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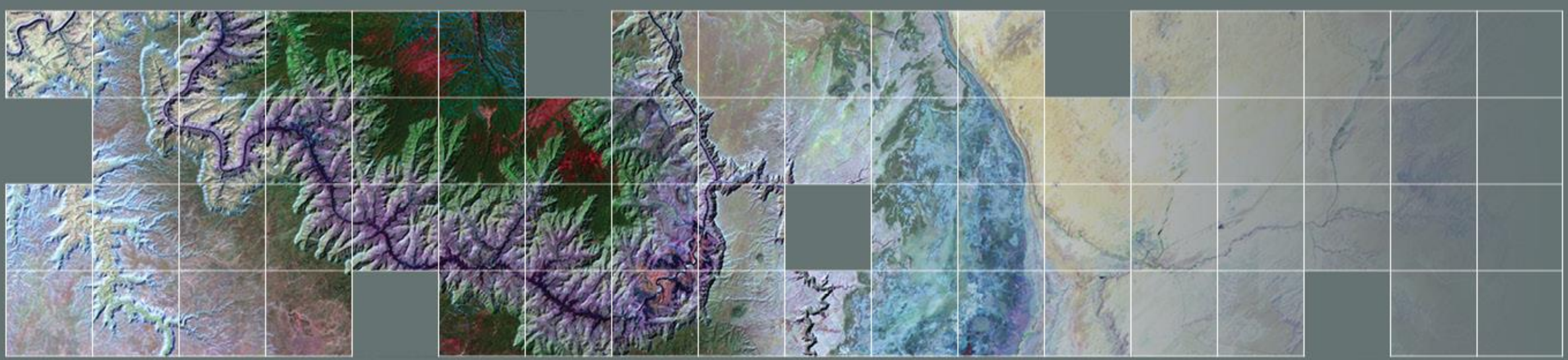
Climate and Land Use Change
Earth Resources Observation and Science (EROS) Center

The Future of Landsat Data Products: Analysis Ready Data and Essential Climate Variables



Steve Foga[1], Brian Davis[1], Brian Sauer[2], John Dwyer[2]
[1] SGT Inc., contractor to USGS EROS Center
[2] USGS EROS Center

U.S. Department of the Interior
U.S. Geological Survey

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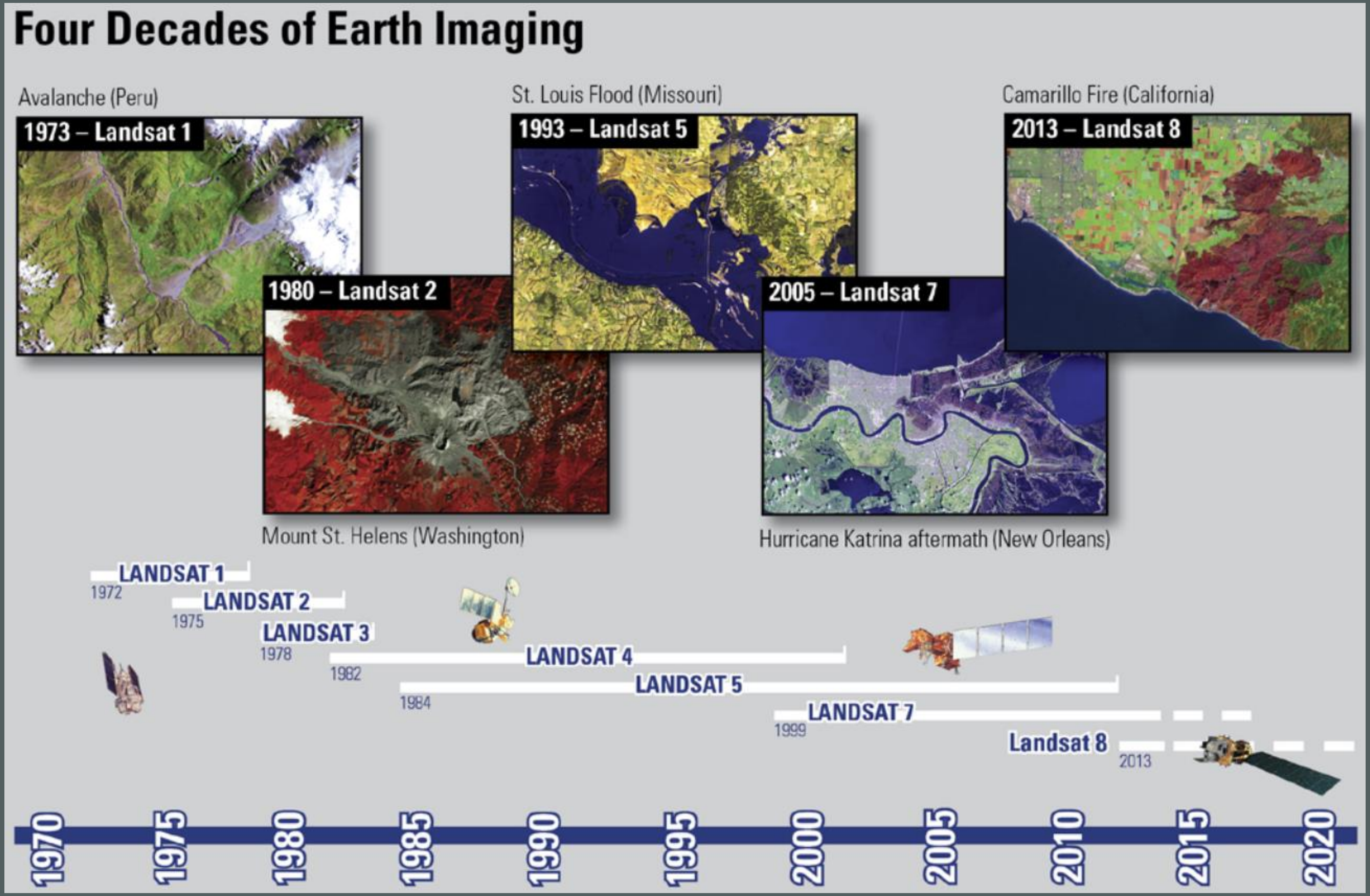
Outline

- **Status Quo**
- **Essential Climate Variables**
- **Data Improvements**
  - Collections
  - Analysis Ready Data
- **Use Cases**

Status Quo

- Landsat Overview



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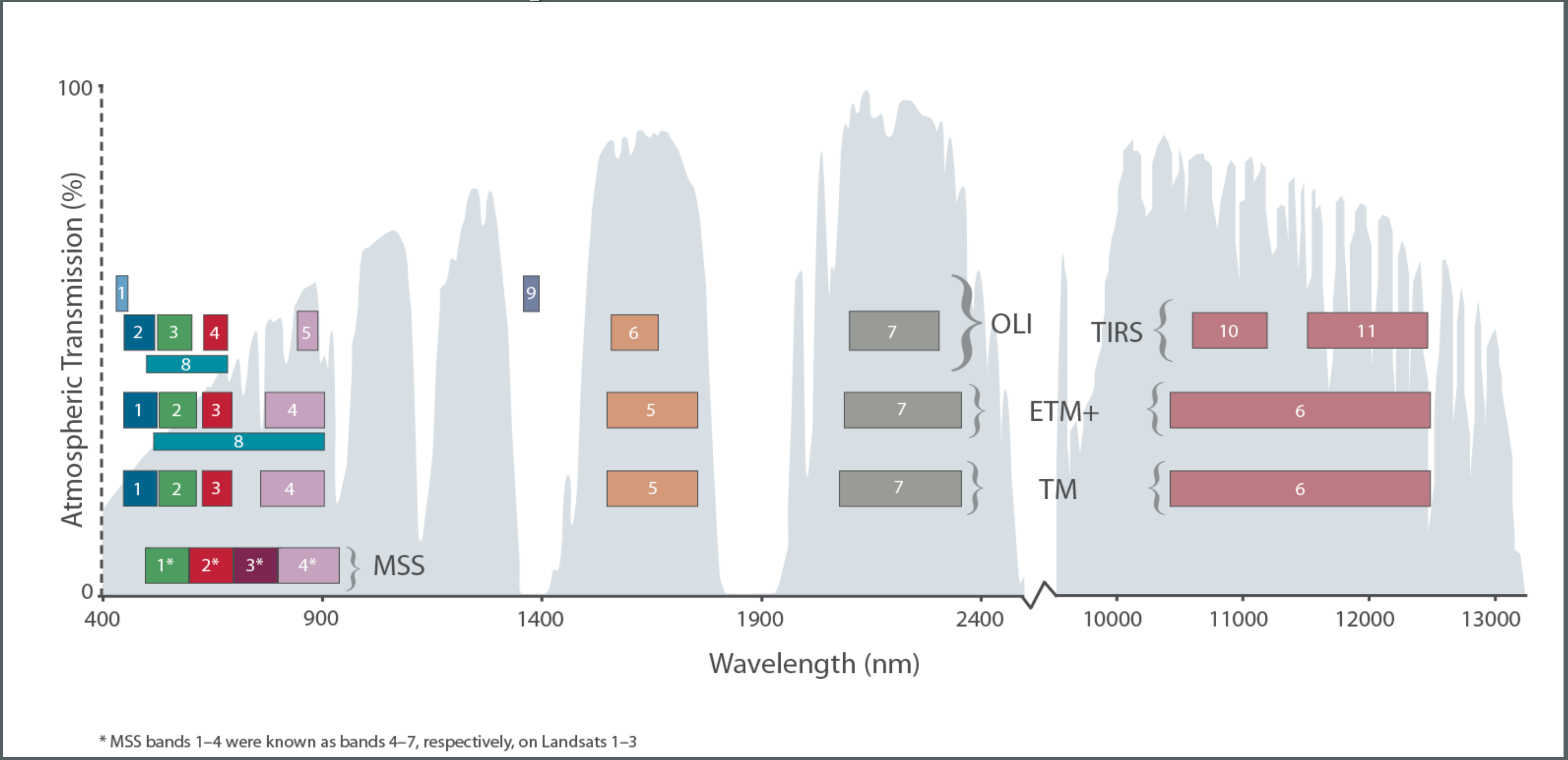
Status Quo

- ## Landsat Bandpasses



MSS = Multispectral Scanner (Landsat 1-5); TM = Thematic Mapper (Landsat 4-5); ETM+ = Enhanced Thematic Mapper Plus (Landsat 7); OLI = Operational Land Imager (Landsat 8); TIRS = Thermal Infrared Sensor (Landsat 8)

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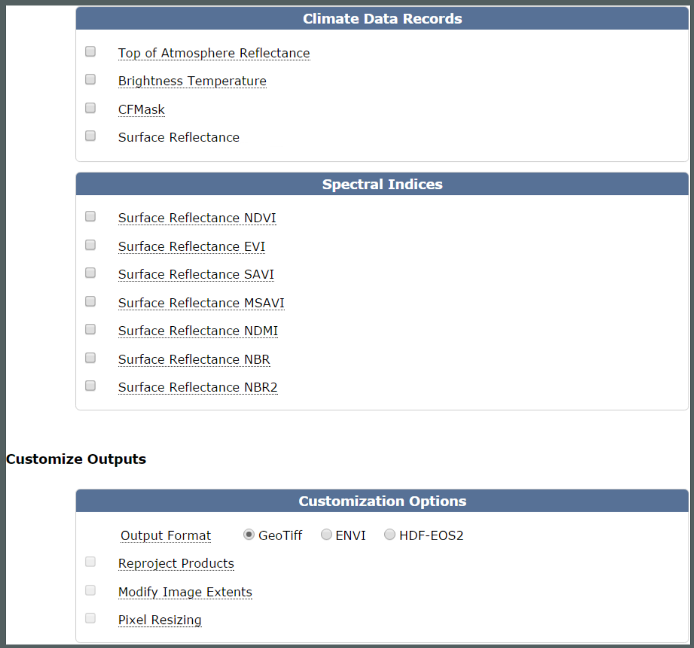
Status Quo

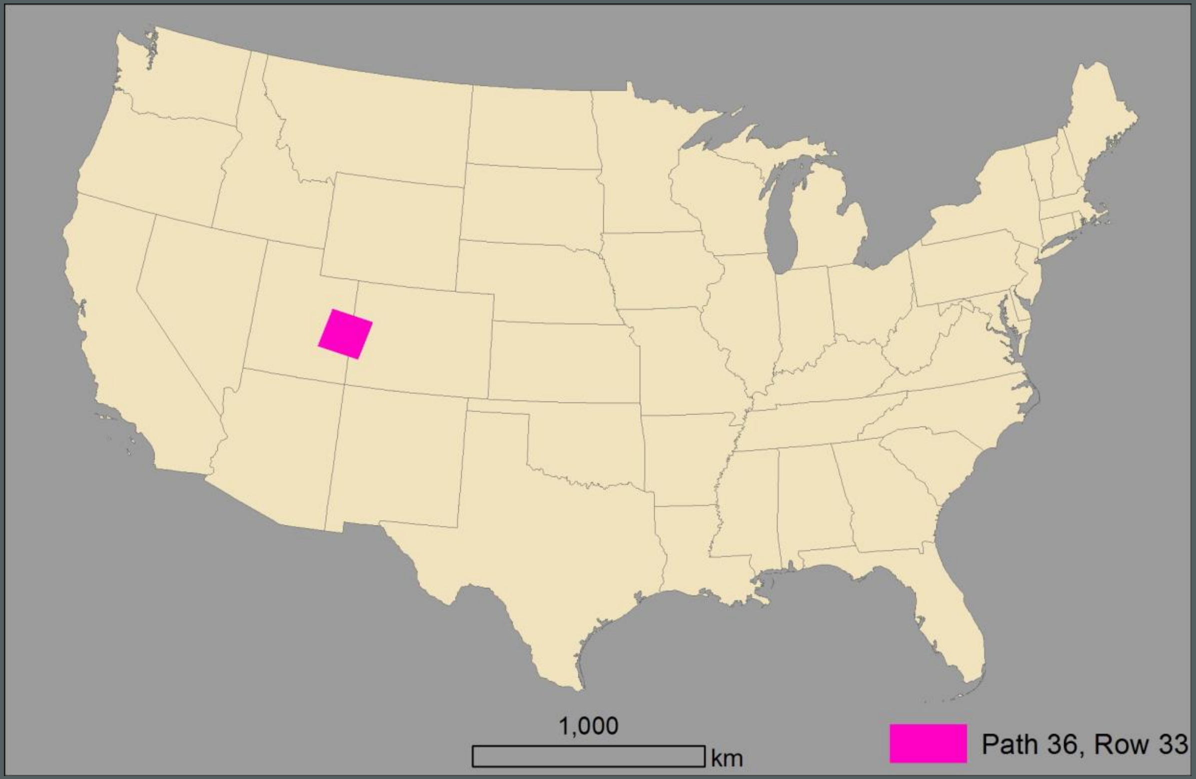
- **Development of higher level data products**
  - Surface Reflectance (SR)
    - Future: land surface temperature
  - EROS Science Processing Architecture (ESPA)
    - Higher level data products, data customization, statistics
    - On Demand Interface (ODI)
    - Application Programming Interface (API)
    - Order options
      - Vegetation/burn indices
      - Top of Atmosphere Reflectance, SR, cloud masks
      - Reprojection, spatial subset, pixel resizing, multiple formats



Order interface layout in ESPA.

Status Quo

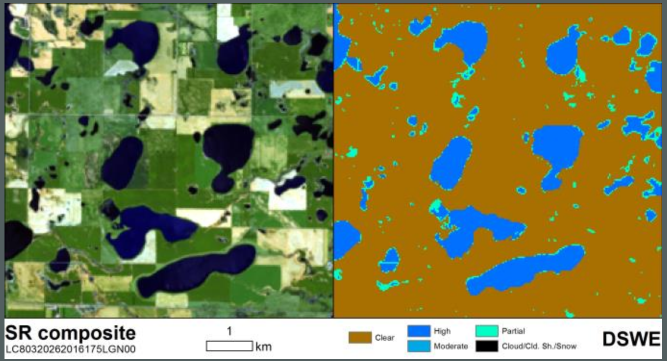
- **Data in a "scene"-based format**
  - Covers ~180 km^2 of land



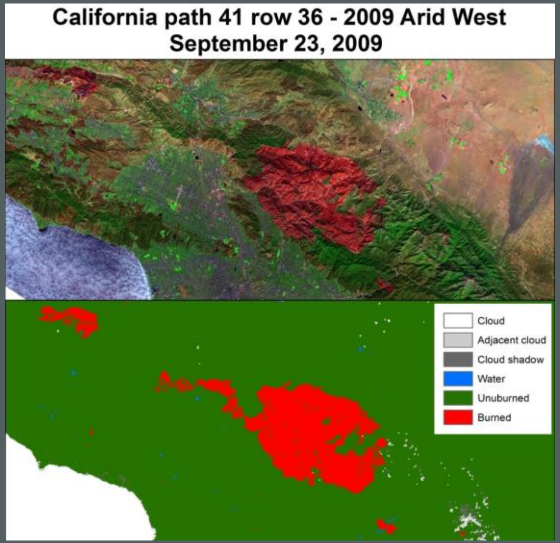
The extent of a single Landsat scene in relation to CONUS.

Essential Climate Variables

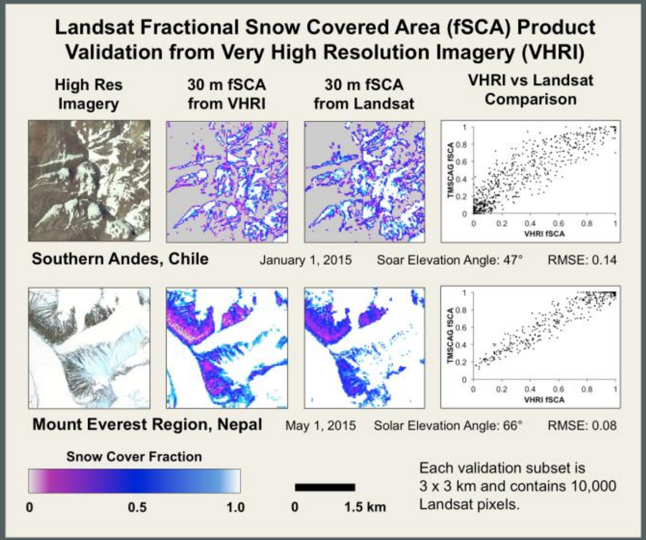
- **PIs across USGS**
- **Physical parameters derived from SR**
  - Dynamic Surface Water Extent (DSWE; *Jones, 2015* [1])
  - Burned Area (BA; *Hawbaker et al., 2016* [2])
  - Fractional Snow Covered Area (fSCA; *Selkowitz, 2015* [3])



Dynamic Surface Water Extent (DSWE) probability product shown over glacier lakes in North-central North Dakota.



Burned Area (BA) classification map over burn scar in California. Product also comes as probability product.



Fractional Snow Covered Area probability product and related validation methodology. From *Selkowitz, 2015* [3].

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Data Improvements

- **Landsat Collections**
  - Buckets known as data *tiers*
    - Consistent radiometry, threshold of scene-wide geometry
    - Tier 1 enables *stackability*
    - Best data can be easily accessed without additional metadata harvesting

Tier	Geometric RMSE	Radiometric	% OLI/TIRS	% ETM+	TM
1	≤ 12m	Static	60.42%*	74.98%	65.41%
2	> 12m	Static	39.58%	25.02%	34.59%
RT **	Recently acquired data with preliminary geometry and radiometry information. Will eventually become Tier 1 or Tier 2.				

* Many OLI/TIRS scenes do not reach geometric threshold due to imaging of oceans, where ground control points (GCP) are often not sufficient.

** RT = “Real Time”

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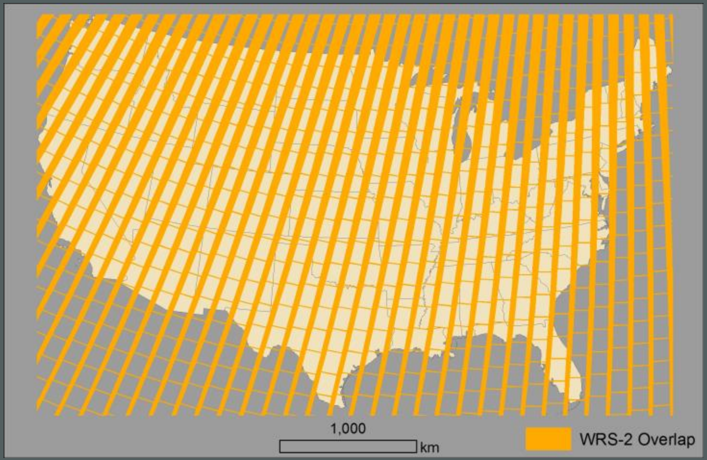
Data Improvements

- **Analysis Ready Data (ARD)**
  - Derived from Collection data
  - To support land use, land change and mapping sciences
  - Data cube
    - Conterminous U.S. (CONUS), Alaska, Hawaii
    - Seamless analysis
      - immediate use of overlapping data
  - Analysis
    - Application Programming Interface
      - API, on-the-fly analysis
    - “Receive answers, not data”



Representation of WRS-2 path/row overlap over CONUS.

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Data Improvements

- ARD Specifications

USGS Analysis Ready Dataset (ARD) Product Projection Parameters			
Projection: Albers Equal Area Conic			
Datum: North American Datum 1983 (NAD83)			
	Conterminous U.S.	**Alaska**	**Hawaii**
First standard parallel	29.5°	55.0°	8.0°
Second standard parallel	45.5°	65.0°	18.0°
Longitude of central meridian	-96.0°	-154.0°	-157.0°
Latitude of projection origin	23.0°	50.0°	3.0°
False Easting	0.0	0.0	0.0
False Northing	0.0	0.0	0.0

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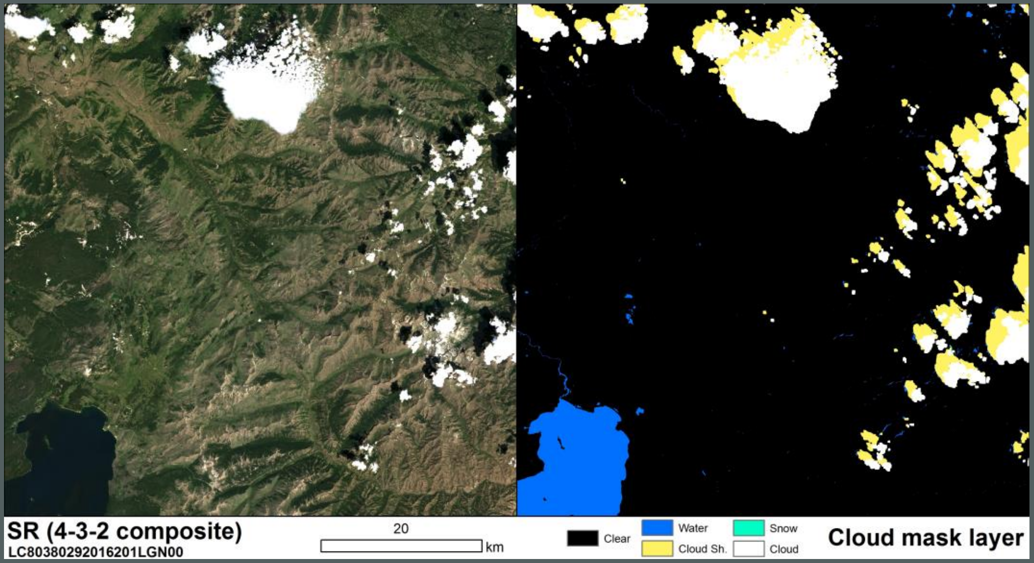
Use cases

- **Quick visualization**
  - Filter pixels by quality assurance (QA) bit(s)
    - Cloud, cloud shadow, snow/ice (below)
    - Saturation, dropped frames, terrain occlusion
  - Best pixel by index and/or threshold
    - Series of tests to create probability map(s)
  - Composite bands to accentuate features



Cloud masking product delivered with Landsat 8 surface reflectance data. Image was acquired over Yellowstone National Park, Wyoming.

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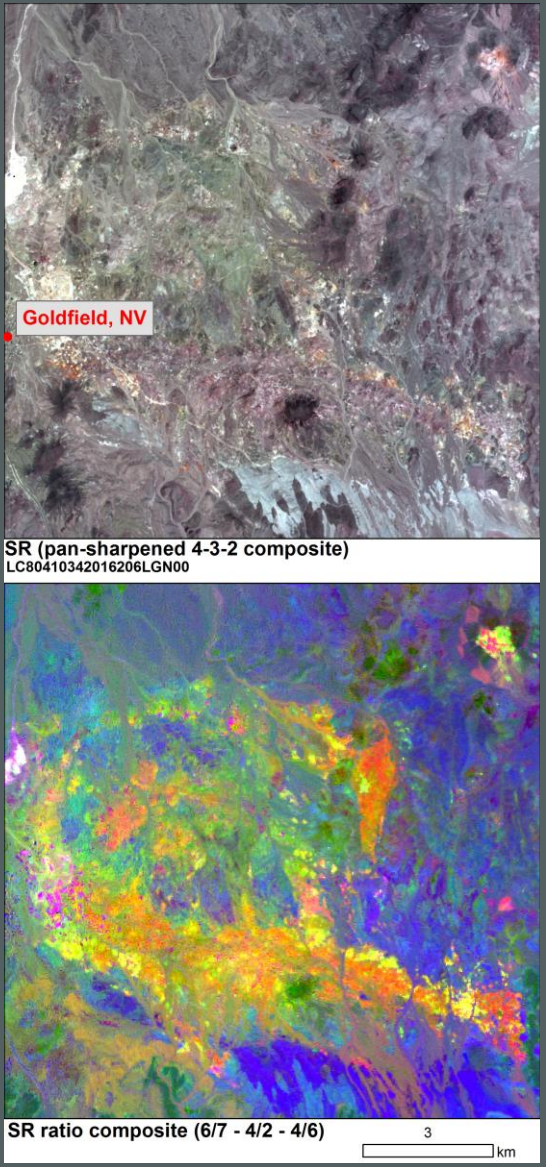
Use cases

- **Lithology, Hydrothermal Alteration maps**
  - Color composites of band ratios (right) to show areas of potential alteration
    - Goldfield mining district, NV, based upon work by *Sabins, 1999* [4]
  - Use of spectral unmixing (e.g., Principal Components Analysis (**PCA**)) to abstract distinct signatures using all bands



Band ratio composite using L8 surface refl. data detailing potential hydrothermal alteration (yellow/orange) in Nevada.

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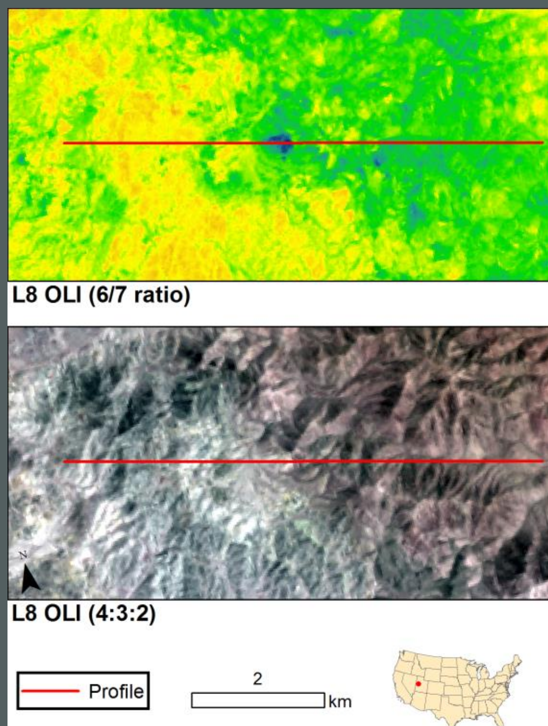
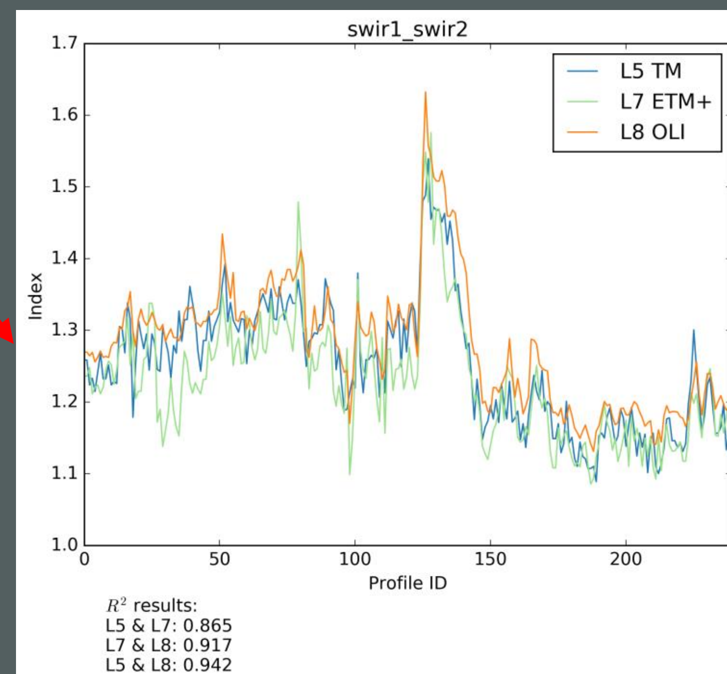
Use cases

- **Sensor compatibility across time**
  - Red, Near Infrared (NIR), Shortwave Infrared (SWIR) 1, SWIR2 narrowed from TM/ETM+ to OLI
  - Quick analysis at hydrothermally altered area near Drum Mountain, Utah
    - Sensors still detect same features, thus are cross-comparable





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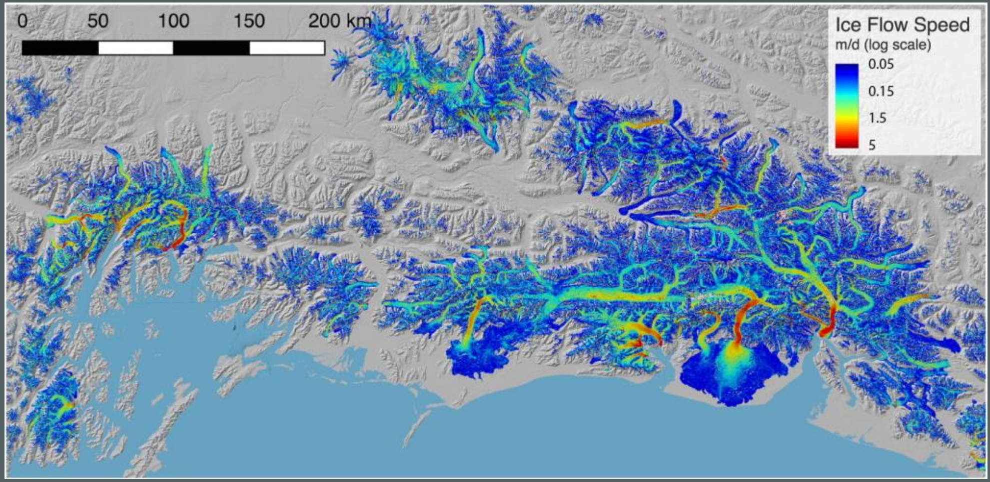
Use cases

- **Derive glacier velocities with feature tracking**
  - Landsat 8 OLI ideal for this
    - High signal-to-noise ratio (SNR)
      - High enough to track snow drifts [5], not just crevasses
    - 15m panchromatic bands (sharper detail)
    - Repeat imaging opportunities
      - Converging fields of view with polar orbit
      - Ascending node imaging during midnight sun at poles
  - Seamless base image creation with ARD



Velocity profile of southern Alaska glaciers, derived from OLI images. Borrowed from *Fahnestock et al., 2015* [5].

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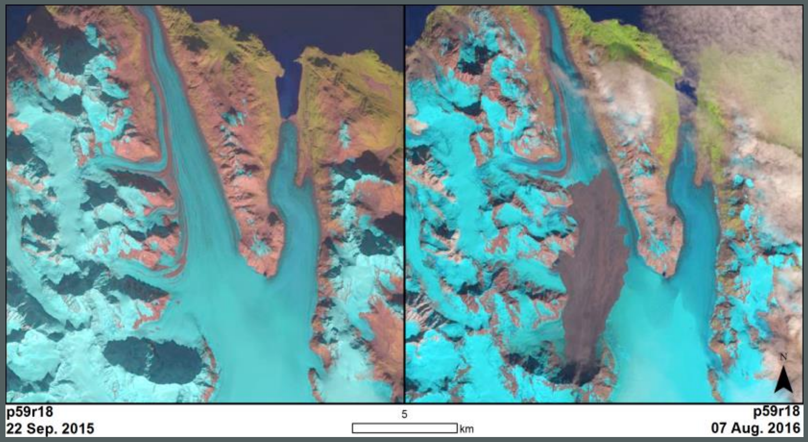
Use cases

- **Hazards**
  - Quickly compile time series to show before/after
  - Composite with SWIR to reduce smoke (below)

Holuhraun lava flow in Iceland captured by Landsat 8. Left: SWIR,NIR,green composite. Center: red,green,blue composite. Right: thermal. Image modified from http://eros.usgs.gov/imagegallery/image-week-2#Iceland_images.



Before (left) and after (right) of landslide at Glacier Bay National Park and Preserve in Alaska captured by Landsat 8.

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Resources

- **Landsat mission webpage: http://landsat.usgs.gov**
  - Collections: http://landsat.usgs.gov/landsatcollections.php
- **Landsat data: http://earthexplorer.usgs.gov/**
- **EROS Science Processing Architecture (ESPA): https://espa.cr.usgs.gov/**

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References

- **[1]** Jones, J. W. (2015). Efficient wetland surface water detection and monitoring via Landsat: Comparison with in situ data from the Everglades Depth Estimation Network. *Remote Sensing*, *7*(9), 12503-12538.
- **[2]** Hawbaker, T., Vanderhoof, M., French, N., Billmire, M., Beal, Y. J. G., Takacs, J., ... & Caldwell, M. (2016, April). Automated mapping of burned areas in Landsat imagery; tracking spatial and temporal patterns of burned areas and greenhouse gas emissions in the Southern Rocky Mountains, USA. In *EGU General Assembly Conference Abstracts* (Vol. 18, p. 10709).
- **[3]** Selkowitz, D. (2015, December). The USGS Landsat Snow Covered Area Science Data Products. In *2015 AGU Fall Meeting*. Agu. Image accessed 01 AUG 2016 from http://landsat.gsfc.nasa.gov/?p=11702.
- **[4]** Sabins, F. F. (1999). Remote sensing for mineral exploration. *Ore Geology Reviews*, *14*(3), 157-183.
- **[5]** Fahnestock, M., Scambos, T., Moon, T., Gardner, A., Haran, T., & Klinger, M. (2015). Rapid large-area mapping of ice flow using Landsat 8. *Remote Sensing of Environment*.

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