Integrating the past, present, and future of Landsat: An update

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Roy et al. L8 Submission

- Landsat occupies a valuable niche in global satellite remote sensing; the platform collects images at a spatial resolution indicative of human interactions with terrestrial ecosystems yet with an image extent compatible with systematic analyses over large areas. A ground-segment based on reliable science provides free and open access to Level 1 products of known, documented, and traceable quality. The integrity of this production chain and the confidence users have in Landsat data has led to a proliferation of science and applications – the Landsat program provides an example to be emulated.

Context and needs:

- Context:
  - Inventory, monitoring,
  - National and international reporting
  - National Forest Inventory, Carbon Accounting Programs
- Basic data:
  - Land cover
  - Land cover change, events, types
  - Forest structure

-- At the national level for multiple time periods in a scientifically robust, transparent, and repeatable manner

How can we get there?

- Field plots
  - Detailed measures, limited number and distribution
- Lidar plots, via transects
  - Detailed measures, limited number and distribution, but less so than field plots
- Fine resolution optical satellite data (Landsat)
  - Wall-to-wall and dense time series
  - compositing

Messages

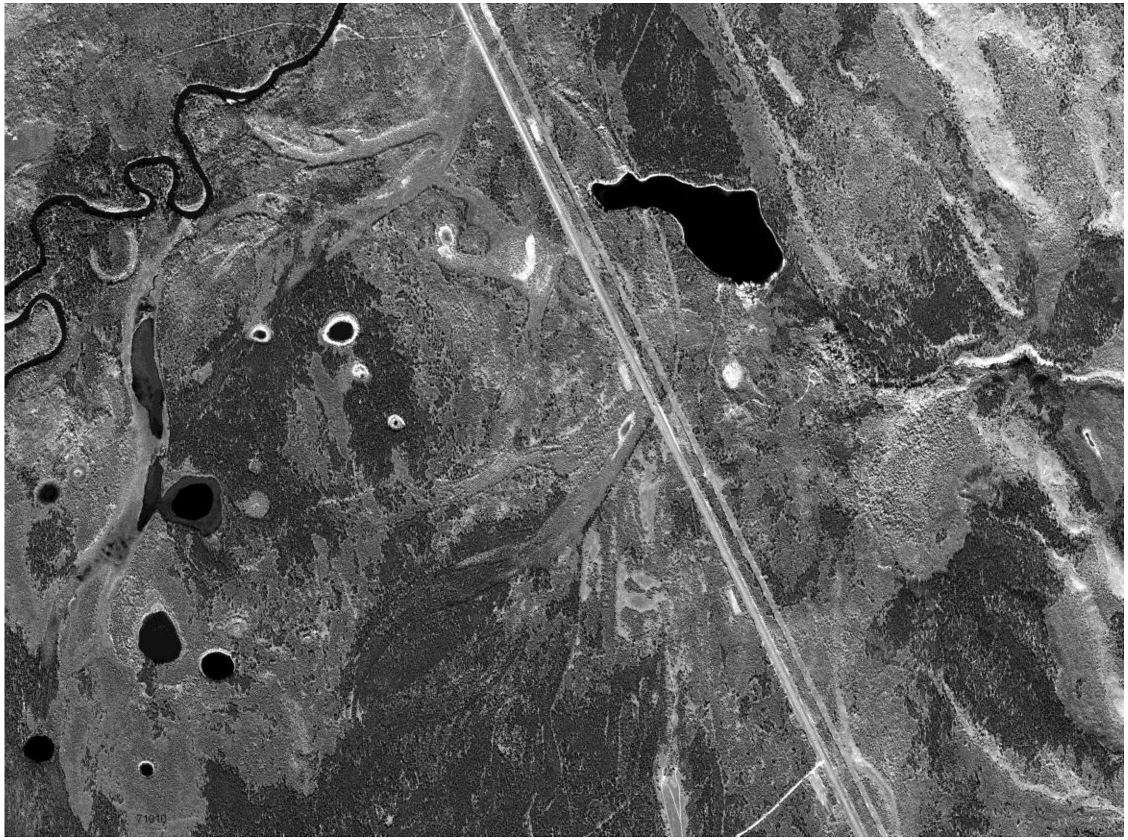
- Image compositing
  - Types
  - Options / implications
- Information needs drive compositing decisions
  - Composites to support land cover, change in cover, and structural attribution
- International options differ from CONUS
- Science and product implications

Part 1. Structure

- Or, context for Landsat estimates of forest structure in the boreal

Effort:
Spatial resolution example

- Goal: stand level forest inventory information
- Support regional and national inventories
- Very high spatial resolution satellite imagery (>1m panchromatic)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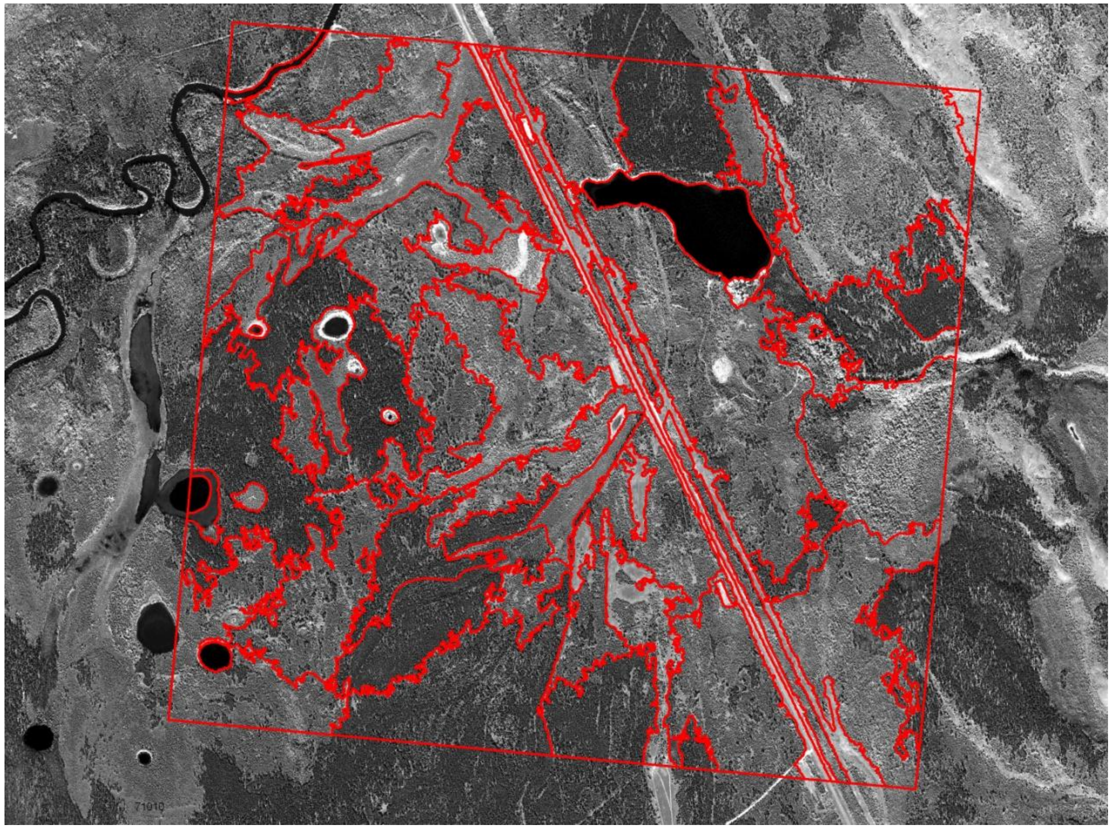
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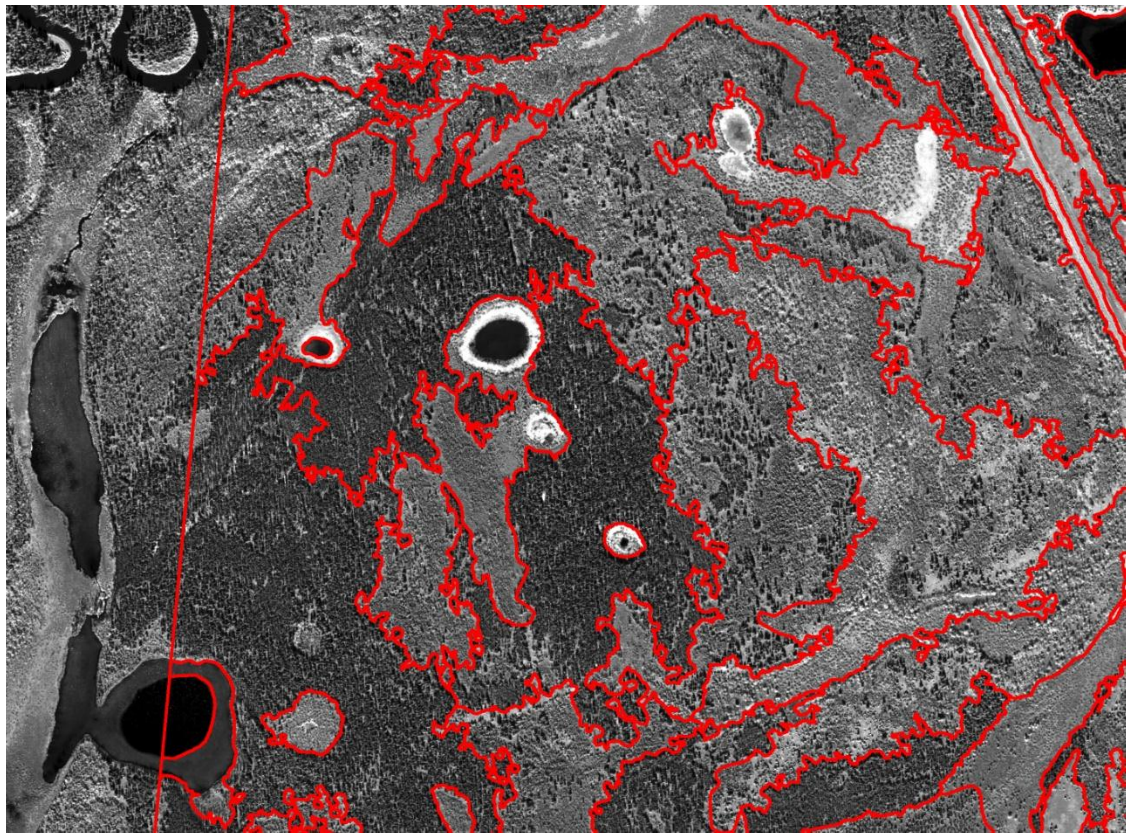
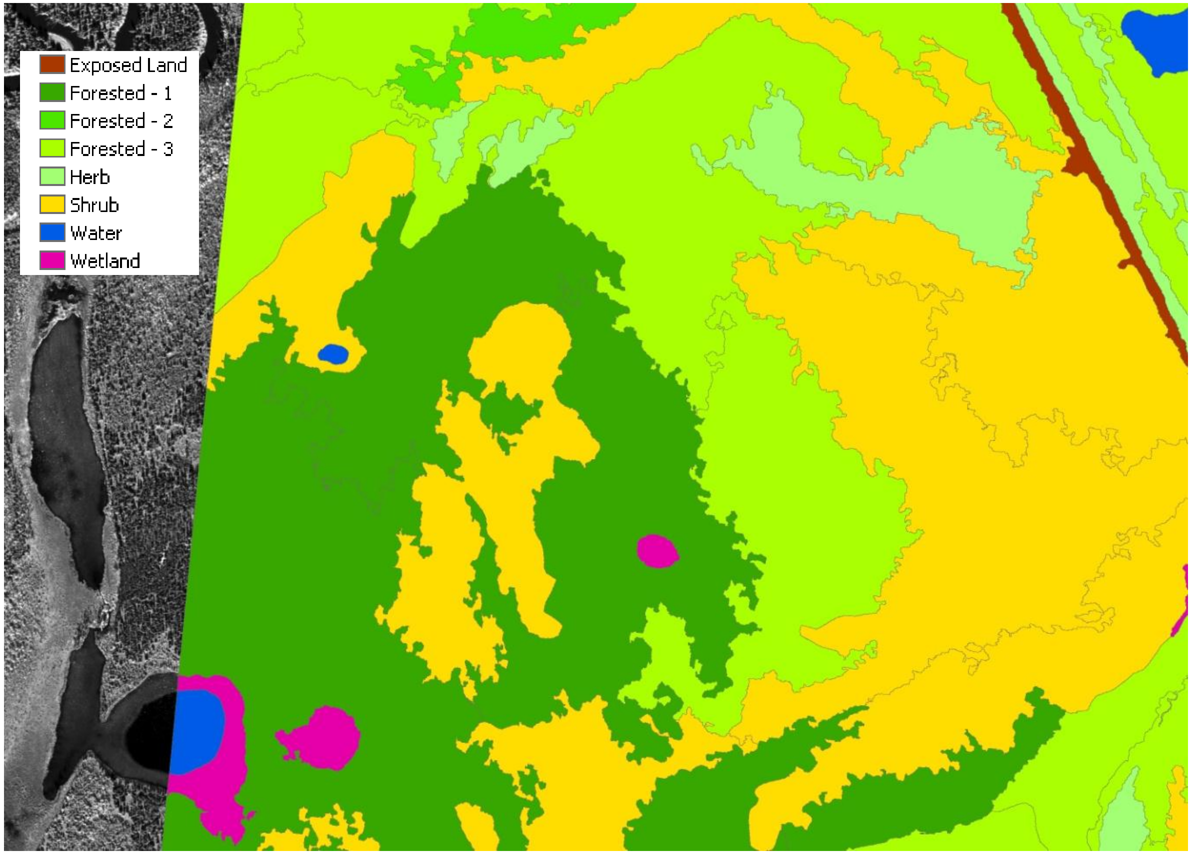
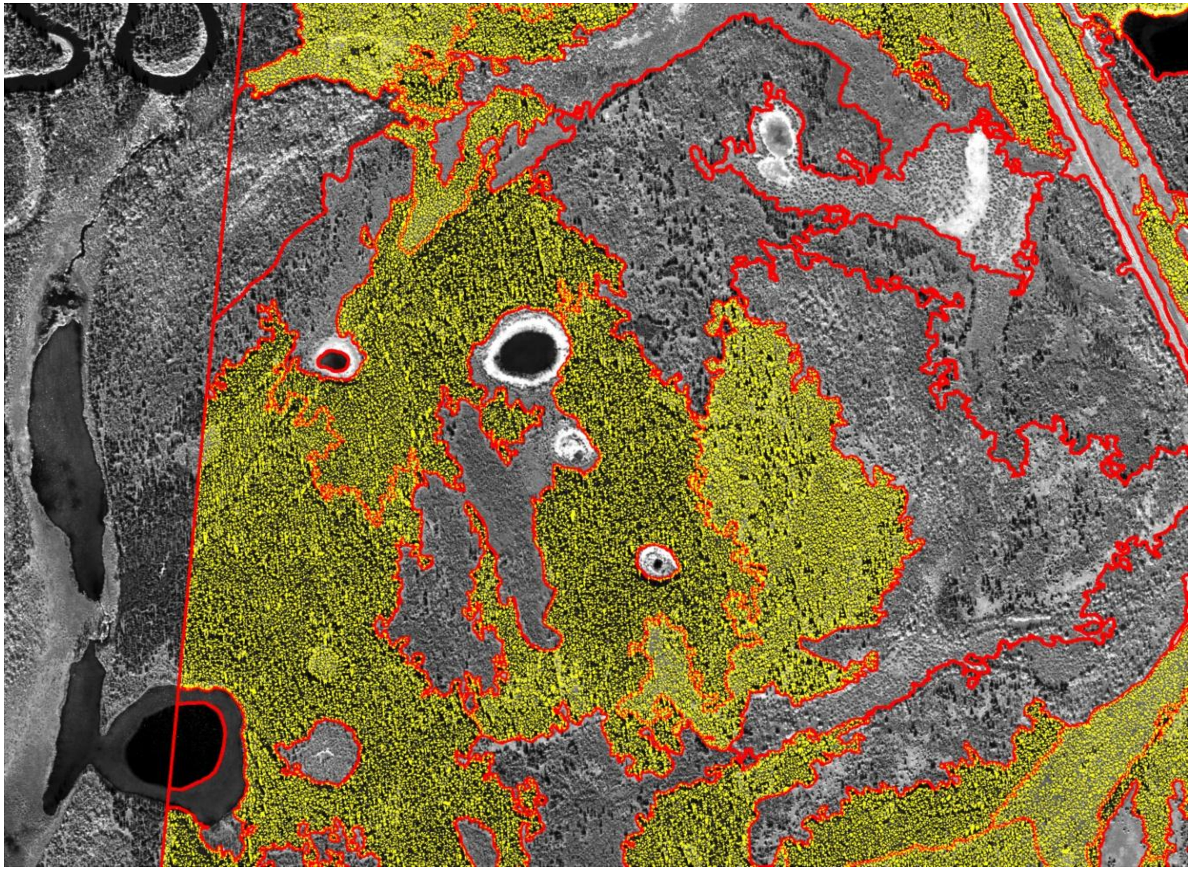
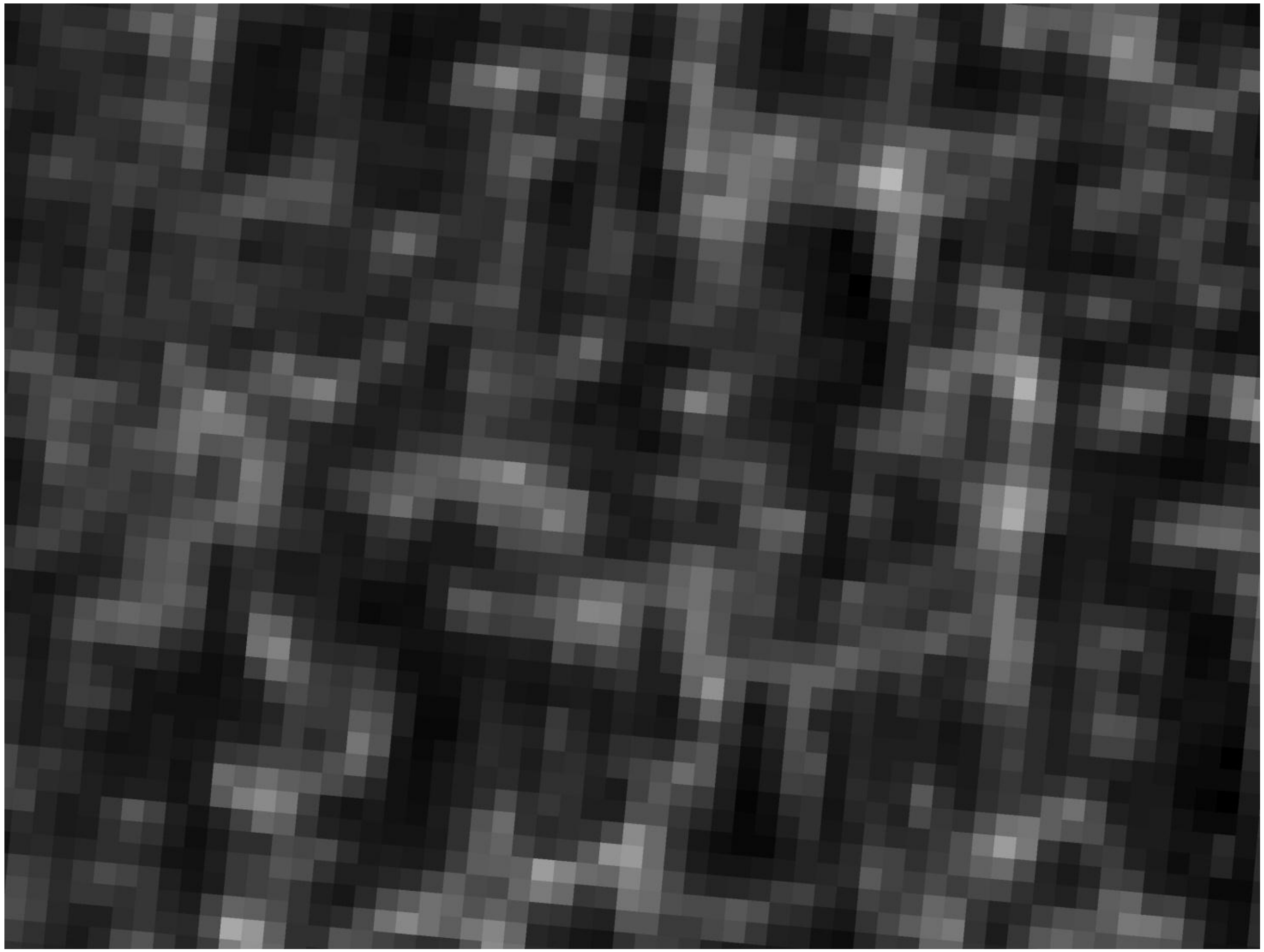
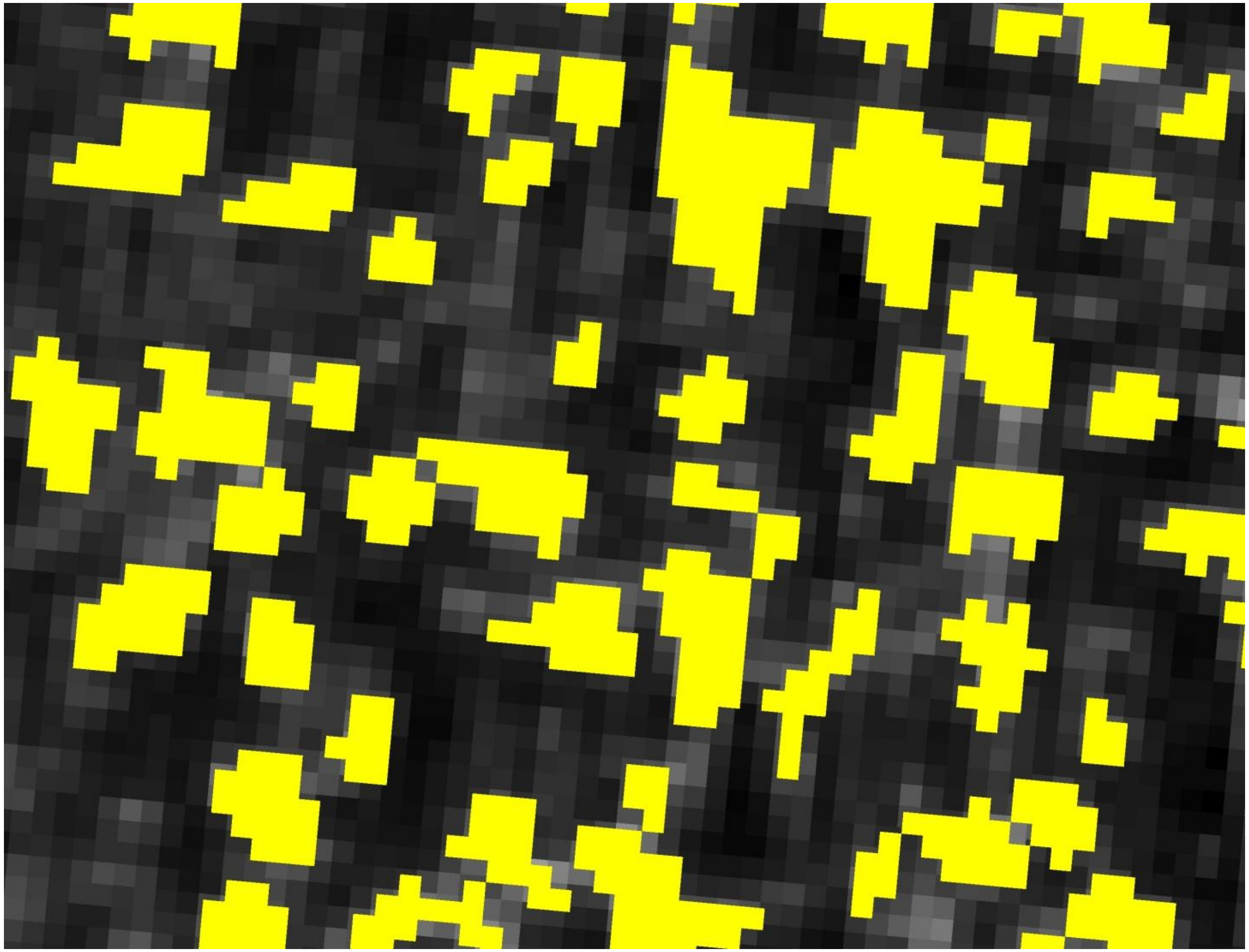




Exposed Land
Forested - 1
Forested - 2
Forested - 3
Herb
Shrub
Water
Wetland





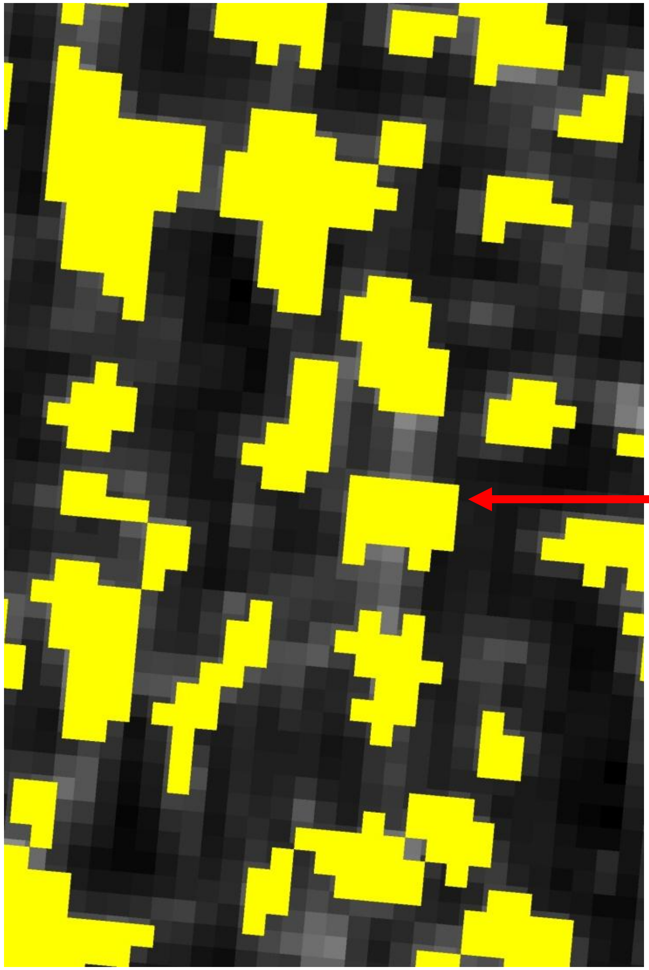


Gougeon, F. (1995). A crown-following approach to the automatic delineation of individual tree crowns in high spatial resolution aerial images. Canadian Journal of Remote Sensing. 21(3):274-284.

Stand and crown metrics

Stand segment metrics

- Photo plot ID: 4
- Stand ID: 94
- Area: 14.85 ha
- Stand type: Conifer
- Leading species: Lodgepole pine
- Mean crown area: 17.8 m^2
- 25th percentile: 9 m^2
- 50th percentile: 14 m^2
- 75th percentile: 23 m^2
- Crown closure: 37%



Result:

Stand height with RMSE of **2.84 m**

Crown metrics

- Crown ID: 1385
- Length: 3.5 m
- Area: 6.8 m
- 40th percentile

Mora, B., M.A. Wulder, and J.C. White (2010). Segment-constrained regression tree estimation of forest stand height from very high spatial resolution panchromatic imagery over a boreal environment. Remote Sensing of Environment. Vol. 114, pp. 2474–2484. (DOI: http://dx.doi.org/10.1016/j.rse.2010.05.022)

Compare to studies using HSR imagery with ground plots or LiDAR samples

- Peuhkurinen et al. (2008) IKONOS and ground plots
  - mean stand height, RMSE = **3.1 m**

- Hilker et al. (2008) QuickBird and LiDAR
  - mean stand height, 2 ha minimum stand size
  - underestimated stand height by an average of **3.5 m**

- Chen et al. (2012) QuickBird and LiDAR
  - mean plot height, plot size = 0.04 ha
  - RMSE for *best* model was **3.37 m**

- Mora et al. (2013). QuickBird and LiDAR
  - mean stand height, RMSE = **2.3 m**

Compare to other studies using Landsat and LiDAR

- Wulder and Seemann (2003)
  - mean stand height, RMSE = **3.3 m**
- Pascual et al. (2011)
  - mean stand height, RMSE = **1.9 – 2.3 m**
- Maselli et al. (2011)
  - mean stand height, RMSE = **3.01 m**
- Varhola and Coops (2013)
  - mean plot height (plot size = 0.25 ha), RMSE = **3.24 m**

What have we learned?

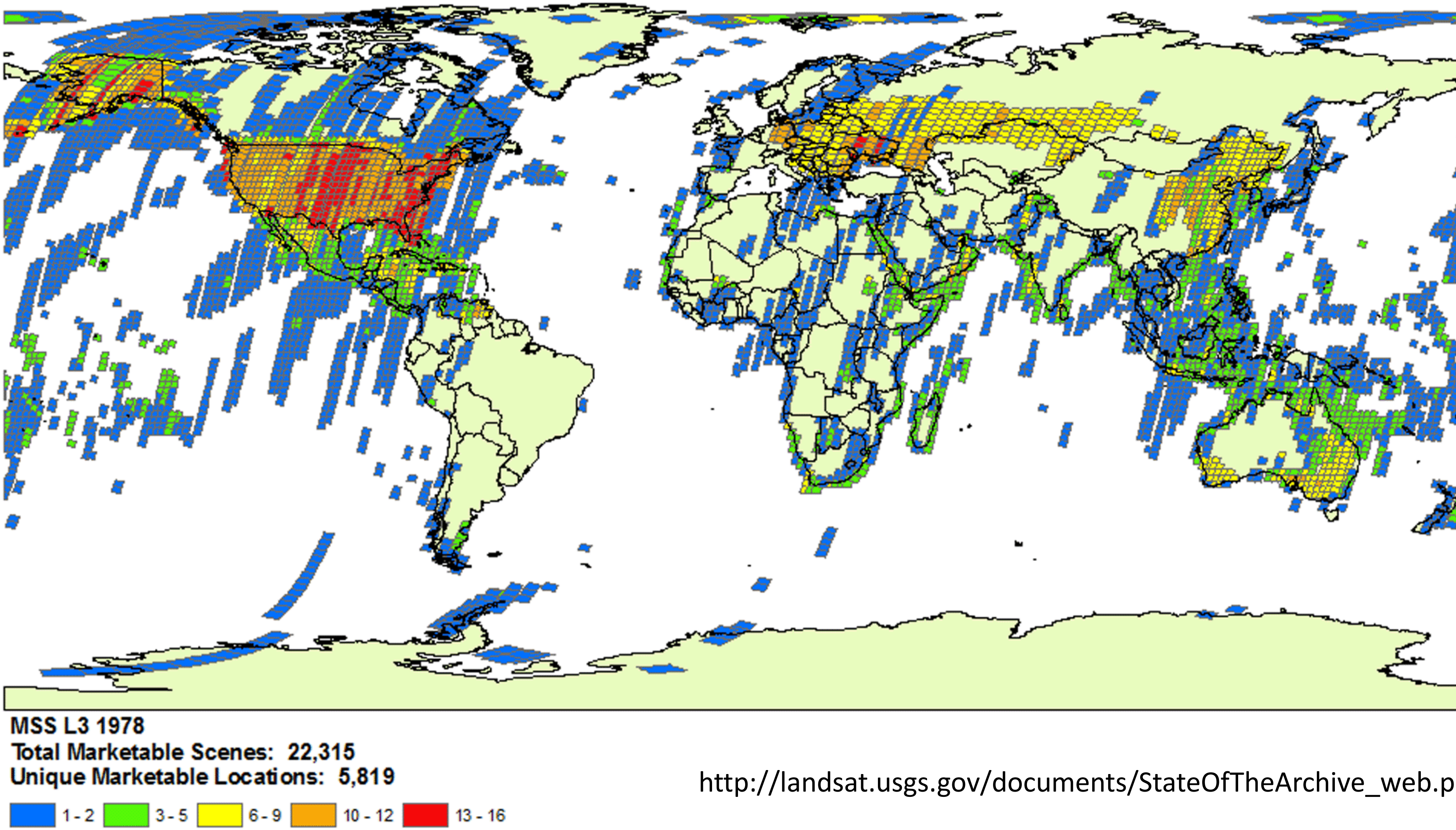
- Similar RMSEs are found when using either field plots or lidar plots
- Similar RMSEs are found when using very high spatial resolution imagery or Landsat

- Value in using lidar plots to provide a well distributed set of plot-like data to calibrate and validate models of forest structure

Part 2. Compositing

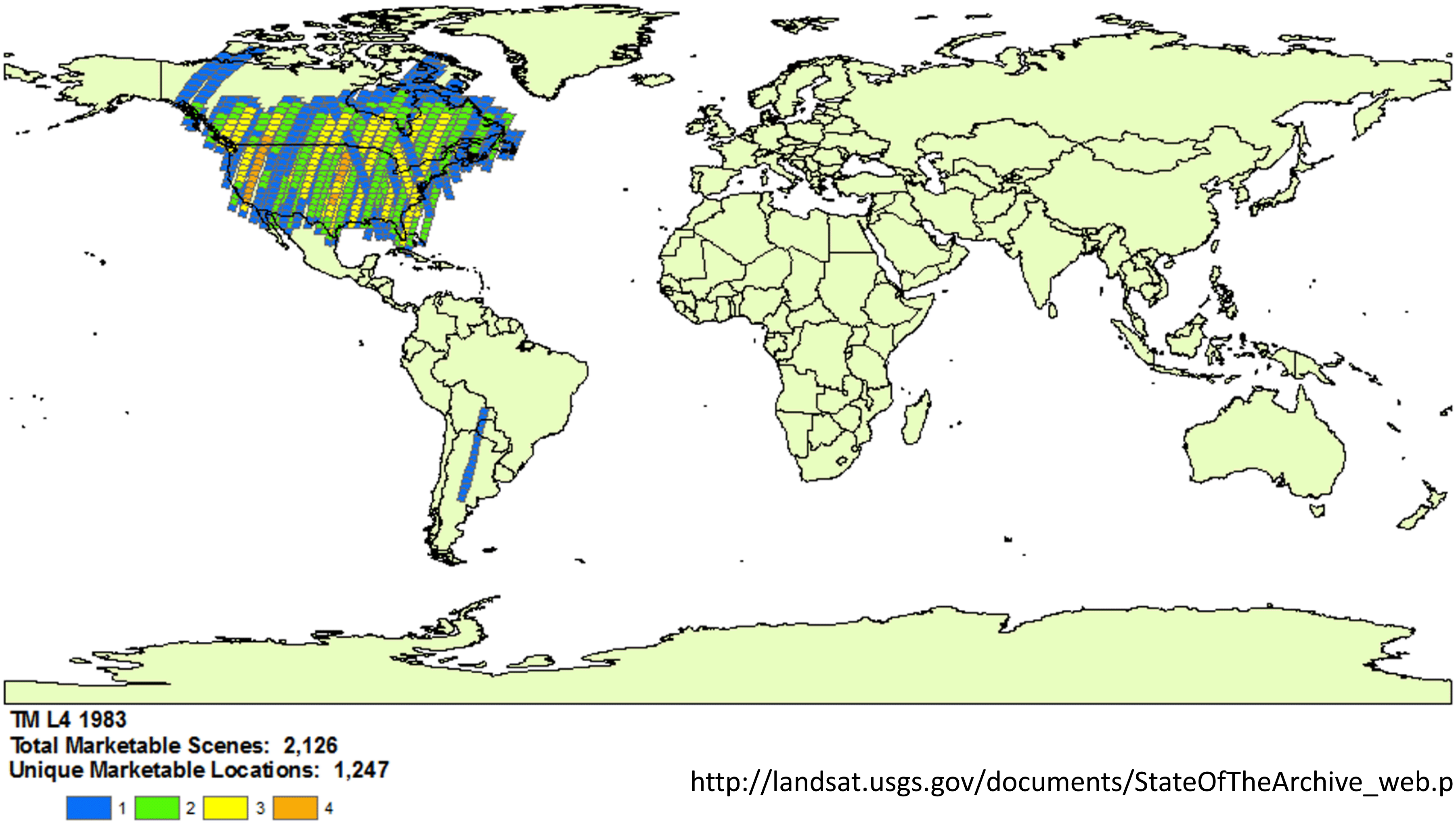
- Or, when the best available pixel is not good enough…

MSS L3 1978



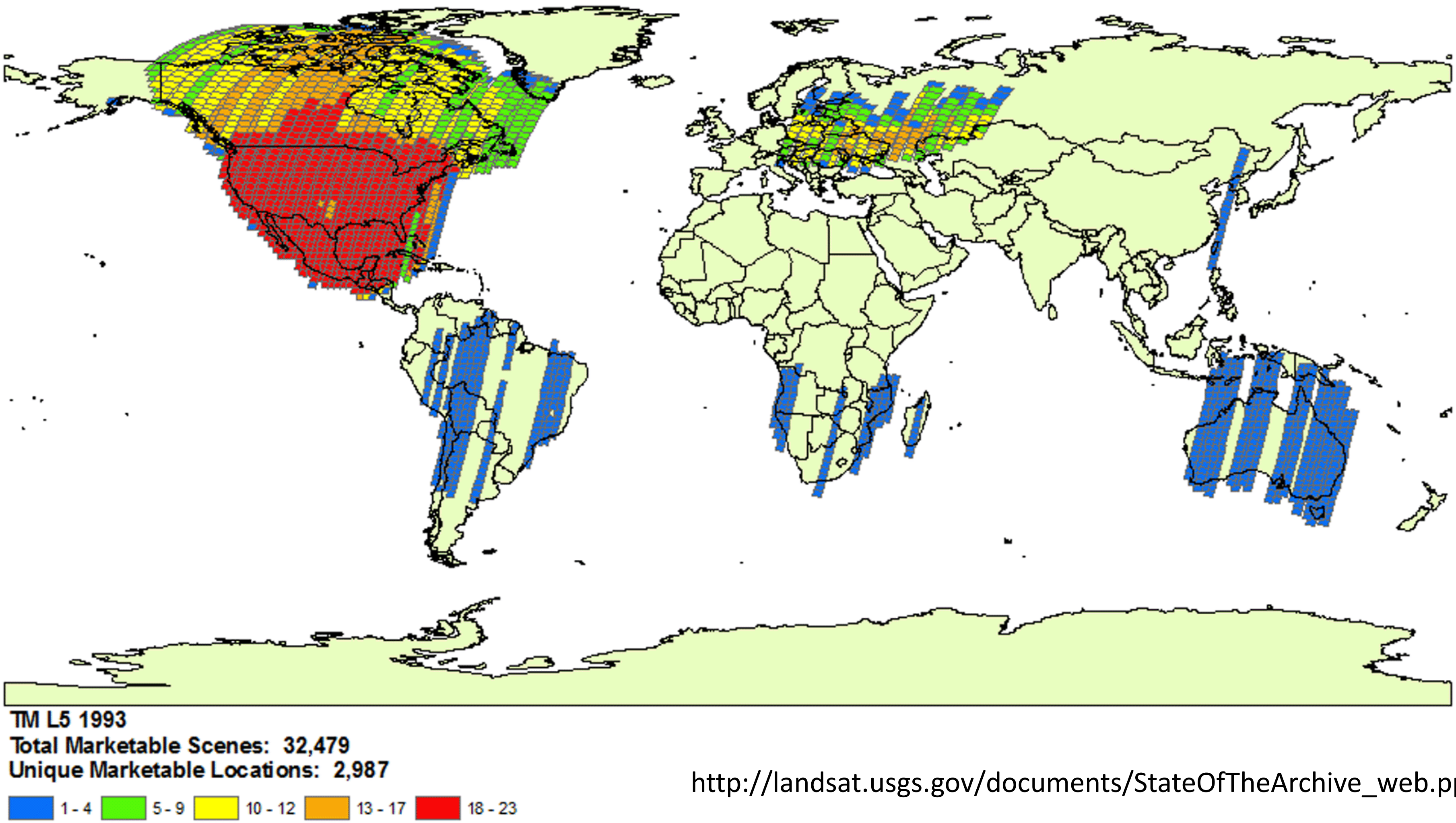
http://landsat.usgs.gov/documents/StateOfTheArchive_web.ppt

TM L4 1983



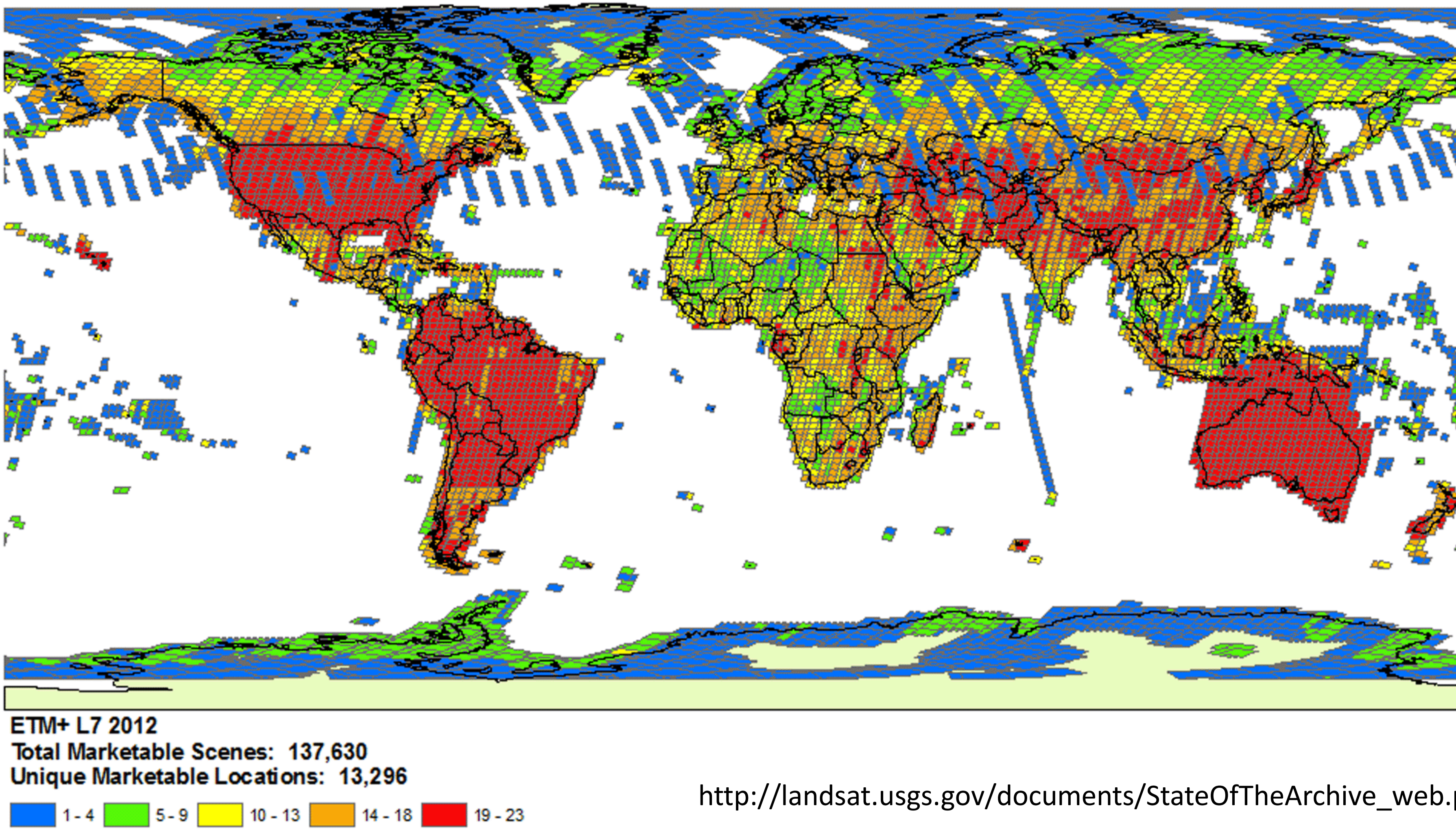
http://landsat.usgs.gov/documents/StateOfTheArchive_web.ppt

TM L5 1993



http://landsat.usgs.gov/documents/StateOfTheArchive_web.ppt

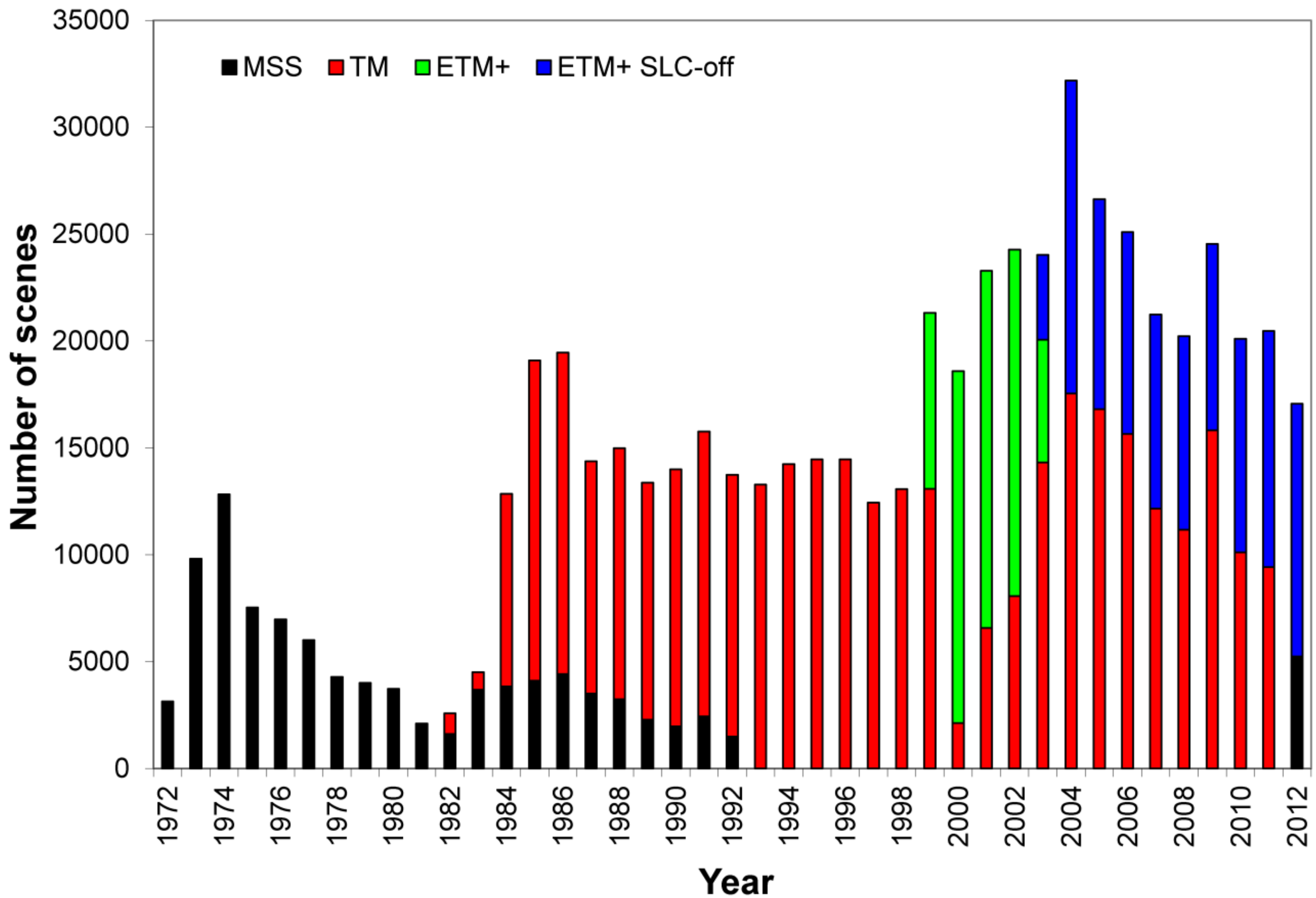
ETM+ L7 2012



http://landsat.usgs.gov/documents/StateOfTheArchive_web.ppt

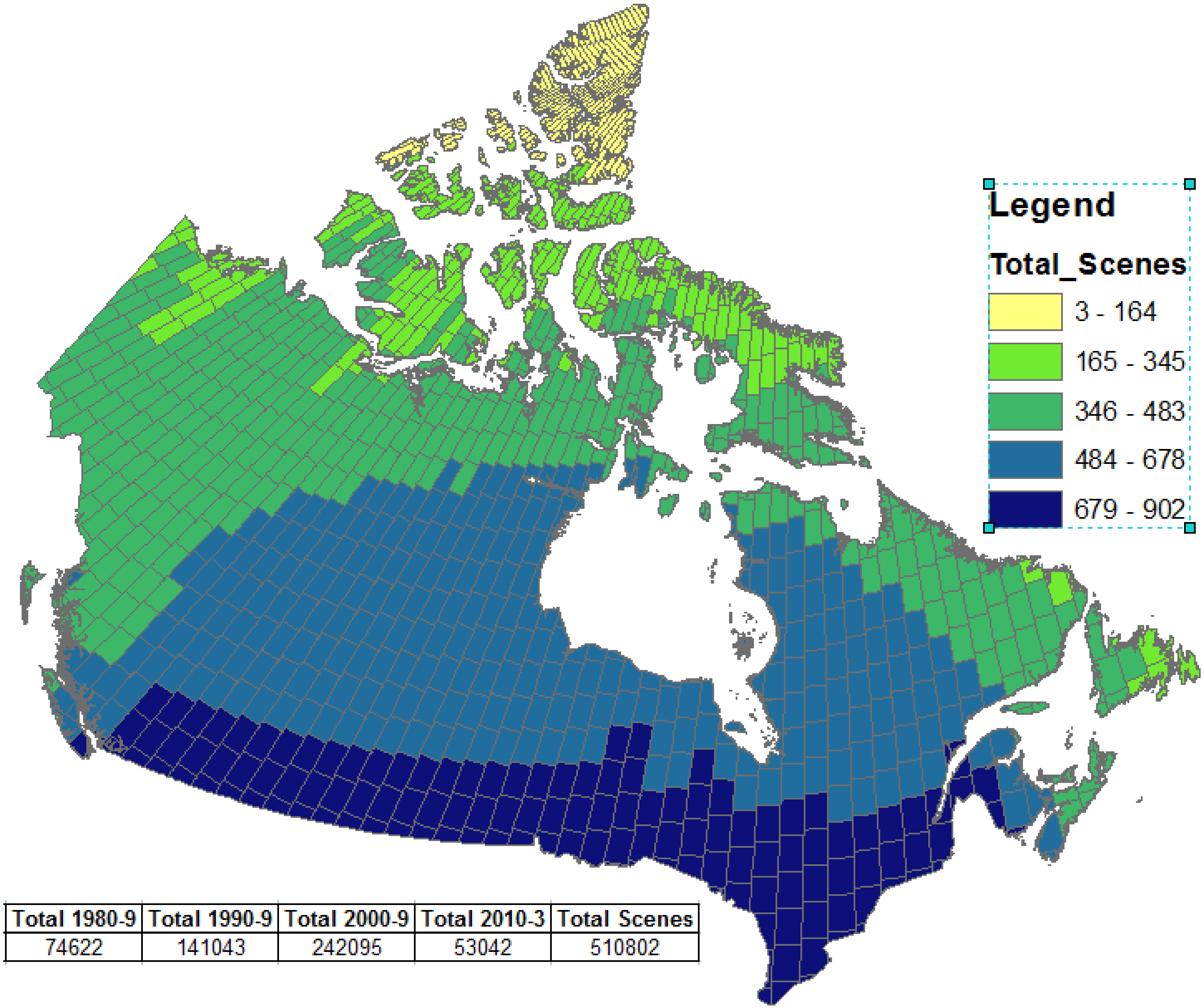
USGS

USGS archive holdings, Canada



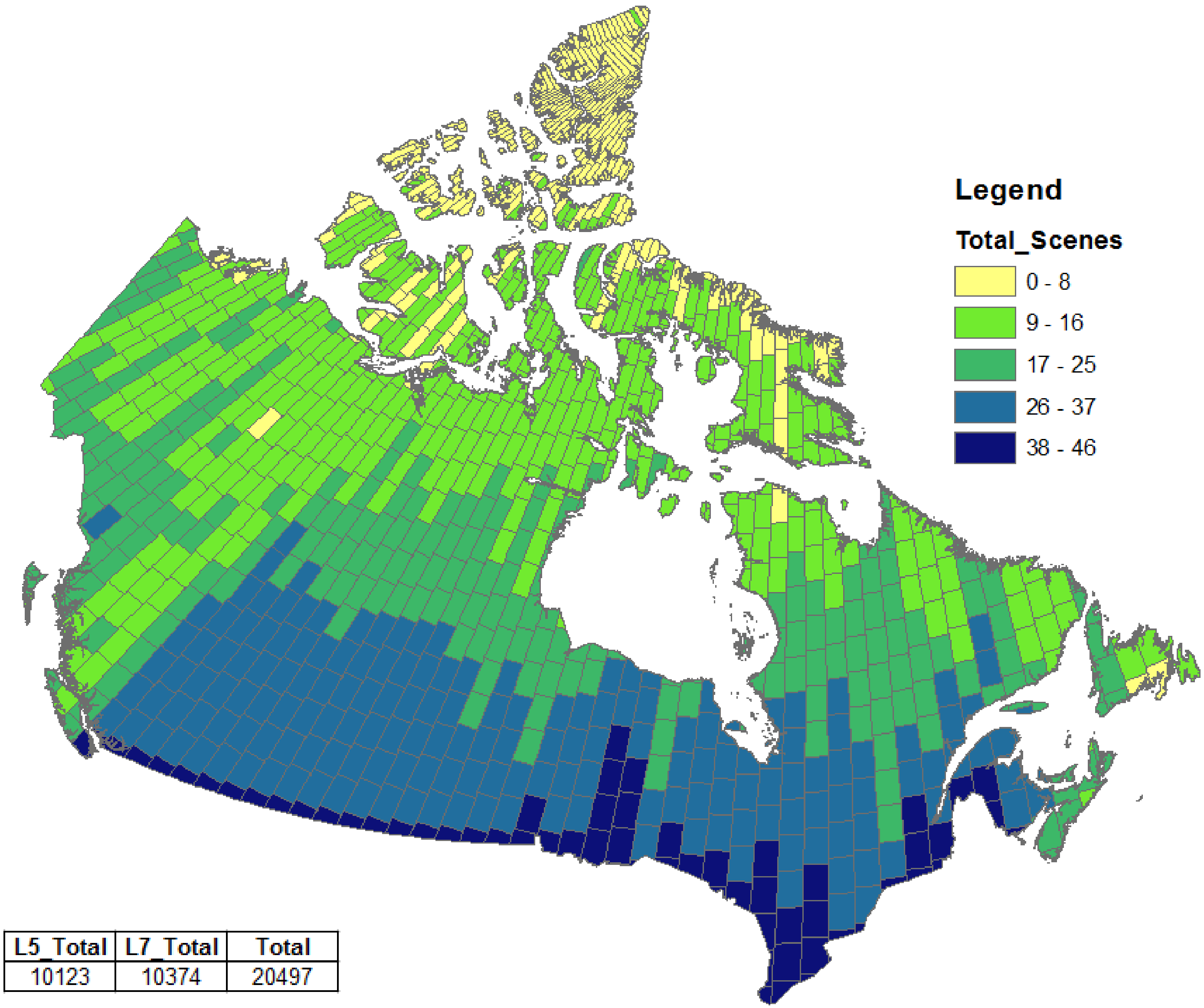
- > 605,000 images in archive

Available Images for 1286 Path Row Scenes Over Terrestrial Canada



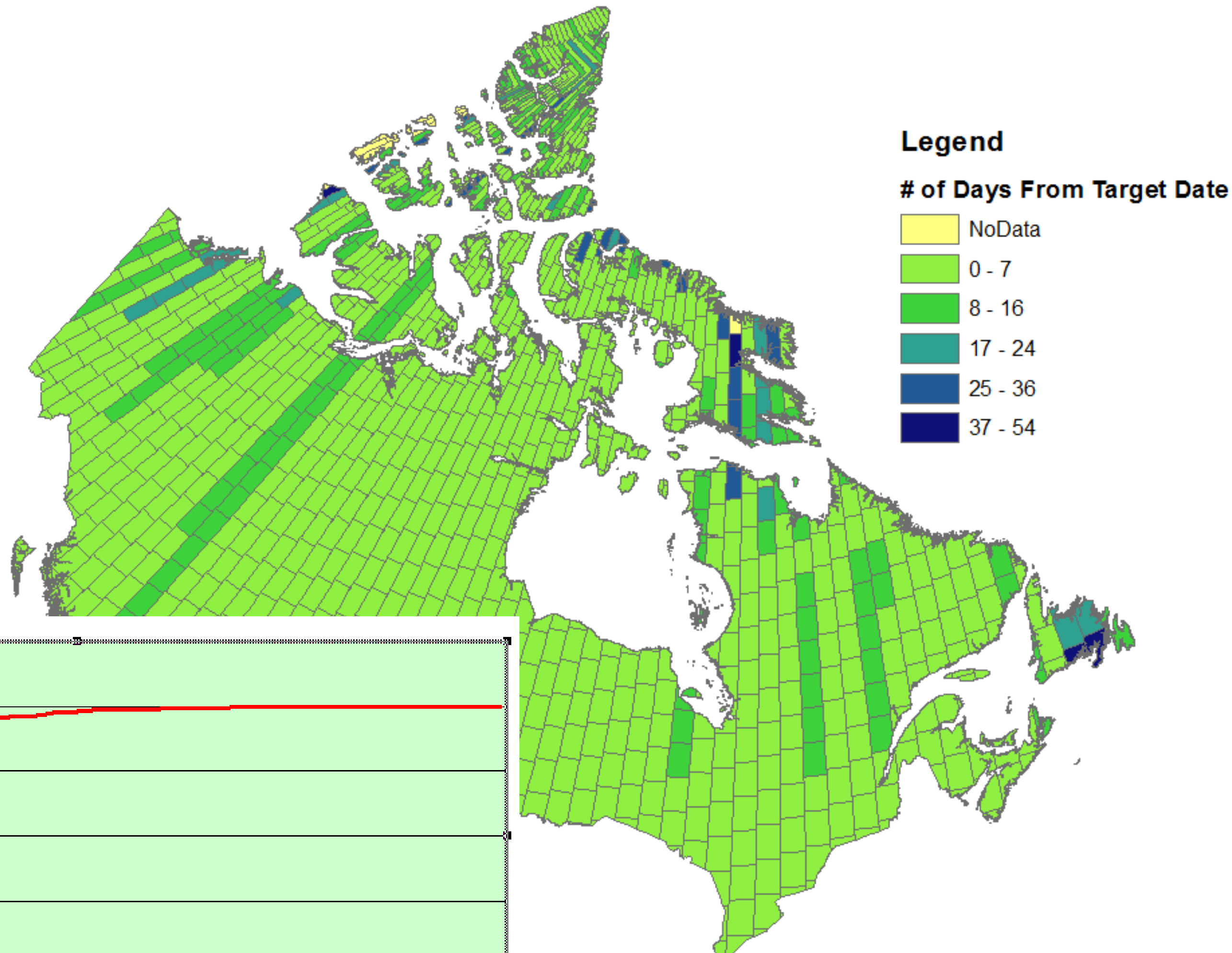
Total 1980-9	Total 1990-9	Total 2000-9	Total 2010-3	Total Scenes
74622	141043	242095	53042	510802

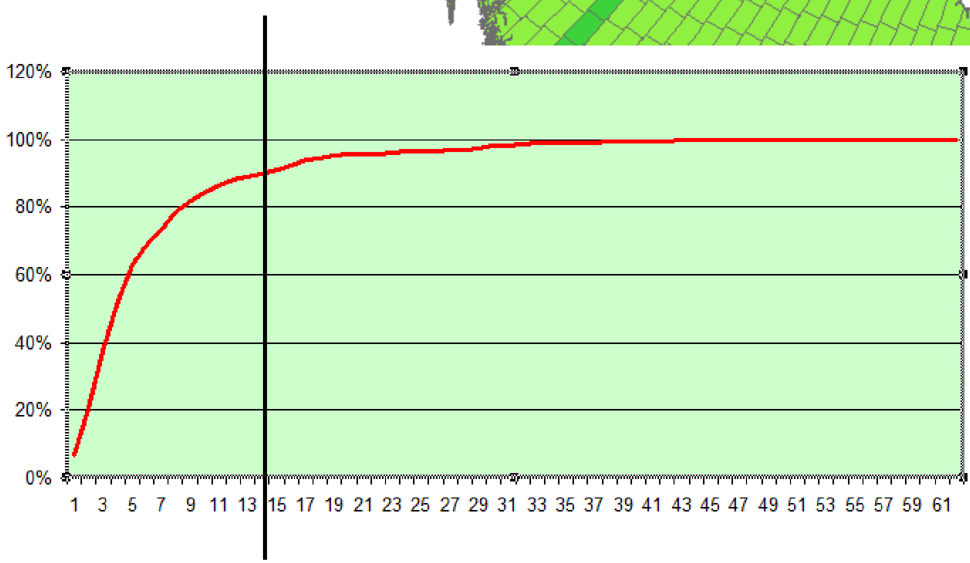
Available 2010 Images for 1286 Path Row Scenes Over Terrestrial Canada



L5_Total	L7_Total	Total
10123	10374	20497

Distance off Target Date for Best Image between June 1 and Sept 30, 2010





Cloud / Shadow…

Best Available Pixel Processing

- Develop pixel based processing, not scene based
- Create composites from many images
- Cloud and shadow screening critical

Hansen, M. C. and Loveland, T. R. 2012. A review of large area monitoring of land cover change using Landsat data. Remote Sensing of Environment. Vol. 122, pp. 66-74.

Roy, D. P.; Ju, J.; Kline, K.; Scaramuzza, P. L.; Kovalskyy, Y.; Hansen, M.; Loveland, T. R.; Vermote, E., and Zhang, C. Web-enabled Landsat Data (WELD): Landsat ETM+ composited mosaics of the conterminous United States. Remote Sensing of Environment. 2010; 114:35-49.

Griffiths, P. et al. 2013. A pixel-based Landsat compositing algorithm for large area land cover mapping. J. Sel. Topics App. Ear. Obs. Rem. Sens. Doi: 10.1109/JSTARS.2012.2228167

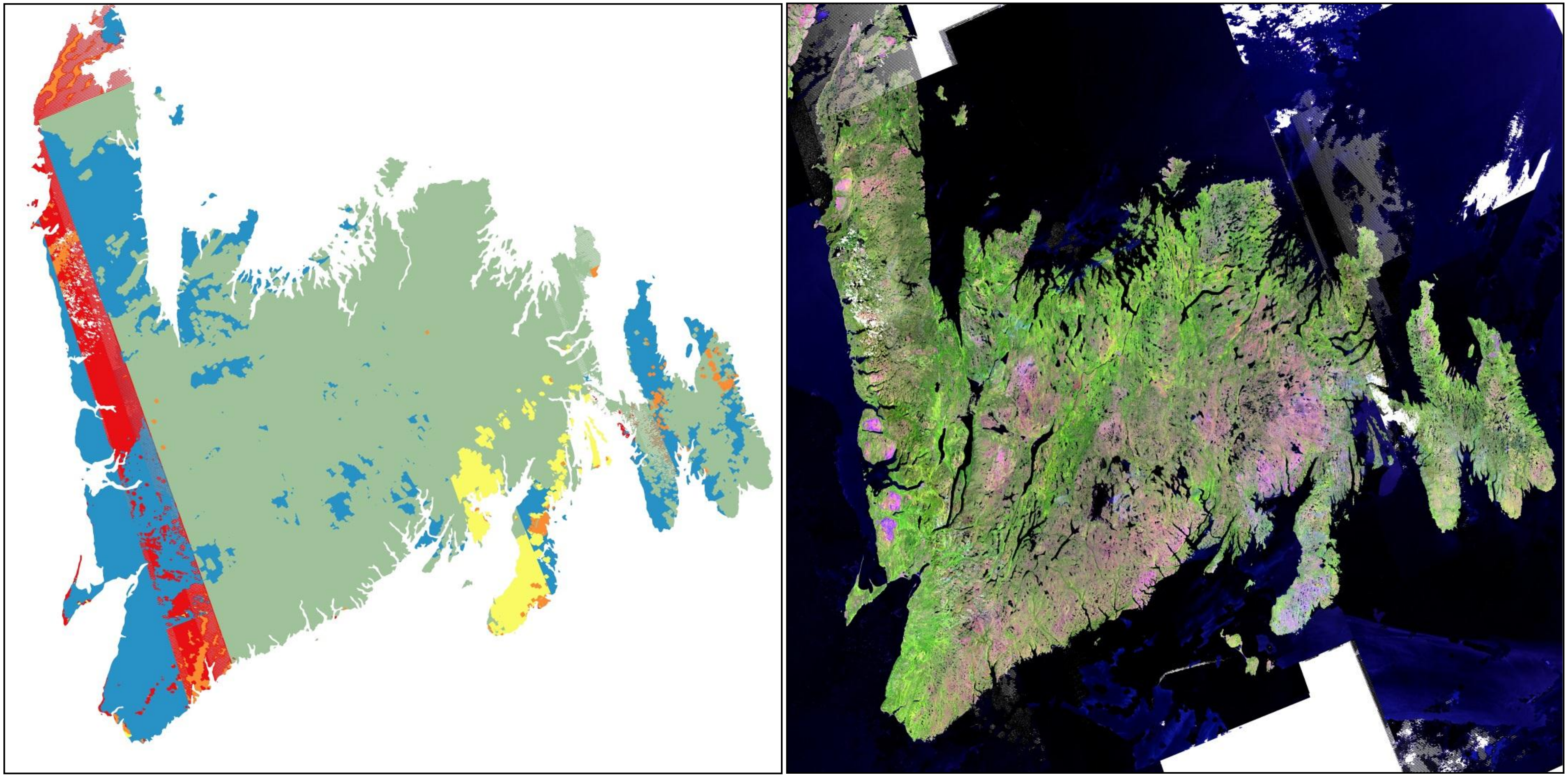
Pixel Assessment

- A score calculated for each pixel
- “Best” pixel then selected, based on:

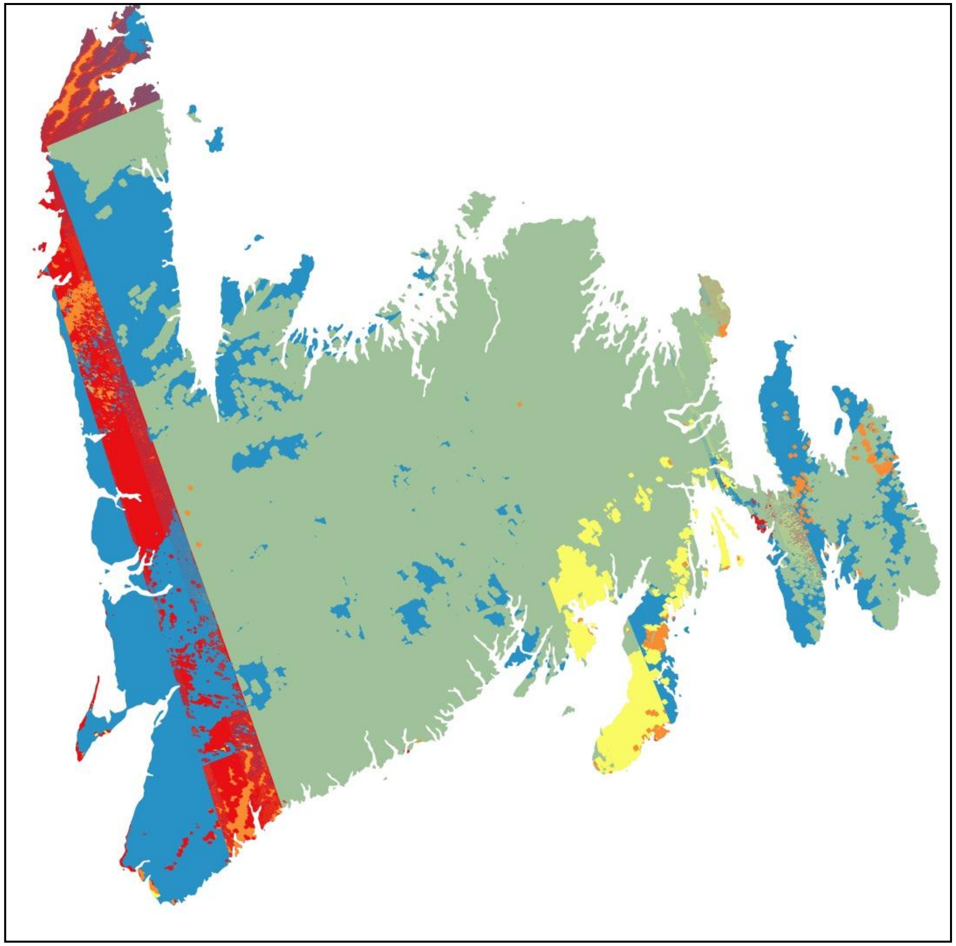
1) Acquisition year
2) Acquisition Day of Year (target August 1, day 213)
3) Distance to cloud/shadow
   - cloud / shadow masking from FMASK
   - Zhu et al. 2012. RSE.
4) Reflectance and opacity from LEDAPS (Masek et al. 2006)
   - Use opacity (haze) to aid in pixel selection

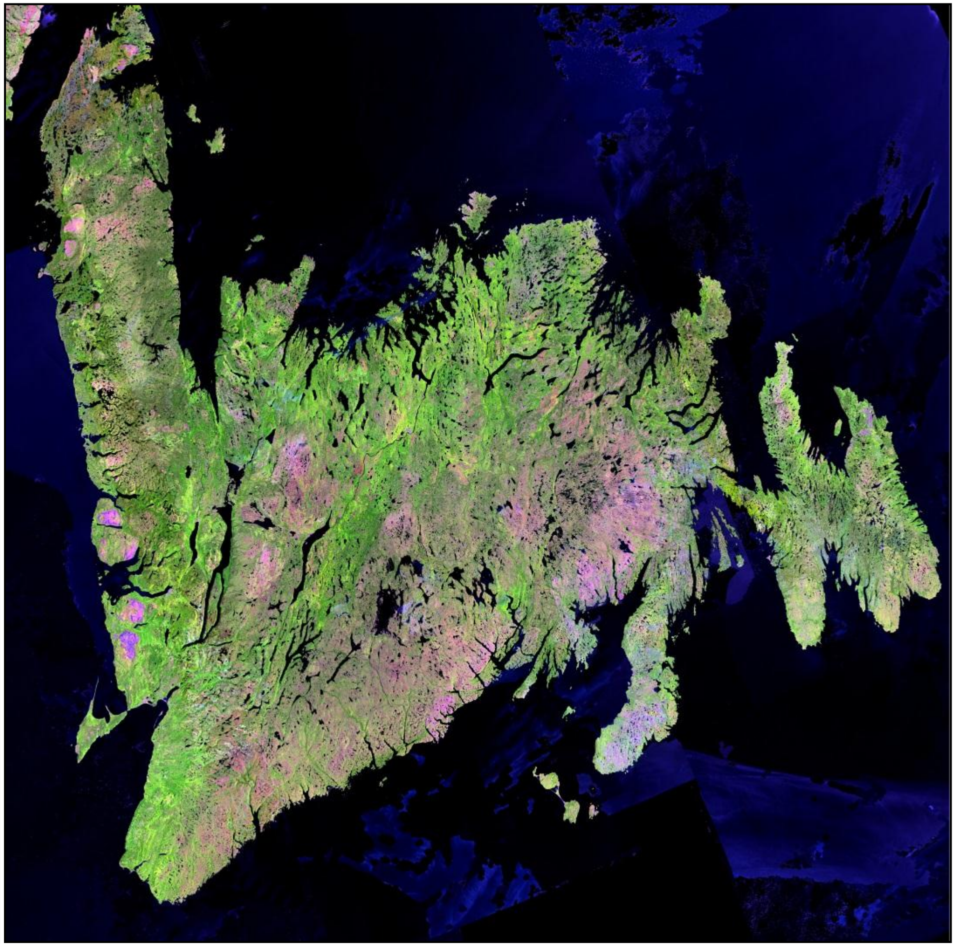
Composites - Lexicon

- Rule-based BAP composite
  - determined by DOY, year, distance to cloud, sensor (L5 or L7), and opacity
  - BAP may come from desired date range in previous or subsequent years
  - goal is consistent phenology with minimal “no data” pixels
- Annual BAP composite
  - determined by DOY, distance to cloud, sensor (L5 or L7), and opacity
  - BAP may come from desired date range *for a given year*
  - “no data” pixels are much more likely to occur
- Proxy annual BAP composite
  - use annual BAP composites as source
  - fill in areas of “no data” by averaging (or some other approach) pixel values from previous/subsequent years
  - some intelligence is envisioned whereby a long-term trajectory of pixel values can be used to identify whether or not the pixel is changed
  - contextual rule-base



BAP annual composite (2003)





D2TD (days)

- 0 - 10
- 11 - 20
- 21 - 30
- 31 - 45
- 46 - 62

BAP multi-year composite (2003)

BAP proxy composite (2003)

Historic reconstruction: Proxy annual BAP composite

- Features:
  - Annual
  - Compensates for haze, image availability
  - Automated, allows for data reduction
  - Allows for applications: cover, change in cover, and surface reflectance for structural attribution
  - Change over time compensates for limitations of compositing (haze, phenology, …). Illogical transitions can be removed. Change capture comes first.
  - Note best pixel approaches will differ outside of CONUS and active IC catchments

- Proxy development:
  - Annual BAP layers (limited by date, haze)
  - First pass filter
  - Figuring out how to deal with disturbance
- Land cover change
  - Spectral change; LandTrendr-lite. Disturbance year, pre-dist trend; post-dist trend, etc
- Land cover
  - Stability, logical transitions, spectral info
- Structure
  - Lidar plots to cal / val estimates of ht, biomass, volume, canopy cover, etc.
- Continuity has made possible

Thank you!

Contact Information:

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Publications:

http://cfs.nrcan.gc.ca/publications/authors/read/11091

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