Land Change Monitoring, Assessment, and Projection
A capability to continuously track and characterize changes in land cover, use, and condition and translate such information into assessments of current and historical processes of change as a science foundation to support evaluations and decisions relevant to environmental management and policy.
General Observations

- The LCMAP concept has 50 year old roots with a foundation established and motivated by:
  - Landsat
  - USGS EROS mission
  - US Global Change Research Program
  - National Research Council study recommendations
  - US Geological Survey science priorities
- Today’s motivations (e.g., needs and requirements) come from an increasingly broad community.
What do USGS land change science priorities have in common?

- Objective science-quality data and information.
- Ongoing monitoring of changes in land and water resources.
- Understanding of past, present, and future land use, cover, and condition change.
- Assessments of the combined impacts of climate and land change on people and natural systems.
LCMAP – Land Change Monitoring Assessment and Projection

- LCMAP is the EROS foundation for an integrated USGS-wide land change science framework
  - An interdisciplinary capability that generates and uses land change data and information to explain how the patterns, processes, and consequences of changes in land use, land cover, and land condition affect people and nature.
  - A capability to continuously track and characterize changes in land cover, use, and condition and translate this information into assessments of current and historical processes of change in order to support evaluations and decisions relevant to resource management and environmental policy.
LCMAP Conceptual Framework and Flow

Information Warehouse and Data Store
- Metadata
- Land cover change/condition products
- Outputs from assessments
- Non-Landsat remote sensor data
- Satellite data
- Airborne
- Non-Landsat rem. sens. prods.
- DEMs & derivatives
- Orthoimagery
- Evapotranspiration
- Vegetation phenology
- Others
- Ground-based data
- Cal/Val data
- Land cover accuracy/valid.
- Others

External data

External research

R&D

Continuous Monitoring
Collection of algorithms to identify types of abrupt and gradual change on a per-pixel basis

- Intact forest
- Thinning
- Clearcut

Gradual Change
Characterize land-cover condition; identify trends; cyclical phase shifts; other gradual change.
- Maps of thematic land-cover change
- Maps of flooding change
- Maps of timing of change
- etc.

Abrupt Change
- Detect land change as it occurs
- Maps of current land-cover and recent change
- Maps of phenological characteristics

Spatial analyses of change

Communications, applications services, outreach, and other users and stakeholder support
- Communications & outreach
- Web-based access to all products
- Web-based analysis portal
- Applications support

Assessments
Syntheses of the geography of land change, land-change processes, characteristics, and consequences relevant to USGS stakeholders.
- Annual land-change assessments (State of the Nation reports)
- Topical assessments (current events, emerging issues, other high-interest topics)
- Stakeholder needs

Projections
Projected patterns of future land use, land cover, and/or land conditions that address potential interactions between current environmental characteristics and drivers of change (e.g., climate, socioeconomic, legislative).
- Maps of trajectory of potential land change
- Maps of likelihood of change
- Maps of directions/intensities of change

External data

Federal partners

Stakeholder interests and info needs
**Analysis Ready Data (ARD)**

- Analysis-ready data (ARD) are consistently processed to the highest scientific standards and level of processing required for direct use in applications.

- A key goal for ARD is to significantly reduce the burden of processing on applications scientists.

- Standard Level-1T products serve as the input used for generating ARD.

- **ARD Specifications**
  - Top of atmosphere reflectance
  - Surface reflectance
  - Brightness temperature
  - Pixel-based quality assurance attributes
  - Common projection (Albers Equal Area Conic) and gridding (30m) – “stackable”

- Initial ARD production is focused on the TM through OLI record (1982 – present) for the U.S., but to eventually back through MSS (1972) and global scale.
Prescriptive Levels of Processing

Provide users with the product most suitable to their needs

Scaled DNs  TOA Reflectance  Surface Reflectance
Notional ARD Data Flow

Existing L1 Capabilities:
- L0R
- Subset
- L0RP
- Nominal L1 Processes

New Single Scene Processes:
- Specified Projection (Parameter; Albers for LCMAP; no reprojection)
- Calc TOA
- Calc SR/BT
- Quality band modifications (e.g., CFmask)

Single Scene TOA & SR/BT:
- Single scene processes compute and carry forward the fmask, quality band, angle bands and other key derivatives that are necessary for downstream processing or other product purposes and are best computed while performing full-scene processing.

Tiling and Downstream Processes:
- Format to WELD Tiles
- SR/BT or TOA Tile Time Series Stack
- Temporal composites, ECV products (optional)
- Land Characterization Algorithms (CCDC, others)
- Downstream LCMAP Activities
Why continuous monitoring?

- Last 25 years the dominant use of optical remote sensing has been to monitor change
- Overwhelmingly based on comparing two images of the same place – which works well for dramatic changes (urbanization, deforestation, etc)
  - Try to get images from the same time of year (minimize phenology effects)
  - Try to get cloud free images
- More recently, use a time series of roughly one image a year to identify change (mostly used for forests)
- Most recently, use all available imagery, or continuous monitoring
  - Minimize the effect of noisy observations (“environmental noise”)
  - Find change as it is happening, better quantify when change happens
  - Detect high temporal frequency changes and events
  - Track trends in condition, stress, recovery, phenology
LCMAP – Land Cover, Use, and Condition Monitoring Objectives

- Generation of science-quality land change products from current and near-real time Earth observations (e.g., Landsat).
- Land change detection system that:
  - Characterizes historical land change at any point across the full Landsat record.
  - Detects land change as it occurs.
- Includes an information delivery capability that (eventually) provides global, seamless, multi-temporal land change (cover and condition) products via the Internet.

Change analysis based on Zhu and Woodcock (2014) Continuous Change Detection and Classification (CCDC) methods.
LCMAP Monitoring: Transitioning from ....

NLCD .................> To LCMAP

"Snapshot " monitoring

Change: 2001 vs 2006

Stop the clock at any time to generate a land cover map

Map the timing of change

Material from C. Woodcock, Boston University
… To LCMAP

Map abrupt & gradual forms of change

- Pre-fire
- Year fire occurred
- Post-fire recovery
- Longer-term recovery

Landsat Mid-infrared Band

Reflectance (scale factor 0.0001)

Date

Current areas for testing and refining the Continuous Change Detection and Classification (CCDC) algorithm
Timing of change

Year of Most Recent Change

- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014

USGS
LCMAP Land Change Assessments

• Assessments will be on land change processes, characteristics, and consequences
• Assessments will include both scheduled and ad hoc topics
  ▪ Ongoing annual series of topical land change assessments – e.g., Rates and characteristics of 2015 land change and an outlook for the next 10 years
  ▪ Periodic assessments on relevant land change topics – e.g., the impacts of Farm Bill legislation on past and future land use and land cover
  ▪ On-demand assessments – e.g., the impacts of the 2012 drought on land use and land condition
• Alert relevant stakeholders to important or emerging land-change events in their jurisdictions.
Land Change Projection (forecasts)

- LULC projections
  - Scenario driven projections of future LULC extents and patterns (e.g., IPCC emissions scenarios)
  - Projecting future LULC based on land requirements for various sectors (e.g., what are the land use requirements needed to meet future food, fiber, and fuel demands given climate and water constraints?)

- Forecasts on the impacts of LULC change on ecosystem health, carbon dynamics, climate change adaptation, etc.
Information Warehouse and Data Store

- Working on end-to-end prototype to demonstrate technology over Puget Sound
- After demonstration, implement data cube in support of ARD Collection 1 and CCDC
  - Notional timeline shifted to right based on feedback from System Concept and Definition Review

Notional IW & DS Timeline

- 4/15 - 12/15: Data Cube Prototype Development in Support of CCDC and ARD
- 2/16 - 4/17: Data Cube Implementation
- 4/17 - 11/17: Data Cube Expansion to Support ARD Collection 2

Key Dates:

- 7/15: Initial Data Cube Specifications Complete
- 10/15: Submit Acquisition Request
- 12/15: Data Cube Acquisition "Go"
- 2/16: Data Cube Acquisition Award
- 9/16: ARD Access Available
- 10/16: CCDC Ready for Operational Implementation
- 5/17: CCDC Initial Operations
Science Execution Environment

- To enable large scale monitoring, assessments, and projections, a science data system is required that includes a high performance computing infrastructure
  - Must enable utilization of compute resources at various institutions
- An approach to this environment was discussed at the System Concept and Definition Review in November
- The team is working on end-to-end prototype to compute change detection over Puget sound
- Opportunities to collaborate (upcoming slide)
Access and Exploration

▪ To achieve LCMAP goals, need to develop the proper toolsets and capabilities for public exploration, discovery and visualization of data

▪ Integrating visualization tools for local scientists
  ▪ Working through use cases for classification data validation and continuous monitoring

▪ Need to continue to work with science to bolster use cases and gather requirements
Why should the USGS implement LCMAP?

- Modernize access to the Landsat archive
- Transform the USGS land cover legacy – from mapping to monitoring
- Set the foundation for a Federal land monitoring system
- Meet USGS land change science needs:
  - Landsat and the land change mission
  - Geographic research on understanding the connections between human activity and natural systems
  - Improve understanding of climate and land use interactions
- Integrate EROS science and operations activities into a focused vision