Landsat 9 and Landsat Collection 2 data products in support of NASA's SnowEx objectives

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Outline

- Landsat mission and NASA-USGS partnership
- Landsat mission measurements
- Landsat 9 and NASA-USGS Sustainable Land Imaging Program
- Landsat Tiered Collections
- Landsat Collection 1 Data Products
- Landsat Collection 2 and Processing
- Landsat Collection 2 Data Products
- Landsat Science Data Products
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- Landsat Data Product Access
- NASA SnowEx relevant Landsat Science Data Products
- Leveraging Landsat in support of NASA SnowEx

Landsat Mission Timeline

Mission goal since 1972: to provide Earth looking measurements to enable detection and attribution of natural verses anthropogenic causes of land surface change

For 2/3rds of Landsat's lifetime there have been two active satellites providing 8-day temporal revisit

source: https://www.usgs.gov/land-resources/nli/landsat/
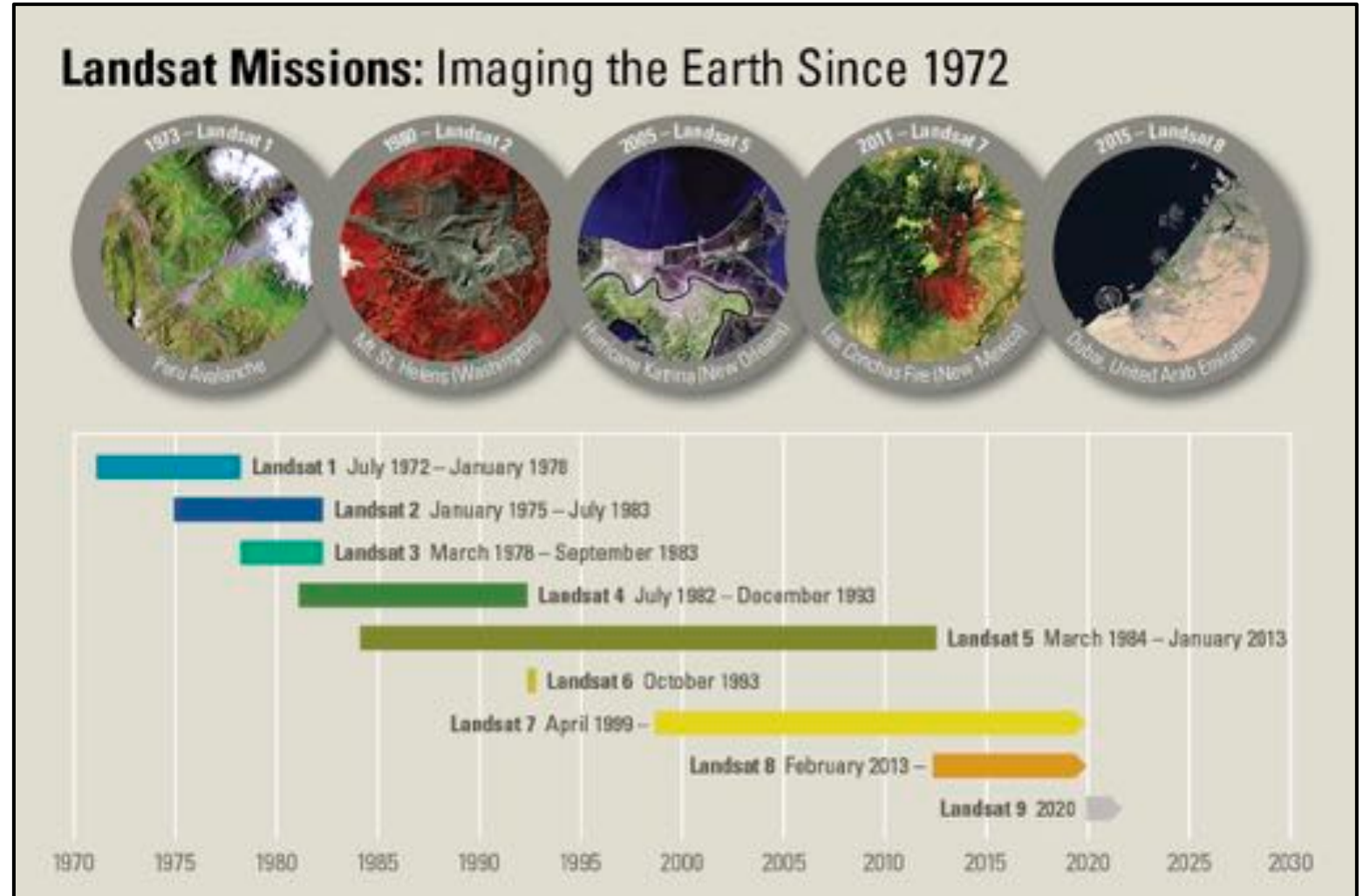
Landsat is a NASA-USGS joint mission partnership

NASA is largely responsible for:

Technology investments, instruments, pre-launch **calibration/validation (cal/val)**, space segment (i.e., launch, checkout, commissioning), **science and applications, and communications and outreach**

USGS is largely responsible for:

User needs, on-orbit operations and data acquisition, post-launch **cal/val**, ground segment (i.e., downlinking, processing, archiving, management, and distribution), data products, **science and applications, and communications and outreach**

Landsat 8 OLI image over Lake Superior Apostle Islands, WI
source: USGS

Landsat mission measurements to-date

Landsat 1-3 Multi-Spectral Scanner (MSS): multispectral visible-to-near infrared (VNIR), 18-day imaging, 79x59 meter ground sampling distance (GSD), 6-bit radiometry

Landsat 4/5 MSS: multispectral VNIR, 16-day imaging, 30 meter GSD, 8-bit radiometry

Landsat 4/5 Thematic Mapper (TM): multispectral visible-to-shortwave infrared (VSWIR) + single channel thermal infrared (TIR), 16-day imaging, 30 and 120 meter GSD, 8-bit radiometry

Landsat 7 Enhanced Thematic Mapper Plus (ETM+): multispectral VSWIR + single channel TIR, 16-day imaging, 30 and 60 meter GSD, 8-bit radiometry

Landsat 8 Operational Landsat Imager (OLI) and Thermal Infrared Sensor (TIRS): multispectral VSWIR + dual channel TIR, 16-day imaging, 30 and 100 meter GSD, 14-bit radiometry (only downlinking 12 bits)

Landsat 1 (ERTS-1), source: USGS

Landsat 8 OLI illustration, source: USGS

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Landsat and the 2017 Earth Science and Applications from Space (ESAS) Decadal Survey

Finding 2C: The USGS has transformed the Landsat program via the Sustainable Land Imaging (SLI) program by operating Landsat, connecting the scientific/user communities and the developers of new measurement technologies, and archiving/distributing data products. This has placed the Landsat measurements on a more operational footing. As long as it is funded, and managed as an operational program, the SLI program will support and motivate widespread usage, benefitting both the operational and scientific communities.

NASA-USGS Sustainable Land Imaging (SLI) Program

Purpose: collaboration between NASA and Department of Interior/USGS to ensure sustained access to land remote sensing observations for U.S. research and operational users

Objective: develop multi-decade, spaceborne system that will provide users with systematic and high-quality global land and near-shore surface measurements that maintains continuity with the Landsat record

Agency Roles/Responsibilities: in line with NASA-USGS joint mission partnership

Key Drivers: (1) 2014 White House Office of Science and Technology Policy's Earth Observation Assessment/Civil Earth Observation Plan rated Landsat as 3rd most important spaceborne system behind GPS and NEXRAD; (2) exponential growth of domestic and international use of Landsat based on no-cost/open access data

Landsat 9 is a cornerstone of the NASA-USGS SLI program

information source: NASA

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Landsat 9

NASA plans to launch Landsat 9 in December 2020 with USGS assuming operations in spring of 2021

The Landsat 9 spacecraft will carry OLI-2 and TIRS-2 with same specifications as Landsat 8 OLI/TIRS with multispectral VSWIR + dual channel TIR, 16-day imaging, 30 and 100 meter GSD, 14-bit radiometry

Advancements include:

(1) use of the Goddard Laser for Absolute Measurement of Radiance (GLAMR) for per-launch OLI-2 characterization

(2) downlinking 14-bit image data with anticipated signal-to-noise improvements

(3) all land/near-shore day-lit imaging greater the 5° solar elevation up to 740 images per day (expanded Polar coverage as is the standard today for Landsat 8)

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Landsat Tiered Collections

In 2016, the USGS reorganized the Landsat 1-8 data archive into a tiered inventory collection structure to enable consistent radiometric and geometric calibration for:

(1) data processing
(2) data traceability and provenance
(3) data management and archiving
(4) data distribution
(5) to support time series data analysis and interpretation

Acquired scenes within the tiered collection structure are denoted by:

Real-Time (RT) – newly acquired data
Tier 1 (T1) – geometric accuracy of <12 meters root mean square error (RSME)
Tier 2 (T2) – geometric accuracy of >12 meters RSME

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Landsat Collection 1 (C1) Operational / On-Demand Scene-based Data Products

C1 Operational Scene-based Data Products:

- Real-Time (RT) Digital Numbers (DNs) for Landsat 7 and Landsat 8
- Level-1 Terrain and Precision (L1TP) corrected Tier 1 DNs for Landsat 1-8
- Level-1 Systematic Terrain (L1GT) and Systematic (L1GS) corrected Tier 2 DNs for Landsat 1-8

Note: Product package includes product metadata, Level-1 per-pixel QA, and per-pixel solar and view angle coefficients

C1 On-Demand Scene-based Data Products:

- Level-1 Top-of-Atmosphere (TOA) reflectance for Landsat 4-8
- Level-1 TOA Brightness Temperature (BT) for Landsat 4-8
- Level-2 Surface Reflectance (SR) for Landsat 4-8
- Level-2 Aquatic Reflectance (Landsat 8 only) (late 2019 release)

Note: Product package includes product metadata, Level-1 per-pixel QA, per-pixel solar and view angle image arrays, Level-2 SR per-pixel aerosol QA, and Level-2 aquatic reflectance per-pixel QA

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Landsat Collection 1 (C1) U.S. Analysis Ready Data (ARD) Products (CONUS, Alaska, Hawaii)

C1 Operational U.S. ARD Products:

- Level-1 Top-of-Atmosphere (TOA) reflectance for Landsat 4-8
- Level-1 TOA Brightness Temperature (BT) for Landsat 4-8
- Level-2 Surface Reflectance (SR) for Landsat 4-8
- Level-2 Surface Temperature (ST) for Landsat 4-8

Note: Product package includes product metadata, Level-1 per pixel quality QA, per-pixel solar and view angle image arrays, Level-2 SR per-pixel aerosol QA, and Level-2 ST per-pixel intermediate QA bands

U.S. ARD product tiles – only T1 data is processed

Landsat Collection 2 (C2) Advancements

In 2018, the USGS started planning and defining specifications for Landsat C2 data products.

Landsat C2 will maintain continuity with C1, but there will several enhancements that harness more recent advancements in processing, algorithm developments, and access and distribution services.

Some of these include:

- Improved per-pixel geodetic accuracy by incorporating Landsat 8 ground control points harmonized with the European Space Agency/Copernicus Sentinel-2 Ground Reference Image (GRI)

- A global inventory of scene-based Level-2 surface reflectance (SR) and surface temperature (ST) data products that meet the solar elevation angle criteria

- The number of Landsat 5/7 Level-1 scenes achieving the T1 Collections criteria will increase due to improvements in terrain precision modeling

Other secondary enhancements include: addition of per-pixel solar and view angle image arrays in the Level-1 product package; evolution of product Object Description Language (ODL) metadata (MTL) and Extensible Markup Language (XML) format, Level-1 and Level-2 per-pixel Quality Assessment (QA) consistency, and minor bug fixes, calibration/validation updates, and Landsat 5/7 Internal Calibrator (IC) shutter intrusion detection flags

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Landsat Collection 2 (C2) Processing and Timeline

Landsat C2 processing is scheduled to begin in early 2020 and it is expected that C2 data products will be available shortly after.

Landsat C2 will be processed in the Amazon Web Services (AWS) commercial cloud through a USGS Cloud Hosting Solutions architecture.

Landsat C1 data products will remain available and accessible for 12 months after C2 processing is complete.

Forward processing on Landsat 7 and Landsat 8 will continue for the 12 month overlap period.

Landsat 9 data products will only be available as part of C2.

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Landsat Collection 2 (C2) Operational / On-Demand Scene-based Data Products

Level-2 SR　　Level-2 ST　　Level-2 ST ASTER emissivity input

C2 Operational Scene-based Data Products:

- Real-Time (RT) Digital Numbers (DNs) for Landsat 7 and Landsat 8
- Level-1 TP corrected (Tier 1) DNs for Landsat 1-9
- Level-1 GT and Level-1 GS corrected (Tier 2) DNs for Landsat 1-9
- Level-2 Surface Reflectance (SR) for Landsat 4-9
- Level-2 Surface Temperature (ST) for Landsat 4-9

Note: Product package includes product metadata, Level-1 per-pixel quality QA, per-pixel solar and view angle image arrays, Level-2 SR per-pixel aerosol QA, and Level-2 ST per-pixel intermediate QA bands
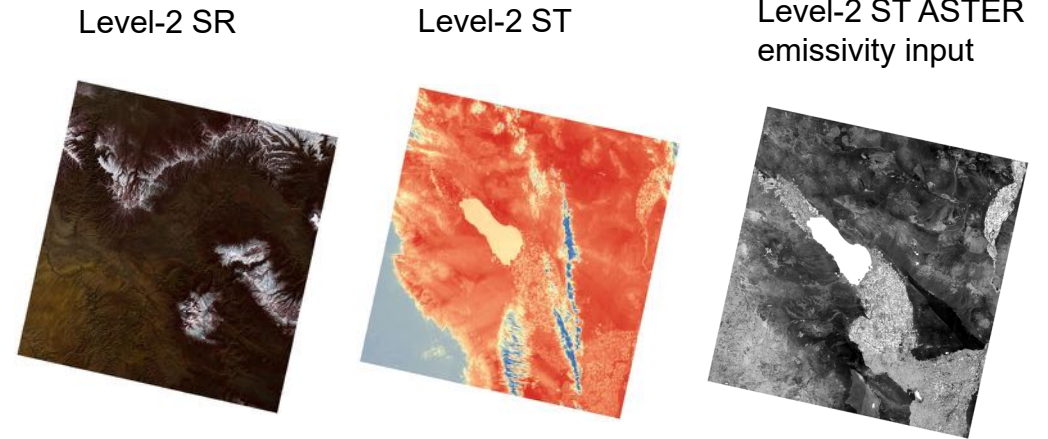
C2 On-Demand Science-based Data Products:

- Level-2 Aquatic Reflectance (Landsat 8 only)
- Level-2 Sentinel-2a/b surface reflectance (SR) (coming in 2020)

Note: Product packaging includes product metadata, Level-1 per-pixel quality QA, per-pixel solar and view angle image arrays, Level-2 surface reflectance per-pixel aerosol QA, and Level-2 aquatic reflectance per-pixel QA
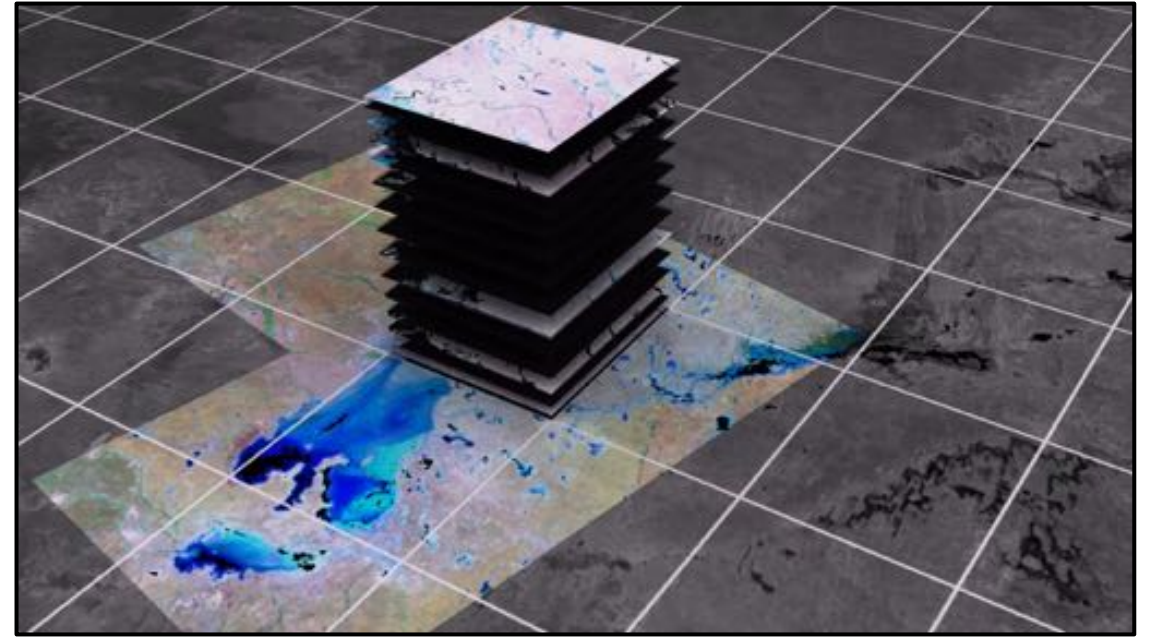
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Landsat Collection 2 (C2) U.S. Analysis Ready Data (ARD) Products (CONUS, Alaska, Hawaii)

C2 Operational U.S. ARD Products:

- Level-1 Top-of-Atmosphere (TOA) reflectance for Landsat 4-9
- Level-1 TOA Brightness Temperature (BT) for Landsat 4-9
- Level-2 Surface Reflectance (SR) for Landsat 4-9
- Level-2 Surface Temperature (ST) for Landsat 4-9

Note: Product package includes product metadata, Level-1 per pixel quality QA, per-pixel solar and view angle image arrays, Level-2 SR per-pixel aerosol QA, and Level-2 ST per-pixel intermediate QA bands

source: Geoscience Australia open data cube

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Landsat Level-3 Science Data Products

For Landsat Level-3 science product development goals, the USGS follows guidance from a **National Resource Council (NRC) 2004 report** on satellite climate data records (CDRs), and the **World Meteorological Organization (WMO)'s Global Climate Observing System program** defined land and water Essential Climate Variables (ECVs)

Level-3 science products are produced with Landsat Collection 1 operational U.S. ARD data. They currently are:

- Level-3 Burned Area (BA) for Landsat 4-8 (CONUS only)
- Level-3 Dynamic Surface Water Extent (DSWE) for Landsat 4-8 (CONUS, Alaska and Hawaii)
- Level-3 Fractional Snow-Covered Area (fSCA) for Landsat 4-8 (western US and Alaska only)
- Level-3 Evapotranspiration (ET) for Landsat 4-8 (planned for 2020 release)

Criteria for Level-3 product development, maturity, and science-to-operations via EROS Science Processing Architecture (ESPA) are:

(1) Two publications in international peer review journals covering the algorithm, its validation, and its science and application
(2) A known resource management stakeholder community with demand for the information
(3) Co-authoring of Algorithm Description Document (ADD) and Product User Guide
(4) Re-distributable algorithm source code (e.g., USGS GitHub repository)

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Landsat Data Product Latency

- Data product latency varies with satellite

- On-orbit auxiliary and calibration dependencies drive long-term latency

- Ingest of atmospheric auxiliary data for Level-2 processing drive short-term latency

- Level-3 products are generated within 24 hours of Level-2 processing
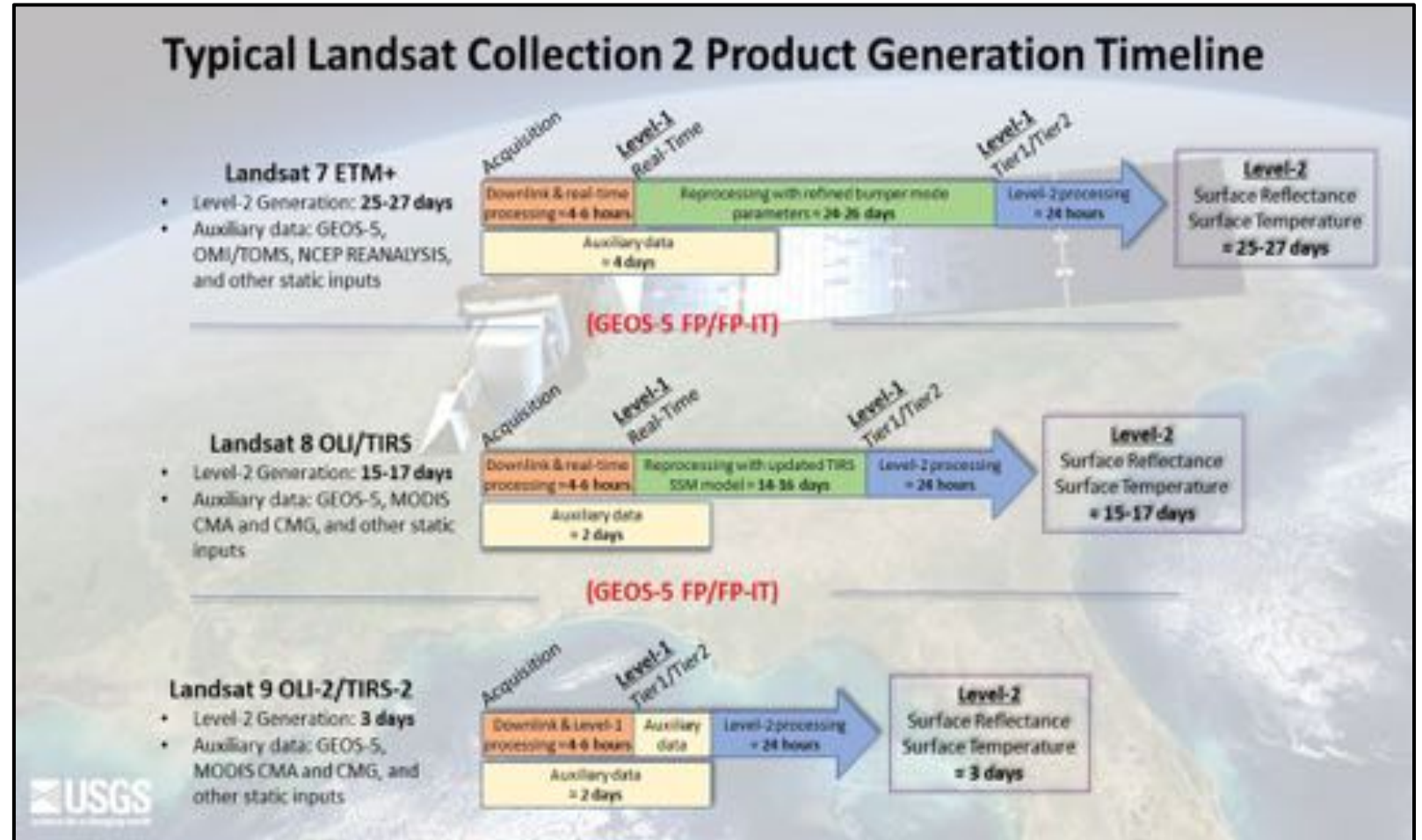
Landsat latency timelines

Landsat Data Product Access and Distribution

Landsat C1 and C2 data products are/will be accessible and distributed through traditional USGS online interfaces

Landsat's no-cost and open access data policy remains intact since its inception in 2008

Earth Explorer (EE) is the primary access point for the suite of Landsat data products. Other interfaces include:

- EROS Science Processing Architecture (ESPA)
- GloVis
- LandsatLook
- NASA AppEEARS

Note: EE and ESPA APIs or bulk download tools are available for large volume users

The USGS is planning to process Landsat C2 on the AWS commercial cloud through an USGS Cloud Hosting Solutions architecture, and a new data access, visualization, and exploitation tool for the cloud is being developed to improve data services after release of C2 publicly. Stay tuned!

Landsat Level-3 fractional Snow-Covered Area (fSCA)

Released in 2018 and produced for:

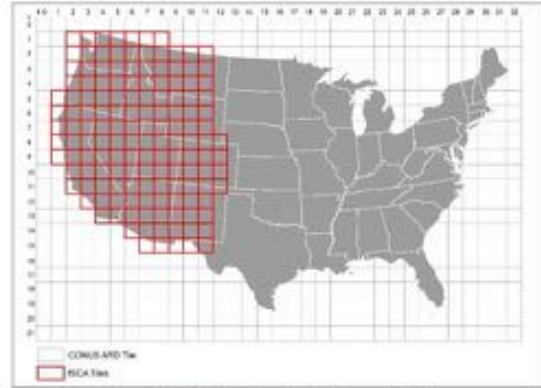Landsat 8: February 14, 2017

Landsat 7: February 15, 2017

Figure 1. Illustrates the fSCA Science Product extent over CONUS
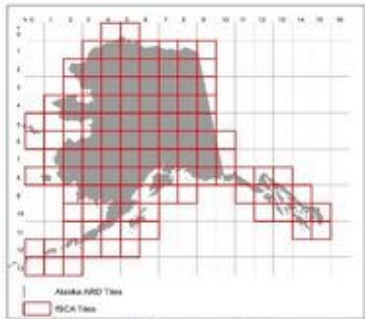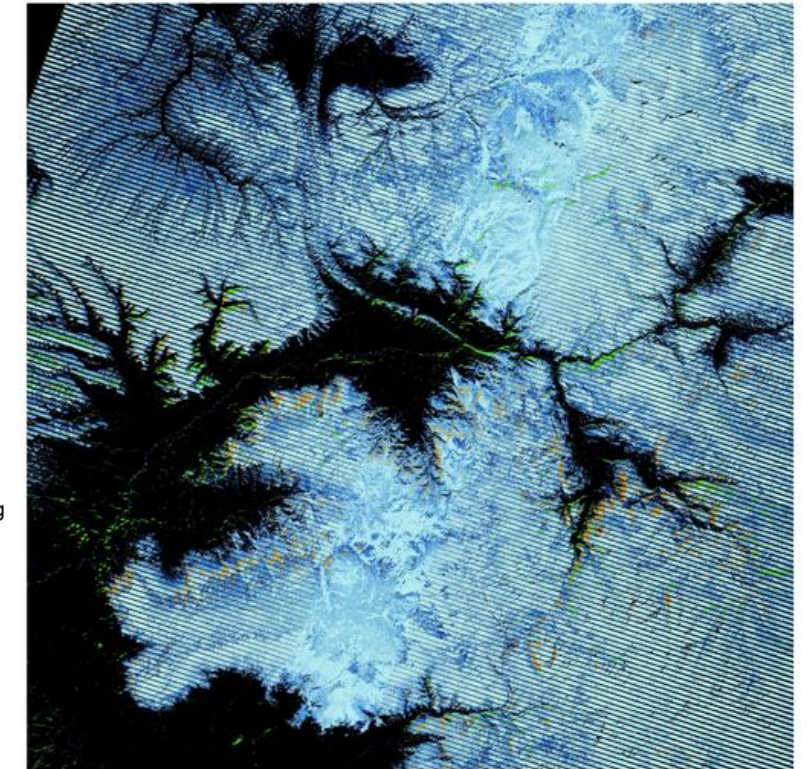

Figure 2. Illustrates the fSCA Science Product extent over Alaska

fSCA

% : 100
% : 0

Cloud Artifact
Cloud
Terrain Shadowing
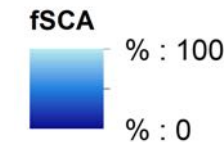


Landsat Level-3 fSCA product shows the extent of snow in western Colorado during NASA's 2017 SnowEx at Grand Mesa.

More information here: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-landsat-level-3-fractional-snow-covered-area

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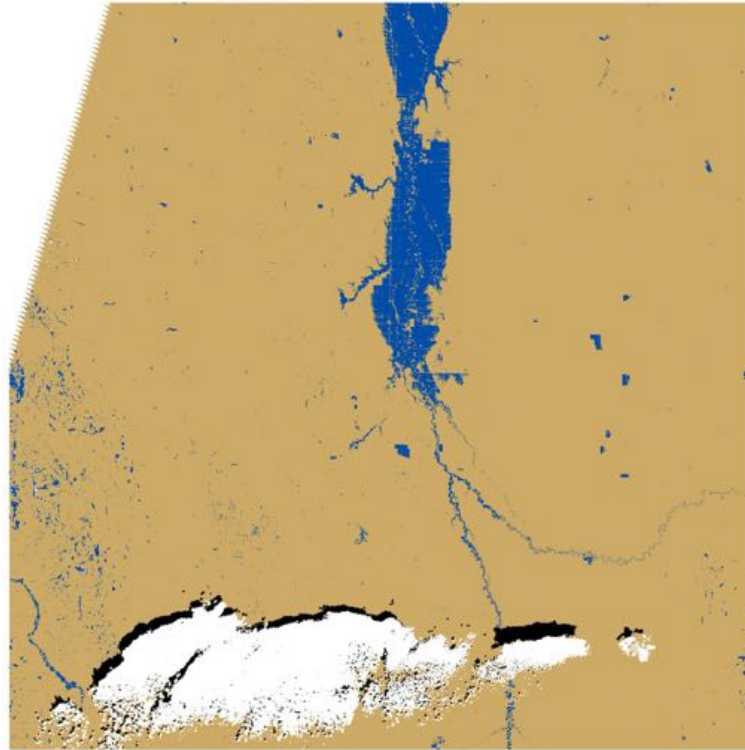NASA SnowEx-Tundra/Boreal Forest Planning Meeting / November 12, 2019

Landsat Level-3 Dynamic Surface Water Extent (DSWE)

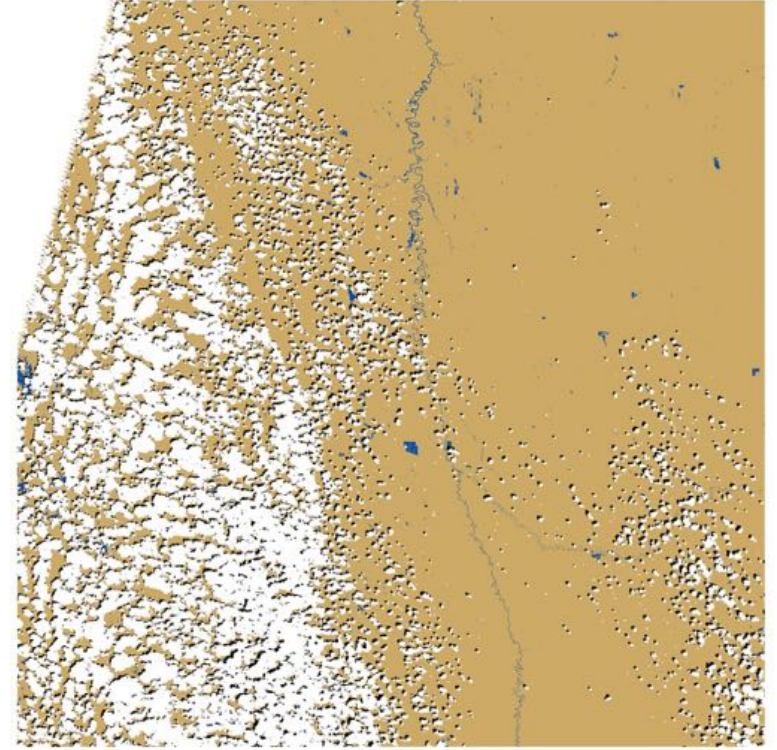Released in 2018 and produced for CONUS, Alaska, and Hawaii
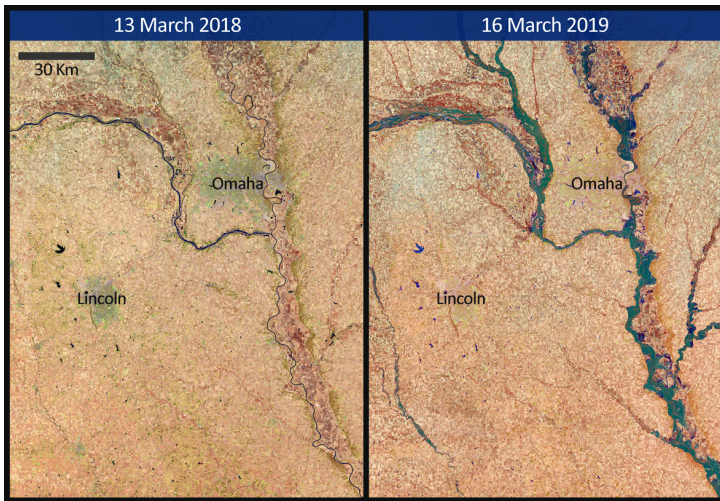
Recent Great Plains spring flooding

Landsat 5: April 25, 2011

Landsat 5: June 28, 2011

Landsat Level-3 DSWE product shows a spring Red River flooding event in the Upper Midwest, US

More information here: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-landsat-level-3-dynamic-surface-water-extent

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Leveraging Landsat in support of NASA SnowEx

Expanding Landsat's snow and hydrological science and applications

Synergistic overlap: Level-1 cal/val, Level-2/3 product validation, current/future algorithm development and new products, and scaling up the operations concept

Exploiting the temporal frequency of the Landsat-Sentinel-2 medium resolution virtual constellation and informing current USGS, NASA, and ESA/Copernicus collaborative engagement

Defining snow and hydrological measurement requirements for future SLI missions

Improving multi-sensor data fusion between optical and microwave remote sensing systems for measurement of snow

Questions

contact info: cjcrawford@usgs.gov or 605.594.2859

Landsat Mission Website: https://www.usgs.gov/land-resources/nli/landsat

Landsat Data Product Feedback: send to custserv@usgs.gov

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