From CCDC to LCMAP

Zhe Zhu[1], LCMAP Group[1,2], and Curtis Woodcock's Group[3]

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ASRC FEDERAL

InuTeq

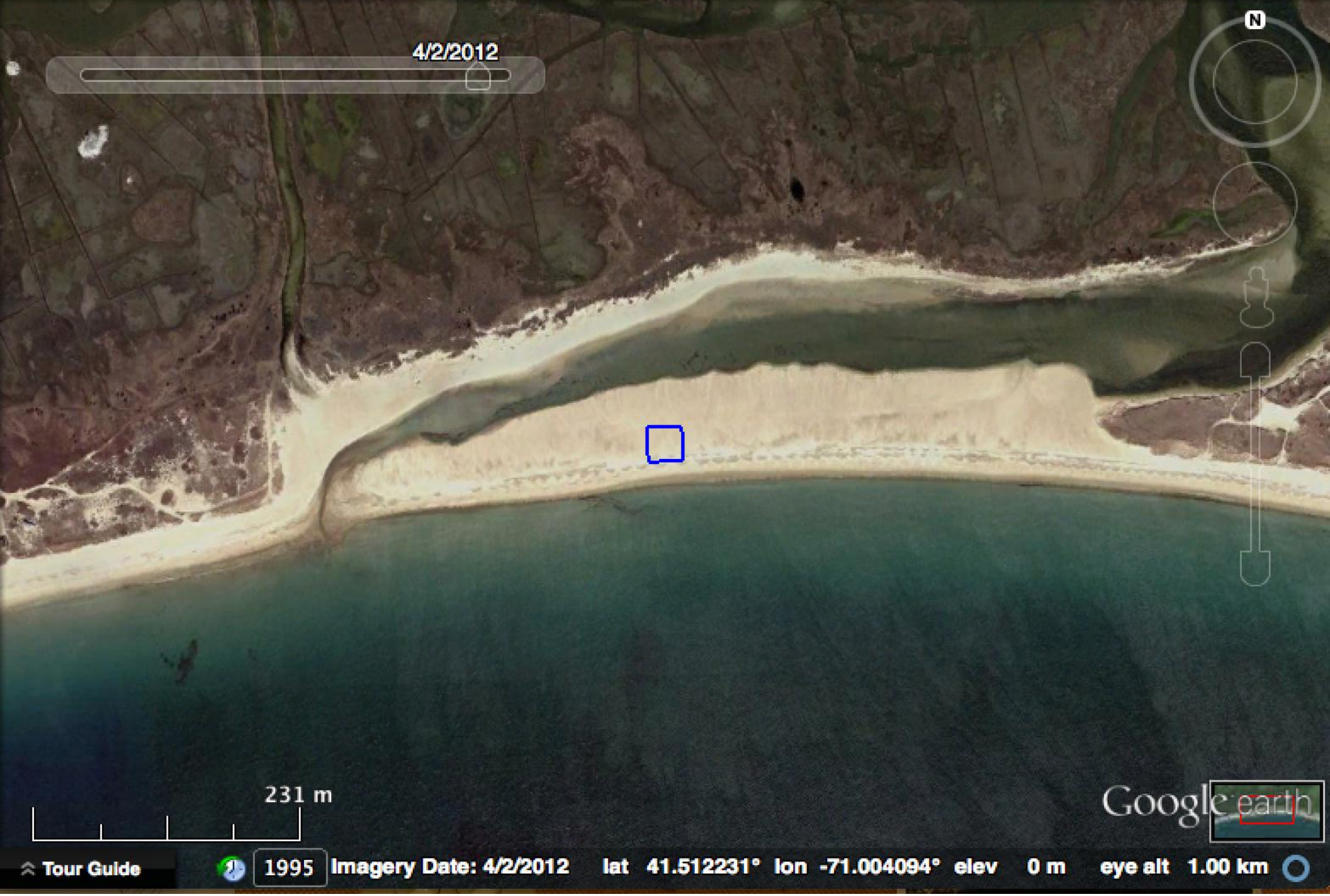
USGS

science for a changing world

BOSTON UNIVERSITY

Outline

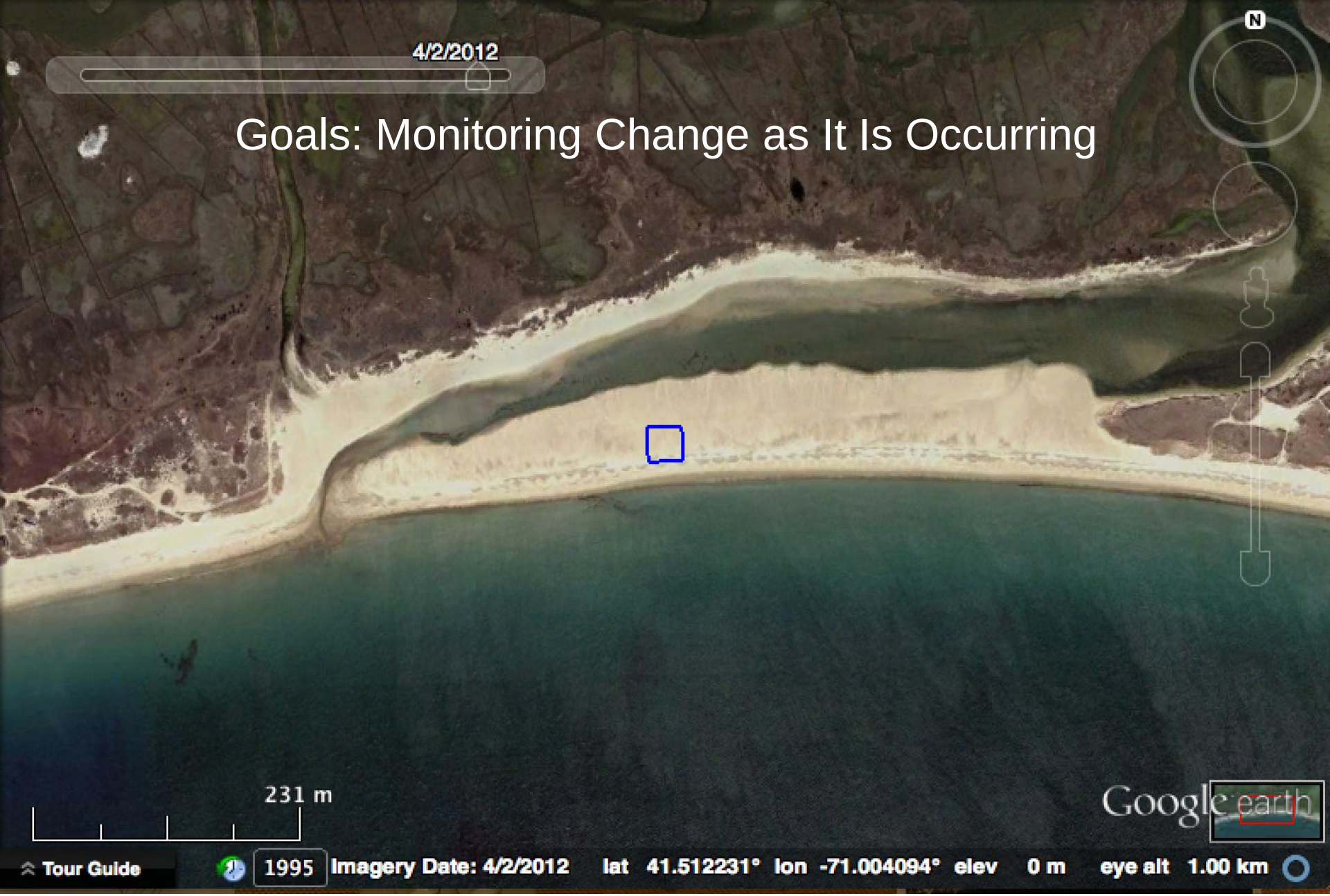
- The Use of All Available Landsat Data
- Continuous Change Detection and Classification (CCDC)
- Land Cover Monitoring, Assessment and Projection (LCMAP)
- Conclusion


4/2/2012
N
231 m
Google earth
Tour Guide
1995
Imagery Date: 4/2/2012
lat 41.512231°
lon -71.004094°
elev 0 m
eye alt 1.00 km

Inlet naturally shifts and closes, re-dig on a ~5 year cycle

Slide from Dr. Robert Buchsbaum, Mass Audubon

Inlet naturally shifts and closes, re-dig on a ~5 year cycle


4/2/2012
Goals: Monitoring Change as It Is Occurring
N
231 m
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Imagery Date: 4/2/2012
lat 41.512231° lon -71.004094° elev 0 m
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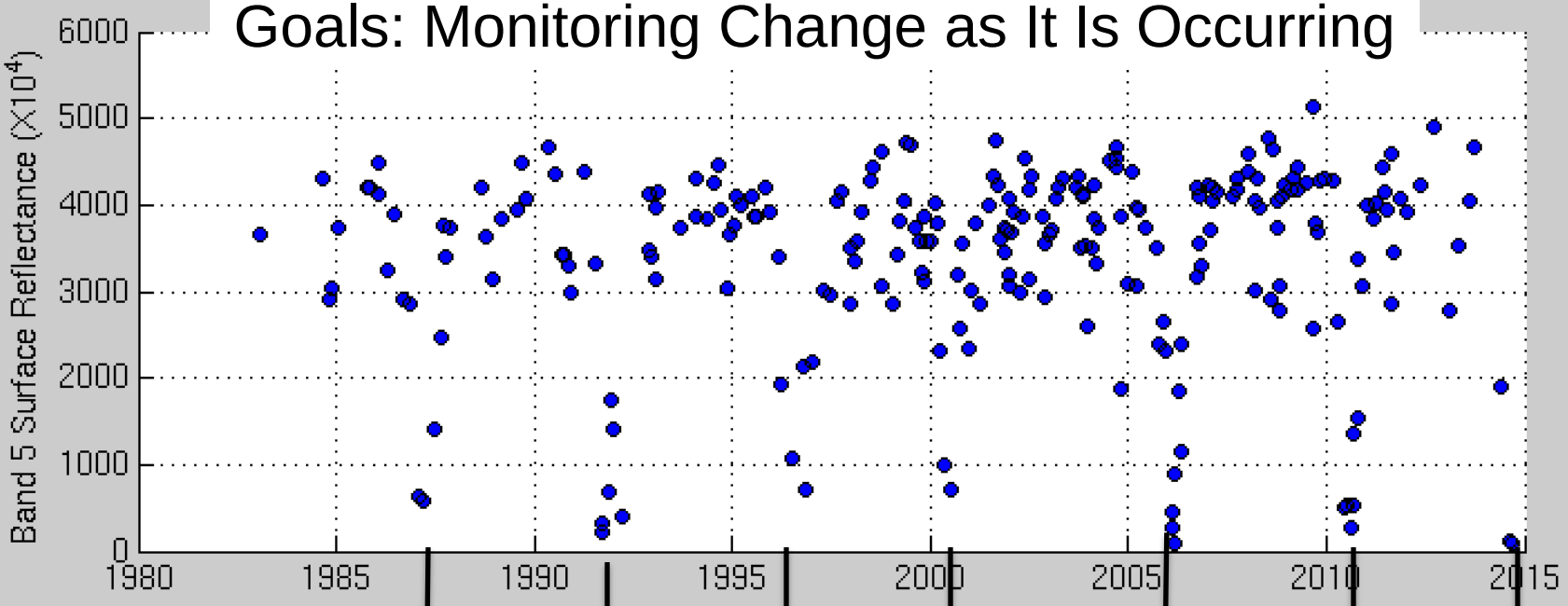
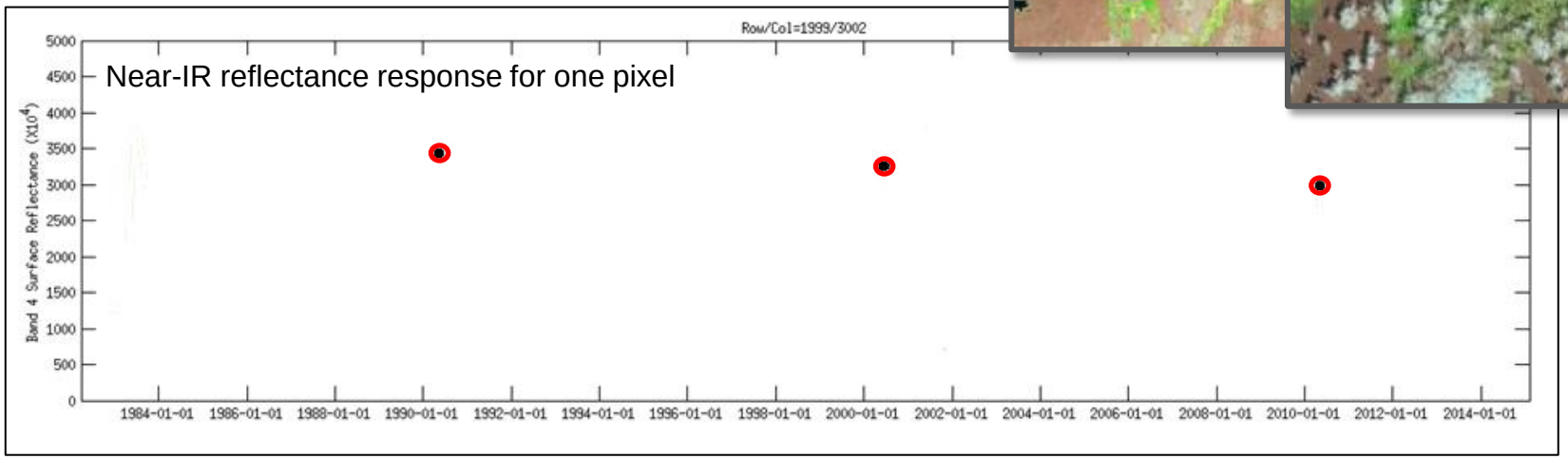
Goals: Monitoring Change as It Is Occurring



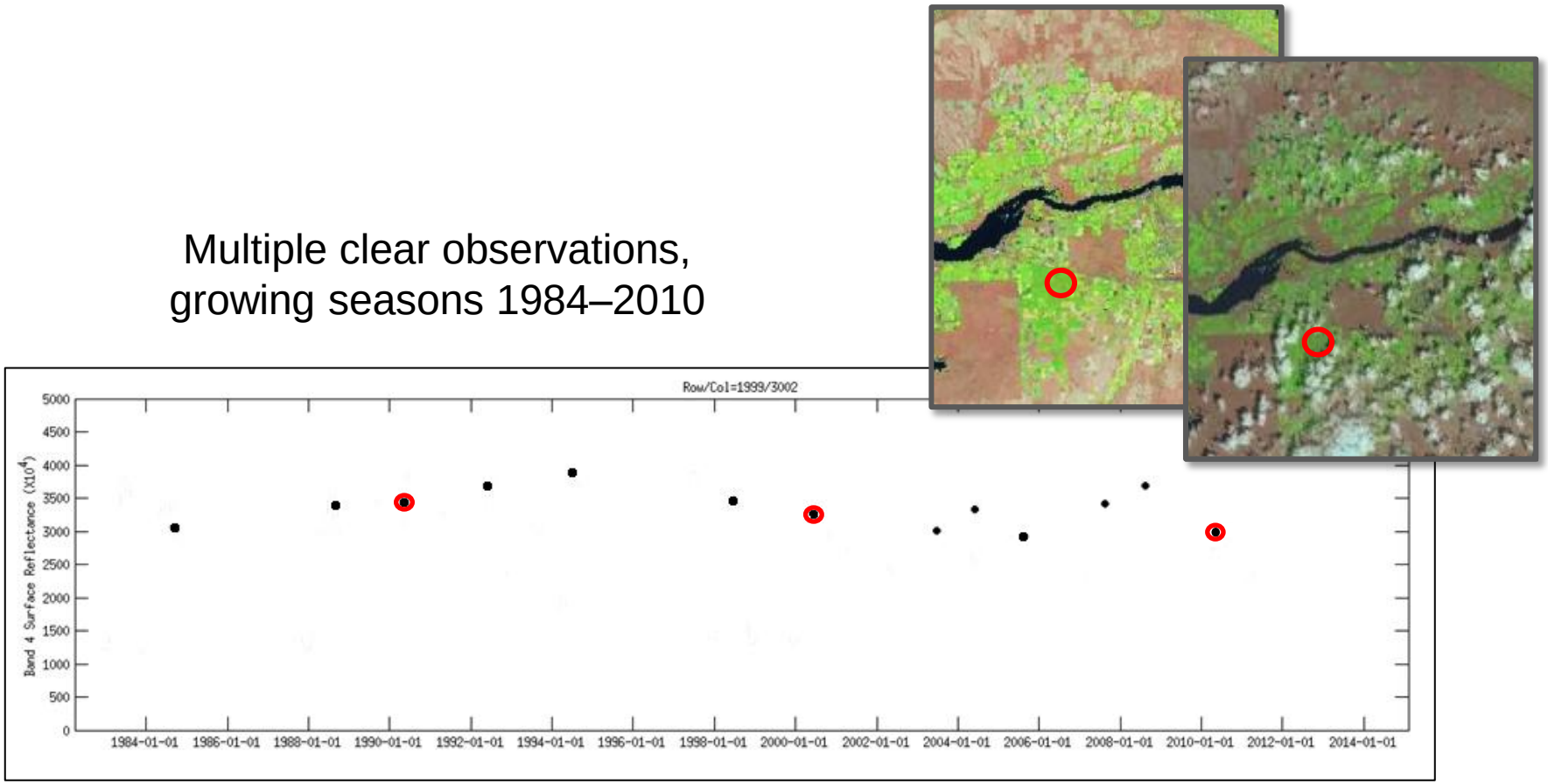
1987 — *5 yrs.* — 1992 — *4 yrs.* — 1996 — *4 yrs.* — 2000 — *5 yrs.* — 2005 — *5 yrs.* — 2010 — *4 yrs.* — 2014

Three decadal observations:
growing seasons 1990, 2000, and 2010



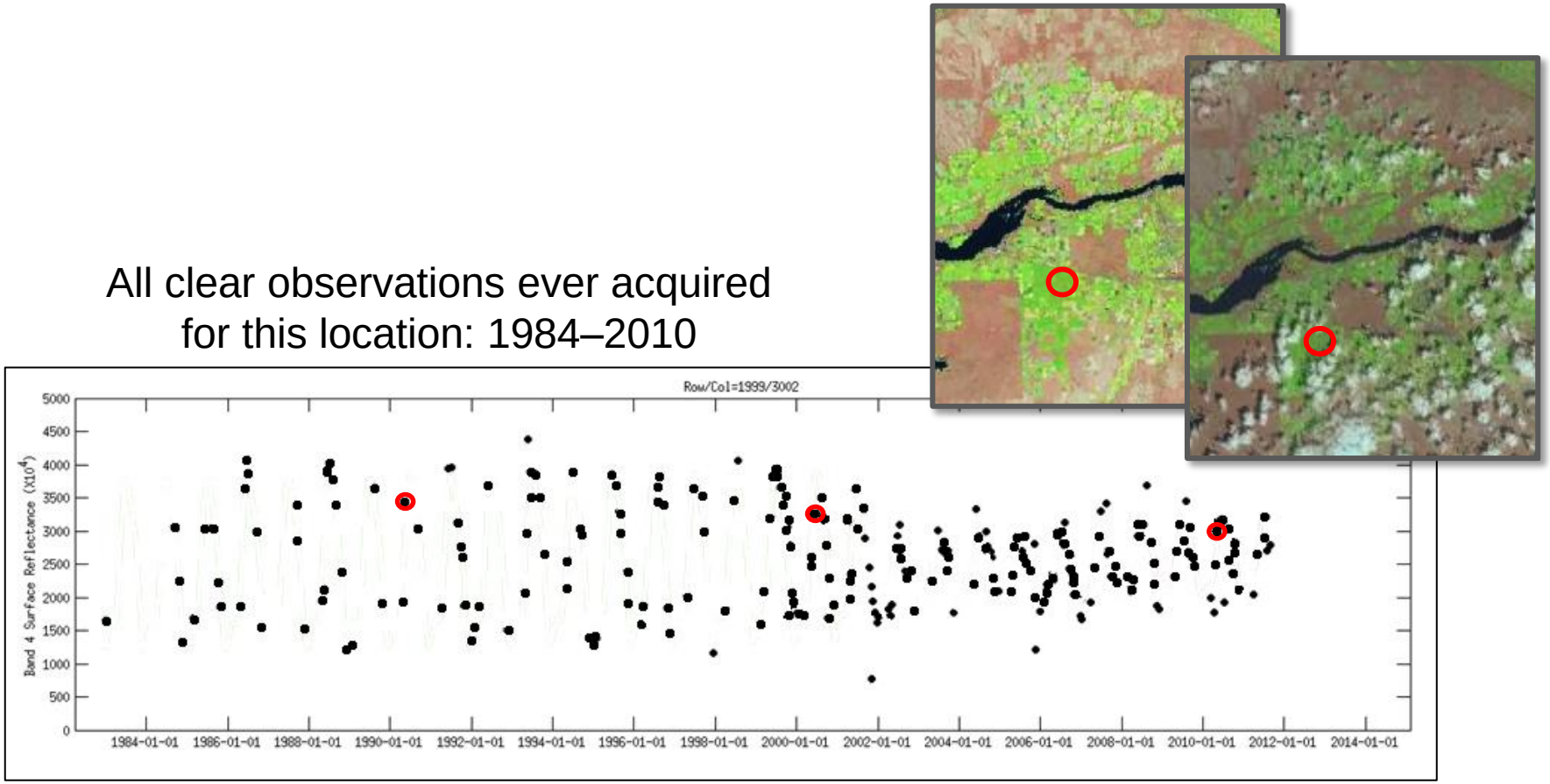
Landsat NIR (band 4) cloud-screened observations converted to surface reflectance using LEDAPS. Pixel row 1999, column 3002; WRS-2 path 12, row 31

Multiple clear observations,
growing seasons 1984–2010



Landsat NIR (band 4) cloud-screened observations converted to surface reflectance using LEDAPS. Pixel row 1999, column 3002; WRS-2 path 12, row 31

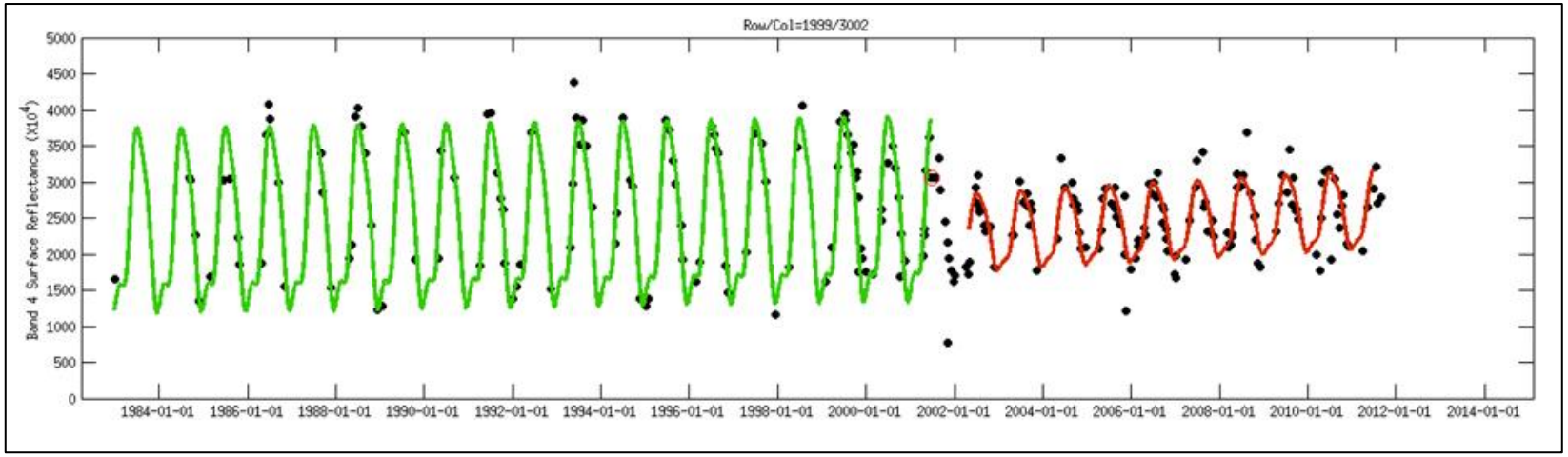
All clear observations ever acquired
for this location: 1984–2010



Landsat NIR (band 4) cloud-screened observations converted to surface reflectance using LEDAPS. Pixel row 1999, column 3002; WRS-2 path 12, row 31

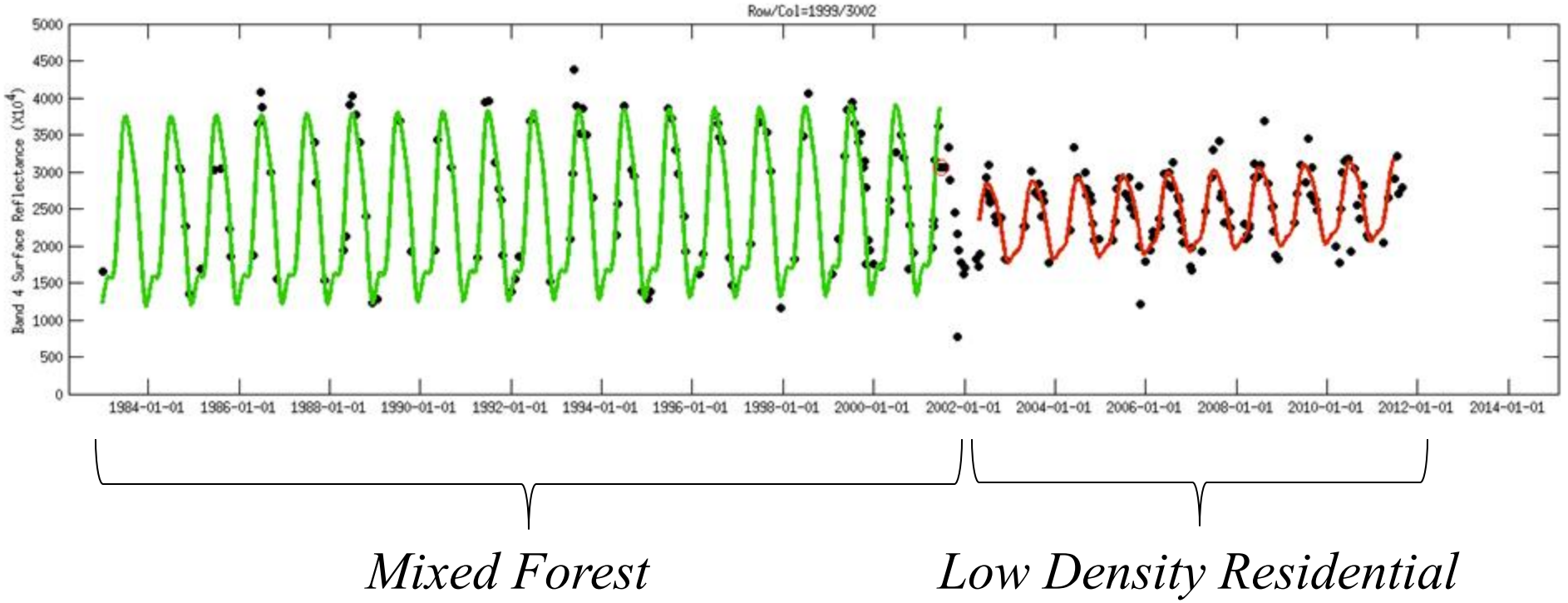
Continuous Change Detectionn and Classification (CCDC)

Mathematical prediction models fit to clear observations



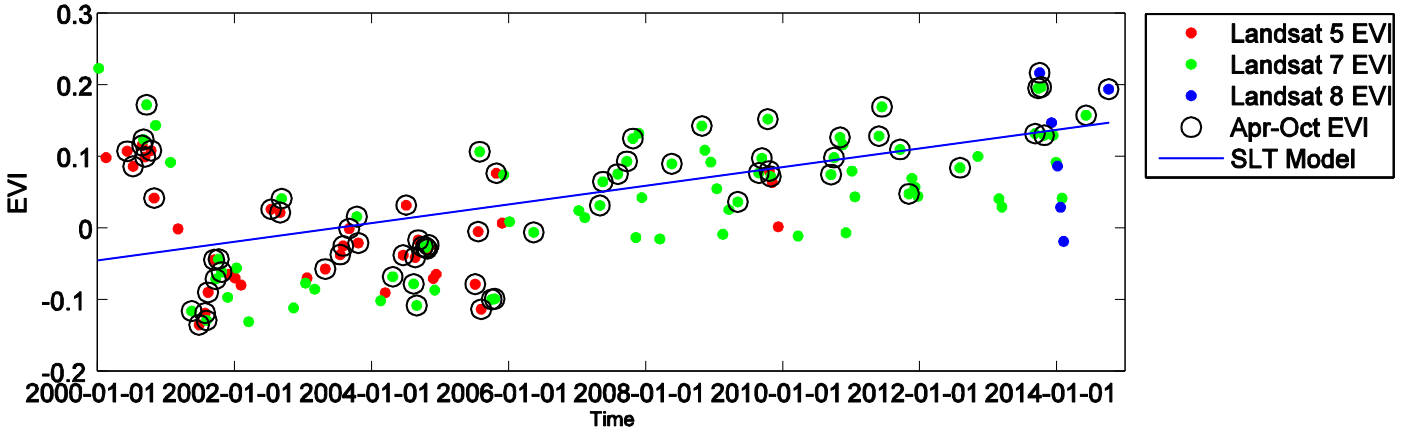
Reference: Zhu, Z. and C.E. Woodcock. 2014. Continuous change detection and classification of land cover using all available Landsat data. Remote Sensing of Environment 144:152–171.

Time Series Model Classified by Land Cover

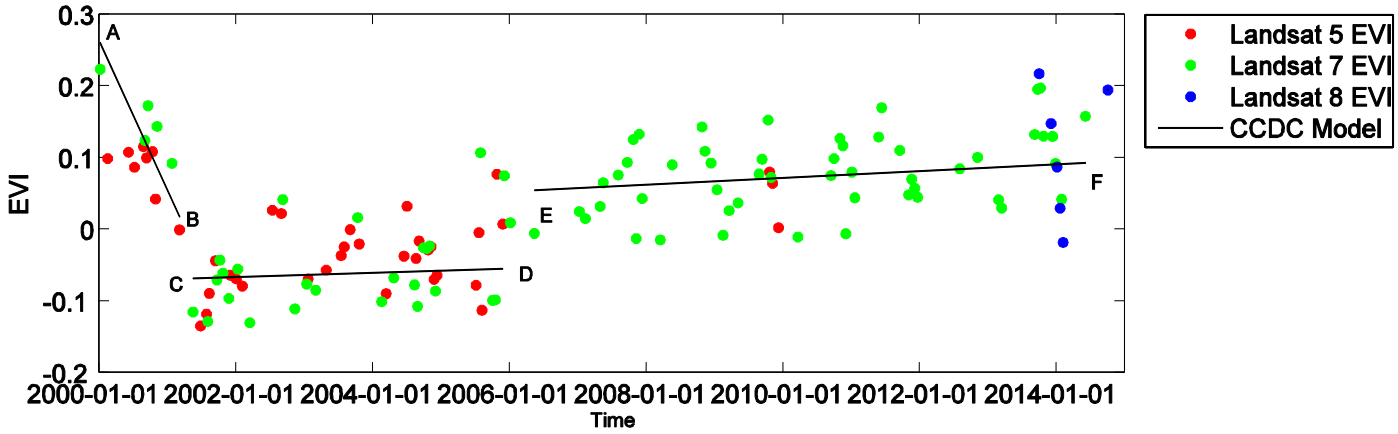


Gradual Change vs Abrupt Change

Simple Linear Trend (SLT)

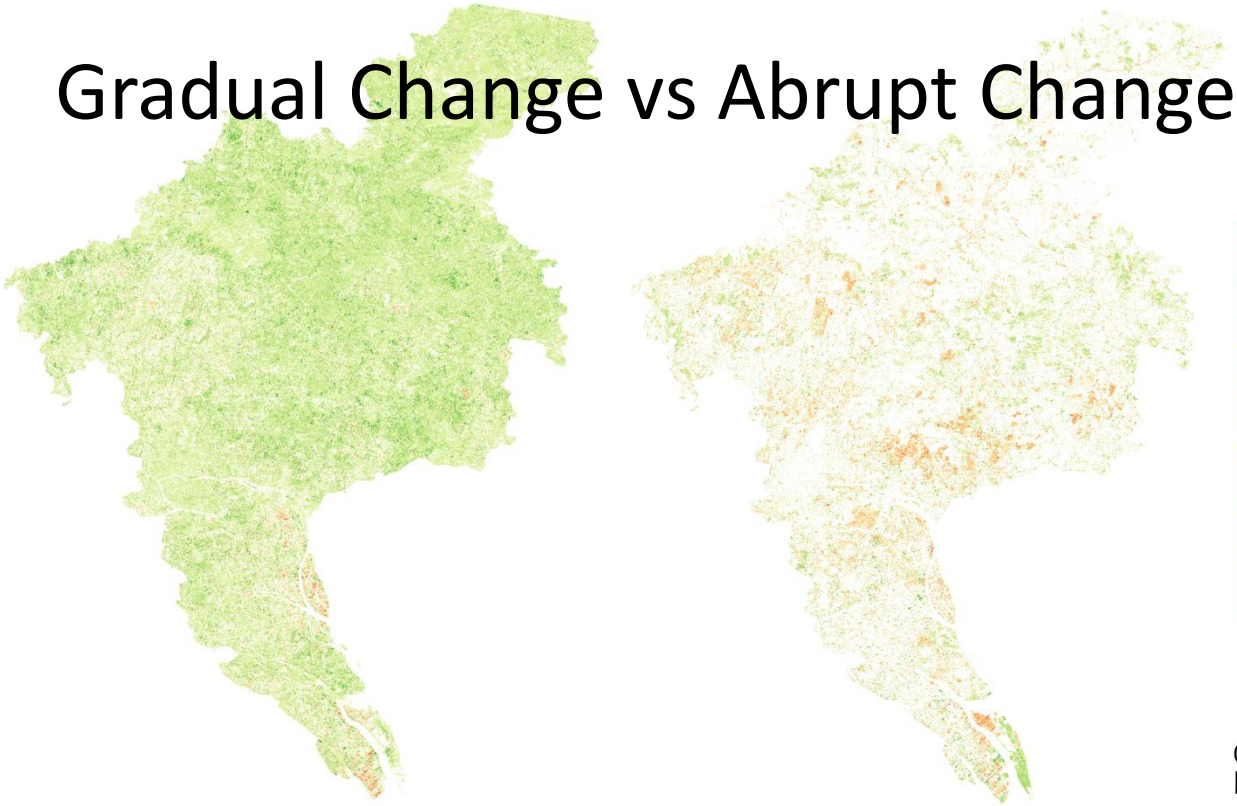


CCDC



EVI Change since 21st Century for Guangzhou City, China

Gradual Change vs Abrupt Change



Legend

EVI Change

- >-1.00
- >-0.50
- >-0.40
- >-0.30
- >-0.20
- >-0.10
- < 0.10
- < 0.20
- < 0.30
- < 0.40
- < 0.50
- < 1.00

0 20 40 60 km

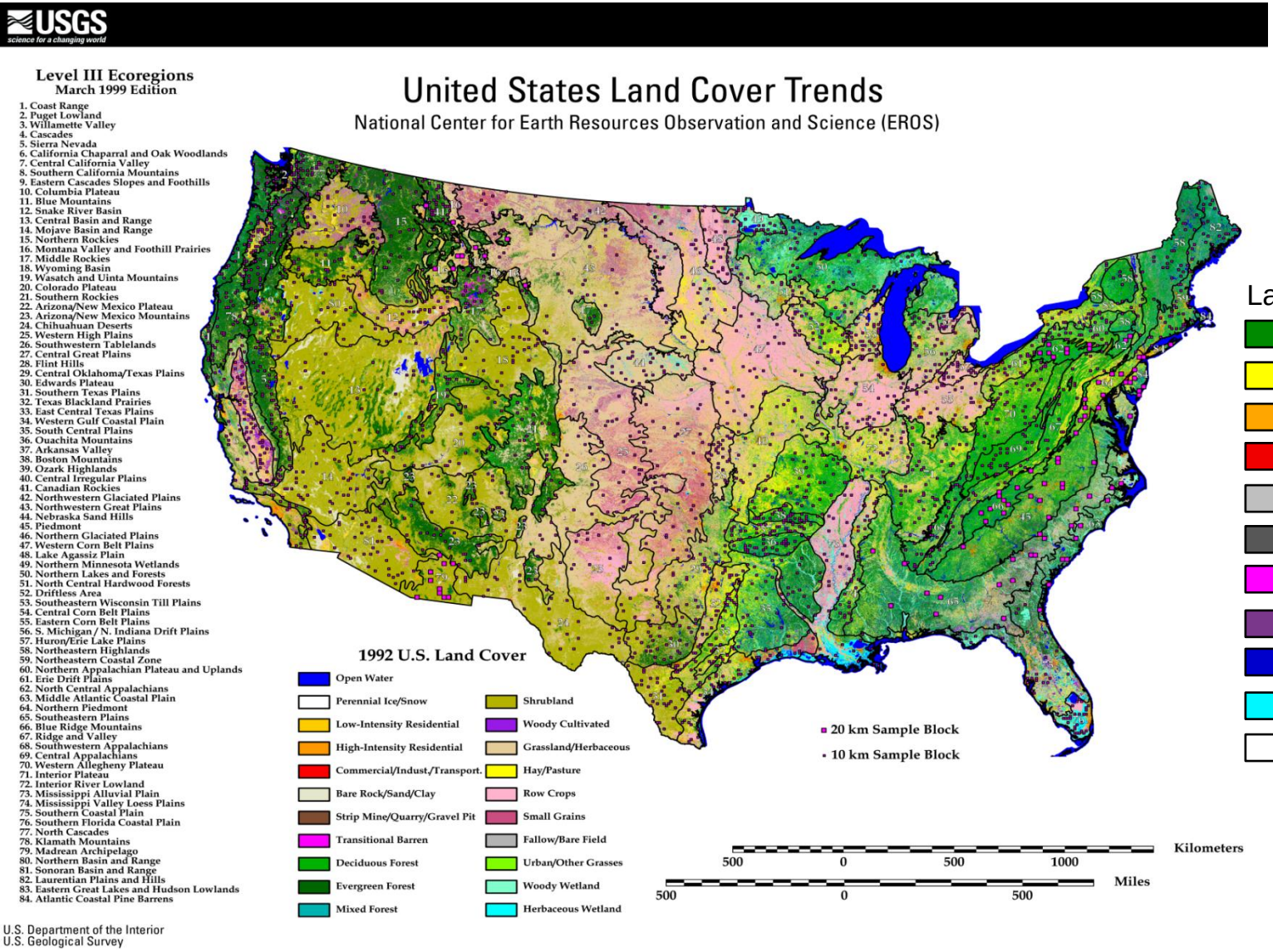
CCDC Flags

https://github.com/bullocke/LandsatDatabase/blob/master/PRmap.geojson

Algorithm Refinements

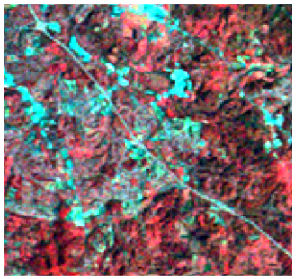
- More clear observations, more accurate time series models
- Least Absolute Shrinkage and Selection Operator (LASSO) fit
- Temporally adjusted threshold
- Change vector magnitude and probability-based threshold
- **Good training strategy**

Training data: USGS Land Cover Trends

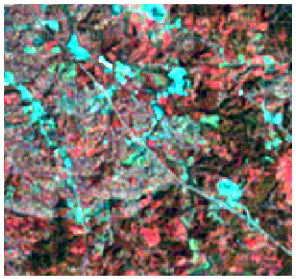


Ecoregion 71, Sample 955
1972 to 2000 Change

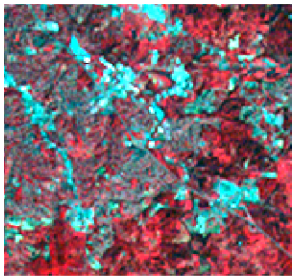
MSS 1972



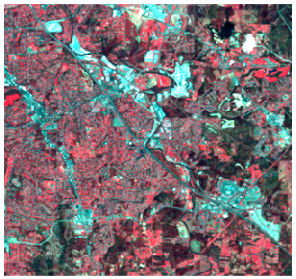
MSS 1979



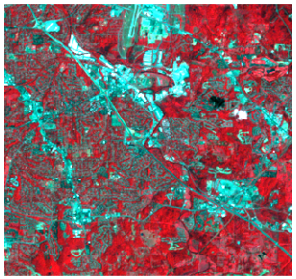
MSS 1986



TM 1992



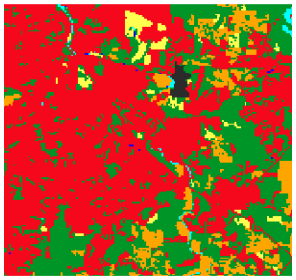
ETM 2000



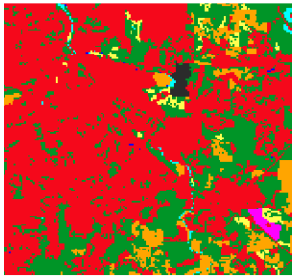
1972 Land Cover

1979 Land Cover

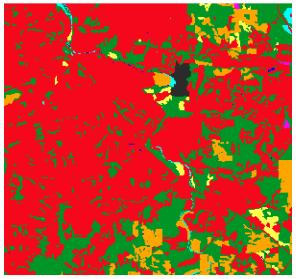
1986 Land Cover



1992 Land Cover

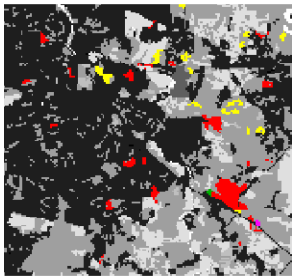


2000 Land Cover

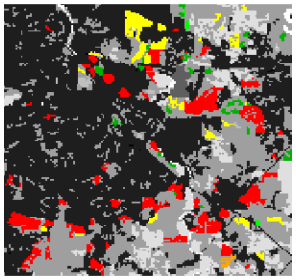


Water
Developed
Mechanical Disturbed
Mined Lands
Natural Barren
Forests and Woodland
Grassland/Shrubland
Cropland and Pasture
Wetland

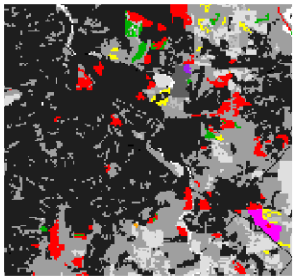
1972 to 1979 Change



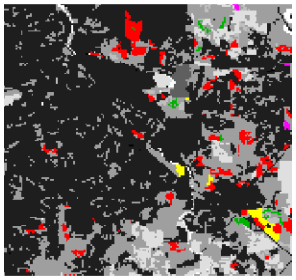
1979 to 1986 Change



1986 to 1992 Change



1992 to 2000 Change



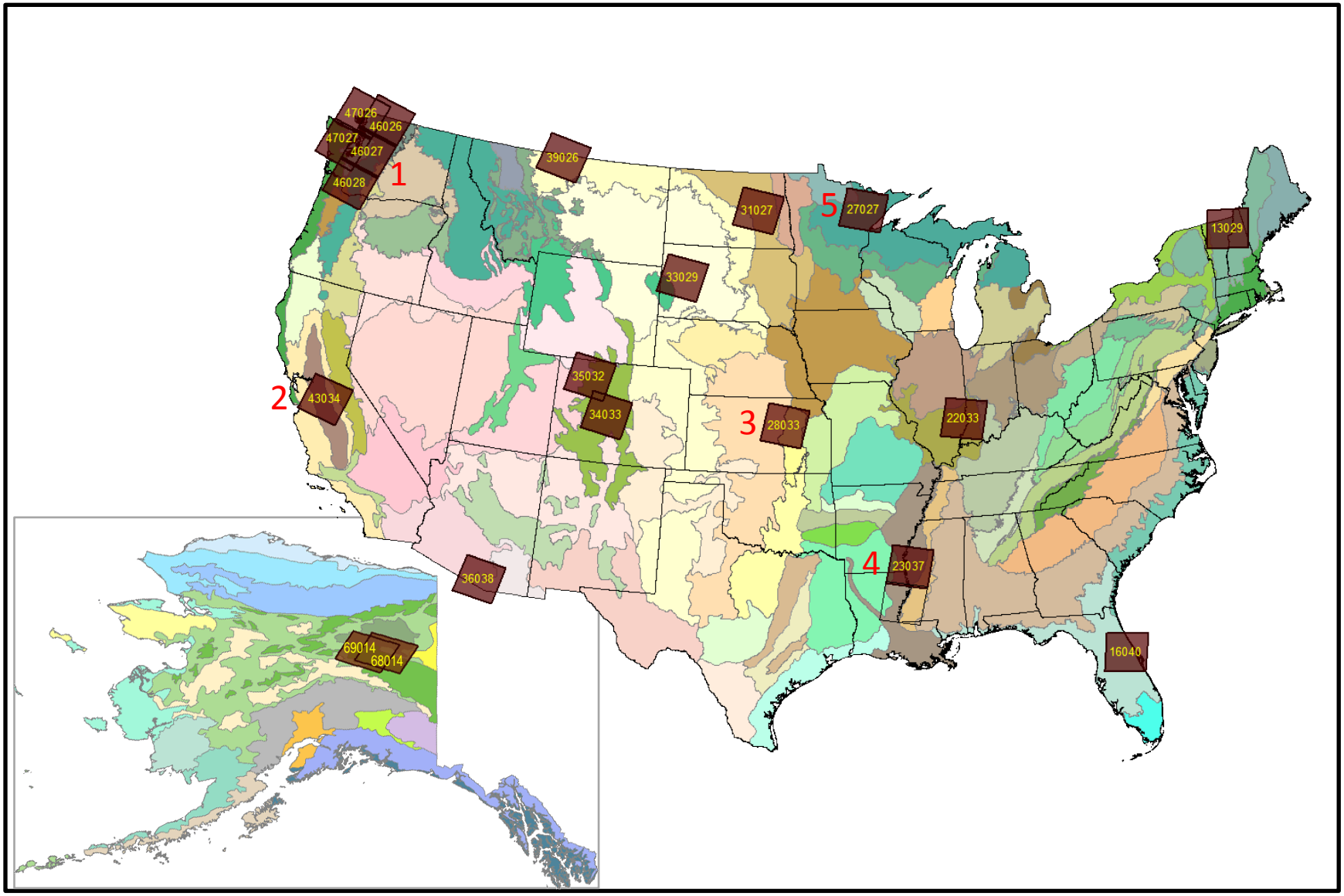
From Forests/Woodland to Grassland/Woodland
From Agriculture to Grassland/Woodland
From Mechanical Disturbed to Grassland/Woodland

From Grassland/Shrubland to Forests/Woodland
From Agriculture to Forests/Woodlands

From Forests/Woodland to Developed
From Grassland/Shrubland to Developed
From Agriculture to Developed

Land Cover Trends
U.S. Geological Survey
EROS Data Center
Sioux Falls, SD

Developing Good Training Strategy



Good Training Strategy

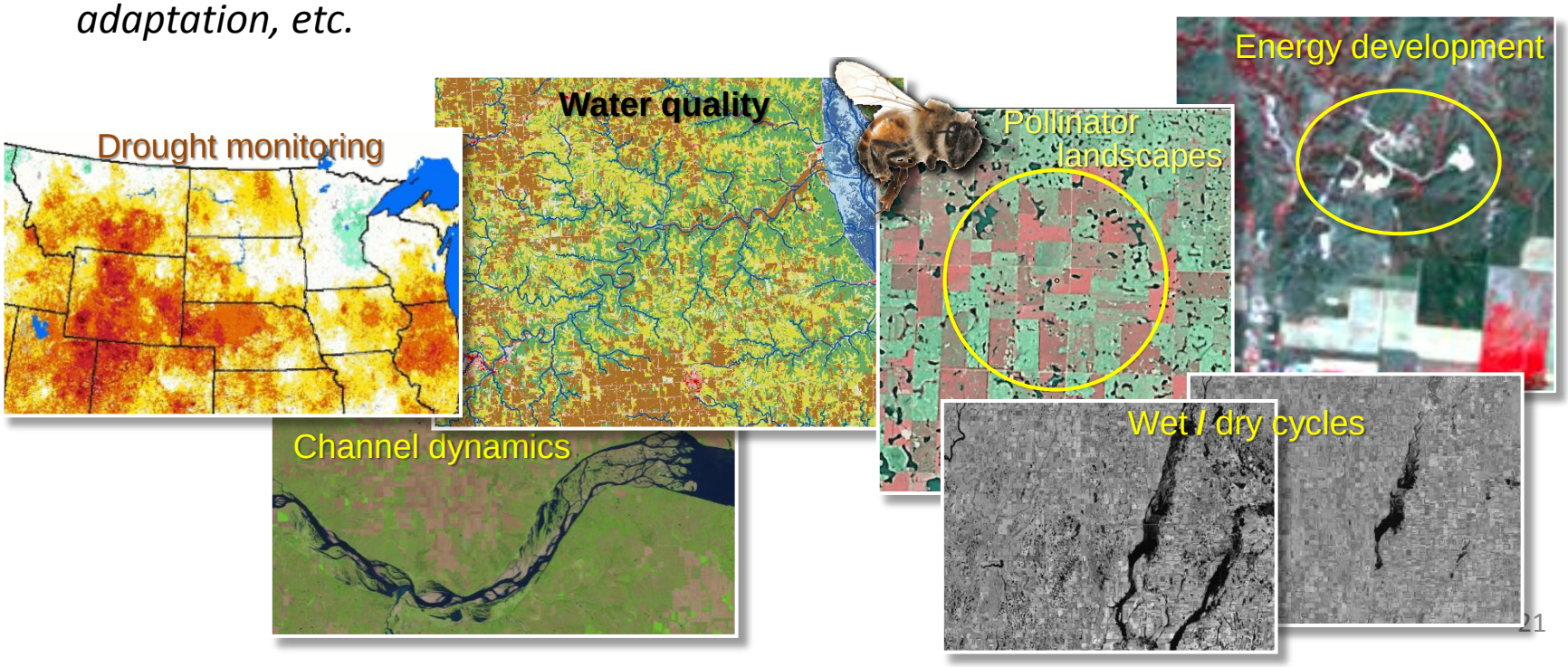
- 1. Equal proportion or equal number?
  - Answer: **Equal proportion** (**5%~15% increase** in overall accuracy)
- 2. What is the optimum number of pixels?
  - Answer: **20,000** (**1%~3% increase** in overall accuracy)
- 3. What is the best minimum and maximum number of training pixel for each class?
  - Answer: **600 minimum and 8000 maximum** (**similar** overall accuracy but **significant increase** in producers and users accuracies for small classes)
- 4. Is ancillary data helpful, if yes, which variable is more important?
  - Answer: It is important. The tested ancillary data include: **DEM**, DEM derivatives (**aspect**, **slope**, **positional index**, compound topographic index), **wetland index**, Fmask statistics (**water probability**, **snow probability**, and **cloud probability**), CCDC change detection ancillary data (number of change and length of change). The important variables are in bold letters. (**0%~4% increase** in overall accuracy)
- 5. Is outlier removal helpful or not?
  - Answer: **Not helpful**

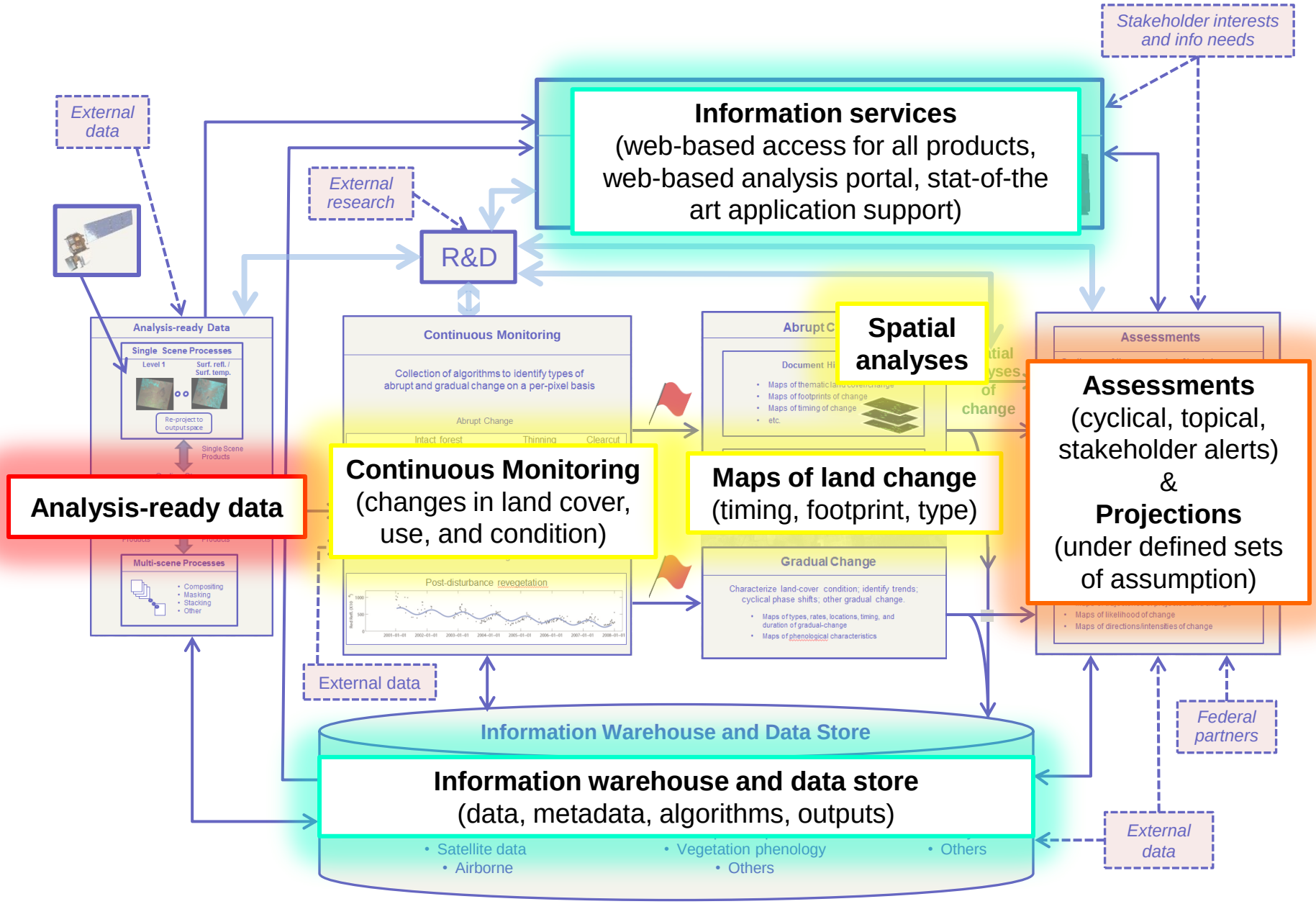
Land Change Monitoring, Assessment, and Projection (LCMAP)

***Monitoring**: continuously monitoring and characterizing changes in land cover, use, and condition.*

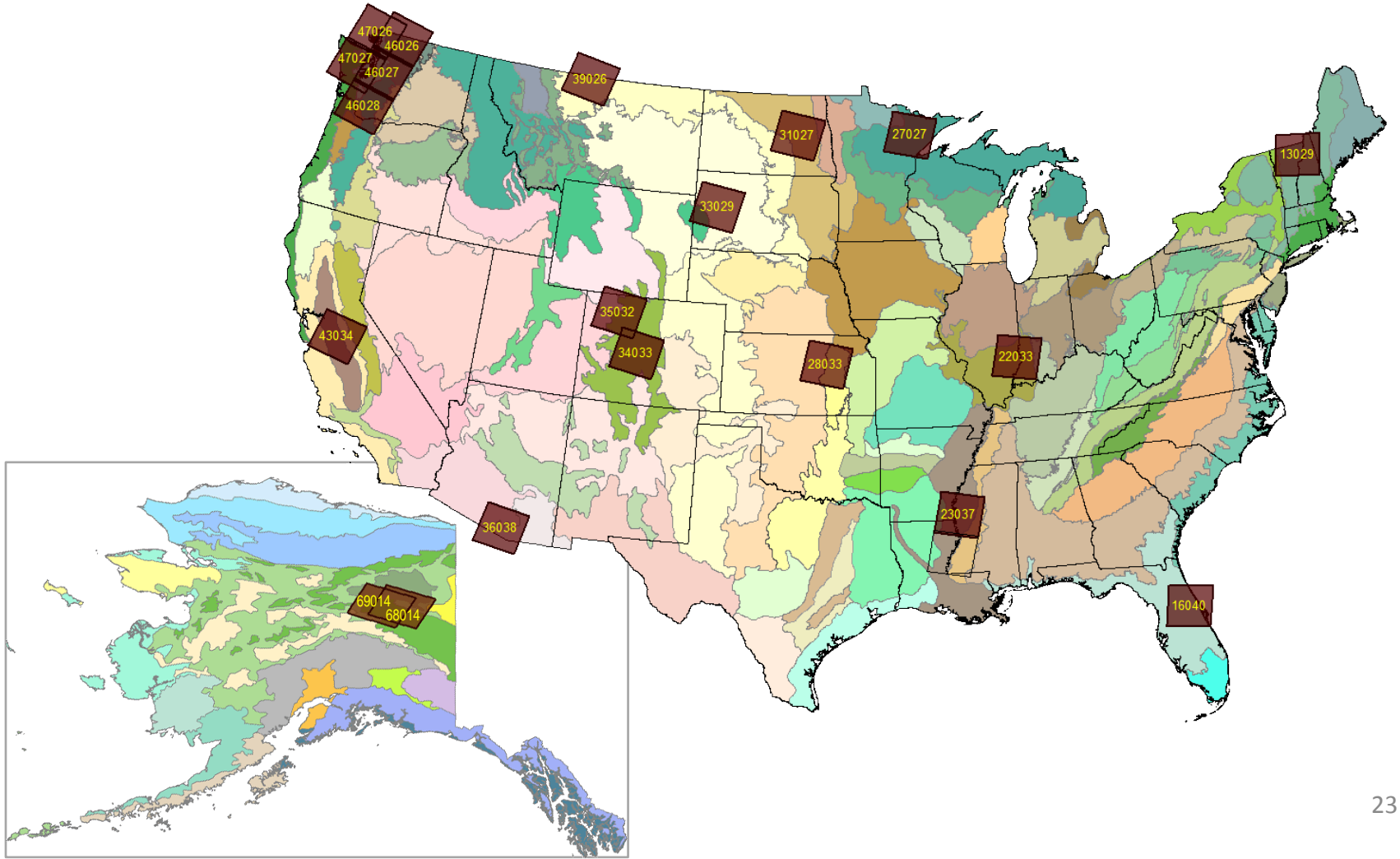
***Assessment**: Assessing land change processes, characteristics, and consequences (climate, water, ecosystems/biological process, natural hazards, etc.).*

***Projection**: Forecasts of future LULC patterns and types, and forecast on the impacts of LULC change on ecosystem health, carbon dynamics, climate change adaptation, etc.*

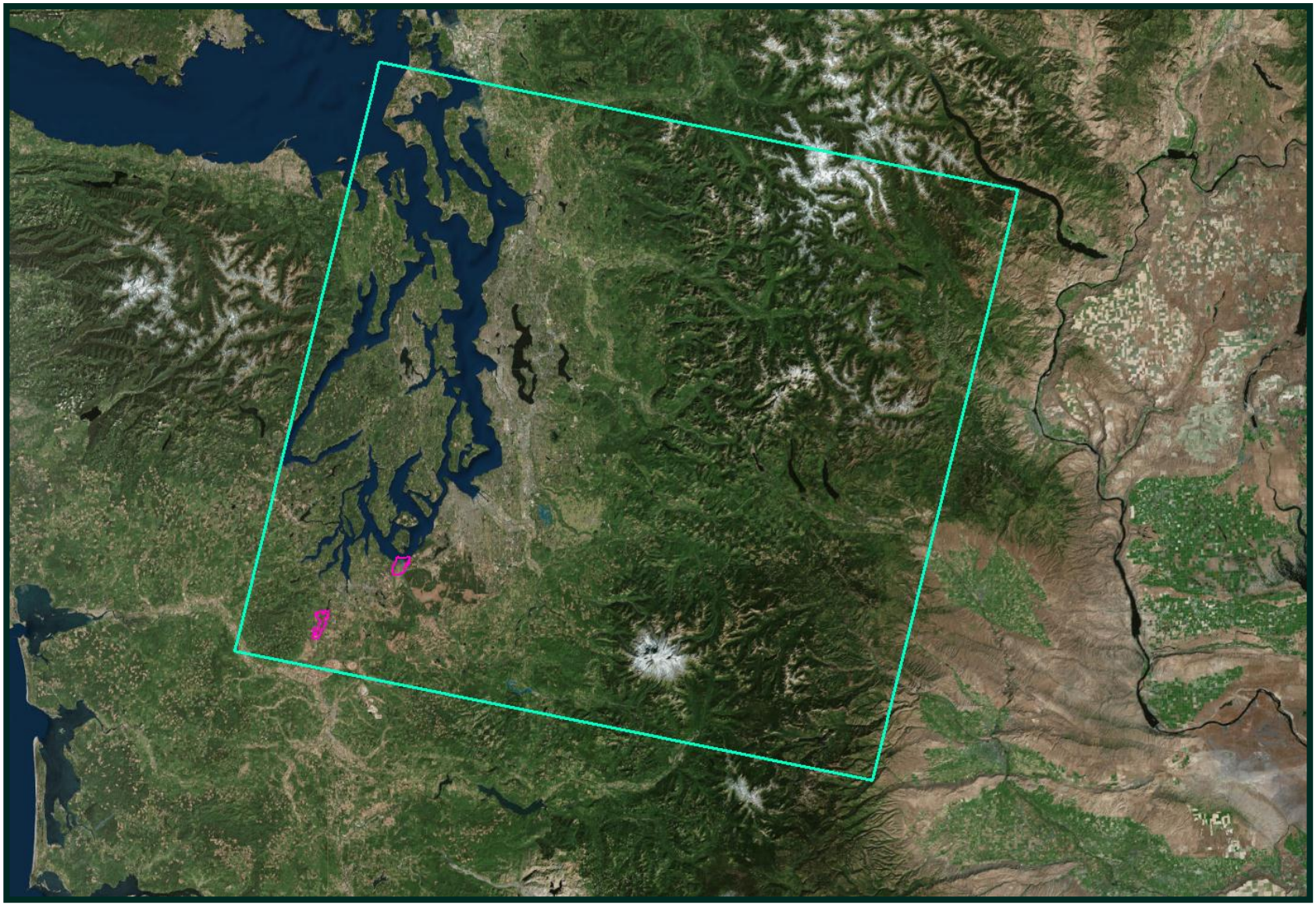



Stakeholder interests and info needs
External data
Information services
(web-based access for all products, web-based analysis portal, stat-of-the art application support)
External research
R&D
Analysis-ready Data
Single Scene Processes
Level 1
Surf. refl. / Surf. temp.
Re-project to output space
Single Scene Products
Multi-scene Processes
Compositing
Masking
Stacking
Other
Continuous Monitoring
Collection of algorithms to identify types of abrupt and gradual change on a per-pixel basis
Abrupt Change
Intact forest
Thinning
Clearcut
Post-disturbance revegetation
Abrupt C
Document Hi
Maps of thematic land cover change
Maps of footprints of change
Maps of timing of change
etc.
Spatial analyses
Gradual Change
Characterize land-cover condition; identify trends; cyclical phase shifts; other gradual change.
Maps of types, rates, locations, timing, and duration of gradual-change
Maps of phenological characteristics
Assessments
Maps of likelihood of change
Maps of directions/intensities of change
Analysis-ready data
Continuous Monitoring
(changes in land cover, use, and condition)
Maps of land change
(timing, footprint, type)
Assessments
(cyclical, topical, stakeholder alerts)
&
Projections
(under defined sets of assumption)
External data
Information Warehouse and Data Store
Information warehouse and data store
(data, metadata, algorithms, outputs)
Satellite data
Airborne
Vegetation phenology
Others
Others
Federal partners
External data

- Comparison across variety of regional environments and landscape settings (20 path/rows)
- Effects on regional change statistics: Puget Lowlands Ecoregion demonstration study

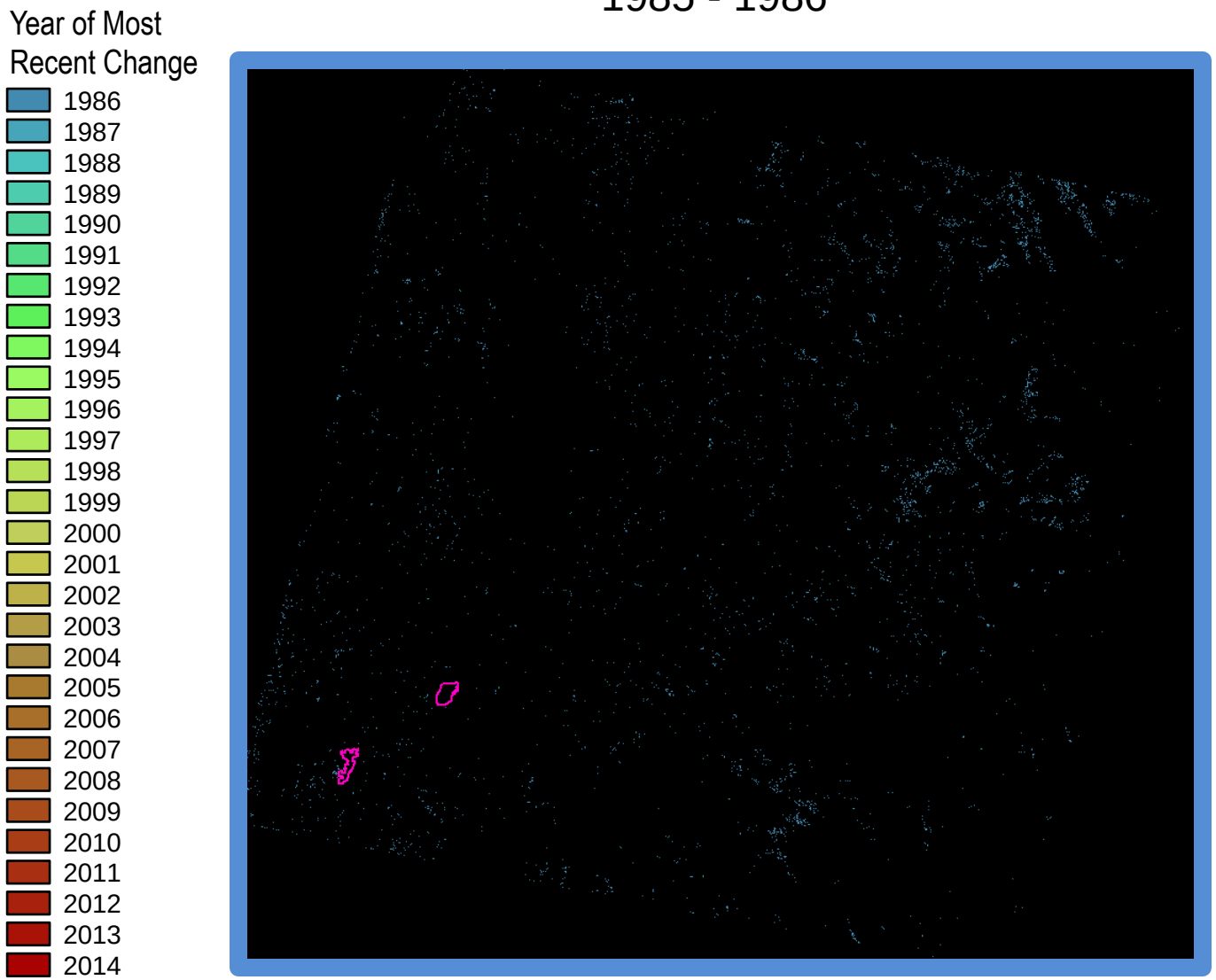


Preliminary “look” at some output for a Landsat scene area (path 46/row 27) with output from the Continuous Change Detection and Classification (CCDC) algorithm.



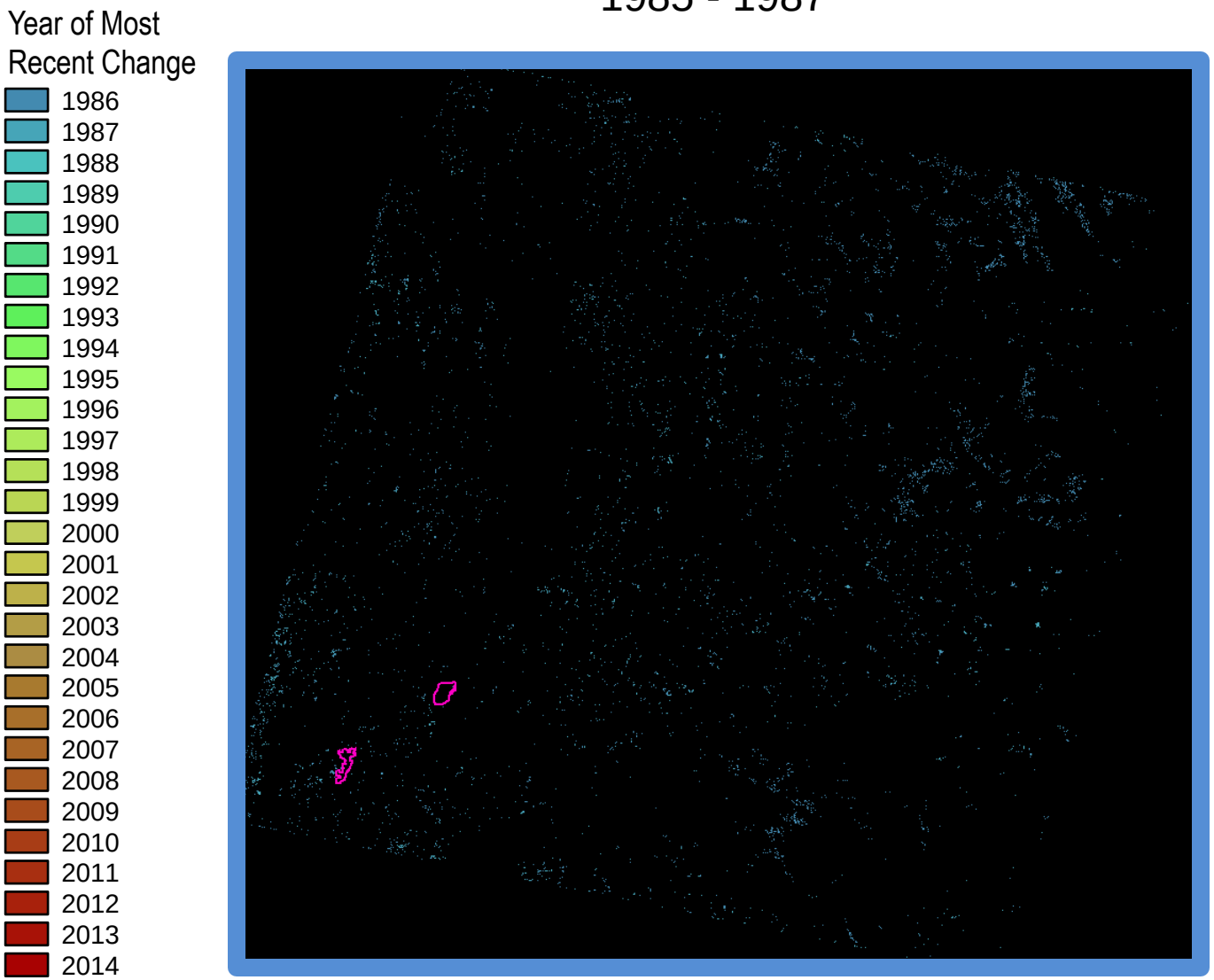
Timing of change

1985 - 1986



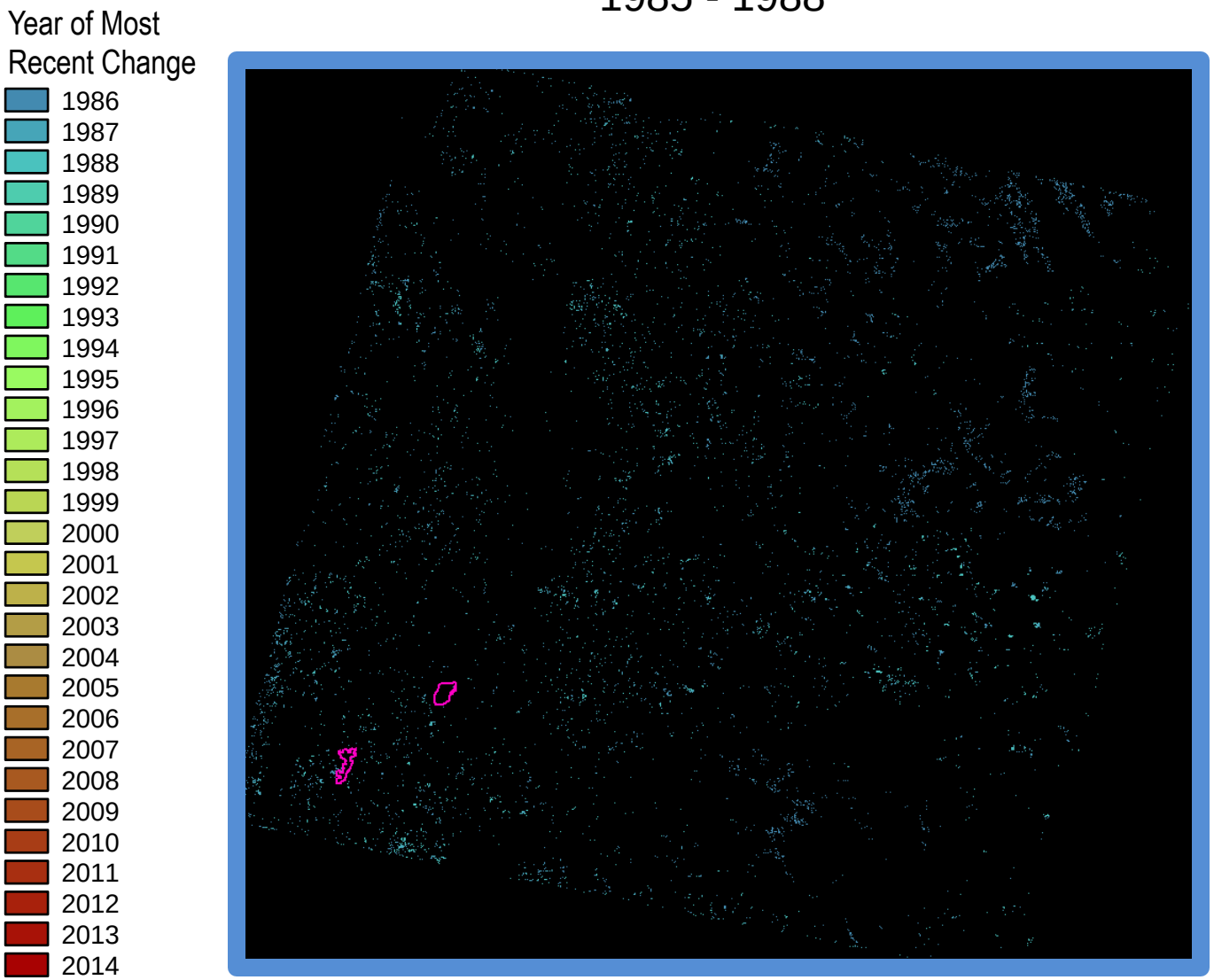
Timing of change

1985 - 1987



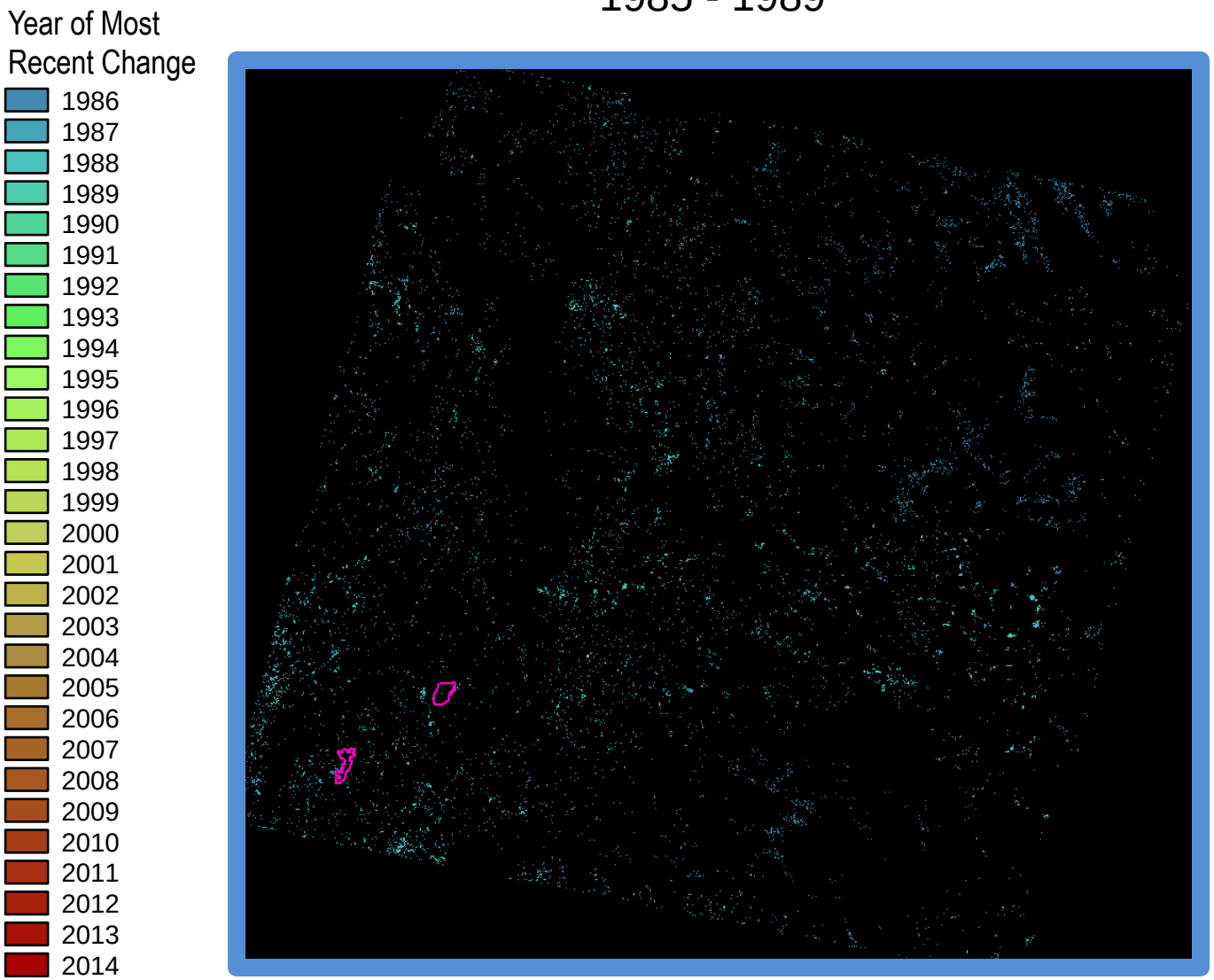
Timing of change

1985 - 1988



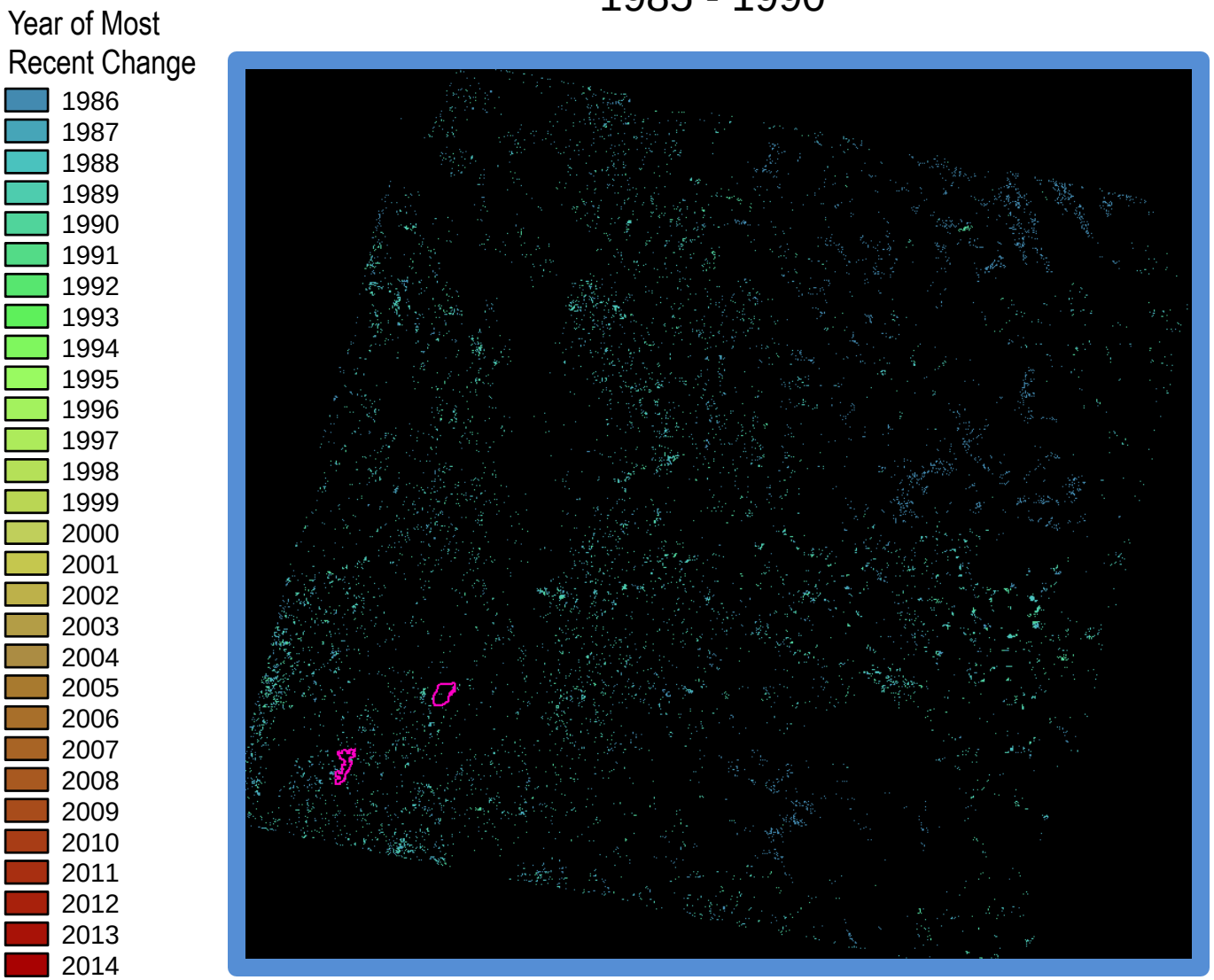
Timing of change

1985 - 1989



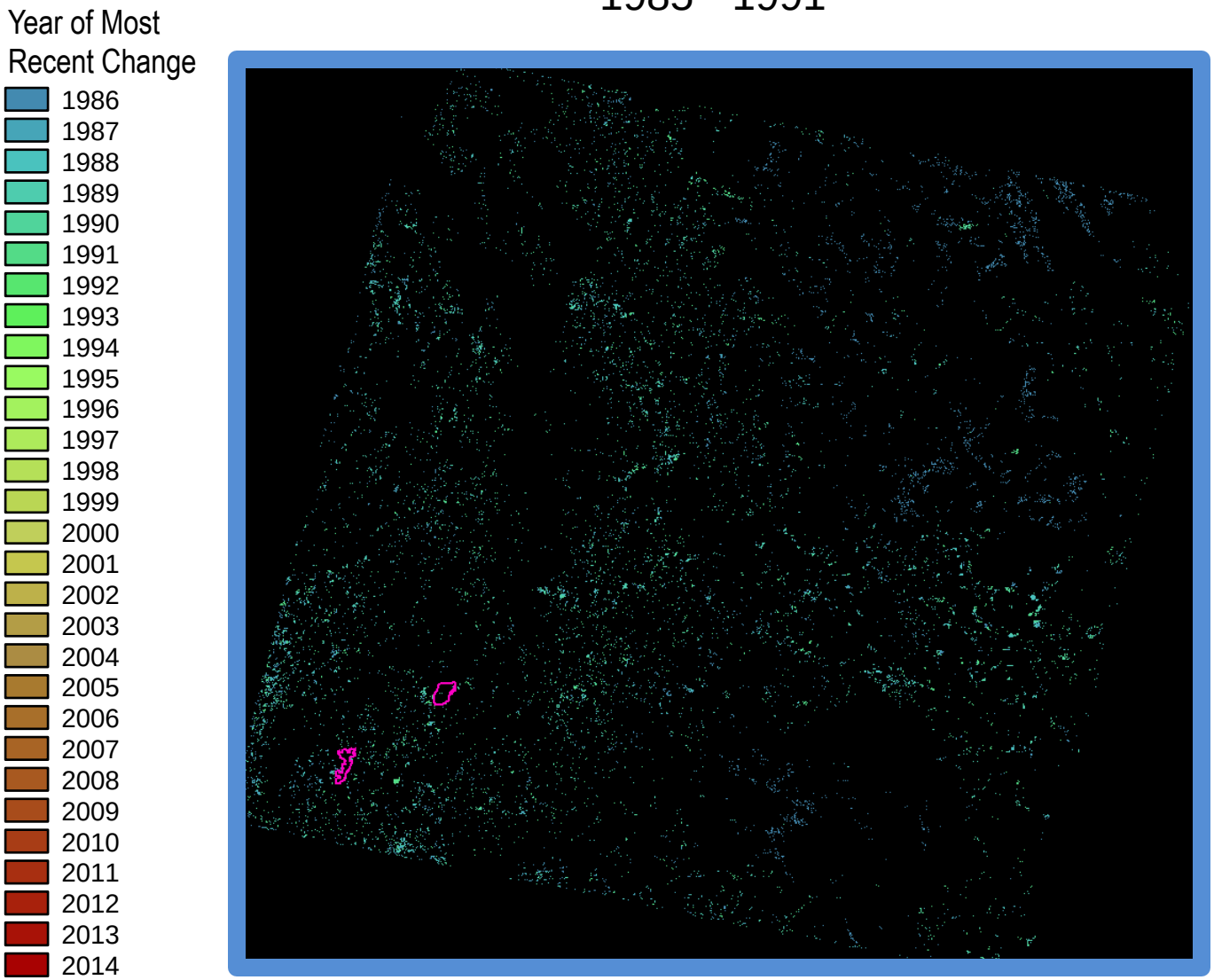
Timing of change

1985 - 1990



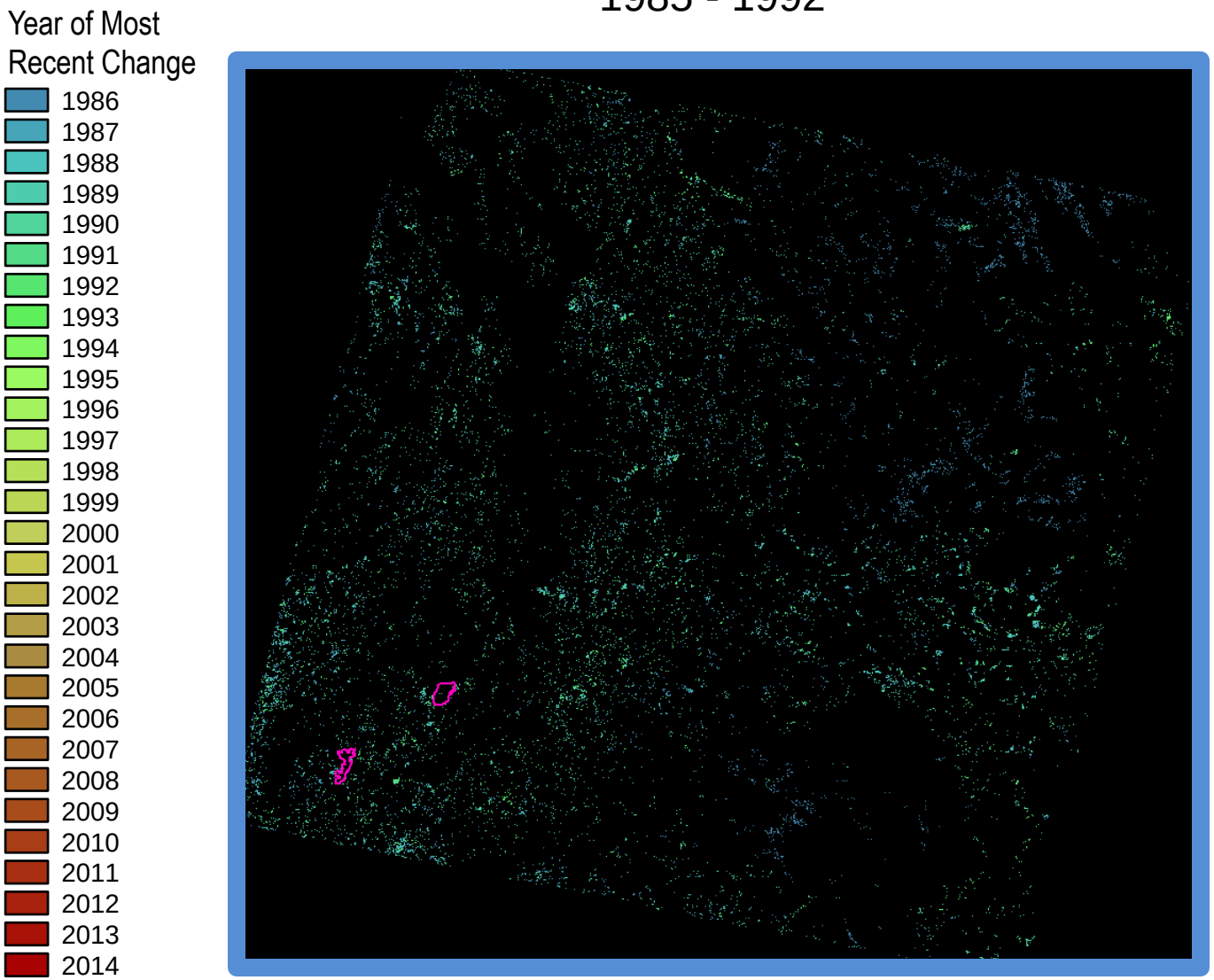
Timing of change

1985 - 1991



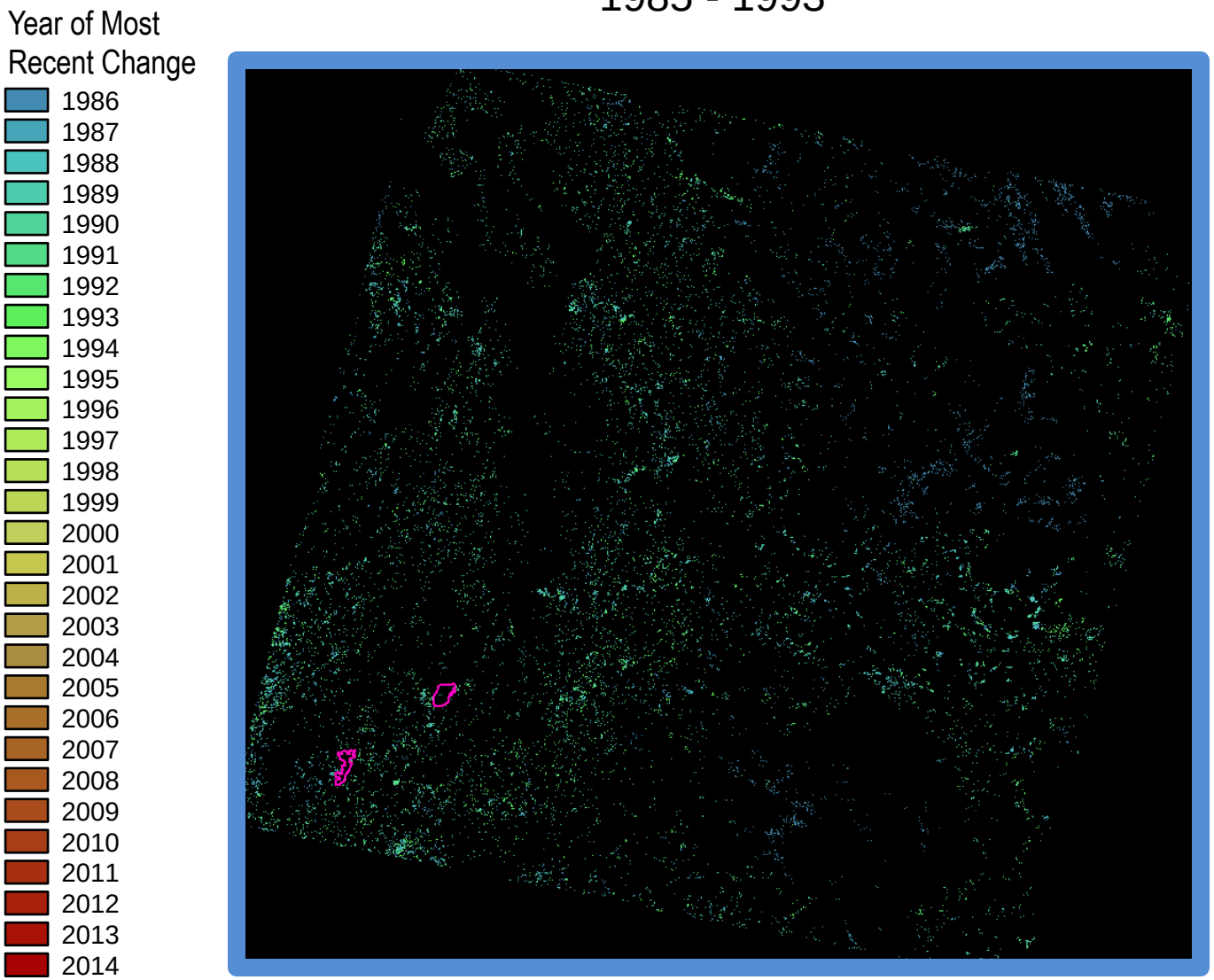
Timing of change

1985 - 1992



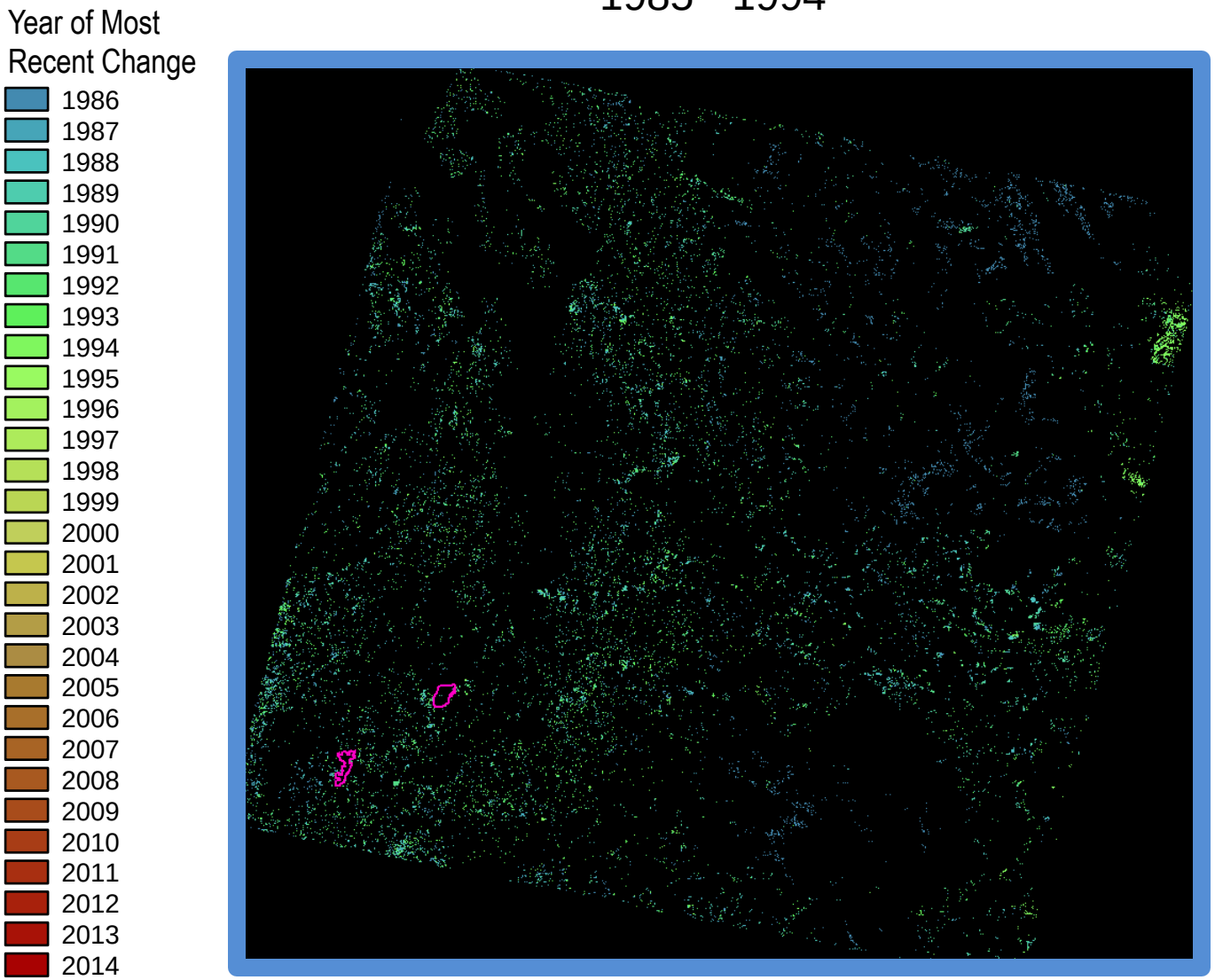
Timing of change

1985 - 1993



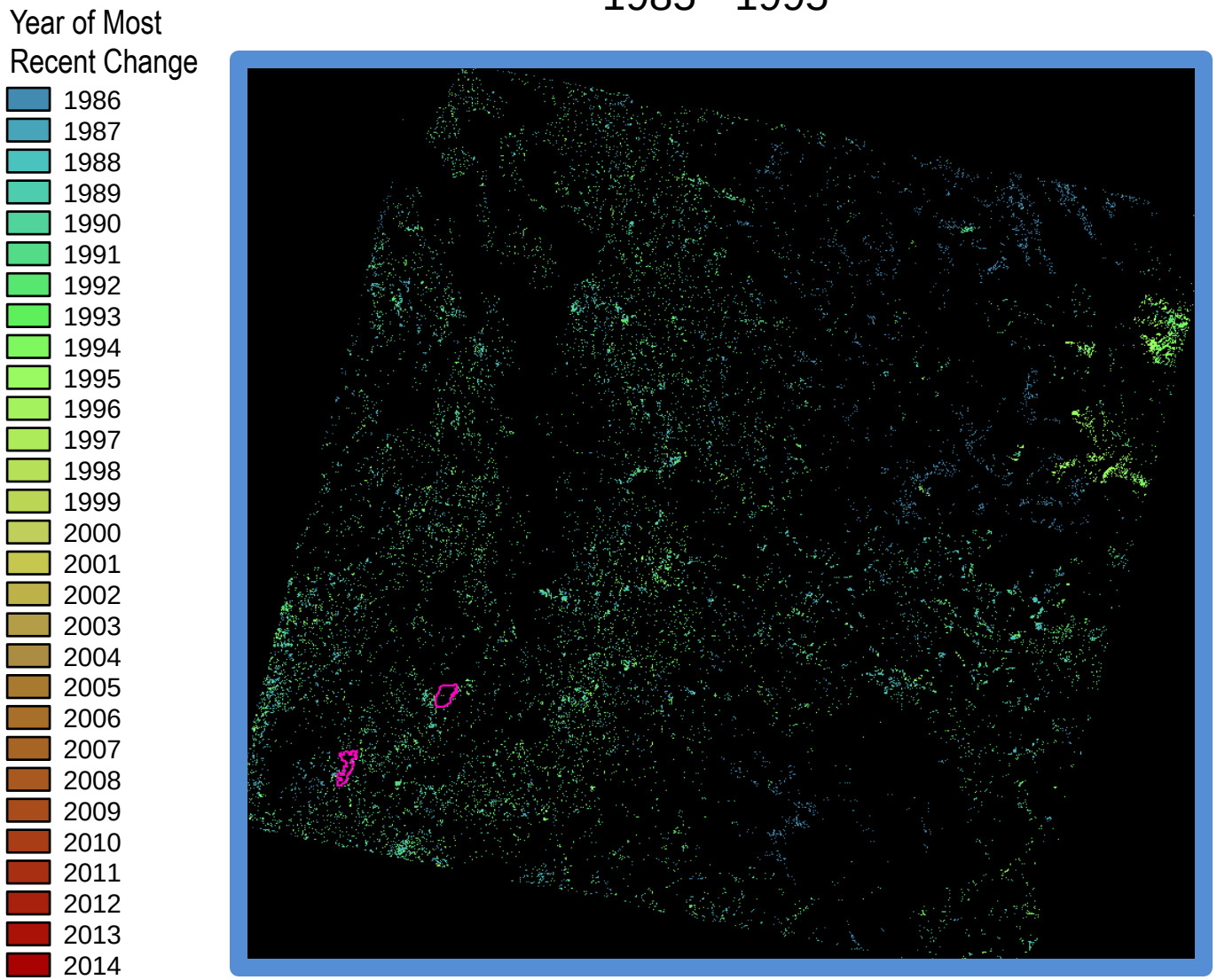
Timing of change

1985 - 1994



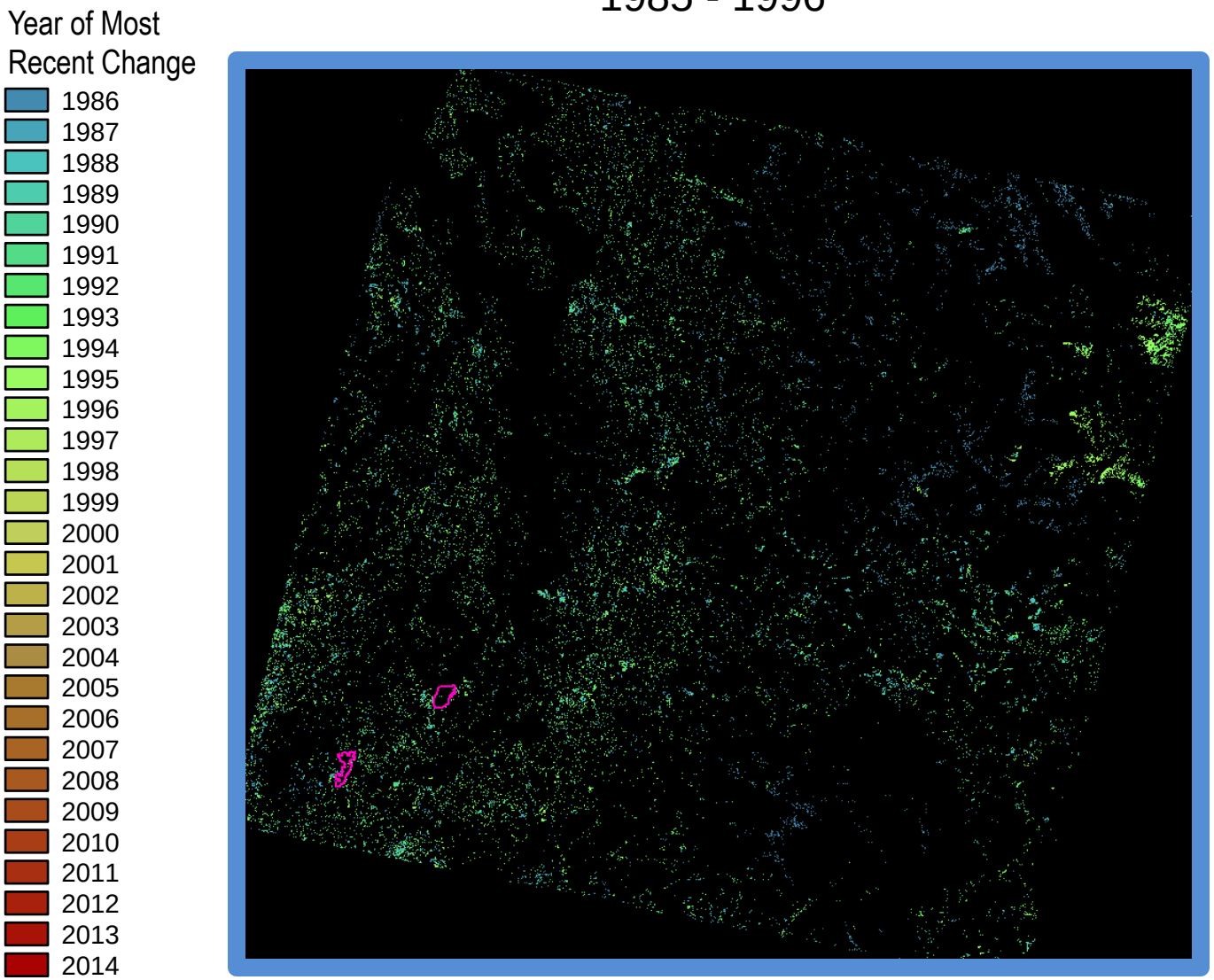
Timing of change

1985 - 1995



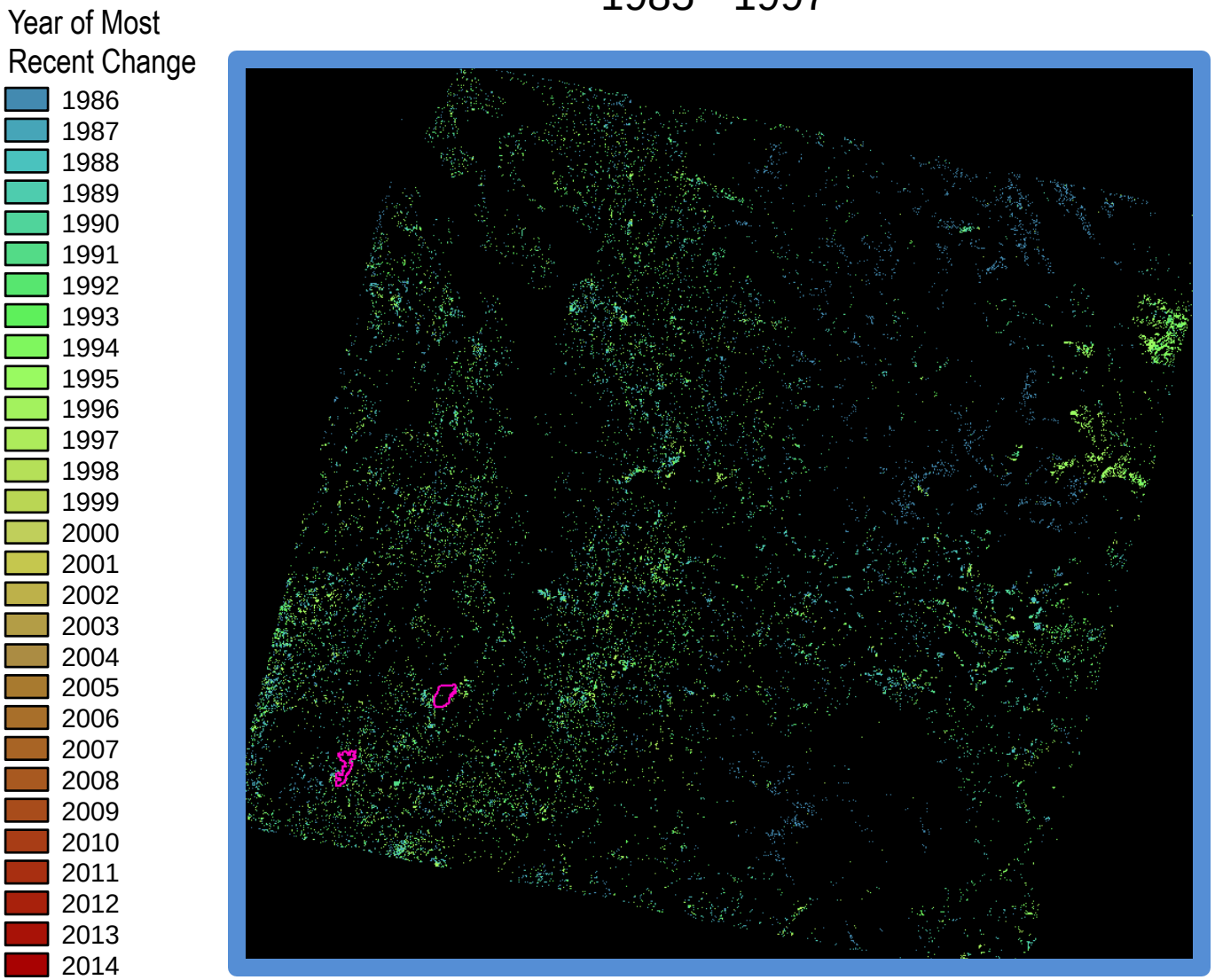
Timing of change

1985 - 1996



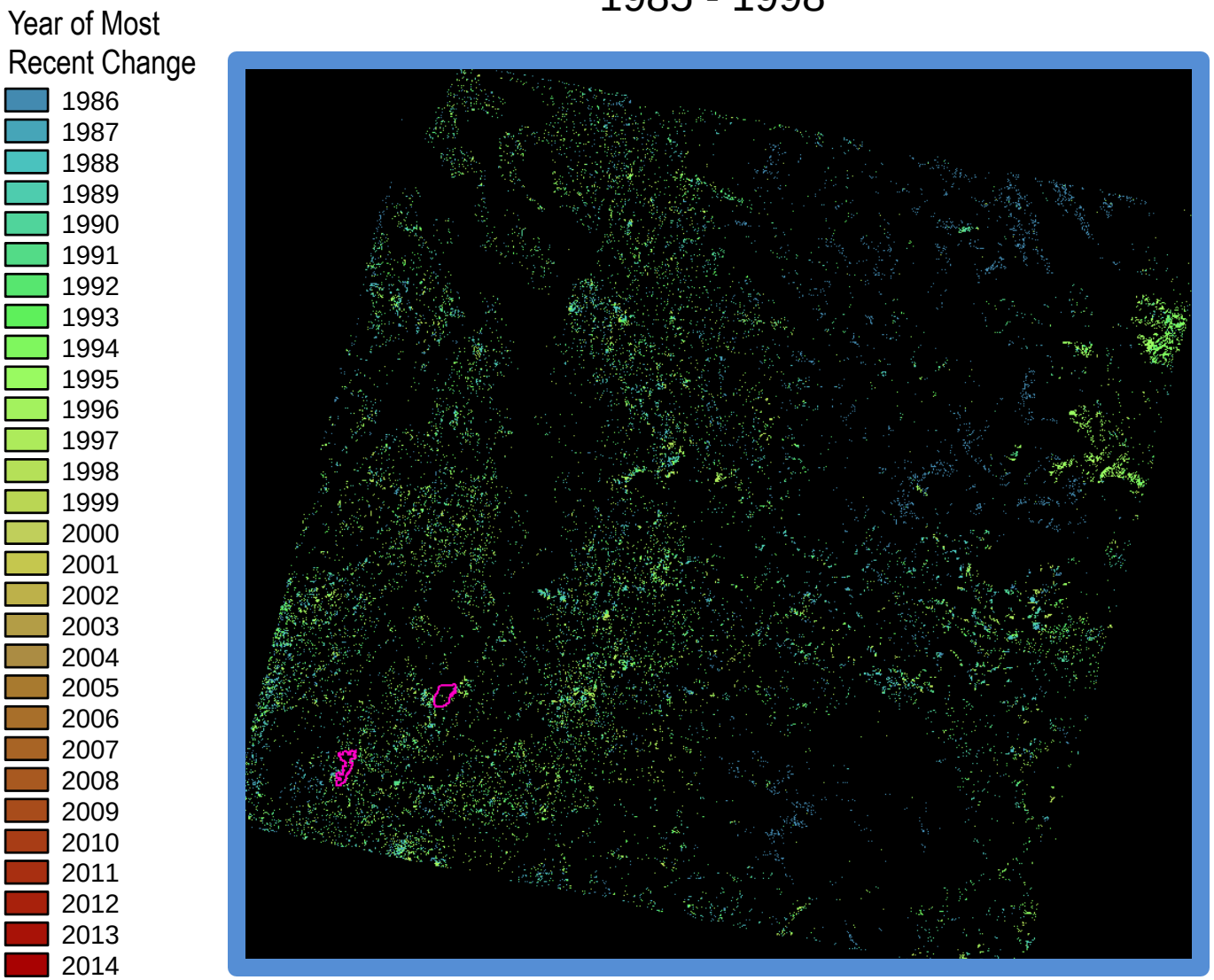
Timing of change

1985 - 1997



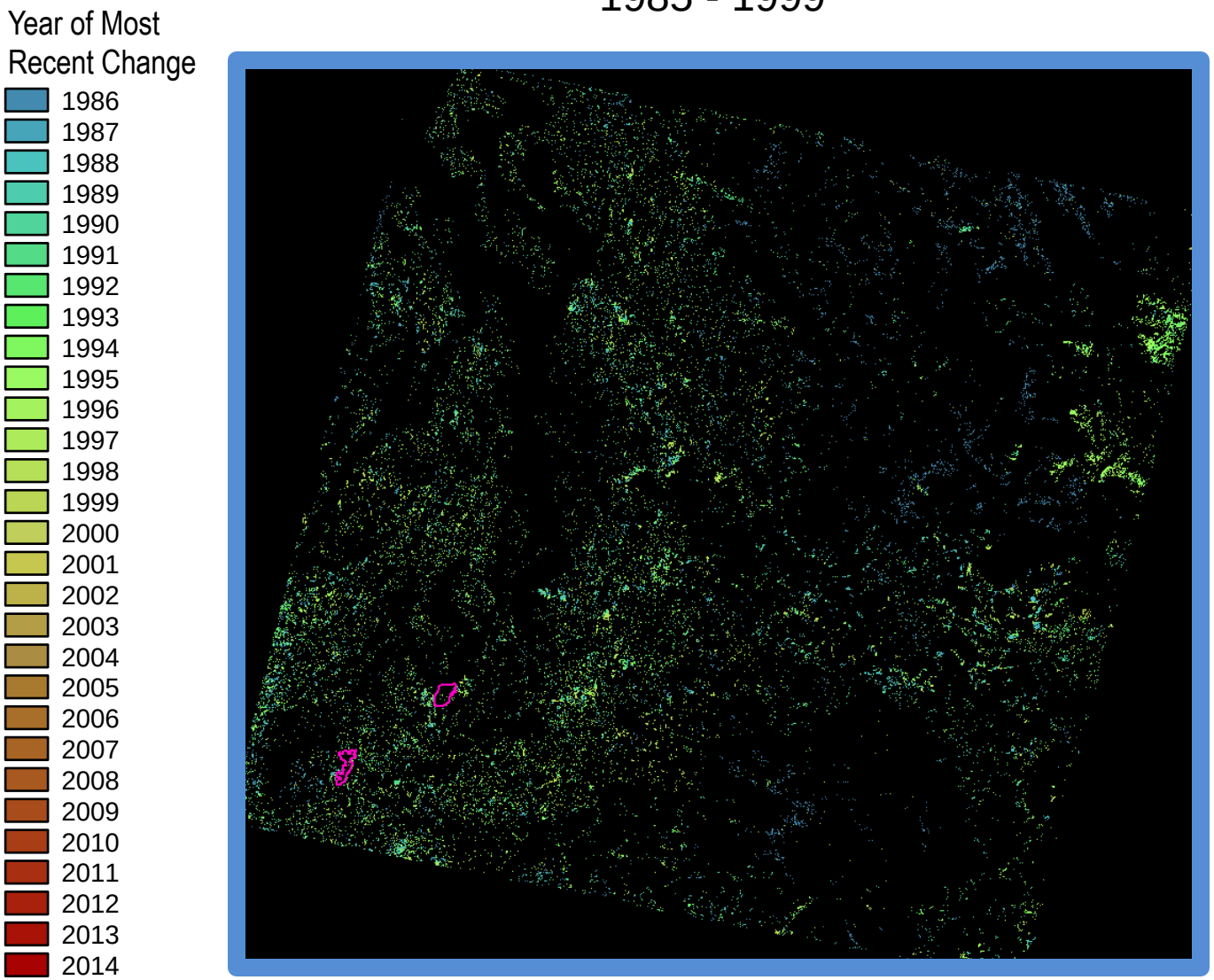
Timing of change

1985 - 1998



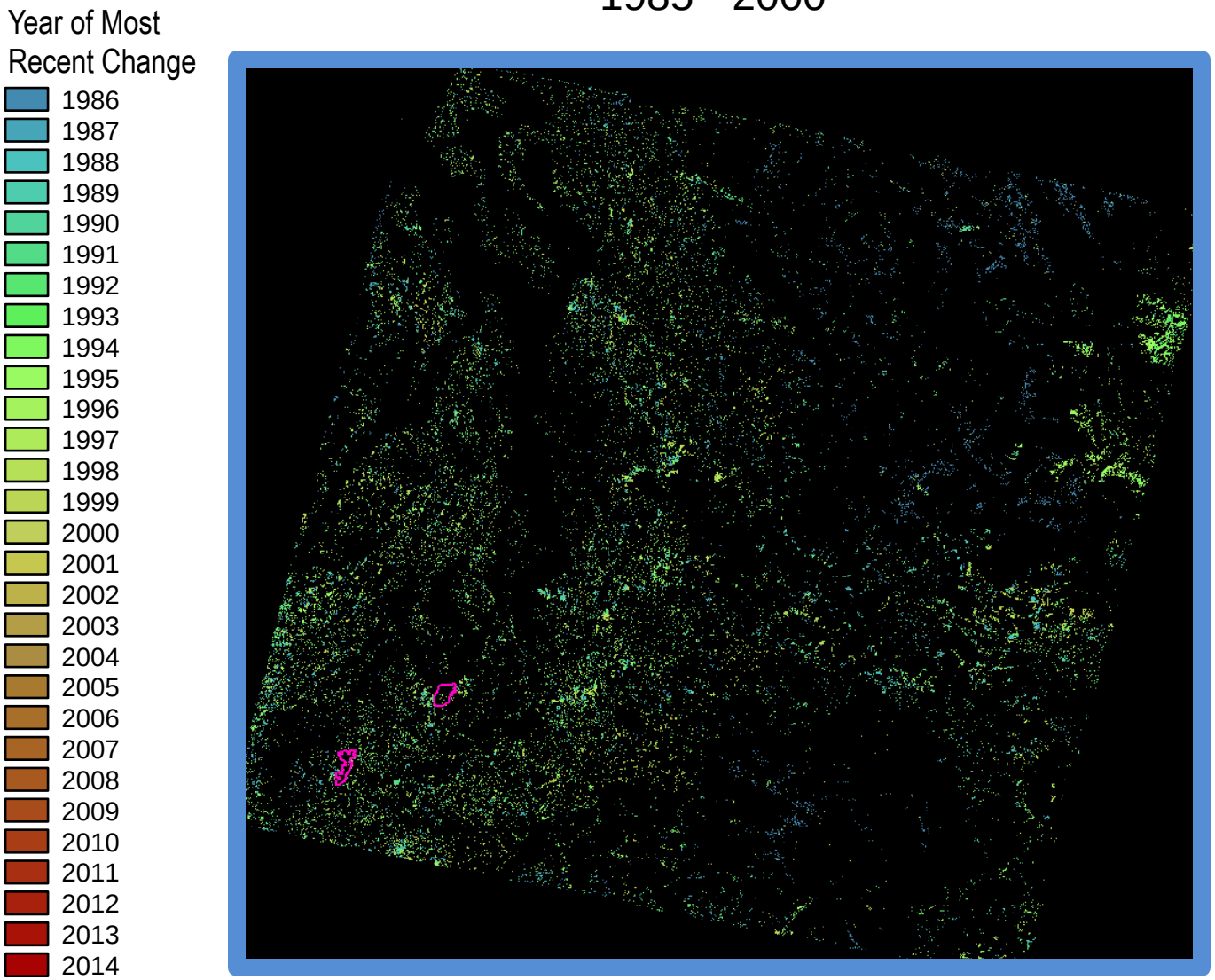
Timing of change

1985 - 1999



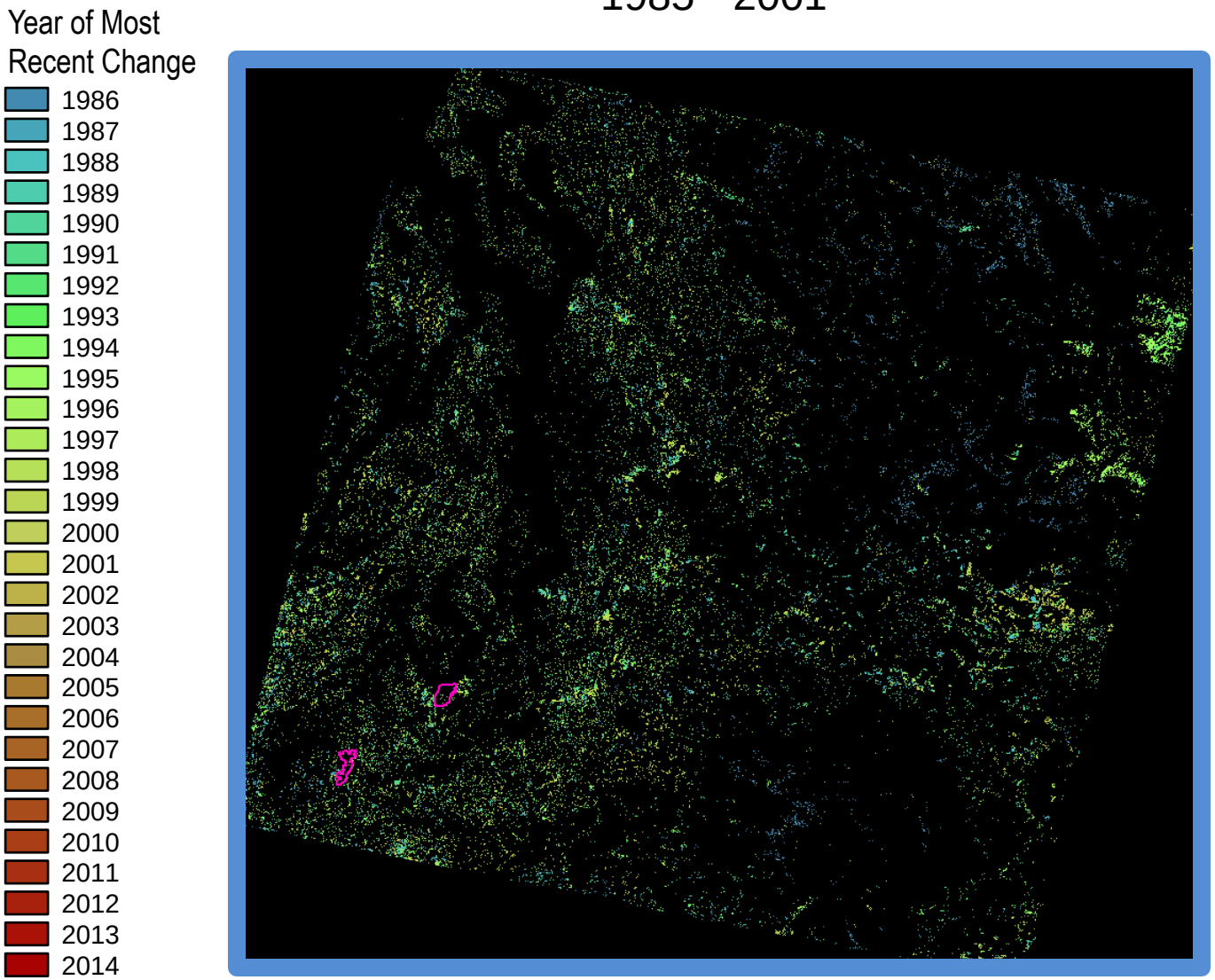
Timing of change

1985 - 2000



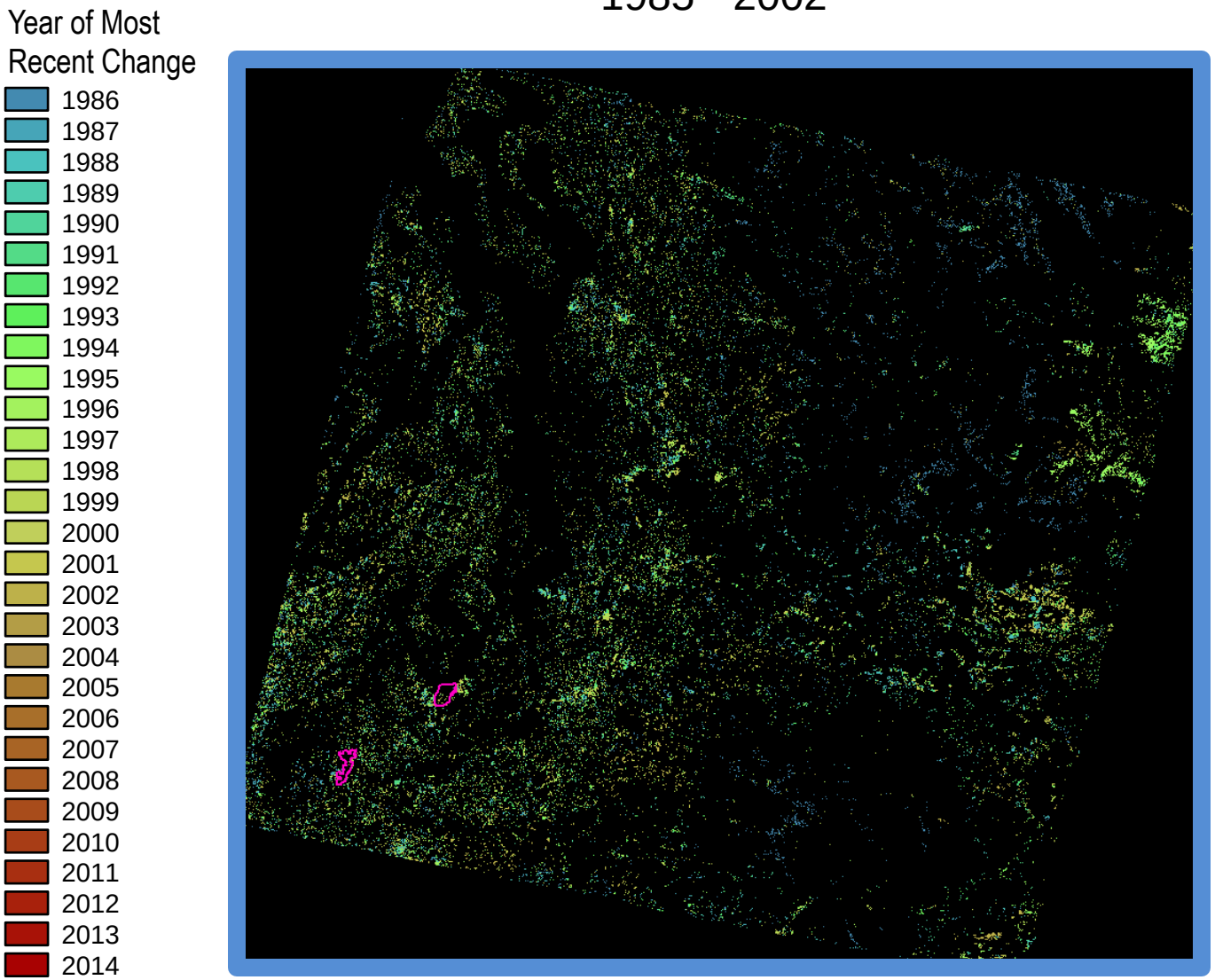
Timing of change

1985 - 2001



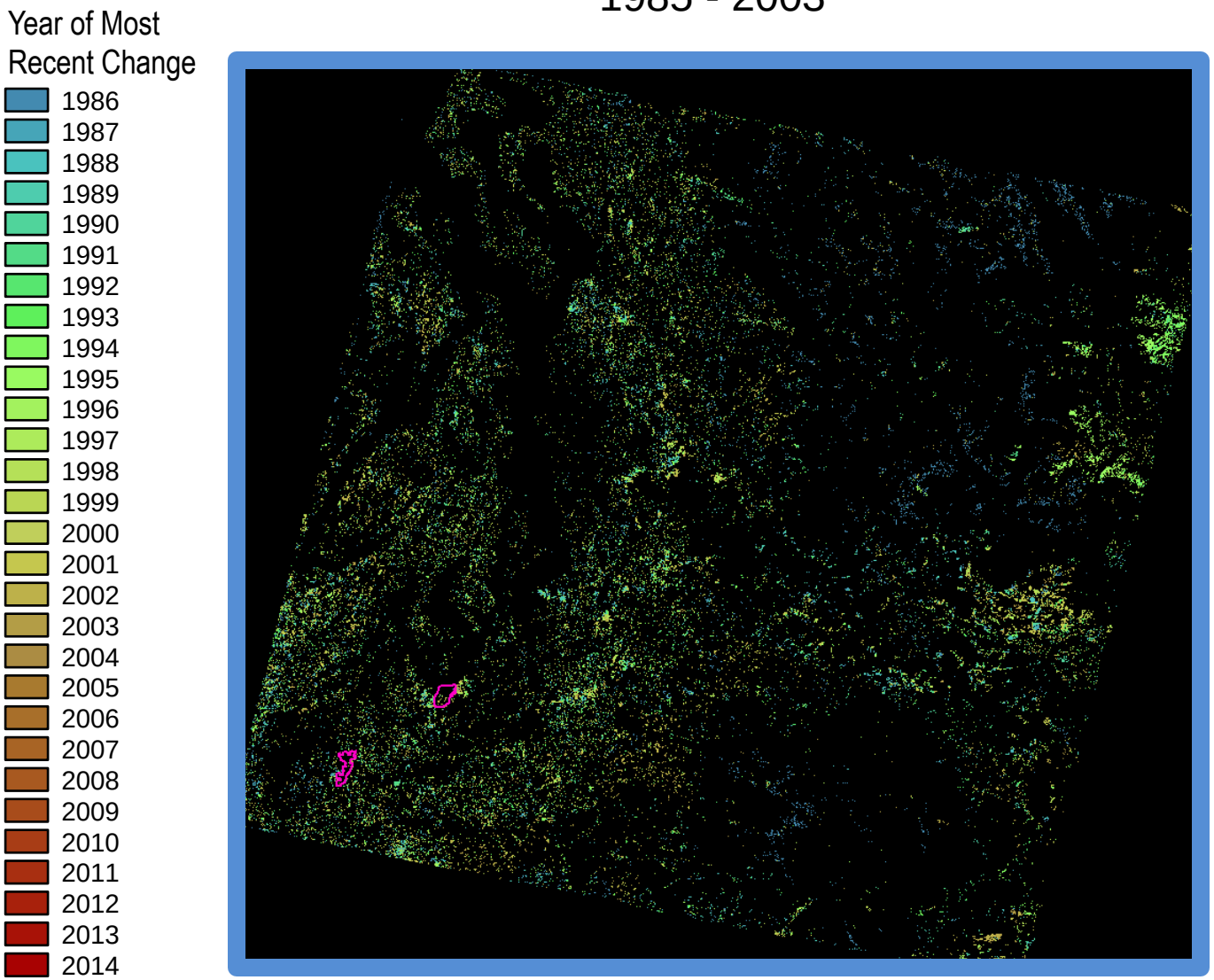
Timing of change

1985 - 2002



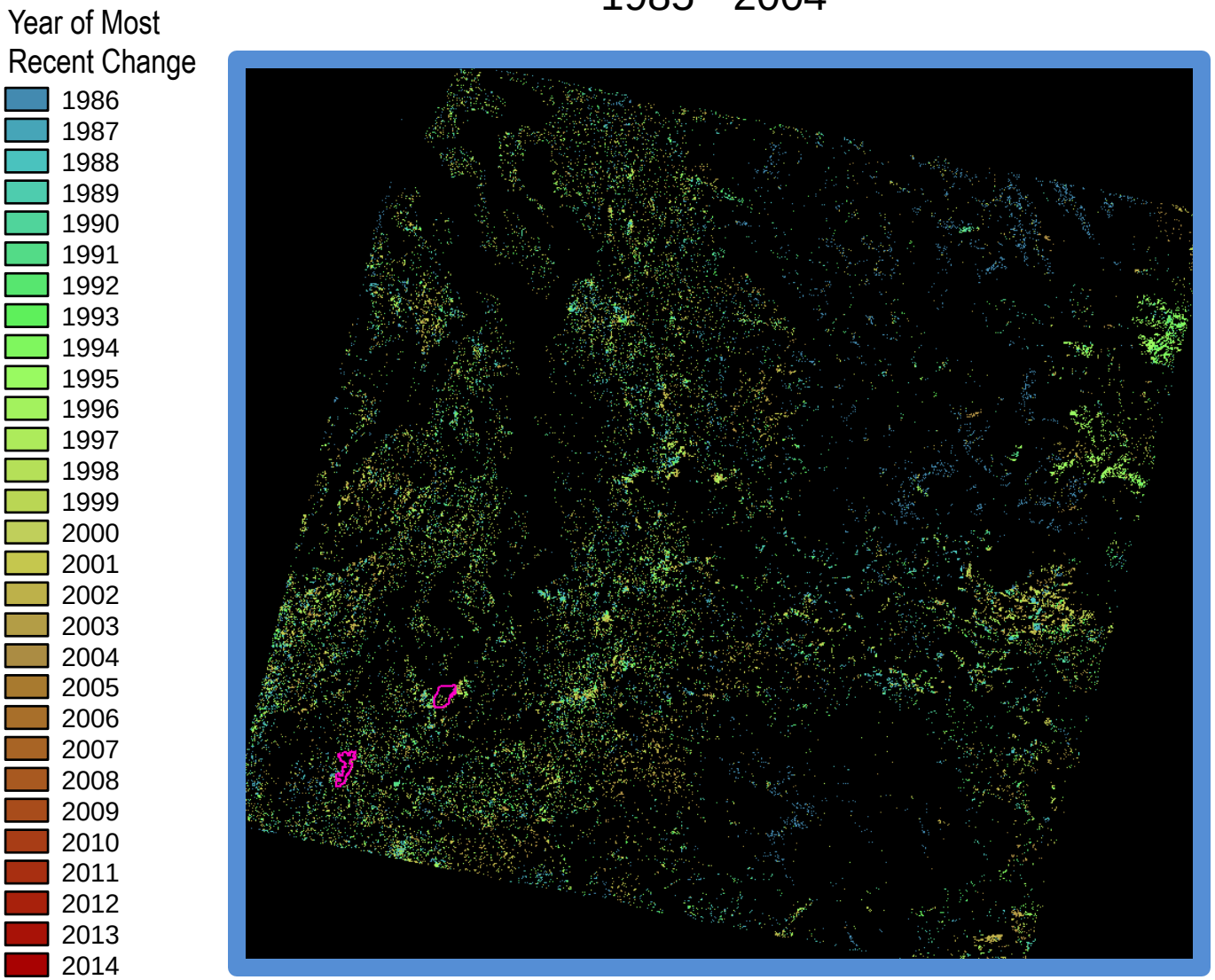
Timing of change

1985 - 2003



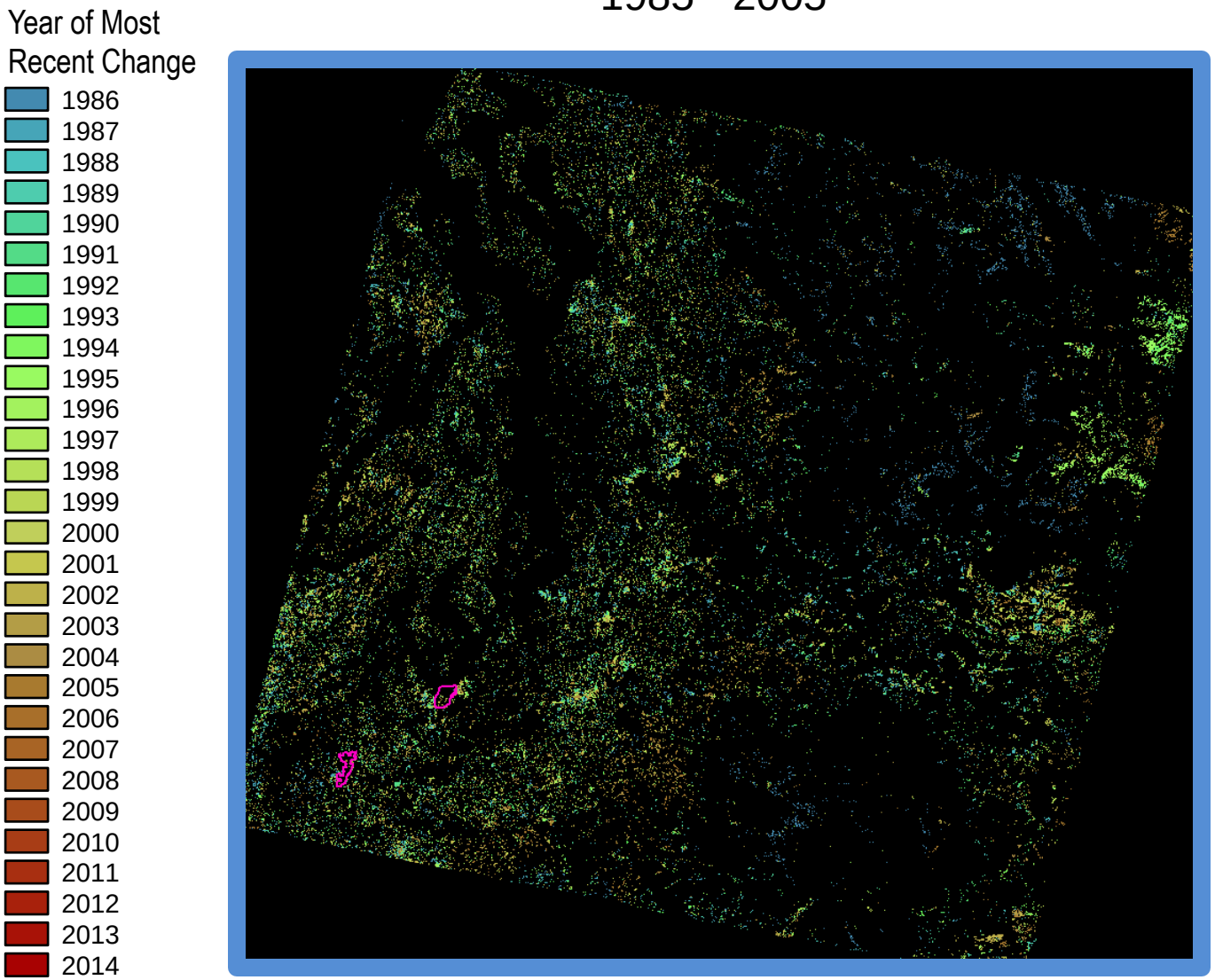
Timing of change

1985 - 2004



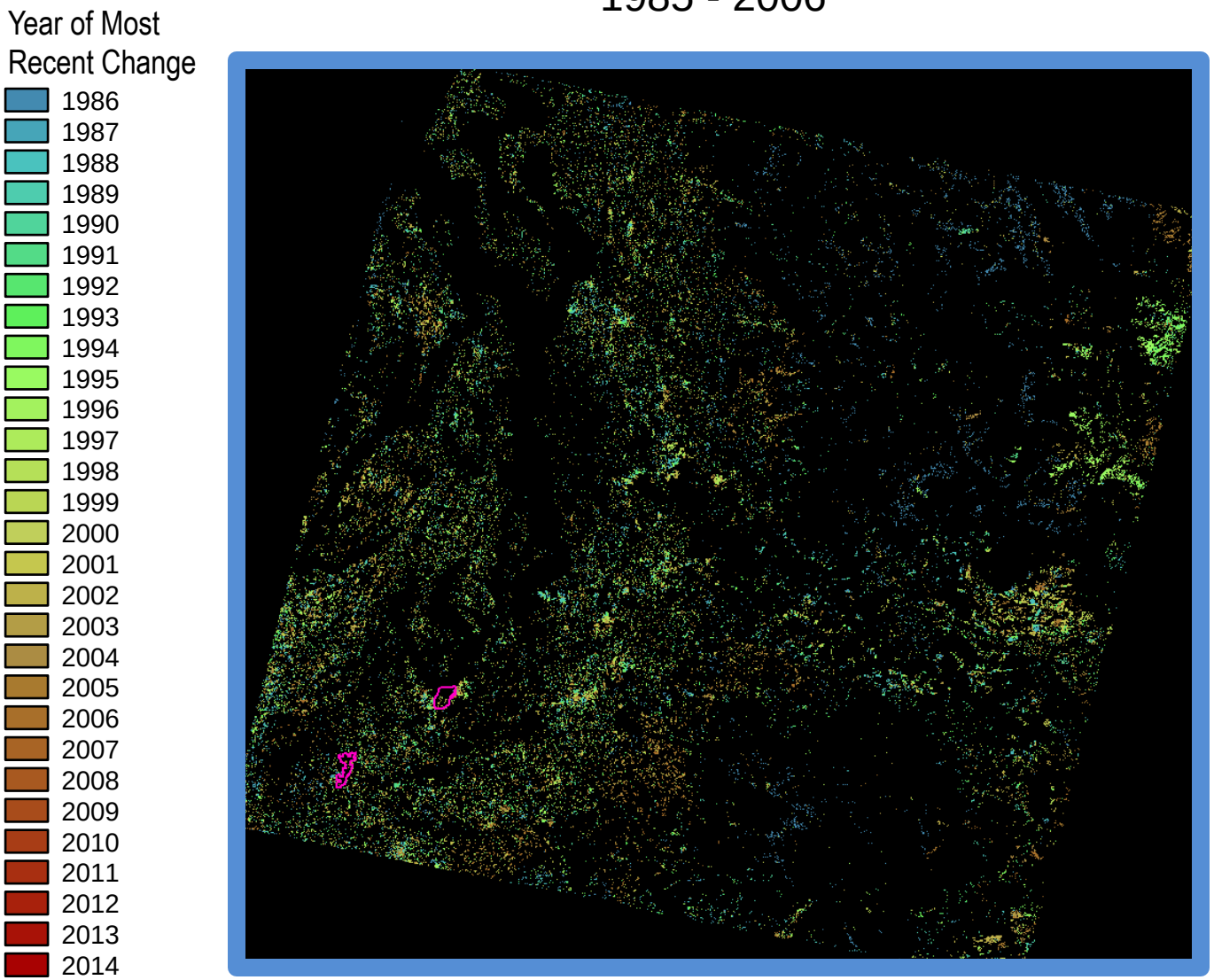
Timing of change

1985 - 2005



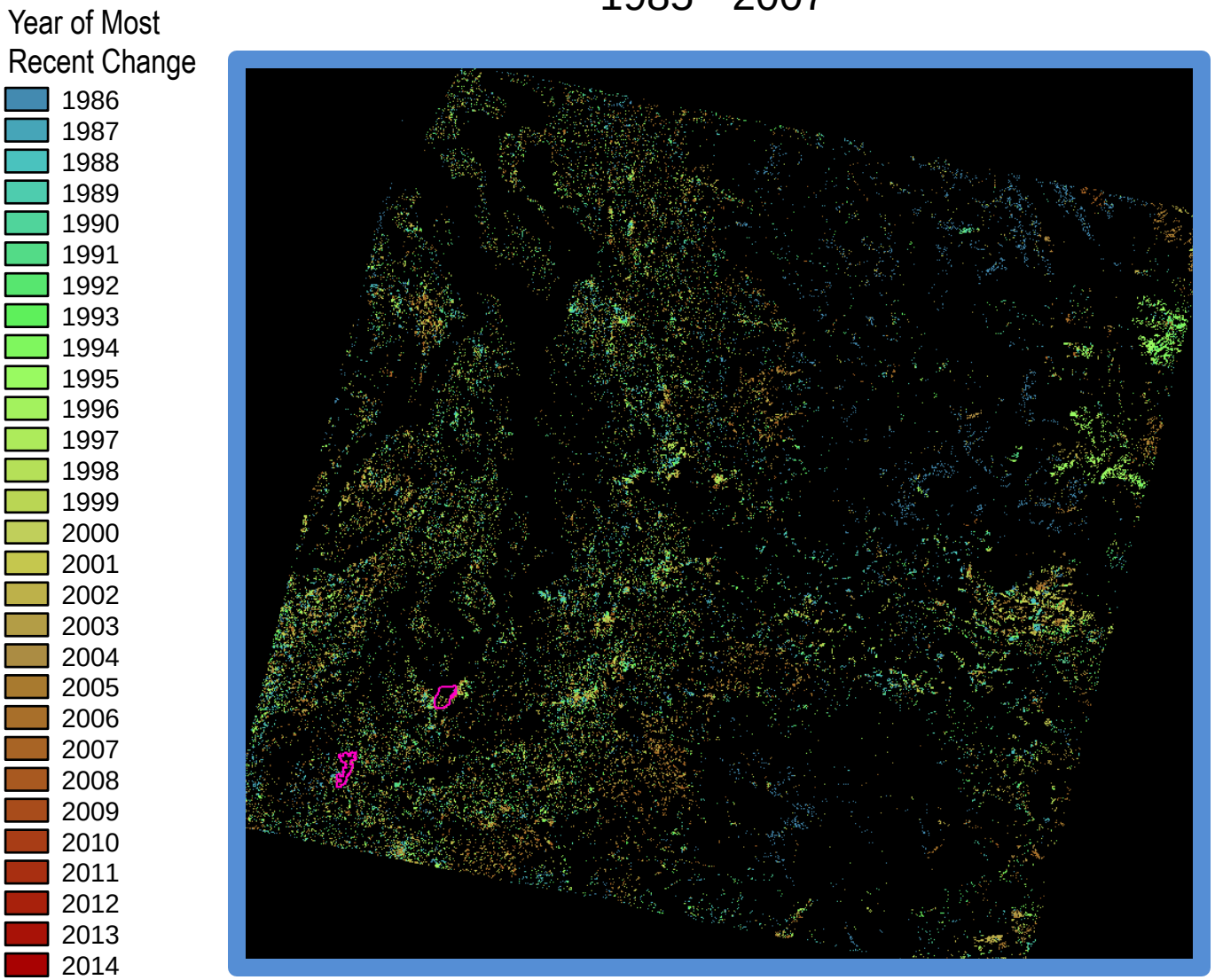
Timing of change

1985 - 2006



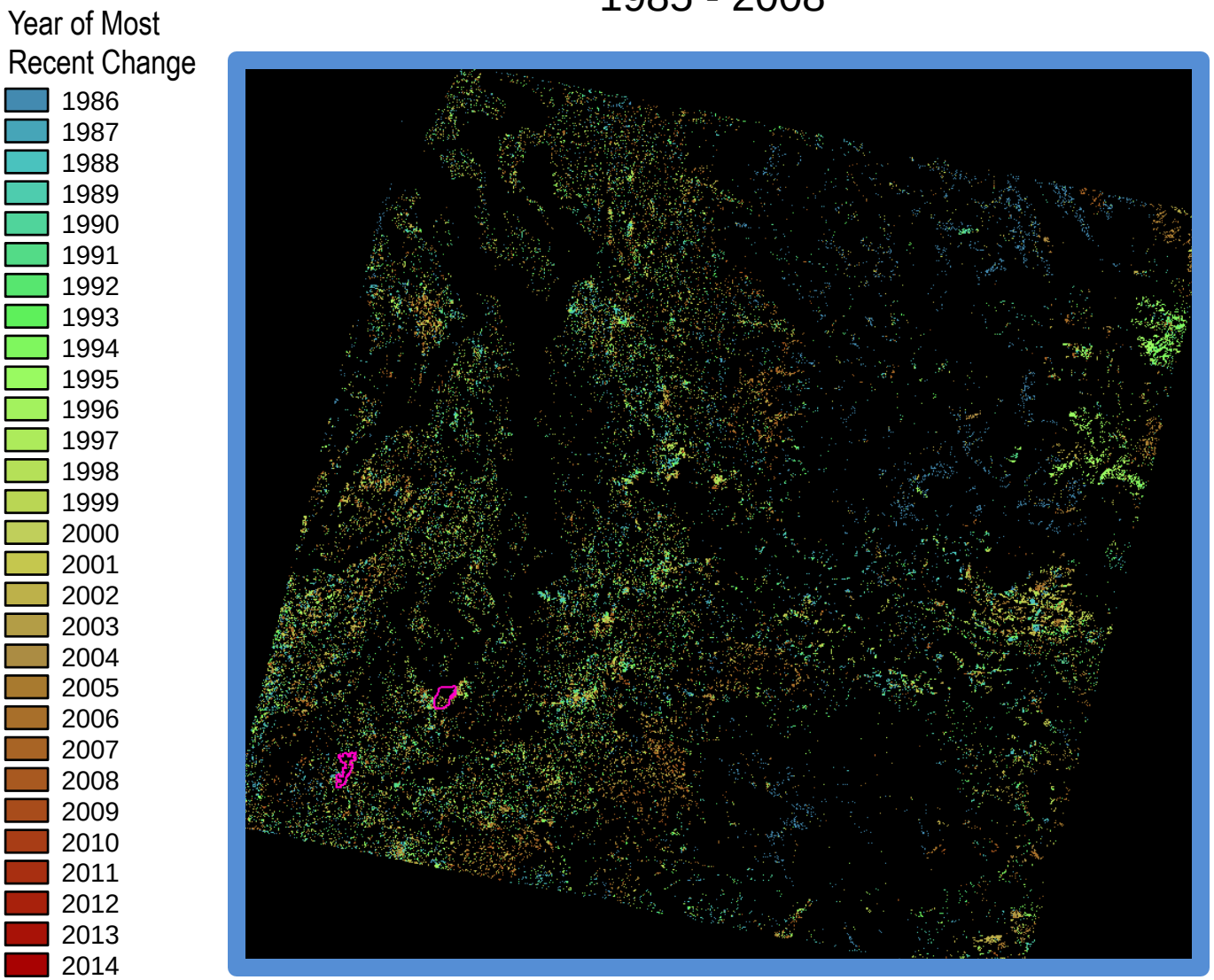
Timing of change

1985 - 2007



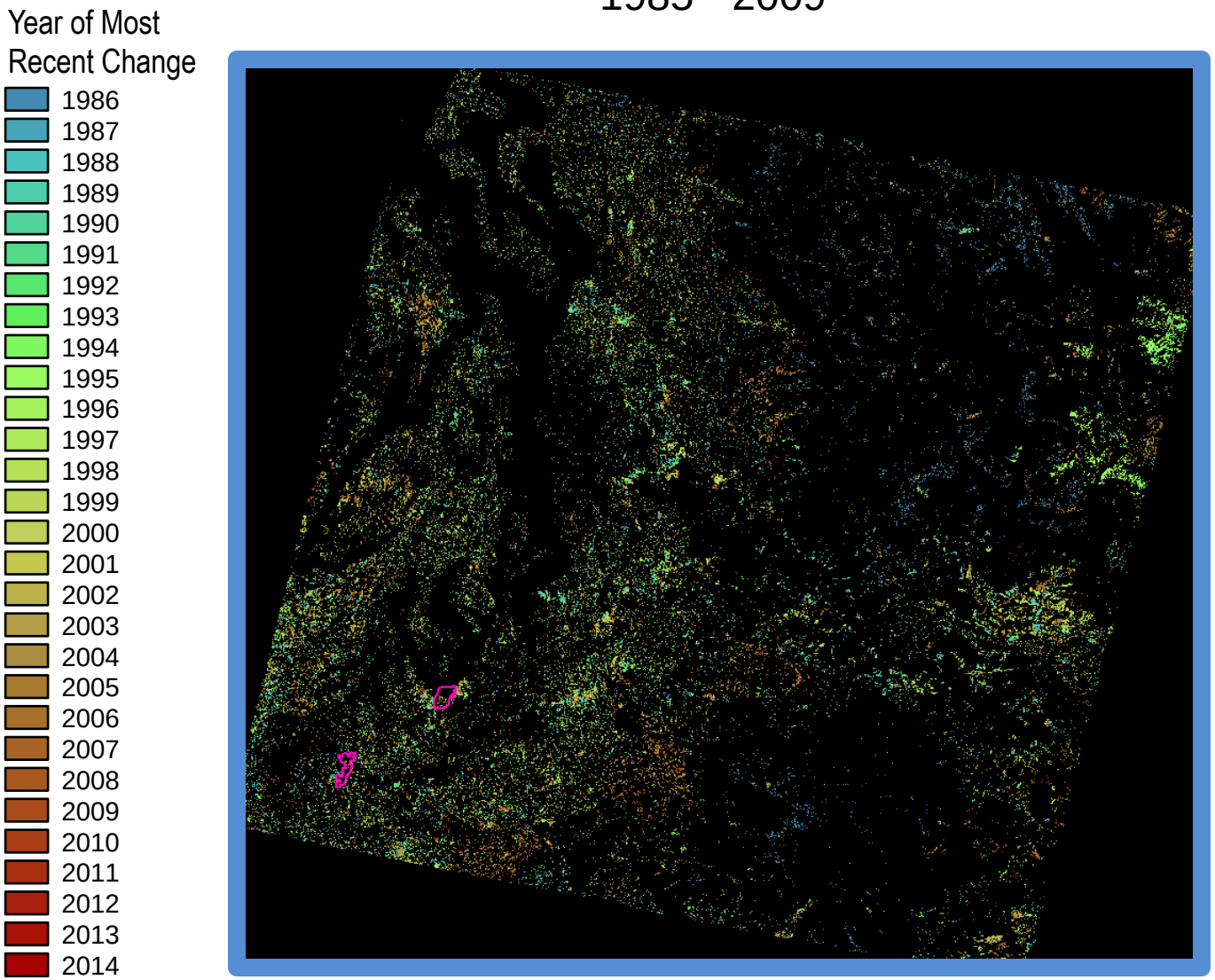
Timing of change

1985 - 2008



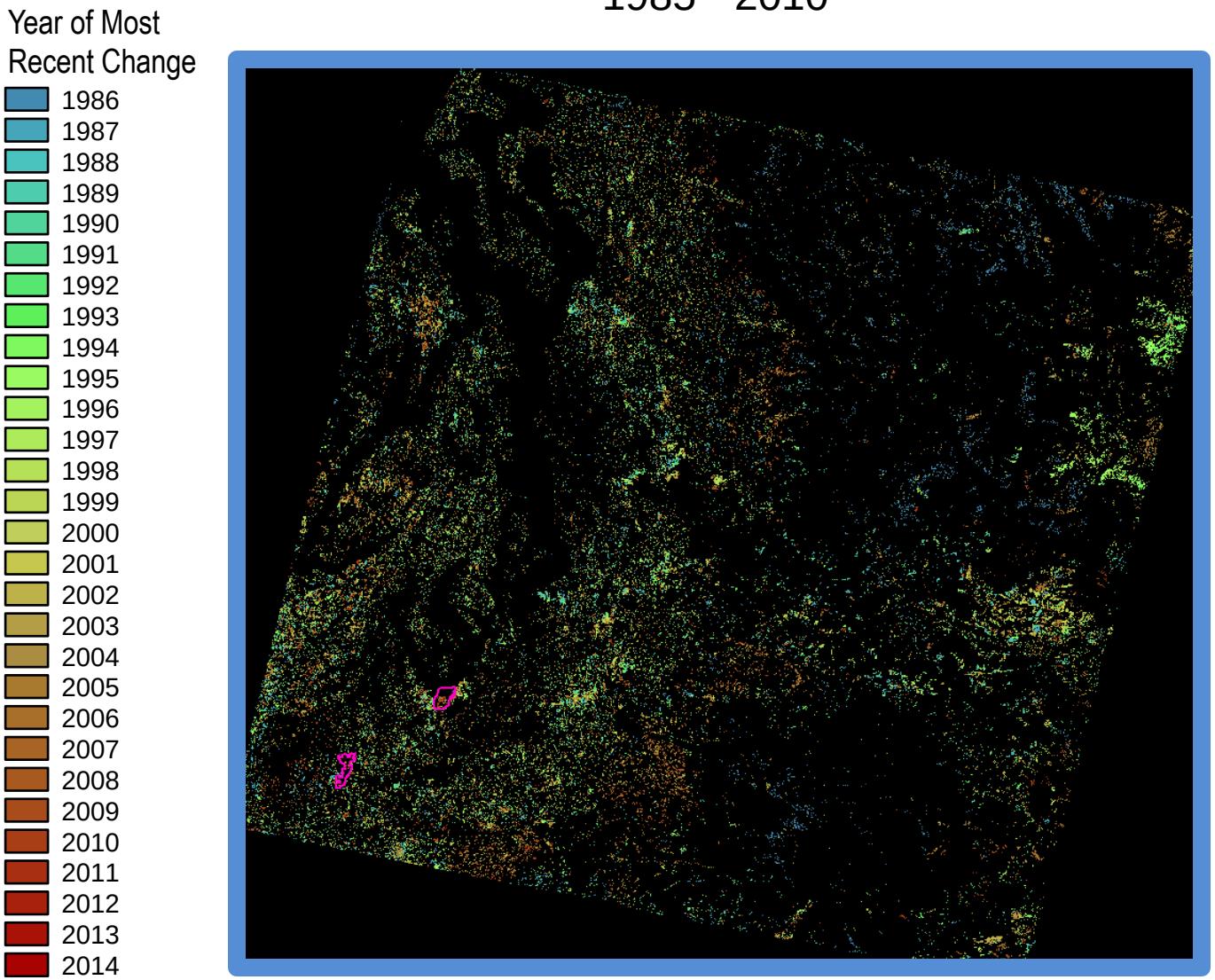
Timing of change

1985 - 2009



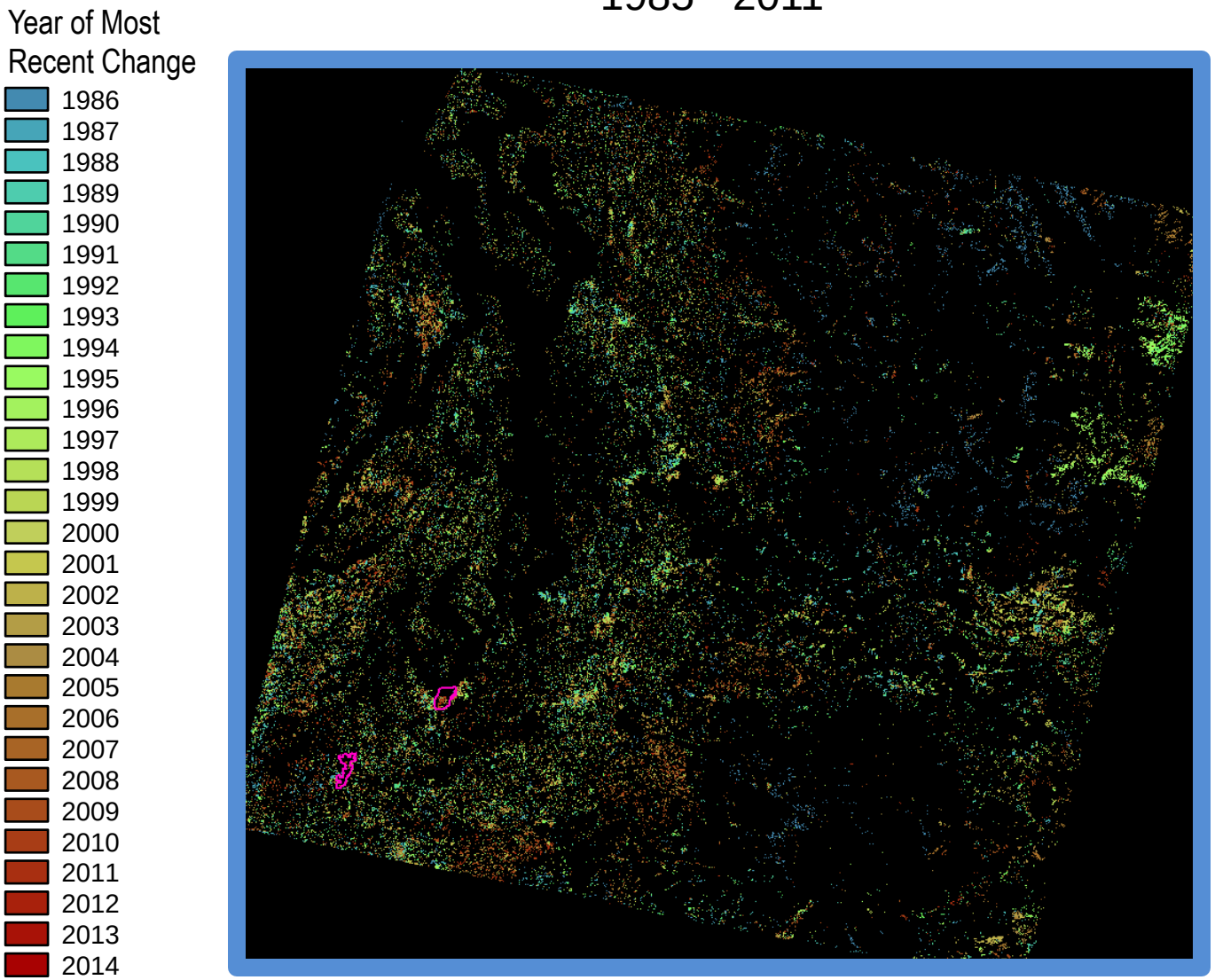
Timing of change

1985 - 2010



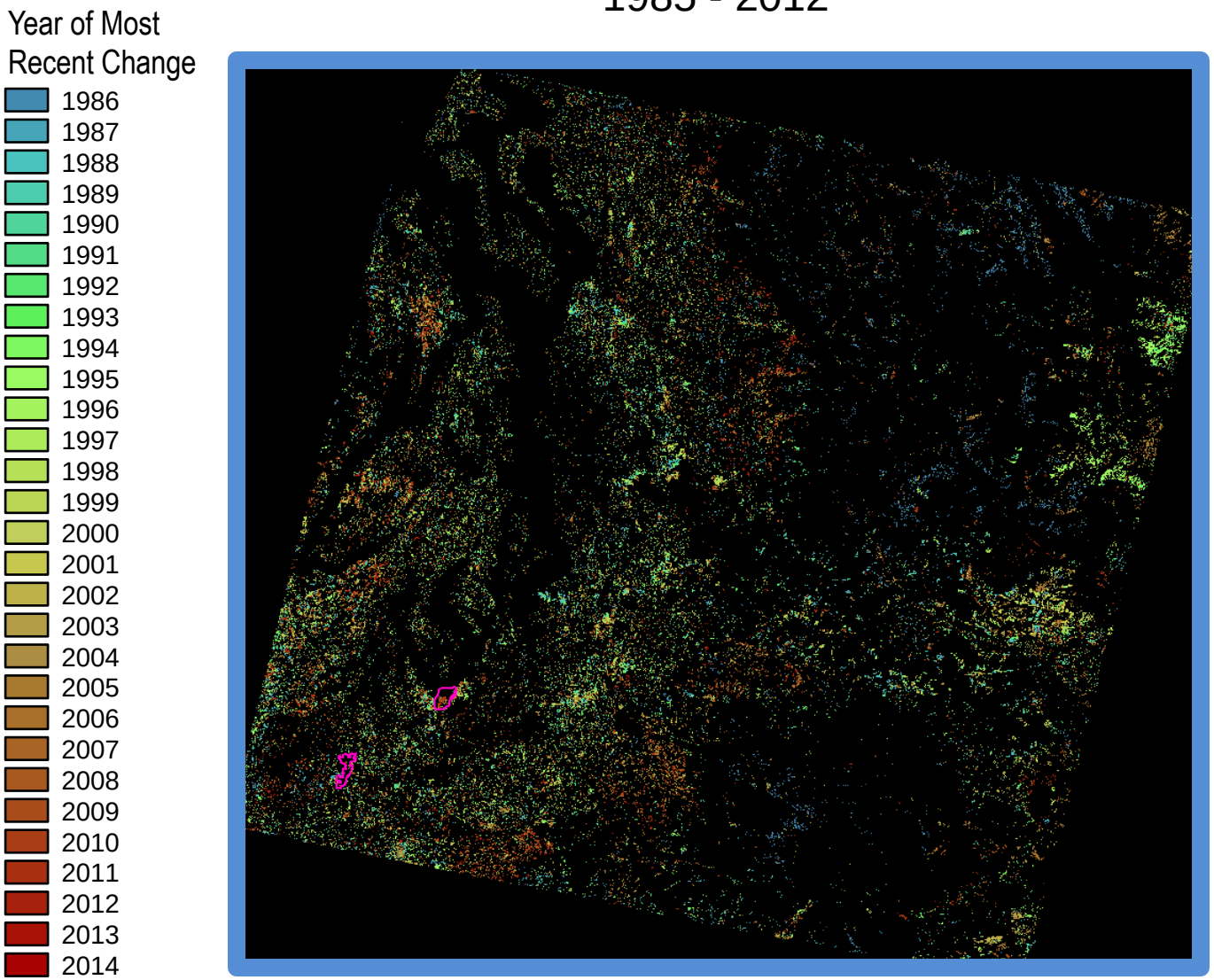
Timing of change

1985 - 2011



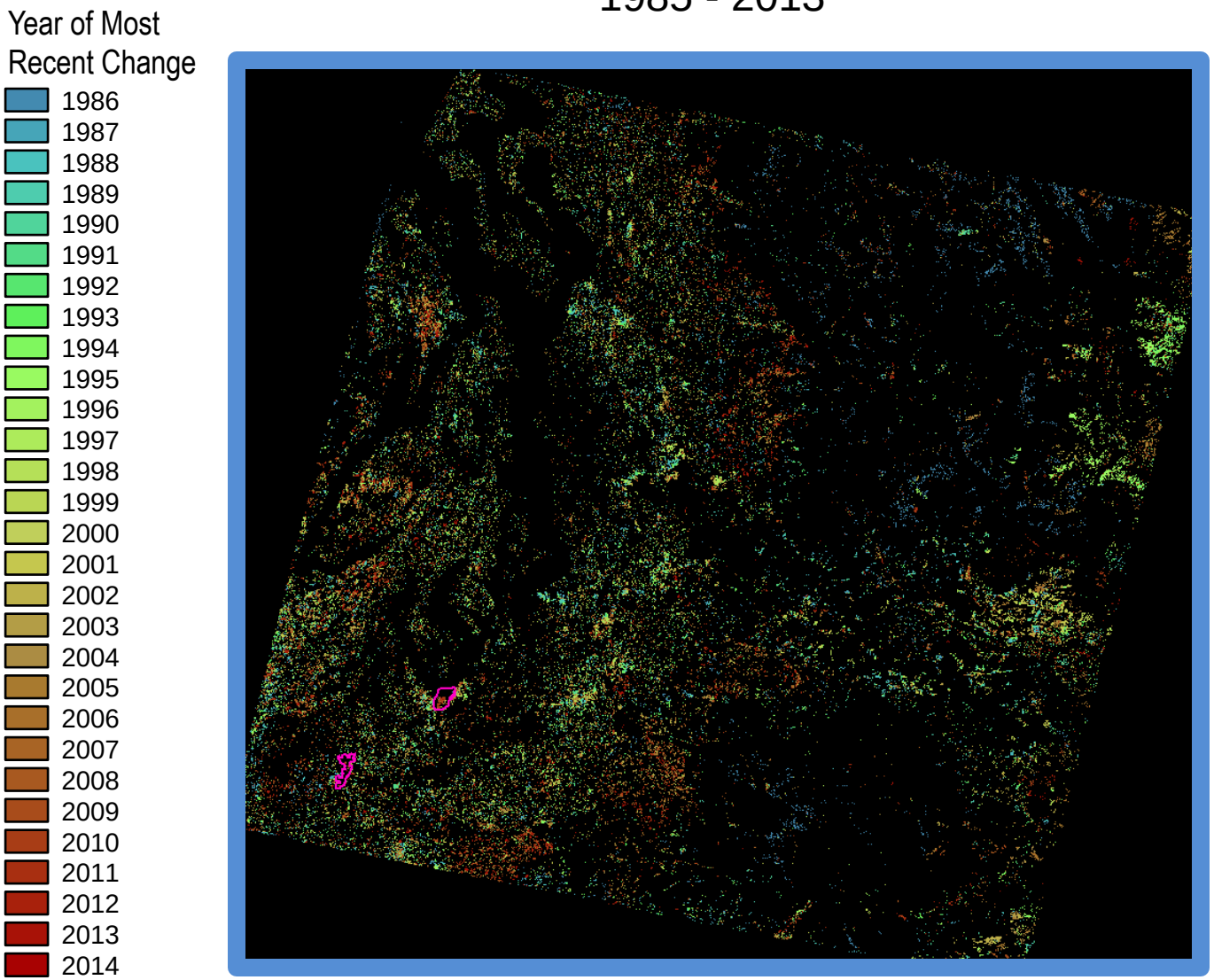
Timing of change

1985 - 2012



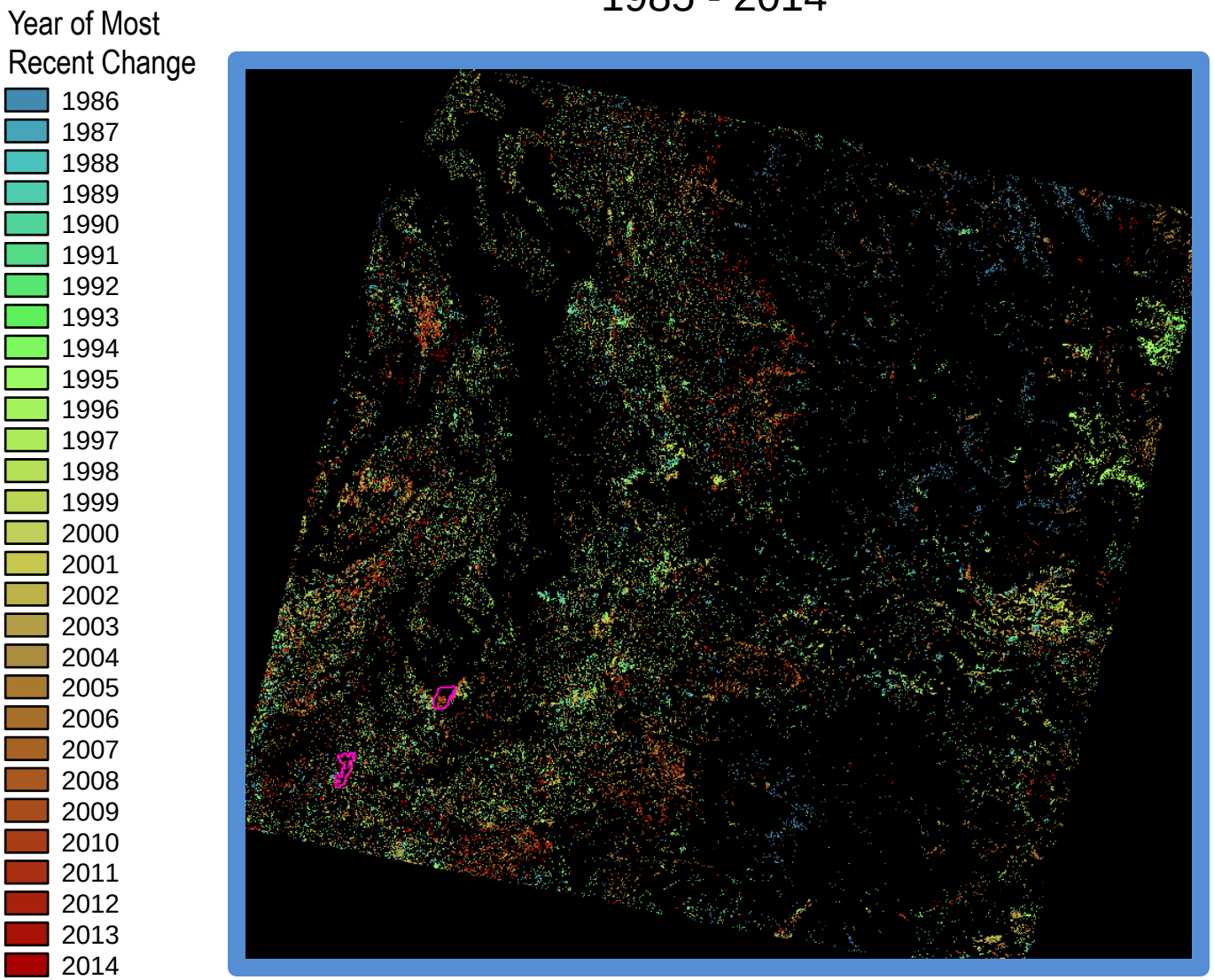
Timing of change

1985 - 2013



Timing of change

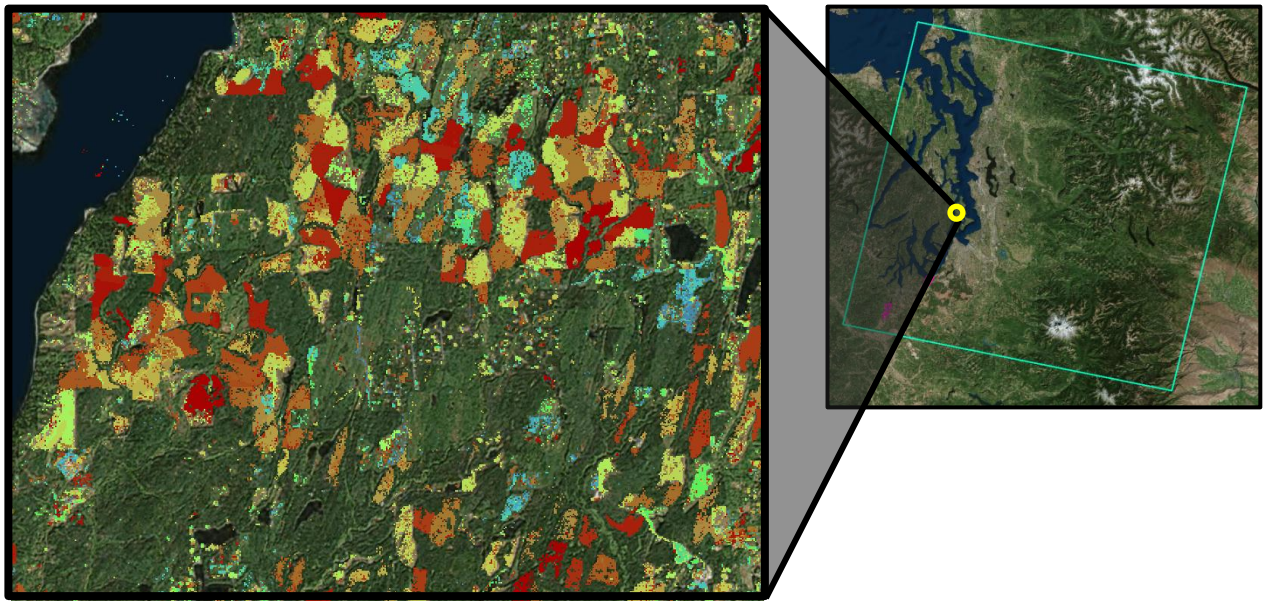
1985 - 2014



Timing of change

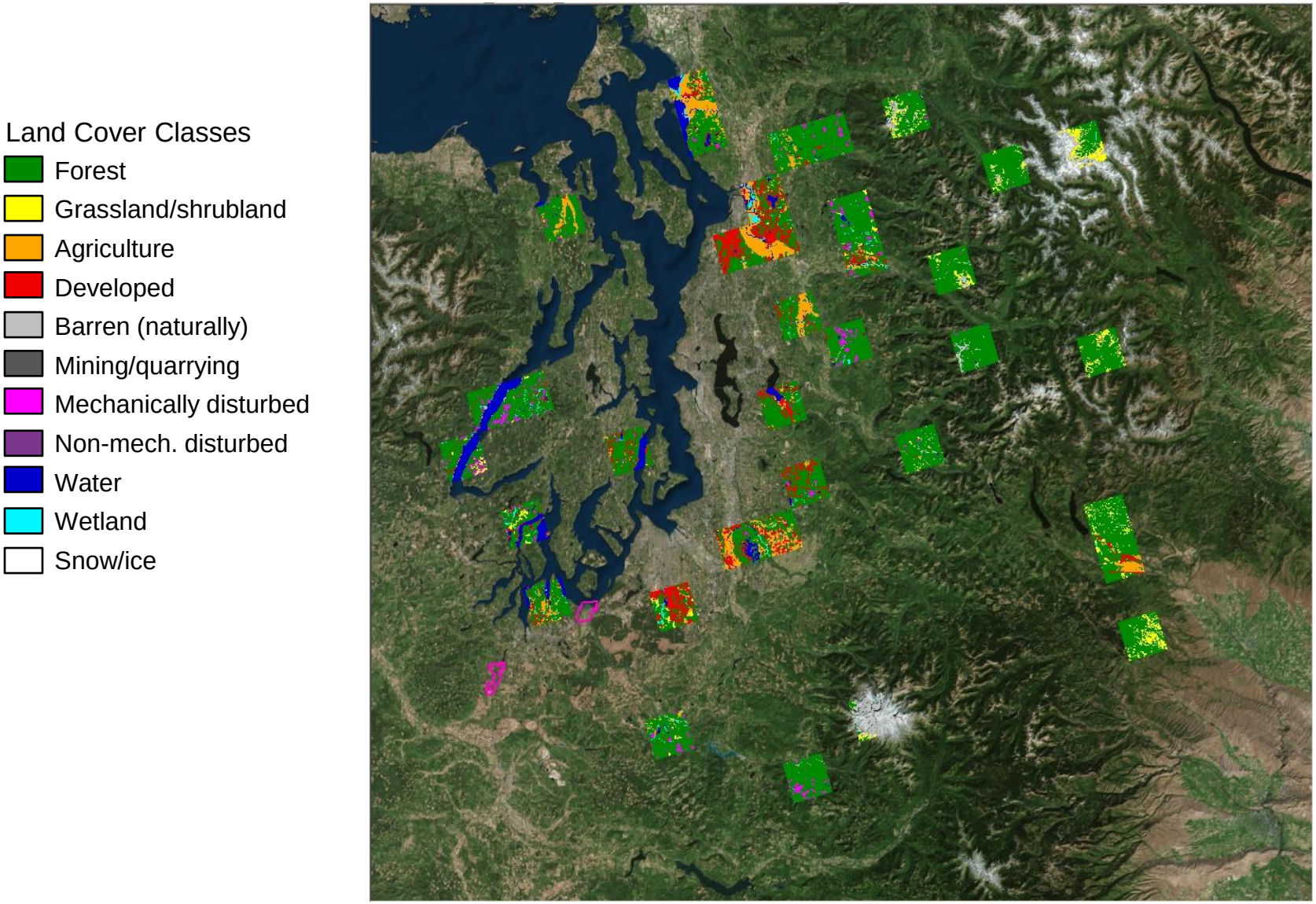
Year of Most Recent Change

- 1986
- 1987
- 1988
- 1989
- 1990
- 1991
- 1992
- 1993
- 1994
- 1995
- 1996
- 1997
- 1998
- 1999
- 2000
- 2001
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014



Example close-up

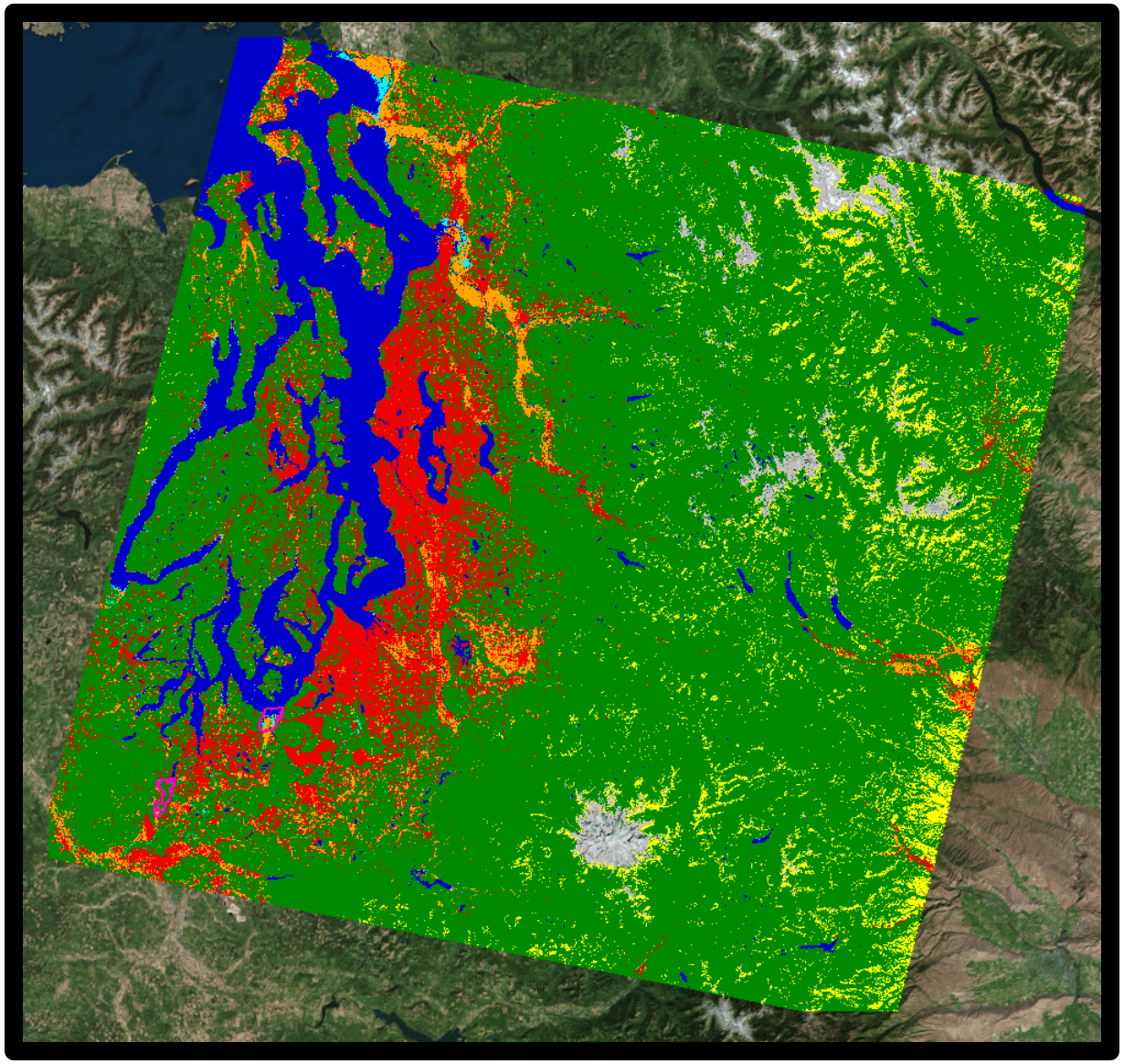
Distribution of landscape samples in Landsat PR 46/27 from the USGS Land Cover Trends Project



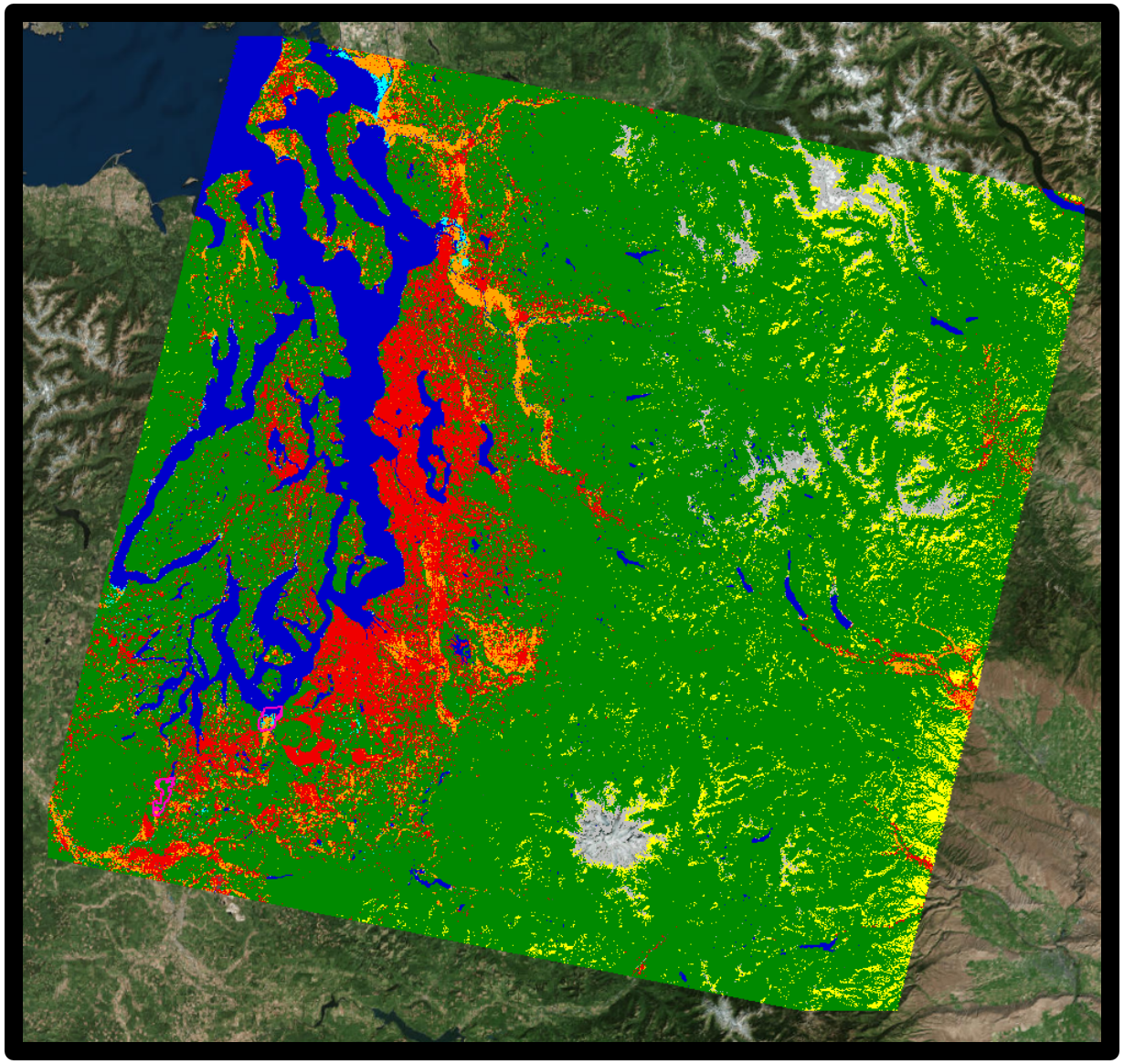
1985

Land Cover Classes

- Forest
- Grassland/shrubland
- Agriculture
- Developed
- Barren (naturally)
- Mining/quarrying
- Mechanically disturbed
- Non-mech. disturbed
- Water
- Wetland
- Snow/ice



1986


Land Cover Classes
Forest
Grassland/shrubland
Agriculture
Developed
Barren (naturally)
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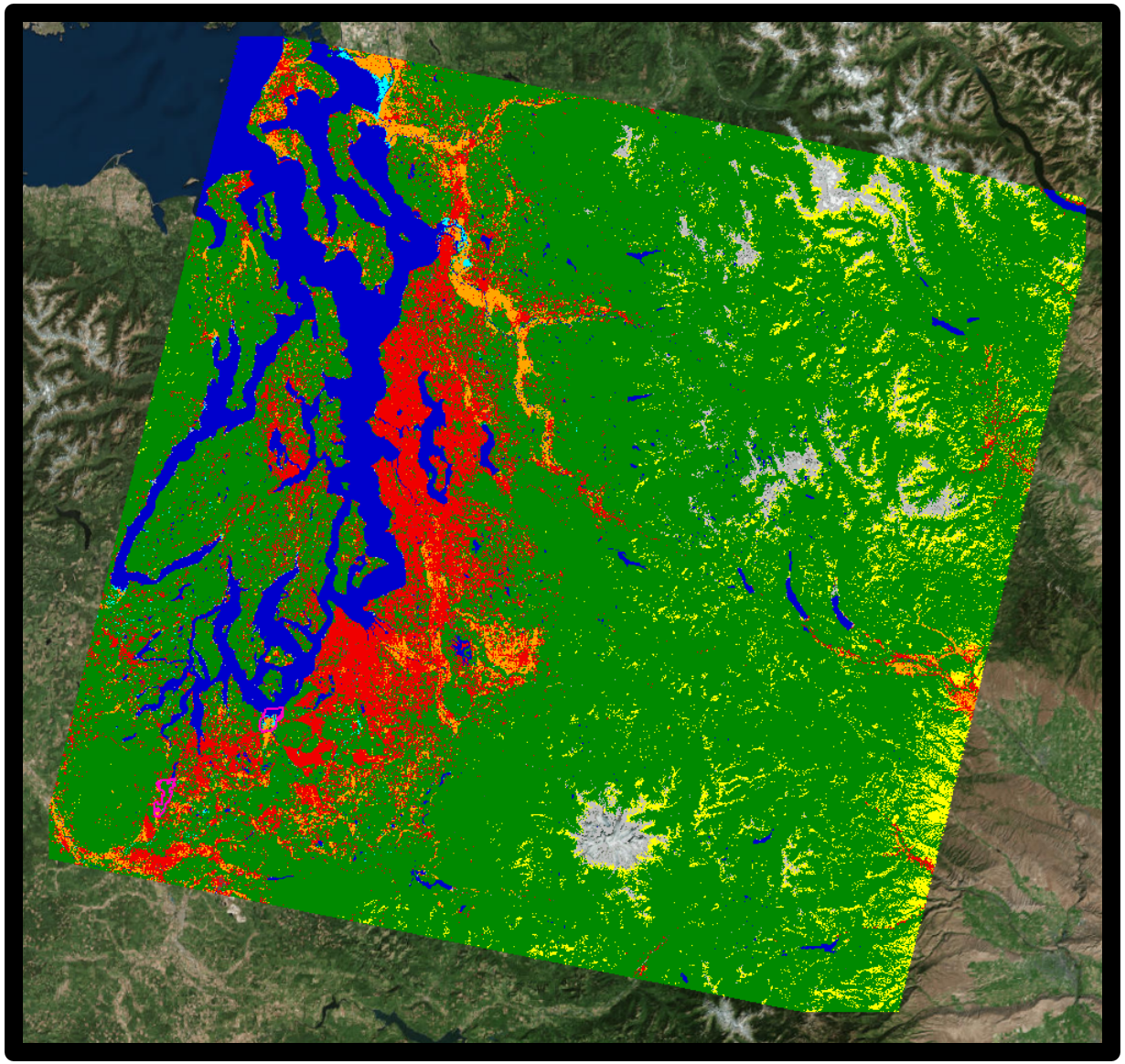
Mechanically disturbed
Non-mech. disturbed
Water
Wetland
Snow/ice

1987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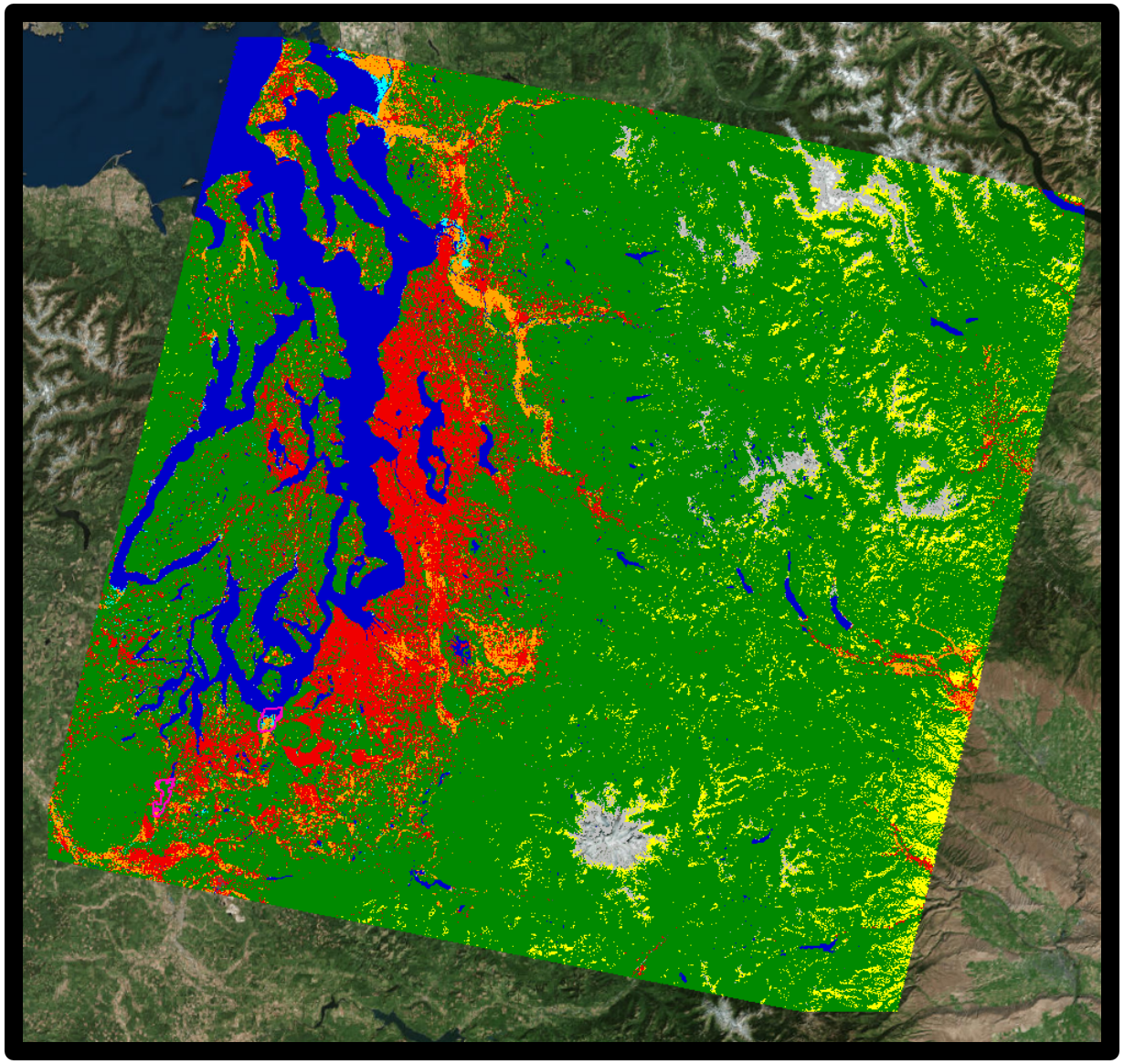
Mining/quarrying
Mechanically disturbed
Non-mech. disturbed
Water
Wetland
Snow/ice

1988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Mechanically disturbed
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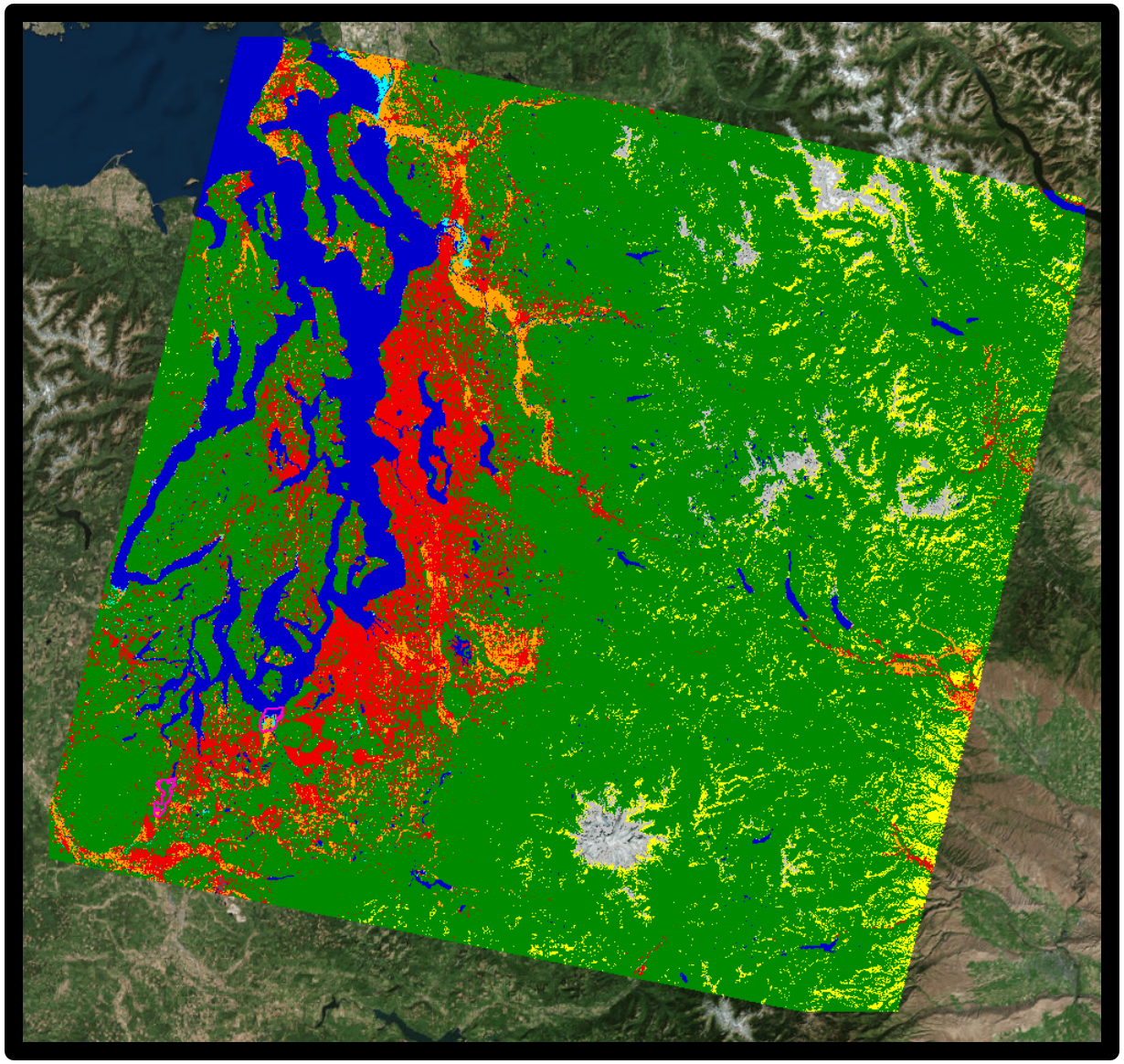
1989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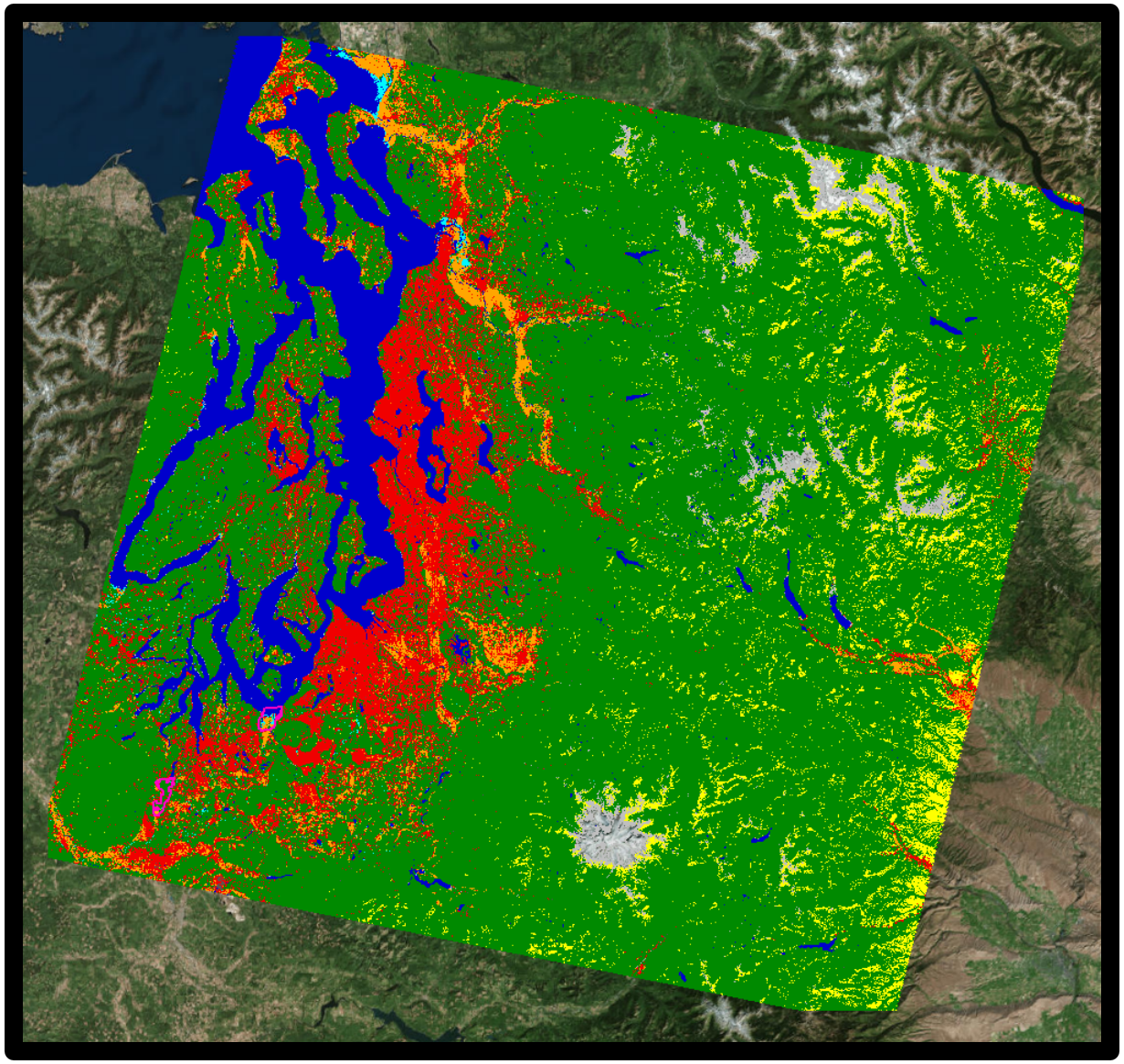
1990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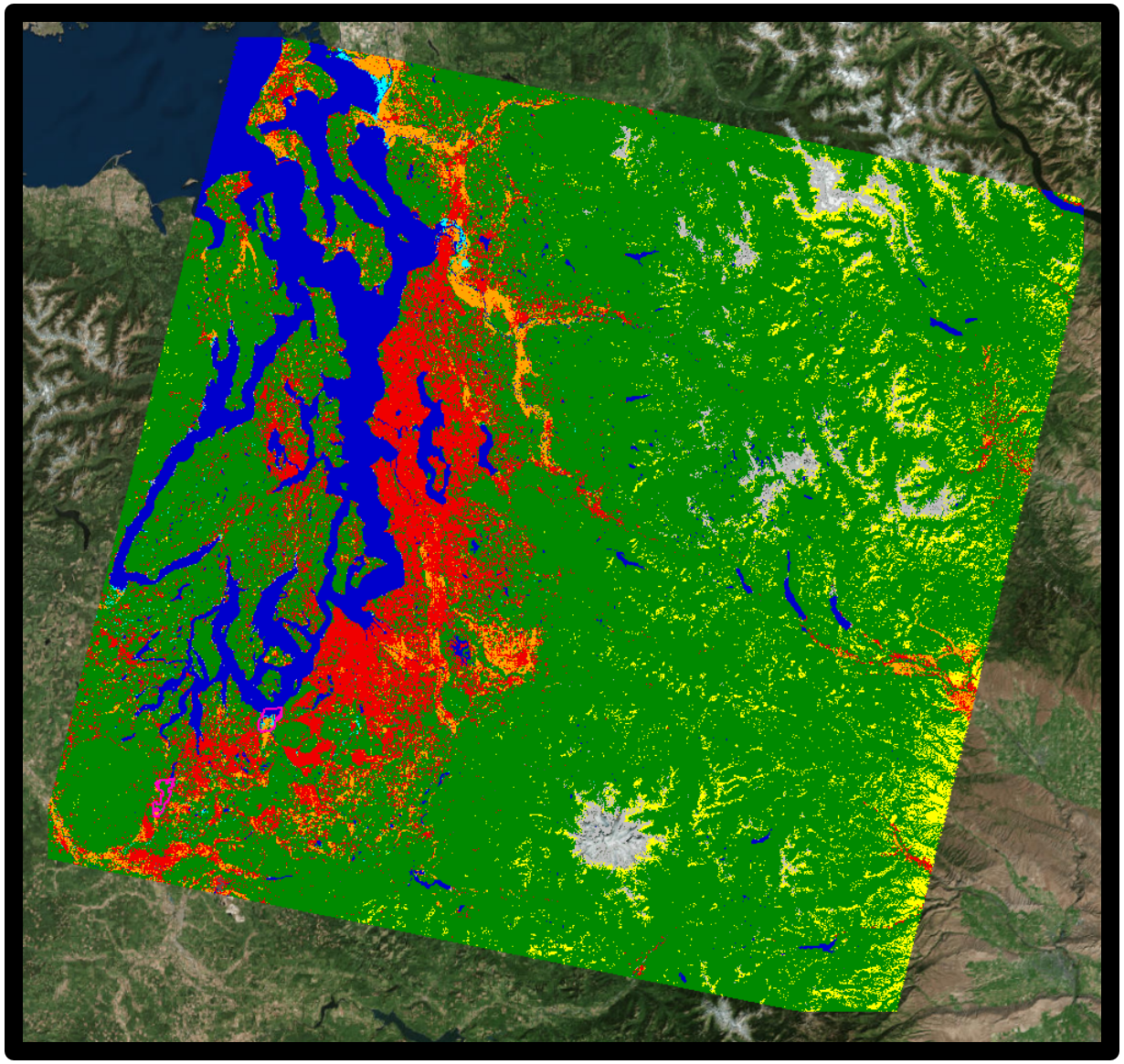
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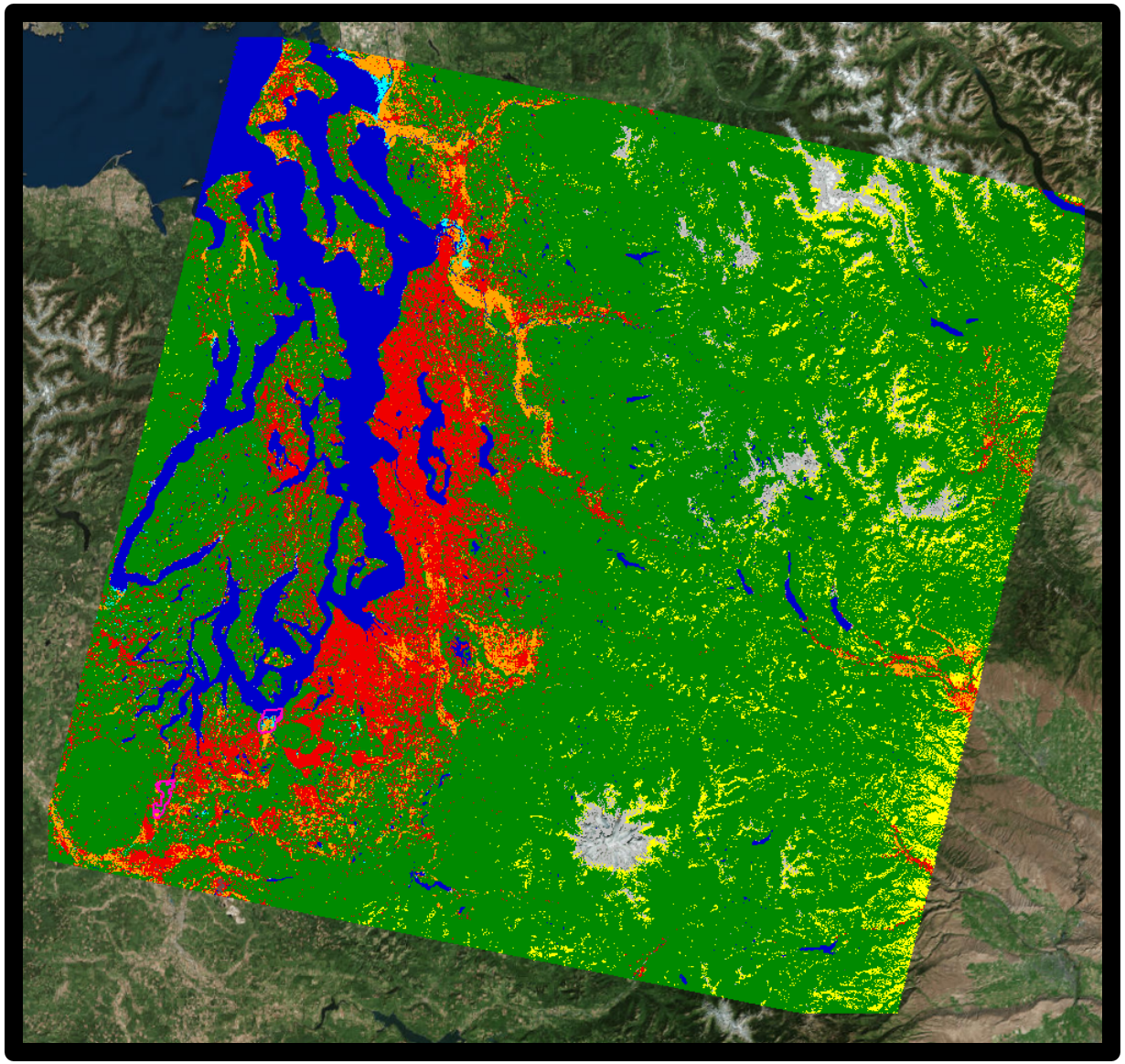
1992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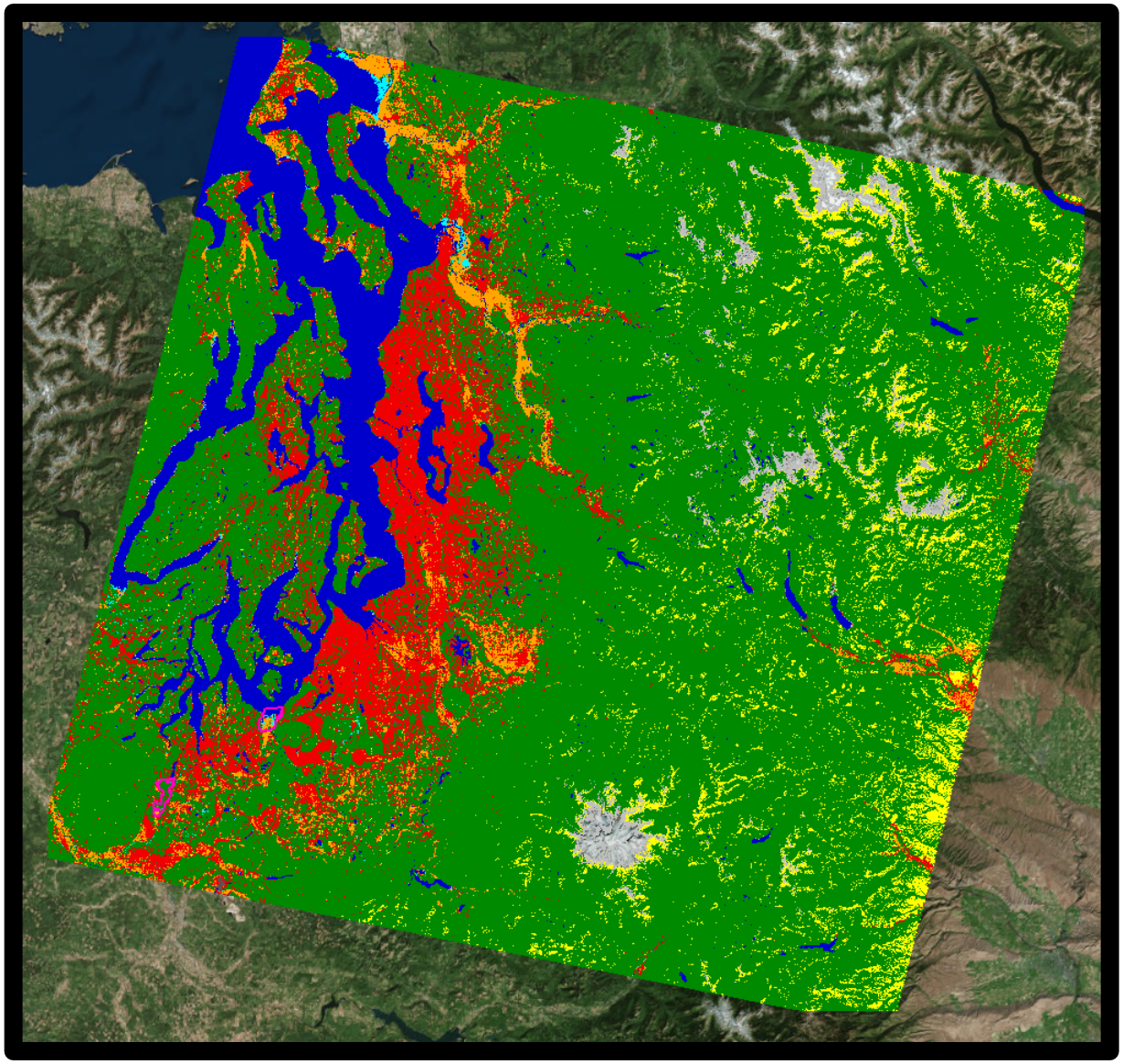
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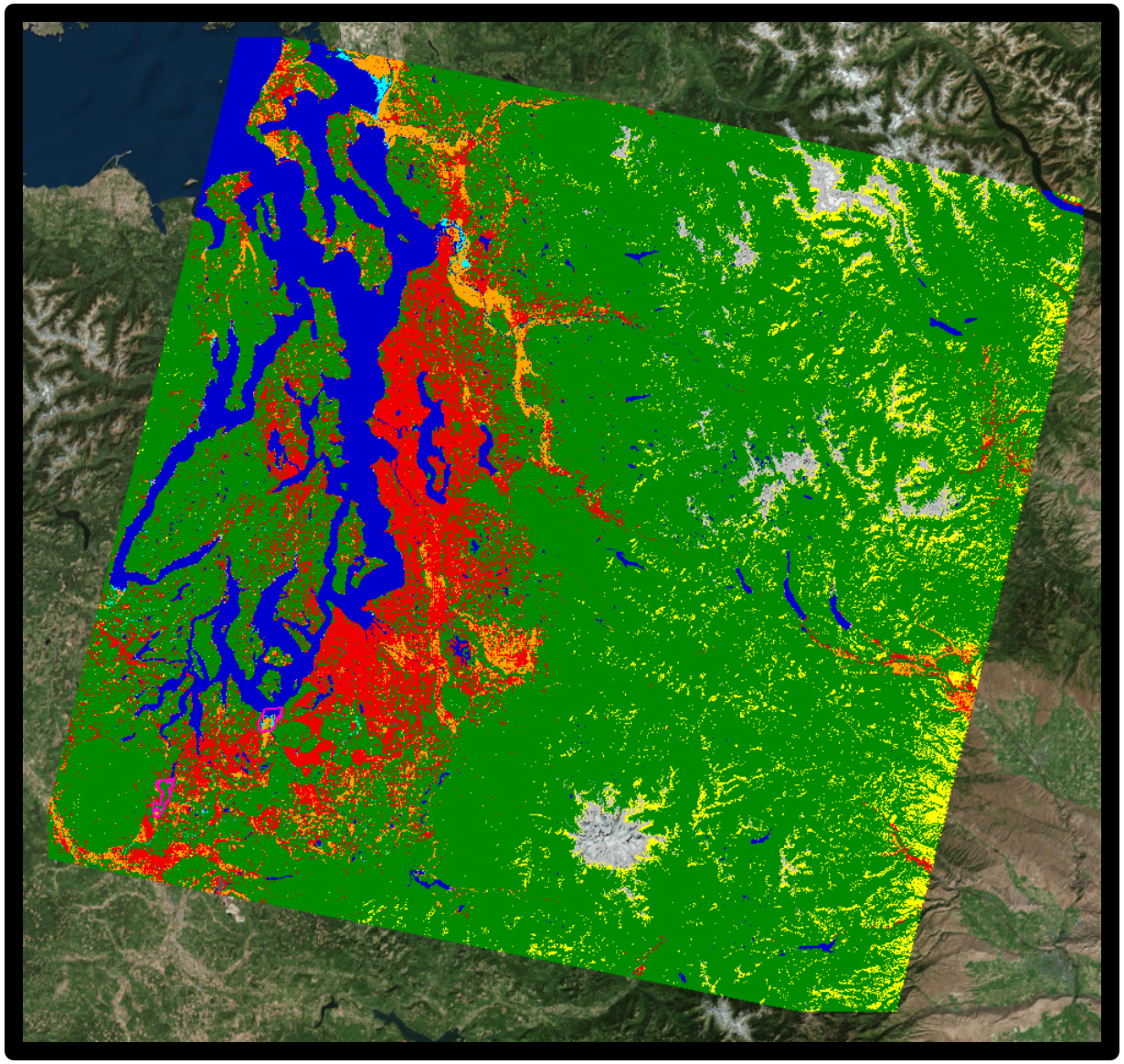
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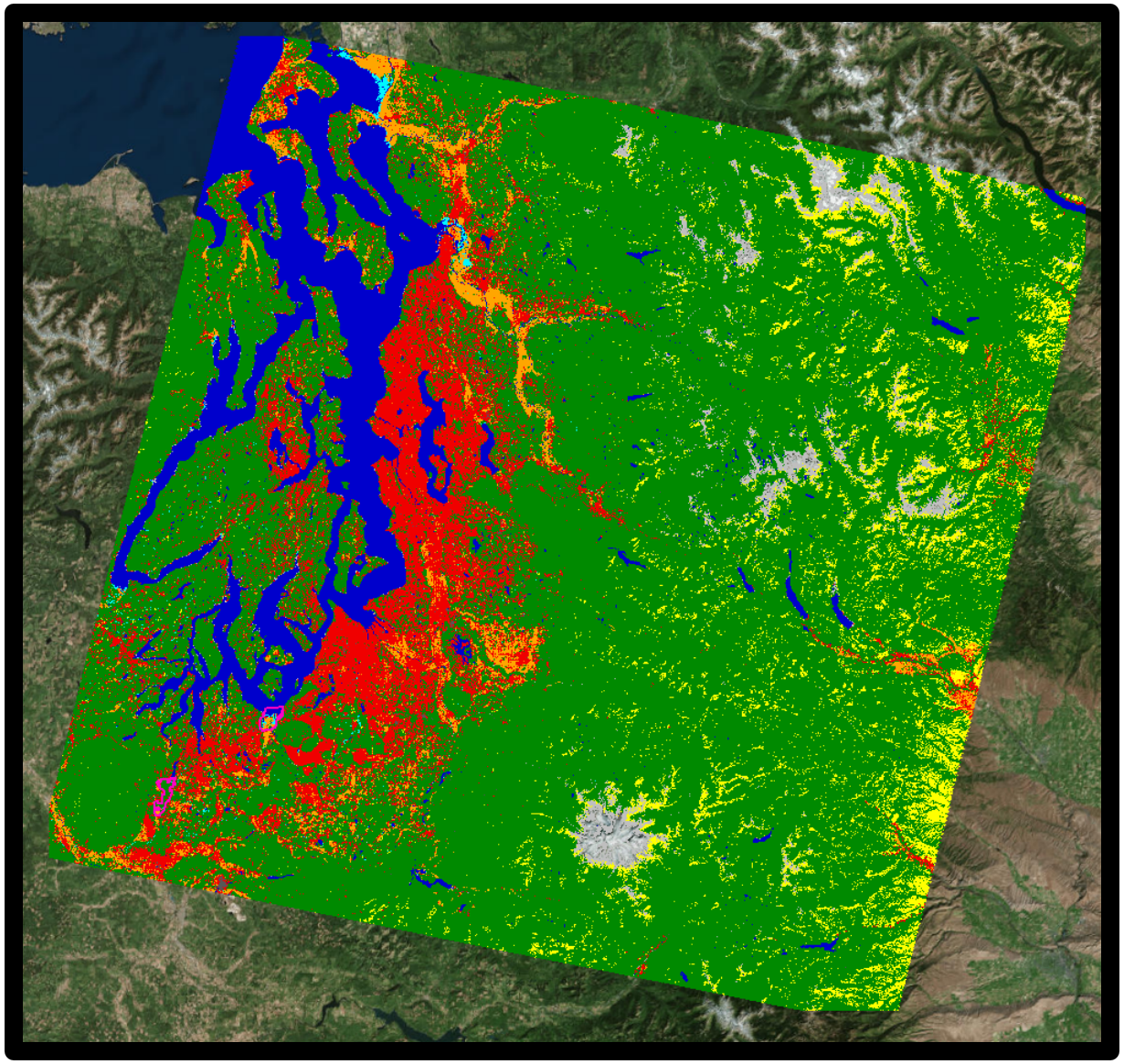
1995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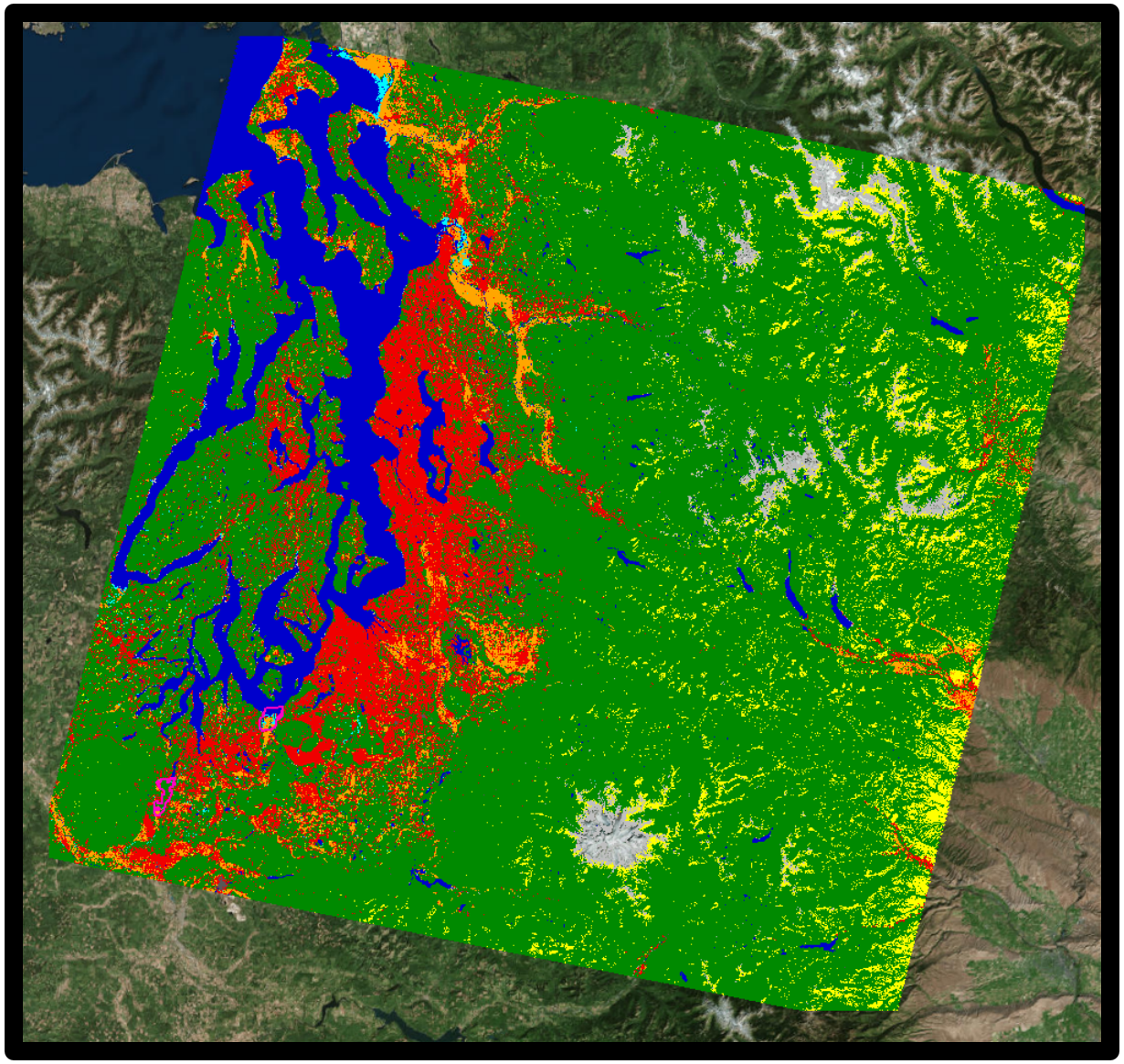
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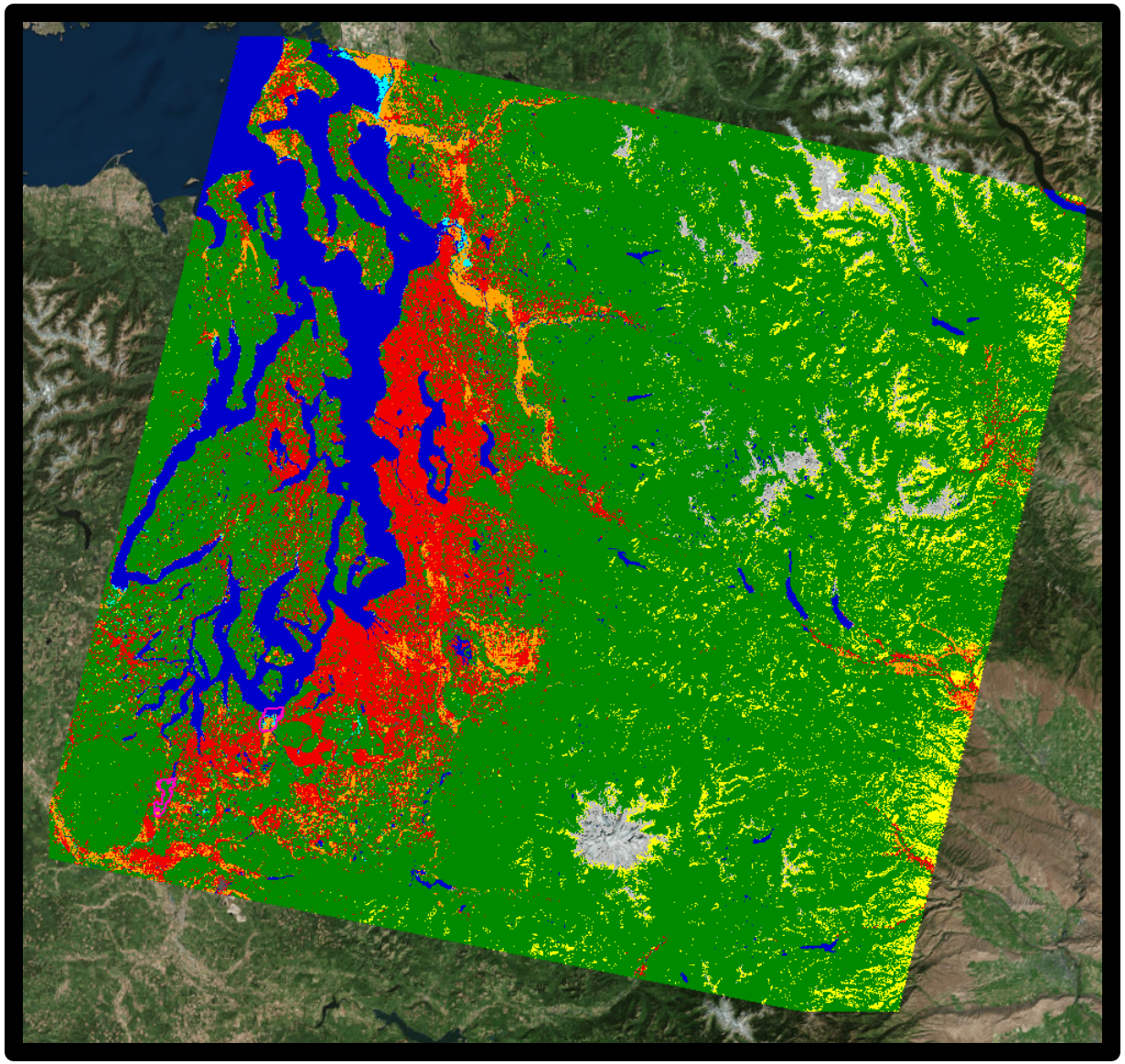
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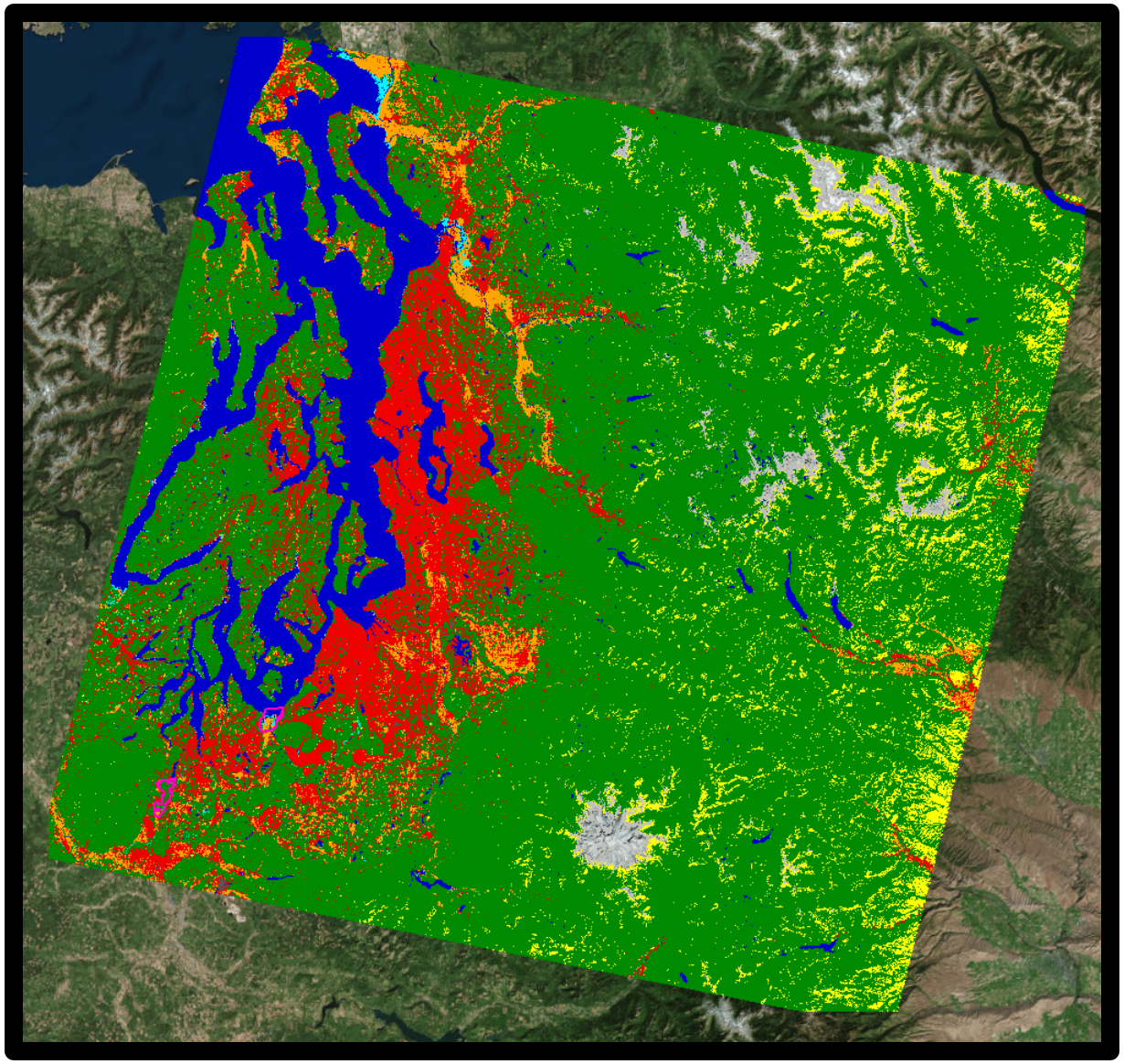
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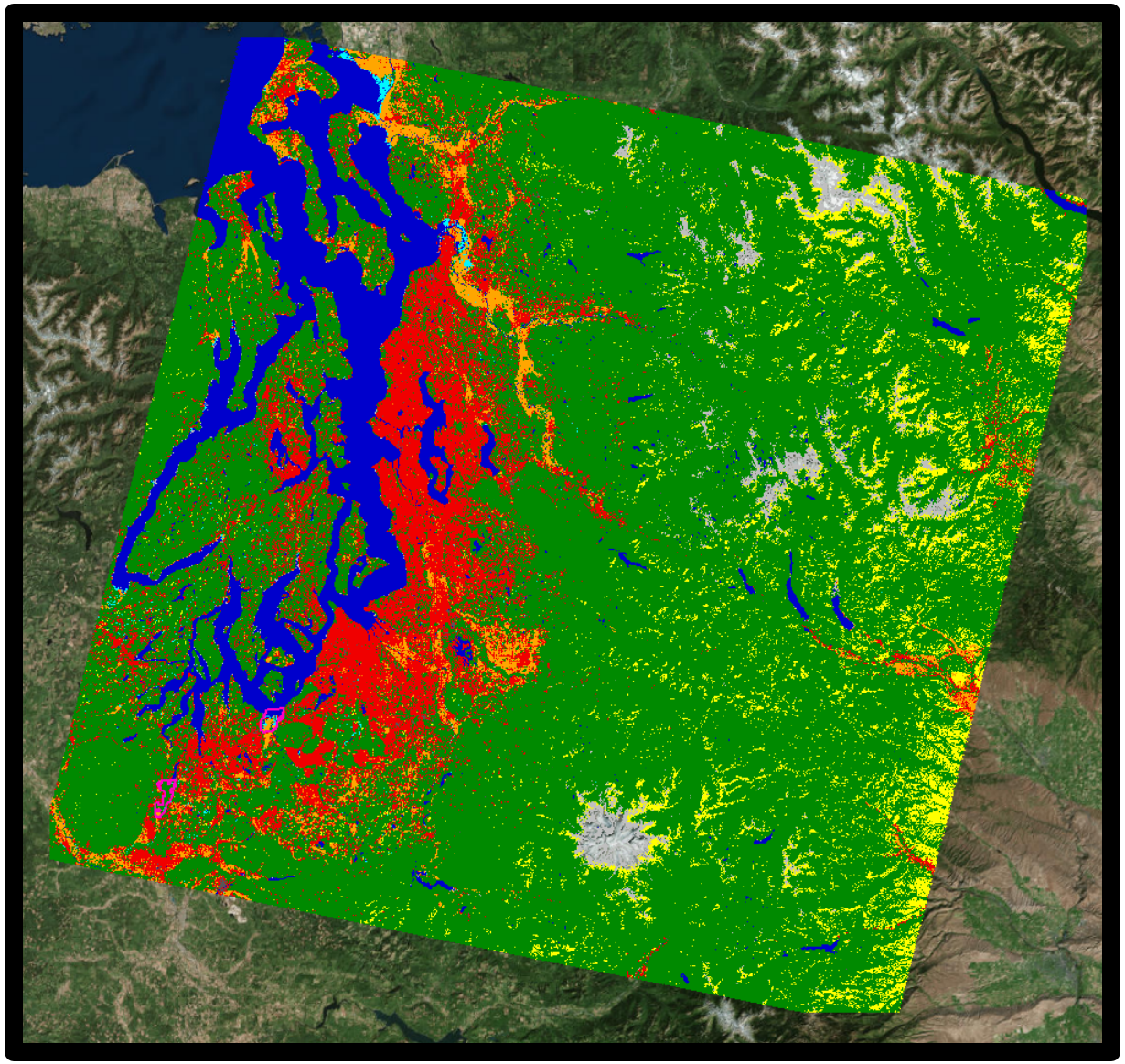
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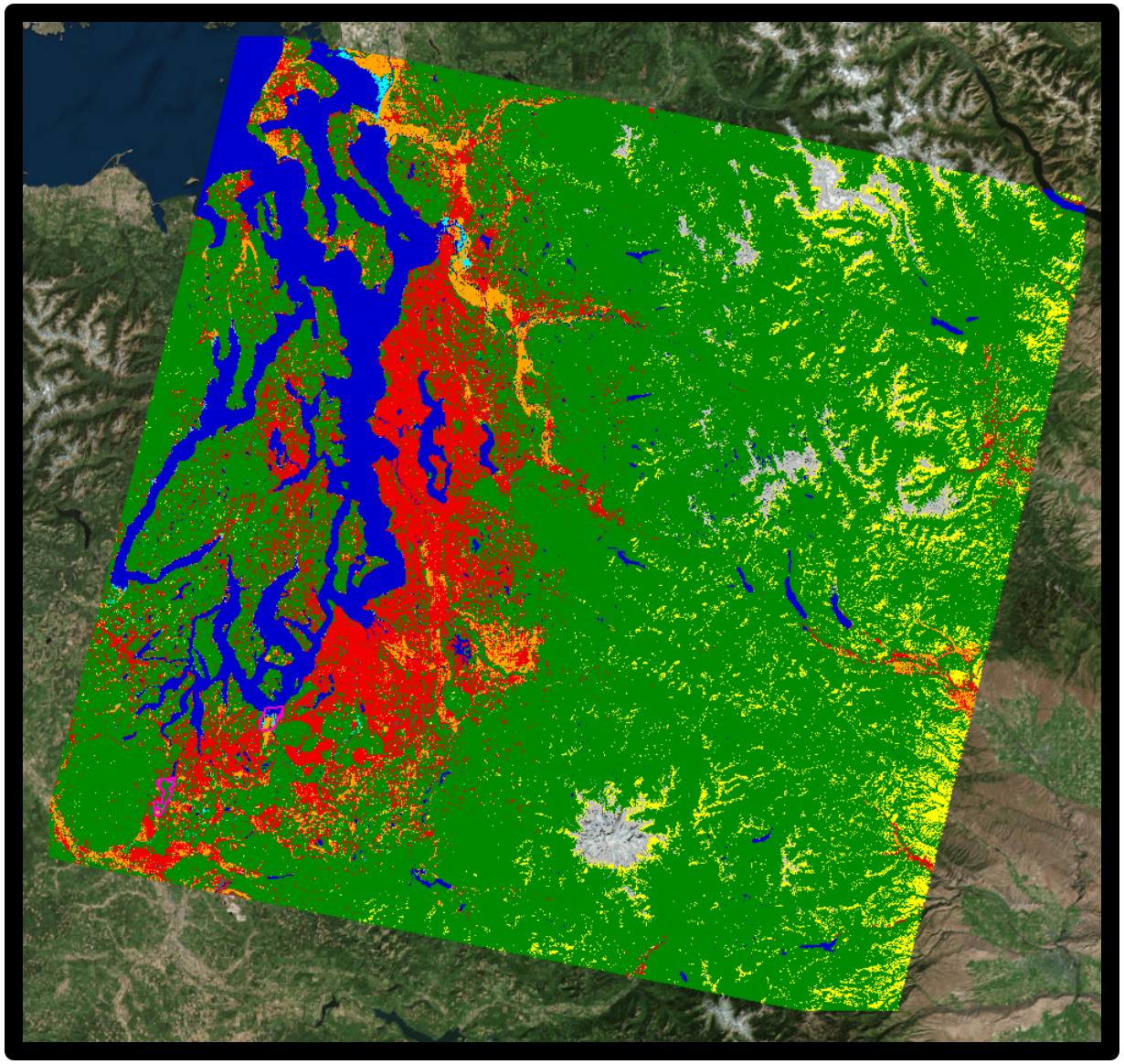

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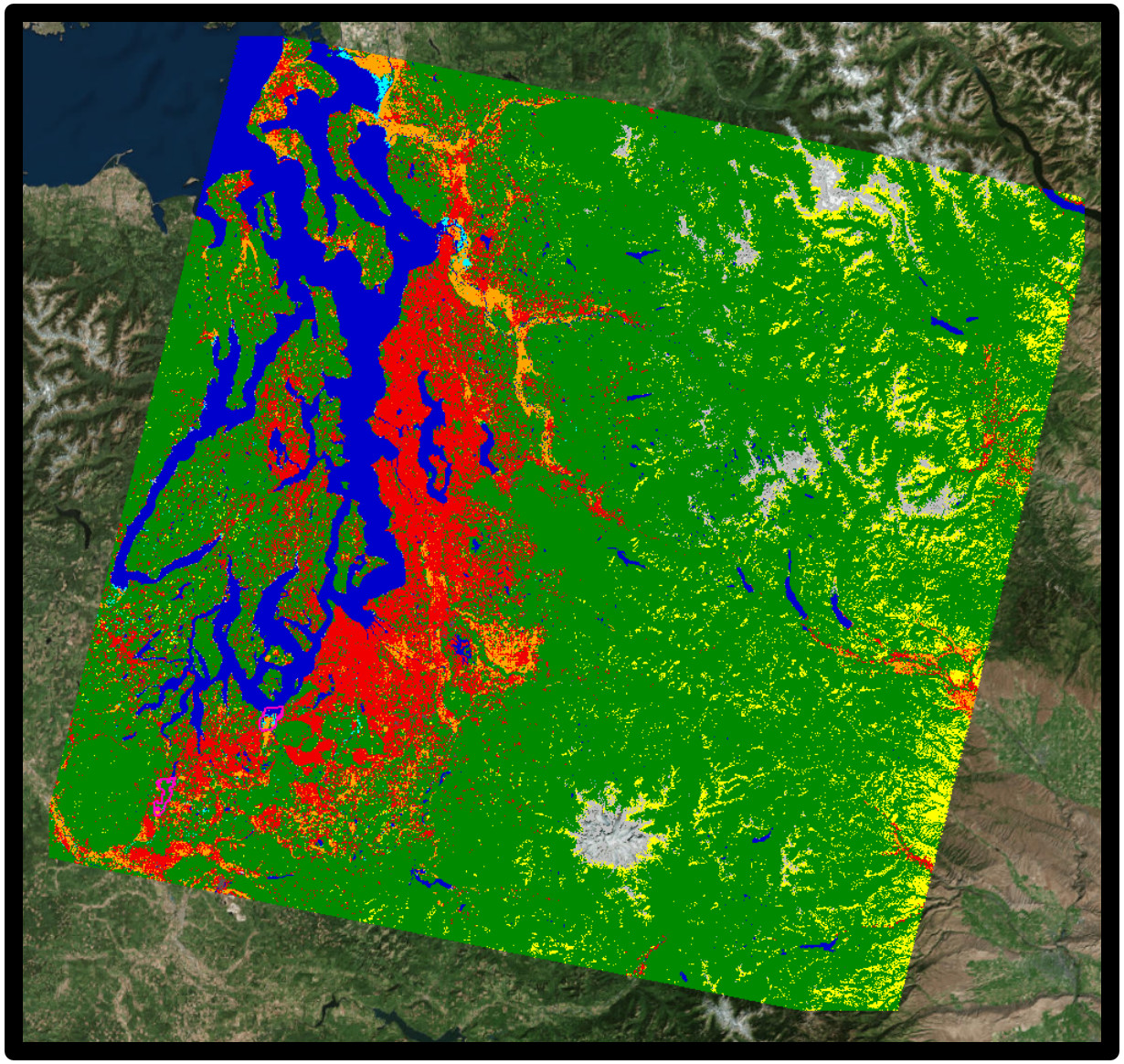
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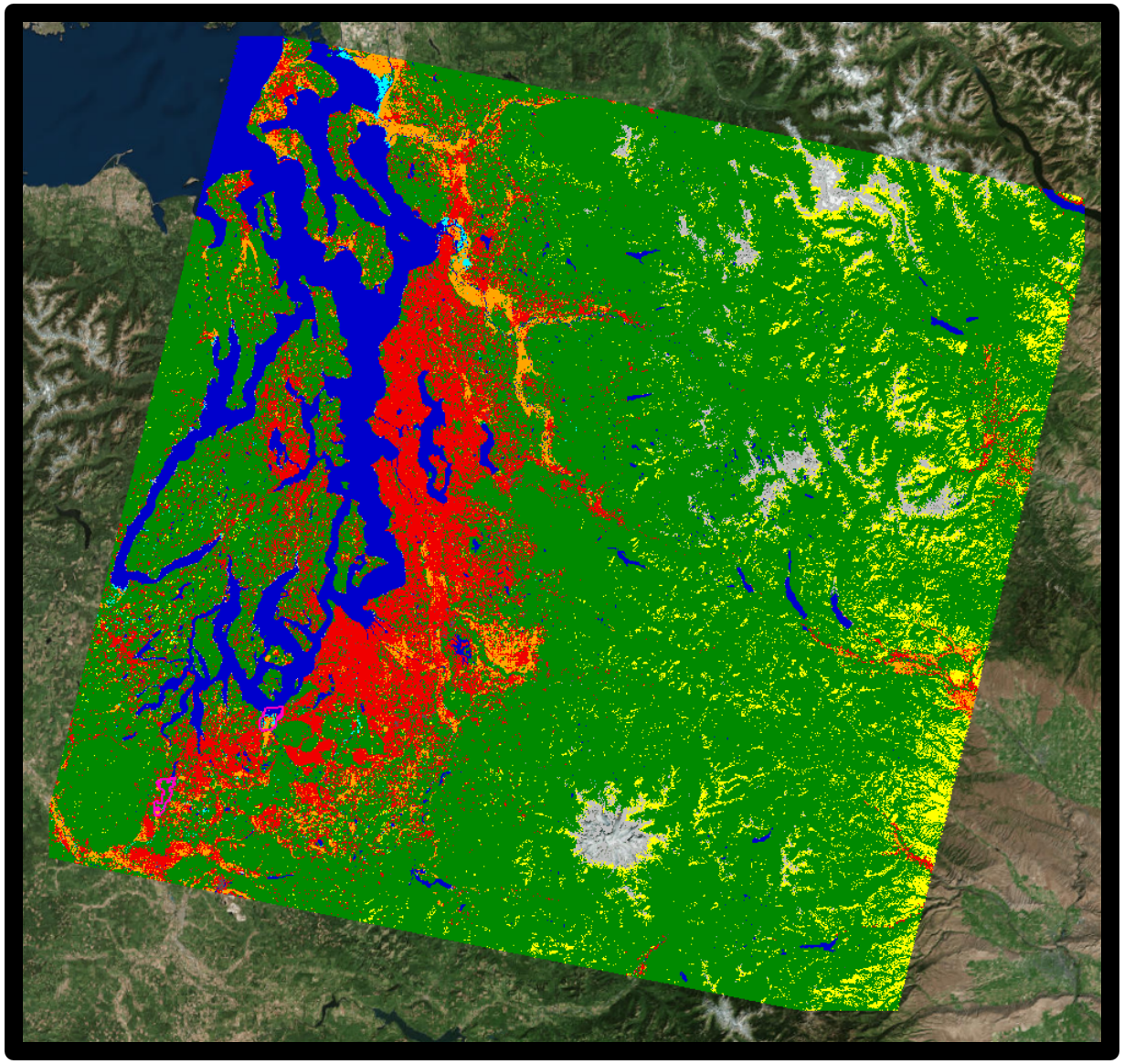

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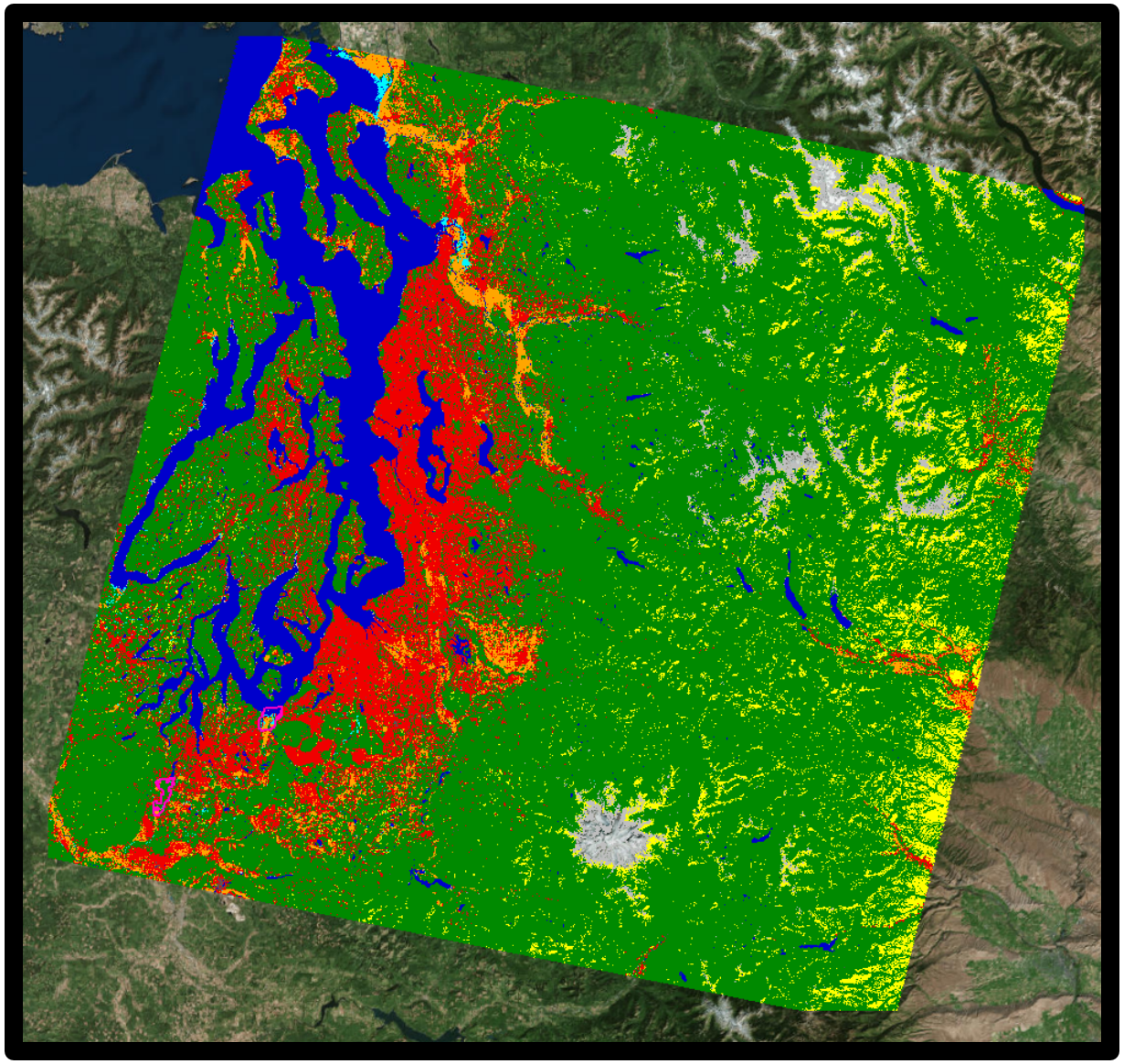
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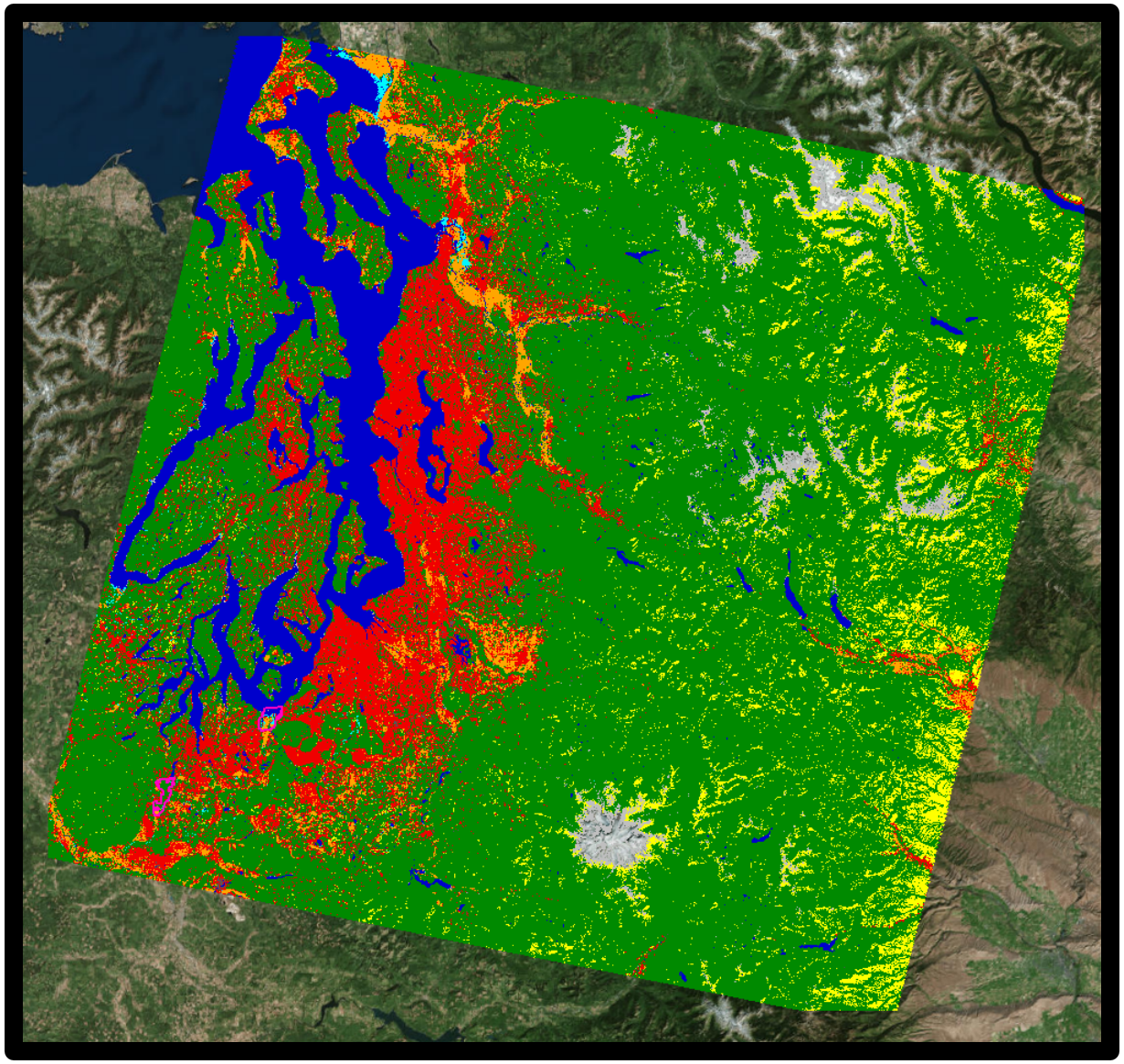
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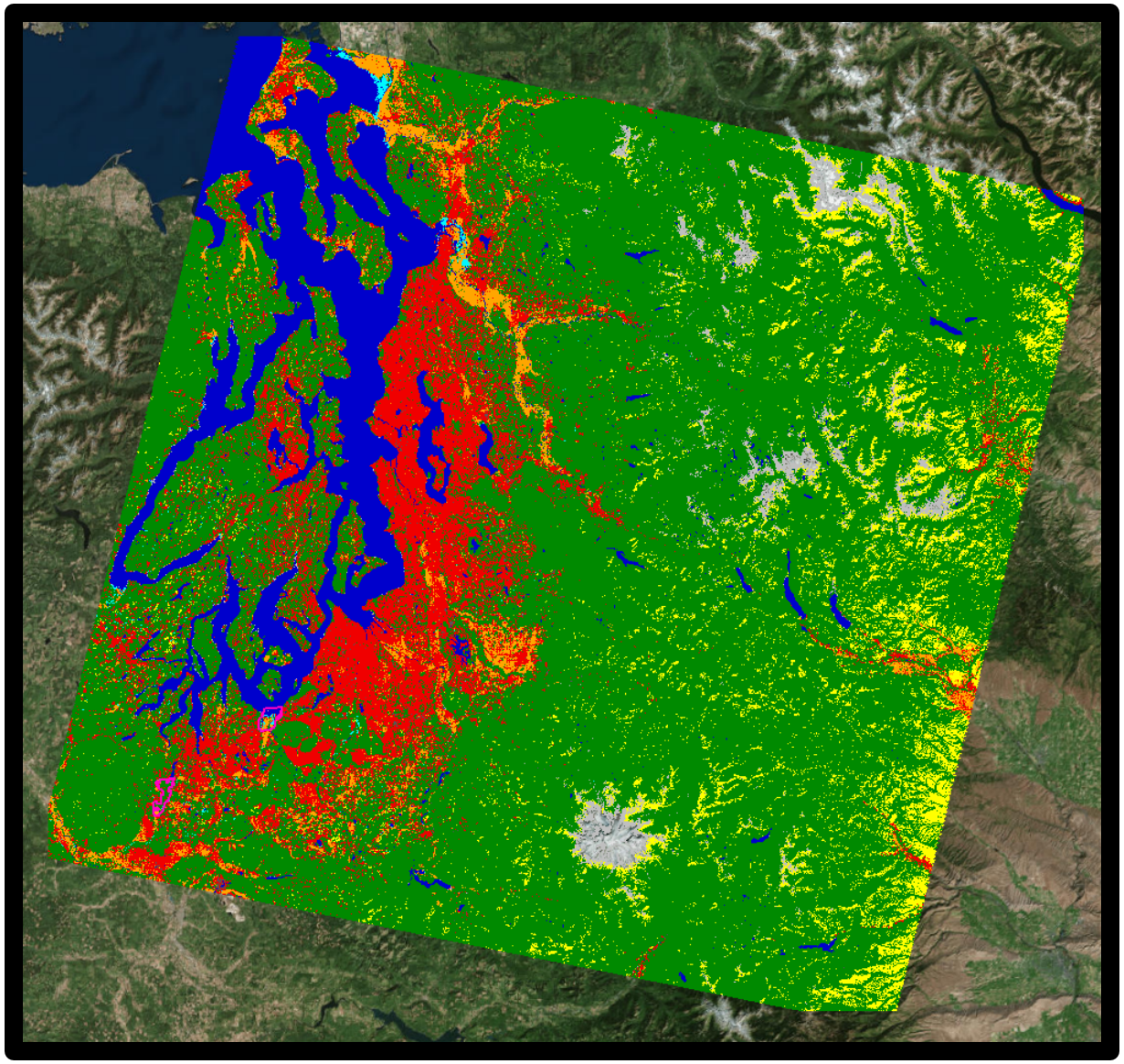
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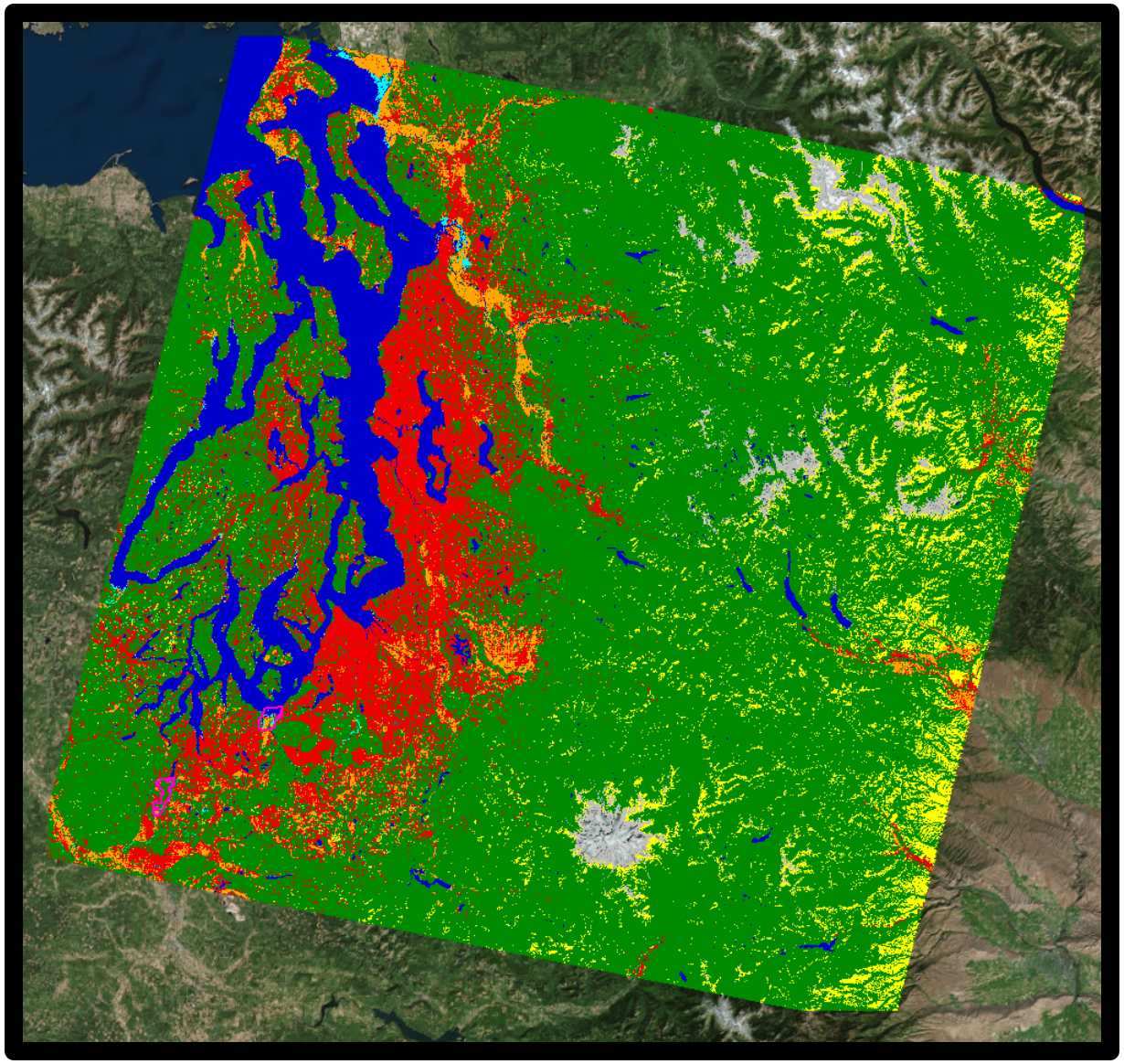
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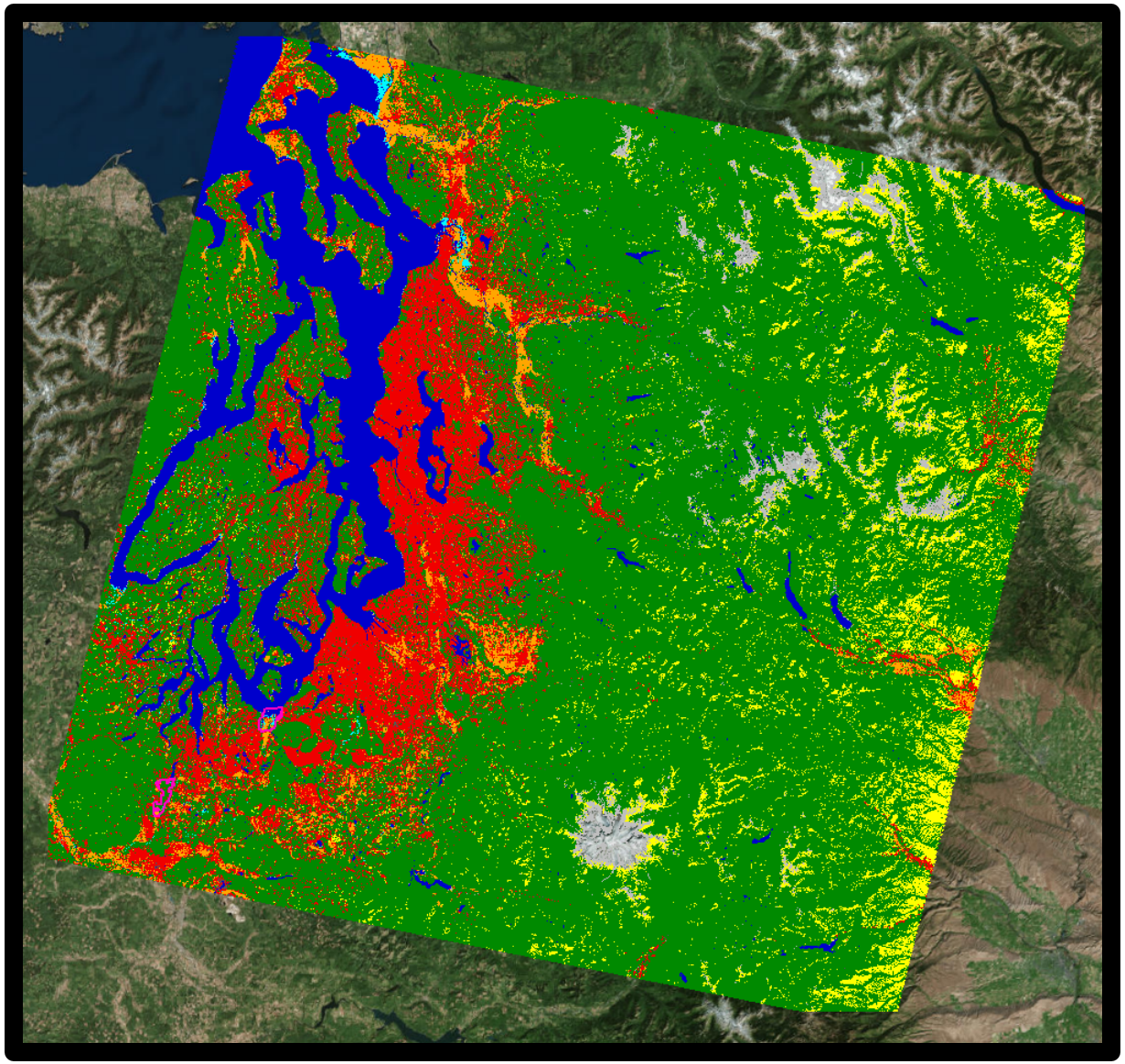
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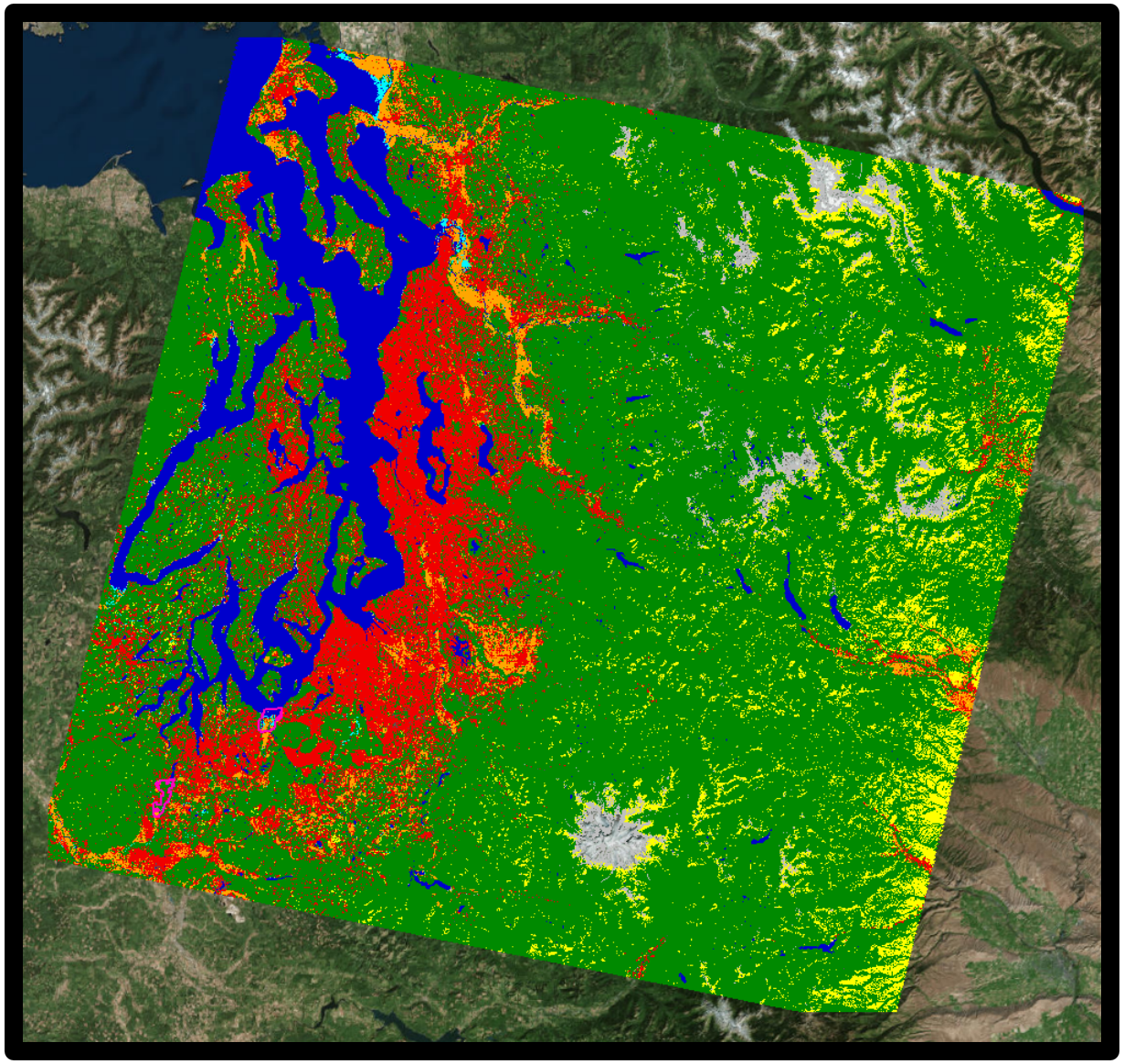
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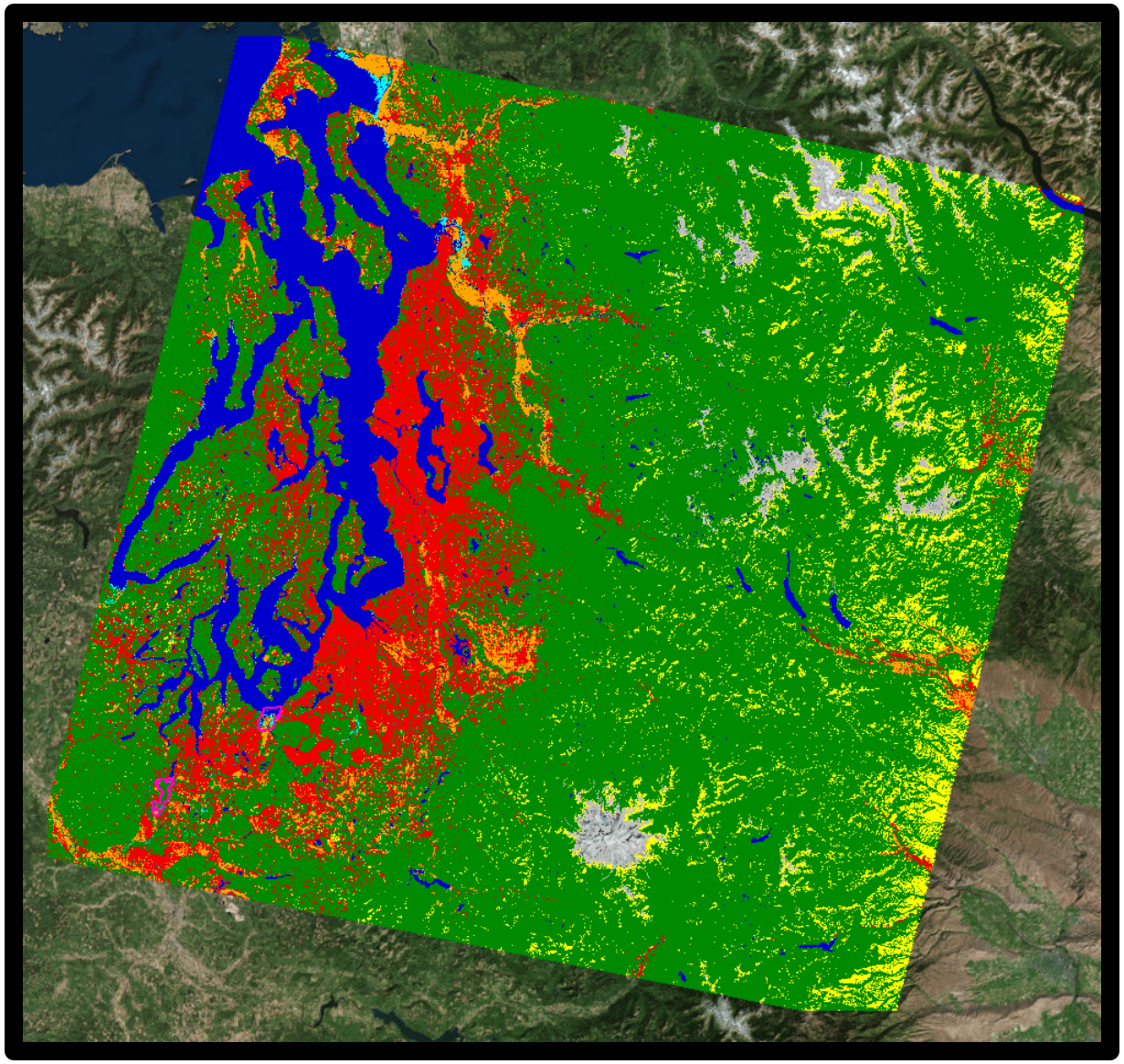
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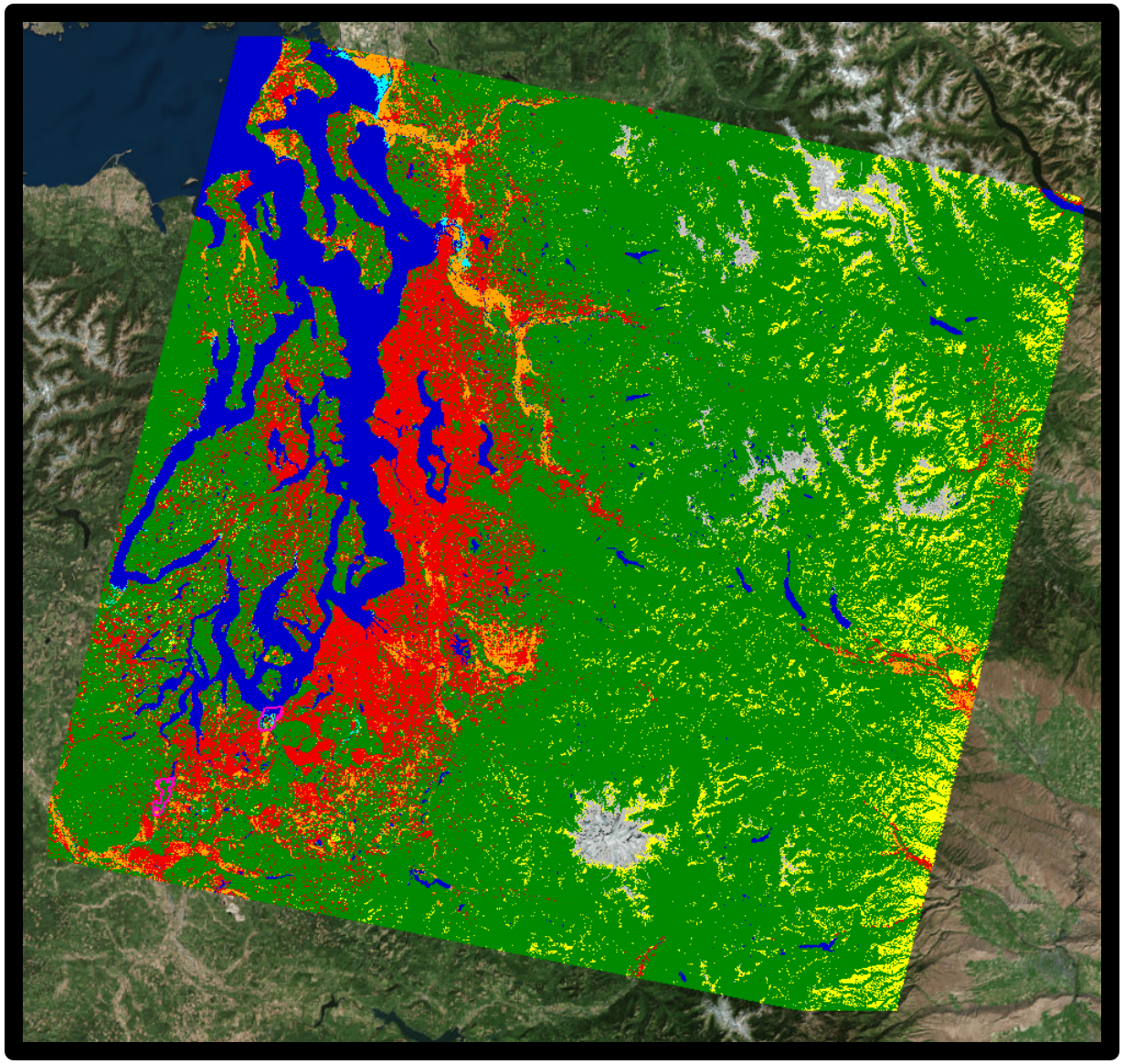
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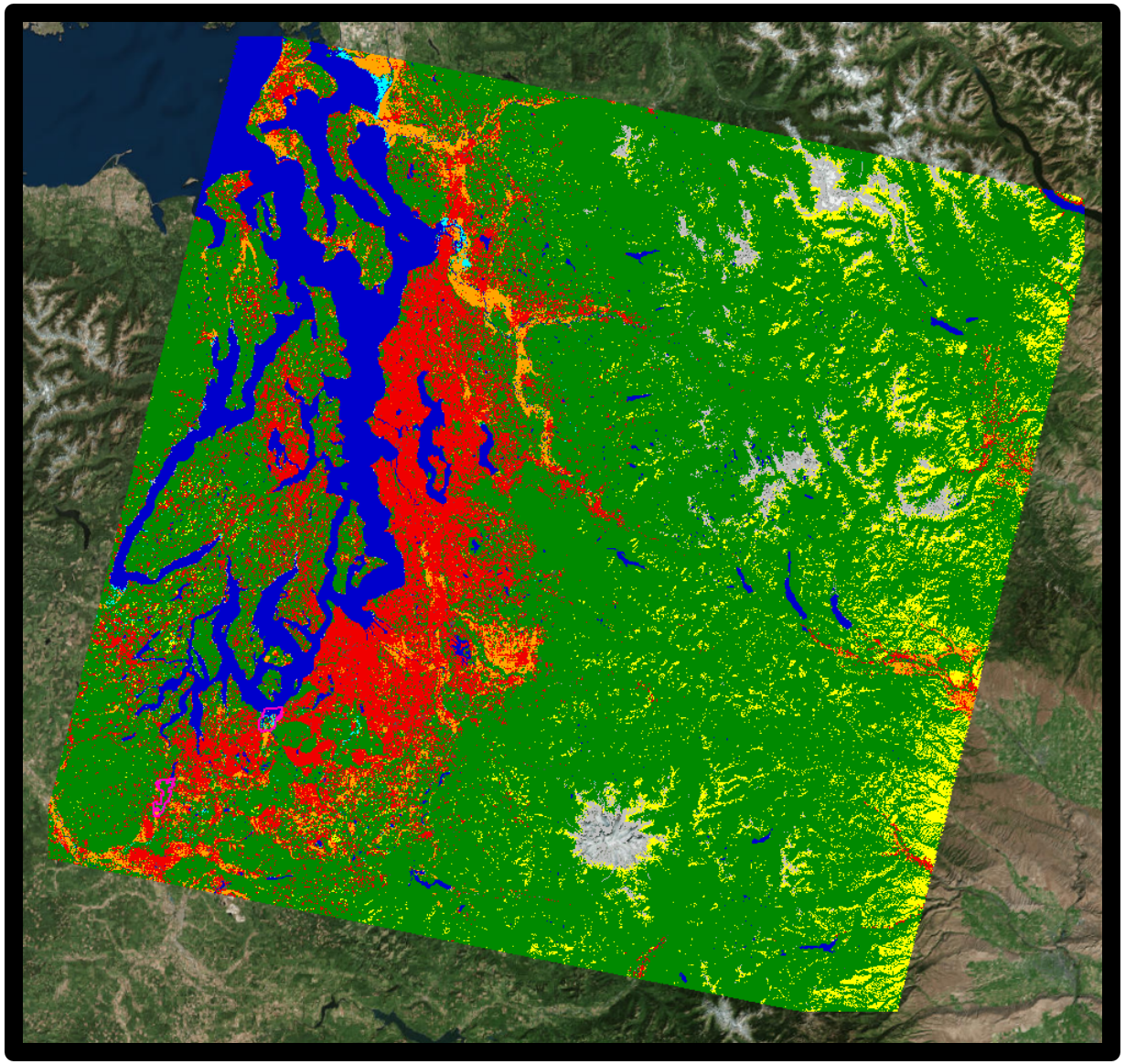
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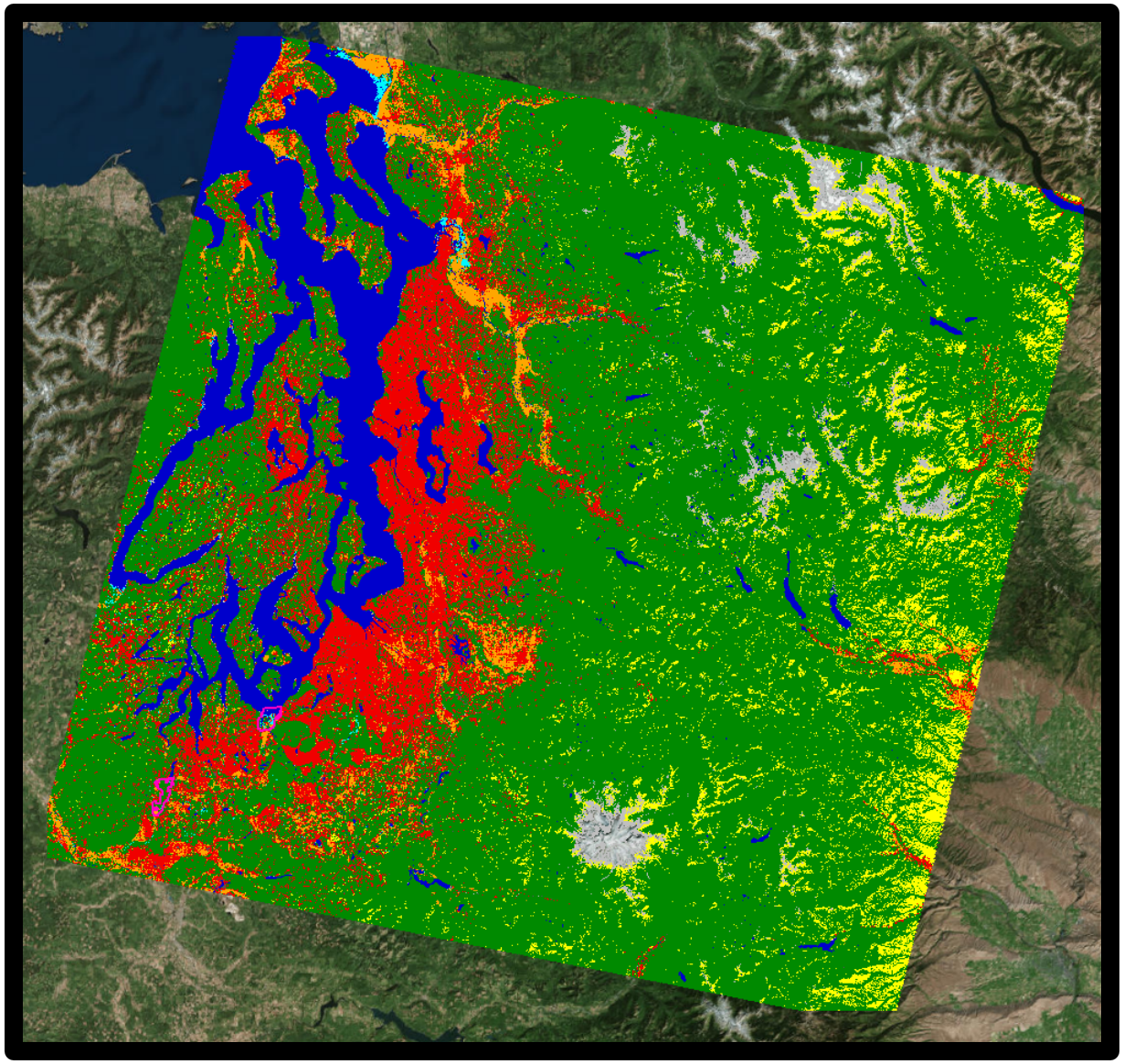
2012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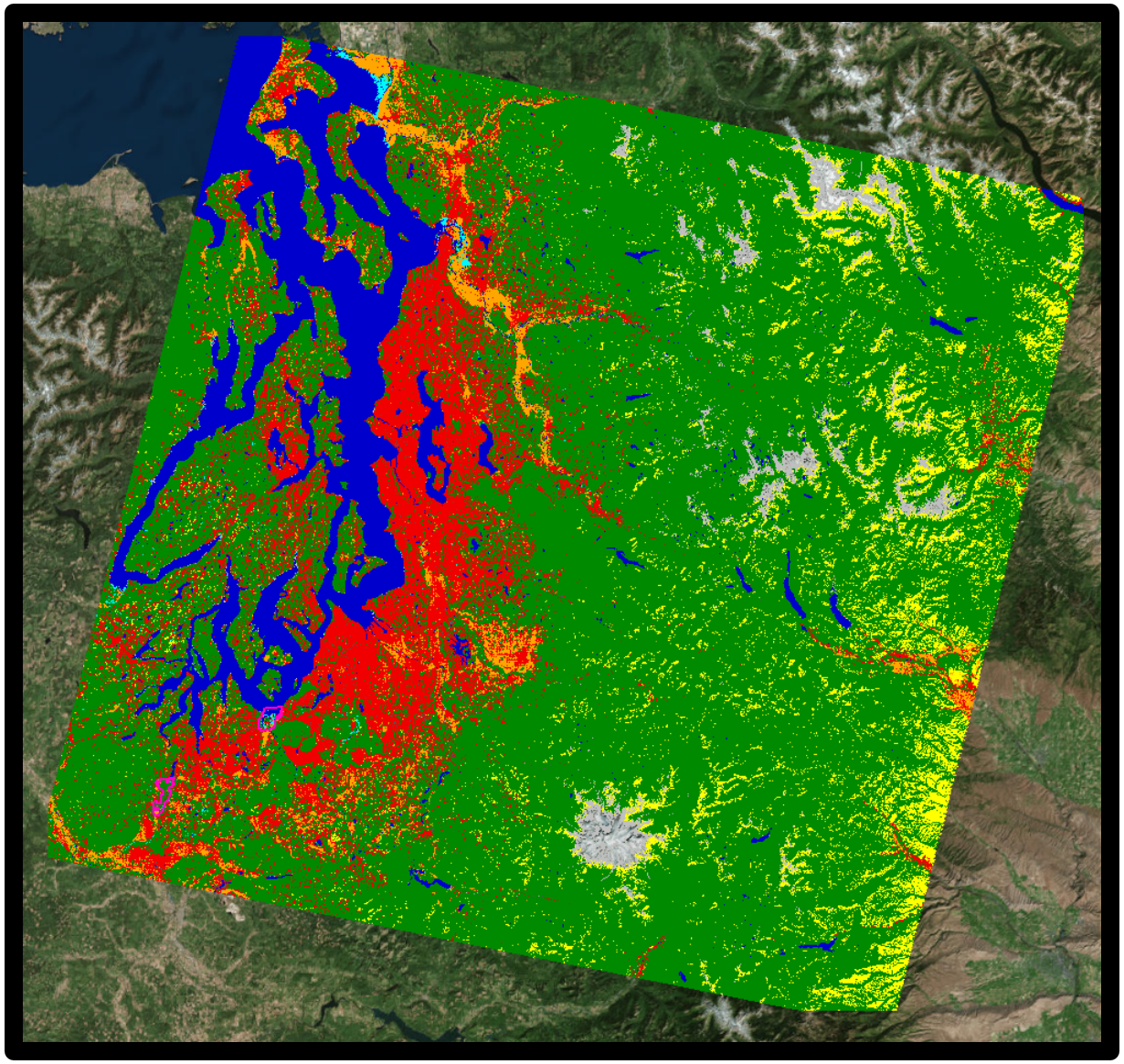
2013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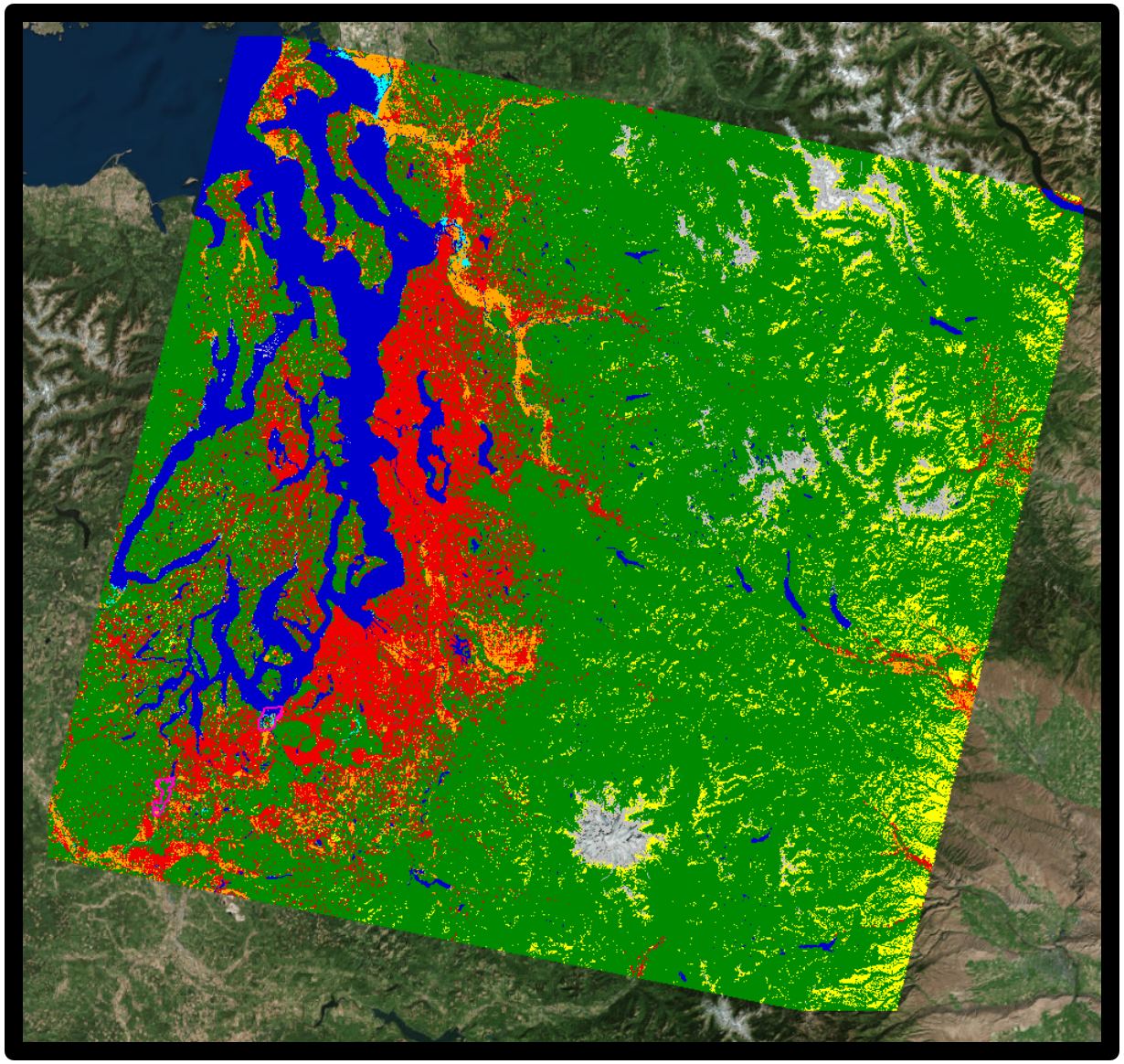
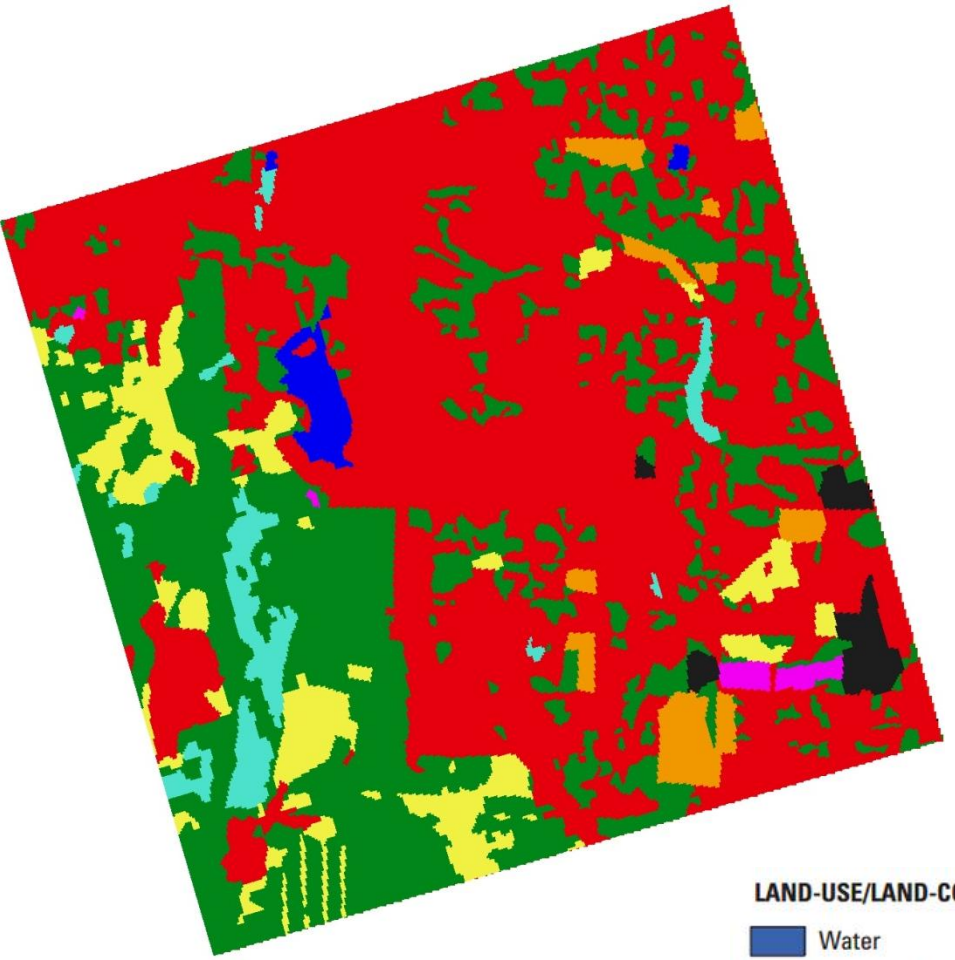
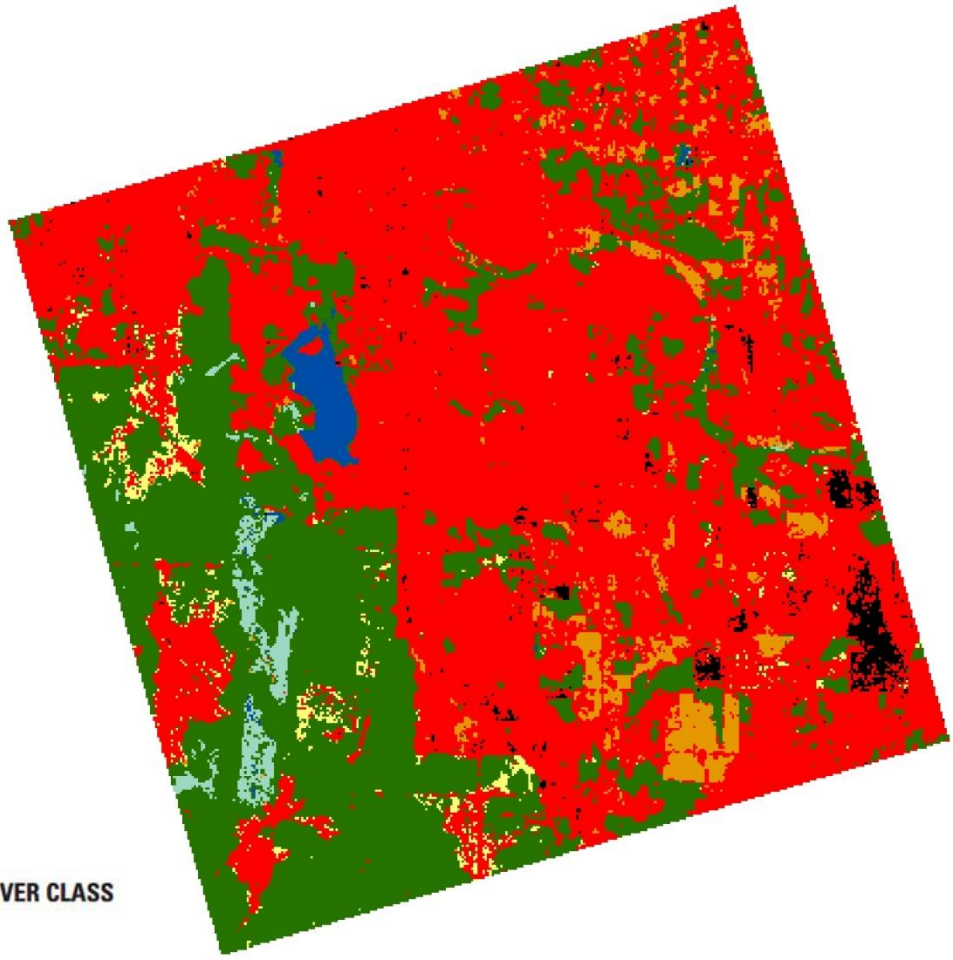
Snow/ice

2014


Land Cover Classes
Forest
Grassland/shrubland
Agriculture
Developed
Barren (naturally)
Mining/quarrying
Mechanically disturbed
Non-mech. disturbed
Water
Wetland
Snow/ice



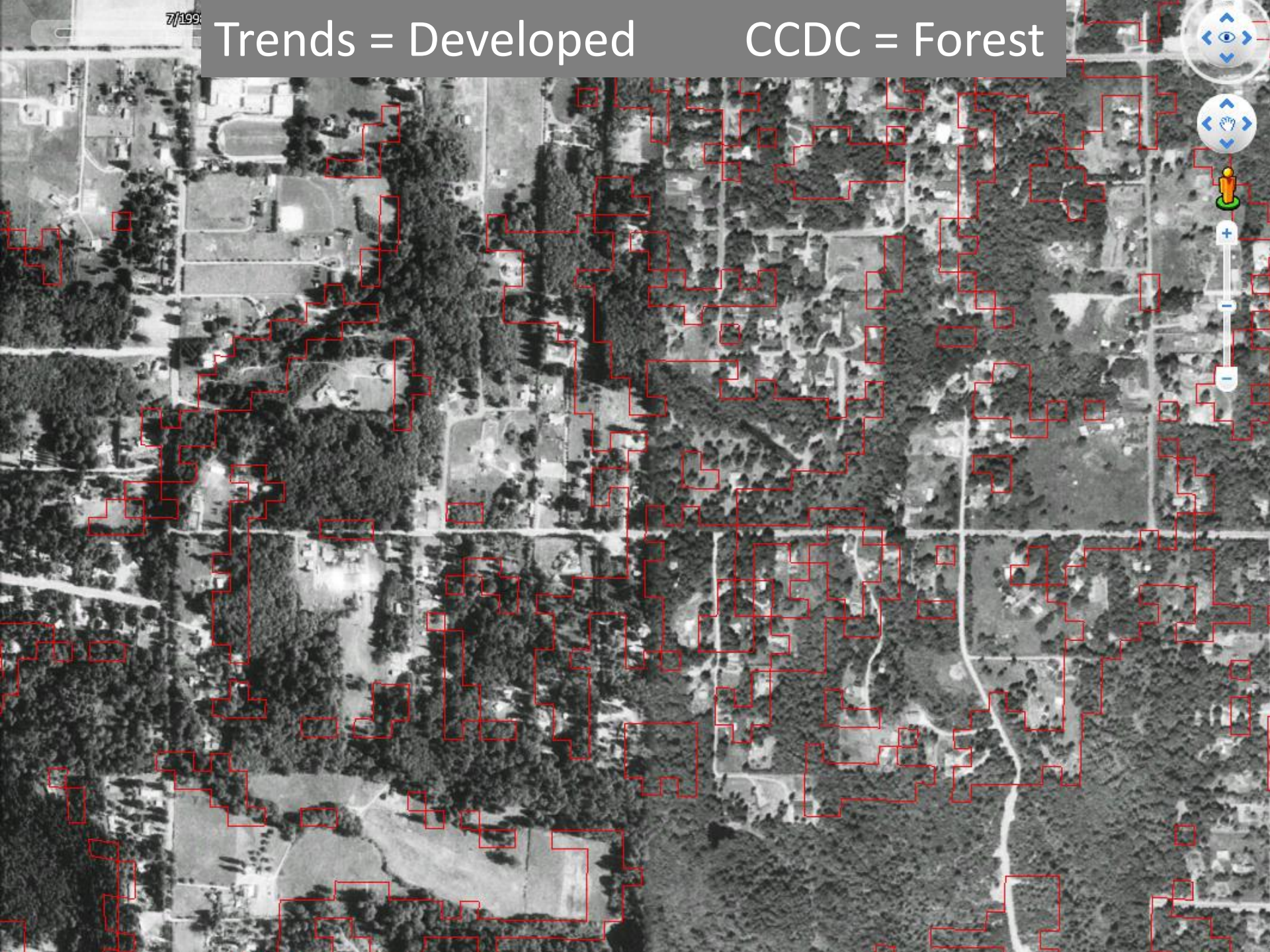


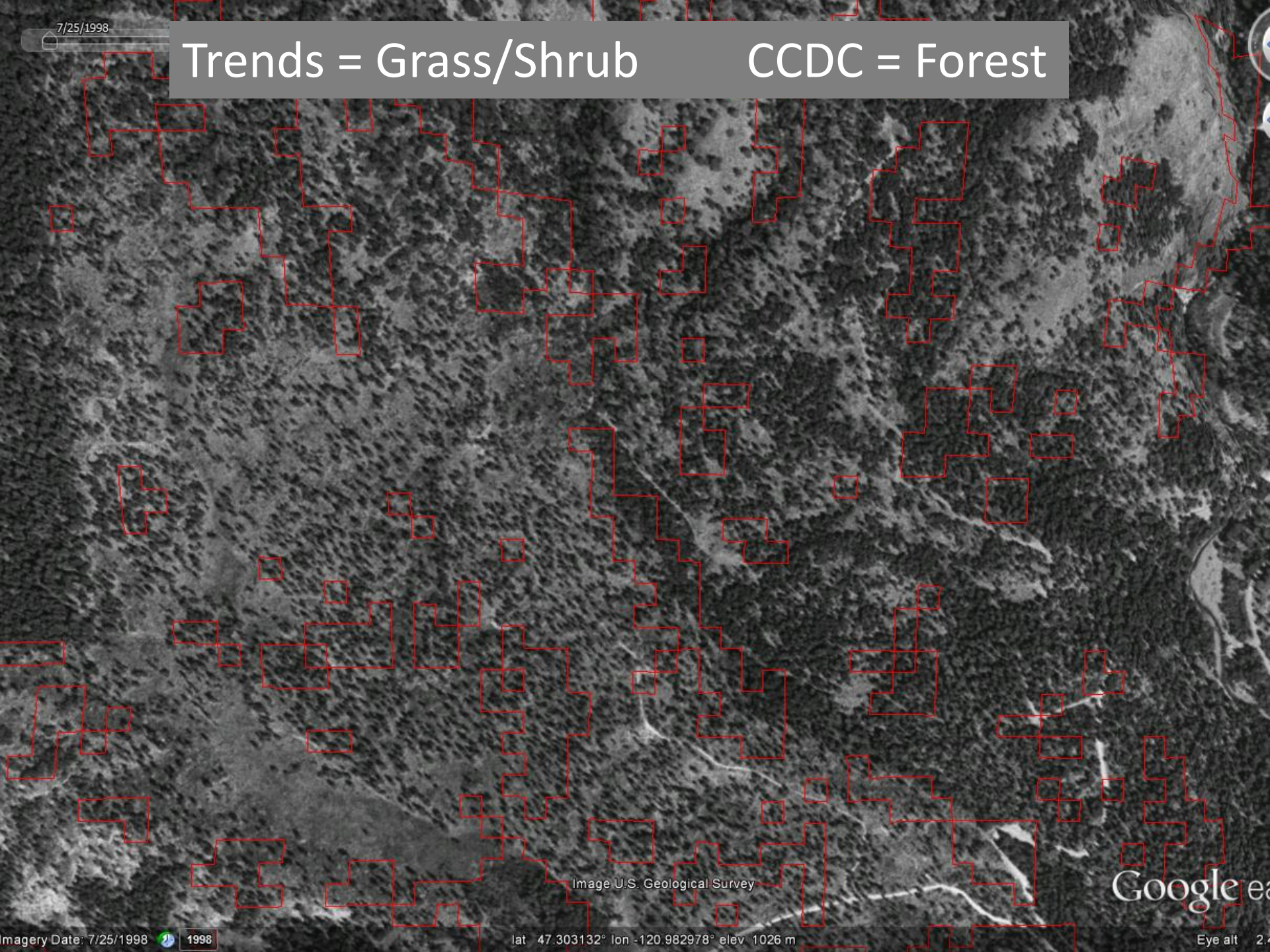
LAND-USE/LAND-COVER CLASS

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow

Trends Block 2000

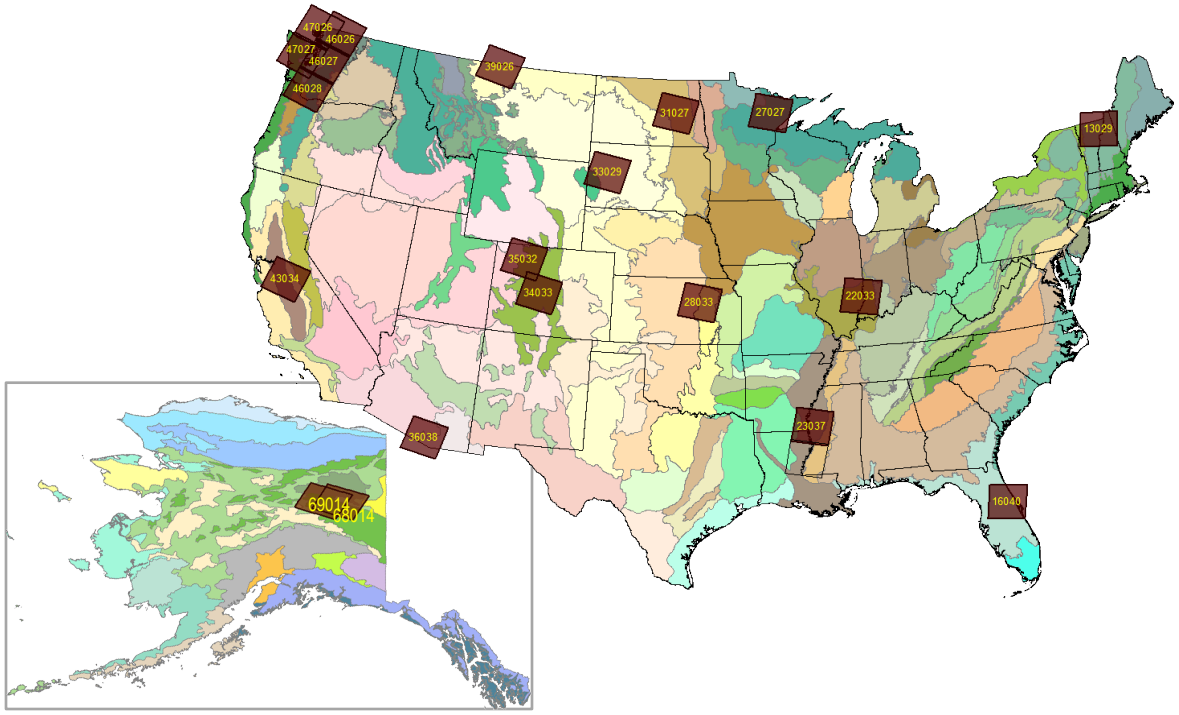
CCDC Landcover 2000


Trends = Developed
CCDC = Forest


7/25/1998
Trends = Grass/Shrub
CCDC = Forest
Image U.S. Geological Survey
Google
Imagery Date: 7/25/1998
1998
lat 47.303132° lon -120.982978° elev 1026 m
Eye alt

Current Status of LCMAP

1. The C version of CCDC continuous change detection component has finished
2. Change detection has done for 18 path/rows, and classification is underway …
3. Three kinds of output (change map, cover map, condition map) will be produced in middle July.



Conclusions

- CCDC is evolving fast.
- Land Cover Trends blocks are great, but not perfect. Use them with care.
- Selecting training data from Land Cover Trends blocks based on good strategy can significantly improve CCDC classification accuracy.
- LCMAP is ambitious, but we are on the way ……