National scale mapping of land cover and change using Landsat data

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GIScCE SDSU NASA USAID USGS CARPE AUSTRALIA Google

Large area land cover extent and change mapping

- AVHRR to MODIS to Landsat - Apply lessons learned from coarse spatial resolution sensors to Landsat
  - Per pixel processing, including quality assessment of clouds, haze, shadow, water
  - Top of atmosphere reflectance and radiometric normalization, including BRDF/view angle
  - Employ decision tree algorithms for QA models and cover extent and change quantification
- Incorporate MODIS for normalization and temporal disaggregation of change dynamics
- Future is WELD for Landsat time-series inputs

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Landsat is unique among medium resolution sensors

- Systematic global acquisition strategy
- No cost
- Easy access
- Minimal pre-processing required

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Monitoring at national scales in the humid tropics – different situations

- Brazil
  - Large-scale change, most of which is located in seasonally cloud-free region, deforestation
- Indonesia
  - Large-scale change, occurring in persistently cloud-affected region, much topography, active forestry
- Democratic Republic of Congo
  - Fine-scale change, occurring in persistently cloud-affected region

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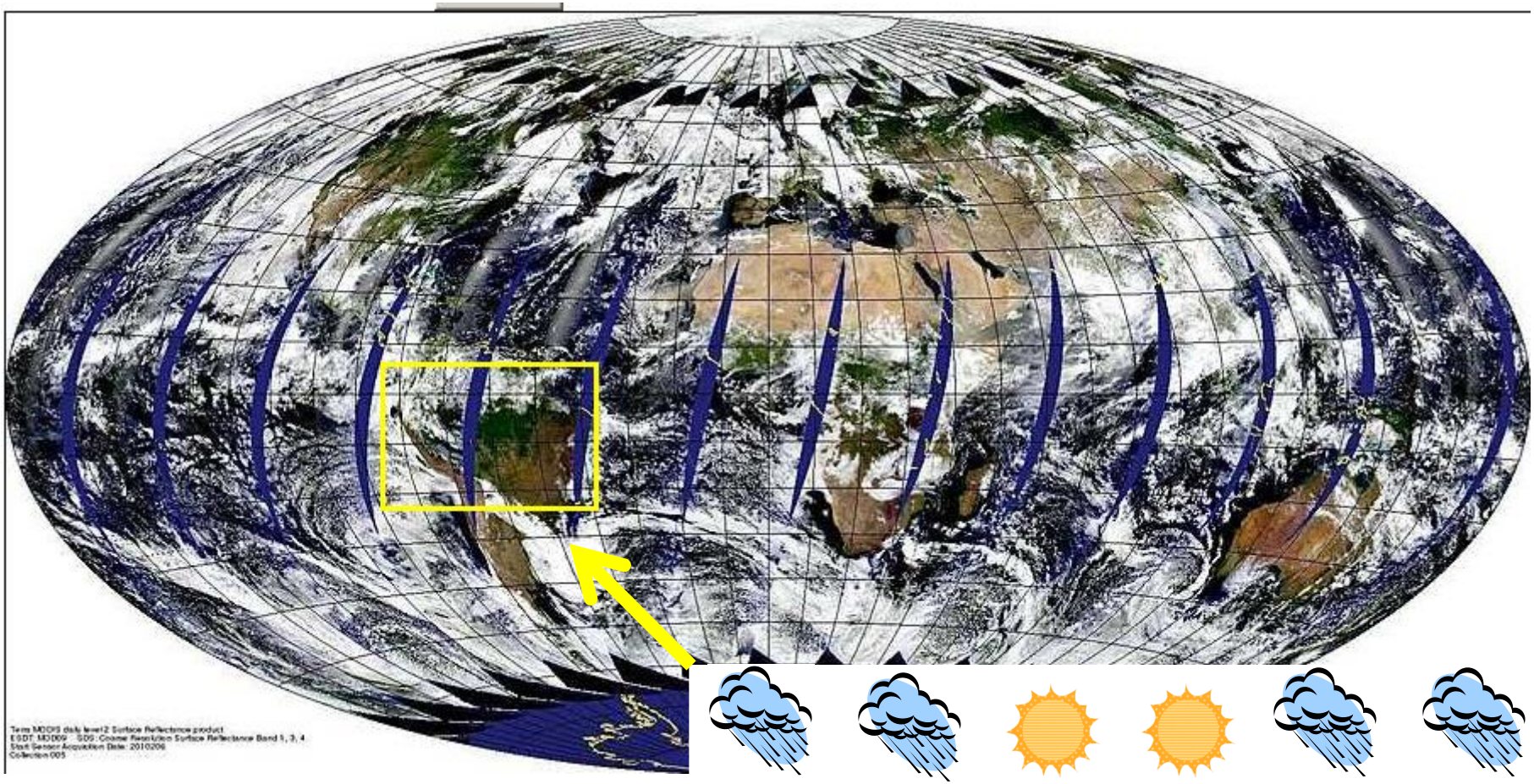
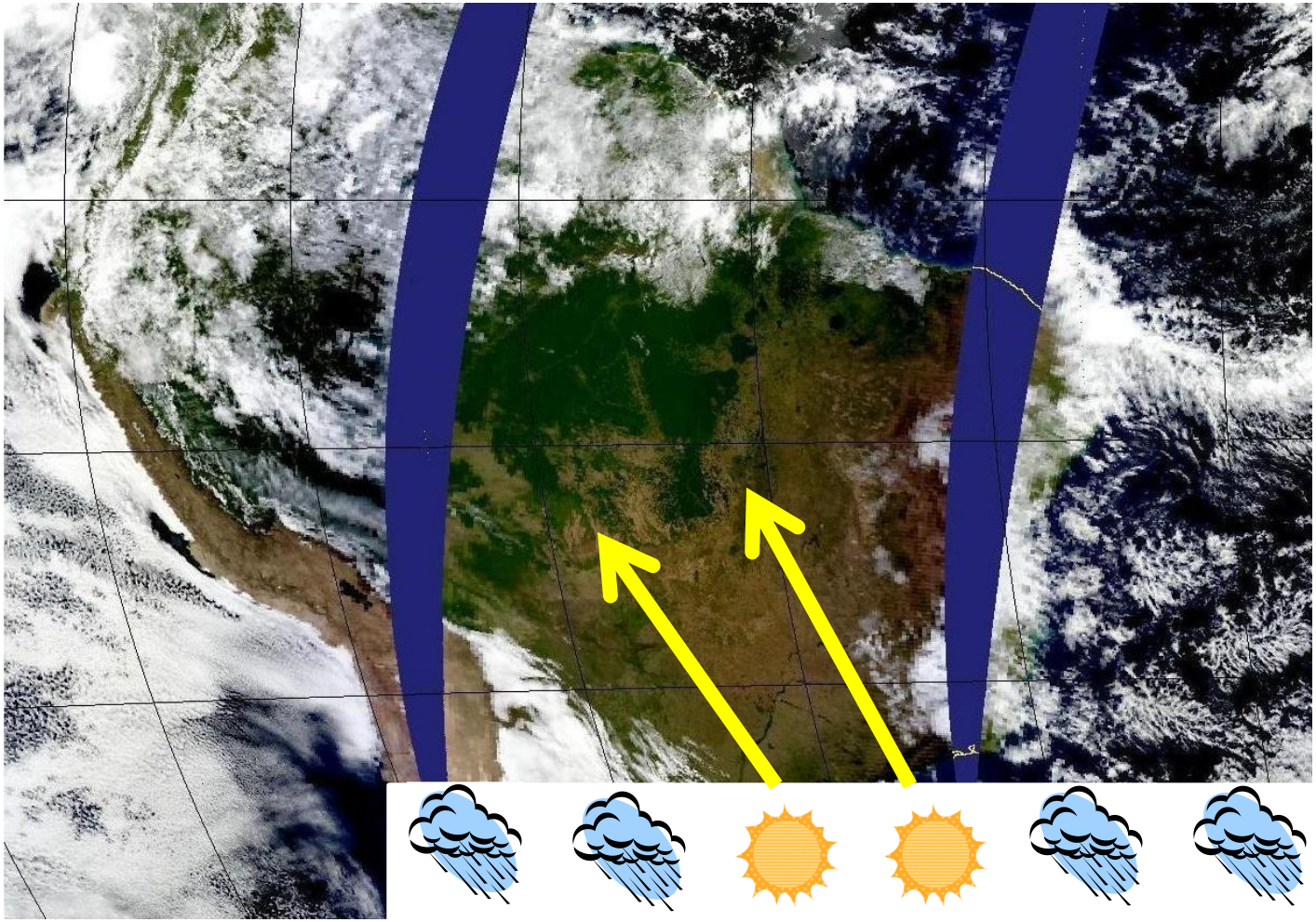
Humid tropical cloud cover

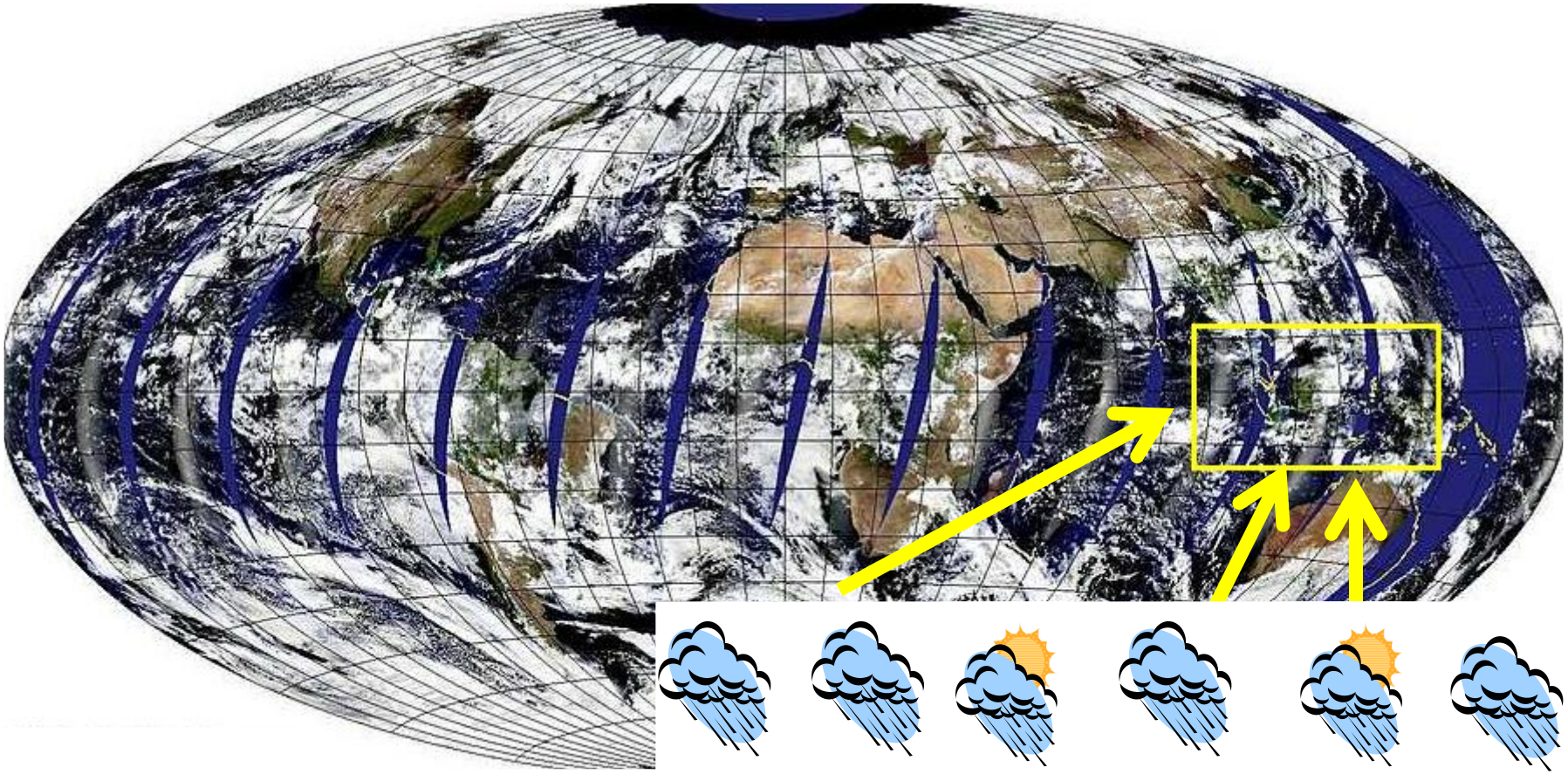
for one day of MODIS data

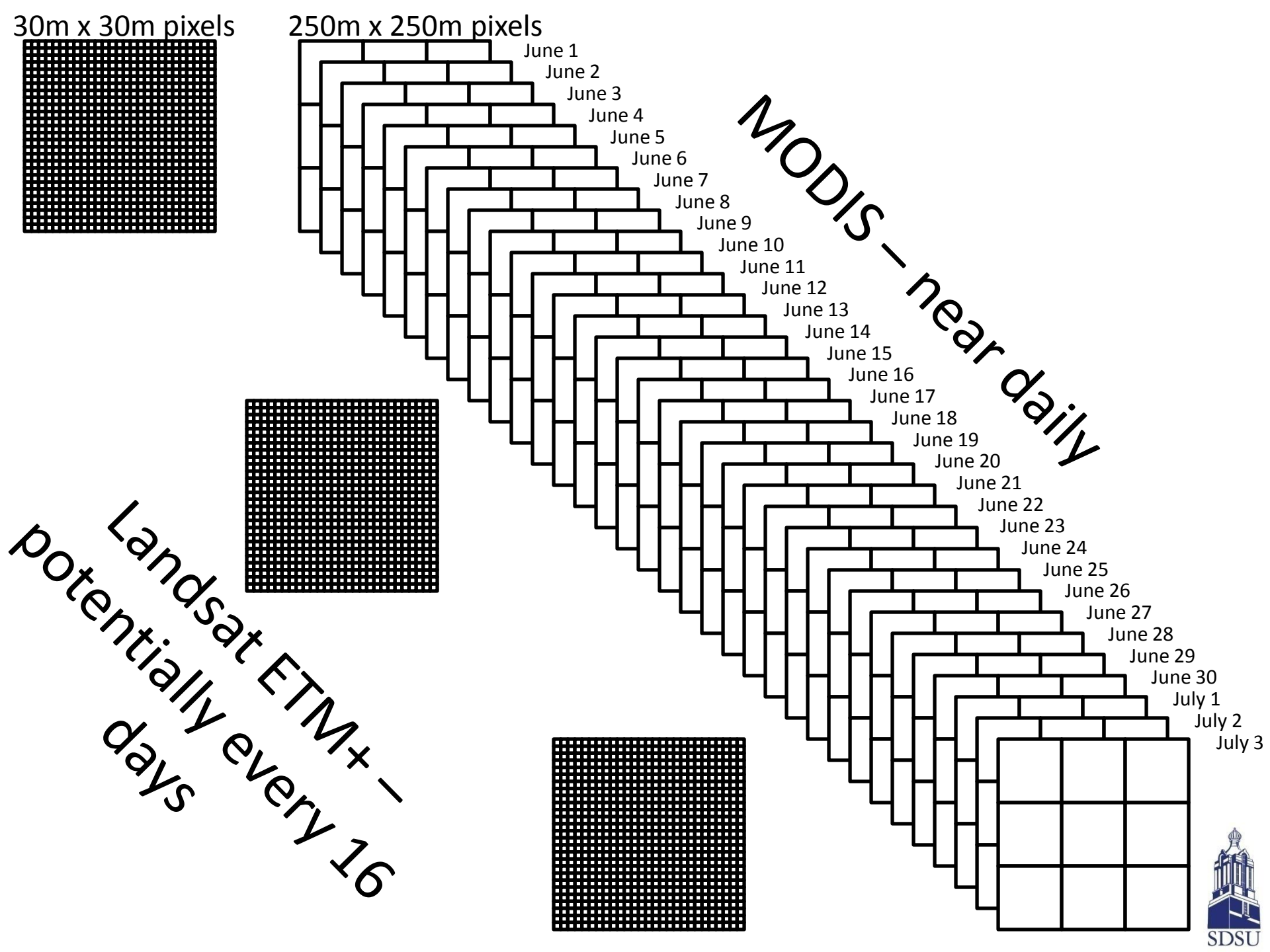


Seasonally cloud-free window over the southern Amazon



Conversely, Indonesia is persistently cloudy




30m x 30m pixels
250m x 250m pixels
June 1
June 2
June 3
June 4
June 5
June 6
June 7
June 8
June 9
June 10
June 11
June 12
June 13
June 14
June 15
June 16
June 17
June 18
June 19
June 20
June 21
June 22
June 23
June 24
June 25
June 26
June 27
June 28
June 29
June 30
July 1
July 2
July 3
MODIS – near daily
Landsat ETM+ – potentially every 16 days
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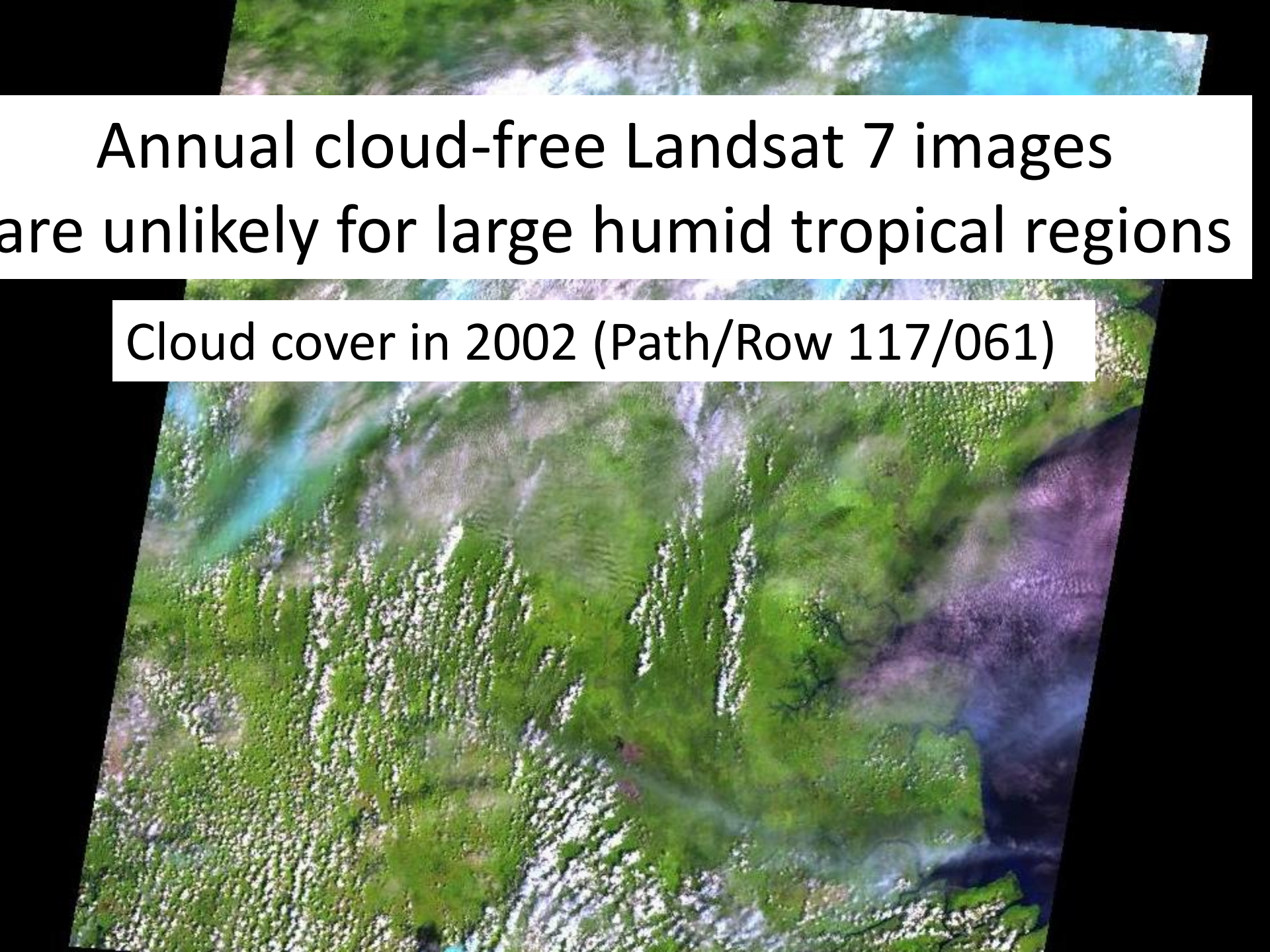
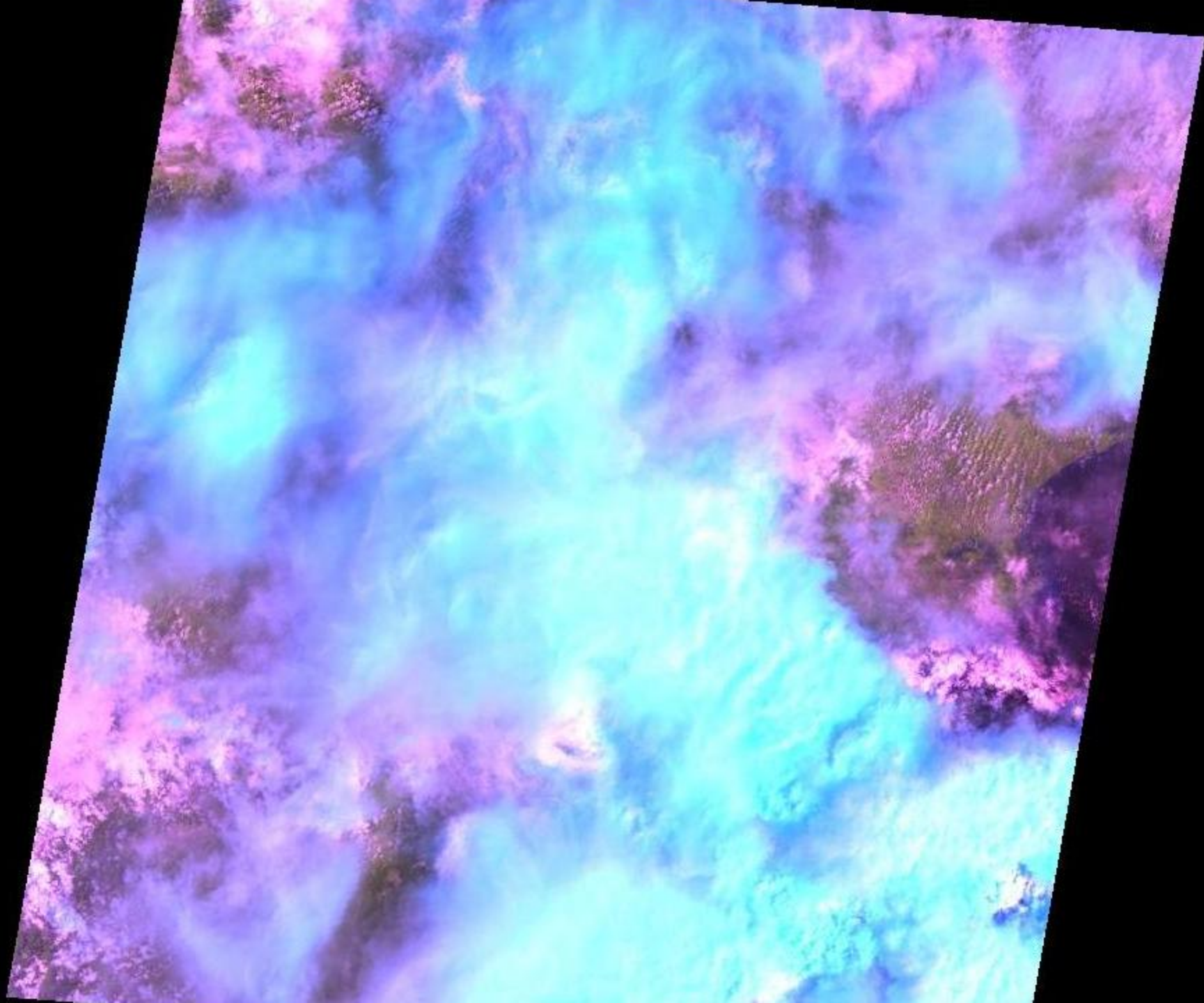
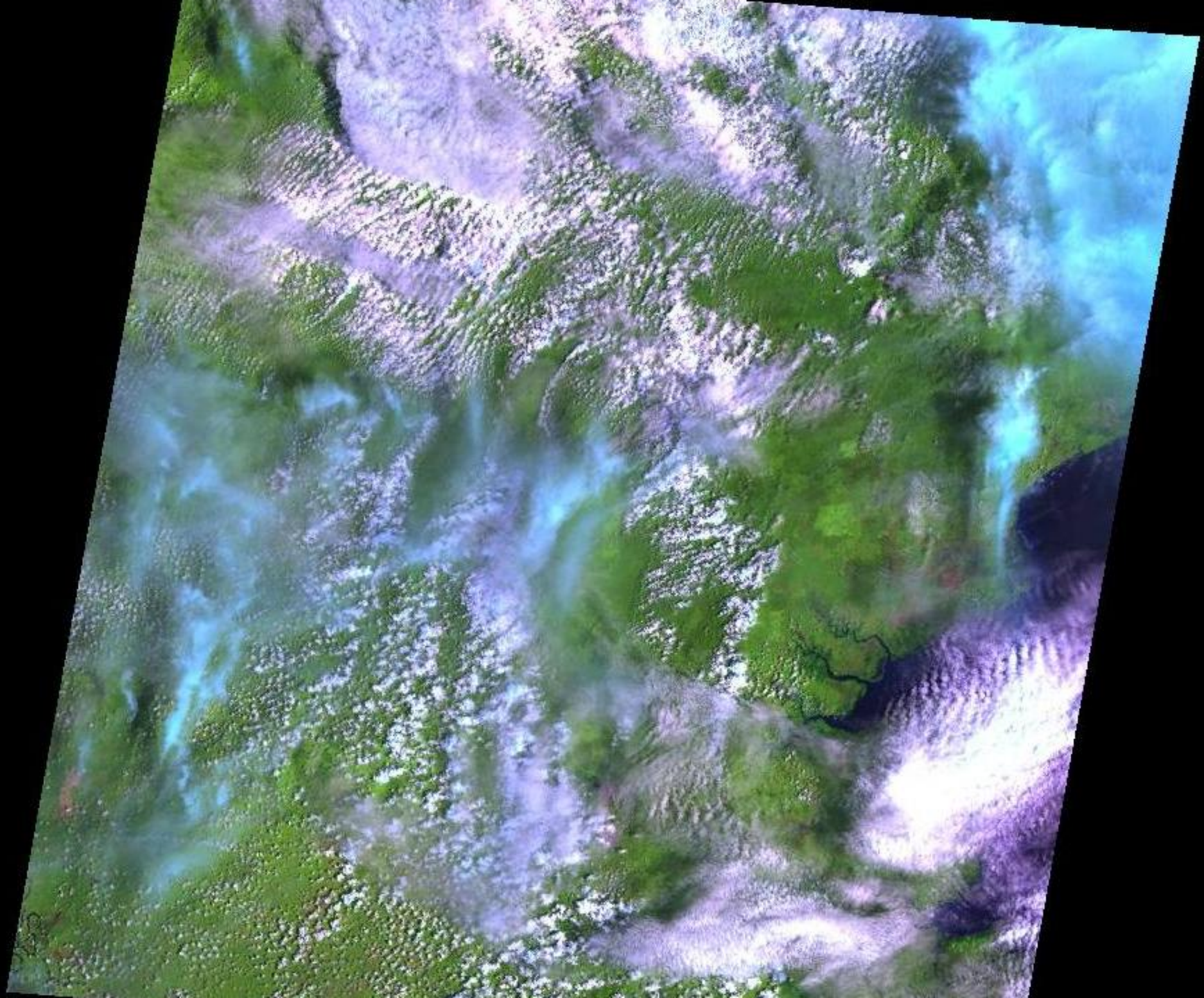
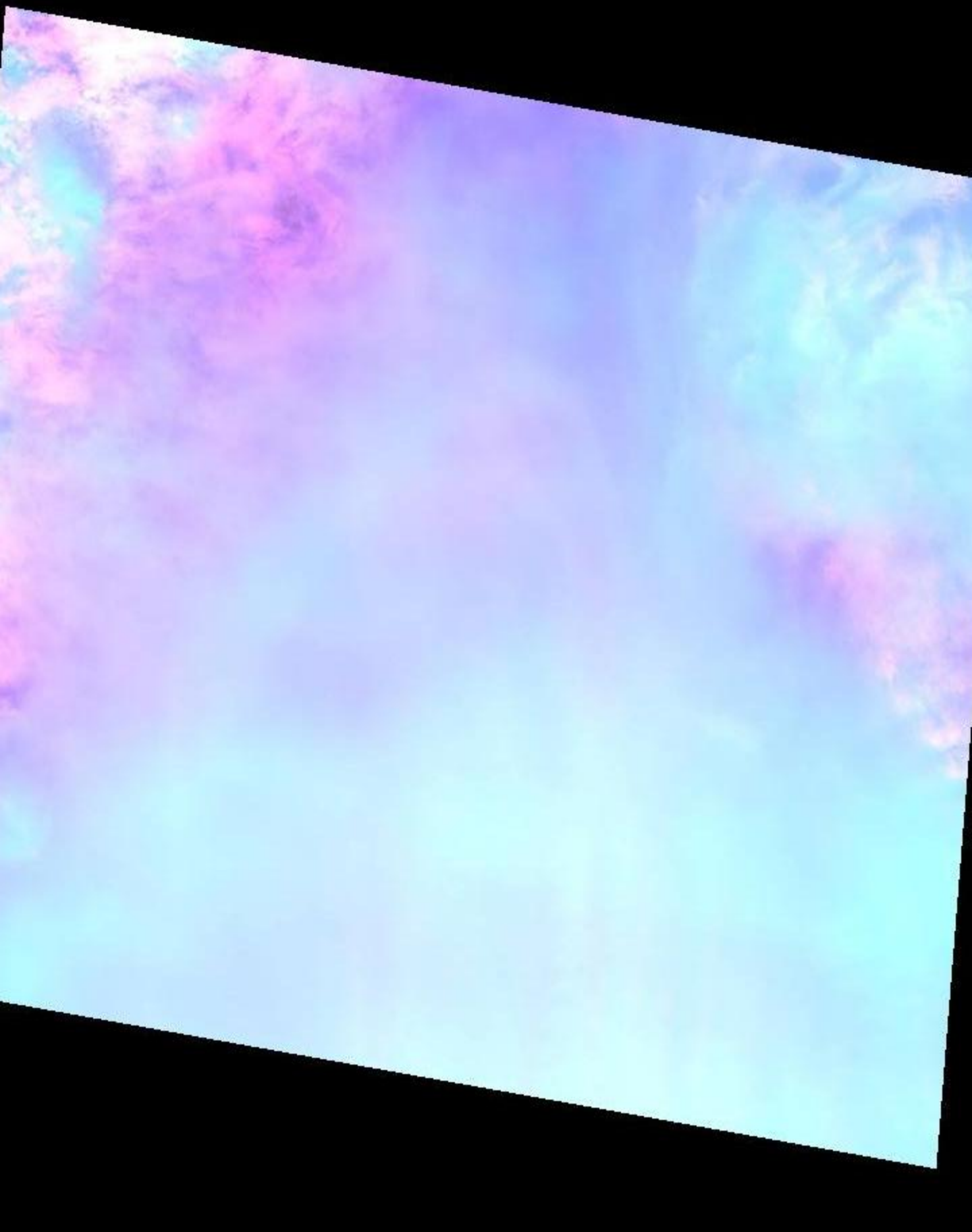
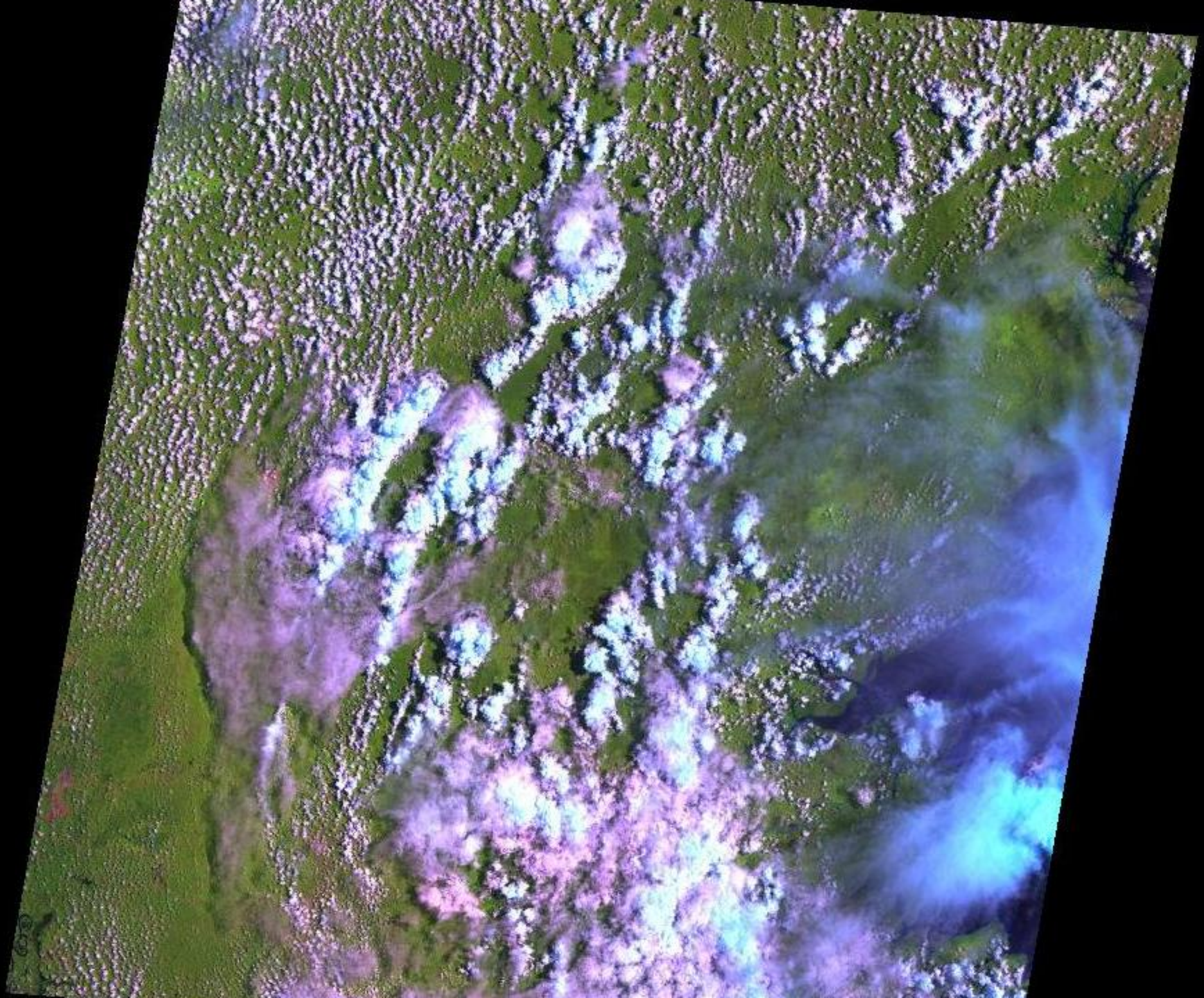
Annual cloud-free Landsat 7 images are unlikely for large humid tropical regions

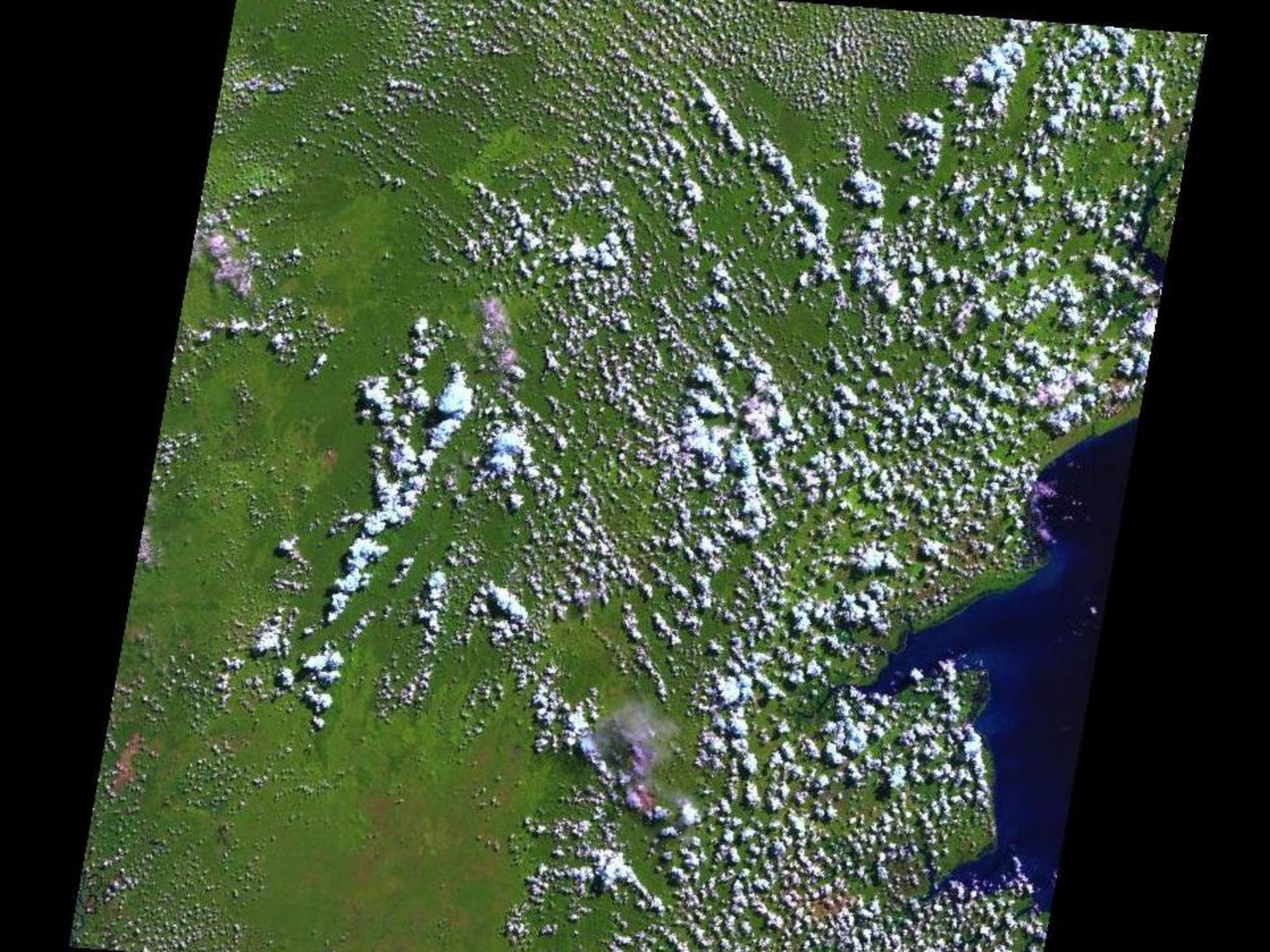


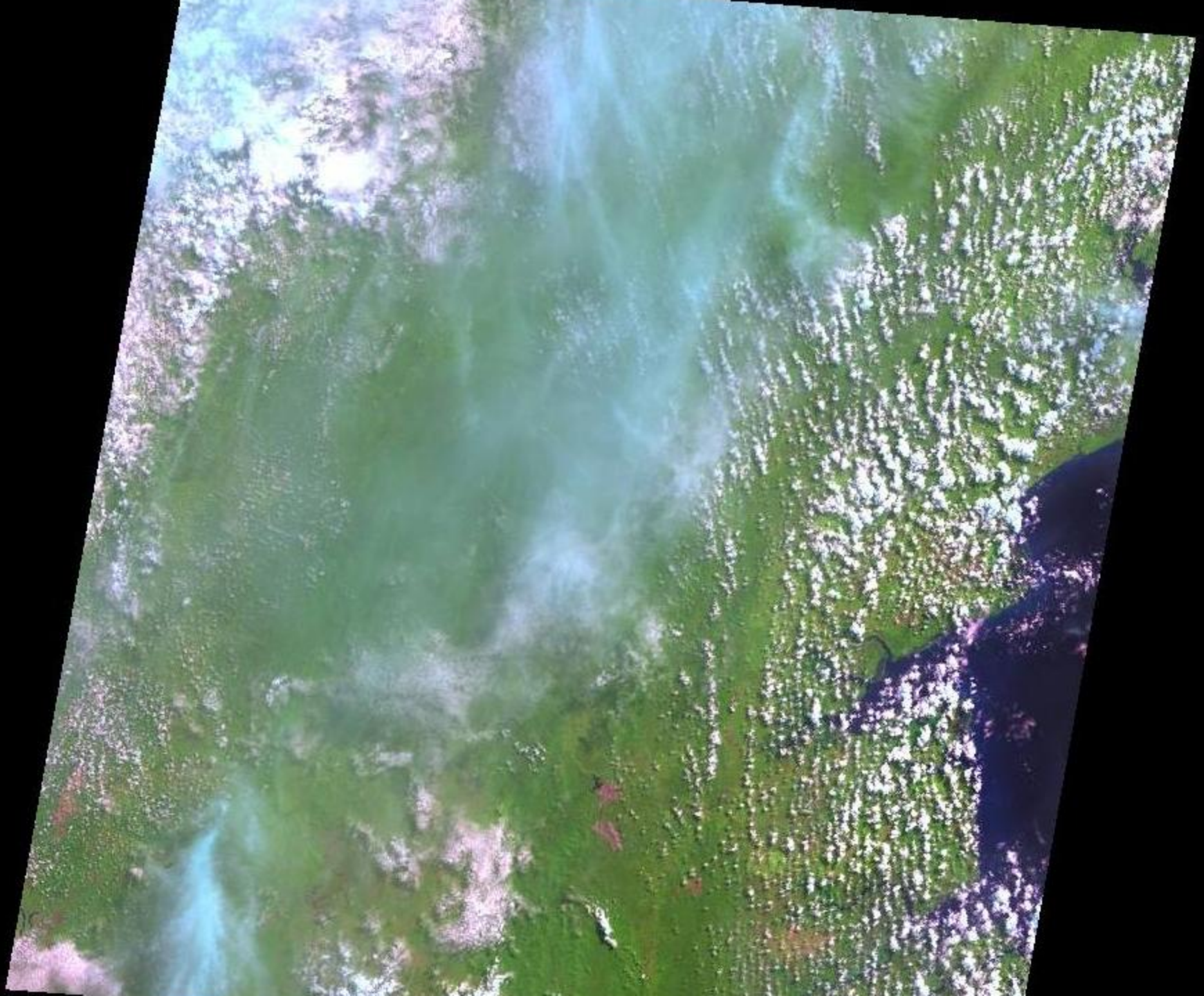


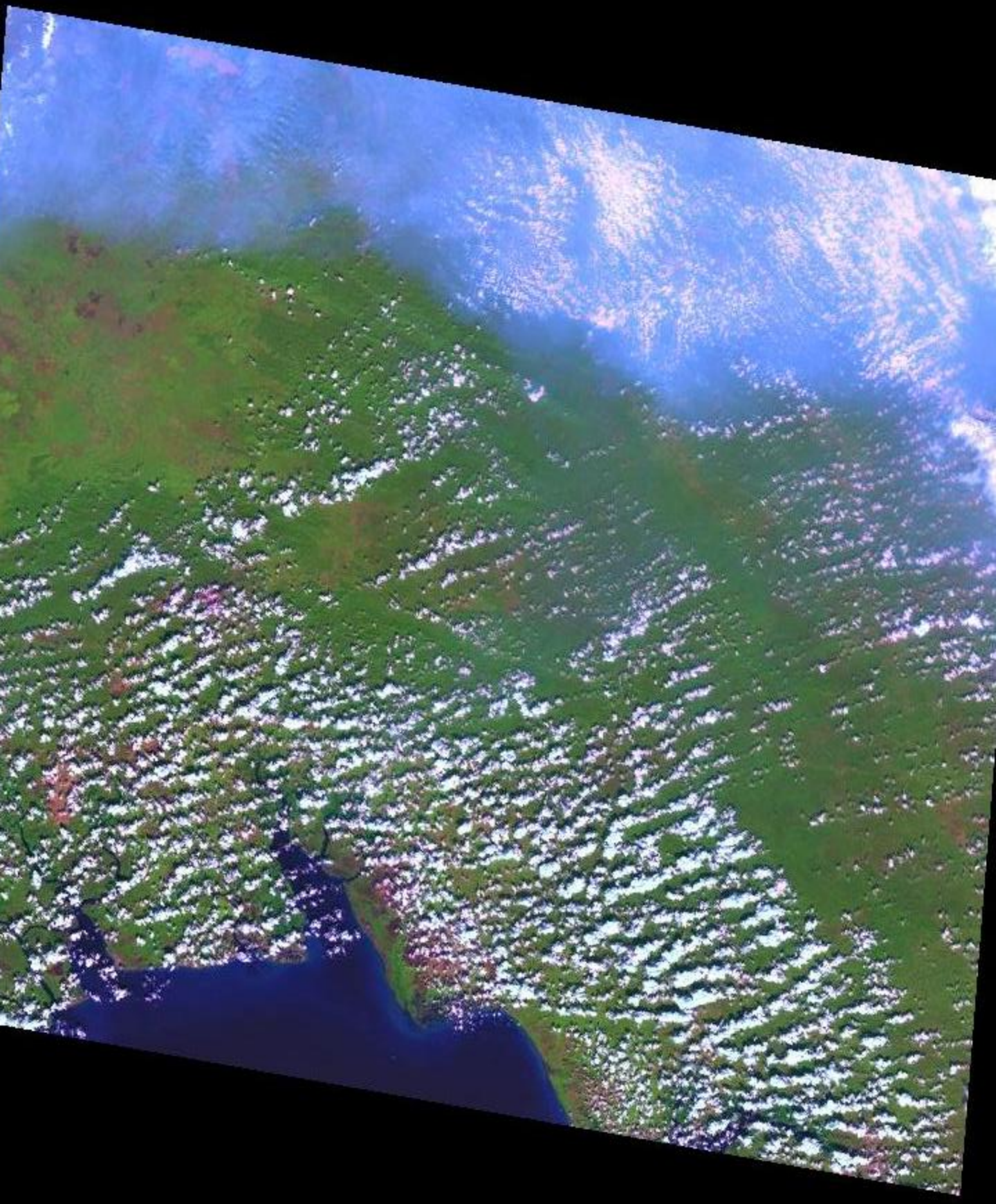


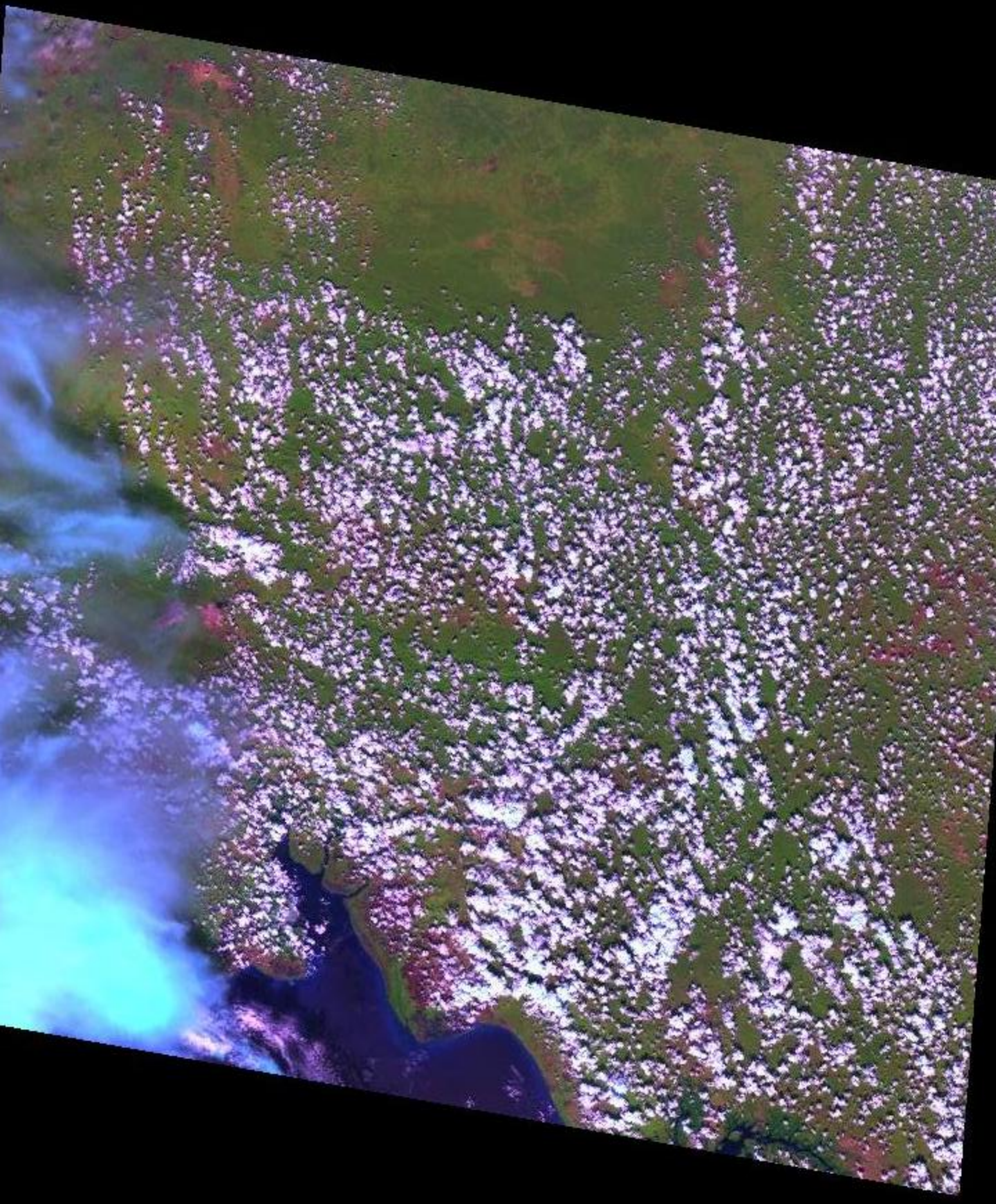


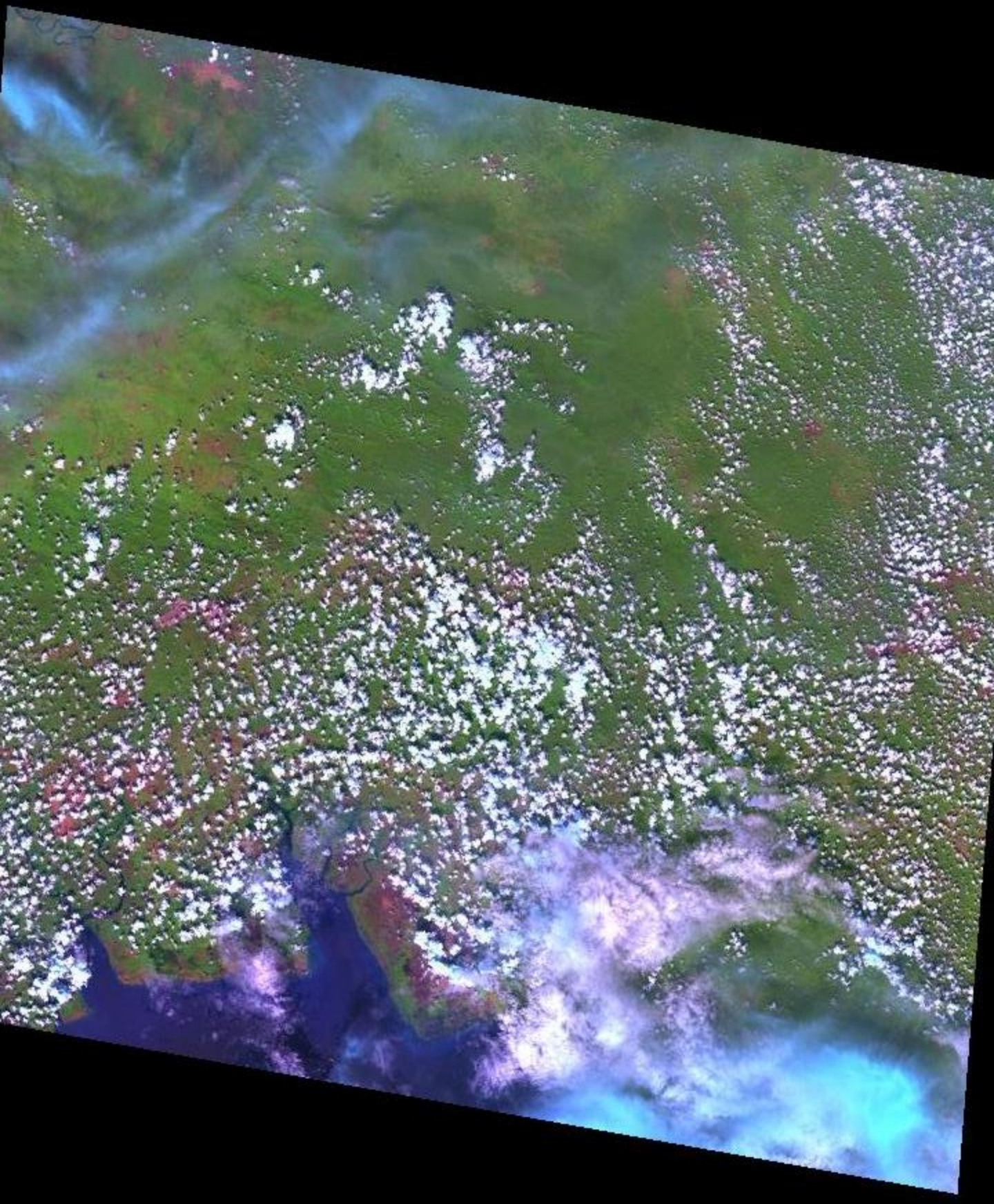


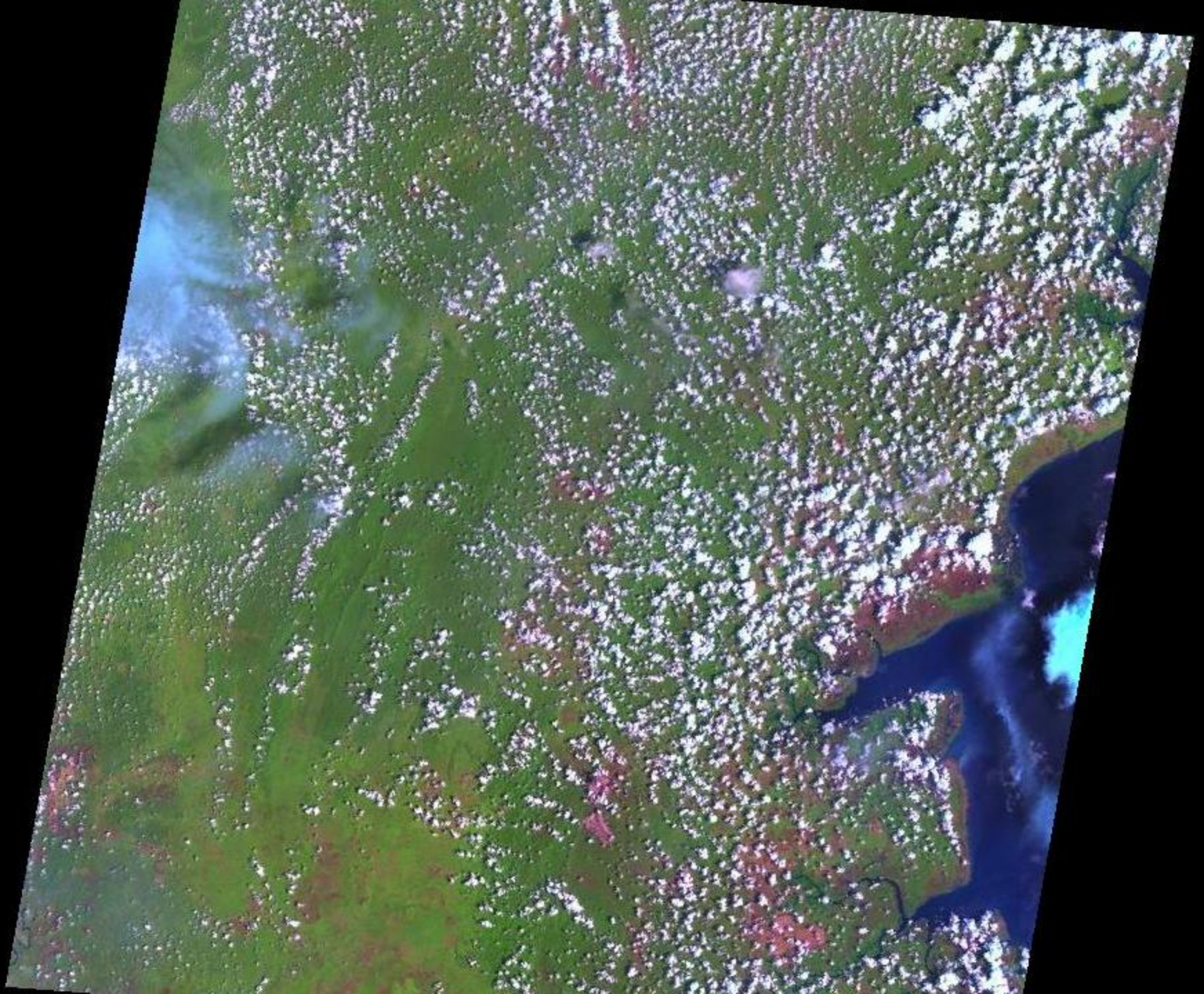


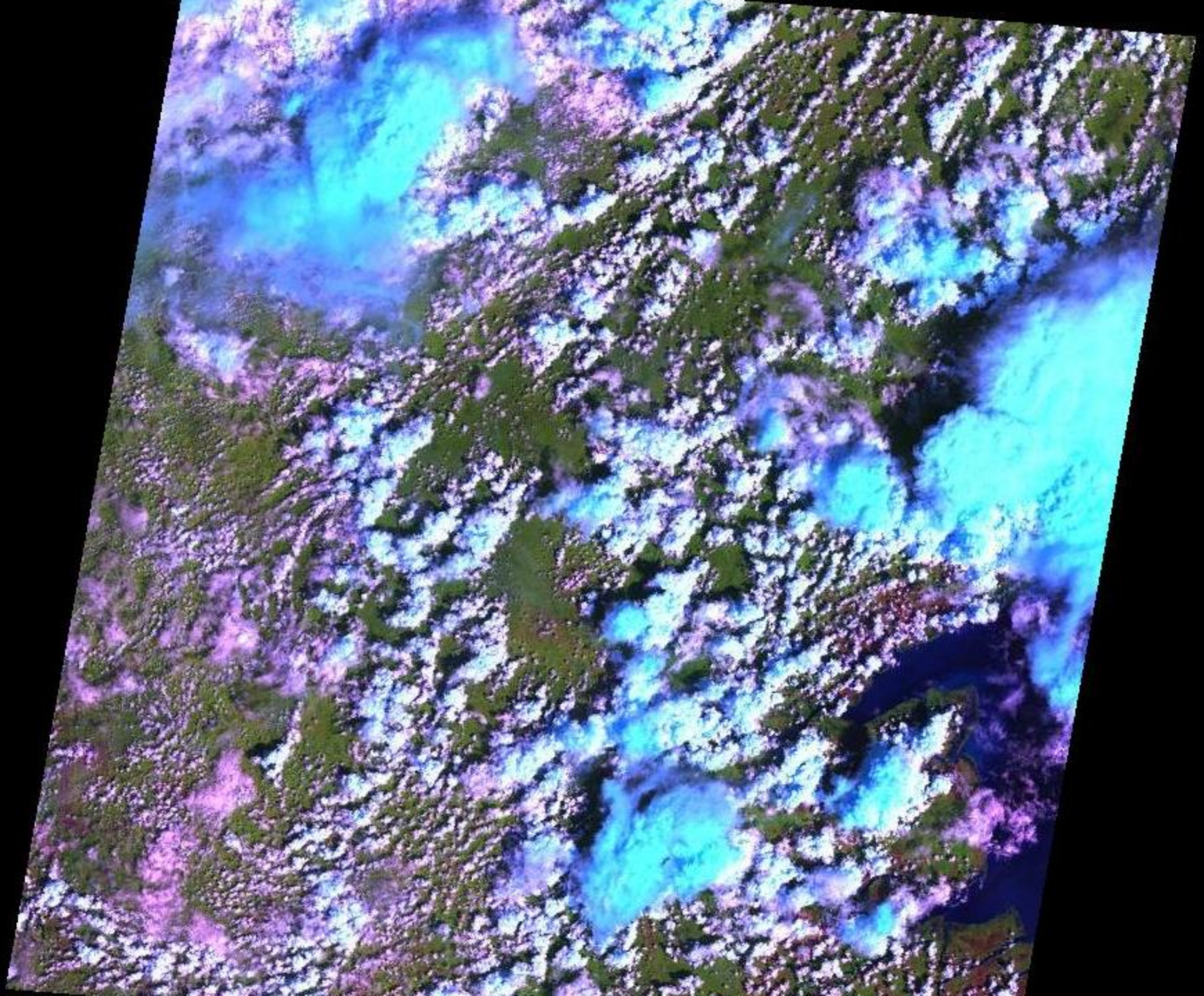


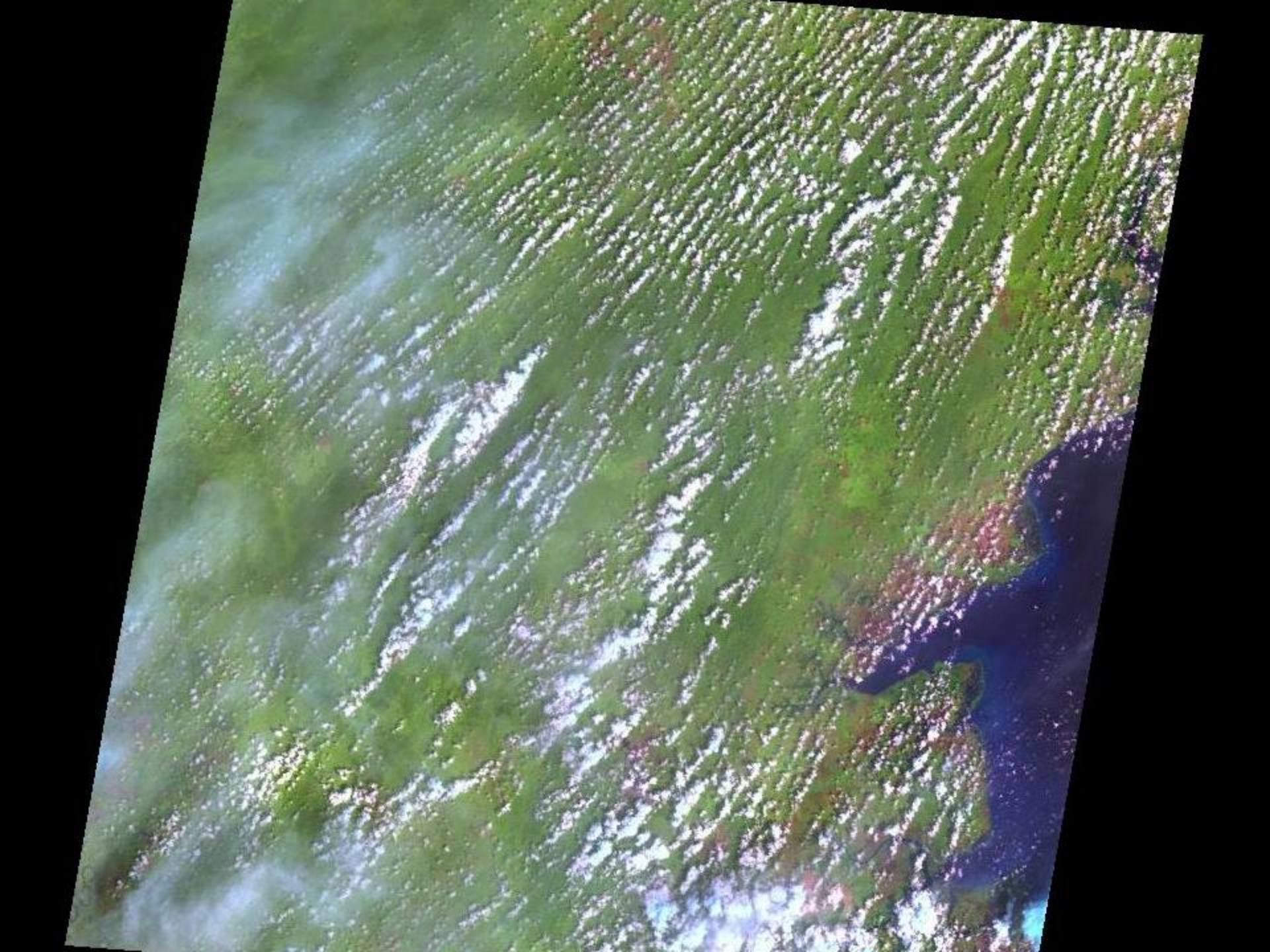


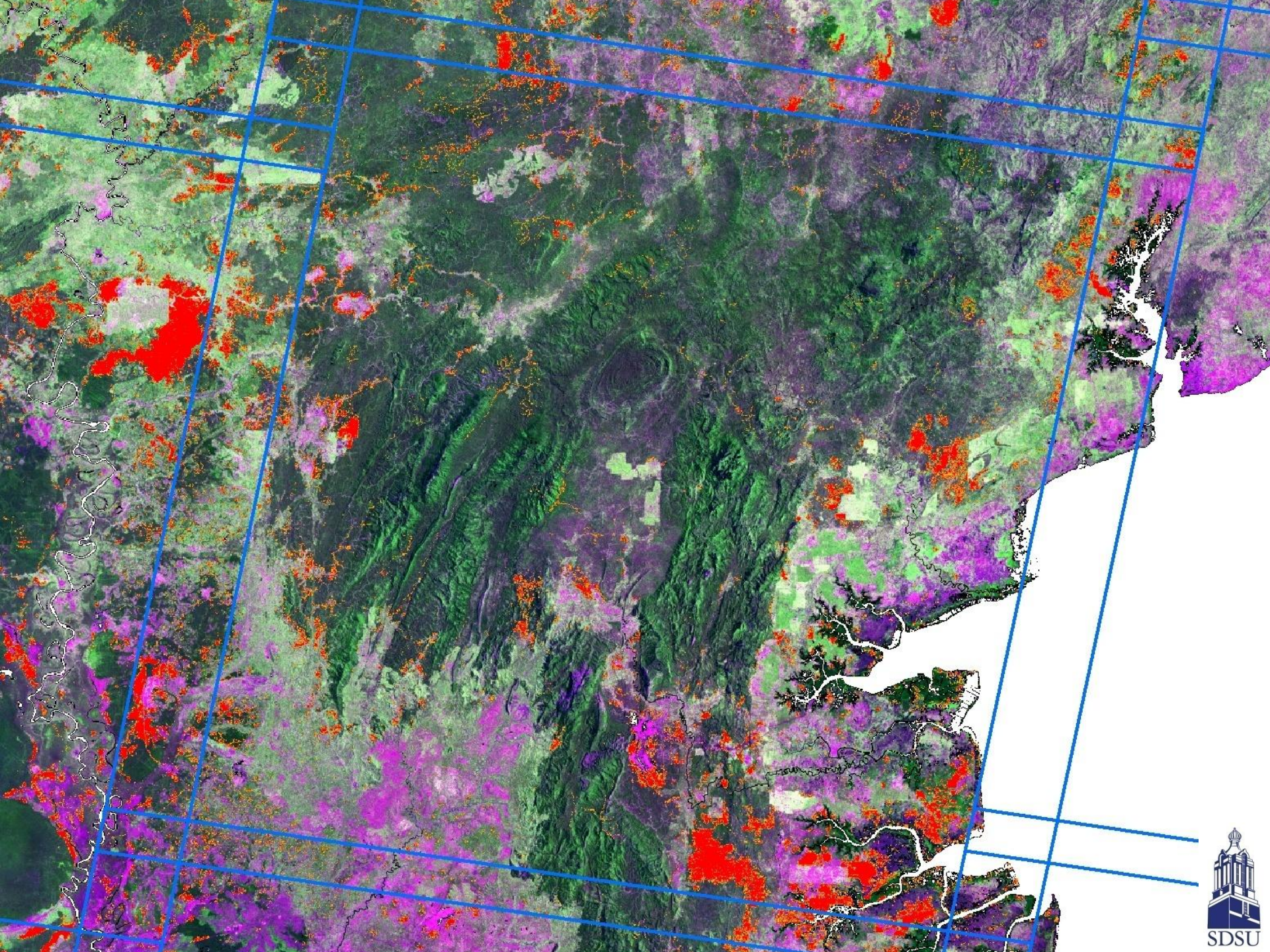








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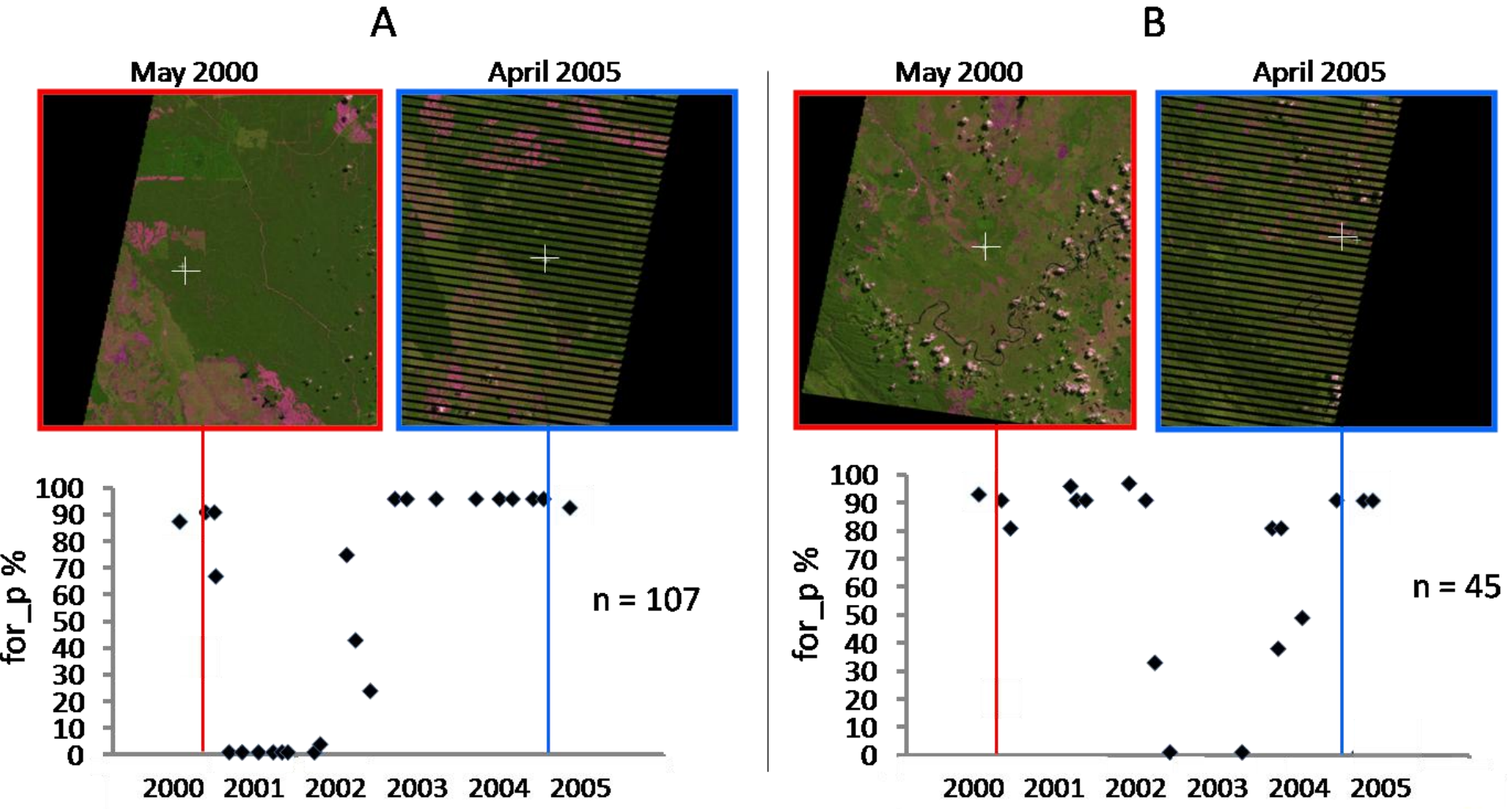
Per pixel time series



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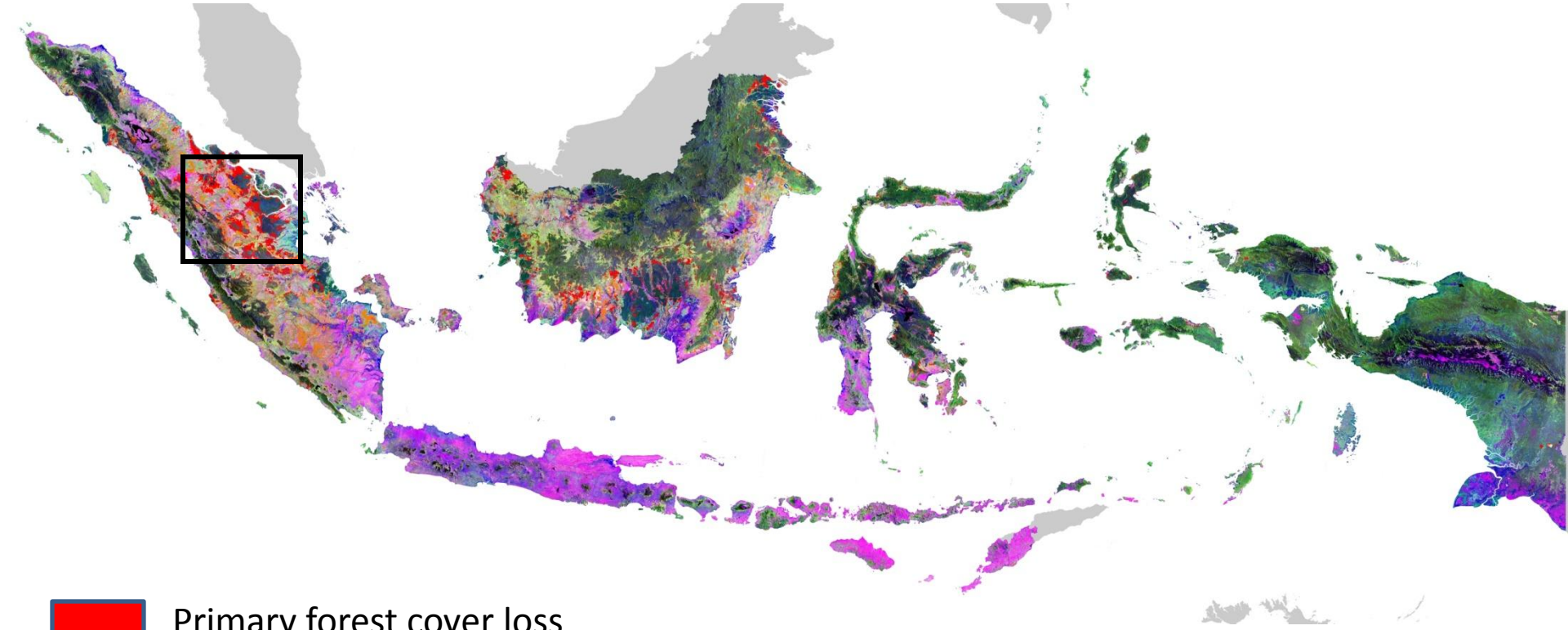
Forest cover loss in Indonesia, 2000 to 2010

15,692 Landsat Enhanced Thematic Mapper Plus images from 1999 to 2010



Primary forest cover loss

Other forest cover loss

Nearly 1 million hectares per year, almost half in primary forests

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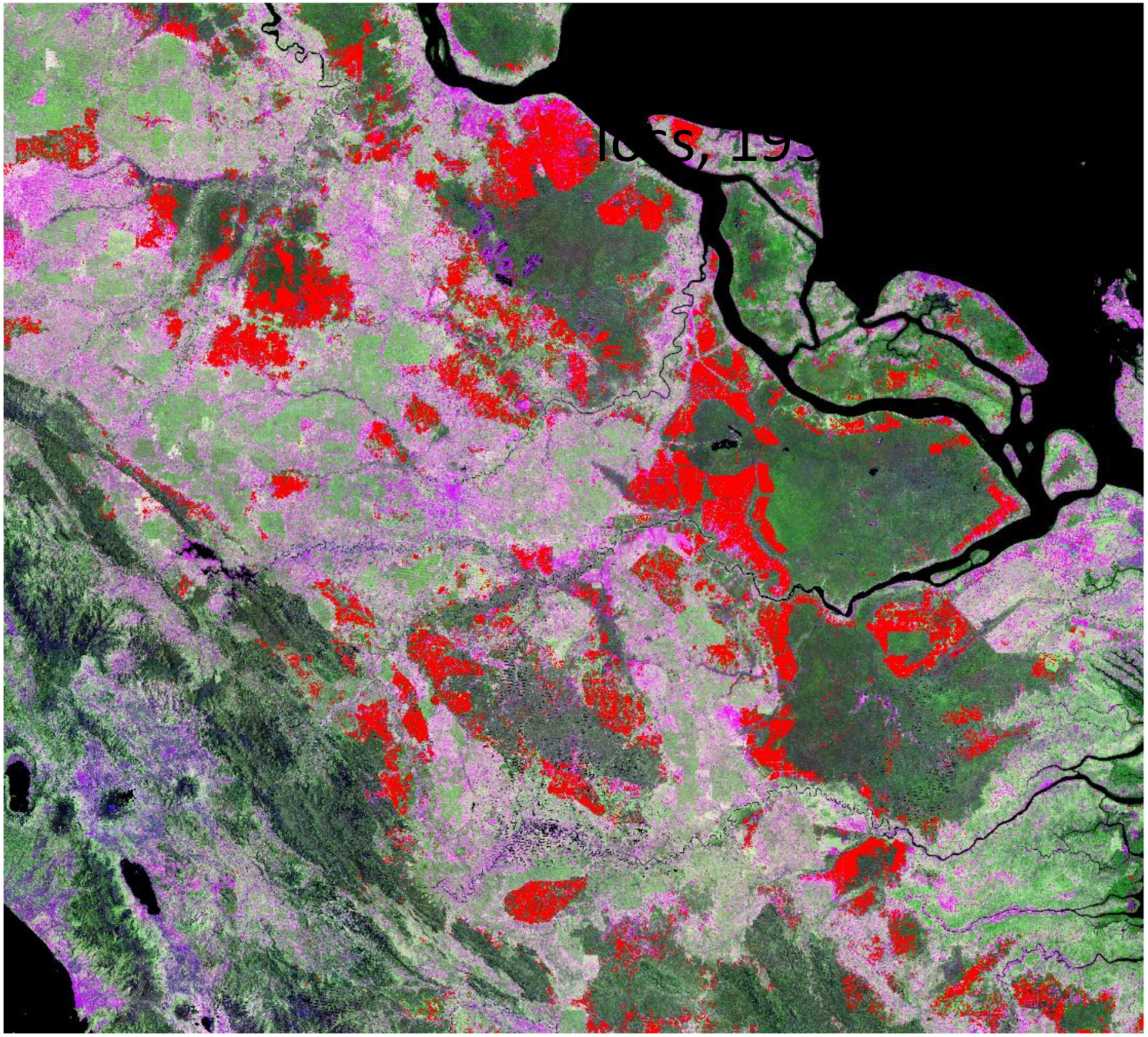
Total forest cover loss

00-08



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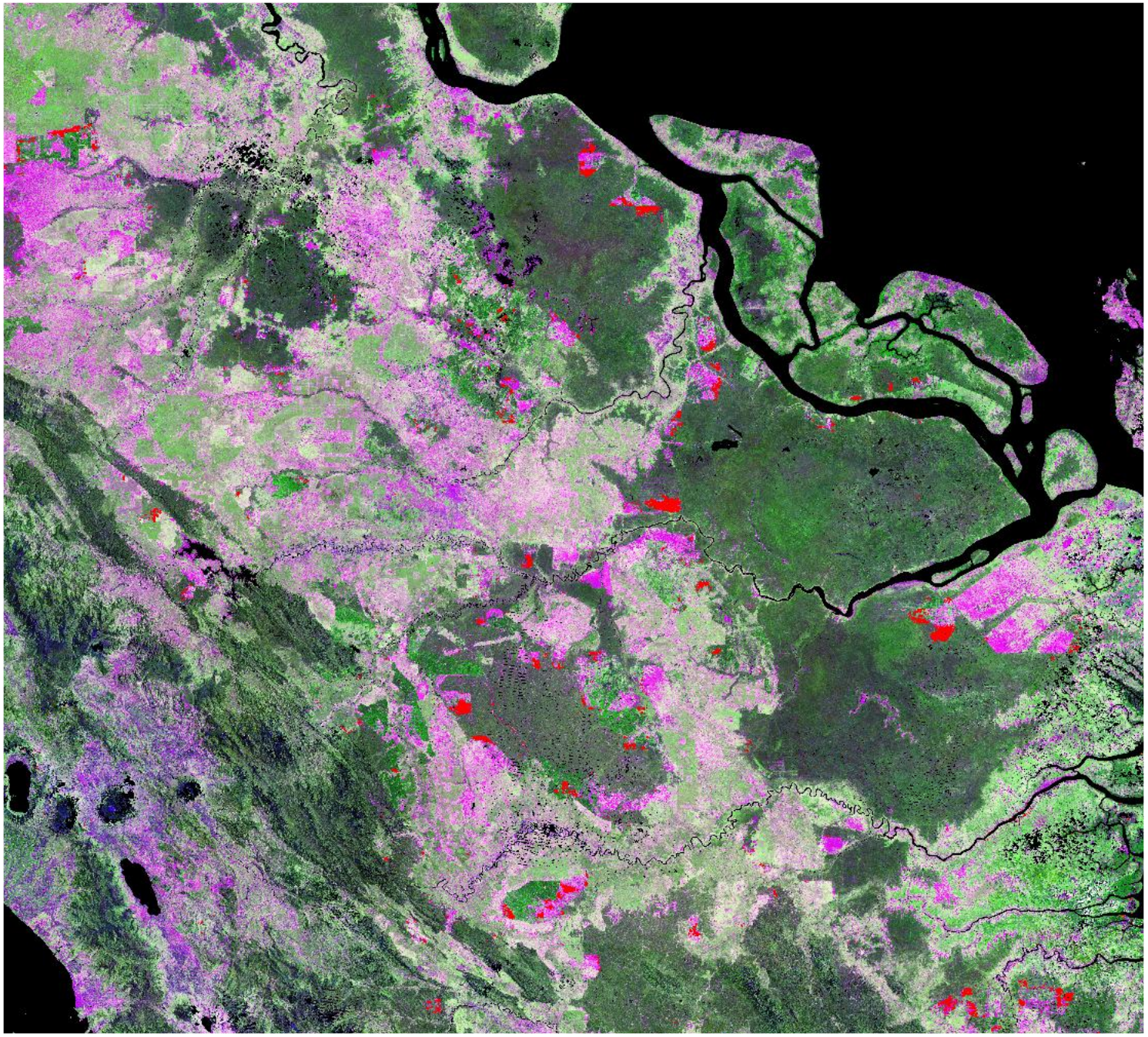
Annual forest cover loss

00-01



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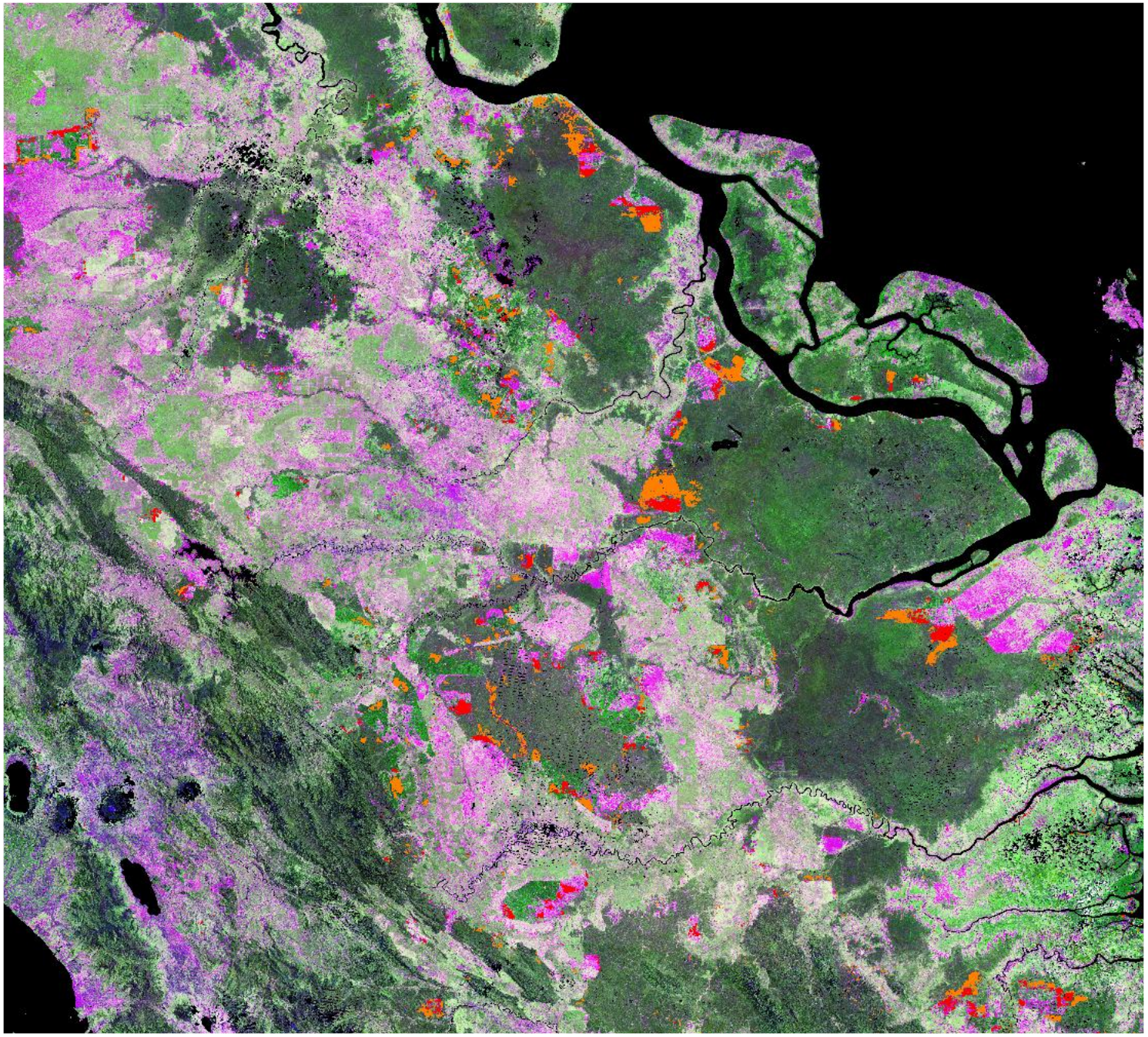
Annual forest cover loss

00-01

01-02



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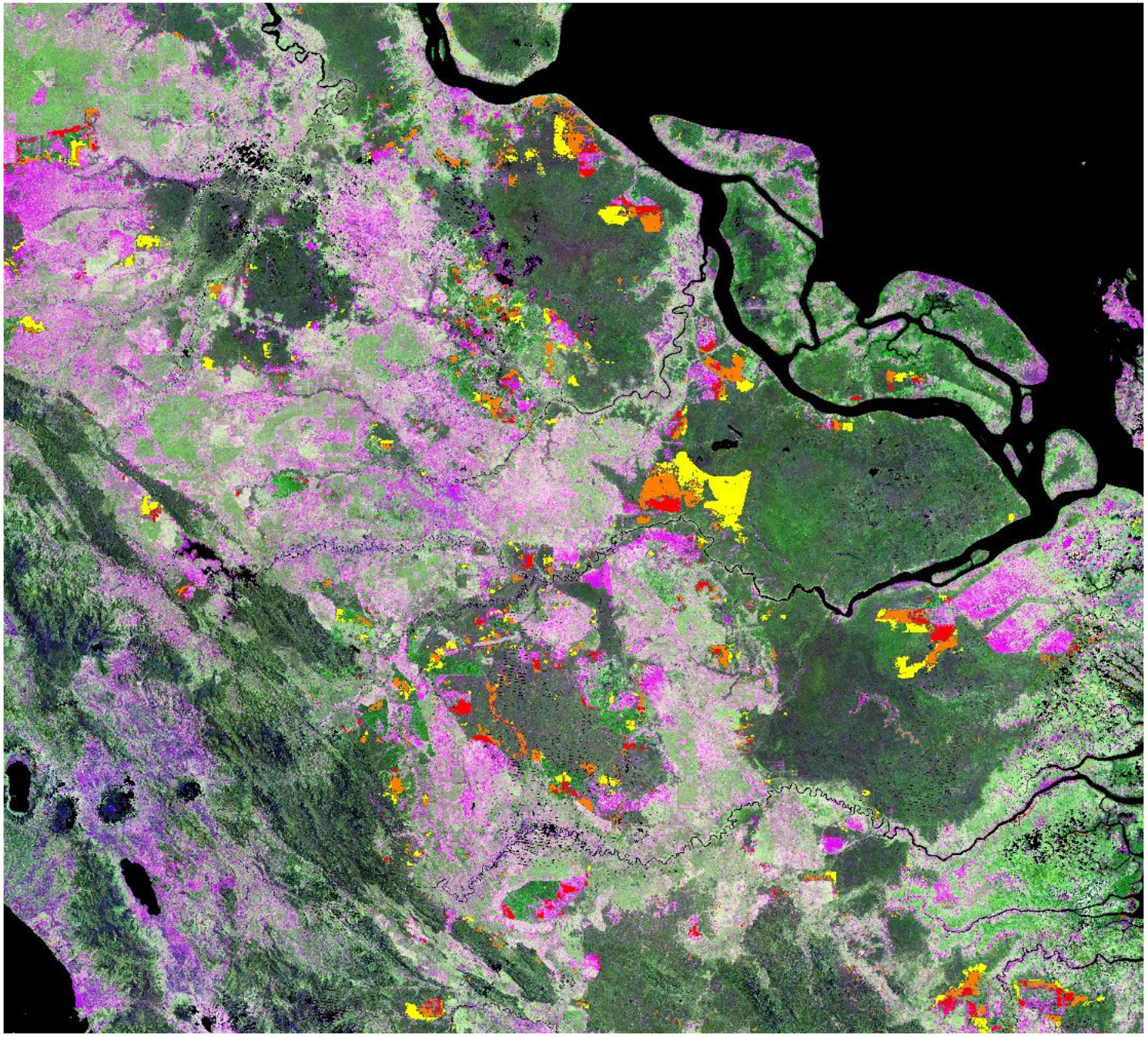
Annual forest cover loss

00-01

01-02

02-03



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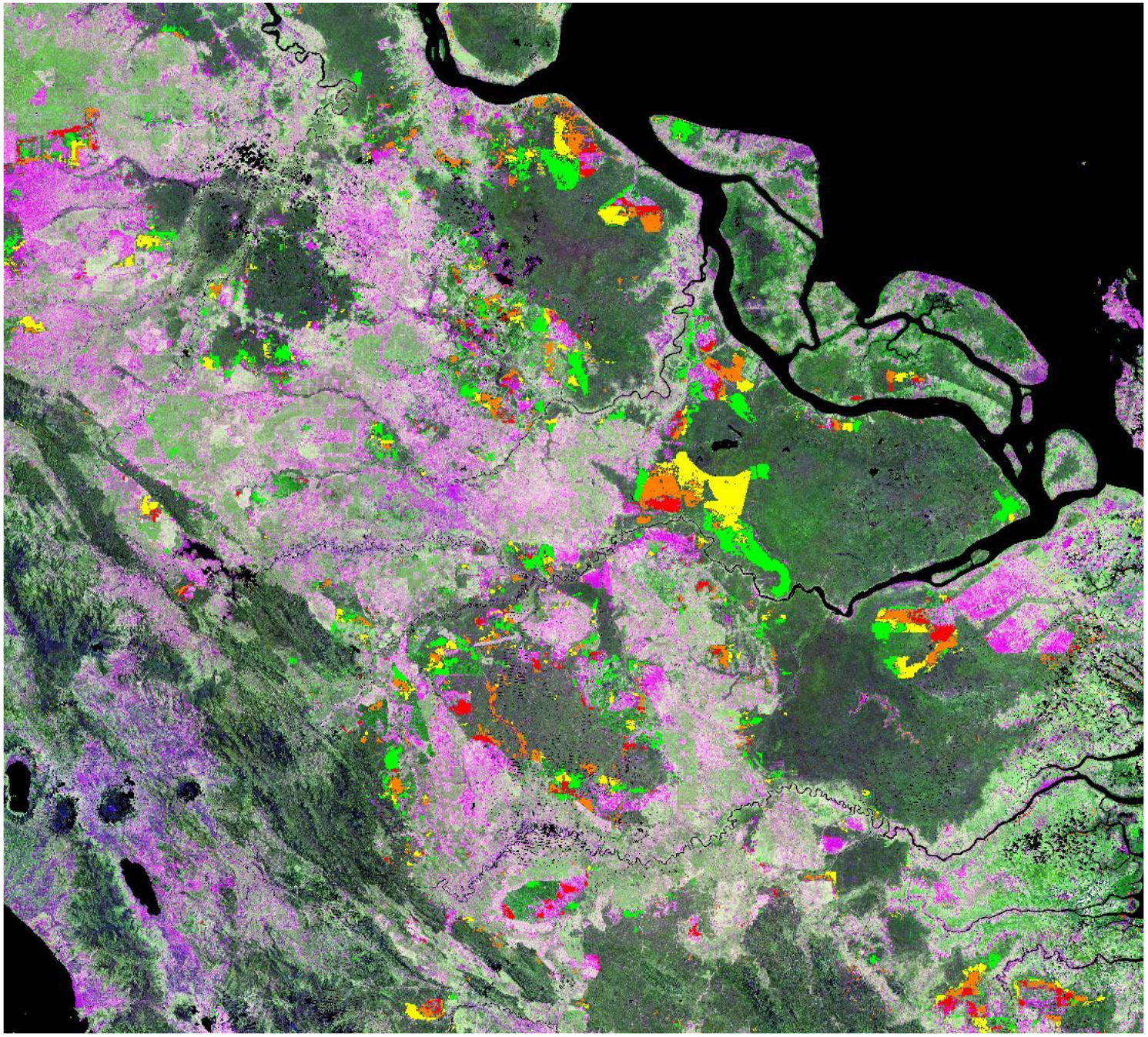
Annual forest cover loss

- 00-01
- 01-02
- 02-03
- 03-04



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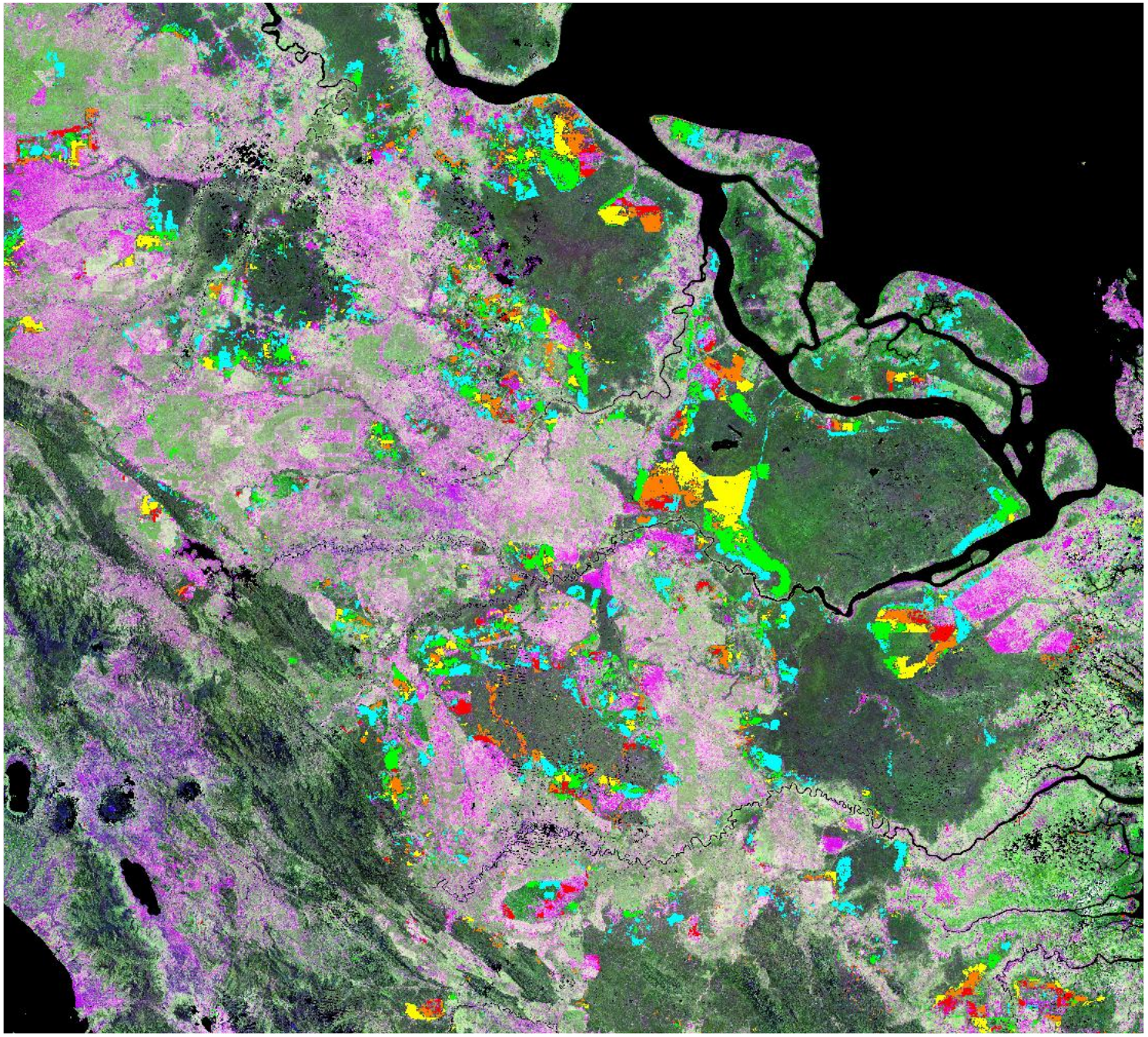
Annual forest cover loss

- 00-01
- 01-02
- 02-03
- 03-04
- 04-05



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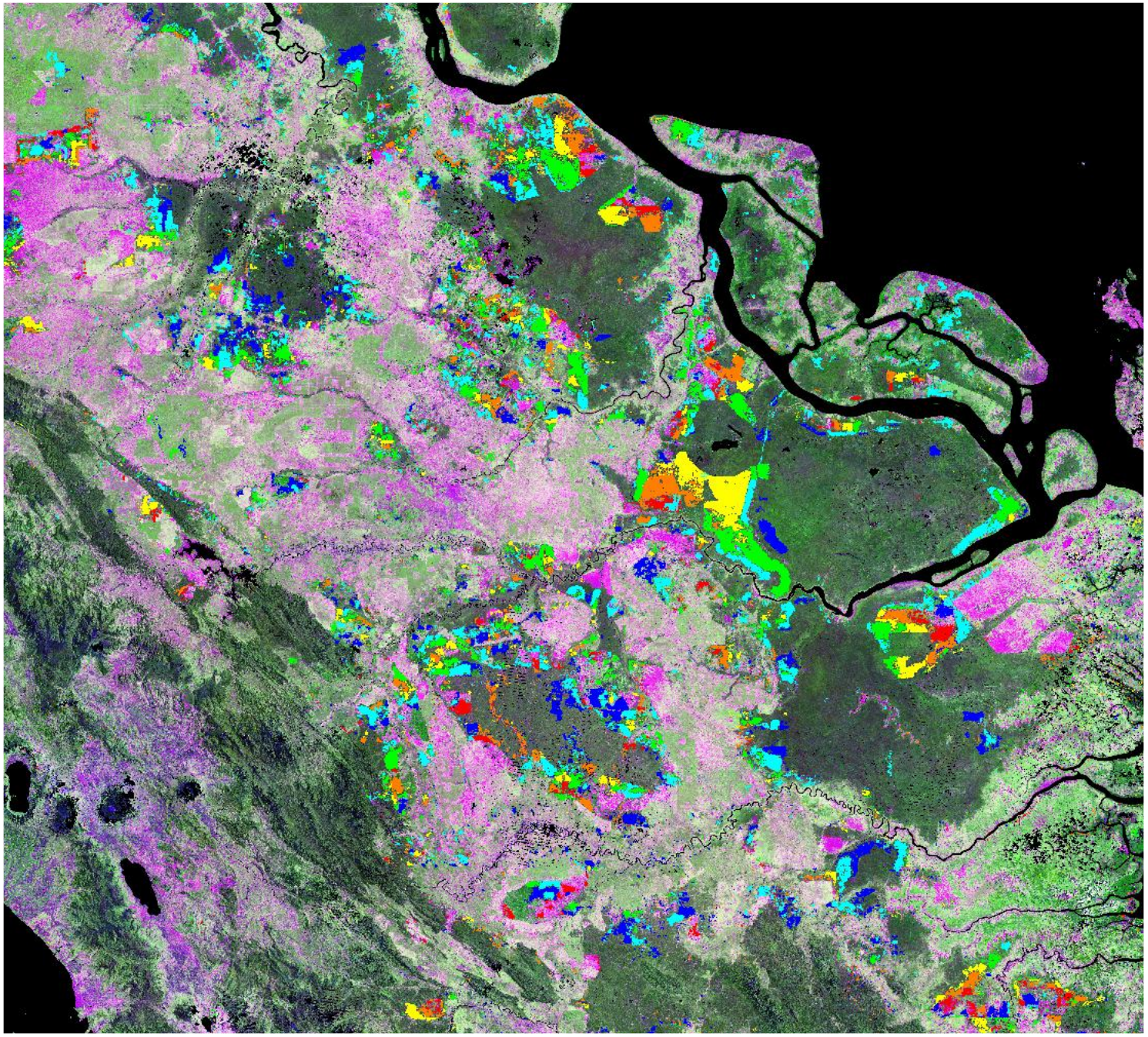
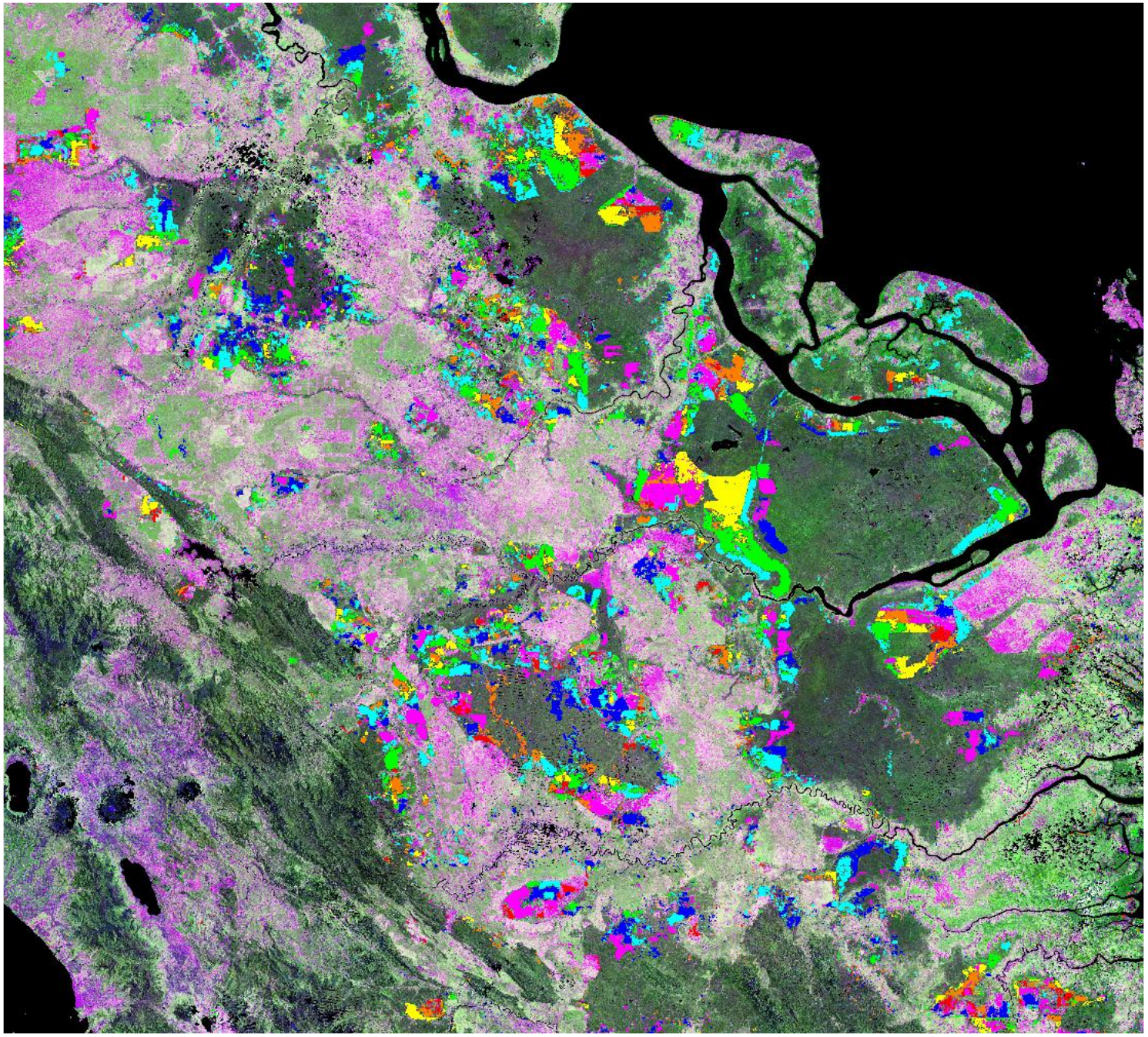
Annual forest cover loss



SDSU

Annual forest cover loss



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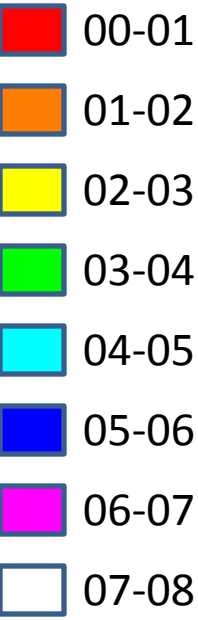
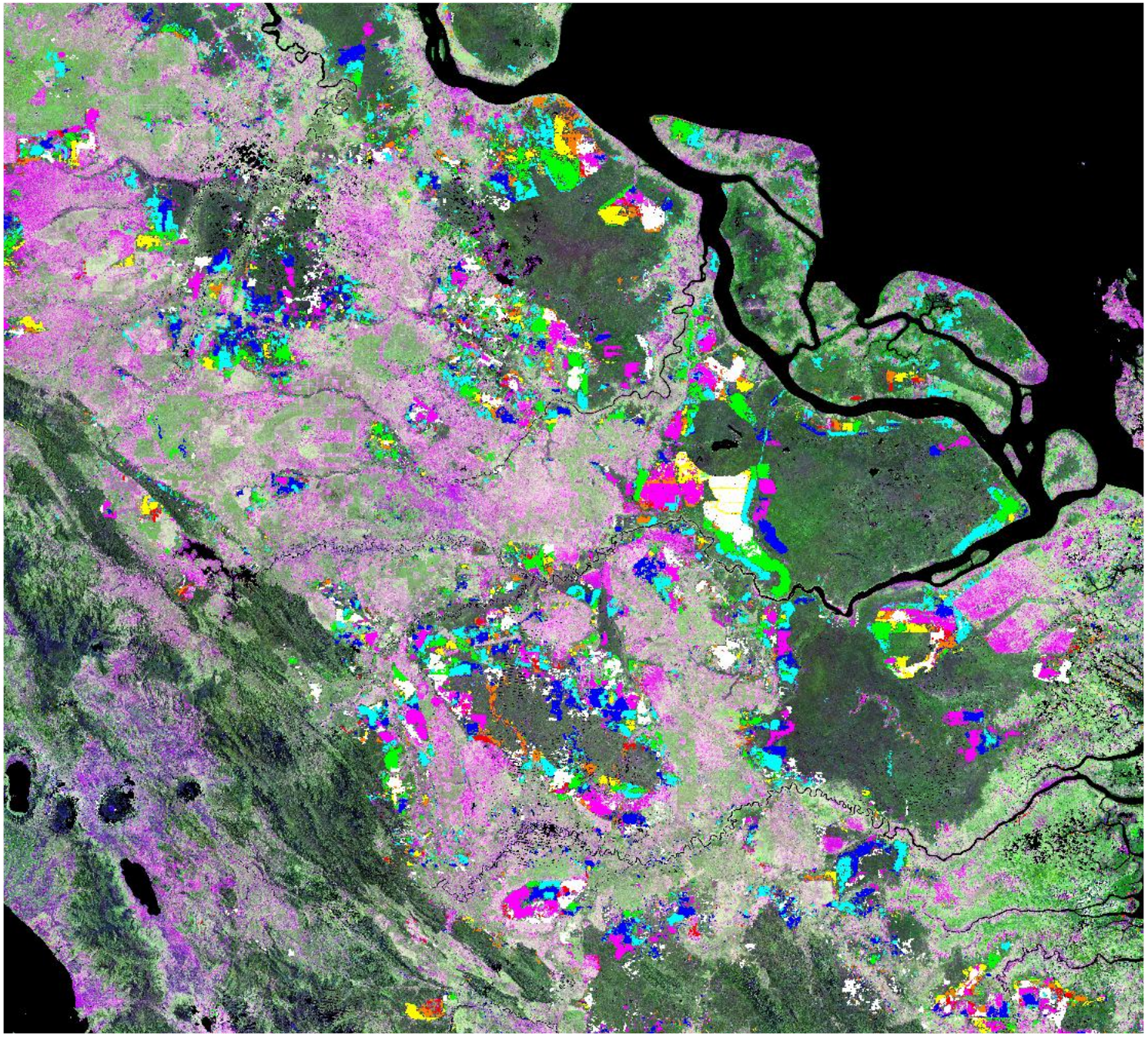
Annual forest cover loss





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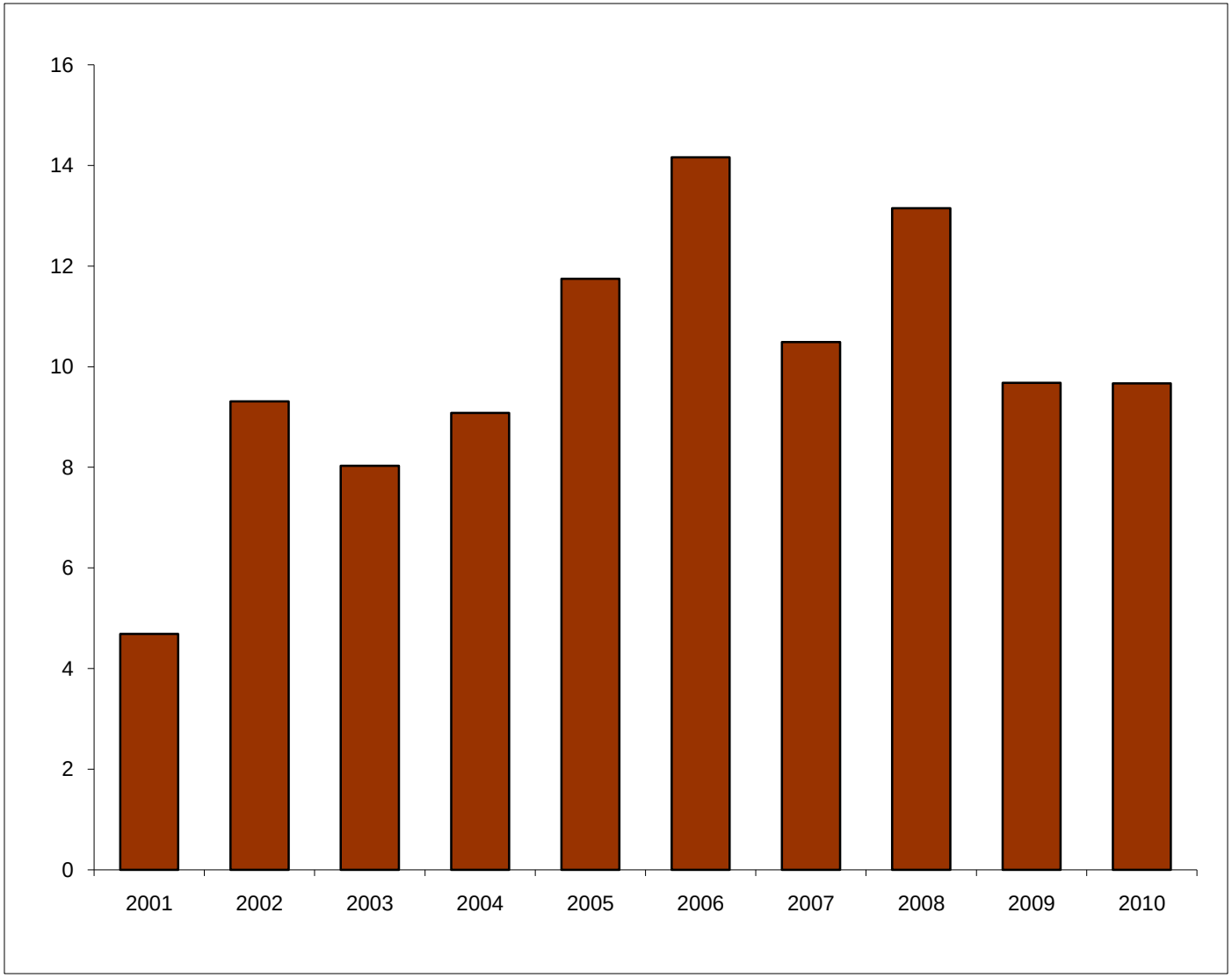
Trend in forest cover loss



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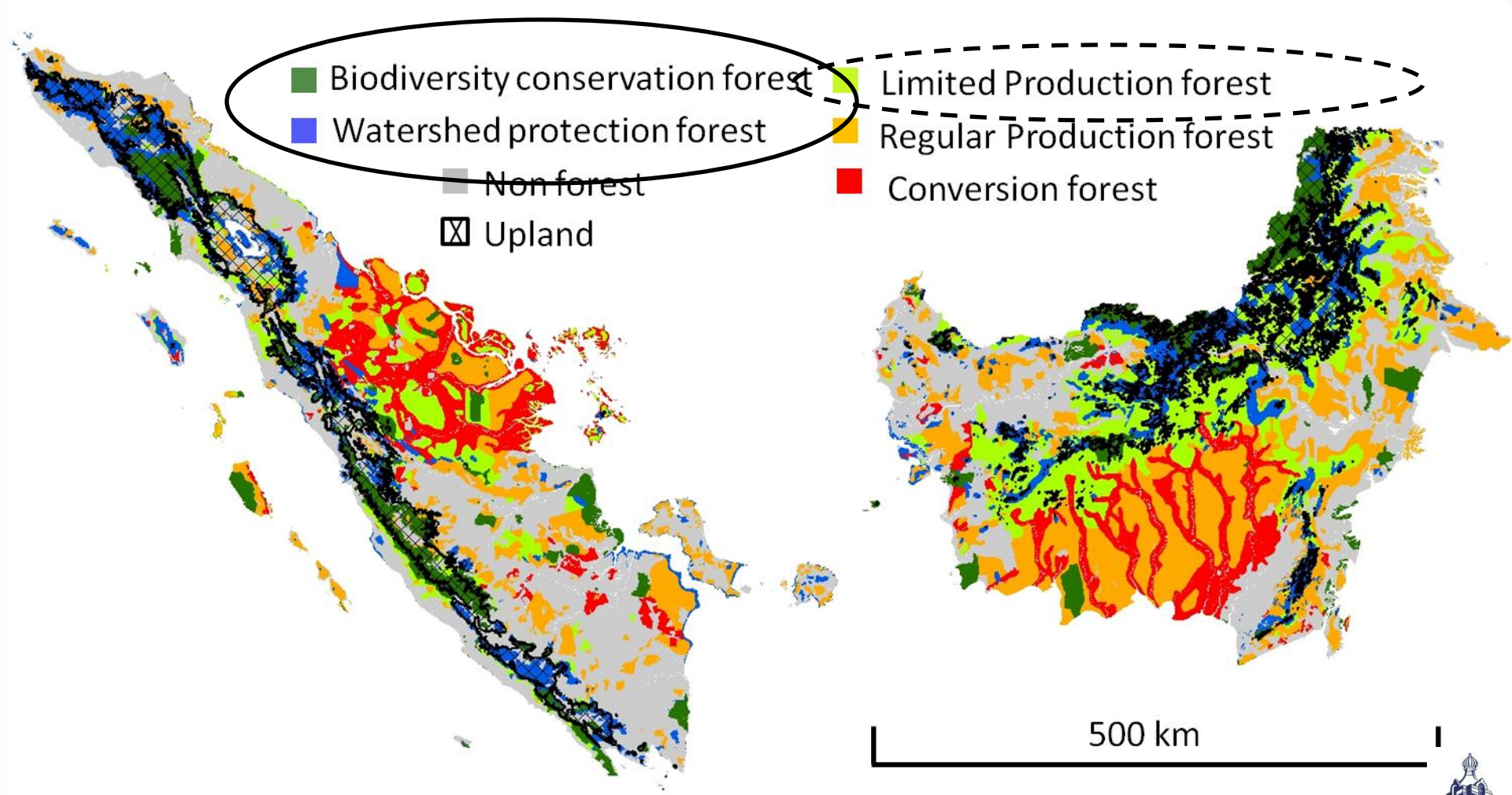
Forest land use zones



Indonesian Ministry of Forestry (2000)

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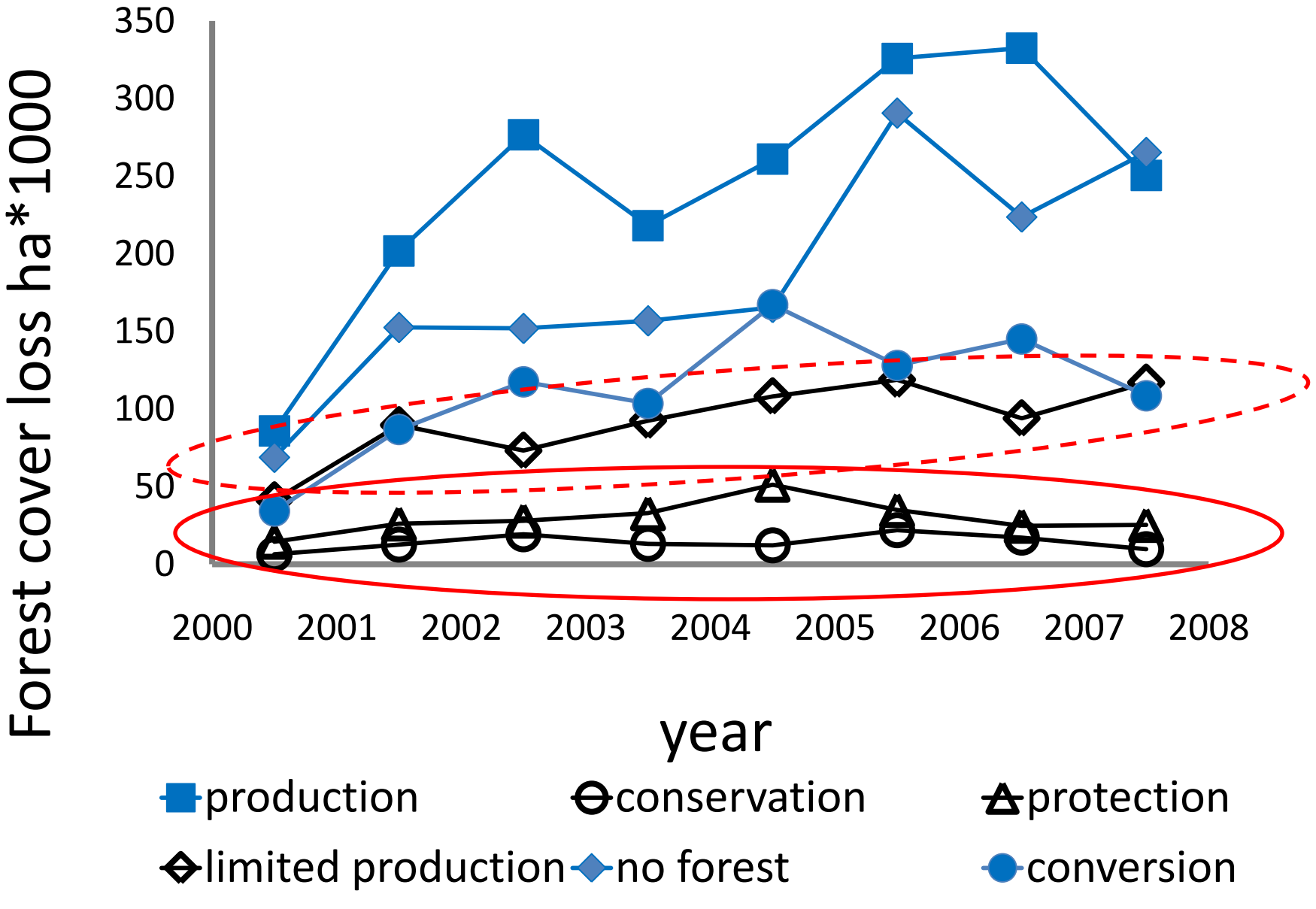
Forest cover loss trends per forest land use zone



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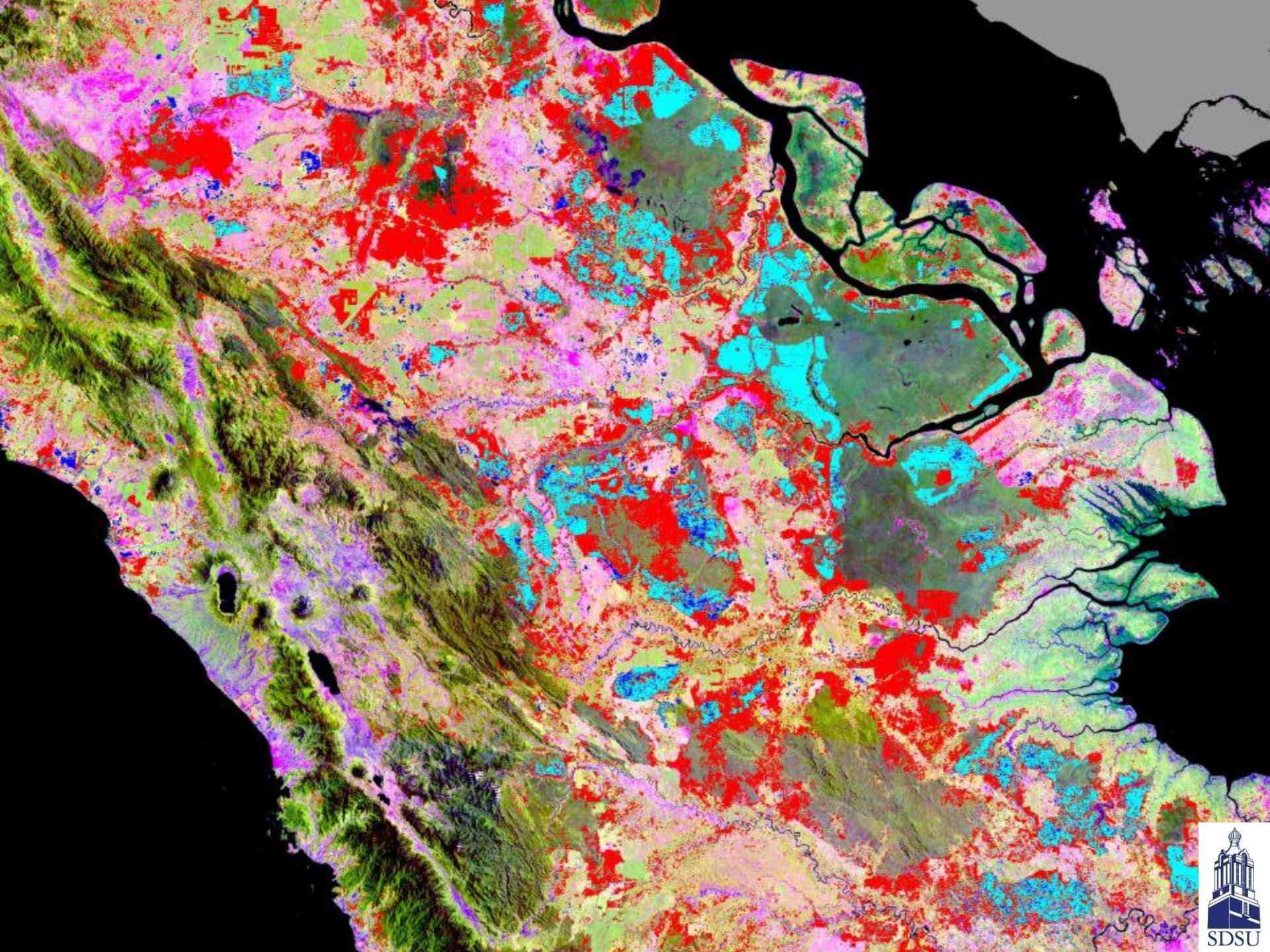
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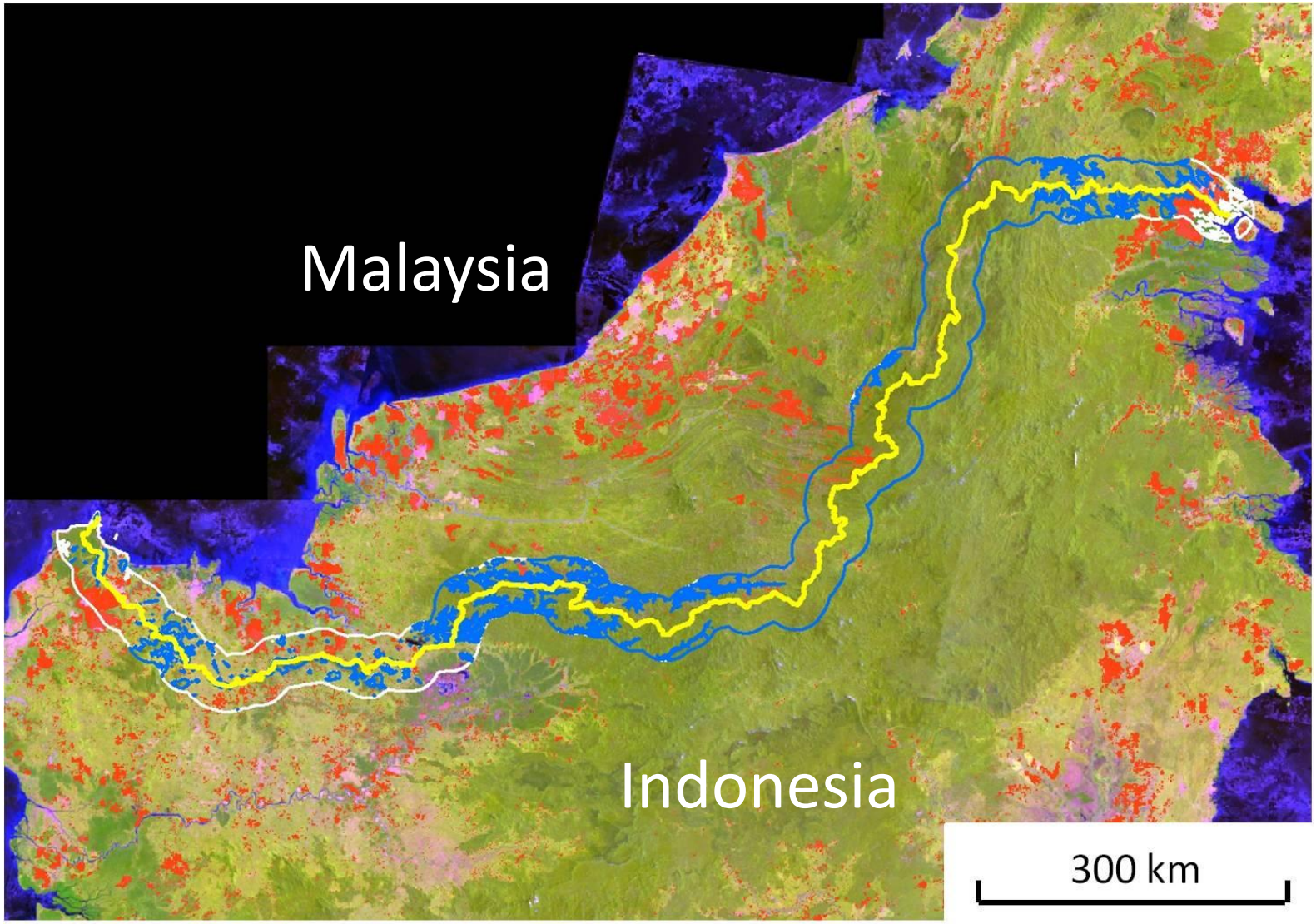
Trans-boundary effects



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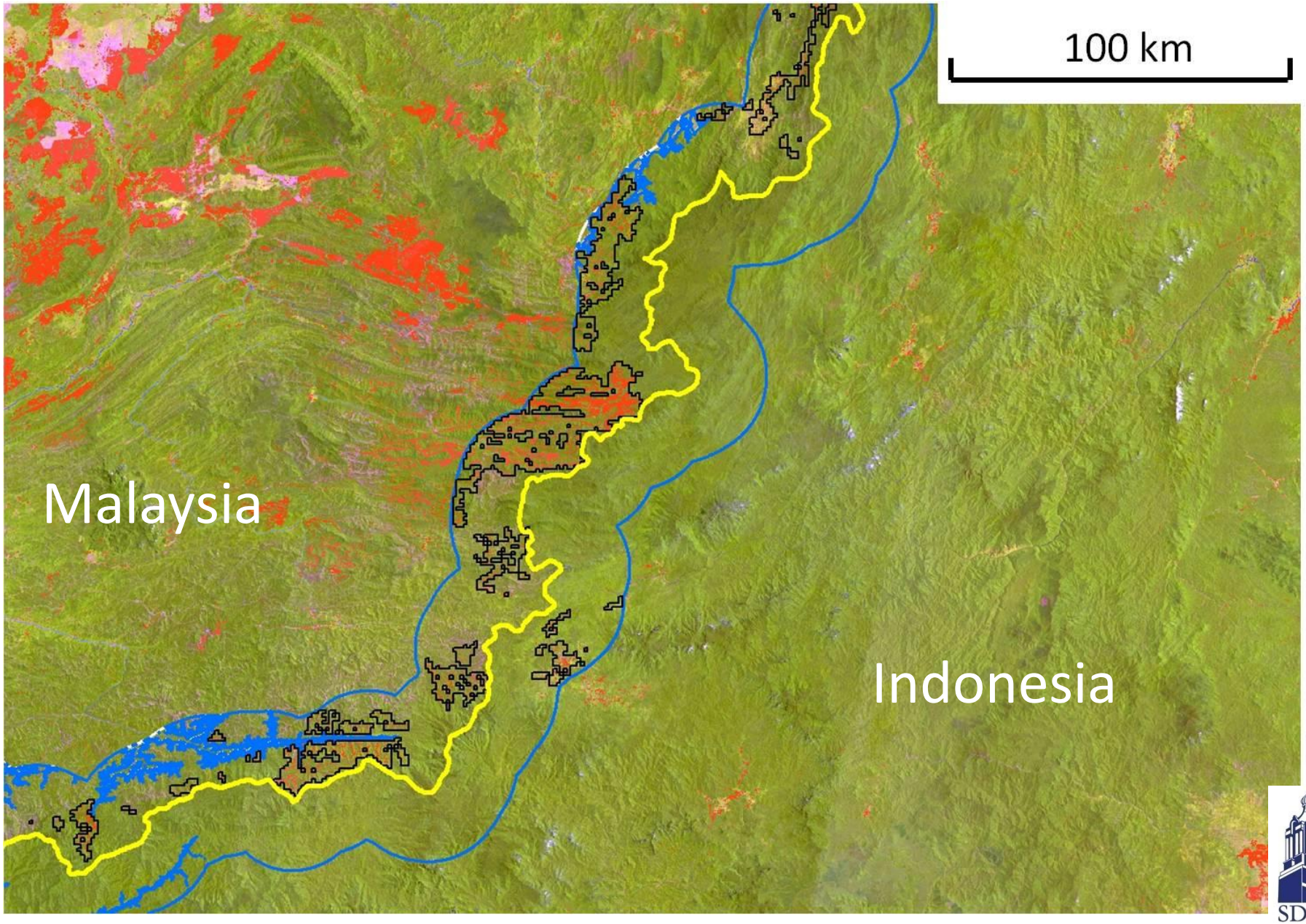
Trans-boundary effects



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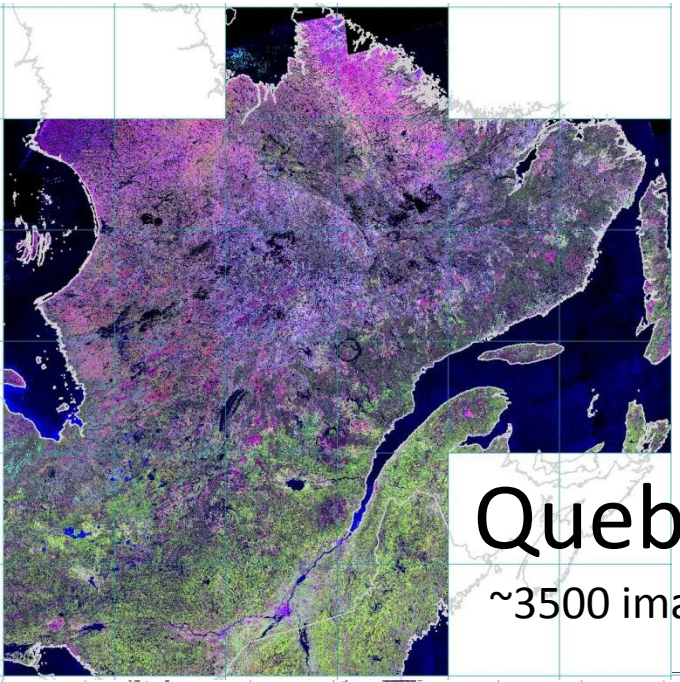
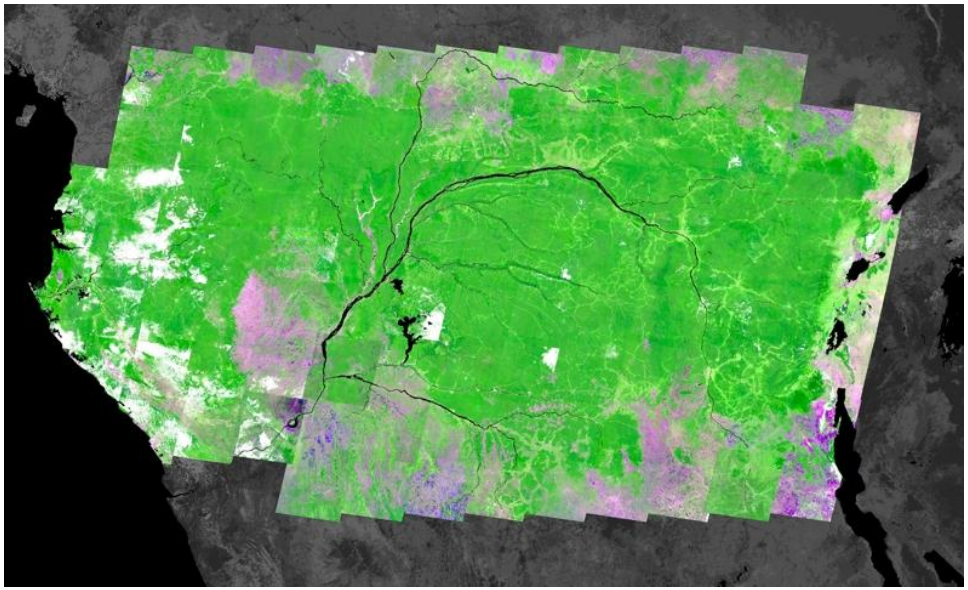
Mining the Landsat archive



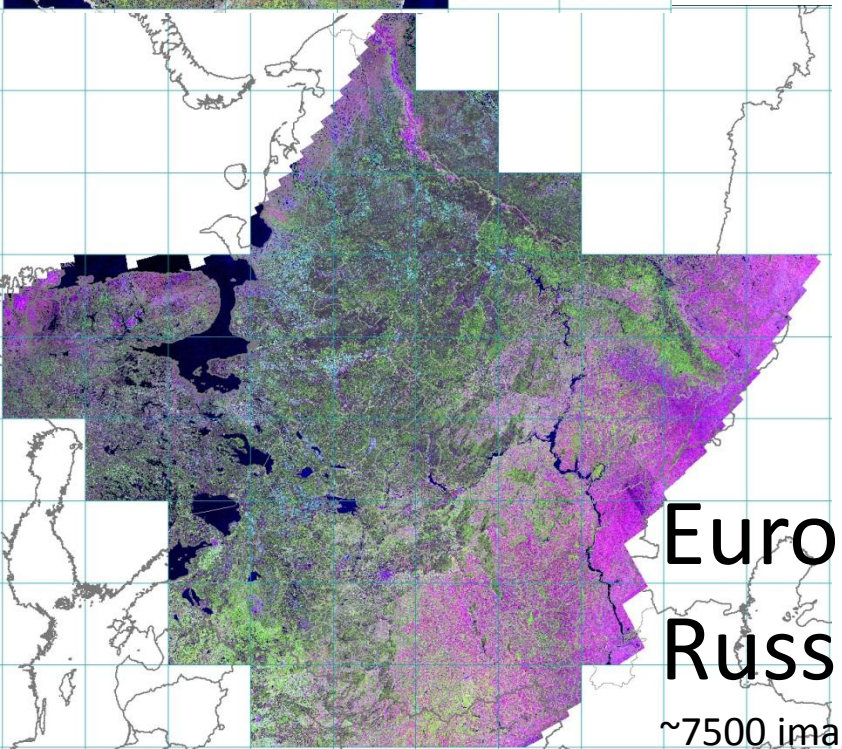
Quebec

~3500 images



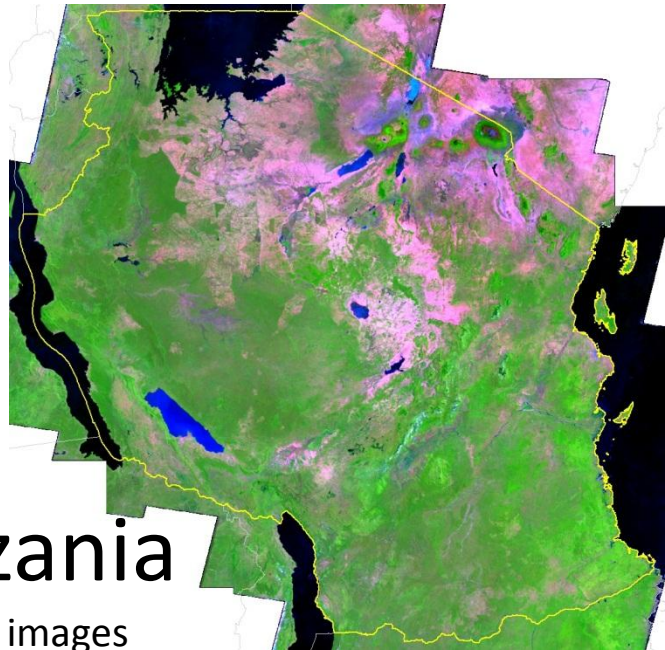
Congo Basin

~8000 images



European Russia

~7500 images



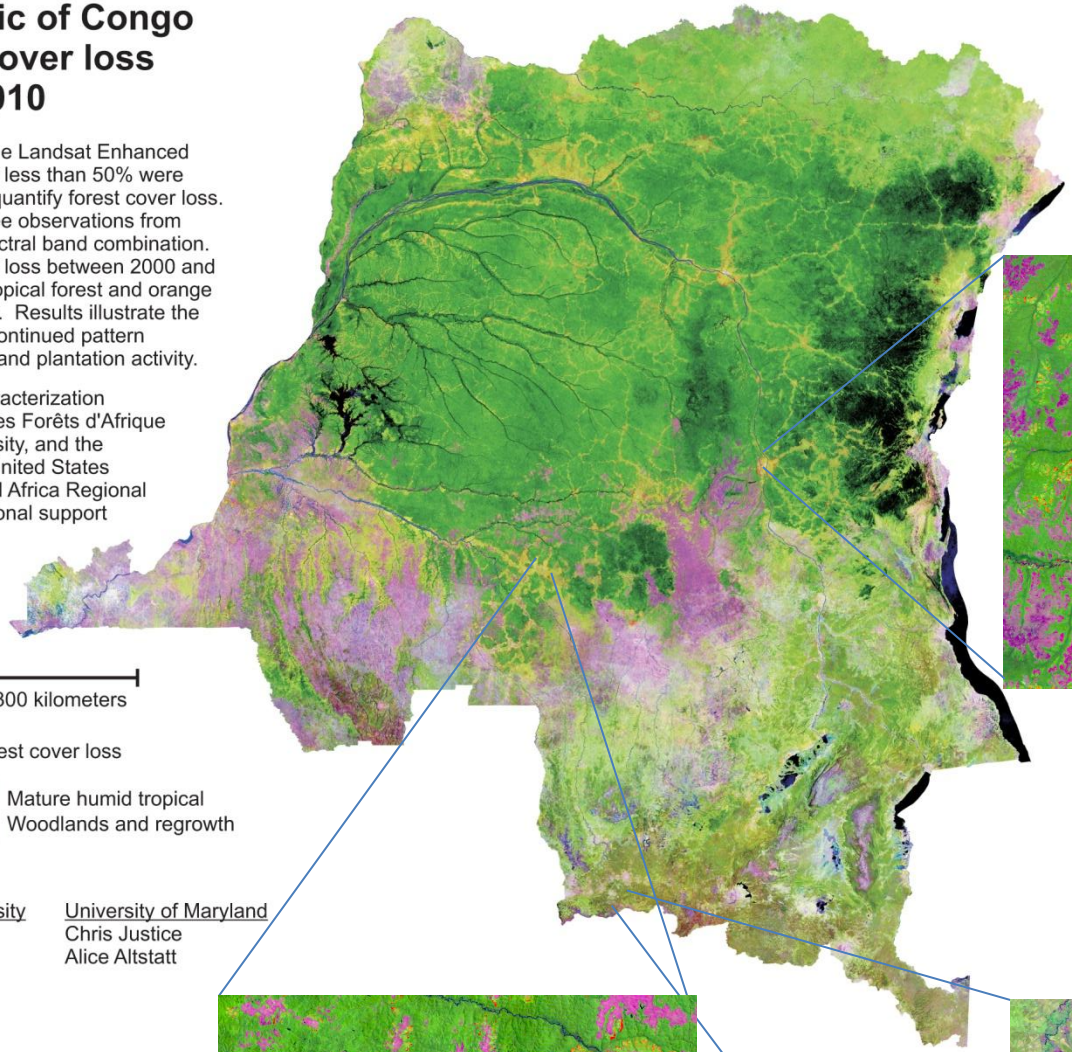
Tanzania

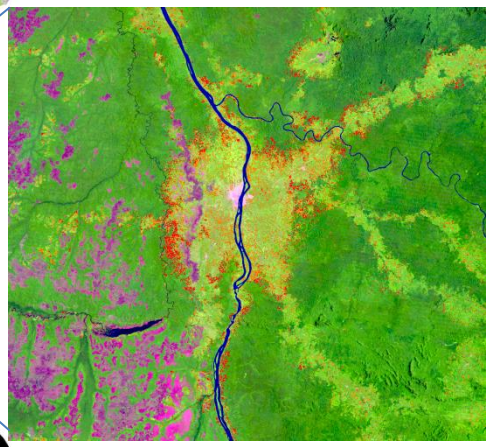
~1000 images

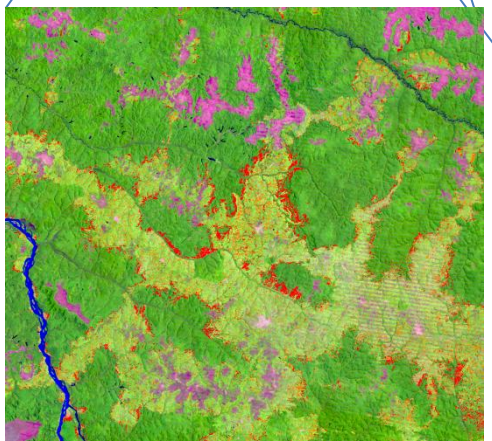
The Democratic Republic of Congo from space - Forest cover loss from 2000 to 2010

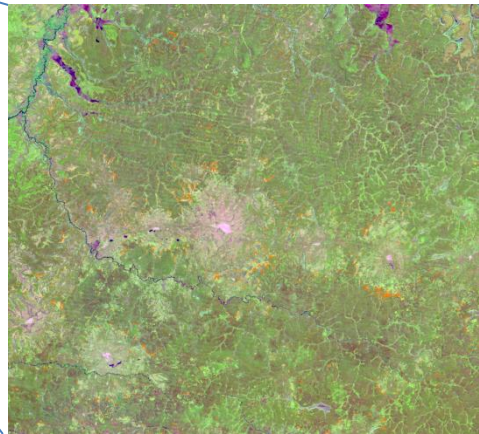
All images from the USGS EROS archive for the Landsat Enhanced Thematic Mapper Plus sensor with cloud cover less than 50% were automatically processed and characterized to quantify forest cover loss. The image composite was made from cloud-free observations from 2005 to 2010 and is displayed with a 5-4-3 spectral band combination. Areas in red and orange represent forest cover loss between 2000 and 2010, where red is clearing of mature humid tropical forest and orange clearing of woodlands and secondary regrowth. Results illustrate the spatial distribution of forest cover loss, with a continued pattern of agricultural clearing, mining, hunting camps and plantation activity.

Application of the Landsat processing and characterization was performed by the Observatoire Satellital des Forêts d'Afrique Centrale (OSFAC), South Dakota State University, and the University of Maryland, and supported by the United States Agency for International Development's Central Africa Regional Program for the Environment (CARPE). Additional support was provided by the United States National Aeronautics and Space Administration and the United States Geological Survey.









300 kilometers

Forest cover loss

- Mature humid tropical
- Woodlands and regrowth

OSFAC
Landing Mane
Patrick Amani
Eddy Bongwele

South Dakota State University
Matthew Hansen
Peter Potapov
Mark Broich
Bernard Adusei

University of Maryland
Chris Justice
Alice Altstatt

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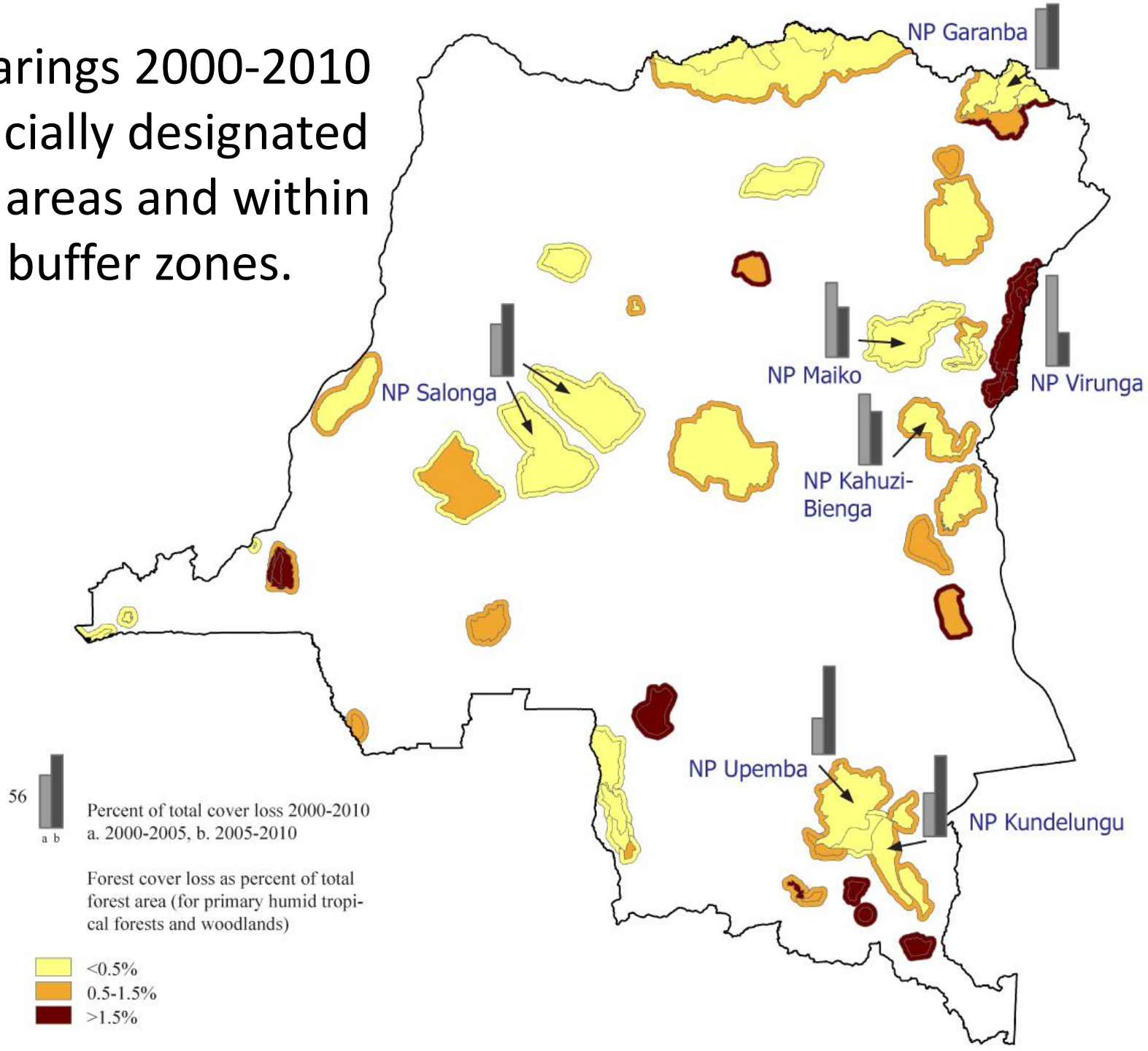
Forest clearings 2000-2010 within officially designated protected areas and within 10-km buffer zones.



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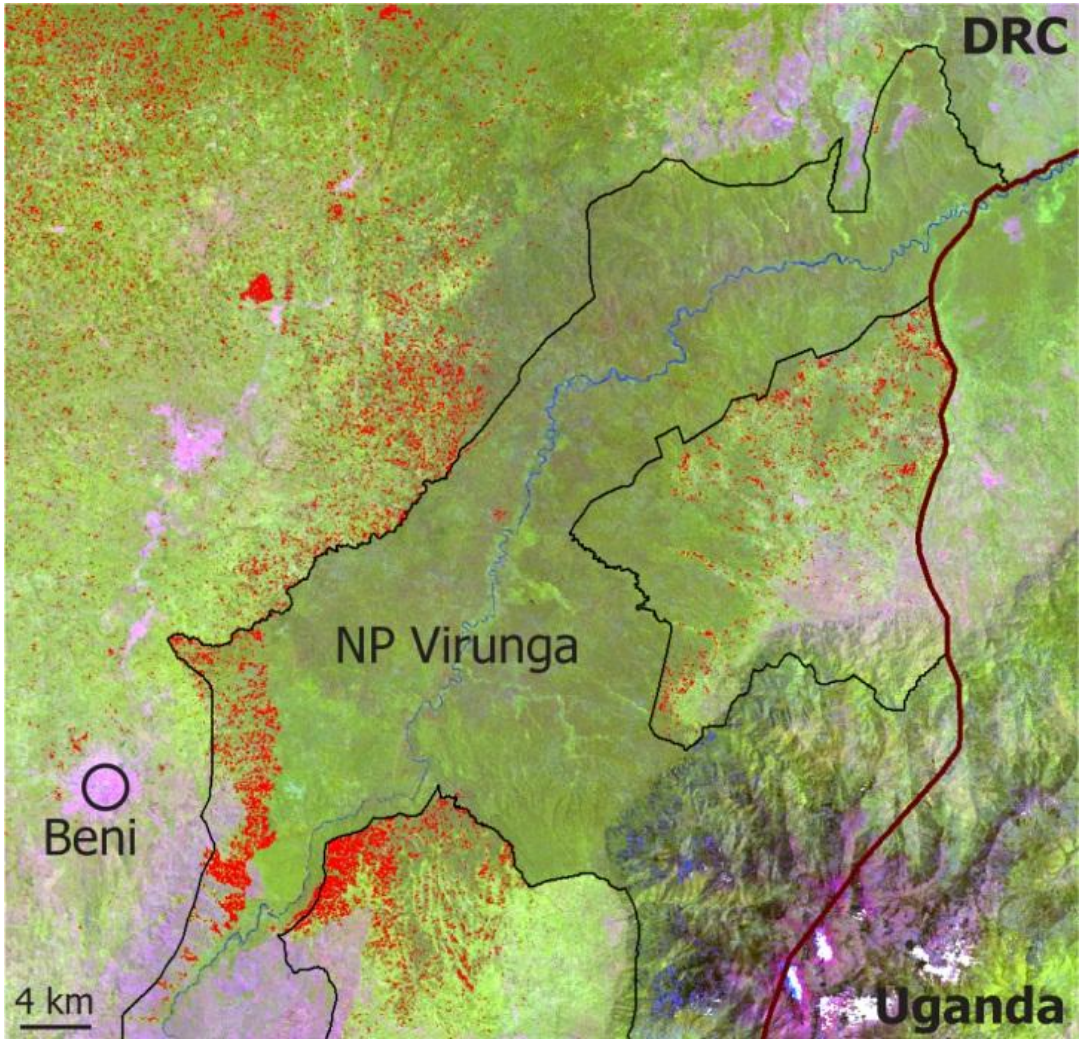
Virunga National Park



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Percent tree crown cover for Mexico

Google

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March to June

Google

SDSU

July to October

Google

SDSU

November to February

Google

SDSU

Percent tree crown cover for Mexico

Google

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WELD Land Cover

- Vegetation Continuous Field approach
  - 30 meter sub-pixel fractional cover estimates
  - Produced annually
    - Maximum percent tree cover
    - Maximum percent vegetation (excluding tree cover)
    - Minimum percent bare ground
    - Minimum surface water extent
    - Minimum snow/ice extent (nested within bare ground)
  - Test products include weekly bare ground, water, snow/ice

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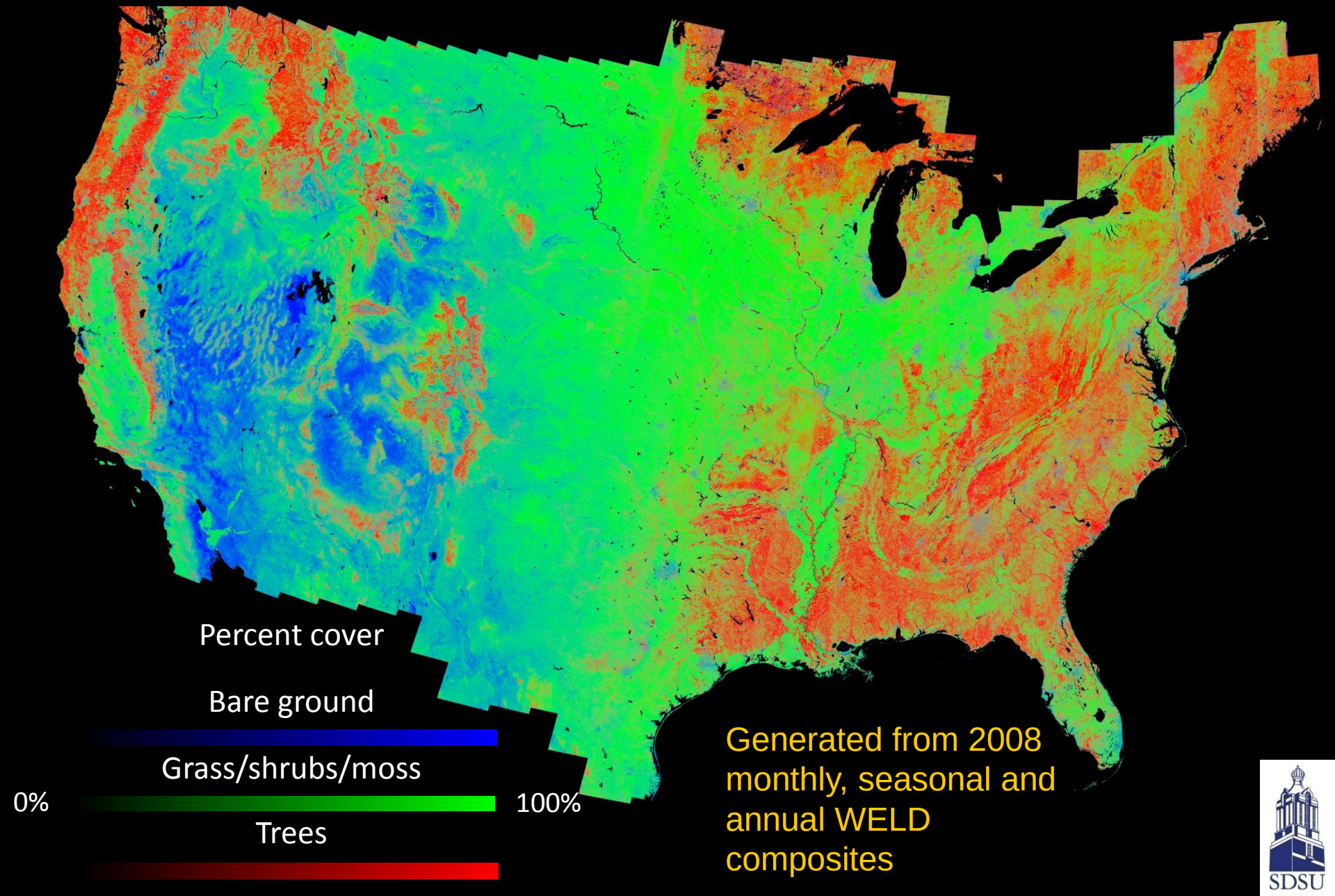
CONUS 30m Vegetation Continuous Fields (%)



Generated from 2008 monthly, seasonal and annual WELD composites

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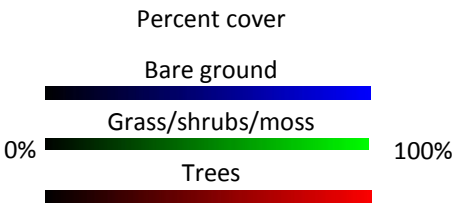
Brookings, SD



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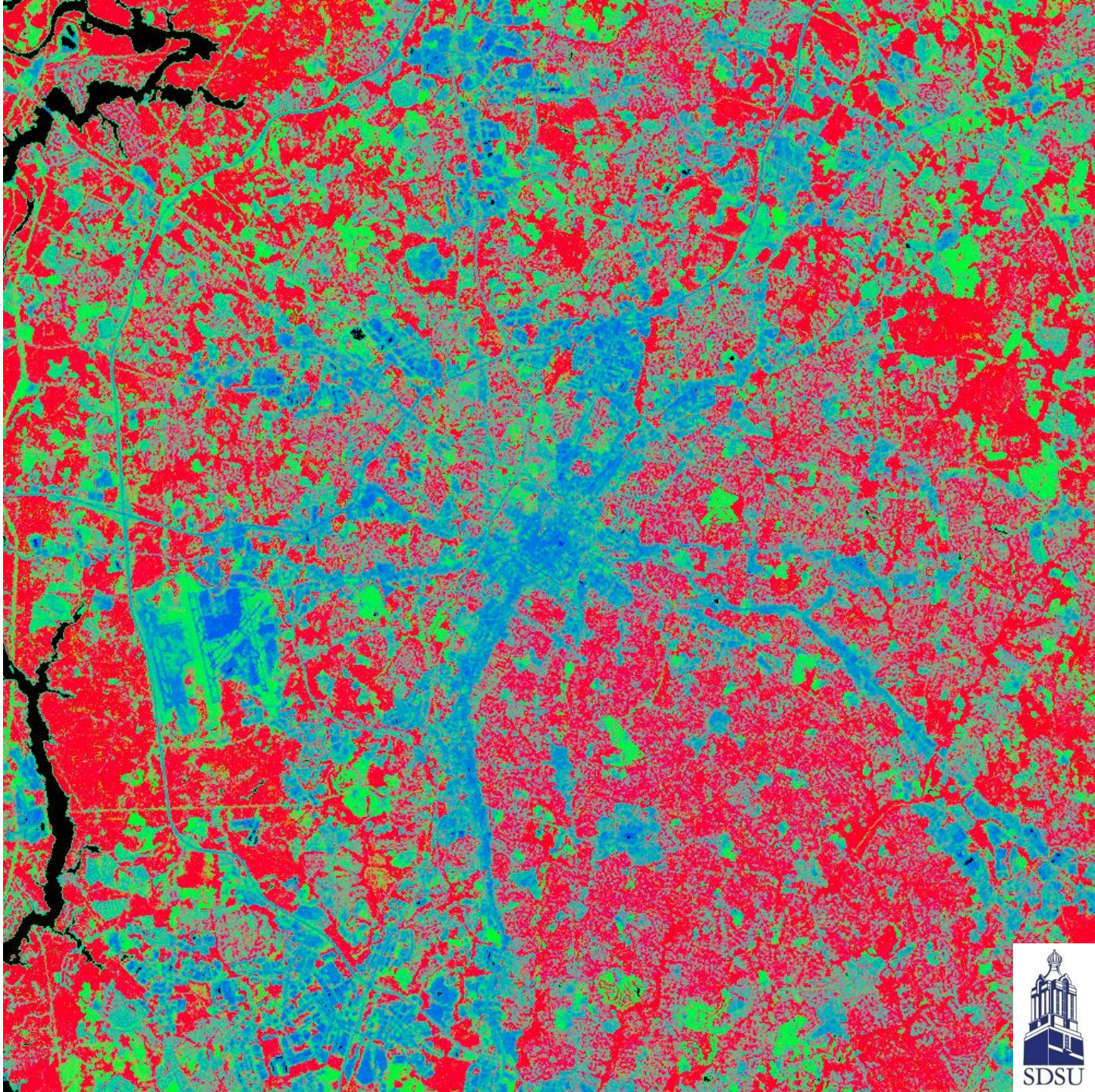
Charlotte, NC



Percent cover

Bare ground

Grass/shrubs/moss

0%

Trees

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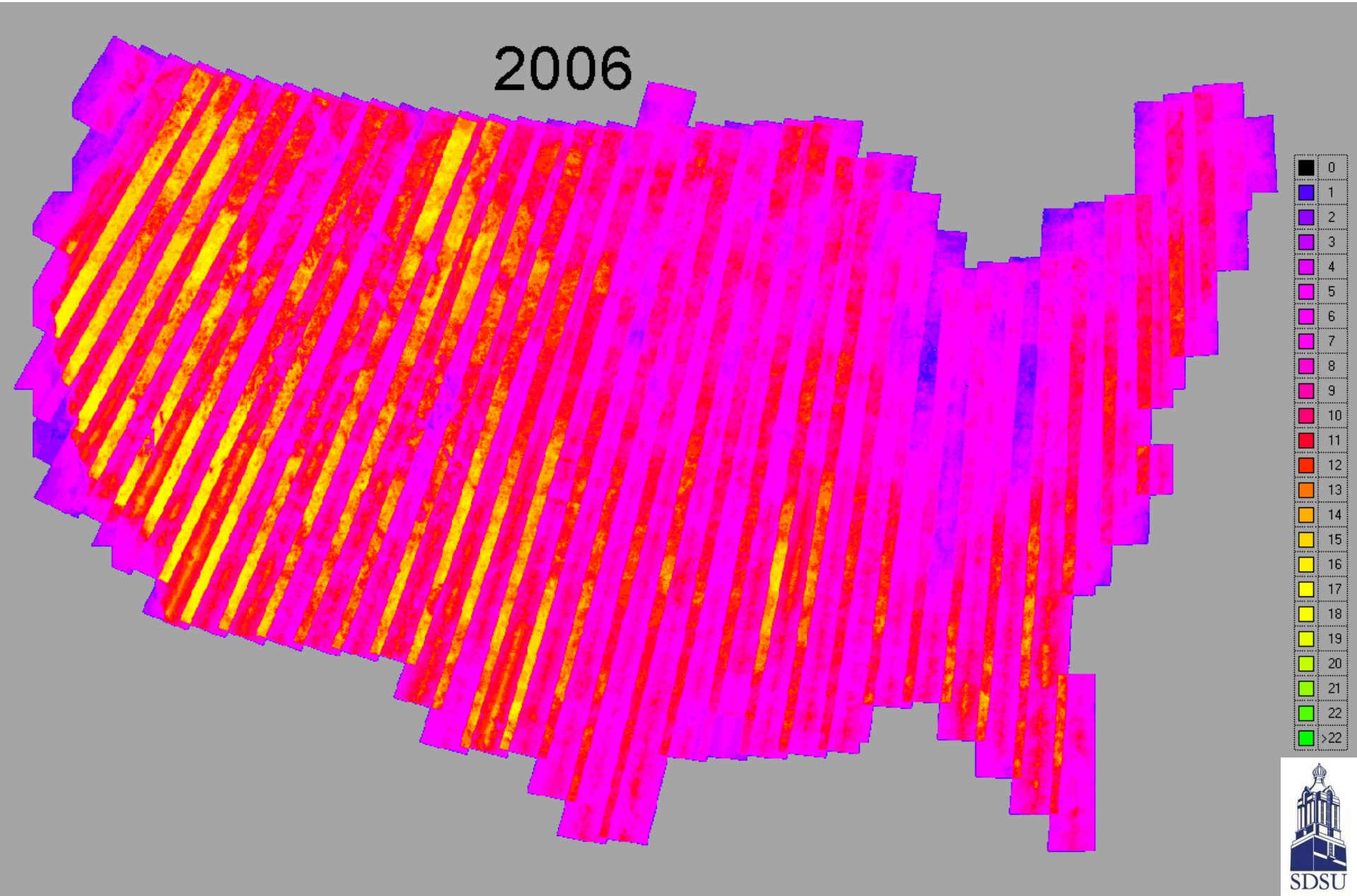
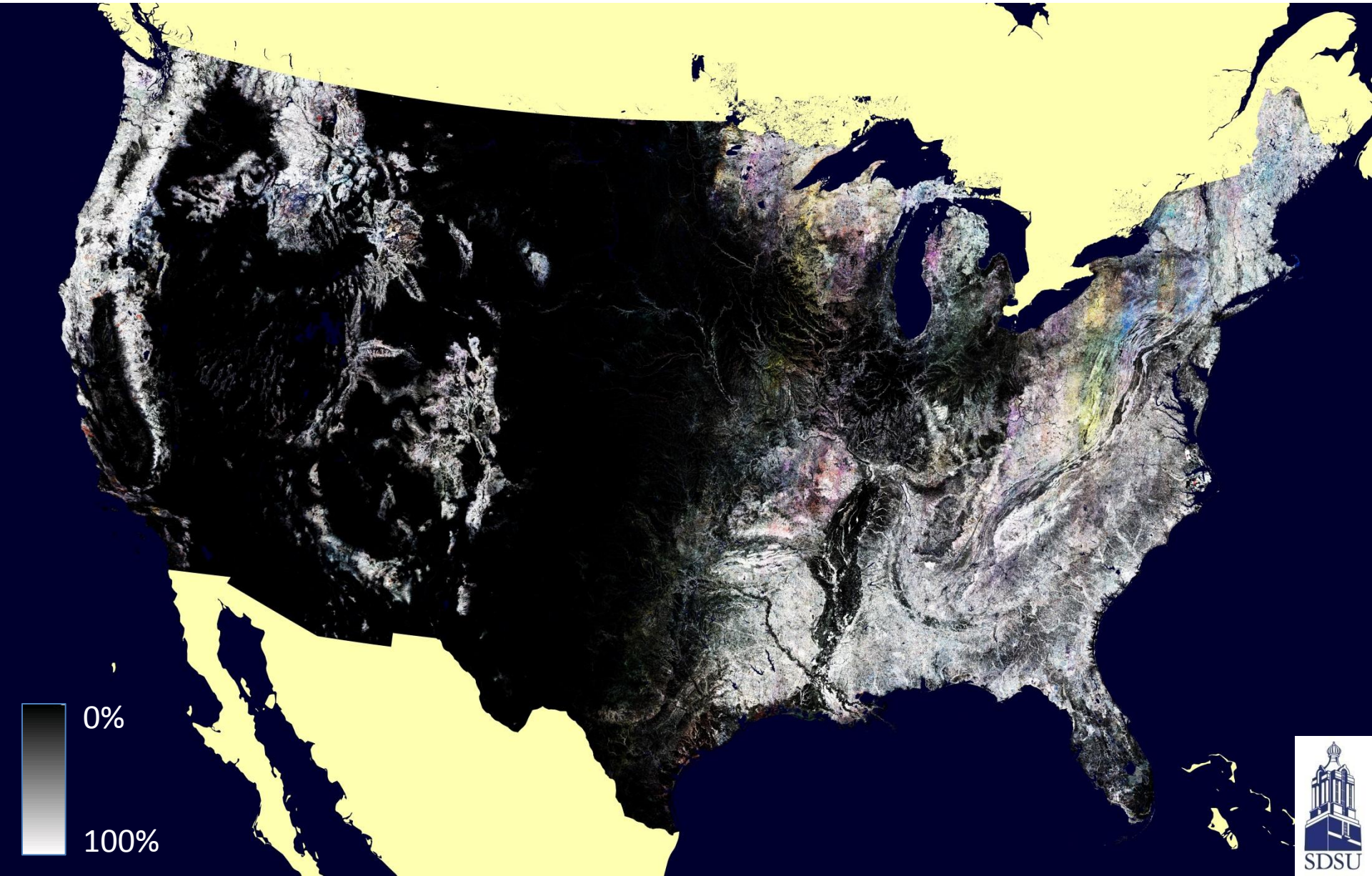
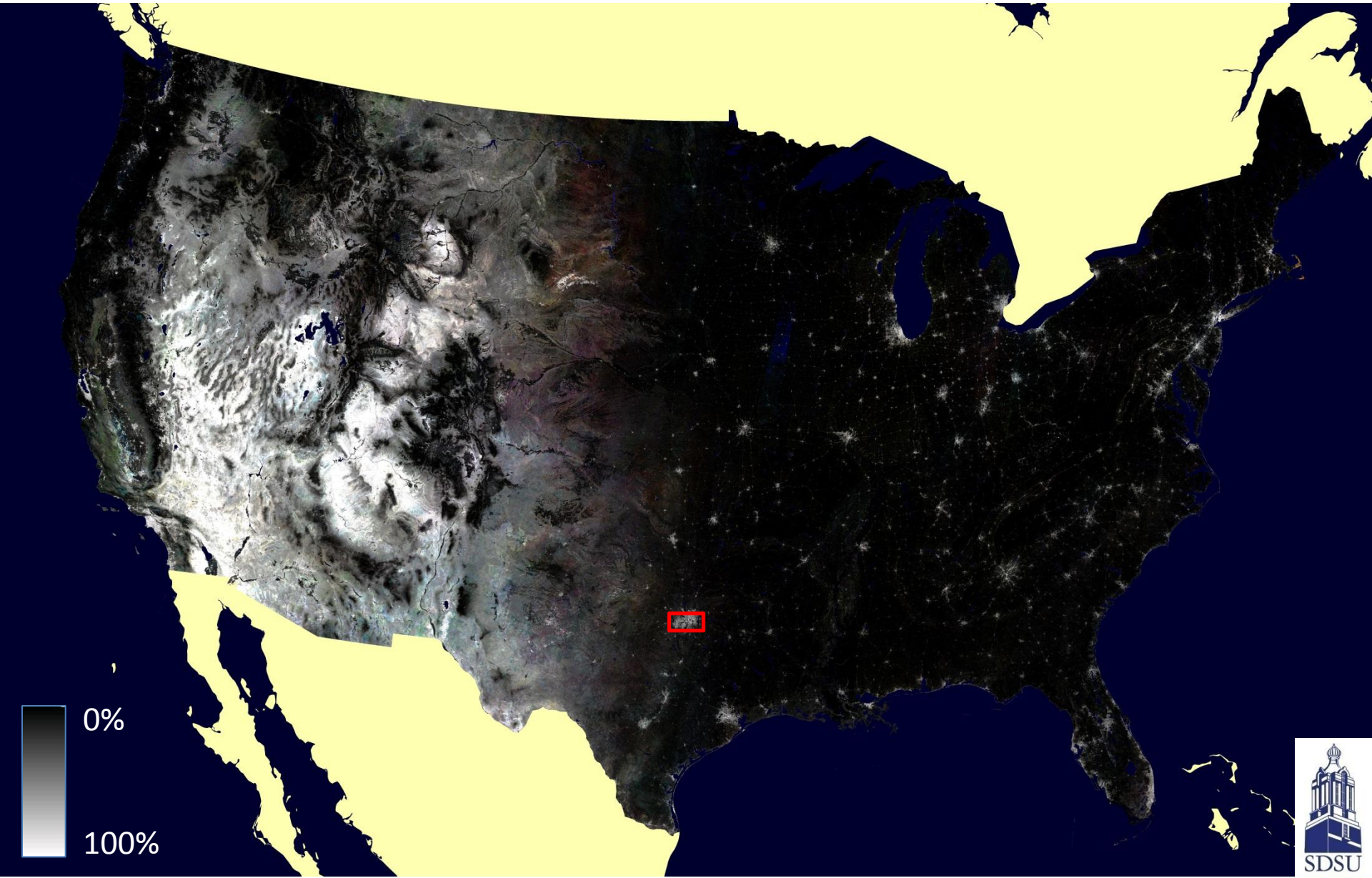
Growing season high quality observation counts



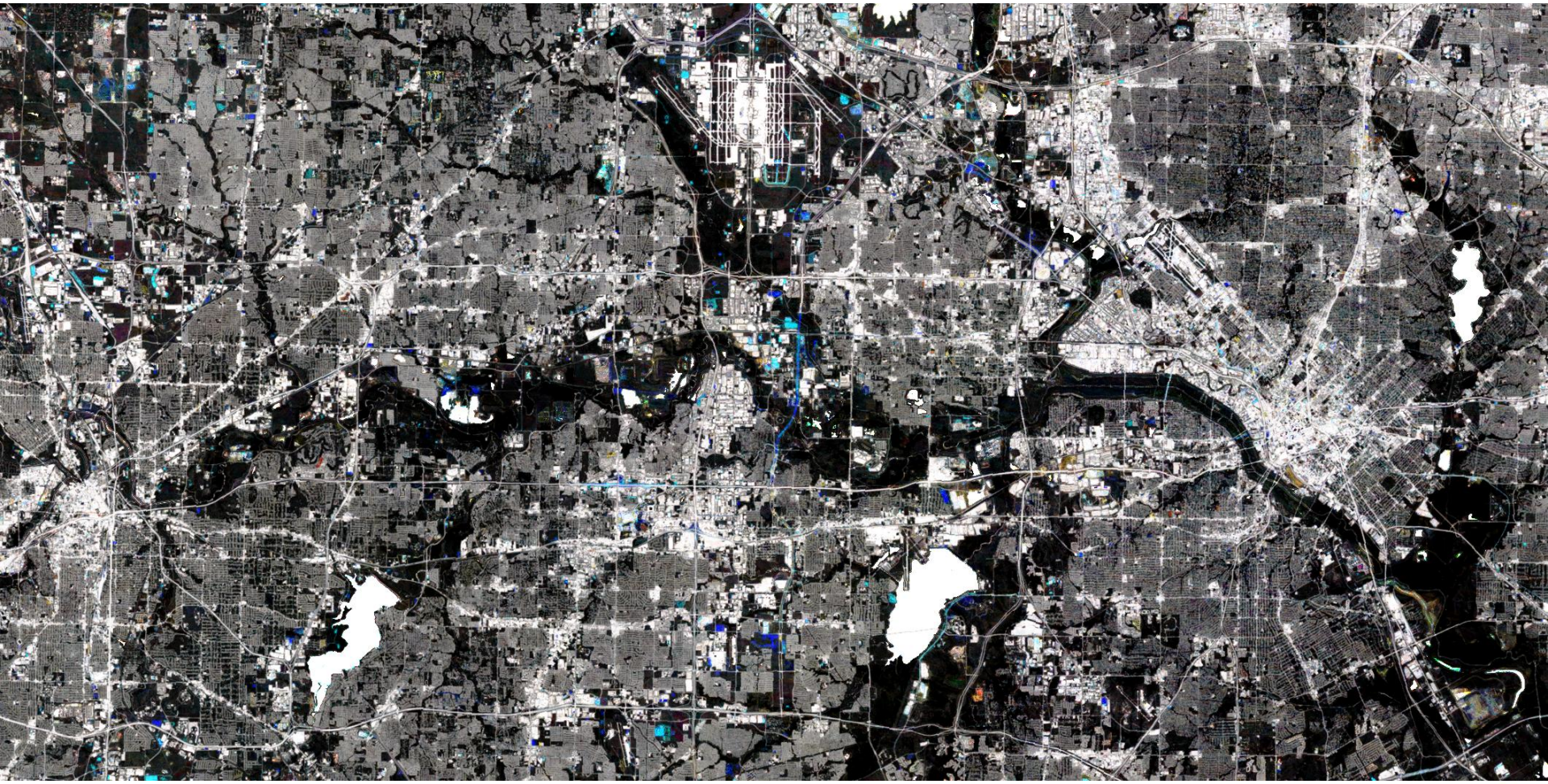
Five years of percent tree cover



Five years of percent bare ground



Dallas – Fort Worth



grey-scale = no change
blue/cyan = increase in bare ground,
red/yellow = decrease in bare ground

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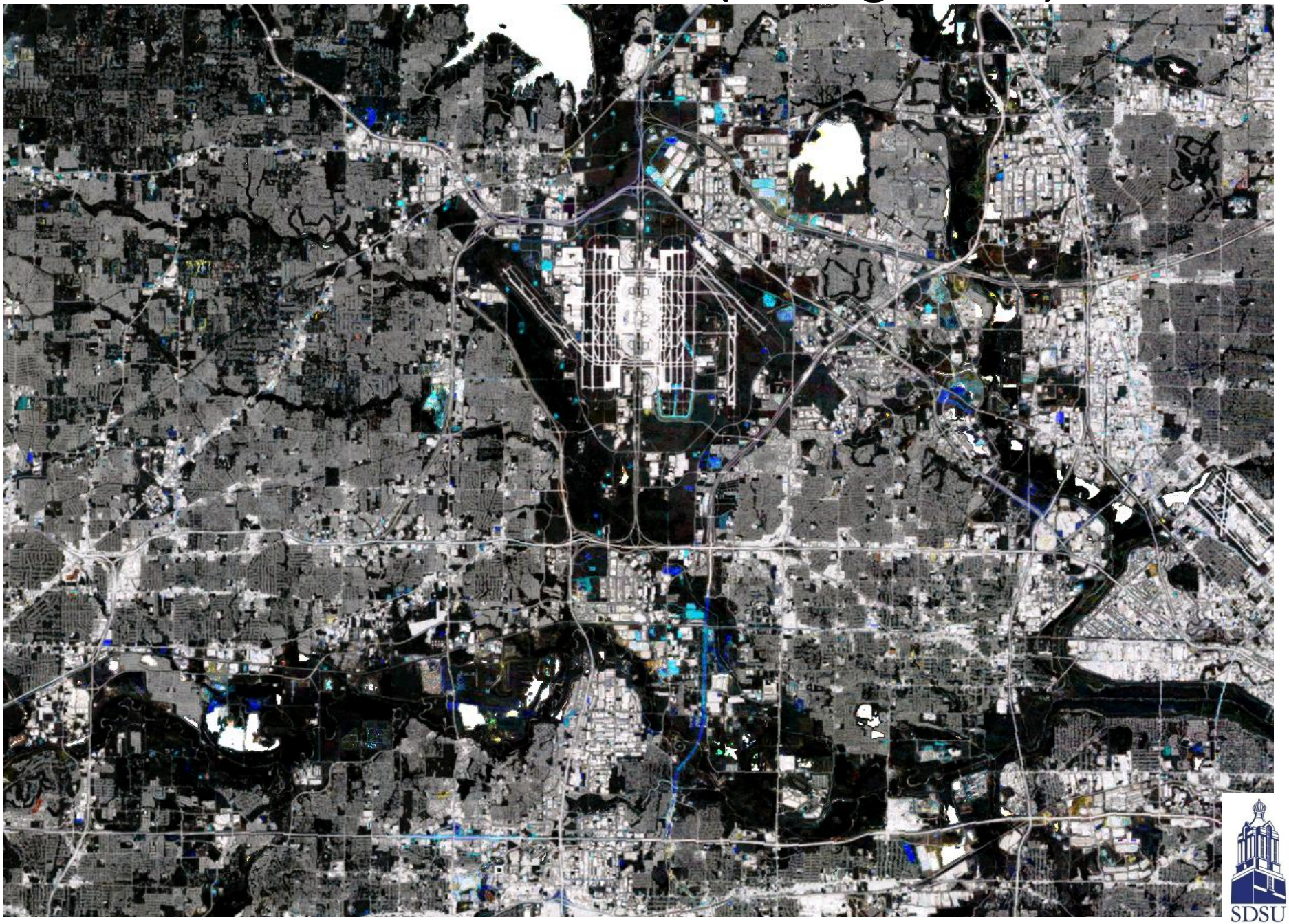
Dallas – Fort Worth (bare ground)



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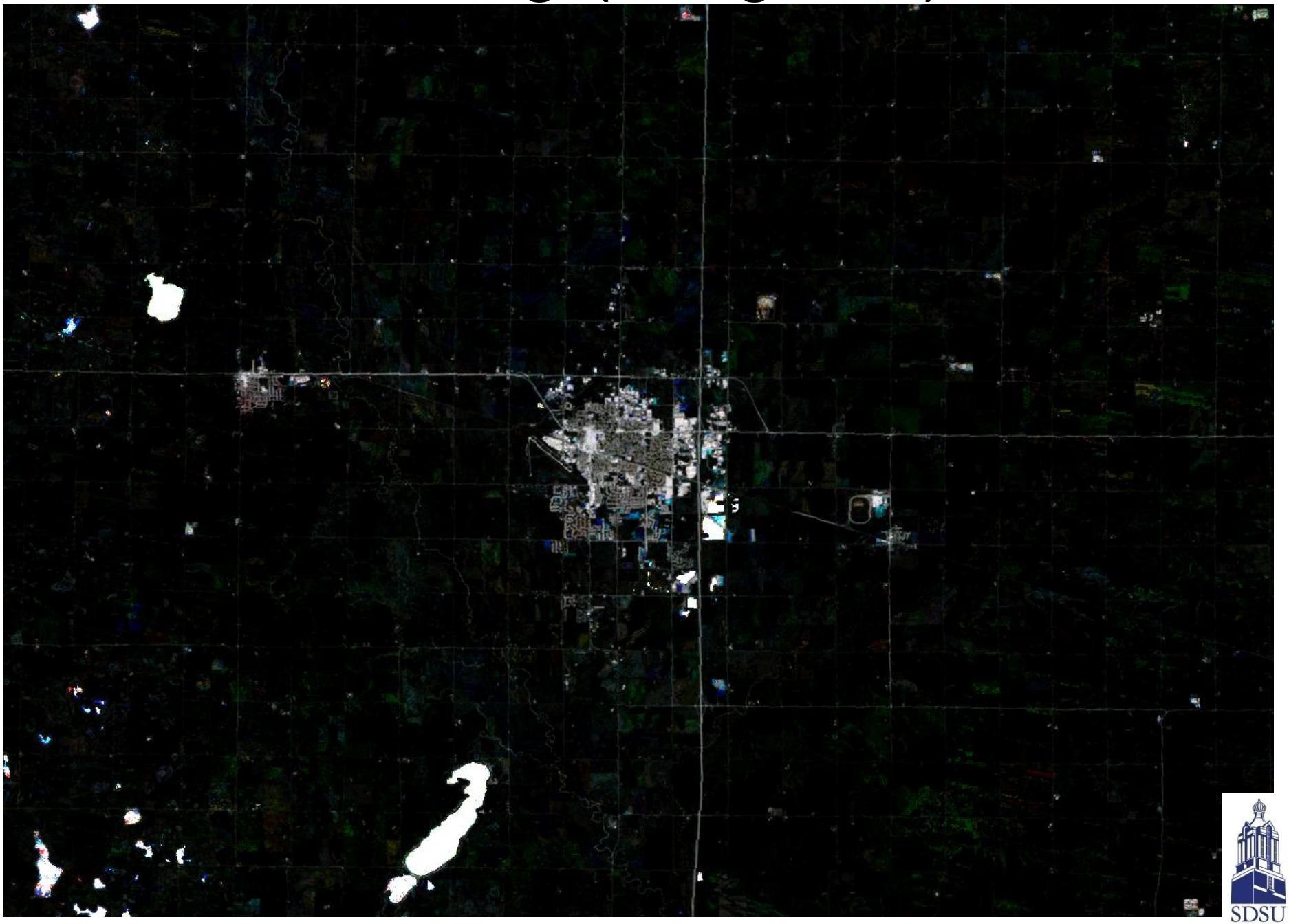
Brookings (bare ground)



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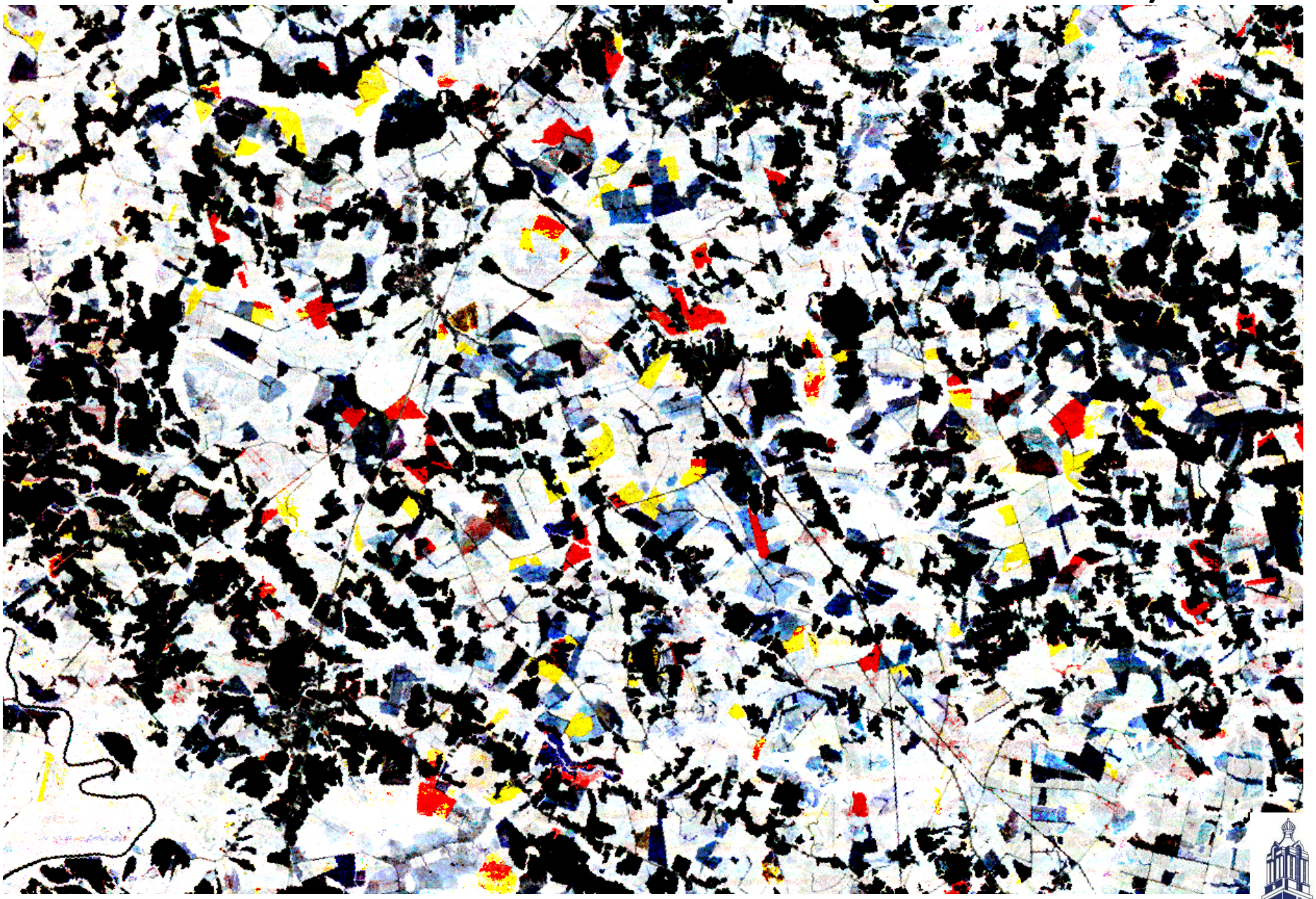
North Carolina coastal plain (tree cover)



ey-scale = no change, blue/cyan = increase in tree cover, red/yellow = decrease in tree cover

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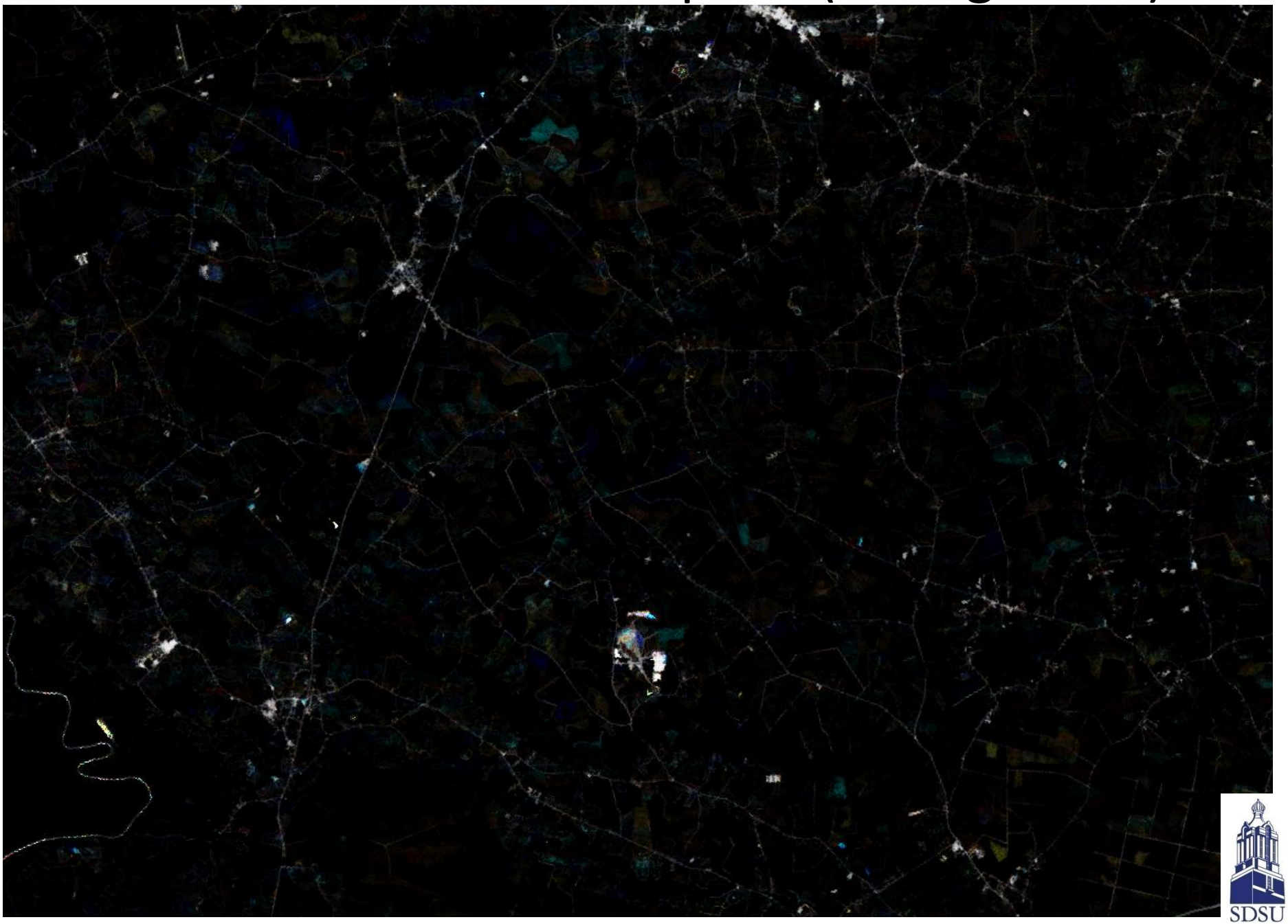
North Carolina coastal plain (bare ground)



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Louisiana (tree cover)

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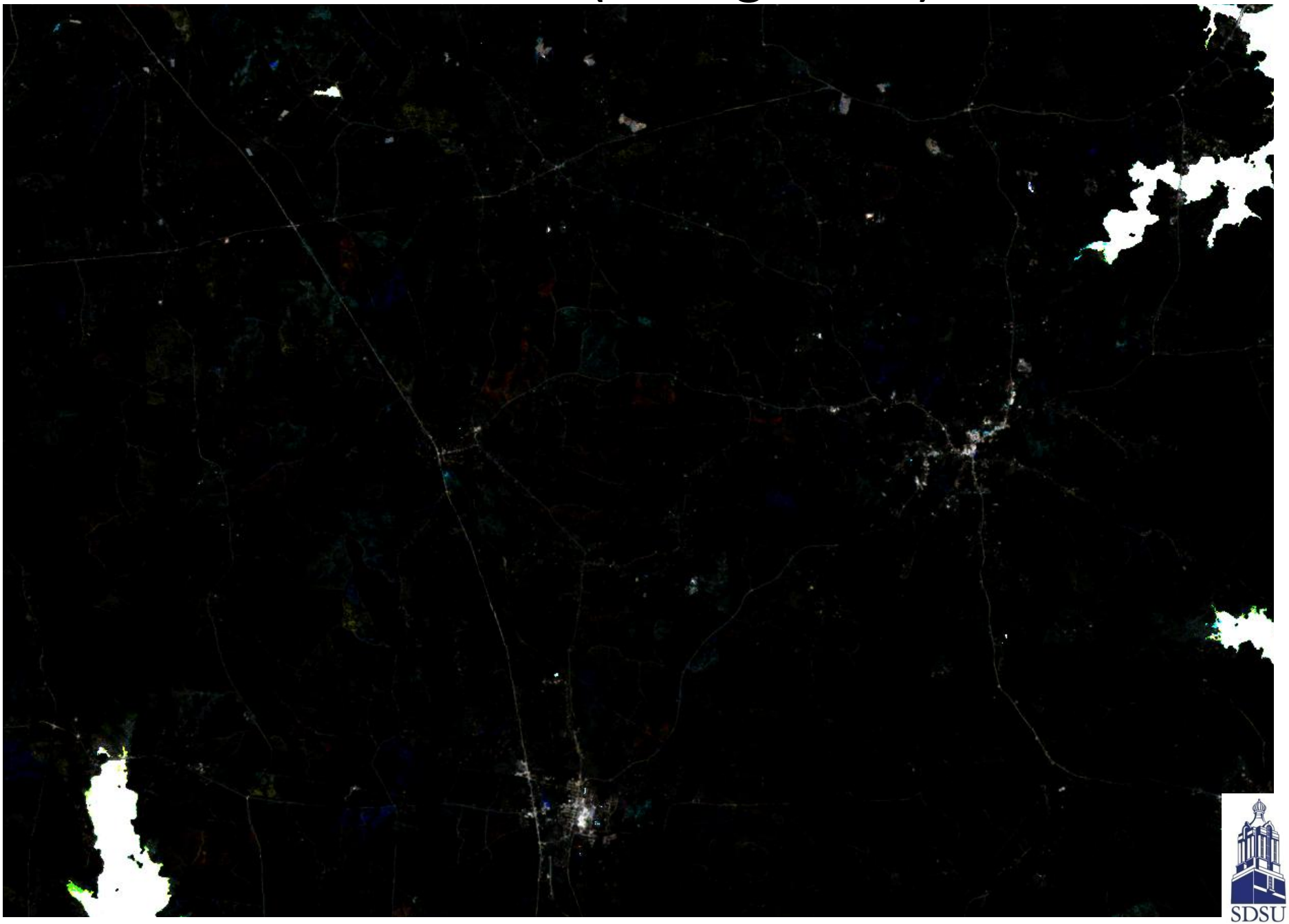
Louisiana (bare ground)



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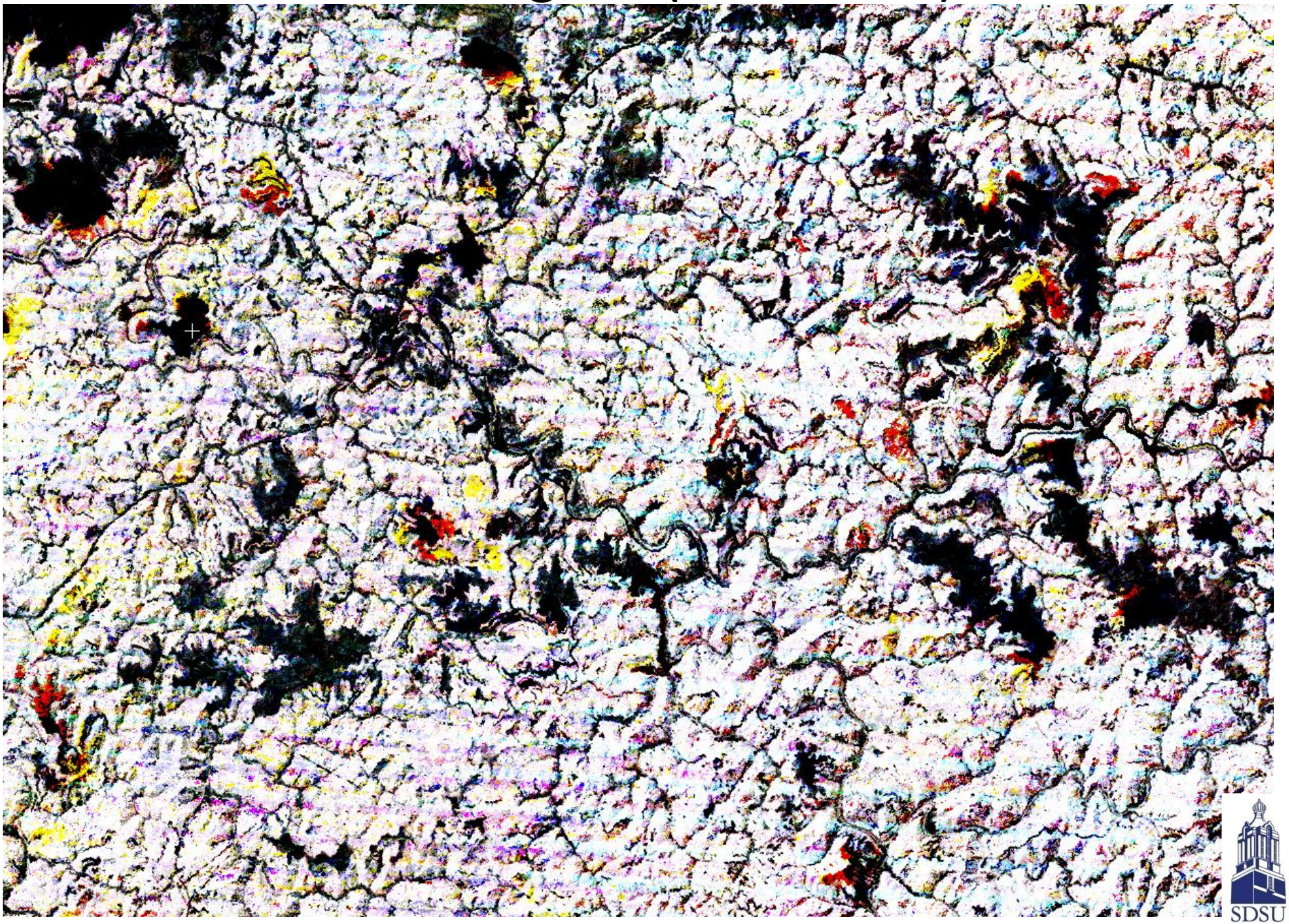
West Virginia (tree cover)



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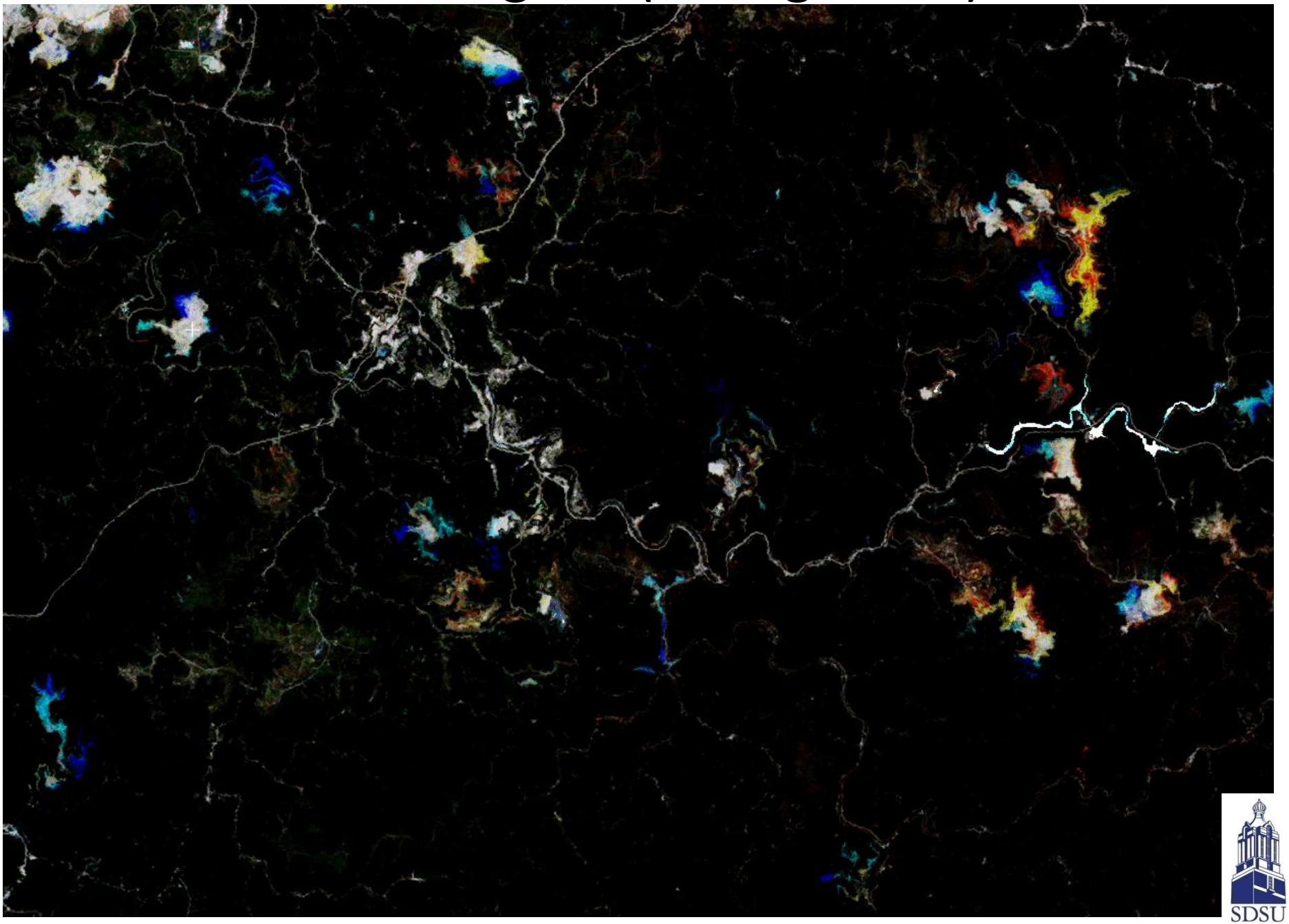
West Virginia (bare ground)



Washington (tree cover)

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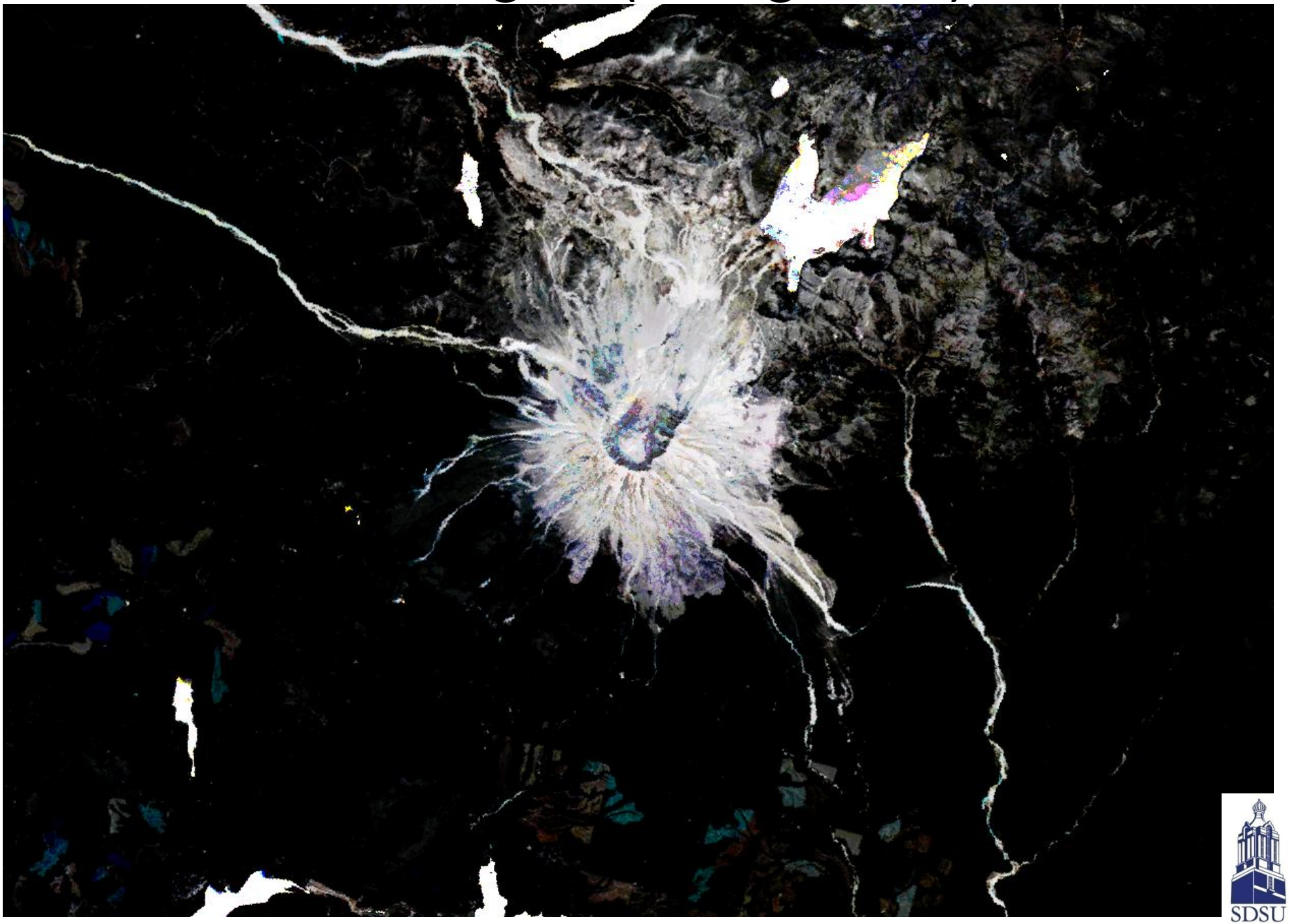
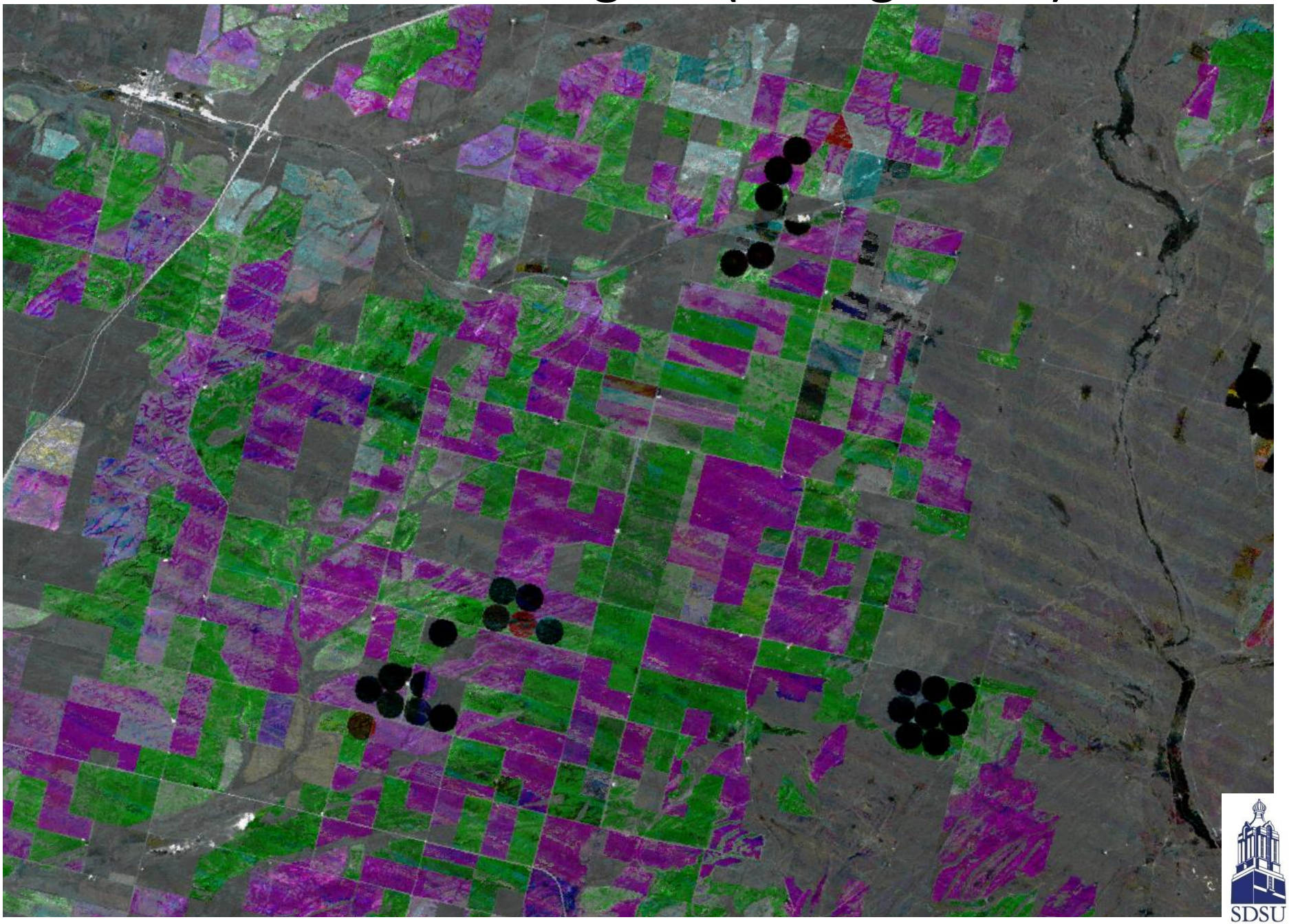
Washington (bare ground)



Eastern Washington (tree cover)

Eastern Washington (bare ground)



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Las Vegas (tree cover)

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Las Vegas (bare ground)

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Factors affecting Landsat processing that differ from heritage MODIS methods

- Acquisition strategy
- Observation frequency (scene overlap/SLC-off)
- Observation quality (clouds/haze/shadow)
- Phenology

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Characterizing land cover with Landsat

- Landsat's infrequent and inconsistent acquisition rate makes annual updates of land cover difficult for many parts of the world
- The U.S. represents our most data-rich case
- Certain land cover themes, such as cropland/crop type, will not be reliably characterized for many regions
- For developing countries needing to monitor forest cover, the open archive is a boon
  - However, high-performance computing is needed as single image-based methods will not work for many regions

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Some references

- Broich, M., Hansen, M., Stolle, F., Potapov, P., Margono, B.A. and Adusei, B., 2011, Remotely sensed forest cover loss shows high spatial and temporal variation across Sumatra and Kalimantan, Indonesia 2000-2008, *Environmental Research Letters*, 6 (1), doi:10.1088/1748-9326/6/1/014010.

- Broich, M., Hansen, M.C., Potapov, P., Adusei, B., Lindquist, E., Stehman, S.V., 2011, Time-series analysis of multi-resolution optical imagery for quantifying forest cover loss in Sumatra and Kalimantan, Indonesia, *International Journal of Applied Earth Observation and Geoinformation,* 13, 277-291.

- Hansen, M.C., Egorov, A., Roy, D.P., Potapov, P., Ju, J., Turubanova, S., Kommareddy, I., and Loveland, T.R., 2011, Continuous fields of land cover for the conterminous United States using Landsat data: first results from the Web-Enabled Landsat Data (WELD) project, *Remote Sensing Letters*, 2, 279-288.

- Potapov, P., Turubanova S., Hansen M.C., 2011, Regional-scale boreal forest cover and change mapping using Landsat data composites for European Russia, *Remote Sensing of Environment, 115,* 548-561.

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