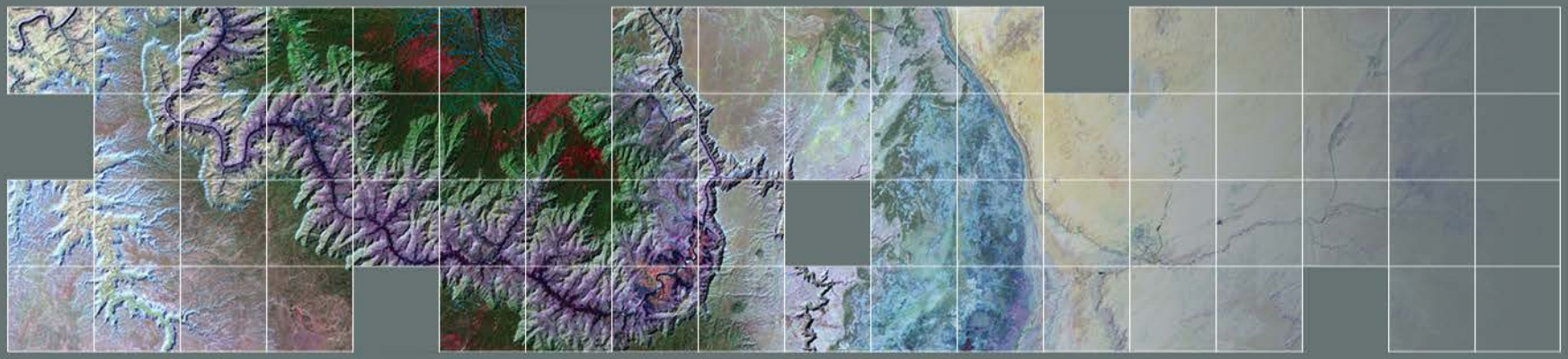
USGS
science for a changing world

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

Capturing land cover change in Alaska over the last 10 years with the National Land Cover Database: Status and Plans



Jon Dewitz
dewitz@usgs.gov Sept. 2016

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

Multi Resolution Land Characteristics Consortium (MRLC)

- Bureau of Land Management (BLM)
- Environmental Protection Agency (EPA)
- National Aeronautics and Space Administration (NASA)
- National Park Service (NPS)
- National Oceanic and Atmospheric Administration (NOAA)
- Natural Resources Conservation Service (NRCS)
- U.S. Geological Survey (USGS)
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- LANDFIRE
- Army Corps of Engineers

NLCD, what it's used for….

- Used for thousands of applications……users download 1,200 large area products every month from EROS
- Many applications within USGS (NAWQA, GAP, National Map)
- 700 on-going applications in the EPA alone, including 60% of analysis involving the Clean Water act
- Imperviousness officially adopted by the Census bureau as a key input to urban delineation criteria
- BLM uses for Rapid Ecosystem Assessment
- Published over 50 related articles, which generally are highly cited

USGS

Alaska NLCD 2001 Land Cover Classes

NLCD Anderson Level II classes, Level I class equivalents, class names, and percent area mapped in Alaska.

Class (Level II)	Level I class	Name	Percent of area
11	10	Open water	14.2
12	10	Perennial ice/snow	4.3
21	20	Developed, open space	0.02
22	20	Developed, low intensity	0.06
23	20	Developed, medium intensity	0.007
24	20	Developed, high intensity	0.003
31	30	Barren land	7.7
41	40	Deciduous forest	3.4
42	40	Evergreen forest	15.5
43	40	Mixed forest	3.5
51[a]	50	Dwarf scrub	17.2
52	50	Shrub/scrub	21.2
71	70	Grassland/herbaceous	0.8
72[a]	70	Sedge/herbaceous	5.7
74[a]	70	Moss	0.03
81	80	Pasture/hay	0.003
82	80	Cultivated crops	0.02
90	90	Woody wetlands	3.5
95	90	Emergent herbaceous wetlands	2.9

[a] Class not mapped in the conterminous U.S.

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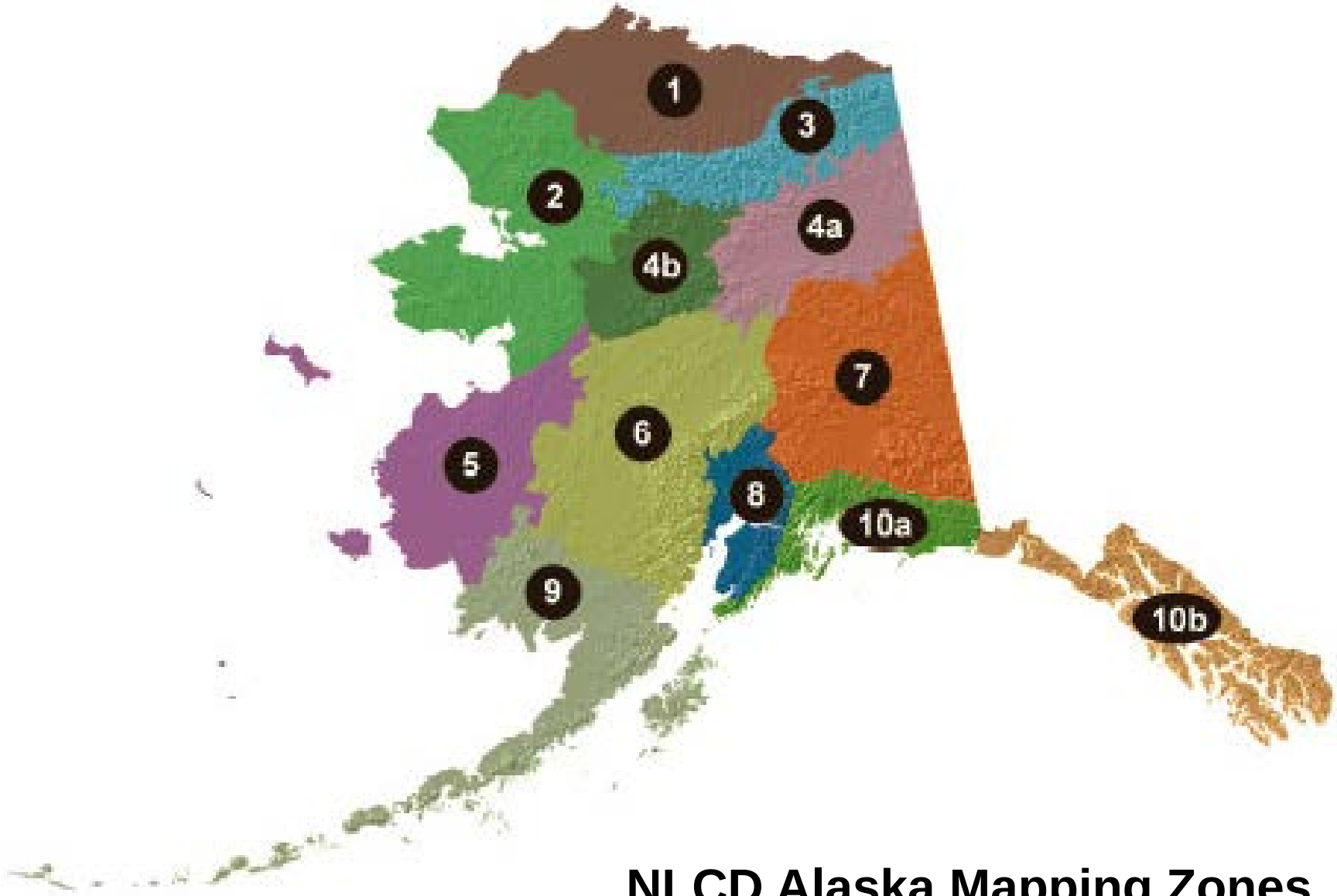

NLCD Alaska Mapping Zones

USGS

NLCD 2001 Field Work, Dave Selkowitz

NLCD 2001 was released for Alaska in March 2008

USGS

Alaska NLCD 2001 Level 2 Accuracy

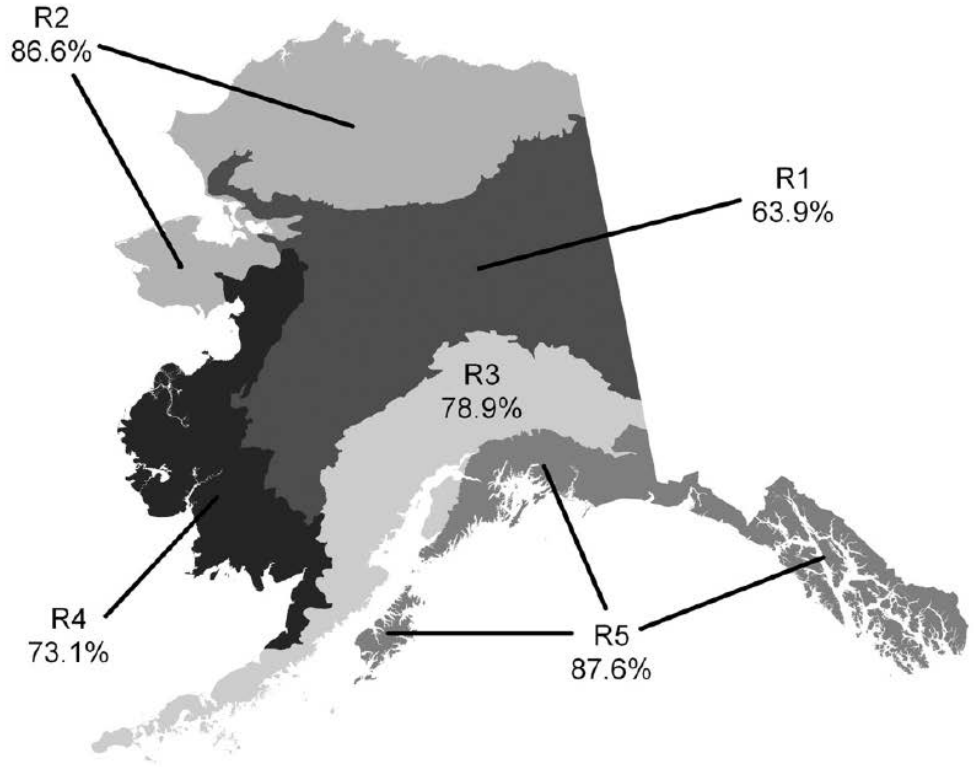

Fig. 2. Level II accuracy assessment results by region. R1 is Interior Boreal, R2 is Arctic and Bering Tundra, R3 is Alaska Range and Alaska Peninsula, R4 is Bering Taiga, and R5 is Coastal Rainforests and Mountains.

Selkowitz and Stehman, 2011, Thematic accuracy of the National Land Cover Database (NLCD) 2001 land cover for Alaska, Remote Sensing of Environment 115 (2011) 1401–1407

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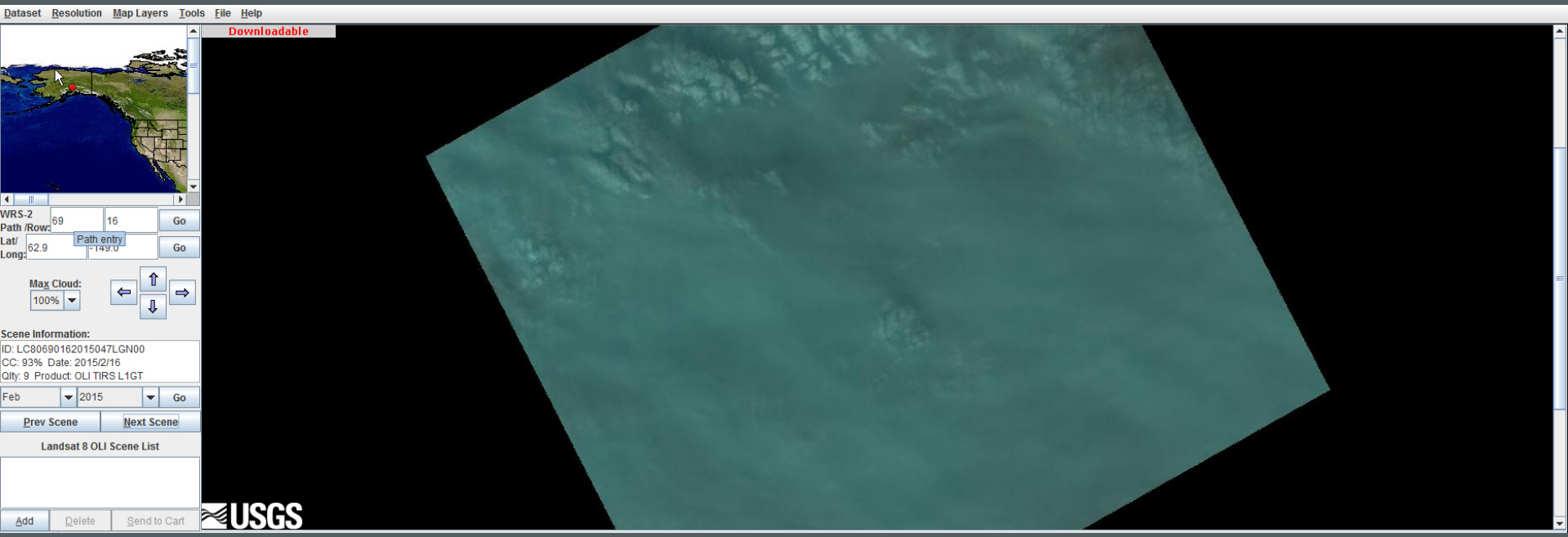
NLCD 2001 was released for Alaska in March 2008

USGS

Imagery, the base of Alaska Work



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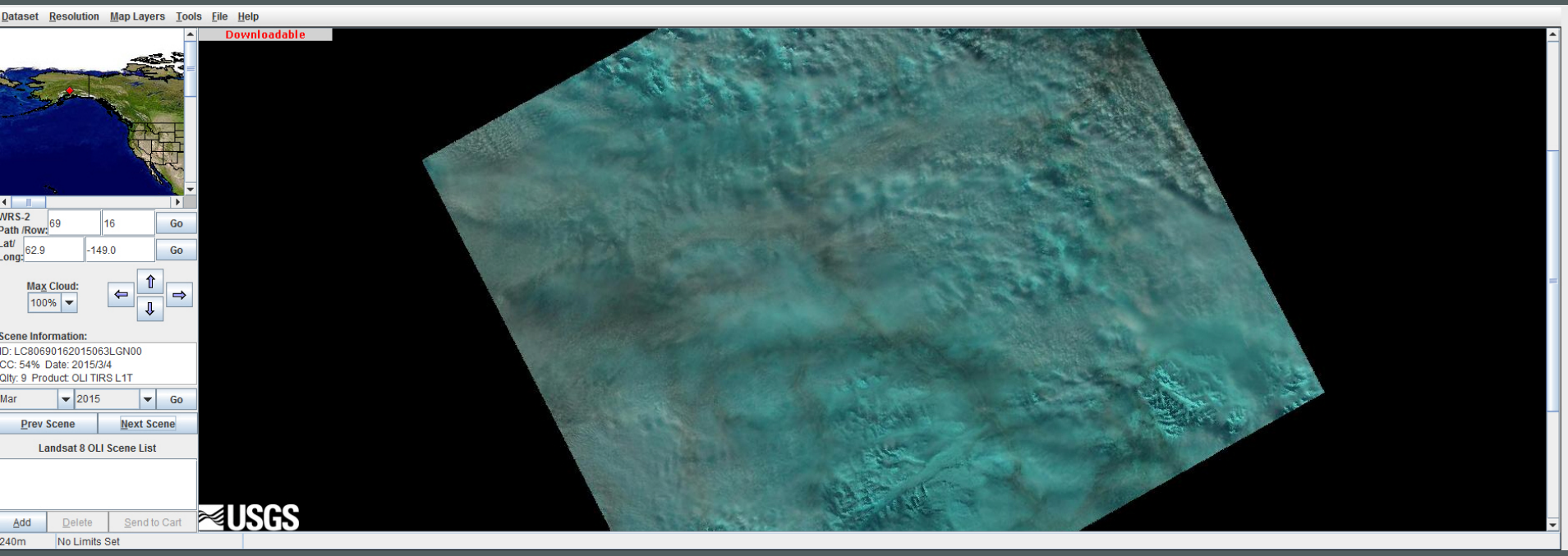
P69R16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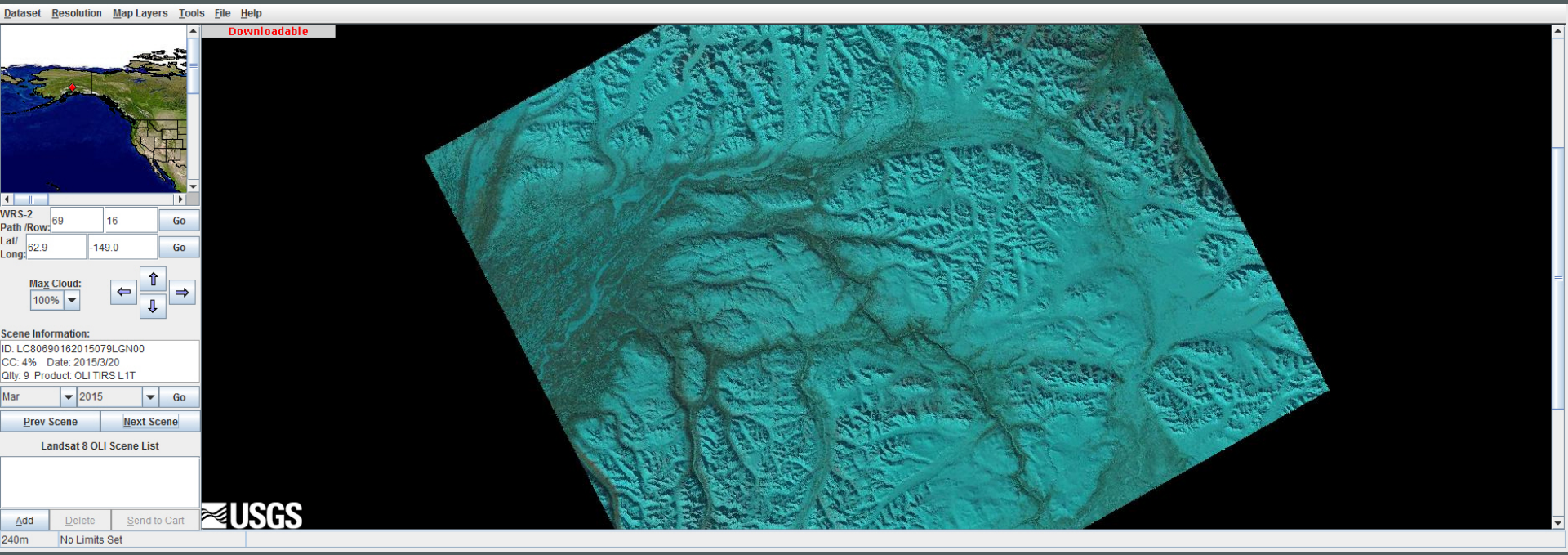
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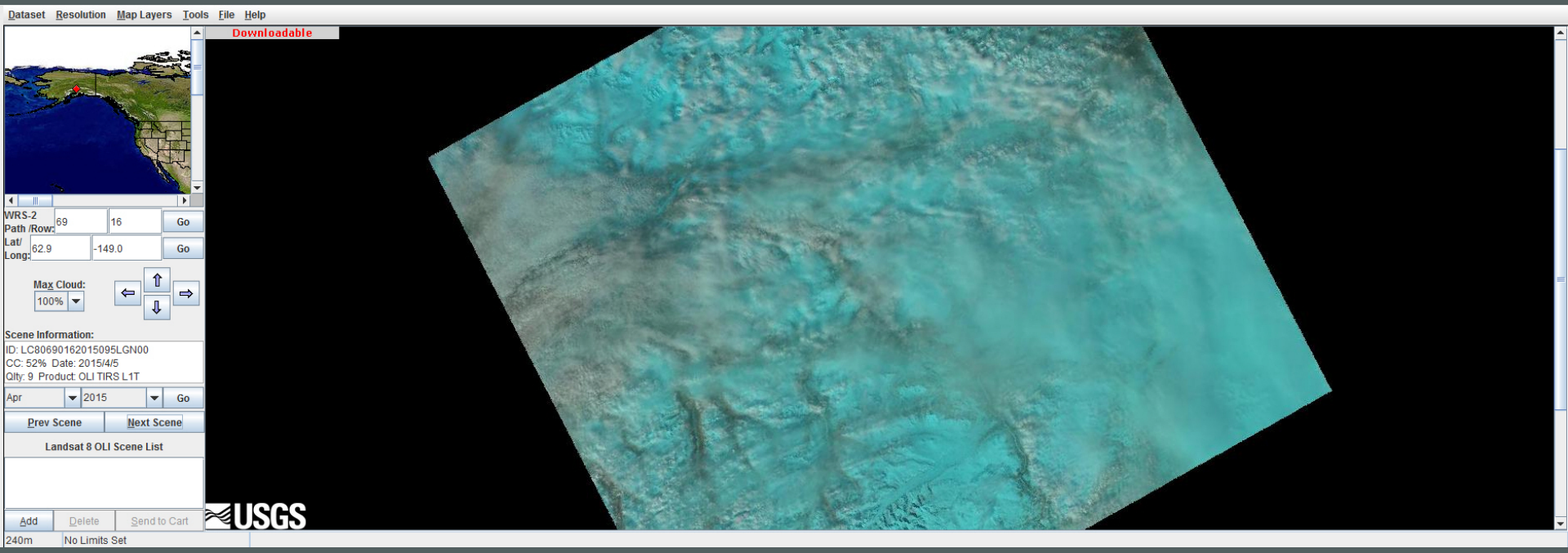
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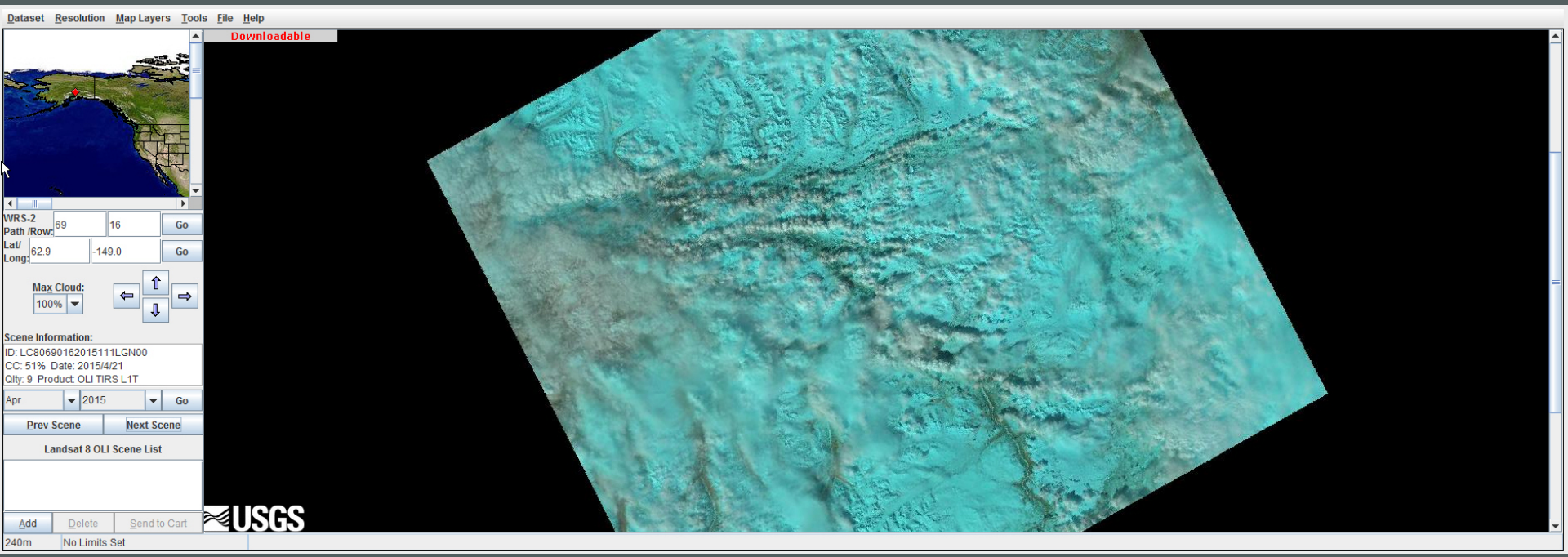
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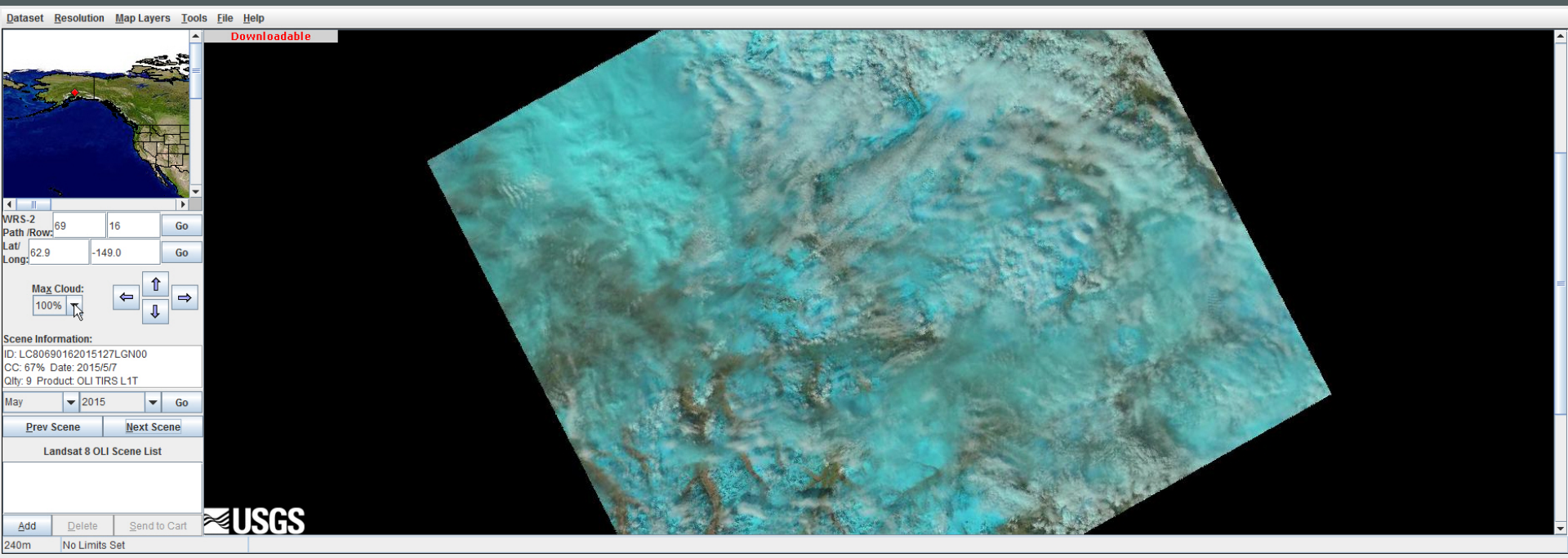
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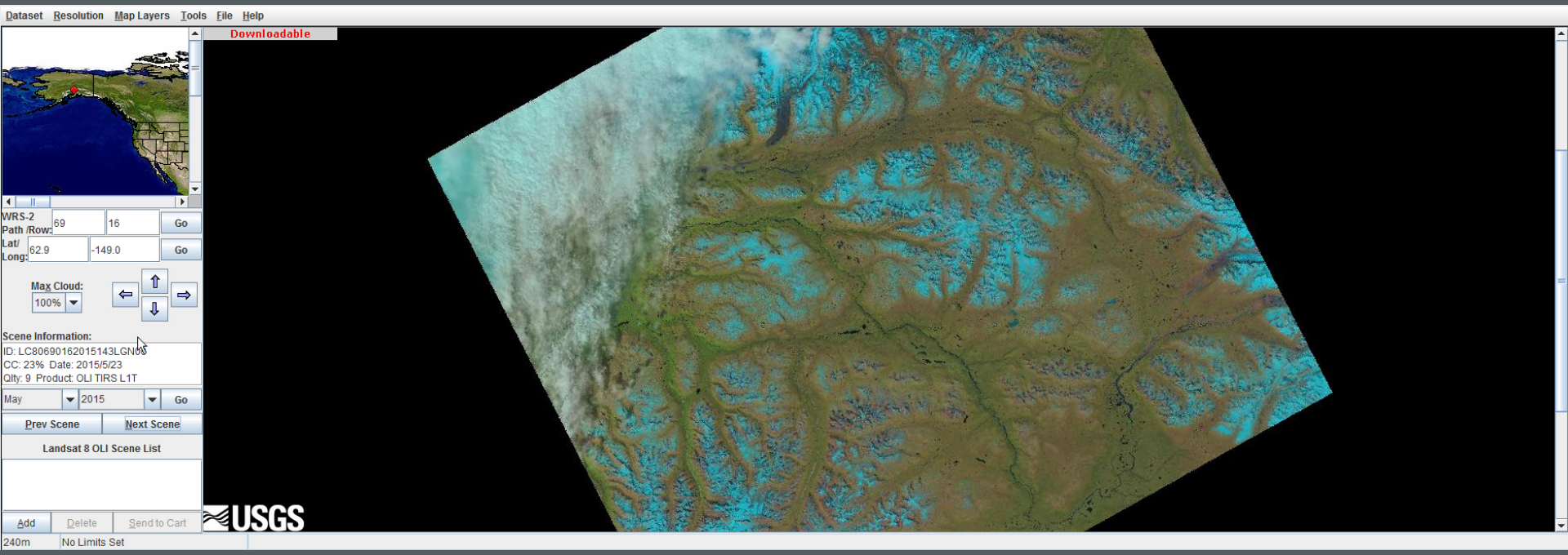
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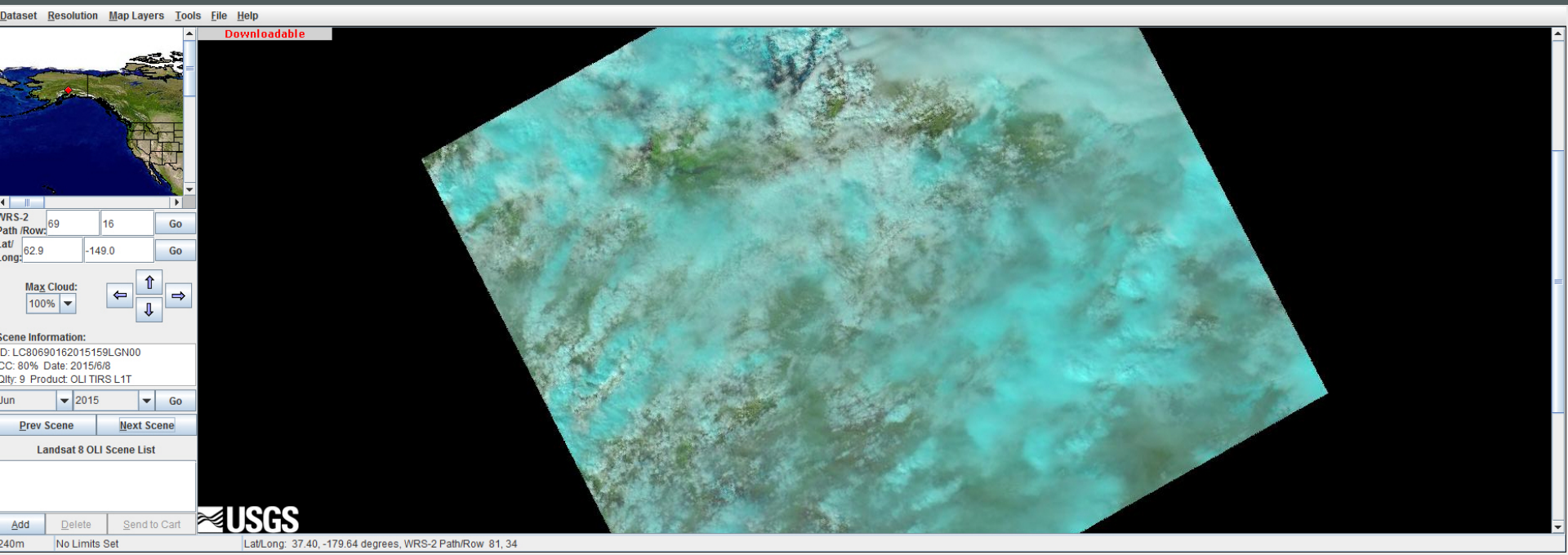
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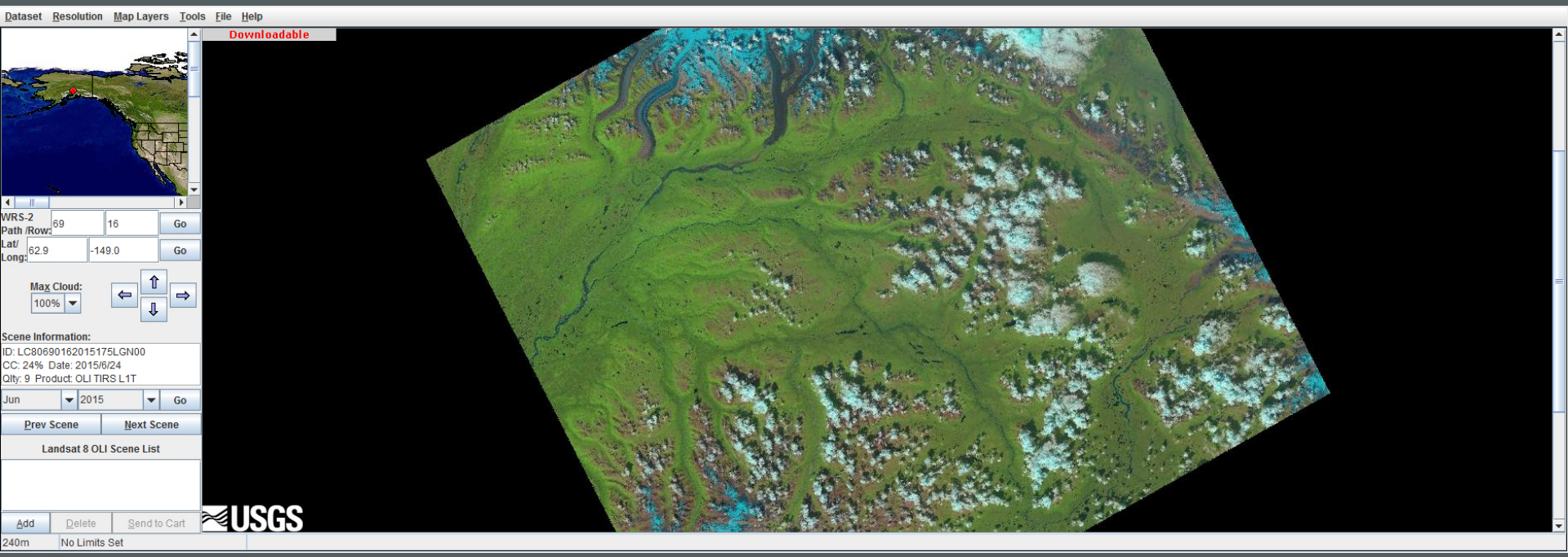
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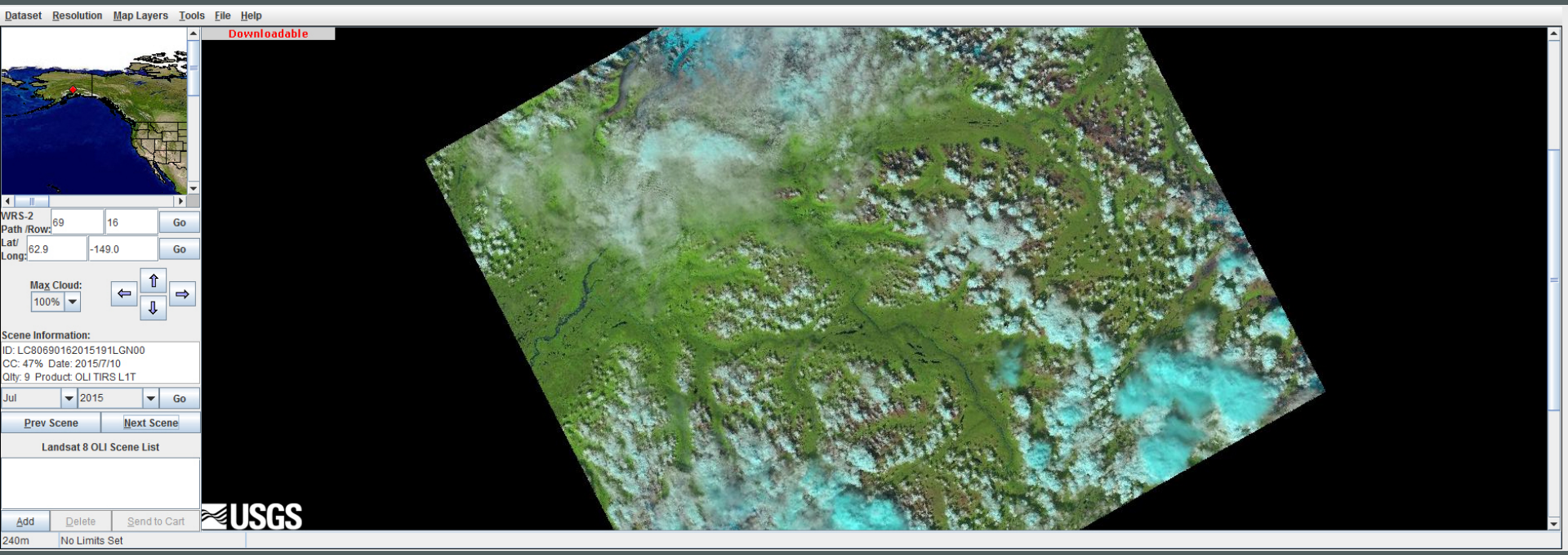
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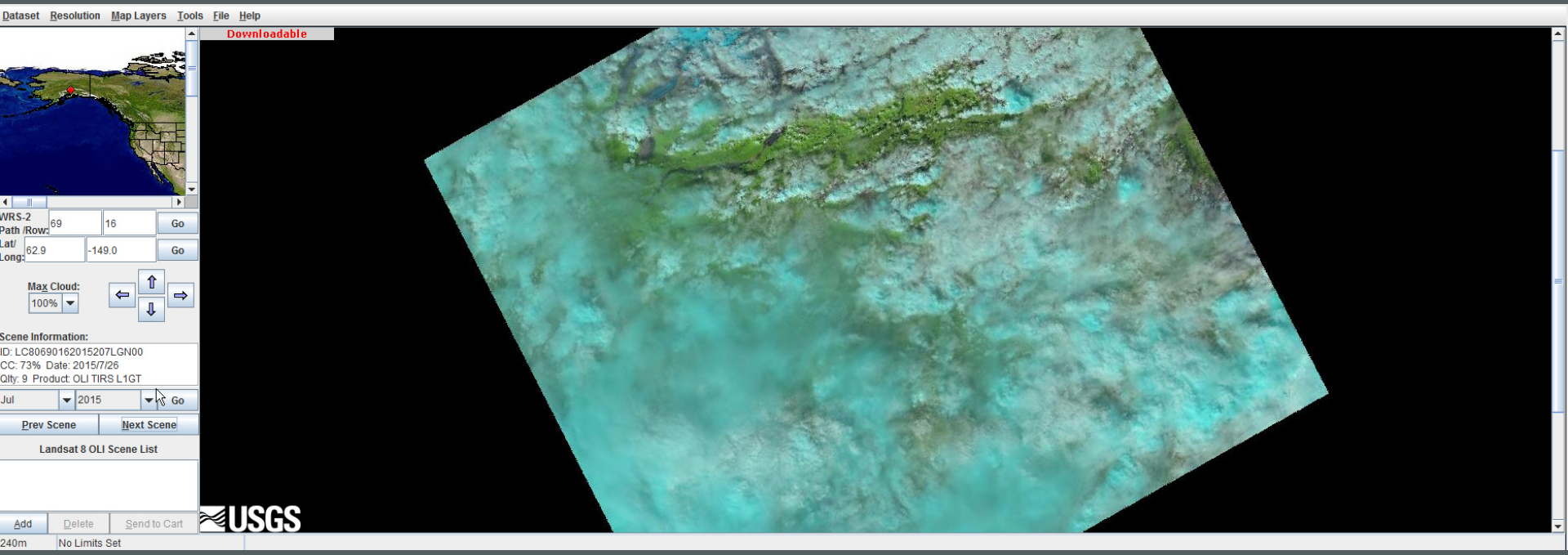
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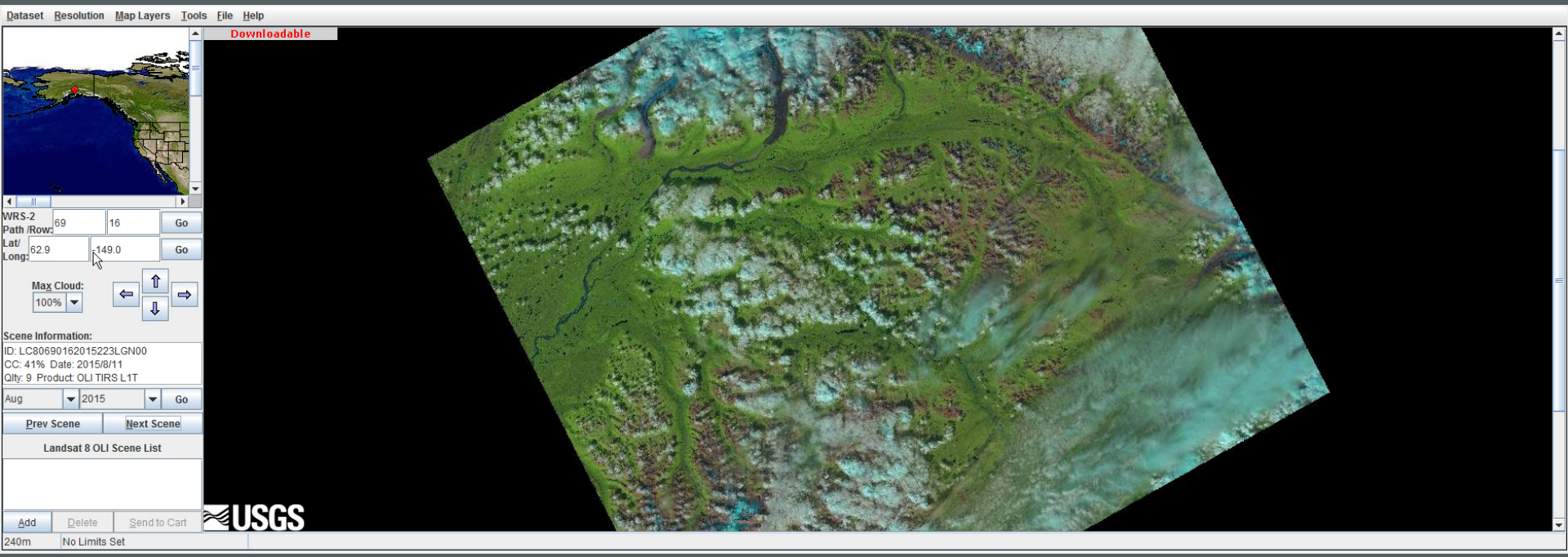
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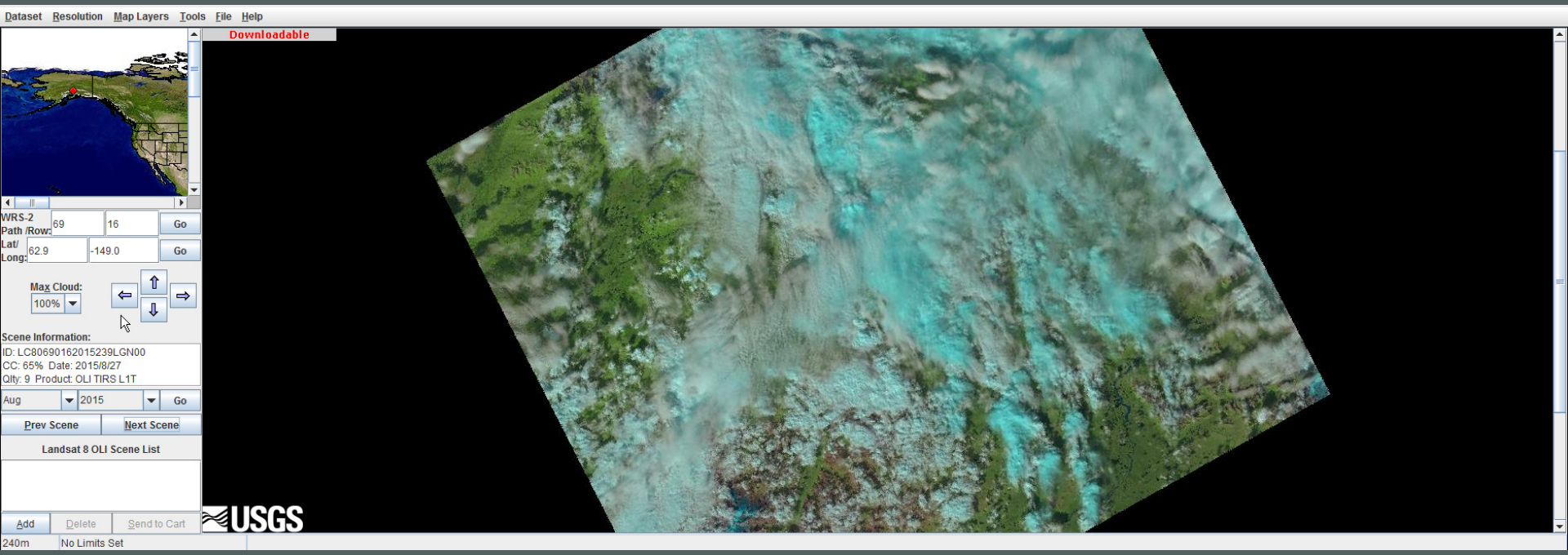
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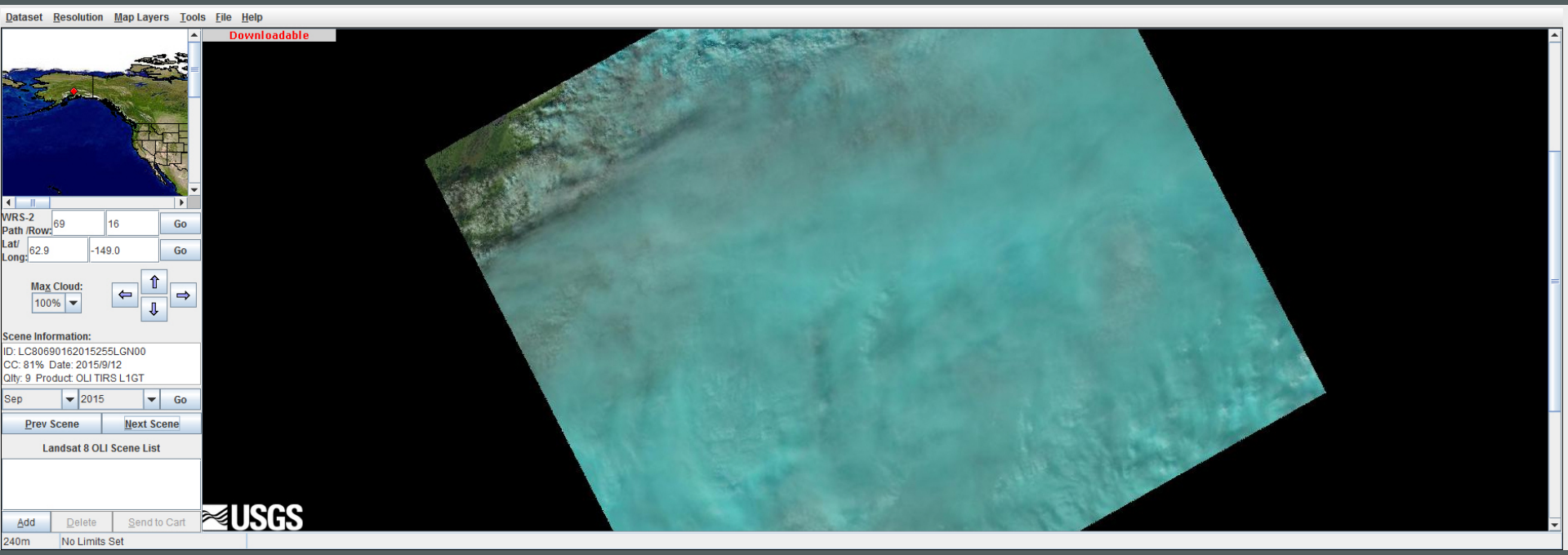
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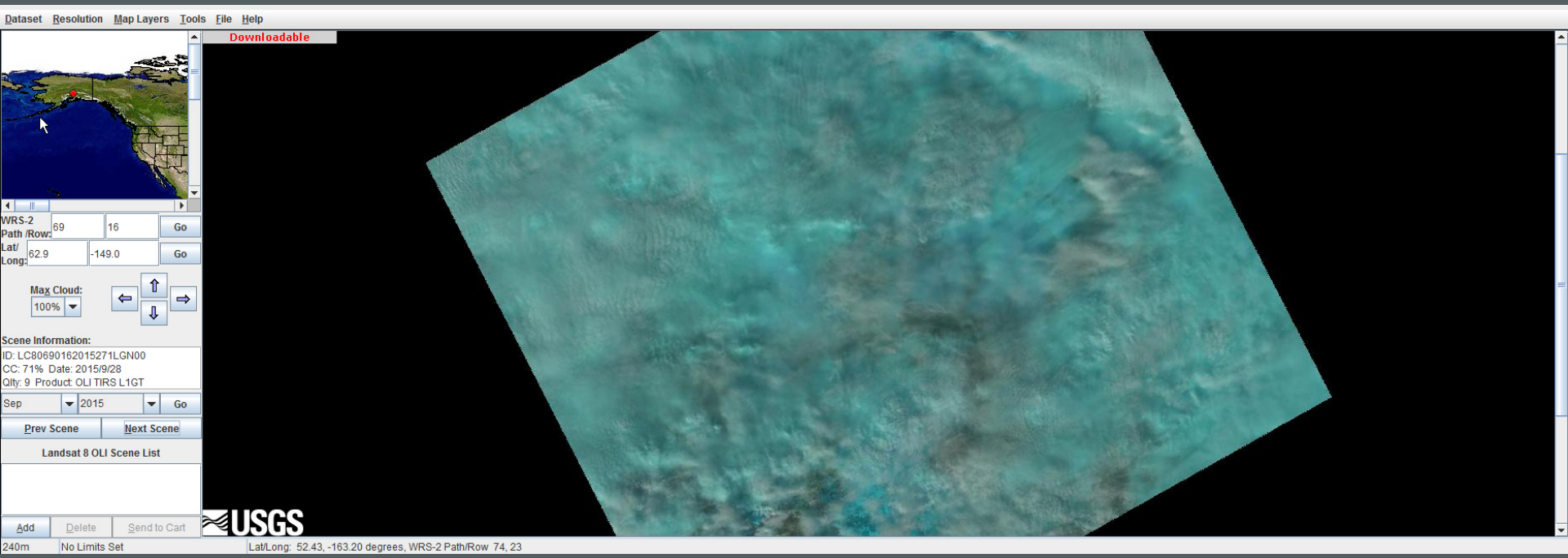
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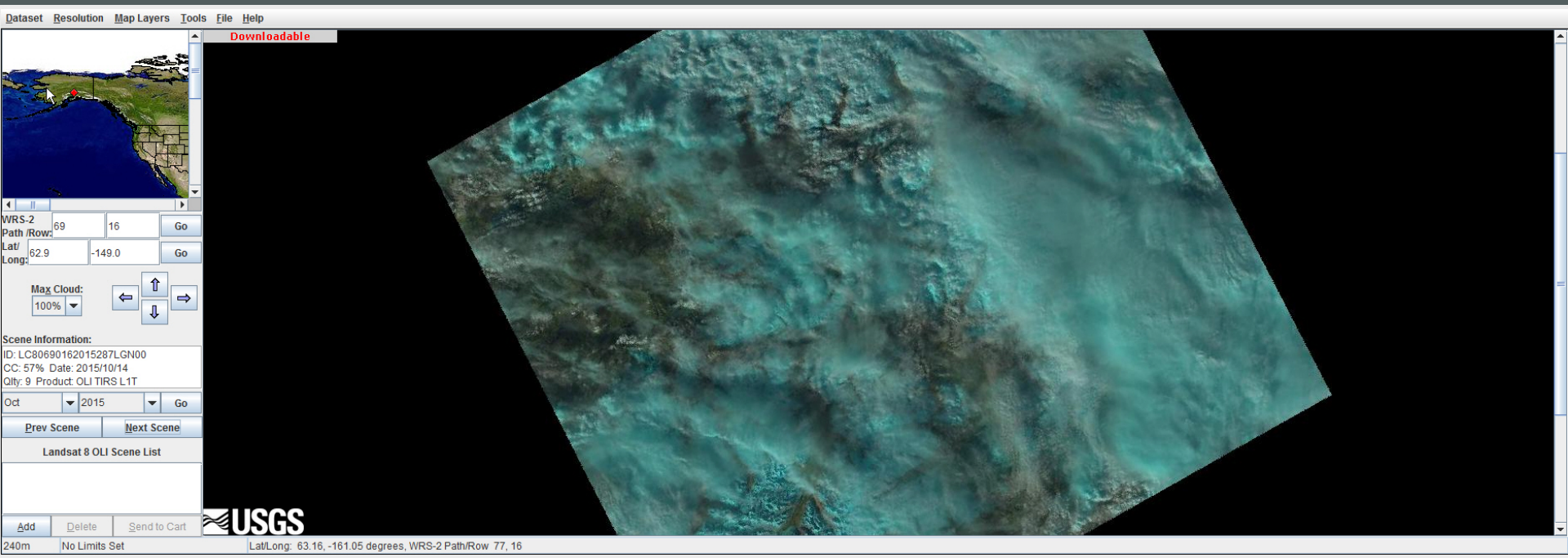
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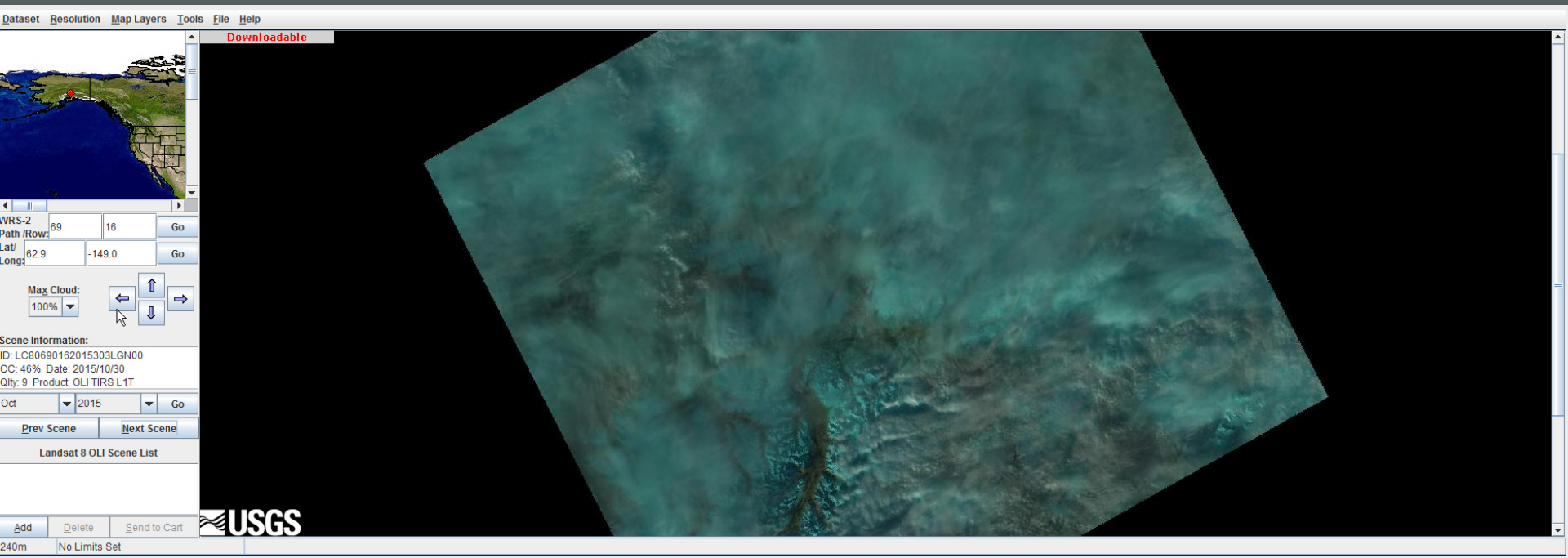
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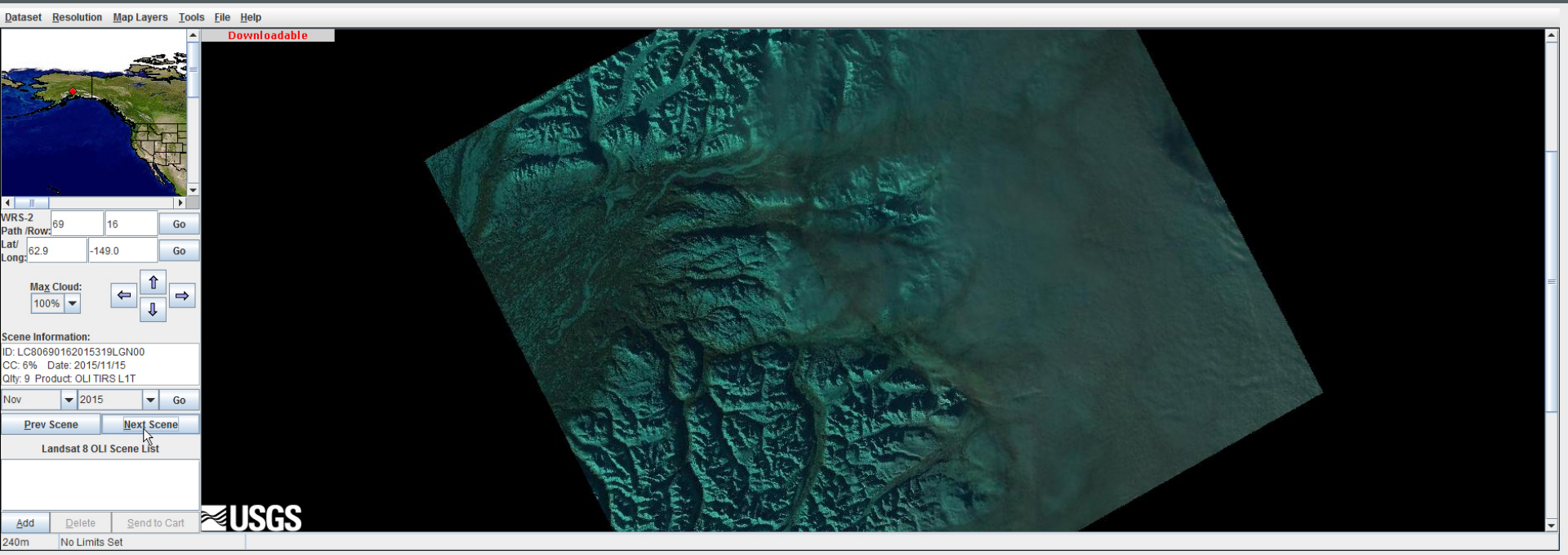
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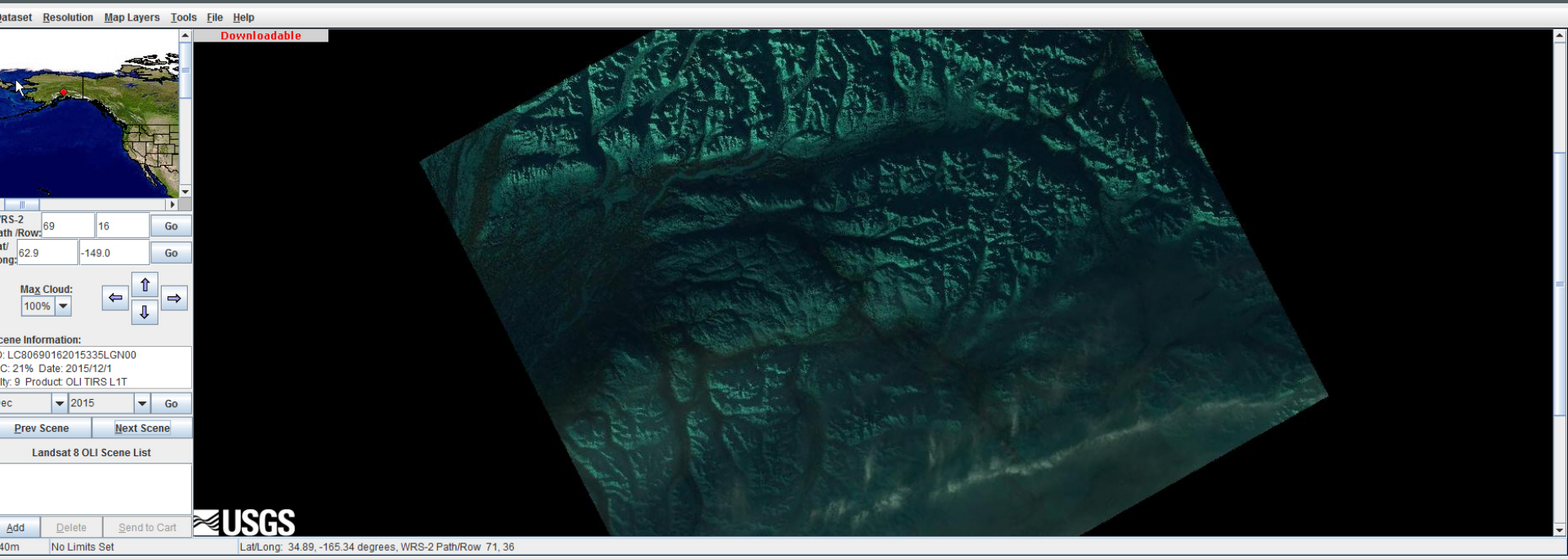
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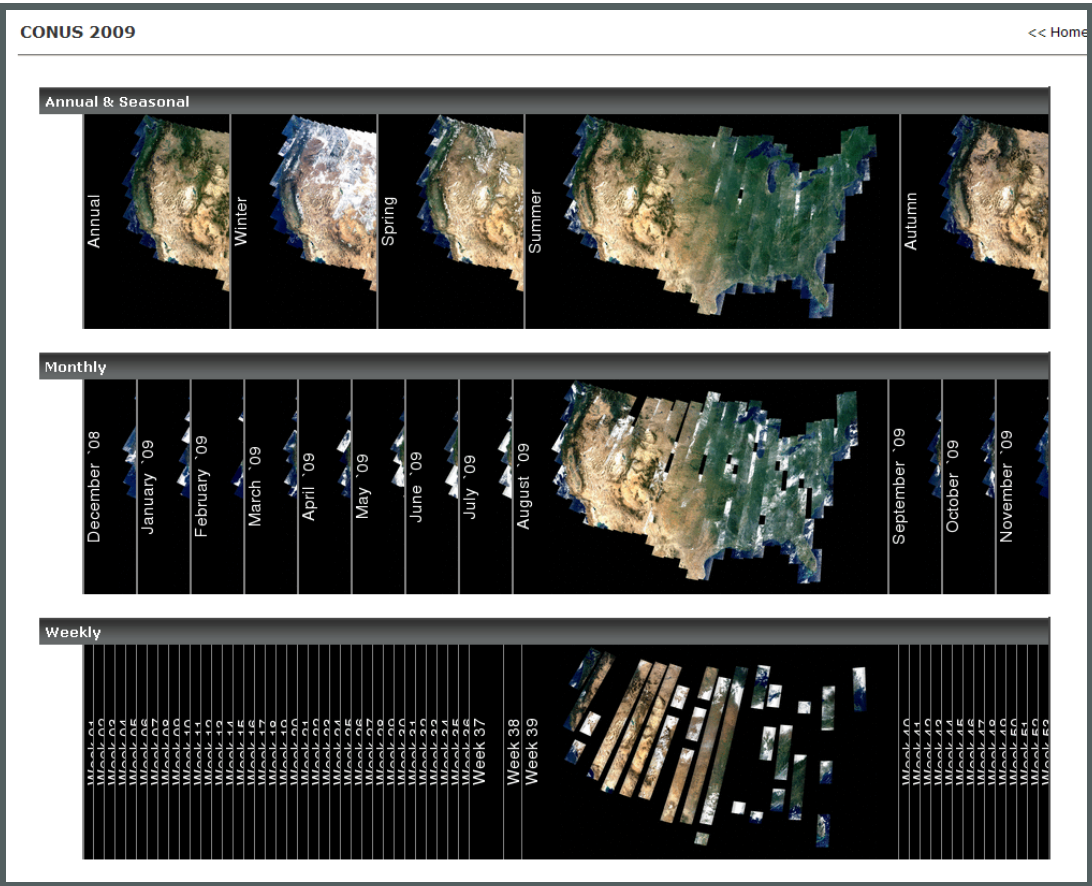
How do we get a better image base? – this is critical, especially for land cover change analysis



Web enabled Landsat data (WELD) example

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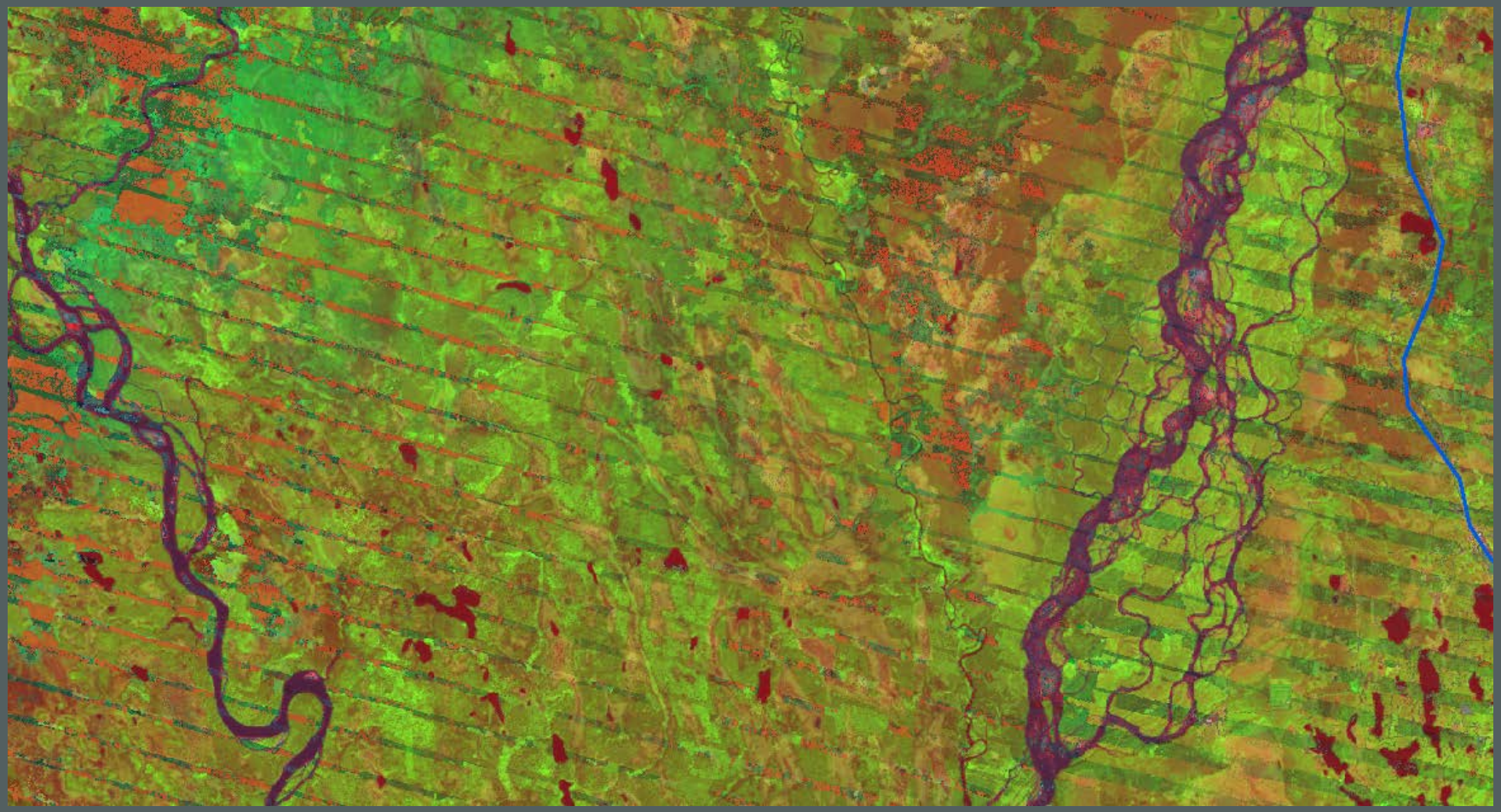
Example of 2011 leaf on WELD for Alaska



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Alaska NLCD 2011 image composite and mosaic strategies

Test and evaluation

Test and assessment of USFS RSAC's Tool

initial Proposed alternative method: concept, test and evaluation, recommendations

USGS

Alaska NLCD 2011 image composite and mosaic strategies

RSAC's method test and evaluation

RSAC's tool consists of a three step procedure:

Step 1 - Select Landsat image with modified GLOVIS tool
Step 2- Run an FMASK to create an automatic cloud mask
Step 3- Create composite of all the images using median values

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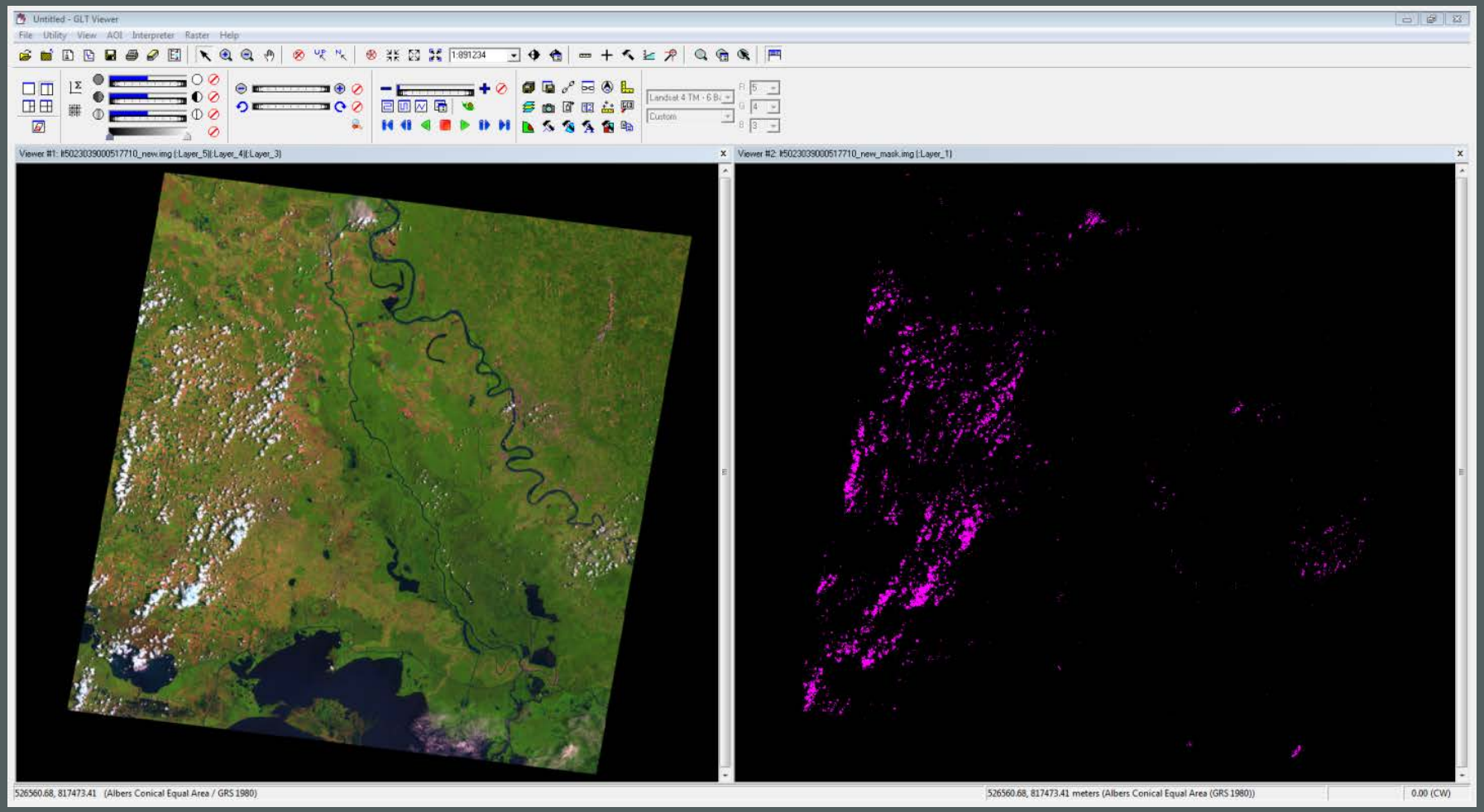
Run Fmask for automatic cloud/shadow mask



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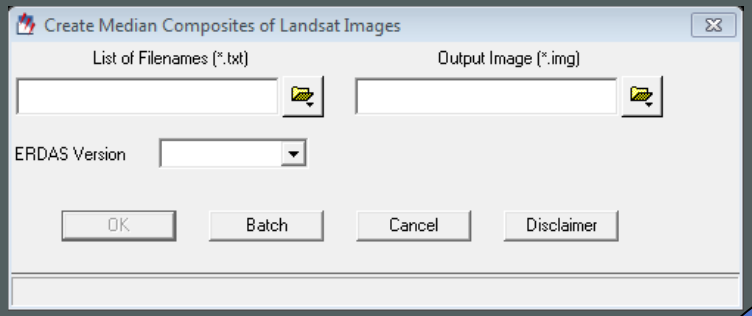
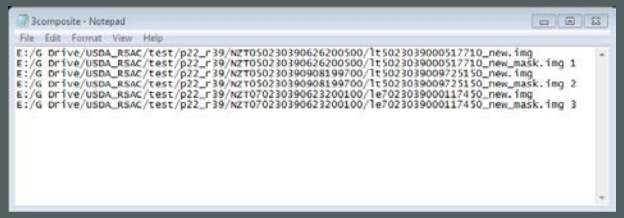
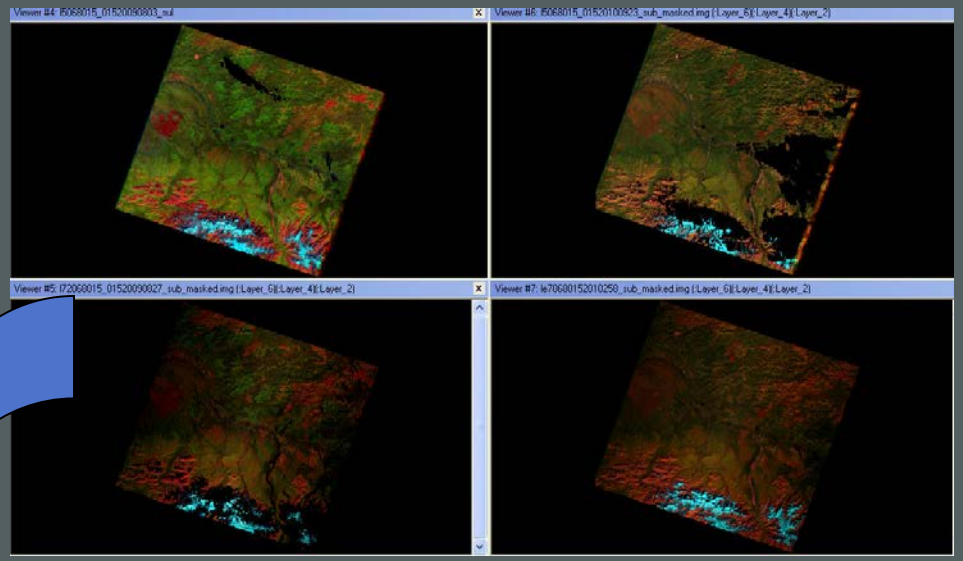
Step 3- Create a pixel-based image composite of all masked images by using median value

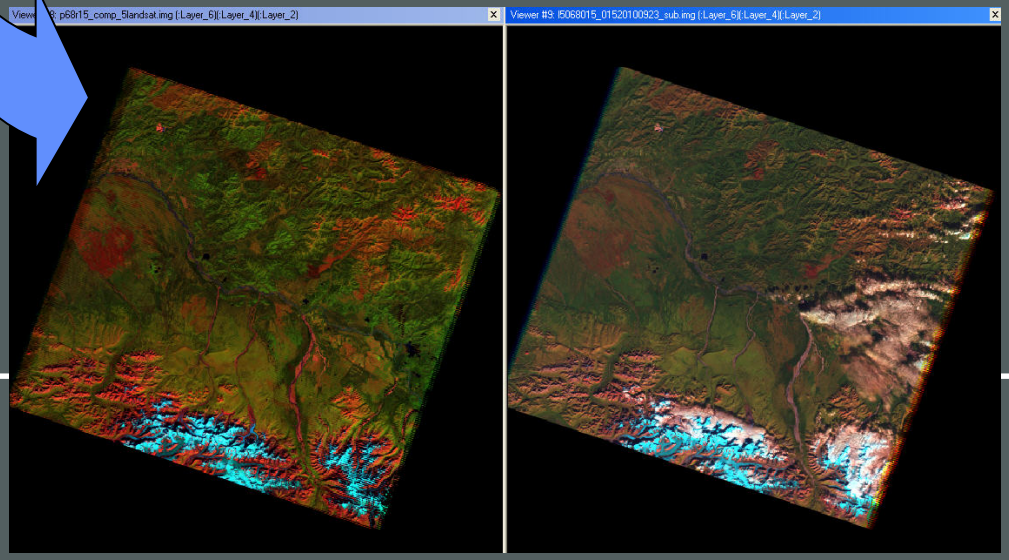






For an odd number of values (1, 2, 5, 7, 8) or (1,2,2,5,7,8), the median is 5.

For an even number of values (1, 2, 4, 6, 7, 8), the median is the arithmetic mean of the two middle terms is (4 + 6)/2 = 5.



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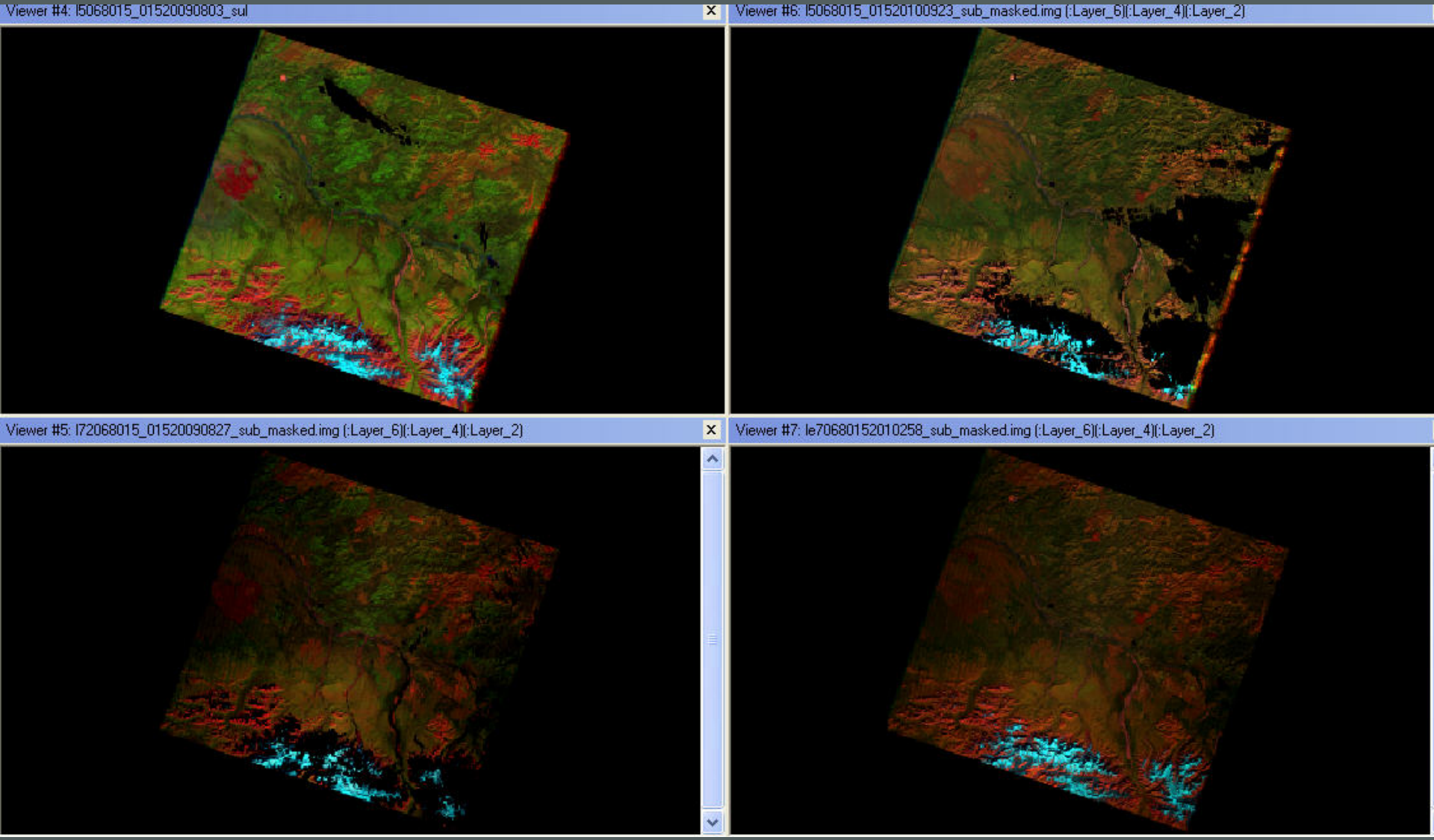
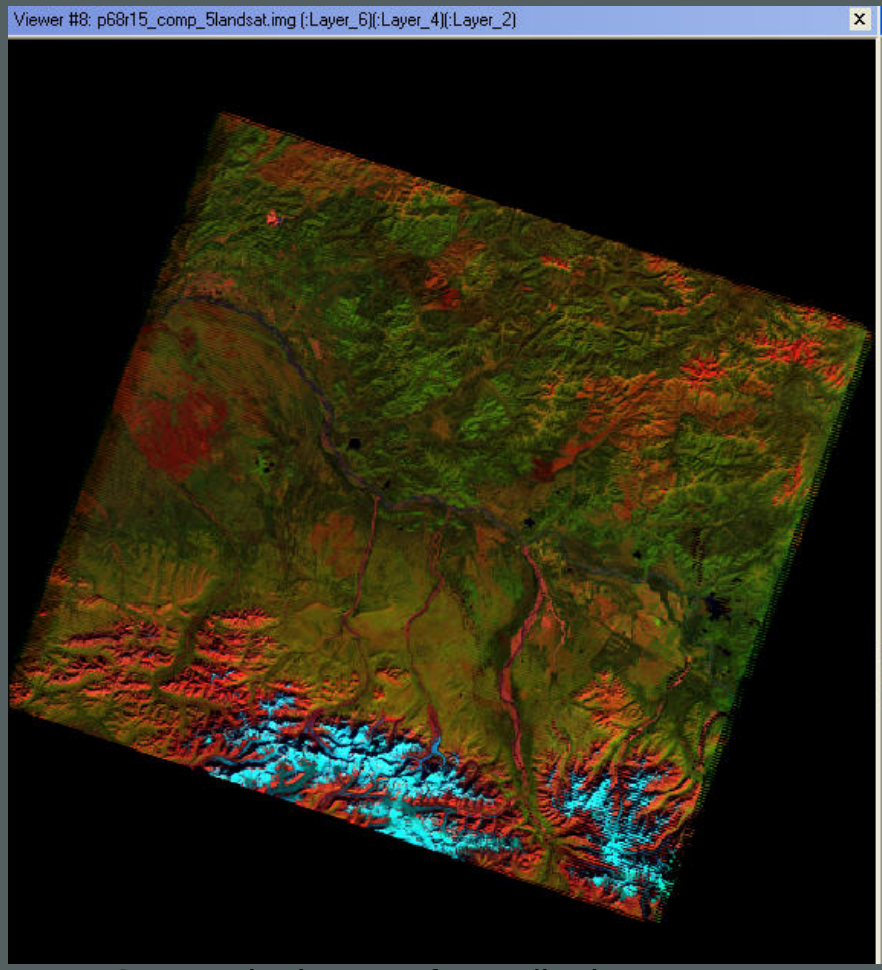
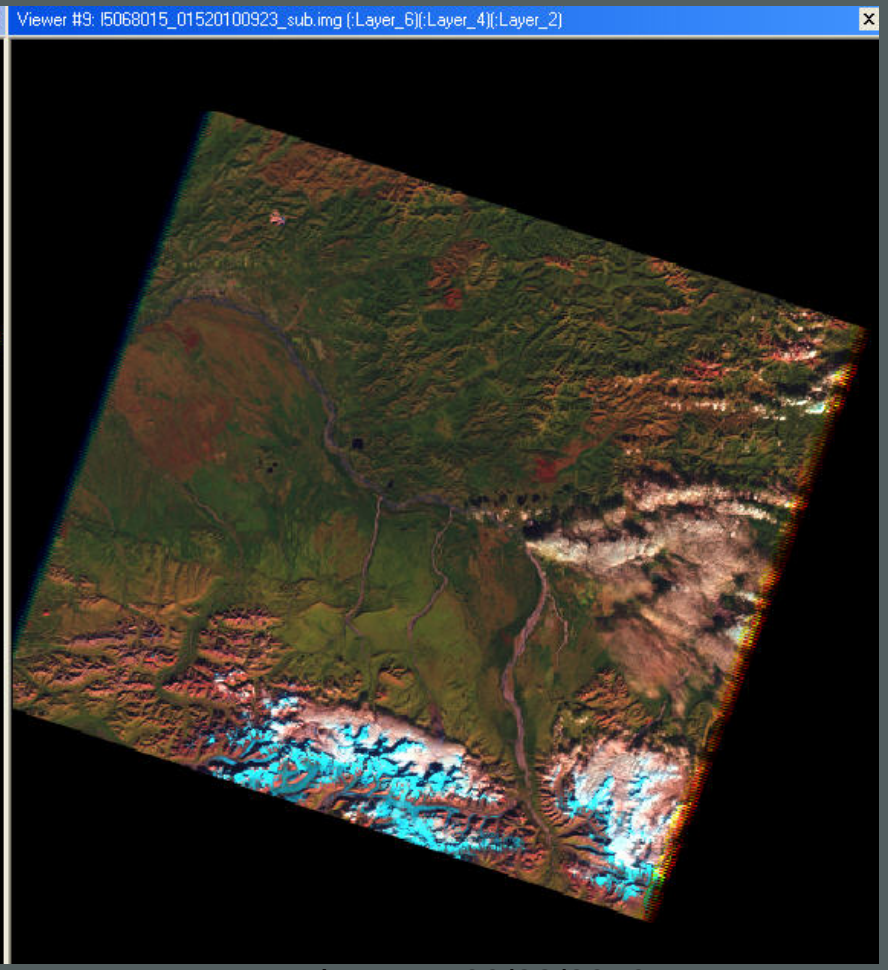
Candidate images (masked) for compositing



Composite result from the RSAC tool



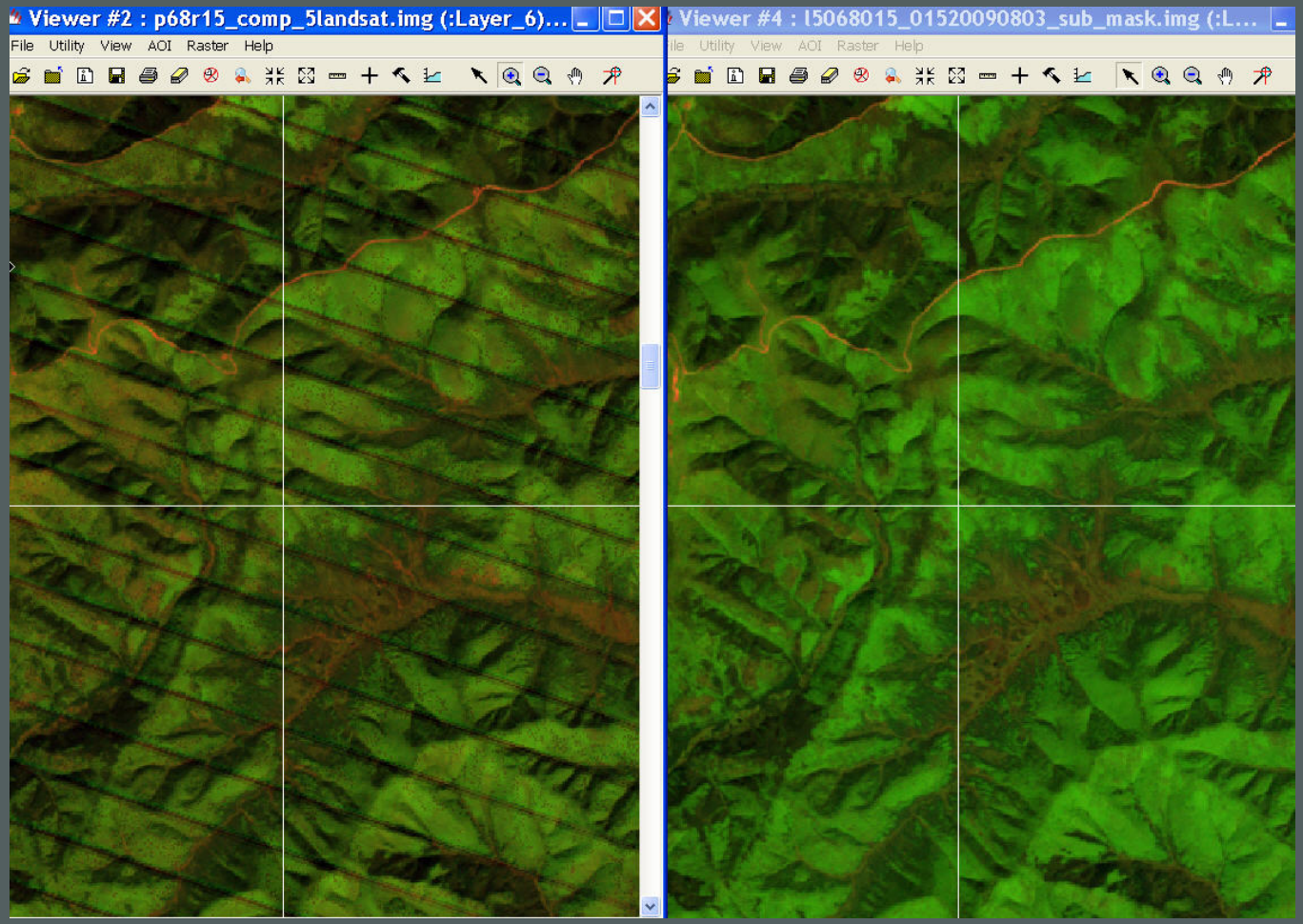
Composite images from all 5 images



Landsat TM, 09/23/2010

USGS

Examples of composite from RSAC tool



Composite images from all 5 images

Landsat TM, 08/03/2009

USGS

Alaska NLCD 2011 image composite and mosaic strategies

Observations of RSAC's tool

The composite process is a pixel-based approach, and the process runs independently band-by-band

For any given pixel, the composite images dependent on the number of available images (given scene selection criteria) and presence/absence of clouds/shadows within the images

Because the composite process handles each band independently, there are possibilities that for a given pixel, different band of the composite image can be drawn from different images

USGS

Alaska NLCD 2011 image composite and mosaic strategies

How to improve compositing?

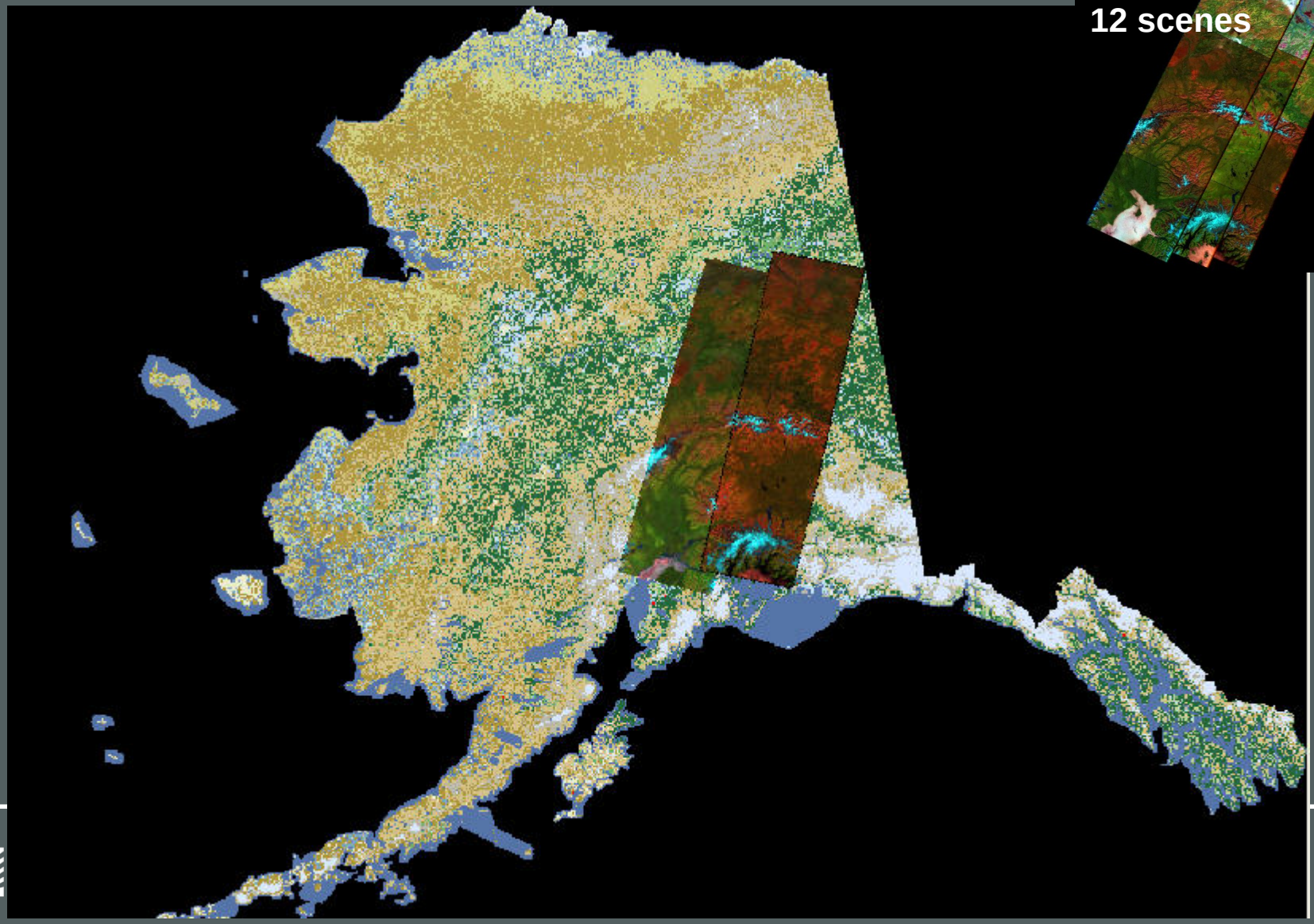
1. Don't use a pixel-based approach, rather, start with the best piece of imagery for the period

2. for gap fill (area of clouds/shadows), instead of relying on filling the gap using a median compositing from many images, select a good base image, fill its gap by another image(s)

   (*a method by Jin et al. IJRS, in press*)

USGS

Alaska NLCD 2011 pilot study area



Circa 2001 image list

P#/R#	L5	L7	Total
69/14	2	10	12
69/15	1	8	9
69/16	1	6	7
69/17	2	8	10
67/14	1	7	8
67/15	0	4	4
67/16	0	5	5
67/17	0	6	6
68/14	0	4	4
68/15	0	6	6
68/16	0	5	5
68/17	0	5	5
Total	7	74	81

Images Selection Criteria:

Year: 1999-2002

Month: May to September

Cloud: less than or equal to or less than 30%

USGS

Circa 2011 image list

P#/R#	L5	L7	Total
68/15	2	4	6
69/15	1	7	8
67/15	9	6	15
68/14	5	6	11
69/14	1	7	8
67/14	7	10	17
68/16	2	1	3
69/16	1	2	3
67/16	2	3	5
68/17	2	2	4
69/17	3	3	6
67/17	2	1	3
Total	37	52	89

Images Selection Criteria:

Year: 2009-2012

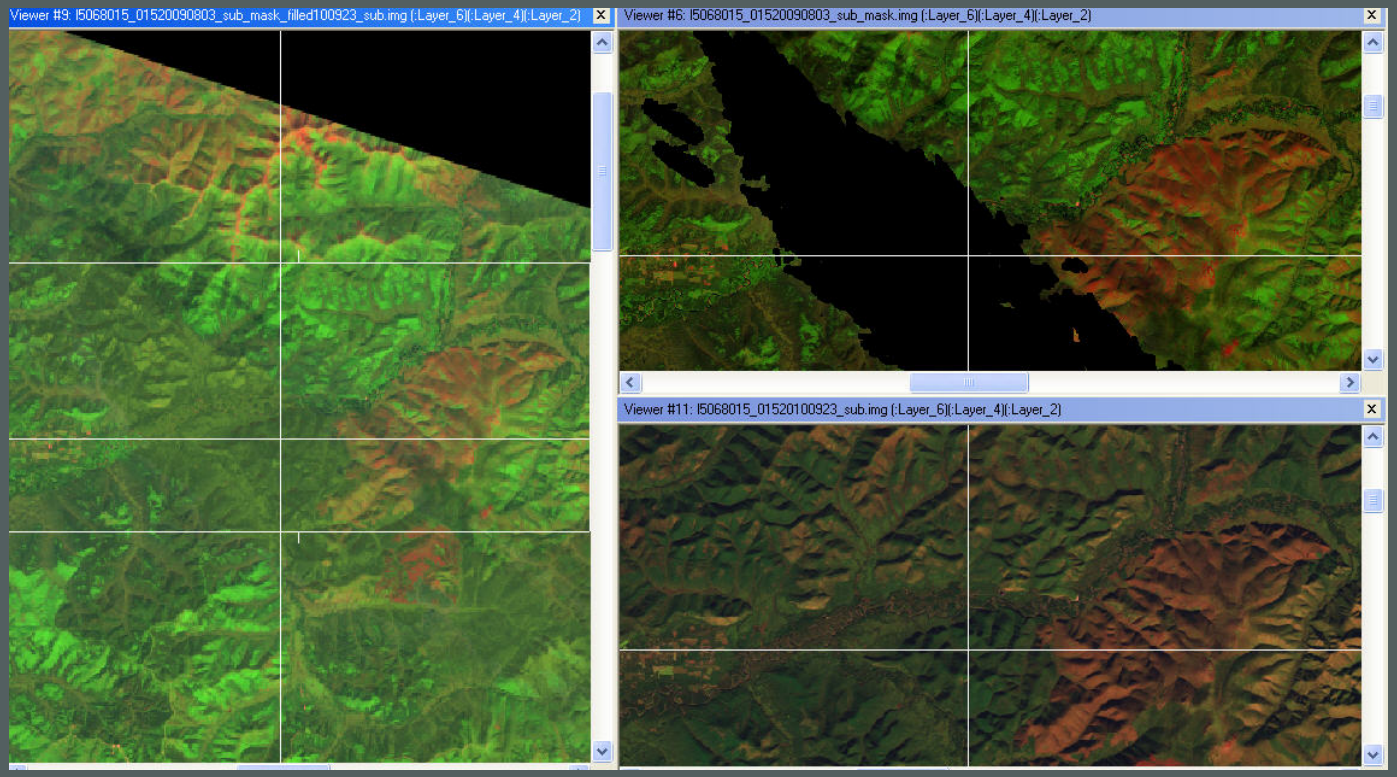
Month: late May to September

Cloud: less than or equal to 30%

USGS

An example: cloud/shadow gap-fill. retain the largest portion of a good based image, fill the gap using SSG method based on a reference image

Base image (with gap)

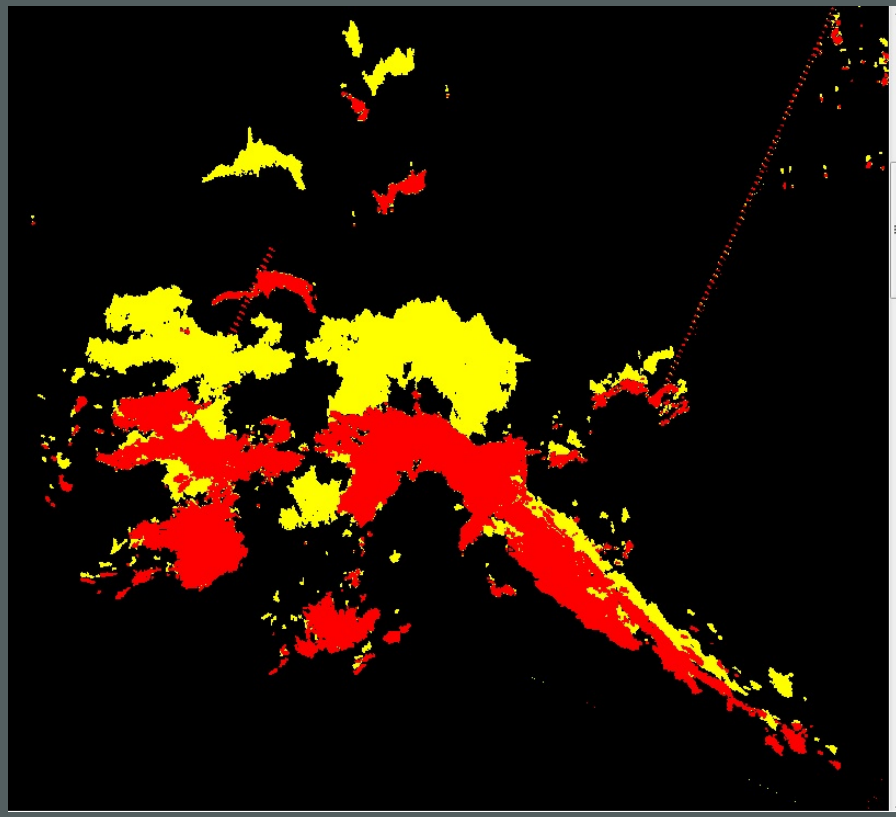


Gap-filled image

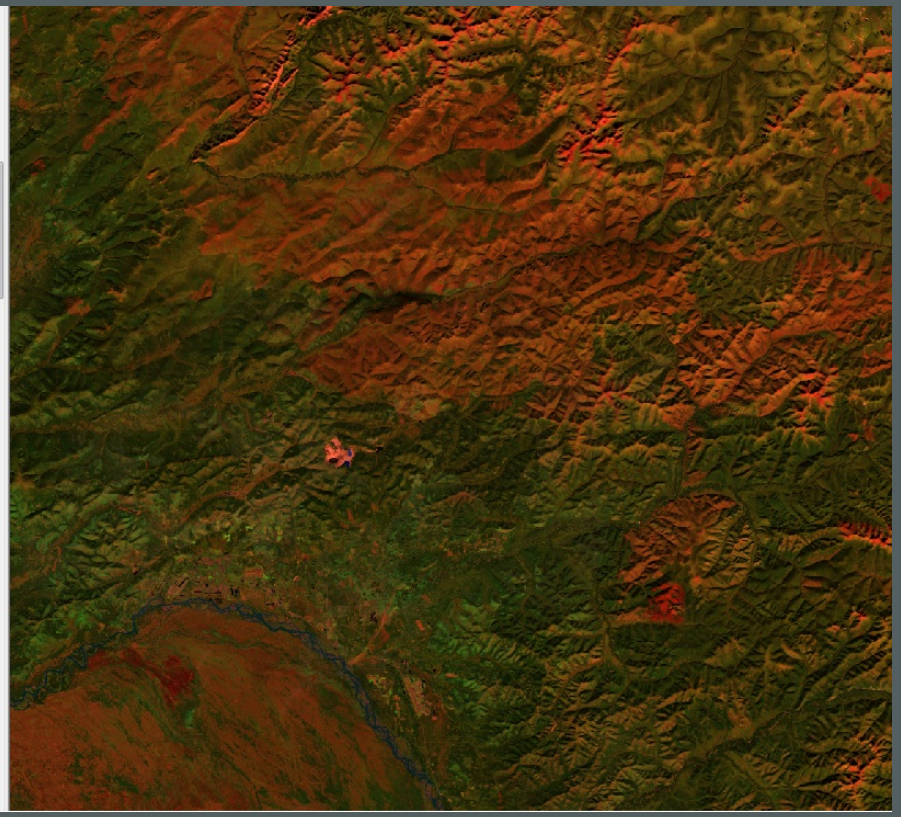
Reference image (no gap)

USGS

An example: cloud/shadow gap-fill



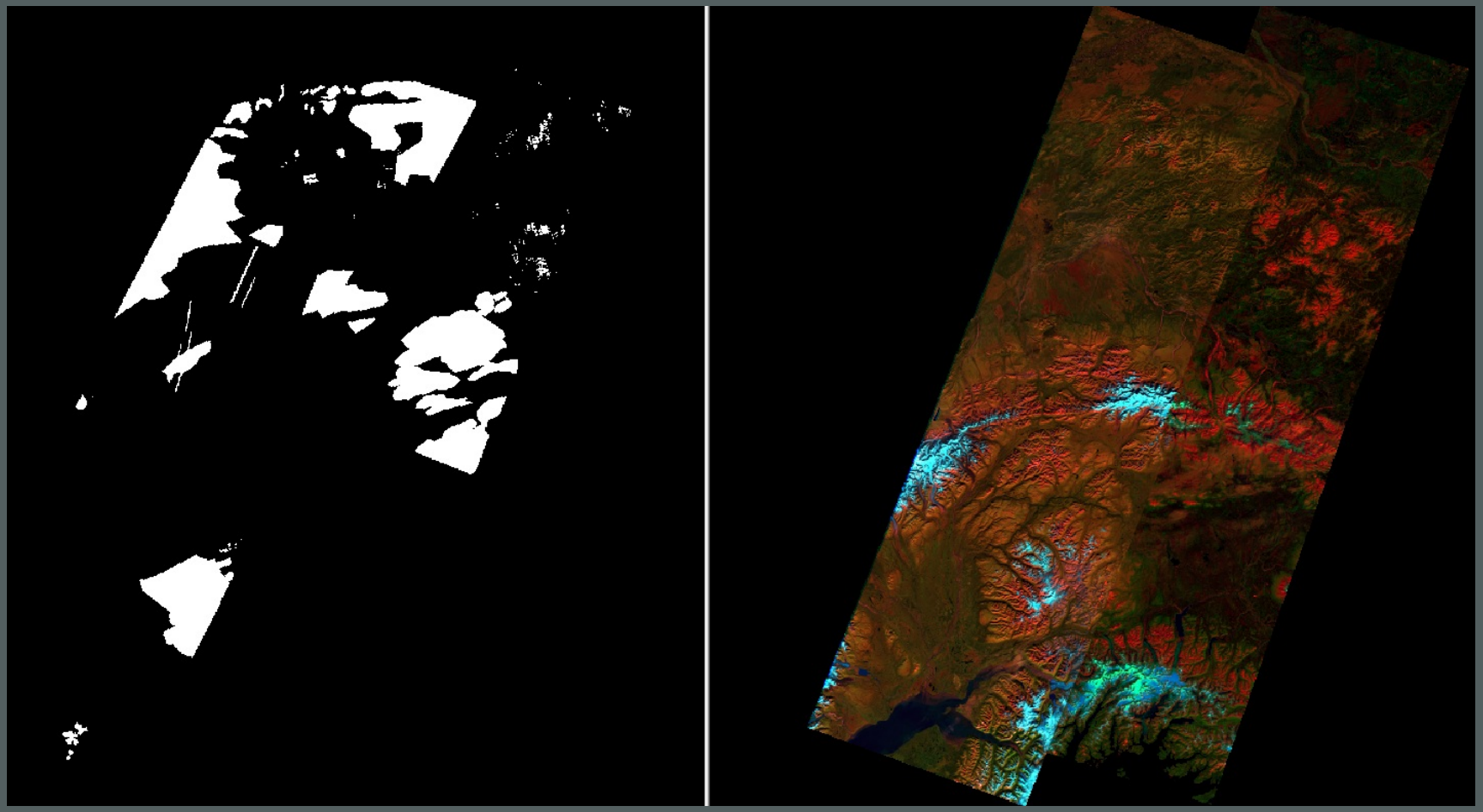
Cloud/shadow mask



Gap-filled image

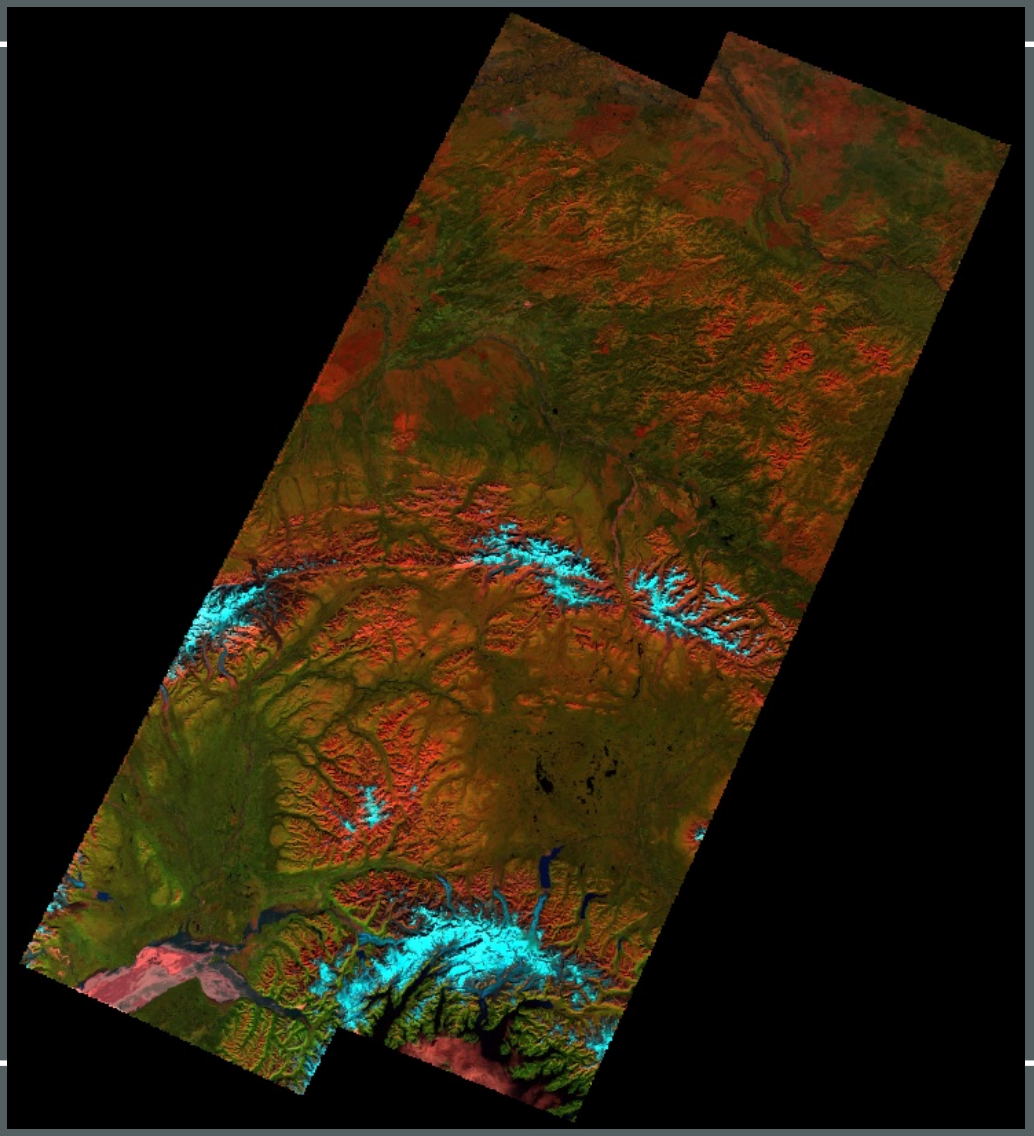
USGS

Images and cloud/shadow/ice mask (circa 2011)

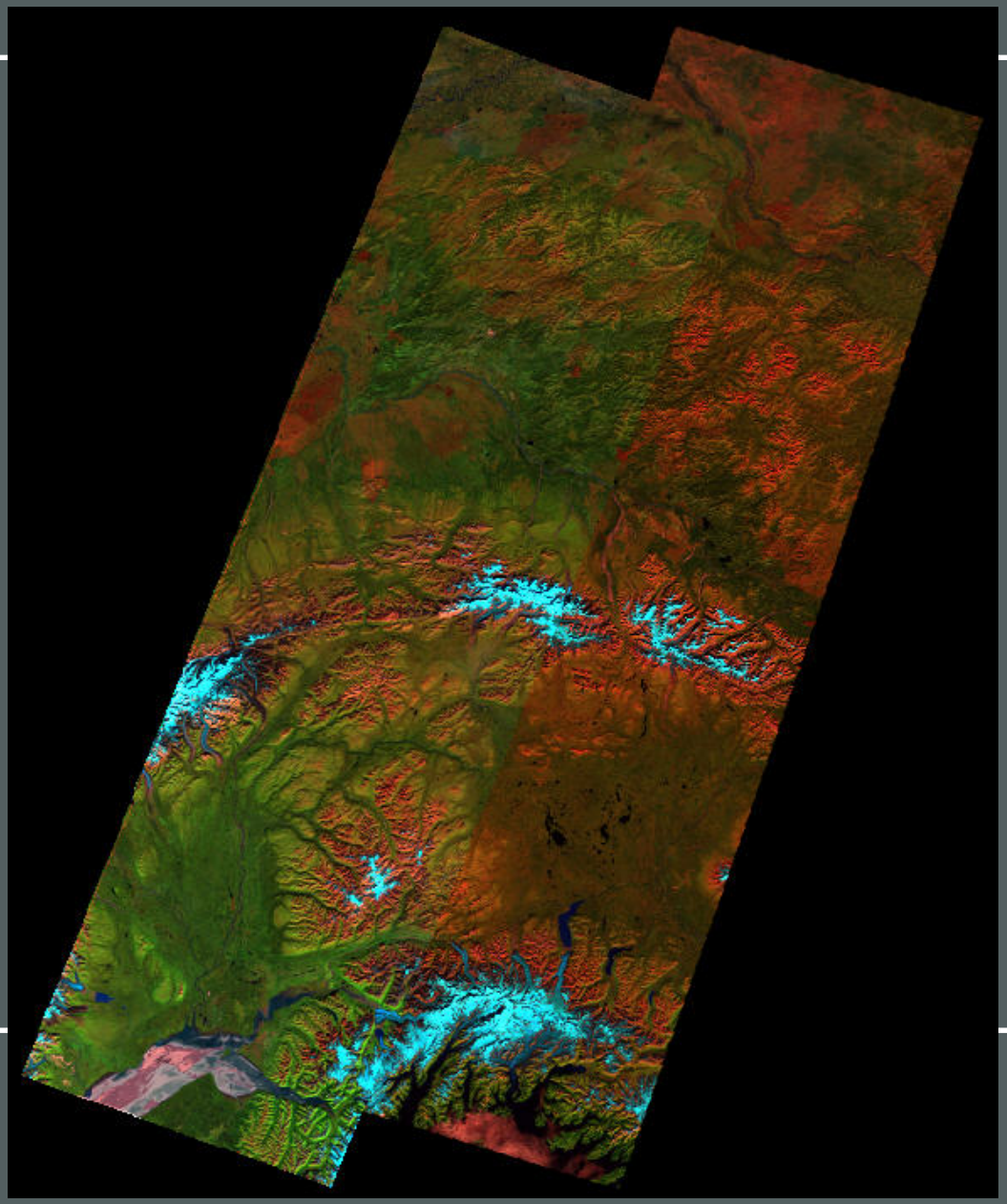


USGS

Composite image mosaic (circa 2011)



Composite image mosaic (circa 2001)



Alaskan Land Cover Mapping Goals

Developed science strategies and completed procedures through pilot studies for a fast-track update of Alaskan NLCD from 2001 to 2011

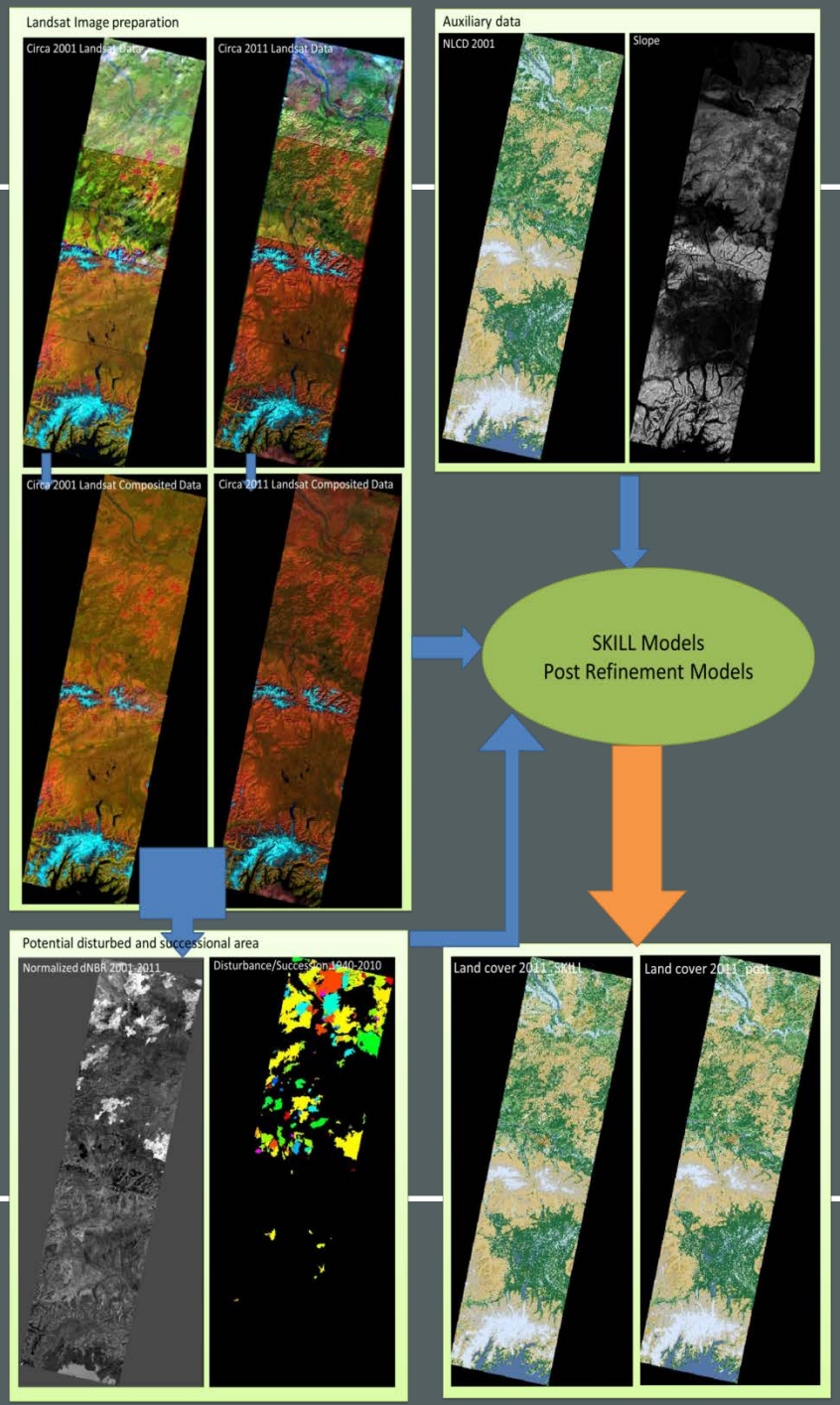
The developed protocol and procedures capture major land cover changes, focusing on:

1) Fire disturbance and succession
2) Forest clearing, harvesting
3) Glacier, snow/ice changes
4) Change in development

USGS

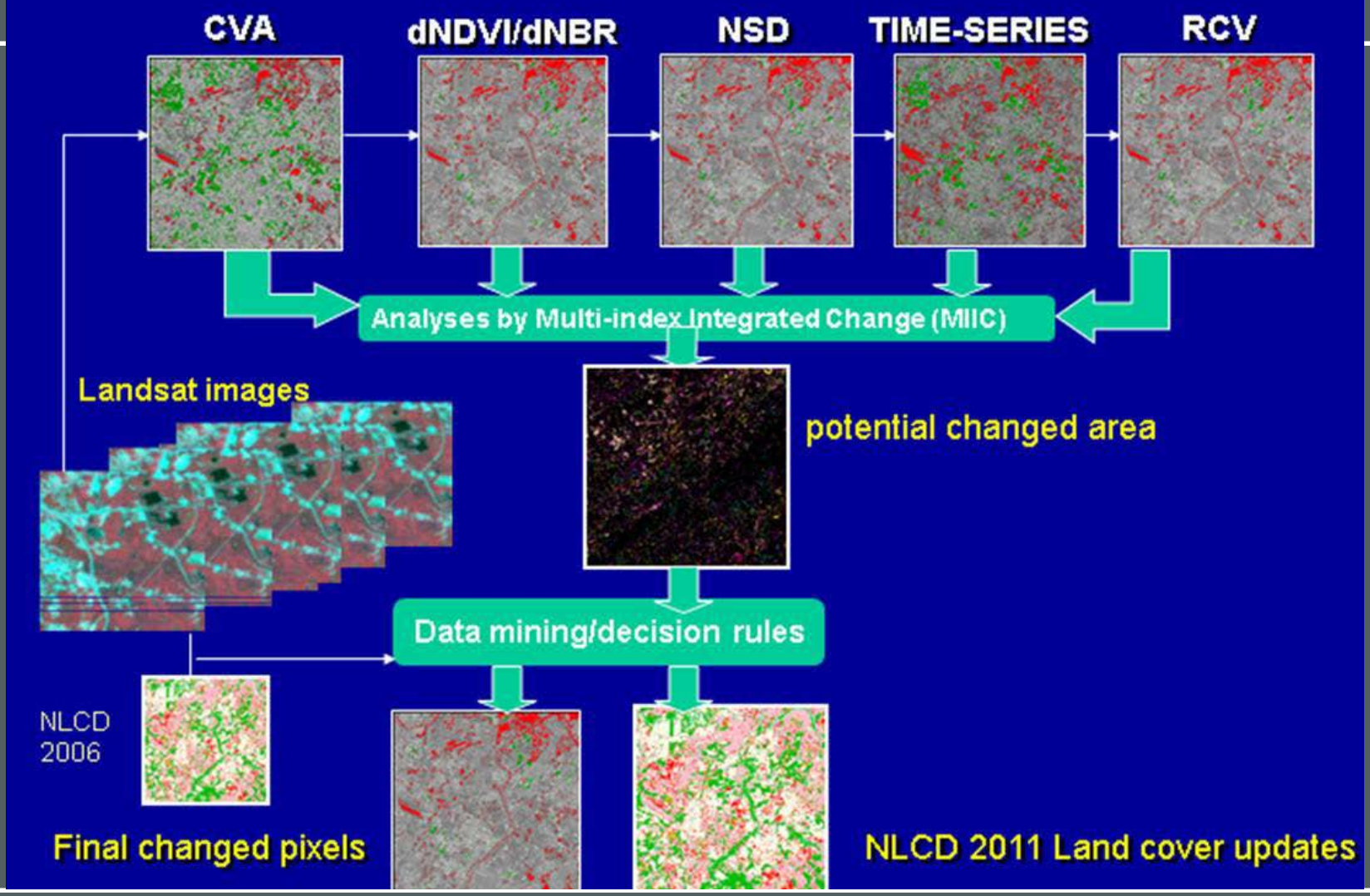
Major components of the procedures

1. A Landsat scene-selection protocol
2. Landsat image pre-processing
3. Ancillary data assembling and processing
4. Integrated modeling for LC change detection and land cover labeling
5. Generate Alaskan NLCD 2011 LC and LC change products



USGS

Multi-criteria Change Detection Concept



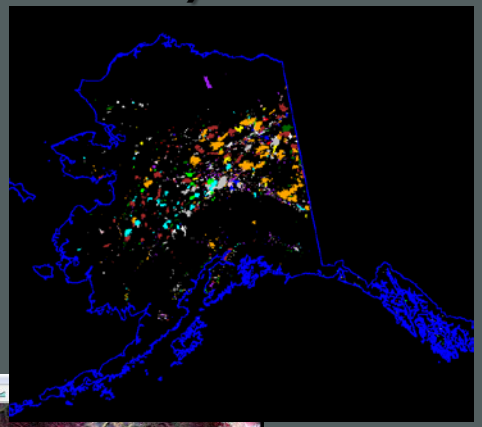
USGS

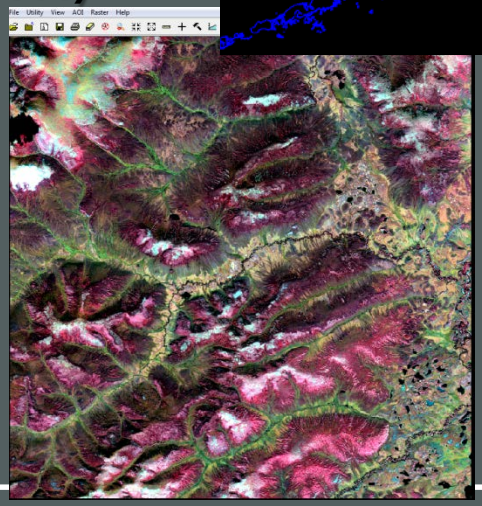
Major ancillary data for the State

1. DEM and derivatives (original used for NLCD 2001, most 2 arc second; the data are being updated continuously using best available source)

2. USGS/USDA FIRE science datasets:

   LANDFIRE Disturbance product (1999-2010)
   MTBS data (1984-2010)
   Alaska historical fire data (1940s-1980s)





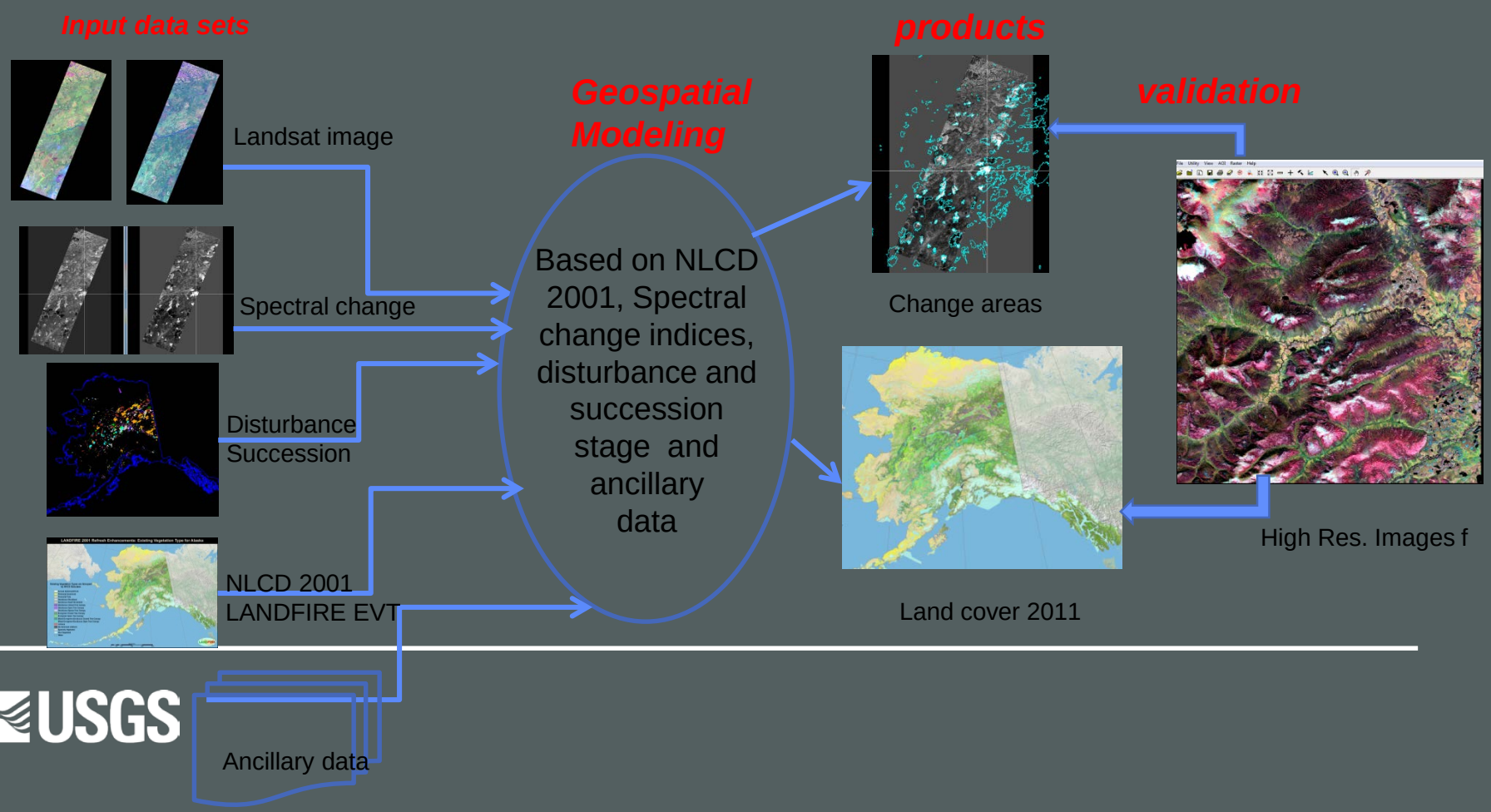
3. Alaskan Digital Mapping Initiative's (SDMI) SPOT 5 ortho-mosaic images 2009 and 2011 for validation

4. MODIS Snow/Ice composite data

USGS

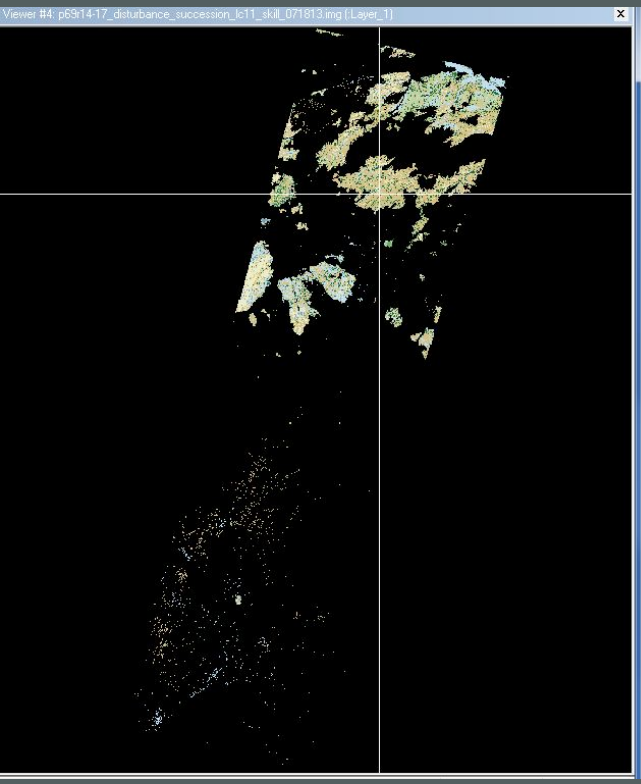
An approach to detecting Land disturbances/succession and provide an initial LC label

1. Integration of multi-source datasets for spatial modeling (use spectral information, land cover history, disturbance time and magnitude)
2. Detect changes (disturbance and succession) and update LC to 2011

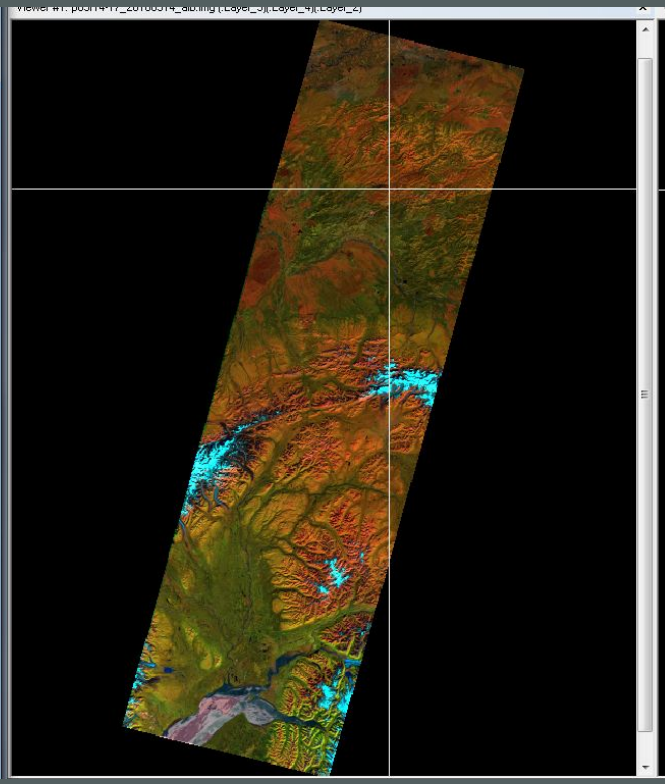


USGS

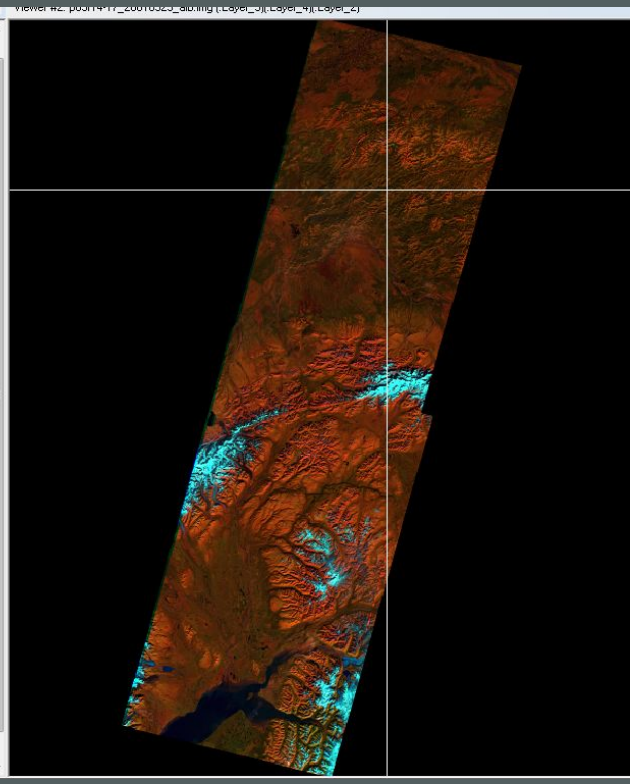
Update of Land cover in disturbed and succession areas (2001-2011)



Updated LC 2011



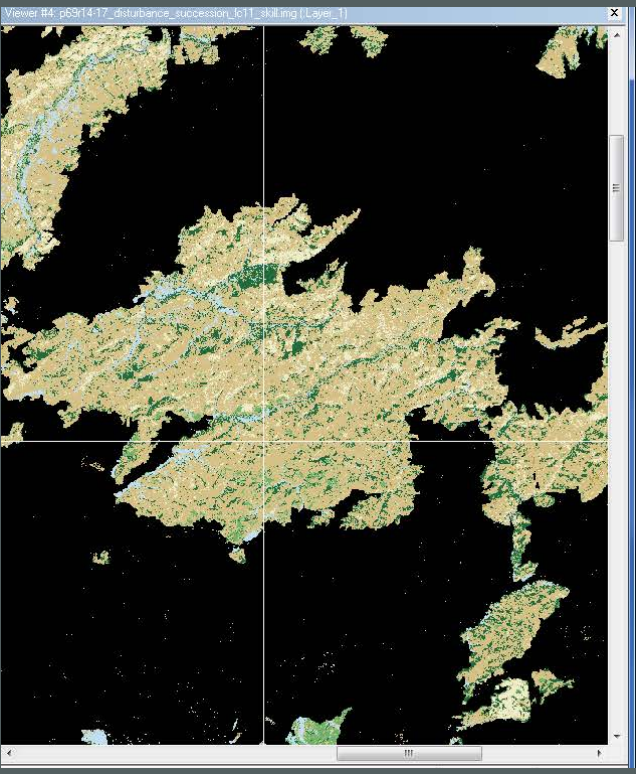
2010



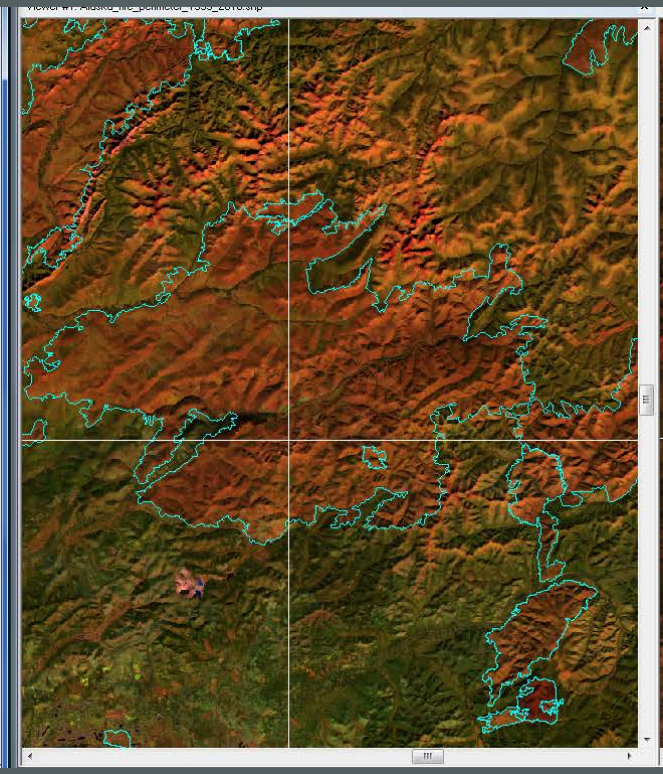
2001

USGS

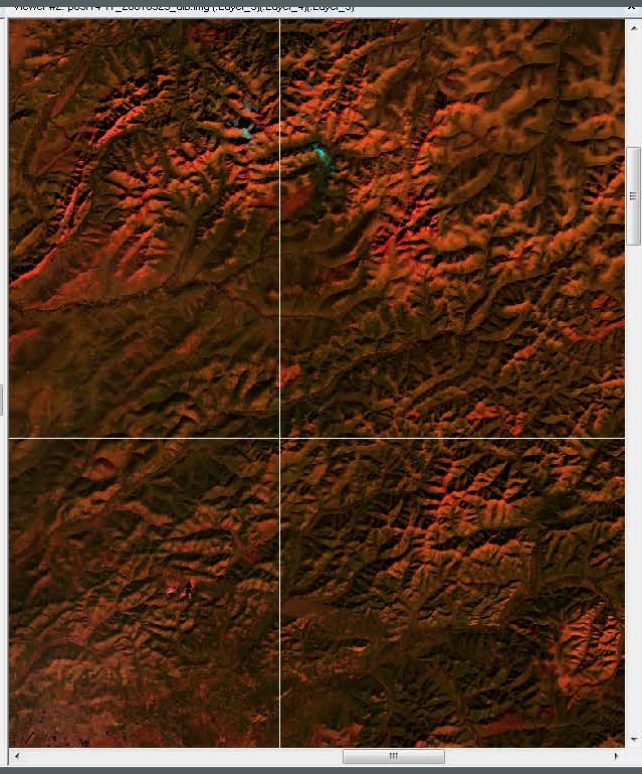
Update of Land cover in disturbed and succession areas (2001-2011)



Updated LC 2011



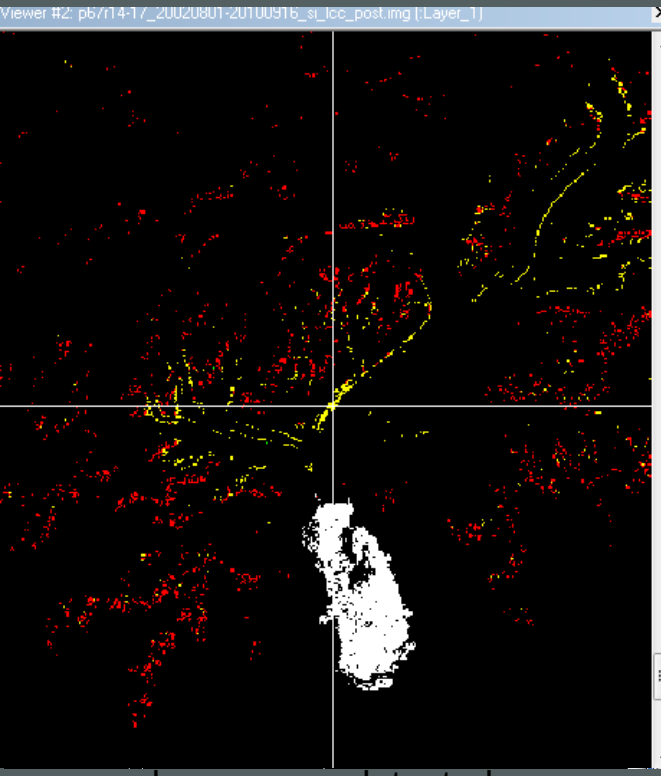
2010



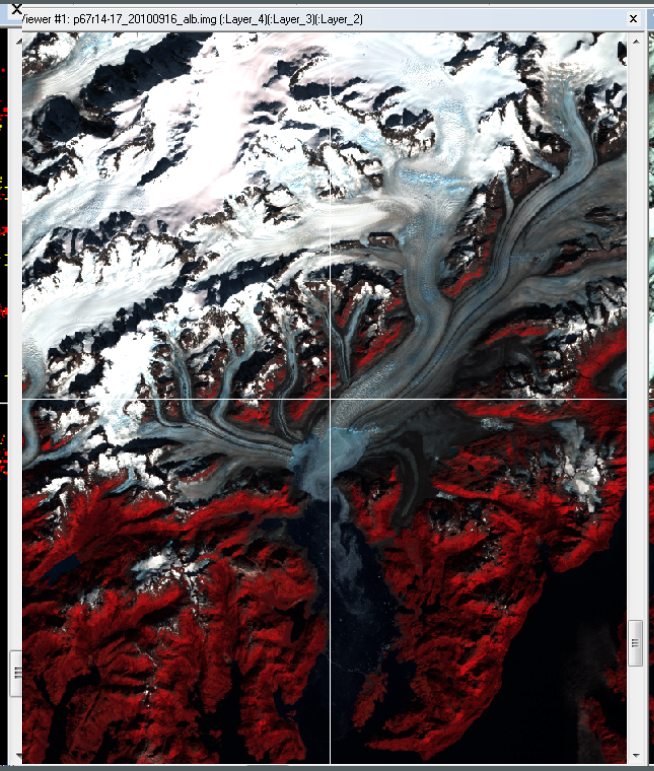
2001

USGS

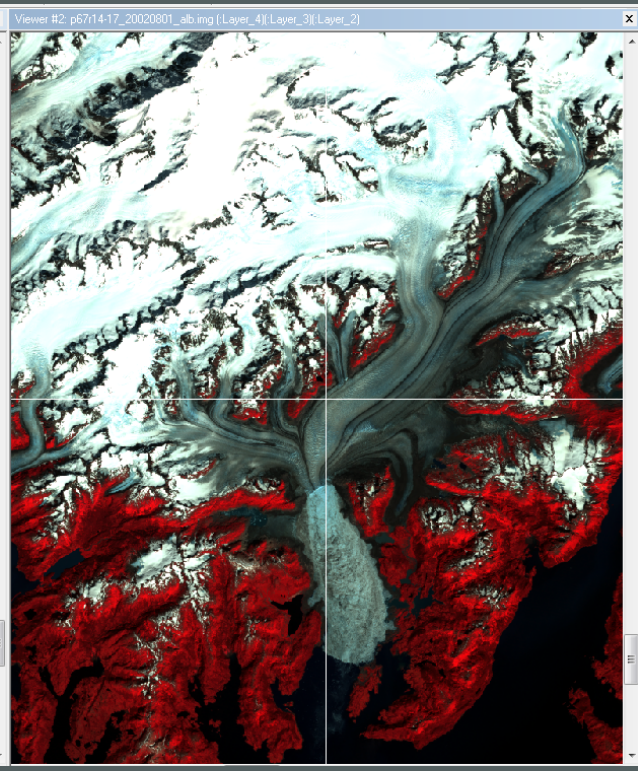
Change of snow/Ice extent (using spectral model, refined by DEM and Land cover)



change area detected



2010



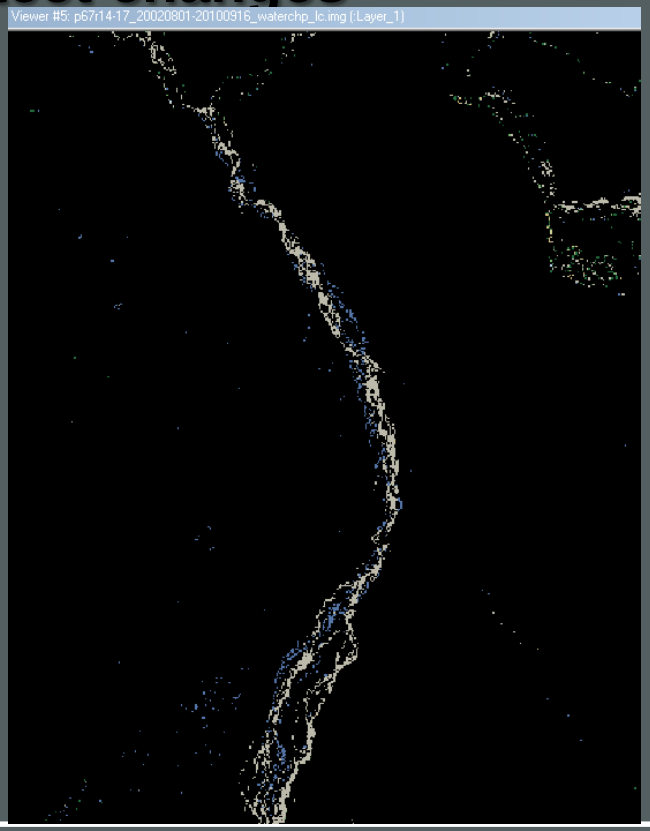
2002

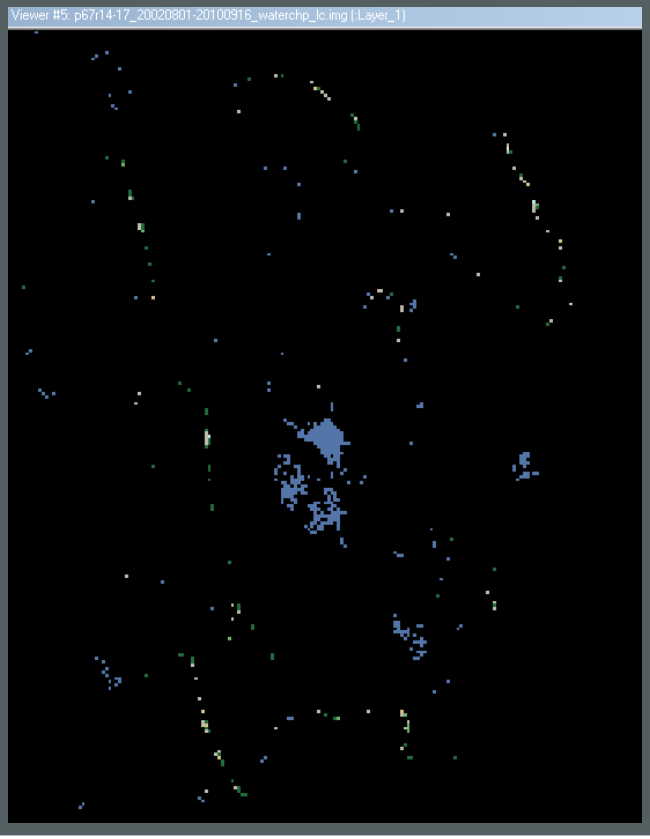
white and yellow: snow/ice to water
Red: snow/ice to barren
Green: increase to snow/ice

USGS

Approach to change detection for water (rivers, lakes)

Use Landsat-based water change detection algorithm, refined by land cover topography data (shadow area) to detect changes





USGS

Final change pixel of water with LC label

Approach to change detection for developed area

1. **involve two processes:**

   impervious modeling (e.g. major cities)

   manual classification (e.g. roads, small towns, pipeline)

2. **calibration with known impervious areas, (e.g. Anchorage area), a crosswalk of the manually interpreted areas to four categories of developed class**

image 2001

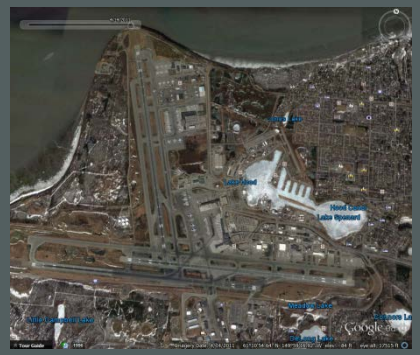
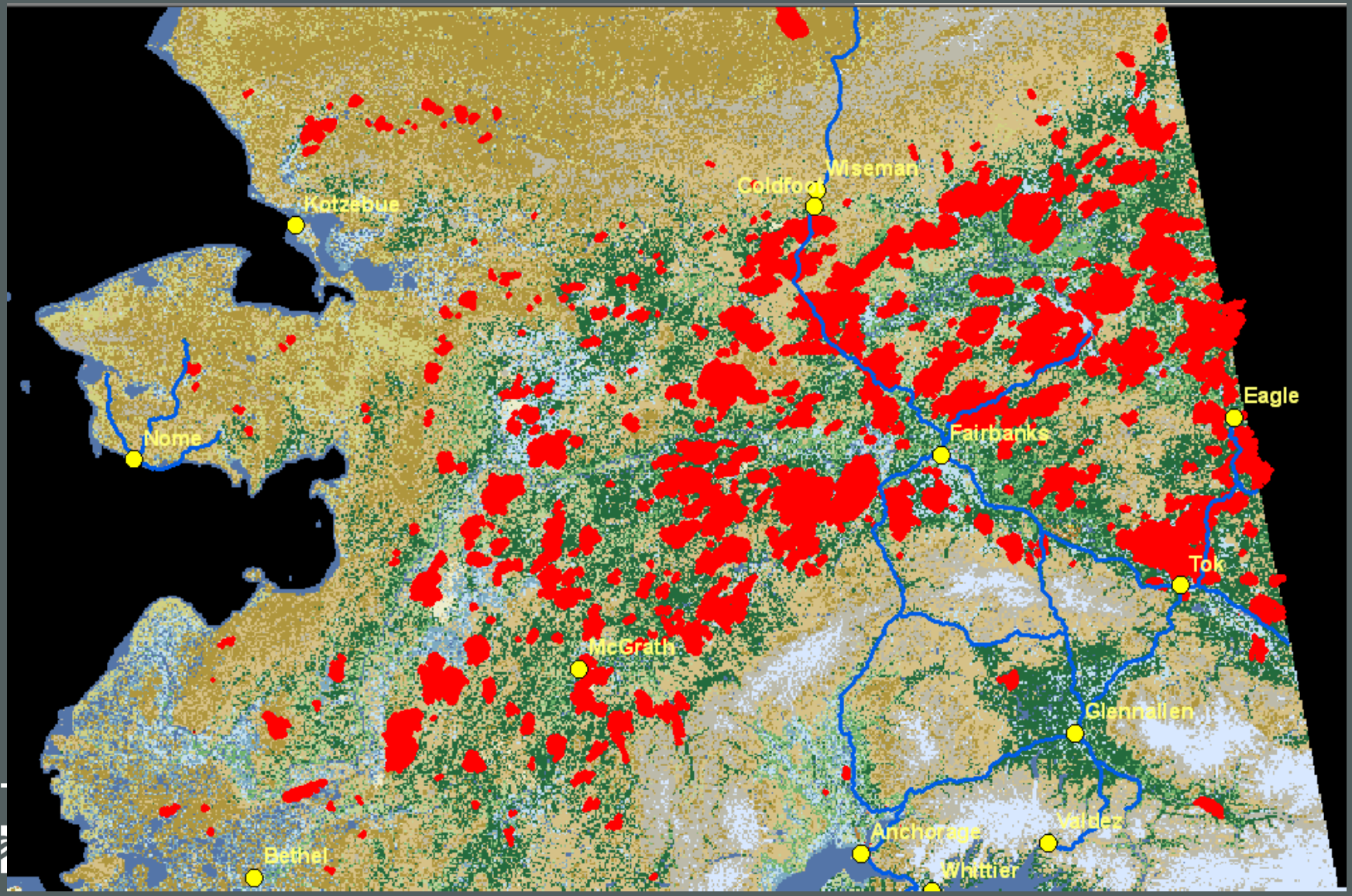


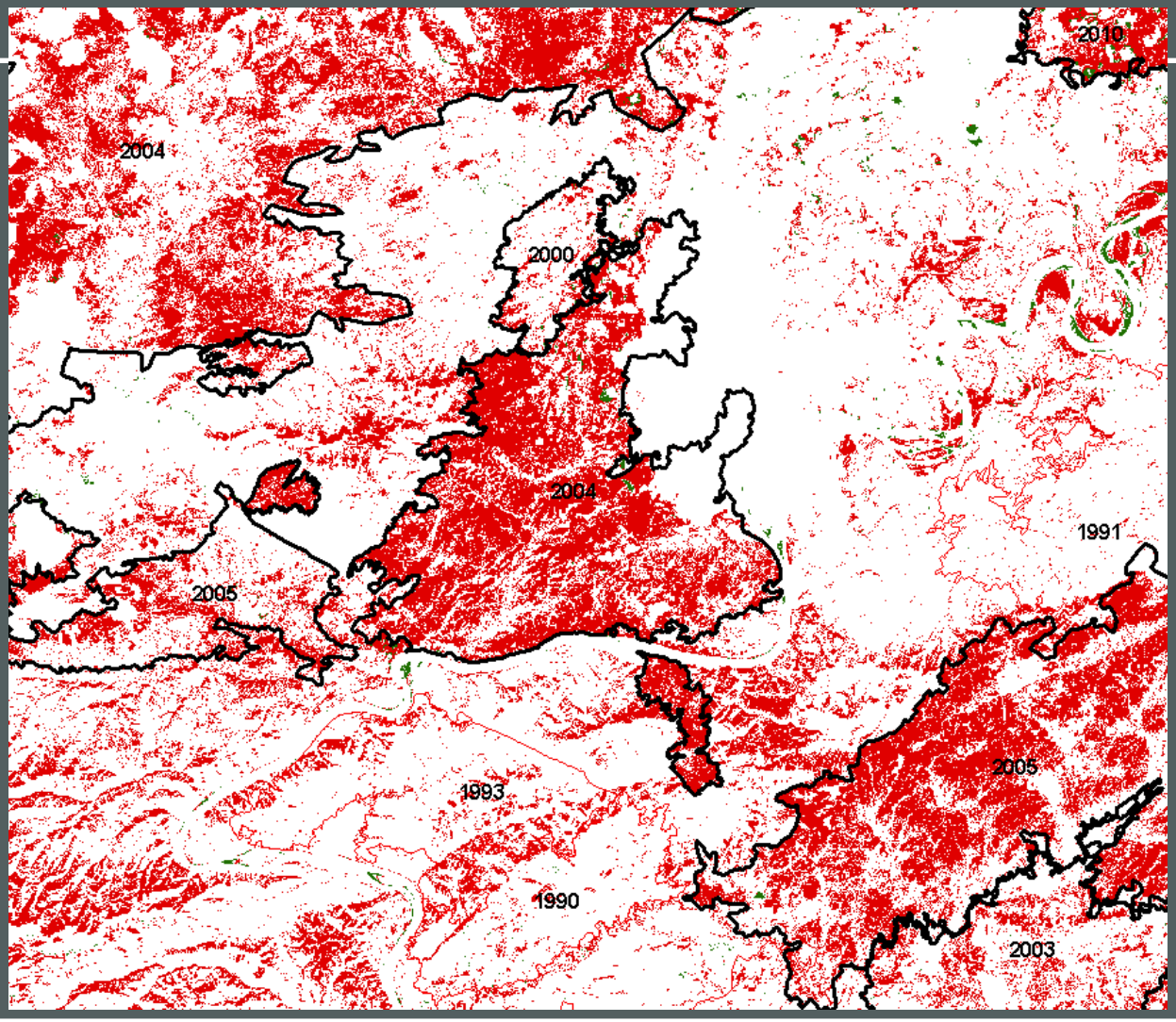
image 2011

USGS

Alaska fires, 1999 to 2010



Example of MICA change around interior Alaska fires



USGS

Types of Alaska change NLCD 2011 land cover addresses

- Fire
- Development
- Forest harvesting
- Water change
- Severe beetle kill
- Snow/ice change
- Other misc.

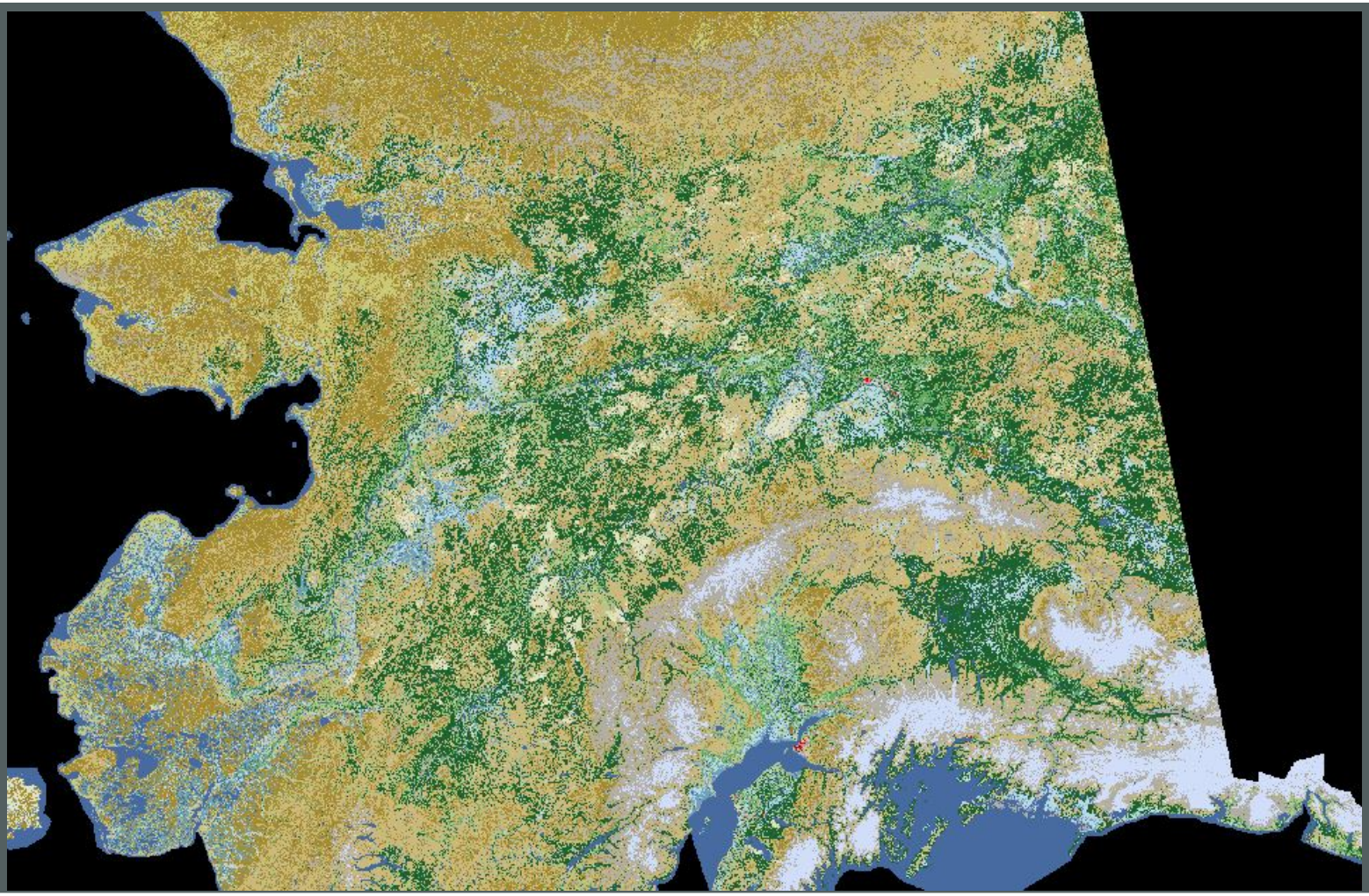
USGS

Summary of Alaska Mapping for NLCD 2011

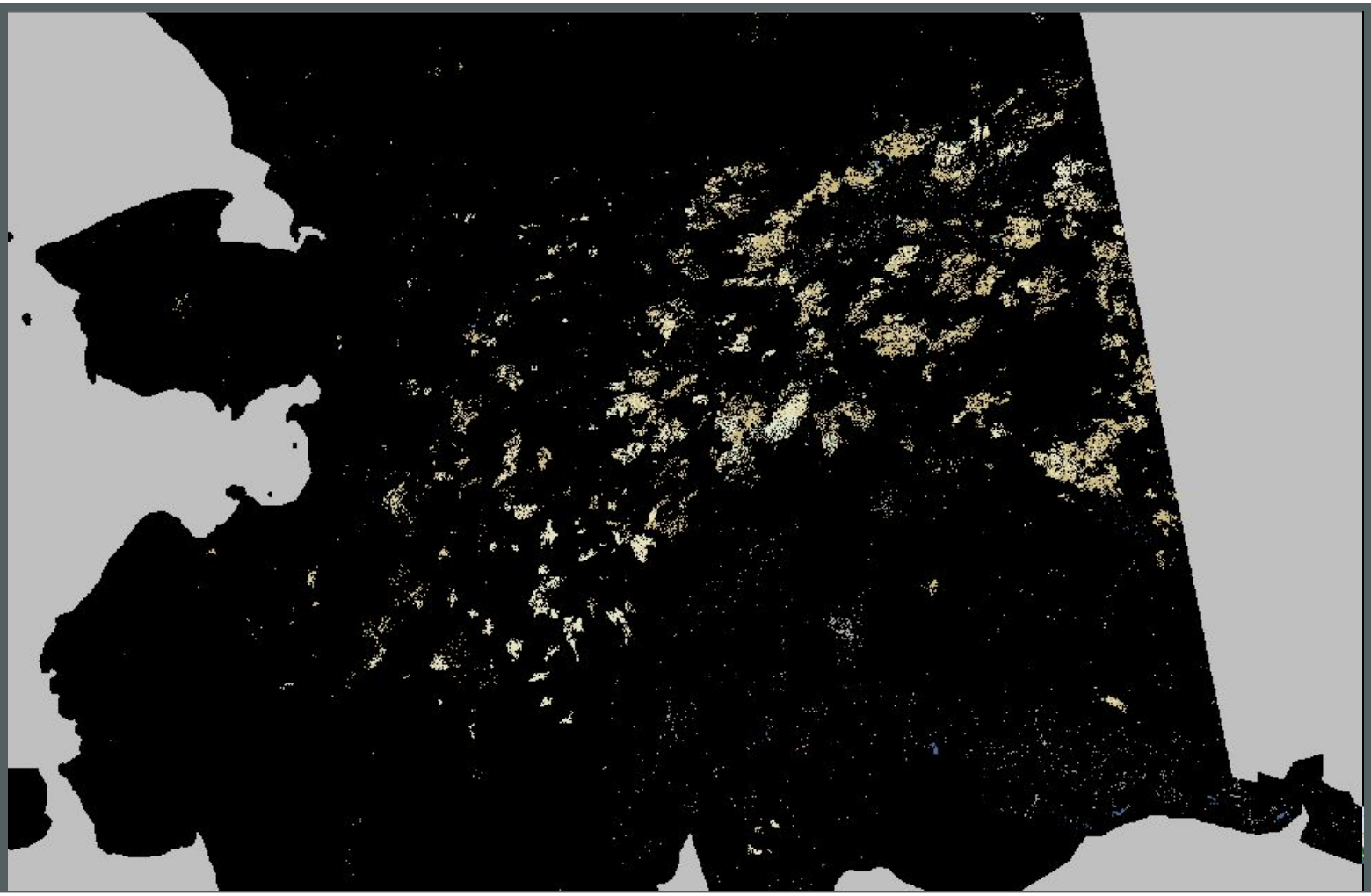
- **Implement image compositing to optimize the 2011 effort**
- **Use multi-criteria change detection method to compare imagery between 2001 and 2011**
- **Identify changes and update the labeling for changed areas using multiple image dates**
  - This process provides a new 2011 map, and reliable estimate of changes between 2001 and 2011
- **Update urban imperviousness for major urban areas**
- **Tree canopy estimate (completed by U.S. Forest Service Remote Sensing Application Center)**

USGS

NLCD 2011 was released in Winter 2014



NLCD 2011 was released in Winter 2014

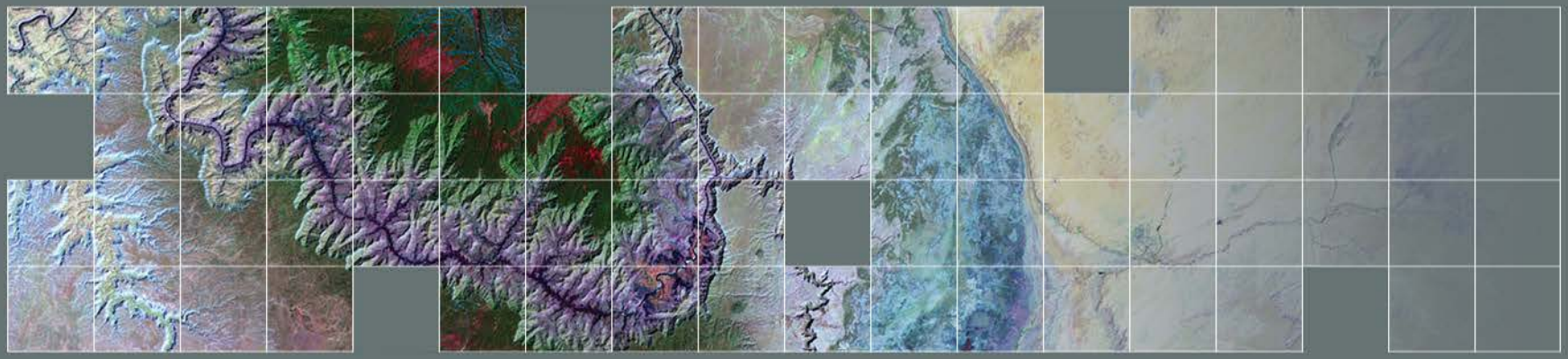


science for a changing world

Climate and Land Use Change

Earth Resources Observation and Science (EROS) Center

NALCMS – U.S. Perspective



Author Collin Homer

Date Oct 2015

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

North American Land Change Monitoring System

- Tri-nation collaboration of 5 federal government institutions and the Commission for Environmental Cooperation (Canada CCRS, U.S. USGS, Mexico INEGI, CONABIO, CONAFOR)
- Administered by the Commission for Environmental Cooperation
- Long-term goal: develop an annual or bi-annual operational system for monitoring land cover change for the continent at 30m

USGS

North American Land Change Monitoring System

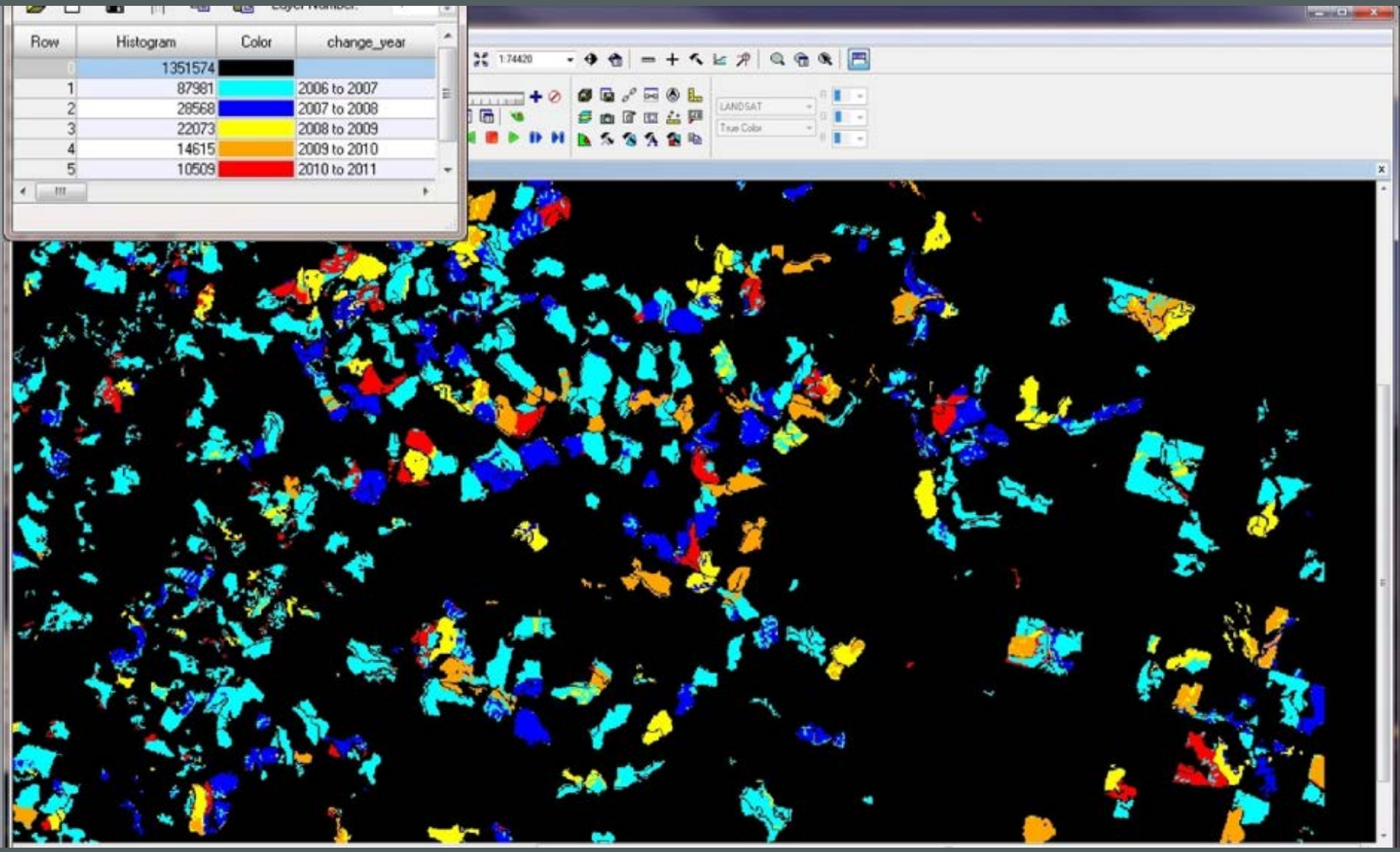
First Product was Modis scale Land Cover change from 2005 to 2010.

NLCD in Alaska and Lower 48 was used as training data

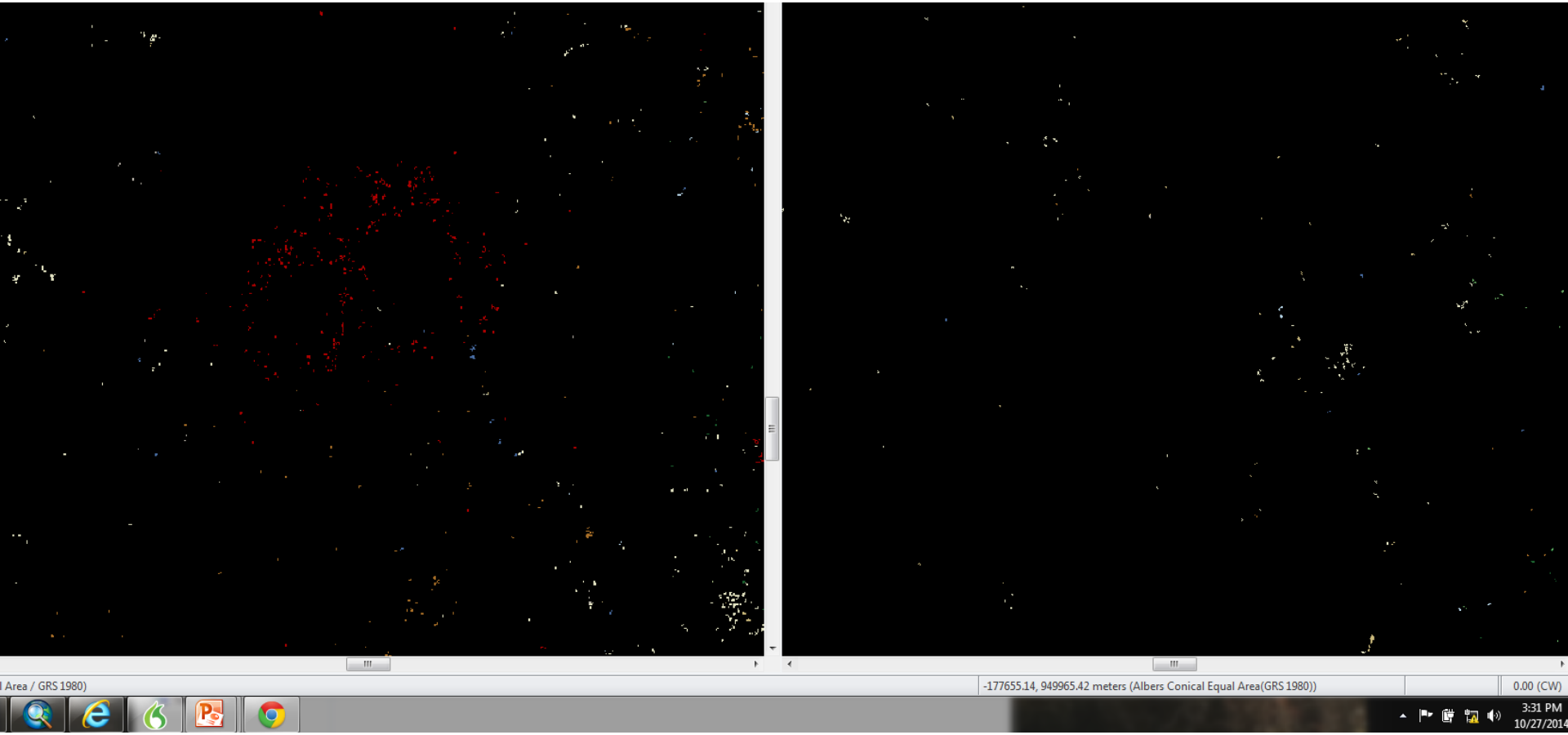
Work Continued towards a biannual 30m product after publication

USGS

We annualized change for 2006-2011 from NLCD

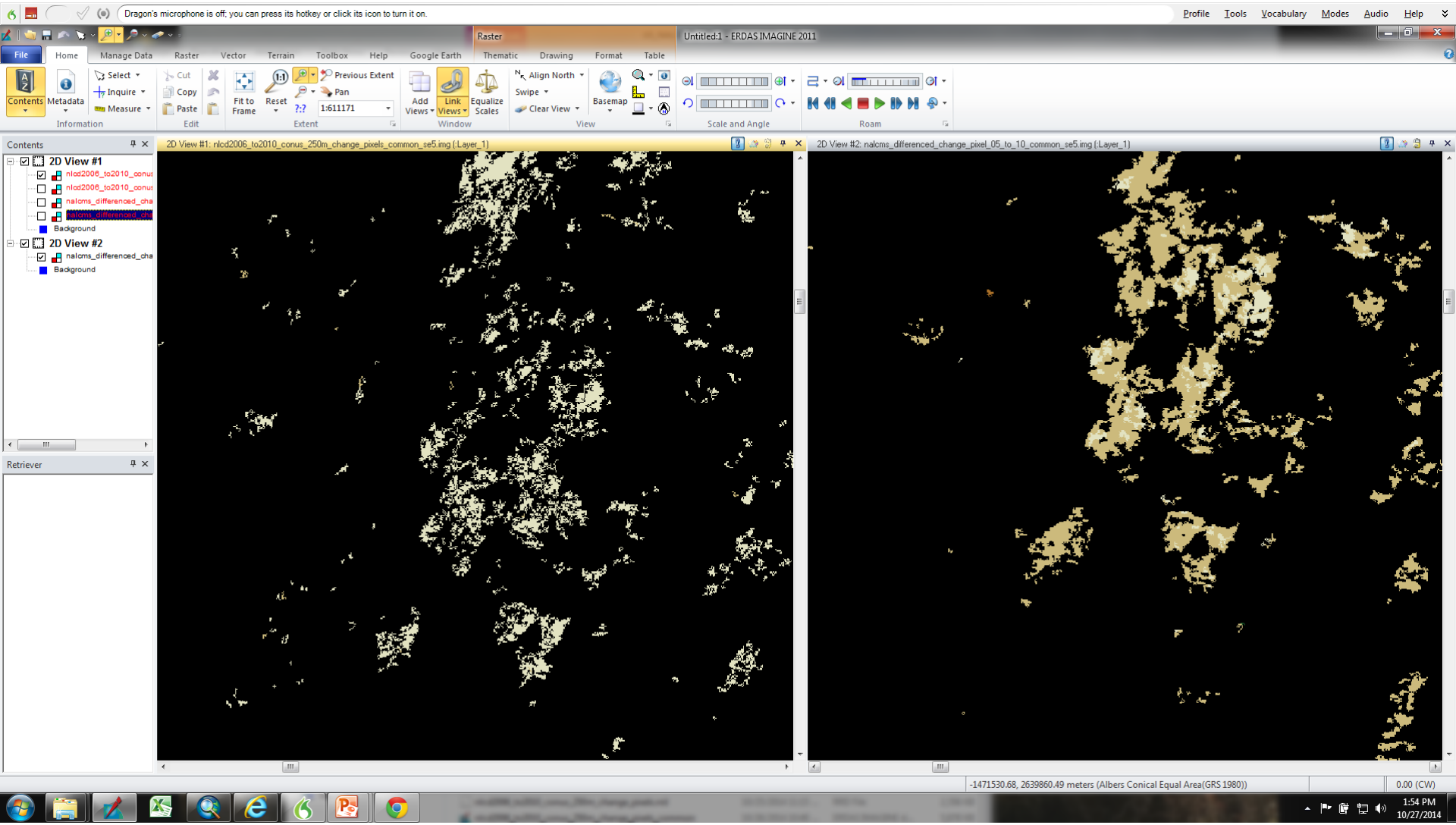


But quite different change patterns…



Landsat

MODIS



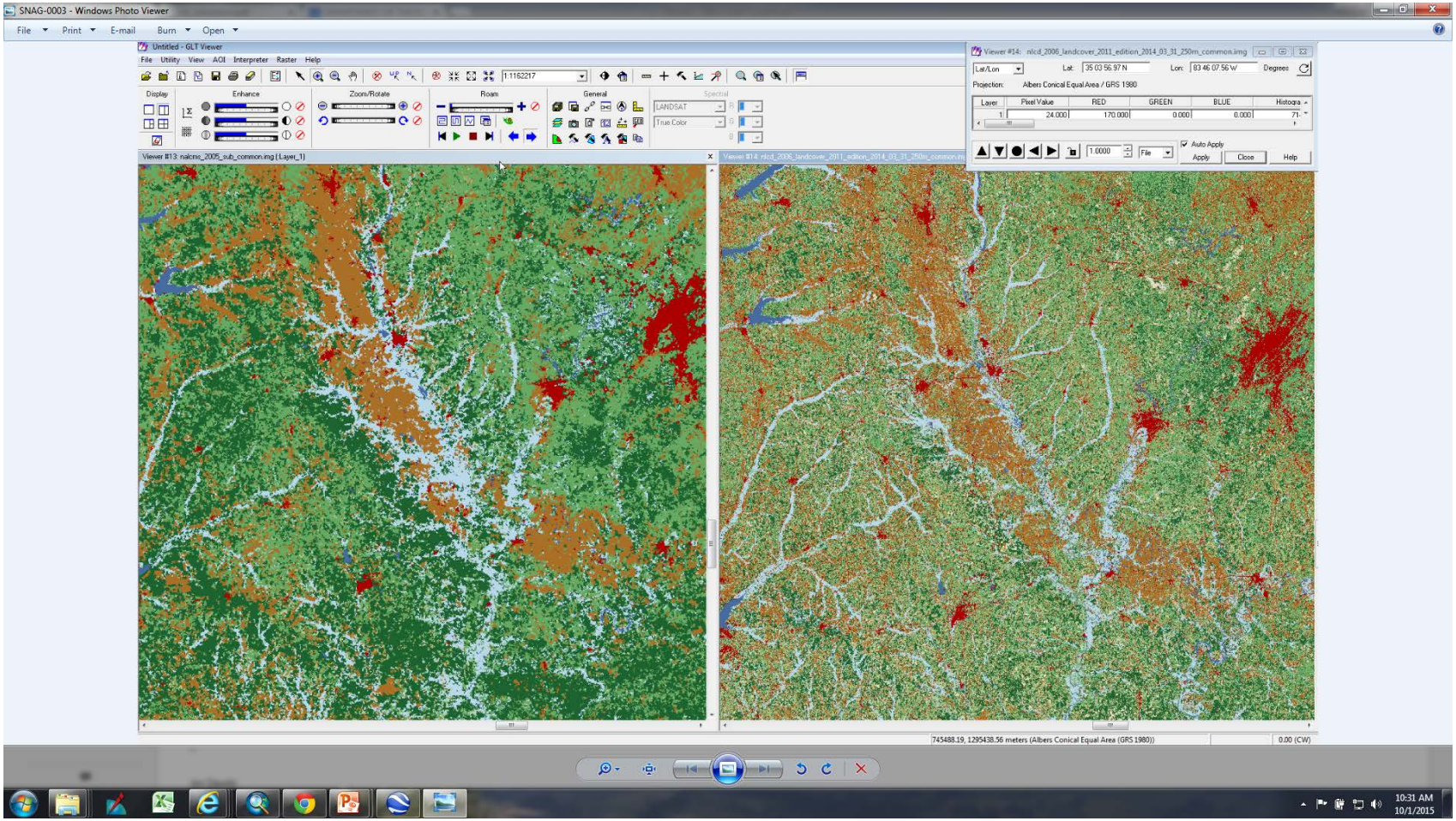
Landsat

MODIS

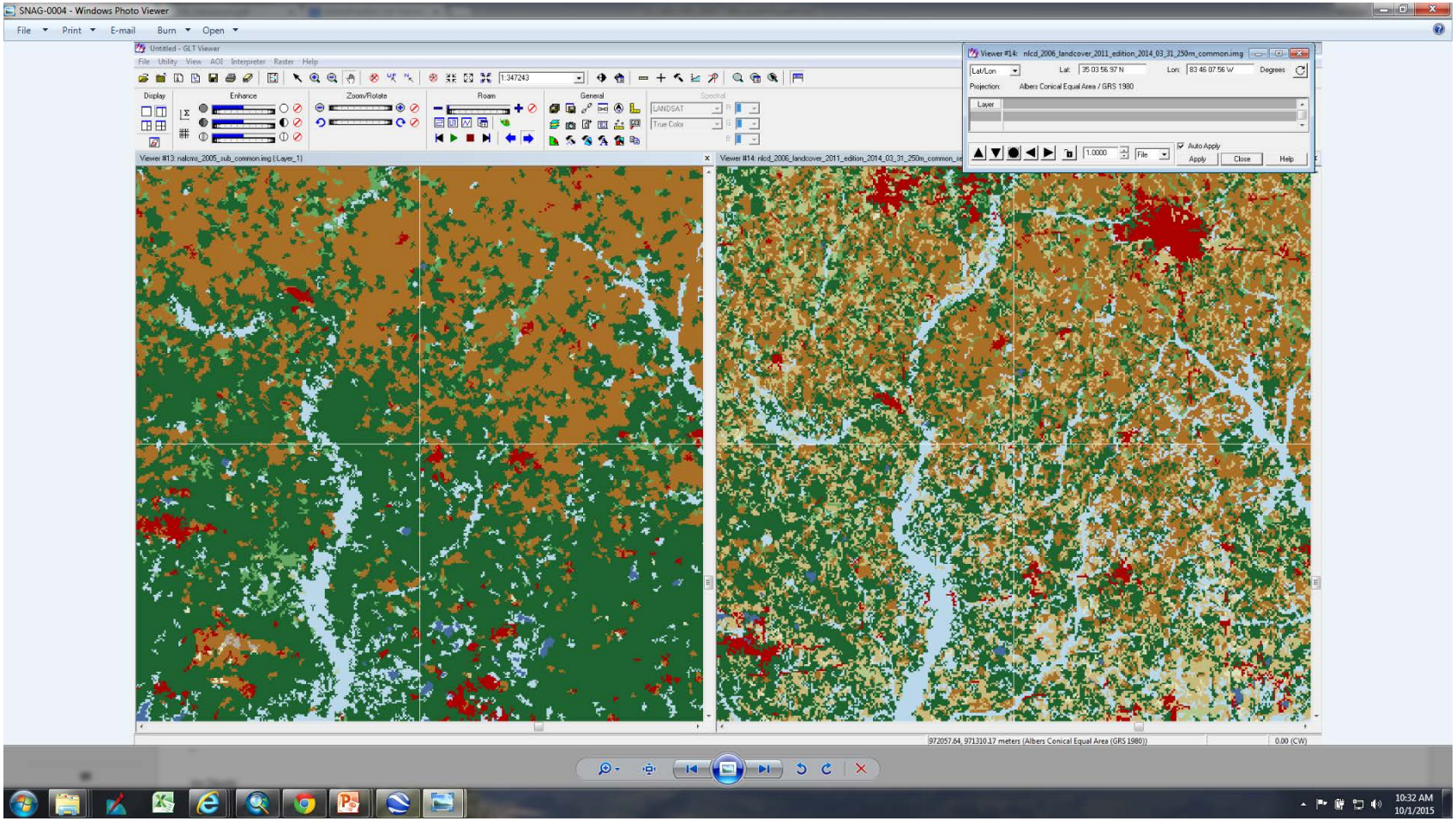
Change comparison

NLCD CLASS	nalcms 05 to 10 change pixels	NLCD 06 to 10 change pixels	nalcms 05 to 10 change pixels se5	NLCD 06 to 10 change pixels se5
0	241,808,297	237,724,434	241,900,426	238,729,535
11	36,280	81,889	33,220	45,359
12	142	0	98	0
24	17,736	210,004	13,706	49,563
31	10,394	62,241	9,828	20,516
41	29,214	27,991	18,479	5,880
42	22,664	234,536	12,221	111,162
43	1,373	7,285	849	1,254
52	247,936	420,809	234,789	236,822
71	154,146	755,229	130,668	486,334
82	69,717	121,534	49,257	41,858
90	21,109	113,792	15,467	31,461
TOTAL	610,711	2,035,310	518,582	1,030,209

NALCMS left, NLCD right



NALCMS left, NLCD right



U.S. 250 annual change product conclusions

- Change was partitioned for every year between 2006-2011 for NLCD (no 2005-2006)
- Several operational issues such as matching projections was problematic and created some differences
- Agreement was marginal when comparing 250m 2005-2010 change patches vs 30m 2006-2011 change patches (most did not overlay or agree)
- A lot of change was in different spots (SE Forest change for example)
- This set up a dilemma of no way to replicate 250m product look and feel with 30m product on annual basis
- Concluded that products would be very different and not worth following through

USGS

NALCMS Status and Future Goals

- Completed and published a 2005 land cover using MODIS (250m resolution) and a 2005-2010 land cover change product
- Published both maps and articles about the product
- Now working on finalizing the next generation higher resolution solution at 30m – In edge-matching phase with Canada and Mexico
- NLCD currently represents U.S. contribution

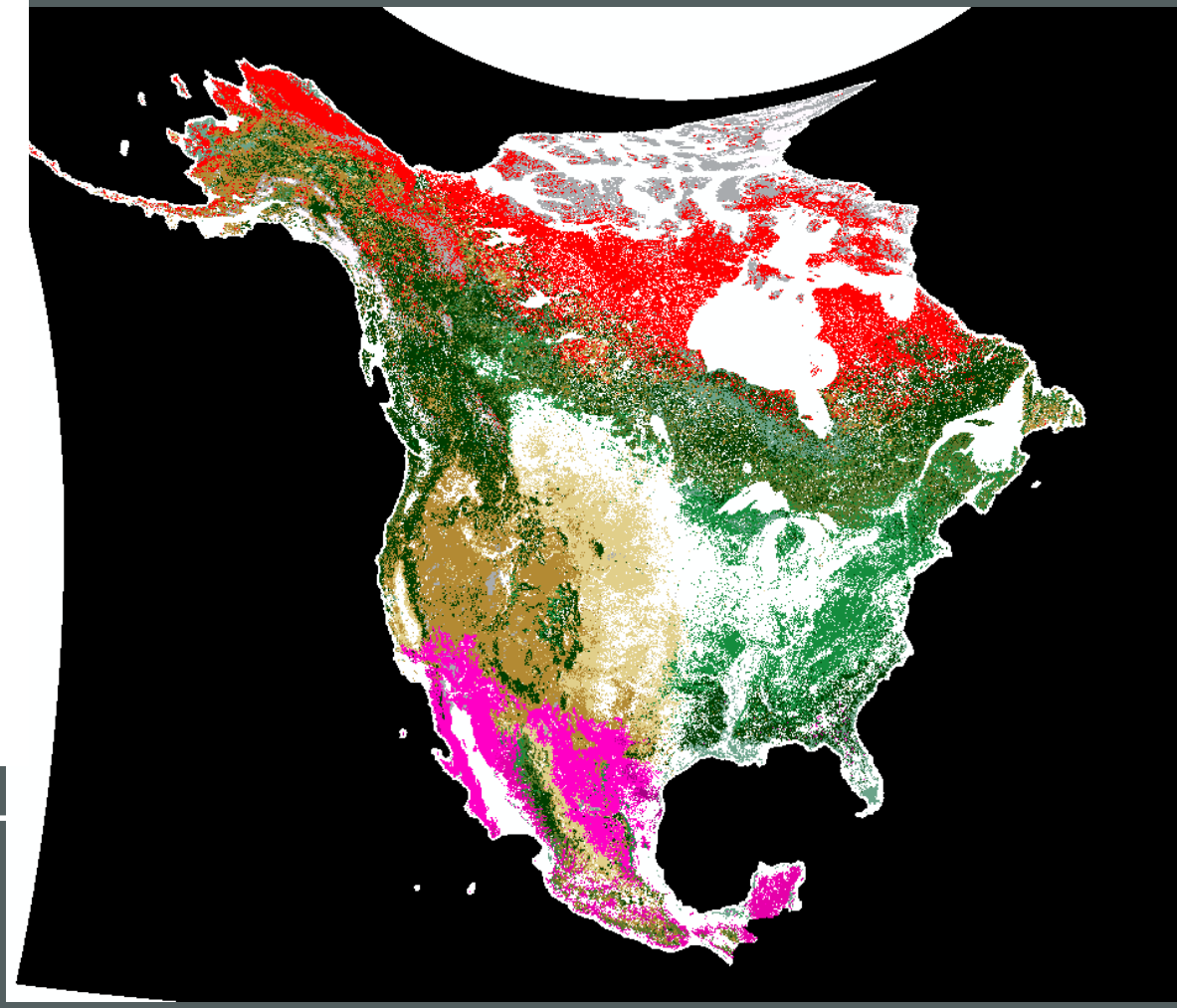
More information and NALCMS data at the Commission for Environmental Cooperation website (http://www.cec.org)

USGS

30 m product released this summer (For NLCD, used eco-regions, prism, climate and DEM to separate)

NA_LandCover_2010_25haMMU.img

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Tropical or sub-tropical broadleaf evergreen forest
- Tropical or sub-tropical broadleaf deciduous forest
- Temperate or sub-polar broadleaf deciduous forest
- Mixed forest
- Tropical or sub-tropical shrubland
- Temperate or sub-polar shrubland
- Tropical or sub-tropical grassland
- Temperate or sub-polar grassland
- Sub-polar or polar shrubland-lichen-moss
- Sub-polar or polar grassland-lichen-moss
- Sub-polar or polar barren-lichen-moss
- Wetland
- Cropland
- Barren land
- Urban and built-up
- Water
- Snow and ice



USGS

Land Cover Map of Canada 2010

Rasim Latifovic, Darren Pouliot, Ian Olthof
Canadian Centre for Mapping and Earth Observation

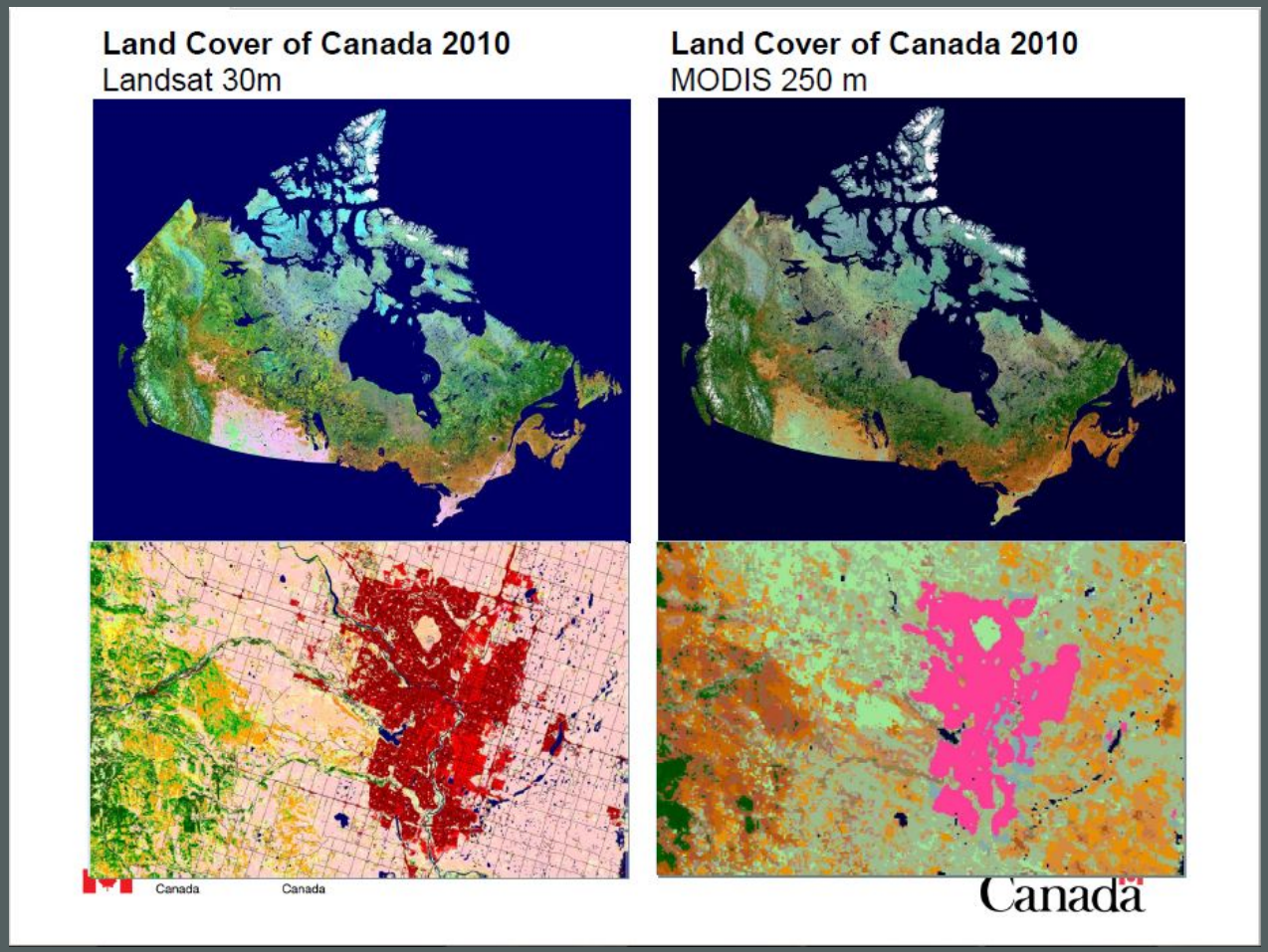
North America Land Change Monitoring System

Montreal, October, 2015

Natural Resources Canada Ressources naturelles Canada

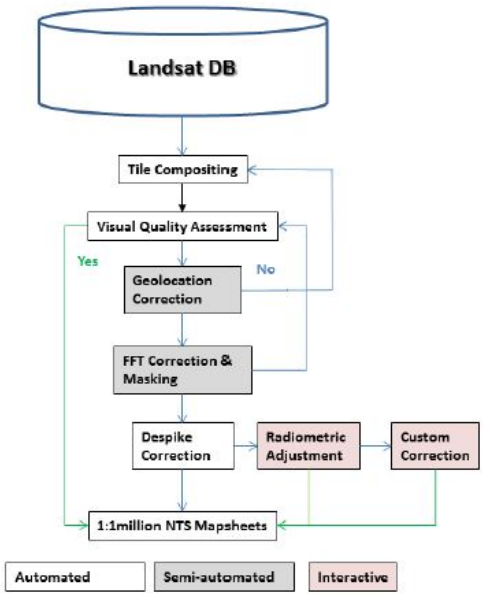
Canada

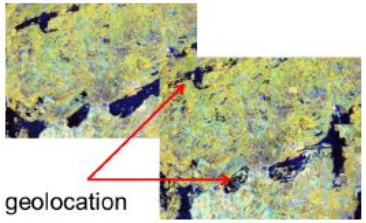
USGS

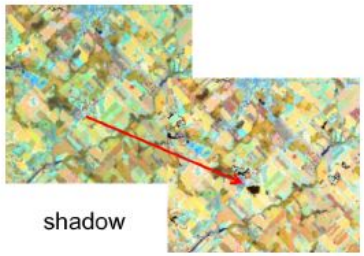

Land Cover of Canada 2010
Landsat 30m
Land Cover of Canada 2010
MODIS 250 m
Canada
Canada
Canada

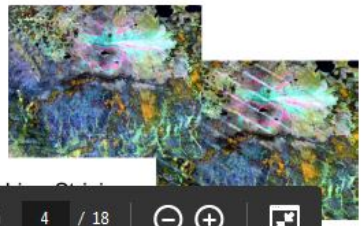
USGS

Quality control









Difference due to:
atmospheric condition
phenology
surface moisture
…

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Canada

USGS

Compositing criteria

Compositing criteria TM/ETM+		Description and rationale
K1	Max NDVI	*appearance of clouds, poor atmospheric conditions, and off-nadir viewing geometries would depress the NDVI values* *disadvantage: poor performance over water and non-vegetated land*
K2	Min Red	*appearance of clouds, poor atmospheric conditions would increase Red reflectance* *disadvantage: preferable selection of cloud shadows over truly clear-sky pixels and discriminating snow from clouds*
K3	Max (NIR/Blue, SWIR1/Blue)	*a certain equivalent of cloud–haze optical depth*
K4	(Blue-Red)/(SWIR1+1)	*a certain equivalent of cloud–haze optical depth*
K5	Min (Delta Time)	*prefer clear pixels closer to the middle of the compositing period*

- cloud mask
- shadow mask
- water mask

$$\max\left(\sum_{i=1}^{n} rank\ K_i * w_i\right)$$

AOSR Mosaic 2013-14 (July–August)
created from Landsat 8 OLI bands 6,5,4

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Canada

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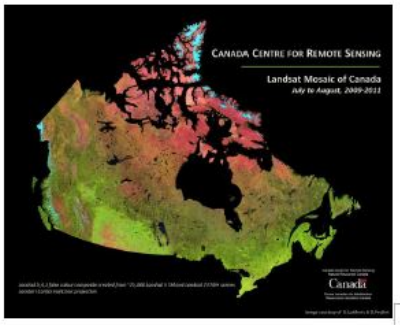
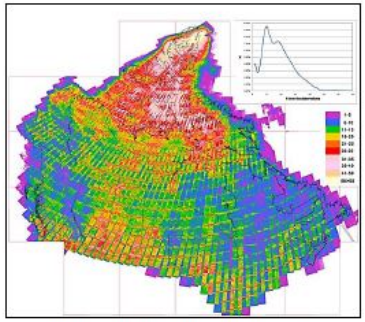
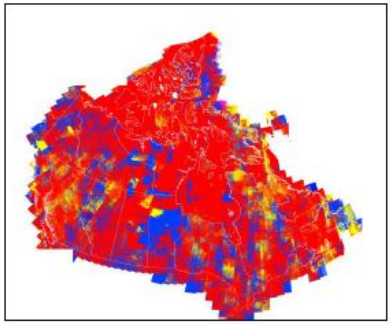
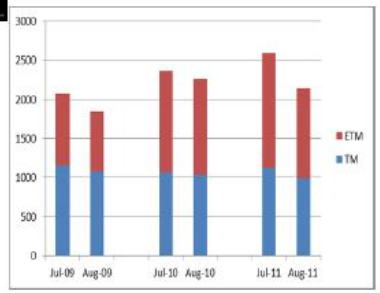


Landsat Mosaic of Canada false color composite TOA reflectance. Red: band-5 (1.55-1.75 µm), Green: band-4 (0.76-0.90 µm) Blue: band-3 3 (0.63-0.69 µm)

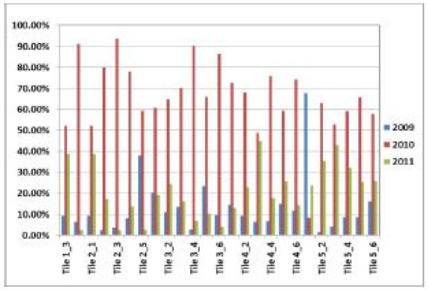




Available number of clear-sky observations per pixel



Number of available Landsat scenes 2009-2011 during July-August period.



Pixels used in the new composite, by tile and acquisition year.

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Canada

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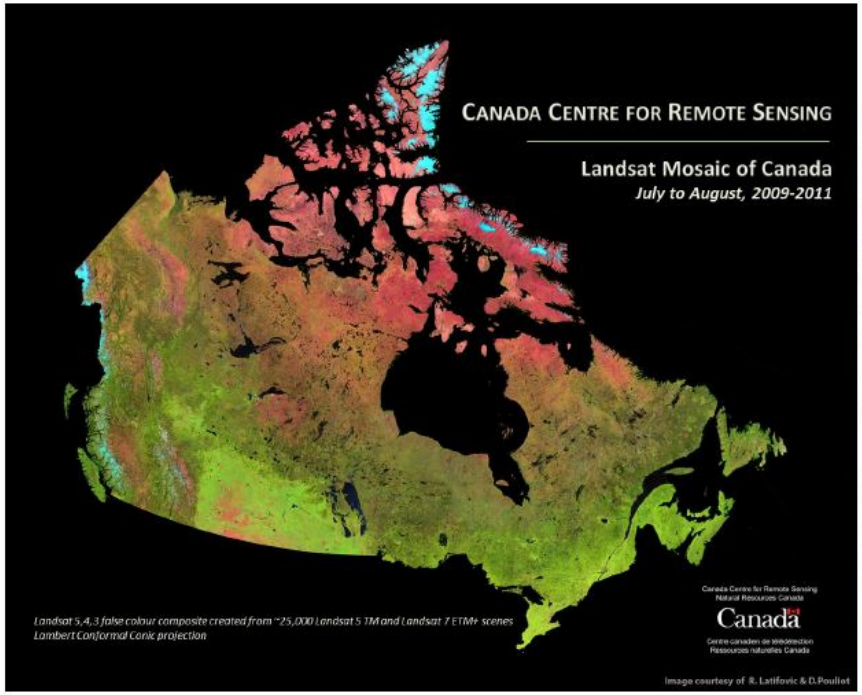
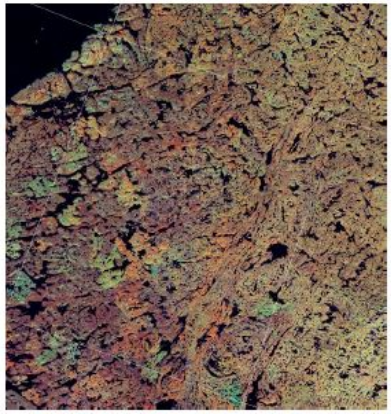
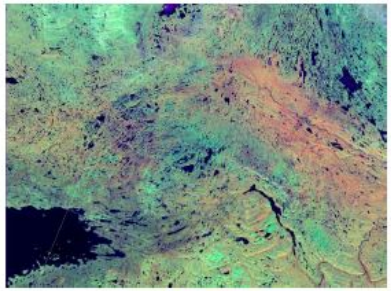
Data set







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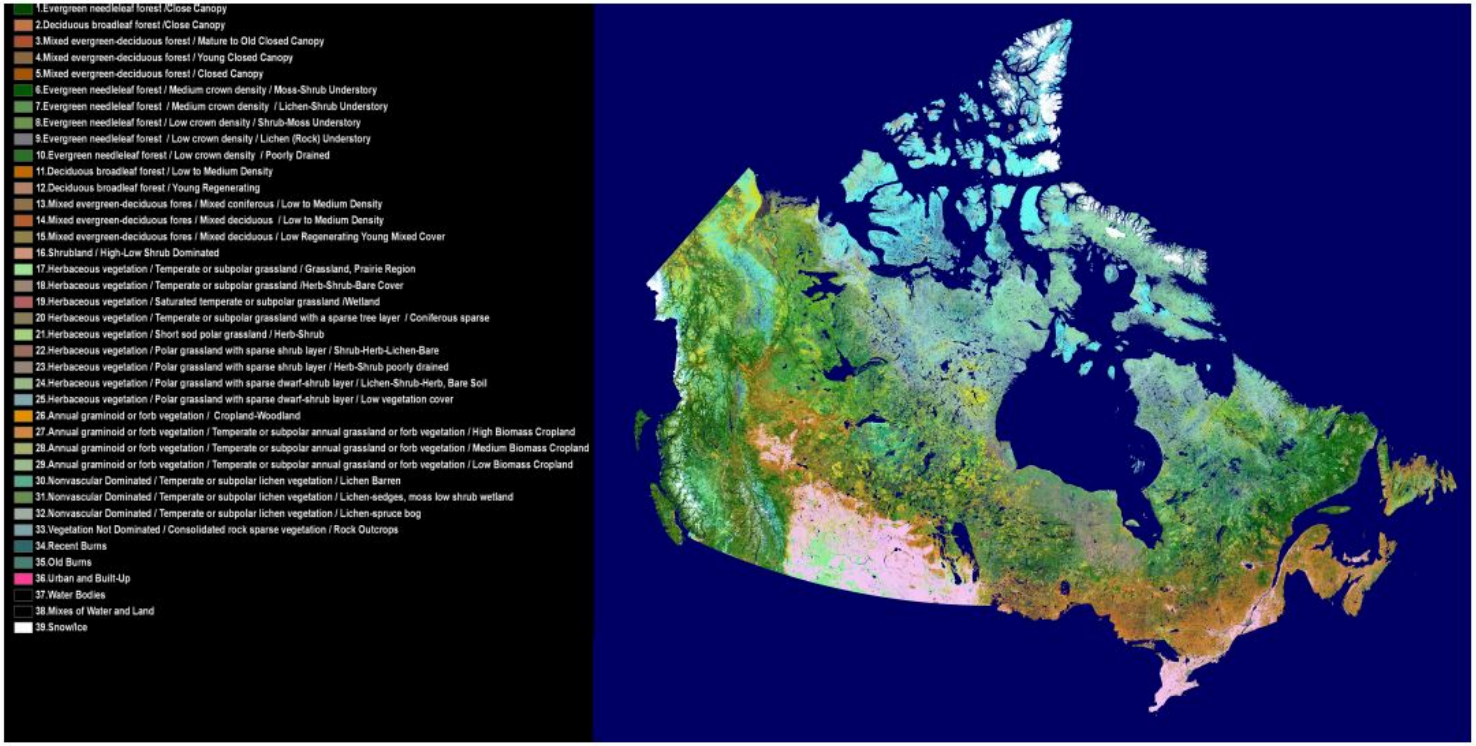
Land Cover of Canada 2010

Legend 39 classes



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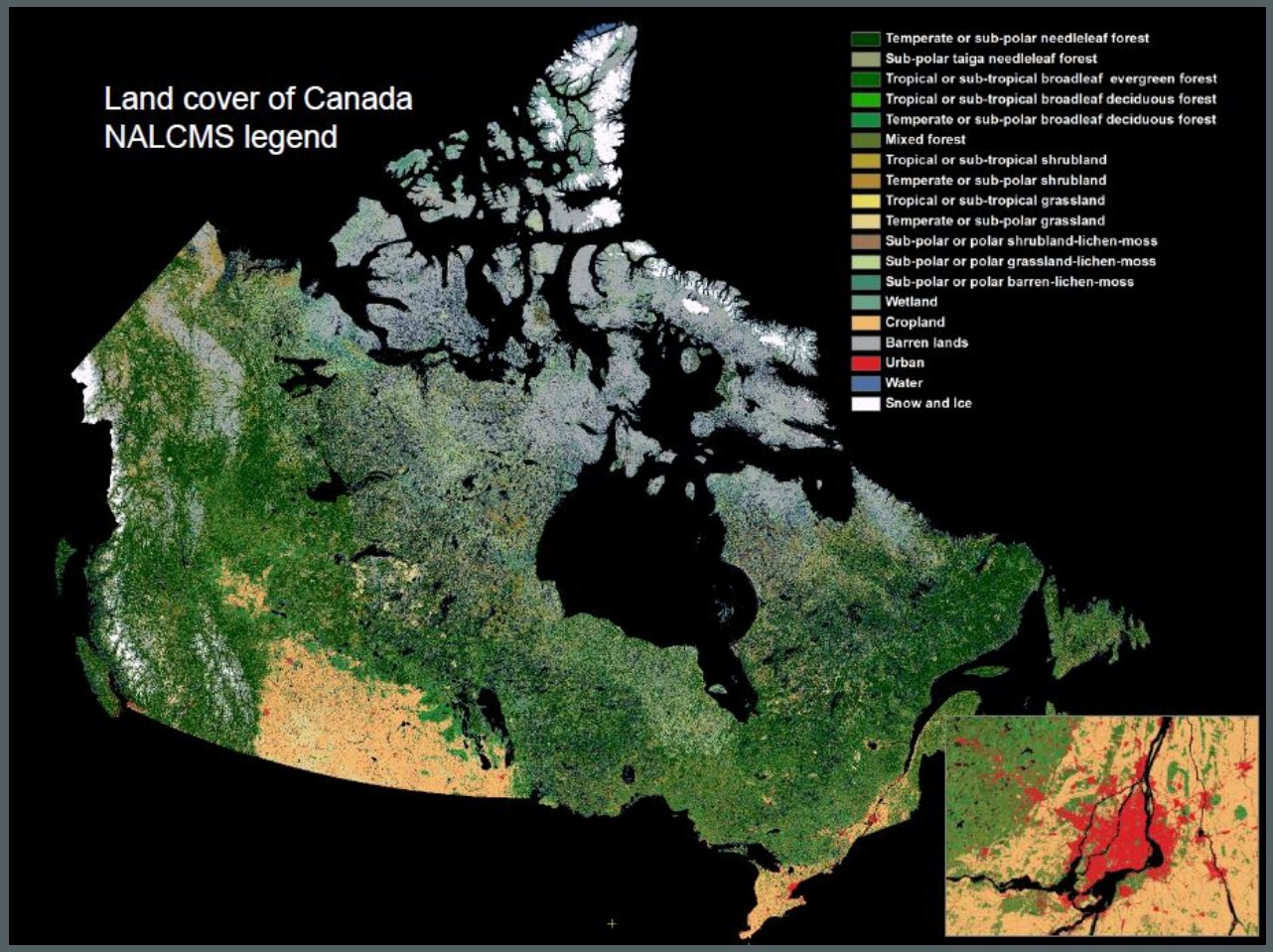
Land cover of Canada
NALCMS legend
Temperate or sub-polar needleleaf forest
Sub-polar taiga needleleaf forest
Tropical or sub-tropical broadleaf evergreen forest
Tropical or sub-tropical broadleaf deciduous forest
Temperate or sub-polar broadleaf deciduous forest
Mixed forest
Tropical or sub-tropical shrubland
Temperate or sub-polar shrubland
Tropical or sub-tropical grassland
Temperate or sub-polar grassland
Sub-polar or polar shrubland-lichen-moss
Sub-polar or polar grassland-lichen-moss
Sub-polar or polar barren-lichen-moss
Wetland
Cropland
Barren lands
Urban
Water
Snow and Ice

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Converting NLCD codes to NALCMS

- Currently working on crosswalking NLCD 2011 to NALCMS classes
- Rely on current NALCMS class distribution and LANDFIRE (Ecological system classification)
- Final product will cover 49 states
- Create future template for how to replicate NALCMS classes

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2016 and beyond……

- Align all NLCD products over all years with the same change mapping process
- improve accuracy
- Increase update frequency

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What's Next for NLCD - NLCD 2016

- Generate a 2016 version of land cover, imperviousness, and tree canopy
- Reset NLCD base land cover as 2016
- Revise NLCD 2001, 2006, 2011 to be in harmony with NLCD 2016
- Add new product lines including fractional cover estimates of shrub, grass and bare ground
- Explore future biannual product cycles beyond 2016

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NLCD 2016 Product Advancements

- Incorporate time signatures with imagery from 1999 – 2016 for more accurate labeling (7 Epochs)
- Unprecedented scripting and hardware use to improve processing speed with massive data stacks
- Improved image pre-processing and staging
- Incorporate segmentation, improved wetland potential, better use of NASS, shrub/grass products and ancillary data to make more accurate products
- Improved imperviousness (road masking more accurate, year of change more accurate, improving capture of new expansion and contraction
- Push advancements through all epochs back to 2001
- *Will result in best ever NLCD base and replacement of existing epochs will result in the most accurate change product ever*

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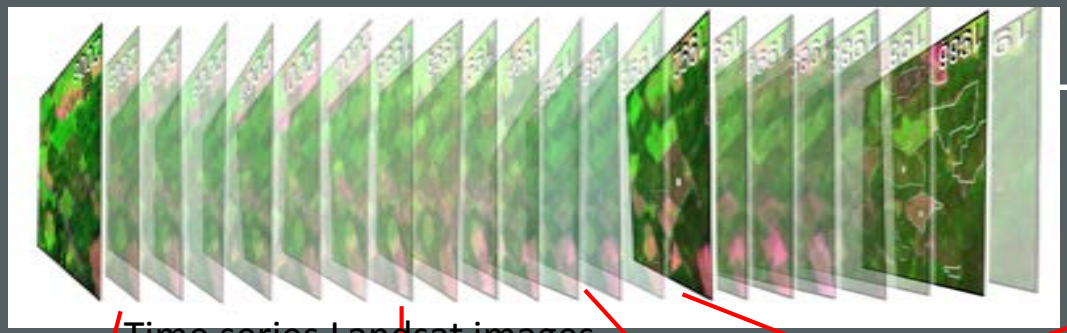
NLCD 2016 will require a series of complex methods



Time series Landsat images

Geospatial ancillary data

Spectral data → Spectral change detection → Spectral change map

Spectral data → Long term time series metrics → Trajectory analyses

Spectral data Ancillary data → Object-based feature extraction → Image segments

Spectral data Ancillary data → Land cover empirical modeling CART → Initial LC

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Integration

Multi-temporal NLCD

Land cover change

NLCD 1986

1986/1991 LC change

NLCD 2001

2001/2006 LC change

NLCD 2006

2006/2011 LC change

NLCD 2011

2011/2016 LC change

NLCD 2016

NLCD 2016

- Focused on NLCD 2016 Operational plan by March 2016
- Production started May 2016
- Big scope increase for methods - will include over 30 models and huge increase in data
- Will include landcover, imperviousness, tree, shrub, grass and bare ground products
- Done in 2018

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NLCD 2016 Details

- A 2016 version of land cover, imperviousness and tree canopy
- Reset NLCD base land cover as 2016
- Re-complete NLCD epochs every 5 years back to 2001
- Create new shrub, grass bare ground products
- Expand validation
- Aim for future biannual product cycles beyond 2016
- Production will include major processes spanning training data development, land cover labeling and post processing refinement and integration

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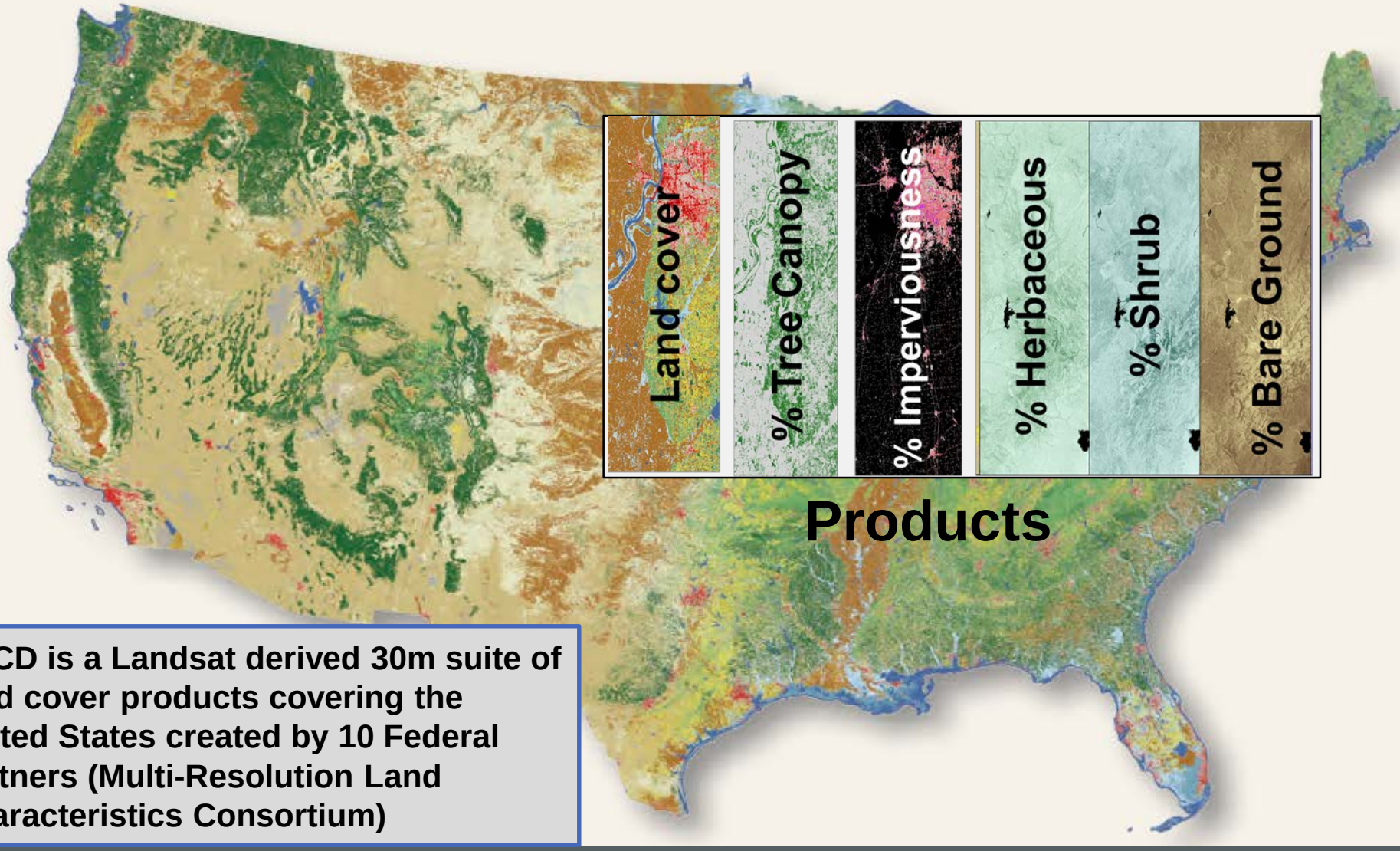
The National Land Cover Database



NLCD is a Landsat derived 30m suite of land cover products covering the United States created by 10 Federal partners (Multi-Resolution Land Characteristics Consortium)

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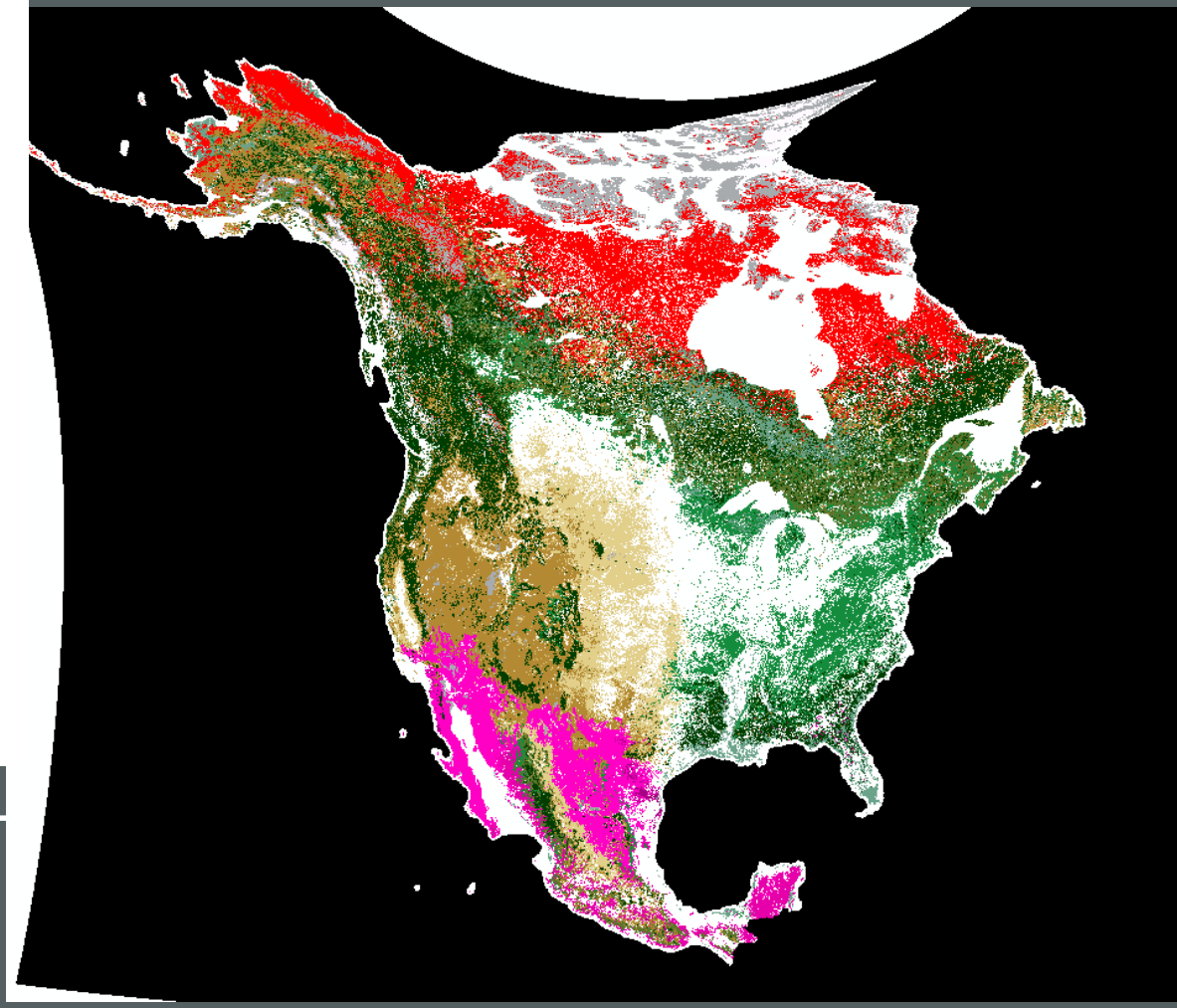
All products available on MRLC website

www.mrlc.gov

30 m product released this summer (For NLCD, used eco-regions, prism, climate and DEM to separate)

NA_LandCover_2010_25haMMU.img

- Temperate or sub-polar needleleaf forest
- Sub-polar taiga needleleaf forest
- Tropical or sub-tropical broadleaf evergreen forest
- Tropical or sub-tropical broadleaf deciduous forest
- Temperate or sub-polar broadleaf deciduous forest
- Mixed forest
- Tropical or sub-tropical shrubland
- Temperate or sub-polar shrubland
- Tropical or sub-tropical grassland
- Temperate or sub-polar grassland
- Sub-polar or polar shrubland-lichen-moss
- Sub-polar or polar grassland-lichen-moss
- Sub-polar or polar barren-lichen-moss
- Wetland
- Cropland
- Barren land
- Urban and built-up
- Water
- Snow and ice



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Summary

- Imagery, imagery, imagery
- NLCD directly feeds into NALCMS and will continue to be the base for future NALCMS work
- NLCD and NALCMS are working toward more frequent updates, at least biannual

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Questions?

- Jon Dewitz
- dewitz@usgs.gov
- NLCD Technical Lead and QA supervisor

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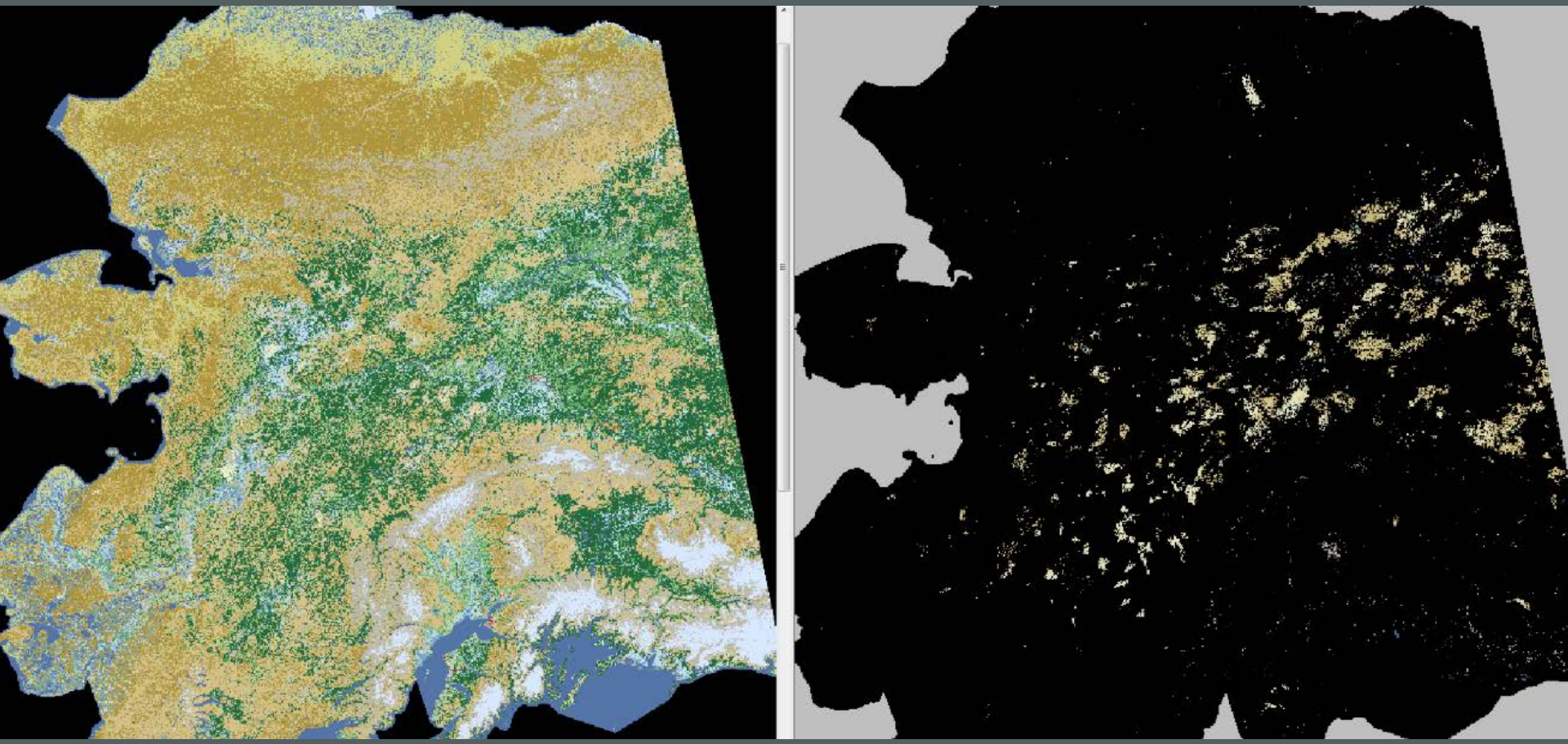
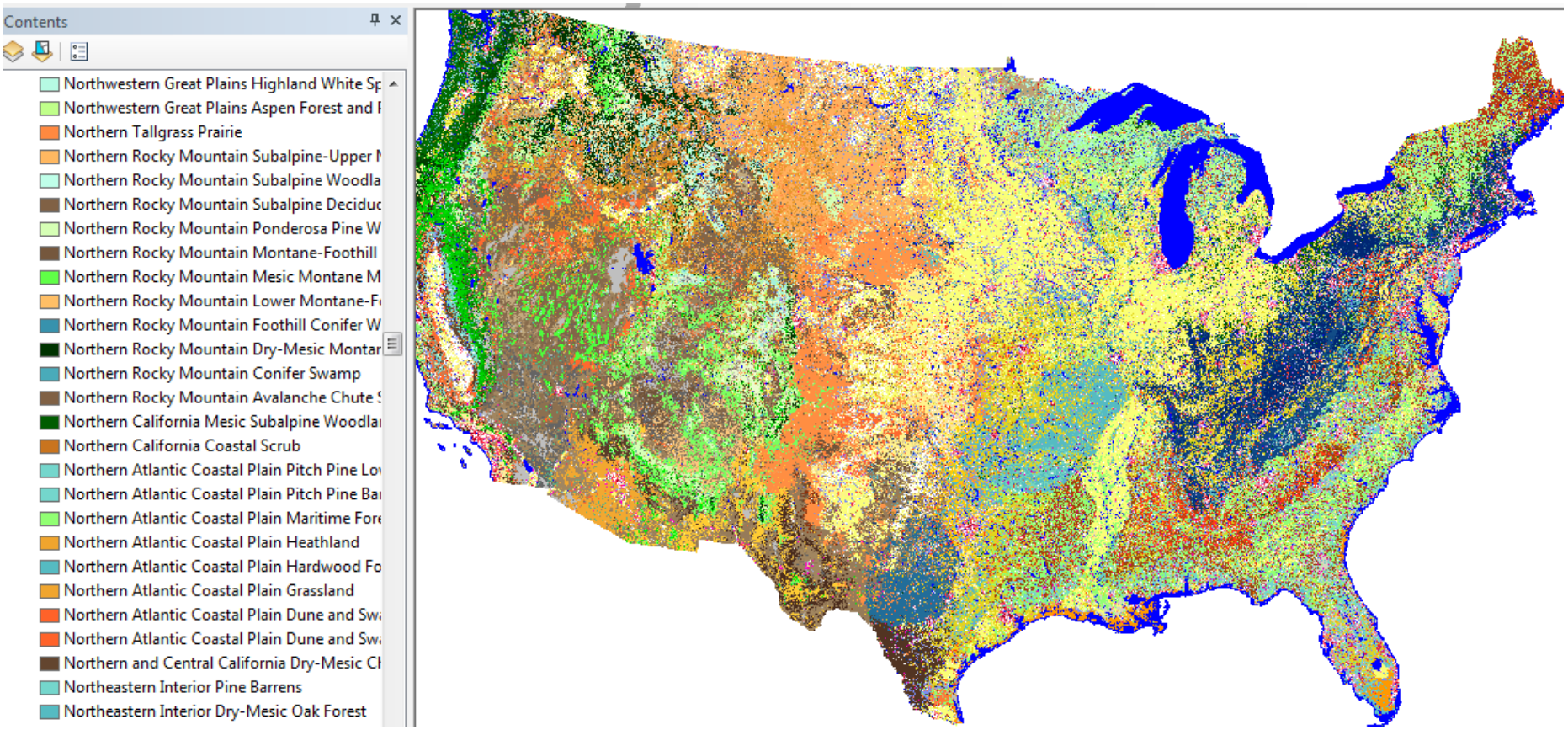
Alaska was completed this last year

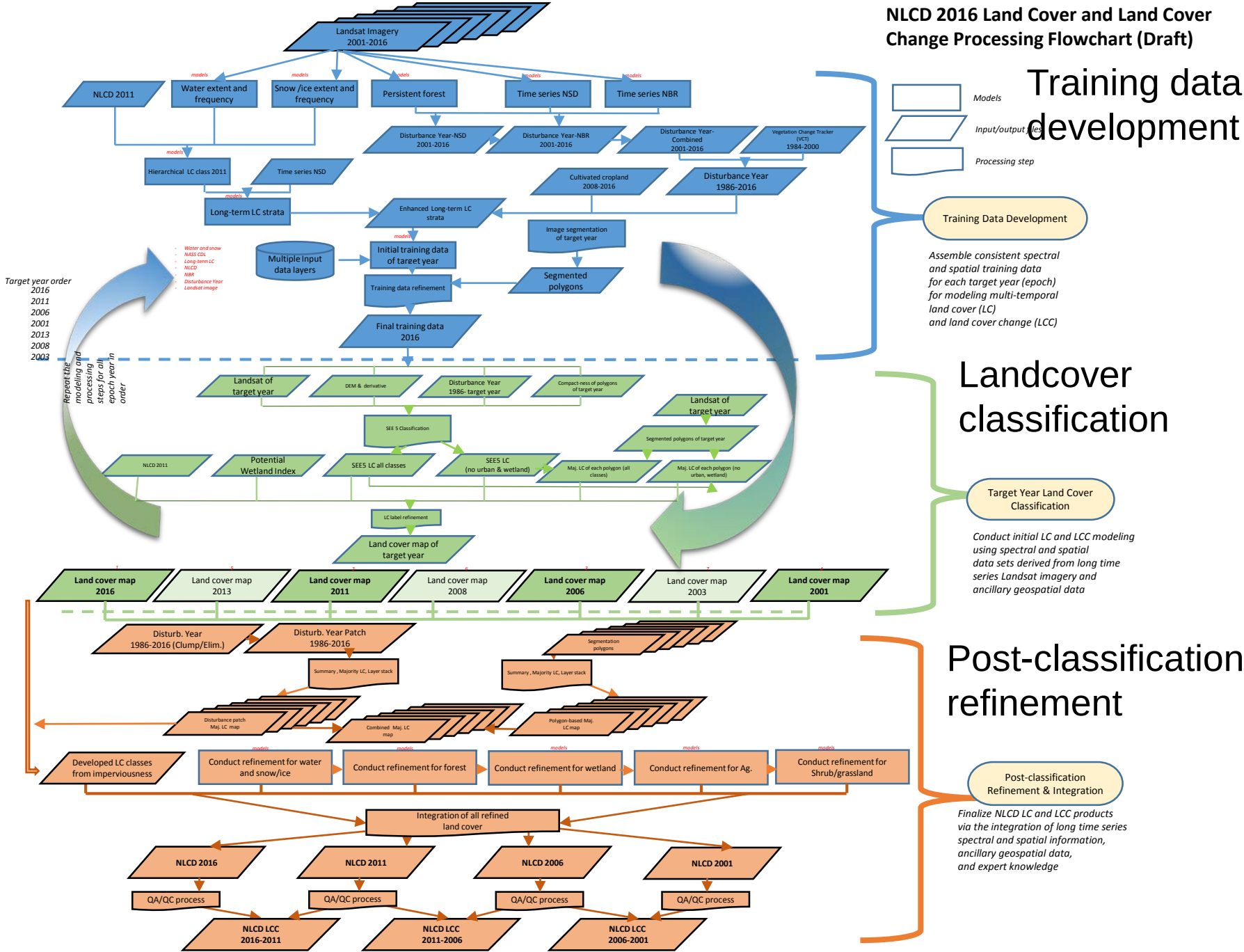


NLCD 2011 Change areas

Example of Landfire Data

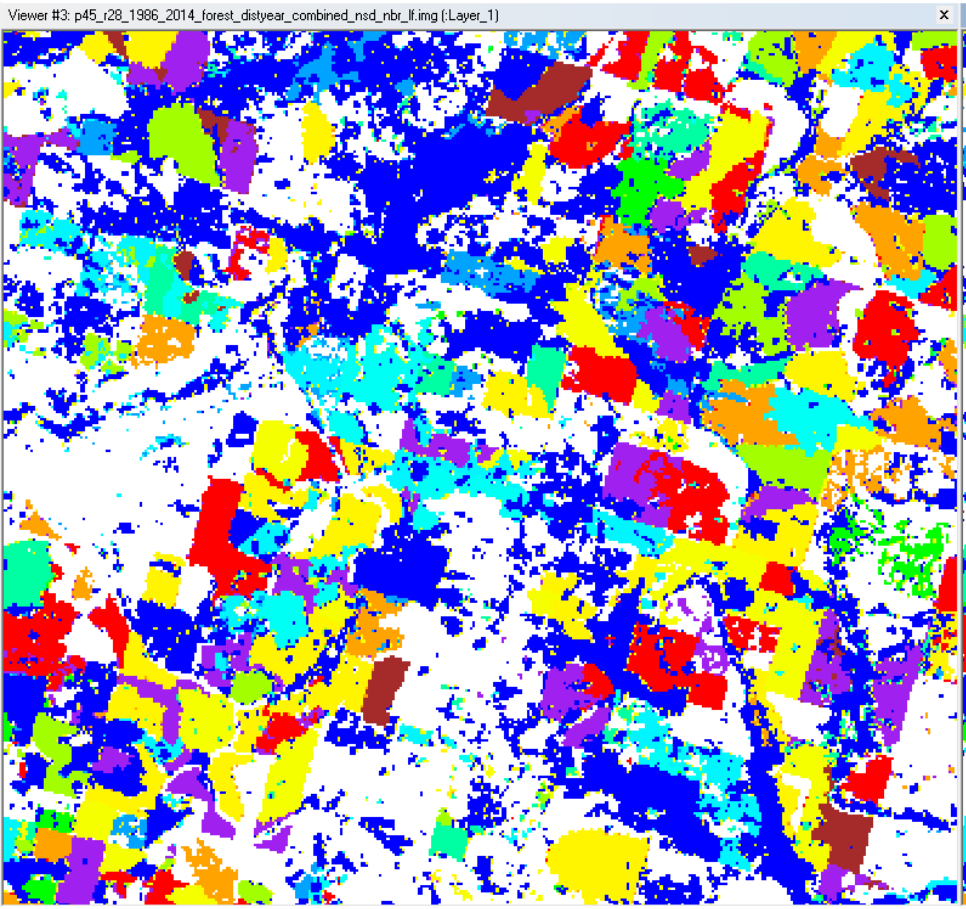


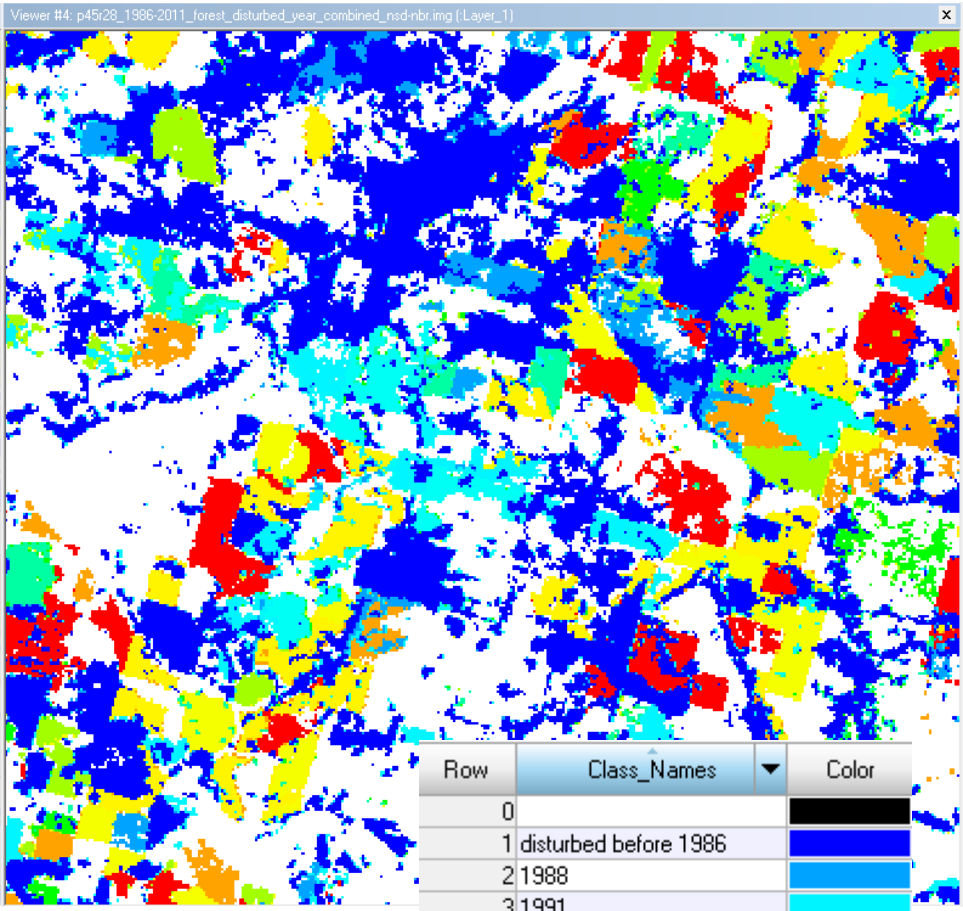
NLCD 2016 Land Cover and Land Cover Change Processing Flowchart (Draft)



Stitched 1986-2014

Image derived 1986-2011

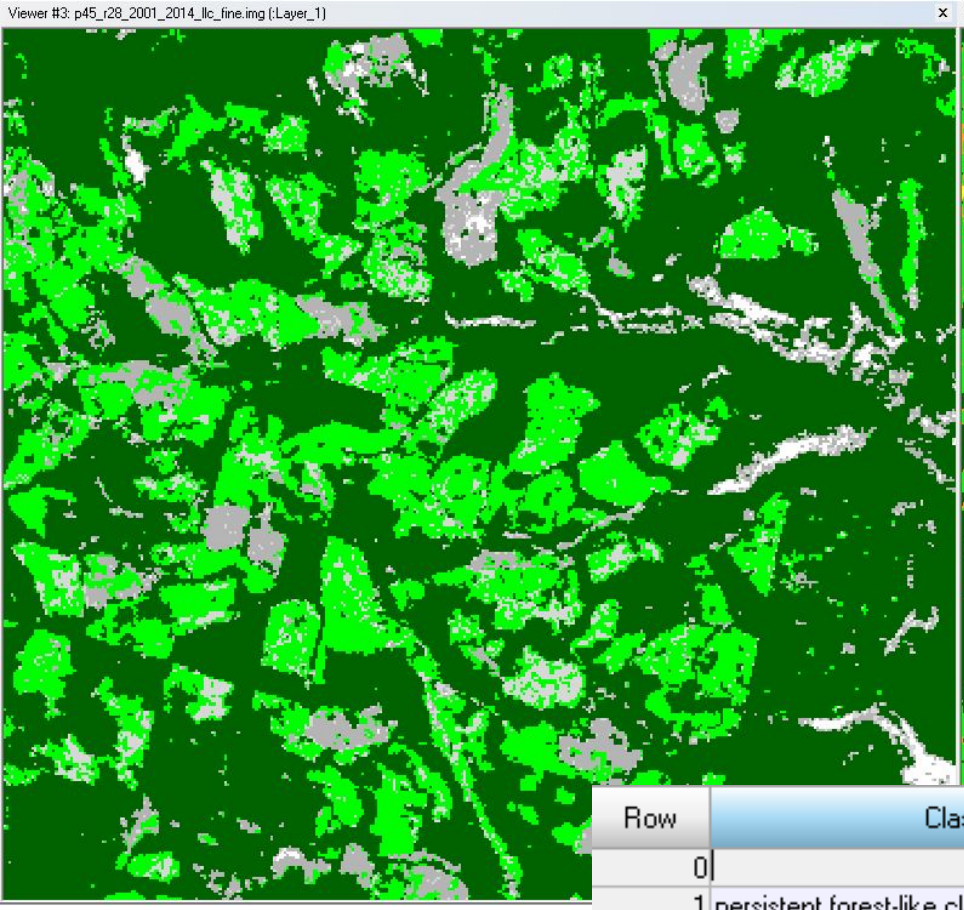


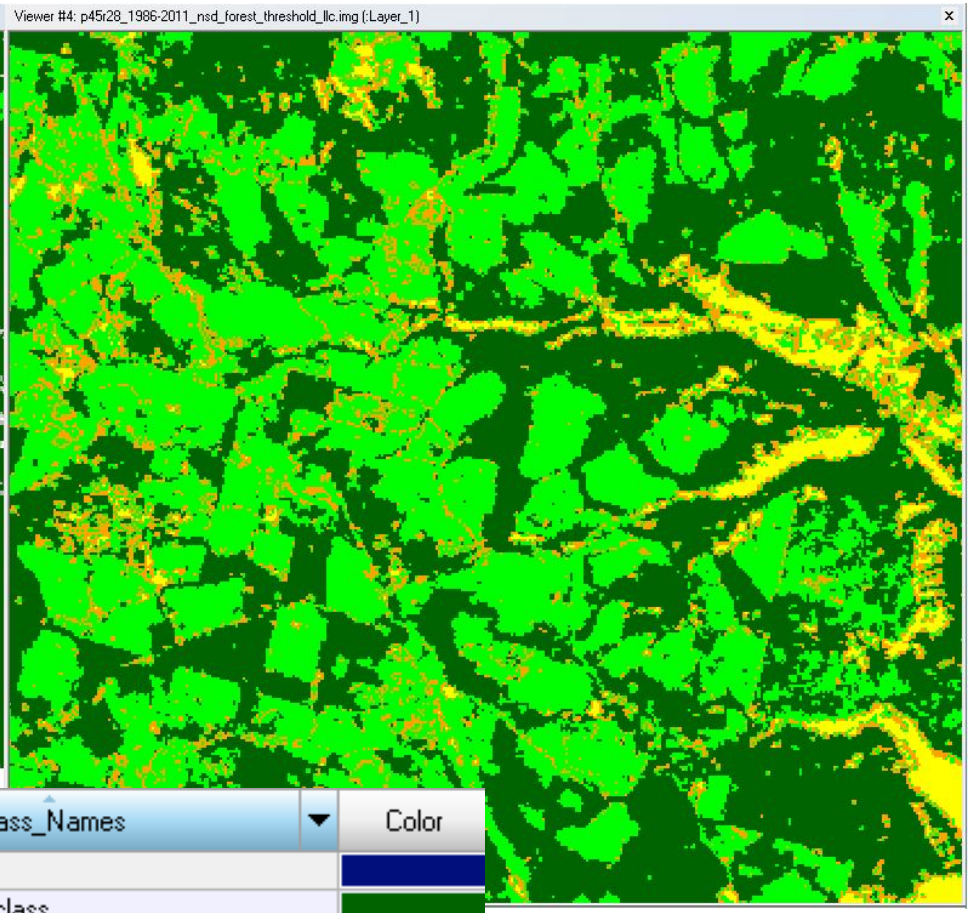


Row	Class_Names	Color
0		
1	disturbed before 1986	
2	1988	
3	1991	
4	1993	
5	1996	
6	1998	
7	2001	
8	2003	
9	2006	
10	2008	
11	2011	
12	2013	
13	2014	
14		
15	no change	

Disturbance-Year Maps Comparison

Long-term Land Cover (LLC) Strata





Row	Class_Names	Color
0		
1	persistent forest-like class	
2	persistent non-forest like class	
3	forest-like transitional class	
4	agricultural-like class	
5	possible persistent herbaceous/shrub from C3	
6	possible persistent herbaceous/shrub from C4	
7	possible persistent herbaceous/shrub from C2	

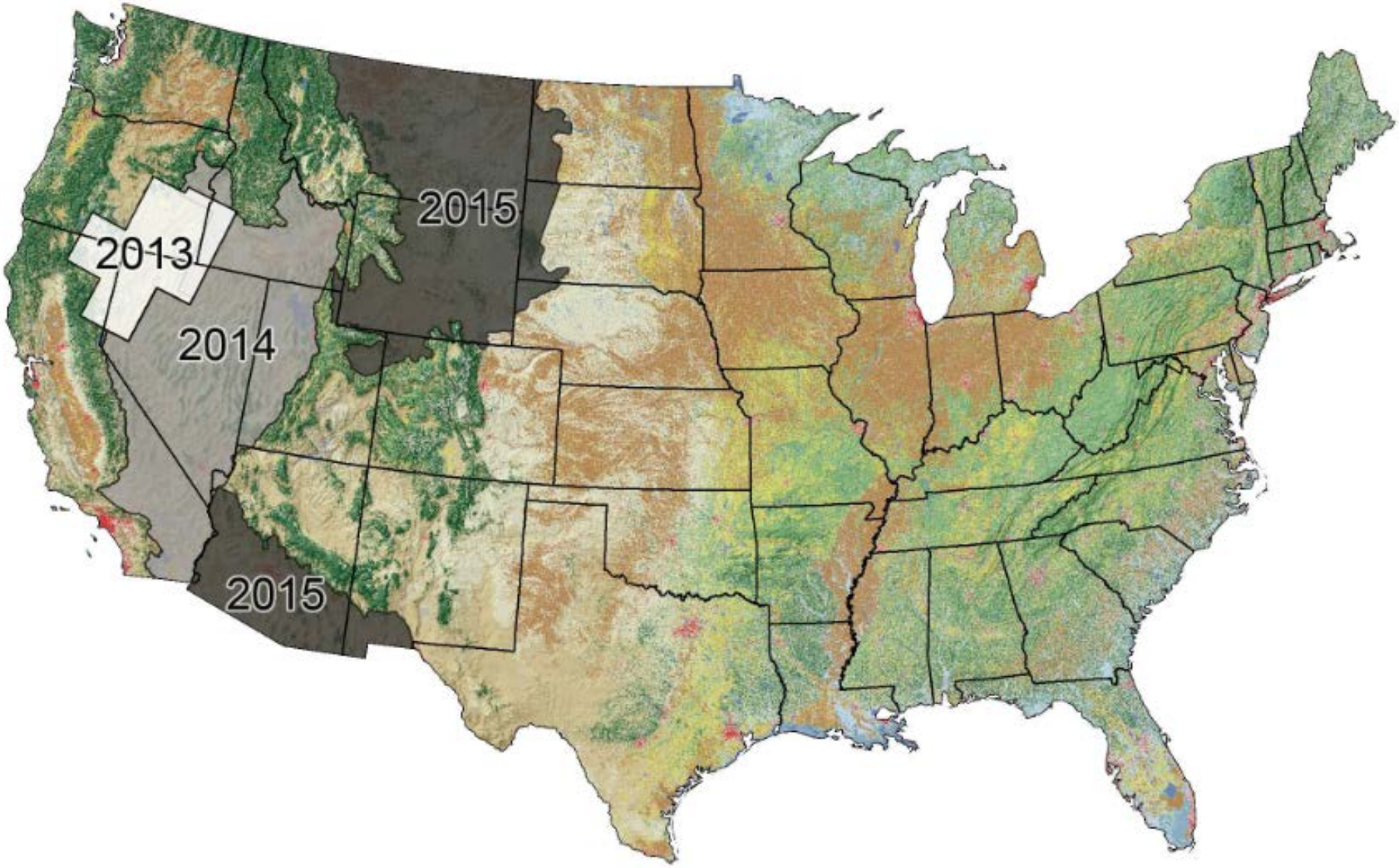
LLC_2001-2014

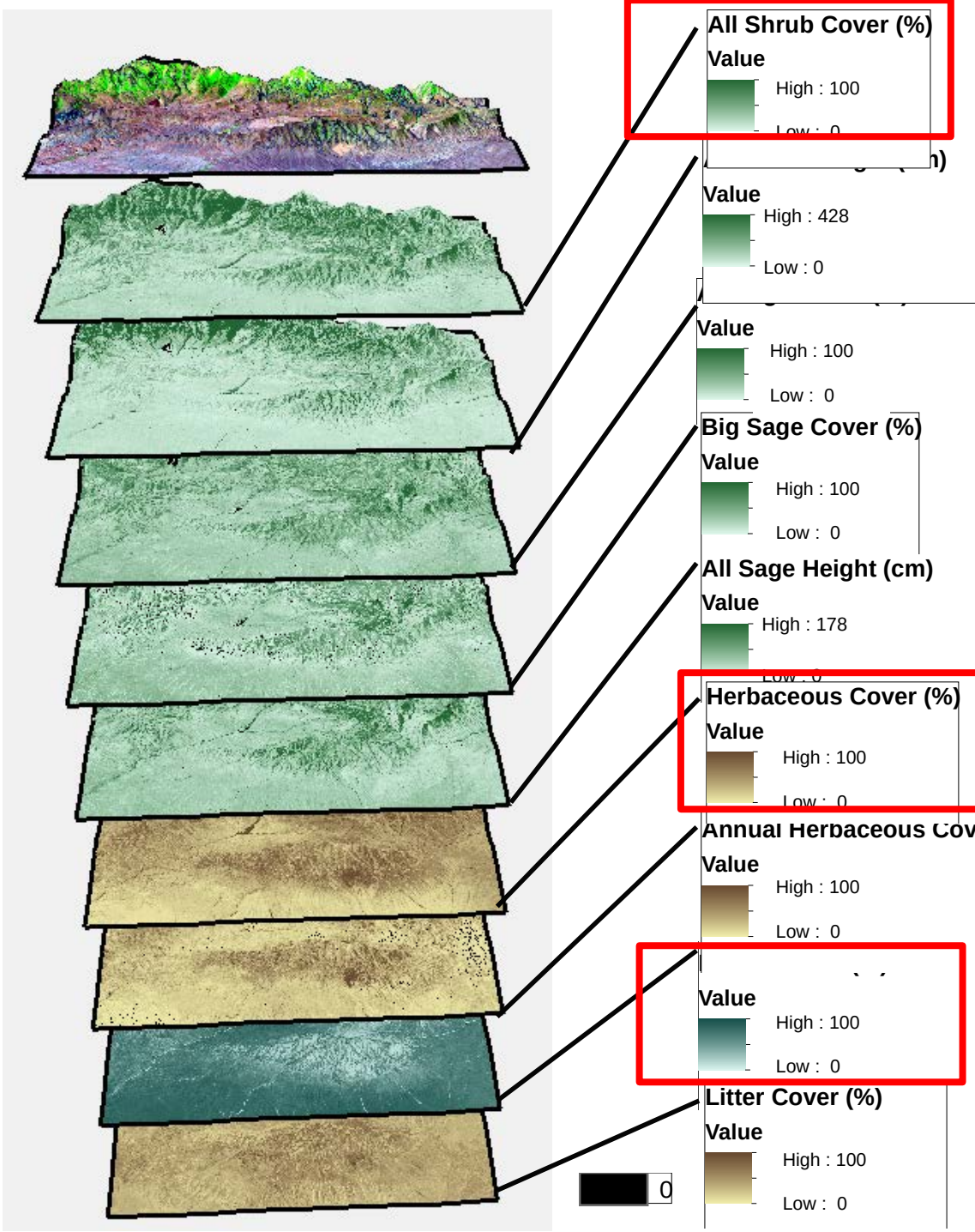
LLC_1986-2011

Proposed methods for NLCD 2016 change detection/labeling

1. Prepare images from 2001-2016 at every 2-3 years interval: one leaf-on image for each period, extra 1-2 Landsat 8 images for 2016
2. Derive disturbance-year map and LLC map
3. Develop training data for 2016 and run classification
4. Use similar procedures developed before to produce new NLCD 2011, NLCD 2006, NLCD 2001; NLCD 2008; NLCD 2003
5. Post-processing (best base, consistent/reasonable changes)

NLCD Shrubland Products Schedule





9 Shrub component products now being produced with values in 1% increments

Red box components proposed for NLCD

U.S. NALCMS Potential contributions

- NLCD 2016 will be finished by 2018
- Data cubes of Landsat will soon be available back 30 years for temporal change analysis
- NLCD 2016 will serve as a base for future versions of landcover on a more frequent basis
- Other fraction veg products and change will continue to be developed and spin off

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Other Future Data Considerations

- **Land Change Mapping and Analysis**
  - Creeating Landsat Data cube for 30 years
  - Also labeling landcover using Woodcock/Boston CCDC alogrythm
- **Essential Climate Variables**
  - ✓ Burned Area
  - ✓ Surface Water Extent
  - Validation Protocols
  - Global 30m Land Cover
  - Snow Covered Area
  - ✓ Above Ground Biomass

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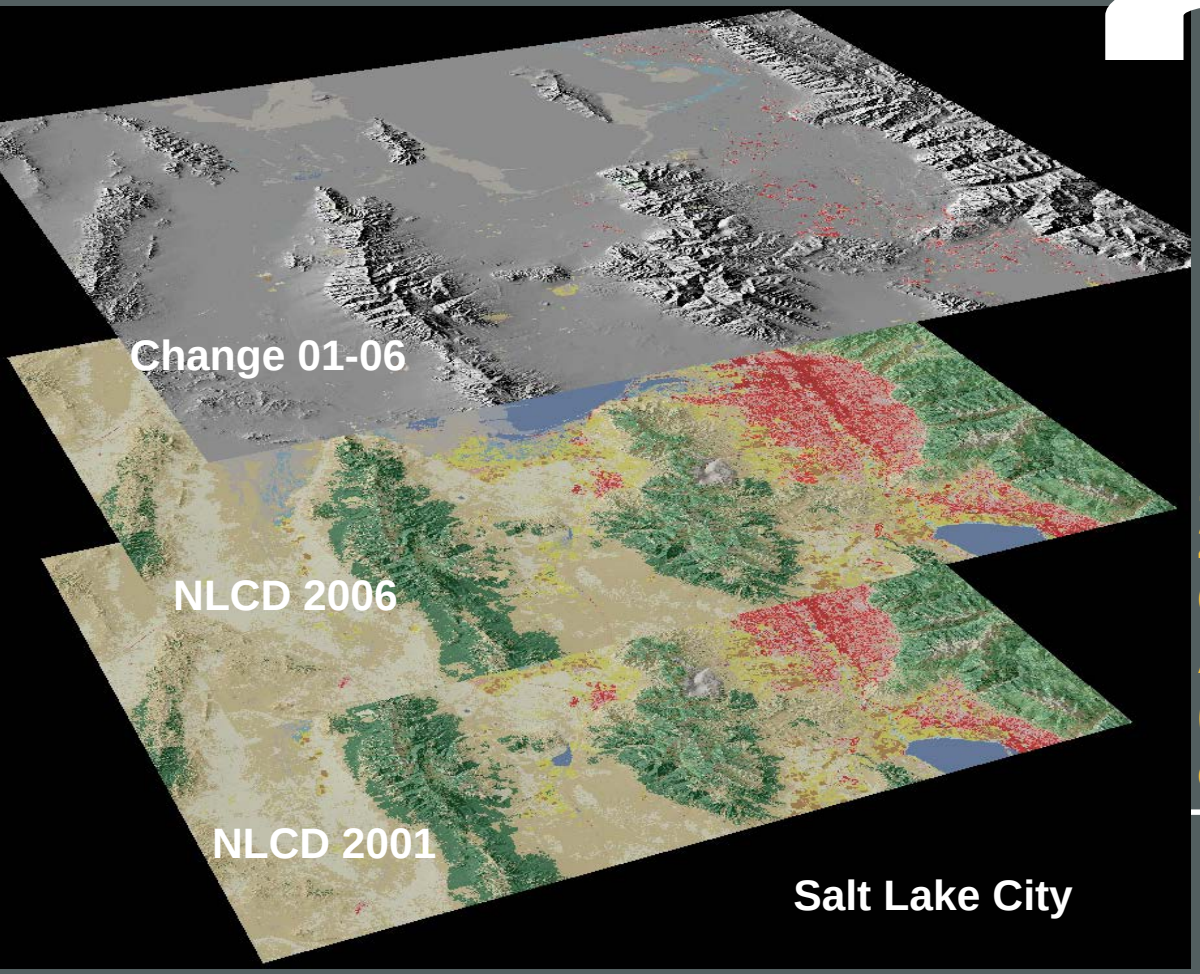
Cut

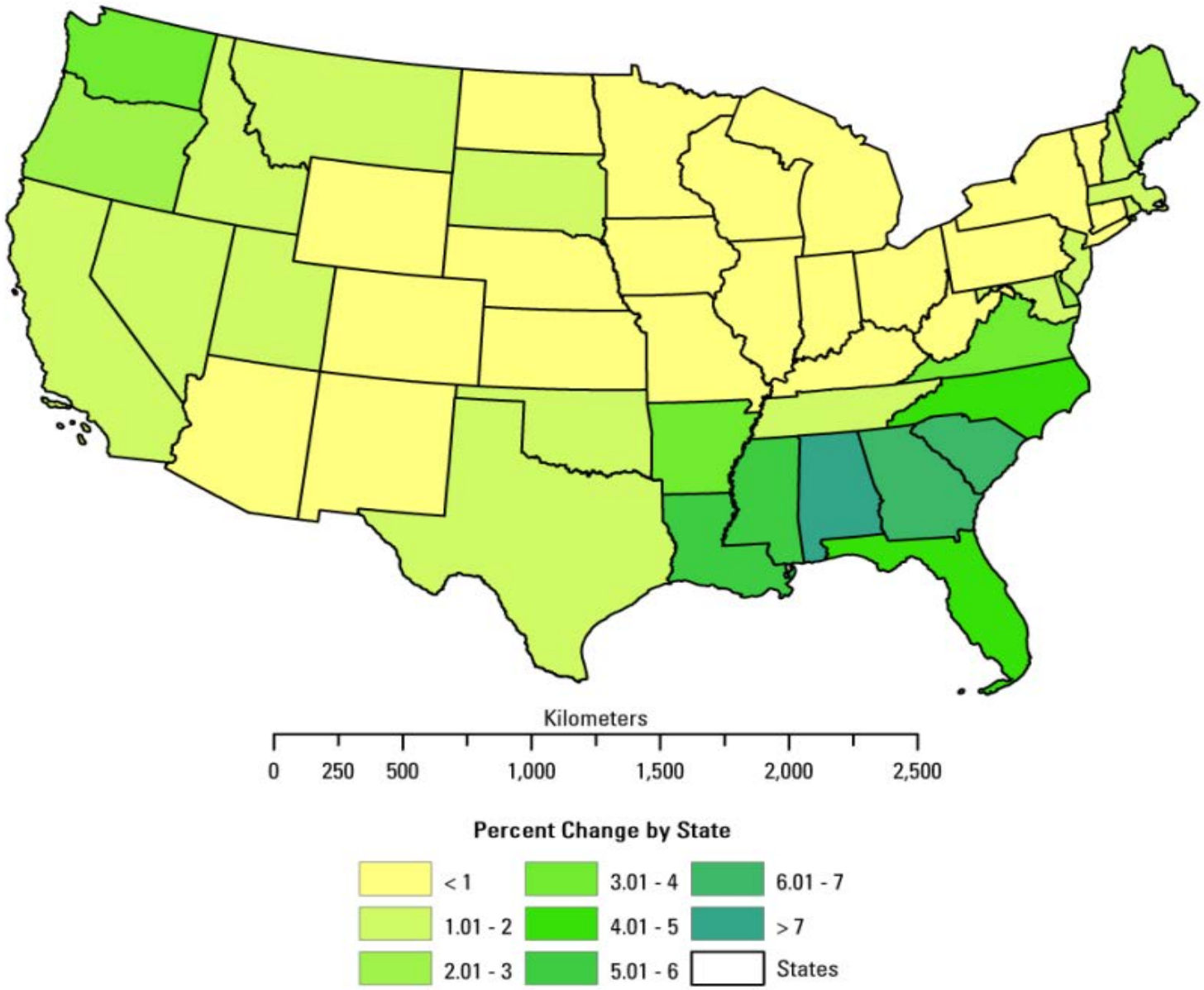
National Land Cover Database (NLCD) 2006 (48 states)

NLCD serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. It is created every 5 years with multiple Federal partners

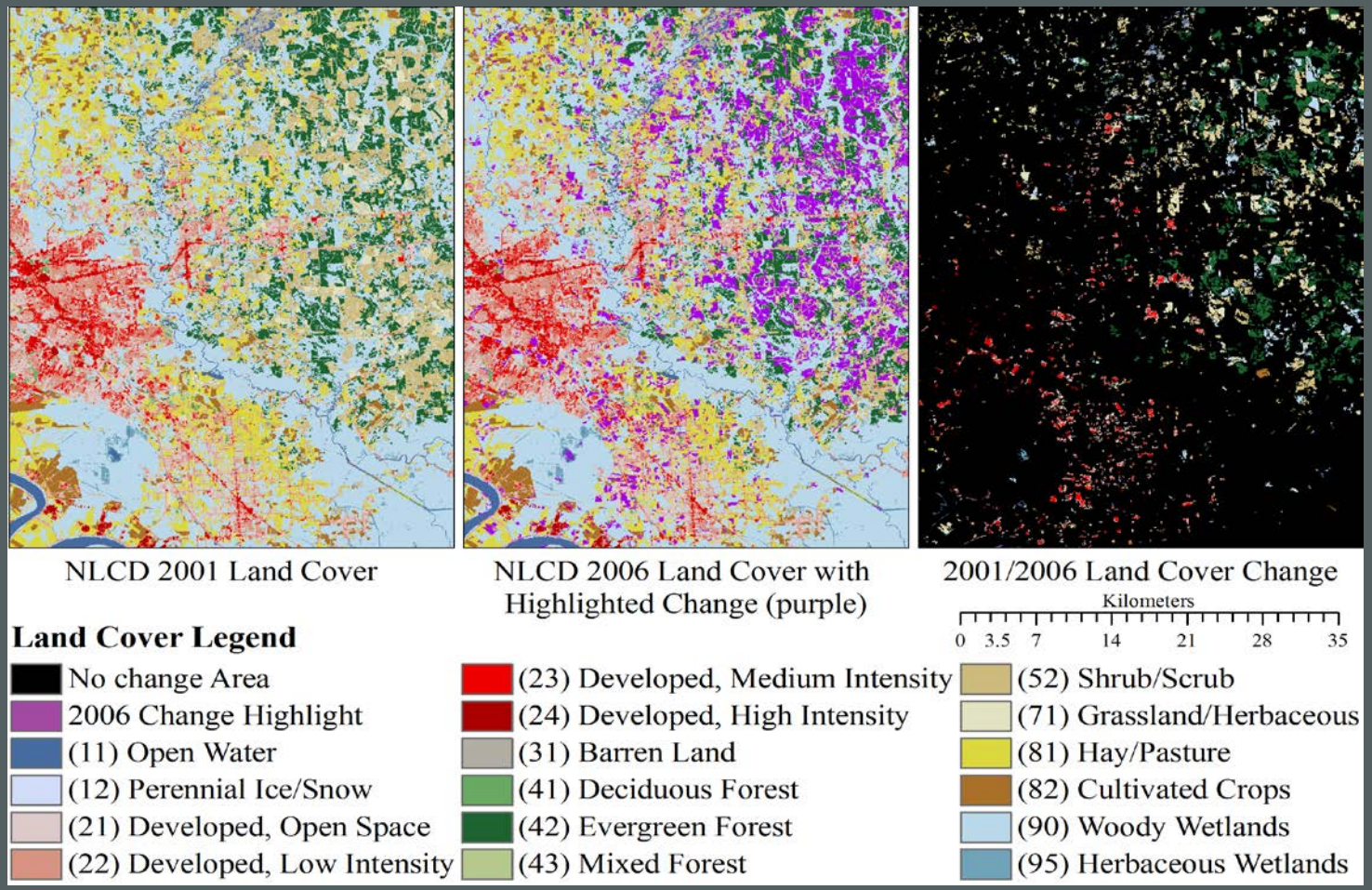


NLCD 2006 documented 1.67% land cover change from 2001–2006 over the Conterminous U.S.
An area of 135,384 sq. km (about the size of the state of Alabama)

NLCD 2001-2006 Total Change, by State



Southeast US is area of most change: NLCD 2006 Land Cover Change Pixels, Forest and Urban Change near: Baton Rouge, LA



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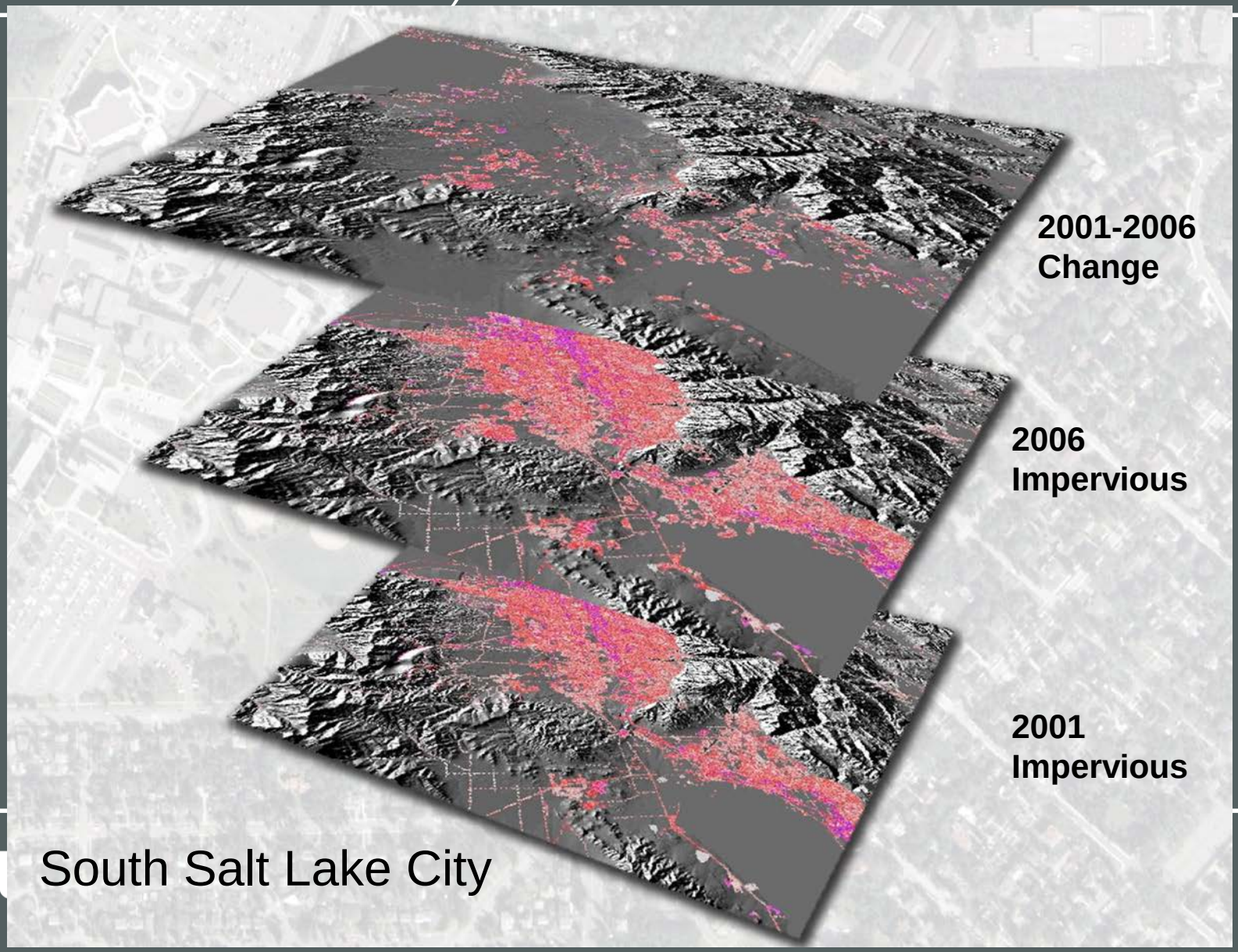
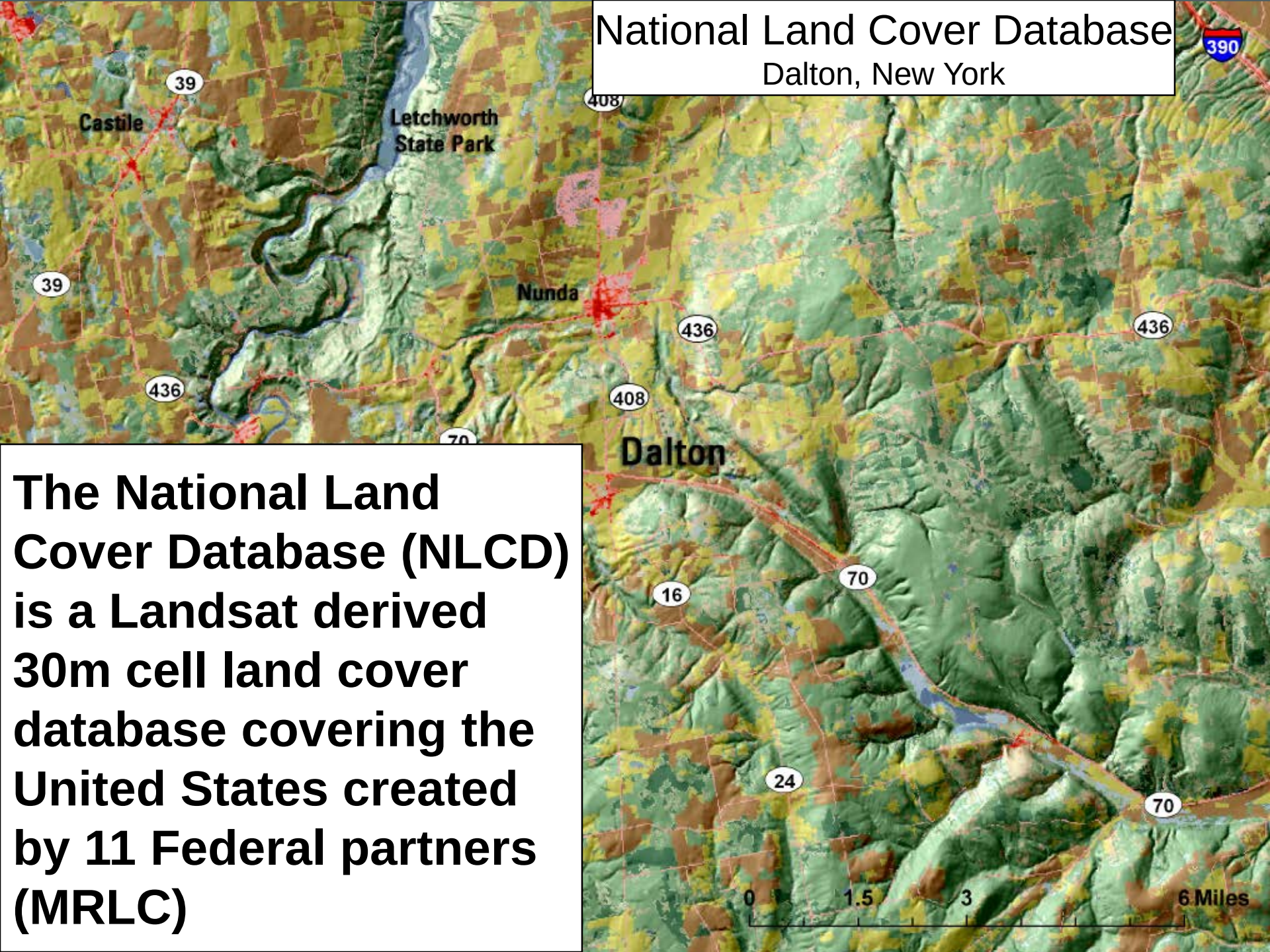
NLCD Imperviousness - monitoring gradual change

(4.11% increase in 48 states)



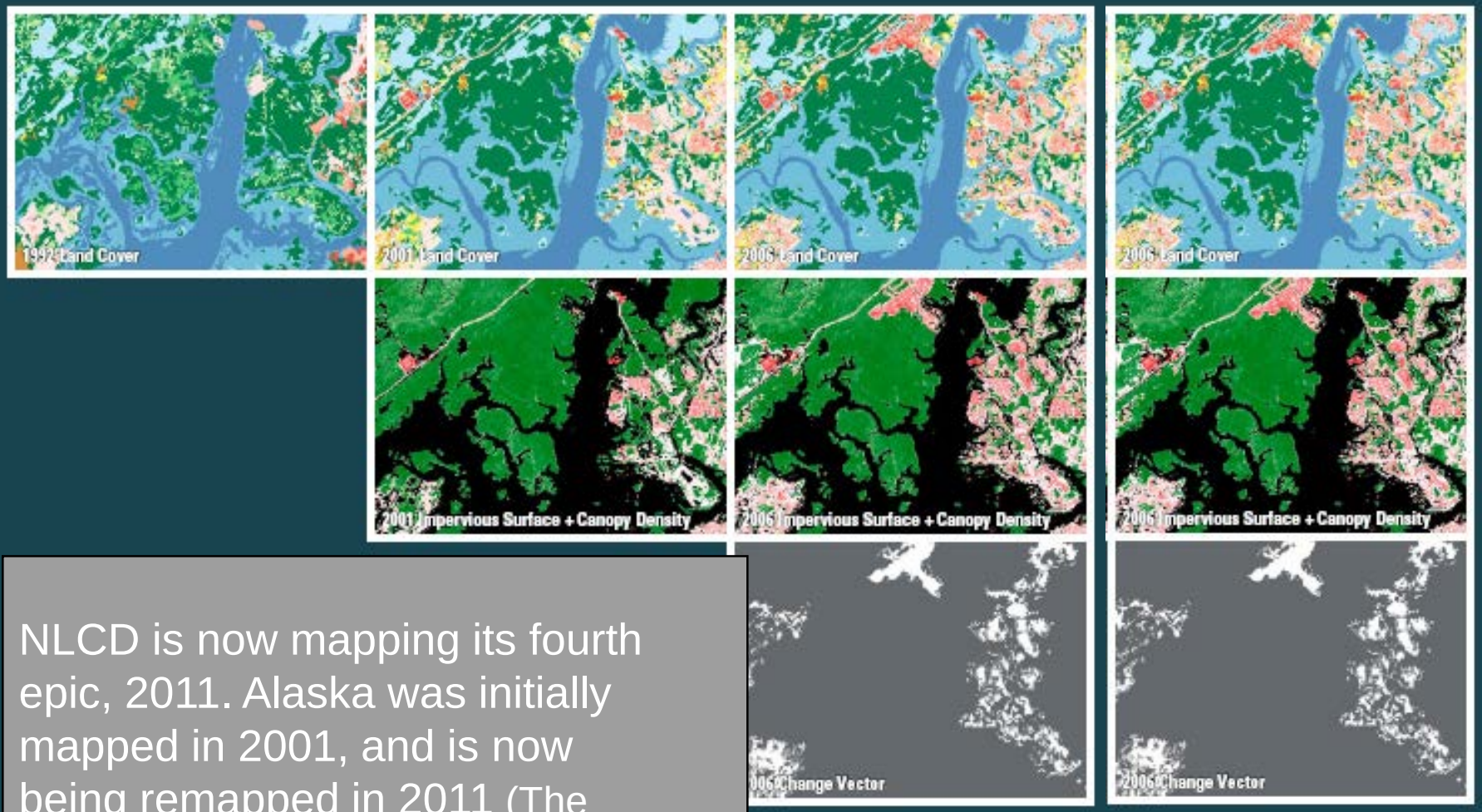
National Land Cover Database

Dalton, New York



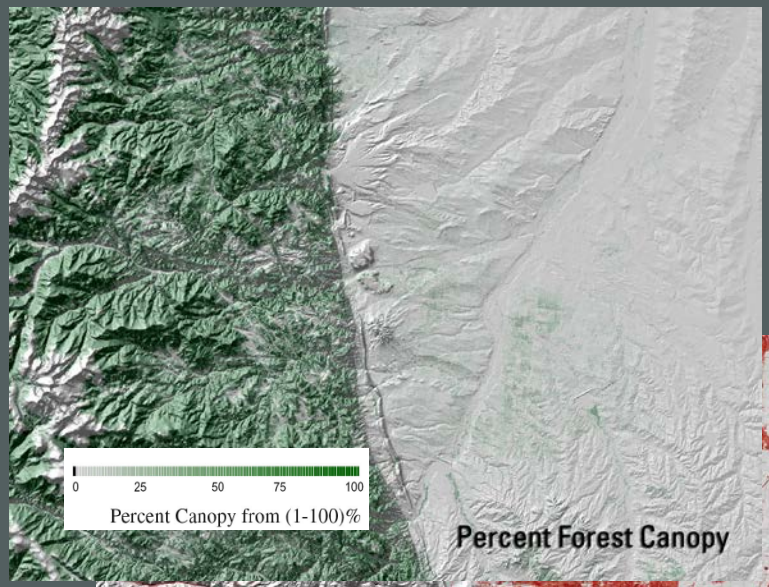
The National Land Cover Database (NLCD) is a Landsat derived 30m cell land cover database covering the United States created by 11 Federal partners (MRLC)

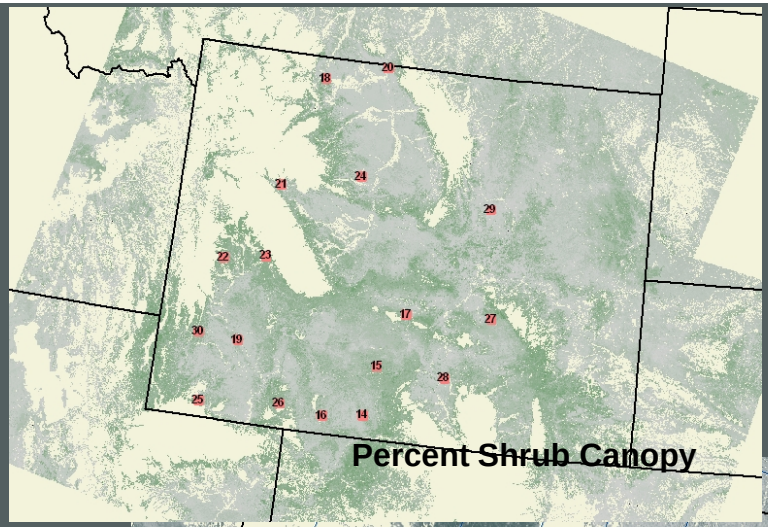
1992 2001 2006 2011

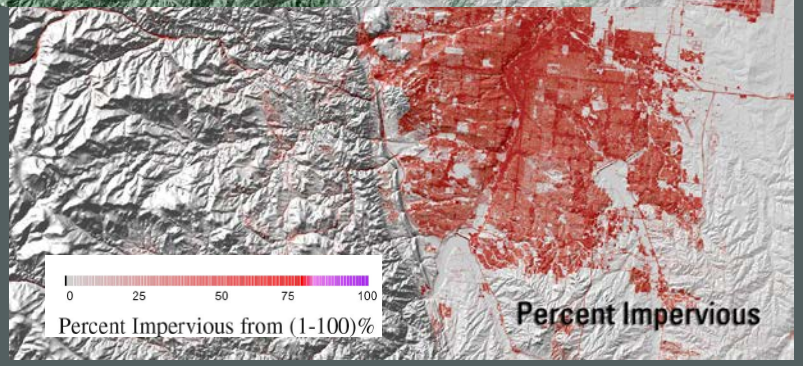


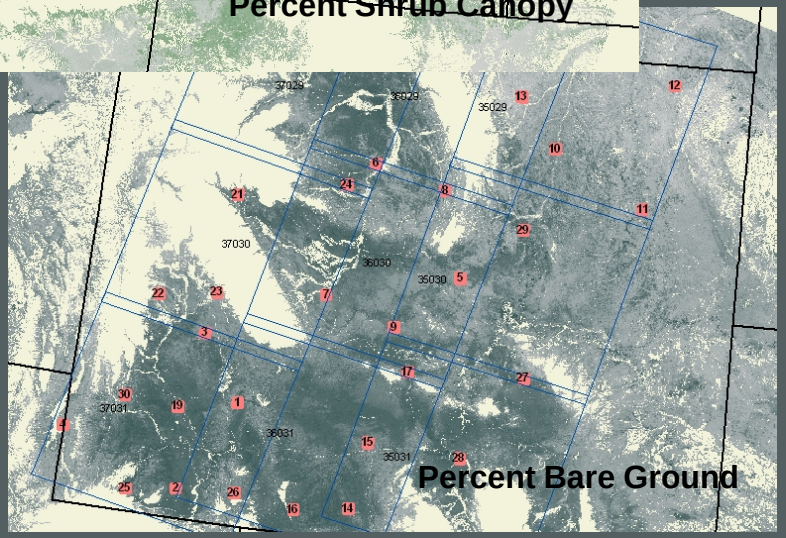
NLCD is now mapping its fourth epic, 2011. Alaska was initially mapped in 2001, and is now being remapped in 2011 (The lower 48 is on a five year interval, Alaska on a 10 year interval)

NLCD 2011 CONUS Products Beyond Land Cover



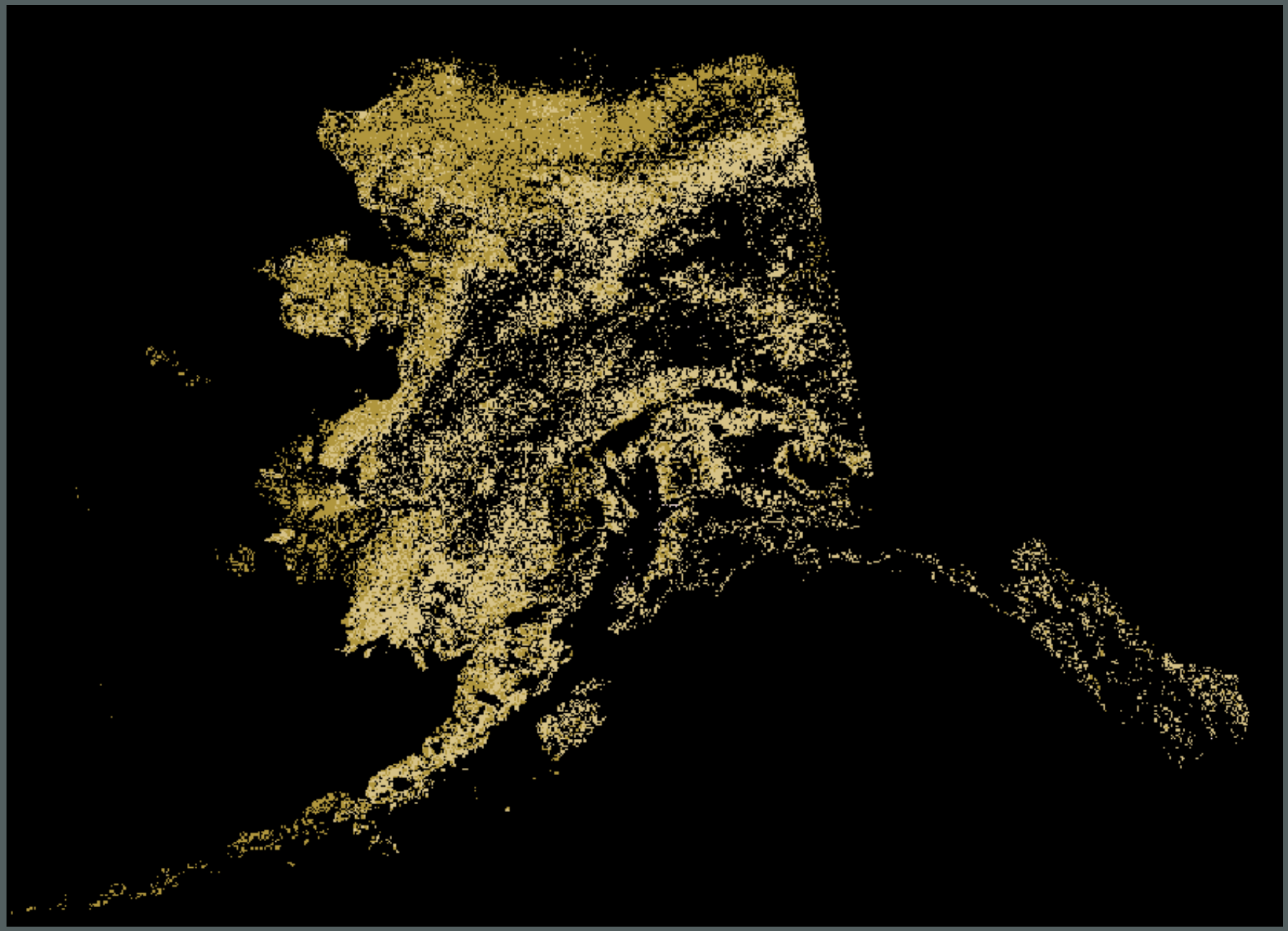






Moving database towards more physically based fractional vegetation (continuous field) products to address gradual change

Alaska NLCD shrub and dwarf shrub



Issues and what's next?

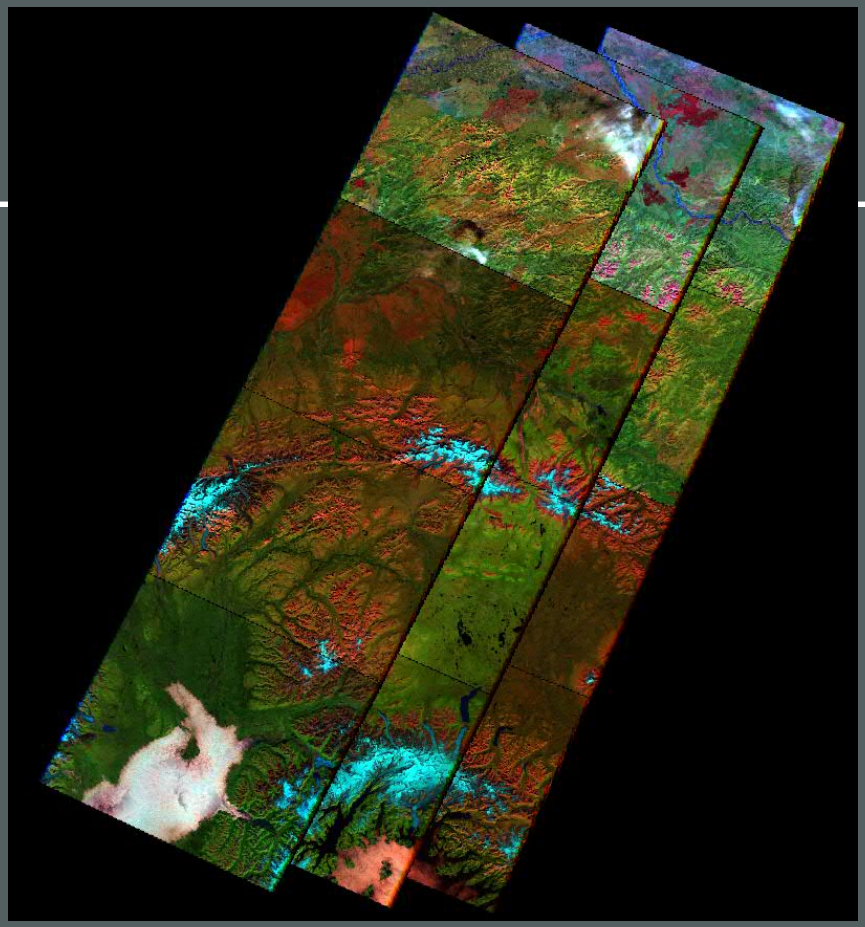
Issues on seasonal/phenology differences within a mosaic circa 2001 (2011) and between circa 2001 and 2011

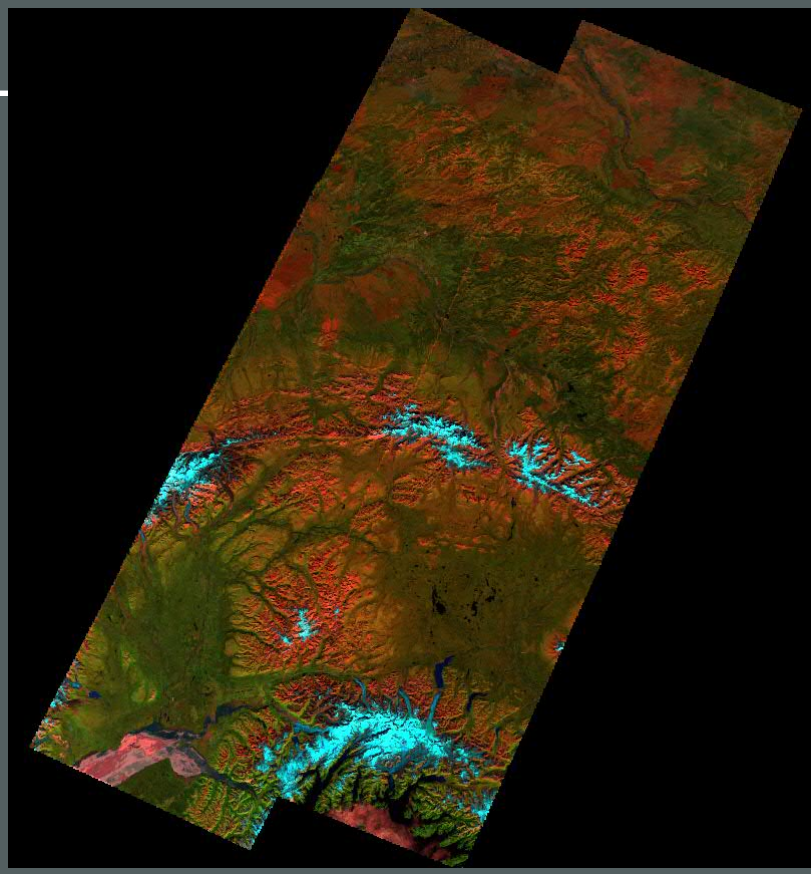
Is normalization process to minimize the seasonal differences needed

Test sensitivity of spectral change detection results using single scene and mosaic (MIICA, ZONE models)

Evaluation of the spectral change detection results by different approach (e.g. single scene vs. mosaic)

Applicability of the method for other areas in Alaska, more test





Example of ”chunk” compositing testing using Landsat 5 in southern Alaska

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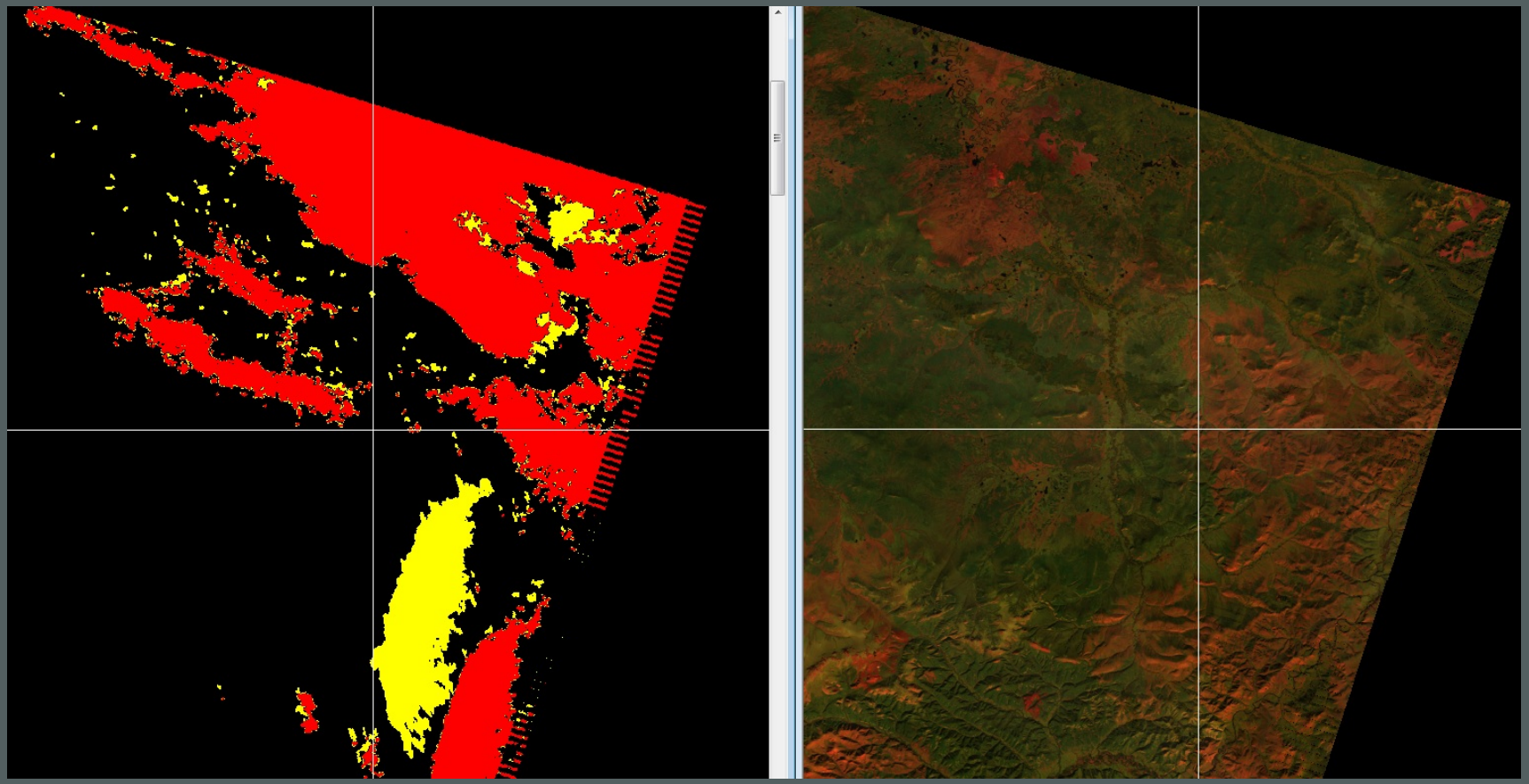
Landsat chunk compositing example in southern Alaska



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On-going activities and schedule

- Initiating Alaska Landsat image selection and pre-processing
- Finalizing key ancillary datasets for mapping
- Conducting test of operational mapping
- The Statewide operation will start early 2014 (coordinated by Leila Gass at USGS Western Center)
- First draft of statewide LC and LCC update by July, 2014
- The final product release by Sept. 2014.

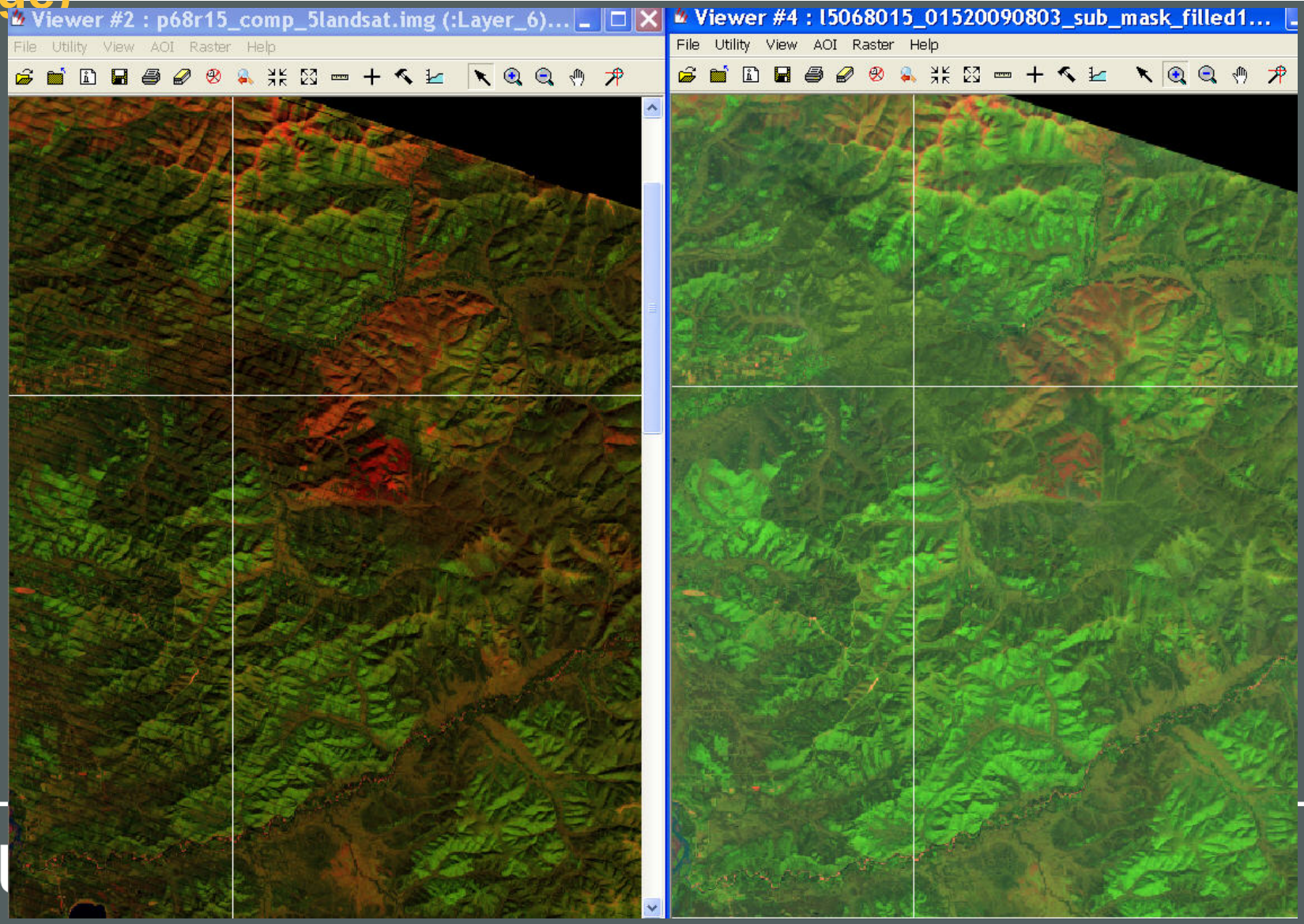
USGS

Outline

- NLCD general background
- Alaska NLCD
- NLCD change protocol and results
- NLCD 2011 Alaska plan
- Future NLCD direction

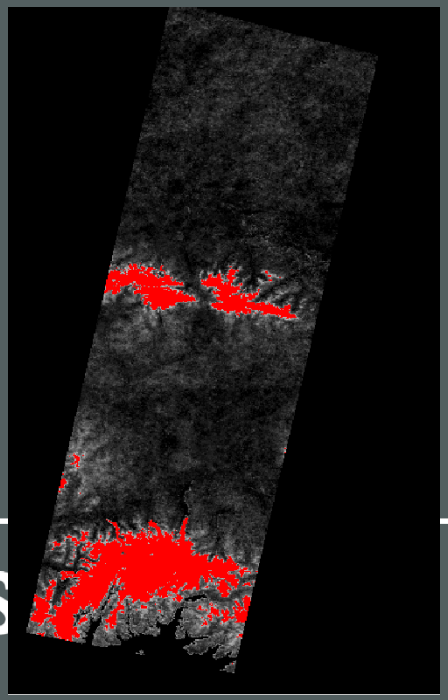
USGS

An example (retain the largest portion of a good based image, fill the gap using SSG method based on a reference image)



Approach to change detection for snow/ice

1. **Use Landsat-based change vector, snow/ice detection algorithm, and topography data (shadow area) to detect changes**
2. **Integration of time series MODIS ice/snow product to measure persistence of the ice/snow**



Snow extent June-Sept. 2010, 2011, 2012

Frequency of snow occurrence (red >80%)