



USGS NATIONAL LAND IMAGING PROGRAM UPDATE – LANDSAT NEXT

TIM NEWMAN

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U.S. GEOLOGICAL SURVEY (USGS)
U.S. DEPARTMENT OF THE INTERIOR*

WSWC SPRING MEETINGS

MAY 23, 2023



What is Landsat?

The world's longest continuously operated land remote sensing satellite series and most widely used and cited land remote sensing data set, helping us understand and manage natural and human-induced landscape change via a multitude of land, water, and natural resource management applications.



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

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

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 satellites)

-> global, seasonal coverage

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

-> 1400 images/day = 18 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 and 4 billion data accesses via Commercial Cloud in the last year alone

Landsat Operations Status

Landsat 9 (2021 -)

Collecting more than 700 new scenes per day; full mission transitioned to USGS in 2022

Landsat 8 (2013 -)

Collecting more than 700 new scenes per day; night and off-nadir imaging of volcanos and fire imaging

Landsat 7 (1999 -)

Lowered into storage orbit; awaiting NASA satellite rendezvous and refueling; still collecting new imagery



Earth Resources Observation and Science Center (EROS)

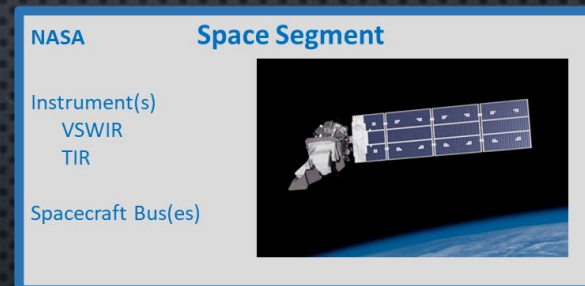
Landsat Archive Operations

Reprocessed Landsat "Collection 2" available on the Amazon Cloud.

On track for more than **10 billion** user accesses this year!

Landsat NASA/USGS Partnership - Sustainable Land Imaging (SLI)

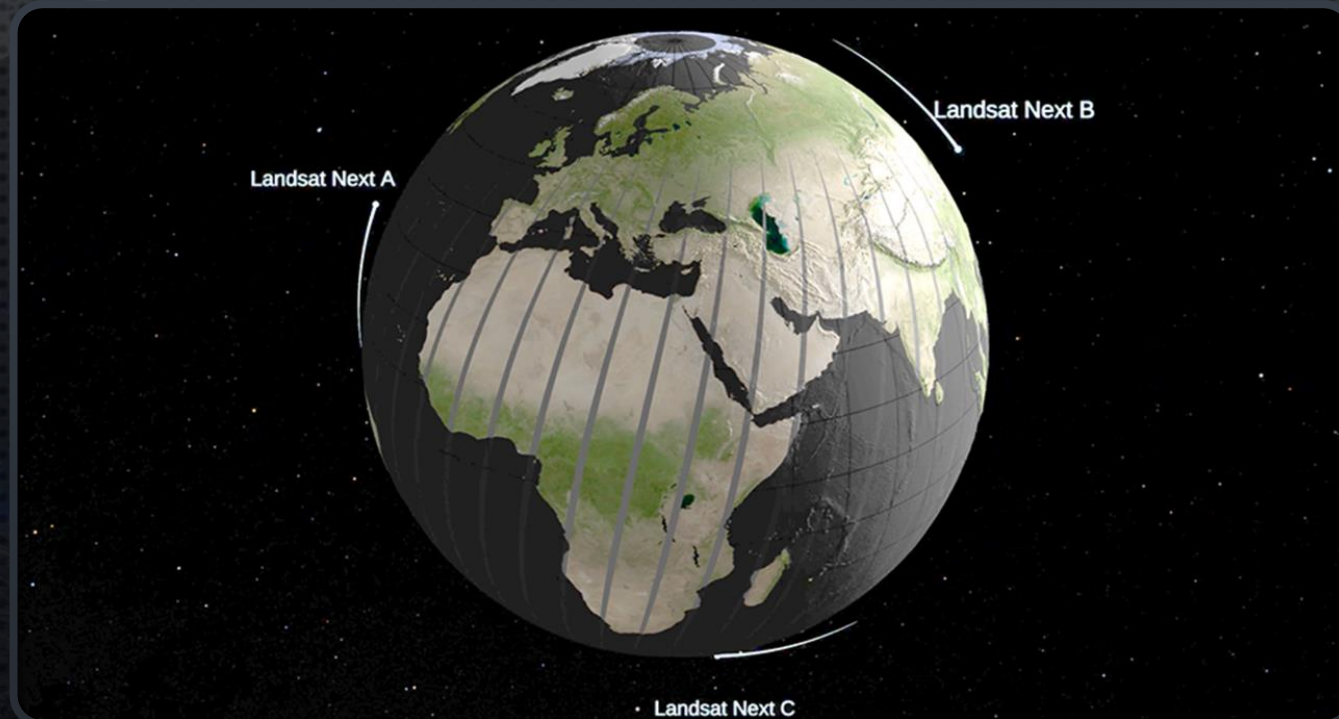
- NASA and Interior/USGS partner to provide independently-funded joint-agency development and operations to sustain the Landsat series of measurements for federal, State, Tribal, local, academic, commercial, non-profit, and international users
 - Both agencies work together to plan for and jointly develop new missions
- NASA is responsible for space segment (imaging instrument(s), Spacecraft), launch and on-orbit checkout
 - Includes engineering support for mission operation readiness and support for on-orbit anomalies
- USGS builds and delivers the ground system, operates the observatories after the commissioning phase and provide data archiving, processing and distribution
 - Systems engineering support during development
 - Mission Operations Center (MOC) (and backup)
 - Ground Network
 - Data Processing and Archive System (DPAS)
 - Provide MOC development and Flight Operations Team



NASA and Interior/USGS SLI Partnership is Developing Landsat Next

Landsat Next

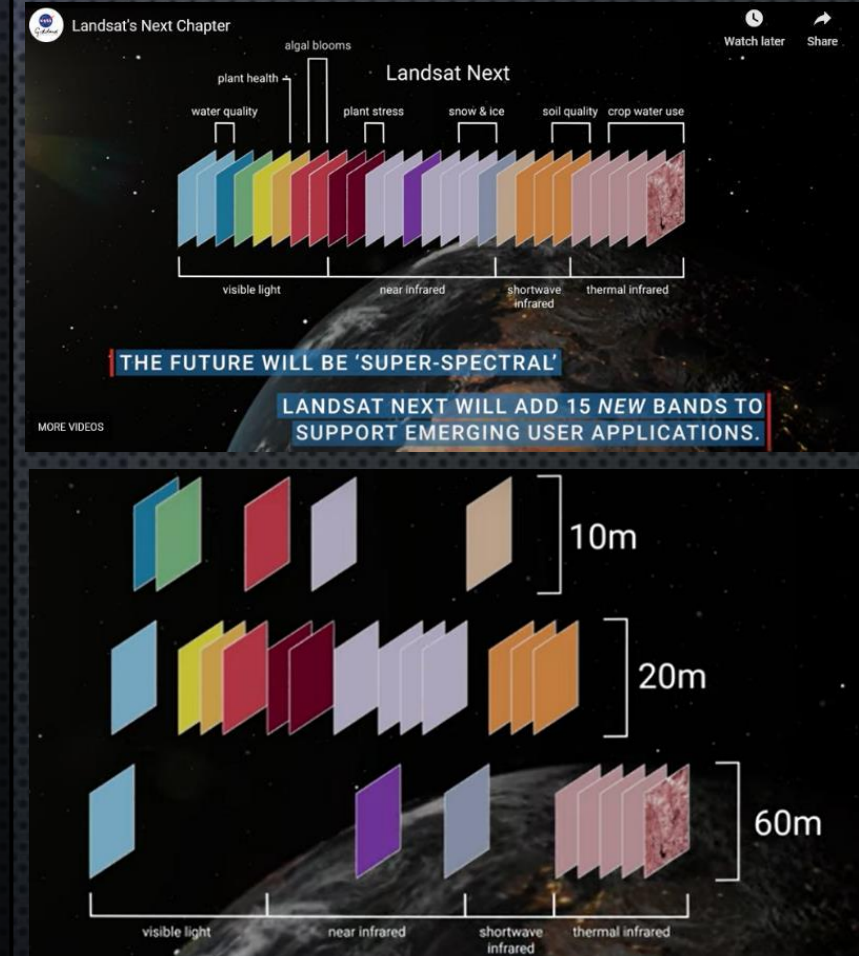
- A robust spaceborne, land imaging system to ensure continued collection of data for processing into useful and efficient information products for use by the wide range of interested science communities
- Mission Concept: Collection of “superspectral” land observations featuring richer spectral information and higher spatial resolution than Landsat 8 and 9 with improved temporal frequency
 - Intended to replace Landsat 8 to ensure continuity of the Landsat data record in the event of an unexpected Landsat 9 failure on-orbit
- Enables users to:
 - Observe areas experiencing the most rapidly changing landscape from drought, glacier and permafrost melt, harmful algal blooms, and urban heat islands
 - Track and monitor Earth surface condition and change, including their drivers and impacts
 - Predict future risk and vulnerabilities for mitigation and adaptation strategies



NASA “Landsat’s Next Chapter” Video <https://svs.gsfc.nasa.gov/14262>

Landsat Next Milestones/Status

- **November 2017:** SLI Joint Steering Group requested a Landsat 10 Architecture Study to develop a set of viable architecture concepts
- **January 2020:** NASA/USGS Architecture Study Team delivered its final report to the SLI Joint Steering Group, with several distinct “Roadmap” options
- **April 2020:** SLI Joint Steering Group approved the Team’s Superspectral “Roadmap 1” recommendation and assigned Landsat Next project teams
- **December 2021:** NASA/USGS projects recommended a “Triplets” Superspectral Landsat Next mission concept, delivering improved spectral/spatial/temporal performance to meet evolving user needs
- **February 2022:** SLI Joint Steering Group approved the project-recommended Landsat Next Superspectral Triplets mission concept, targeting 2029 launch
- **November 2022:** Landsat Next Project successfully passed its Key Decision Point A milestone to enter NASA Phase A, working toward 2030/2031 launch
- **February 2023:** NASA released Landsat Instrument Suite (LandIS) Draft Request for Proposals and key procurement documents
- **April 2023:** NASA awarded spacecraft studies for analyzing engineering questions to solidify spacecraft requirements
- **Spring/Summer 2023:** NASA will release the Landsat Instrument Suite (LandIS) Final Request for Proposals
- **Spring/Summer/Fall 2023:** USGS conducting studies to better understand the required Landsat Next mission ground system elements



Landsat Next Requirements Meet Emerging Needs

Multi-spectral → Super-spectral

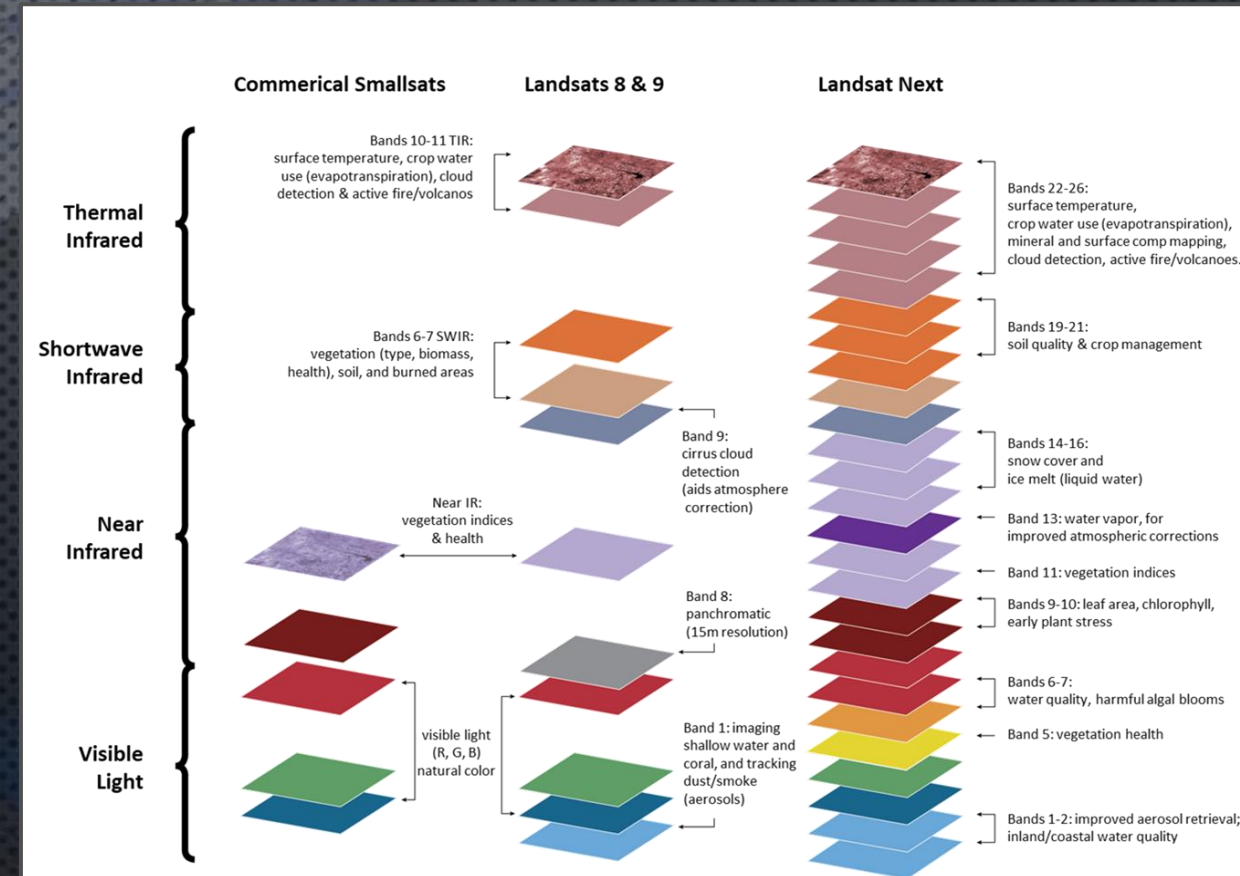
The USGS spent several years engaging with the user community to develop and validate requirements and set priorities for Landsat Next to meet emerging needs:

Improved revisit frequency (6-day vs 8-day) to support applications which require ~weekly clear views, such as crop health and productivity, forestry, disasters, water quantity/quality, snow/ice state, wildfire

Higher spatial resolution (10/20-meter data vs 30-meter for VSWIR and 60-meter vs 100-meter for TIR) to support monitoring of small agricultural fields, land use/land cover, glacier/ice sheet studies, coastal applications, forest disturbance, urbanization, and other applications

Additional targeted spectral bands to support emerging applications in water quality, snow hydrology, soil mapping, and other areas

Maintaining radiometric quality established by Landsat 8/9



Landsat Next will provide more than twice as many spectral bands as Landsat 8/9, with spatial resolution improved by a factor of 2, and significantly improved repeat coverage (from 8 to 6 days)



Driving Applications for Landsat Next

Societal Benefit Area	Application	Science Benefits from Landsat Next
Agriculture	U.S and global agricultural monitoring	Landsat Next will allow USDA Foreign Agricultural Service (FAS), Farm Service Agency (FSA) and National Agricultural Statistics Service (NASS) more precise observation of crop emergence.
	Crop residue monitoring/soil conservation	Landsat Next observations in the early growing season can allow USDA Natural Resources Conservation Service to detect cover crop and crop residue for soil conservation at the field-scale.
Forestry	Forest health monitoring	Landsat Next will aid USFS, BIA, BLM, FWS, NPS and USGS in the detection and identification of insect/disease agents for forest health monitoring, since symptoms are often seasonal and transient.
Water Resources	Evapotranspiration and water use	Landsat Next frequent observations of evapotranspiration (ET) are needed for field-scale ET estimates and continuous water use monitoring operationally by BOR, USGS, FAS, NASS and Western States.
Water Quality	HAB detection and monitoring	The new targeted spectral bands for water quality provided by Landsat Next will enable detection of specific organisms that cause harmful blooms.
Cryosphere	Snow/water availability	Higher temporal frequency and new targeted spectral measurement capabilities of Landsat Next will reduce cloud cover contamination while increasing detection.
Public Health	Monitoring urban heat islands	Landsat Next can help capture more frequent, intense, and longer heat waves as climate change indicators.
Wildfire	Pre- and post-fire assessment	Landsat Next higher temporal revisit is needed to capture the onset of more frequent wildfires and provide immediate post-fire response.

2023 is a Huge Year for Communicating the Value of Landsat!

Challenge: How to convey the need to develop another Landsat mission in a cost-constrained and inflationary budget environment?

Solution: Engage prolifically across many audiences to describe why Landsat matters and continues to be needed in the decades ahead.

Key Messages:

- To meet the Nation's growing needs for continued science-quality Earth observations, **NASA** and **USGS** are developing the next-generation Landsat Next mission as part of a comprehensive operational land-observing program using international partnerships and commercial data buys.
- As with the Global Positioning System and weather data, Landsat data are used every day to help us better understand our dynamic planet.
- Landsat Next ensures future generations will continue to reap the benefits of the Landsat series of measurements--trusted scientific data guiding a myriad of science and operational applications.

We need your help to ensure we reach as wide an audience as possible

Congressional Communications Update

- USGS Director Applegate and NASA Earth Science Division Director St. Germain briefed staffers from the House Science, Space and Technology Subcommittee on Space and Aeronautics and from the House Committee on Natural Resources Subcommittee on Energy and Mineral Resources on 11/9/22
 - Included details on the planned Triplets architecture
- USGS Associate Director Kevin Gallagher participated on an expert panel with representatives of NASA, NOAA, Maxar and the University of Colorado at a Senate Commerce Committee Space and Science Subcommittee Hearing on 12/1/22: "Landsat at 50 & the Future of U.S. Satellite-based Earth Observation"
 - Senators Hickenlooper (D-CO) and Lummis (R-WY) presided; Senators Cantwell (D-WA), Blumenthal (D-CT), and Fischer (R-NE) attended at least some of the hearing

Briefing to House staffers on 11/9/22:

"NASA and USGS project teams recommended a Landsat Next mission concept with three identical smaller satellites launched together into a lower orbit than today's Landsats, meeting user requirements for improved spectral, spatial and temporal resolution"

Senate Hearing on Landsat 12/1/22



<https://www.commerce.senate.gov/2022/12/landsat-at-50-the-future-of-u-s-satellite-based-earth-observation>

Landsat Next Programmatics



Federal Landsat Next activities are funded from two Congressional committees:

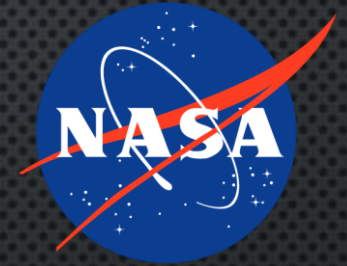
- Commerce, Justice, Science and Related Agencies for NASA
- Interior, Environment, and Related Agencies for DOI/USGS

NASA Landsat Next funding is contained within the NASA Earth Science Division

- Development of the space and launch segments – **Landsat Next** funding line
- Technology development – **Sustainable Land Imaging – Technology** line

DOI/USGS Landsat Next funding is contained within the National Land Imaging Program of the USGS Core Science Systems Mission Area

- Development and operation of the ground system and flight operations is through the **Satellite Operations** component of the NLI program funding line
- Science and applications work is through the **Science, Research and Investigations** (SRI) NLI funding line



Both NASA and USGS require full funding in FY24 to develop Landsat Next



U.S. Senate

Senate Appropriations Committee

Full Committee Members

Majority - Democrat	Minority - Republican
• Patty Murray, Washington, <i>Chair</i> • Dianne Feinstein, California • Dick Durbin, Illinois • Jack Reed, Rhode Island • Jon Tester, Montana • Jeanne Shaheen, New Hampshire • Jeff Merkley, Oregon • Chris Coons, Delaware • Brian Schatz, Hawaii • Tammy Baldwin, Wisconsin • Chris Murphy, Connecticut • Joe Manchin, West Virginia • Chris Van Hollen, Maryland • Martin Heinrich, New Mexico • Gary Peters, Michigan	• Susan Collins, Maine, <i>Vice Chair</i> • Mitch McConnell, Kentucky • Lisa Murkowski, Alaska • Lindsey Graham, South Carolina • Jerry Moran, Kansas • John Hoeven, North Dakota • John Boozman, Arkansas • Shelley Moore Capito, West Virginia • John Kennedy, Louisiana • Cindy Hyde-Smith, Mississippi • Marco Rubio, Florida • Bill Hagerty, Tennessee • Katie Britt, Alabama • Deb Fischer, Nebraska



U.S. House of Representative

House of Representatives Appropriations Committee

Full Committee

Majority - Republican	Minority - Democrat
• Kay Granger, Texas, <i>Chair</i> • Hal Rogers, Kentucky • Robert Aderholt, Alabama • Mike Simpson, Idaho • John Carter, Texas • Ken Calvert, California • Tom Cole, Oklahoma, <i>Vice Chair</i> • Mario Díaz-Balart, Florida • Steve Womack, Arkansas • Chuck Fleischmann, Tennessee • David Joyce, Ohio • Andy Harris, Maryland • Mark Amodei, Nevada • Chris Stewart, Utah • David Valadao, California • Dan Newhouse, Washington • John Moolenaar, Michigan • John Rutherford, Florida • Ben Cline, Virginia • Guy Reschenthaler, Pennsylvania • Mike Garcia, California • Ashley Hinson, Iowa • Tony Gonzales, Texas • Julia Letlow, Louisiana • Michael Cloud, Texas • Michael Guest, Mississippi • Ryan Zinke, Montana • Andrew Clyde, Georgia • Jake LaTurner, Kansas • Jerry Carl, Alabama • Stephanie Bice, Oklahoma • Scott Franklin, Florida • Jake Ellzey, Texas • Juan Ciscomani, Arizona	• Rosa DeLauro, Connecticut, <i>Ranking Member</i> • Steny Hoyer, Maryland • Marcy Kaptur, Ohio • Sanford Bishop, Georgia • Barbara Lee, California • Betty McCollum, Minnesota • Dutch Ruppersberger, Maryland • Debbie Wasserman Schultz, Florida • Henry Cuellar, Texas • Chellie Pingree, Maine • Mike Quigley, Illinois • Derek Kilmer, Washington • Matt Cartwright, Pennsylvania • Grace Meng, New York, <i>Vice Ranking Member</i> • Mark Pocan, Wisconsin • Pete Aguilar, California • Lois Frankel, Florida • Bonnie Watson Coleman, New Jersey • Norma Torres, California • Ed Case, Hawaii • Adriano Espaillat, New York • Josh Harder, California • Jennifer Wexton, Virginia • David Trone, Maryland • Lauren Underwood, Illinois • Susie Lee, Nevada • Joseph Morelle, New York



U.S. Senate

Senate Appropriations Committee

Subcommittee Interior, Environment, and Related Agencies



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Lisa Murkowski, Ranking Member – Alaska (R)

Majority Members

Dianne Feinstein, California

Jack Reed, Rhode Island

Jon Tester, Montana

Chris Van Hollen, Maryland

Martin Heinrich, New Mexico

Gary Peters, Michigan

Minority Members

Mitch McConnell, Kentucky

Shelley Moore Capito, West Virginia

John Hoeven, North Dakota

Deb Fischer, Nebraska

Katie Britt, Alabama

Subcommittee Commerce, Justice, Science, and Related Agencies



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Jerry Moran, Ranking Member – KS (R)

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Jack Reed, RI

Christopher Coons, DE

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Shelley Moore Capito, WV

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Bill Hagerty, TN

Katie Britt, AL

Deb Fischer, NE



U.S. House of Representative

House of Representatives Appropriations Committee

Subcommittee Interior, Environment, and Related Agencies



Majority-Republican

Rep. Mike Simpson (ID) – Chair

Rep. Chris Stewart (UT)

Rep. Mark Amodei (NV)

Rep. Guy Reschenthaler (PA)

Rep. Michael Cloud (TX)

Rep. Ryan Zinke (MT)

Rep. Jake Ellzey (TX)

Minority-Democrat

Rep. Chellie Pingree, Maine - Ranking Member

Betty McCollum, Minnesota

Derek Kilmer, Washington

Josh Harder, California

Subcommittee Commerce, Justice, Science, and Related Agencies



Majority-Republican

Rep. Hal Rogers (KY) – Chair

Rep. Robert Aderholt (AL)

Rep. John Carter (TX)

Rep. Ben Cline (VA)

Rep. Mike Garcia (CA)

Rep. Tony Gonzales (TX)

Rep. Andrew Clyde (GA)

Rep. Jake Ellzey (TX)

Minority-Democrat

Rep. Matt Cartwright, PA – Ranking Member

Rep. Grace Meng, NY

Rep. C.A. Dutch Ruppersberger, MD

Rep. David Trone, MD

Rep. Joe Morelle, NY

Senate Resolution (S. Res. 721) celebrating Landsat's 50th Anniversary

July 26, 2022

Recognized the important contributions that data produced by the Landsat program provides to decision-makers worldwide and the desire to continue the Landsat program into the next 50 years through Landsat Next



117th Congress
2d Session

S. Res. 721

In the Senate of the United States

July 26, 2022

Celebrating the 50th Anniversary of the Inaugural Launch of the Landsat Series of Earth Observation Satellites, a Joint Mission of the United States Geological Survey and the National Aeronautics and Space Administration

Whereas, on July 23, 2022, the United States Geological Survey (referred to in this preamble as "USGS") and the National Aeronautics and Space Administration (referred to in this preamble as "NASA") celebrate the 50th anniversary of the launch of the Landsat series of Earth Observation satellites (commonly known as the "Landsat program");

Whereas, through satellite remote sensing, which in 1972 constituted a new scientific instrument, the Landsat program introduced a powerful tool for humankind to observe the resources of Earth and the long-term changes in the condition of the land surfaces of Earth;

Whereas, as the first civilian program in the United States for the systematic observation of the land surfaces of Earth, the Landsat program has exemplified the highest ideals of the United Nations Committee on the Peaceful Uses of Outer Space, while helping to position the United States as a global leader in the field of satellite remote sensing;

Whereas data and imagery of Earth produced by the Landsat program have been used for 50 years in the United States and around the world—(1) to analyze crop conditions, soil moisture, and global crop production; (2) to forecast the needs of the world to ensure food security; (3) to monitor water consumption; (4) to facilitate emergency responses to and post-event analyses of natural disasters, including earthquakes, volcanoes, floods, tsunamis, hurricanes, and wildfires; (5) to monitor forests and changing land-use patterns; (6) to track receding glaciers and changes in sea-ice extent; and (7) to survey urban growth;

Whereas data and imagery produced by the Landsat program have been applied by—(1) many Federal, State, and local agencies, particularly agencies within the Department of the Interior and the Department of Agriculture; and (2) the governing bodies of Indian Tribes and Alaska Natives to solve difficult and expensive problems for their members at minimum cost to the taxpayers of the United States;

Whereas, since 2008, calibrated on-board data and imagery produced by the Landsat program have been made globally available at no cost to the public, greatly amplifying the use of such data and imagery, expanding growing markets for commercial remote sensing data and analysis, providing the foundation for commercial innovations in land remote sensing, and serving as a trusted reference for the calibration of instruments and improvement of commercial data products;

Whereas data produced by the Landsat program has been estimated to provide billions of dollars in value to the economy of the United States each year;

Whereas 50 years of continuous Landsat observations—(1) supply the world with impartial, fundamental evidence to support a scientific understanding of a changing global climate; and (2) form the basis for thousands of peer-reviewed, scientific publications that have documented changes in the land surface of Earth;

Whereas data produced by the Landsat program provide an invaluable common vocabulary and a shared set of references for the state of Earth that can inform international, Federal, and local efforts to address difficult environmental and public policy issues;

Whereas USGS and NASA are currently developing mission concepts for Landsat Next, the follow-on mission to Landsat 9;

Whereas Landsat 9 and the Sustainable Land Imaging program will build on and strengthen this key resource of the United States to provide a sustainable, space-based system to extend and improve the 50-year series of science-quality, global land imaging measurements produced by the Landsat program—the longest time series of the land surface of Earth; and

Whereas, during July 2022, USGS, NASA, scientists, engineers, land managers, and the people of the United States will celebrate 50 years since the launch of the first Earth-observing satellite of the Landsat program: Now, therefore, be it

Resolved, That the Senate—(1) celebrates the 50th anniversary of the inaugural launch of the Landsat series of Earth Observation satellites (commonly known as the "Landsat program"); (2) recognizes the scientific, engineering, and analytical expertise of the United States Geological Survey (referred to in this resolution as "USGS"), the National Aeronautics and Space Administration (referred to in this resolution as "NASA"), and the advisory Landsat Science Team; (3) recognizes the important contributions that data produced by the Landsat program provides to decision-makers worldwide and the desire to continue the Landsat program into the next 50 years through Landsat Next; (4) designates July 23, 2022, as "Landsat 50th Anniversary Day", or "Landsaturday"; and (5) respectfully requests that the Secretary of the Senate transmit an enrolled copy of this resolution to the Director of USGS and the Administrator of NASA.

Attest:



America A. Berry
Secretary.

Landsat Next Summary

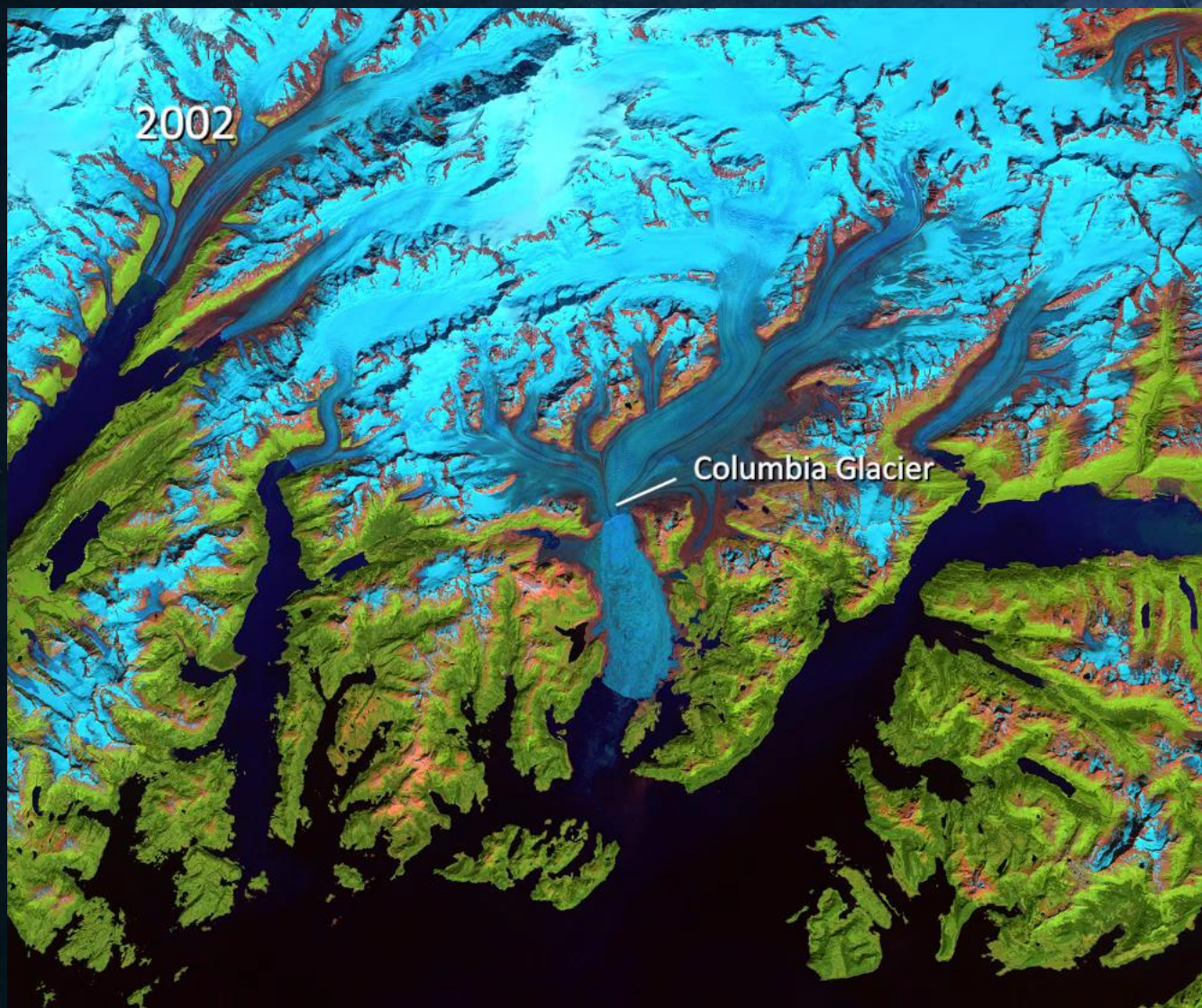
- **Landsat Next will continue and improve the 50-year Landsat data record**
 - Relied upon by Federal/State/Tribal/local government, commercial, industrial, educational communities
 - Landsat is the most widely used land remote sensing data source within Federal civil agencies
 - Commercial data providers need Landsat's rigorous calibration standards to build/improve products
- **Provides a completely new and improved Landsat for the next generation**
 - Much better spatial resolution (10 meter), twice as many spectral bands (new ones for agriculture, water use, HABs, mineral mapping, volcanos), and improved revisit (6-day) while retaining continuity
 - Ensures projected climate change impacts on the land can be rigorously monitored & assessed
- **Continues substantial economic benefits to the U.S. economy (~\$2 billion/year)**
 - Much like GPS and weather data, Landsat data are used every day to help us better understand our dynamic planet – and to continue tracking the effects of global climate change
 - Information from Landsat contributes to day-to-day decisions on land, water, and resource use that protect life and property; safeguard the environment; advance science, technology and education; support climate resiliency; and grow the U.S. economy

Landsat Next ensures future generations will continue to reap the benefits of the Landsat series of measurements-- trusted scientific data guiding numerous research and operational uses

LANDSATNEXT

NASA "Landsat's Next Chapter" Video <https://svs.gsfc.nasa.gov/14262>

Embedded Video



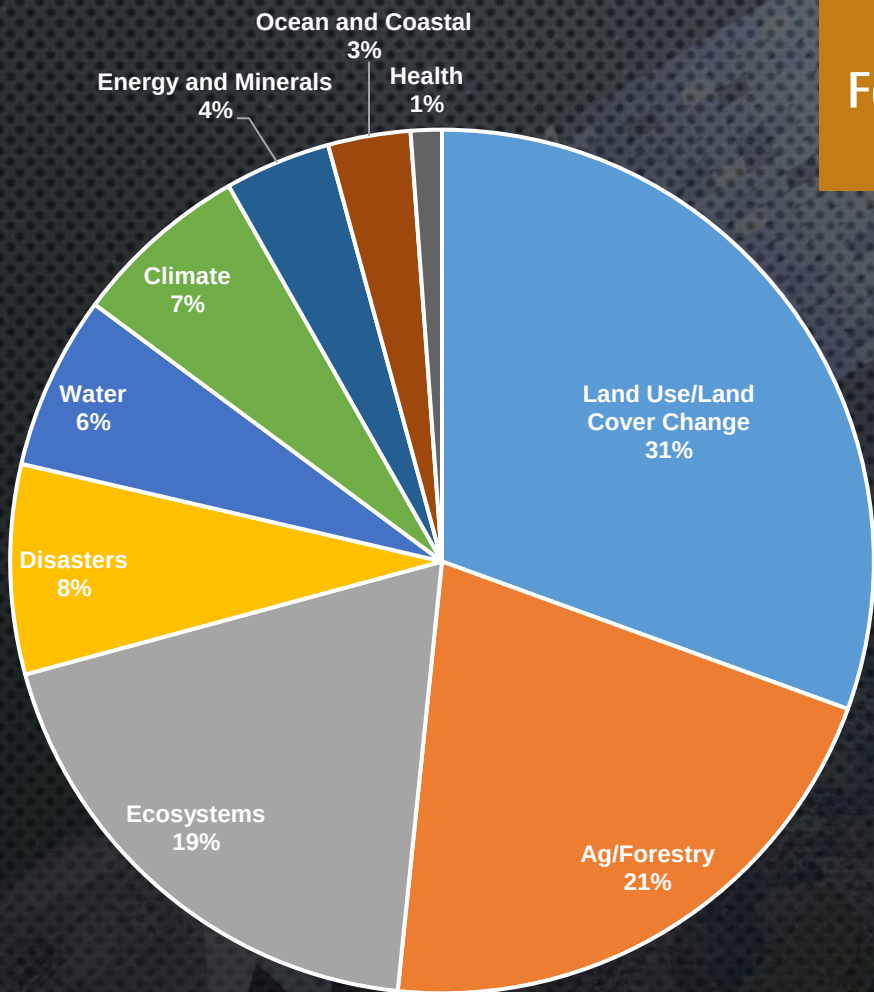
Thank You!

Mr. Timothy Newman
National Land Imaging Program Coordinator
U.S. Geological Survey
U.S. Department of the Interior
tnewman@usgs.gov



Landsat Applications and Users

Landsat Applications by registered users at USGS EarthExplorer



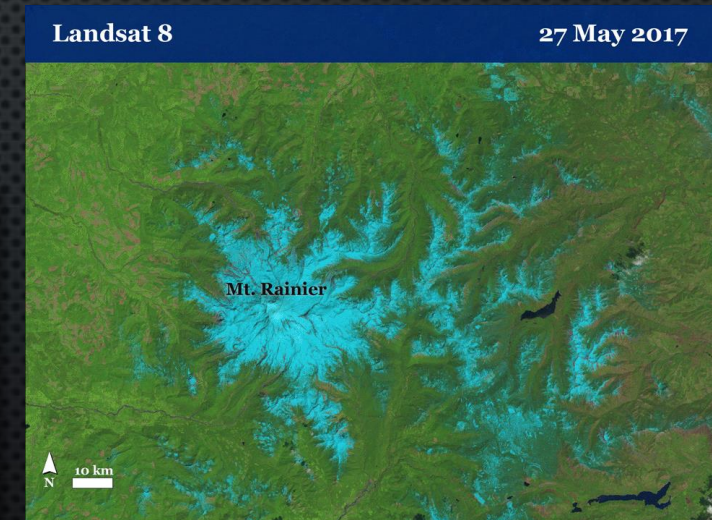
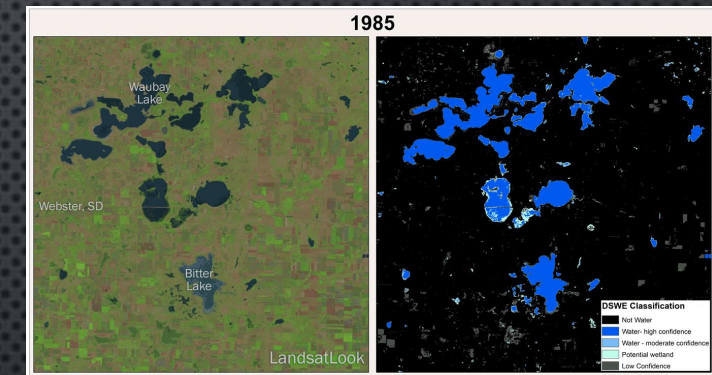
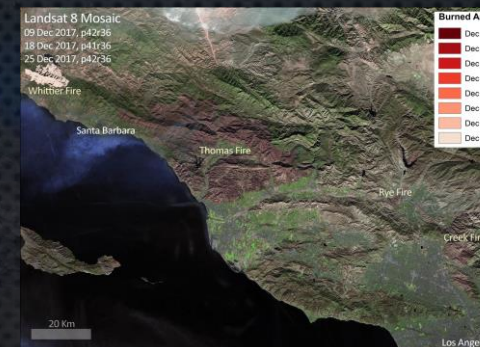
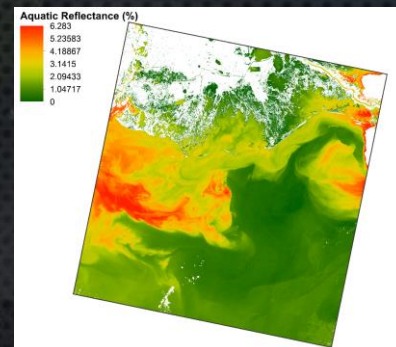
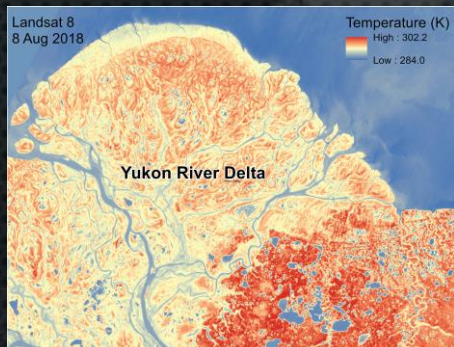
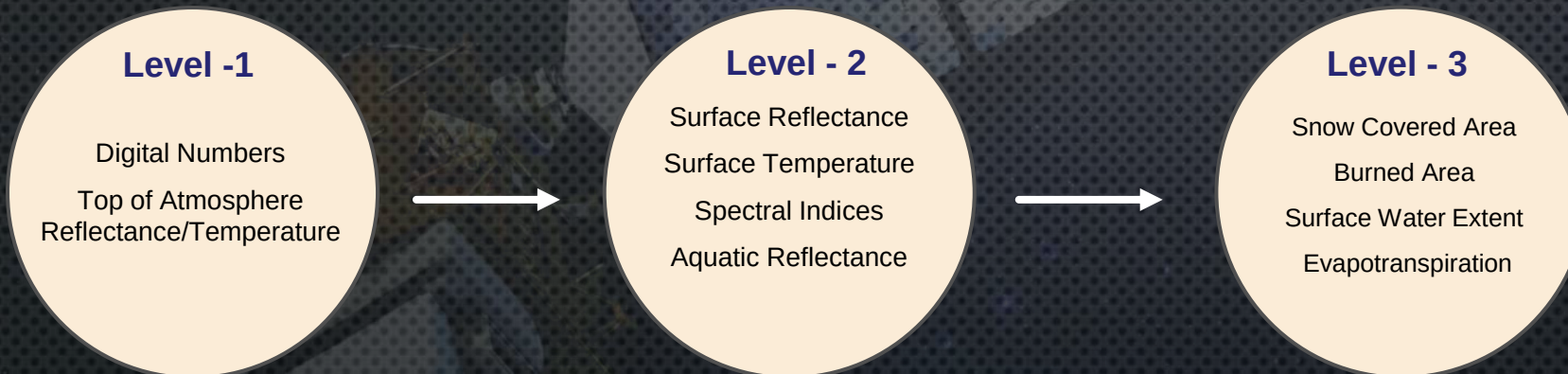
Landsat is the **single most-used** land imaging data set by U.S. Federal users and has the **2nd** highest societal benefit impact (behind only GPS) of 1,300 Earth observation systems (USGEO, 2016)

- Federal agencies (e.g., DOI, USDA, EPA, NASA, DOD, NOAA, State, USAID)
- State agencies (planning, natural resources, transportation)
- University researchers and educators
- International organizations (e.g., United Nations agencies, Group on Earth Observations)
- 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, L3Harris, ITT, MDA Federal)
- Foreign space agencies
- U.S. and foreign commercial satellite operators
- Cloud service providers (e.g., Amazon Web Services, Google Earth Engine)
- General public

Supports Federal, State, Tribal, local, academic, commercial, non-profit, and international use.

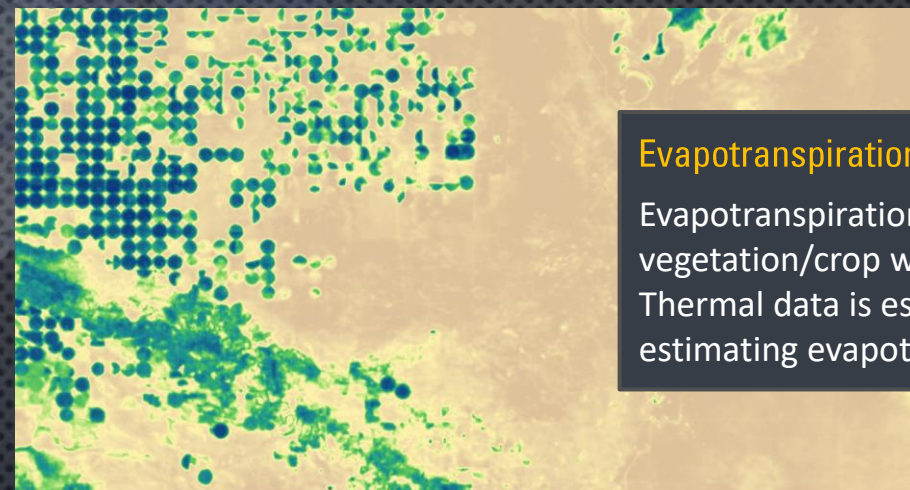
Landsat Science Products

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



Landsat Thermal Imaging Uses

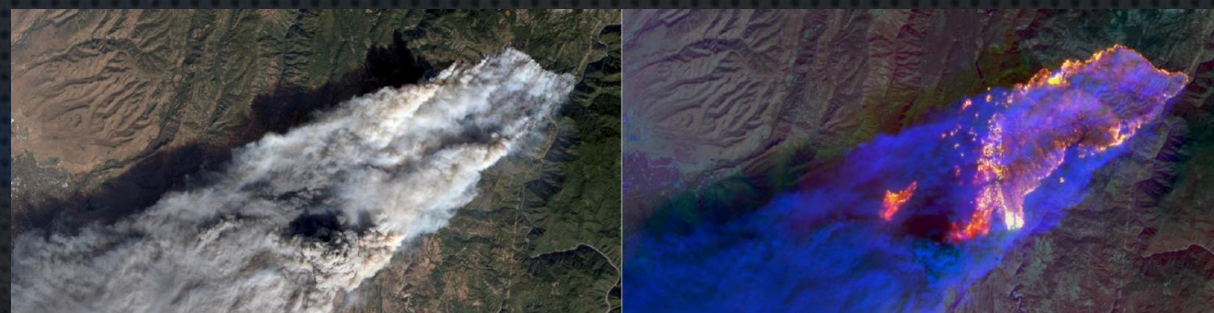
- Evapotranspiration and Water use
 - Vegetation health /crop monitoring
 - Drought monitoring
- Urban heat island – Human health
- Fire detection
 - Mapping thermally active areas
 - Locating underground intense fires (e.g., coal fires)
- Thermal signatures in water bodies
- Volcanic hazard assessment, monitoring, and recovery
- Monitoring glaciers and glacial lakes
- Soil moisture mapping (irrigation, trafficability, etc.)
- Cloud detection for calibration applications



Evapotranspiration

Evapotranspiration represents vegetation/crop water use. Thermal data is essential for estimating evapotranspiration.

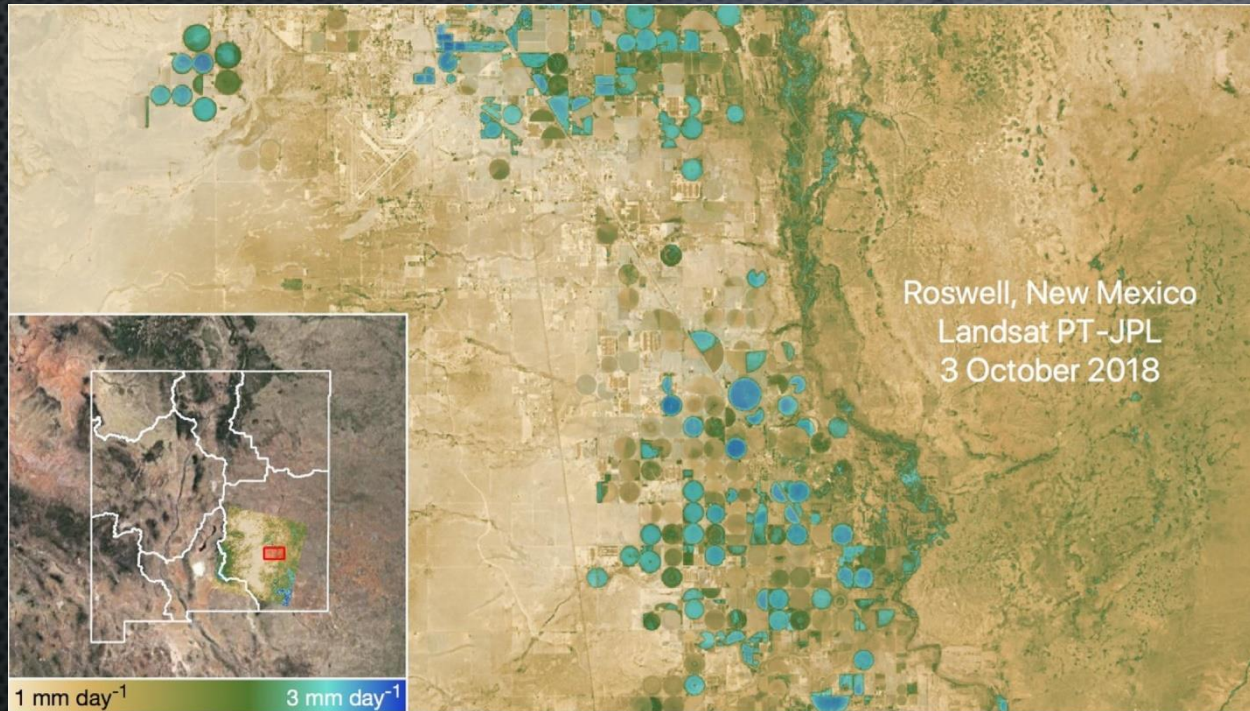
San Luis Basin, CO from Landsat 9 based thermal imagery



Active fire showing Landsat visible imagery on the left and thermal imagery on the right.

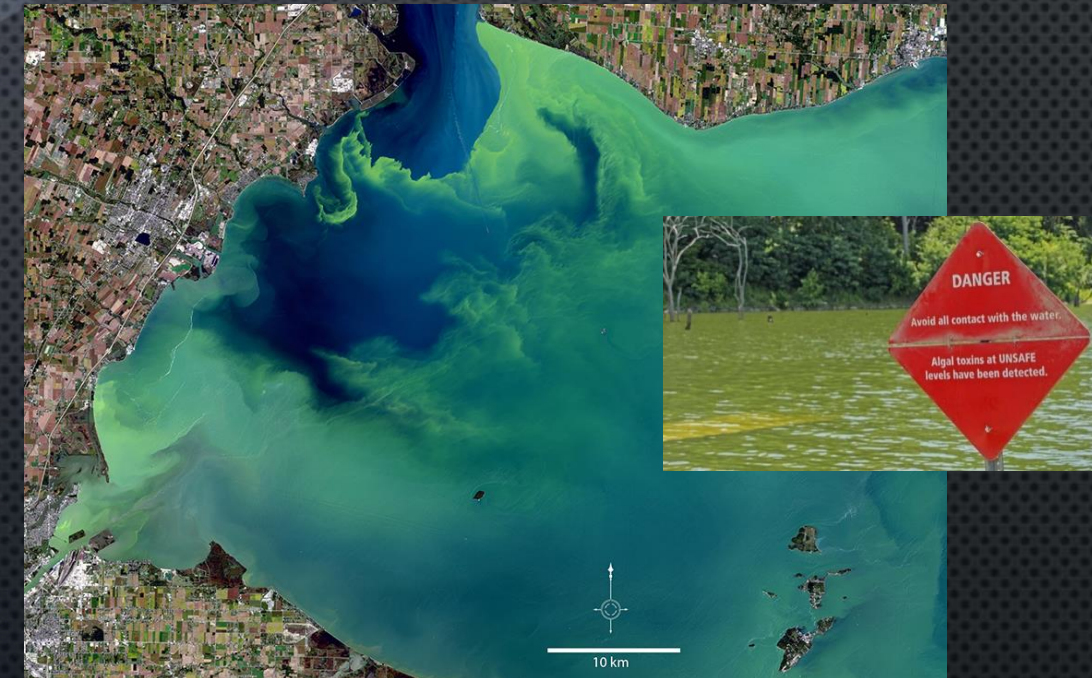
Landsat and Water Monitoring

Western States use 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. Credit: Fisher et al., NASA, AGU19

Landsat helps 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



Water Consumption

Agriculture accounts for 80-90% total US consumptive water use. In California alone, agricultural exports totaled \$21.7 billion in 2019

Field-level evapotranspiration (ET) and continuous water use monitoring operationally benefit local/international farmers and water managers

- **Landsat-derived actual ET** helped one large almond grower save ~25,000 gallons and a southern California grape grower saved 50% (~100,000 gallons) across 100 acres of vineyard.
- Continuous monitoring of irrigated water use requires **at least weekly observation**.



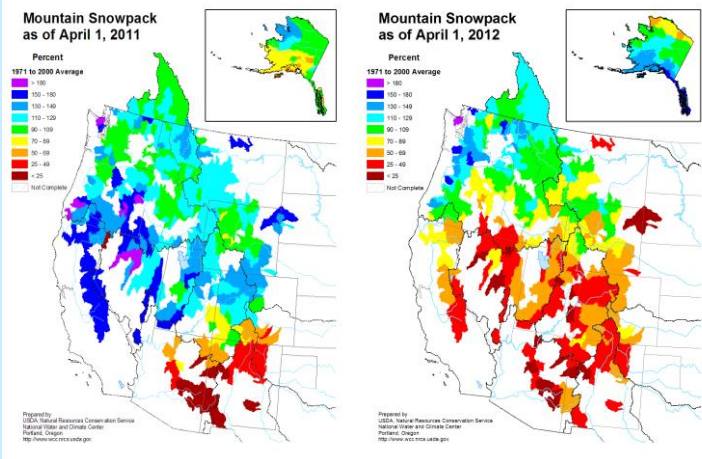
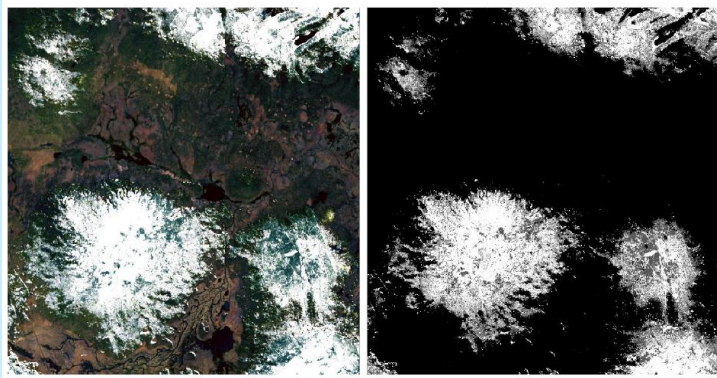
Water Quality

In the U.S. alone up to 48 million Americans drink from sources susceptible to Harmful algal blooms (HABs). HABs occur with increasing frequency and impact human health, the fishing industry, coastal and lakeside property, and tourism

- For Lake Erie, a summer-long algal bloom could result in 3600 fewer fishing licenses issued and \$2.25 million to \$5.58 million in lost economic activity.

New spectral capabilities are needed to better detect the specific organisms that cause harmful blooms at higher frequency to allow early detection and timely mitigation

- Narrow visible bands are needed for cyanobacteria tracking.
- A recent study indicates that Landsat Next spectral bands will improve the accuracy of HAB mapping by **up to 50%** compared to Landsat 8/9 (Zolfaghari et al., 2021)



Snow Hydrology

Landsat is needed to map and quantify snow-covered area and extent, snow cover duration and melt timing, surface albedo and light absorbing impurities.

- Long term trends in decreasing Northern Hemisphere spring snow cover show significant correlations with warming temperatures
- Western US seasonal snowpack contributes between 50 to 70% of available annual water quantity in storage reservoirs
- Light absorbing impurities on snow trigger earlier melt in dust prone regions

Increased temporal frequency and new spectral measurement capabilities are needed for snow hydrology to:

- Reduce cloud cover contamination while increasing detection of rapidly evolving snow processes and melt timing
- Measure the presence of liquid water content and snow grain size for melt state determination

In collaboration with

OPENET

OpenET, a public-private collaboration with over 30 experts in remote sensing science and technology. That includes NASA, USGS, USDA, DRI, the Environmental Defense Fund, and Google Earth Engine, to name a few!

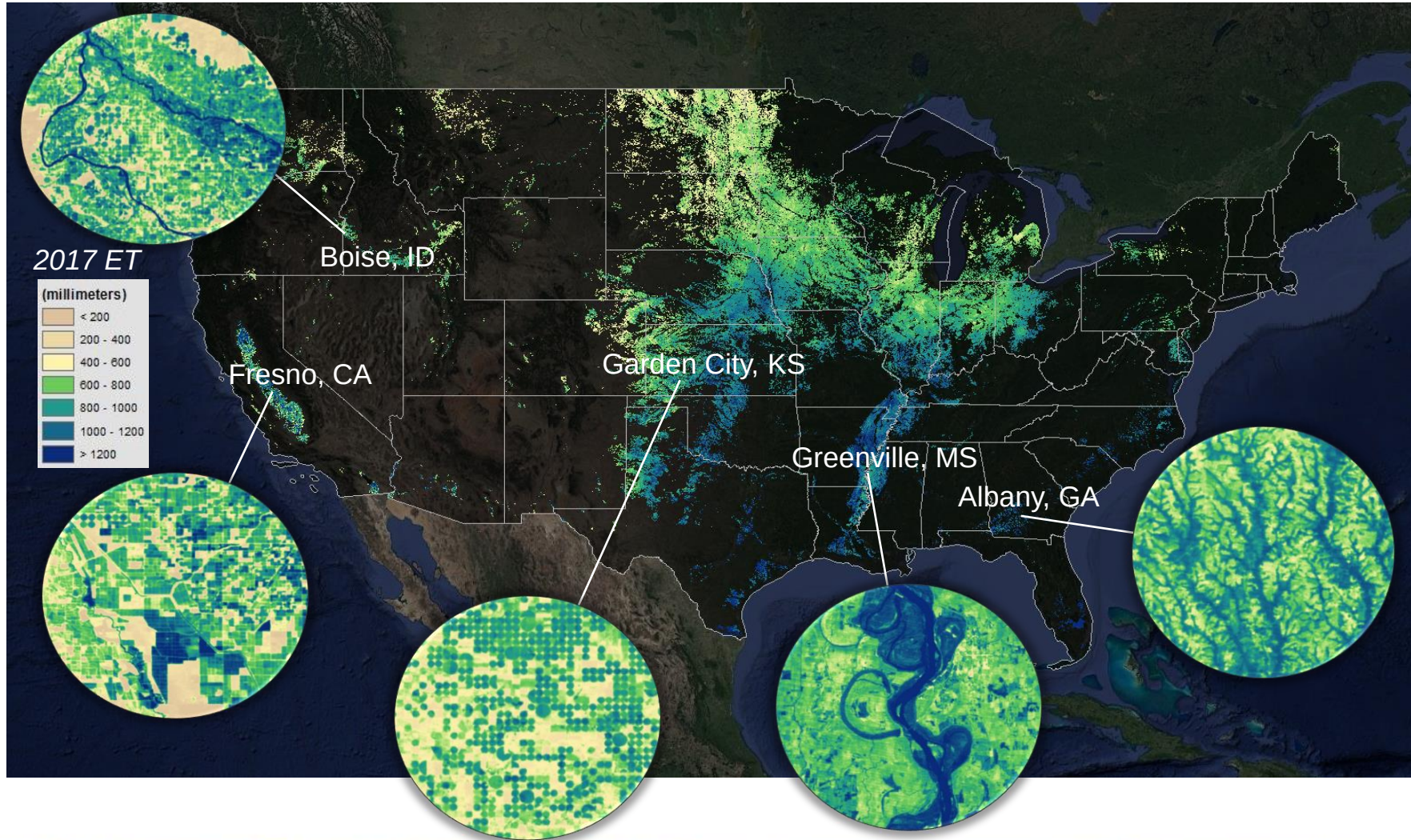
The result is after years of effort from partnering Federal agencies, universities, environmental groups, water managers, and farmers who use water to irrigate crops.

Find Data at:

<https://openetdata.org>

***Landsat provides
crucial thermal
information for
estimating
evapotranspiration and
water use***

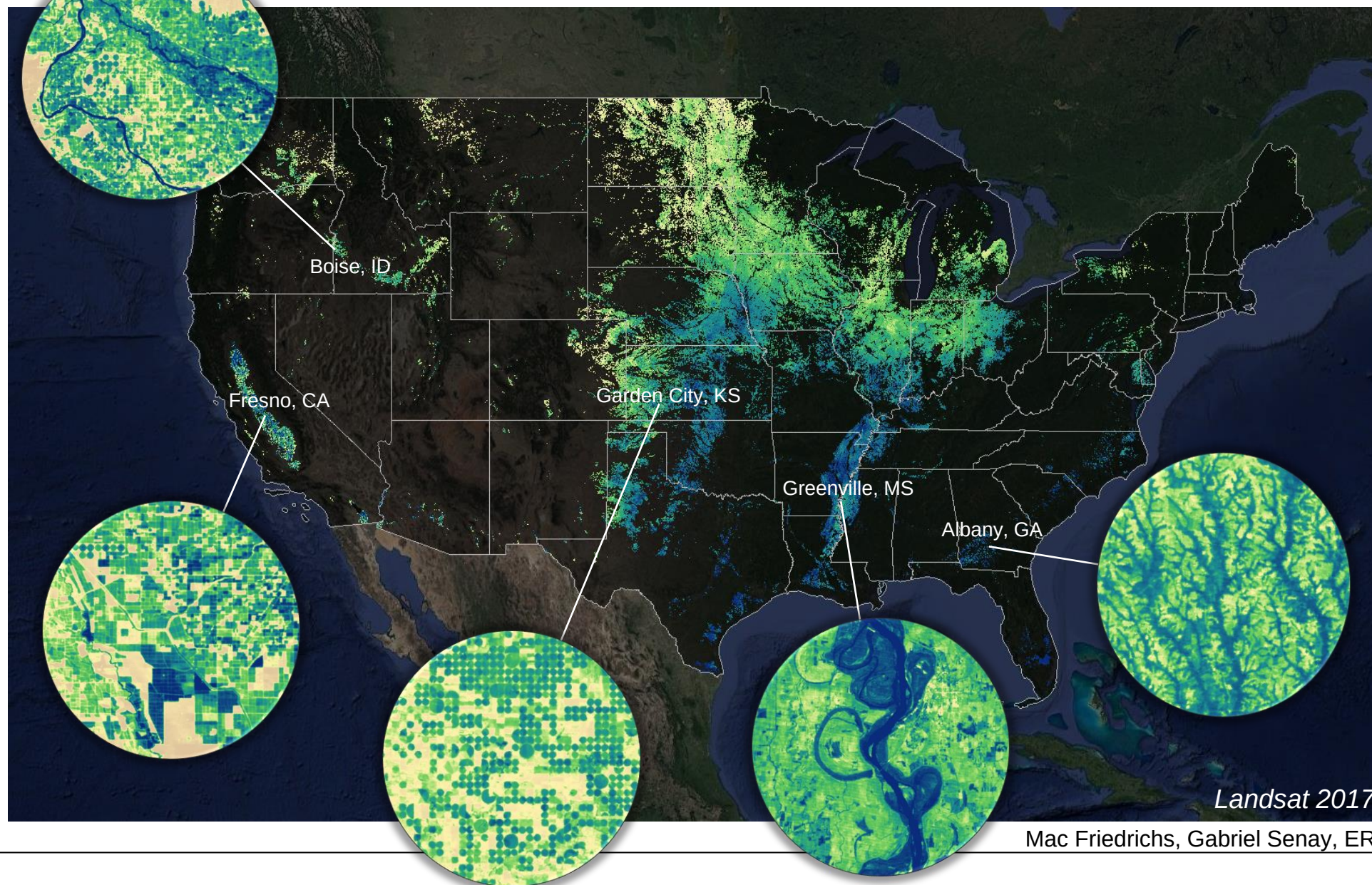
Field Scale Evapotranspiration with Landsat



- Map crop water use for the nation
- Quantify water use trends since 1980s
- Improve water allocation and irrigation efficiency
- Monitor implementation of water management decisions

Landsat-based SSEBop
ET, 100 m.

Landsat Actual Evapotranspiration Science Product



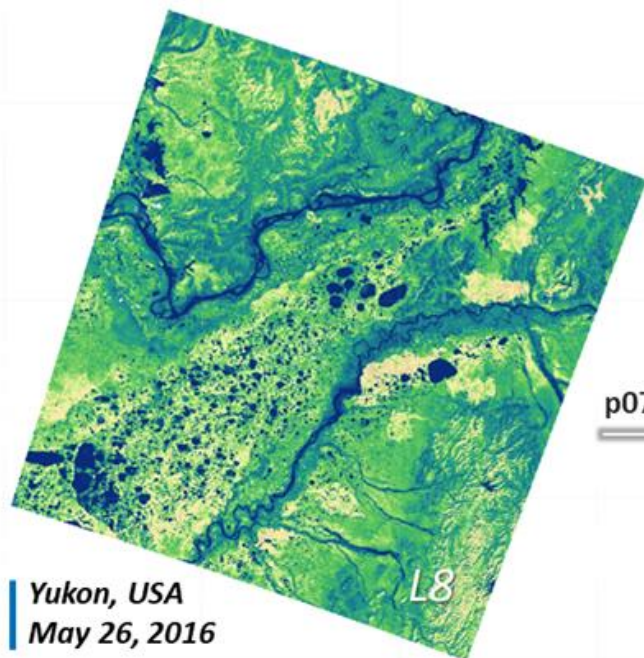
- A provisional Landsat-derived Actual Evapotranspiration science product for the U.S. will be available in summer 2020.
- Example here captures cropland ET and water use.

Mac Friedrichs, Gabriel Senay, EROS

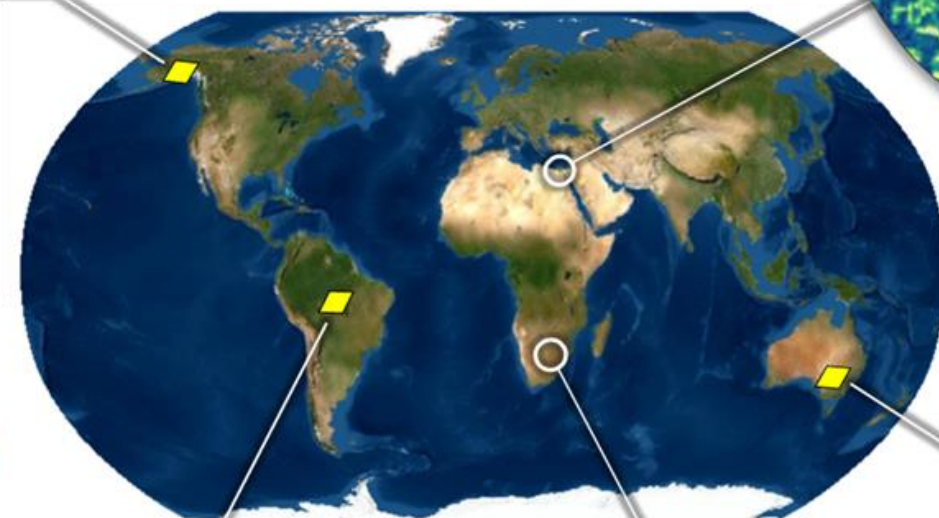
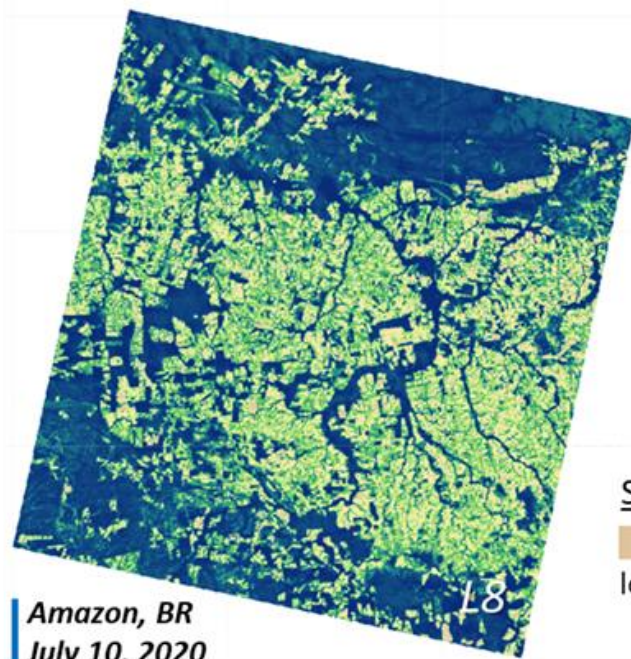
USGS Landsat Actual Evapotranspiration

Collection 2 Level 3 Scene products

<https://espa.cr.usgs.gov/>

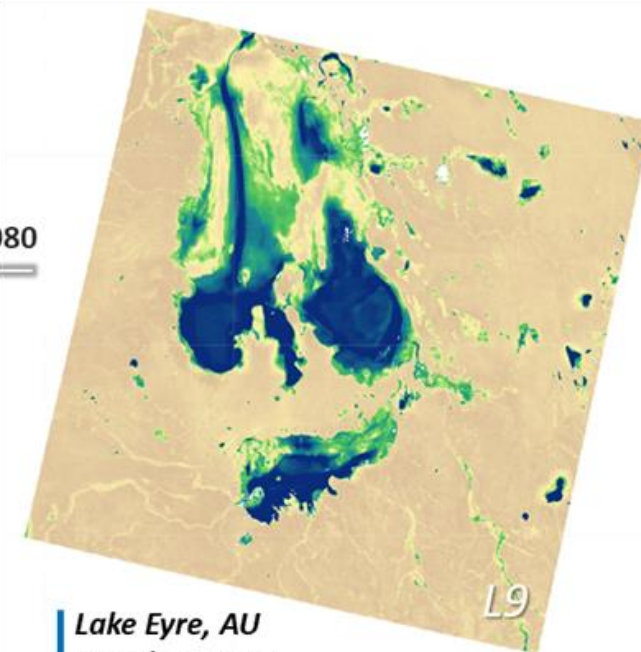
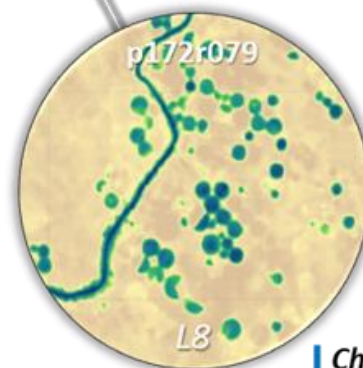
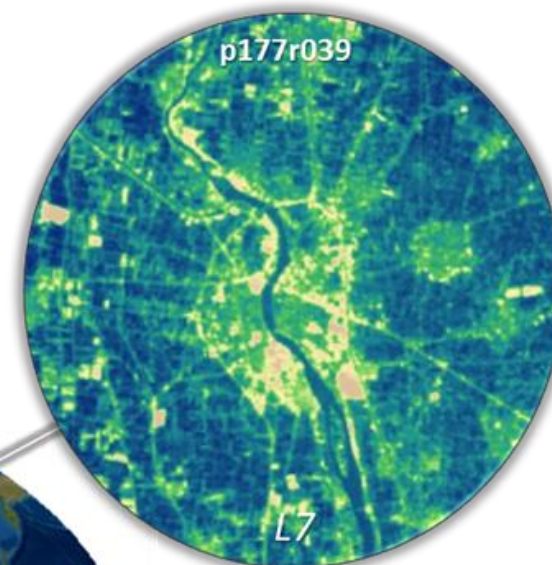


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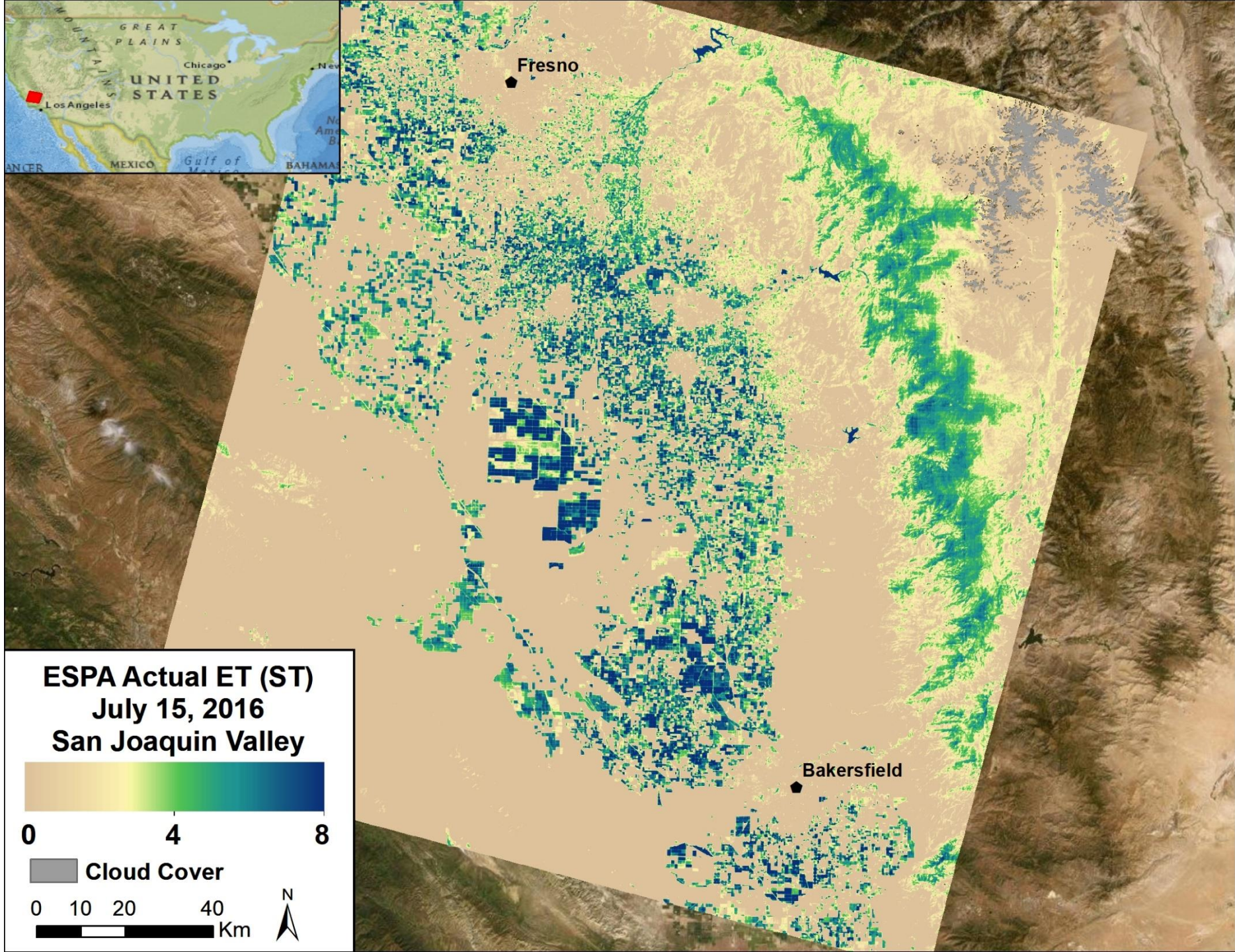
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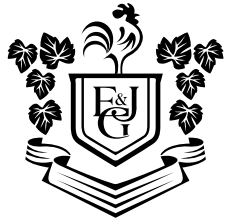
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SSEBop ETa / Water Use (mm/day)







E&J Gallo Winery

Improving Irrigation Technology and Grape and Wine Quality

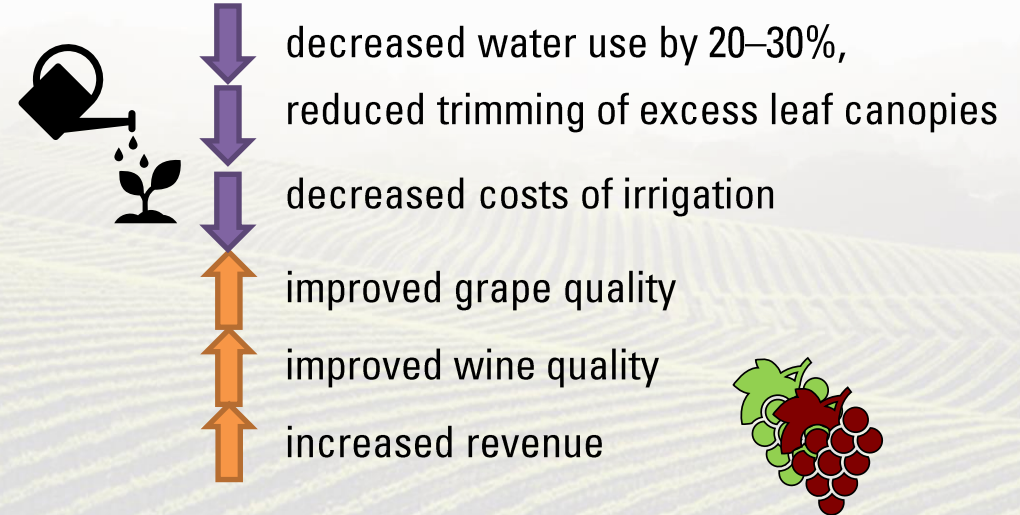
A pioneer of efficient water-management practices through the use of Landsat imagery:

- Gallo uses Landsat imagery on approximately 150,000 acres of vineyards in Southern California to:
 - estimate the **potential water use**,
 - measure **actual water use**, and
 - develop **area-specific water budgets**
- Gallo uses Landsat to **support land acquisition based on water availability and quality**.
- Gallo downloads **every available Landsat image** during the grape growing season. Irrigation generally starts in March and continues through October.

LANDSAT CASE STUDY:



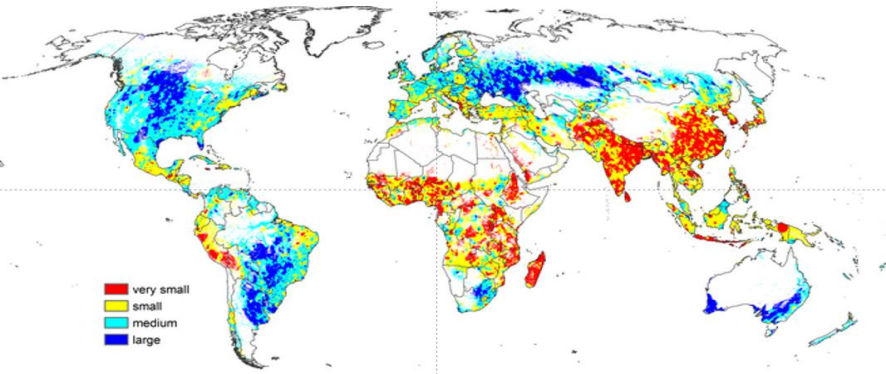
Through the use of Landsat imagery, Gallo:



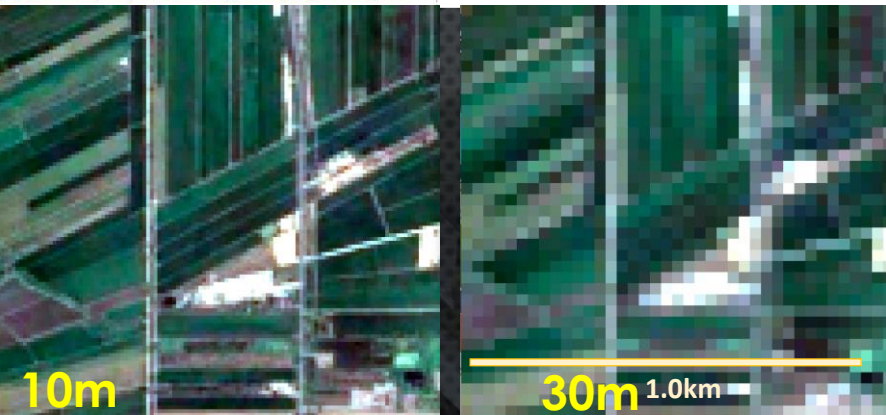
- Gallo continues to use Landsat imagery with their goals to expand through the Pacific Northwest and international properties.
- Gallo remains an avid supporter of the Landsat Mission and expressed great interest in improving Landsat's observation frequency.



Global Cropland and Field Size



(1km) based on interpolation of field size data collected via a crowdsourced campaign using Geo-Wiki
 Global Change Biology
 Volume 21, Issue 5, pages 1980-1992, 16 JAN 2015 DOI: 10.1111/gcb.12838
<http://onlinelibrary.wiley.com/doi/10.1111/gcb.12838/full#gcb12838-fig-0004>



Monitoring Global Croplands

Food and Agriculture Association (FAO) estimates the gross value of global agricultural production at over \$5 trillion.

The world population experiencing food insecurity ranges from 0.76 to 1 billion people.

Global impacts of improved spatial resolution arise from smaller field sizes in many regions

- Food insecurity occurs in countries where smaller farmland areas are hard to monitor and delay international humanitarian assistance.
- Landsat Next at 10m will capture most of the 40% of global croplands currently missed by Landsat (Lesiv et al. 2018), and 20-25% more U.S. croplands

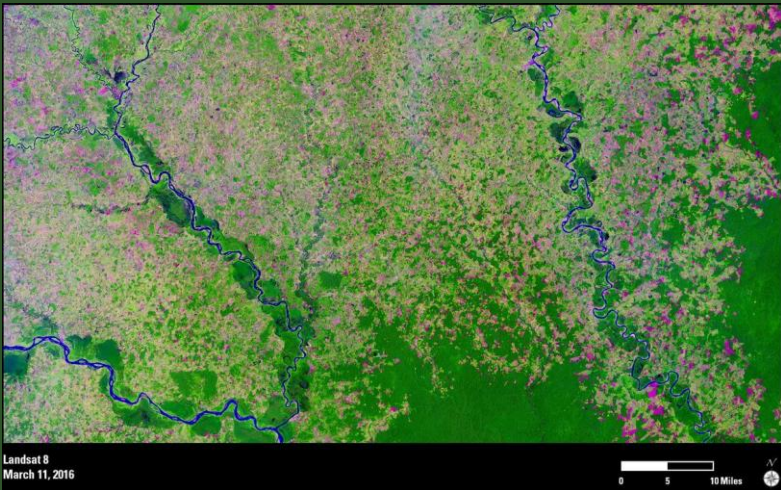
Forest Monitoring – Global Deforestation & Carbon

During 2020, Landsat was used to measure a net change of 12 million ha in global tree cover

- Deforestation of primary tropical forest was equal in area to the Netherlands, and carbon emissions were equal to 570 million cars (double the number of cars on the road in the US).
- Worldwide operational alert systems based on Landsat data have allowed countries in Africa to reduce losses by 18% in five years.

Landsat Next will improve monitoring of global deforestation & net loss:

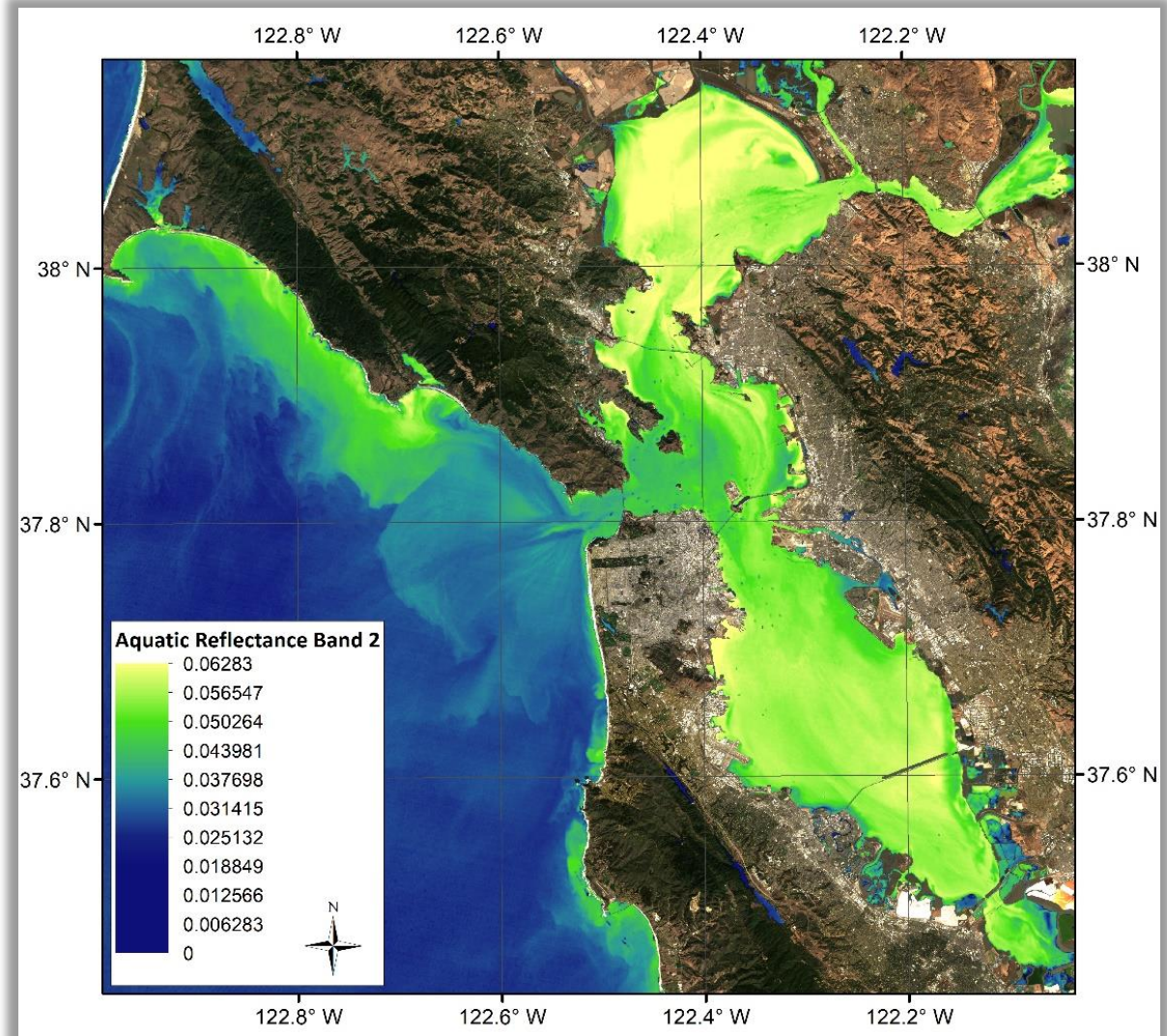
- Shortening the revisit time from 16 to 6 days will help obtain unobstructed views in persistently cloudy tropical regions.
- Forest degradation -- a reduction in tree density, diversity and health -- will be detected with Landsat Next's finer spatial resolution and enhanced spectral capability



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.

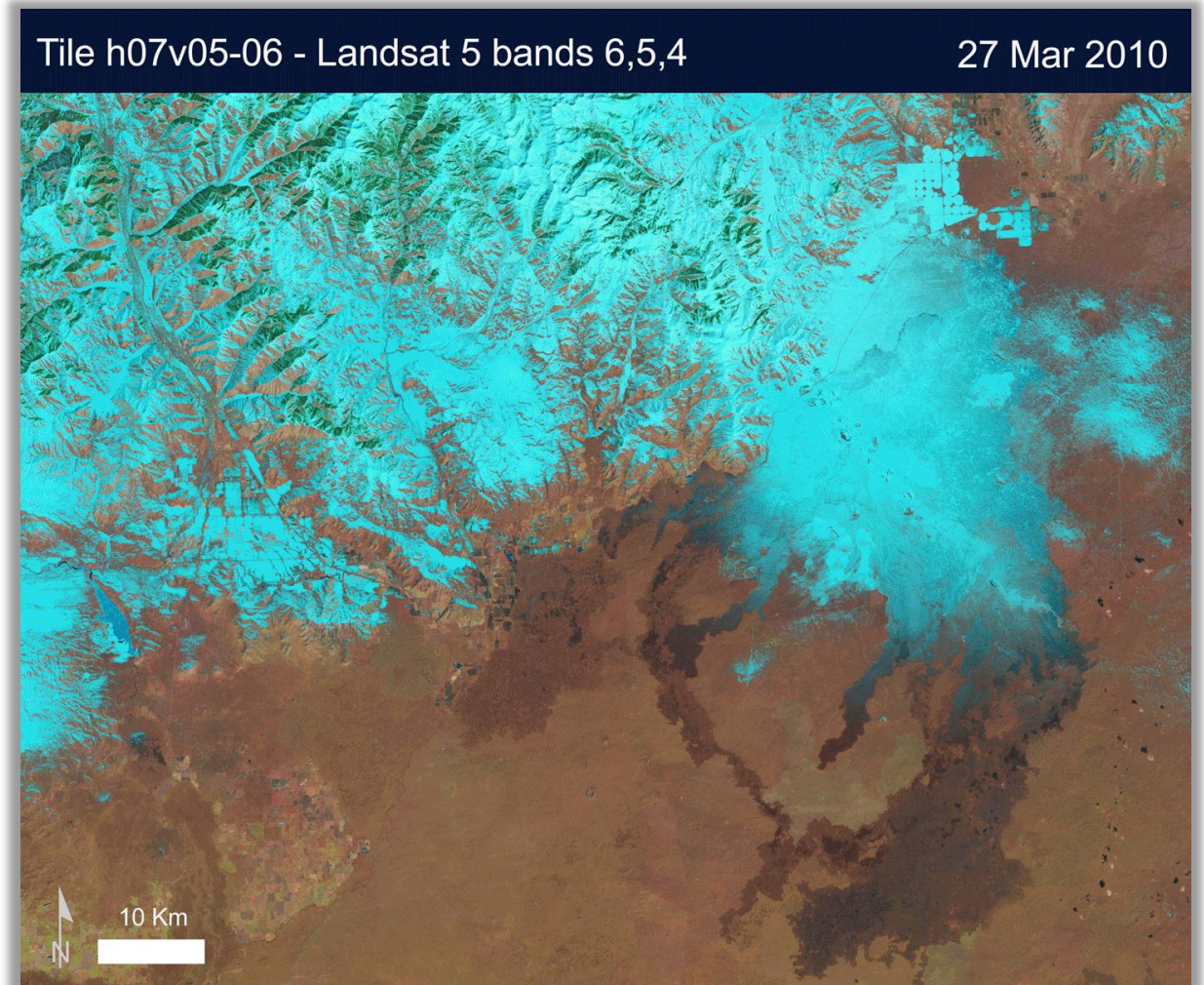
Landsat Fractional Snow Covered Area

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](#)

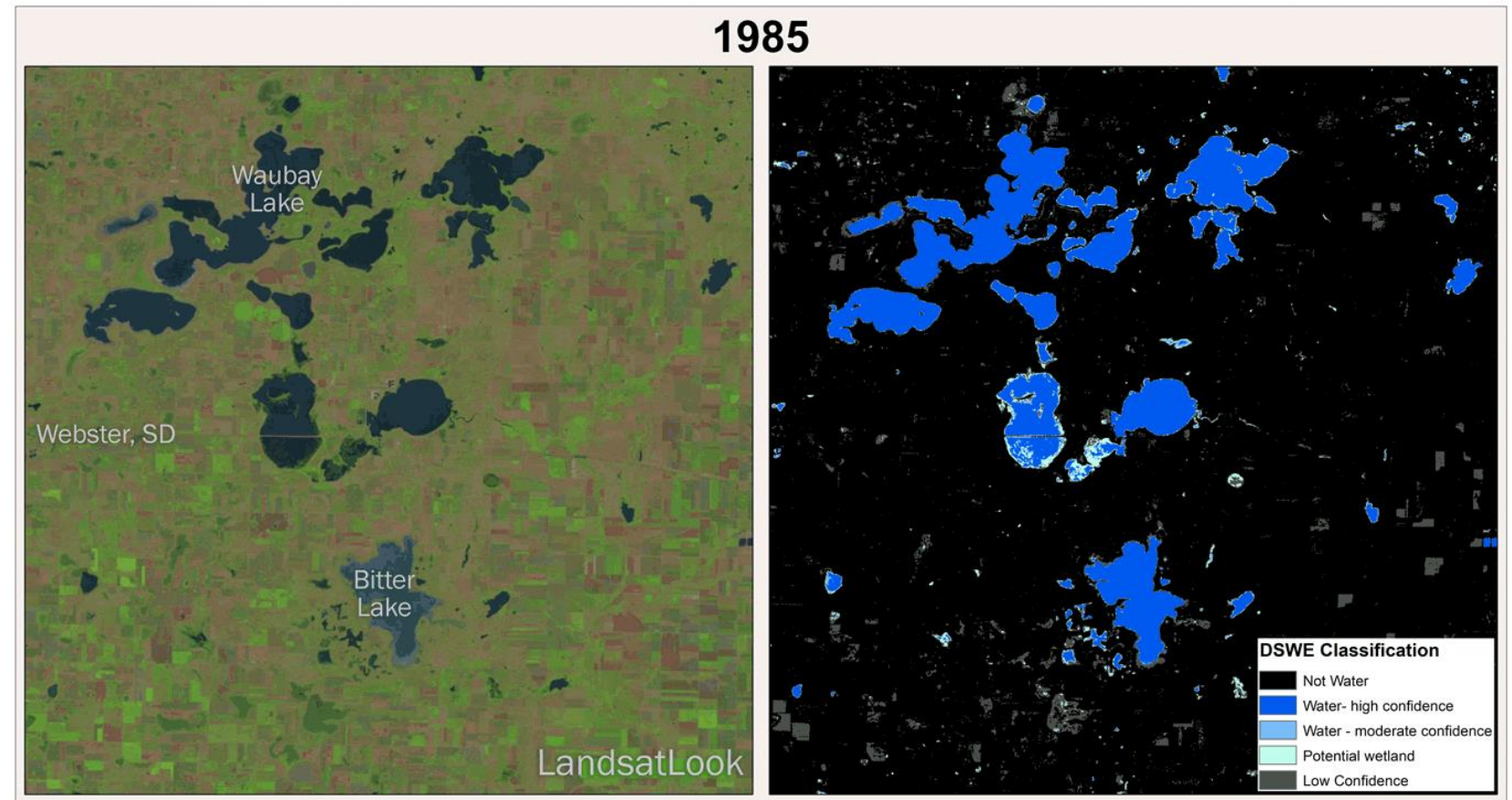


Craters of the Moon National Monument & Preserve, 2010.

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.

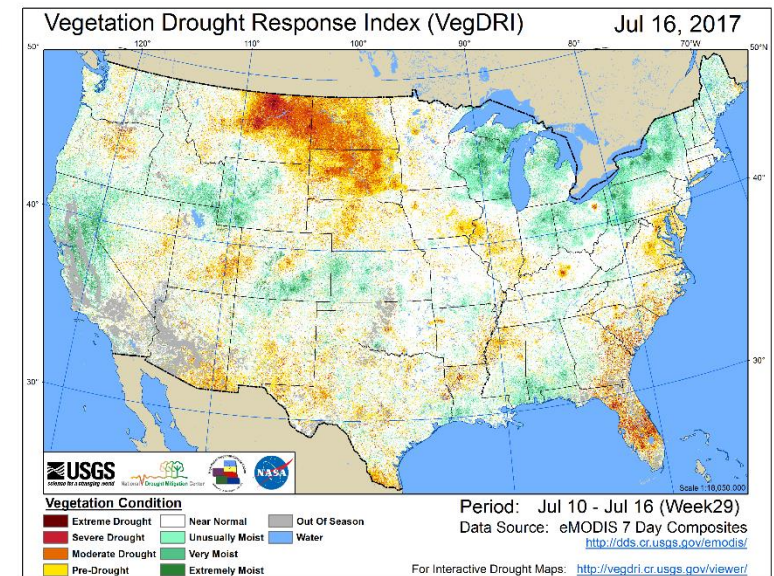
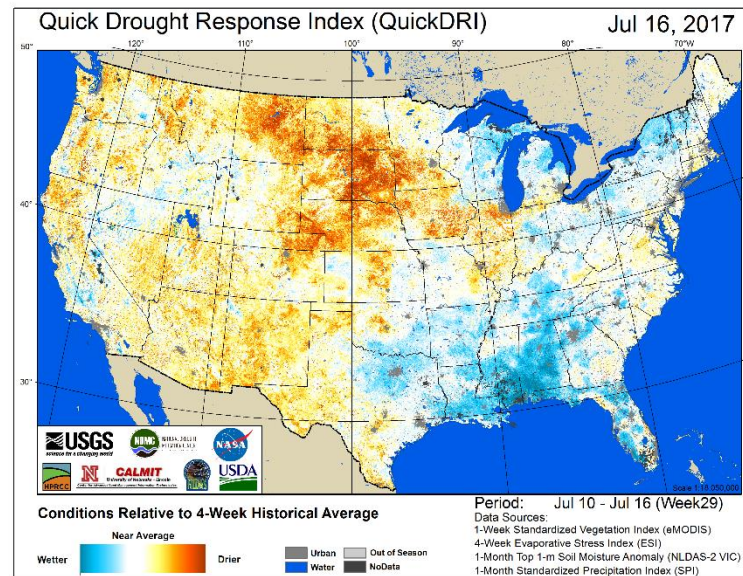
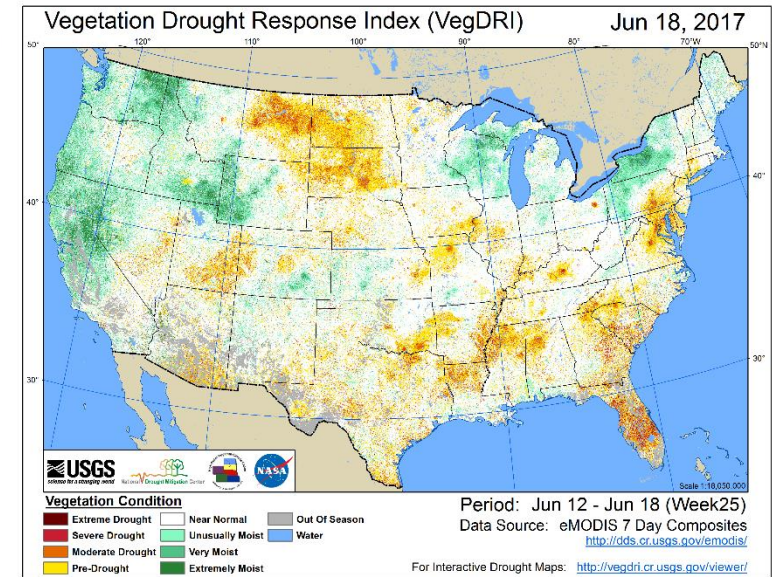
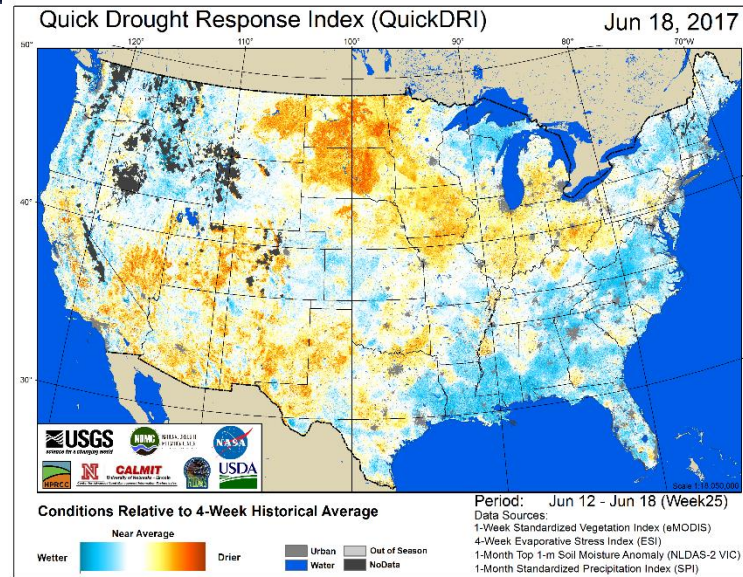
Jones, J.W., 2019. Improved Automated Detection of Subpixel-Scale Inundation—Revised Dynamic Surface Water Extent (DSWE) Partial Surface Water Tests. Remote Sens., 11, 374



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

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?”



Societal Benefit Area	Application	Science Benefits from Landsat Next Hybrid Triplets
Agriculture	U.S and global agricultural monitoring	Sub-weekly revisit will allow USDA FAS, FSA and NASS more precise observation of crop emergence – a critical growth stage for modeling crop development and monitoring crop condition – enabling capture of key phenological dates to estimate crop yield, such as greening and leaf area amount and health – key indicators for predicting food supply and food shortage, foreign aid and global food security. USDA RMA relies on high frequency Landsat data for continuous monitoring in detection of possible instances of fraud, waste, and abuse.
	Crop residue monitoring/soil conservation	Sub-weekly observation in early growing season can allow USDA NRCS to detect cover crop and crop residue for soil conservation at the field-scale. Cost-share programs encourage use of cover crops to achieve conservation objectives, relying on cover crop termination dates to determine incentive payments to farmers. Requires weekly clear observations to determine crop termination dates accurately; timing of crop residue monitoring critical – missing an image means missing the opportunity to see crop residue before cultivation.
Forestry	Forest health monitoring	At least weekly revisit will aid USFS, BIA, BLM, FWS, NPS and USGS in the detection and identification of insect/disease agents for forest health monitoring, since symptoms are often seasonal and transient. Aids global forest monitoring for carbon sequestration and emissions. Global Forest Watch relies on Landsat to generate deforestation alerts and requires more frequent observation to detect deforestation before agricultural planting and vegetation recovery “hide” the forest loss, capturing onset of deforestation, impact and swift response.
Water Resources	Evapotranspiration and water use	At least weekly observations of evapotranspiration (ET) are needed for field-scale ET estimates and continuous water use monitoring operationally by BOR, USGS, FAS, NASS and Western States. The improved capabilities will provide more timely and accurate water use information to water managers and other stakeholders.
Water Quality	HAB detection and monitoring	The new targeted spectral bands for water quality provided by Landsat Next will enable detection of specific organisms that cause harmful blooms such as cyanobacteria at higher frequency to allow early detection and timely warning/mitigation, used by EPA, NOAA, USGS, NIH, NASA and other state/local water resources and public health agencies.
Cryosphere	Snow/water availability	Higher temporal frequency and new targeted spectral measurement capabilities of Landsat Next will reduce cloud cover contamination while increasing detection of rapidly evolving snow processes and melt timing and measure the presence of liquid water content and snow grain size for melt state determination, which together improve prediction of water availability and volume.
Public Health	Monitoring urban heat islands	At least weekly revisit can help capture more frequent, intense, and longer heat waves as climate change indicators, and help define more effective mitigation strategies for NIH, FEMA and local governments for urban heat wave seasons at urban district/residential area scales.
Wildfire	Pre- and post-fire assessment	Sub-weekly revisit is needed to capture onset of more frequent wildfires and provide immediate post-fire response to Federal, state and local land management agencies by assessing burn severity, and mapping and monitoring post-fire landslide hazards, providing timely information for effective post-fire burned area emergency response—BAER teams need Landsat imagery within 7 days of containment.