Landsat Next:
The Future of Earth Observation

Timothy Stryker

Chief, Outreach and Collaboration Branch
National Land Imaging Program
U.S. Geological Survey (USGS)
U.S. Department of the Interior

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What is Landsat?

- The world's longest continuously operated land remote sensing satellite series
- The most widely used and cited land remote sensing data set; critical to understand land, water, and natural resources
- An indispensable tool to understand and effectively 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 satellites)
-> global, seasonal coverage

Broad area collection => 12,000+ square miles per image
-> 1400 images/day = 20 million square miles/day

Highly calibrated "science quality" data
-> to resolve long-term trends & retrieve biophysical variables
->to improve commercial EO satellite data & applications

Free and Open Data policy since 2008
-> Hundreds of millions of data and product accesses, vastly accelerating landscape science and improving related public and private services.

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

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**VNIR: Visible Near-Infrared   SWIR: Shortwave Infrared   TIR: Thermal Infrared

Landsat: The Backbone of Past, Current, and Future Earth Observations

- **Five-decade-plus record of land cover, land use, and vegetation condition**
- **Large area coverage for global, continental and regional land cover studies**
- **Landsat remains the most cited land remote sensing system in the peer-reviewed scientific literature - and the citation rate is increasing**
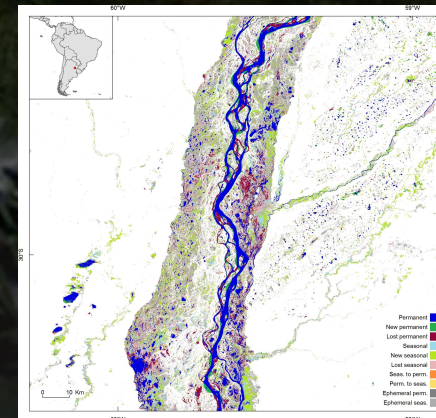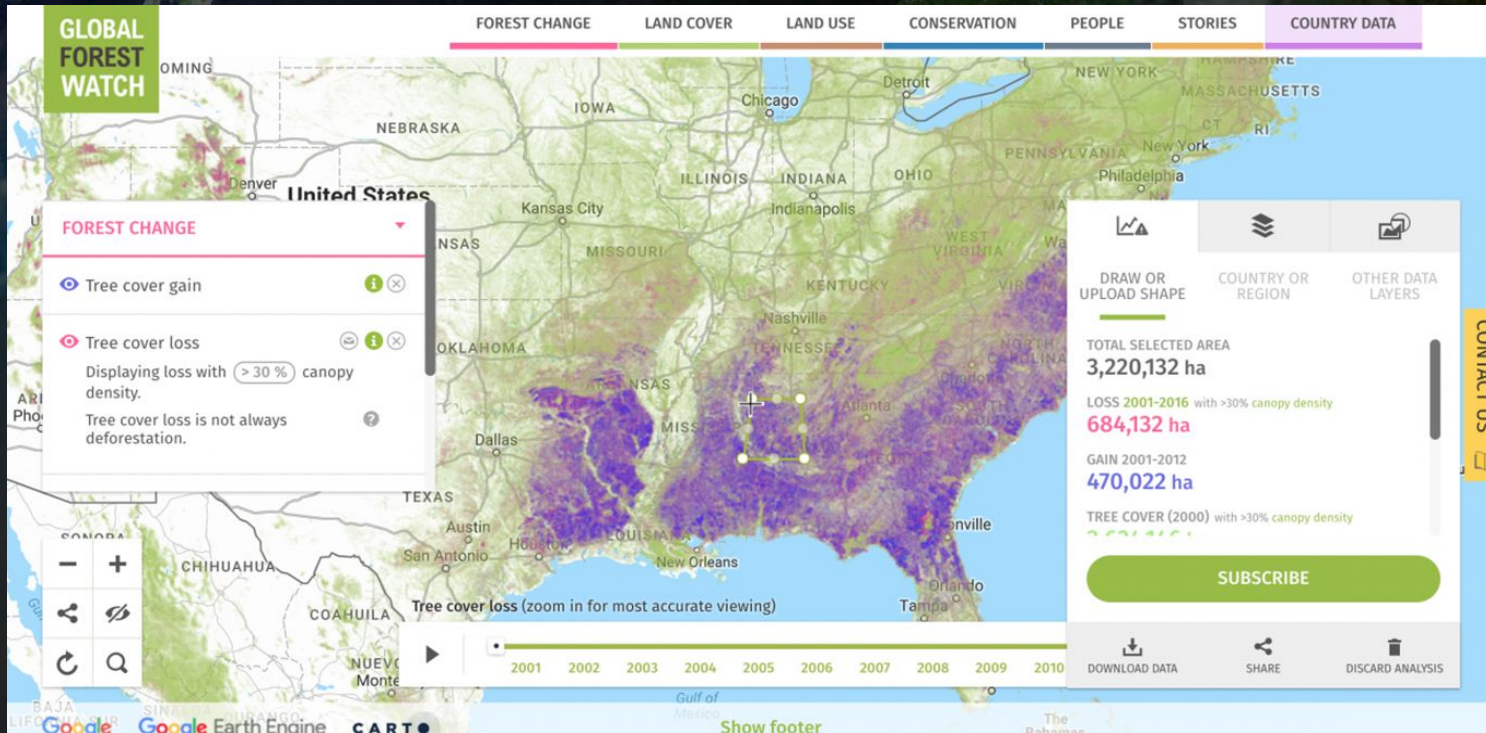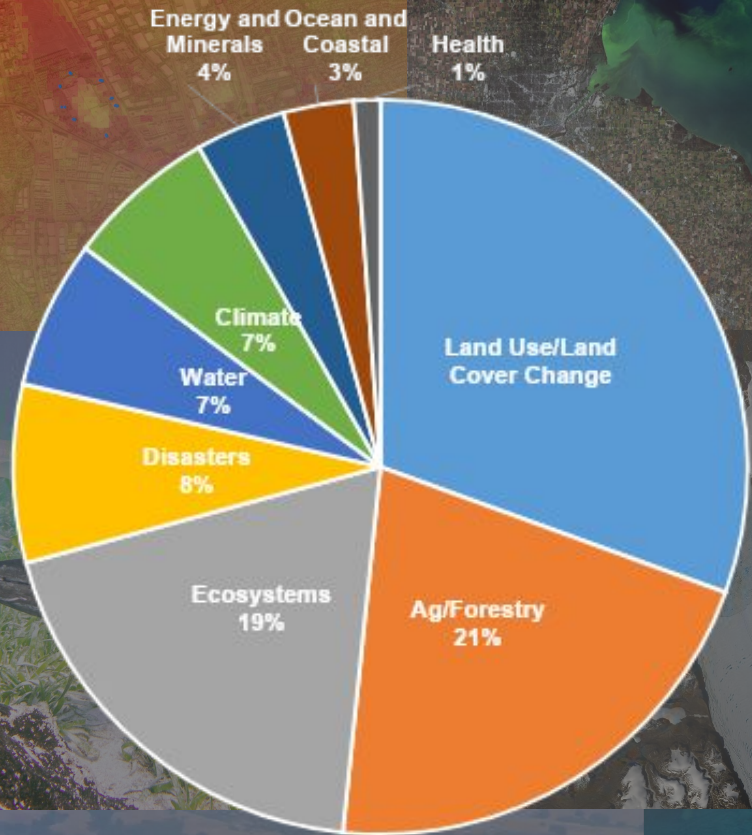

Global Surface Water Change, Pekel, et al., Nature 2016
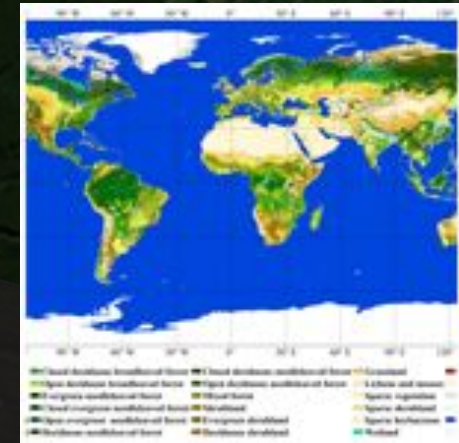
Mapping Global Cropland, Phalke, et al, ISPRS 2020

• Global Forest Watch provides a "**near-real time**" view of deforestation (and reforestation) around the world using millions of Landsat images through Google's cloud computing and online access (https://globalforestwatch.org)

Landsat Applications and Users

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

- Federal Agencies
- State Agencies (planning, natural resources, Transportation)
- University Researchers and Educators
- International Organizations
- Non-Governmental Organizations
- Commercial
- Foreign space agencies
- U.S. and foreign commercial satellite operators
- Cloud Service Providers
- Tribal Governments
- Academic Institutions
- General Public

Pie chart:
- Energy and Minerals 4%
- Ocean and Coastal 3%
- Health 1%
- Land Use/Land Cover Change
- Climate 7%
- Water 7%
- Disasters 8%
- Ecosystems 19%
- Ag/Forestry 21%

Landsat Science Products - 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
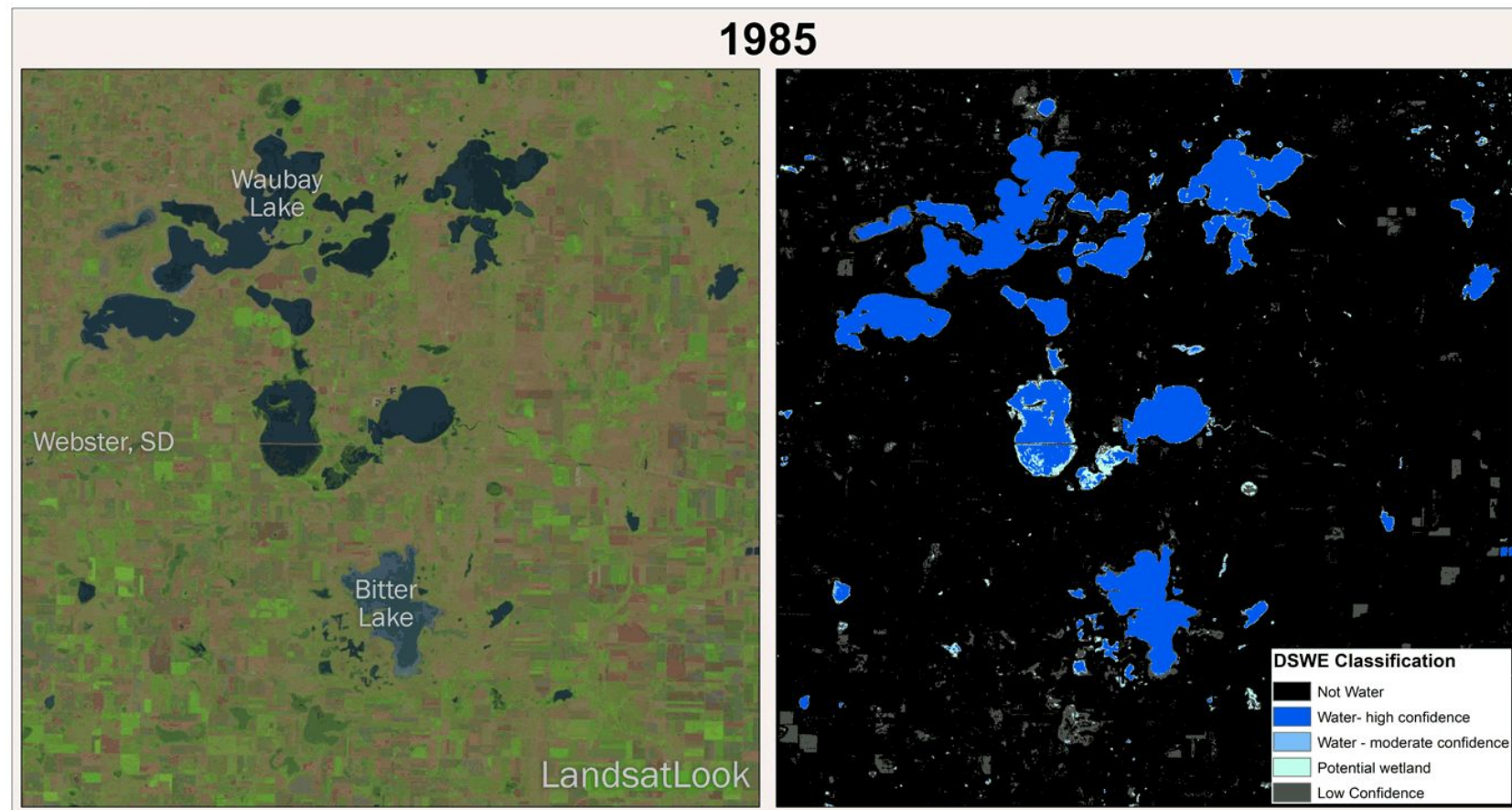
Landsat Science Products - Fractional Snow-Covered Area

Landsat Fractional Snow-Covered Area is an information product that maps snow cover over wide areas such as mountain ranges and river basins.

This product is a crucial input to some Western States' sustainable water supply and resource management objectives.
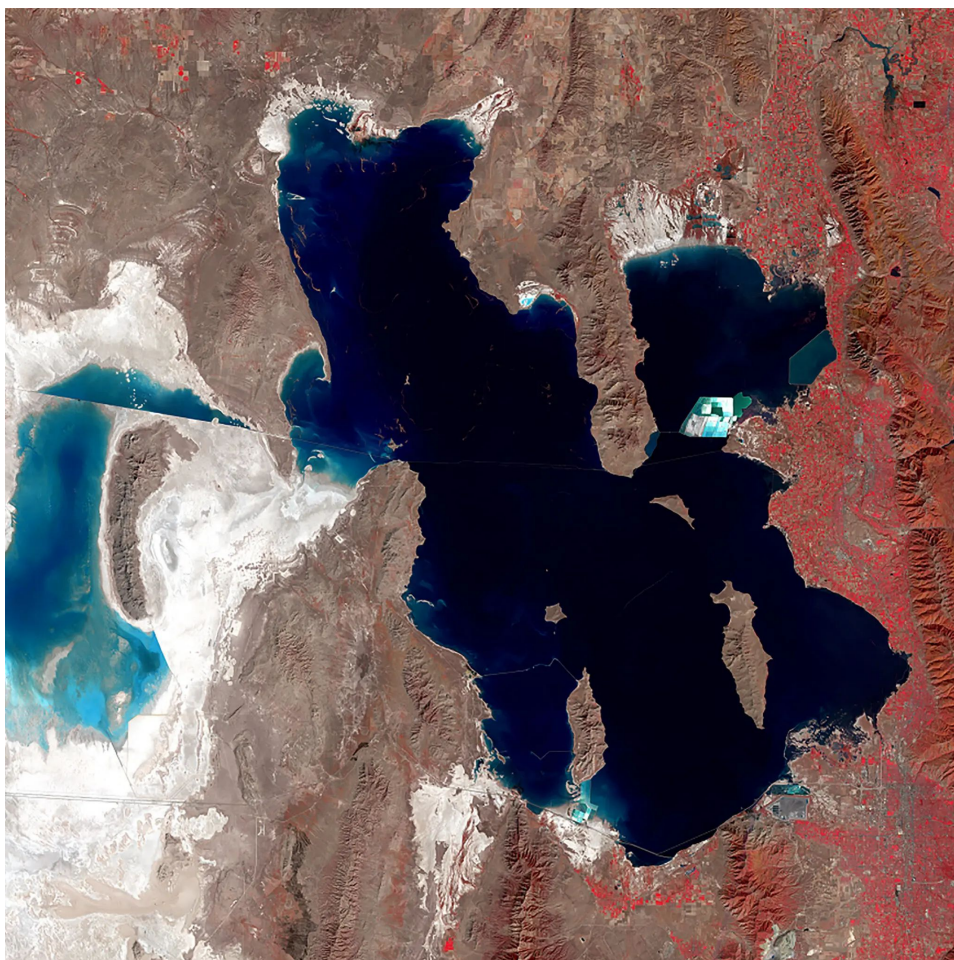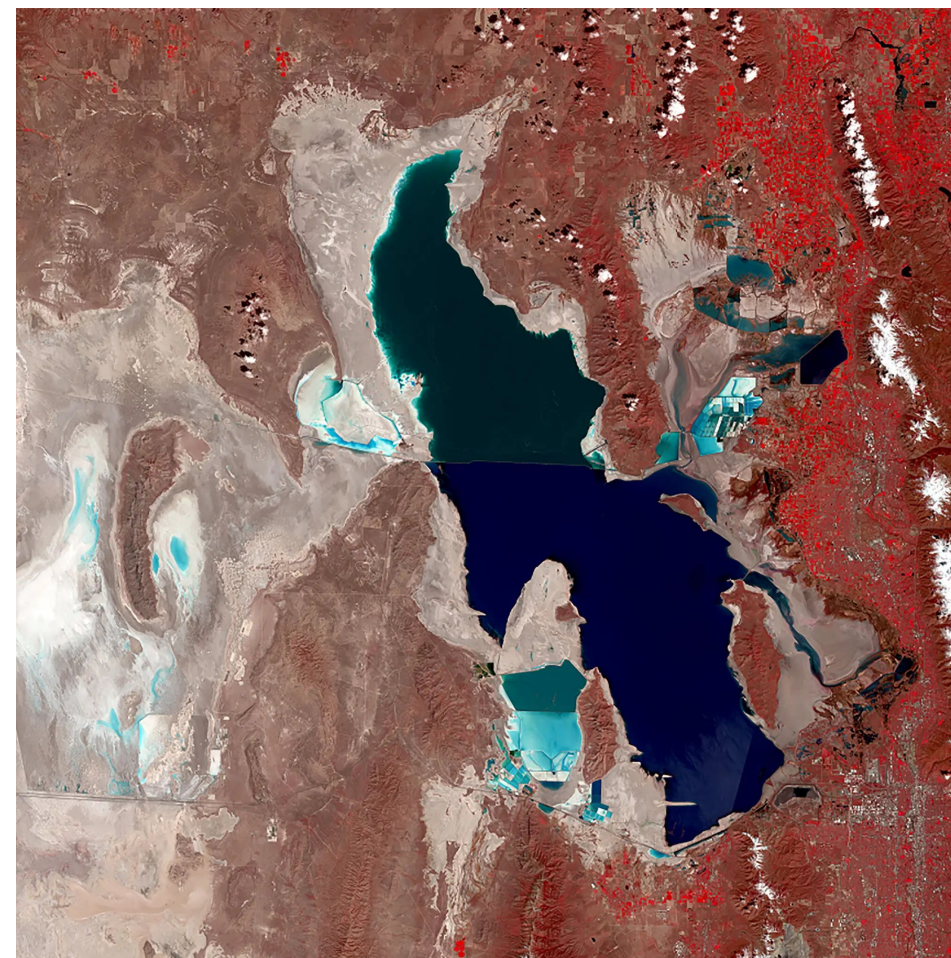

Tile h07v05-06 - Landsat 5 bands 6,5,4   27 Mar 2010

10 Km
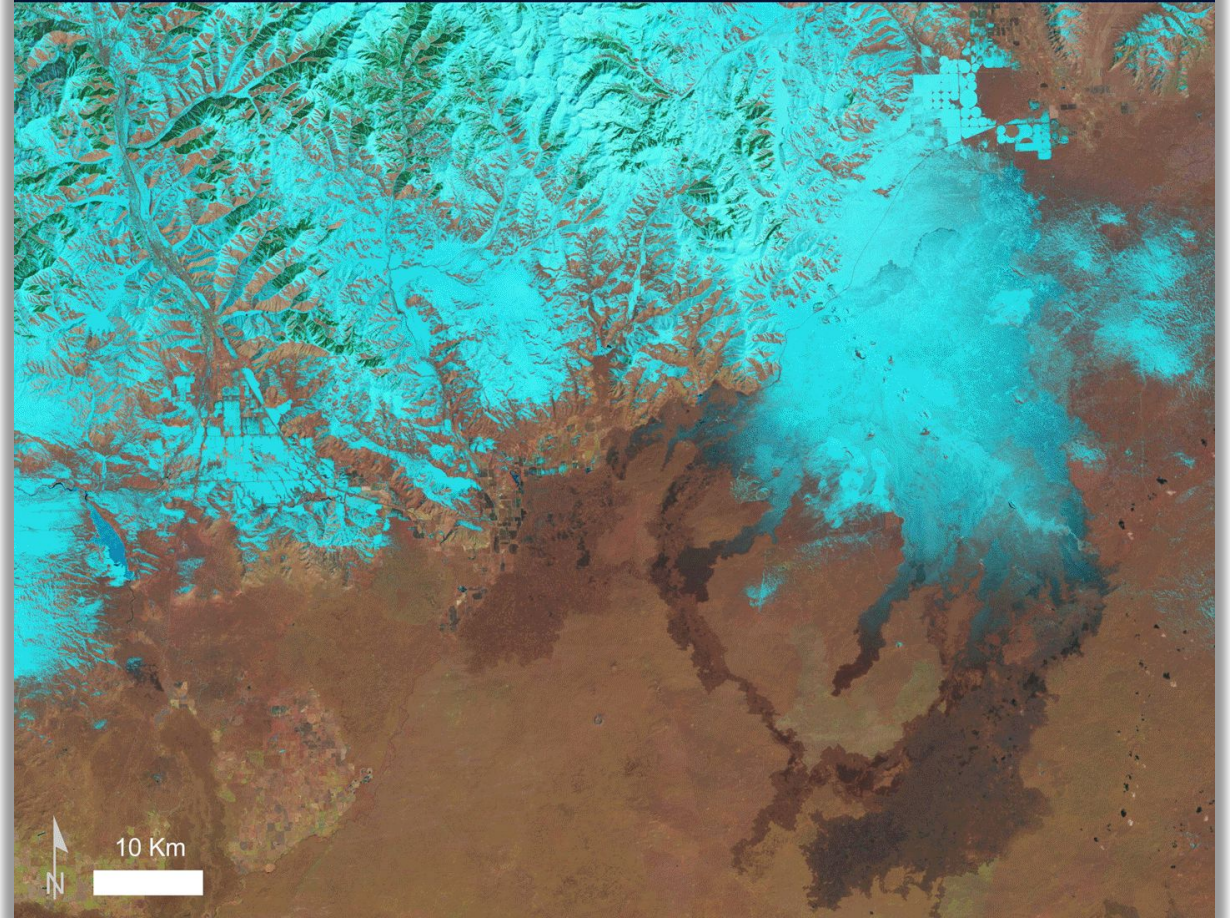
Craters of the Moon National Monument & Preserve, Idaho, 2010.

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Great Salt Lake, UT, September 1987

Great Salt Lake, UT, May 2021

Landsat Actual Evapotranspiration Science Product

Annual total evapotranspiration 2017 from Landsat

Boise, ID

Fresno, CA

Garden City, KS

Greenville, MS

Albany, GA
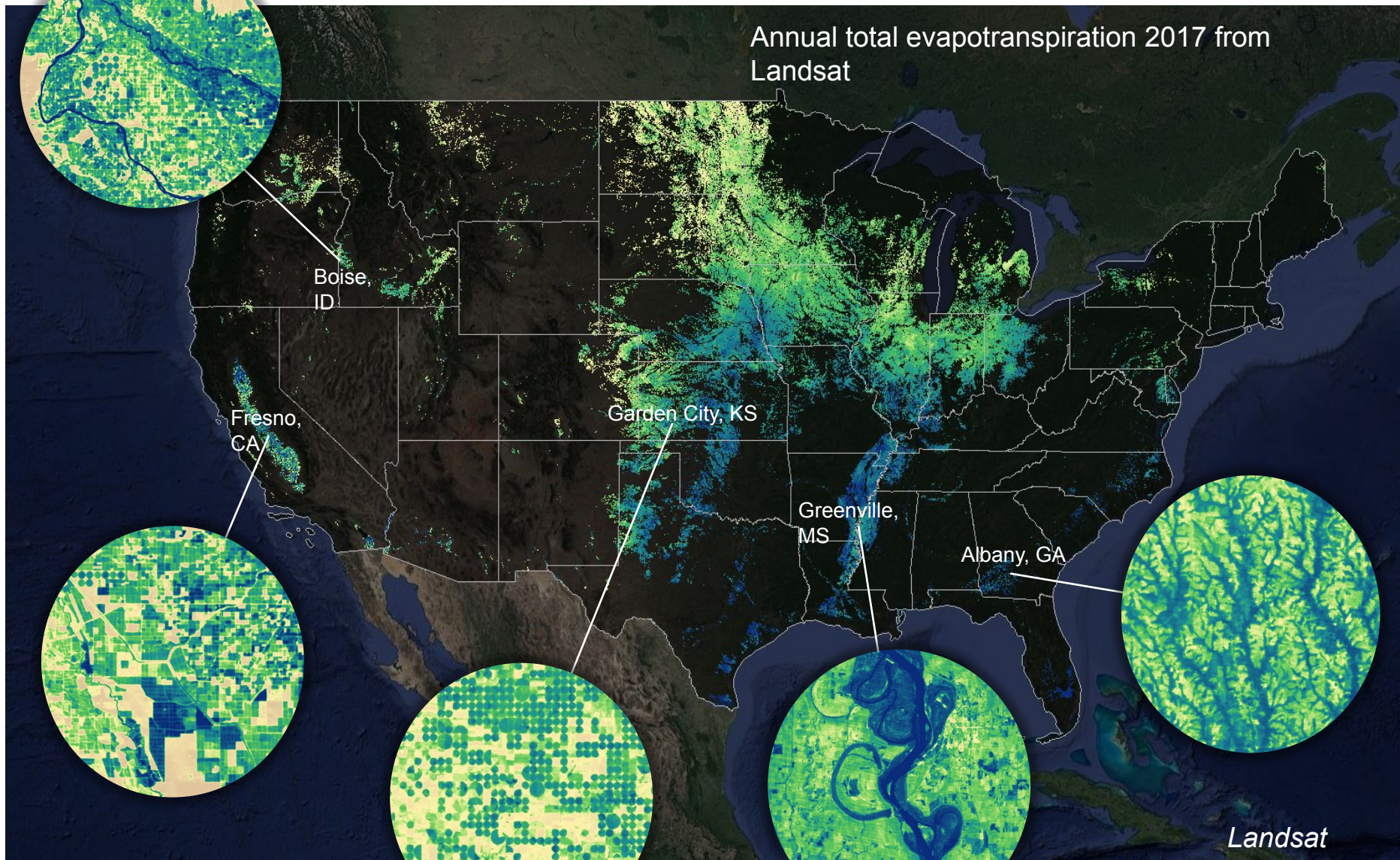
Landsat

- Landsat-derived provisional Actual Evapotranspiration science products from 1985 are available globally.

- Example here captures cropland ET and water use.

Mac Friedrichs, Gabriel Senay, EROS

In collaboration with

OpenET, a public-private collaboration with over 30 experts in remote sensing science and technology, including NASA, USGS, USDA, DRI, the Environmental Defense Fund, Google Earth Engine, and more.

The result of years of effort by partnering Federal agencies, universities, environmental groups, water managers, and farmers who use water to irrigate crops. Open ET employs an ensemble approach of leading ET algorithms to provide the most comprehensive estimates of ET for water use in the Western US.
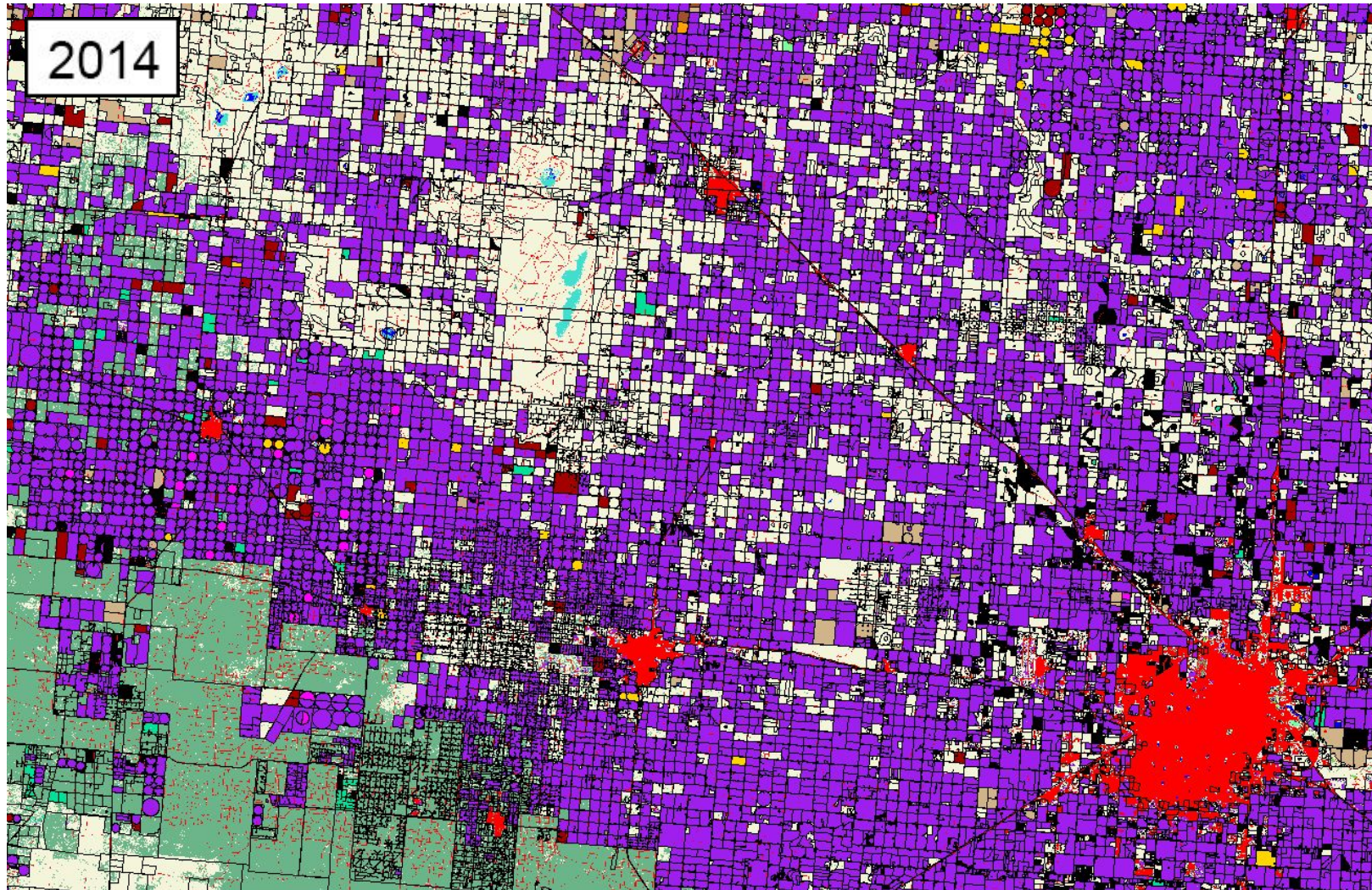
Find Data at:
https://openetdata.org
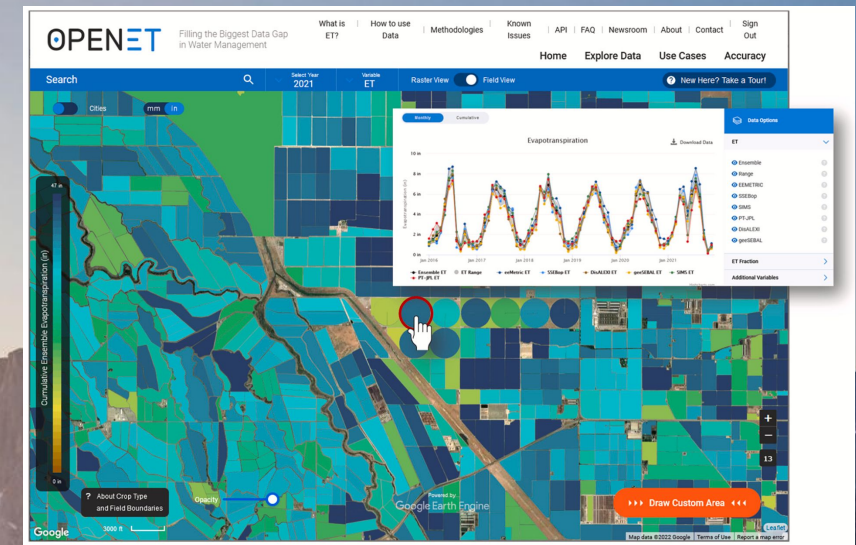
Landsat provides crucial thermal information for estimating evapotranspiration and water use

Lubbock, TX region

- USGS scenario-based modeling of future landscape change 2014-2100

- Combines climate scenarios, land and water use modeling using real land ownership and land management boundaries to mimic real patterns of landscape change.

- As the aquifer becomes depleted and the climate changes, irrigated cotton (purple) can no longer be supported, and ag fields shift either to dryland wheat, or revert to grass or shrub states.

Based on USGS FOREcasting SCEnarios of Land–use Change (FORE-SCE).

Sustainable Land Imaging (SLI)

A DOI/USGS-NASA partnership to ensure sustained access to high-quality, global, land-imaging measurements compatible with the existing 50-year Landsat record for research and operational users

- NASA is responsible for developing the space segment, launch, and on-orbit check-out

- DOI/USGS is responsible for establishing user needs, developing the ground segment, and flight and ground system operations

BUILDING ON THE LANDSAT LEGACY

Landsat 1 1972-1978
Landsat 2 1975-1982
Landsat 3 1978-1983
Landsat 4 1982-1993
Landsat 5 1984-2013
Landsat 6 1993
Landsat 7 1999 –
Landsat 8 2013 –
Landsat 9 2021 –

1972   1980   1990   2000   2010   2020   2030

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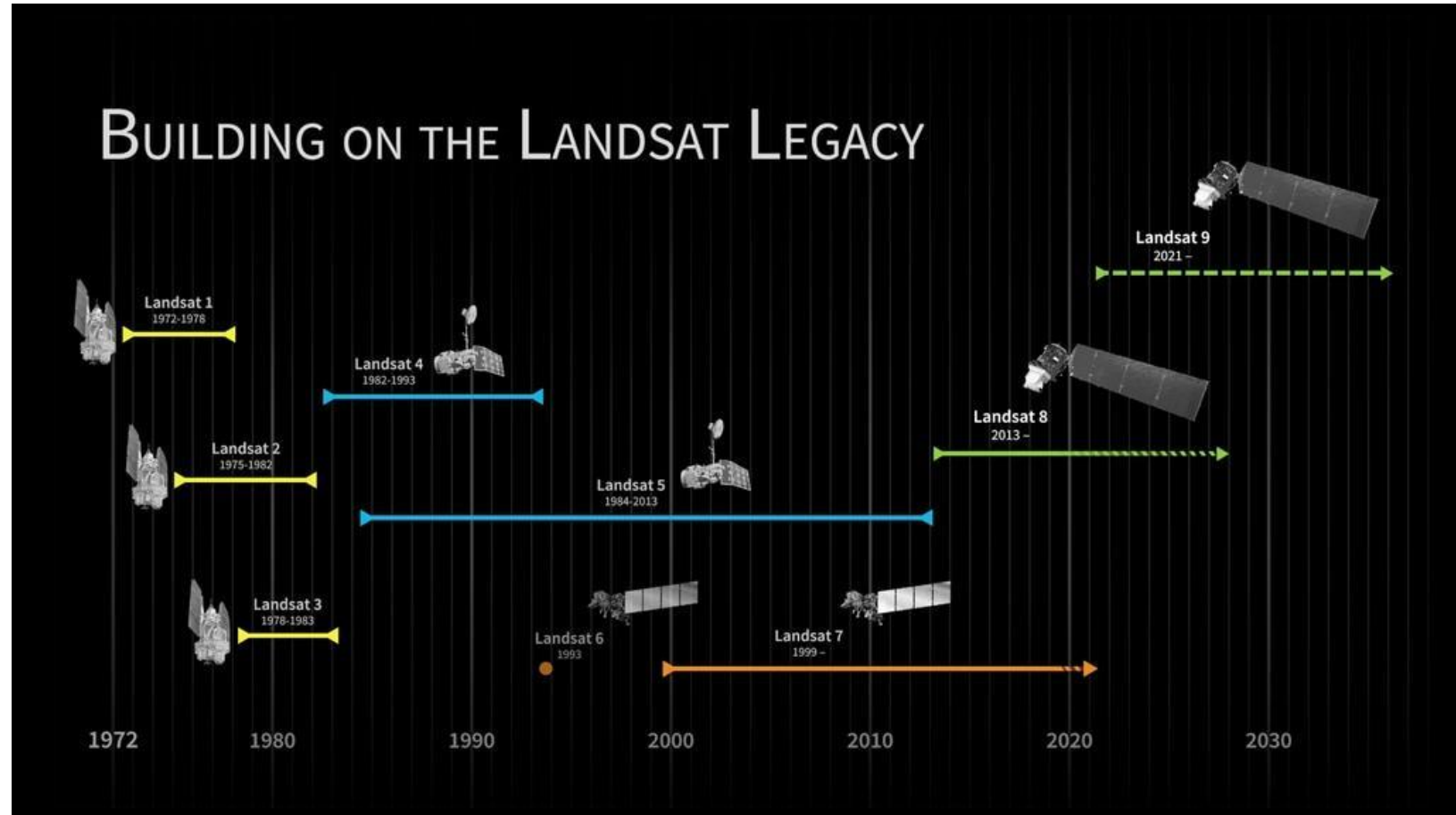
Requirements, Capabilities, and Analysis

Core Science Systems – National Land Imaging Program

Landsat Next

- **Landsat Next "Superspectral Triplets" mission**, the result of **six years** of needs assessment, technology investment, architecture studies and early project development, **provides a completely new next-generation Landsat, meeting the users' needs** for richer spectral information and improved spatial and temporal resolution and **maintaining U.S. leadership in Earth observation**

  - **Improved revisit frequency** to support applications requiring ~weekly clear views, such as crop health & productivity, water quality, snow/ice state, wildfire

  - **Higher spatial resolution** (10/20-meter data for VSWIR and 60-meter for TIR) to support monitoring of small agricultural fields, forest disturbance, urbanization, and other applications

  - **Additional spectral bands** to support emerging applications in water quality, snow hydrology, soil mapping, and other areas; improve atmospheric correction and surface temperature retrieval

  - **Maintaining radiometric quality** established by Landsat 8/9

- NASA and USGS Landsat Next project teams, established in 2020, are in development phase A and on track for instrument award in 2024

> **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**
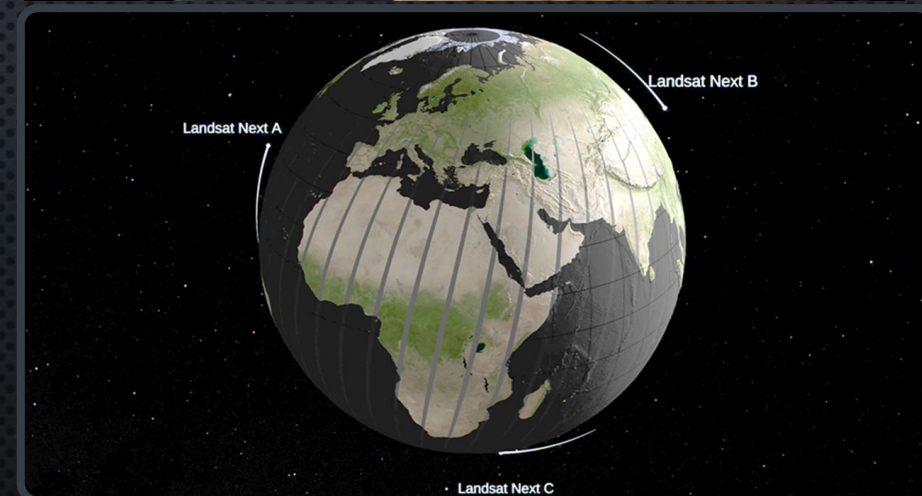

NASA "Landsat's Next Chapter" Video
https://svs.gsfc.nasa.gov/14262

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	Landsat Next higher temporal revisit is needed to capture the onset of more frequent wildfires and

Landsat Next Adds Benefits for Water Applications

Landsats 8 & 9

Landsat Next

Visible light

Near Infrared

Shortwave Infrared

Thermal Infrared
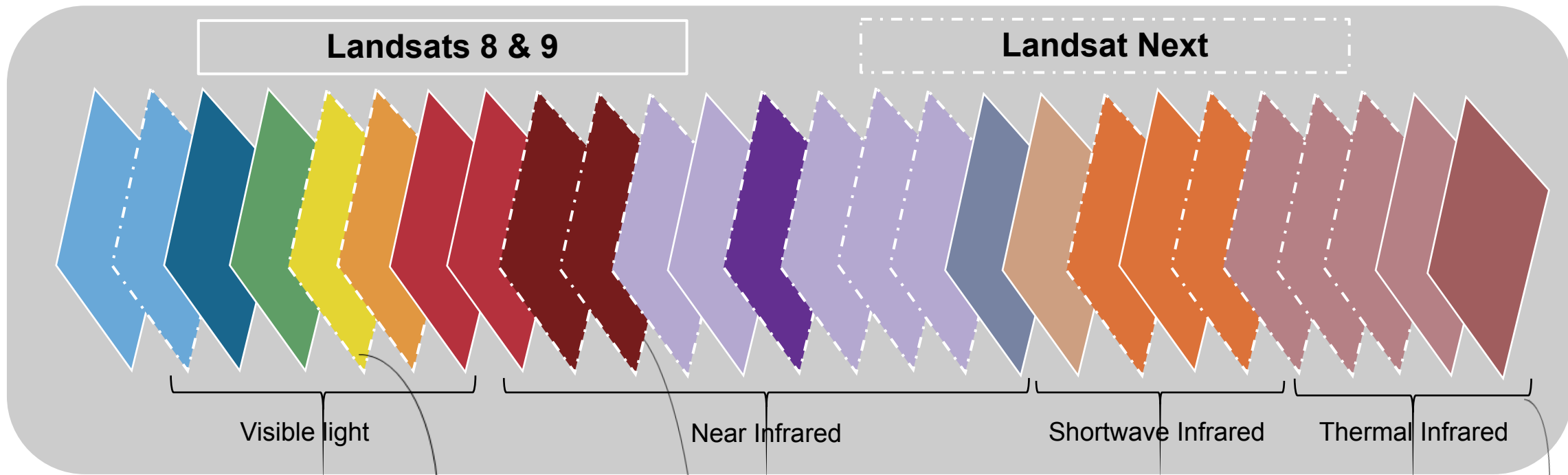
Bands: 6 - 7
Application Area: Water Quality
New Band Impact: Enhances detection of the specific organisms that cause harmful algal blooms.

Bands: 9 - 10
Application Area: Crop condition monitoring
New Band Impact: Improves early detection of crop stress.

Bands: 22 - 26
Application Area: Agriculture
New Band Impact: Improves monitoring of crop water use.

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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

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

- Landsat Next development & operations is in **Satellite Operations (+12M in FY25)**
  - Develop the satellite ground system enabling enhanced observing capabilities

- Landsat Science is in **Science, Research & Investigations (+9.25M in FY25)**
  - Support science research for algorithm development to translate data into information products to take maximum advantage of space system capabilities

NASA and USGS each require their full FY25 Landsat Next funding requests to maintain Landsat Next development, reduce threats of a data gap, and enable improved and emerging resource and environmental management applications.
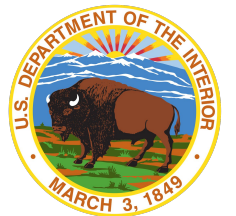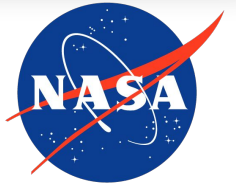
Summary

Landsat Next will continue and improve the 50-year Landsat data record

- 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 and improve their products.

Provides a completely new and improved Landsat for the next generation

- Better spatial resolution (10 meter vs 30 meter) and twice as many spectral bands (new ones for agriculture, harmful algal blooms, water use, mineral mapping, volcanos), with improved revisit (6-days) to track ever-increasing rates of change on the land surface.

Continues substantial economic benefits to the U.S. economy (~$2 billion/ year)

- 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.

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Columbia Glacier, Alaska 2002 - 2021
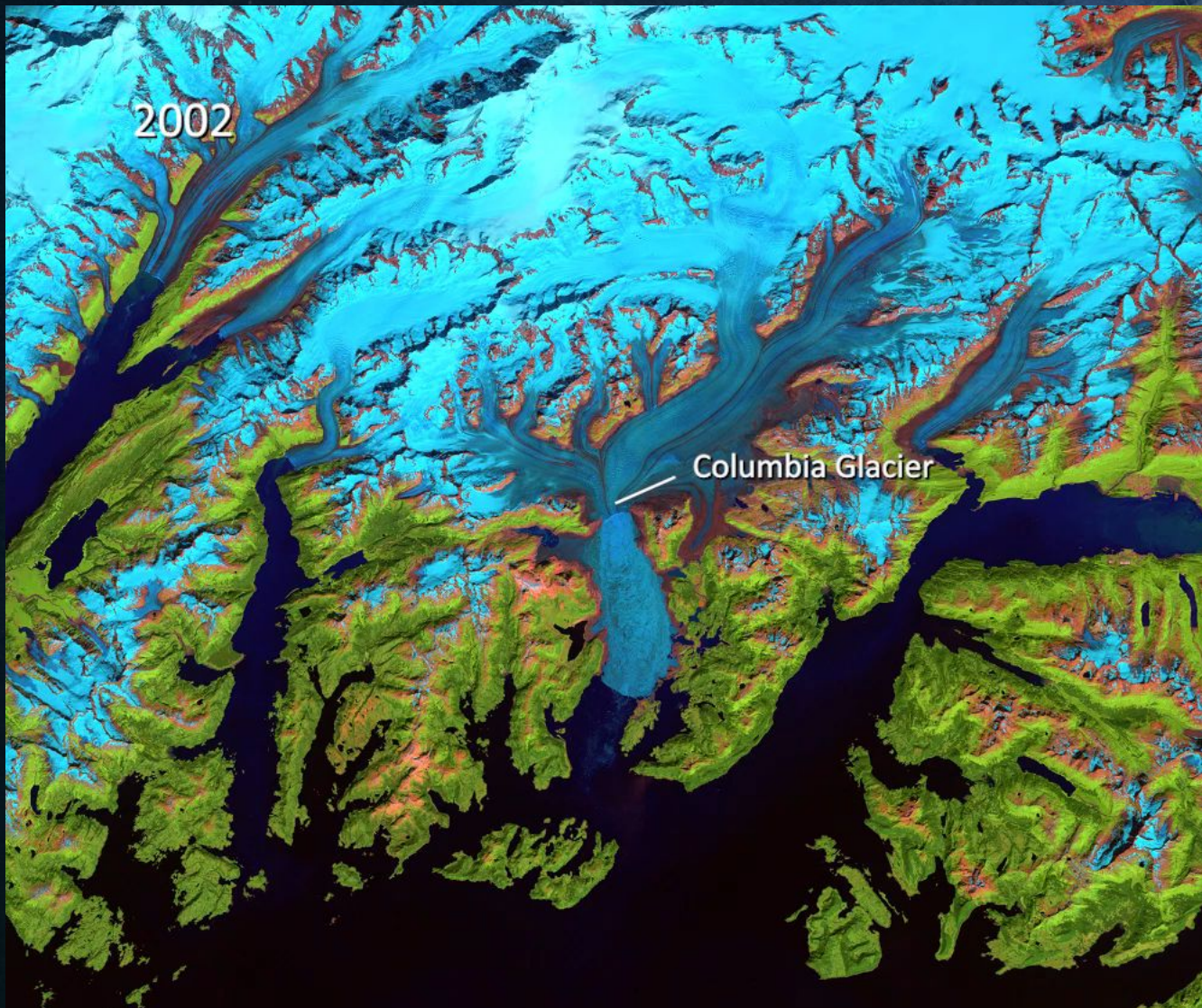
Thank You!

Timothy Stryker
Chief, Outreach and Collaboration Branch
National Land Imaging Program
U.S. Geological Survey
U.S. Department of the Interior
tstryker@usgs.gov

Landsat Operations Status
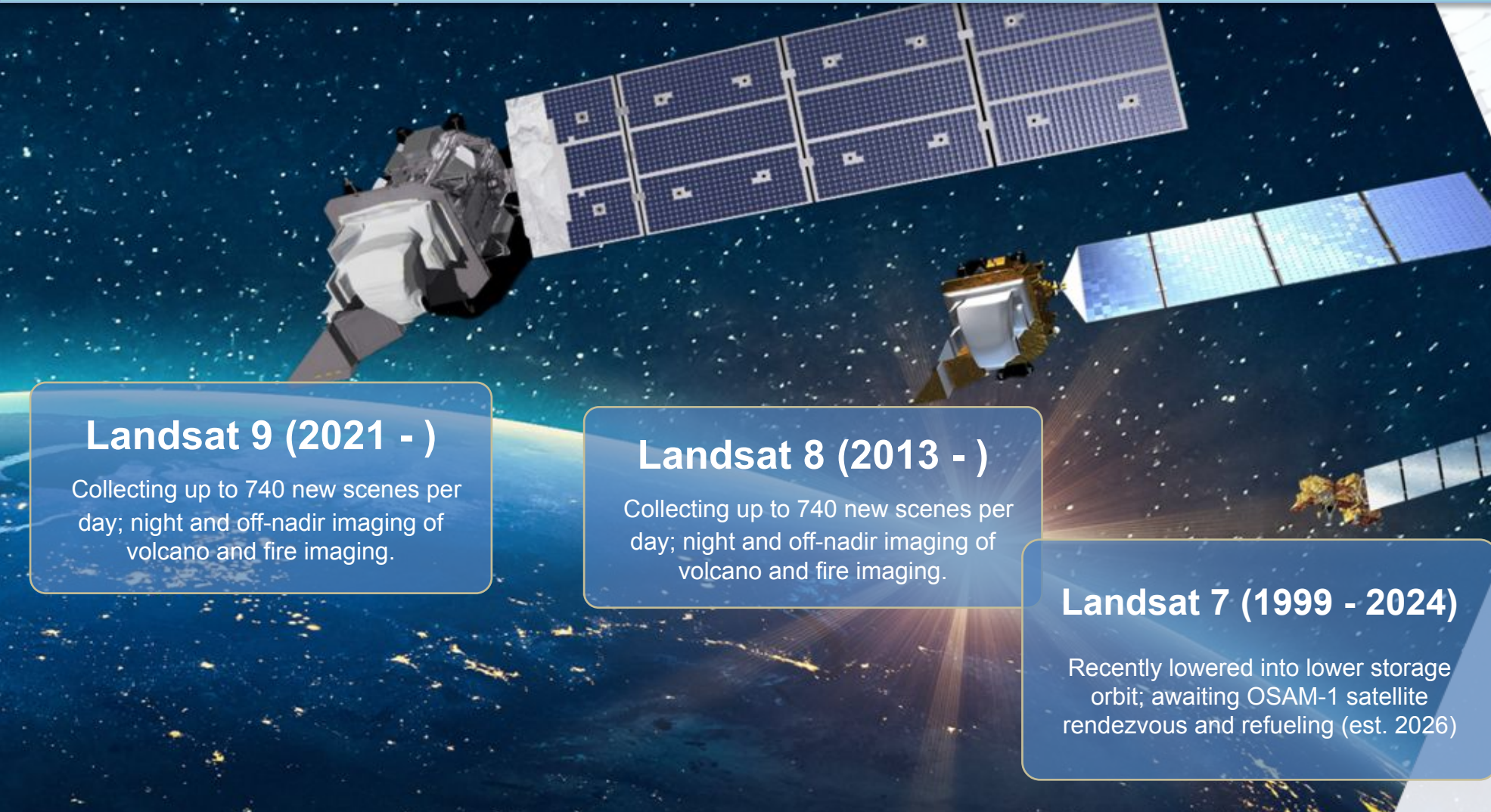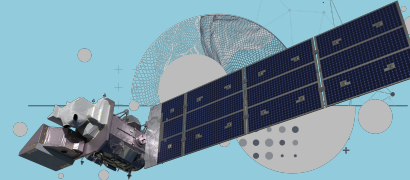
Landsat 9 (2021 -)

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

Landsat 8 (2013 -)

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

Landsat 7 (1999 - 2024)

Recently lowered into lower storage orbit; awaiting OSAM-1 satellite rendezvous and refueling (est. 2026)

Earth Resources Observation and Science Center (EROS)

Landsat Archive Operations

11+ million unique Landsat scenes available in the over 50-year archive, with well over 100 million downloads in the last year alone.

–

"Collection 2" available on the Amazon Cloud – more than 14 billion accesses in the last year alone.

Sustainable Land Imaging Governance
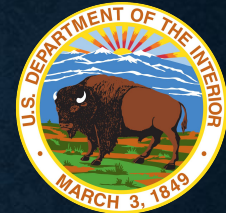
- **New ten-year SLI agreement signed in December 2021**

- **Joint NASA-DOI/USGS leadership commitment and structure to continue and improve the Landsat data record**

NASA		DOI
Associate Administrator, Science Mission Directorate	**SLI Joint Steering Group**	Assistant Secretary, Water and Science
Director, Earth Science Division		Director, United States Geological Survey
Associate Director, Flight Programs	**SLI Roundtable**	Associate Director, Core Science Systems
Program Executive, SLI		Program Coordinator, National Land Imaging
NASA Project Manager(s)		USGS Project Manager(s)

Joint Leadership and Management Structure

Multi-Decadal Sustainable Land Imaging Program

First Phase of SLI

Landsat 9

Second Phase of SLI

Landsat Next

Commercial/Interagency/International Partnerships

SLI Technology Development and Infusion (NASA)
(USGS)

User Needs Development (USGS)

2010

LANDSAT 8

SLI Architecture Study 2013-2014

11/22/2017 JSG

SLI Architecture Study 2018-2019

04/01/2020 JSG

2020

02/10/2022 JSG

LANDSAT 9

SLI Architecture Study 2025-2026

LANDSAT NEXT   NET 2030

LANDSAT BEYOND

21

JSG=Joint Steering Group Meeting

SLI "Second Phase" Program Activities

- **Three new elements**

  - **Landsat Next** – Government-managed, contractor-built observing system
    - High-quality calibrated data continuity and traceability with 50-year Landsat data record
    - Supports applications with validated user needs
    - Provision of commercially unavailable and unviable spectral bands (Shortwave and Thermal Infrared)
  - **Expanded International partnerships**
    - Continue international data harmonization efforts with the European Sentinel 2 mission
    - Provide technical assistance to the Space-based Cross-calibration Radiometer (SCR) project with Australia
  - **Commercial Data Program**
    - Exploring use of commercially available high spatial resolution and high revisit of Visible-to-Near-Infrared data

Temporal Coverage Impacts of Landsat Next on Agency Needs

LNext — Landsat Next

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Science Applications and Agencies for User Needs Satisfaction	Climate		Landsat Heritage		Landsat Next
	Climate Indicators	Critical Measures	L8+L9		**Triplets**
			8-day Revisit	16-day Revisit	**6-day Revisit**
Agriculture & Forestry (FAS, FSA, NASS, NRCS, RMA, USFS, BIA, BLM, FWS, NPS, USGS, EPA, USAID, NASA, DOE)	ST, LC	CT, CY, LAI, VC	🟨	🟥	🟩
Emergency/Disasters (USGS, OSMRE, BOEM, BSEE, USFS, NOAA, USAID, NIH, FEMA, NASA, DOE)		AF, VA, SWE, OSE	🟥	🟥	🟥
Public health/Water Quality (USGS, NPS, EPA, NOAA, NIH, NASA)	ST	UHI, WQWC	🟨	🟥	🟨
Water resources monitoring (BOR, USGS, FAS, NASS, NASA, DOE)	ST	ET, WQWC	🟨	🟥	🟩
Wildfire Response and Assessment (BIA, BLM, FWS, NPS, USGS, USFS, NRCS, NASA)	ST, LC	BABS, VC, LULC	🟨	🟨	🟨
Cryosphere (BOR, USGS, NRCS, NOAA, NASA, DOE)	ST, GLI	GLI, SCE, SGS	🟨	🟥	🟩
Ecosystems/Land Use (USDA, DOI, EPA, NOAA, USAID, FEMA, NASA, DOE)	ST, LC	fPAR, LULC, VC	🟨	🟥	🟩

ST – Surface Temperature
LC – Land Carbon
GLI – Glacier & Ice Sheets

CT – Crop Type
CY – Crop Yield
LAI – Leaf Area Index
VC – Vegetation Condition
BABS – Burned Area/Burn Severity
AF - Active Fires
VA – Volcanic Activity
SWE – Surface Water Extent

OSE – Oil Spill Extent
UHI – Urban Heat Island
WQWC – Water Quality/Water Chemistry
ET – Evapotranspiration
LULC – Land Use/Land Cover
SCE – Snow Cover Extent
SGS – Snow Grain Size
fPAR - Photosynthetically Active Radiation

Reflects varying spatial and spectral capabilities

GREEN = > 2/3 of user revisit needs met
YELLOW = 1/3 – 2/3 met
RED = < 1/3 met

Key to Agencies
FAS: Foreign Agriculture Service
FSA: Farm Service Agency
NASS: National Agricultural Statistics Service
NRCS: Natural Resources Conservation Service
RMA: Risk Management Agency
USFS: U.S. Forest Service
BIA: Bureau of Indian Affairs
BLM: Bureau of Land Management
FWS: U.S. Fish and Wildlife Service
NPS: National Park Service
USGS: U.S. Geological Survey
EPA: Environmental Protection Agency
USAID: U.S. Agency for International Development
NASA: National Aeronautics & Space Administration
DOE: Department of Energy
OSMRE: Office of Surface Mining Reclamation and Enforcement
BOEM: Bureau of Ocean Energy Management
BSEE: Bureau of Safety and Environmental Enforcement
NOAA: National Oceans and Atmospheric Administration
NIH: National Institutes of Health
FEMA: Federal Emergency Management Agency
BOR: Bureau of Reclamation
USDA: U.S. Department of Agriculture
DOI: Department of the Interior

National Land Imaging Science Portfolio

The National Land Imaging science portfolio conducts research and delivers information products to:

- Improve understanding of rates, causes, and consequences of land change

- Anticipate future landscape changes

- Deliver landscape change information to natural resource managers and stakeholders

- Mitigate adverse effects of environmental change
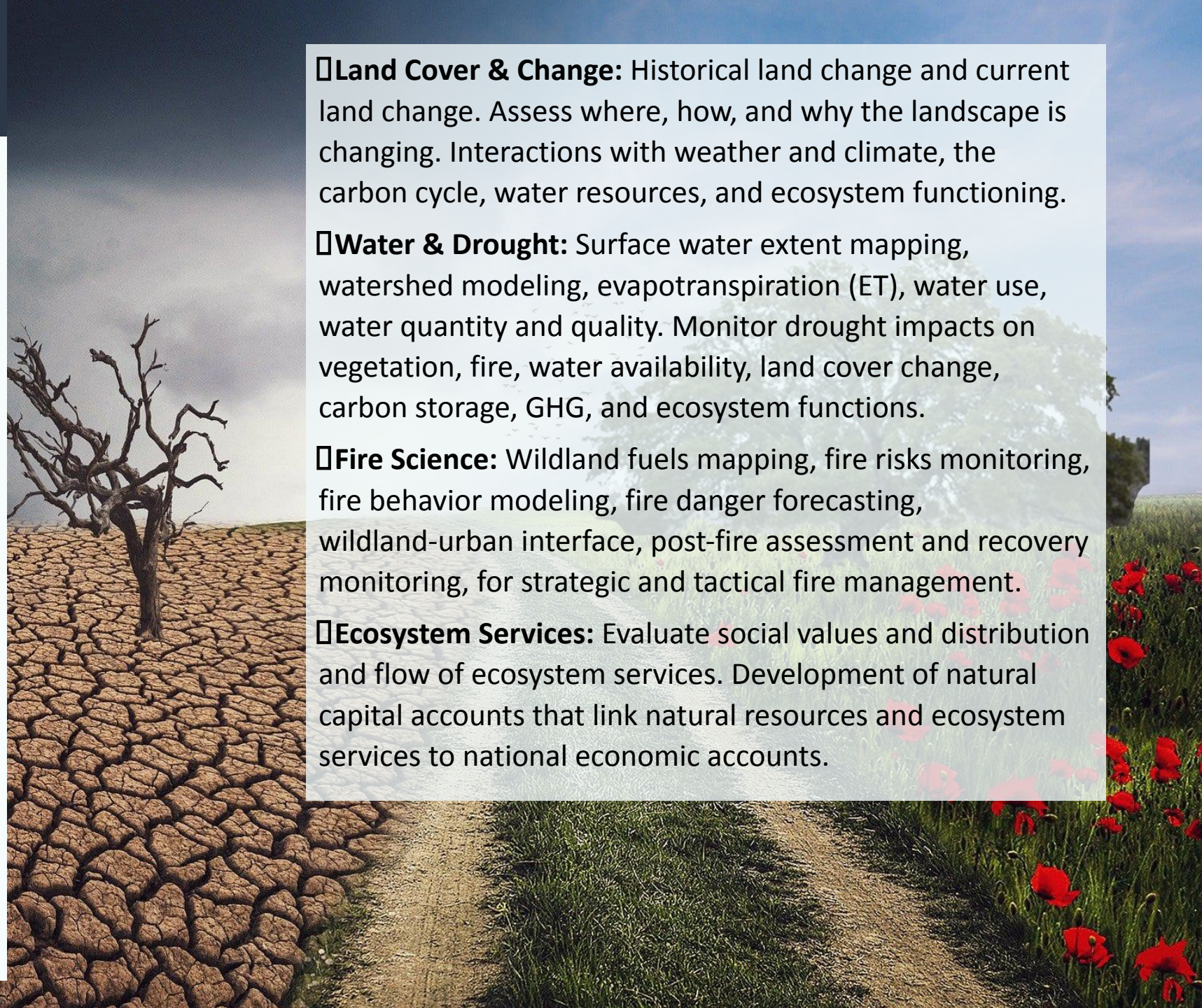
Land Cover & Change: Historical land change and current land change. Assess where, how, and why the landscape is changing. Interactions with weather and climate, the carbon cycle, water resources, and ecosystem functioning.

Water & Drought: Surface water extent mapping, watershed modeling, evapotranspiration (ET), water use, water quantity and quality. Monitor drought impacts on vegetation, fire, water availability, land cover change, carbon storage, GHG, and ecosystem functions.

Fire Science: Wildland fuels mapping, fire risks monitoring, fire behavior modeling, fire danger forecasting, wildland-urban interface, post-fire assessment and recovery monitoring, for strategic and tactical fire management.

Ecosystem Services: Evaluate social values and distribution and flow of ecosystem services. Development of natural capital accounts that link natural resources and ecosystem services to national economic accounts.
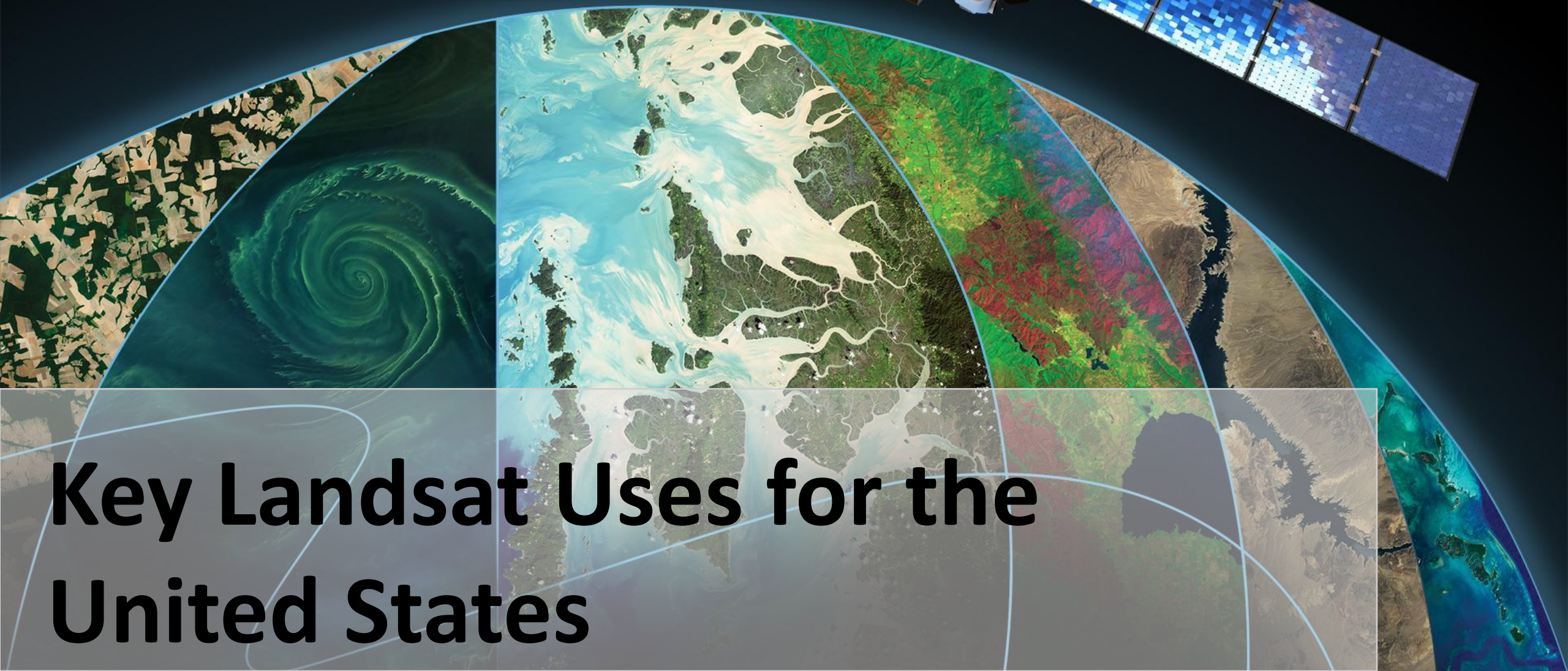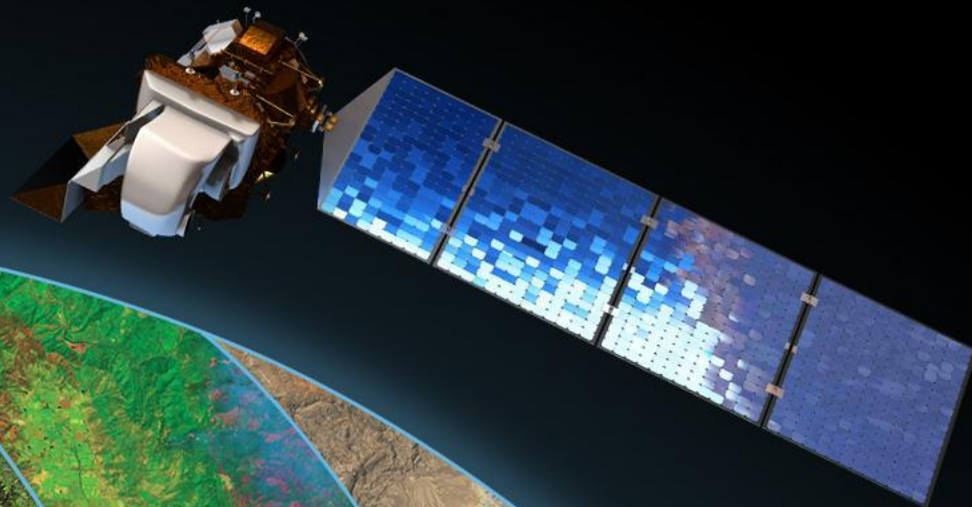
Key Landsat Uses for the United States

1 Development (towns and cities): Landsat helps identify urban heat islands in the hottest regions of the U.S.

ISSUE

- Urban population in the U.S. has increased >6.3% in last 40 years
- More than 80% of U.S. population resides in urban areas (U.S. Census, 2020)
- Urban heat islands due to urban infrastructure absorbing + re-emitting heat from the sun can lead to physical discomfort, higher rates of illness and death

SOLUTION

- Consistent, reliable, and historically unique Landsat data archive and thermal imaging capabilities provide important tools for high-heat states (i.e., TX, CA) to track extreme urban heat events, enhancing economic and public health outcomes

LANDSAT NEXT

- Using Landsat Next's improved thermal resolution, scientists and data users can map the temperature of urban areas in finer detail and may enable more sustainable urban development

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Water: Landsat supports monitoring water use and quality, in addition to public health alert systems

ISSUE

- Monitoring water use and quality requires over $65 billion/year in federal funding
- Overabundance of nutrients from agricultural runoff + other pollutants can cause harmful algal blooms (HAB)
- HABs make water toxic for humans and wildlife

SOLUTION

- Landsat data offers alternative to complex volunteer collection efforts to survey for HABs (cyanobacteria concentration)
- Highly sensitive and accurate multi-spectral capabilities allow detection of algal growth (chlorophyll a)

LANDSAT NEXT

- Landsat Next's new superspectral capabilities will improve the accuracy of HAB mapping by up to 50% compared to Landsat 8/9 by detecting phycocyanin, a pigment specific to HABs) (Boucher and others, 2018; Zolfaghari et al., 2021)
- Allows for earlier detection and more timely treatment (Wolf and others, 2017)

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3 Forests: Landsat supports monitoring and improved land management decision making

ISSUE
- Forests provide essential jobs, natural resources, consumer products, environmental benefits, and recreation
- Forests maintain natural heritage, support economic growth, enable innovative products (e.g., hydrogen fuel w/ carbon capture and mass timber)

SOLUTION
- Landsat 8/9 is essential for effective forest management and conservation
- Forest monitoring in the U.S. and worldwide is enabled by Global Forest Watch science products built on the Landsat archive
- Products provide info on tree cover loss, deforestation hotspots, near real time deforestation alerts

LANDSAT NEXT
- Landsat Next will increase the timeliness and detail of deforestation and wildfire tracking
- New info from red edge bands + more timely data will allow better forest health tracking

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4

Disasters: Landsat helps monitor and manage disasters, and post disaster recovery

ISSUE
- In 2022 disasters produced $165.1 billion in damages across the United States
- Recently, Western U.S. has witnessed increased fire frequency and intensity, and broader burned area
- Between 2013-2022, U.S. spent an average >$2 billion/year to fight wildfires, including $3.5 billion in 2022
- Disasters threaten people, wildlife, infrastructure, strategic forests and rangelands, and other natural resources

SOLUTION
- Wildfire severity mapped by the USGS and USFS Monitoring Trends in Burn Severity (MTBS) program across the U.S. use the Landsat archive
- Landsat 8/9-powered near real time active fire monitoring via NASA-USFS Fire Information for Management System (FIRMS) program

LANDSAT NEXT
- Greater frequency and detail of Landsat Next observations will improve the frequency of monitoring and management of wildfires and other disasters + post-event recovery activities

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Agriculture: Landsat improves crop treatments and production forecasting across America's heartland

ISSUE
- Agriculture, food, and related industries contributed $1.420 trillion to the US GDP in 2022
- Each growing season, the USDA issues several reports to forecast the year-end tally for major crops including corn, soybeans, and wheat
- Multi-million-dollar US agricultural commodities market relies on crop predictions when conducting future trading

SOLUTION
- Since 2009, the USDA's National Agricultural Statistics Service, or NASS, has drawn on Landsat data to monitor dozens of crops in the lower 48 states as part of NASS's Cropland Data Layer program.
- Landsat data enables accuracy of USDA and state forecasts and monitoring

LANDSAT NEXT
- Finer (10-meter) spatial resolution will allow monitoring and crop yield estimation for 20-25+% more fields
- Enhanced spectral imaging capabilities will improve crop health monitoring and early stress detection
- Improved revisit time (16 to 6 days) will enable more timely reporting and analysis.

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