Image Mosaics and Composites: A user's perspective

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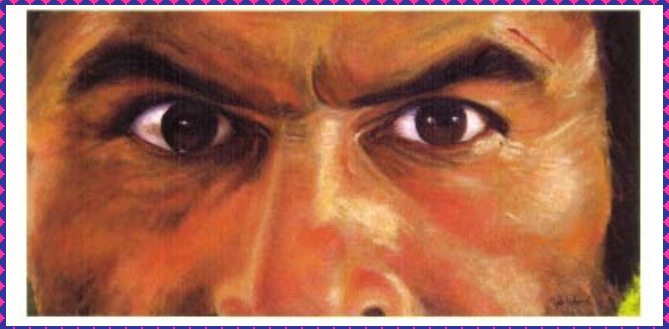
Mosaics and Composites: The good, the bad and the ugly



Jim Vogelmann

USGS/EROS

To help set the stage….

- NLCD 2000 mosaics for land cover mapping (also used for LANDFIRE)
  - Based on ecological regions
  - Based on at-sensor reflectance (no other normalization used)
  - Mosaics developed using best dates of imagery (and not the best pixel) representing a 3-year epoch
- AVHRR/MODIS/WELD composites
  - Moves us more from mosaics generated using the best scene towards composited mosaics using best pixels

NLCD 2000 Mosaics

Spring

Summer

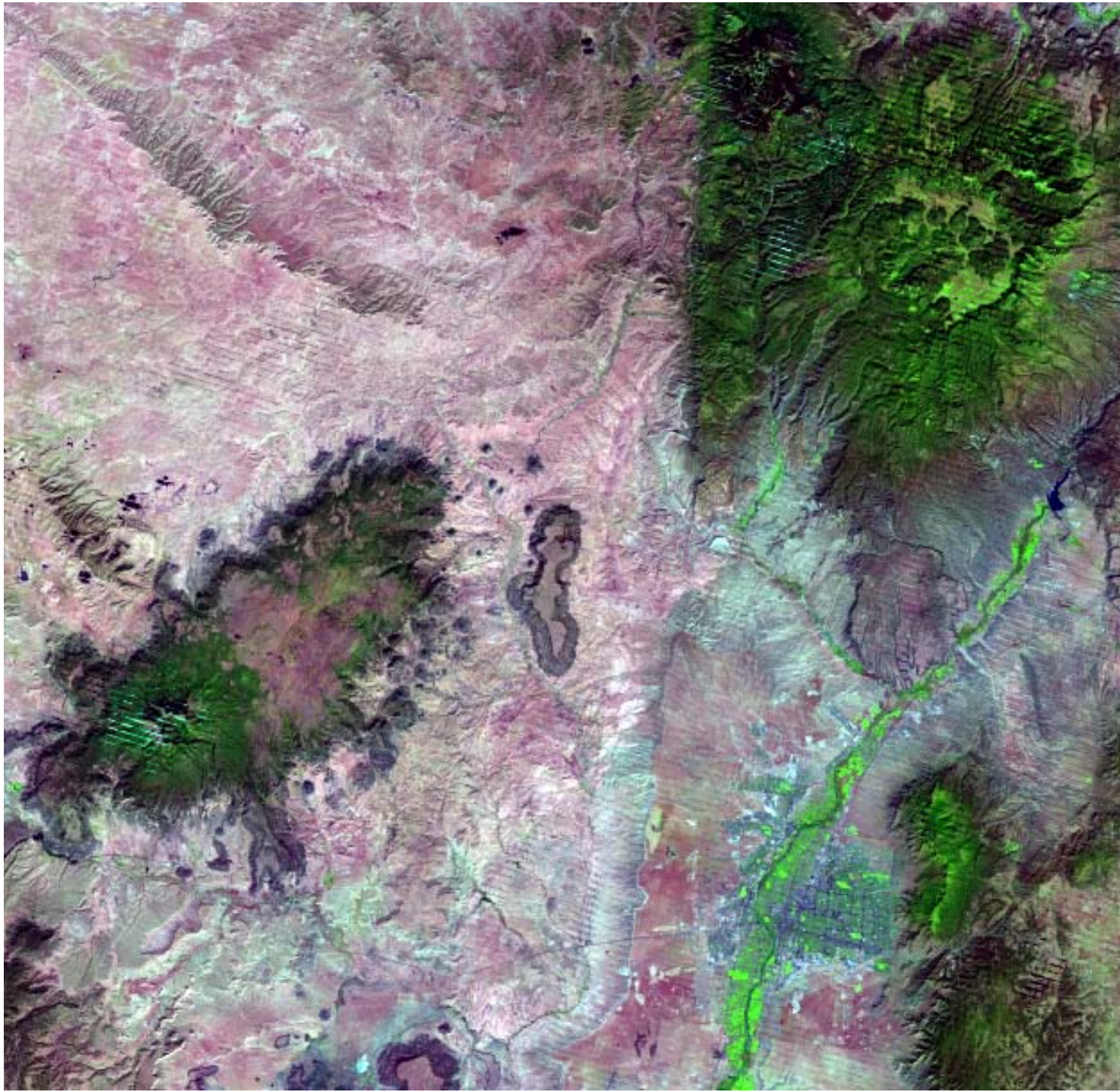
Autumn

NLCD 2000's mosaic with cloud issues

Another NLCD 2000's Mosaic; Gerrymandering

WELD tile from NM; Autumn 2008

Data set created using just Landsat SLC-OFF data

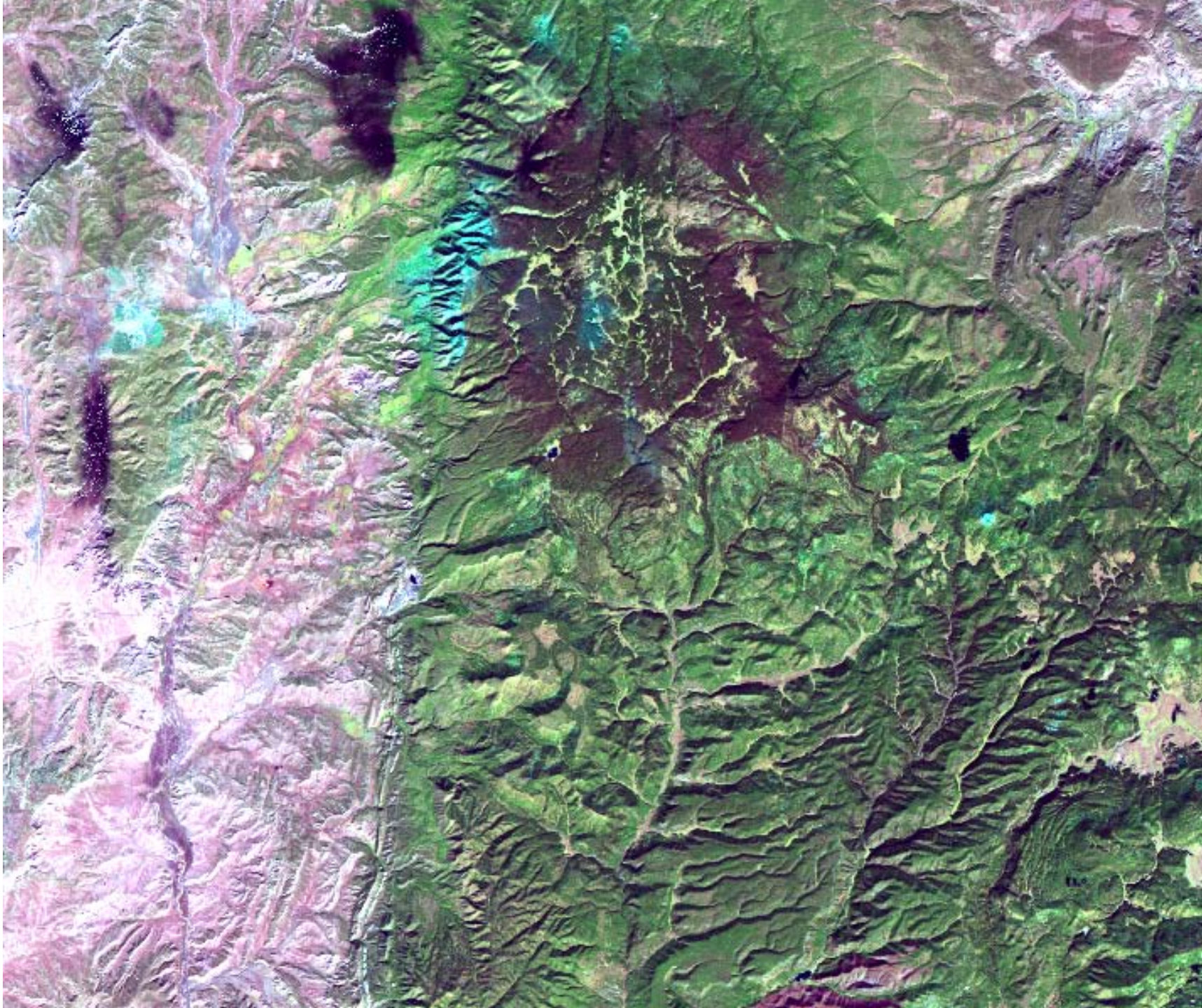


WELD; San Pedro Parks Area in NM Autumn 2008

How much can Landsat 5 improve the composite?

- Generated WELD-like data composite (pseudo-WELD) using just L5 data using best available data for Autumn 2008
- Composite generated using “greenest” pixel approach from NDVI
- Did not worry much about clouds or cloud shadows (or ice or BRDF or other artifacts)

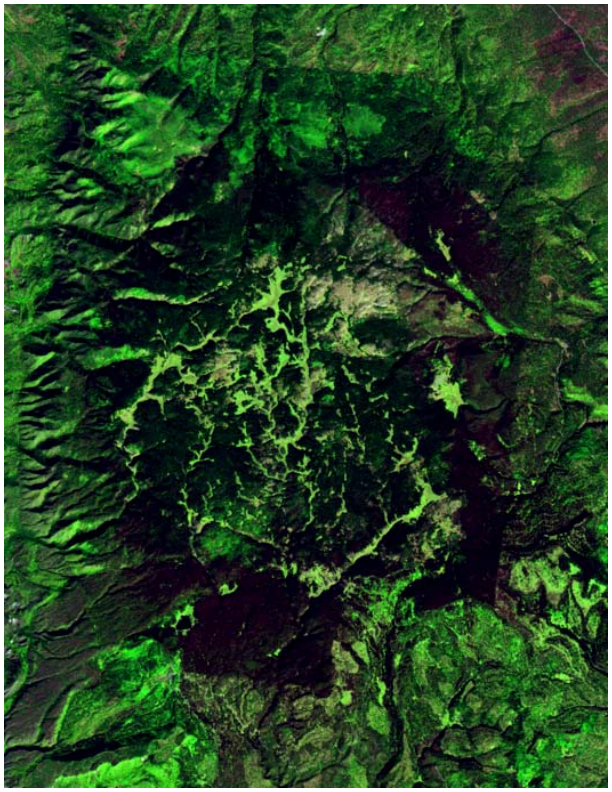
L 5 2008 Autumn Compo-site



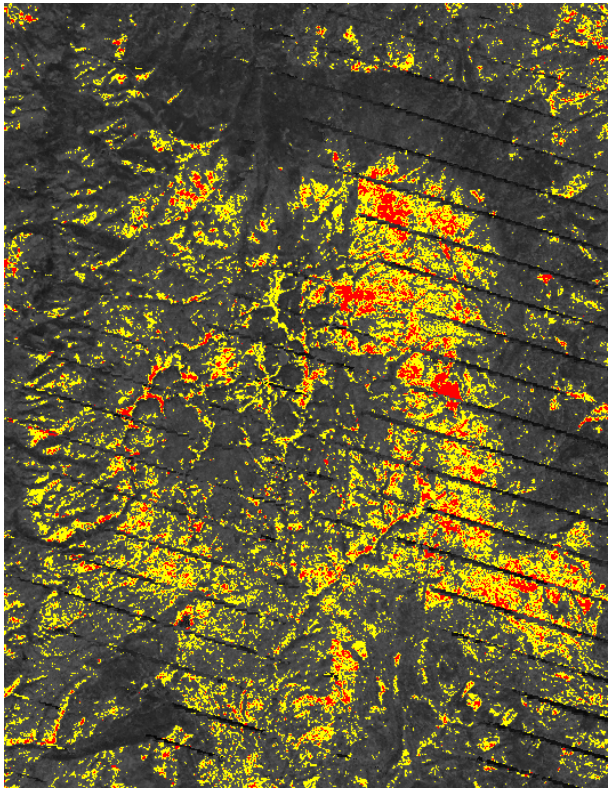
WELD; San Pedro Parks Area In NM Autumn 2008

Combo Using WELD And Pseudo-WELD data (greenest pixel and some gerryman-dering)

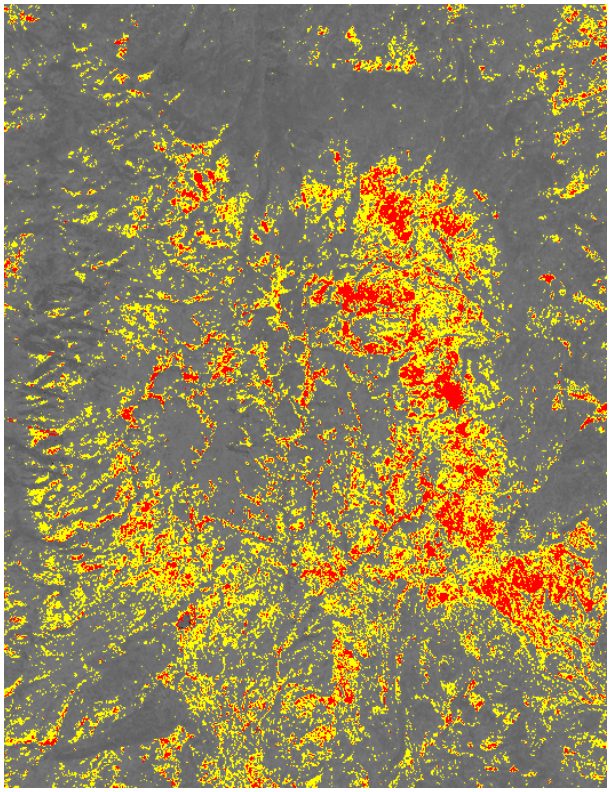
Areas of SWIR/NIR Increases Associated with Changes due to western spruce budworm (yellow and red) at San Pedro Peaks (NM)



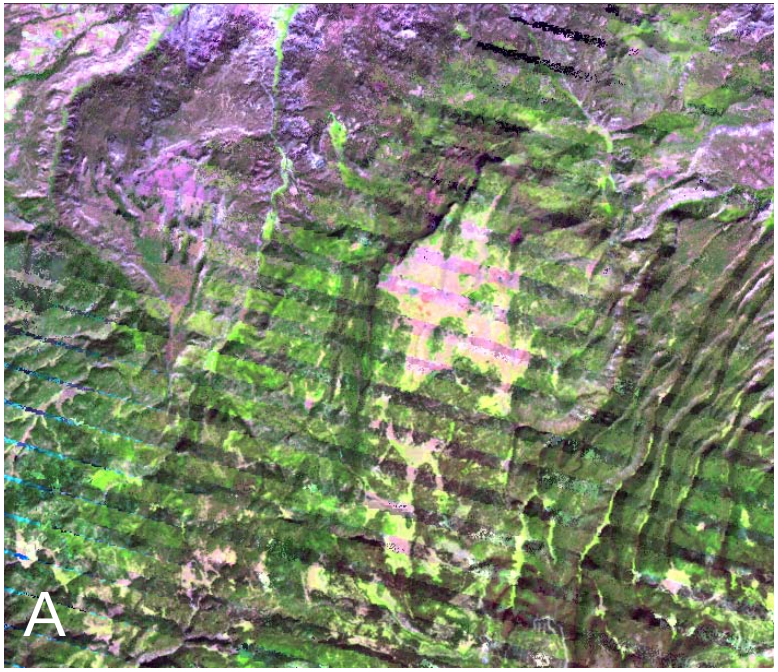
September 1998 TM data

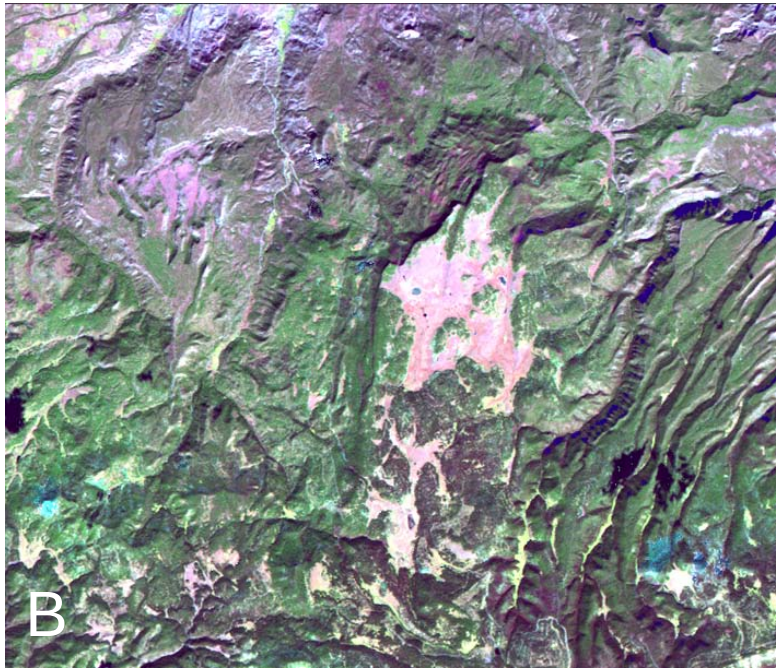


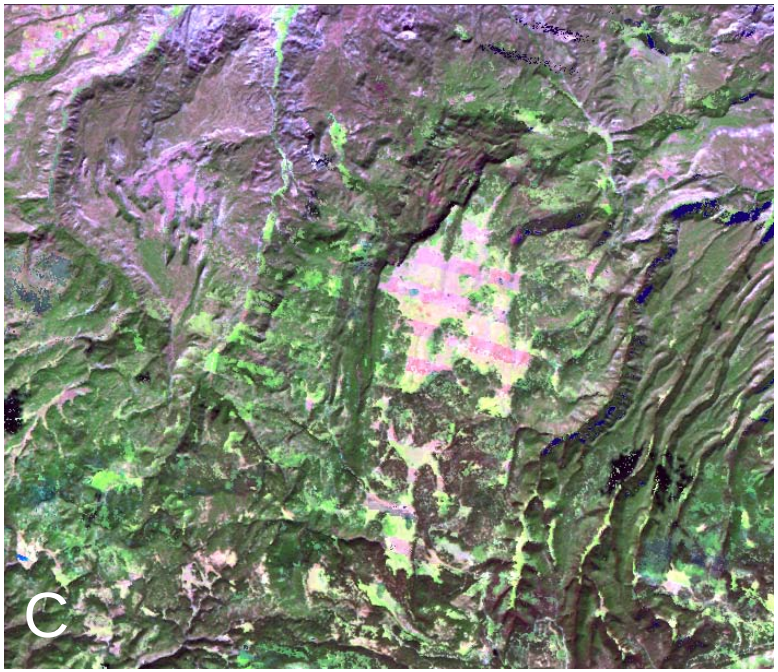
SWIR/NIR Difference Image (1998-2008 WELD)



SWIR/NIR Difference Image (1998-2008 L5-7 “Best Pixel” Combination)







A. 2008 Autumn WELD

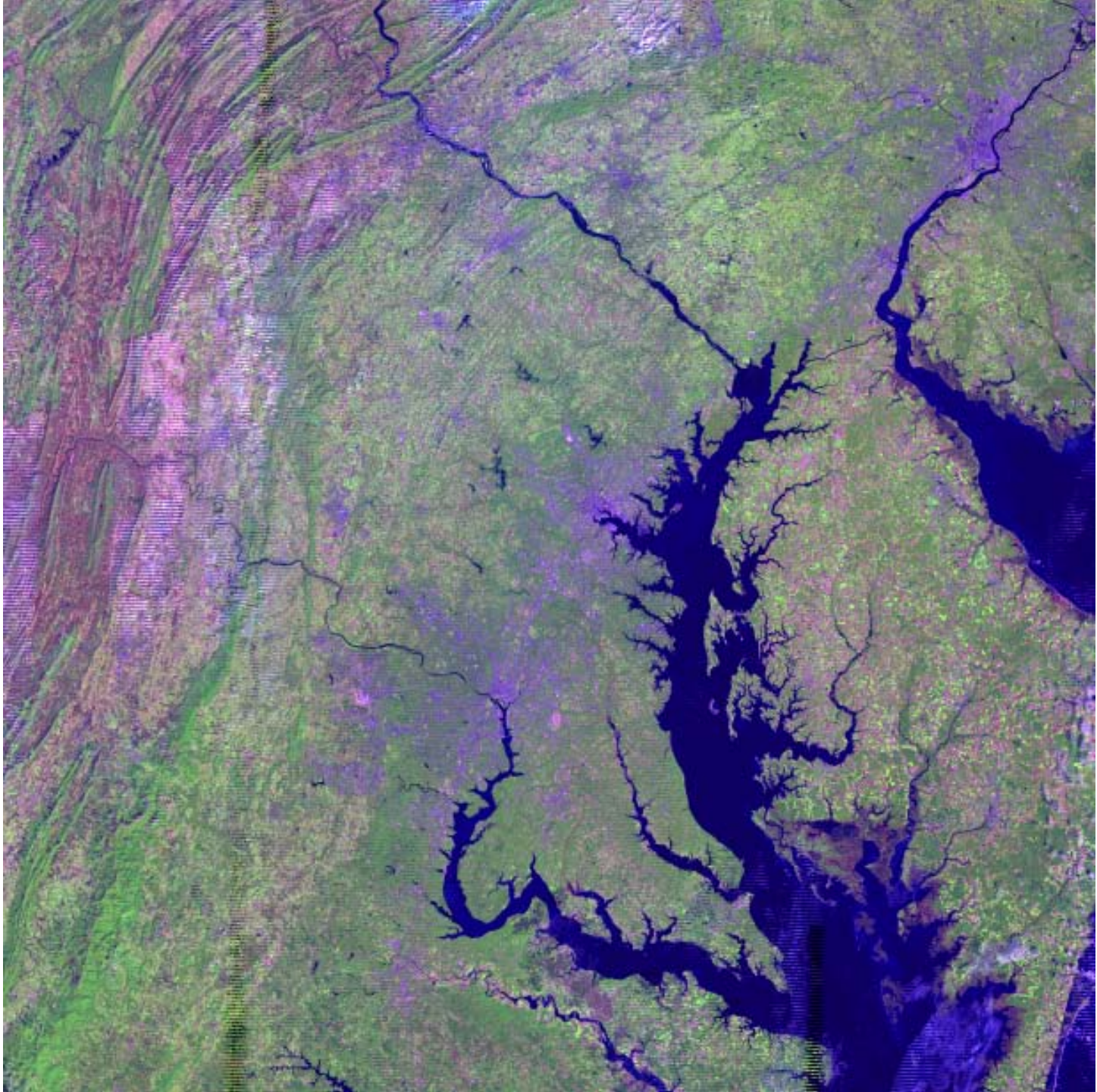
B. 2008 Autumn Pseudo-WELD

C. Composite derived using the greenest pixel from both WELD and Pseudo-WELD

A Few Initial Observations

- Combination of WELD with “Pseudo-WELD” improves composites
  - “Best quality” data sets are what the applications community needs
  - Seasonality/phenology is a really big issue in the world of mosaics and composites
- The WELD-Pseudo-WELD combo composite generated was about 2/3 Landsat TM, and 1/3 ETM+ pixels
- This is not a particularly cloudy part of the world!
  - Investigation proceeded to the east coast…..

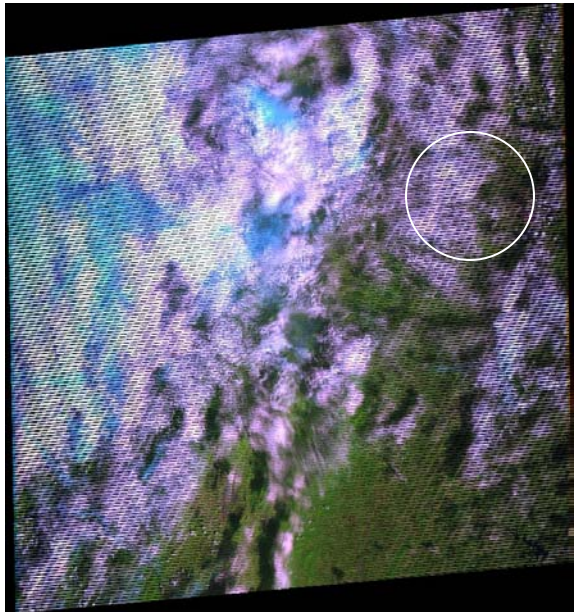
Autumn 2008
WELD data;
4 Tiles



WELD Data Set; Close-up Of Dulles Airport

Autumn 2008

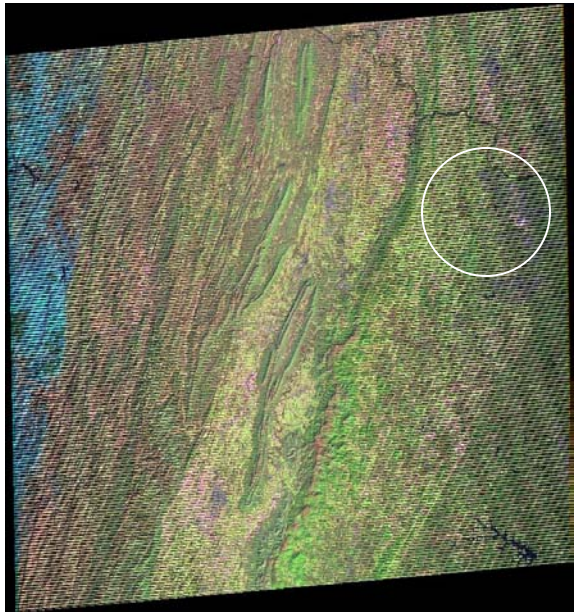
Spring NLCD/ LANDFIRE Mosaic (early 2000's)



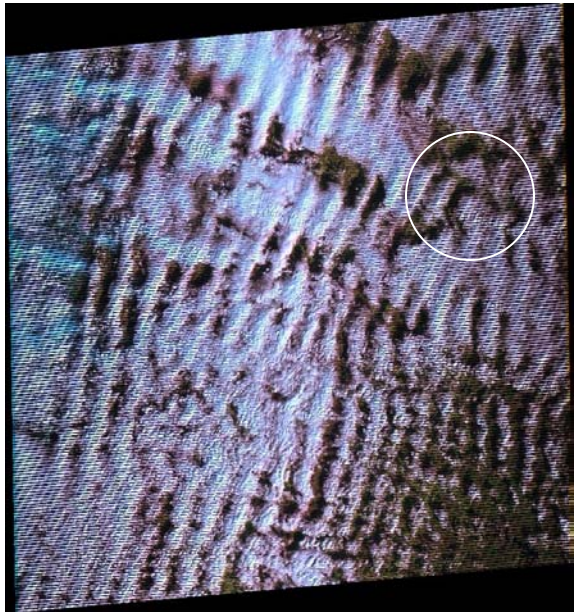
Sept 13, 2008

Sept 29, 2008

Oct 15, 2008



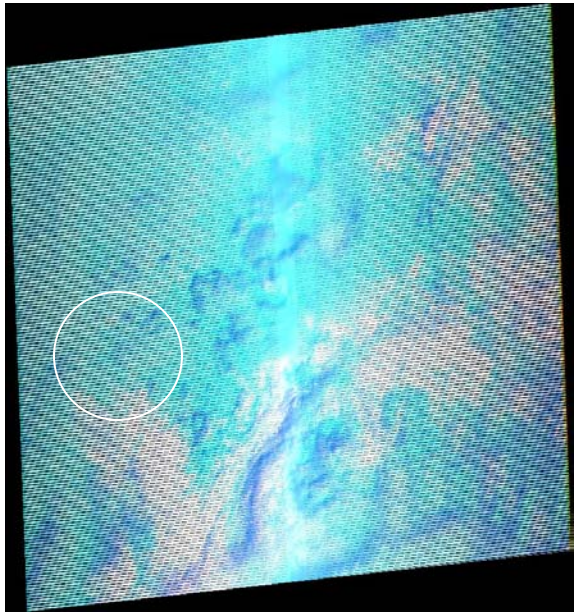
Oct 31, 2008



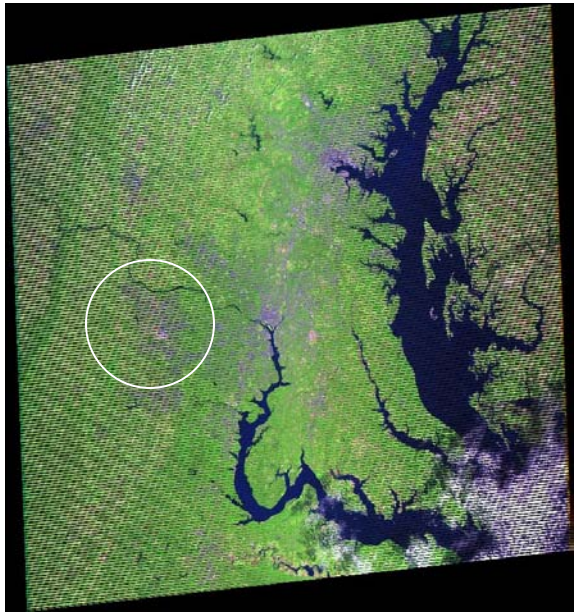
Nov 16, 2008

Available Autumn
SLC-OFF 2008
Scenes for Path 16
Row 33

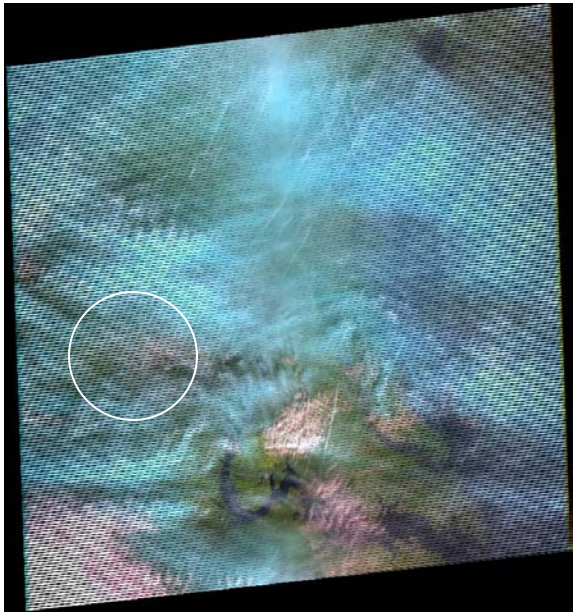
Circle shows approximate location of Dulles Airport



Sept 6, 2008

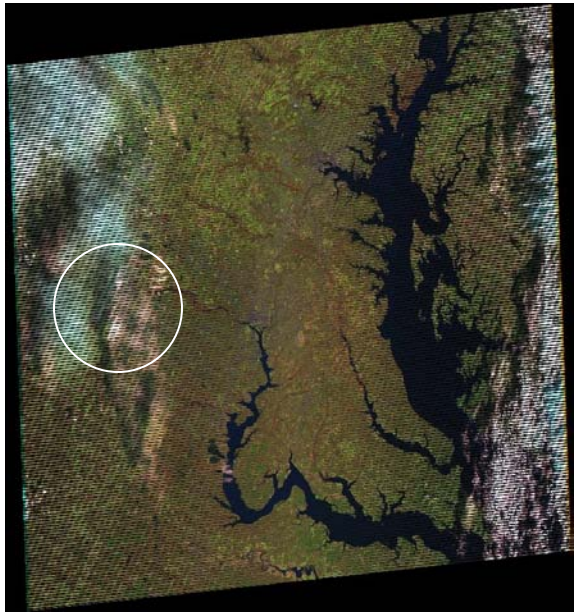


Sept 22, 2008



Oct 24, 2008

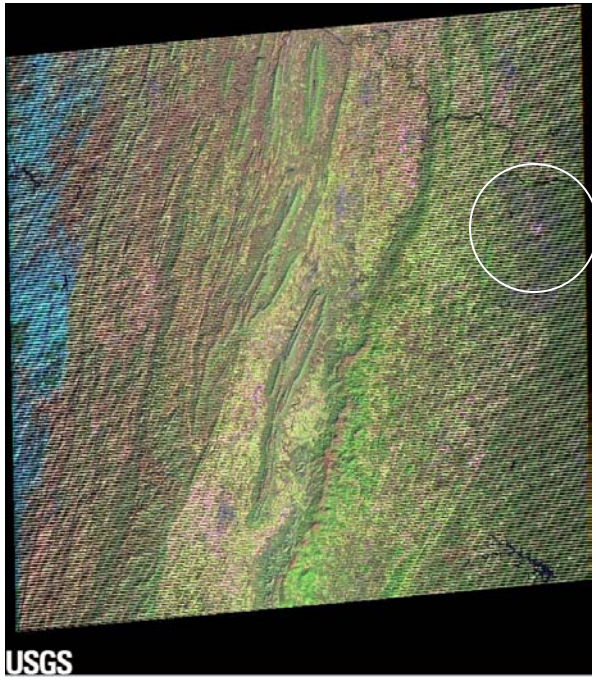
Nov 9, 2008



Nov 25, 2008

Available Autumn SLC-OFF 2008 Scenes for Path 15 Row 33

Actual Scenes used in WELD process for Dulles Airport Region



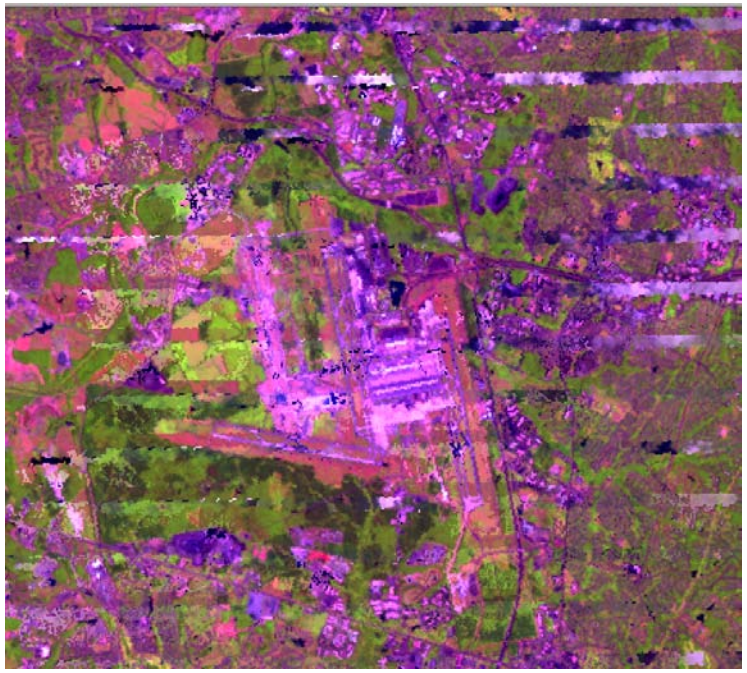
October 31, 2008

September 22, 2008

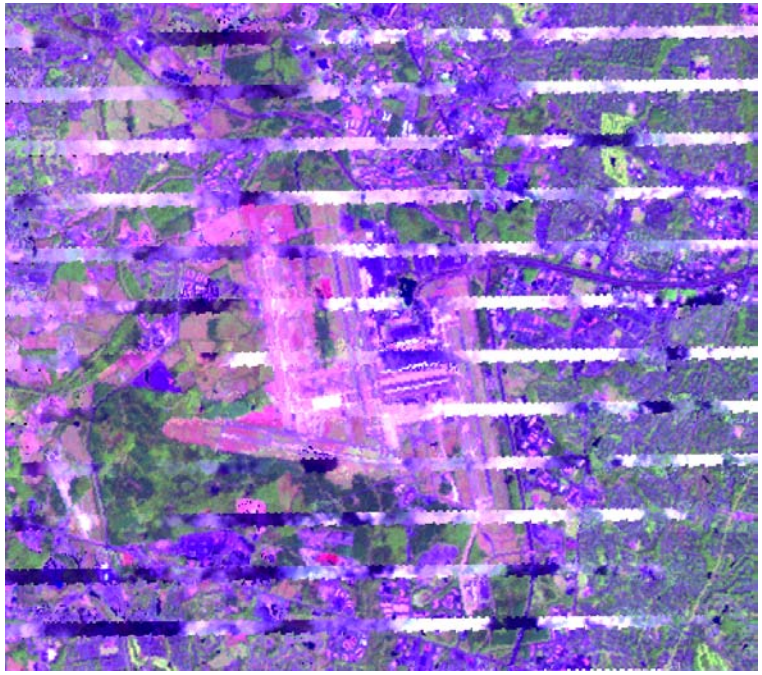
Nov 9, 2008

Mixing dates from beginning and end of autumn problematic from a user's standpoint (phenology issues). What if we generate composites using data sets representing a more phenologically stable period of time? (e.g. July, Aug and Sept; next slide)

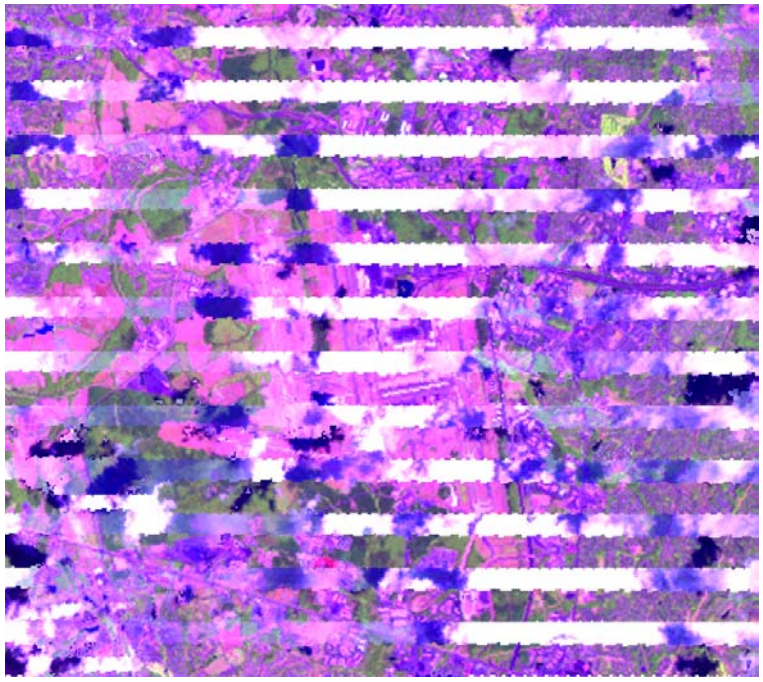
July



Sept

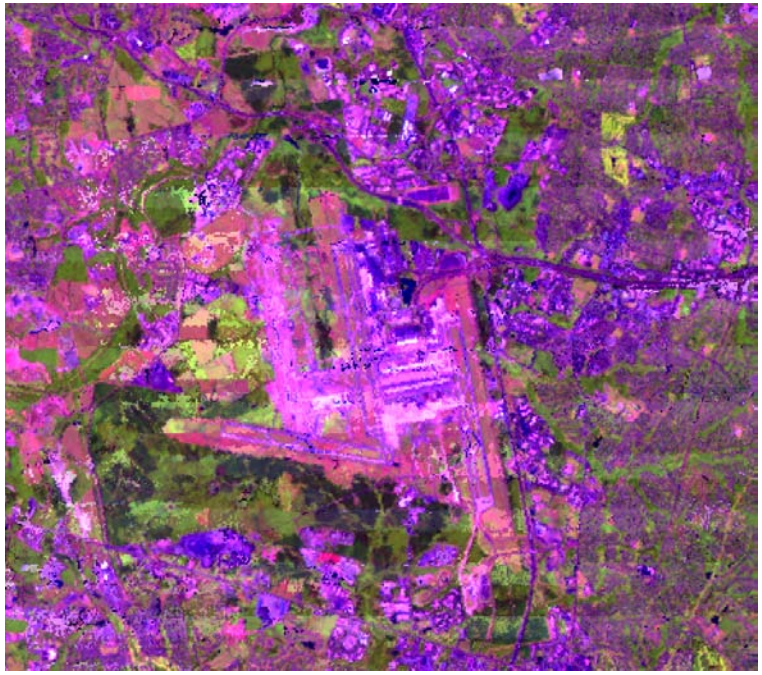


Aug



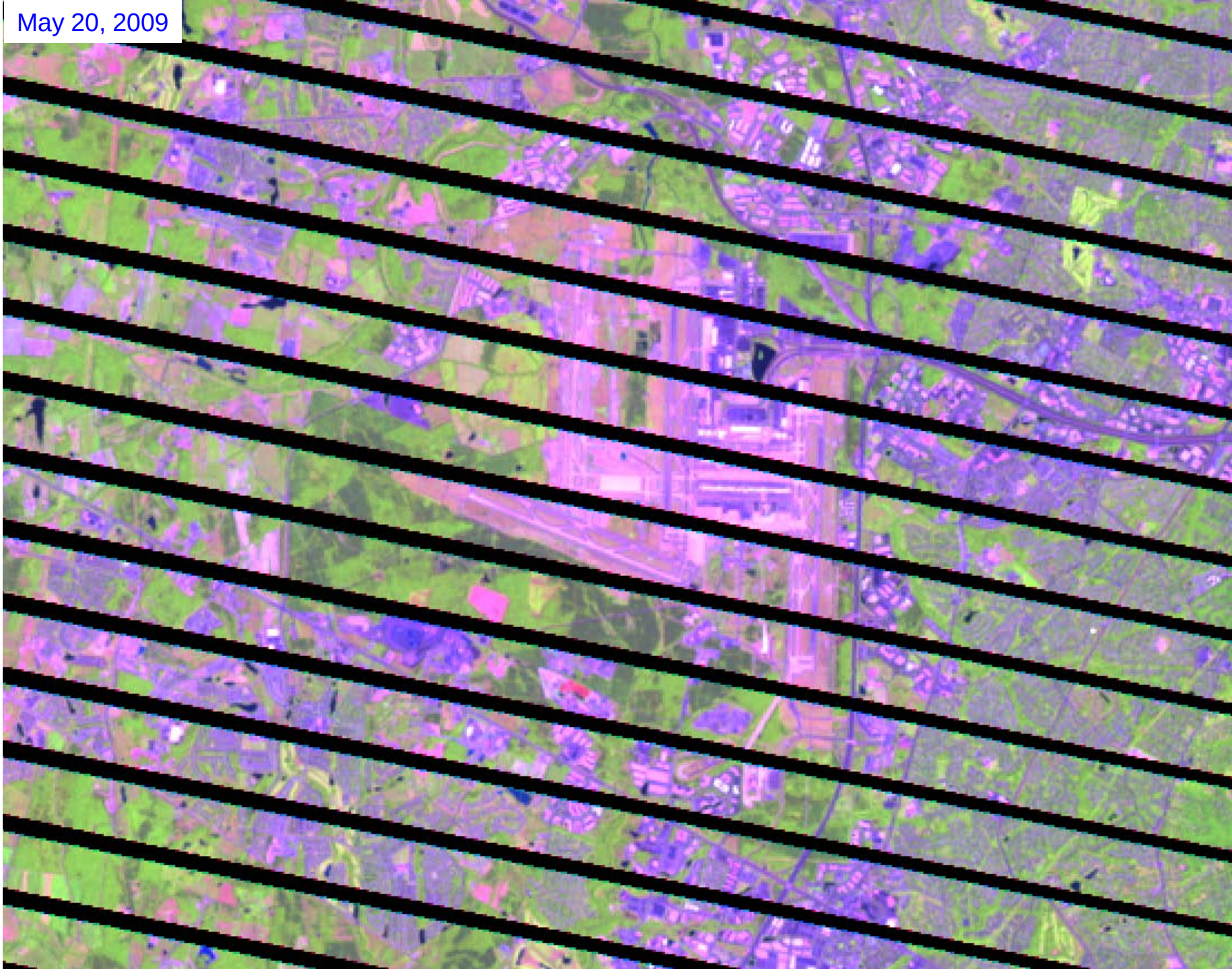
July through Sept

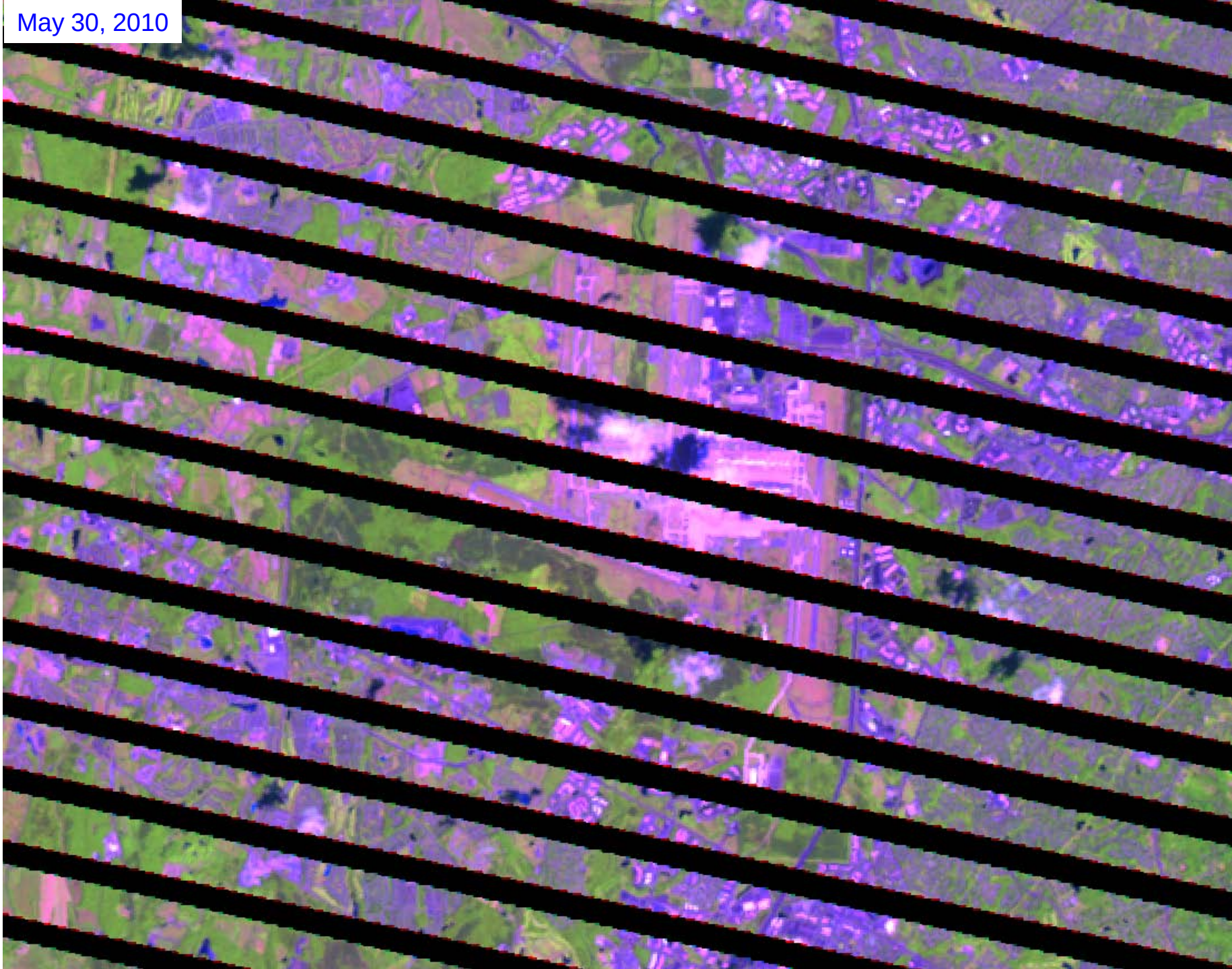
New WELD com-posite



Some Comments

- Not many cloud-free scenes to work with, especially within a given year
- Do we really want to “mix” September with November scenes? (potential for large phenological differences in the mosaic)
- Manipulating monthly WELD data to create your own composite is not a trivial task
- One option is to use narrower seasonal windows (e.g. September) acquired over several years (representing an “epoch” e.g. NLCD) using BEST available data


May 20, 2009


May 30, 2010


May 2009-10 Composite; 2009 data “filled” with 2010 data

May 2009-10 Composite; 2009 data “filled” with normalized 2010 data

Same as before, but two clouds removed

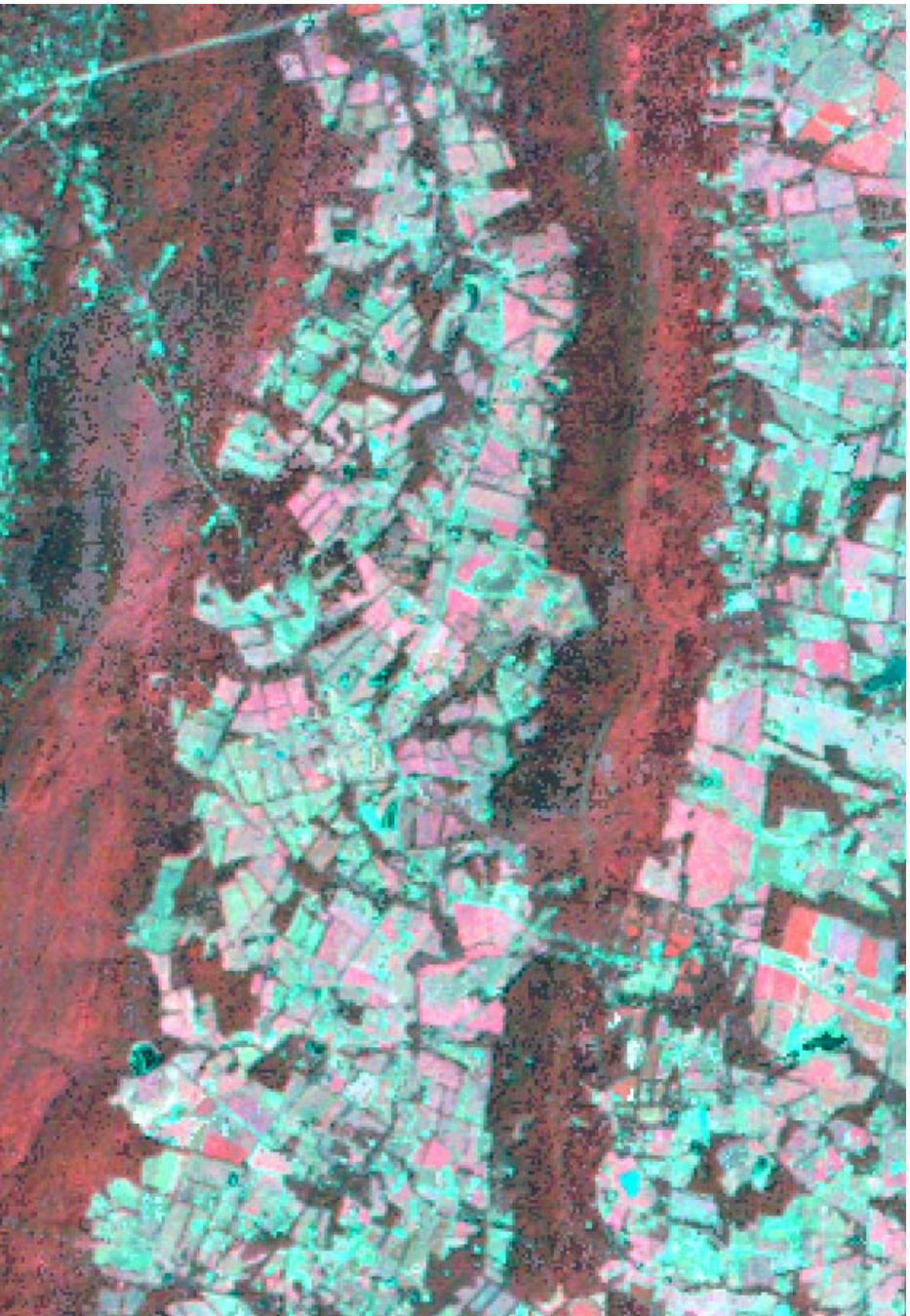
A Few More Observations

- Very good composites can be generated using SLC-OFF data….
  - If we pick the “right” scenes
  - More scenes are not necessarily better for generating the most usable composite
  - A certain amount of “hand crafting” can improve upon the data sets
    - Interscene normalization
    - Cloud filling

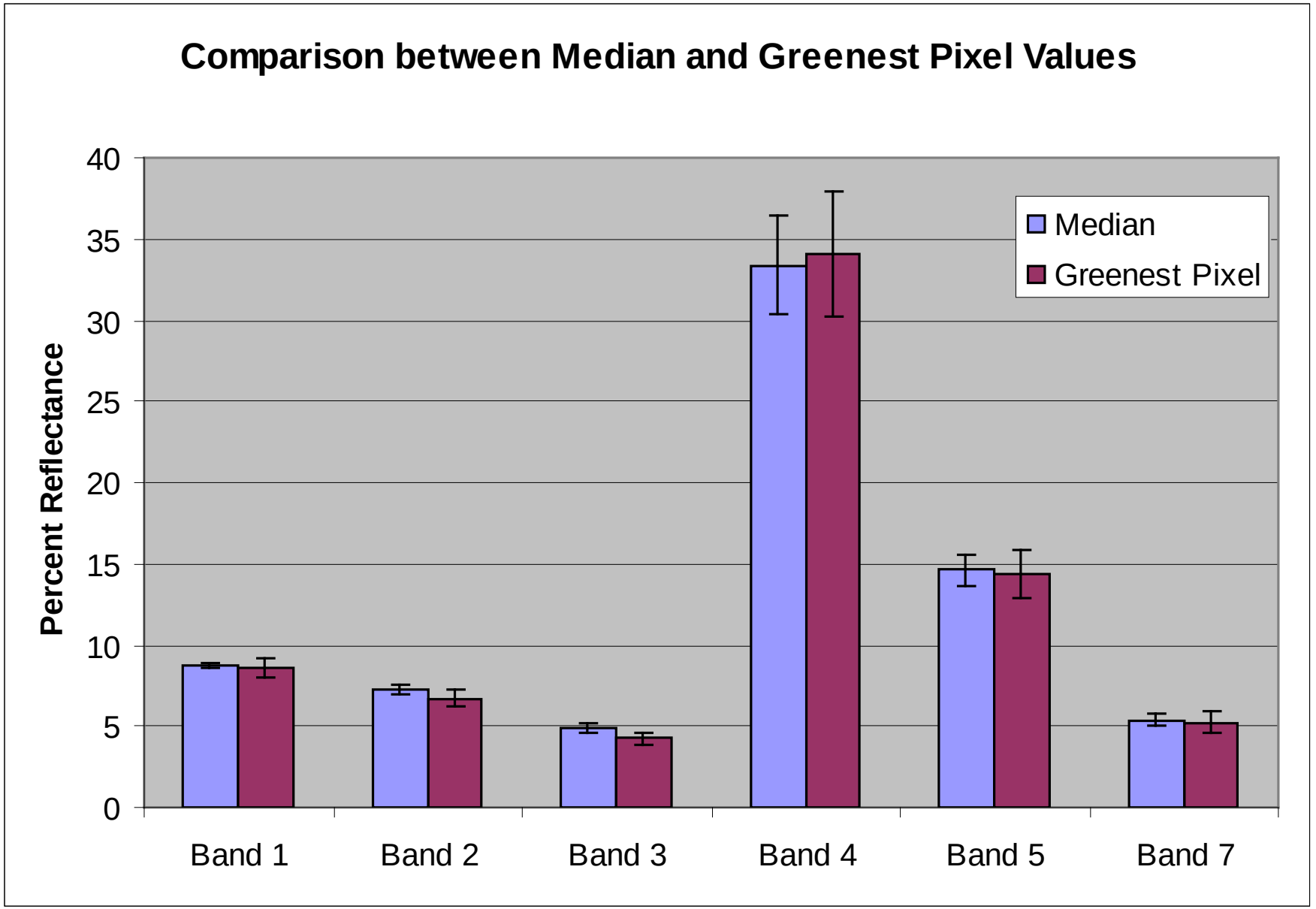
Is the Greenest Pixel Always the Best Approach?

- Some anomalies
  - Speckling
  - Alteration of overall image characteristics
- Median pixel approach
  - Uses statistical “central tendency” rather than “highest” (i.e. greenest) value, which can have high statistical variance

Greenest Pixel Image (7 2001-2009 Autumn Scenes; B 4 3 2) Median Pixel Image



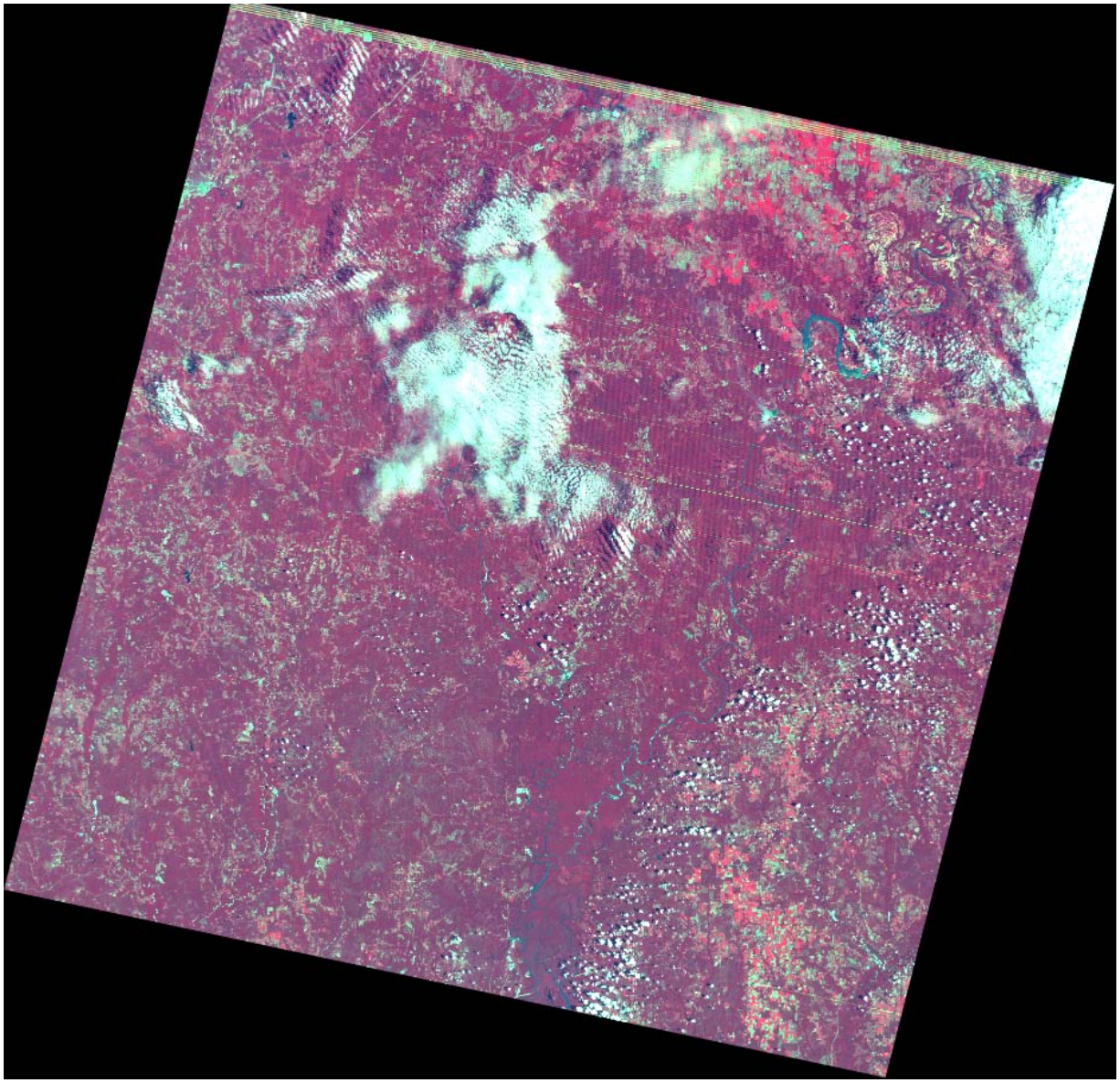
Results from Cunningham Falls State Park Forest

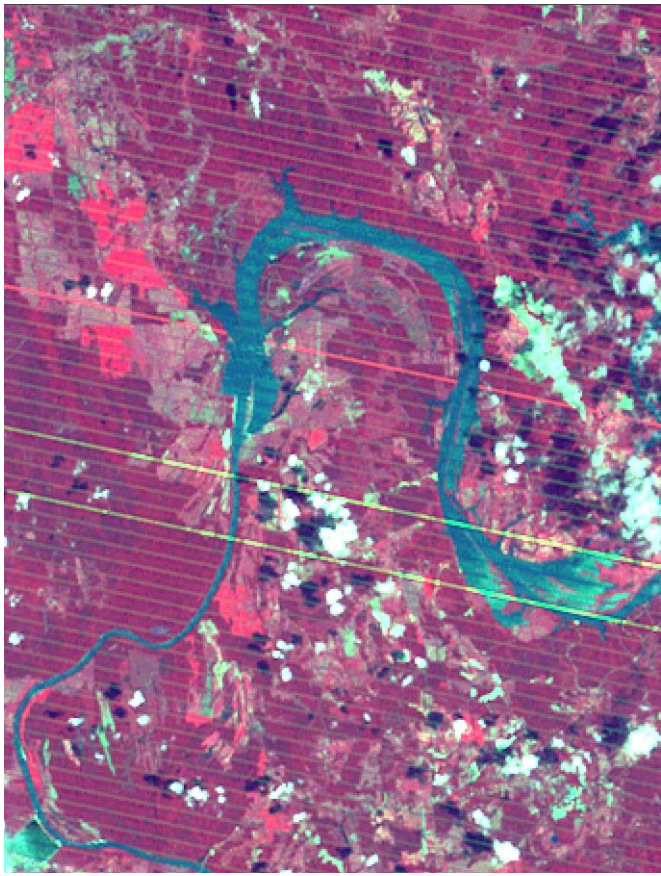


MSS Data

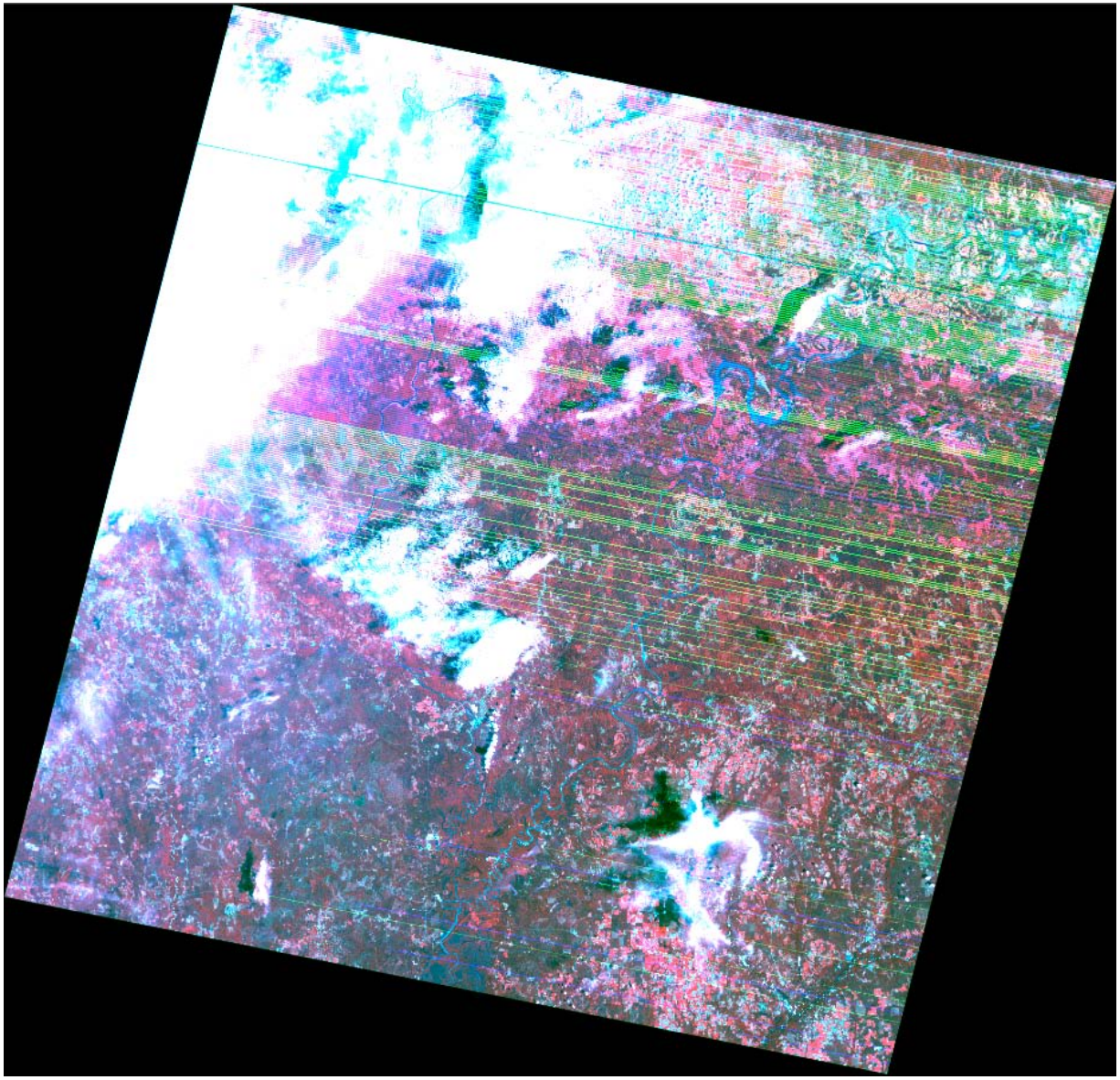
The way backwards!

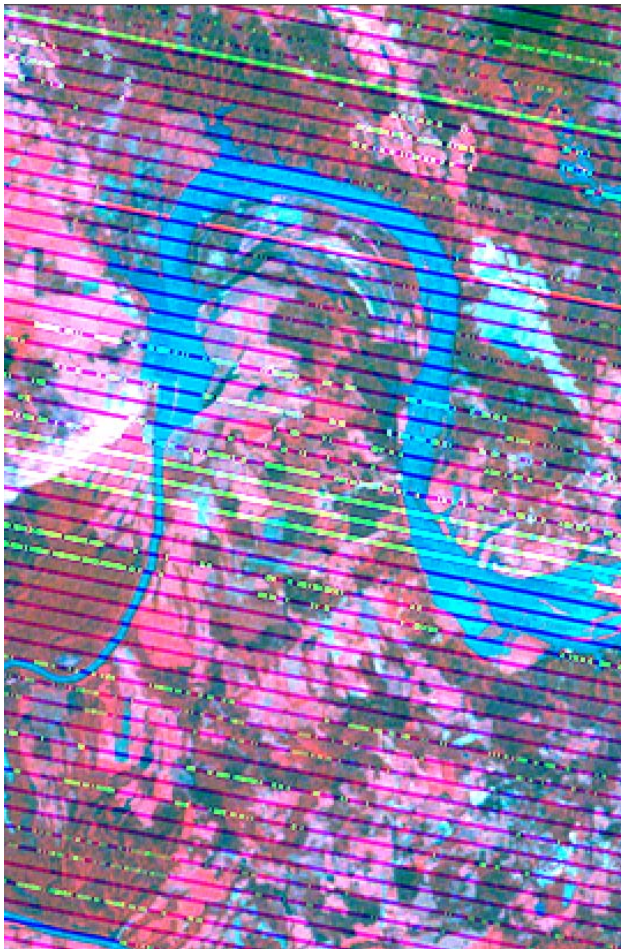
Scenes from southern Alabama (Path 22 Row 38)



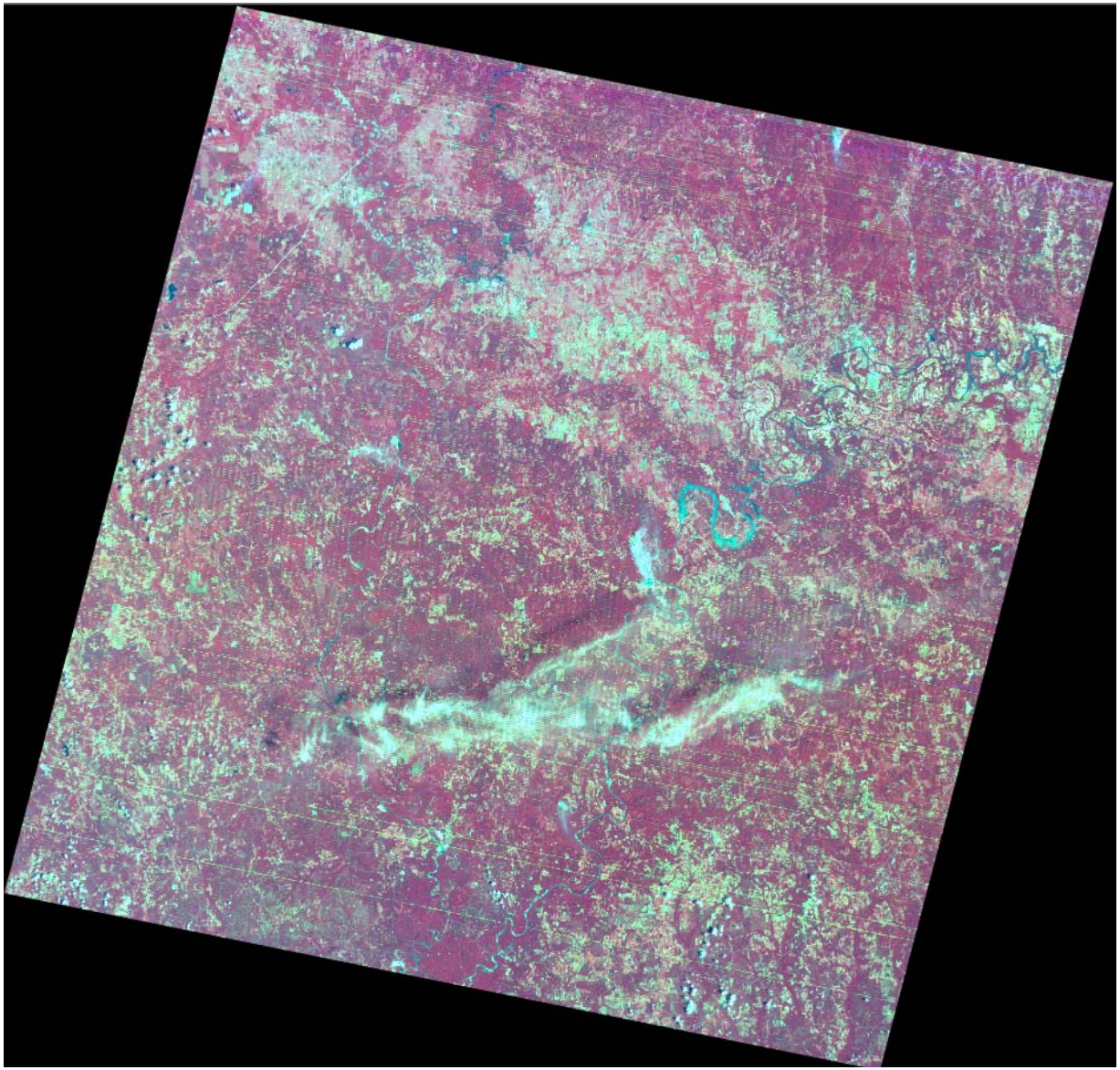


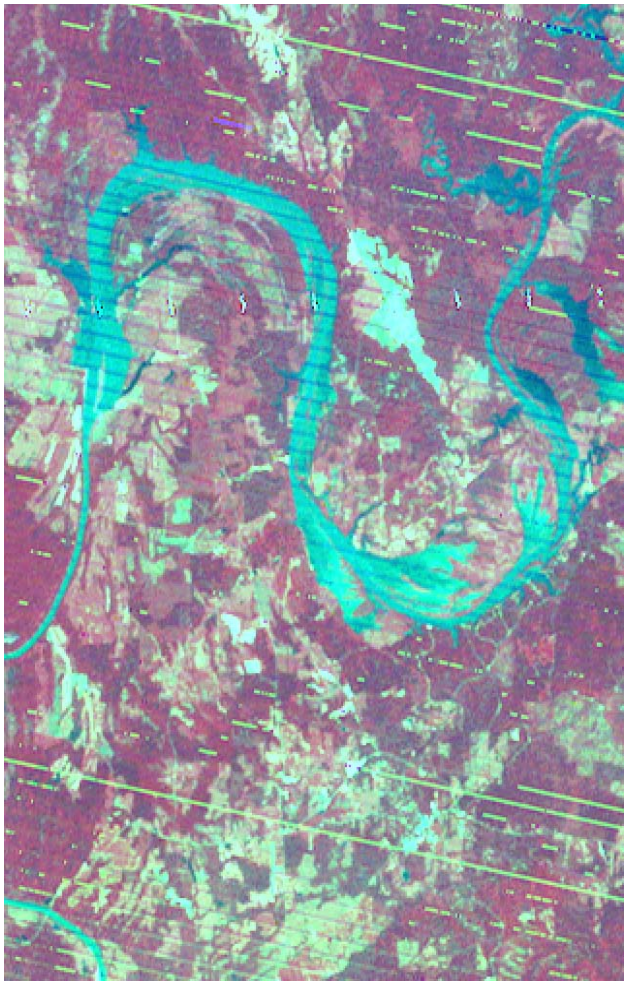
August 21 1976 Landsat 1



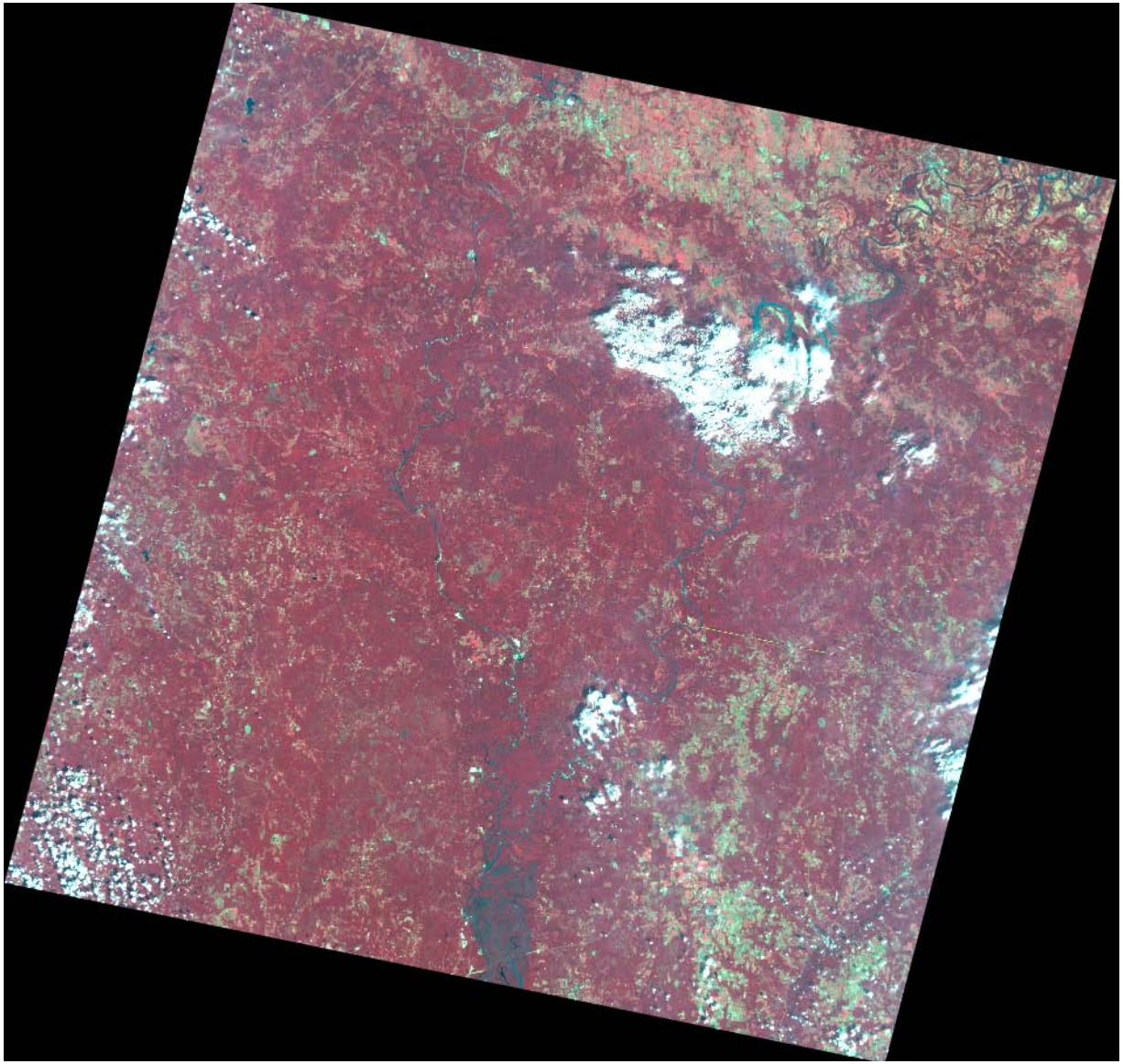


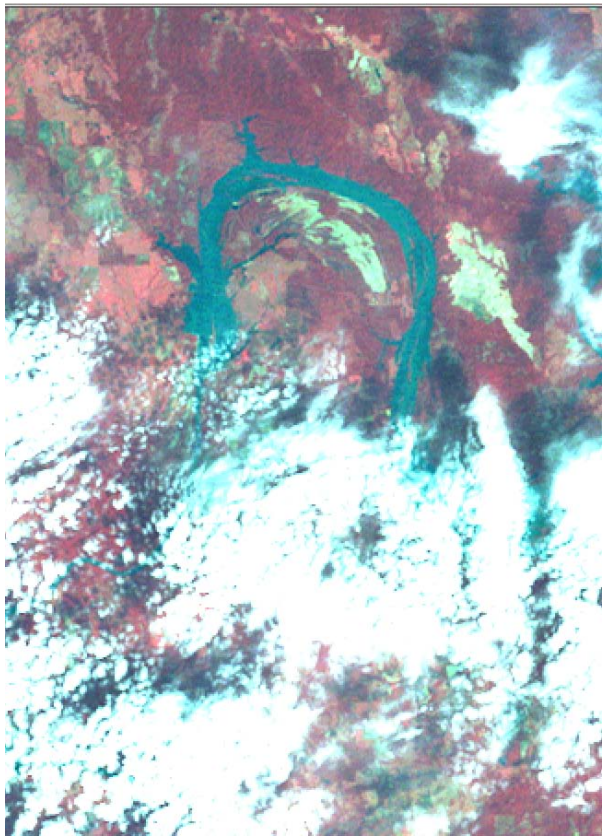
August 30 1976 Landsat 2



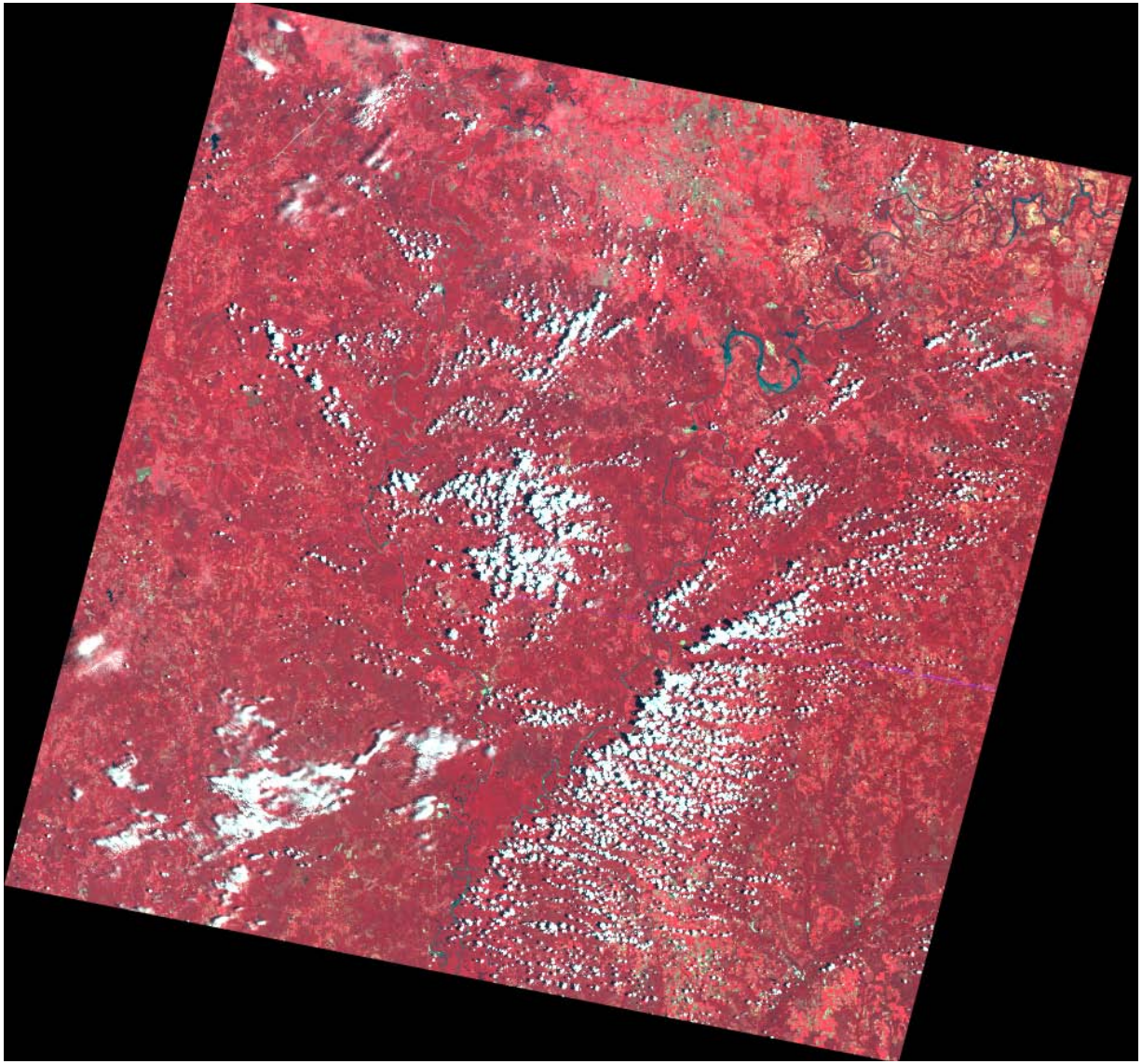


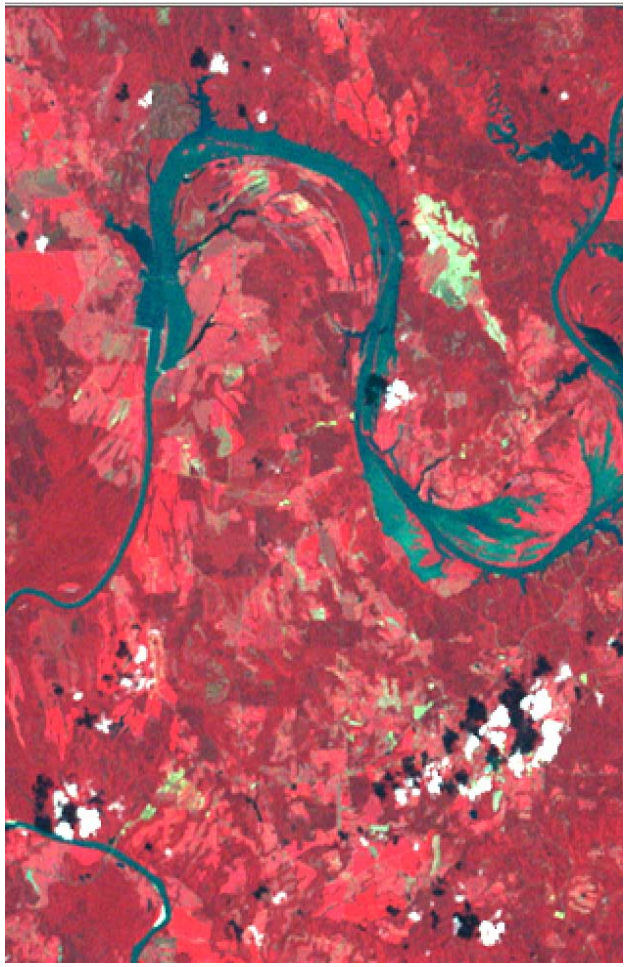
August 12 1976 Landsat 2





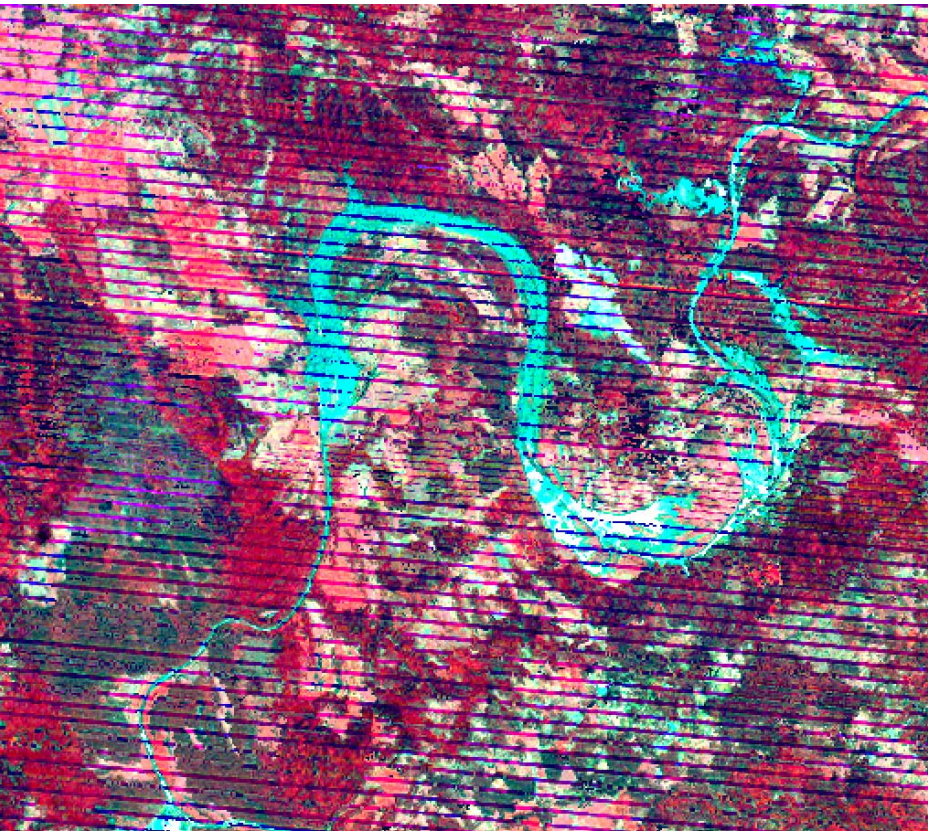
October 5, 1976 Landsat 2



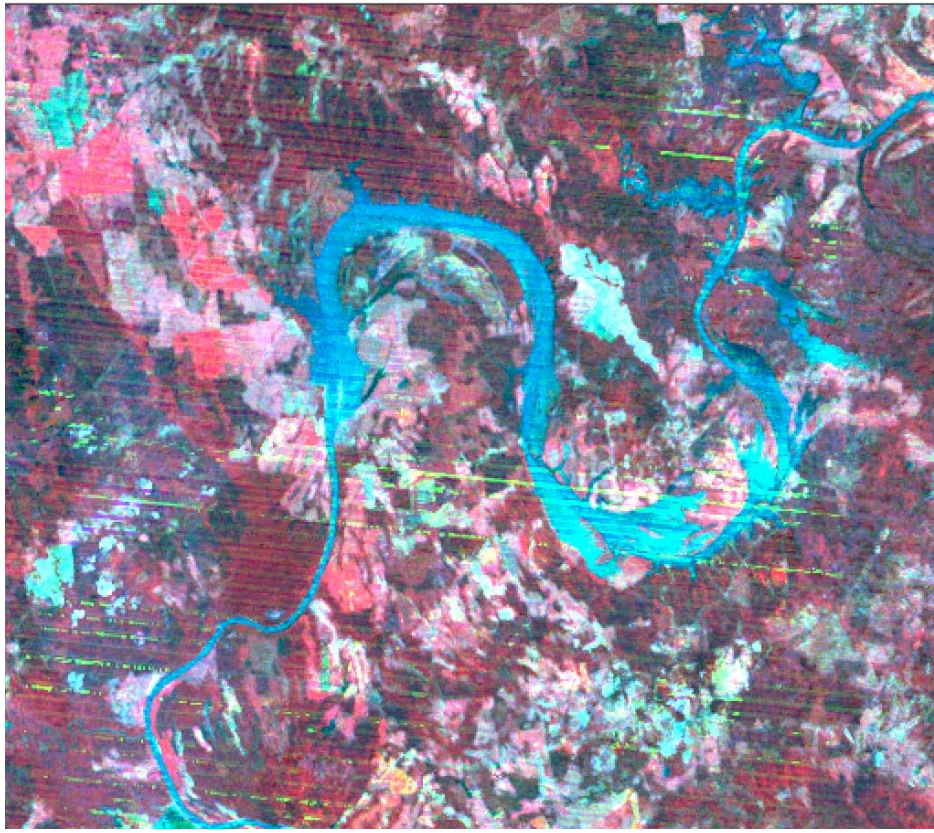


August 7 1977 Landsat 2

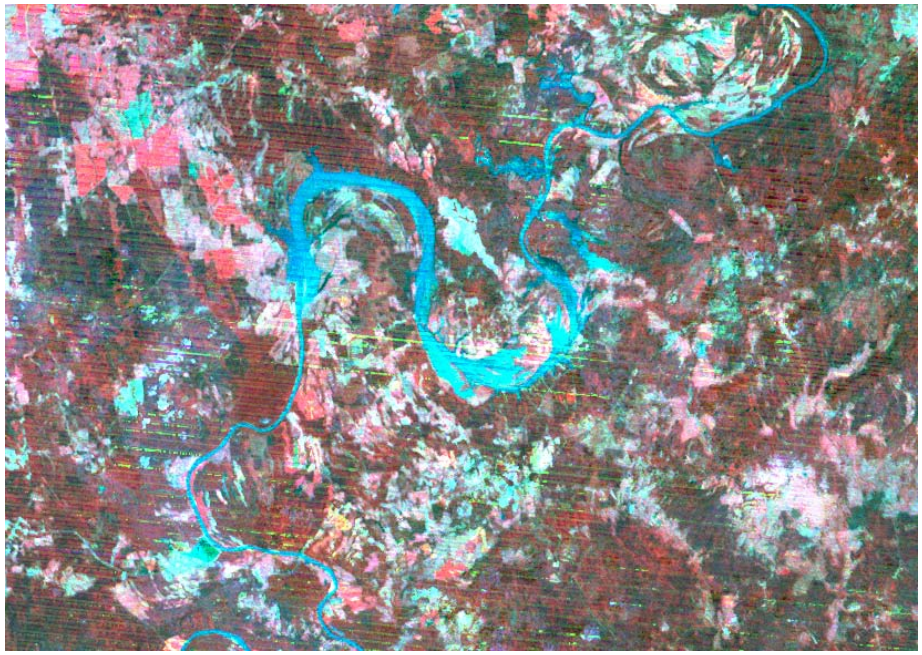
1976-1977 Summer Composites

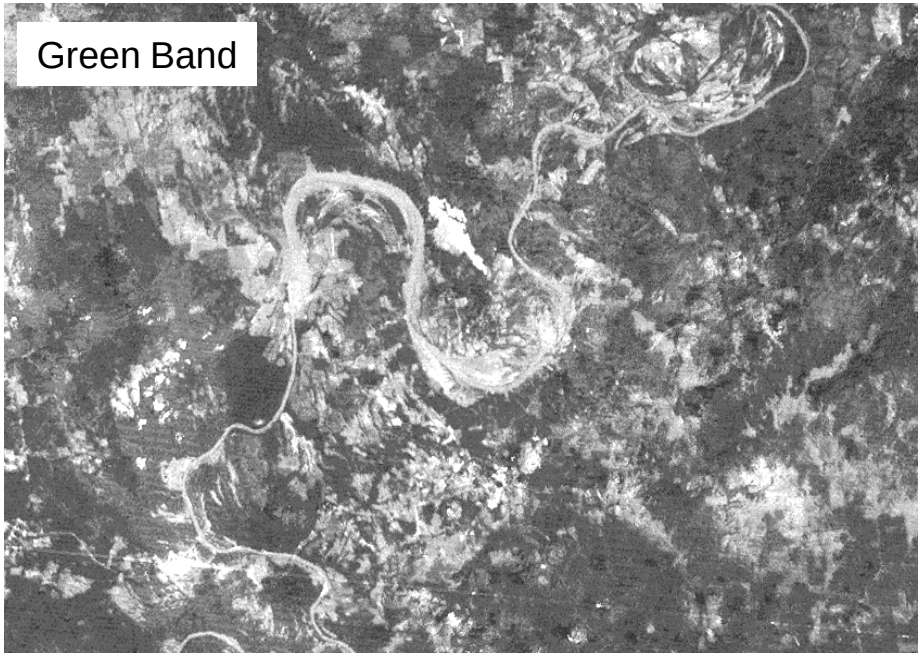


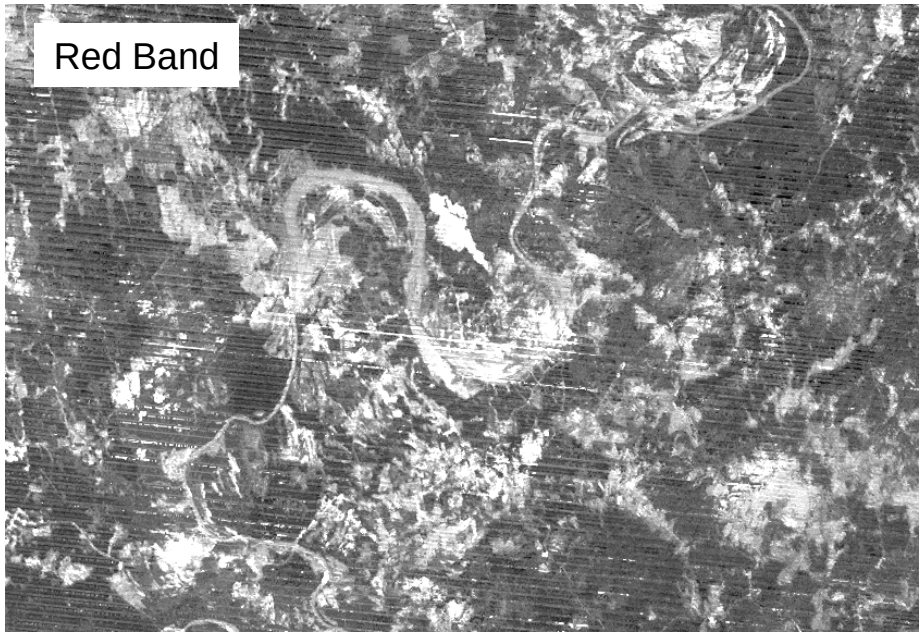
Using the Greenest Pixel Approach

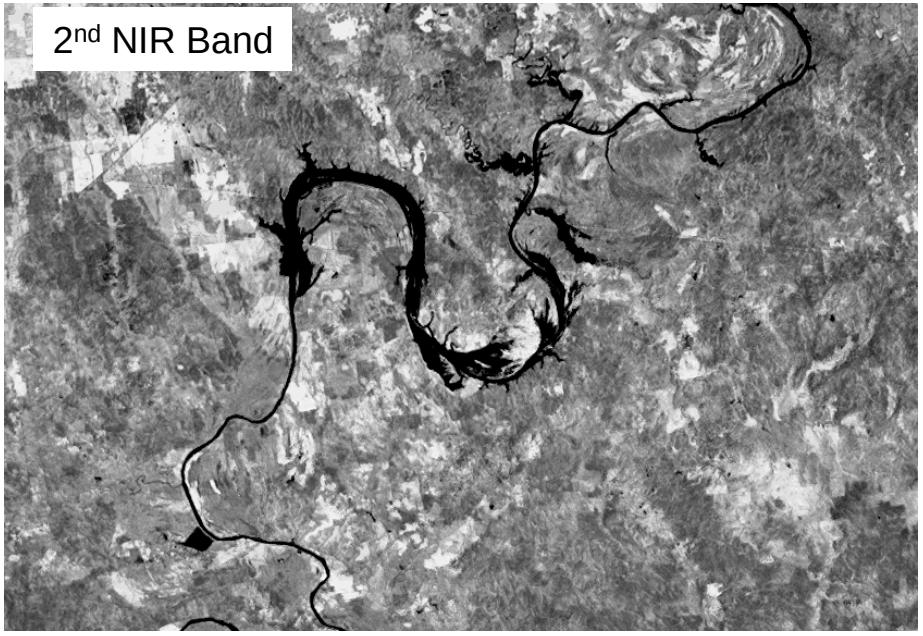


Using the Median Pixel Approach



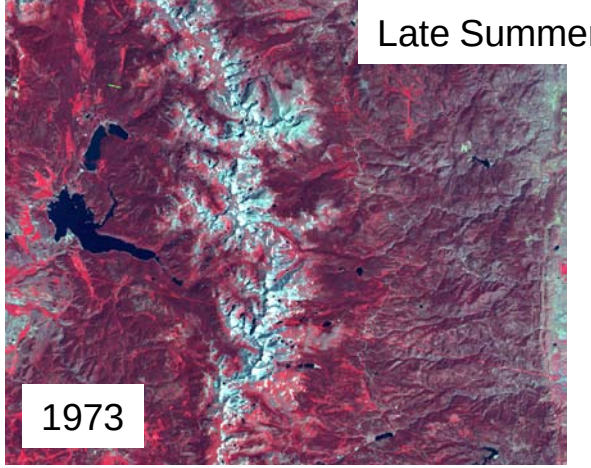


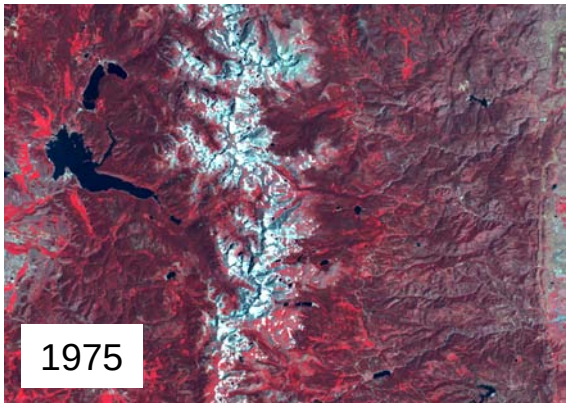


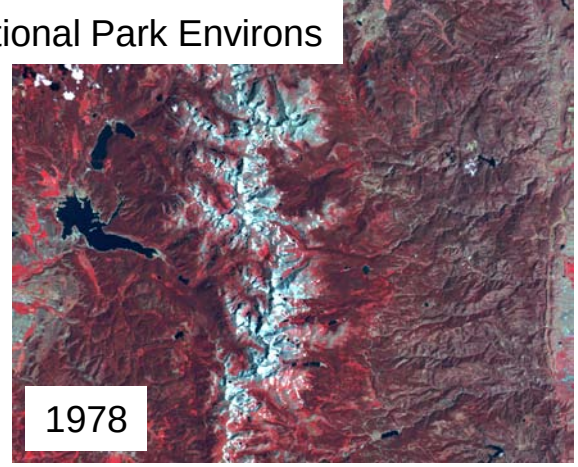


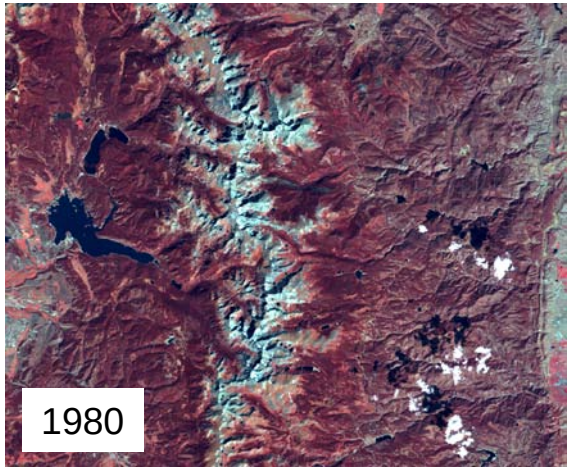
Median Pixel Composite Deconstructed (1976-1977; Southern Alabama)

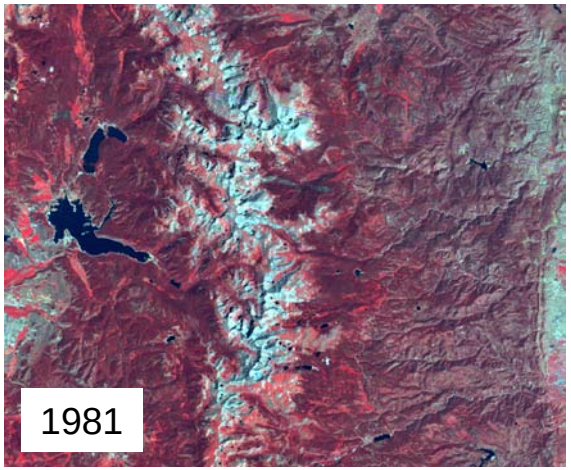
Late Summer MSS Data from Rocky Mountain National Park Environs

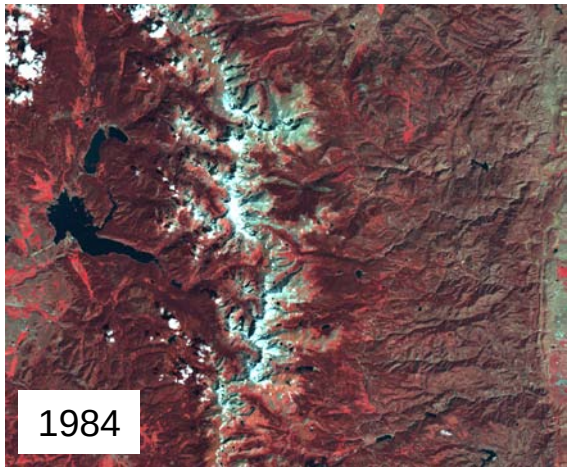


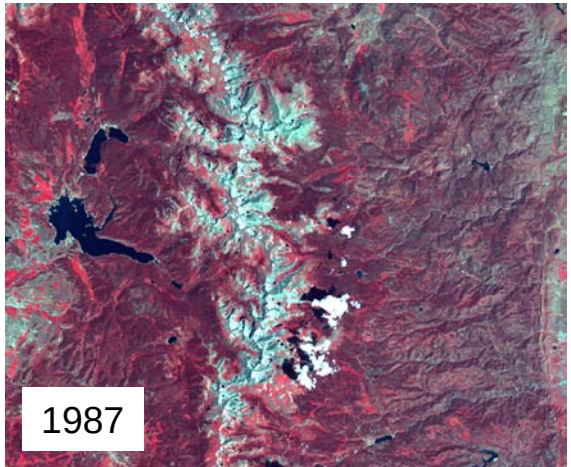


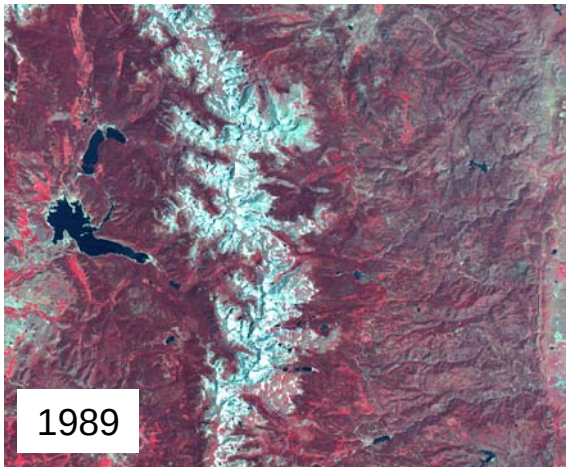


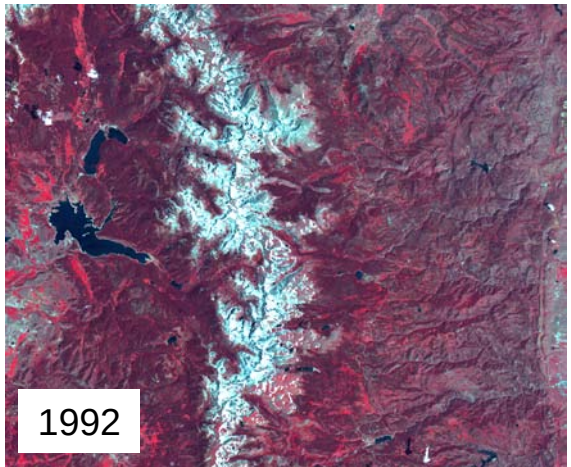


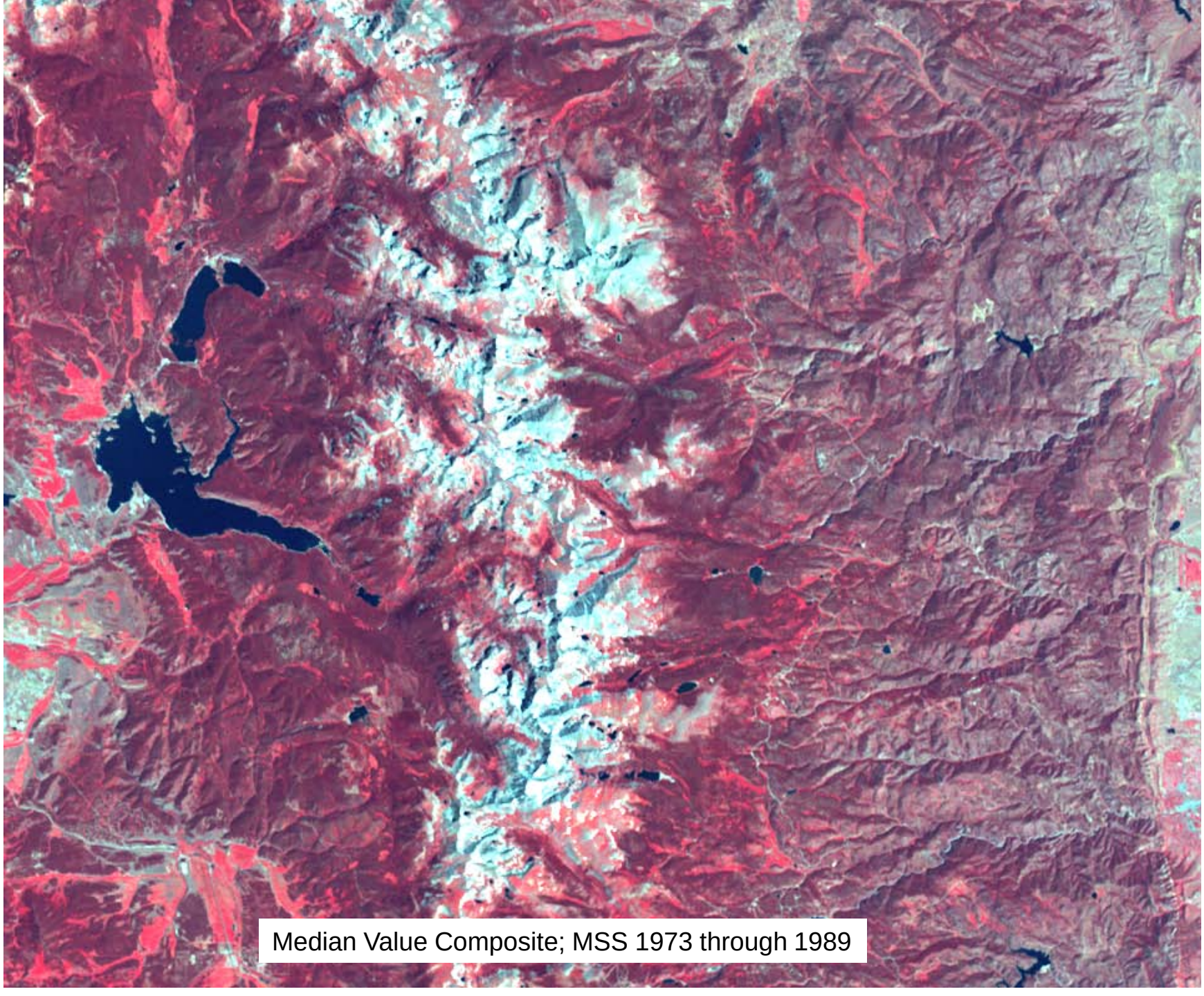








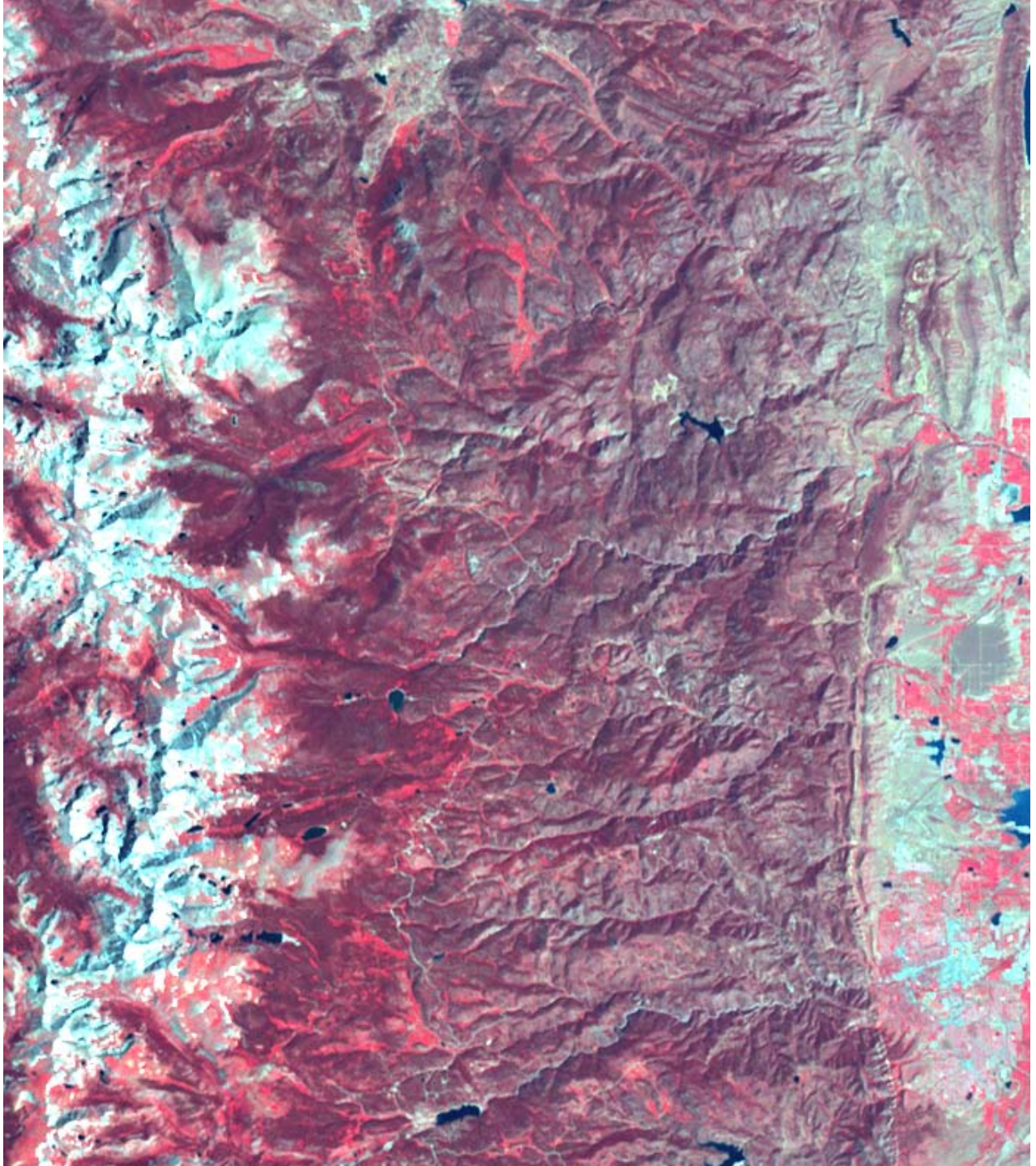




Median Value Composite; MSS 1973 through 1989

Median MSS Data Set (1973-1984)

Summer

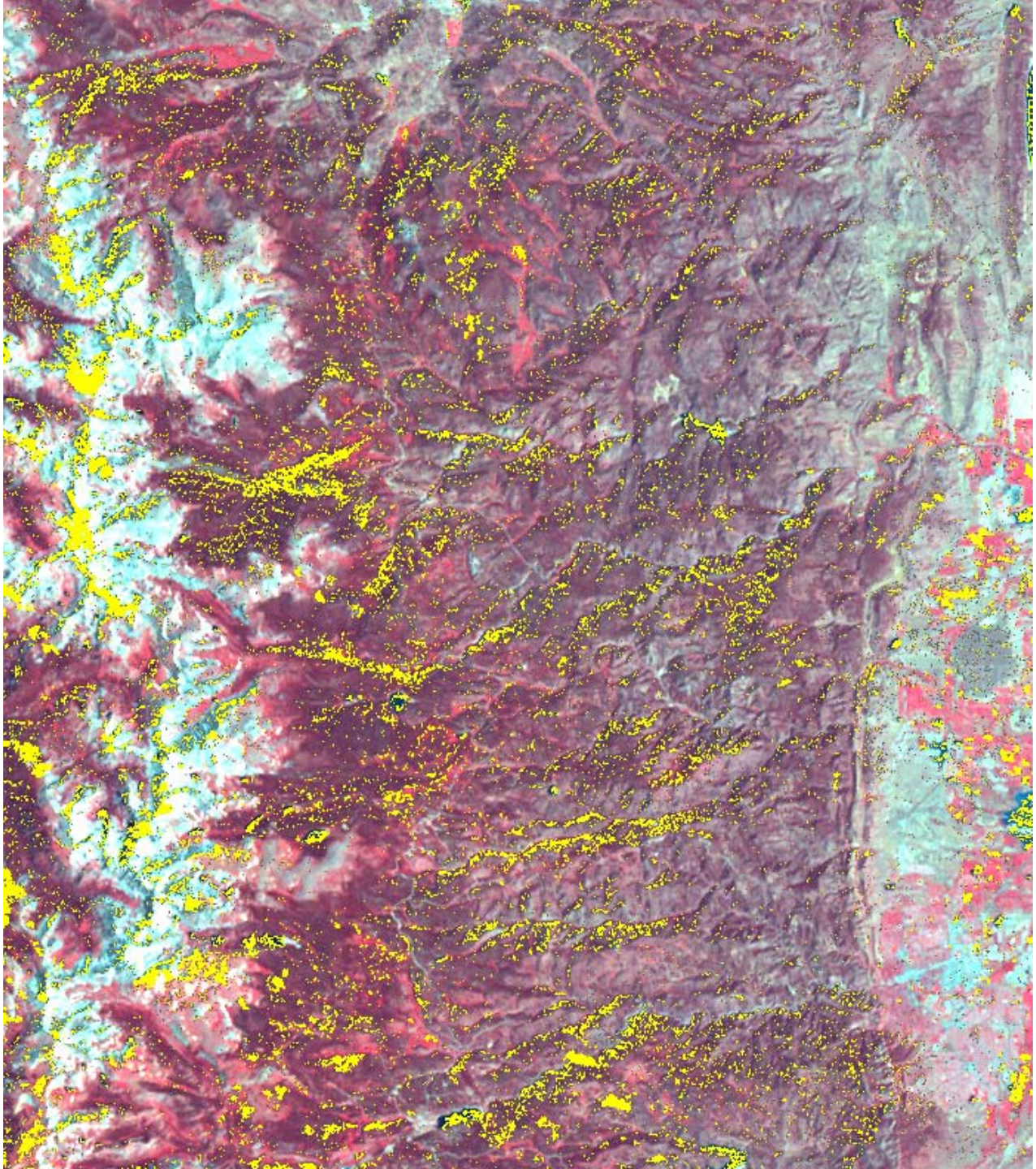


Deviation from
The Median
Data set

(1984-Median)

Yellow indicates
abnormally
low 1984 NDVI
values

(Likely caused
by mountain
pine beetle)



Some Issues with early MSS data

- Some of the early data are quite good!
- Radiometric quality issues in some scenes
  - Compositing can help to “remove” SOME of the striping
  - “Greenest pixel” approach enhances MSS “noise”
- Precision geometric corrected scenes sometimes off by as many as 8 pixels
  - Within-scene inconsistencies occur in some scenes
  - Will require additional or alternative geometric processing to make the scenes overlay appropriately
  - When scenes do not overlay well, any composite generated will be “blurry”
- Migration to different processing system (LPGS) might help?

So where does this leave us regarding MSS data?

- MSS data can be really tricky to work with. We could help by making the data more “user friendly”
- Should consider generating the “best MSS data” composited mosaics for certain time periods
  - Could borrow from the WELD approach “WELD-MSS”
- How much of a priority do we want to make this?
  - As a user interested in landscape changes, I would welcome “ready to analyze” data sets

Summary Recommendations

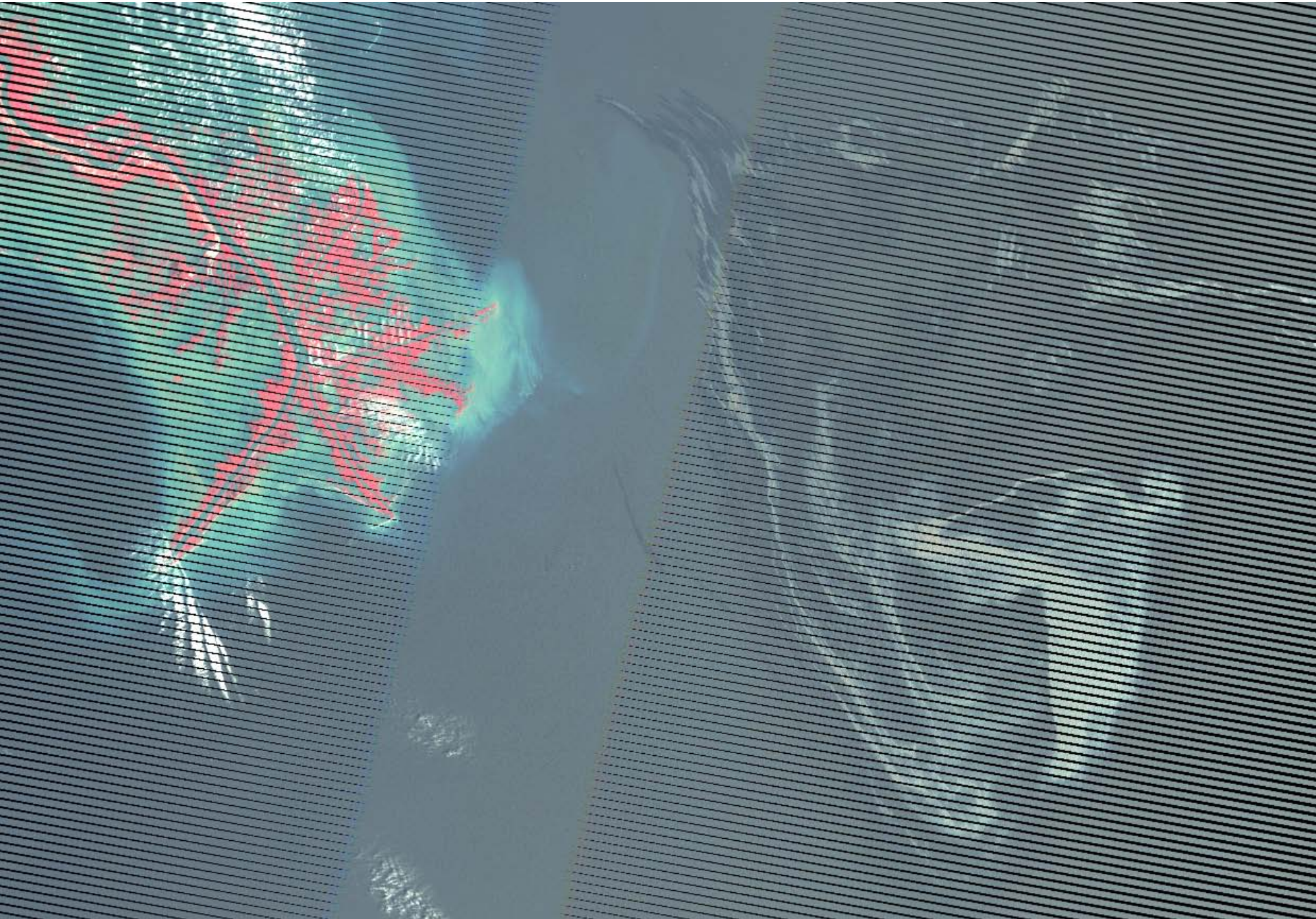
- We should generate best image data sets possible. As part of this, we should expand upon the WELD concept:
  - Current Landsat composites should include both Landsat 5 and 7data (at least for as long as L5 data are available…)
  - Consider generating monthly composites for defined (3 yr?) epochs
  - Consider generating alternative types of composites in addition to “greenest pixel” composites
  - Consider generating composites using MSS data (especially for the earliest time periods)

In order to generate the most accurate ECV’s possible, we need the best composites/mosaics possible as starting points.

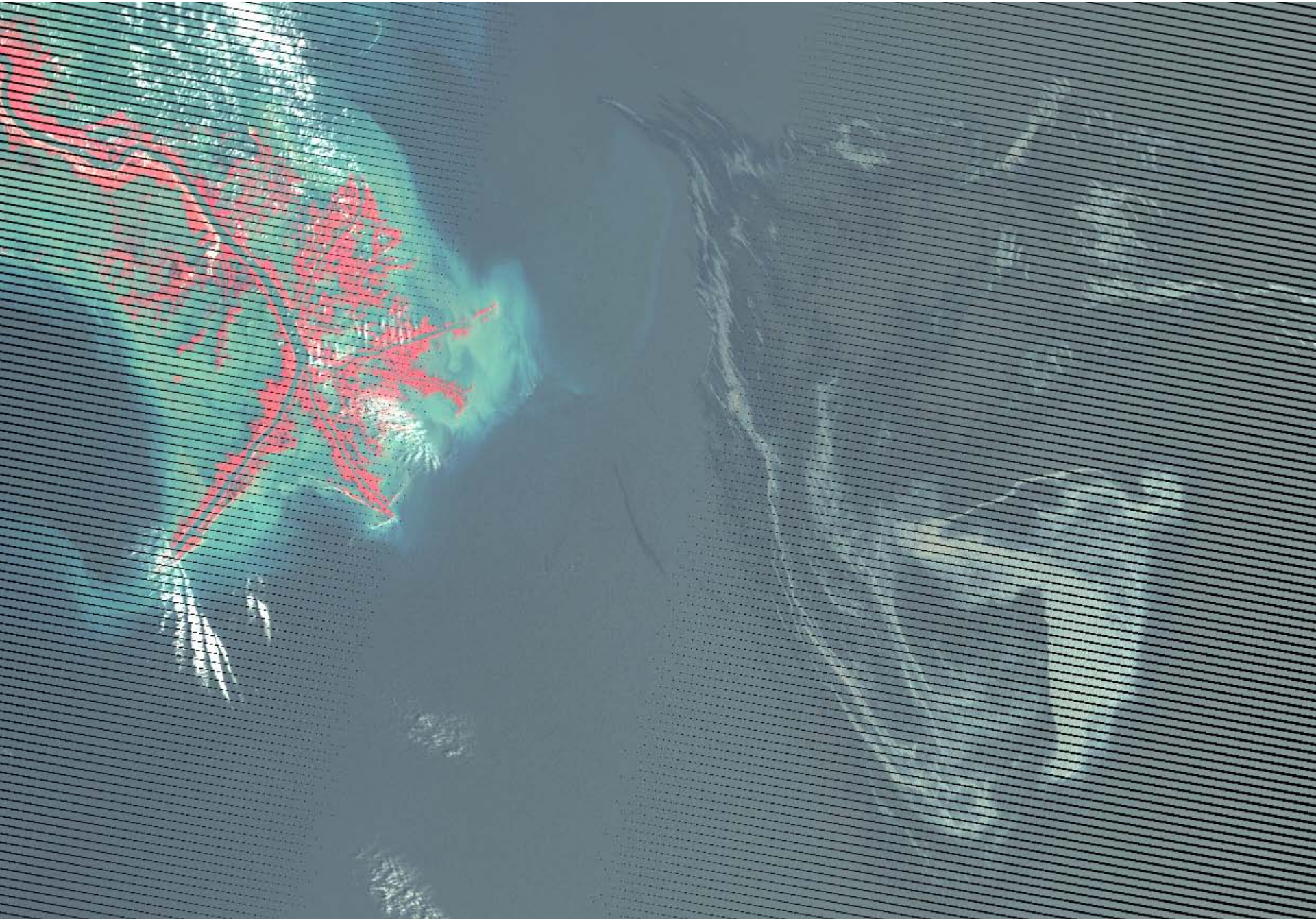
L7 SLC-OFF Interpolation Exercise

Just how far can we push within-scene interpolations
for L7 SLC-OFF gap filling?

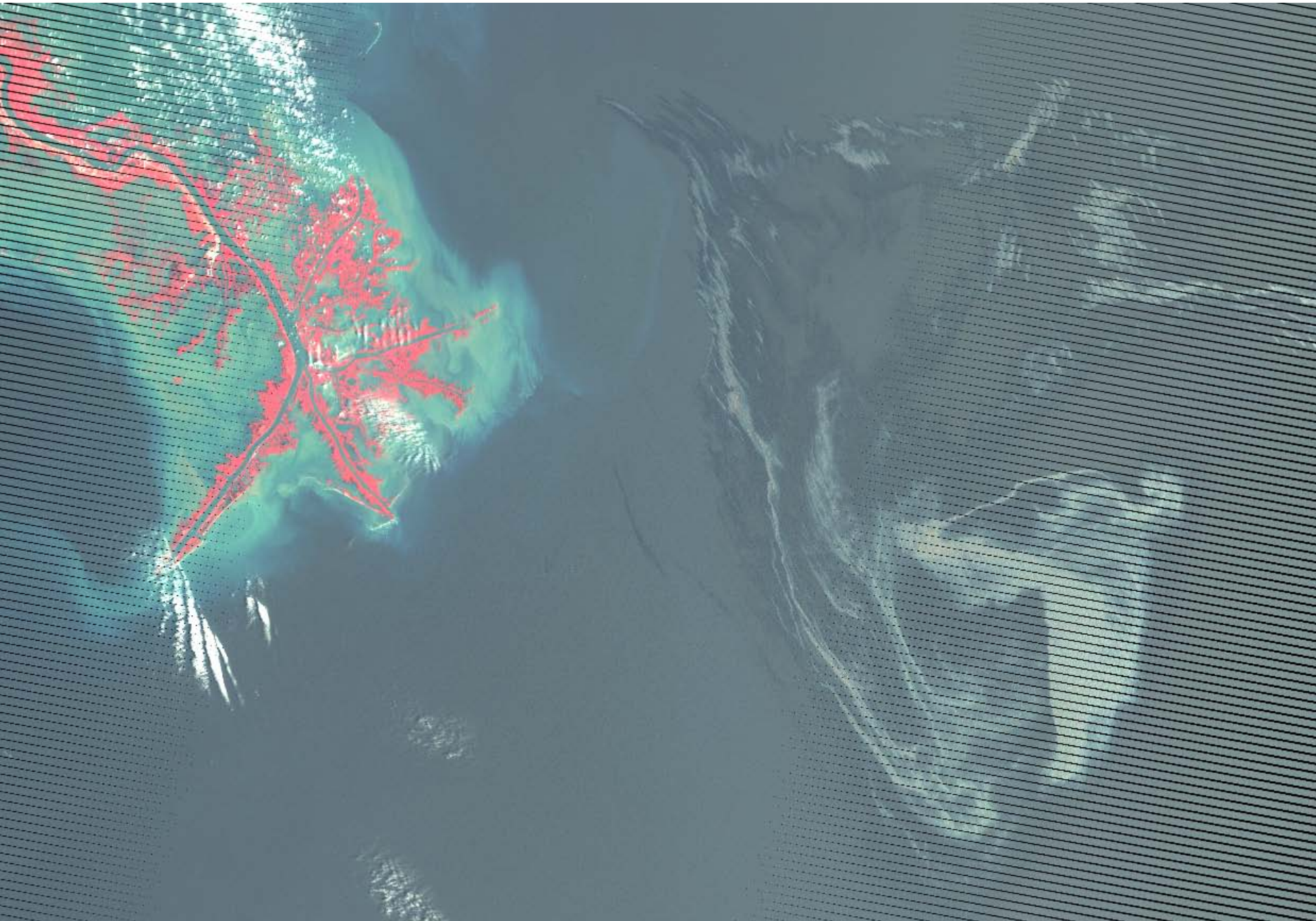
May 1, 2010 SLC-OFF data; Oil Spill off coast of Louisiana



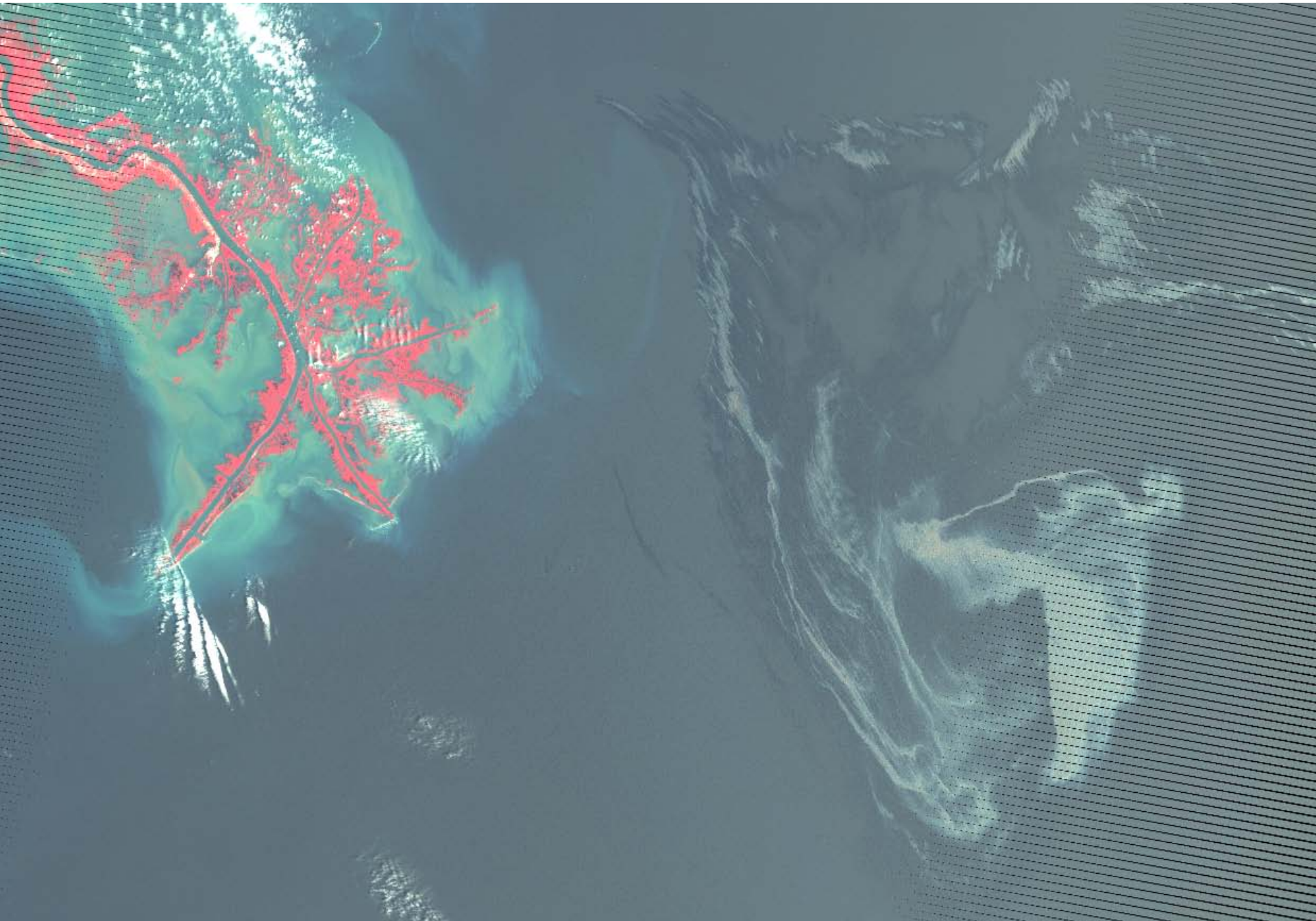
After 1 pass using 3x3 mean focal window replacing “0” values (excluding 0 values in calculation of mean)



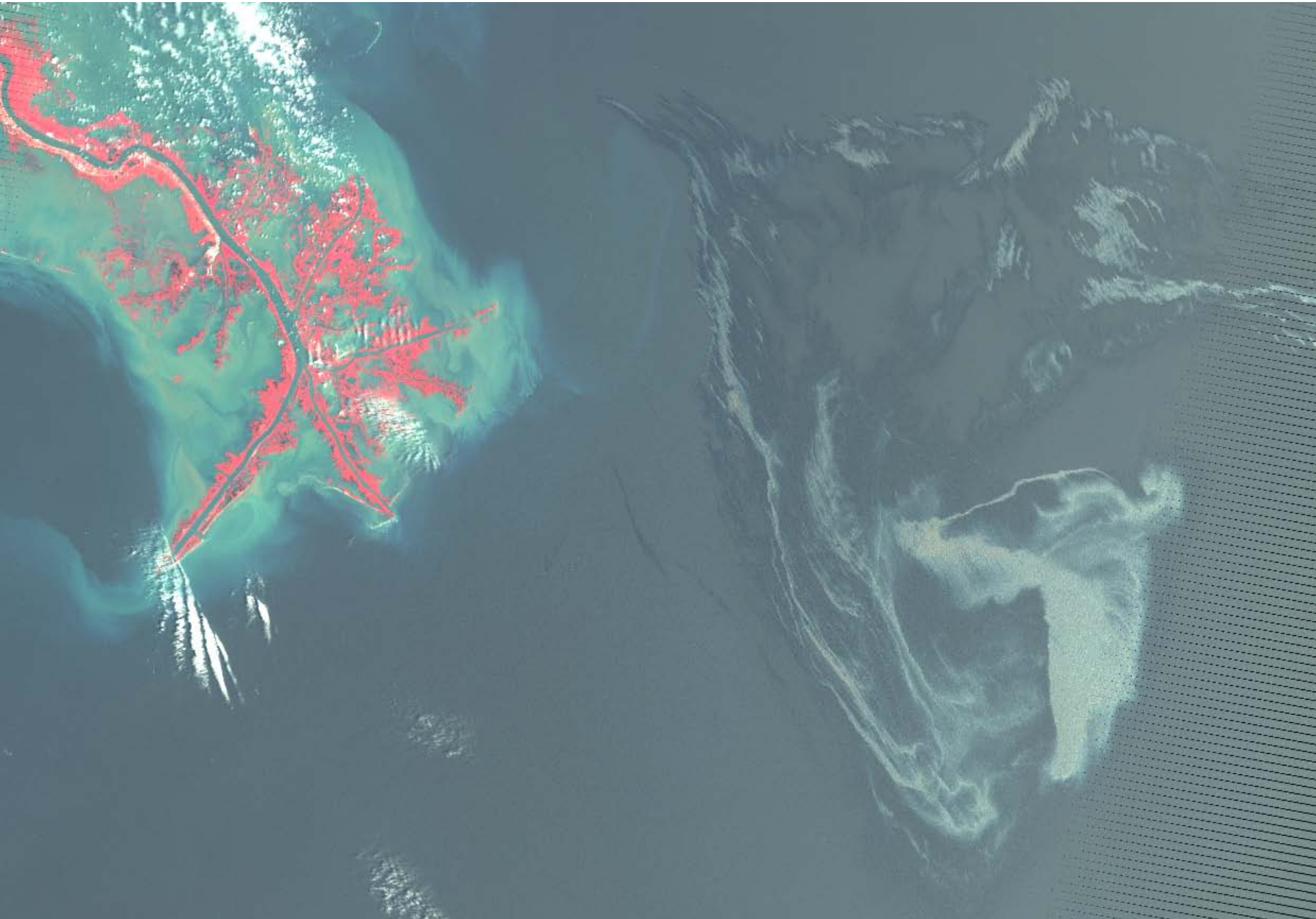
After 2nd focal window pass



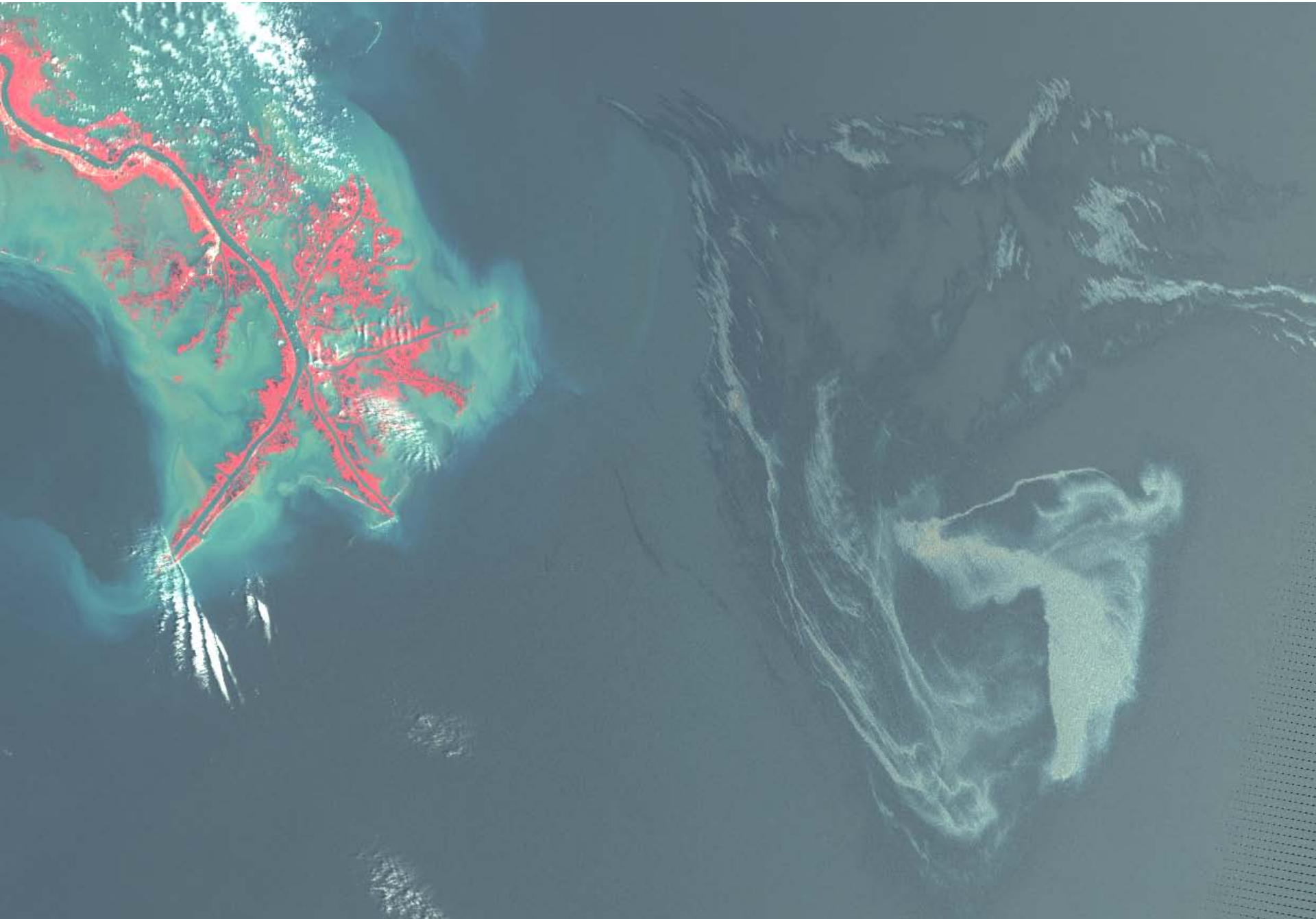
After 3rd focal window pass



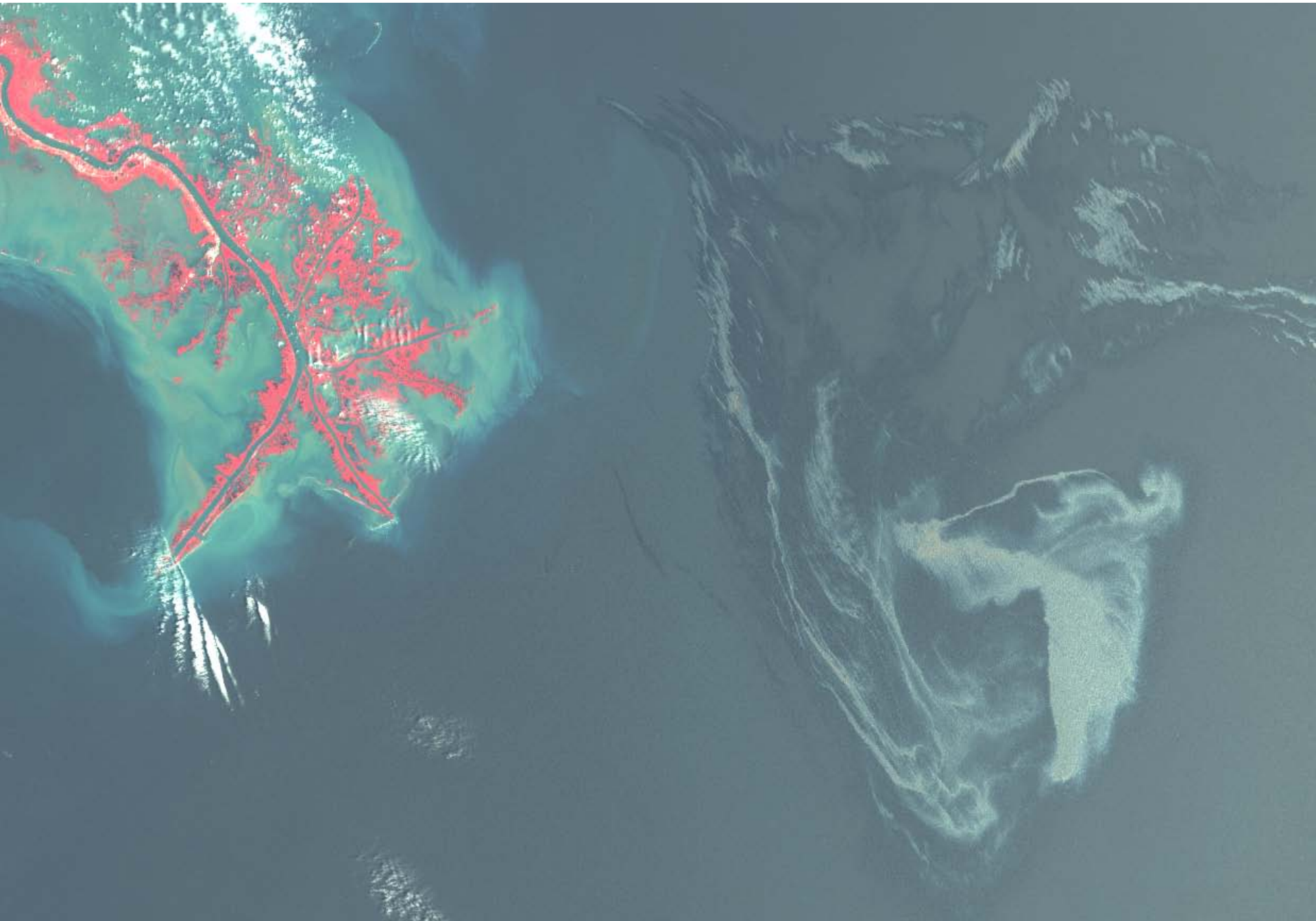
After 4th focal window pass



After 5th focal window pass



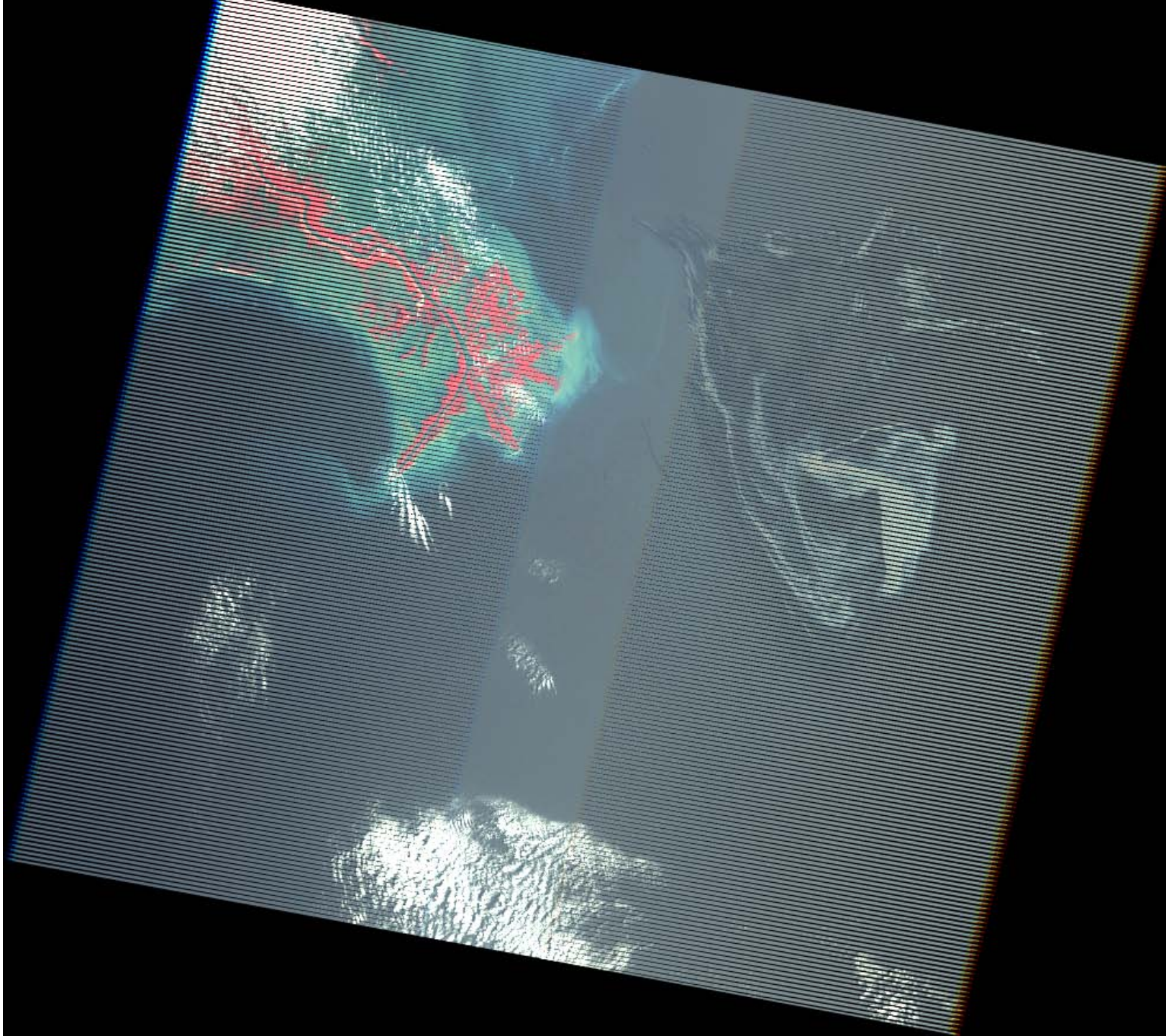
After 6th focal window pass



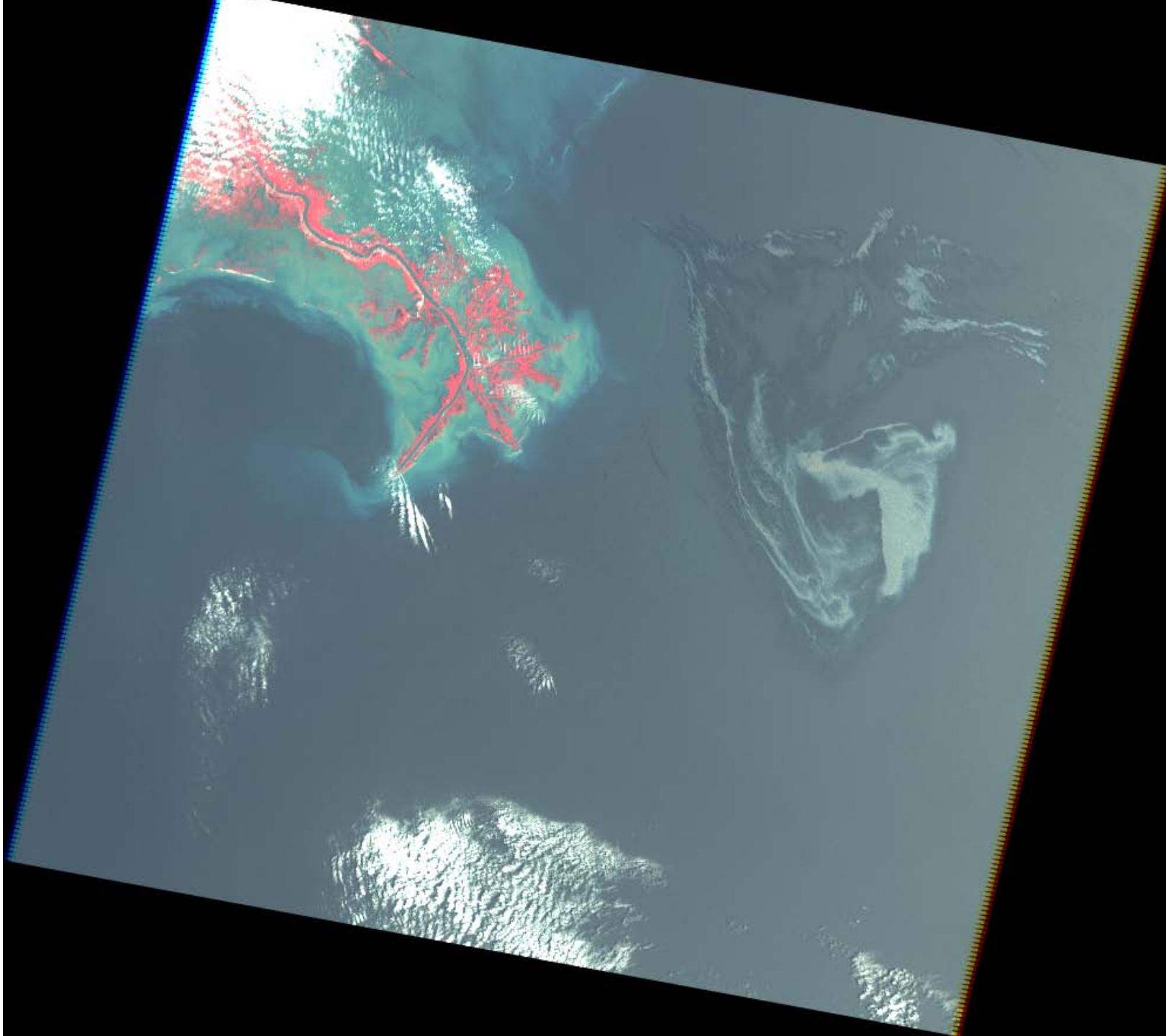
Close-up from along Louisiana coast

Close-up of Louisiana Coastline Gap-filled

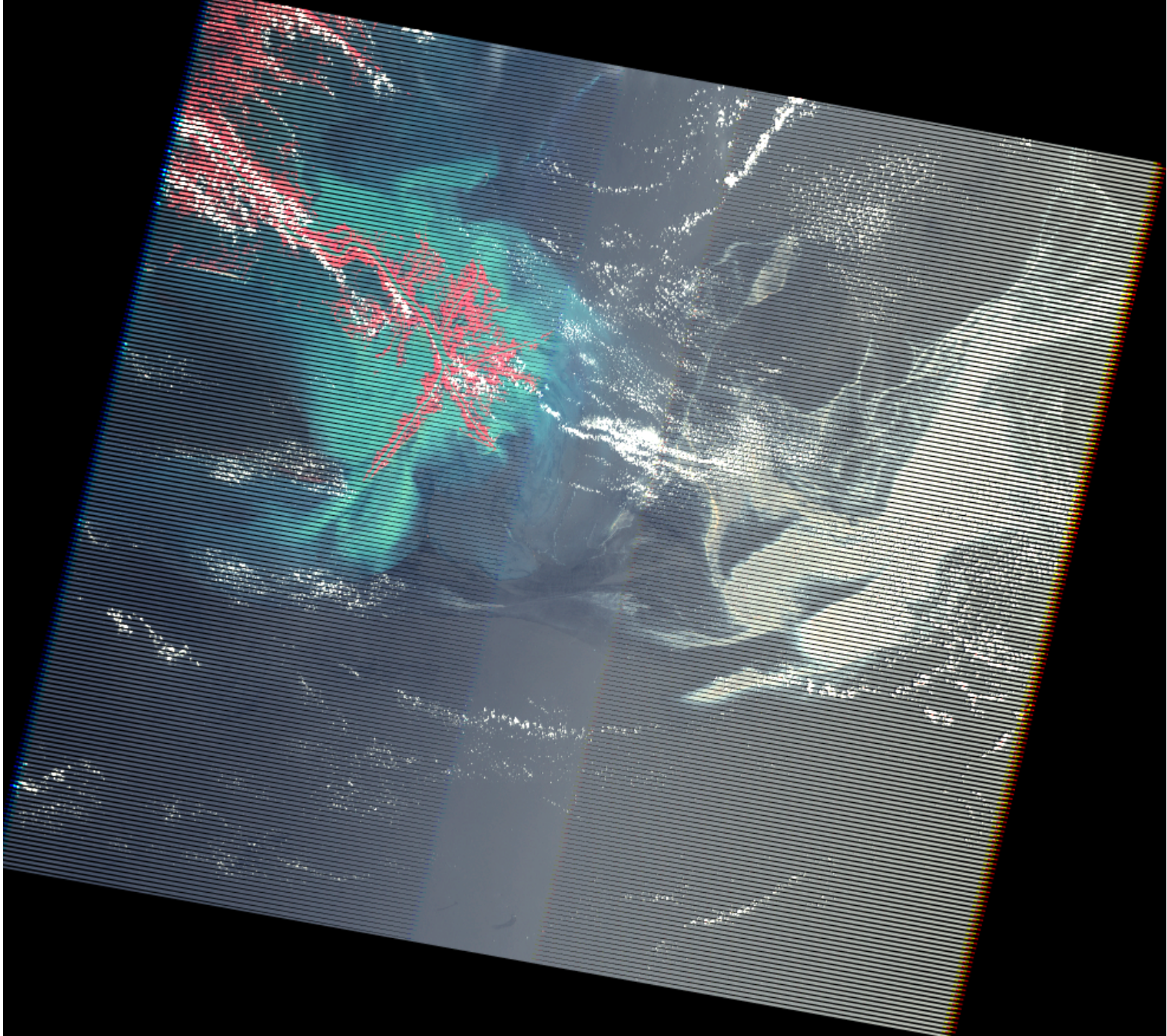
May 1,2010



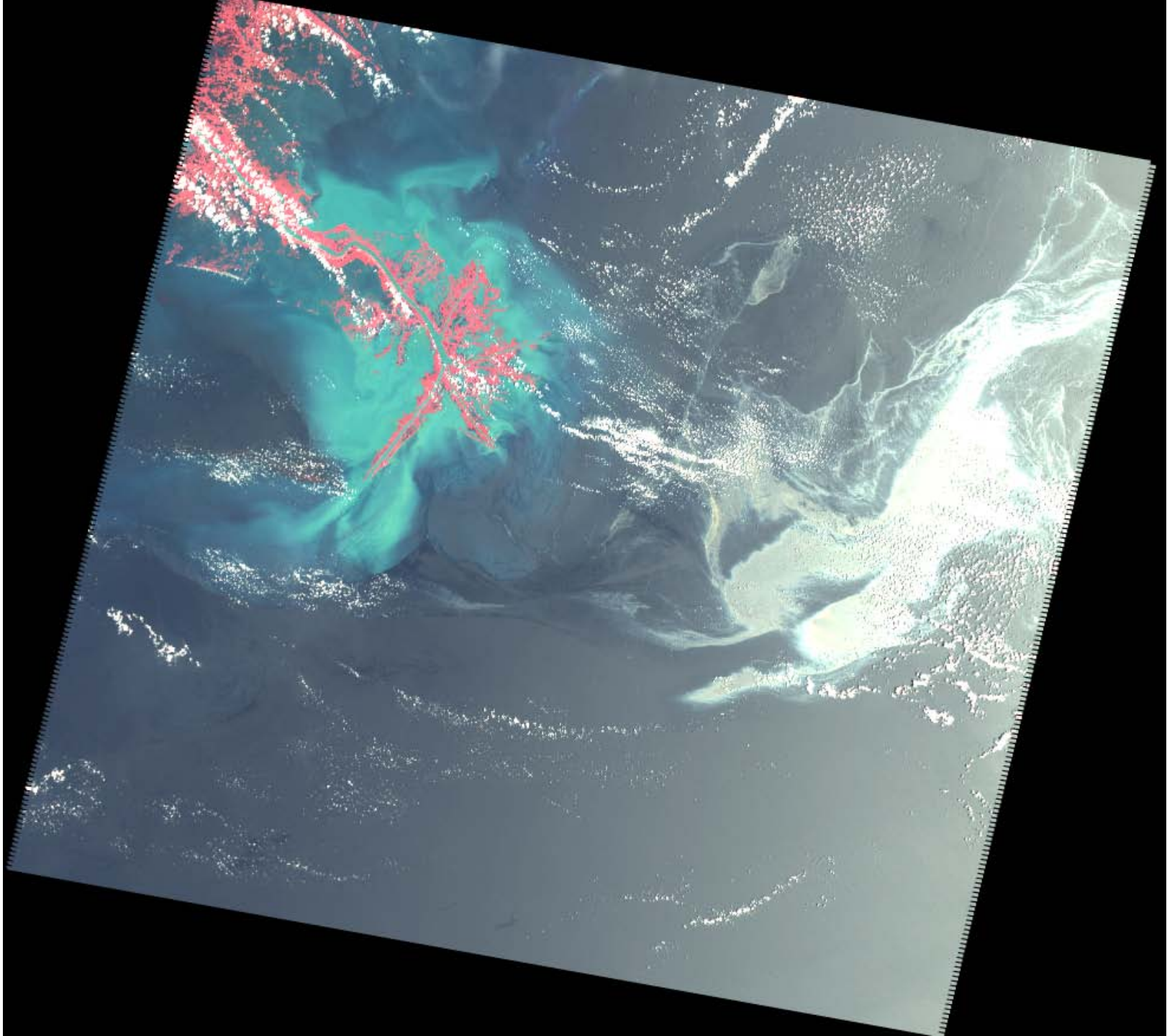
May 1, 2010
(interpolated)

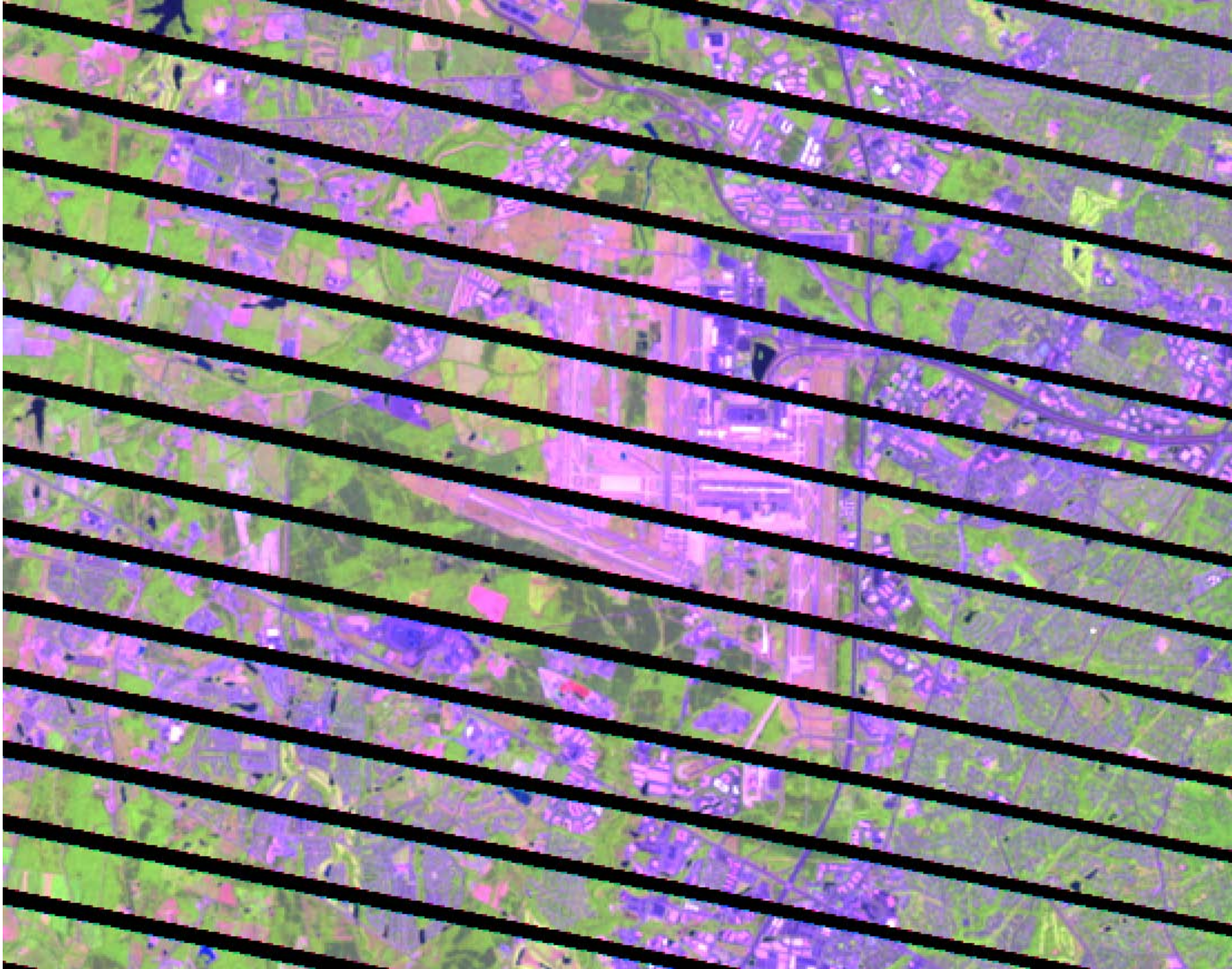


May 17,2010



May 17,2010
(interpolated)

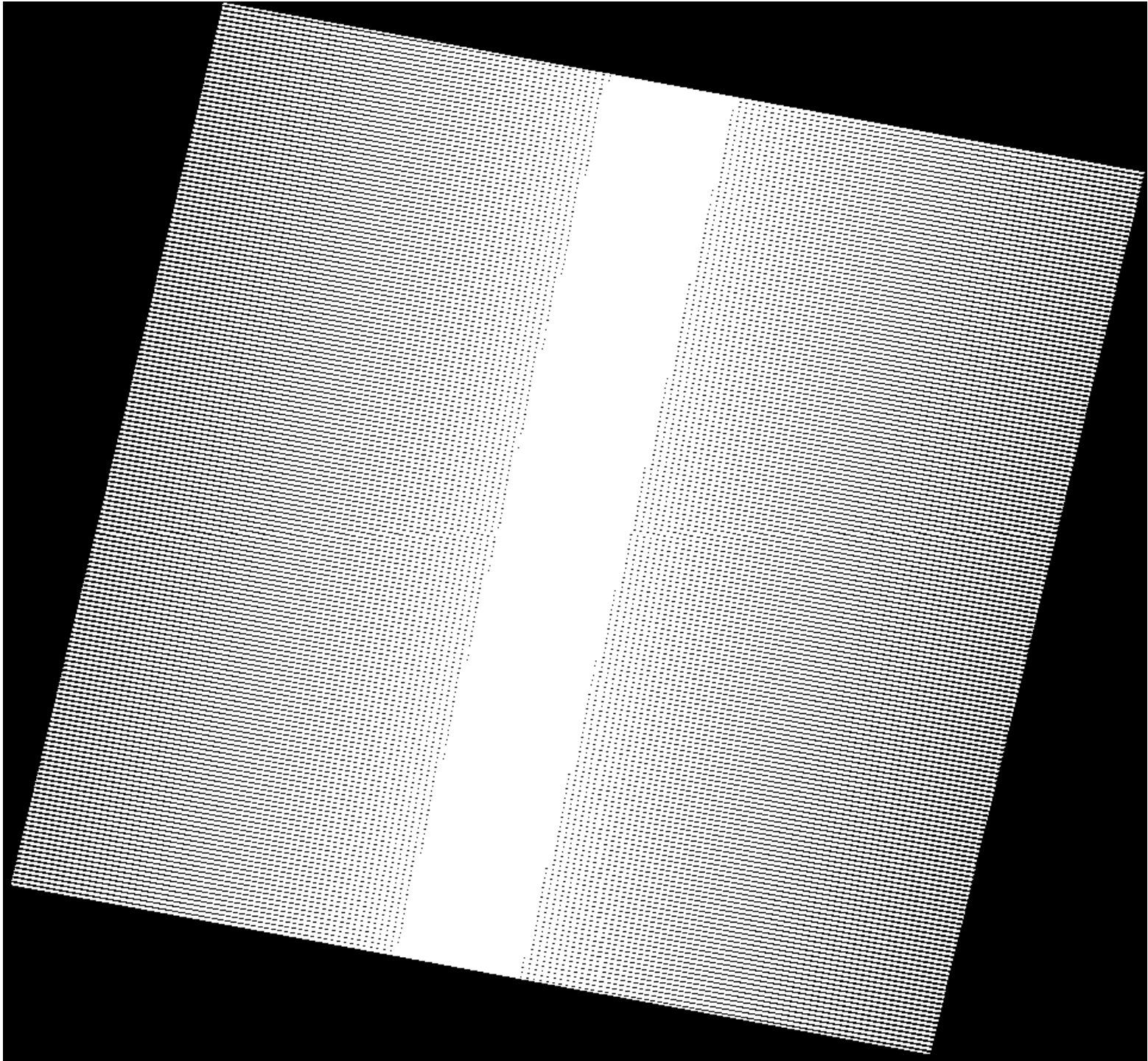




SLC-OFF Mask Based on Band 1

Gaps represent 20.7% of scene Area

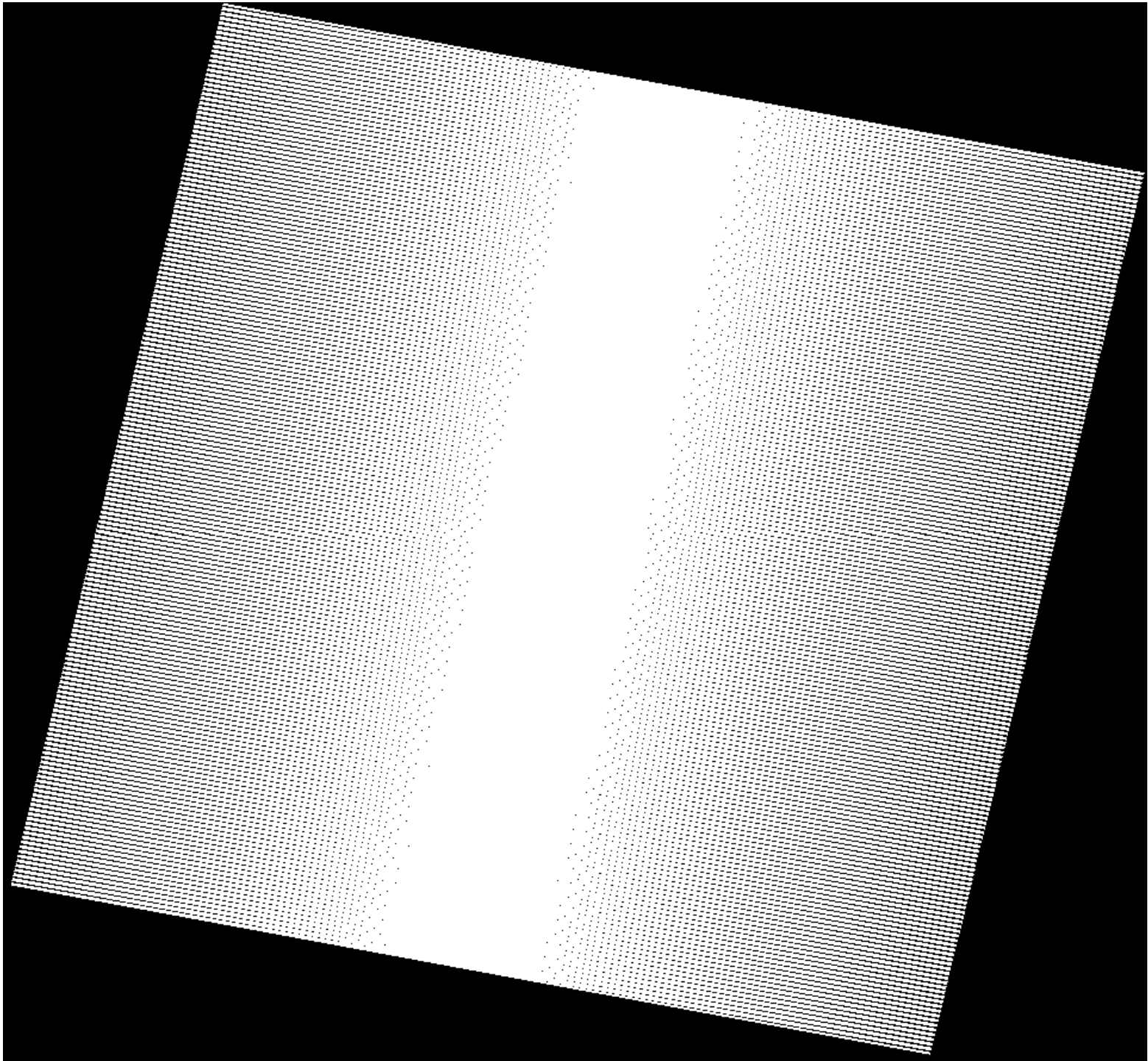
Scene is 79.3% Filled



Mask after 1st filter pass (nibbled in one row on each side of gaps)

Gaps represent 14.5% of scene Area

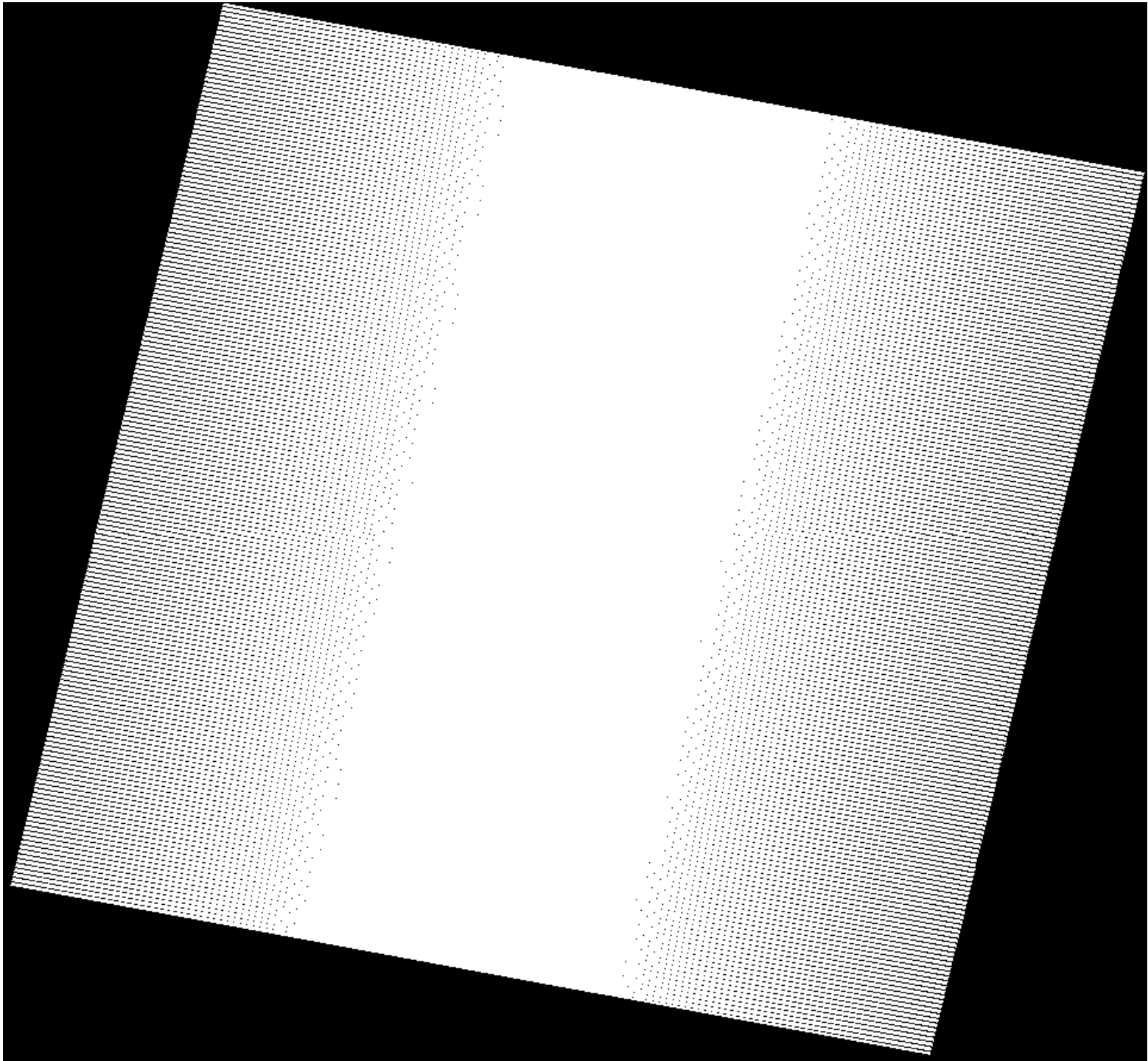
Scene is 85.5% Filled



Mask after 2nd filter pass (nibbled in two rows on each side of gaps)

Gaps represent 9.1% of scene Area

Scene is 90.9% Filled



Some thoughts about these interpolations….

- Within-scene interpolation can work well to generate good pictures (as long as we don't zoom in too far along the scene edges….)
- One of the reasons these products look as good as they do is that we are keeping pixels in same "spectral space"
- For compositing purposes, if we allow "nibbling" by one or two pixels into gaps, we get 85-91% of the scene "filled" (probably with minimal impact to the user….)