Advancing global land mapping and monitoring

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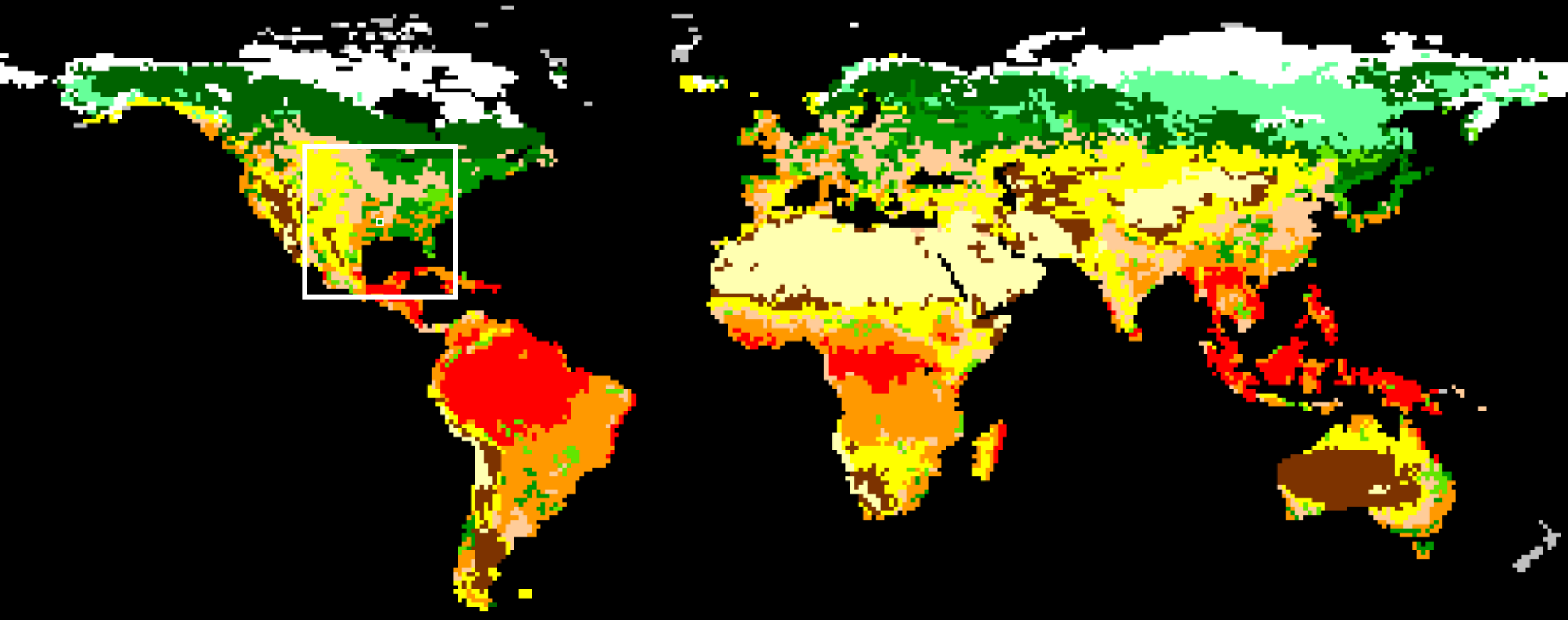
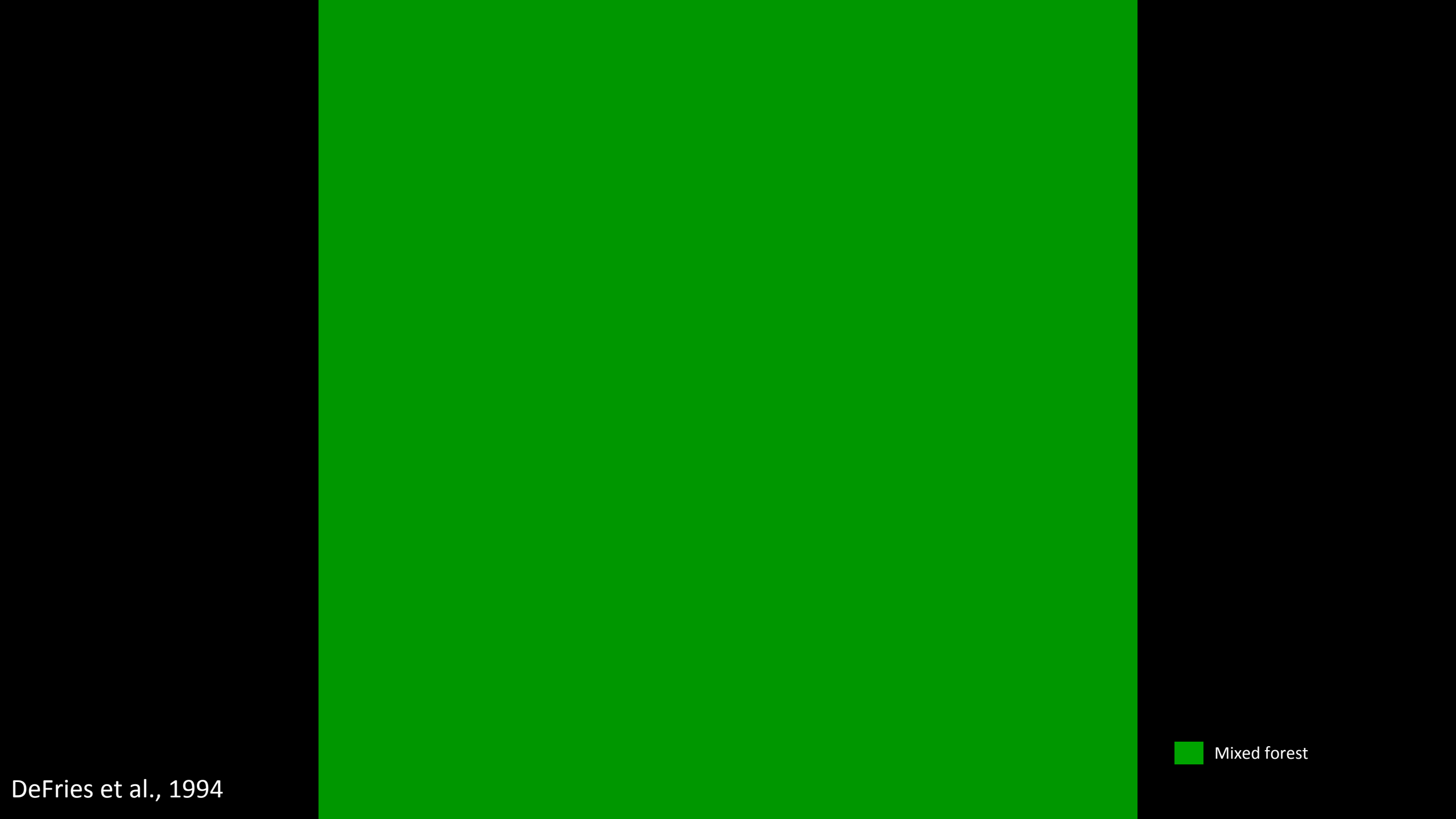
GLAD
GLOBAL LAND
ANALYSIS & DISCOVERY

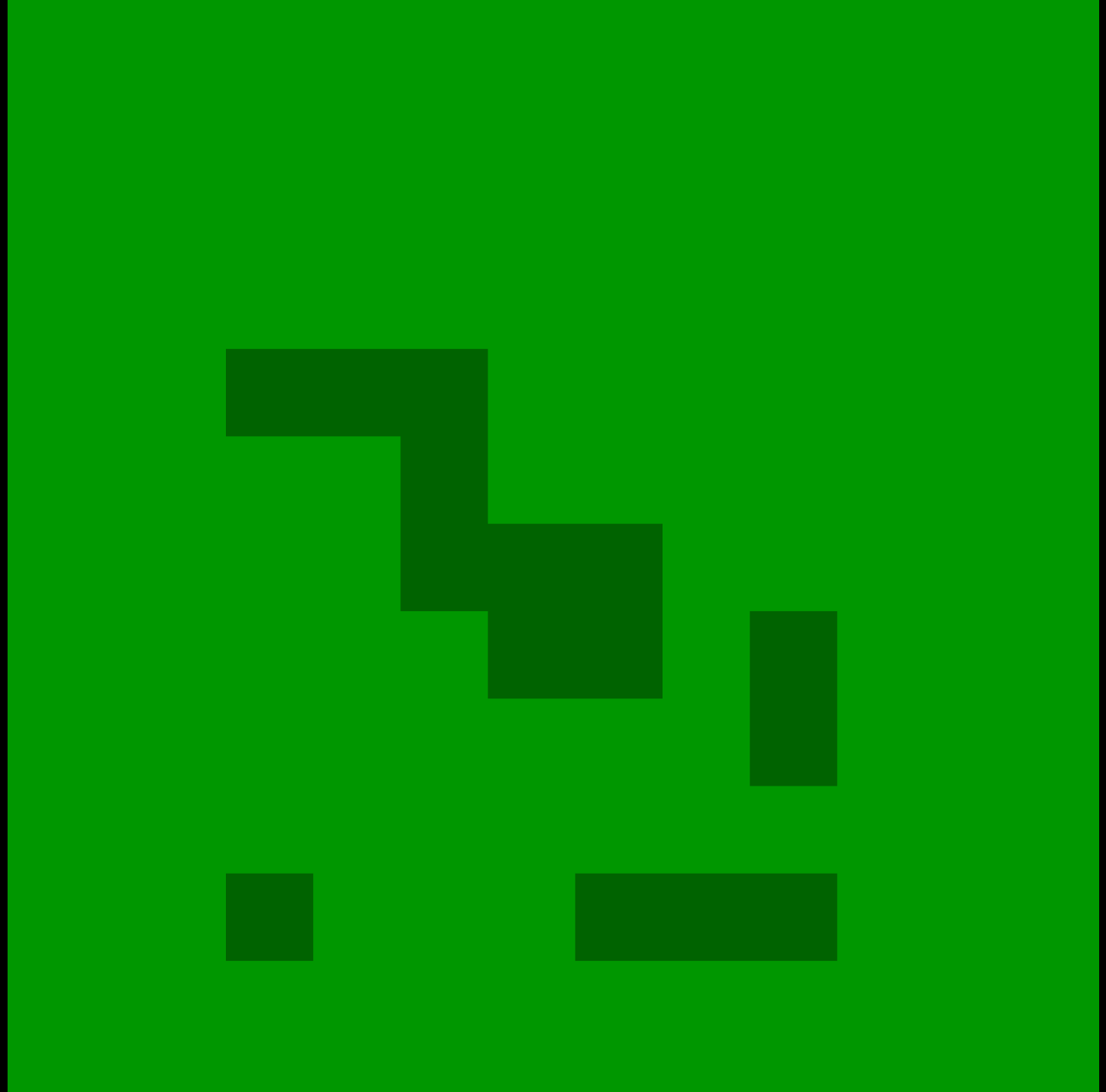
UNIVERSITY OF
MARYLAND

Quantifying global land cover





DeFries et al., 1994

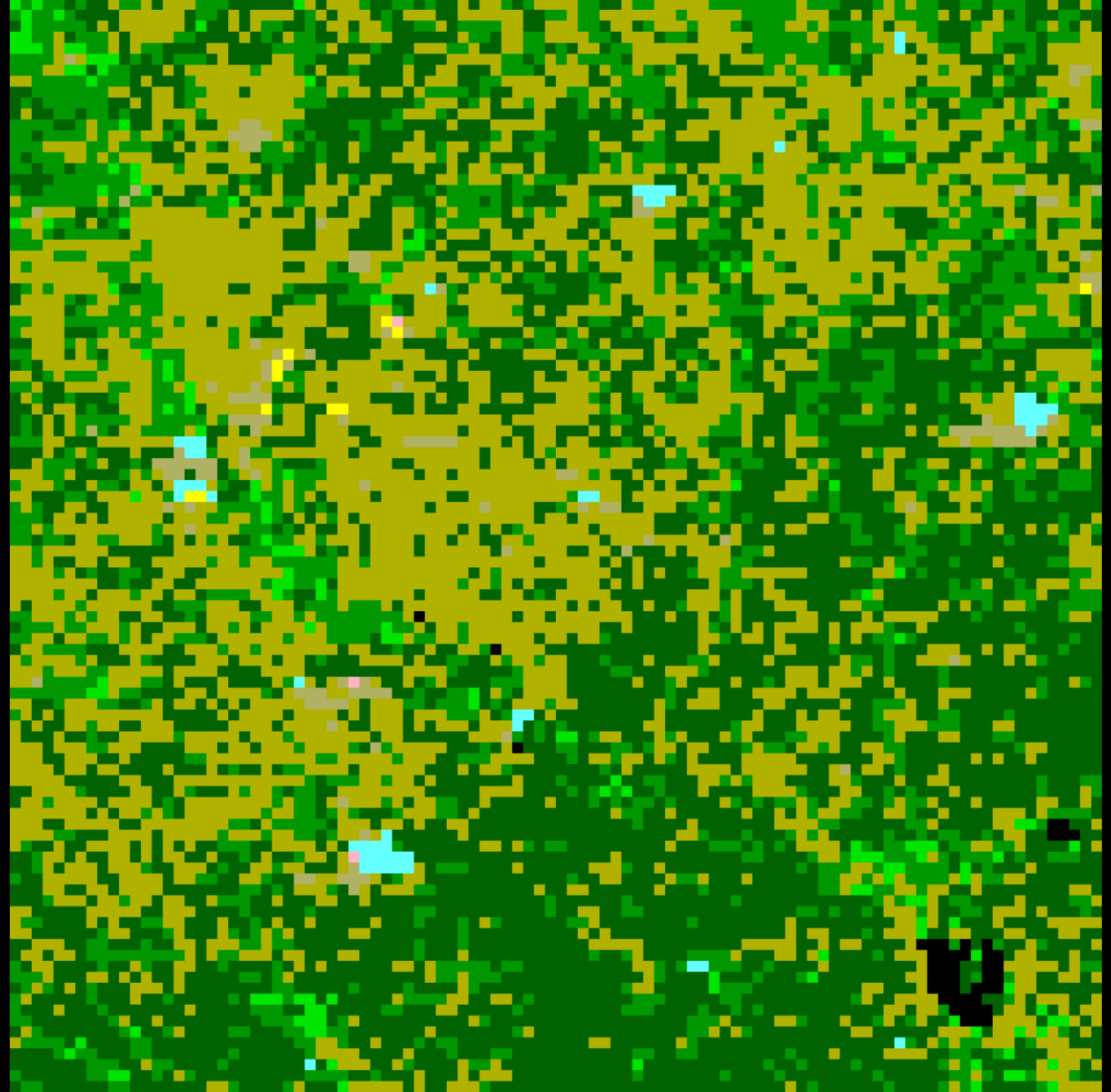


8km AVHRR

DeFries et al., 1998

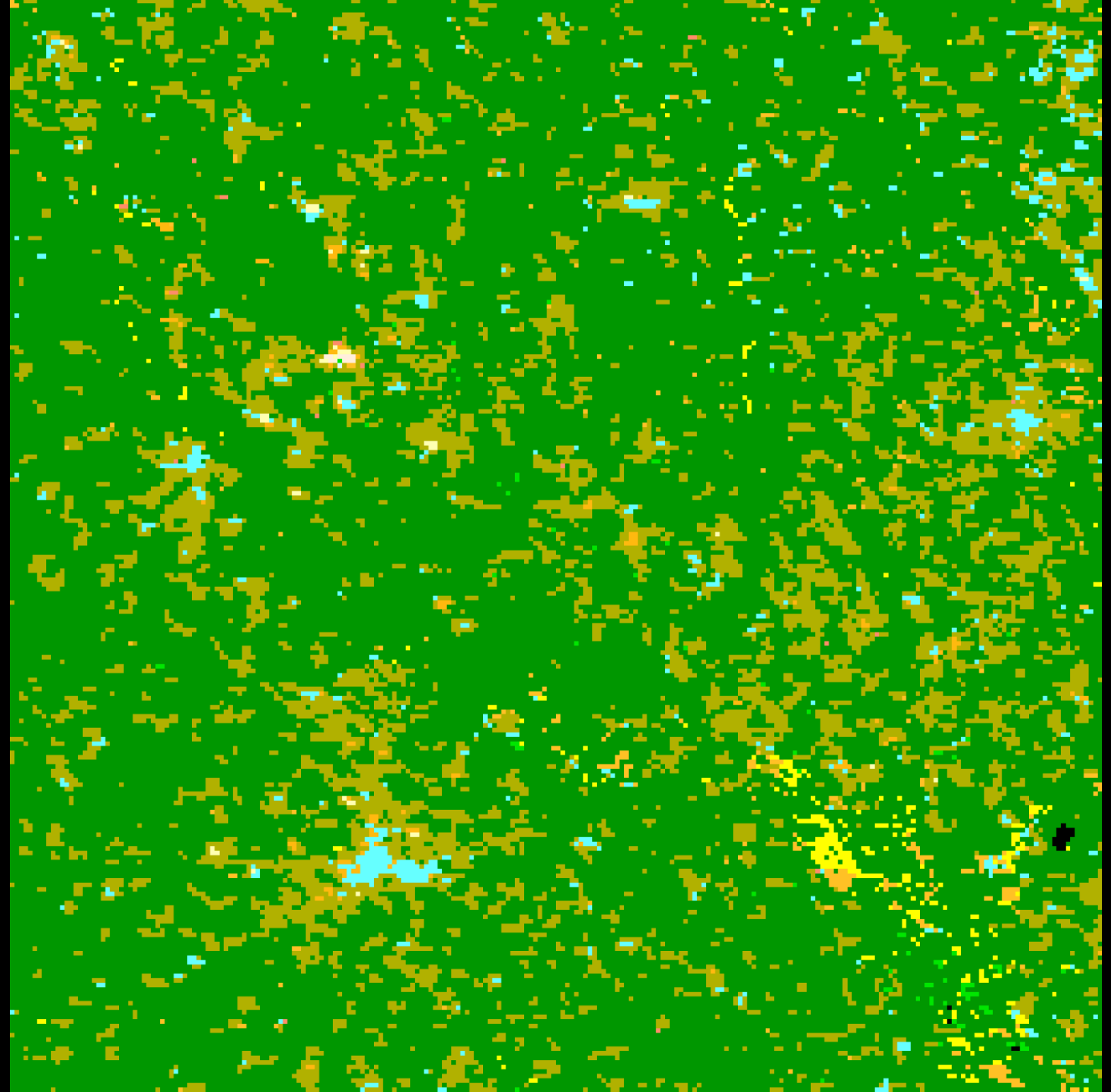
Mixed forest

Evergreen needleleaf forest



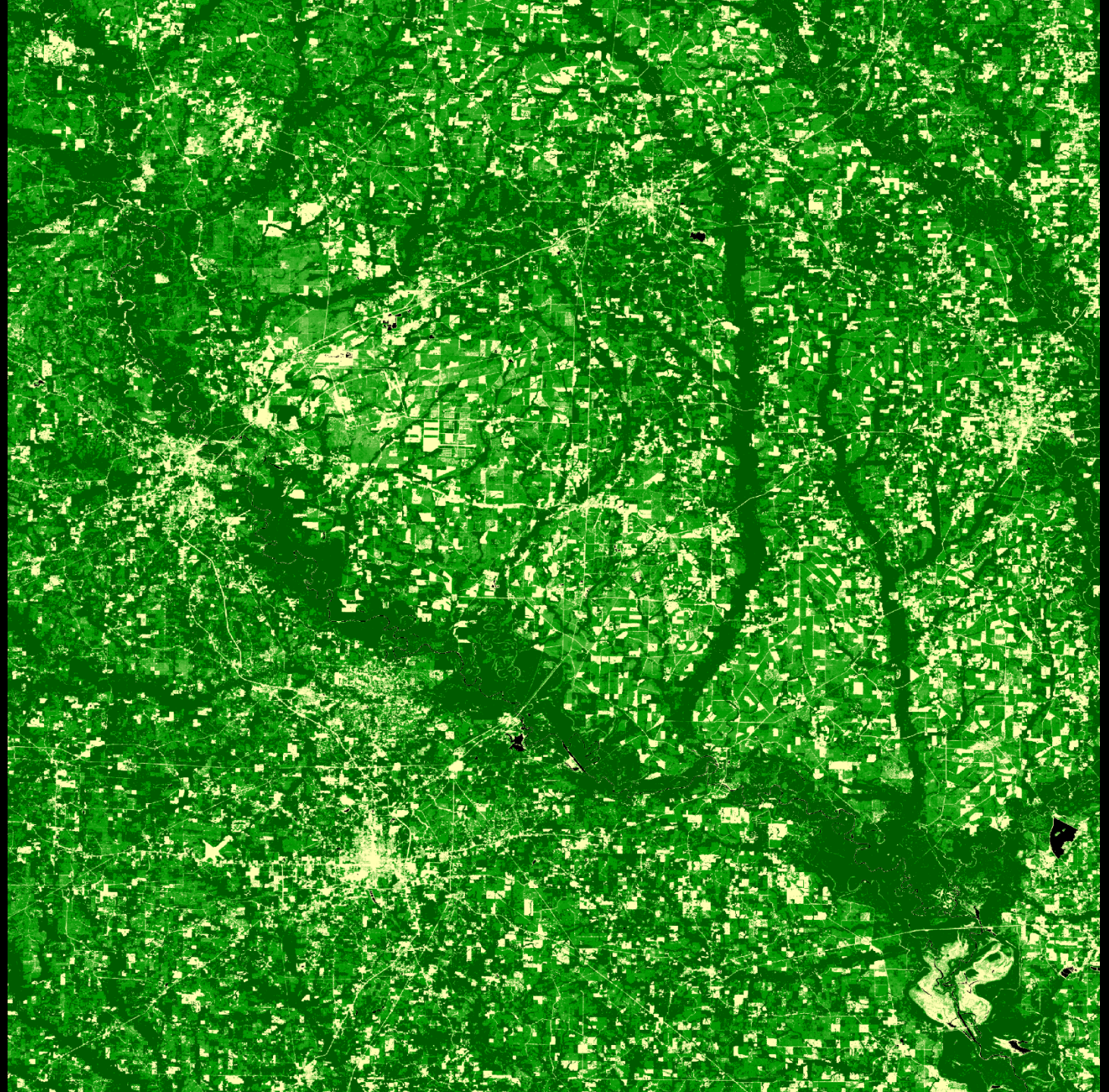
1km AVHRR

Loveland et al., 2000
Hansen et al., 2000 *
Bartholomé et al., 2005



250m MODIS

Friedl et al., 2002 *
Hansen et al., 2002
Arino et al., 2008



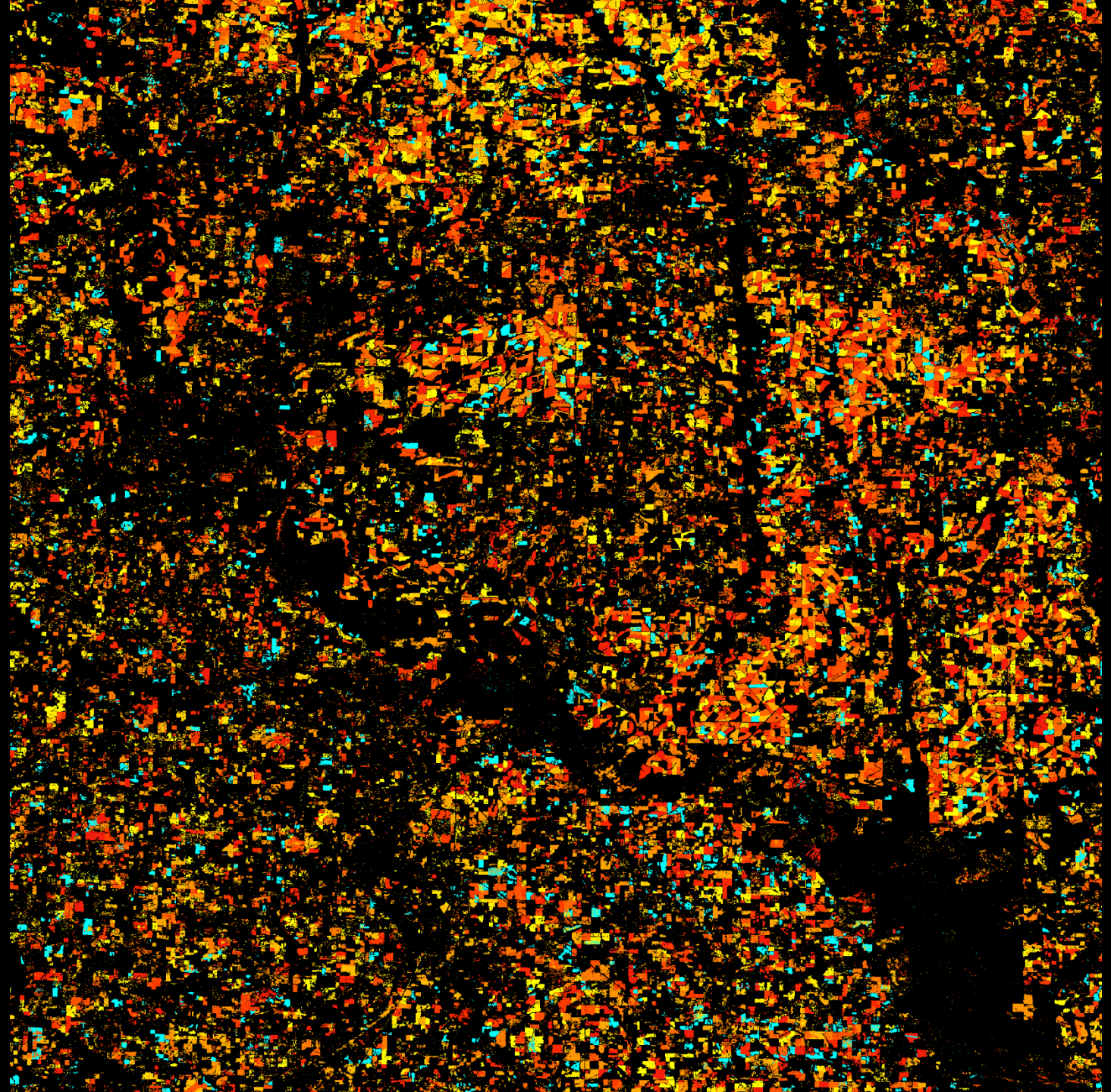
30m Landsat

Hansen et al., 2013 *
Sexton et al., 2013
Gong et al., 2013

Tree cover

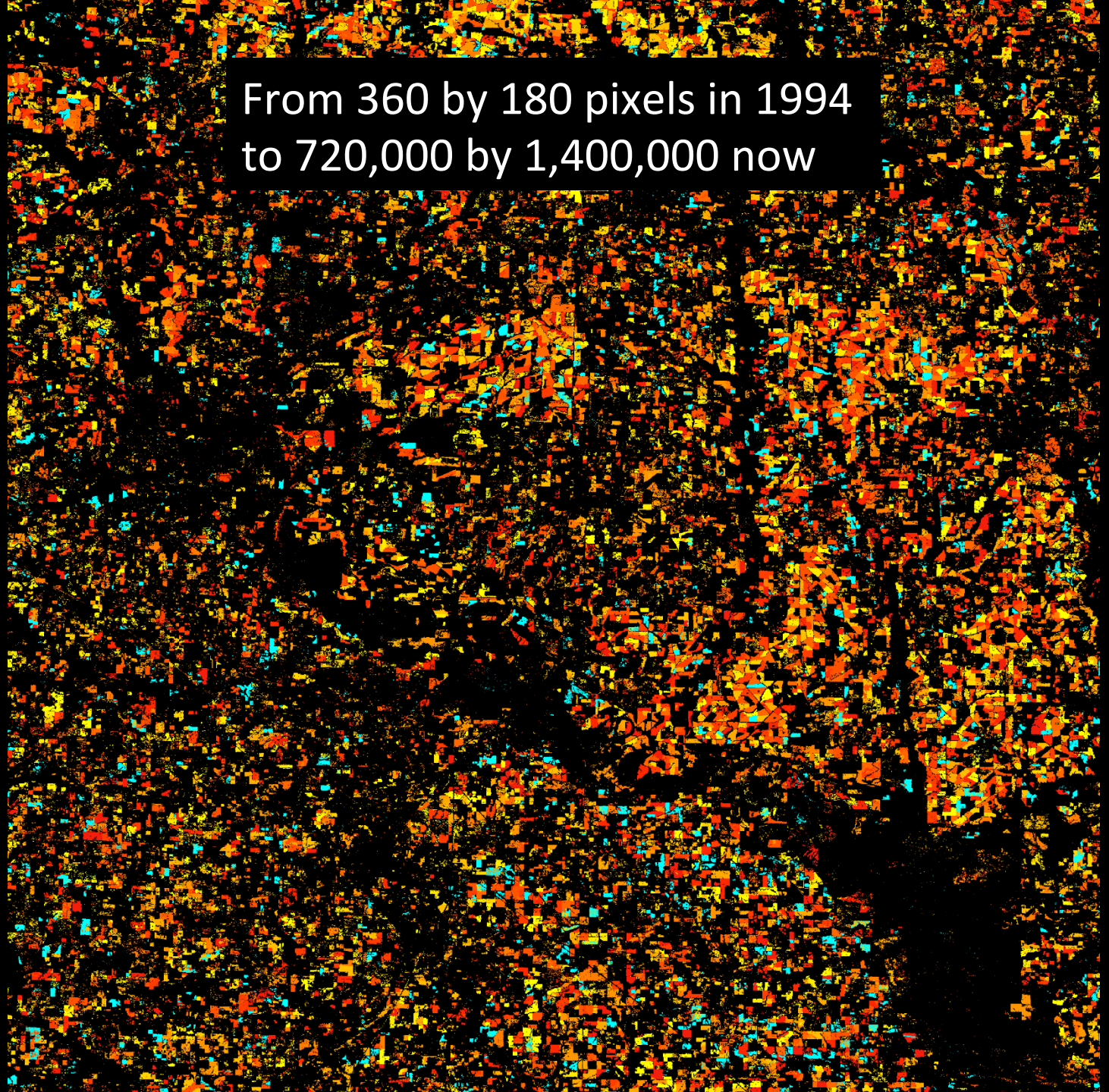
100%

0%



30m Landsat

Hansen et al., 2013 *
Kim et al., 2014



30m Landsat

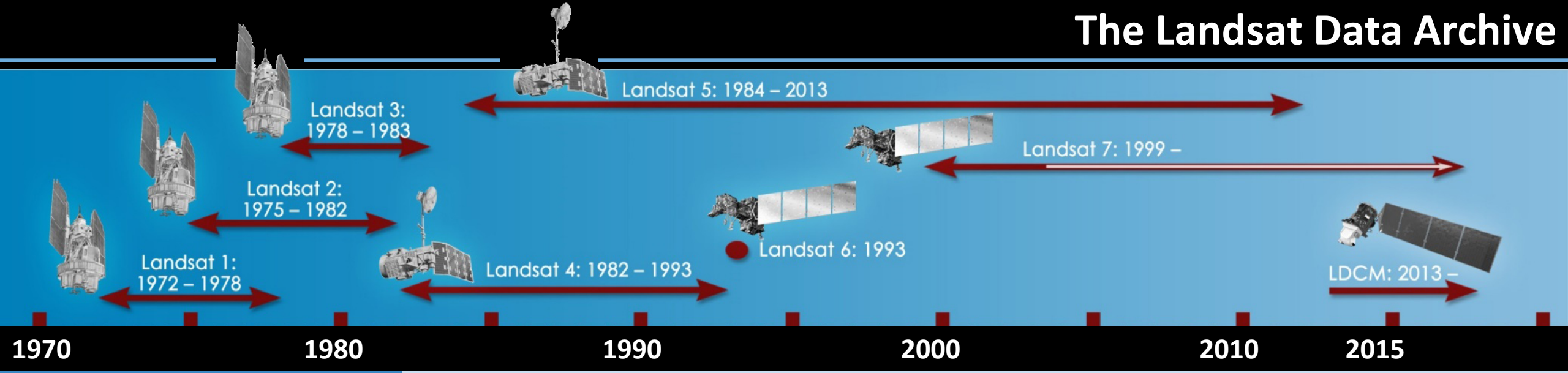
Hansen et al., 2013 *
Kim et al., 2014

Year of forest loss

2013

2001

The Landsat Data Archive

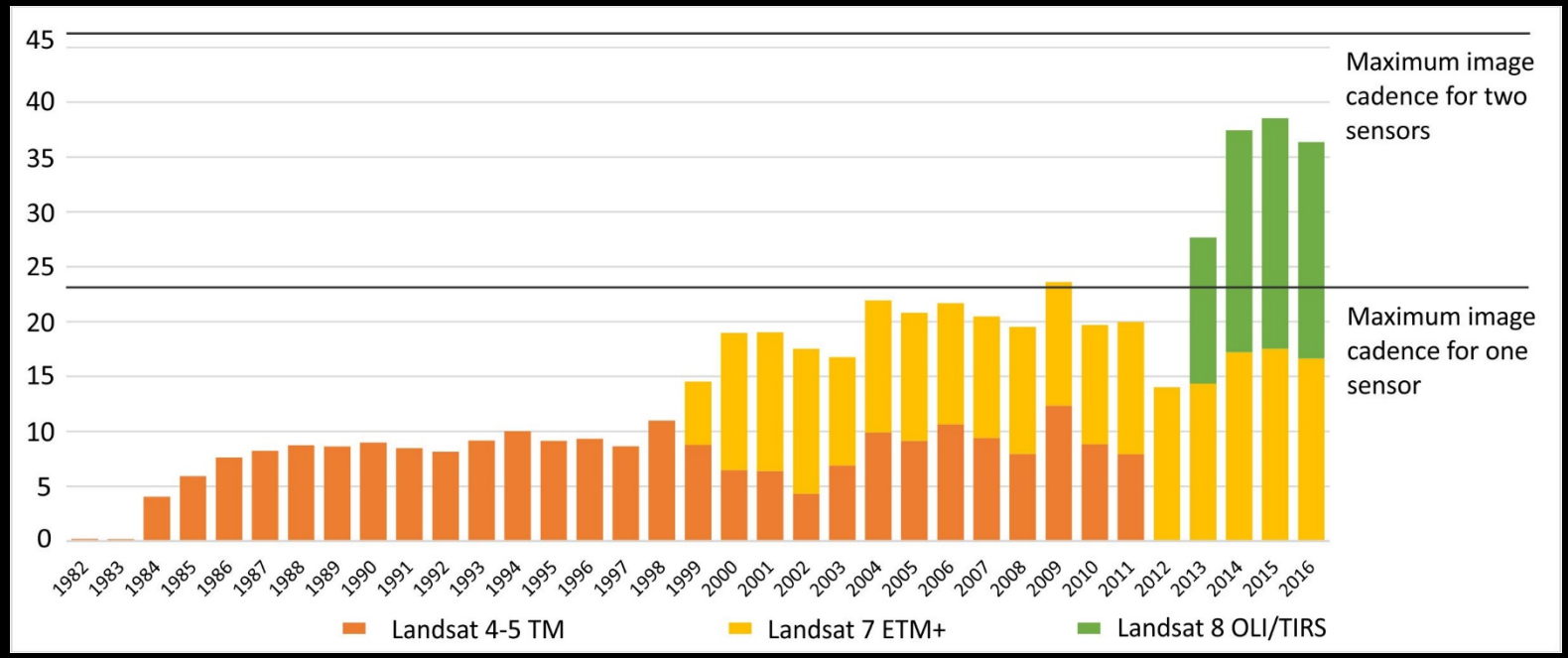


MSS data

30-m TM/ETM+/OLI data

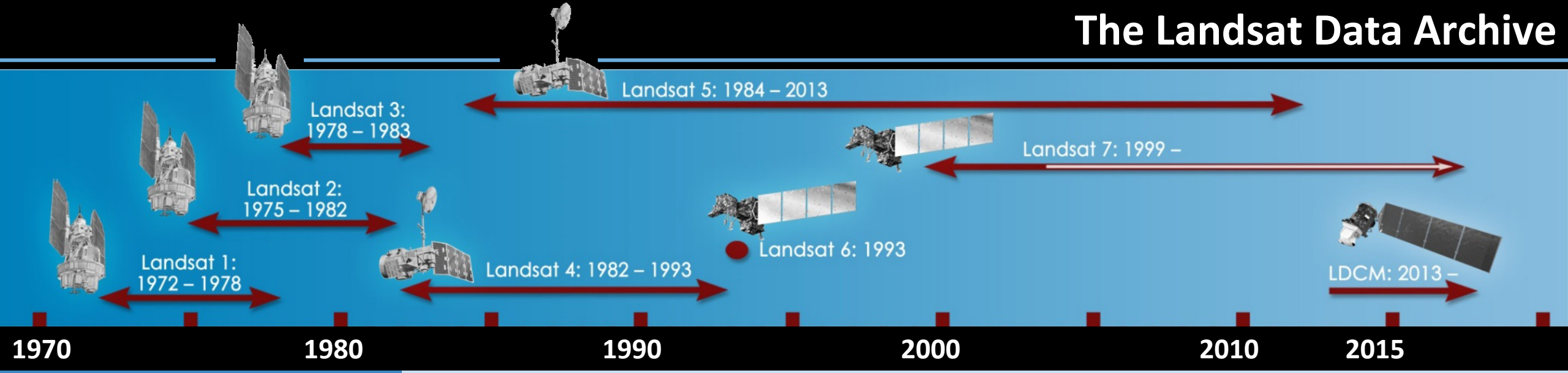
Data are free since 2008

- Systematic global acquisitions
- Free of charge
- Easy access
- Minimal pre-processing required



Total archive of 30-m observations, average number of images per year per scene

The Landsat Data Archive



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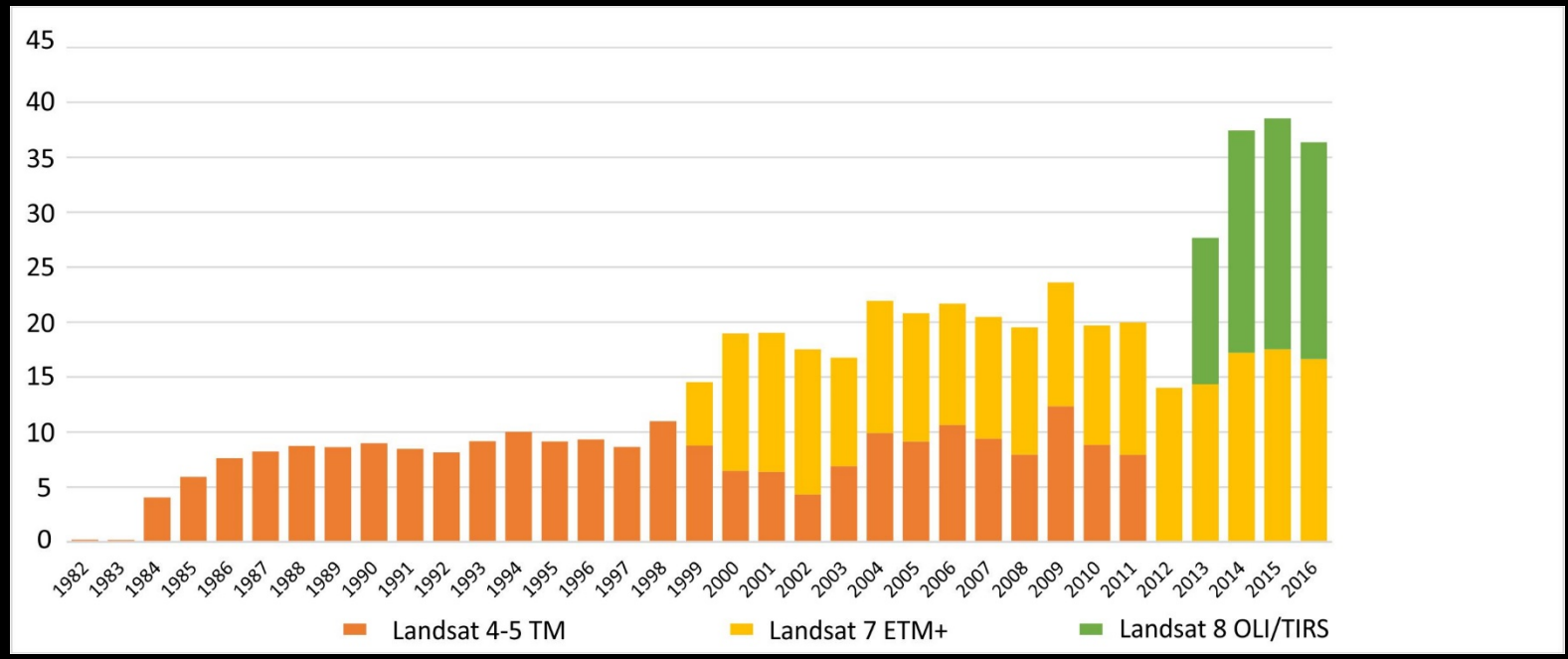
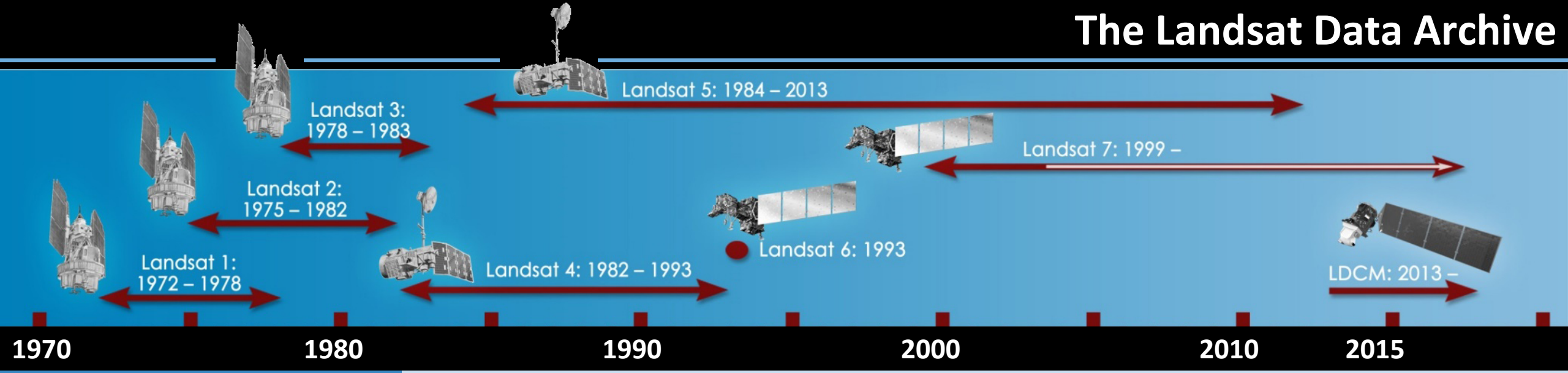


Total archive of 30-m observations, average number of images per year per scene

The Landsat Data Archive



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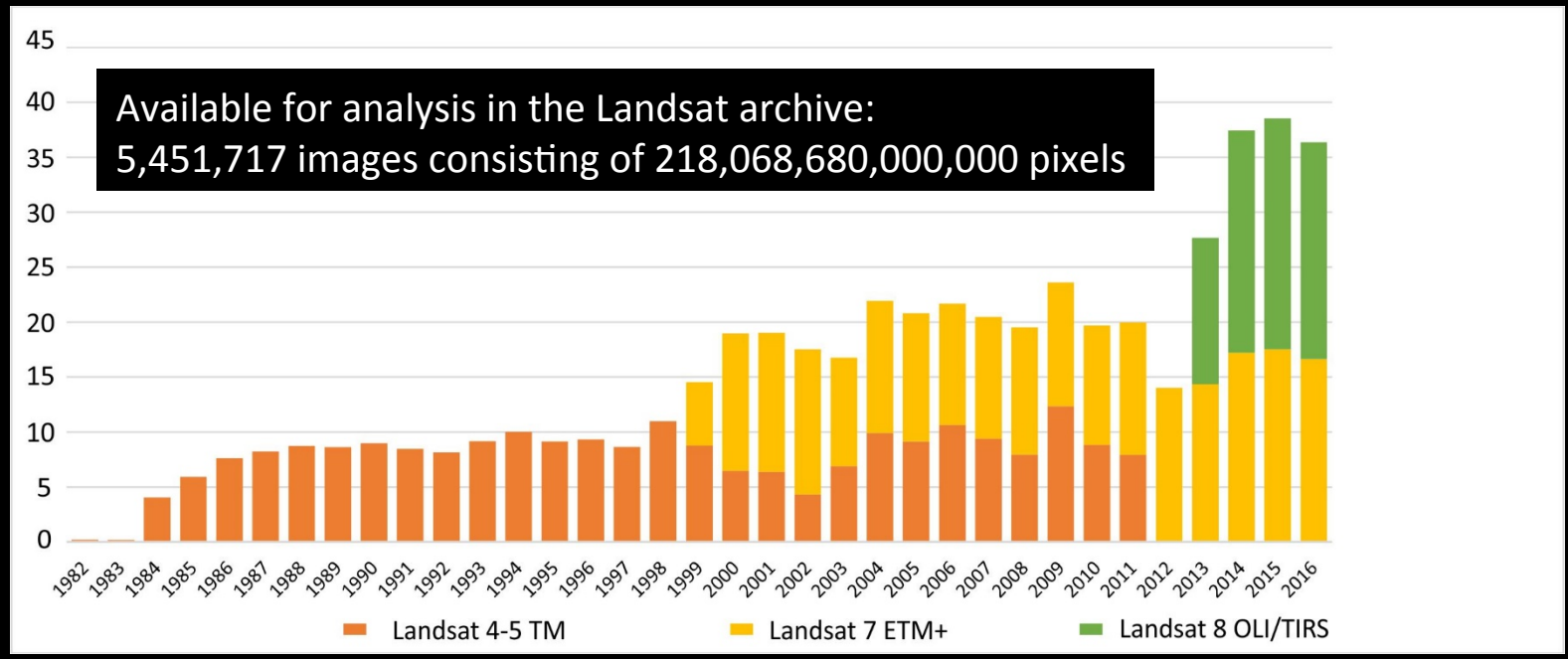
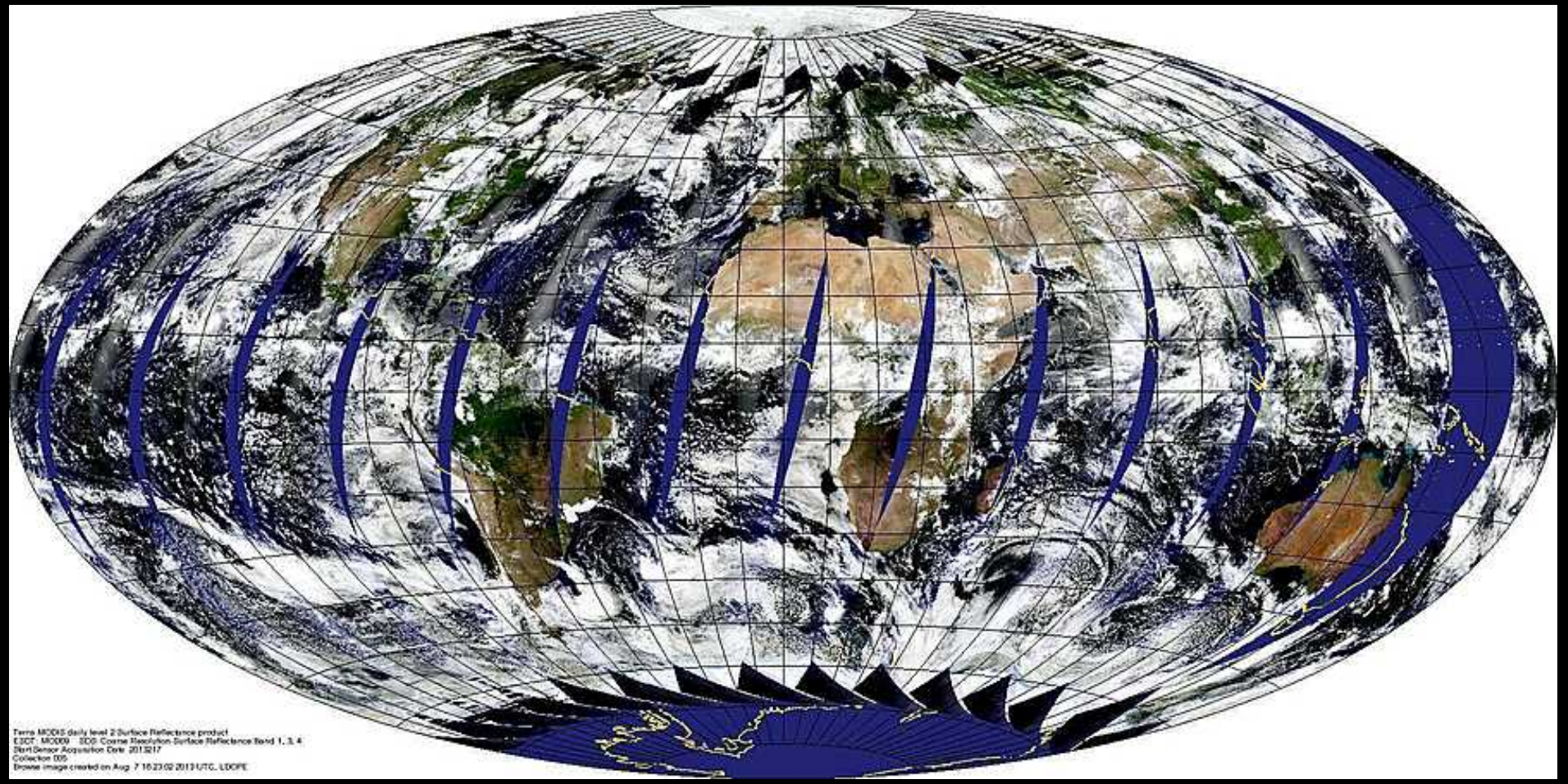
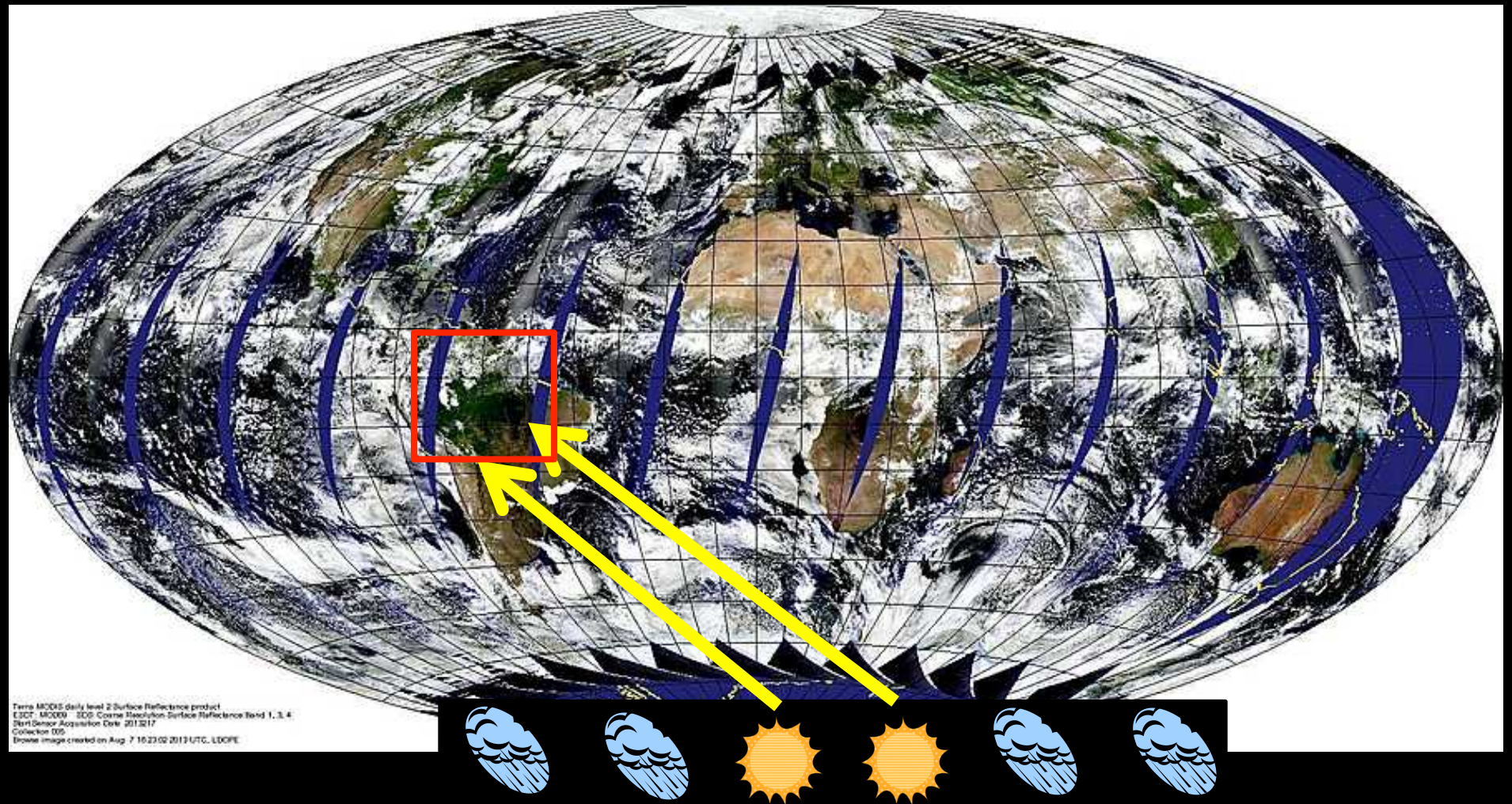


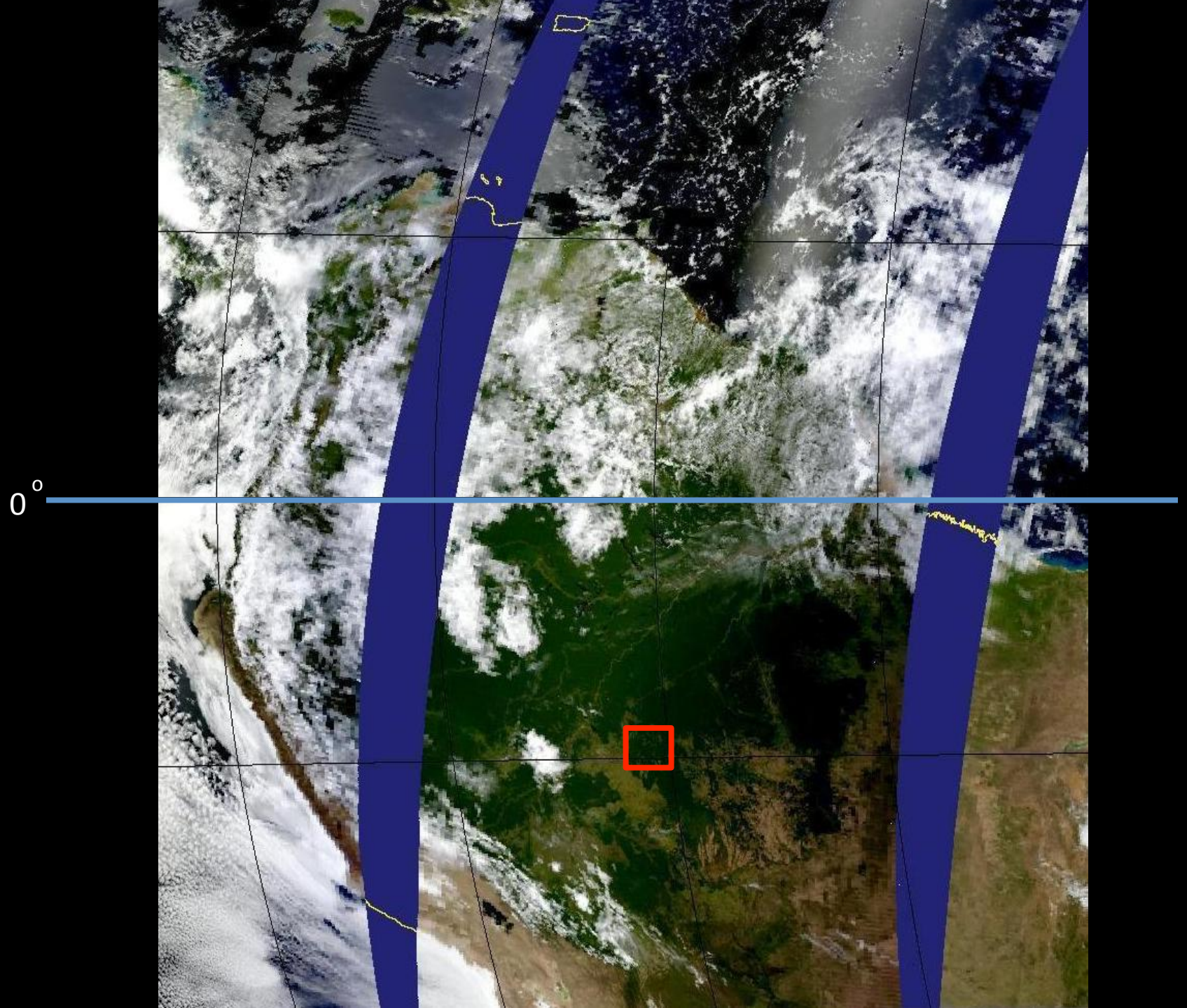
Total archive of 30-m observations, average number of images per year per scene

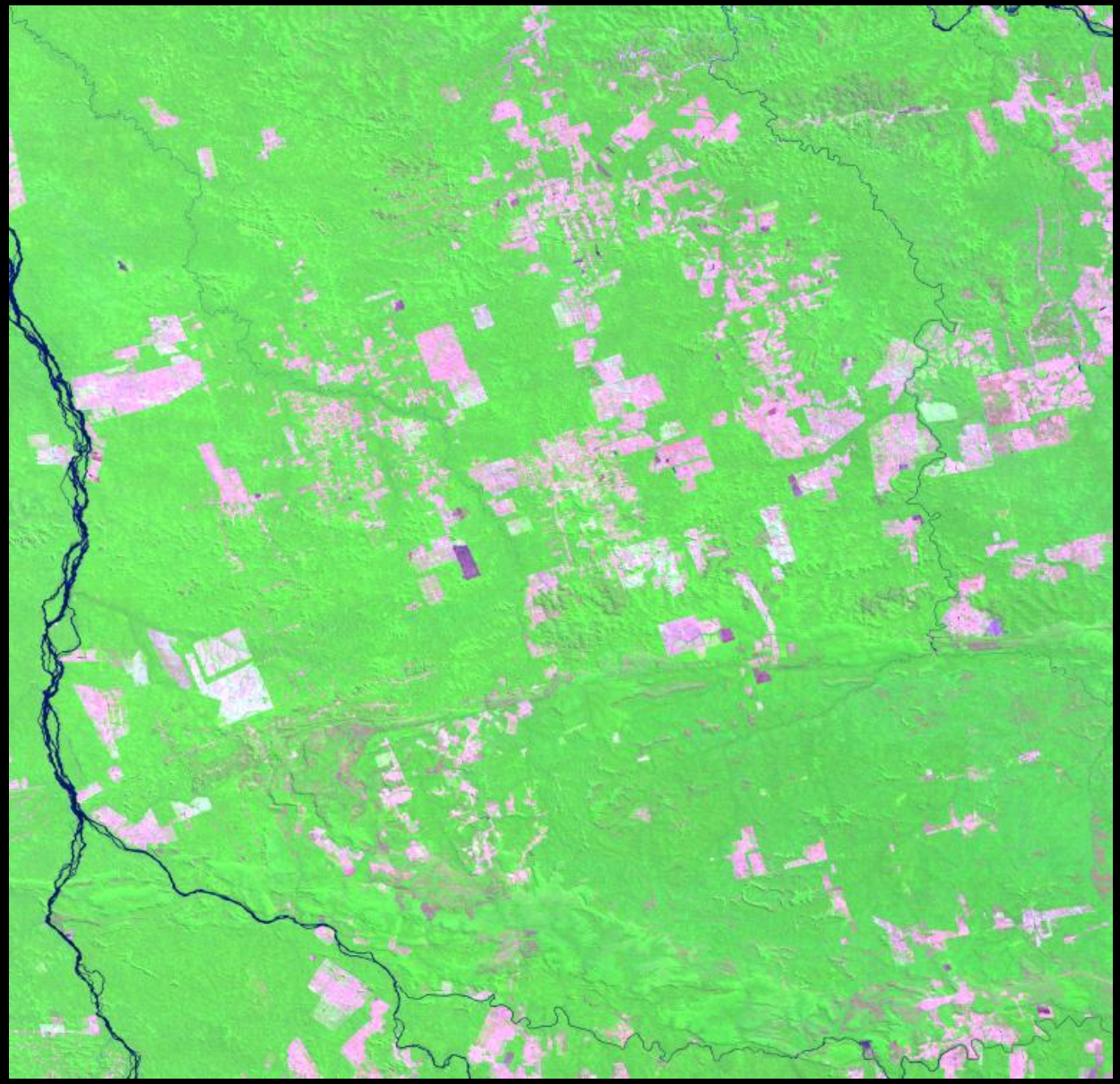
Daily MODIS image for August 5, 2013



Seasonally cloud-free window over the southern Amazon

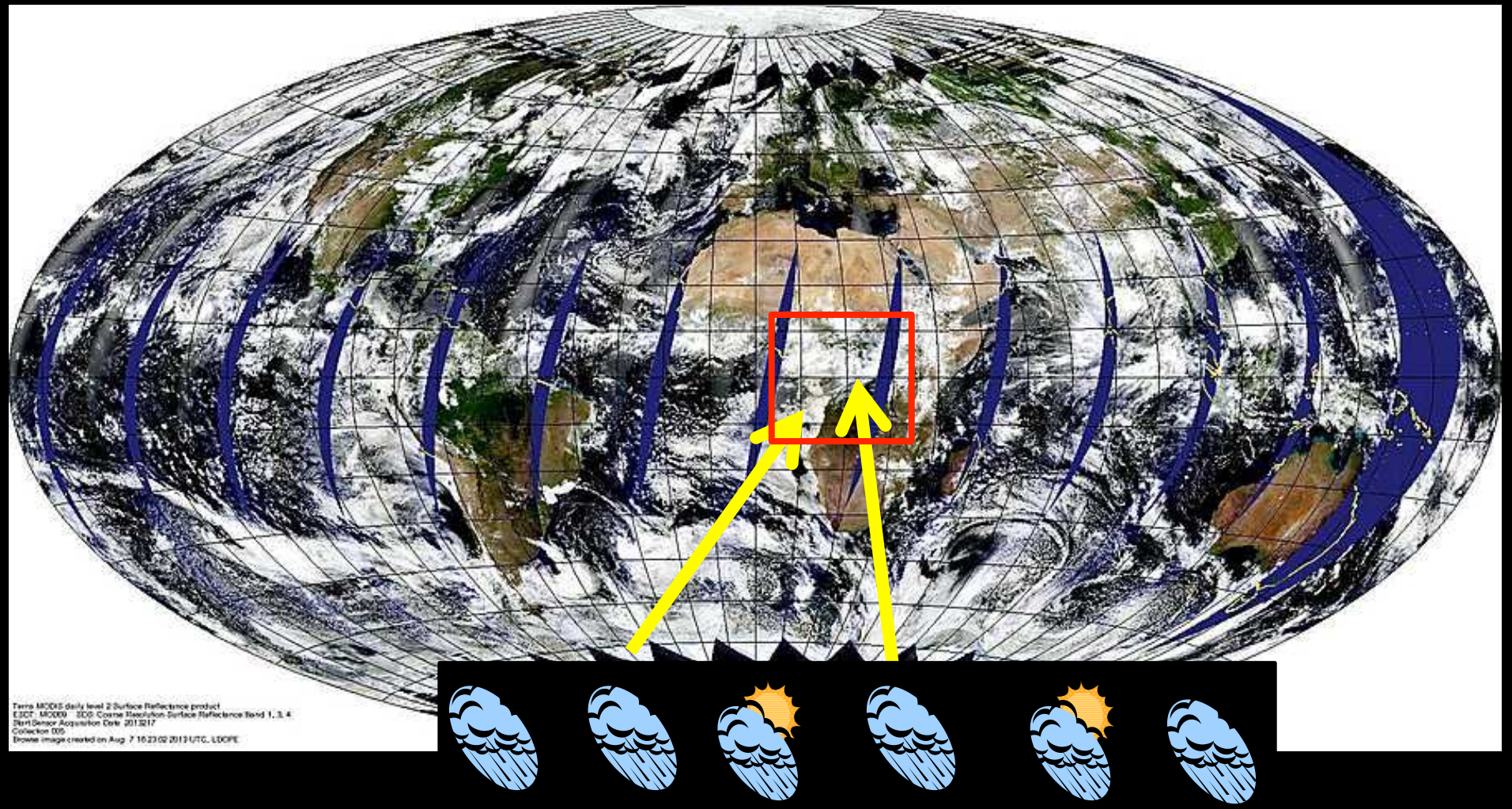


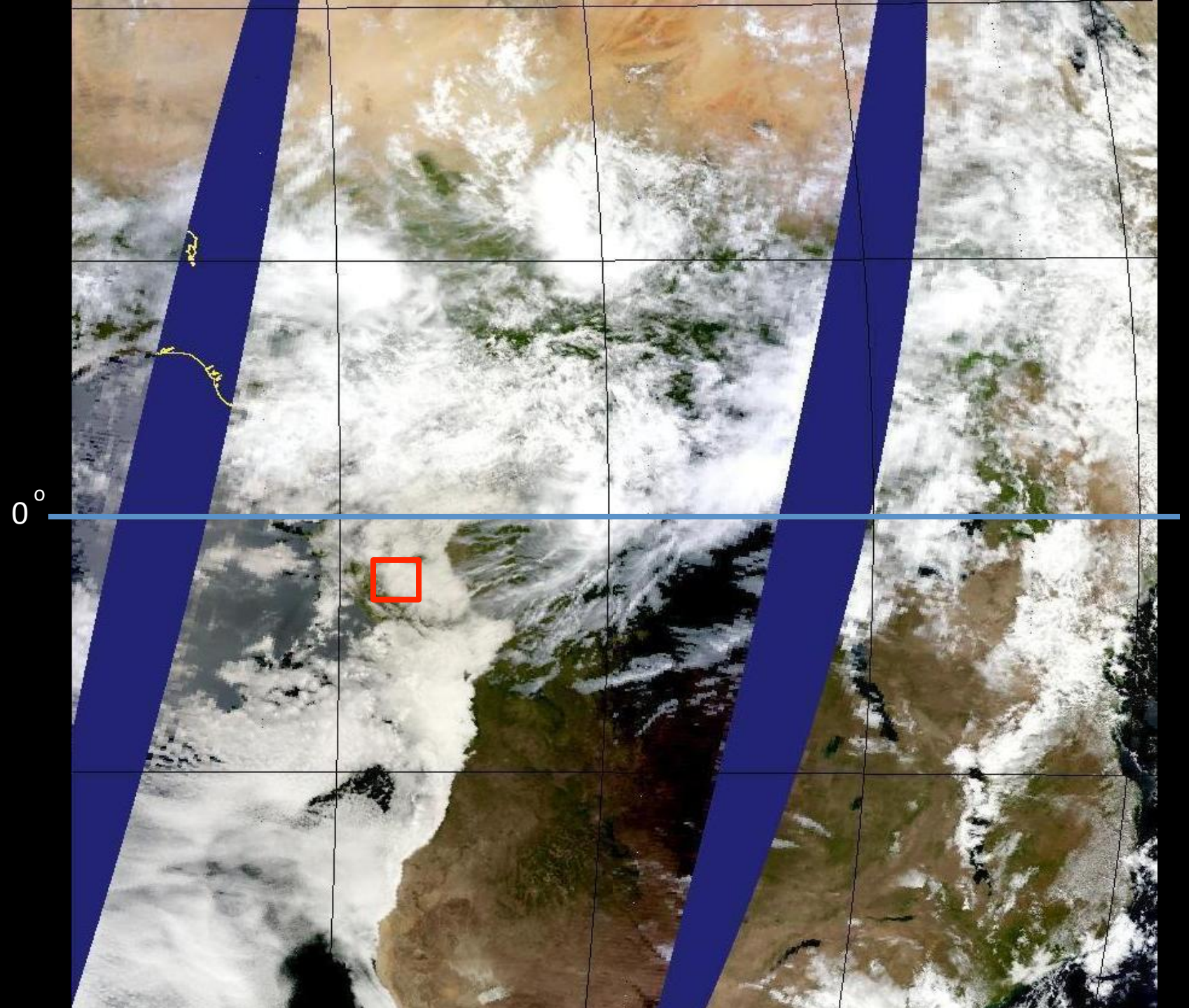

0 °

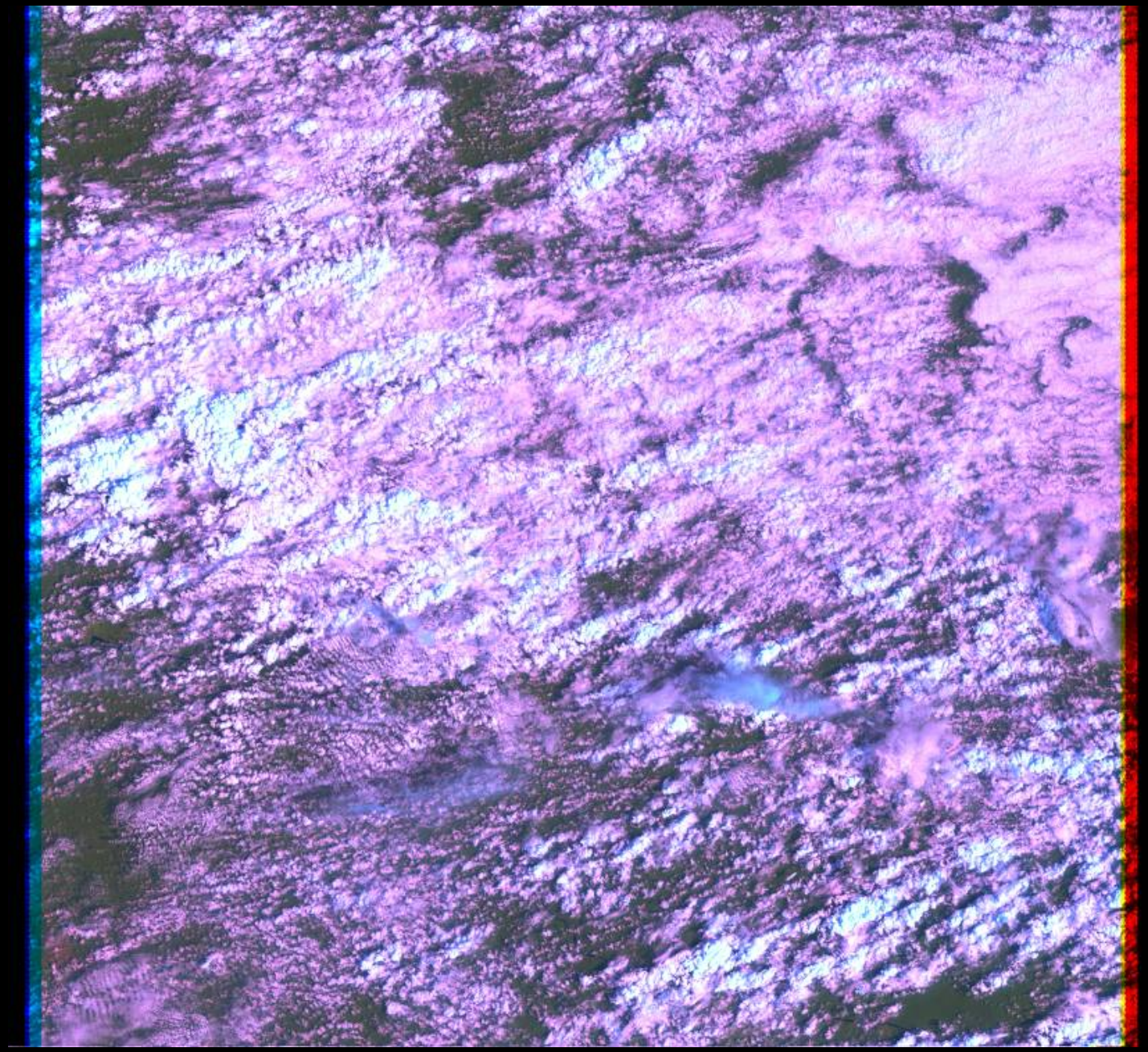


2000 day 208

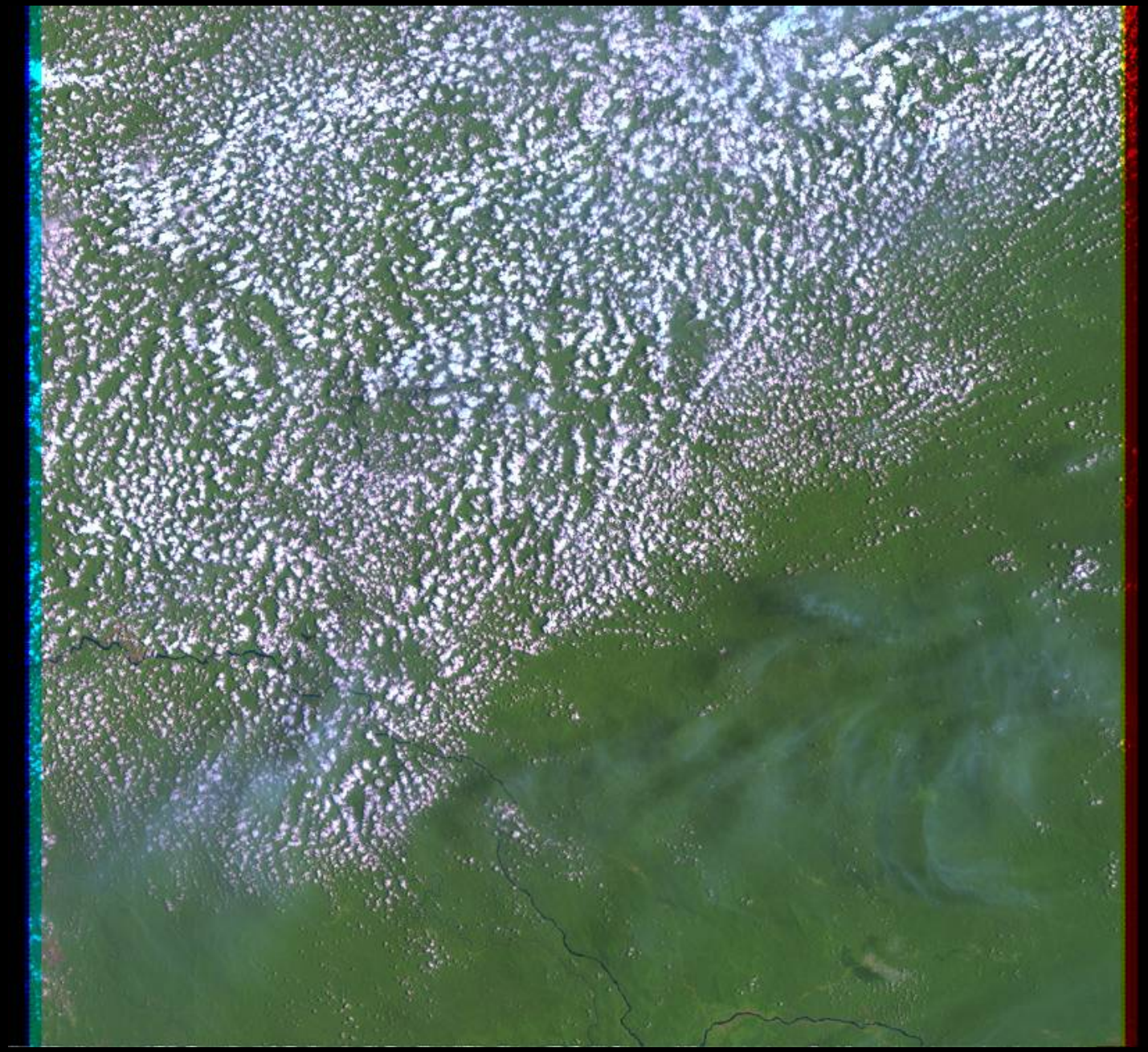
Conversely, Central Africa is persistently cloudy



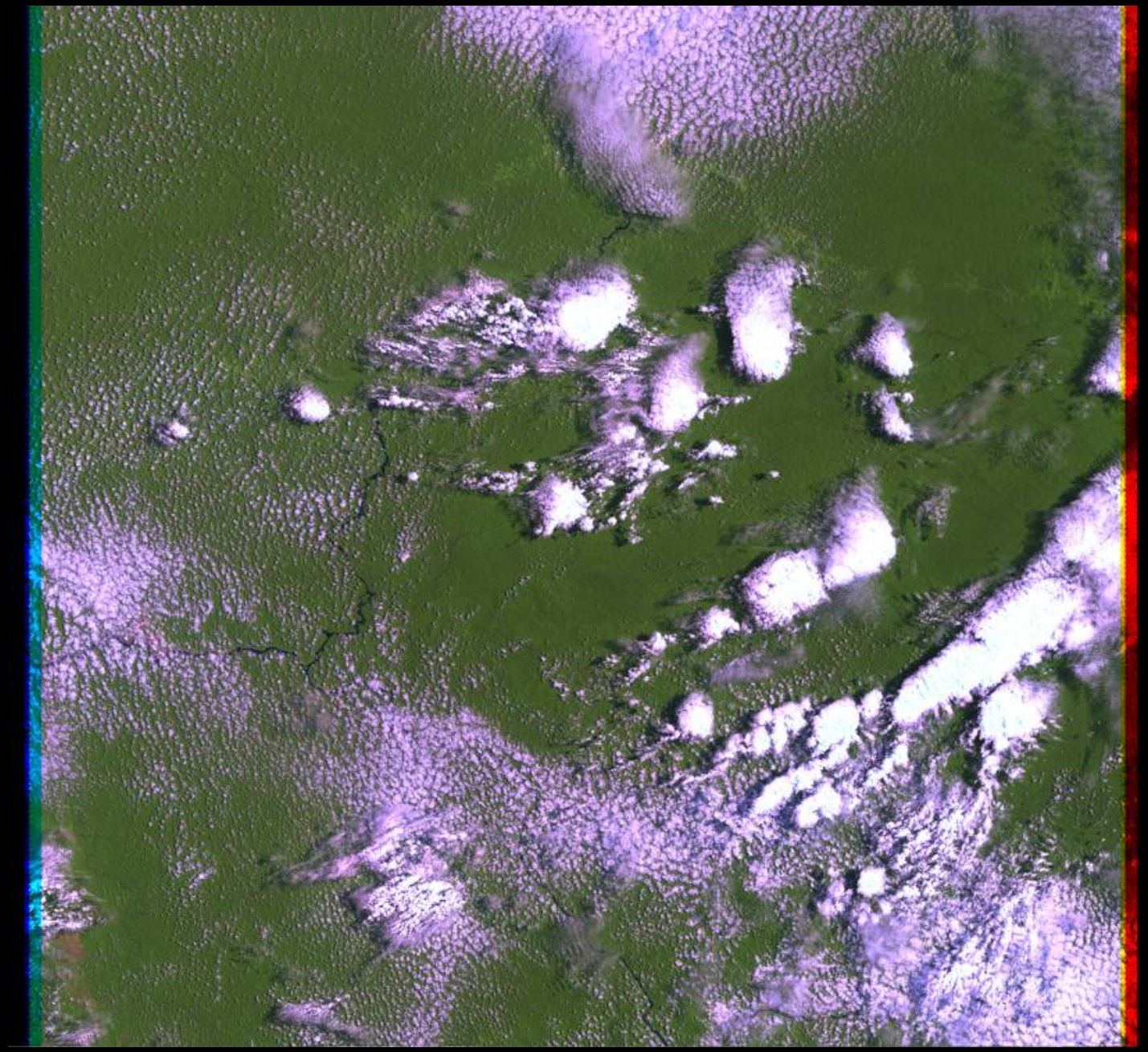

0 °



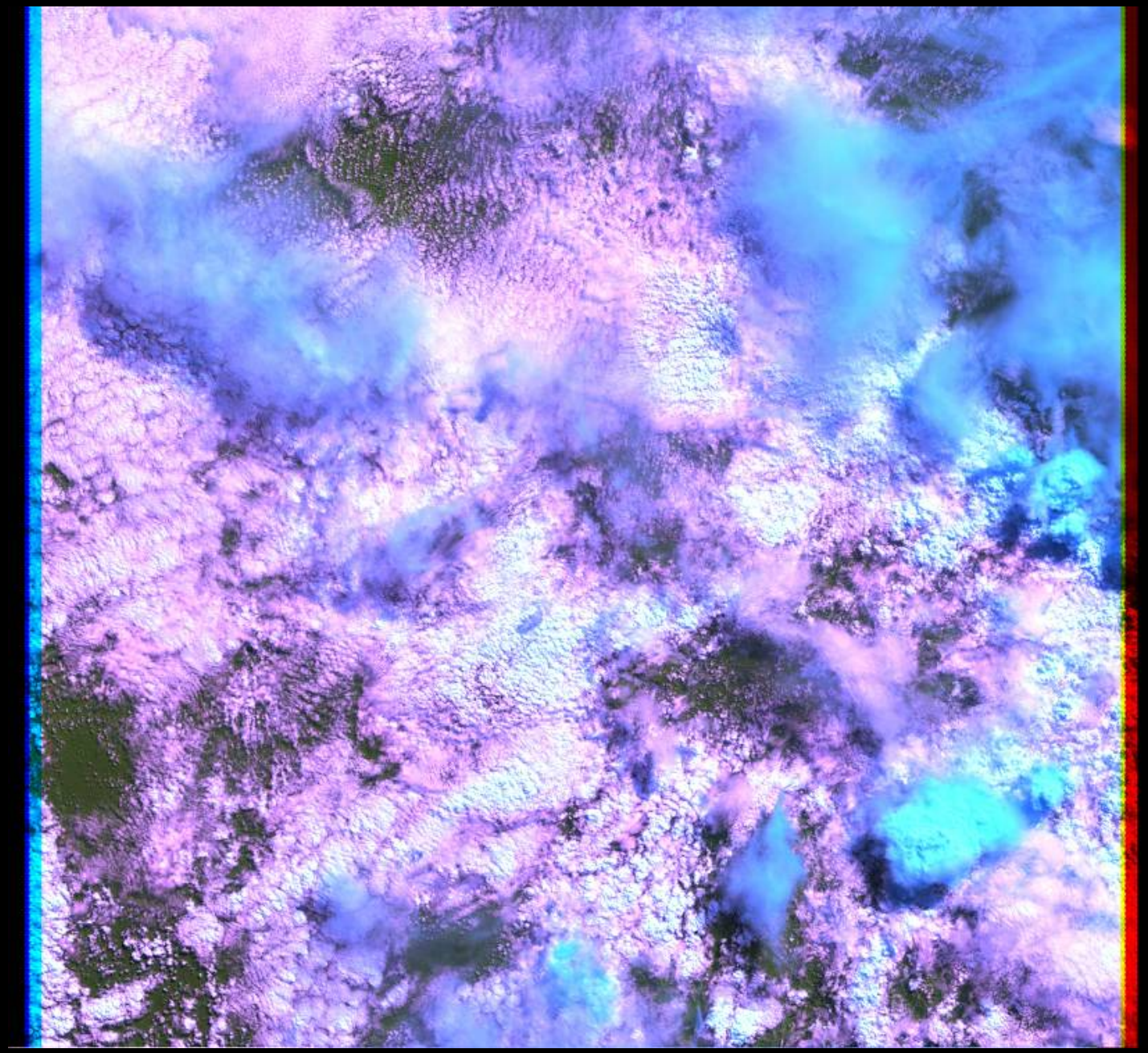
2000 day 36



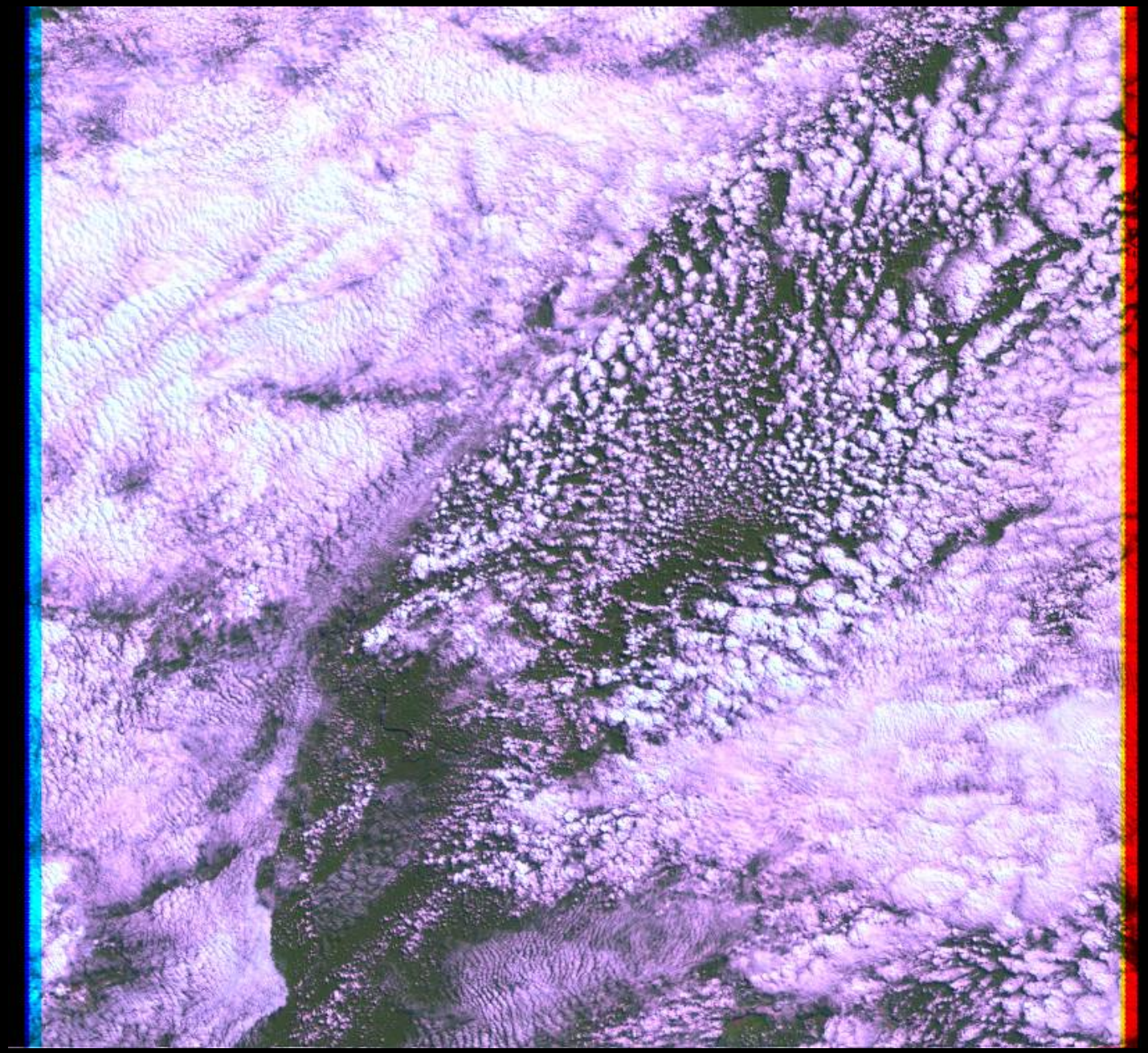
2000 day 68



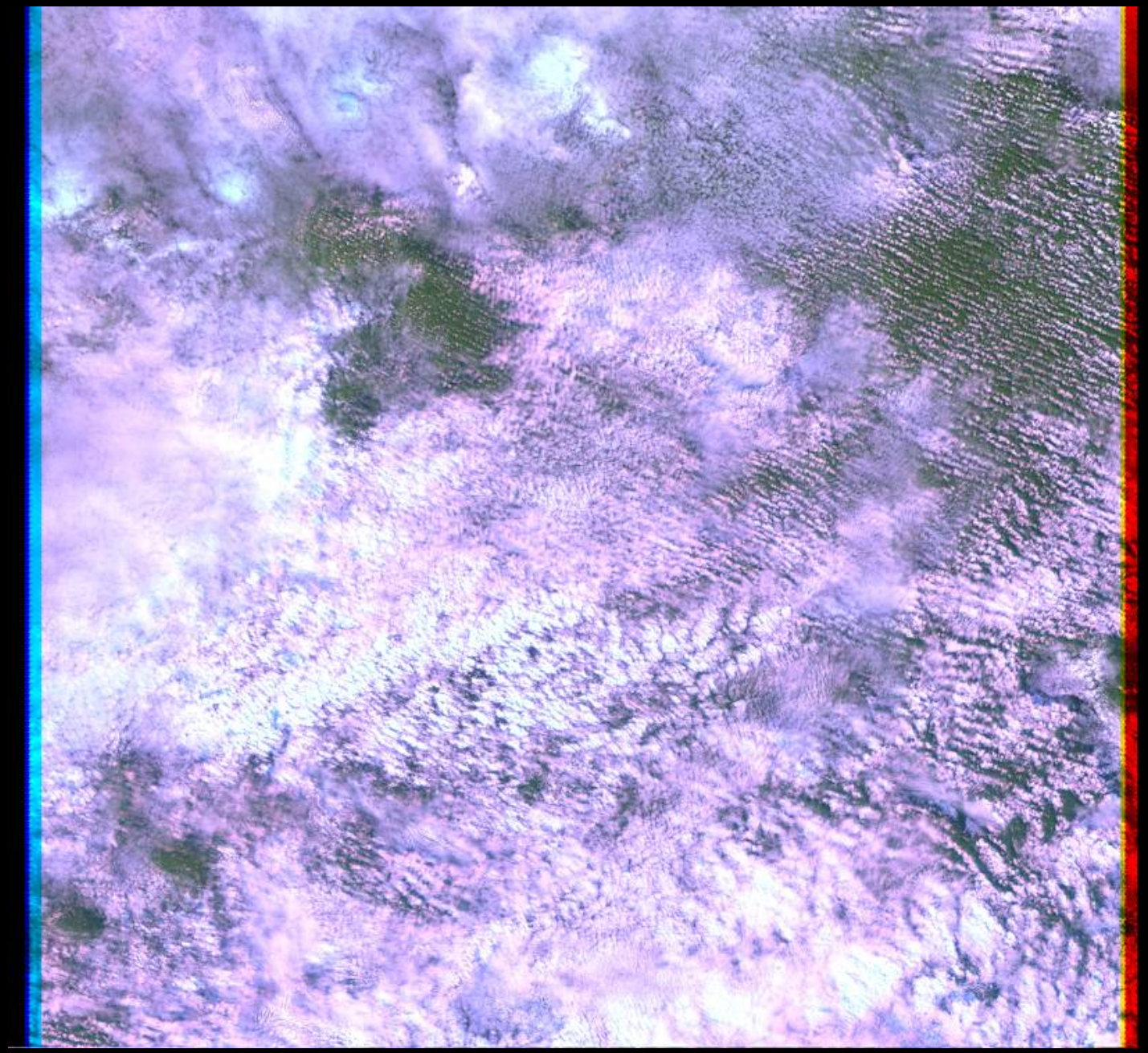
2000 day 84



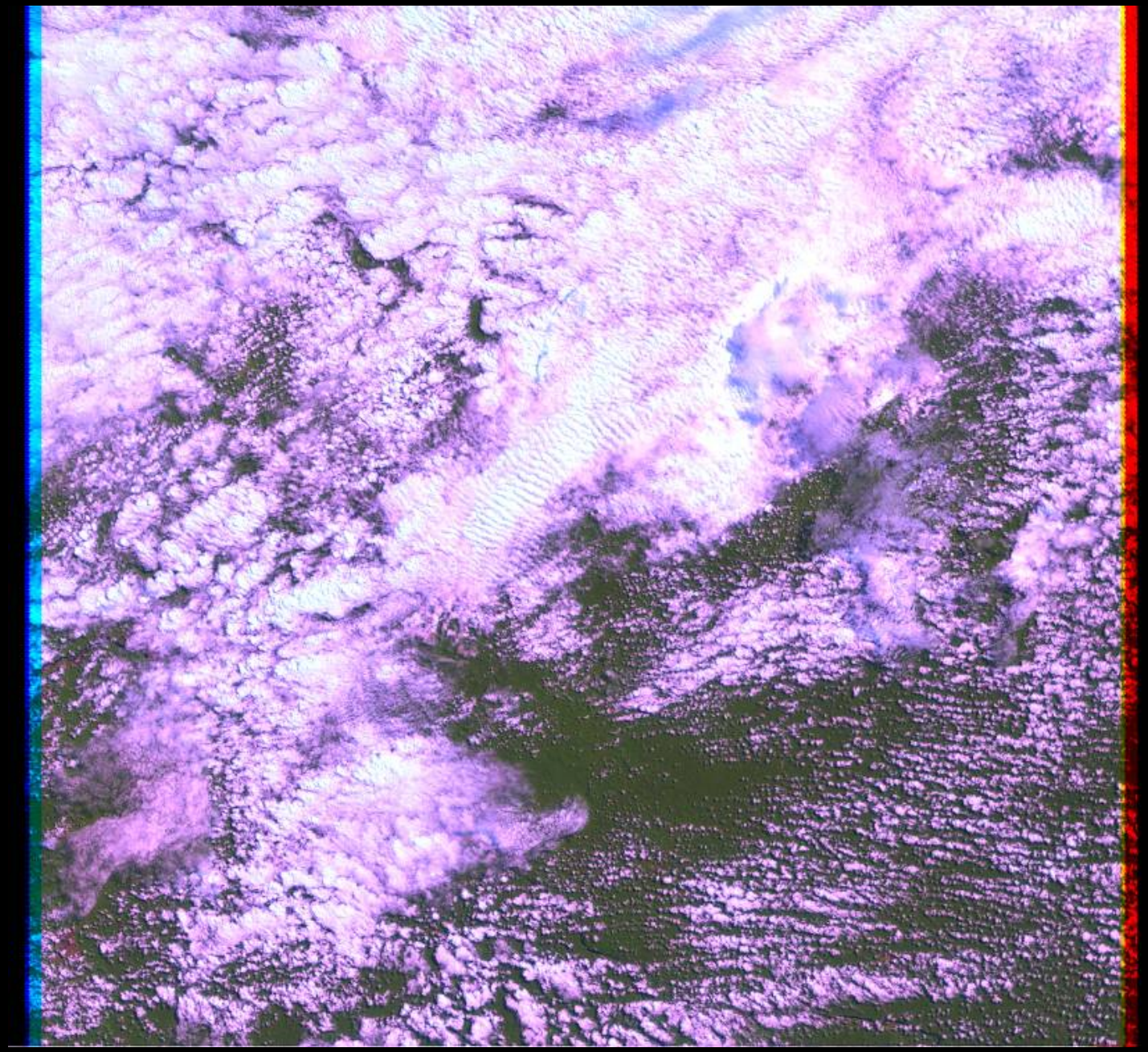
2000 day 180



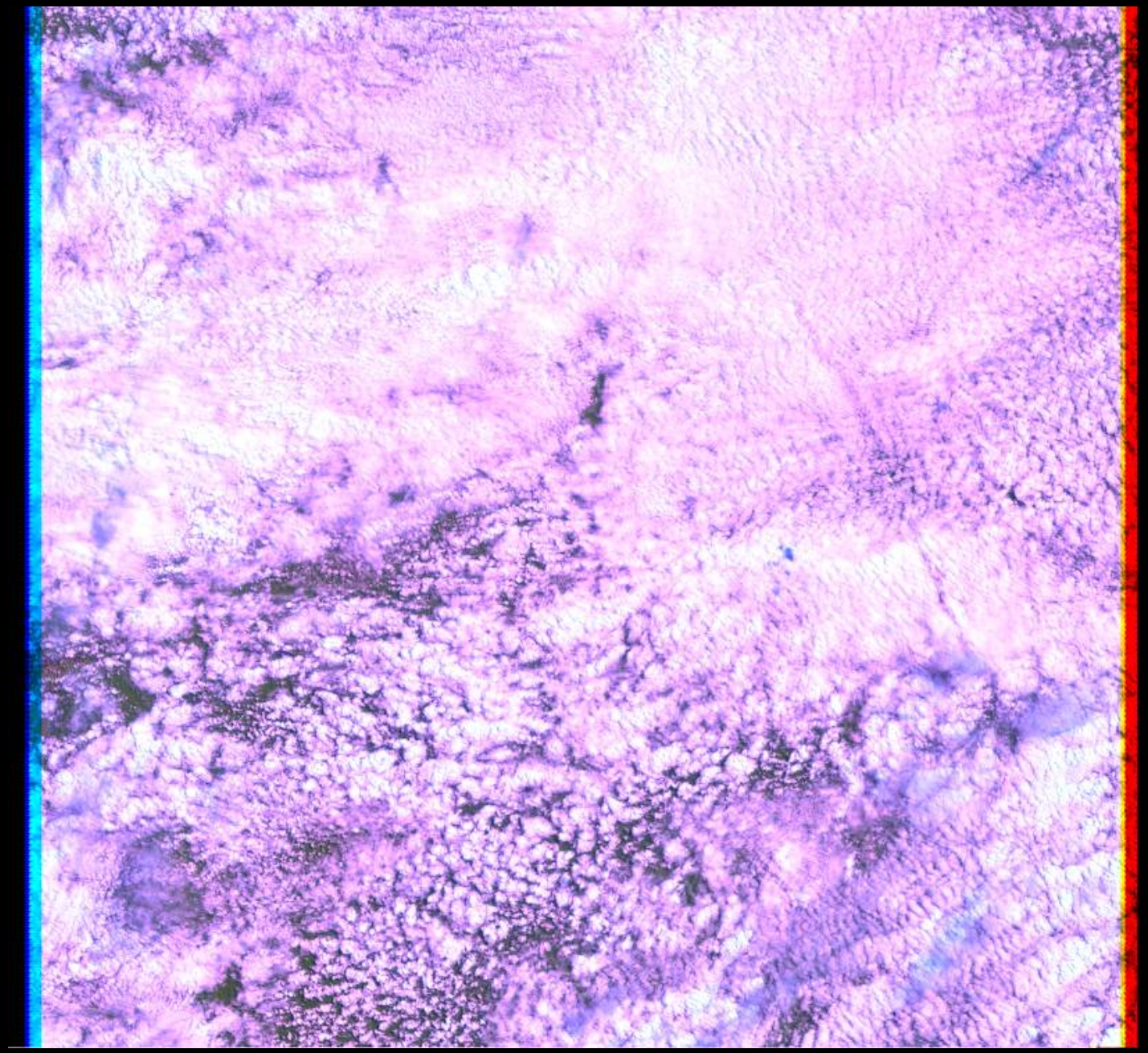
2000 day 196



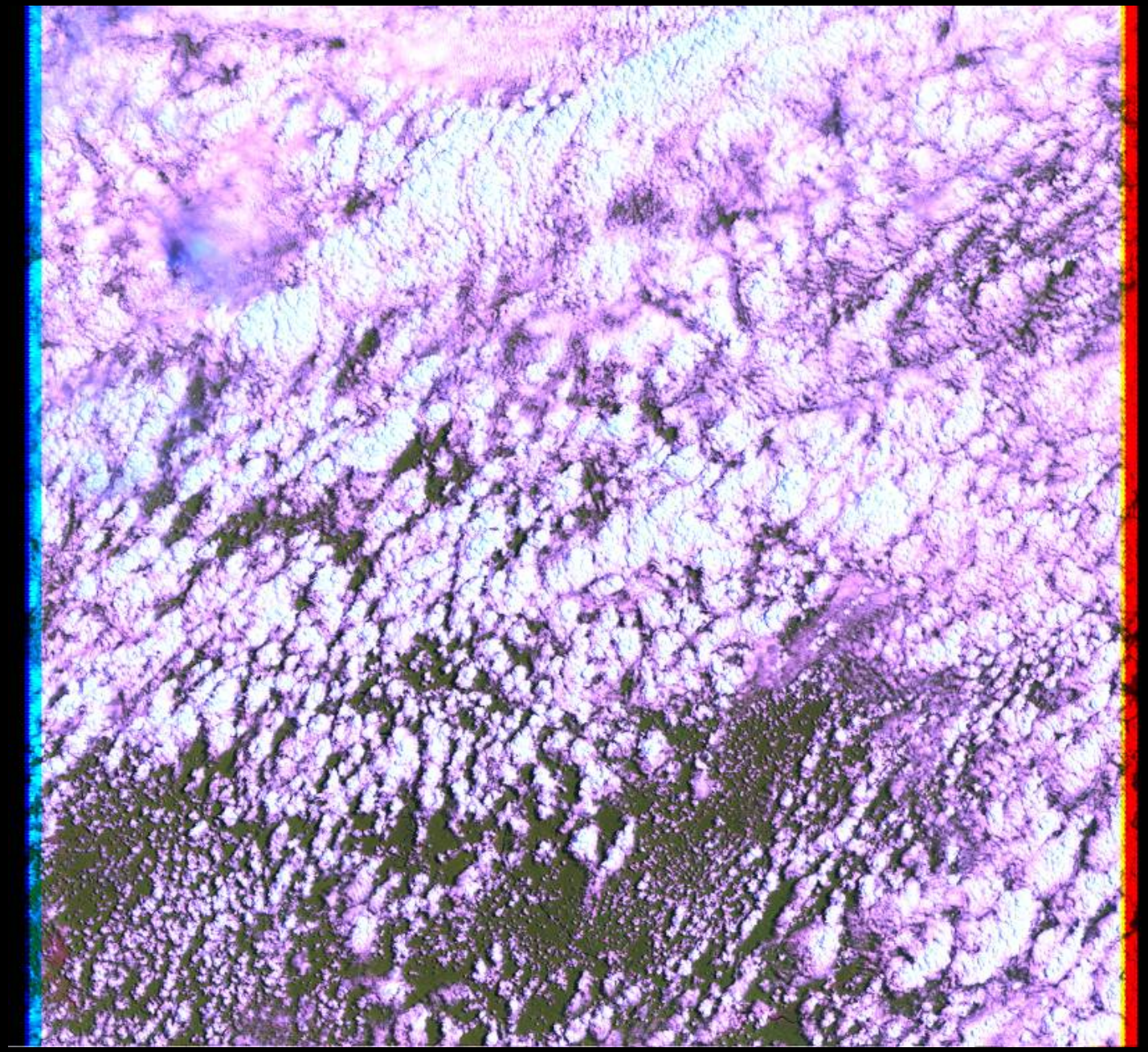
2000 day 212



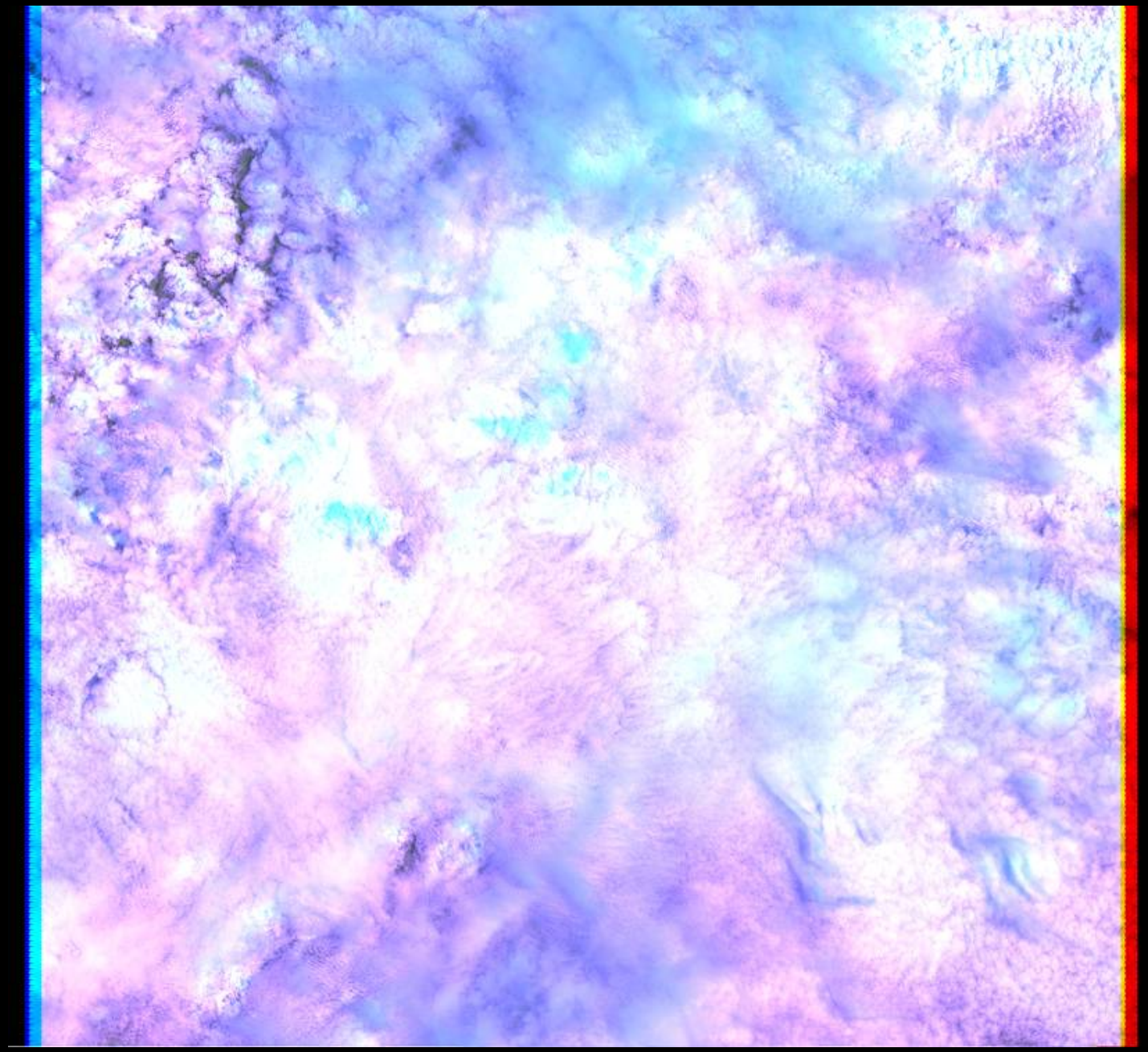
2000 day 228



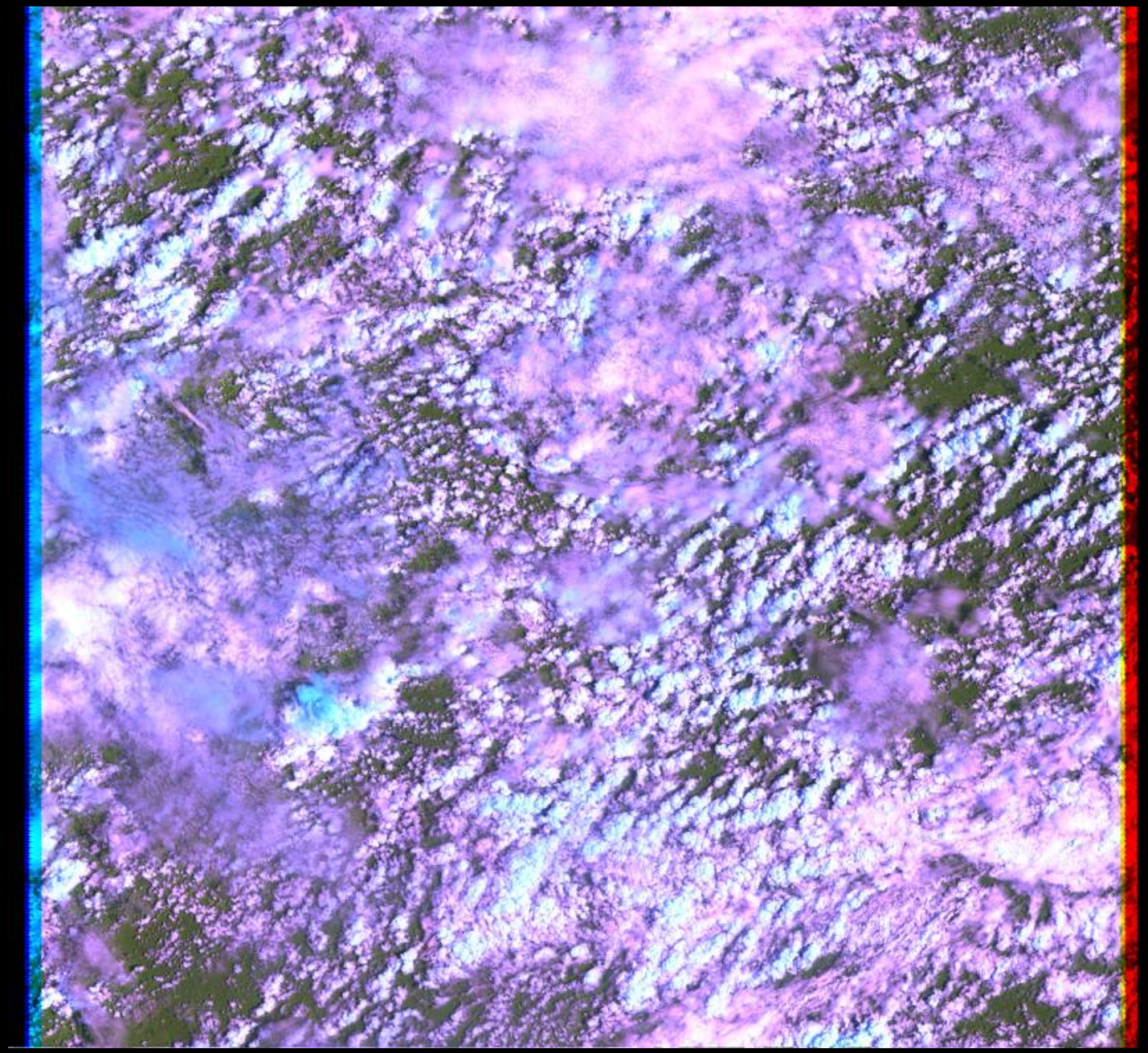
2000 day 244



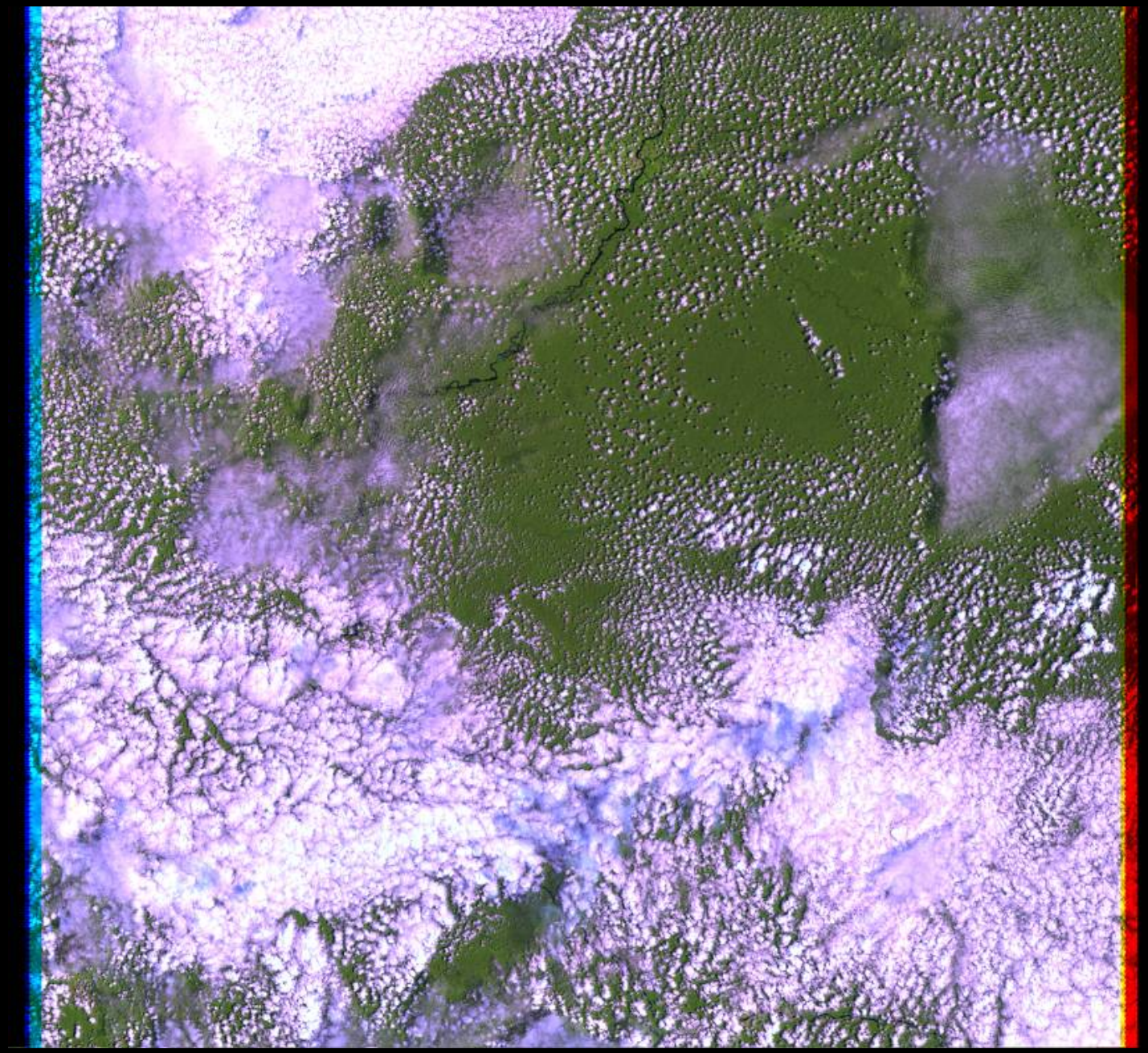
2000 day 260



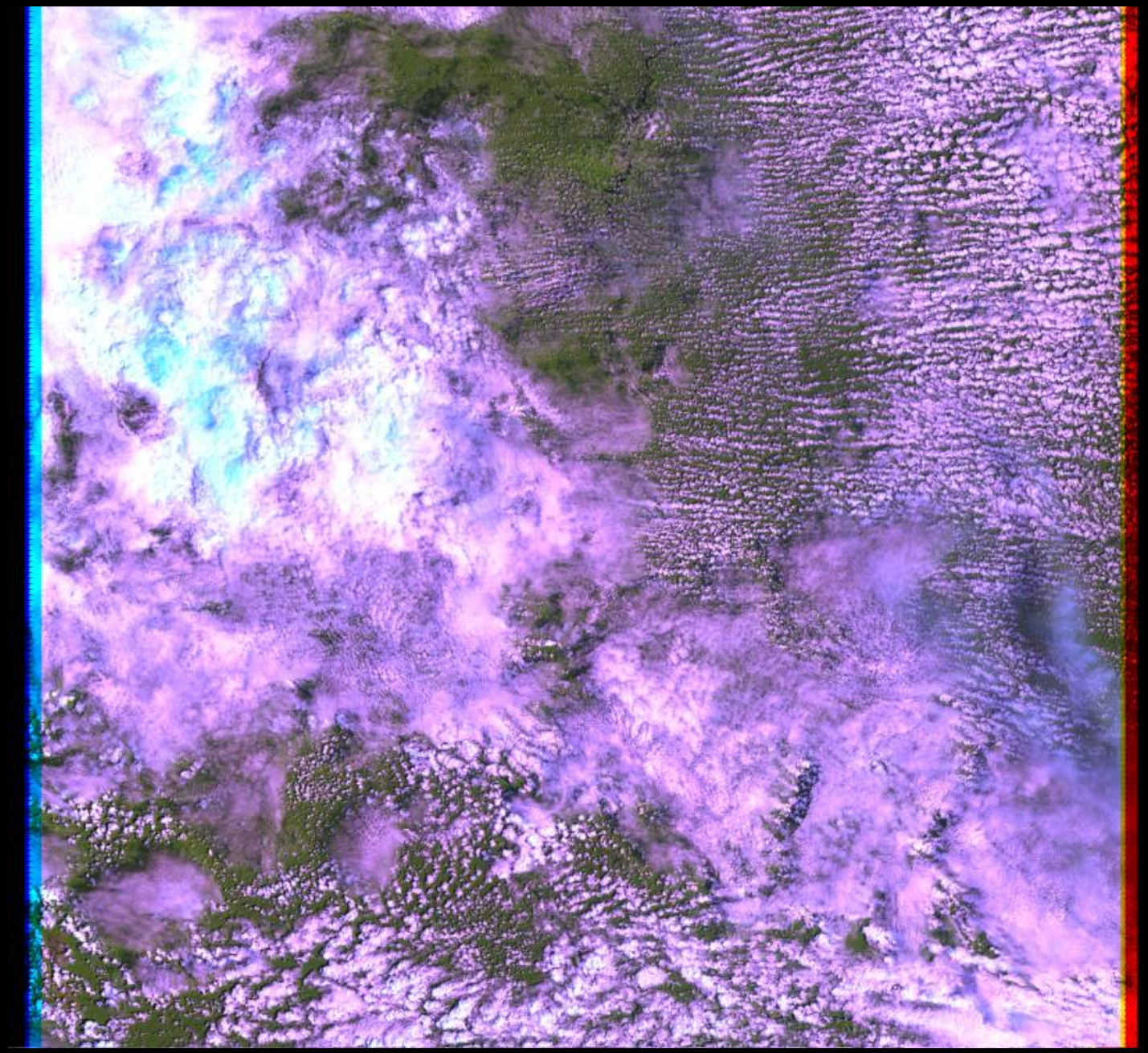
2000 day 276



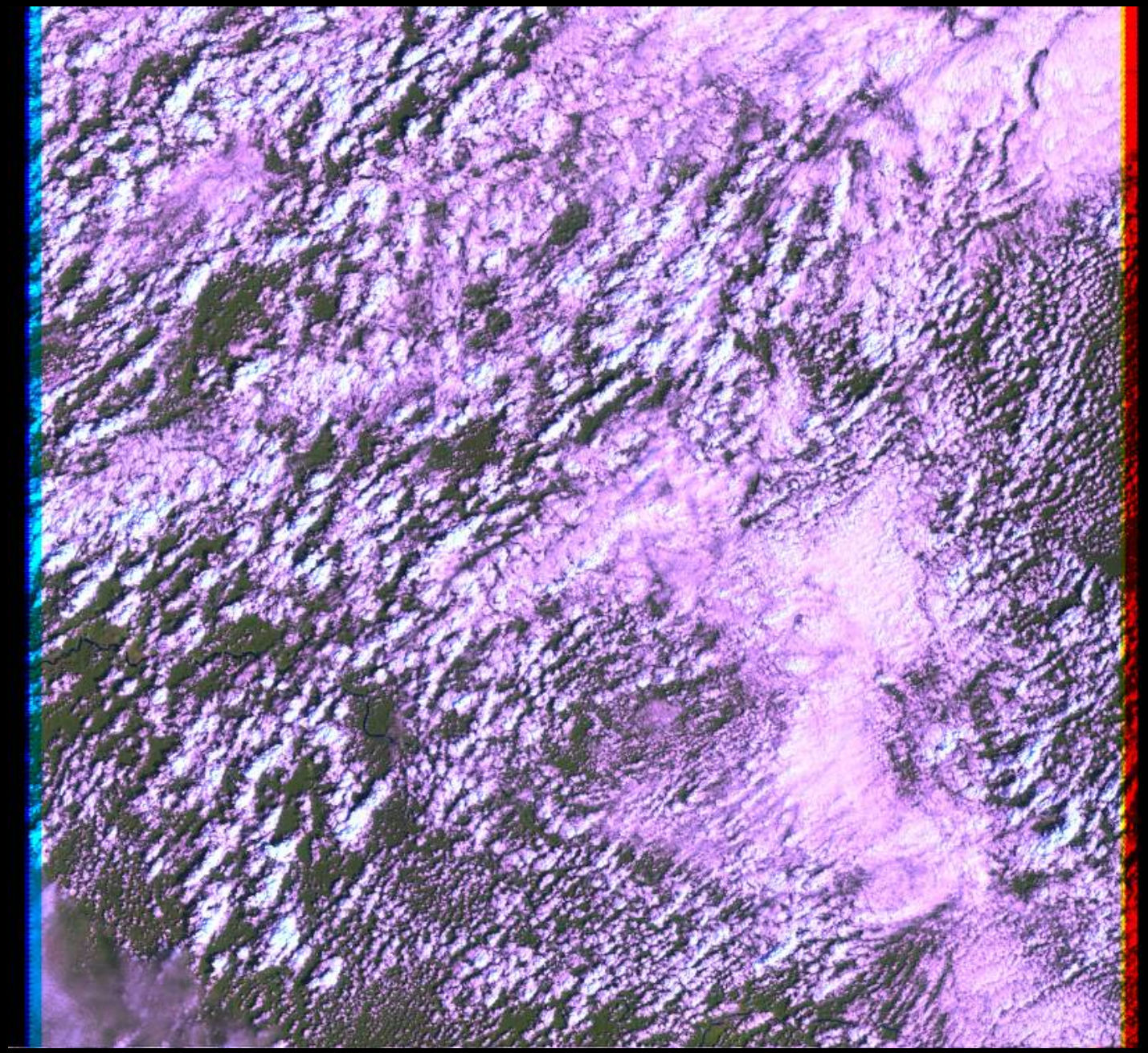
2000 day 292



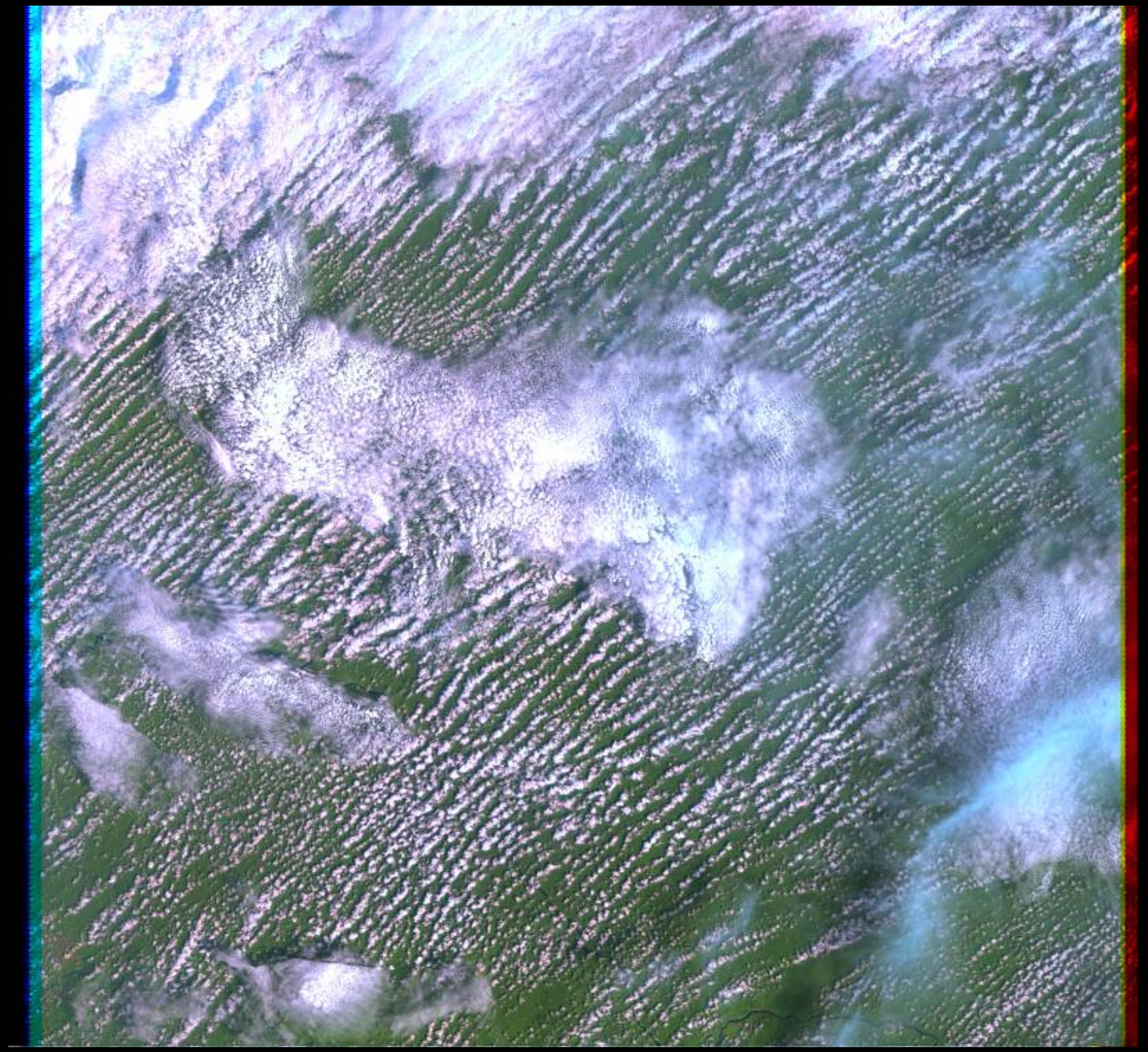
2000 day 308



2000 day 324

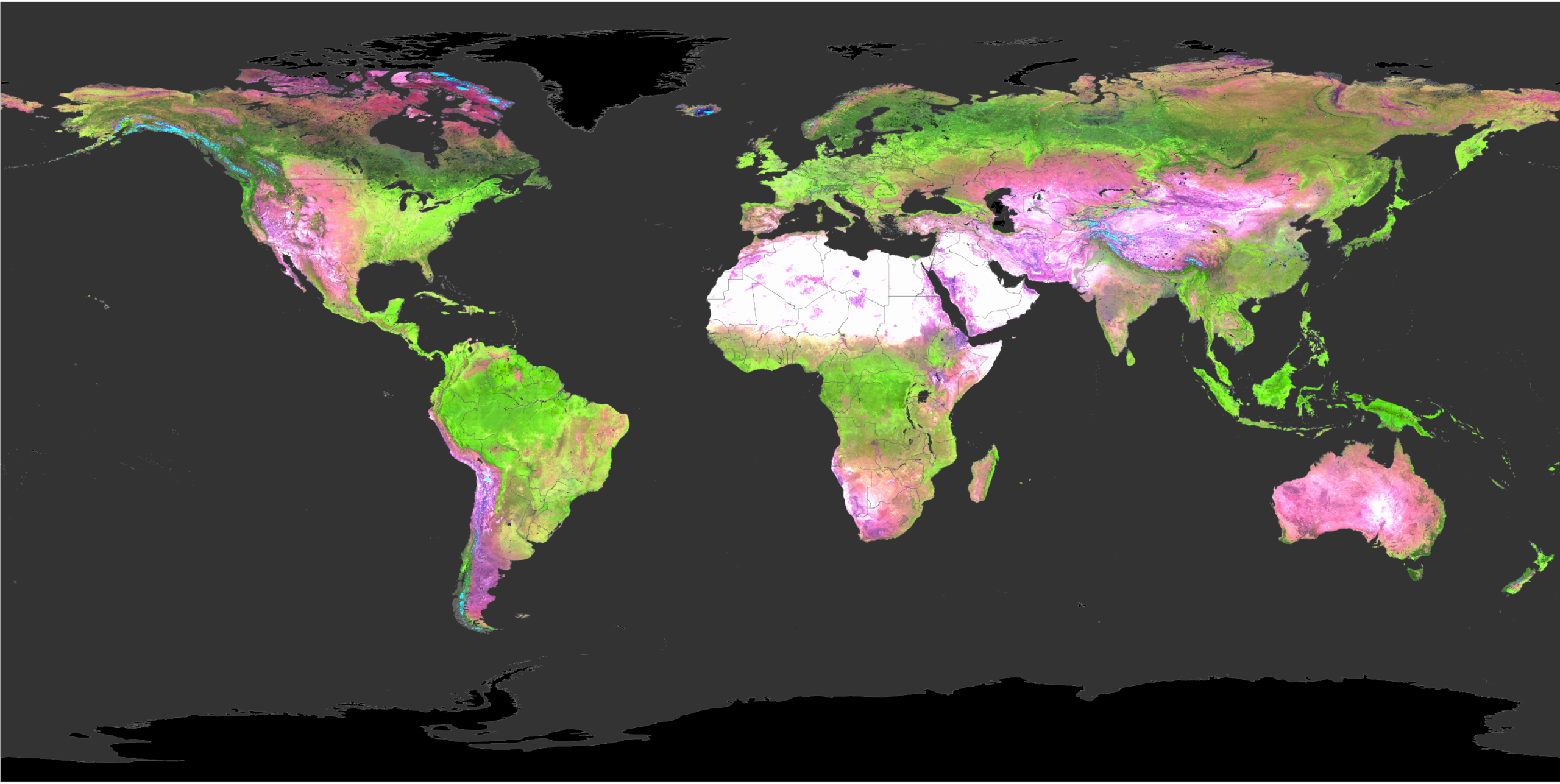


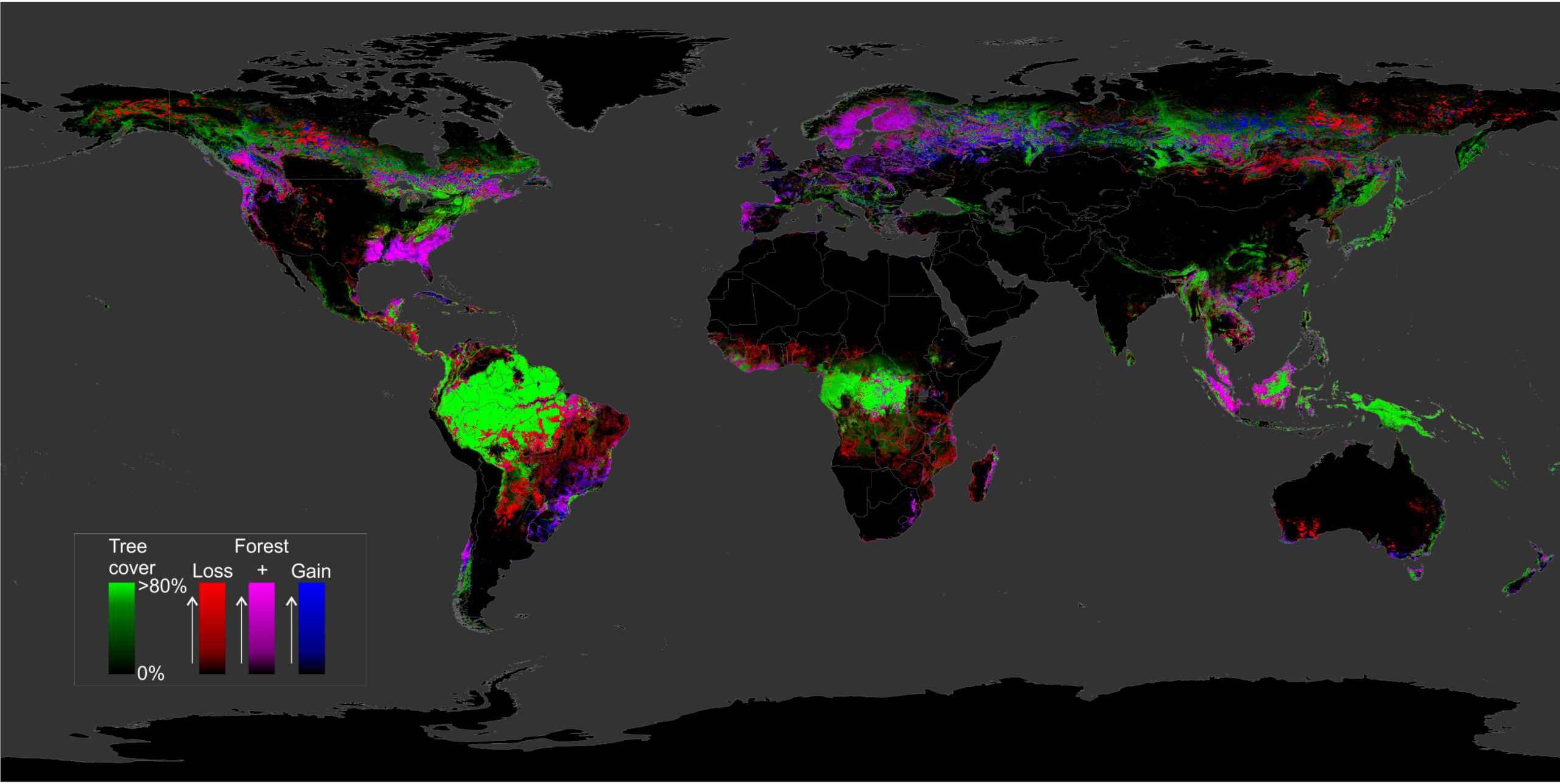
2000 day 340

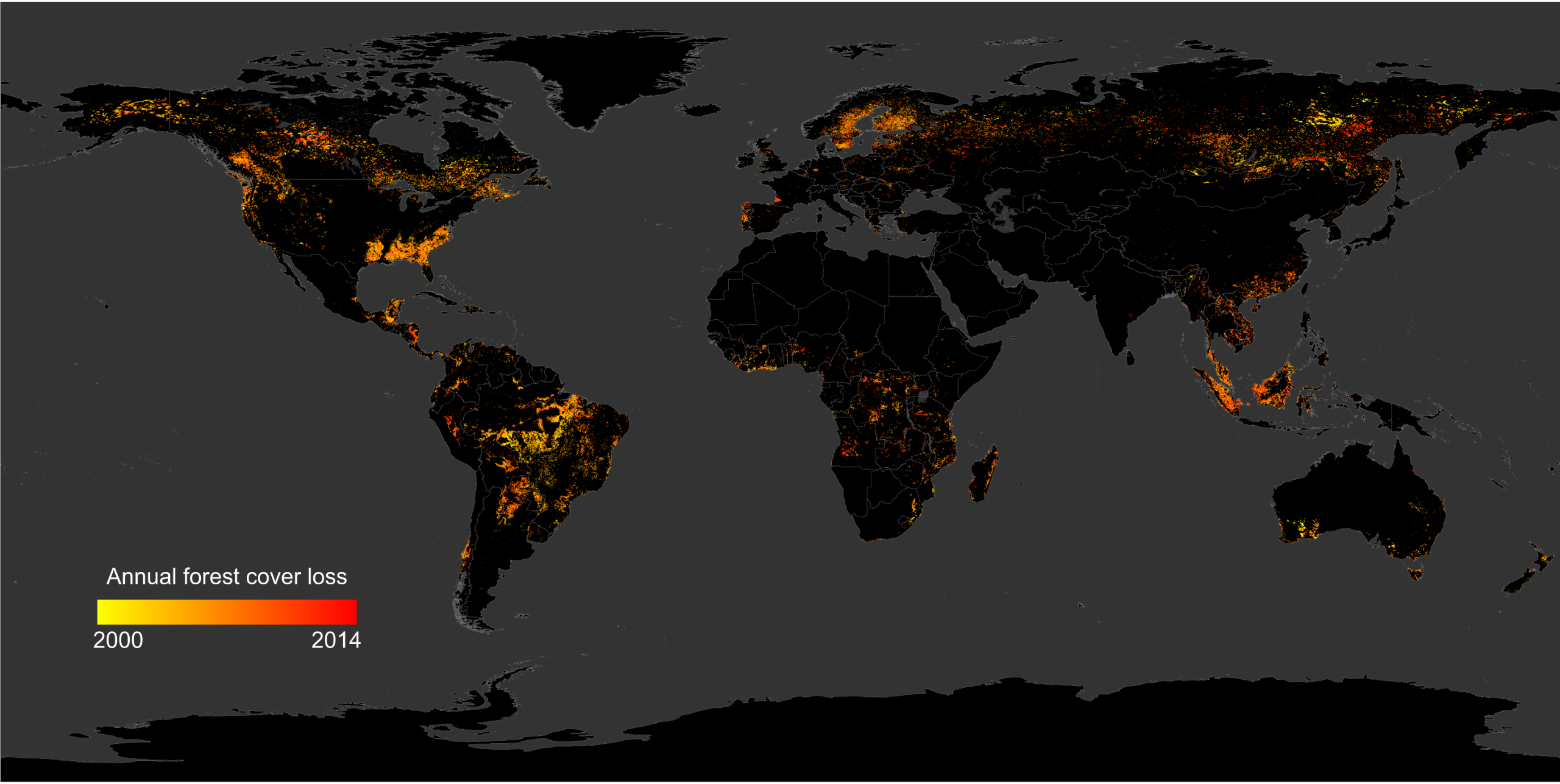


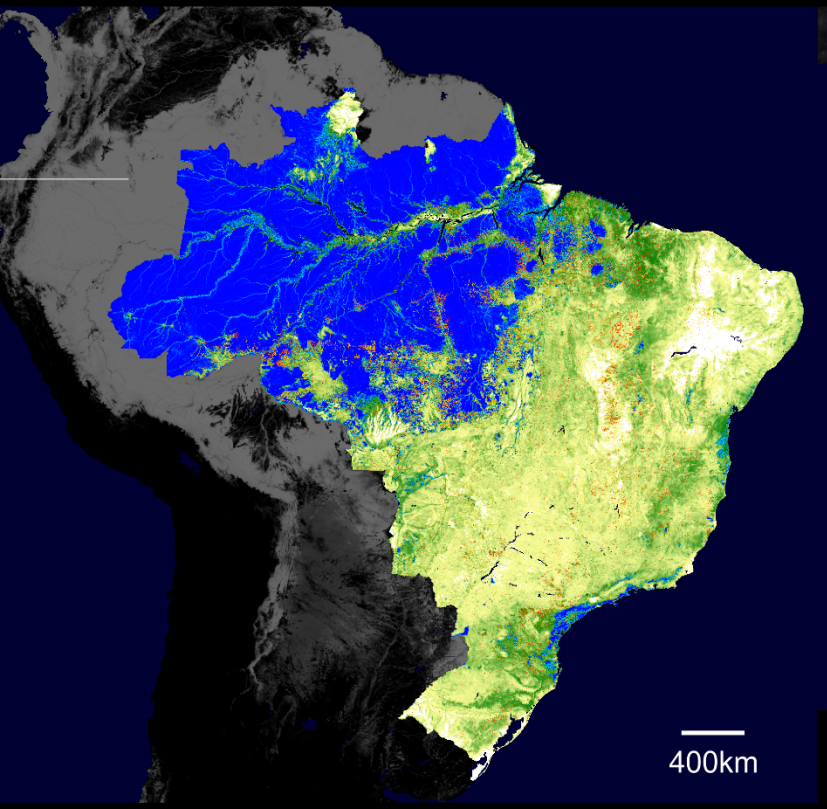
2000 day 356

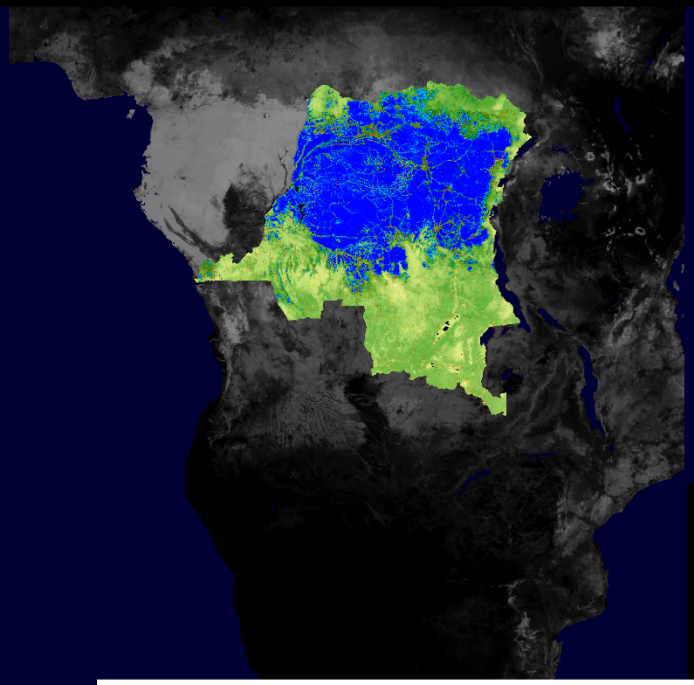
~2000 image composite

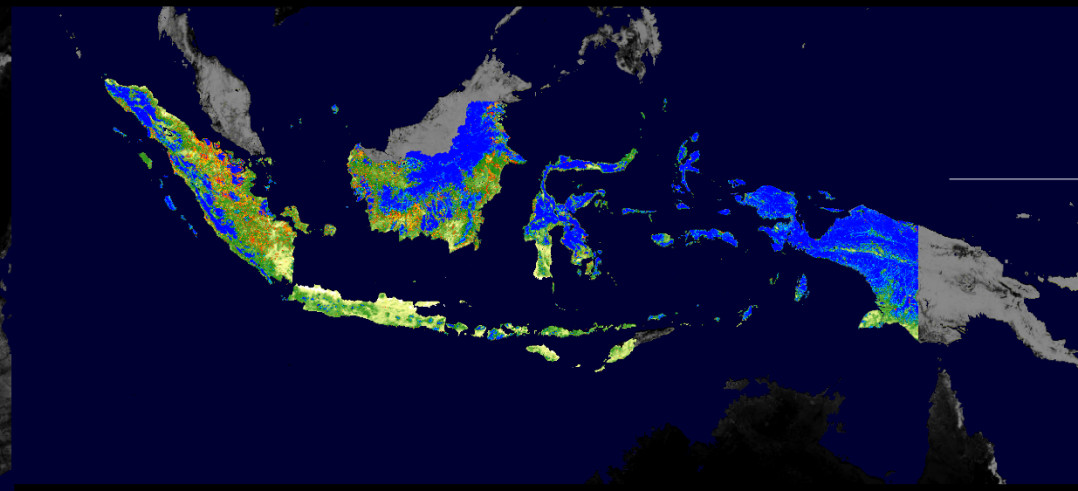



Tree
cover
>80%
0%
Forest
Loss
+
Gain


Annual forest cover loss
2000
2014



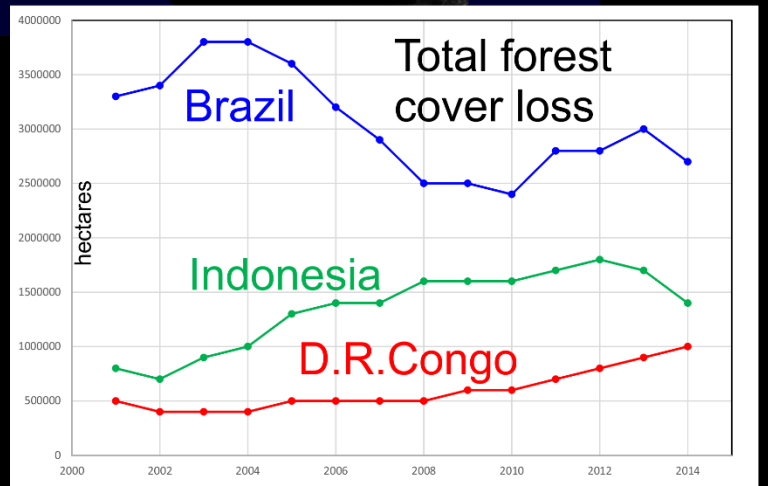


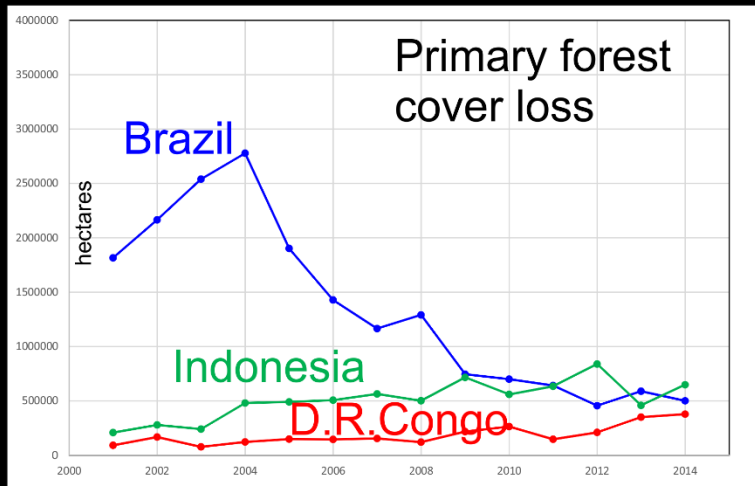


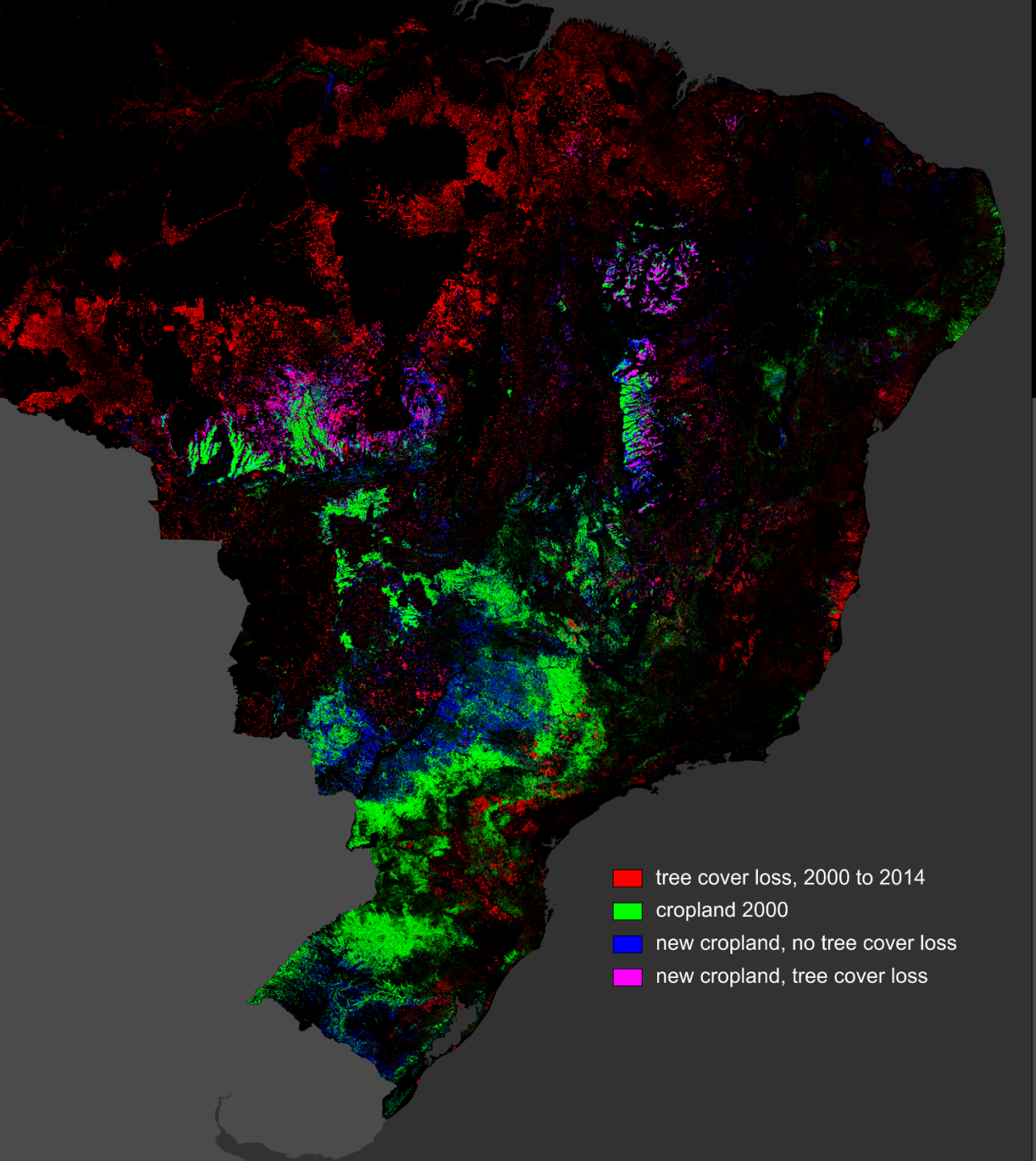
2000 percent tree cover: 100 / 0

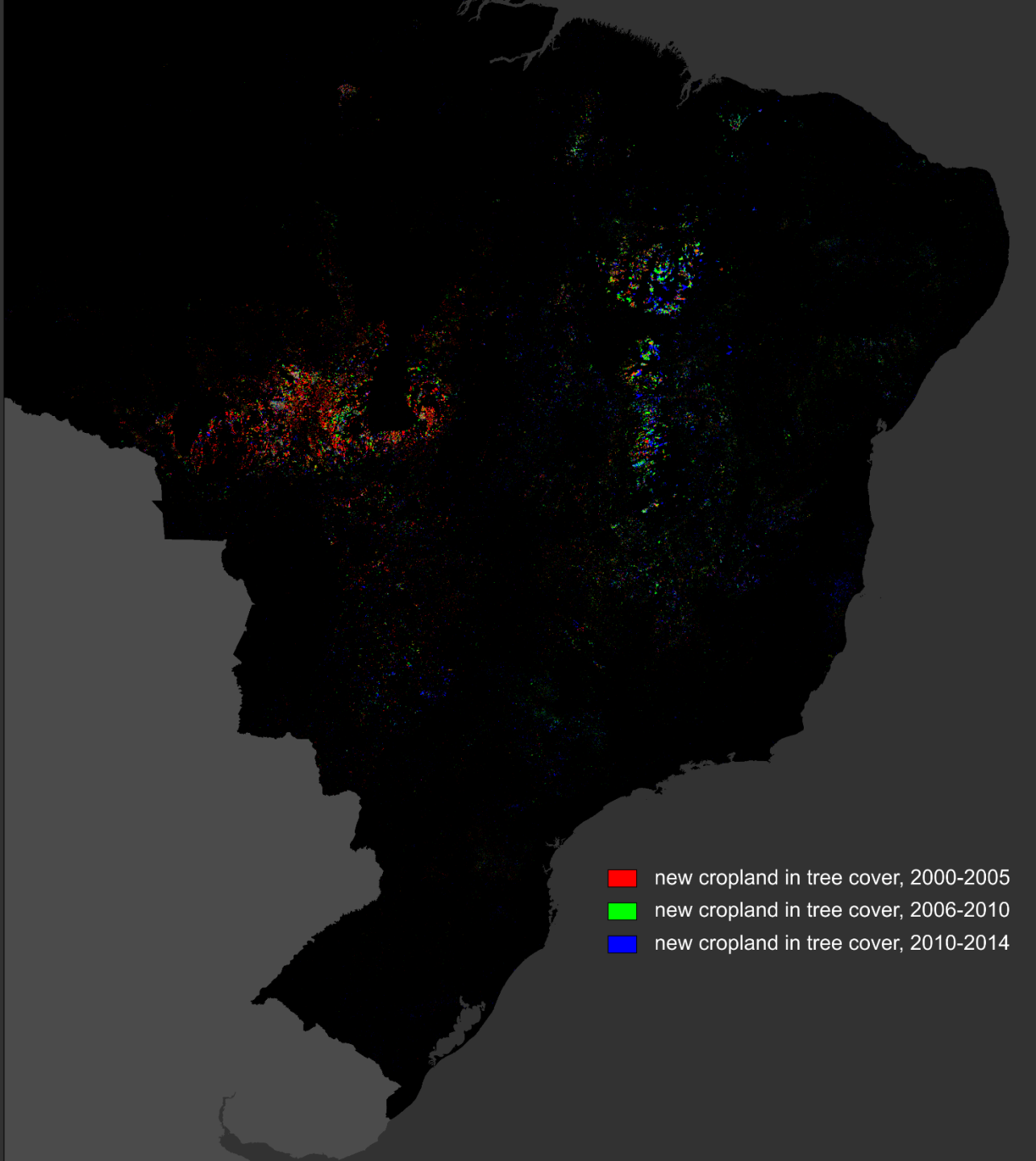
2000 primary forest cover extent: 100 / 10

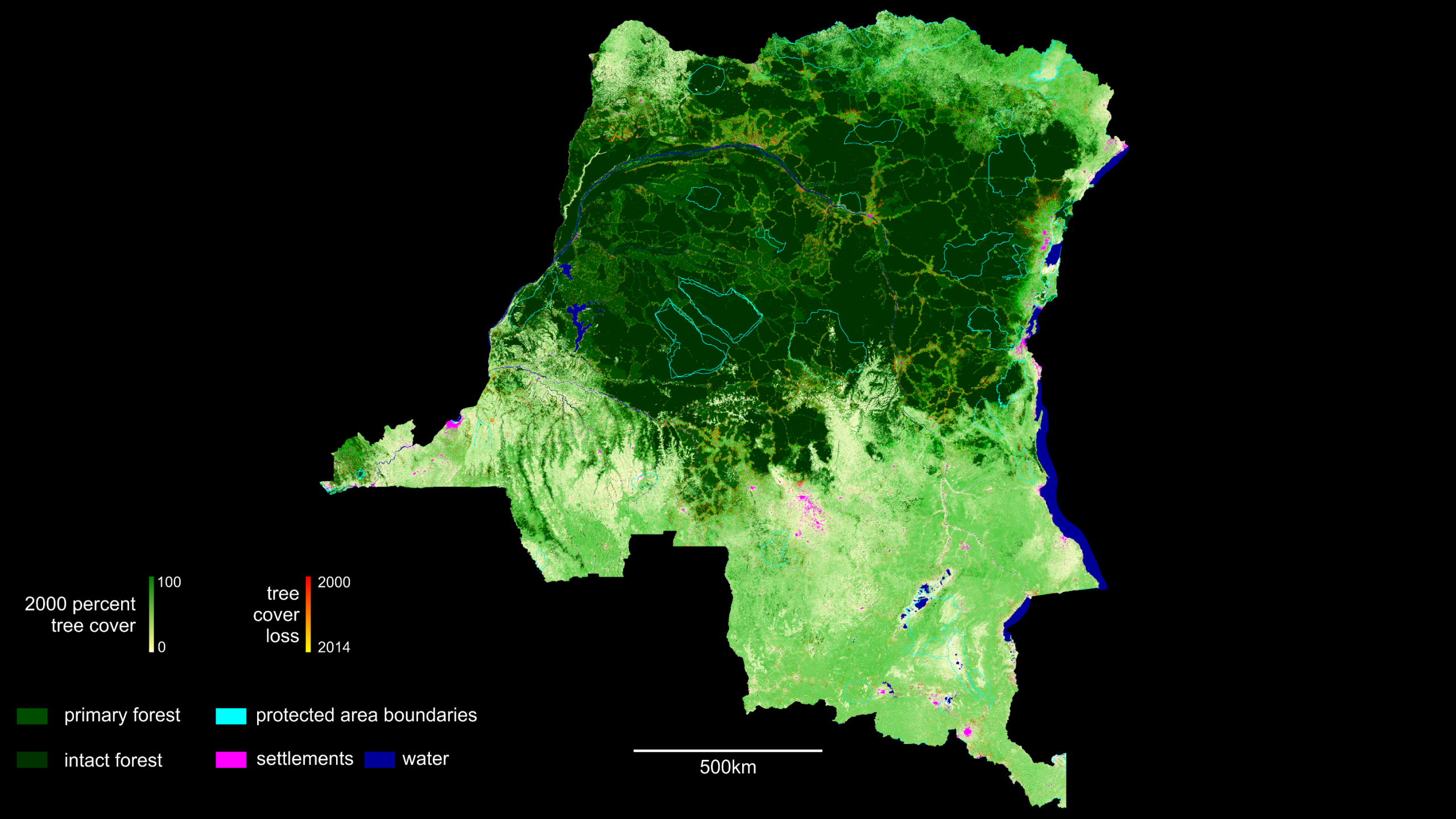
tree cover loss: 2000 / 2014

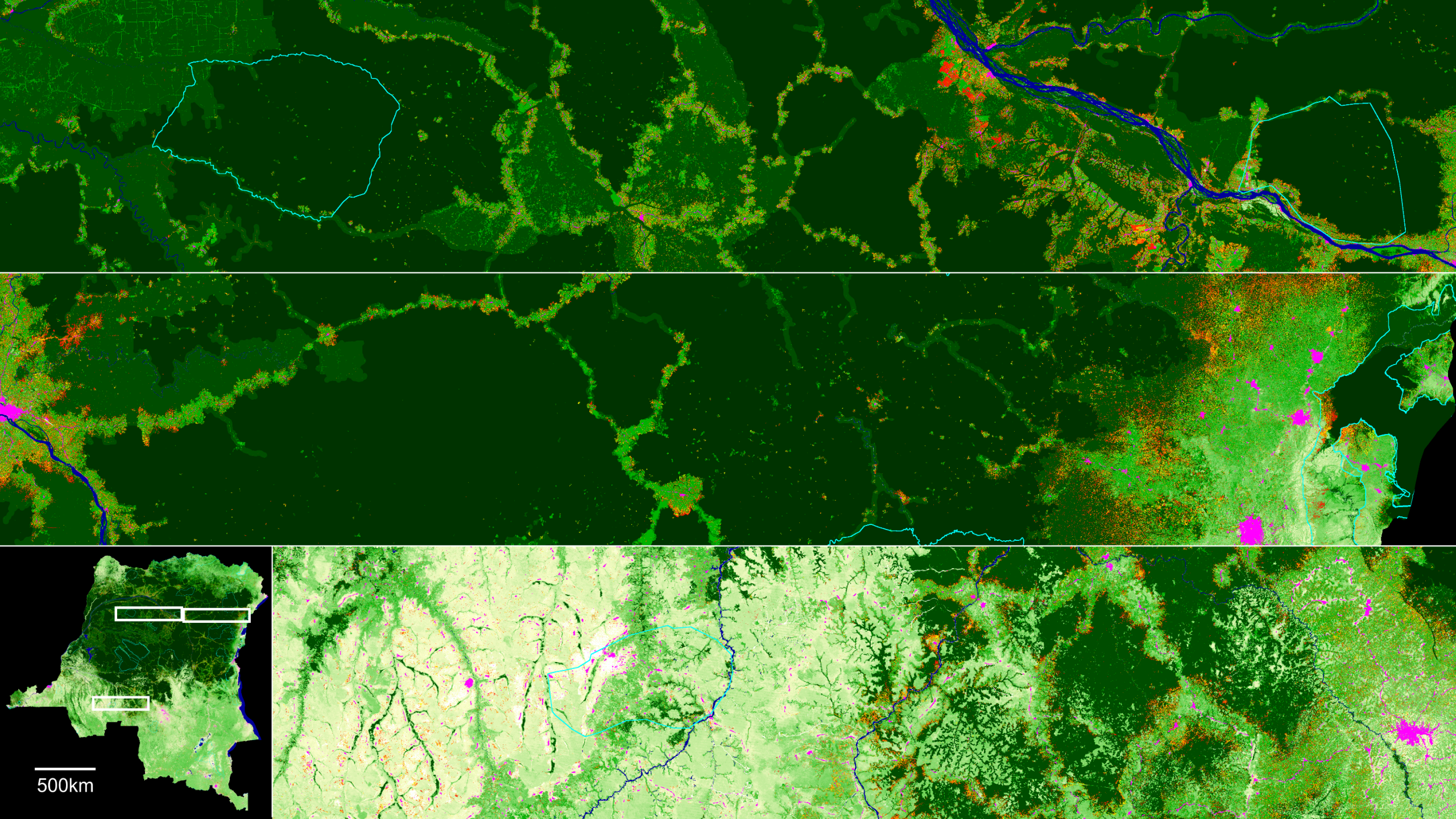


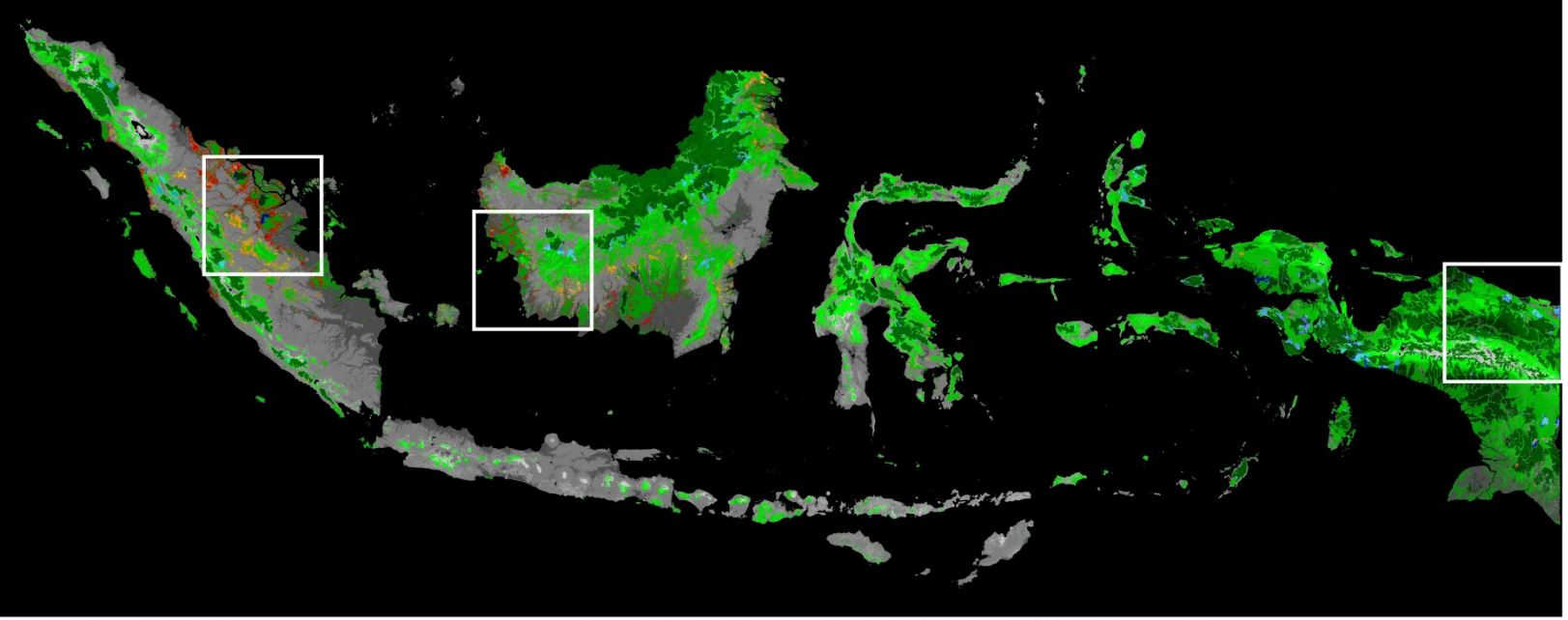


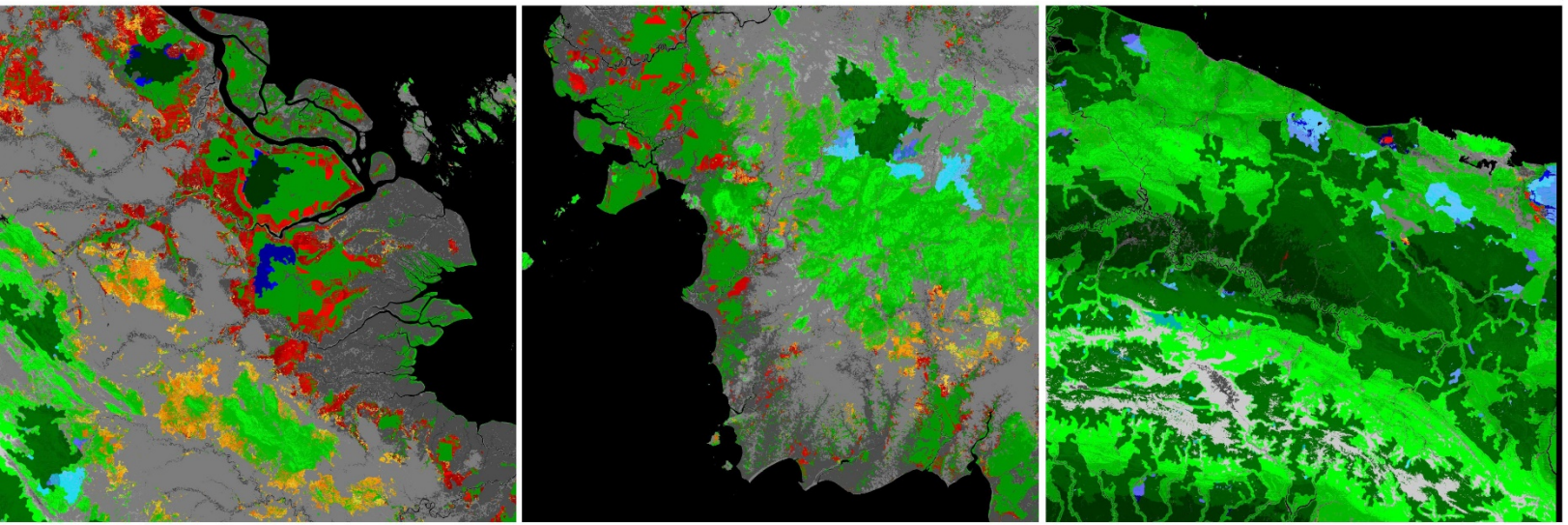

tree cover loss, 2000 to 2014
cropland 2000
new cropland, no tree cover loss
new cropland, tree cover loss


new cropland in tree cover, 2000-2005
new cropland in tree cover, 2006-2010
new cropland in tree cover, 2010-2014


2000 percent tree cover
100
0
tree cover loss
2000
2014
primary forest
intact forest
protected area boundaries
settlements
water
500km


500km

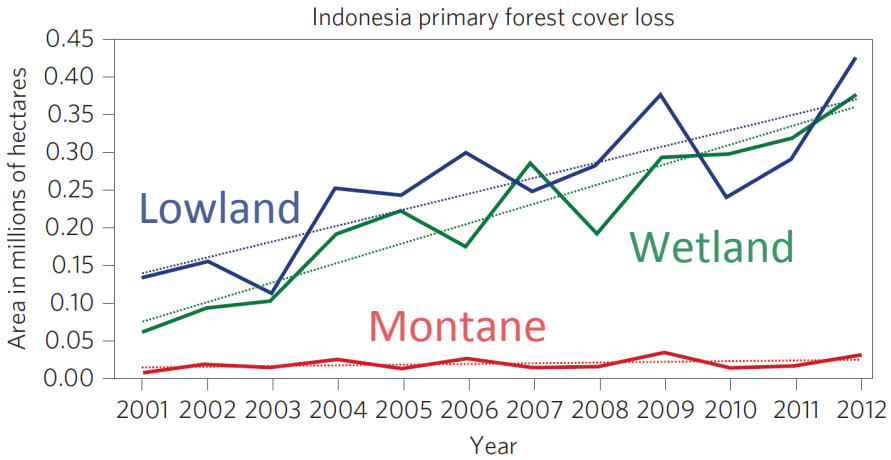




15.7Mha of mapped gross forest cover loss
14.4 ± 2.0Mha of reference gross forest cover loss

6.2Mha mapped primary forest loss
7.5 ± 2.2Mha of reference primary forest loss

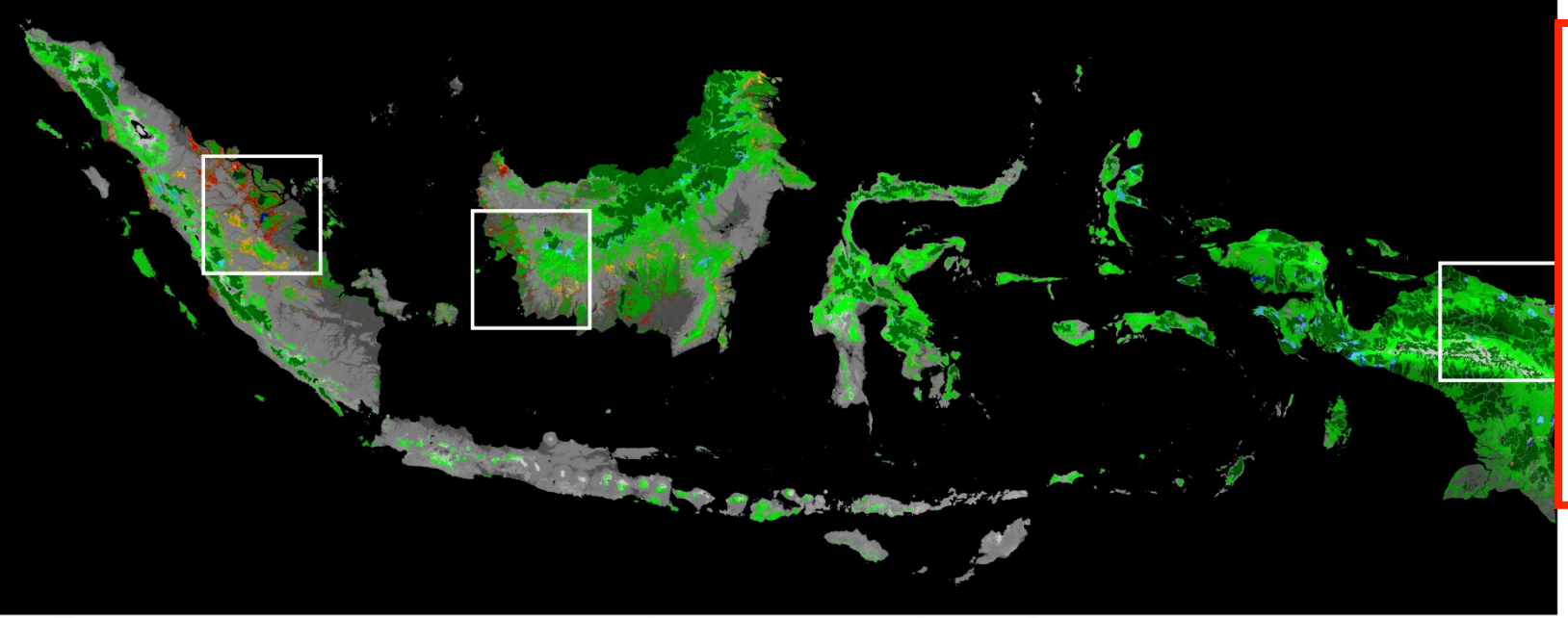
10.7Mha of forest loss by Ministry of Forestry

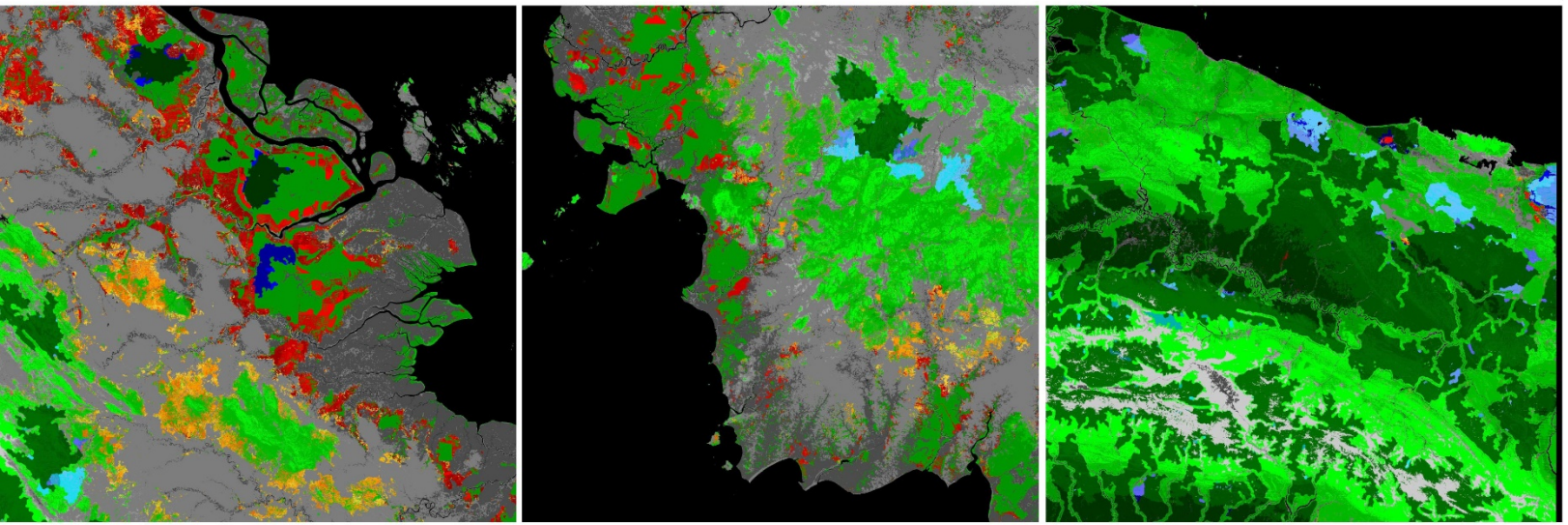


Annual primary forest loss disaggregated by landform for Indonesia as a whole, and the island groups of Sumatra, Kalimantan and Papua. Dashed lines are linear fits to the data

- wetland
- lowland
- montane
- intact wetland forest
- intact lowland forest
- intact montane forest
- degraded wetland forest
- degraded lowland forest
- degraded montane forest
- wetland forest loss 00-05
- wetland forest loss 05-10
- wetland forest loss 10-12
- lowland forest loss 00-05
- lowland forest loss 05-10
- lowland forest loss 10-12
- montane forest loss 00-05
- montane forest loss 05-10
- montane forest loss 10-12
- wetland forest degradation 00-05
- wetland forest degradation 05-10
- wetland forest degradation 10-12
- lowland forest degradation 00-05
- lowland forest degradation 05-10
- lowland forest degradation 10-12
- montane forest degradation 00-05
- montane forest degradation 05-10
- montane forest degradation 10-12

Margono et al., 2014,
Primary forest cover loss in Indonesia, 2000 to 2012,
Nature Climate Change





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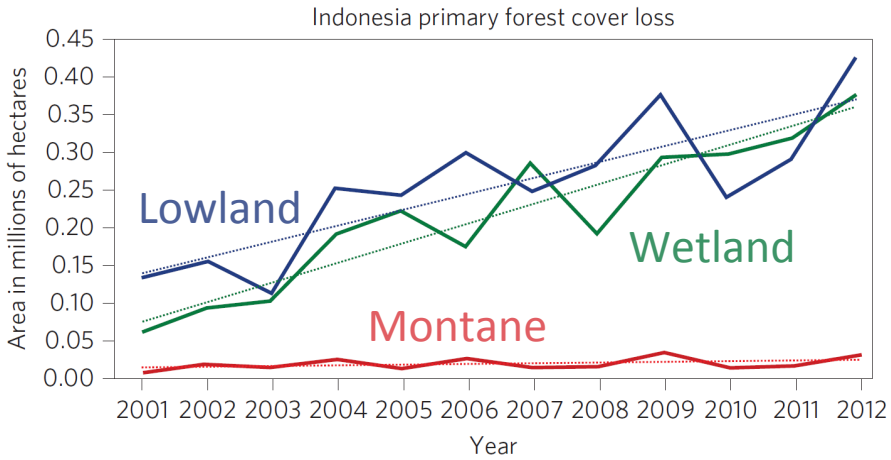
10.7Mha of forest loss by Ministry of Forestry



Annual primary forest loss disaggregated by landform for Indonesia as a whole, and the island groups of Sumatra, Kalimantan and Papua. Dashed lines are linear fits to the data

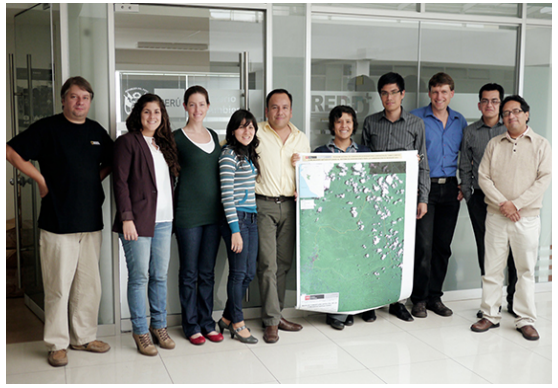
- wetland
- lowland
- montane
- intact wetland forest
- intact lowland forest
- intact montane forest
- degraded wetland forest
- degraded lowland forest
- degraded montane forest
- wetland forest loss 00-05
- wetland forest loss 05-10
- wetland forest loss 10-12
- lowland forest loss 00-05
- lowland forest loss 05-10
- lowland forest loss 10-12
- montane forest loss 00-05
- montane forest loss 05-10
- montane forest loss 10-12
- wetland forest degradation 00-05
- wetland forest degradation 05-10
- wetland forest degradation 10-12
- lowland forest degradation 00-05
- lowland forest degradation 05-10
- lowland forest degradation 10-12
- montane forest degradation 00-05
- montane forest degradation 05-10
- montane forest degradation 10-12

Margono et al., 2014,
Primary forest cover loss in Indonesia, 2000 to 2012,
Nature Climate Change

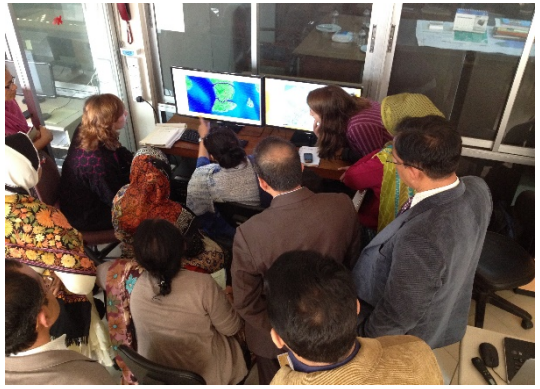
01/16/2014

National Implementation of GLAD Forest Monitoring

Republic of Congo
Ministry of Forestry

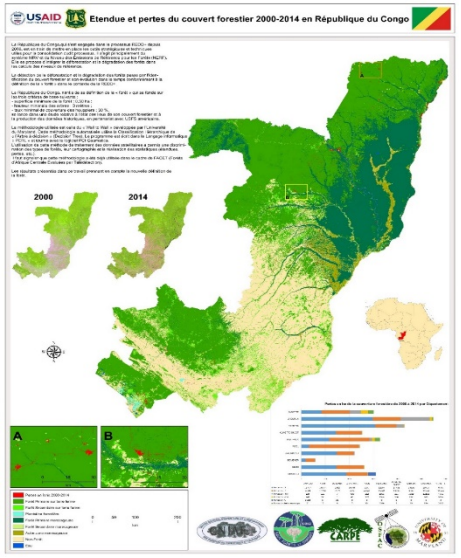


Peru
Ministry of Environment

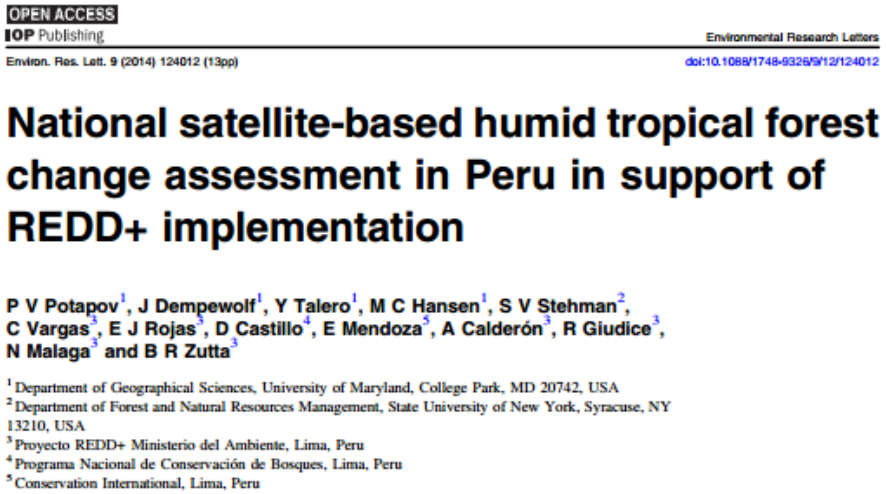


Bangladesh
Ministry of Forests and Environment

National forest extent and change baseline data sets



Joined peer-review publications

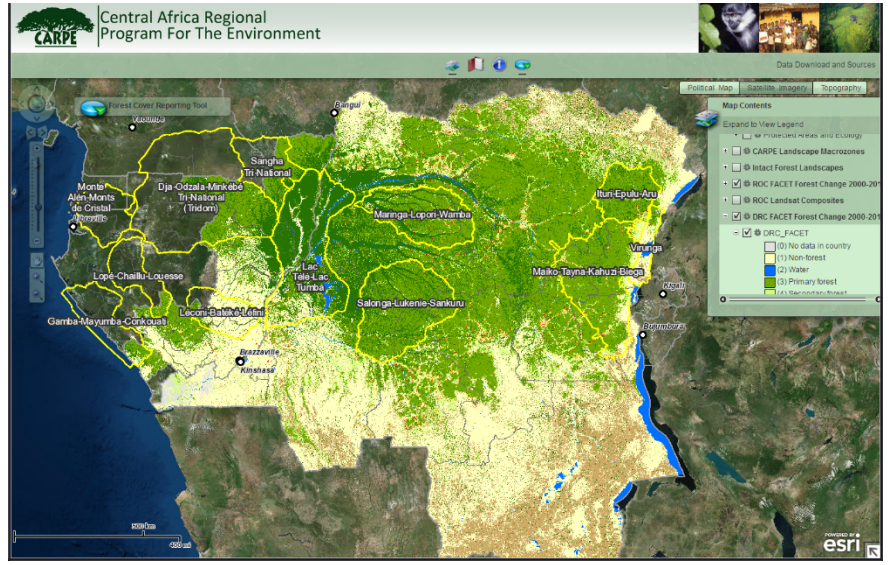

OPEN ACCESS
IOP Publishing
Environmental Research Letters
Environ. Res. Lett. 9 (2014) 124012 (13pp)
doi:10.1088/1748-9326/9/12/124012

National satellite-based humid tropical forest change assessment in Peru in support of REDD+ implementation

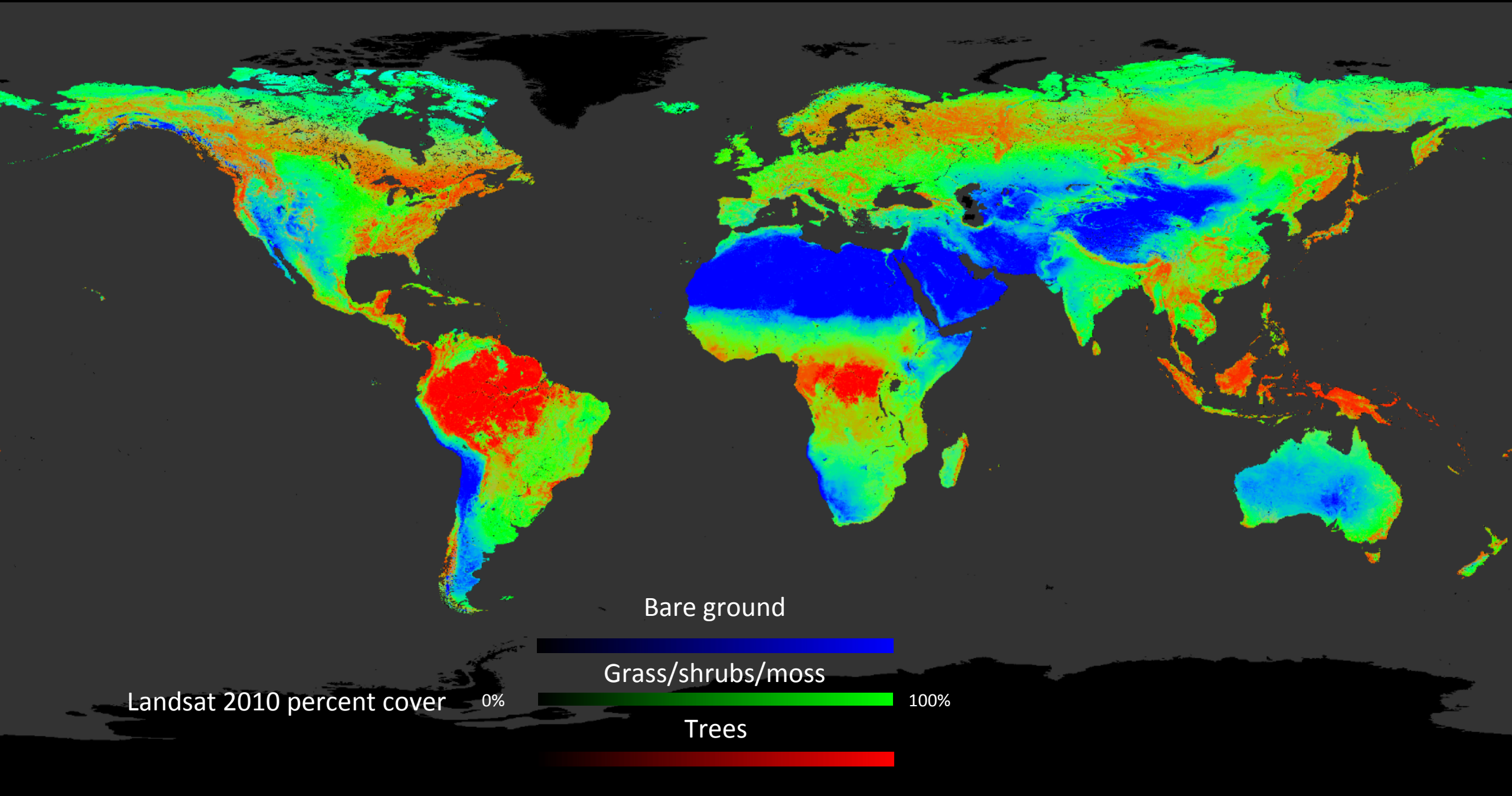
P V Potapov[1], J Dempewolf[1], Y Talero[1], M C Hansen[1], S V Stehman[2], C Vargas[3], E J Rojas[3], D Castillo[4], E Mendoza[5], A Calderón[3], R Giudice[3], N Malaga[3] and B R Zutta[3]

[1] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
[2] Department of Forest and Natural Resources Management, State University of New York, Syracuse, NY 13210, USA
[3] Proyecto REDD+ Ministerio del Ambiente, Lima, Peru
[4] Programa Nacional de Conservación de Bosques, Lima, Peru
[5] Conservation International, Lima, Peru

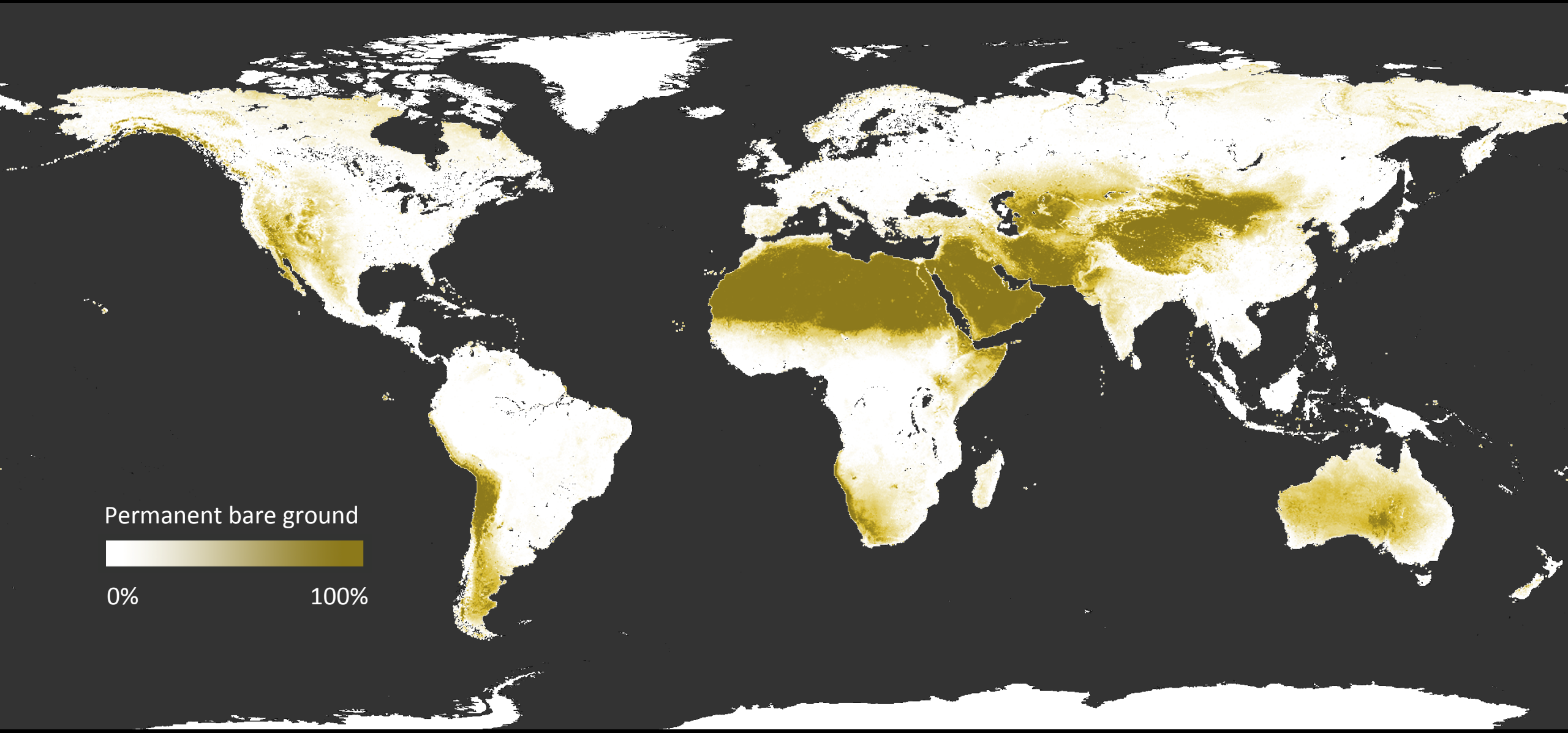
On-line maps and reports



Vegetation continuous fields

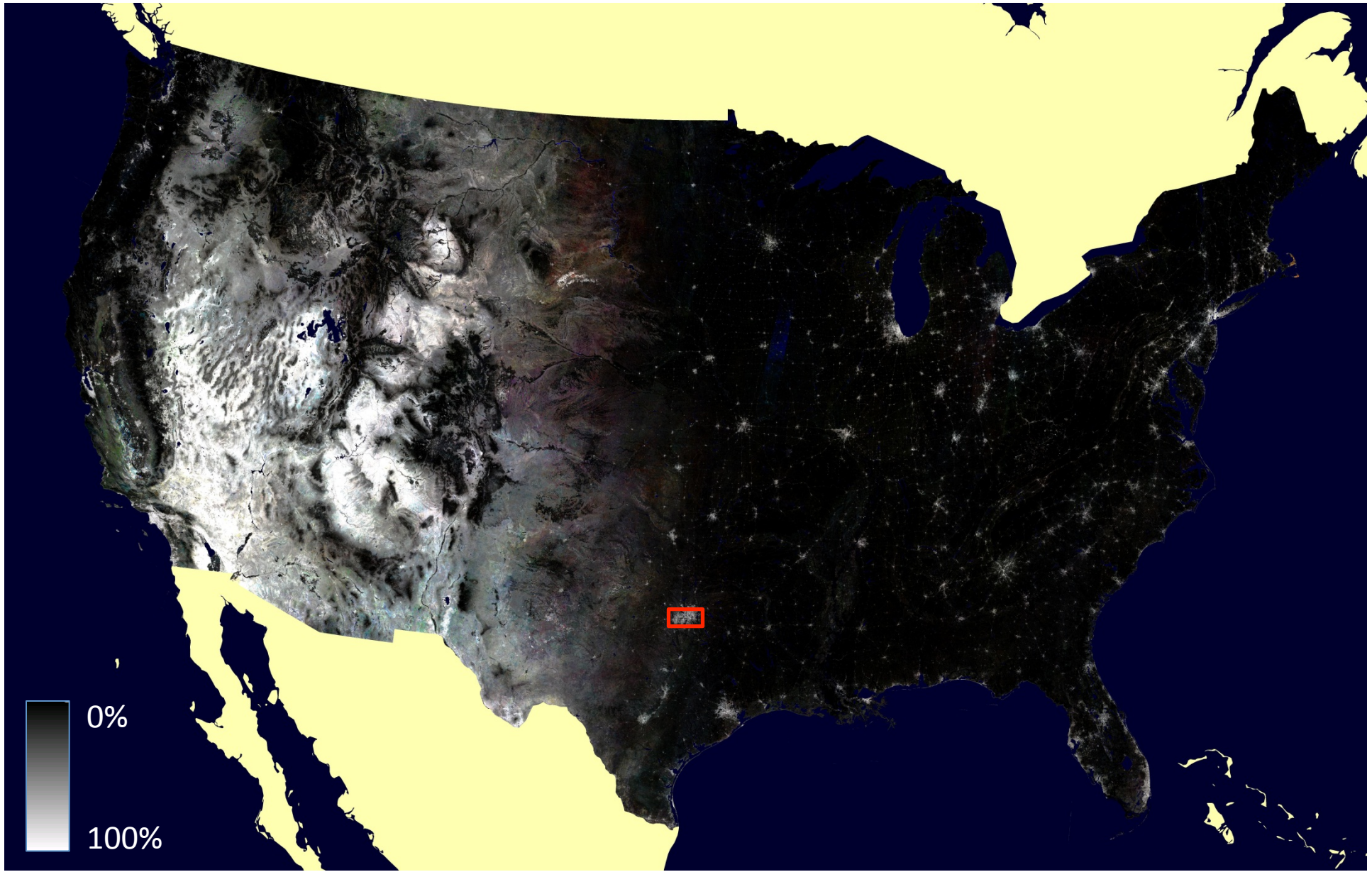


Global bare ground

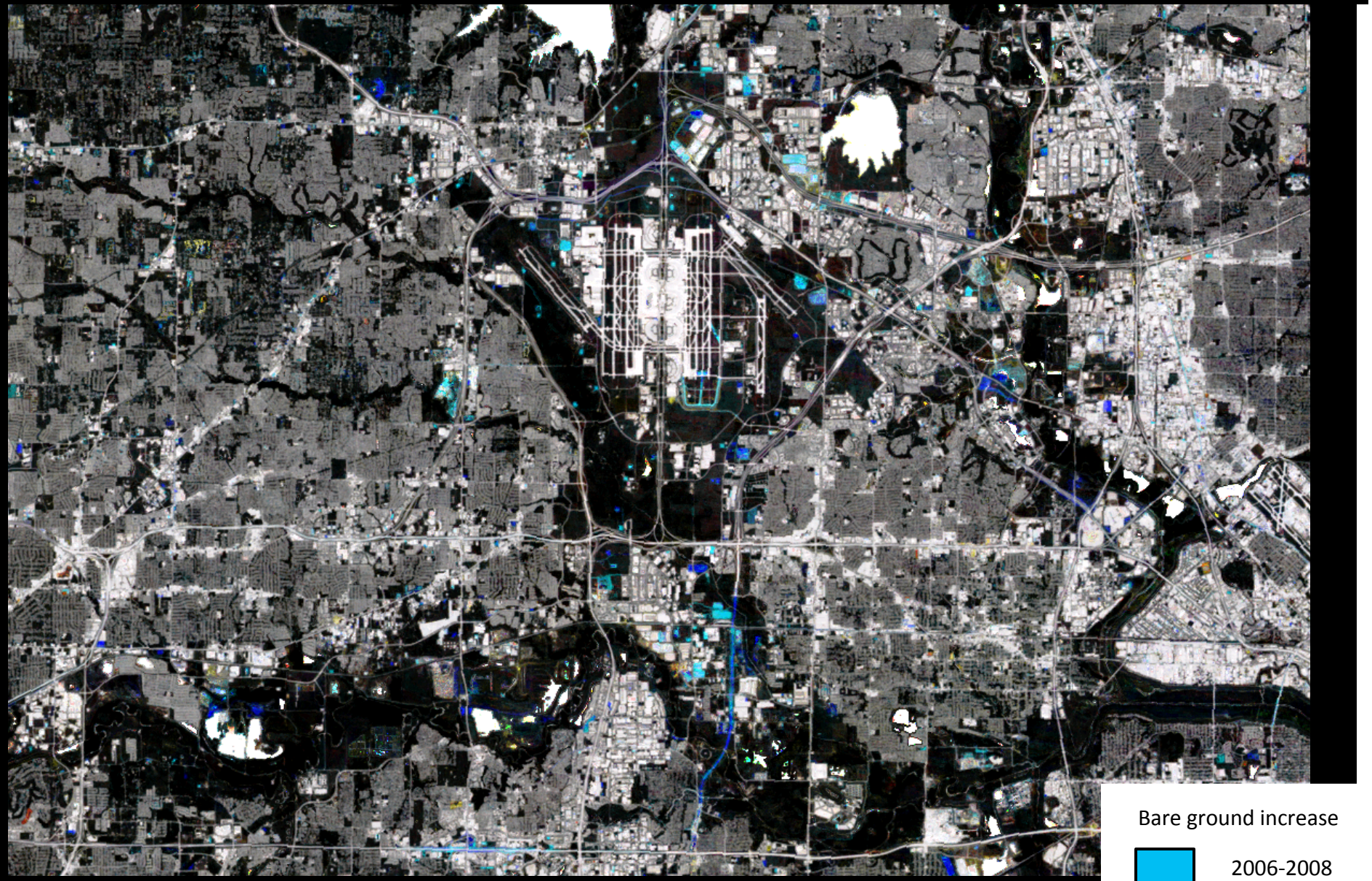


Permanent bare ground, 2000-2012

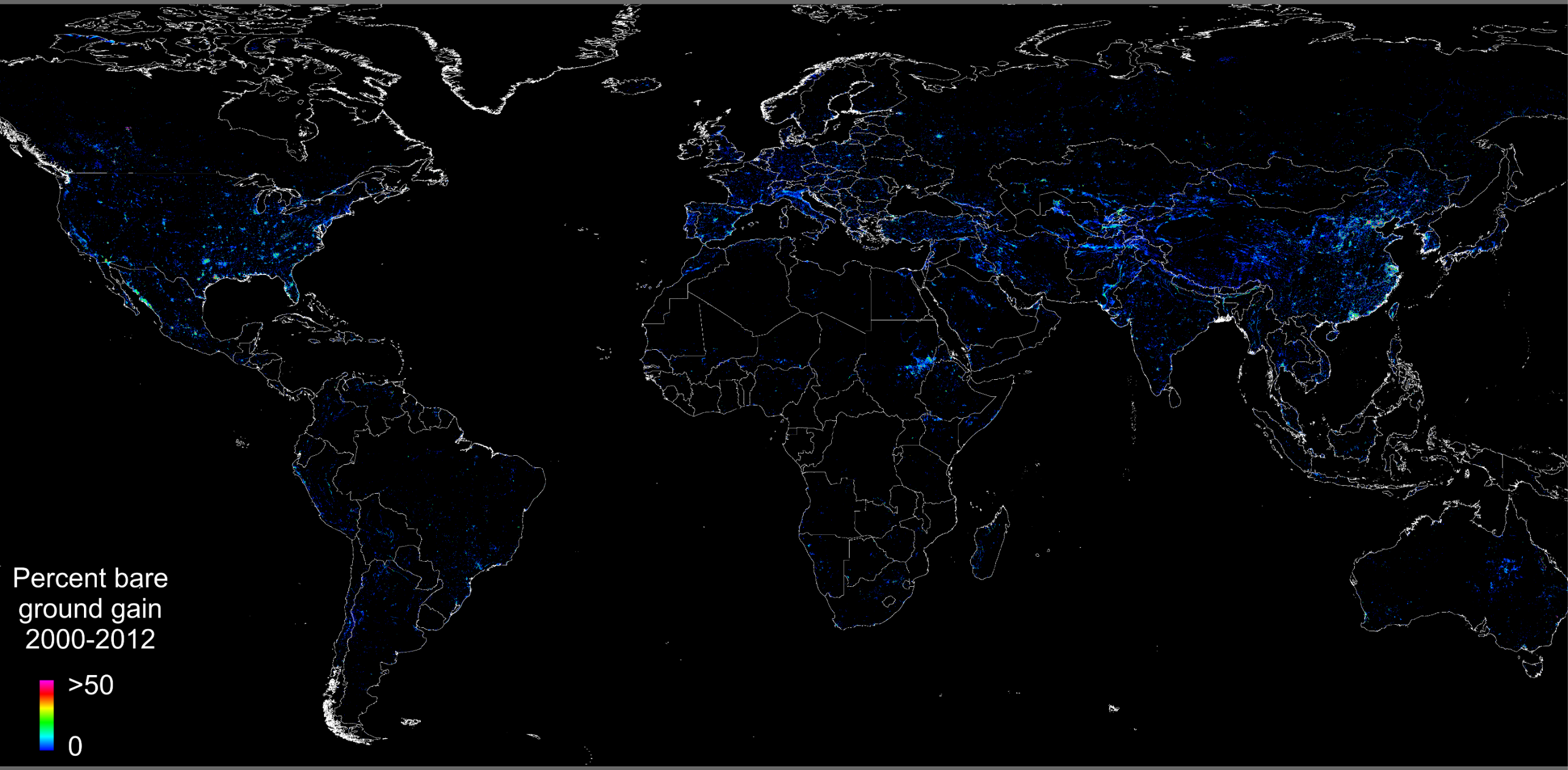
Percent bare ground times-series

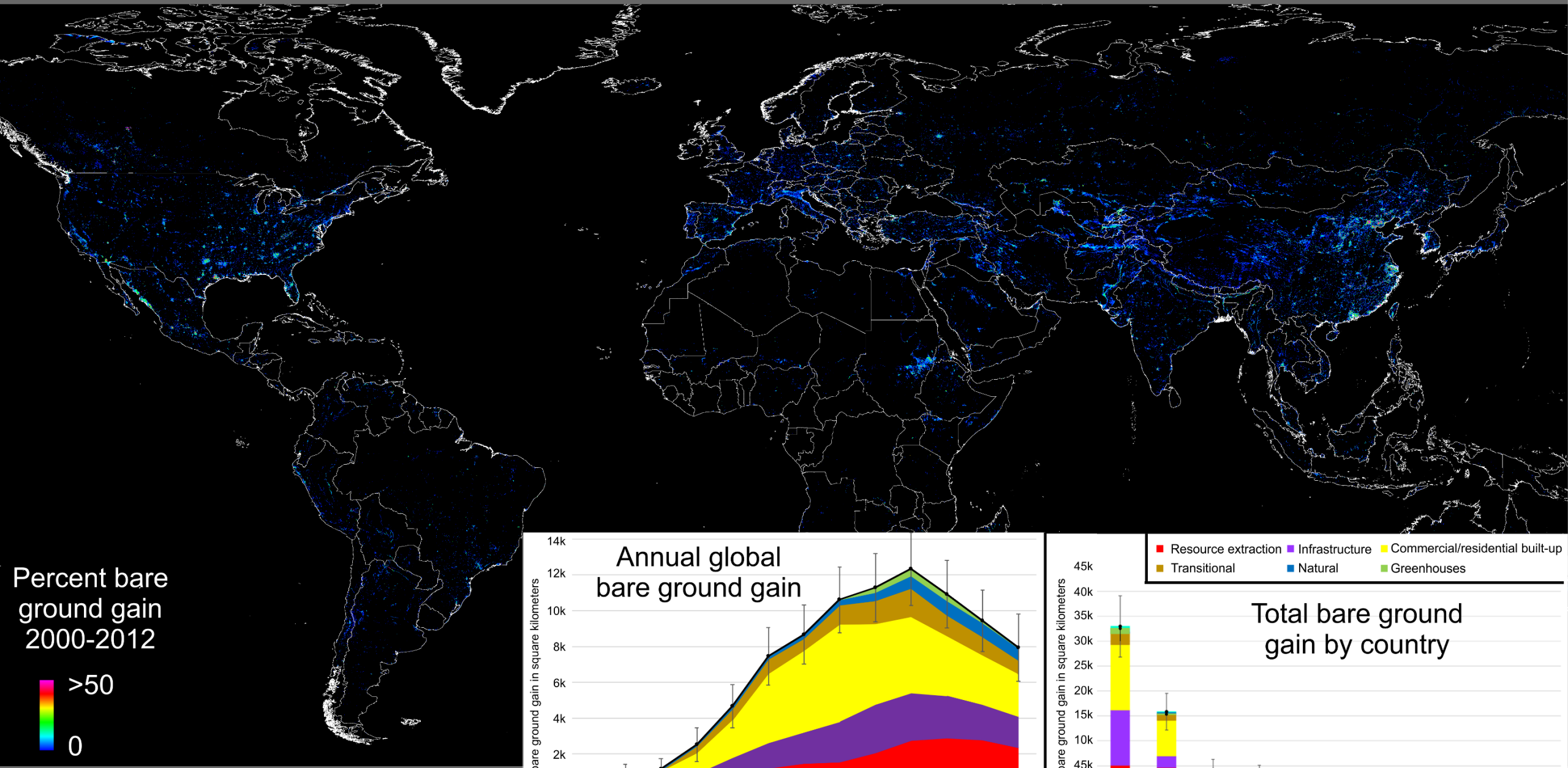


Urbanization



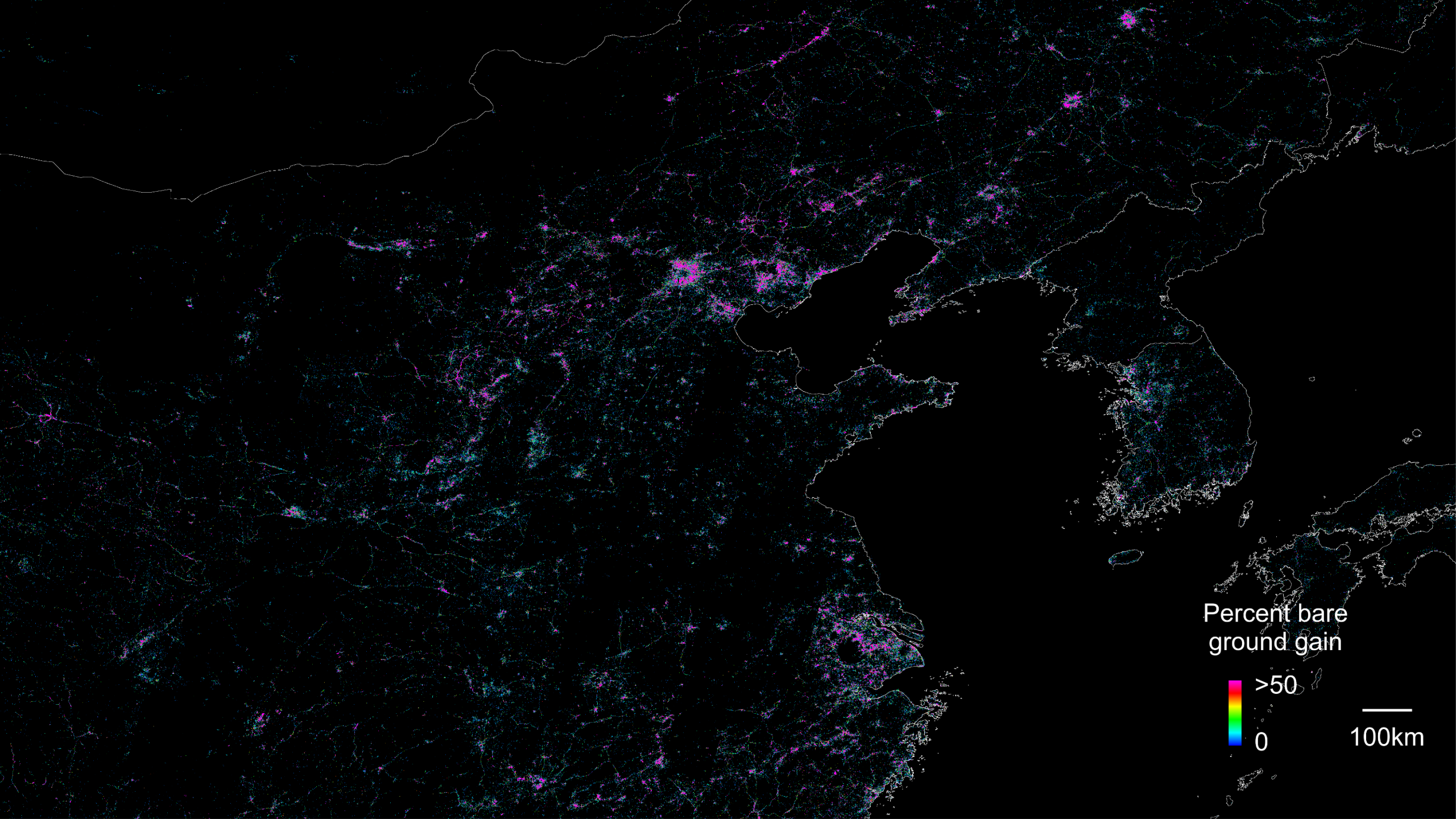
Dallas-Fort Worth, TX

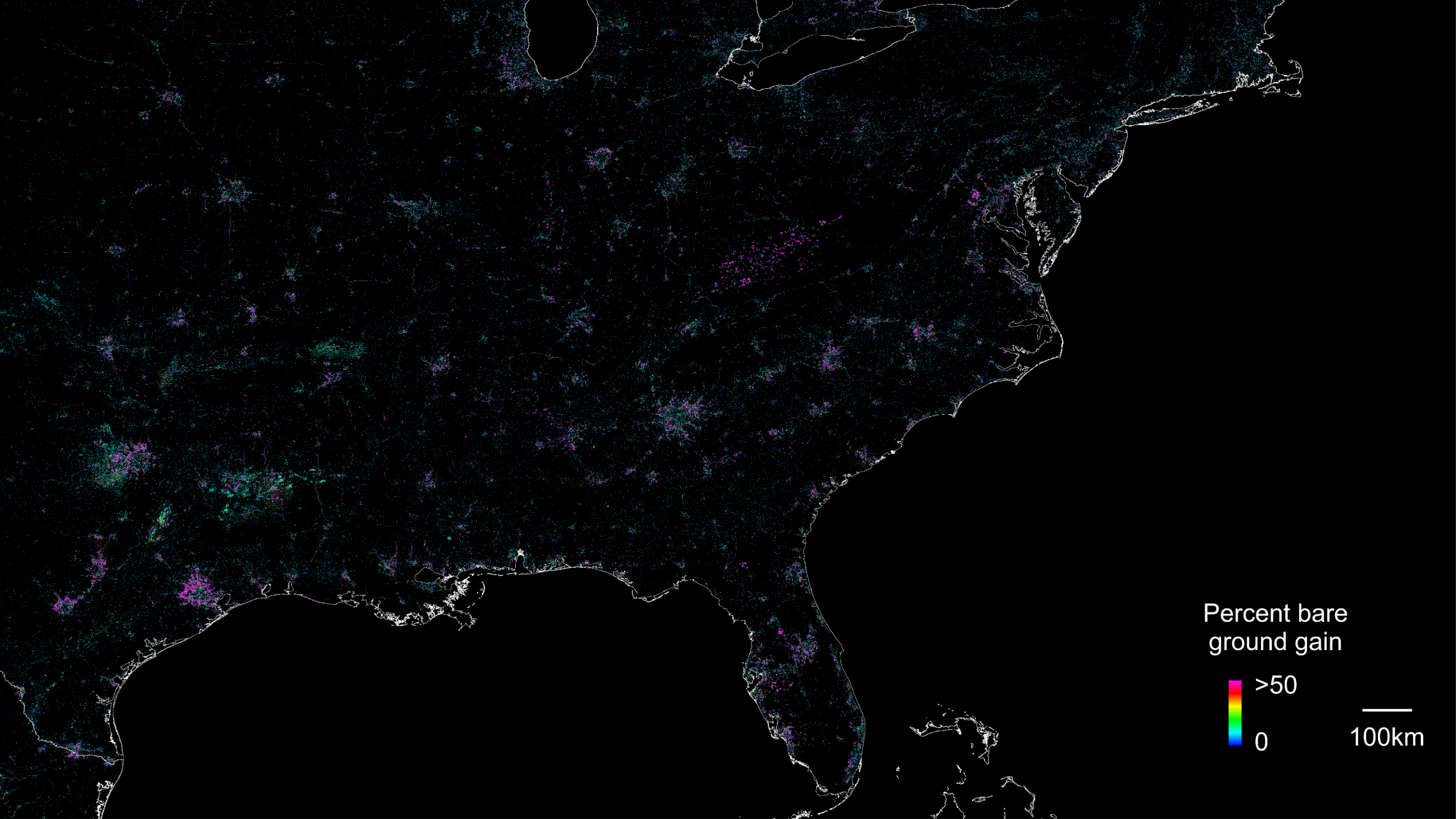

Percent bare
ground gain
2000-2012
>50
0


Percent bare ground gain 2000-2012
>50
0

Annual global bare ground gain
bare ground gain in square kilometers
14k
12k
10k
8k
6k
4k
2k
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

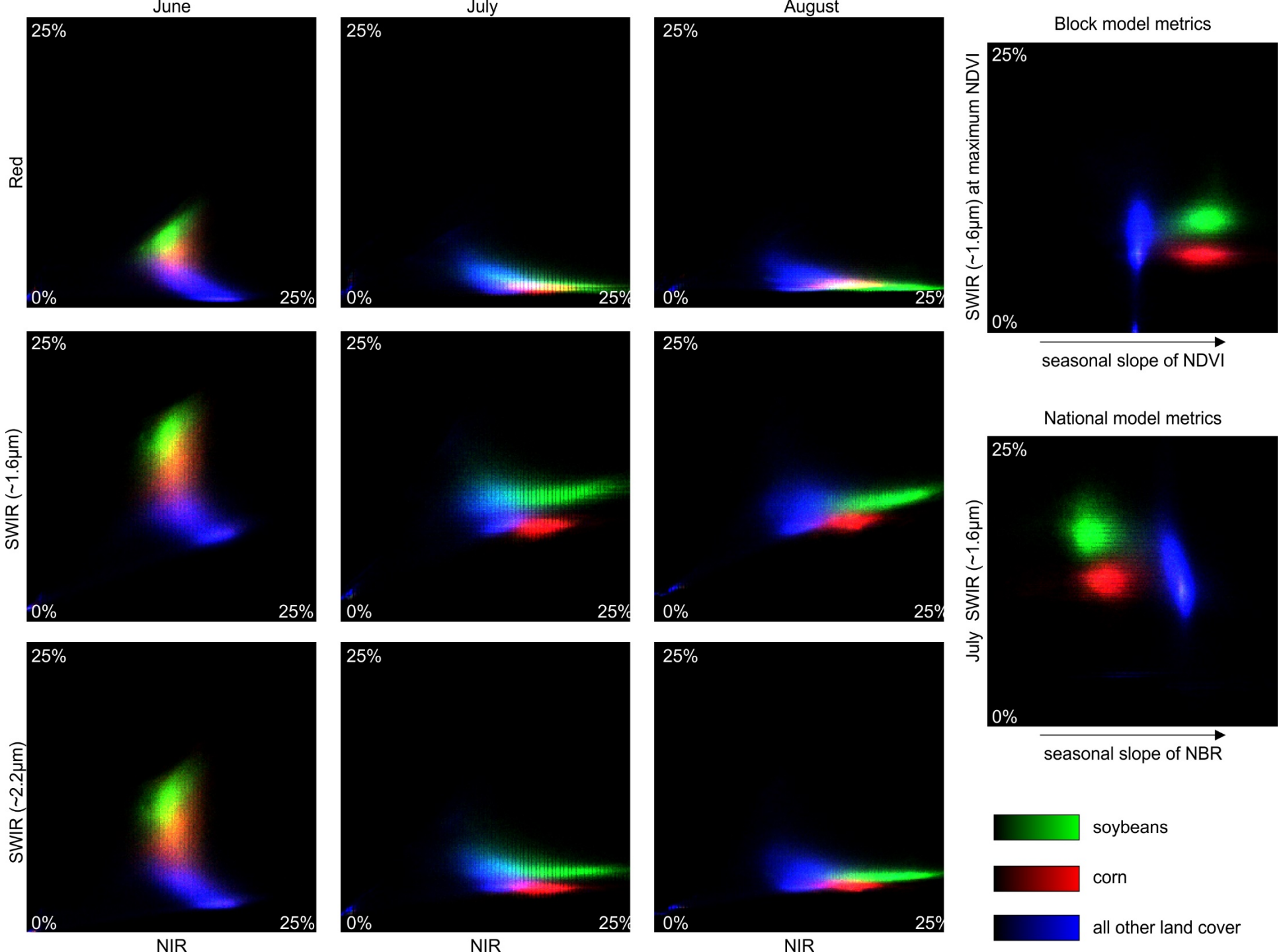
Resource extraction
Infrastructure
Commercial/residential built-up
Transitional
Natural
Greenhouses
Total bare ground gain by country
bare ground gain in square kilometers
45k
40k
35k
30k
25k
20k
15k
10k
45k
0
China
U.S.
Brazil
Canada
Russia
India
Mexico
Spain
Turkey
Australia

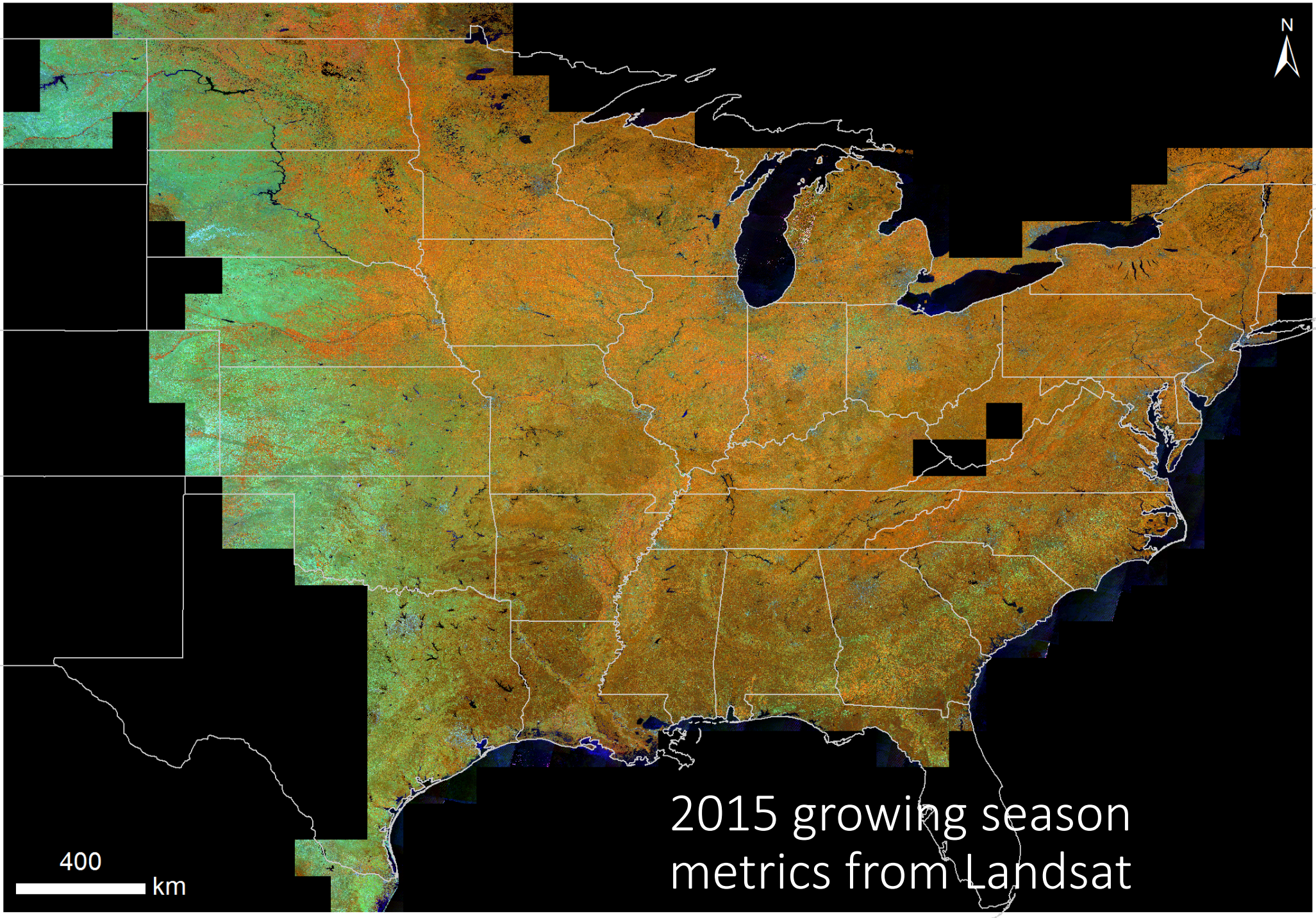

Percent bare
ground gain
>50
0
100km

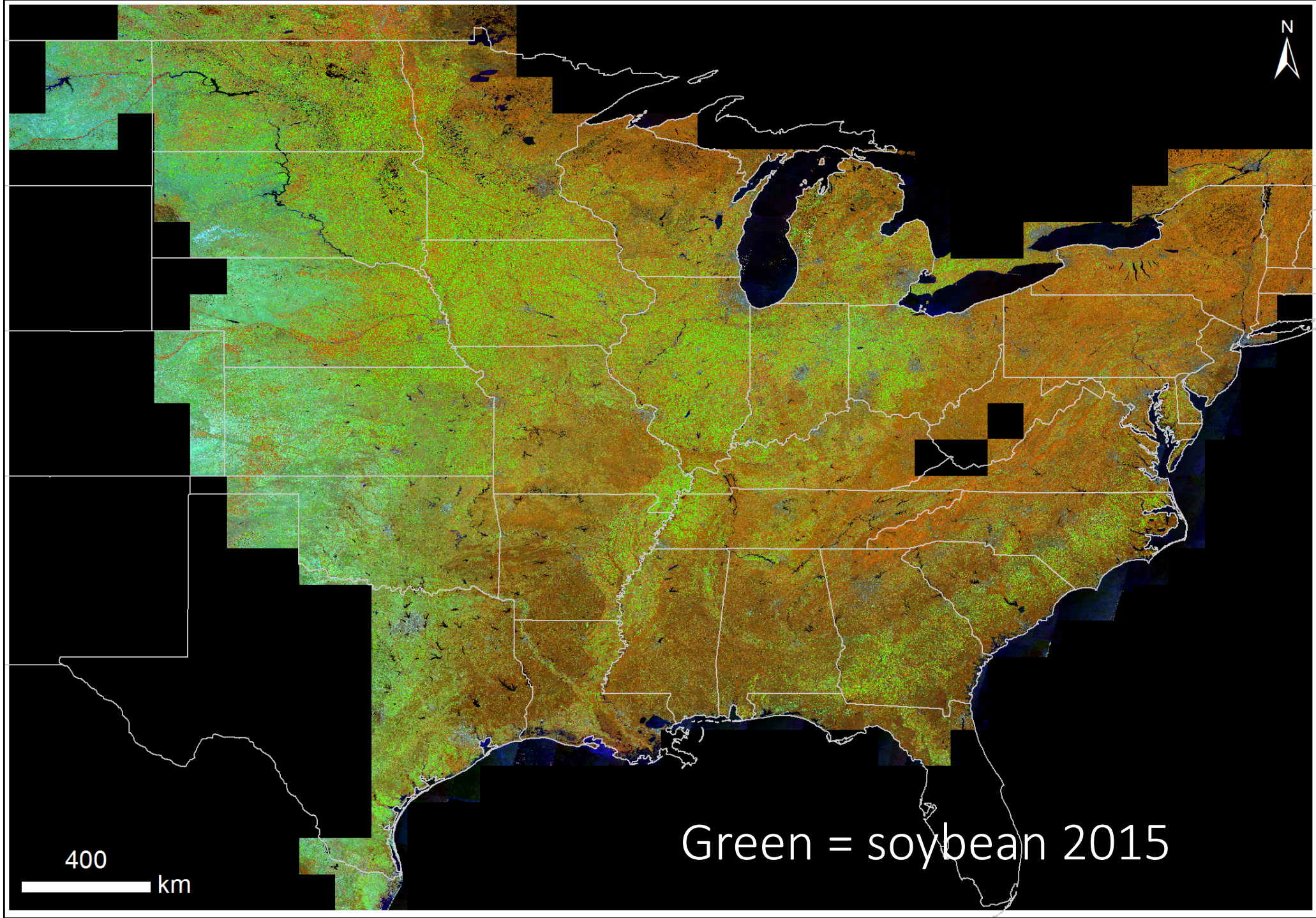

Percent bare
ground gain
>50
0
100km

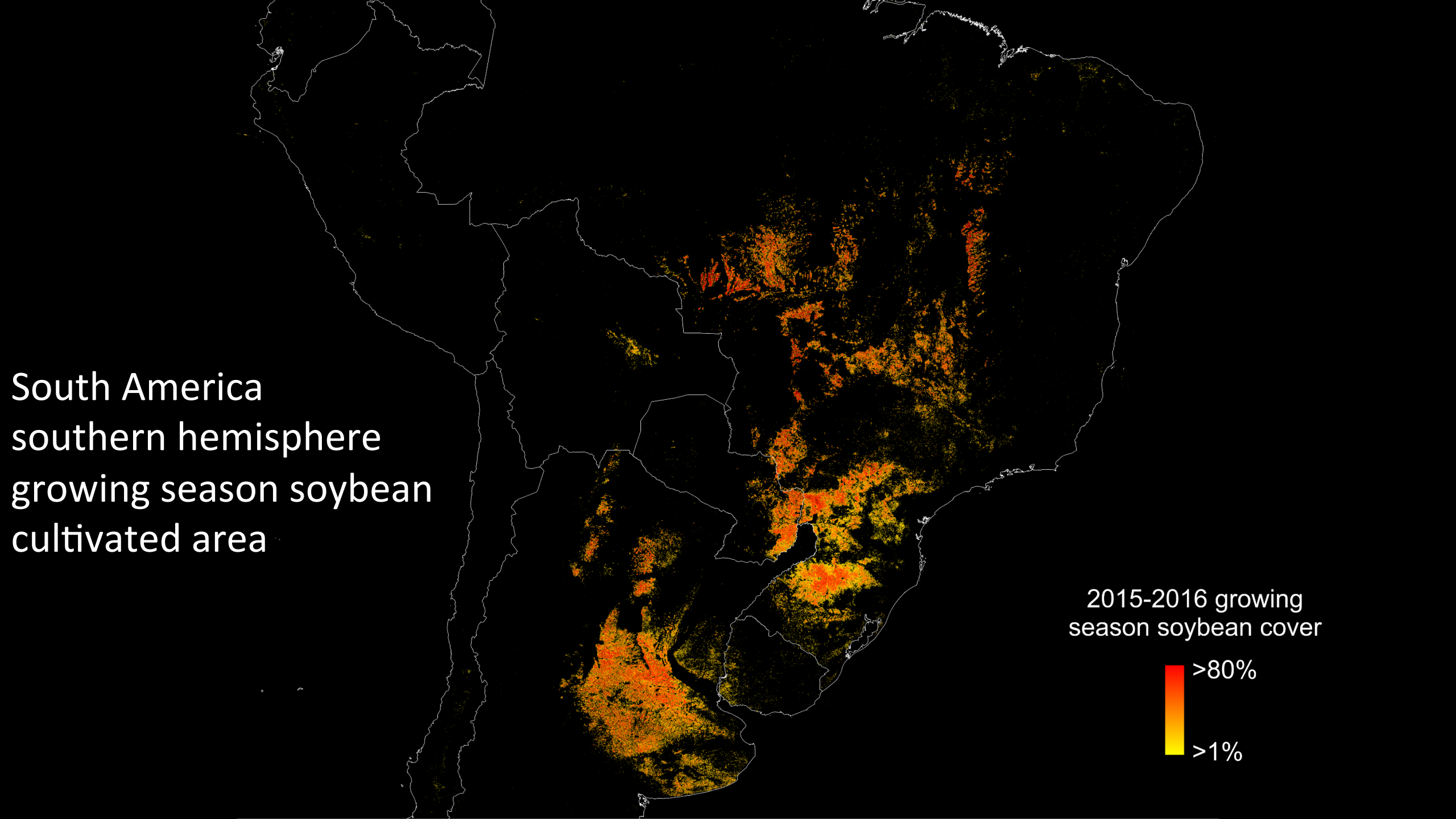
Crop type mapping

example from Ohio – soybean and corn

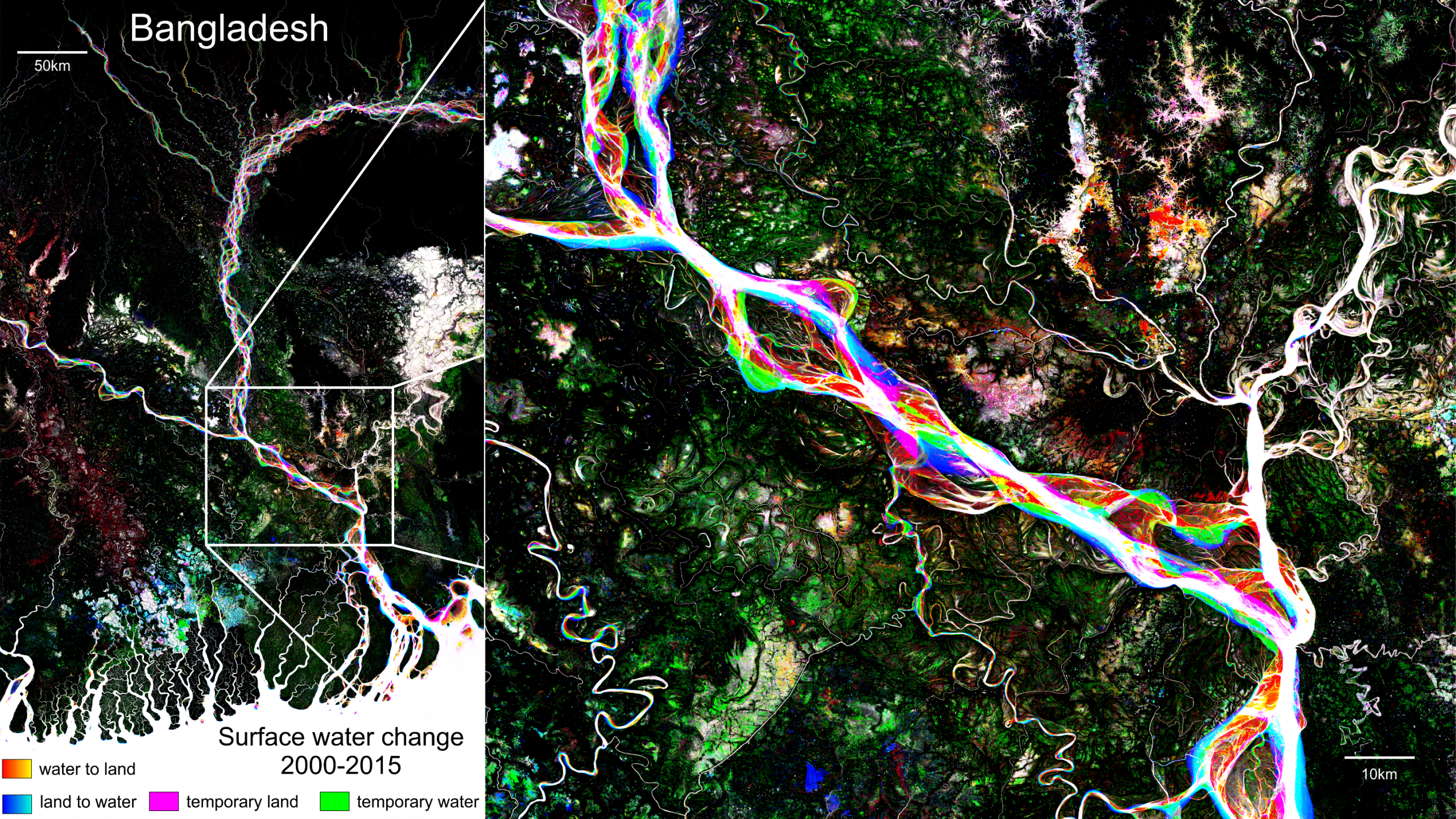


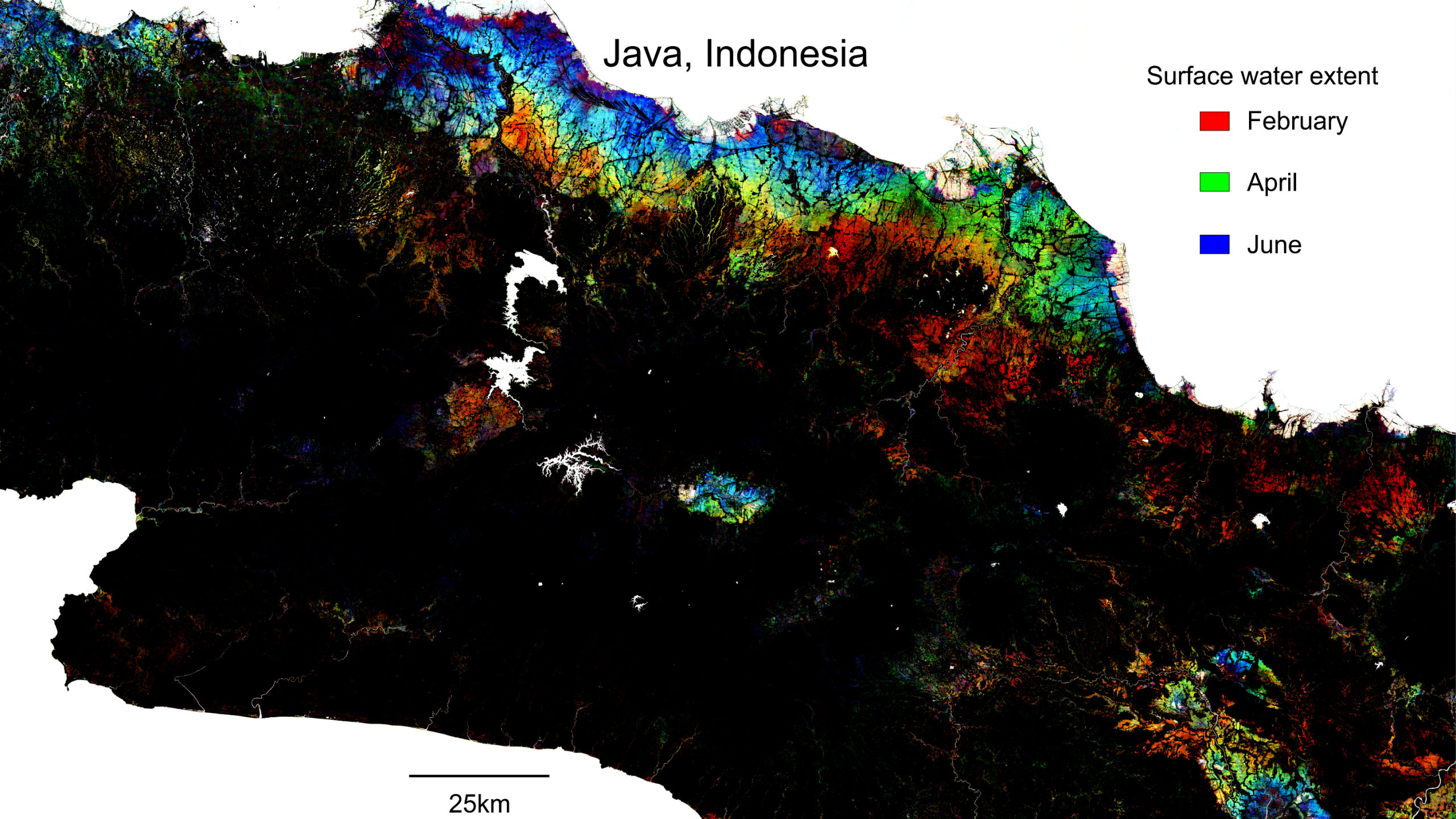

N
400
km
2015 growing season
metrics from Landsat


N
400
km
Green = soybean 2015

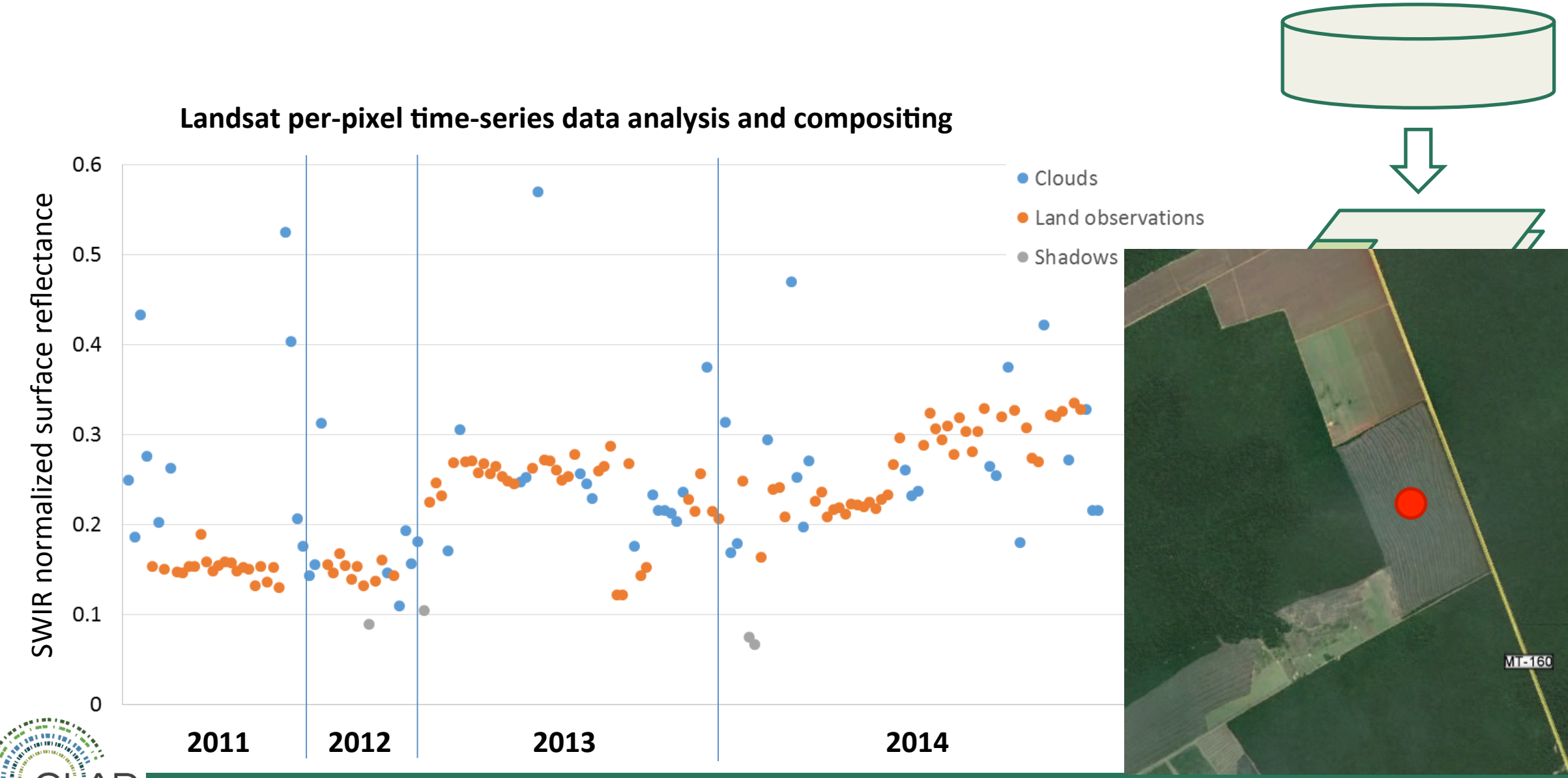

South America
southern hemisphere
growing season soybean
cultivated area
2015-2016 growing
season soybean cover
>80%
>1%

Surface water dynamics

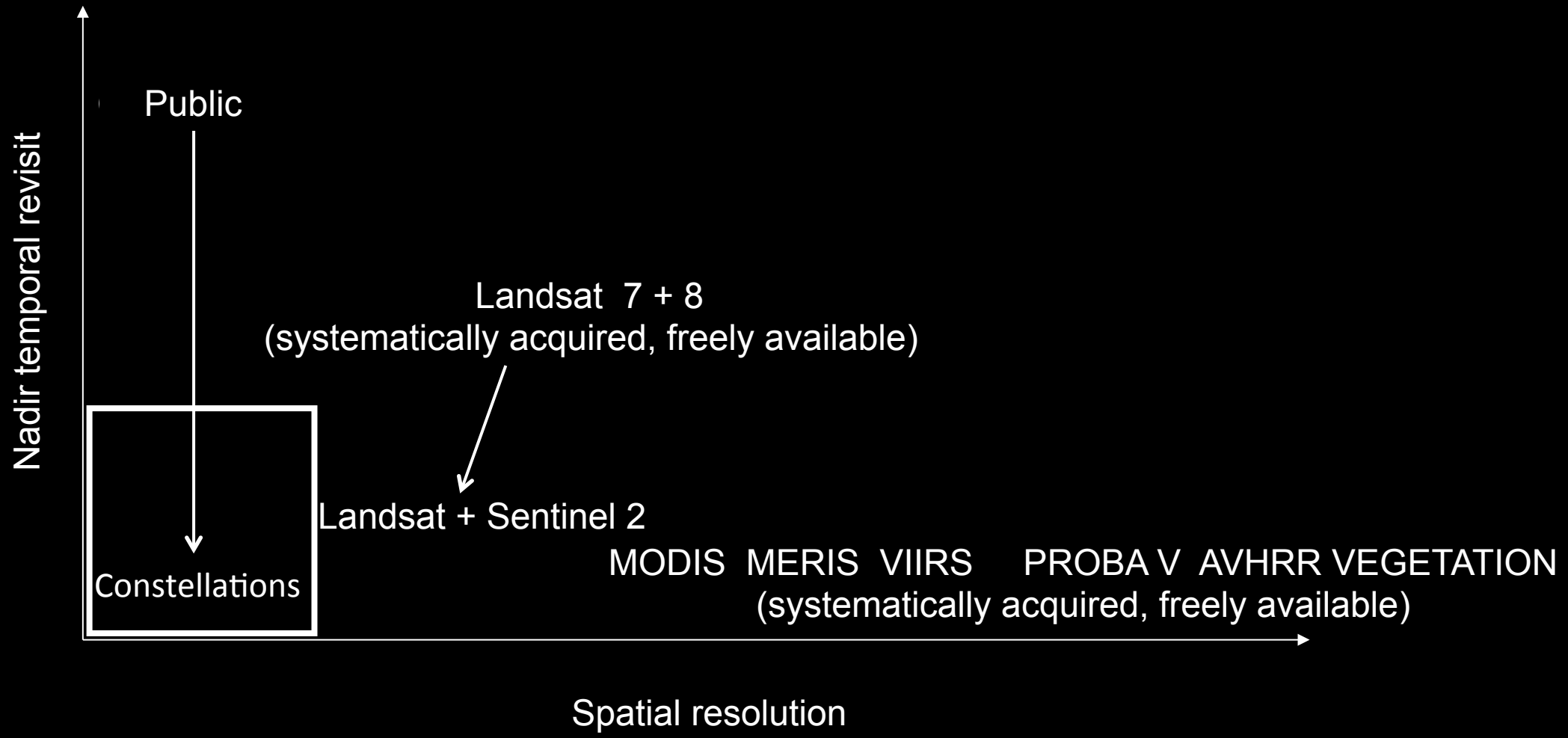

Bangladesh
50km
Surface water change
2000-2015
water to land
land to water
temporary land
temporary water
10km


Java, Indonesia
Surface water extent
February
April
June
25km

Big data = time-series



Operational land monitoring using multi-spectral data



A few conclusions

- Big data is a given for global land monitoring, but not everyone works at the global scale
  - How do we most efficiently share methods in advancing accurate and transparent knowledge of our changing earth system?
  - We borrow from the MODIS Land Science team and focus on data reduction and characterization methods, as with our forest monitoring work in support SilvaCarbon, while some advocate 'all observation' applications
  - Online cloud-based solutions are increasingly popular, i.e. Google Earth Engine

- Global land cover and land use mapping and monitoring is rapidly maturing
  - Advances in relevant themes, spatial detail, and timeliness of product generation
  - Using maps as area estimators needs to be demonstrated per theme via good practice accuracy assessment
  - Repeatable, turn-key methods are needed to move from research to operations

- From-to changes by cover type/condition, as well as change factor (primary forest -> mechanical clearing -> palm oil) are a priority
  - Generate per pixel land use histories
  - Differentiate ephemeral from permanent change dynamics

- Operational earth observing systems with open data policies are required for long-term monitoring of global land change
  - Landsat + Sentinel will offer sub-weekly cadence
  - How do commercial systems approximate global public EO systems in data acquisition, access and processing?

- Operational time-series data should leverage other data as warranted
  - Lidar for calibration of structure, radar for overcoming limitations of optical data