U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center – Fiscal Year 2013 Accomplishment Report

Compiled by Becky A. Foster

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CONTENTS

ACRONYMS **5**

INTRODUCTION **10**

FISCAL YEAR 2013 IN REVIEW **10**

Science and Applications Activities **10**

Fire Science 11

The LANDFIRE Program Maintains Timeliness of LANDFIRE National Vegetation and Fuel Datasets by Evolving National Disturbance Mapping Processes – LANDFIRE Updating 2010 11
Remote Sensing Support for DOI Burned Area Emergency Response Teams 13
Monitoring Trends in Burn Severity Fire Assessments Approach 17,000 15
Enhanced Wildland Fire Management Decision Support Using Lidar-Infused LANDFIRE Data 16
Forecasting Large Wild Fires 18

Land Characterization and Trends 20

National Land Cover Database 2011: Designed and in Production 20
North American Land Change Monitoring System: New Land Cover Change Product for North America for 2005-2010 21
Historical Land Cover "Backcasts" for the Great Plains: 1938-1992 23
Land Cover Projections for Four Intergovernmental Panel on Climate Change Scenarios for the Conterminous United States: 1992-2100 24
USGS Science Helps Disseminate Multi-Scale U.S. Land Use Land Cover Change Knowledge 26

Landscape Dynamics and Global Change 32

Characterizing the Environmental Conditions and Estimating Aboveground Biomass Productivity for Switchgrass in the Great Plains 33
Data Driven Carbon Flux 34
How Fire Affects Cheatgrass Performance in the Northern Great Basin 36
Grassland Condition and Carbon Fluxes 37
How Much Corn Stover Can Be Used Sustainably for Biofuel Production in the Conterminous United States? 39
Fire Impacts on Vegetation Photosynthesis in Alaska 41
Assessment on Potentials for Carbon Sequestration and Greenhouse Gas Emissions Reduction in the Eastern United States 42
Investigating Changes in Surface Water Availability and Their Impact on Ecosystems 45

Topographic Science, Elevation, and Lidar 47

New Million-Scale Datasets from the National Atlas of the United States® 47
The National Elevation Dataset: Continued Growth and Development in Support of Scientific and Mapping Applications 51
Coastal National Elevation Database: San Francisco Bay, California 52

Early Warning, Environmental Monitoring, and Hazards Management 54

West African Successes in Land Management: Time-Series Imagery for Discovery and Analysis of Sustainable Practices in Agroforestry, Soil Conservation, and Sustainable Agriculture 54
Connecting Local Changes to Global Audiences through Environmental Hotspots 58
Hydropower Assessment of Peru Using Shuttle Radar Topography Mission 1 Arc-Second Digital Elevation Model 60
Modeling and Mapping Irrigated Areas in Afghanistan Using Remote Sensing 63

Exceptionally Warm Sea Surface Temperatures, Hydrologic Forecasts, and Humanitarian Earth Science 66
Assessment of Regional Increase in Irrigated Agriculture Across the High Plains Aquifer 72
Landsat-Scale Evapotranspiration for the Apalachicola-Chattahoochee-Flint and Delaware River Basins 74
Development of a Data Center for the Afghanistan Geological Survey 76

Remote Sensing Activities 78

Landsat Program 78

Remarkable, Record-Setting Satellite 78
Landsat 8 Operations 79
Climate Data Records and Essential Climate Variables 80

New Missions 84

Landsat Data Continuity Mission Development Project 84
The National Land Imaging Requirements Project: An Innovative Approach to Documenting User Requirements 92
Landsat Science Team: Advancing Landsat Science and Applications 93

Data Management and Distribution 96

Lidar Transition to EarthExplorer 97
Earth Observing-1, Satellite Pour l'Observation de la Terre Level-1 Terrain-Corrected Processing. 98
National Agriculture Imagery Program Data Distribution 99
Landsat 8 Released to EarthExplorer 100
Hazards Data Distribution System Explorer Release 103
eMODIS Product Expansion 105
Leverage NASA Earth Science Data for Socio-Economic Applications 106
Land Processes Distributed Active Archive Center – Reaching Applied Users Efficiently, Effectively, and Collaboratively 108
Community-Wide Standards Improve Lidar Quality 108
USGS Continues Demonstrating Leadership in Data Characterization 111
Release of Compressed Product for *The National Map* 113
Release of New Image Collection on Land Remote Sensing Program Website 114
Consolidated Archive and Distribution Data Report: A Monthly "Consolidated Report" for All Data Managed and Distributed at EROS 116

Coordination and Collaboration 123

Emergency Operations Supports Hurricane Sandy Impact Areas 123
Emergency Operations Support is on Fire 126
International Charter Fosters New Access Opportunities 128

Center Support Activities 130

Communicating EROS Science to the World 130
Data Center Consolidation: EROS Designation as a Core Site for USGS 132

CONCLUSION 132

APPENDIX A. FY 2013 RESEARCH AND TECHNICAL PUBLICATIONS 134

Executive Summary of Research and Technical Publications 134

Complete Record of Research and Technical Publications 139

Journal Articles 139
Book Chapters 149
USGS Series Reports 150
Other Agency Reports 155
Conference Papers 155
Conference Abstracts and Posters 155
Magazine and Newsletter Articles 161
Guest Editor Forewords/Prefaces to Journal Issues 161

Acronyms

3D	Three Dimensional
3DEP	3D Elevation Program
AAAI	Association for the Advancement of Artificial Intelligence
ACF	Apalachicola-Chattahoochee-Flint
AHAP	Alaska High Altitude Aerial Photography
AGCM	Atmospheric General Circulation Model
AGRHYMET	Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center
AGS	Afghanistan Geological Survey
ALI	Advanced Land Imaging
API	Application Program Interface
ASAS	Advanced Solid State Array Spectrometer
ASI	Italian Space Agency: *Agenzia Spaziale Italiana*
ASPRS	American Society for Photogrammetry and Remote Sensing
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AWiFS	Advanced Wide Field Sensors
BAER	Burned Area Emergency Response
BIA	Bureau of Indian Affairs
BIL	Band Interleaved by Line
C	Carbon
°C	Degree Celsius
CasRT	CasaNOSA Analysis Tool. A NOAA-developed desktop sofware tool that retrieves and matches observing requirements and capabilities.
CO	Carbon Monoxide
CO_2	Carbon Dioxide
C&O	Communications and Outreach
CAF	Corporación Andina de Fomento
CAP	Civil Air Patrol
CBH	Canopy Base Height
CC	Canopy Cover
CDR	Climate Data Record
CEC	Commission for Environmental Cooperation
CEOS	Committee on Earth Observation Satellites
CH	Canopy Height
CH_4	Methane
CHIRPS	Climate Hazard group Infrared Precipitation with Stations
CHISLIC	Creating Hybrid Structure from LANDFIRE/lidar Combinations
CLICK	Center for Lidar Information Coordination and Knowledge
CLU	Climate and Land Use Change (CLU) Mission Area
cm	Centimeter
CMGP	Coastal Maine and Geology Program
CONABIO	Mexican National Commission for the Knowledge and Use of Biodiversity
CONAFOR	Mexican National Forestry Commission

CoNED	Coastal National Elevation Database
CONUS	Conterminous United States
CORL	Consolidated Observing Requirement List
COSMO	COnstellation of small Satellites for the Mediterranean basin Observation
CSA	Canadian Space Agency
CSV	Comma Separated Value. File format used to exchange data between disparate applications.
DEM	Digital Elevation Model
DLG	Digital Line Graph
DLR	National aeronautics and space research centre – Germany
DMC	Disaster Monitoring Constellation
DMCii	DMC International Imaging
dNBR	differenced Normalized Burned Ratio
DOI	Department of the Interior
DOQQ	Digital Orthophoto Quarter Quadrangles
DOT	Department of Transportation
DRG	Digital Raster Graphics
DTED	Digital Terrain Elevation Data
ECHO	EOS Clearing House
ECV	Essential Climate Variables
EE	EarthExplorer
eMODIS	EROS MODIS
ENSO	El Niño Southern Oscillation
EO	Earth Observation
EO-1	Earth Observing-1
EORES	Earth Observation Requirements Evaluation System
EOS	Earth Observing System
EPA	Ecosystem Performance Anomaly
EROS	Earth Resources Observation and Science (EROS) Center
ESA	Ecological Society of America
ESPA	EROS Science Processing Architecture
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FAQ	Frequently Asked Question
FCT	Fundação para a Ciência e Tecnologia. National funding agency for science and research in Portugal.
FEWS	Famine Early Warning Systems
FEWS NET	FEWS Network
FGDC	Federal Geographic Data Committee
FLDAS	FEWS NET Land Data Assimilation System
FORE-SCE	FOREcasting SCEnarios of land use change (FORE-SCE) model
FWS	U.S. Fish and Wildlife Service
FY	Fiscal Year
GEMS	General Ensemble biogeochemical Modeling System
GEO	Group on Earth Observation

GeoTIFF	Georeferenced Tagged Image File Format
GHG	Greenhouse Gas
GIS	Geographic Information System
GloVis	Global Visualization Viewer
GLS	Global Land Survey
GPP	Gross Primary Production
GRID	Global Resource Information Database
GRT	Ground Readiness Test
GSFC	Goddard Space Flight Center
GSN	Growing Season integrated NDVI
GTOPO30	Global 30 Arc-Second Elevation. GTOPO30 is a global DEM with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer).
GUI	Graphical User Interface
GWP	Global Warming Potential
ha	Hectare
HCCM	Heat Capacity Mapping Mission
HDDS	Hazards Data Distribution System
HDF	Hierarchical Data Format
HPA	High Plains Aquifer
IEEE	Institute of Electrical and Electronics Engineers
IKONOS	Commercial earth observation satellite that derived its name from the Greek term *eikōn* for image.
INEGI	Instituto Nacional de Estadística y Geografía (Mexican National Institute for Statistics and Geography)
IOP	Institute of Physics
IPCC	Intergovernmental Panel on Climate Change
IPDS	Information Product Data System
IT	Information Technology
JACIE	Joint Agency Civil/Commercial Imagery Evaluation
KARI	Korea Aerospace Research Institute
km	Kilometer
KML	Keyhole Markup Language. An XML based file that expresses geographic annotation and visualization for earth viewing software such as Google Earth.
KMZ	Keyhole Markup language Zipped. A file extension for a placemark file used by Google Earth. stands for Keyhole Markup language Zipped.
L1Gst	Level-One Georeference Systematically Terrain-Corrected
L1T	Level-One Terrain-Corrected
LANDFIRE	Landscape Fire and Resource Management Planning Tools
LAS	Land Analysis System
LDCM	Landsat Data Continuity Mission
LEDAPS	Landsat Ecosystem Disturbance Adaptive Processing System
LF	LANDFIRE
Lidar	Light Detection and Ranging
LP DAAC	Land Processes Distributed Active Archive Center

LRS	Land Remote Sensing
LST	Land Surface Temperature
LTA	Long Term Archive
LULC	Land Use Land Cover
m	Meter
MIICA	Multiple Indices Integrated Change Analysis
MIrAD-US	MODIS Irrigated Agriculture Data for the United States
MODIS	Moderate Resolution Imaging Spectroradiometer
MRLC	Multi-Resolution Land Characterization
MRTWeb	MODIS Reprojection Tool on the Web
MSR	Minimum Stover Requirement
MSW	Middlewear Software
MTBS	Monitoring Trends in Burn Severity
N_2O	Nitrous Oxide
NAIP	National Agriculture Imagery Program
NALCMS	North American Land Change Monitoring System
NAPP	National Aerial Photography Program
NASA	National Aeronautics and Space Administration
NBR	Normalized Burned Ratio
NCA	National Climate Assessment
NCAI	National Climate Assessment Indicators
NDVI	Normalized Difference Vegetation Index
NED	National Elevation Dataset
NEP	Net Ecosystem Productivity
NGA	National Geospatial-Intelligence Agency
NGP	National Geospatial Program
NHAP	National High Altitude Program
NLCD	National Land Cover Database
NLIR	National Land Imaging Requirements
NOAA	National Oceanic and Atmospheric Administration
NOSA	NOAA Observing Systems Architecture
NOSIA	NOAA Observing System Integrated Analysis
NPK	Nitrogen (N), Phosphorus (P), and Potassium (K)
NRCAN	Natural Resources Canada (NRCAN) Centre for Topographic Information, Sherbrook, Ottawa
OLI	Operational Land Imager
OIV	On-orbit Initialization and Verification
PALMA	Portfolio AnaLysis MAchine. A computer program that helps decision-makers select the best portfolio (combination) of investments from a set of potential investment options.
PAR	Photosynthetically-Active Radiation
QA	Quality Assurance
QC	Quality Control
Reverb	NASA's next generation metadata and service discovery tool. Reverb searches against the ECHO metadata clearinghouse which facilitates all data discovery and order processing capabilities. To

	Reverberate is to "echo back or reecho." Data Pool is another NASA search service tool.
RSAC	Remote Sensing Applications Center
RSLC	Remote Sensing of Landscape Change
RSS	Rich Site Summary
RST	Remote Sensing Technologies
SAR	Synthetic Aperture Radar
SBA	Small Business Administration
SCAR	Scientific Committee on Antarctic Research
SDW	Spatial Data Warehouse
SEDAC	Socio-Economic Data and Applications Center
SIR-C	Spaceborne Imaging Radar C-band
SLC	Scan Line Corrector
SME	Subject Matter Expert
SOC	Soil Organic Carbon
SPOT	Satellite Pour l'Observation de la Terre
SRES	Special Report on Emissions Scenarios
SRTM	Shuttle Radar Topography Mission
SSEB	Simplified Surface Energy Balance
SSEBop	Simplified Surface Energy Balance operational model
SST	Sea Surface Temperature
tb	Terabyte
TFBSO	Task Force for Business and Stability Operations
TgC	Teragrams of Carbon
TGRS	Transactions on the Geoscience and Remote Sensing
TIRS	Thermal Infrared Scanner
UNEP	United Nations Environment Programme
USACE	U.S. Army Corps of Engineers
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
UWG	User Working Group
VIC	Variable Infiltration Capacity
VIIRS	Visible Infrared Imaging Radiometer Suite
WaterSMART	Water for Sustainable Management of America's Resources for Tomorrow
WELD	Web Enabled Landsat Data
WFAS	Wildland Fire Assessment System
WGCV	Working Group on Calibration and Validation
WRS	World Reference System
XML	Extensible Markup Language. A textual data format that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.

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Introduction

This desk reference is intended to provide an overview of the scientific, engineering, and operational achievements and illustrate the range and scope of the activities and accomplishments at EROS throughout fiscal year (FY) 2013. Additional information concerning the achievements can be obtained from the scientific papers and other documents published by the scientists, engineers, and information professionals affiliated with EROS. Appendix A provides both a summary and a complete list of the Center's extensive publishing records from throughout the fiscal year.

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/.

Fiscal Year 2013 in Review

Science and Applications Activities

The Center's science and applications activities include multidisciplinary Earth science research, remote sensing applications development, and generation of associated products such as oral presentations, publications, workshops, databases, and websites. Science and applications activities are aligned with the USGS strategic science goals and priorities set by the Climate and Land Use Change (CLU) Mission Area.

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

Science partners and collaborators include the USGS CLU Programs and other USGS mission areas and their associated programs, other bureaus and agencies within the U.S. Department of the Interior (DOI), bureaus and agencies in other departments of the Federal Government, State agencies, tribal governments and universities, non-Government agencies, academic institutions, and international organizations.

The EROS research and applications activities take full advantage of the Center's extensive national and global archive of remotely sensed data.

Fire Science

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

The LANDFIRE Program Maintains Timeliness of LANDFIRE National Vegetation and Fuel Datasets by Evolving National Disturbance Mapping Processes – LANDFIRE Updating 2010

LANDFIRE (LF), the Landscape Fire and Resource Management Planning Tools program, has been a joint effort between wildland fire management programs of the U.S. Department of Agriculture Forest Service and the U.S. Department of Interior with a cooperating partner of The Nature Conservancy. The USGS EROS Fire Science Team's role has been and continues to be a provider of science and innovation leadership for the mapping component of this program and has been a key component in this fire program since it was chartered in 2004. LF applies consistent methodologies and processes to attain a goal of creating comprehensive spatial data and models describing vegetation and wildland fire/fuel characteristics across the United States.

Mapped data products produced by this program are based on both Landsat satellite imagery and an extensive database of field-reference data. LF provides the first implementation of methodologies and processes to develop and combine intermediate-scale spatial vegetation and fire information consistently across the entire United States. Such a suite of integrated vegetation, fuel, and fire regime data sets has not previously been created by the public or private sectors. LF data products facilitate national and regional (large landscape level) fire planning activities and the reporting of wildland fire management activities. LF products provide managers with the data needed for collaborative, landscape-scale, cross-boundary, interagency planning and implementation. LF data support land management to (1) identify fuel where fire hazards and fire risks to local communities may be located, (2) identify vegetation and fuel conditions where rehabilitation may benefit fire-dependent landscapes, (3) prioritize resources for national budget formulation and allocation, and (4) enhance management knowledge of fire behavior to improve firefighting safety. Programs within the wildland fire community that use LF data include the National Cohesive Wildland Fire Management Strategy, the Wildland Fire Decision Support System, Fire Program Analysis, and the Hazardous Fuel Prioritization and Allocation System.

LF is now focused on updates to the suite of national LF data products in order to reflect current landscape conditions. This focus is on updating landscape-level vegetation changes, such as those resulting from wildland fire, fuel and vegetation/silvicultural treatments, mortality from insects and disease, storm damage, invasive plants, and other natural or anthropogenic events where relevant data were available for the years 2008-2010.

In 2013, the USGS EROS Fire Science Team completed updates to LF data products incorporating landscape changes that had occurred from 2008 through 2010. Landsat imagery was used to detect vegetation change and landscape disturbance. The disturbance was mapped by using the National Land Cover Database Multi-Index Integrated Change Analysis model where multiple Landsat scenes for each year are processed to identify what LF identifies as the Remote Sensing of Landscape Change (RSLC) product. The RSLC analysis for the LF 2010 updating process utilized 4,380 Landsat scenes across the conterminous United States (CONUS). In addition to the satellite data, LF coordinates a yearly collection of recent natural disturbance and land management activities contributed from land managers across the country. This information is combined into a spatial LF events database. This events database contained some 450,000 different event perimeters for the 2010 update, including events dating back to 1999. The RSLC and LF events products are used along with information on large fires from the Monitoring Trends in Burn Severity (MTBS) Project to produce a yearly LF disturbance product. This disturbance product is used to update existing vegetation and fuel layers, and these updated vegetation and fuels layers are then used to update other LF data products. To view a complete list of LF products, please visit the LF web site at http://www.landfire.gov/.

In addition to the CONUS-wide RSLC update, LF mapping was extended to insular territories and associated states in the Caribbean and Pacific Basin. Topography, vegetation, and fuels data were produced in American Samoa, Northern Mariana Islands, Guam, Federated States of Micronesia, Palau, Marshall Islands, Puerto Rico, and the U.S. Virgin Islands for the first time. Landsat image composites for each island group, along with, synthetic aperture radar data, plus airborne and spaceborne lidar (light detection and radar) were used to map vegetation type and structure.

In Alaska, forest height was remapped using airborne and spaceborne lidar data to build statistical models relating forest height to Landsat imagery. These models were then applied statewide to produce a more accurate and more detailed map of forest height than previously produced by LF (fig. 1).

LF teams have begun planning for the next round of updates, termed LANDFIRE 2012. This effort will largely be a continuation of the LF 2010 work using Landsat imagery. One innovation being developed for LF 2012 is a compositing and tiling approach to using Landsat 7 Scan Line Corrector (SLC)-Off data. This approach will allow multiple scenes to be combined to fill SLC-Off gaps, cloudy, or shadowed areas in the change detection products. These methods are expected to provide higher quality data with less time spent accounting for anomalies in the change detection outputs, yielding more

efficient processing. For further information, contact Jeffery Eidenshink, USGS EROS, eidenshink@usgs.gov.

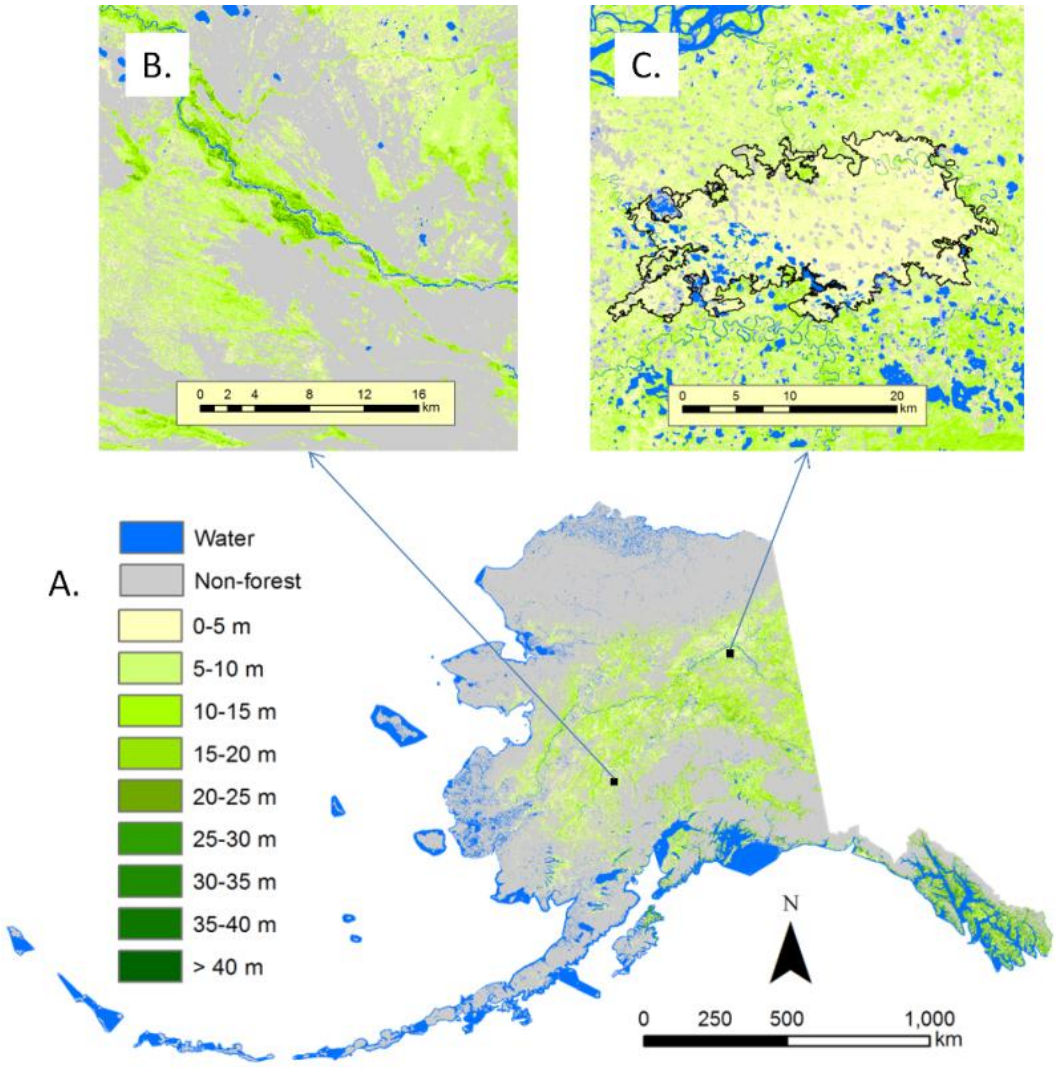

Figure 1. (A) LF 2010 existing forest canopy height map for Alaska. (B) Close-up view of a riparian corridor, with taller heights along river. (C) Close-up showing the perimeter (black outline) of a 2004 fire, with shorter heights corresponding with burned areas. Fire perimeter data were acquired from the Monitoring Trends in Burn Severity Project.

Remote Sensing Support for DOI 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 wildfires on Department of Interior (DOI) and USFS managed lands and to satisfy soil burn severity and other mapping requirements of Burn 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. 2), generally in less than 2 days after image acquisition. In 2013, the availability of the new Landsat 8 satellite greatly enhanced USGS capability to respond to the needs of fire rehabilitation managers in a timely manner. Historically, 8 to 9 years ago, BAER soil burn severity mapping was done by manually sketch mapping severity patterns on topographic maps, perhaps with the aid of a digitized fire perimeter. Today, burn severity mapping derived using satellite imagery has replaced the manual method for BAER teams, except in cases where timely high quality imagery is not available due to excessive clouds, smoke, or active fire issues.

This was a demanding year for BAER burn mapping support. The 1.8-million acres mapped in 2013 was less than the yearly average acres mapped since 2001. However, the 116 fires mapped was the fourth most fires mapped in one year since 2001. In total from 2001 through 2012, USGS EROS and USFS RSAC have mapped over 1,300 wildfires representing almost 40-million burned acres in support of BAER and other local DOI and USFS land managers. Additionally, USGS EROS and USFS RSAC have provided support for U.S. BAER teams deployed to international wildfire events including Chile in 2012 and Australia, Greece, and the Democratic Republic of Georgia in 2009. For further information, contact Randy McKinley, USGS EROS, rmckinley@usgs.gov.

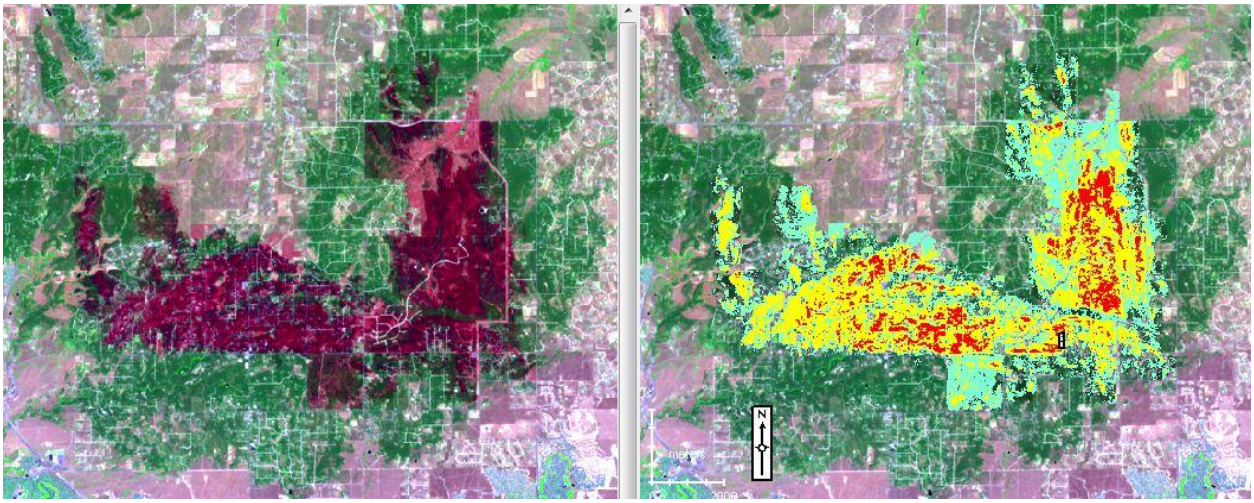

Figure 2. BAER map products, Landsat 8 image (left) and soil burn severity map (right), for the Black Forest fire located near Colorado Springs, Colorado. This was a high-priority fire in 2013, impacting an estimated 14,000 acres and over 480 homes. The fire was mapped after containment to provide local fire rehabilitation managers with timely soil 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.

Monitoring Trends in Burn Severity Fire Assessments Approach 17,000

The Monitoring Trends in Burn Severity (MTBS) Project began in response to the need for land management agencies to develop and implement consistent and comprehensive methods to assess fires and identify national trends. The data generated by MTBS are used to provide information necessary to monitor the effectiveness of the National Fire Plan and identify national trends in burn severity. Since 2006, the USGS EROS and the Forest Service Remote Sensing Applications Center have mapped and released 16,685 fire assessments. The assessments cover large fires that were reported from 1984 to 2011. Only the northeastern states of New Hampshire, Vermont, Connecticut, and Rhode Island have not reported a large fire from that time frame.

To assess burn severity for a reported fire, MTBS analysts evaluate Landsat imagery acquired after the fire is out. Usually, a post-fire scene is compared to a pre-fire scene to estimate the impact of the fire upon the landscape. The Normalized Burn Ratio (NBR) is derived for each image, and the differenced NBR (dNBR) is computed by subtracting the post-fire NBR from the pre-fire NBR. The dNBR image is manually interpreted to delineate a fire perimeter and to estimate burn severity (unburned to low, low, medium, high). The resulting map, perimeter, Landsat imagery, and burn severity statistics for each fire are staged at http://mtbs.gov.

As outlined above, the current MTBS process relies heavily upon manual procedures to report and assess fires. During 2013 and using funding provided by a grant from NASA, the USGS EROS developed procedures to take advantage of near-real-time active fire detections from other satellite resources such as MODIS (Moderate Resolution Imaging Spectroradiometer) and the Advanced Very High Resolution Radiometer (AVHRR). The fire detections are combined with burned-area polygons derived from a process that scans recent Landsat acquisitions, looking for the spectral signature of recently burned areas and then delineating burned-area polygons. The fire detections and burned-area polygons remove the reliance upon manual reporting methods and provide a more complete and timely accounting of fire occurrence across the United States. They also allowed the development of an automated process to search and order Landsat scenes that are suitable to map fires. Figure 3 shows hazard mapping system fire detections for northern Florida, the detections overlain on a Landsat scene, burned area polygons derived from the scene and close-ups of several burned area polygons and resulting burn severity images.

Further development of these automated fire detection and mapping processes will be pursued in 2014 to increase the speed and efficiency of MTBS analysts. The MTBS project will continue to produce fire assessments into the future. For further information, contact Stephen Howard, USGS EROS, smhoward@usgs.gov.

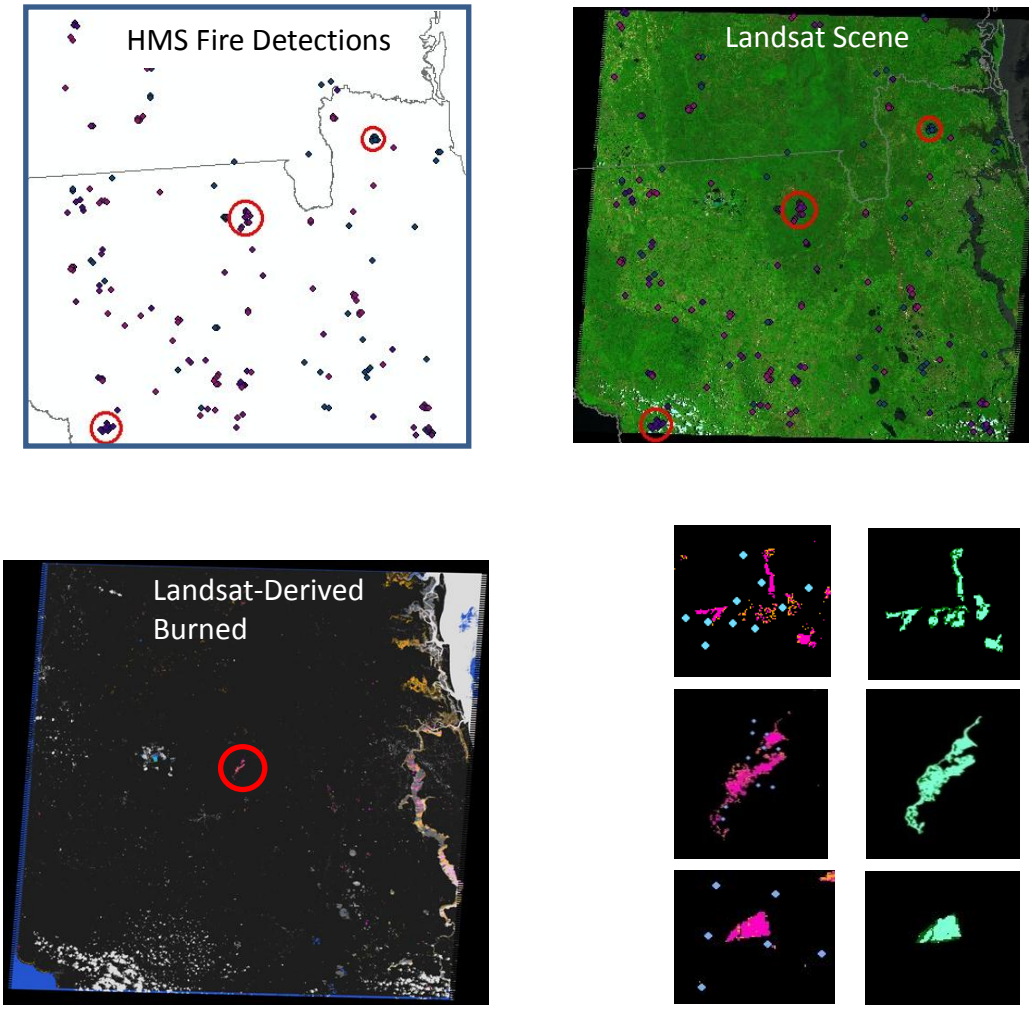

Figure 3. The images show hazard mapping system fire detections for northern Florida, the detections overlain on a Landsat scene, burned area polygons derived from the scene, and close-ups of several burned area polygons and resulting burn severity images.

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

Accurate information about three-dimensional canopy structure and wildland fuel is needed for using fire behavior modeling systems to predict how wildfires will spread across landscapes under various conditions. Remotely sensed data are instrumental for assessing these canopy characteristics at regional to national scales; and lidar data, in particular, are uniquely suited for quantifying three-dimensional canopy structure. However, lidar-derived fuel data are still relatively rare, which can be attributed in part to two underlying issues. First, the LF program is the default source of large-scale fire behavior modeling inputs as it provides consistent, nationwide, landscape-level vegetation structure, and fuel data. LF does not currently incorporate lidar data into the

vegetation and fuel mapping process because they are not consistently available nationwide. Second, while lidar data are available for many land management units across the United States, there is a lack of local personnel trained to process and analyze these data. This one-year, NASA-funded, project has addressed both of these issues by developing the Creating Hybrid Structure from LANDFIRE/lidar Combinations (CHISLIC) tool. The primary purpose of CHISLIC is to infuse LF products with lidar data to improve spatial and informational detail.

Numerous studies have shown how lidar data can be used for characterizing forest canopies. In these studies, the typical approach has been to model vegetation structure or fuel attributes from lidar height, density, and variance metrics. Although this approach has proven effective in research studies, there has been little work produced to demonstrate an operational application for large areas and across vegetation types. The results of these previous studies informed the CHISLIC algorithm selection for calculating canopy height (CH), canopy cover (CC), and canopy base height (CBH) from lidar. The algorithms selected for use in CHISLIC for estimating CH, CC, and CBH were evaluated through comparisons with field data from test sites representing different forest types within the United States. The final algorithms were globally robust, being able to accurately derive the canopy metrics for different types of forest vegetation.

CHISLIC allows users to automatically generate a suite of vegetation structure and fuel parameters from lidar data and infuse these into existing LF products. CHISLIC thereby ensures both maps based on the best data available and data continuity through the linkage with LF. The higher degree of information that can be generated from the integration of the LF products and lidar data will result in better understanding of fire behavior across the landscape through improved modeling inputs.

An important part in determining the usefulness of CHISLIC is testing its functionality and accuracy. To accomplish this, alpha versions of CHISLIC were released in June, August, and September of 2013 for testing and assessment by project team members. Members assessed the tool interface for clarity and usability by potential end users, ran the tool to ensure that it could handle different types of data and data volumes, and compared tool outputs to products generated manually outside of the tool environment. Subsequently, a beta version of CHISLIC has been released to a broader test group to further evaluate the tool and its products.

The results of current testing indicate that CHISLIC delivers more detailed products that can be used in fire behavior applications. This is illustrated in figure 4, showing a subset of a study area located in Grand County, Colorado. CHISLIC will soon be available for wider distribution to the public through a growing partnership with the Wildland Fire Assessment System (WFAS). WFAS is one of the primary systems used to support tactical and strategic wildland fire management decisions. For further information, contact Jeffery Eidenshink, USGS EROS, eidenshink@usgs.gov.

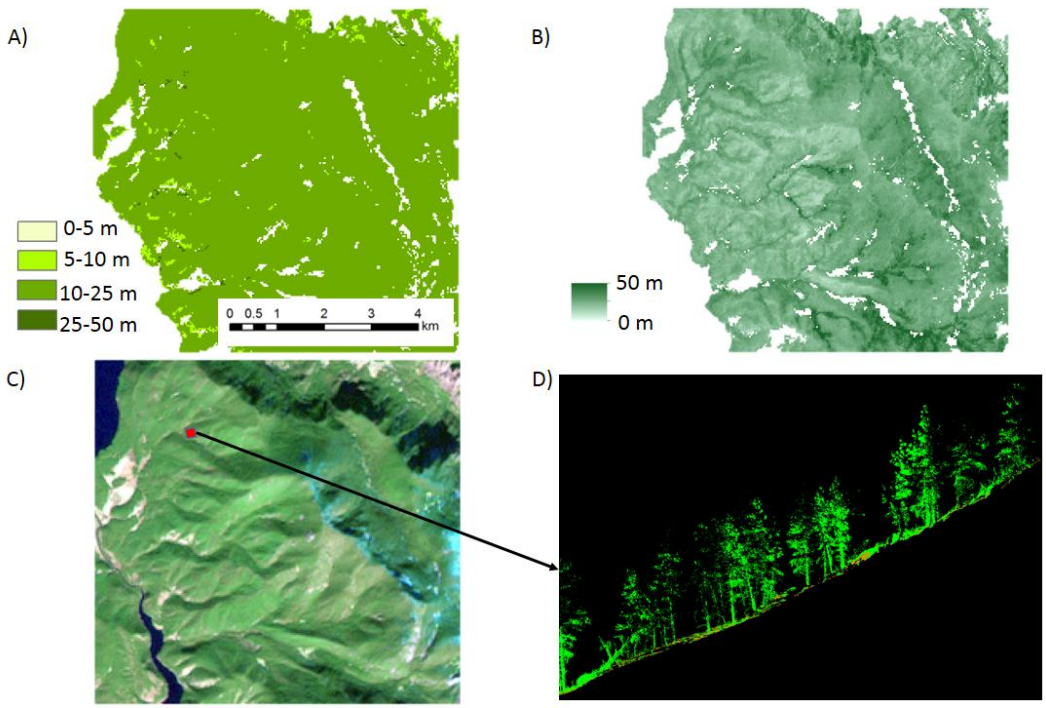

Figure 4. Illustration shows canopy height products from LANDFIRE (Panel A) and CHISIC (Panel B) and primary remote sensing data types used to develop them for an example area in Grand County, Colorado. Panel C shows the Landsat Thematic Mapper (Bands 5, 4, and 2) imagery used to generate LANDFIRE products. Panel D shows the airborne lidar used to produce the CHISLIC outputs.

Forecasting Large Wild Fires

USGS scientists, in partnership with the USFS, have developed forecasts of the number of large fires to expect in specific geographic regions for the forthcoming week. The weekly forecasts of the location and number of large fires is provided for the nation for each predictive service area.

The convergence of plentiful dry wildland fuels and weather favorable for fire ignition and spread signifies high potential for uncharacteristically large and dangerous fires. The ability to characterize the potential for hazardous fire activity requires measurements of fuel condition combined with information from weather forecasts. The availability of long fire histories adds a third dimension, fire probability, which can improve the ability to develop weekly forecasts of the location and number of large fires over a given region (Preisler et. al. 2008).

The USGS uses satellite information to assess live fuel condition for estimating fire danger. Using 25 years of vegetation condition measurements, we are able to determine the relative greenness of current live fuels. High relative greenness values indicate that the vegetation is healthy and vigorous. Low greenness values indicate that

the vegetation is under stress, dry (possibly from drought), is behind in annual development, or dead. Forest, shrub, and grassland vegetation with low relative greenness is susceptible to fire ignition during the fire season.

The forecast begins with the fire potential index, which integrates satellite derived vegetation condition information and daily weather information to identify the area most susceptible to fire ignition (Burgan et.al. 1998). The fire potential index combines the relative greenness of vegetation and weather information to estimate the moisture condition of the live and dead vegetation. The fire potential index provides local and regional fire planners a quantitative measure of fire ignition risk.

The final step in the forecast is to incorporate the historical record of large fire occurrence to determine the probability of large fire occurrence. By combining fire potential with the probability of fire occurrence, we can determine the probability of one or more large fires within a geographic region (fig. 5). This forecast is produced daily by the USGS for all lands in the lower 48 states.

The USGS EROS Center in collaboration with the USFS provides the forecast daily on two primary websites; http://firedanger.cr.usgs.gov/viewer/viewer.htm and http://www.wfas.net/index.php/large-fire-potential-and-fire-potential-indexes-external-products-107. For more information, contact Jeffery Eidenshink, USGS EROS eidenshink@usgs.gov.

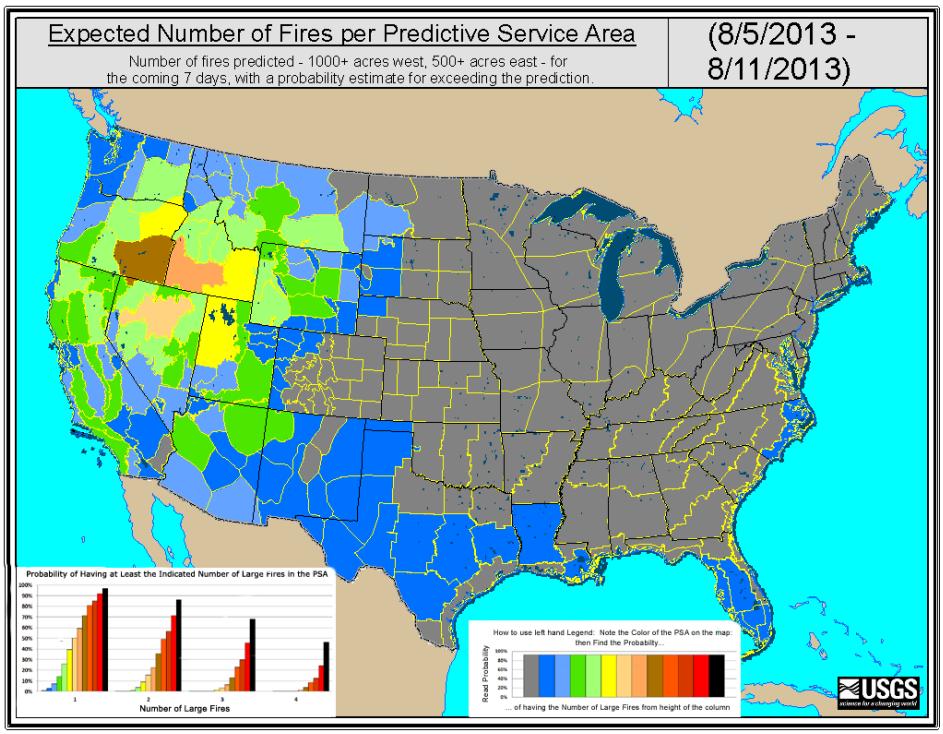

Figure 5. Expected number of fires per predictive service area for the week of August 5, 2013.

Land Characterization and Trends

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

National Land Cover Database 2011: Designed and in Production

The USGS, working in partnership with the interagency Multi-Resolution Land Characteristics (MRLC) Consortium, has completed over 80 percent of the production of the National Land Cover Database (NLCD) 2011 for the conterminous United States. The NLCD serves as the definitive Landsat-based, 30-meter pixel resolution, land cover database for the nation. NLCD provides spatial reference and descriptive data for land surface characteristics such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover.

The USGS EROS Center science strategy team developed two primary advances for production of the NLCD 2011 products. This includes the development of a new change detection approach called the multiple indices integrated change analysis (MIICA), which uses two pairs of multi-temporal Landsat scenes from different seasons within the same year to characterize change more effectively than the single scene pair used for NLCD 2006. Another advance was the development of processing models for change analysis and percent imperviousness estimates that significantly automated the production process over NLCD 2006. This automation has reduced the interval between data acquisition and product release, while improving product relevance and timeliness. NLCD 2011 is scheduled to be delivered by March 31, 2014.

In addition to land cover and percent imperviousness products, NLCD 2011 will also contain a new percent canopy estimate produced in cooperation with the USFS Remote Sensing Applications Center, in Salt Lake City, Utah. The new process uses the application “Random Forest” to model tree canopy cover using a highly automated process that depends on field collected forest inventory analysis plot data to train models. Cooperation with the USFS on the tree canopy cover for NLCD 2011 is one example of many successful collaborative efforts with MRLC partners over the past two decades. Figure 6 illustrates a typical land cover change in areas where forest has been harvested.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, analytical modeling, and geographic information system technologies to support participating MRLC members and the NLCD user community. For further information, contact Collin Homer, USGS EROS, homer@usgs.gov.

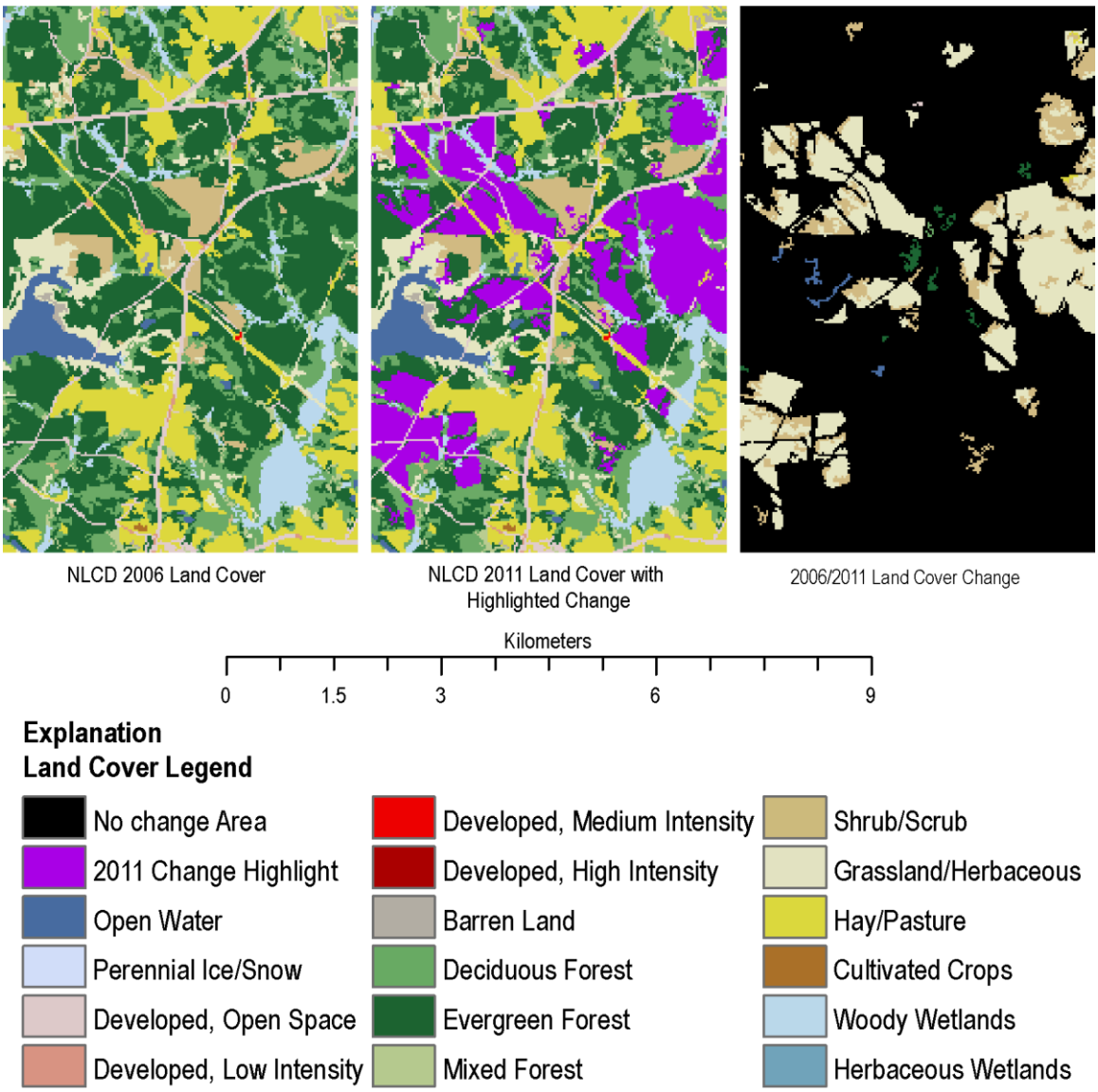

Figure 6. An example of land cover change in Pike County, Georgia (Landsat Path 19, Row 37). In the area shown, a majority of the change is from coniferous forest in 2006 to grass or shrub in 2011 – a typical land cover change in areas where forest has been harvested.

North American Land Change Monitoring System: New Land Cover Change Product for North America for 2005-2010

The USGS, working in partnership with the Commission for Environmental Cooperation (CEC), the Canada Centre for Remote Sensing (CCRS), the Mexican National Institute for Statistics and Geography (INEGI), the Mexican National Commission for the Knowledge and Use of Biodiversity (CONABIO), and the Mexican National Forestry

Commission (CONAFOR) have produced the first-ever change product for the North American Land Change Monitoring System (NALCMS) (fig. 7).

This change product was developed using collaborative methodology among the three nations to generate a consistent continental wide change product. The change product represents land cover change that occurred across North America between the 5-year interval from 2005-2010 at a spatial resolution of 250 meters or greater. The product will soon be publically released on the CEC website (www.cec.org). This product represents the changing physical land cover across the continent with 15 land cover classes that have been defined using the Food and Agriculture Organization (FAO) standardized definitions. Both the change and classification process rely on data from the Moderate Resolution Imaging Spectroradiometer (MODIS). Information provided by this land cover database can be used to address issues such as climate change, carbon sequestration, biodiversity loss, and changes in ecosystem structure and function through better understanding of the dynamics and continental-scale patterns of North America's changing land cover.

The NALCMS group is now working on representing land cover change across North America with annual change products at 250-meter resolution and 5-year interval products at 30-meter resolution.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, analytical modeling, and geographic information system technologies to support participating NALCMS members. For further information, contact Collin Homer, USGS EROS, homer@usgs.gov.

Figure 7. An example of the North America Land Change Monitoring System land cover database from 2005, used to develop land cover change between 2005 and 2010 for North America.

Historical Land Cover "Backcasts" for the Great Plains: 1938-1992

Scientists at the USGS EROS have produced annual, historical land cover "backcast" maps from 1938 to 1992 for the Great Plains of the United States. Figure 8 illustrates backcast land cover near Dallas/Fort Worth, Texas. Urban expansion, reservoir construction, and changes in agricultural lands are all evident. USGS EROS scientists have historically played a vital role in providing relevant, consistent land cover data based on remote sensing data such as Landsat. However, consistent, large-region remote sensing data is not available prior to 1972. Historical land cover data prior to 1972 is valuable for assessing historical impacts of land cover change on ecological processes such as hydrology and water quality, carbon and greenhouse gas emissions, and biodiversity. A modeling environment can produce valuable, wall-to-wall, thematically detailed land cover data for historical periods where large-area remote-sensing data are not available.

USGS scientists used the Forecasting Scenarios of land use change (FORE-SCE) model to produce historical land cover data for the Great Plains. FORE-SCE produces spatially explicit land cover maps, but requires information on the amount of land cover change for a modeled time frame. USGS land cover trends data, based on sampled Landsat data interpretation, were used to provide information on land cover change from 1972 to 1992. Other data sources were also needed to drive FORE-SCE, especially for dates prior to 1972. These included the census of agriculture data, census data on housing and population density, a "drained lands" database providing information on wetland loss, and data on reservoir construction dates for the United States. FORE-SCE ingested reconstructed proportions of historical land cover change and produced spatially explicit maps, modeling change in areas most suitable to support a given historical land cover class.

Annual, 250-meter resolution land cover maps from 1938 to 1992 were produced for the Great Plains, with 17 unique land cover classes. Comparison of modeled historical land cover with historical data such as the census of agriculture indicates FORE-SCE performs well in reconstructing regional landscape histories. While invaluable for producing realistic reconstructions of historical land cover for dates prior to the availability of large-area remote sensing data, the efficiency and speed of the modeling methodology also makes it a practical choice when traditional remote sensing based land cover mapping is too costly or technically challenging.

The historical land cover backcasts are being used by USGS scientists to analyze the impacts of historical land cover change on water quality, sediment flow, and other hydrologic processes. The backcast data were designed to be compatible with 1992 to 2100 scenario-based land cover projections produced at USGS EROS, resulting in a consistent, annual land cover database from 1938 to 2100. The combined data sets offer scientists the capability to examine, past, present, and potential future impacts of land cover change on ecological processes. USGS EROS scientists continue to work on backcast land cover data for the rest of the conterminous United States, with the goal of completing the work in early 2015.

The spatially explicit historical land use land cover data are available through a USGS EROS land cover modeling website (http://landcover-modeling.cr.usgs.gov). For further information, contact Terry Sohl, USGS EROS, sohl@usgs.gov.

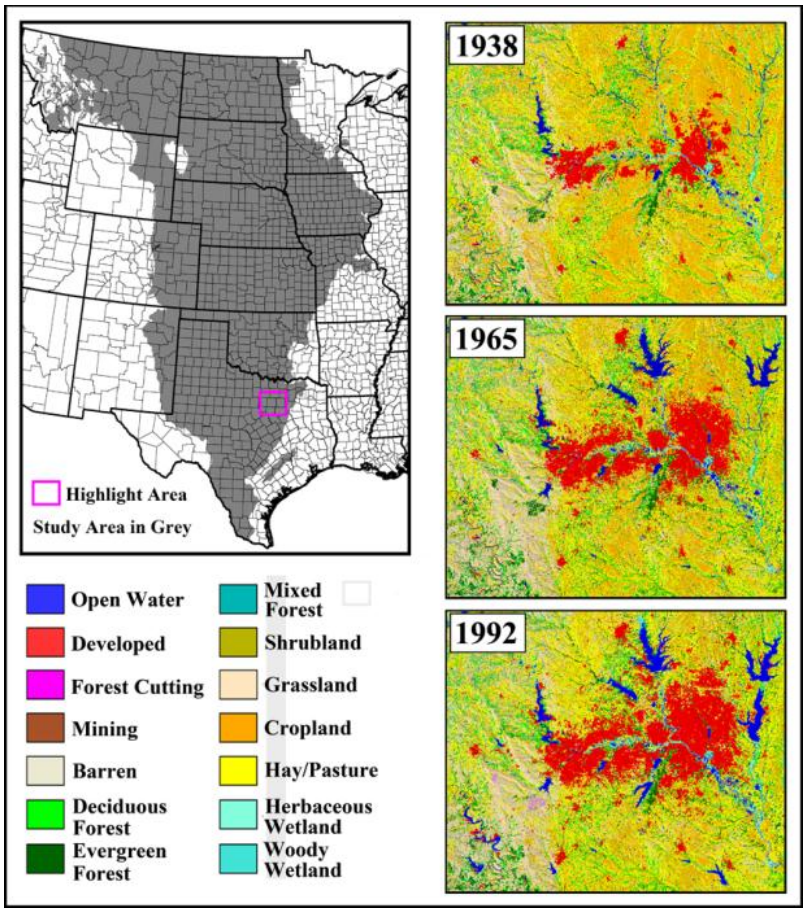

Figure 8. Backcast land cover near Dallas/Fort Worth, Texas. Urban expansion, reservoir construction, and changes in agricultural lands are all evident.

Land Cover Projections for Four Intergovernmental Panel on Climate Change Scenarios for the Conterminous United States: 1992-2100

USGS scientists have produced a unique set of land cover projections for the conterminous United States, based on Intergovernmental Panel on Climate Change (IPCC) scenarios. The 2007 Energy Independence and Security Act passed by the U.S. Congress directed the DOI to analyze the potential for biological carbon sequestration on our Nation's lands. Changes in land use and land cover (LULC) have considerable influence on biogeochemical cycles, including effects on the emission or storage of carbon and other greenhouse gases. Scenario-based projections of LULC change are needed to quantify the potential for biological carbon sequestration, and to analyze strategies to mitigate impacts of greenhouse gas emissions.

The FORE-SCE model was used to produce the LULC projections. Four scenarios were generated, each consistent with storylines from the IPCC Special Report on Emissions Scenarios (SRES) (scenarios A1B, A2, B1, and B2). Scenario storylines were quantified to regional proportions of LULC change in a workshop that relied on existing modeling frameworks, historical information on LULC change, and expert knowledge. FORE-SCE uses the quantified scenarios to produce spatially explicit, annual LULC maps for each scenario, matching the quantity of prescribed LULC change from each scenario. Figure 9 is an example of modeled LULC change from 2006 through 2100 near Kansas City, Missouri.

FORE-SCE produced annual, 250-meter resolution LULC maps for each of the four IPCC SRES scenarios, from 1992 to 2100. With 17 individual LULC classes modeled, these projections are the first to provide high thematic resolution data for the conterminous United States, at a relatively high spatial resolution. FORE-SCE also produces data layers on forest stand age, information that scientists can use to represent forest structure in the future. The projections have been used to generate the first, high spatial resolution analysis of future carbon sequestration and greenhouse gas emissions for the conterminous United States. The fine temporal, spatial, and thematic resolution also make the scenario-based projections useful for analyzing the influence of projected LULC change on other ecological processes, including hydrology and water quality, biodiversity, and regional weather and climate variability.

Both the spatially explicit LULC projections and the forest stand age data layers are available through a USGS EROS land cover modeling website (http://landcover-modeling.cr.usgs.gov). For further information, contact Terry Sohl, USGS EROS, sohl@usgs.gov.

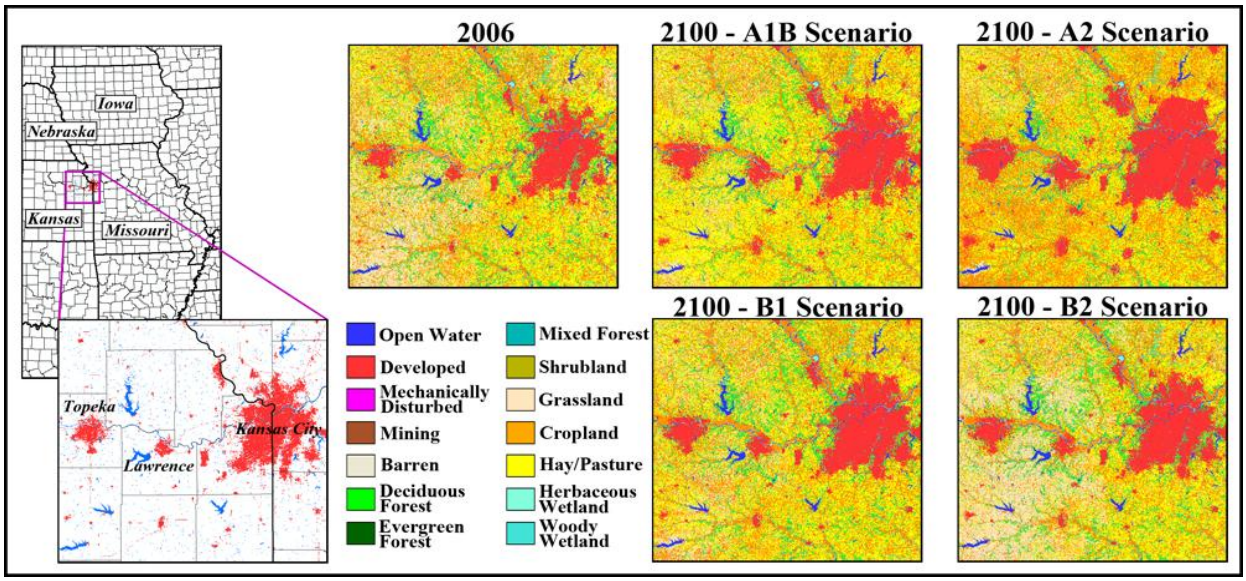

Figure 9. An example of modeled land use land cover change from 2006 through 2100 near Kansas City, Missouri, for the four Intergovernmental Panel on Climate Change scenarios.

USGS Science Helps Disseminate Multi-Scale U.S. Land Use Land Cover Change Knowledge

The USGS National Land Change Assessment Project (Principal Investigator, Mark Drummond of the Geosciences and Environmental Change Science Center) provides national and regional assessments of U.S. land use land cover change and their driving forces. Roger Auch is the main USGS EROS researcher of the National Land Change Assessment Project and was the lead or co-author of four publications that were completed or accepted for publication during FY 2013. These include a case study of an individual midwest ecoregion that experienced both significant urbanization and increased agricultural production between 1973 and 2000, the contemporary intra-regional differences of LULC change within three corn belt ecoregions, a CONUS-scale national assessment of LULC change between 1973 and 2000 (a legacy publication of the USGS Land Cover Trends Project), and a continental-to-national scale assessment of the amounts of urbanized land in North America and its impacts on biodiversity.

All four the publications used remote sensing (primarily Landsat) derived LULC change data from the USGS Land Cover Trends Project and one of the publications (the book chapter) used USGS North American and National Land Cover Dataset Project data as well. All four of the publications went beyond just a description of the land change numbers but went on to discuss the drivers associated with the changes and other topics of interest. Together, the land change data along with why change is occurring conveys land change knowledge to users interested in understanding U.S. land change.

Regional LULC Change Publication #1 – *Can substantial urbanization and increased agricultural production coexist in a regional context?*

Roger Auch and academic colleague Chris Laingen have a publication accepted by T*he Professional Geographer* (a journal of the Association of American Geographers) entitled *Having it Both Ways? Land Use Change in a U.S. Midwestern Agricultural Ecoregion* that deals with this question. The article describes both substantial developed land cover change (USGS Land Cover Trends data) as well increased agricultural production in an important agricultural ecoregion. It is offered as a counterpoint to the often repeated perception in both the media and certain scholarly articles that increased urbanization decreases agricultural output and is a threat to U.S. food security (see table 1 and figure 10 as examples from this article).

Regional LULC Change Publication #2 – *A uniformly perceived region can have sub-regional patterns of similarity and differences of LULC change based on biophysical and socioeconomics conditions. The drivers of LULC change can change over time.*

Roger Auch, academic colleague Chris Laingen, fellow USGS scientists Mark Drummond, Kristi Sayler, and Jeffery Danielson, and USGS contract scientists Ryan Reker and Michelle Bouchard describe such land change events in an article that has been accepted and soon to be published in the journal *FOCUS on Geography* (a journal of the American Geographical Society). The article discusses the similarities and

differences in recent LULC change within the U.S. Corn Belt. The combination of specific human and biophysical drivers helped create three different land change profiles between 1973 and 2000. Both unidirectional (more permanent) and multi-directional (tend to be more transitory) changes were occurring in the larger region that is generally perceived as uniform in land use (see figures 11-13 as examples from this article).

National LULC Change Publication #1 – *What were the rates and regional differences in LULC change across the conterminous U.S. in the recent past?*

Roger Auch was a co-author (along with USGS scientists Ben Sletter, Thomas Loveland, Terry Sohl, Kristi Sayler, Mark Drummond, William Acevedo, and academic colleague Steve Stehman). Ben Sletter was the lead author who published national (CONUS) results of the USGS Land Cover Trends Project entitled *Land Cover Change in the Conterminous United States from 1973 to 2000*. The article was published in the journal *Global Environmental Change.* The publication documented the overall spatial extent of CONUS LULC change, the leading types of change, estimates areas of change, the temporal nature and rates of change, and the regional differences in change. It was the first such integrated all thematic and all ownership assessment done for the nation that is known and can be used as a building base of what general LULC change is occurring now and how does it compare with the recent past (see figure 14 as an example from this article).

National (and Continental) LULC Change Publication #2 – *How much of North America and its principal nations is and are urbanized and how is biodiversity within and near urban areas affected?*

Roger Auch was a co-author with academic colleagues Timon McPhearson and Marina Alberti in writing a short book chapter that was included in *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities, a Global Assessment* that was published by Springer. Auch's involvement came from a cold solicitation from one of the book's editors to help out finishing the North American chapter. The publication is a brief summary of urbanization rates and their overall impacts on biodiversity in North America as well as ecosystem services provided by urbanized areas. Auch used three sources of USGS land cover data (North American, National Land Cover Dataset, and Land Cover Trends Project) to place the amount of urbanized land of the continent and nation into context. Auch stressed that even though the direct impacts of urbanization are not found in deeply rural areas, the secondary impacts of natural resource use (agriculture, forestry, mining) to support urbanized areas can be found in such locations and affect the biodiversity there as well (see figure 15 as an example from this publication).

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

Table 1. The top five individual land use land cover changes between 1973 and 2000 in the Eastern Corn Belt Ecoregion.

Individual Land Use Land Cover Changes	Area Changed (km^2)	Margin of Error (+/- km^2)	Percent of all changes
Agriculture to Developed	3708	1726	66.4
Forest to Developed	403	303	7.2
Agriculture to Grassland/Shrubland	388	134	7.0
Agriculture to Mechanically Disturbed	206	152	3.7
Forest to Agriculture	171	45	3.1
All Others	710	n/a	12.7

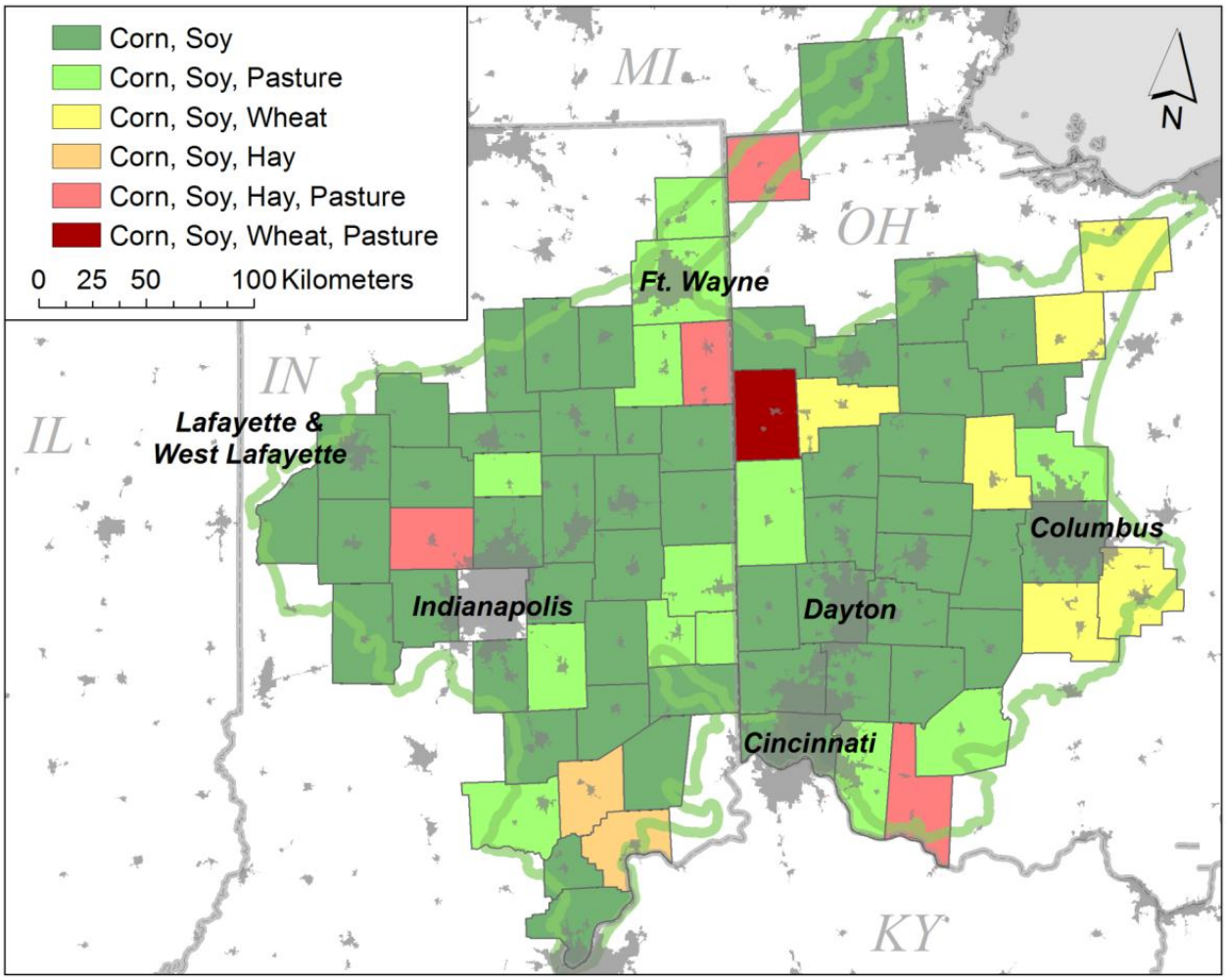

Figure 10. Counties that experienced an increase in corn (tonnes), soybeans (tonnes), wheat (tonnes), hay (tonnes), or pasture (hectares). Note: Oats (tonnes), decreased in all counties, and only one county (Indianapolis' core) experienced a decrease for all categories.

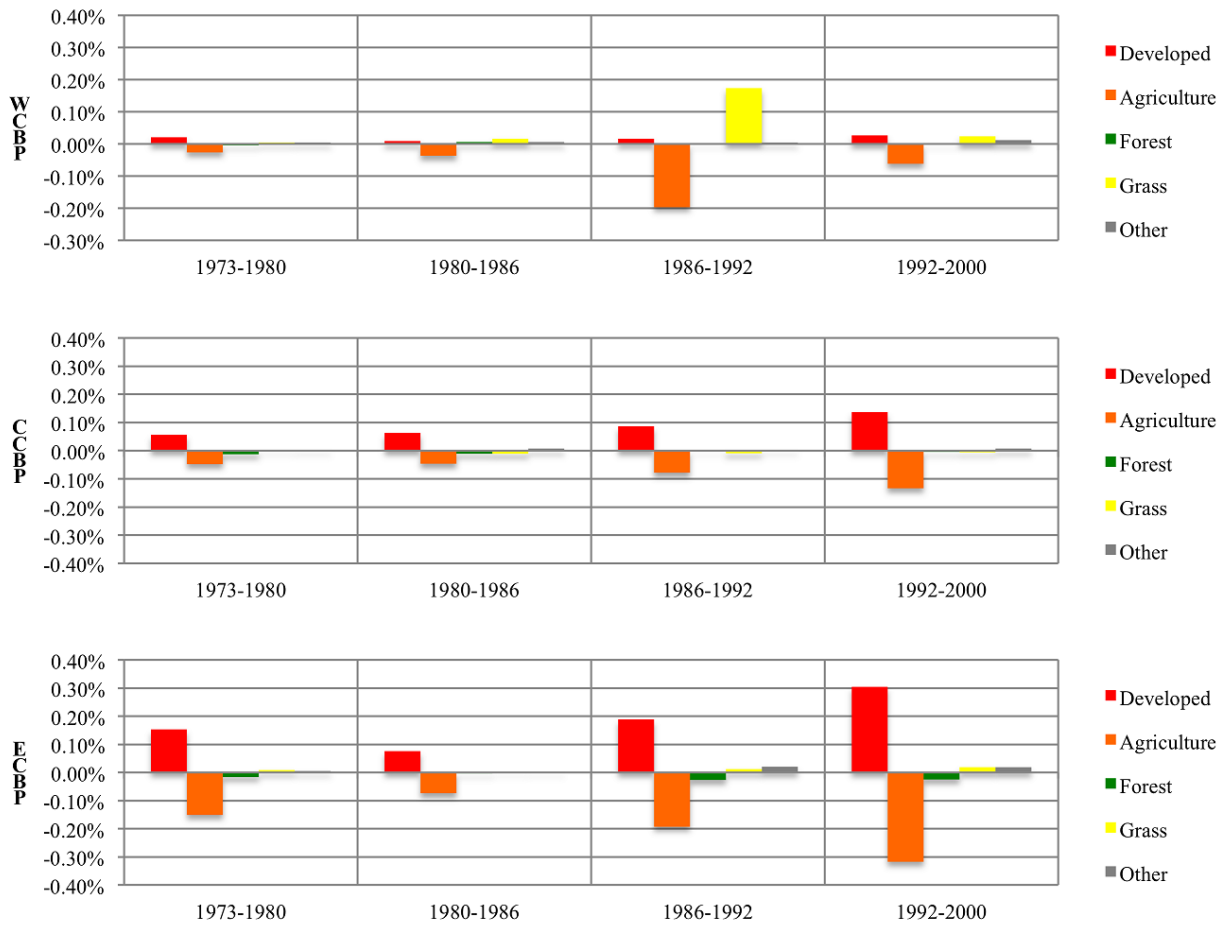

Figure 11. Overall estimated percent land use land cover change between 1973 and 2000 among the Corn Belt Ecoregions.

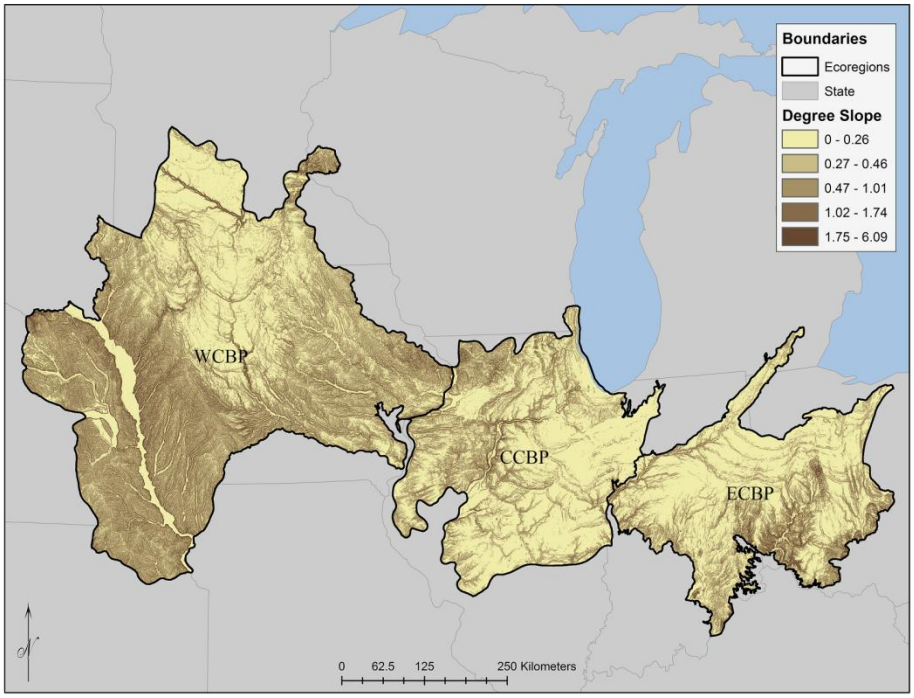

Figure 12. Mean degree of slope across the three Corn Belt Ecoregions at a 500-meter grid resolution using USGS's National Elevation Dataset.

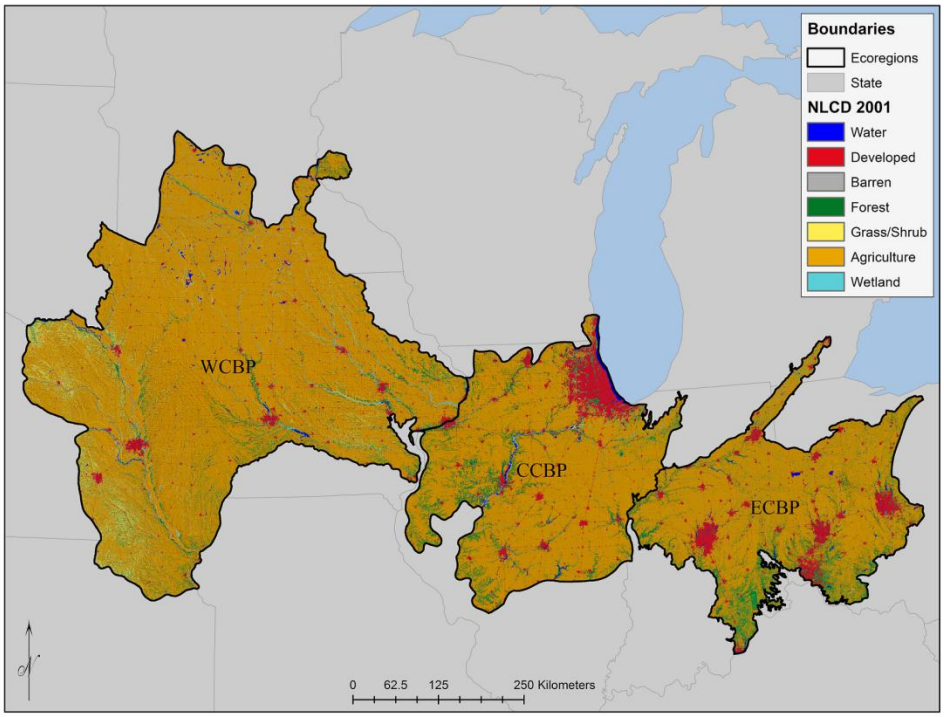

Figure 13. The U.S. Environmental Protection Agency's three "Corn Belt" Level III Ecoregions (1999) shown with 2001 National Land Cover Dataset land covers with a Anderson I (Anderson et al. 1976) classification system.

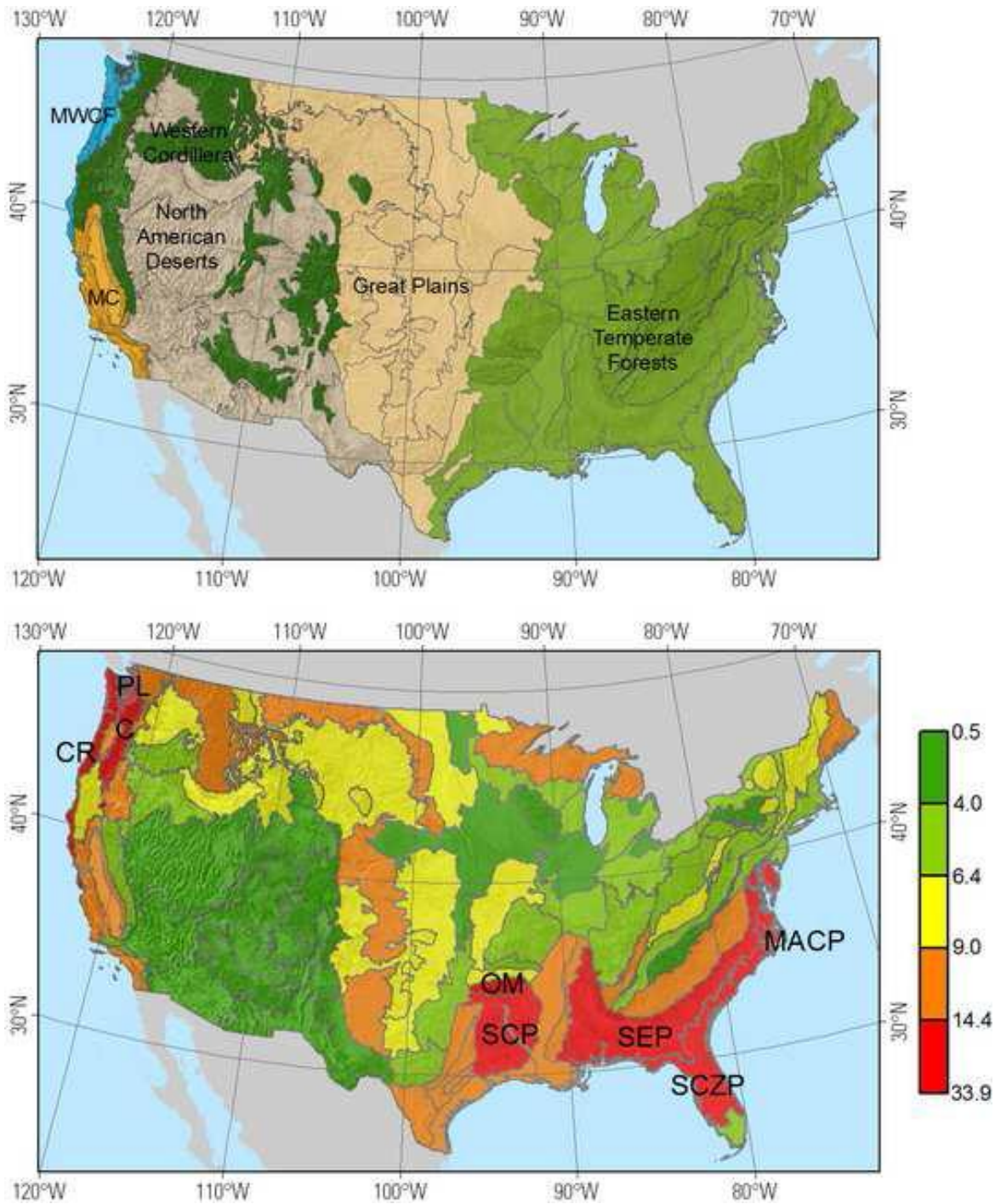

Figure 14. (Top Image) Six reporting regions partitioning the conterminous United States (MWCF is Marine West Coast Forests, MC is Mediterranean California, WC is Western Cordillera, NAD is North American Deserts, GP is Great Plains, and ETF is Eastern Temperate Forests), and (Bottom Image) the estimated land change footprint (LCF) for 1973-2000 (percent of ecoregion area).

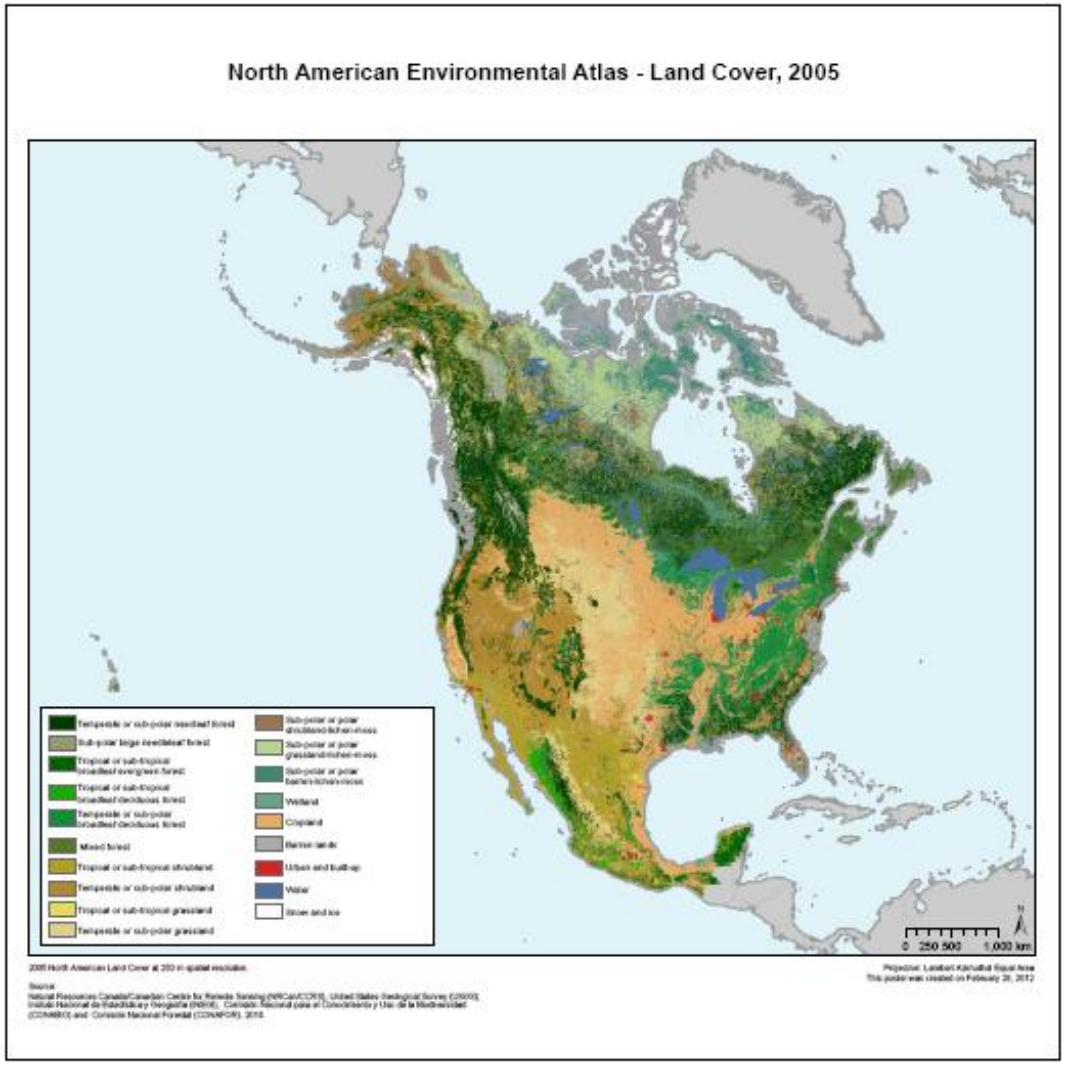

Figure 15. Land cover in North America, 2005. (Published with kind permission of ©Commission for Environmental Cooperation 2005, part of the North American Land Change Monitoring System, a joint project between the United States, Canada, and Mexico. All Rights Reserved.)

Landscape Dynamics and Global Change

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

Characterizing the Environmental Conditions and Estimating Aboveground Biomass Productivity for Switchgrass in the Great Plains

Switchgrass (Panicum virgatum), a perennial grass and a highly productive species, has been evaluated as a potential feedstock source for cellulosic biofuels and is being cultivated in several regions of the United States. Growing switchgrass for biofuel is more economically and environmentally sustainable than using corn for producing ethanol. For example, the use of switchgrass will minimize the effects of corn-based ethanol development on the global food supply, reduce soil erosion and water quality impairment from pesticides and fertilizer, and help preserve and augment soil carbon sinks. However, studies on the relationships between site conditions and switchgrass productivity to identify the important climate and environment drivers for the highly productive switchgrass over large areas are still under investigation.

USGS scientists have investigated the relationships between site biophysical, geophysical, climate, and weather conditions and switchgrass biomass productivity across different locations and developed a data-driven multiple regression switchgrass biomass productivity model to estimate the current and the future switchgrass productivity for the entire Great Plains based on remote sensing and ground observations.

Simple regression analyses between each individual environmental variable and switchgrass biomass productivity (growing season integrated normalized difference vegetation index (GSN)) were performed. The correlation coefficients (r) between each environmental variable and GSN were calculated and the strength of the relationship for each pair was evaluated. The general environmental conditions for the highly productive (i.e., GSN > 0.6) and unproductive (i.e., GSN < 0.3) switchgrass pixels were summarized. A multiple regression switchgrass productivity model was developed and the important environmental variables which contribute more for the switchgrass productivity model were identified. Results show that spring precipitation has the strongest correlation with switchgrass productivity (r = 0.92, 176 samples) and spring minimum temperature has the weakest correlation with switchgrass productivity (r = 0.16). An anticipated switchgrass productivity map for the entire Great Plains based on the site environmental and climate condition was generated (fig. 16b). The estimated switchgrass biomass productivity map indicates that highly productive switchgrass areas are mainly located in the eastern part of the Great Plains.

Results from this study can help land managers and biofuel investors better understand the general environmental conditions influencing switchgrass growth and make optimal land use decisions regarding switchgrass development in the Great Plains.

The USGS EROS Center provided remote sensing data, ecological modeling, geographic information science technology, and scientific analysis to generate biofuel feedstock potential datasets, maps, and results that can be used as a reference by land managers and biofuel investors for future biofuel feedstock development in the Great Plains. For further information, contact Bruce Wylie, USGS EROS, wylie@usgs.gov.

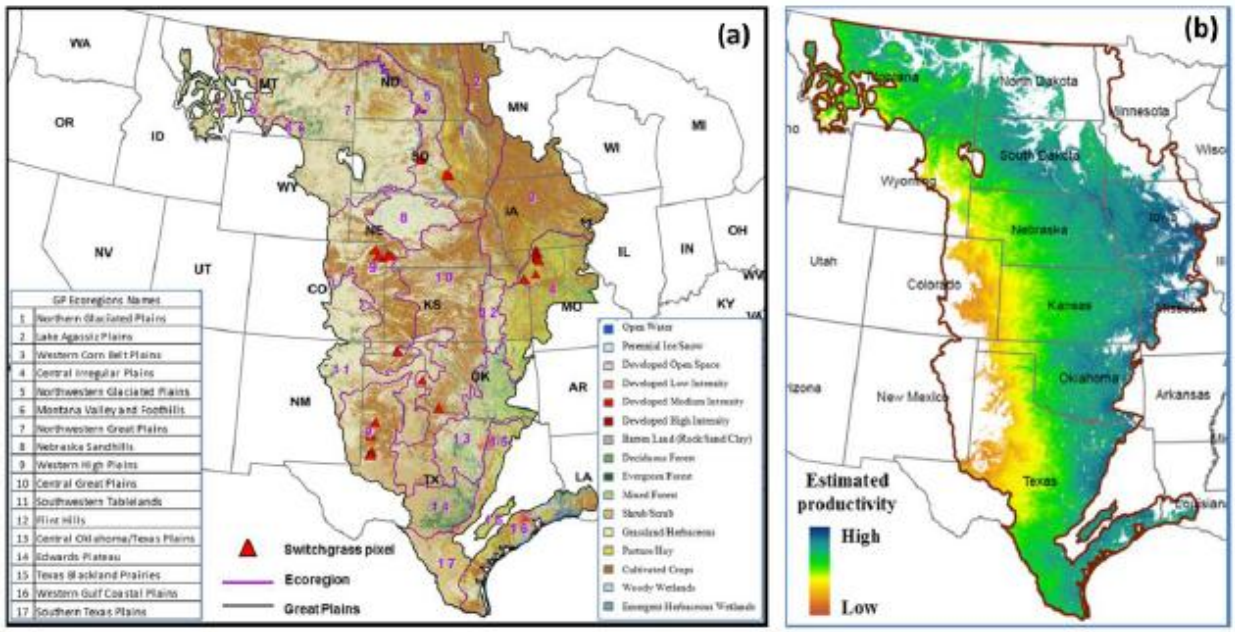

Figure 16. Maps showing (a) switchgrass land cover and (b) switchgrass biomass productivity estimation for the Great Plains.

Data Driven Carbon Flux

Grasslands are some of the most altered ecosystems in the world with large scale conversion from grassland to cropland. The Great Plains was once dominated by native prairie, but is now known as the breadbasket of the world with recent crop intensification driven by high crop prices and demand for biofuels. Grasses store most of their carbon below ground while annual crops extract carbon from the soil during the growing season and, with little carbon returning to the soil after harvest and tend to deplete soil carbon stocks. With increasing atmospheric levels of greenhouse gases, such as CO_2, knowledge of where terrestrial carbon sink and sources occur along with their frequencies and magnitudes are important. Quantification of terrestrial carbon fluxes aids in the identification of regions acting as carbon sinks or sources, the understanding of the drivers behind these phenomena, and can be influential to land-management, policy research and development, and decision making.

Carbon flux towers on grassland and cropland across the Great Plains quantify CO_2 movement into plants (photosynthesis) or out of soils, animals, and plants (respiration). Remotely sensed time series data and other digital map products are used with data-driven algorithms to map crop types and CO_2 fluxes at a weekly time step.

Grasslands of the Great Plains are usually near carbon equilibrium (weak carbon sinks), but dry and hot periods (droughts) can cause significant carbon sources. This results in climate-driven fluctuations in the carbon balance of the Great Plains. Crops of wheat and soybean have lower carbon uptake and often result in annual atmospheric carbon

sinks, while corn can have fairly consistent atmospheric carbon sinks (fig. 17). Atmospheric carbon sinks and sources do not include lateral carbon transfers related to crop harvests and the ultimate food consumption. With the addition of the newly developed crop maps, our flux mapping has become more comprehensive and accurate. Different crop types have varying photosynthetic pathways (C_3 versus C_4), which have different light and water use efficiencies. Different crops also have significant leaf structures (broad leaf versus grass-like leaves), which impacts light interception.

Quantification of terrestrial carbon sinks and sources helps to inform land management decisions, improve the understanding of carbon flux drivers, and assess sustainability. USGS scientists hope to extend this data-driven approach to grass and crop types across the conterminous United States, assess flux difference between grass and crops, and predict future fluxes. This work, supported by the USGS Land Change Science Program, makes use of the efforts of the Ameriflux network, Fluxnet, and the North American Carbon Program. For further information, contact Bruce Wylie, USGS EROS, wylie@usgs.gov.

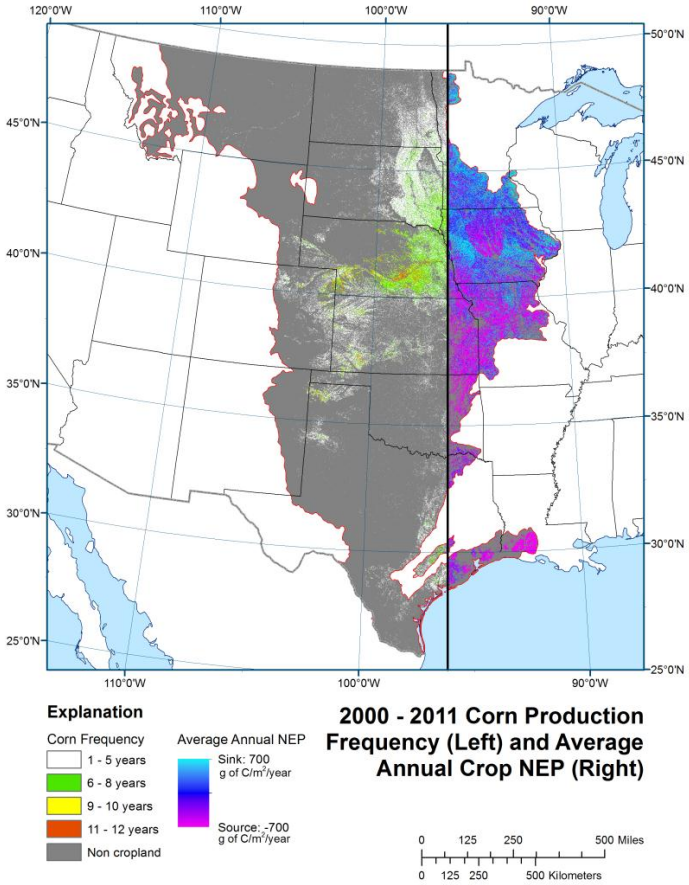

Figure 17. Corn production frequency 2000-2011 (left) and average annual net ecosystem productivity (NEP, g of C /m^2/year) for 2000-2011 (right) show areas with high corn frequency act primarily as a strong carbon sink.

How Fire Affects Cheatgrass Performance in the Northern Great Basin

Degradation of Northern Great Basin ecosystems caused by the cheatgrass invasion, and its subsequent dieoff, has led to a multi-year collaborative relationship between USGS EROS Center scientists and Bureau of Land Management personnel. This partnership resulted in the development of a cheatgrass performance anomaly time series (2000-2010) for the Northern Great Basin. This time series can help explain how cheatgrass performance is affected by fire. This science-based data and interpretation can increase land managers understanding of cheatgrass dynamics and enable them to make better decisions in areas where cheatgrass has degraded ecosystems and habitats. The degraded ecosystems and habitats reduce biodiversity and threaten wildlife species' survival.

Scientists have determined that the presence of cheatgrass in the Great Basin substantially increases fire frequency and fire size. As a result, a keystone species in this area, sagebrush, is much less common than before. Scientists have also determined that fire can kill cheatgrass seed. Some cheatgrass seed survives fire, and decreased plant density, but increased plant vigor has been observed one year after fire. In light of these discoveries, scientists wanted to know what affect fire would have on cheatgrass performance anomaly through time, so we cross referenced our time series with areas of known fires. The resulting graphic (fig. 18) tracked mean cheatgrass ecosystem performance anomaly (EPA) values for 10 years in burned areas. Large negative EPA values indicate *lower than* expected cheatgrass performance given weather and site conditions. Near zero EPA values represent expected cheatgrass performance, and large positive EPA values indicate *greater than* expected cheatgrass performance.

Individual post-fire EPA values can vary dramatically based on circumstances like fire intensity, fire severity, location characteristics, and post-fire management actions. This caused substantial post-fire EPA variation among burned areas. Therefore, understanding the mean EPA values can be valuable. Figure 18 shows that for one year post-fire, mean EPA values dropped significantly from the previous three years, when values were stable. Cheatgrass EPA values spiked during the second year post-fire and remained relatively stable during the third year post-fire. Cheatgrass EPA values dropped during the fourth year post-fire. The substantial drop in first year post-fire EPA values matches expectations when less seed would be available for germination. The second year spike in performance could be reflective of seed bank recovery because of vigorous plant growth combined with likely increased soil nutrients.

Performance anomalies produced a consistent time series of cheatgrass performance normalized for weather and site conditions. This allowed time series analysis in old burn areas to focus on cheatgrass variations related primarily to fire effects rather than on interannual variations in weather. Post-fire cheatgrass EPA values were low the first year after a fire, but during the second and third years' post-fire, the values were slightly greater than pre-fire cheatgrass EPA values. This regional summarization may indicate that optimal cheatgrass control may be the first year after the fire. The post-fire boost in

cheatgrass primarily during the second and third years' post-fire may indicate these are critical years of fine fuel build up, which increases wildfire probabilities. For further information, contact Bruce Wylie, USGS EROS, wylie@usgs.gov.

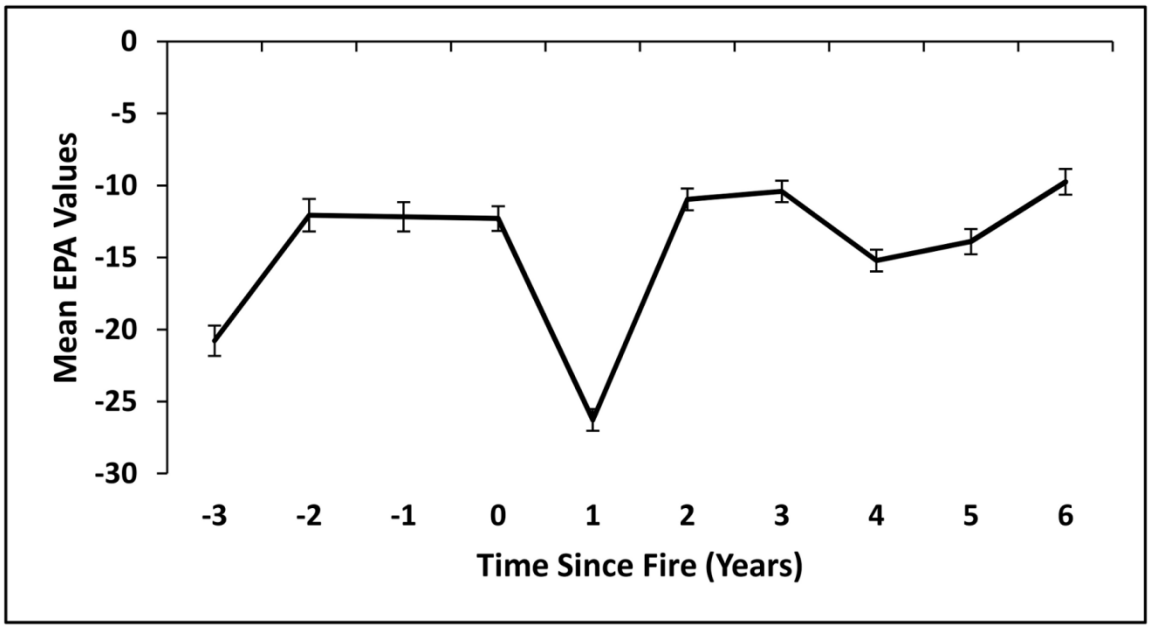

Figure 18. The effects of fire on cheatgrass performance graph shows the mean cheatgrass ecosystem performance anomaly values of 17,050 pixels for up to three years pre-fire, the year of fire, and up to six years post-fire. The standard error of the mean is displayed as whiskers. Data are from a sample of 1,295 fires that burned from 1997-2010 in the Northern Great Basin.

Grassland Condition and Carbon Fluxes

Suitable management and sufficient precipitation on grasslands can provide carbon sinks. The net carbon accumulation of a site from the atmosphere, modeled as the net ecosystem productivity (NEP), is a useful means to gauge carbon balance. Previous research has developed methods to combine flux tower data with MODIS to estimate NEP across large regions. A separate method uses the ecosystem performance anomaly (EPA) as a satellite-derived indicator of disturbance intensity. Grasslands in the Northern Great Plains tend to have a long-term cumulative carbon balance near equilibrium or slightly positive (sink). Improved understanding of grassland carbon fluxes are needed to determine their potential role in mitigating increasing atmospheric CO_2 concentrations and global change and the influence of management on ecosystem carbon.

Scientists evaluated the relationship between EPA and NEP data at the 250-meter scale for grasslands in the Central Great Plains, United States (ranging from semi-arid

to mesic). Also, weekly estimates of NEP were used to evaluate the phenology of carbon dynamics, classified by EPA (i.e., by level of disturbance impact) (fig. 19).

Overall, NEP increased with precipitation ($R^2 = 0.39$, $P < 0.05$) from west to east. Disturbance influenced NEP phenology; however, climate and biophysical conditions were usually more important (fig. 19). The NEP response to disturbance varies by ecoregion, and more generally by grassland type, where the shortgrass prairie NEP is most sensitive to disturbance, the mixed-grass prairie displays a moderate response, and tallgrass prairie is the least impacted by disturbance (as measured by EPA).

Sustainable management practices in the tallgrass and mixed grass prairie may potentially induce a period of average net carbon sink until a new equilibrium soil organic carbon is achieved. In the shortgrass prairie, management should be considered sustainable if carbon stocks are simply maintained. Results clarify the seasonal and interannual dynamics of NEP, specifically the influence of disturbance and moisture availability. The USGS has developed an online platform to view and manipulate EPA data http://lca.usgs.gov/blm/viewer.php?region=uppercolorado. These maps, datasets, and graphs can be used to improve the efficiency and quality of land management practices.

This work is useful in the assessment of carbon sink potential of grasslands and identifying regions where changes in management practices could induce a carbon sink. This information can support range management decisions in private and Federal (U.S. Forest Service National Grasslands, Bureau of Land Management, and Bureau of Indian Affairs) lands, leading to more efficient allocation of resources to sequester additional carbon and improved range condition. This work, funded by the USGS Land Change Science Program, also supports the North American Carbon Program and could help quantify rangeland carbon credits. For further information, contact Bruce Wylie, USGS EROS, wylie@usgs.gov.

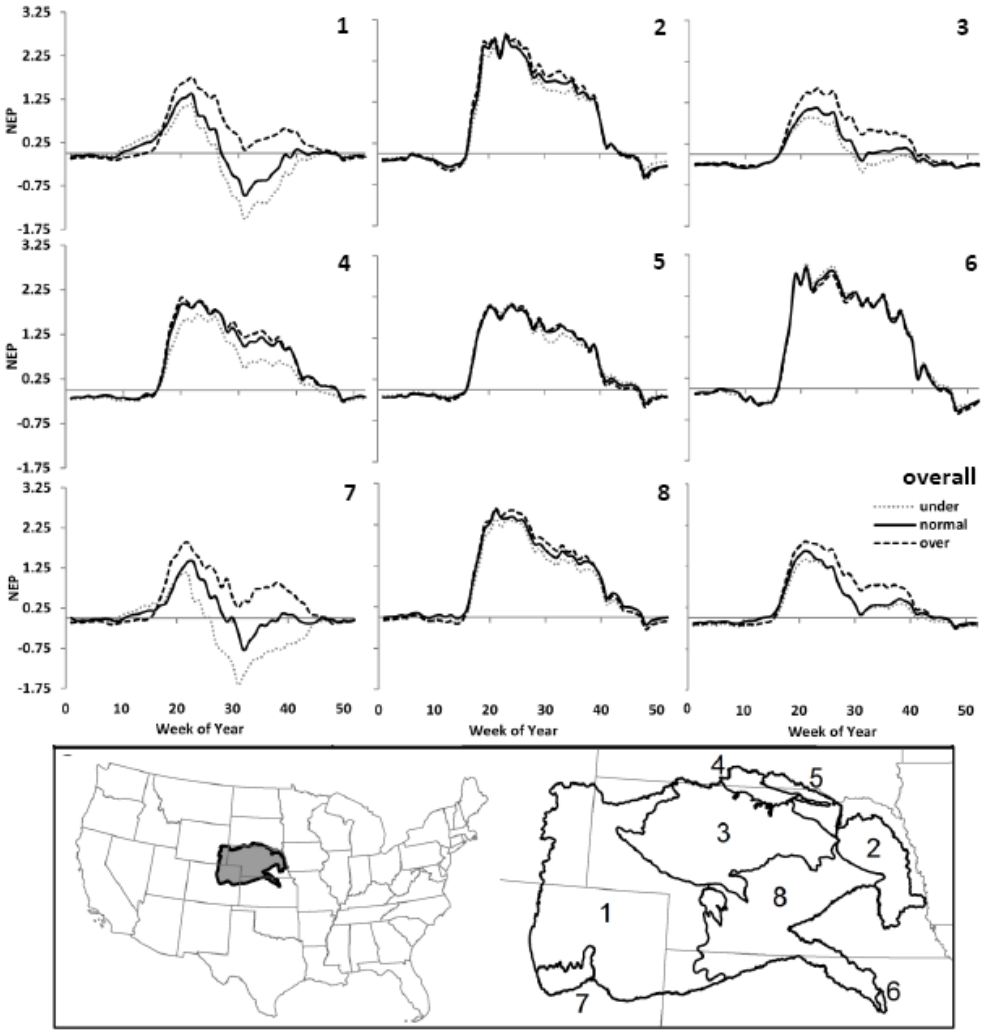

Figure 19. Figure shows 2000-2008 average weekly net ecosystem productivity (g C m-2·day-1) by ecosystem performance anomaly classes (underperforming, normal performing, and over performing) in the (1) High Plains, (2) Western Corn Belt Plains, (3) Nebraska Sand Hills, (4) Northwestern Great Plains, (5) Northwestern Glaciated Plains, (6) Flint Hills, (7) Southwest Tablelands, (8) Central Great Plains ecoregions, and overall average. Carbon uptake by plants represents a positive net ecosystem productivity and release to the atmosphere is a negative value.

How Much Corn Stover Can Be Used Sustainably for Biofuel Production in the Conterminous United States?

The increasing societal need for renewable energy from the agricultural sector offers new opportunities and challenges as we redefine ecosystem goods and services in view of sustainable land use and management under changing climates. There is a great potential for using corn stover as a feedstock for biofuel production in the United States,

but harvesting excessive amounts of corn stover could have long-term negative impacts on soil quality, soil carbon stock, and nutrient balances. The challenge is to develop cropping systems that can balance the demand for increased biofuel feedstock production with the maintenance of other critical ecosystem services.

This project was designed to evaluate the extent to which the corn stover can be sustainably harvested as cellulosic feedstock for biofuel production and its impacts on soil organic carbon (SOC) and nutrient budgets in the conterminous United States at present and in the future.

Scientists conducted research using the following procedures: (1) compile published field observation data that show how corn stover removal affects SOC content under various conditions; (2) develop a framework to define the minimum stover requirement (MSR) for maintaining SOC level in association with the baseline SOC content, tillage practices, corn grain yield, and crop rotation systems; (3) formulate three MSR level scenarios to compute the harvestable stover amount; and (4) calculate the amounts of soil nitrogen (N), phosphorus (P), and potassium (K) being removed and requirements with each harvestable stover level.

The county-based harvestable stover yields at present (A) and in 2050 (B) are presented in figure 20. The magnitude of the current harvestable stover amount is limited (31×10^{12} g y^{-1}, dry matter) due to the high minimum stover requirement for maintaining the current SOC content at a high level. An alternative definition of minimum stover requirement for soils with a moderate level of SOC content could significantly increase the annual harvestable stover amount to 68×10^{12} g y^{-1} with no significant influence on soil organic carbon and soil NPK contents. In the future, a greater potential for stover feedstock could come from an increase in stover yield, areal harvest index, and manure application.

The research results have been published in journals of “Biomass and Bioenergy” (2012) and “Global Change Biology-Bioenergy” (in press). For further information, contact Dr. Shuguang Liu, USGS EROS, sliu@usgs.gov.

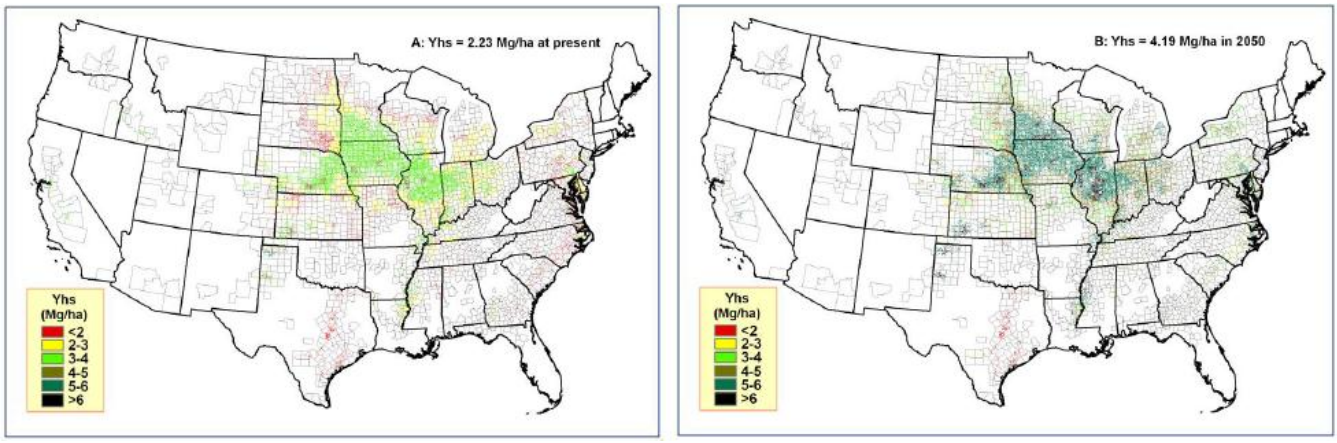

Figure 20. County-based harvestable stover yields at present and in 2050.

Fire Impacts on Vegetation Photosynthesis in Alaska

USGS scientists, in partnership with the Washington State University and University of California, have integrated satellite images and flux tower measurements to model spatially explicit fire impact on vegetation production in interior Alaska.

Gross primary production (GPP) is the amount of carbon fixed by vegetation through photosynthetic assimilation; it is critical in land surface-atmosphere interactions and a key component of ecosystem carbon fluxes. However, fires change the carbon dynamics, and the impact of fires on GPP is spatially heterogeneous, which is difficult to evaluate using limited point-based comparisons or satellite vegetation indexes.

Remote sensing from space allows USGS scientists to capture the pre- and post-fire images, which can be used for depicting the change in vegetation cover and density. Flux tower measurements allow calibrating a model that represents the efficiency of vegetation using solar light or photosynthetically-active radiation (PAR). Therefore, USGS scientists combined remote sensing and flux tower measurements for this study.

Satellite images show the study area was covered by evergreen needleleaf forest (EF, 54 percent), deciduous broadleaf forest (DF, 11 percent), and shrub/grass mixed (SG, 35 percent) before the fire in 1998 (fig. 21). After the fire, the percentages changed to 11 percent, 20 percent, and 69 percent in 2004. Flux tower measurements show the maximum light efficiency for EF, DF, and SG are 1.1556, 1.3336, and 0.5098 gC/MJ PAR. With the combination of remote sensing and flux tower data, the study showed rapid post-fire recovery of GPP with a 24 percent recovery immediately after burning and 43 percent one year later. For the fire scars with an age range of 2-17 years, the recovery rate ranged from 54 percent to 95 percent.

The methodology developed for this study revealed the spatial heterogeneity of fire impact on GPP, allowing one to examine the spatially explicit GPP change caused by fires. The approach of integrating satellite images and flux tower data can be widely used for investigating the effect of disturbance on carbon cycle.

The partners include USGS, NASA, the FLUXNET (a "network of regional networks" that coordinates regional and global analysis of observations from micrometeorological tower sites), and the universities who are involved in satellite image processing and field data collection.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, ecological modeling, and geographic information system technologies to support this project. For further information, contact Dr. Shuguang Liu, USGS EROS, sliu@usgs.gov.

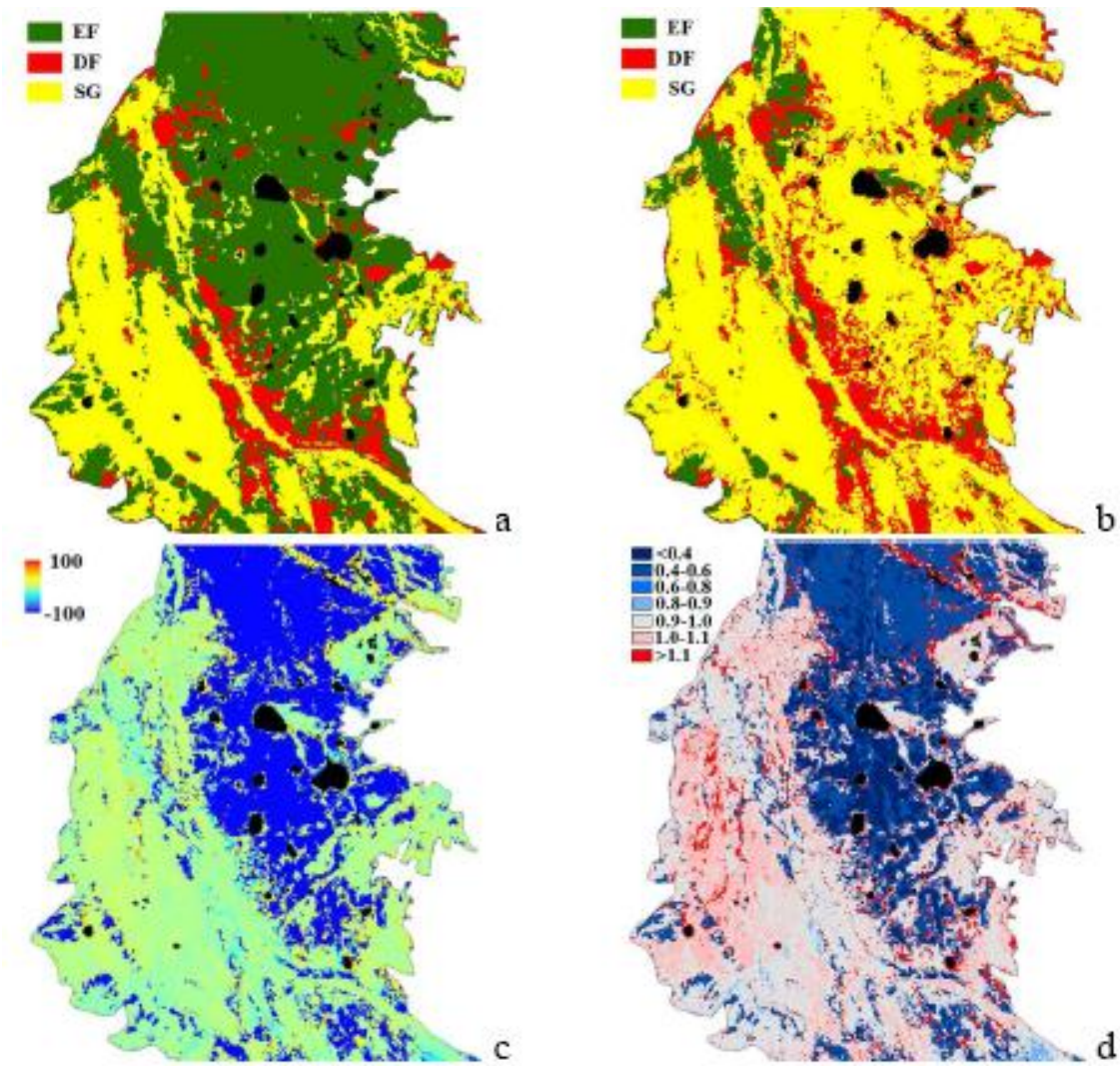

Figure 21. The satellite images during pre-fire (a) and post-fire (b) that show the change in evergreen needleleaf forest (EF), deciduous broadleaf forest (DF), and shrub/grass mixed (SG). These images were used to model the gross primary production change absolutely (c, in unit of gC/m^2) and relatively (d, a unitless ratio). Width 10.5 kilometer and height 11.5 kilometer.

Assessment on Potentials for Carbon Sequestration and Greenhouse Gas Emissions Reduction in the Eastern United States

This is a part of the USGS effort to fulfill the requirements of section 712 of the Energy Independence and Security Act of 2007 to conduct a comprehensive national assessment of potentials for carbon (C) sequestration and reduction of greenhouse gases (GHGs) emissions (CO_2, CH_4, and N_2O). This assessment covers all major terrestrial ecosystems (forests, grasslands/shrublands, agricultural lands, and wetlands) and aquatic ecosystems (rivers, streams, lakes, estuaries, and coastal waters) from 2001 to 2050 in the eastern United States.

Consistent with the approach used for two other regional assessments conducted for the Great Plains (Zhu and others, 2011) and the western United States (Zhu and Reed, 2012), the General Ensemble biogeochemical Modeling System (GEMS) was used for simulating ecosystem biogeochemical cycles including carbon stock and fluxes and GHGs emissions under various LULC change and climate change scenarios developed in accordance with storyline A1B, A2, or B1 from the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios.

The average carbon storage in biomass and soils (up to 20 cm in depth) was estimated to be 26,962 TgC for the baseline period (2001 to 2005) for the eastern United States (fig. 22), and was projected to increase to 37,082 TgC in 2050. The baseline carbon sequestration rate (or net ecosystem carbon balance) was estimated to be -279.4 TgC/year (negative sign denotes a carbon sink – land absorbs carbon from the atmosphere). However, the strengthen of carbon sequestration was projected to decline with an average of -224.9 TgC/year from 2006 to 2050. The global warming potential (GWP) of the GHGs emissions was estimated to be -656.9 $TgCO_{2\text{-}eq}$/year for the baseline period $TgCO_{2\text{-}eq}$/year, respectively, equivalent to 11.7 percent of the nationwide fossil-fuel emissions in 2010 (EPA, 2012). The overall GWP for the period of 2006 to 2050 was averaged at -300 $TgCO_{2\text{-}eq}$/year. More detailed information can be found in the upcoming USGS report for the eastern United States.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides scientific analyses based on remote sensing, ecological modeling, and geographic information system technologies to support this project. For further information, contact Dr. Shuguang Liu, USGS EROS, sliu@usgs.gov.

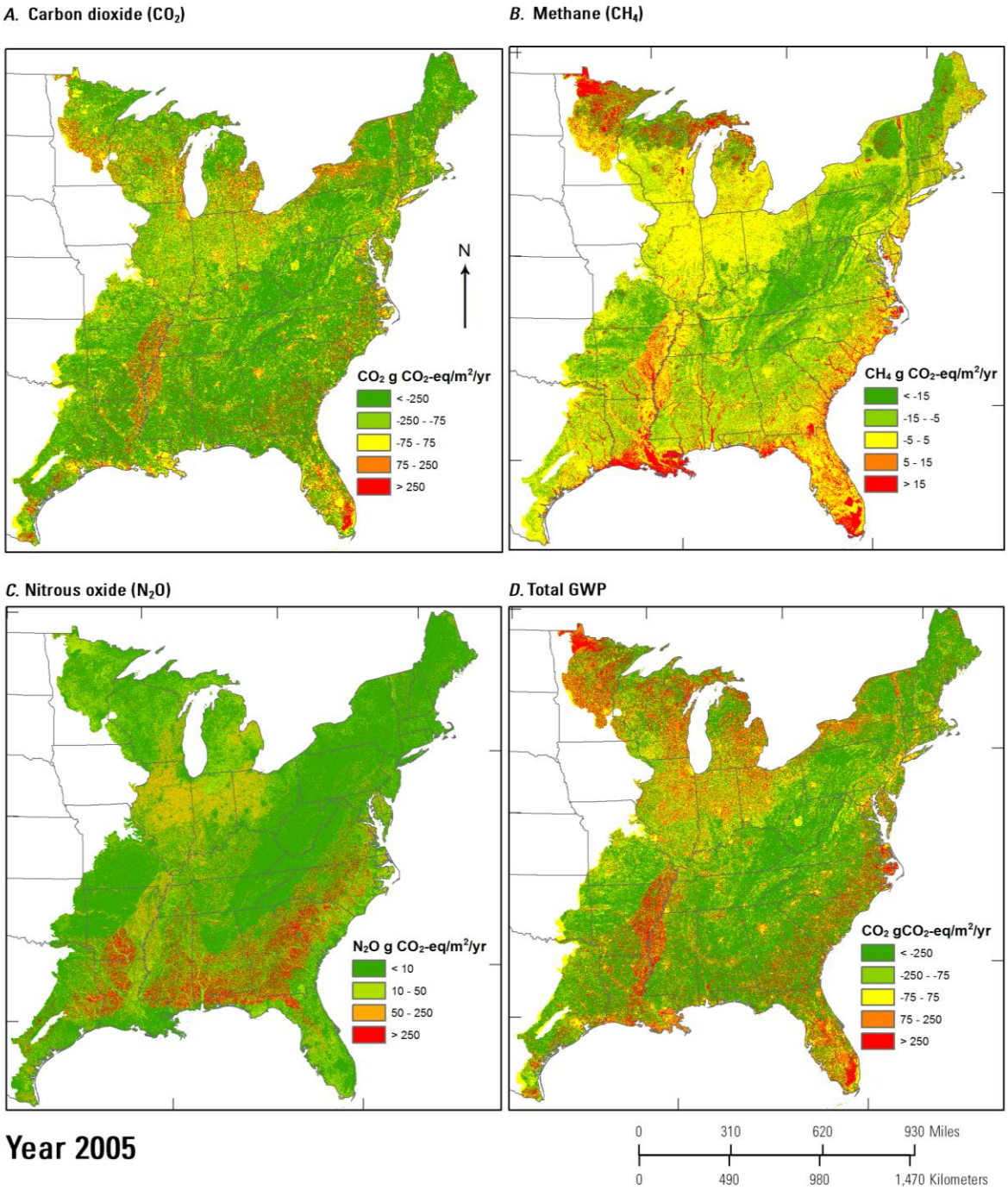

Figure 22. Maps showing the spatial distribution of the average annual carbon dioxide, methane, and nitrous oxide fluxes and their total global warming potential from 2001 to 2005 in the eastern United States.

Investigating Changes in Surface Water Availability and Their Impact on Ecosystems

Inland waters, such as lakes, rivers, and wetlands, can display dynamic behavior in response to natural or manmade events. Sometimes the dynamic fluctuations are in response to seasonal changes in weather or snowpack while at other times, the changes are a result of near-by land change, or even a catastrophic event (fig. 23). Identifying where and how much change occurred are necessary to investigate the processes involved and the impacts on water availability. Remote sensing is a useful tool for evaluating change over large regions with thousands of lakes and wetlands. The project has study areas ranging in size from just under 30,000 km^2 to nearly 1 million km^2. The temporal scale also varies from the 1970s to present. Data acquired from the Landsat program provides observations of inundated areas for these spatial and temporal scales.

Methodology includes the analysis of numerous remotely sensed observations to identify where water bodies occur. The results identify how water bodies change over time and which water bodies have significant increases or decreases in their inundated area. The data and results are useful for many additional water-related studies carried out by scientist from the USGS, the U.S. Fish and Wildlife Service (FWS), and the National Geospatial-Intelligence Agency (NGA). For example, one study aggregates water bodies with similar trends or changes over decadal periods into groups using traditional classifications schemes. This helps identify areas where groundwater or subsurface flow may influence water balance. In Alaska, one study answered questions about how permafrost and soil properties influenced lake change. In another study, the differences in water dynamics between lakes and lake water isotope data were used to determine how source water and climate influenced the long-term trends in lake-area extent.

Future projects include incorporating aerial waterfowl survey data collected by FWS, identifying changes in the inundated areas of playas located in the Great Plains, investigating whether surface water changes can be identified in fracking areas, and looking at relationships between water quality parameters and changes in lake extents (fig. 24). Models will be developed to investigate waterfowl nesting habitat in past years and how that relates to habitat and water availability. Changes in water extent within playas and various ancillary data such as land use and climate data will explore shorebird, water bird, and stop-over migratory birds. The data should also provide a means to estimate the recharge potential to the Ogallala aquifer. Modeling lake processes can also be used to monitor and predict where changes in water availability are most likely to occur. This information will be useful for forecasting potential changes considered detrimental to wildlife and society, and may provide an opportunity to circumvent some of the negative consequences. For further information, contact Jennifer Rover, USGS EROS, jrover@usgs.gov.

Figure 23. This photo of a lake in central Alaska captures the exposed lakebed shortly after a catastrophic event. The deeply eroded channel on the upper-right side of the lake formed in the spring of 2013 and allowed water to drain quickly from the lake. Fireweed (pink flowering vegetation) is visible around the perimeter of the lake and beyond in areas where a wild fire recently occurred.

Figure 24. Water quality parameters collected by the U.S. Fish and Wildlife Service and U.S. Geological Survey from sample lakes provide information about each lake, potential habitat, and are expected to explain lake change processes.

Topographic Science, Elevation, and Lidar

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

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

The National Atlas of the United States® produces maps, datasets, and geographic information at regional and national scales for use by Government agencies, mapping professionals, and the public. The project is funded by the USGS National Geospatial Program (NGP) under Core Science Systems and is managed by Jay Donnelly. In FY 2013, the National Atlas continued to work on 1:1,000,000-scale datasets, representing the USGS's first original compilation in many years of a comprehensive, national-coverage base dataset.

Two accomplishments have been highlighted from the body of work performed in support of million-scale dataset development by the National Atlas Project at EROS in FY 2013:

1. Several new 1:1,000,000-scale National Atlas base data layers were created as 100-meter resolution images: Elevation and several derivatives, including color-sliced elevation (fig. 25); land cover; impervious surfaces; tree canopy; Landsat mosaic; and Natural Earth. These 100-meter datasets, together with co-registered vector overlays, were introduced at a special National Atlas of the United States session of the North American Cartographic Information Society (NACIS) Conference in October 2012, where they drew a high level of interest from the professional cartographic community.

   To make them cartographically useful, all of the new 100-meter images were masked and filled to the National Atlas 1:1,000,000-scale coastline, a two-step process shown for land cover in figures 26a, 26b, and 26c. This approach was presented at the NACIS Conference.

2. Populated places (cities, towns, etc.) are a critical part of million-scale base mapping, and are a major dataset still under development. National Atlas staff at the USGS EROS are responsible for cartographic review of million-scale populated places; review is now 73 percent complete (31,190 cities out of 41,103 checked) (fig. 27 and 28).

In the future, the National Atlas will function as the small-scale component of NGP's National Map Project. Small-scale datasets, like the million-scale data compiled by the National Atlas, are important sources for both government and professional cartographers to build products for maps, viewers, and as a framework for science

dataset development. For further information, contact John Hutchinson, hutch@usgs.gov.

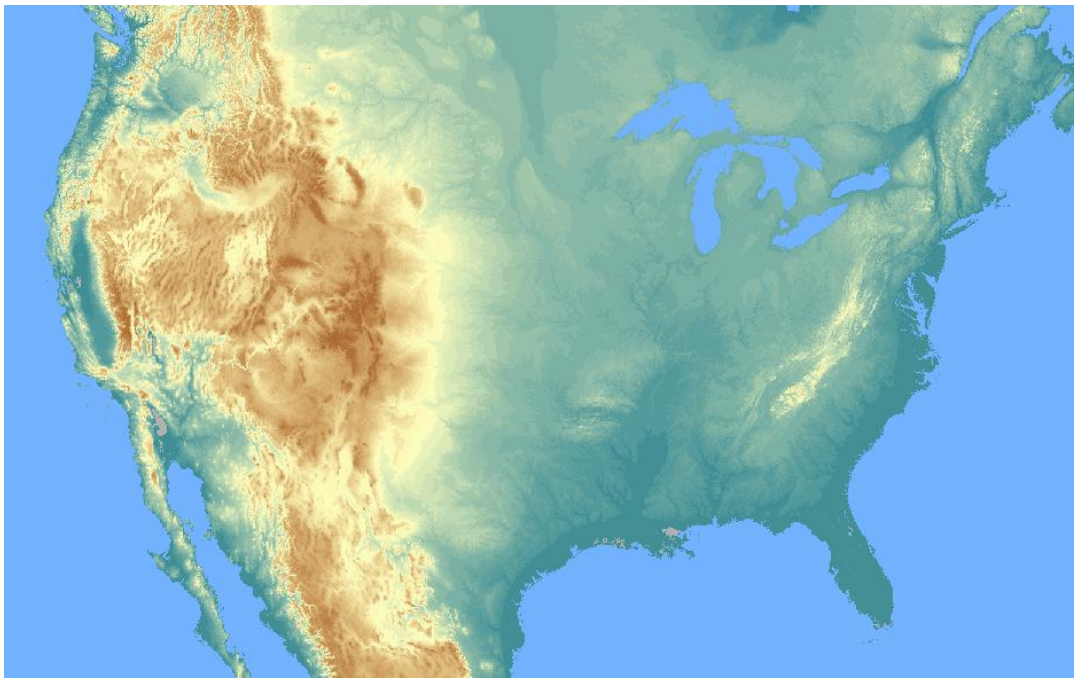

Figure 25. Figure shows 100-meter color-sliced elevation, a new 1:1,000,000-scale National Atlas product.

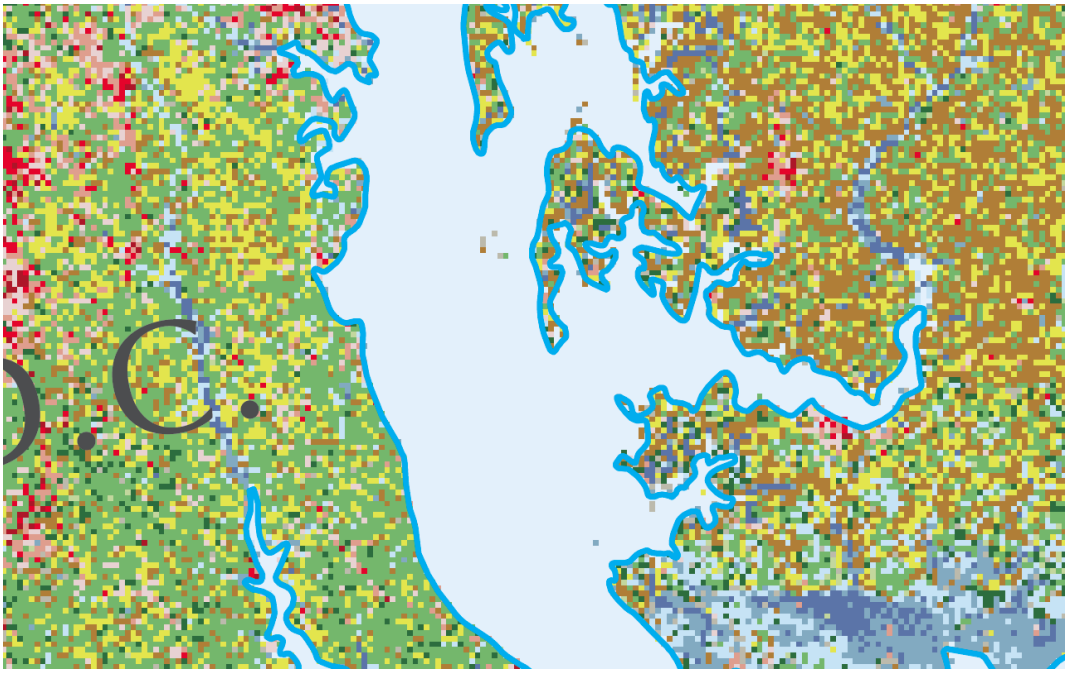

Figure 26a. Figure 26a shows the original land cover data at 100-meter resolution, before any masking or filling.

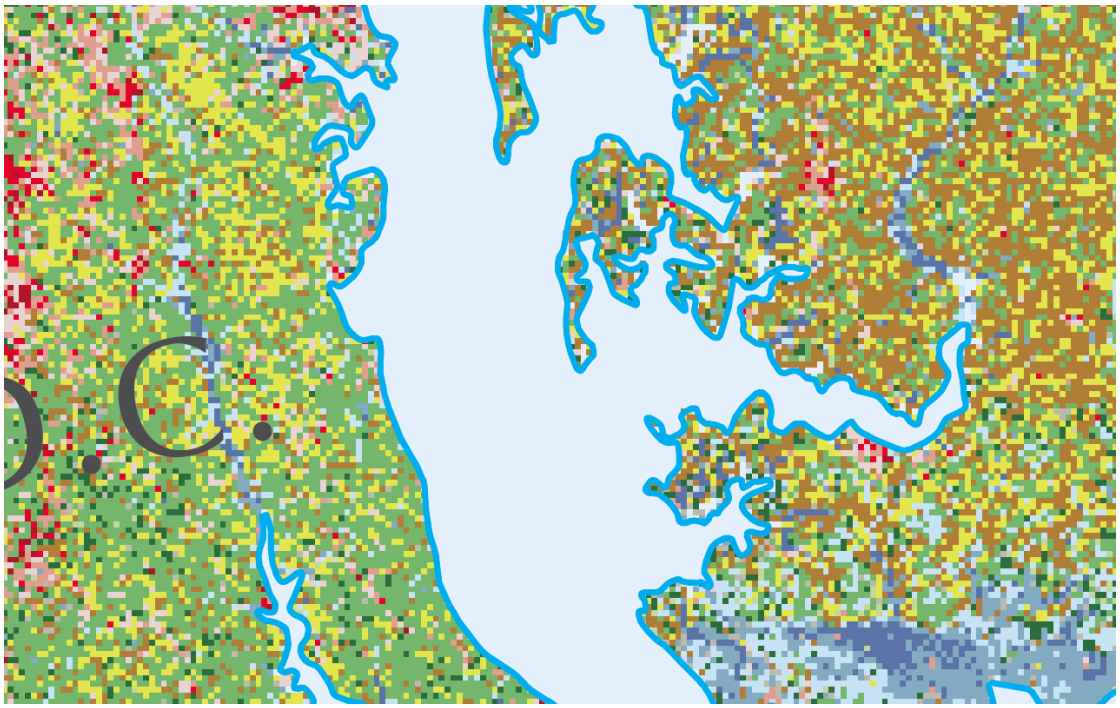

Figure 26b. Figure 26b shows the results of masking: 100-meter land cover to the 1:1,000,000-scale coastline.

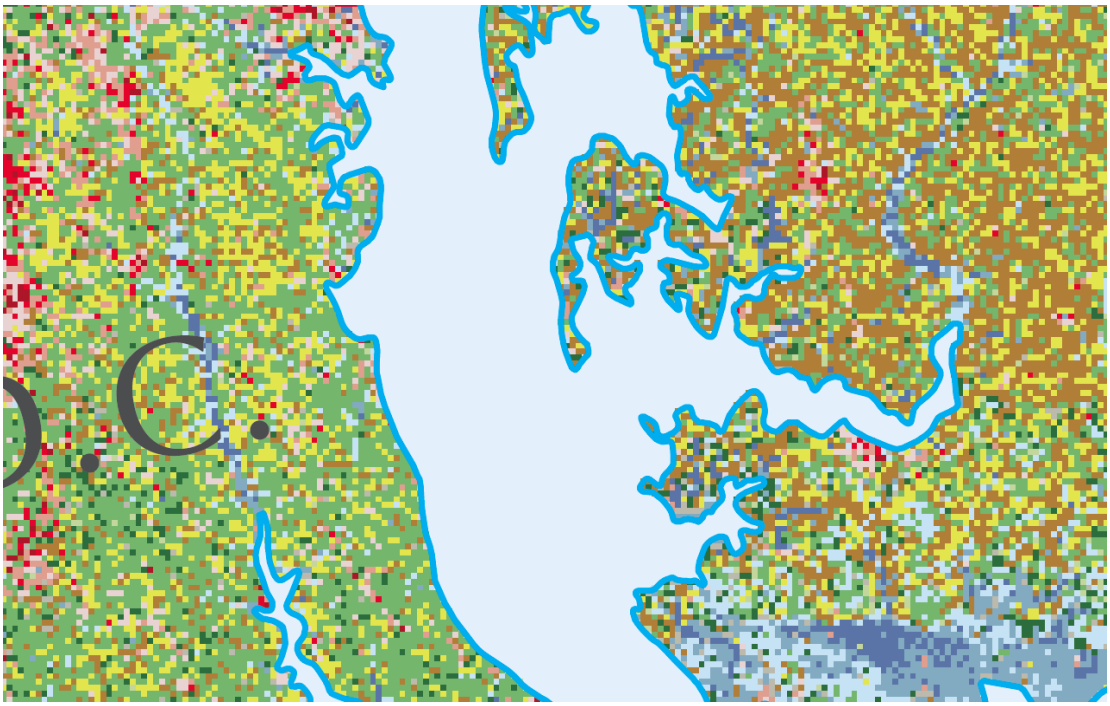

Figure 26c. Figure shows the results of filling 100-meter land cover out to the 1:1,000,000-scale coastline.

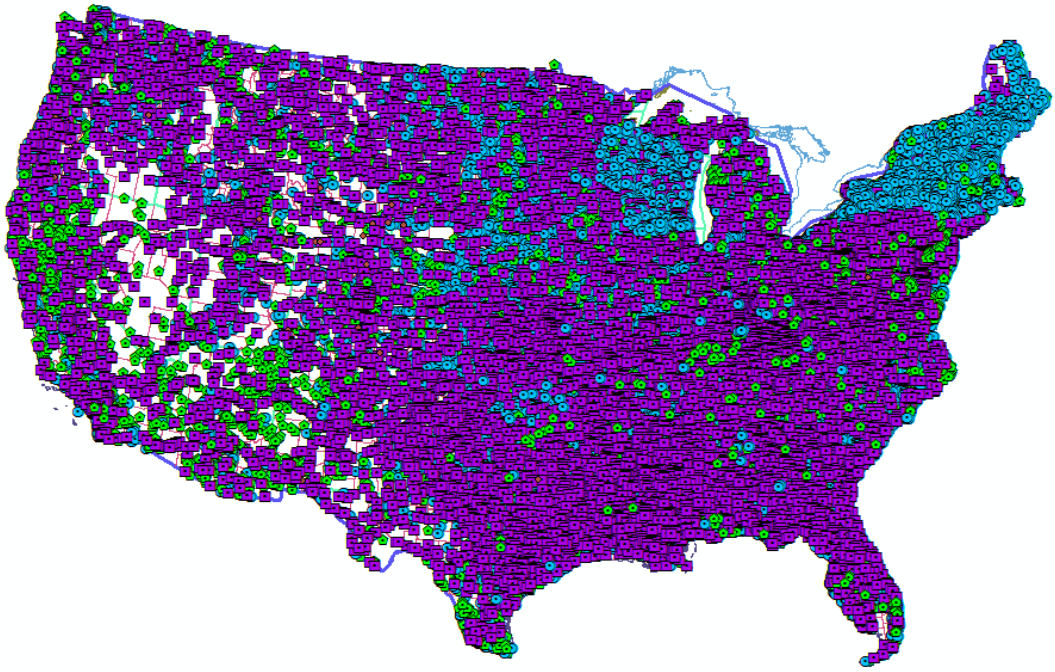

Figure 27. There are 41,103 populated places in conterminous United States being reviewed for depiction at 1:1,000,000 scale.

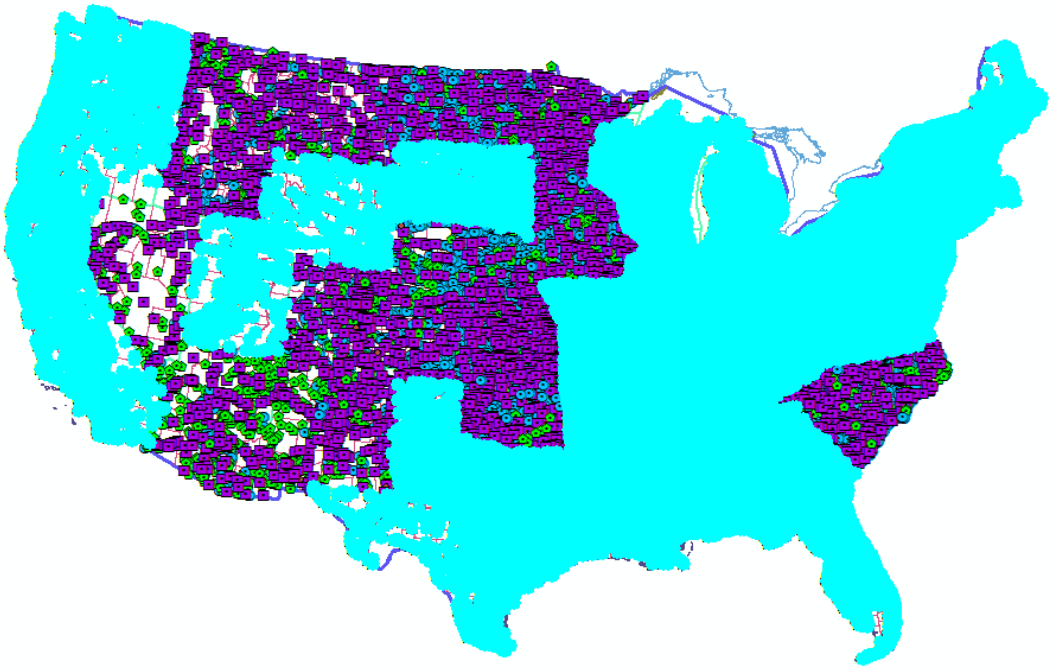

Figure 28. Review of populated places is 73 percent complete (blue highlighted states have been reviewed).

The National Elevation Dataset: Continued Growth and Development in Support of Scientific and Mapping Applications

The National Elevation Dataset (NED) is the primary elevation data product produced and distributed by the USGS in partnership with the National Geospatial Program. The NED provides seamless raster elevation data of the conterminous United States, Alaska, Hawaii, and the island territories. It is derived from diverse source data that are processed to a specification with a consistent resolution, coordinate system, elevation units, and horizontal and vertical datums. The NED is the result of the maturation of the long-standing USGS elevation program, and serves as the elevation layer of *The National Map*. The NED provides elevation information for Earth science studies and mapping applications in the United States, and is available nationally at grid spacings of 1- and 1/3-arc-second (~30 meter and 10 meter respectively) for the conterminous United States, and 1/9-arc-second (~3 meter or better) for parts of the United States.

Topobathymetric data have become a new component to the NED data collection. These data are created by merging topography (land elevation) and bathymetry (water depth) into a seamless elevation product useful for applications such as wetland modeling, sea level rise assessment, and storm surge. It is centered over San Francisco Bay, California, and dramatically illustrates many prominent geophysical features of the area: the seafloor of the Golden Gate Strait separating San Francisco and Marin County, the San Andreas Fault, and the Farallon Islands and Escarpment to name a few.

The addition of 2,759,150 square miles of Canadian data to the NED 1-arc-second data layer provides near full coverage of the North American continent (fig. 29). NED went international with an interagency collaboration with the Mexico's National Institute of Statistics and Geography (INEGI) resulting in the addition of Mexico in October 2008. In 2012, a similar collaboration with the Natural Resources Canada (NRCAN) Centre for Topographic Information-Sherbrook, Ottawa, led to the addition of Canadian data along the adjoining Canadian and United States borders completing shared watersheds. The data used to complete Canada in 2013 were also provided by NRCAN. This cooperative North America elevation model provides efficiency to customers as seamless elevation data across country boundaries can be accessed from one provider.

Improvement of Alaska elevation data has been a main goal for the past several years and will continue to be a focus in the future. For years, Alaska has only been covered by 2-arc-second (~60 meter) source data, which was mostly developed with source maps dating back prior to 1950. Over the last few years, acquisitions of lidar and Interferometric Synthetic Aperture Radar have been added to the NED collection resulting in 37 percent of Alaska being cover by 10-meter or better source data.

Several lidar workshops, presentations, elevation technical workshops, and panel discussions were led in FY 2013 in support of the lidar specification, lidar processing, and status of lidar datasets destined for the NED collection. The NED team is always looking for new and better ways to provide scientists and resource manager with the

best available science-ready digital elevation data to support global change research, hydrologic modeling, resource monitoring, mapping and visualization, and many other applications. For further information, contact Gayla Evans, USGS EROS, gevans@usgs.gov.

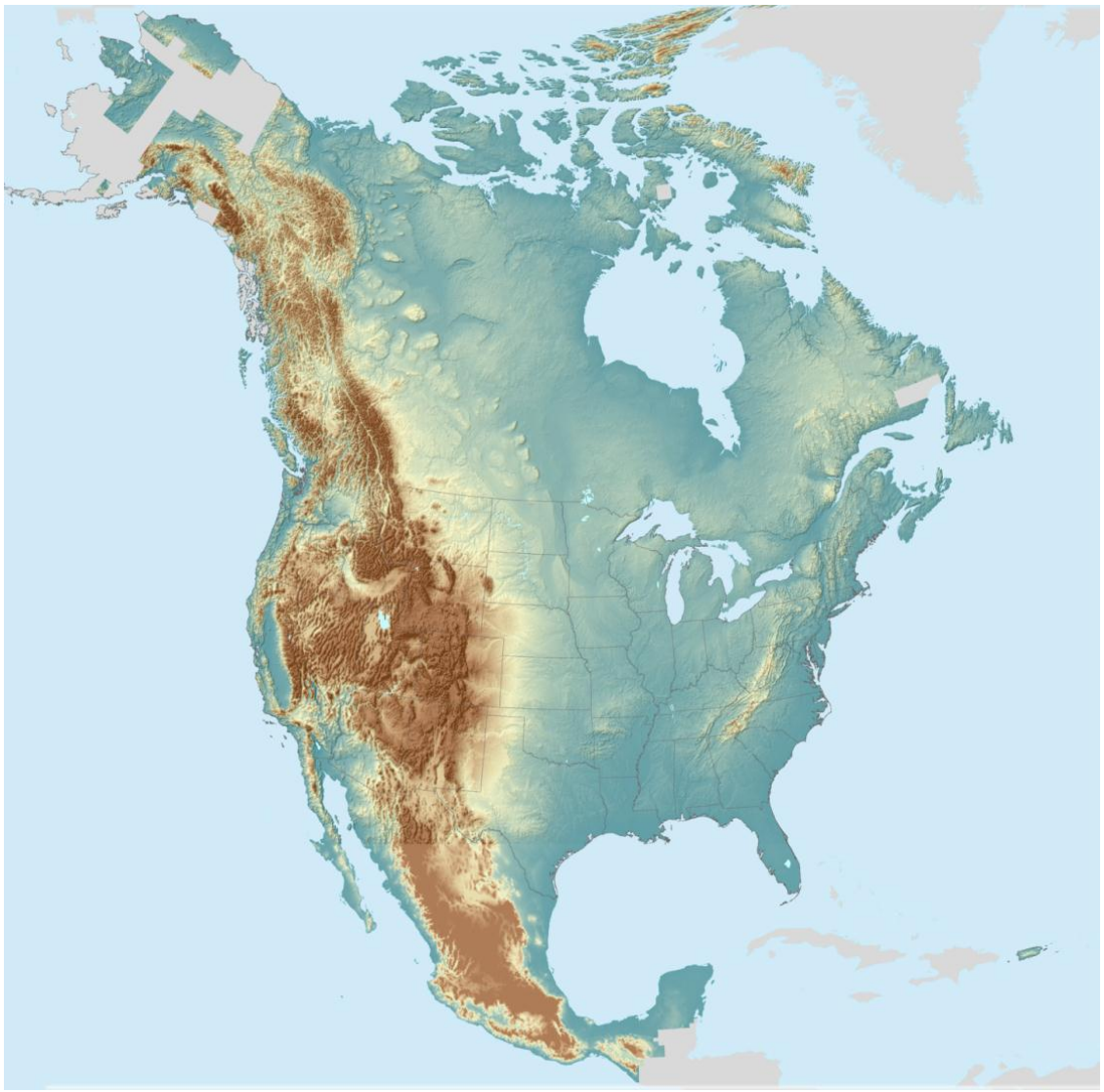

Figure 29. Elevation of the North American continent.

Coastal National Elevation Database: San Francisco Bay, California

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. 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 (DEMs) 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.

A 2-meter topobathymetric elevation model was developed for San Francisco Bay by integrating dozens of high-resolution lidar and bathymetric surveys acquired by numerous sources (fig. 30). San Francisco Bay is a productive, shallow estuary that receives water from the Sacramento and San Joaquin rivers, which drain the Sierra Nevada mountains, through the Bay to the Pacific Ocean. Coastal research scientists are using the high-resolution integrated elevation surface in the assessment of sea level rise vulnerability and with the numerical modeling of sediment resources and contaminants.

The CoNED Project in FY 2014 plans to release a 3-meter topobathymetric elevation model for Southern Louisiana that will extend from the Alabama/Florida border on the east to the Louisiana/Texas border on the west that encompasses the offshore barrier island systems in the Gulf of Mexico. In addition, topographic and bathymetric elevation data from multiple sources will be processed and combined with the NED to create seamless and integrated topobathymetric models at 1-meter within the Hurricane Sandy impact area. A regional topobathymetric elevation database (CoNED) and derivative products for the entire Hurricane Sandy impact region will be constructed to serve post-Hurricane Sandy recovery and other needs, including assessing coastal landscape change and vulnerability; designing restoration, redevelopment, and protection projects; predicting future hurricane storm surge, coastal and inland flooding and; and devising strategies for climate change adaptation from sea-level rise and other effects. For further information, contact Jeffrey Danielson, USGS EROS, daniels@usgs.gov.

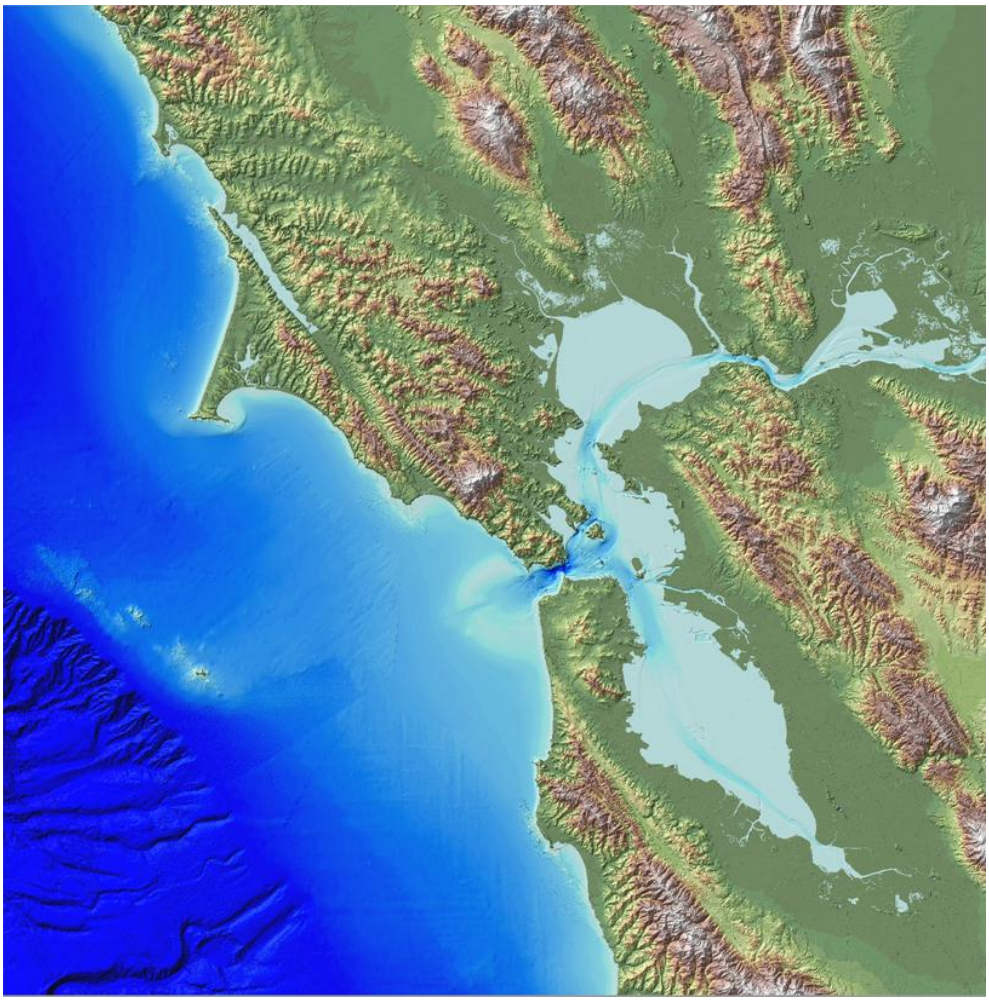

Figure 30. San Francisco Bay 2-meter topobathymetric model.

Early Warning, Environmental Monitoring, and Hazards Management

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

West African Successes in Land Management: Time-Series Imagery for Discovery and Analysis of Sustainable Practices in Agroforestry, Soil Conservation, and Sustainable Agriculture

The 16 nations of West Africa are experiencing unprecedented changes, even by global standards. The region is one of the world's fastest growing populations. Climate change is already taking affect. These forces are placing great pressure on its natural resources – land, soil, water, minerals, forests, wildlife, and fish – all essential to the

livelihoods of the still growing numbers of people in rural areas, dominating the economies of these developing countries. Rural areas are heterogeneous and diverse, but many areas face major challenges in common. There are or will be widespread difficulties in producing enough goods and services – especially food and ecosystems services to economies – for the over 340 million people now living in West Africa. There are issues of responding to threats such as climate change, loss of biodiversity, and degradation of other environmental services and functions.

A team of EROS geographers and geospatial technology specialists are working with foresters, ecologists, land managers, and agricultural scientists across West Africa to map and monitor land resources. They have just completed a second year under the project "West Africa Land Use Dynamics and Adaptation to Climate Change Project," funded by the U.S. Agency for International Development (USAID)/West Africa. A major goal is to promote the awareness of the trends and use of spatial information about natural resource trends among national and regional policymakers. This heightened level of awareness will help them formulate sound and sustainable policy responses, leading to better natural resource management, conservation, food security, and resilience and adaptation to climate change.

A central goal of the project is to produce accurate land use and land cover maps and trends for each of the 16 countries for several periods spanning from 1975 to 2010 (fig. 31). The maps are based on 40 years of time-series Landsat imagery. The maps are being produced by teams from each country, with technical assistance from the EROS team, provided through a series of training workshops in West Africa (fig. 32a and 32b).

Another major dimension of the project is to use remote sensing to facilitate the discovery and analysis of many dozens of "hotspots" across West Africa. Hotspots are landscapes where satellite imagery indicates anomalies representing significant changes relative to surrounding areas. Some can be negative, related to problems of land degradation, desertification, and climate change. Others are positive, a result of environmental transformations that can often be traced to successes in land management. A number of these hotspots provide encouraging evidence of successes in land management, biodiversity conservation, increases in food production, and adaptation to climate change. Because of the potential to positively influence USAID development projects on the ground, the EROS team and its counterparts are focusing on positive hotspots to highlight success stories in land management.

As the project team looks across West Africa with its time-series imagery supported with field work, they have found that, surprisingly, the semi-arid Sahel is the scene of some of the biggest successes in land management, resulting in an improved environment and better living conditions for large numbers of rural people. In Niger and Burkina Faso, hundreds of thousands of farmers have transformed large swaths of the region's arid lands into a greener landscape, improving food security for about 3-million people. Once-degraded and denuded landscapes have been restored to open tree parklands that provide a much-improved environment for crops, livestock, and people (fig. 33).

Sahelian farmers achieved their success through innovations that modify traditional agroforestry, water, and soil management practices. This agro-environmental transformation has led to increases in biomass, carbon, biodiversity, and food and fodder production. It is a prime example of adaptation to climate change. Specific knowledge of the extent and impact of such a transformation, and of its driving factors will enable USAID to work with national and regional policy makers to begin scaling up such successes, thereby reducing the vulnerability of people and their livelihoods to the negative impacts of climate change and improving the resiliency of the natural resource base.

Notably, the role of remote sensing is not merely important in the hotspot studies – it has been crucial. Many of the hotspots were discovered solely on the basis of the imagery and its analysis. Following on the first steps of discovery, EROS scientists and their West African colleagues began visiting some of these hotspots in the field. The resulting narratives and imagery provide encouraging evidence of successes in land management, biodiversity conservation, increases in food production, and adaptation to climate change. For further information, contact Gray Tappan, USGS EROS, tappan@usgs.gov.

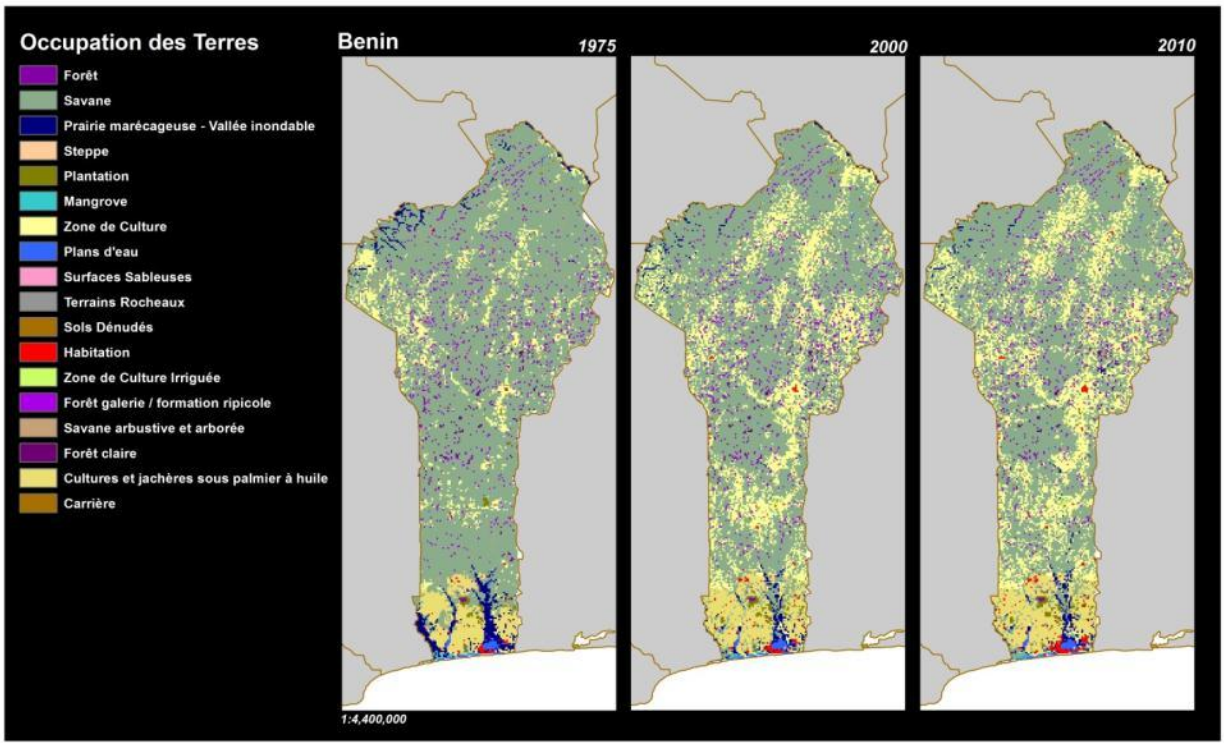

Figure 31. Example of a national land use and land cover map of Benin, showing major changes from 1975 to 2000 to 2010. One of the main drivers of change is the expansion of rainfed agriculture (yellow areas). Benin is one of 16 countries for which time-series maps and trends are being produced.

Figures 32a and 32b. The EROS team and its counterparts at the Agricultural-Hydrological-Meteorological (AGRHYMET) Regional Center have carried out a series of training workshops in Niamey and Ouagadougou to facilitate land use and land cover mapping by national teams. The project uses 40 years of Landsat imagery to map and monitor landscape changes.

Figure 33. This landscape in the Sahel ecological region of Burkina Faso is an example of one of the many successes in land management being documented by the project. The land use is entirely agricultural, with continuous cropland under a sea of trees (the crops have already been harvested in this dry season view). Farmers are increasingly integrating native trees into their fields, creating an agro-forest system that is much more resilient to drought and climate change.

Connecting Local Changes to Global Audiences through Environmental Hotspots

As changes to ecosystems and the environment continue to occur in response to growing population pressure and natural processes, ways to measure and observe these changes on a regular basis will become increasingly important. Satellite imagery offers an important method to provide evidence of such changes and connect local changes to wider audiences. The staff at the United Nations Environment Programme (UNEP) Global Resource Information Database (GRID) Sioux Falls Office has developed and employed a dynamic administrative tool that enables easy upload of satellite images and related storyline, including ground photos, to the GRID Sioux Falls website (http://na.unep.net/). This tool allows for the continuation of monitoring impacts of environmental change across the globe. The environmental change images feature a time series of two or more satellite images to demonstrate positive or negative large-scale local environmental changes; each location is referred to as a 'hotspot.' Satellite images of these hotspots, accompanied by a short storyline and ground photos, serve as an important method for communicating environmental changes and their impacts to the international community. These hotspots can also function as a unique decision-support tool for policy and decision makers.

The Landsat series of satellites is most often used to create UNEP hotspot change pairs and to perform additional scientific analysis, as they are free to download from the USGS EROS Center archive (http://earthexplorer.usgs.gov/). Images captured by the Landsat satellites, including those from Landsat 8 launched in 2013, have different bands that can be combined to create an image that allows users to detect different environmental change elements such as fire scars, drought, and variations in land use, making it an advantageous observation and monitoring tool. The environmental change hotspots identified by UNEP have enabled scientists, decision-makers, and the general public to visualize changes related to deforestation, reduction in glacial coverage in mountainous zones and polar regions, impact of diversion of water sources for irrigation, significant changes in land use, ensuing impacts due to introduction of resource extraction activities, efforts of reforestation, and many more environment related issues. Recent uses of Landsat imagery, as presented in figure 34, align closely with the range of UNEP's hotspots visualization coverage.

Hotspot images illustrate changes over millions of hectares of land and coastline spanning more than 100 countries and all seven continents (fig. 35). The four major themes used to classify the hotspots are: *Ecosystems*, *Resource Extraction*, *Climate Change and Atmosphere*, and *Disasters and Conflicts*. Globally, UNEP has identified 222 hotspots of environmental change in its *Atlas of Our Changing Environment* series and other publications, and continues to do so through constant monitoring and research. The tool supports updating of existing hotspots and adding new hotspots from UNEP Atlases and other publications to the website, making the hotspots relevant and accessible to a wider group of audience. The system also allows for quick and easy updating of existing information, keeping the hotspots relevant. Impacts of identifying and highlighting the hotspots include increased environmental management and restoration efforts around the world, like the Mau Forest Complex in Kenya, Lake

Urmia in Iran, and Lake Faguibine in Mali. To date, the hotspots have had over 16-million views in the website. For further information, contact James Rowland, USGS EROS, rowland@usgs.gov.

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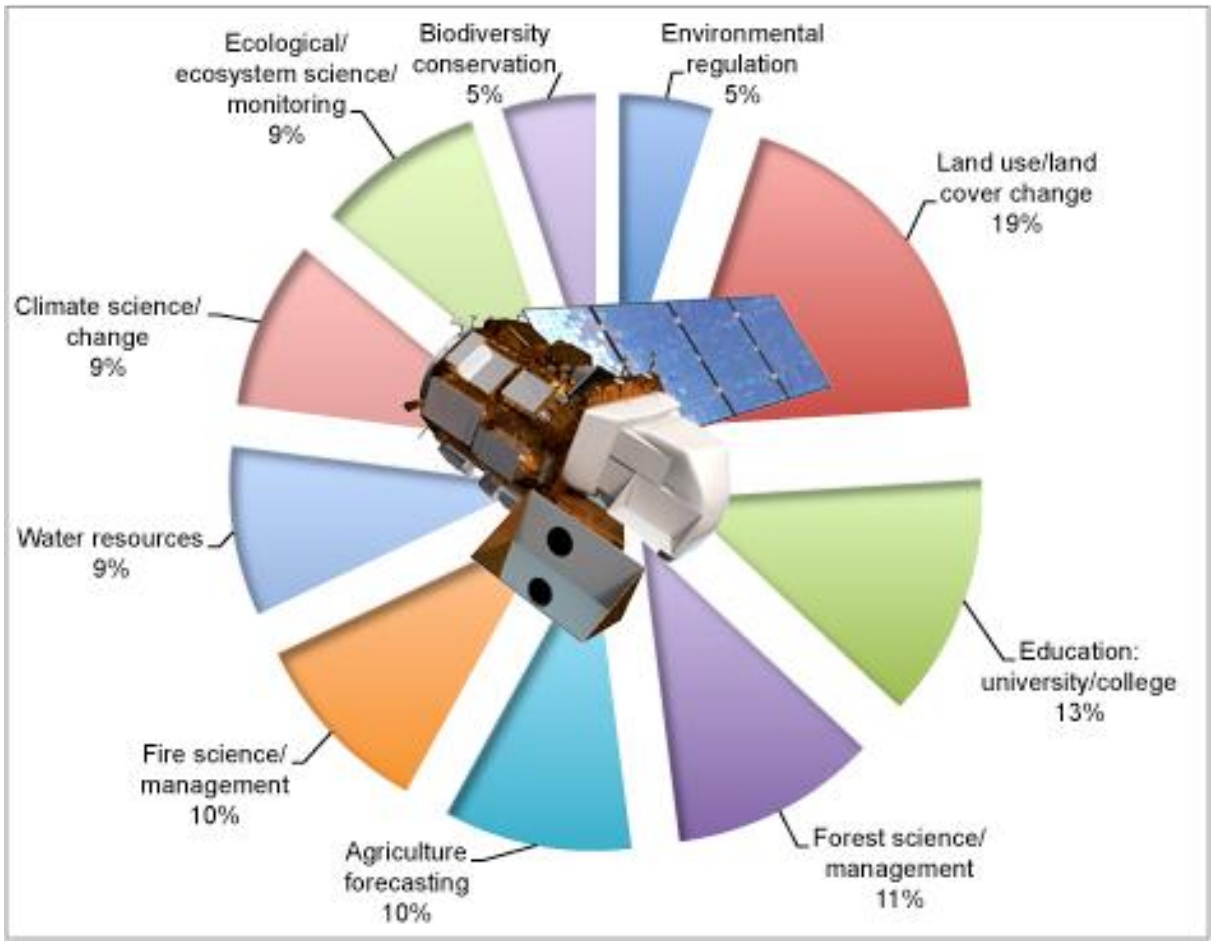

Figure 34. Primary uses of Landsat as recorded by the U.S. Geological Survey from October 1, 2012, to October 31, 2013. Source: Adapted from U.S. Geological Survey 2013; visualization by United Nations Environment Programme/Global Resource Information Database – Sioux Falls.

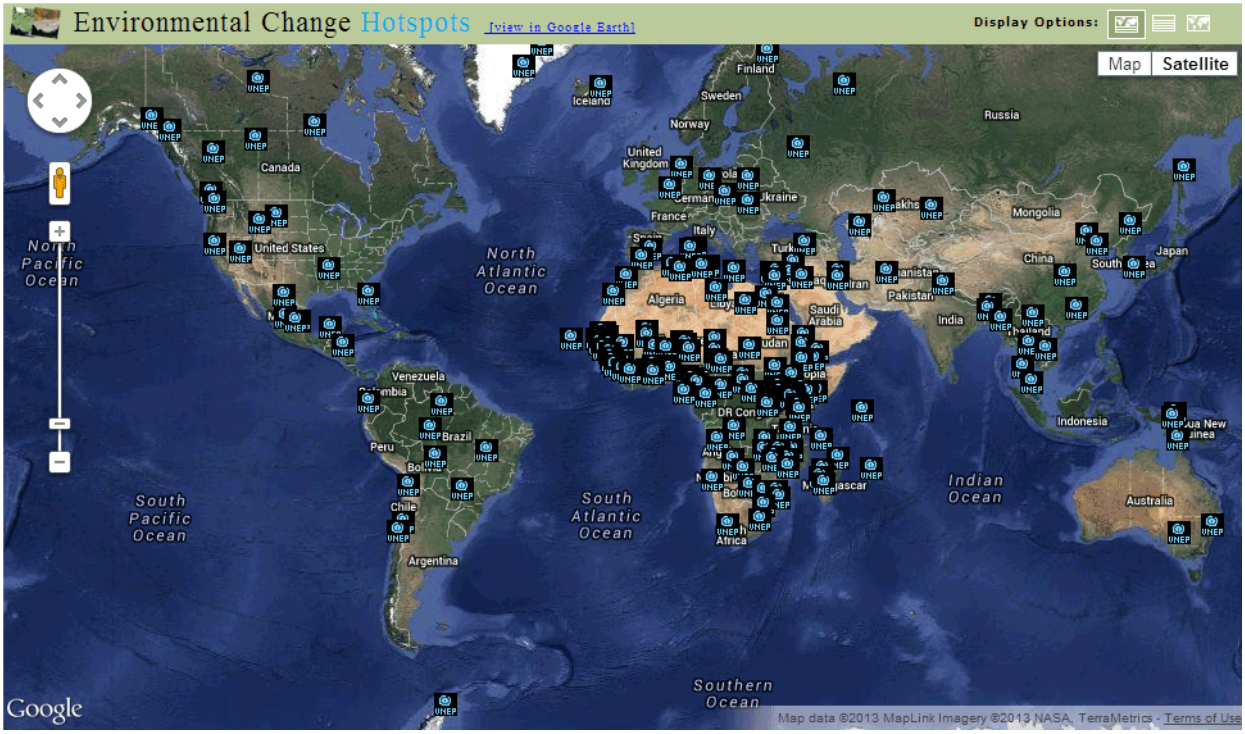

Figure 35. Screenshot of the environmental change hotspots page. Source: United Nations Environment Programme/Global Resource Information Database website http://na.unep.net/atlas/google.php.

Hydropower Assessment of Peru Using Shuttle Radar Topography Mission 1 Arc-Second Digital Elevation Model

USGS scientists developed a comprehensive assessment of hydropower potential for all stream segments that are entirely within the territory of Peru or that drain into Peruvian territory. The project was funded by the Corporación Andina de Fomento (CAF). The objective of the work was to build datasets to help developers of large and small hydropower plants. Although power estimations can be extracted for both types, it was designed with emphasis on small hydropower by estimating power for every 1-kilometersegment. Small hydropower plants offer the opportunity to provide off-grid power in remote areas where the installation of power grids is often prohibitively expensive. Small hydropower plants do not require storage of the stream water and have fewer negative environmental impacts compared to large hydropower projects. For this project, a geospatial model was developed to calculate potential hydropower with associated exceedance probability levels. Data used were hydro-meteorological data (from South American collaborators and from global datasets) and the restricted-access Shuttle Radar Topography Mission (SRTM) 30-meterDigital Terrain Elevation Data (DTED2) (Farr, 2007).

The first process to be undertaken was the hydro-conditioning of the 30-meterSRTM DEM data. The hydro-conditioning of the raw SRTM data is the process where the

DEM are hydrologically corrected and filled for voids and artificial sinks. The DTED2 data have some data voids in areas that are in the shadow of the Andes Mountains. The DEM data voids were filled with data from the USGS GTOPO30 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) global DEM databases. The DEM generally worked well for areas having moderate to high relief and a well-developed drainage network. In areas with low relief differences, the synthetic hydrography derived from the first DEM processing deviated from the Peruvian-supplied hydrographic network. In cases where the synthetic streams deviated substantially from the hydrography layer, a conditioning process was applied to better align synthetic streams to the topographic hydrographic data. Figure 36 shows a pairing of synthetic streams from the DEM and the hydrography dataset from Peru in a portion of the study area. In general, there is a good spatial agreement between the two datasets.

After the DEM, rainfall and streamflow data are the most import hydro-meteorological data for the assessment of hydropower potential. The study area lacks an adequate network of rain gauges to characterize rainfall. We acquired additional rainfall data from the neighboring countries of Brazil and Ecuador. Even with the additional rain gauges, there were still areas with no gauges for hundreds of kilometers. An ordinary co-kriging scheme was used to optimally combine rainfall from the available rain gauges with rainfall data from the International Water Management Institute World Water and Climate Atlas. Figure 37 shows the final rainfall dataset, along with the assembled rainfall datasets used to produce it.

A third major process was the development of regionalized hydrologic models; hydrologic regionalization models were developed for all the watersheds in the study area. The models used had the form:

$$Q = e^{Co}\, X_1^{C1}\, X_2^{C2} \ldots\ldots X_n^{Cn}\, e^{\varepsilon}$$

where Q is the observed annual streamflow in a gauged basin (m^3/sec); Xi are the various physical and climatic characteristics attributes such as average annual precipitation, elevation, and drainage area; Ci are the ordinary least square regression coefficients; and ε is the residual of the model.

The result of the study was a comprehensive estimate of the magnitude of hydropower potential available in the streams that traverse Peru. Potential hydropower was calculated for each stream segment that is 1-kilometerlong (most of time stream segments were less than 1 kilometerbecause of a stream bifurcation). The total theoretical potential hydropower of the country is defined as the annual energy that is available if all natural runoff at all the streams were to be harnessed down to sea level on the Pacific coast or to the border of the country for the streams that drain to the Atlantic, all without any energy losses. Streams that are in Peru but have a contributing area outside of its borders were included in the analysis, as were streams that Peru shares with other countries as a border.

In addition to the theoretical annual mean hydropower estimates, theoretical potential hydropower estimates with flow rates with exceedance probabilities of 40 percent, 60 percent, 70 percent, and 90 percent are provided with the datasets. The flow rate exceedance probabilities were estimated with regionalization models of the flow-duration curves. The final product of the hydropower assessment is a streams vector layer segmented every 1 kilometerwith attributes containing estimated flows, head drop (m), and theoretical power potentials (MW) at the five exceedance probabilities mentioned above. Figure 38 summarizes the results of the theoretical potential hydropower for the basins considered in the analysis within the boundaries of Peru. For further information, contact Matthew Cushing, USGS EROS, at mcushing@usgs.gov.

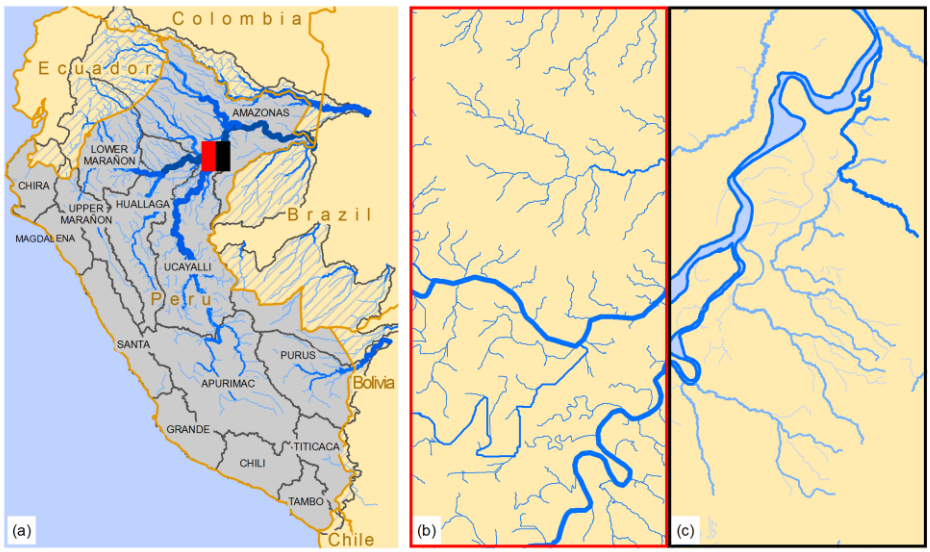

Figure 36. The ancillary hydrography layer compared to synthetic streams in a small section of the study area. The synthetic streams are shown in panel b, and the Peru-supplied hydrography is in panel (c). The comparison area is shown in red in panel (a).

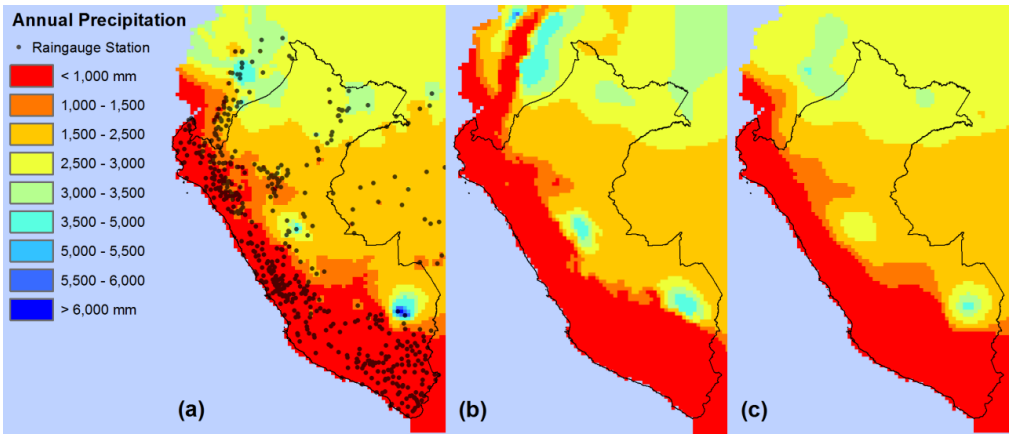

Figure 37. Annual average rainfall of the study area (c). The rainfall was calculated from rain gauge data (a), and from International Water Management Institute's Climate Atlas dataset (b).

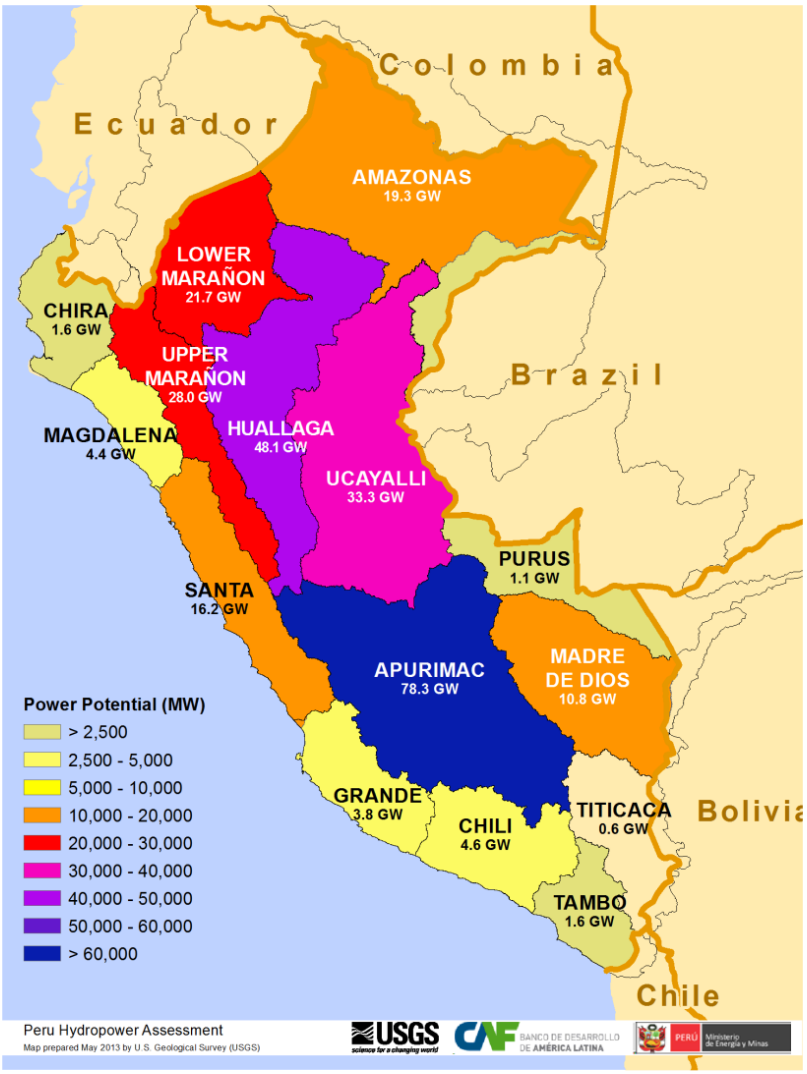

Figure 38. Theoretical potential hydropower of the major basins that are within Peru.

Modeling and Mapping Irrigated Areas in Afghanistan Using Remote Sensing

USGS is one of the key partners in a multi-agency effort to monitor and provide early warning of drought and other hazards that threaten food security around the world. Through the Famine Early Warning Systems Network (FEWS NET), USGS provides geoscience information to participating local and international partners that informs of environmental conditions related to food vulnerabilities and environmental hazards. Due to the large contribution that irrigated crops make to total food production (>80 percent) in Afghanistan, the year-to-year variability of the irrigated land can be examined for monitoring food security conditions for the country. This requires consistent mapping of annual irrigated areas on a near-real time basis at a national scale.

Using 16-day composites of Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI), scientists derived seasonal peak values and temporal profiles as inputs to a threshold-dependent decision tree algorithm developed to map irrigated areas for the past 13 years. In the decision tree algorithm, the regionally adjusted NDVI thresholds for distinguishing irrigated areas from non-irrigated areas were obtained empirically, through an iterative process, by comparing model results with high resolution Google Earth imagery. The NDVI-derived irrigated area maps were ultimately verified with irrigated areas derived from Landsat 5 optical, infrared, and thermal sensor images.

The maps (fig. 39) portray a highly dynamic irrigated agriculture practice in Afghanistan, where the amount of irrigated area is largely determined by the availability of surface water, especially from snowmelt, and can vary on average by as much as 30 percent between water surplus and water deficit years. During the past 13 years, 2004 had one of the lowest levels of irrigated area (~1.5-million hectares), attesting to the severe drought conditions that year, whereas 2012 had one of the highest amounts of irrigated area (~2.5-million hectares), due to record snowpack and snowmelt in the region. Inter-annual variability of the irrigated area tracks well with that of total cereal production, implying that fluctuations in the irrigated area estimates are reflective of the country's potential food production and availability (fig. 40).

The model was implemented for the 2013 season at the end of September. Results showed an estimated 1.95 percent increase in irrigated area for 2013 over 2012, which was previously the highest irrigated area of the last 13 years. Such analysis can provide crucial information about current-year food security conditions. This process will provide timely and beneficial information for U.S. Agency for International Development FEWS NET partner agencies, as well as for local administration and stakeholders in Afghanistan.

Publication of the irrigated area model and modeled results of spatially distributed irrigated area maps for Afghanistan is in the peer-review process. Plans for FY 2014 are to upgrade the model to use 10-day composite NDVI data and to study the feasibility of modeling and mapping irrigated areas for similar regions such as Tajikistan. For further information contact Mike Budde, USGS EROS, mbudde@usgs.gov.

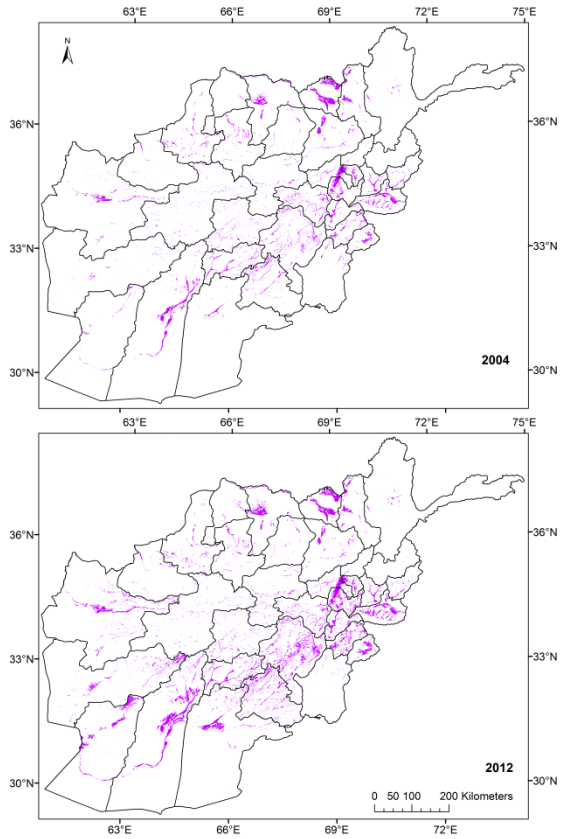

Figure 39. Spatial distribution of irrigated areas in Afghanistan for a water deficit (2004) and water surplus (2012) year.

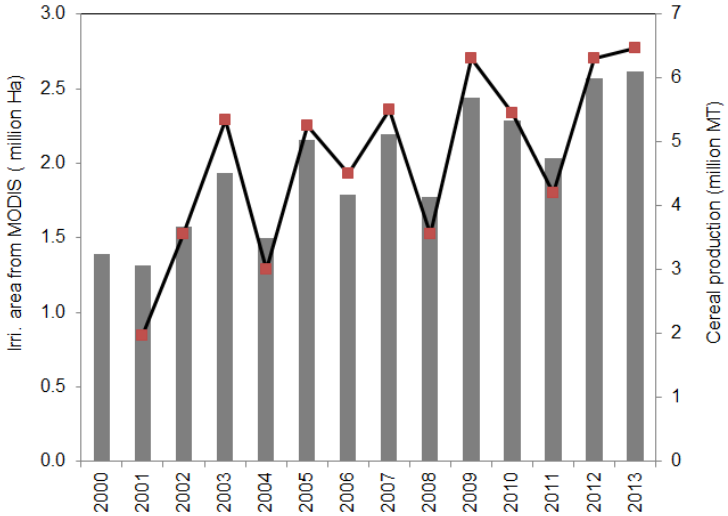

Figure 40. Irrigated area based on analyses of Moderate Resolution Imaging Spectroradiometer Normalized Difference Vegetation Index (bar graph) and cereal production for 2001-2013 (line graph). Cereals include wheat, milled rice, maize, and barley.

Exceptionally Warm Sea Surface Temperatures, Hydrologic Forecasts, and Humanitarian Earth Science

Twenty-first century hydrologic prediction systems should try to take advantage of the strong gradients associated with emergent pockets of exceptionally warm sea surface temperatures (SST). While the ocean is warming rapidly, this shift in sea surface temperatures has not manifested itself as a uniform warming of the world's oceans, but rather a semi-random combination of external anthropogenic forcing and internal natural variability associated with processes like the El Niño Southern Oscillation (ENSO) and natural decadal variations. The result has been 'pockets' of exceptional warming in the Indian Ocean, western Pacific, Pacific convergence zones, tropical Atlantic and north polar seas (Compo and Sardeshmukh, 2010; Solomon and Newman, 2012). These areas have limited spatial extents, and often lie alongside areas with much cooler SSTs. This can create strong SST gradients, which can trigger vigorous atmospheric responses (Hoell and Funk, 2013), which can impact regional climate patterns in predictable ways. This information is most useful when it is integrated with process-based studies, downscaling procedures, effective weather monitoring systems, and hydrologic models to anticipate impacts by seamlessly blending observations and climate predictions.

Seasonal monitoring is the first line of defense in any hydrologic warning system. Simulations, scenarios, and quantitative predictions are important, but need to be accompanied by 'situational awareness' – how exceptional is the global climate state? Metrics associated with ENSO are useful, but fail to tell the whole story. One useful strategy for tracking regions of exceptional warmth is to identify regions that were very unlikely to be so under pre-industrial conditions. For example, we can define exceptionally warm locations as places having warm SST values that were very infrequent (with expected return periods of 40 years or greater), given the observed 1854-1953 distribution. The contoured regions in figure 41 identify such regions. The shading in these maps show standardized SST anomalies based on 1854-1953 means and standard deviations. The contoured regions identify those areas in which the observed SST was exceptional (with expected return periods of 40 years or greater) based on the 1854-1953 base period. These contours range from two to four standard deviations warmer than the mean. These warm regions tend to occur in the Indian Ocean, tropical Atlantic, and western Pacific, and are often associated with exceptionally strong SST gradients. Twenty-first century hydrologic early warning systems may be able to benefit from predictability associated with these strong differential SST anomaly patterns. We briefly mention two case studies – East African rainfall and the central United States air temperatures.

The pattern of April-May-June (April-June) anomalies (fig. 41a) conformed closely to teleconnection patterns linked to East African drought (Hoell and Funk, in press a; Liebmann and others, in press; Lyon and DeWitt, 2012). Exceptionally warm SSTs (Lyon and DeWitt, 2012; Hoell and Funk, in press b; Liebmann and others, in press). Exceptionally warm SST near the maritime continent and across the sub-tropical convergence zones helped intensify the Walker circulation, increase precipitation over

the western Pacific, and increase subsidence over the eastern Horn of Africa. In March of 2011, a map like figure 41a, together with our improved understanding of the western Pacific's critical role in controlling East African April-June rainfall, might have motivated a higher level of preparedness, saving more lives when the April-June rains failed. Usually, SSTs in the teleconnected portions of the Indo-Pacific are highly persistent and predictable, and the extremely warm (>+2.5 standardized anomaly) April-June SST and the associated East African aridity could have been predicted with more precision and accuracy if the condition had been recognized at the time. In 2012, ad hoc climate forecasts produced successful forecasts (Funk and others, 2013), and new research has led to improved operational forecast systems (Funk and others, in press b).

Exceptionally warm western and north-western Pacific SST may have contributed to the exceptionally warm central United States air temperatures in 2012, and these impacts may also indicate an opportunity for prediction. During April-June of 2012, the pattern of exceptional warming looked quite different in the Pacific (fig. 41b). Near the equator, warm SST were located in the central and eastern Pacific, in contrast to the La Niña-like conditions in 2011. A strong band of exceptionally warm SST, however, continued to extend from just east of the maritime continent to just west of Hawaii. We briefly present some ongoing research linking warming in the western Pacific to warm air temperatures in the central United States.

In our work for the U.S. Agency for International Development, we have developed a two pronged approach to understanding climate variability. In 'research mode' we drive Atmospheric General Circulation Models (AGCMs) with SST patterns to explore causal linkages (Hoell and Funk, in press a). In 'forecast mode' we use statistical models to predict terrestrial weather anomalies. These forecasts can then be used to develop 'climate smart' bootstrapping probabilities (Husak and others, 2013) that are used to resample historical forcing inputs and combined with real-time monitoring systems to produce an integrated hydrologic forecasting system. Ideally, atmospheric AGCMs simulations and statistical models provide consilient information, so that we can have some confidence that the observed correlations do indeed represent causation. For example, while we find that both boreal spring and winter East African rains are predictable (cross-validated correlations of >0.6), the associated teleconnection patterns are quite different (Liebmann and others, in press), and these differing teleconnection structures can be verified with AGCMs. The spring teleconnection pattern resembles the western Pacific SST pattern shown in figure 41a. AGCM simulations, forced with similar western Pacific SST trend patterns, also indicate East African drying.

We have been surprised to learn, however, that SST trend-driven AGCM simulations (Hoell and Funk, in press a), originally created to explore East African drying trends, also appear linked to dramatic warming over the central United States. When these simulations were forced with SST trends similar to figure 41, they produced the March-April-May (March-May) United States temperature changes (in °C), shown in figure 42a. Warming in the western Pacific may be shifting the large scale circulation in a manner conducive to substantial temperature increases across the central United States. Figure 42a indicates that exceptional warming in the western Pacific has likely played a

substantial role in creating increased air temperatures, and heat waves, across the central United States. The individual heat wave events that make up the central United States warming may even be predictable. We are just beginning to explore the possibility that this teleconnection may provide a basis for better predictions. Figure 42b shows the correlation between 1981-2012 central United States (109°W-85°W, 37°N-42°N) July temperatures and 1981-2012 *March* SST. In 2010, 2011, and especially 2012, United States air temperatures were extremely warm, and our preliminary statistical forecasts based on March SST indicate reasonably high levels of cross-validated skill (r=0.64). The 2012 heat wave was linked to extreme (historically unprecedented) air temperatures (Diffenbaugh and Sherer, 2013), contributing to crop failures, all-time high corn prices, Gross Domestic Product loss of perhaps $65-75 billion, widespread drought disaster declarations, and the third worst fire year in the Western United States. The correlation structure (fig. 42b) differentiates between the western and eastern Pacific, and exploratory application of statistical models (Funk and others, in press b) suggests strong March SST gradients (like those shown in fig. 41b) can be translated into effective early estimates of above-average United States air temperatures. Exceptionally warm SSTs may help us predict both East African rainfall and central United States air temperatures.

Hydrologic forecasts, however, can take advantage of more than just the skill associated with persistent SSTs and the large scale climate. A great deal of information comes from antecedent weather conditions, represented by the current soil moisture conditions (Shukla and others, 2013). Current research at the USGS and the University of California, Santa Barbara, focuses on combining climate models, statistical downscaling, and hydrologic and crop models to provide better early warning systems. A great deal of information comes from antecedent weather conditions, represented by the current soil moisture conditions (Shukla and others, 2013). In East Africa, to take advantage of this information, we have developed an integrated monitoring system that combines the NASA-developed “Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS),” the Variable Infiltration Capacity (VIC) hydrologic model, the 1981-present 0.05° Climate Hazard group Infrared Precipitation with Stations (CHIRPS) rainfall estimates (Funk and others, in press a), and bootstrapped sampling (Husak and others, 2013) from a historic archive of forcing data (CHIRPS and other surface parameters) to combine observations with projected surface forcings to predict soil moisture and crop water stress through end-of-season. Mid-season, we use observations to drive hydrology and crop models to date. We then draw random samples from the historic archive, and produce ensembles of hydrologic forecasts for the remainder of the season (Shukla and others, in press). This approach, assuming climatology, can produce surprisingly skillful hydrologic forecasts. See, for example, figure 43, drawn from materials produced for monitoring the current East African short rains (October-November-December), which have been below normal. This figure shows that in eastern East Africa, where millions of food insecure people are dependent on winter rains, observed conditions through November 5th provide a very good estimate of conditions (at a resolution of 0.25°) through December or January, when crops have completed grain filling and are ready for harvest.

As the 21st century brings more extreme SST (fig. 41), understanding (fig. 42a-b) and predicting (fig. 42c-d) the climate impacts of these SSTs will be increasingly important. Hydrologic forecast systems that combine SST monitoring and climate forecasts with integrated modeling systems that take advantage of the information contained in antecedent soil moisture conditions will help us better identify, mitigate, and adapt to 21st century hydrologic extremes. These systems can help improve our 'humanitarian earth science,' leveraging our observing systems, models, and understanding to blunt the impact of future climate extremes. For further information, contact Chris Funk, USGS EROS, cfunk@usgs.gov.

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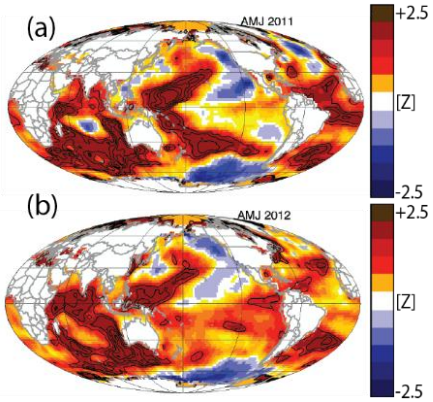

Figure 41. Standardized seasonal sea surface temperatures anomalies. Contours denote regions with 1854-1953 return periods of 40 years or greater, individual contours denote 2.5, 3, 3.5 and 4 sigma deviations. (a) April-June (AMJ) 2011, (b) April-June 2012.

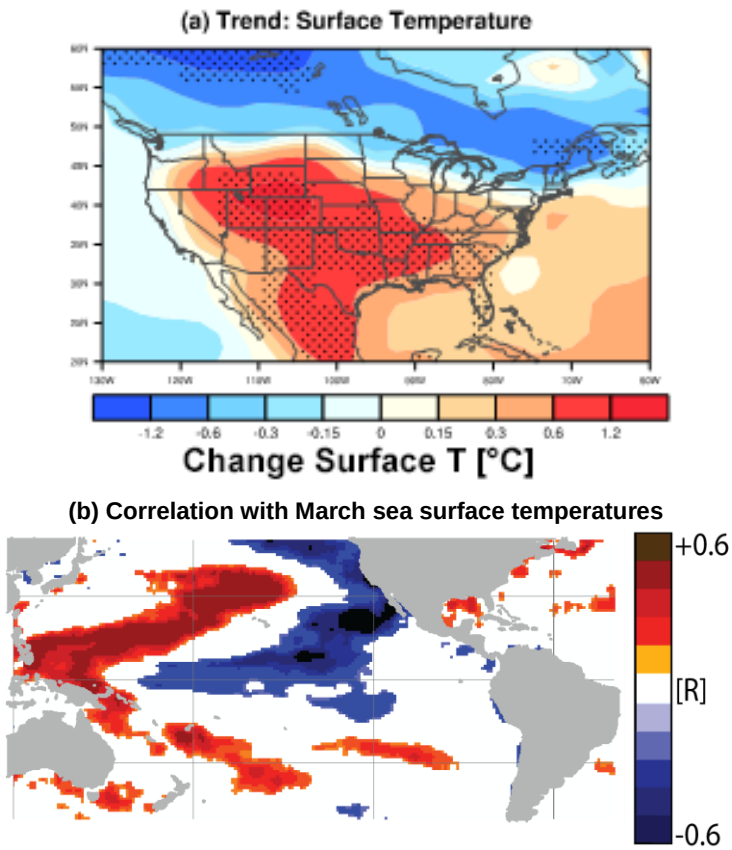

Figure 42. (a) March-May air temperature responses from an Atmospheric General Circulation Model (CAM5) driven with the Indo-Pacific trend pattern (similar to contoured regions in figure 41). (b) the 1981-2012 correlations between observed March sea surface temperatures and July air temperatures over the central United States. Insignificant ($p < 0.1$) correlations have been set to zero. Panel (a) was prepared by Andrew Hoell.

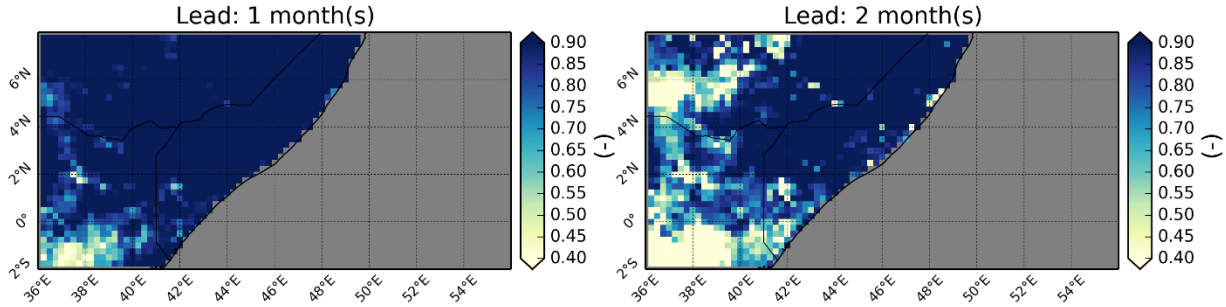

Figure 43. East African seasonal soil moisture forecast skill (correlation), based on the soil moisture forecast made on November 5th of each year between 1993-2012. Skill is calculated by comparing hydrologic model (Variable Infiltration Capacity) generated soil moisture forecasts with model simulations that were driven by observed atmospheric forcings. This figure was produced by Shrad Shukla.

Assessment of Regional Increase in Irrigated Agriculture Across the High Plains Aquifer

An assessment of recent land use change across the High Plains Aquifer (HPA) focused on the areal change of irrigated agriculture revealed a more dynamic landscape than expected. The HPA supplies water to 25 percent of irrigated lands. From 2002 to 2007, the irrigated area increased by 519 thousand ha (net increase of 8.7 percent) regionally, higher than the national net increase for the same period (less than 3 percent), shown in figure 44. Like the historical rise in irrigation, multiple factors influenced this expansion, including economic incentives such as crop prices and land values, government policies related to land and water use, climate fluctuations, and the demand for corn as the primary stock for biofuels (Brown and Pervez, in review).

This research relied on a consistent, wall-to-wall methodology to rapidly map national irrigated agriculture developed by scientists at the USGS EROS Center. The method employed a spatial dis-aggregation model built on irrigation statistics from the U.S. Department of Agriculture in addition to several remote-sensing based input data layers. The methodology utilized a geospatial modeling framework to integrate irrigation statistics with remotely sensed parameters describing vegetation growth conditions in areas with agricultural land cover to spatially identify irrigated lands at a spatial detail of 250-m^2 (Pervez and Brown, 2010).

New national irrigation maps for 2002 and 2007 were created, called the MODIS Irrigated Agriculture Data for the U.S. (MIrAD-US) (Brown and Pervez, in review). The 2007 MIrAD-US data had estimated overall accuracy of 92, 94 and 89 percent, respectively, based on regional assessments completed for central California, Snake River plains in Idaho, and the central Great Plains.

The MIrAD-US national geospatial irrigated area data have been used to improve EROS wall-to-wall drought monitoring models (Brown and others, 2008), as well as by researchers in the USGS, universities, agricultural seed companies, and private research labs. Investigators have tested the data for its potential in a variety of applications, including estimating biophysical carbon sequestration, predicting agricultural productivity and crop-water use, investigating how land use practices affect biogeochemistry (e.g., carbon and nitrogen exchange), and determining the effects of irrigation within a mesoscale weather forecasting model. For further information, contact Jesslyn Brown, USGS EROS, jfbrown@usgs.gov.

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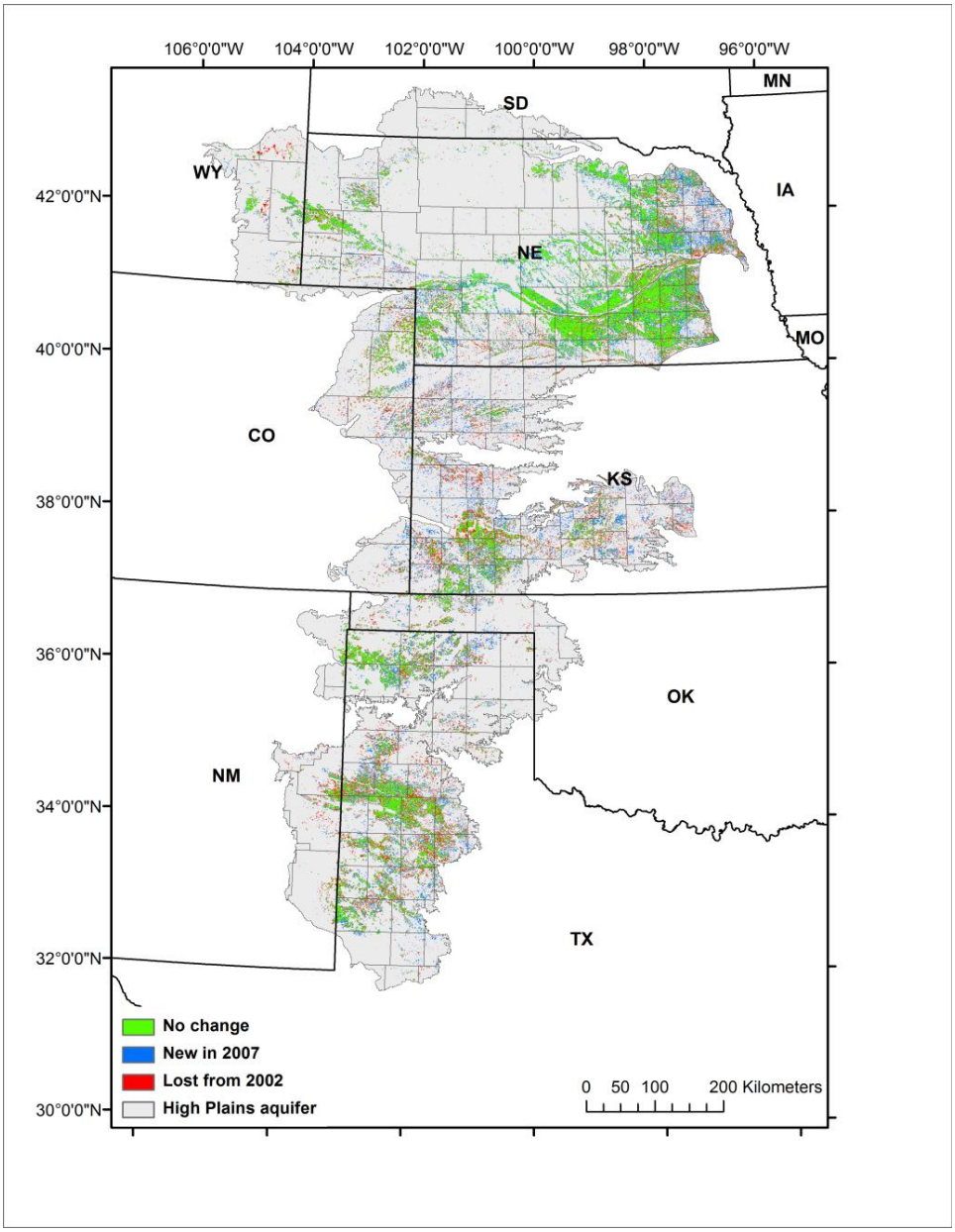

Figure 44. Change in irrigated agriculture between 2002 and 2007 across the High Plains Aquifer derived from Moderate Resolution Imaging Spectroradiometer Irrigated Agriculture Data for the United States, 2002 and 2007.

Landsat-Scale Evapotranspiration for the Apalachicola-Chattahoochee-Flint and Delaware River Basins

The USGS WaterSMART (Water for Sustainable Management of America's Resources for Tomorrow) Project aims to quantify the year-to-year variability of vegetation water use (consumptive use), with a focus on irrigated lands, in a cost-effective and timely manner, i.e., previous year consumptive use estimates need to be available before the next irrigation season starts. USGS scientists improve upon existing hydrologic models to estimate and validate evapotranspiration (ET) from irrigated lands and the general landscape using a combination of satellite data and weather datasets. In the current effort, the first ever basin-wide ET was produced for the Apalachicola-Chattahoochee-Flint (ACF) and Delaware River basins at the Landsat scale using the Operational Simplified Surface Energy Balance (SSEBBop) Approach.

The USGS EROS approach to ET estimation allows the quantification of ET at two important scales: (1) field, using Landsat data, and (2) basin, using MODIS data. Field-scale ET will be used for water use estimation to understand and quantify where, by whom, and how much water is being used in the landscape.

Quantifying water use and water availability is a critical component of the WaterSMART objectives. Irrigation water use information is used for the planning and implementation of water resources allocation and curtailment guidelines. Similarly, ET information is critical in understanding groundwater withdrawal and recharge rates, as well as for drought monitoring. The primary users of this product are State water engineers and hydrologists, and USGS water scientists.

In this work, seamless monthly and annual ET maps for 2010 were produced for the ACF (fig. 45) and Delaware (fig. 46) basins for the first time. These products show clearly the spatial distribution of ET in the basin and magnitude differences associated with different land cover types. For example, it was demonstrated that irrigated lands have a lower annual ET than natural vegetation systems in the eastern basins, as opposed to what was observed in the Colorado River basin that was evaluated in the previous year. The main difference between the two geographic regions is the large contribution of rainfall in the east to meet the ET demands while irrigation is the predominant source of ET in the Colorado River basin.

The ability to estimate seamless ET at the Landsat scale will enable the creation of a basin-wide consistent ET for hydrological applications that are relevant for local decision making in water resources planning and management. This exercise demonstrates the potential to create a nationwide ET at the Landsat scale using the Landsat 8 data stream.

Collaborative work with USGS Water Science Centers will continue in the evaluation and application of Landsat-based ET for consumptive use change detection, trend analysis, and groundwater recharge/withdrawal studies. For further information, contact Gabriel Senay, USGS EROS, senay@usgs.gov.

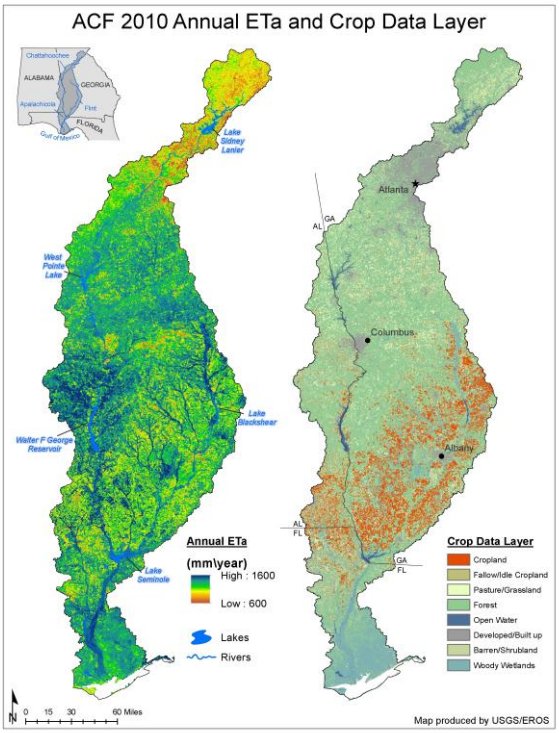

Figure 45. Annual evapotranspiration map and a crop data layer for 2010 in the Apalachicola-Chattahoochee-Flint River Basin.

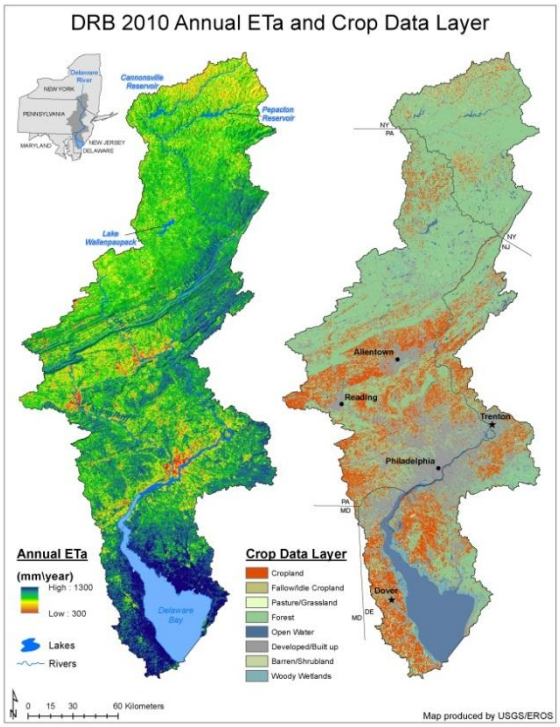

Figure 46. Annual evapotranspiration map and a crop data layer for 2010 in the Delaware River Basin.

Development of a Data Center for the Afghanistan Geological Survey

In 2004, the USGS began providing technical assistance to Afghan government ministries and agencies to help assess natural resources and participate in the rebuilding of institutions and infrastructure. A primary focus involved working to restore and revitalize earth science organizations, upgrade facilities, and retrain technical staff. The training effort took a variety of forms, from inviting Afghan scientists and staff to attend special classes at USGS facilities in the United States to holding seminars, workshops, and courses in Afghanistan and neighboring countries taught by USGS instructors, industry specialists, and/or representatives from professional or academic institutions working under the auspices of international organizations or other U.S. Government agencies.

A second focus of USGS activities in Afghanistan has been gathering new natural resource data via wide-spread collaborative fieldwork, drilling and coring, satellite remote sensing, airborne geophysics and seismic surveys, establishment of stream gage networks, and extensive studies in ground and surface water quality and quantity. These newly collected data have enhanced and broadened Afghanistan's existing natural resource datasets, and are vital for both short-term and long-range planning regarding management of these resources, as well as for identifying potential new resources that may attract foreign investment and create employment opportunities for Afghans.

USGS projects in Afghanistan are coordinated with other U.S. Government organizations including the Departments of State, Interior, Treasury, and Defense, the U.S. Embassy in Kabul, the U.S. Agency for International Development, and the Trade and Development Agency. Within Afghanistan, USGS collaborates with numerous Afghan ministries – including the Ministry of Mines, Ministry of Energy and Water, Ministry of Agriculture, Irrigation, and Livestock, Ministry of Rural Rehabilitation and Development, Ministry of Transport and Civil Aviation, and Ministry of Communications and Information Technology – and works closely with Kabul University and the Afghanistan Information Management Services.

In 2010, the Afghanistan Ministry of Mines asked the Task Force for Business and Stability Operations (TFBSO) of the U.S. Department of Defense to assist the Afghanistan Geological Survey (AGS) in establishing an agency Data Center. This Data Center would serve both the AGS and the Ministry of Mines to which it belongs. The TFBSO in turn asked USGS to provide the technical lead of the activity. The primary role of this Data Center is to enable the comprehensive management of all the agency's scientific data and facilitate AGS's eventual web-based distribution of key spatial datasets, replicating the functionality of the USGS Afghanistan Project website located at EROS (http://afghanistan.cr.usgs.gov/).

The hardware and software for the Data Center was officially delivered by USGS to the Ministry of Mines of Afghanistan in June 2011. In 2012, EROS took responsibility for building the capacity of AGS to develop and maintain the information technology (IT)

infrastructure for both the Data Center and AGS as a whole. This activity, which has run through FY 2013 and will continue on at least through FY 2014, has been implemented by EROS in two phases.

Phase 1, AGS IT Capacity Building (FY 2012-FY 2014), consists of the establishment of a functioning, integrated IT infrastructure that is internal to the AGS facility structured through the implementation of newly developed data management policies by AGS leadership. Activities required to accomplish this have included:

- Increasing internet bandwidth
- Power stabilization
- Backup planning and implementation
- Development of data management policies
- Completion of a routable AGS network
- Activation of multiple servers
    - main internal server
    - web server
    - active directory
    - web proxy
- Increasing data storage capacity
- Installation of robust virus protection
- Maintenance/management of core network equipment
- Ongoing technical support by EROS of the AGS IT team
- Ongoing equipment and software licensing procurement

Phase 2, Web-Mapping Development (FY 2014), will consist of providing AGS with the ability to provide its staff and eventually the public with access to web-based data visualization, data delivery, and mapping services.

Despite the wide range of difficulties in working in post-conflict Afghanistan, USGS EROS has collaborated with the Afghanistan Geological Survey to create a capable IT team, which has been demonstrated by the successful running of its new agency Data Center. For further information, contact Eric Wood, USGS EROS, woodec@usgs.gov.

Remote Sensing Activities

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

Landsat Program

The Landsat Program is a joint effort of the USGS and NASA to gather Earth resource data using a series of land observing satellites. Whereas NASA's role is the development and launch of Earth observing instruments and spacecrafts, the USGS is responsible for flight operations, maintenance, and management of all ground data reception, processing, archiving, product generation, and distribution. A primary objective of the Landsat Program is to ensure a collection of consistently calibrated Earth imagery. The Landsat Project at EROS manages two active satellites – Landsat 7 and Landsat 8 – and the entire historic archive of data collected since 1972. Key accomplishments are given in the following sections.

Remarkable, Record-Setting Satellite

Landsat 5 was designed to operate for 3 years when it was launched in March 1984 (fig. 47). But this fifth satellite in the USGS-managed Landsat Program turned out to be far more tenacious than anyone ever imagined. On June 5, 2013, Landsat 5 was officially decommissioned after capturing high-quality images of Earth's land surface for 29 years! It set the new Guinness World Record for the longest-operating Earth observation satellite in history.

Landsat 5's remarkable lifespan is a testament to the talents of the NASA engineers who designed it and the heroic efforts of the USGS Flight Operations team that kept it running for nearly 3 decades. Landsat 5 experienced a number of significant technical problems over the years. But as batteries lost power and parts wore out, the team devised creative workarounds and operational fixes that repeatedly breathed new life into an aging satellite.

All told, Landsat 5 orbited Earth over 150,000 times and sent back more than 2.5-million images. These images are Landsat 5's unique legacy, one that lives on as part of the vast archive of satellite imagery maintained at the USGS EROS Center. The archive's holdings represent an unbroken record of the Earth's changing surface that spans more than 40 years. For further information, contact Kristi Kline, USGS EROS, kkline@usgs.gov.

Figure 47. Artist's rendition of the Landsat 5 satellite in orbit.

Landsat 8 Operations

While the USGS saw the end of the longest-operating Earth observing satellite mission with the decommission of Landsat 5, it also saw the introduction of the newest in the line of Landsat satellites with Landsat 8 transition to full operations on May 30, 2013.

Landsat 8 was designed to maintain data continuity with previous missions to allow for a consistent comparison of the Earth's surface through time, and its instruments also provide capabilities beyond previous Landsat missions. The major improvements over previous missions include a higher daily data collection rate, higher signal-to-noise ratio in all bands, greater radiometric quantization (12-bit versus 8-bit), new spectral bands on the Operational Land Imager (OLI) and a second thermal band on the Thermal Infrared Sensor (TIRS).

Prior to declaring the mission operational, and the associated public release of data products, it was necessary to calibrate the instruments. The calibration validation team completed a large number of analyses of preflight test data during observatory integration and test, followed by more rigorous processing and analysis of data during on-orbit initialization and verification (OIV). An underfly of the then named Landsat Data Continuity Mission (LDCM) with Landsat 7 afforded a unique and valuable opportunity to collect data to facilitate the cross-calibration of the OLI instrument with the enhanced thematic mapper plus (fig. 48). This was further strengthened by field campaigns to collection vicarious calibration data at numerous times during OIV.

The successful accomplishment of calibration validation activities during OIV can be largely attributed to the solid teamwork between Government agencies (USGS and NASA), contractors, and university collaborators. The OLI instrument performance exceeds the science requirements and design specifications, and performance will be monitored by the calibration validation team during the operations phase of the mission. Early results from investigations by the Landsat Science Team affirm the superior radiometric and geometric performance of the instruments and indicate that scientific research and applications will significantly benefit from the improved quality of Landsat 8 data.

After the completion of OIV, the hand-off of operations from NASA to USGS on May 30, 2013, all products processed since reaching the operational orbit on April 12, 2013, were available for download via EarthExplorer, the LandsatLook Viewer and GloVis. During the OIV checkout period, the acquisition rate was ramped up from the design value of 400 images per day to well over 500 images per day. An analysis is now underway to determine the optimal operating point which balances science needs against the conservation of any life-limiting instrument or spacecraft components to allow Landsat 8 operations to continue beyond its intended design life. For further information, contact Jim Lacasse, USGS EROS, jmlacasse@usgs.gov.

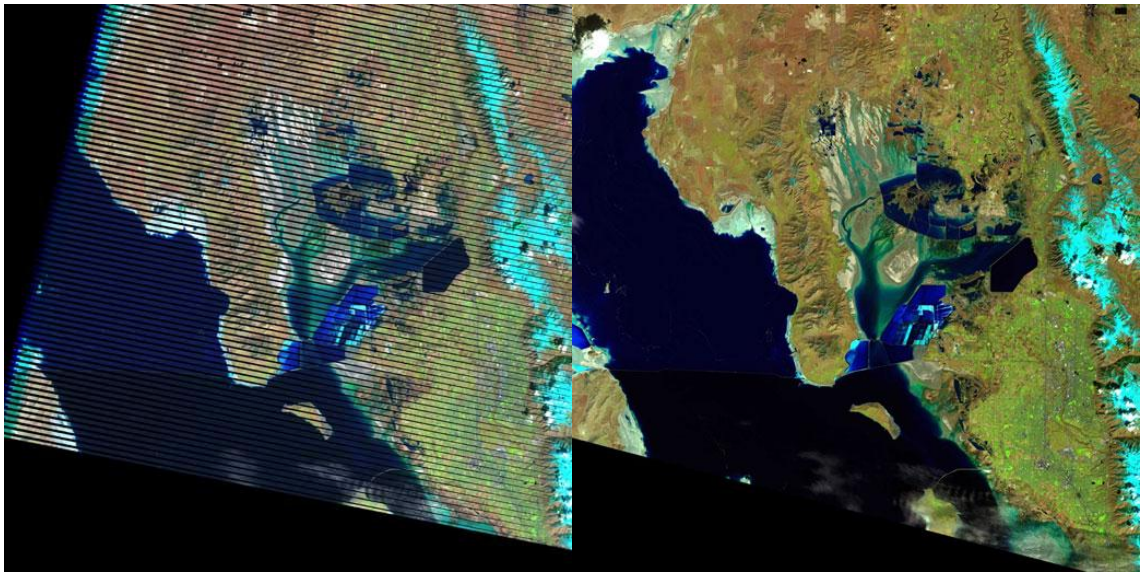

Figure 48. Underflight data comparison – Landsat 7 bands 543 (left), Landsat 8 bands 654 (right). Both images were acquired on March 29, 2013, over the Great Salt Lake, Utah.

Climate Data Records and Essential Climate Variables

The Land Remote Sensing Program continued to sponsor the development of climate data records (CDRs) and essential climate variables (ECVs) from Landsat data during FY 2013. This project is being supported by scientists from the USGS Science Centers

in Alaska, Flagstaff, Reston, and Denver, with the EROS Center providing project management, product generation, and distribution functions. The project achieved several significant accomplishments in FY 2013 in the areas of infrastructure development, algorithm and software integration, product release, documentation, and publications. What follows is a summary of the EROS Center accomplishments for the project.

The EROS Science Processing Architecture (ESPA) provides the computing and storage capabilities for CDR and ECV product development and is built upon an open source software environment, and the code is managed and made available using Google Projects (http://code.google.com/p/espa/). Numerous versions of the ESPA code were released this year as additional functional capabilities evolved. Of notable significance was the establishment of an operational baseline of the Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) software used to generate the surface reflectance CDR products. The LEDAPS code is also maintained and managed as open source code in Google Projects (http://code.google.com/p/ledaps/).

The Landsat surface reflectance CDR was publicly released this year as an on-demand product option through EarthExplorer and a controlled user interface to ESPA. In addition, the Global Land Survey (GLS) collections for 2000, 2005, and 2010 were also processed to surface reflectance and made publicly available. An algorithm description document for LEDAPS was published as a USGS Open-File Report (Schmidt and others, 2013); and our methodology for characterizing uncertainties in the surface reflectance products was also published (Maiersperger and others, 2013). A user guide for the product was developed and made available online, and software tools for unpacking the quality assurance (QA) bits in the product's QA band were also developed and made available for download from the Landsat web site.

Prototype code for the burned area and surface water extent ECVs were delivered to EROS for integration into ESPA. This code was transcribed into operational software, tested, and verified through iterations with the original developers in Denver and Reston. These products have undergone initial validation and will be moved to "provisional" status for evaluation by stakeholders during FY 2014. A product maturity matrix, adapted from the Committee on Earth Observing Satellites (CEOS) Working Group on Climate is being used as the model to monitor and document the maturity of the products as they evolve. Using the burned area product as an example, figure 49a shows World Reference System-2 (WRS-2) path 17, row 39 for which a stack of surface reflectance data were processed (fig. 49b) from which the annual burn probability for 2010 (fig. 49c) was computed and from which an annual burn classification is derived (fig. 49d).

Our next set of milestones and deliverables includes processing and distributing "provisional" quality surface temperature, burned area, and surface water extent products for stakeholders to evaluate and provide feedback. The product generation algorithms and methodologies for characterizing product uncertainties will be submitted for publication in peer reviewed journals. Product validation and the characterization

and quantification of uncertainties will continue and serve as a basis from which operational quality assurance could be established. For further information, contact John Dwyer, USGS EROS, dwyer@usgs.gov.

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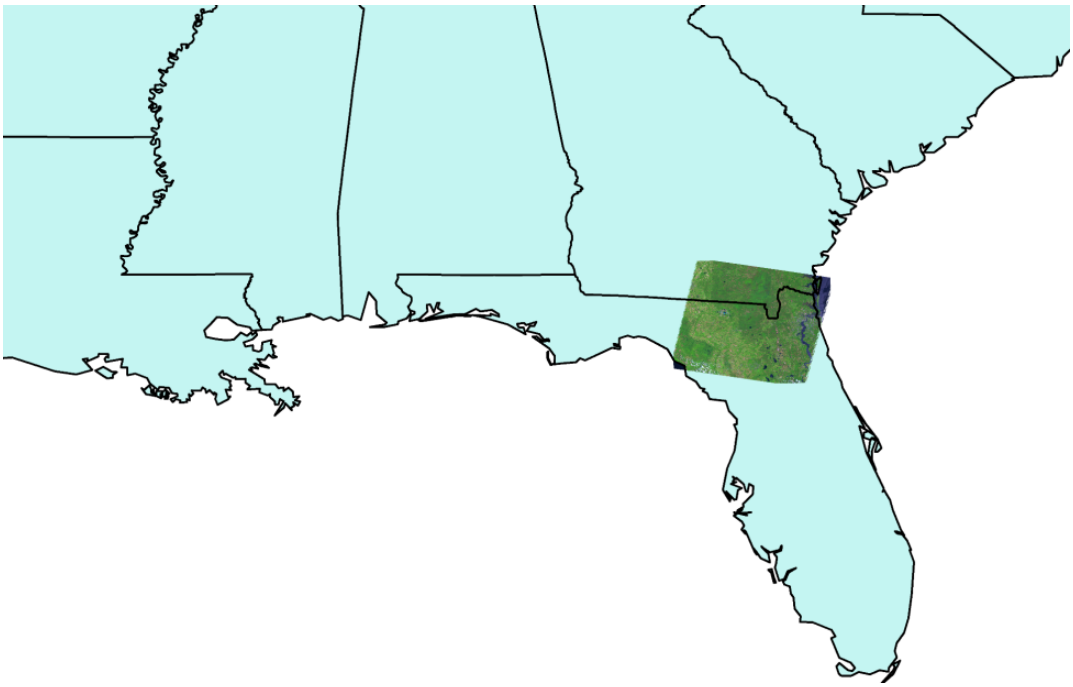


Figure 49a. Geographic locations of World Reference System-2, path 17, row 39.

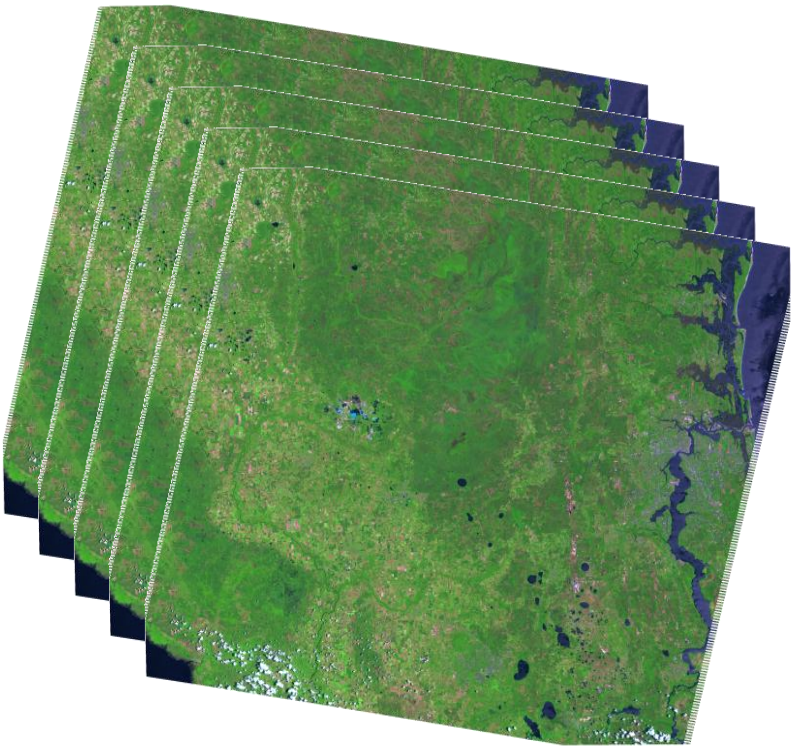


Figure 49b. Stack of surface reflectance data for 2010 covering World Reference System-2, path 17, row 39.

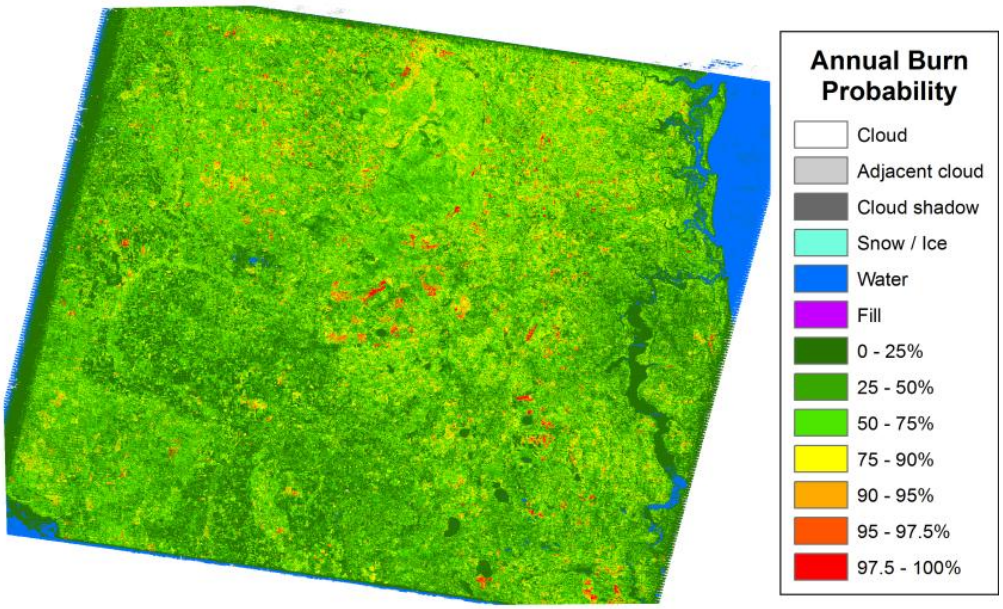


Figure 49c. The annual burn probability for 2010 computed from the surface reflectance time series.

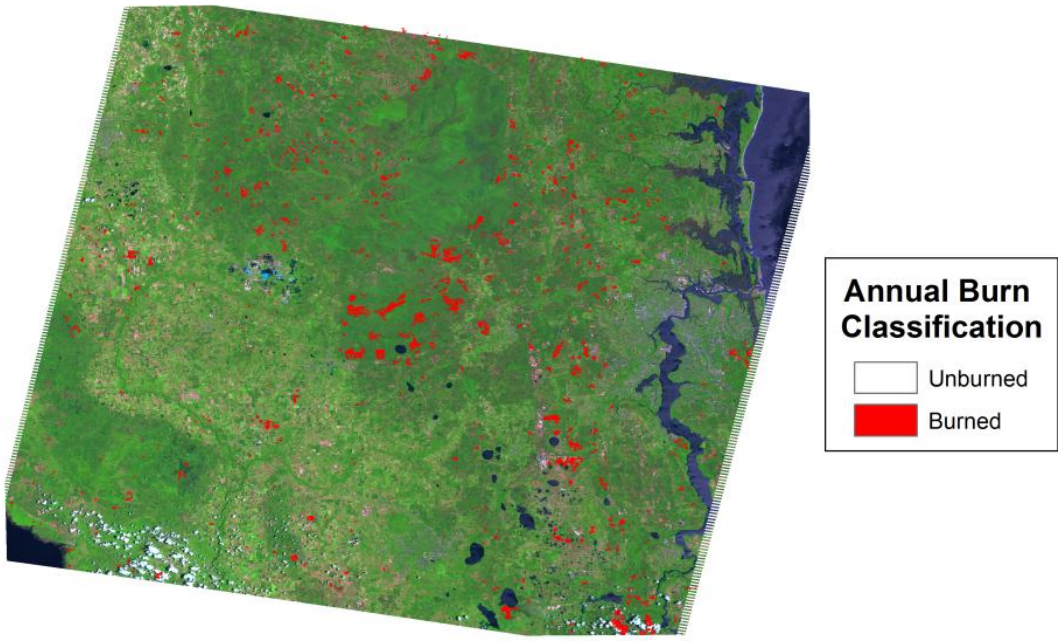


Figure 49d. The annual burn classification is derived from the annual burn probability surface.

New Missions

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

Landsat Data Continuity Mission Development Project

The Landsat Data Continuity Mission (LDCM) continued the legacy of the Landsat series of satellites. The LDCM Project completed several significant development milestones during FY 2013.

The Ground System Development Team completed final deliveries of the Data Processing and Archive System, Ground Network Element, Mission Operations

Element, and Collection Activity Planning Element prior to the launch freeze in mid-December 2012. The Ground System also completed the capstone Ground Readiness Test, GRT 4d, which verified the ground system's ability to support launch, commissioning, and operations. All requirements assigned to the test were successfully verified, signifying the ground system's readiness for launch and operations.

The Operations Team completed significant operations testing prior to launch, including numerous Mission Operations Simulations, Operations Readiness Tests, and Day In The Life tests nearly continuously from November 2012 to launch in February 2013. A Flight Operations Review Peer Review was held in late November 2012, and the Operations Readiness Review was held in January 2013 to ensure readiness for LDCM operations.

The LDCM observatory completed environmental testing in November 2012 (fig. 50 and 51). The LDCM Team completed the final Mission Readiness Tests between the Mission Operations Center and the LDCM observatory in parallel with environmental testing, completing in early December 2012. The LDCM observatory completed the Pre-Ship Review on December 14-15 and was shipped from the spacecraft facility in Gilbert, Arizona, to the launch site at Vandenberg Air Force Base in California on December 18-19 (fig. 52). Integration with the launch vehicle followed, including encapsulation in the payload fairing on January 23, 2013, and transport to the launch pad on January 25th (fig. 53).

The LDCM observatory was successfully launched on an Atlas V rocket from Vandenberg Air Force Base on February 11, 2013, at 10:02 a.m. (fig. 54). The launch and orbit insertion were flawless, including successful spacecraft separation 90 minutes after launch (fig. 55). Once in orbit, the LDCM Team began the 90-day commissioning period of the observatory. Observatory activation and commissioning activities went very smoothly, culminating in the collection of the first image from the OLI and TIRS instruments on March 18th (fig. 56, 57, and 58). Also during commissioning, the team successfully demonstrated the ability to downlink data in real-time to international cooperator ground stations in Australia and Indonesia.

The LDCM Project worked collaboratively with NASA on the transition of the mission from NASA to the USGS following successful on-orbit checkout of the observatory. The Project successfully held a Post Launch Assessment Review and Mission Transition Review on May 29th and 30th, respectively. At this point, the LDCM mission was turned over from NASA to the USGS, and the mission was subsequently renamed to Landsat 8 (fig. 59). NASA contracts for the spacecraft, OLI instrument, Mission Operations Element, and the Svalbard ground station services were transitioned to the USGS, as well. In addition, all data collected from the LDCM observatory since arriving on World Reference System-2 on April 12th (approximately 20,000 scenes) were made available to the public at no cost and without restriction, consistent with existing Landsat data policy. The Landsat 8 observatory and ground system have been performing very well in operations, producing beautiful imagery that is extending the unbroken 41-year collection of Landsat data (fig. 60).

Following transition to operations, the remainder of the LDCM Development Project pursued an “LDCM in Retrospect” activity, where the team 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. In this way, the Project provided key messages, themes, and major factors of success for senior decision makers, along with detail and context associated with a retrospective assessment of strategic decisions, key events, impacts and lessons learned for future land imaging implementers. A draft of the LDCM in Retrospect Report was completed in September 2013, with a final release planned for late December 2013.

Overall, the LDCM project was very successful continuing the Landsat legacy. For further information, contact Jim Nelson, USGS EROS, jnelson@usgs.gov.

Figure 50. Landsat Data Continuity Mission observatory in electromagnetic interference chamber.

Figure 51. Landsat Data Continuity Mission observatory after thermal vacuum testing.

Figure 52. Landsat Data Continuity Mission transporter shipping Landsat Data Continuity Mission observatory from the spacecraft facility at Orbital Sciences Corporation in Gilbert, Arizona, to the launch site at Vandenberg Air Force Base in California.

Figure 53. Encapsulation of the Landsat Data Continuity Mission observatory in the payload fairing.

Figure 54. Launch of the Landsat Data Continuity Mission observatory on an Atlas V rocket from Vandenberg Air Force Base on February 11, 2013.

Figure 55. Spacecraft separation.

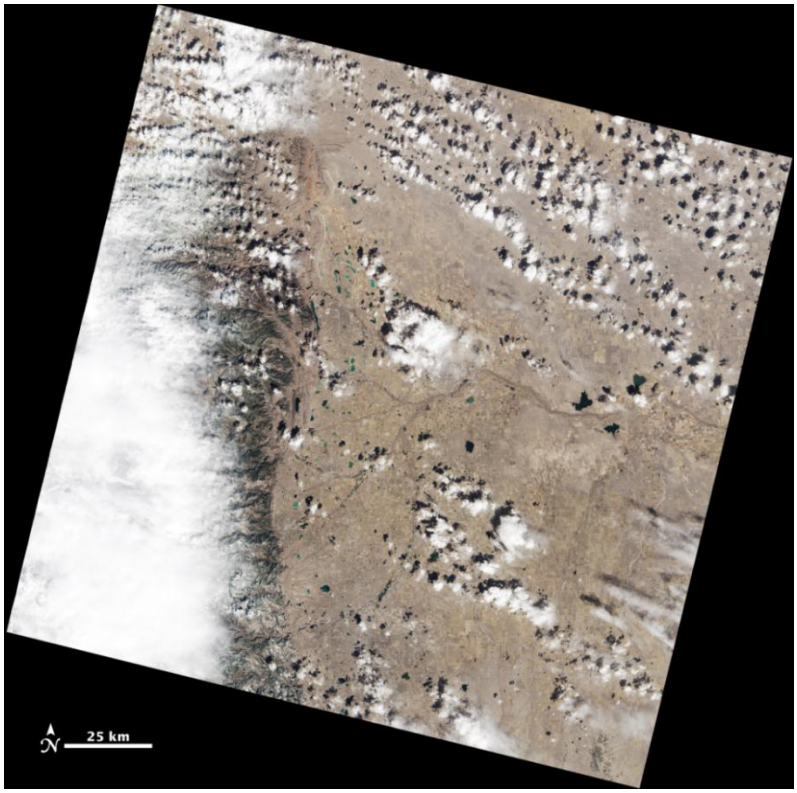


Figure 56. First Landsat Data Continuity Mission image, taken on March 18, 2013, over the front range of the Rocky Mountains of Colorado and Wyoming.

Figure 57. A closer look at a portion of the first Landsat Data Continuity Mission image, over Fort Collins, Colorado, in natural color (blue, green, red).

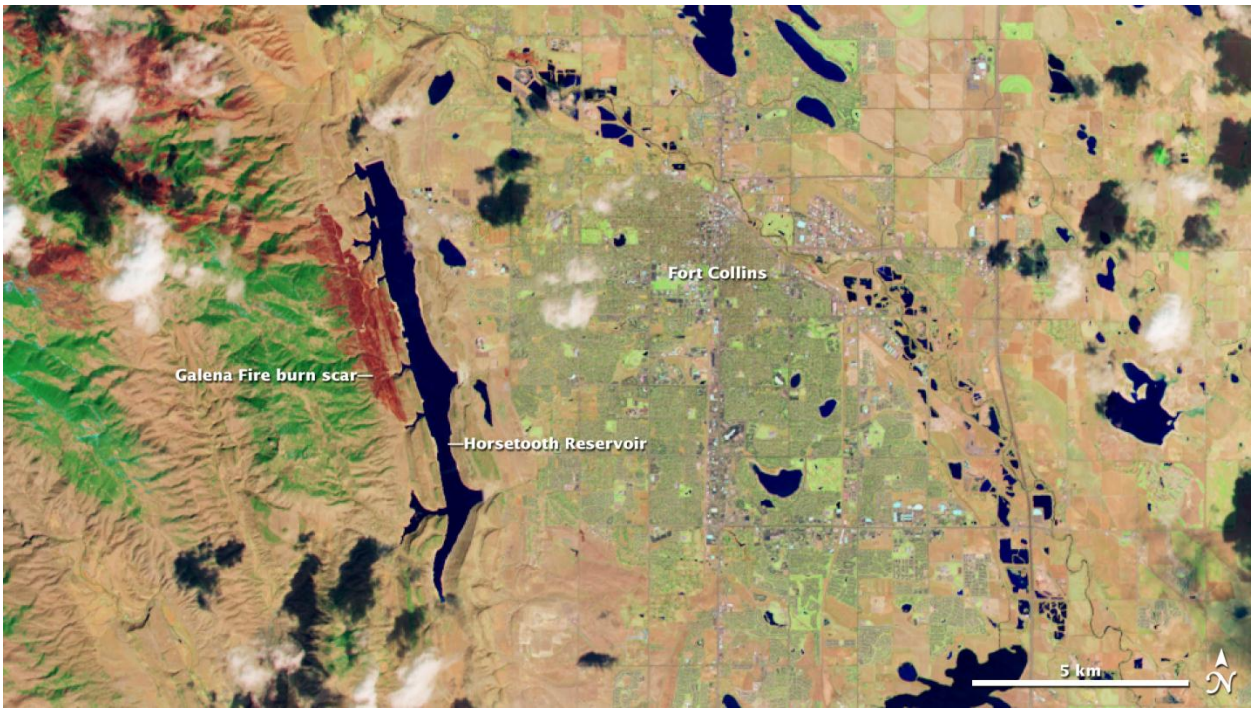


Figure 58. A closer look at a portion of the first Landsat Data Continuity Mission image, over Fort Collins, Colorado, in false color (green, near infrared, and short wave infrared).

Figure 59. Landsat Data Continuity Mission transition certificate.

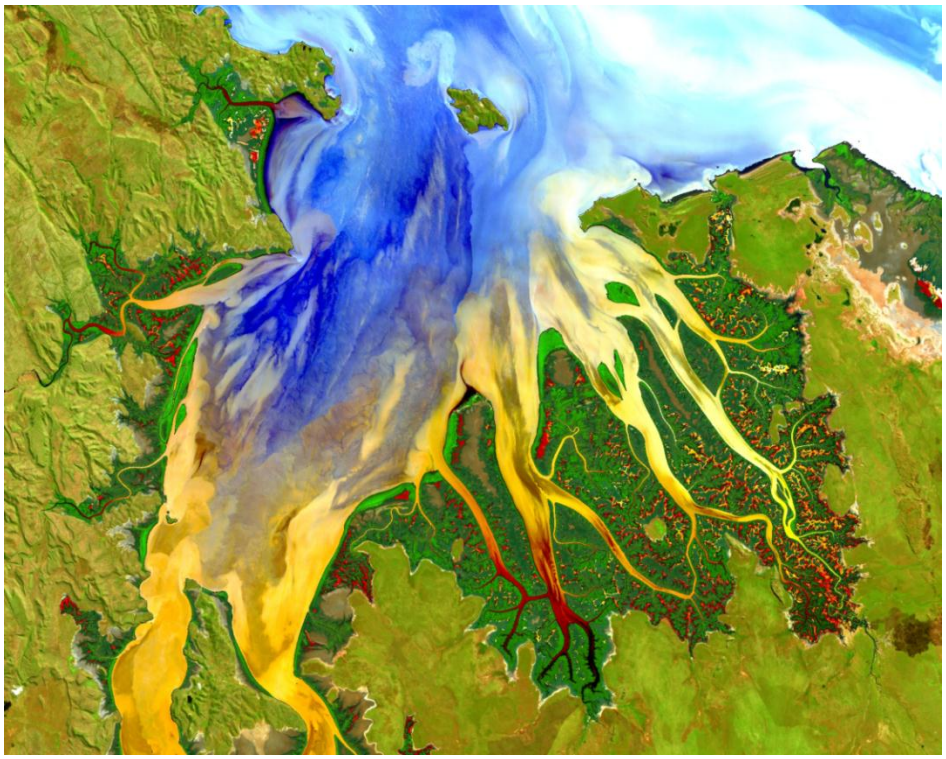


Figure 60. This image is a portion of a Landsat 8 scene acquired May 12, 2013, in western Australia. Geoscience Australia, a Landsat international cooperator and a Landsat science team member, produced this enhanced image. Water and land were masked, separately enhanced, and then reassembled.

The National Land Imaging Requirements Project: An Innovative Approach to Documenting User Requirements

In FY 2013, USGS initiated the National Land Imaging Requirements (NLIR) Project as a collaborative effort between the USGS Land Remote Sensing Program, USGS EROS Center, and National Oceanic and Atmospheric Administration (NOAA). Under this project, USGS, in seamless partnership with NOAA, will design, develop and operate the next generation system to obtain, characterize, manage, maintain and prioritize user requirements for Earth observation (EO) data. The comprehensive insight afforded by this capability will enable an unprecedented view of requirements and allow effective matching of Earth observing capabilities and data to user needs. NLIR builds upon NOAA's excellent efforts over the past 10 years and will deliver the next generation of analytical tools to meet common needs of both agencies. This innovative program will bring improved business processes that enable true data-driven decision making for USGS Earth observing programs.

The NLIR Project employs a fundamentally different approach to user requirements. Rather than defining needs in terms of a particular technology or solution as has historically been the case, user requirements are stated as needs for specific information such as land surface temperature, land surface topography, and vegetation type, which are derived from Earth observations. Each requirement includes relevant attributes that define where, when, and at what spatial and temporal resolution the information is needed. Through this approach, user requirements become "solution agnostic" and can be evaluated against all potential solutions including existing and future technologies. This different approach ensures a long "shelf life" for requirements. The NLIR Project consists of two components: (1) the expert elicitation process and (2) the Earth Observation Requirements Evaluation System (EORES). The fully documented elicitation process is used to gathers user requirements; and the jointly designed and developed EORES open-source web-based suite of tools and databases serves as the repository for EO requirements, the EO systems and technologies, and the assessments performed against the stored data. As shown in figure 61, the EORES will be become the next generation Observation Requirements, Observing Systems, and Portfolio Analysis system replacing the previous Consolidated Observing Requirement List (CORL), NOAA Observing Systems Architecture (NOSA), and NOAA Observing System Integrated Analysis (NOSIA) suite.

To date, the Project has completed early system development using an agile approach and a pilot project that developed and exercised the process for the elicitation and development of user requirements. In 2013, the NLIR Moderate Resolution Land Imaging Satellite Pilot Project completed an expert elicitation of operational land imaging user requirements. This effort was done to refine and enhance the elicitation processes for the larger NLIR effort, and to provide information to the joint NASA USGS Sustainable Land Imaging Team who are developing a plan for the next 20 years of land imaging. In 2014, the NLIR Project will deliver the requirements repository and evaluation system for initial operation and will plan and begin the full-scale user requirements elicitation and development.

The NLIR Project is highly visible and important in the EO community since it is tied into numerous requirement efforts in the USGS, NOAA, and U.S. Group on Earth Observation. This unprecedented effort capitalizes on USGS land domain expertise and brings in NOAA's in-depth knowledge of the atmospheric and oceanic domains, to provide a starting point for a comprehensive picture of national needs for Earth observation.

Using innovative processes and tools for data driven decision-making, the USGS will gain key insights into the formulation of what future systems and technologies will best serve the EO users' needs. Outputs from this activity will also contribute directly to the second triennial national Earth Observation Assessment due to the Executive Office of the President in September 2015. For further information, contact Gregory Stensaas, USGS EROS, stensaas@usgs.gov.

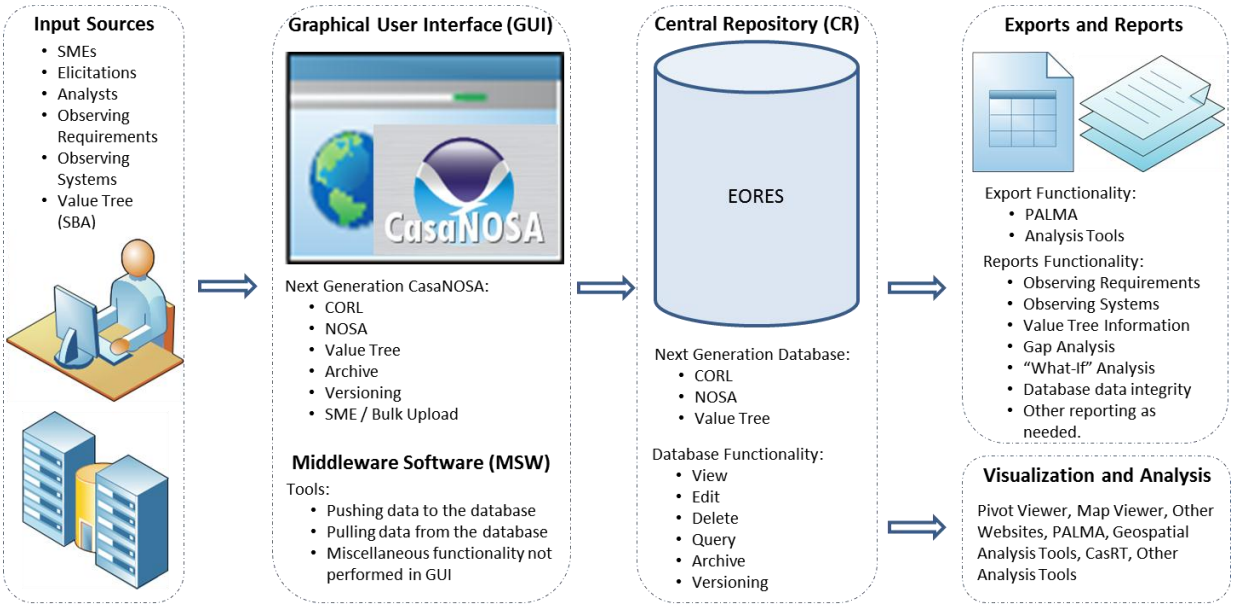


Figure 61. An overview of the Earth Observation Requirements Evaluation System.

Landsat Science Team: Advancing Landsat Science and Applications

In late 2012, the USGS, in partnership with NASA, announced the membership of the Landsat Science Team. The team of scientists and engineers was selected through a competitive process to serve a 5-year term (2012-2017) and 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 members contribute to USGS and NASA scientific and technical strategies affecting all Landsat users. Team members are playing a key role in ensuring that the Landsat Data Continuity Mission (LDCM) – now Landsat 8 – is successfully integrated with past, present, and future remotely sensed missions for the

purpose of observing national and global environmental systems. Table 2 lists the 2012-2017 Landsat Science Team members and the topics emphasized by their research.

The team met twice during FY 2013. The first meeting was held December 12-13, 2012, in Washington, D.C., at the Stewart Udall Department of the Interior Building. The second meeting was held February 10-14, 2013, in Buellton, California, in conjunction with the LDCM launch (fig. 62).

The initial Landsat Science Team meeting in December 2012 focused on introducing the science and engineering expertise of each of the new Team members and shaping a Team agenda for the next 5 years. The Team's priorities include: (1) evaluating the new Landsat 8 capabilities and identifying new science and applications opportunities, (2) defining science and applications requirements for future Landsat satellites and working toward long-term observation continuity, (3) identifying international land imaging constellation opportunities, and (4) establishing strategies and technical elements for Landsat land condition and change science products.

The second meeting was held in Buellton, California, in conjunction with the LDCM launch. As part of launch events, the Team promoted Landsat science through participation in media events and public information activities. In addition, the Team received in-depth briefings on the status of all Landsat assets, and especially LDCM's capabilities. Based on those briefing, they developed post-launch data evaluation plans, and reviewed and discussed current Landsat mission activities.

In FY 2014, the Team will continue to evaluate Landsat 8's capabilities and will actively contribute scientific and technical information that supports the NASA-USGS sustained land imaging initiative. For further information, contact Thomas Loveland, USGS EROS, loveland@usgs.gov.

Table 2. Landsat Science Team and topics emphasized by their research.

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. Ayse Kilic University of Nebraska	
Dr. Justin Huntington Desert Research Institute	
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.

Member and Affiliation	Topic Emphasized by Their Research
Dennis Helder South Dakota State University	Landsat data continuity: advanced radiometric 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	
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 62. A group photograph of the Landsat Science Team members while in Buellton, California.

Data Management and Distribution

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

Lidar Transition to EarthExplorer

Light detection and ranging (lidar) data are being acquired, ingested, archived, processed, and distributed through the EarthExplorer interface at the EROS Center for the USGS Land Remote Sensing and National Geospatial Programs, complementing other land remote sensing data. These data were previously distributed through the USGS Center for Lidar Information Coordination and Knowledge.

To facilitate a more timely and cost effective solution to distribute lidar data to the user community, the Long Term Archive (LTA) coordinated with the Spatial Data Warehouse (SDW) on the design and implementation of an enhanced data service using the EarthExplorer system. The lidar data and metadata are archived and managed under the LTA and web enabled through the EarthExplorer client (fig. 63).

The lidar discrete-return point cloud data are available in American Society for Photogrammetry and Remote Sensing (ASPRS) LAS format. The ASPRS LAS format is a standardized binary format for storing three-dimensional point cloud data and point attributes along with header information and variable length records specific to the data. Millions of data points are stored as a three-dimensional data cloud as a series of x (longitude), y (latitude), and z (elevation) points. Over 32 terabytes of point cloud data are available for download through EarthExporer.

The move to EarthExplorer resulted in greater access to the data. In FY 2013, 329,976 files were downloaded totaling 22 terabytes of data. The primary countries downloading lidar data were the United States, followed by Canada, Italy, and Germany. The demographic usage for United States users indicated the key uses of lidar are agricultural management, energy/minerals exploration/development, software development, and education. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

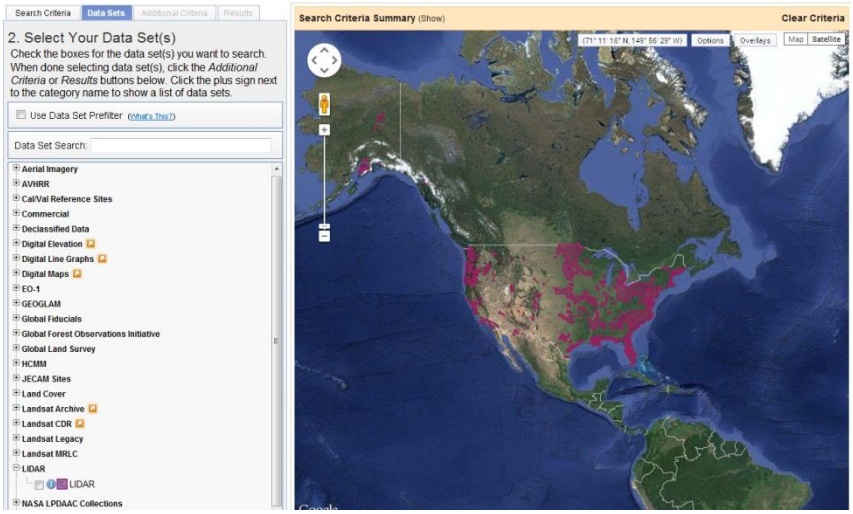


Figure 63. Lidar dataset coverage in EarthExplorer depicting the area of coverage of lidar data.

Earth Observing-1, Satellite Pour l'Observation de la Terre Level-1 Terrain-Corrected Processing

The USGS expanded the processing and usefulness of the Satellite Pour l'Observation de la Terre (SPOT) and Earth Observing-1 (EO-1) data by developing a level-1 terrain-corrected (L1T) processing flow for each data set (fig. 64). The first step in the process was to create a L1Gst (georeference systematically terrain corrected) product based on satellite ephermous information and no ground control. To make the L1Gst product more useable, the Long Term Archive image processing team developed a processing flow utilizing L1Gst product with the Global Land Survey 2000 Landsat dataset, that was already georeferenced using ground control, and the Land Analysis System (LAS) image-to-image processing capabilities to create a L1T EO-1 and SPOT data set.

The processing of SPOT and EO-1 data to L1T products provides the most accurate product for the science community to use with other L1T products (for example, Landsat) to investigate climate change. The SPOT and EO-1 L1Gst and L1T products are both available through the EarthExplorer system for product query and download at no cost to the user. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

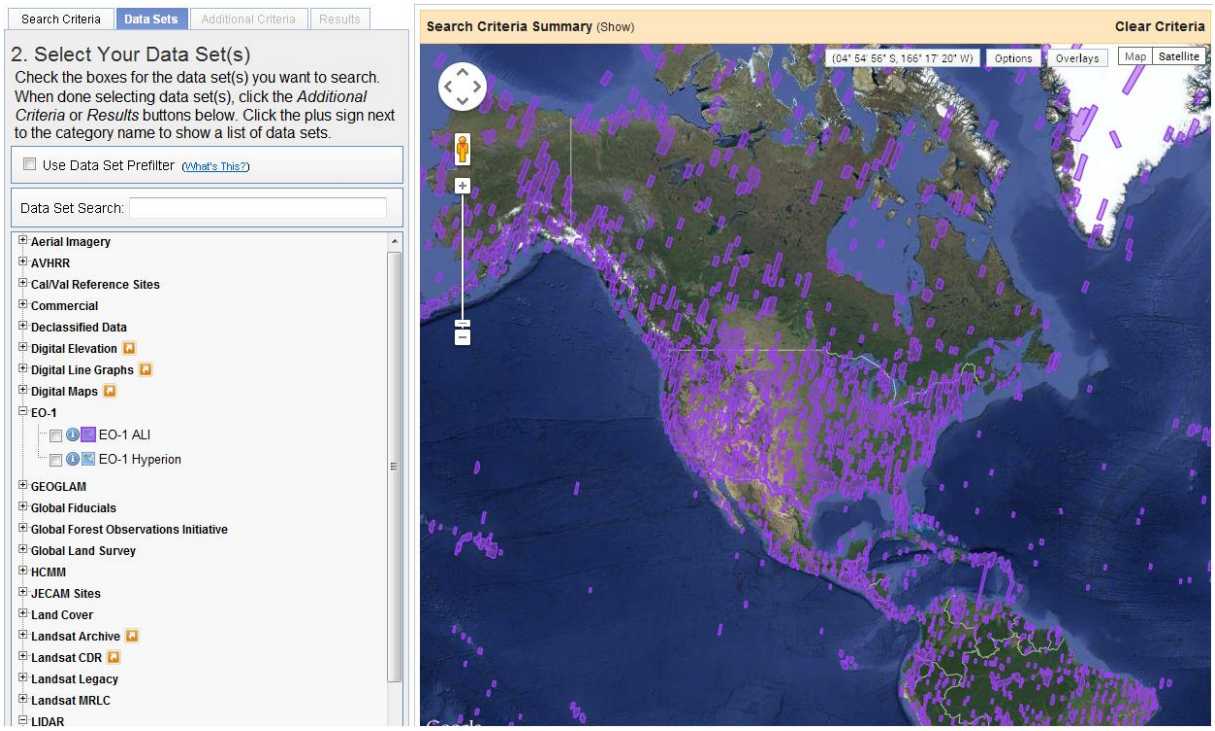


Figure 64. Earth Observing-1 data coverage.

National Agriculture Imagery Program Data Distribution

The National Agriculture Imagery Program (NAIP) is administered by the U.S. Department of Agriculture's (USDA) Farm Service Agency through the Aerial Photography Field Office in Salt Lake City, Utah. NAIP acquires orthorectified imagery at a resolution of 1-meter ground sample distance for the United States during the agricultural growing season, or "leaf on" conditions. Orthorectified images combine the image characteristics of an aerial photograph with the georeferenced qualities of a map.

To provide scientist and land managers greater access to the data, the Long Term Archive augmented the USDA data distribution efforts by managing and distributing NAIP products in JPEG2000 10:1 lossy compressed file format, which is embedded with georeferencing information (fig. 65). The data were made available through the EarthExplorer system which provides an easy to use, geographic search capability for the user community. The data is available for download to all registered users.

To support the requirements for full-resolution distribution of NAIP data for the DOI, NAIP full-resolution data is made available through the same EarthExplorer interface but limits access by providing a special registered user role for the National Park Service, Bureau of Land Management, Bureau of Indian Affairs, Bureau of Reclamation, U.S. Geological Survey, Office of Surface Mining Reclamation and Enforcement, Bureau of Ocean Energy Management, Regulation and Enforcement, and Office of Natural Resource Revenue. The data format is a full-resolution Georeferenced Tagged Image File Format (GeoTIFF).

NAIP data is used in support of disaster preparedness and response, land planning, historical analysis in support of agricultural research, and coordination planning between Federal, State and local Government agencies. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

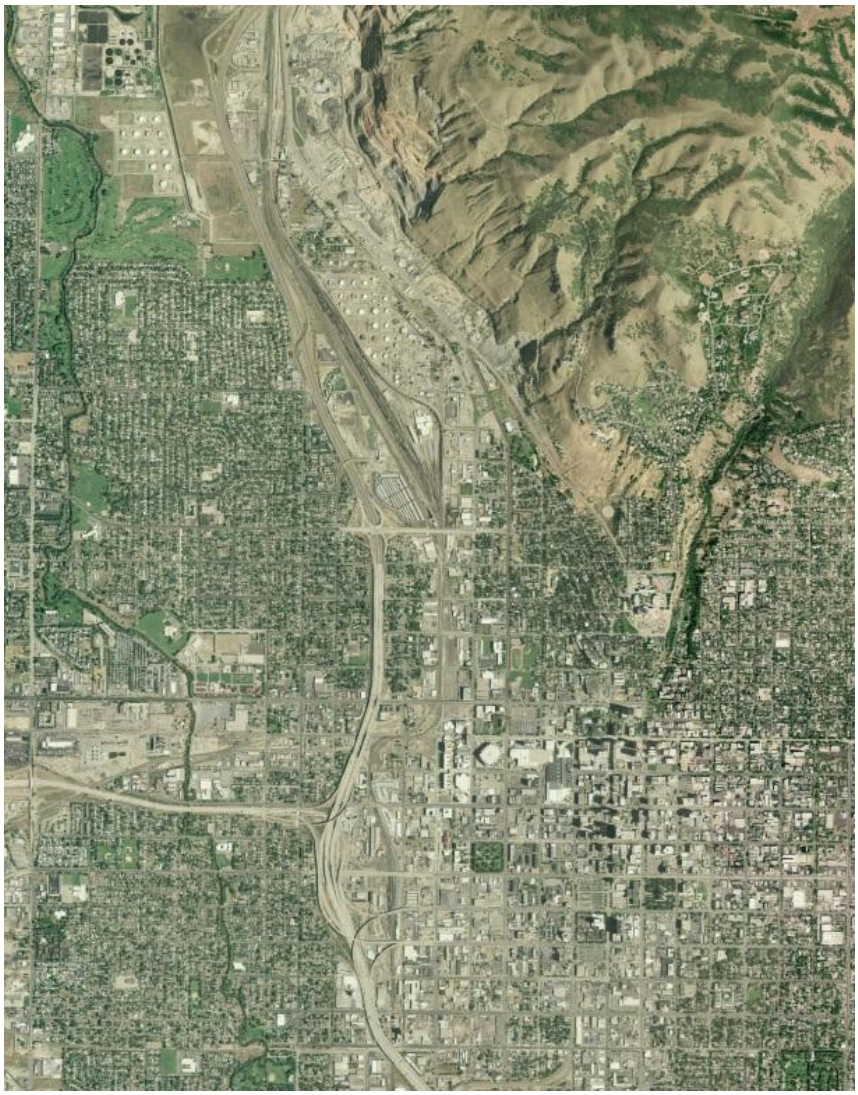


Figure 65. National Agriculture Imagery Program JPEG2000 image of Salt Lake City, Utah.

Landsat 8 Released to EarthExplorer

The Long Term Archive and Landsat Data Continuity Mission teamed together to design, develop, and implement the new EarthExplorer (earthexplorer.usgs.gov) system in support of the Landsat 8 mission. With the successful launch of Landsat 8, the OLI and TIRS data can be easily accessed and downloaded by the user community.

EarthExplorer provides various options for searching for data, using either geographic coordinates, path/row, address/place names, and a map interface for selecting the area-of-interest through the use of the Google Maps API (application program interface). Predefined areas such as states, congressional districts, and counties can also be used to define an area of interest along with shape files and KML file uploads.

The additional criteria tab can be used to further define search criteria for Landsat 8 data. WRS path/row, a specific sensor on the Landsat 8 platform, cloud cover, and day/night scenes are some of the additional criteria that can be used to further define a search.

Search results on Landsat 8 data through EarthExplorer provide capability to view metadata, graphically display the coverage area using a footprint and full-resolution browse overlays (fig. 66). The full metadata on each image can be displayed, as well as exporting metadata to CSV, Shapefile, KMZ, comma-delimited, and FGDC (Federal Geographic Data Committee) formats. Multiple browse can also be displayed to show Landsat 8 natural color, thermal, and quality bands (fig. 67).

EarthExplorer provides a visualization tool to aid users in determining the best image to select. The Compare Browse tool (fig. 68) allows a user to select multiple browse images and compare the images in a separate browser window. Multiple browse can be selected to compare coverage and cloud cover. Opacity percentages can be applied for each image to allow analysis over multiple images.

The Bulk Order tool integrated with the EarthExplorer provides greater access to large amount of data. The Bulk Order tool offers the ability to download a large number of scenes to the user's desktop or on user-provided external media unattended by the user. This provides greater flexibility for the large users of Landsat and other remote sensing data.

The successful launch of Landsat 8 and the integration of Landsat 8 data within EarthExplorer provides users with a powerful tool to support scientific research and data downloads. The extensibility of EarthExplorer allows scientists and other users of land science data to query for Landsat 8 data, as well as Landsat 7, NAIP, lidar, aerial photos and other valuable sources of data to compare temporal coverage over their area of interest. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

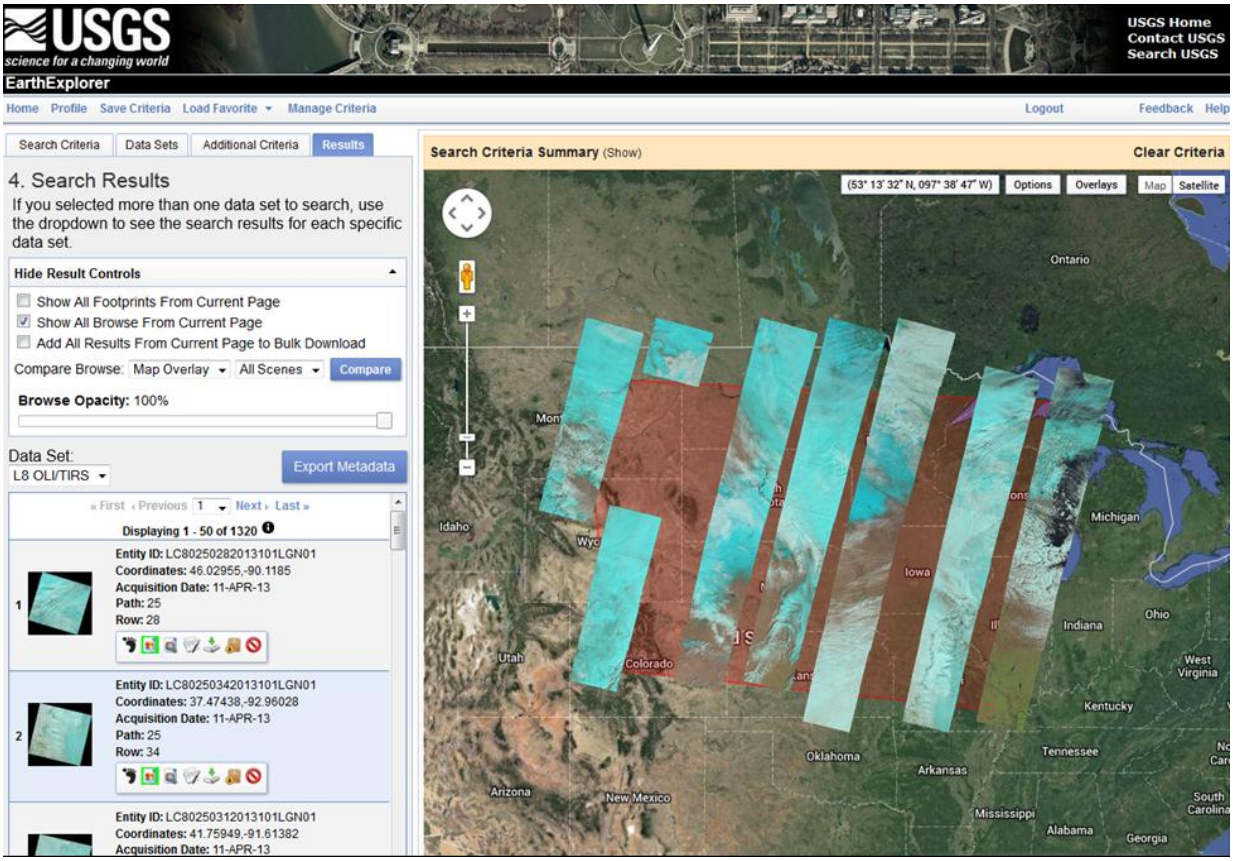


Figure 66. A full-resolution web map service of Landsat 8 Operational Land Imager and Thermal Infrared Sensor images in EarthExplorer.

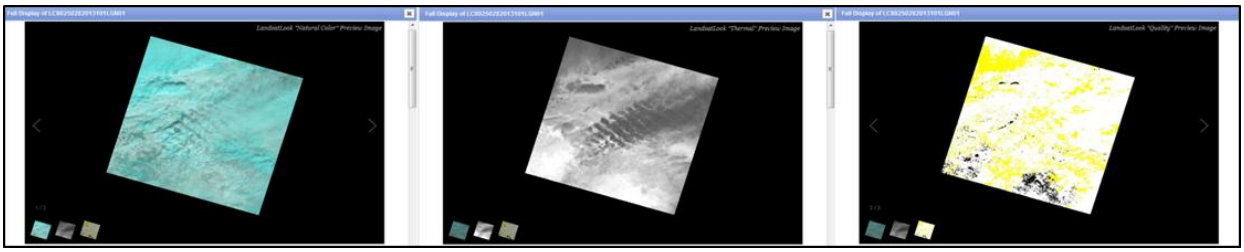


Figure 67. Ability to view natural color, thermal, and quality browse images.

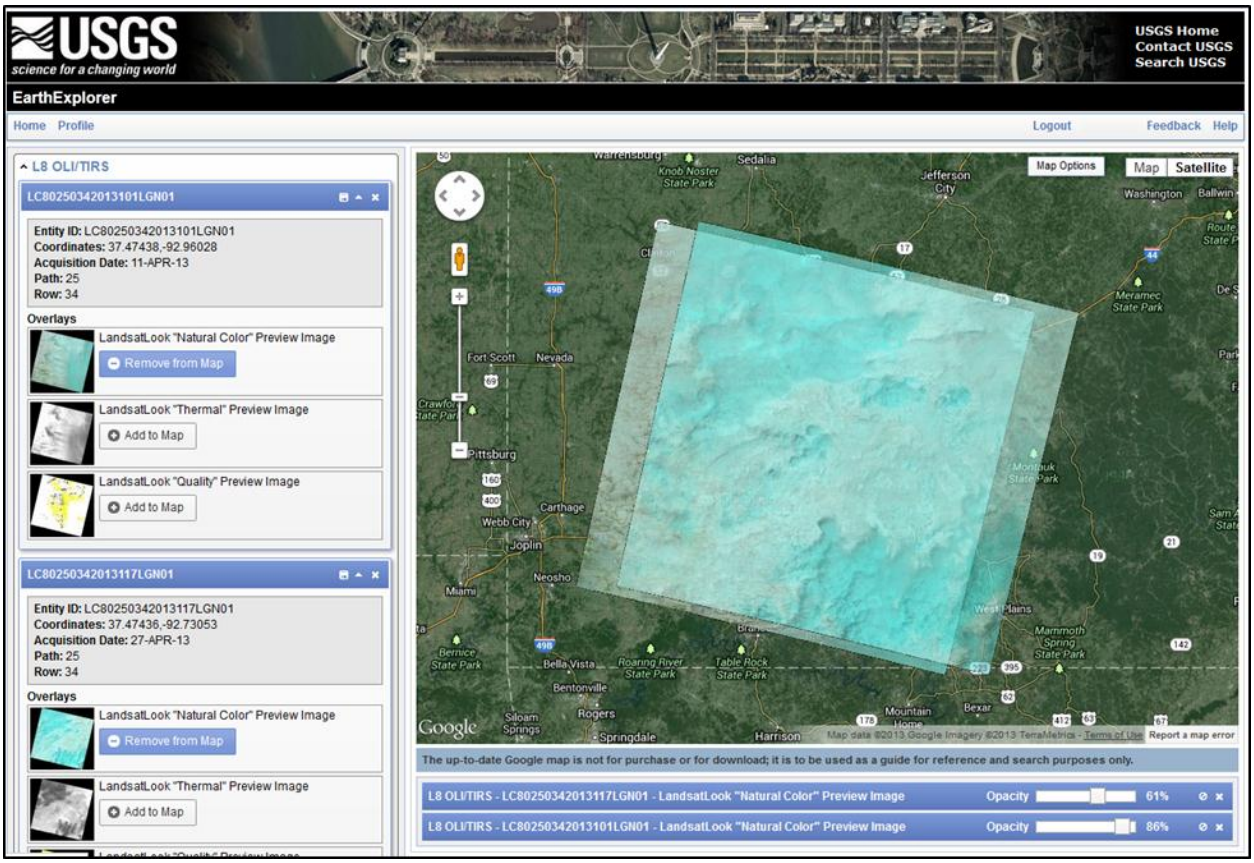


Figure 68. Compare multiple browse and opacity.

Hazards Data Distribution System Explorer Release

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

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

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

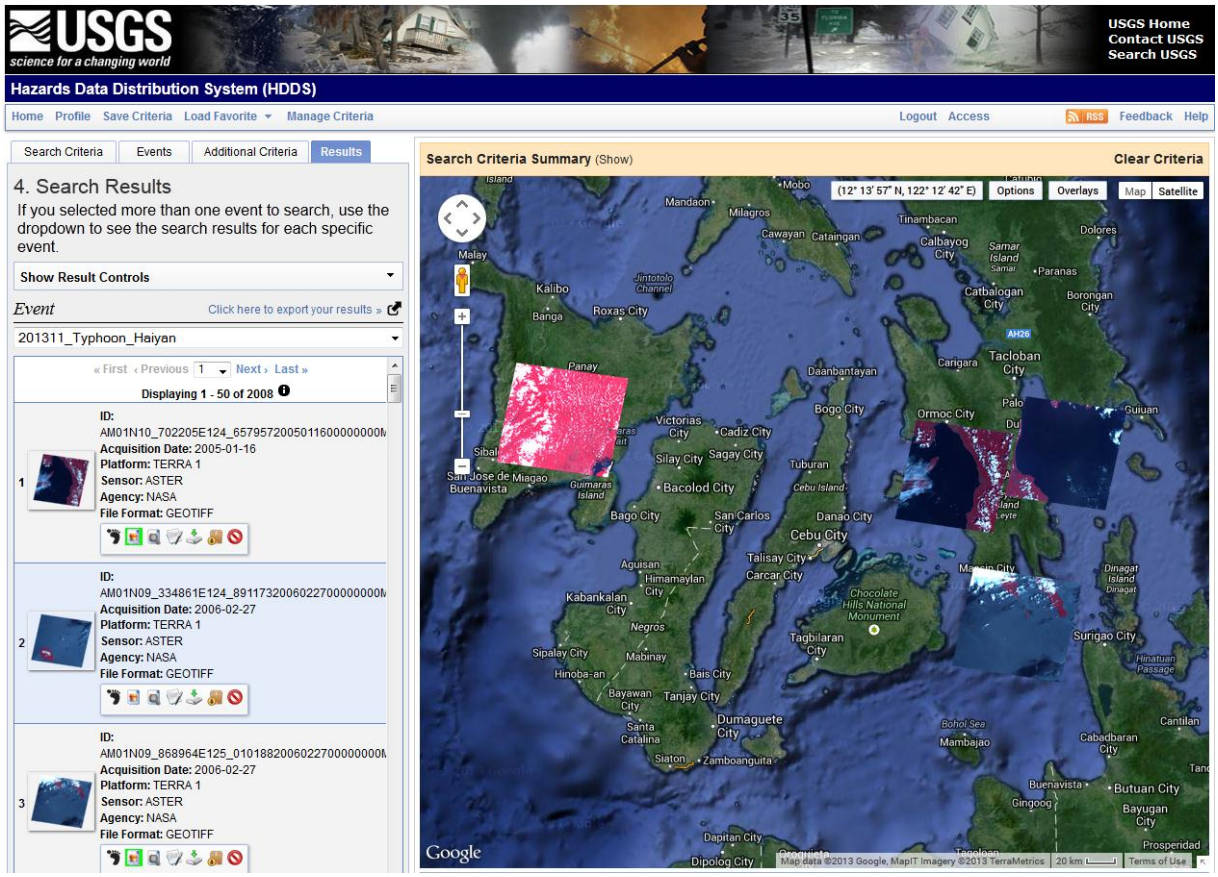


Figure 69. Hazards Data Distribution System Explorer search results.

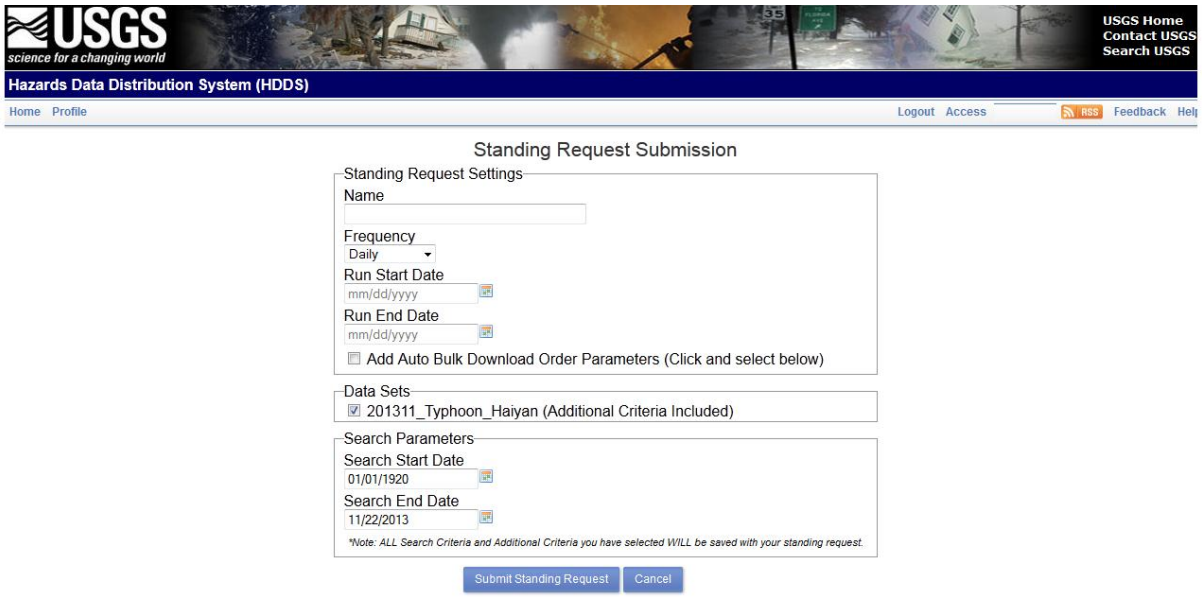


Figure 70. Standing request functionality in Hazards Data Distribution System Explorer.

eMODIS Product Expansion

The USGS EROS Center distributes a collection of satellite-derived vegetation products generated from MODIS. These products, known as EROS MODIS (eMODIS) products, respond to operational land monitoring applications requiring near-real time NDVI data for comparison against historical records.

The eMODIS NDVI composites are produced for multiple areas around the world including Alaska, conterminous United States, Africa, Central Asia, and Central America/Caribbean regions in the GeoTIFF. The composite interval periods can range from 5, 7, 10, or 14 days, depending on the particular region. Continental United States expedited products are generated daily on a 7-day interval; continental United States historical area is generated on 7- and 14-day intervals; Central America/Caribbean, Africa, and Central Asia are produced every 5 days on 10-day intervals. Alaska historical products are generated on a 7-day interval basis. Time is the prominent factor defining early warning capabilities, and such users strive to limit the latency between acquisition and usability. In response, the near real-time eMODIS 250-meter NDVI avoids the time delay correlated with the standard NASA Earth Observing System (EOS) MODIS products. Additionally, eMODIS is well suited for operational early warning models as it is processed directly into a usable GeoTIFF format, eliminating the post-processing transformations needed to handle the latency, map projection, compositing interval, and Hierarchical Data Format (HDF) present in the standard NASA EOS products.

The Long Term Archive staff recently went global and expanded the production processing of eMODIS data with the development of a global land surface temperature (LST) product for the Famine Early Warning Systems. The eMODIS global LST product (fig. 71) is the average of LST and emissivity during a 10-day period of each month. The products are used to support studies such as drought conditions, vegetation monitoring, regional, and global climate changes. For further information, contact Wayne Miller, USGS EROS, wamiller@usgs.gov.

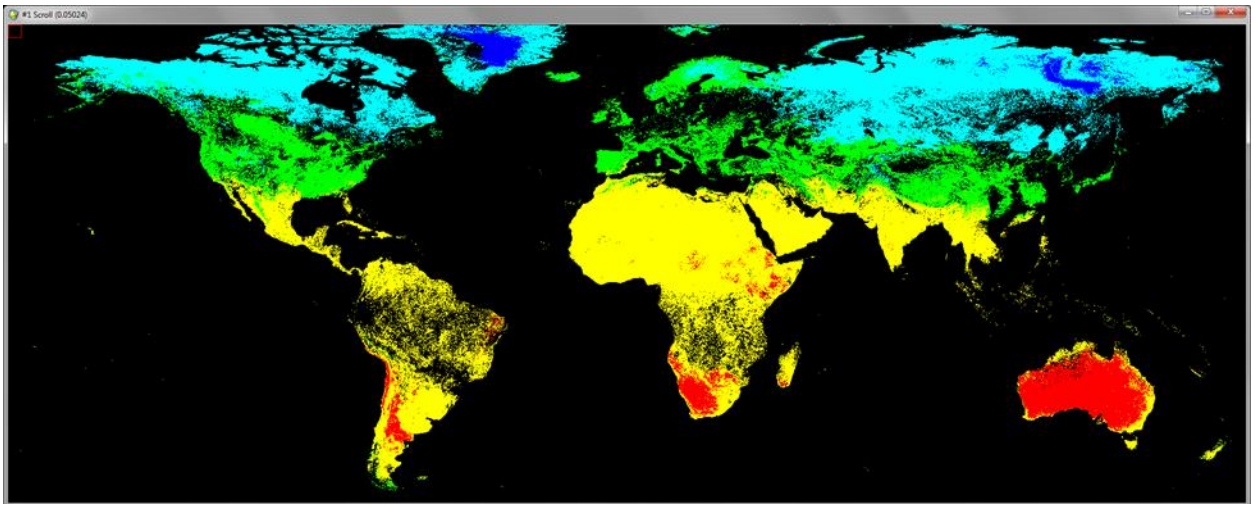


Figure 71. Global land surface temperature product.

Leverage NASA Earth Science Data for Socio-Economic Applications

The User Working Group (UWG) of the Land Processes Distributed Active Archive Center (LP DAAC) provides consultation, peer review, and recommendations to the LP DAAC. The UWG convenes yearly to ensure the LP DAACs resources and efforts are responsive to the needs of Earth science research.

On May 9-10, 2013, the UWG participated in a joint technical interchange with the UWG of the Socio-Economic Data and Applications Center (SEDAC) of Columbia University to explore collaboration between the two NASA-funded centers. The exchanges focused on two areas: (1) supporting the National Climate Assessment Indicators (NCAI) under development by the U.S. Global Change Research Program, and (2) coordinating resources in support of global urban mapping applications.

The two UWG's met in concurrent NCAI and urban mapping breakout sessions. Participants in each session identified science questions of interest to both UWGs, and offered specific recommendations to address them. These recommendations played a key role in planning LP DAAC and SEDAC FY 2014 activities.

Breakout Group on DAACs Support to the National Climate Assessment (NCA).

- The NCA has identified the need for a coherent set of physical, ecological, and societal indicators to support ongoing assessment and decision-making related to climate change, impacts, vulnerability, and preparedness. An indicators work group has been established and a set of technical teams have been formed, with the aim of establishing a prototype system by early 2014 and formally launching the indicator system by 2015. Indicators would necessarily rely on ongoing measurement and monitoring programs and data sources, such as those provided by the DAACs.

- Recommendations from this breakout included identification of derived products of interest as potential indicators to the NCA, relevant existing or upcoming data streams to develop indicators, and test cases for the two centers to work with (such as the Trans-boundary Water Assessment Program). Particular emphasis was placed on internal provenance and quality assessment, interoperability between centers using open protocols, and consideration of non-specialists on the use of indicator products and services.

Breakout Group on Potential Applications of LP DAAC and SEDAC Data for Urban Area Delineation.

- The 2012-2015 Work Plan for the Group on Earth Observations (GEO) includes a task targeting a coherent observation and information system framework for urban areas around the globe. As producers of geospatial products for the natural and social sciences, LP DAAC and SEDAC can help address this by establishing criteria for delineation of urban extent that are consistent with processes of interest to both natural and social scientists. These criteria could be defined in the context of both form and function so that the definition of urban extent can be both application-dependent and consistent across multiple applications.

- This breakout group identified collaboration opportunities between LP DAAC and SEDAC to address current gaps and future needs of the GEO task. Science questions identified by the group include urban development applications, natural hazards/disaster risk reduction, urban impacts on/from climatic processes, human-environment interactions/sustainability, and the accurate identification of urban heat islands. Specific recommendations include nighttime tasking of both ASTER and Landsat 8 over urban areas, urban green space mapping, and a range of applications making use of night observations from the Visible Infrared Imaging Radiometer Suite.

For further information, contact David Meyer, USGS EROS, dmeyer@usgs.gov.

Land Processes Distributed Active Archive Center – Reaching Applied Users Efficiently, Effectively, and Collaboratively

The LP DAAC, funded by NASA's Earth Science Data Systems Program to manage and distribute MODIS data products, is uniquely situated to expose and promote these products to the Earth science applications community. Products generated from MODIS include land surface temperature, reflectance, vegetation indices, phenology, land cover, albedo, and photosynthesis. The 98th Annual Ecological Society of America (ESA) Meeting provided a forum to reach a large segment of this community through a workshop, conducted in collaboration with the Oak Ridge National Laboratory, on how to find, access, manipulate, subset, and download MODIS products without special knowledge or software experience.

The LP DAAC adapted and reused content elements from a 2-day workshop conducted in 2011 in coordination with the DOI Remote Sensing Working Group, delivered at the Denver Federal Center to DOI agency users. At the conclusion of the DOI workshop, attendees were able to understand remote sensing data product characteristics, policies, uses, access, and future plans.

Prior to the ESA workshop, none of the ecologists registered for the workshop considered themselves to be MODIS users. During the workshop, they learned how to find, access, manipulate, subset, and download MODIS data without special knowledge or software experience. The workshop assisted both beginning and advanced ecologists from beginner to advanced users through the USGS visualization tools EarthExplorer and GloVis; HDF-EOS data collection with Data Pool and Reverb; and reprojection using MRTWeb. In addition to the NASA and USGS access methods covered in the 2011 DOI workshop (e.g., EarthExplorer, GloVIS, MRTWeb, Reverb etc.), the ESA workshop included data discovery and subsetting tools developed by Oak Ridge National Laboratory to produce MODIS time series.

At the conclusion of the workshop, all attendees anticipated using MODIS in the future. Several attendees met with LP DAAC staff after the workshop for extensive one-on-one consultations on appropriate data use and optimizing access. LP DAAC will further adapt and reuse content elements during a half-day workshop at the ASPRS 2014 Annual Conference.

Information at http://eco.confex.com/eco/2013/webprogram/Session8910.html is available about the workshop; or for further information, contact David Meyer, USGS EROS, dmeyer@usgs.gov.

Community-Wide Standards Improve Lidar Quality

In addition to the work that the Remote Sensing Technologies (RST) Project performs carrying out quality and accuracy assessments of various remote sensing systems, the Project has been working diligently with other Government agencies, industry, and

academia to develop new lidar standards for quality and the means and methods to measure these standards (fig. 72 and 73).

Lidar data is well on its way to becoming as ubiquitous as aerial imagery. However, the standards of quality assurance and control that transform aerial imagery from a pretty picture to a measurement are not as developed for lidar data. The current lidar data quality assessment methods are inadequate in reporting: (a) the quality of calibration of the lidar system, which is an essential indicator of the overall quality of data, and (b) the absolute horizontal accuracy of the data. The current methods to measure the absolute accuracy of lidar data only attempt to quantify the vertical accuracy of the data, while leaving horizontal accuracy undefined. Since lidar is three-dimensional data, it is important to quantify the accuracy of measurement in all three dimensions. The necessity for new standards and procedures will be felt particularly for large national projects like the 3DEP (3D Elevation Program). The 3DEP envisages the collection of 3D data for the entire nation over a number of years. Therefore, it is extremely important that consistent and correct methods for specifying procurement requirements and assessing the quality of data are available.

Recognizing this, the USGS has partnered with the ASPRS Lidar Division and the Aerial Lidar Committee to promote a set of guidelines and tools to help assess the quality of lidar data. USGS-ASPRS approved guidelines (titled Guidelines on Geometric Accuracy and Quality of Lidar Data (fig. 73)) for Quality Assurance/ Quality Control (QA/QC) processes will accelerate the acceptance of lidar data across agencies, increasing confidence in the data and increasing its scientific applications.

Work done to date includes the formation of a lidar standards group in conjunction with ASPRS to provide input and guidance to the USGS as these QA guidelines are developed. The group includes Government, academia, and industry and will also provide first testing and review of the standards and tools as they are developed.

The USGS has developed algorithms for lidar data quality measures that allow assessment of the 3D characteristics of lidar data and reporting them in a consistent manner. The community currently does not have a method to measure data quality between lidar swathes (fig. 74) and across the collection lift. These algorithms are being turned into test software that will automate the handling of large lidar data collections and report statistics and will provide a methodology to do so.

As wider testing of these tools and methods by the lidar advisory group continues in FY 2014, the USGS plans to report on the Lidar QA Guidelines at the February 2014 International Lidar Mapping Forum in Denver, Colorado, and then again and more fully at the ASPRS Annual conference in Louisville, Kentucky, in April 2014. For further information, contact Gregory Stensaas, USGS EROS, stensaas@usgs.gov.

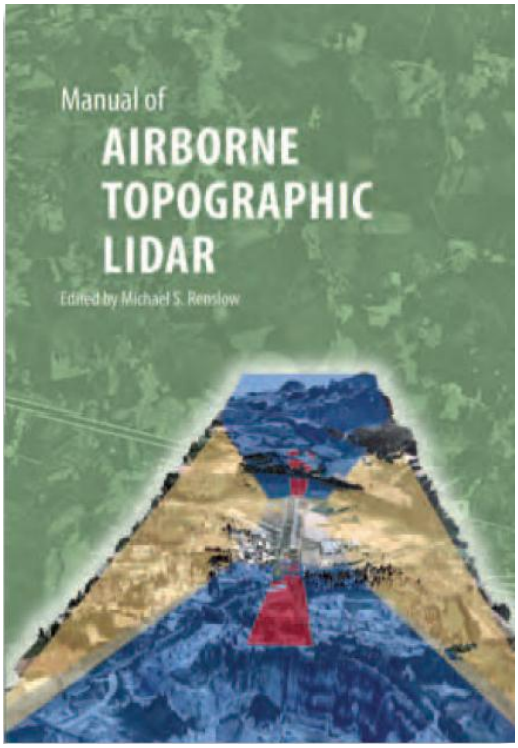
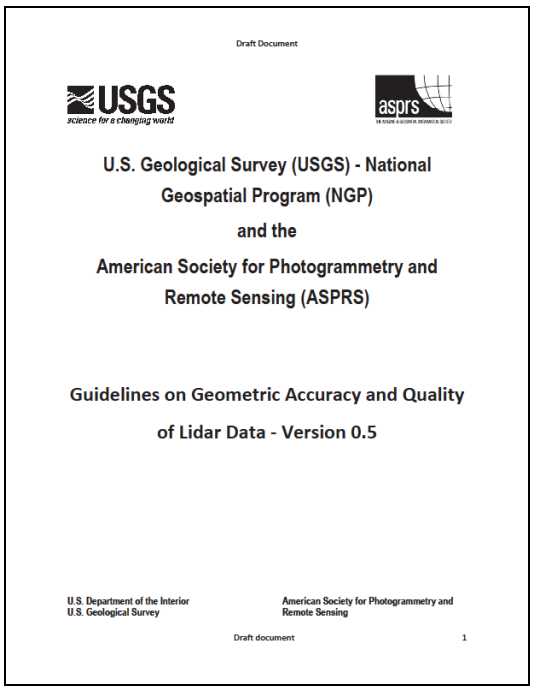


Figure 72. Appendix B of the American Society for Photogrammetry and Remote Sensing Lidar Manual introduced this year was largely taken from the Remote Sensing Technologies-developed Lidar USGS Guidelines.



Draft Document

U.S. Geological Survey (USGS) - National Geospatial Program (NGP)

and the

American Society for Photogrammetry and Remote Sensing (ASPRS)

Guidelines on Geometric Accuracy and Quality of Lidar Data - Version 0.5

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

American Society for Photogrammetry and Remote Sensing

Draft document 1

Figure 73. Draft U.S. Geological Survey/American Society for Photogrammetry and Remote Sensing Guideline being developed with full community support.

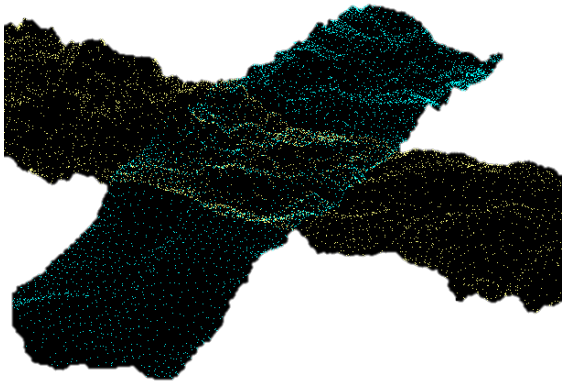


Figure 74. The intersection of overlapping lidar swaths is being used to understand the overall three-dimensional lidar quality.

USGS Continues Demonstrating Leadership in Data Characterization

The Remote Sensing Technologies Project at the USGS EROS continued to demonstrate technical and cooperative leadership in FY 2013 in monitoring and researching the quality of remotely sensed data. System characterization work, where RST staff characterize the quality and accuracy of data from satellites and other sensors, continued this year with the analysis of the Advanced Wide Field Sensors-2 (AWiFS-2) aboard India's ResourceSat-2 satellite, Astrium's high-resolution Pleiades-1a satellite, Spain's Deimos medium resolution satellite, and the Japanese ASTER dataset.

Additionally, RST continued leadership of the Joint Agency Civil/Commercial Imagery Evaluation (JACIE) Team, as it has done since 2006, resulting in a successful JACIE Workshop held in St. Louis, Missouri, April 16-18, 2013. Although attendance was reduced due to the effects of the Federal budget "sequestration," attendees from across the United States and multiple foreign countries were able to view the testing and research results from the USGS and others presenting at the workshop.

The RST Project continues to lead the JACIE group and is looking forward to an exciting 2014 workshop, to be held for the first time in conjunction with the ASPRS annual conference in April 2014. Through these ongoing efforts, the JACIE Proceedings database on the RST website has grown to over 400 documents; http://calval.cr.usgs.gov/jacie/.

In another example of leadership, RST concluded a very successful 2-year chairmanship of the Committee on Earth Observation Working Group on Calibration and

Validation (WGCV) in November 2012. During the chairmanship of Greg Stensaas, the WGCV saw one of its most active and productive periods in recent years (fig. 75).

One final example of leadership shown by the RST Project was the publication of a special issue of the *Institute of Electrical and Electronics Engineers* Transactions on the Geoscience and Remote Sensing dedicated to satellite characterization and calibration (fig. 76). RST staff served as guest editor of this 500-page journal and contributed six of the issue's 45 papers. Additionally, RST staff published several other papers on calibration, data quality, and testing over the fiscal year. For further information, contact Gregory Stensaas, USGS EROS, stenaas@usgs.gov.

Figure 75. Greg Stensaas recognized for his 4 years of service as Chair and Vice Chair of the Working Group on Calibration and Validation by Committee on Earth Observation's Chair from the Indian Research and Space Organization, Dr. Kiran Kumar.

IEEE TRANSACTIONS ON

GEOSCIENCE AND REMOTE SENSING

A PUBLICATION OF THE IEEE GEOSCIENCE AND REMOTE SENSING SOCIETY

DECEMBER 2004 VOLUME 42 NUMBER 12 IGRSD2 (ISSN 0196-2892)

SPECIAL ISSUE ON LANDSAT SENSOR PERFORMANCE CHARACTERIZATION

Landsat 5 and Landsat 7 sensor calibration and characterization. (Left) Landsat images of calibration sites. (Bottom) Various forms of surface and airborne reference data collection. (Background) Flowchart of the geometric calibration within the Landsat-7 Image Assessment System.

IEEE

Figure 76. U.S. Geological Survey lead publication on satellite characterization and calibration.

Release of Compressed Product for *The National Map*

As one of the cornerstones of the USGS National Geospatial Program, *The National Map* is a collaborative effort among the USGS and other Federal, State, and local partners to improve and deliver topographic information for the nation. EROS has supported *The National Map* by providing land cover, elevation, and orthoimagery visualization and data services since its inception. The orthoimagery provides the basemap for new topographic map products and is the largest dataset (by storage volume) of any dataset supporting *The National Map*. Figure 77 is an aerial image of the USGS National Center acquired in February 2011 and shows an example of the orthoimagery collection.

Orthoimagery supporting *The National Map* amounts to tens of terabytes (TB) of data storage. As the resolution, coverage, and depth of the imagery increases, the storage costs increase. Introduction of compressed storage for both visualization and data delivery directly impact the amount of storage required which impacts the cost.

The introduction of a JPEG2000 based compression in the product production process for delivery achieves a 5:1 compression ratio with no loss of fidelity to the product. Therefore, there is not only a reduction in storage costs for the project, but also a smaller product delivered to the end user. That means lower cost and faster data transmission for both the project and the end user. By converting the TIFF to JPEG2000 for delivery, size of data stored decreased by over 70 TBs.

Compression also applies to the storage used for visualization. In this instance, it is a JPEG (not JPEG2000) compression that has a very minor effect on the visualization quality. Since, the visualization service design for achieving a set level of performance already required such compression; the application of the compression to the stored product means cost savings to the project with no change to the public users. The new storage reduces the data storage required by almost 15:1. Actual size of data stored decreased by over 180 TBs.

The major cost savings to the project allow for the continued support of orthoimagery delivery support without increasing the costs, even though the orthoimagery data volume consistently grows. Any person downloading data with the compression should be able to realize faster downloads using less bandwidth.

The USGS EROS Center, located in Sioux Falls, South Dakota., provides data ingest, archiving, and distribution to support *The National Map*. For further information, contact Ryan Longhenry, USGS EROS, rlonghenry@usgs.gov.

Figure 77. U.S. Geological Survey Headquarters in Reston, Virginia, February 2011.

Release of New Image Collection on Land Remote Sensing Program Website

The fundamental goal of the Land Remote Sensing Program is to provide the Federal Government and the public with a primary source of remotely sensed data and applications and to be a leader in defining the future of land remote sensing, nationally and internationally. The Spatial Data Warehouse Project supports this LRS Program goal by maintaining several web sites including the Remote Sensing site at http://remotesensing.usgs.gov/.

This support includes the image collection where the LRS Program highlights USGS data that is pertinent to current events, shows the analysis capabilities, or striking images. Figure 78 shows an example of the image collection holdings which visualize changes over time.

Showcasing the products available from LRS related projects on the web site provides users with the breadth of products available and the analysis capabilities thereof. The website was redesigned this year to provide better access to these showcase data products.

Redesigning the image collection allowed integration of social media, searching, and allowed multiple EROS project resources to be much more efficient. The social media aspects include things like media RSS, and links to a host of online resources. New

categories along with a better search interface utilizing location, keywords, and date make finding images easier and allows for new ways of displaying images like the scrolling thumbnails. Every image has improved metadata, which includes geospatial location information and enables linking to science topics and FAQs related to the image. Integration of the Landsat, Media Services, and LRS Science projects means more imagery is available in the image collection. Each product displayed has more metadata available, and includes links directly to the data.

Along with the improved online interface, an effort has taken place to standardize the production process across EROS image collections, which will lead to better integration down the road as this works into other EROS projects.

The new Land Remote Sensing web site image collection capability displays the science products with additional capabilities and in a way that make them more available to the end user promoting a better understanding of what products are available and how to use those. All of this means that public users will find more remote sensing data, quicker and easier than before.

The USGS EROS Center, located in Sioux Falls, South Dakota, provides web site hosting and coordination to support the USGS Land Remote Sensing Program. For further information, contact Ryan Longhenry, USGS EROS, rlonghenry@usgs.gov.

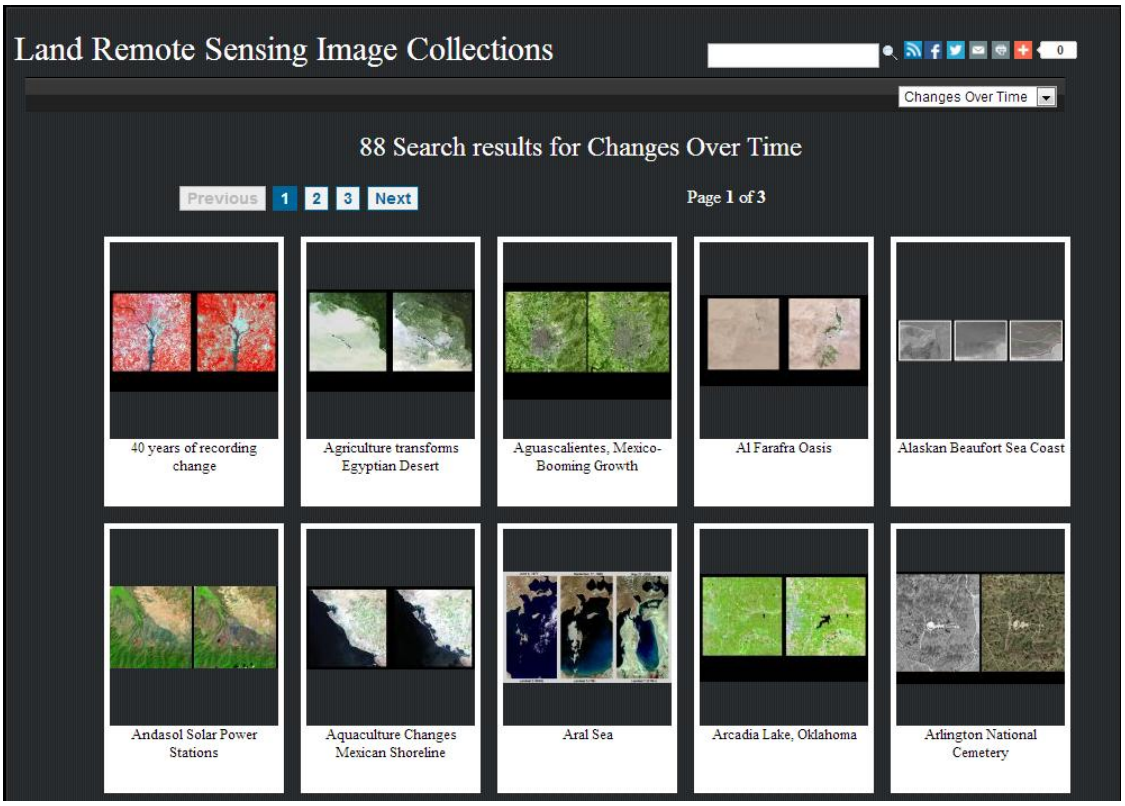


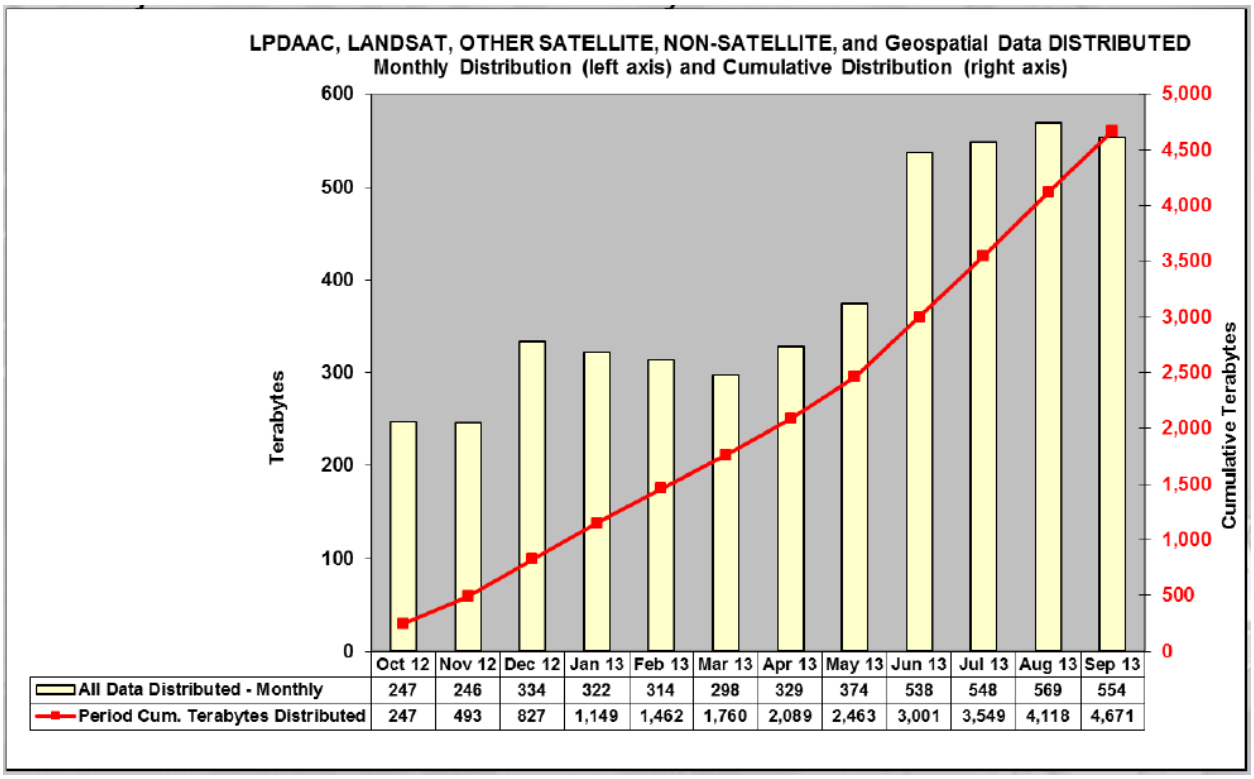
Figure 78. A screen capture showing the new search capability of the Land Remote Sensing Image Collections.

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

The USGS EROS has a prepared report template used by the EROS projects for inputting their respective data managed and distributed. The template, reviewed by the projects and the USGS LRS Program, gives statistics in terabytes distributed and managed in FY 2013.

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

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



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
All Data Distributed - Monthly	247	246	334	322	314	298	329	374	538	548	569	554
Period Cum. Terabytes Distributed	247	493	827	1,149	1,462	1,760	2,089	2,463	3,001	3,549	4,118	4,671

Figure 79. FY 2013 Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.

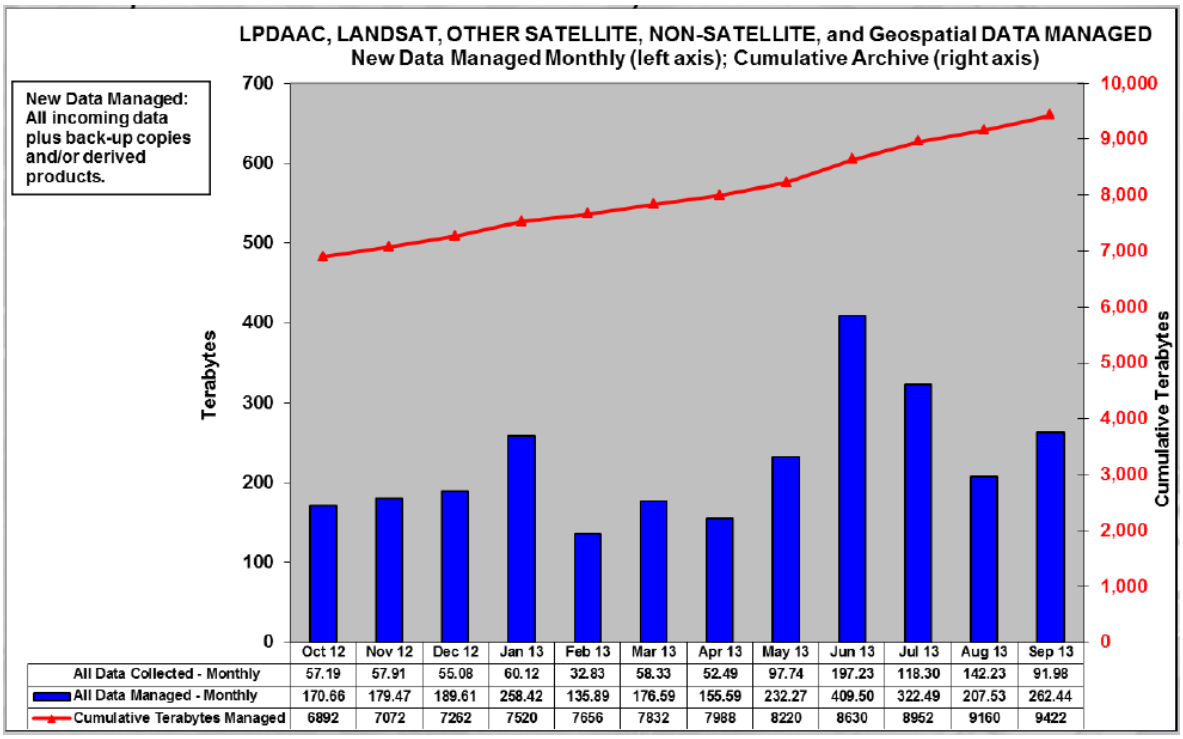


Figure 80. FY 2013 Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.

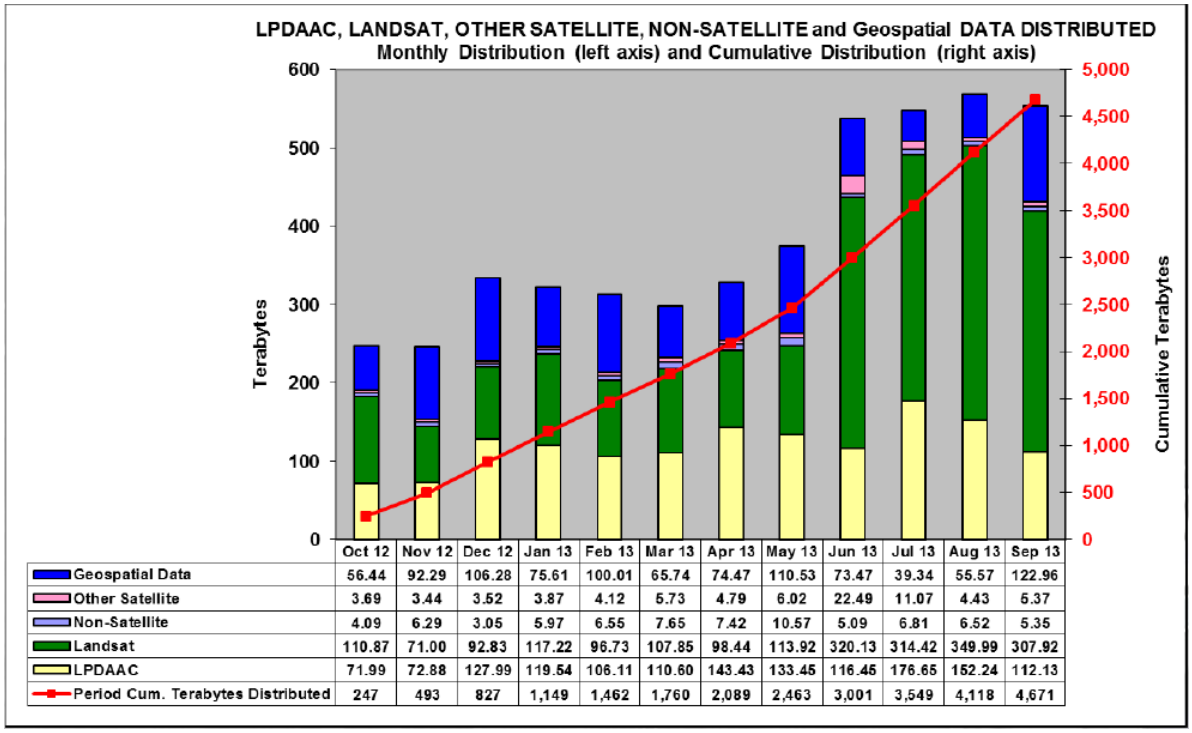
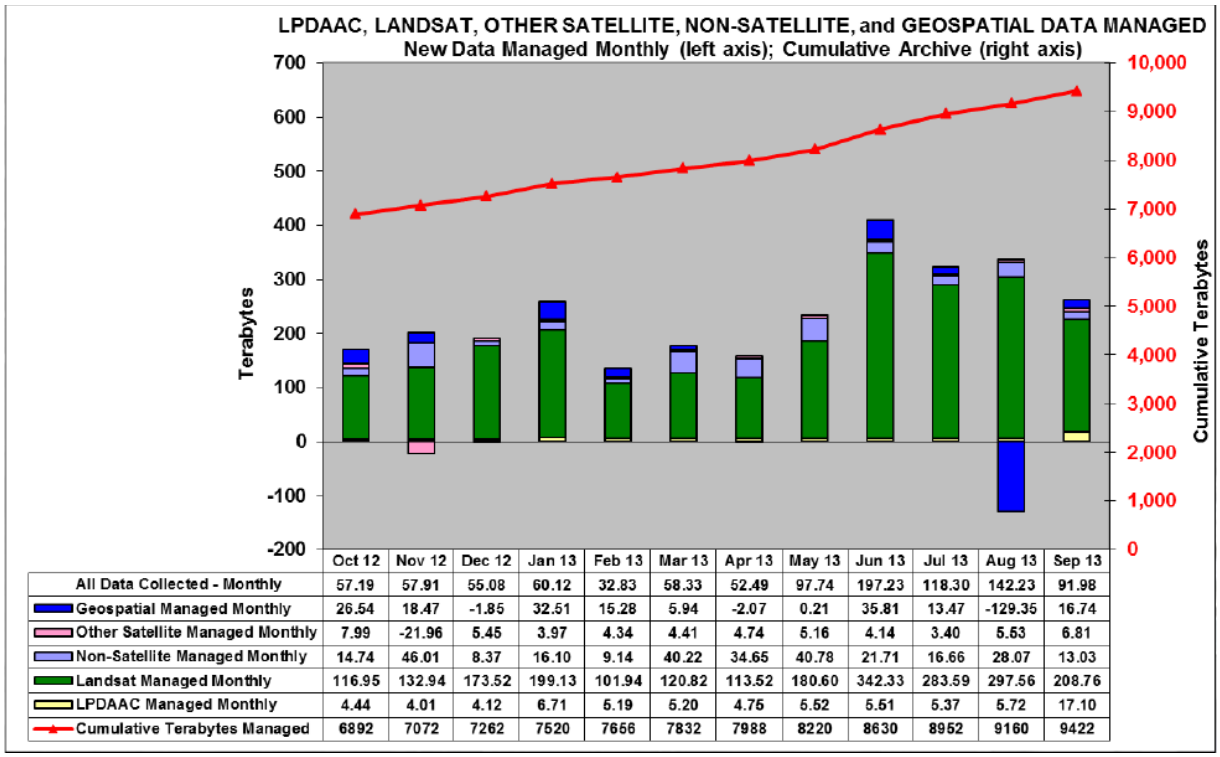
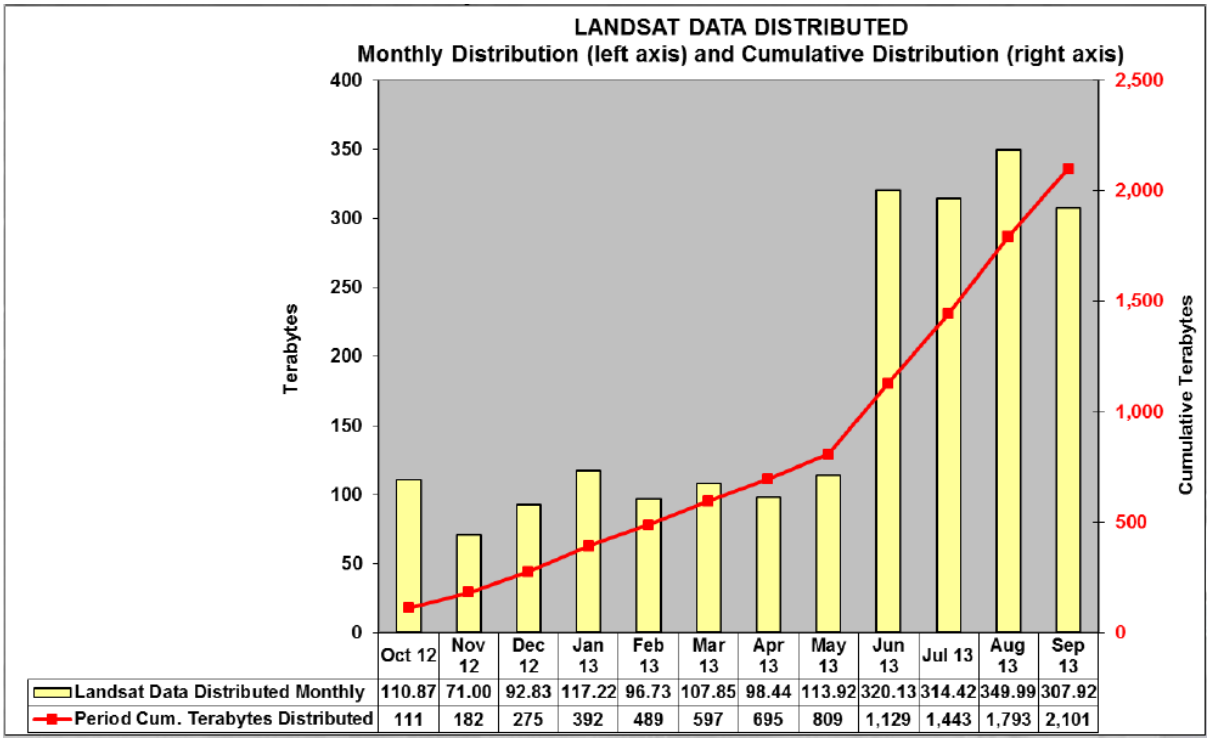


Figure 81. FY 2013 Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data distributed.



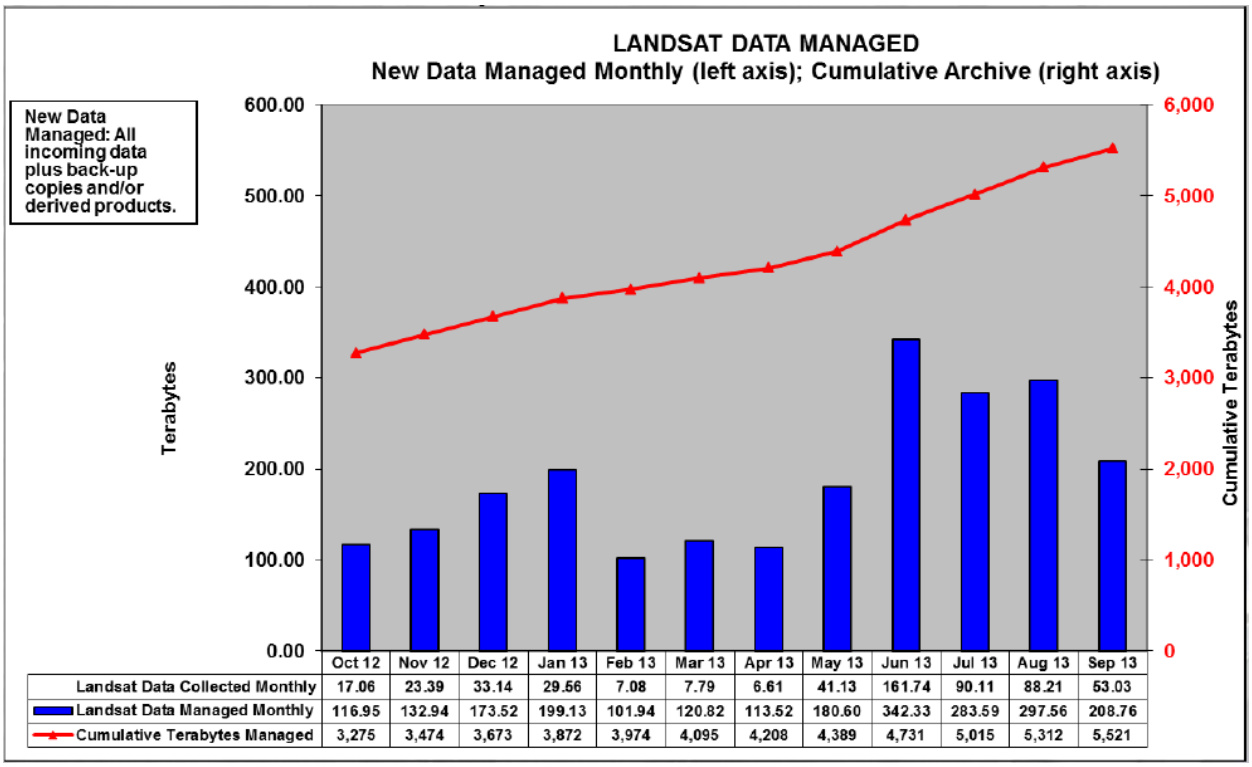
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
All Data Collected - Monthly	57.19	57.91	55.08	60.12	32.83	58.33	52.49	97.74	197.23	118.30	142.23	91.98
Geospatial Managed Monthly	26.54	18.47	-1.85	32.51	15.28	5.94	-2.07	0.21	35.81	13.47	-129.35	16.74
Other Satellite Managed Monthly	7.99	-21.96	5.45	3.97	4.34	4.41	4.74	5.16	4.14	3.40	5.53	6.81
Non-Satellite Managed Monthly	14.74	46.01	8.37	16.10	9.14	40.22	34.65	40.78	21.71	16.66	28.07	13.03
Landsat Managed Monthly	116.95	132.94	173.52	199.13	101.94	120.82	113.52	180.60	342.33	283.59	297.56	208.76
LPDAAC Managed Monthly	4.44	4.01	4.12	6.71	5.19	5.20	4.75	5.52	5.51	5.37	5.72	17.10
Cumulative Terabytes Managed	6892	7072	7262	7520	7666	7832	7988	8220	8630	8952	9160	9422

Figure 82. FY 2013 Land Processes Distributed Active Archive Center, Landsat, other satellite, non-satellite, and geospatial data managed.



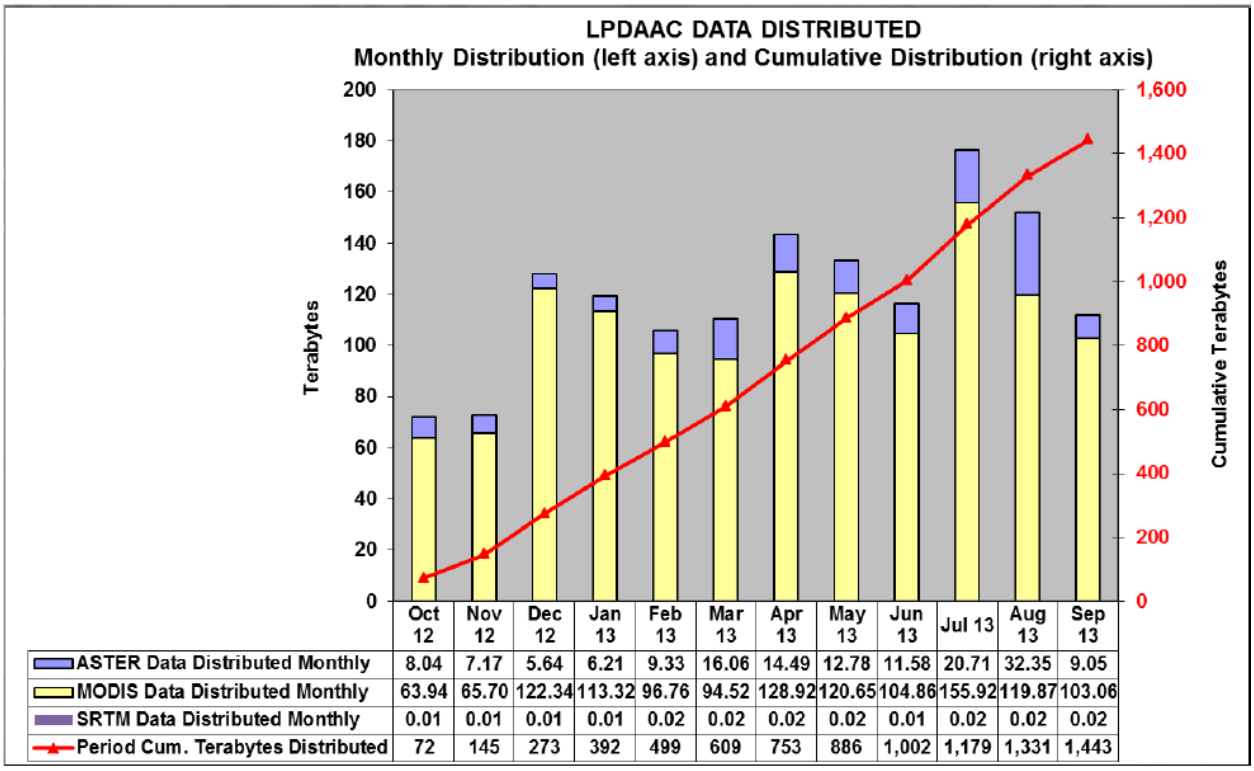
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Landsat Data Distributed Monthly	110.87	71.00	92.83	117.22	96.73	107.85	98.44	113.92	320.13	314.42	349.99	307.92
Period Cum. Terabytes Distributed	111	182	275	392	489	597	695	809	1,129	1,443	1,793	2,101

Figure 83. FY 2013 Landsat data distributed.



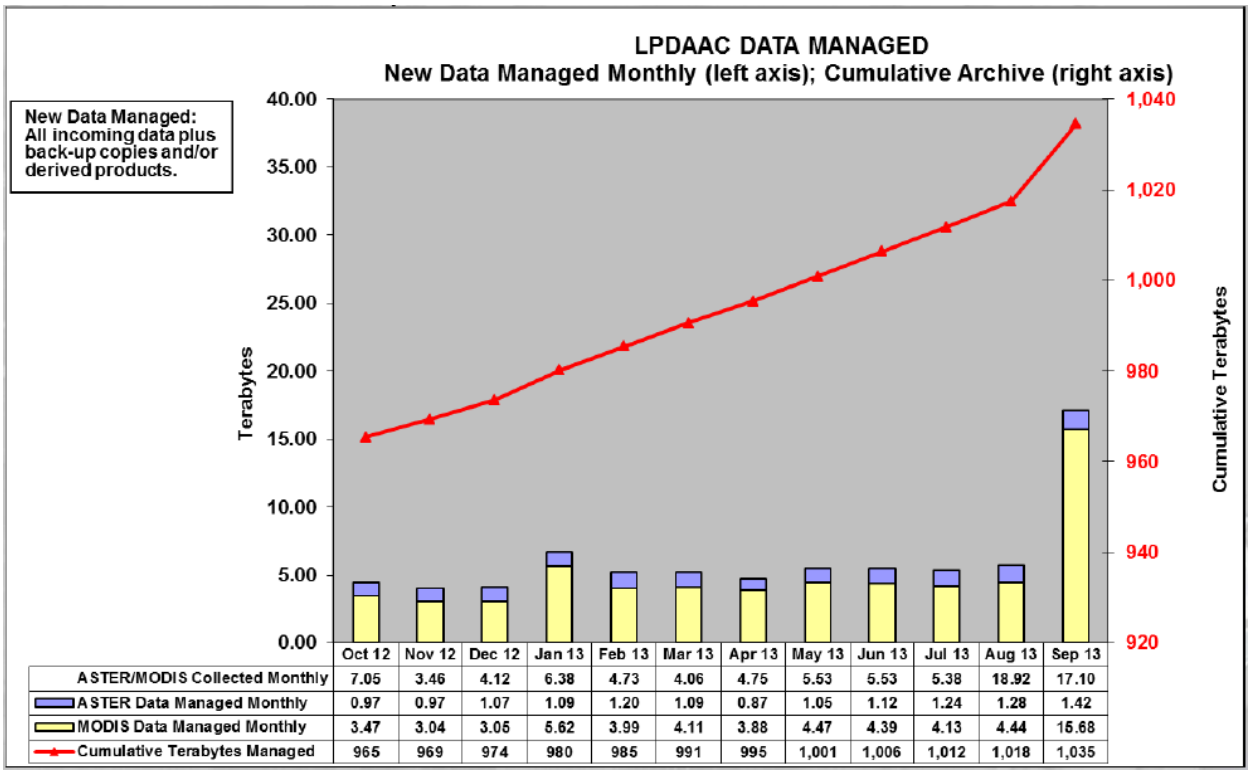
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Landsat Data Collected Monthly	17.06	23.39	33.14	29.56	7.08	7.79	6.61	41.13	161.74	90.11	88.21	53.03
Landsat Data Managed Monthly	116.95	132.94	173.52	199.13	101.94	120.82	113.52	180.60	342.33	283.59	297.56	208.76
Cumulative Terabytes Managed	3,275	3,474	3,673	3,872	3,974	4,095	4,208	4,389	4,731	5,015	5,312	5,521

Figure 84. FY 2013 Landsat data managed.



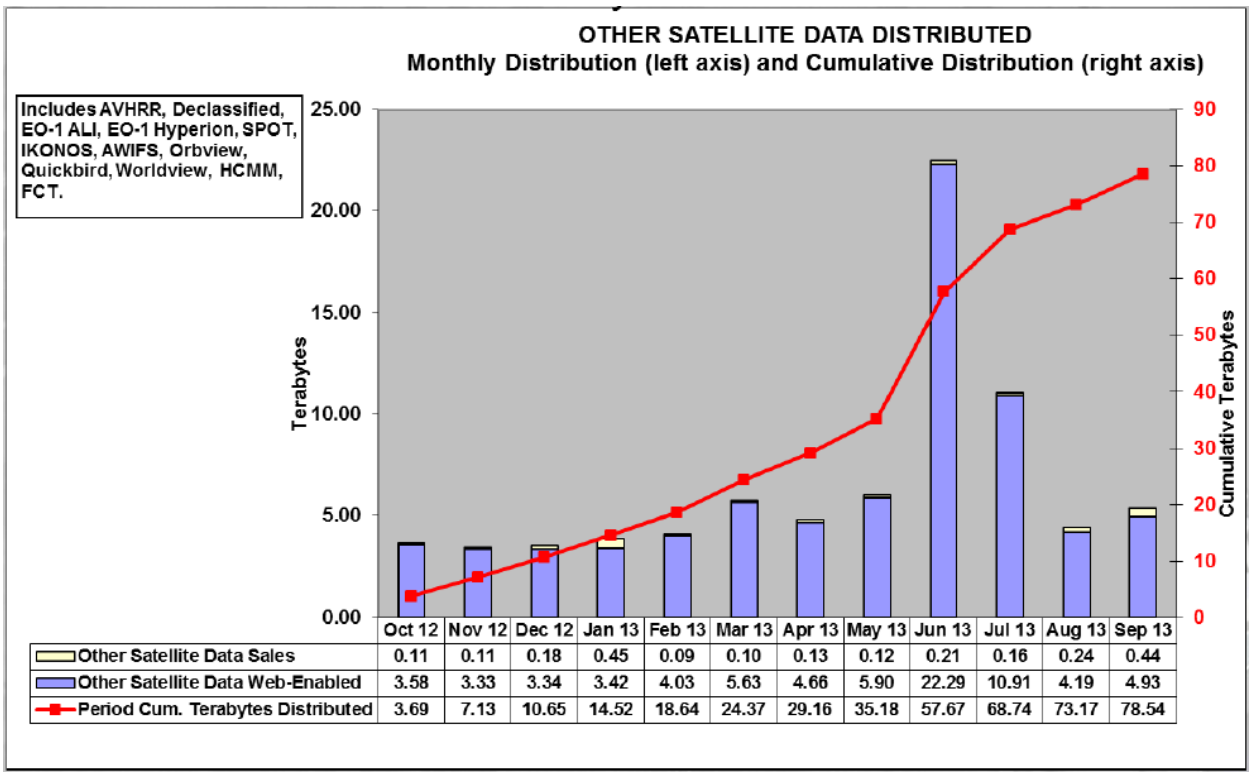
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
ASTER Data Distributed Monthly	8.04	7.17	5.64	6.21	9.33	16.06	14.49	12.78	11.58	20.71	32.35	9.05
MODIS Data Distributed Monthly	63.94	65.70	122.34	113.32	96.76	94.52	128.92	120.65	104.86	155.92	119.87	103.06
SRTM Data Distributed Monthly	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Period Cum. Terabytes Distributed	72	145	273	392	499	609	753	886	1,002	1,179	1,331	1,443

Figure 85. FY 2013 Land Processes Distributed Active Archive Center data distributed.



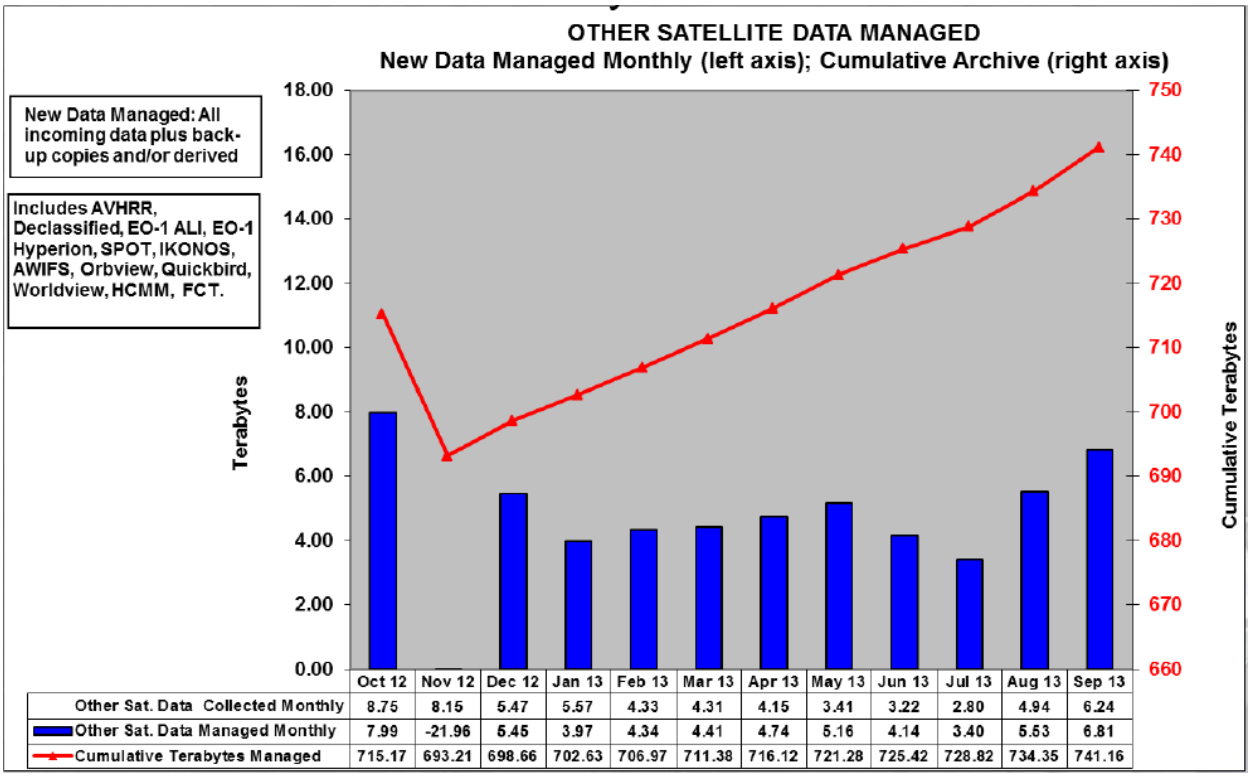
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
ASTER/MODIS Collected Monthly	7.05	3.46	4.12	6.38	4.73	4.06	4.75	5.53	5.53	5.38	18.92	17.10
ASTER Data Managed Monthly	0.97	0.97	1.07	1.09	1.20	1.09	0.87	1.05	1.12	1.24	1.28	1.42
MODIS Data Managed Monthly	3.47	3.04	3.05	5.62	3.99	4.11	3.88	4.47	4.39	4.13	4.44	15.68
Cumulative Terabytes Managed	965	969	974	980	985	991	995	1,001	1,006	1,012	1,018	1,035

Figure 86. FY 2013 Land Processes Distributed Active Archive Center data managed.



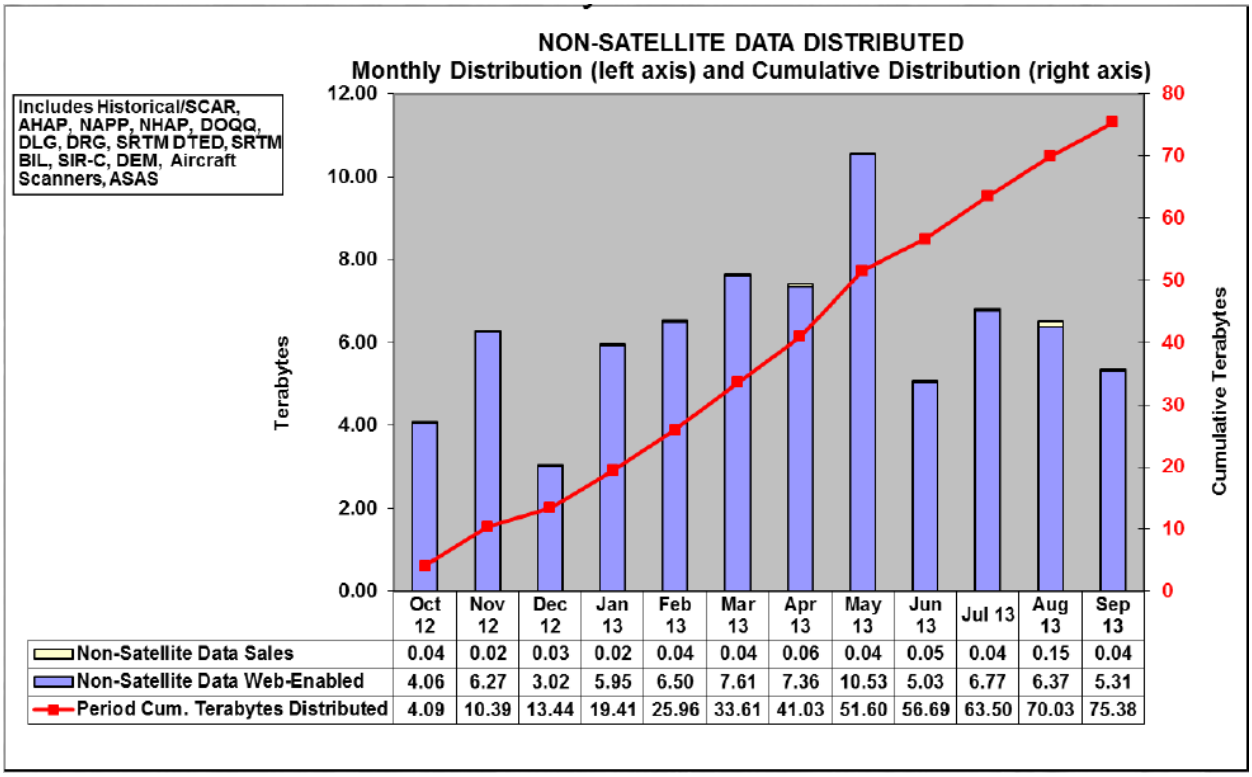
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Other Satellite Data Sales	0.11	0.11	0.18	0.45	0.09	0.10	0.13	0.12	0.21	0.16	0.24	0.44
Other Satellite Data Web-Enabled	3.58	3.33	3.34	3.42	4.03	5.63	4.66	5.90	22.29	10.91	4.19	4.93
Period Cum. Terabytes Distributed	3.69	7.13	10.65	14.52	18.64	24.37	29.16	35.18	57.67	68.74	73.17	78.54

Figure 87. FY 2013 other satellite data distributed.



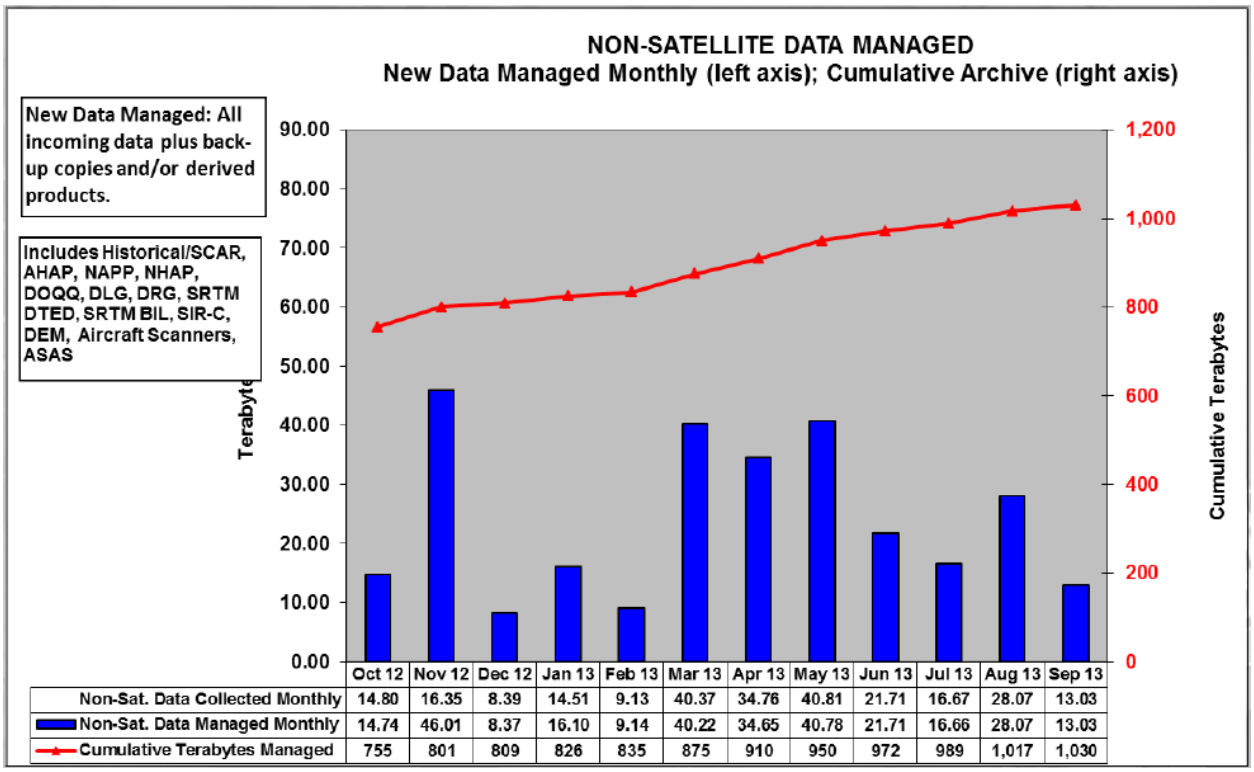
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Other Sat. Data Collected Monthly	8.75	8.15	5.47	5.57	4.33	4.31	4.15	3.41	3.22	2.80	4.94	6.24
Other Sat. Data Managed Monthly	7.99	-21.96	5.45	3.97	4.34	4.41	4.74	5.16	4.14	3.40	5.53	6.81
Cumulative Terabytes Managed	715.17	693.21	698.66	702.63	706.97	711.38	716.12	721.28	725.42	728.82	734.35	741.16

Figure 88. FY 2013 other satellite data managed.



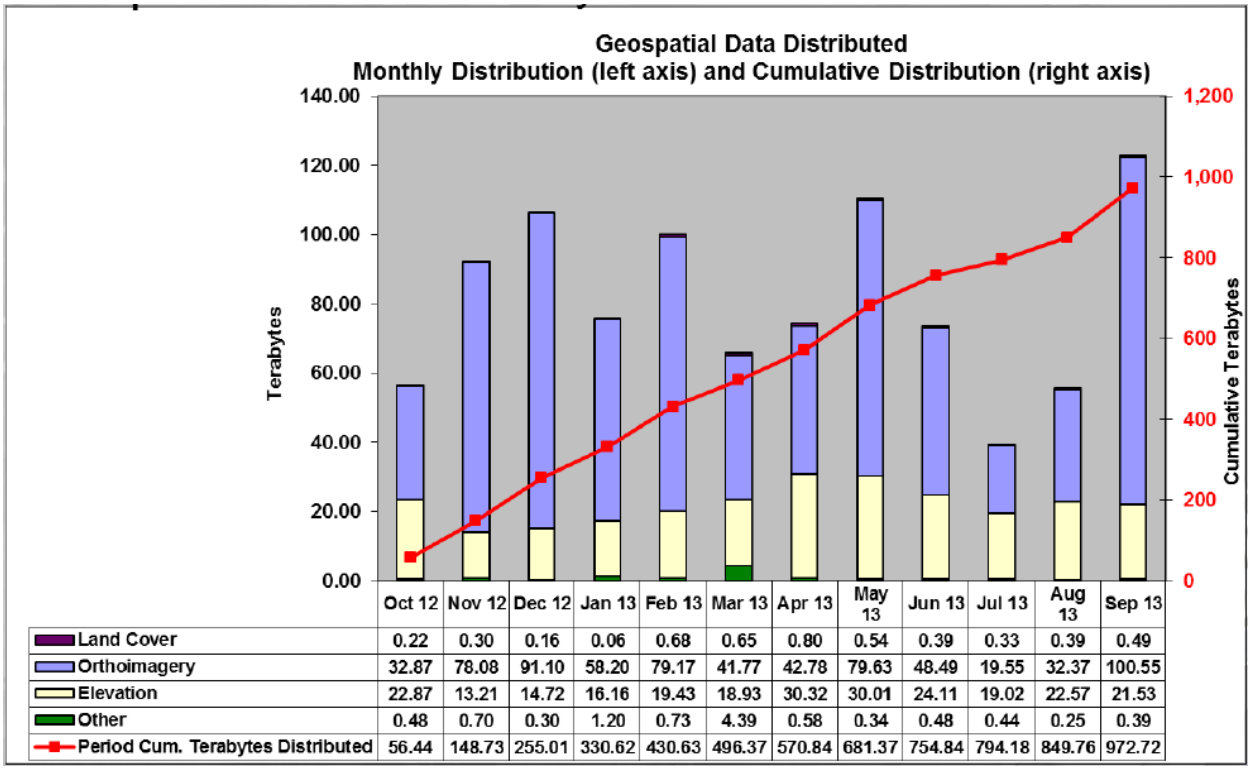
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Non-Satellite Data Sales	0.04	0.02	0.03	0.02	0.04	0.04	0.06	0.04	0.05	0.04	0.15	0.04
Non-Satellite Data Web-Enabled	4.06	6.27	3.02	5.95	6.50	7.61	7.36	10.53	5.03	6.77	6.37	5.31
Period Cum. Terabytes Distributed	4.09	10.39	13.44	19.41	25.96	33.61	41.03	51.60	56.69	63.50	70.03	75.38

Figure 89. FY 2013 non-satellite data distributed.



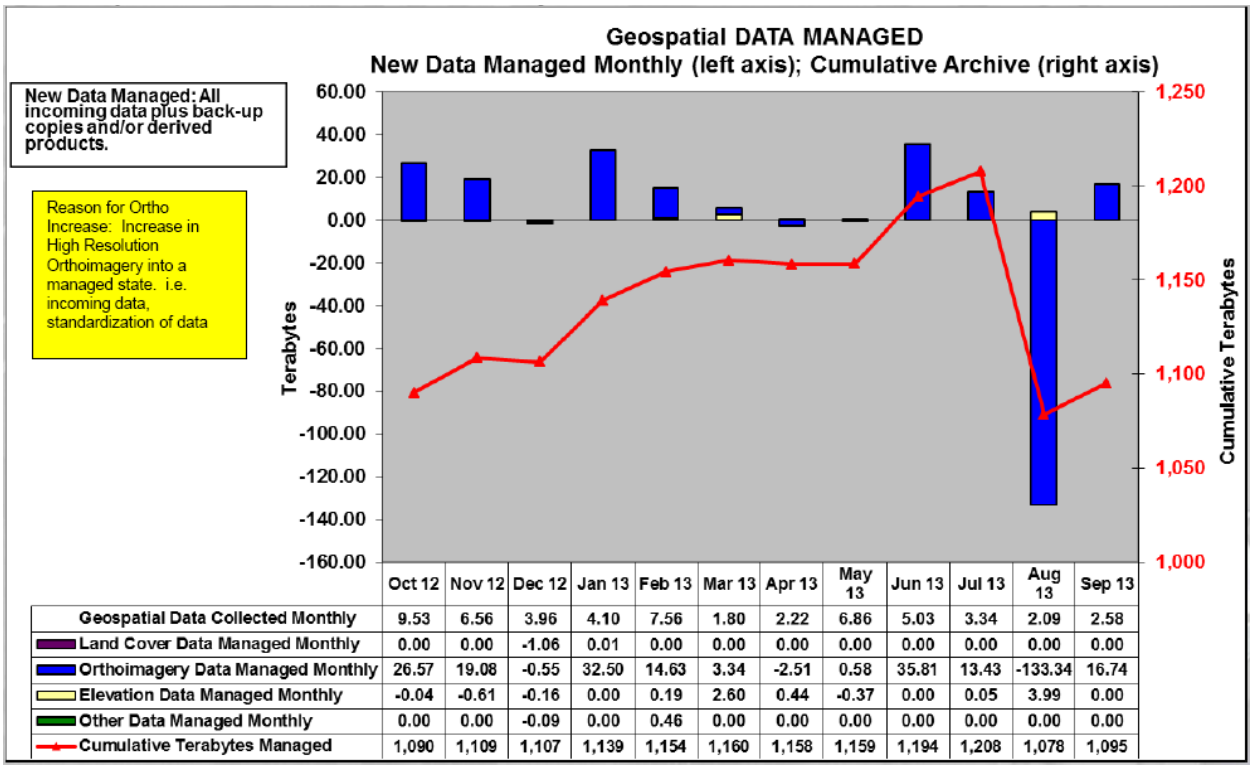
	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Non-Sat. Data Collected Monthly	14.80	16.35	8.39	14.51	9.13	40.37	34.76	40.81	21.71	16.67	28.07	13.03
Non-Sat. Data Managed Monthly	14.74	46.01	8.37	16.10	9.14	40.22	34.65	40.78	21.71	16.66	28.07	13.03
Cumulative Terabytes Managed	755	801	809	826	835	875	910	950	972	989	1,017	1,030

Figure 90. FY 2013 non-satellite data managed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Land Cover	0.22	0.30	0.16	0.06	0.68	0.65	0.80	0.54	0.39	0.33	0.39	0.49
Orthoimagery	32.87	78.08	91.10	58.20	79.17	41.77	42.78	79.63	48.49	19.55	32.37	100.55
Elevation	22.87	13.21	14.72	16.16	19.43	18.93	30.32	30.01	24.11	19.02	22.57	21.53
Other	0.48	0.70	0.30	1.20	0.73	4.39	0.58	0.34	0.48	0.44	0.25	0.39
Period Cum. Terabytes Distributed	56.44	148.73	255.01	330.62	430.63	496.37	570.84	681.37	754.84	794.18	849.76	972.72

Figure 91. FY 2013 geospatial data distributed.



	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Geospatial Data Collected Monthly	9.53	6.56	3.96	4.10	7.56	1.80	2.22	6.86	5.03	3.34	2.09	2.58
Land Cover Data Managed Monthly	0.00	0.00	-1.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthoimagery Data Managed Monthly	26.57	19.08	-0.55	32.50	14.63	3.34	-2.51	0.58	35.81	13.43	-133.34	16.74
Elevation Data Managed Monthly	-0.04	-0.61	-0.16	0.00	0.19	2.60	0.44	-0.37	0.00	0.05	3.99	0.00
Other Data Managed Monthly	0.00	0.00	-0.09	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cumulative Terabytes Managed	1,090	1,109	1,107	1,139	1,154	1,160	1,158	1,159	1,194	1,208	1,078	1,095

Figure 92. FY 2013 geospatial data managed.

For further information, contact John Faundeen, USGS EROS, faundeen@usgs.gov.

Coordination and Collaboration

As the USGS endeavors to provide overall leadership for land imaging, both nationally and internationally, the USGS must continue to enhance leadership visibility, improve communications between and among the Federal and non-Federal sectors regarding remote sensing observations of the Earth, and promote excellence in remote sensing for understanding the Earth's land environment through education and training. The USGS continues to serve as the lead United States agency to the International Charter "Space and Major Disasters." EROS will continue to develop and offer a variety of ongoing education and training that together provide remotely sensed data users, and especially potential users, with opportunities to become more informed and educated about all aspects of the science and technology of land remote sensing. Key accomplishments are given in the following sections.

Emergency Operations Supports Hurricane Sandy Impact Areas

As part of its national and international mission to support emergency response, USGS EROS leveraged satellite imagery from the Landsat archive and other land imaging data

sets to support Hurricane Sandy emergency operations and recovery efforts. EROS operational activities supporting Hurricane Sandy response included:

- Updating pre-event baseline coastal imagery with recent high-resolution orthorectified data sets.
- Coordinating image requirements for SPOT imagery through U.S. Air Force EagleVision.
- Facilitating broad access to response-related imagery collected by numerous data providers, such as Civil Air Patrol (CAP).
- Supporting Federal, State, and local agencies, including Federal Emergency Management Agency; Bureau of Indian Affairs; U.S. Department of Agriculture; National Park Service; U.S. Geological Survey; U.S. Coast Guard; and the States of New York, New Jersey, Virginia, North Carolina, and others.

After Hurricane Sandy made landfall, the Federal Emergency Management Agency provided mission assignments to the CAP to fly sorties over the affected areas. The sorties resulted in over 160,000 handheld oblique aerial photos being collected (fig. 93). The CAP is often the first organization to collect aerial imagery after a disaster. CAP collects high-resolution photographs of damaged buildings and critical infrastructure from high (10,000 feet above ground level) to relatively low altitudes (1,000-1,500 feet above ground level).

USGS Emergency Operations received and posted on the Hazards Data Distribution System more than 160,000 aerial images, including more than 158,000 geographically retrievable oblique photos from the CAP, and more than 1,000 satellite images from Landsat and other sensors including the International Charter Space and Major Disasters satellite assets. Table 3 shows the sources of imagery posted on the Hazards Data Distribution System.

The imagery was used for damage assessment, evacuations, evaluation of critical infrastructure, location of flooding, location of fires, evaluation of hazardous materials sites, evaluation of communication nodes, shelter locations, etc. For further information, contact Brenda Jones, USGS EROS, bkjones@usgs.gov.

Table 3. Sources of imagery posted on the Hazards Data Distribution System.

Platform	Vendor	Source
Aerial Camera	AAAI	AAAI
COSMO SAR	ASI	NGA
Oblique Aerial	CAP	FEMA
QuickBird	DigitalGlobe	NGA
WorldView	DigitalGlobe	NGA
SPOT	Astrium	Eagle Vision
RapidEye	Astrium	Eagle Vision
EO-1	NASA	NASA
International Space Station	NASA	NASA

Platform	Vendor	Source
Terra ASTER	NASA	NASA
Aerial Camera	North Carolina DOT	North Carolina DOT
Aerial Camera	New Jersey National Guard	New Jersey National Guard
Aerial Camera	NOAA	NOAA
Aerial	Photo Science	Photo Science
DEM	USGS	USGS
Landsat	USGS	USGS
Lidar	USGS	USGS
Lidar	USACE	USACE
DMCii	DMCii	International Charter
IKONOS	DigitalGlobe	NGA
Radarsat	CSA	EagleVision
Radarsat	CSA	NGA
TerraSAR-X	DLR	NGA
TerraSAR-x	DLR	International Charter
Kompsat	KARI	International Charter
RapidEye	DLR	International Charter

Figure 93. This New Jersey Civil Air Patrol image from December 5, 2012, shows some of the destruction from Hurricane Sandy.

Emergency Operations Support is on Fire

Responding to catastrophic natural disasters requires information. When the flow of information on the ground is interrupted by crises such as earthquakes, landslides, volcanoes, fires, and floods, satellite imagery and aerial photographs become invaluable tools in revealing post-disaster conditions and in aiding disaster response and recovery efforts. USGS is a global clearinghouse for remotely sensed disaster imagery.

USGS Emergency Operations provided remote sensing and geospatial product support for 69 domestic and international disaster events in FY 2013. Of those 69 events, 16 were in support of 42 individual fires in the United States. Fire support was requested by various State and Federal agencies including the States of California, Colorado, Nebraska, New Mexico, Montana, and Wyoming, U.S. Forest Service, Bureau of Land Management, U.S. Geological Survey, National Park Service, National Guard Bureau, Department of Interior, Department of Agriculture, U.S. Army, and U.S. Air Force. Table 4 provides a list of the fires supported through the Hazards Data Distribution System in FY 2013.

The data provided for these fires was used for a variety of purposes including checking areas inside the fire where there were unburned timber fuels, planning for emergency watershed protection work resulting from the fires, creating a data layer of post-fire vegetation condition which is used in flood modeling and the development of the final soil burn severity maps, and for post-fire assessments of debris flows and landslides (fig. 94). The imagery is also used by response agencies to help determine potential shelter requirements, status of transportation systems, status of communications systems, status of medical facilities, status of utilities, and status of shelters and other essential facilities such as hospitals and schools.

USGS provides access to the fire and other disaster imagery through the Hazards Data Distribution System (https://hdds.usgs.gov/hdds2). The HDDS Graphical User Interface assists the users in searching for the imagery they need. The users can also view the metadata and browse images to determine which scenes they want to download. For further information, contact Brenda Jones, USGS EROS, bkjones@usgs.gov.

Table 4. List of fires supported through the Hazards Data Distribution System in FY 2013.

Fire Name	State	Month
Hopkins Prairie	Florida	March 2013
Springs	California	May 2013
Powerhouse	California	May 2013
Thompson Ridge	New Mexico	June 2013
Tres Lagunas	New Mexico	June 2013
Silver	New Mexico	June 2013
Jaroso	New Mexico	June 2013

Fire Name	State	Month
Black Forest	Colorado	June 2013
Royal Gorge	Colorado	June 2013
West Fork Complex	Colorado	June 2013
Lion Gulch	Colorado	June 2013
East Peak	Colorado	June 2013
Chisana River	Alaska	June 2013
Lime Hills	Alaska	June 2013
Yarnell Hill	Arizona	July 2013
Stuart Creek #2	Alaska	July 2013
Mountain	California	July 2013
West Mullan	Montana	July 2013
Moose Meadow	Montana	July 2013
Gold Pan	Montana	July 2013
Pine Creek	Idaho	July 2013
Lodgepole	Idaho	July 2013
Leggit	Idaho	July 2013
Hill Top	Idaho	July 2013
Beaver Creek	Idaho	July 2013
Mc Can	Idaho	July 2013
Unknown	Idaho	July 2013
Elk Complex	Idaho	July 2013
Gold Pan	Idaho	July 2013
Mile Marker	Washington	July 2013
Colockup Tarps	Washington	July 2013
Goslin	Utah	August 2013
Grouse Mountain	Oregon	August 2013
Big Windy	Oregon	August 2013
Mississippi	Alaska	August 2013
Mountain	California	August 2013
Falls Fire	California	August 2013
Rim	California	August 2013
Lolo Creek	Montana	September 2013
Rock Creek	Montana	September 2013
Miner Paradise	Montana	September 2013
Hard Luck	Wyoming	September 2013

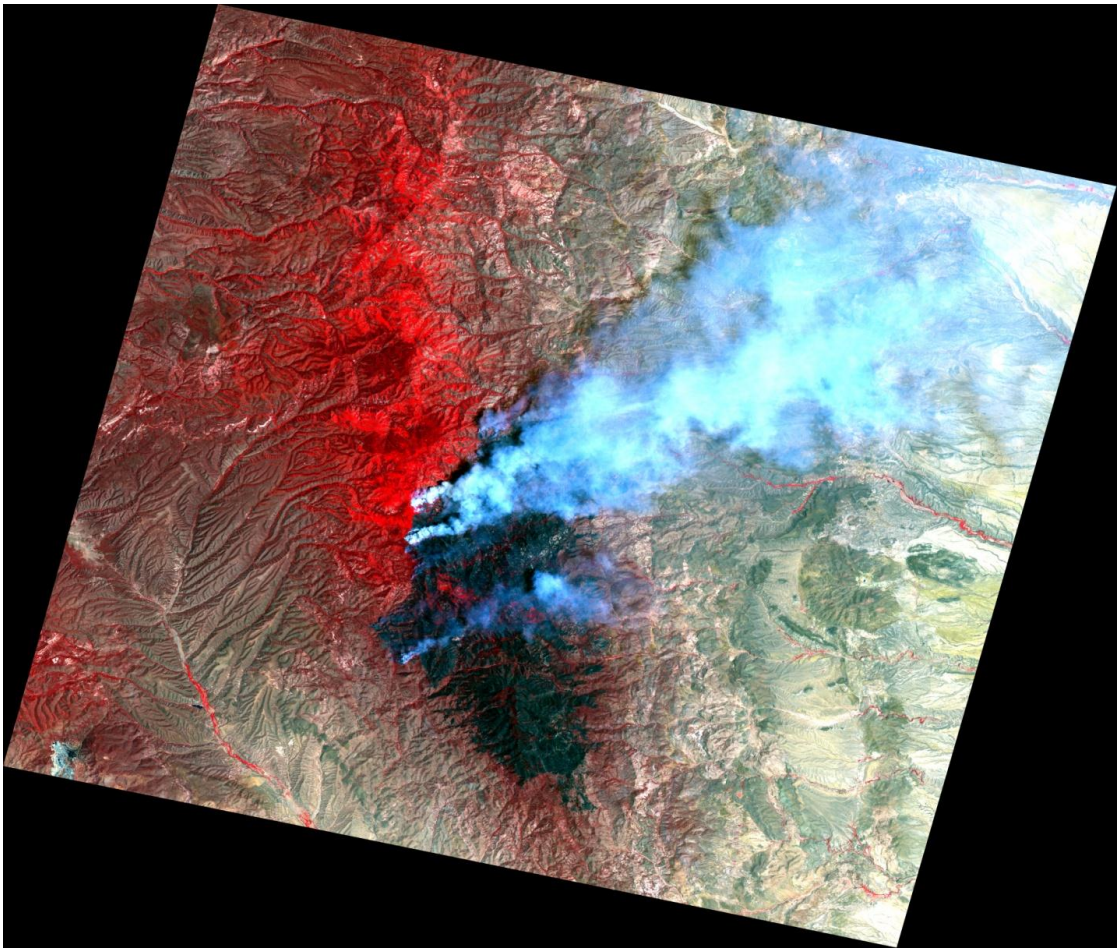


Figure 94. This Satellite Pour l'Observation de la Terre (SPOT) image shows smoke (bluish white) and burned area (black) of the Silver Fire in New Mexico in June 2013. Data provided by EagleVision. © CNES 2013 distribution Spot Image S.A., all rights reserved.

International Charter Fosters New Access Opportunities

The International Charter provides a unified system of satellite data acquisition and delivery to those affected by natural or human-made disasters. Each member has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property.

The USGS participates in the Charter and receives foreign remote sensing data in support of U.S. disaster response and recovery efforts, and also ensures provision of U.S. land imaging data to support foreign disaster response and recovery efforts. The USGS contribution to the Charter continues to grow on a yearly basis. In 2013, the USGS provided support by providing project managers, satellite image archive access, new satellite collections, activation requests, and participation in the Universal Access outreach and training efforts.

Charter members, conscious of the need to improve Charter access globally, have adopted the principle of Universal Access: any national disaster management authority will be able to submit requests to the Charter for emergency response. Proper procedures will have to be followed, but the affected country will not have to be a Charter member.

A registration process is available for national authorities to express interest in participating in the Charter. A completed registration form is sent to the Charter Executive Secretariat to be reviewed for completeness. After review by the Executive Secretariat, the final acceptance of a national user is subject to the approval and written acceptance of the Charter Board, the policy body of the Charter. The new users are then asked to sign a letter of agreement to Charter rules and following that will undergo a simple training exercise to simulate the steps of a Charter activation.

The entity or its delegated agency should have a national mandate to coordinate emergency response measures in the respective country. The material provided by the Charter could be either remotely sensed imagery or derived information products such as crisis or damage assessment maps (fig. 95). For further information, contact Brenda Jones, USGS EROS, bkjones@usgs.gov.

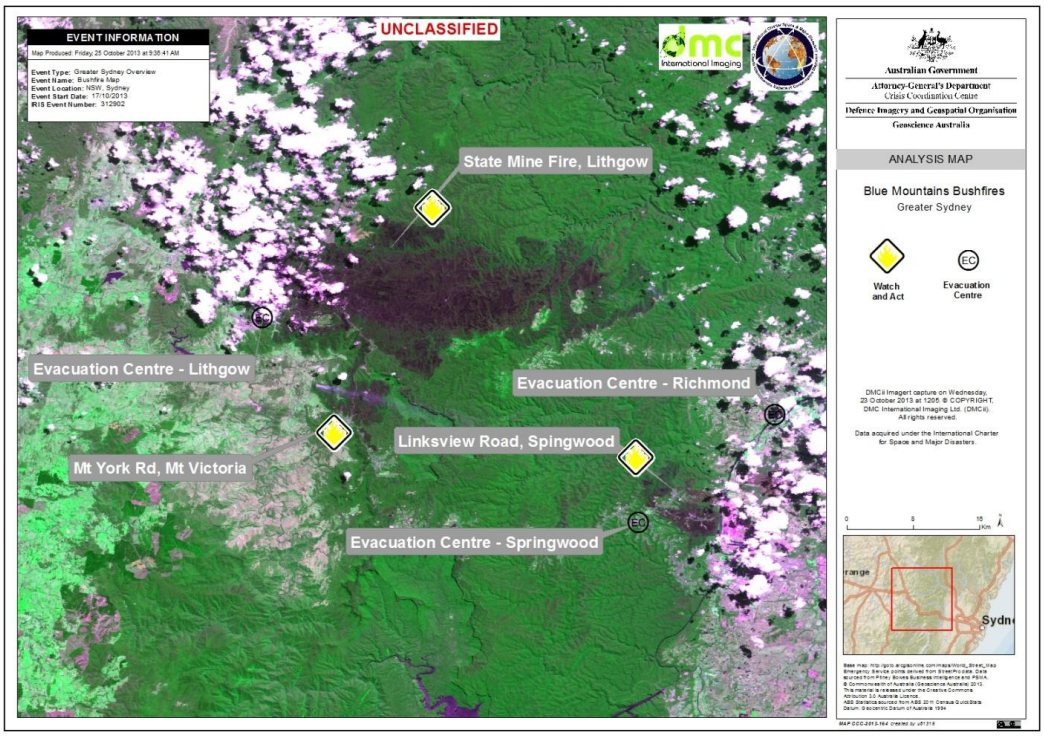


Figure 95. This crisis map shows burn scars from the State Mine fire in Australia. This product was created during the first Charter activation by a non-member Authorized User, GeoScience Australia. The Disaster Monitoring Constellation (DMC) image was provided to the Charter through DMC International Imaging (DMCii).

Center Support Activities

Center support activities at the USGS EROS provides a wide range of services for numerous and highly complex science, engineering, and operational projects, diverse contracts, intricate partner and customer relationships, and national and international activities. Key accomplishments are given in the following sections.

Communicating EROS Science to the World

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

C&O efforts this past year centered on the launch of the Landsat Data Continuity Mission on February 11, 2013, and the LDCM to Landsat 8 NASA/USGS Transition Ceremony on May 30, 2013. Several significant accomplishments supporting these activities included new information exhibits for our Visitor Center, including a one-third scale model of the Landsat 8 satellite; a record number of Media Advisories, Press Releases, and Social Media Announcements all of which drew interest from local, national, and international television and radio networks, newspapers, scientific journals, and social media outlets; and installed a Landsat exhibit at the Kirby Science Discovery Center at the Washington Pavilion in Sioux Falls, South Dakota.

A proud first for EROS was the development and implementation of the USGS/NASA Landsat 8 Going Operational Media-Social event held at EROS. People who use social networking sites such as Twitter, Facebook, and Google+ were invited to attend the official hand-off ceremony. Twenty people, from across the country, were selected and treated to presentations by the Landsat Mission science and engineering teams; behind the scenes tours of the EROS Center; attendance at the LDCM to Landsat 8 Transition Ceremony; and each participant had the opportunity to meet fellow Landsat enthusiasts – by all accounts a huge success.

In support for the EROS 40th Anniversary, C&O staff created a 3D EROS History display, which is now permanently on display in the EROS Visitor Center; an interactive 40-foot timeline outlining the history of EROS; and a self-guided behind-the-scenes tour that was offered to employees' families and other invited guests during the 40th open house.

C&O produced over 460 media products in support of USGS Headquarters, the Director's Office, science conferences, exhibits, and Visitor Center displays. The team updated the EROS exhibit at the South Dakota Air and Space Museum at Ellsworth Air Force Base in Rapid City by designing a new 10-wall display. They also designed the March cover of the Photogrammetric Engineering and Remote Sensing Magazine featuring the Phoenix V Scanners.

C&O continues to make the EROS mission visible to the public with the production of Image of the Week posters, Views of the News (image based short stories), and Featured Sites articles, all accessible via the EROS web page.

C&O is always researching and developing innovative methods that allow easy access to our science and mission though web development. In 2013, the team created a plan and tools to assist Land Remote Sensing Program staff in gathering information and publishing the 2011 DOI Remote Sensing Report online, converted the external website's content management system to Drupal, created a new design for the EROS virtual tour, worked with USGS Headquarters to develop web supported materials in response to Congressional and other requests, updated and added new locations to the Earthshots website, which is a companion to our printed Earthshots cards used in classrooms, presentations, and conferences.

The C&O web team, working closely with the EROS librarian, developed a publications search tool providing easy access to EROS staff publications and developed methods that enabled EROS projects to tap into the search tool from their specific websites.

The EROS library continued to provide support to our science and professional staff by assisting with more than 840 research requests of literature and reference resources, leading two EndNote technical exchanges.

An important goal for C&O is to engage children in understanding the EROS mission by introducing them to our remote sensing, science, and research endeavors. Throughout the year, staff hosted numerous school group tours, visited schools in the region, hosted job shadow requests, assisted in planning and coordination of the Women In Science event, presented at the South Dakota Water Festival, and It's All About Science Festival. Staff also developed a new module about flooding to add to the "Tracking Change Over Time" lesson plans for middle school grades.

The USGS implemented a new and improved Information Product Data System (IPDS) in 2013. EROS C&O staff assisted authors with training and by updating more than 600 open entries that remained in the old system. There were 211 EROS publications approved through IPDS during FY 2013.

Throughout FY 2013, C&O welcomed over 5,000 visitors and led 300 guided tours. For further information, contact Janice Nelson, USGS EROS, jsnelson@usgs.gov.

Data Center Consolidation: EROS Designation as a Core Site for USGS

In response to a 2010 Federal initiative, the Department of Interior has been looking at options to:

- promote the use of green information technology by reducing the overall energy and real estate footprint of DOI data centers;
- reduce the cost of data center hardware, software, and operations;
- increase the overall DOI IT security; and
- increase the use of more efficient computing platforms and technologies.

EROS is one of the largest USGS/DOI data centers. The Center has a robust and low-cost IT environment, with a widely experienced IT staff, extensive network and satellite connectivity, a history of hosting and operating systems for external cooperators, and inexpensive/green commercial electricity; all of which identifies EROS as a potential provider for consolidation support to other DOI activities.

Throughout FY 2013, EROS staff met with USGS and DOI staff, providing detailed technical information and discussing the EROS mission, operations concept, infrastructure, and experience. EROS can be considered a data center, one that is organized and operated around its mission, rather than its information technology. Some of the discussions were to understand the differences between the two, and how they are related.

In May 2013, DOI designated six data centers as "Core Data Centers" with EROS being the sole USGS site on the list. As part of the Federal Data Center Consolidation Initiative, DOI plans to optimize core data centers and consolidate non-core data centers. Since the announcement, EROS staff has begun working with USGS and DOI staff on how EROS could best support the consolidation activities for USGS and the DOI, within the mission, schedule, and cost constraints of everyone involved. These discussions, as well as defining what being a Core Data Center means to DOI, USGS, and EROS, are ongoing in FY 2014. For further information, contact Thomas Kalvelage, USGS EROS, kalvelage@usgs.gov.

Conclusion

The EROS mission, *contributing to the understanding of a changing Earth*, is specifically focused on land change monitoring. This focus 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 2015-2016 is underway, the accomplishments of 2013 and initiating actions of 2014 are making great strides in achieving our mission goals in global land change monitoring 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 2013 Research and Technical Publications

Executive Summary of Research and Technical Publications

In FY 2013, 112 scientists, engineers, and information professionals from throughout the USGS EROS Center contributed to the Center's extensive publishing record. The complete record for fiscal 2013 totaled 172 publications. The 2013 record includes:

- 81 journal articles (10 of which were published in a top-ranking journal as measured by Thomas Reuters Impact Factor: *Agriculture, Ecosystems, and Environment; Agricultural and Forest Meteorology; Bulletin of the American Meteorological Society; Remote Sensing of Environment*)
- 38 reports (37 USGS Series reports and 1 other agency report)
- 9 book chapters
- 37 conference presentations (full papers, abstracts, posters, and slide presentations) at 11 different conferences
- 3 magazine/newsletter articles
- 4 journal issue editorships, including 3 forewords/prefaces

The following six categories of bibliographic citations are highlighted in 2013 for professional contributions made to top-ranking journals, publisher highlights, rapid downloads, industry attention, guest editors, and journal cover art. To search all EROS publications, see http://eros.usgs.gov/#/Publications. For further information, contact Janice Nelson, USGS EROS, jsnelson@usgs.gov.

Top-Ranking Journals. These 10 journal articles were published in 4 top-ranking journals.

Funk, C.C., Husak, G., Verdin, J.P., and Rowland, J.D., in press, **Attribution of 2012 and 2003-2012 rainfall deficits in Kenya and Somalia: Bulletin of the American Meteorological Society.** (Also available online at http://dx.doi.org/10.1175/BAMS-D-13-00085.1.)

Gilmanov, T.G., Wylie, B.K., Tieszen, L.L., Meyers, T.P., Baron, V.S., Bernacchi, C.J., Billesbach, D.P., Burga, G.G., Fischer, M.L., Glenn, A.J., Hanan, N.P., Hatfield, J.L., Heuer, M.W., Hollinger, S.E., Howard, D.M., Matamala, R., Prueger, J.H., Tenuta, M., and Young, D.G., 2013, **CO2 uptake and ecophysiological parameters of the grain crops of midcontinent North America—estimates from flux tower measurements**: Agriculture, Ecosystems and Environment, v. 164, p. 162-175. (Also available online at http://dx.doi.org/10.1016/j.agee.2012.09.017.)

Gutman, G., Huang, C., Chander, G., Noojipady, P., and Masek, J.G., 2013, **Assessment of the NASA–USGS Global Land Survey (GLS) datasets**: Remote Sensing of Environment, v. 134, p. 249-265. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.02.026.)

Hansen, M.C., Egorov, A., Potapov, P., Stehman, S.V., Tyukavina, A., Turubanova, S.A., Roy, D.P., Goetz, S.J., Loveland, T.R., Ju, J., Kommareddy, A., Kovalskyy, V., Forsythe, C., and Bents, T., 2014, **Monitoring conterminous United States (CONUS) land cover change with Web-Enabled Landsat Data (WELD)**: Remote Sensing of Environment, v. 140, p. 466-484. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.08.014.)

Huang, S., Liu, H., Dahal, D., Jin, S., Welp, L.R., Liu, J., and Liu, S., 2013, **Modeling spatially explicit fire impact on gross primary production in interior Alaska using satellite images coupled with eddy covariance**: Remote Sensing of Environment, v. 135, p. 178-188. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.04.003.)

Jin, S., Yang, L., Danielson, P., Homer, C.G., Fry, J.A., and Xian, G., 2013, **A comprehensive change detection method for updating the National Land Cover Database to circa 2011**: Remote Sensing of Environment, v. 132, p. 159-175. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.01.012.)

Maiersperger, T.K., Scaramuzza, P.L., Leigh, L., Shrestha, S., Gallo, K.P., Jenkerson, C.B., and Dwyer, J.L., 2013, **Characterizing LEDAPS surface reflectance products by comparisons with AERONET, field spectrometer, and MODIS data**: Remote Sensing of Environment, v. 136, p. 1-13. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.04.007.)

Velpuri, N.M., Senay, G.B., Singh, R.K., Bohms, S., and Verdin, J.P., 2013, **A comprehensive evaluation of two MODIS evapotranspiration products over the conterminous United States—using point and gridded FLUXNET and water balance ET**: Remote Sensing of Environment, v. 139, p. 35-49. (Also available online at http://dx.doi.org/10.1016/j.rse.2013.07.013.)

Wickham, J.D., Stehman, S.V., Gass, L., Dewitz, J.A., Fry, J.A., and Wade, T.G., 2013, **Accuracy assessment of NLCD 2006 land cover and impervious surface**: Remote Sensing of Environment, v. 130, p. 294-304. (Also available online at http://dx.doi.org/10.1016/j.rse.2012.12.001.)

Zhang, L., Guo, H., Jia, G., Wylie, B.K., Gilmanov, T.G., Howard, D.M., Ji, L., Xiao, J., Li, J., Yuan, W., Zhao, T., Chen, S., Zhou, G., and Kato, T., 2014, **Net ecosystem productivity of temperate grasslands in northern China—an upscaling study: Agricultural and Forest Meteorology**, v. 184, p. 71-81. (Also available online at http://dx.doi.org/10.1016/j.agrformet.2013.09.004.)

Publisher Highlights. These 2 journal articles were highlighted in the News section of Environmental Research Web, a community website from IOP (Institute of Physics) Publishing.

Velpuri, N.M., and Senay, G.B., 2013, **Analysis of long-term trends (1950-2009) in precipitation, runoff and runoff coefficient in major urban watersheds in the United States**: Environmental Research Letters, v. 3, no. 2, article number 024020, available only online at http://dx.doi.org/10.1088/1748-9326/8/2/024020.
News Highlight

Wu, Y., Liu, S., Sohl, T.L., and Young, C.J., 2013, **Projecting the land cover change and its environmental impacts in the Cedar River Basin in the midwestern United States**: Environmental Research Letters, v. 8, no. 2, article number 024025. (Also available online at http://dx.doi.org/10.1088/1748-9326/8/2/024025.)
News Highlight

Rapid Downloads. There were 3 journal articles published in Elsevier journals, which are among the "top" downloads in their respective journals.

Giri, C.P., Pengra, B.W., Long, J.B., and Loveland, T.R., 2013, **Next generation of global land cover characterization, mapping, and monitoring**: International Journal of Applied Earth Observation and Geoinformation, v. 25, p. 30-37. (Also available online at http://dx.doi.org/10.1016/j.jag.2013.03.005.)
4th most downloaded article in this journal, last 90 days, as of 11/11/13

Sleeter, B.M., Sohl, T.L., Loveland, T.R., Auch, R.F., Acevedo, W., Drummond, M.A., Sayler, K.L., and Stehman, S.V., 2013, **Land-cover change in the conterminous United States from 1973 to 2000**: Global Environmental Change, v. 23, no. 4, p. 733-748. (Also available online at http://dx.doi.org/10.1016/j.gloenvcha.2013.03.006.)
14th most downloaded article in this journal, last 90 days, as of 11/11/13

Wu, Y., and Chen, J., 2013, **Investigating the effects of point source and nonpoint source pollution on the water quality of the East River (Dongjiang) in South China**: Ecological Indicators, v. 32, p. 294-304. (Also available online at http://dx.doi.org/10.1016/j.ecolind.2013.04.002.)
14th most downloaded article in this journal, last 90 days, as of 11/11/13

Industry Attention. There was 1 journal article that received industry attention under "Key Scientific Articles" on the Renewable Energy Global Innovations web site.

Tan, Z., Liu, S., Bliss, N.B., and Tieszen, L.L., 2012, **Current and potential sustainable corn stover feedstock for biofuel production in the United States**: Biomass & Bioenergy, v. 47, p. 372-386. (Also available online at http://dx.doi.org/10.1016/j.biombioe.2012.09.022.)

Guest Editors.

Gyanesh Chander (formerly with Systems Engineering, now with NASA), was a guest editor of the *IEEE Transactions on Geoscience and Remote Sensing Special Issue: Intercalibration of Satellite Instruments*. Dr. Chander also authored/coauthored 6 papers and the foreword in the special issue.

Chander, G., Helder, D.L., Aaron, D., Mishra, N., and Shrestha, A.K., 2013, **Assessment of spectral, misregistration, and spatial uncertainties inherent in the cross-calibration study**: IEEE Transactions on Geoscience and Remote Sensing, v. 51, no. 3, p. 1282-1296. (Also available online at http://dx.doi.org/10.1109/TGRS.2012.2228008.)

Chander, G., Hewison, T.J., Fox, N., Wu, X., Xiong, X., and Blackwell, W.J., 2013, **Foreword to the special issue on intercalibration of satellite instruments**: IEEE Transactions on Geoscience and Remote Sensing, v. 51, no. 3, p. 1052-1055. (Also available online at http://dx.doi.org/10.1109/TGRS.2013.2240331.)

Chander, G., Hewison, T.J., Fox, N., Wu, X., Xiong, X., and Blackwell, W.J., 2013, **Overview of intercalibration of satellite instruments**: IEEE Transactions on Geoscience and Remote Sensing, v. 51, no. 3, p. 1056-1080. (Also available online at http://dx.doi.org/10.1109/TGRS.2012.2228654.)

Chander, G., Mishra, N., Helder, D.L., Aaron, D.B., Angal, A., Choi, T., Xiong, X., and Doelling, D.R., 2013, **Applications of spectral band adjustment factors (SBAF) for cross-calibration**: IEEE Transactions on Geoscience and Remote Sensing, v. 51, no. 3, p. 1267-1281. (Also available online at http://dx.doi.org/10.1109/TGRS.2012.2228007.)

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Photogrammetric Engineering and Remote Sensing, v. 79, no. 2, cover image created by Jason M. Stoker.

Photogrammetric Engineering and Remote Sensing, v. 79, no. 3, cover image created by Aaron Neugebauer.

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