Web-enabled Landsat data (WELD): a consistent seamless near real time MODIS-Landsat data fusion for the terrestrial user community

a NASA Making Earth System data records for Use in Research Environments (MEASURES) funded project

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Geographic Information Science Center of Excellence

South Dakota State University (SDSU), USA

Landsat Data Products Workshop
Boston University
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What the Landsat user community ultimately wants …

- Derived data products for free

- Systematic, consistent, community endorsed data processing
  - calibration, geolocation
  - radiometric normalization / BRDF correction, atmospheric correction
  - cloud-screened, snow-screened, SLC-off gap filling
  - needed in order to derive higher level bio/geophysical products

- Composited large-area data product mosaics
  - updated at the pixel level
  - using all the Landsat data, not just select acquisitions
  - processed shortly after acquisition i.e. “near real time”

- A long term Landsat data product record

- *Similar to the NASA MODIS land products but at high spatial resolution*

- *Above is what this 5 year NASA funded project is seeking to achieve, building on our 10 year MODIS Land product development, processing (and reprocessing) experience.*

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Reviewer # 3 Comment:

This is very timely, well-explained, applicable to current and future research. This paper addresses the next logical step in Landsat product development, given the recent provision of archive data at no cost. An important omission for the Landsat program is a well-defined long-term data record, generated on a global scale. We really do need to take this next step toward generation of a long-term data record in order to have credibility with the White House and Congress when we ask for funding for an operational system. The process defined in this paper takes advantage of the newly available data and starts us on the path toward such a data record. I think this should be emphasized more in the abstract, introduction and summary sections. It's a very important point.

Roy, D.P., Ju, J., Kline, K., Scaramuzza, P.L., Kovalskyy, V., Hansen, M.C., Loveland, T.R., Vermote, E.F., Zhang, C., Web-enabled Landsat Data (WELD): Landsat ETM+ Composited Mosaics of the Conterminous United States, *Remote Sensing of Environment,* In Press.

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Weld Products (may change after community feedback)

ETM+ composited mosaics for all CONUS & Alaska, 7 years

Monthly Composite	Seasonal (3 month) Composite	Annual Composite

WELD Production & Distribution

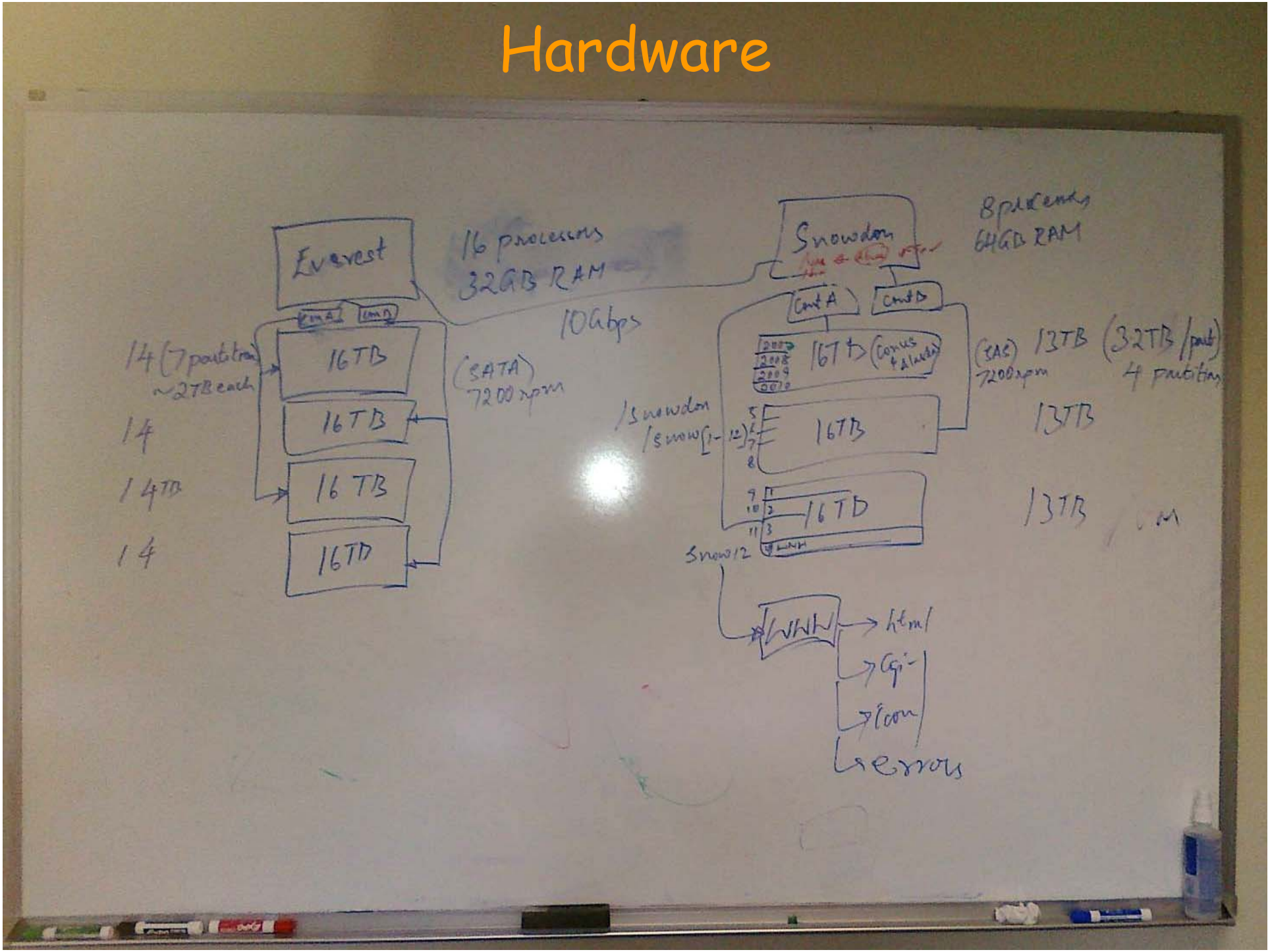
- WELD production system being developed at SDSU
  - C code on Linux architecture
  - products updated at the pixel level as the ETM+ data are acquired and processed

- WELD production system will be migrated to EROS in year 3 of project

- The processing approach is intentionally designed to
  - facilitate automated processing with minimal human intervention
  - enable composited mosaics to be updated regardless of the chronological order of the Landsat acquisition and processing dates
  - provide processing in near-real time, i.e., updating composited mosaics shortly after the Landsat L1T data are acquired.

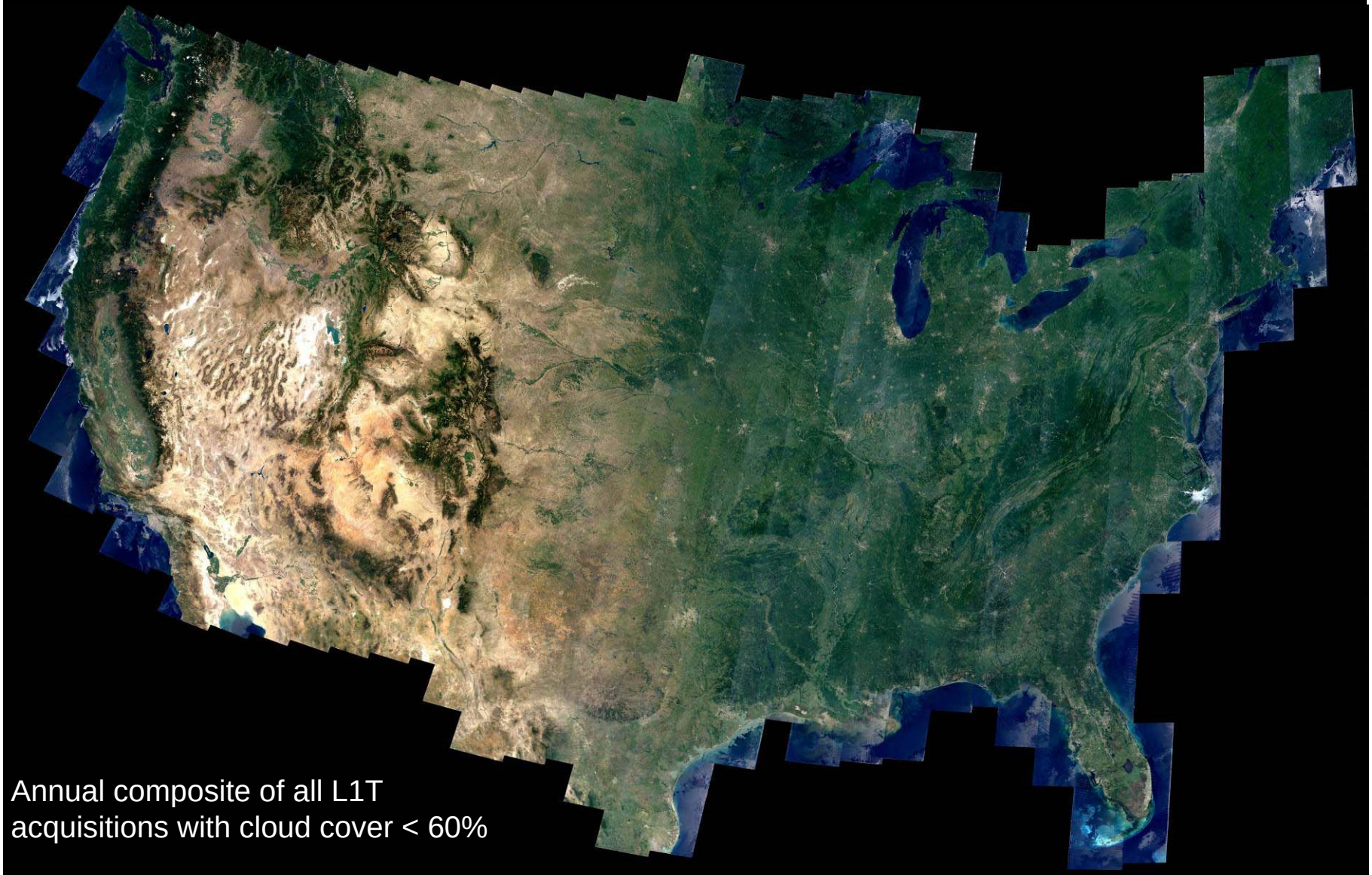
- WELD products will be accessible via the internet from EROS
  - prototype distribution already up
  - intuitive WYSIWY interface developed

Hardware


Everest
16 processors
32GB RAM
10Gbps
cmdA
cmdB
14 (7 partitions ~2TB each)
16TB
16TB
16 TB
16TD
14
14TB
14
(SATA)
7200 rpm
Snowdon
8 processors
64GB RAM
cmdA
cmdB
16TB (cores + slots)
(SAS)
7200 rpm
13TB
(32TB / part)
4 partitions
/snowdon
/snow[1-12]
16TB
13TB
16TD
13TB
Snow12
WWW
html
cgi-
icons
errors

Annual 2008 (Dec 2007- Nov 2008)

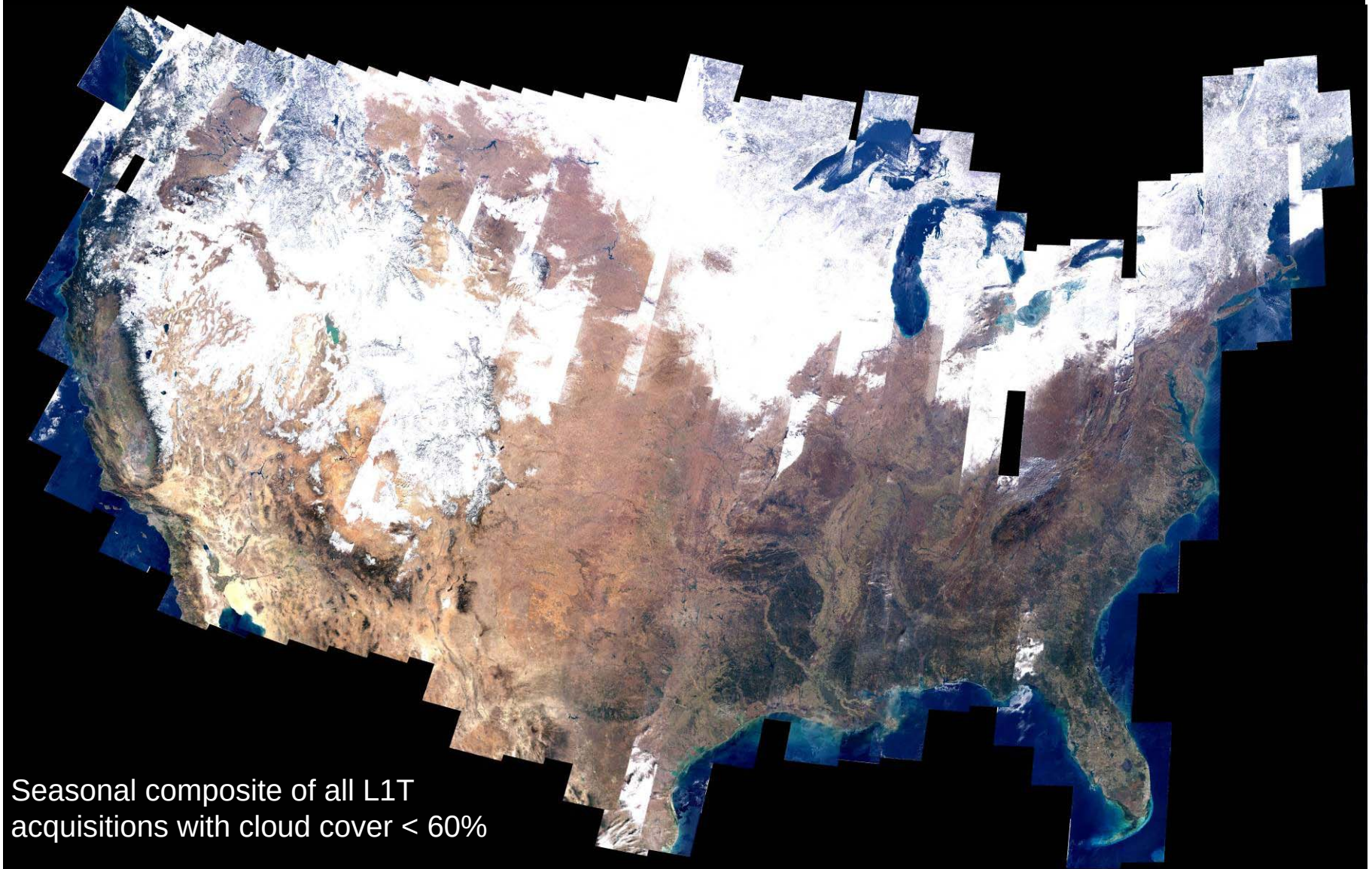
500m Browse (9706x6471 pixels)



Annual composite of all L1T
acquisitions with cloud cover < 60%

Winter 2007 (Dec '07, Jan, Feb '08)

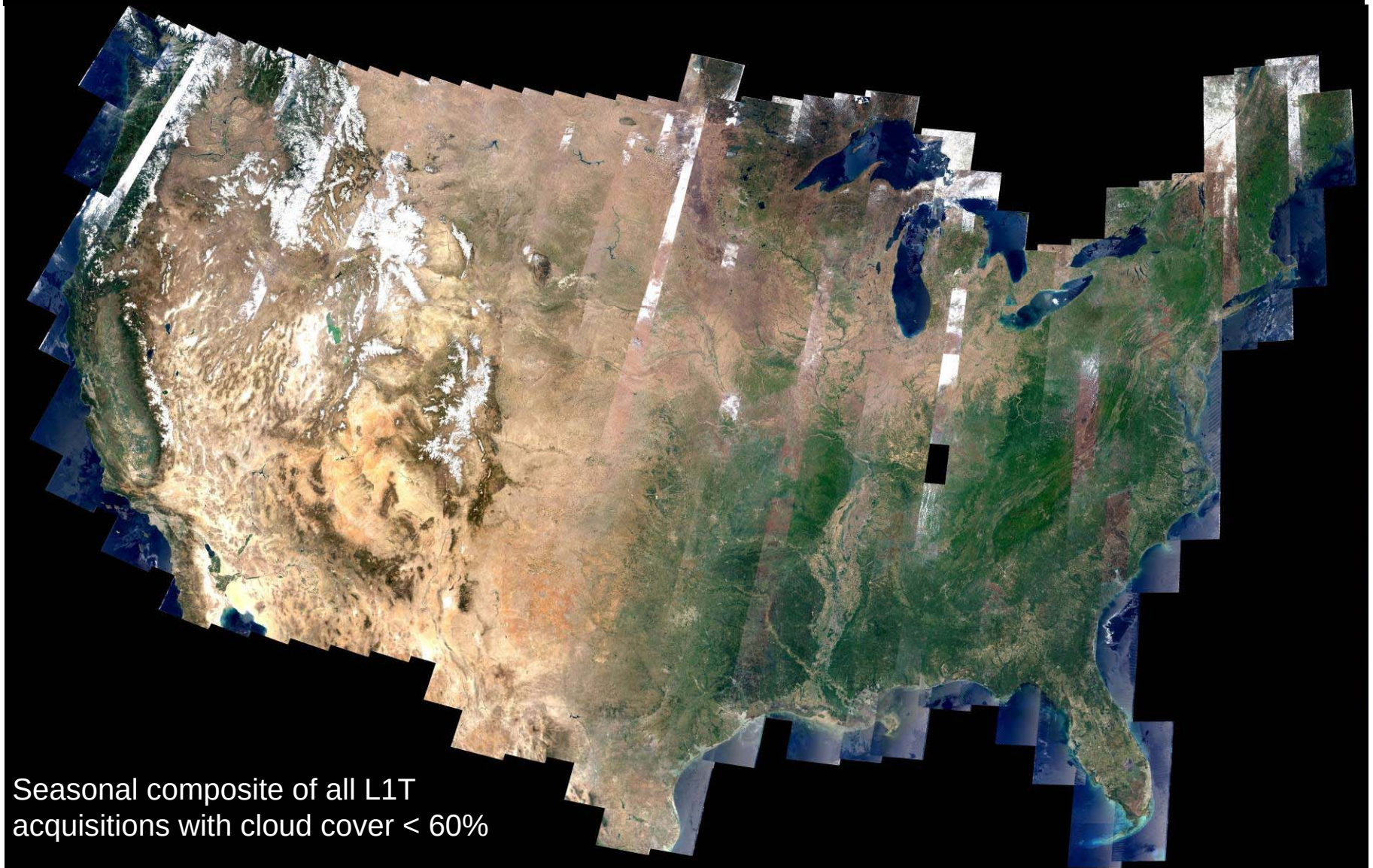
500m Browse (9706x6471 pixels)



Seasonal composite of all L1T acquisitions with cloud cover < 60%

Spring 2008 (March, April, May)

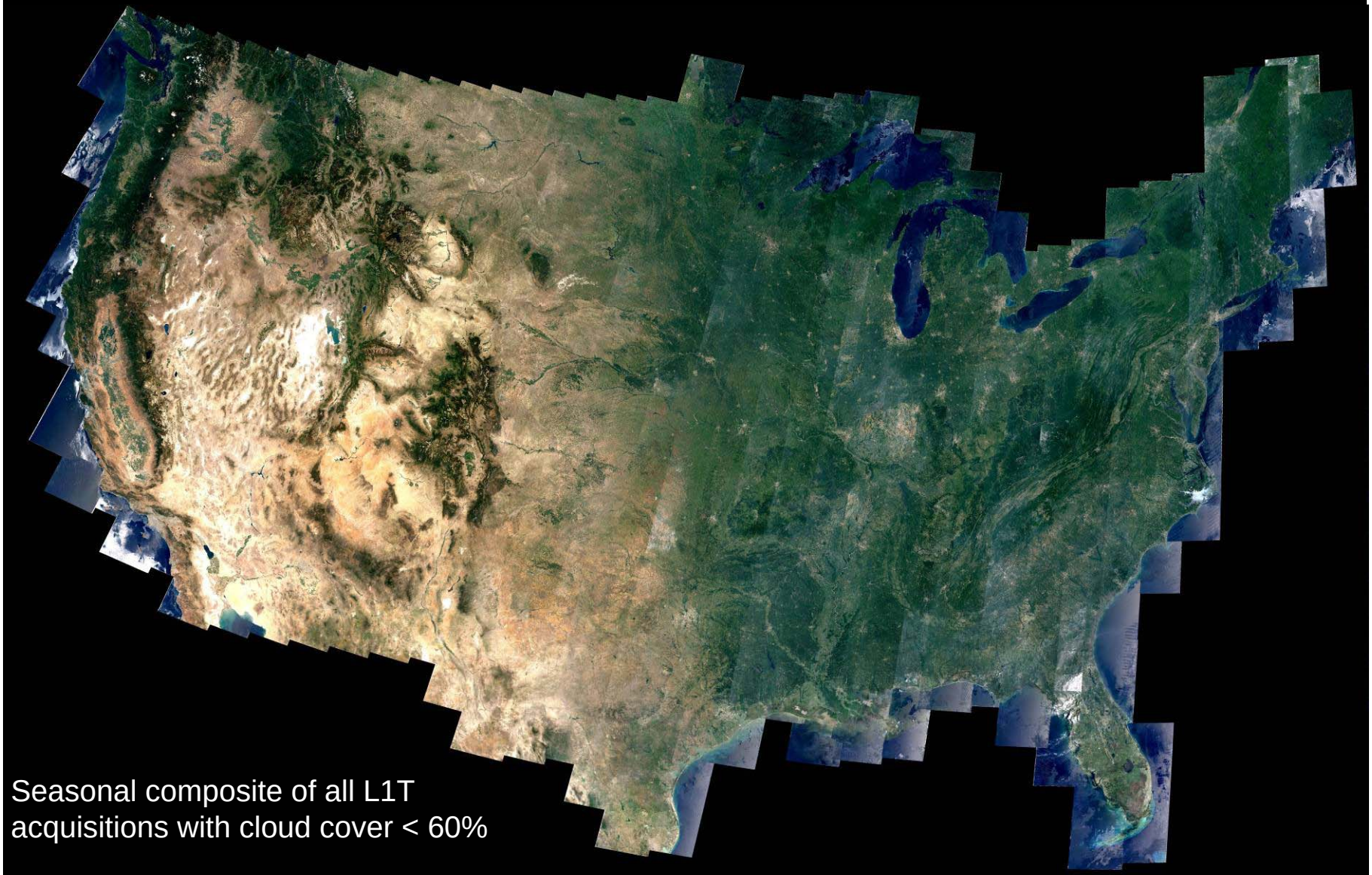
500m Browse (9706x6471 pixels)



Seasonal composite of all L1T
acquisitions with cloud cover < 60%

Summer 2008 (June, July, August)

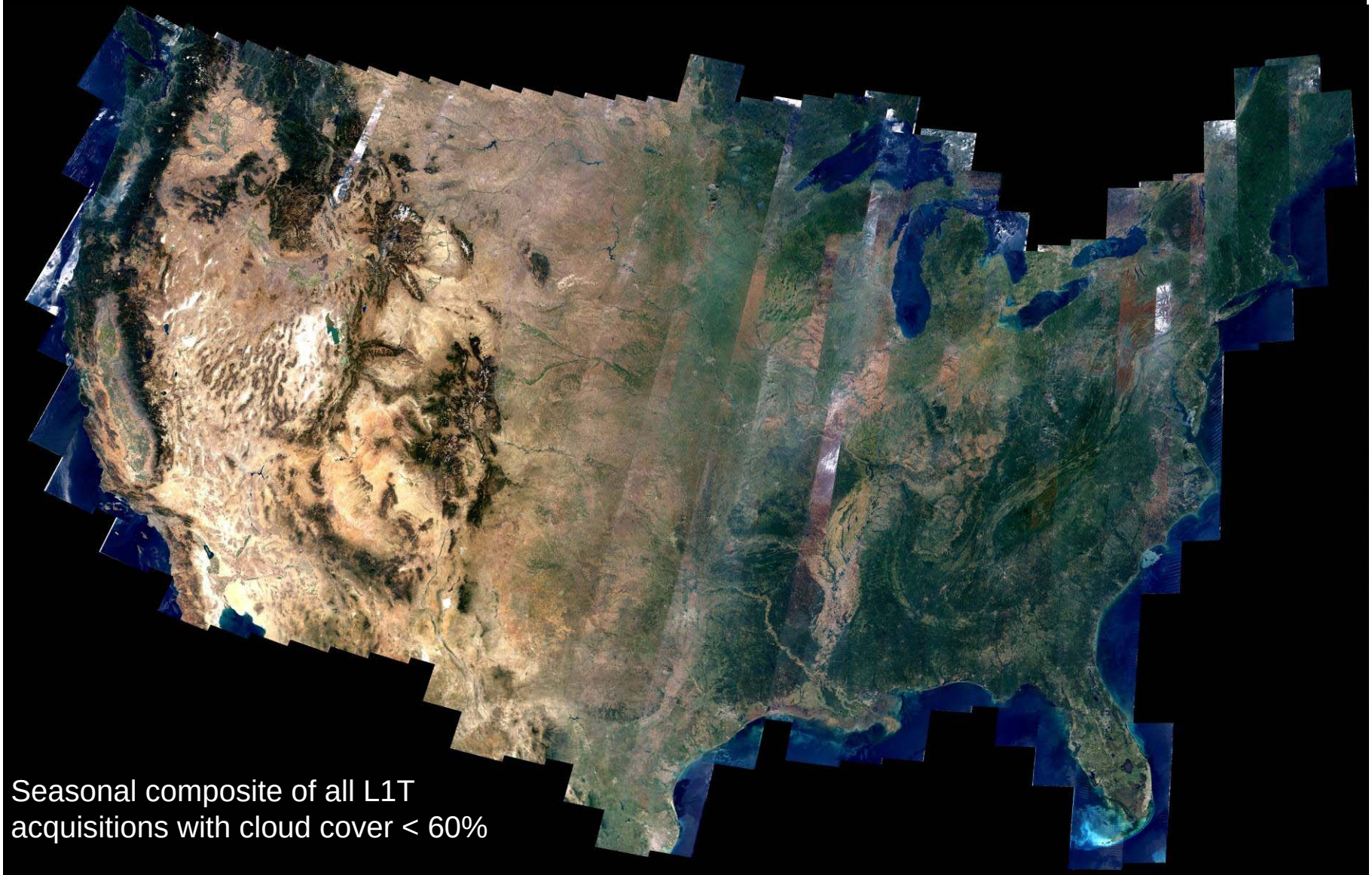
500m Browse (9706x6471 pixels)



Seasonal composite of all L1T
acquisitions with cloud cover < 60%

Autumn 2008 (Sept, Oct, Nov)

500m Browse (9706x6471 pixels)



Seasonal composite of all L1T
acquisitions with cloud cover < 60%

WELD ETM+ ARCHIVE at SDSU

as of September 17th 2009

	CONUS (459 path/row) <80% cloud	**Alaska** (232 path/row) <80% cloud
2007	5,572	453
2008	8,251	1,666
2009	5,104	1,267

WELD ETM+ ARCHIVE at SDSU

as of October 23rd 2009

	CONUS (459 path/row) <80% cloud	**Alaska** (232 path/row) <80% cloud
2007	5,641 + 69	495 + 42
2008	8,272 + 21	1,668 + 2
2009	5,706 + 602	1,374 + 107

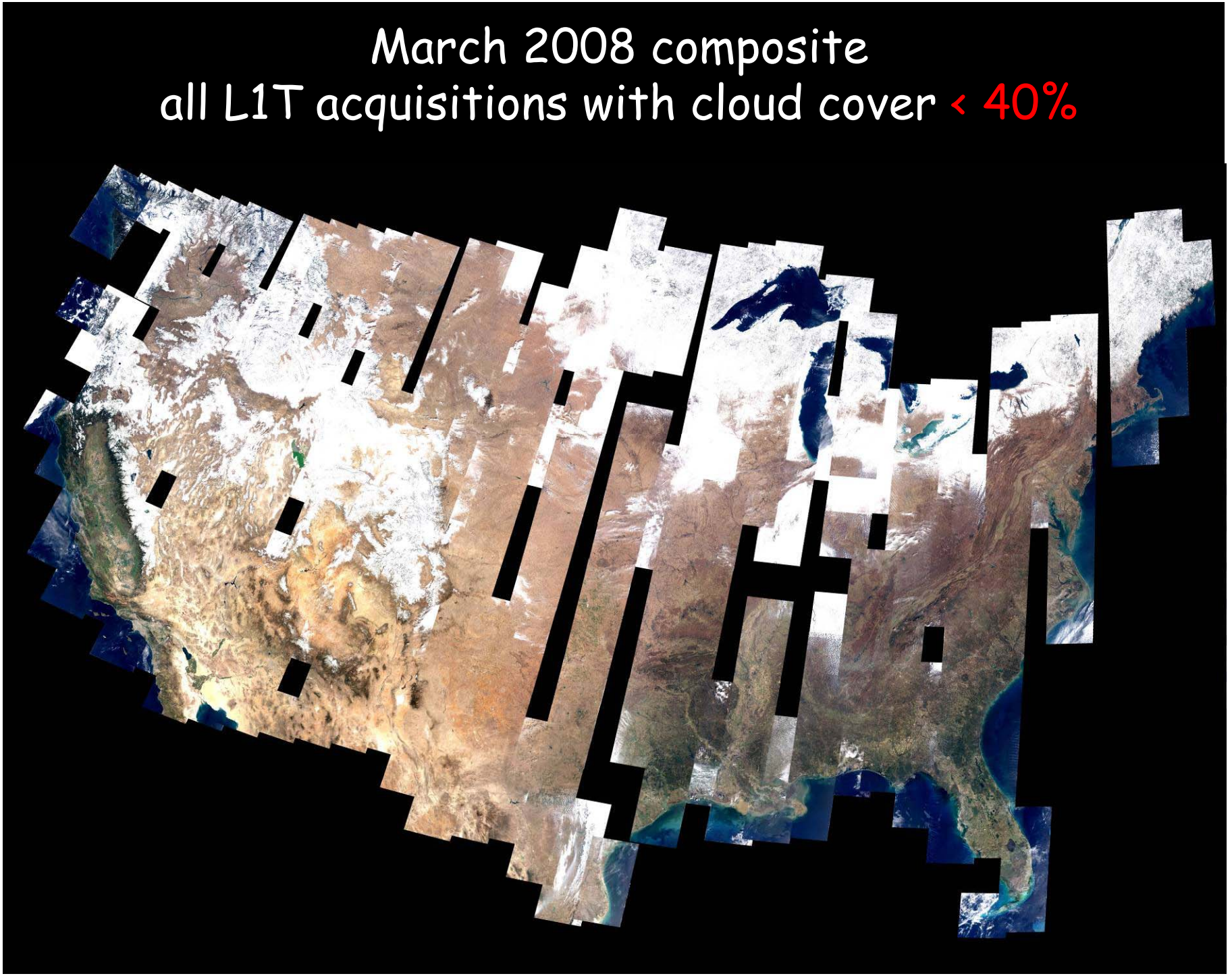
WELD ETM+ ARCHIVE at SDSU

as of October 23rd 2009

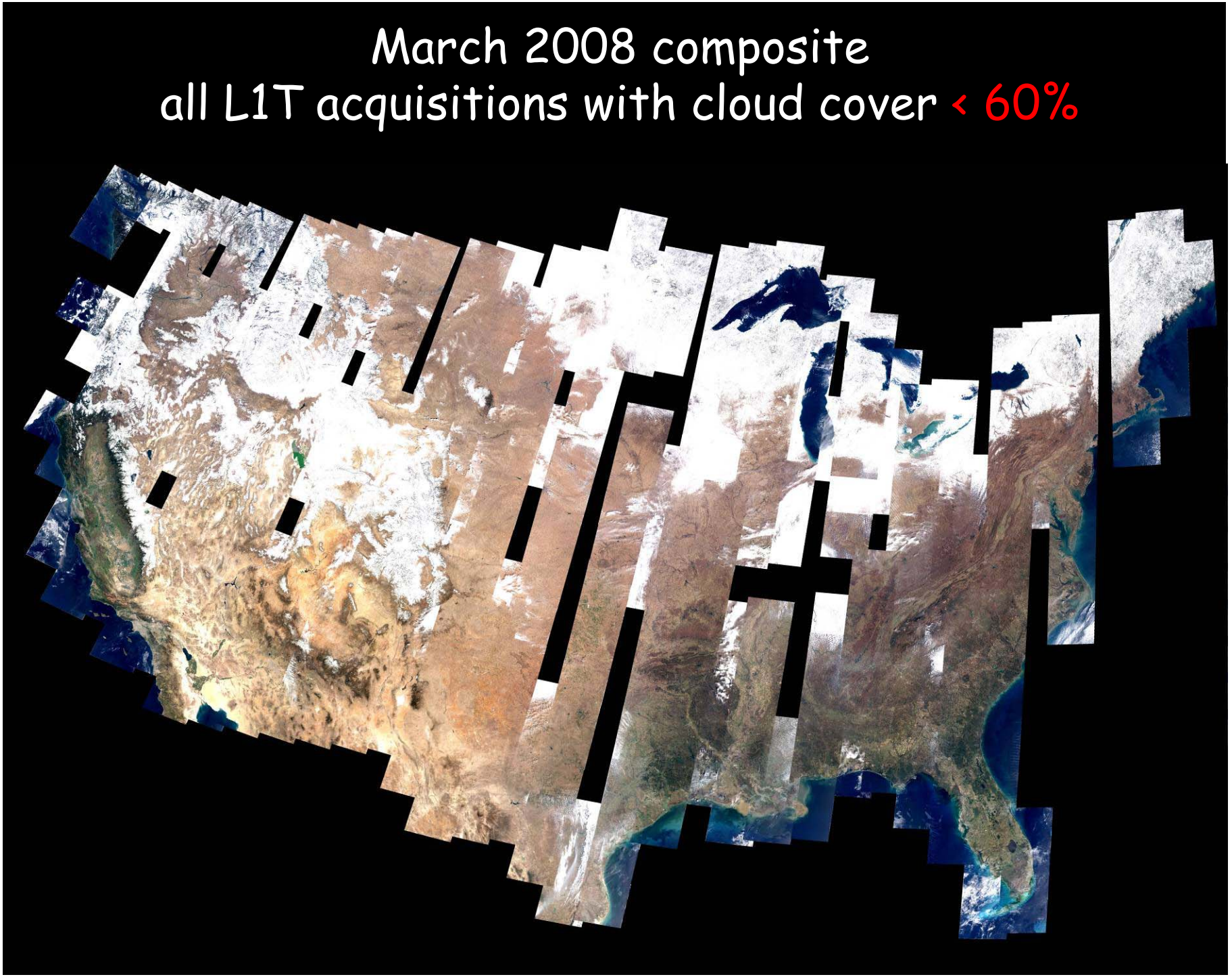
	CONUS (459 path/row) <80% cloud	**Alaska** (232 path/row) <80% cloud	**Africa** (1300 path/row but LTAP not every) <40% cloud
2007	5,641	495	0
2008	8,272	1,668	9,972
2009	5,706	1,374	8,482

Total 41,610 acquisitions [$25 million at $600/acquisition]

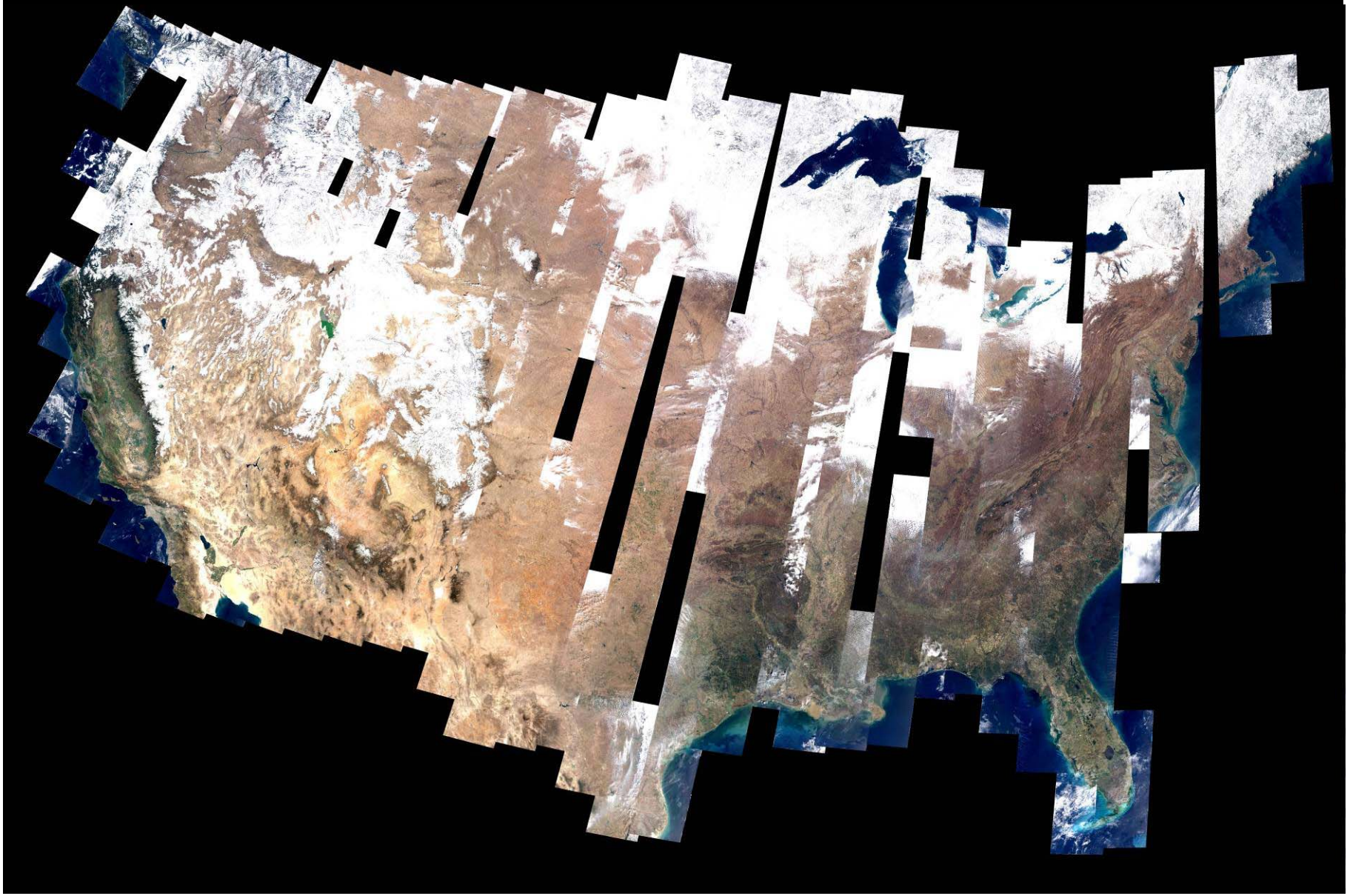
March 2008 composite
all L1T acquisitions with cloud cover < 40%



March 2008 composite
all L1T acquisitions with cloud cover < 60%



March 2008 composite
all L1T acquisitions with cloud cover < 80%

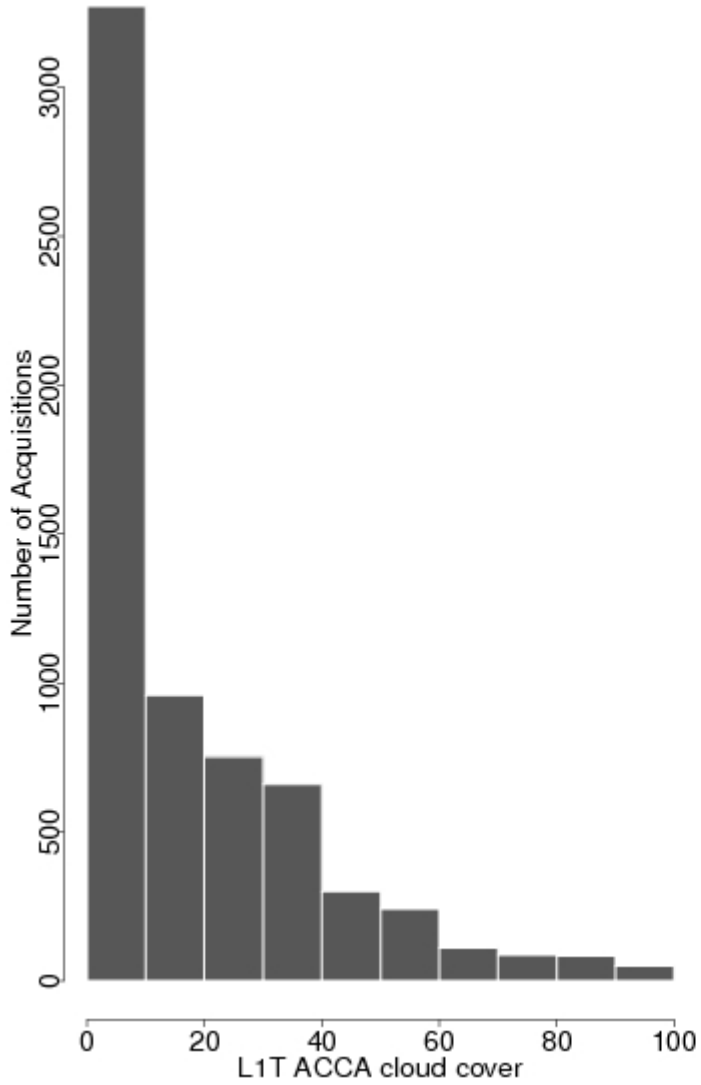


Typically for a year of

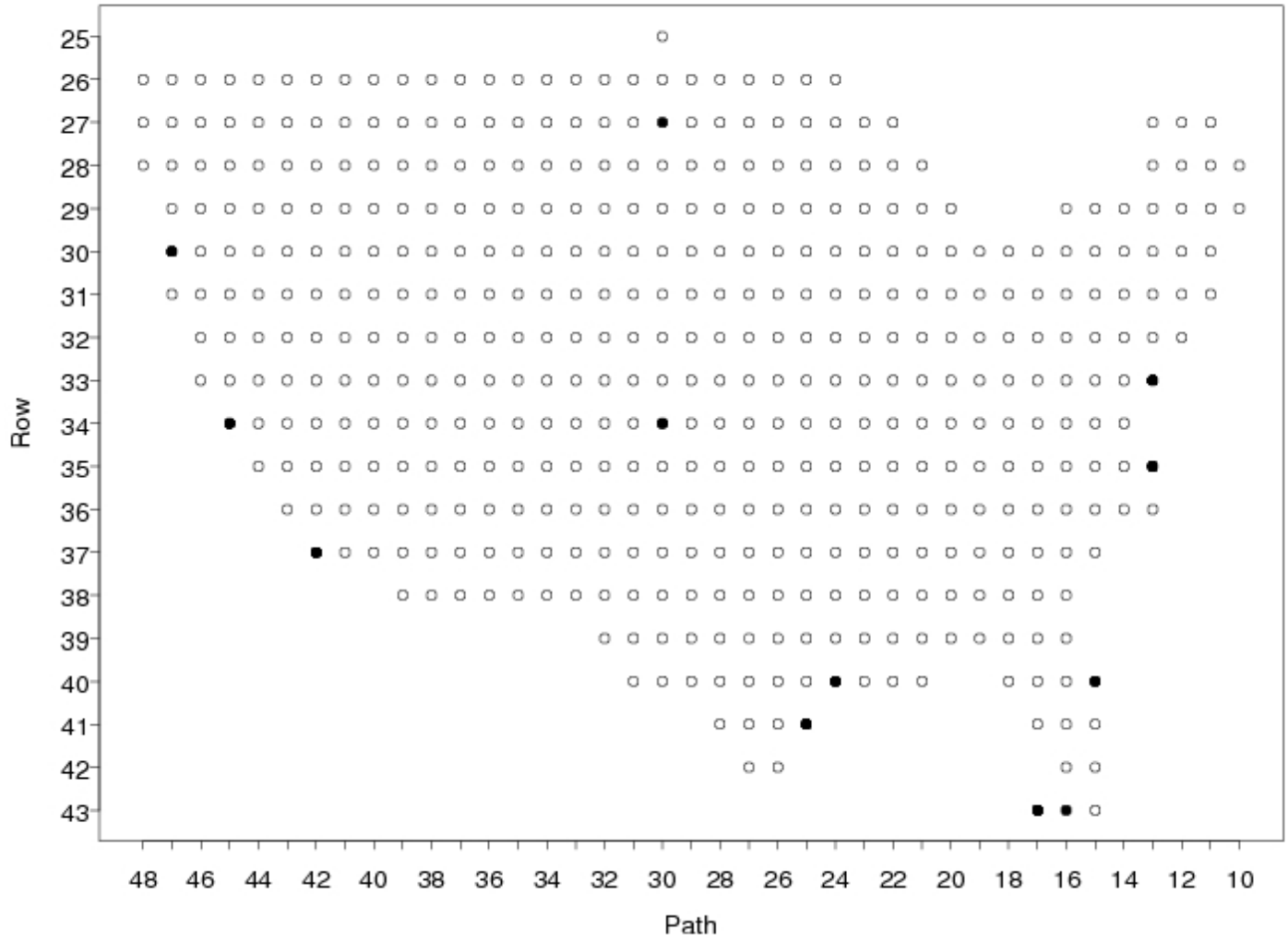
CONUS data ~5% could not be processed as L1T

Alaska data ~40% could not be processed as L1T

these are processed and made available as L1G; we reject these

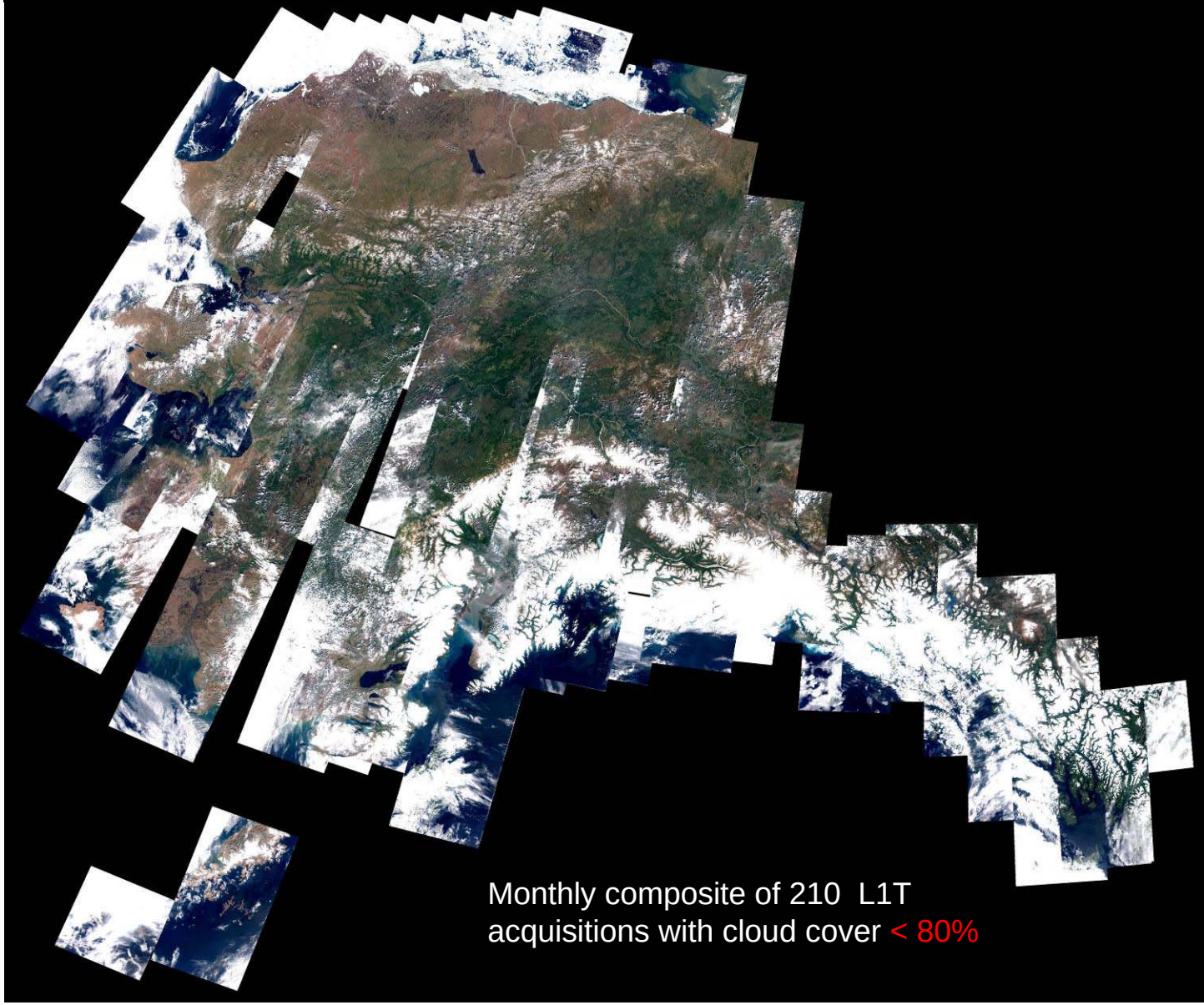


Black filled circles show path/row where web-enabled ETM+ acquisitions over a year had <20% ACCA cloud cover BUT were processed as L1G not L1T



June 2008

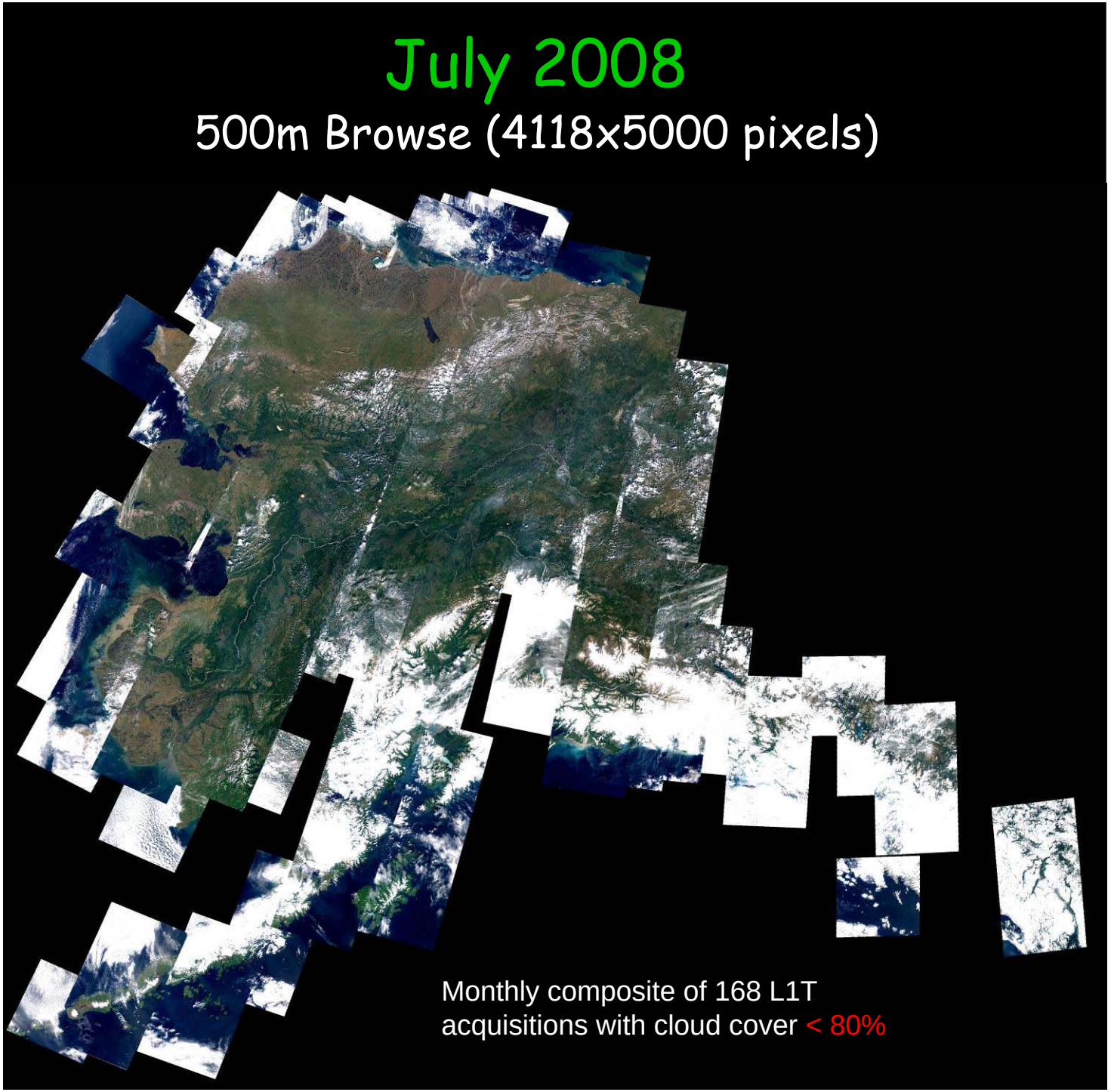
500m Browse (4118x5000 pixels)



Monthly composite of 210 L1T
acquisitions with cloud cover < 80%

July 2008

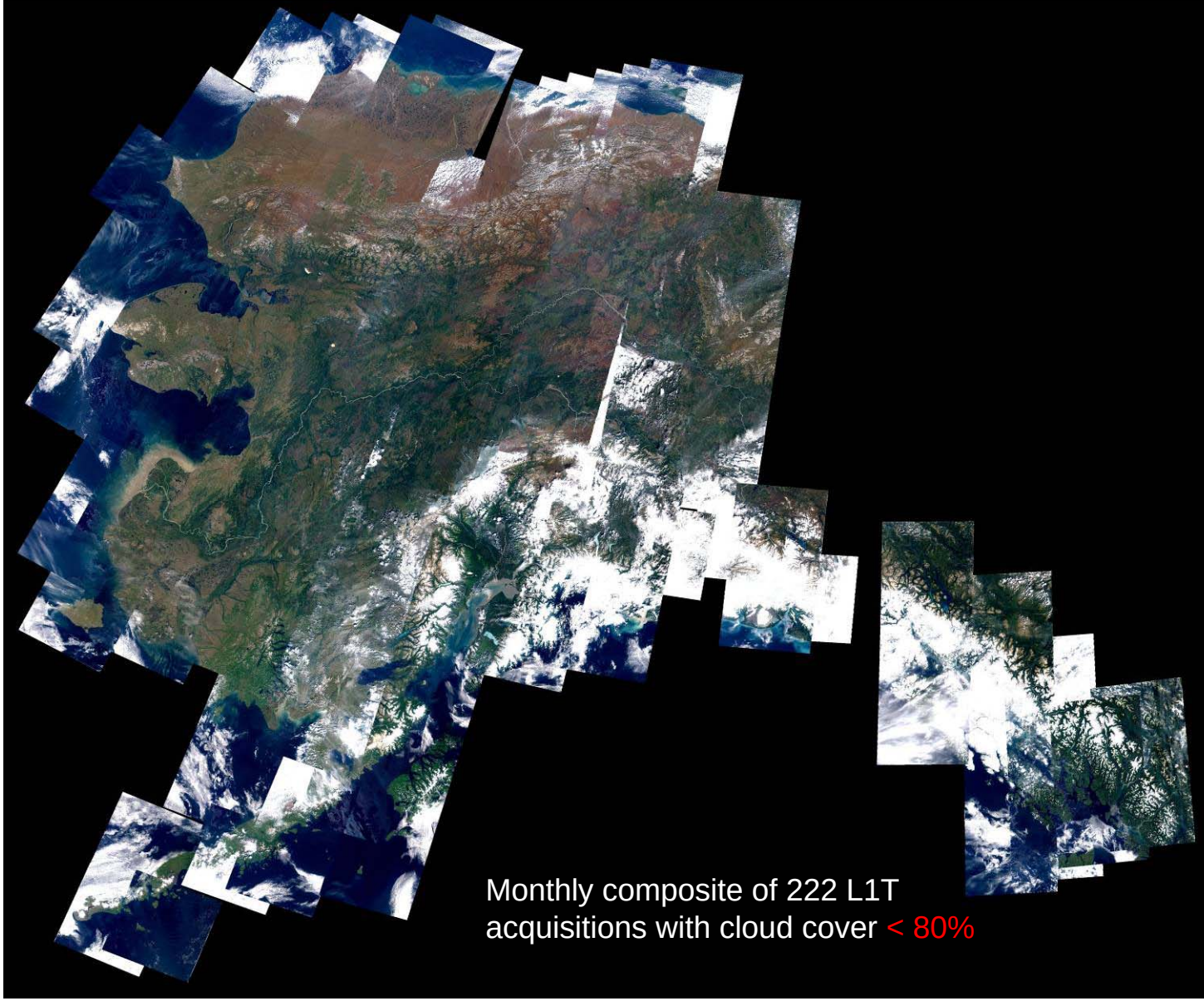
500m Browse (4118x5000 pixels)



Monthly composite of 168 L1T
acquisitions with cloud cover < 80%

August 2008

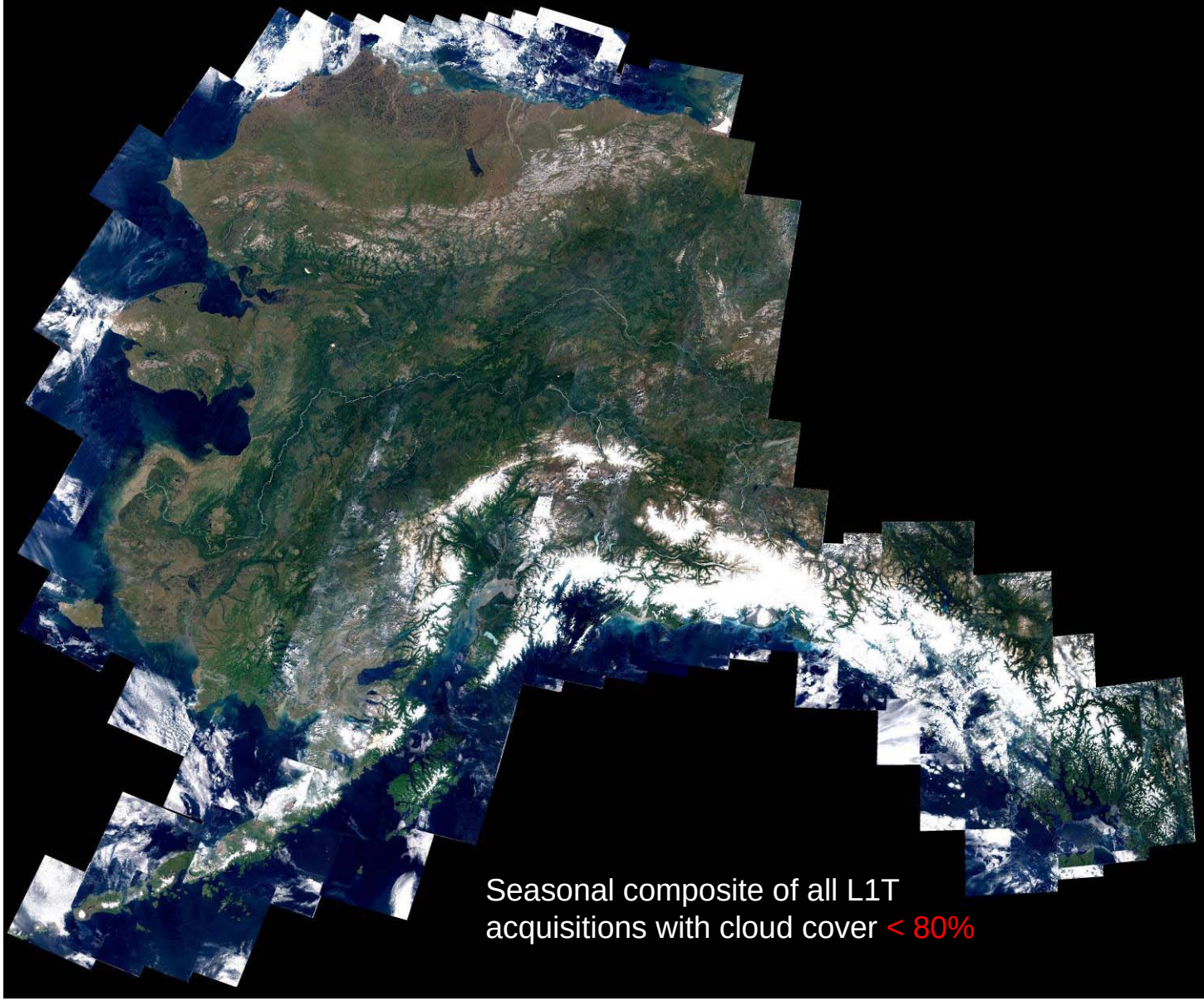
500m Browse (4118x5000 pixels)



Monthly composite of 222 L1T
acquisitions with cloud cover < 80%

Summer 2008 (June, July, August)

500m Browse (4118x5000 pixels)

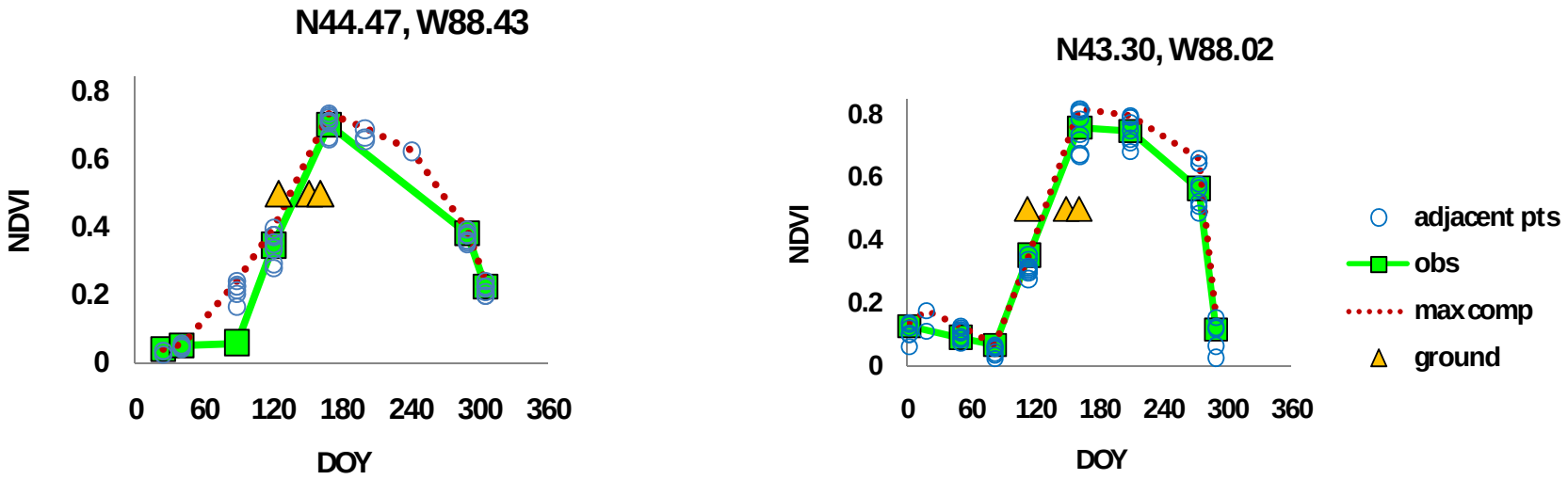


Seasonal composite of all L1T
acquisitions with cloud cover < 80%

Stable Radiometry

US Phenology Network Example:

Lilac ground data bounds the rapid increase in WELD NDVI



Orange triangles show the 3 phenophases of lilac in chronological order:

95% leaf out -> full bloom -> last bloom

(Geoff Henebry)

WELD ETM+ Data Processing Steps

- TOA reflectance & brightness temperature
- View and Solar Geometry Computation
- Cloud mask
- SLC-Off and cloud gap filling
- Reprojection: UTM to Albers map projection
- Compositing: monthly, seasonal, annual
- Atmospheric correction
- Radiometric/BRDF normalization
- Land cover characterization
- Browse generation

WELD ETM+ Data Processing Steps

Steps that use contemporaneous MODIS Products

- TOA reflectance & brightness temperature
- View and Solar Geometry Computation
- Cloud mask
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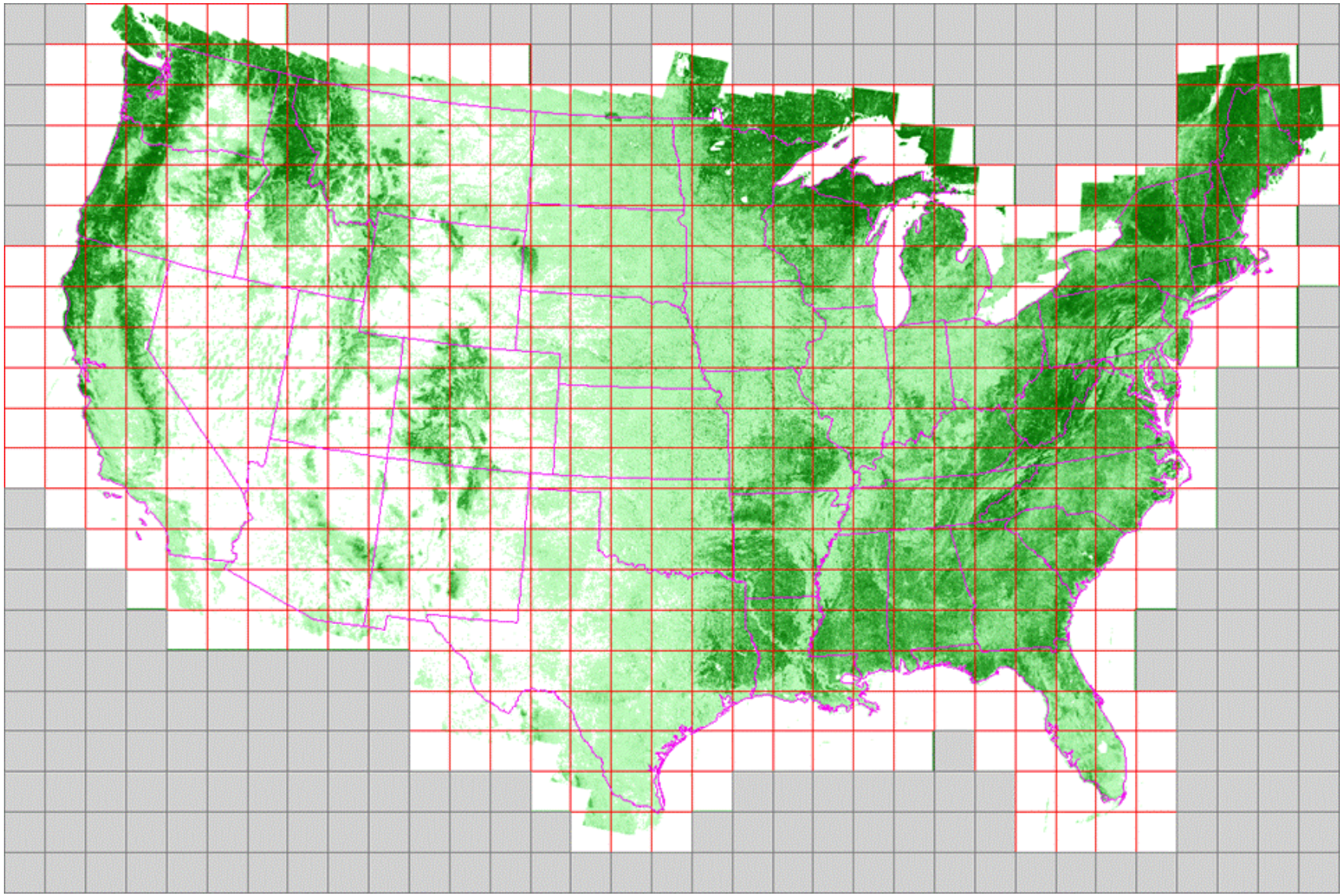
WELD 30m Land cover characterization

Annual

- % Tree
- % Herbaceous
- % Water
- % Bare Ground
- % Snow / Ice

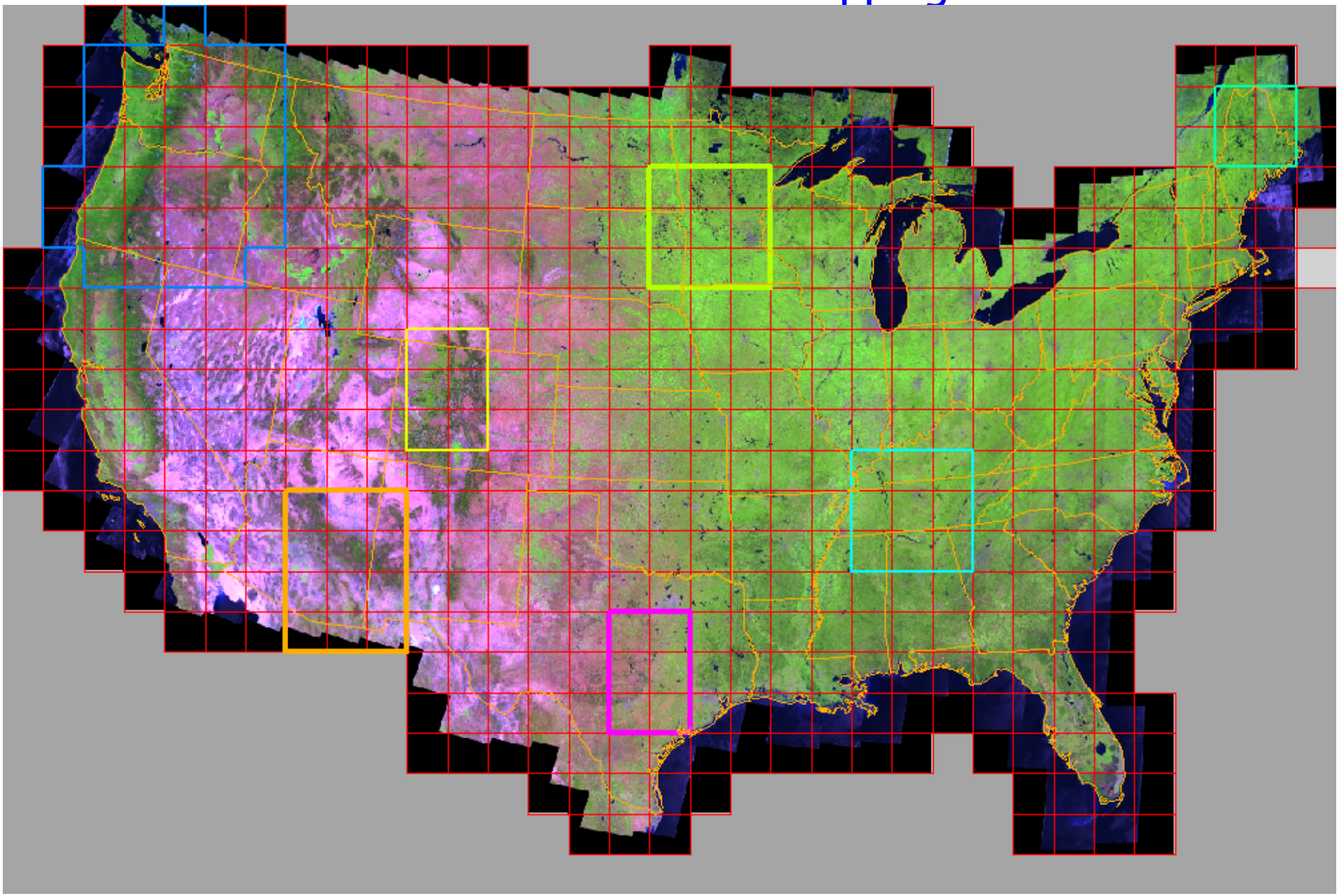
- Initial testing
  - MODIS VCF forest/non-forest training data
  - Metrics derived from
    - annual, summer, fall WELD composites
  - create a forest probability map (*not a %Tree cover map*)
  - demonstrates the use of a single algorithm for mapping CONUS forest cover with WELD inputs.

CONUS 30m WELD Forest Probability classification

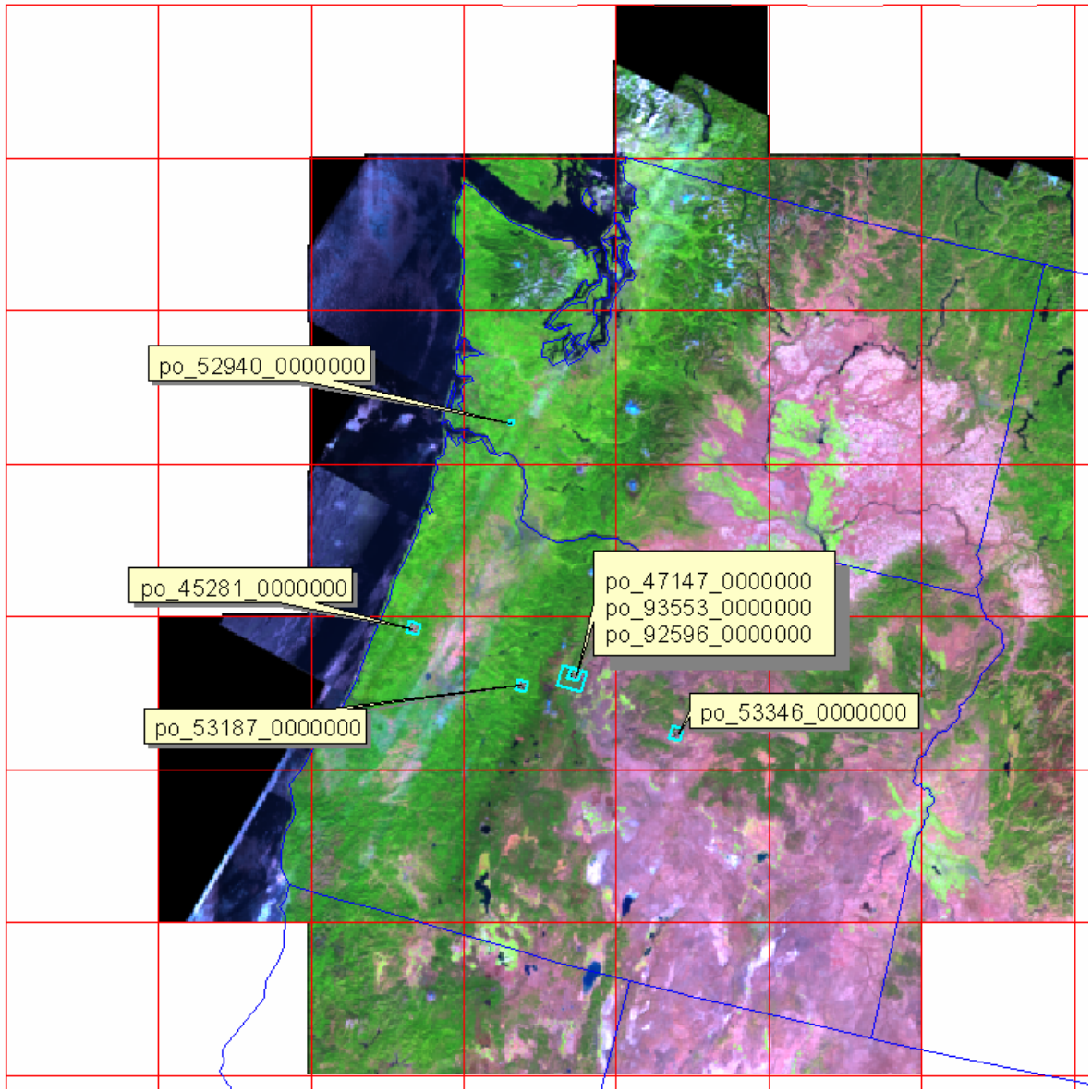


(Alexy Egorov & Matt Hansen)

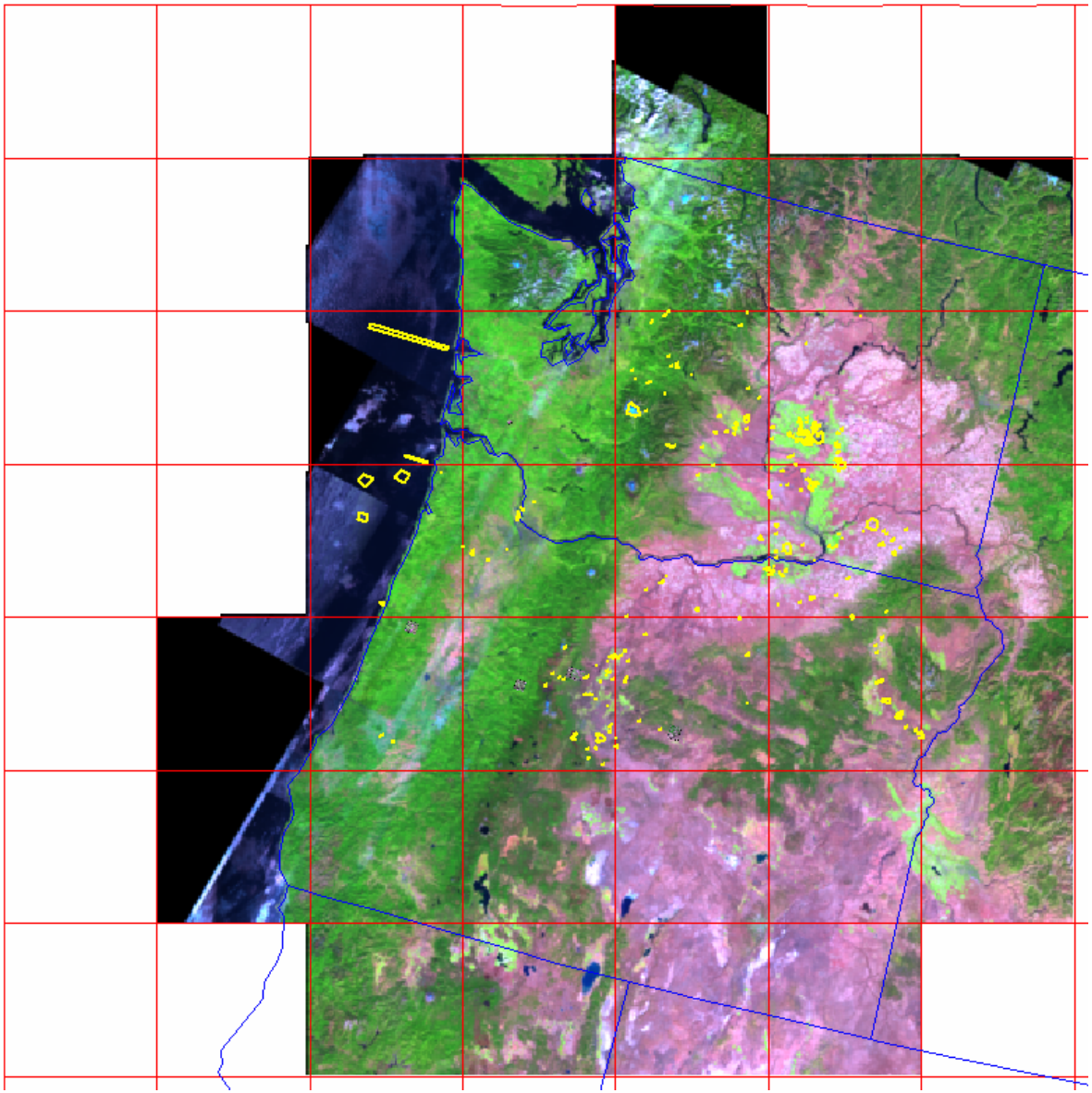
Different parts of US, selected as test areas for %Tree Cover mapping



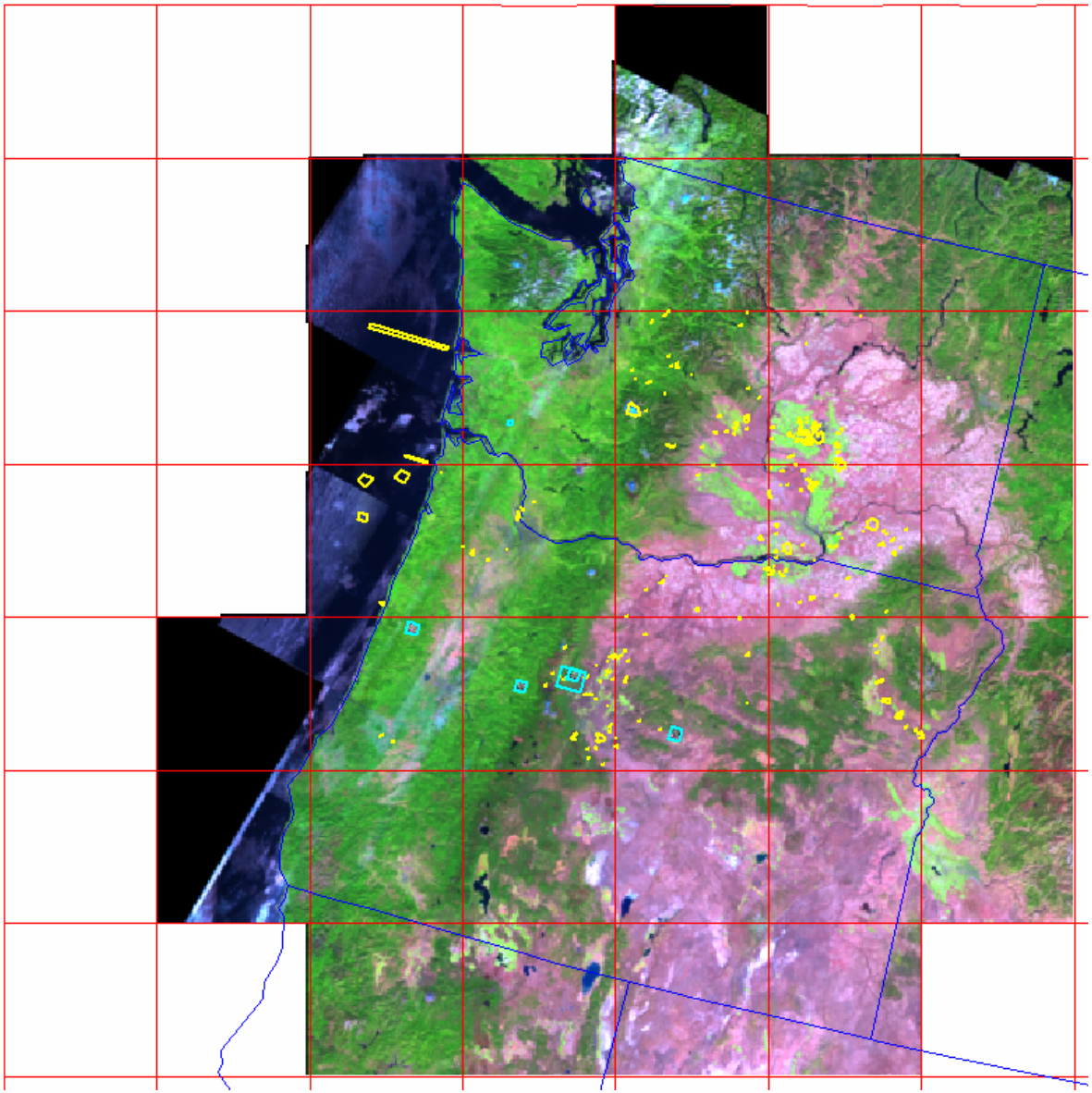
7 Ikonos scenes are used for creating training



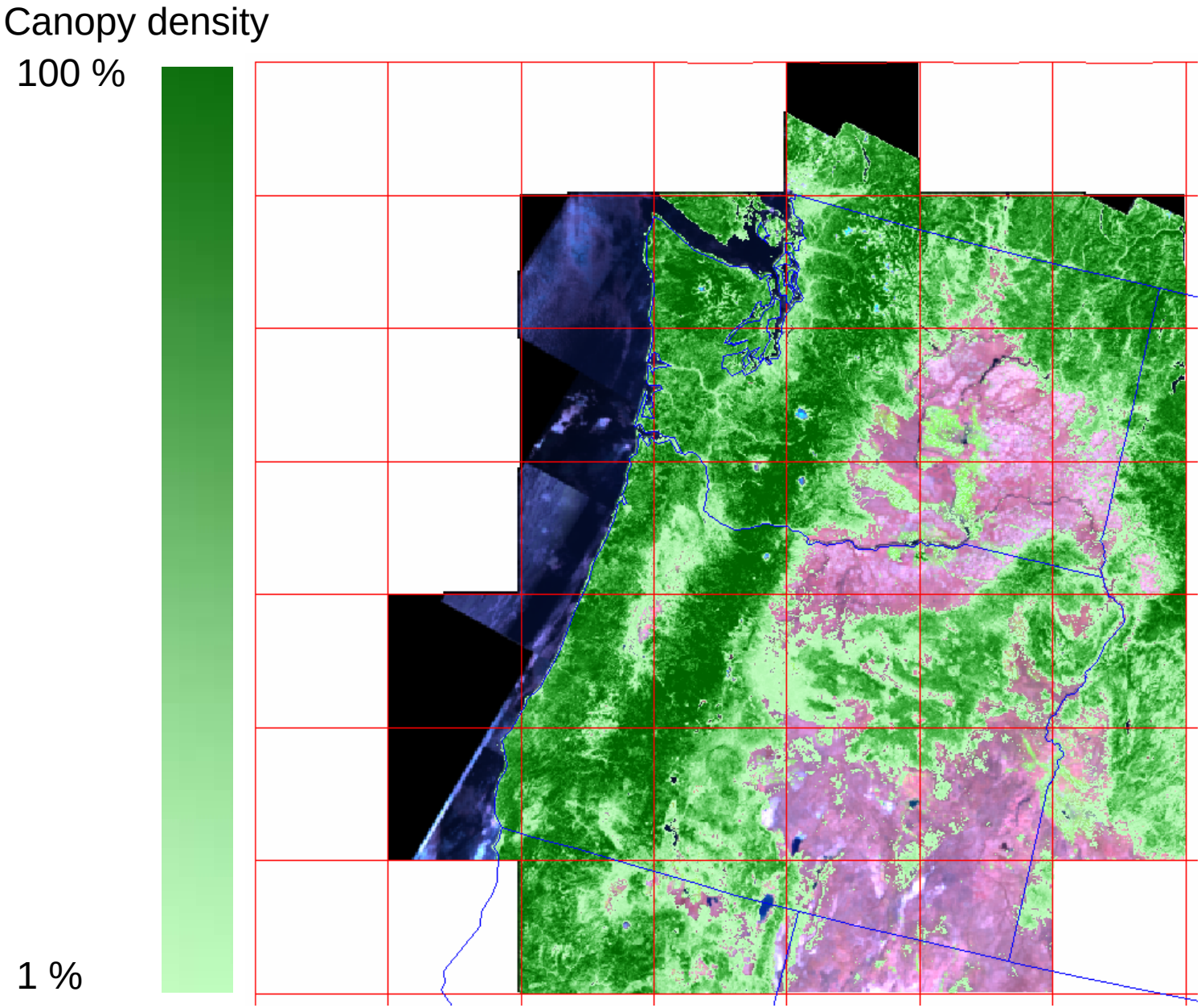
500 polygons acquired from Google Earth also used



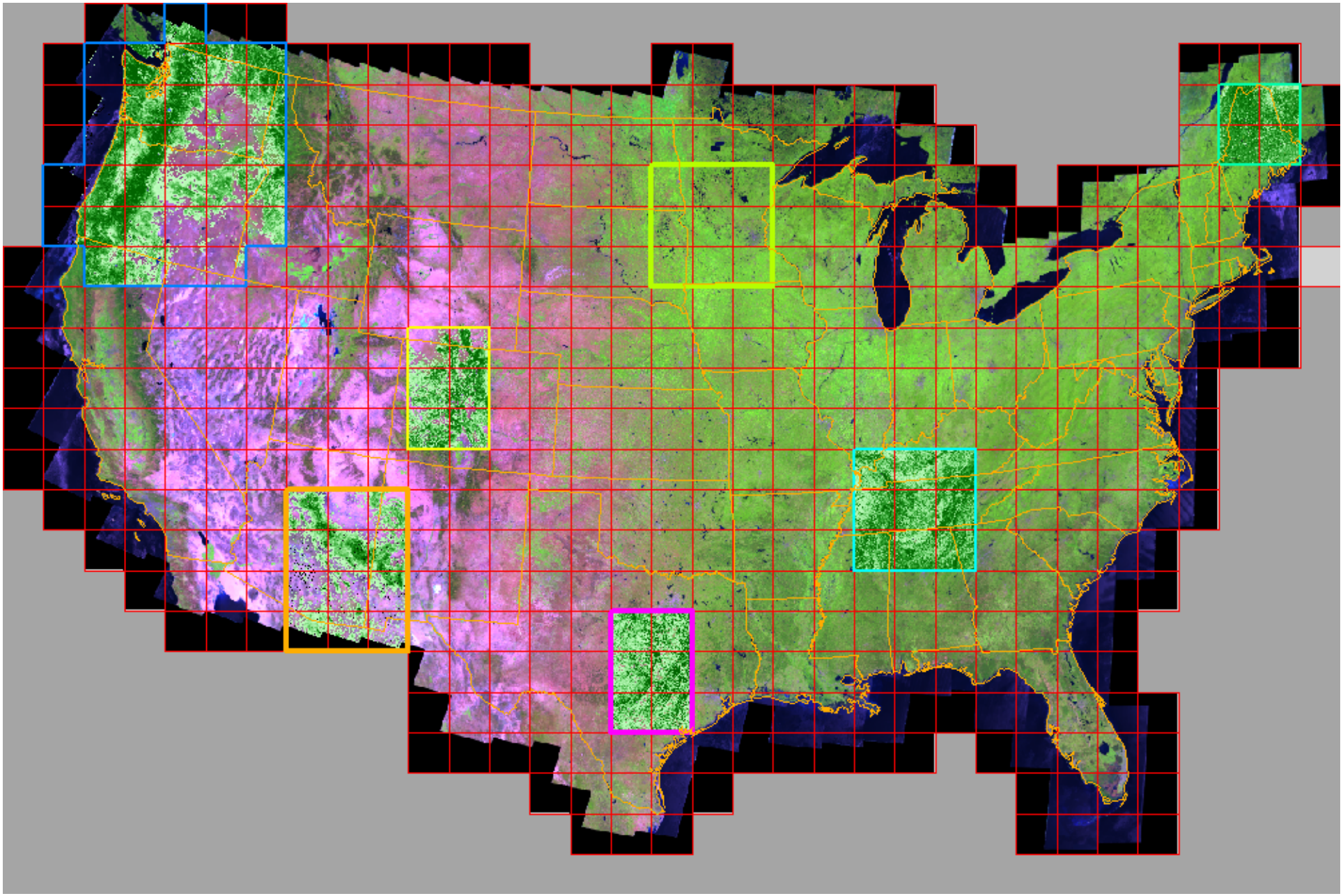
Regression tree generated using 2,084,883 pixels



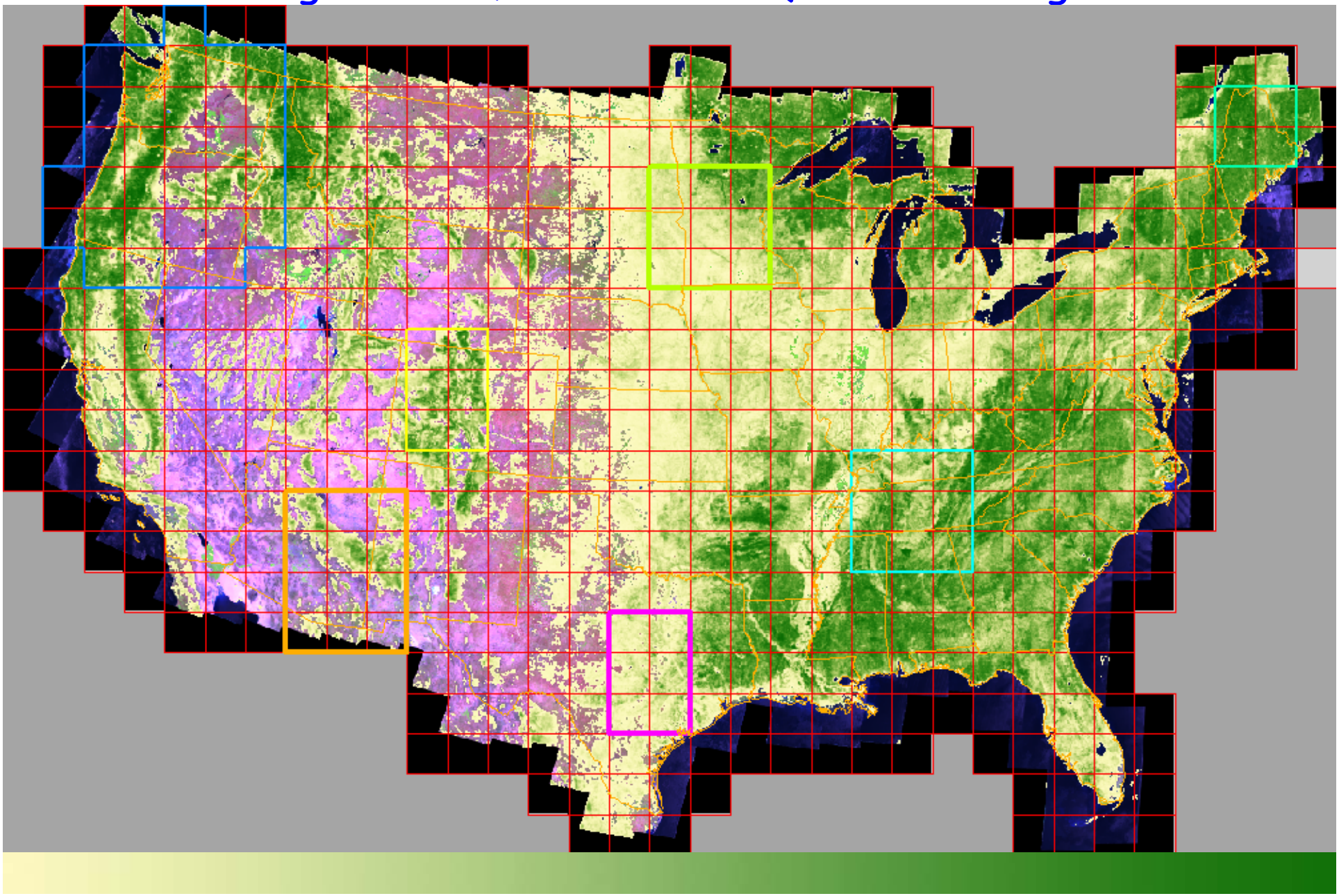
Percent Tree Cover Classification result based on Ikonos and Google Earth training



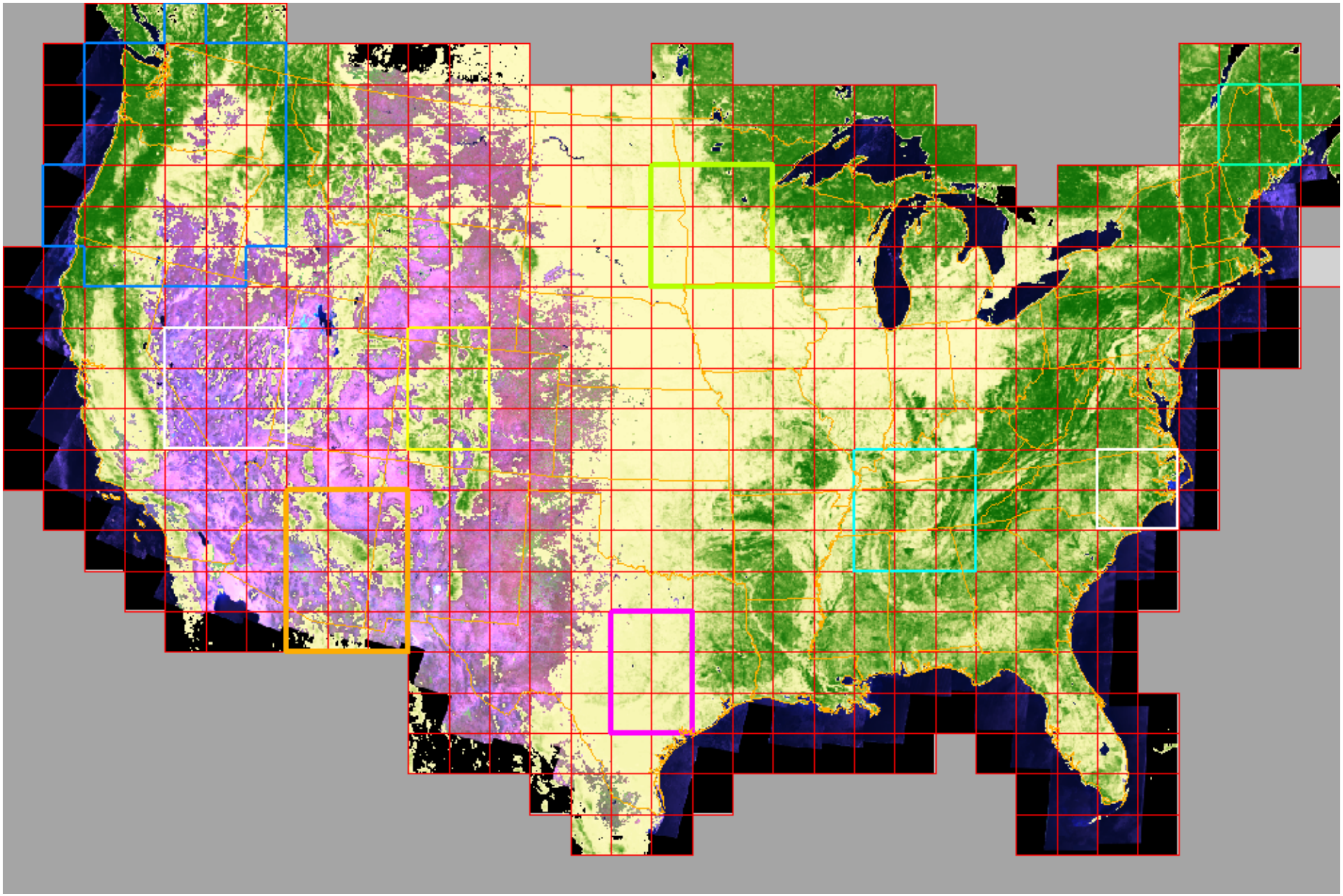
Test areas and %Tree classification results



Preliminary %Tree classification with training derived from Google Earth, Ikonos and QuickBird images



MODIS VCF 500 meters per pixel with same palette.



WELD ETM+ Data Processing Steps

Focus of this Talk, Some new Provisional Results

- TOA reflectance & brightness temperature
- View and Solar Geometry Computation
- Cloud mask
- SLC-Off and cloud gap filling
- Reprojection: UTM to Albers map projection
- Compositing: monthly, seasonal, annual
- Atmospheric correction
- Radiometric/BRDF normalization
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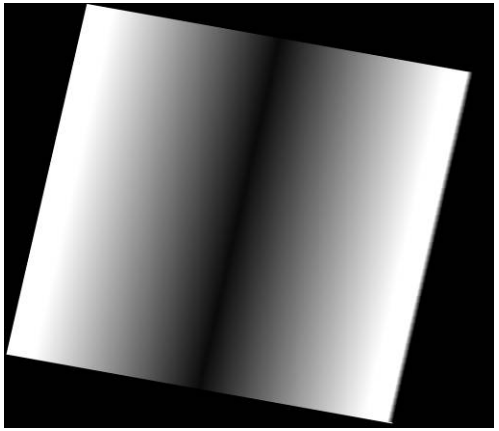
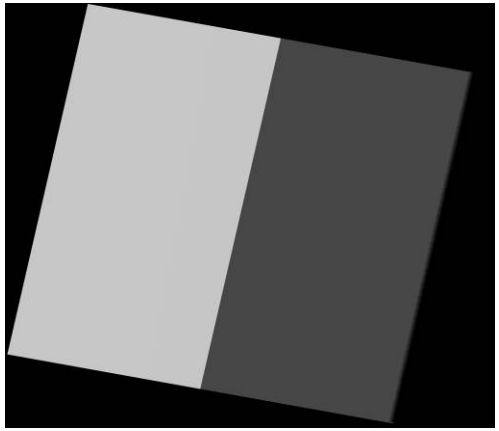
Example viewing and solar geometry, computed for each L1T pixel

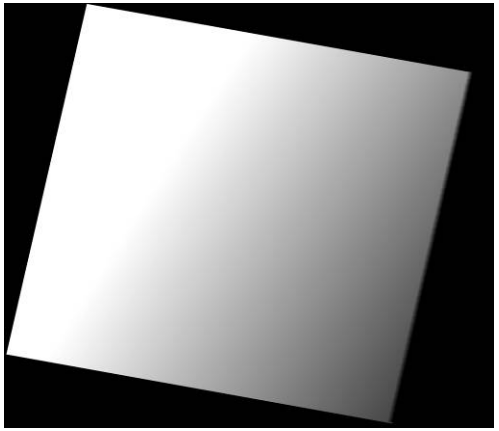
The Landsat ETM+ L1T metadata carries no view vector data and only the solar geometry and time of acquisition at the acquisition centre



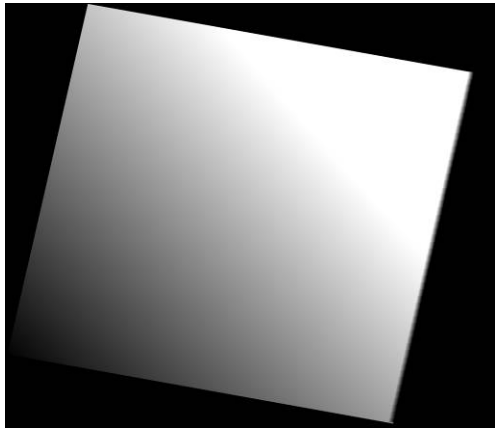
Sensor zenith



Sensor azimuth



Solar zenith



Solar azimuth

Uses the L1T pixel coordinates of ETM+ band 4 (which lies closest to the focal plane center with a known pixel offset), models the Landsat “bumper” scanning geometry, assumes a constant altitude.

Landsat SLC-off and cloud Gap Filling

The MODIS 16-day 500m BRDF/Albedo product includes spectral BRDF model parameters that may be used to compute the directional MODIS reflectance at any desired view or solar angle.

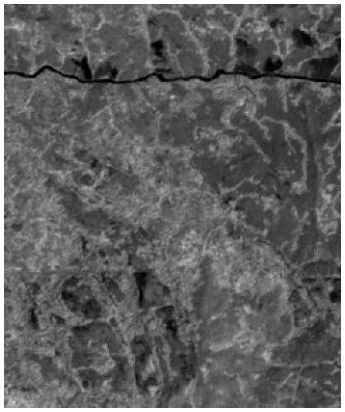
Assume that a MODIS 500m scaling factor *c* is representative of the reflectance variation at 30m ETM+ scale for spectrally similar wavelengths.

Landsat reflectance at *t2* predicted from a Landsat observation at *t1 as*:

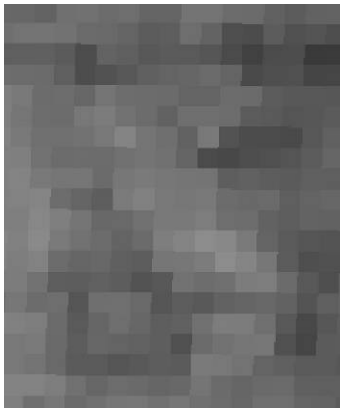
$$\hat{\rho}_{ETM+,t2}\left(\lambda_{ETM+},\Omega_{new},\Omega'_{new}\right) = c \times \rho_{ETM+,t1}\left(\lambda_{ETM+},\Omega_{observed},\Omega'_{observed}\right)$$

$$c = \frac{\hat{\rho}_{MODIS,t2}\left(\lambda_{MODIS},\Omega_{new},\Omega'_{new}\right)}{\hat{\rho}_{MODIS,t1}\left(\lambda_{MODIS},\Omega_{observed},\Omega'_{observed}\right)}$$

Thus, Landsat reflectance may be predicted on the same, an antecedent, or, subsequent Landsat acquisition date.

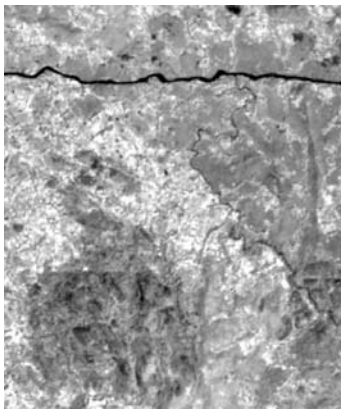


ETM+ observed Jan 9 ρ

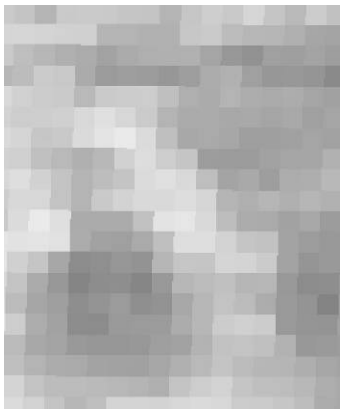


MODIS predicted Jan 9 ρ

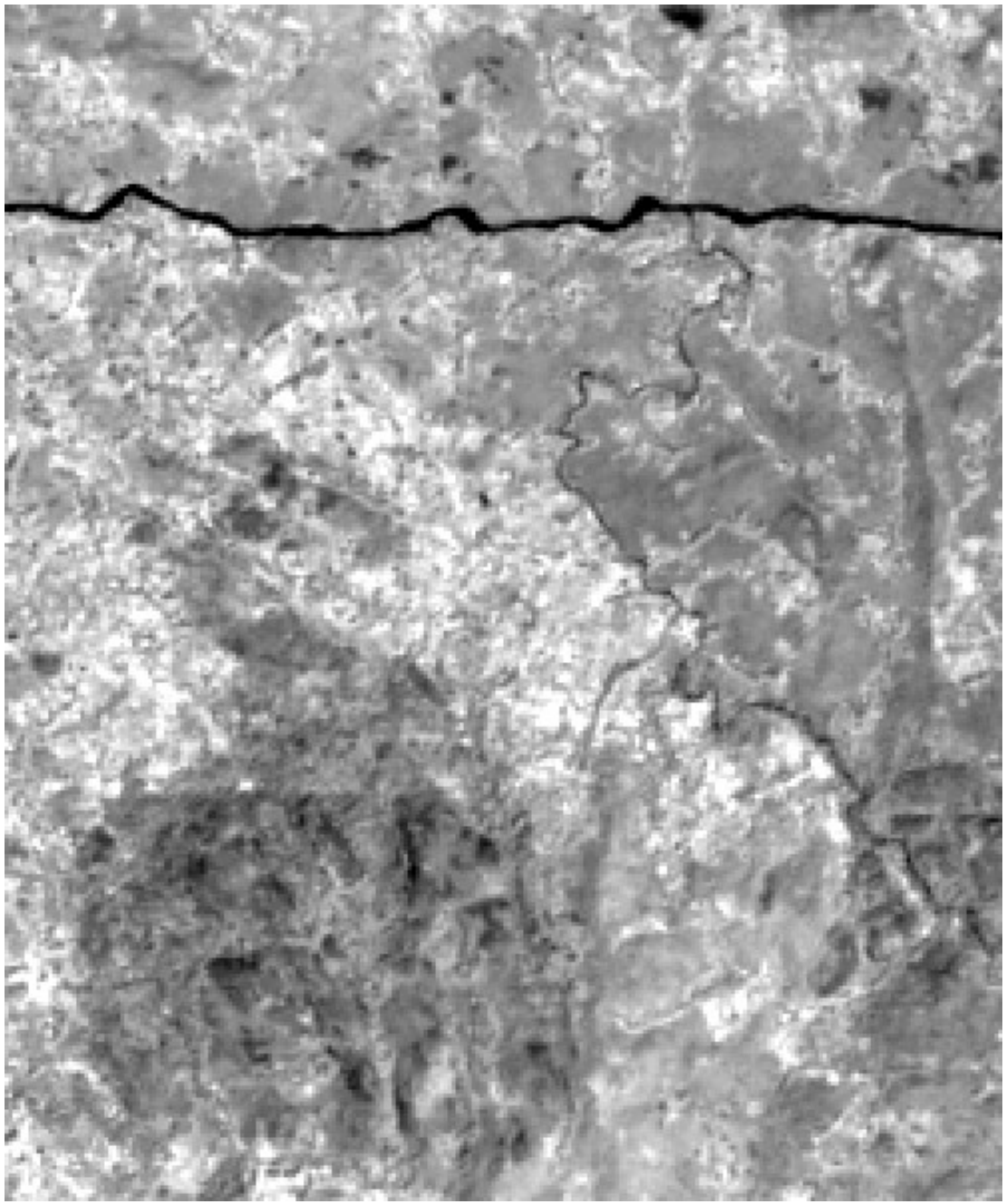
Illustrative near-infrared (NIR) ETM+ reflectance prediction for a 7.5km x 9km subset of Congo scene (shown with same contrast stretch)



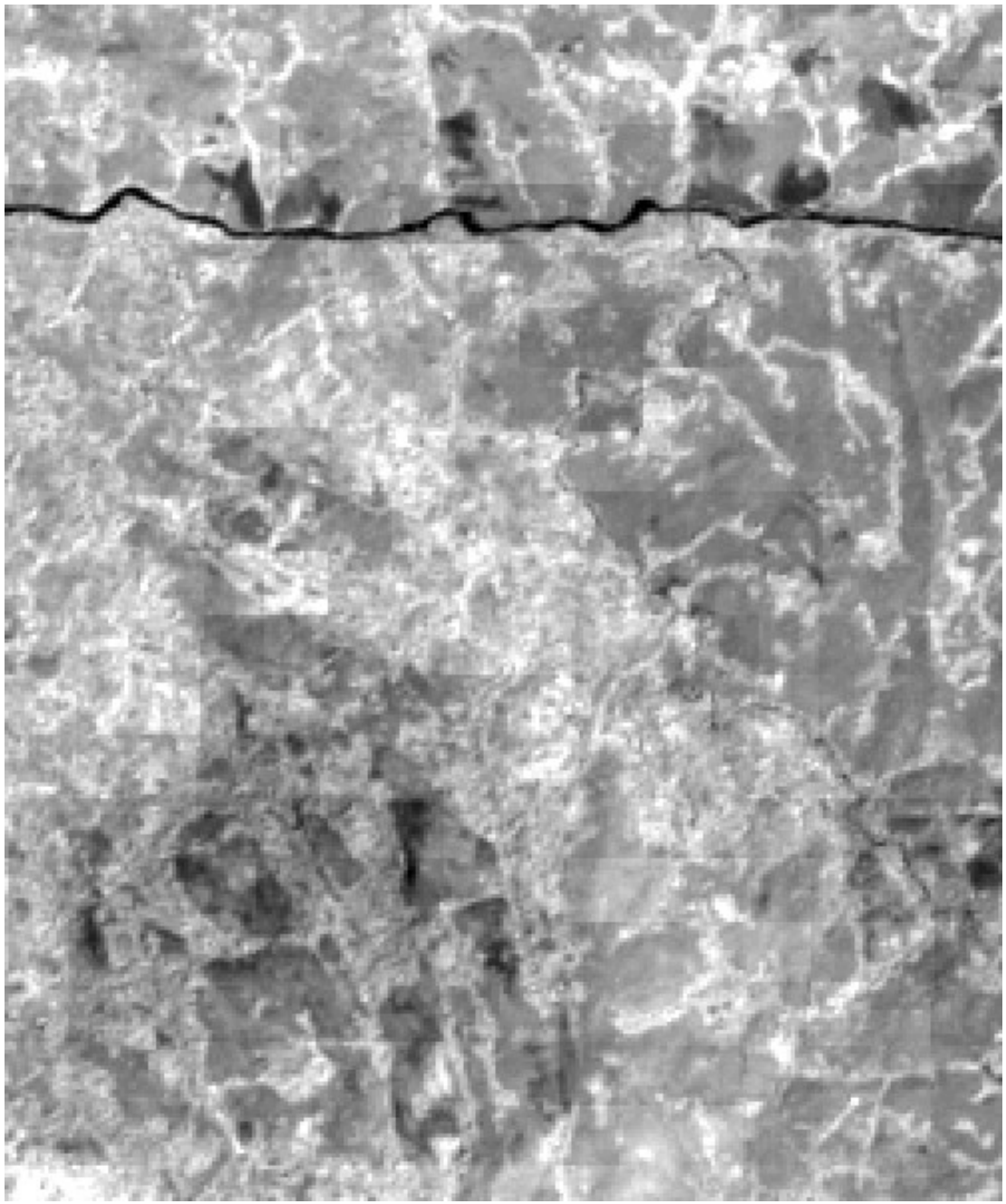
ETM+ observed Nov 25 ρ



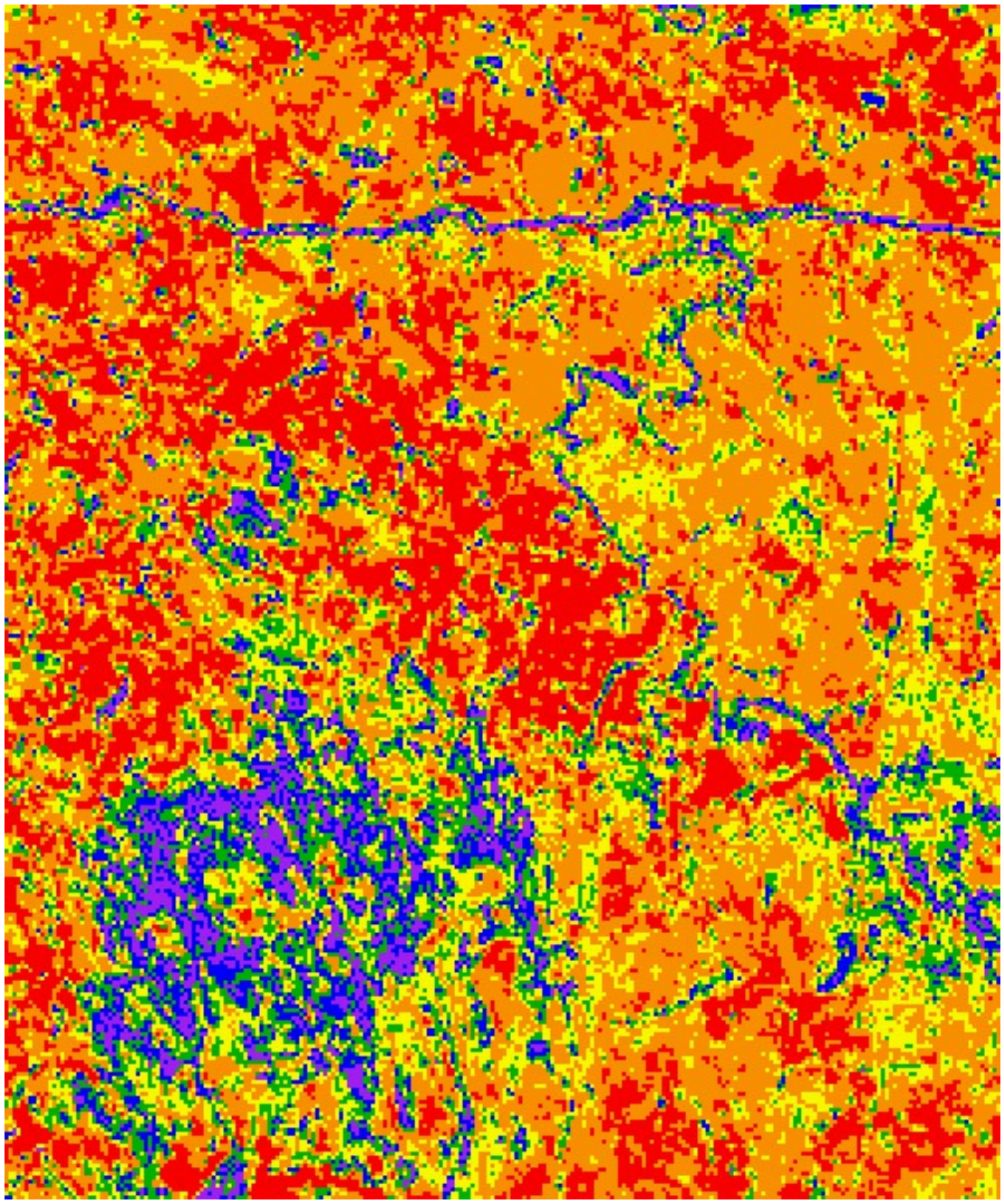
MODIS predicted Nov 25 ρ



ETM+ observed November 25 ρ



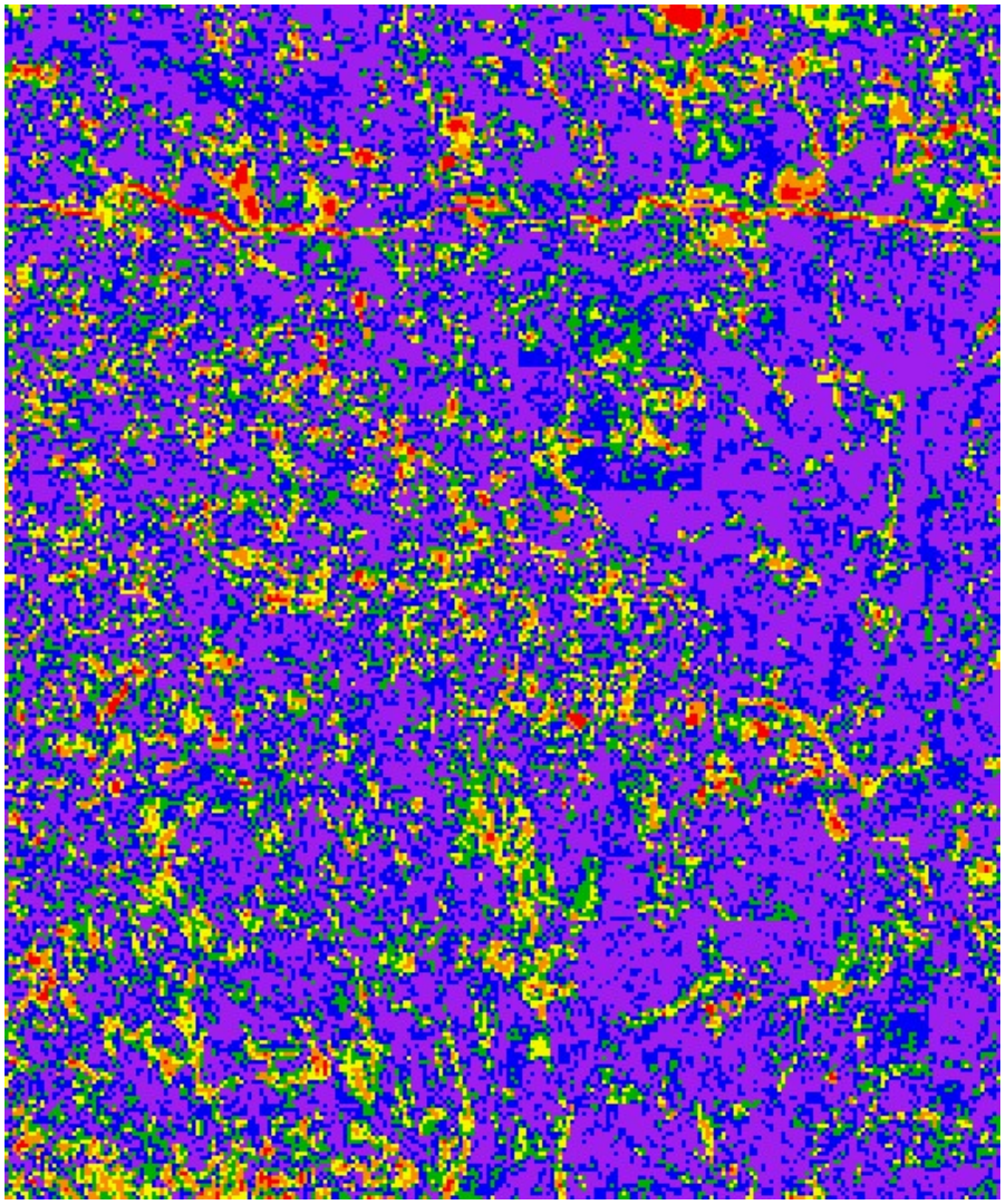
ETM+ predicted November 25 ρ



$\Delta_{temporal}$

0.000 <= purple	< 0.015
0.015 <= blue	< 0.030
0.030 <= green	< 0.045
0.045 <= yellow	< 0.060
0.060 <= orange	< 0.090
0.090 <= red	

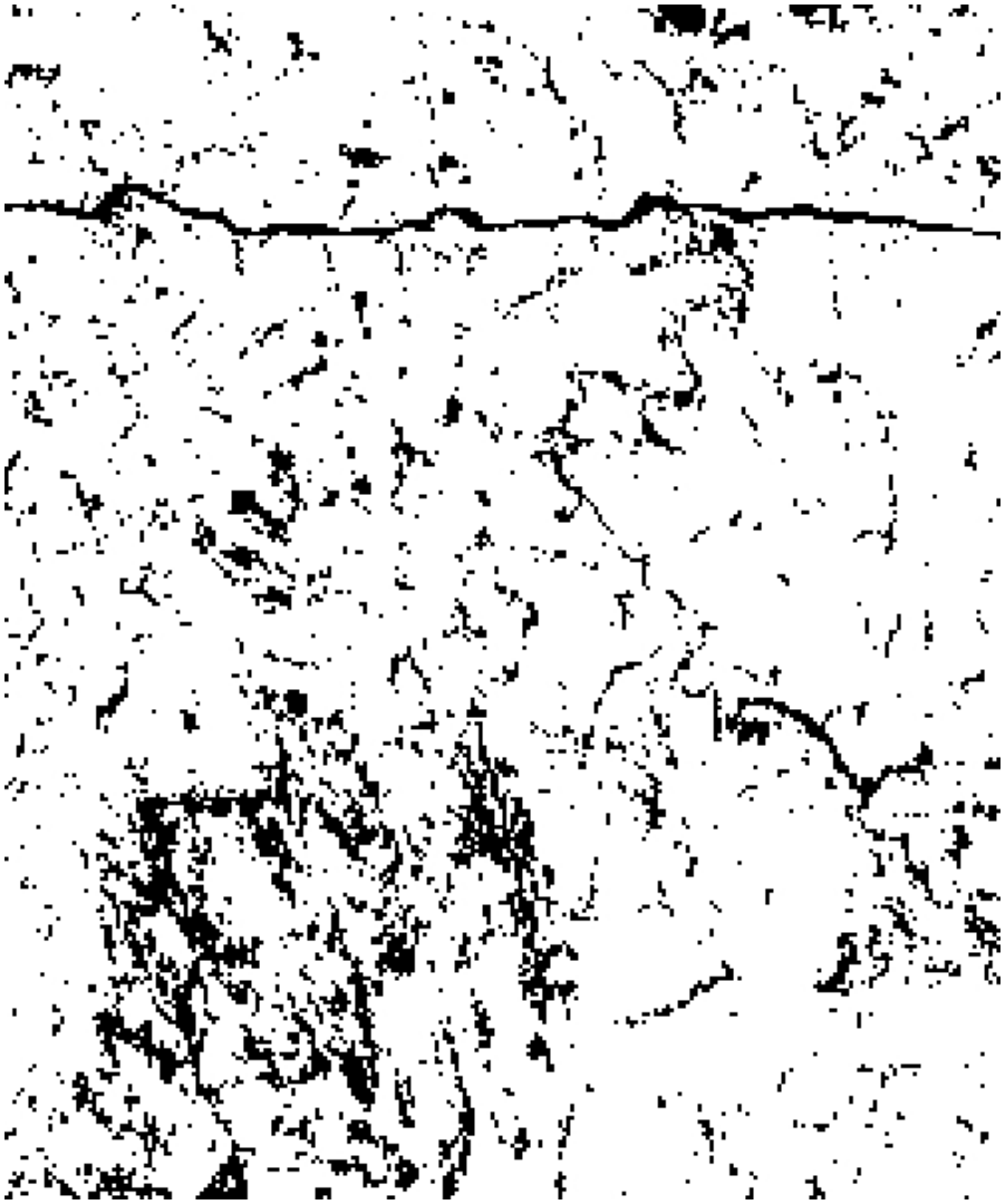
/ ETM+ observed November 25 ρ – observed January 9 ρ /



$\Delta_{prediction}$

0.000 <= purple	< 0.015
0.015 <= blue	< 0.030
0.030 <= green	< 0.045
0.045 <= yellow	< 0.060
0.060 <= orange	< 0.090
0.090 <= red	

/ ETM+ predicted – observed November 25 ρ /



$$black = \Delta_{prediction} > \Delta_{temporal}$$

Radiometric Normalization

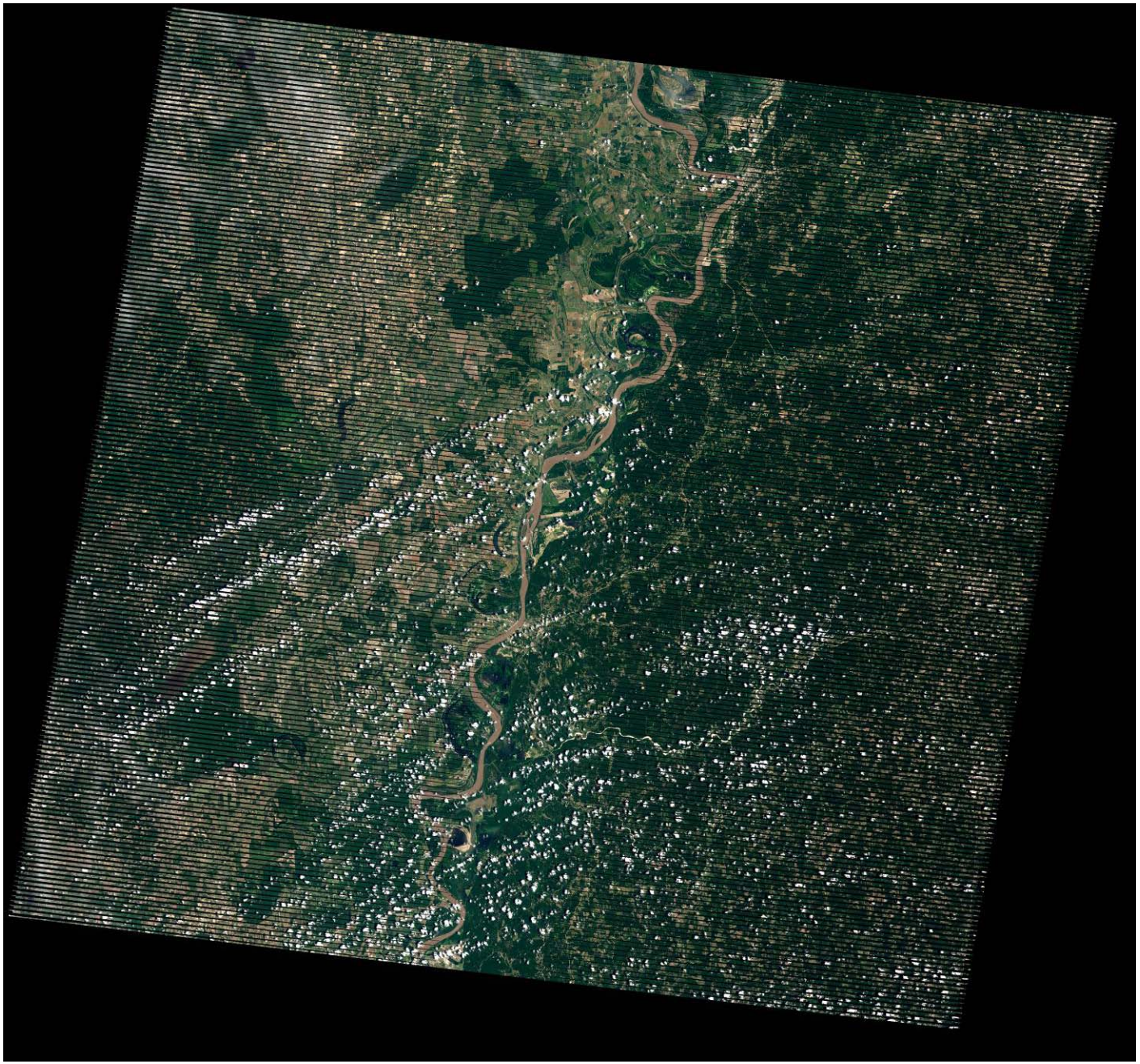
- The radiometric consistency of Landsat data may change spatially and temporally,
  - atmospheric variations
  - sensor calibration changes
  - cloud and shadow contamination
  - differences in illumination and observation angles.

- The WELD processing (conversion to TOA reflectance, cloud screening, compositing) will largely remove reflectance variations in the monthly, seasonal and annual composites, except for reflectance differences due to illumination and observation angles.

$$\hat{\rho}_{ETM+,t1}\left(\lambda_{ETM+},\Omega_{nadir},\Omega'_{solar\ noon}\right)=c\times\rho_{ETM+,t1}\left(\lambda_{ETM+},\Omega_{observed},\Omega'_{observed}\right)$$

$$c=\frac{\hat{\rho}_{MODIS,t1}\left(\lambda_{MODIS},\Omega_{nadir},\Omega'_{solar\ noon}\right)}{\hat{\rho}_{MODIS,t1}\left(\lambda_{MODIS},\Omega_{observed},\Omega'_{observed}\right)}$$

Thus, Landsat reflectance may be normalized to some desired geometry e.g., nadir view zenith and local solar noon.

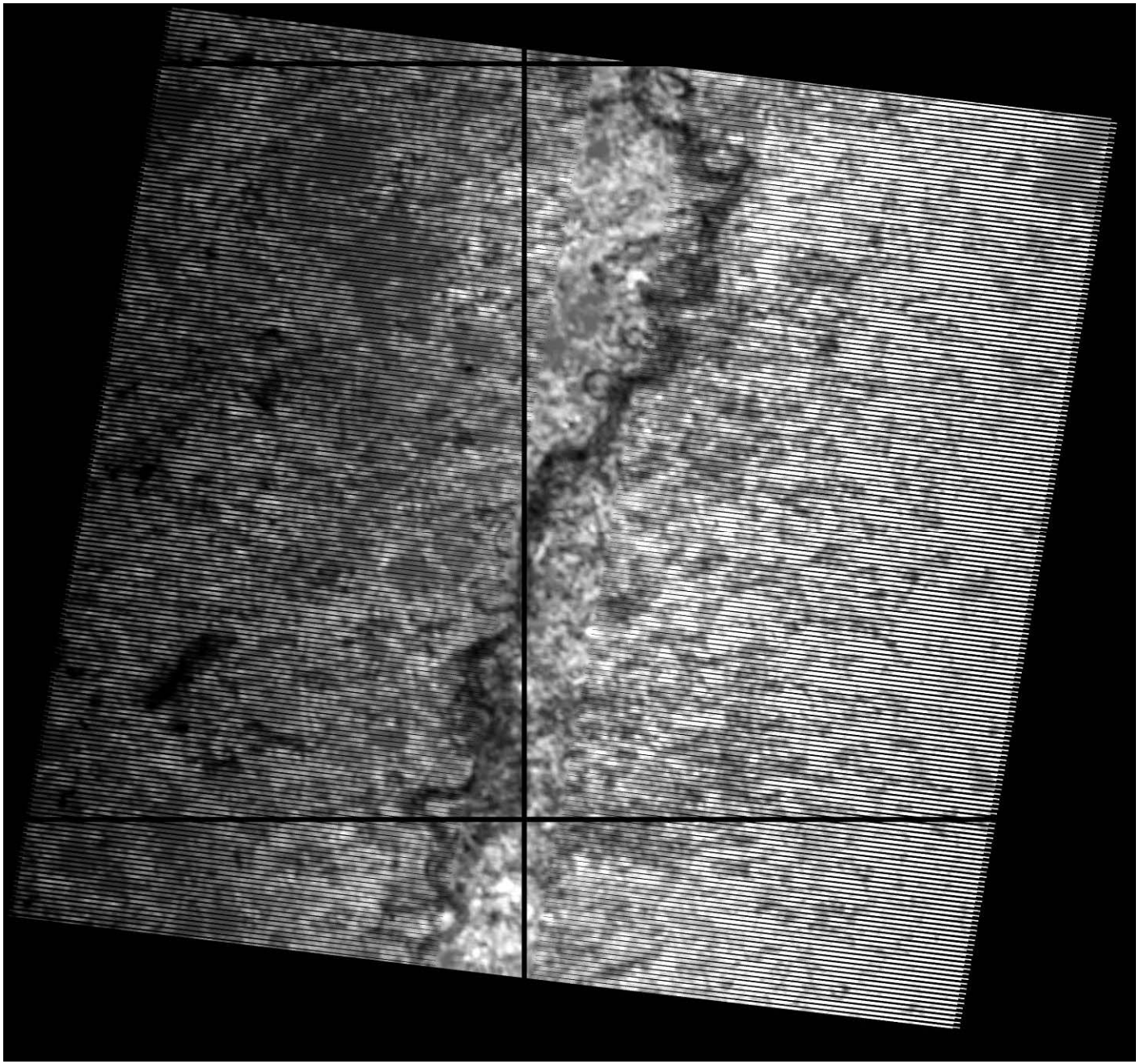


Path 23 Row 38,
July 12, 2008

Band 3, 2, 1
(red, green, blue)
TOA reflectance

Before
radiometric
normalization

Albers WELD
projection



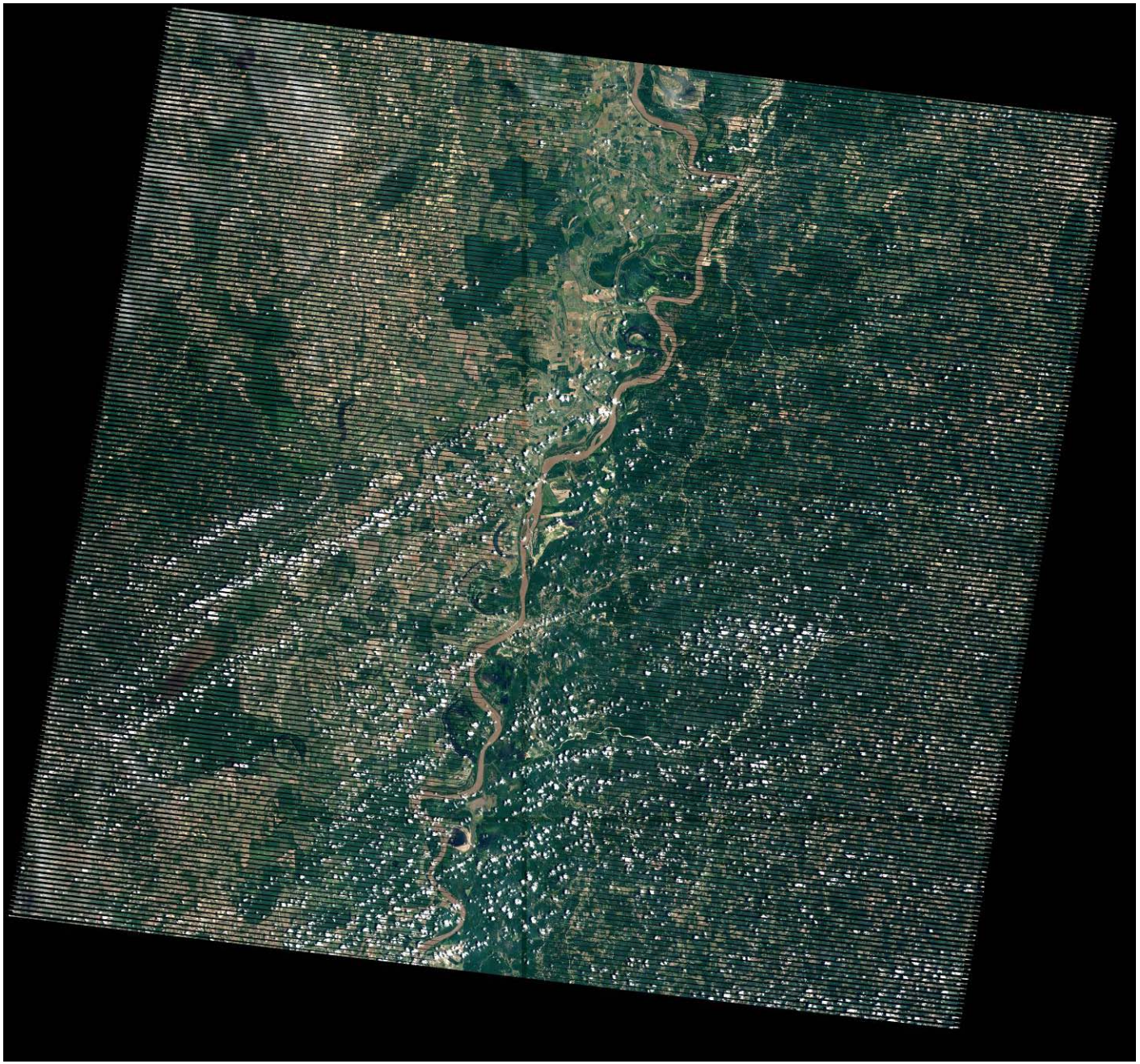
Path 23 Row 38,
July 12, 2008

Band 3 (red)

Scaling Factor
derived from
MODIS MCD43

(0.94 - 1.40)

Albers WELD
projection

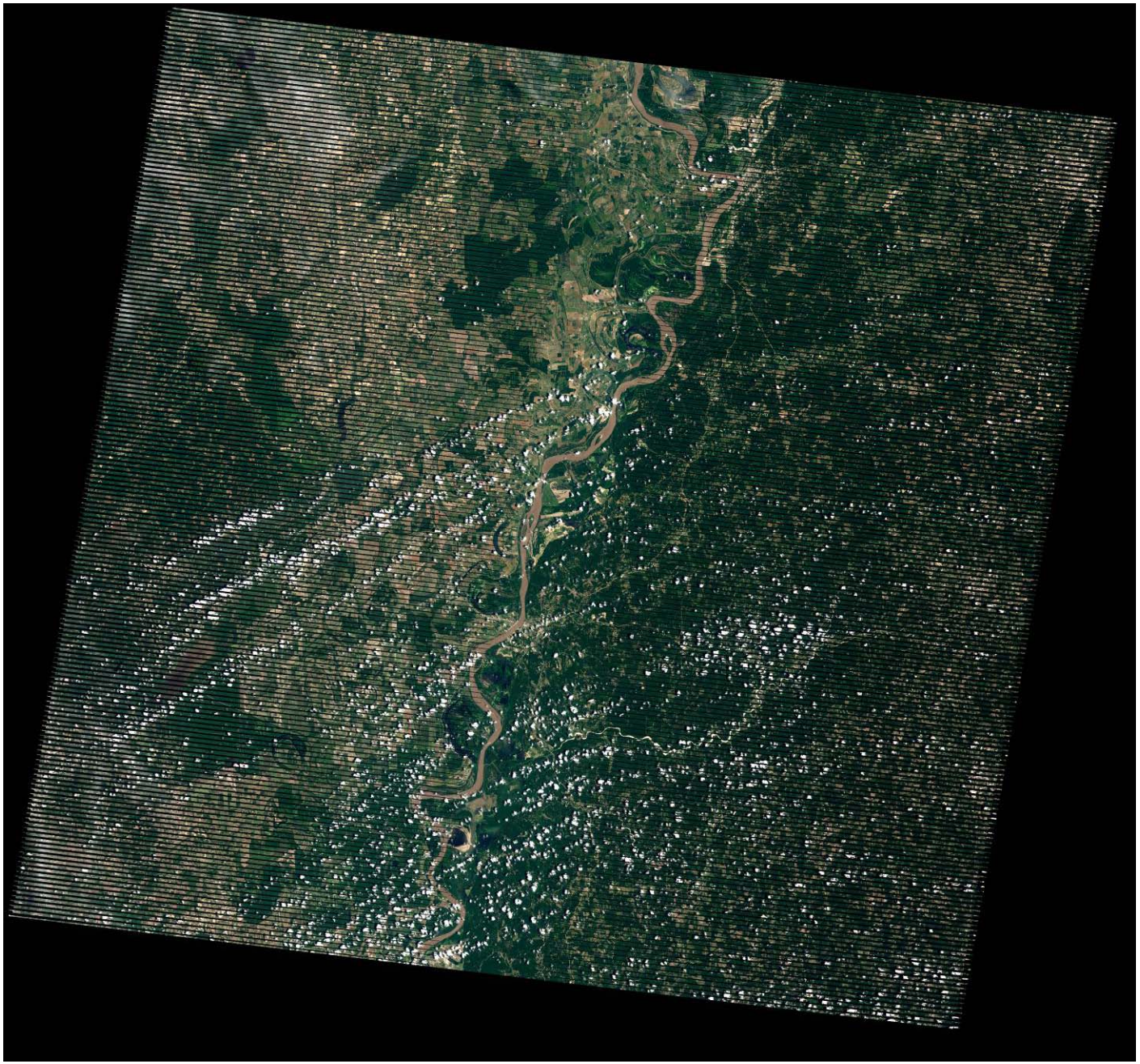


Path 23 Row 38,
July 12, 2008

Band 3, 2, 1
(red, green, blue)
TOA reflectance

After
radiometric
normalization

Albers WELD
projection



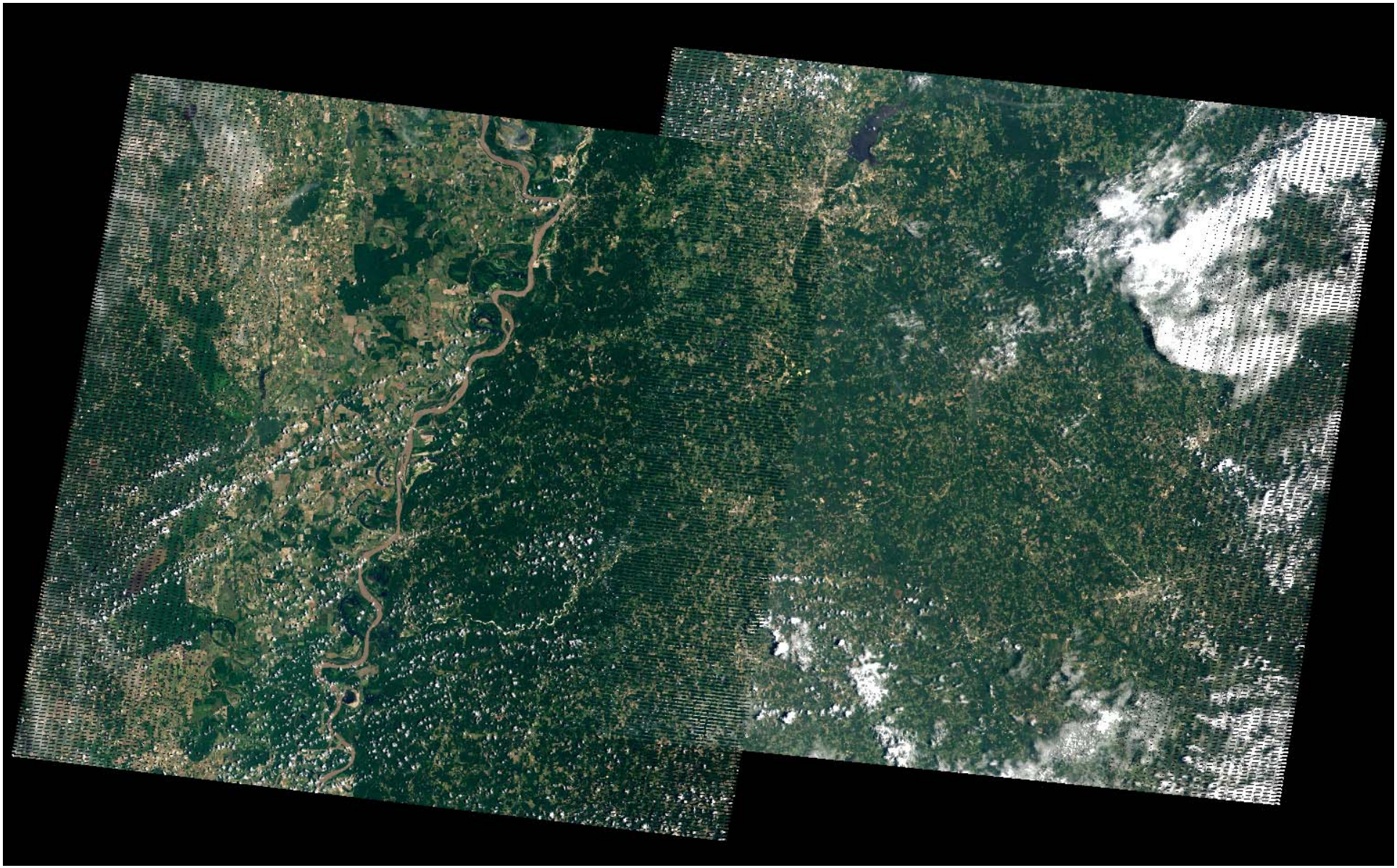
Path 23 Row 38,
July 12, 2008

Band 3, 2, 1
(red, green, blue)
TOA reflectance

Before
radiometric
normalization

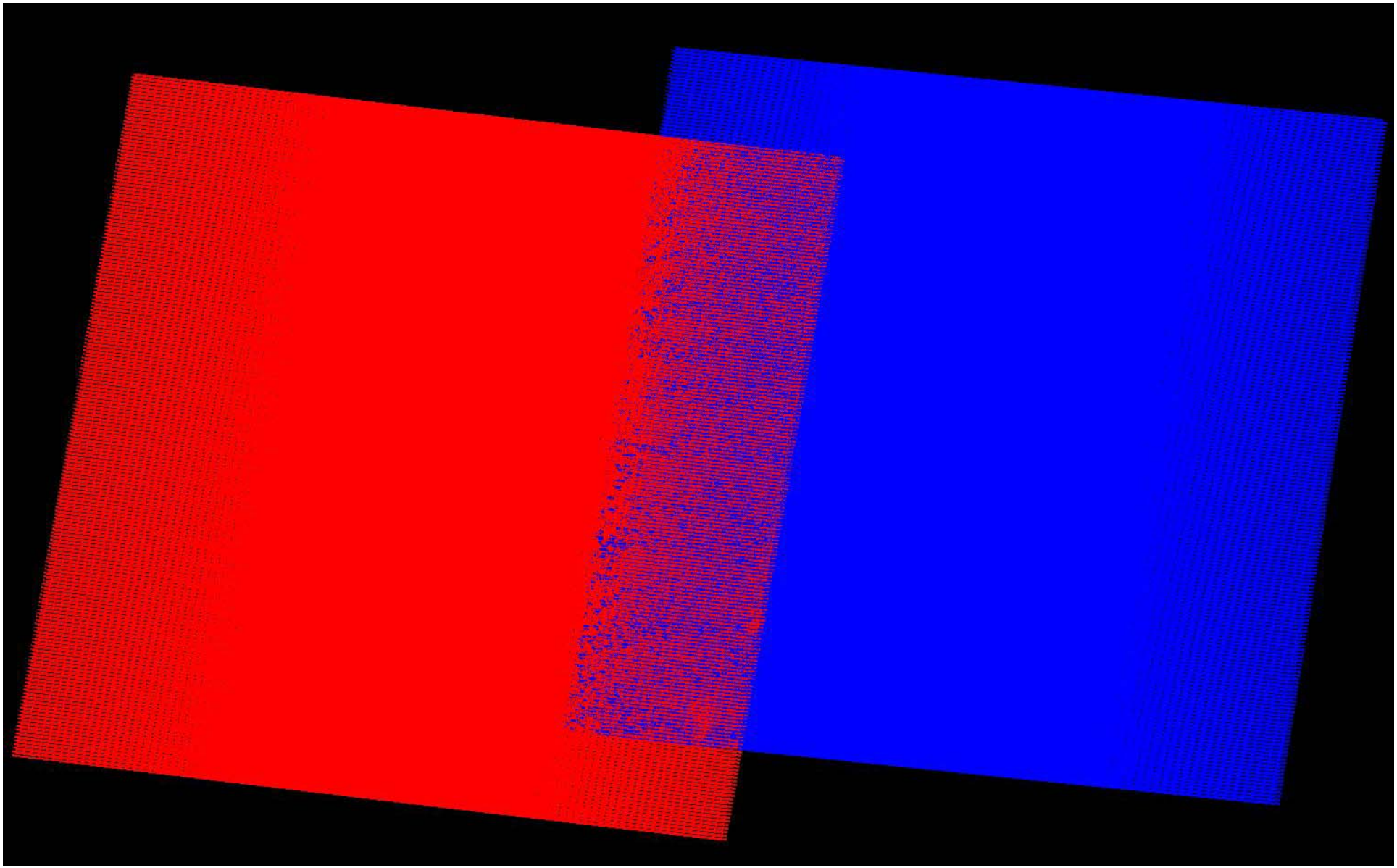
Albers WELD
projection

Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
Band 3, 2, 1 (red, green, blue) TOA reflectance
Before radiometric normalization

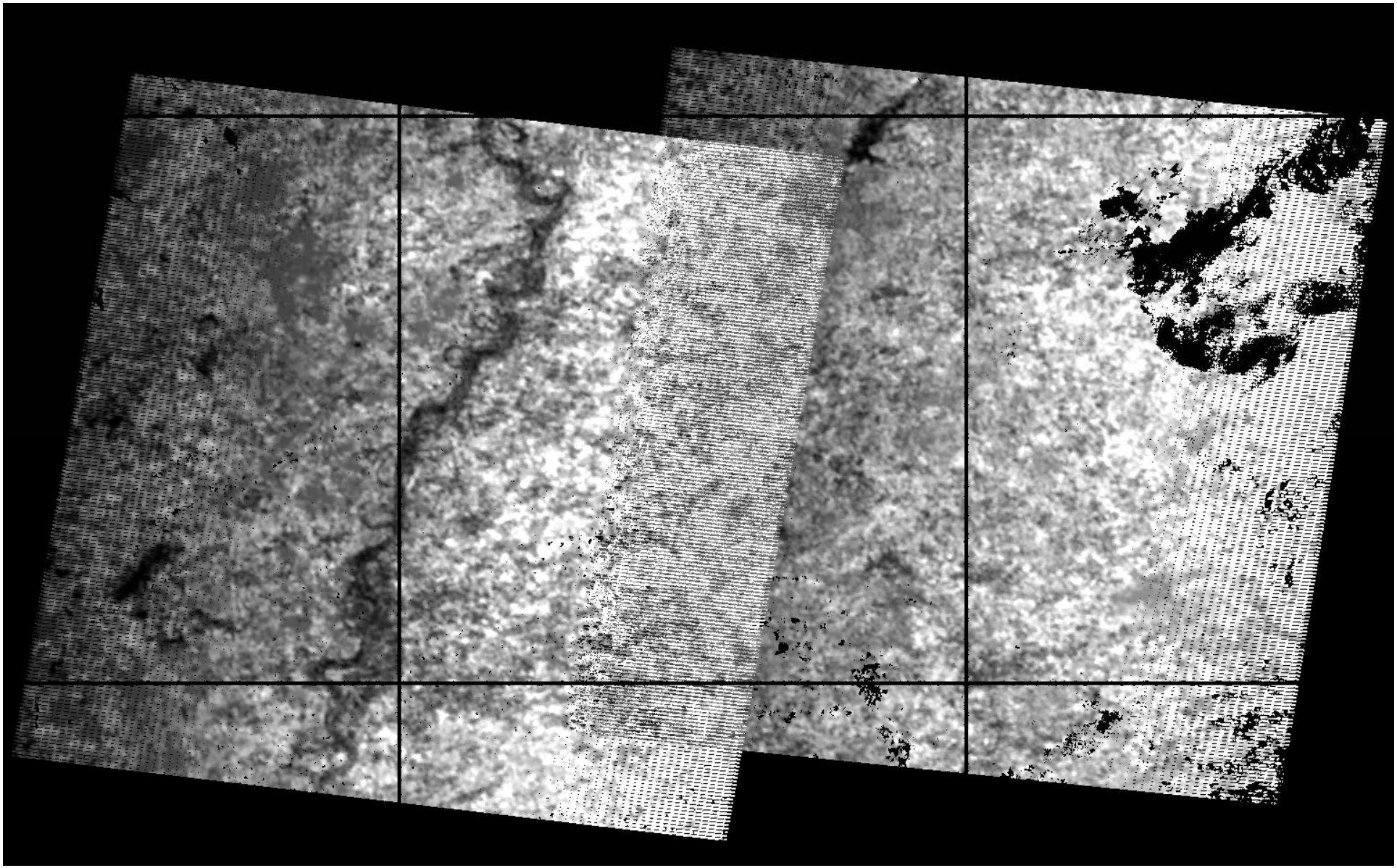


Composited Day of Year

Red: July 12 Blue: July 5



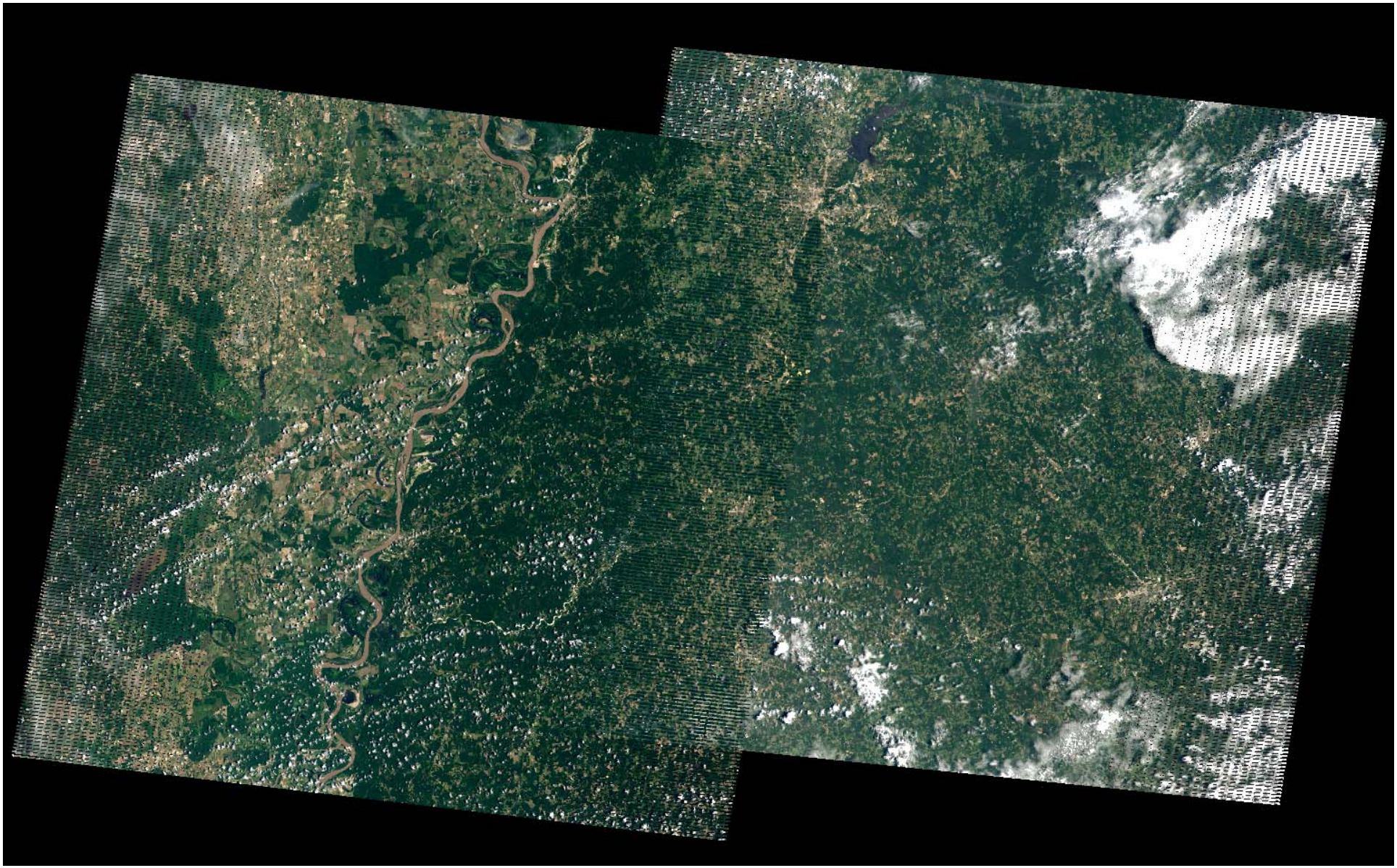
Band 3 (red, 0.63-0.69 μm)
MODIS derived scaling factors (range: 0.97-1.43)



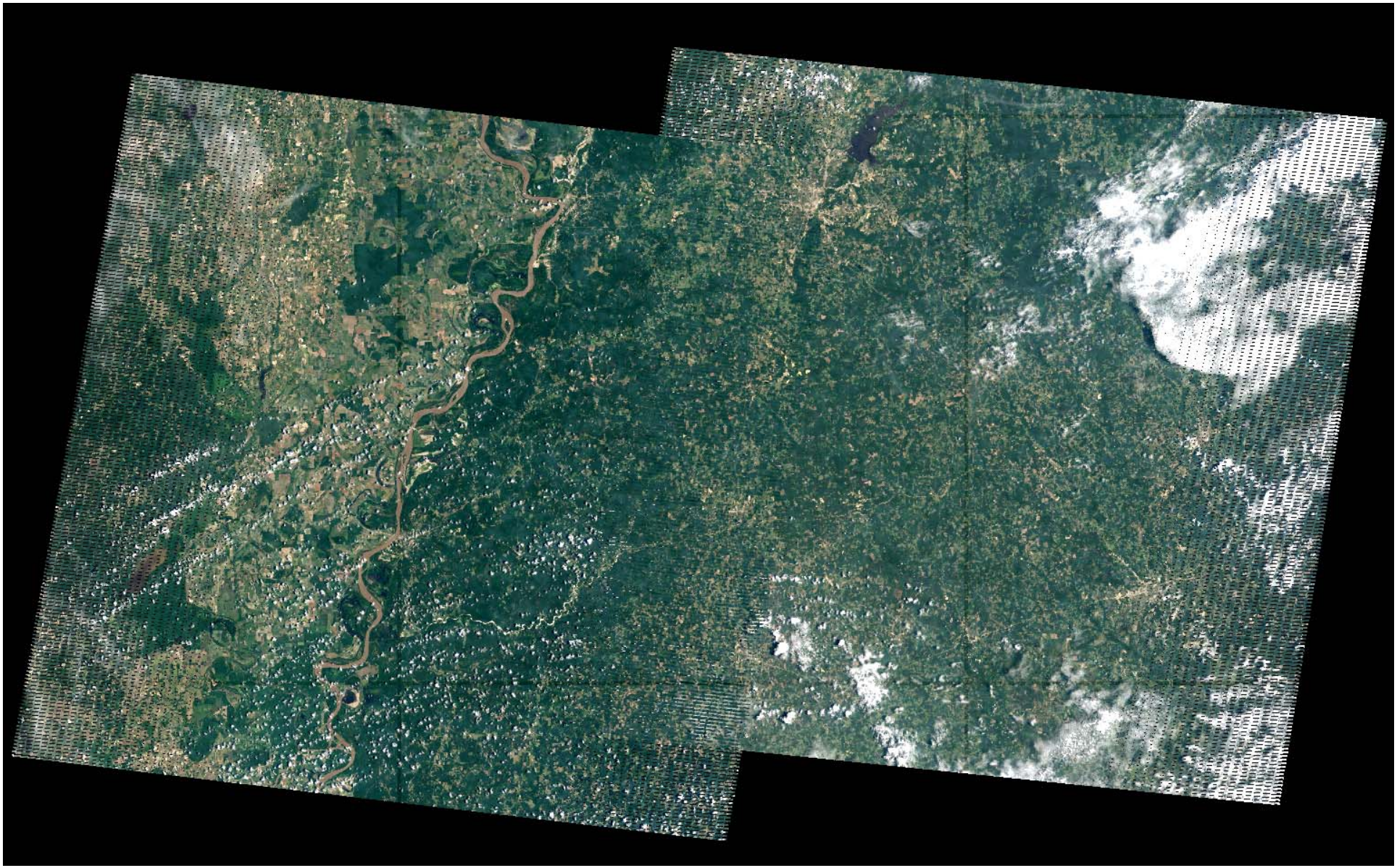
j3 i

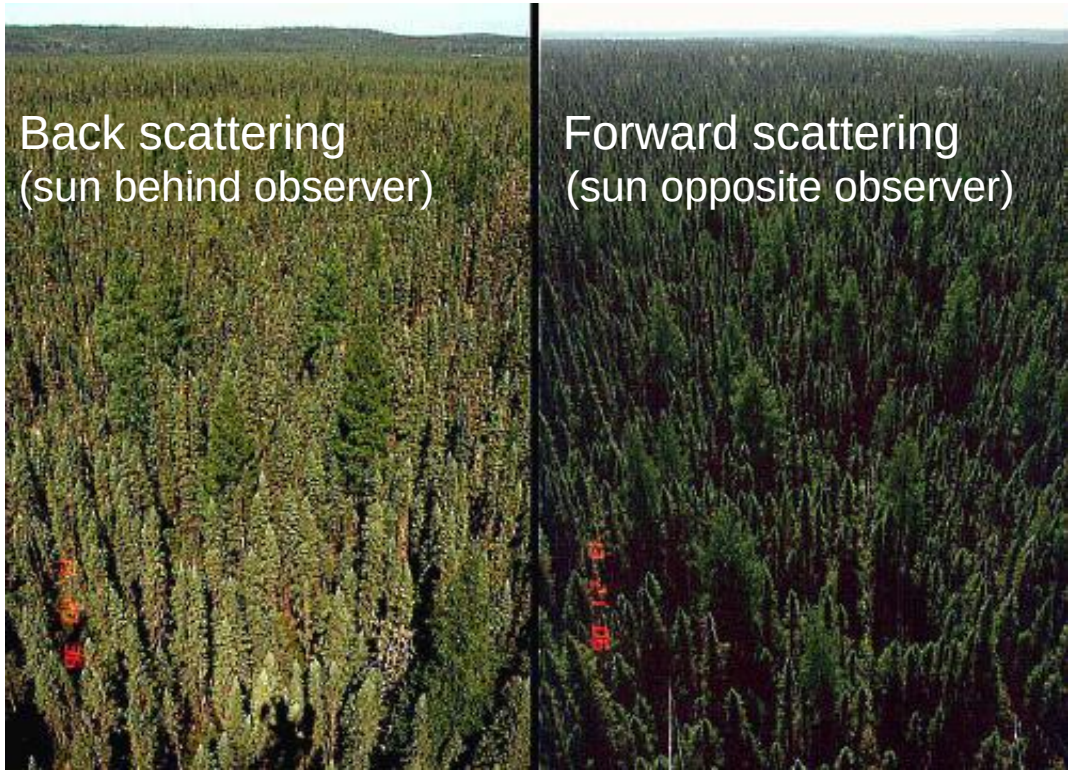
junchang.ju, 10/23/2009

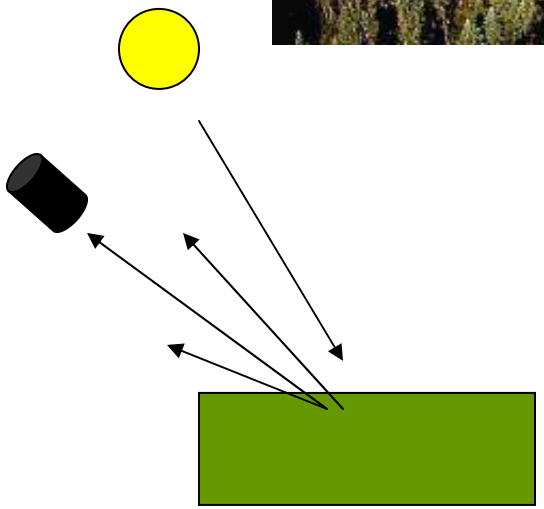
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
Band 3, 2, 1 (red, green, blue) TOA reflectance
Before radiometric normalization



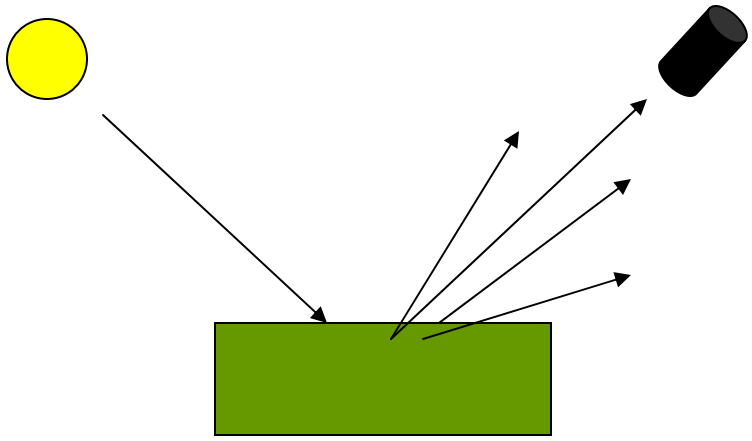
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
Band 3, 2, 1 (red, green, blue) TOA reflectance
After radiometric normalization







Back scatter direction



Forward scatter direction

Atmospheric Scattering Phase Function Effects

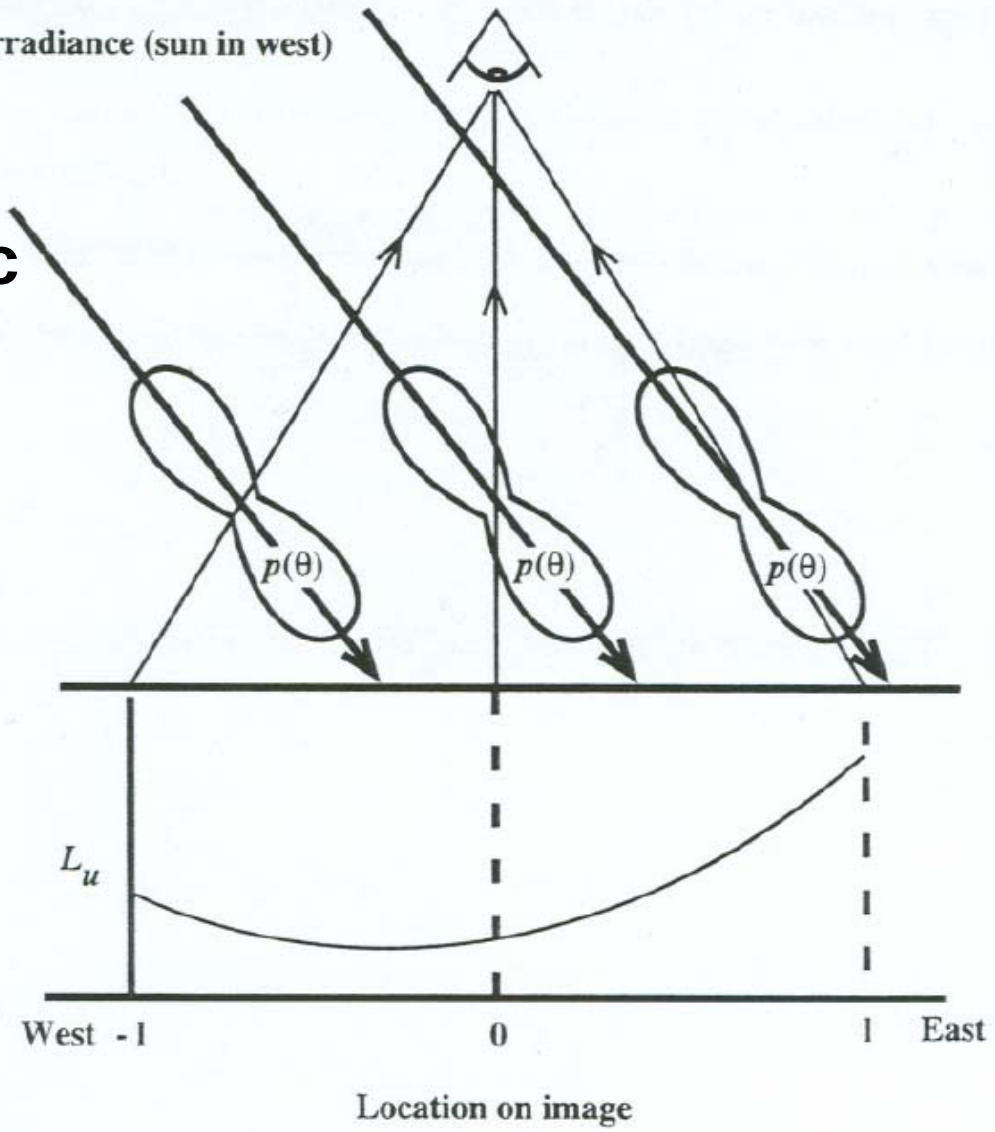
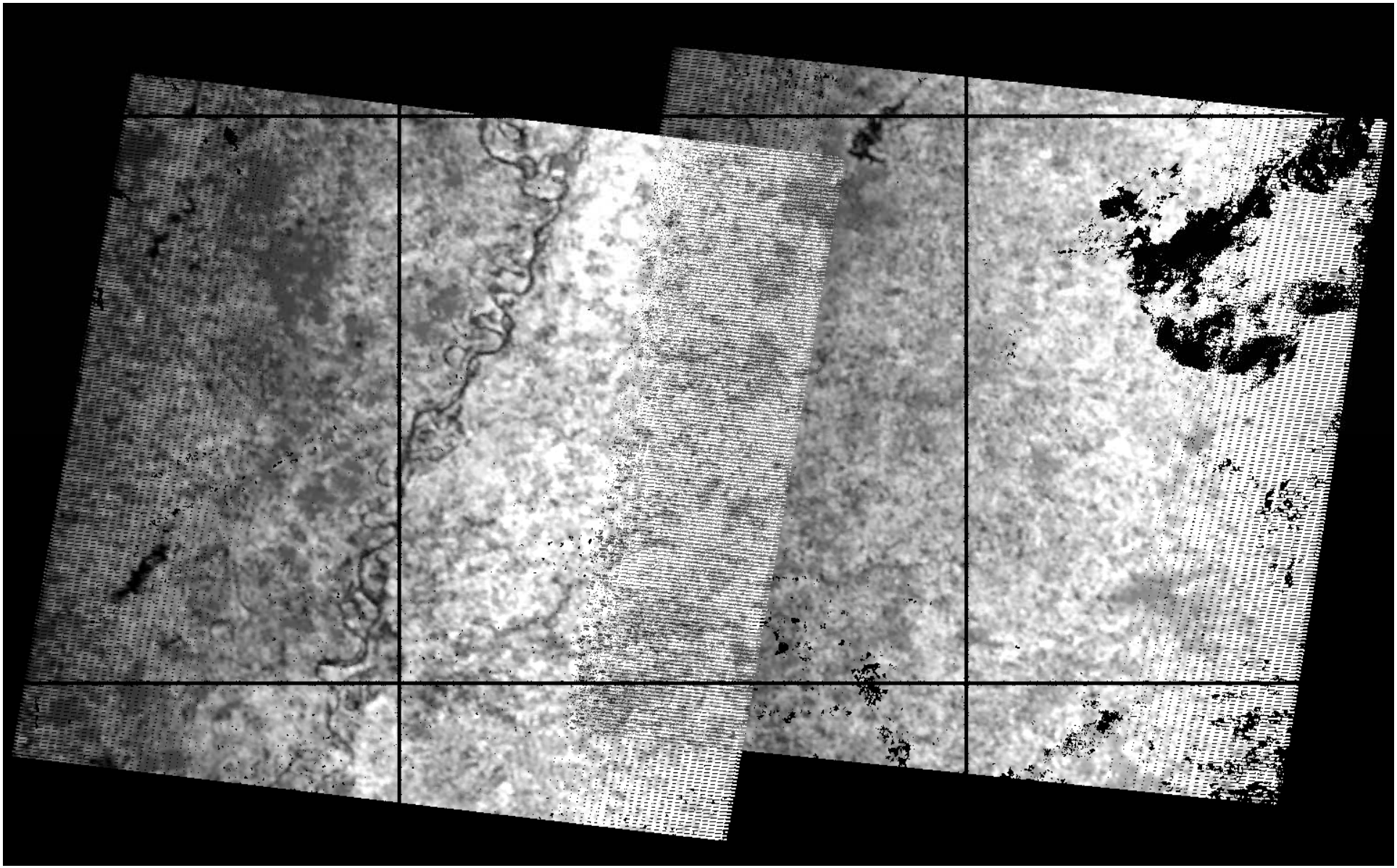


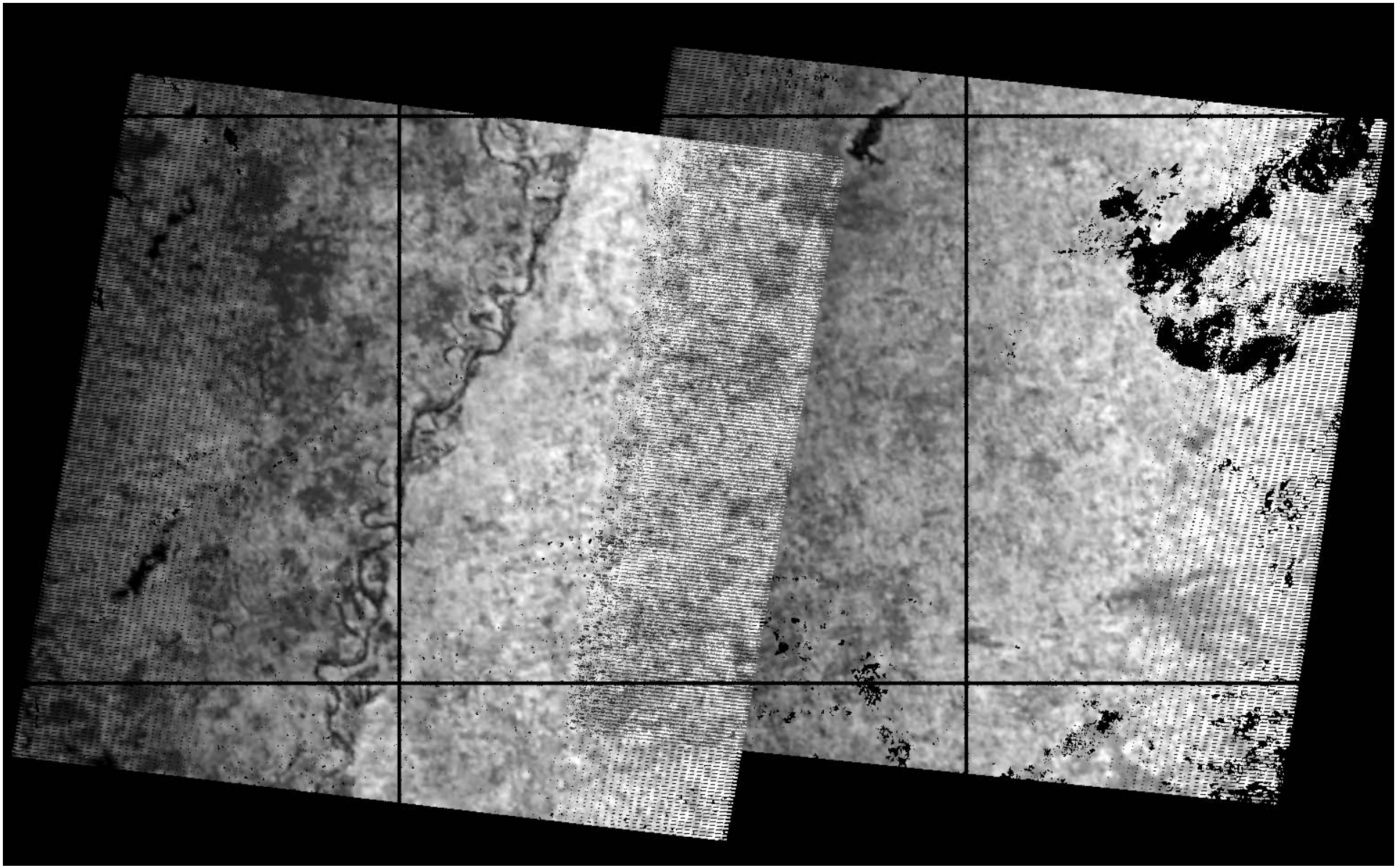
Figure 4.11 Variation in path radiance with view angle. A Rayleigh phase function is shown for refe

Band 7 (2.09-2.35 μm)
MODIS derived scaling factors (range: 0.98-1.38)

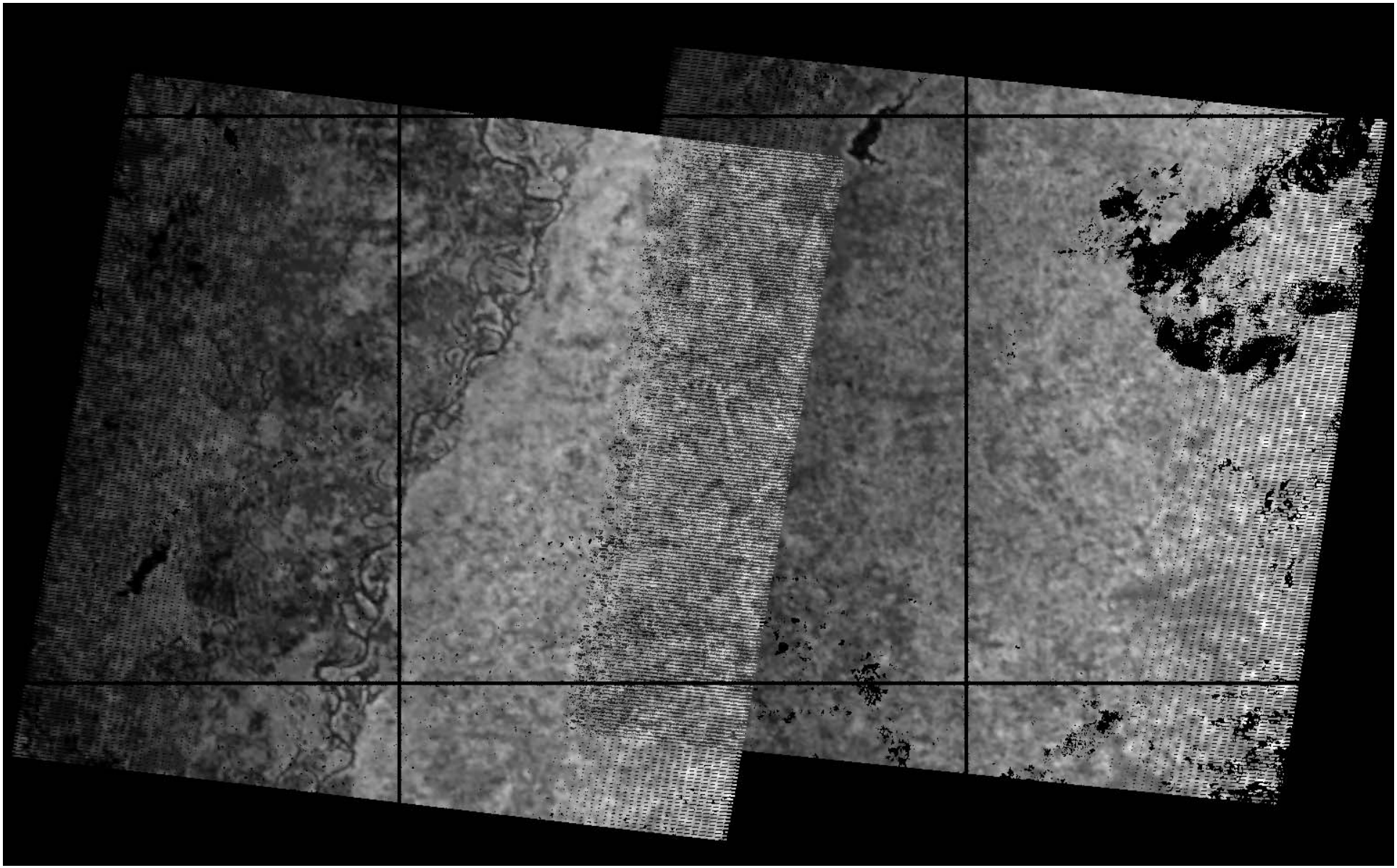


Band 5 (1.55-1.75 μm)

MODIS derived scaling factors (range: 0.98-1.28)

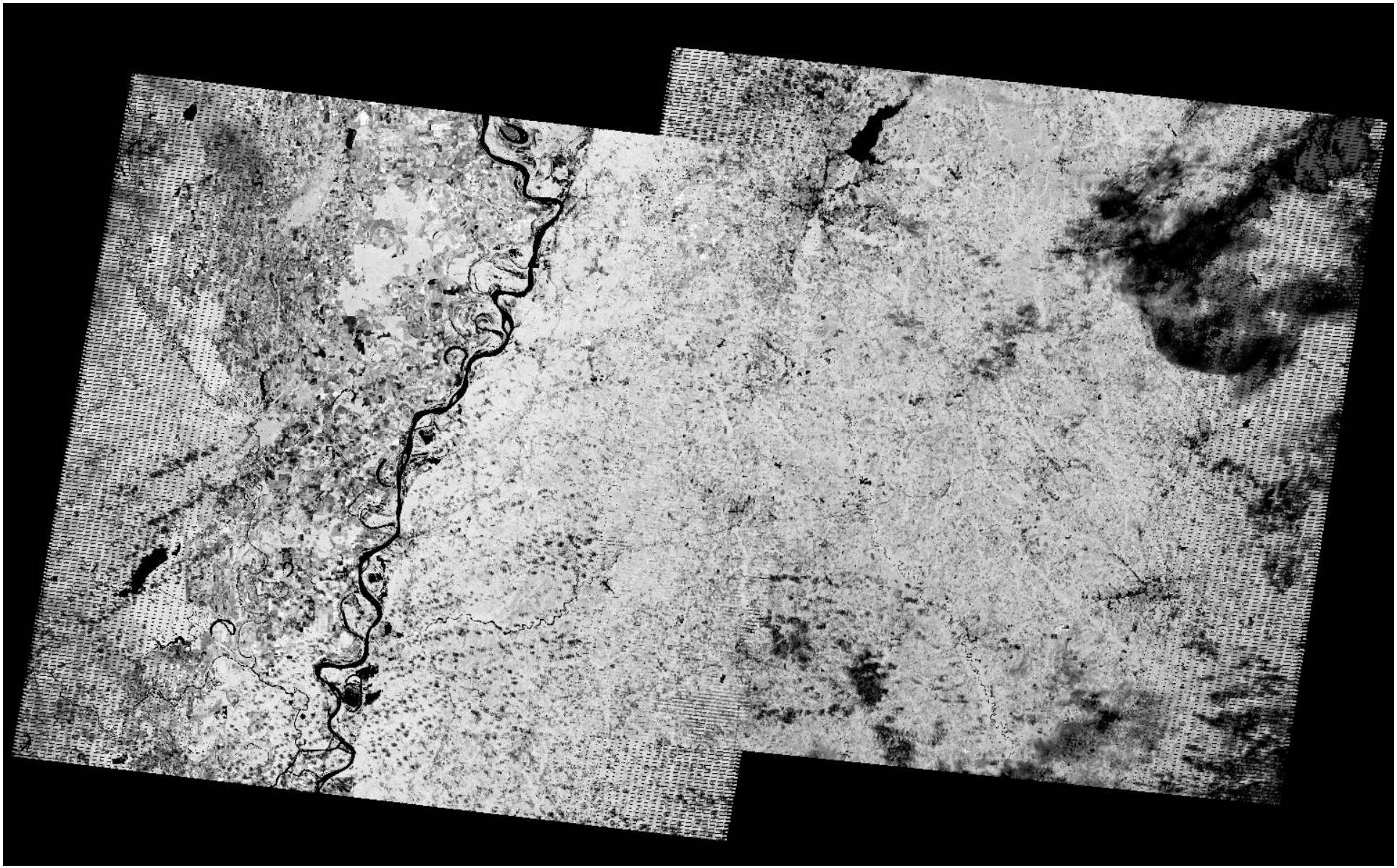


Band 4 (NIR, 0.78-0.90 μm)
MODIS derived scaling factors (range: 0.99-1.22)



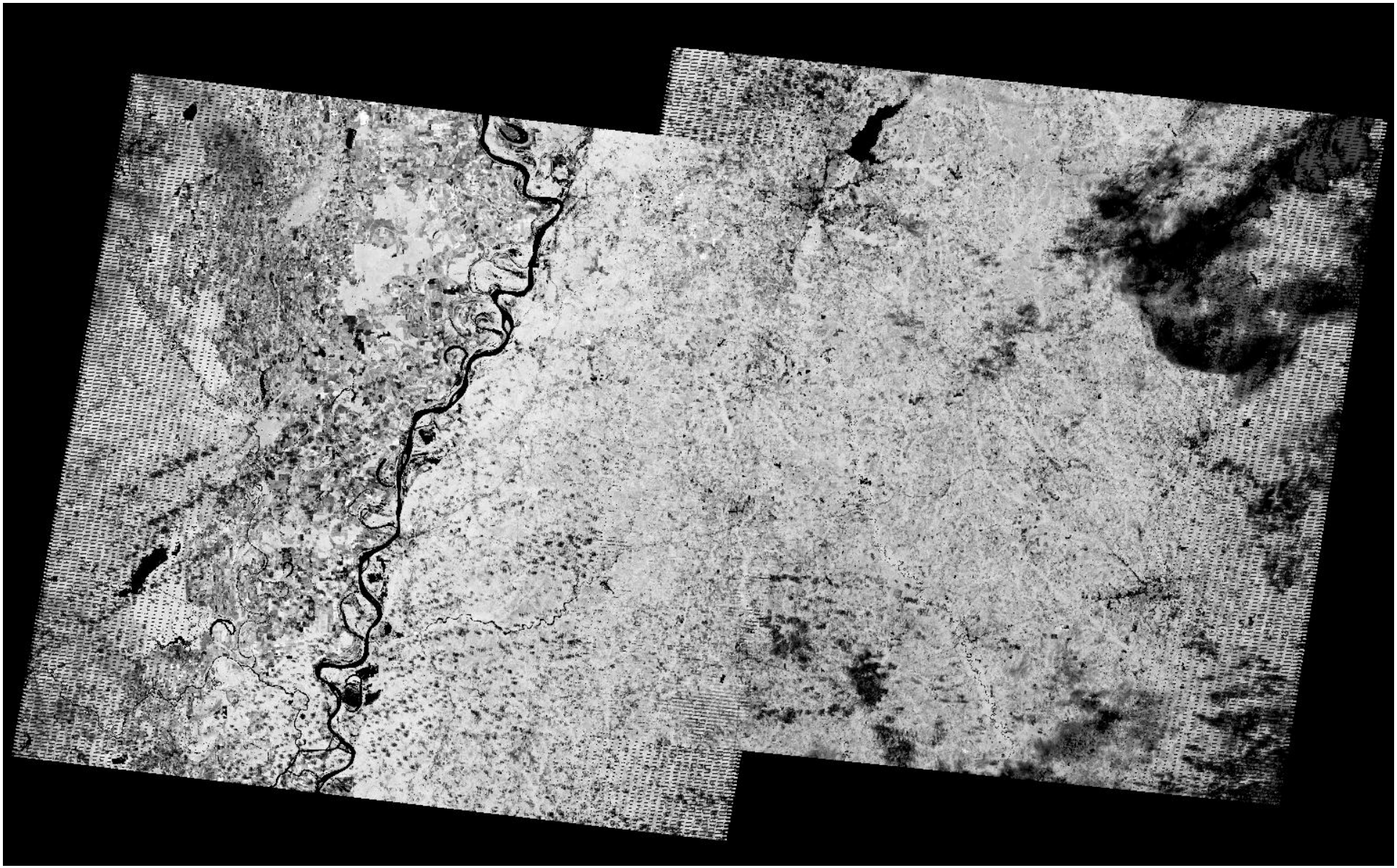
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
NDVI

Before radiometric normalization



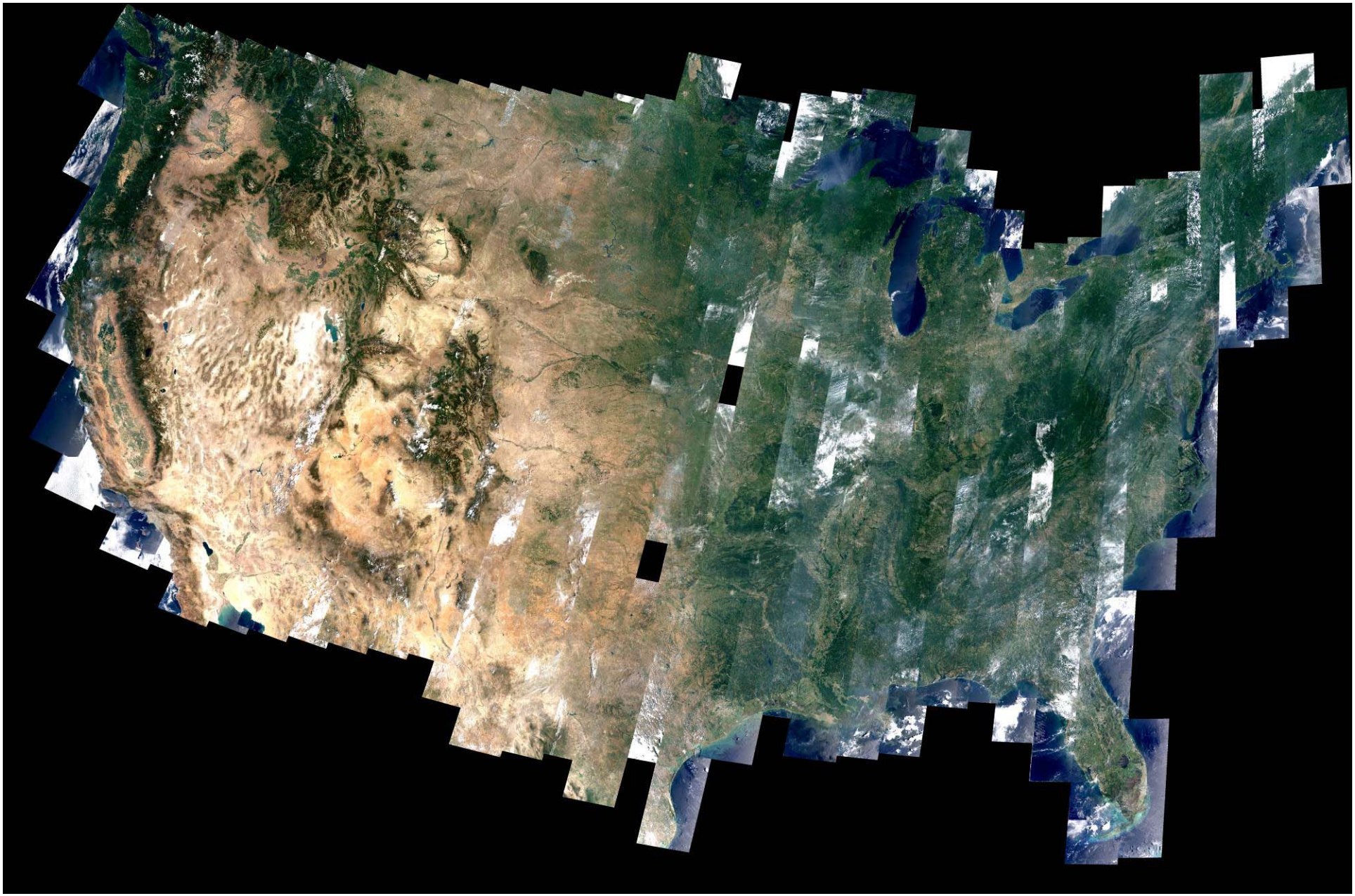
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
NDVI

After radiometric normalization



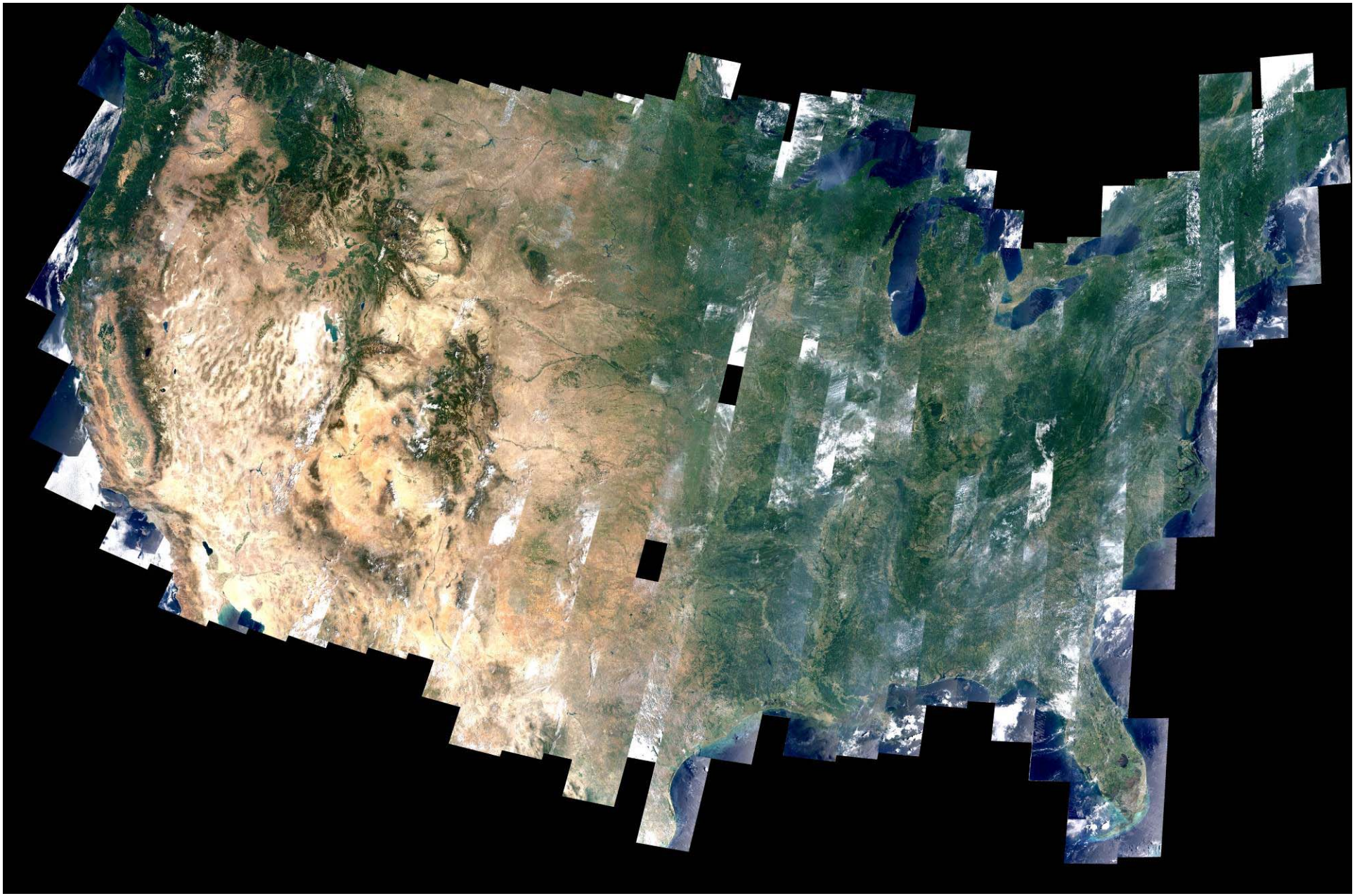
July 2008 composite. Band 3, 2, 1 (red, green, blue) TOA reflectance

Before radiometric normalization



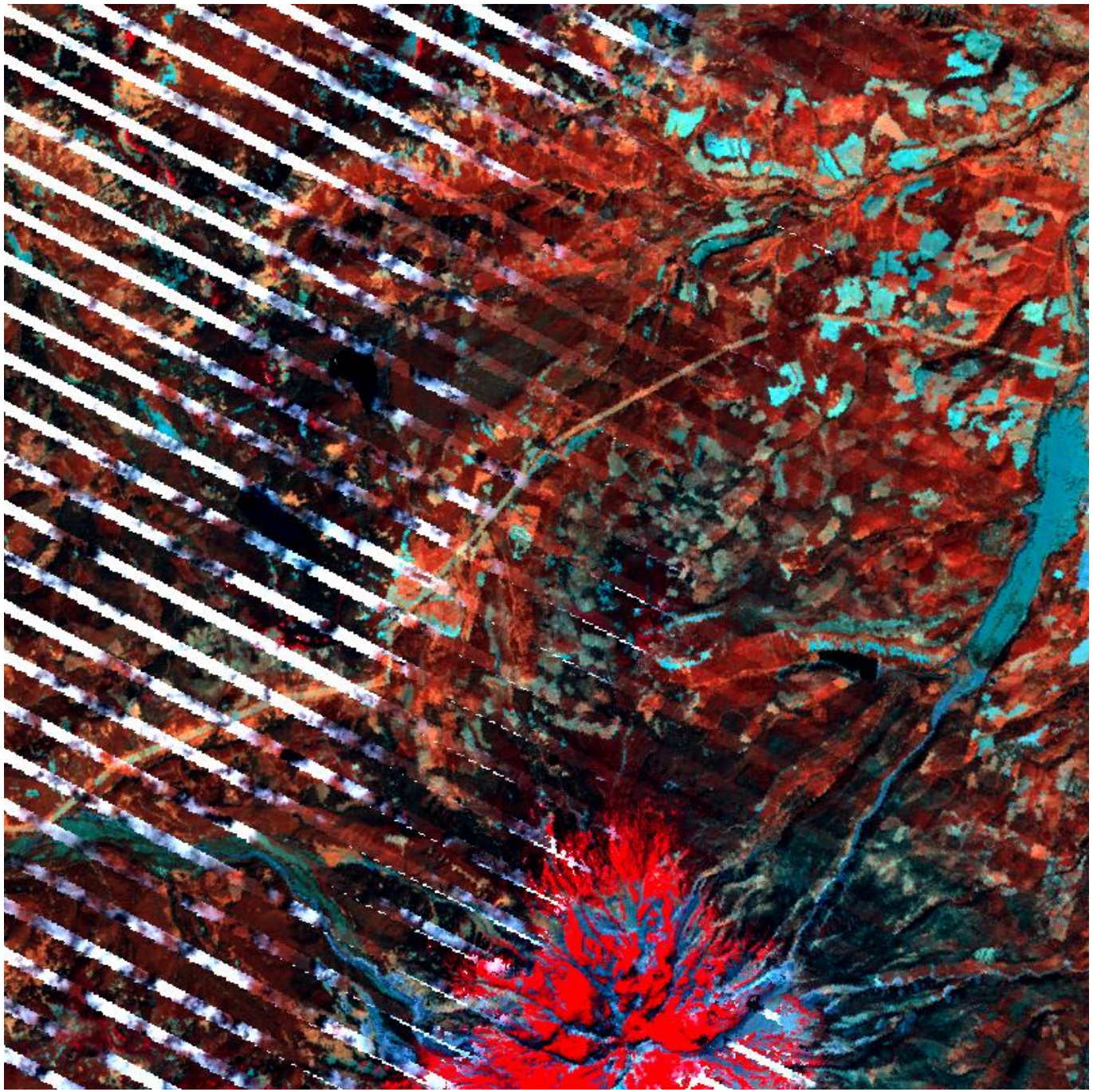
July 2008 composite. Band 3, 2, 1 (red, green, blue) TOA reflectance

After radiometric normalization



Band 3 (red, 0.63-0.69 μm)

MODIS derived scaling factors (range: 0.97-1.43)



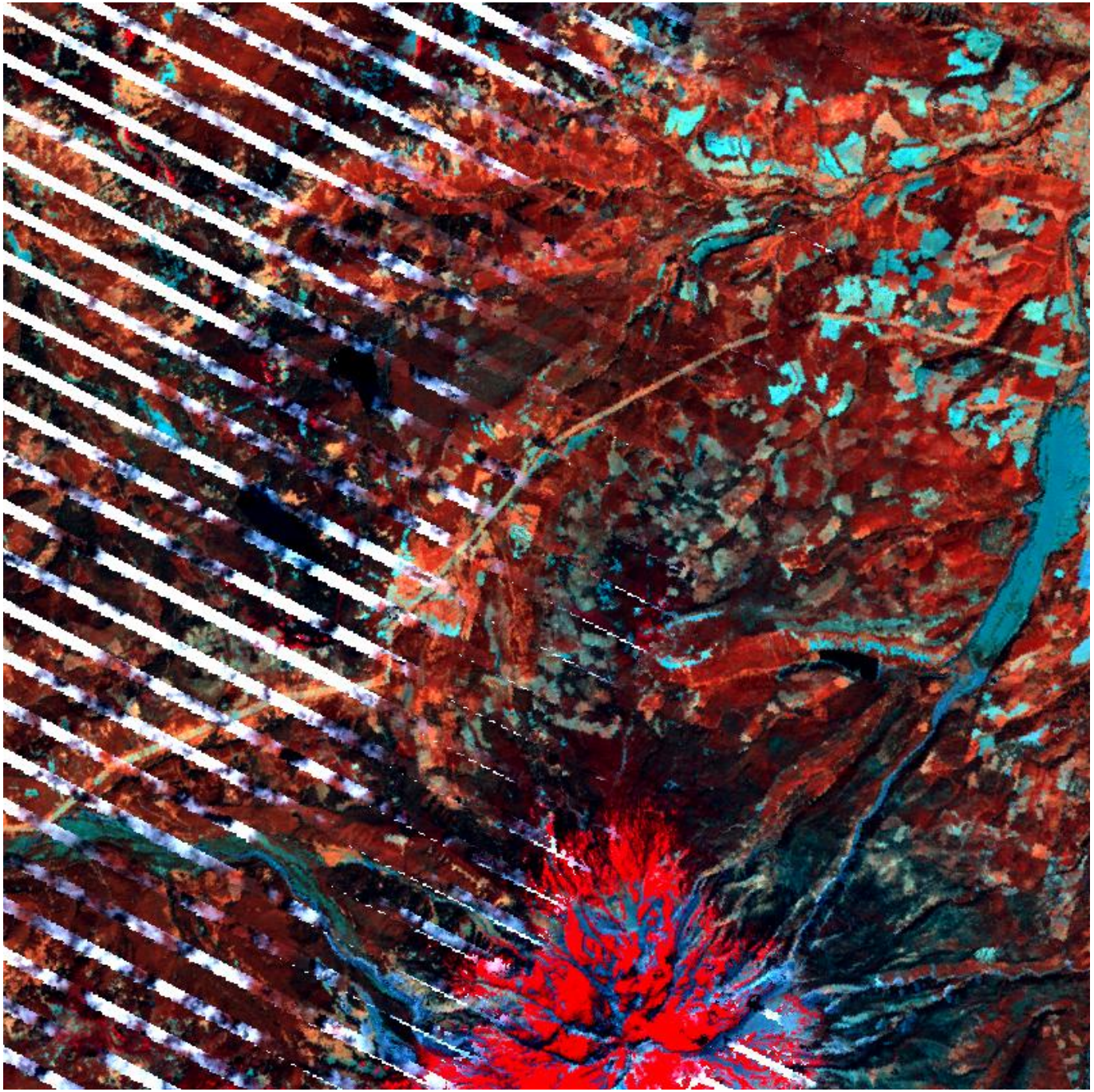
July 2008

3 dates composited

Bands 4,5,7

700 x 700
30m pixels

Before radiometric normalization



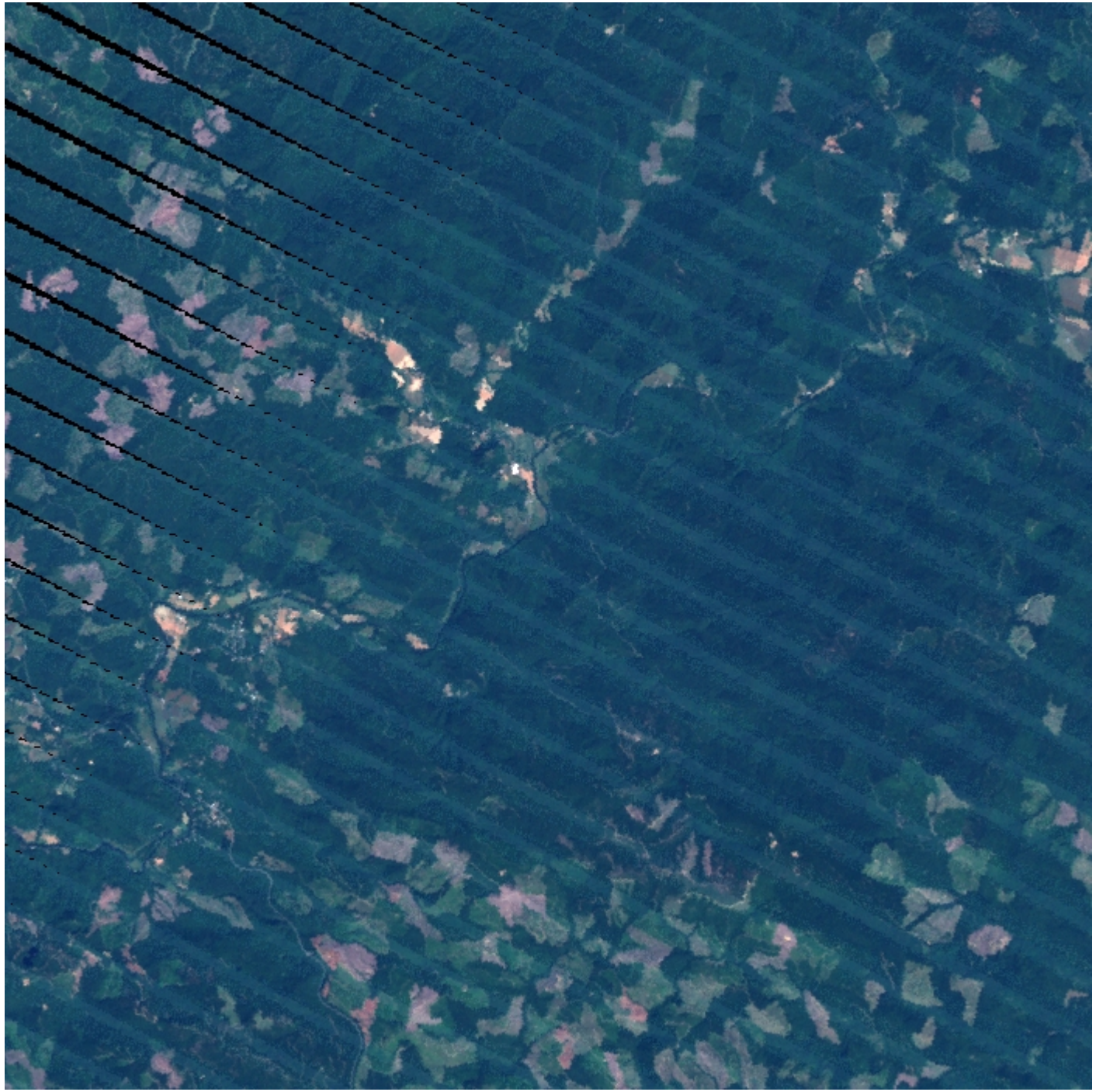
July 2008

3 dates composited

Bands 4,5,7

700 x 700
30m pixels

After radiometric normalization



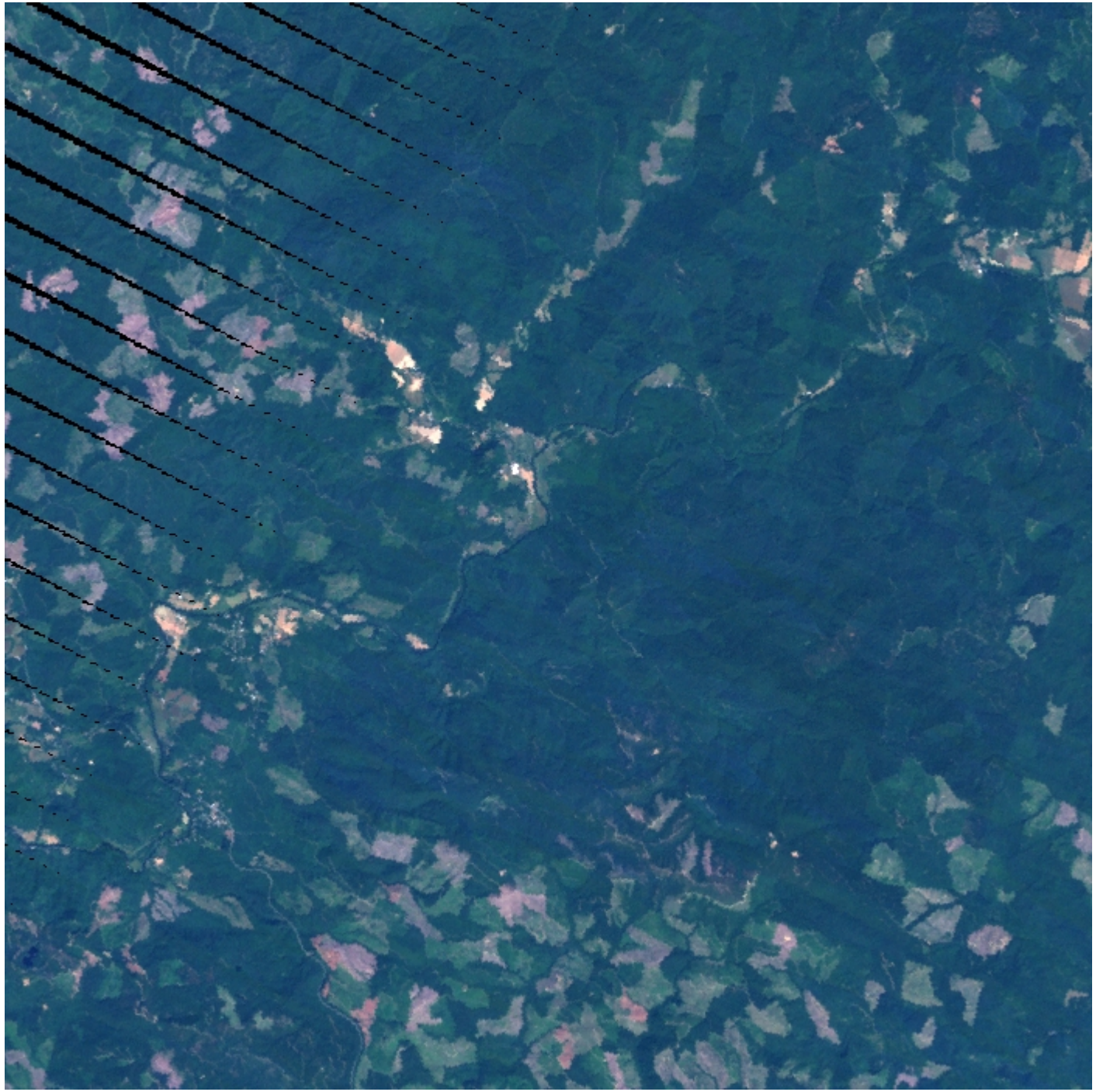
July 2008

2 dates composited

Bands 3,2,1

700 x 700
30m pixels

Before radiometric normalization



July 2008

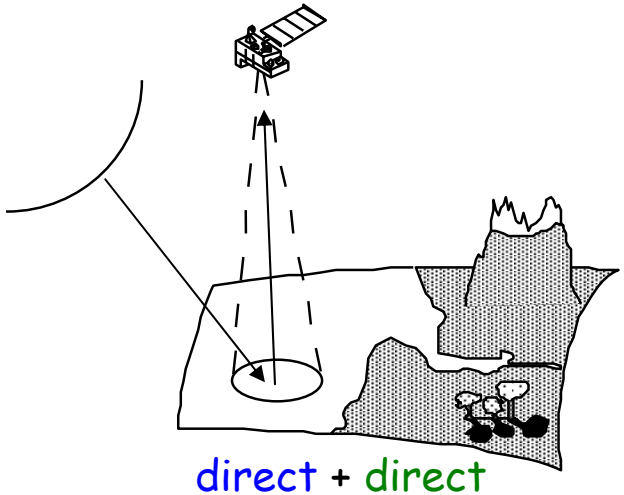
2 dates composited

Bands 3,2,1

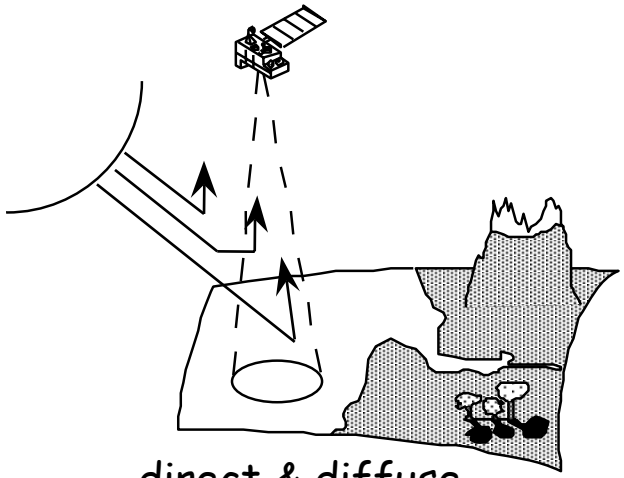
700 x 700
30m pixels

After radiometric normalization

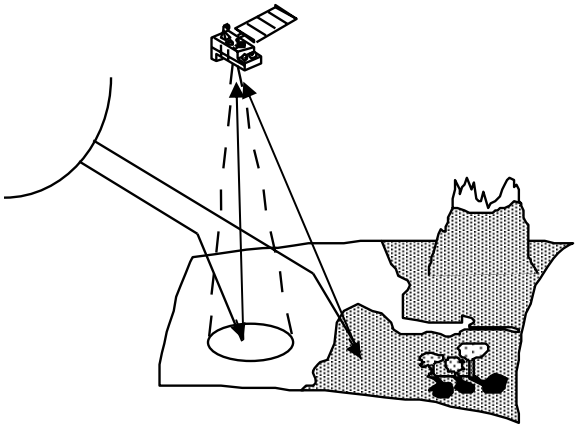
Atmospheric Correction – remove atmospheric effects for shortwave energy (paths up and down)



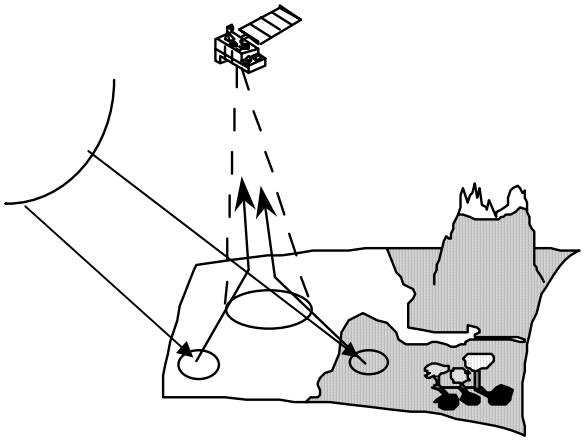
direct + direct



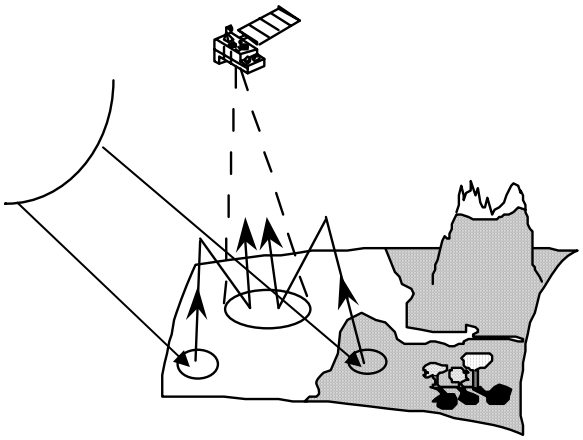
direct & diffuse
(purely atmospheric contribution, aka path radiance)



diffuse + direct



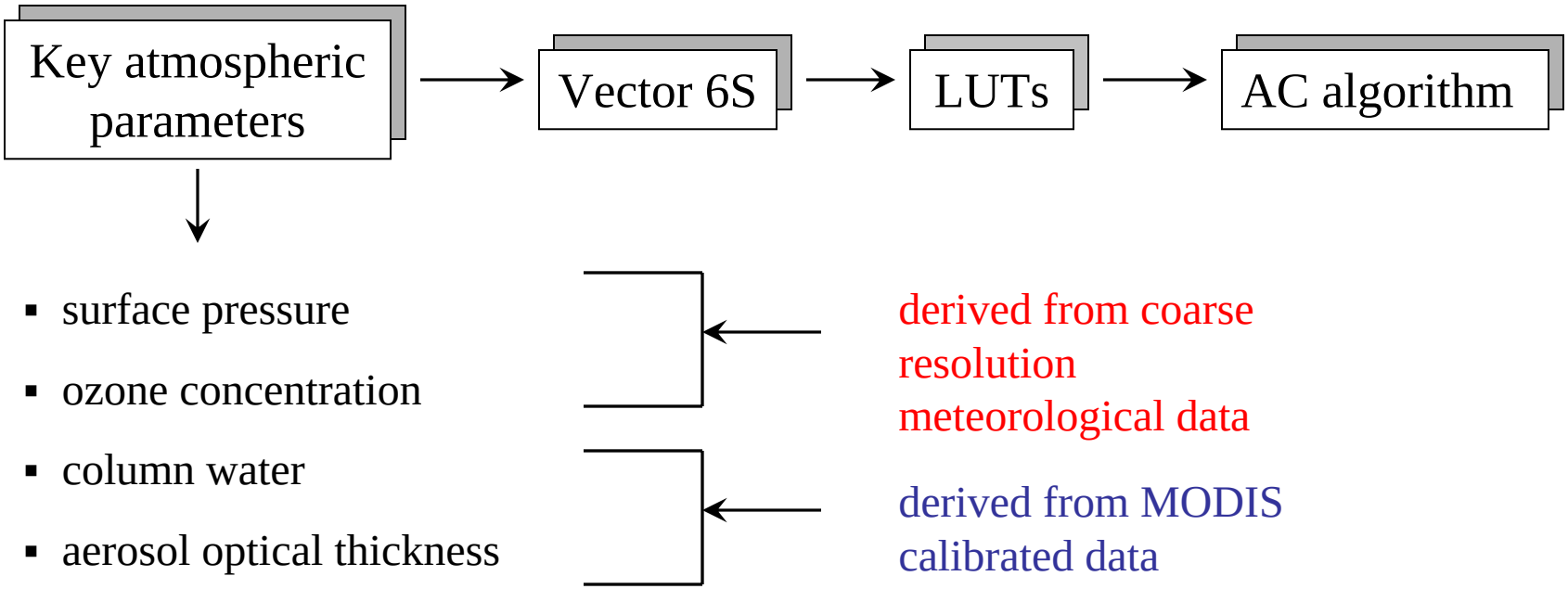
direct + diffuse



multiple scattering

Eric Vermote

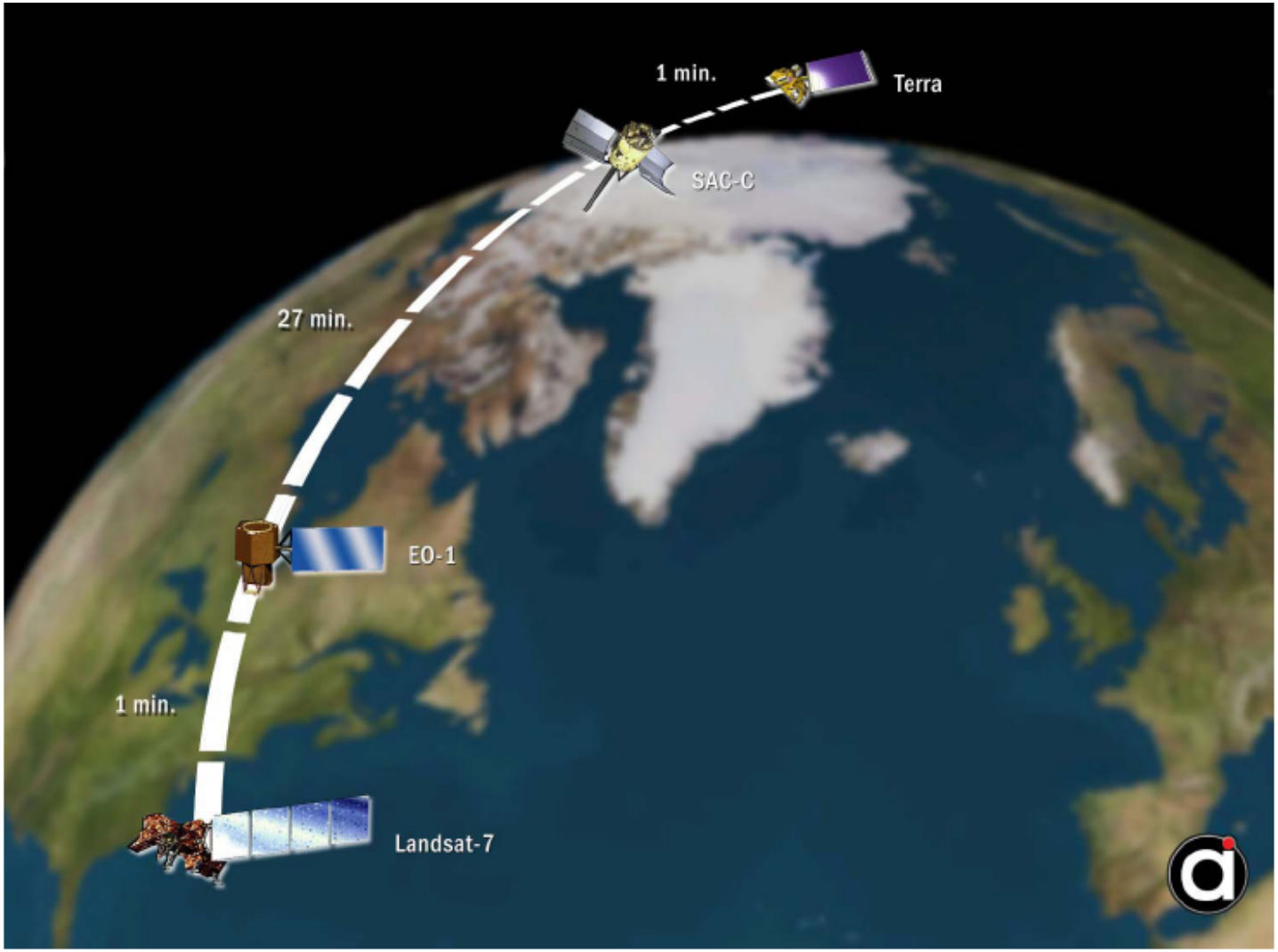
MODIS Atmospheric Correction



The Collection 5 atmospheric correction algorithm relies on the use of accurate radiative transfer modeling (6SV) of the coupled atmosphere-surface system, and per-generated Look Up Tables (LUT), and the inversion of key atmospheric parameters (aerosol and water vapor).

(Eric Vermote)

Landsat ETM+ and MODIS Terra in same orbit



GSFC

Advanced Landsat Atmospheric Correction

- Atmospheric correction look up table (LUT) specific to the ETM+ sensor

- Obtains parameters for the 6SV1.1 (vectorial) radiative transfer code

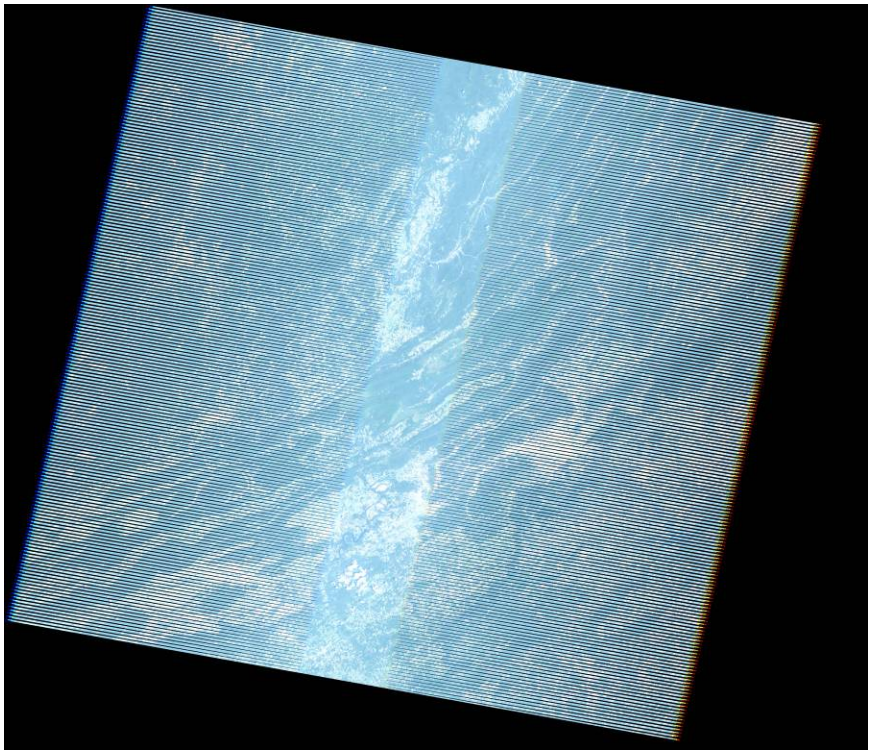
- Coupled with spatially and temporally explicit MODIS atmosphere parameterization data for each Landsat pixel in the contemporaneous orbit

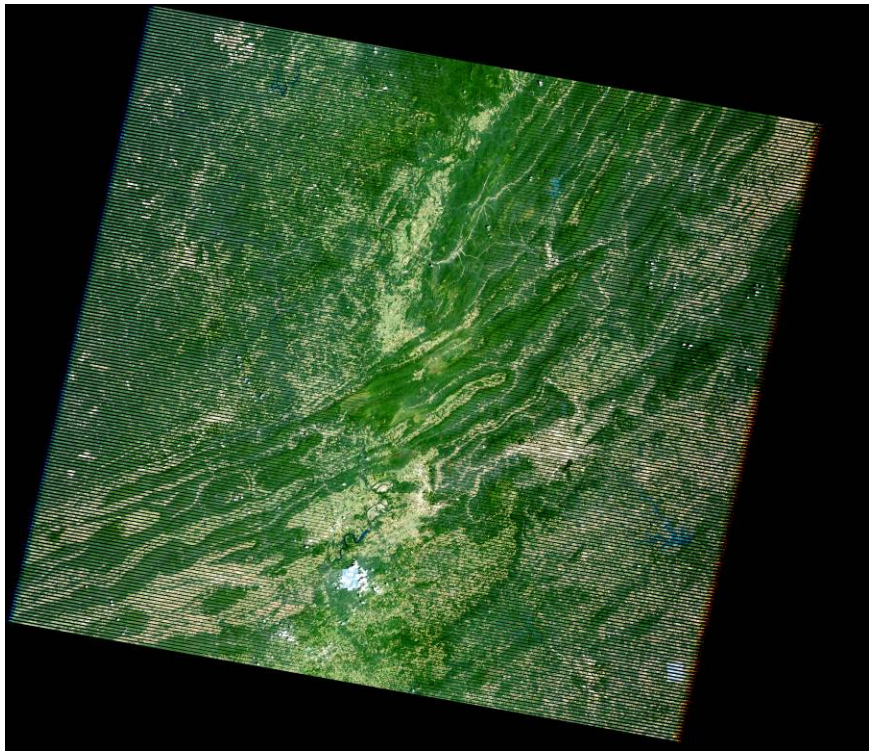
- MODIS atmosphere parameterization data define at 0.05º
  - integrated ozone amount
  - integrated water vapor amount
  - aerosol optical thickness at 550nm (urban clean model currently)
  - mean sea level pressure

(Eric Vermote)

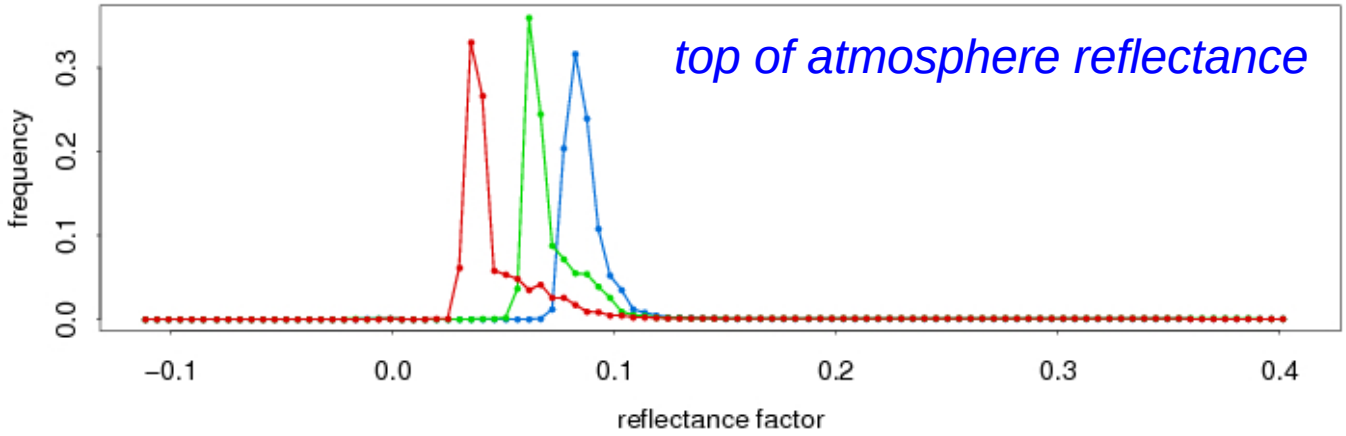
North West: Top of atmosphere Landsat ETM+ true color (red , green and blue bands); **South East:** Corresponding Surface reflectance computed using contemporaneous MODIS atmosphere parameterization data.

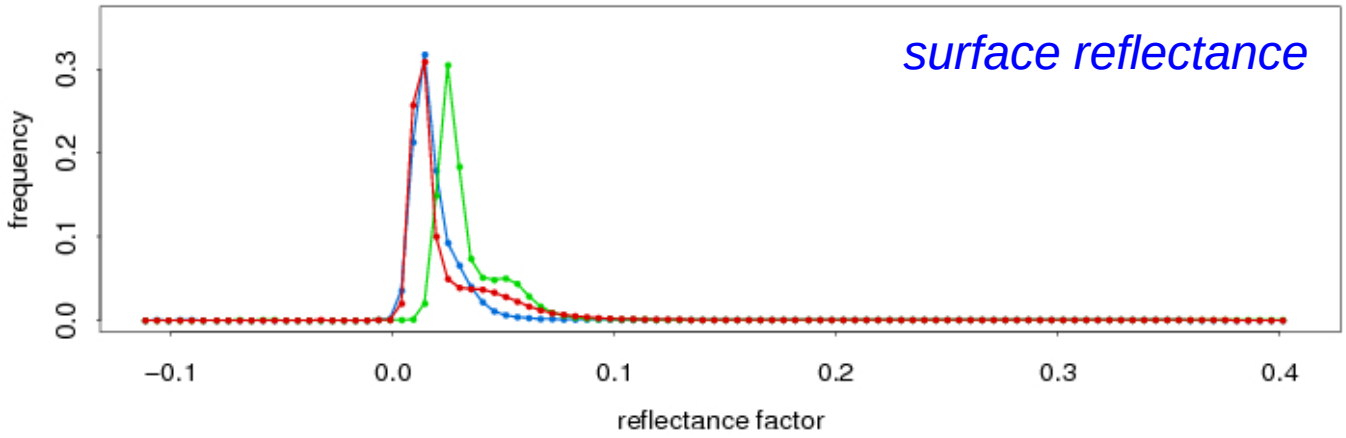
(Landsat Path 17 Row 34, Giles, Virginia, acquired July 18, 2008).





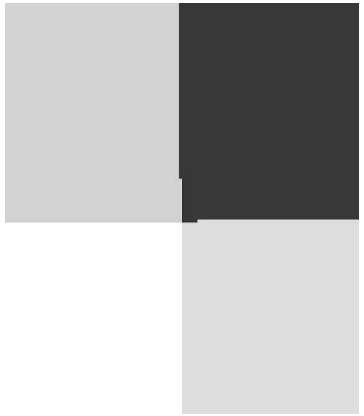
The atmospheric correction reduces visible reflectance, greatest reductions in the shorter wavelength blue band which has more atmospheric scattering, and with the green atmospherically corrected band showing greater reflectance after correction which is expected given that the scene is dominated by veg.



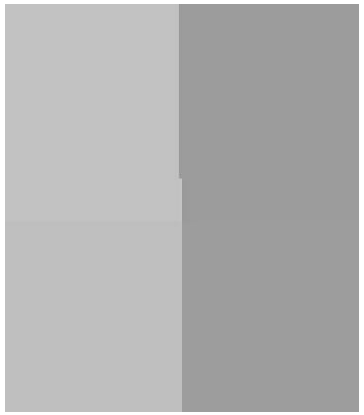


Blockiness due to 0.05° MODIS atmospheric paramerization

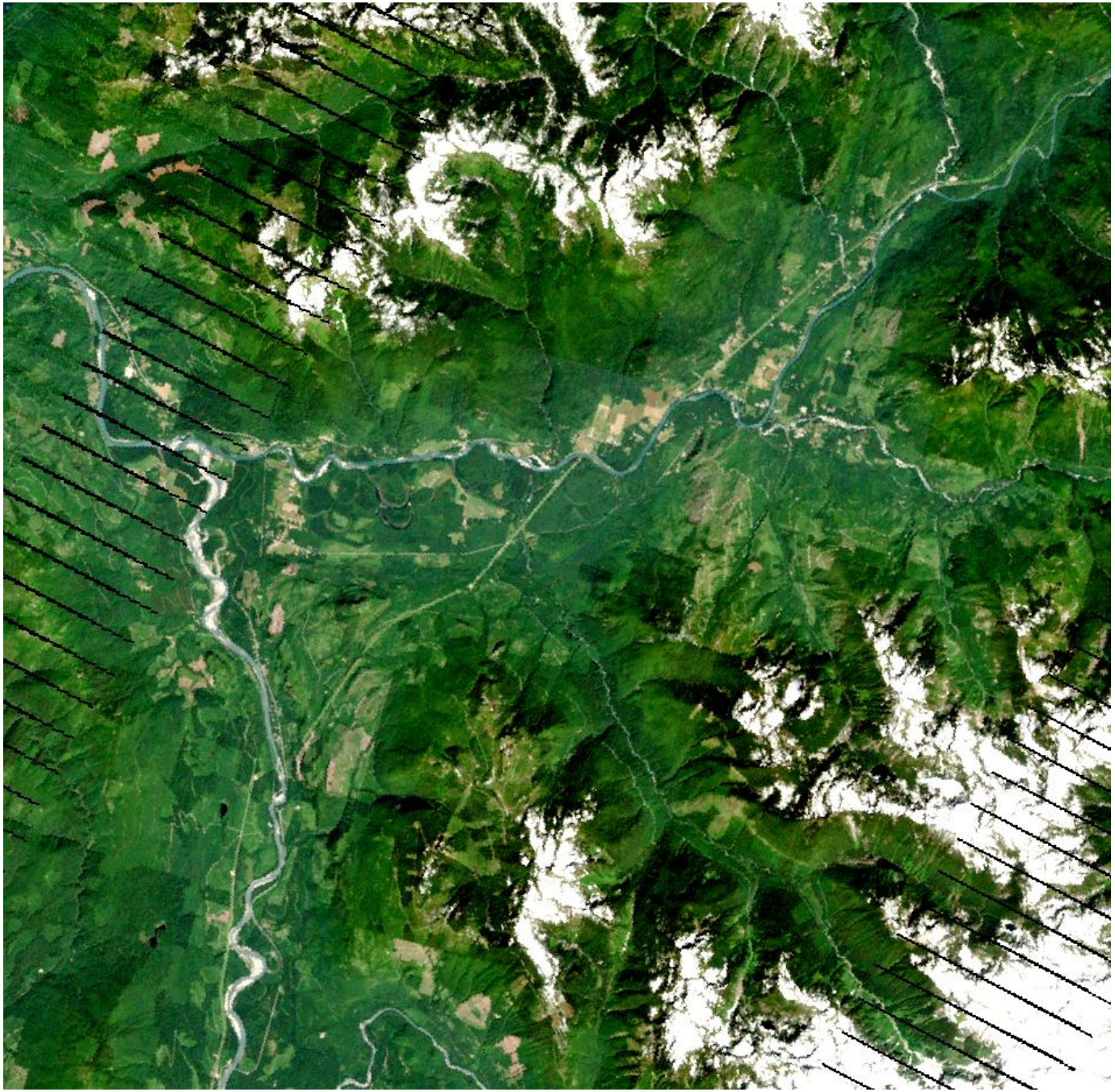
Surf reflectance true color



AOT



Water vapor

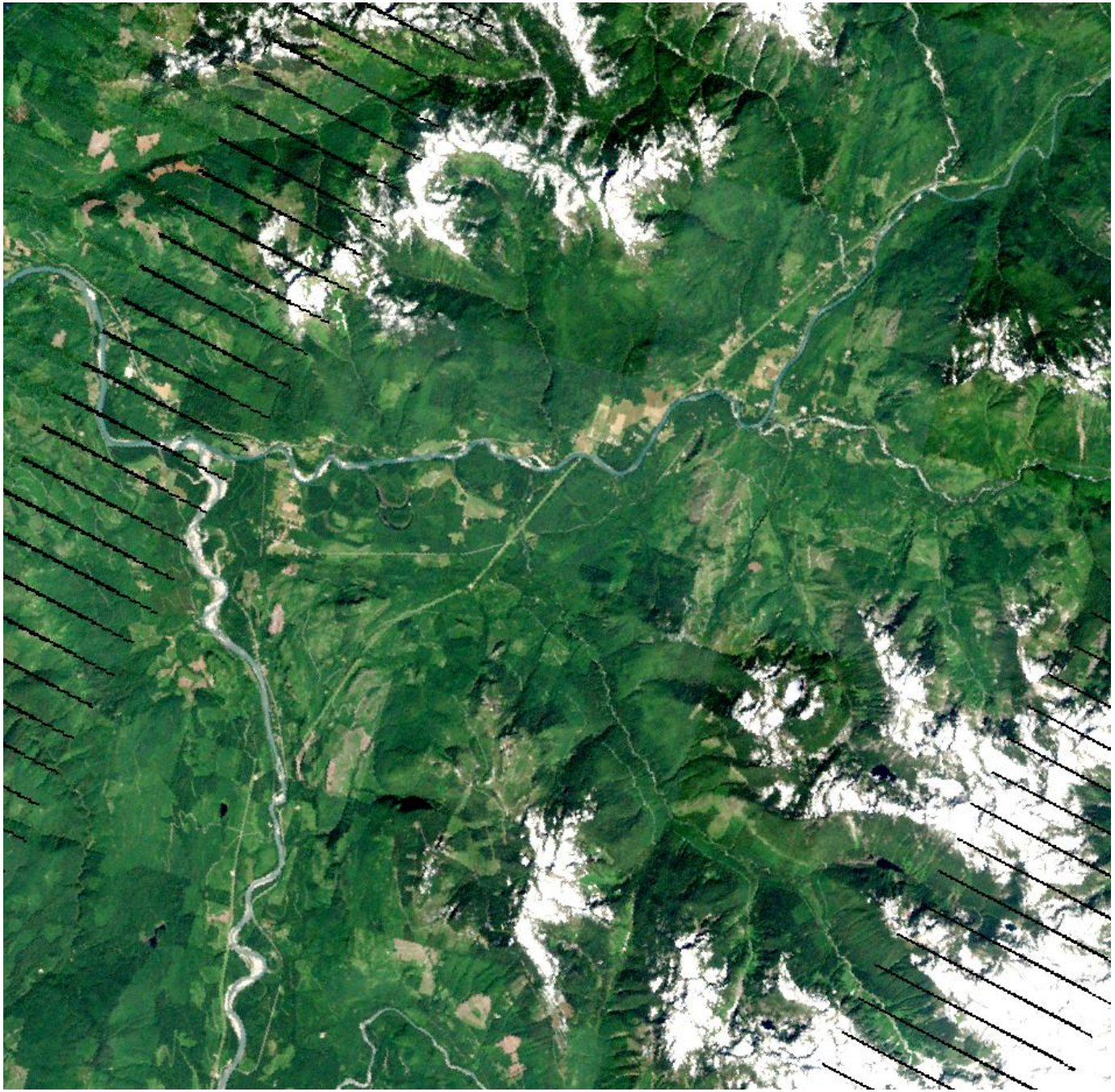


951 x 933 30m pixels, near Seattle

Landsat ETM+
July 2008 composited mosaic

Red, Green, Blue
Surface Reflectance

Computed using
contemporaneous
daily atmospheric
characterization used
to correct MODIS
&
surface pressure
parameterized for
fixed 0m elevation

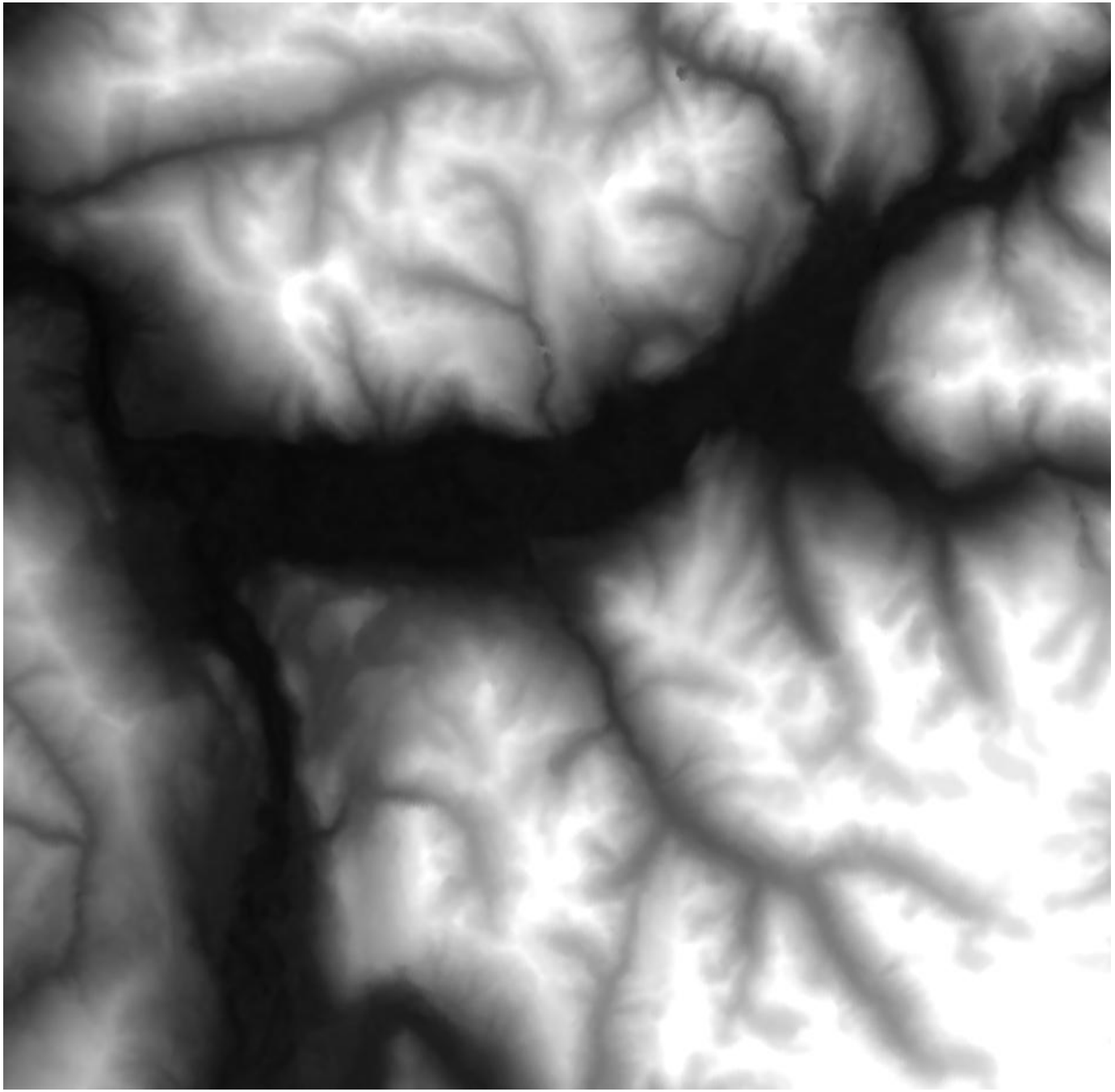


951 x 933 30m pixels, near Seattle

Landsat ETM+
July 2008 composited mosaic

Red, Green, Blue
Surface Reflectance

Computed using
contemporaneous
daily atmospheric
characterization used
to correct MODIS
&
surface pressure
parameterized from
2009 ASTER DEM



951 x 933 30m pixels, near Seattle

WELD Project
Landsat ETM+
July 2008 composited mosaic

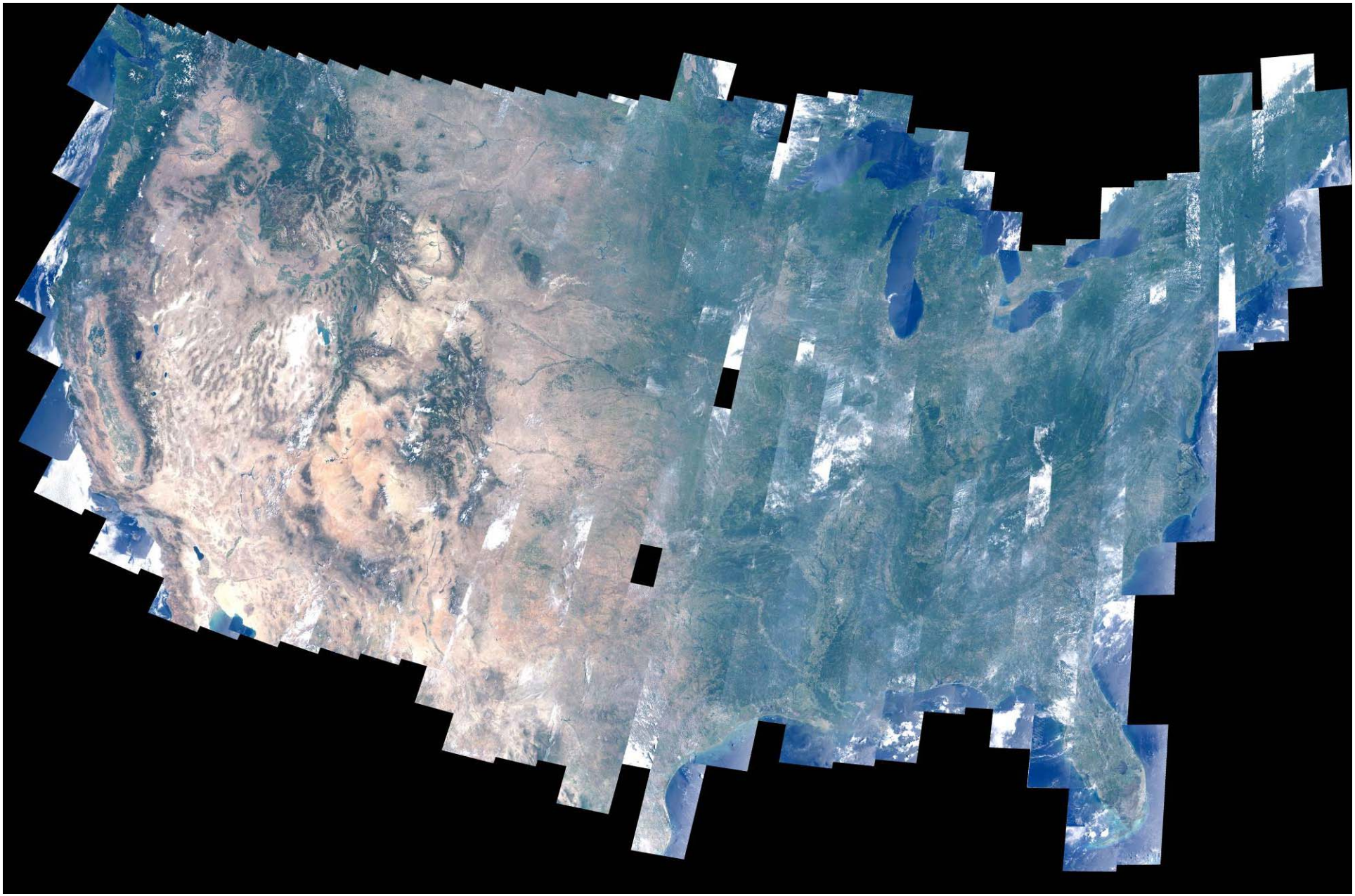
Red, Green, Blue
Surface Reflectance

Computed using
contemporaneous
daily atmospheric
characterization used
to correct MODIS
&
surface pressure
parameterized from
2009 ASTER DEM

Stable Geometry

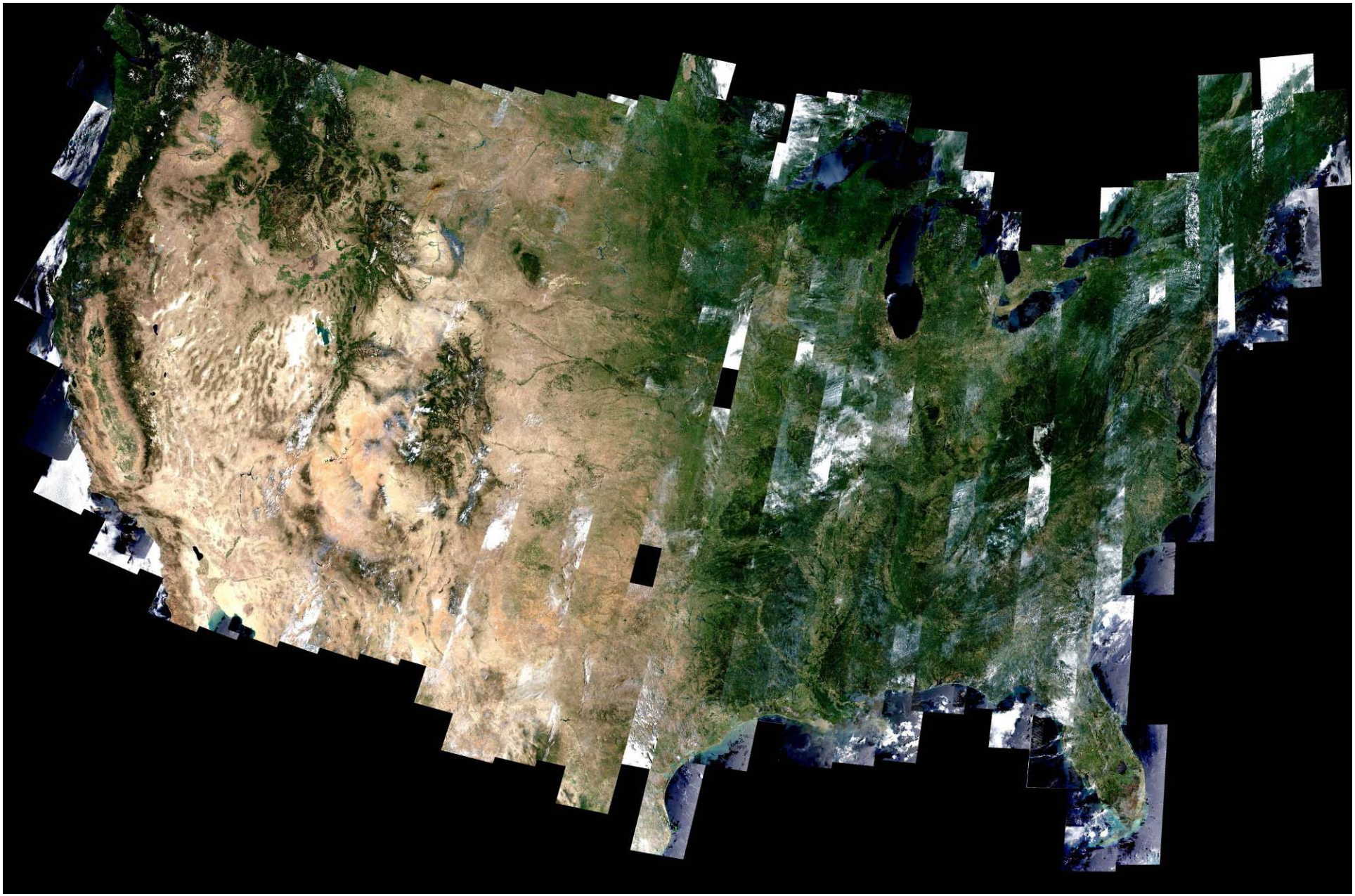
July 2008 composite. Band 3, 2, 1 (red, green, blue)

Top of Atmosphere Reflectance



July 2008 composite. Band 3, 2, 1 (red, green, blue)

Surface Reflectance – using advanced MODIS Landsat method



Landsat Missions - Mozilla Firefox

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http://landsat.usgs.gov/WELD.php

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Conterminous United States Landsat ETM+ Annual Mosaic

Web-Enabled Landsat Data (WELD) Project

Current EROS WELD Prototype Distribution

The Web-Enabled Landsat Data (WELD) project will improve the consistency and quality of Landsat Enhanced Thematic Mapper Plus (ETM+) data through a fusion with MODIS land products to systematically generate "seamless" consistent mosaicked ETM+ data sets with per-pixel quality assessment information and derived land cover characterization at monthly, seasonal, and annual time periods. The resulting high spatial resolution Landsat mosaic products will be generated for the conterminous USA and Alaska for a 7-year period and made freely available to the user community. The WELD project is funded by NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) program.

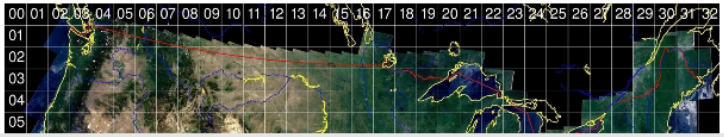
A preliminary WELD data set is available here, specifically, a 12-month annual composite of the conterminous U.S. generated from ETM+ orthorectified and terrain-corrected data acquired December 2007 to November 2008. In the future, other annual, seasonal, and monthly, mosaic data sets will be made available for evaluation by the user community. The large image below shows the ETM+ red, green, and blue wavelength bands of the annual mosaic, please click on it to see a higher-resolution version.

These data are defined with 30m pixels in the Albers Equal Area projection with standard parallels 29.5°N, 45.5°N, and central Meridian 96°W. The data are stored in Hierarchical Data Format (HDF) with HDF internal compression. HDF is a data file format designed by the National Center for Supercomputing Applications to assist users in the storage and manipulation of scientific data across diverse operating systems and machines. For example, it is used to store the standard MODIS products. In this version, each pixel has 14 bands (termed HDF science data sets) storing the information described in the Table. Future product versions will have refined processing and content, most notably atmospheric correction, radiometric/BRDF normalization, improved cloud and ETM+ SLC-off gap-filling, and land-cover characterization.

WELD Annual Mosaic Version 1.0 Product Format

Science Data Set Name	Data Type	Valid Range	Scale factor	Units	Fill Value	Notes
Band1_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	Top of atmosphere (TOA) reflectance and brightness temperature, computed using standard formulae and calibration coefficients associated with the sensed ETM+ granule. The conventional ETM+ band number scheme is used. Band 6 brightness temperature data are resampled to 30m.
Band2_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	
Band3_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	
Band4_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	
Band5_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	
Band61_TOA_REF	int16	-32767 -- 32767	100	Degrees Celsius	-32768	
Band62_TOA_REF	int16	-32767 -- 32767	100	Degrees Celsius	-32768	
Band7_TOA_REF	int16	-32767 -- 32767	10000	unitless	-32768	
NDVI_TOA	int16	-10000 -- 10000	1	unitless	-32768	Normalized Difference Vegetation Index value generated from Band3_TOA_REF and Band4_TOA_REF.
Day_Of_Year	int16	1 -- 366	1	Day	0	Day of year the selected ETM+ pixel was sensed on. Note days 1-335 were sensed in 2008 and days 336-365 were sensed in December 2007.
Saturation_Flag	uint8	0 -- 255	1	unitless	None	The least significant bit to the most significant bit corresponds to bands 1, 2, 3, 4, 5, 61, 62, 7 with a bit set to 1 signifying saturation in that band and 0 not saturated.
DT_Cloud_State	uint8	0, 1, 2, 200	1	unitless	255	Decision Tree Cloud Classification, 0 = not cloudy, 1 = cloudy, 2 = not cloudy but adjacent to a cloudy pixel, 200 = could not be classified reliably.
ACCA_State	uint8	0, 1	1	unitless	255	ACCA Cloud Classification, 0 = not cloudy, 1 = cloudy.
Num_Of_Obs	uint8	0 -- 255	1	unitless	None	Number of ETM+ observations considered over the 12 months.

The data are stored in tiles of 5000 x 5000 30m pixels. There are a total of 513 land tiles referenced using a two digit horizontal (HH) and vertical (VV) tile coordinate system reflected in the filename as conus.hHHvVV.2007dec-2008nov.v1.0.hdf. The image below illustrates the tile coordinate system, please click on it to see a higher-resolution version.



A tile location tool is provided to locate pixels and tiles for given longitude and latitude coordinates. The tool is available for computers running Unix/Linux operating systems, the C source code and installation instructions can be downloaded **HERE**. A web-interface version of this tool will be available shortly. In addition, for each tile there is a static conus.hHHvVV.coordinates.hdf file that contains the geographic latitude and longitude for the center of each 30m pixel (datum WGS84).

WELD Static Latitude and Longitude Product Format

Science Data Set Name	Data Type	Valid Range	Scale factor	Units	Fill Value	Notes
Longitude	float32	-180 -- 180	1	Decimal degrees	None	Longitude
Latitude	float32	-90 -- 90	1	Decimal degrees	None	Latitude

The tile data are available from this EROS web site by clicking HERE.

Note that each mosaic tile is typically 240MB and the total size of all 513 mosaic tiles is 108GB, and that each static geographic latitude and longitude file is typically 110 MB and the total size of all 513 tiles is 54GB.

The WELD project is a collaboration between the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center and its academic partner, the South Dakota State University Geographic Information Science Center of Excellence (GIScCE). The processing, based on heritage techniques and contemporaneous fusion of MODIS land products, is being prototyped at the GIScCE with planned systematic processing to be undertaken at EROS. The WELD data products will be updated in near real time and made available to the user community through a modified EROS internet distribution interface. This is a 5-year proposal funded by the NASA MEaSUREs program with significant USGS cost sharing. The aim of the MEaSUREs program is to support projects providing services and consistent long-term Earth science data products driven by NASA's Earth science goals and contributing to advancing NASA's "missions to measurements" concept. The WELD project contributes to the Land measurement theme. For more information on the WELD project and products please contact **David Roy**.

Geographic Information Science
Center of Excellence
South Dakota State University

WELD Product Distribution

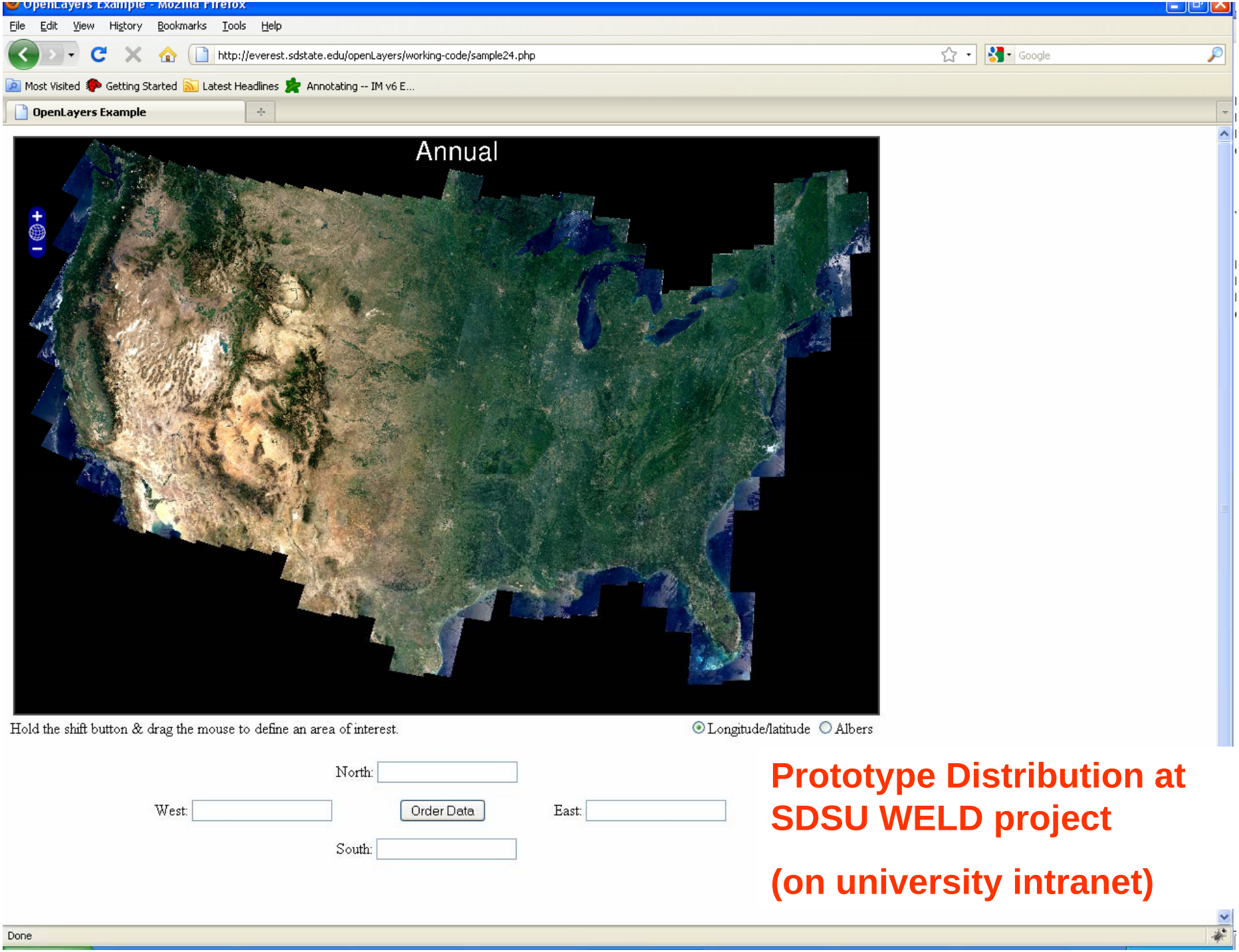
- Need a dedicated interface to distribute WELD products out of EROS; this will need to be behind the same fire-wall as the WELD production system when it is migrated to EROS

- Simple & Intuitive Interface
- What You See Is What You Get (WYSIWG)

- Pan & Zoom against browse product of interest
  - Region (CONUS/Alaska)
  - Year (2007,2008,….)
  - Composited period (monthly/seasonal/annual)

- Order *any* arbitrary rectangular area up to 2GB file size
  - Rubber band box selection
  - Geographic or Albers coordinates

- Distribution prototype already developed at SDSU



Prototype Distribution at SDSU WELD project

(on university intranet)

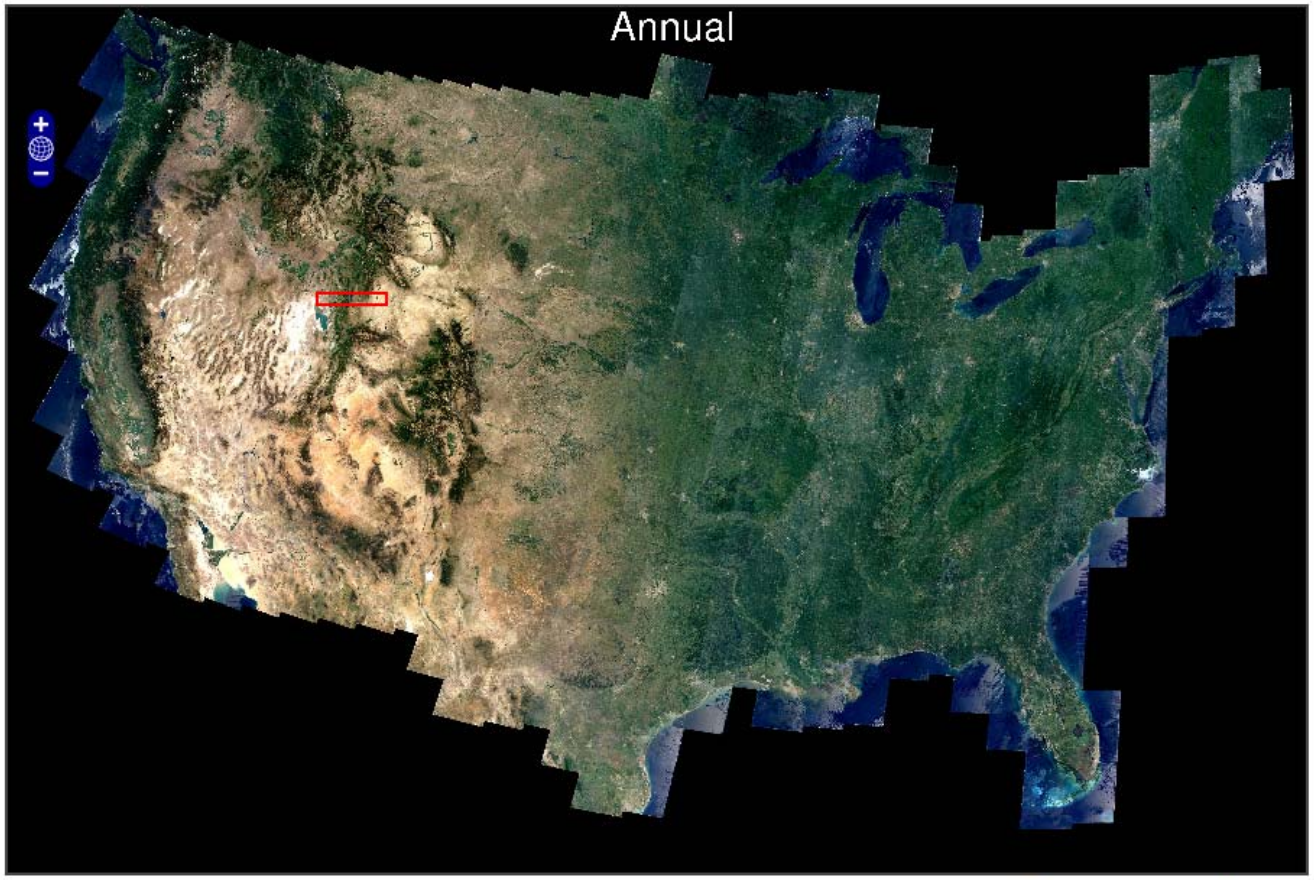
OpenLayers Example - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://everest.sdstate.edu/openLayers/working-code/sample24.php

Most Visited Getting Started Latest Headlines Annotating -- IM v6 E...

OpenLayers Example



Hold the shift button & drag the mouse to define an area of interest.

Longitude/latitude Albers

North: 2229784.226425

West: -1389426.759940 Order Data East: -1139444.321430

South: 2196040.100290

Done

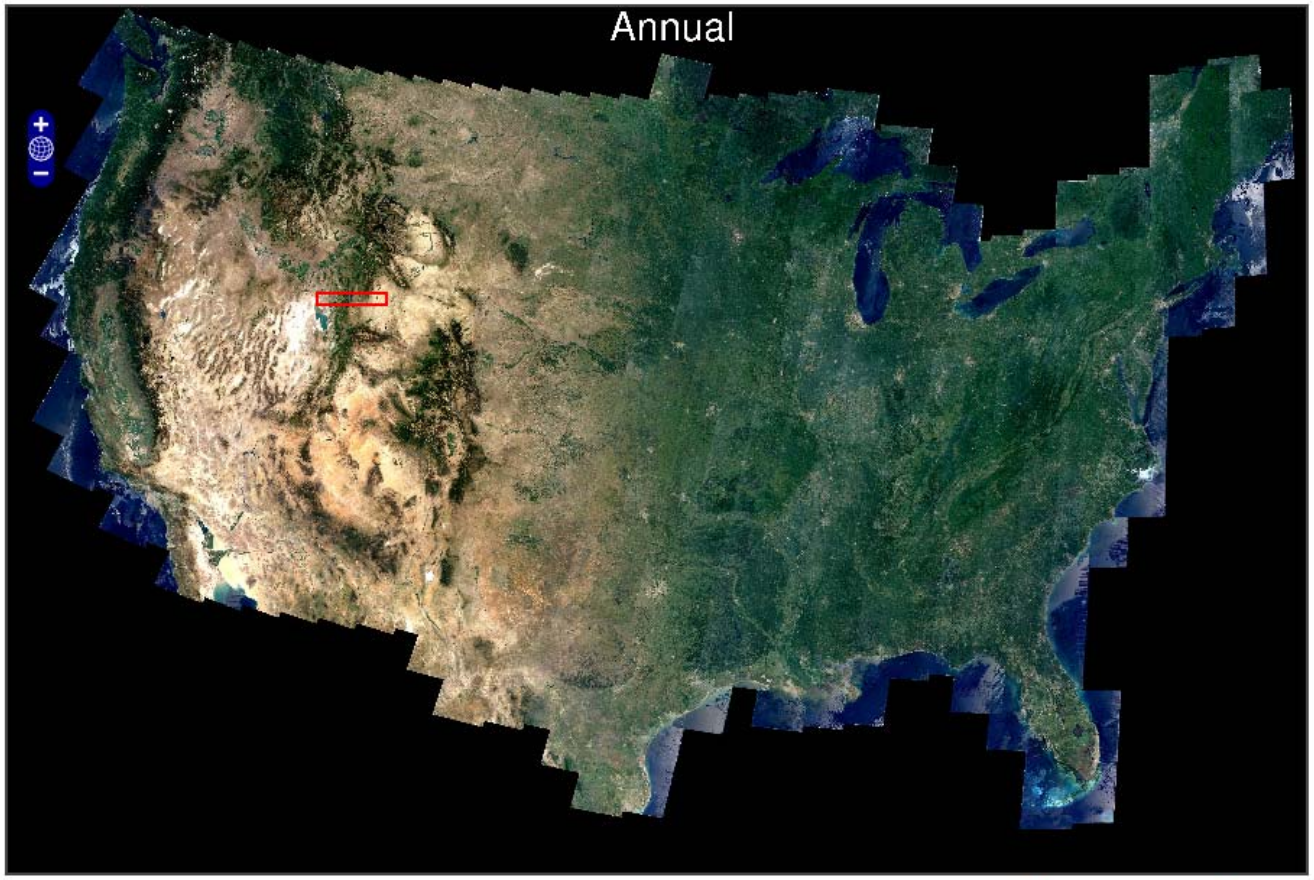
OpenLayers Example - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://everest.sdstate.edu/openLayers/working-code/sample24.php

Most Visited Getting Started Latest Headlines Annotating -- IM v6 E...

OpenLayers Example



Hold the shift button & drag the mouse to define an area of interest.

Longitude/latitude Albers

North: 42.313050

West: -112.895044 Order Data East: -109.963184

South: 41.654062

Done

OpenLayers Example - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://everest.sdstate.edu/openLayers/working-code/sample24.php

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Done

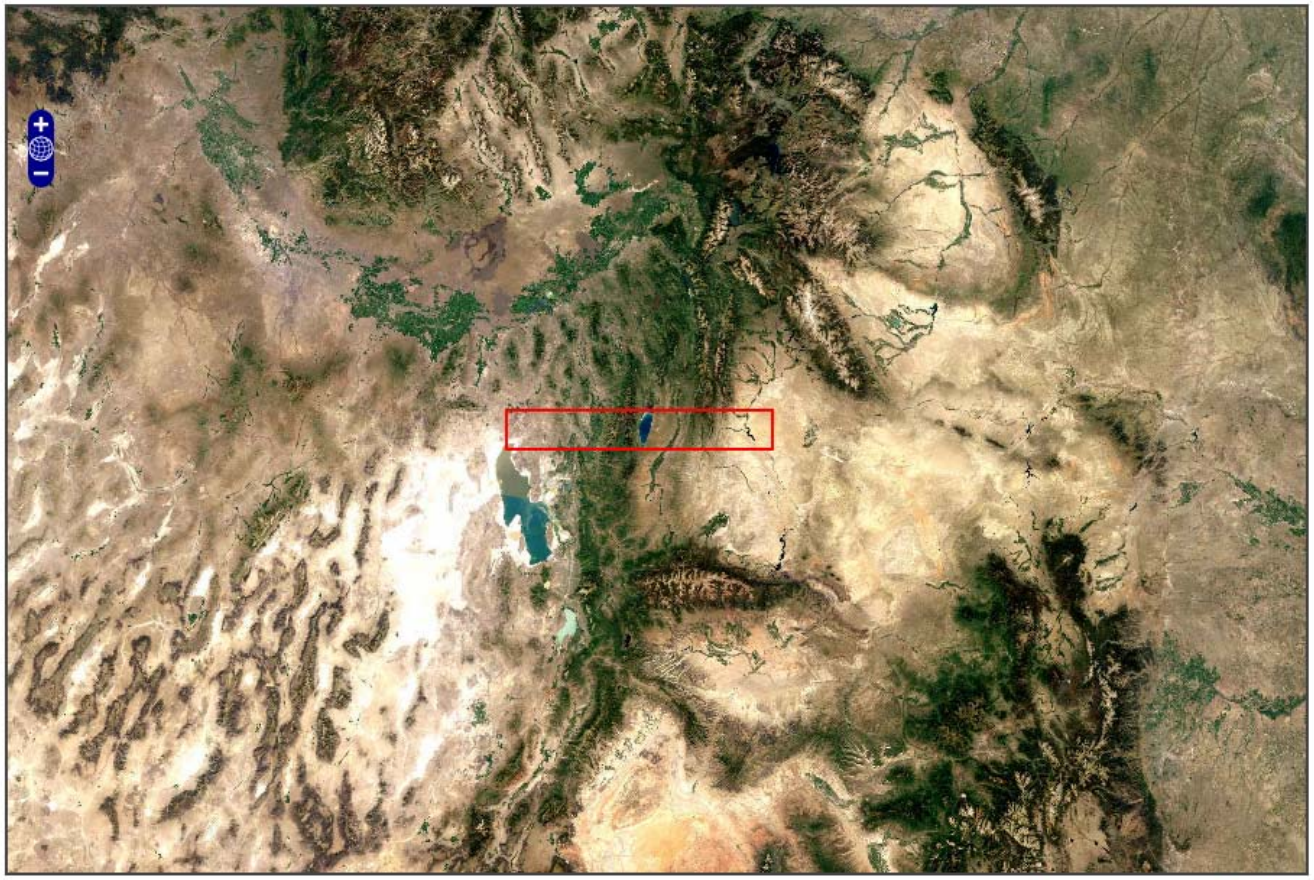
OpenLayers Example - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://everest.sdstate.edu/openLayers/working-code/sample24.php

Most Visited Getting Started Latest Headlines Annotating -- IM v6 E...

OpenLayers Example



Hold the shift button & drag the mouse to define an area of interest.

Longitude/latitude Albers

North: 42.313050

West: -112.895044 Order Data East: -109.963184

South: 41.654062

Done

OpenLayers Example - Mozilla Firefox

File Edit View History Bookmarks Tools Help

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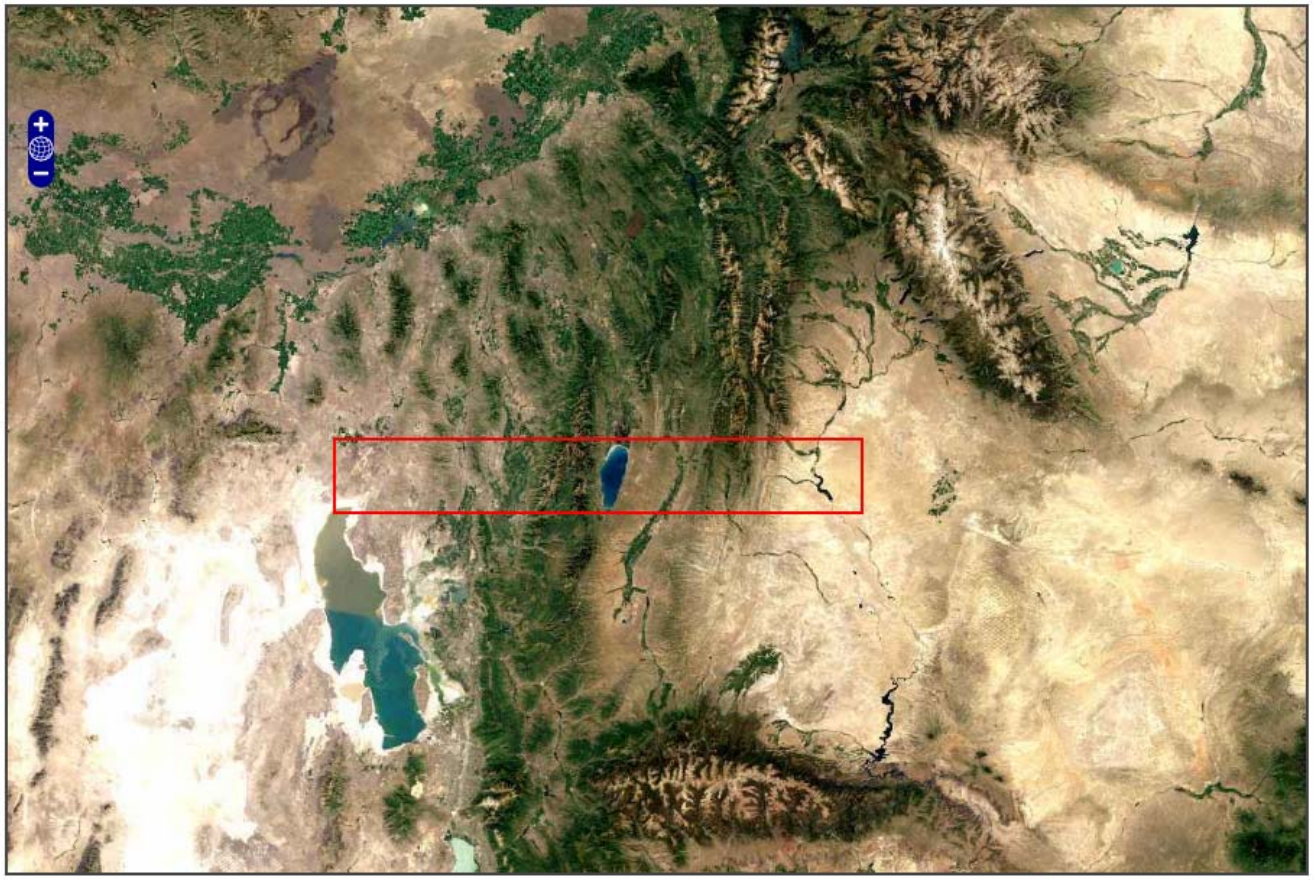
OpenLayers Example



Hold the shift button & drag the mouse to define an area of interest.

Longitude/latitude Albers

North: 42.313050

West: -112.895044 Order Data East: -109.963184

South: 41.654062

Done

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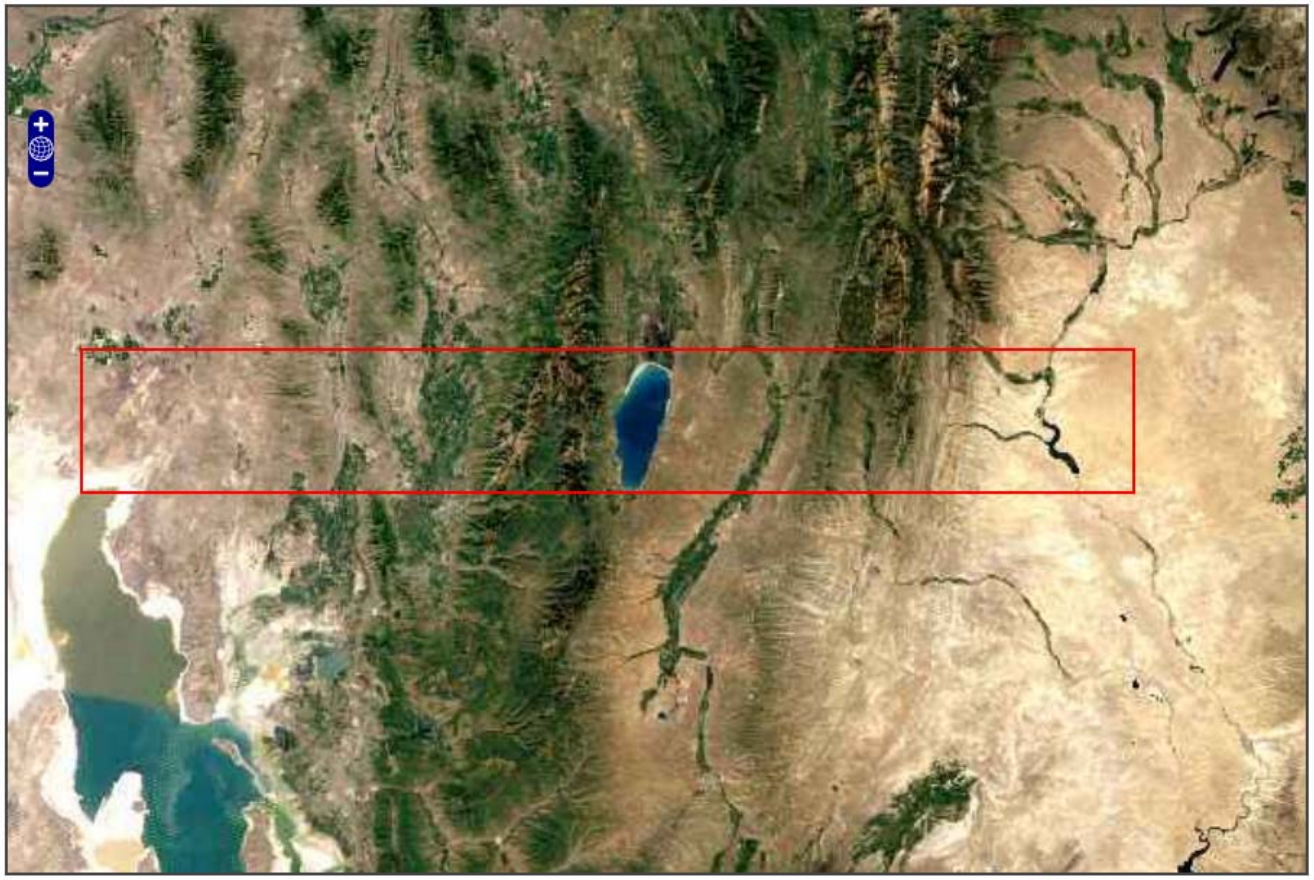
OpenLayers Example



Hold the shift button & drag the mouse to define an area of interest.

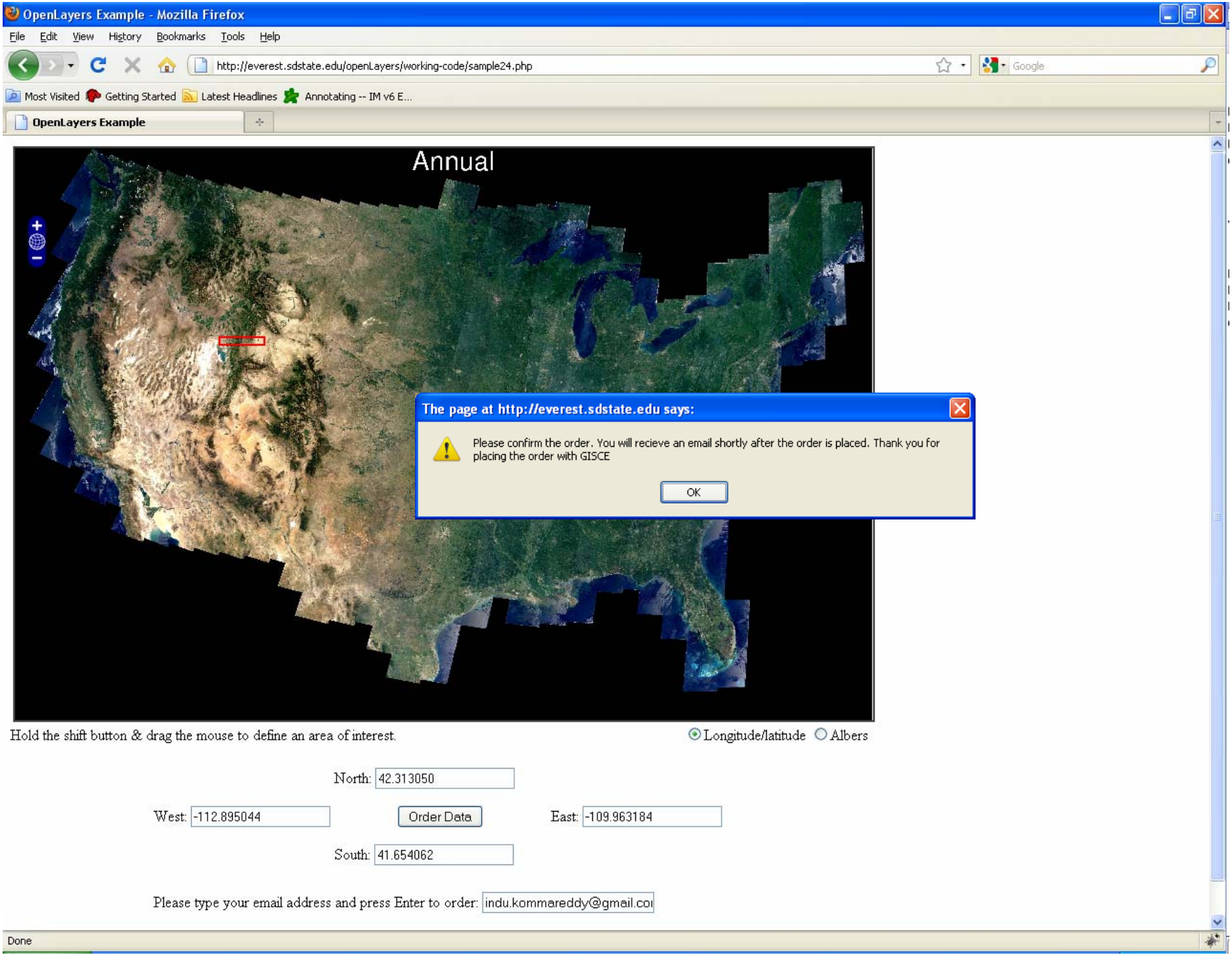
Longitude/latitude Albers

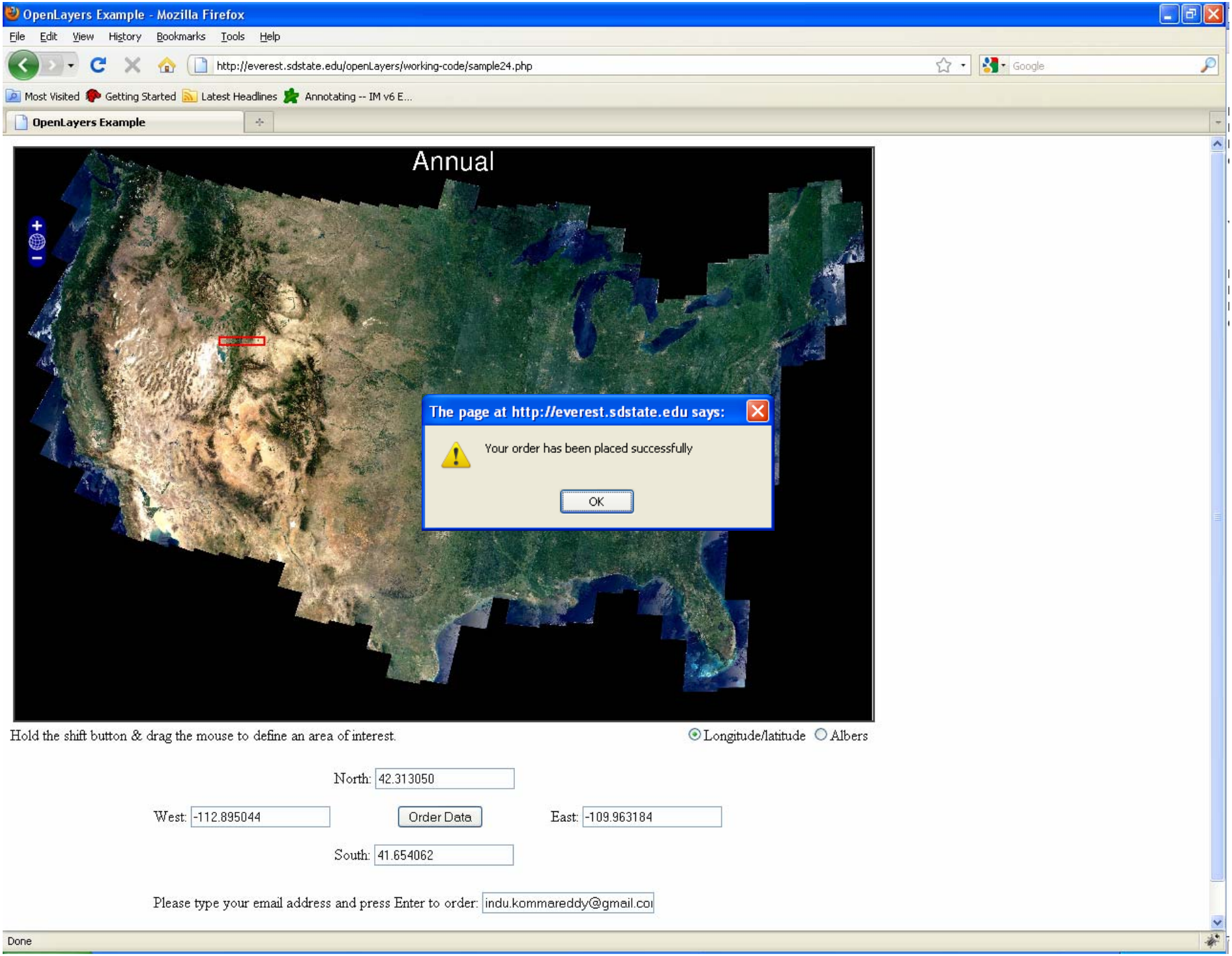
North: 42.313050

West: -112.895044 Order Data East: -109.963184

South: 41.654062

Done


OpenLayers Example - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://everest.sdstate.edu/openLayers/working-code/sample24.php
Most Visited Getting Started Latest Headlines Annotating -- IM v6 E...
OpenLayers Example
Annual
The page at http://everest.sdstate.edu says:
Please confirm the order. You will recieve an email shortly after the order is placed. Thank you for placing the order with GISCE
OK
Hold the shift button & drag the mouse to define an area of interest.
Longitude/latitude
Albers
North: 42.313050
West: -112.895044
Order Data
East: -109.963184
South: 41.654062
Please type your email address and press Enter to order: indu.kommareddy@gmail.co
Done


OpenLayers Example - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://everest.sdstate.edu/openLayers/working-code/sample24.php
Most Visited Getting Started Latest Headlines Annotating -- IM v6 E...
OpenLayers Example
Annual
The page at http://everest.sdstate.edu says:
Your order has been placed successfully
OK
Hold the shift button & drag the mouse to define an area of interest.
Longitude/latitude
Albers
North: 42.313050
West: -112.895044
Order Data
East: -109.963184
South: 41.654062
Please type your email address and press Enter to order: indu.kommareddy@gmail.co
Done

« Back to Inbox | Archive | Report spam | Delete | Move to ▾ | Labels ▾ | More actions ▾

GISCe Product request

Inbox | X

Indrani Kommareddy to me — show details 2:34 PM (3 minutes ago) — Reply

---

Dear Landsat WELD user,

Your order for CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf has been placed.

Thank you.

Reply | Forward

43 deleted messages in this conversation. View messages or delete forever.

« Back to Inbox | Archive | Report spam | Delete | Move to ▾ | Labels ▾ | More actions ▾

Order Notification

Inbox | X

Indrani Kommareddy to me — show details 2:34 PM (4 minutes ago) — Reply

---

Dear Landsat WELD user,

Your order for:
CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf

has been processed and is available at the following ftp site:

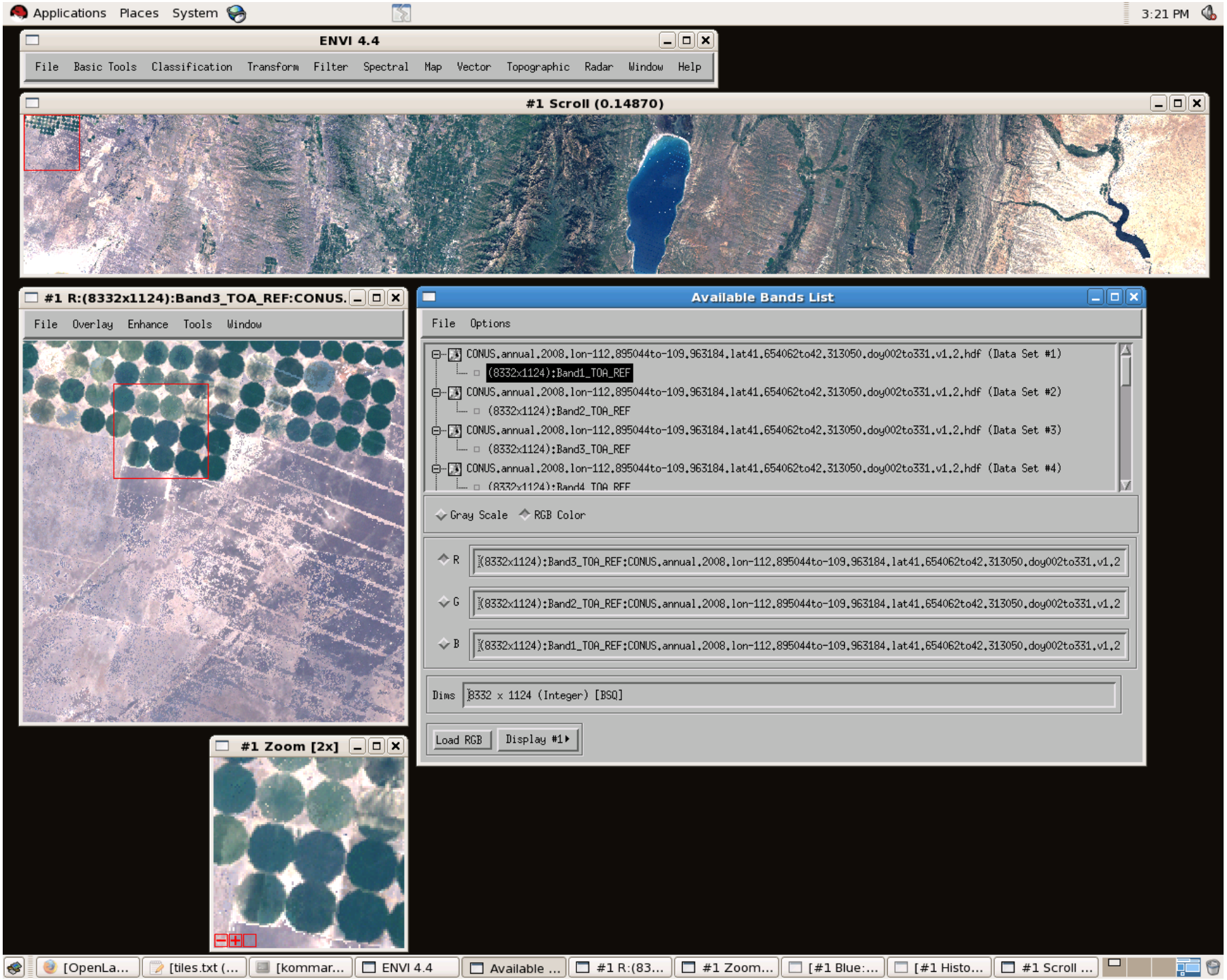
/everest/weld5/www/html/openLayers/temp.temp/sFbjuz/

You have 4 days to retrieve this order before it is removed from the ftp server.

Thank you,

Reply Forward

43 deleted messages in this conversation. View messages or delete forever.


Applications
Places
System
3:21 PM
ENVI 4.4
File
Basic Tools
Classification
Transform
Filter
Spectral
Map
Vector
Topographic
Radar
Window
Help
#1 Scroll (0.14870)
#1 R:(8332x1124):Band3_TOA_REF:CONUS.
File
Overlay
Enhance
Tools
Window
#1 Zoom [2x]
Available Bands List
File
Options
CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf (Data Set #1)
(8332x1124):Band1_TOA_REF
CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf (Data Set #2)
(8332x1124):Band2_TOA_REF
CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf (Data Set #3)
(8332x1124):Band3_TOA_REF
CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2.hdf (Data Set #4)
Gray Scale
RGB Color
R
(8332x1124):Band3_TOA_REF:CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2
G
(8332x1124):Band2_TOA_REF:CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2
B
(8332x1124):Band1_TOA_REF:CONUS.annual.2008.lon-112.895044to-109.963184.lat41.654062to42.313050.doy002to331.v1.2
Dims
8332 x 1124 (Integer) [BSQ]
Load RGB
Display #1
[OpenLa...
[tiles.txt (...
[kommar...
ENVI 4.4
Available ...
#1 R:(83...
#1 Zoom...
[#1 Blue:...
[#1 Histo...
#1 Scroll ...

Weld Products (may change after community feedback)
ETM+ composited mosaics for all CONUS & Alaska, 7 years

Monthly Composite	Seasonal (3 month) Composite	Annual Composite
Surface reflectance: 6 ETM+ 30m reflective λ bands	*As monthly but no land cover characterization*	*As monthly*
Brightness temperature: 2 ETM+ resampled 30m thermal λ bands		
NDVI		
Band saturation		
Cloud masks: ACCA & classificiation tree		
Day of year selected		
Number of observations considered		
QA & algorithm processing path		
Land cover characterization: % Tree, % Herbaceous, % H_20 % Bare Ground, %Snow / Ice		

Products will be updated at the pixel level as the ETM+ data are acquired and processed

What the Landsat user community ultimately wants …

- Derived data products for free

- Systematic, consistent, community endorsed data processing
  - calibration, geolocation
  - radiometric normalization / BRDF correction, atmospheric correction
  - cloud-screened, snow-screened, SLC-off gap filling
  - needed in order to derive higher level bio/geophysical products

- Composited large-area data product mosaics
  - updated at the pixel level
  - using all the Landsat data, not just select acquisitions
  - processed shortly after acquisition i.e. “near real time”

- A long term Landsat data product record

- *Similar to the NASA MODIS land products but at high spatial resolution*

- *Above is what this 5 year NASA funded project is seeking to achieve, building on our 10 year MODIS Land product development, processing (and reprocessing) experience.*

Roy, D.P., Ju, J., Kline, K., Scaramuzza, P.L., Kovalskyy, V., Hansen, M.C., Loveland, T.R., Vermote, E.F., Zhang, C., Web-enabled Landsat Data (WELD): Landsat ETM+ Composited Mosaics of the Conterminous United States, *Remote Sensing of Environment,* In Press.

Response to Reviewer # 3 Comment

Thanks for the comment we have added to the conclusion:

"The generation of long-term Landsat data records, for example from 1972 to present, and at continental to global scale, is technically feasible using the approach described in this paper but will be constrained primarily by Landsat data access and the ability to calibrate and geolocate the data in a consistent manner.

The planned Landsat Data Continuity Mission (LDCM) will provide an opportunity to continue the development of such a long-term large-area data record. "