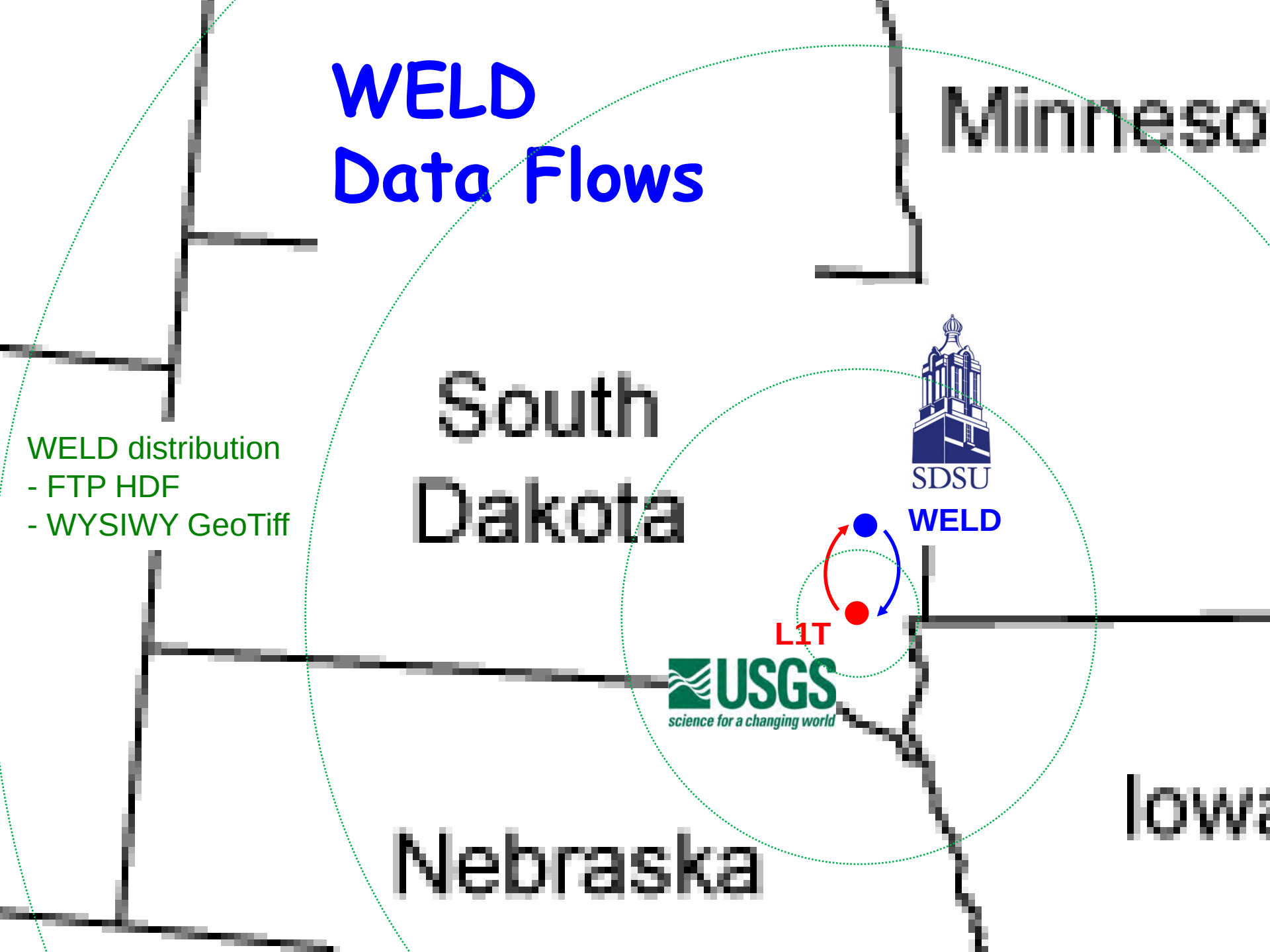
Continuity of the Web Enabled Landsat Data (WELD) Product Record in the Landsat 8 Era

David Roy, Valeriy Kovalskyy, Indrani Kommareddy
Geographic Information Science Center of Excellence,
South Dakota State University, USA

Landsat Science Team Meeting,
USGS EROS Center, Sioux Falls, USA
29-31 October 2013

Current Status of NASA funded WELD activities

WELD Data Flows



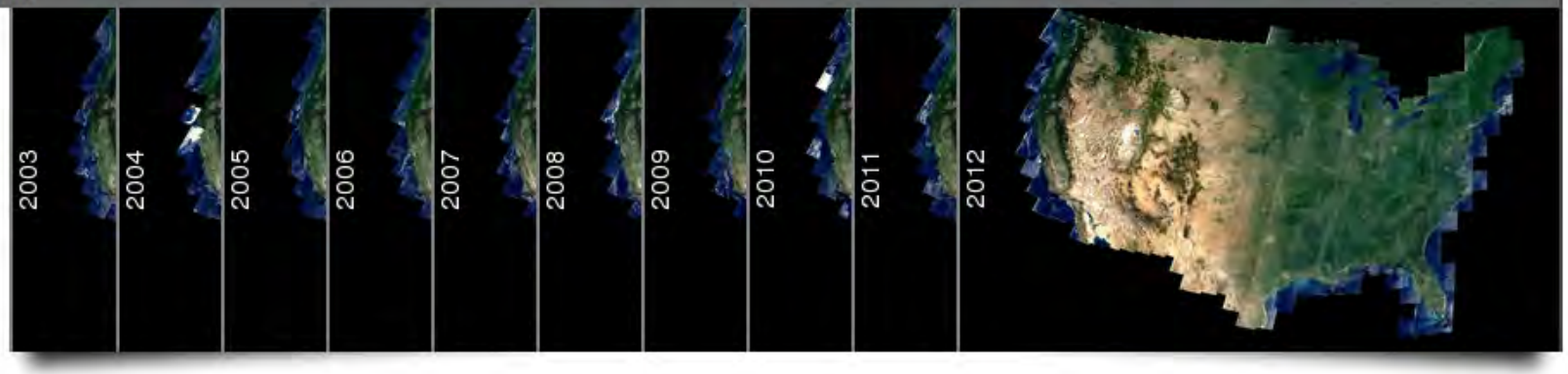
WELD distribution
- FTP HDF
- WYSIWY GeoTiff

WELD: Web - Enabled Landsat Data

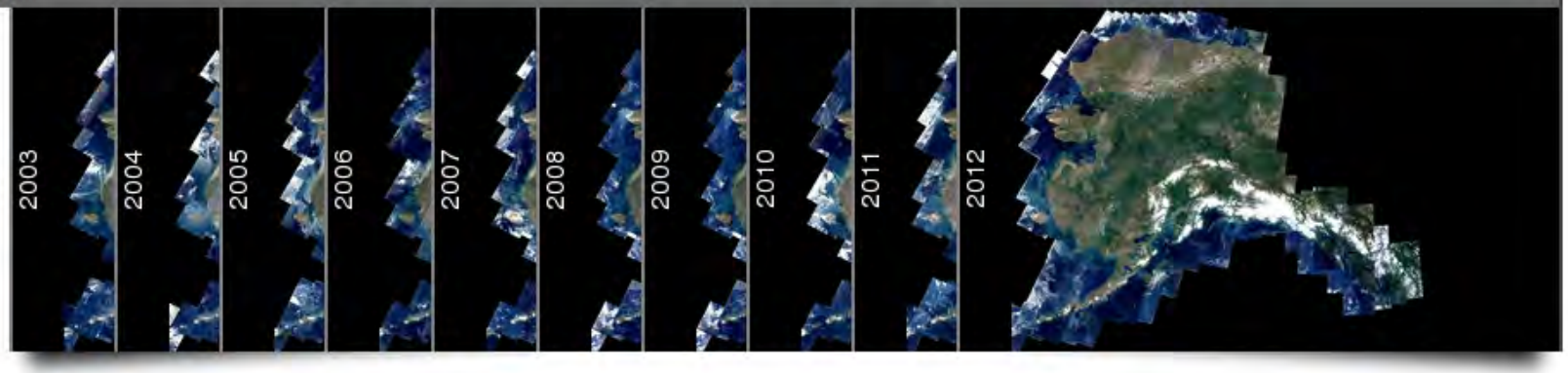
USGS Home
Contact USGS
Search USGS

Available Years:

CONUS



Alaska

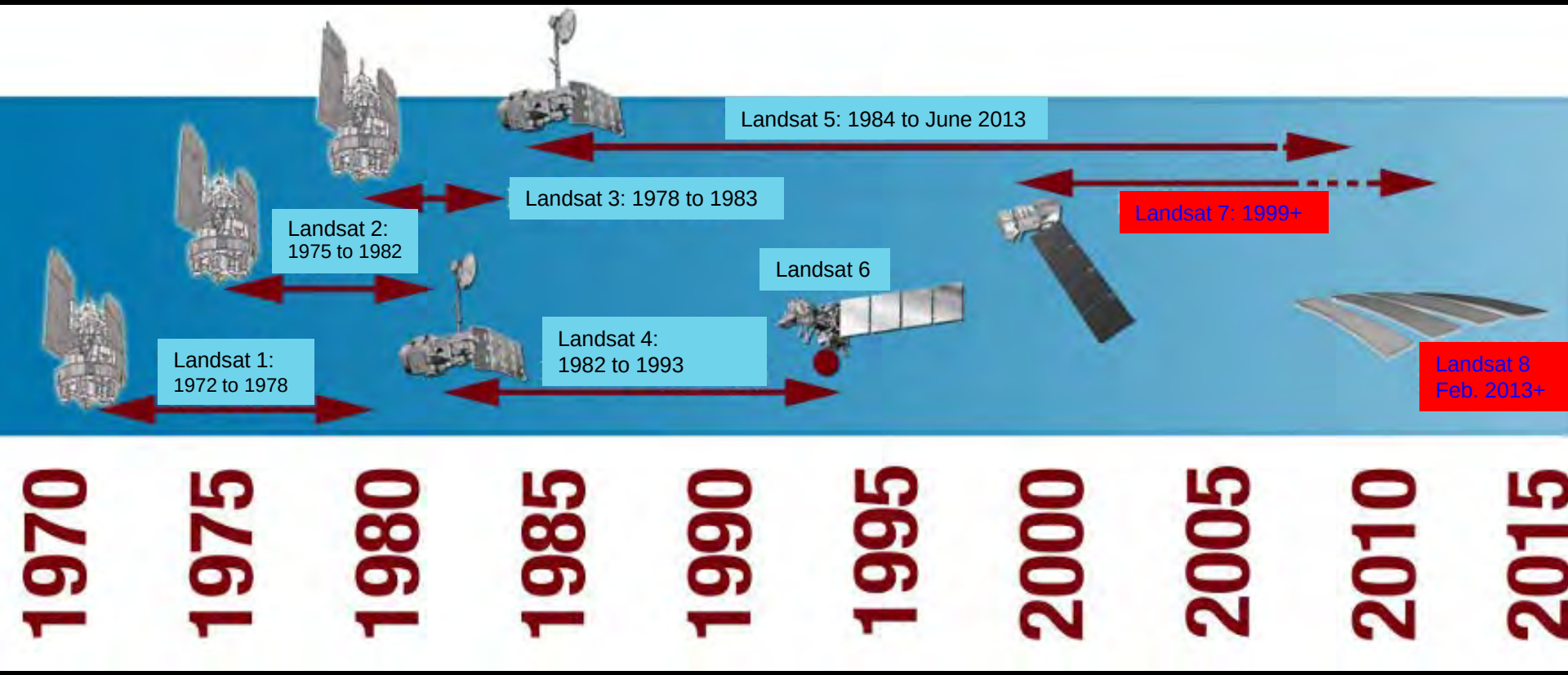


10 years of CONUS and Alaska products (40TB) online at EROS

>0.5 million files, >130TB, have been distributed to >1200 users

Interface Help | WELD Product Information | Distribution Metrics

New NASA 5-year Funding



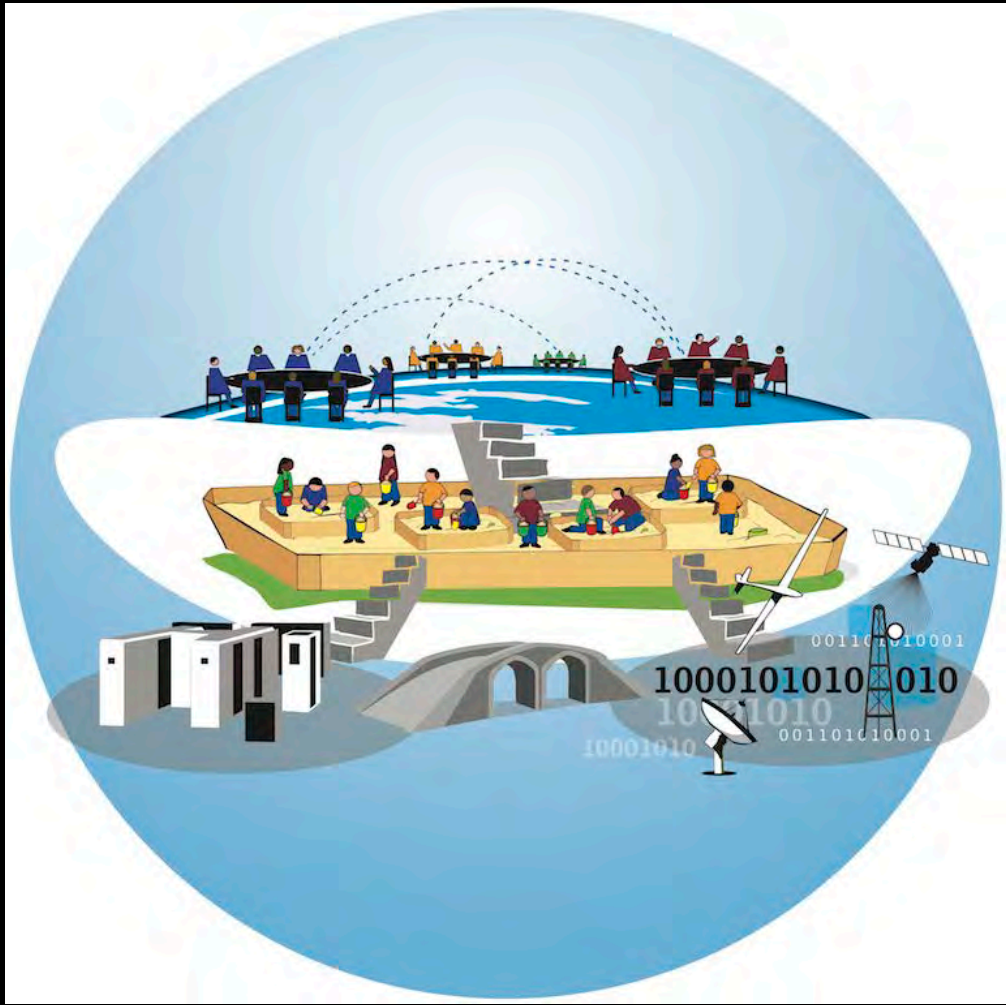
WELD process 30m Landsat TM & ETM+

Global Archive

Global Landsat Processing

Need fast computer, fast I/O, big disk

NASA Earth Exchange (NEX)



COLLABORATION (over 250 members)

Pleiades

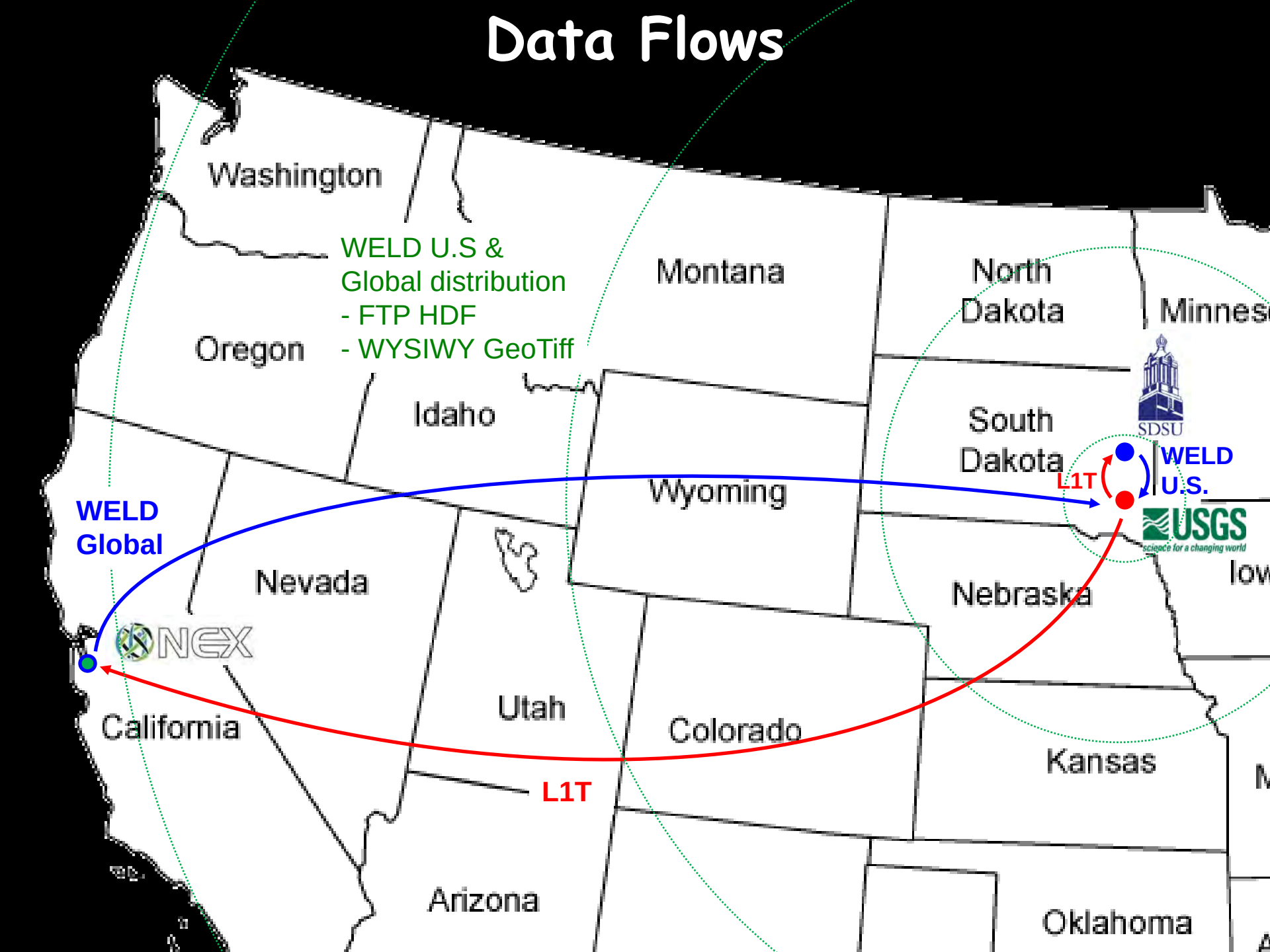
NASA's fastest supercomputer

COMPUTING (9PB, 180,000 cores)

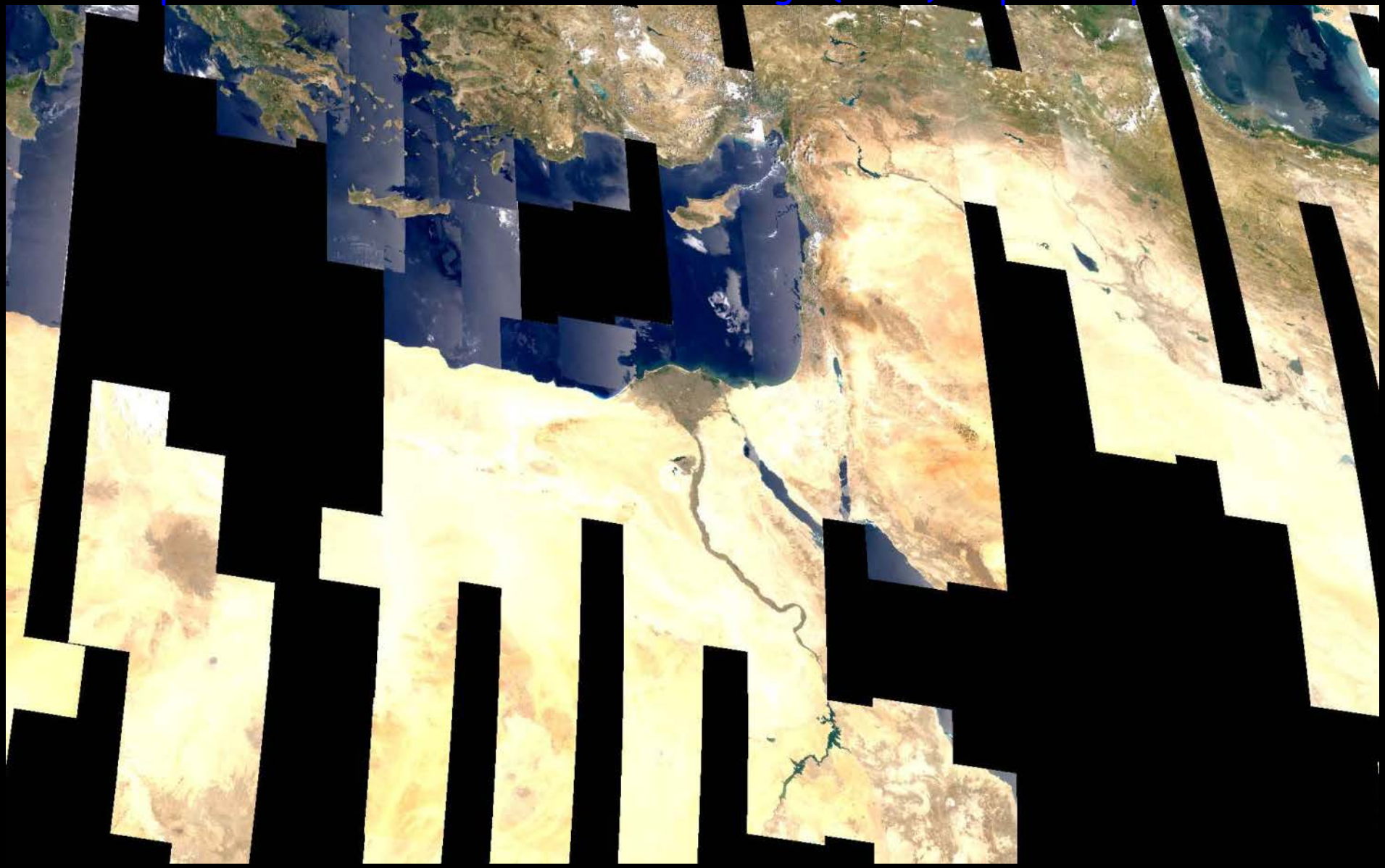
Data Repository (over 400 TB of data)

- 9PB on-line storage, 50PB tape storage
- 180,000 total available cores

Data Flows


Washington
WELD U.S &
Global distribution
- FTP HDF
- WYSIWY GeoTiff
Montana
North
Dakota
Minnes
Oregon
Idaho
South
Dakota
SDSU
WELD
U.S.
L1T
Wyoming
WELD
Global
USGS
science for a changing world
Nevada
Nebraska
low
NEX
California
Utah
Colorado
Kansas
L1T
Arizona
Oklahoma

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



MODIS Land Sinusoidal Projection

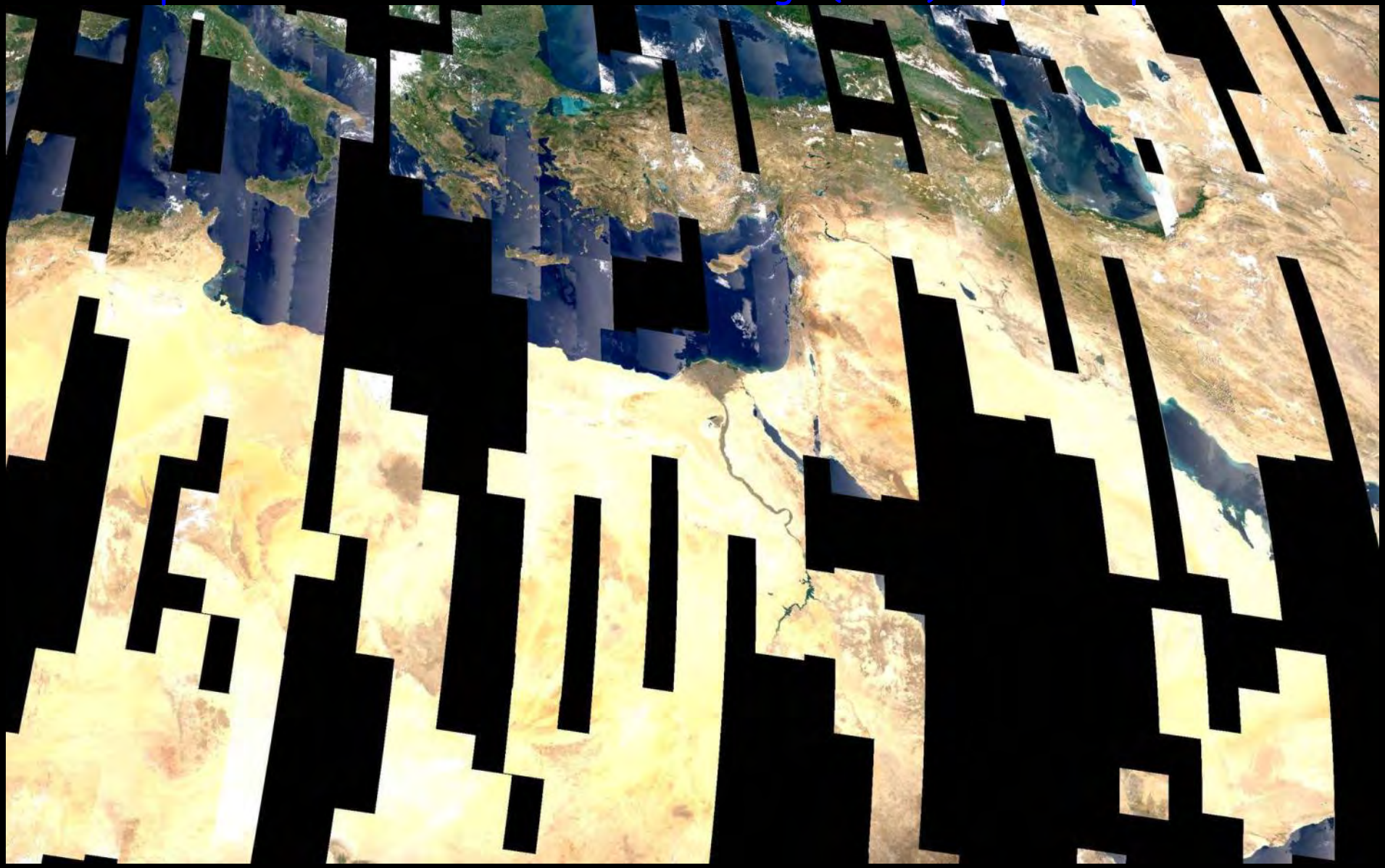
Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer

MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer

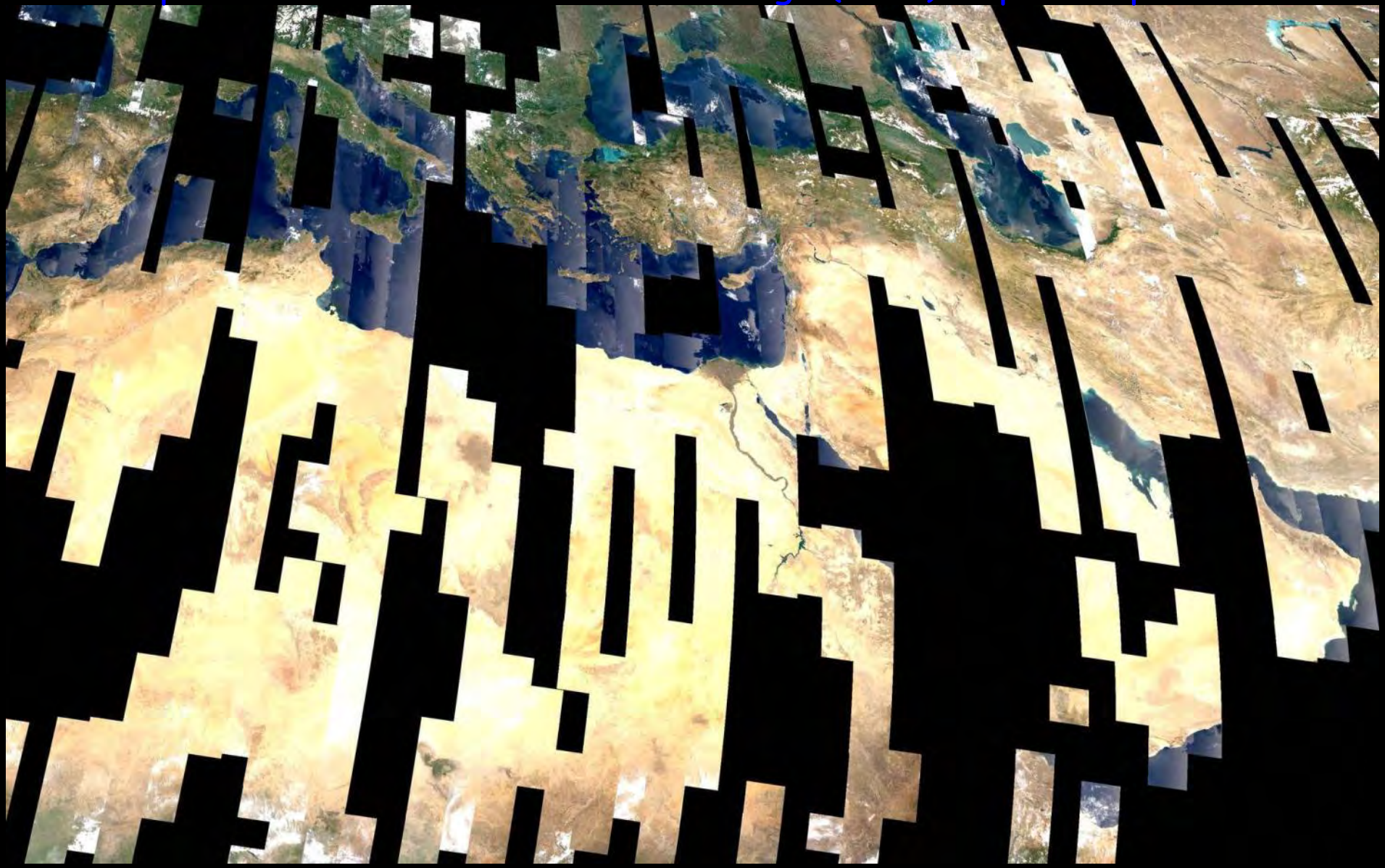
MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



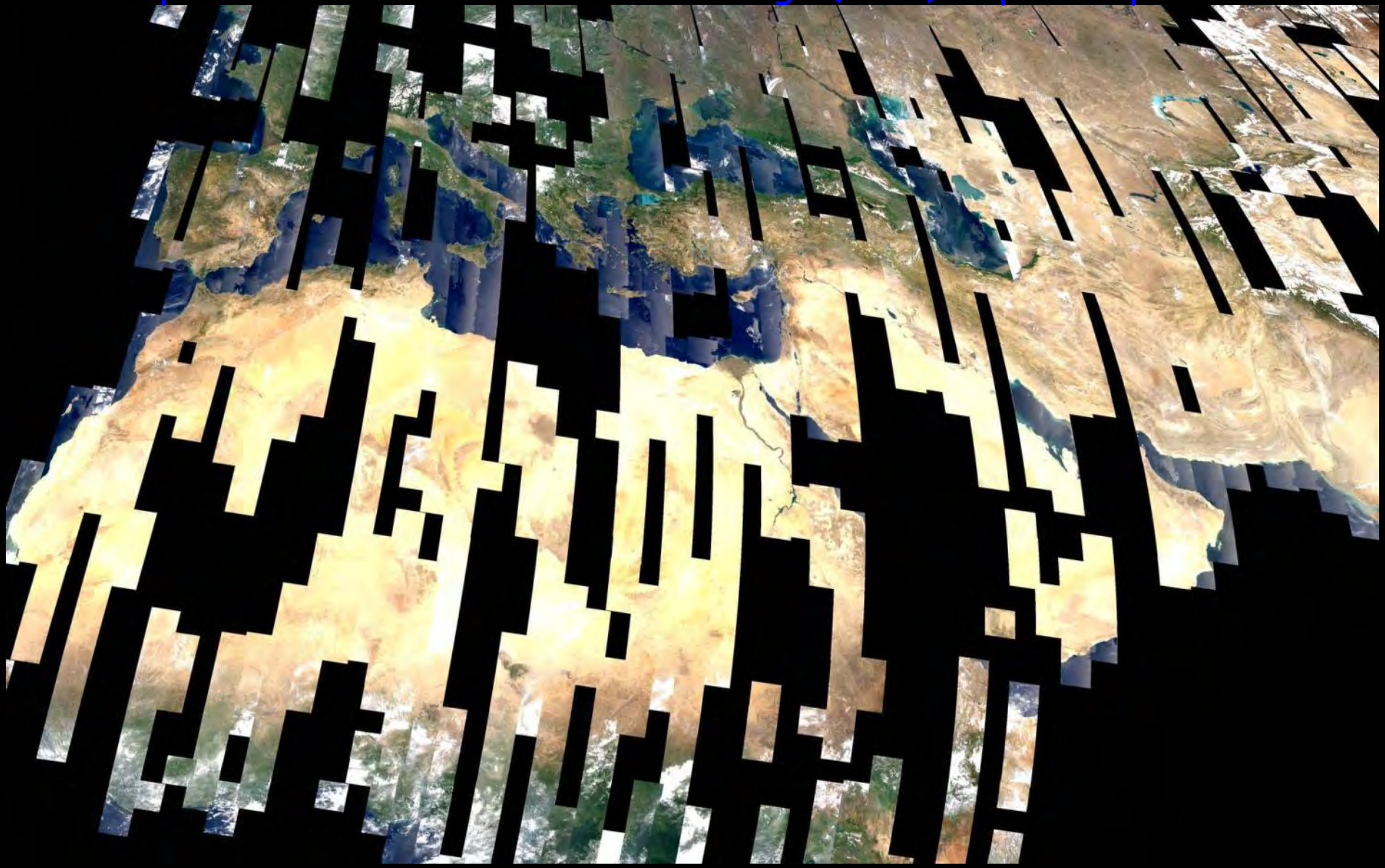
MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



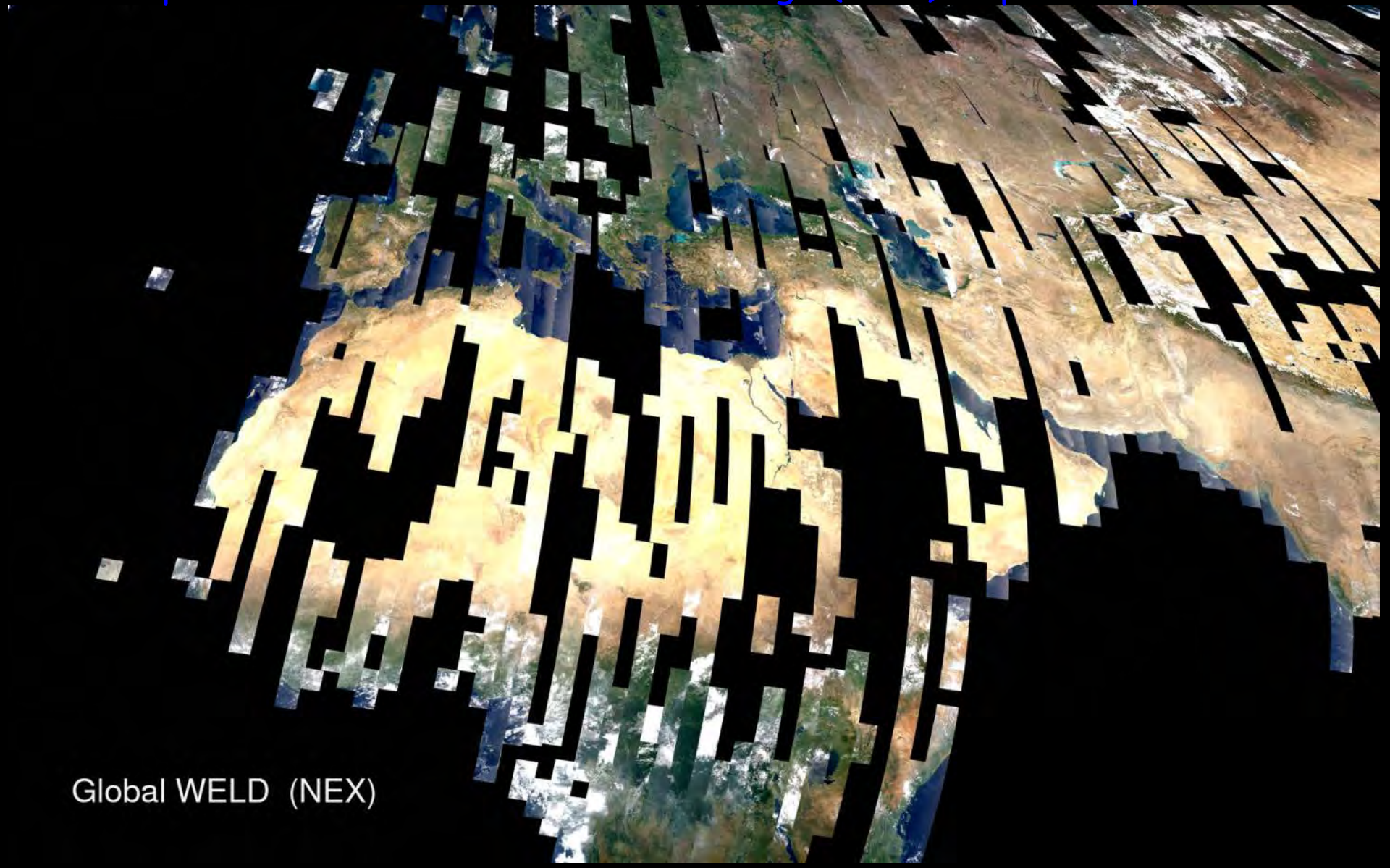
MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



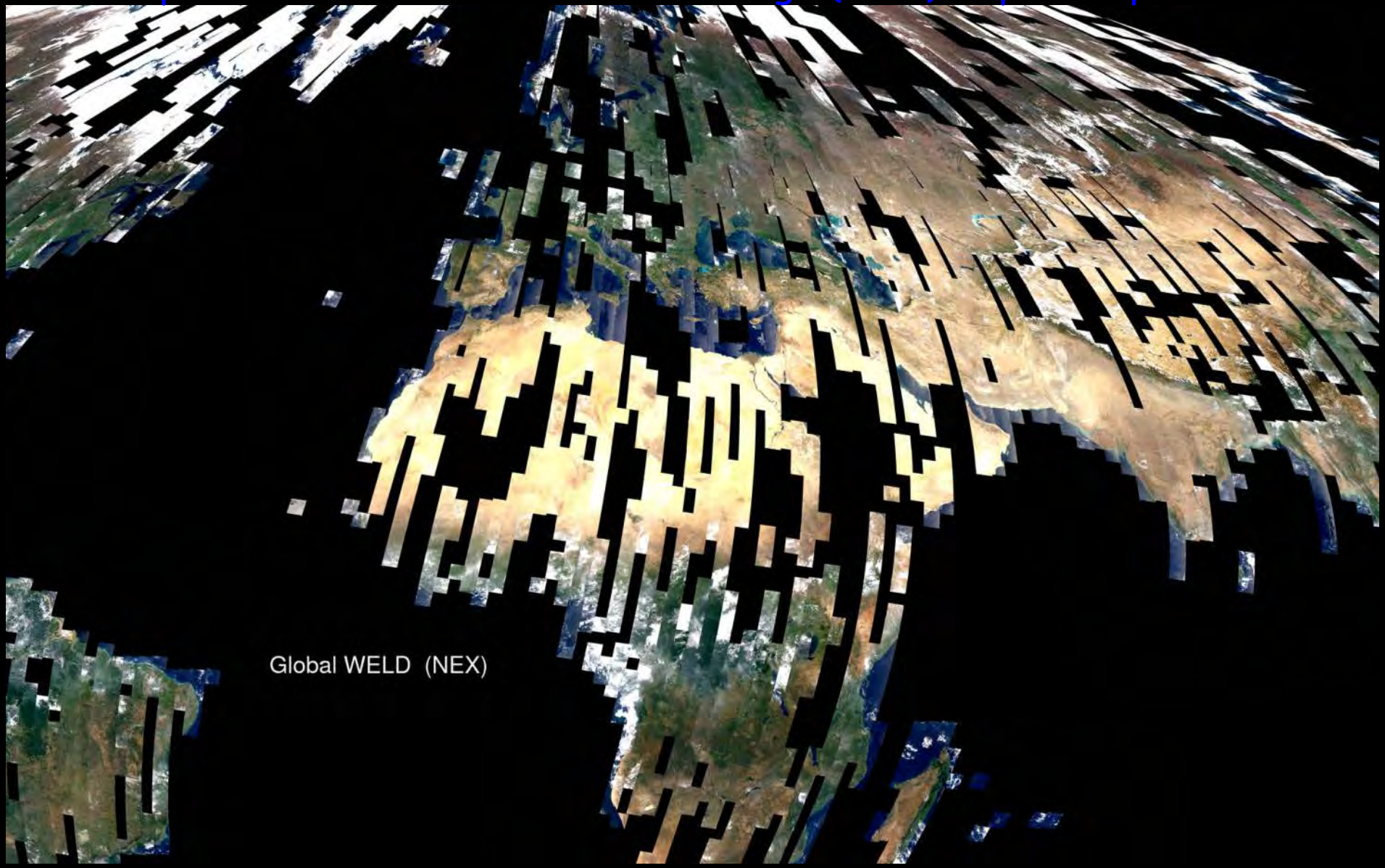
MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



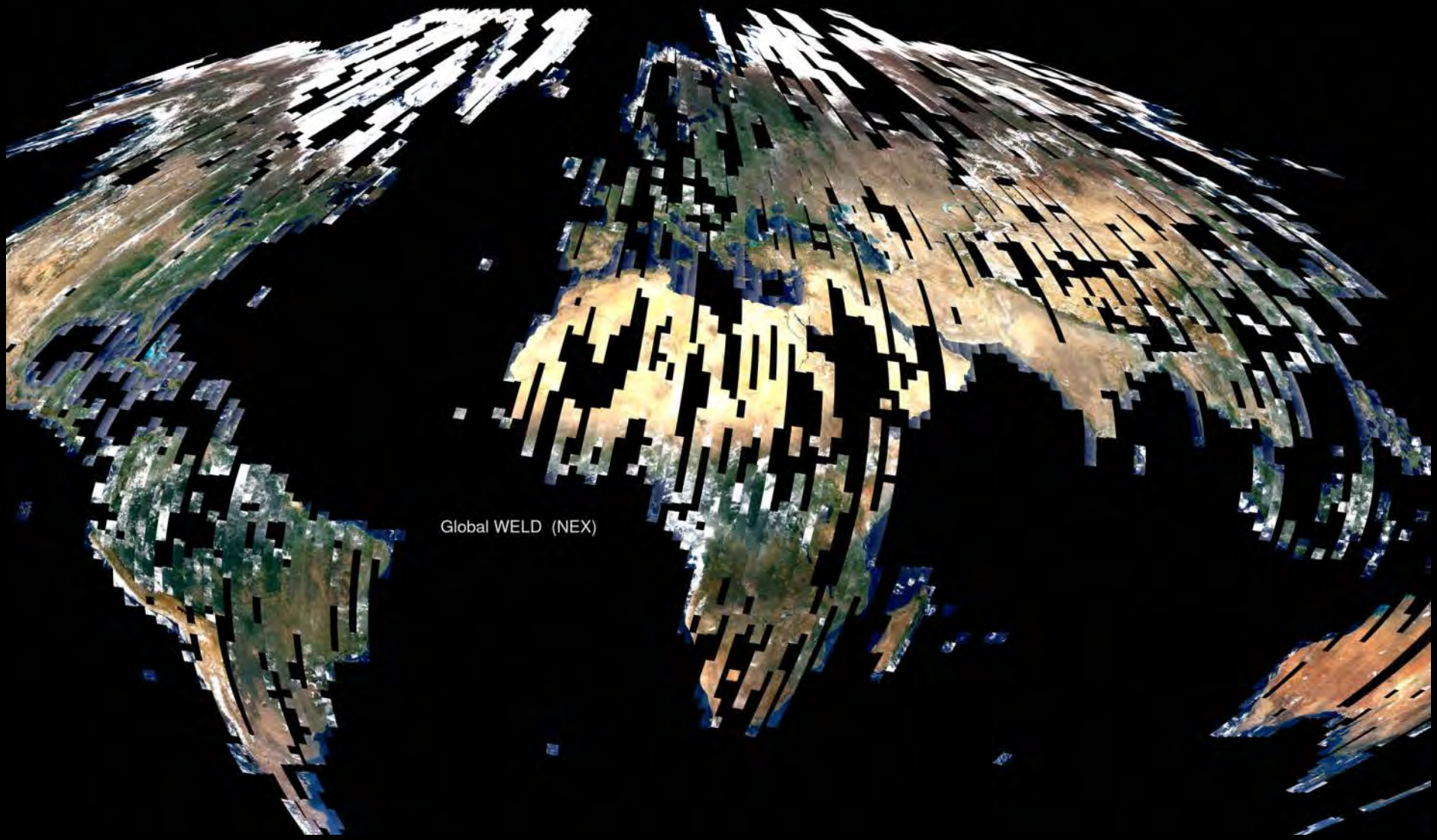
MODIS Land Sinusoidal Projection

Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



MODIS Land Sinusoidal Projection

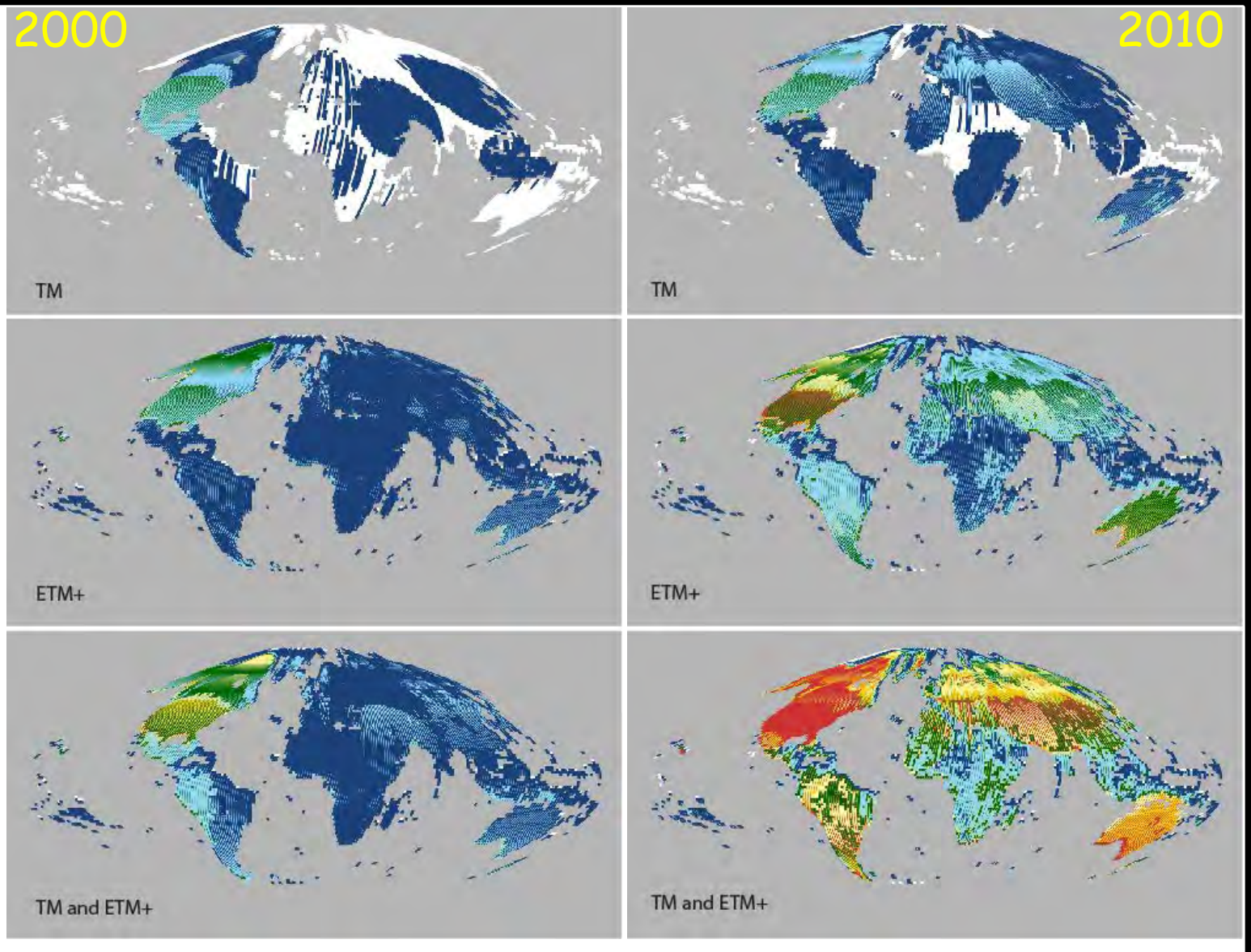
Global WELD prototype, Landsat 7 ETM+, 7300 May 2010 acquisitions, processed on NASA Earth Exchange (NEX) Supercomputer



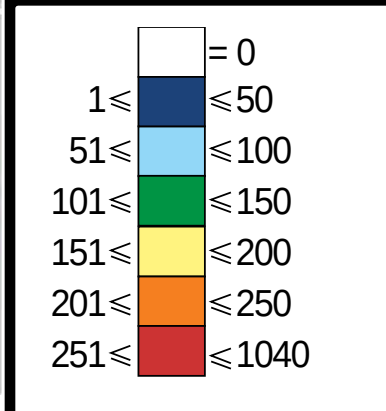
MODIS Land Sinusoidal Projection

More utility in combing Landsat 5 and Landsat 7

Number of Landsat acquisitions per land location in 36 months



Kovalskyy, V. and Roy, D.P., 2013, The global availability of Landsat 5 TM and Landsat 7 ETM+ land surface observations and implications for global 30m Landsat data product generation, *Remote Sensing of Environment*, 130, 280–293.



New WELD compositing (KFC algorithm)

August 2008

Landsat 5 TM
(12 acquisitions)

~30% cloudy

California

5000 x 5000 30m pixels

New WELD compositing (KFC algorithm)

August 2008

Landsat 7 ETM+
(12 acquisitions)

~15% cloudy

California

5000 x 5000 30m pixels

New WELD compositing (KFC algorithm)

August 2008

Landsat 5 & 7
(24 acquisitions)

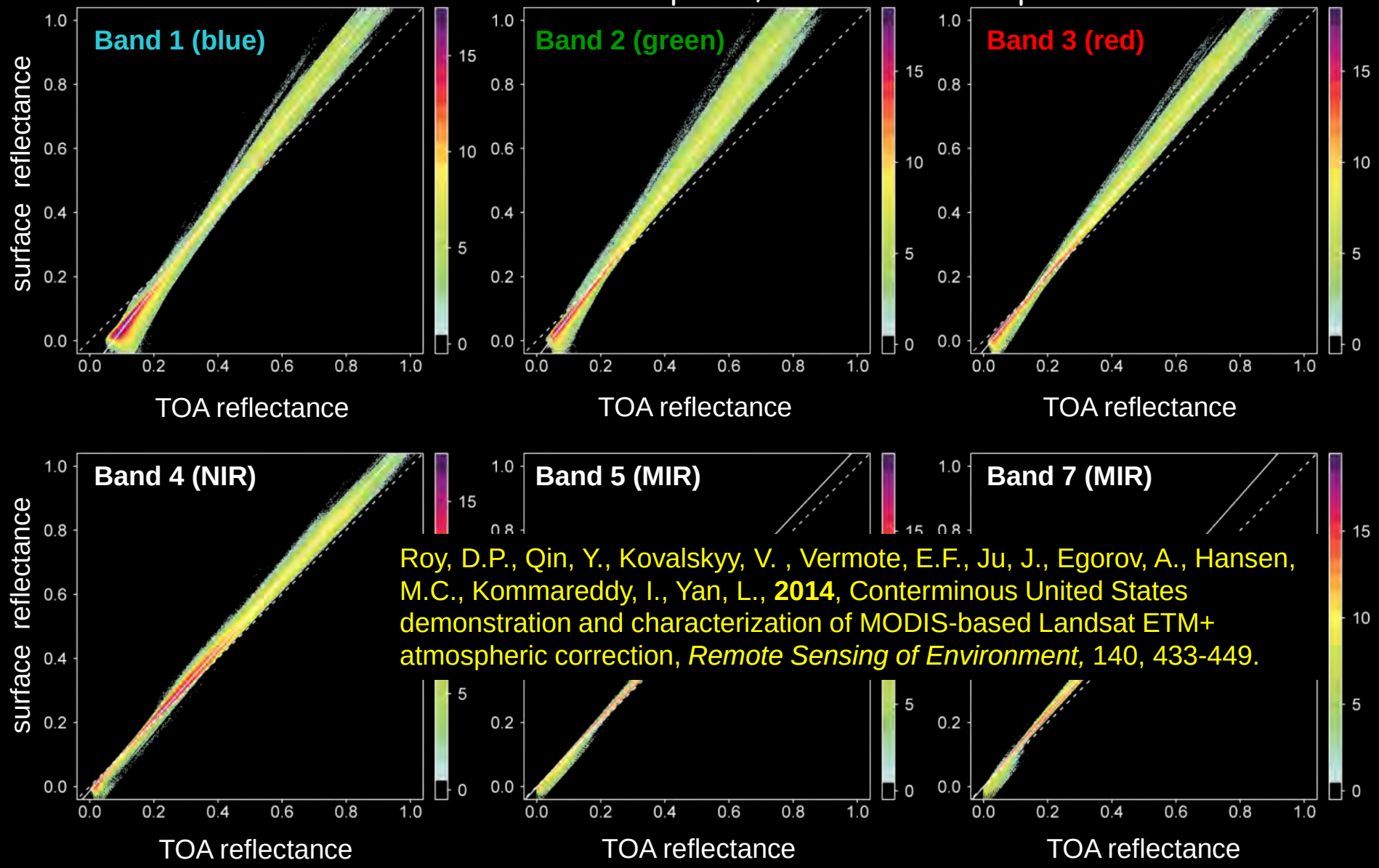
~1% cloudy

California

5000 x 5000 30m pixels

KFC Landsat compositing algorithm informed by analysis of impact of atmosphere on WELD TOA reflectance

Pixels sampled every 40 pixels across CONUS from 12 monthly WELD composites, ignoring cloud and saturated WELD pixels, ~ 53 million 30m pixels

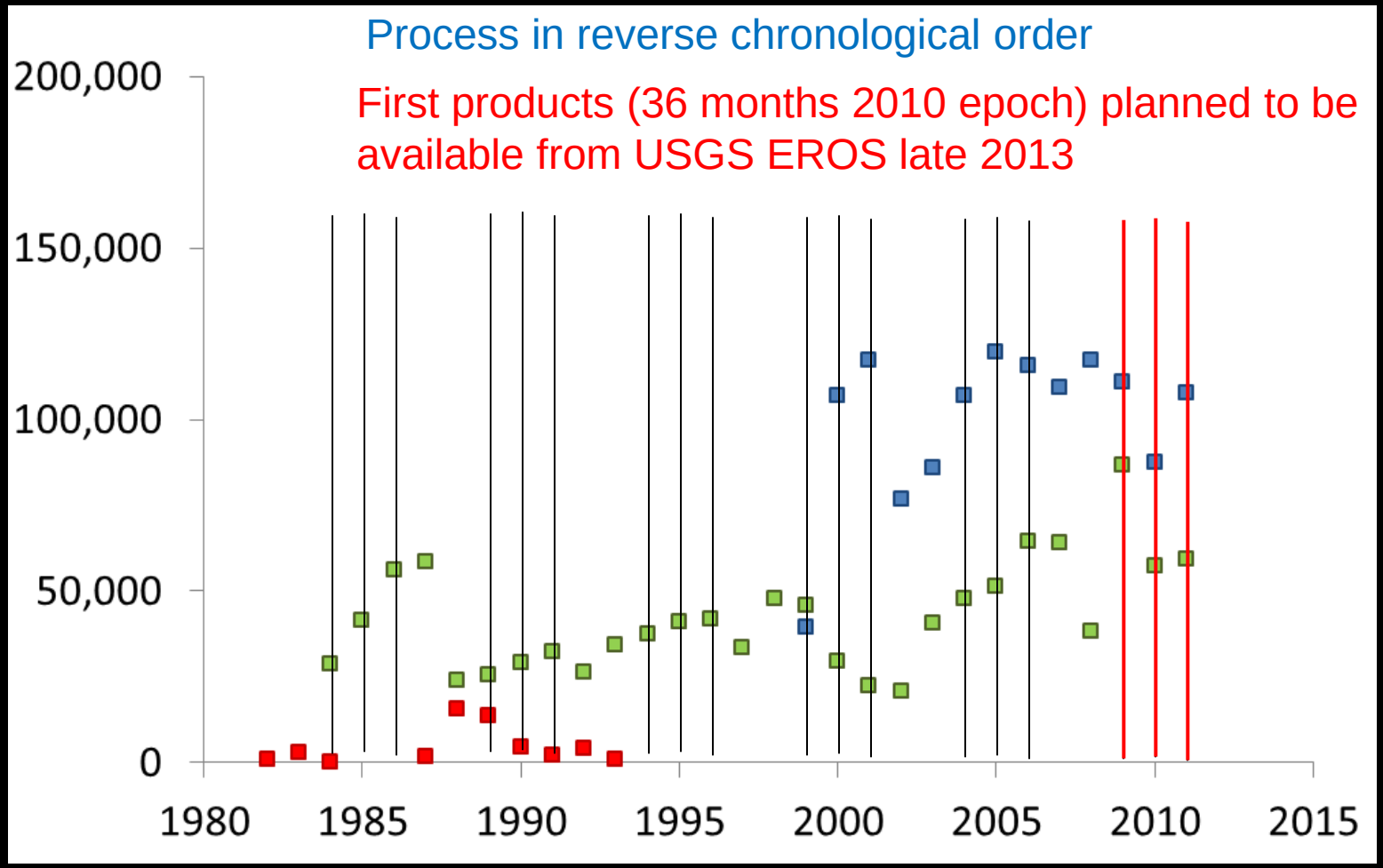


Roy, D.P., Qin, Y., Kovalskyy, V. , Vermote, E.F., Ju, J., Egorov, A., Hansen, M.C., Kommareddy, I., Yan, L., **2014**, Conterminous United States demonstration and characterization of MODIS-based Landsat ETM+ atmospheric correction, *Remote Sensing of Environment,* 140, 433-449.

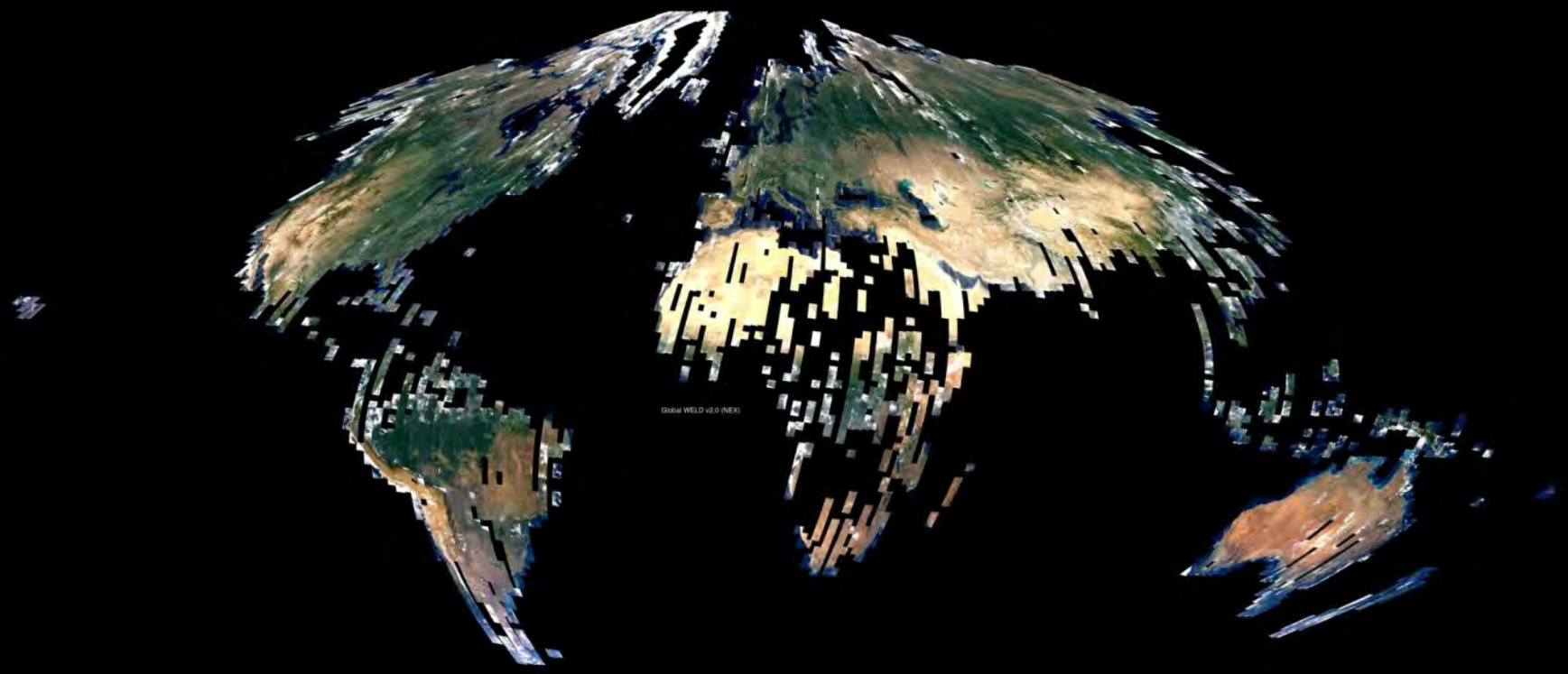
Planned Global WELD Production on NEX

monthly 30m products, fusion of contemporaneous Landsat 4,5,7
6 epochs of 36 months

Number of Landsat scenes in U.S. archive



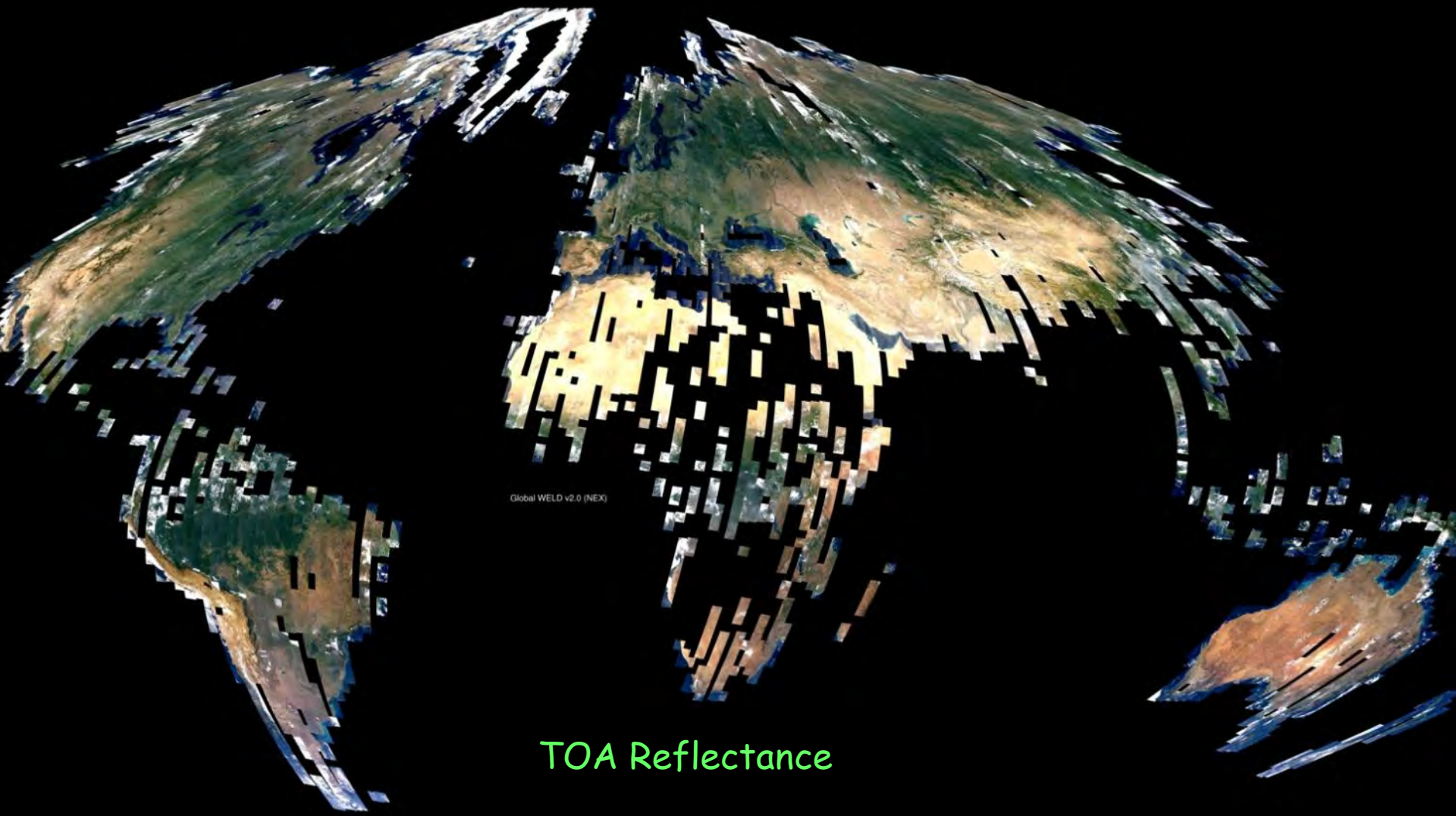
Global WELD Processing July 2010
Landsat 5 TM and Landsat 7 ETM+ scenes



TOA reflectance

MODIS sinusoidal projection

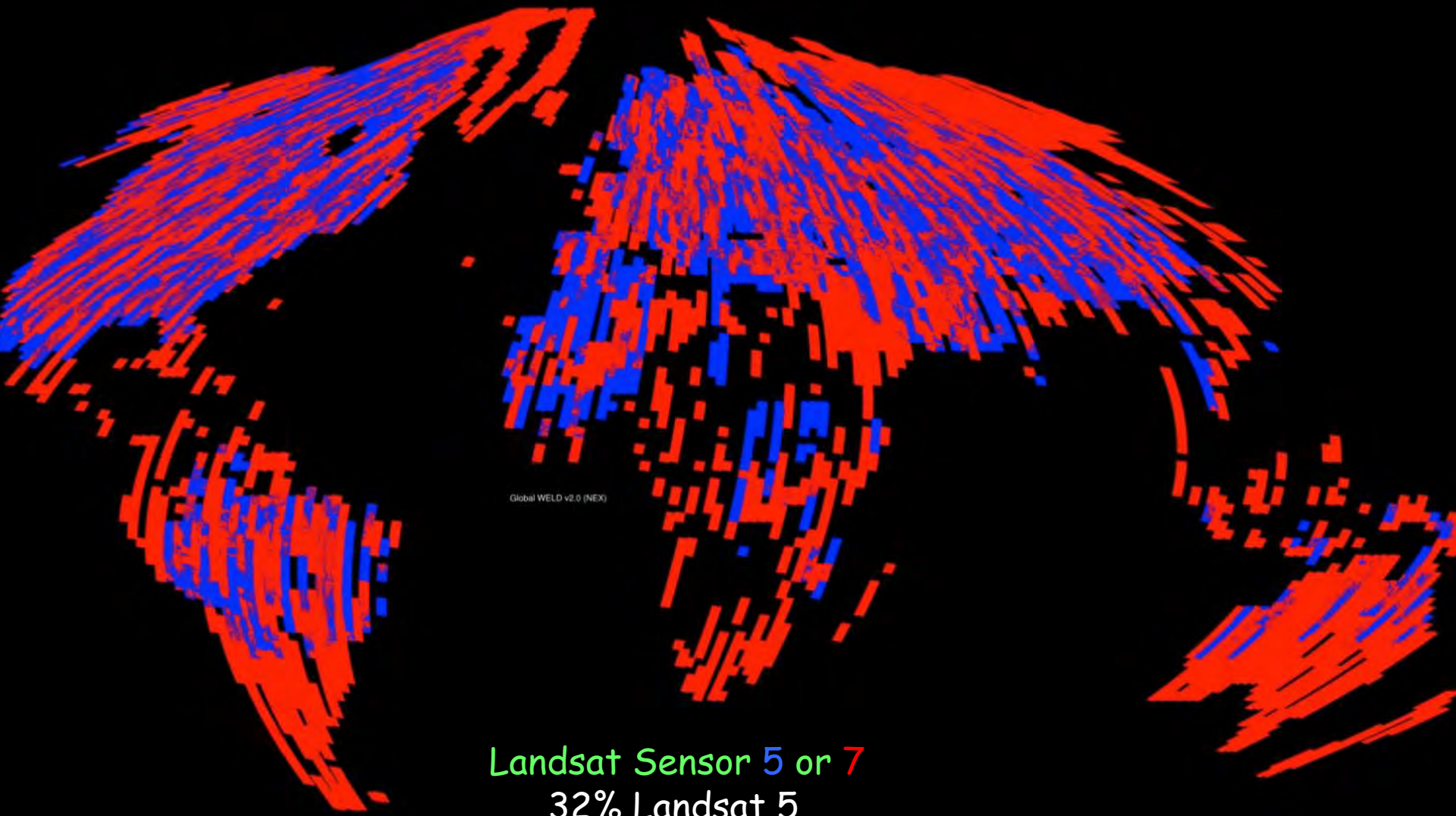
Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes



TOA Reflectance

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

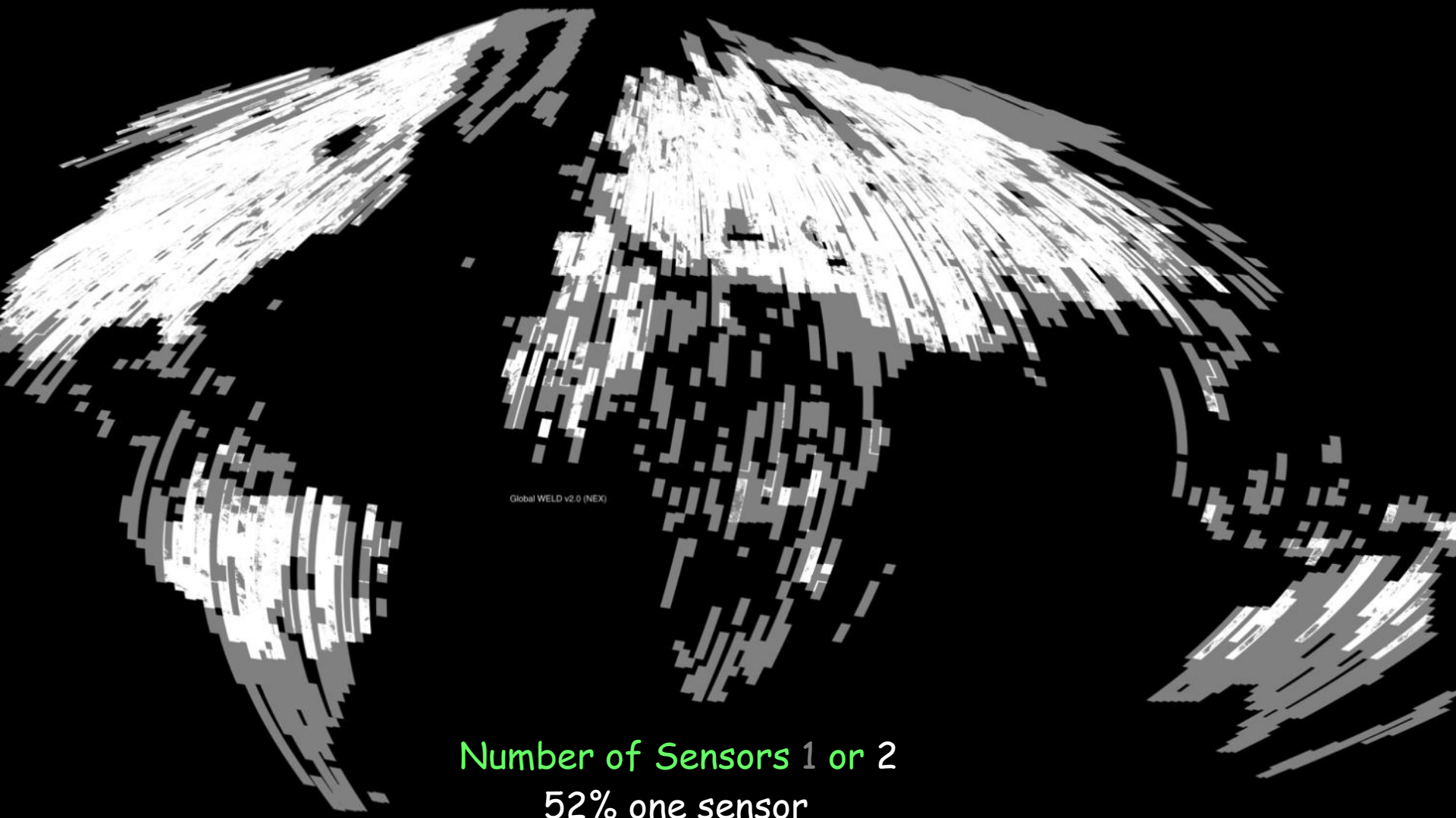
Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes



Landsat Sensor 5 or 7
32% Landsat 5
68% Landsat 7

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes



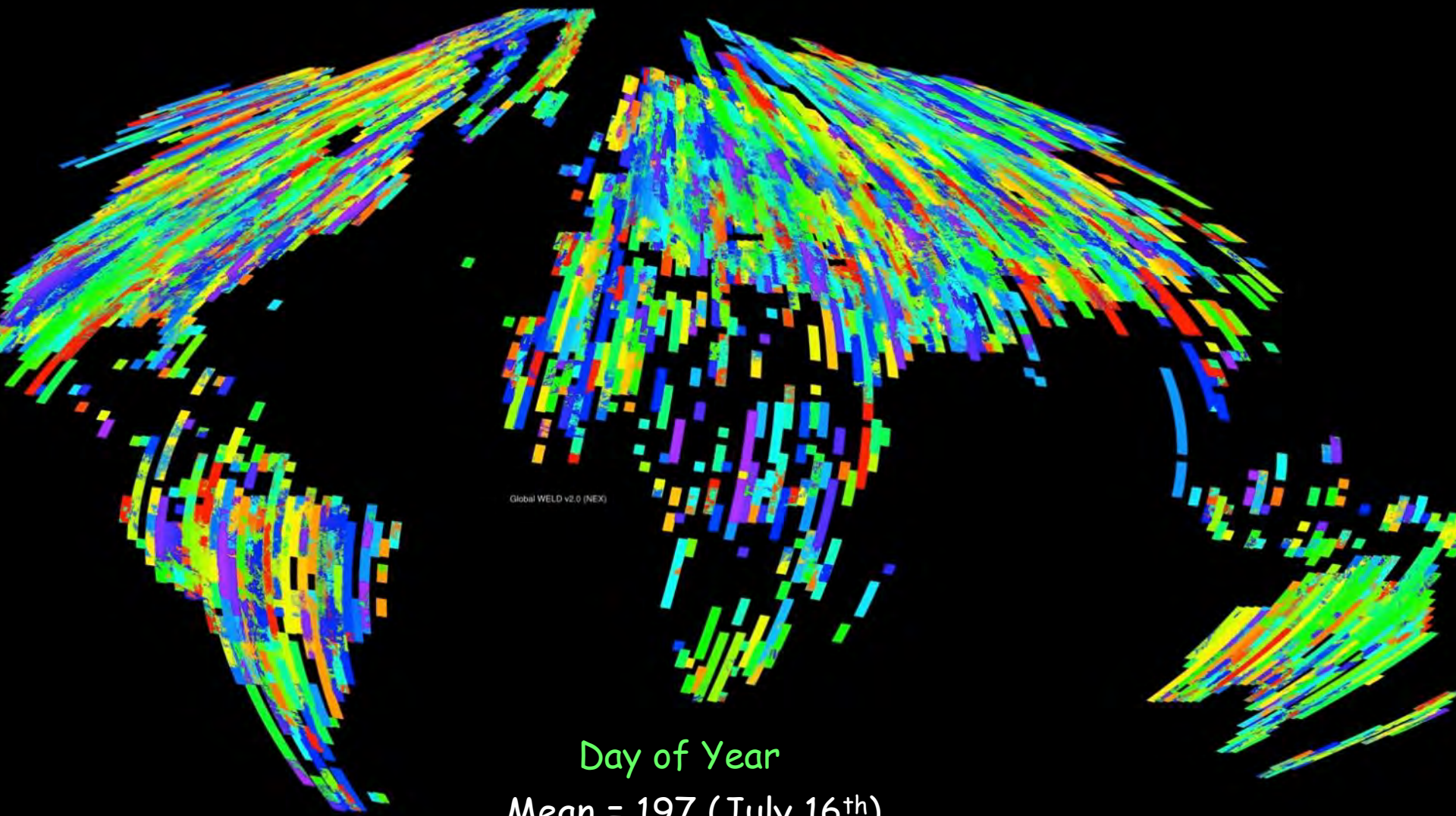
Number of Sensors 1 or 2

52% one sensor

48% two sensors

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes

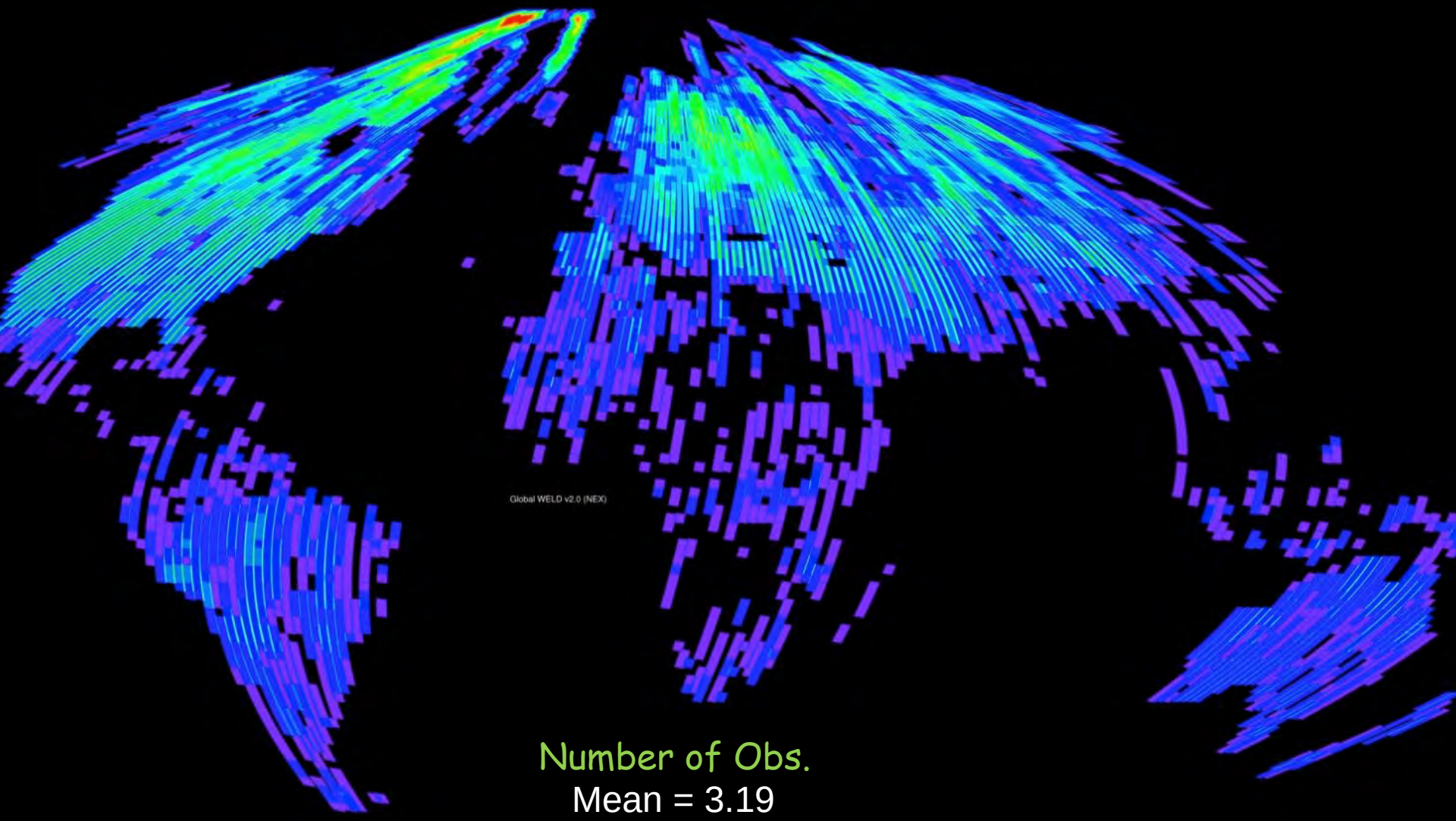


Day of Year

Mean = 197 (July 16th)

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

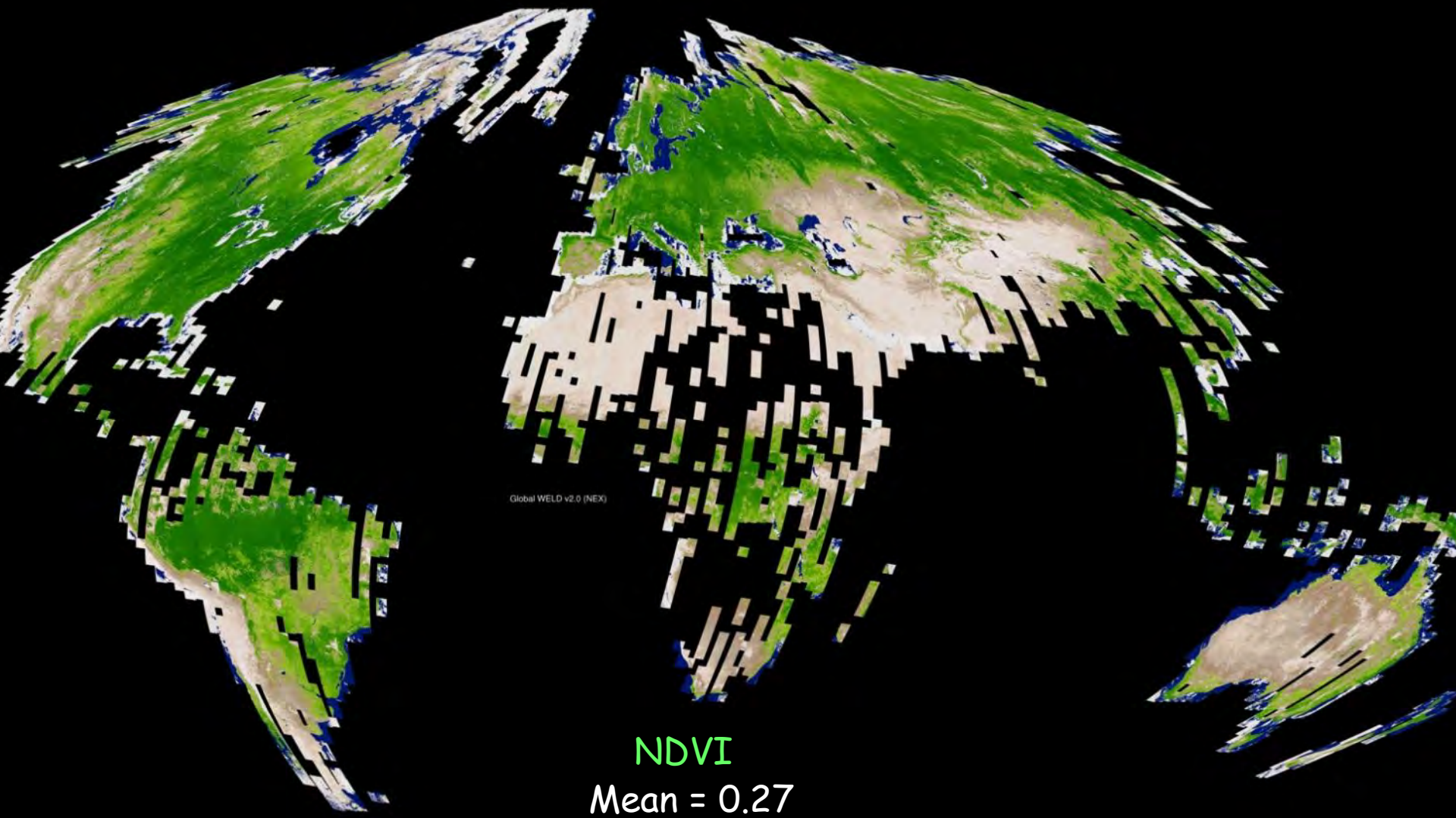
Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes



Number of Obs.
Mean = 3.19

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes

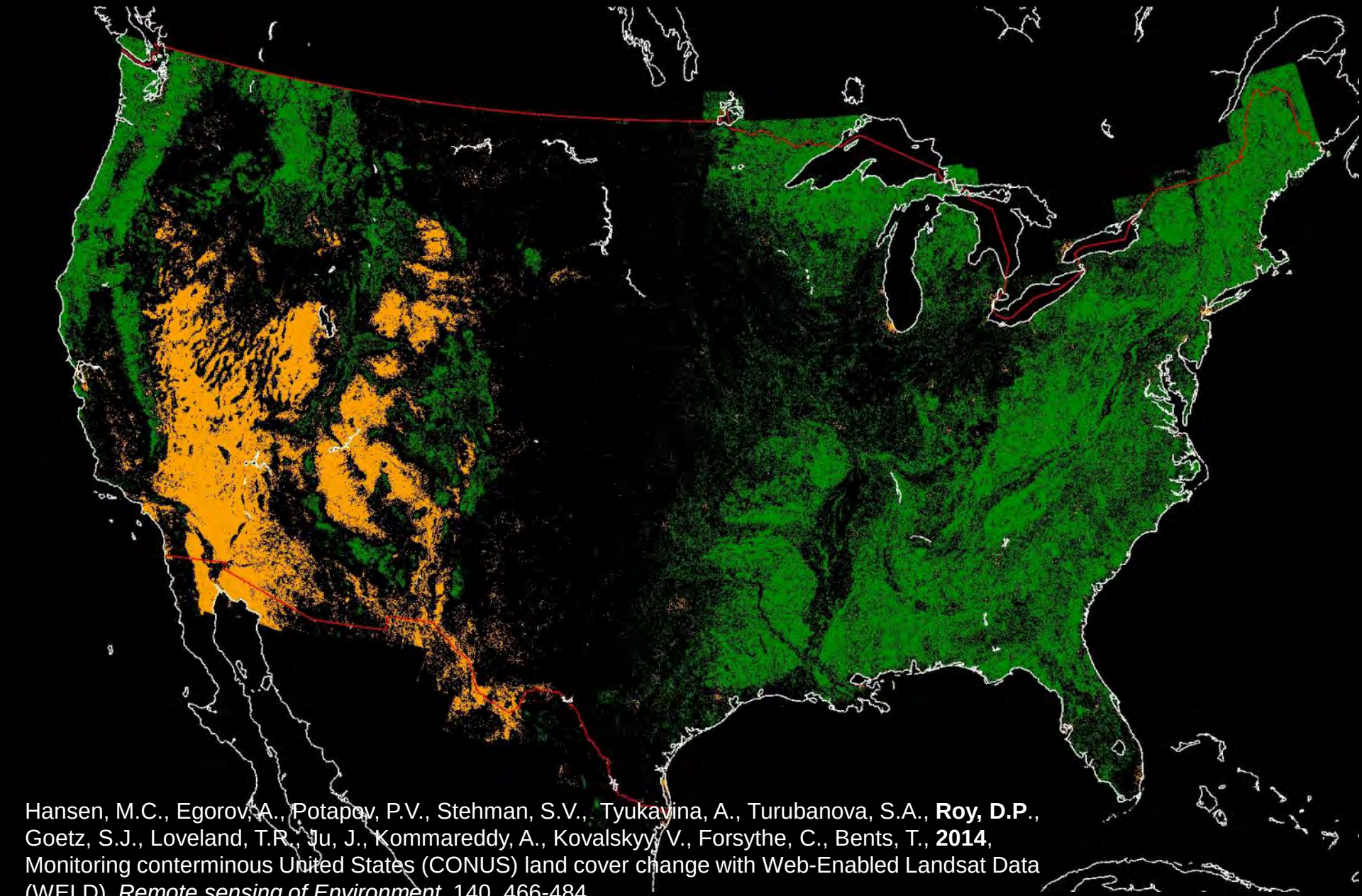


NDVI

Mean = 0.27

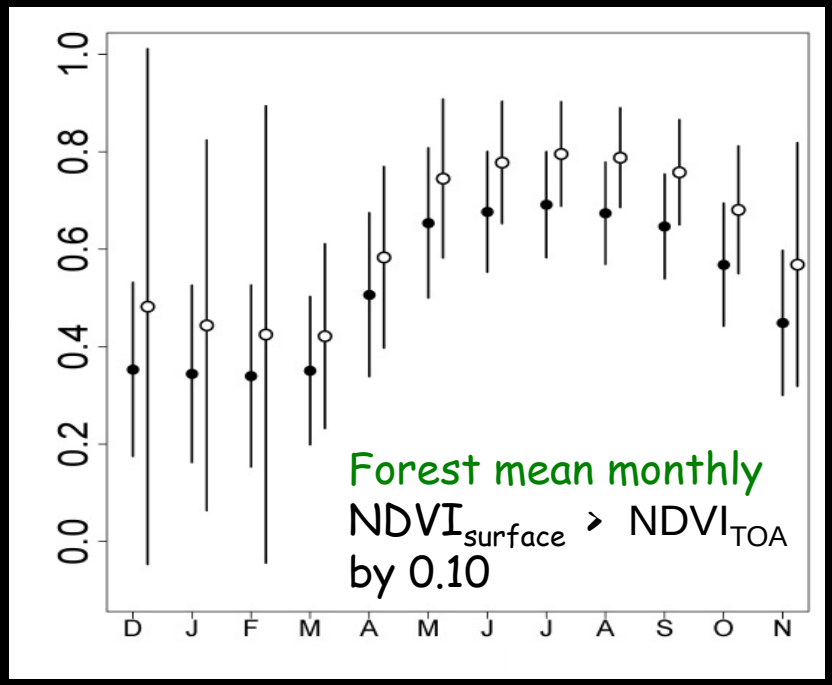
MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

CONUS Forest (green) & Bare Ground (orange) locations defined by the 30m 5-year (2006 to 2010) WELD Land Cover Land Cover Change (LCLCC) product

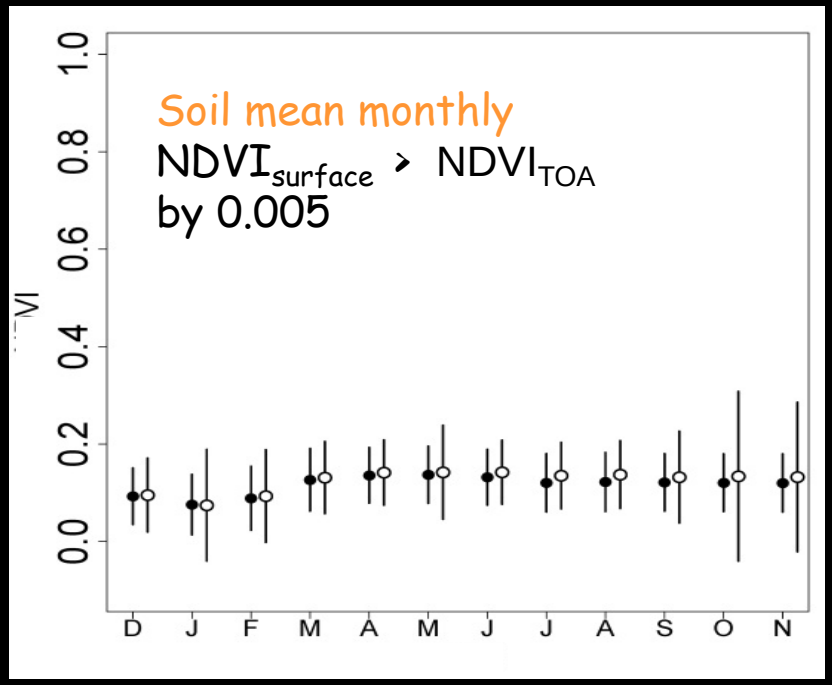


Hansen, M.C., Egorov, A., Potapov, P.V., Stehman, S.V., Tyukavina, A., Turubanova, S.A., **Roy, D.P.**, Goetz, S.J., Loveland, T.R., Ju, J., Kommareddy, A., Kovalskyy, V., Forsythe, C., Bents, T., **2014**, Monitoring conterminous United States (CONUS) land cover change with Web-Enabled Landsat Data (WELD), *Remote sensing of Environment*, 140, 466-484.

NDVI



NDVI



Month

Summary CONUS statistics (mean ± standard deviation) of top of atmosphere (filled circles) and MODIS based atmospherically corrected (open circles) Landsat 7 NDVI

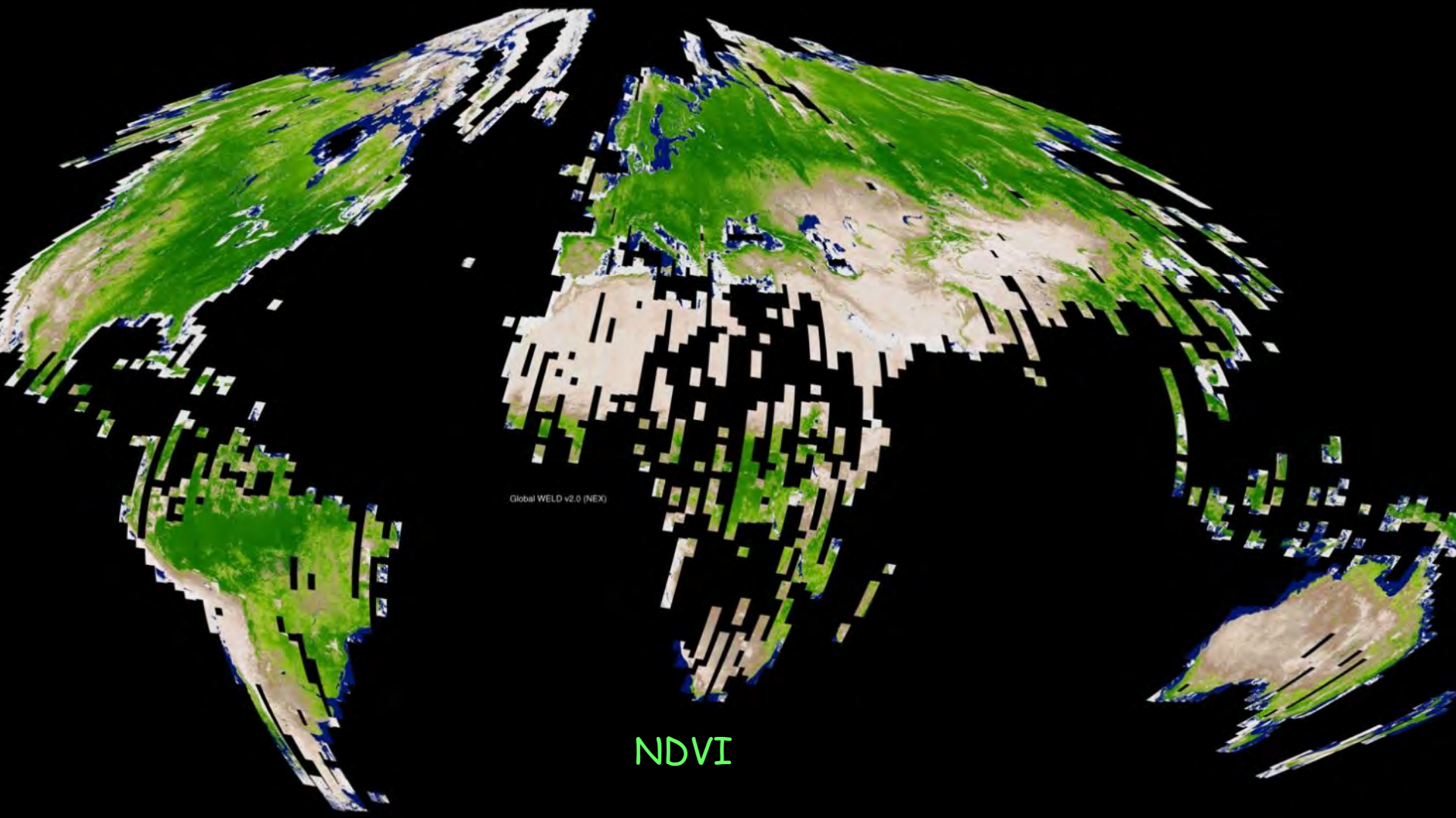
Extracted from 12 monthly (Dec. 2009 to Nov. 2010) WELD monthly products considering only non-cloudy non-saturated non-interpolated atm. characterization pixels.

Forest: 2.4 to 4.6 million pixels per month

Soil: 1 to 1.9 million pixels per month

Roy, D.P., Qin, Y., Kovalskyy, V. , Vermote, E.F., Ju, J., Egorov, A., Hansen, M.C., Kommareddy, I., Yan, L., **2014**, Conterminous United States demonstration and characterization of MODIS-based Landsat ETM+ atmospheric correction, *Remote Sensing of Environment,* 140, 433-449.

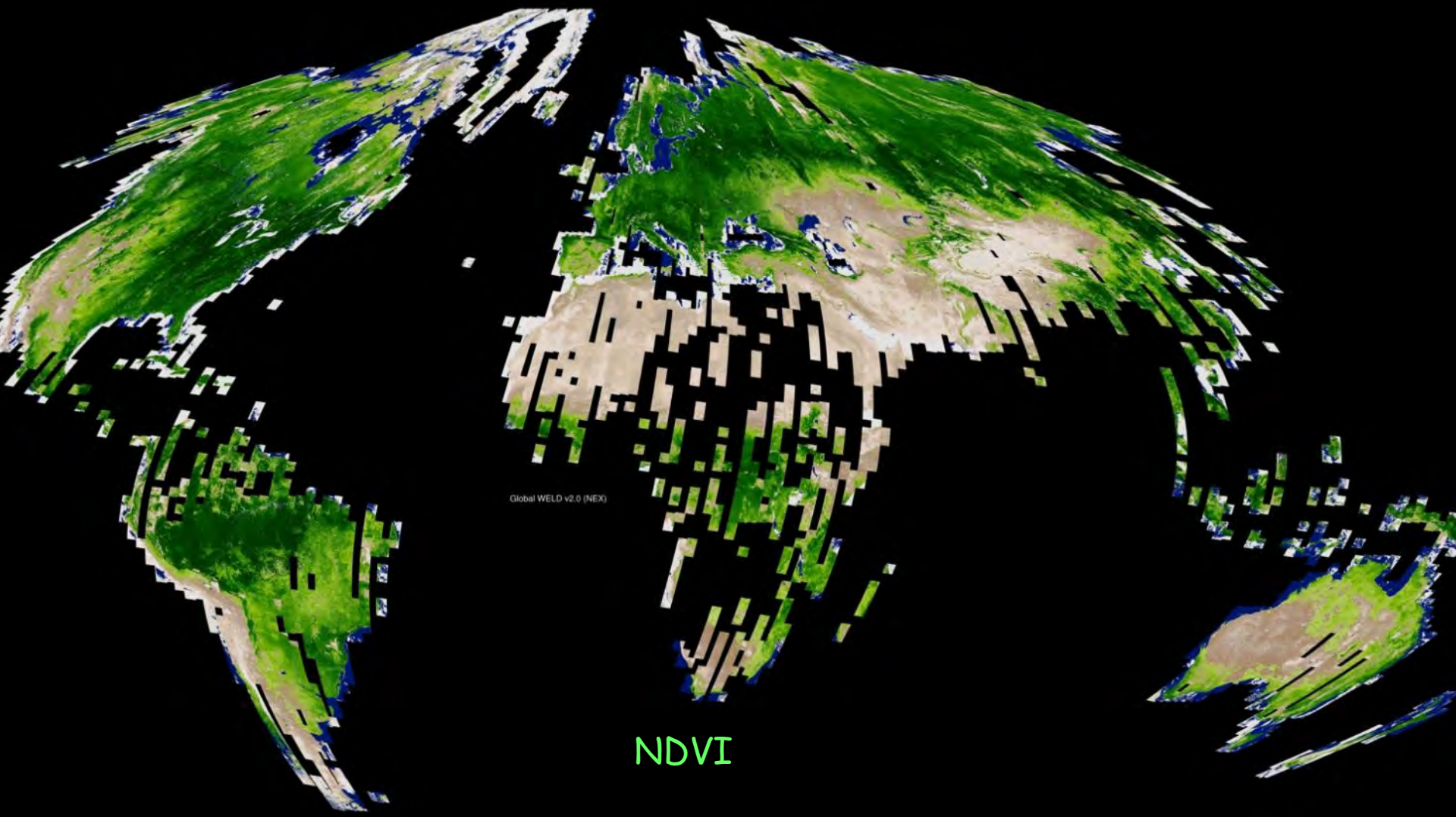
Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes



NDVI

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

Global WELD Processing July 2010
4840 Landsat 5 TM and 7534 Landsat 7 ETM+ scenes

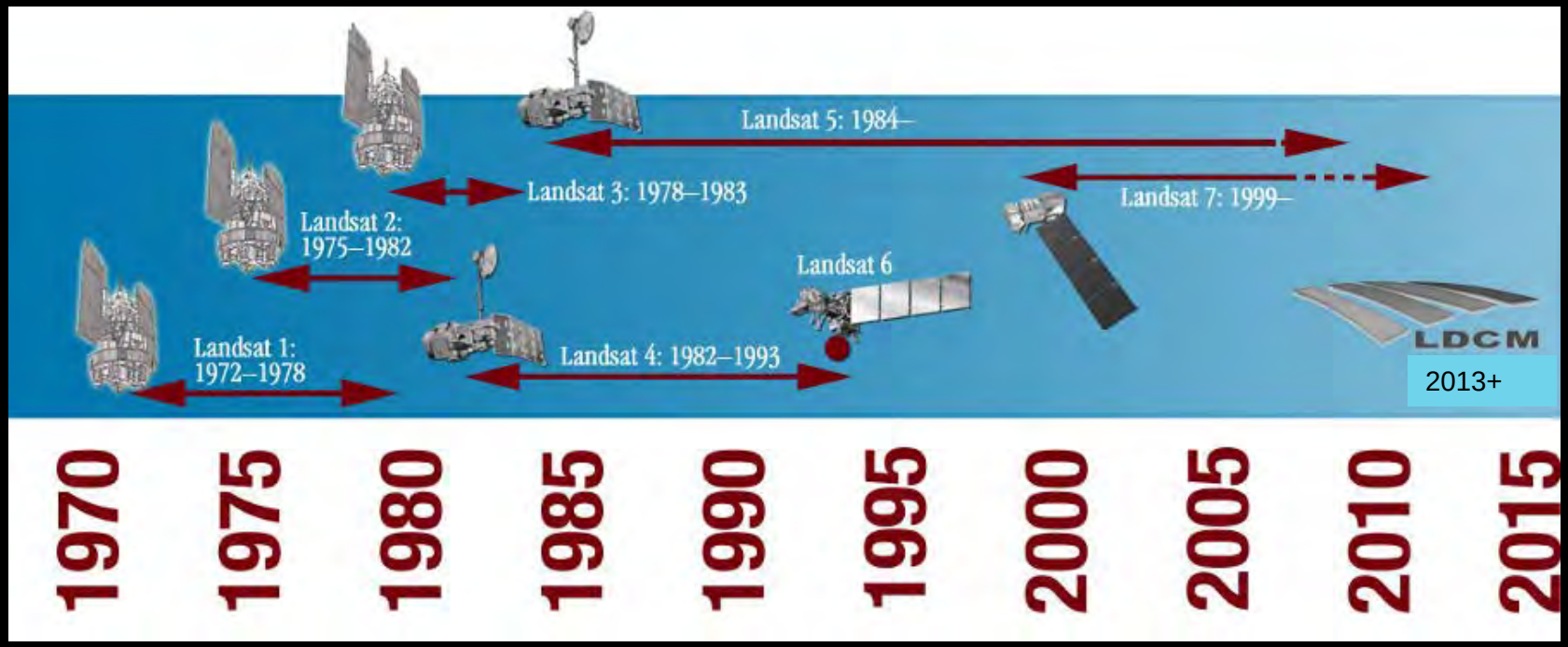


NDVI

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels

Landsat Satellite Series

The longest Land surface observation record



WELD process L8 data

(CONUS)

Landsat 8 Science Team: Proposed Tasks

1. WELD product continuity into the Landsat 8 era
   - generation of WELD Landsat 8 products

2. WELD Landsat 8 product performance
   - quality assessment
   - validation
   - characterization of the consistency of the WELD TM, ETM+, Landsat 8 product time series

3. The utility of the WELD product record to develop "higher-level" derived products
   - collaboration with Sci. Team, NASA & USGS staff, academia

4. Expansion of the WELD internet product distribution interface to support WELD Landsat 8 products

Current Focus (recognizing that data is a moving target)

1. WELD product continuity into the Landsat 8 era
   - generation of WELD Landsat 8 products

2. WELD Landsat 8 product performance
   - quality assessment
   - validation
   - characterization of the consistency of the WELD TM, ETM+, Landsat 8 product time series

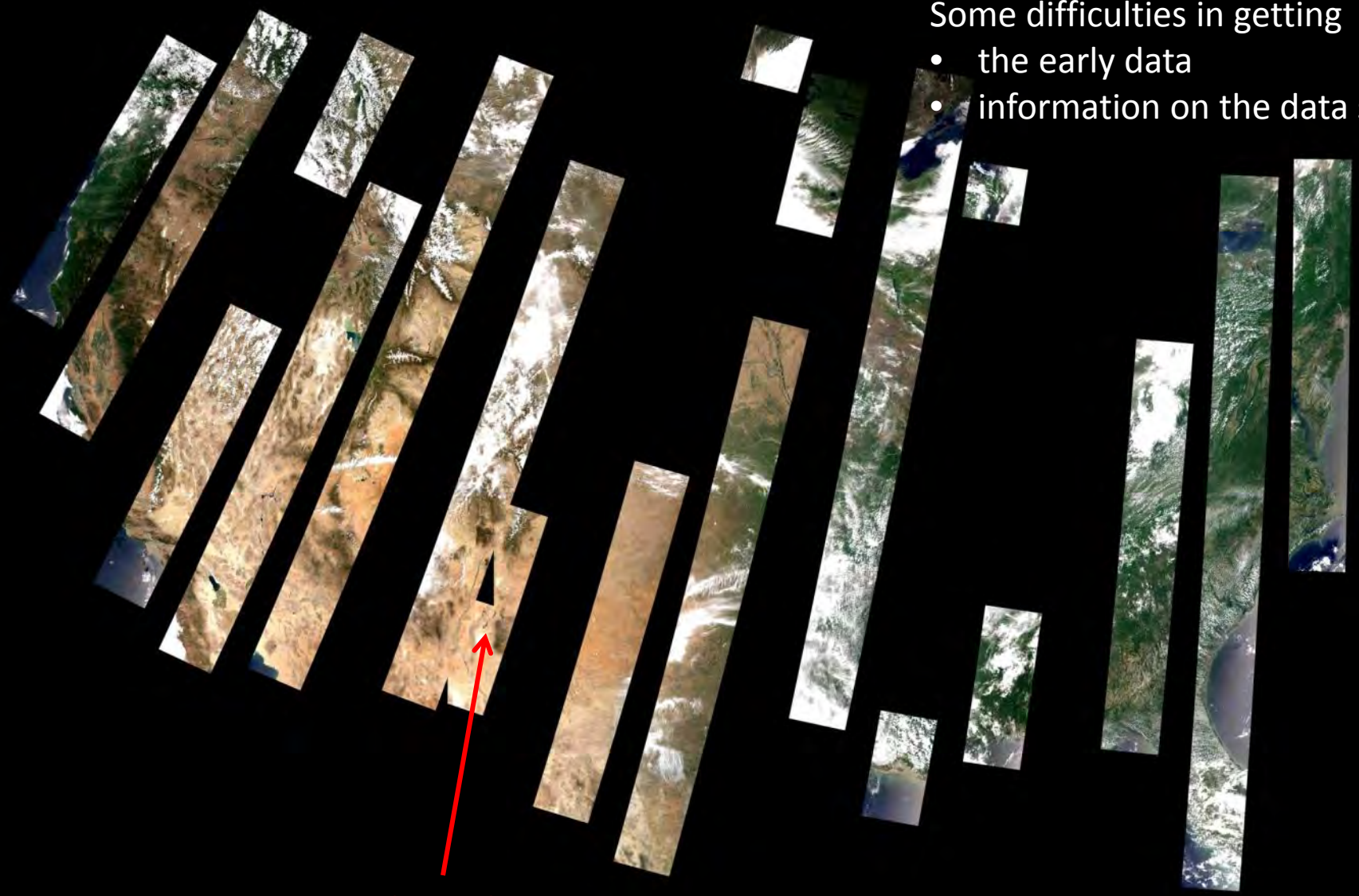
3. The utility of the WELD product record to develop "higher-level" derived products
   - collaboration with Sci. Team, NASA & USGS staff, academia

4. Expansion of the WELD internet product distribution interface to support WELD Landsat 8 products

First week of public data
Landsat 8 CONUS WELD processed Week 22 2013

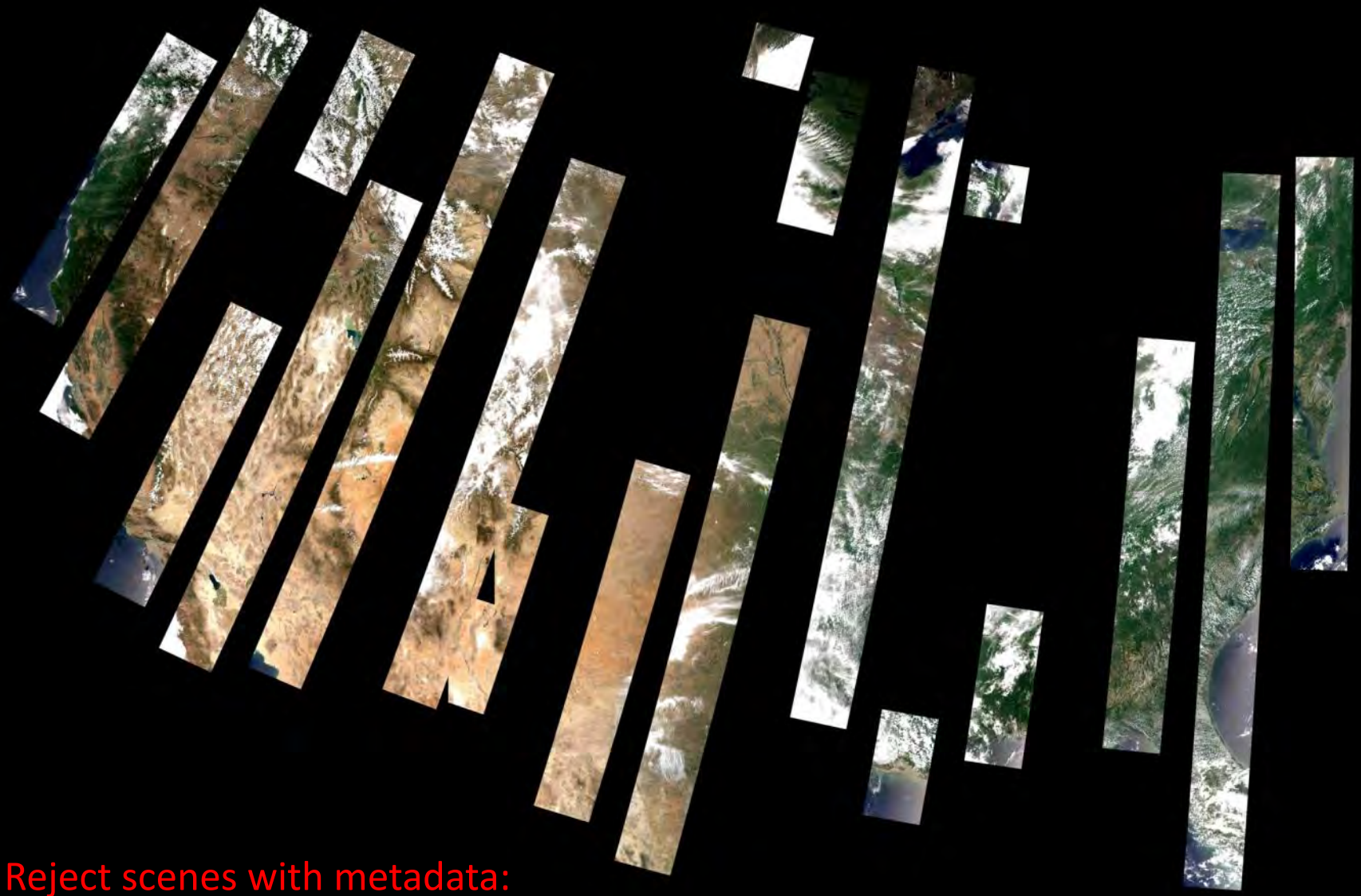
Some difficulties in getting

- the early data
- information on the data schedule



Albers projection

First week of public data
Landsat 8 CONUS WELD processed Week 22 2013

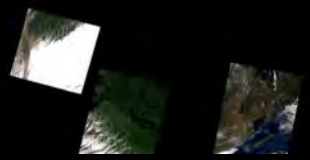


Reject scenes with metadata:

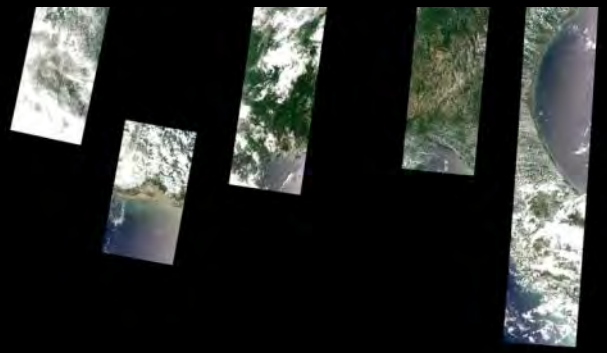
NADIR_OFFNADIR == "OFFNADIR "

Albers projection

First week of public data
Landsat 8 CONUS WELD processed Week 22 2013



"The recommended off-nadir policy is to only use the capability for national emergencies in which loss of life is at stake. We believe off-nadir imaging should be extremely rare. Global imaging remains the priority. There is a process to consider off-nadir requests for important scientific purposes or other reasons, but the policy that is in the final stages of approval is to place very strict limits on off-nadir imaging" (Tom Loveland)

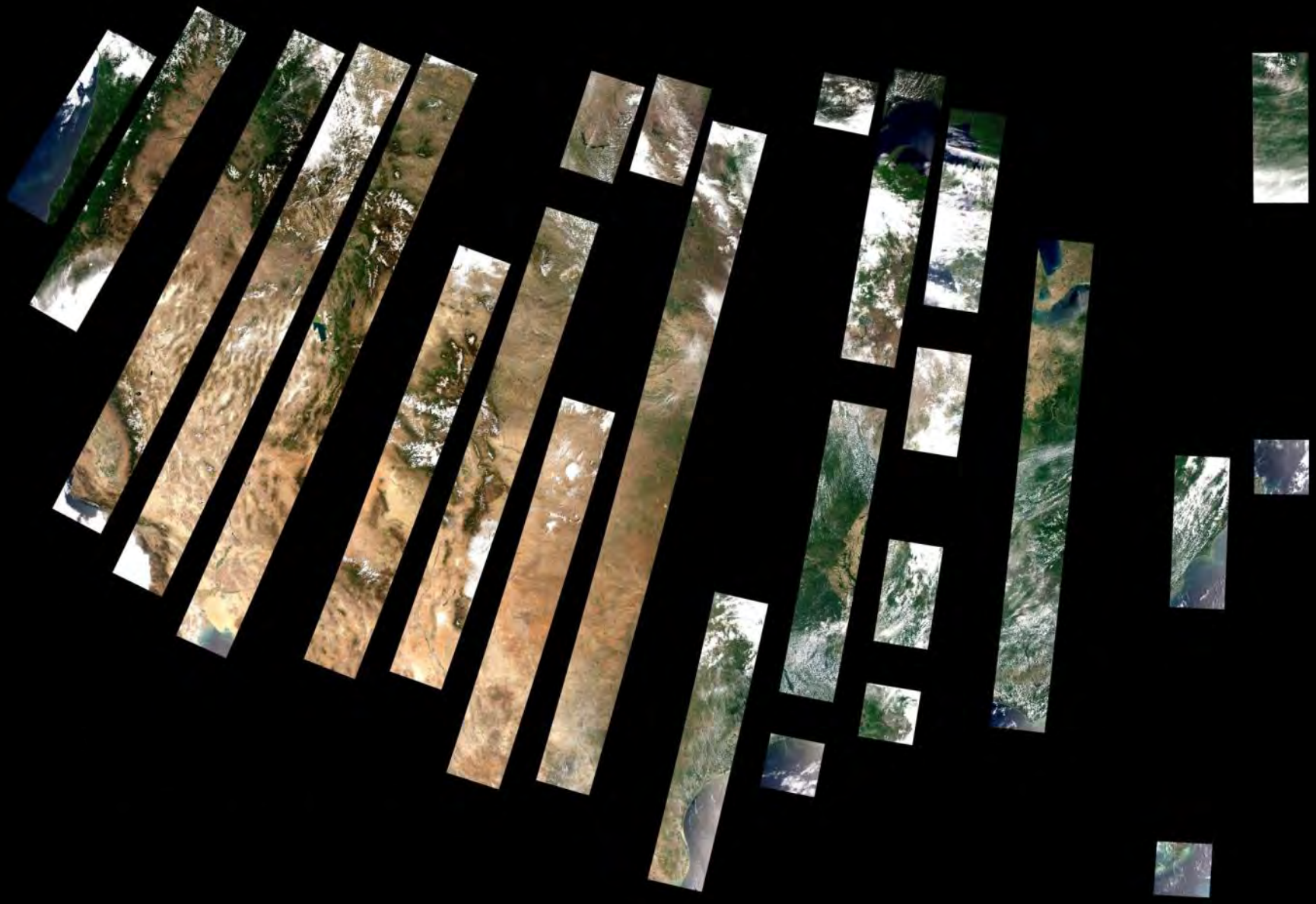


Reject scenes with metadata:

NADIR_OFFNADIR == "OFFNADIR "

Albers projection

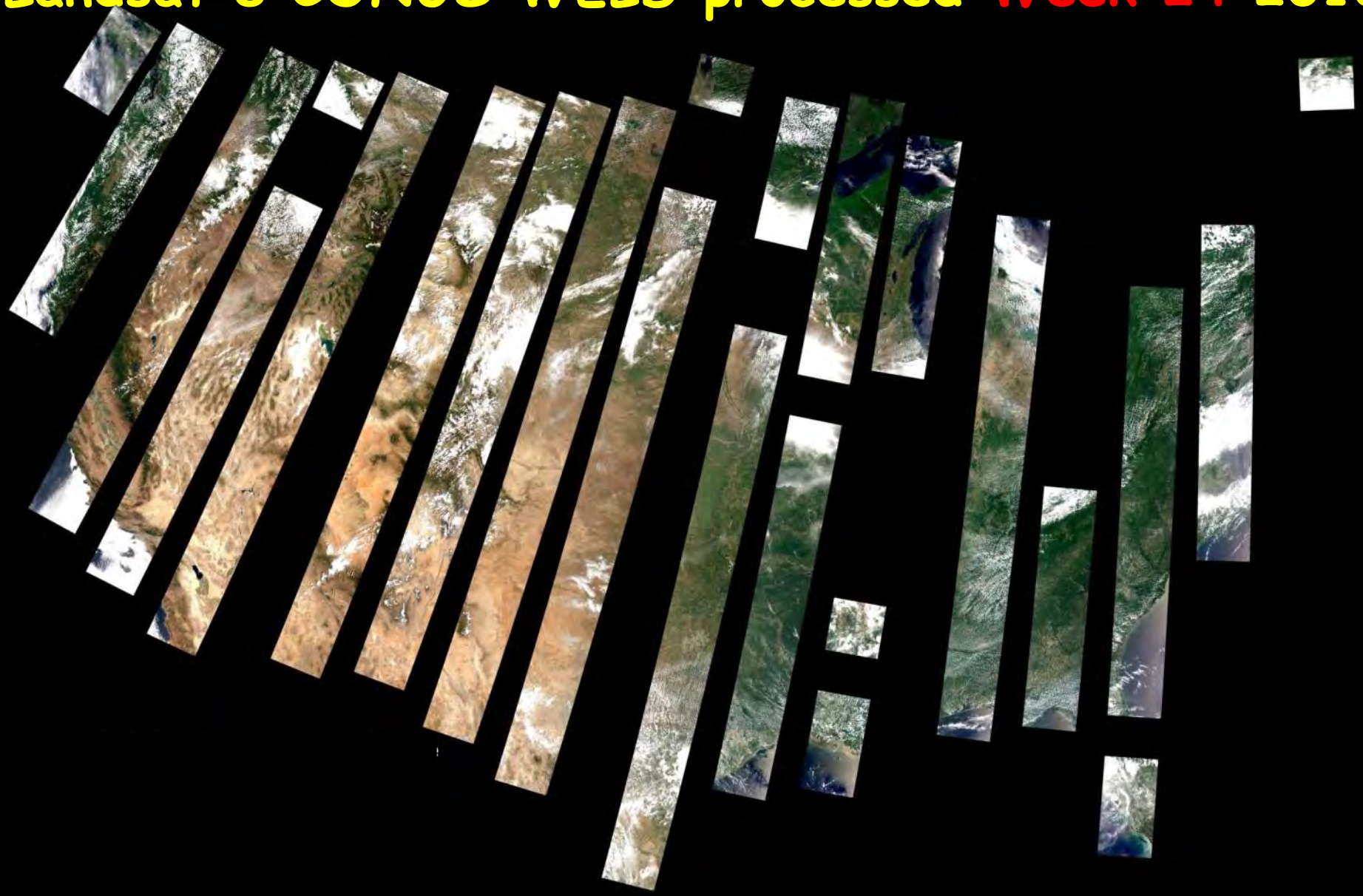
First light results
Landsat 8 CONUS WELD processed Week 23 2013



Albers projection

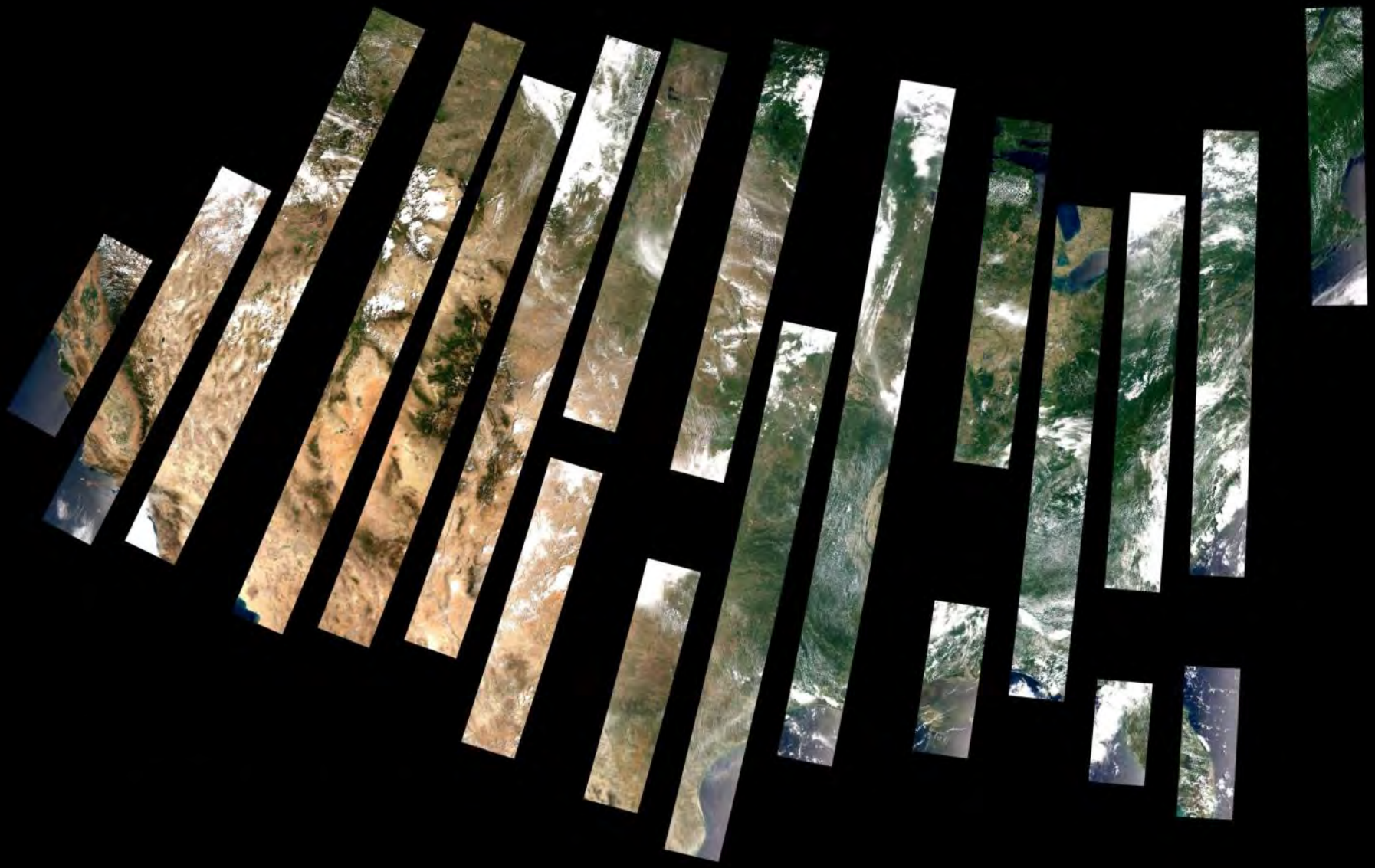
First light results

Landsat 8 CONUS WELD processed Week 24 2013



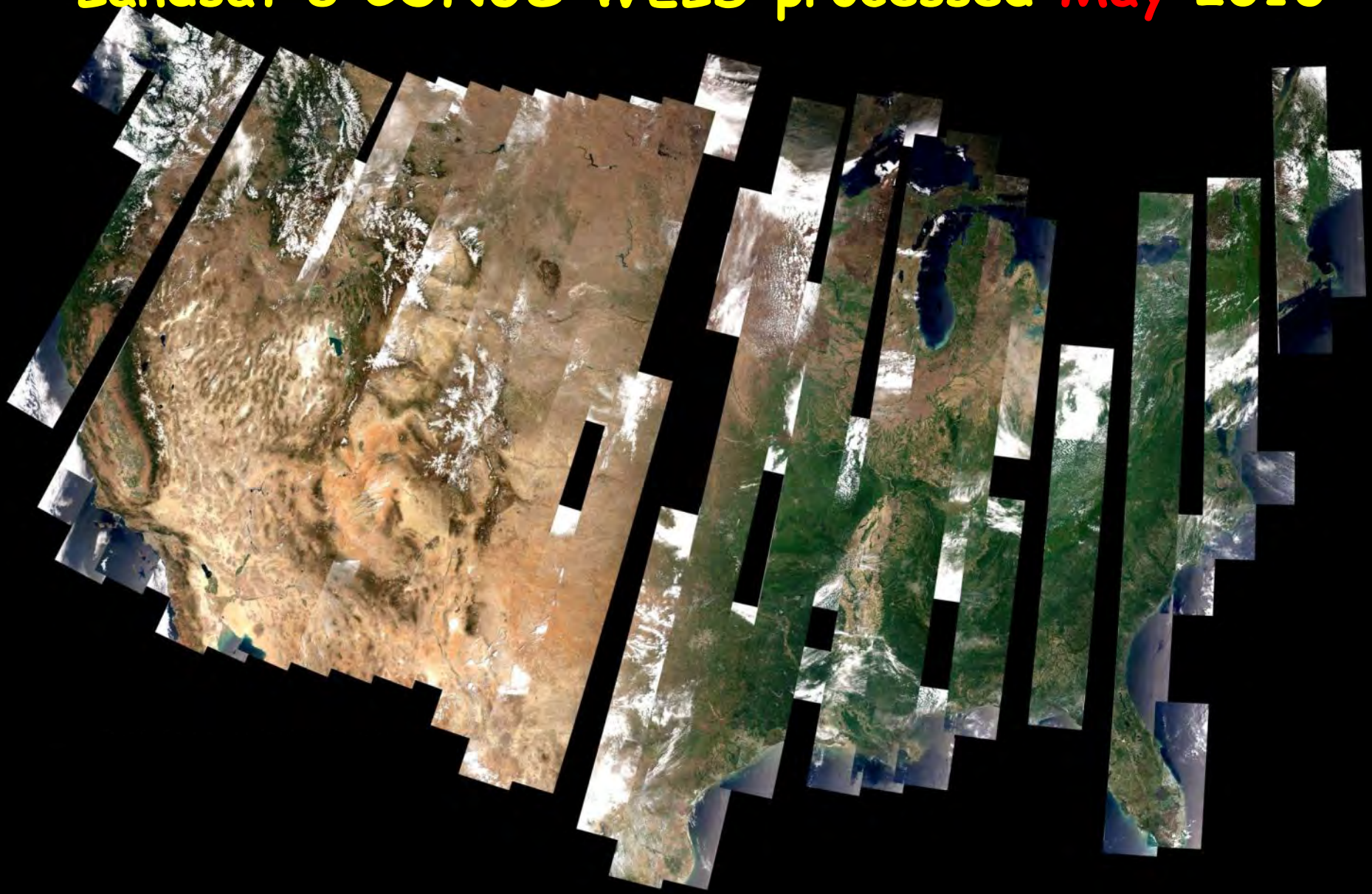
Albers projection

First light results
Landsat 8 CONUS WELD processed Week 25 2013



Albers projection

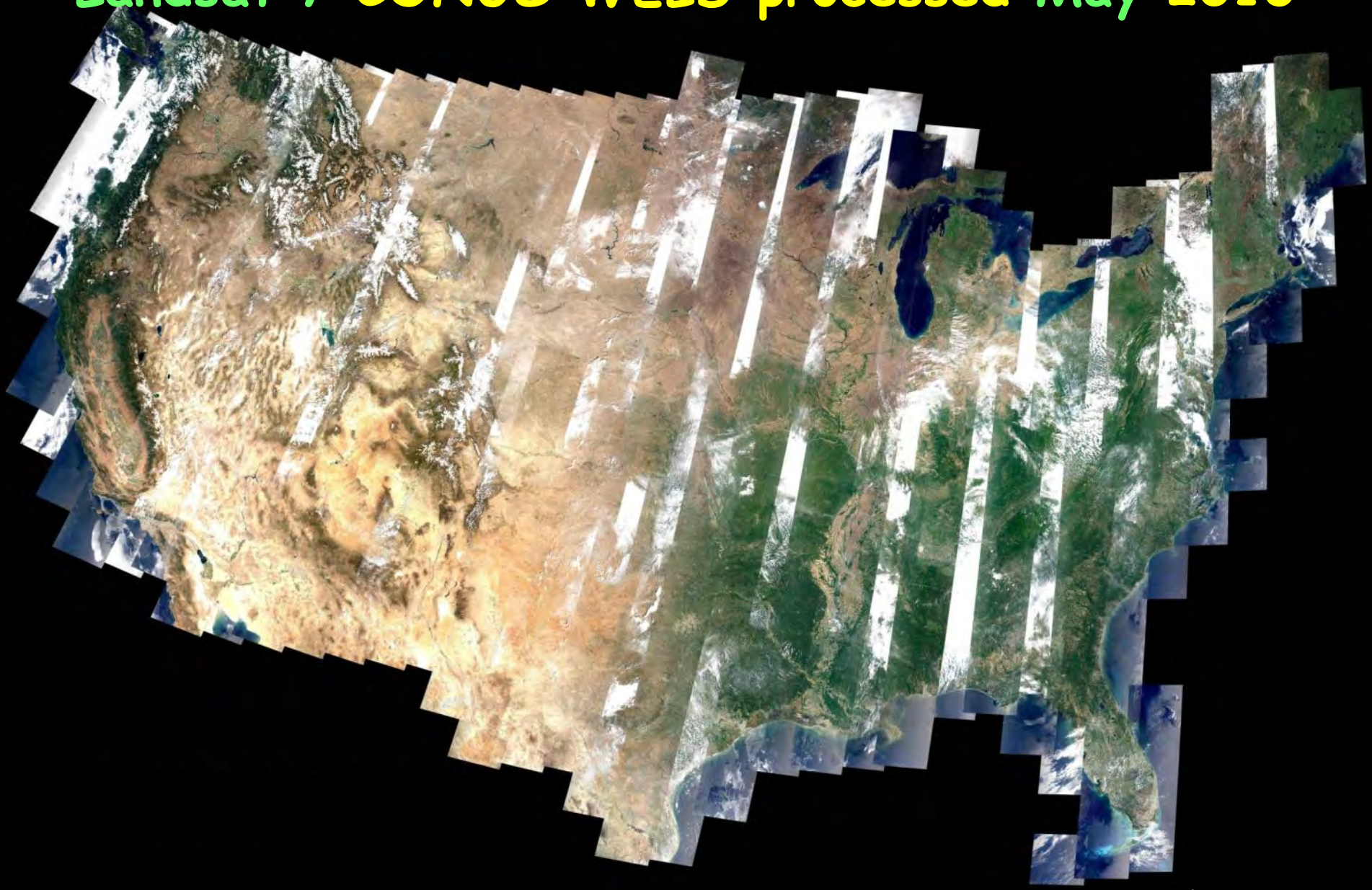
First month of public data
Landsat 8 CONUS WELD processed May 2013



Albers projection

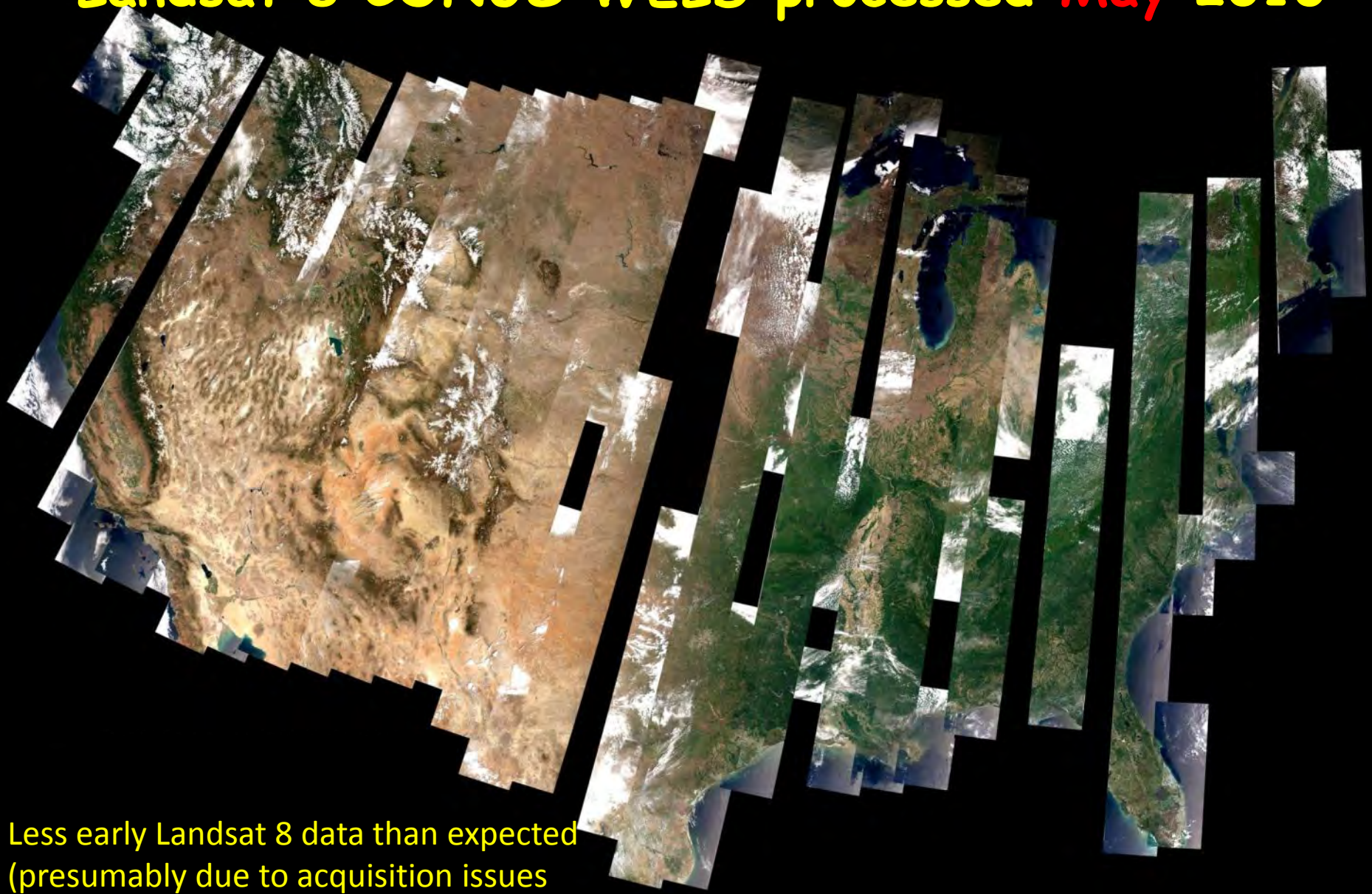
Comparison

Landsat 7 CONUS WELD processed May 2013



Albers projection

First month of public data
Landsat 8 CONUS WELD processed May 2013



Less early Landsat 8 data than expected
(presumably due to acquisition issues
and not due to L1T processing issues)

Albers projection

Part of a single WELD Landsat 8 OLI
WELD tile located over southern
Colorado and northern New Mexico,
May 2013

Part of a single WELD Landsat 7 ETM+
WELD tile located over southern
Colorado and northern New Mexico,
May 2013

Part of a single WELD Landsat 8 OLI WELD tile located over southern Colorado and northern New Mexico, **May 2013**
No SLC-off stripes !
No apparent saturation over clouds

WELD Landsat 5 and 7 generated from only L1T data due to need for sub-pixel geolocation accuracy

Landsat 8 L1T has a 90% confidence level circular geolocation error uncertainty requirement <12 m.

Jim Storey (today) L1G accuracy ~11m !

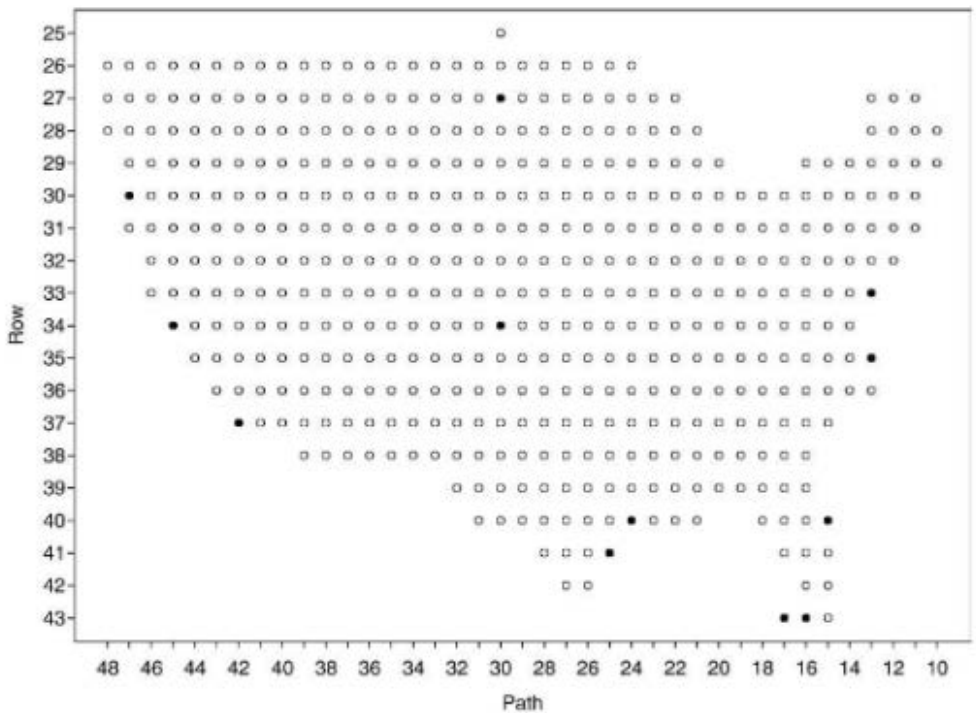
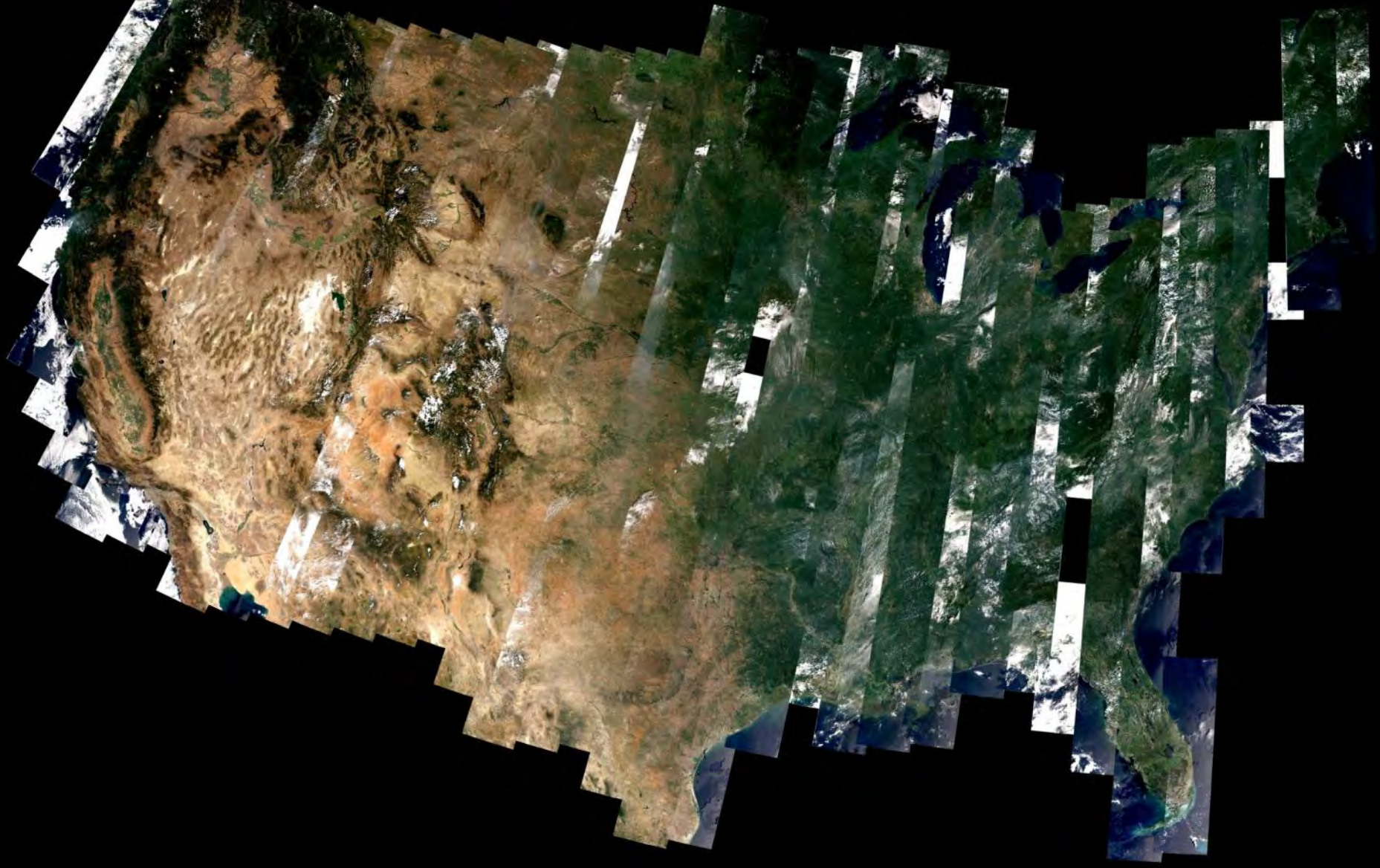


Fig. 1. The Landsat ETM+ path and row coordinates (circles) defining the conterminous United States (CONUS) study area. The black filled circles show path/row coordinates where 105 web-enabled ETM+ acquisitions over the 12 month study period had less than 20% ACCA cloud cover but could not be processed as L1T and so were processed as L1G by the U.S Landsat project.

Landsat 8 CONUS WELD August 2013

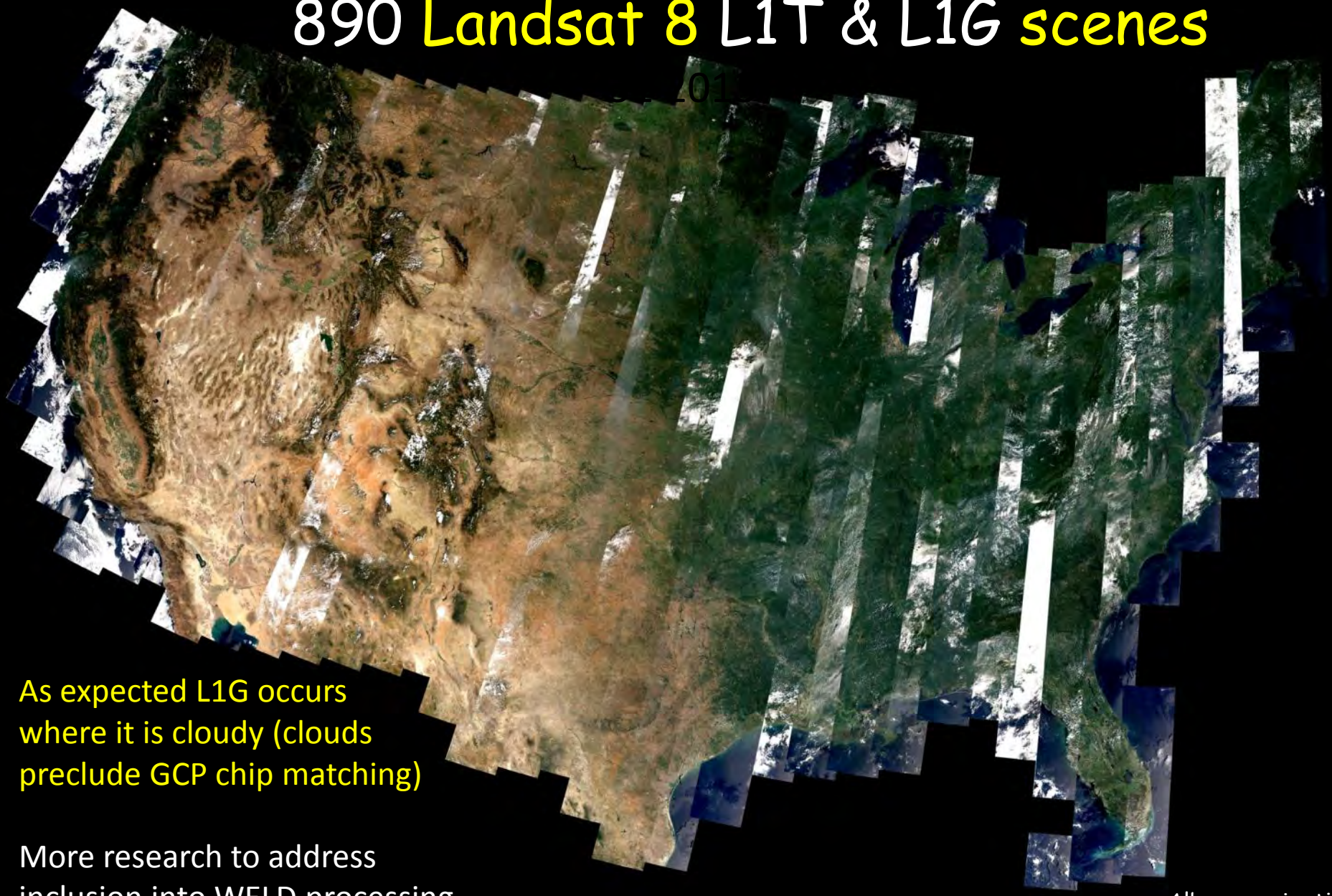
877 Landsat 8 L1T scenes



Albers projection

Landsat 8 CONUS WELD August 2013

890 Landsat 8 L1T & L1G scenes



As expected L1G occurs where it is cloudy (clouds preclude GCP chip matching)

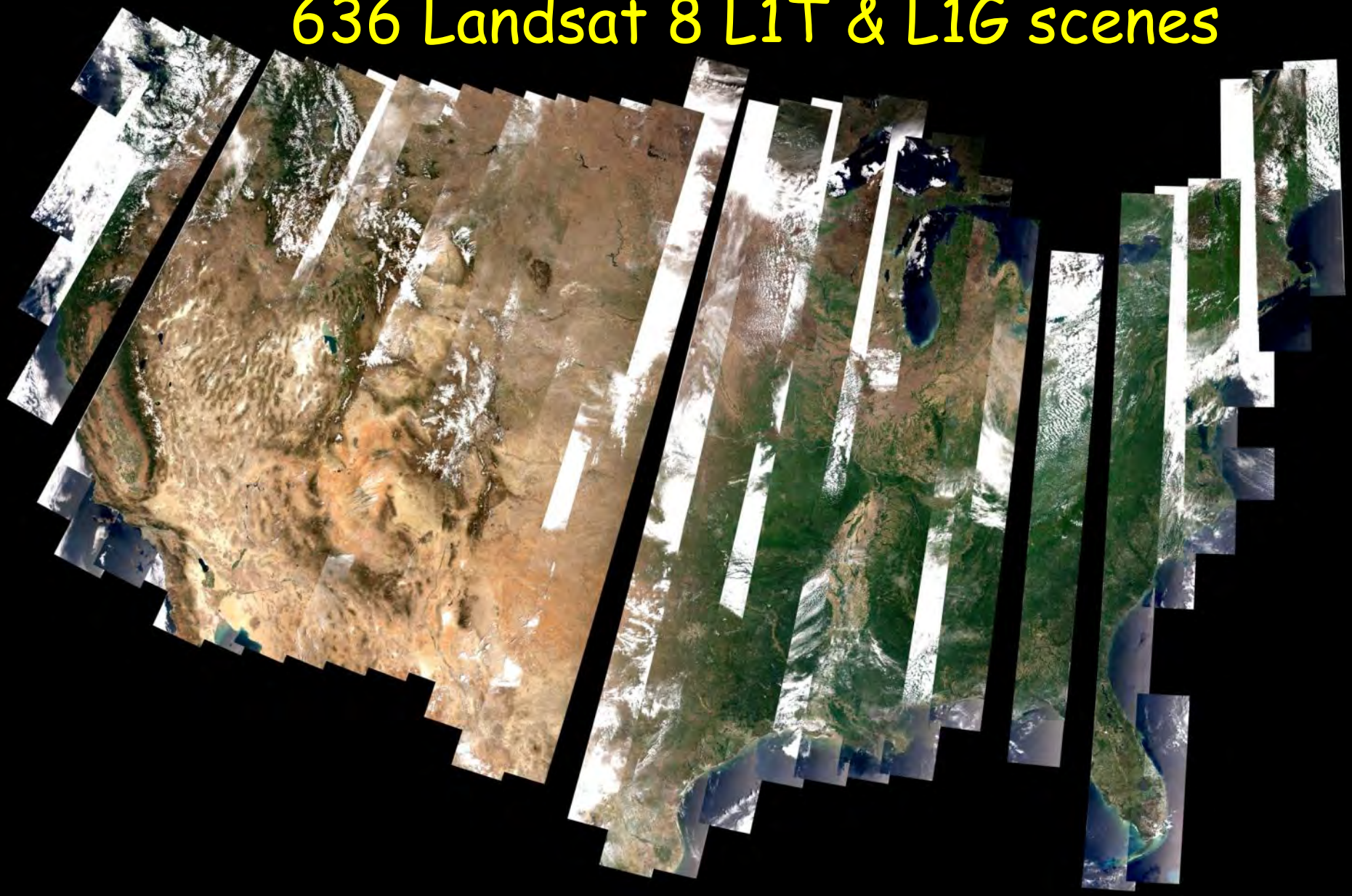
More research to address inclusion into WELD processing

Albers projection

Some monthly runs

Landsat 8 CONUS WELD May 2013

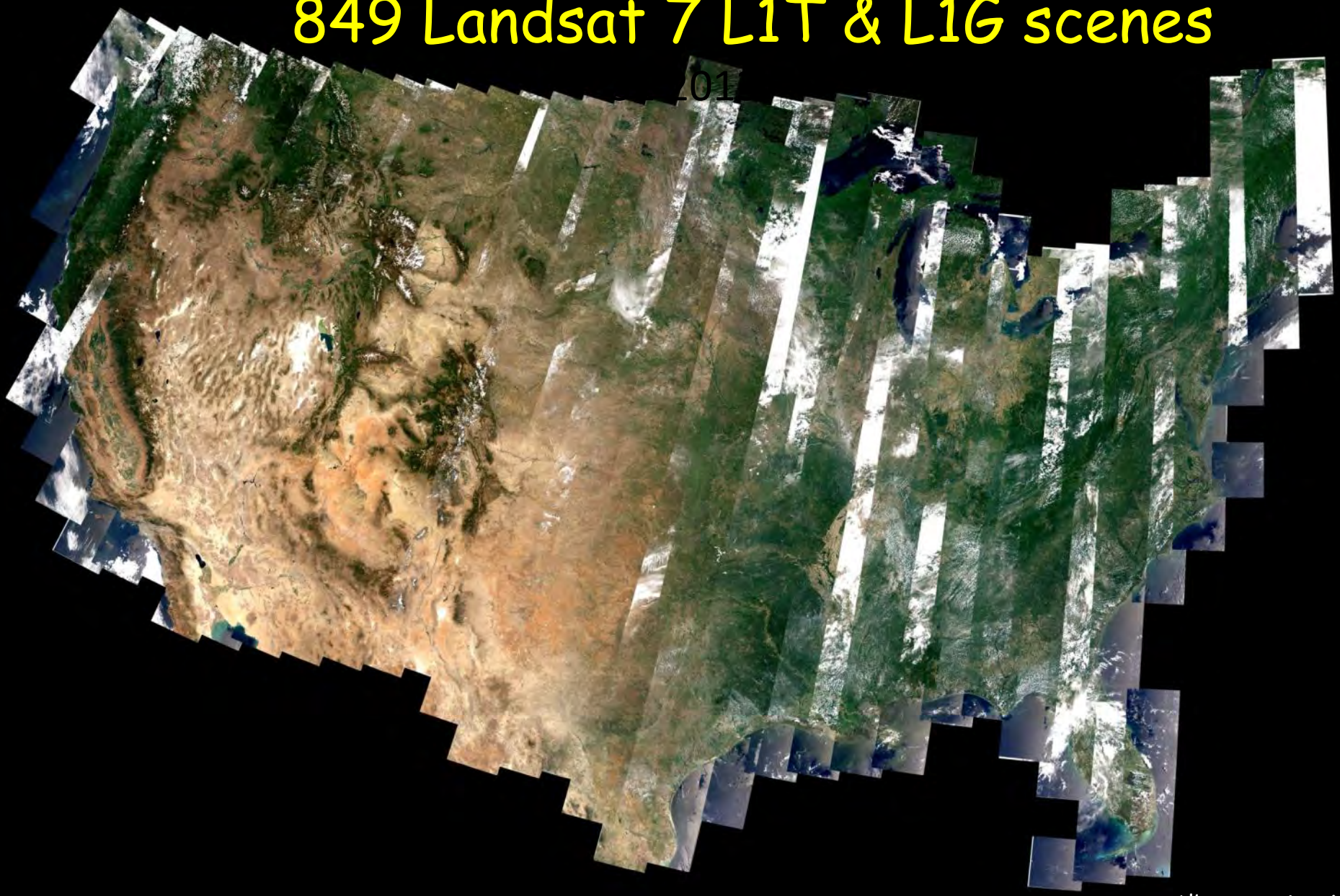
636 Landsat 8 L1T & L1G scenes



Albers projection

Landsat 8 CONUS WELD June 2013

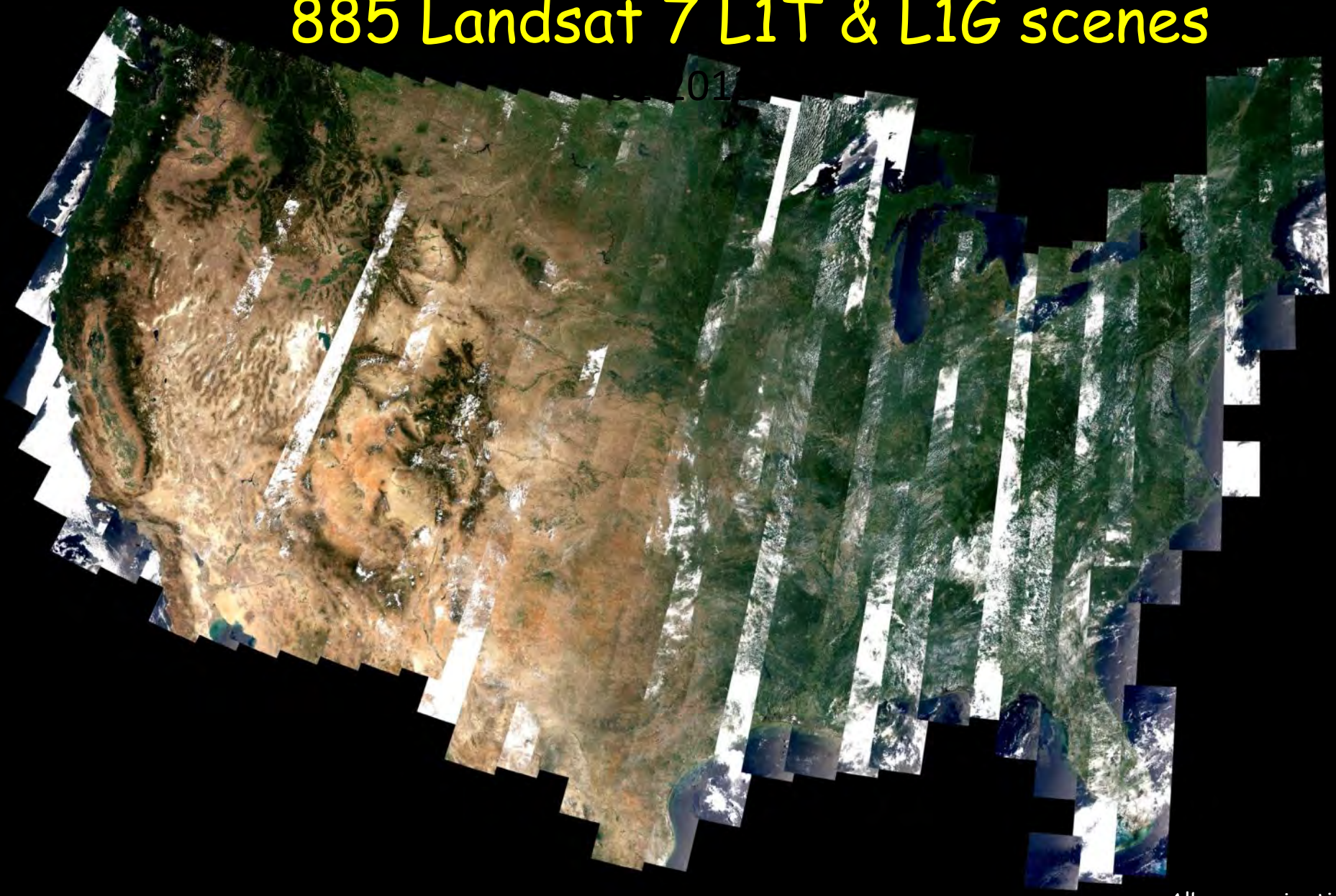
849 Landsat 7 L1T & L1G scenes



Albers projection

Landsat 8 CONUS WELD July 2013

885 Landsat 7 L1T & L1G scenes



Albers projection

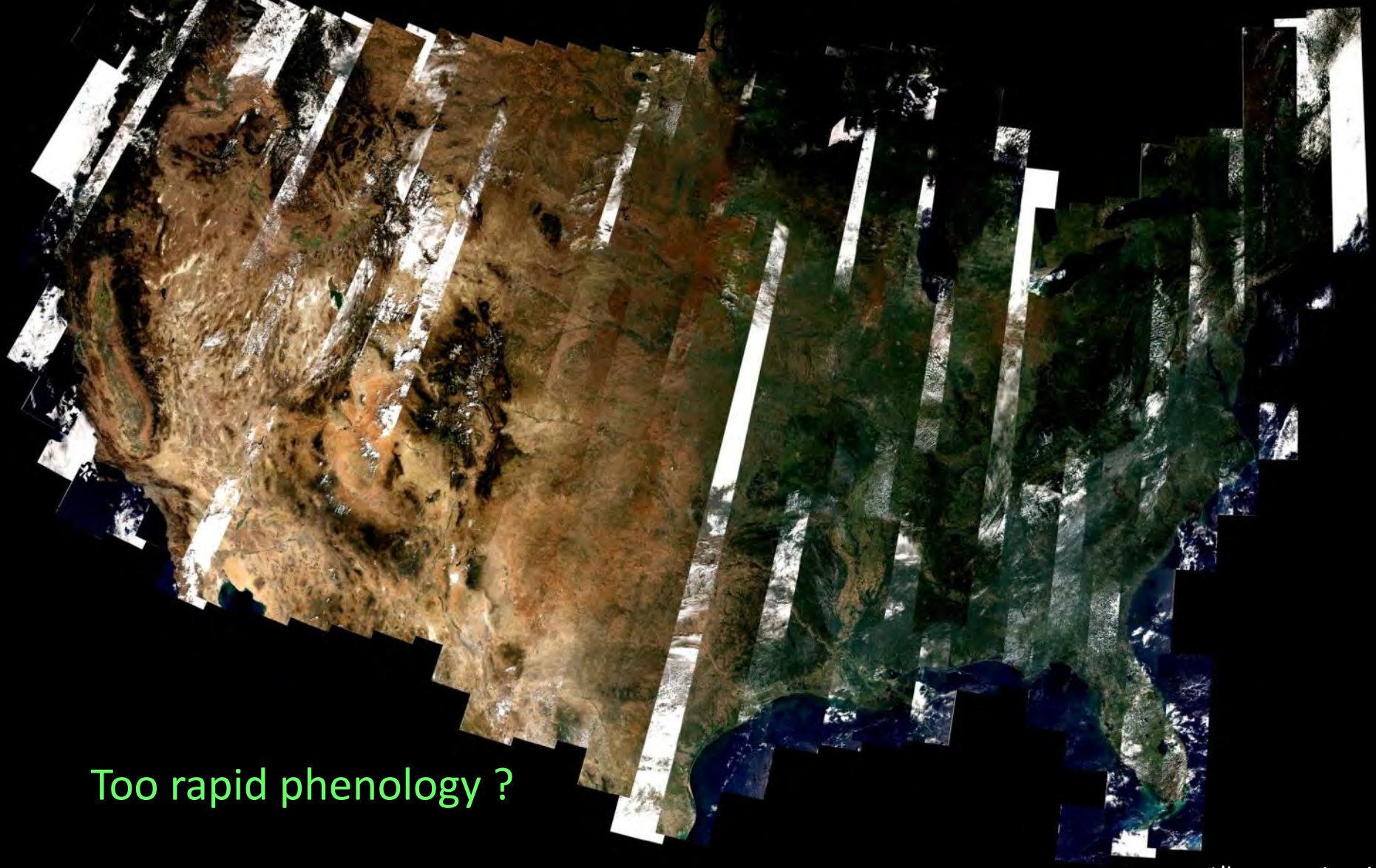
Landsat 8 CONUS WELD August 2013

890 Landsat 7 L1T & L1G scenes

Albers projection

Landsat 8 CONUS WELD September 2013

829 Landsat 7 L1T & L1G scenes



Too rapid phenology ?

Albers projection

Landsat 8 Alaska
WELD processed
August 2013
433 L1T and L1G scenes
What the ?
Albers projection

http://landsat.usgs.gov/Landsat8_Using_Product.php

Conversion to TOA Reflectance

OLI band data can also be converted to TOA planetary reflectance using reflectance rescaling coefficients provided in the product metadata file (MTL file). The following equation is used to convert DN values to TOA reflectance for OLI data as follows:

$$\rho\lambda' = M_\rho Q_{cal} + A_\rho$$

where:

$\rho\lambda'$ = TOA planetary reflectance, without correction for solar angle. Note that $\rho\lambda'$ does not contain a correction for the sun angle.

M_ρ = Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number)

A_ρ = Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number)

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

TOA reflectance with a correction for the sun angle is then:

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\theta_{SZ})} = \frac{\rho\lambda'}{\sin(\theta_{SE})}$$

where:

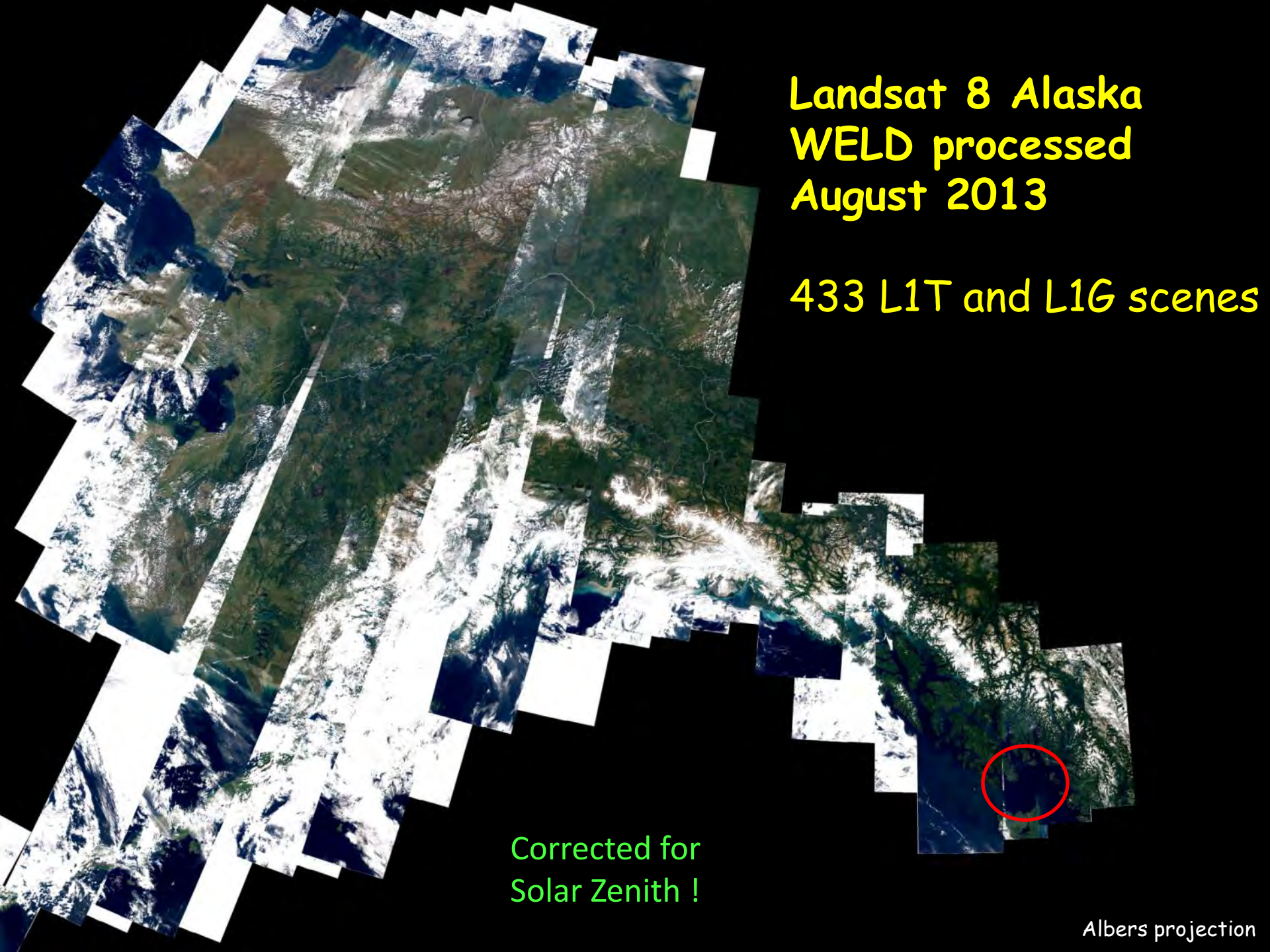
$\rho\lambda$ = TOA planetary reflectance

θ_{SE} = Local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION).

θ_{SZ} = Local solar zenith angle; $\theta_{SZ} = 90° - \theta_{SE}$

For more accurate reflectance calculations, per pixel solar angles could be used instead of the scene center solar angle, but per pixel solar zenith angles are not currently provided with the Landsat 8 products.

Landsat 8 Alaska
WELD processed
August 2013
433 L1T and L1G scenes
Albers projection


Landsat 8 Alaska
WELD processed
August 2013
433 L1T and L1G scenes
Corrected for
Solar Zenith !
Albers projection

Landsat 8 Alaska WELD processed August 2013 monthly composite

Alaska WELD tile h15v11
(Graham Island Prince Rupert, BC)

5000 x 5000 30m pixels

Generated reading Landsat 8 cloud mask

Landsat 8 Alaska WELD processed August 2013 monthly composite

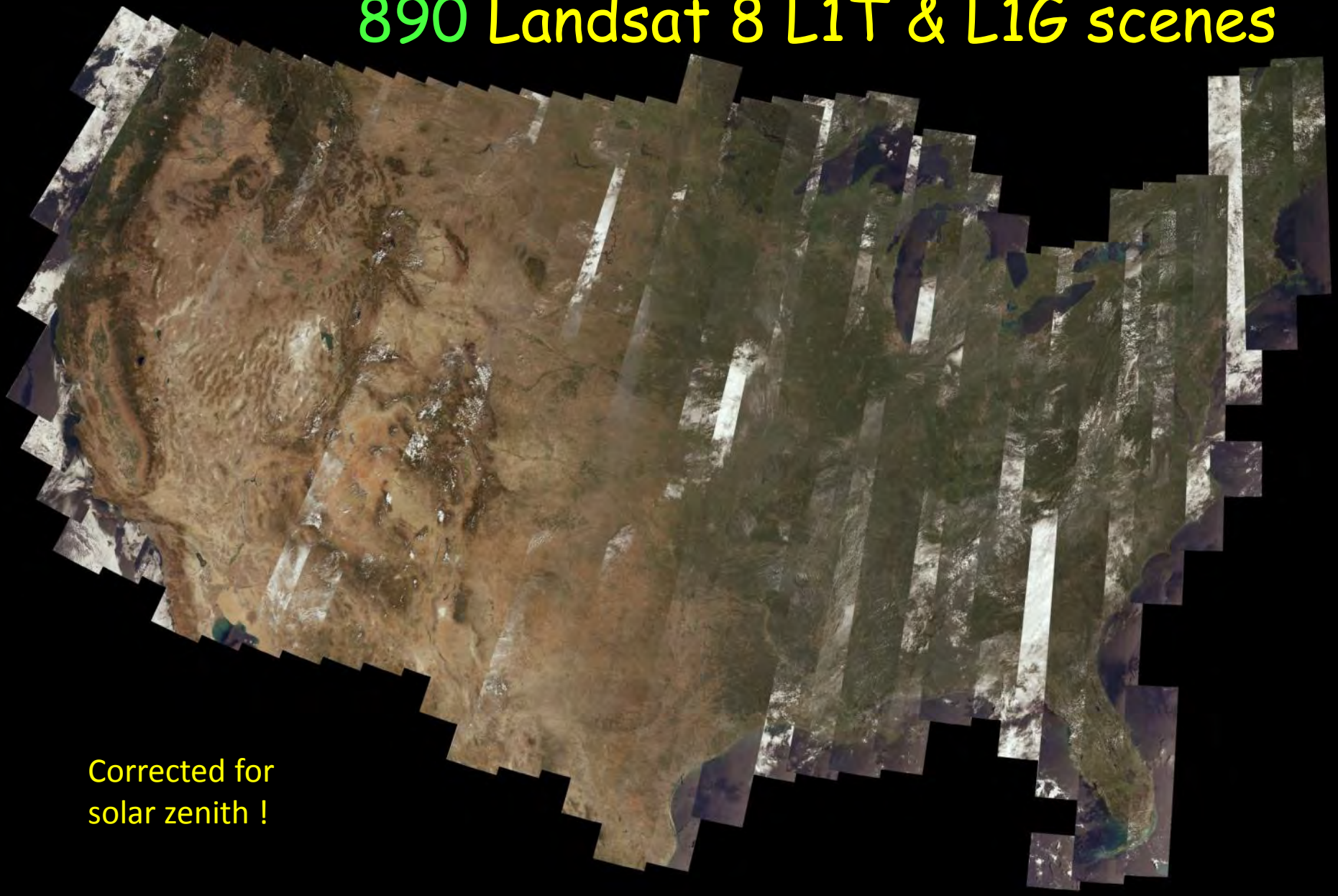
Alaska WELD tile h15v11
(Graham Island Prince Rupert, BC)

5000 x 5000 30m pixels

Generated without reading Landsat 8 cloud mask

Landsat 8 CONUS WELD August 2013

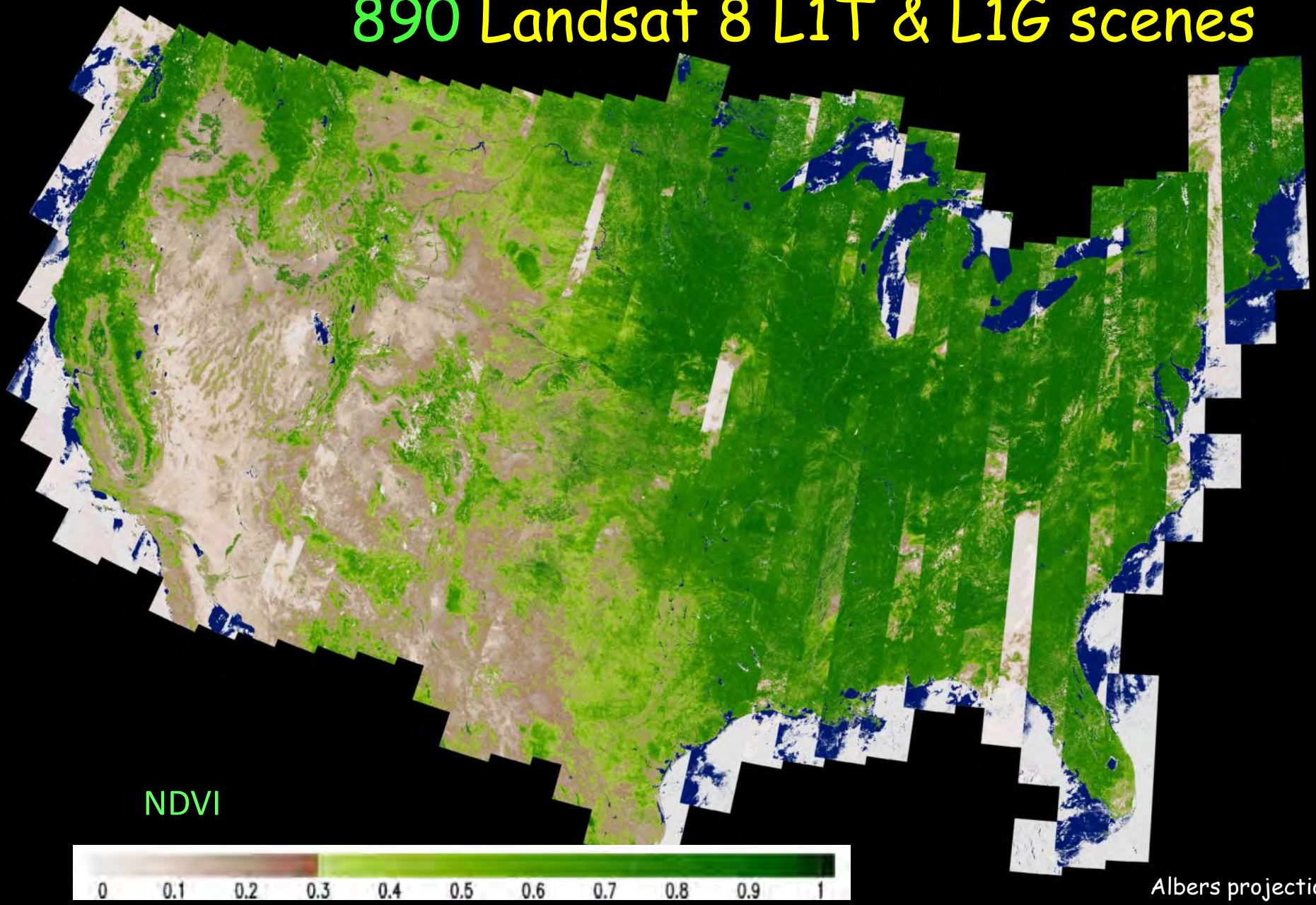
890 Landsat 8 L1T & L1G scenes



Corrected for
solar zenith !

Landsat 8 CONUS WELD August 2013

890 Landsat 8 L1T & L1G scenes



Californian subset (450 km × 750 km) of the August 2013 WELD product browse

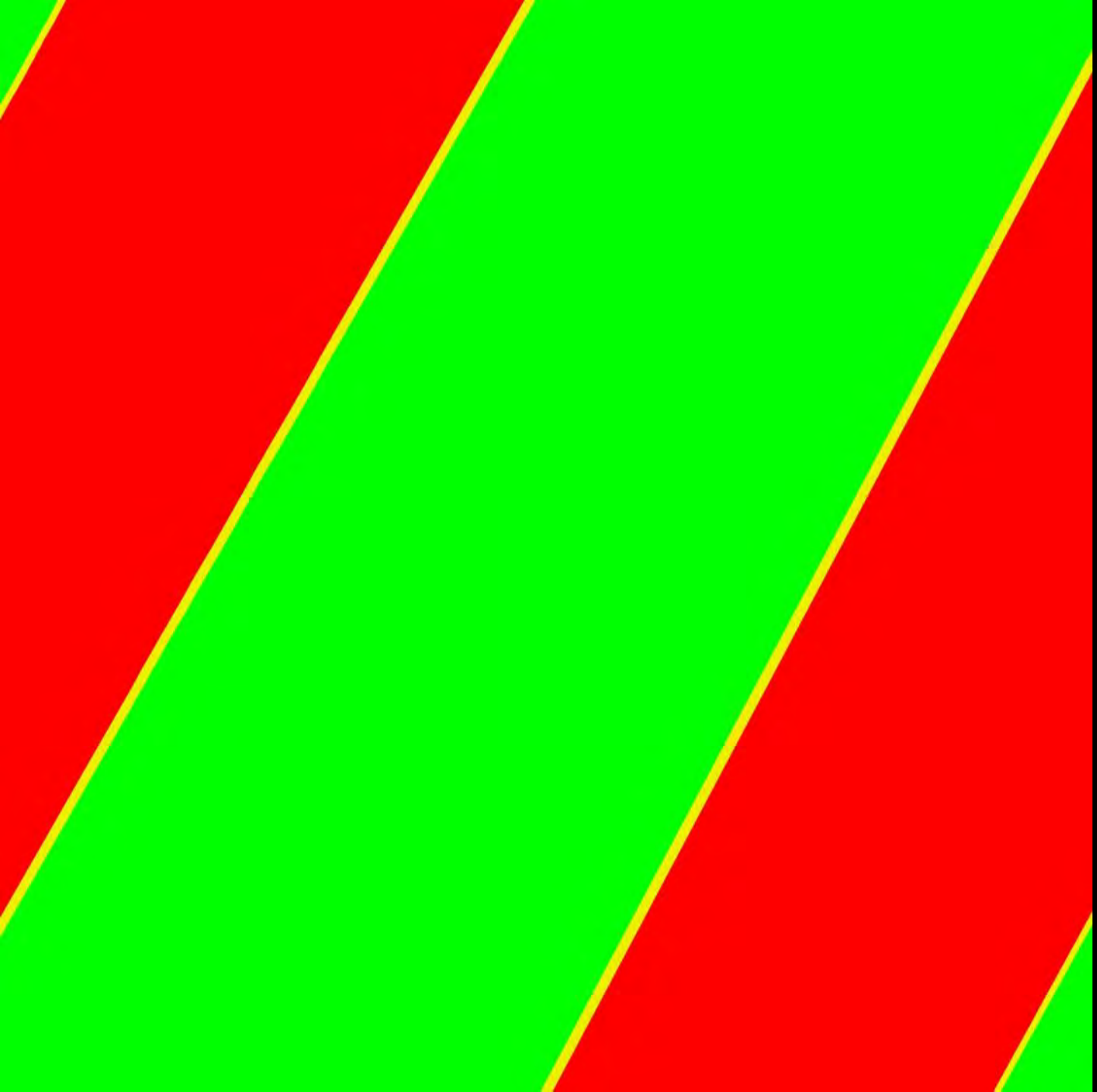
Californian subset (450 km × 750 km) of the August 2013 WELD product browse

Landsat 8 CONUS WELD processed August 2013 monthly composite

14 L1T & L1G scenes

CONUS WELD tile h02v08
(Sacramento, CA)

5000 x 5000 30m pixels



Number of Landsat 8 observations composited in month

2 – Green

3 - Yellow

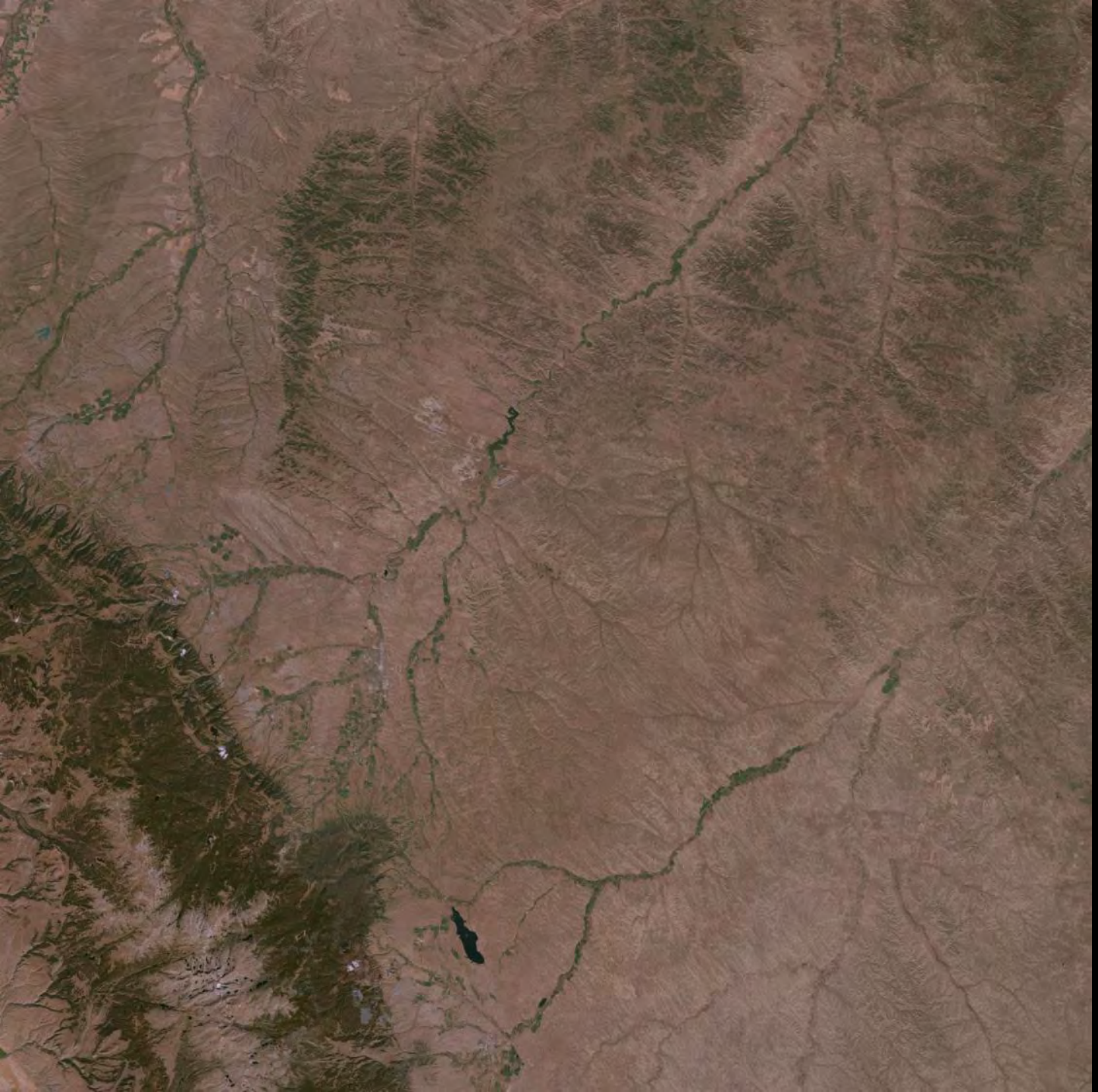
4 - Red

Landsat 8 CONUS WELD processed August 2013 monthly composite

14 L1T & L1G scenes

CONUS WELD tile h10v02
(Buffalo Bill State Park, Big Horn Nat. Forest, WY)

5000 x 5000 30m pixels

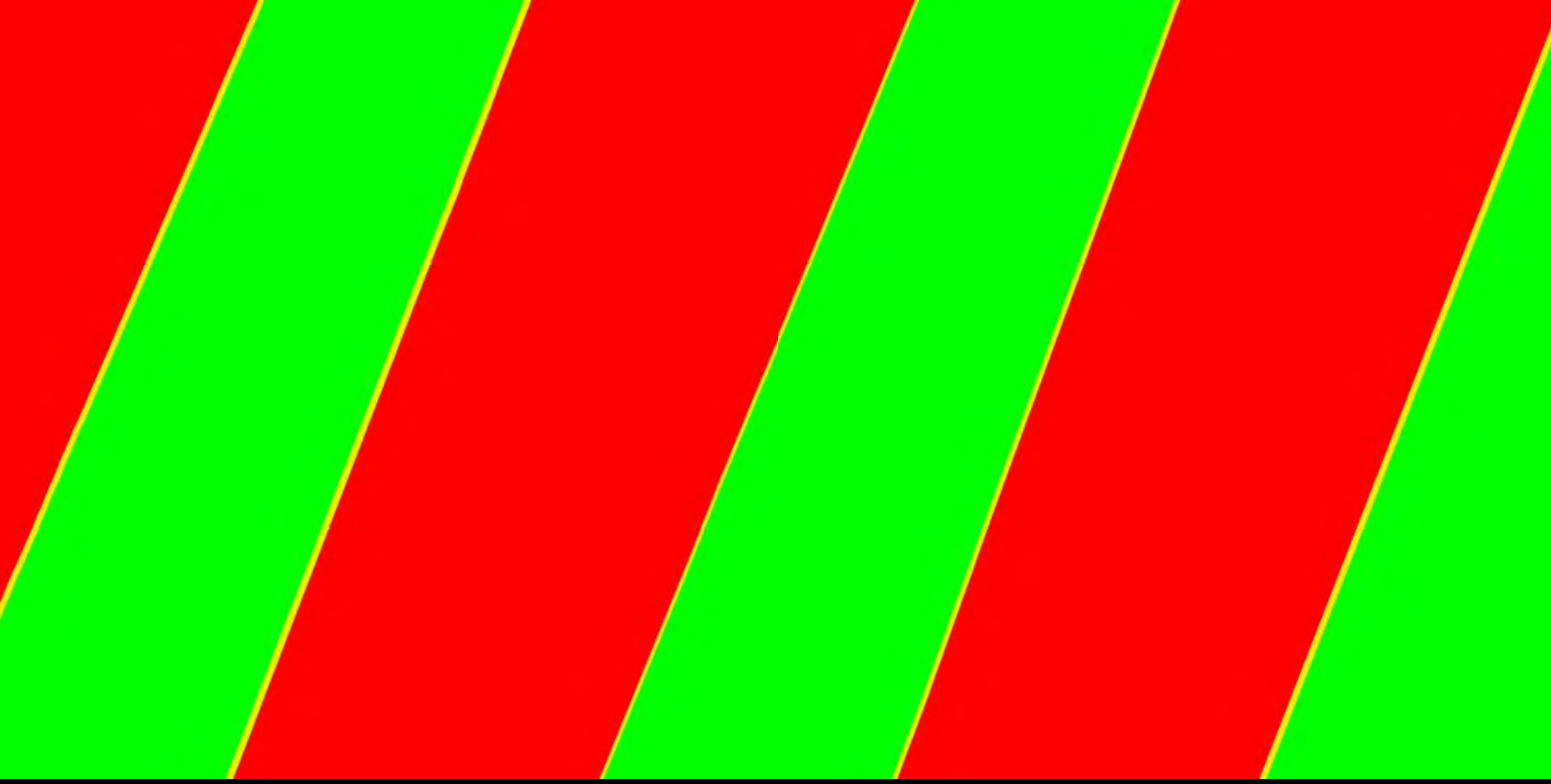


Landsat 8 CONUS WELD processed August 2013 monthly composite

14 L1T & L1G scenes

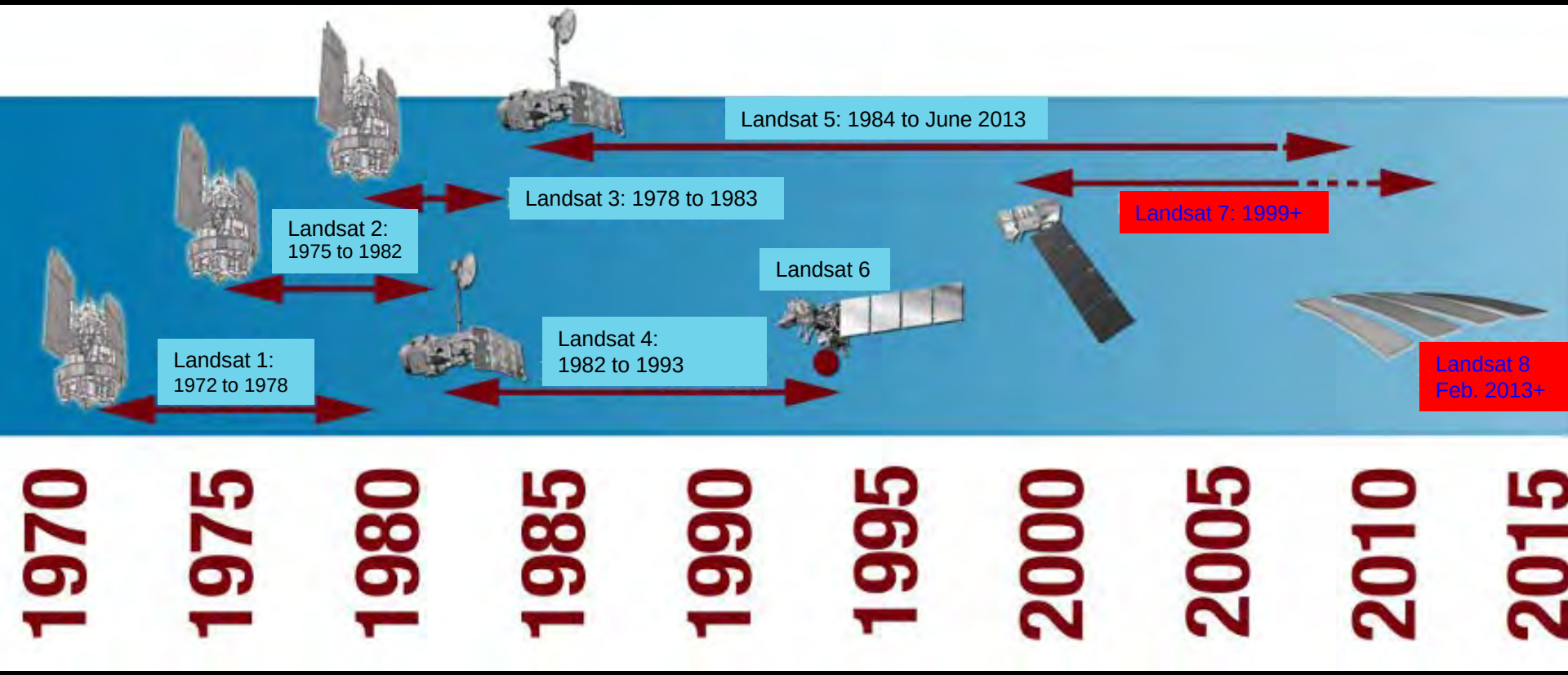
CONUS WELD tile h10v02
(Big Horn Nat. Forest, WY)

5000 x 5000 30m pixels



Landsat Satellite Series

The longest Land surface observation record



WELD process L8 data

(Global)

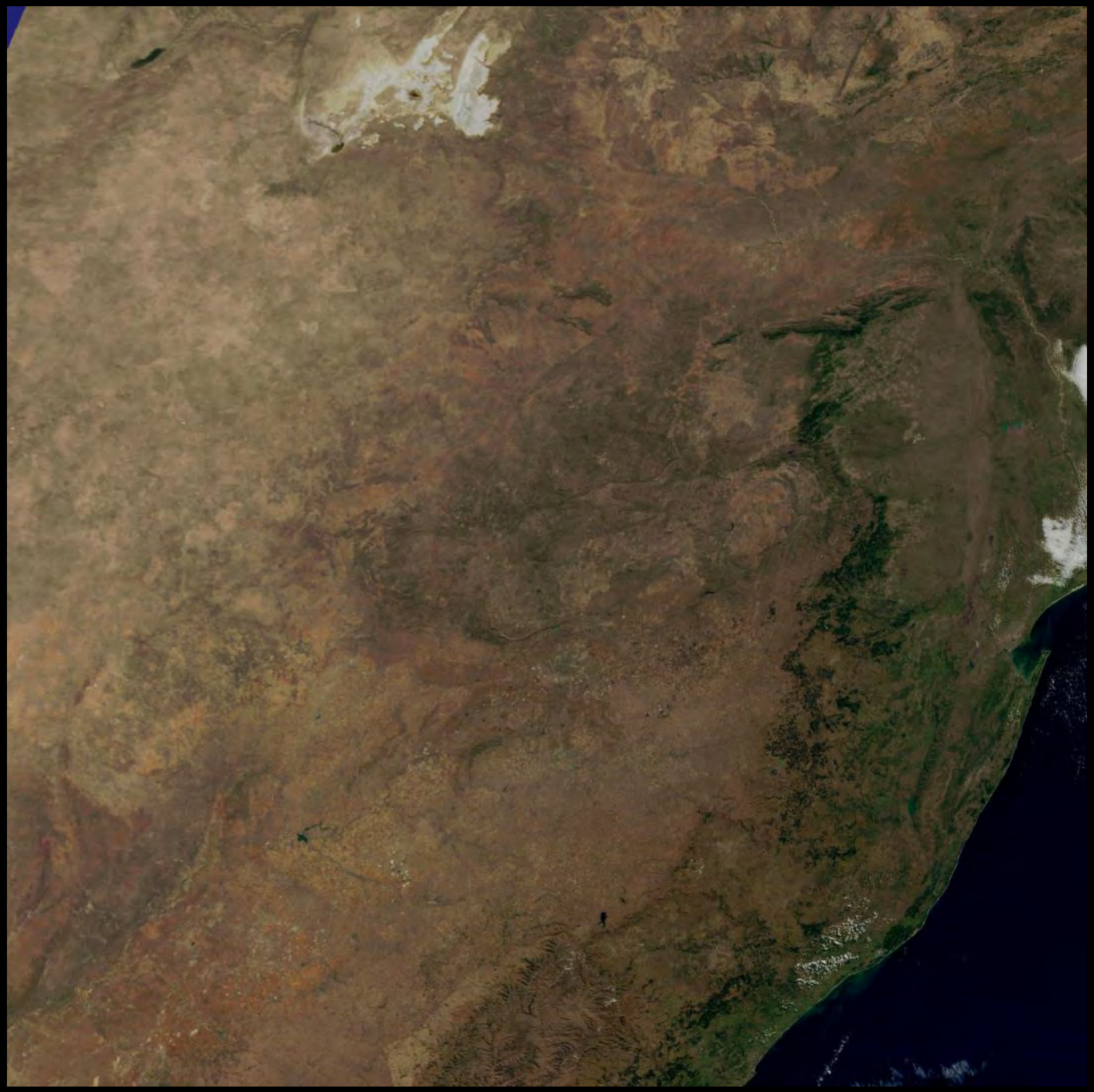
MODIS
tile h20v11
South Africa, Mozambique

500m surface reflectance

May 31st 2013

Sinusoidal Projection

1200 x 1200 km



Nested WELD tiles each 5295 x 5295 30m pixels

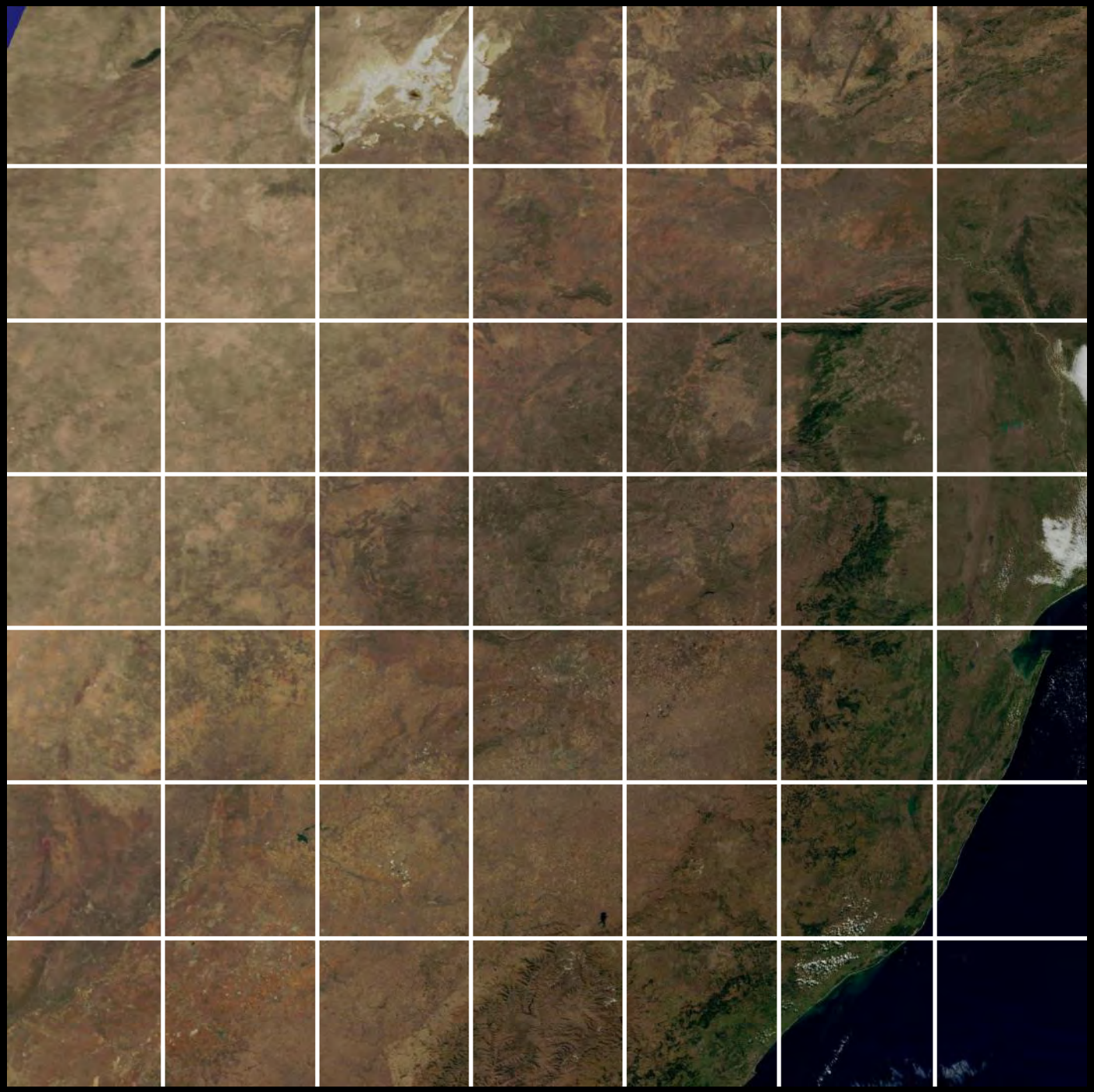
MODIS
tile h20v11
South Africa, Mozambique

500m surface reflectance

May 31st 2013

Sinusoidal Projection

1200 x 1200 km



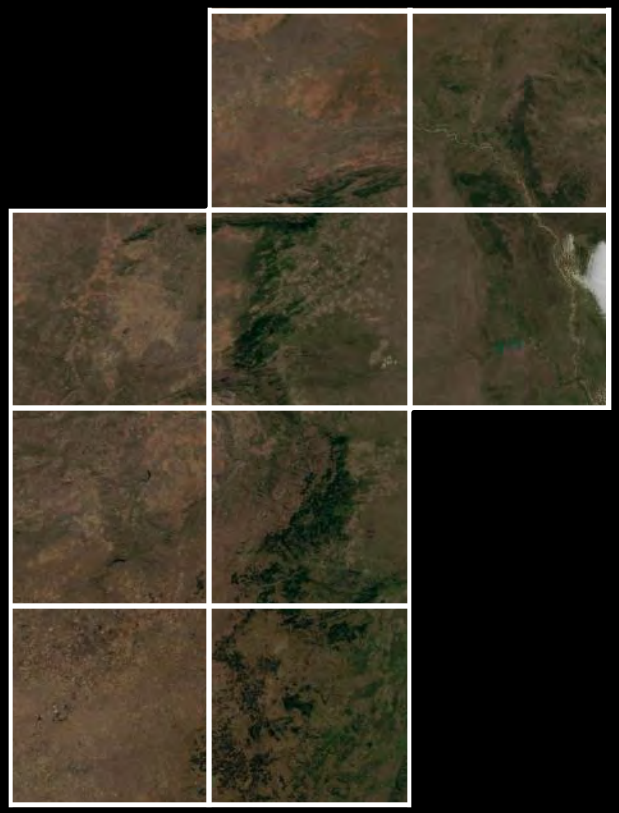
MODIS
tile h20v11
South Africa,
Mozambique

500m surface
reflectance

May 31st 2013

Sinusoidal
Projection

1200 x 1200 km



Landsat 8

WELD 30m true color reflectance

May 30th 2013

3 South Africa National Space Agency (SANSA) scenes

- LC81690762013150JSA00
- LC81690772013150JSA00
- LC81690782013150JSA00

MODIS Sinusoidal Projection

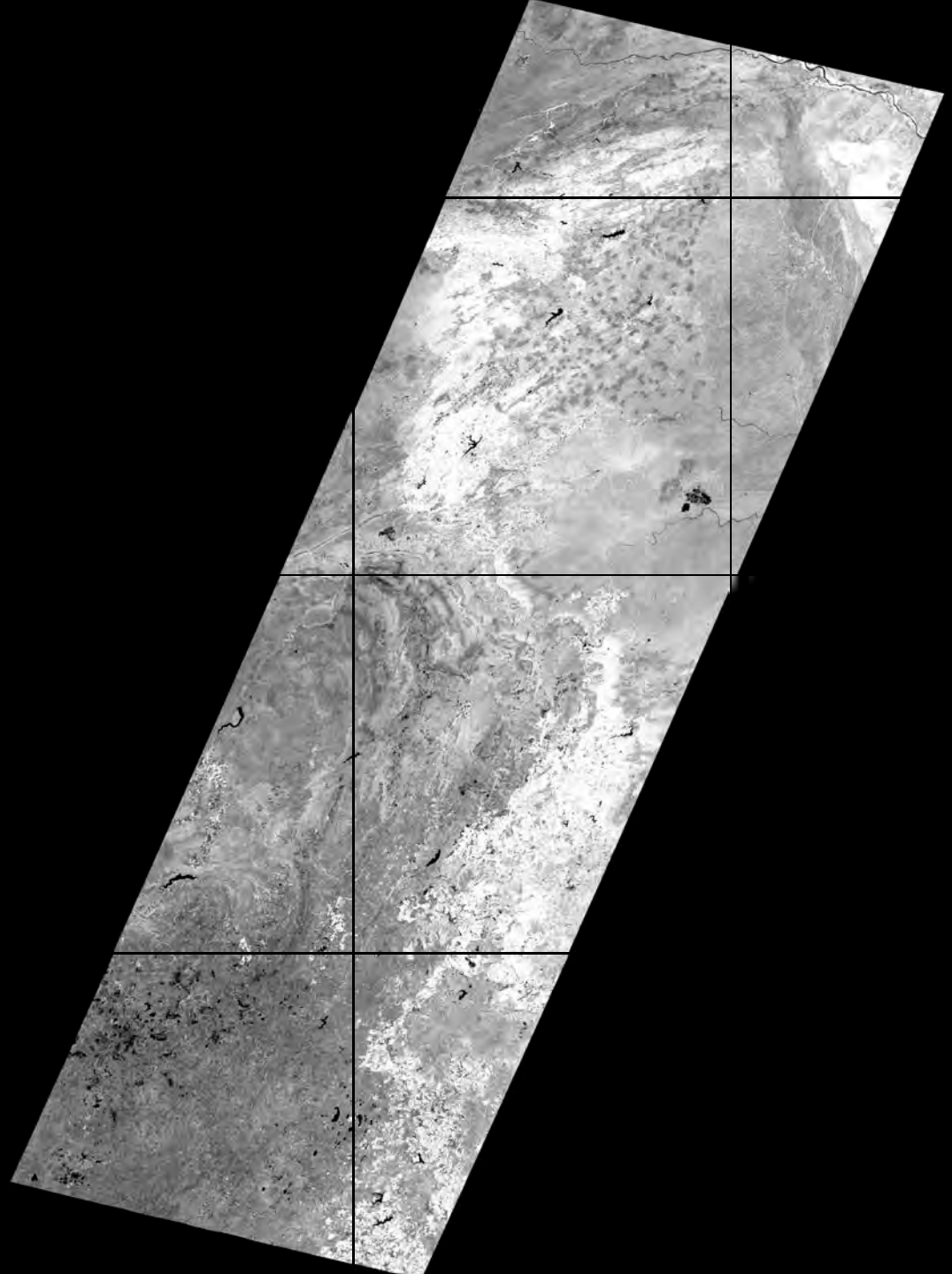
Landsat 8

WELD 30m NDVI

May 30th 2013

3 South Africa National Space Agency (SANSA) scenes

- LC81690762013150JSA00
- LC81690772013150JSA00
- LC81690782013150JSA00



MODIS Sinusoidal Projection

Landsat 8

WELD 30m true color reflectance

May 30th 2013

3 South Africa National Space Agency (SANSA) scenes

- LC81690762013150JSA00
- LC81690772013150JSA00
- LC81690782013150JSA00

MODIS Sinusoidal Projection

Landsat 8

May 30th 2013

True Color Reflectance

Detail of one

5295 x 5295

30m pixel

WELD tile

Landsat 8

May 30th 2013

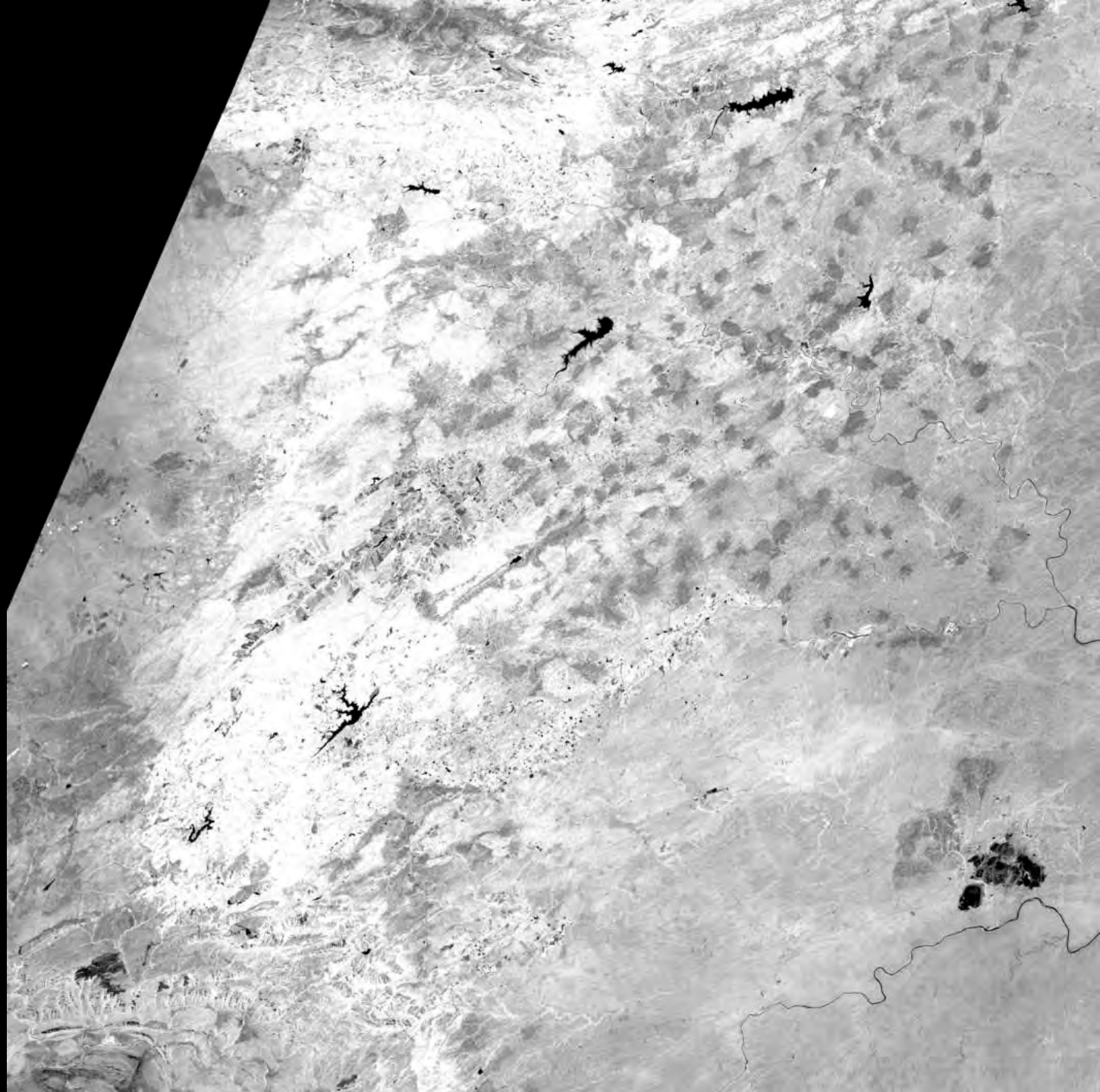
NDVI

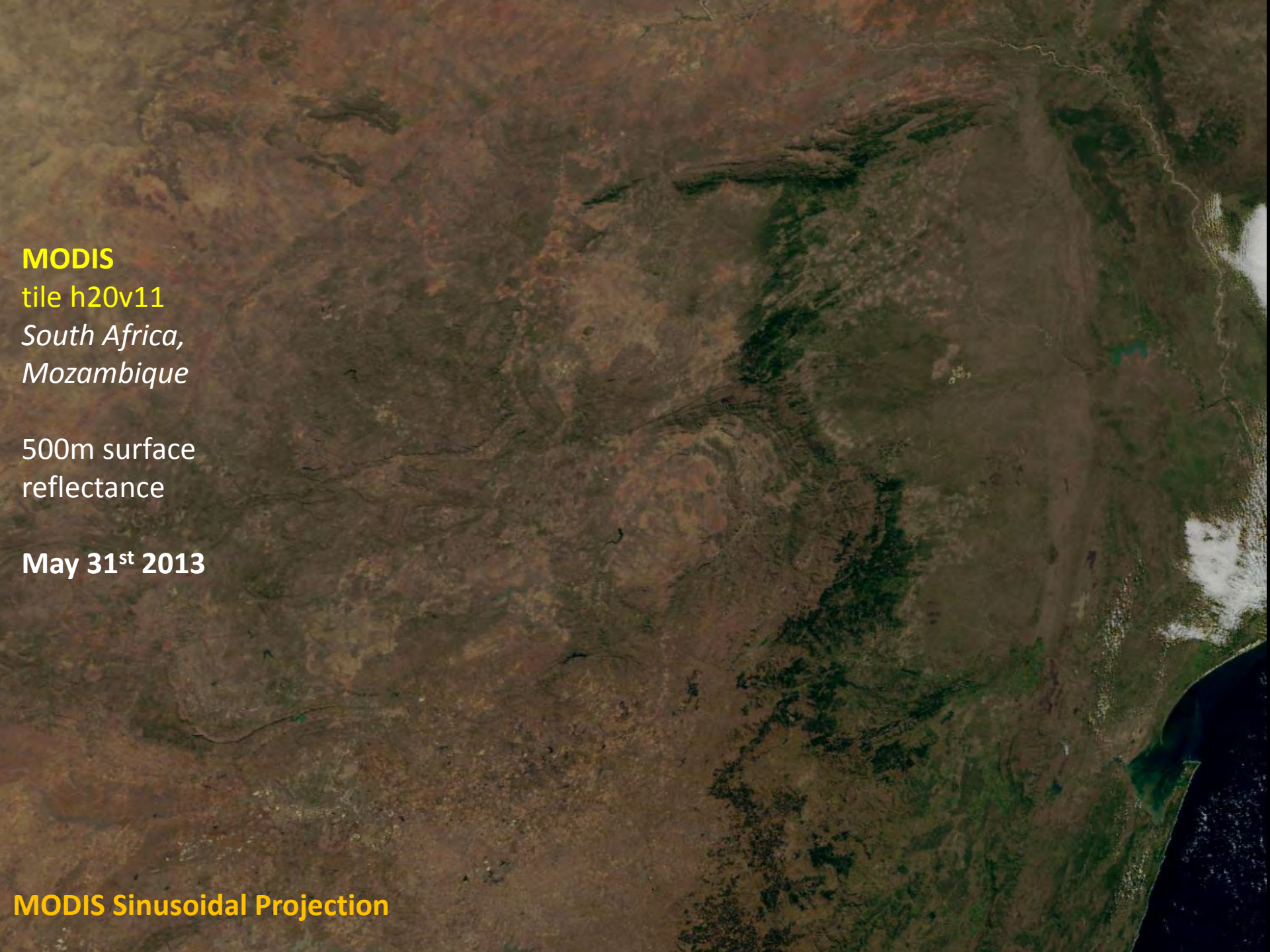
Detail of one

5295 x 5295

30m pixel

WELD tile




MODIS
tile h20v11
South Africa,
Mozambique
500m surface
reflectance
May 31st 2013
MODIS Sinusoidal Projection

Landsat 8

30m true color reflectance

May 30th 2013

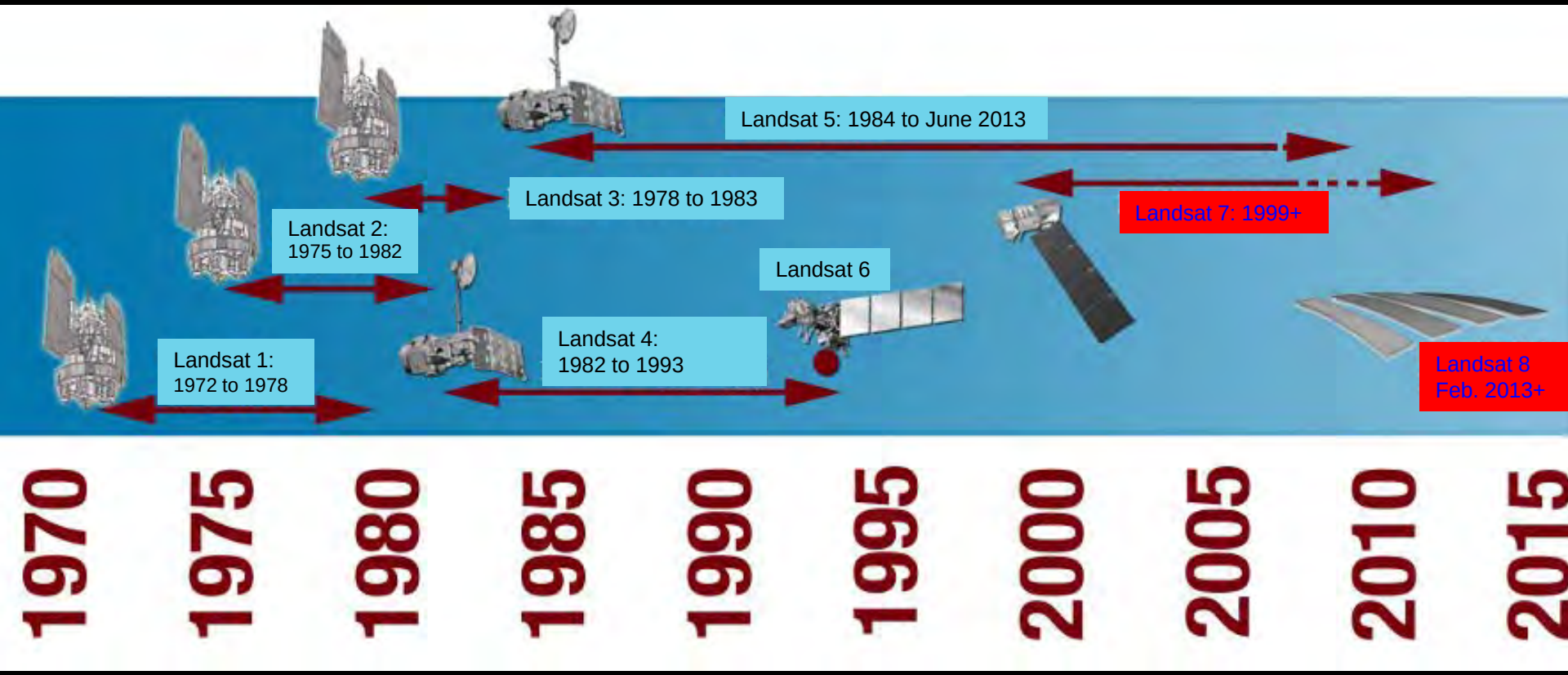
3 South Africa National Space Agency (SANSA) scenes

- LC81690762013150JSA00
- LC81690772013150JSA00
- LC81690782013150JSA00

MODIS Sinusoidal Projection

Landsat Satellite Series

The longest Land surface observation record



L8 →

← L7

← L5 & L7

Landsat Science Team Paper
Submitted October 7th 2013 (currently under review)

Remote Sensing of Environment

Contact us
Help ?

Editors' Update Ethics Special Part I is live!

home | main menu | submit paper | guide for authors | register | change details | log out

Username: david.roy@sdstate.edu
Role: Author

Version: EES 2013.9

Submissions Being Processed for Author David Roy, PhD.

Page: 1 of 1 (1 total submissions)

Action	Manuscript Number	Title
Action Links	RSE-D-13-00848	Landsat-8: science and product vision for terrestrial global change research

Page: 1 of 1 (1 total submissions)

<< Author Main Menu

Landsat Science Team Paper
Submitted October 7th 2013 (currently under review)

Title: Landsat-8: science and product vision for terrestrial global change research

Article Type: Full length article

Keywords: Landsat 8, OLI, TIRS, Landsat Science Team

Corresponding Author: Dr. David Roy, PhD.

Corresponding Author's Institution: South Dakota State University

First Author: David P Roy

Order of Authors: David P Roy; David Roy, PhD.; Mike Wulder; Tom Loveland; Curtis Woodcock; Rick Allen; Martha Anderson; Dennis Helder; Jim Irons; Dave Johnson; Robert Kennedy; Ted Scambos; Crystal Schaaf; John Schott; Yongwei Sheng; Eric Vermote; Alan Belward; Robert Bindschadler; Warren Cohen; Feng Gao; Jim Hipple; Patrick Hostert; John Huntington; Chris Justice; Ayse Kilic; Valeriy Kovalskyy; ZhongPing Lee; Leo Lymburner; Jeff Masek; Joel McCorkel; Yanmin Shuai; Ricardo Trezza; Jim Vogelmann; Randy Wynne; Zhe Zhu

Paper research highlights

- initial understanding of Landsat 8 capabilities, new science & applications opportunities
- Landsat Science Team identified priorities
- derived 'higher-level' Landsat products
- international synergies with other moderate resolution remote sensing satellites
- successor Landsat mission requirements