including highlighted scenes of change. The other three kiosks included two focused on understanding satellite data, and one on the LP DAAC.

All five new interactive kiosks were put in the lobby in time for the 25th anniversary of the LP DAAC, along with the new welcome display (fig. 67). The new kiosks provide interactive information highlighting data products available through EROS. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

Figure 67. Screenshots of the EROS lobby kiosks and welcome display.

Migration of LANDFIRE Site to Spatial Data Warehouse Infrastructure

The LANDFIRE project has used the Spatial Data Warehouse to provide infrastructure support for many years. The LANDFIRE infrastructure was a copy of the architecture that provided data and services to *The National Map* utilizing mirrored hardware and software. As the underlying hardware reached its end of life, LANDFIRE initiated a transition to move to SDW resources, rather than maintaining their own hardware, and update all the software to the newest versions.

The SDW coordinated with LANDFIRE to transition data to the SDW hosted Spatial Data Engine, setup new virtual infrastructure, update software versions, and do this with minimal downtime. The SDW has also assisted with excessing the old LANDFIRE hardware. Several components of the architecture required modification or updates to work in the newest software environments.

Recent downsizing and optimization of the SDW National Map infrastructure allowed SDW to satisfy LANDFIRE requirements within the existing shared resources. LANDFIRE is now running on the shared infrastructure (fig. 68), with updated versions of the software used to provide services. This includes the underlying operating system which required updates to comply with security requirements. All layers of the LANDFIRE architecture now map to the SDW assets, including the data loading components.

LANDFIRE now has improved compliance with security restrictions, and the updated software infrastructure provides new capabilities such as Web coverage service functionality. The shared infrastructure should result in sustainable long-term costs that include future infrastructure lifecycle changes. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

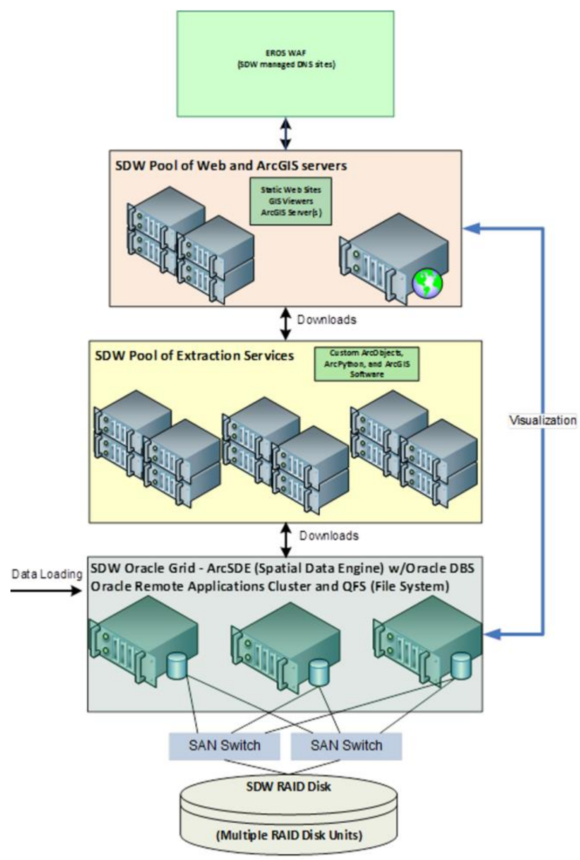


Figure 68. The Spatial Data Warehouse infrastructure that LANDFIRE uses.

LandsatLook 1.5 Release Completion

The initial version of the LandsatLook Viewer was based upon a transition of code donated from the Environmental Sciences Research Center (ESRI) to the USGS, with minor modifications to run in the USGS environment. This initial prototype version was a proof of concept to demonstrate a base level of functionality. It was successful, but suffered from a number of issues that required some development to provide improved usability and easier access to Landsat full-resolution browse and other Landsat image products.

In late 2013, a small interdepartmental team was assembled to develop a strategy to move LandsatLook from its prototype status to an operational interface. As part of this activity, the team collected and prioritized over 150 user requests, identifying and implementing a multi-phased strategy for major improvements to the design, functionality, and performance. The most critical updates were implemented as "Version 1.5" with most changes developed and released by mid 2015. While most changes were related to usability and functionality, there were also some updates to enhance the stability and performance of underlying infrastructure.

The phase 1.5 changes to the LandsatLook Viewer were implemented with no downtime. There were some delays to data updates, but the main interface remained continually operational throughout the upgrades. Some of the specific changes with LandsatLook 1.5 included: (1) faster incorporation of new Landsat browse products, (2) improved user experience and design flow, and (3) enhanced data discovery tools and mechanisms.

As a result of this work, LandsatLook (fig. 69) is better positioned to be maintained in an operational capacity, meaning that external users can rely on this important capability for accessing the Landsat full-resolution browse products and underlying source imagery. The enhanced interface is more user-friendly and now supports more frequent updates with incoming new imagery. The LandsatLook Viewer has now become an excellent tool for exploring and visualizing the EROS Landsat archive. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

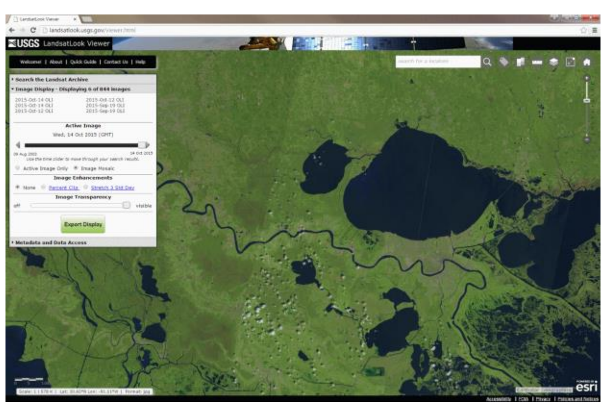


Figure 69. LandsatLook screen capture.

Release of New Web Pages for ECVs, CEOS, and RCA-EO

The Spatial Data Warehouse provides hosting and support for the Land Remote Sensing Program Web site. This includes hosting new pages and their content, and revising existing content.

SDW provided the infrastructure and technical assistance for releasing three new or updated pages. This was done using the LRS and World-Wide Web (WWW) environments that SDW already maintains.

The new Essential Climate Variables (ECV) page was developed externally and released to the LRS hosting environment. The Committee on Earth Observation Satellites (CEOS) page involved coordination and development to release updated content hosted in the WWW environment. The Requirements, Capabilities, and Analysis for Earth Observation (RCA-EO) page was developed in a separate environment, but moved to the SDW supported LRS environment.

All three pages (fig. 70) are now available as part of the LRS and WWW hosting environments that SDW maintains. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

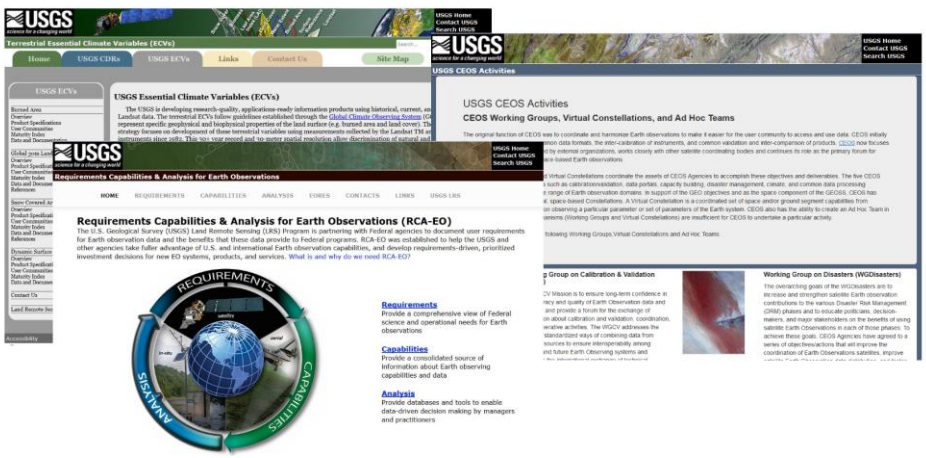


Figure 70. Screen captures of new Web pages for Essential Climate Variables; Committee on Earth Observation Satellites; and Requirements, Capabilities, and Analysis for Earth Observation.

Migration of Baseline Inventory Site to NatWeb Infrastructure

The Land Remote Sensing Program developed an application to track information about the projects within the program. This application required broad access across the LRS sites, and used a MySQL database with a Hypertext Preprocessor (PHP) front-end. While this originally ran within the LRS environment maintained at EROS by the Spatial

Data Warehouse, its self-contained nature made it an excellent application to move to the NatWeb Infrastructure to reduce the hosting costs.

The SDW has used NatWeb as the contingency location for existing sites, but not for complete and primary site hosting. The migration to the NatWeb environment involved additional testing and duplicating the interface pieces to ensure everything worked.

The migration went smoothly, and the baseline inventory site (fig. 71) is now up and running in NatWeb. The original site was removed from the LRS environment and archived.

The NatWeb provides a reliable, and low cost hosting environment that should reduce the costs for LRS to maintain this baseline inventory. For further information, contact USGS EROS, Chris Rusanowski, crusanow@usgs.gov.

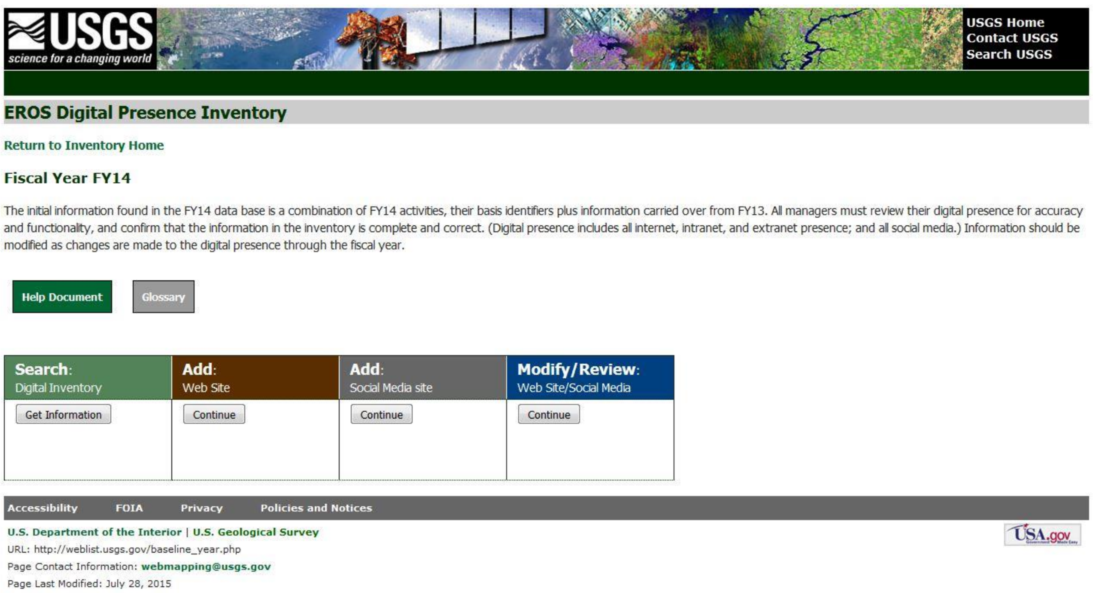


Figure 71. Baseline inventory site.

Unmanned Aircraft Systems

The USGS Unmanned Aircraft Systems (UAS) program was formalized in 2008 and has been actively flying missions for select principal investigators since then. In FY 2015, participants of the LRS Program made the decision that it was timely to more proactively distribute the USGS UAS acquisitions beyond the principal investigators.

The Long Term Archive (LTA) project designed, tested, and delivered a data management plan and released five UAS product types through EarthExplorer as a grant effort sponsored by the USGS Community for Data Integration (CDI) program. The LTA UAS data management plan and data ingest capabilities created for this CDI grant establishes the framework for future UAS product deliverables with a pathway to end users that need access to the UAS datasets in a timely manner. The LTA UAS capability released in September 2015 supports the following data products: orthos, photos, point cloud, videos, and supporting documents.

The data management plan and overall architecture has been designed with flexibility in mind. Figure 72 depicts the UAS data flow. As the UAS programs within the USGS, DOI, and Federal sector continues to evolve, EROS has put itself in a position to evolve with it. For further information, contact USGS EROS, Ryan Longhenry, rlonghenry@usgs.gov.

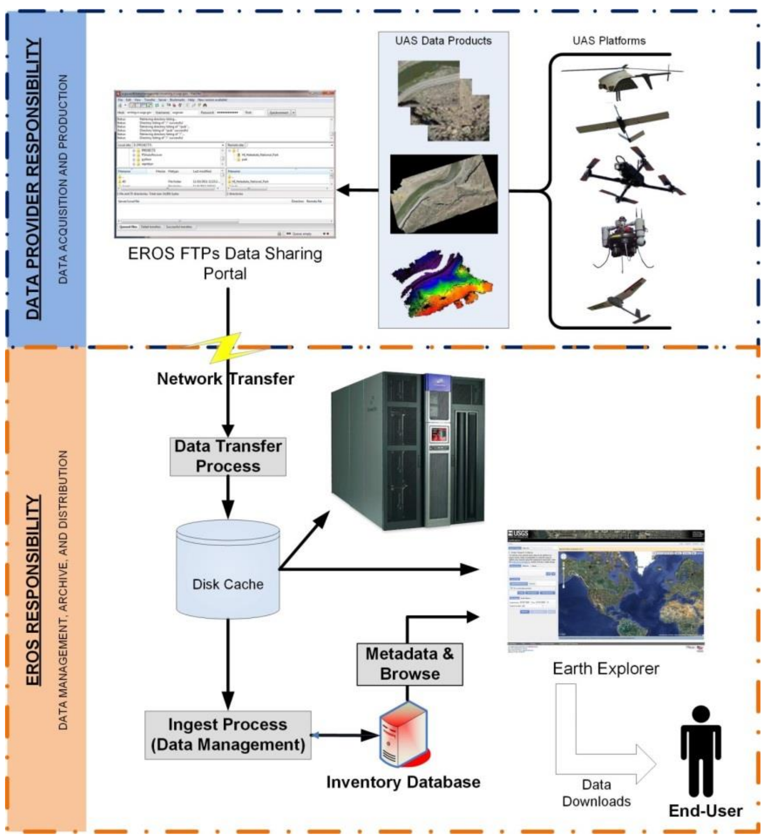


Figure 72. Unmanned aircraft systems data flow.

Bureau of Land Management Aerial Film Scanning

As the digital world continues to advance, aerial film archives of all types continue to become an issue regarding stability, usability, and distribution. The years of aerial film collections are greatly affected by this "transition." Emerging remote sensing techniques and the value of information contained within film media are converging at a rapid pace, and the general public expects on-line availability of the Nation's historical aerial photography.

A reimbursable aerial film scanning agreement was made between the Bureau of Land Management and the Long Term Archive project to scan 232,000 frames of historical color, color infrared, and black and white film for photography acquired by BLM over ten western States. The funding agreement is designed to span the course of multiple years. The BLM LTA project began in November 2014 with the scanning of six USGS-held BLM projects over the states of California, Colorado, Idaho, and Wyoming. Activities continued in December with a focus on Oregon (fig. 73) with the receipt of five film shipments from the BLM Denver Film Library (685 film rolls). By the close of FY 2015, the LTA had scanned 65,299 BLM frames at 14 micron and had made them all available as no cost downloads through EarthExplorer. Browse imagery and single frame coordinate updates were also provided for the BLM records, and a copy of all of the 14 micron Oregon scans were shipped to the BLM Portland Office.

The collaborative work with BLM helps to show the vast range of expertise and efficiency available through EROS-provided services while also making a valuable dataset available to the remote sensing community for years to come. For further information, contact USGS EROS, Ryan Longhenry, rlonghenry@usgs.gov.

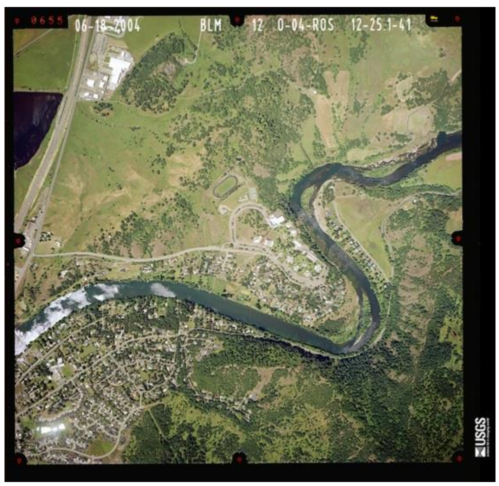


Figure 73. Bureau of Land Management scanning example over Roseburg, Oregon.

Declass-3 Availability in EarthExplorer

USGS EROS began working in the declassified realm back in the late 1990s with the receipt of the Declass-1 collection, which was followed up in 2002 with the Declass-2 collection. These first two collections were received by EROS as a full compilation of redacted photography released to the National Archives and Records Administration (NARA) and the USGS to promote science availability of these unique world-wide collections. However, the latest collection, Declass-3, was not scheduled to be delivered to EROS. That being said, the USGS Advanced System Center (ASC) had a subset “copy of convenience” of their science areas of interest, and that collection was looking for a long-term home.

The ASC subset was delivered to USGS EROS in FY 2014 where it was inventoried in a classified room. In FY 2014, a process was also developed and approved for the redaction of sensitive images still contained on the rolls. This redaction work began in mid FY 2015. The first 1,700 Declass-3 redacted images of the KH-9 Hexagon mission were digitized and released through EarthExplorer in September 2015 (figs. 74 and 75). This was the first of multiple releases yet to come as the Long Term Archive project continues to open up access the USGS ASC Declass-3 rolls that were transferred to EROS in 2014, redacted, and added to the USGS film archive.

A total of 346 rolls were redacted in FY 2015 from the 1,550 ASC duplicate rolls stored in the EROS secure archive. All of the Declass-3 frames are being offered as on-demand film scans at $30 per image (7-micron scans for black and whites and 14 micron for color infrared images). For further information, contact USGS EROS, Ryan Longhenry, rlonghenry@usgs.gov.

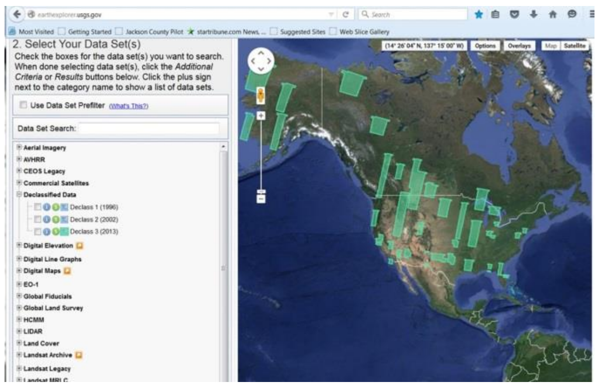


Figure 74. Declass-3 coverage in EarthExplorer, period ending September 30, 2015.

Figure 75. Declass-3 color infrared subset over Augusta, Kansas.

Phoenix VI Scanner Design and Implementation

The USGS EROS Long Term Archive project has always taken pride in its “can-do” attitude when tackling problems associated with data management. Although data management is commonly associated with database tables, data formats, and archiving, sometimes opportunities exist when technology and system development also become an active role in resolving data access challenges.

The LTA project designed, fabricated, and released to production the Phoenix VI system (fig. 76) to capture browse imagery from the variable length Declass-3 black and white and color infrared film. The Phoenix VI continues the innovative tradition established by the previous Phoenix systems to automatically advance the film through the data capture process. This system utilizes a digital camera to video record the entire roll in a single pass. The video stream is later edited and composited to produce the seamless browse product hosted through EarthExplorer.

Although the Phoenix VI system was designed with the Declass-3 collection in mind, the video capture functionality truly does allow any length of images to be captured digitally. As our popularity in the analog to digital realm continues to evolve, so will the technology that we utilize to accomplish the task. For further information, contact USGS EROS, Ryan Longhenry, rlonghenry@usgs.gov.

Figure 76. The Phoenix VI system.

OPeNDAP and MiddleWare Services

The Land Processes Distributed Active Archive Center (LP DAAC) currently hosts an OPeNDAP instance that provides users access to tiled Moderate Resolution Imaging Spectrometer (MODIS) data held in the LP DAAC archive (i.e., Data Pool). OPeNDAP is an acronym for " Open-source Project for a Network Data Access Protocol.” The Data Pool is the publicly available portion of the LP DAAC online holdings. The Data Pool provides a more direct way to access files by foregoing their retrieval from the nearline tape storage devices. All Data Pool holdings are available at no cost to the user.

OPeNDAP allows users to extract discrete subsets of data from remote data sources via Uniform Resource Locators (URLs). To increase the usability and ease of data access from OPeNDAP, a series of middleware services and software tools have been developed to consume OPeNDAP services. These services and tools greatly simplify interactions with OPeNDAP, and provide a foundation for the development of a Web application aimed at accessing, extracting, and returning subsets of tiled land MODIS data from the LP DAAC archive.

The Application for Extracting and Exploring Analysis-Ready Samples (AppEEARS) is a Web application that provides users an intuitive interface for the extraction of data values from tiled MODIS layers for point locations (fig. 77). The AppEEARS also provides users with the ability to visualize and interact with the data values in a series of dynamically generated graphs. Users are able to utilize AppEEARS functionality without downloading any data to their local machine; however, should the user decide to download their data request from AppEEARS, they will be provided with a near analysis-ready dataset in a format able to be imported into most third-party software applications.

AppEEARS, in combination with OPeNDAP services, gives users the ability to quickly and easily acquire subsets of problem-specific MODIS data, and the time traditionally spent gathering and processing MODIS granule data is ultimately reduced. For further information, contact USGS EROS, Chris Doescher, cdoesch@usgs.gov.

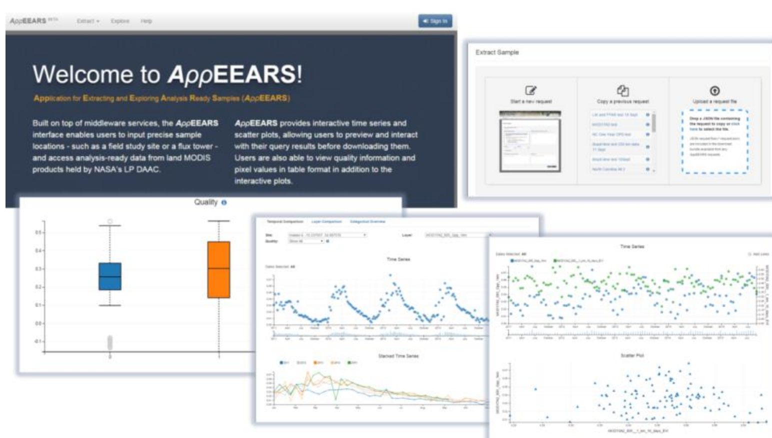


Figure 77. Illustration of the AppEEARS (Application for Extracting and Exploring Analysis-Ready Samples) Web application.

Release of ASTER Precision Terrain Corrected Product

In March 2015, the Land Processes Distributed Active Archive Center (LP DAAC) began processing the Advanced Spaceborne Thermal Emission and Reflection

Radiometer (ASTER) Level-1 Precision Terrain Corrected Registered At-Sensor Radiance (AST_L1T) product. The new AST_L1T product (fig. 78) provides quick turn-around of consistent geographic information system (GIS)-ready data as a multi-file product, which includes a Hierarchical Data Format (HDF) data file, full-resolution composite images (FRIs) as Georeferenced Tagged Image File Formats (GeoTIFFs) for tasked sensors (e.g., visible-near/shortwave infrared (VNIR/SWIR) and thermal infrared (TIR)), and associated metadata files. In addition, each AST_L1T granule contains related products including low-resolution browse, and when applicable, a Quality Assessment (QA) browse and QA text report.

The NASA LP DAAC has created the AST_L1T product by applying modified Landsat geometric algorithms to ASTER Level 1 data. The AST_L1T algorithm applies Earth and satellite models, control points, and elevation models, ultimately projecting the result onto a rotated north-up map at full-instrument resolution.

The AST_L1T data are available over the United States and territories at no charge to all users. In addition, approved NASA-supported researchers and their affiliates, educational users, and Federal partners may order AST_L1T from the LP DAAC global collection. To become approved for global access, users must first register by creating a NASA account to search and order, then complete and submit an application form available online at https://lpdaacaster.cr.usgs.gov/afd/index.php.

For further information, contact USGS EROS, Christopher Torbert, ctorbert@usgs.gov. Additional supporting documentation such as the AST_L1T Algorithm Theoretical Basis Document, User Guide, and Product Specification will be released as they become available.

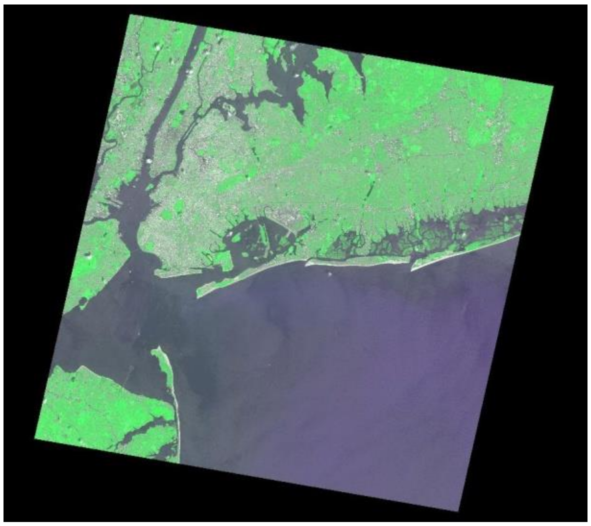


Figure 78. This sunny day in New York, June 24, 2015, is an example of an Advanced Spaceborne Thermal Emission and Reflection Radiometer Level-1 Precision Terrain Corrected Registered At-Sensor Radiance (ASTER AST_L1T) product.

EROS Receives the Data Seal of Approval

In February 2015, the USGS EROS Center was accredited with the Data Seal of Approval (DSA) (fig. 79). The DSA was established by a number of institutions committed to the long-term archiving of research data. By assigning the seal, the DSA community "seeks to guarantee the durability of the data concerned, but also to promote the goal of durable archiving in general." The DSA is granted to repositories that are committed to archiving and providing access to research data in a sustainable way.

Achieving the DSA means the data archive or repository is in compliance with 16 DSA guidelines, as determined through an assessment procedure governed by the DSA Board. The board consists of members from the following institutions: Data Archive and Network Services (DANS), The Netherlands; CINES - (National Computing Center for Higher Education), France; Inter-University Consortium for Political and Social Research (ICPSR), United States; Max Planck Institute (MPI) for Psycholinguistics, The Netherlands; Deutsche National Bibliothek, Germany and the UK Data Archive, United Kingdom.

The primary benefit received is having the USGS EROS Center recognized in the community as a trustworthy source of data. For further information, contact USGS EROS, John Faundeen, faundeen@usgs.gov.

Figure 79. Illustration of the Data Seal of Approval.

Consolidated Report: Data Distributed and Managed, and Products Distributed

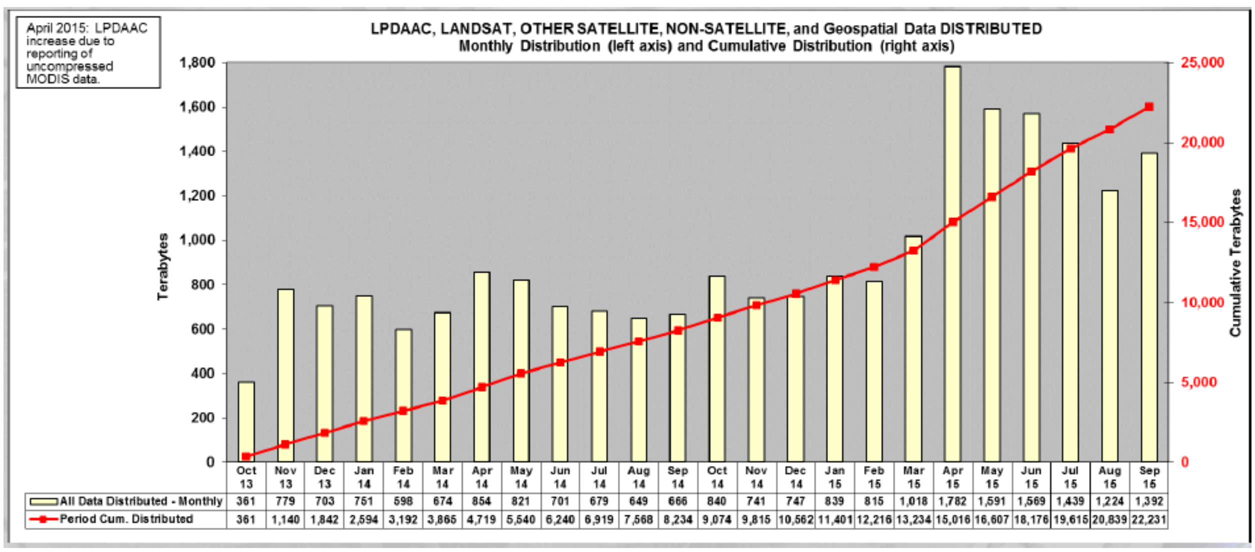
The USGS EROS prepares reports depicting data distributed and managed, and products distributed by the largest projects. The volume of data managed and distributed gives statistics in terabytes over a 24-month period (i.e., FY 2014-2015). The volume of products distributed gives statistics in thousands over a 12-month period (i.e., FY 2015).

The data distributed and managed is illustrated in figures 80-93, followed by the products distributed in figures 94-100. For further information, contact USGS EROS, John Faundeen, faundeen@usgs.gov.

Data Distributed and Managed

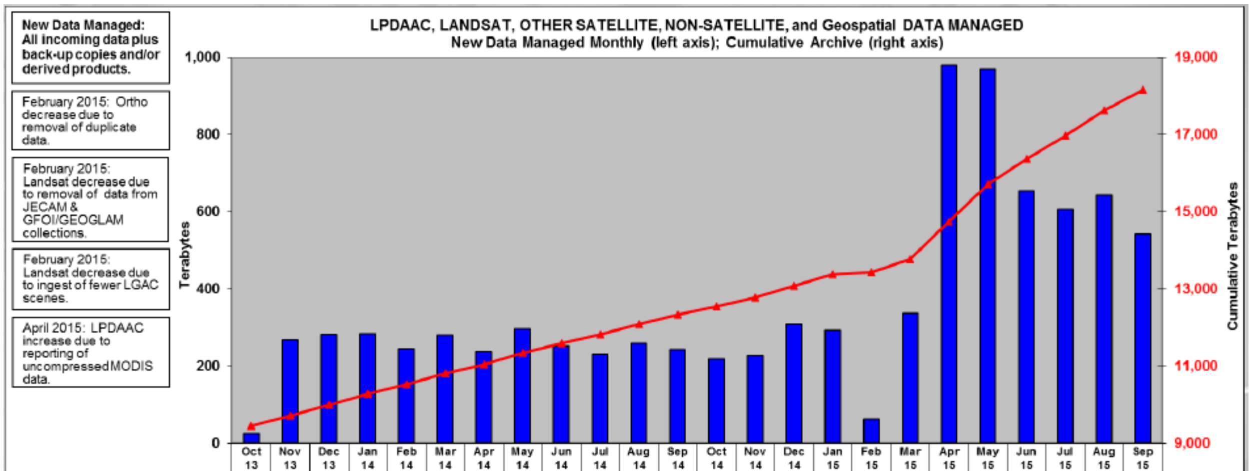
Data distributed and managed for all projects, showing both monthly and cumulative, is shown in figures 80-83. Data distributed and managed for the following groupings is shown in figures 84-93:

- Landsat (fig. 84 and 85)
- LP DAAC (fig. 86 and 87)
- Other Satellite (fig. 88 and 89)
- Non-Satellite (fig. 90 and 91)
- Geospatial (fig. 92 and 93)



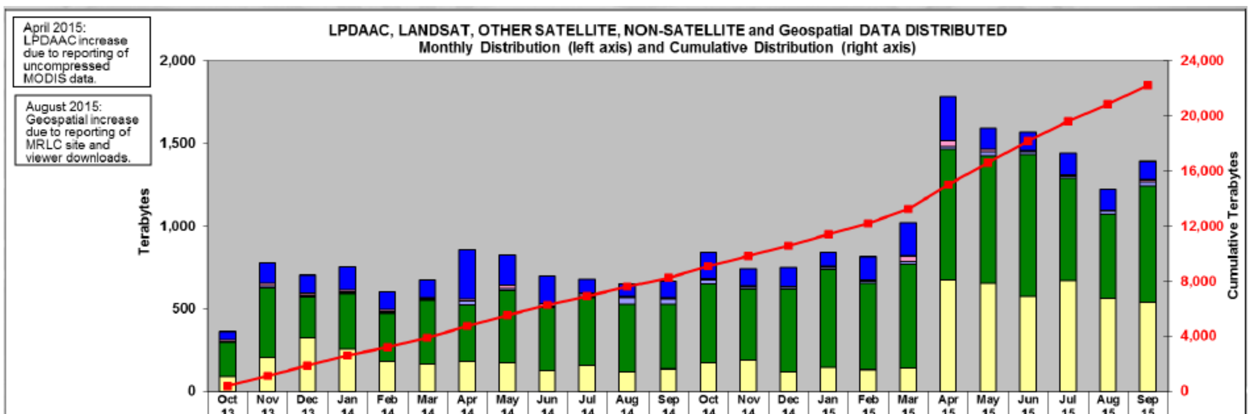
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
All Data Distributed - Monthly	361	779	703	751	598	674	854	821	701	679	649	666	840	741	747	839	815	1,018	1,782	1,591	1,569	1,439	1,224	1,392
Period Cum. Distributed	361	1,140	1,842	2,594	3,192	3,865	4,719	5,540	6,240	6,919	7,568	8,234	9,074	9,815	10,562	11,401	12,216	13,234	15,016	16,607	18,176	19,615	20,839	22,231

Figure 80. FY 2014-2015 of all projects combined. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.



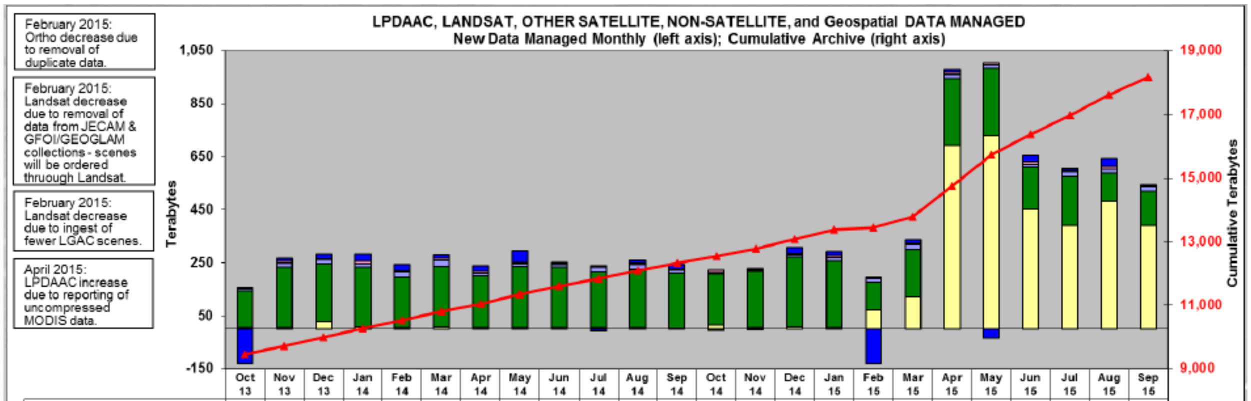
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
All Data Collected - Monthly	64.9	90.4	95.2	108	84.3	100	83.1	85.1	70.9	83.8	98.4	96.8	111	79.4	109	113	150	285	813	881	565	572	773	606
All Data Managed - Monthly	24.9	267	283	283	244	280	238	297	252	232	259	243	219	227	308	293	62.9	336	979	969	654	605	643	543
Cumulative Managed	9447	9714	9997	10280	10,525	10,805	11,043	11,340	11,592	11,823	12,083	12,325	12,544	12,771	13,079	13,373	13,436	13,772	14,751	15,720	16,374	16,979	17,622	18,165

Figure 81. FY 2014-2015 of all projects combined. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.



	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Geospatial Data	51.2	127	112	140	107	105	296	181	172	88.8	75.3	97.5	158	105	112	83.3	140	199	267	125	112	129	128	113
Other Satellite	10.7	16.4	13.7	10.7	9.98	11.6	11.9	17.0	13.5	14.8	6.13	8.72	8.43	5.80	7.73	6.59	7.28	36.2	35.2	17.1	10.6	7.88	7.13	9.98
Non-Satellite	4.15	8.64	8.12	10.7	7.57	8.43	22.5	13.4	11.2	9.49	43.6	35.1	22.3	13.8	11.4	14.0	15.0	16.7	16.2	24.6	12.6	14.4	18.1	27.1
Landsat	206	421	244	337	292	383	342	438	377	411	406	389	480	430	497	594	524	630	789	771	857	620	510	704
LPDAAC	89	205	325	253	181	165	181	171	127	154	118	135	171	186	118	141	129	136	675	653	577	668	561	538
Period Cum. Distributed	361	1,140	1,842	2,594	3,192	3,865	4,719	5,540	6,240	6,919	7,568	8,234	9,074	9,815	10,562	11,401	12,216	13,234	15,016	16,607	18,176	19,615	20,839	22,231

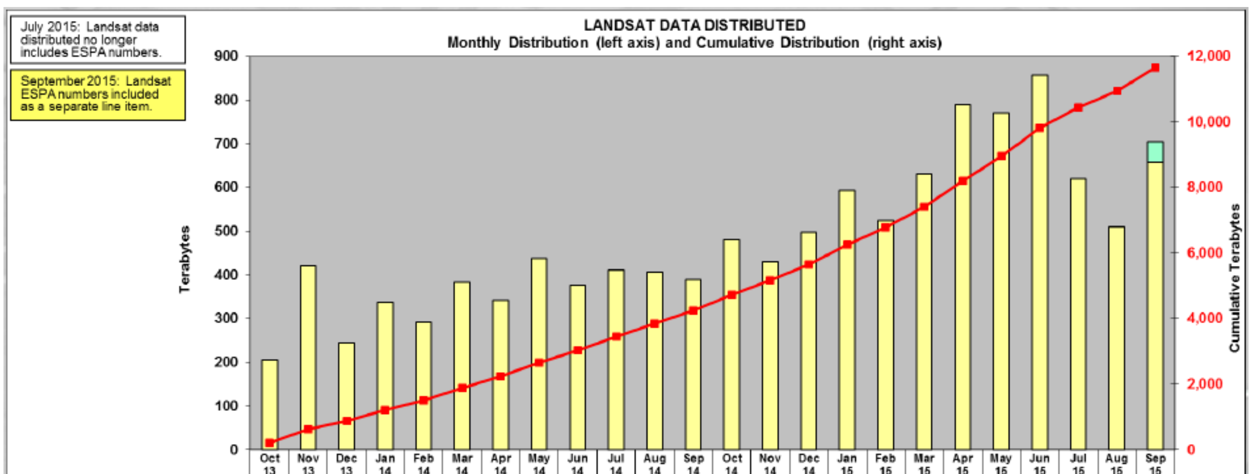
Figure 82. FY 2014-2015 of all projects with detail. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.



	Oct 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	64.9	90.4	95.2	108	84.3	100	83.1	85.1	70.9	83.8	98.4	96.8
Geospatial Managed Monthly	-131	9.47	18.9	27.6	23.4	13.2	19.0	45.8	3.38	-6.63	11.5	16.0
Other Sat. Managed Monthly	3.1	9.8	2.7	9.2	5.4	7.5	8.4	5.3	4.86	5.19	3.73	4.46
Non-Sat. Managed Monthly	9.9	14.4	14.8	13.3	20.6	23.5	10.8	8.8	8.71	17.4	17.0	12.3
Landsat Managed Monthly	138	228	218	226	190	229	195	231	229	209	222	208
LPDAAC Managed Monthly	4.59	5.09	28.0	6.93	4.90	7.32	5.27	5.51	5.98	6.29	4.96	1.70
Cumulative Managed	9447	9714	9997	10280	10,525	10,805	11,043	11,340	11,592	11,823	12,083	12,325

	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
All Data Collected - Monthly	111	79.4	109	113	150	285	813	881	565	572	773	606
Geospatial Managed Monthly	-5.58	-0.04	22.6	14.9	-131	13.2	12.2	-34.3	22.1	8.09	29.5	0.2
Other Sat. Managed Monthly	9.82	3.23	5.87	7.70	4.77	4.69	6.80	6.69	11.3	5.24	8.80	6.28
Non-Sat. Managed Monthly	5.27	6.21	7.80	13.8	11.4	16.8	13.9	13.8	9.60	15.8	16.1	17.2
Landsat Managed Monthly	194	212	265	252	105	181	253	254	160	185	105	130
LPDAAC Managed Monthly	15.3	5.77	7.44	5.24	73.0	121	693	728	451	392	483	390
Cumulative Managed	12,544	12,771	13,079	13,373	13,436	13,772	14,751	15,720	16,374	16,979	17,622	18,165

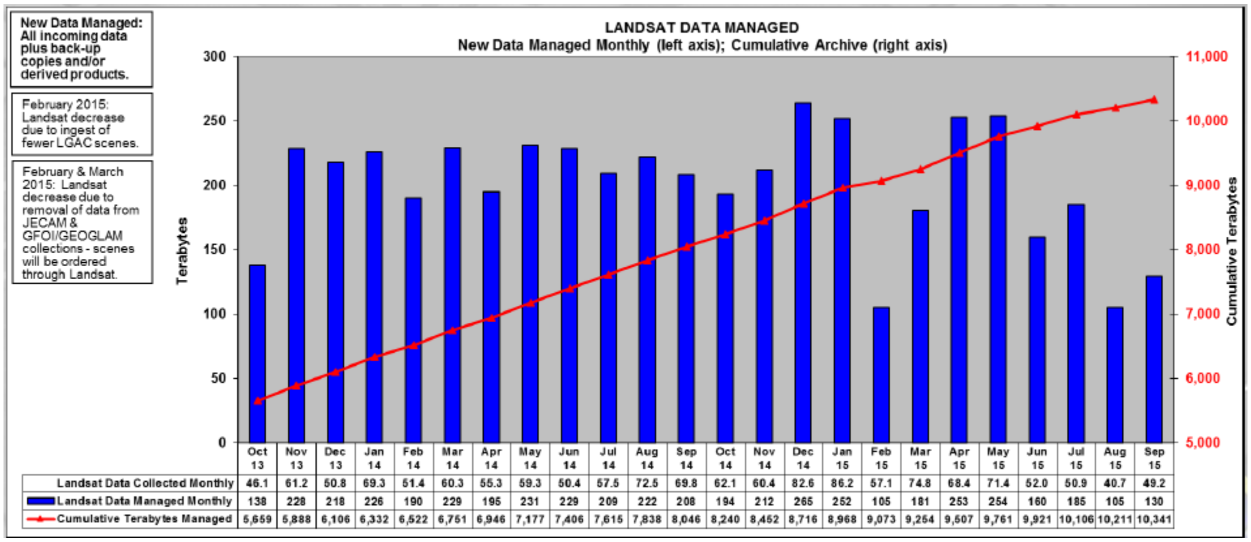
Figure 83. FY 2014-2015 all projects with detail. A 24-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.



	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14
Landsat ESPA Distributed Monthly	-	-	-	-	-	-	-	-	-	-	-	-
Landsat Data Distributed Monthly	206	421	244	337	292	383	342	438	377	411	406	389
Period Cum. Distributed	206	627	871	1,208	1,500	1,883	2,226	2,664	3,040	3,452	3,858	4,247

	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Landsat ESPA Distributed Monthly	-	-	-	-	-	-	-	-	-	-	-	47
Landsat Data Distributed Monthly	480	430	497	594	524	630	789	771	857	620	510	657
Period Cum. Distributed	4,727	5,157	5,655	6,248	6,772	7,402	8,191	8,962	9,819	10,439	10,949	11,653

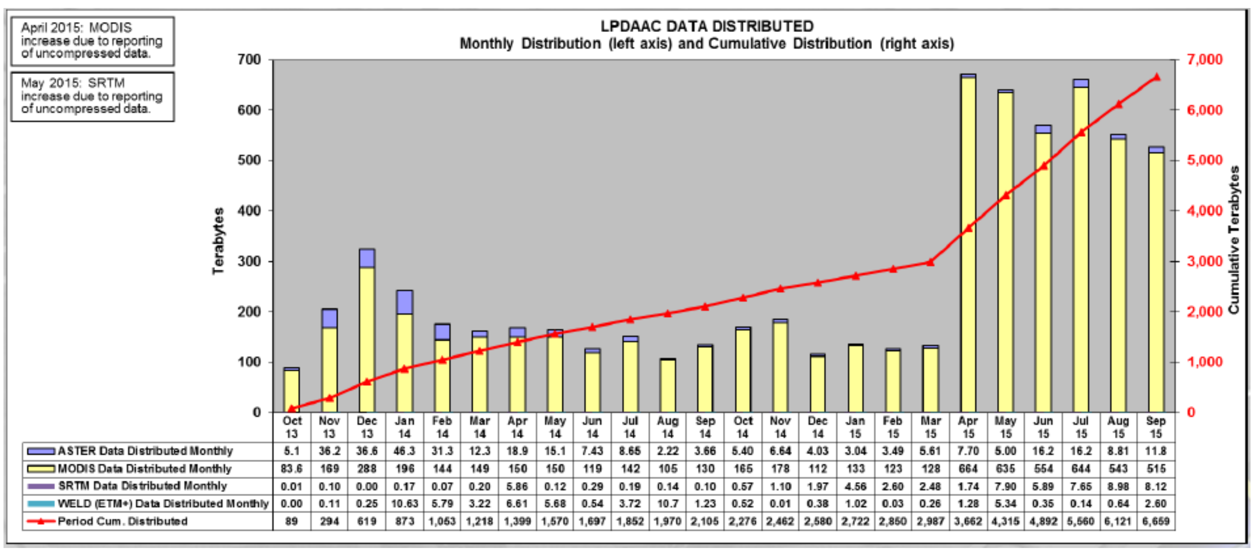
Figure 84. FY 2014-2015. A 24-month volume of Landsat data distributed.



	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 Data Collected Monthly	46.1	61.2	50.8	69.3	51.4	60.3	55.3	59.3	50.4	57.5	72.5	69.8
Landsat Data Managed Monthly	138	228	218	226	190	229	195	231	229	209	222	208
Cumulative Terabytes Managed	5,659	5,888	6,106	6,332	6,522	6,751	6,946	7,177	7,406	7,615	7,838	8,046

	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Landsat Data Collected Monthly	62.1	60.4	82.6	86.2	57.1	74.8	68.4	71.4	52.0	50.9	40.7	49.2
Landsat Data Managed Monthly	194	212	265	252	105	181	253	254	160	185	105	130
Cumulative Terabytes Managed	8,240	8,452	8,716	8,968	9,073	9,254	9,507	9,761	9,921	10,106	10,211	10,341

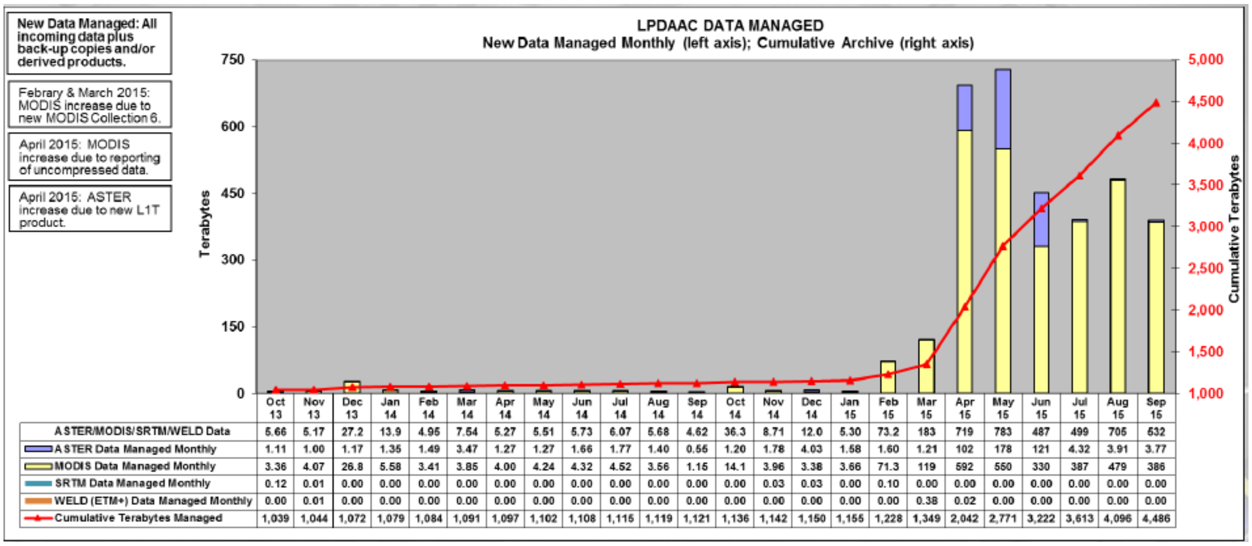
Figure 85. FY 2014-2015. A 24-month volume of Landsat data managed.



	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 Data Distributed Monthly	5.1	36.2	36.6	46.3	31.3	12.3	18.9	15.1	7.43	8.65	2.22	3.66
MODIS Data Distributed Monthly	83.6	169	288	196	144	149	150	150	119	142	105	130
SRTM Data Distributed Monthly	0.01	0.10	0.00	0.17	0.07	0.20	5.86	0.12	0.29	0.19	0.14	0.10
WELD (ETM+) Data Distributed Monthly	0.00	0.11	0.25	10.63	5.79	3.22	6.61	5.68	0.54	3.72	10.7	1.23
Period Cum. Distributed	89	294	619	873	1,063	1,218	1,399	1,570	1,697	1,852	1,970	2,105

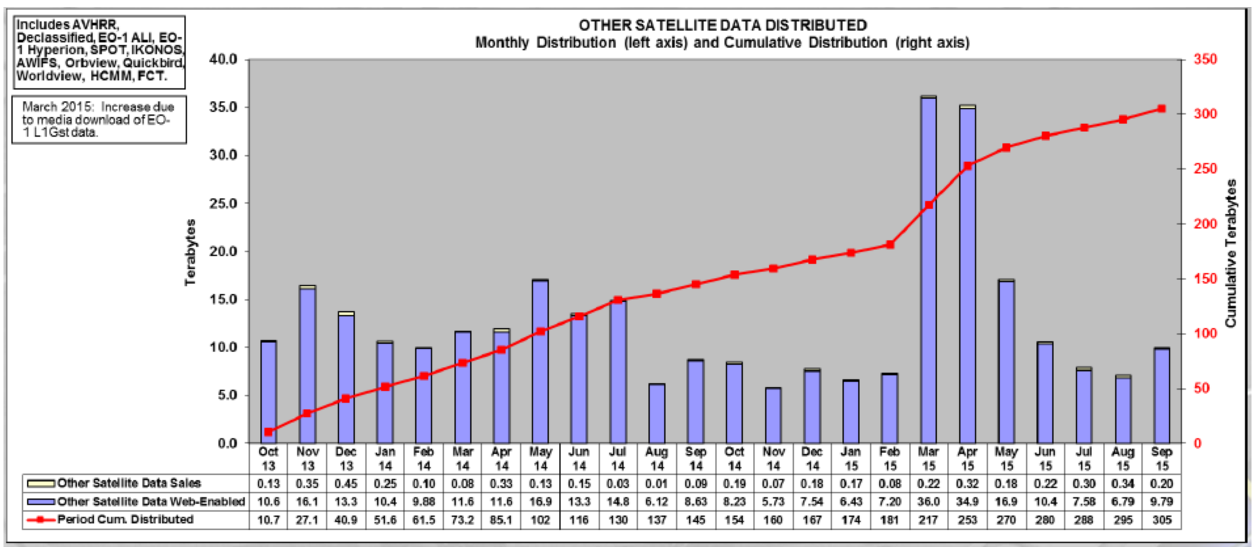
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
ASTER Data Distributed Monthly	5.40	6.64	4.03	3.04	3.49	5.61	7.70	5.00	16.2	16.2	8.81	11.8
MODIS Data Distributed Monthly	165	178	112	133	123	128	664	635	554	644	543	515
SRTM Data Distributed Monthly	0.57	1.10	1.97	4.56	2.60	2.48	1.74	7.90	5.89	7.65	8.98	8.12
WELD (ETM+) Data Distributed Monthly	0.52	0.01	0.38	1.02	0.03	0.26	1.28	5.34	0.35	0.14	0.64	2.60
Period Cum. Distributed	2,276	2,462	2,580	2,722	2,850	2,987	3,662	4,315	4,892	5,560	6,121	6,659

Figure 86. FY 2014-2015. A 24-month volume of Land Processes Distributed Active Archive Center data distributed.



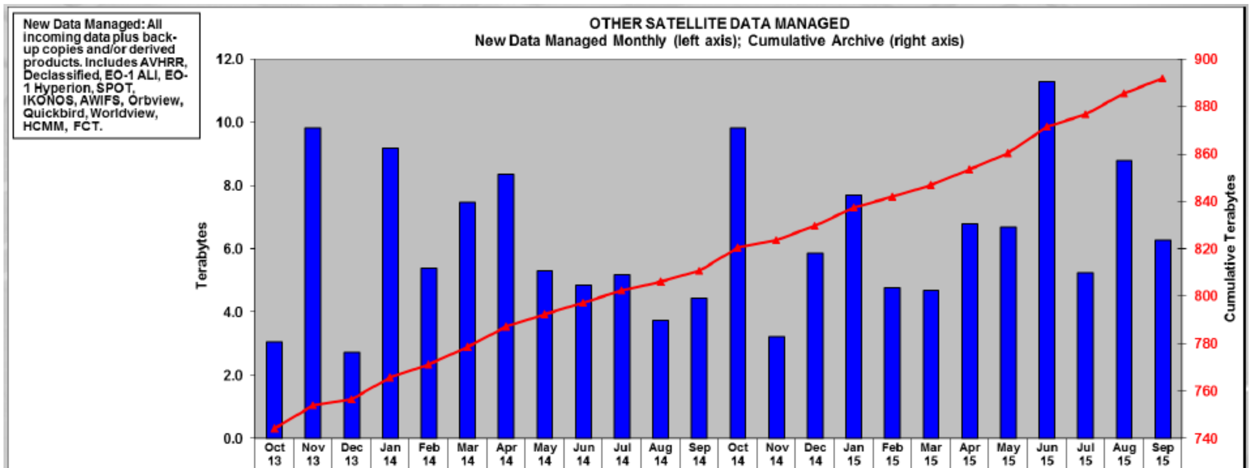
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
ASTER/MODIS/SRTM/WELD Data	5.66	5.17	27.2	13.9	4.95	7.54	5.27	5.51	5.73	6.07	5.68	4.62	36.3	8.71	12.0	5.30	73.2	183	719	783	487	499	705	532
ASTER Data Managed Monthly	1.11	1.00	1.17	1.35	1.49	3.47	1.27	1.27	1.66	1.77	1.40	0.55	1.20	1.78	4.03	1.58	1.60	1.21	102	178	121	4.32	3.91	3.77
MODIS Data Managed Monthly	3.36	4.07	26.8	5.58	3.41	3.85	4.00	4.24	4.32	4.52	3.56	1.15	14.1	3.96	3.38	3.66	71.3	119	592	550	330	387	479	386
SRTM Data Managed Monthly	0.12	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WELD (ETM+) Data Managed Monthly	0.00	0.01	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	0.38	0.02	0.00	0.00	0.00	0.00	0.00
Cumulative Terabytes Managed	1,039	1,044	1,072	1,079	1,084	1,091	1,097	1,102	1,108	1,115	1,119	1,121	1,136	1,142	1,150	1,155	1,228	1,349	2,042	2,771	3,222	3,613	4,096	4,486

Figure 87. FY 2014-2015. A 24-month volume of Land Processes Distributed Active Archive Center data managed.



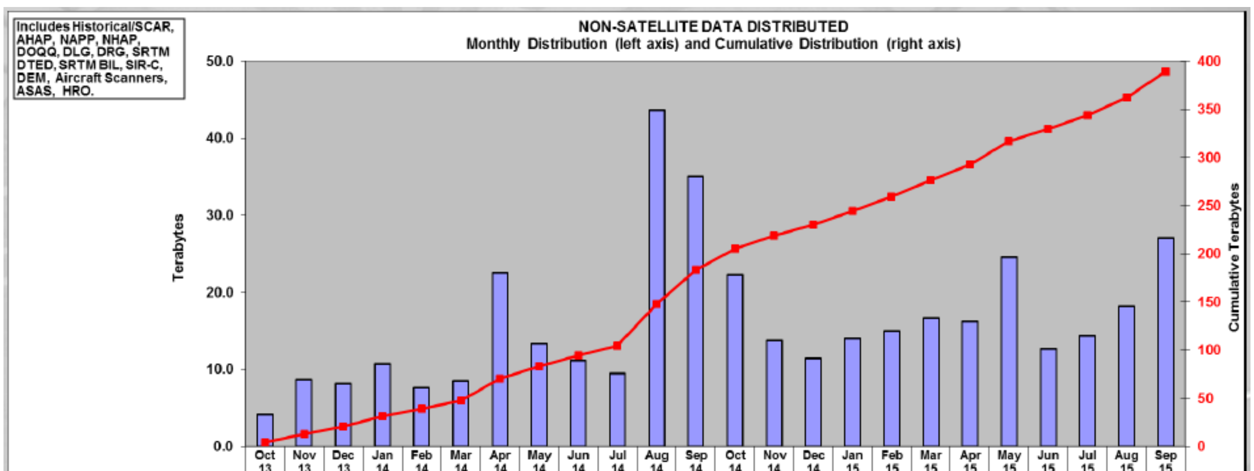
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Other Satellite Data Sales	0.13	0.35	0.45	0.25	0.10	0.08	0.33	0.13	0.15	0.03	0.01	0.09	0.19	0.07	0.18	0.17	0.08	0.22	0.32	0.18	0.22	0.30	0.34	0.20
Other Satellite Data Web-Enabled	10.6	16.1	13.3	10.4	9.88	11.6	11.6	16.9	13.3	14.8	6.12	8.63	8.23	5.73	7.54	6.43	7.20	36.0	34.9	16.9	10.4	7.58	6.79	9.79
Period Cum. Distributed	10.7	27.1	40.9	51.6	61.5	73.2	85.1	102	116	130	137	145	154	160	167	174	181	217	253	270	280	288	295	305

Figure 88. FY 2014-2015. A 24-month volume of other satellite data distributed.



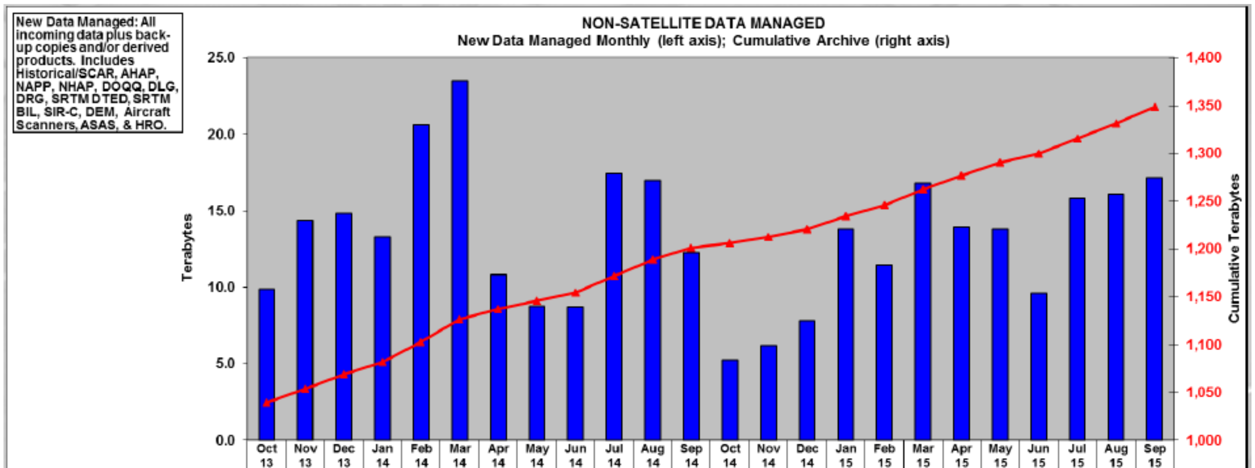
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Other Sat. Data Collected Monthly	2.76	9.13	1.96	8.07	4.40	6.69	8.37	5.31	4.81	5.19	3.72	4.46	5.44	3.22	5.86	7.64	4.68	4.72	6.90	6.70	11.3	5.47	8.78	6.28
Other Sat. Data Managed Monthly	3.05	9.83	2.72	9.17	5.40	7.49	8.36	5.31	4.86	5.19	3.73	4.46	9.82	3.23	5.87	7.70	4.77	4.69	6.80	6.69	11.3	5.24	8.80	6.28
Cumulative Managed	744	754	757	766	771	779	787	792	797	803	806	811	821	824	830	837	842	847	854	860	872	877	886	892

Figure 89. FY 2014-2015. A 24-month volume of other satellite data managed.



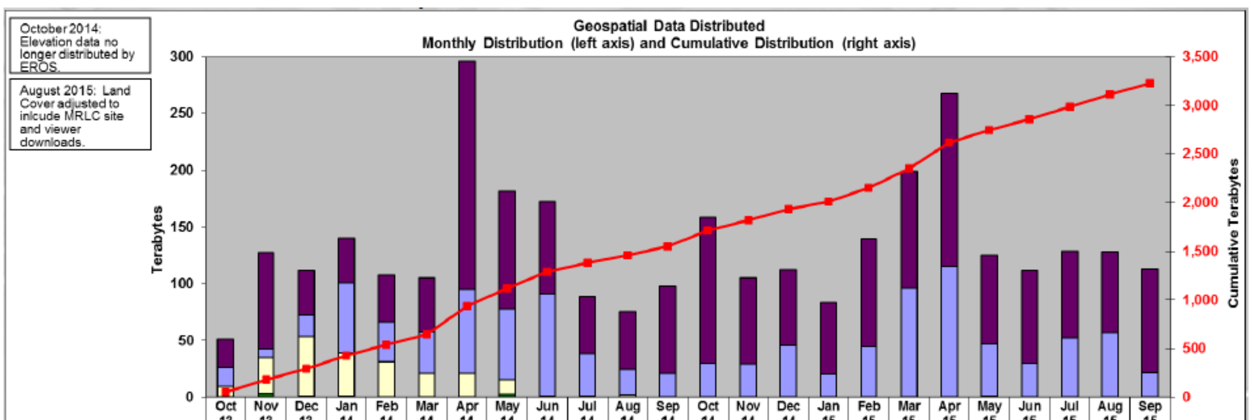
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Non-Satellite Data Sales	0.02	0.02	0.02	0.04	0.02	0.03	0.03	0.05	0.12	0.05	0.03	0.14	0.07	0.08	0.04	0.04	0.13	0.10	0.03	0.03	0.03	0.02	0.02	0.03
Non-Satellite Data Web-Enabled	4.14	8.62	8.10	10.7	7.55	8.41	22.5	13.4	11.1	9.44	43.6	35.0	22.2	13.7	11.4	13.9	14.9	16.6	16.2	24.5	12.6	14.3	18.1	27.0
Period Cum. Distributed	4.15	12.8	20.9	31.6	39.2	47.6	70.1	83.6	94.8	104	148	183	205	219	231	245	260	276	293	317	330	344	362	389

Figure 90. FY 2014-2015. A 24-month volume of non-satellite data distributed.



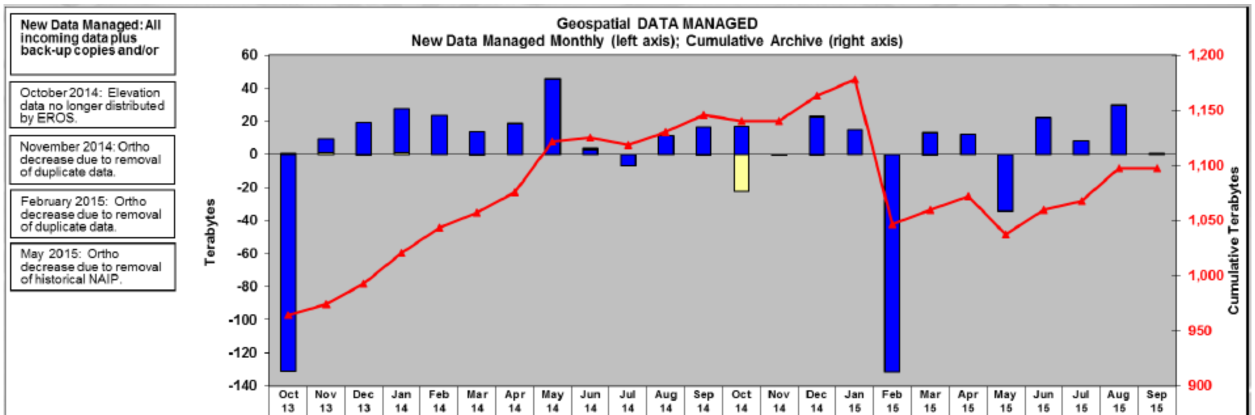
	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Non-Sat. Data Collected Monthly	9.86	14.4	14.9	13.4	18.6	23.6	11.4	9.3	8.19	12.4	15.8	12.3	5.25	6.22	7.80	13.8	11.5	20.5	15.1	13.8	11.8	15.8	16.1	17.2
Non-Sat. Data Managed Monthly	9.86	14.4	14.8	13.3	20.6	23.5	10.8	8.8	8.71	17.4	17.0	12.3	5.27	6.21	7.80	13.8	11.4	16.8	13.9	13.8	9.60	15.8	16.1	17.2
Cumulative Managed	1,040	1,054	1,069	1,082	1,103	1,126	1,137	1,146	1,155	1,172	1,189	1,201	1,206	1,213	1,220	1,234	1,246	1,262	1,276	1,290	1,300	1,316	1,332	1,349

Figure 91. FY 2014-2015. A 24-month volume of non-satellite data managed.



	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Land Cover	24.7	84.6	39.3	39.4	41.0	47.8	201	104	81.0	50.3	51.1	76.8	128	76.0	66.8	63.2	95.3	103	152	78.2	81.7	76.9	71.7	91.0
Orthoimagery	17.4	7.87	19.1	61.6	35.2	36.5	74.1	62.1	90.0	37.6	22.0	20.2	29.5	28.7	45.3	19.9	44.2	95.6	115	46.0	29.8	51.7	56.3	21.7
Elevation	9.06	31.2	52.6	38.5	30.8	20.4	20.3	12.9	0.71	0.64	2.05	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.03	3.52	0.68	0.57	0.30	0.51	0.31	2.68	0.25	0.29	0.18	0.34	0.32	0.45	0.32	0.23	0.26	0.07	0.48	0.88	0.22	0.37	0.12	0.07
Period Cum. Distributed	51.2	178	290	430	537	643	939	1,120	1,292	1,381	1,456	1,554	1,712	1,817	1,929	2,013	2,152	2,351	2,618	2,743	2,855	2,984	3,112	3,225

Figure 92. FY 2014-2015. A 24-month volume of geospatial data 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
Geospatial Data Collected Monthly	0.63	0.53	0.38	3.51	4.93	2.07	2.77	5.76	1.83	2.67	0.63	5.59
Land Cover Data Managed Monthly	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	-131	8.5	19.5	26.5	23.4	13.4	18.5	45.4	2.93	-6.63	11.5	16.6
Elevation Data Managed Monthly	0.34	0.96	-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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.57
Cumulative Managed	964	974	993	1,020	1,044	1,057	1,076	1,122	1,125	1,118	1,130	1,146

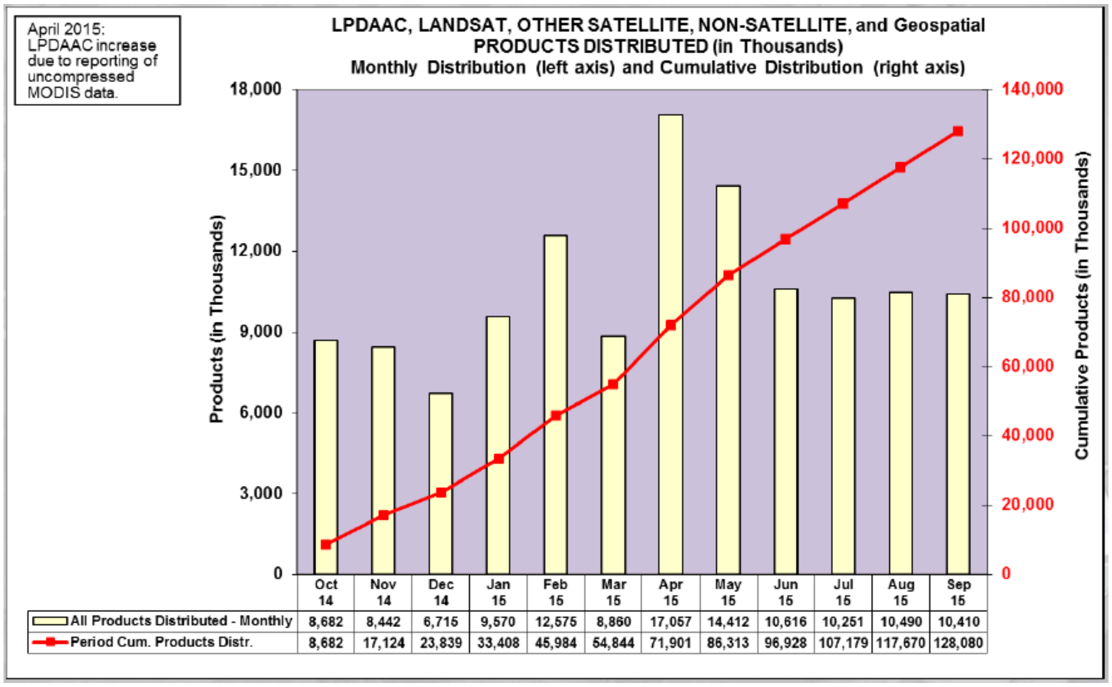
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Geospatial Data Collected Monthly	1.61	0.90	0.49	0.00	3.46	2.38	3.23	6.20	3.08	0.69	2.07	1.06
Land Cover Data Managed Monthly	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthoimagery Data Managed Monthly	16.7	-0.04	22.6	14.9	-131	13.2	12.2	-34.3	22.1	8.09	29.5	0.2
Elevation Data Managed Monthly	-22.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Data Managed Monthly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumulative Managed	1,140	1,140	1,163	1,178	1,046	1,060	1,072	1,038	1,060	1,068	1,097	1,097

Figure 93. FY 2014-2015. A 24-month volume of geospatial data managed.

Products Distributed

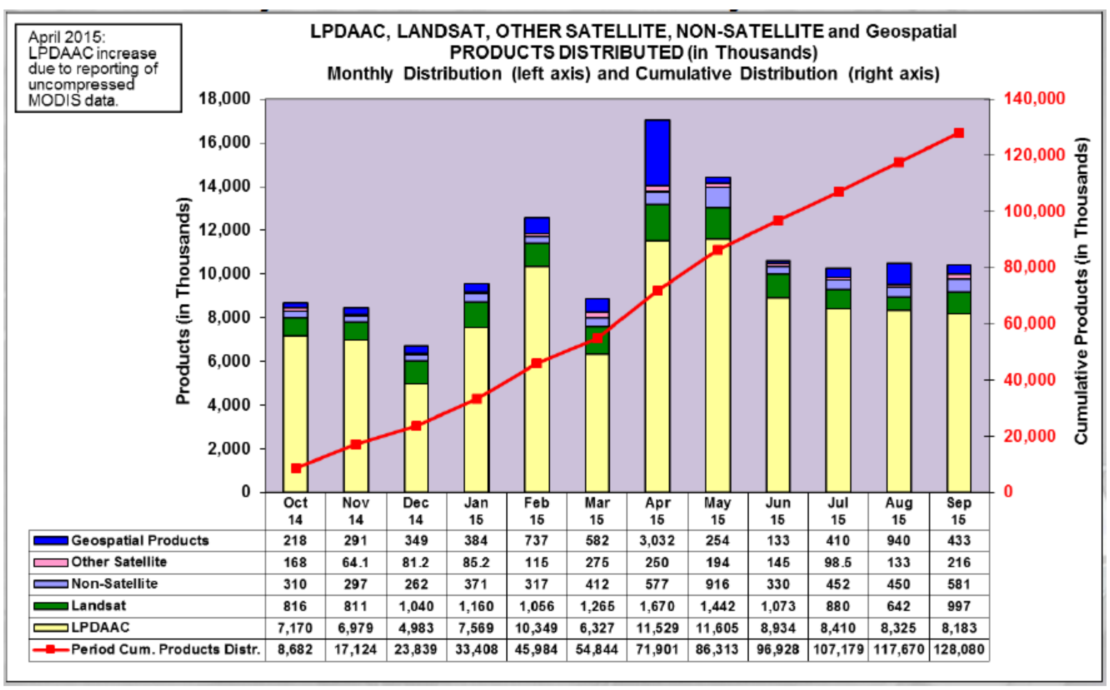
Products distributed for all projects, showing both monthly and cumulative, are shown in figures 94-95. Products distributed for the following groupings are shown in figures 96-100:

- Landsat (fig. 96)
- LP DAAC (fig. 97)
- Other Satellite (fig. 98)
- Non-Satellite (fig. 99)
- Geospatial (fig. 100)



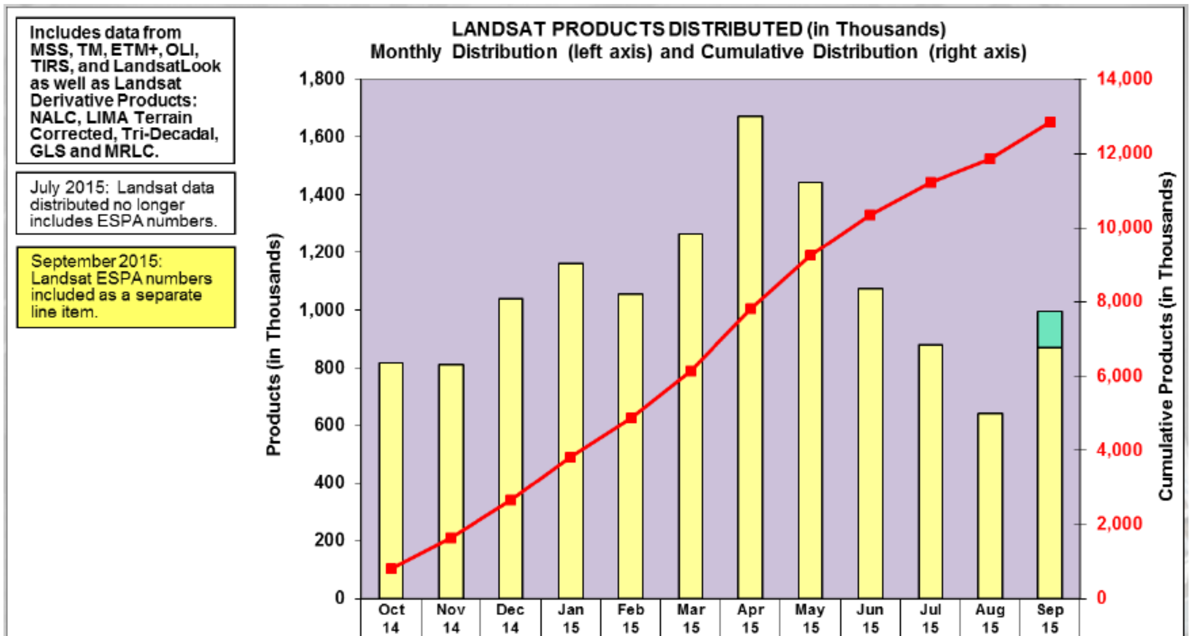
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
All Products Distributed - Monthly	8,682	8,442	6,715	9,570	12,575	8,860	17,057	14,412	10,616	10,251	10,490	10,410
Period Cum. Products Distr.	8,682	17,124	23,839	33,408	45,984	54,844	71,901	86,313	96,928	107,179	117,670	128,080

Figure 94. FY 2015 all projects combined. A 12-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial products distributed.



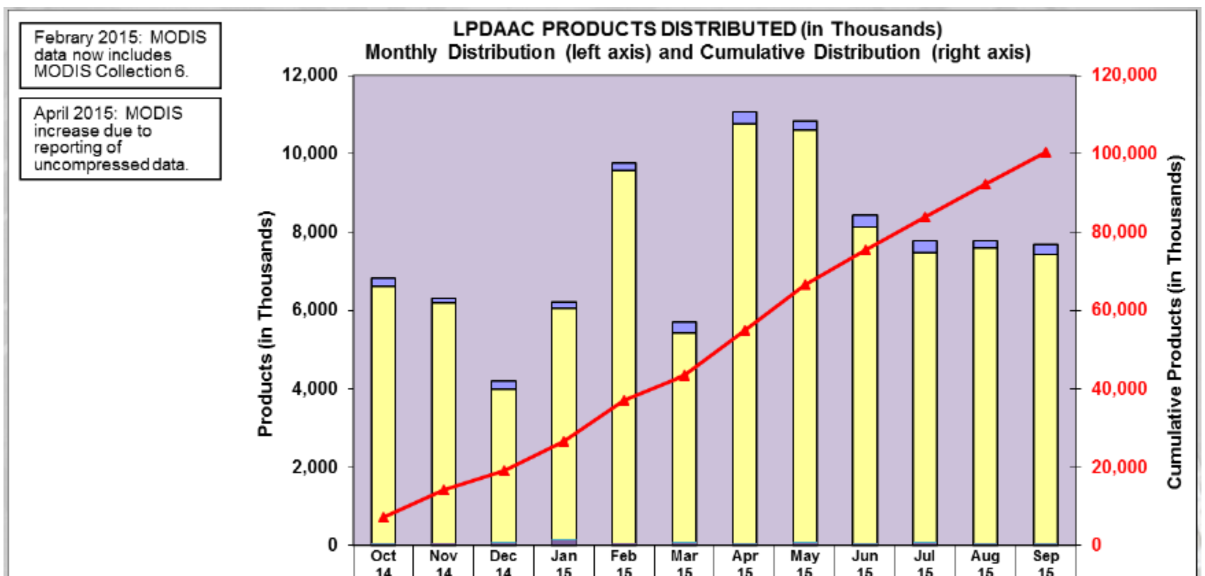
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Geospatial Products	218	291	349	384	737	582	3,032	254	133	410	940	433
Other Satellite	168	64.1	81.2	85.2	115	275	250	194	145	98.5	133	216
Non-Satellite	310	297	262	371	317	412	577	916	330	452	450	581
Landsat	816	811	1,040	1,160	1,056	1,265	1,670	1,442	1,073	880	642	997
LPDAAC	7,170	6,979	4,983	7,569	10,349	6,327	11,529	11,605	8,934	8,410	8,325	8,183
Period Cum. Products Distr.	8,682	17,124	23,839	33,408	45,984	54,844	71,901	86,313	96,928	107,179	117,670	128,080

Figure 95. FY 2015 all projects with detail. A 12-month volume of Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial products distributed.



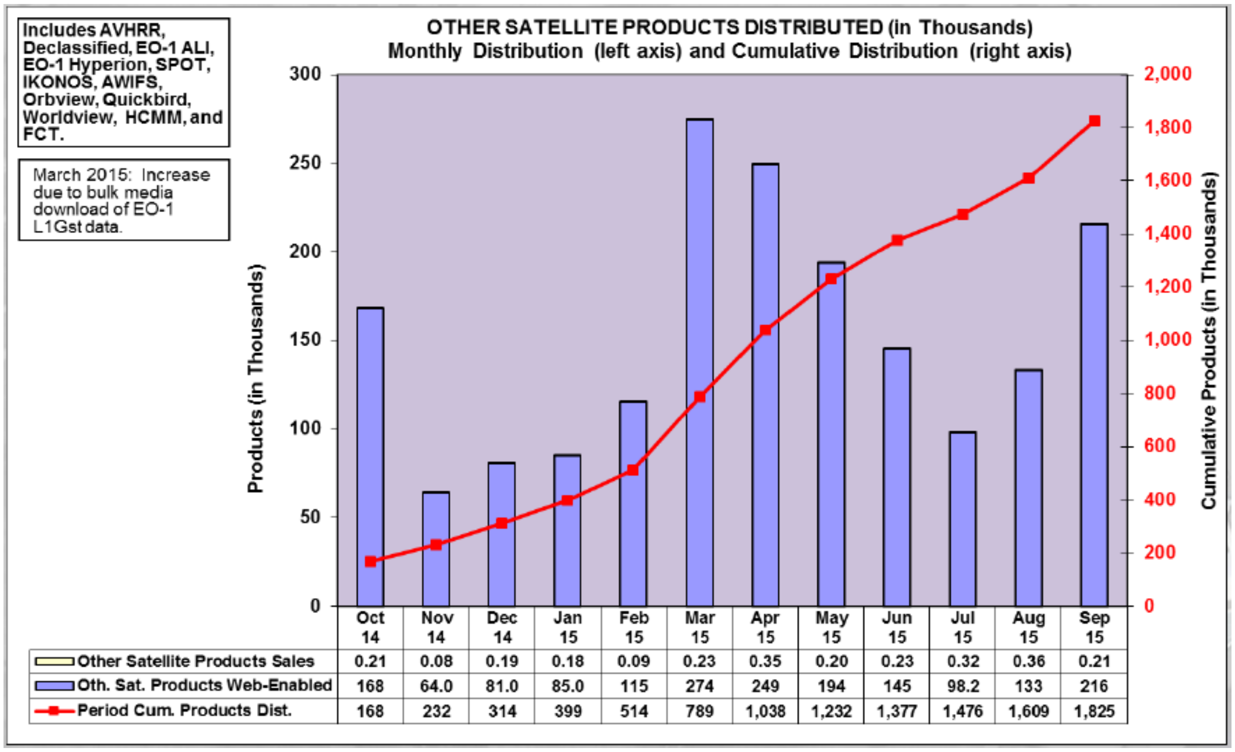
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Landsat ESPA Distributed Monthly	-	-	-	-	-	-	-	-	-	-	-	126
Landsat Products Distributed Monthly	816	811	1,040	1,160	1,056	1,265	1,670	1,442	1,073	880	642	870
Period Cum. Products Distributed	816	1,628	2,668	3,828	4,884	6,149	7,819	9,261	10,335	11,215	11,857	12,853

Figure 96. FY 2015. A 12-month volume of Landsat products distributed.



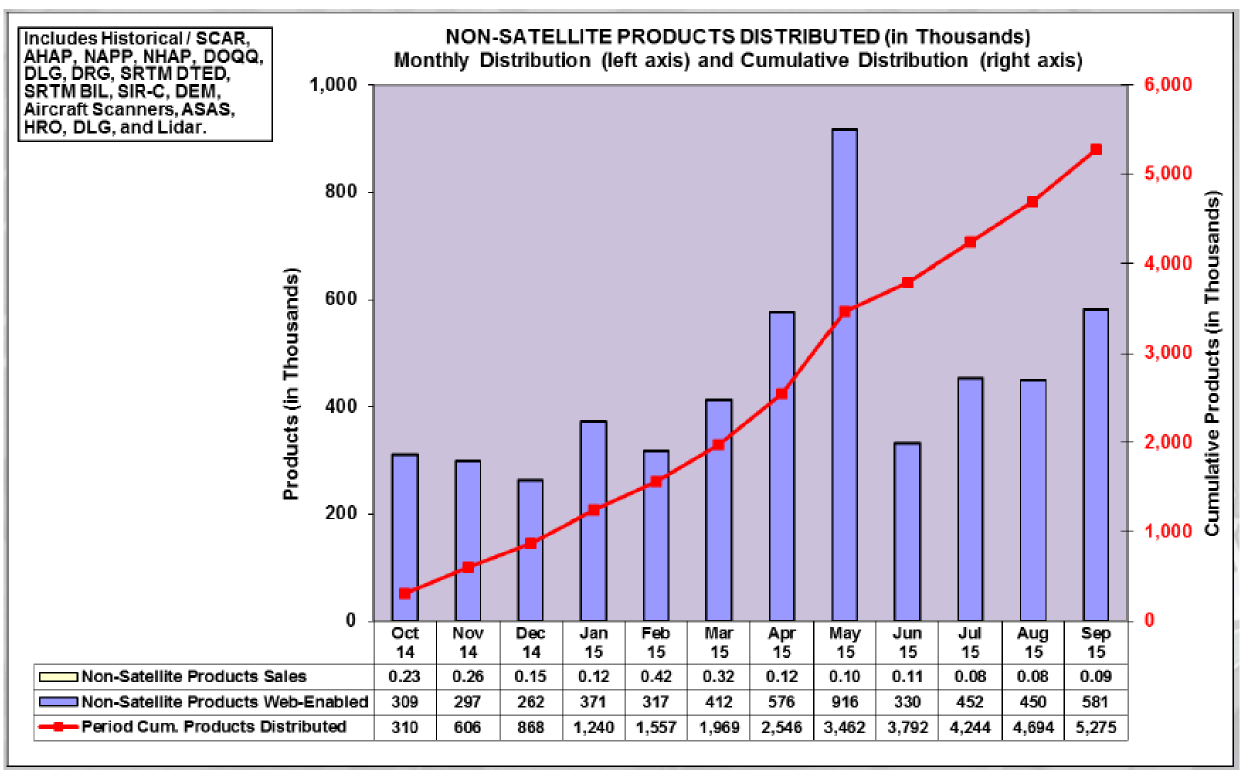
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
ASTER Products Distr. Mthly	213	132	210	164	183	283	291	233	298	304	177	242
MODIS Products Distr. Mthly	6,609	6,178	3,991	6,055	9,584	5,408	10,768	10,600	8,129	7,473	7,589	7,433
WELD (ETM+) Products Distr. Mthly	3.00	0.00	1.00	5.00	0.00	1.00	5.00	25.0	2.00	1.00	5.00	21.00
SRTM Products Distr. Mthly	345	669	781	1,345	582	635	465	747	505	632	554	487
Period Cum. Products Distr.	7,170	14,149	19,132	26,701	37,050	43,377	54,906	66,511	75,445	83,855	92,180	100,363

Figure 97. FY 2015. A 12-month volume of Land Processes Distributed Active Archive Center products distributed.



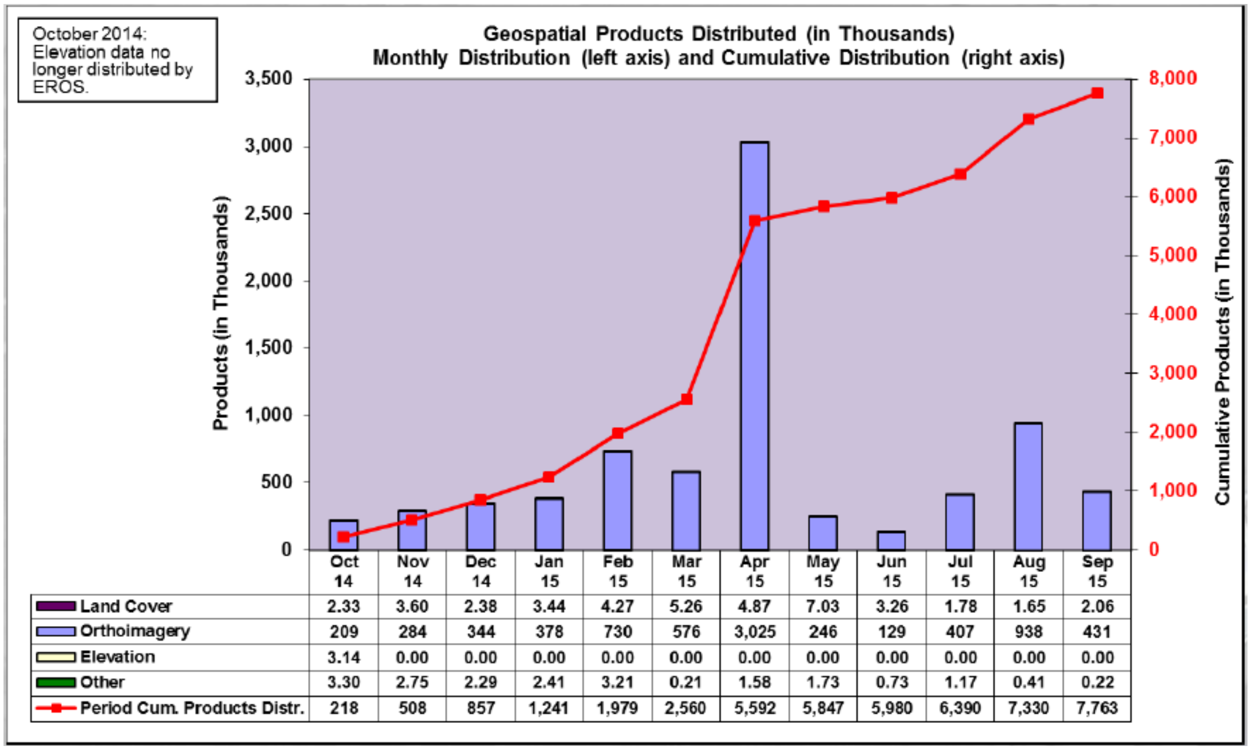
	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Other Satellite Products Sales	0.21	0.08	0.19	0.18	0.09	0.23	0.35	0.20	0.23	0.32	0.36	0.21
Oth. Sat. Products Web-Enabled	168	64.0	81.0	85.0	115	274	249	194	145	98.2	133	216
Period Cum. Products Dist.	168	232	314	399	514	789	1,038	1,232	1,377	1,476	1,609	1,825

Figure 98. FY 2015. A 12-month volume of other satellite products distributed.



	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Non-Satellite Products Sales	0.23	0.26	0.15	0.12	0.42	0.32	0.12	0.10	0.11	0.08	0.08	0.09
Non-Satellite Products Web-Enabled	309	297	262	371	317	412	576	916	330	452	450	581
Period Cum. Products Distributed	310	606	868	1,240	1,557	1,969	2,546	3,462	3,792	4,244	4,694	5,275

Figure 99. FY 2015. A 12-month volume of non-satellite products distributed.



	Oct 14	Nov 14	Dec 14	Jan 15	Feb 15	Mar 15	Apr 15	May 15	Jun 15	Jul 15	Aug 15	Sep 15
Land Cover	2.33	3.60	2.38	3.44	4.27	5.26	4.87	7.03	3.26	1.78	1.65	2.06
Orthoimagery	209	284	344	378	730	576	3,025	246	129	407	938	431
Elevation	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	3.30	2.75	2.29	2.41	3.21	0.21	1.58	1.73	0.73	1.17	0.41	0.22
Period Cum. Products Distr.	218	508	857	1,241	1,979	2,560	5,592	5,847	5,980	6,390	7,330	7,763

Figure 100. FY 2015. A 12-month volume of geospatial products distributed.

Partnerships, Collaboration, and Communication

Partnerships provide the USGS and EROS a capacity to achieve what may not otherwise be possible. There are a host of stakeholders, cooperators, and users for which EROS communicates, collaborates, and serves: including but not limited to other Federal agencies, educational institutions, state, county, and city governments, Native American institutions and tribes, foreign governments, and international (non-government), and others. Their needs are increasingly complex and continually growing. Communicating the value of the Center's data, information, and products, both internally and externally, is critical to our mission success. Connecting the Center's data, information, services, and knowledge to current and potential stakeholders through development of user friendly communication and education capabilities is key to ensuring the value of our data, products, and services is well known, understood, and applied in service to critical requirements. Engagement with users is needed at all levels, nationally and internationally, to better understand customer requirements and assistance needs. Our future depends on the unique knowledge, information, and technology exchanged through our ongoing partnerships, collaboration, and communication. Key accomplishments are given in the following sections.

USGS Takes Over Chairmanship of the International Charter on Space and Major Disasters

On the 22nd of October, 2015, the USGS took over the rotating chair of the International Charter on Space and Major Disasters succeeding the Indian Space Research Organisation (ISRO). USGS will lead the Charter for 6 months until mid-April 2016. The Charter is a joint effort between member space agencies to place their satellite resources at the disposal of rescue authorities in the event of disasters of both human or natural origin. The wealth of Earth observation data for which USGS is responsible makes it a major player in the International Charter.

In the same week, more than 32 delegates of the Charter Member agencies came together in Sioux Falls, South Dakota, for the 34th meeting of the International Charter (fig. 101). Participants in the 34th meeting of the Charter met at the USGS EROS Center to discuss operational matters and other items. For further information, contact USGS EROS, Frank Kelly, fkelly@usgs.gov.

Figure 101. Delegates of the charter member agencies in Sioux Falls, South Dakota, in October 2015, for the 34th meeting of the International Charter.

Fifteen Years of Collaborative Disaster Response

The International Charter on Space and Major Disasters formed in November 2000 and has been providing a unified system of emergency response satellite data to areas that have been struck by disasters resulting in loss of life and widespread destruction around the world. The Charter draws on the capabilities and resources of its 15 national space agencies and space operators to quickly provide satellite data at no cost to those in need.

Over the last 15 years, the Charter has brought space assets into action in over 115 countries for over 450 natural and technological disasters, including flooding, hurricanes, tsunamis, earthquakes, forest fires, and oil spills. The Charter coordinates data from dozens of international satellites at varying resolutions to provide a quick response to disaster-afflicted areas.

The Charter member representatives celebrated by wearing matching International Charter 15th Anniversary t-shirts (fig. 102). To commemorate this special anniversary, the European Space Agency (ESA) coordinated the production of this scribble video, https://www.youtube.com/watch?v=vif1kqwfCEc, highlighting the organization.

For further information, contact USGS EROS, Brenda Jones, bkjones@usgs.gov.

Figure 102. USGS EROS celebrates International Charter 15th anniversary.

Mapping for the Ebola Crisis

Remotely sensed datasets such as satellite imagery and aerial photography can be invaluable resources to support the response to and recovery from many types of emergency events such as floods, earthquakes, landslides, wildfires, and other natural or human-induced disasters. When disasters strike there is often an urgent need and high demand for rapid acquisition and coordinated distribution of pre- and post-event geospatial products and remotely sensed imagery. These products and images are necessary to record change, analyze impacts of, and facilitate response to the rapidly changing conditions on the ground.

When USGS received a request to provide International Charter support for the Ebola crisis in Western Africa, the requirements for imagery to be used as a source for change detection changed. The data provided on the Hazards Data Distribution System (http://hddsexplorer.usgs.gov) (fig 103.) in support of the ebola crisis was instead used for base mapping of much of southwestern Africa, to help locate infrastructure such as ebola treatment centers, hospitals, schools, roads, and border crossings. The initial activation by the National Geospatial-Intelligence Agency (NGA) was followed very closely by an activation from the United Nations on behalf of the World Health Organization (WHO). While the NGA produced atlases (fig. 104) that were made publicly available, the WHO were provided access to Web mapping services that supplied them with the information they required at the ebola treatment centers and the surrounding areas. For further information, contact USGS EROS, Brenda Jones, bkjones@usgs.gov or Hazards Data Distribution System http://hddsexplore.usgs.gov.

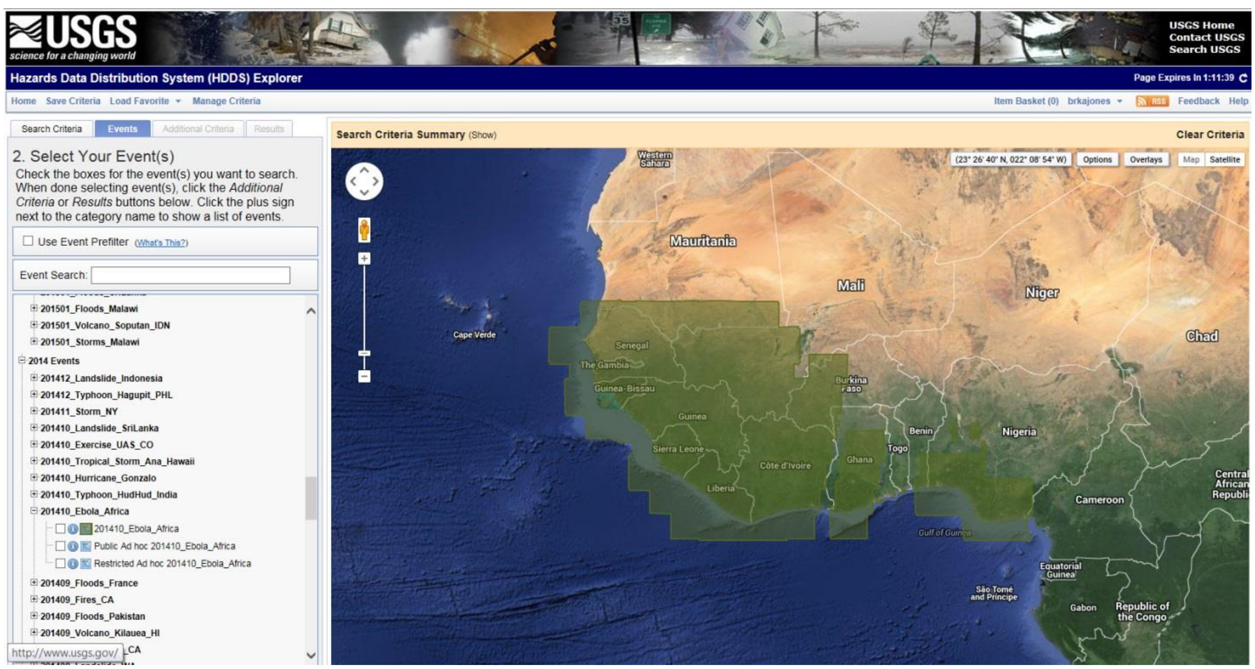


Figure 103. Hazards Data Distribution System screen capture showing coverage area for the ebola event.

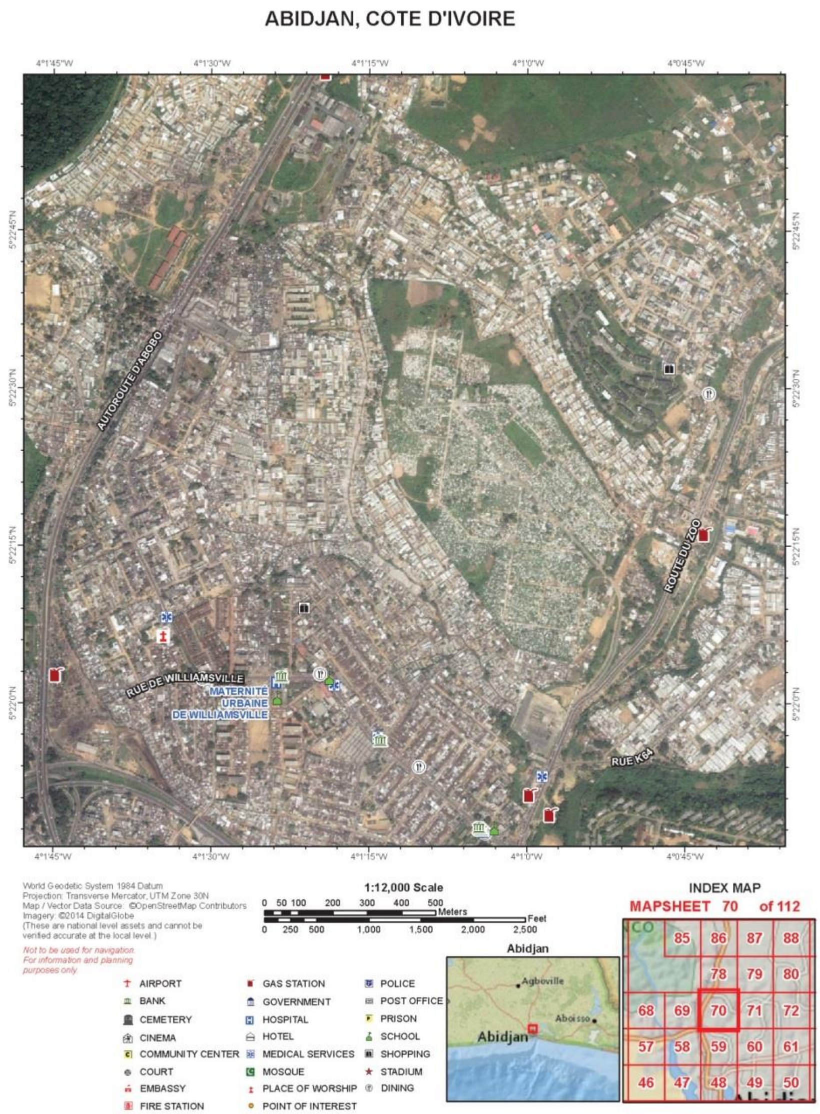


Figure 104. Example page from the Abidjan Atlas produced by the National Geospatial-Intelligence Agency.

Nepal Earthquake Support

Shortly before noon on April 25, 2015, a massive earthquake registering 7.8 on the Richter scale struck central Nepal. Just 3 hours later – around 4 a.m. Central Time – the EROS disaster response coordinators were contacted by the emergency on-call officer from the International Charter on Space and Major Disasters: Could they provide coordinates to the National Geospatial-Intelligence Agency so they could task several of their satellites to acquire high-resolution images of the quake zone?

Getting such a call is nothing new, as the USGS has been providing support to the International Charter since becoming a member in 2005. The Charter is a mechanism for rapidly acquiring satellite imagery of locations impacted by natural or human-made disasters and getting that data, and products derived from them, (fig. 105) into the hands of emergency responders and relief agencies as quickly as possible, at no charge.

How does it work? When an earthquake, flood, oil spill, or other disaster occurs, a specially trained authorized user submits a request for satellite imagery and whatever other data or products are needed. Authorized users can initiate the Charter response for a disaster occurring in their own country, or on behalf of someone from another country. The request sets in motion the tasking of satellites (usually within just 2 to 3 hours) to capture images, and the subsequent delivery of data to whomever needs it.

USGS has provided access to over 5,000 images on the Hazards Data Distribution System (http://hddsexplorer.usgs.gov) for the response to the Nepal earthquake. The 2,100 high-resolution commercial images, which were provided by NGA through their contract with Digital Globe, have been made available to responders in 28 countries. For further information, contact USGS EROS, Brenda Jones, bkjones@usgs.gov or International Charter on Space and Major Disasters http://www.disasterscharter.org.

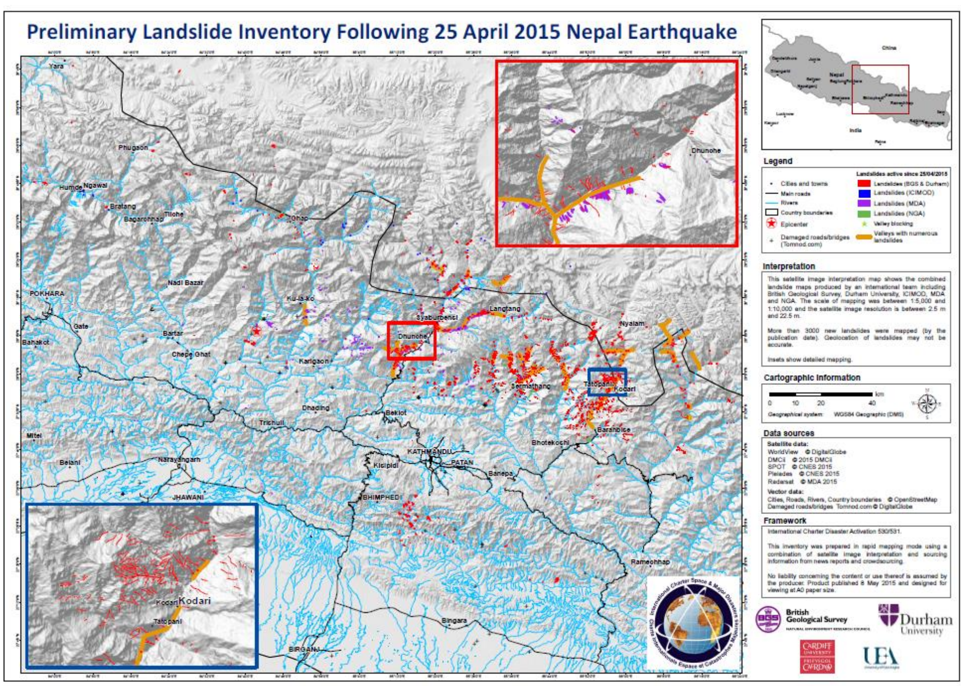


Figure 105. Landslide indicator map showing the locations of landslides as a result of the April 25, 2015, earthquake in Nepal. Imagery was provided through the U.S. Geological Survey to the users of the International Charter on Space and Major Disasters.

Enhanced Services and Tools for Emergency Response

As part of its mission to provide timely and relevant remotely sensed imagery and related datasets for disaster support, the USGS EROS Emergency Operations project implemented several new tools and capabilities intended to expand on existing services for domestic and international emergency response.

The first new capability was an interactive, map-based Collection Management Tool (CMT) for incoming user requests, which was released in February 2015. Concurrent with the CMT release, a new emergency response Web portal was developed to provide supporting information on the USGS EROS emergency response capabilities, services and data access, and other topics. The third major development to be completed in October 2015 will provide an enhanced capability for search, access, and visualization of image-derived map products and other related datasets through the USGS Hazards Data Distribution System (HDDS).

All three of these new capabilities were developed and tested in direct response to end user input, experiences, and feedbacks. Together, this suite of new tools and services will allow USGS to continue to enhance its support for the broad community of agencies and organizations engaged in emergency response.

Collection Management Tool. The new CMT, http://cmt.usgs.gov/, is a public Web portal that allows end users to enter and manage their image requirements in support of event-related disaster response efforts (fig. 106). The map-based interface allows end users to submit data acquisition requests for image support and monitor the collection status. Users may also view publicly designated image requests and areas of interest that have been submitted by other end users, allowing improved coordination of requirements across the various agencies and organizations that may be involved in an event response. For data delivery, the tool provides direct linkage to HDDS for image download, and also supports automated user notification via email, as imagery is collected in support of the user request.

The development and release of the new CMT was supported by funds that were requested and received through the Superstorm Sandy "Supplemental" funding package. Many of the specific CMT system requirements were based on community needs and inputs that were identified during and after the multi-agency Superstorm Sandy event response.

Emergency Operations Web Portal. Concurrent with the CMT release, a new emergency operations Web portal, http://eoportal.usgs.gov/, was developed and released to provide enhanced information on the USGS EROS emergency response activity, user support and data access, and other topics (fig. 107). Unlike the earlier information portal, the new Web site is based on a content management system, which will provide improved capability for rapid and easy updates of Web information related to event response information.

The new Web site includes updated information from the heritage Web site, in addition to many new content areas, including an overview of emergency operation activities and capabilities, procedures for requesting support, and detailed information on data access, licensing, and citation. The site also features information on the USGS role in support of the International Charter on Space and Major Disasters, along with any other topics.

The development and release of the new Web portal was a supporting component of the CMT activity, based on funds that were requested and received through the Superstorm Sandy "Supplemental" package. Many of the Web site requirements and enhanced content areas were developed in response to community needs that were identified during and after the multi-agency Superstorm Sandy event response.

Enhanced Access to Disaster Information Products. A new capability has been developed to support the enhanced search, access, and visualization for disaster-related map products that are provided to USGS by contributors for sharing across the response community during an emergency event response (fig. 108). The contributed maps and other information products were already hosted and delivered via the existing USGS Hazards Data Distribution System, http://hddsexplorer.usgs.gov/. However, this system was previously developed and optimized for image delivery, and image-derived maps or other products that were not easy to visualize or access.

The HDDS is a public map-based Web portal that provides a consolidated point of entry and distribution system for remotely sensed imagery and other geospatial datasets related to emergency response. When disasters occur, the system provides a critical source of satellite and aerial imagery (and now also maps) for the emergency response community. The imagery and datasets on HDDS includes imagery and related products provided by USGS, as well as contributed datasets from many other Government agencies and collaborators. After ingest, the HDDS-hosted imagery is accessed by end users from all levels of Government (Federal, state, local, tribal, and international) as well as many other organizations and communities engaged in emergency event support.

For map and other information products, a new ingest capability was developed and integrated within the HDDS to allow map products and other related datasets to be easily searched, discovered, previewed, and downloaded by end users. The ingested products can now be readily discovered and accessed, alongside all other HDDS-hosted imagery.

For further information, contact USGS EROS, Brenda Jones, bkjones@usgs.gov.

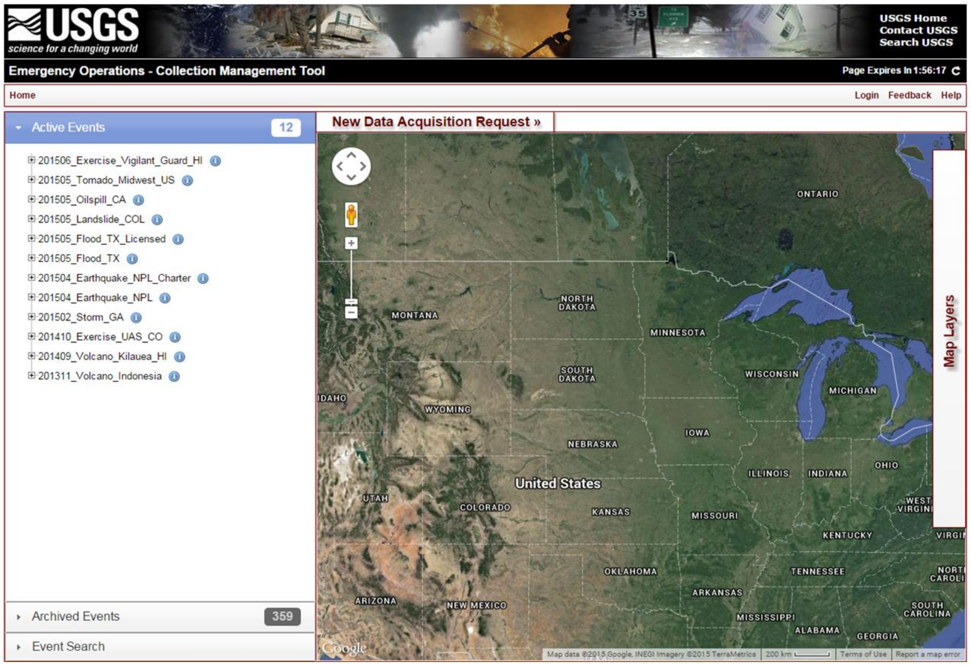


Figure 106. Screen example showing the new Collection Management Tool that was released in February 2015. The tool provides an online Web-based portal that allows users and staff to enter, monitor, and manage image collection requirements for emergency response.

Figure 107. Screen example showing the emergency operations Web portal that was released in February 2015. The updated Web site features many new and expanded content areas, and includes information on USGS EROS emergency response services, data access, International Charter, and many other topics.

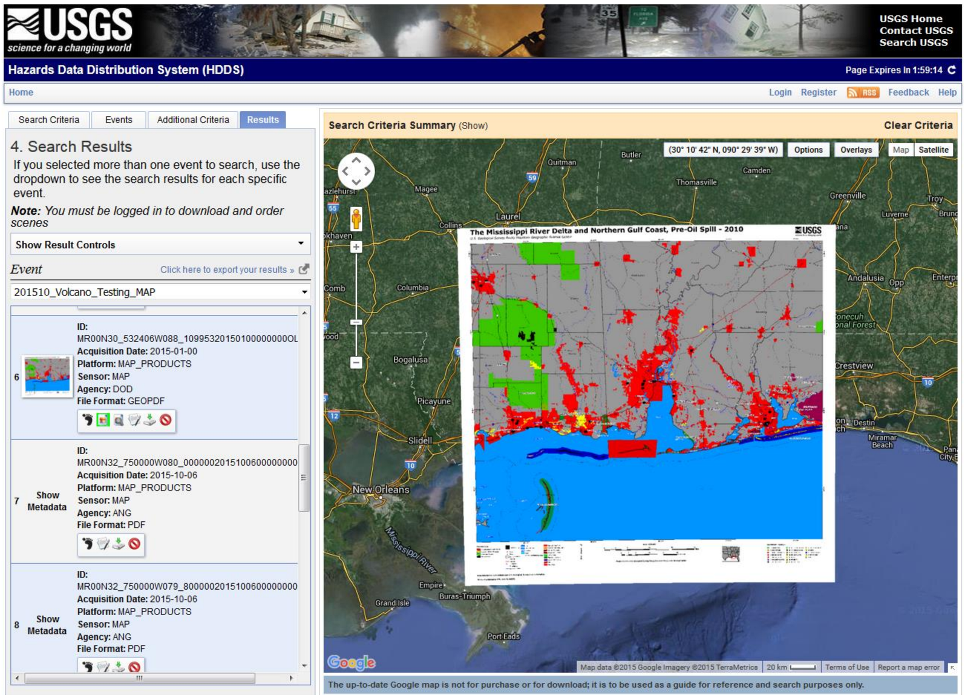


Figure 108. Screen example showing the Hazards Data Distribution System (HDDS) interface, showing the search results and "browse" view now available for ingested map products. With a new HDDS ingest capability for maps and other products, these datasets will be more easily discovered, visualized, and accessed by end users on HDDS.

Reinventing User Services

The Data Services Branch began reinventing the EROS user services presence as a high priority for FY 2015. As a consequence of our data services paradigm shift, the Center's historical customer services functions will need to evolve and expand to a user support services model – moving from a provider of data to a provider of information, services, and solutions. The long-term goal is to develop a more robust capability for support of user applications and science, in addition to the historic role of addressing basic customer questions about our products and data access. With several hundred datasets and numerous projects represented by customer service activities, there was also a need for our user-focused interactions, processes, and levels of support to become more consistent across projects and datasets (i.e., "transparent" to the user).

To accomplish this, we have moved from a project-driven customer support model to an EROS Center-wide user services model, improving user communications and providing more consistent levels of user support across the projects. For several major projects, Landsat, Long Term Archive, Spatial Data Warehouse, and LANDFIRE, the user support activities have been defined and divided into three levels, referred to as tiers of service. Tier 1 involves answering user queries with a goal for addressing as many questions as possible within a single contact, and redirecting appropriate questions to tier 2 and or subject matter experts. Tier 2 provides higher-level support for technical product issues or questions, and also supports testing of system and product changes, user documentation, and communication of changes to products or systems that will affect the customer. Tier 3 consists of a defined set of subject matter experts located throughout the Center that can serve as technical resources to help answer high-level customer questions or support other tier 2 functions. We have always had a good tier 1 capability, so the FY 2016 emphasis will be placed on improving tier 2 support in a consistent fashion, regardless of project or dataset.

One of the first major changes with the user services consolidation has been the implementation of a single, common application and database to collect all incoming customer questions and contacts. Every response is now being captured for future reference by user services within a shared knowledge-base. Going forward, the use of topical "tags" and metrics from this system should provide an efficient tool for collection of customer feedbacks to help identify and mitigate our most common user issues, and perhaps even suggest future product and system improvements based on specific user inputs.

Emphasis is also being placed on establishing a consistent set of processes and strategy for customer-oriented activities, such as the integration of new products or product line changes. The end result will be to assure adequate and timely communications are provided for any new products or system changes that affect our customers. To assist this, a Landsat product control board was implemented within the production operations group to better identify product updates, product changes, user impacts, and user notification methodologies. For further information, contact USGS EROS, Rynn Lamb, lamb@usgs.gov.

Communicating EROS Science

The Communications and Outreach (C&O) project at the USGS EROS Center strives to increase local, national, and global awareness and understanding of the Center's mission, goals, and science – focusing on schools and universities, organizations, science communities, and the public.

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 2016-2021 is underway, the accomplishments of 2015 and initiating actions of 2016 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.

Throughout FY 2015, C&O supported a wide variety of routine tasks, which included: USGS headquarters and media requests; research and creation of *Image of the Week* and *Views of the News* features; refreshing the *Around the Center* feature on a regular basis; logistics for special meetings; maintaining EROS Web sites; supporting local/regional/bureau conferences; updating publications and educational materials; presenting at local schools and organizations; supporting the EROS library; supporting the reception desk; and managing EROS scheduled and self-guided tours.

Several new methods for sharing the EROS story were developed in FY 2015, specifically:

- Earth As Art 4, using Landsat 8 images from around the world. Mexico's Biosphere (fig. 109) is an image featured in Earth As Art 4. The Earth As Art 1, 2, and 3 series proved to be very popular and an exceptional way to engage viewers' curiosity about the Earth and remote sensing.

- Visitor Center Exhibits. We completed the first phase of our updated visitor center plan, by adding exhibits (fig. 110) intended to walk visitors through a logical flow that tells the story of what we do at EROS and how the work impacts society. Several of the displays use interactivity – providing hands-on experiences using data – this allows visitors the opportunity to manipulate imagery and hopefully gain a better understanding of how scientists might use remote sensing.

- Land Remote Sensing Program Support. LRS Program support included assisting in the production of the DOI Remote Sensing Report, creation of factsheets and other outreach materials, and managing the LRS Web content.

- On-Line Based Training and or Information Modules. These modules are short, on-screen demonstrations on how to use tools to research and download imagery, what each database consists of, and how the data is used. The modules will be housed on the EROS Web site as well as the USGS YouTube channel.

- Support, planning, and logistics for several special meetings and events: the Pecora 19 Symposium, the LP DAAC 25th Anniversary Celebration, and the USGS assuming Chairmanship of the International Charter on Space and Major Disasters.

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/.

Figure 109. Mexico's Biosphere. Much of this image consists of the Reserva de la Biosfera Pantanos de Centla, a biosphere reserve in southern Mexico that protects wetlands in the area. The water bodies, mangroves, and forests are a sanctuary for a great variety of wildlife. Sediment carried away by the Grijalva River appears as a sweeping light blue brushstroke flowing into the Gulf of Mexico at the top of the image.

Figure 110. New visitor center exhibits. This photograph shows a portion of the new EROS visitor center exhibits.

Social Media Activities

As part of an effort to broaden the reach and depth of public user engagement, USGS EROS continued to operate and expand social media communications through three active Twitter accounts: (1) USGS Landsat; (2) USGS Land Cover; and (3) USGS Hazards Data Distribution System.

All three of these accounts were originally developed to provide enhanced public messaging and notification capability, allowing users to stay abreast of product availability and other developments related to EROS data and services. By providing brief announcements along with Web links, the Twitter presence is typically used to help communicate important product- and mission-related topics, helping to drive traffic to essential Web pages containing detailed information such as data availability, project milestones, data issues or changes, and other announcements. The Twitter accounts are also used to help amplify messaging from other related accounts (e.g. NASA Landsat, International Charter, etc.) and to help keep the general public informed about the importance and relevance of our products.

Each of the current Twitter capabilities provides an important mechanism to enhance unilateral user communications. With each account tailored to a specific community requirement, the current suite of Twitter accounts provides a unique and powerful means to enhance the engagement between USGS and its various user communities.

Along with unilateral messaging, the three Twitter accounts also provide an important mechanism for listening to customer perspectives or experiences in near real-time, and providing public response and input as necessary. As a supplement to traditional email, the Twitter platform provides an important capacity for gathering user feedbacks, and responding to the user community through unilateral or multilateral conversation and response. Through the selective use of hashtags, each of the Twitter accounts is engaged with a unique set of "niche" communities, and therefore well-positioned to listen and/or contribute as knowledge, information, and experiences are shared within the relevant user communities.

USGS Landsat (@USGSLandsat). The USGS Landsat Twitter account (fig. 111) was first launched in September 2009, and has a highly active and engaged social media community. The primary goal of this account is to notify users of spacecraft and mission news, product-related developments, Landsat-related headlines and publications, and information on data access, interpretation and analysis, and image data that may have particular interest (e.g., glaciology, flooding, wildfires, etc.). The account is also used to commemorate historical milestones and notable mission events, such as launch dates and delivery milestones.

As of November 2015, the Landsat Twitter account has over 10,000 followers and representation on 367 member lists. The Landsat Twitter community is highly engaged and enthusiastic, and covers a broad spectrum of Landsat data users from the science and remote sensing fields. The followers also include Government and policy makers, academics and educators, press and communications, and general public.

- Follow @USGSLandsat at: https://twitter.com/USGSLandsat
- Common hashtags include: *#landsat, #landsat8, #opendata, #Landsatscienceteam, #changedetection, #landcover, #remotesensing*

USGS Land Cover (@USGSLandCover). The USGS Land Cover Institute joined Twitter in February 2011, and this account (fig. 112) serves as an important focal point for advancing the science, knowledge, and application of land use and land cover information. The Twitter presence is used to provide announcements regarding the availability of the latest USGS land cover datasets, land cover related project news, and to generally communicate the relevance and importance of land cover science activities. Along with general information, Twitter has also become an important mechanism for assisting users, due to the ability to respond quickly to technical questions and further assist users through follow-up email or phone conversation.

As of November 2015, this Twitter account has over 4,400 followers and representation on 169 member lists. The primary targeted audience is the land use and land cover science community, including USGS scientists, private researchers, policy makers, and educators. However, there are also followers from the media (i.e., Public Broadcasting Service), Governments, and general public seeking information about USGS land cover activities.

- Follow @USGSLandCover: https://twitter.com/USGSLandCover
- Common hashtags include: *#landcover, #landuse, #landchange, #NLCD, #MRLC, #landsat*

USGS Hazards Data Distribution System (@USGS_HDDS). The USGS HDDS Twitter account (fig. 113) was launched by the Emergency Operations project in November 2012, as part of its mission to provide timely and relevant remotely sensed imagery and information for disaster support. The account was originally intended to provide "operational" HDDS user information on imagery available for domestic and international emergency response. The HDDS is a public map-based Web portal that provides a consolidated point of entry for accessing remotely sensed imagery and other geospatial datasets related to emergency response. When disasters occur, the system provides a critical source of satellite and aerial imagery for the emergency response community. However, as the Twitter membership has grown and evolved to reach many users outside the remote sensing community, the scope and content of this Twitter account has been expanded to include many other general interest topics such as the dissemination of publicly available disaster related information, such as map information products based on HDDS imagery, crowd sourced disaster mapping campaigns, USGS emergency response activities, public announcements on data availability and access, and updates on the USGS role in the International Charter on Space and Major Disasters.

As of early November 2015, the USGS HDDS Twitter account has over 1,060 followers. The primary targeted audience is the emergency response and disaster management community. However this account also includes many followers from Government agencies, research organizations, academics, private companies, media, educators, and general public seeking information about USGS disaster response activities.

- Follow @USGS_HDDS at: https://twitter.com/USGS_HDDS
- Common hashtags include: *#landsat, #WorldView, and event-specific hashtags (e.g. #NepalEarthquake, #Hagupit, #KingFire, etc.)*

For further information, contact USGS EROS, Rynn Lamb, lamb@usgs.gov.

Figure 111. Screen example showing USGS Landsat Twitter account (@USGSLandsat). As of November 2015, the USGS Landsat account has over 10,000 followers.

Figure 112. Screen example showing USGS Land Cover Twitter account (@USGSLandCover). As of November 2015, the USGS Land Cover account has over 4,400 followers.

Figure 113. Screen example showing USGS Hazards Data Distribution System Twitter account (@USGS_HDDS). As of November 2015, the USGS HDDS account has over 1,050 followers.

Praise for Pecora

"Outstanding!"
"The keynotes were excellent!"
"A huge success at every level!"

These comments are just a sampling of the enthusiastic responses received from attendees of the Pecora 19 Symposium, which ran from November 17-20, 2014, in Denver, Colorado, and was held in conjunction with the Joint Symposium of the International Society for Photogrammetry and Remote Sensing Technical Commission I and the International Association of Geodesy Commission 4. Pecora 19 brought together nearly 500 participants from more than 25 countries to exchange ideas and learn about the latest developments and challenges in the field of satellite remote sensing, including topics such as existing and emerging sources of data, the importance of light detection and ranging (lidar) technology, the anticipated role of the upcoming Sentinel-2 mission, and much, much more.

Pecora 19 theme – *Sustaining Land Imaging: Unmanned Aircraft Systems (UAS) to Satellites* – was emphasized throughout the 3-day event, beginning with the opening address by Dr. Berrien Moore entitled "*Landsat: A Vision Realized!*". Immediately following the opening address, representatives of USGS and NASA jointly presented the 2014 William T. Pecora Awards. These are given annually to individuals and or groups who make outstanding contributions toward understanding the Earth by means of remote sensing. The Pecora Awards are among the most prestigious – if not *the* most prestigious – awards given in our field, and this year's recipients were indeed worthy of the honor. The 2014 group and individual awards were:

2014 Group Award: Landsat 8 Team – For outstanding contributions toward understanding the Earth's land surface and surrounding coastal regions (fig. 114).

> The Landsat Data Continuity Mission was successfully launched on February 11, 2013. Renamed Landsat 8 on May 30, 2013, this mission continues the goals established by William Pecora and other visionaries 50 years ago. The Landsat 8 Team, consisting of NASA, USGS, and industry partners, has performed at the highest levels from the beginning of mission development to the present.

2014 Individual Award: Christopher Owen Justice, Ph.D. – For outstanding contributions toward understanding the Earth by means of remote sensing (fig. 115).

> Dr. Christopher Owen Justice, Professor and Chair of Geographical Sciences, University of Maryland, has dedicated his career to remote-sensing education, research, and service. Dr. Justice has advanced remote sensing science, contributed to a better understanding of the changing Earth, and enriched the lives of many of today's leading remote sensing scientists as an advisor, educator, and research director.

Throughout the duration of the conference, attendees listened to a wide variety of speakers, took in panel discussions led by experts in various fields, and interacted one-on-one with dozens of poster presenters. The number, balance, and quality of presentations throughout the entire technical program was truly outstanding.

The closing plenary session drew a standing-room-only crowd when Google Inc.'s Ms. Rebecca Moore, founder of Google Earth Outreach and Earth Engine, gave a talk titled "*Petapixel Computing for All: Transforming Remote Sensing in the 21st Century*" during which she demonstrated a selection of Google's most recent mapping tools that showcase some of the world's most pressing problems in environmental conservation, human rights, and cultural preservation. In her presentation she stated that remote sensing 'is not about pixels, it is about knowledge and insights.' She reminded everyone in attendance that it is our collective responsibility to truly move beyond pixels and focus on bringing together data, methods, and user needs in innovative ways to provide the best environmental information about the planet for decisionmakers and natural resource managers in ways that maximize benefits to society.

The Pecora Symposium series has its roots deep in EROS history. Former USGS Director, William T. Pecora, was a driving force in the 1960s and early 1970s behind the development of civilian space-based Earth observations and the first Earth Resources Technology Satellite, a.k.a., Landsat 1. In recognition of Pecora's unique contributions to Earth observation science, USGS and NASA created the Pecora Symposium. The first Pecora Symposium was held in 1975, in Sioux Falls, South Dakota; and it has been going strong ever since. Pecora 19 was a great success on every level, and some might think a hard act to follow. But the stage is already set for Pecora 20, which will be back in Sioux Falls in mid-November 2017. For further information, contact USGS EROS, Thomas Holm, holm@usgs.gov.

Figure 114. Pecora 19 Group Award. Landsat 8 Team – For outstanding contributions toward understanding the Earth's land surface and surrounding coastal regions.

Figure 115. Pecora 19 Individual Award. Christopher Owen Justice, PhD – For outstanding contributions toward understanding the Earth by means of remote sensing.

Building Global Connections: The GOFC-GOLD Data Initiative Workshop

Remember dial-up? Glacially slow downloads? Connections that invariably failed just before a task was complete, forcing you to start all over again – and cost you an arm and a leg? All that may feel like ancient history in an environment where dependable high-speed Internet connections are commonplace, and the transfer of large amounts of data at lightning speed is an everyday occurrence. It is easy to make the mistake of assuming that everyone in the world enjoys the same level of access to digital data via the Internet.

The reality is that in many parts of Africa, Asia, and Latin America, Internet access remains poor and unreliable. For scientists working in these locations, downloading Landsat imagery and other types of Earth observation data can be a slow, arduous, even impossible task – and therefore a serious impediment to their research.

EROS contributed to overcoming this obstacle by hosting the Fifth Data Initiative Workshop of the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) Program, July 20-24, 2015. GOFC-GOLD ("goff-see-gold") is a coordinated, international program designed to provide ongoing space-based and in-situ land cover data important to the study of carbon sequestration, land cover change, and the sustainable management of forests and other natural resources worldwide. The data initiative workshops are a way to disseminate relevant Landsat and other data to scientists in regions where currently available distribution methods are not effective, and also to provide technical training in data extraction and analysis. The workshops are the result of a partnership involving USGS, EROS, NASA, and the SysTem for Analysis, Research, and Training (START), an international non-profit that works to build capacity for advancing knowledge on global environmental change in Africa and the Asia-Pacific region.

The Fifth Data Initiative Workshop brought together nine scientists from Bulgaria, India, Togo, Madagascar, Nepal, South Africa, Uganda, Vietnam, and Zimbabwe (fig. 116). Working intensively with EROS staff, the participants spent the week learning about various data products held in the EROS archive, as well as how to access the data for use in their scientific research projects.

During the workshop, participants were able to download several datasets, including Landsat imagery, relevant to their particular projects and that they would use at a follow-on workshop at Boston University held July 27-August 7, 2015. There, the visiting scientists were scheduled to learn more about data analysis and how to redistribute the data to their associates upon returning home.

There was no doubt that EROS also gained by hosting and interacting with the nine dynamic and dedicated participants. The data initiative workshops have given EROS staff unique insights into the evolving use of Landsat and other EROS remotely sensed datasets, and contributed to a better understanding on how to provide more efficient access to EROS holdings. This is an important community service that contributes to improving the use of objective information needed to understand global changes and improve management of natural resources.

The partnerships the GOFC-GOLD groups build while at EROS are long-lasting. The participants over the years have had a distinct eagerness to learn, and to accumulate as much knowledge and data as possible. Every year there is a bond that forms within the groups, and these relationships continue to grow and build within their networks. There was a friendly rivalry between past groups and within this group as to who could download the most data the fastest. They also came up with innovative ways of creating their own archives.

Long-lasting partnerships? An eagerness to learn? Relationships that continue to grow? Sounds like a workshop worth its weight in gold. For further information, contact USGS EROS, Thomas Loveland, loveland@usgs.gov.

Figure 116. Participants and co-coordinators of the Fifth Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) Data Initiative Workshop included (left to right): Charles Trautwein (EROS), Thomas Loveland (EROS), Shiva Khanal (Nepal),

Godfrey Pachavo (Zimbabwe), Ilina Kamenova (Bulgaria), Mercy Ojoyi (South Africa), Nivohary Ramaroson (Madagascar), John Wasige (Uganda), Ngoc Pham (Vietnam), Suryakant Sawant (India), Maléki Badjana (Togo), and Anya Hartpence (EROS).

The Land Processes Distributed Active Archive Center: An Enduring Partnership

On August 28, 1990, USGS and NASA entered into a partnership that established the Land Processes Distributed Active Archive Center, or LP DAAC, here at EROS. A 65,000-square-foot addition was constructed to accommodate "the DAAC" as it came to be called. This specialized NASA archive added a new dimension to EROS in that the DAAC would be processing, archiving, and distributing remotely sensed land imagery acquired primarily by the MODIS and ASTER sensors on board NASA's Earth Observing System (EOS) Terra and Aqua satellites. Twenty-five years later, officials from DOI, USGS, and NASA headquarters joined EROS staff in celebrating the DAAC's 25th anniversary on August 27-28, 2015.

From the start, the LP DAAC has been a source of great pride and innovation. Since 1990, this NASA USGS partnership has brought numerous technological advances to EROS. Some examples would be the ability to house multiple large datasets in one archive, manage an archive entirely on spinning disk, and implement new database technologies that allow for faster ingesting of data. Over the years, every advance has been focused on improving our ability to mine the vast NASA archives and develop new services that scientists can use to learn more about our changing Earth.

The DAAC's holdings have undergone tremendous expansion since 2000, which was the first year of active data archiving. It currently maintains 2 petabytes (2,000 terabytes) of remotely sensed land data. Annually, the DAAC distributes thousands of terabytes of these data to some 120,000 users in 126 different countries. Here are a few highlights:

- MODIS and ASTER data, together with Landsat and other types of satellite imagery, are used by expert fire-assessment teams to determine the severity and potential impacts of wildfires on Federal lands across the United States; these assessments are crucial to post-fire recovery efforts.
- The Global Land Ice Measurements from Space (GLIMS) project – an international collaboration involving more than 60 research institutions – uses ASTER data to measure the current extent of some 160,000 glaciers worldwide, and to track how much, and how fast, each glacier is changing over time.
- The National Park Service is using MODIS data for long-term monitoring of vegetation, drought impacts, snow cover, invasive species, and large-scale disturbances across 16 national parks, monuments, and historic sites on the Colorado Plateau, including Arches, Bryce Canyon, and Zion National Parks.
- The Western Australian Centre of Excellence for 3D Mineral Mapping (C3DMM) – led by Australia's national science agency, the Commonwealth Scientific and Industrial Research Organization (CSIRO) – recently released an

ASTER Geoscience Map of Australia, the world's first continent-scale map of the Earth's surface mineralogy, created using roughly 3,500 ASTER scenes. ASTER data are invaluable for mineral mapping from space because, unlike many other multispectral satellite sensors, it acquires data in spectral bands that span wavelengths sensitive to a variety of minerals.

- MODIS data provide a foundation for reports, maps, and advisories issued by the Famine Early Warning Systems Network (FEWS NET), which works to identify and classify food insecurity levels and alert authorities to potential food crises in sub-Saharan Africa, Afghanistan, Central America, and Haiti.

The DAAC is also considered by many to be a model for successful partnerships between Government agencies. It is a partnership between USGS and NASA that gives us the trusted scientific data and information that are the foundation for decisionmaking by leaders and citizens worldwide.

This 25-year anniversary celebration served a dual purpose; it provided us with an opportunity to look back, to see where we have been in a broader context and to fully appreciate all that has been accomplished. It also enabled us to look ahead with the benefit of experience in anticipation of all the good things yet to come. For further information, contact USGS EROS, Chris Doescher, cdoesch@usgs.gov.

Science Support Activities

EROS is on a Federal campus and is a USGS-owned facility. Our physical infrastructure and qualified Federal and contractor workforces require effective administrative and performance management measures, at both headquarters and in the field. These measures are integrated into processes across the Center, incorporated into our strategic efforts, and used to inform our decisions. Effective management of the scientific, physical, and human resources is imperative to delivering the right products and services at the right time. Science support activities at the Center provide 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.

Enriching the Annual Planning Process

The annual planning process is used by EROS to prepare for, help shape, and respond to guidance from our customers. At its simplest, it is projects responding on their own to customers' guidance. The annual planning process aids and ensures that EROS strategic planning, priorities, and objectives are incorporated within and across projects' work plans and sponsors' guidance.

As part of the FY 2015 EROS priority "Execute a Center-wide Process for Planning, Prioritizing, and Measuring our Work", the annual planning process addresses the current (executing) year, the next (proposal) year, and the (initiatives) year following that.

In FY 2015, in preparation for FY 2016's work, the Center held a series of planning and prioritization efforts. These included a priority-gathering questionnaire; a findings-and-recommendation offsite; a criteria-based work package prioritization exercise by EROS Senior Staff; and project-level peer reviews. These resulted in a set of Center-wide FY 2016 priorities, which were incorporated into the proposed FY 2016 work plans and budgets that were submitted to six USGS programs. For the first time, a review of reimbursable work was presented to Center management for consideration, making even more of the Center's work visible and available for cross-Center collaboration. Execution of the annual planning process for FY 2016 was much more operational than it was for FY 2015 – although one lesson learned was that the process will continue to be tweaked year to year, as experience and the environment dictate.

In preparation for FY 2016 performance metrics and reporting methods, an integrated master schedule (IMS) concept was investigated and will be exercised during FY 2016 execution. A prototype IMS was done during FY 2015 to support LCMAP execution in FY 2016, plus an initial Center-wide IMS version will be used in FY 2016.

Working toward the year after next (FY 2018) and beyond, the EROS Director issued the 2016-2021 EROS Strategic Plan (fig. 117), which streamlines and integrates much of the planning and prioritization done separately for FY 2016. Much of the work in FY 2016 will be to fully integrate the Strategic Plan's future directions into the FY 2017+ annual planning processes and work management across the Center. For further information, contact USGS EROS, Thomas Kalvelage, kalvelage@usgs.gov.

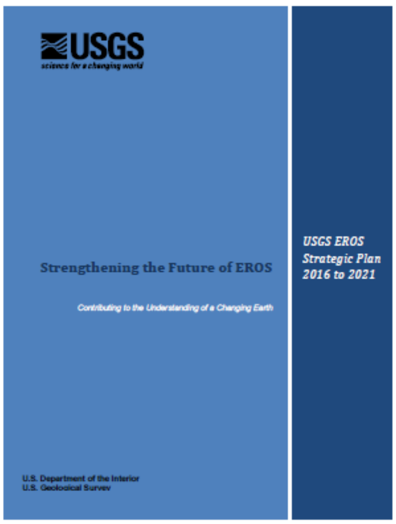


Figure 117. The USGS EROS Strategic Plan, 2016 to 2021, is the basis for annual planning and prioritization processes across the Center.

Technical Support Services Contract Awarded to Stinger Ghaffarian Technologies, Inc.

Scientists and engineers at the USGS EROS Center provide the definitive data and information required to understand and monitor landscape characteristics, natural processes, and land management practices that affect society and the environment. EROS provides informed and unbiased assessments of emerging science and engineering requirements to the land remote sensing and Earth science communities. The EROS staff works to ensure the long-term viability of remotely sensed data as a scientific resource through the renewal and enrichment of the contents and capabilities of the EROS archive. The work performed at EROS to preserve and distribute remotely sensed data and to conduct scientific research and applied science that ensures that these data will contribute to a greater understanding of our changing world.

Since the early 1970s, the USGS EROS Center has been staffed by a small number of Federal employees, who direct the work of the Center, while using support service contracts to carry out the majority of the Center's work. The Technical Support Services Contract (TSSC) encompasses the broad scope of the missions and responsibilities of EROS science, research, remote sensing, and geographic data and information operations projects.

In FY 2015, EROS staff worked with the USGS Office of Acquisition and Grants at headquarters to prepare contract competition documents and review proposals by several companies. The new contract was awarded to Stinger Ghaffarian Technologies, Inc. Performance management of the Center's contractor-related work requirements is a joint effort of the USGS Contracting Officer, the Contracting Officer's Representative, and the Center's management and project teams. Contractor performance criteria are tailored to meet USGS project milestones, deliverables, and performance factors.

The current TSSC contract is a performance-based, indefinite delivery/indefinite quantity, task order contract with a 5-year period of performance and a maximum $300-million contract value. For further information, USGS EROS, Kristi Kline, kkline@usgs.gov.

EROS Architecture Study Team Report

The EROS Director established the EROS Architecture Study Team (EAST) in October 2014 to assess the vision for and the road map to an EROS system and infrastructure architecture best positioned to meet the Center's upcoming strategic challenges: including the Landsat series of missions; land change monitoring, assessment, and projection capabilities; and evolving technology and user needs.

The EAST, made up of USGS EROS, NASA, NOAA, and Aerospace staff, defined high-level concepts, considerations, assumptions, risks and benefits, and alternatives for the future EROS architecture and infrastructure (fig. 118). It considered new technologies and cost efficient approaches, potential international and private sector partnerships, and refined or enhanced capabilities requested by stakeholders and multiple internal and external user communities. The analysis done by EAST members readily verified that without a centralized architectural establishment, the architectural direction would be determined by individual projects, branches, or funding sources. EAST defined the challenge, documented the as-is architecture, identified three alternative architectures, and developed a roadmap to the future architecture.

In July 2015, the EAST recommended EROS move toward an enterprise architecture, which was accepted by the EROS Director and Steering Committee. The EAST Final Report, which is being released as a USGS Open-File Report in FY 2016, provided a high-level concept and roadmap for a systems architecture, required infrastructure, and business processes required to meet these strategic objectives and ensure the Center's future information technology systems operate in as an effective manner as possible. Key recommendations (backed by supporting information) for implementation planning and execution were:

- Develop an enterprise architecture implementation plan based on the provided roadmap;
- Fully develop and implement a Center-wide agile and nimble business model;
- Transition to target architecture in an evolutionary versus revolutionary way; and
- Build upon interagency partnerships established during EAST in implementation.

For further information, contact USGS EROS, Jim Nelson, jnelson@usgs.gov or Kenneth Klinner, kklinner@usgs.gov.

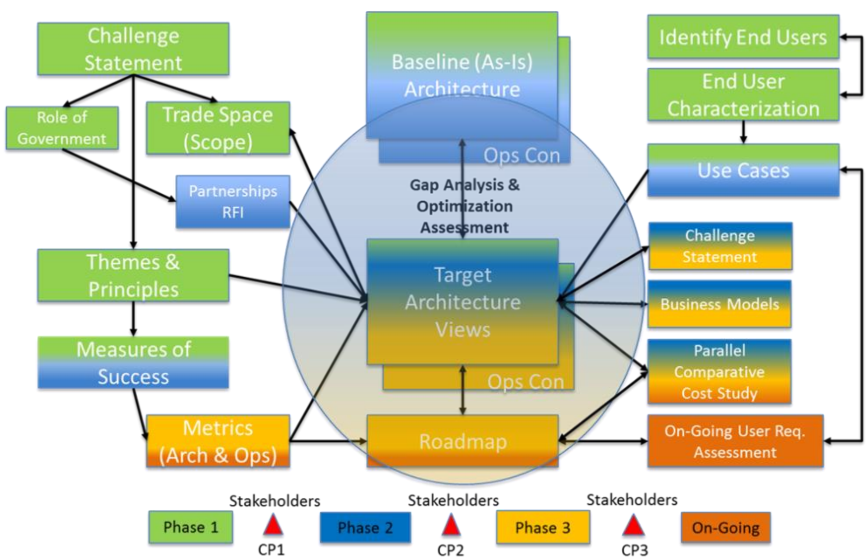


Figure 118. The graphic depicts the process used by the EROS Architecture Study Team to define high-level concepts, considerations, assumptions, risks and benefits, and alternatives for the future EROS architecture and infrastructure.

EROS Identified as a Department of the Interior Core Data Center

The USGS EROS Center was designated by the DOI as one of its core data centers. DOI core data centers are considered to be key facilities that perform essential functions, and provide backbone infrastructure capabilities for the Department. EROS earned this designation due to its high visibility mission-focused projects, its current infrastructure and capabilities, potential for hosting additional services, and proven track record of performance.

Additionally, EROS is taking the lead in the development and implementation of an Information Technology Enterprise Service Management operational strategy. The intent of this strategy is to provide standardized and optimized processes for IT services available across the DOI data centers. DOI identifies three primary benefits of this methodology as listed in figure 119.

In support of the DOI's overall mission, EROS has coordinated its efforts with other agencies within the Department and has performed the following:

- Drafted a preliminary enterprise IT business model (fig. 120);
- Began investigating and selecting IT infrastructure (e.g., network, computer processing, storage, etc.) that will be able to meet the growing needs of the Center and hosted partners;
- Implemented enhanced cyber security functions to protect systems and detect threats;
- Developed a standardized service level catalog that lists and defines IT service offerings and objectives (fig. 121); and
- Developed a base template service level agreement which lists specific tasks, costs, and expectations (fig. 122).

Additionally, EROS has seen an overall increase in hosting of external organizations IT requirements. Some of these include:

- Implementing a secondary site for the USDA Forest Service Remote Sensing Applications Center; and
- Hosting of additional systems for the USGS Office of Enterprise Information.

For further information, contact USGS EROS, Kenneth Klinner, kklinner@usgs.gov, or Clinton Store, cstore@usgs.gov.

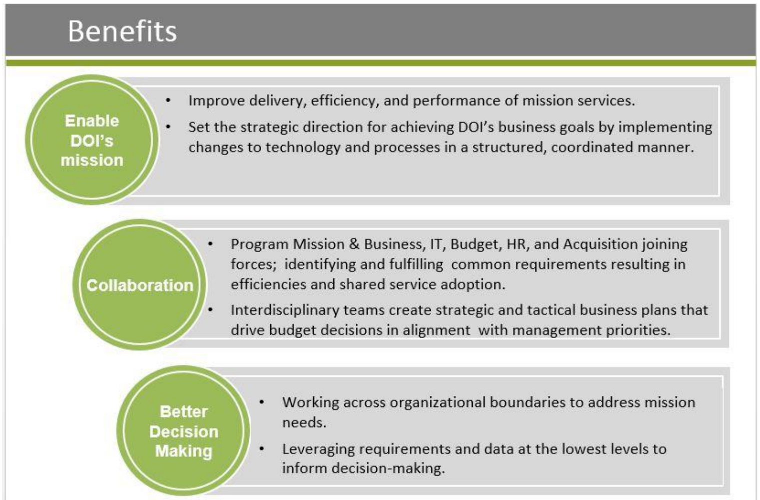


Figure 119. The Department of the Interior's defined benefits.

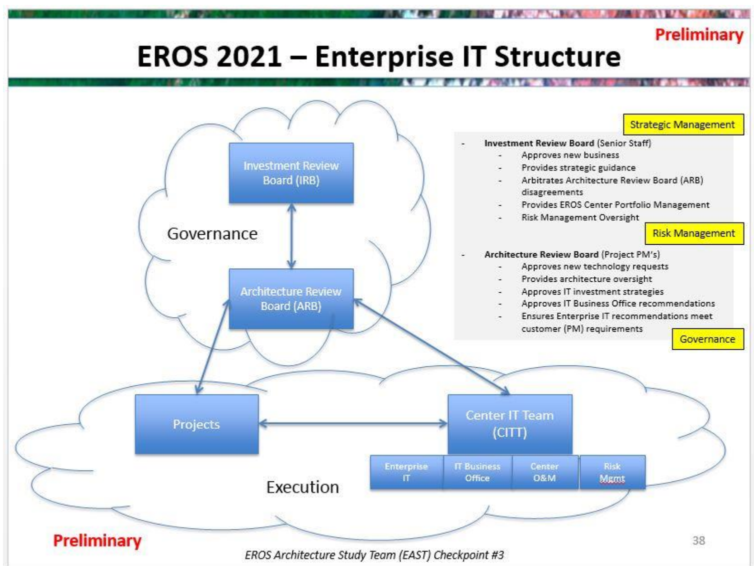
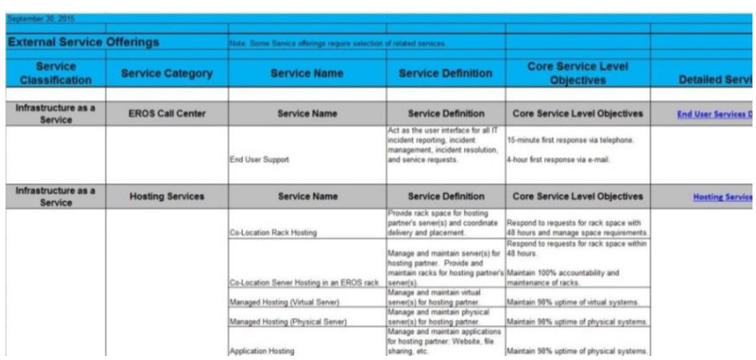


Figure 120. Preliminary enterprise information technology strategy.



September 30, 2015

External Service Offerings — Note: Some Service offerings require selection of related services.

Service Classification	Service Category	Service Name	Service Definition	Core Service Level Objectives	Detailed Servi
Infrastructure as a Service	EROS Call Center	Service Name	Service Definition	Core Service Level Objectives	End User Services D
		End User Support	Act as the user interface for all IT incident reporting, incident management, incident resolution, and service requests.	15-minute first response via telephone. 4-hour first response via e-mail.	
Infrastructure as a Service	Hosting Services	Service Name	Service Definition	Core Service Level Objectives	Hosting Service
		Co-Location Rack Hosting	Provide rack space for hosting partner's server(s) and coordinate delivery and placement.	Respond to requests for rack space with 48 hours and manage space requirements.	
		Co-Location Server Hosting in an EROS rack	Manage and maintain server(s) for hosting partner. Provide and maintain racks for hosting partner's server(s).	Respond to requests for rack space within 48 hours. Maintain 100% accountability and maintenance of racks.	
		Managed Hosting (Virtual Server)	Manage and maintain virtual server(s) for hosting partner.	Maintain 98% uptime of virtual systems.	
		Managed Hosting (Physical Server)	Manage and maintain physical server(s) for hosting partner.	Maintain 98% uptime of physical systems.	
		Application Hosting	Manage and maintain applications for hosting partner: Website, file sharing, etc.	Maintain 98% uptime of physical systems.	

Figure 121. Information technology service catalog.

Tier 2: System Administration	
System Administration (SA) EROS provides System Administration (SA) support as requested. **USGS EROS Responsibility** USGS EROS will provide SA support as requested by the <HOSTING PROJECT> Administrators to access the system. <HOSTING PROJECT> must provide passwords at the time of the event. SA assistance is available during business core hours. **Service Level Objective** • SA configuration begins within two (2) hours of customer notification and receipt of the password within business core hours.	
System Administration (SA) (Tier 2 Services)	**Budgeted Hours**
System Administration (SA) Support	

Tier 2: Media Relocation	
Media Relocation EROS provides media relocation support as requested. **USGS EROS Responsibility** USGS EROS will locate and insert media into systems identified by <HOSTING PROJECT> upon request. <HOSTING PROJECT> will provide a library of media. In the event that the requested media is not available in the library, reasonable accommodations will be made in an attempt to satisfy the requirements. Media relocation support is available during business core hours. **Service Level Objective** • EROS will respond to media requests within four (4) hours of customer notification.	
Media Relocation (Tier 2 Services)	**Budgeted Hours**
Insert media into identified systems (confirm functionality)	
Media Library maintenance	

Figure 122. Base template service level agreement.

Security Enhancements Across the Center

The USGS EROS Center Information Technology Team (CITT) has taken a holistic risk management approach to cyber security through process improvements in incident response; vulnerability management; patch management; continuous diagnostics and monitoring; and reporting. Security awareness initiatives have been expanded through CITT lead role based training; IT interest group meetings; brown bag sessions, and CITT security stories. CITT has partnered with project contract security staff to collaborate and gain efficiencies in compliance requirements and reporting.

Cyber security monitoring has also been enhanced by optimization of existing tools and the introduction of new security tools. An intrusion prevention system software was added to EROS managed firewalls to gain visibility in external attacks and proactively block external attacks against Internet facing EROS servers. A ForeScout Network Access Control (NAC) appliance was added that provides real-time monitoring and compliance enforcement of all devices on the network (fig. 123). These additional tools have added additional visibility into EROS and will continue to enhance our overall security posture.

EROS information security has taken two approaches to enhance the Centers overall security posture. The first is compliance with the USGS National Institute of Standards and Technology 800-53 security controls. Secondly, EROS information security has additionally focused on the adequacy of operational processes, monitoring, response, and reporting. Adequacy ensures that compliance controls are not only met but also defined, managed, and finally optimized following the capability maturity model.

As a result of these efforts, monitoring tools such as the EROS Security Incident Event Management (SIEM) LogRhythm tool has improved dashboards and integration with threat intelligence databases. This allows the security team to quickly review unsuccessful and potentially successful attacks against EROS. Vulnerability and patch management process improvements have contributed in a sharp decline in critical and high vulnerabilities across the Center. Improvement in these capabilities also enhanced the Center's abilities to support and comply with DOI cyber sprint activities after the Office of Personnel Management breach. Automation of these tools have also reduced vulnerability reporting burden by nearly 4 full-time equivalent days per month.

The ForeScout NAC real-time visibility into systems security health has reduced the mean time to discovery and remediation of server, desktop, and laptop security configurations and security software issues. The NAC appliance detects endpoint or device compliance to ensure our laptops, desktops, and servers have the latest security software, patches, and policies enforced. Endpoint security deficiencies that in the past may have taken months to discover are now found in real-time and quickly remediated, greatly enhancing EROS overall security posture.

Security awareness efforts will continue to be a priority at the Center. Over 300 employees participated in one or more of the three role-based security sessions provided at the Center in FY 2015. More than 130 employees attended privileged account training early this summer. Since December 2014, over 20 CITT security stories have been distributed for employee awareness. CITT has received positive and constructive feedback on security awareness initiatives, which have greatly enhanced the security awareness program.

Although there has been great progress in reducing vulnerabilities, finding efficiencies through process improvement, and addition of new tools to enhance monitoring and reporting, there is more to do. It is said, "Security is a journey, not a destination." The CITT security program will continue to be vigilant and agile as new threats emerge through tools, people, process improvements, and compliance. For further information, contact USGS EROS, Philip Egeberg, pegeberg@usgs.gov.

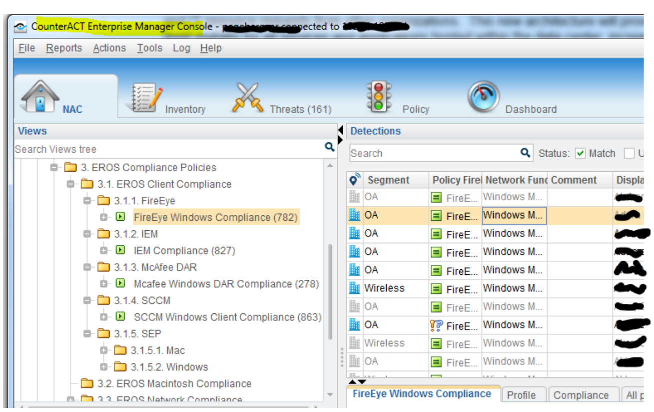


Figure 123. Screenshot of ForeScout Network Access Control appliance compliance capabilities.

Network Infrastructure Changing to Meet Growing Requirements

The Center IT Team is modernizing the EROS network infrastructure to support capabilities such as In-House Applications as a Service (IHAS), Software as a Service (SaaS), Platform as a Service (PaaS), Network as a Service (NaaS), and Infrastructure as a Service (IaaS).

This modernization will converge the management of network and applications services into centralized, configuration platforms to automate provisioning and configuration throughout the EROS data center infrastructure.

Software-defined networking (SDN) was selected by EROS as the approach to designing, building, and managing networks (fig. 124). This approach separates the two networking planes: (1) The Data Plane (Leaf), and the Control Plane (Spine). This configuration keeps traffic flowing along the same data plane until the data is needed at a different plane decreasing unnecessary routing and increasing speed. With SDN, the data applications drive the requirements of the network, making the network infrastructure a business resource. This SDN architecture will provide EROS with the networking infrastructure to support an enterprise capable backbone and pathways for connecting the data centers and future customers of the EROS data enter at speeds of 10 gigabits per second (Gbps) with the ability to upgrade to 40 Gbps without the cost of having to replace chassis.

As one of the USGS core data centers, EROS has already seen an increase in data hosting and IT resource requests from external organizations. The SDN architecture will provide device-level visibility for all services and applications hosted within the data center. It will also increase automated security and network performance metrics and reporting.

SDN is a policy-based solution that will automate deployment and reduce errors resulting in application development that takes one-fourth of the implementation time than what is required currently.

Initial research and a request for information has been completed. A request for quotation is being prepared and will be submitted in FY 2016, quarter 1. Delivery and implementation is expected in FY 2016, quarter 3. For further information, contact USGS EROS, Mia Calla D. Lee, mdlee@usgs.gov.

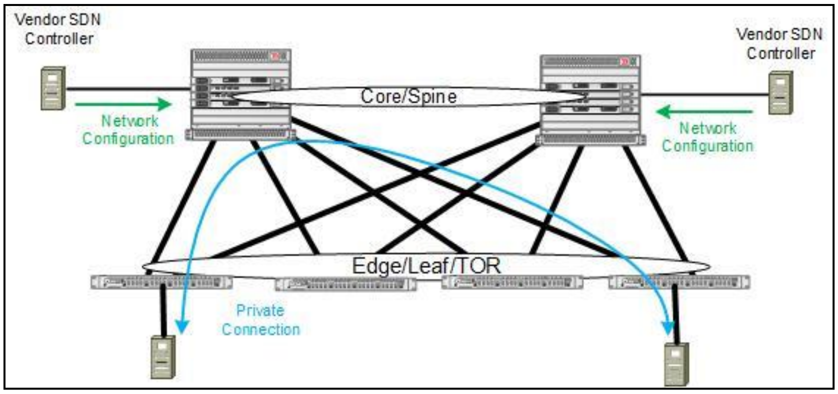


Figure 124. Illustration of software-defined networking selected by EROS as the approach to designing, building, and managing networks.

Center Information Technology Team – End User Services

EROS End User Services (EUS) has been working diligently to improve and proliferate virtualization throughout EROS in both the server and workstation environments. This effort has not been limited to just the Center IT Team, but has been spreading across most of the projects in the Center.

This year EUS presented multiple cost benefit analyses (CBAs) for different virtualization projects, and all were accepted and executed. These resulted in the increases listed in table 3.

Throughout the year we have been adjusting to the increasing demand from the projects at EROS in order to offer as much virtual processing capability as requested. Our virtualization upgrades that were planned for FY 2015 and forecasted for the FY 2016 and FY 2017 budget will replace aging IBM blade servers.

Virtualization in both the server and user workstation areas have also seen a significant improvement in security vulnerability remediation. There has been a noticeable improvement in this area, which can be directly attributed to our efforts in virtualization.

CITT has achieved respectable increases across the board in virtualization and will continue to strive to provide the utmost in this area well into the coming fiscal years. This was due to in part by our avid use of CBAs and will continue to do thorough market research in order to improve our virtualization efforts. For further information, contact USGS EROS, Gene Renschler, nrenschler@usgs.gov.

Table 3. Increase of virtualization usage at EROS.

CITT Managed Servers	63 servers	+ 13 percent
Science Managed Servers	69 servers	+ 25 percent
Virtual Desktop Infrastructure Active Users	62 users	+ 63 percent

Service Management: Making I.T. Happen

The EROS Center IT Team is redefining its current operational strategy in order to better meet the technology demands of today and tomorrow. Management of IT services is a critical foundational framework that brings together all the elements that support overall project goals. Making I.T. work for the project and customer is the #1 goal.

In the past, IT services at EROS have functioned similar to other EROS projects where each individual project or branch functioned on its own "island." CITT managed their own internal IT functions and then "piggy-backed" off of the EROS Center-wide infrastructure for administrative support to meet Internet access, user computing, and backup storage demands. Projects and customers were able to get support for their requirements, but the strategy was not optimized for the overall Center.

EROS is now moving to an enterprise IT model that focuses on customer IT requirements at the core (fig. 125) and then centrally manages the entire process via an enterprise review board. The move to an enterprise IT model is a primary step as part of the EROS Architecture Study Implementation (EASI). The goal of EASI is to standardize and coordinate IT efforts across the Center (fig. 126). EROS has developed the following in support of this effort:

- Drafted a new operational strategy that reviews all IT activities from an enterprise perspective and process changes via a collaborative architecture review board (fig. 127);
- Developed a standardized service level catalog that lists and defines IT service offerings and objectives (fig. 128); and
- Developed a base template service level agreement which lists specific tasks, costs, and expectations.

These actions will result in an overall improvement of IT service management consisting of: ensuring that IT solutions meet or exceed the project and customer requirements, optimizing resource utilization, reducing individual implementation and maintenance costs through cost sharing, improving change management processing time, improving the efficiency and initiation process in hosting services for external organizations, and promoting collaborative efforts and activities awareness across the Center. Additionally, EROS is collaborating with the DOI to implement this service model at the Department level. For further information, contact USGS EROS, Clinton Store, cstore@usgs.gov.

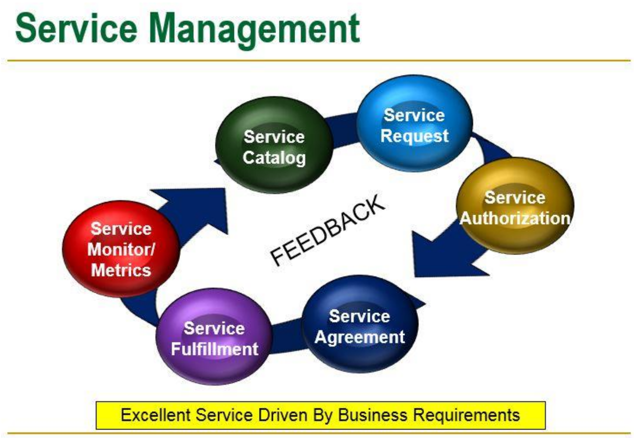


Figure 125. Service management method.

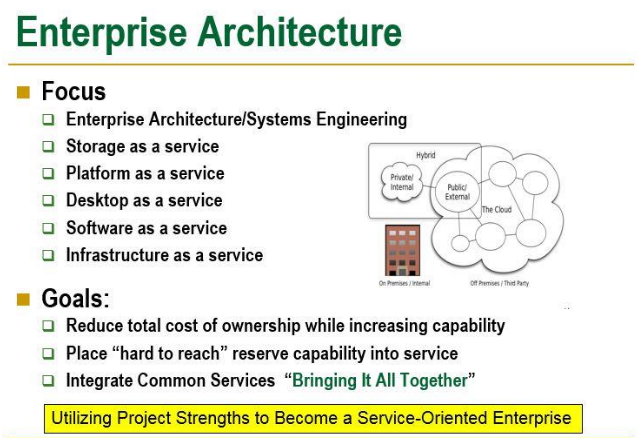


Figure 126. Enterprise architecture strategy.

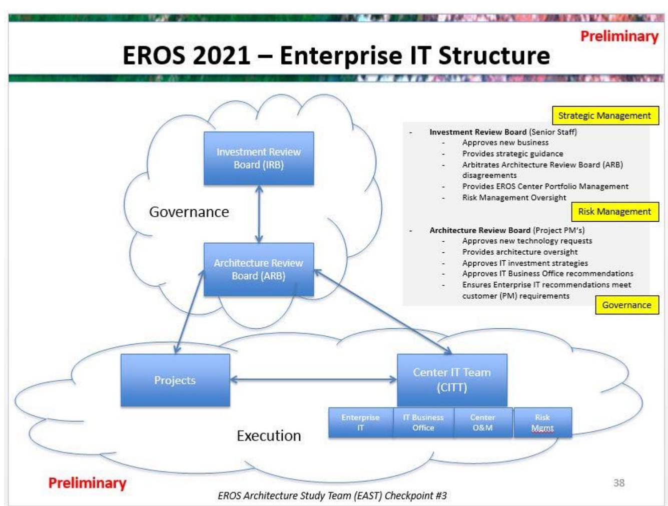


Figure 127. Service management via enterprise architecture review.

September 30, 2015					
External Service Offerings		Note: Some Service offerings require selection of related services.			
Service Classification	**Service Category**	**Service Name**	**Service Definition**	**Core Service Level Objectives**	**Detailed Servi**
Infrastructure as a Service	**EROS Call Center**	**Service Name**	**Service Definition**	**Core Service Level Objectives**	End User Services D
		End User Support	Act as the user interface for all IT incident reporting, incident management, incident resolution, and service requests.	15-minute first response via telephone. 4-hour first response via e-mail.	
Infrastructure as a Service	**Hosting Services**	**Service Name**	**Service Definition**	**Core Service Level Objectives**	Hosting Service
		Co-Location Rack Hosting	Provide rack space for hosting partner's server(s) and coordinate delivery and placement.	Respond to requests for rack space with 48 hours and manage space requirements.	
		Co-Location Server Hosting in an EROS rack	Manage and maintain server(s) for hosting partner. Provide and maintain racks for hosting partner's server(s).	Respond to requests for rack space within 48 hours. Maintain 100% accountability and maintenance of racks.	
		Managed Hosting (Virtual Server)	Manage and maintain virtual server(s) for hosting partner.	Maintain 98% uptime of virtual systems.	
		Managed Hosting (Physical Server)	Manage and maintain physical server(s) for hosting partner.	Maintain 98% uptime of physical systems.	
		Application Hosting	Manage and maintain applications for hosting partner: Website, file sharing, etc.	Maintain 98% uptime of physical systems.	

Figure 128. Service catalog.

Upgrade of the EROS 1973 Heating, Ventilating, and Air Conditioning Systems

The USGS EROS Center, Facilities Team, in partnership with USGS Facilities Management Branch is responsible, among other things, for the operation and maintenance of real property assets. As one of the largest USGS owned facilities, the cost effective management of these assets is critical to the on-going mission of USGS.

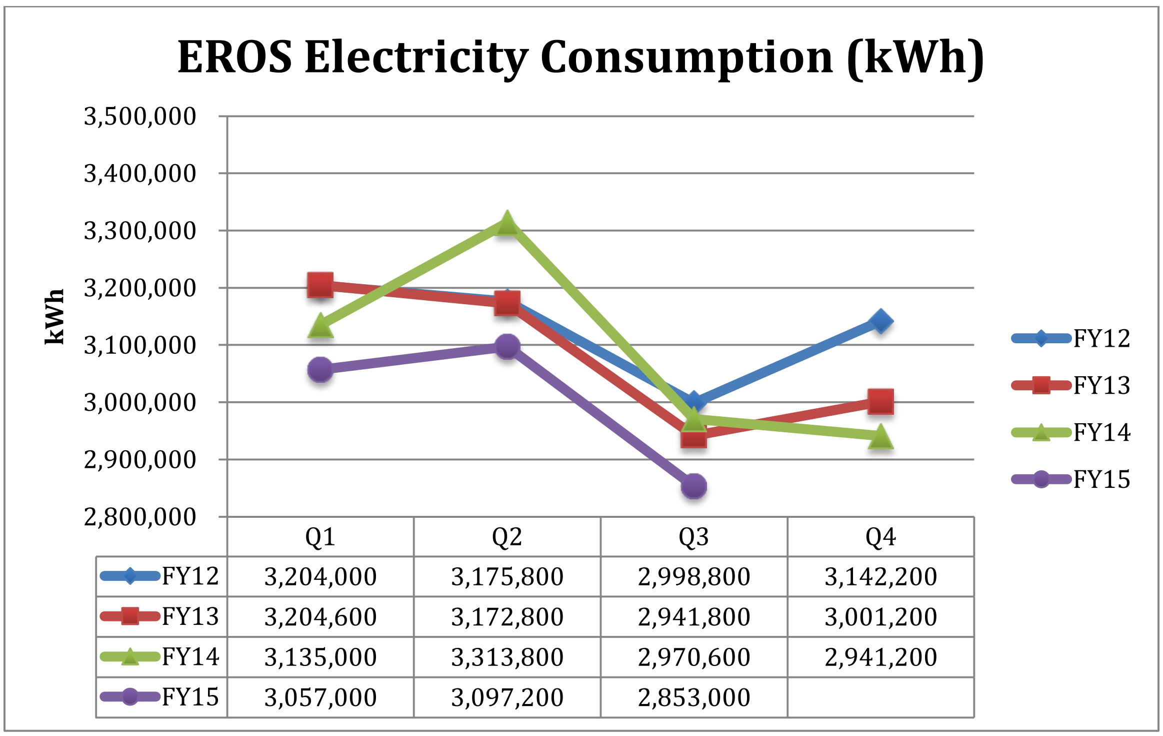
The EROS 1973 Heating, Ventilating, and Air Conditioning (HVAC) systems were identified by a 2005 Facility Condition Assessment as being in need of replacement due to being at end of life. In addition, this HVAC project was determined to be necessary in order to meet energy reduction goals for EROS established by various Energy Policy Acts and Executive Orders. Funding for the project was provided by the Deferred Maintenance and Capital Improvement (DMCI) program through annual USGS appropriations.

In 2011, an Architectural-Engineering firm was selected to design a lifecycle, cost-effective replacement for the HVAC system. Various technologies were evaluated including a geothermal water system. However, due to the low cost of energy, it was determined that a geothermal water system was not cost effective. Instead a design which utilized variable air volume and energy recovery wheels was selected.

A construction contract for approximately $4.4 million was awarded in July 2013. It was the largest DMCI project in the USGS for that fiscal year. Phasing of the work and the movement of personnel into a “swing” space allowed the contractor to continuously perform removal of the old systems and installation of the new systems while keeping the building operational throughout the process.

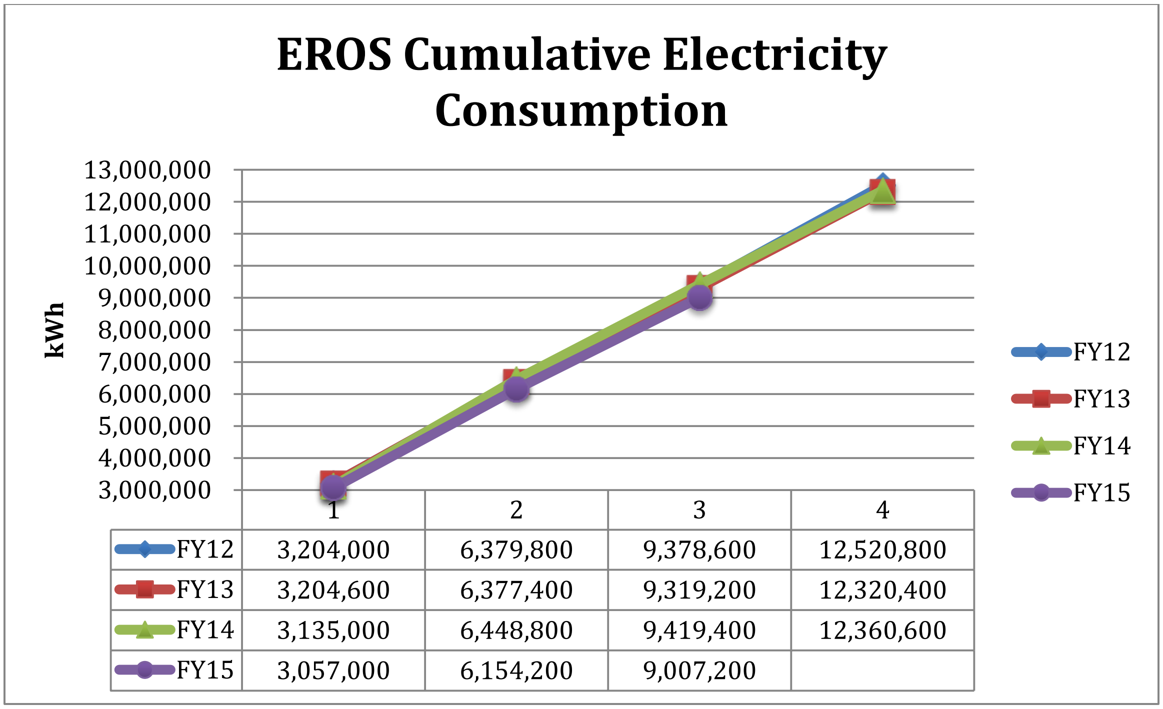
Upgrade of the HVAC systems was able to be completed in July 2015 with less than one percent increase from the original cost. Annual cost savings due to reduction of energy usage and maintenance are projected to be approximately $100,000. This equates to a decrease of eight percent. As a result, EROS will be able to meet established energy reduction goals and contribute to the overall cost-effectiveness and carbon footprint reduction for the entire USGS (figs. 129 and 130).

The USGS EROS Center continues to be a leader not only in the areas of remote sensing, environment modeling, and geographic information systems technologies, but also in the areas of energy reduction and cost effective management of real property assets. For further information, contact USGS EROS, Rodney Paulson, rpaulson@usgs.gov.



	Q1	Q2	Q3	Q4
FY12	3,204,000	3,175,800	2,998,800	3,142,200
FY13	3,204,600	3,172,800	2,941,800	3,001,200
FY14	3,135,000	3,313,800	2,970,600	2,941,200
FY15	3,057,000	3,097,200	2,853,000	

Figure 129. Decrease of electrical consumption from quarter 2 to quarter 3 (approximate completion time of project).



	1	2	3	4
FY12	3,204,000	6,379,800	9,378,600	12,520,800
FY13	3,204,600	6,377,400	9,319,200	12,320,400
FY14	3,135,000	6,448,800	9,419,400	12,360,600
FY15	3,057,000	6,154,200	9,007,200	

Figure 130. Cumulative chart showing consumption levels are lower than previous years.

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 2017-2018 is underway, the accomplishments of 2015 and initiating actions of 2016 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 2015 Research and Technical Publications

Executive Summary of Research and Technical Publications

In FY 2015, **109** scientists, engineers, and information professionals from throughout the USGS EROS Center contributed to the Center's extensive publishing record. The complete record for fiscal year 2015 totaled **157** publications. The metrics provided in the executive summary are a snapshoot in time; therefore, it is likely many of these metrics will increase over time. As of the date of this printing, the FY 2015 record includes:

- **62** journal articles, **8** of which were published in a top-ranking journal as measured by the Thomas Reuters Journal Impact Factor (JIF) (*Agriculture, Ecosystems & Environment, Global Change Biology; Remote Sensing of Environment;* and *Water Resources Research),* and **42** of which were published in or have been accepted for publication in a journal ranked in the first quartile of at least one of the 2013 Thomson Reuters JIF categories. EROS authors published in **35** different journals across **15** JIF disciplinary categories, and collaborated on journal articles with researchers in **16** different countries and **100+** institutions, including universities, federal agencies, research centers, and non-governmental organizations/intergovernmental organizations.
- **16** USGS Series reports/report parts.
- **4** book chapters.
- **74** conference presentations, including **4** invited conference presentations (full papers, abstracts, posters, and slide presentations) at **14** different conferences.
- **1** magazine/newsletter article.

The following **8** bibliographic citations from FY 2015 are provided for those journal articles published in **4** top-ranking journals. Names in bold type are affiliated with EROS. For further information, contact Janice Nelson, USGS EROS, jsnelson@usgs.gov.

Lewis, T.L., Lindberg, M.S., Schmutz, J.A., Heglund, P.J., **Rover, J.A.**, Koch, J.C., and Bertram, M.R., 2015, Pronounced chemical response of subarctic lakes to climate-driven losses in surface area: Global Change Biology, v. 21, no. 3, p. 1140-1152, at http://dx.doi.org/10.1111/gcb.12759.
Global Change Biology is ranked #1 in Biodiversity Conservation.

Midekisa, A., **Senay, G.B.**, and Wimberly, M.C., 2014, Multisensor Earth observations to characterize wetlands and malaria epidemiology in Ethiopia: Water Resources Research, v. 50, no. 11, p. 8791–8806, at http://dx.doi.org/10.1002/2014WR015634.
Water Resources Research is ranked #1 in Limnology.

Pastick, N.J., Jorgenson, M.T., **Wylie, B.K.**, Nield, S.J., Johnson, K.D., and Finley, A.O., 2015, Distribution of near-surface permafrost in Alaska—Estimates of present and future conditions: Remote Sensing of Environment, v. 168, p. 301-315, at http://dx.doi.org/10.1016/j.rse.2015.07.019.
Remote Sensing of Environment is ranked #1 in Imaging Science & Photographic Technology and #1 in Remote Sensing.

Pengra, B.W., Long, J.B., Dahal, D., Stehman, S.V., and **Loveland, T.R.**, 2015, A global reference database from very high resolution commercial satellite data and methodology for application to Landsat derived 30m continuous field tree cover data: Remote Sensing of Environment, v. 165, p. 234–248, at http://dx.doi.org/10.1016/j.rse.2015.01.018.
Remote Sensing of Environment is ranked #1 in Imaging Science & Photographic Technology and #1 in Remote Sensing.

Senay, G.B., Velpuri, N.M., Bohms, S., Demissie, Y., and Gebremichael, M., 2014, Understanding the hydrologic sources and sinks in the Nile Basin using multi-source climate and remote sensing datasets: Water Resources Research, v. 50, no. 11, p. 8625-8650, at http://dx.doi.org/10.1002/2013WR015231.
Water Resources Research is ranked #1 in Limnology.

Tan, Z., and **Liu, S.**, 2015, Corn Belt soil carbon and macronutrient budgets with projected sustainable stover harvest: Agriculture, Ecosystems & Environment, v. 212, p. 119-126, at http://dx.doi.org/10.1016/j.agee.2015.06.022.
Agriculture, Ecosystems & Environment is ranked #1 in Agriculture, Multidisciplinary.

Verdin, A., Rajagopalan, B., Kleiber, W., and **Funk, C.C.**, 2015, A Bayesian kriging approach for blending satellite and ground precipitation observations: Water Resources Research, v. 51, no. 2, p. 908–921, at http://dx.doi.org/10.1002/2014WR015963.
Water Resources Research is ranked #1 in Limnology.

Xian, G., Homer, C.G., Rigge, M.B., Shi, H., and **Meyer, D.K.**, 2015, Characterization of shrubland ecosystem components as continuous fields in the northwest United States: Remote Sensing of Environment, v. 168, p. 286-300, at http://dx.doi.org/10.1016/j.rse.2015.07.014.
Remote Sensing of Environment is ranked #1 in Imaging Science & Photographic Technology and #1 in Remote Sensing.

Significant Attention on the Web.

Publications receiving notable attention on the Web in science news, professional networking, mass media, and social media venues, and at the publication Web site include:

Grace, K., Davenport, F., Hanson, H., **Funk, C.C.**, and Shukla, S., 2015, Linking climate change and health outcome—Examining the relationship between temperature, precipitation and birth weight in Africa: Global Environmental Change, v. 35, p. 125-137, at http://dx.doi.org/10.1016/j.gloenvcha.2015.06.010.

- Among the highest-scoring outputs from *Global Environmental Change Part A: Human & Policy Dimensions* (#18 of 629) tracked by Altmetric.
- In the top 5 percent of all research outputs scored by Altmetric.
- Altmetric has registered mentions by 4 news outlets, 2 blogs, and 1 Facebook page, and 6 tweets by individuals in North America, Europe, and Asia.
- Highlighted in ScienceDaily and EurekAlert!.

Heidemann, H.K., 2014, Lidar base specification (ver. 1.2, November 2014): U.S. Geological Survey Techniques and Methods book 11, chap. B4, 67 p., with appendixes, at http://dx.doi.org/10.3133/tm11B4.

- Highlighted by the USGS Newsroom and *Earth Imaging Journal*.

Homer, C.G., Xian, G., Aldridge, C.L., **Meyer, D.K., Loveland, T.R.**, and O'Donnell, M.S., 2015, Forecasting sagebrush ecosystem components and greater sage-grouse habitat for 2050—Learning from past climate patterns and Landsat imagery to predict the future: Ecological Indicators, v. 55, p. 131-145, at http://dx.doi.org/10.1016/j.ecolind.2015.03.002.

- Among the highest-scoring outputs from *Ecological Indicators* (#15 of 466) tracked by Altmetric.
- It is also in the top 5 percent of all research outputs scored by Altmetric.
- Highlighted by the USGS Newsroom and *Earth Imaging Journal*.

Lewis, T.L., Lindberg, M.S., Schmutz, J.A., Heglund, P.J., **Rover, J.A.**, Koch, J.C., and Bertram, M.R., 2015, Pronounced chemical response of subarctic lakes to climate-driven losses in surface area: Global Change Biology, v. 21, no. 3, p. 1140-1152, at http://dx.doi.org/10.1111/gcb.12759.

- 87 Reads on ResearchGate.
- Highlighted in *Nature Climate Change*.

Pastick, N.J., Jorgenson, M.T., **Wylie, B.K.**, Nield, S.J., Johnson, K.D., and Finley, A.O., 2015, Distribution of near-surface permafrost in Alaska—Estimates of present and future conditions: Remote Sensing of Environment, v. 168, p. 301-315, at http://dx.doi.org/10.1016/j.rse.2015.07.019.

- In the top 5% of all research outputs scored by Altmetric.
- Among the highest-scoring outputs from *Remote Sensing of Environment* (#1 of 517) tracked by Altmetric.
- High score compared to outputs of the same age (98th percentile) as tracked by Altmetric.

- Altmetric has registered mentions by 11 news outlets, 5 blogs, and 1 Google+ user, and 7 tweets by individuals across North America and Europe.
- Highlighted by the USGS Newsroom and in many other online venues, including Alaska Native News, Climate Central, Earth Imaging Journal, Environmental News Network, EurekAlert!, Eye on the Arctic, The Guardian, National Geographic News, ScienceDaily, Scientific American, and Technology.org.

Rose, R.A., Byler, D., Eastman, J.R., Fleishman, E., Geller, G., Goetz, S., Guild, L., Hamilton, H., Hansen, M., Headley, R., Hewson, J., Horning, N., Kaplin, B.A., Laporte, N., Leidner, A., Leimgruber, P., Morisette, J., Musinsky, J., Pintea, L., Prados, A., Radeloff, V.C., Rowen, M., Saatchi, S., Schill, S., Tabor, K., Turner, W., Vodacek, A., **Vogelmann, J.E.**, Wegmann, M., Wilkie, D., and Wilson, C., 2015, Ten ways remote sensing can contribute to conservation: Conservation Biology, v. 29, no. 2, p. 350-359, at http://dx.doi.org/10.1111/cobi.12397.

- Among the highest-scoring outputs from *Conservation Biology* (#13 of 1,474) tracked by Altmetric.
- In the top 5 percent of all research outputs scored by Altmetric.
- Altmetric has registered mentions by 8 news outlets, 1 blog, and 7 Facebook pages, and 70 tweets by individuals in North America, Europe, Asia, Africa, and Australia.
- 140 readers on Mendeley.
- 177 Reads on ResearchGate.

Sadinski, W.J., Roth, M.F., Hayes, T., Jones, P., and **Gallant, A.L.**, 2014, Indicators of the statuses of amphibian populations and their potential for exposure to atrazine in four midwestern U.S. conservation areas: PLoS ONE, v. 9, no. 9, p. 1-21, at http://dx.doi.org/10.1371/journal.pone.0107018.

- Earned a score in the 93rd percentile of all *PLoS ONE* articles of the same age tracked by Altmetric.
- In the top 5 percent of all research outputs scored by Altmetric.
- Altmetric has registered mentions by 2 news outlets and 1 blog, and 29 tweets by individuals in North America and Asia.
- 2,885 full-text downloads/views and 74 shares recorded by the journal Web site.

Shukla, S., Safeeq, M., Aghakouchak, A., Guan, K., and **Funk, C.C.**, 2015, Temperature impacts on the water year 2014 drought in California: Geophysical Research Letters, v. 42, no. 11, p. 4384-4393, at http://dx.doi.org/10.1002/2015GL063666.

- Earned a score in the 93rd percentile of all *Geophysical Research Letters* articles of the same age tracked by Altmetric.
- In the top 5 percent of all research outputs scored by Altmetric.

- Altmetric has registered mentions by 6 news outlets, 4 blogs, 1 Facebook page, and 1 Google+ user, and 36 tweets by individuals in North America, South America, Europe, and Australia.
- 76 Reads on ResearchGate.

Sohl, T.L., 2014, The relative impacts of climate and land-use change on conterminous United States bird species from 2001 to 2075: PLoS ONE, v. 9, no. 11, article number e112251, at http://dx.doi.org/10.1371/journal.pone.0112251.

- Earned a score in the 96th percentile of all *PLoS ONE* articles of the same age tracked by Altmetric
- In the top 5 percent of all research outputs scored by Altmetric.
- Altmetric has registered mentions by 11 news outlets and 6 Facebook pages, and 14 tweets by individuals in North America, Europe, and Asia.
- 59 Reads on ResearchGate.
- 4,390 downloads/full-text views and 30 saves recorded by the journal Web site.
- Highlighted in *Popular Science* with a brief article and infographic.

Tan, Z., Liu, S., Sohl, T.L., Wu, Y., and **Young, C.J.**, 2015, Ecosystem carbon stocks and sequestration potential of federal lands across the conterminous United States: Proceedings of the National Academy of Sciences of the United States of America, v. 112, no. 41, p. 12723-12728, at http://dx.doi.org/10.1073/pnas.1512542112.

- Earned a score in the 95th percentile compared to outputs of the same age tracked by Altmetric.
- In the top 5 percent of all research outputs scored by Altmetric.
- Altmetric has registered mentions in 3 blogs and 10 tweets by individuals in North America.
- 467 full-text downloads recorded by the journal Web site.
- Highlighted in Climate Central and The Equation.

Other Publications with More than 100 Downloads/Views.

Bastiaanssen, W.G.M., Karimi, P., Rebelo, L.-M., Duan, Z., **Senay, G.B.**, Muttuwatte, L., and Smakhtin, V., 2014, Earth observation based assessment of the water production and water consumption of Nile Basin agro-ecosystems: Remote Sensing, v. 6, no. 11, p. 10306-10334, at http://dx.doi.org/10.3390/rs61110306. *Downloaded/full-text viewed 1494 times from the journal Web site (17 Nov 2015).*

Funk, C.C., Verdin, A., Michaelsen, J., Peterson, P., **Pedreros, D.H.**, and Husak, G., 2015, A global satellite-assisted precipitation climatology: Earth System Science Data, v. 7, no. 2, p. 275-287, at http://dx.doi.org/10.5194/essd-7-275-2015. *Downloaded/full-text viewed 162 times from the journal Web site (17 Nov 2015).*

Gallant, A.L., 2015, The challenges of remote monitoring of wetlands: Remote Sensing, v. 7, no. 8, p. 10938-10950, at http://dx.doi.org/10.3390/rs70810938.
Downloaded/full-text viewed 601 times from the journal Web site (17 Nov 2015).

Giri, C.P., and **Long, J.B.**, 2014, Land cover characterization and mapping of South America for the year 2010 using Landsat 30m satellite data: Remote Sensing, v. 6, no. 10, p. 9494-9510, at http://dx.doi.org/10.3390/rs6109494.
Downloaded/full-text viewed 1840 times from the journal Web site (17 Nov 2015).

Gu, Y., and **Wylie, B.K.**, 2015, Downscaling 250-m MODIS growing season NDVI based on multiple-date Landsat images and data mining approaches: Remote Sensing, v. 7, no. 4, p. 3489-3506, at http://dx.doi.org/10.3390/rs70403489.
Downloaded/full-text viewed 801 times from the journal Web site (17 Nov 2015).

Ji, L., Wylie, B.K., Nossov, D.R., **Peterson, B.E.**, Alexander, H.D., Mack, M.C., **Rover, J.A.**, Waldrop, M.P., McFarland, J.W., Chen, X., and **Pastick, N.J.**, 2015, Spatially explicit estimation of aboveground boreal forest biomass in the Yukon River Basin, Alaska: International Journal of Remote Sensing, v. 36, no. 4, p. 939-953, at http://dx.doi.org/10.1080/01431161.2015.1004764.
Downloaded/full-text viewed 167 times from the journal Web site (17 Nov 2015).

Mishra, N., **Haque, M.O.**, Leigh, L., Aaron, D.B., Helder, D.L., and Markham, B.L., 2014, Radiometric cross calibration of Landsat 8 Operational Land Imager (OLI) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+): Remote Sensing, v. 6, no. 12, p. 12619-12638, at http://dx.doi.org/10.3390/rs61212619.
Downloaded/full-text viewed 2608 times from the journal Web site (17 Nov 2015).

Morfitt, R.A., Barsi, J.A., Levy, R., Markham, B.L., **Micijevic, E.**, Ong, L., **Scaramuzza, P.L.**, and **Vanderwerff, K.**, 2015, Landsat-8 Operational Land Imager (OLI) radiometric performance on-orbit: Remote Sensing, v. 7, no. 2, p. 2208-2237, at http://dx.doi.org/10.3390/rs70202208.
Downloaded/full-text viewed 1024 times from the journal Web site (17 Nov 2015).

Peterson, B.E., and **Nelson, K.J.**, 2014, Mapping forest height in Alaska using GLAS, Landsat composites, and airborne LiDAR: Remote Sensing, v. 6, no. 12, p. 12409-12426, at http://dx.doi.org/10.3390/rs61212409.
Downloaded/full-text viewed 938 times from the journal Web site (17 Nov 2015).

Peterson, B.E., Nelson, K.J., Seielstad, C., **Stoker, J.M.**, Jolly, W.M., and Parsons, R., 2015, Automated integration of lidar into the LANDFIRE product suite: Remote Sensing Letters, v. 6, no. 3, p. 247-256, at http://dx.doi.org/10.1080/2150704X.2015.1029086.
Downloaded/full-text viewed 104 times from the journal Web site (17 Nov 2015).

Poppenga, S.K., and **Worstell, B.B.**, 2015, Evaluation of airborne lidar elevation surfaces for propagation of coastal inundation—The importance of hydrologic

connectivity: Remote Sensing, Special Issue on Remote Sensing in Flood Monitoring and Management, v. 7, no. 9, p. 11695-11711, at http://dx.doi.org/10.3390/rs70911695.
Downloaded/full-text viewed 380 times from the journal Web site (17 Nov 2015).

Shukla, S., **Funk, C.C.**, and Hoell, A., 2014, Using constructed analogs to improve the skill of National Multi-Model Ensemble March-April-May precipitation forecasts in equatorial East Africa: Environmental Research Letters, v. 9, no. 9, at http://dx.doi.org/10.1088/1748-9326/9/9/094009.
Downloaded/full-text viewed 613 times from the journal Web site (17 Nov 2015).

Shukla, S., McNally, A., Husak, G., and **Funk, C.C.**, 2014, A seasonal agricultural drought forecast system for food-insecure regions of East Africa: Hydrology and Earth System Sciences, v. 18, no. 10, p. 3907-3921, at http://dx.doi.org/10.5194/hess-18-3907-2014.
Downloaded/full-text viewed 928 times from the journal Web site (17 Nov 2015).

Singh, R.K., Senay, G.B., Velpuri, N.M., Bohms, S., and **Verdin, J.P.**, 2014, On the downscaling of actual evapotranspiration maps based on combination of MODIS and Landsat-based actual evapotranspiration estimates: Remote Sensing, v. 6, no. 11, p. 10483-10509, at http://dx.doi.org/10.3390/rs61110483.
Downloaded/full-text viewed 1281 times from the journal Web site (17 Nov 2015).

Storey, J.C., Choate, M.J., and Lee, K., 2014, Landsat 8 Operational Land Imager on-orbit geometric calibration and performance: Remote Sensing, v. 6, no. 11, p. 11127-11152, at http://dx.doi.org/10.3390/rs61111127.
Downloaded/full-text viewed 1503 times from the journal Web site (17 Nov 2015).

Storey, J.C., Choate, M.J., and **Moe, D.**, 2014, Landsat 8 thermal infrared sensor geometric characterization and calibration: Remote Sensing, v. 6, no. 11, p. 11153-11181, at http://dx.doi.org/10.3390/rs61111153.
Downloaded/full-text viewed 1082 times from the journal Web site (17 Nov 2015).

Toté, C., Patricio, D., Boogaard, H., van der Wijngaart, R., Tarnavsky, E., and **Funk, C.C.**, 2015, Evaluation of satellite rainfall estimates for drought and flood monitoring in Mozambique: Remote Sensing, v. 7, no. 2, p. 1758-1776, at http://dx.doi.org/10.3390/rs70201758.
Downloaded/full-text viewed 1121 times from the journal Web site (17 Nov 2015).

Wu, Y., Liu, S., Young, C.J., Dahal, D., Sohl, T.L., and **Davis, B.N.**, 2015, Projection of corn production and stover-harvesting impacts on soil organic carbon dynamics in the U.S. temperate prairies: Scientific Reports, v. 5, article number 10830, at http://dx.doi.org/10.1038/srep10830.
Downloaded/full-text viewed 472 times from the journal Web site (17 Nov 2015).

Invited Conference Presentations.

These four abstracts were invited by American Geophysical Union annual meeting session conveners:

Bawden, G., **Jones, B.K.**, and **Lamb, R.M.**, 2014, Using satellite imagery from the International Charter to support disaster response management (Invited) [abs.], *in* Fall Meeting, San Francisco, Calif., 15-19 December 2014, Fall Meeting Abstracts: Washington, D.C., American Geophysical Union, abstract number NH14A-08, at http://abstractsearch.agu.org/meetings/2014/FM/NH14A-08.html.

Funk, C.C., Peterson, P., Shukla, S., Husak, G.J., Landsfeld, M.F., Hoell, A., **Pedreros, D.H.**, Roberts, J.B., Robertson, F.R., Tadesse, T., Zaitchik, B.F., **Rowland, J.D.**, and **Verdin, J.P.**, 2014, Improved rainfall estimates and predictions for 21st century drought early warning (Invited) [abs.], *in* Fall Meeting, San Francisco, Calif., 15-19 December 2014, Fall Meeting Abstracts: Washington, D.C., American Geophysical Union, abstract number GC31D-05, at http://abstractsearch.agu.org/meetings/2014/FM/GC31D-05.html.

Harriman, L.M., 2014, Climate change implications and use of early warning systems for global dust storms (Invited) [abs.], *in* Fall Meeting, San Francisco, Calif., 15-19 December 2014, Fall Meeting Abstracts: Washington, D.C., American Geophysical Union, abstract number GC31D-08, at http://abstractsearch.agu.org/meetings/2014/FM/GC31D-08.html.

Minsley, B.J., Ball, L.B., Bloss, B.R., Kass, A., **Pastick, N.J.**, Smith, B.D., Voss, C.I., Walsh, D.O., Walvoord, M.A., and **Wylie, B.K.**, 2014, Mapping permafrost with airborne electromagnetics (Invited) [abs.], *in* Fall Meeting, San Francisco, Calif., 15-19 December 2014, Fall Meeting Abstracts: Washington, D.C., American Geophysical Union, abstract number NS34A-01, at http://abstractsearch.agu.org/meetings/2014/FM/NS34A-01.html.

Complete Record of Research and Technical Publications

The work cited is the Center's complete record of work published in FY 2015. Names in bold type are affiliated with EROS. Online addresses are provided, where available. If a problem or an error is experienced while attempting to access an address, copy and paste the address into your web browser for access. For further information, contact USGS EROS, Janice Nelson, jsnelson@usgs.gov. As of the date of this printing, the FY 2015 record includes:

Journal Articles

In Press/Accepted.

Huang, S., Liu, H., **Dahal, D., Jin, S.**, Li, S., and **Liu, S.**, in press, Spatial variations in immediate greenhouse gases and aerosol emissions and resulting radiative forcing from wildfires in interior Alaska: Theoretical and Applied Climatology, p. 0-0, at http://dx.doi.org/10.1007/s00704-015-1379-0.

Moody, J.A., Ebel, B.A., Nyman, P., Martin, D.A., Stoof, C., and **McKinley, R.A.**, in press, Relations between soil hydraulic properties and burn severity: International Journal of Wildland Fire, p. 0-0, at http://dx.doi.org/10.1071/wf14062.

Palaseanu-Lovejoy, M., **Danielson, J.J.**, Thatcher, C.A., Foxgrover, A., Barnard, P., Brock, J.C., and Young, A., in press, Automatic delineation of sea-cliff limits using lidar-derived high-resolution DEMs in southern California: Journal of Coastal Research, Special Issue on the Advances in Topobathymetric Mapping, Models, and Applications, p. 0-0.

Poppenga, S.K., and **Worstell, B.B.**, in press, Hydrologic connectivity—Quantitative assessments of hydrologic-enforced drainage structures in an elevation model: Journal of Coastal Research, Special Issue on the Advances in Topobathymetric Mapping, Models, and Applications, p. 0-0.

Soulard, C.E., **Acevedo, W.**, Stehman, S.V., and Parker, O.P., in press, Mapping extent and change in surface mines within the United States for 2001 to 2006: Land Degradation and Development, p. 0-0, at http://dx.doi.org/10.1002/ldr.2412.

Published.

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