



# USGS Land Remote Sensing Program Directions

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Land Remote Sensing  
U.S. Geological Survey

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# Acknowledgements

- Earth Resources Observation and Science (EROS) Center
- NASA Goddard Space Flight Center
- Geoscience Australia
- Landsat Science Team
- Boston University



# USGS Mission Areas

1. Climate and Land Use Change
2. Core Science Systems
3. Ecosystems
4. Energy and Minerals
5. Environmental Health
6. Natural Hazards
7. Water



# USGS Mission Areas

## 1. Climate and Land Use Change

- Land Remote Sensing Program
- Earth Resources Observation and Science (EROS)
- Land Change Science
- Carbon Sequestration
- National Climate Change & Wildlife Science Center
- Climate R&D

## 2. Core Science Systems

## 3. Ecosystems

## 4. Energy and Minerals

## 5. Environmental Health

## 6. Natural Hazards

## 7. Water

# USGS Land Remote Sensing

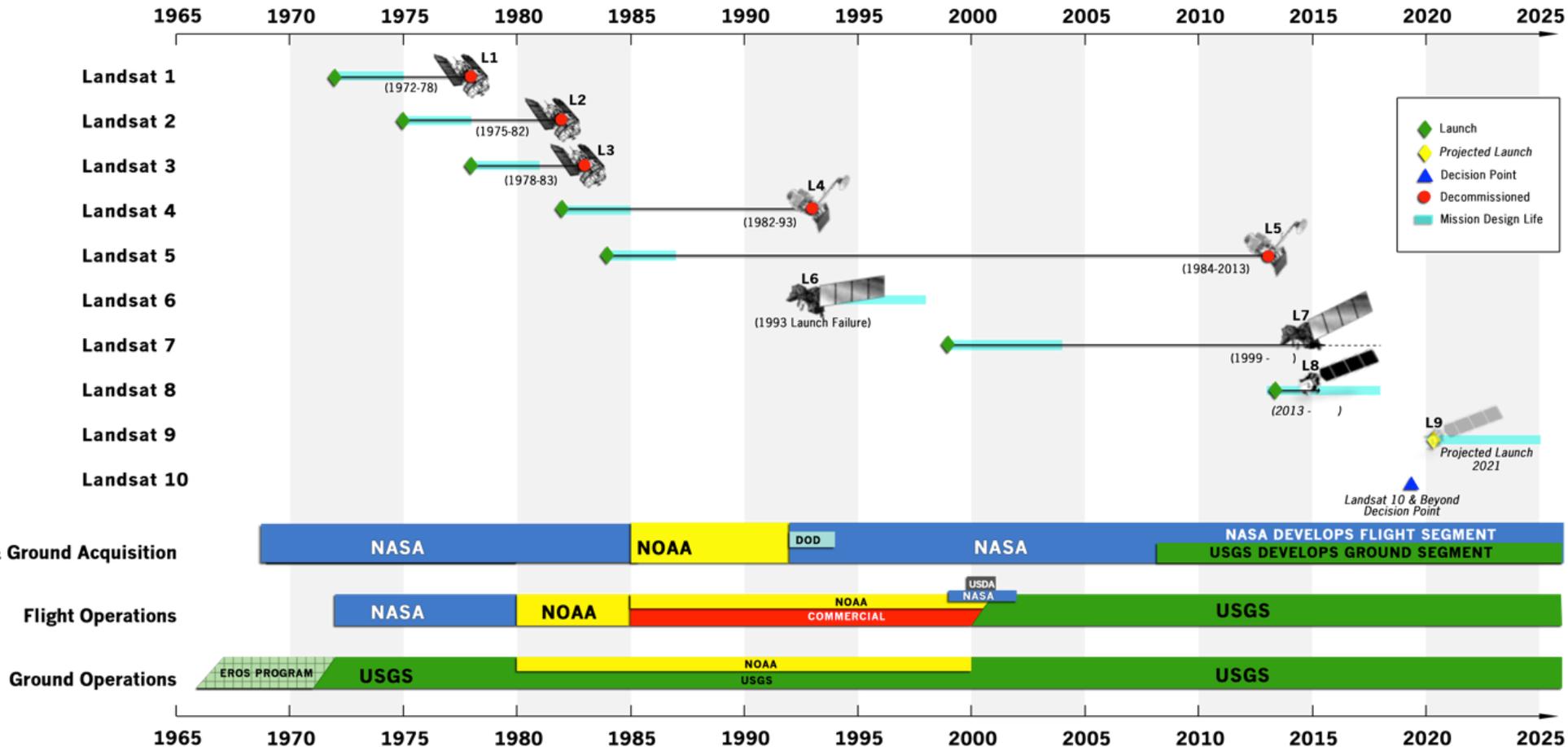
The USGS delivers a national and global capability to ensure broad public and scientific availability of observations of the Earth's land surface:

- Create and preserve a long-term record of the Earth's land surface at local, regional, and global scales
- Expand scientific understanding and application of remotely sensed data to government and private users nationally and globally
- Support decision makers and policy officials in fulfilling their public responsibilities
- Guide National decisions about meeting current and future needs in land science and land observation
- Coordinate and integrate civil Earth observation with other sources of data including commercial and National Security space systems

**Fundamental goal: Ensure public availability of a primary data record about the current state and historical condition of the Earth's land surface**



# Landsat– going on half a century

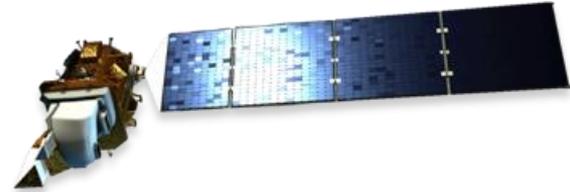


The Landsat Program has amassed the longest and most comprehensive record of the Earth's land surface in existence

# Landsat operational satellite status

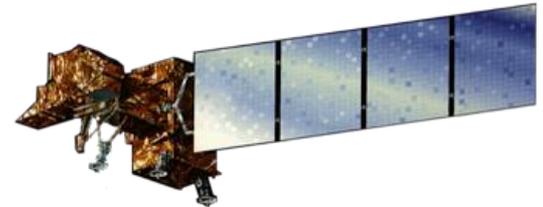
## ***Landsat 8 (2013)***

- Collecting up to 725 new scenes per day; supports 8-day revisit.
- Thermal Infrared Sensor (TIRS) continues to operate on B-side subsystems with observatory engineers closely tracking hardware performance.



## ***Landsat 7 (1999)***

- Collecting about 475 new scenes per day; about 22% of pixels missing per scene (faulty scan-line corrector)
- The latest fuel estimate projects L7 operating into 2020/2021 (depending upon lowering strategy)
- Restore-L (<http://ssco.gsfc.nasa.gov/>)



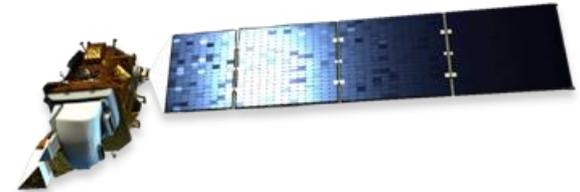
# Sustainable Land Imaging (SLI)



**NRC Space Studies Board:** The U.S. Government should establish a “Sustained and Enhanced Land Imaging Program” with persistent funding....

## *Landsat 9 (late 2020)*

- Upgraded Thermal Infrared Sensor (TIRS-2) design— from risk class C to B redundancy upgrades
- Going to 14 (from 12) bit depth resolution for OLI-2



## *Landsat 10 (~2025-30)*

- EVERYTHING IS ON THE TABLE at this point
- Measurements that enable **backward and forward assessments**
- Technology and requirements studies underway to support a 2018 decision point



# Sustainable Land Imaging Architecture Study Team (AST) Evaluating Future Alternatives for SLI (2014)

## Land Imaging AST Charge

- Define *a global, Sustainable Land Imaging (SLI) system for a 20-year period* starting in 2018
- Provide cost effective options for near-term capabilities, continuity risk mitigations, and technology infusion
- Consider refined capabilities requested by the user communities
- *Include new measurement approaches & potential international and private sector partnerships*

## Key AST Finding

- *The Landsat 8 Rebuild has the lowest technical risk*; consistent with Senate and Landsat community desires; avoids competitive process delays for first SLI mission; enables several years for SLI to prepare for efficient implementation of future architecture; direct data continuity with Landsat 8

# How does USGS determine requirements?

## USGS Requirements, Capabilities & Analysis (RCA) Activity

- **Requirements Elicitation** identifies fundamental information needed by the user (what needs to be observed or measured): Geographic Coverage, Horizontal & Vertical Resolution, Sampling Interval, Accuracy, Length of data record, Data latency, etc.

## USGS Requirements Surveys

- USGS/NASA Landsat Applications Survey of 33 Landsat products (2012)
- USGS National Land Imaging Requirements Pilot Project with 12 federal agencies (2014)

## Landsat Science Team (Co-chaired by USGS and NASA)

- 21 scientists & engineers from the Federal Government, academia & international organizations

## National Geospatial Advisory Council Landsat Advisory Group

- Provides advice to the Federal Government on Landsat requirements, objectives and actions

## DOI Remote Sensing Working Group

- Team of remote sensing experts from all DOI bureaus working together to share expertise

## OSTP-led Activities

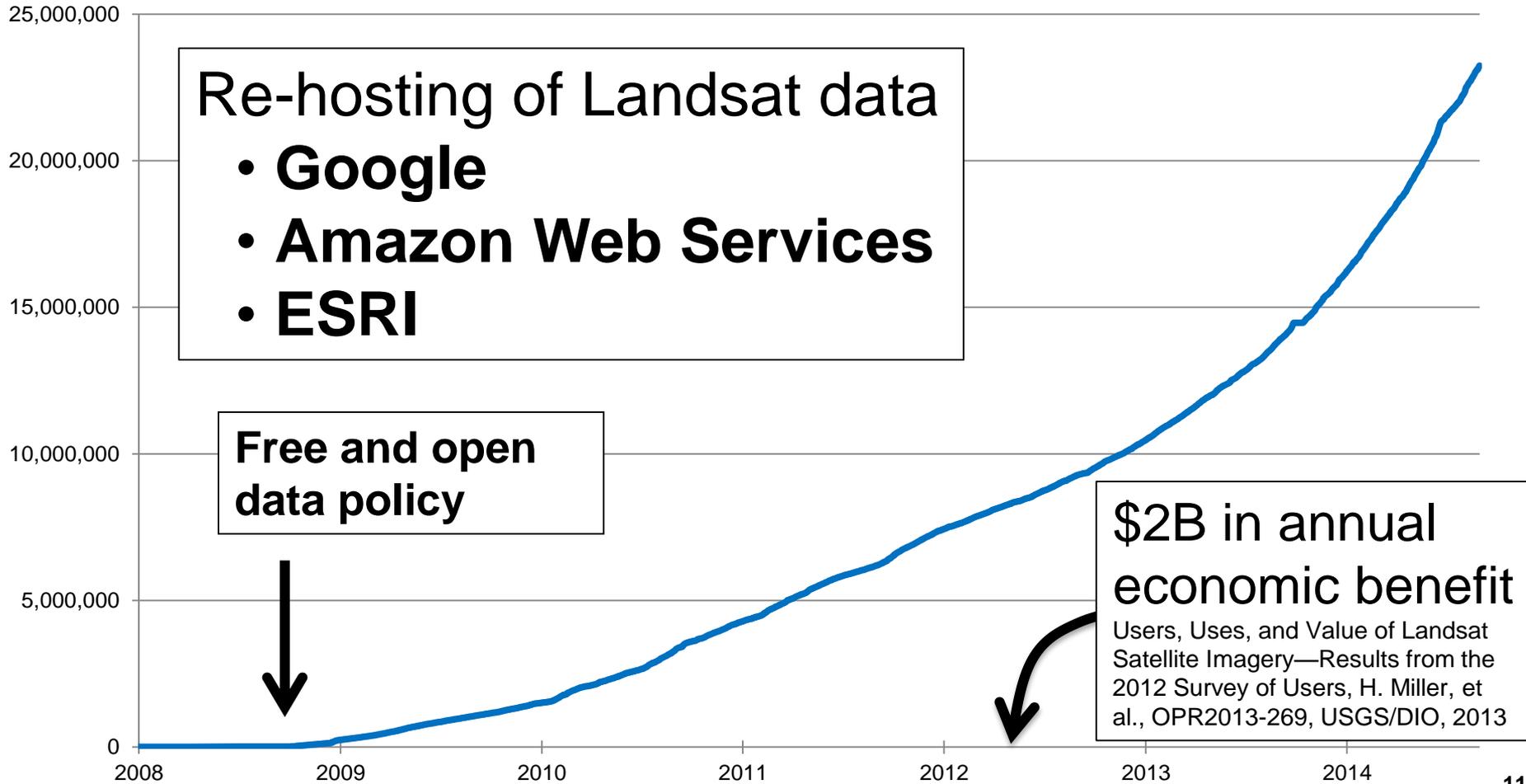
- National Plan for Civil Earth Observations (2014), Earth Observation Assessments (2012, 2016)

**Others:** NRC Reports, USGEO activities, AmericaView, Case Studies, User feedback

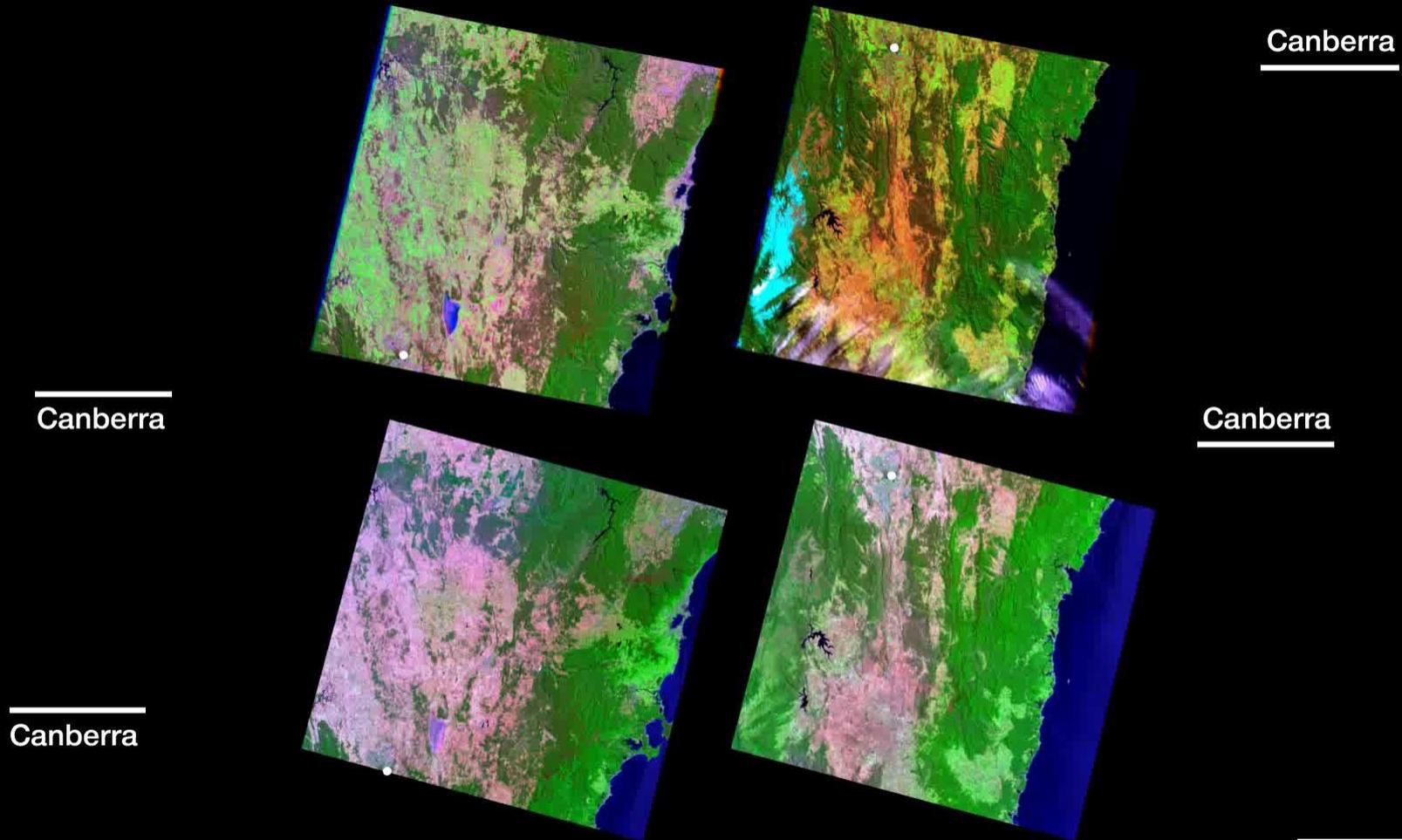


# Move to free data policy in 2008 changed everything

Landsat Scenes Downloaded from USGS EROS Center<sup>3</sup> (Cumulative)



# Time-series Data Cubes



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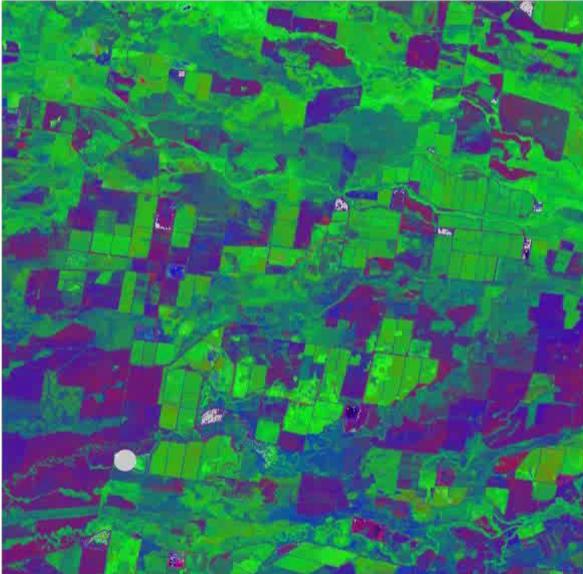


Australian Government

Geoscience Australia

# Land use change: cropping patterns

Land Management – Keytah Station. ‘Fractional cover’



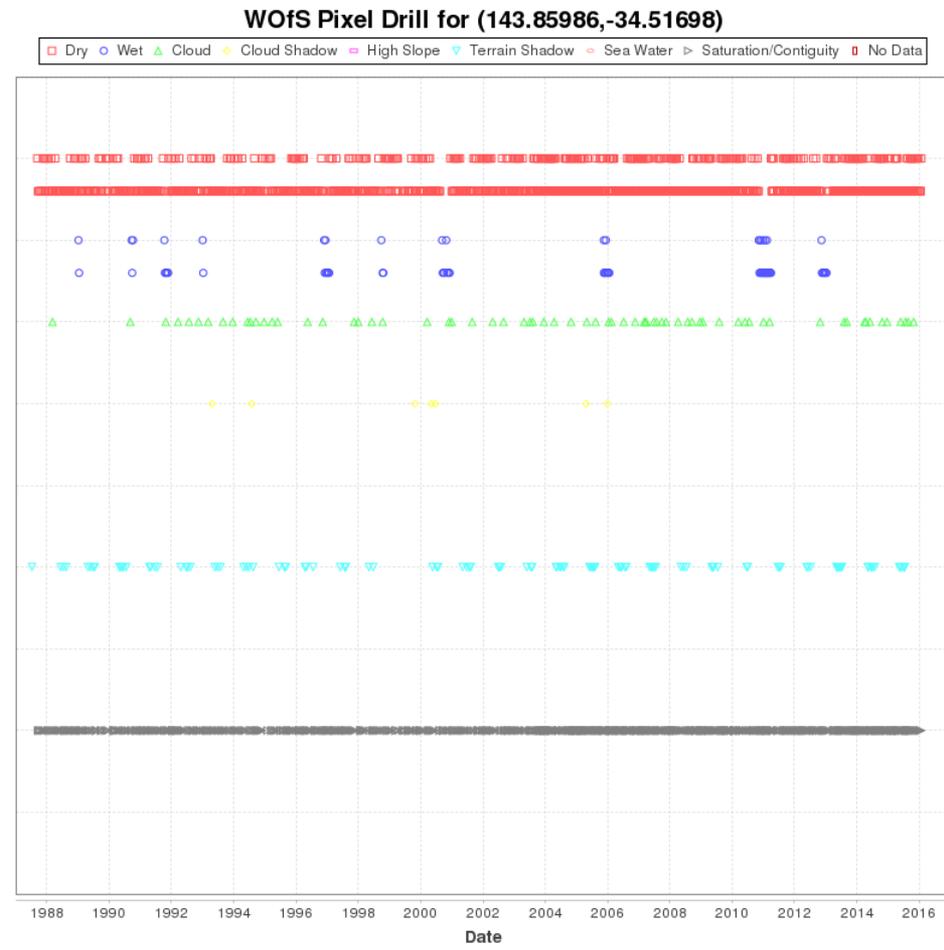
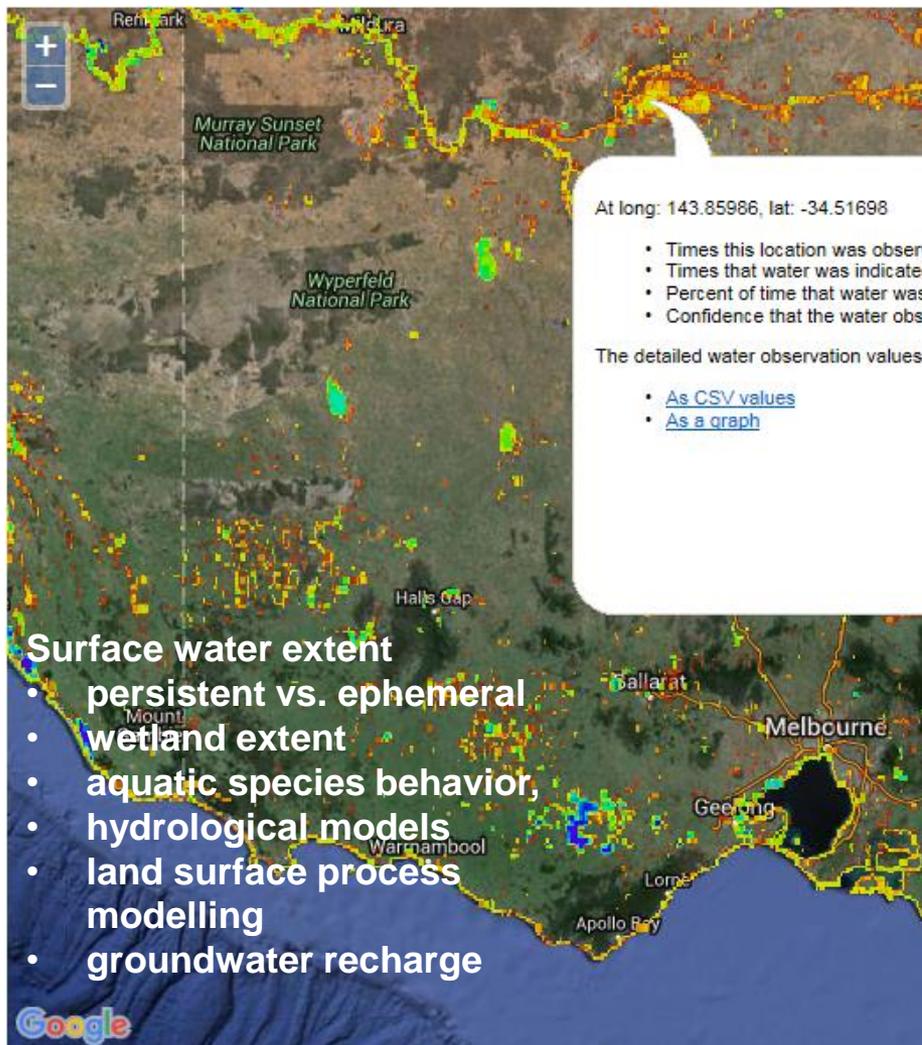
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Australian Government

Geoscience Australia

# Water observations from space

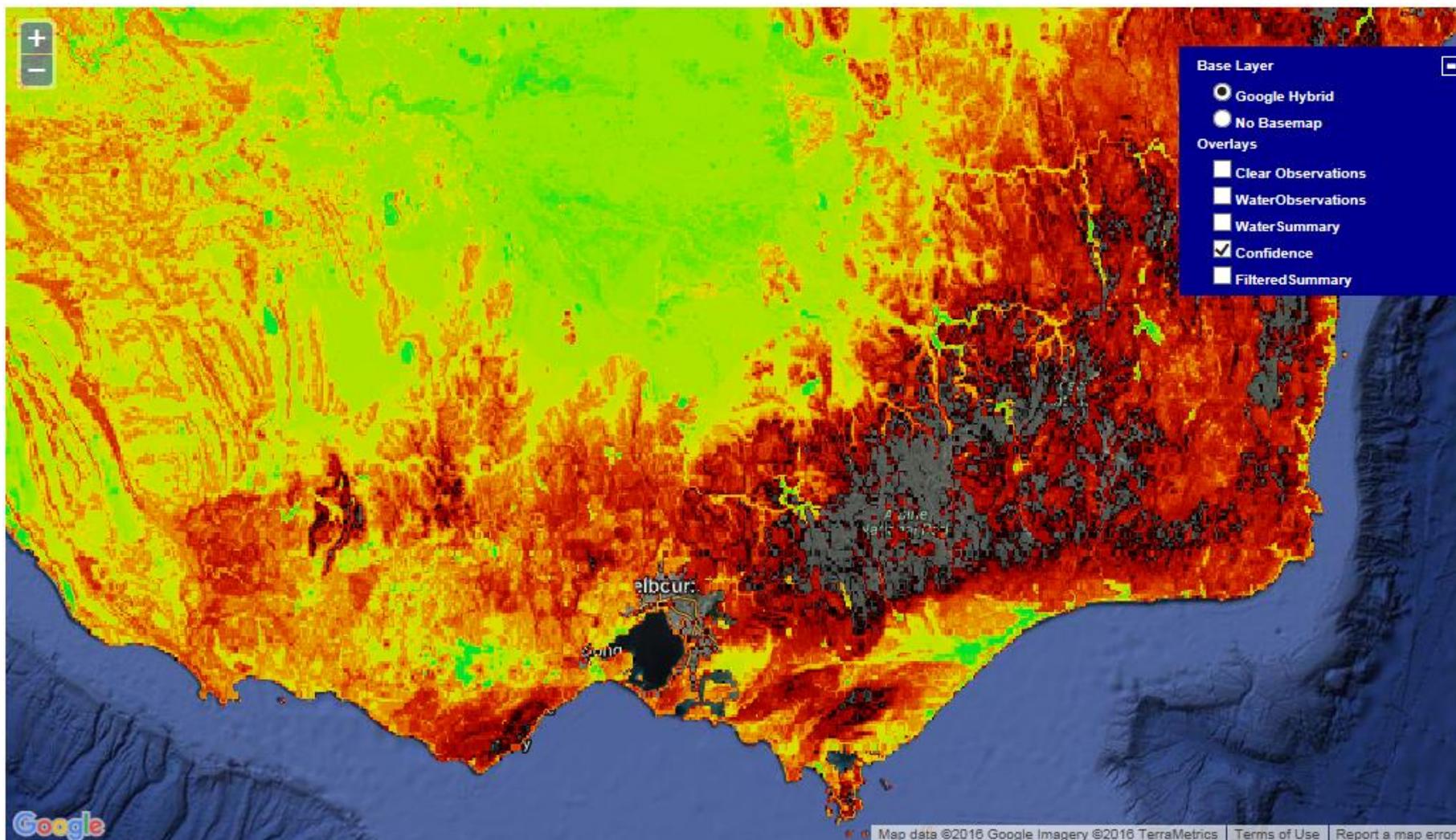


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[http://eos-test.ga.gov.au/geoserver/www/remote\\_scripts/WOfS\\_v1.6.htm](http://eos-test.ga.gov.au/geoserver/www/remote_scripts/WOfS_v1.6.htm)

Mueller, M., et al., Water observations from space: Mapping surface water from 25 years of Landsat imagery across Australia, *Remote Sensing of Environment*, v174, pp 341-352, 2016.

# Water observations from space (confidence)



[http://eos-test.ga.gov.au/geoserver/www/remote\\_scripts/WOfS\\_v1.6.htm](http://eos-test.ga.gov.au/geoserver/www/remote_scripts/WOfS_v1.6.htm)

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# LCMAP – Land Change Monitoring, Assessment, and Projection

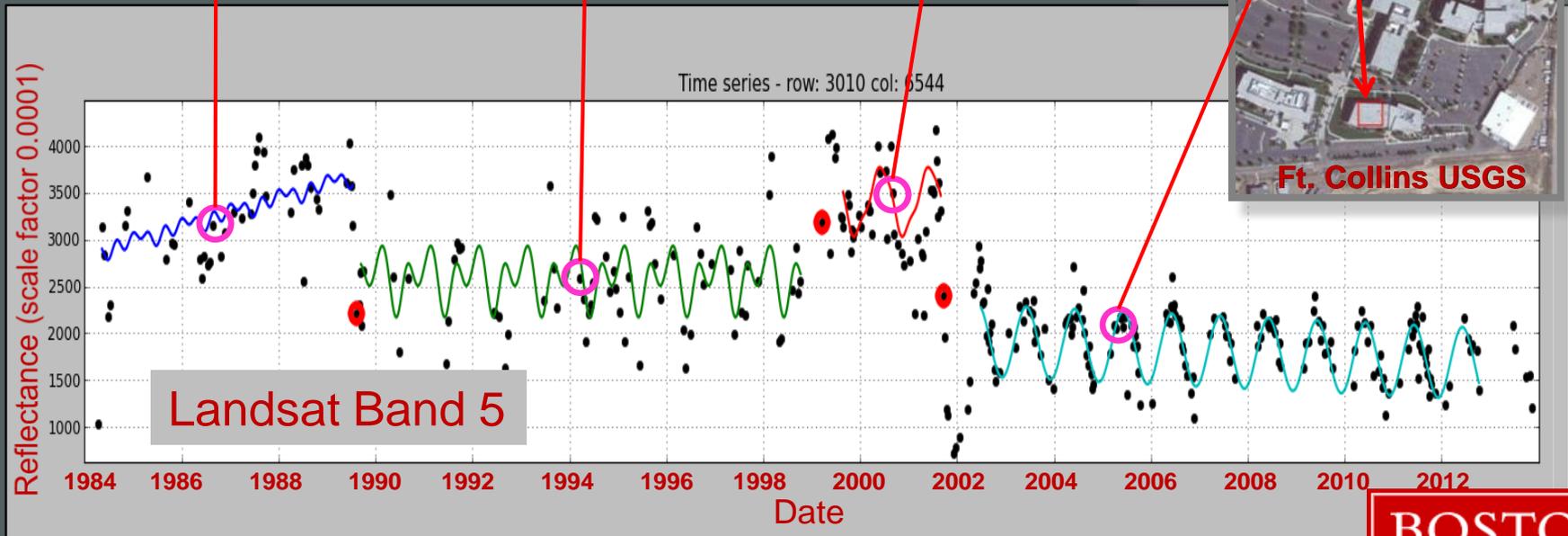
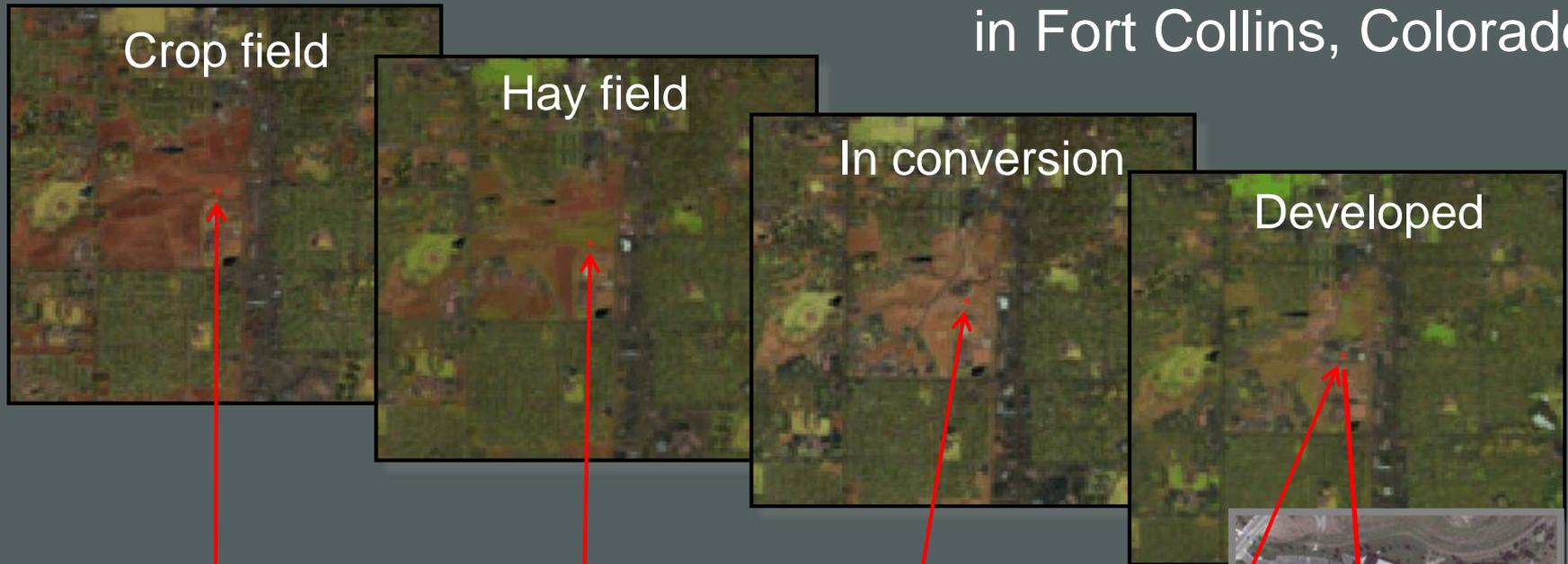
- Generation of science-quality land change products from current and near-real time Earth observations (e.g., Landsat).
- Land change detection system that:
  - Characterizes historical land change at any point across the full Landsat record.
  - Detects land change as it occurs.
- Includes an information 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.



# Spectral history of a location in Fort Collins, Colorado

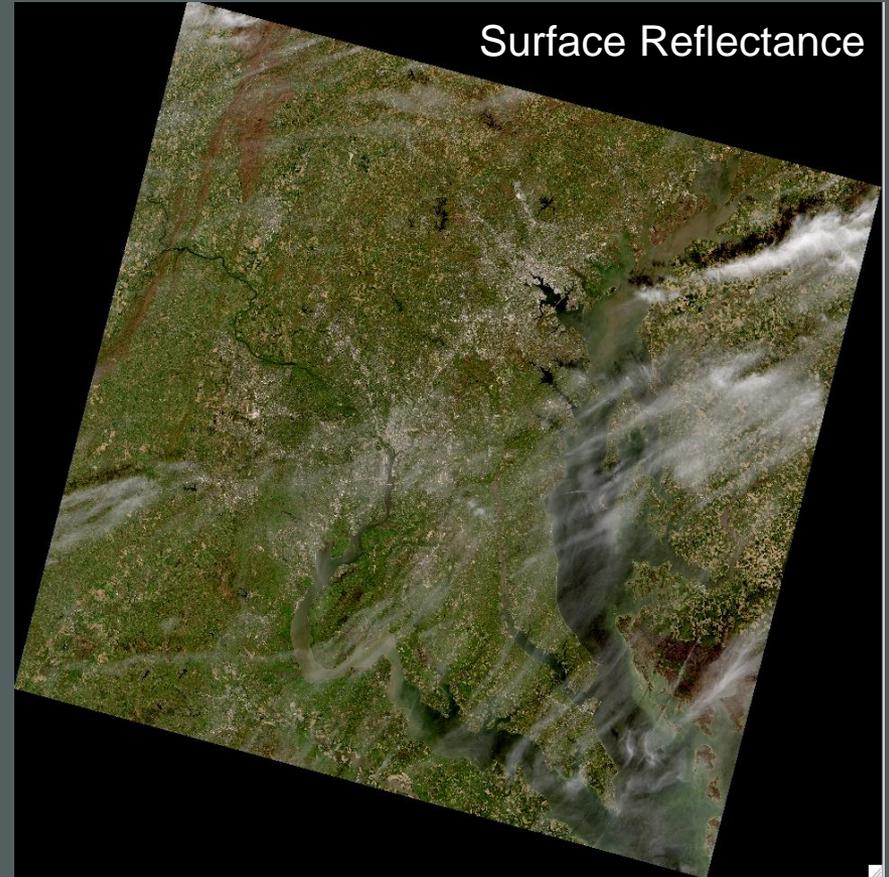
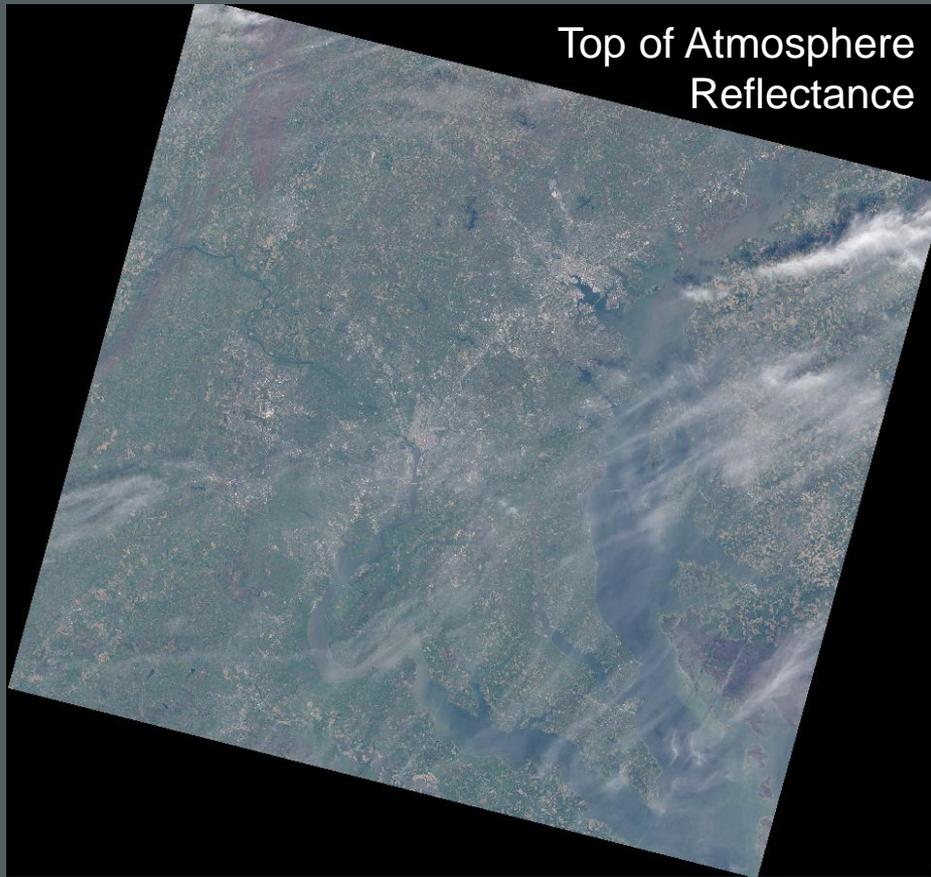


Zhu, Z. and C.E. Woodcock. 2014. Continuous change detection and classification of land cover using all available Landsat data. *Remote Sensing of Environment* 144:152–171.

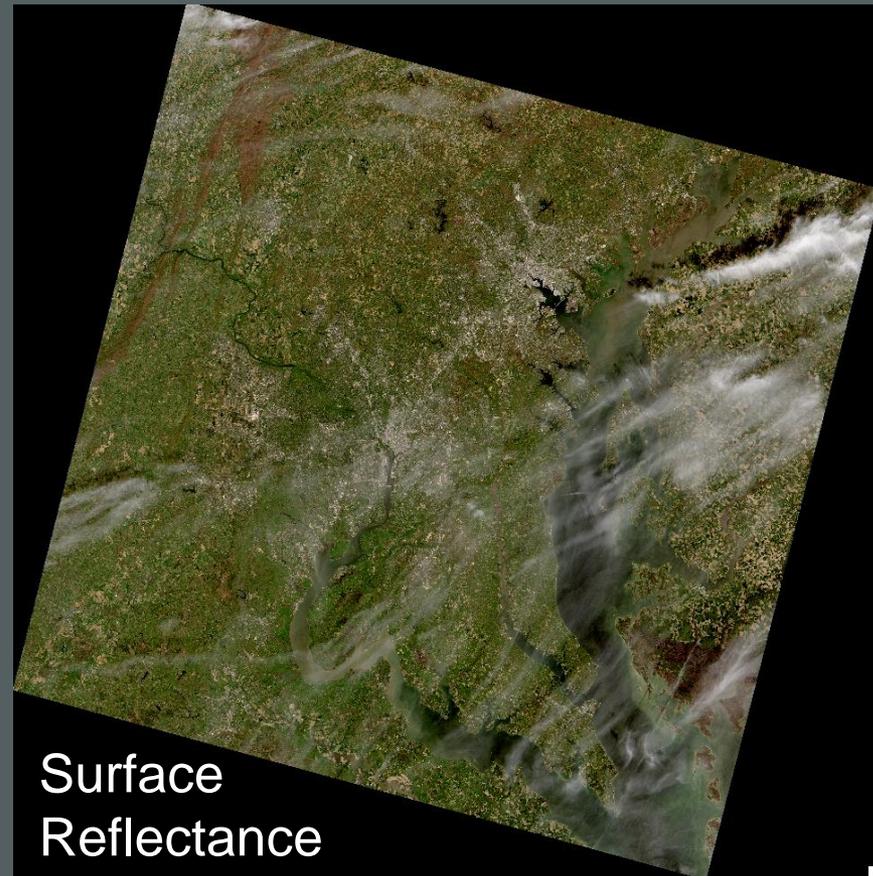
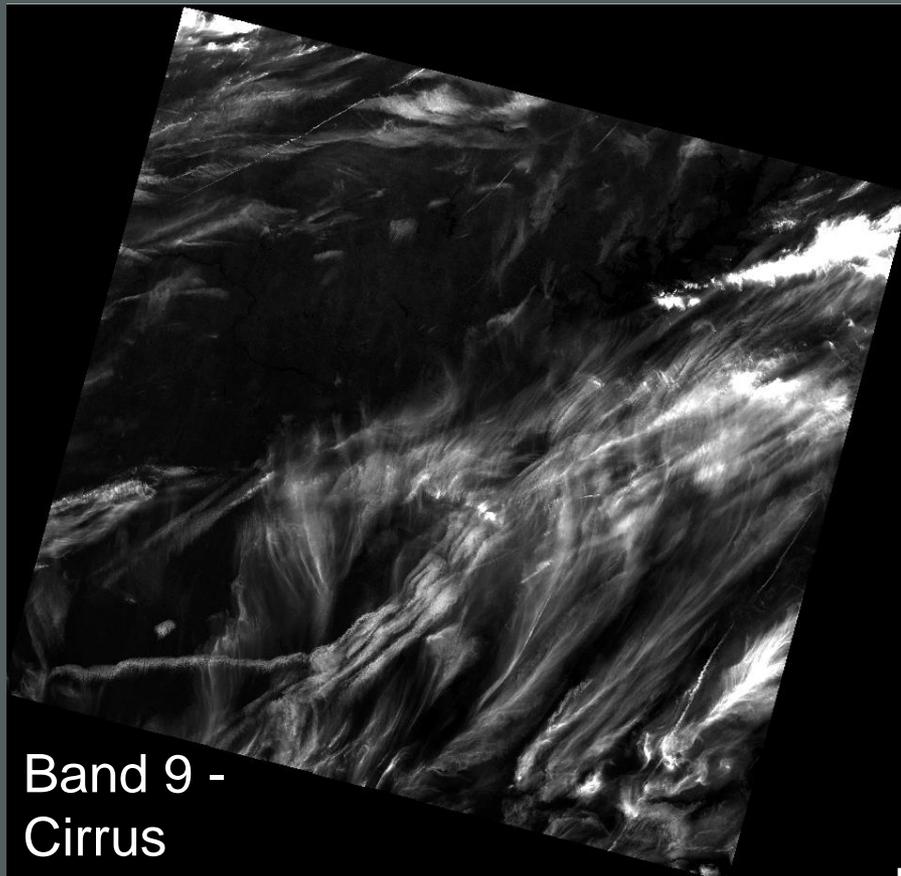
# Analysis Ready Data (ARD)

- 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
- The ARD product consists of Landsat top of atmosphere reflectance, *surface reflectance*, and brightness temperature data that are consistently processed, gridded to a common cartographic projection, and accompanied by appropriate metadata to enable further processing while retaining traceability of data provenance.
- Products derived from the ARD include, but are not limited to: maps of land cover and land-cover change, spectral indices, temporal composites, and other geophysical and biophysical parameters

# Landsat 8 prototype Surface Reflectance



# Landsat 8 improved cloud detection

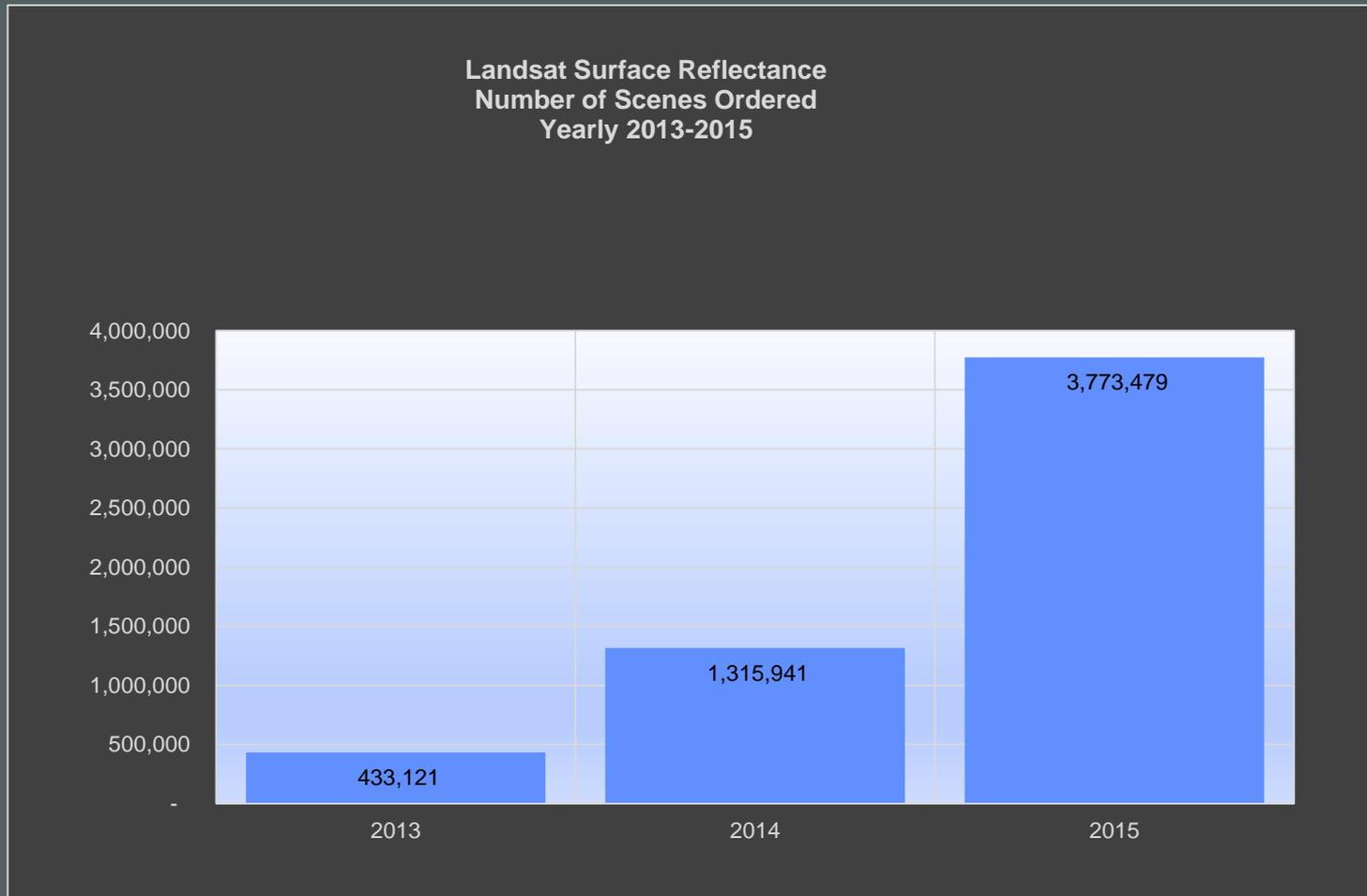


Detection of cirrus clouds using band 9 improves atmospheric correction of Landsat 8 multispectral data.

# Surface Reflectance availability

- **Landsat TM and ETM+**
  - LEDAPS heritage
  - Released October 2012
- **Landsat OLI/TIRS**
  - New code (L8SR), based on MODIS/MISR/VIIRS and using MODIS aerosol & water vapor CMGs
  - Released December 2014
- **Accessible through EarthExplorer and EROS Science Processing Architecture (ESPA)**

# SR annual distribution since release



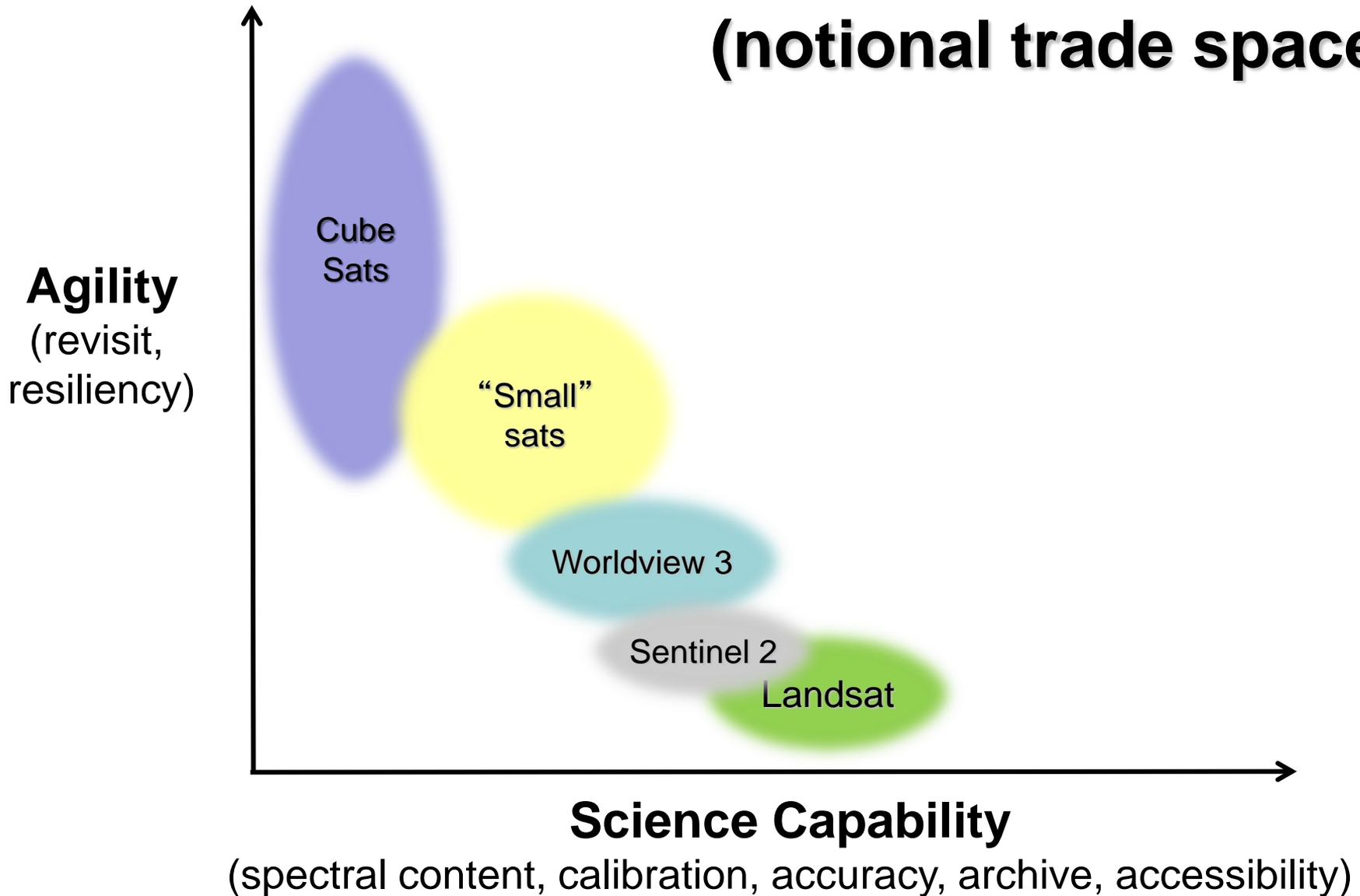
# Cal/val of MSS data (L1-L5)

## 1.3M scenes in archive

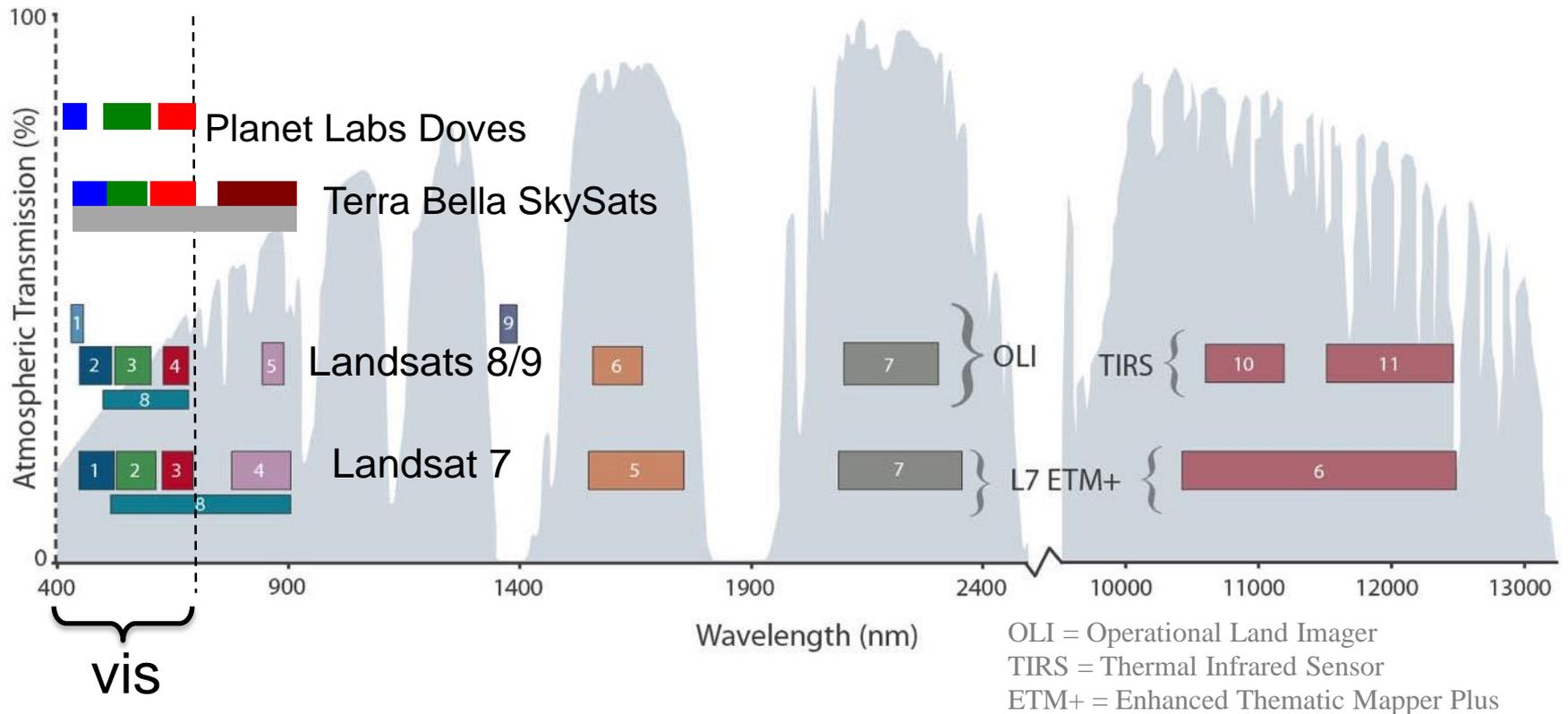
- Potential for some improvement to MSS archive
  - Requires significant work, especially from geometry team
    - May be significant work for radiometry team
  - Some MSS products will not be improved
    - Impossible to predict which scenes and how many until attempted
- LGAC (Landsat Global Archive Consolidation) effort will continue to increase EROS MSS archive
  - As MSS volume increases, further issues may arise



# A few words on cube sats (notional trade space)



# Spectral comparisons



# Summary

- JACIE is performing a vital service by educating the community on the often under-appreciated topic of cal/val
- Temporal data cube analysis– where “data science” meets remote sensing and cal/val
- Small sat community– independent cal/val needed to bring them into the fold
- Characterizing the *propagation* of cal/val error into subsequent higher level products for decision makers
  - Analytical methods
  - Numerical simulation methods (Monte Carlo)
  - Error-aware GIS and visualization



# Landsat and Commercialization

- **Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365)**
  - Belief that remote sensing would easily follow the path set by commercial telecommunications satellites
  - NOAA selected EOSAT Corp. to operate satellites, sell data, develop new missions
  - By 1992, the venture was deemed a failure
    - Prices rose significantly, stifling the user market
    - EOSAT ceased global collection of imagery
    - Instrument characterization and calibration were degraded, reducing the data's usefulness
    - EOSAT opportunities for commercial expansion were limited, particularly facing new competition from the French SPOT satellite
  - To ensure future continuity of Landsat data and operations, Federal development and operations were restored under the Land Remote Sensing Policy Act of 1992 (P.L. 102-555)
- **Landsat Data Continuity Mission Data Buy (2002)**
  - After the successful launch of Landsat 7, NASA attempted to outsource Landsat as a 'Data Buy' that would combine assurance of public and private data rights
  - NASA awarded two study contracts -- to Resource21 and DigitalGlobe – to examine public/private partnership approaches
  - The subsequent Source Selection was cancelled as one bidder dropped out and the other bidder did not generate sufficient capital to meet the Government's terms

**Despite commercialization failures, it remains an option for the future**

