Web-enabled Landsat data (WELD) Project Status

a US$3.3 million 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, USA

Landsat Science Team Meeting, January 19-21, 2010

Computer History Museum, 1401 N Shoreline Boulevard, Mountain View, CA 94043

What the Landsat user community wants …

- Derived Landsat 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.*

Proposed Weld Products

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

Monthly Composite	Seasonal (3 month) Composite	Annual Composite

Presentation Overview: WELD Status

- Product Availability
- Production System
- Some recent algorithm developments
- Distribution System
- 2010 schedule for WELD port to EROS

WELD Product Availability

- http://landsat.usgs.gov/WELD.php
- Version 1.3 placed online January 15th 2010
- One year: 2008 (December 2007 – November 2008)
  - CONUS
  - Alaksa
  - Annual, Seasonal, Monthly composited mosaics
  - 2.6TB

Landsat Missions - Mozilla Firefox

File Edit View History Bookmarks Tools Help

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

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Web-enabled Landsat data (WELD) Project

The WELD project is systematically generating 30 m composited Landsat ETM+ mosaics at weekly, monthly, seasonal and annual time periods for the conterminous USA (CONUS) and Alaska. The composited mosaics are designed to provide consistent Landsat data that can be used to derive land cover and geo physical and bio physical products for regional assessment of surface dynamics and to study Earth system functioning.

Version 1.3 of the WELD monthly, seasonal and annual products generated from Landsat ETM+ terrain corrected (Level 1T) data with cloud cover ≤80% sensed December 2007 to November 2008 are available here.

WELD Browse Imagery

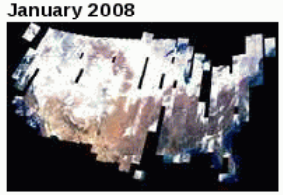
The thumbnail images below illustrate the currently available Version 1.3 WELD data products, please click on them to see a higher resolution version. These true color browse images show the Landsat ETM+ red, green and blue wavelength bands at approximately 500 m resolution.

CONUS Annual

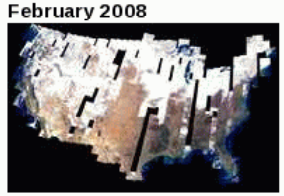
Winter

December 2007

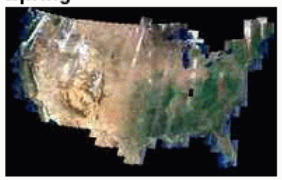
January 2008



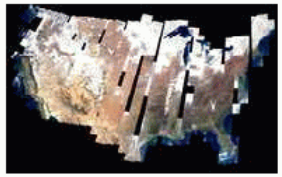
February 2008



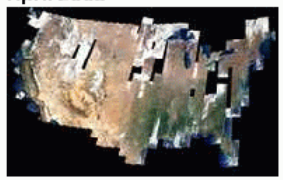
Spring



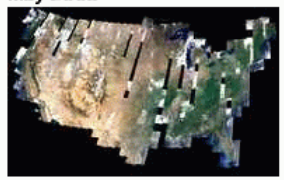
March 2008



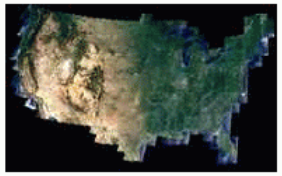
April 2008



May 2008

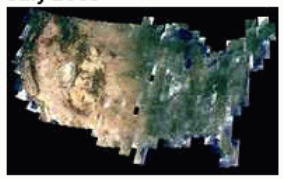


Summer

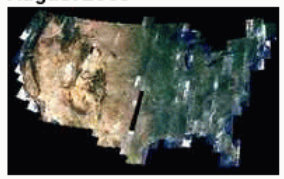


June 2008

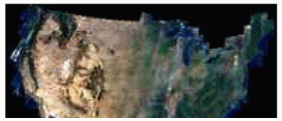
July 2008



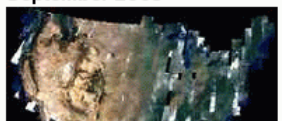
August 2008



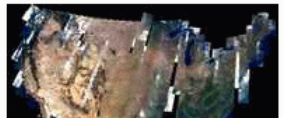
Autumn



September 2008



October 2008



November 2008

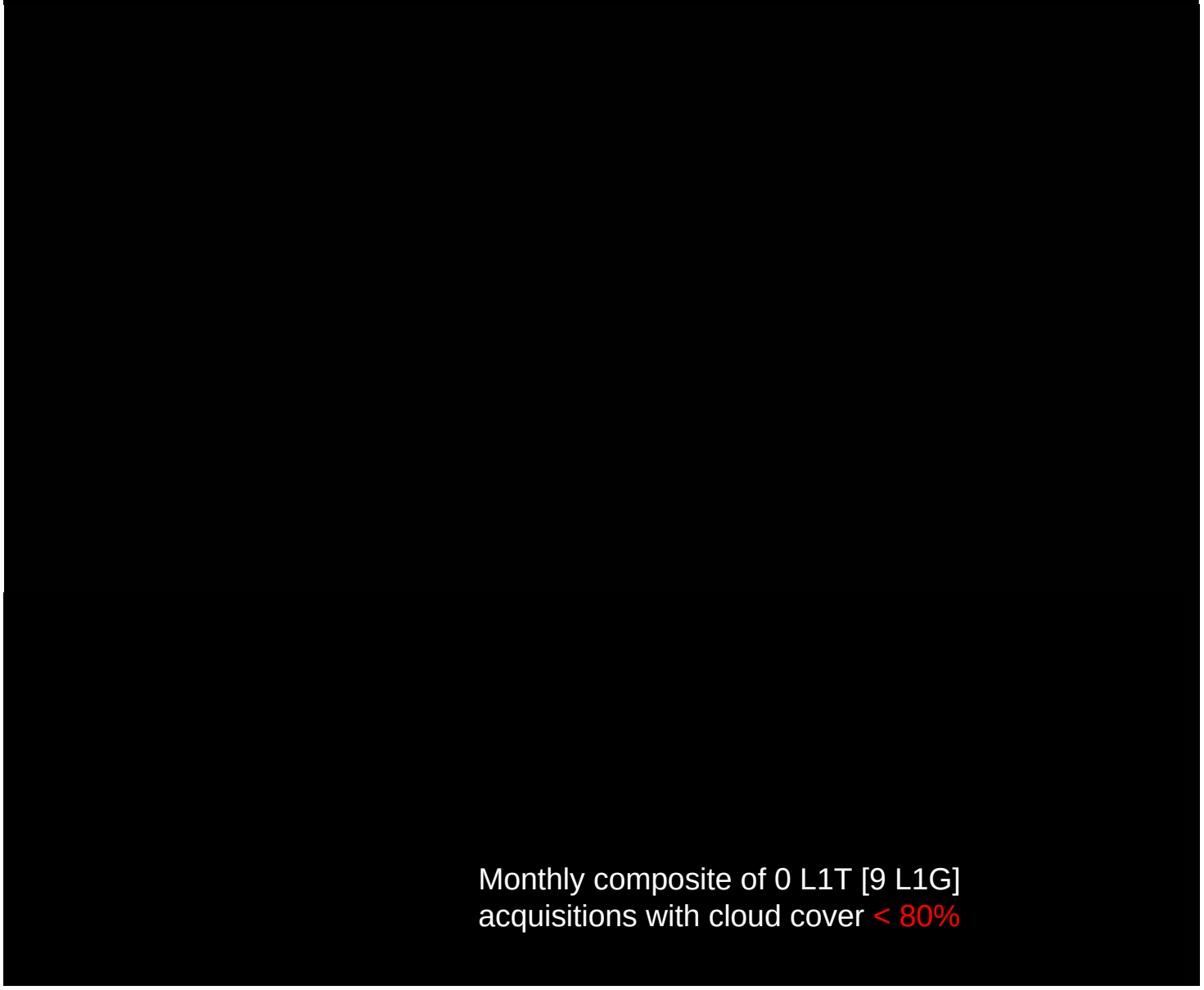
Version 1.3 WELD Product Format (all pixels are 30m)

Science Data Set Name	Data Type	Valid Range	Scale factor	Units	Fill Value
Band1_TOA_REF	int16	-32767 -- 32767	10000	Unitless	-32768
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_BT	int16	-32767 -- 32767	100	Degrees Celsius	-32768
Band62_TOA_BT	int16	-32767 -- 32767	100	Degrees Celsius	D-32768
Band7_TOA_REF	int16	-32767 -- 32767	10000	Unitless	-32768
NDVI_TOA	int16	-10000 -- 10000	10000	Unitless	-32768
Day_Of_Year	int16	1 -- 366	1	Day	0
Saturation_Flag	uint8	0 -- 255	1	Unitless	None
DT_Cloud_State	uint8	0, 1, 2, 200	1	Unitless	255
ACCA_State	uint8	0, 1	1	Unitless	255
Num_Of_Obs	uint8	0 -- 255	1	Unitless	None
Sensor_Zenith	int16	0 -- 9000	100	Degrees	-32768
Sensor_Azimuth	int16	-18000 -- 18000	100	Degrees	-32768
Solar_Zenith	int16	0 -- 9000	100	Degrees	-32768
Solar_Azimuth	int16	-18000 -- 18000	100	Degrees	-32768

Each WELD file ~300MB

Alaska December 2007

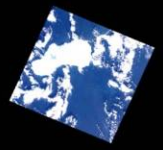
500m Browse (4118x5000 pixels)



Monthly composite of 0 L1T [9 L1G]
acquisitions with cloud cover < 80%

Alaska January 2008

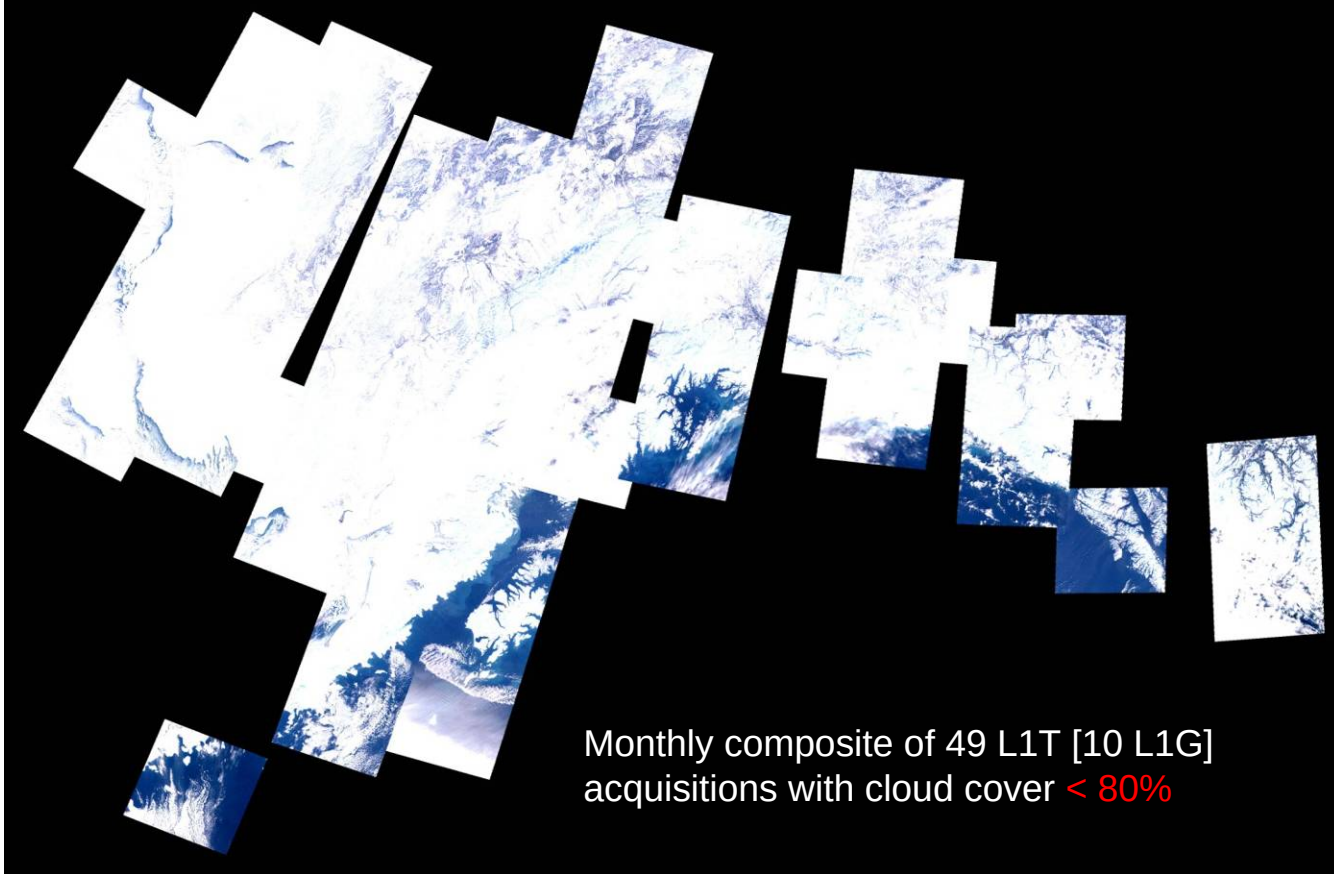
500m Browse (4118x5000 pixels)



Monthly composite of 2 L1T [0 L1G]
acquisitions with cloud cover < 80%

Alaska February 2008

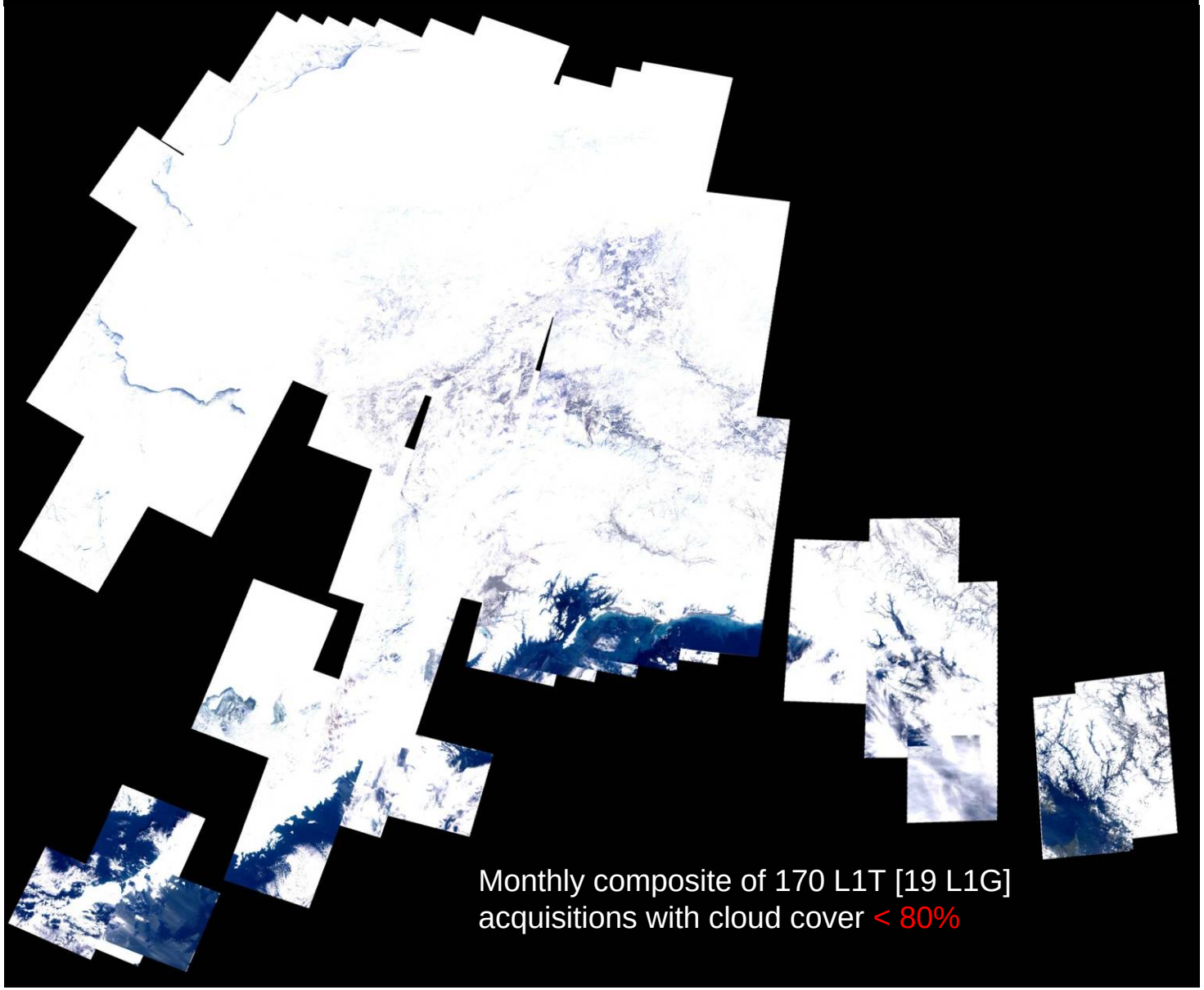
500m Browse (4118x5000 pixels)



Monthly composite of 49 L1T [10 L1G] acquisitions with cloud cover < 80%

Alaska March 2008

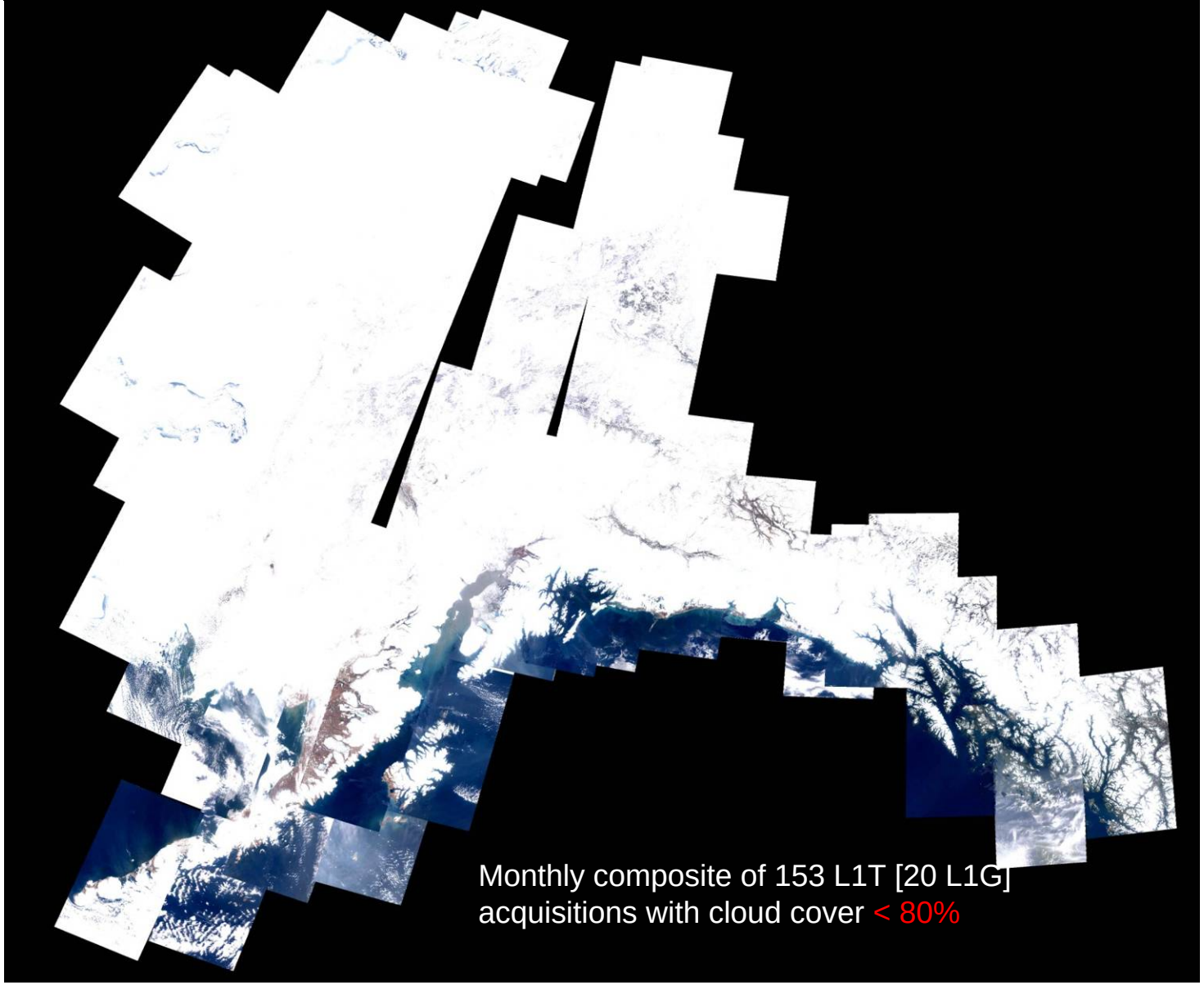
500m Browse (4118x5000 pixels)



Monthly composite of 170 L1T [19 L1G]
acquisitions with cloud cover < 80%

Alaska April 2008

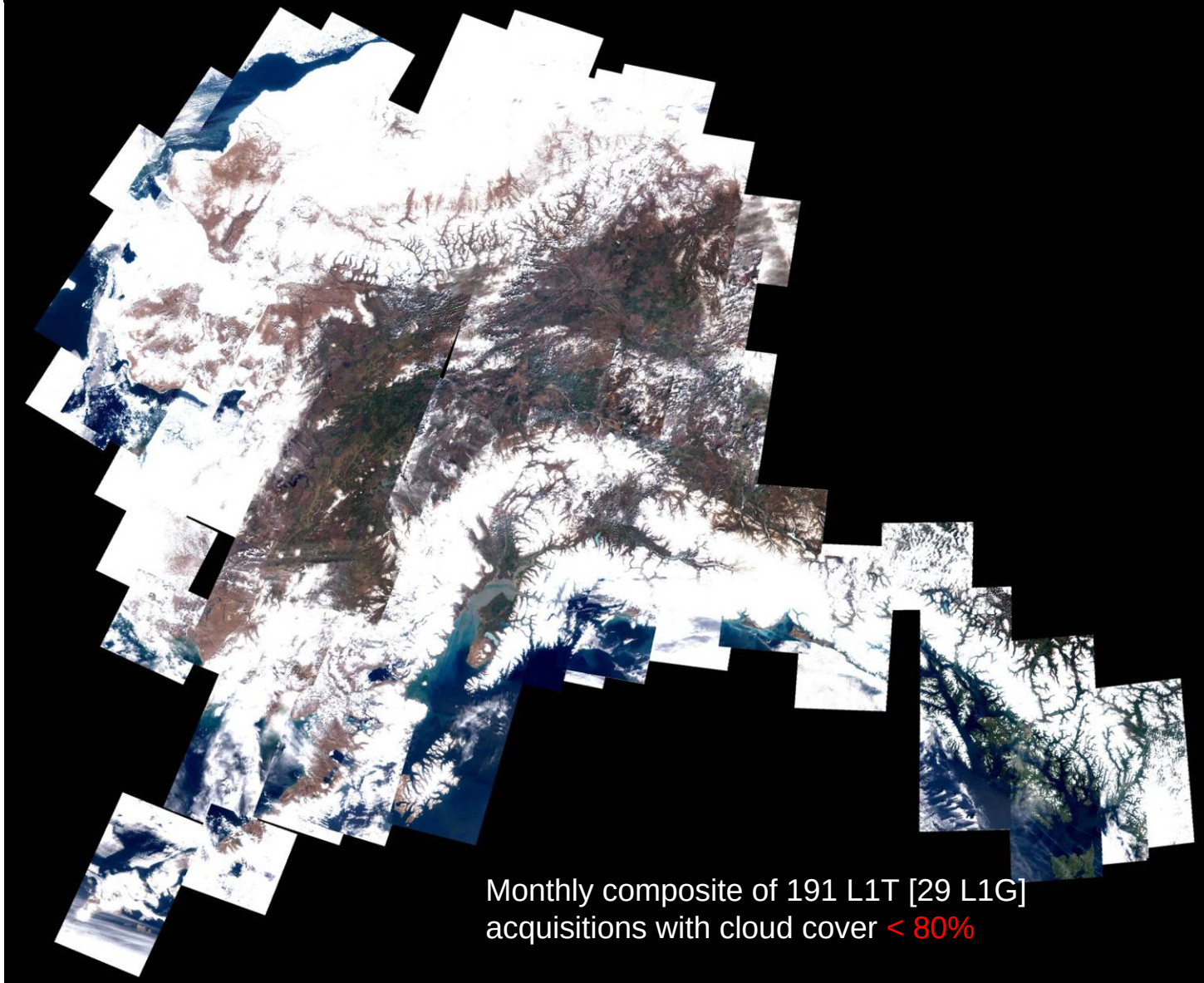
500m Browse (4118x5000 pixels)



Monthly composite of 153 L1T [20 L1G] acquisitions with cloud cover < 80%

Alaska May 2008

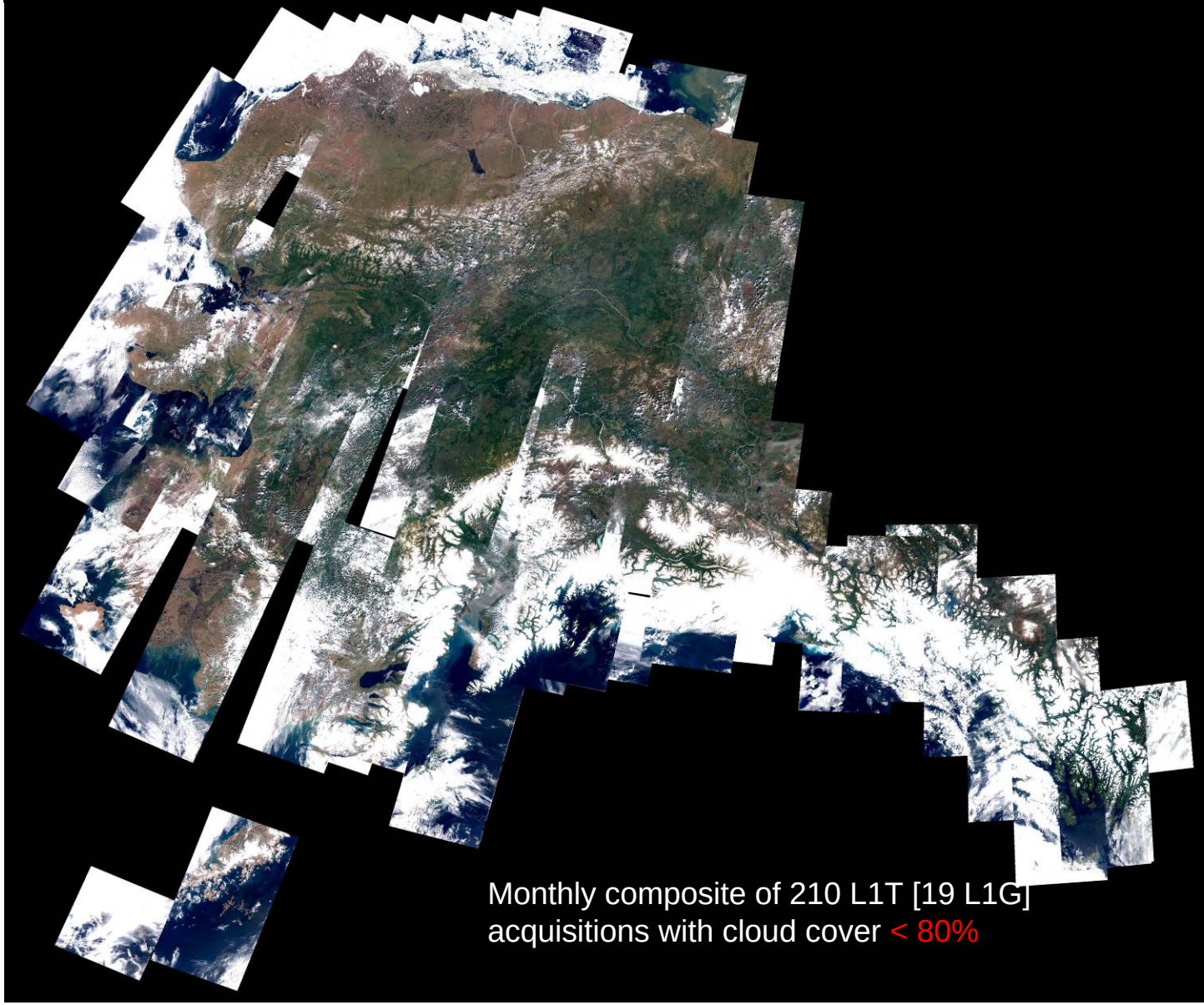
500m Browse (4118x5000 pixels)



Monthly composite of 191 L1T [29 L1G] acquisitions with cloud cover < 80%

Alaska June 2008

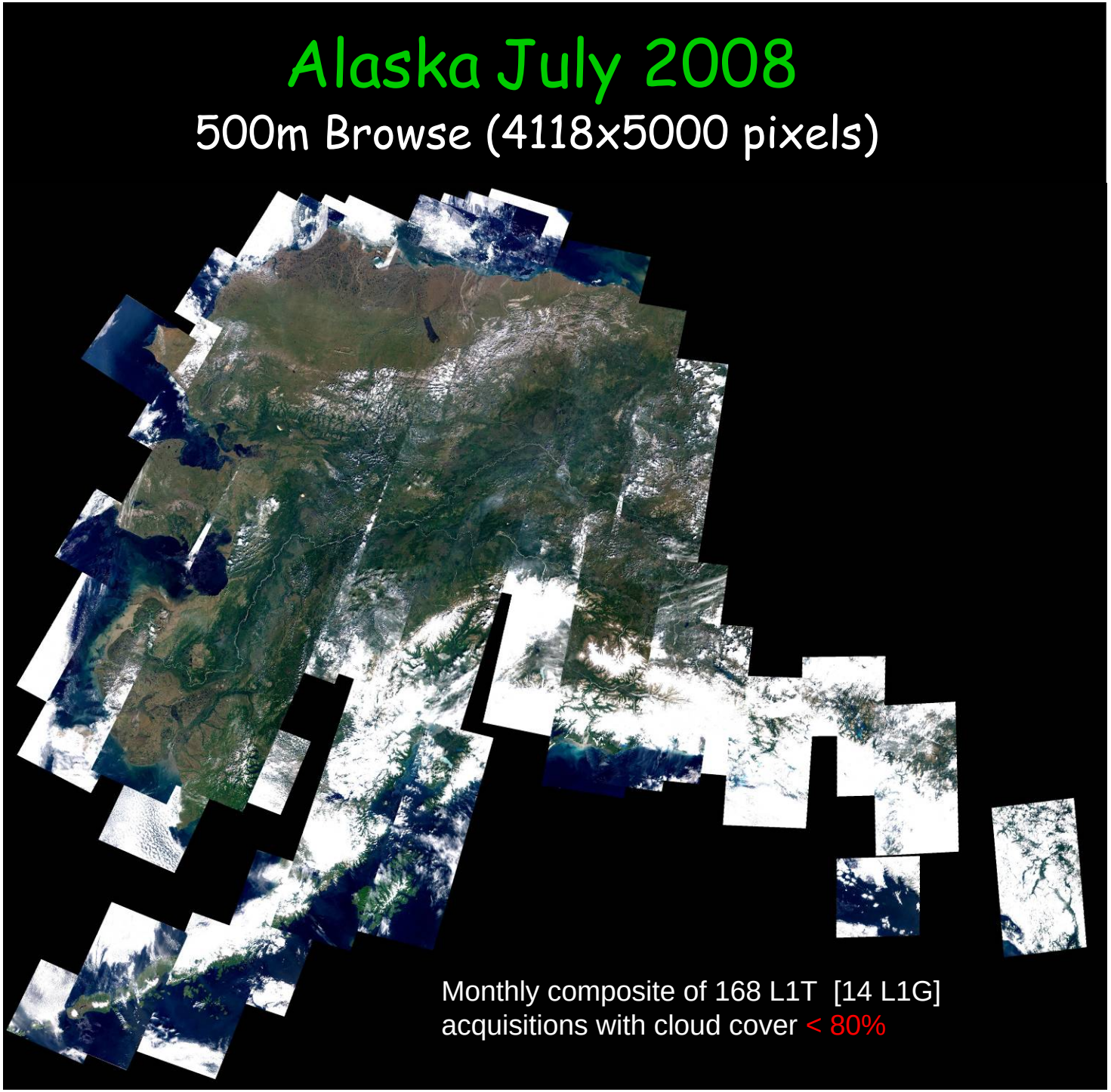
500m Browse (4118x5000 pixels)



Monthly composite of 210 L1T [19 L1G] acquisitions with cloud cover < 80%

Alaska July 2008

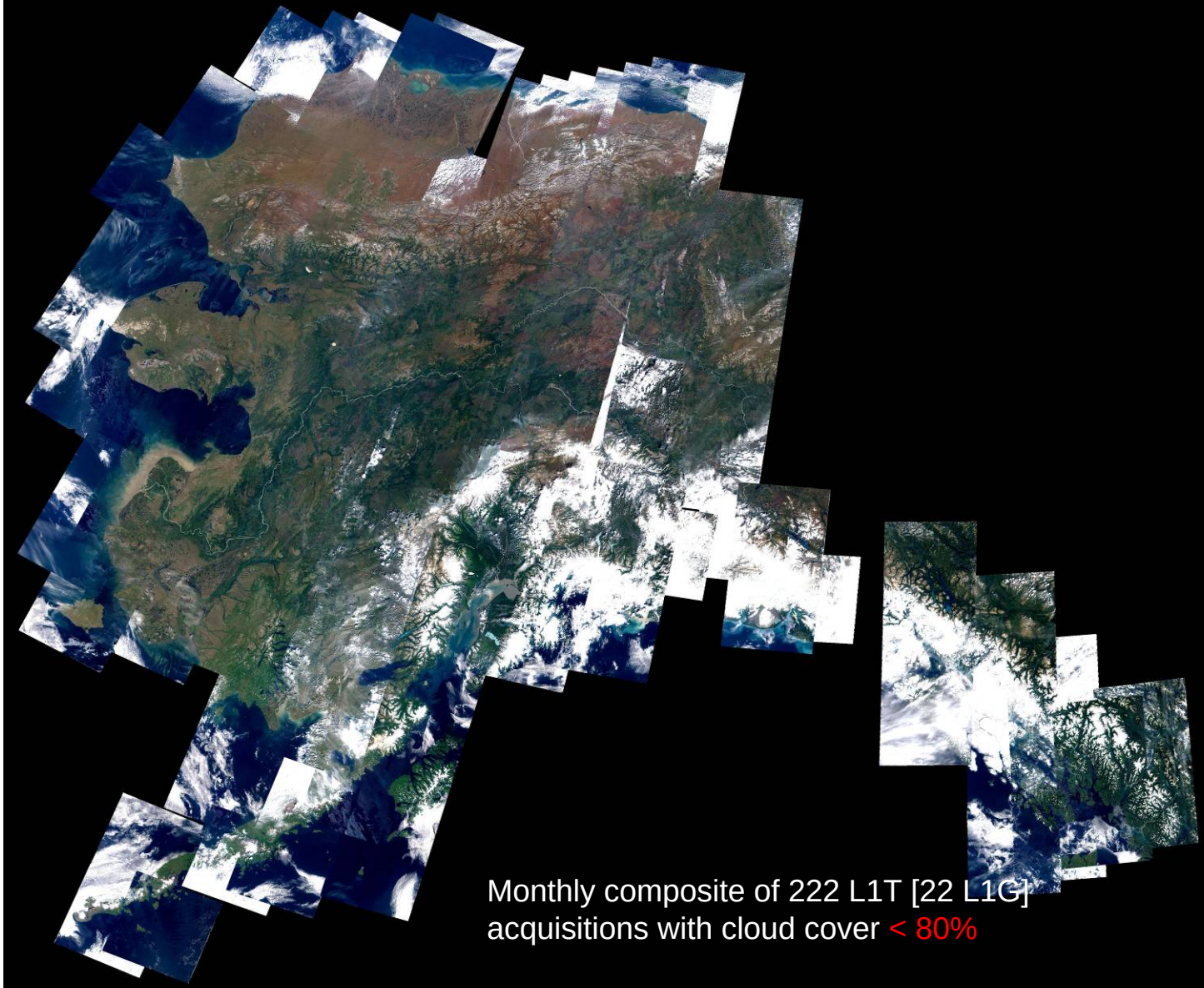
500m Browse (4118x5000 pixels)



Monthly composite of 168 L1T [14 L1G]
acquisitions with cloud cover < 80%

Alaska August 2008

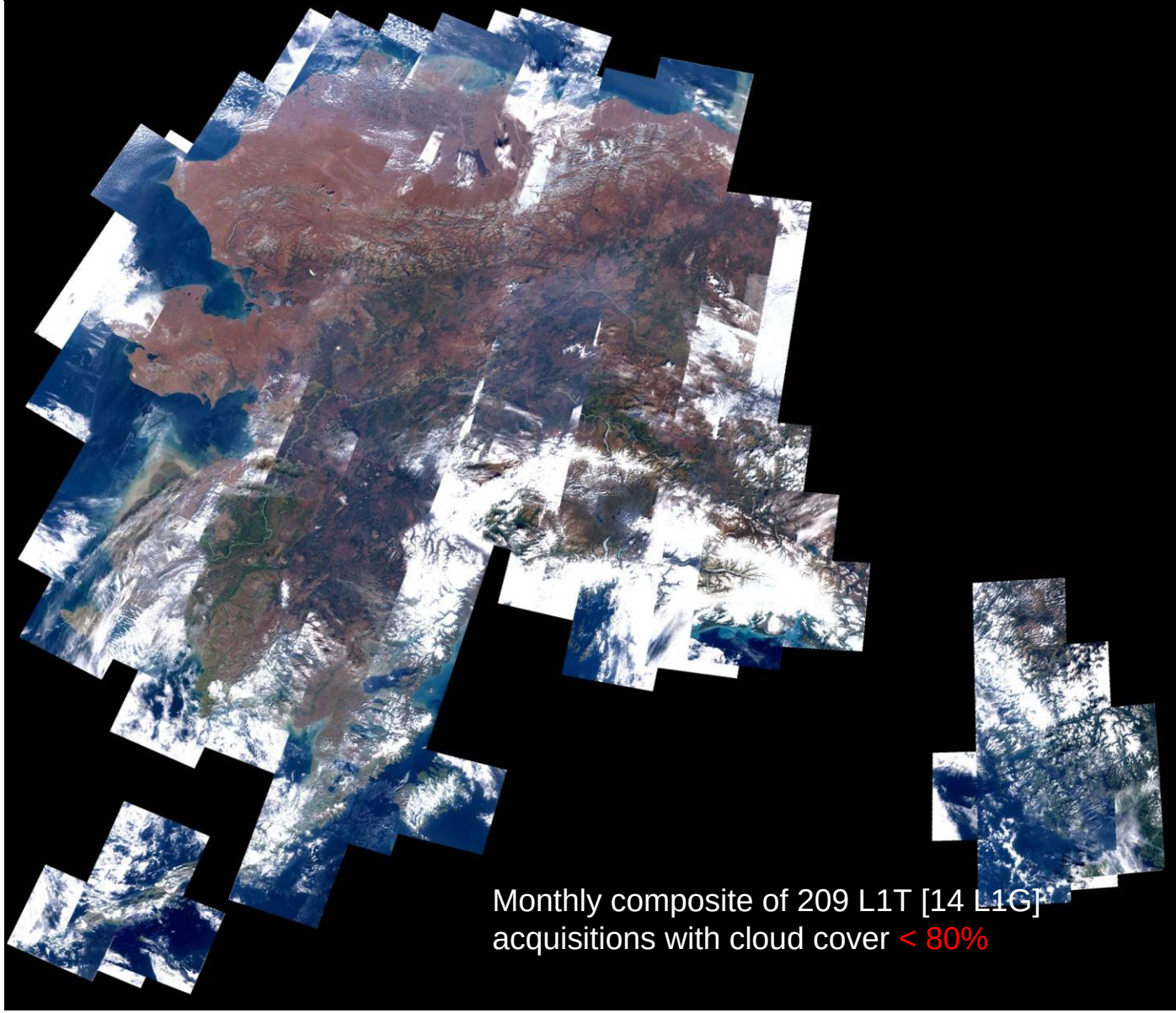
500m Browse (4118x5000 pixels)



Monthly composite of 222 L1T [22 L1G] acquisitions with cloud cover < 80%

Alaska September 2008

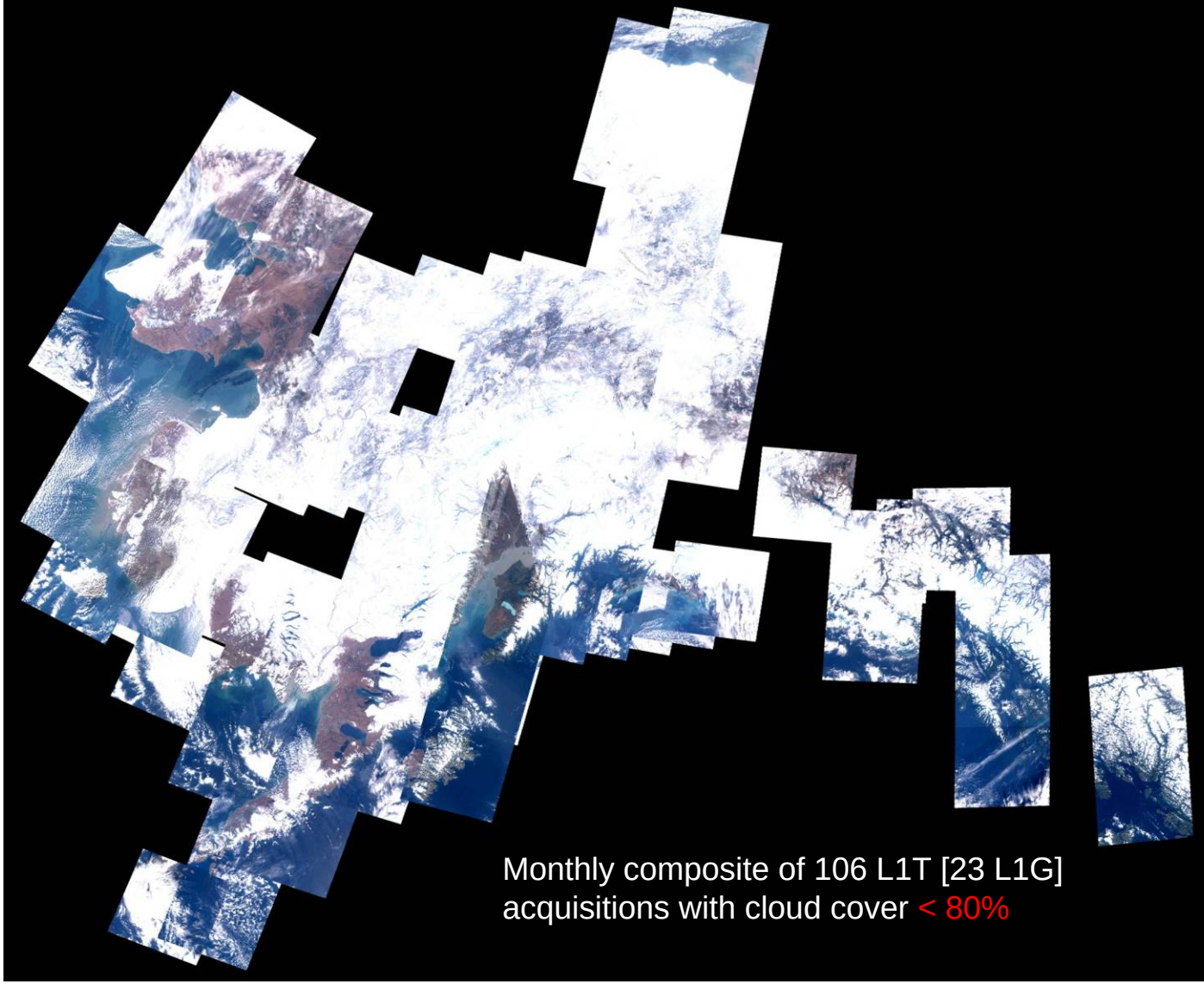
500m Browse (4118x5000 pixels)



Monthly composite of 209 L1T [14 L1G] acquisitions with cloud cover < 80%

Alaska October 2008

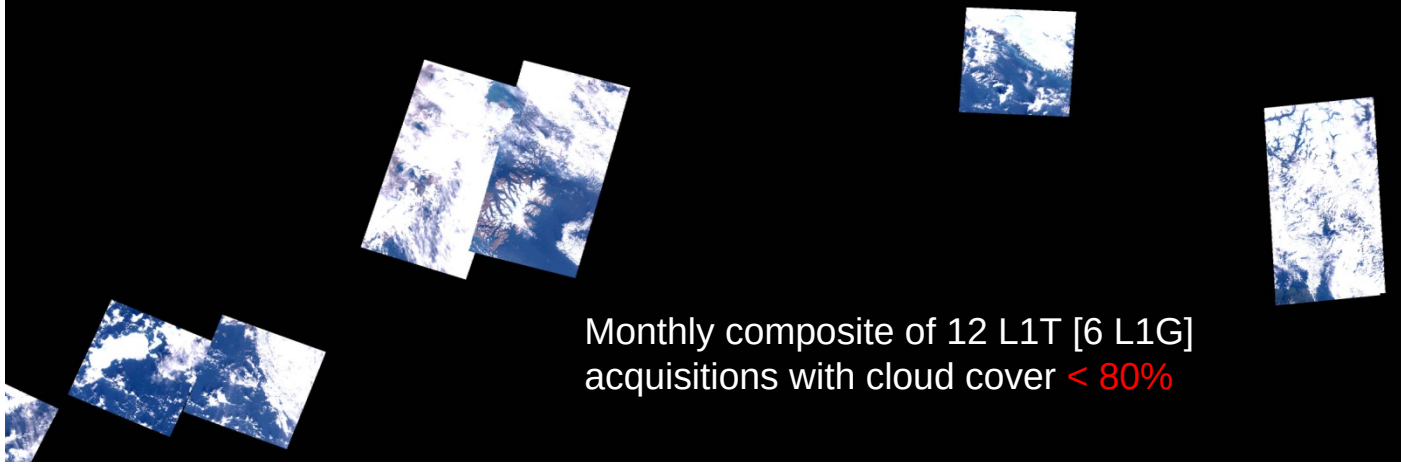
500m Browse (4118x5000 pixels)



Monthly composite of 106 L1T [23 L1G]
acquisitions with cloud cover < 80%

Alaska November 2008

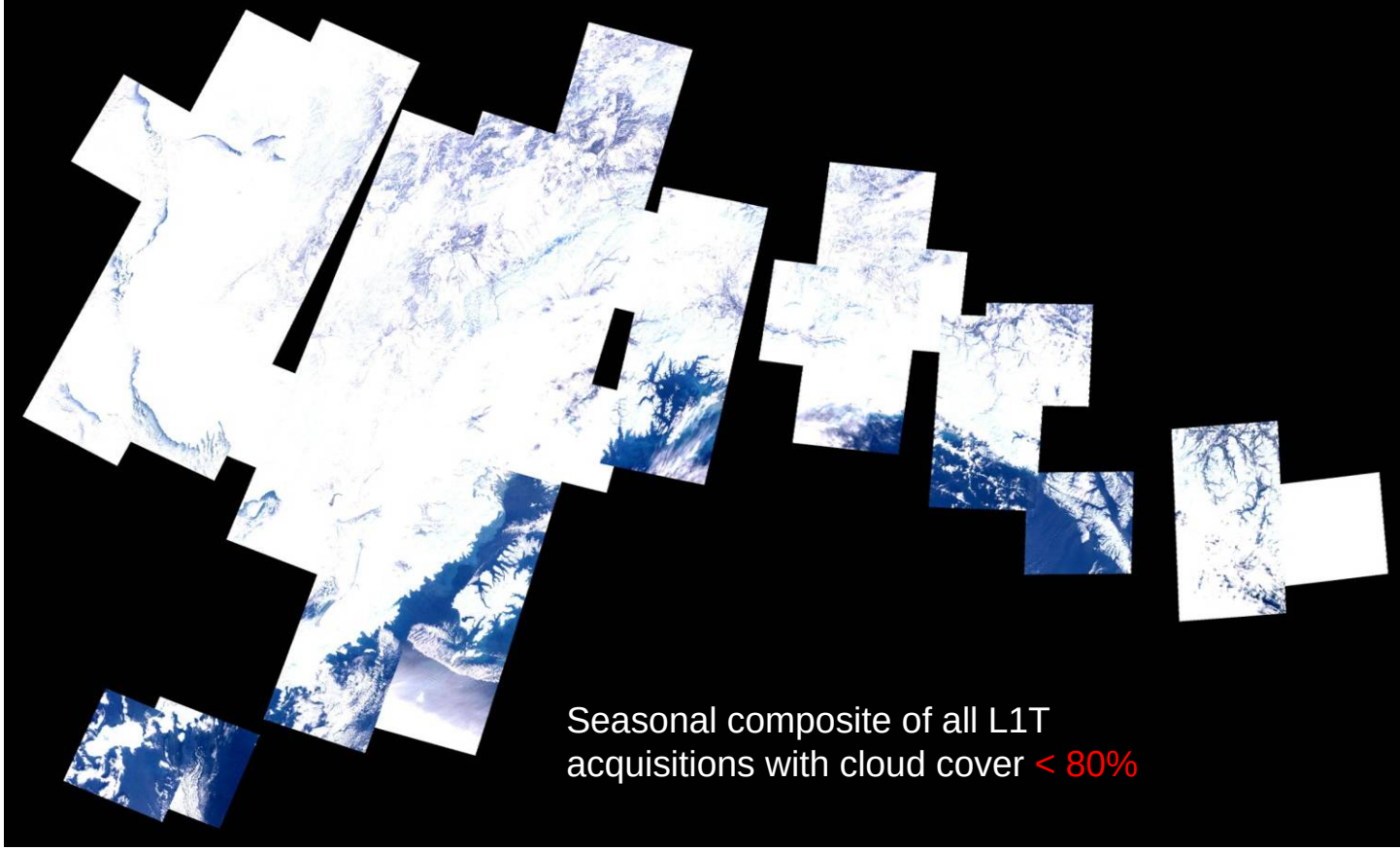
500m Browse (4118x5000 pixels)



Monthly composite of 12 L1T [6 L1G]
acquisitions with cloud cover < 80%

Winter 2008 (Dec. 07, Jan., Feb)

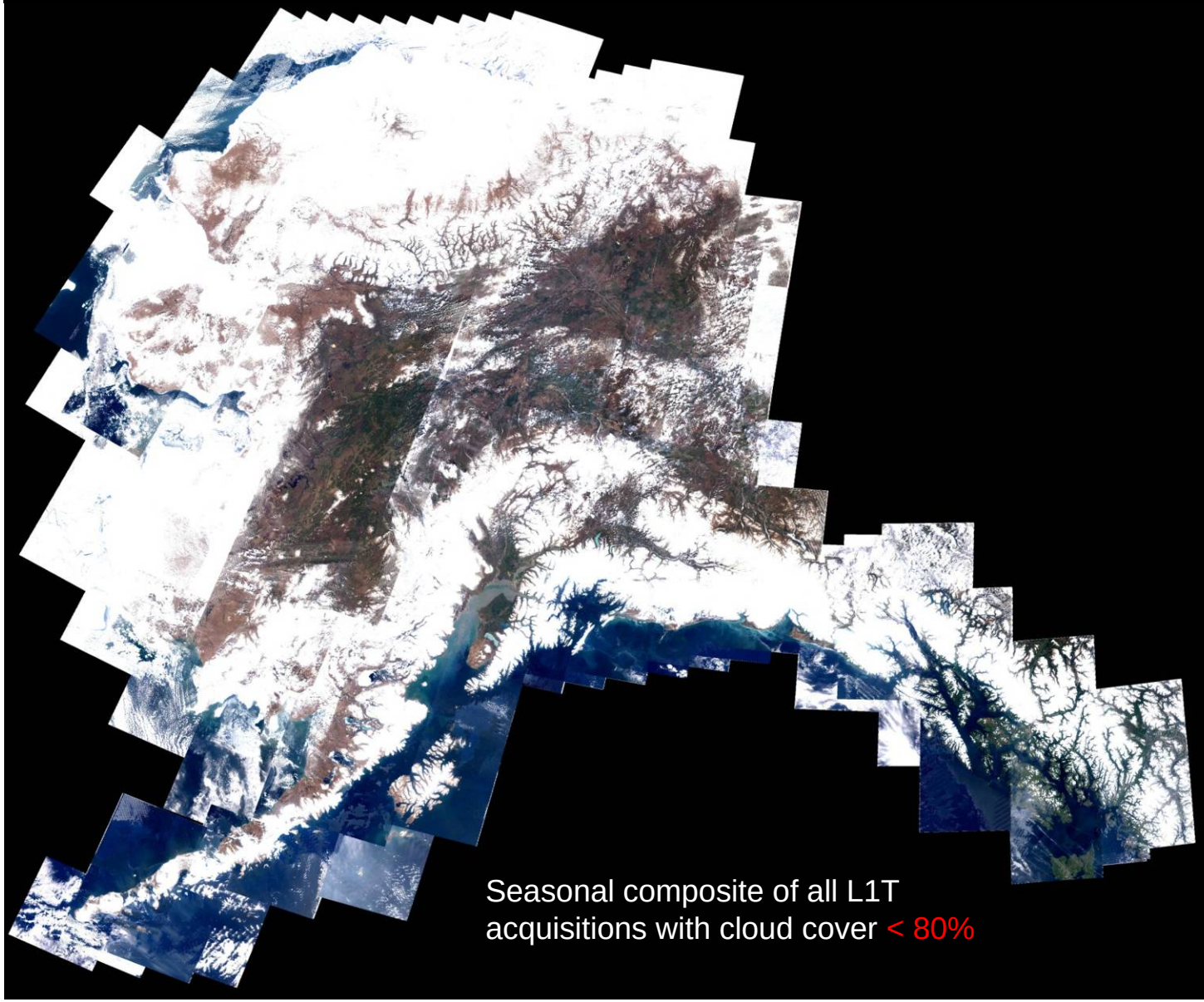
500m Browse (4118x5000 pixels)



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

Spring 2008 (March, April, May)

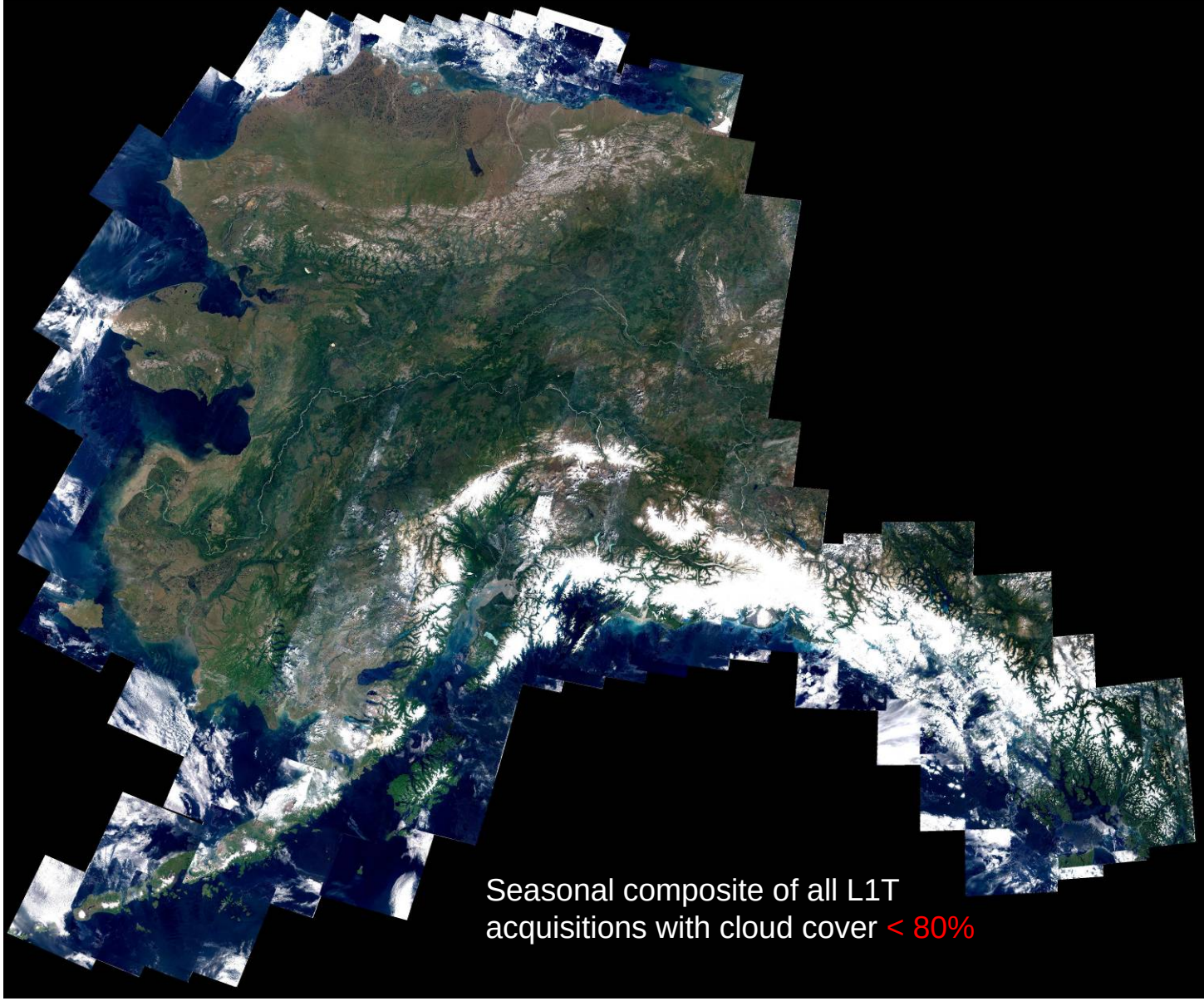
500m Browse (4118x5000 pixels)



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

Summer 2008 (June, July, August)

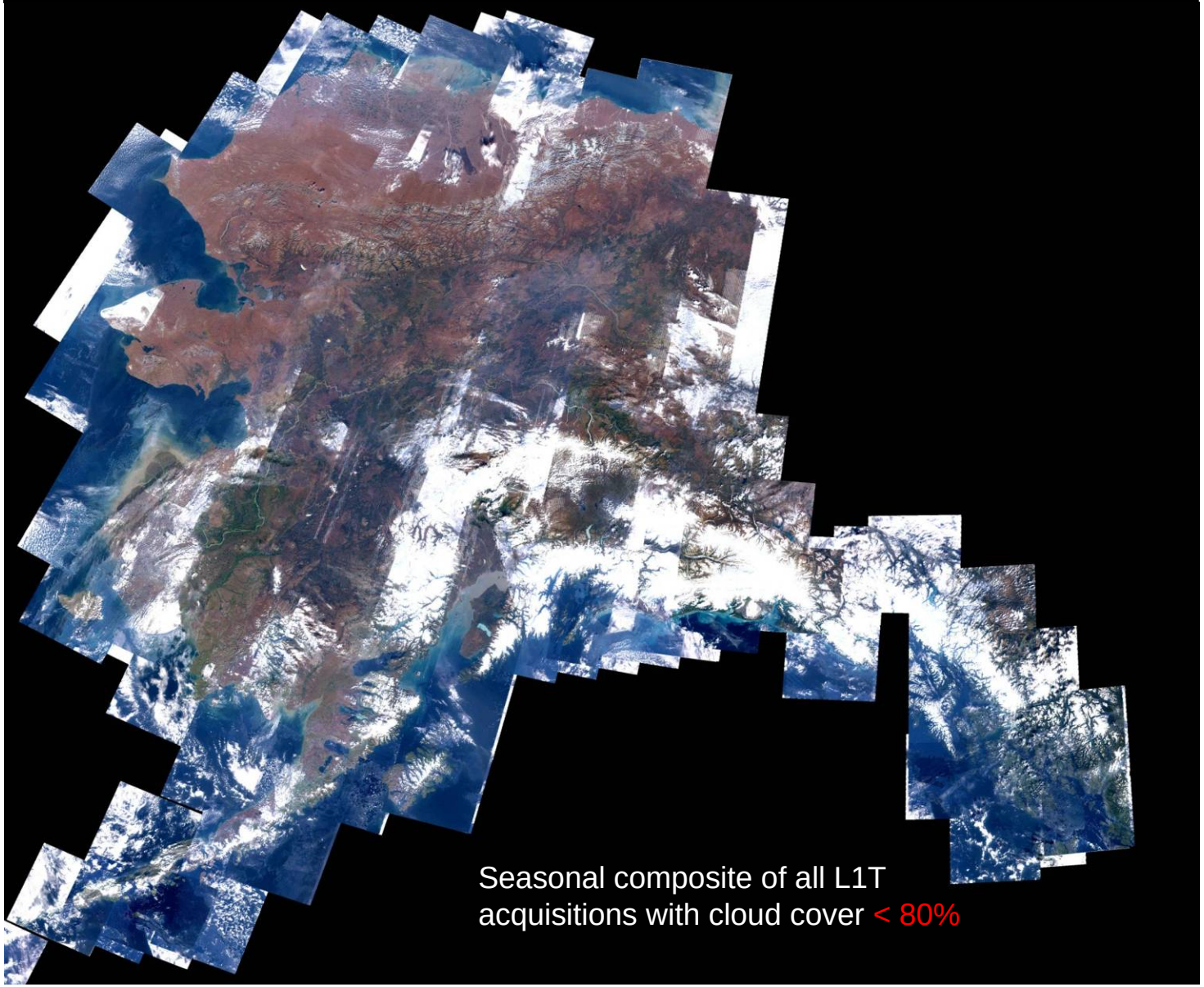
500m Browse (4118x5000 pixels)



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

Fall 2008 (Sept.,Oct.,Nov.)

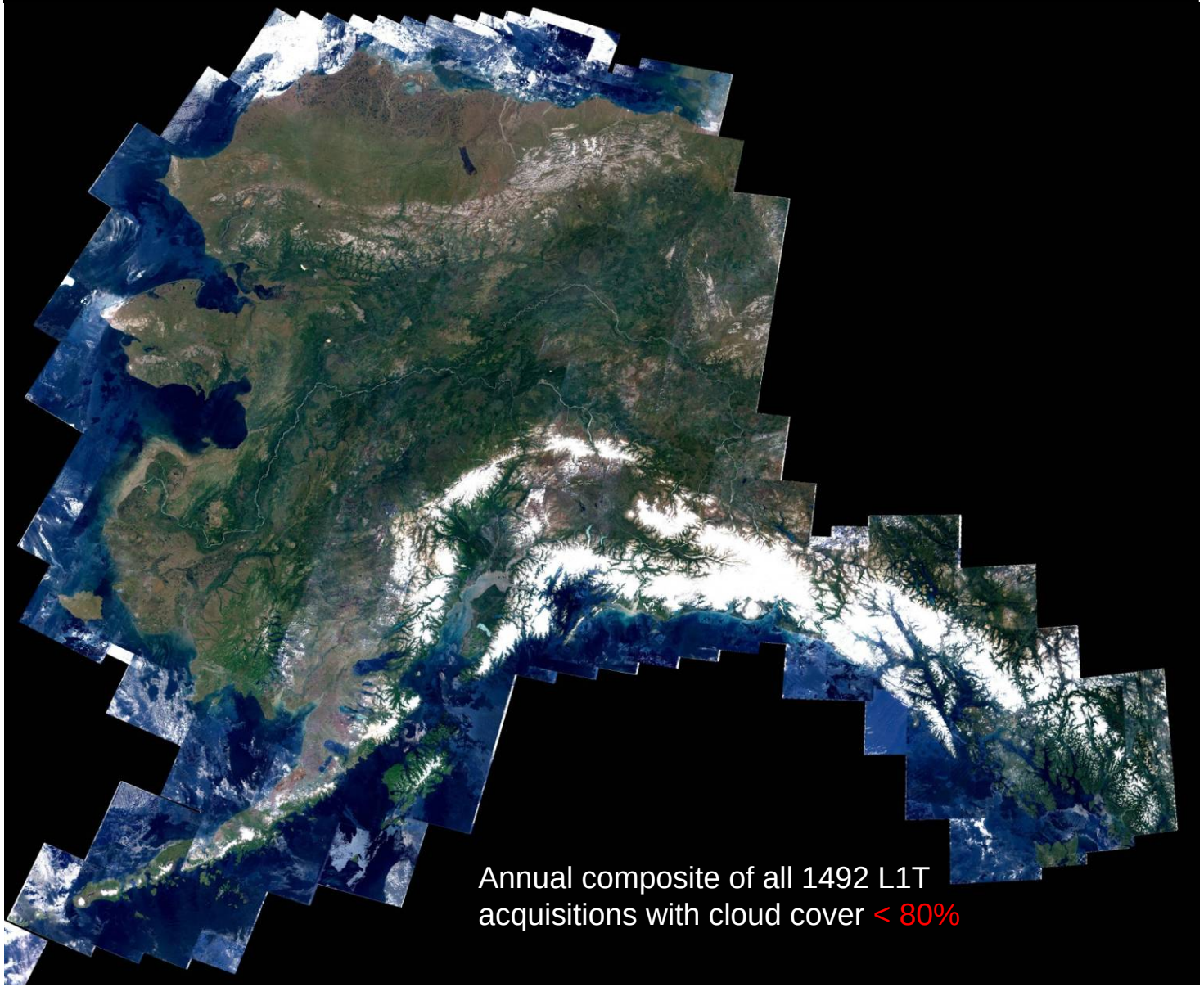
500m Browse (4118x5000 pixels)



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

Annual 2008 (June, July, August)

500m Browse (4118x5000 pixels)



Weld Products

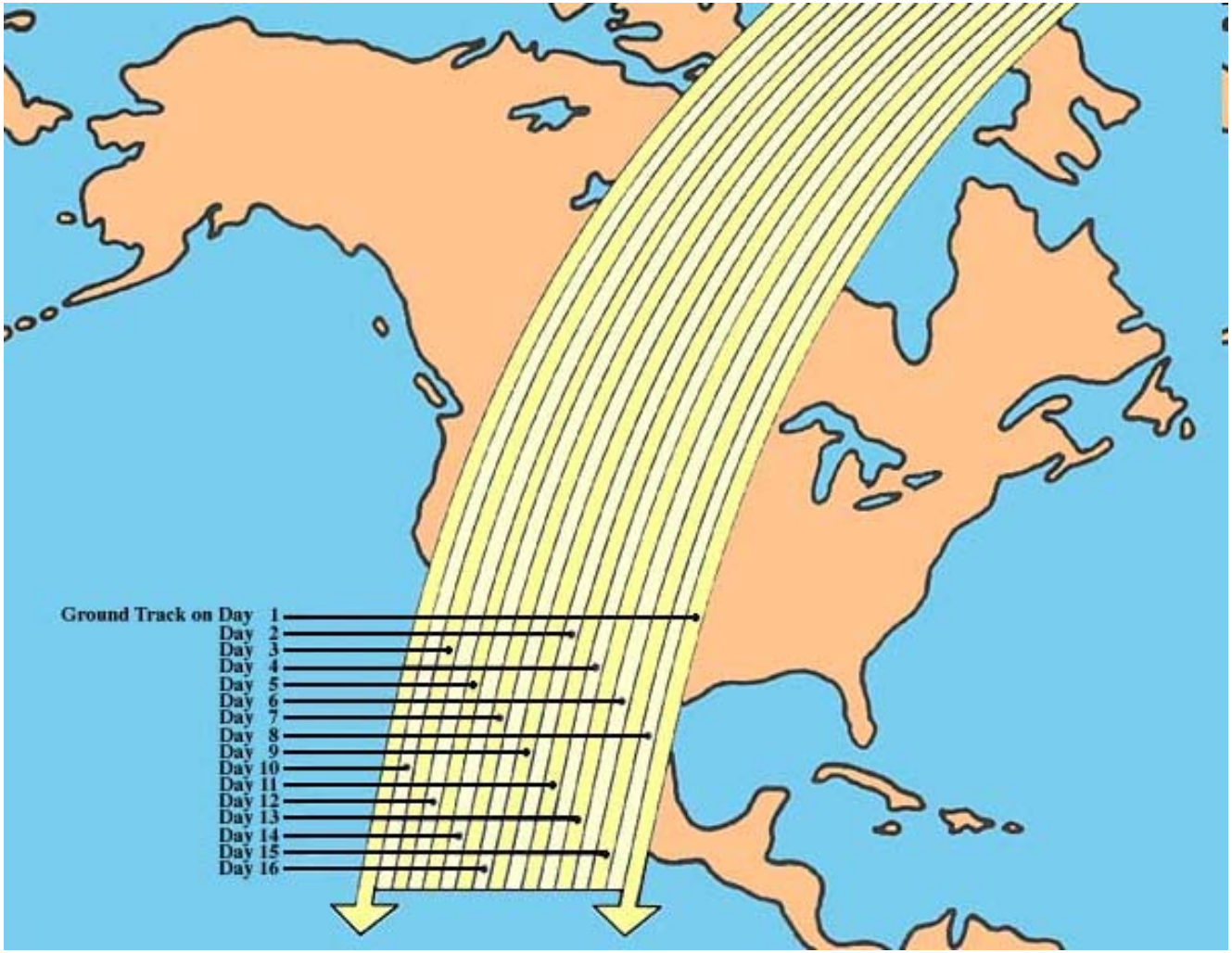
ETM+ composited mosaics for all CONUS & Alaska, 7 years

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		

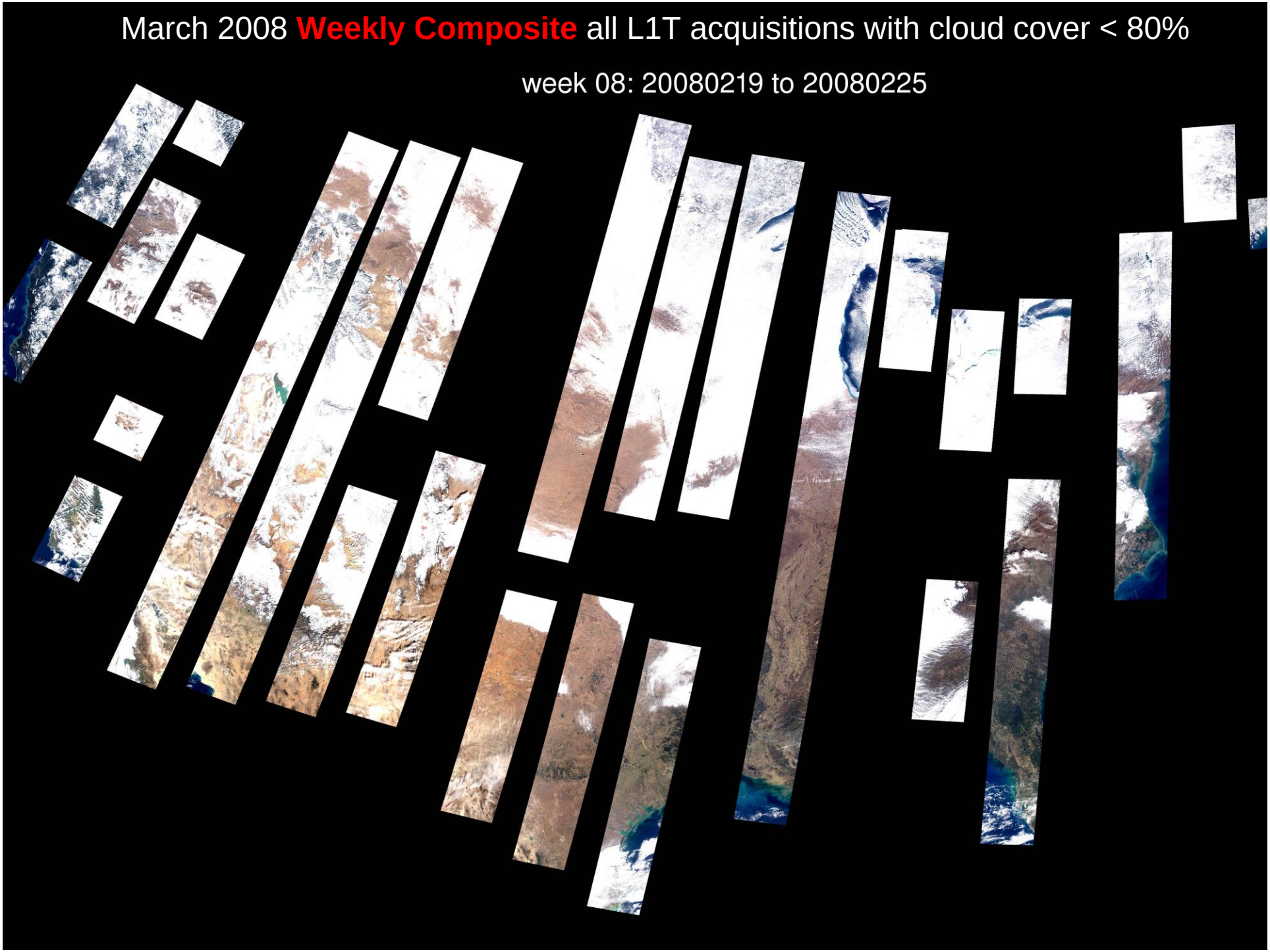
New Weekly (7 day) Composites

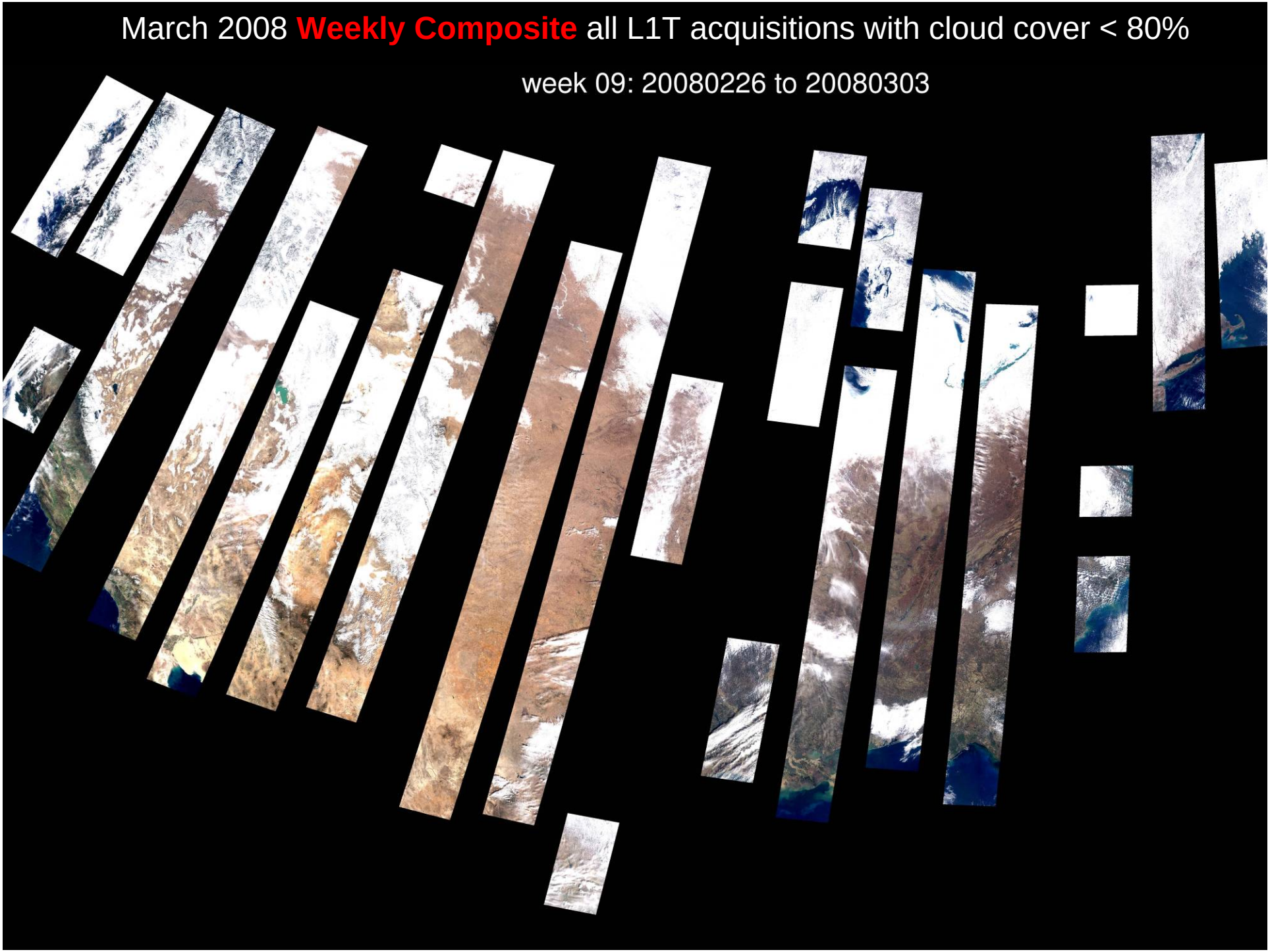
As monthly but no land cover characterization

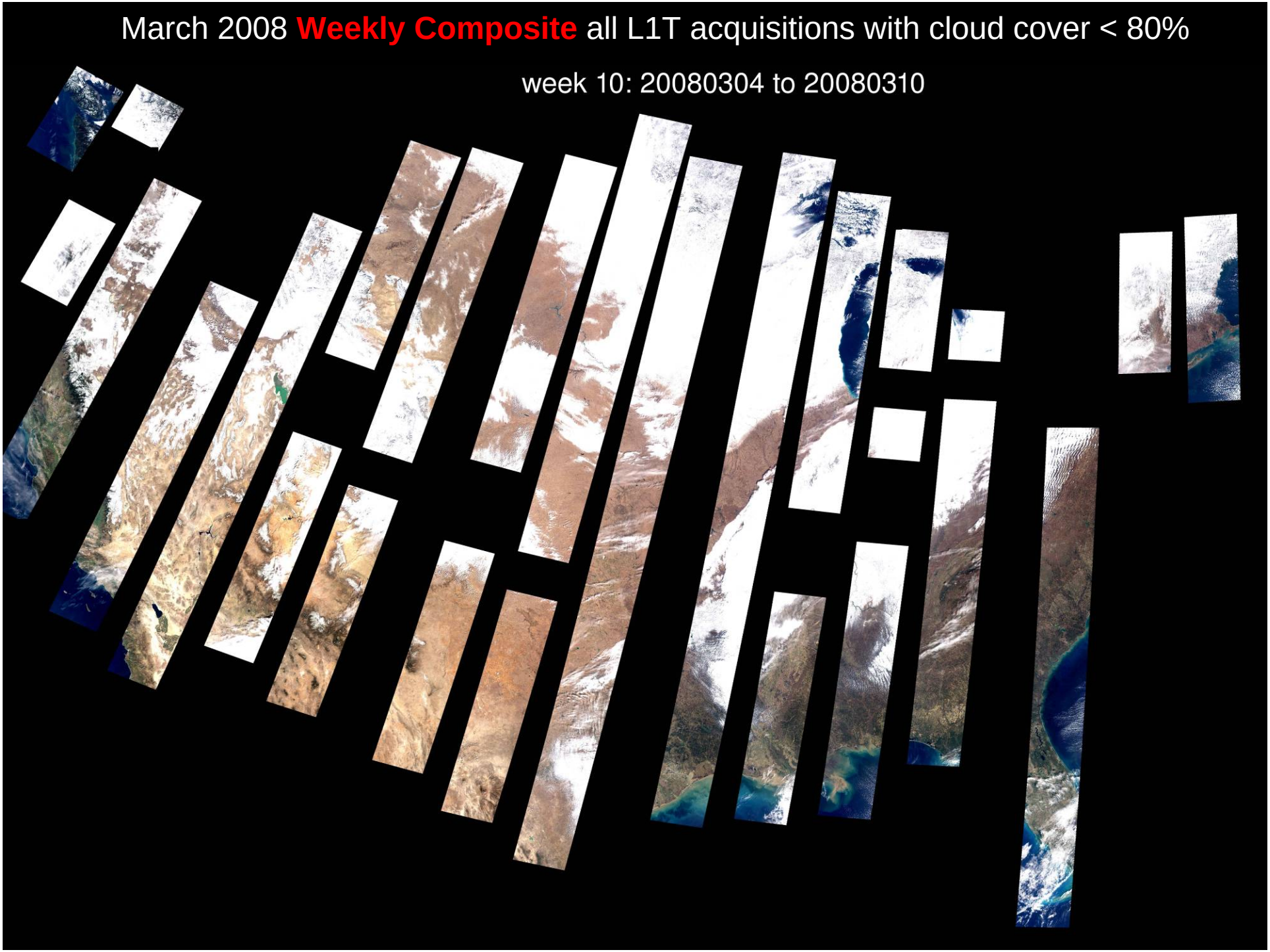
Landsat Orbit Geometry / Swath Pattern



http://landsathandbook.gsfc.nasa.gov/handbook/handbook_htmls/chapter5/htmls/swath_pattern.html


March 2008 Weekly Composite all L1T acquisitions with cloud cover < 80%
week 08: 20080219 to 20080225


March 2008 Weekly Composite all L1T acquisitions with cloud cover < 80%
week 09: 20080226 to 20080303


March 2008 Weekly Composite all L1T acquisitions with cloud cover < 80%
week 10: 20080304 to 20080310

WELD Production

- FTP Process
  - Retrieve Landsat ETM+ acquisitions from EROS FTP directory shortly after they are placed there
- Production System Process
  - Make temporally composited mosaics
- Distribution System Process
  - Distribute composited mosaics via internet using WYSIWYG interface and harvest distribution metrics.

WELD Development

- Production & distribution systems being developed at SDSU
- Systems will be migrated to EROS in year 3 of project
- The processing approach designed
  - for automated processing with minimal human intervention
  - to enable composited mosaics to be updated regardless of the chronological order of the Landsat acquisition and processing dates
  - to provide processing in near-real time, i.e., updating composited mosaics shortly after the Landsat L1T data are acquired
  - parallel processing
  - process latest version with reprocessing capability
- Linux, C & open source software (Php, Perl, MySQL, etc.)
- Database driven process control

Weld Overview

- FTP Process
  - Retrieve Landsat acquisitions from EROS FTP directory shortly after they are placed there
- Production System Process
  - Make temporally composited mosaics CONUS & Alaska
- Distribution System Process
  - Distribute composited mosaics via internet using WYSIWYG interface and harvest distribution metrics.

WELD ETM+ ARCHIVE at SDSU

November 13th 2009

	CONUS (459 path/row) <80% cloud	**Alaska** (232 path/row) <80% cloud
2007	5,688 + 116	554 + 101
2008	8,300 + 49	1,705 + 39
2009	6,036 +932	1,400 +133

Number of new acquisitions ftp'd in previous month

WELD ETM+ ARCHIVE at SDSU

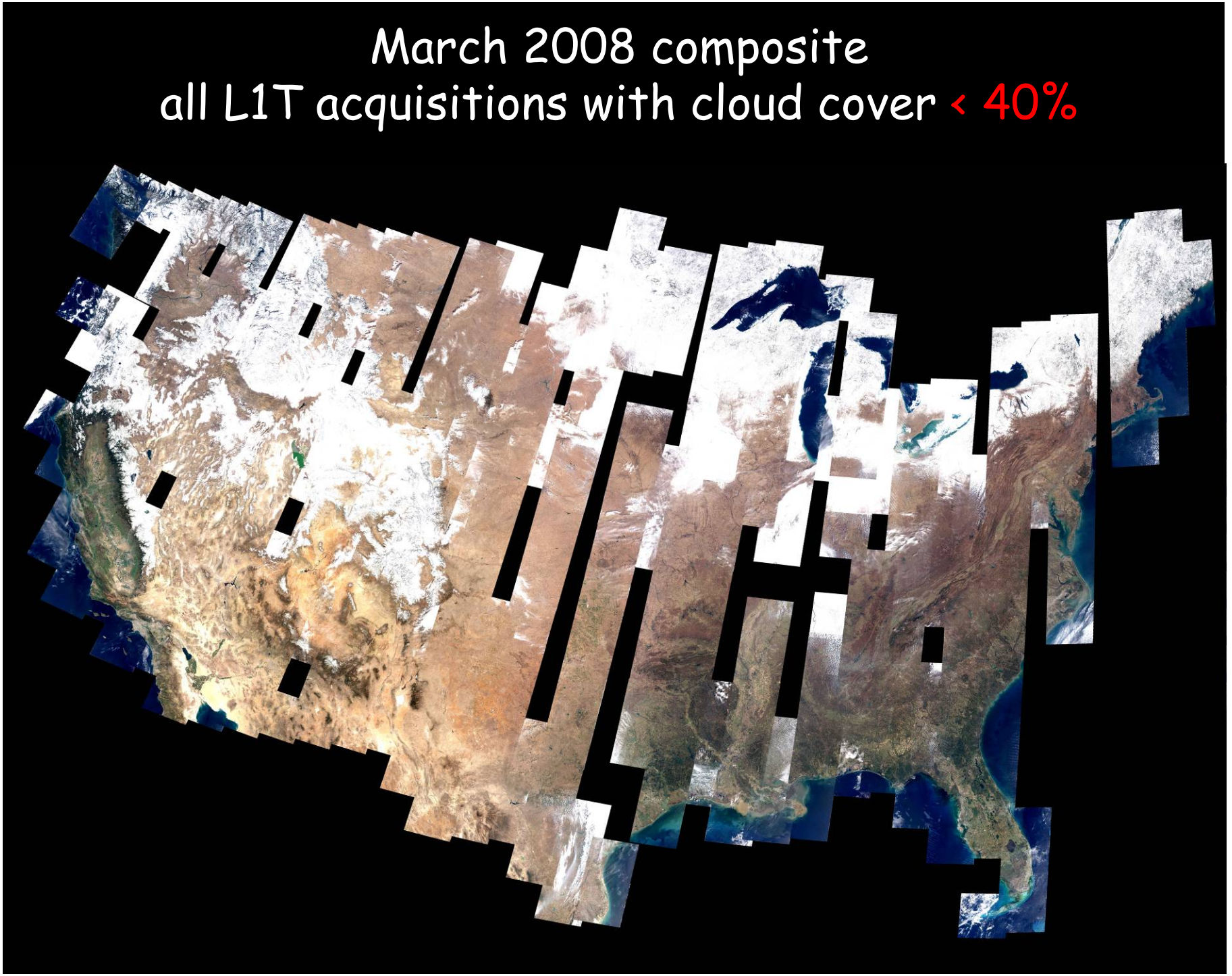
January 15th 2010

	CONUS (459 path/row) <80% cloud	**Alaska** (232 path/row) <80% cloud
2007	5,817	568
2008	8,314	1,706
2009	7,664	1,734

25,603 CONUS and Alaska acquisitions

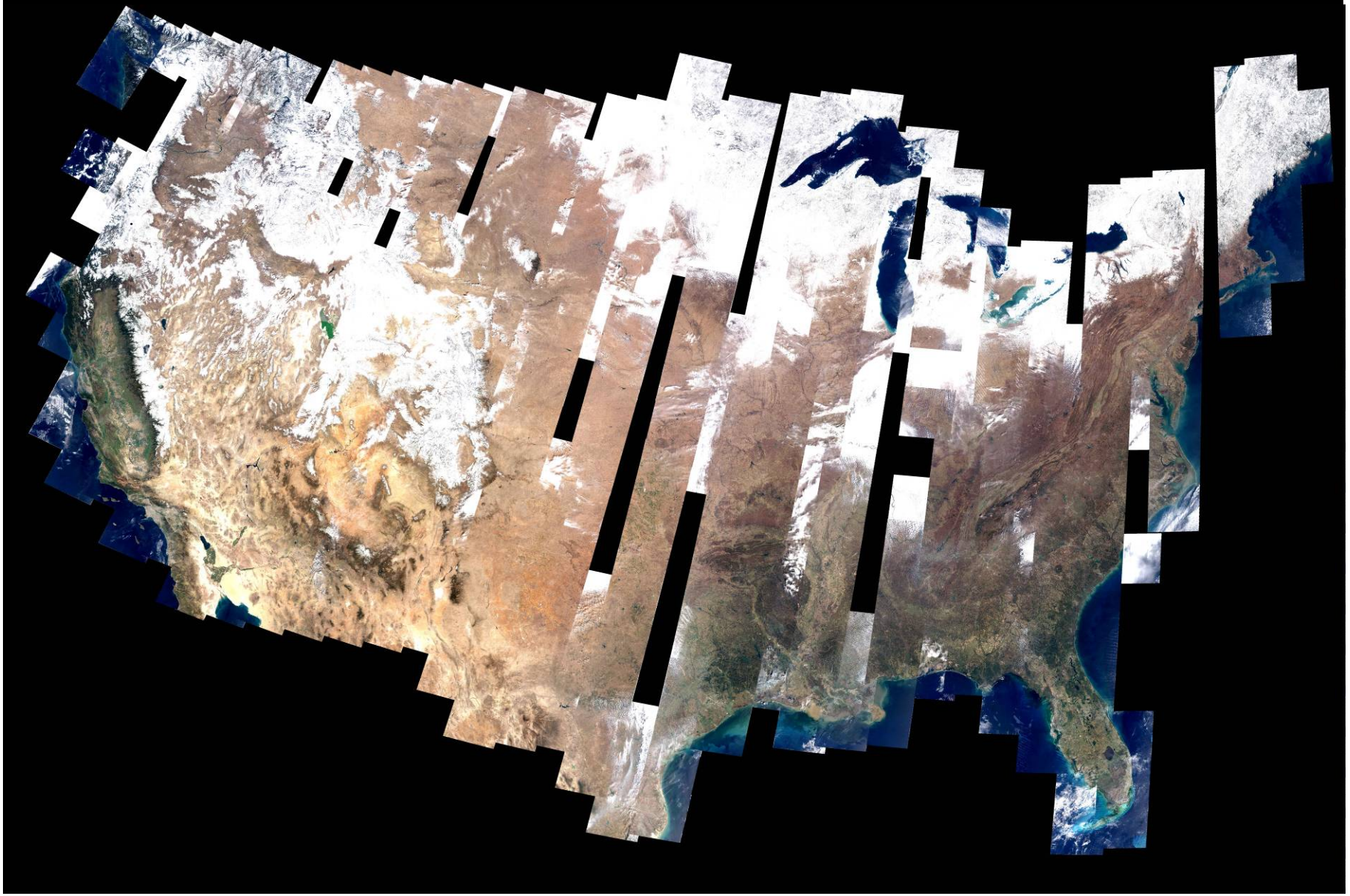
24,085 Africa acquisitions

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%



Weld Overview

- FTP Process
  - Retrieve Landsat acquisitions from EROS FTP directory shortly after they are placed there
- Production System Process
  - Make temporally composited mosaics
- Distribution System Process
  - Distribute composited mosaics via internet using WYSIWYG interface and harvest distribution metrics.

WELD product file name convention

(descriptive, simple, amenable to scripting)

- The WELD products are generated in fixed tiles and stored in Hierarchical Data Format (HDF) with the following filename convention:

<Region>.<Period>.<Year>.h<xx>v<yy>

.doy<min DOY>to<max DOY>.v<Version Number>.hdf

e.g. *CONUS.month06.2008.h08v14.doy001to016.v1.3.hdf*

<Region> = CONUS/Alaska

<Period> = annual, spring/summer/autumn/winter,
month01/month02/,…,/month12,
week01/week02/,…,/week52

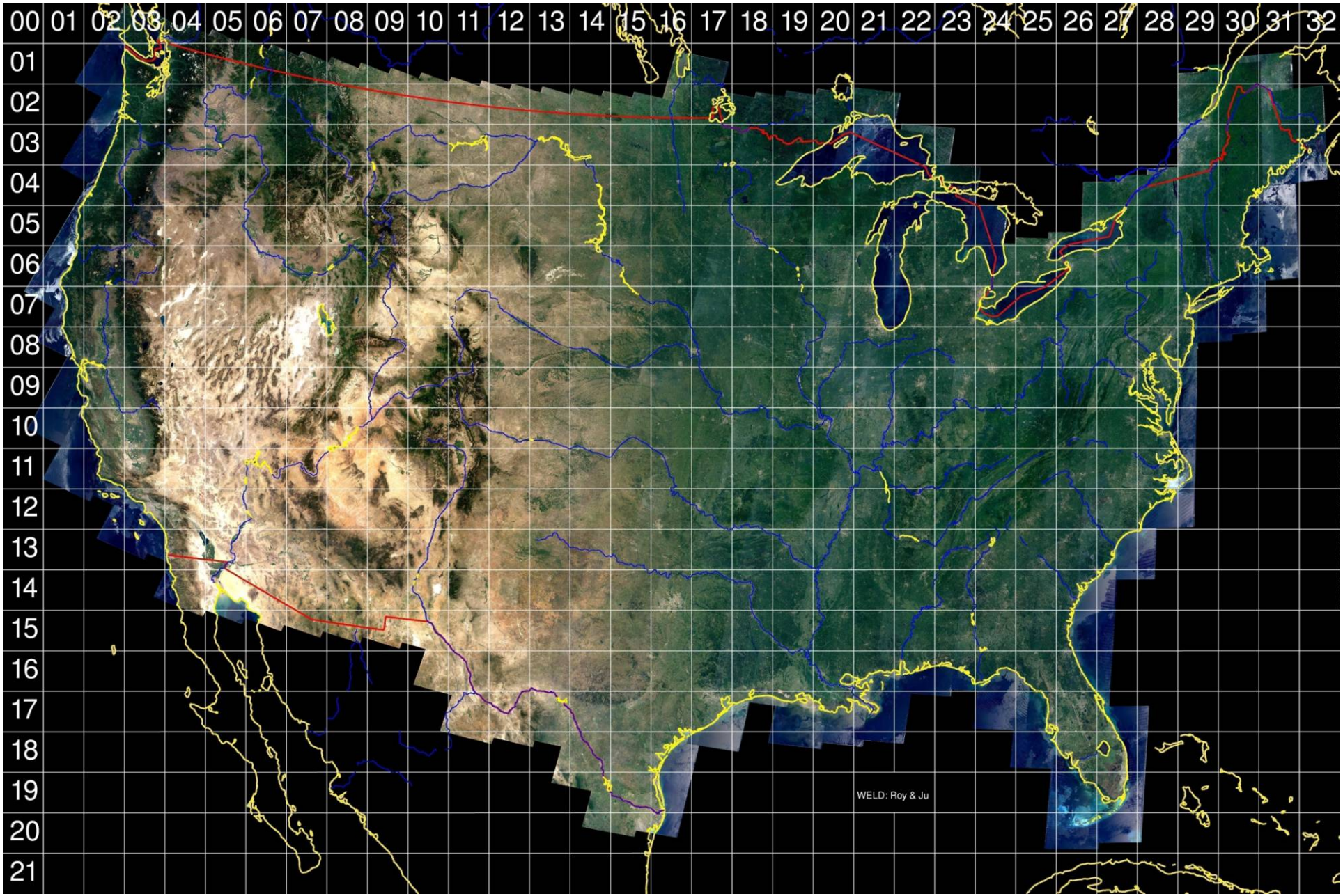
<Year> = 2007, 2008, ….

<xx> = 00,01,..,32 <yy> = 00,01,..,21

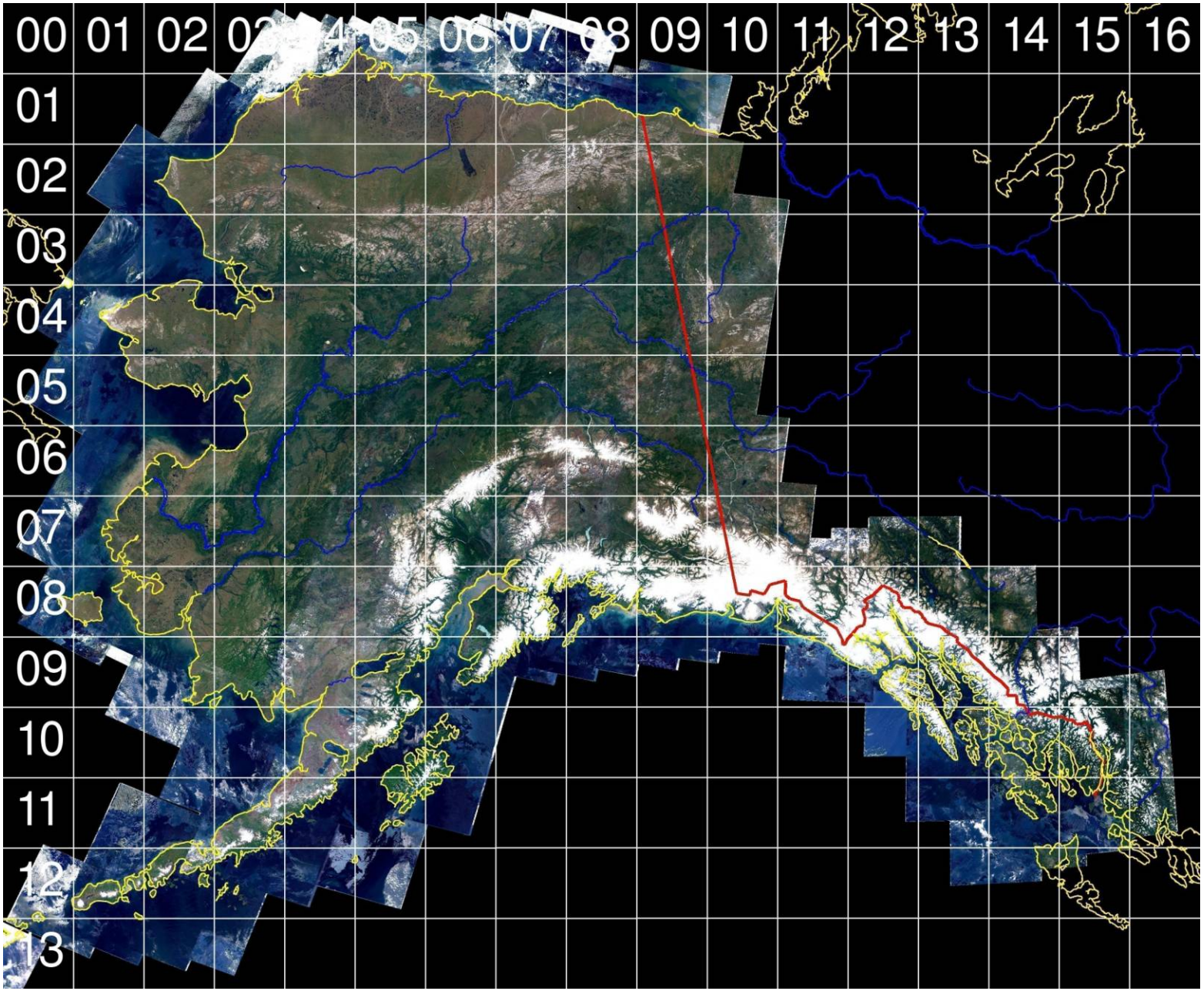
<min DOY> = 000,001,002,…, 366 <max DOY> = 000,001,002,…,366

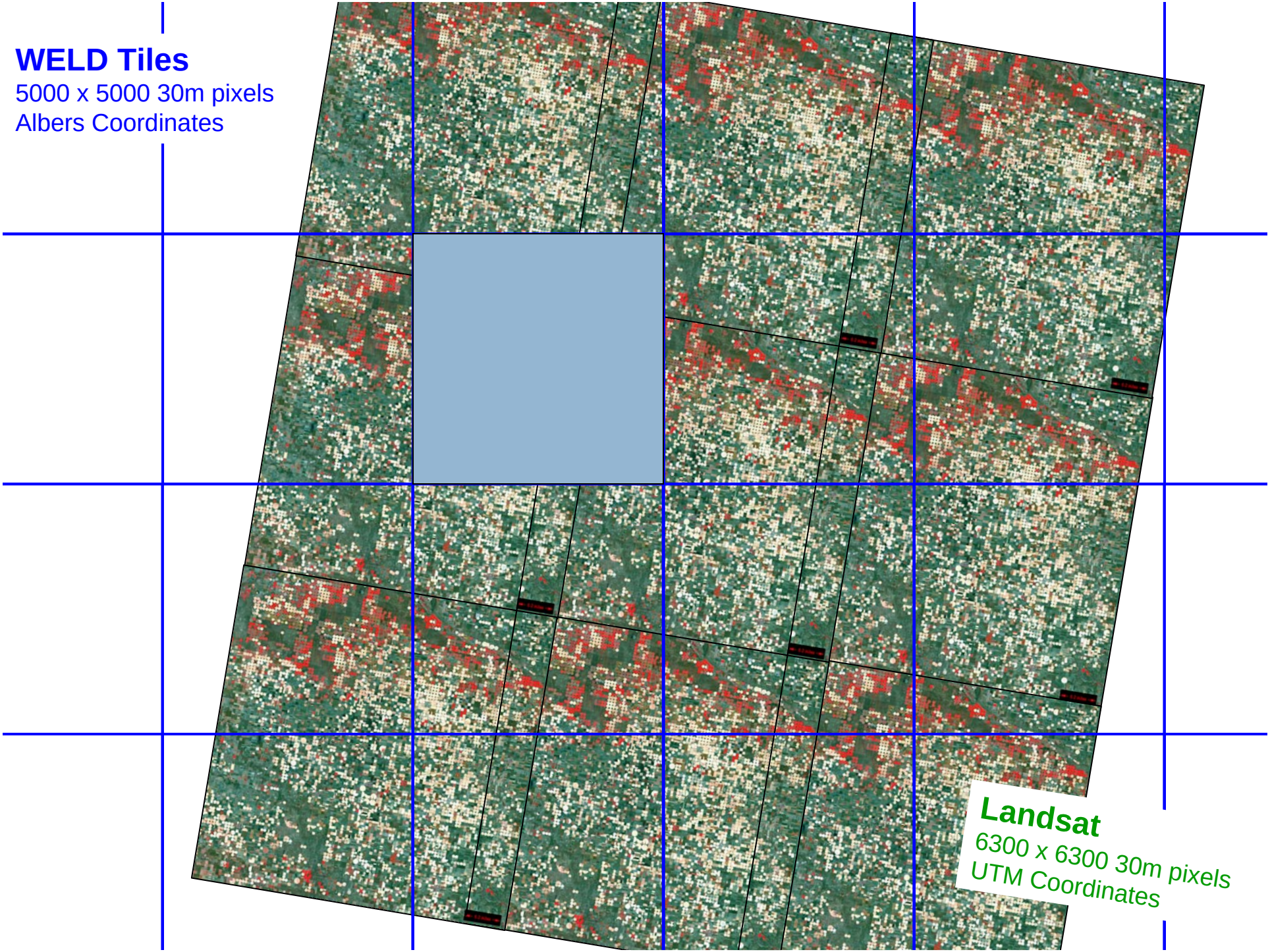
<Version Number> = 1.1, 1.2, … 2.1, 2.2, …

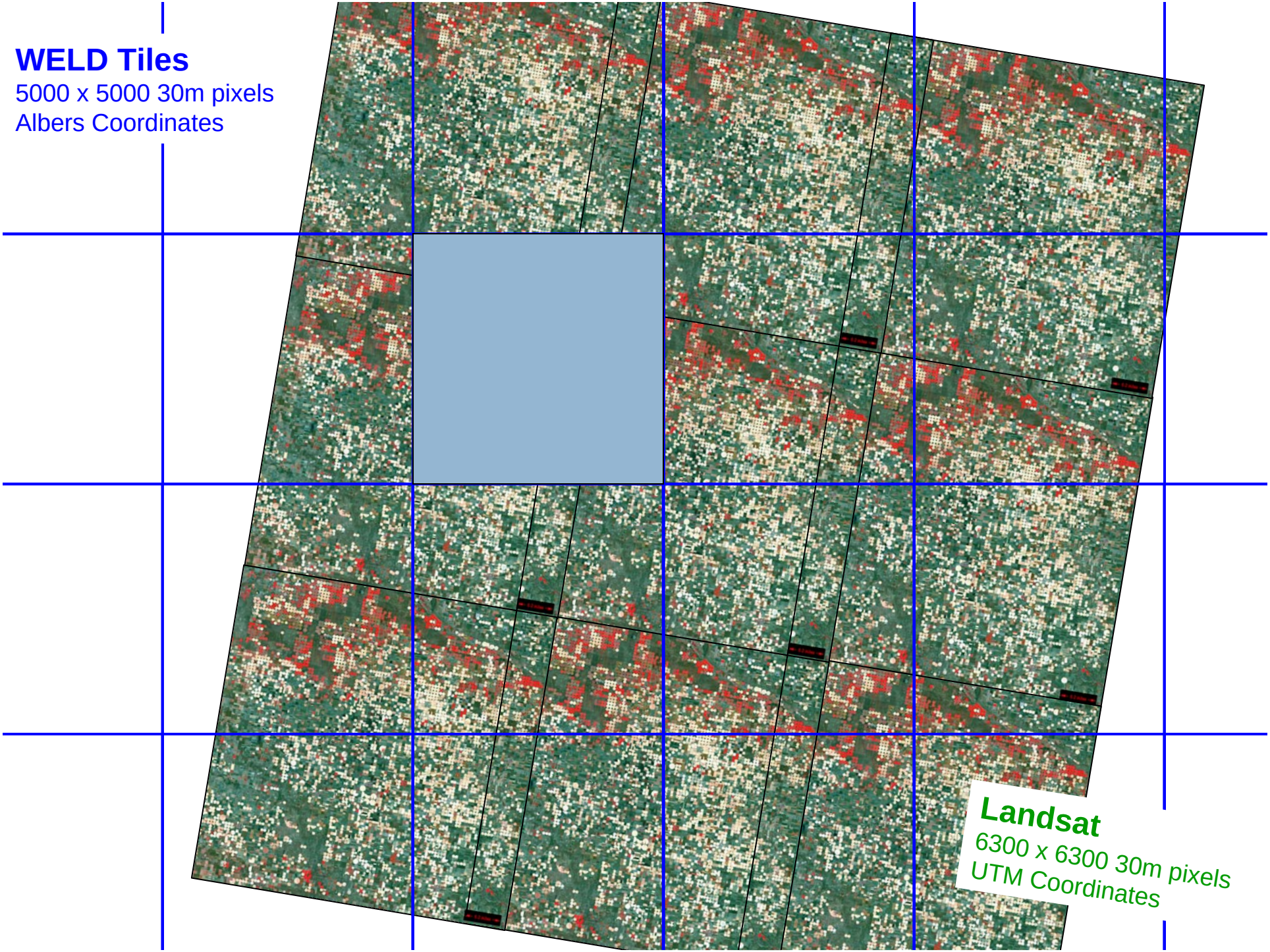
WELD Tile Map (CONUS has 501tiles in Albers)



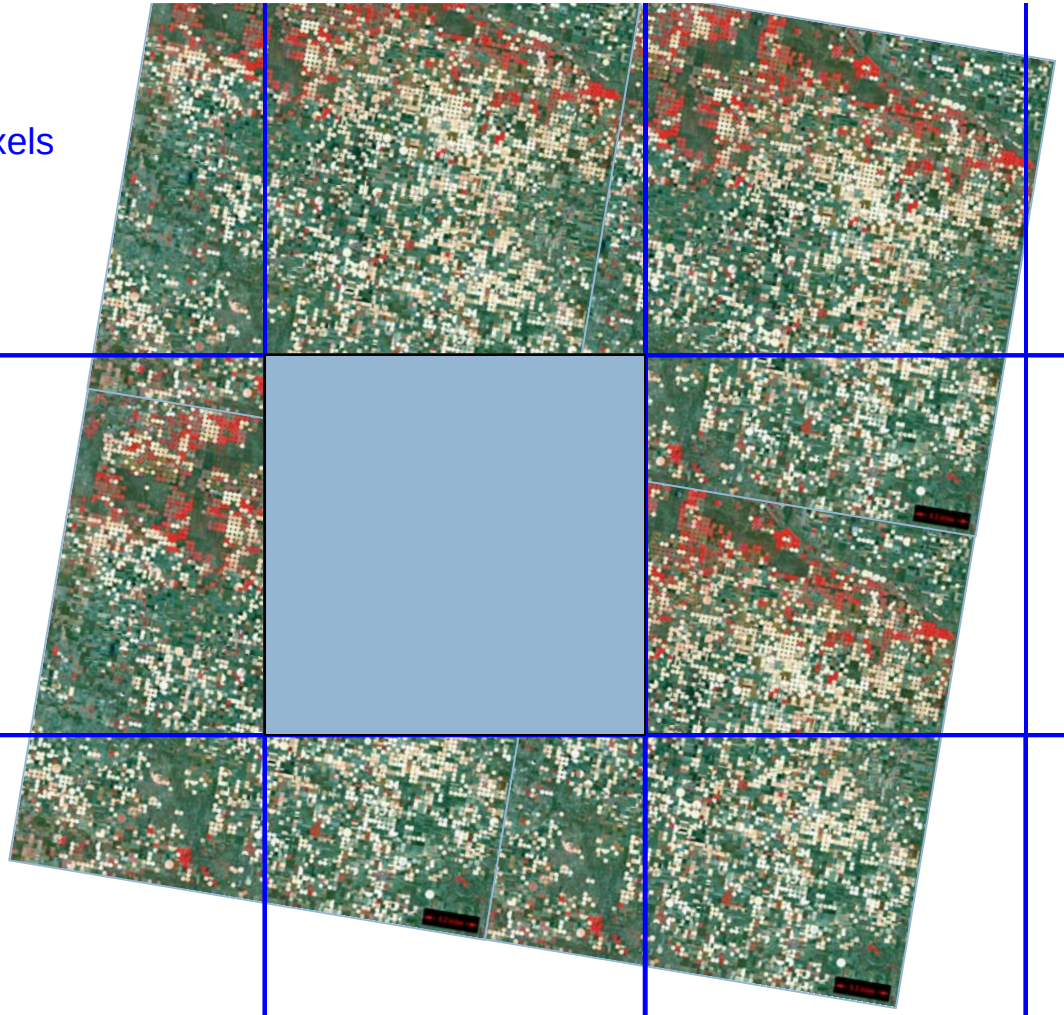
WELD Tile Map (Alaska has 162 tiles in Albers)




WELD Tiles
5000 x 5000 30m pixels
Albers Coordinates
Landsat
6300 x 6300 30m pixels
UTM Coordinates

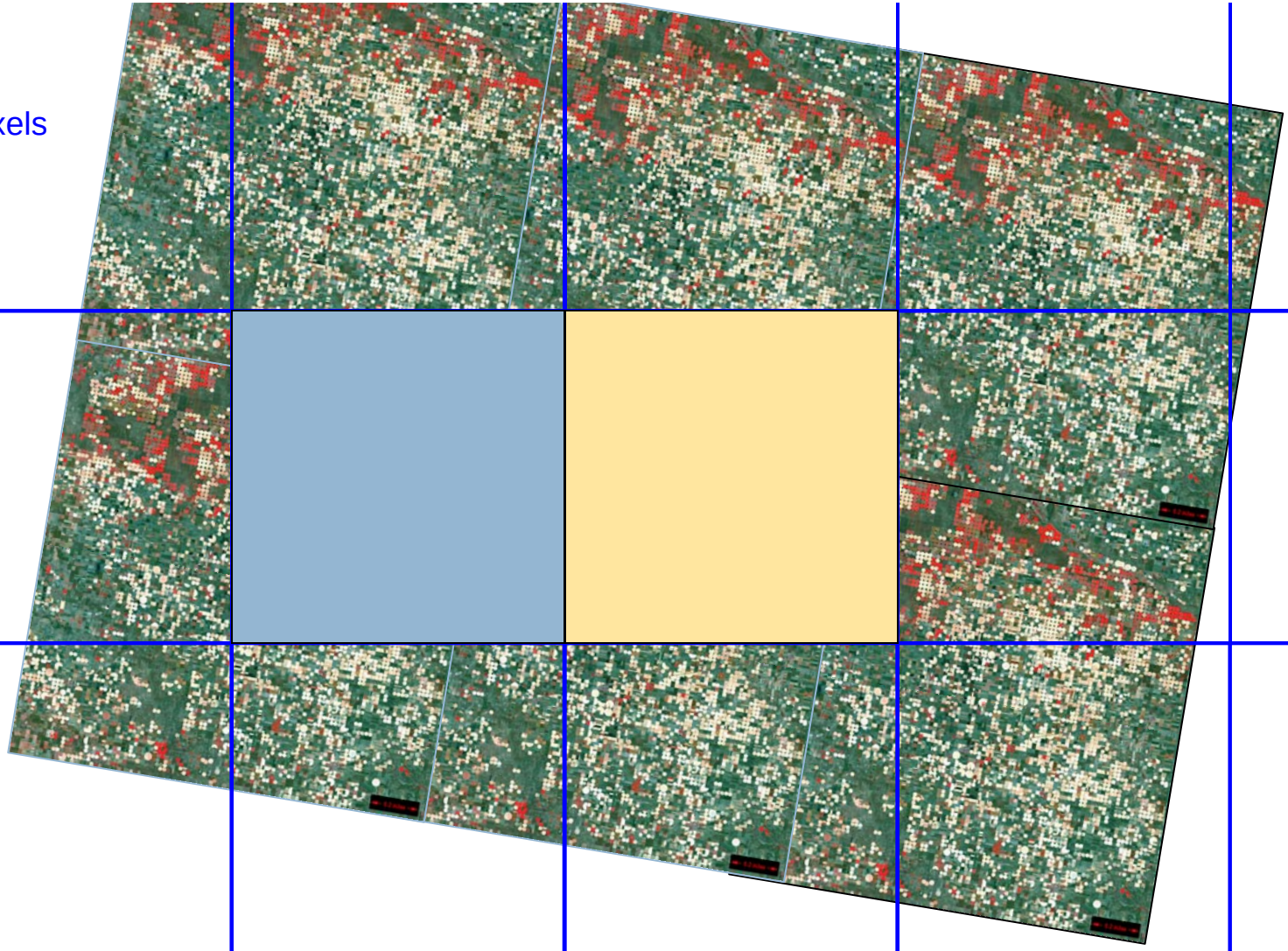

WELD Tiles
5000 x 5000 30m pixels
Albers Coordinates
Landsat
6300 x 6300 30m pixels
UTM Coordinates

WELD Tiles
5000 x 5000 30m pixels
Albers Coordinates



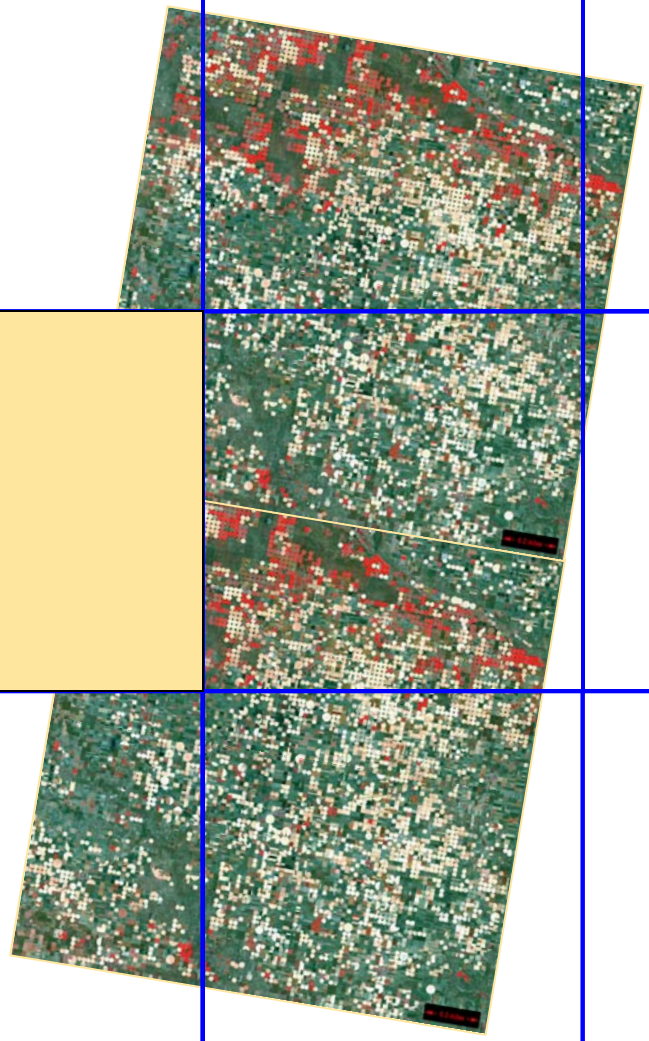
Landsat
6300 x 6300 30m pixels
UTM Coordinates

WELD Tiles
5000 x 5000 30m pixels
Albers Coordinates



Landsat
6300 x 6300 30m pixels
UTM Coordinates

WELD Tiles
5000 x 5000 30m pixels
Albers Coordinates



Landsat
6300 x 6300 30m pixels
UTM Coordinates

Some recent algorithm developments

- Atmospheric correction
- Radiometric/BRDF normalization/ Gap Filling
- Land cover characterization

WELD ETM+ Data Processing Steps

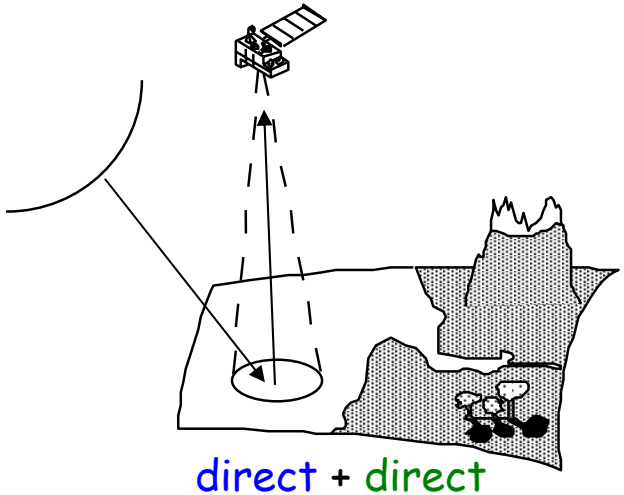
- TOA reflectance & brightness temperature
- View and Solar Geometry Computation
- Cloud mask
- SLC-Off and cloud gap filling
- Reprojection: UTM to Albers map projection
- Compositing: monthly, seasonal, annual
- Atmospheric correction
- Radiometric/BRDF normalization
- Land cover characterization
-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

WELD ETM+ Data Processing Steps

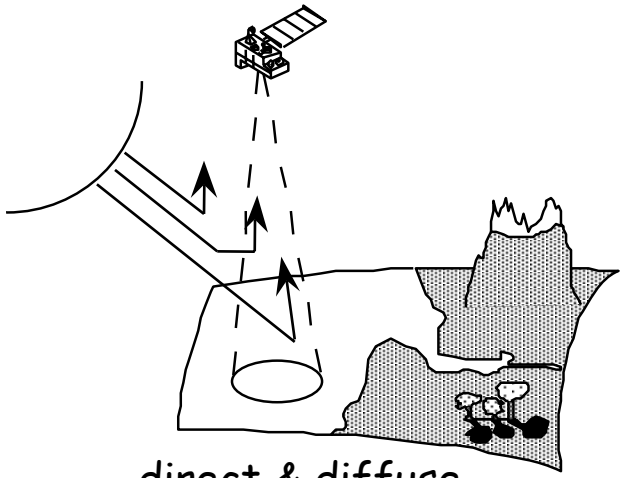
Steps that use contemporaneous MODIS Products

- TOA reflectance & brightness temperature
- View and Solar Geometry Computation
- Cloud mask
- 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

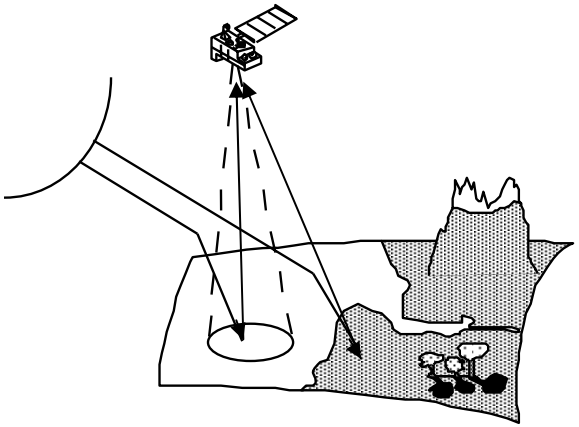
Atmospheric Correction – remove atmospheric effects for shortwave energy (paths up and down)



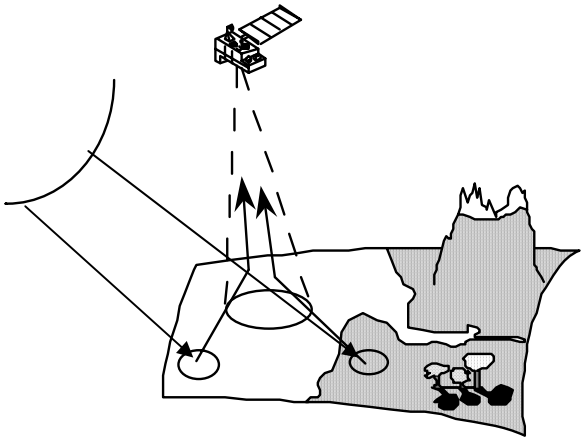
direct + direct



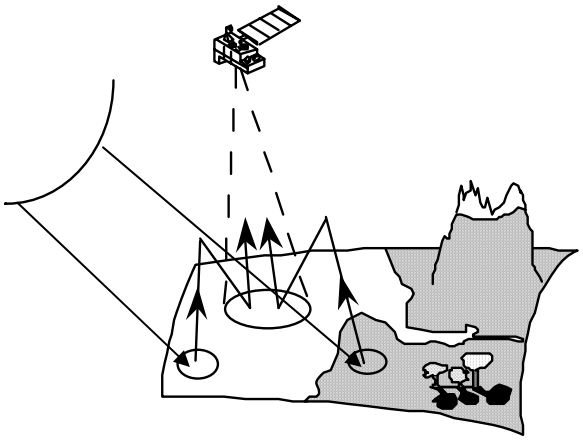
direct & diffuse
(purely atmospheric contribution, aka path radiance)



diffuse + direct



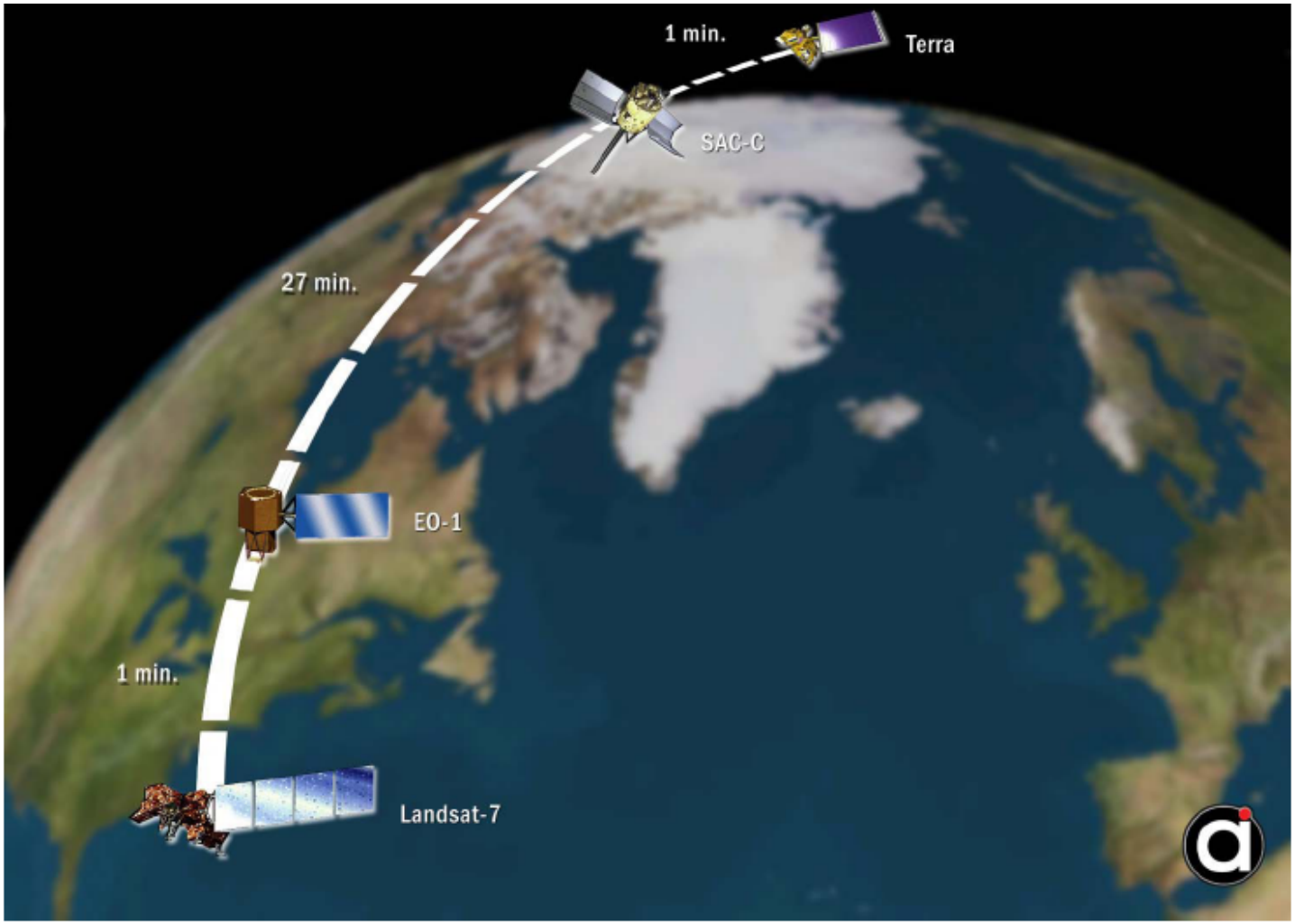
direct + diffuse



multiple scattering

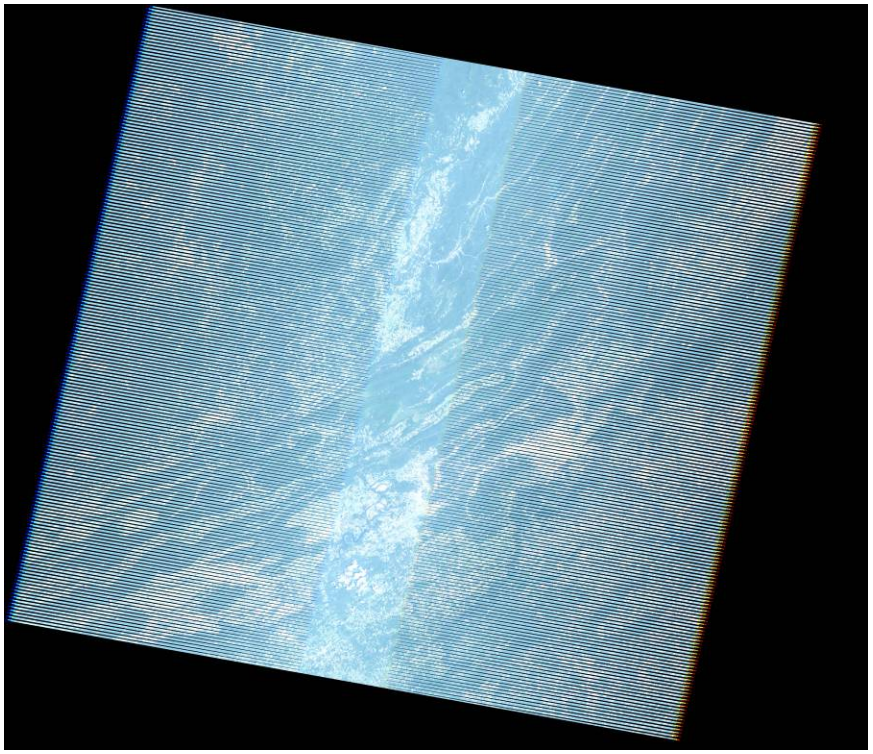
Eric Vermote

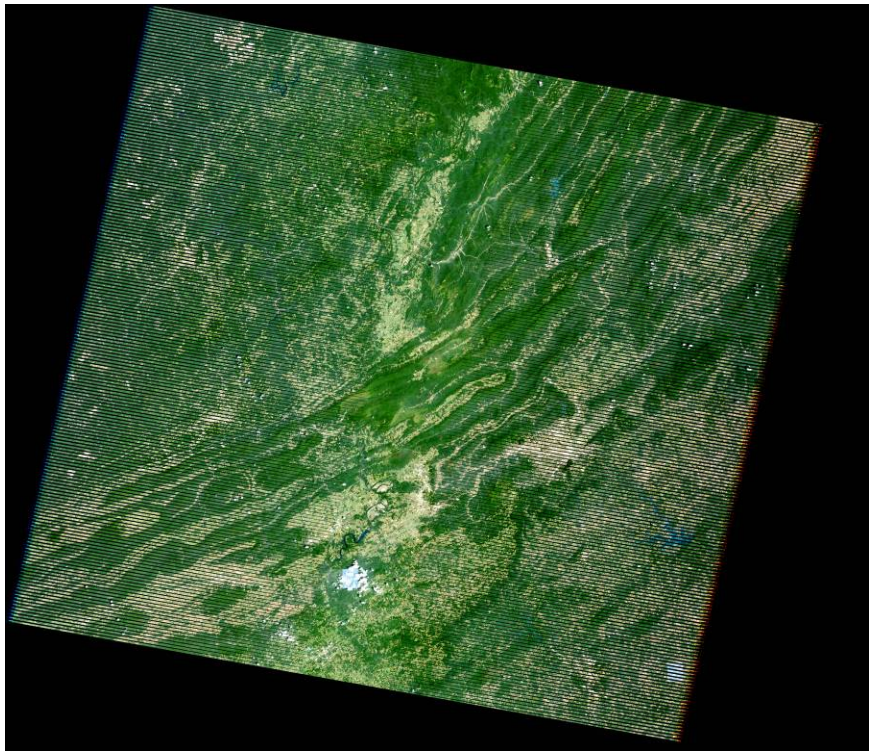
Landsat ETM+ and MODIS Terra in same orbit



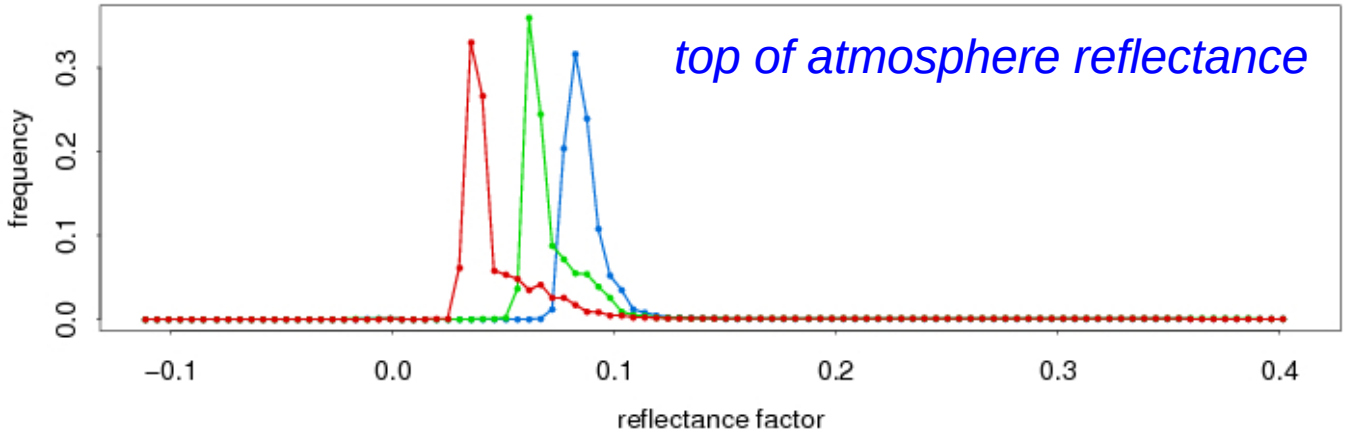
North West: Top of atmosphere Landsat ETM+ true color (red , green and blue bands); **South East:** Corresponding Surface reflectance computed using contemporaneous MODIS atmosphere parameterization data.

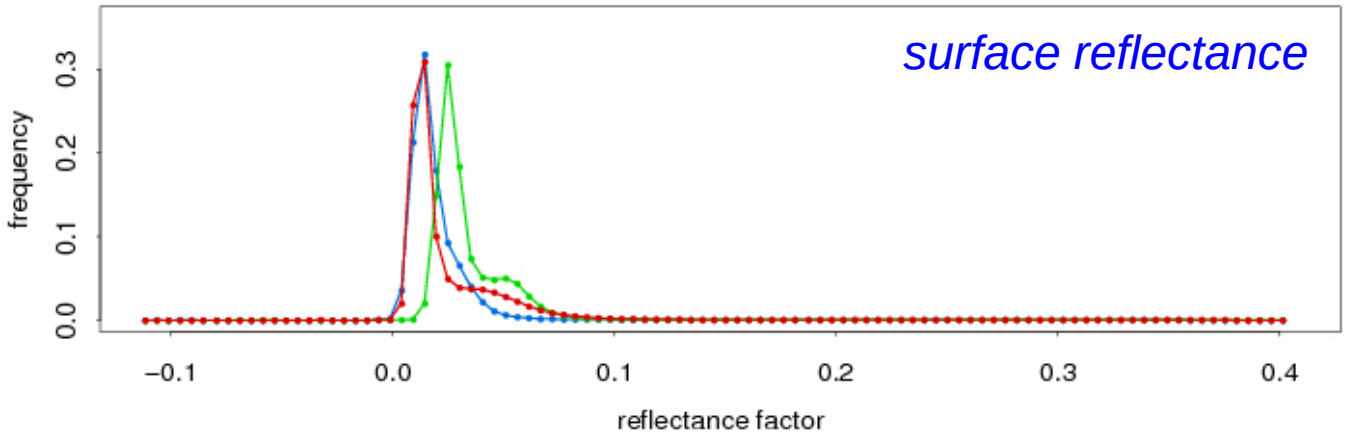
(Landsat Path 17 Row 34, Giles, Virginia, acquired July 18, 2008).





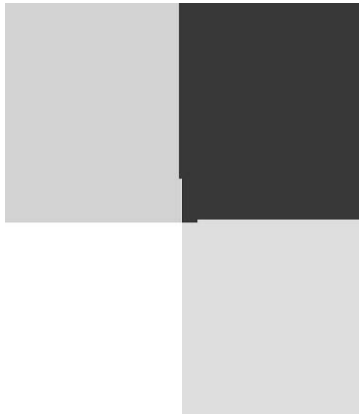
The atmospheric correction reduces visible reflectance, greatest reductions in the shorter wavelength blue band which has more atmospheric scattering, and with the green atmospherically corrected band showing greater reflectance after correction which is expected given that the scene is dominated by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



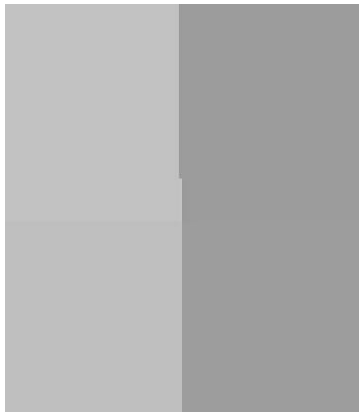


Blockiness due to 0.05° MODIS atmospheric paramerization

Surf reflectance true color



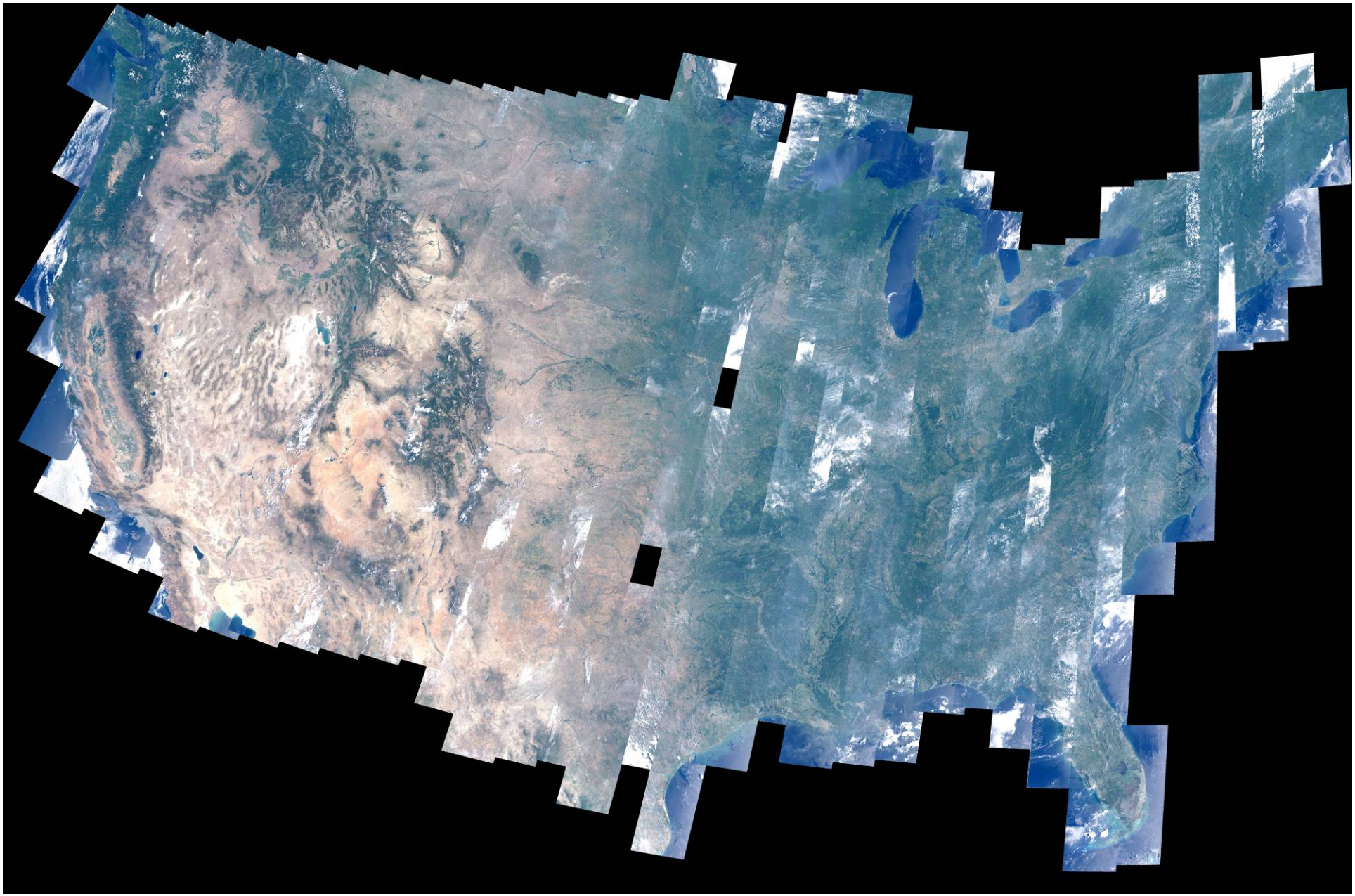
AOT



Water vapor

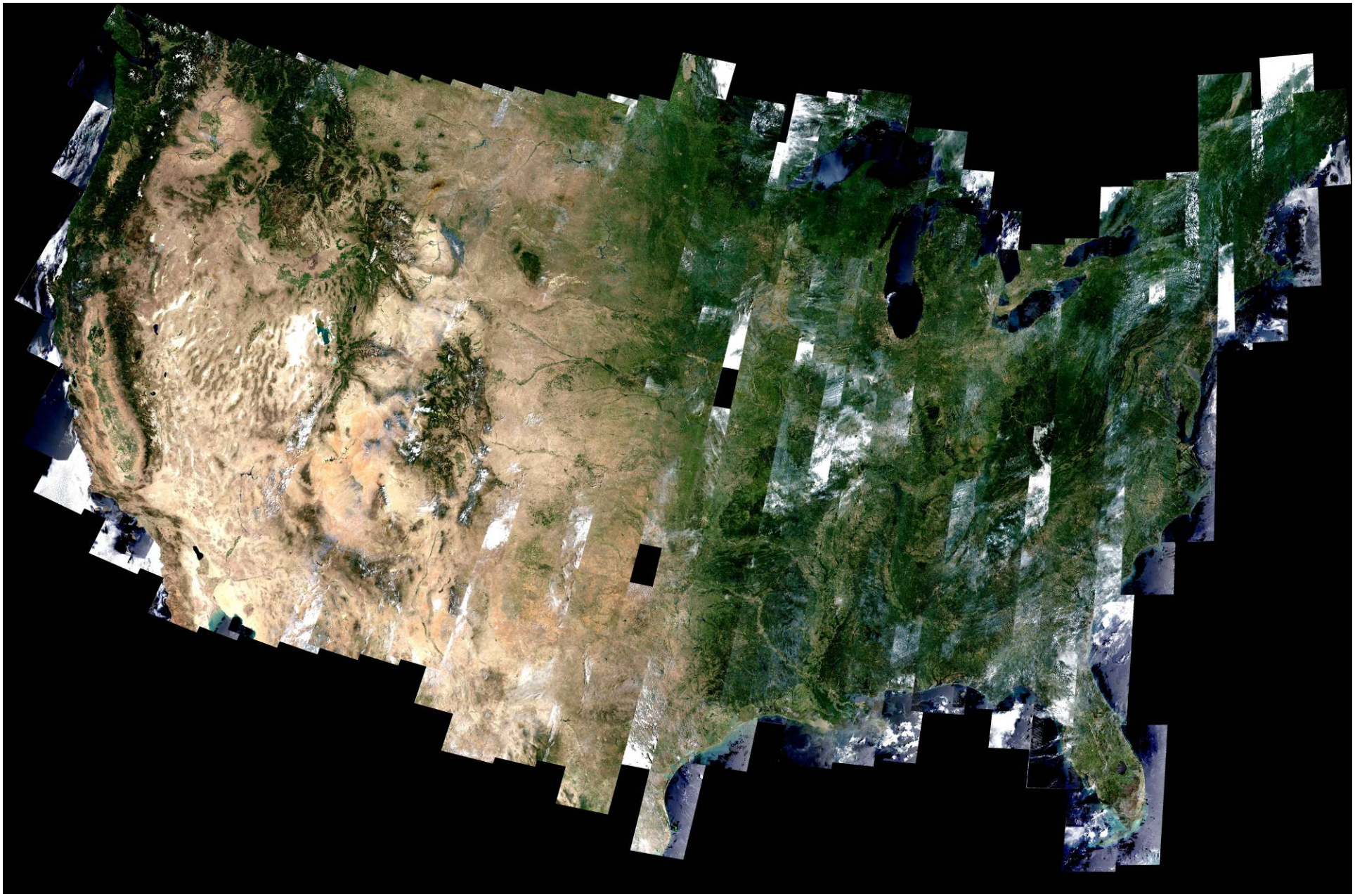
July 2008 composite. Band 3, 2, 1 (red, green, blue)

Top of Atmosphere Reflectance



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

Surface Reflectance – using advanced MODIS Landsat method



Radiometric Normalization

- WELD processing (conversion to reflectance, cloud screening, atmospheric correction, compositing) will largely remove reflectance variations

- Except for reflectance differences due to illumination & observation angles

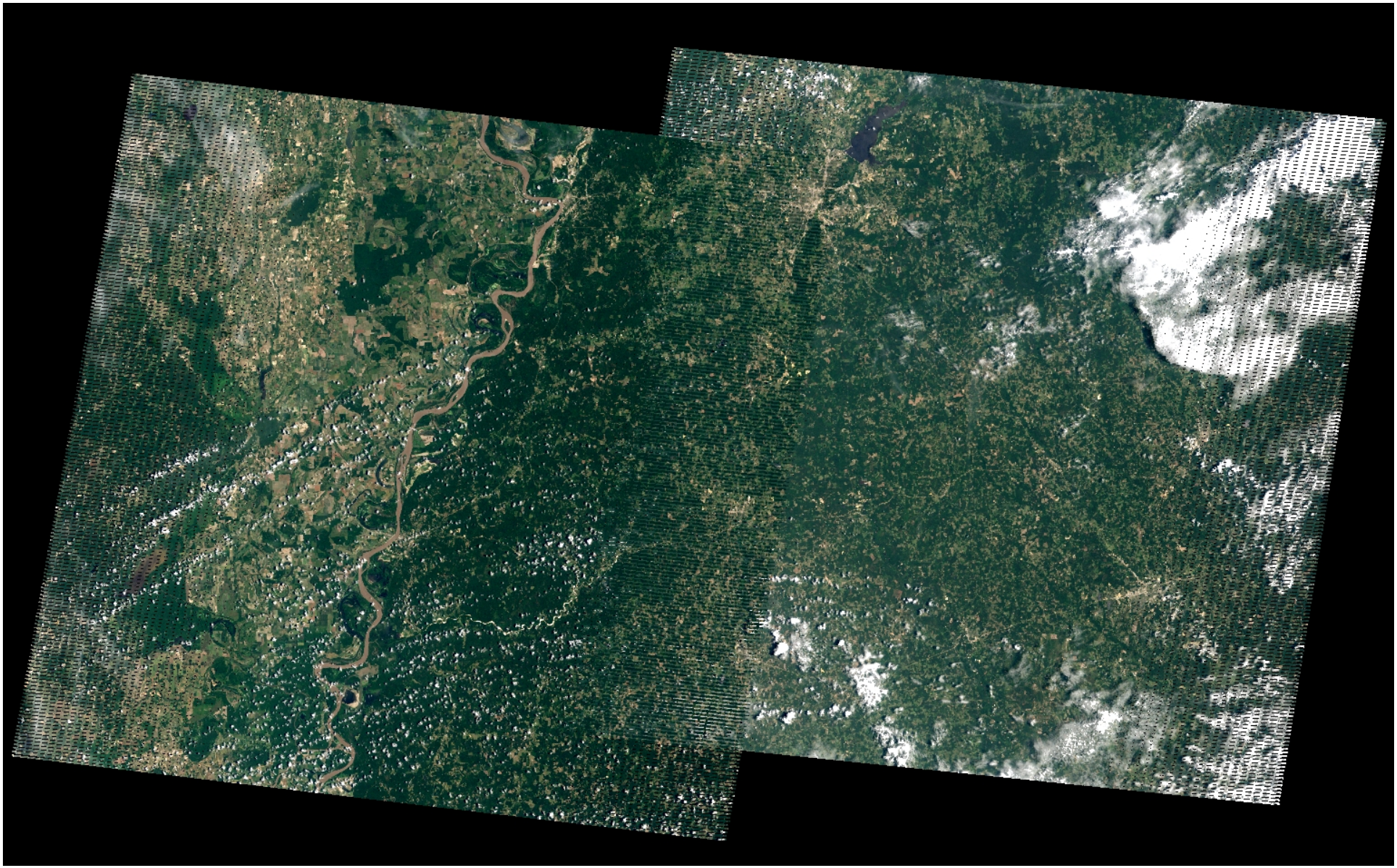
$$\hat{\rho}_{ETM+,t1}\left(\lambda_{ETM+},\Omega_{nadir},\Omega'_{solar\ noon}\right)=c\times\rho_{ETM+,t1}\left(\lambda_{ETM+},\Omega_{observed},\Omega'_{observed}\right)$$

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

$\hat{\rho}_{MODIS}$ computed from MODIS 16-day 500m BRDF/Albedo product spectral BRDF model parameters

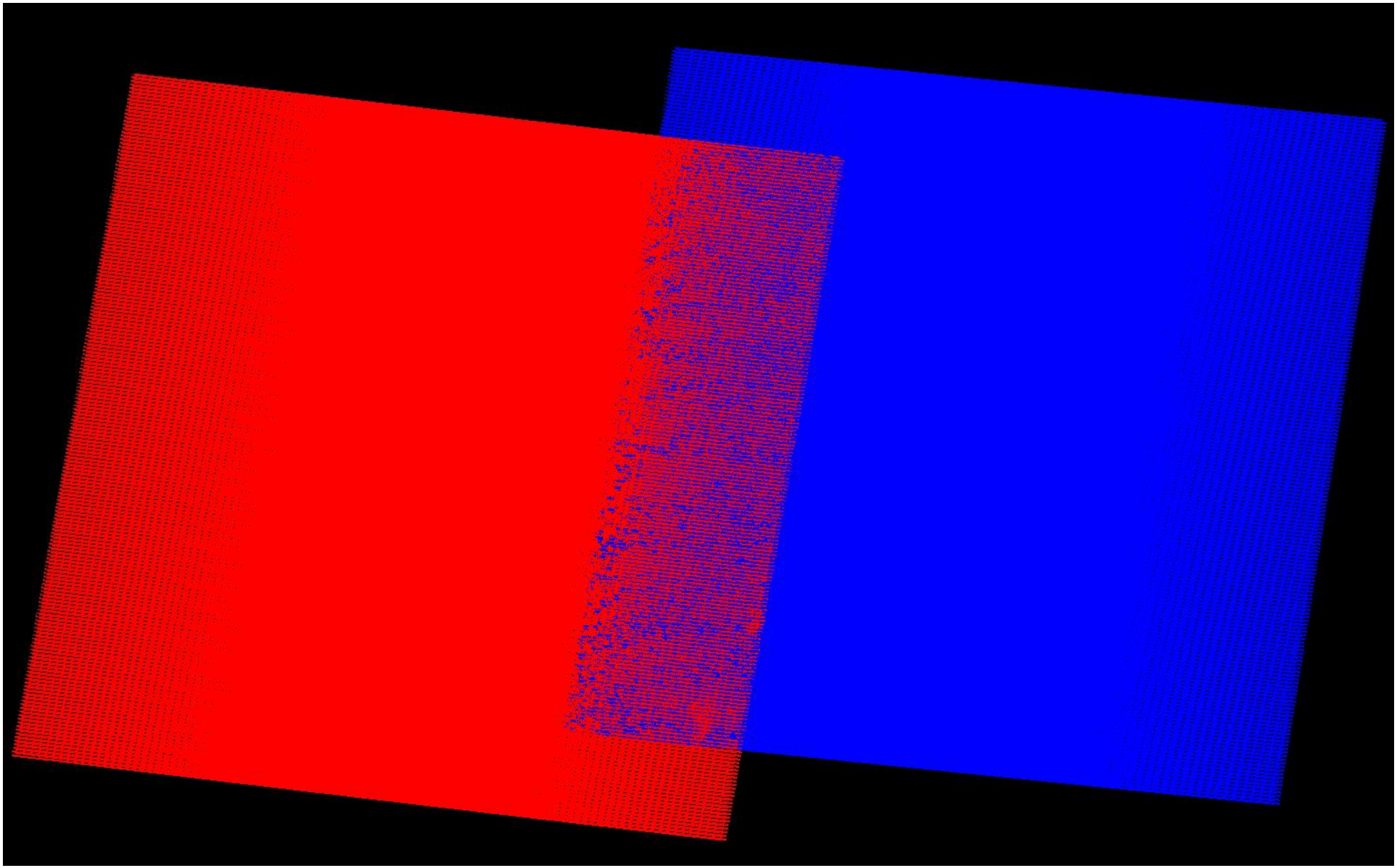
Thus, Landsat reflectance may be normalized to some desired geometry e.g., nadir view zenith and local solar noon, for each 500m MODIS pixel.

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



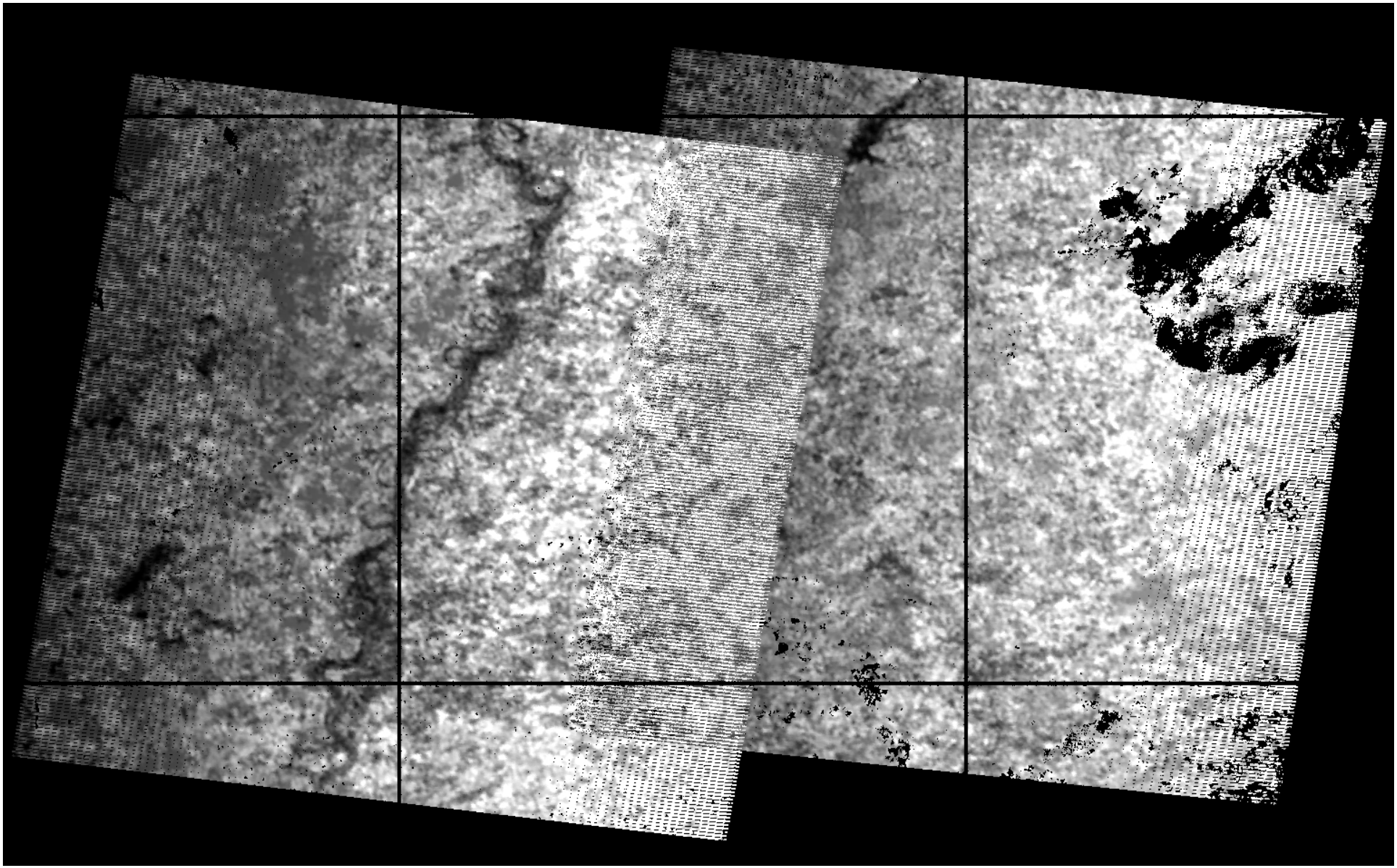
Composited Day of Year

Red: July 12 Blue: July 5



Band 3 (red, 0.63-0.69 μm)

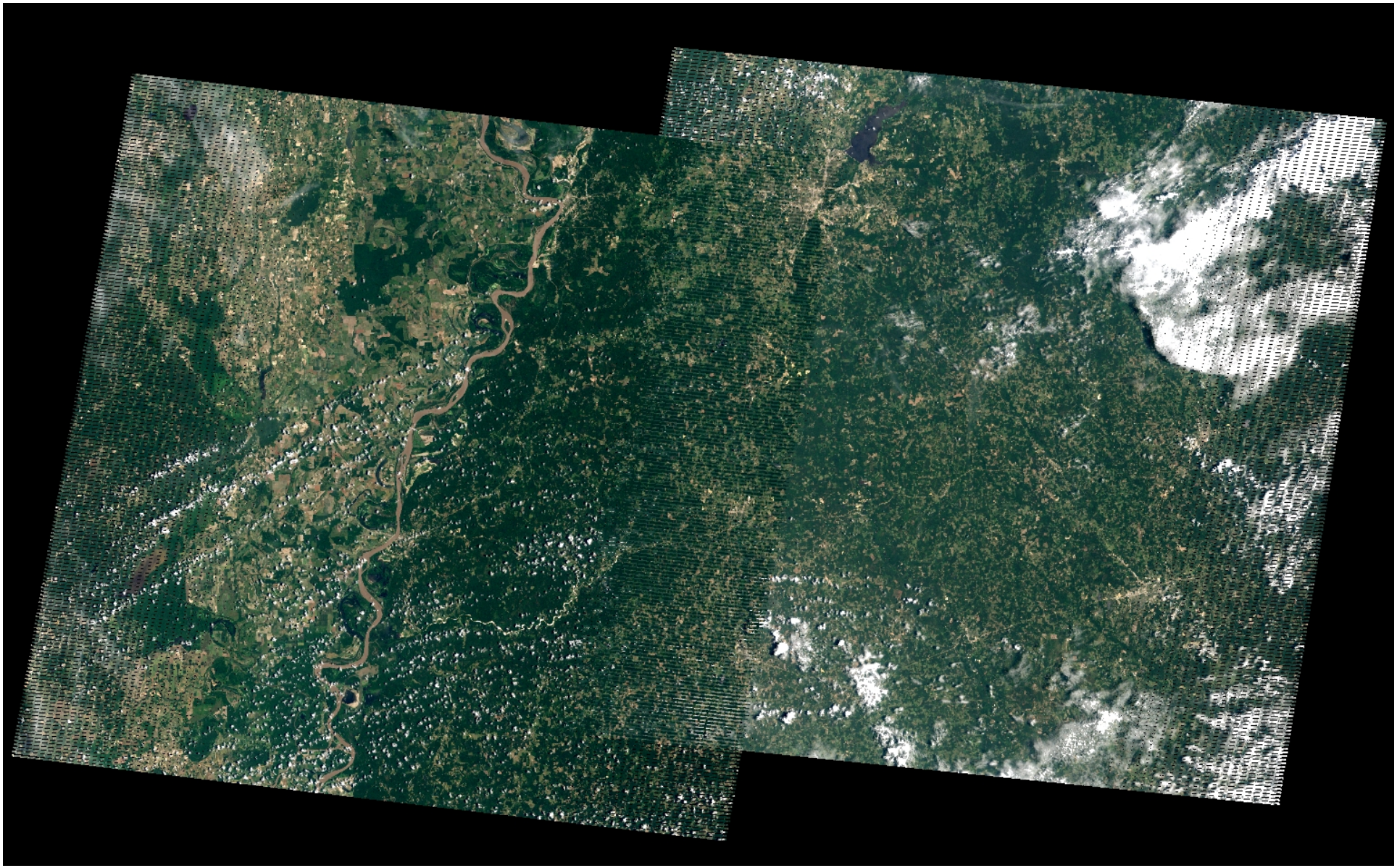
MODIS derived scaling factors (range: 0.97-1.43)



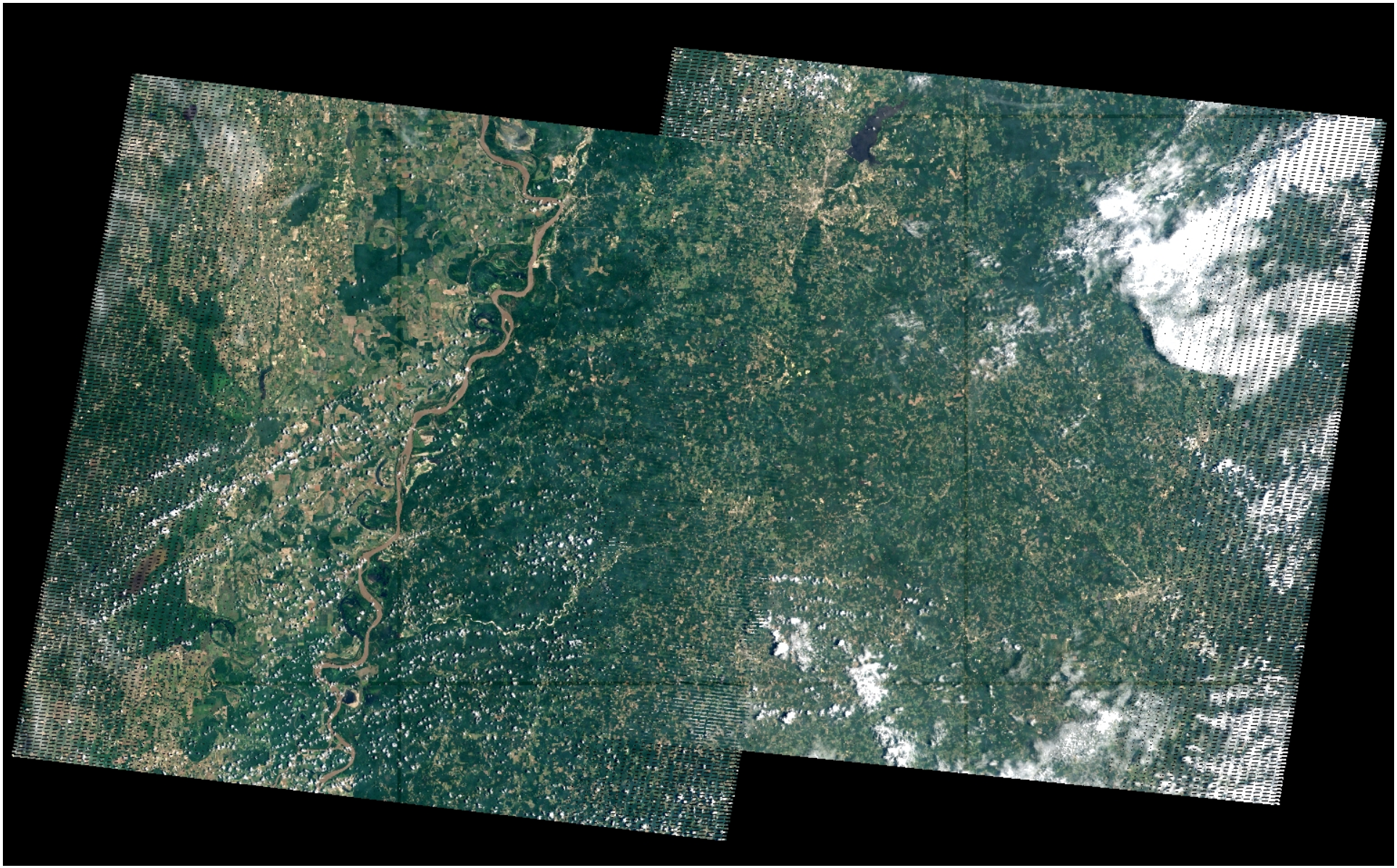
j3 i

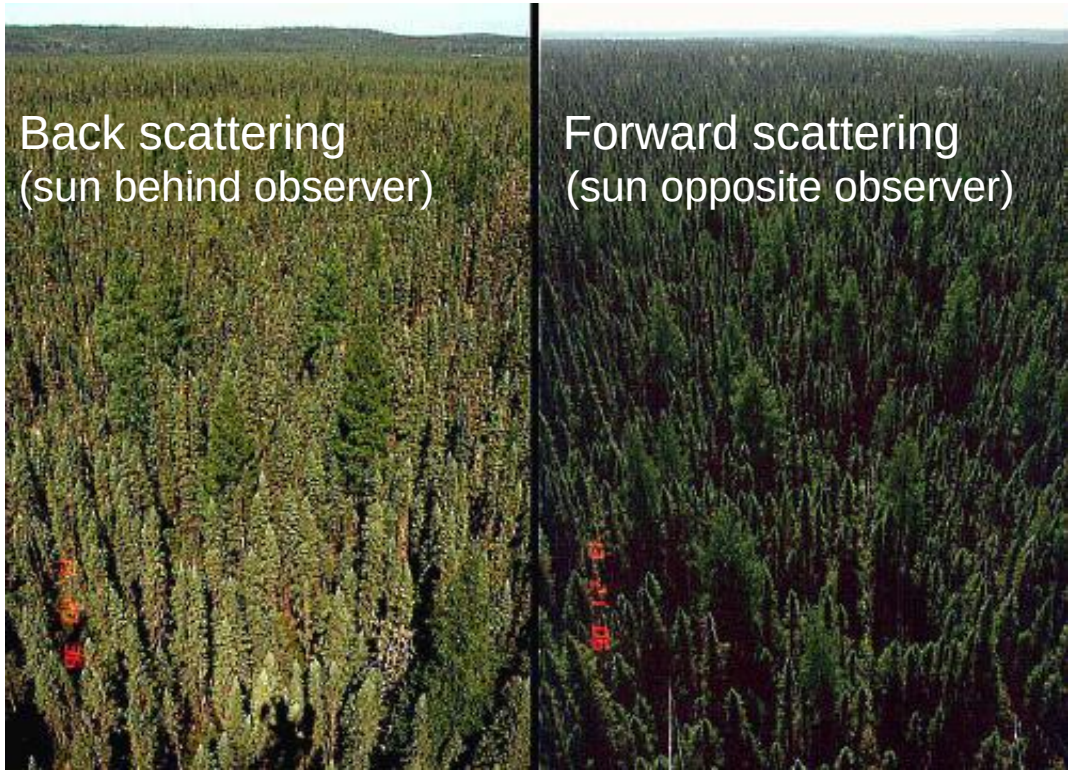
junchang.ju, 10/23/2009

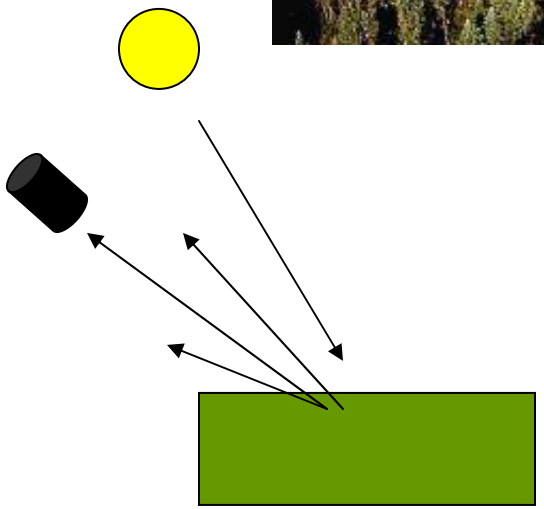
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
Band 3, 2, 1 (red, green, blue) TOA reflectance
Before radiometric normalization



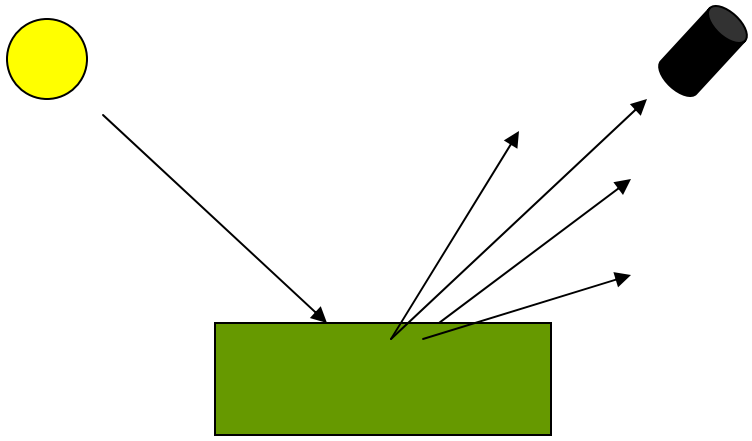
Path 23 Row 38, July 12 & Path 22 Row 38, July 5, 2008
Band 3, 2, 1 (red, green, blue) TOA reflectance
After radiometric normalization







Back scatter direction



Forward scatter direction

Atmospheric Scattering Phase Function Effects

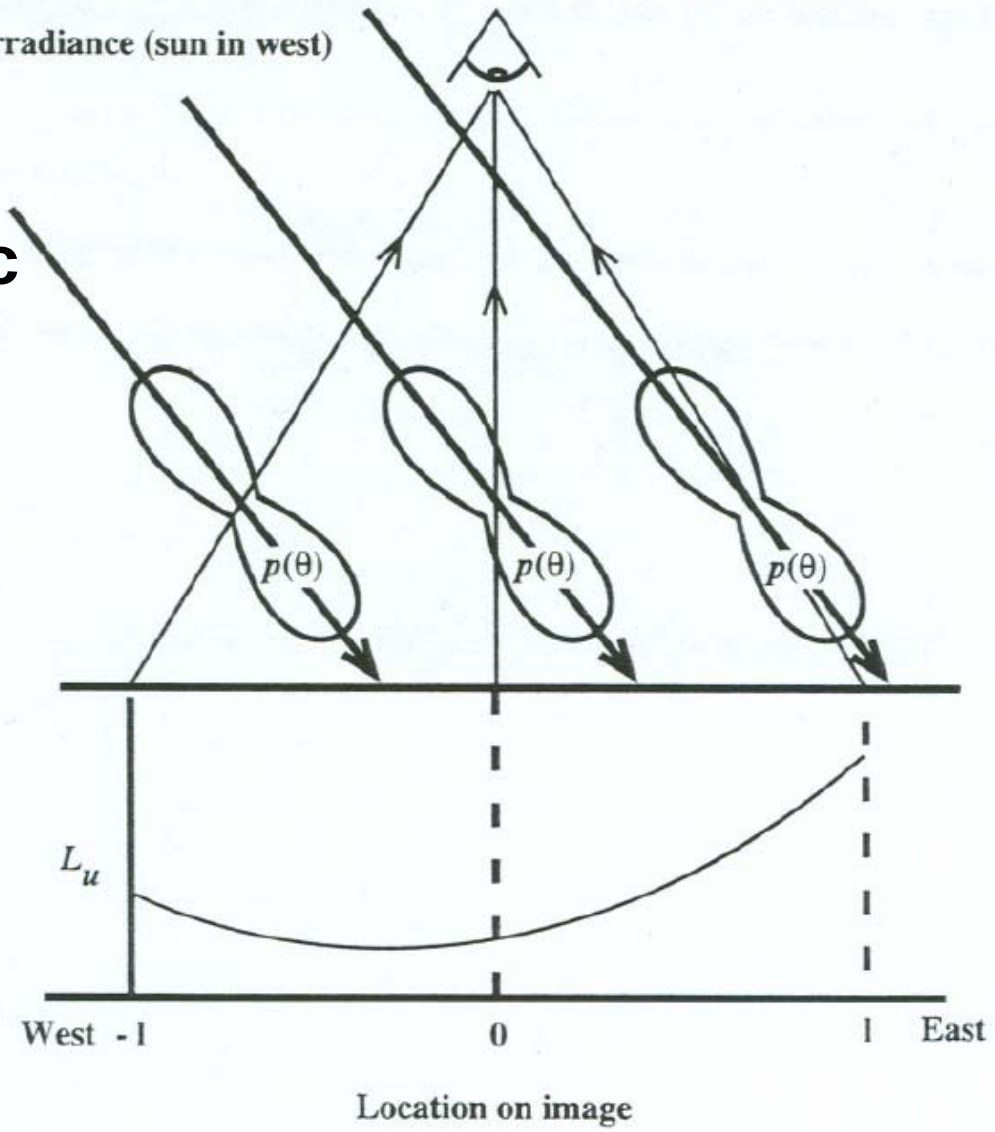
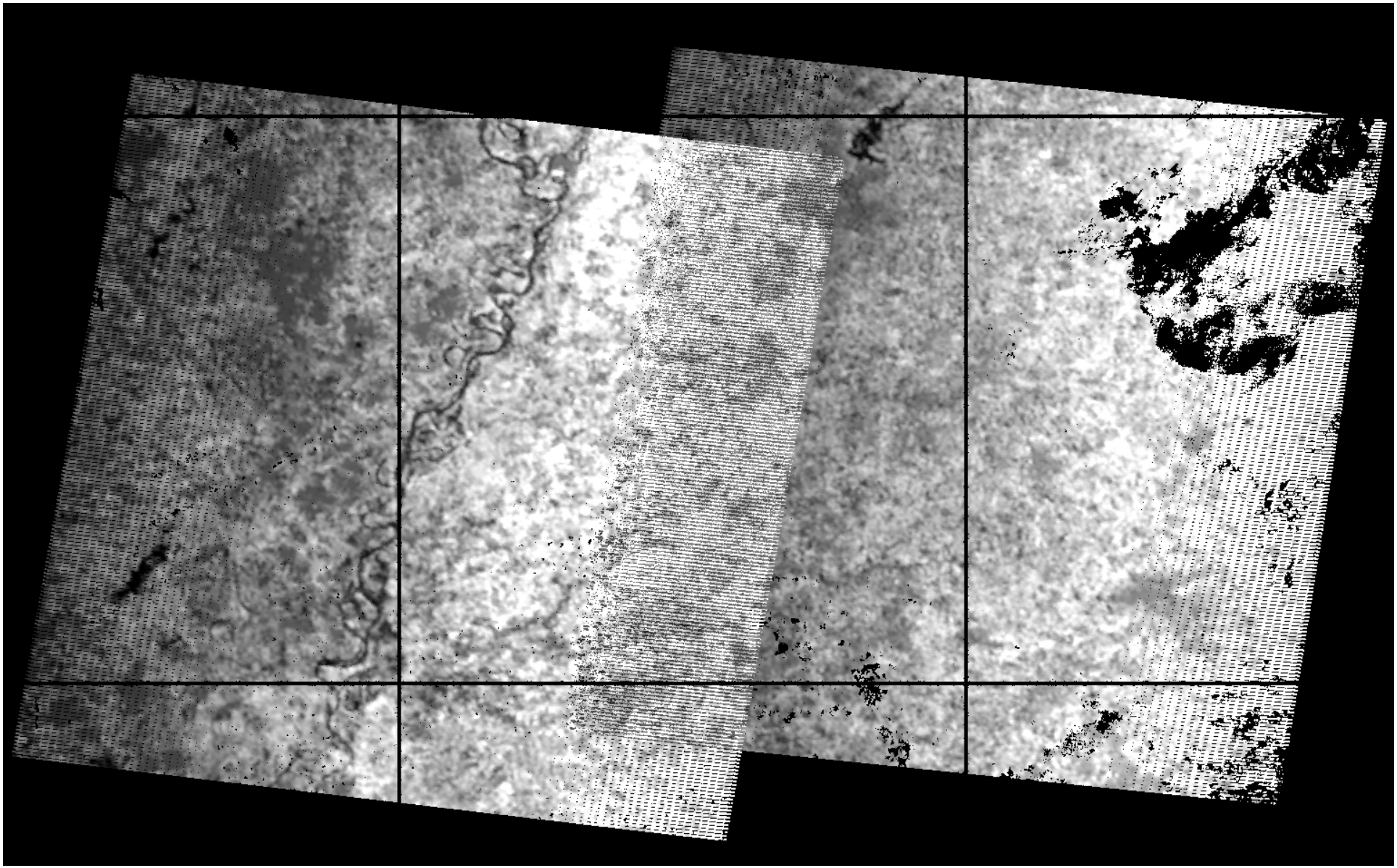
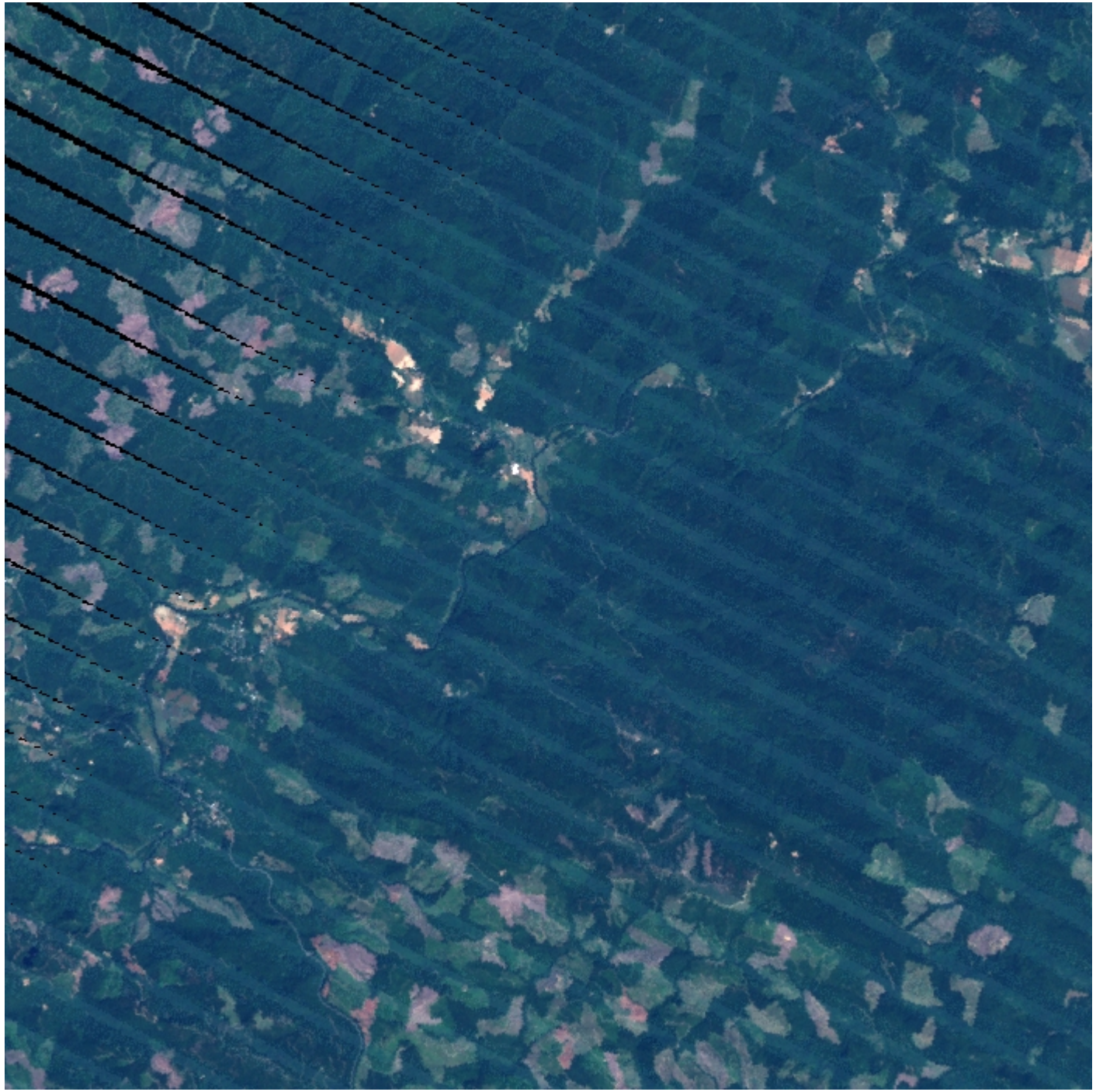


Figure 4.11 Variation in path radiance with view angle. A Rayleigh phase function is shown for refe

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





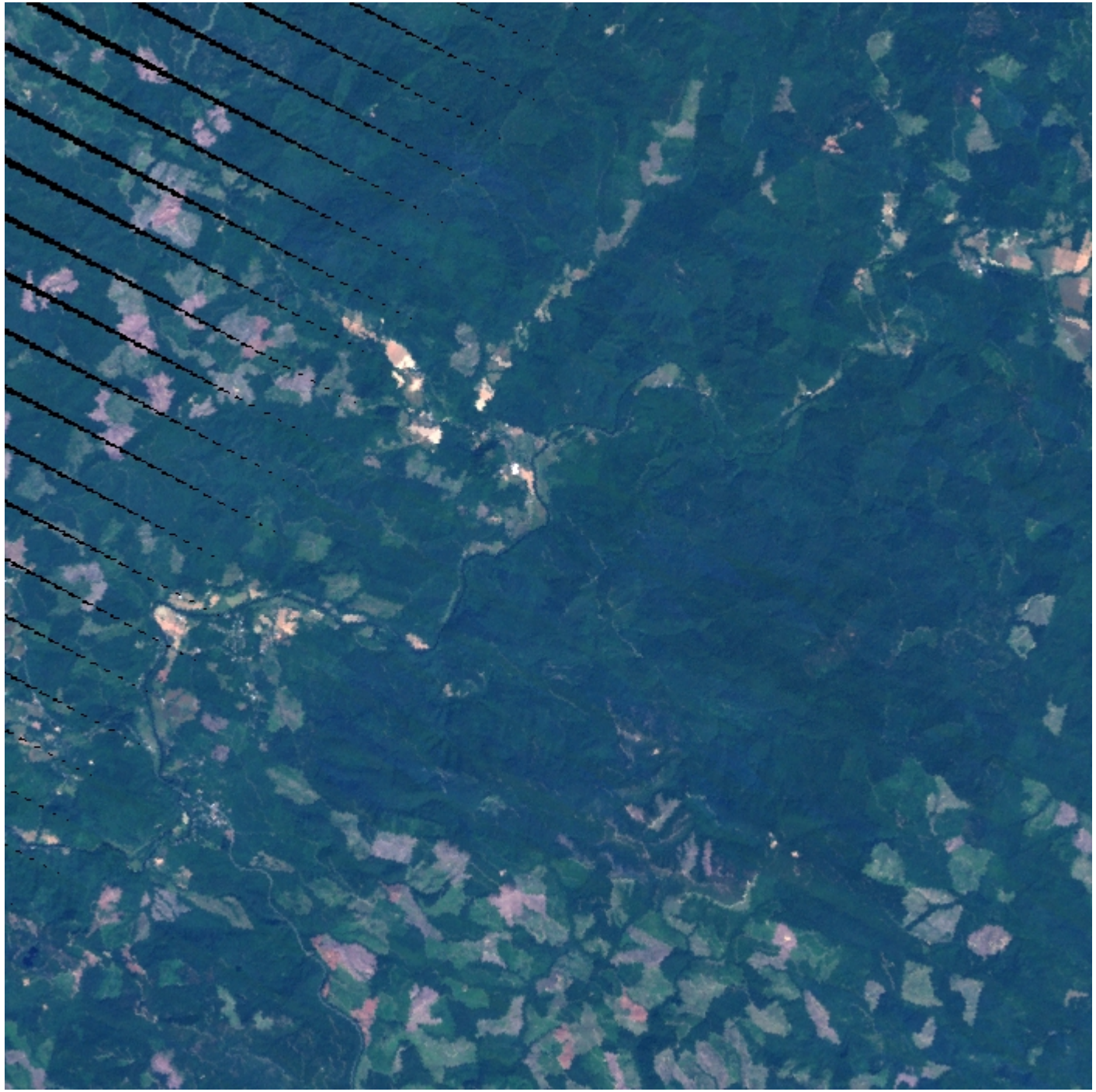
July 2008

2 dates composited

Bands 3,2,1

700 x 700
30m pixels

Before radiometric normalization



July 2008

2 dates composited

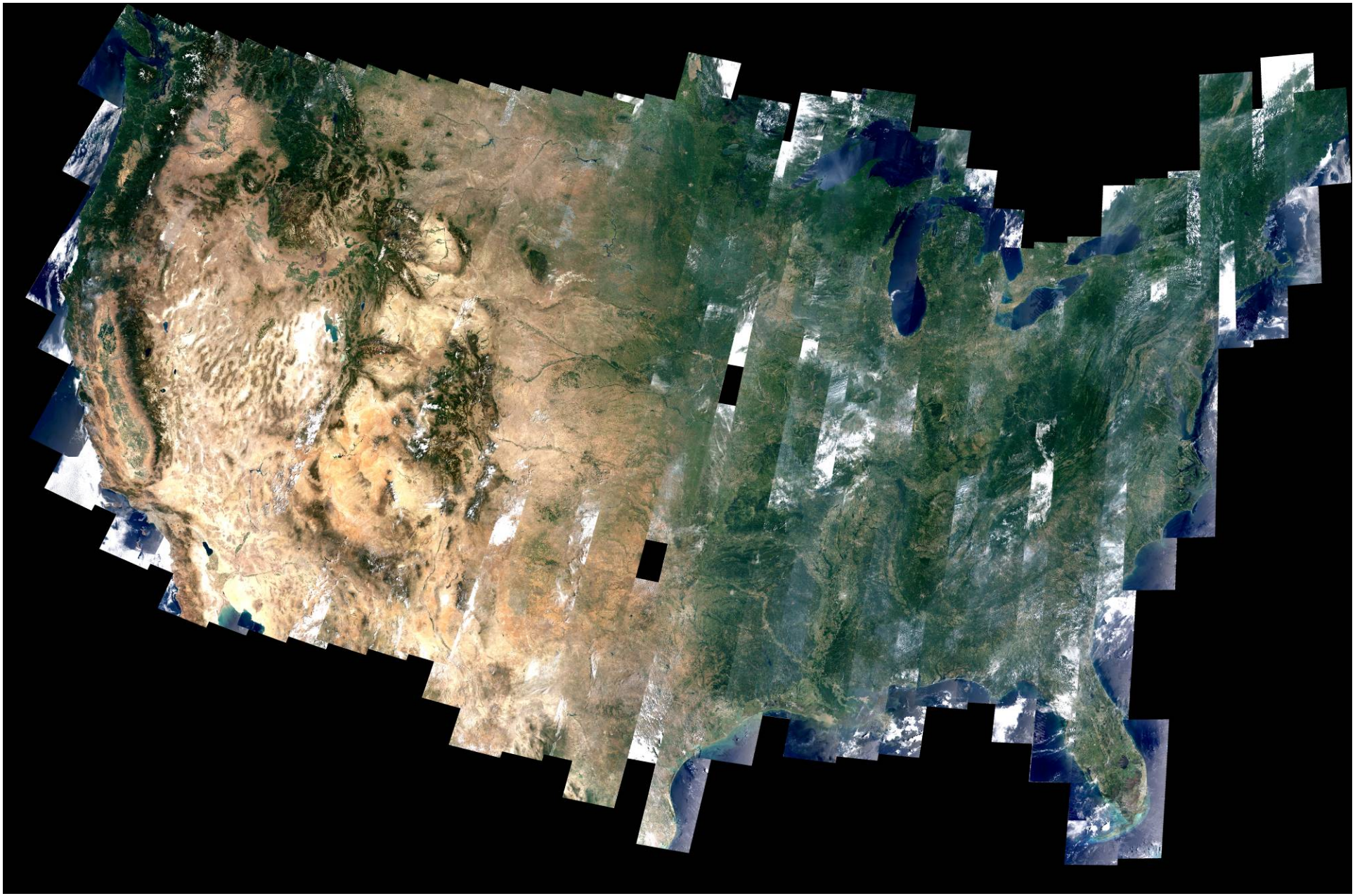
Bands 3,2,1

700 x 700
30m pixels

After radiometric normalization

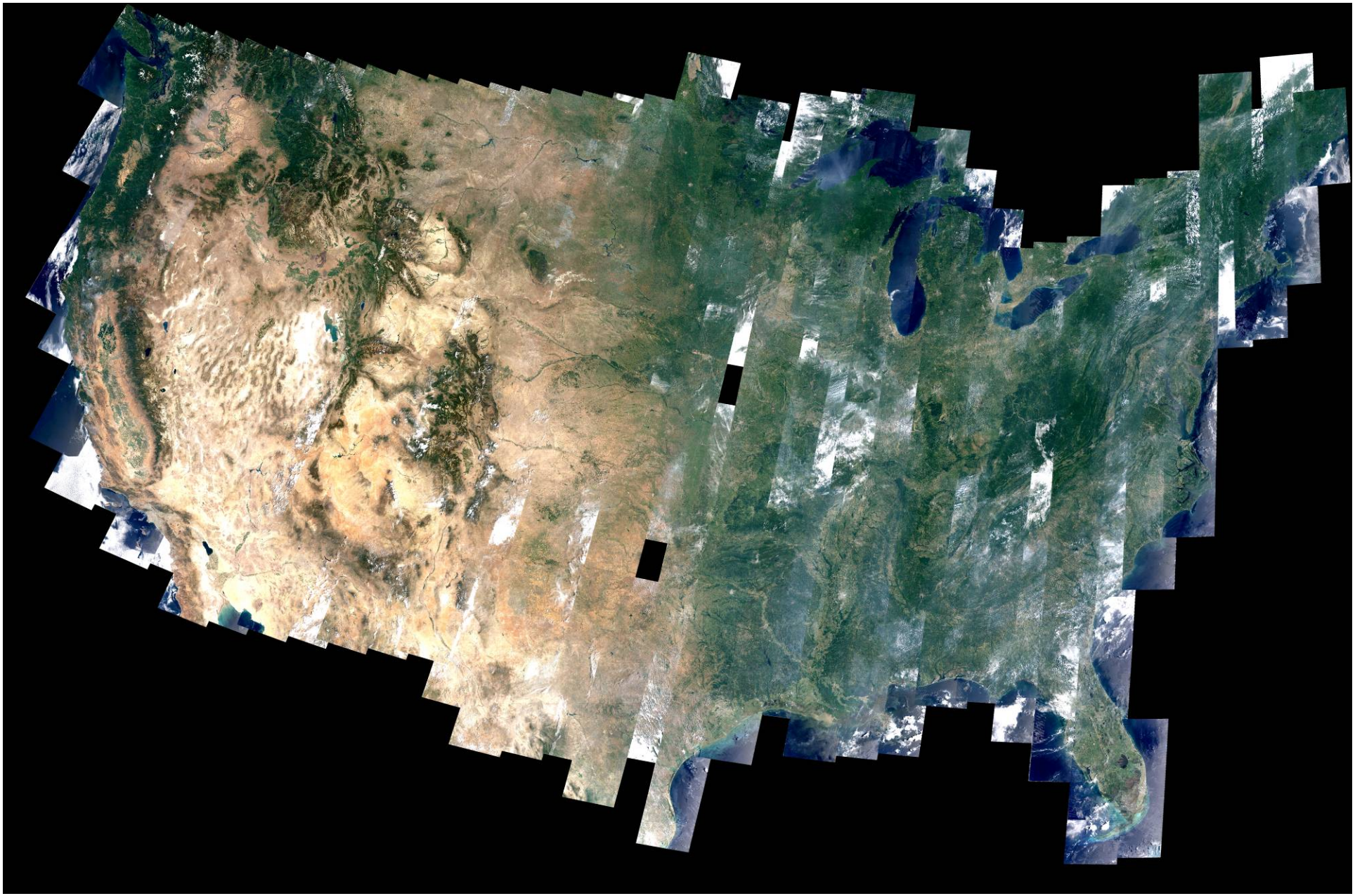
July 2008 composite. Band 3, 2, 1 (red, green, blue) TOA reflectance

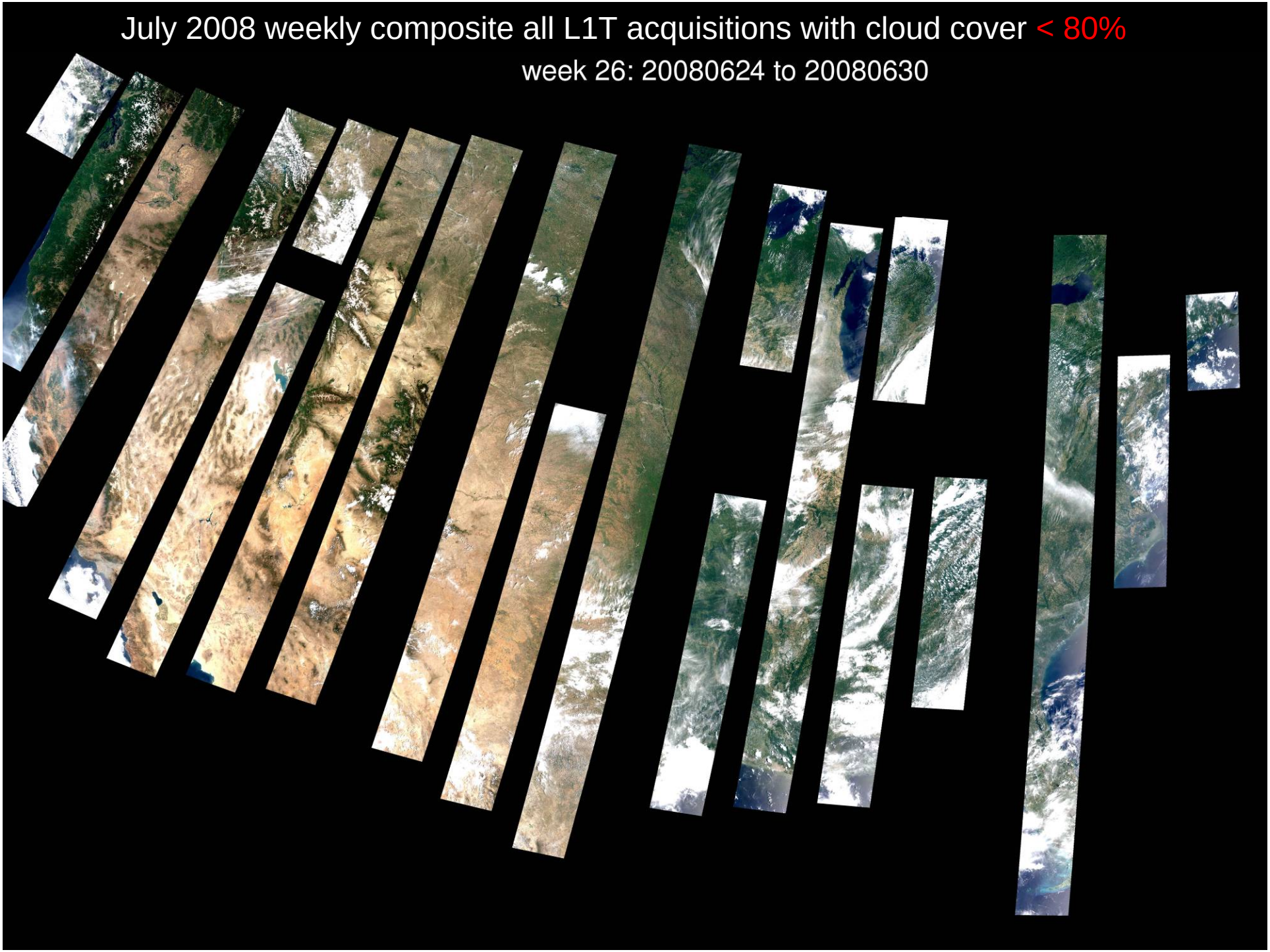
Before radiometric normalization

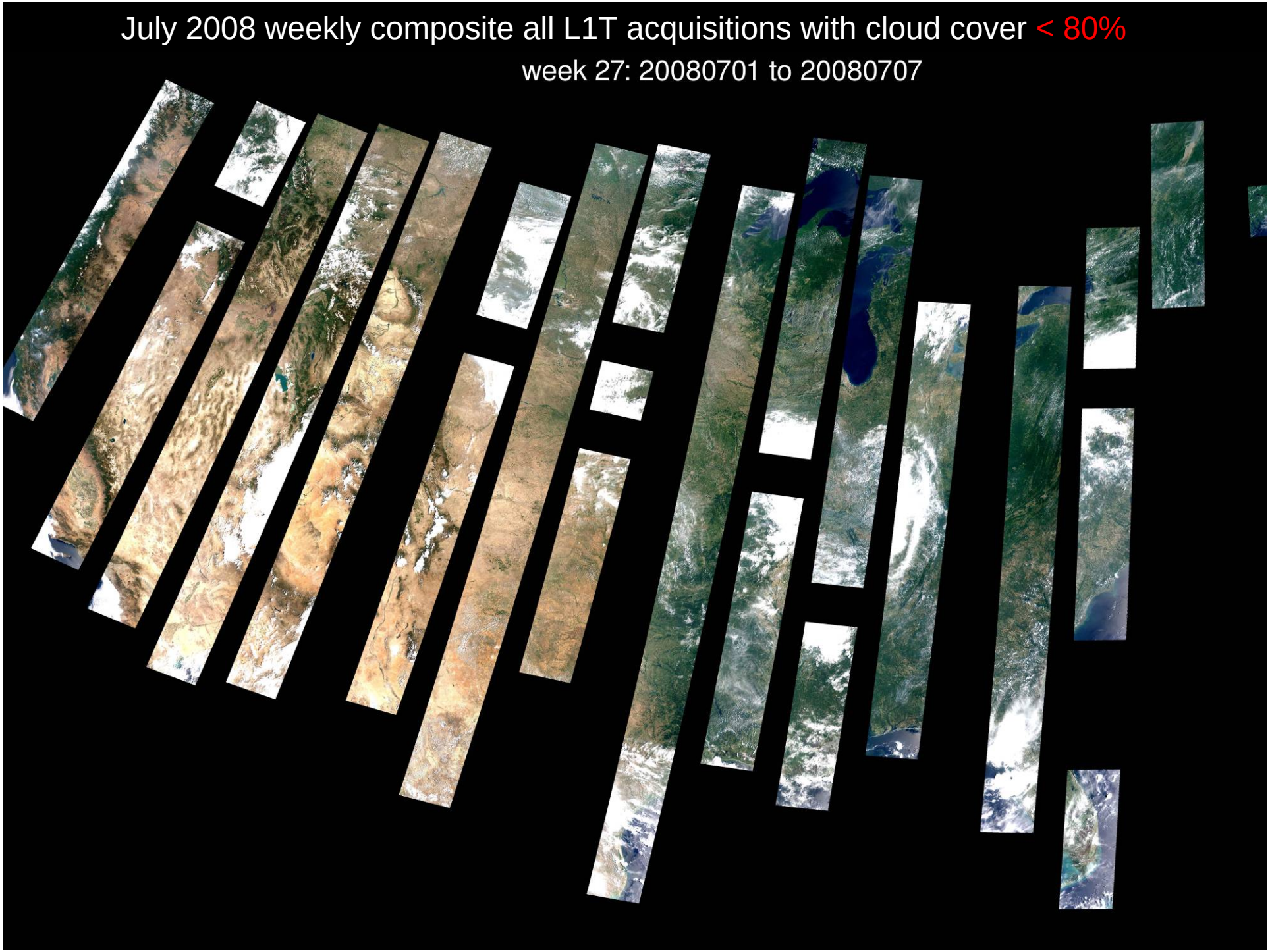


July 2008 composite. Band 3, 2, 1 (red, green, blue) TOA reflectance

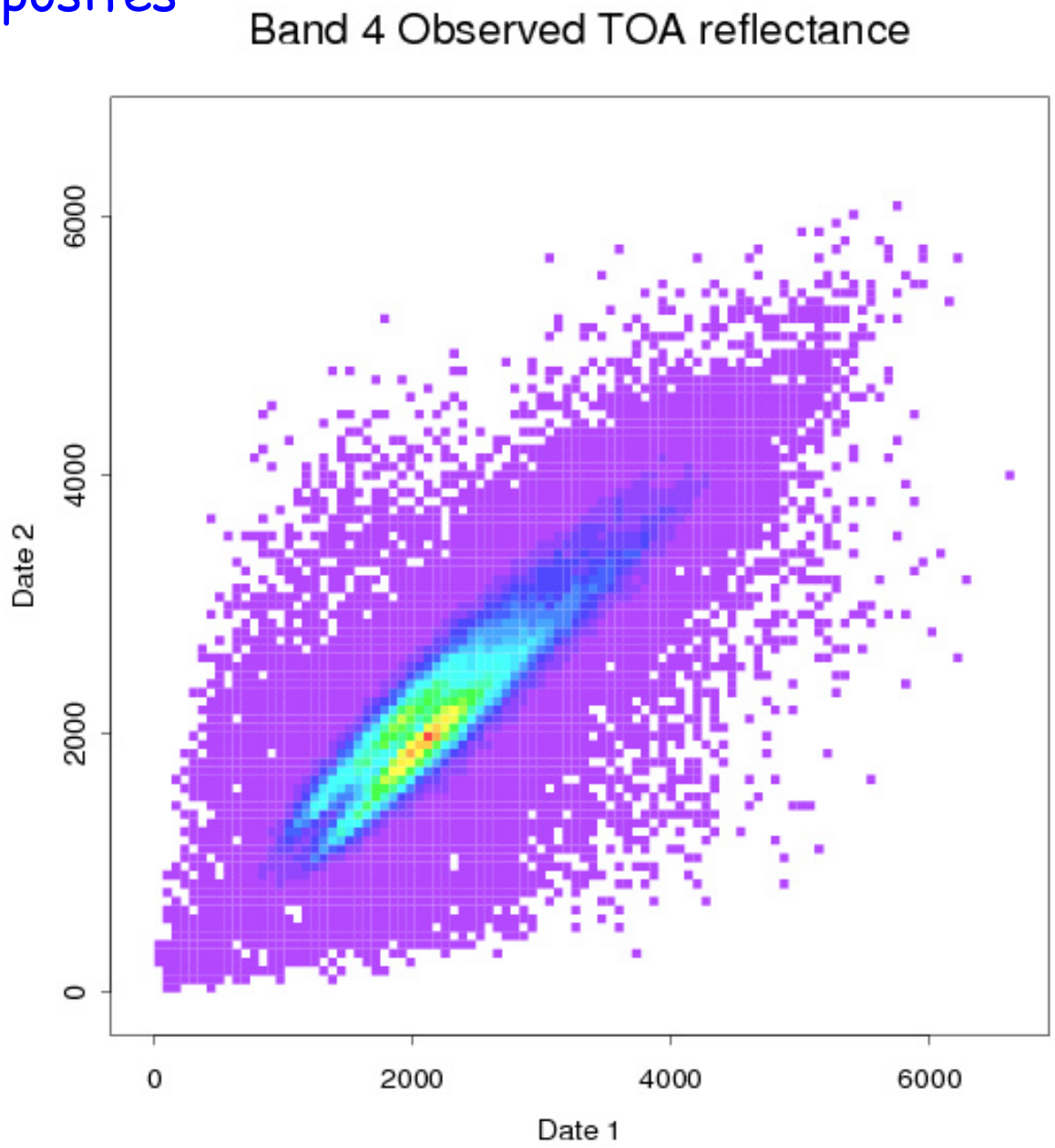
After radiometric normalization



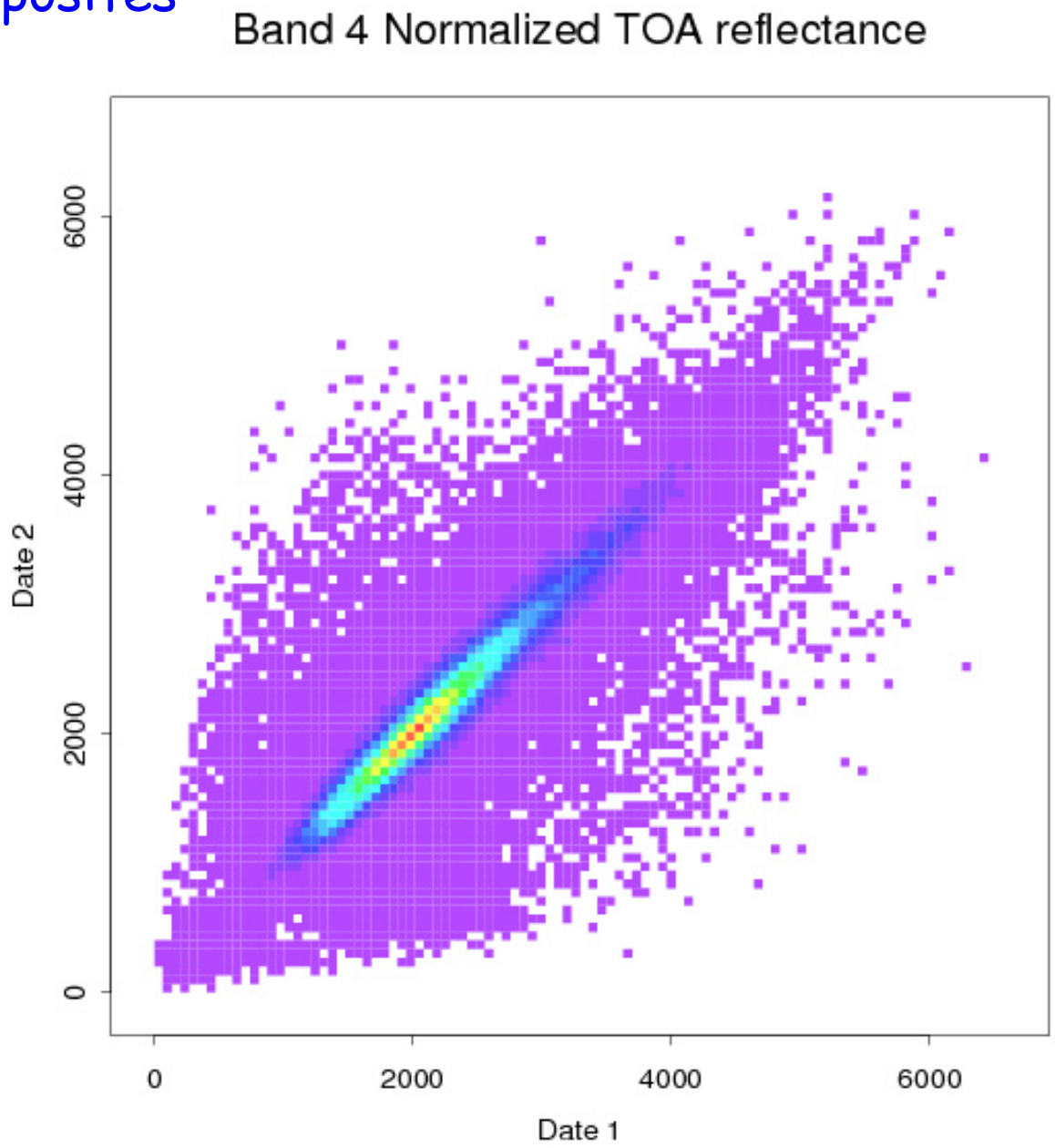

July 2008 weekly composite all L1T acquisitions with cloud cover < 80%
week 26: 20080624 to 20080630


July 2008 weekly composite all L1T acquisitions with cloud cover < 80%
week 27: 20080701 to 20080707

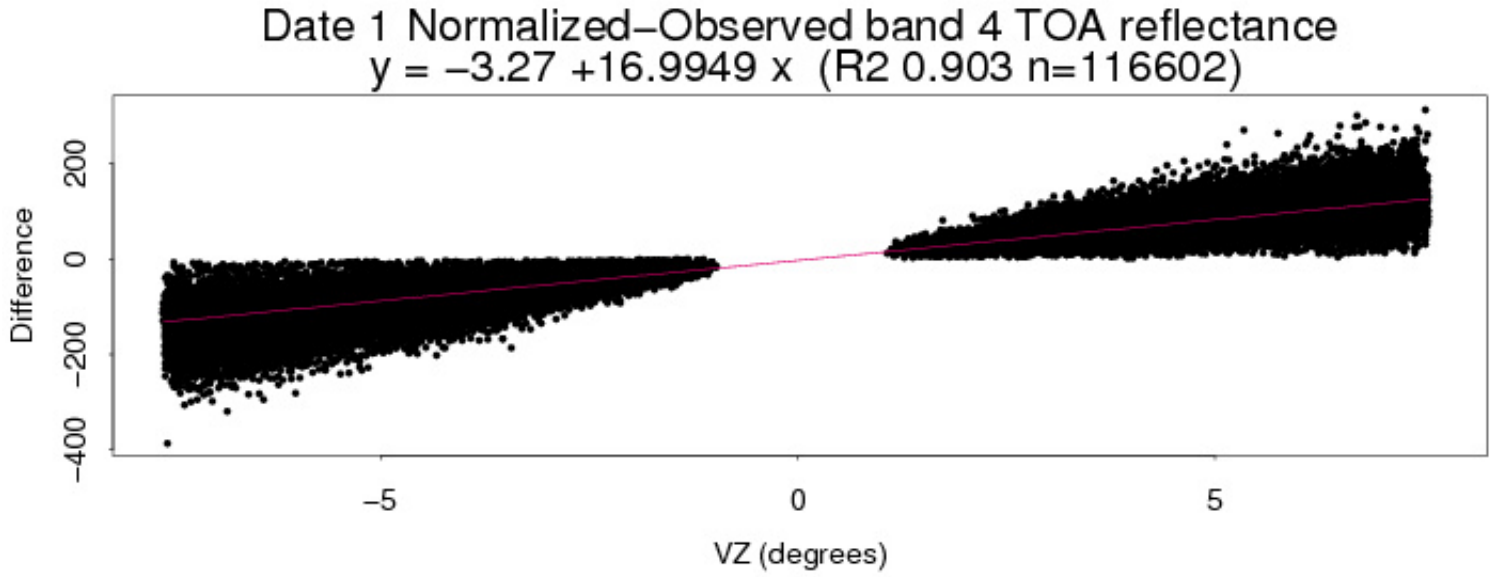
Temporal reflectance comparison of 2 successive July 2008 weekly CONUS composites

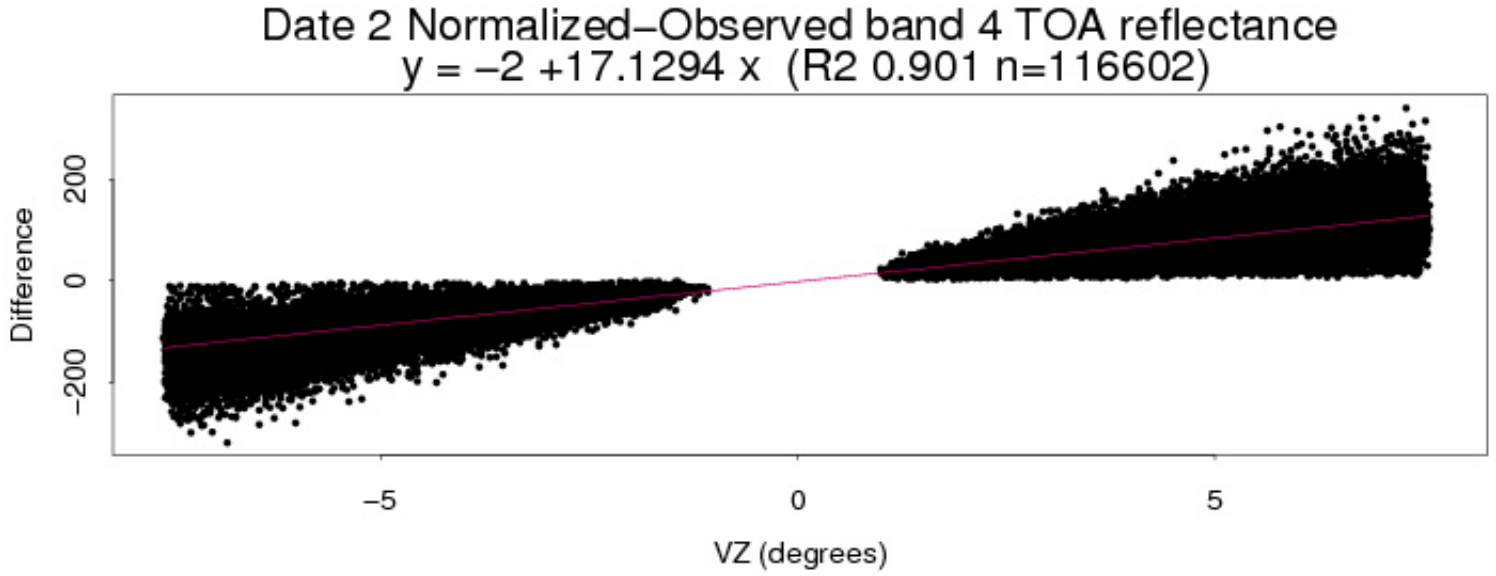


Temporal reflectance comparison of 2 successive July 2008 weekly CONUS composites



Temporal reflectance comparison of 2 successive July 2008 weekly CONUS composites





Radiometric Normalization

- The WELD processing (conversion to TOA reflectance, cloud screening, atmospheric correction, compositing) will largely remove reflectance variations

- except for reflectance differences due to illumination & observation angles

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

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

$\hat{\rho}_{MODIS}$ computed from MODIS 16-day 500m BRDF/Albedo product spectral BRDF model parameters

Thus, Landsat reflectance may be normalized to some desired geometry e.g., nadir view zenith and local solar noon, for each 500m MODIS pixel.

Landsat SLC-off and cloud Gap Filling

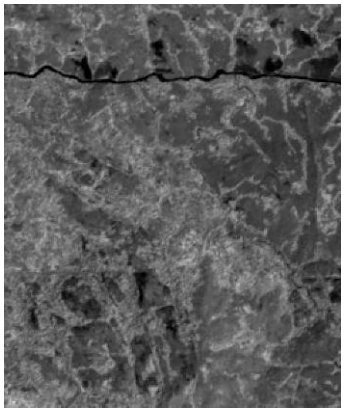
- For reflective bands can use the Radiometric Normalization approach

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

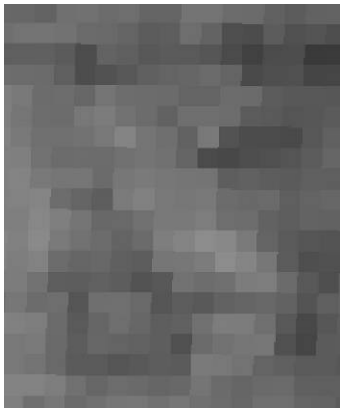
$$c = \frac{\hat{\rho}_{MODIS,t2}\left(\lambda_{MODIS},\Omega_{new},\Omega'_{new}\right)}{\hat{\rho}_{MODIS,t1}\left(\lambda_{MODIS},\Omega_{observed},\Omega'_{observed}\right)}$$

$\hat{\rho}_{MODIS}$ computed from MODIS 16-day 500m BRDF/Albedo product spectral BRDF model parameters

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

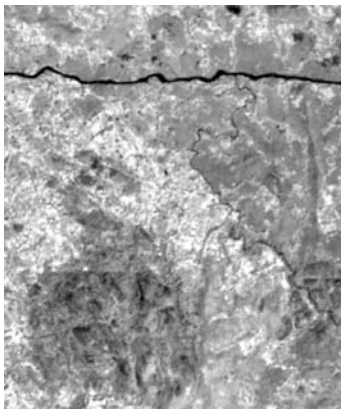


ETM+ observed Jan 9 ρ

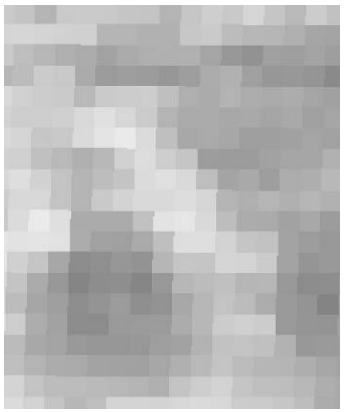


MODIS predicted Jan 9 ρ

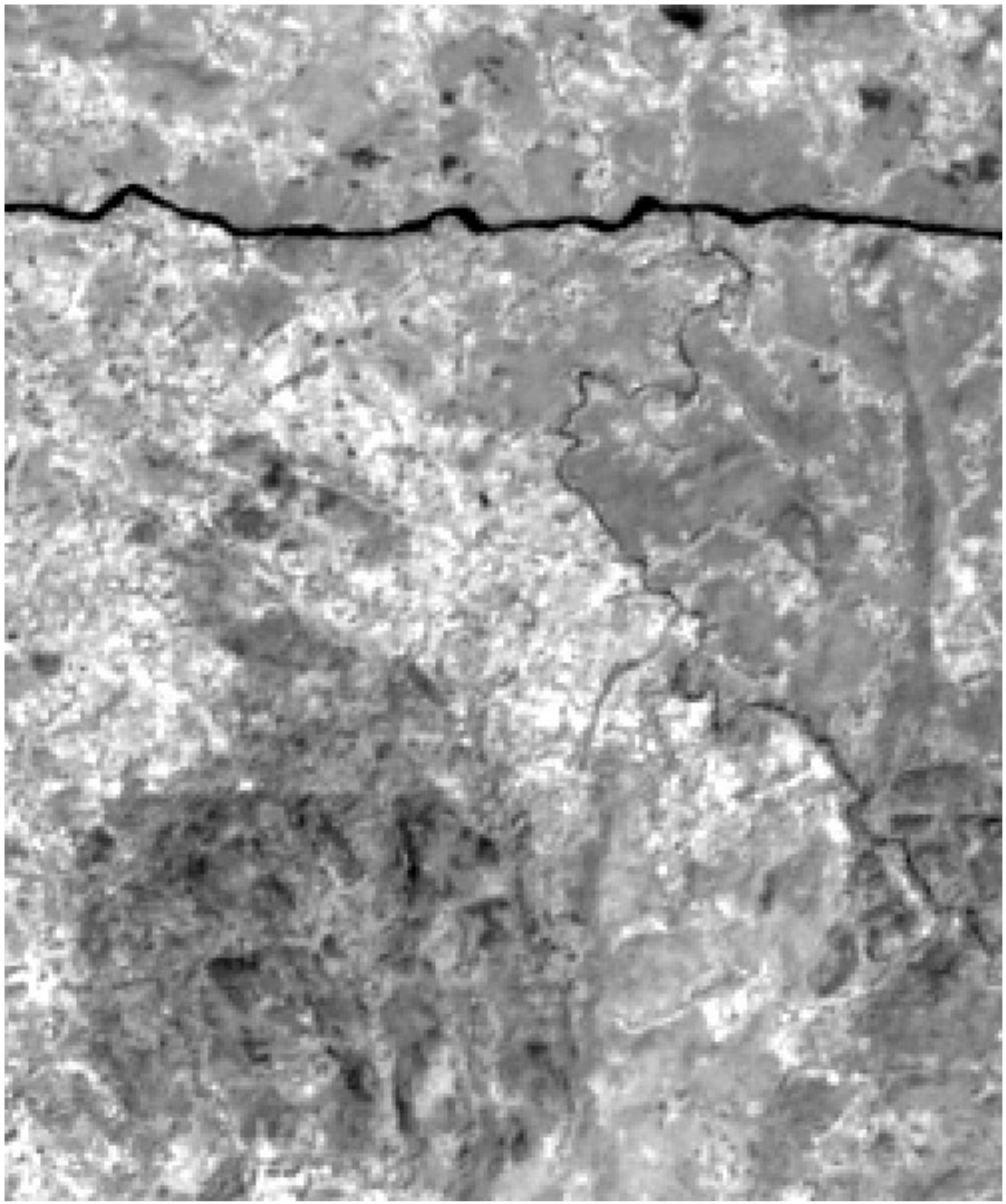
Illustrative near-infrared (NIR) ETM+ reflectance prediction for a 7.5km x 9km subset of Congo scene (shown with same contrast stretch)



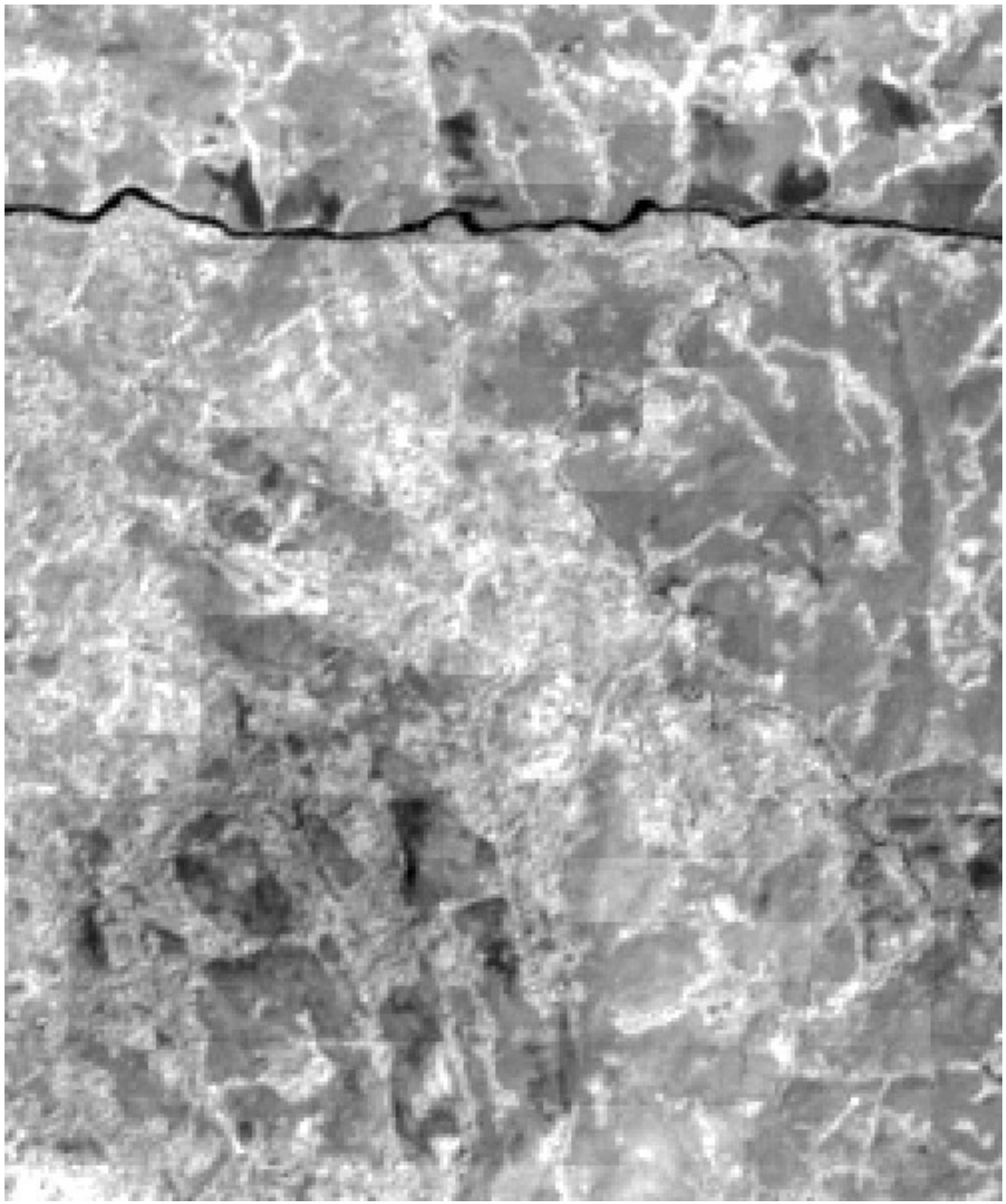
ETM+ observed Nov 25 ρ



MODIS predicted Nov 25 ρ

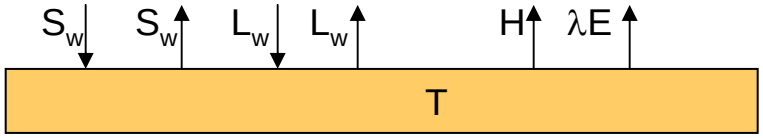


ETM+ observed November 25 ρ



ETM+ predicted November 25 ρ

Cannot use a Temporal Gap Filling for Band61 & Band62 Brightness Temperature



$$S_w^{\downarrow} + L_w^{\downarrow} = S_w^{\uparrow} + L_w^{\uparrow} + H + \lambda E + C_p \Delta T + \text{miscellaneous}$$

where

$S_w^{\downarrow}$ = Incoming shortwave radiation
$L_w^{\downarrow}$ = Downward longwave radiation
$S_w^{\uparrow}$ = Reflected shortwave radiation
$L_w^{\uparrow}$ = Upward longwave radiation
H = Sensible heat flux
λ = latent heat of vaporization
E = Evaporation rate
C_p = Heat capacity of surface slab
ΔT = Change in slab's temperature, over the time step
misc. = energy associated with soil water freezing, plant chemical energy, heat content of precipitation, etc.

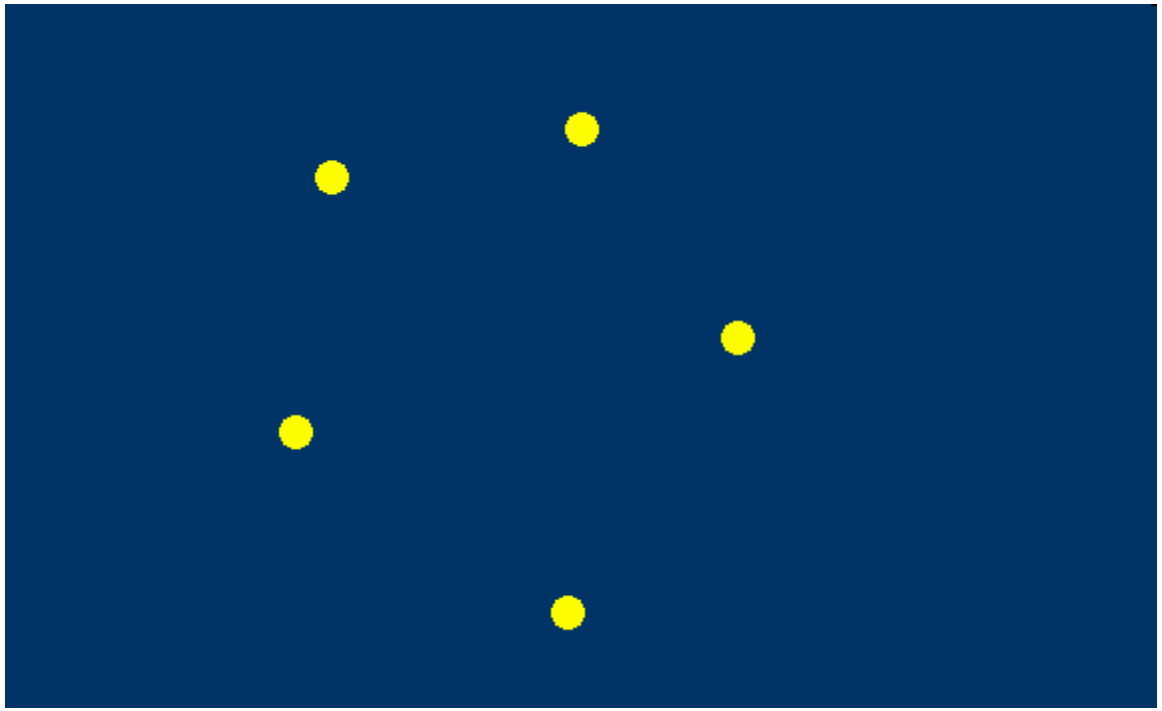
Energy Balance of a Single Land Surface Slab (without snow) (P. Houser)

Need a spatial Interpolation applied to individual acquisitions.

Which Spatial Interpolation ?

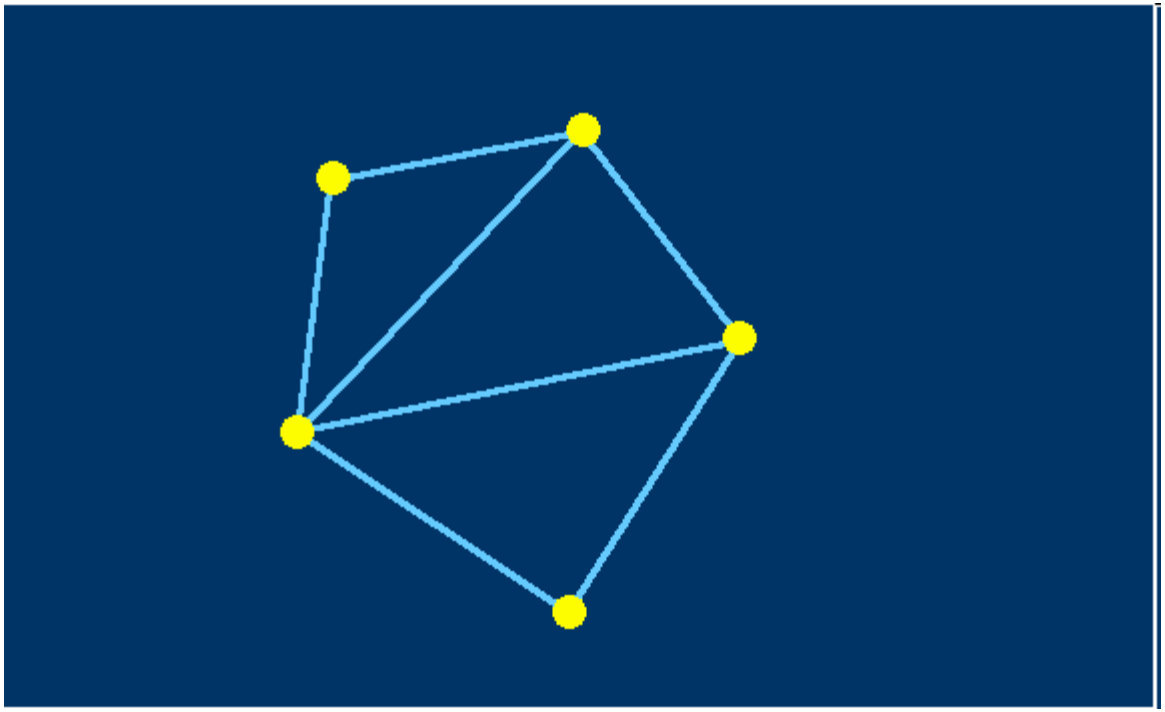
- Geostatistical interpolants (kriging etc.) are computationally expensive
- Spline based interpolants fit to a large surrounding sample data area and the interpolated values may be outside the range of the sample data
- Inverse distance weighting interpolants are computationally inexpensive but perform poorly for irregular sample data distributions
- Natural neighbor (aka Sibson or “Area-stealing” interpolation) has elegant properties
  - no tuning parameters
  - local interpolant, i.e. can gap fill with only a 2 pixel buffer around gap
  - interpolated values
    - guaranteed to be within the range of the samples used
    - pass through the input samples
    - smooth everywhere except at locations of the input samples
    - Rick Allen et al. ET local study demonstration with ArcGIS
- Developed natural neighbor interpolation C code in WELD system
  - ~1.5 minutes / thermal band / acquisition

Non-missing pixel values



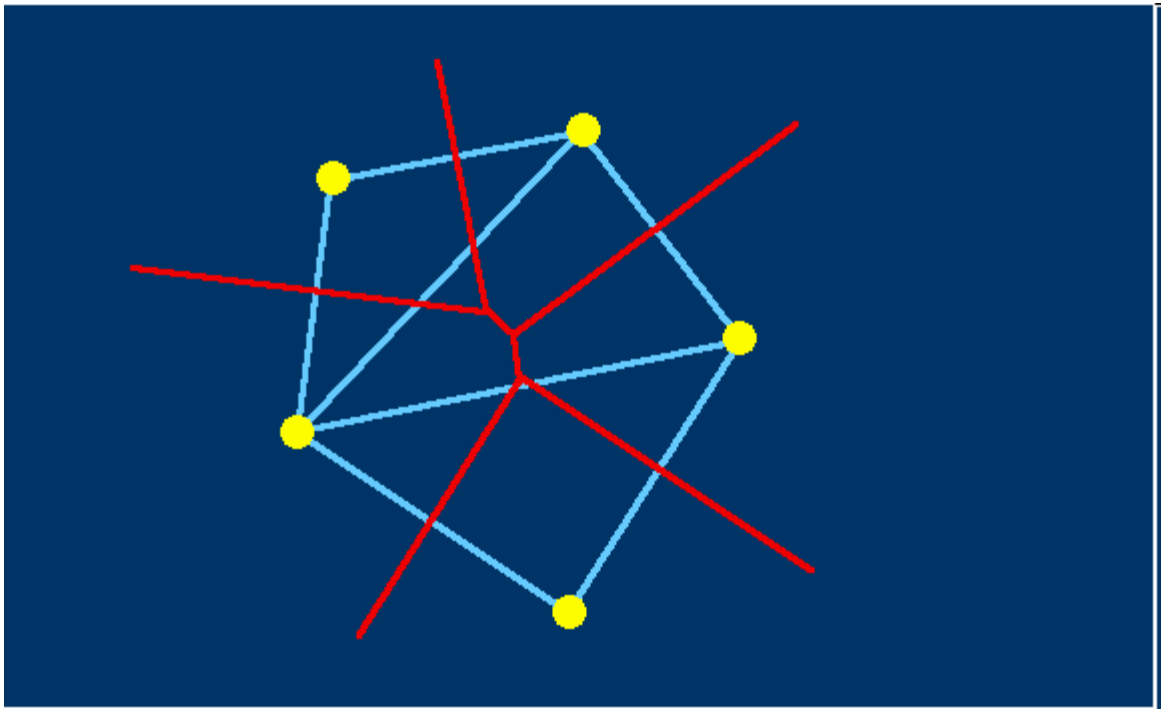
Graphics: http://rses.anu.edu.au/cadi/NN/HTML_Presentation/Theory/Theory1.html

Delaunay triangulation of non-missing pixel values



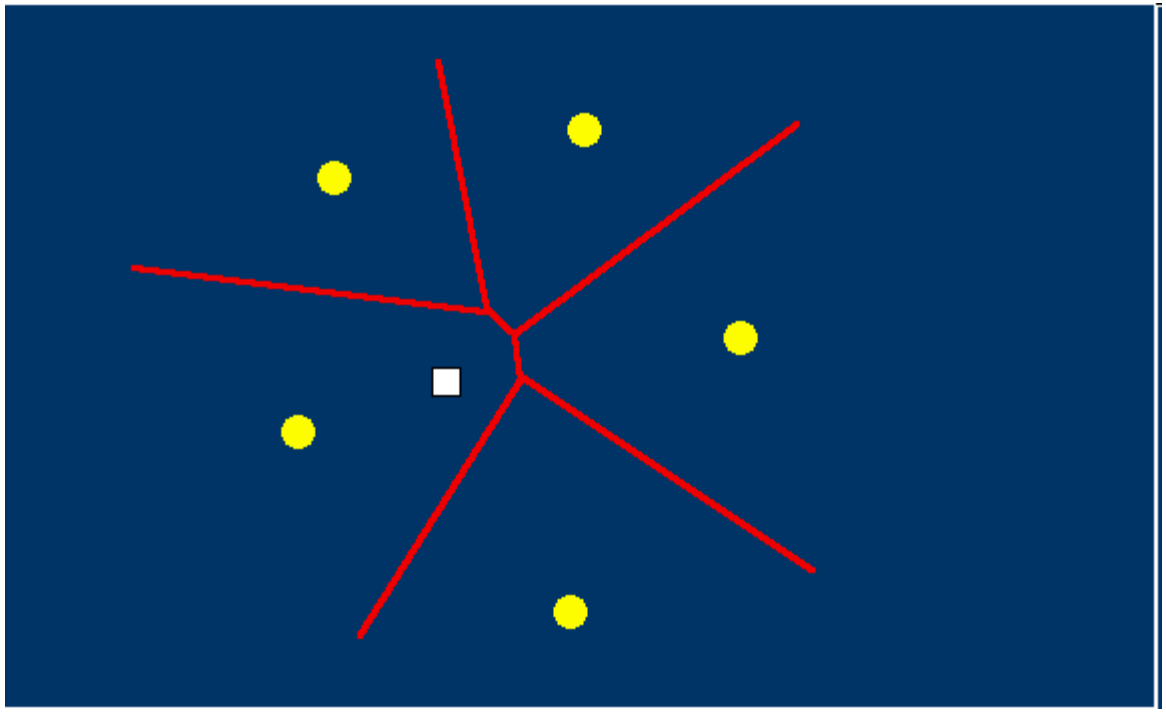
Delaunay triangulation of non-missing pixel values

Voronoi polygons of non-missing pixel values



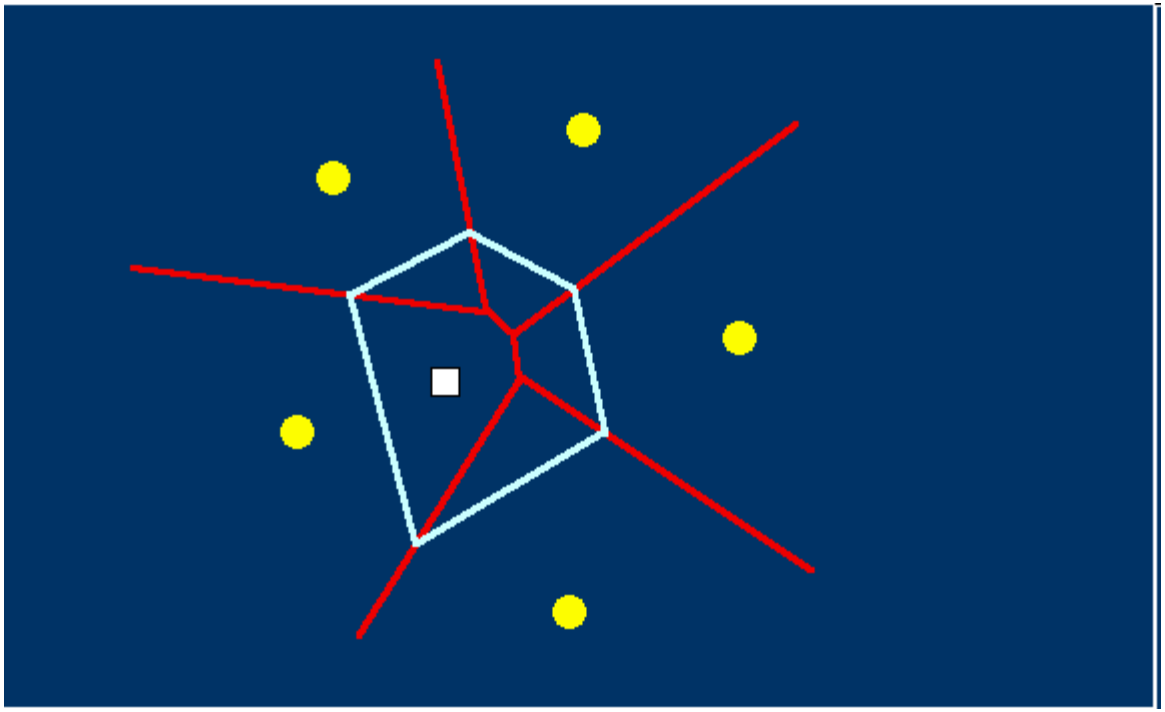
Voronoi polygons of non-missing pixel values

Point to be Interpolated



Voronoi polygons of non-missing pixel values

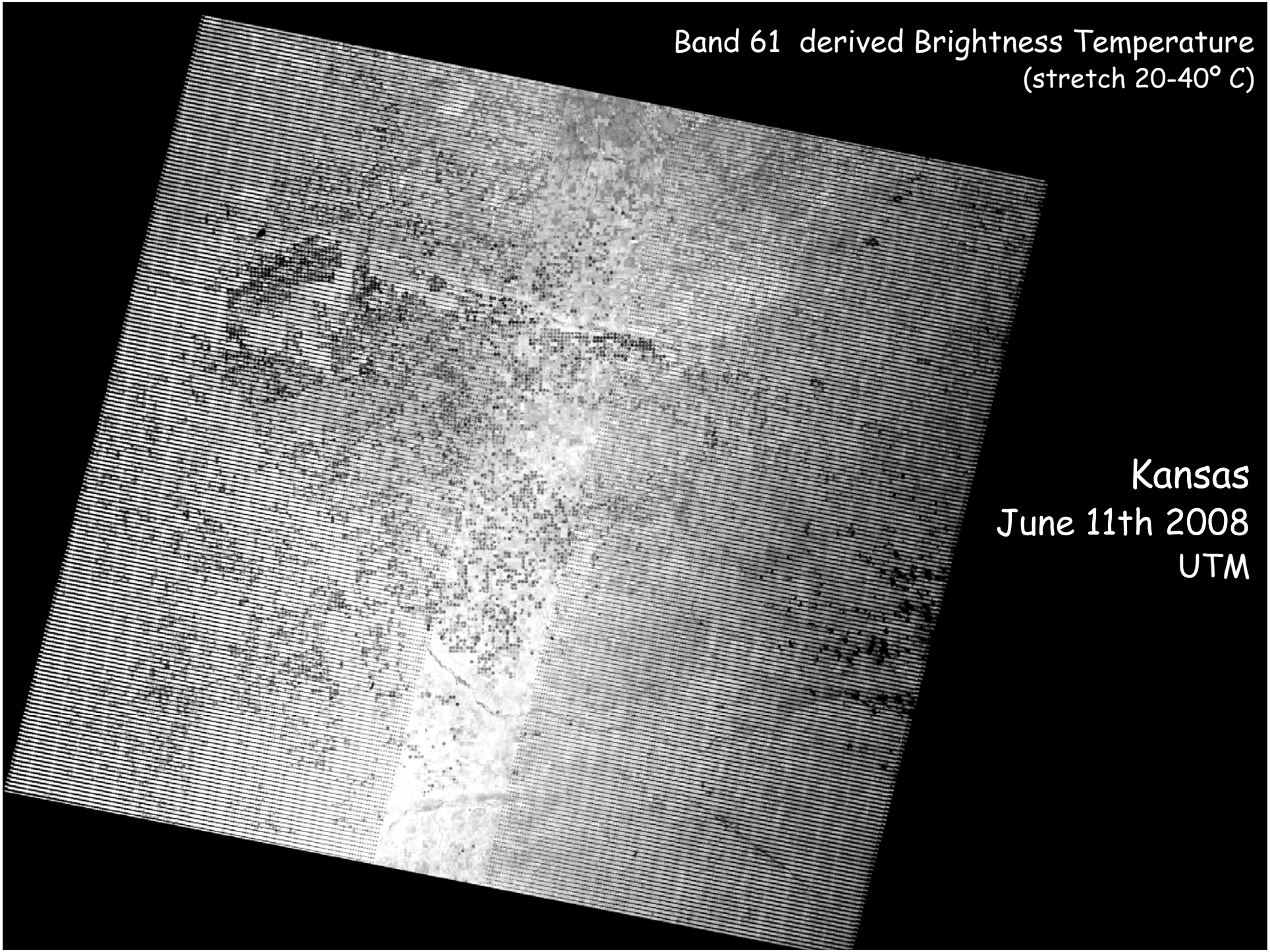
Revised Voronoi polygon including Point to be Interpolated

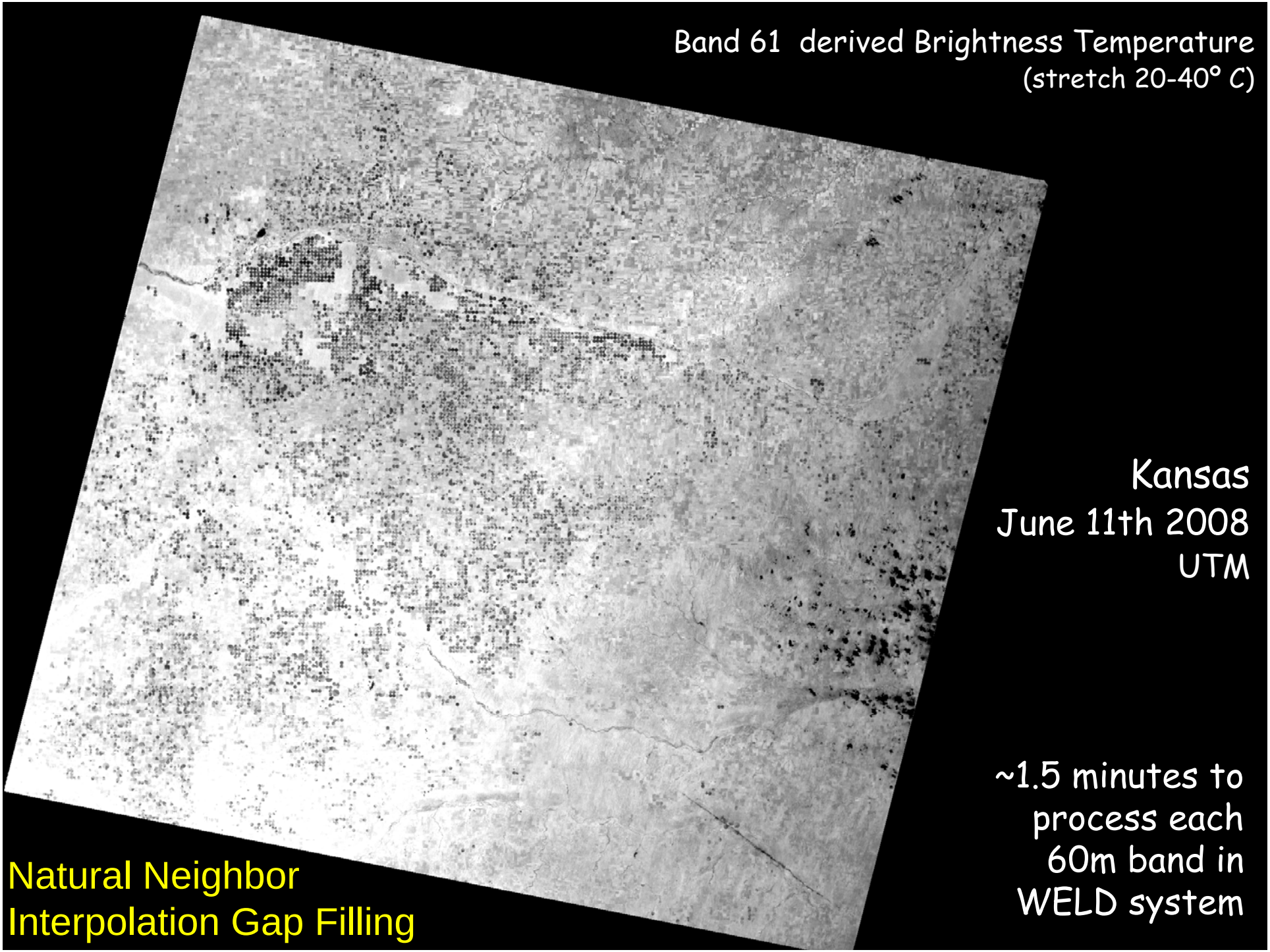


The areal proportion of overlap between new polygon and the initial polygons provide the interpolation weight for each non-missing pixel:

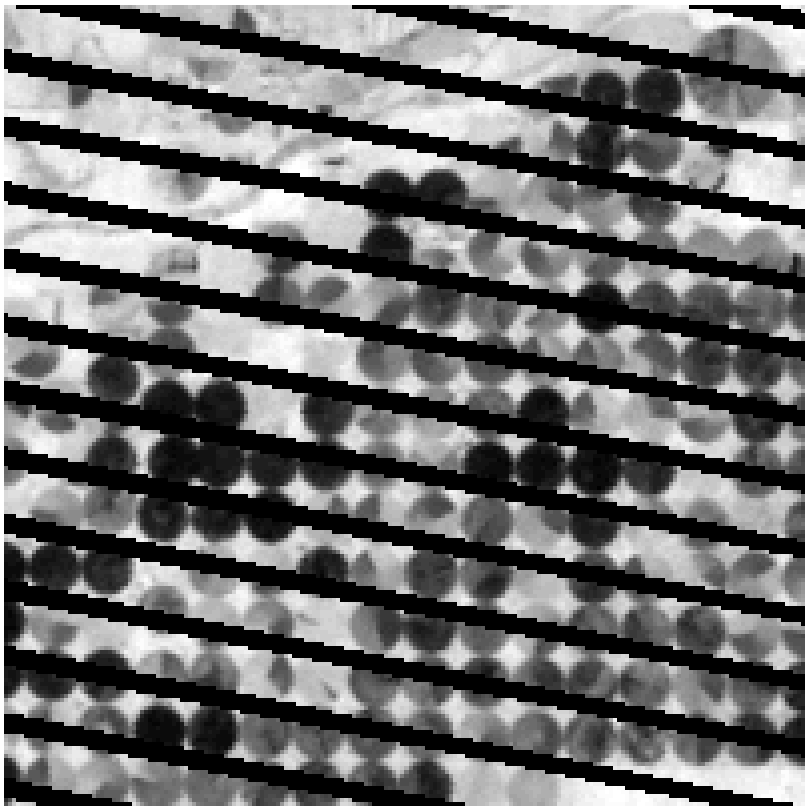
$$\hat{\rho}(x,y) = \sum_{i=1}^{n} w_i \ \rho(x_i, y_i)$$

$\hat{\rho}(x,y)$	interpolated value
n	number of nearest neighbors used for interpolation
$\rho(x_i, y_i)$	pixel value at (x_i,y_i)
w_i	weight associated with pixel at (x_i,y_i)


Band 61 derived Brightness Temperature
(stretch 20-40° C)
Kansas
June 11th 2008
UTM

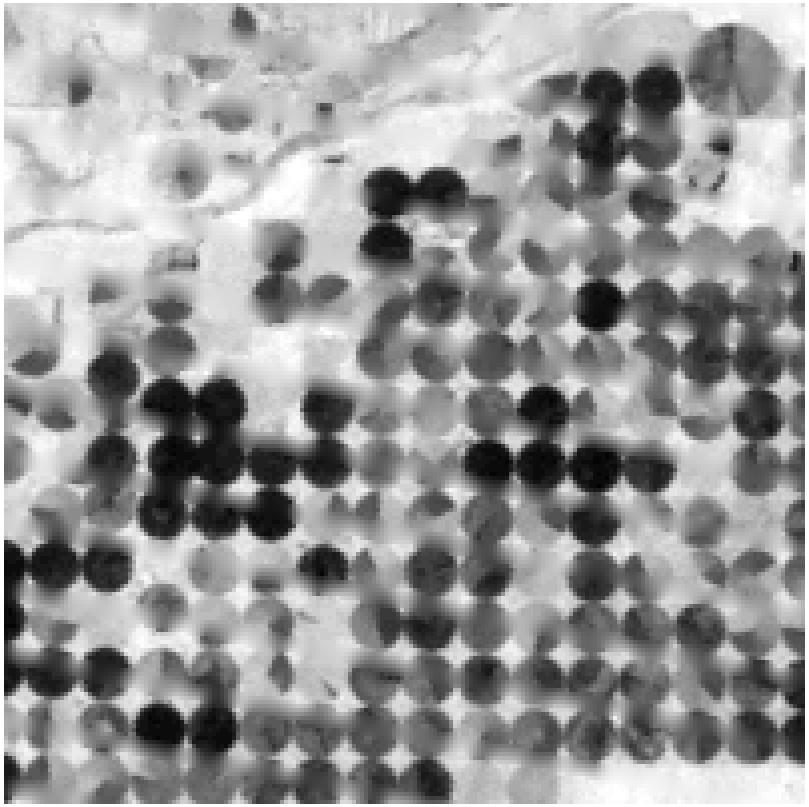

Band 61 derived Brightness Temperature
(stretch 20-40° C)
Kansas
June 11th 2008
UTM
~1.5 minutes to
process each
60m band in
WELD system
Natural Neighbor
Interpolation Gap Filling

Band 61 derived Brightness Temperature
Kansas, Pivot Irrigation detail, June 11th 2008



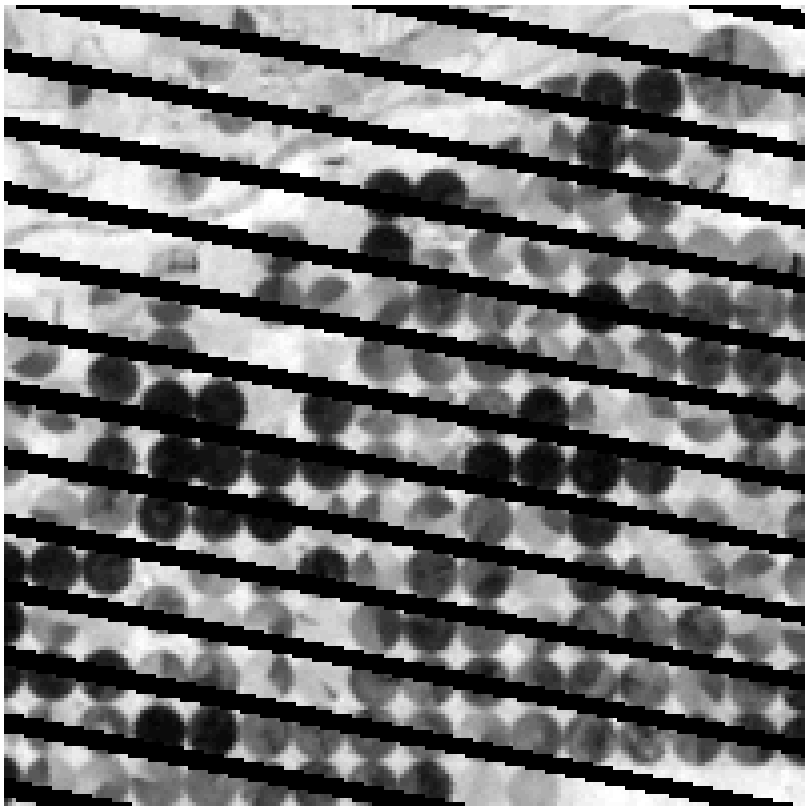
200 x 200 60m pixels

Band 61 derived Brightness Temperature
Kansas, Pivot Irrigation detail, June 11th 2008
Natural Neighbor Interpolation Gap Filling

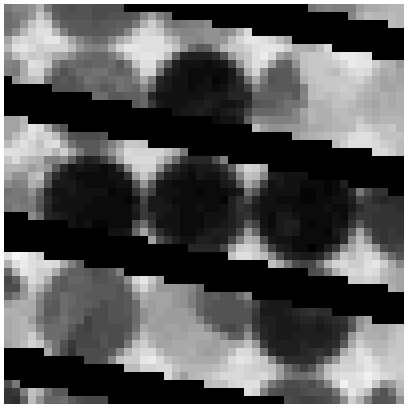


200 x 200 60m pixels

Band 61 derived Brightness Temperature
Kansas, Pivot Irrigation detail, June 11th 2008

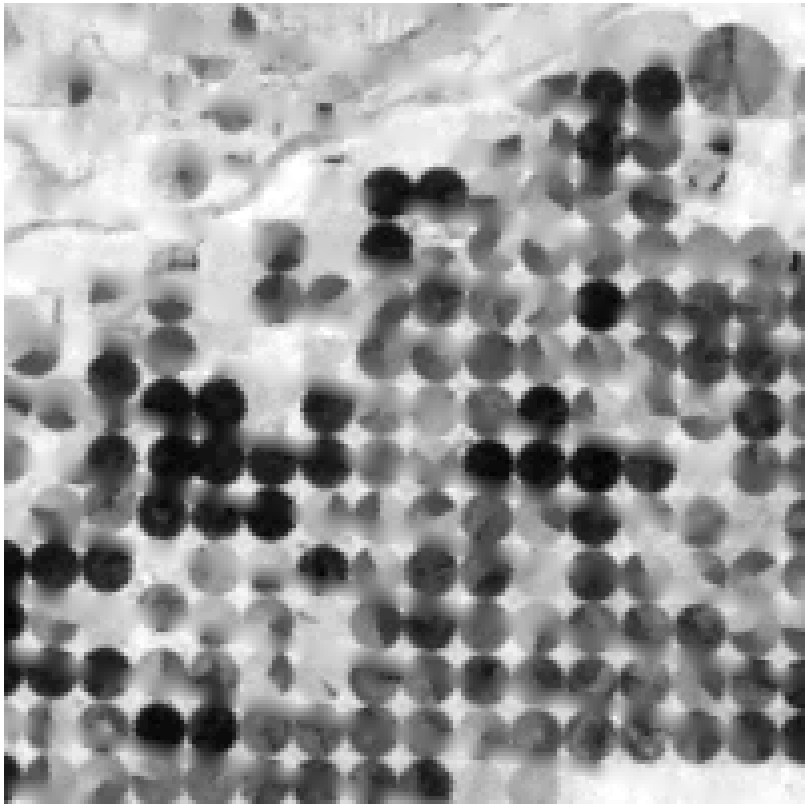


200 x 200 60m pixels

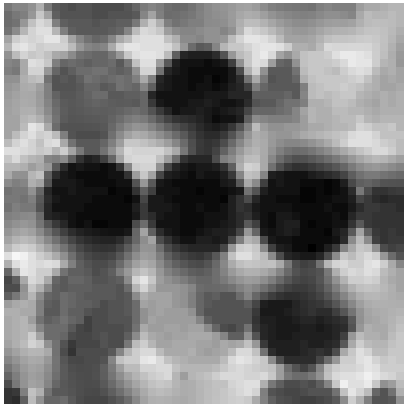


50 x 50 60m pixels

Band 61 derived Brightness Temperature
Kansas, Pivot Irrigation detail, June 11th 2008
Natural Neighbor Interpolation Gap Filling



200 x 200 60m pixels



50 x 50 60m pixels

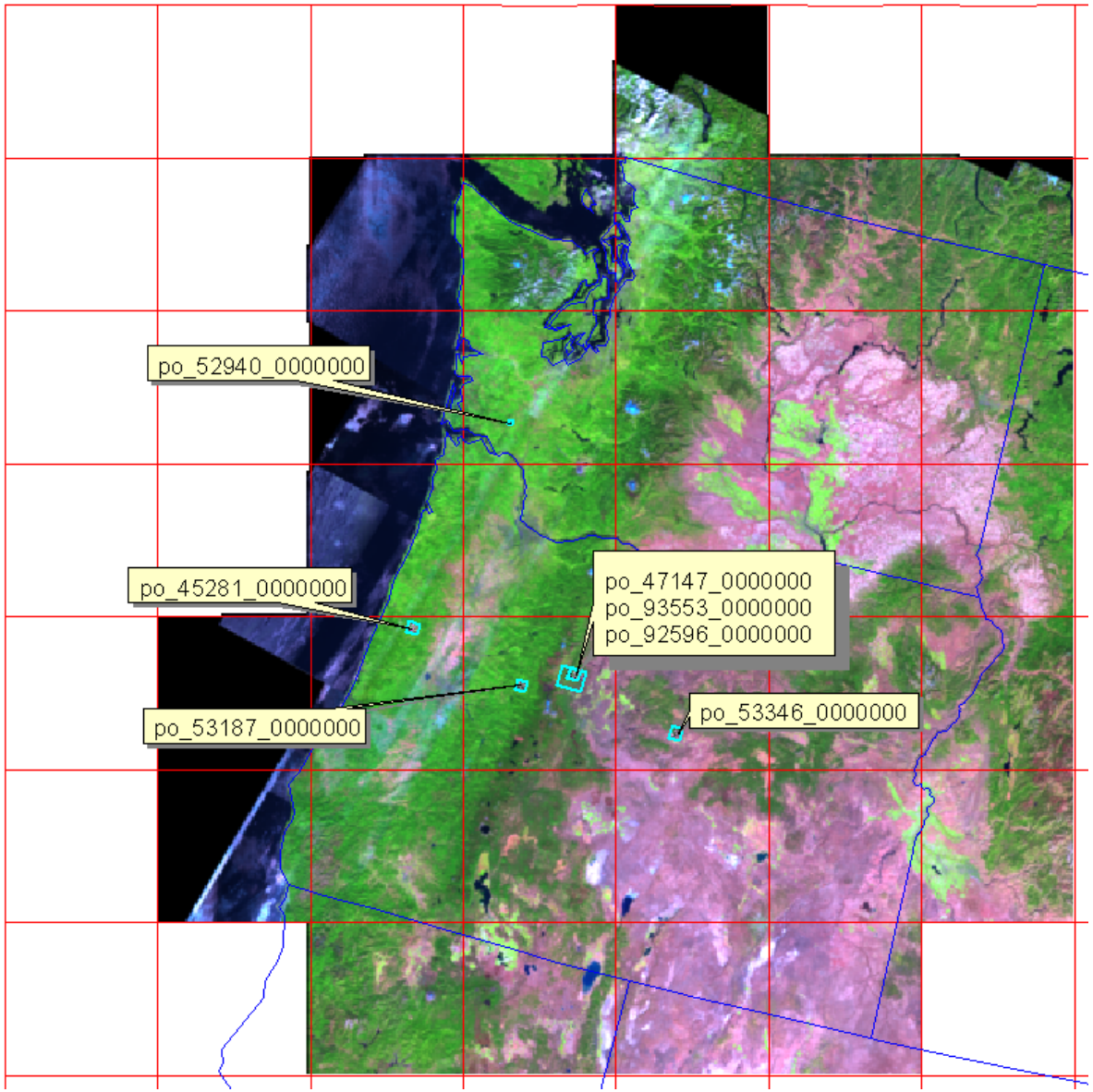
Weld Products

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

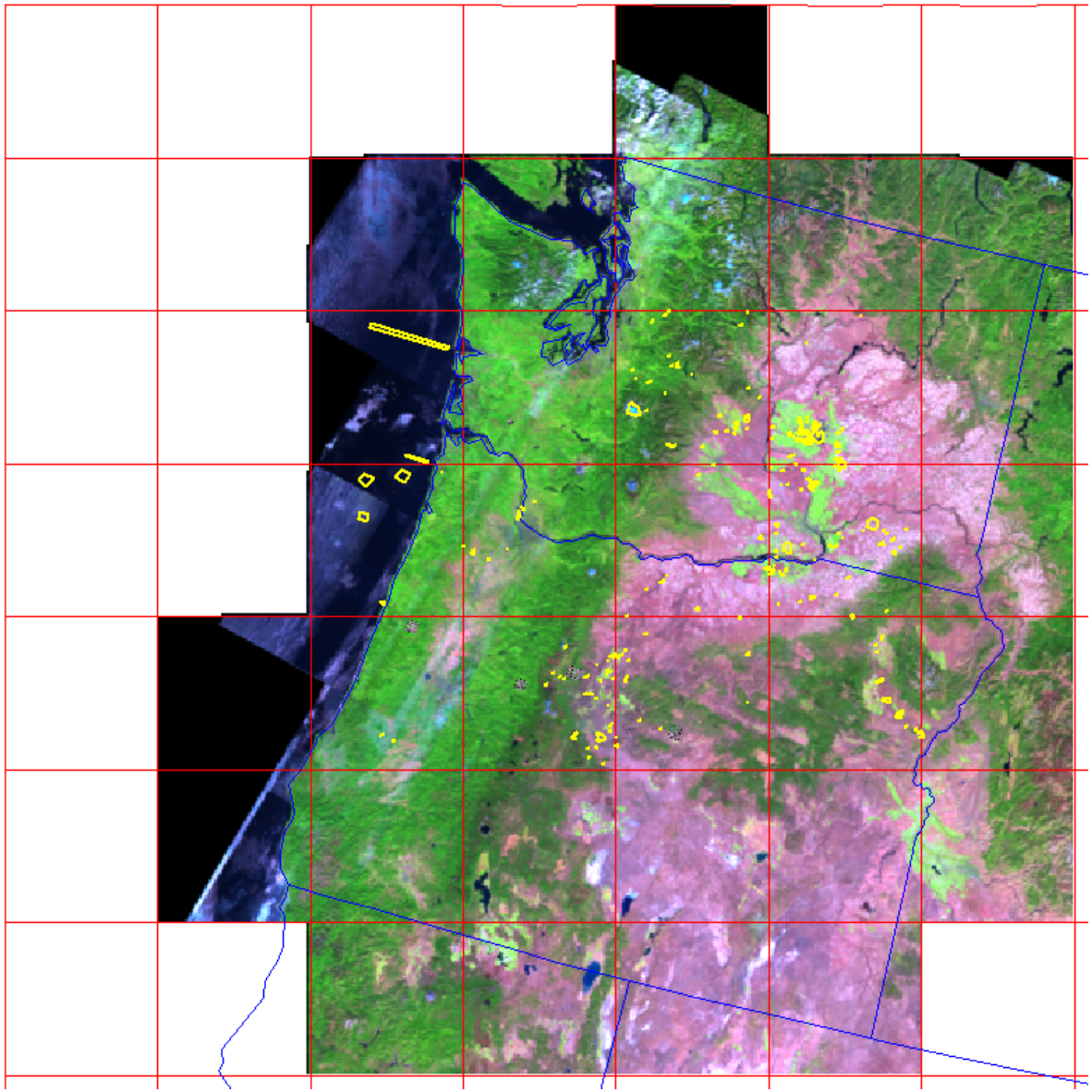
Monthly Composite	Seasonal (3 month) Composite	Annual Composite
Surface reflectance: 6 ETM+ 30m reflective λ bands	*As monthly but no land cover characterization*	*As monthly*
Brightness temperature: 2 ETM+ resampled 30m thermal λ bands		
NDVI		
Band saturation		
Cloud masks: ACCA & classificiation tree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

Weekly (7 day) Composites, *As monthly but no land cover characterization*

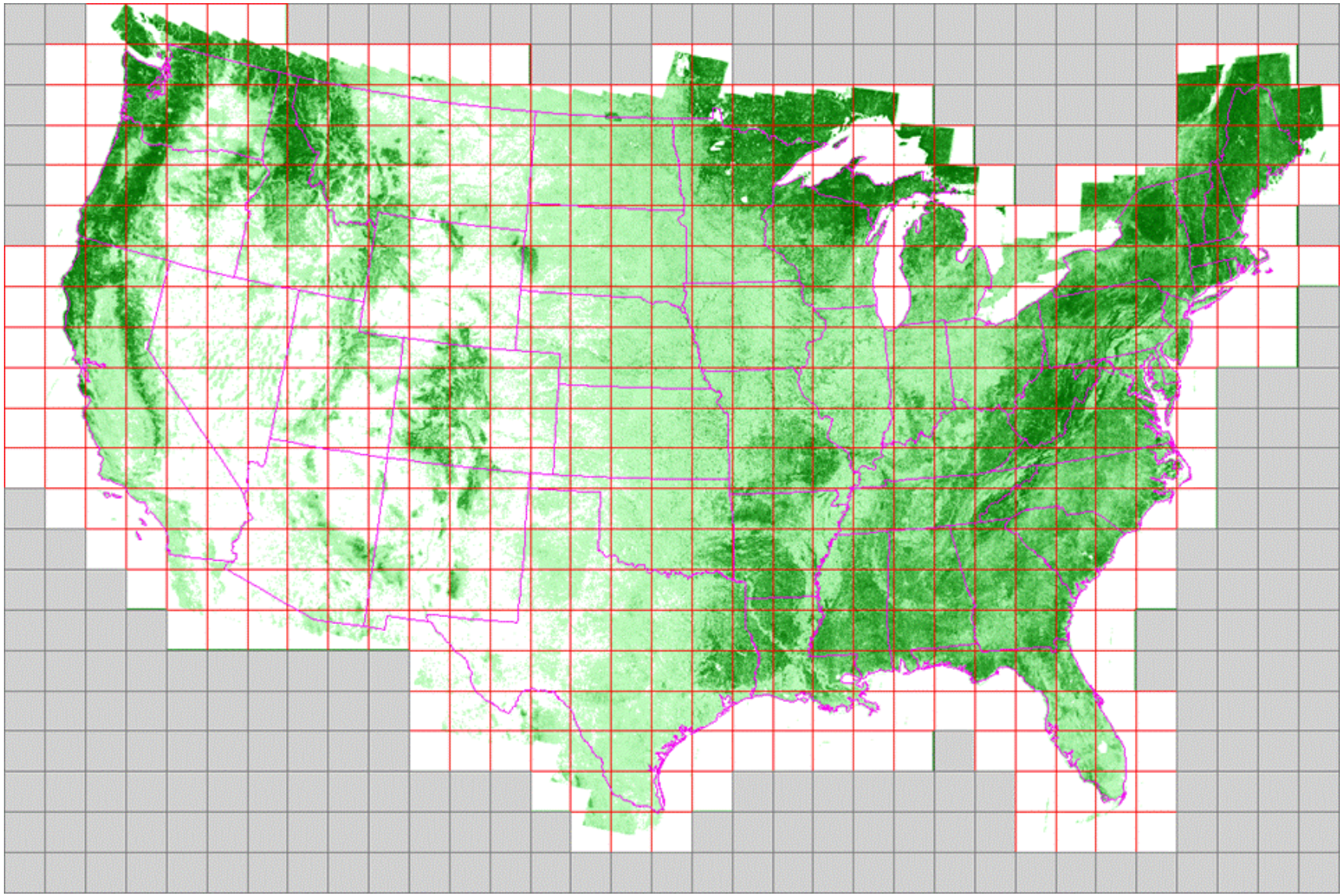
Ikonos & Quickbrid scenes are used for creating training



Google Earth polygons also used

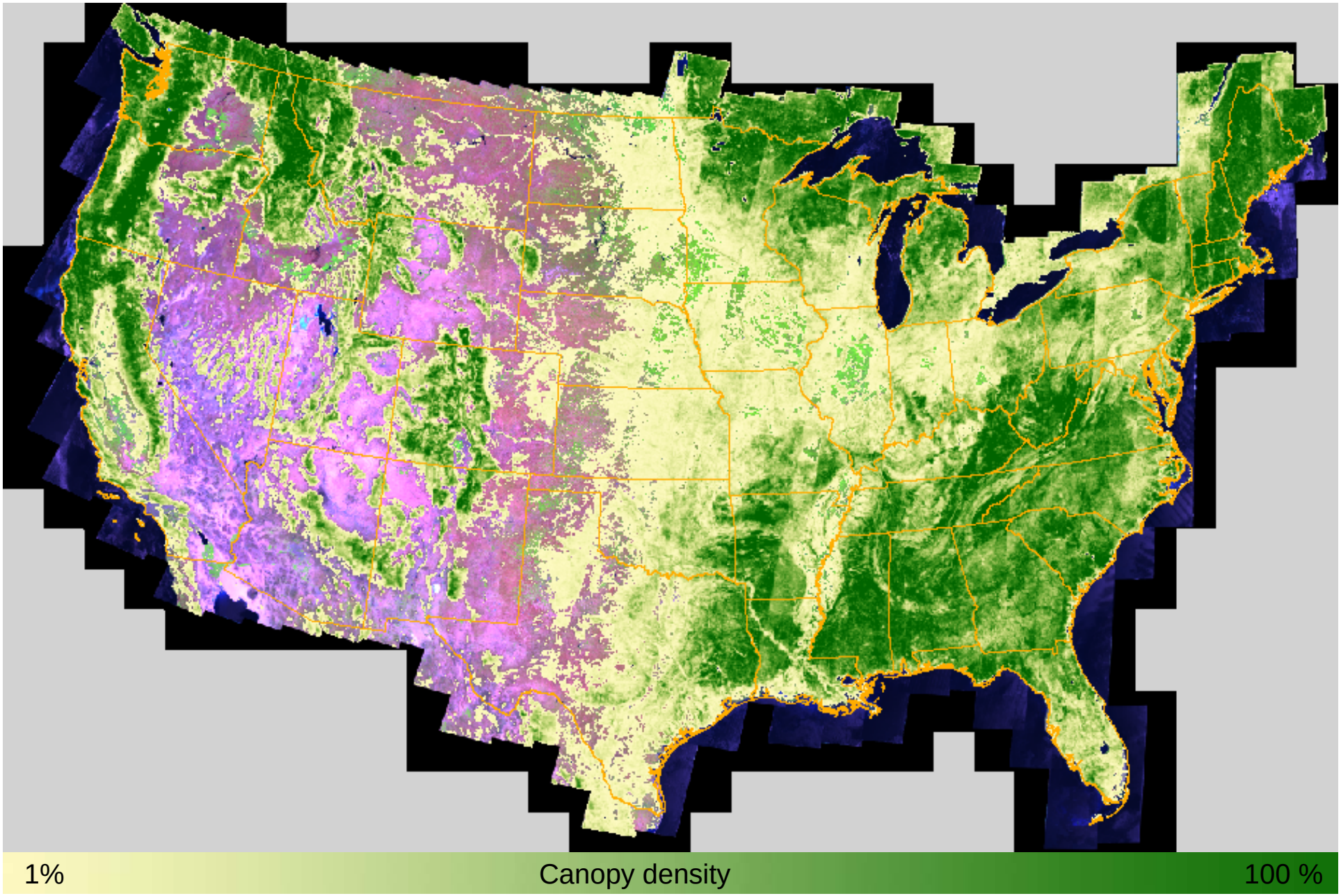


1st (Spring 2009) Version 30m Forest Probability

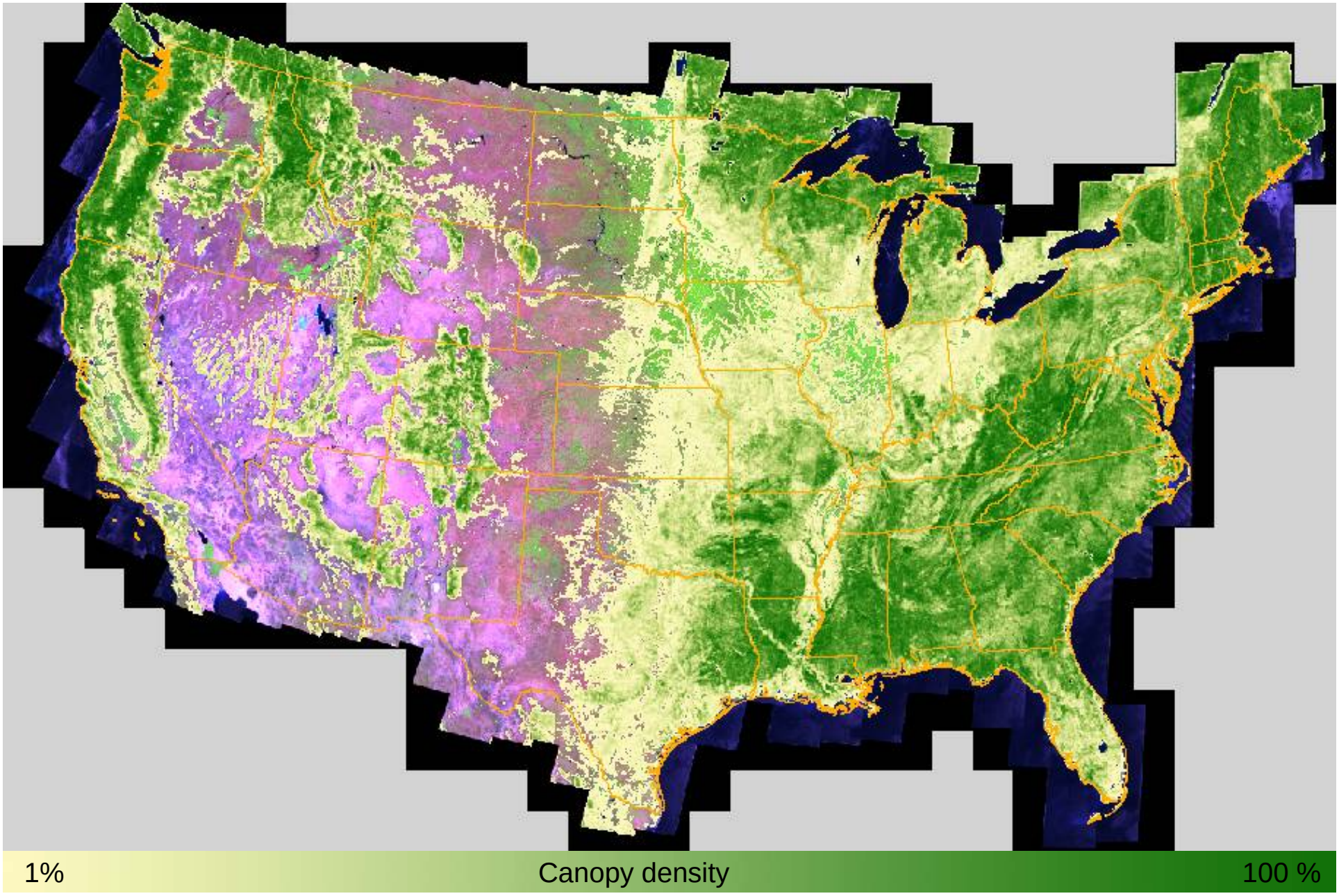


(Alexey Egorov & Matt Hansen)

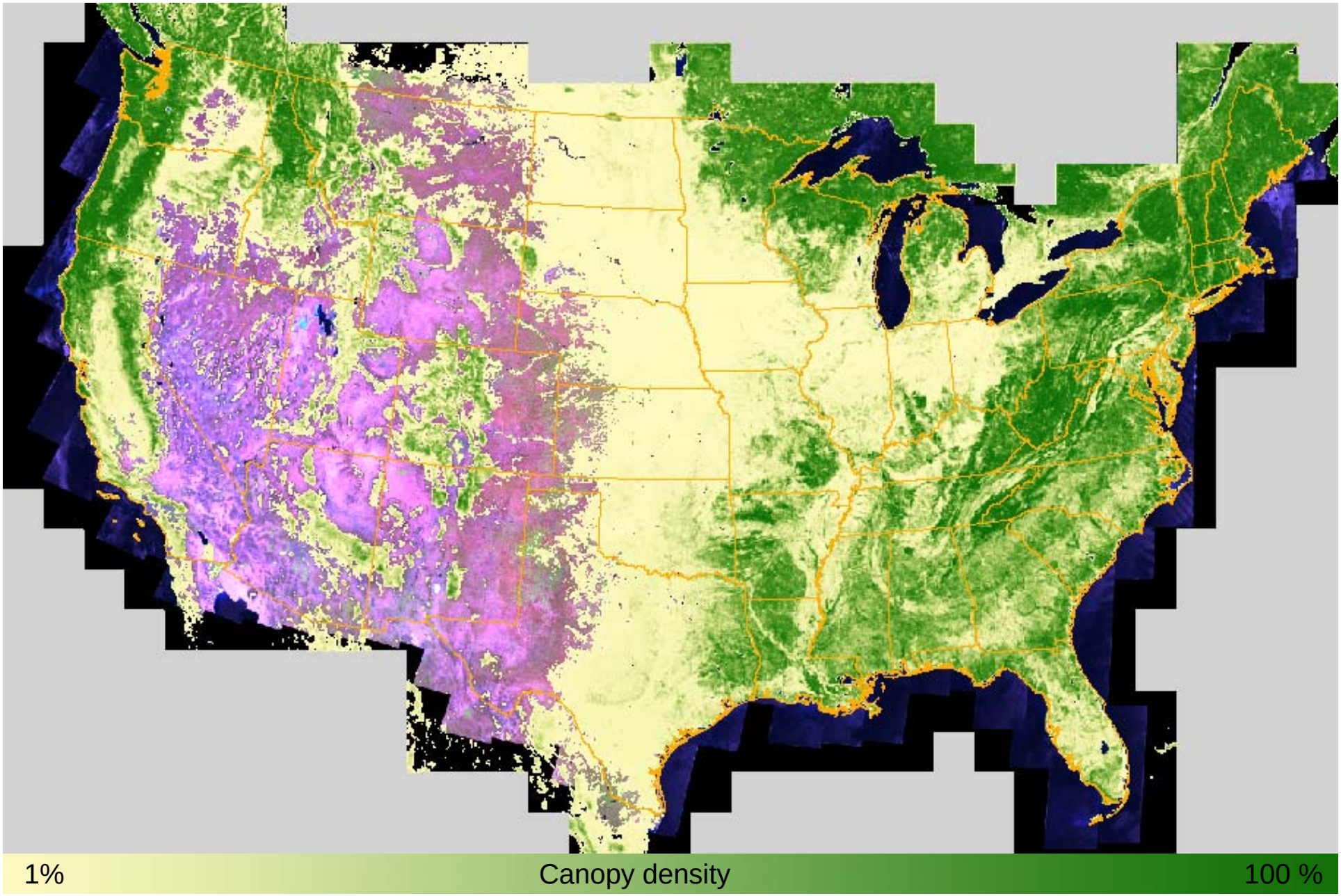
2nd (Fall 2009) Version 30m % Tree Cover



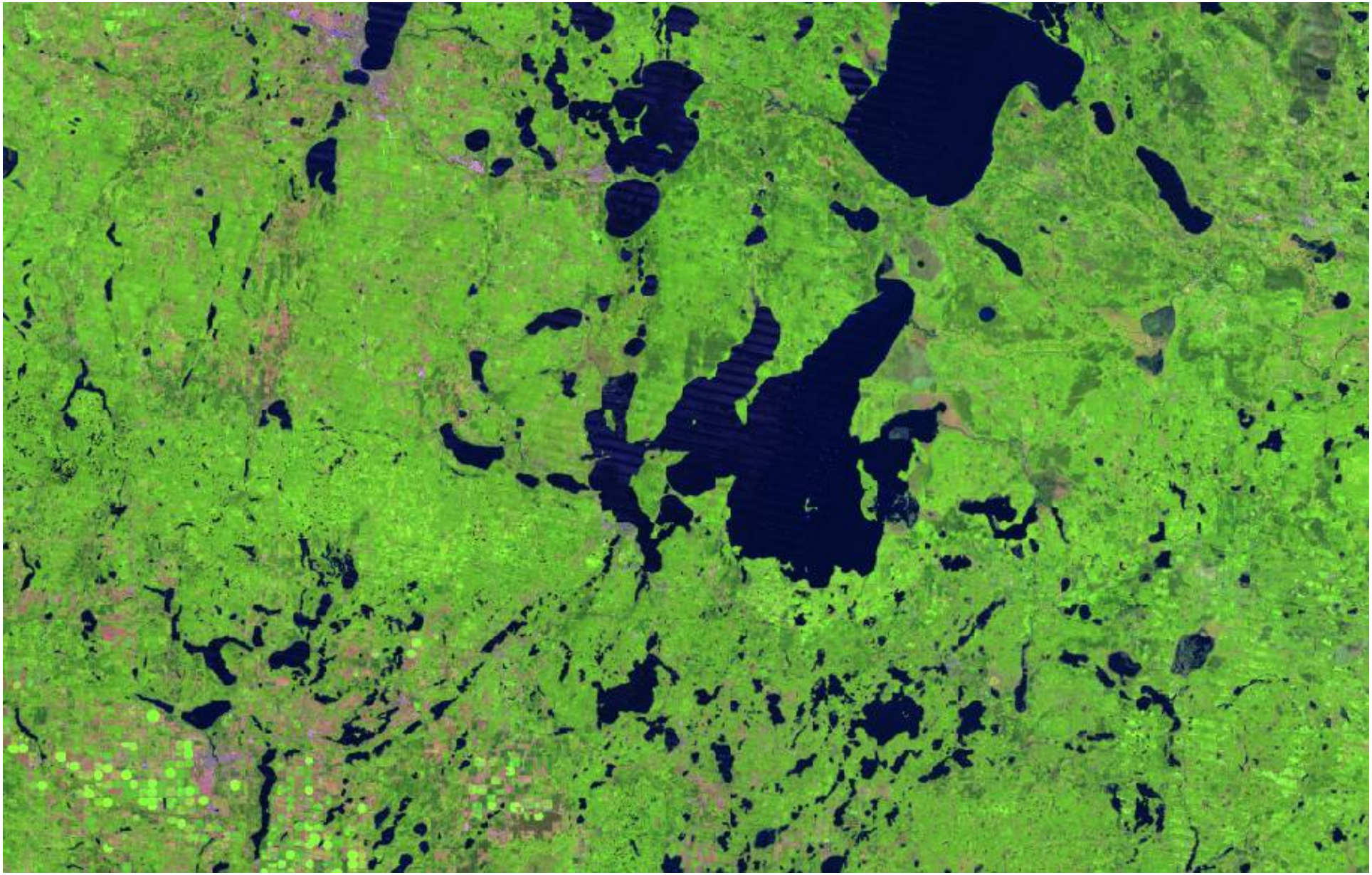
3rd (Spring 2010) Version 30m %Tree Cover



MODIS 500 m % Tree Cover with same palette

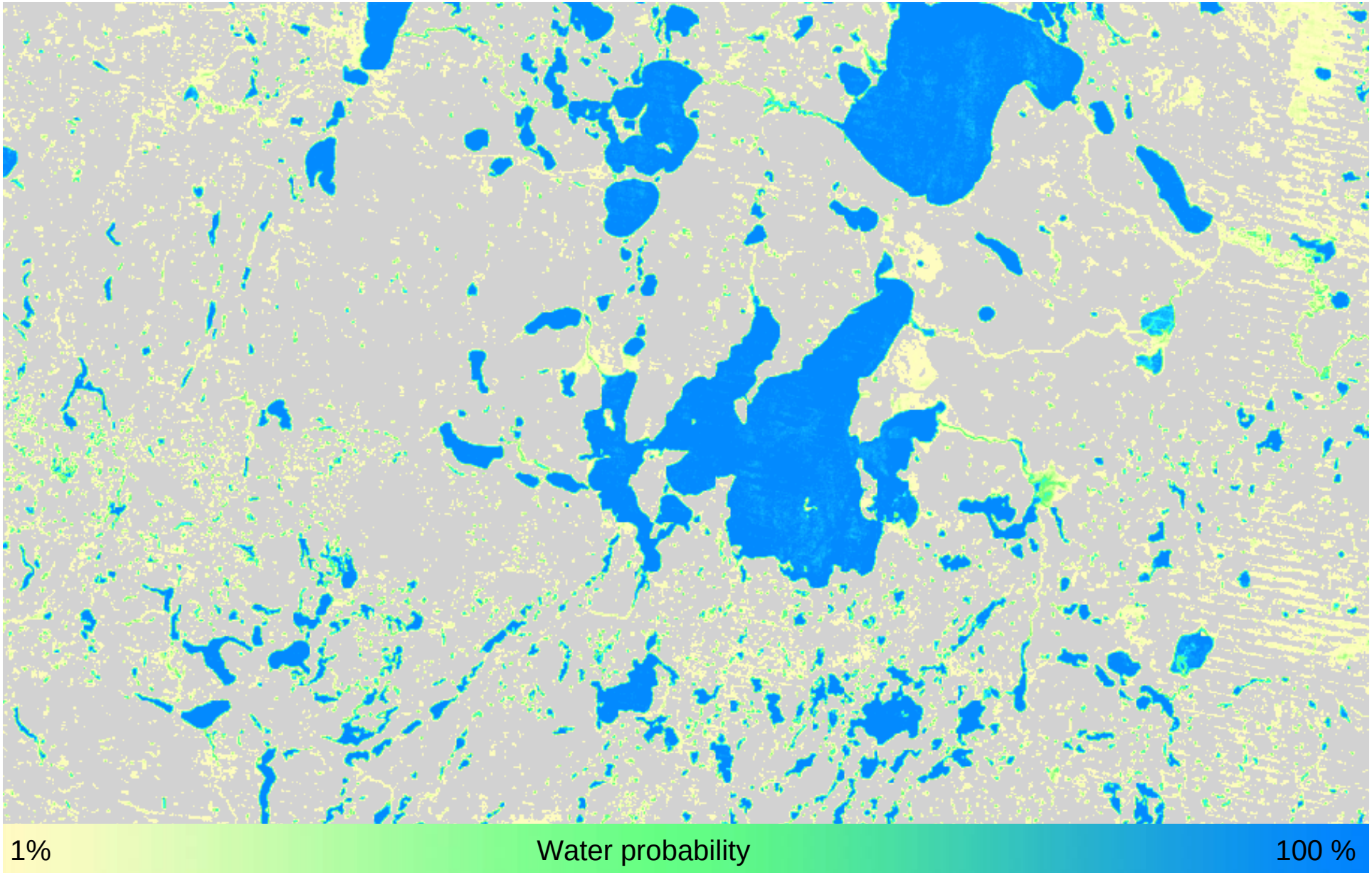


North Minnesota (Leech Lake), 120 x 100 km
WELD 2008 Annual composite, bands 5,4,3 as RGB



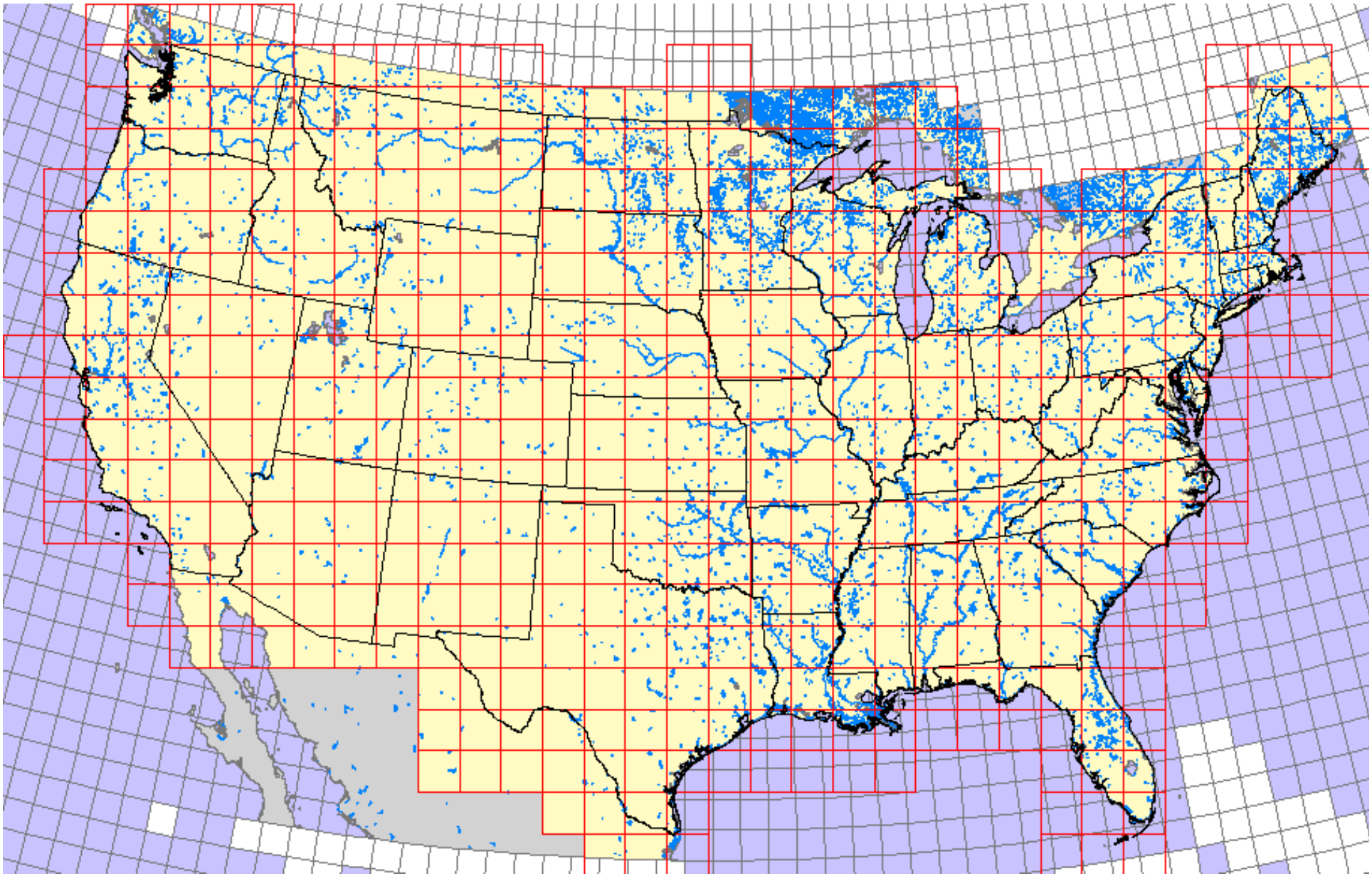
1st (Spring 2010) Version 30m Water Probability

(Gray = 0 probability)



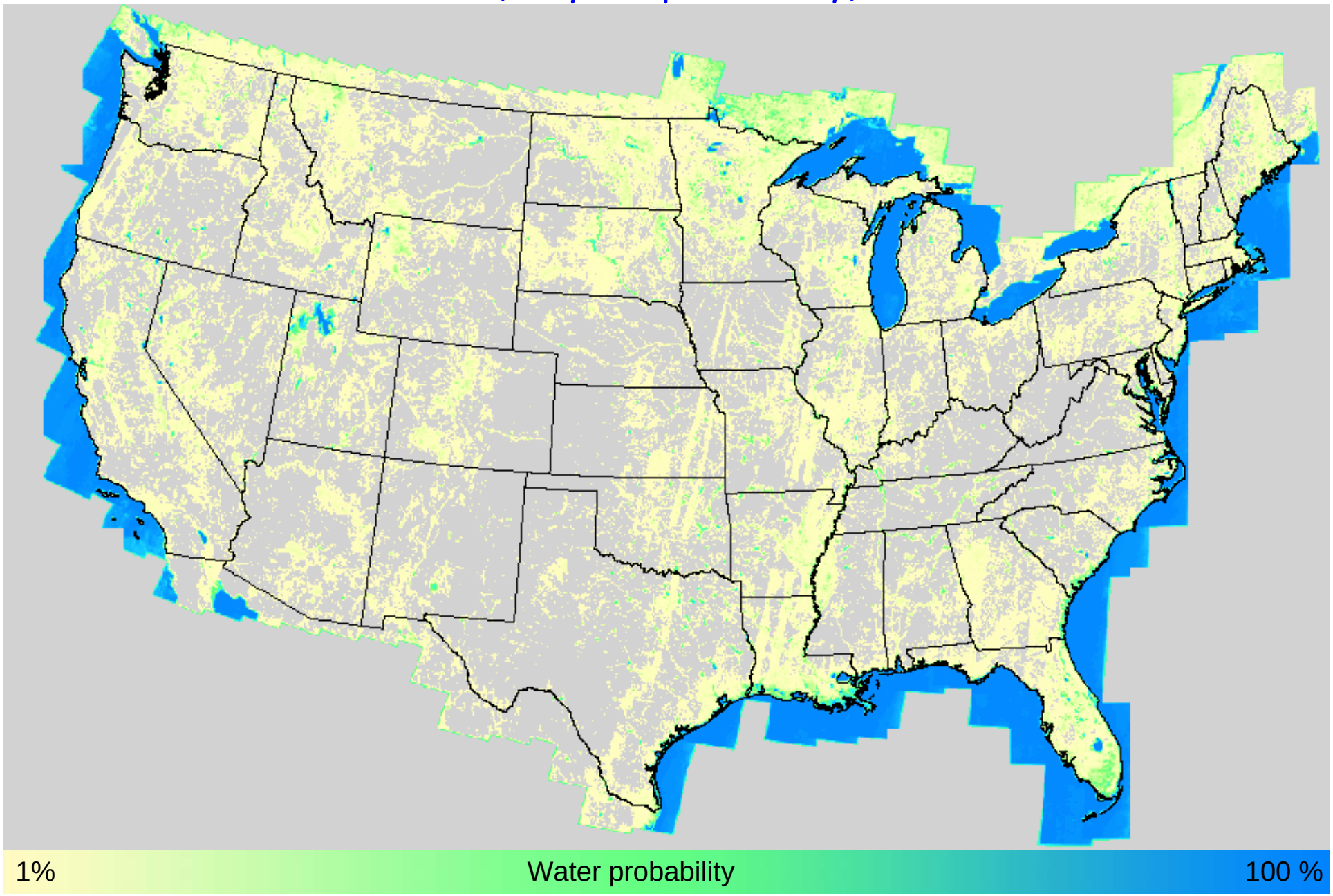
30m SRTM vector Water Body Data used to generate training

- Water Training: 25% random sample of 30m SRTM inland water bodies
- Non water Training: 1 % random sample of 30m non-water bodies



1st (Spring 2010) Version 30m Water Probability

(Gray = 0 probability)



Weld Overview

- FTP Process
  - Retrieve Landsat acquisitions from EROS FTP directory shortly after they are placed there
- Production System Process
  - Make temporally composited mosaics CONUS & Alaska
- Distribution System Process
  - Distribute composited mosaics via internet using WYSIWYG interface and harvest distribution metrics.

WELD Product Distribution

- Dedicated Web Interface

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

- Pan & Zoom against browse product of interest
  - Region
  - Composited period

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

- Thick Client prototype developed at SDSU

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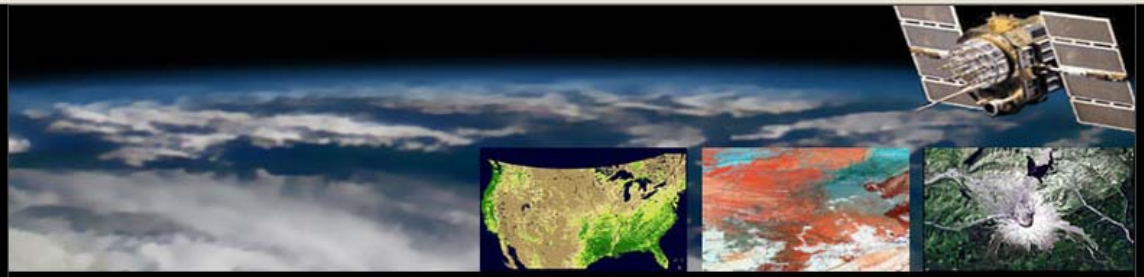
http://snowdon.sds..._distribution.php



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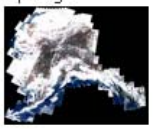
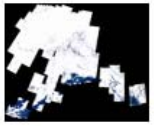
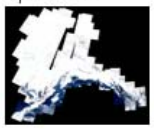
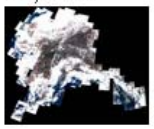
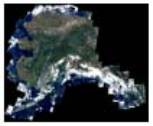
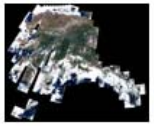
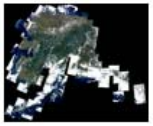
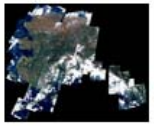
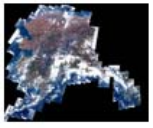
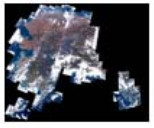
ALASKA 2008

Annual 	Winter 	December 2007 	January 2008 	February 2008 
	Spring 	March 2008 	April 2008 	May 2008 
	Summer 	June 2008 	July 2008 	August 2008 
	Autumn 	September 2008 	October 2008 	November 2008 

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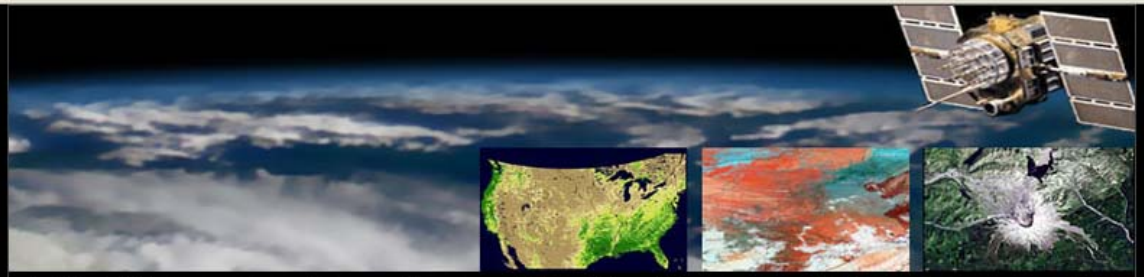

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CONUS 2008

Annual	Winter	December 2007	January 2008	February 2008
	Spring	March 2008	April 2008	May 2008
	Summer	June 2008	July 2008	August 2008
	Autumn	September 2008	October 2008	November 2008

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CONUS 2008: WINTER

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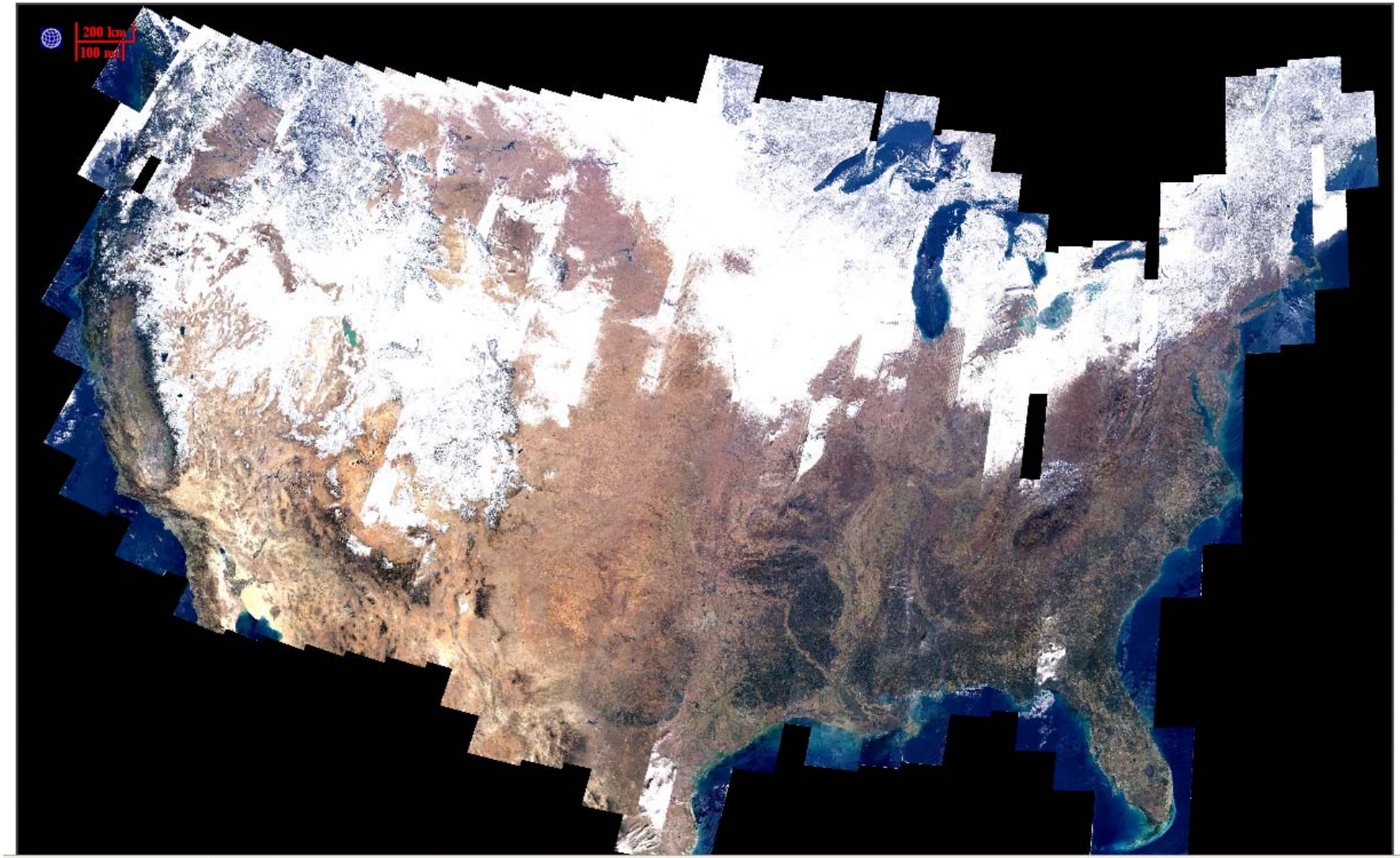

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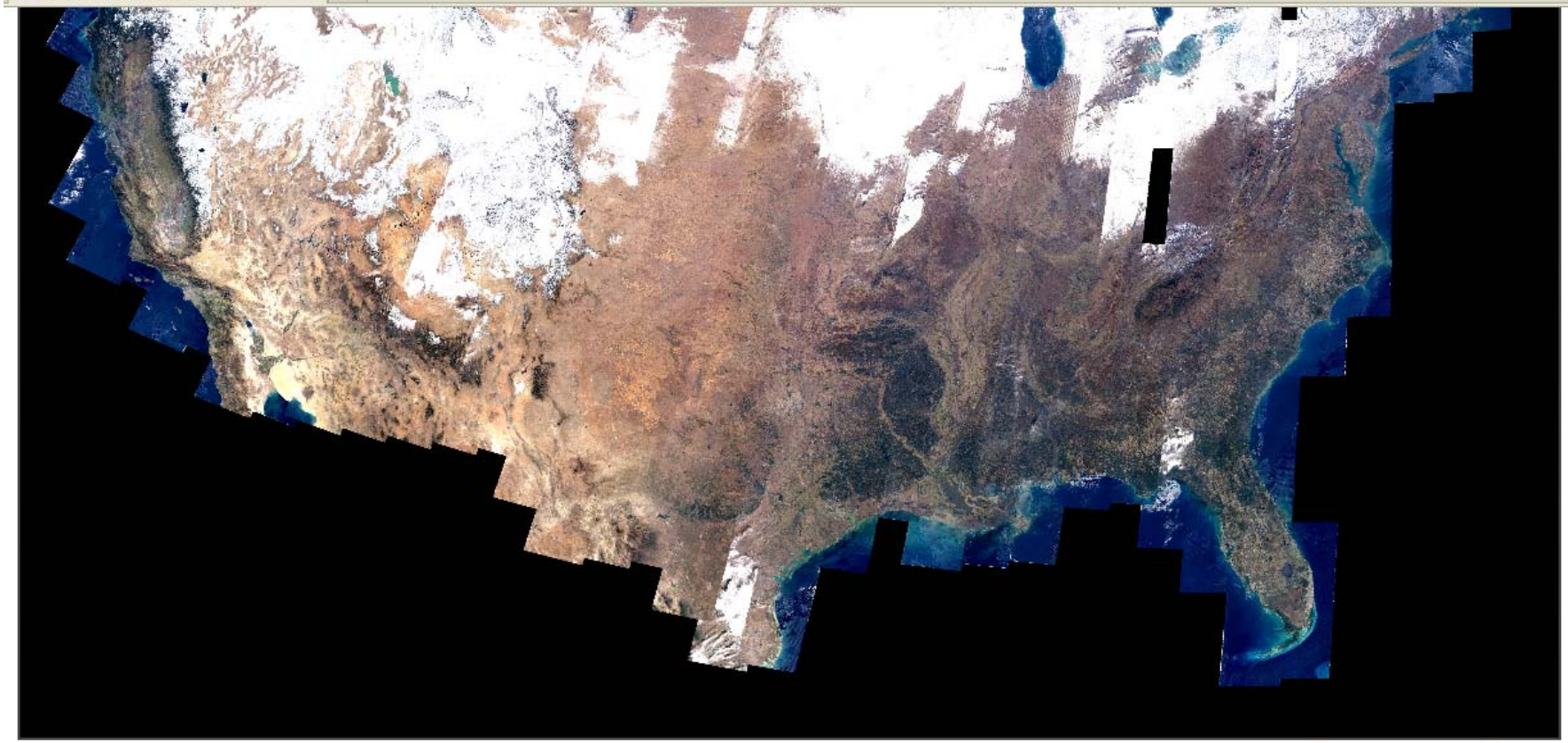

Hold the shift button & drag the mouse to define an area of interest for ordering data

Longitude/latitude Albers

North:

West: East:

South:

Order Data

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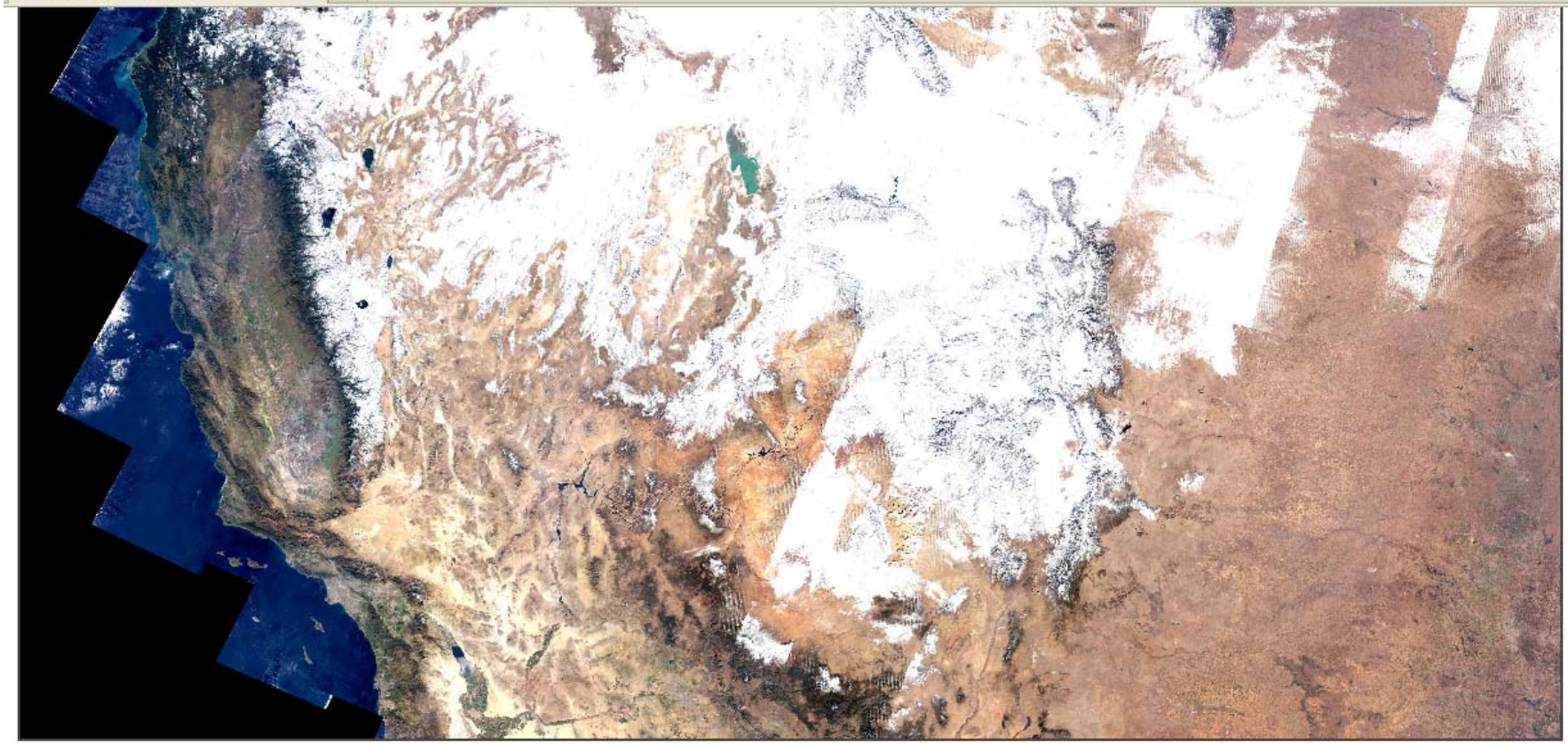


Hold the shift button & drag the mouse to define an area of interest for ordering data

Longitude/latitude Albers

North:

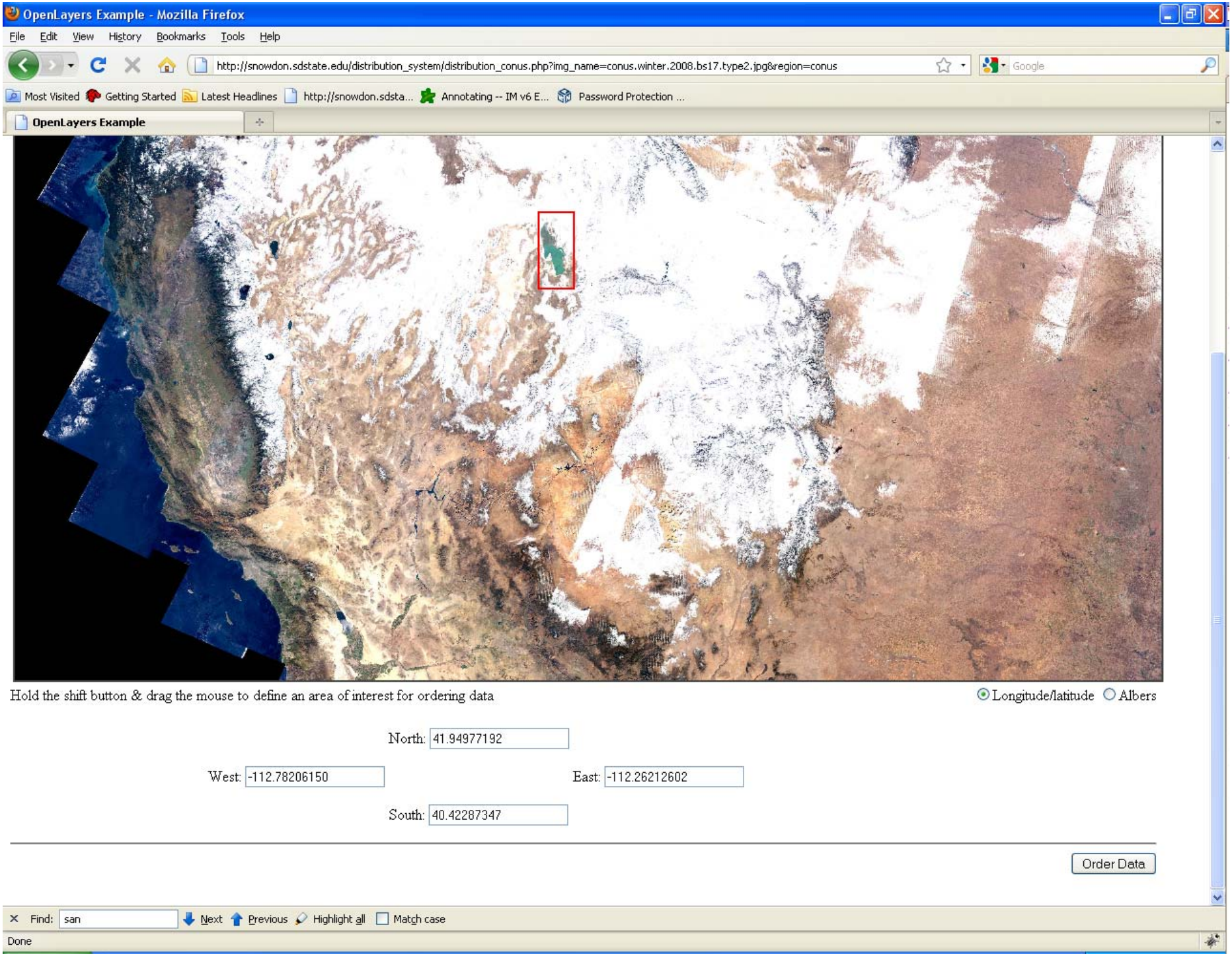
West: East:

South:

Order Data

Find: san Next Previous Highlight all Match case

Done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Hold the shift button & drag the mouse to define an area of interest for ordering data
Longitude/latitude
Albers
North: 41.94977192
West: -112.78206150
East: -112.26212602
South: 40.42287347
Order Data
Find: san
Next
Previous
Highlight all
Match case
Done

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Email: indrani.kommareddy@sdstate.edu

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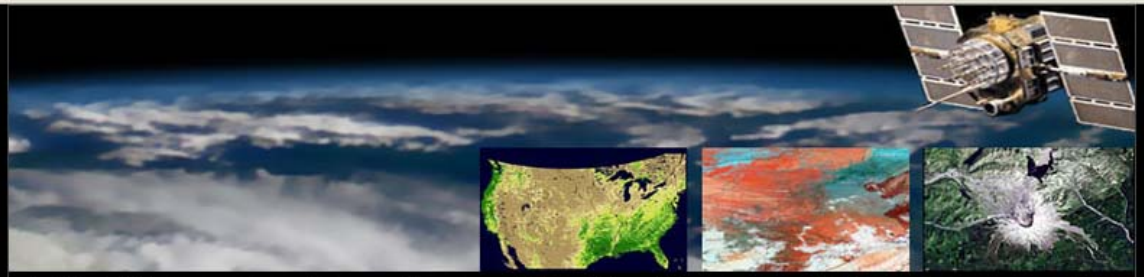
http://snowdon.sd...em/user_info.php



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Home

Create Account

Country: Select a Country

Affiliation: Select Affiliation

Primary Use: Select a primary use

Secondary Use (Please select all that apply):

☐ Agriculture	☐ Forestry	☐ Natural Resources
☐ Climate Change	☐ Geology	☐ Planning
☐ Cryosphere	☐ Human Ecology	☐ Socioeconomics
☐ Ecosystem Studies	☐ Human Health	☐ Telecommunications
☐ Education	☐ Insurance	☐ Terrestrial Monitoring
☐ Emergency Response	☐ International Land Issues	☐ Visualization
☐ Energy	☐ Land Change	☐ Water
☐ Fire	☐ National Security	☐ Other

Password:

Confirm Password:

(>9 words, including one lower case, one upper case and one number.)

Sumbit

Find: san Next Previous Highlight all Match case

Done

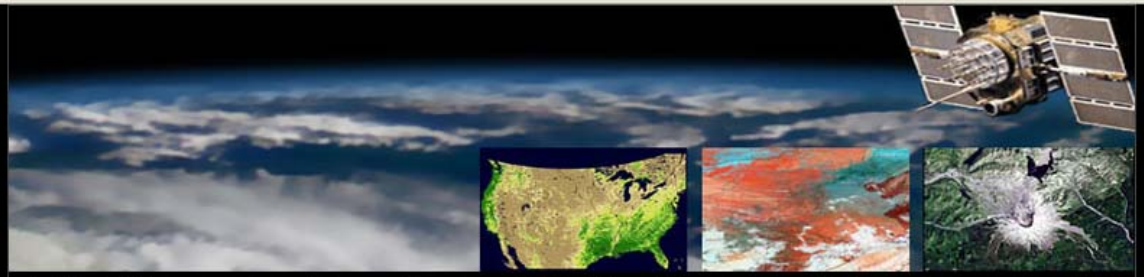
Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://snowdon.sdstate.edu/distribution_system/user_info.php

Most Visited Getting Started Latest Headlines http://snowdon.sdsta... Annotating -- IM v6 E... Password Protection ...

http://snowdon.sd...em/user_info.php



MODIS-Landsat Data Fusion For The Terrestrial User Community

Home

Create Account

Country: INDIA

Affiliation: Educational

Primary Use: Select a primary use

Secondary Use (Please

- Agriculture
- Climate Change
- Cryosphere
- Ecosystem Studie
- Education
- Emergency Respo
- Energy
- Fire
- Natural Resources
- Planning
- Socioeconomics
- Telecommunications
- Terrestrial Monitoring
- Visualization
- Water
- Other

Issues

Select a primary use
Agriculture
Climate Change
Cryosphere
Ecosystem Studies
Education
Emergency Response
Energy
Fire
Forestry
Geology
Human Ecology
Human Health
Insurance
International Land Issues
Land Change
National Security
Natural Resources
Planning
Socioeconomics

Password: (>9 words, including one lower case, one upper case and one number.)

Confirm Password:

Sumbit

Find: san Next Previous Highlight all Match case

Done

Mozilla Firefox

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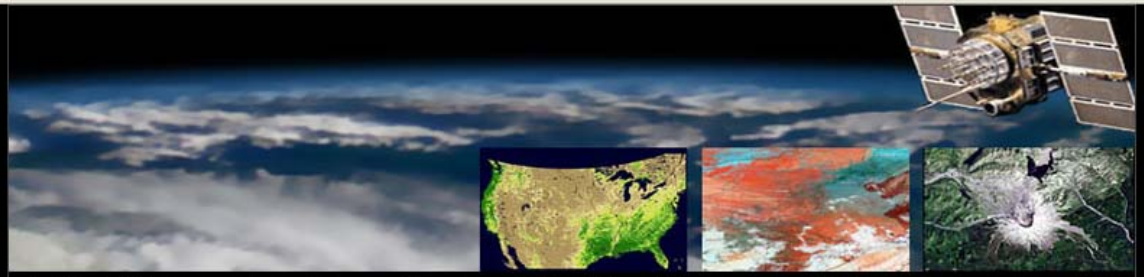
http://snowdon.sdstate.edu/distribution_system/user_info.php

Most Visited Getting Started Latest Headlines http://snowdon.sdsta... Annotating -- IM v6 E... Password Protection ...

http://snowdon.sd...em/user_info.php



MODIS-Landsat Data Fusion For The Terrestrial User Community

Home

Create Account

Country: INDIA

Affiliation: Educational

Primary Use: Education

Secondary Use (Please select all that apply):

☐ Agriculture	☐ Forestry	☐ Natural Resources
☐ Climate Change	☐ Geology	☐ Planning
☐ Cryosphere	☐ Human Ecology	☐ Socioeconomics
☐ Ecosystem Studies	☐ Human Health	☐ Telecommunications
☐ Education	☐ Insurance	☐ Terrestrial Monitoring
☐ Emergency Response	☐ International Land Issues	☐ Visualization
☐ Energy	☐ Land Change	☐ Water
☐ Fire	☐ National Security	☑ Other

Password: ••••••••••

Confirm Password: ••••••••••

(>9 words, including one lower case, one upper case and one number.)

Sumbit

Find: san Next Previous Highlight all Match case

Done

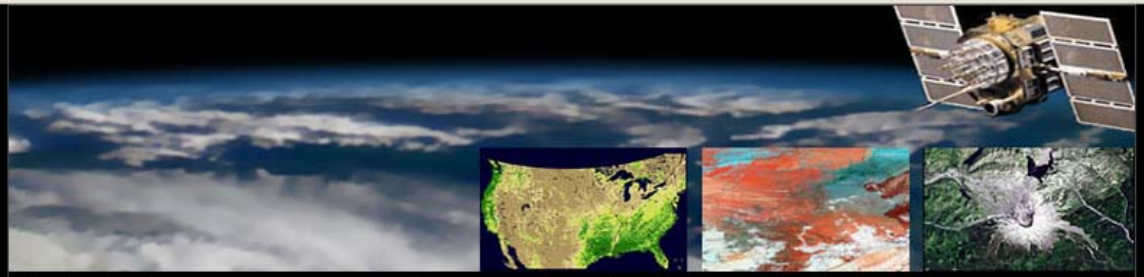
Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://snowdon.sdstate.edu/distribution_system/user_info.php

Most Visited Getting Started Latest Headlines http://snowdon.sdsta... Annotating -- IM v6 E... Password Protection ...

http://snowdon.sd...em/user_info.php



MODIS-Landsat Data Fusion For The Terrestrial User Community

Home

Create Account

Account successfully created

Your order has been placed successfully. You will be redirected to the distribution system in few seconds

Country: Select a Country

Affiliation: Select Affiliation

Primary Use: Select a primary use

Secondary Use (Please select all that apply):

- ☐ Agriculture
- ☐ Climate Change
- ☐ Cryosphere
- ☐ Ecosystem Studies
- ☐ Education
- ☐ Emergency Response
- ☐ Energy
- ☐ Fire
- ☐ Forestry
- ☐ Geology
- ☐ Human Ecology
- ☐ Human Health
- ☐ Insurance
- ☐ International Land Issues
- ☐ Land Change
- ☐ National Security
- ☐ Natural Resources
- ☐ Planning
- ☐ Socioeconomics
- ☐ Telecommunications
- ☐ Terrestrial Monitoring
- ☐ Visualization
- ☐ Water
- ☐ Other

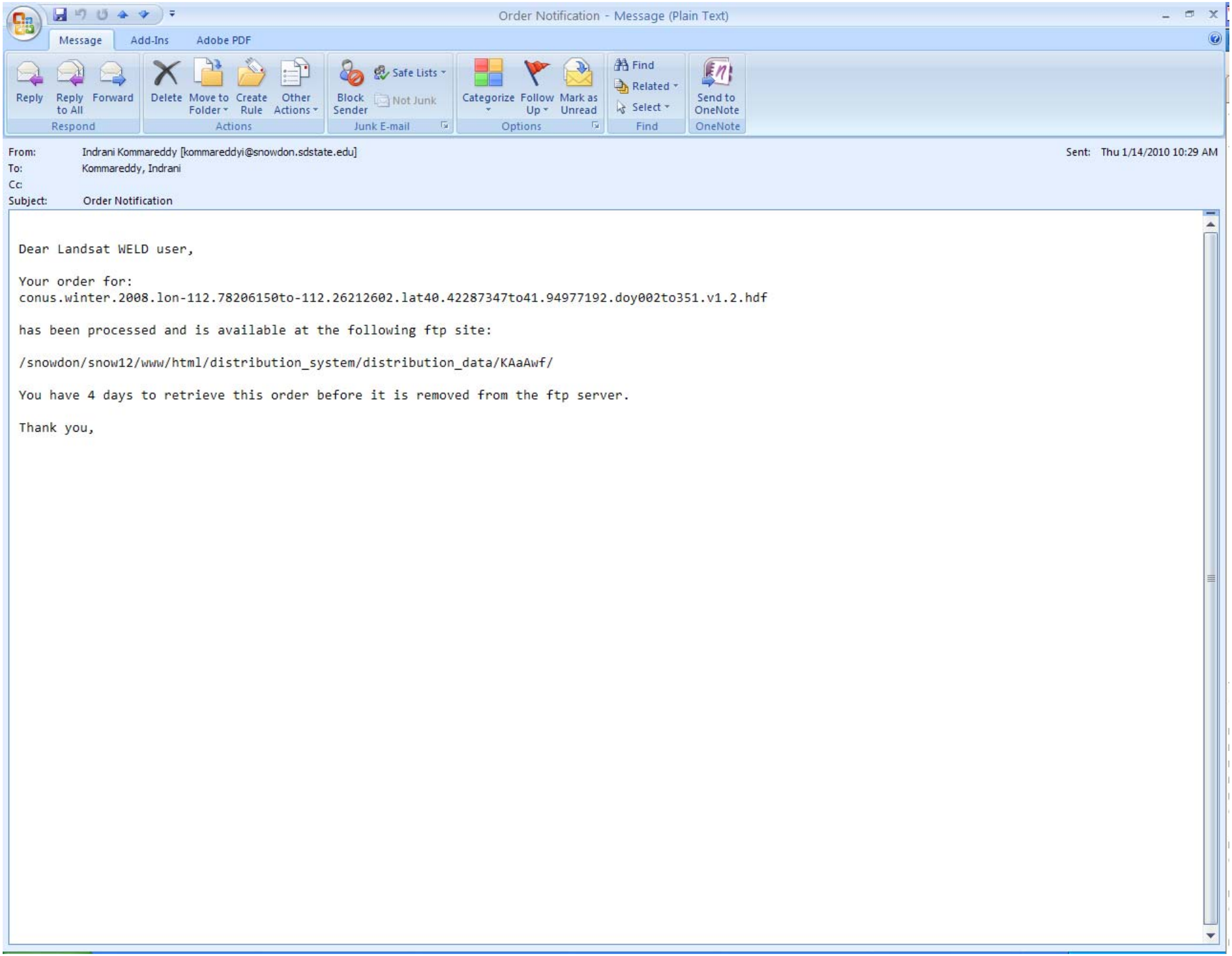
Password:

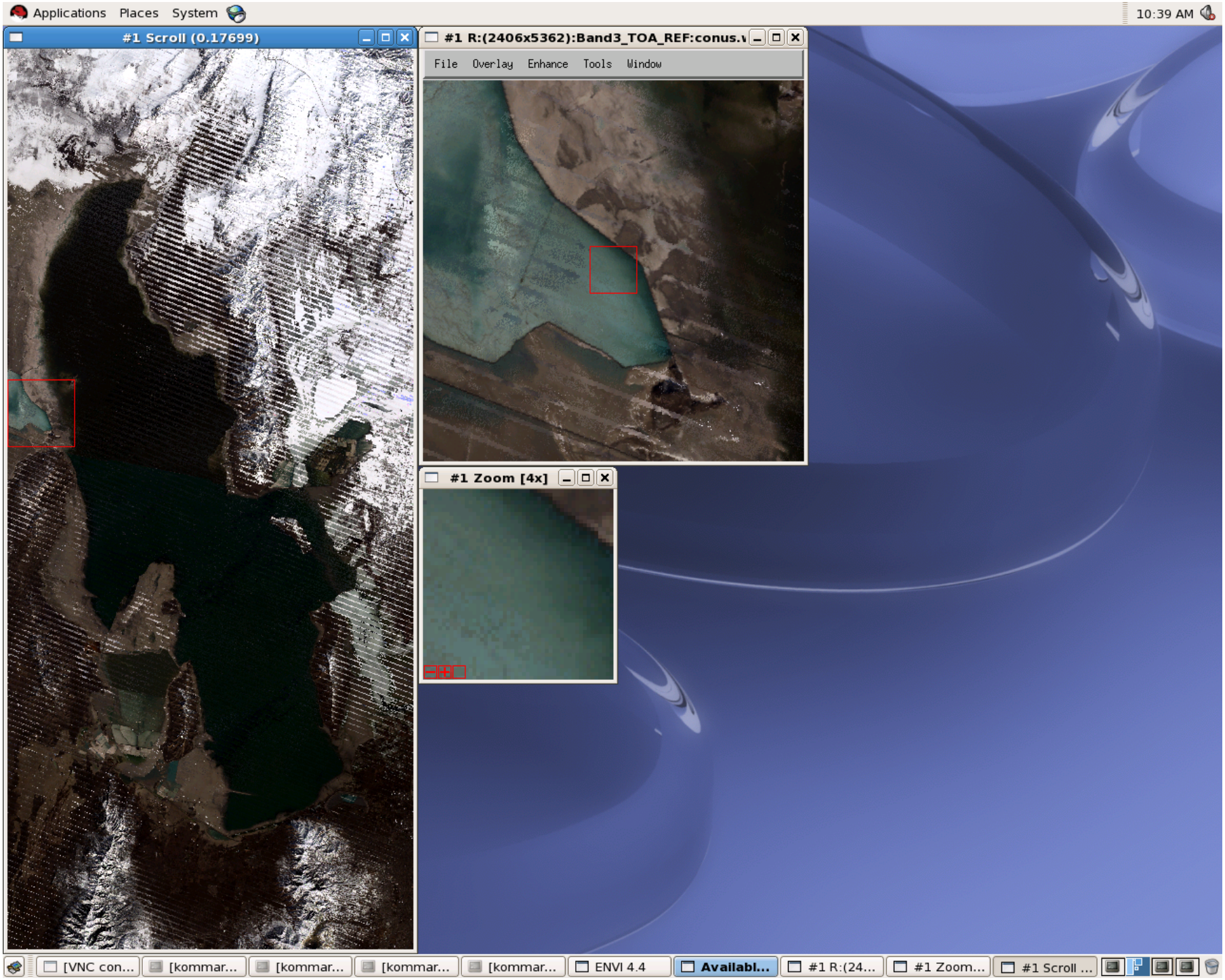
Confirm Password:

(>9 words, including one lower case, one upper case and one number.)

Find: san Next Previous Highlight all Match case

Done


Order Notification - Message (Plain Text)
Message
Add-Ins
Adobe PDF
Reply
Reply to All
Forward
Delete
Move to Folder
Create Rule
Other Actions
Block Sender
Safe Lists
Not Junk
Categorize
Follow Up
Mark as Unread
Find
Related
Select
Send to OneNote
Respond
Actions
Junk E-mail
Options
Find
OneNote
From: Indrani Kommareddy [kommareddyi@snowdon.sdstate.edu]
Sent: Thu 1/14/2010 10:29 AM
To: Kommareddy, Indrani
Cc:
Subject: Order Notification
Dear Landsat WELD user,
Your order for:
conus.winter.2008.lon-112.78206150to-112.26212602.lat40.42287347to41.94977192.doy002to351.v1.2.hdf
has been processed and is available at the following ftp site:
/snowdon/snow12/www/html/distribution_system/distribution_data/KAaAwf/
You have 4 days to retrieve this order before it is removed from the ftp server.
Thank you,


Applications
Places
System
10:39 AM
#1 Scroll (0.17699)
#1 R:(2406x5362):Band3_TOA_REF:conus.
File
Overlay
Enhance
Tools
Window
#1 Zoom [4x]
[VNC con...
[kommar...
[kommar...
[kommar...
[kommar...
ENVI 4.4
Availabl...
#1 R:(24...
#1 Zoom...
#1 Scroll ...

2010 Schedule for WELD system port from SDSU to EROS

- WELD Version 1.3 sample distribution
  - **Done Jan. 15th 2010**
- WYSISWY Distribution System
  - 2007/2008/2009
  - CONUS & Alaska
  - weekly/monthly/seasonal/annual composited mosaics
  - **Summer 2010**
- Preliminary production system
  - Running Version 2.0 algorithms (radiometric normalization & gap-filling)
  - **Fall 2010**

Landsat Missions - Mozilla Firefox

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

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Web-enabled Landsat data (WELD) Project

The WELD project is systematically generating 30 m composited Landsat ETM+ mosaics at weekly, monthly, seasonal and annual time periods for the conterminous USA (CONUS) and Alaska. The composited mosaics are designed to provide consistent Landsat data that can be used to derive land cover and geo physical and bio physical products for regional assessment of surface dynamics and to study Earth system functioning.

Version 1.3 of the WELD monthly, seasonal and annual products generated from Landsat ETM+ terrain corrected (Level 1T) data with cloud cover ≤80% sensed December 2007 to November 2008 are available here.

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

WELD Browse Imagery

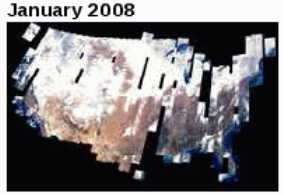
The thumbnail images below illustrate the currently available Version 1.3 WELD data products, please click on them to see a higher resolution version. These true color browse images show the Landsat ETM+ red, green and blue wavelength bands at approximately 500 m resolution.

CONUS Annual

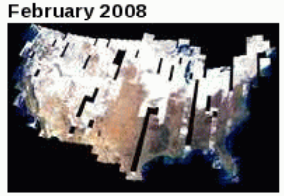
Winter

December 2007

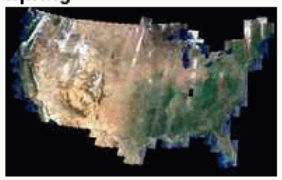
January 2008



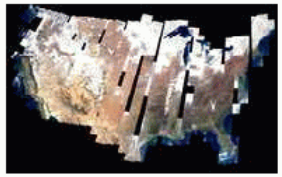
February 2008



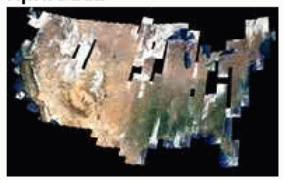
Spring



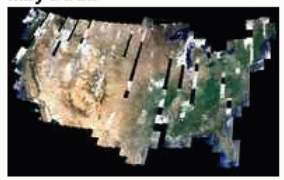
March 2008



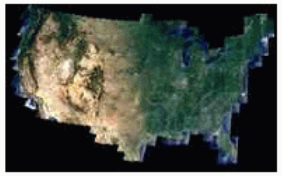
April 2008



May 2008

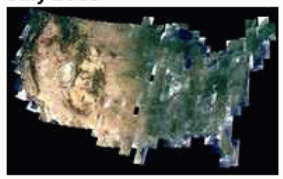


Summer

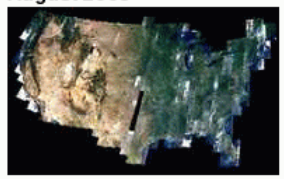


June 2008

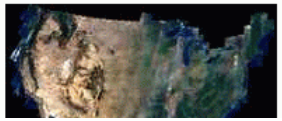
July 2008



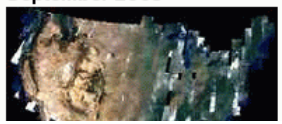
August 2008



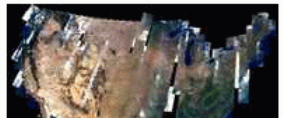
Autumn



September 2008



October 2008



November 2008