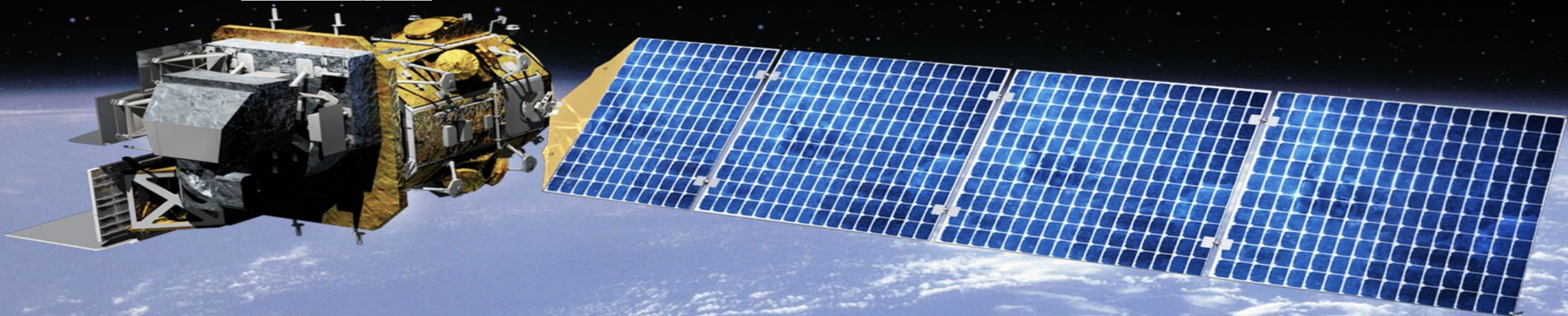




USGS National Land Imaging Program Update

WestFAST Webinar
24 June 2020

Timothy Newman
*USGS National Land Imaging
Program Coordinator*

USGS National Land Imaging (NLI) Program

Satellite Operations

Develop and operate systems to acquire, produce, preserve, and deliver products and services to meet civil Earth observation research and operational requirements

- Collect, archive, process & disseminate Landsat & Landsat-like data (Landsat 1-8, S-2)
- Operate the Landsat 7 and 8 satellites, calibrate and validate the incoming data
- Develop the Landsat 9 ground system in concert with NASA for FY 2021 launch
- Collect, maintain and analyze user requirements; inform 2020 follow-on Landsat Next decision

Science, Research & Investigations

Conduct science, research and technology investigations to improve upon and develop new products and services

- Applied science & applications, including drought monitoring, global cropland estimates
- Remote sensing research and development, including unmanned aircraft systems

Manage National Civil Applications activities

- Provide National Security Space system geospatial data supporting USGS applications
- Facilitate Federal civil agency use of these systems via Civil Applications Committee

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

What is Landsat?

The singular and unique data source for analysis, modeling, and decision support for a multitude of land, water, and natural resource management actions. Its 48-year time series, the world's longest, most widely used and cited land remote sensing data set, helps us to understand and manage natural and human-induced landscape change.



Multi-spectral coverage in VNIR-SWIR-TIR

-> to map surface composition & temperature

15 / 30 / 100 meter spatial resolution

-> to resolve human-scale land dynamics

16-day revisit frequency (8-days w/ two operational satellites)

-> global, seasonal coverage

Broad area collection => 12,000+ square miles per image

-> 1200 images/day = 15 million square miles/day

Highly calibrated “science quality” data

-> to resolve long-term trends & retrieve biophysical variables

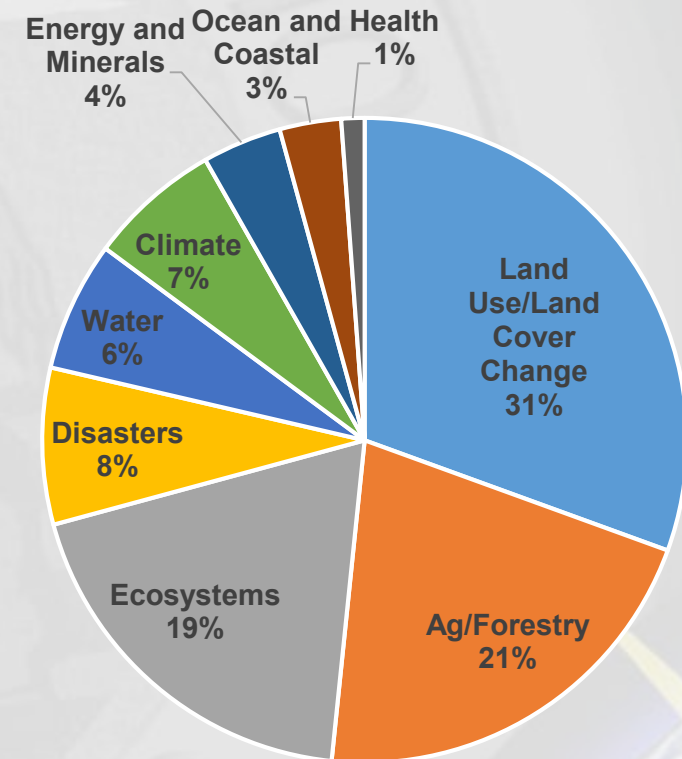
Free and Open Data policy since 2008

-> 30 million products distributed by USGS last year

Common Uses of Landsat data by Federal Agencies, States, and the private sector:

- | | | |
|------------------------------|-------------------------------|---------------------------|
| ● Agriculture and Forestry | ● Water Quality and Resources | ● Famine Early Warning |
| ● Regional Land Use Planning | ● Global Change Science | ● Carbon Assessment |
| ● Land Use/Land Cover | ● Flood Management | ● Drought Monitoring |
| ● Fire/Disaster Management | ● National Security | ● Transportation Planning |
| ● Energy and Mineral Mapping | ● Ecosystem Monitoring | ● Calibration/Validation |

User Applications



Landsat Users and Applications

Landsat is the most widely used land remote sensing data source within Federal civil agencies

Multiple Users:

- Federal Agencies (e.g. DOI, USDA, EPA, NASA, DOD, NOAA, State, USAID)
- State Agencies (Planning, Natural Resources, Transportation)
- University Researchers
- International Organizations
- Non Governmental Organizations (e.g., The Nature Conservancy, World Resources Institute, World Wildlife Fund, Resources for the Future)
- Commercial (e.g., Exxon-Mobil, MapBox, Descartes Labs, Esri, Gallo, Harris Corp, ITT, MDA Federal)
- Foreign space agencies and U.S. and foreign commercial operators
- Cloud Service Providers (e.g. Amazon Web Services, Google)
- General Public

Major Operational Programs:

- USDA National Agricultural Statistics Service Crop Type Mapping
- USDA Foreign Agricultural Service Commodity Forecasting
- USDA Risk Management Agency (Crop Insurance)
- USGS/EPA National Land Cover Dataset (NLCD)
- DOI/USDA LANDFIRE Program
- **Western States Consumptive Water Use**
- NOAA Coastal Change Analysis Program
- Global Forest Watch Forest Change Products

Multiple Applications:

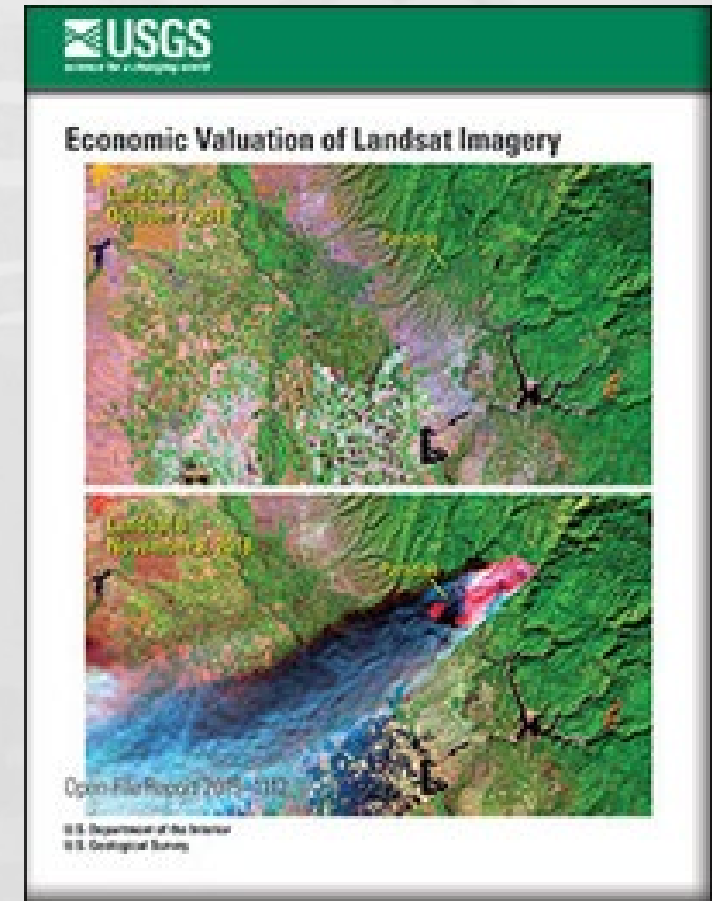
- Land use, land cover change
- Agriculture monitoring and forecasting
- **Water resource management, availability, quality, usage**
- Forest health, forest productivity, wildfire mapping and remediation
- Crop type mapping, yield estimation, efficacy of nutrients and pesticides
- Vegetation dynamics, ecosystem services, rangeland condition
- Land resource management
- Energy exploration and production
- Geologic mapping and mineral resource assessment
- Hazards monitoring and mitigation
- Emergency response, disaster assessment, risk mitigation
- Natural resource inventorying and monitoring
- Recreational planning & site suitability analysis
- Urban planning and development

Reference for Instrument Calibration and Base Data Layer for More Advanced Products

Updated economic valuation of Landsat

“Landsat imagery provided domestic and international users an estimated **\$3.45 billion in benefits in 2017** compared to \$2.19 billion in 2011, with U.S. users accounting for \$2.06 billion of those benefits.”

(Does not include value of scenes downloaded by cloud vendors or other downstream economic benefits such as value-added products)



Economic Valuation of Landsat Imagery

Open-File Report 2019-1112

Crista L. Straub, Stephen R. Koontz, and John B. Loomis

<https://doi.org/10.3133/ofr20191112>

Landsat Operations and Development Status

Landsat 7 Flight Operations (1999-)

- Collecting about 470 new scenes per day; latest fuel estimate projects operations into 2021.

Landsat 8 Flight Operations (2013-)

- Collecting up to 740 new scenes per day; frequent night and off-nadir imaging of volcano and fire imaging.

Landsat Archive Operations

- Over 8 million Landsat scenes available; many other datasets: ResourceSat-2 over US, Sentinel-2, Commercial satellite data, aerial photography, Unmanned aircraft system data.

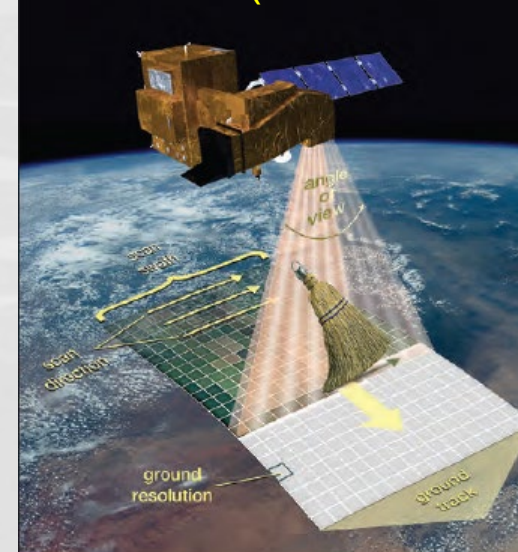
Landsat 9 (Launch in 2021)

- Essentially a copy of Landsat 8, but with important improvements for accuracy and resiliency (upgrade to fully Risk Class B); 14-bit data.

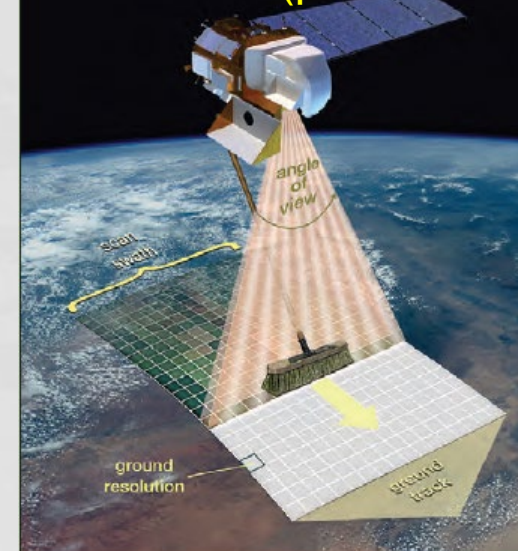
Landsat Next (~late 2020s launch)

- Technology and user needs studies over the past year led to an architecture study; team delivered report in January.
- NASA and DOI/USGS working together to agreed to a multi-component architecture; details to be announced with FY22 Budget.

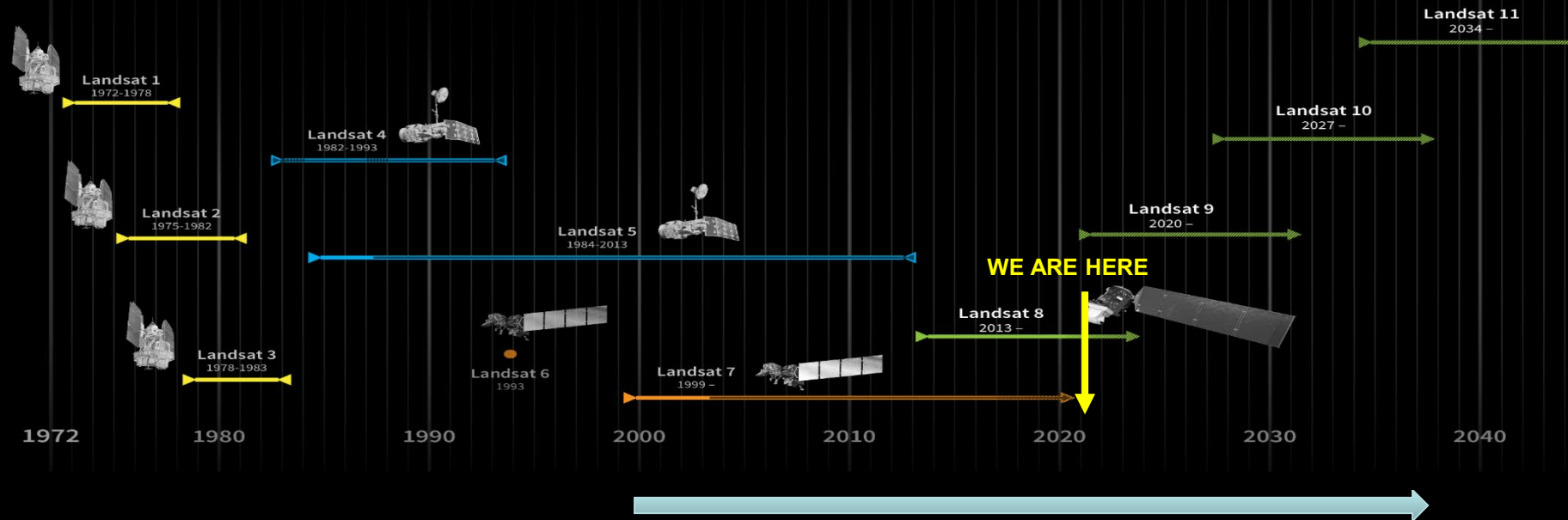
Landsat 7 (whiskbroom)



Landsat 8/9 (pushbroom)



BUILDING ON THE LANDSAT LEGACY



NASA-USGS Interagency Partnership

- NASA: Space Segment and Launch
- USGS: Operations & Data Processing/Distribution

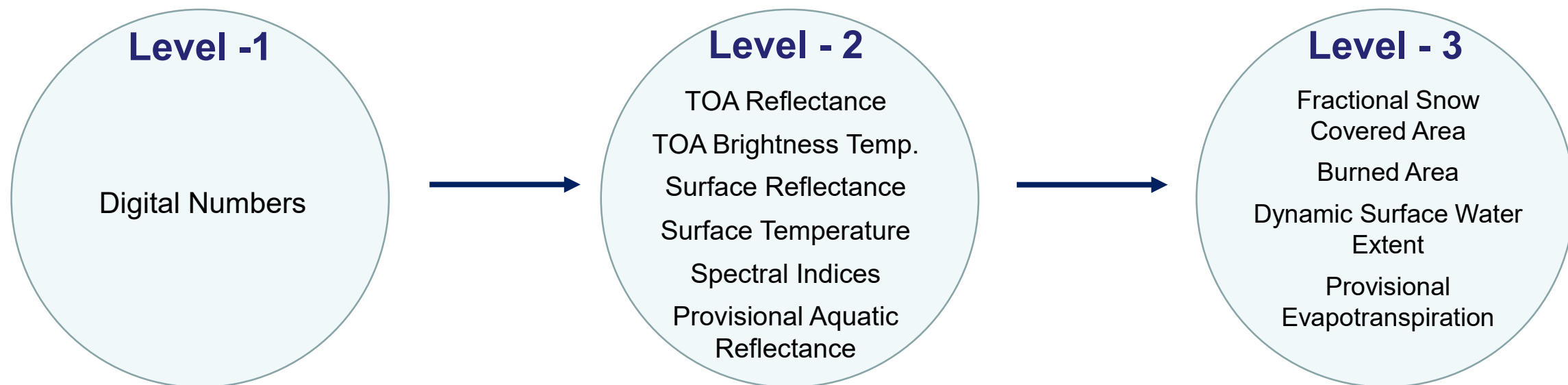
➤ **Sustainable Land Imaging (SLI) is a partnership between DOI/USGS and NASA to maintain a sustainable program for spaceborne land imaging**

- ❑ Landsat-9 development is on track to meet a FY 2021 launch date
- ❑ USGS documented user requirements across Federal agencies; NASA conducted technology investigations to reduce cost and risk in future missions
- ❑ Joint SLI Architecture Study Team (AST) completed its final report; AST delivered a set of viable architecture concepts for the next mission providing a basis for formulating future acquisition strategies
 - » NASA and USGS Leadership working to develop details and options as part of their FY 2022 budget requests



Landsat Science Products

- Relieve the burden of post-processing from the data users
- Help facilitate time-series analysis and land change studies
- Each level of products are tracked to the original data



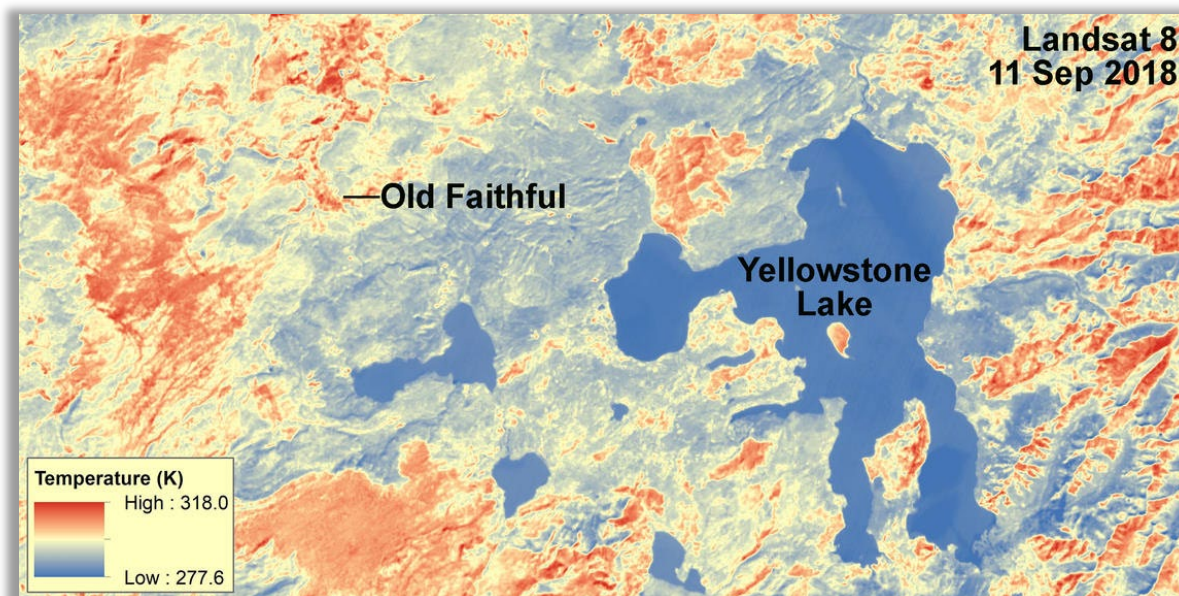
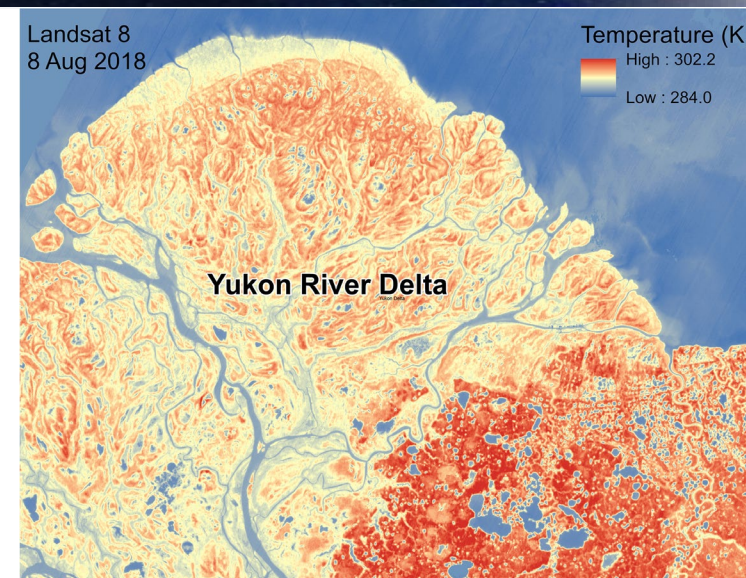
Landsat Surface Temperature

Goal: Enable monitoring of Earth surface temperature from space at 30m resolution from 1982 to the present. Used for energy balance, hydrological modeling, crop and vegetation health, extreme heat events, natural disasters and urban heat island effects.

➤ Available for the US, and Globally in summer 2020 (Landsat Collection 2)

➤ Data Access

- ❑ U.S. Landsat Analysis Ready Data via earthexplorer.usgs.gov
- ❑ Scene-based globally via earthexplorer.usgs.gov (summer 2020)
- ❑ [Product web page](#)

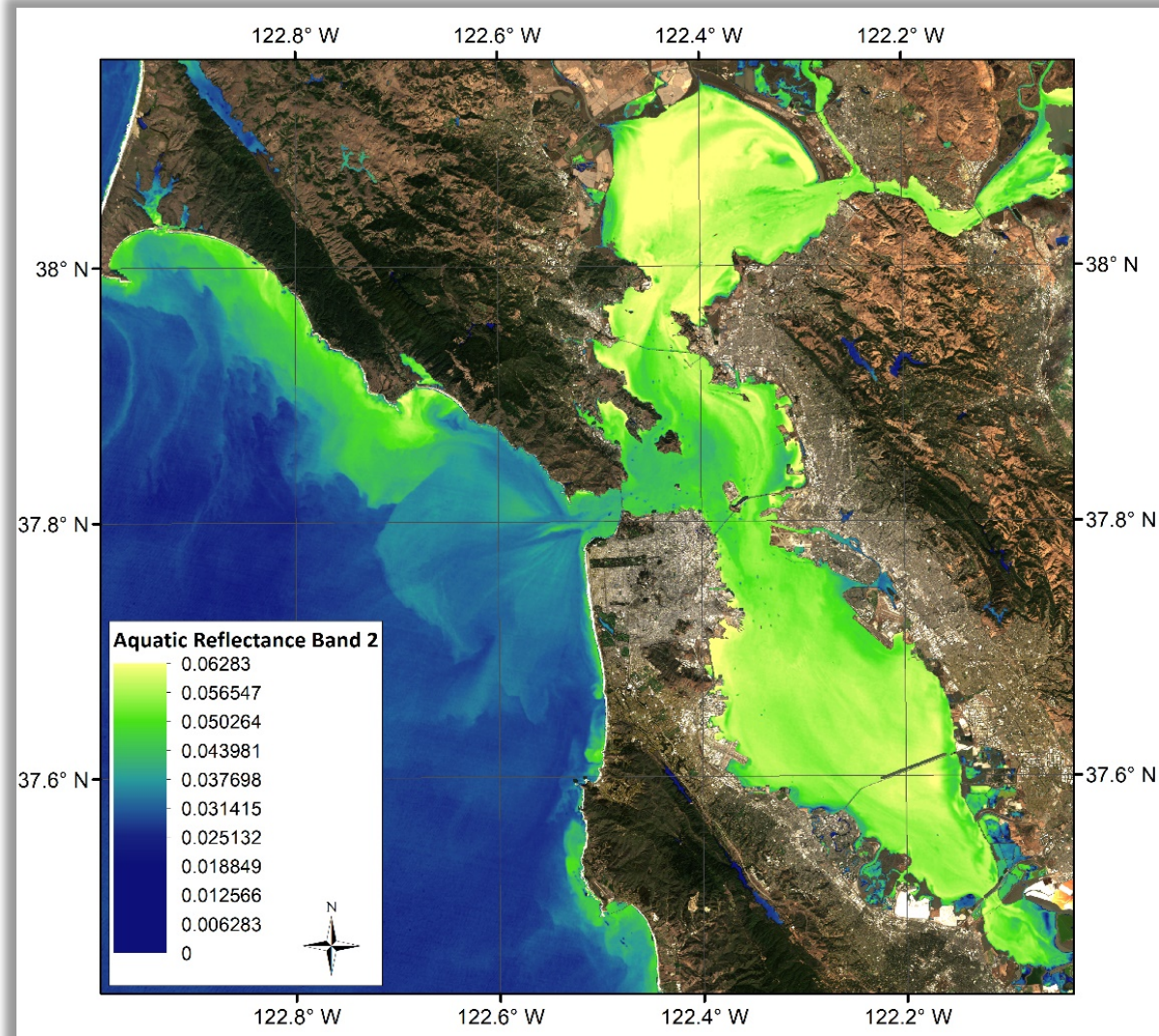




Landsat Provisional Aquatic Reflectance

Goal: Landsat 8 Provisional Aquatic Reflectance provides the foundational input to map optically active components of the upper water column in inland and near-shore waters. The moderate resolution (30m) offers the capability to map and monitor water constituents in coastal/inland water bodies and in marine/freshwater ecosystems, such as harmful algal blooms (HAB).

- Provisional Aquatic Reflectance for the conterminous U.S.
 - ❑ Landsat 8 (2013 - present)
- On-demand, scene-based via EROS Science Processing Architecture (ESPA)
 - ❑ espa.cr.usgs.gov/
 - ❑ [Product web page](#)



San Francisco Bay, 2018.



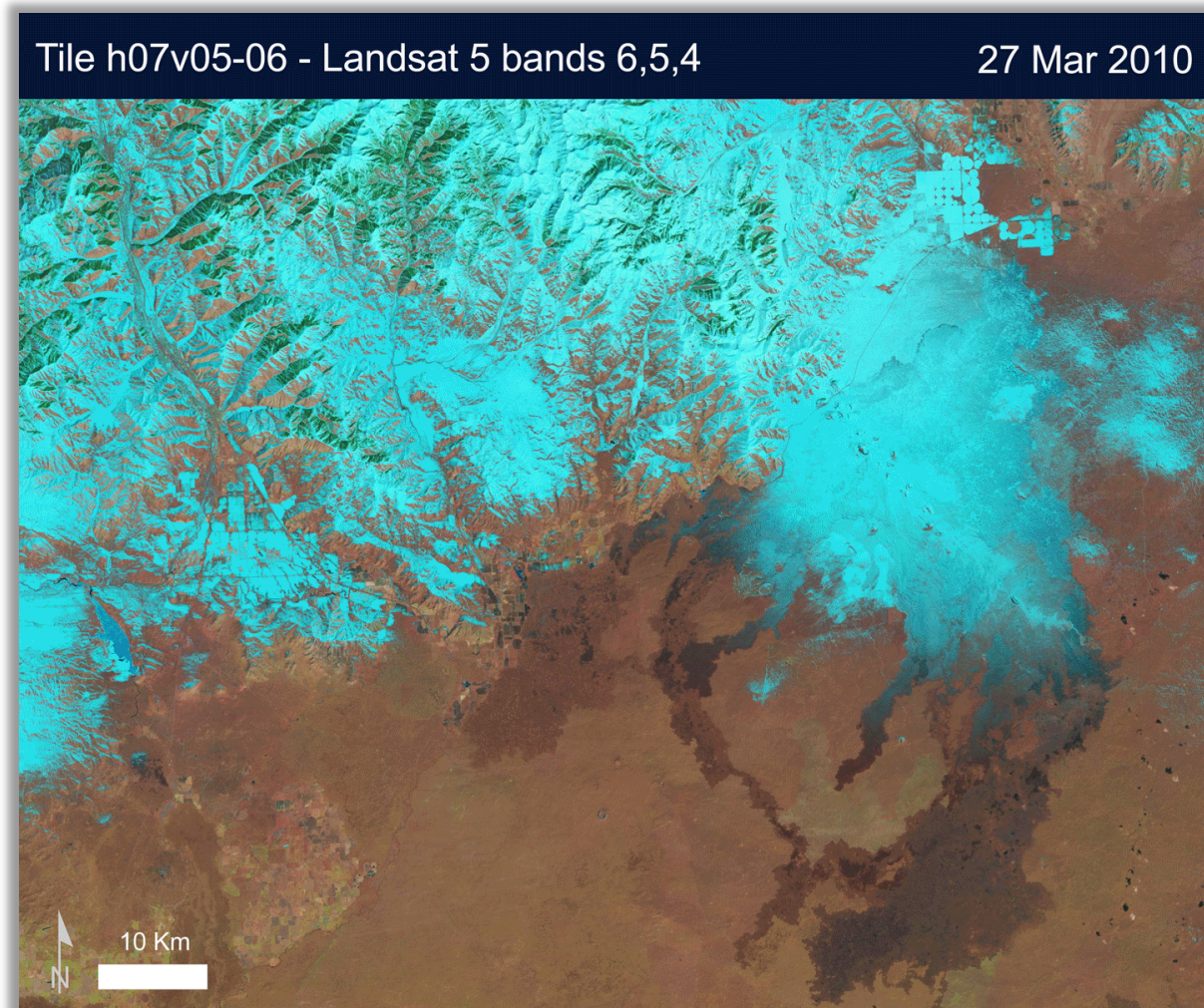
Landsat Fractional Snow Covered Area

Goal: Landsat Fractional Snow Covered Area (fSCA) products provide per-pixel fractional snow cover maps at the spatial resolution needed to resolve snow cover patterns across the Western U.S. Snow cover is crucial for Western States water supply and resources management.

- Available across Western U.S. at 30m from 1984 to present and monthly/annual fractional composite products will be available in summer 2020.

➤ Data Access

- ❑ earthexplorer.usgs.gov
- ❑ [Product web page](#)

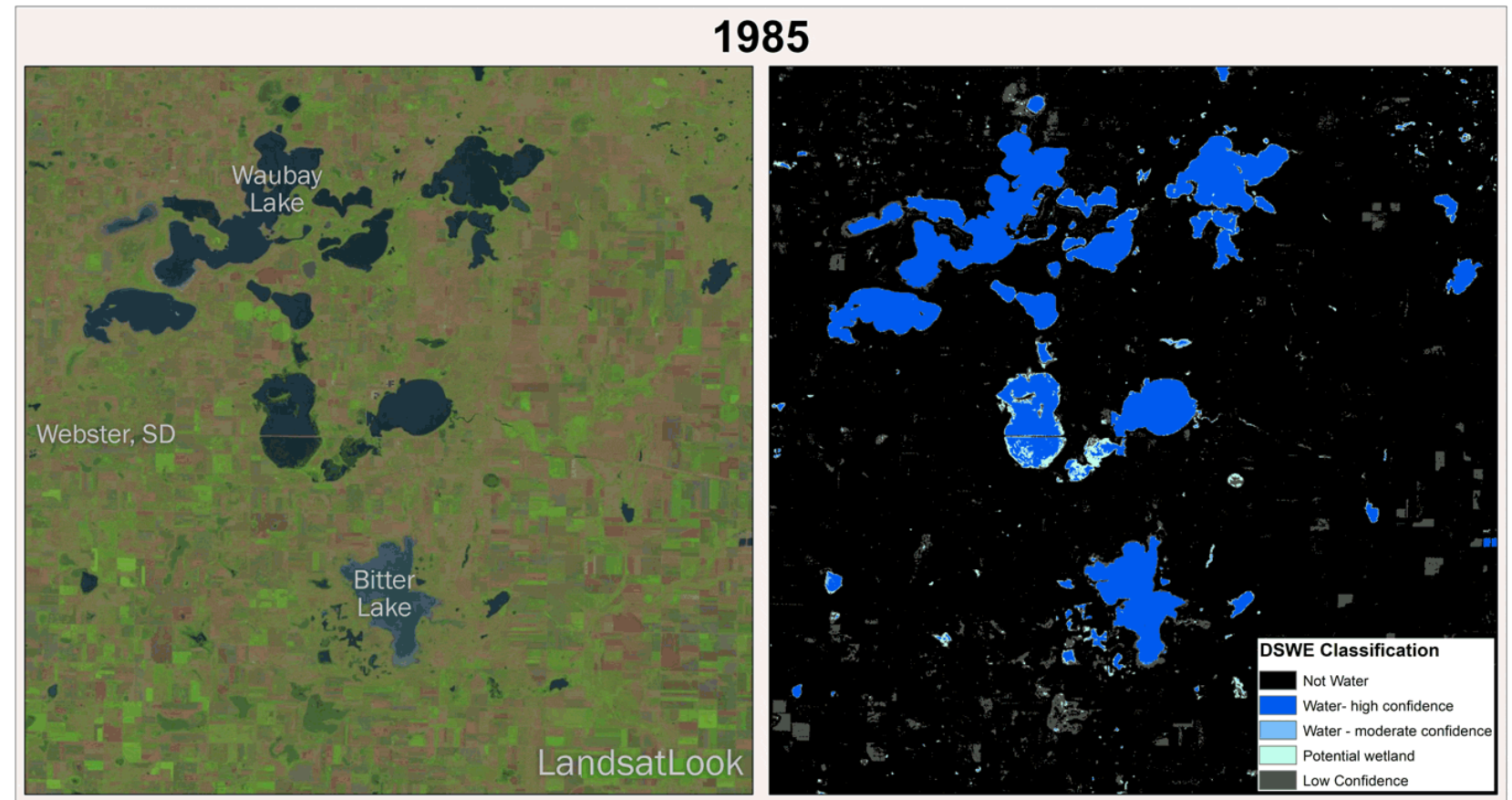


Craters of the Moon National Monument & Preserve, 2010.

Dynamic Surface Water Extent

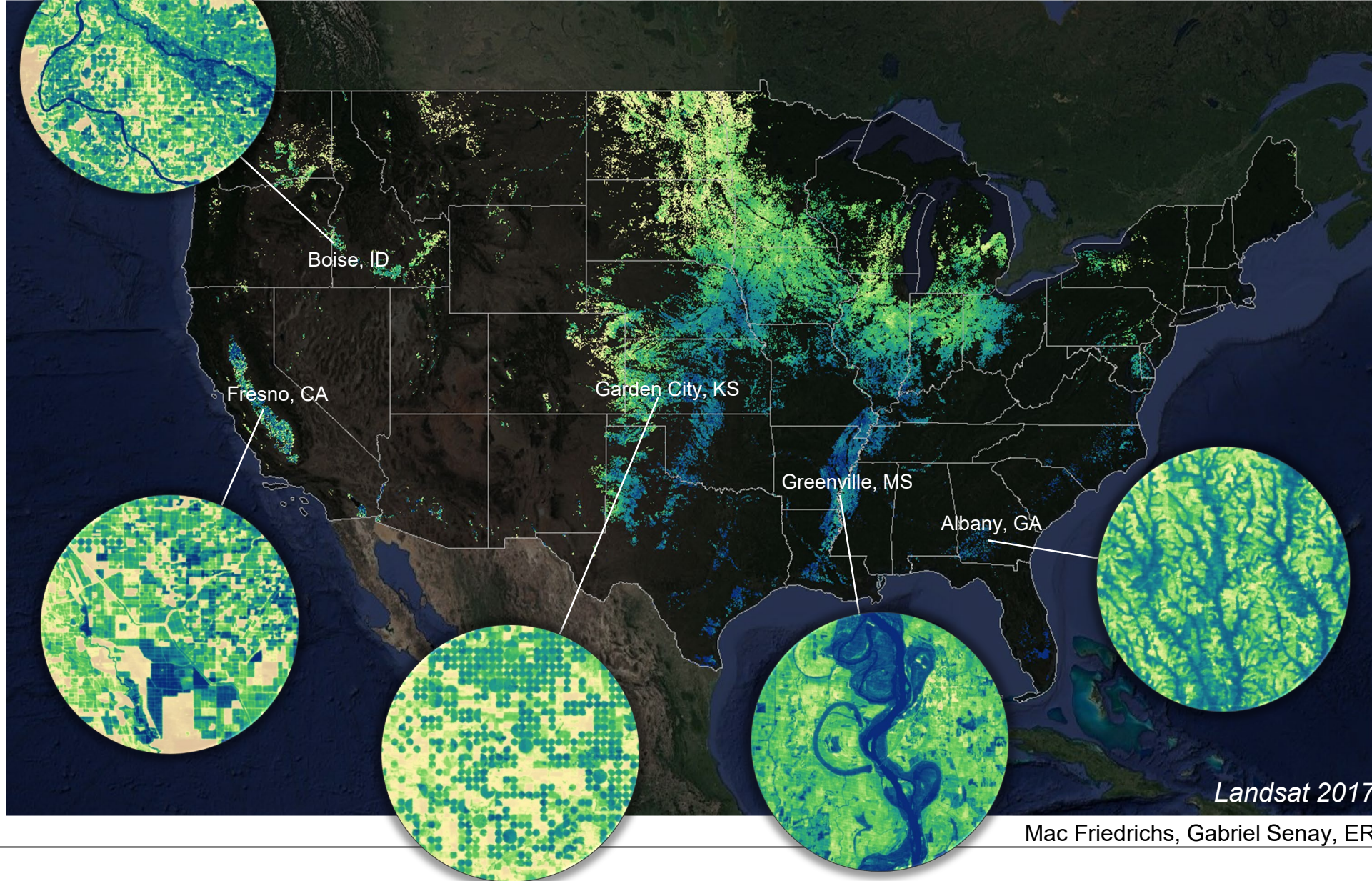
Goal: Enable monitoring of surface water from Landsat imagery at spatial and temporal resolutions useful for climate, hydrology and biologic science as well as land/water resource management.

Jones, J.W., 2019. Improved Automated Detection of Subpixel-Scale Inundation—Revised Dynamic Surface Water Extent (DSWE) Partial Surface Water Tests. Remote Sens., 11, 374



- ☐ Available for the US
- ☐ Data Access:
 - earthexplorer.usgs.gov
 - [Product web page](#)

Landsat Actual Evapotranspiration Science Product



- A provisional Landsat-derived Actual Evapotranspiration science product for the U.S. will be available in summer 2020.
- Example here captures cropland ET and water use.

Mac Friedrichs, Gabriel Senay, EROS

LCMAP

Land Change Monitoring Assessment and Projection

- **Monitoring**: Continuous tracking of land surface change using Landsat Analysis Ready Data
- **Assessment**: Summarizing landscape change, its causes, and consequences
- **Projection**: Modeling past and future landscapes and facilitating applications
 - Map Land Cover at any point across the full Landsat record
 - Understand and explain historical change to better anticipate future land change to inform decision makers

Expansion of urban and
agriculture classes,
Richland Washington



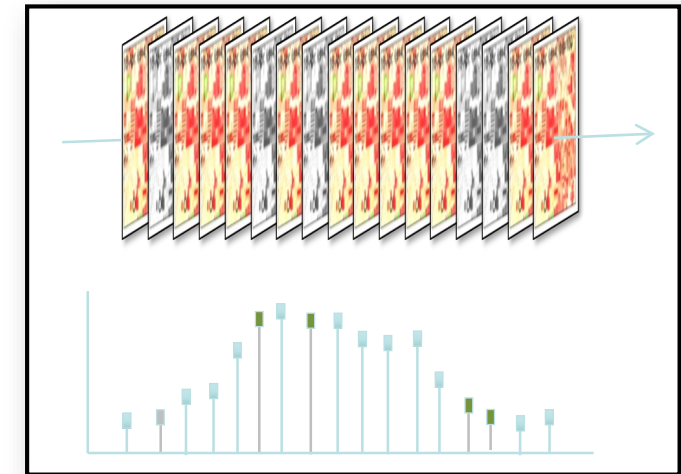


LCMAP Products: Descriptions

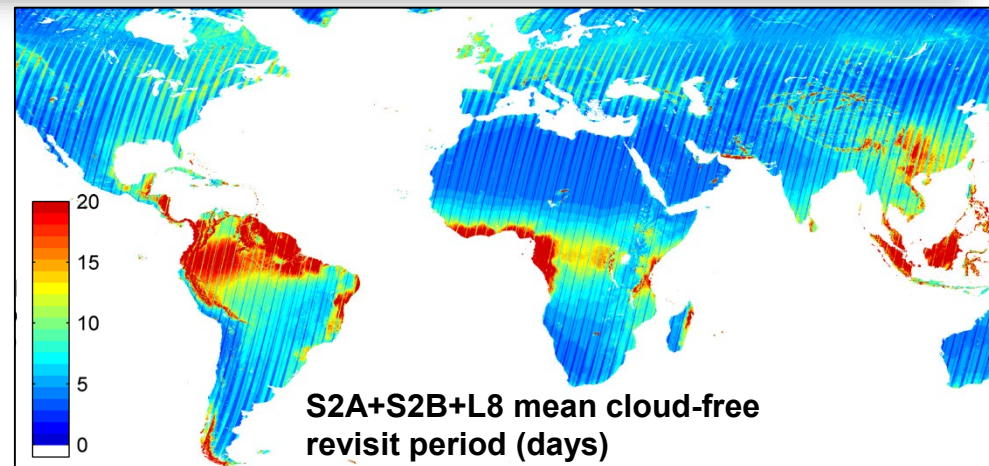
Name	Description	Note
Land Surface Change Products		
Time of Spectral Change (SCTIME)	The day that a spectral change was detected for a given year	Provides data indicating location and timing of spectral breaks
Change Magnitude (SCMAG)	A measure of the spectral magnitude of the change found within a given year	Higher values may be indicative of different types of changes
Time Since Last Change (SCLAST)	The cumulative number of days since the last spectral change occurred as of July 1 st of the given year	Provides an indicator of how long a location has been in its current state
Spectral Stability Period (SCSTAB)	A measure of the amount of time in days that a pixel has been spectrally stable	Provides information of the frequency of land surface change
Model Quality (SCMQA)	Characterization of time series model quality as it relates to model input data and model fit	Provides a spatial measure for interpreting LCMAP product results
Land Cover Products		
Primary Land Cover (LCPRI)	Land cover classification consisting of eight general land cover types	Classes: Developed, Cropland, Tree Cover, Grass/shrub, Wetland, Water, Ice/Snow, Barren
Secondary Land Cover (LCSEC)	Land cover classification consisting of eight general land cover types	Alternative cover class with the 2 nd highest algorithmic probability, same as primary LC classes
Primary Land Cover Confidence (LCPCONF)	A measure of confidence in the primary land cover class designation	Measure from 0 to 100; higher values imply higher levels of confidence
Secondary Land Cover Confidence (LCSCONF)	A measure of confidence in the secondary land cover class designation	Measure from 0 to 100; higher values imply higher levels of confidence
Annual Land Cover Change (LCACHG)	Indicator of thematic land cover change that has occurred from the prior year to the current year (in other words, From:To land cover)	Categories that indicate two land cover states, the prior year land cover and the current year land cover

Harmonized Landsat Sentinel-2 (HLS)

- Merging Sentinel-2 and Landsat 8 data streams can provide **~3 day global coverage**
- Goal is “seamless” near-daily 30m surface reflectance record including atmospheric corrections, spectral and BRDF adjustments, re-gridding
- Processing migrated to Amazon Web Services (AWS) via NASA Earth Science Technology Office (ESTO)
- Landsat-8 data set: 1,100k products From Mar-2013 to Present (135 TB); Sentinel-2 data set: 420k products From Jun-2015 to Present (60 + 274 TB)
- Prototype for a **multi-sensor Analysis Ready Data** product



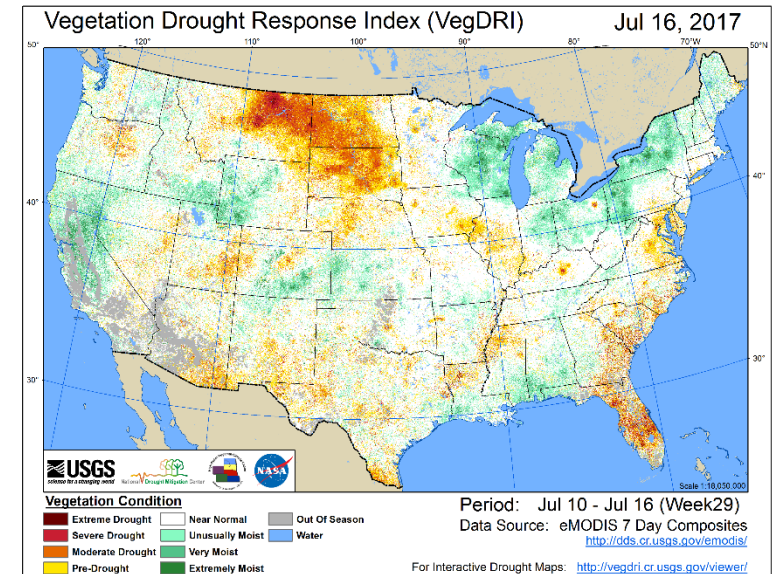
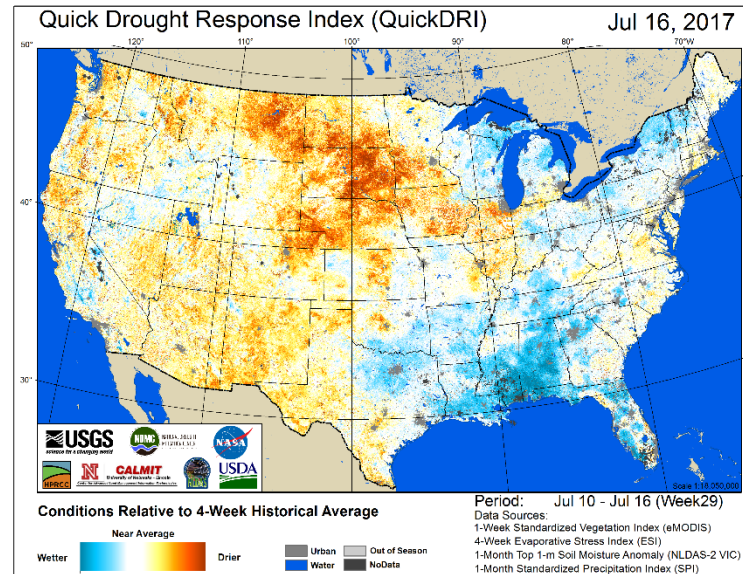
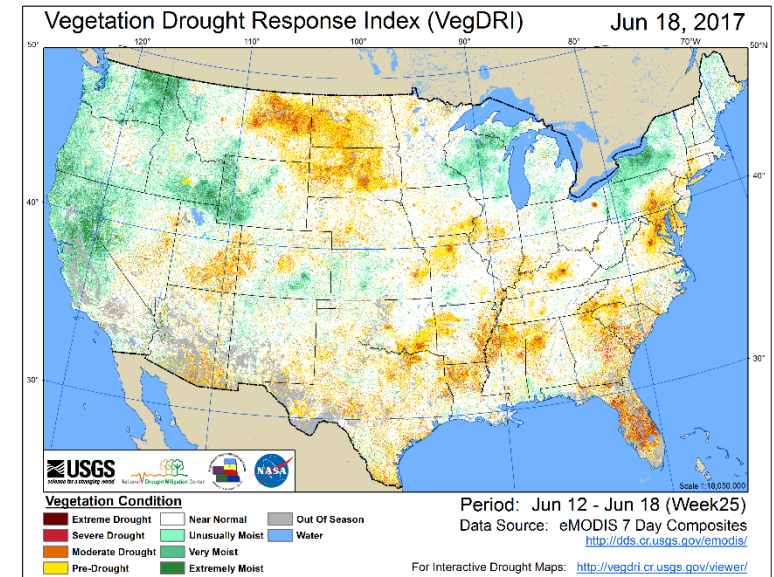
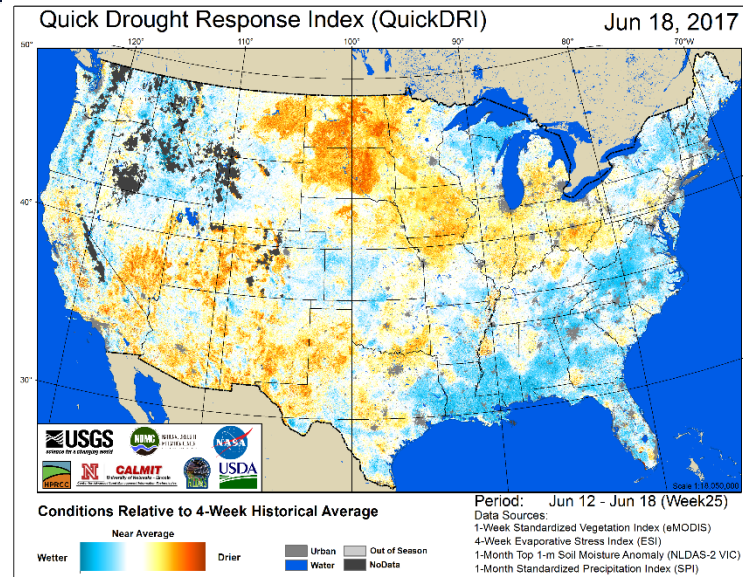
Claverie, M, et al. "The Harmonized Landsat and Sentinel-2 surface reflectance data set." *Remote sensing of environment* 219 (2018): 145-161.



Credit: Jeff Masek, NASA

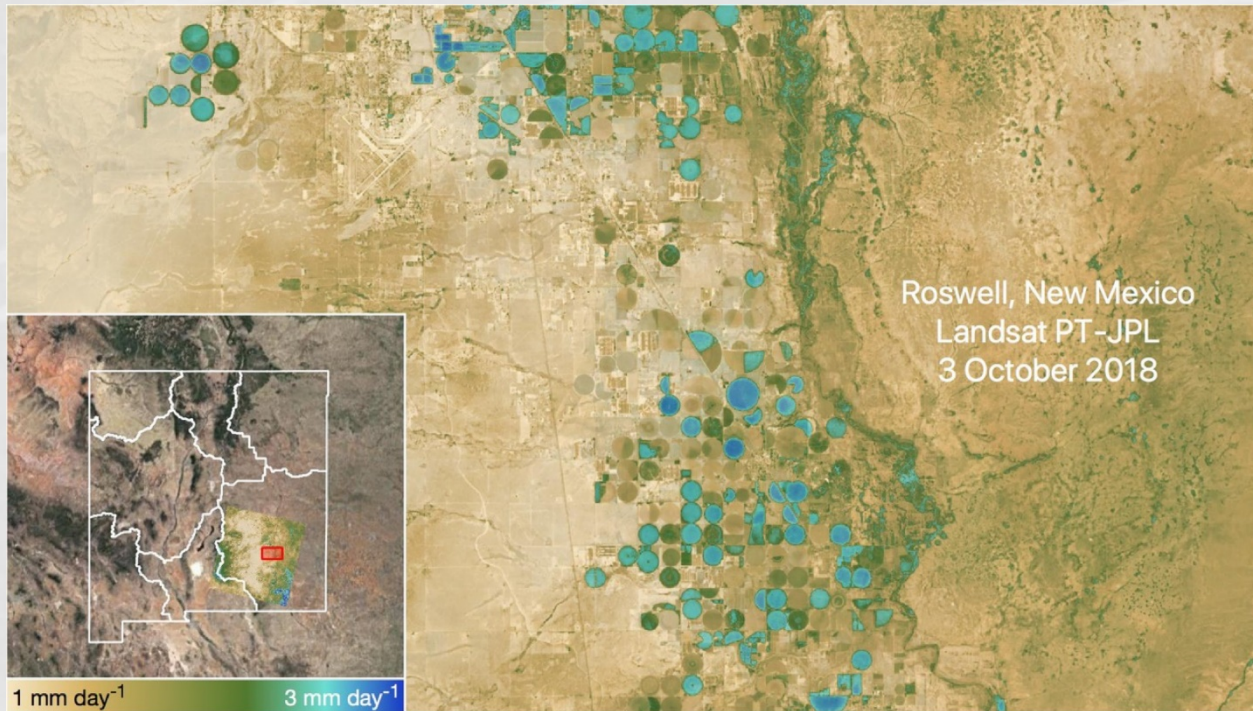
National Drought Monitoring for decision support

Goal: Improving monitoring of vegetation drought stress, phenological cycles and irrigated agriculture. Contribute to answering the questions “What are interrelations among climate, land cover, land use and water resources?” and “How does the relative strength of different drivers and controls on vegetation condition and water resources vary across time and space?”



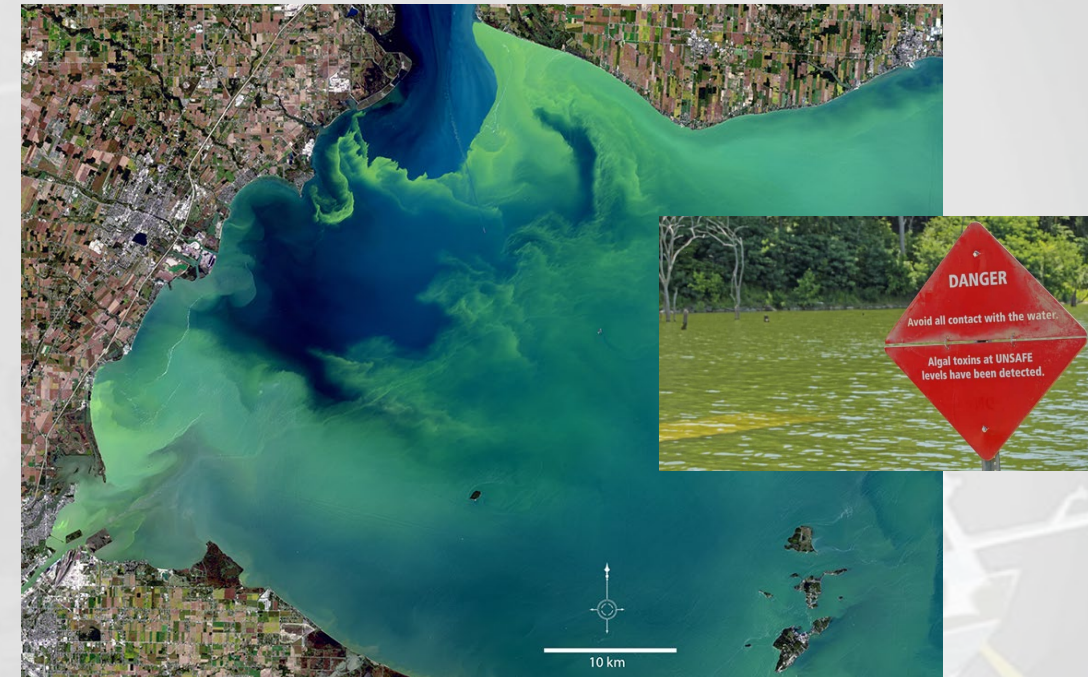
Landsat and Water Monitoring

Every Western State uses Landsat's unique thermal capability for managing consumptive water use and facilitating water rights transfers and agreements



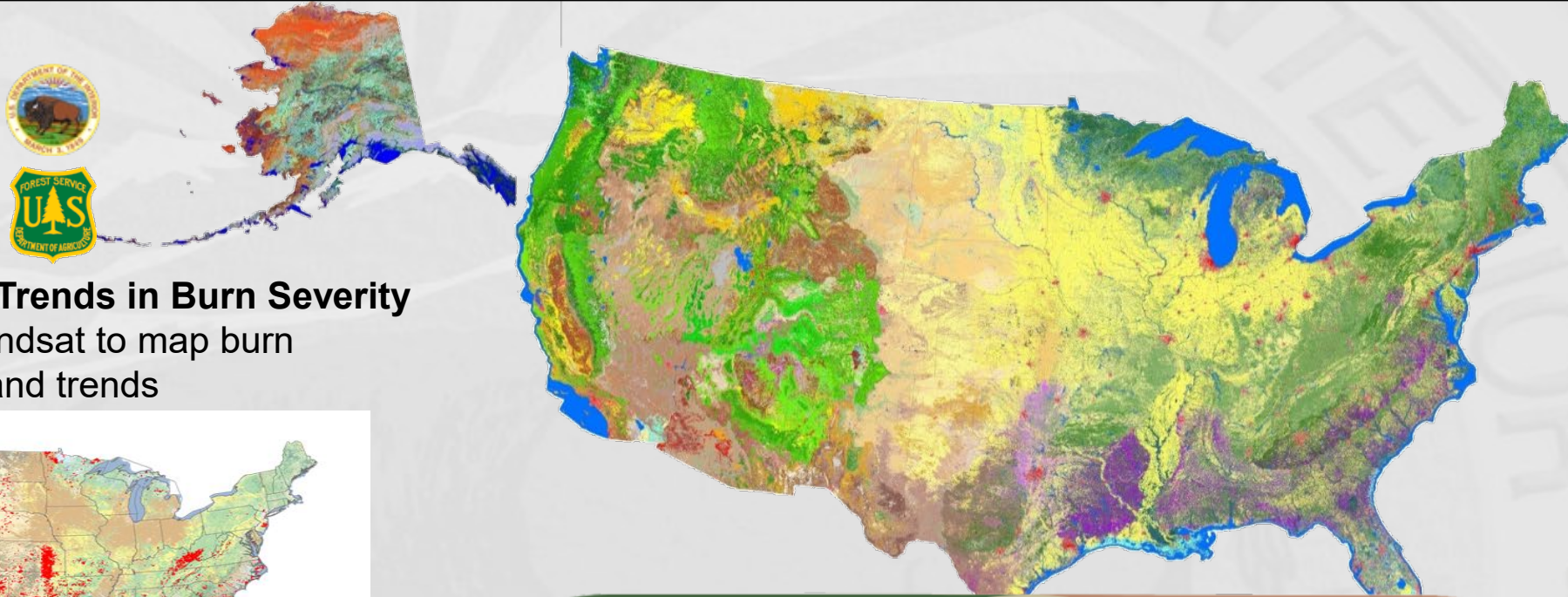
Landsat-derived map of water use by center pivot irrigation fields in Roswell, New Mexico in October 3, 2018. Image credit: Fisher et al. NASA, AGU19

Landsat is used to detect and address harmful algal blooms in lakes and coastal waters



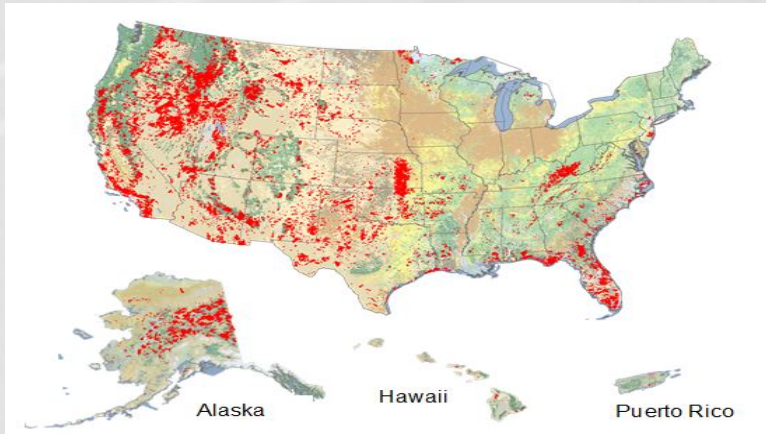
A hazardous algal bloom containing the toxin *microcystis* covered large portions of western Lake Erie in September 2017. Swirls of algae can be seen south of the Detroit River's mouth in this natural-color Landsat 8 image. Credit: USGS EROS

Landsat and Vegetation and Fire-Fuels Mapping (DOI/USDA)



LANDFIRE team gathering field data in a remap prototype area of central Idaho

The Monitoring Trends in Burn Severity program uses Landsat to map burn severity, extent, and trends



The Burned Area Emergency Response program equips ground teams with Landsat-based burn severity maps immediately following fires to aid in remediation efforts

LAND

- land cover/disturbance change
- endangered species monitoring
- climate-carbon-ecological modeling/research
- wildlife/habitat activities

- regional/national use
- informs budgets
- natural resource management
- strategic decision support
- updated regularly

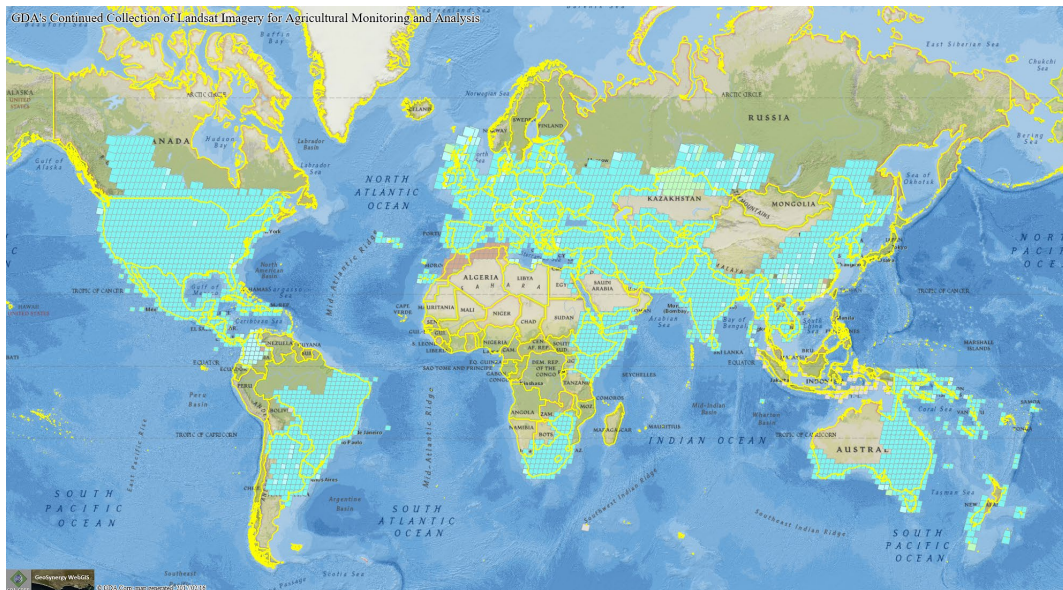
FIRE

- fuel treatments
- fire suppression
- fire management planning
- active fire management

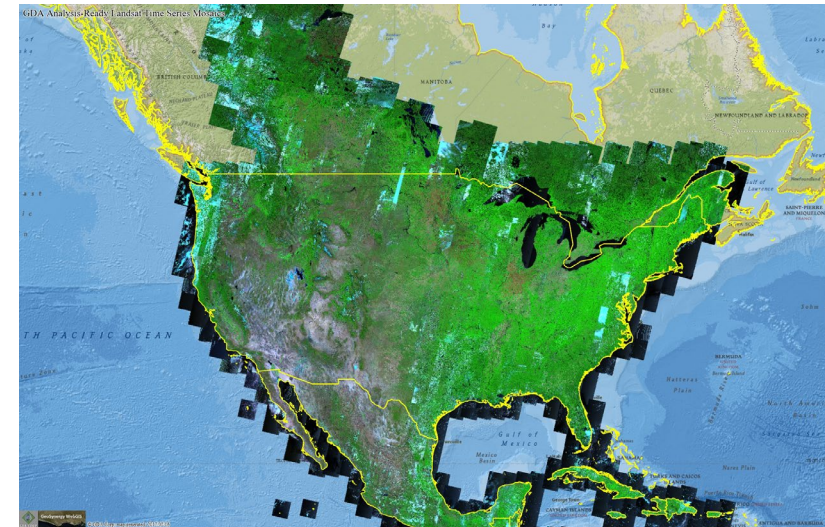
LANDFIRE uses Landsat to provide a common "all-lands" set of vegetation and wildland fire/fuels information, for strategic fire and resource management planning and analysis via 20+ national geospatial layers, databases, and eco-models

Monitor and Forecast Global Crops Using Landsat Data

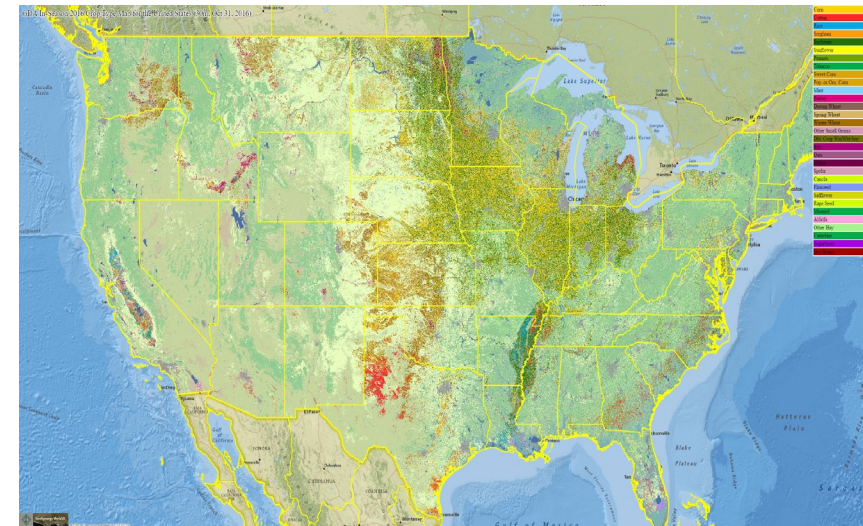
- Global crop mapping, monitoring, assessments, and forecasting.
- Use analysis-ready calibrated Landsat data for global crop analysis, supporting field-to-country assessments, and reducing more than 80 percent of the imagery data volume.



Landsat imagery coverage for global crop areas



Analysis-ready Landsat data for the US



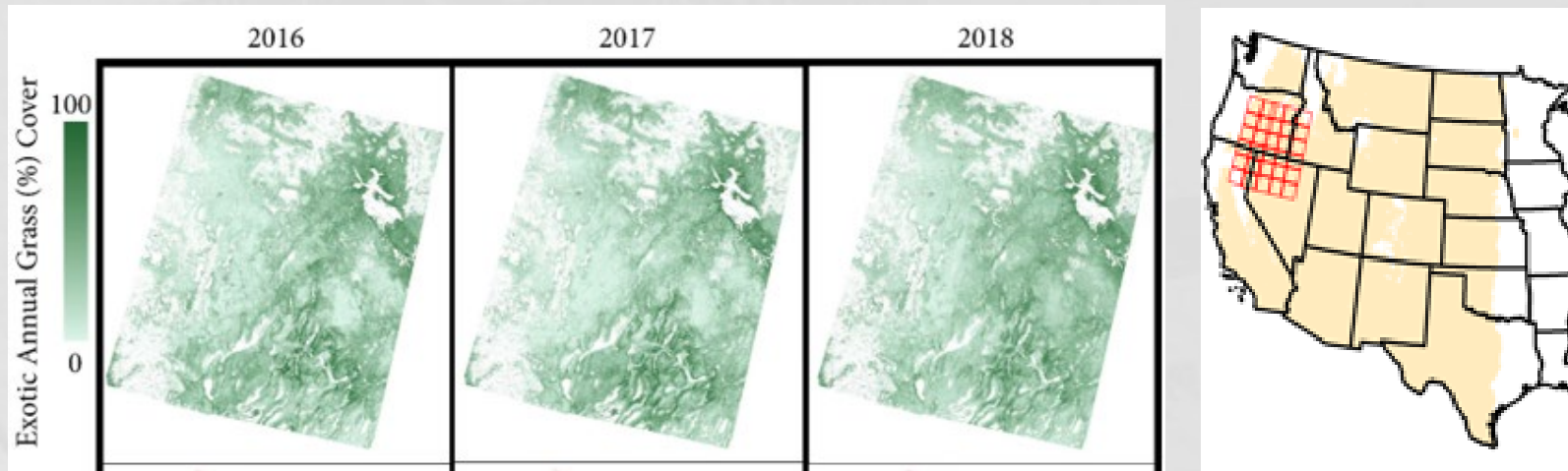
Crop map of the US

Invasive Species Mapping

- Invasive grasses such as cheatgrass contribute to ecosystem degradation and increased fire intensity in the Western United States.
- Landsat data, combined with Europe's Sentinel-2 data can provide 2-3x/week observation frequency for Western state land managers' early detection and rapid response.
- Contributes to BLM Sagebrush Ecosystem Conservation and the Integrated Rangeland Fire Management Strategy Actionable Science Plan.



Mapping invasive grass cover using Harmonized Landsat and Sentinel-2 data



Expanding mapping effort to all Western U.S. using the USGS Denali Tallgrass High Performance Computing capability and the Landsat archive

National Land Imaging Future Directions

Leveraging the diversity of Earth Observations to meet the Diverse Needs of Science & Operational Users

Improve Operational Capabilities

Enhance Research, Development and Innovation

Expand Product and Service Usability

Ensure Community Engagement

Landsat Next

Cross-Calibration of sensors

Hyperspectral Technology Investigations

International & Commercial Partnerships

Landsat 9

Sentinel/Landsat Ops & Data Harmonization

Investigate new science and technologies

National Security Space Data & Services

Land Change Monitoring Assessment and Projection / EarthMAP

Analysis Ready Data

Thoroughly understand user needs and capabilities available to meet them

Landsat 8 Flight & Ground Operations

Increasing User Satisfaction