Department of the Interior

Land Imaging Report

2009

Summary of the Department of the Interior Bureaus' Land Remote Sensing Activities

Summaries prepared by DOI Bureau Representatives
of the
Department of the Interior Remote Sensing Working Group
(DOIRSWG)

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One of the Administration's key science and technology activities is

"Enhancing our capabilities in space, which are essential for communications, geopositioning, intelligence gather, Earth observation, and national defense, as well as for increasing our understanding of the universe and our place in it."

from *Science and Technology Priorities for the FY 2011 Budget*, August 4, 2009. The activities in this report are a summary of the Department's efforts using Earth observation data, information and services.

Introduction

In 2008 the Department of the Interior (DOI) re-established a Remote Sensing Working Group designed to foster and encourage the use of remote sensing data and technology and data applications within the Department.

The DOI Remote Sensing Working Group provides a forum for the Department's bureaus to discuss remote sensing data, technology and applications, exchange ideas and information, and provide input and guidance in meeting DOI's land management mission. In addition, the DOIRSWG promotes communication and education between and among the bureaus regarding remote sensing observations of the Earth.

Responsibilities of the DOI Remote Sensing Working Group (DOIRSWG):

- Provide operational and scientific remote sensing requirements for the DOI;
- Advise on remote sensing data and information availability for DOI and cooperator purposes, including assurance of the means and method of data and information access and distribution;
- Perform research, development and training to promote and expand the range of uses of remote sensing and related products to meet DOI user needs;
- Advise on the advanced technologies necessary to ensure that future DOI remote sensing needs will be met;
- Interface with other Federal agency remote sensing groups;
- Provide advocacy for remote sensing activities internally and externally;
- Promote the regular and frequent exchange of information on remote sensing activities;
- Identify the breadth and variety of remote sensing capabilities and applications that are necessary to perform the diverse scientific mission of the USGS; and
- Discuss future initiatives.

DOIRSWG Membership: Membership to this working group is open to those who represent the remote sensing interests within the DOI and their cooperators. Points of Contact (POC) for fiscal year 2009 for each Bureau are provided below. These POCs ensure that information is shared across their respective Bureaus. Membership is not limited to these POCs. The POC for the U.S. Geological Survey chairs this working group.

Bureau of Indian Affairs (BIA) – Ken Bailey

Bureau of Land Management (BLM) – Matt Bobo

Bureau of Reclamation (BOR) – David Eckhart

Bureau of Ocean Energy Management, Regulation & Enforcement – Mark Bloemker *(formerly MMS)*

National Park Service (NPS) – Dave Duran

Office of Surface Mining (OSM) – Diane Osborne

U.S. Fish and Wildlife Service (USFWS) – Brian Huberty

U.S. Geological Survey (USGS) – Bruce Quirk

Remotely sensed data are important to the success of activities within the Department of the Interior agencies. From traditional aerial photography, moderate resolution Landsat satellite data, and more specialized data collection systems, Department personnel find remotely sensed data systems useful in evaluating land surface conditions over the vast areas for which the Department has responsibility. This report from the DOI Remote Sensing Working Group highlights the major applications of remote sensing across the Department's Bureaus in fiscal year 2009.

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Bureau of Indian Affairs (BIA)

The Bureau of Indian Affairs (BIA) had a request from the Navajo Regional office to provide them with time series mosaics of different compositions such as burn scar detection, vegetation and true color composites. The BIA processed 15 Landsat 7 ETM+ tiles per mosaic for each composition and pan-merged them. The time series covered three years from 1999 through 2003. The Navajo Regional Office has come to rely on satellite imagery for their GIS base layer and for change detection.

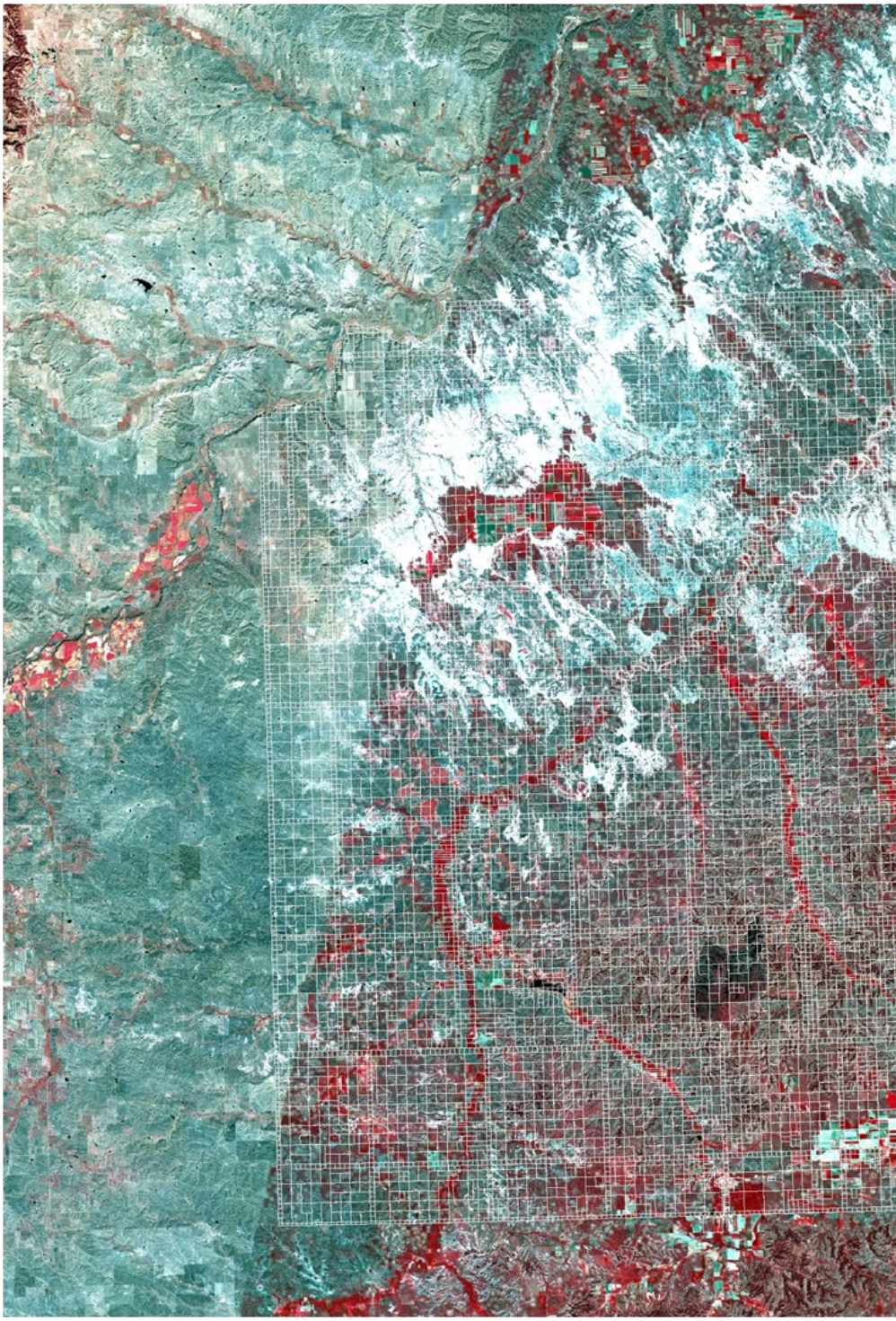
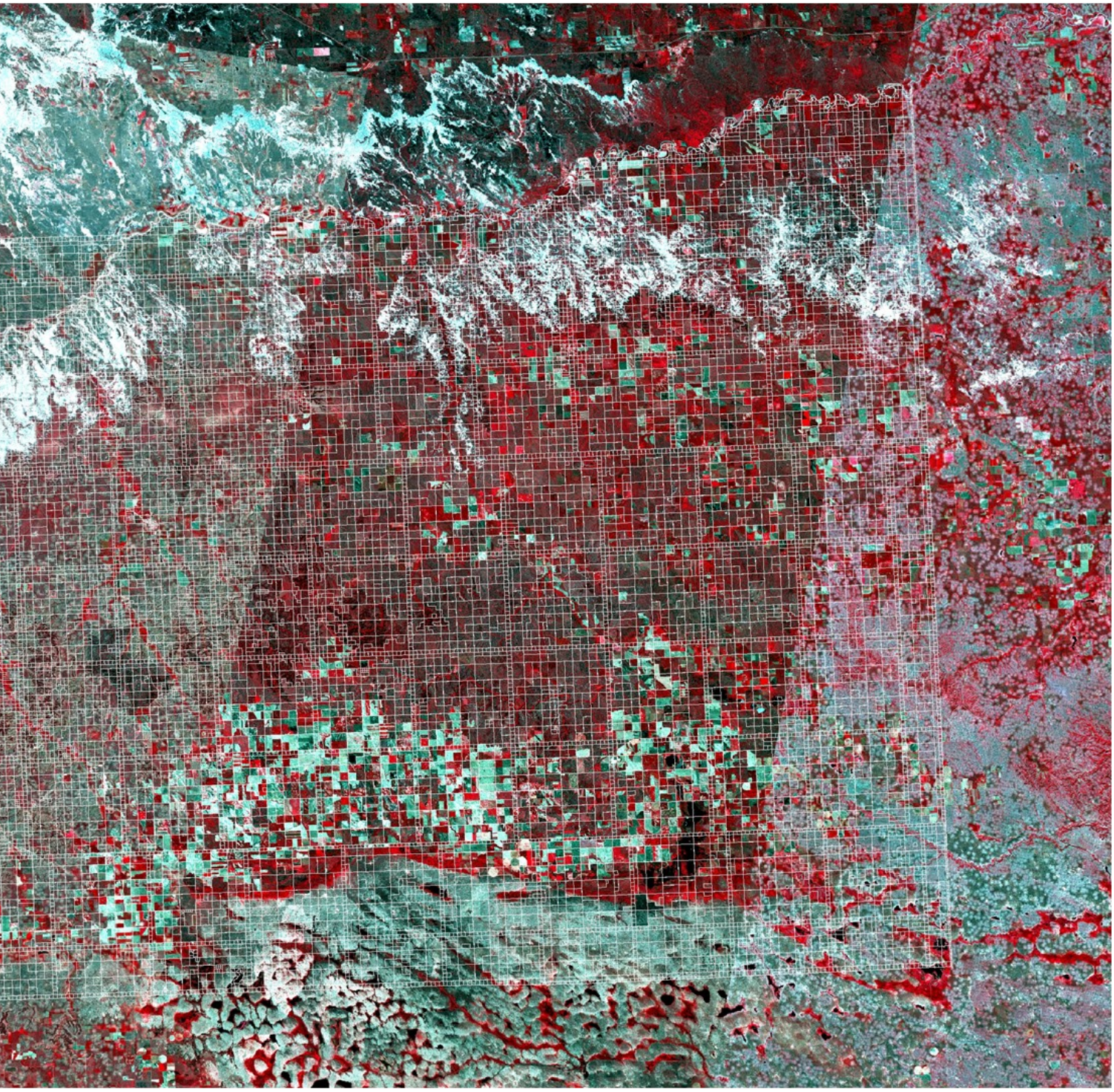


Figure 1: BIA pan-sharpened mosaic of 15 Landsat 7 ETM+ images for the Navajo Regional Office



Bureau of Land Management (BLM)

The Bureau of Land Management (BLM) used an array of remote sensing technologies to inventory, monitor, and address concerns about resource conditions, as well as energy and mineral resource extraction on public lands. The technologies ranged from simple digital SLR cameras to global-monitoring satellites (e.g., MODIS, Landsat). The BLM recognizes two intrinsic values that are uniquely provided by remote sensing: data that can be used at multiple scales (from plot level to Western-wide) and consistent/quantifiable data over time. Both of these values provide the foundation to support BLM's long-term resource management and monitoring goals.

Interagency Collaboration

Most of BLM's remote sensing activities leverage the skills and expertise of our many partners. Partnerships represent a key component in BLM's long-term plans. Inter-agency partnerships that coordinate orthoimagery, elevation, and digital sensor evaluations that benefit the BLM continued into 2009. The National Digital Orthophoto Program (NDOP), National Digital Elevation Program (NDEP), and the Inter-Agency Digital Imagery Working Group (IADIWG) have proved to be excellent partnership venues for the exchange of technical and project level information regarding orthoimagery, elevation, and airborne digital sensors.

Fiscal Year 2009 was the single largest year ever for the BLM acquiring the Farm Service Agency (FSA) National Agriculture Imagery Program (NAIP) orthoimagery. Nine western states, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Washington, and Wyoming, all had NAIP wall-to-wall, full state imagery acquired. Due to the massive landscapes covered by the NAIP program, this imagery dataset has proven to be the de facto base orthoimagery dataset for the BLM. NAIP uses range from change detection studies and surface disturbance delineation; road development updates and route inventory creation crucial to planning efforts; characterization of land exchanges, mining, reclamation and recreation facilities; monitor the health of rangelands and oil and gas development impacts; vegetation treatments, fire planning, trespass studies, and more. As the use of NAIP and other commercial remote sensing datasets have become more commonplace in the BLM, the need to provide easy access to the imagery has become a pressing need. The BLM National Operations Center (NOC) and State Offices of Oregon, New Mexico, and Alaska in conjunction with the United States Forest Service (USFS) Remote Sensing Applications Center (RSAC) coordinated to develop shared image serving capabilities. BLM has found that using centralized image services provide a far more efficient and effective way of delivering orthoimagery throughout our states.

Traditionally and for 2009, the widest use of remote sensing data was for fire-related activities. Most of the activities centered on interpretation of active fires, post-fire perimeter delineation, and vegetation classification for fire/fuel risk modeling and disturbance mapping. However, the utility of remote sensing data goes far beyond the fire world. BLM, with its partners, conducted a large range of natural resource management projects that leveraged remote sensing data and analyses to support our mission. Below is a sample of projects

across the natural resources spectrum that occurred in 2009.

Satellite Imagery Applications for Natural Resources Management

Forest Inventory:

BLM Oregon partnered with multiple agencies to capture LIDAR data in 2007. These data were processed in 2009 to provide updated forest stand inventory at an estimated cost savings of greater than 60%. The inventory also proved to be more accurate than traditional methods because the data are derived from measurements throughout the area rather than interpreted from sample sites.

Vegetation Mapping:

The BLM in Utah (USO) supported the national Forest Vegetation Information System (FORVIS) through the mapping of 1.2 million acres vegetation cover types, including forest stands, woodlands, shrubs, grasses, agriculture, and urban areas. Both aerial photography and Landsat data were used in the model, as well as several indices depicting vegetation, slope, aspect, elevation, and other statistical representatives. This is a statewide effort and an ongoing project until the entire State of Utah is completed. (figure 2.)

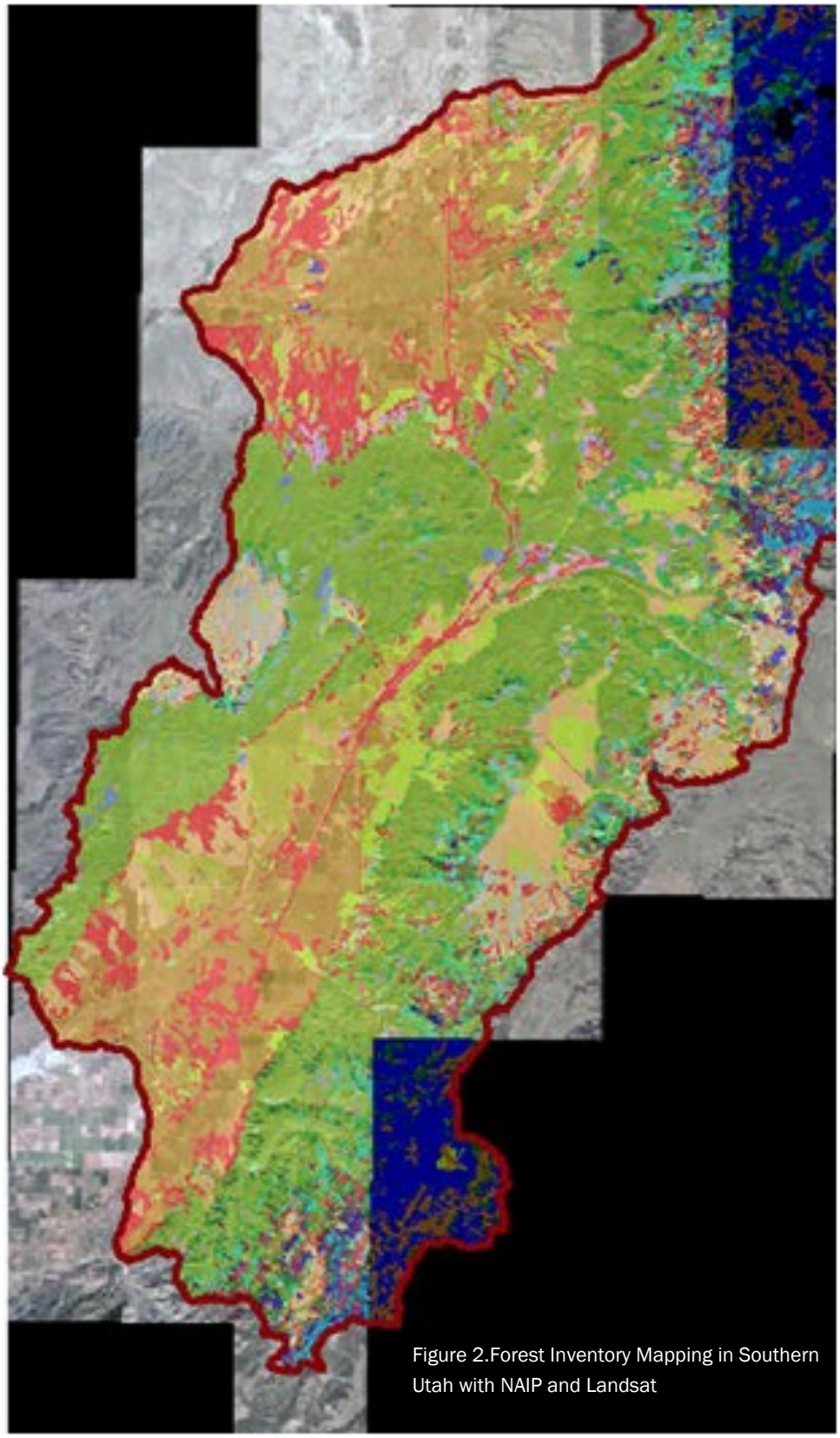


Figure 2.Forest Inventory Mapping in Southern Utah with NAIP and Landsat

Wildlife Habitat Modeling:

In 2008, The Billings, Montana Field Office began work on a new resource management plan (RMP). From the RMP development standpoint, resource specialists need a baseline description of vegetation within the planning area to support monitoring management effectiveness over time. To fill this baseline need, BLM contracted the USGS EROS Center to apply their continuous field mapping techniques to develop local and regional scale models of vegetation covering 90% of the field office boundary. Eight model components were generated for this project: continuous field estimates (from 1-100%) of percent bare ground, herbaceousness (grass and forb), shrub, litter, sagebrush, big sagebrush, Wyoming sagebrush, and vegetation height. USGS successfully completed this mapping work and 2009 saw the integration of these continuous field data to produce a variety of derived habitat mapping products to be used for RMP activities.

Rangeland Condition Monitoring:

USGS researchers created ecosystem performance anomaly data sets for nine years (2000-2008) for the Owyhee Uplands. Similar work was done for the Upper Colorado River Basin, but only for 2004-2008. The analysis team began developing projections of sagebrush performance anomalies based on projected climate for 2040 in both study areas. Upon completion of nine annual performance anomaly maps, they were sent to collaborators for feedback. Model validation is being performed using percent bare ground and stocking rate data.

Surface Disturbance:

Change detection and surface disturbance analysis studies were completed in the Wyoming Buffalo Field Office. The Powder River Basin Oil & Gas Project Environmental Impact Statement was approved in 2003. The EIS included limits for surface disturbance due to oil & gas development and required monitoring of this disturbance for development planning. The study evaluated the level of disturbance by computing the location and acreage of disturbance.

Environmental Assessment:

The Red Rock/Sloan Field Office completed a feasibility study and programmatic environmental assessment for the development of a trail system within the Red Rock Canyon National Conservation Area (RRCNCA). LIDAR elevation data and natural color orthoimagery were acquired over the RRCNCA west of Las Vegas, Nevada. These products were used by engineering and landscape design specialist for the design and development of the new trails and facilities for use by the general public.

Rare Plant Mapping:

Both true color and color infrared aerial 2006 NAIP photography were used to delineate potential habitat for the Pine Nut Mountains Ivesia, a rare endemic species known only to occur within the higher elevations of the Pine Nut Mountains in western Nevada. Remote sensing greatly improved our efficiency and effectiveness as we located likely habitat based on vegetation reflectance and ground texture. This allowed us to locate all meadows and playas in the target area which would have been difficult and time-consuming to locate by scouting on the ground.

Invasive Species:

Several images of the Swan Lake area, just north of Reno, Nevada, were made available to our office by our partners at the Washoe County GIS department. Invasive plant species have been noted over the years

but no quantitative data existed on the extent or rate of spread of the invasive vegetation. A spatio-temporal analysis was conducted using imagery from 1997 to 2008 to determine the rate of invasive vegetation spread. The analysis allowed our office to document changes to the hydrology of the lake and its feeder streams, including modification to the channel geometry over time. The analysis also allowed us to quantify the threat to the habitat posed by the spreading invasive vegetation and to document trends. The information will be used by the Swan Lake Advisory group to design future habitat improvement projects.

Photogrammetric Applications for Natural Resource Management

BLM continues to be a leader in the field of photogrammetry – pioneering the use of close range and traditional photogrammetry for a host of applications, such as cultural resource preservation and quantifying erosion impacts due to Off-Highway vehicle activity, as well as applying traditional techniques for hazardous waste management, engineering projects, and boundary dispute litigation. Multiple photogrammetric projects were undertaken in 2009. These included:

Water Rights:

NOC completed the Judith River project for the Lewistown, Montana Field Office in 2009. This project involved photogrammetrically creating detailed topographic and surface data from 3" resolution digital aerial imagery. These data enabled BLM hydrologists to characterize and model stream flows on the Judith River, and ultimately, to quantify federal reserved water rights on the Upper Missouri Breaks National Monument.

Mining Remediation:

NOC produced detailed topographic maps of parts of the Randsburg, California mining district for BLM's California State Office and the Ridgecrest Field Office. The Randsburg area is littered with many heavy metal laden tailings areas from past mining activities. These tailings are both in close proximity to residential areas, and are heavily used as All Terrain Vehicle (ATV) recreation areas. The tailings contribute significant amounts of hazardous pollutants, both in an airborne form and in run-off during storm events. The topographic data will be used for inventorying and quantifying the areas of concern, and also as a basis for creating plans to remediate and reclaim these hazardous areas.

Resource Preservation:

In the fall of 2007, the occurrence of dinosaur tracks was reported to the BLM Kanab Field Office by a group of hunters. The North Moccasin Mountain Tracksite (NMMT) reveals multiple track levels in the Early Jurassic Navajo Formation (age ~185 million years) in a slickrock sandstone area covering about 1,000 m2. Due to the high occurrence, ichnotaxonomic diversity, and morphological variations, the tracks at the NMMT provide an uncommon glimpse of an oasis in the midst of the vast Jurassic Navajo desert.

To better understand the track diversity that is present and to provide a baseline, documentation and mapping of the site began in March of 2008. A combination of terrestrial-based and low-level aerial photography of the site, using a specially outfitted Bellranger helicopter, was employed to produce high-resolution three-dimensional image datasets. (Figure 3) The resulting resolution of the images ranged from 10cm to 5mm. Products from this flyover include digital elevation surface and also an overall digital orthomosaic of the area. This composite image in Figure 3 illustrates selected camera locations (in blue) and individual terrain points calculated from the imagery (in

yellow) from the helicopter flyover. In 2009, final analysis and model development was completed incorporating the multiple scales of photography into a unified real-world coordinate system for display and analysis in a Geographic Information System. The digital virtual representations provided an effective tool for presenting the uniqueness of the site to OHV enthusiasts and other members of the general public, to land managers, and to the scientific community.

Fine-Scale Habitat Monitoring:

BLM continued its partnership with the NOC, ARS, and USGS to conduct remote sensing work for the Powder River Aquatic Task Group (PRATG). Coalbed Methane (CBM) development produces saline and sodic discharge water at 5-15 gallons/minute/well. Current permits allow 51,000 wells in the Powder River Basin by 2010, giving a potential discharge of 1.1 billion gallons/day. As a result of the unknown environmental impacts, the Powder River Aquatic Task Group (PRATG) decided to explore the possibility of using remote sensing data and techniques to develop economical and effective means of monitoring change in affected aquatic and riparian habitat.

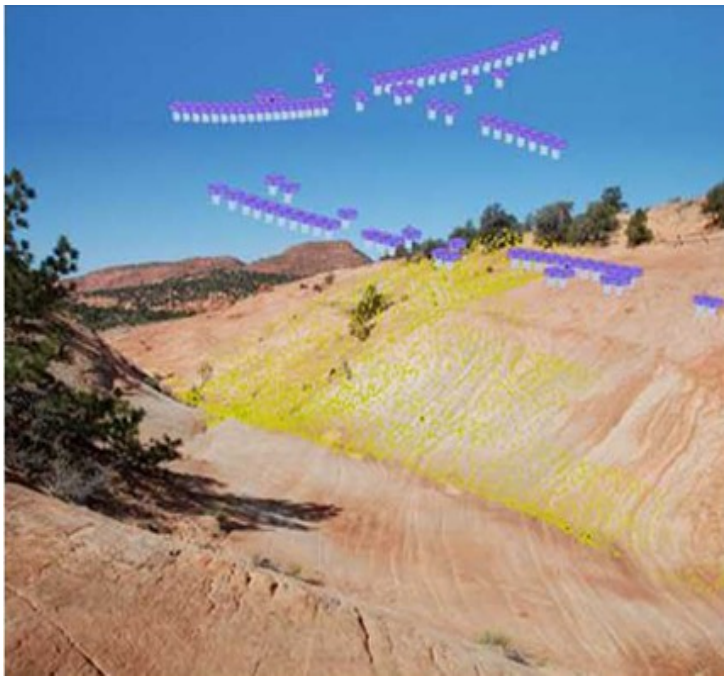


Figure 3. Photo locations used to map dinosaur tracks for North Moccasin Mountain in Utah

Fiscal Year 2009 represented the third year of collecting monitoring data through remote sensing sources. The remote sensing work has three primary focus areas to monitor the impacts of CBM discharge water on aquatic and riparian habitat in the Powder River:

1) Aquatic habitat sample collection using very large-scale aerial (VLSA) photography;
2) Upland, riparian, and aquatic habitat mapping using AEROCam and Quickbird imagery; and
3) photogrammetric processing of VLSA to accurately register imagery for monitoring purposes as well as provide detailed terrain data to examine bank stability.

With three years of data, we have now completed a series of predictive models that quantify various aquatic habitat conditions based on the flow rate of the Powder River.

Bureau of Reclamation (BOR)

The Bureau of Reclamation (BOR) continued its use of Landsat TM (Thematic Mapper) satellite imagery, digital aerial imagery, LIDAR (light detection and ranging), IfSAR (interferometric synthetic aperture radar) and SONAR (sound navigation and ranging) data to support its water resource management mission.

Hydraulic Modeling for Environmental and Engineering Applications

Reclamation used LIDAR data supplemented with ground surveys using RTK-GPS and bathymetry data obtained from SONAR to produce high-resolution digital representations of topography under reservoirs and river channels. These elevation data helped to quantify reservoir sedimentation rates, and were input to hydraulic models which mapped river flow velocities and depths at a number of river discharge scenarios. Hydraulic model results were used in sediment transport studies to aid in the design of hydraulic structures. When combined with vegetation and water temperature maps generated from aerial remote sensing data, hydraulic model results were also used to characterize riverine habitat for fish species at specific river discharges, and to estimate river flow rates needed to maintain riparian ecosystems. (http://www.usbr.gov/pmts/sediment)

Hydraulic Modeling for Dam Failure Scenarios

Reclamation used digital elevation data from various sources, including USGS NED, IfSAR, and LIDAR as input to hydraulic models which are used to estimate inundation area associated with a range of dam failure / canal breach scenarios. These analyses are performed on large dams and canals throughout the western 17 states. Inundation polygons are combined with census data, high-resolution aerial photography, and other spatial data sets to estimate loss-of-life and economic impacts associated with specific failure scenarios.

Water Use

Reclamation also used remotely sensed data to estimate consumptive water use from agricultural crops, riparian vegetation, and open water in the Central Valley of California, the Newlands Irrigation Project, Nevada, and at several locations within the Colorado River Basin. Consumptive water use data are required to monitor water use compacts, and to verify compliance with fallowing programs associated with water conservation programs. Evapotranspiration (ET) was estimated using both energy balance models and models based on land-cover maps. Energy balance models use estimates of net radiation, soil heat flux, and sensible heat flux derived from a time series of image and surface-measured data to produce spatially-varying maps of ET. The land cover approach applies daily water use coefficients which estimate ET from weather data to vegetation class acreages obtained from maps generated from remotely sensed imagery.

Fish Habitat

Reclamation used digital aerial multispectral and thermal imagery to map riparian and in-stream habitat to support salmon recovery activities in the Columbia and San Joaquin River Basins. Reclamation also used LIDAR data supplemented with GPS and ground survey data to produce digital representations of river channel and floodplain topography. These elevation data were input to hydraulic models which predicted river flow velocities and depths at a number of river discharge scenarios. Model results were used to help characterize riverine habitat for fish species at specific river discharges.

Bureau of Ocean Energy Management, Regulation & Enforcement (BOEMRE) *formerly Minerals Management Service (MMS)*

On June 18, 2010, by Secretarial Order 3302, Interior Secretary Ken Salazar formally changed the name of the Minerals Management Service to The Bureau of Ocean Energy Management, Regulation & Enforcement (BOEMRE). The text below reflects the bureau's name and organizational reporting structure for the time period covered in this report.

Natural Gas Flaring

Minerals Management Service's (MMS) Gulf of Mexico Regional Office (GOMR) and European Space Agency's (ESA) World Fire Atlas Data group began a fully collaborative effort to improve detection of natural gas flaring events from Gulf of Mexico federal waters. ESA is currently using the AATSR sensor onboard Envisat to collect world-wide "fire event and hot spot" data. ESA's "World Fire Atlas Data" have been collected since late 1995, and unique to ESA's data collection is the ability to record fire events from offshore oil and natural gas production operations. Gulf of Mexico natural gas flaring is an MMS regulated production activity. The ESA group has developed a new proprietary processing algorithm with improved detection sensitivity. ESA is providing flare event data to MMS using the new algorithm and MMS is providing in-situ data of detected flares to enhance instrument calibration.

Hurricane Disaster Planning

Approximately 135 production platforms were destroyed by Hurricanes Ivan in 2004, Katrina and Rita in 2005, and Gustav and Ike in 2008. To assist in future post-storm infrastructure assessment MMS, in collaboration with NOAA, collected baseline synthetic aperture radar (SAR) imagery of production infrastructure in the Gulf. The baseline data will be compared to SAR imagery (figure 4) collected post-hurricane to identify infrastructure destruction, damage, and oil spills. Approximately 20 to 25 percent of the domestic production of natural gas and crude oil comes from the Gulf. There are over 3,500 fixed oil and gas production platforms in the federal waters of the Gulf. These structures are connected by thousands of miles of seafloor pipelines that ultimately tie into onshore production and processing facilities. Post-storm SAR imagery will assist MMS to rapidly assess destruction and damage to infrastructure, identify oil spills, document navigation hazards, assess the impact to human health and safety, and respond to potential environmental damage.

Oil Slick Detection

The Naval Research Laboratory at Stennis Space Center, in collaboration with NASA/Langley Research Center, and NOAA/STAR received NASA funding for their Gulf of Mexico "Oil Slick Detection Using NASA Active and Passive Sensors" research proposal. The sensors to be employed are the AQUA/Moderate Resolution Imaging Spectroradiometer (MODIS), the Cloud Aerosol LIDAR with Orthogonal Polarization (CALIOP), Synthetic Aperture Radar (SAR), and Landsat. MMS will supply in-situ data of reported oil spills and natural seeps, results of inspections and investigative reports, and GIS database resources.

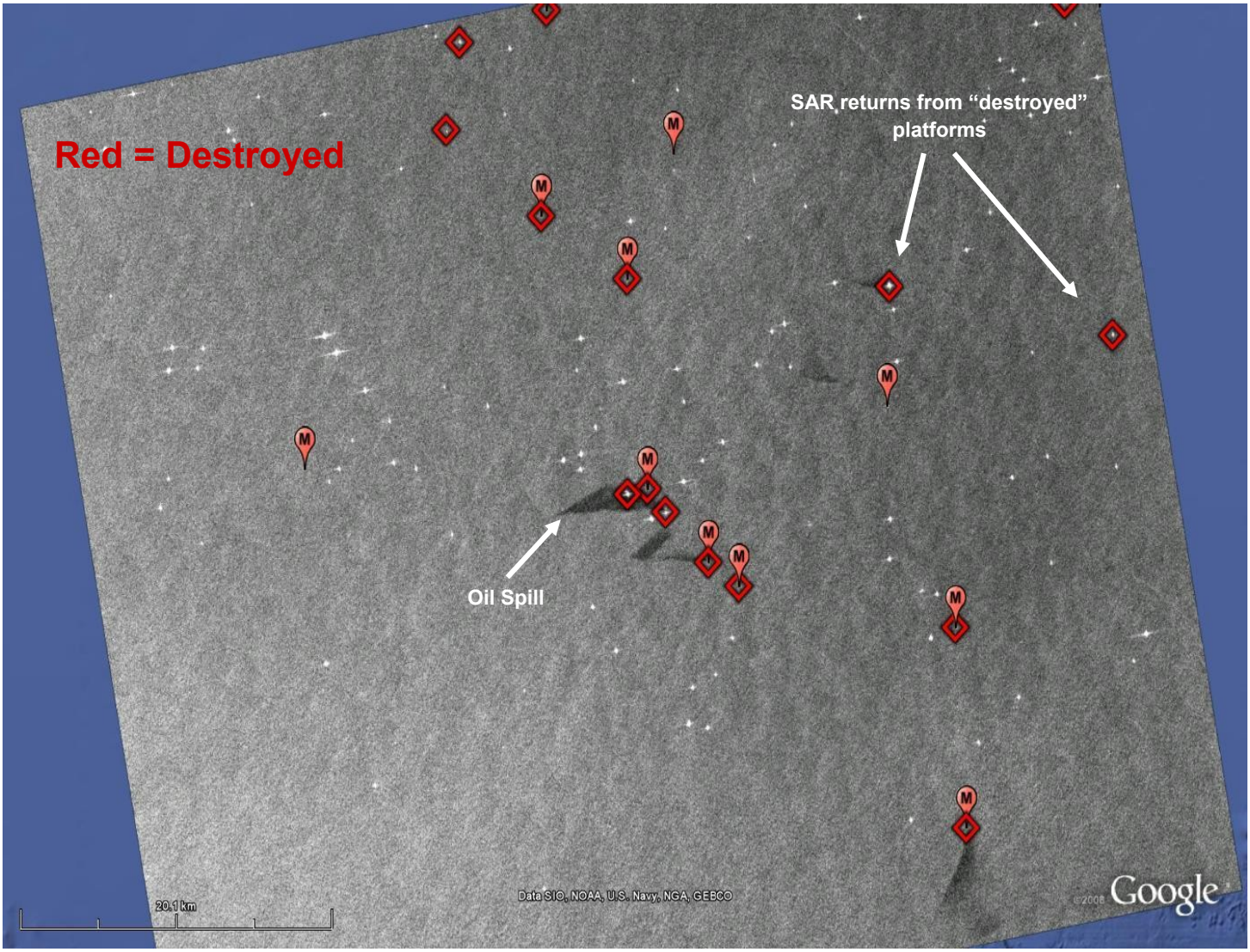


Figure 4: Example of Gulf of Mexico SAR imagery.

- **136 platform positions covered by this image**
- **10 of 18 destroyed platforms designated as missing (M)**
- **8 destroyed (severely damaged) platforms with SAR returns**

National Park Service (NPS)

The National Park Service (NPS) has a long history and standing investment in remote sensing and GPS technologies. A wide range of projects and programs have business requirements that utilize aerial and space borne platforms ranging from acquisition to applications and the use of imagery in reports and related products.

NPS Inventory & Monitoring Program

The NPS Inventory & Monitoring Program (I & M) program conducts 12 baseline inventories of over 270 parks spanning over 30 million acres of public lands for the support of land management decisions. The Geology, Soils, Vegetation, and Base Cartography baseline inventories are developed using multiple sources of space based remote sensing. http://science.nature.nps.gov/im/I&M_ProgramBrief.pdf

The NPS continued a longstanding use and demand for imagery-derived products to support the vegetation inventories on 270 national parks. Many park vegetation maps are using remote sensing, with 9 million acres mapped, 8.2 million acres underway, and 12 million remaining. The use of National Agricultural Imaging Program (NAIP) resources, sometimes coupled with Landsat TM, and a variety of SPOT, Quickbird, and IKONOS products are used to support these inventories. The list of ongoing projects can be viewed at the NPS & USGS collaborative project Web sites: http://biology.usgs.gov/npsveg/ and http://science.nature.nps.gov/im/inventory/veg/

GPS is also a critical tool in checking field data, accuracy assessments, and project mapping. The use of Continuously Operating Referenced Station (CORS) data and the National Differential GPS system maintained by the US Coast Guard are critical tools in resource assessments. http://www.ngs.noaa.gov/CORS

In 2009 the Landscape Monitoring Project (NPScapes) project packaged Landsat Thematic Mapper, National Land Cover Data, GAP Land Cover, LANDFIRE and various metrics from these data for all of the NPS units in order to allow parks to start monitoring Landscape Dynamics in and around their units. This will be expanded in the future to include Land Cover data for all of North America derived from MODIS imagery and NOAA's C-CAP data. http://science.nature.nps.gov/im/monitor/npscape/

Northeast and Coastal & Barrier

The Northeast and Coastal Barrier Network (NCBN) of the I&M collaborated with the USGS Florida Integrated Science Center to collect Light Detection and Ranging (LIDAR)) data and aerial photography at Fire Island National Seashore and Gateway National Recreation Area in support of the network's coastal geomorphologic monitoring program. These data are used to generate highly accurate elevation models of beach, dune, and other coastal features, and are used by park natural resource managers to assess rates of erosion and deposition. Ongoing monitoring of the NCBN coastal parks using LIDAR will also assist managers in assessing the effects of climate change (such as sea-level rise) on these coastal systems. http://science.nature.nps.gov/im/units/ncbn/

Colorado

The US Fish and Wildlife Service will be co-locating with the NPS I&M program in Colorado to stand up a set of I&M parallel efforts for Wildlife Refuges, and the sharing of resources, techniques, and space based data will be a critical tool for this new joint effort. This data sharing and teamwork is part of the new changing climate based initiative to demonstrate agency collaboration and leverage data collection and analysis efforts.

Alaska

In FY2009 the NPS used remote sensing technologies in several key areas to support the NPS mission and operations in Alaska. The information obtained from remotely sensed data was used by park managers, scientists, and planners to manage Alaska park resources. Aerial photography, satellite imagery, and GPS technologies were used to map and monitor changes in glaciers, snow and ice extents, wildfires, landcover (vegetation), and soils, among others. Highlighted activities include:

Land Cover Mapping:

Under an Interagency Agreement with the USFS–Pacific Northwest Research Station, the Southwest Alaska Network (http://science.nature.nps.gov/im/units/swan/) developed methods for using Landsat data to detect changes in land cover in Lake Clark National Park and Preserve (1987–2005), including loss of tree cover due to fire or insect outbreaks, shrub establishment on glacial outwash and/or abandoned river channels, and pond drying. The new analytical approach resulted in more stable and thematically consistent labels for changes occurring on the landscape and better integration of information from the existing land cover maps. Additional funding from NASA supported the analysis of scenes from Katmai National Park and Preserve.

Coastline Mapping:

A University of Colorado research team, in coordination with the Alaska Arctic Inventory and Monitoring Network, continued to assess rates of coastal erosion and accretion along the shores of Bering Land Bridge National Preserve and Cape Krusenstern National Monument. The team used repeat aerial photography with time series from the 1950s, 1980s, and 2003 as well as IKONOS satellite imagery to determine coastline changes. The project will assist NPS in developing protocols to continue acquiring aerial photographs and satellite imagery for long-term monitoring of the coastline. Significant changes to the 450 kilometers of coastline along the park shorelines became evident by comparing the imagery. These changes affect animal habitat, water, soil, permafrost, and other aspects of coastal ecosystems, cultural resources, and local communities. http://science.nature.nps.gov/im/units/arcn/documents/documents/NPS-ARCN-DMSOP-2010-01_Accessing_Coastal_Erosion_Imagery_v1.1_201001.pdf

Glacier and Permafrost monitoring:

Glacier monitoring using IKONOS commercial and LANDSAT satellite imagery, historic aerial photography, as well as LIDAR elevation data continued to be utilized throughout National parklands in Alaska. IKONOS imagery collected through the NPS's Inventory and Monitoring (I&M) Inventory Program were provided to researchers at the Alaska Pacific University, and Brooks Range Region of the Global Land Measurements from Space (GLIMS) program to identify and monitor glacier boundaries. http://science.nature.nps.gov/im/units/swan/index.cfm?theme=glacial_extent

The Southwest Alaska Network used a combination of high-resolution IKONOS imagery, Landsat data, and historic aerial photographs to quantify decadal changes in glacier ice cover (1973–2002) and to document land cover change

(1955–2005) in three national park units (figure 5). In addition, MODIS data assisted in documenting seasonal variation in lake ice and in calculating growing season metrics across the study region. IKONOS imagery was used to map thermokarst disturbance and erosion features related to thawing permafrost.

The Southwest Alaska Network, in cooperation with NASA, used Landsat data to quantify current glacial extent and changes in ice cover over a roughly 30-year period in Kenai Fjords, Katmai, and Lake Clark National Park and Preserve. Scientists used automated classification techniques and manual interpretation to delineate ice boundaries. In addition, the NPS and USGS developed a baseline Digital Elevation Model (DEM) for the Bear and Exit Glaciers using LIDAR data acquired through a partnership grant. Mapping of glacial extent in Katmai NPPr and Kenai Fjords showed losses of 7.7% and 1.6%, respectively.

Snow and Lake Ice Monitoring:

The Southwest Alaska Network, in partnership with the U.S. Geological Survey, continued to use Moderate Resolution Imaging Spectroradiometer (MODIS) data to monitor internal variation in lake ice (timing of ice formation and break-up), snow cover (extent and duration of snowpack), and productivity (start and end of growing season for vegetation) across the Network. MODIS calibrated radiance, daily and 8-day snow cover, and NDVI products were used in the analyses. http://science.nature.nps.gov/im/units/swan/index.cfm?theme=ls_process

Wildland Fire Mapping:

Evaluating approximately 423,952 acres of parklands, researchers generated wild land fire burn severity products from Landsat data for 18 fires that occurred between 2005 and 2007 within Alaska national parks.

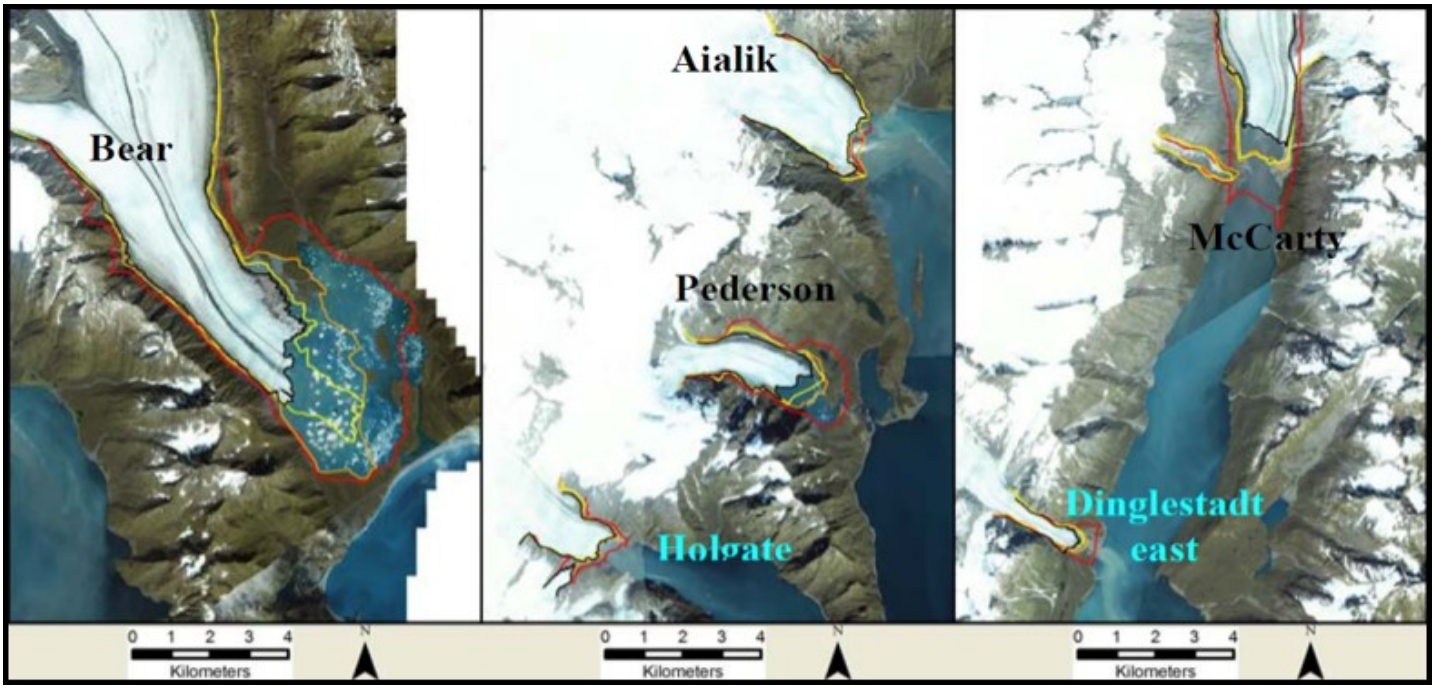


Figure 5: Bear Glacier (left), Aialik, Pederson and Holgate Glaciers (center), and McCarty and Dinglestadt Glaciers (right), KEFJ, Alaska. Glacier terminus positions indicated for 1951 (red), 1986 (orange), 2000 (yellow) and 2005 (black). (Images from 2005 are from Ikonos.

Resulting data products included burn severity datasets and detailed fire perimeters, which NPS distributed to park staff and public users. In FY2009, the Denali Landcover Map was updated with fire perimeter information generated from burn scars found within LANDSAT imagery to produce a map that reflects post-fire vegetation changes for fires dating back to 1986. This map provides vegetation and fuels information for use in spatially explicit fire behavior modeling tools and fire suppression activities. Additionally, LANDSAT and IKONOS satellite imagery of Denali NPPr was provided to the Alaska Natural Heritage program at the University of Alaska Anchorage (AkNHP) to verify Landcover (vegetation) classes and field plot data for a LANDFIRE dataset accuracy assessment.

Land Cover Inventory and Vegetation Mapping:

The NPS's I& M Regional Inventory program used IKONOS satellite data to conduct preliminary field evaluations and post field season site verification for land cover mapping in Aniakchack National Monument and Preserve. IKONOS satellite data for Gates of the Arctic National Park and Preserve were also provided to the USGS Alaska Science Center, where staff used the imagery to develop techniques for mapping fractional shrub cover over large areas, such as National Parks. MODIS satellite data was used to detect broad-scale changes in vegetation and landscape features within the region. Annual vegetation growth (NDVI) differences were monitored using MODIS and AVHRR data to look for multi-year trends in greenness (as a proxy for biomass and productivity). Finally, the I&M Arctic Network used low altitude aerial photos and historical air photos (AHAP and others) to document environmental changes such as shrub expansion and lake drainage network within parks.

Under an Interagency Agreement with the USFS–Pacific Northwest Research Station, the Southwest Alaska Network developed methods for using Landsat data to detect changes in land cover in Lake Clark National Park and Preserve (1987–2005), including loss of tree cover due to fire or insect outbreaks, shrub establishment on glacial outwash and/or abandoned river channels, and pond drying. The new analytical approach resulted in more stable and thematically consistent labels for changes occurring on the landscape and better integration of information from the existing land cover maps. Additional funding from NASA supported the analysis of scenes from Katmai National Park and Preserve.

Soils Inventory Mapping:

NPS used park-wide color-infrared orthophotography of Yukon-Charley Rivers National Preserve (YUCH) for photo-interpretation and soils mapping activities within the park. Full soil profile descriptions and vegetation community characterizations were completed for 283 field sites using this imagery. A land area of 1,000,000 acres was aerially assessed and field checked.

Digital Elevation Models:

Digital Elevation Models (DEMs) derived from space based sensors such as IKONOS provided elevation information essential for generating geospatial layers such as slope, aspect, elevation contours, and relief maps. All of these data layers were used to aid daily activities such as aviation and backcountry route planning, evaluating cultural resource locations, and conducting search and rescue operations within the NPS Alaska Region. DEMs also provided important elevation information for mapping floodplains, hydrologic drainage patterns, and landforms. They were used in habitat modeling and vulnerability assessments, simulating storm surge and tsunami scenarios, testing sea level rise scenarios, developing three-dimensional models that illustrate changes in glacial volume, as well as aided wildfire

prediction models, among other applications. As part of an effort to improve outdated and course DEM baseline datasets for Alaska parklands, in FY 2009 the Alaska region received an IKONOS generated DEM for the northern portion of Lake Clark National Park and Preserve.

GPS Applications

The Alaska Exotic Plant Management Team used GPS to map invasive weed species within NPS Alaska parks. The data were used to: track infestations over time to evaluate treatment efficacy; analyze species movement outside of park boundaries to reveal new priority species; and assist with prioritizing inventory areas to try and catch new invasions of species.

The NPS Alaska Facilities Management Program used GPS for mapping building footprints. These geographic features and condition photographs are being collected for all NPS buildings in Alaska Parks for managing theses assets and their maintenance status. These features are linked through a common ID to the facility management system enabling both spatial and attribute analysis and mapping capabilities in a GIS.

Researchers in Denali National Park gathered GPS points during flights over the park. These data were used to document the location of park air traffic and to evaluate the current balance between research use versus negative effects of noise, etc. Some of the ongoing data collections using GPS have included documentation of a variety of natural and cultural resources including beaver dam locations, road crossings by GPS-collared sheep or bears, location of archeology sites, and location of exotic plants.

Trail mapping in Alaska parks is an on-going mission that uses mapping grade GPS for collection of trail location as well as attributes about trail condition. In FY2009, the Regional Trail Program Team collected data in many of the parks, with a centerline mapping effort and detailed physical condition assessment of 519 miles of Off Highway Vehicle (OHV) trails. The staff also developed a set of sustainable trail design guidelines that guides the evaluation of existing trails and establishes standards for new construction.

Backcountry rangers used GPS to collect locations for case incident reporting. In addition, photographs taken of the incident are stored with the latitude / longitude of the incident imbedded in header information of the photos.

Yellowstone National Park

Yellowstone NPS staff continues to utilize the Web Access and Retrieval Portal from the National Geospatial Intelligence Agency (NGA) to acquire satellite imagery for the Park. As this website is updated constantly, Yellowstone staff query the site for updated imagery quarterly or as needed for specific data requests. This imagery is used for numerous park projects, including updating building, roads, utilities, vegetation, and trails GIS data layers. Since high-resolution imagery has become the de facto background for park operations maps, this imagery will also be used as background imagery for cartographic products.

High-resolution imagery from the National Agricultural Imagery Program and DigitalGlobe's QuickBird satellite sensor were used to locate helicopter landing sites for the Presidential visit to Yellowstone in August 2009. The imagery was also used by law enforcement rangers for event planning. This is one of many examples where recent remote sensing imagery is essential as an up-to-date base map for field personnel – rather than relying on outdated topographic maps and institutional memory.

Fire:

NPS Yellowstone National Park staff used a temporal series

of high-resolution (1-meter resolution or less) commercial imagery and Landsat-derived Normalized Burn Ratio products to delineate stand-replacing fire effects from 1988 to the present in Yellowstone National Park.

Vegetation Change:

Yellowstone Park staff are working with researchers at Idaho State University to quantify high-alpine vegetation change over time using current and historic remotely sensed imagery. Working with the USGS Earth Resources and Observation Science (EROS) Center, historic aerial photo negatives of Yellowstone National Park and the surrounding high alpine areas are being scanned to digital format. Landsat, IKONOS, QuickBird, and WorldView satellite imagery were also pulled from the archive, as well as new satellite tasking ordered for the study areas.

Habitat Mapping:

Natural Resource staffs are using Landsat-derived products to run models developed by the Yellowstone Ecological Research Center and the NASA Ames Research Center. Their model is designed to predict the amount of forage available at the end of the growing season, which may affect the movement of ungulate species such as bison, elk, deer, and pronghorn. Archival Landsat imagery and GPS collar locations of bison are being used to test the model for 1990 through present.

Great Lakes

The Great Lakes Network is implementing a land cover monitoring program based on work by Robert Kennedy and others at Oregon State University, using a suite of algorithms known collectively as LandTrendr, (Landsat-based detection of trends in disturbance and recovery). This process exploits the full 25-year archive of Landsat 5 and 7 imagery in order to identify land cover disturbances. The Network is then validating each of these changes, primarily using high resolution aerial photography and satellite imagery; these include NAIP, State aerial photo projects, Network-funded aerial photo flights, and IKONOS, SPOT and Digital Globe satellite imagery.

Fire Burn Severity Mapping

Starting in 2005, the NPS became the DOI sponsoring agency for the Monitoring Trends in Burn Severity (MTBS) project as a joint venture between the DOI and USFS, with the USGS and the USFS Remote Sensing Application Center (RSAC) responsible for the project. MTBS maps all wild land and prescribed fires greater than 1,000 acres in the west and 500 acres in the east from the present back to the early 1980s. An example is found in Figure 6 and 7 below. http://mtbs.gov/

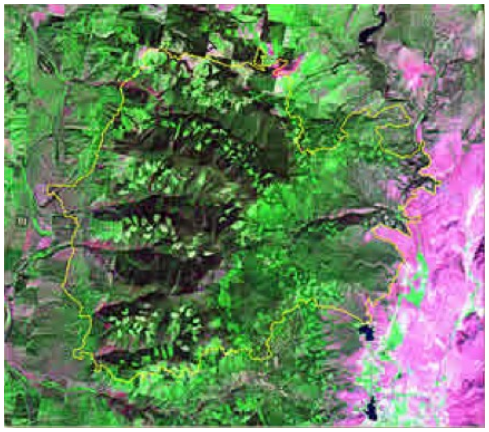


Figure 6: Pre-fire Landsat Scene

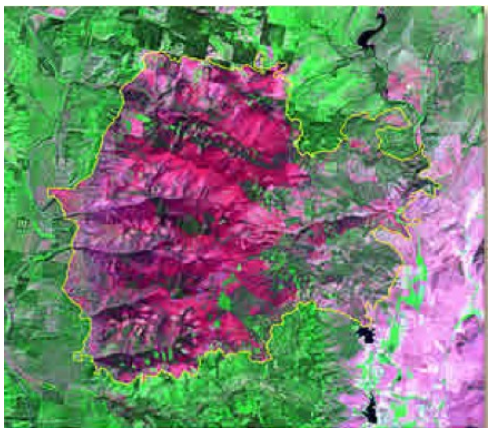


Figure 7: Post-fire Landsat Scene

Office of Surface Mining Reclamation and Enforcement (OSM)

During FY 2009, the Office of Surface Mining (OSM) continued to acquire and use high resolution satellite imagery and GPS to support on-the-ground Surface Mining Control and Reclamation Act activities. Particular focus was placed on inter-agency and inter-departmental partnership and outreach to reduce image acquisition costs, improve efficiency in defining like data requirements, and enhance effectiveness by eliminating redundancy of on-line remote sensing course development.

Remote sensing project activities include the continuation of a two-year pilot project working with USGS and NGA to determine the best methods for acquisition and delivery of image data, products and services for OSM's regulatory program; and determining which remote image data products and services support virtual inspection.

The State of West Virginia is using high resolution satellite imagery for approximating original contours to support the regulatory program in West Virginia, with realized cost savings over using GPS field devices on the ground.

OSM staff continue to work with high resolution satellite imagery along with other geospatial tools to assist in the inventory of abandoned mine land (AML) sites in the State of Virginia; resulting in identification of acid mine drainage sites, dangerous highwalls, apple cores, gob piles and spoil piles.

Training

In addition, remote sensing education outreach is an integral part of the program, with OSM staff conducting a "Basics of Remote Sensing" course at the 2009 American Society for Mining and Reclamation Conference. The use of remotely sensed imagery to support on-the-ground SMCRA activities will continue in FY 2010.

GPS Applications

OSM and state regulatory staff have been employing GPS devices to spot check approximate original contour elevations and reclaimed slope profiles on mine sites nationwide as part of a new OSM National Area of Emphasis Oversight Inspection Team. New high accuracy Trimble ProXRT dual frequency GPS systems have been deployed to each of the three OSM regions for OSM, state and Tribal partner checkout use in georeferencing for Geographic Information System building and other GPS applications which had formerly required RTK GPS use. The use of these and other GPS devices to support OSM and state regulatory activities will continue in FY 2010.

U.S. Fish and Wildlife Service (FWS)

The U.S. Fish and Wildlife Service (FWS) uses a diverse set of remotely sensed data, from traditional aerial images to satellite radar imagery, to support a wide variety of habitat and land management activities as varied as habitat, wetland and vegetation mapping, monitoring fish and wildlife populations, refuge management, trend analysis and modeling, climate change mapping, and strategic habitat conservation planning.

Habitat Modeling

The Gulf Coast Joint Venture (GCJV) used a combination of aerial photography and satellite imagery to develop habitat models for priority bird species along the western Gulf Coast. The GCJV has used both USGS and USDA orthophotography for estimating the amount of available foraging habitat for wintering waterfowl in emergent coastal marshes. Landsat imagery has been used to model pond use by redhead ducks for protection and enhancement of ponds based on available shallow shoal grass, distance to freshwater basins from foraging sites, and degree of isolation and permanence. The GCJV also used Landsat imagery to develop estimates of seasonal surface water on agricultural landscapes for wintering waterfowl and fall migrating shorebirds. The GCJV is currently using NAIP photography to assess a coastal marsh/permanent water mask derived from NLCD and National Wetland Inventory land cover classes, and applying this mask to seasonal surface water classifications of Landsat imagery.

Starting with North Carolina in the Service's Southeast Region, Multiple Return LIDAR data from the North Carolina Floodplain Mapping Program were processed using free open source geospatial software to complete a forest canopy height model for all of North Carolina. This canopy height model was then compared to known nesting locations of different bird species to derive species preference models for canopy heights. A simulated 1-meter sea level rise was also applied using the North Carolina Floodplain Mapping 20-foot elevation grid. The resulting mask was used to approximate the impact of sea level rise on different canopy height classes along the North Carolina coast.

The Arctic Goose Joint Venture (AGJV) purchased satellite imagery through the Hudson Bay Project and conducted a vegetation change detection analysis for the Thompson Point area on Cape Churchill, Manitoba. Recent staging and nesting activity of lesser snow geese there have caused severe damage, similar to the historic damage at La Perouse Bay. The AGJV will also be acquiring satellite imagery for Southampton Island goose

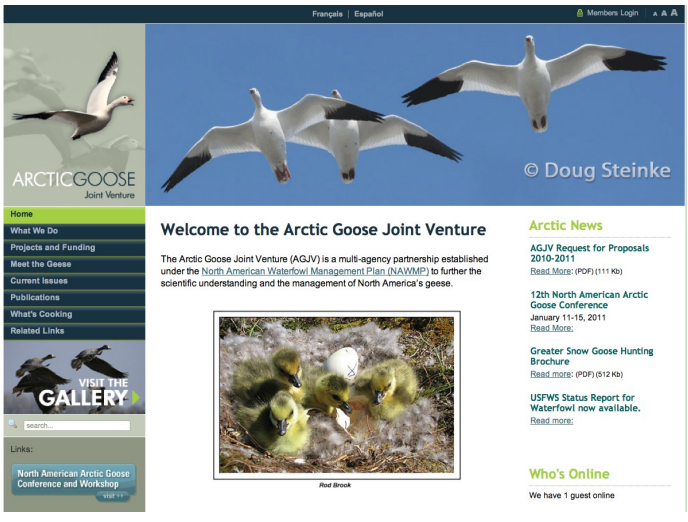


Figure 8: Arctic Goose Joint Venture website www.agjv.ca

habitats to conduct similar vegetation analyses, in concert with ground surveys, to assess the impacts of goose foraging (figure 8).

Migratory Birds

The Division of Migratory Birds works in partnership with NASA and the Yellowstone Ecological Research Center on a project to identify environmental variables derived from NASA's TOPS (Terrestrial Observation and Prediction System) that influence long-term productivity and abundance of waterfowl in the Prairie Pothole Region of the United States and Canada. This project makes use of 55-plus years of aerial survey data collected by pilots in the Branch of Migratory Bird Surveys, combined with vegetation, hydrologic, and climatic variables derived from MODIS, AVHRR, Landsat, and other sensors.

The Division of Migratory Birds is also engaged in several satellite telemetry projects, including those involving sand hill cranes and king rails. A project was initiated to band the eastern population of sand hill cranes with Northstar Telemetry Solar GPS satellite transmitters in order to delineate migration corridors, breeding/ wintering grounds, and to evaluate the current FWS/ state agency Eastern Population Fall survey. High-resolution aerial imagery and satellite imagery will be used to analyze habitat at crane telemetry locations. A similar project is underway using Microwave Technology Platform Transmitter Terminal (PPT) satellites to band king rails within the Mississippi Flyway in order to better understand migration patterns and delineate breeding/ wintering grounds.

Other uses of remotely sensed land cover data include the development of energetic (i.e., kilocalorie) surfaces that are input into the development of a migration model, and general land cover summary statistics assessment of net landscape changes in the Atlantic Coast Joint Venture (ACJV) administrative boundary. During 2009, the ACJV initiated a project in collaboration with USGS to use LIDAR data to assess the impact of sea level rise on populations of priority bird species in salt marshes in the mid-Atlantic and New England portion of the joint venture. The ACJV also uses DEMs to calculate landscape metrics (e.g., slope, aspect, surface roughness, etc.) that are useful in modeling species response to landscape features. The ACJV is also supporting a project that uses NEXRAD data to map bird migration hot spots. These data are useful in determining areas that are important in maintaining populations of migratory species, but which are not commonly considered when developing focus areas for conservation actions.

The Great Lakes Restoration Initiative has enabled a variety of remote sensing approaches to be proposed and implemented by a variety of Canadian, federal, state, tribal, and local governments, and non-government organizations in the Great Lakes Basin. In one of the more interesting applications, the U.S. Fish and Wildlife Service will be implementing a ground-based radar mapping trailer that tracks and maps migratory bird patterns in flight out over the Great Lakes coastal zones, establishing documentation prior to any wind energy development. (See Figure 9)

Wetland Mapping

The 2008 Intergovernmental Panel on Climate Change (IPCC) Climate Change and Water Technical Paper described wetlands as the most vulnerable habitat on Earth. As a result, the need to map and monitor wetland habitats substantially increased, not only for habitat and landscape planning, but also for assessing climate change impacts on fish, wildlife and human resources. Recent user surveys have confirmed the need to provide

updated wetland maps on a 5-year cycle.

The FWS is the lead federal agency for a publication produced by the Office of Management and Budget (OMB) through the National Wetland Inventory program: Circular A-16: National Spatial Data Infrastructure (NSDI) Wetland Data Theme. In 2009 the National Wetland Inventory became the endorsed Federal Geographic Data Committee standard. The National Wetland Inventory began over 30 years ago by mapping wetland types using USGS spring, leaf-off, high altitude aerial photography using the Cowardin classification system. Where available, the National Wetland Inventory uses today a variety of state or local government-acquired spring, leaf-off aerial digital imagery to inventory and update wetland maps due to the lack of a national program for spring aerial imagery.

In the Division of Bird Habitat Conservation, Joint Ventures http://www.fws.gov/birdhabitat/jointventures/files/JointVentureFactSheet.pdf rely on remotely sensed data

Figure 9: Ground mapping MERLIN radar. Image courtesy of DeTect.

to provide information on habitat restoration, inventory, and management. Most joint ventures use National Wetland Inventory and NLCD datasets, and in some years acquire aerial photographs to assess habitat conditions and report progress in wetland restoration. In central Nebraska, the Rainwater Basin Joint Venture (RWBJV) collected the final season of 2-foot resolution CIR aerial photography as part of a 5-year project (2004-2009) to document spring wetland conditions. They have also acquired LIDAR data to delineate wetlands and create hydrologic models that can be used to prioritize wetland restoration efforts. The Atlantic Coast Joint Venture (ACJV) uses land-cover data derived from Landsat imagery in a variety of analyses to support the conservation of bird habitat from Florida to Maine. In the Southeast Region, ACJV is currently using the data from the USGS Southeast ReGAP project to determine the capacity of the existing landscape to support populations of priority species. One active research project is using these data to predict future land cover to evaluate the likelihood of alternative management scenarios for maintaining bird populations (e.g., to the year 2100). Also, landscape metrics such as percent cover, amount of edge, contagion, etc. are computed for use in modeling species' response to vegetative characteristics.

In the future, an integrated approach of using Radar and LIDAR imagery will be used more to upgrade and better characterize wetlands into a four dimensional product (area and elevation change over a season). With InSAR, for example, it has already been shown by Ohio State University that it is possible to map water elevation changes in wetlands accurate to within a few inches with the use of satellite radar imagery. This application will not only help improve fisheries and wildlife population forecasts, but will also help improve flood extent and prediction maps, erosion estimates, and water-based shipping capacities for inland waters.

Through the Great Lakes Restoration Initiative, Michigan Technological University is implementing the use of PALSAR radar imagery to improve wetland extent and change delineation as well as more cost-effective and accurate invasive plant species mapping (Phragmites). (See Figure 10) The Midwest Region NWI program of the U.S. Fish and Wildlife Service is working in concert with the University of Minnesota and Michigan Technological University to build this capacity for the Service and partners such as USGS, Agreement with the Canadian Ducks Unlimited, St. Mary's University, SharedGeo, State Natural Resource Management Programs, Tribes and others. Key to expanding this radar wetland mapping work for North America will be improved access to radar data in partnership with the Canadian Center for Remote Sensing and others.

Figure 10: Harsens's Island, MI invasive Phragmites map using satellite radar imagery courtesy of MTRI.

Vegetation Mapping

For vegetation mapping, there are a variety of ongoing projects around the country which use a variety of

sensors. For example, Yukon Flats National Wildlife Refuge is acquiring 10-meter multi-spectral SPOT imagery of the refuge to update information derived from early 1980s high altitude CIR aerial photography. It will be used to examine changes in wetland extent and vegetation communities; and habitat and population assessments for moose, black bear and wolves. With a goal of acquiring new imagery for the entire 8.6-million acre Refuge, 3-5 SPOT scenes will be acquired each year. The area covered by the SPOT scenes is depicted in Figure 11.

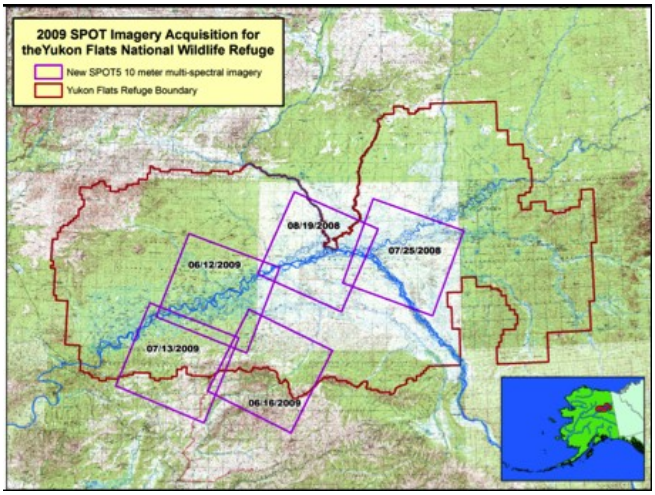


Figure 11: The area covered by the acquired SPOT scenes

In addition, 10 satellite GPS collars have been placed on wolves to study their kill rate on the low density moose population on the Yukon Flats.

The Midwest Region of the FWS recently acquired a medium format digital aerial mapping camera to replace an aging film camera system. It is used to support an Upper Mississippi River vegetation mapping project being led by USGS. It will also be used for land management monitoring and migratory bird applications. An example of a digital true color image acquired by the Region 3 FWS medium format camera, of a Waterfowl Production Area located in Polk County Minnesota, is depicted in Figure 12. An example of a digital color infrared image acquired by the Region 3 FWS medium format camera of an upland sandpiper study plot, located in upper Michigan, is depicted in Figure 13.

Figure 12: A digital image acquired by the Region 3 FWS medium format camera of a Waterfowl Production Area in Polk County, Minnesota.

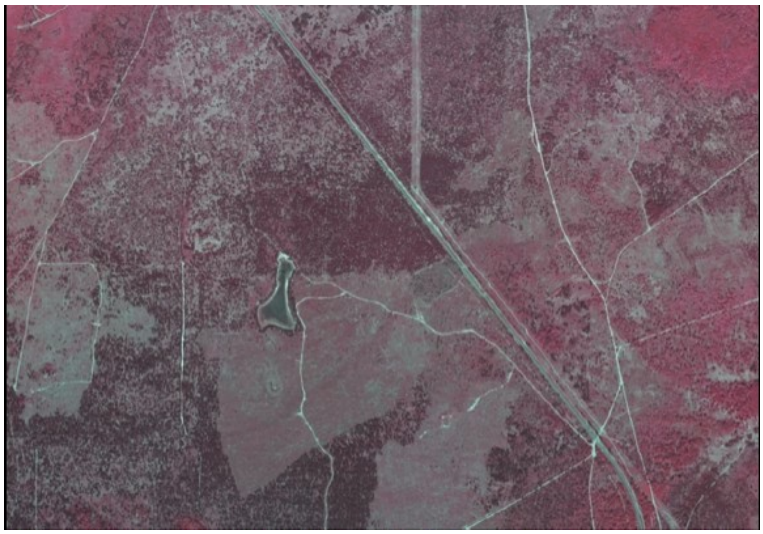


Figure 13: A digital image acquired by the Region 3 FWS medium format camera of an upland sandpiper study plot in Upper Michigan.

In a supporting role, the FWS contributes toward and collaborates with the multi-agency Multi-Resolution Land Characteristics (MRLC) program, which uses Landsat datasets to create the National Land Cover Dataset (NLCD).

U.S. Geological Survey (USGS)

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 spacecraft, 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.

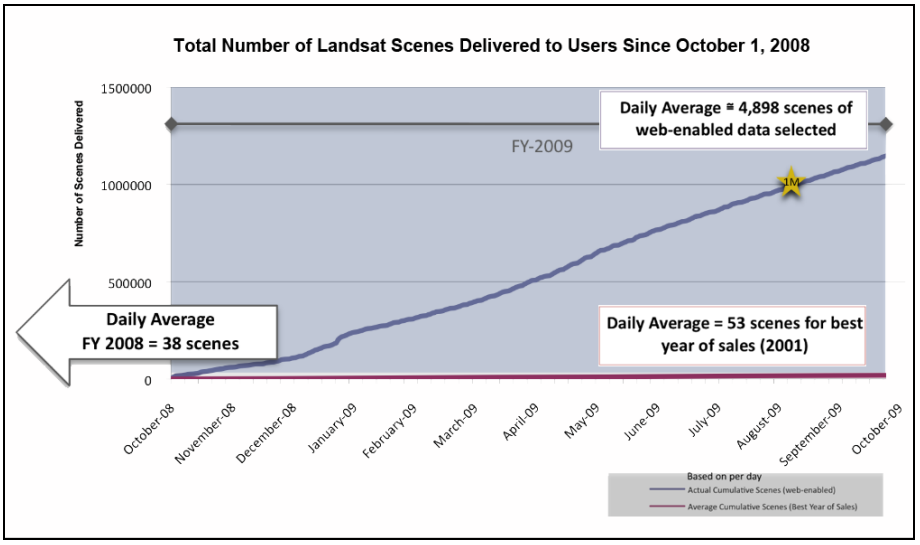


Figure 14: Comparison of Landsat scene distribution

Today, the Landsat Project at USGS manages two active satellites – Landsat 5 and Landsat 7 – and the entire historic archive of data collected since 1972 – more than 2.4 million images. In 2009, a change in data policy (no charge, web-enabled data) transformed the distribution of Landsat data for scientists and operational users worldwide; and as a result, more than 1.1 million Landsat

Figure 15: Landsat 5 25th Anniversary Timeline

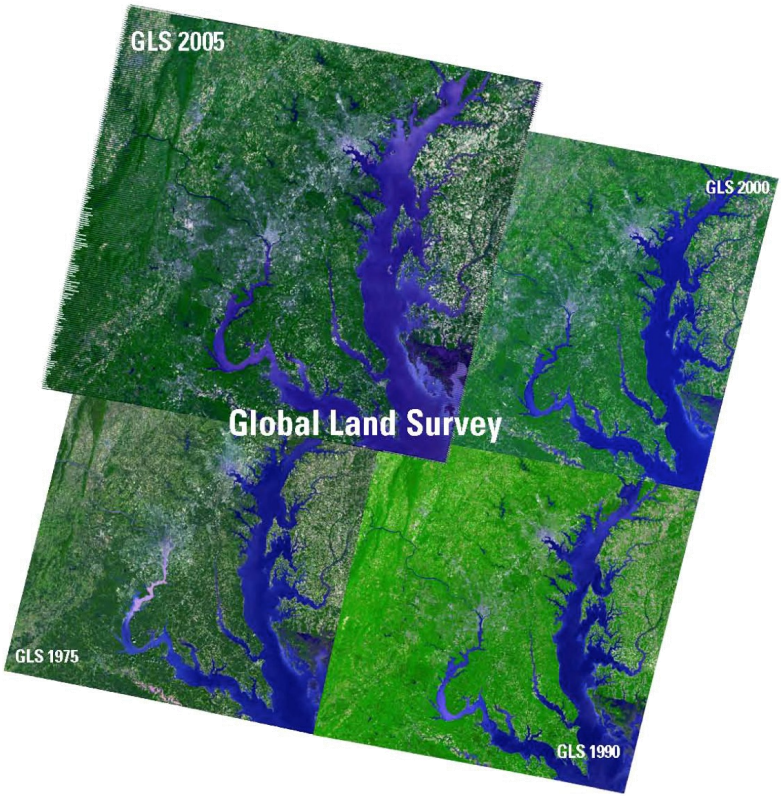


Figure 16. Example of imagery available through the Global Land Survey

images were delivered to customers!

In 2009, the Landsat Project also reached milestones with both satellites. Landsat 5 celebrated 25 years in orbit, and Landsat 7 reached 10 years in orbit. With the respective design life of 3 years and 5 years, both of these satellites continue to provide essential data to scientists well beyond their expected lifespan. The Landsat team is working to extend the longevity of the satellites in orbit, enhance Landsat data quality, improve systems used to archive, process, and access Landsat data, and is leading the design and development of the ground system for the Landsat Data Continuity Mission.

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

To extend this multi-decadal Landsat data collection, NASA and the USGS again partnered to develop the Global Land Survey 2005 (GLS 2005), a new global land dataset with core acquisition dates from 2005-2006. The data consists of Landsat TM and ETM+ and Earth Observing-1 (EO-1) data, making GLS 2005 the first-ever global dataset built with data from multiple sensors. The entire dataset is nearing completion with more than 95 percent currently (2009) available for free download. Plans to collaborate on the GLS 2010 are in the works and expected to begin in late 2009 (figure 16).

The Landsat Data Continuity Mission (LDCM) is in the development phase for the next Landsat mission (Landsat 8). In 2009, the LDCM project has been busy responding to the challenges of new mission requirements. The original launch date of July 2011 has moved to December 2012 to satisfy NASA's criteria for a 70 percent probability of meeting schedule and staying within budget, and it includes the addition of a thermal infrared sensor (TIRS).

Satellite Imagery Applications

Fire:

Using images from the Landsat data archive, the USGS, in collaboration with the U.S. Forest Service (USFS), has generated and provided access to burn severity assessments for thousands of fires from 1984 to 2007. In FY 2009, all large historical fires were assessed for the Southeastern United States, as well as those that occurred

in 2007 across all 50 United States. Additionally, the USGS began providing support to the LANDFIRE refresh effort where burn severity assessments for smaller fires are provided directly to the LANDFIRE project to support the updating of data products. Burn severity data are used to monitor vegetation recovery and analyze long-term fire effects. These facilitate assessment of ecological or socio-economic factors that are affected by wildland fire. These data are used to study the effectiveness of management practices implemented in response to the National Fire Plan and the Healthy Forest Restoration Act.

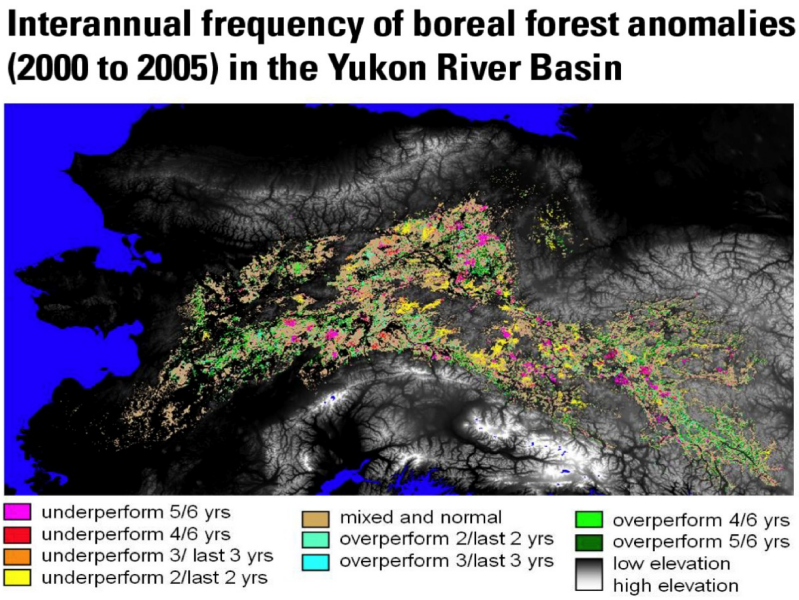


Figure 17. Disturbances in the boreal forests of the Yukon River Basin

Yukon River Basin:

Climate change effects are being expressed in high northern latitudes more dramatically than other parts of the globe. Understanding how climate change will impact permafrost, carbon dynamics, and watershed hydrology will help scientists predict future ecosystem responses. Cooperation with the Canada Centre for Remote Sensing (CCRS) allows the USGS to collaborate, secure Canadian imagery, and examine the entire Yukon River Basin (YRB). Models and maps of boreal forest growing season vegetation change, a surrogate for ecosystem productivity, are produced from interpolated weather and site potential using MODIS data at a resolution of 250 meters. Expected productivity maps are then compared to actual productivity maps to identify anomalous areas, or areas, which are more or less productive than expected

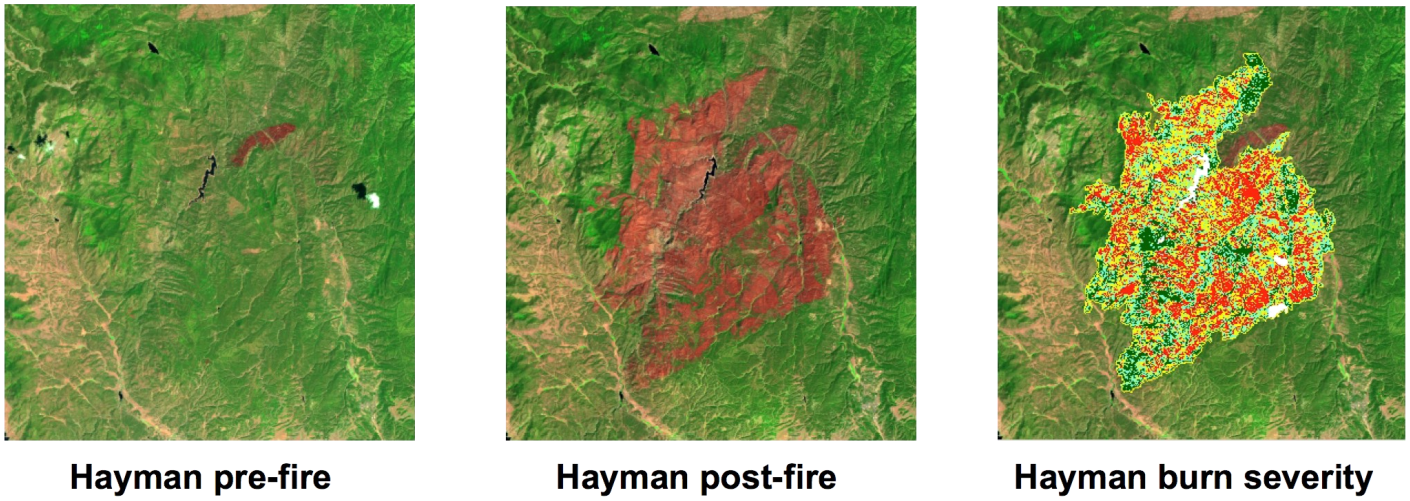


Figure 18. These Landsat images show the Hayman fire, which burned more than 135,000 acres near Denver, Colorado, in 2002. Analyzing the change between the pre-fire image and post-fire image allows land managers to identify the most severely affected areas (red) and concentrate their erosion mitigation and landscape rehabilitation efforts in those areas.

during any given year's weather conditions. This approach accounts for inter-annual variations associated with weather to reveal effects caused by insect infestation, fires, changed drainage patterns, and permafrost degradation, all of which are of increasing concern as warming continues. Anomalous areas that are persistent over multiple years are mapped and can be used by modelers to account for disturbances in boreal forests of the YRB.

West Africa:

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

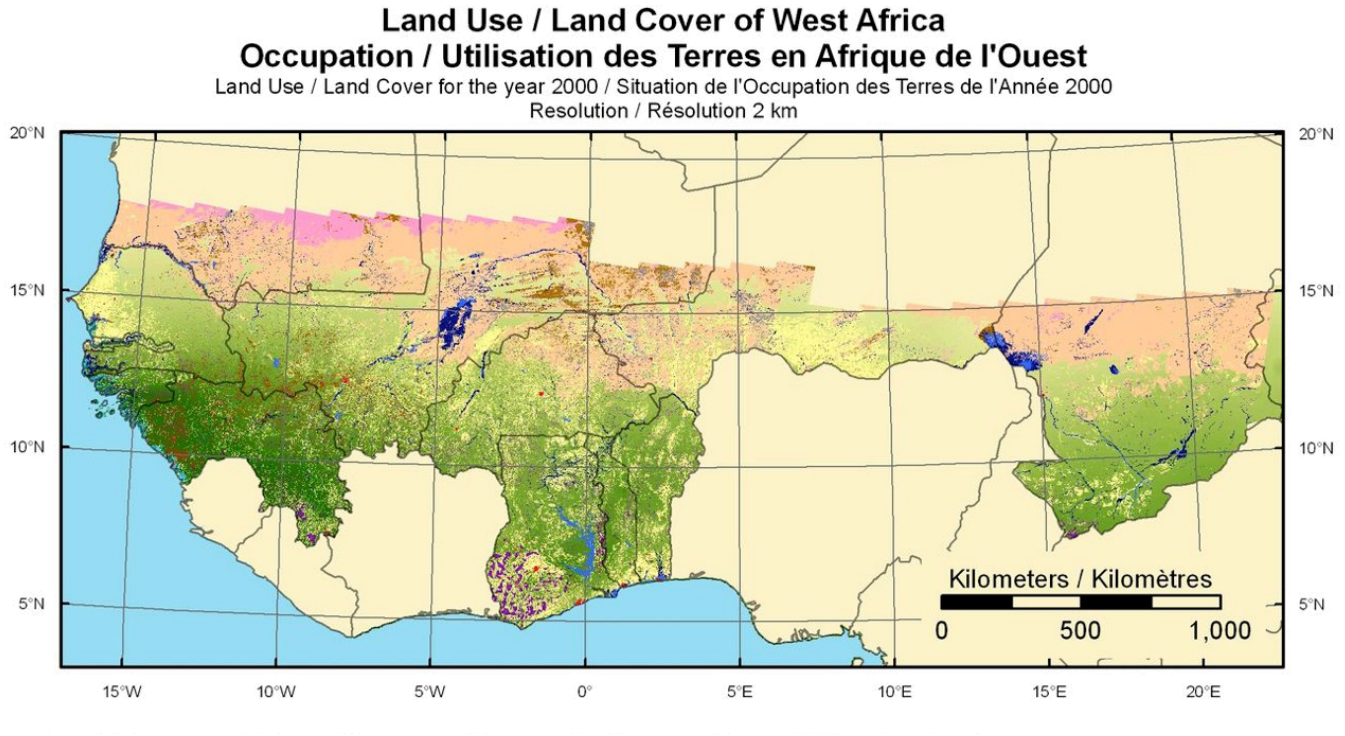


Figure 19. Land use and land cover map of the 12-country region in West Africa for the year 2000

Louisiana Flooding:

Satellite Envisat ASAR image data collected during Hurricane Ike provided the first satellite view of surge flooding in southwest Louisiana due to persistent and extensive cloud cover preventing useable satellite optical image collections. The ASAR images were used by FEMA to support search and rescue planning and efforts.

Land Deformation:

USGS staff are participating in an initiative to build a civil-operational radar remote sensing system that provides national strategic mapping of earth deformation and water issues. If successful, the USGS program will build on established satellite optical and radar abilities to map risks and resource sustainability associated with (1) land deformation related to subsurface extractions and injections, (2) deformations related to volcanic activities and crustal movements, and (3) changing surface and canopy subsurface water inundation extents and depths.

Water Quality:

Dissolved organic material (DOM) exported from land complicates the analysis of remote sensing by NASA satellites of water quality in coastal waters. In addition, the variability of DOM chemistry is a useful indicator of watershed processes and, as such, can be used to monitor climate effects on carbon cycling by identifying trends in land-to-sea carbon transport as a function of changing precipitation patterns. USGS Scientists in the Water Resources Discipline (National Research Program, Boulder, CO and Maine Water Science Center), in association with oceanographers at the Bigelow Laboratory for Ocean Sciences conducted a project designed to study DOM in the Penobscot River, its influences on the DOM in the Gulf of Maine, and the complications posed by its presence on remote sensing of water quality in the Gulf of Maine. Results showed that high rates of river discharge during fall storms export the greatest amount of DOM per unit area of the watershed. In addition, large variations in exported DOM were observed throughout the year. These large inter-annual variations were related to strong upward trends in the absorption properties of DOM and detritus over the entire Gulf of Maine and are currently being incorporated into algorithms designed to utilize MODISderived absorption data to determine DOM concentrations in the Gulf of Maine.

Collaboration with NASA on Planetary Science:

The Astrogeology Science Center of the USGS continued to be involved heavily in the Mars Exploration Rovers (MER) mission, whose twin rovers Spirit and Opportunity both surpassed 2100 sols (martian days) of surface operations in FY09. Since the rovers' landings in January 2004, USGS Astrogeology Science Center members led efforts to plan, acquire, archive, and interpret data from the rover cameras, principally the Microscopic Imager on the instrument arm, along with analysis of color Panoramic Camera data of rocks, soils, and active processes on the surface of Mars. The USGS also contributed leadership of the Science Operations Working Group to plan each day of rover operations alongside science team members throughout the world and engineers at the Jet Propulsion Laboratory. The Opportunity rover spent most of last year navigating south from the 800-meter-diameter Victoria impact crater, on its way toward the 22-km-diameter crater Endeavour (about 7 km away). During this southerly traverse, Opportunity continued to analyze the sulfate-rich, layered sandstones that outcrop amid the dark, rippled sands, and discovered more iron-nickel meteorites along the way. Spirit began the year driving around the northern edge of the 80-m-diameter volcanic plateau known as "Home Plate." However, since late April

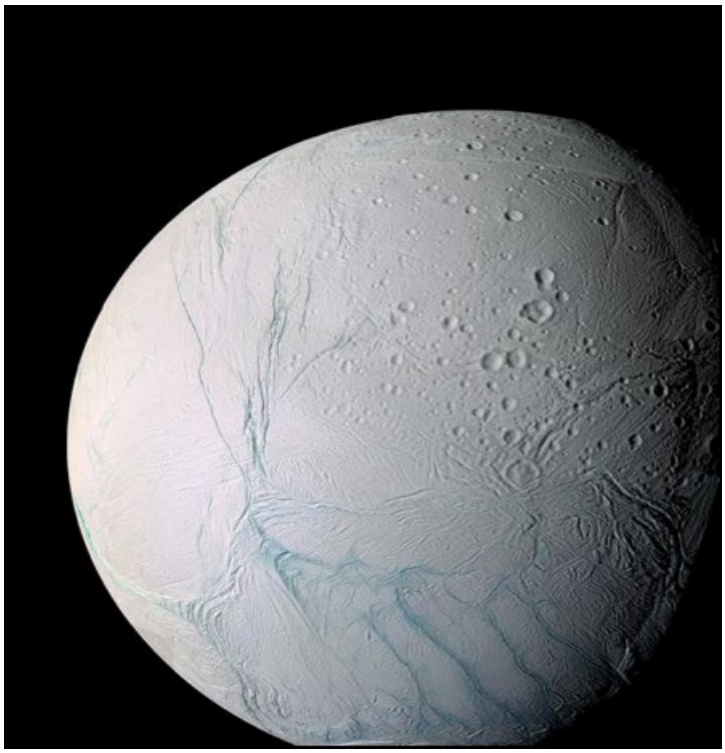


Figure 20: Cassini Mission photos of Enceladus, a moon of Jupiter. Top picture shows tiger stripe patterns characteristic of its southern polar region through which geyser eruptions are commonly noted. The surface around these regions is generally devoid of impact craters, indicating that it has been continuously reworked by new ice formation.

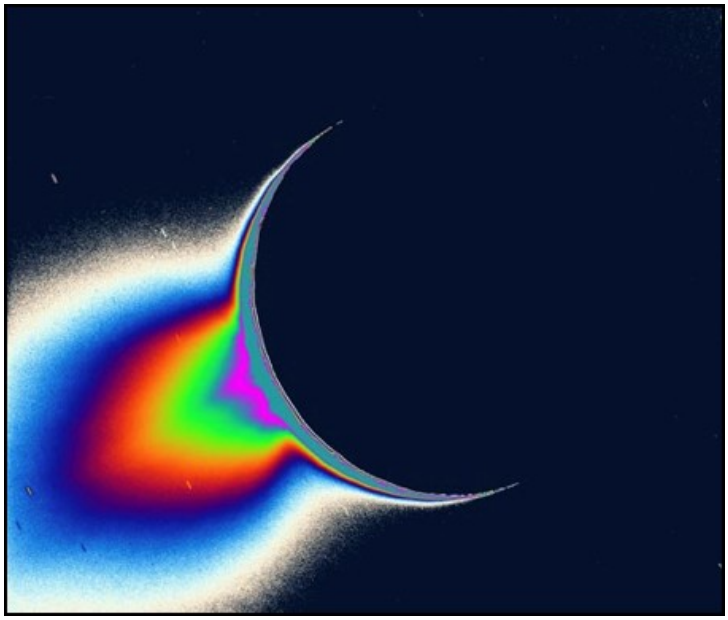


Figure 21: Bottom picture is the image of the geyser water plume, which also entrains substantial quantities of methane, acetylene, and ammonia.

2009 Spirit has been embedded in sand on the west side of Home Plate. Engineering tests using a test bed rover at the Jet Propulsion Laboratory, combined with tests using Spirit on Mars, have thus far been unable to free the rover. As the next martian winter arrives in May 2010, Spirit will need to at least tilt itself toward the north to receive sufficient sunlight to power the rover's heaters to survive the winter cold.

USGS scientists working with other scientists, discovered an ancient acid-saline lake deposit consisting of layered clay and sulfate minerals in the bottom of Cross Crater, located in the southern highlands of Mars, using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) orbital spectrometer and High Resolution Imaging Science Experiment (HiRISE) high spatial resolution imager. This discovery adds another puzzle piece to the emerging picture of early Mars, and provides insights that may help future rover missions focus on the trail of water in their search for evidence of ancient life. A new unnamed mineral was recognized spectrally from orbit above Mars at this site and others. Known by its simple chemical formula Fe(OH)SO4, it is manufactured for its desirable pigment properties. Efforts are underway, at the USGS, to find a natural terrestrial occurrence so this mineral can be formally named.

The USGS Astrogeology Science Center directly supported the testing, calibration, operation, and analysis of images acquired by the High Resolution Imaging Science Experiment (HiRISE) camera aboard the Mars Reconnaissance Orbiter (MRO). This camera provides the highest resolution images of Mars from orbit (~30 cm/pixel) and is being used to certify future spacecraft landing sites for the 2011 Mars Science Laboratory rover, as well as to support numerous Mars

science investigations. The USGS supported a major portion of HiRISE image processing and analysis software development and maintenance in FY09, and two Astrogeology scientists served as guest editors for the HiRISE special issue of the journal Icarus. The Astrogeology Science Center and the University of Arizona used this software to process high-resolution black-and-white and color images acquired by HiRISE, as well as construct the highest resolution digital elevation models of Mars ever made. These topographic maps have been the subject of many recently published studies of Mars. In addition, images of the terrain explored by the Mars Exploration Rovers (including the rovers themselves!) served to guide the MER team in their journey. MRO is now in its Extended Science Phase, continuing to discover interesting geologic features and monitor changes in seasonal frost evolution, recent impact craters, gullies, and wind-related features.

USGS scientists from the Astrogeology and Crustal Imaging and Characterization Centers continued their participation as Science Team Members on the NASA Cassini-Huygens Mission to Saturn and its moon Titan, including:

(1) searching for seasonal changes in the lakes and larger seas of hydrocarbon around Titan's north pole, detecting a mirror like reflection from the northern seas at infrared wavelengths, and investigating lakes near the south pole with radar for the first time;

(2) continuing to monitor Titan's rotation, which suggests that the body may have an internal ocean, by comparing the latest radar images with older ones they overlap;

(3) generating digital elevation models of Titan from stereo pairs of radar images, including a complete map of the north polar region, to provide quantitative information about liquid transport, ice volcanism, dune activity, and other processes;

(4) producing a set of high-level Titan map products containing all prime-mission radar observations, including image mosaics, topographic models, and maps of microwave emission and scattering properties relevant to understanding surface composition;

(5) producing a complete set of maps of Titan with multiple color images from the Visual-Infrared Mapping Spectrometer,

(6) mapping the composition of Saturn's' rings and satellites,

(7) representing science teams for planning future observations, and

(8) calibrating returned imaging spectroscopy data.

USGS scientists led or contributed to authoring several chapters in the book "Titan from Cassini-Huygens," which is likely to remain the key reference for several decades.

USGS Crustal Imaging and Characterization Center scientists continued their participation on the NASA/ Indian Chandrayaan-1 mission, Moon Mineralogy Mapper. USGS imaging spectroscopy scientists made a major discovery of water and hydroxyl on the sunlit areas of the lunar surface where many said it was impossible for it to exist. USGS scientists found water with two spacecraft: the Chandrayaan-1 and Cassini.

Two scientists from the USGS Astrogeology Science Center are science instrument team members and three are involved as Participating Scientists in the NASA Lunar Reconnaissance Orbiter (LRO) mission. This spacecraft is the first robotic precursor for the return of US astronauts to the Moon. LRO launched in June 2009 and has since been providing a wealth of data and images of the lunar surface useful for future planning. Astrogeology team

members have been working on exploration and identification of water ice at the lunar poles with LRO radar and radiometer data, with studying unusual volcanic and impact crater deposits with camera data, and with developing image mosaics and topographic maps of the surface to support future robotic and human in-situ lunar exploration. The Astrogeology Science Center also continued to support software development for the LRO radar and camera systems to produce image mosaics and topographic maps of the lunar surface, and the development of standards for such mapping.

Computer scientists and cartographers from the USGS Astrogeology Science Center played key roles in making a global image mosaic of Mercury. Using images obtained by the MESSENGER spacecraft during its third flyby of Mercury, USGS team members assembled images from the previous two flybys and images from the Mariner 10 mission (1973) to assemble a large mosaic that will be vital to planning future observations of the planet when MESSENGER goes into an elliptical orbit around Mercury in 2011.

Imaging Spectroscopy Library:

USGS imaging spectroscopy scientists continued measuring the spectral properties of rocks, minerals, organic and other compounds developing a reference library for widespread application in remote sensing, including environmental assessments, geologic mapping, mineral and resource exploration, ecosystem studies and solar system exploration.

Earthquakes:

Geodetic networks provide essential information about the massive, slow deformation (strain) of the land surface near faults and the forces that cause earthquakes. Geodetic monitoring stations use precise Global Positioning System (GPS) techniques to measure changes in the shape of the Earth's surface that help reveal how strain accumulates on earthquake faults, and how those faults are slipping at depth. Precise geodetic data provides new constraints on the likely rate of large earthquakes in a region.

In FY2009, USGS worked with universities, local agencies, and the Plate Boundary Observatory component of the National Science Foundation's (NSF) EarthScope program to conduct geodetic investigations using GPS, Light Detection And Ranging (LIDAR), Interferometric Synthetic Aperture Radar (InSAR), creepmeters, and sensitive long-baseline and borehole strainmeters. To address the problem of hazards in the urban Los Angeles region, the USGS continued to operate approximately 100 continuous GPS stations along the San Andreas fault and in the densely-populated urban area, and process data from state-of-the-art, continuously operating GPS stations operated by the Scripps Institution of Oceanography and the Plate Boundary Observatory (PBO). In addition, the USGS continued to work with partners to use LIDAR and InSAR data to quickly and accurately produce large aerial maps of pre- and post-earthquake land deformation.

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High-resolution LIDAR data continued to be key to identifying active faults in Oregon and Washington that have the potential to generate damaging earthquakes. The USGS used funds from the multi-hazards initiative to collect and analyze LIDAR data in four at-risk areas in Oregon and Washington. In the Portland area, LIDAR studies identified sites for field studies aimed at clarifying whether the Gales Creek fault has slipped in the recent geologic past and, thus, remains a hazard. Near Mount Hood, LIDAR revealed a set of faults, each with about two meters of surface displacement that may be part of the southern extension of the Saint Helens seismic zone and will be the subject of further investigations by USGS and the Oregon Department of Geology and Mineral Industries (DOGAMI). In eastern Washington, LIDAR studies identified a major north-south fault that is approximately perpendicular to faults previously mapped in the Yakima fold and thrust belt in the Columbia Plateau. Finally, LIDAR continued to be used to analyze the potential interaction of faults in the Cascade Range and the Yakima fold and thrust belt in Central Washington where a massive landslide occurred on October 14, 2009.

Volcanoes:

Satellite interferometric synthetic aperture radar (InSAR) and GPS are essential elements of the USGS' volcano hazards mitigation strategy. The USGS used InSAR and GPS data to track minute surface motion due to volcanic processes in Hawaii; the Cascade Range of WA, OR, and CA; Yellowstone, WY; Long Valley, CA; and the Aleutian volcanoes of Alaska. USGS scientists use these data to model the subsurface flow of water and molten rock, including the depth and volume of new magma under a volcano. GPS data contributed to the reliability of forecasts and warnings during the Redoubt Volcano, Alaska unrest and eruption of January to May 2009. Communities, businesses, and federal agencies, particularly the Federal Aviation Administration, National Weather Service, and U. S. Coast Guard depended up USGS information to minimize damage to property and loss of life during the eruption. The USGS used combined InSAR and GPS data to advise the National Park Service on an intense seismic swarm in Yellowstone National Park around New Year's Day 2009 and on the threat to visitor safety from the ongoing eruption of Kilauea Volcano, Hawaii.

A team of scientists from Washington State University, NASA's Jet Propulsion Laboratory and the U.S. Geological Survey's Cascade Volcano Observatory developed a prototype rapid-deployment hazard monitoring instrumentation network and applied it to volcano monitoring. The Optimized Autonomous Space In-Situ Sensor web (OASIS) has two-way communication capability between ground and satellites, uses ground and space data for optimal allocation of power and bandwidth resources to send data to the observatory, and can autonomously request re-tasking of satellites if monitoring data suggest a significant change in monitoring parameters. The sensor web can also reconfigure itself for the best data pathway, for example, if ash in the air from explosive eruptions blocks monitoring signals or if a station in the web is destroyed. Helicopters can rapidly deploy the sensor web without landing, thereby minimizing risk to scientists. The team successfully tested the system on Mount St Helens. Future applications include response to unrest at unmonitored volcanoes in foreign countries, response to natural and human-caused

disasters where conditions on the ground are hazardous and planetary exploration.

Landslides:

USGS scientists from the Geologic Hazards Team and Center for Earth Resources and Science (EROS) Data Center, in collaboration with the China Geological Survey and funded in part by the USAID Office of Foreign Disaster Assistance (OFDA), began assessing the distribution and influence of geologic, topographic, and ground-shaking conditions on the hundreds of thousands of landslides triggered by the 2008 M7.9 We chuan earthquake in the Himalayan foothills in Sichuan, China. For this work, they have been relying on data from the Shuttle Radar Topography (SRTM) mission and Aster topography from the Terra mission, along with imagery from the Quickbird, IKONOS, and WorldView-1 commercial sensors.

Carbon Sequestration:

The U.S. Geological Survey is conducting a national-scale assessment of the potential for ecosystem carbon sequestration under various climate, policy, and land-use change scenarios as required by Section 712 of the Energy Independence Security Act of 2007. The disturbance modeling team, composed of interdisciplinary scientists, has produced a series of statistical and process-based models that predict future disturbances including wildfires and insect outbreaks. These models rely heavily on datasets derived from remotely sensed imagery, especially from the Landsat and MODIS sensors. USGS is leading the development of the disturbance modeling effort with the objective of producing disturbance models for the southern Mississippi River Valley (the prototype assessment area). The initial results will be presented at a December 2010 disturbance modeling workshop organized by the North American Carbon Program, and the International Congress on Fire Ecology and Management and American Geophysical Union conferences.

Wyoming Land Conservation Initiative:

USGS scientists have developed indicators for use in long-term monitoring programs in the Wyoming Land Conservation Initiative (WLCI). The work used conceptual models of how major ecosystems in the WLCI respond to anthropogenic stressors to identify and prioritize indicators for monitoring. Over the course of two workshops, a list of indicators were developed and finalized. The conceptual models are being used by local planning teams to make more effective land use decisions. Efforts are underway to develop dynamic land change modeling scenarios to simulate the multiplicative effects of energy development and climate change on native vegetation, and a suite of exotic plant species. A key component of the land-change modeling effort is the contemporary mapping of surface disturbances due to energy development and other major land uses. This mapping provides an essential baseline for modeling future change. A fusion of recent Landsat and NAIP imagery is being used to develop a 3-band and IR image product which in turn, is used with object extraction methods to delineate key thematic types of surface disturbance (e.g., major and two-track roads, oil/gas pads, pipelines, water features, urban development). Ecosystem service valuation methods will be applied to energy fields in the WLCI to understand the cumulative effects of energy development on natural systems and value this impact. The work compares oil and gas well disturbance maps created from remotely sensed data created before and after an energy field was developed, and assesses ecosystem service impacts using the program INVEST.

National Land Cover and Land Use Status and Trends:

The USGS is conducting multi-year monitoring and analysis of land use and land cover change for the Nation and its ecological regions using the extensive Landsat data archive and other information. The project, in conjunction with NASA and the EPA, has recently completed the development of the Great Plains land cover change database, a synthesis report of results, and conducted preliminary analyses of the implications of contemporary land transformation. The analyses are providing valuable information about the rates, causes, and consequences of land use change in the Great Plains region since 1973 (figure 22). Additionally, an analysis of land cover trends in the ecoregions of the eastern US, using a land cover change database completed in prior years, has also been completed. The study shows that recent land use pressures have caused a significant decline in eastern US forest cover causing an important transition from a mode of regional forest cover gain to one of forest cover loss caused by timber cutting cycles, urbanization, and other land use demands. Information from the Great Plains and eastern US studies are being used to develop estimates of the land use impact on ecological processes including carbon sequestration, to understand future scenarios of change, and to develop future forecasting capabilities. Subsequent years will focus on the West and Midwest, as well as a national synthesis of land use and land cover trends.

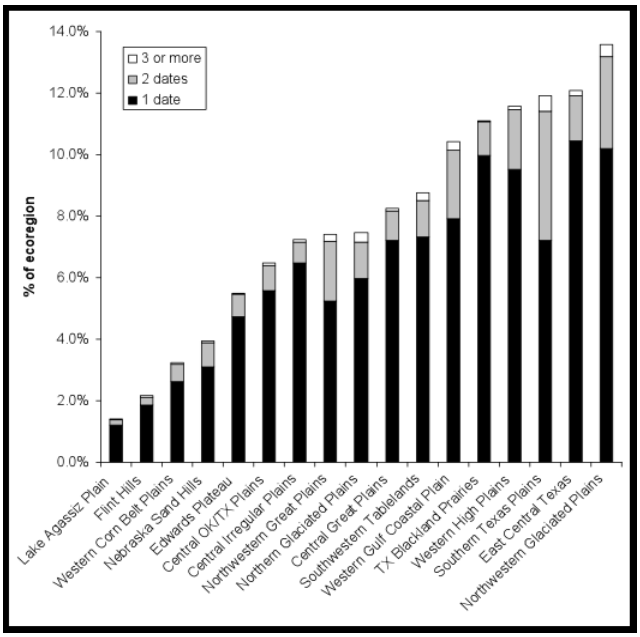

Figure 22: The extent of land cover change in all US Great Plains ecoregions between 1973 and 2000. Each bar also shows the proportion of the ecoregion that underwent change during 1, 2, or 3 time intervals.

Ecosystems Mapping:

The U.S. Geological Survey (USGS) Geography Discipline, with support from NatureServe, has completed a three year effort to model the potential distribution of terrestrial ecosystems for the conterminous United States. This geospatial modeling effort resulted in the mapping of 419 different types of terrestrial ecosystems, based on the ecosystems classification developed by NatureServe, and used a comprehensive biophysical stratification approach to identify distinct biophysical environments and associate them with known vegetation distributions. The approach was first prototyped for South America) and subsequently modified and implemented for the conterminous United States (Figure 23) at a base resolution of 30 m. Each of the major structural components of ecosystems was mapped: isobioclimates, land surface forms, lithology, and topographic moisture potential. These components were then spatially combined to produce a new map of biophysical settings for the nation, resulting in a massive biophysical stratification of the nation into a set of unique physical environments. These physically distinct areas are considered as the fundamental structural units ("building blocks") of ecosystems, and were subsequently aggregated and labeled using the NatureServe

classification. The labeling was accomplished using a semi-automated process based on rule-set formulations for attribution of each ecosystem.

This activity is part of a larger global effort commissioned by the Group on Earth Observations (GEO) to classify and map global ecosystems. The United States is the GEO-designated member nation leading the global ecosystem mapping task, and the USGS is the responsible federal agency for the work. The USGS and NatureServe are currently modeling the terrestrial ecosystems of Africa with funding from the U.S. Agency for International Development (USAID), and over the next two to three years the USGS will work to satisfy its obligation to GEO and deliver a standardized global ecosystems map.

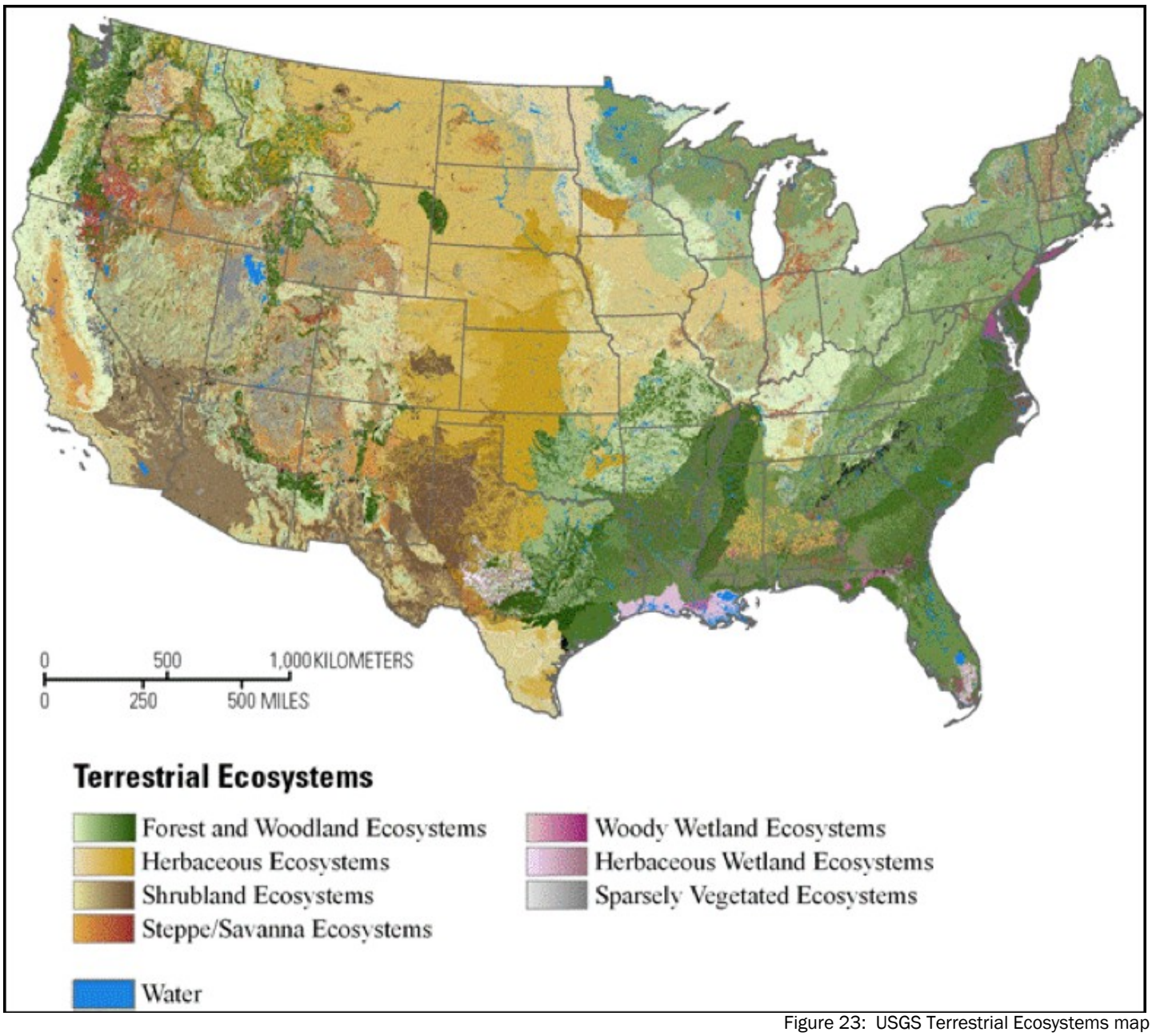

Figure 23: USGS Terrestrial Ecosystems map

The models and data produced from this effort will provide critical information to organizations and global conventions involved in a variety of ecosystems activities, including climate change studies, land management, and gap analysis. In fact, a prerequisite to ecosystem management is an understanding of the types, distributions, and condition of the ecosystems that occur on the landscape/seascape. These data are critical for assessing the representation of ecosystems in protected areas. That information is useful for decision makers in government and civil society working to protect and sustainably manage a country's ecosystems.

Applications with Airborne LIDAR

Coastal Mapping:

The USGS Coastal and Marine Geology Program (CMGP) conducted airborne LIDAR surveys in several coastal and reverie environments using a legacy-NASA system known as the Experimental Advanced Airborne Research LIDAR (EAARL). The EAARL system provides unique capabilities to survey coral reefs, near shore benthic habitats, coastal vegetation, and sandy beaches. Operating in the blue-green portion of the electromagnetic spectrum, the EAARL is specifically designed to measure submerged topography and adjacent coastal land elevations seamlessly in a single scan of transmitted laser pulses. The USGS CMGP conducted EAARL surveys in collaboration with the National Park Service at Fire Island National Seashore, Cape Canaveral National Seashore, and Gateway Recreation Area to assess beach and dune morphology and extend the time series of LIDAR surveys conducted for NPS as part of its Inventory and Monitoring Protocol. An EAARL survey was also conducted at Trinity River and Klamath River, CA in collaboration with the US Bureau of Reclamation to acquire detailed bathymetric and topographic data for deriving metrics of geomorphic/topographic complexity, habitat assessments, and quantifying changes in bed-material storage. The data were processed using the USGS Airborne LIDAR Processing System (ALPS), which isopen-source software specifically designed to convert raw waveform data acquired by the EAARL to digital elevation model (DEM) products of bare-earth, submerged, and sub-aerial topography.

In 2009, 33 DVD-based products for LIDAR surveys conducted by Coastal and Marine Geology Program in the past decade along the Atlantic and Gulf of Mexico coast were published as USGS Data Series Reports. These DVD products contained quick-look maps, point cloud (x,y,z) data, and gridded DEMs along with associated Federal Geographic Data Committee -compliant metadata. The published DVD products were distributed to federal, state, and local agencies that needed access to the data. These data products are also served online and are available via a Google Maps interface at

http://ngom.usgs.gov/dsp/.

Applications with Aerial Photography

Wind Energy:

U.S. Geological Survey scientists used National Agricultural Imagery Program (NAIP) imagery to identify and inventory the environmental impacts of wind energy infrastructure development. The features mapped include individual turbines, roads and power lines. The mapping was done on a subset of wind generation facilities across the nation, specifically chosen to vary in turbine capacity, overall facility size (number of turbines), topography (flat plains, ridgelines, and hilly regions), and land use (farmland, brownfields, and natural habitat). The new maps provide baseline data for understanding how aspects of wind production

(turbine spacing, energy output, capacity factor, and levels of disturbed land) change with the aforementioned variables. To date, the majority of studies projecting wind energy market penetration estimate the land surface requirements of wind power with theoretical relationships that relate the power in wind given a known windspeed and blade height to the area of land required to capture this wind. The mapping and modelling done by USGS scientists will allow empirical estimates to replace theoretical relationships and more fully specify the effects of geographic location, topography and land use on wind energy production, improving future projections and contributing to the optimized placement of wind generation facilities within the US.

Fire Incident Support:

Rapid Assessment of Values at Risk (RAVAR) is a modeling effort that provides dollar estimates of values (structures, infrastructure, etc.) as well as assessments of nonmonetary values such as critical habitats that are threatened by a wildfire. When county-level parcel data are not available, the U.S. Forest Service requests the USGS to conduct an analysis of remotely sensed imagery to identify structures located within the area of concern. The National Agricultural Imagery Program (NAIP) photography has served as the primary source of imagery. On average, the USGS has provided the locations of over 11,000 structures for fifty 1:24,000 scale 7.5-minute quadrangles to the USFS for analysis and use by the fire science and incident support communities. The response time from request to data provisioning is normally around 5 hours.

Applications with the National Imagery Systems

The USGS is making available to the public declassified images from the Global Fiducials Library (GFL). The GFL maintains a long-term archive of images from U.S. National Imagery Systems for selected environmentally sensitive and scientifically important sites to support current and future researchers and policy makers in identifying and understanding long-term environmental trends and processes (figure 24).These images are being released to the public through the Global Fiducials Library website (http://gfl.usgs.gov) to support analysis of global climate-related science and environmental change. "We

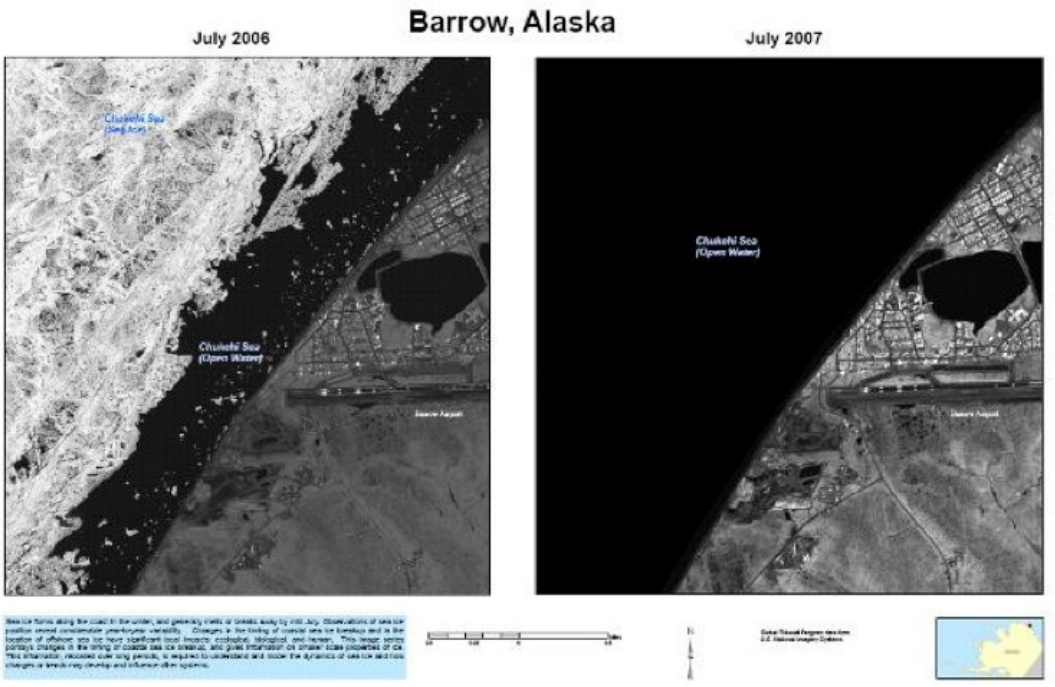

Figure 24: The public poster showing a one year difference in the breakup of ice near Barrow, Alaska. The image series collected over this Global Fiducial site helps monitor changes in the timing of fast ice breakup, and gives information on smaller scale properties of ice.

need the best data from all places if we are to meet the challenges that rising carbon emissions are creating," said Secretary Salazar. "This information will be invaluable to scientists, researchers, and the public as we tackle climate change and the risks it poses in the Arctic and around the world."

Steve Wiles, National Reconnaissance Office- "It is just super seeing the Global Fiducials Library up and running. You have done a fine job of presenting historical data that will be helpful in many to-be-determined ways by current and future scientist. … This is truly a fantastic web site."

Mountain Pine Beetle:

The outbreak of mountain pine beetle (Dendroctonus ponderosae; MPB) that has killed millions of lodgepole pine trees west of the Continental Divide is now spreading across the eastern slopes of the Rocky Mountains in Colorado. This epidemic represents a major potential disturbance to ecosystems and communities in Colorado's Front Range, where many of the state's residents and visitors live, work, and obtain important ecosystem services such as clean water and diverse opportunities for recreation. USGS scientists have investigated the possible ecological and social impacts of the MPB epidemic in a field study which collected extensive data on forest health, insect activity, management history, fire fuels, etc. at 40 sites along the Front Range. Results of this proactive, applied, inter-agency research will address whether MPB will fully transition from its original host species (lodgepole pine) into another (ponderosa pine, dominant at lower elevations in the Front Range) and whether certain forest management practices more effectively increase resilience to MPB than others.

The USGS developed a methodology for the use of medium resolution remotely sensed imagery for the assessment of conifer health in Grand County, Colorado. Landsat and ASTER multispectral sensors were employed for this effort because their spatial resolution was discrete enough to characterize health conditions at the forest landscape level, cover a suitably large geographic mapping area, and are cost-effective. Due to the intense interest in the outcome of these methodologies, the pilot project was expanded to cover the entire state of Colorado. (Figure 25) The current investigation is looking at new sources of imagery with the goal of better defining the discrete categories of conifer health. The benefit is two-fold: the first being the capability to map large landscape disturbances using remote sensing technologies; the second benefit will be an inventory of the MPB infestation in the state of Colorado which may expand into a regional to national data set.

Applications with Unmanned Aircraft Systems

The USGS Unmanned Aircraft Systems (UAS) Project Office is leading the implementation of an exciting new technology that will transform the methods and techniques employed across the Department of the Interior. Technology originally developed by the U.S. Army is now available to monitor environmental conditions, analyze the impacts of climate change, respond to natural hazards, understand landscape change rates and consequences, conduct wildlife inventories and support related land management missions. USGS is teaming with the Department of the Interior's Aviation Management Directorate (AMD) to lead the safe and cost effective adoption of UAS technology by the Department of the Interior Agencies and USGS scientists. An important milestone was reached during 2009, when the USGS sponsored the first UAS training for DOI employees. The course was attended by participants representing USGS, National Park Service, Bureau of Land Management, AMD, and the U.S. Forest Service. Each participant received

instruction in basic and advanced flight skills, airspace management, aviation safety, emergency procedures, crew coordination, and mission planning. This impressive accomplishment helped establish USGS and DOI as pioneers in the civilian applications of Unmanned Aircraft.

Harry Kieling, Aviation Management Directorate Alaska Regional Director and a participant in the first class said: "A big segment of the future of aviation will include Unmanned Vehicles. They will not replace manned aviation, but a lot of DOI missions will be better and more safely performed by UAS. This Raven training is a big first step for DOI toward that goal." A second training course is being planned for 2010. The course is being coordinated with New Mexico State University. The course will be designed to help scientists and managers better understand how this emerging technology can support a wide variety of USGS and DOI missions. Pictures and videos from the first UAS operator certification course can be found at http://rmgsc.cr.usgs.gov/UAS/. In addition the lessons learned from the training and early implementation of the technology will support the construction of the first civil agency UAS Road Map. The road map will detail the phased adoption of UAS technology by USGS and our partners. The ultimate goal of the USGS UAS Project Office is to help fill the current gaps in earth observations to gain the knowledge required to provide actionable information to decision makers.

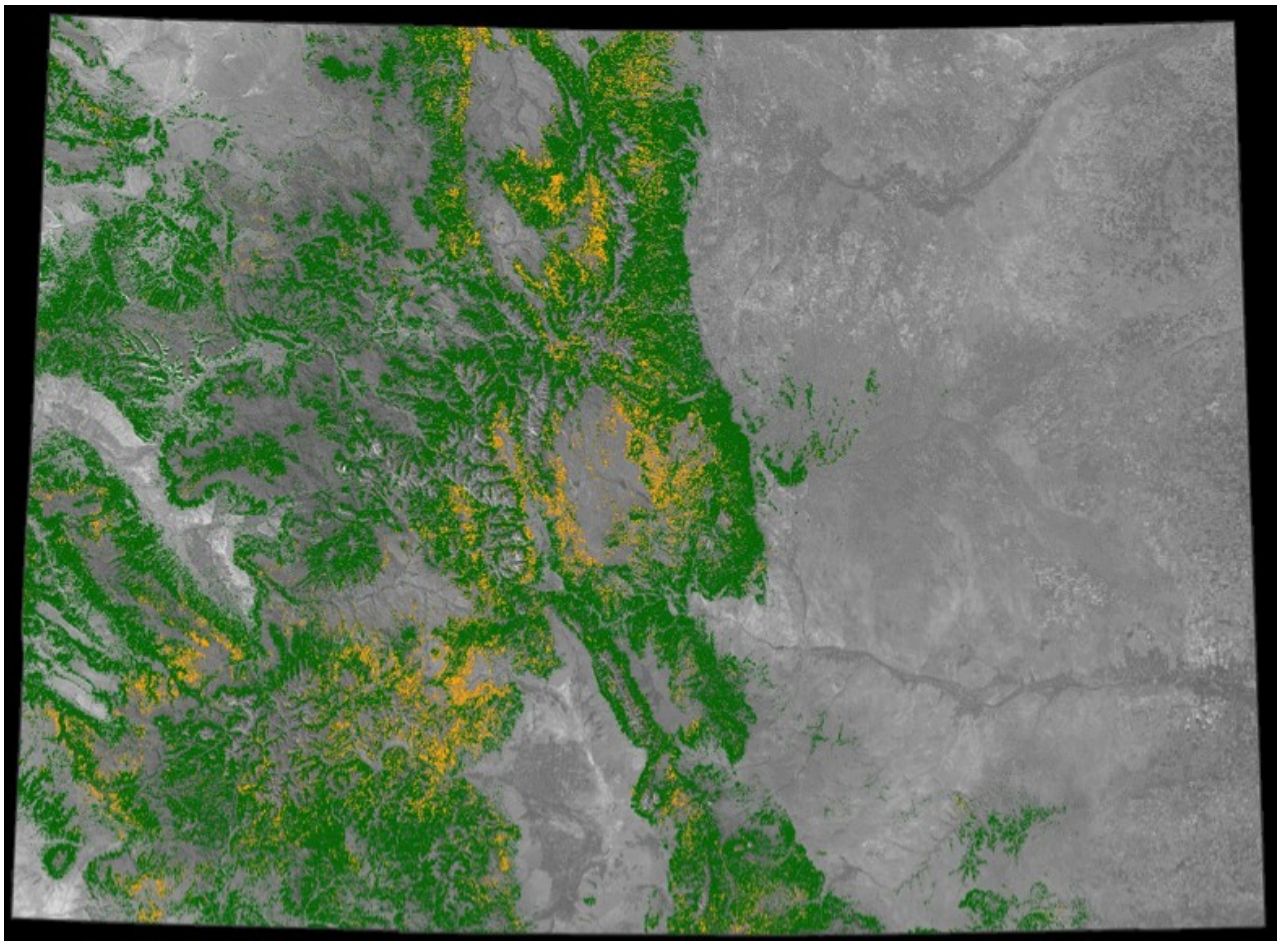

Figure 25: Mountain pine beetle infestation in Colorado.

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