USGS Update and Interest in the Decadal Survey

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Chesapeake Bay
Landsat 8 surface reflectance mosaic, 2014
USGS Background and Update
Remote sensing + *in situ* science: Drought

**Long-term geologic record:**
(Climate R&D Program)

![Graph showing CaCO₃ percentage and time]

- Late Classic Period Drought

**Modern satellite record:**
Weekly Vegetation Drought Response Index
(Land Remote Sensing Program)

![Map of vegetation condition in the United States]

**Visualization facilities for stakeholder scenario Development:**
(Climate Science Centers)

- Paleo-droughts in the Maya Lowlands
Remote sensing + \textit{in situ} science: Land-sector carbon

- 2014-2016 pilot studies at National Wildlife Refuges (wetlands), collecting \textit{in situ} data on effects of specific wetland restoration and land management activities.
- Developing decision support tools for land managers
- Contributing to EPA Greenhouse Gas Inventory
Landsat Status: Satellites

**Landsat 7**
- Launched in 1999
- Scan Line Corrector hardware failure in 2003 results in a loss of 22% of each scene
- Expected to be decommissioned in 2019-20

**Landsat 8**
- Launched in 2013
- Operational Land Imager operating superbly
- Thermal Infrared Sensor (TIRS) collecting data but not distributing; new calibration algorithm expected before N. American growing season
  - No apparent effect on longevity
- Currently collecting 725 scenes/day (exceeding the requirement of 400 scenes/day)
- Fuel could last nearly 20 years based on operational consumption to date
Status: Landsat-based Information Products

- Standard orthorectified L1T calibrated radiance Landsat scenes (10M downloaded in 2014)
- LandsatLook (full-resolution, 3-band L1T JPEG browse/print images)
- Landsat 5/7 (TM/ETM+) surface reflectance product released in Earth Explorer May 2013. (Several recent publications characterizing product’s quality)
  - 0.5M TM/ETM+ products served in December 2015
  - Landsat 8 (OLI) initial surface reflectance product very popular, but not finalized; will coordinate with Sentinel-2 algorithm
- Global 30m Land Cover Forest Gain/Loss product available through Google Earth Engine
- Provisional surface temperature products released March 2014
- Provisional Burned Area Extent product released March 2015 for evaluation
- Provisional Dynamic Surface Water Extent product released March 2015 for evaluation
- New OLI surface temperature product Q1 FY15
- Global 30m Land Cover Percent Tree Cover 2010 and validation data available for evaluation via USGS Visualization tool
- Fractional Snow Covered Area product available in “provisional” status Q4 FY15
- Biomass product in early stages of development (modeling and estimation)
New Landsat 8 capabilities

Landsat 8 design and operational improvements include:

• More image data, all available within 5 hours of sensor acquisition
  – Designed for 60% more coverage than L7 (400 scenes/day vs. 250)
  – 41 year record will be extended to 45-50 years or more
  – All L8 images acquired globally go to USGS archive (vs. ~40% from L7)

• Better image data – improves detection of changes in surface properties
  – 5x improvement in signal to noise ratios (SNR)
  – 12 bit quantization (256 vs 4096)
  – Improved cartographic accuracy due to advanced geo-location capabilities

• New measurements
  – Coastal aerosol band (0.433–0.453 μm) – detection of water column constituents (e.g., chlorophyll, suspended materials)
  – Cirrus band (1.360–1.390 μm) – improves overall image quality derived from better cloud screening
Landsat 8 Signal-to-Noise Ratio

L7 Enhanced Thematic Mapper (ETM) vs. L8 Operational Land Imager (OLI)

Improved SNR supports more accurate detection and characterization of subtle land and water conditions and changes.
Landsat 8’s 12-bit quantization eliminates bright target saturation

Landsat 1-7 signal saturation that affected the ability to detect subtle changes in bright surfaces is no longer an issue. This is improving the detection and mapping of land degradation and the characterization of snow and ice.

Leo Lymburner, Geosciences Australia
Effects of Landsat 8 on Applications

All Landsat applications benefit from L8’s larger data volume, superior data quality, improved cloud detection, plus improved radiometric and geometric performance:

• Google Earth, Amazon, Esri, Mapbox, DevelopmentSEED, and other geospatial businesses provide L8-derived services and distribute millions of value-added Landsat images
• Water management agencies in 17 states conduct Landsat-based water-consumption measurements
• L8 performance improvements have created greater confidence in Landsat products, therefore expanding use

Applications growing rapidly include:

• Water quality studies – due to the improved signal/noise and 12-bit measurements
• Cryosphere investigations – due to improved geometry, higher acquisition rates, and improved radiometric performance
• International land-change investigations – due to higher imagery acquisition rates
Analysis by John Schott, RIT, demonstrates that Landsat 8 performance is sufficient to measure chlorophyll, colored dissolved organic material, and suspended materials in near-shore areas.
Landsat 8 data improving land cover classification

In classification tests over New Orleans and Boston, Landsat 8’s land cover results were 20% better than Landsat 7’s.

Curtis Woodcock, Boston University
New cirrus band improves cloud detection
Improved Landsat 8 geodetic control supports accurate measurements of ice motion

The high precision of Landsat 8 scene geo-location, as well as the improved radiometric fidelity, is enabling accurate measurement of glacial ice motion.

Using pairs of Landsat 8 panchromatic bands, 0.3 pixels (about 5 meters) of ice motion were detected over a 32 day period in the summer of 2013.

M. Fahnestock, personal communication
USGS Interest in the Decadal Survey
USGS Roles and Dependencies

• USGS is an owner (Landsat), data provider (LP DAAC and other land imagery), and user of space-based Earth observing systems

  o Landsat perspective:
    o Time horizon: Administration has committed to Landsat-compatible land imaging for Landsat 9 + 20 years
    o Uses are in both research and decision support
    o Priorities include both continuity and innovation, driven by users’ needs
    o Capabilities should not be static. For next generation of Landsat, need input on emerging capabilities and benefits to users.

• Of recent NASA ESD missions, Department of the Interior’s heaviest uses have been:
  o Rely heavily on: MODIS, VIIRS, ASTER, GRACE.
  o Also heavily used: Aura, EO-1 (fewer users but critical for those uses), CALIPSO.
  o Also very useful: TRMM, QuikSCAT.
Increasing understanding of users and uses

Used for both research and decision support. For example:

- Agriculture and forestry:
  - E&J Gallo Winery uses Landsat data to reduce irrigation water usage and improve grape quality
  - At least 8 western states use a model based on Landsat thermal infrared measurements for water consumption monitoring, planning, and management
  - USDA Risk Management Agency uses Landsat data to detect multi-million-dollar crop-insurance fraud

- Wildfire and disaster monitoring and response
- Regional land use planning and land management
- Many other uses: coastal mapping, mineral resources surveys, flood monitoring, ....

\[\text{Landsat Scenes Downloaded from USGS EROS Center}^{1} \text{ (Cumulative)}\]

\(^{1}\) Includes only downloads from the USGS EROS. (Google Earth delivers approximately 1 billion Landsat scenes to users per month.)
Recent studies on Landsat users’ needs

• 2/3 of studied Landsat products require 8-day or more frequent revisit
• 3/4 require simultaneous visible/near-infrared/shortwave infrared (V/NIR/SWIR) data
• 1/3 require thermal infrared (TIR) data in combination with either V/NIR or SWIR bands

• Assessment of 362 Earth observing systems’ contributions to 13 societal benefit areas
• Among 132 satellite systems, Landsat ranks second-highest in impact, behind only GPS (#1 for contributions in Biodiversity, Ecosystems, and Energy; #2 in Agriculture/Forestry, Climate, Human Health, and Water)

• Coverage/repeat cycle requirement: “Ability to acquire and make available imagery anywhere on Earth, except perhaps for areas very the near poles, at approximately weekly frequency.”

USGS National Land Imaging Requirements Moderate-Resolution Pilot Project (2014)
• Formalized process also used for OSTP’s Assessment and for NOAA
• Elicited requirements for 11 application areas across 12 Federal agencies
• 60% of requirements collected require 8-day or more frequent revisit
Sample findings: Spectral, temporal, spatial requirements

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<th>Spectral Requirements</th>
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<td>NIR</td>
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<td>USGS/USFS Landfire</td>
<td>Vegetation characteristics</td>
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<td>Forest change maps</td>
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<td>Crop area</td>
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<td>USDA National Ag. Statistics Service</td>
<td>National cropland data layer (crop type)</td>
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<td>USDA Crop Insurance</td>
<td>Verify crop insurance/damage claims</td>
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<td>Cloud/shadow mask</td>
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<td>USDA Tillage/Residue Monitoring</td>
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<td>Landsat Image Mosaic of Antarctica</td>
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Sample findings: Federal uses of Landsat


• Used GEO Societal Benefit Areas
• Assessment criteria included:
  – What’s critical for 1 SBA
  – What’s infrastructural/used by many
  – What’s in need of attention (either continuity or new technology)
• 10 of 13 SBAs use Landsat
• 31 of 52 Sub-areas use Landsat

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Continuity

• In discussions of the Solar and Space Physics Decadal Survey, Dan Baker has noted that a big lesson learned was: Don’t assume specific missions will always be there. We have a similar lesson from the first Earth Science Decadal.
  – First Earth science Decadal assumed sustained operations (i.e. no attention needed) for Landsat, NPOESS, & Global Precipitation Mission.
  – Final priorities focused on new observations, with language like “The importance of the Landsat-class measurements in establishing a long-term baseline of land-cover measurements cannot be overstated.” However, the final recommendations do not include sustained land imaging.
  – Recent SSB report on continuity
Focus on needs and products vs. technologies and measurements

- Landsat users are asking for continuity and incremental improvement to better support consistent research directions and decision support needs.
- USGS is developing national Landsat products for multi-temporal land change monitoring, assessment, and projection in many fields, including:
  - Drought indicators
  - Snow cover
  - Water quality
  - Energy development
  - Surface water extent
  - Burned area extent
  - River channel dynamics
- How can new NASA missions – Landsat and others – improve standardized land-change (cover and condition) maps at national and global scales?