

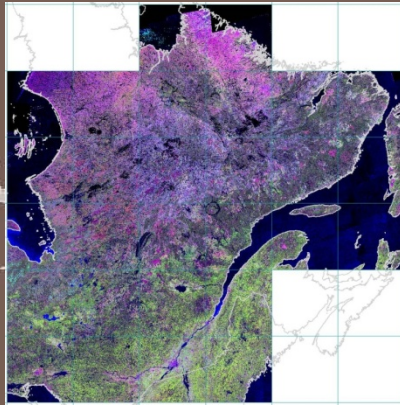
MODIS and Landsat Regional Products – example of Indonesia forest monitoring

Matt Hansen, Peter Potapov, Svetlana Turubanova
University of Maryland

Belinda Arunarwati, Mark Broich
South Dakota State University

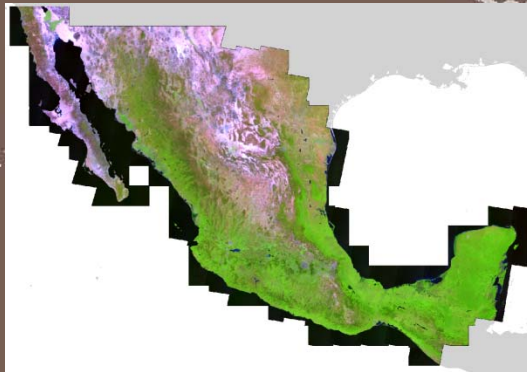
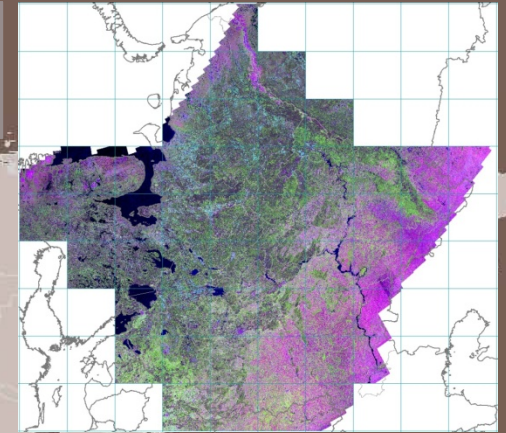


National scale forest monitoring examples

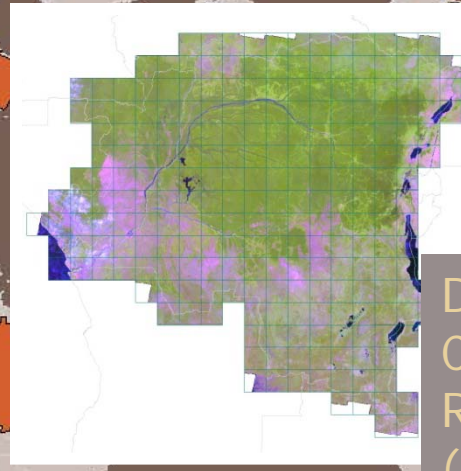


Quebec, Canada
(2000-2005)

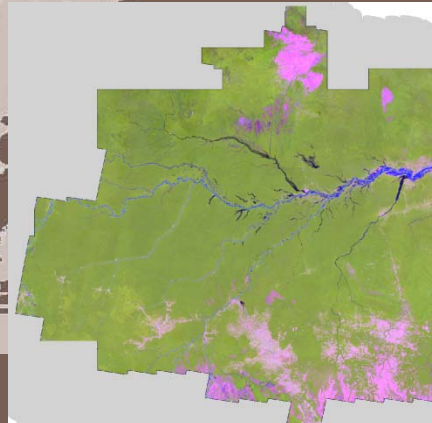
European Russia
(2000-2005)



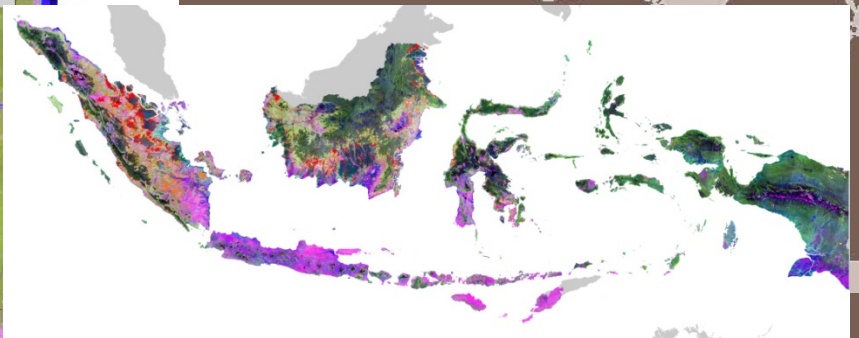
Mexico (2000-2010)



Dem. Rep. of the
Congo;
Rep. of Congo
(2000-2010)



Brazilian Amazon
(2000-2005)



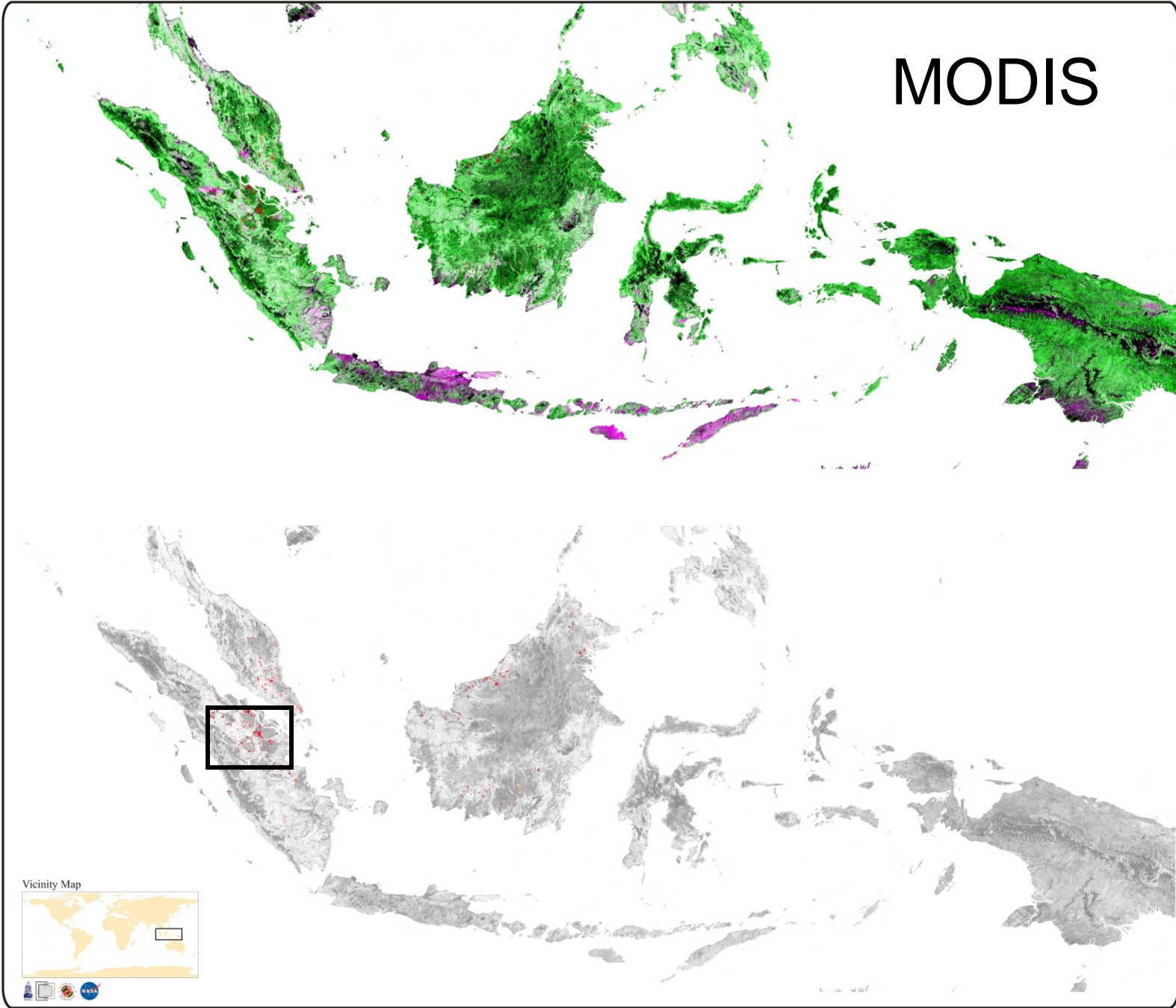
Indonesia (2000-2010)

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 standard products (WELD) of Landsat time-series data sets


Forest cover monitoring examples from Indonesia using MODIS and Landsat

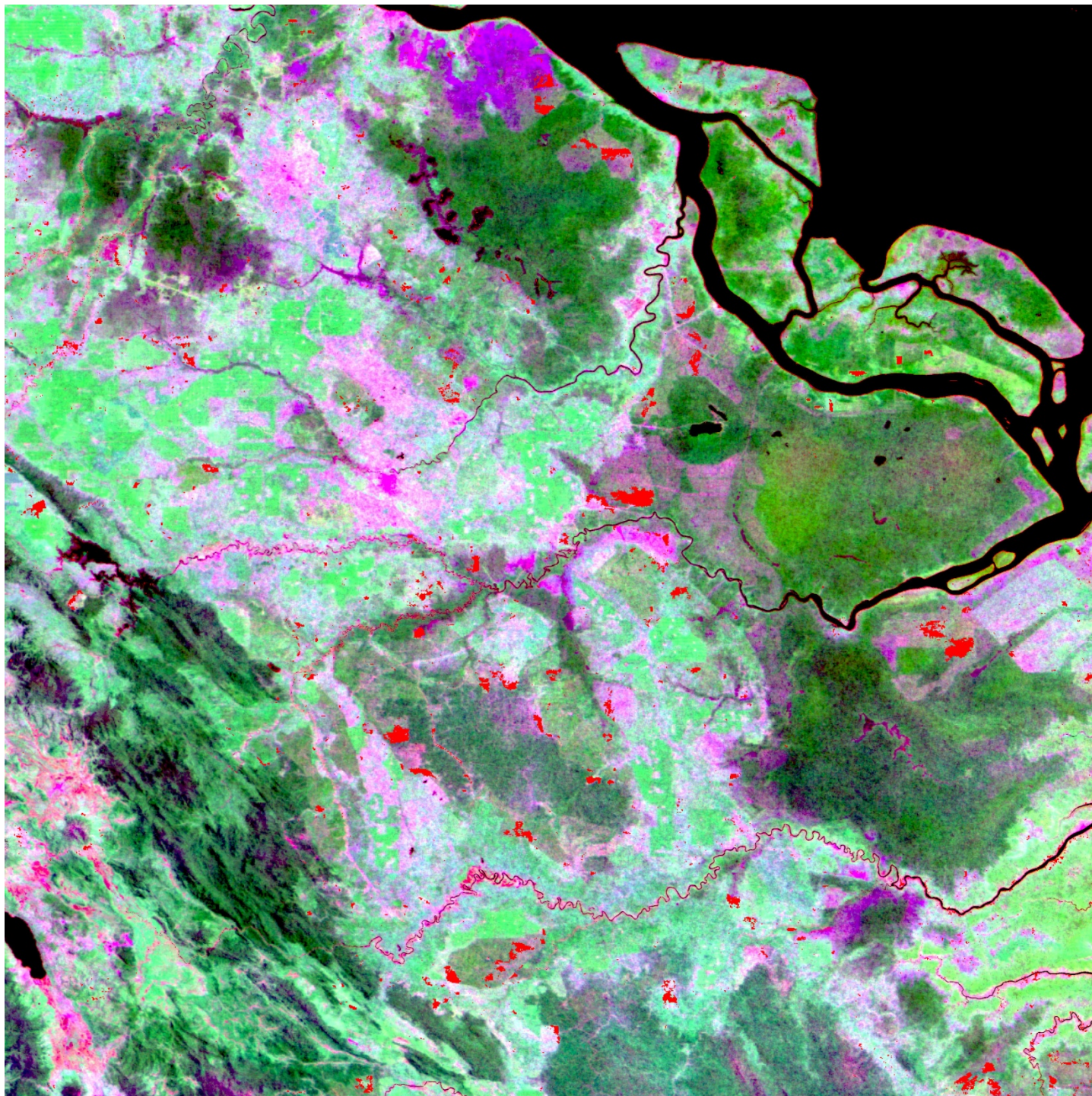
- Forest/non-forest extent and change (loss and later gain)
- Forest type mapping
 - Agroforestry
 - Intact and degraded primary forest
 - Wetland / peatland forest



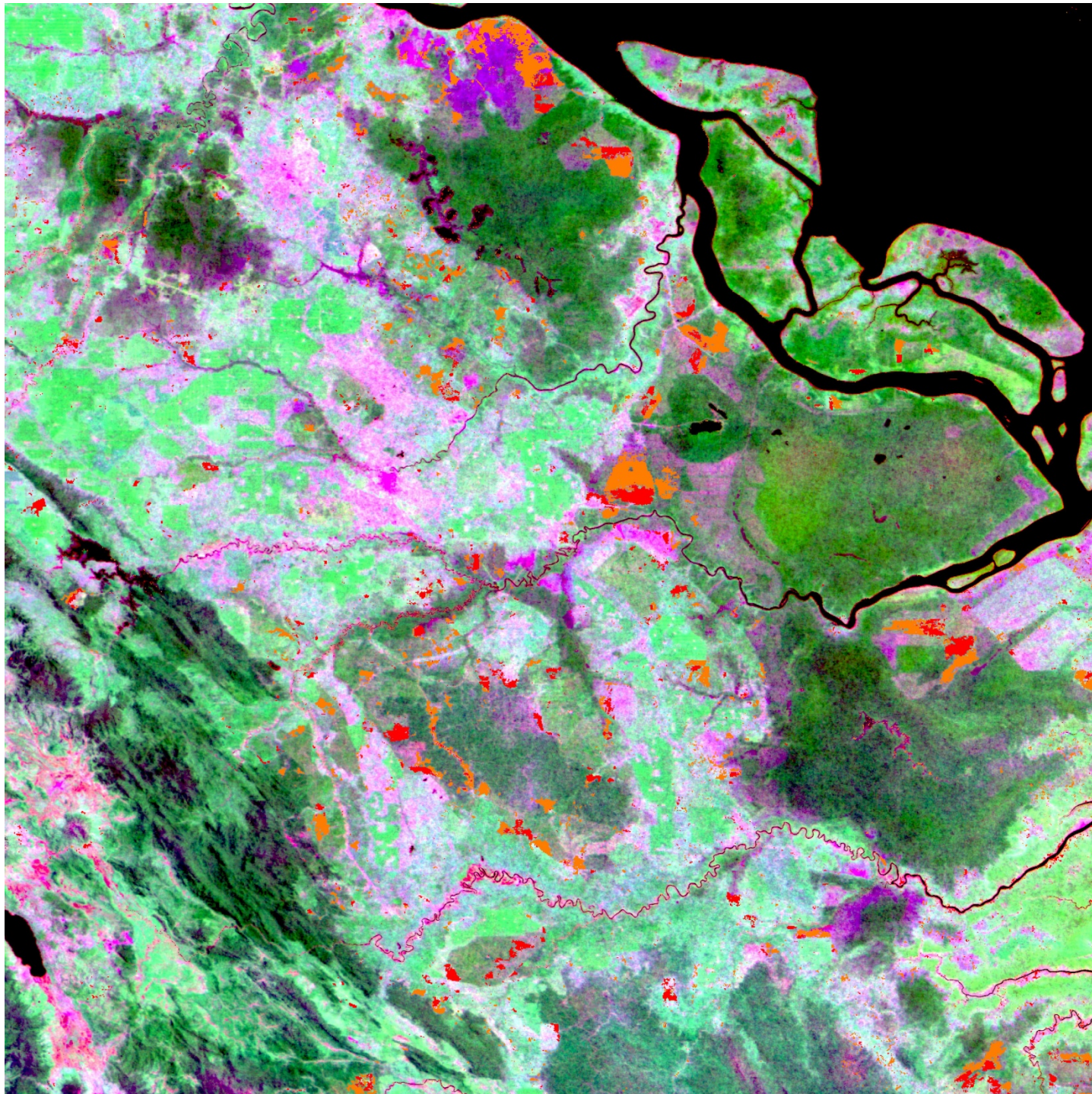
Forest Change in Insular Southeast Asia

Annual
forest
cover
loss

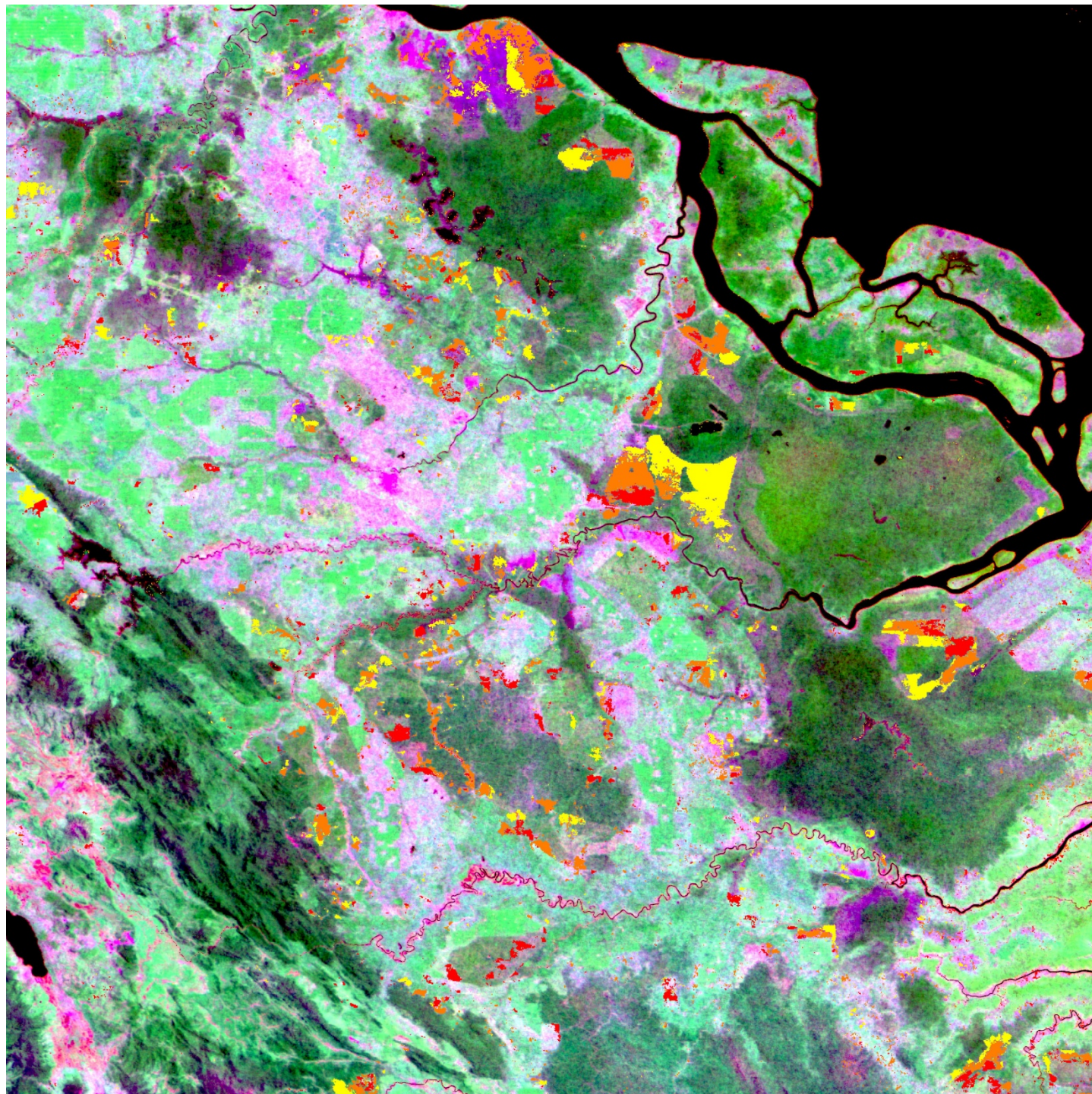
 00-01



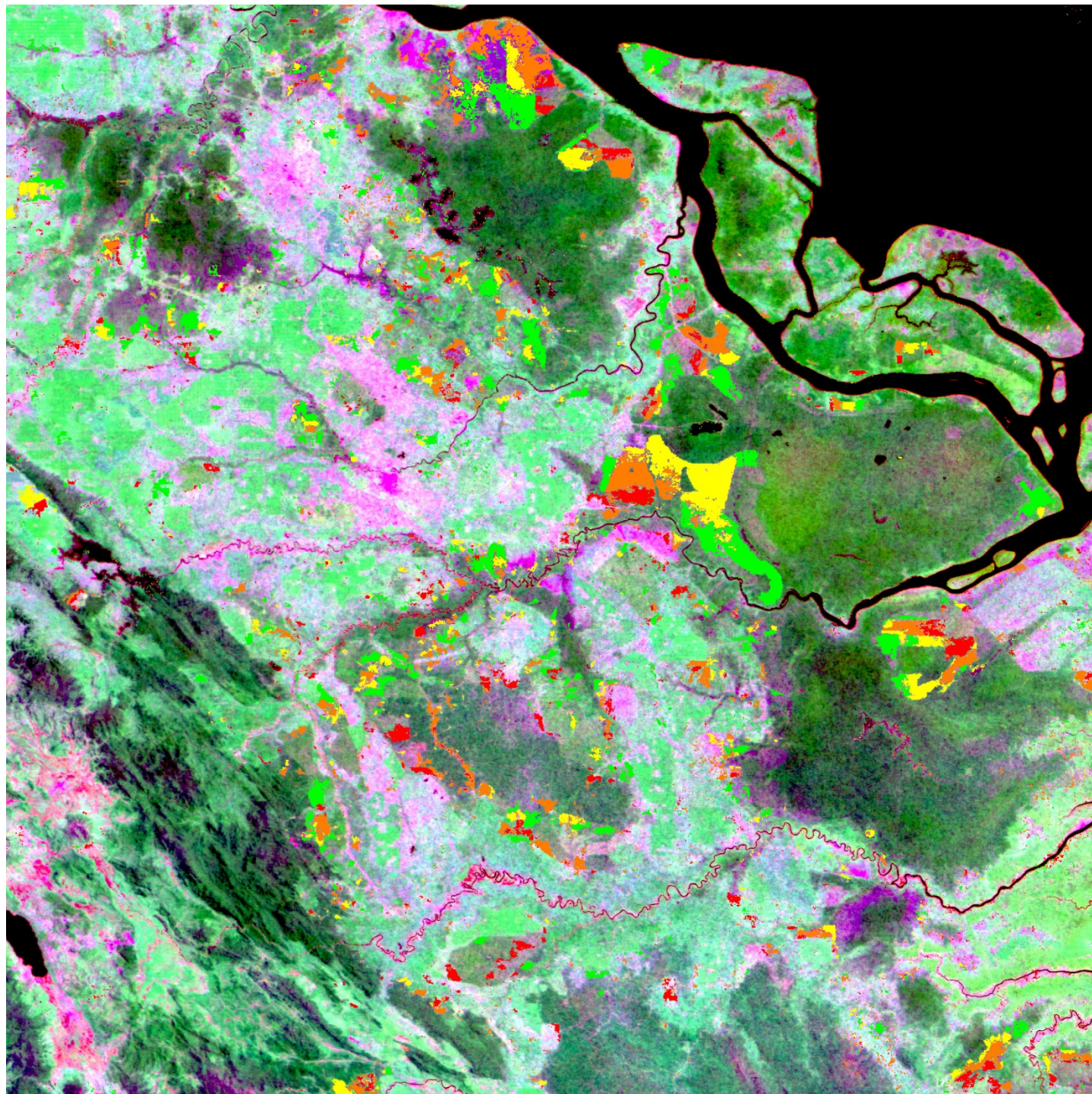
Annual
forest
cover
loss



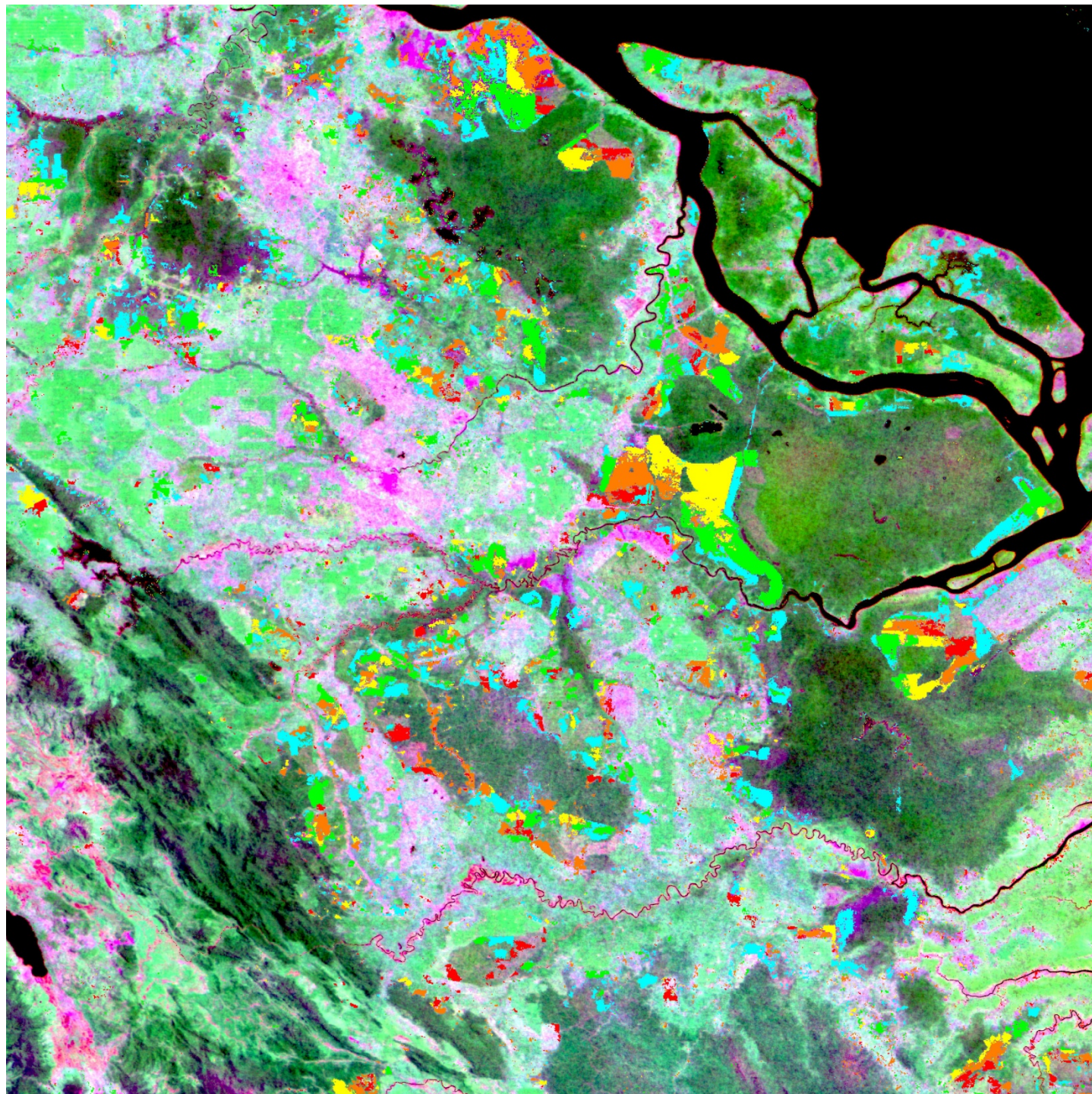
Annual
forest
cover
loss



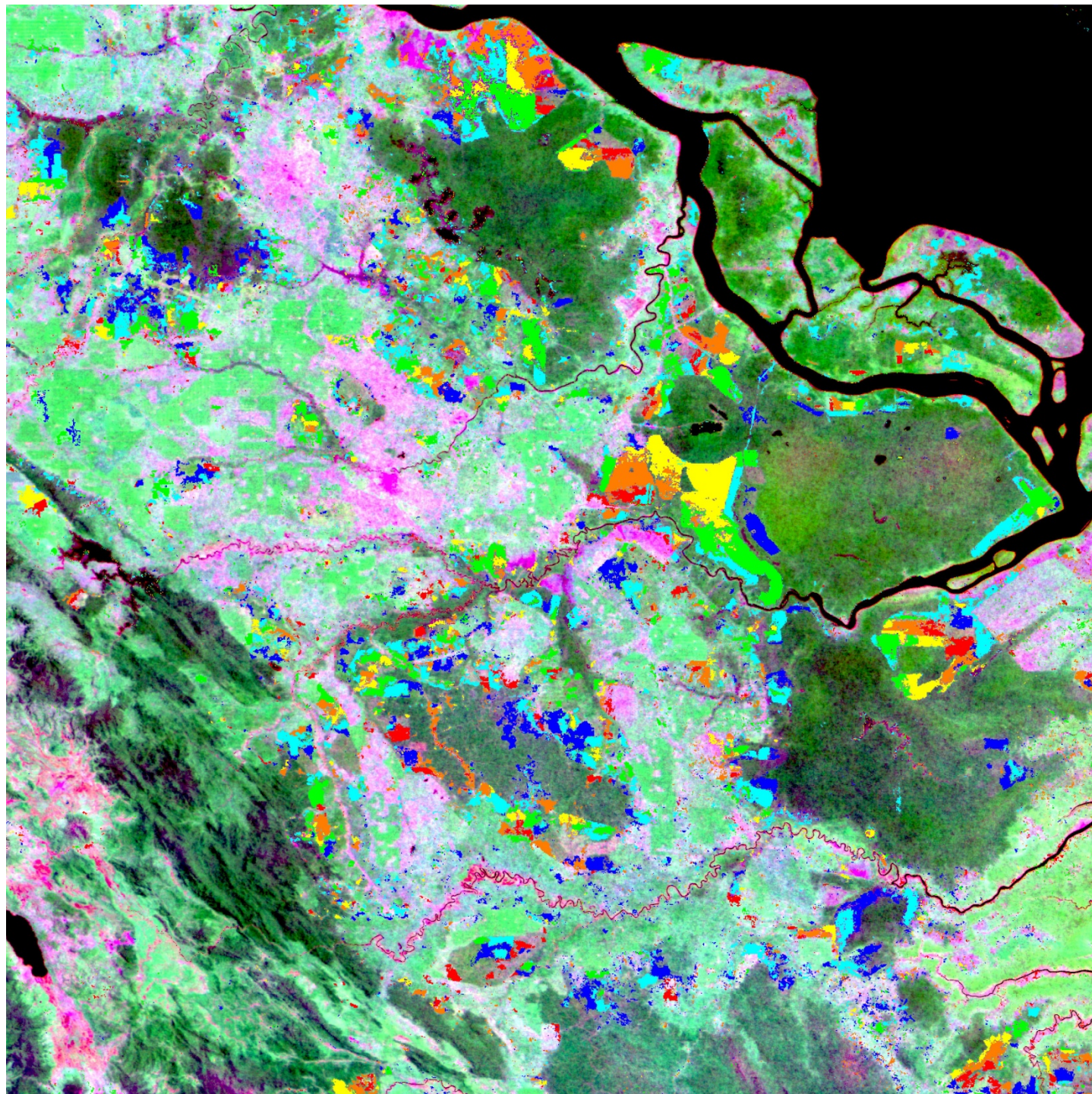
Annual
forest
cover
loss



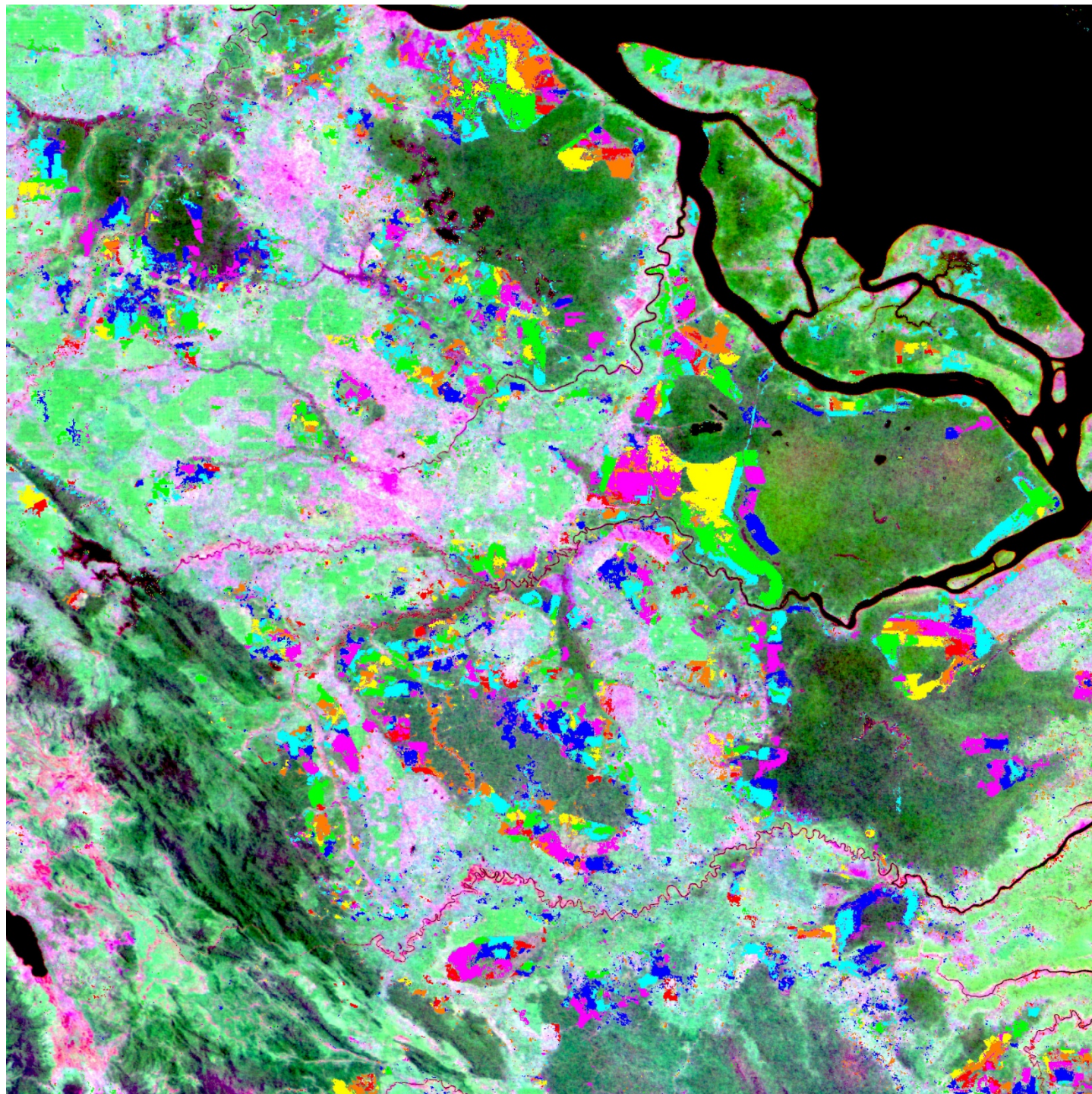
Annual
forest
cover
loss



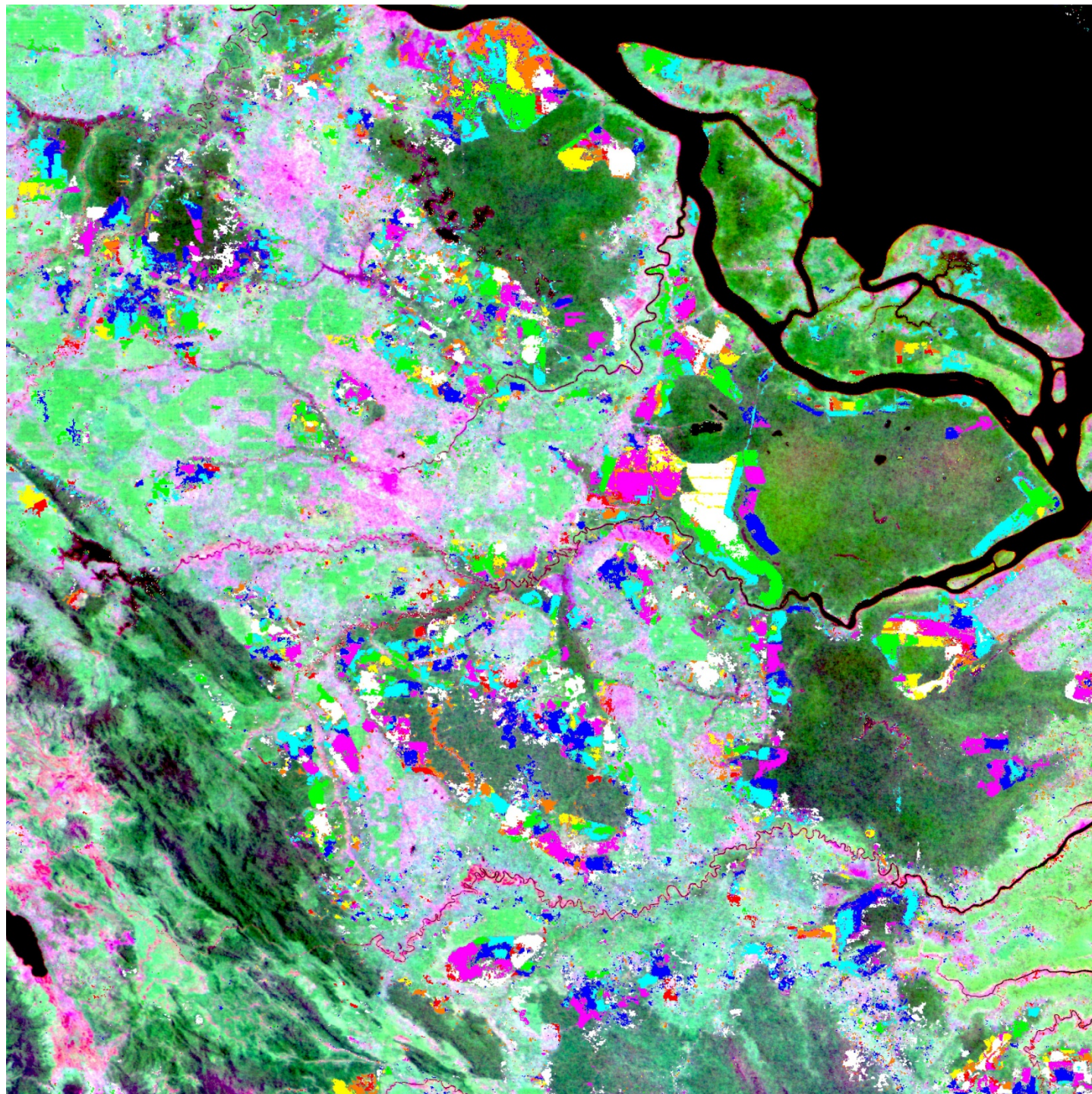
Annual
forest
cover
loss



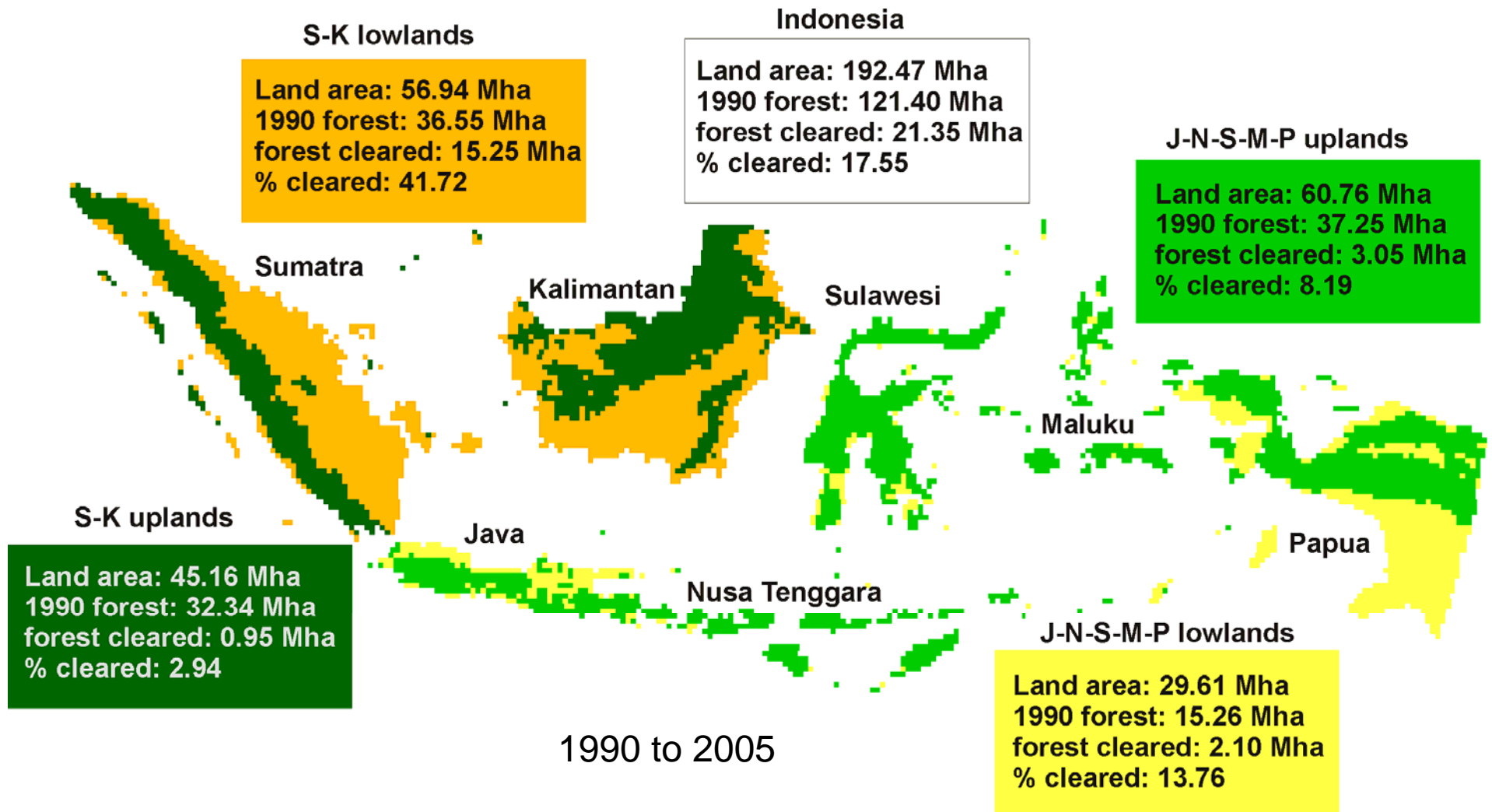
Annual
forest
cover
loss



Annual
forest
cover
loss



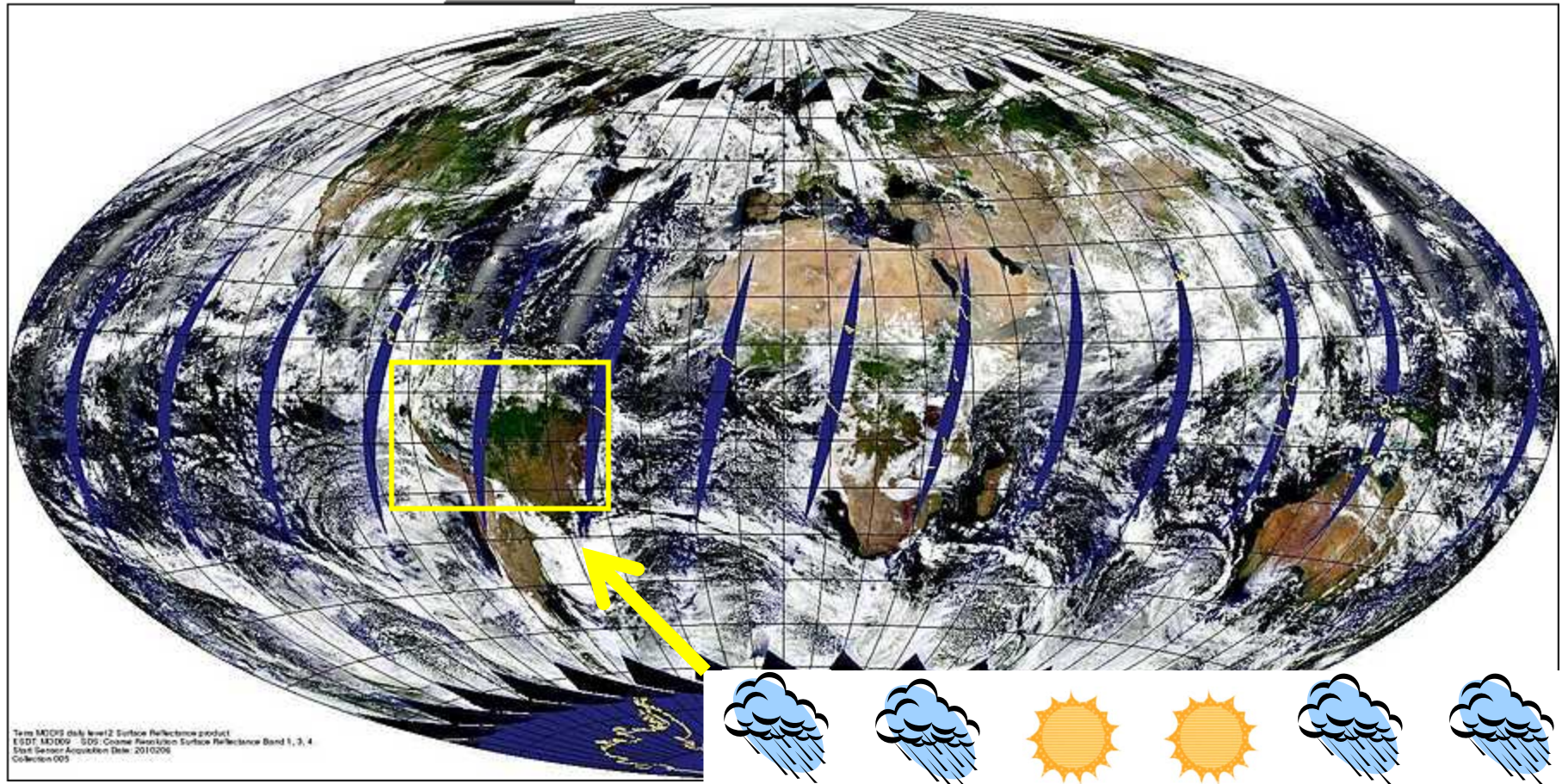
MODIS changed used to guide Landsat samples for estimating forest cover extent and loss



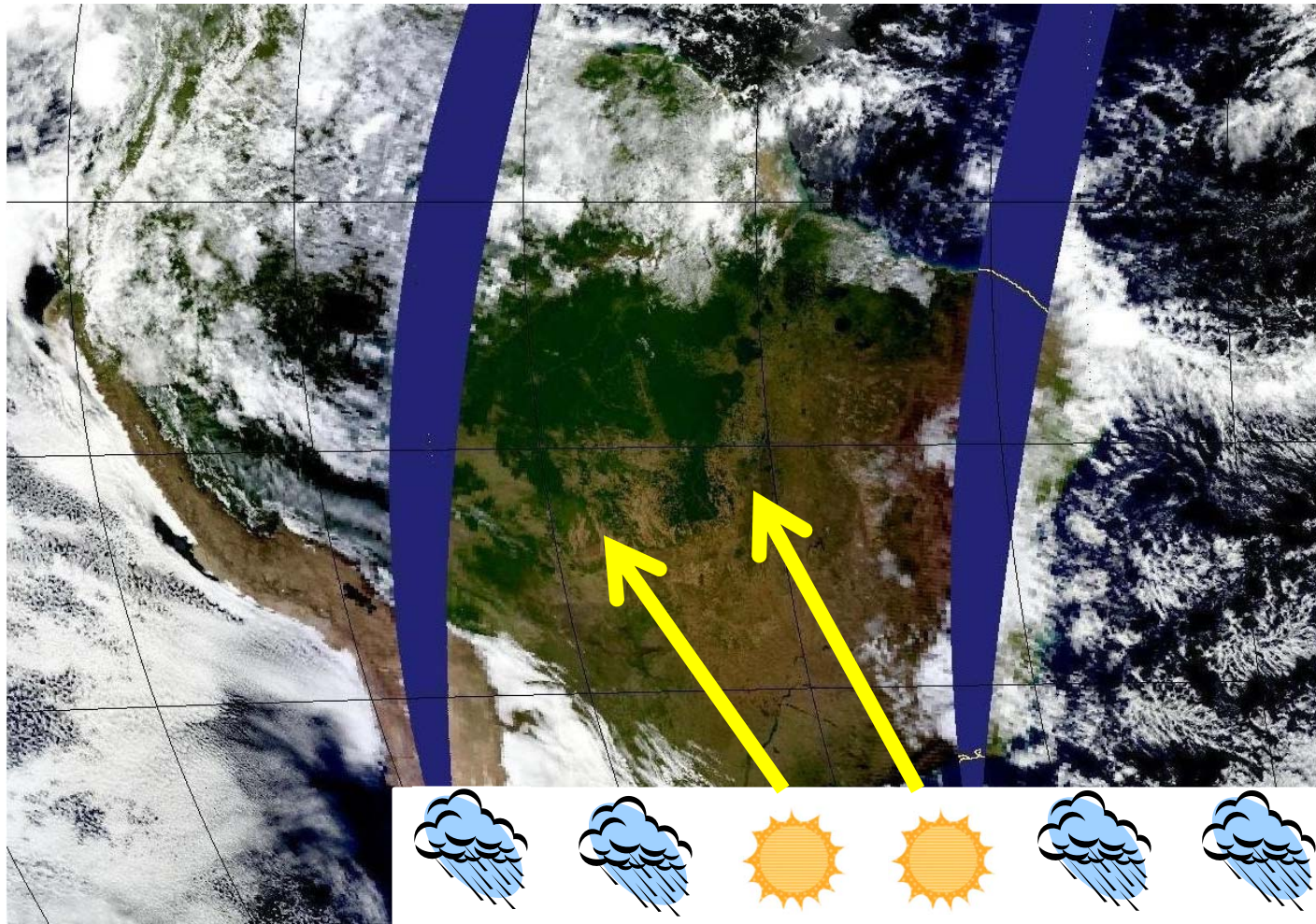
Monitoring at national scales in the humid tropics – different situations

- 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

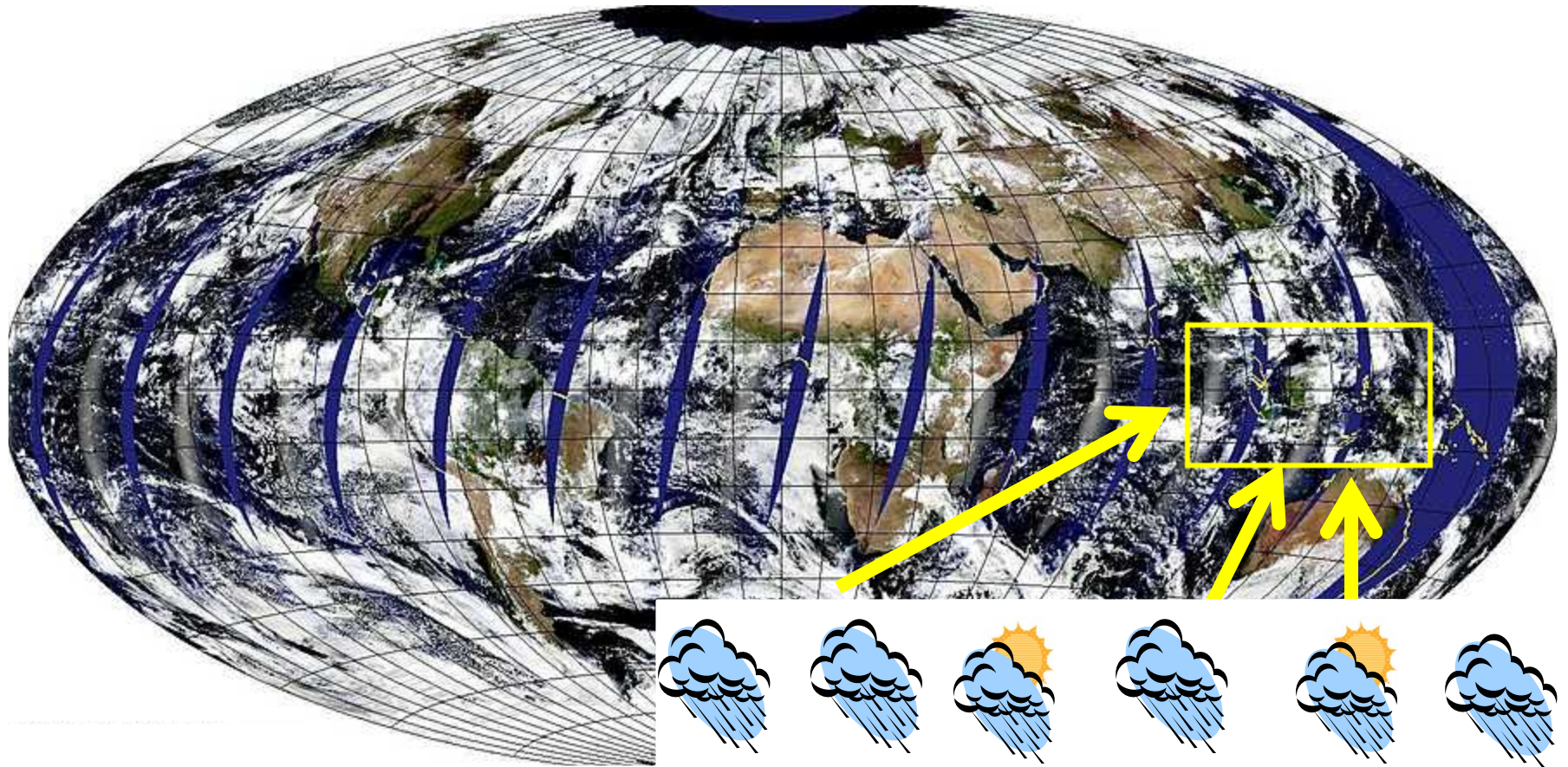
Humid tropical cloud cover for one day of MODIS data



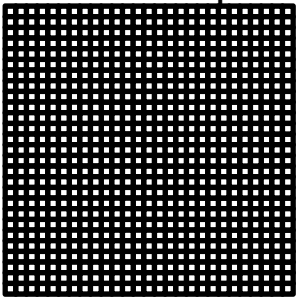
Seasonally cloud-free window over the southern Amazon



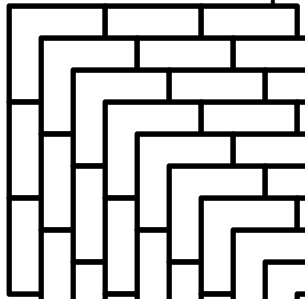
Conversely, Indonesia is persistently cloudy



30m x 30m pixels

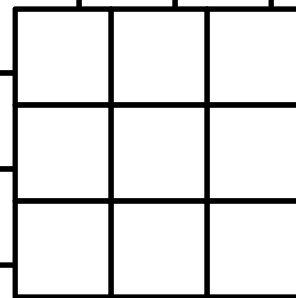
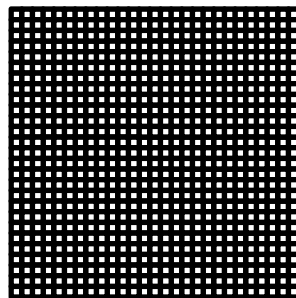
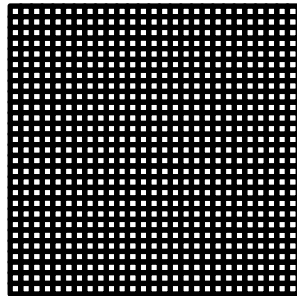


250m x 250m pixels

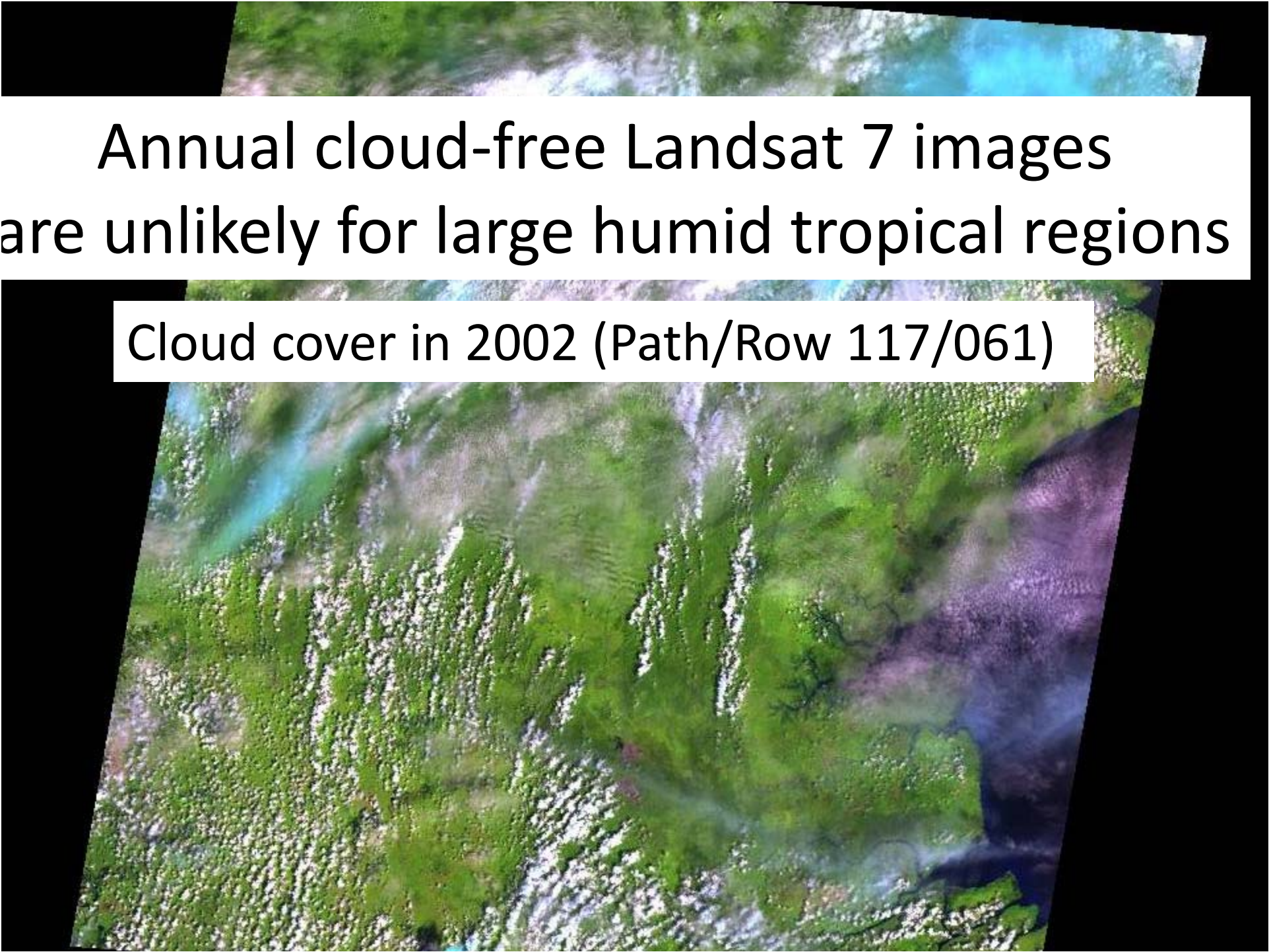


- August 1
- August 2
- August 3
- August 4
- August 5
- August 6
- August 7
- August 8
- August 9
- August 10
- August 11
- August 12
- August 13
- August 14
- August 15
- August 16
- August 17
- August 18
- August 19
- August 20
- August 21
- August 22
- August 23
- August 24
- August 25
- August 26
- August 27
- August 28
- August 29
- August 30
- August 31
- Sep. 2
- Sep. 3

MODIS – near daily

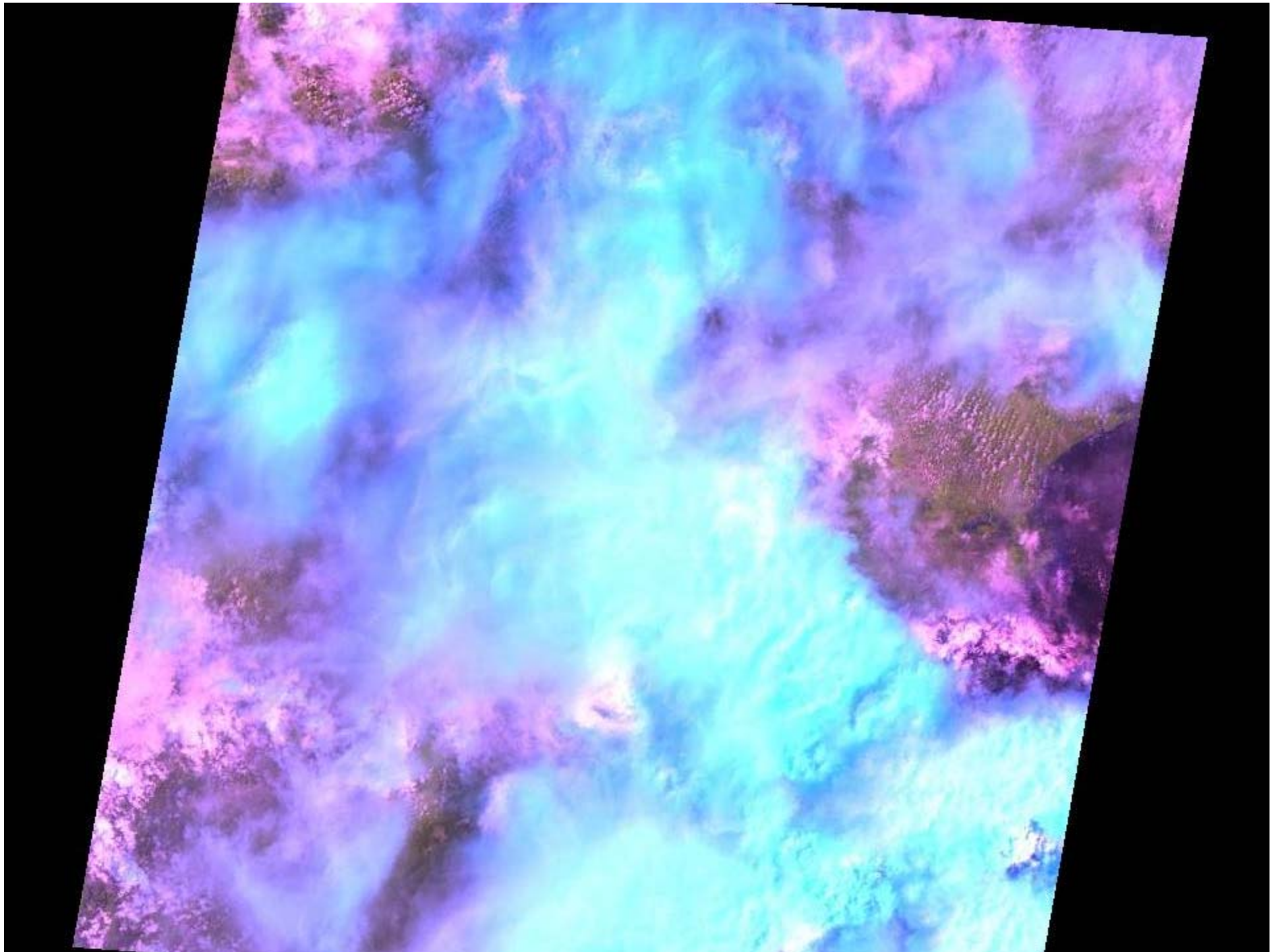


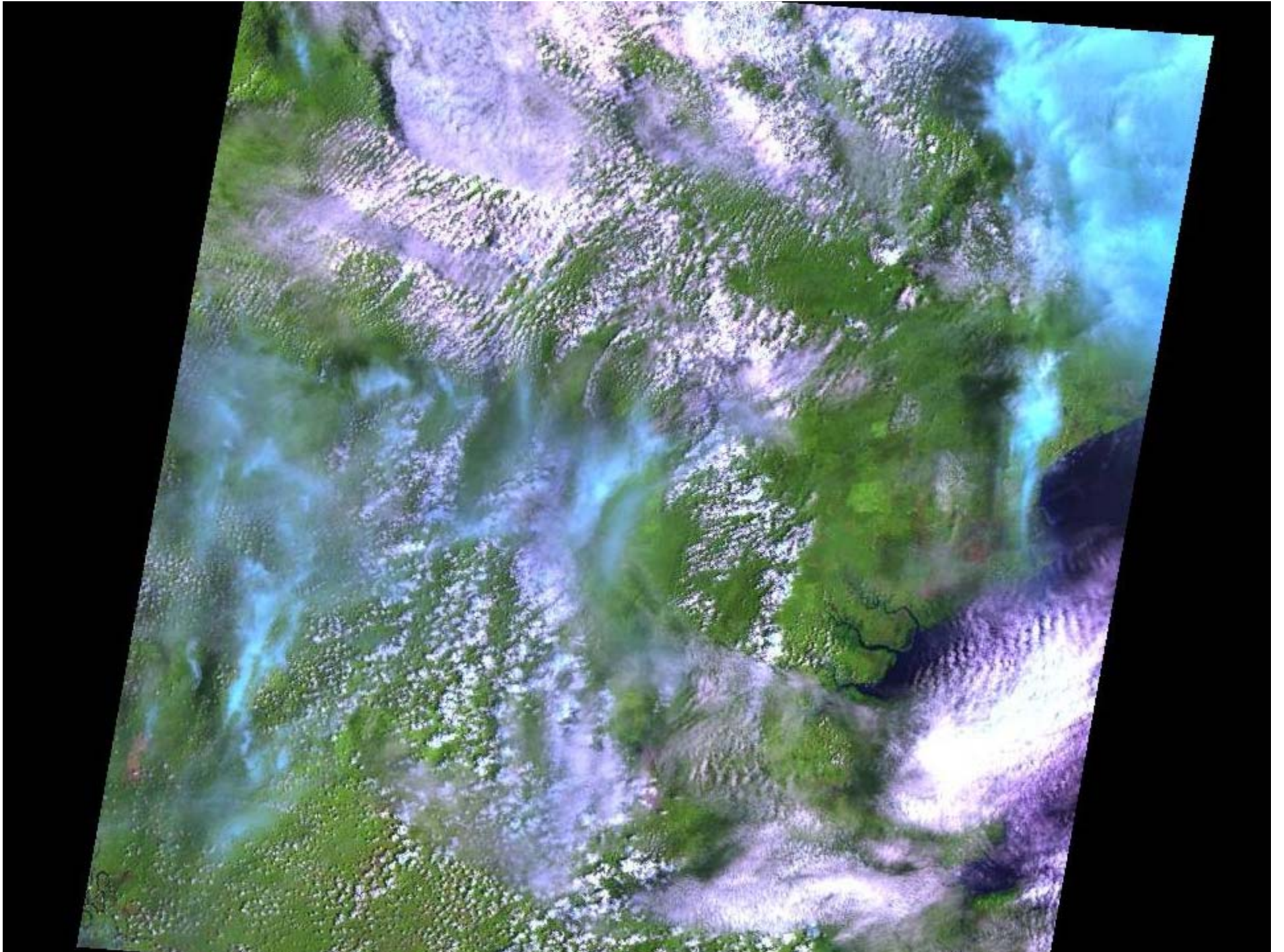
Landsat ETM+ –
potentially every 16
days

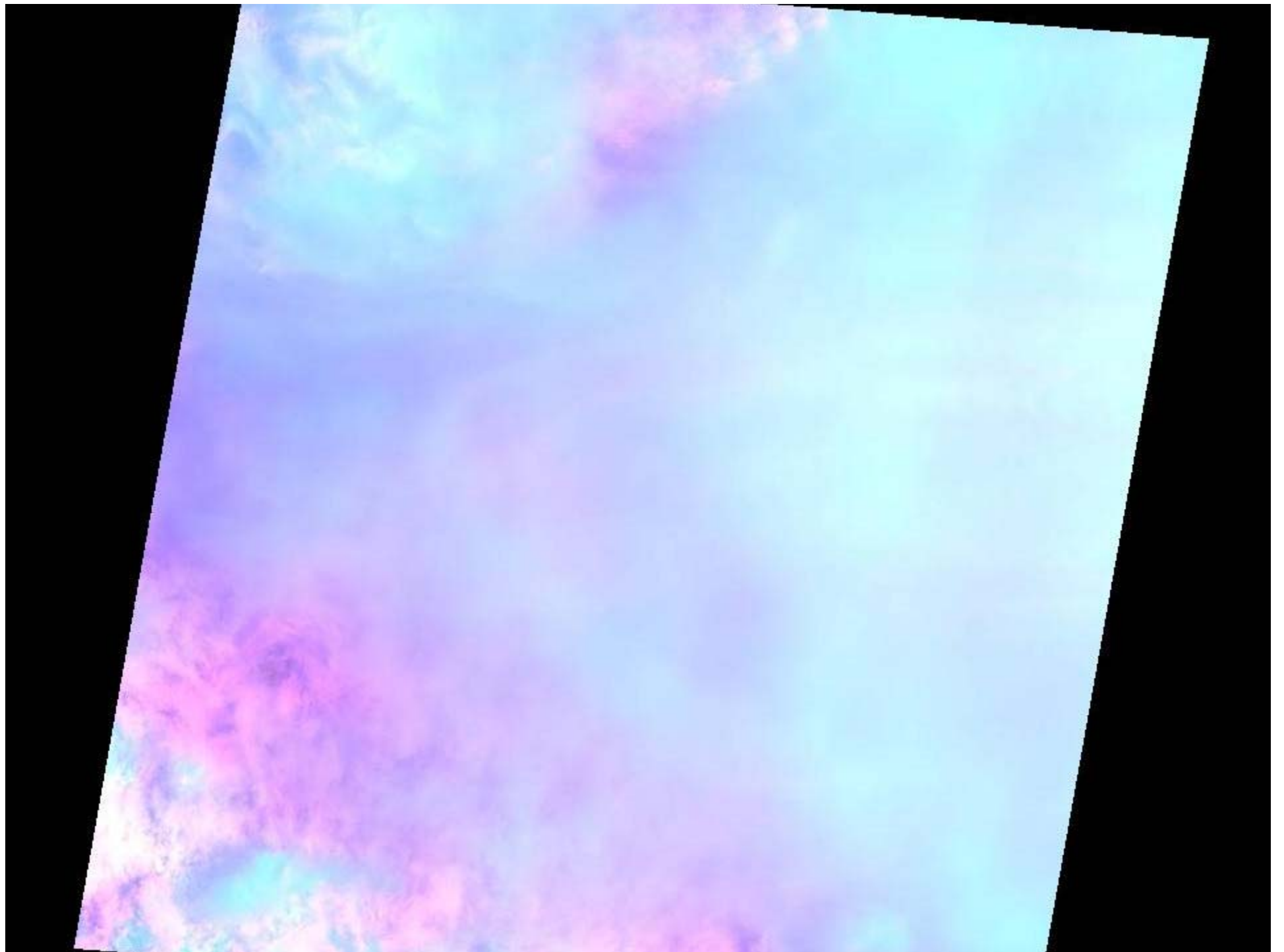


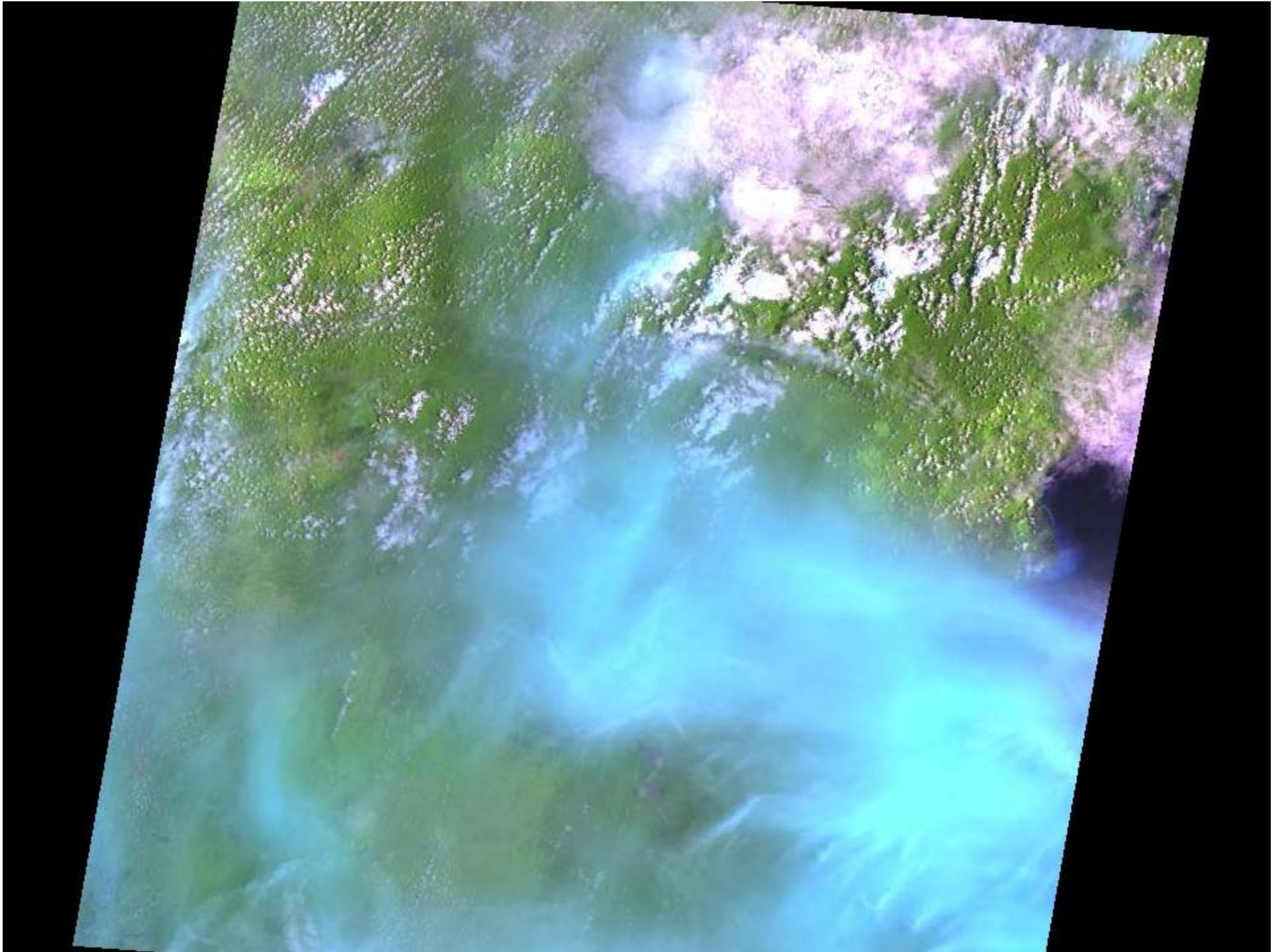
Annual cloud-free Landsat 7 images
are unlikely for large humid tropical regions

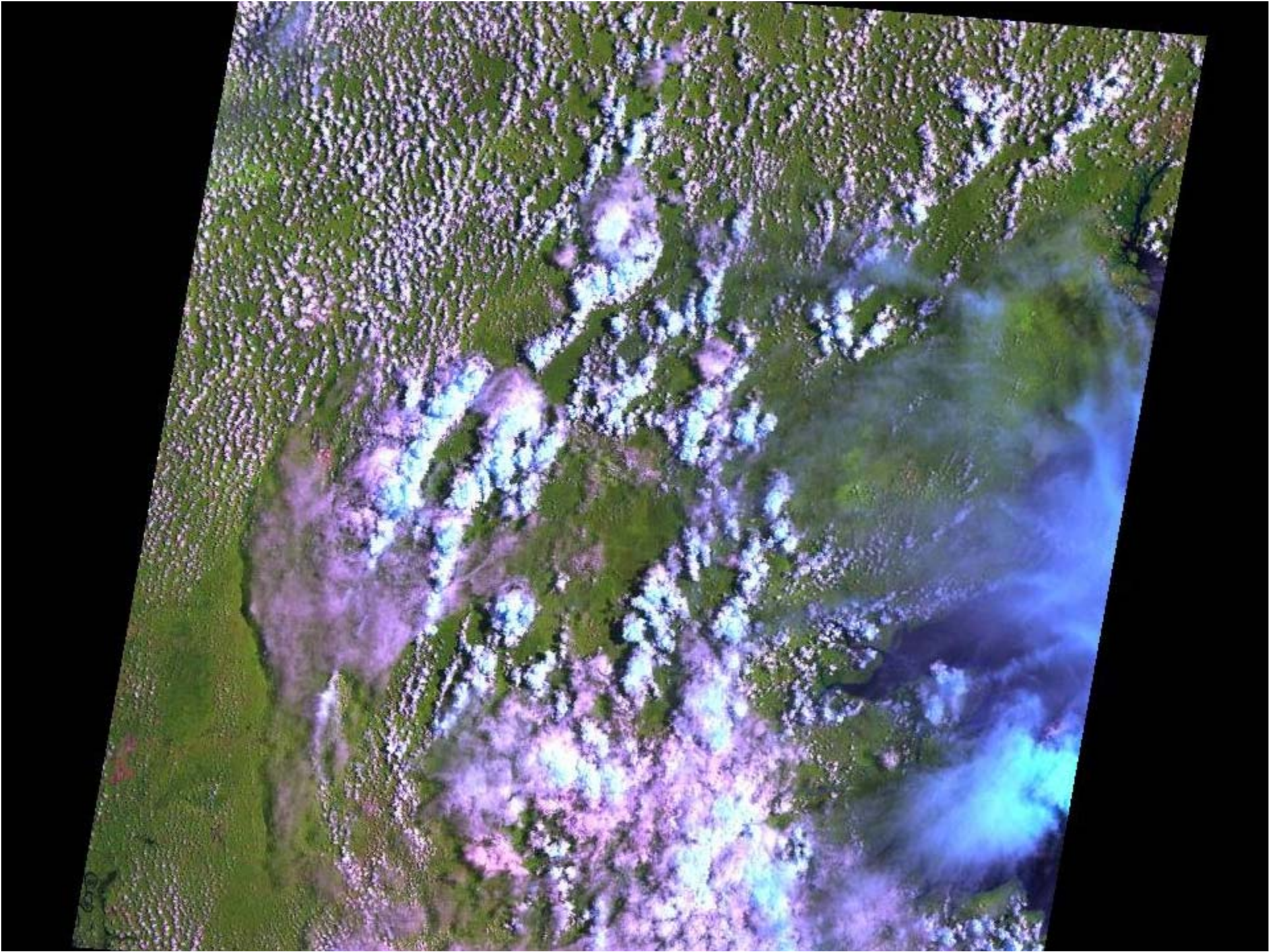
Cloud cover in 2002 (Path/Row 117/061)

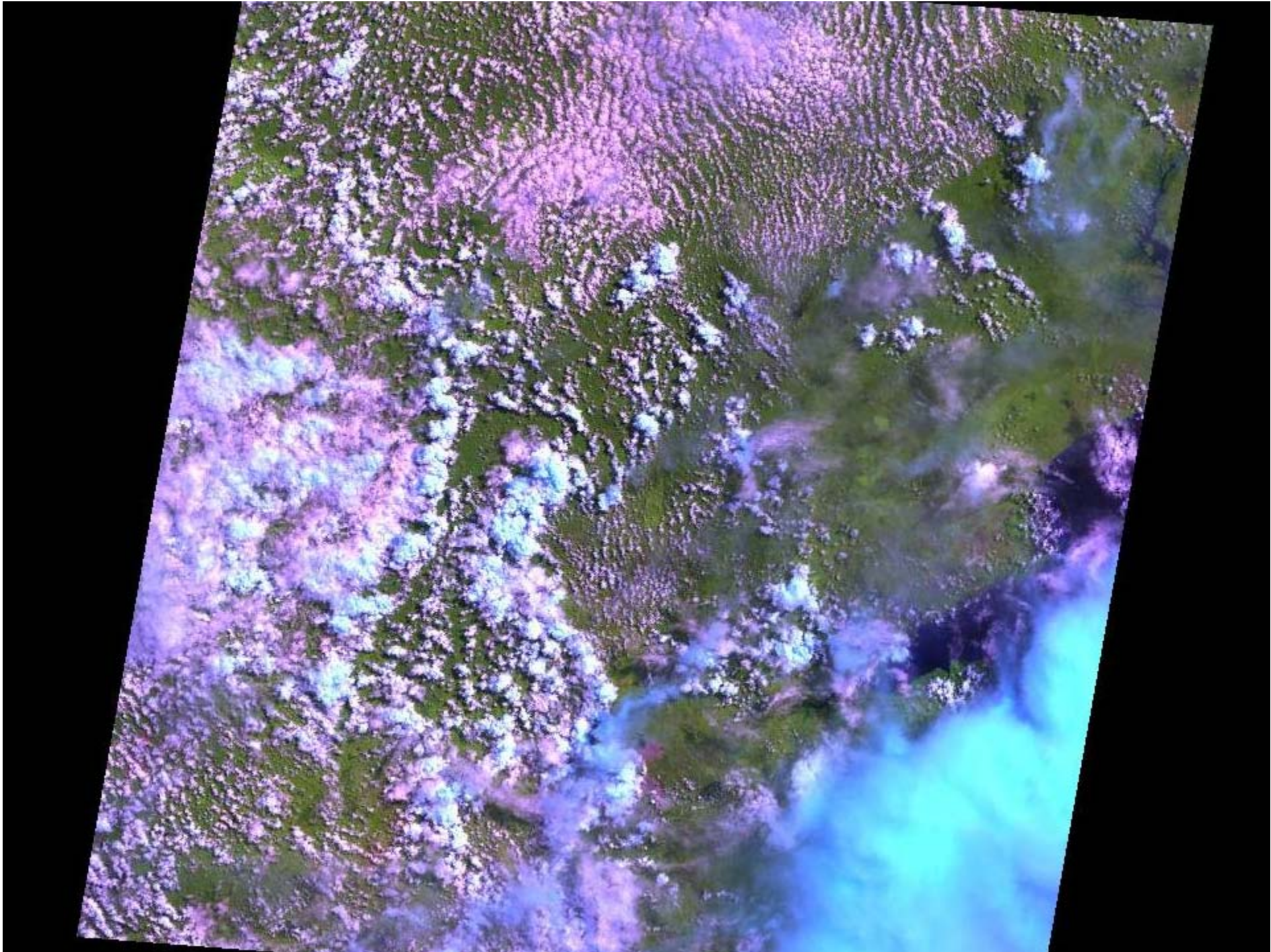


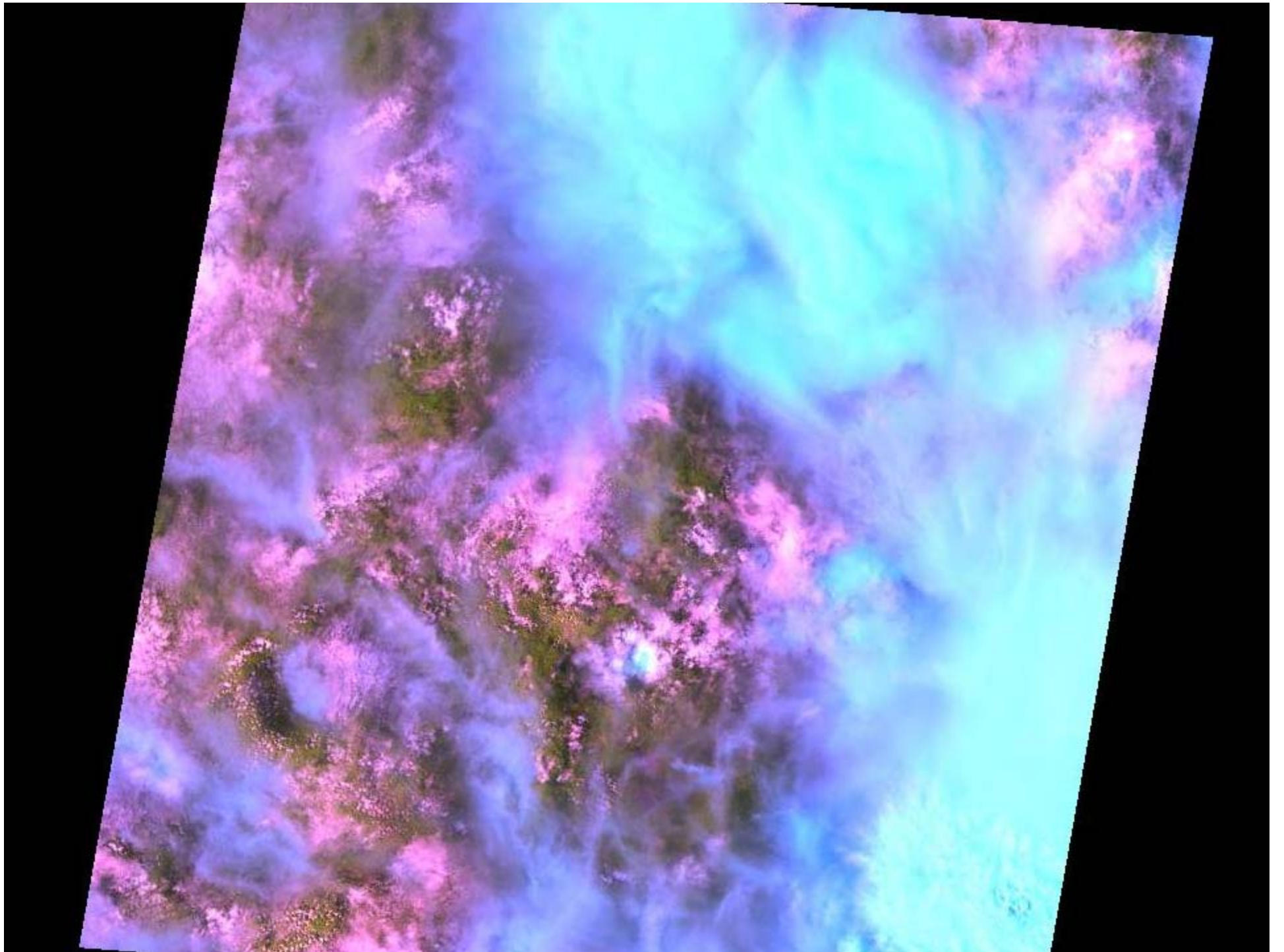


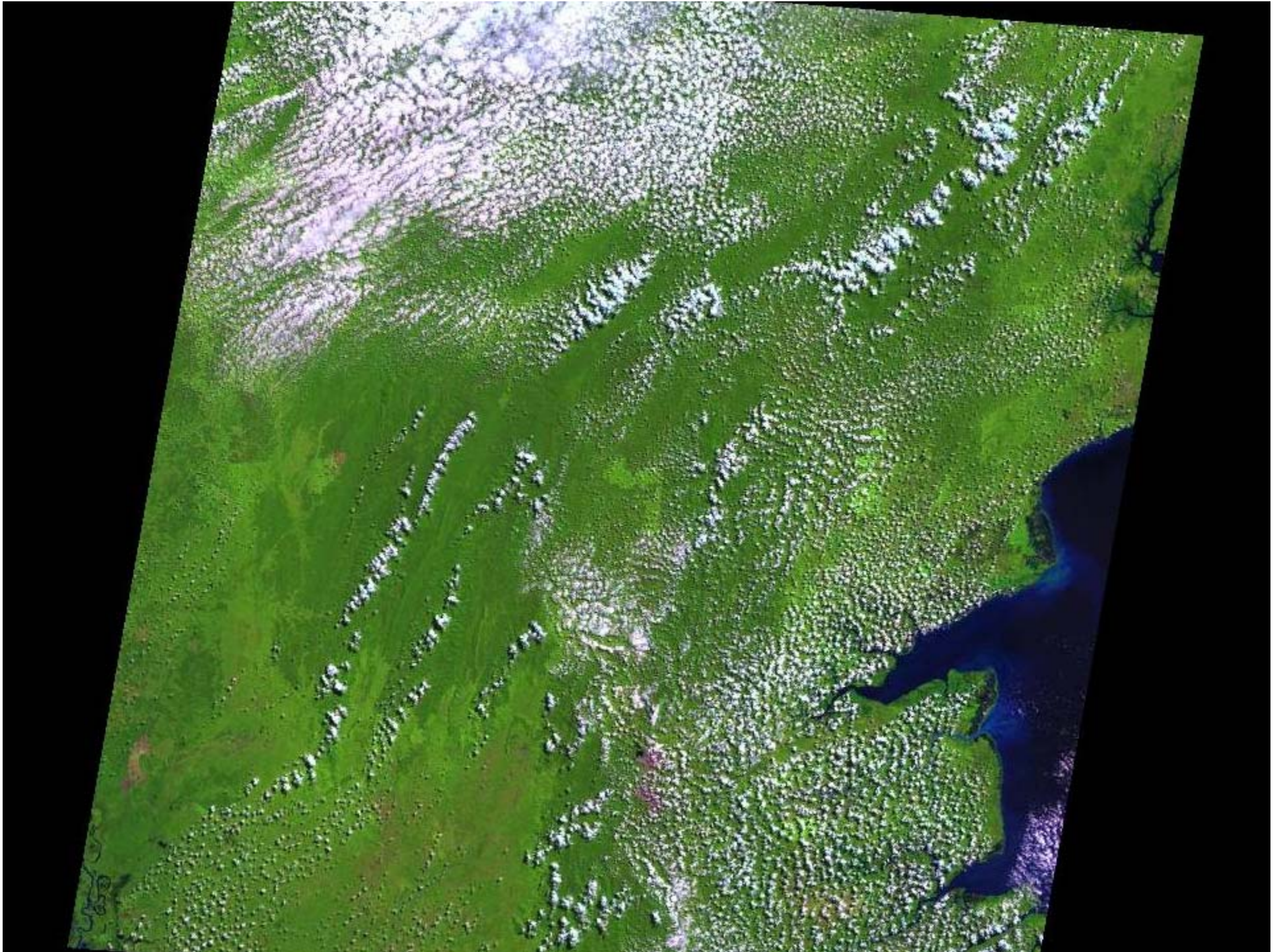


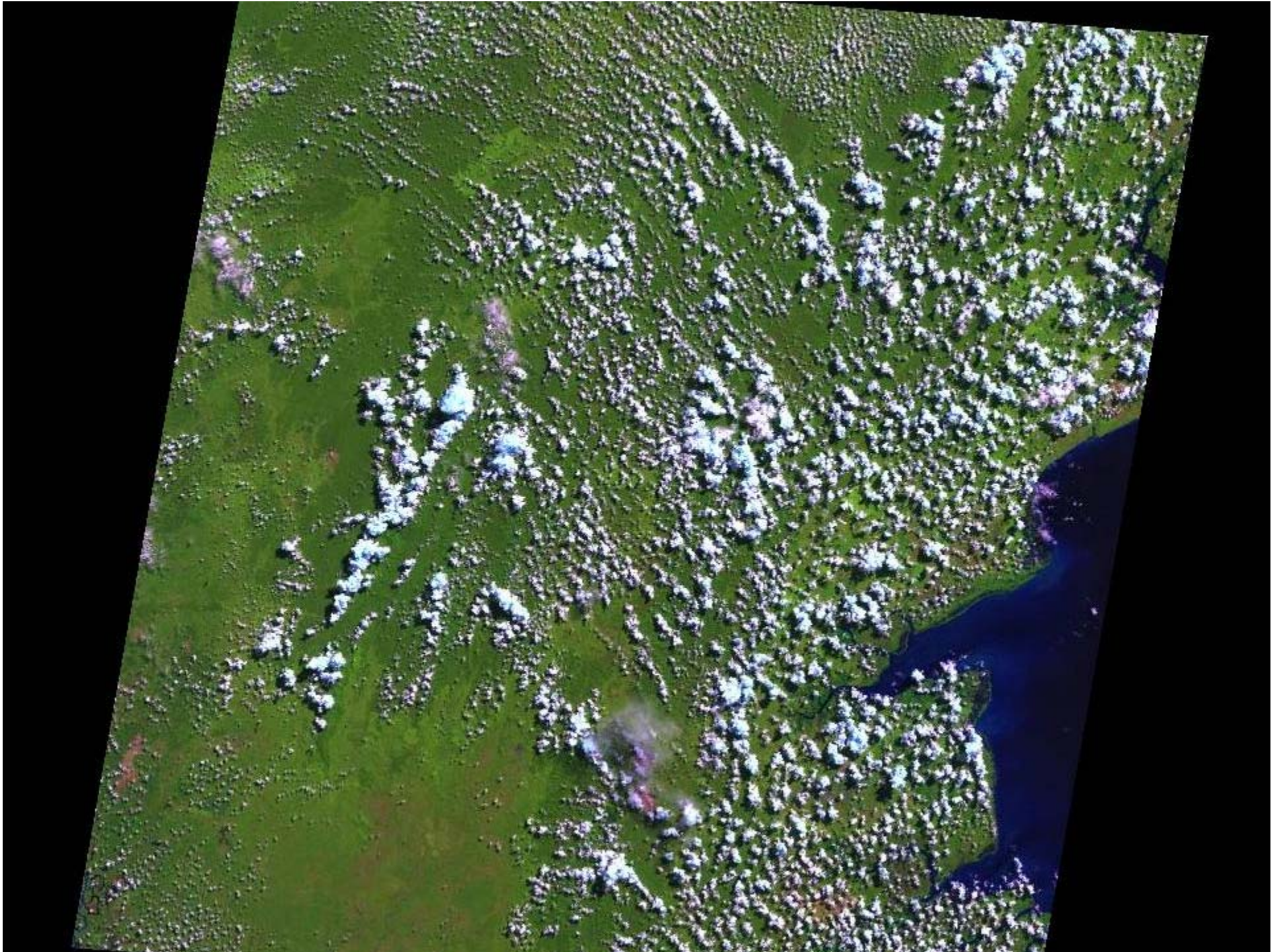


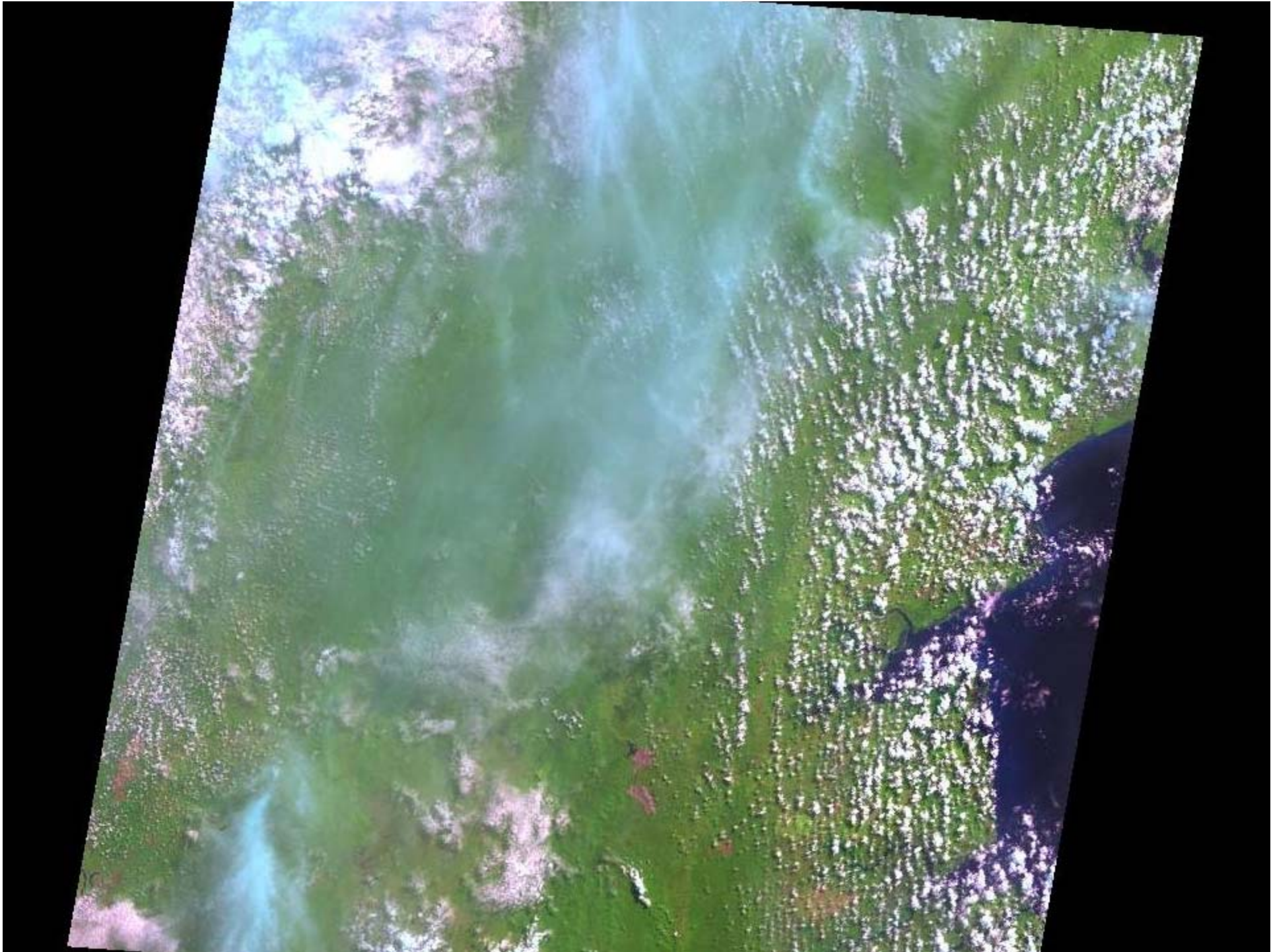


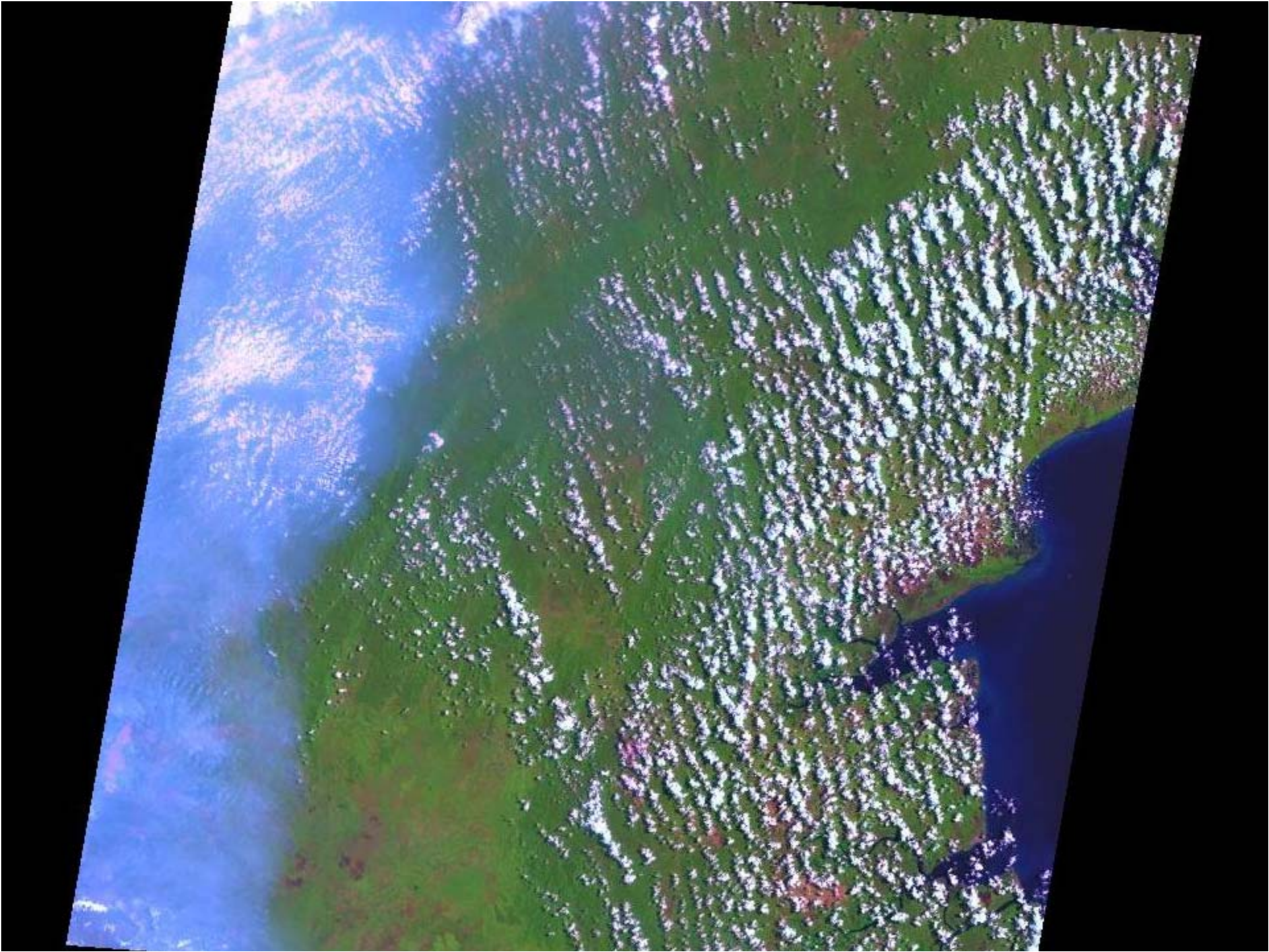




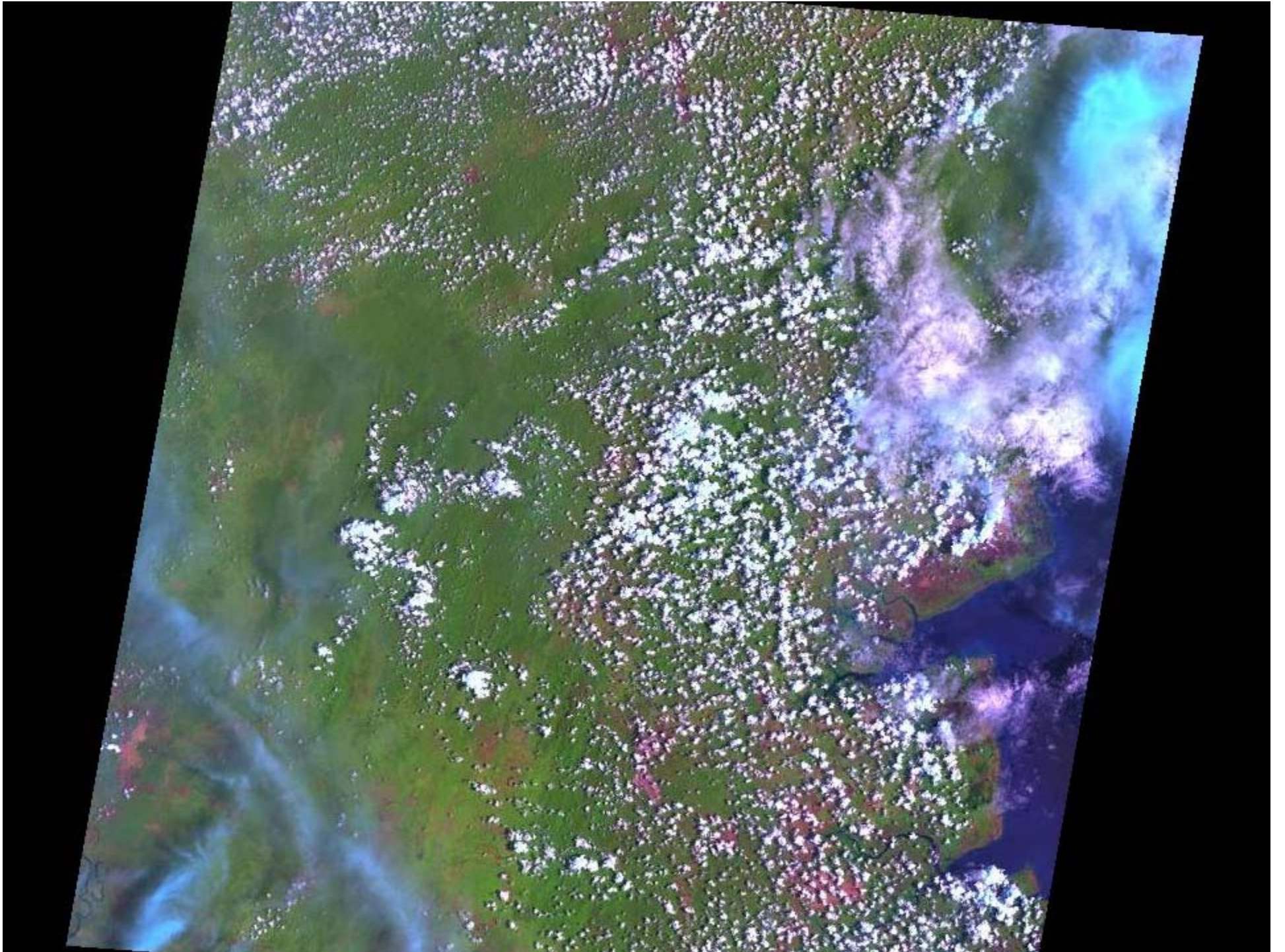


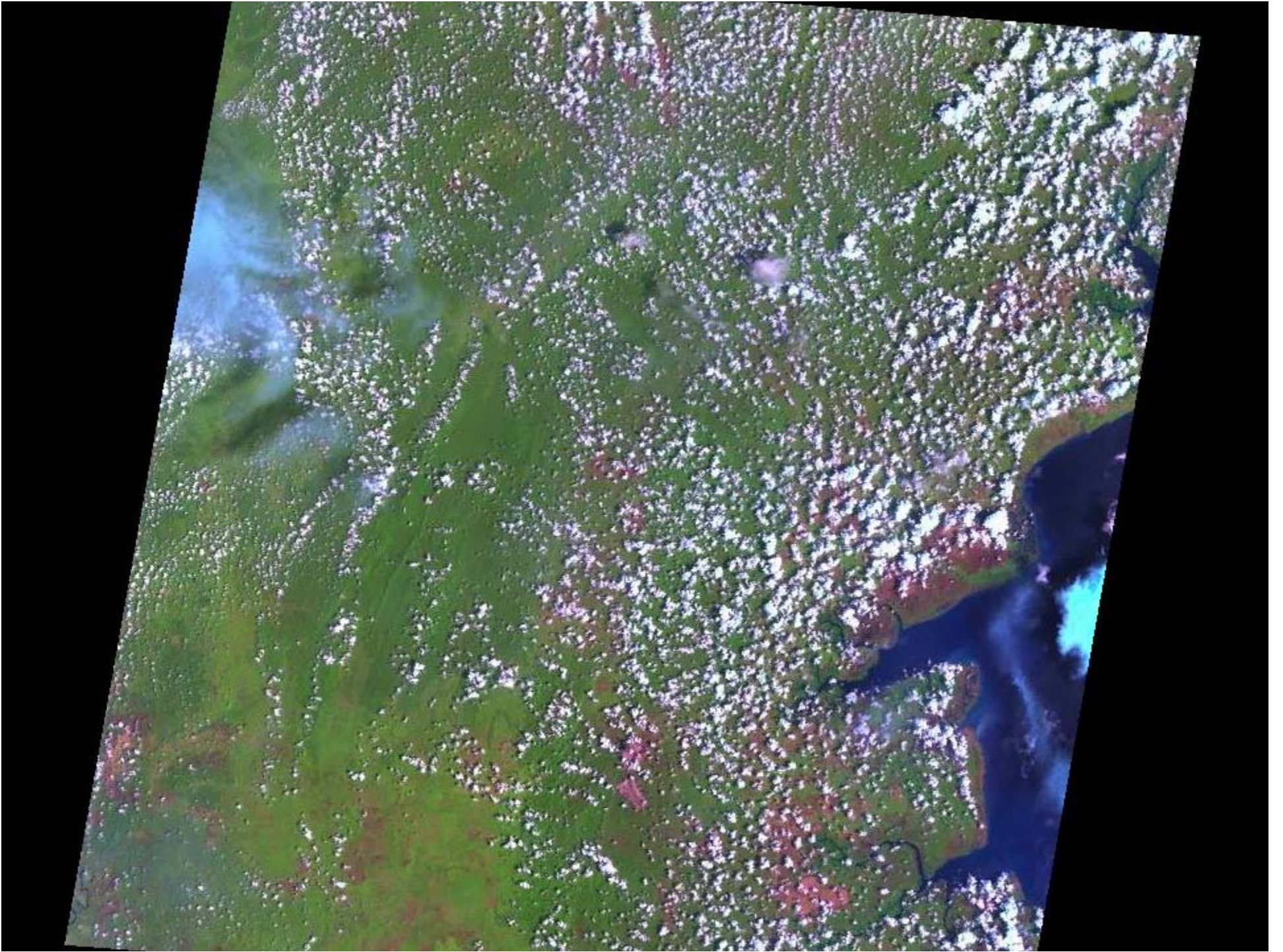


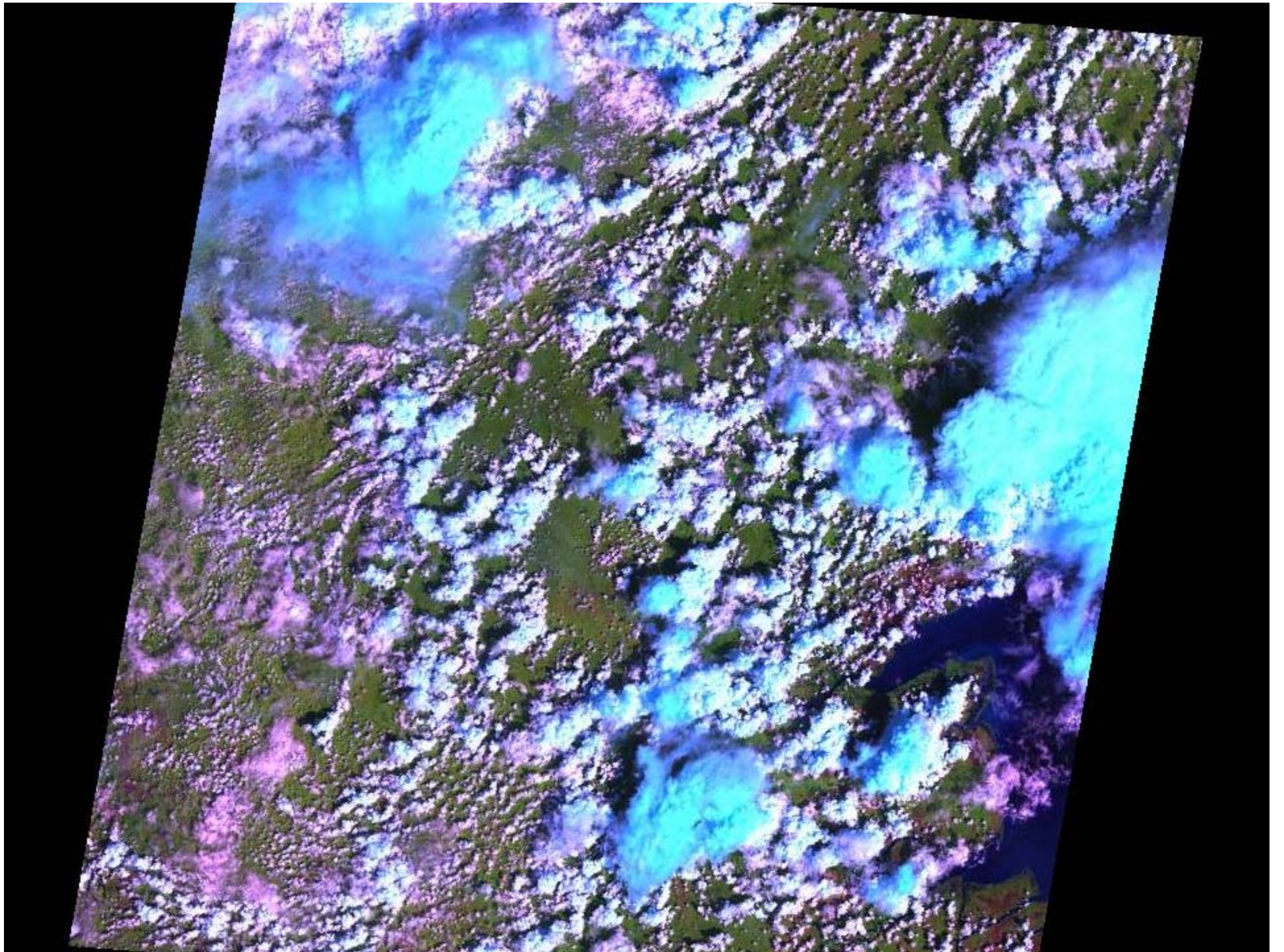


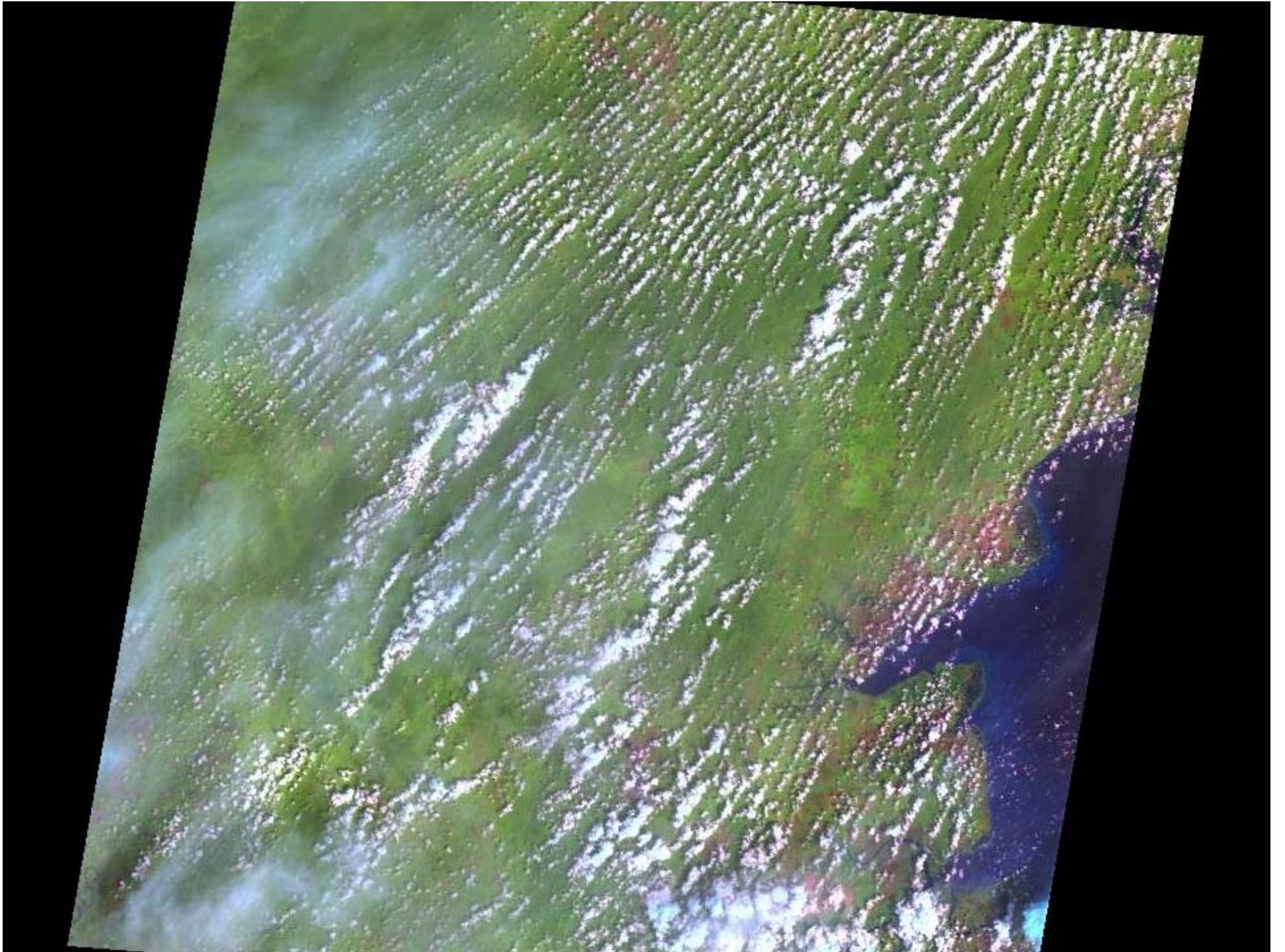


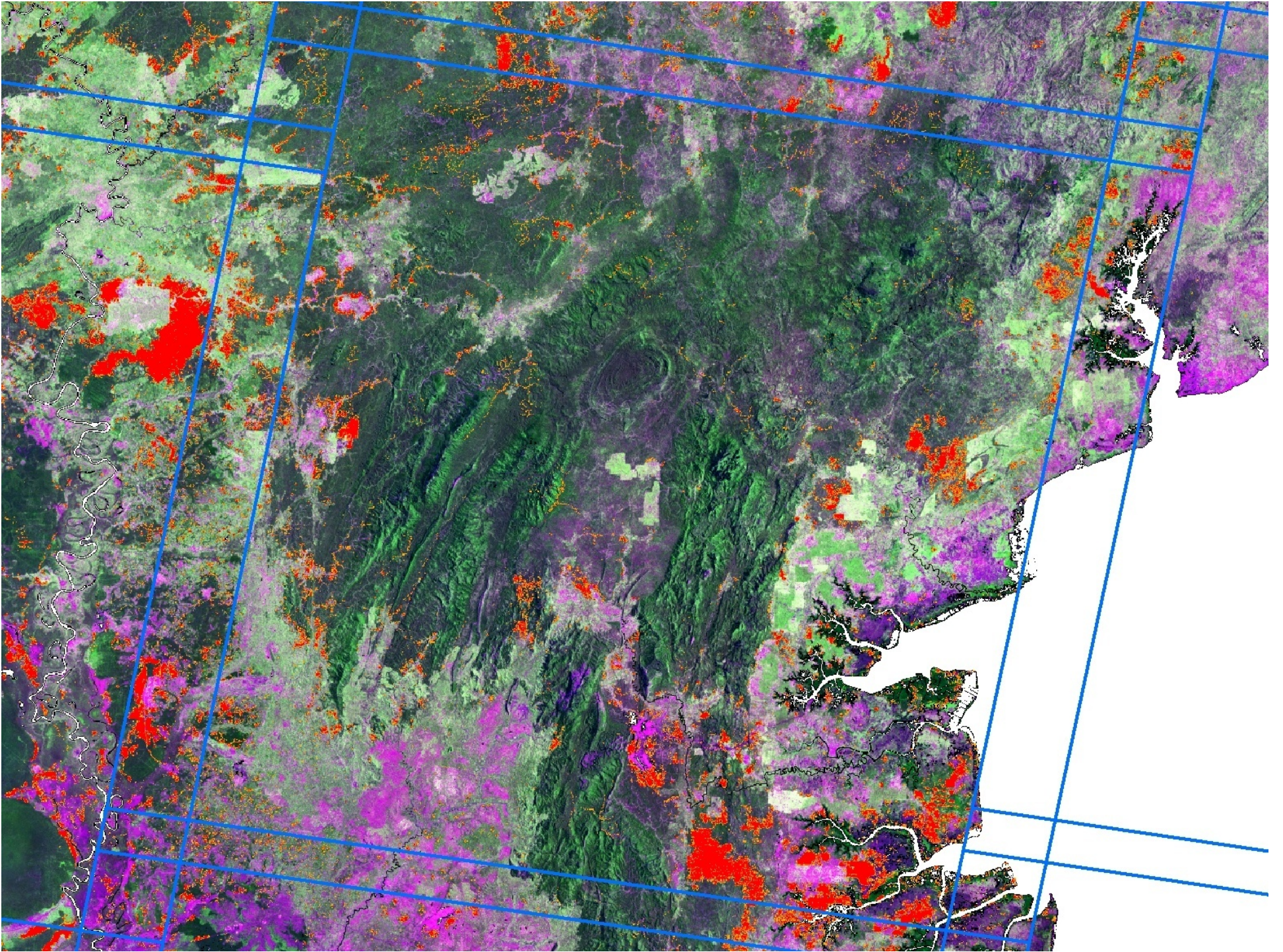






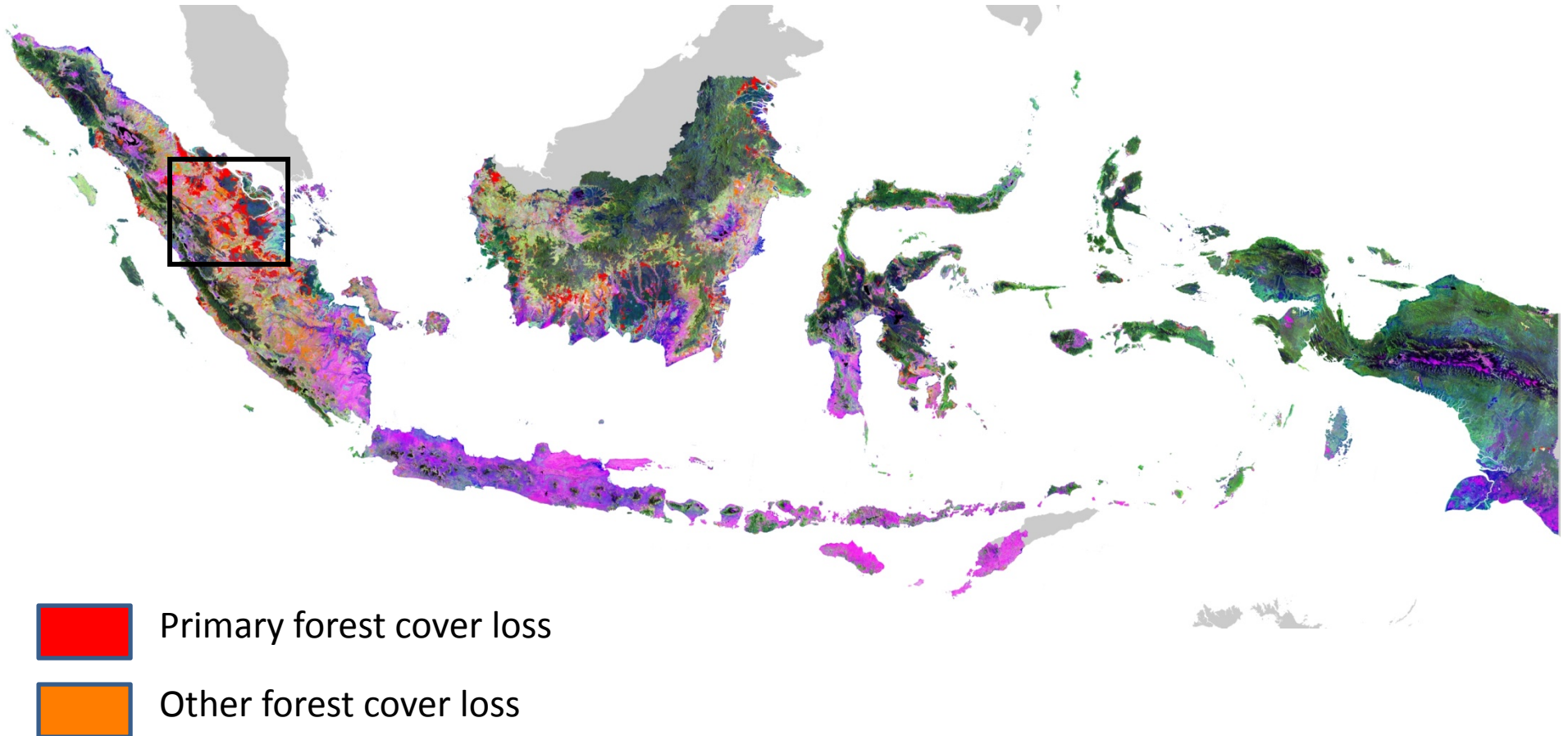







Forest cover loss in Indonesia, 2000 to 2010

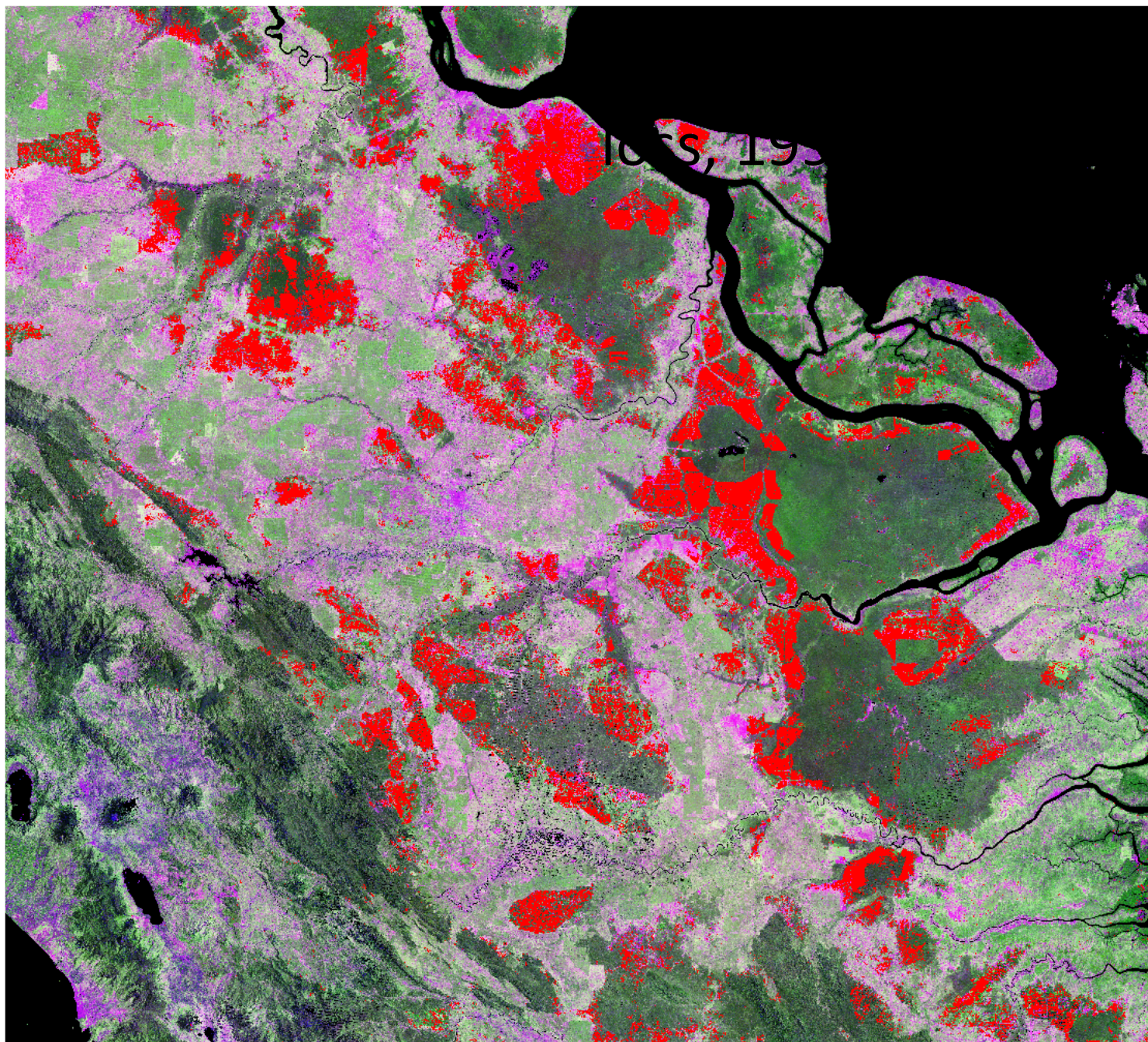
15,692 Landsat Enhanced Thematic Mapper Plus images from 1999 to 2010




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

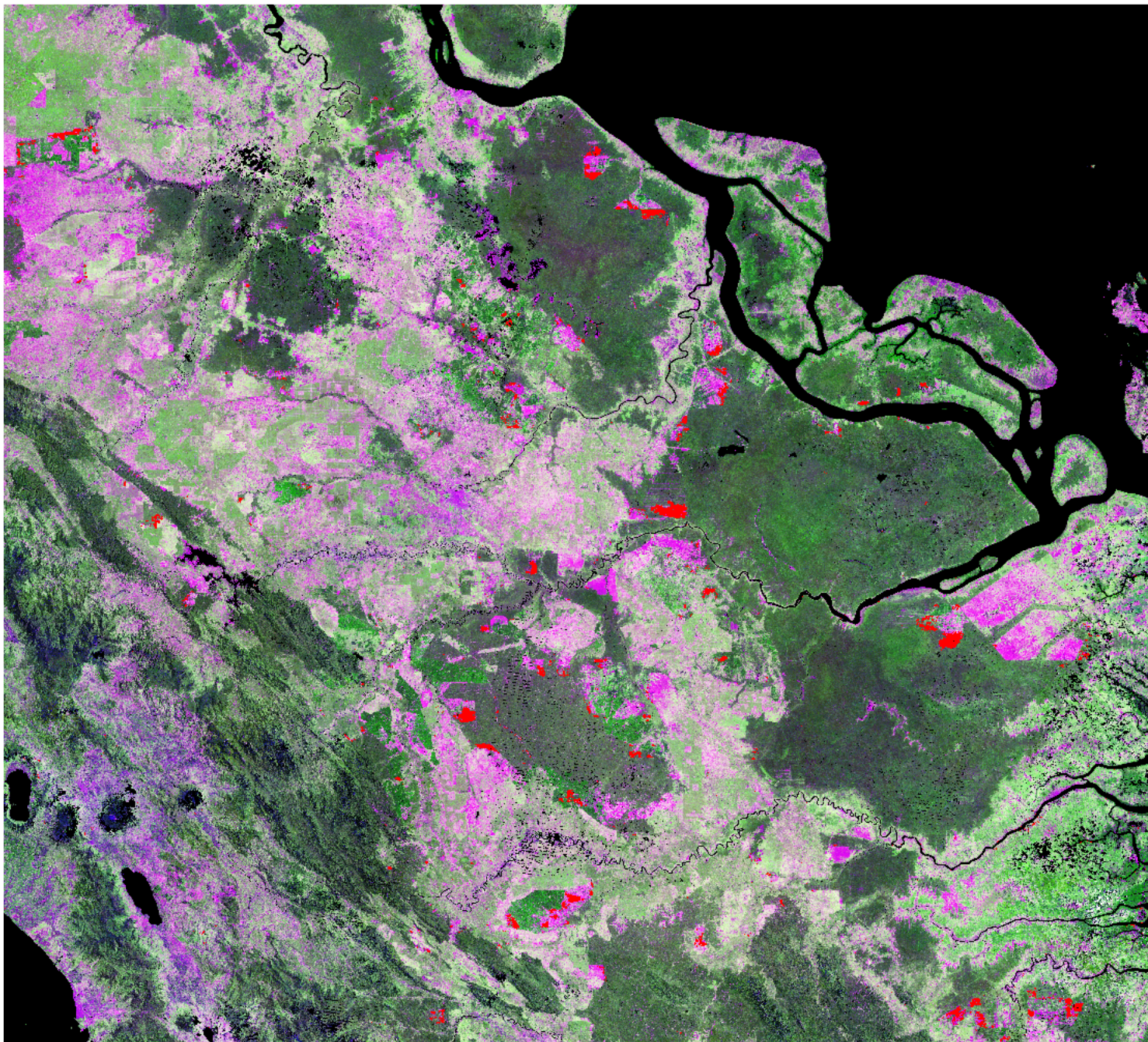
Total
forest
cover
loss

 00-08

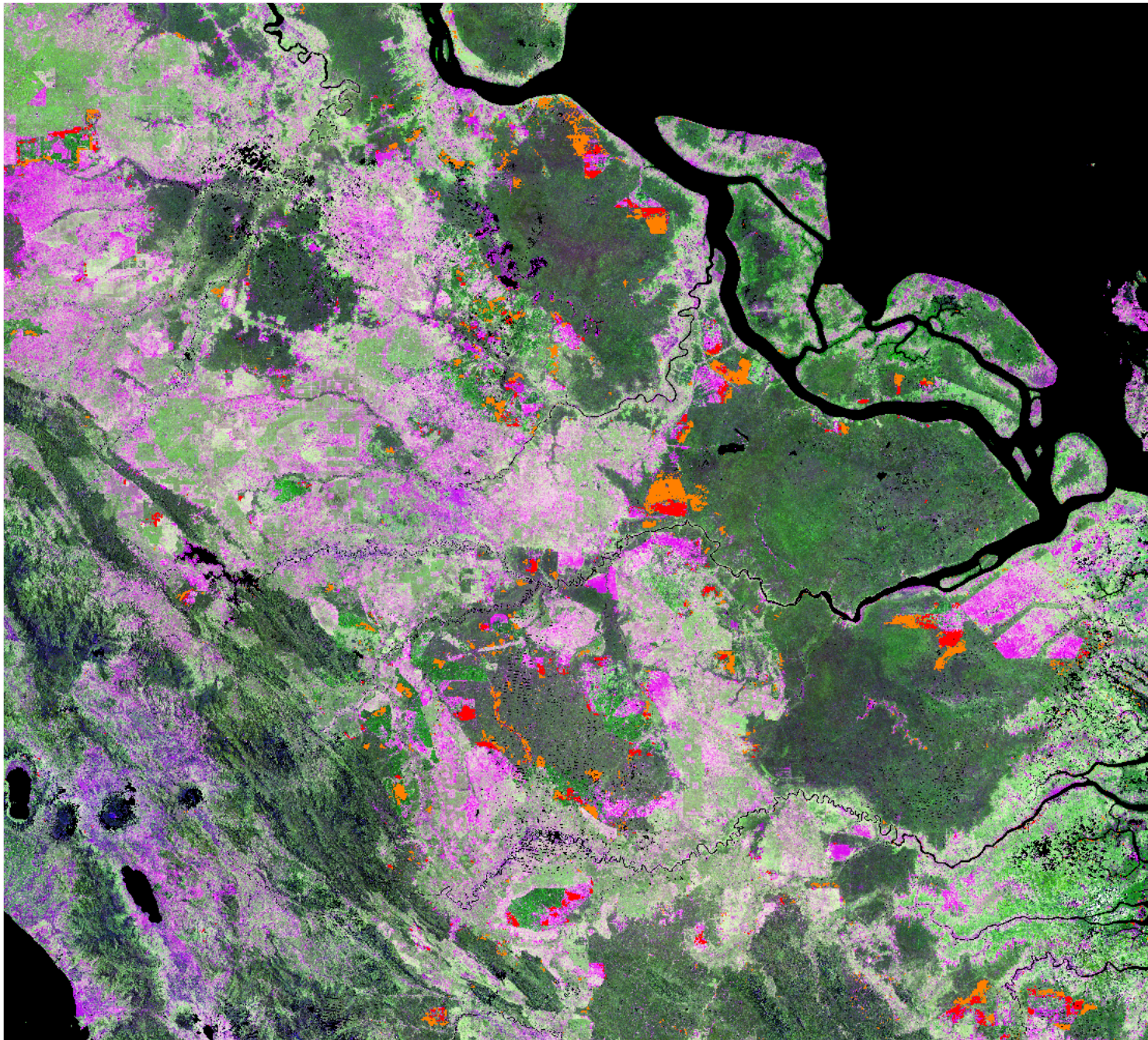


Annual
forest
cover
loss

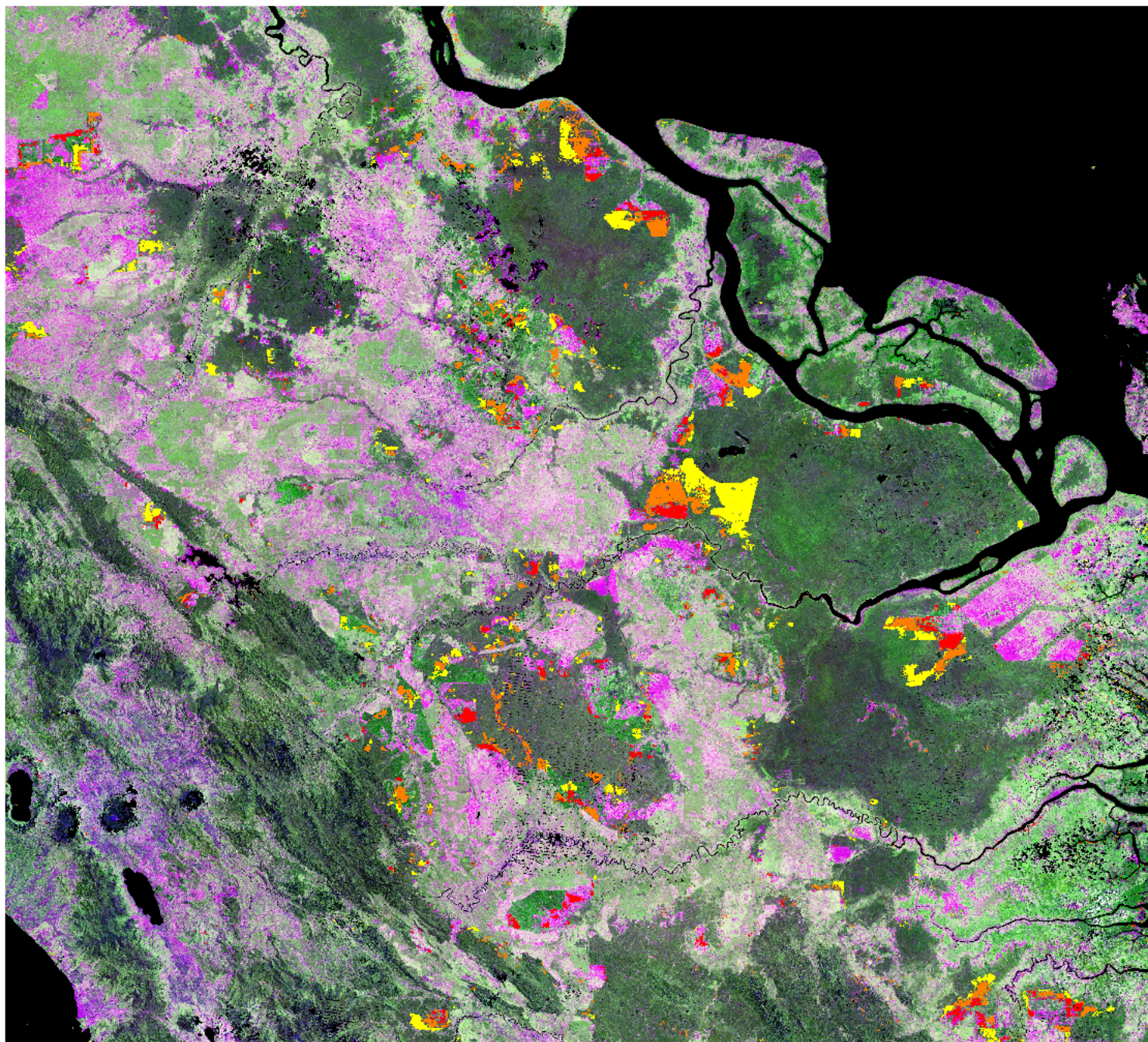
 00-01



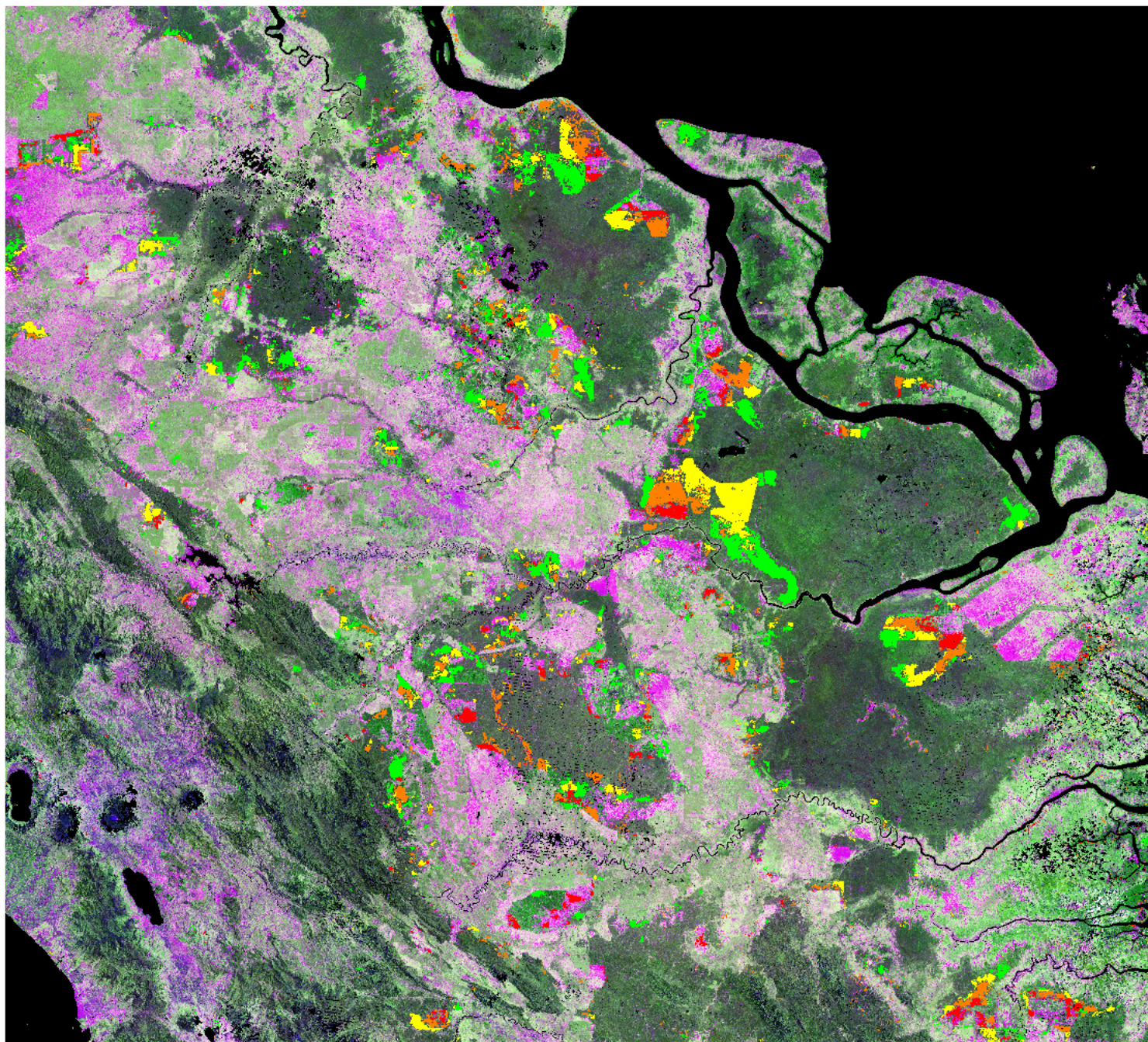
Annual
forest
cover
loss



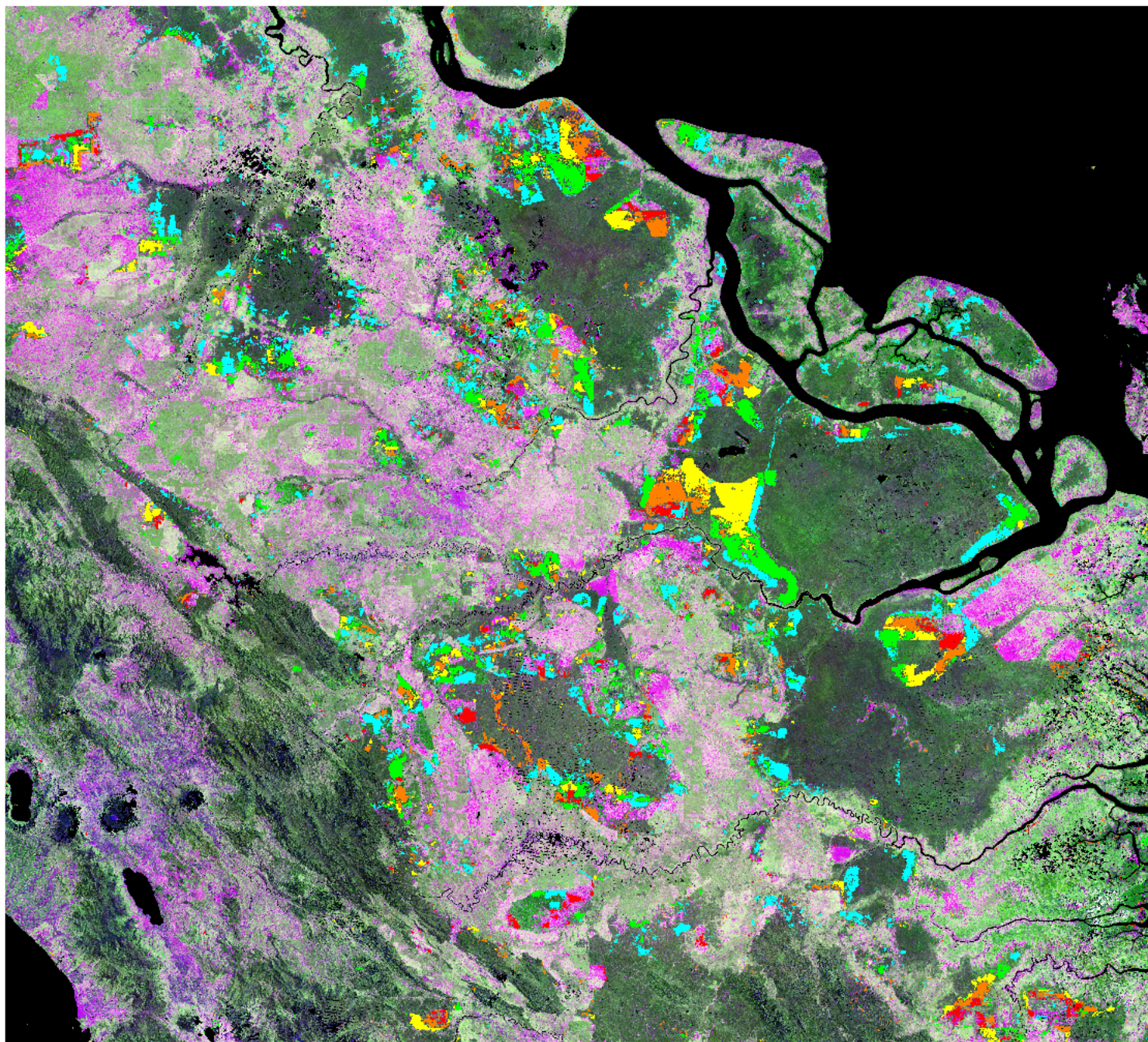
Annual
forest
cover
loss



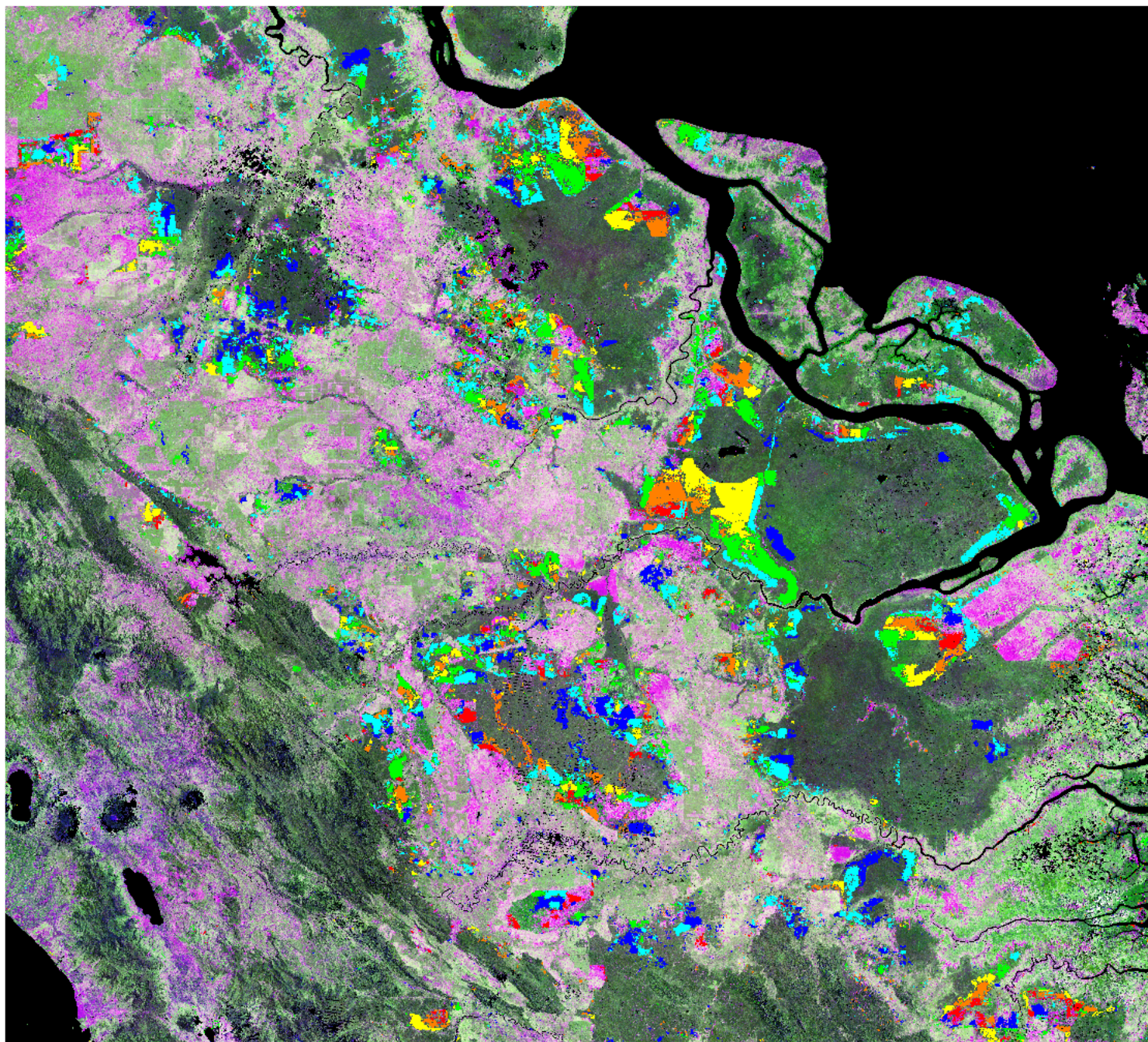
Annual
forest
cover
loss



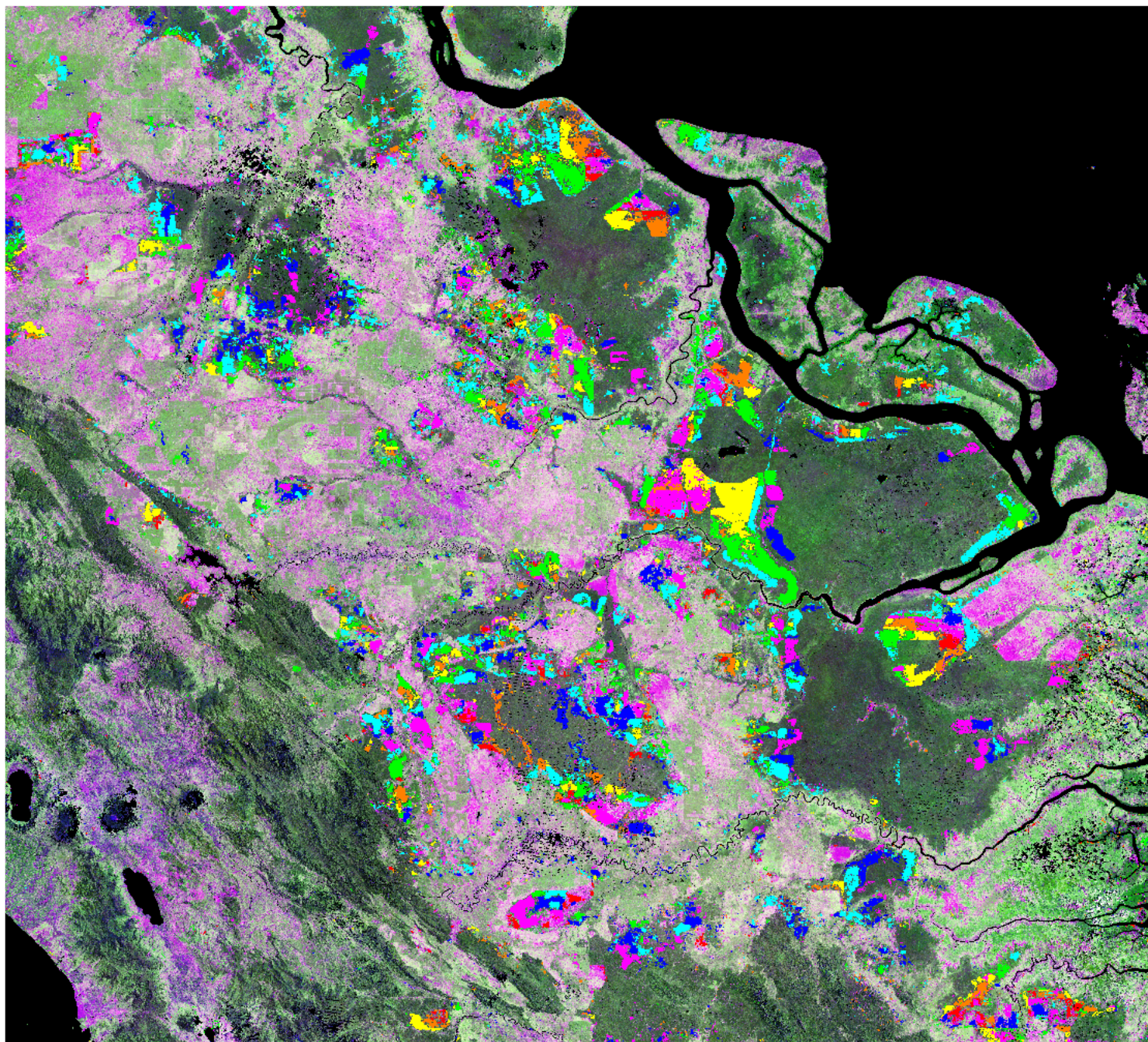
Annual
forest
cover
loss



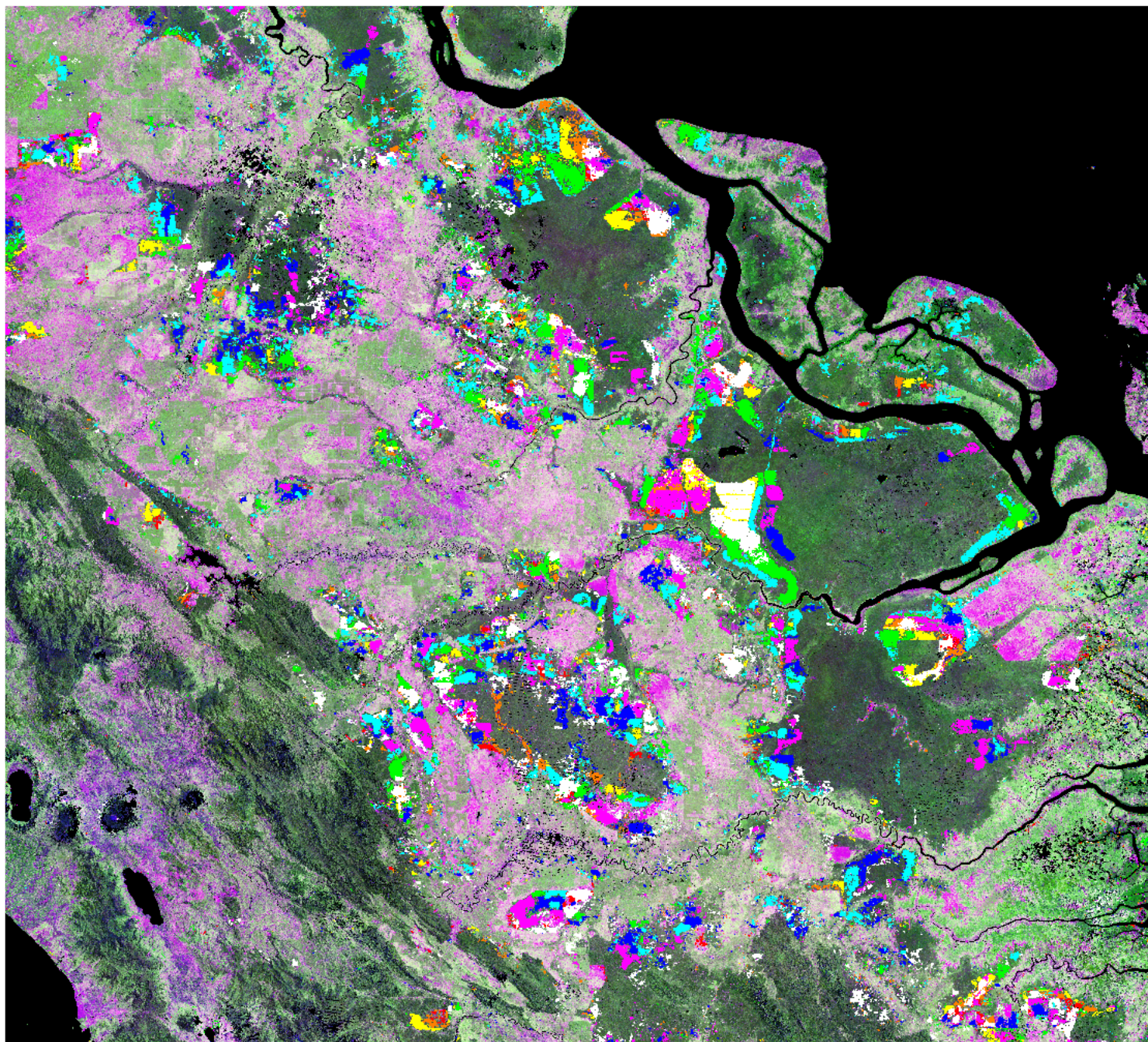
Annual
forest
cover
loss



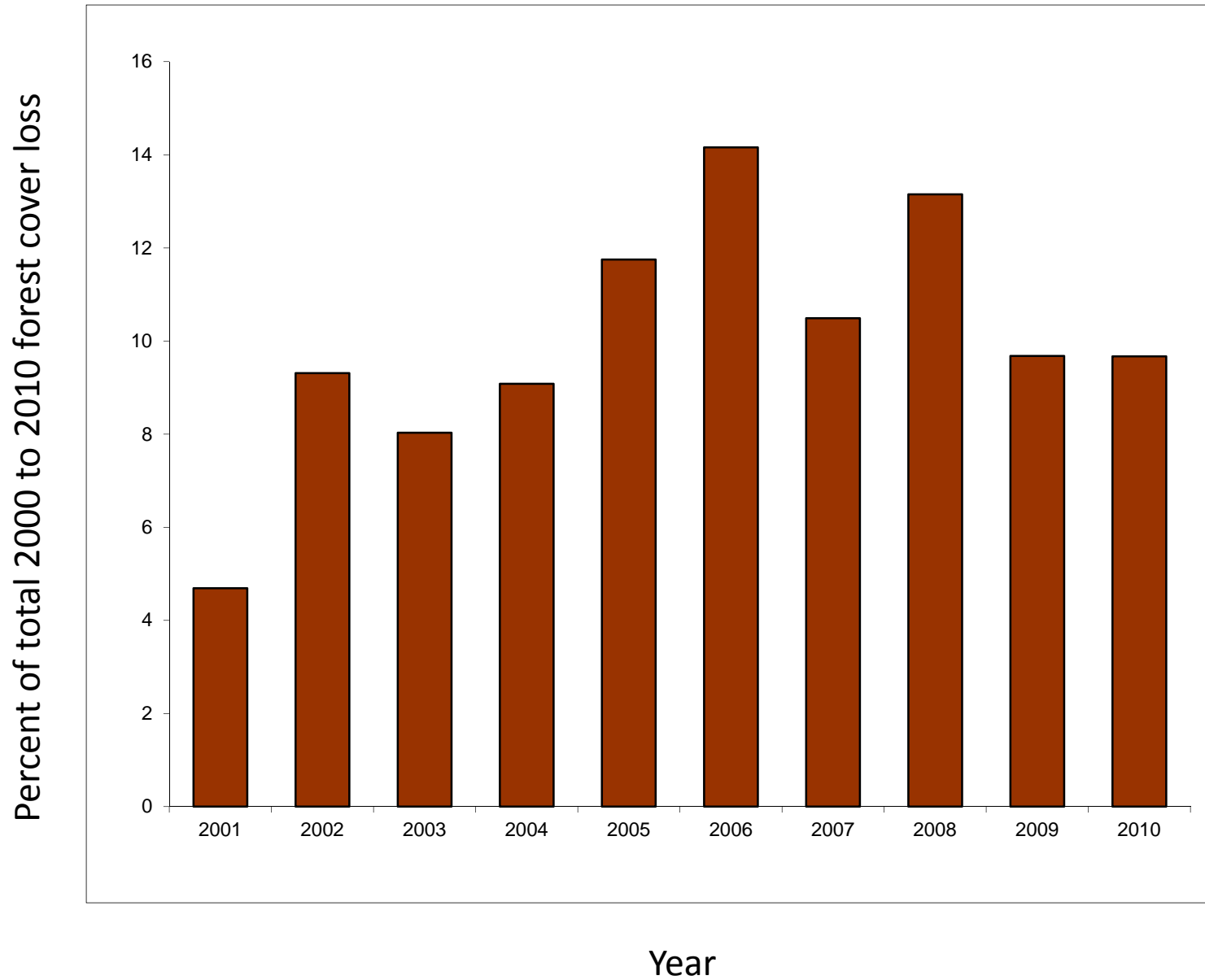
Annual
forest
cover
loss



Annual
forest
cover
loss



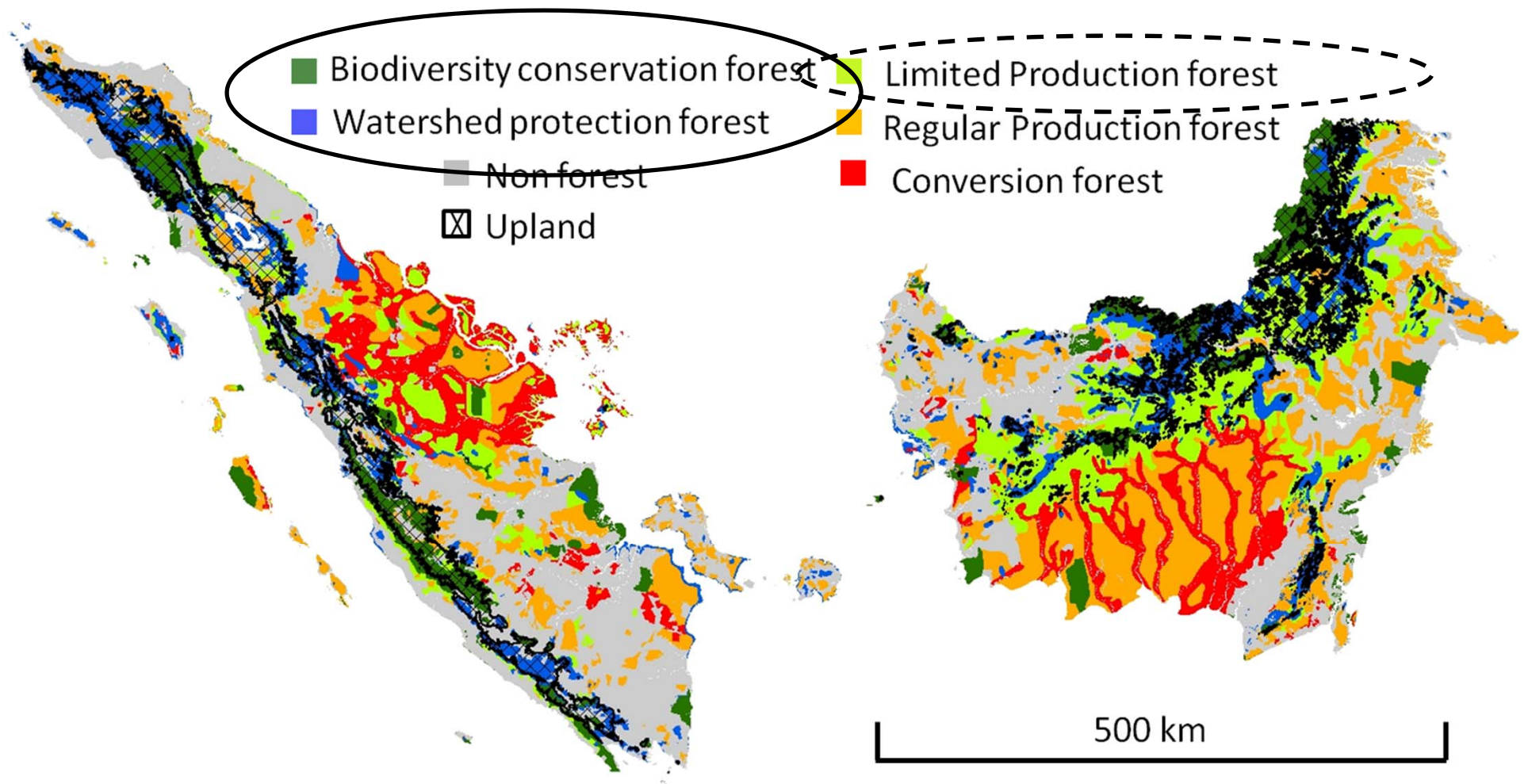
Trend in forest cover loss



Summary forest cover loss dynamics in Indonesia, 2000 to 2010

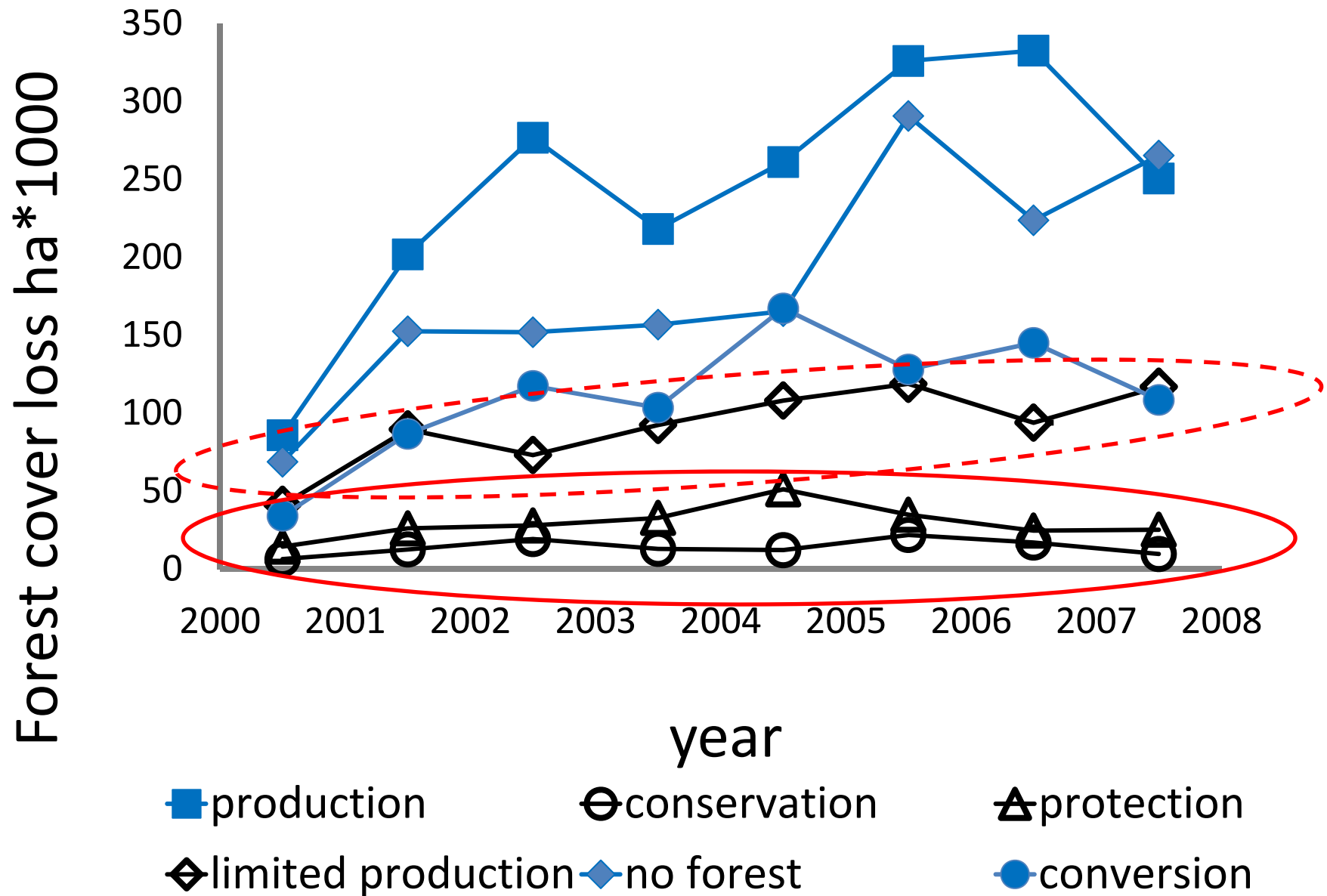
- Nearly 1 million hectares cleared per year from 2000 to 2010
- 50% increase from 2005 to 2010 compared to 2000 to 2005
- Nearly half of all clearing from 2000 to 2010 occurred in primary intact or primary degraded forests

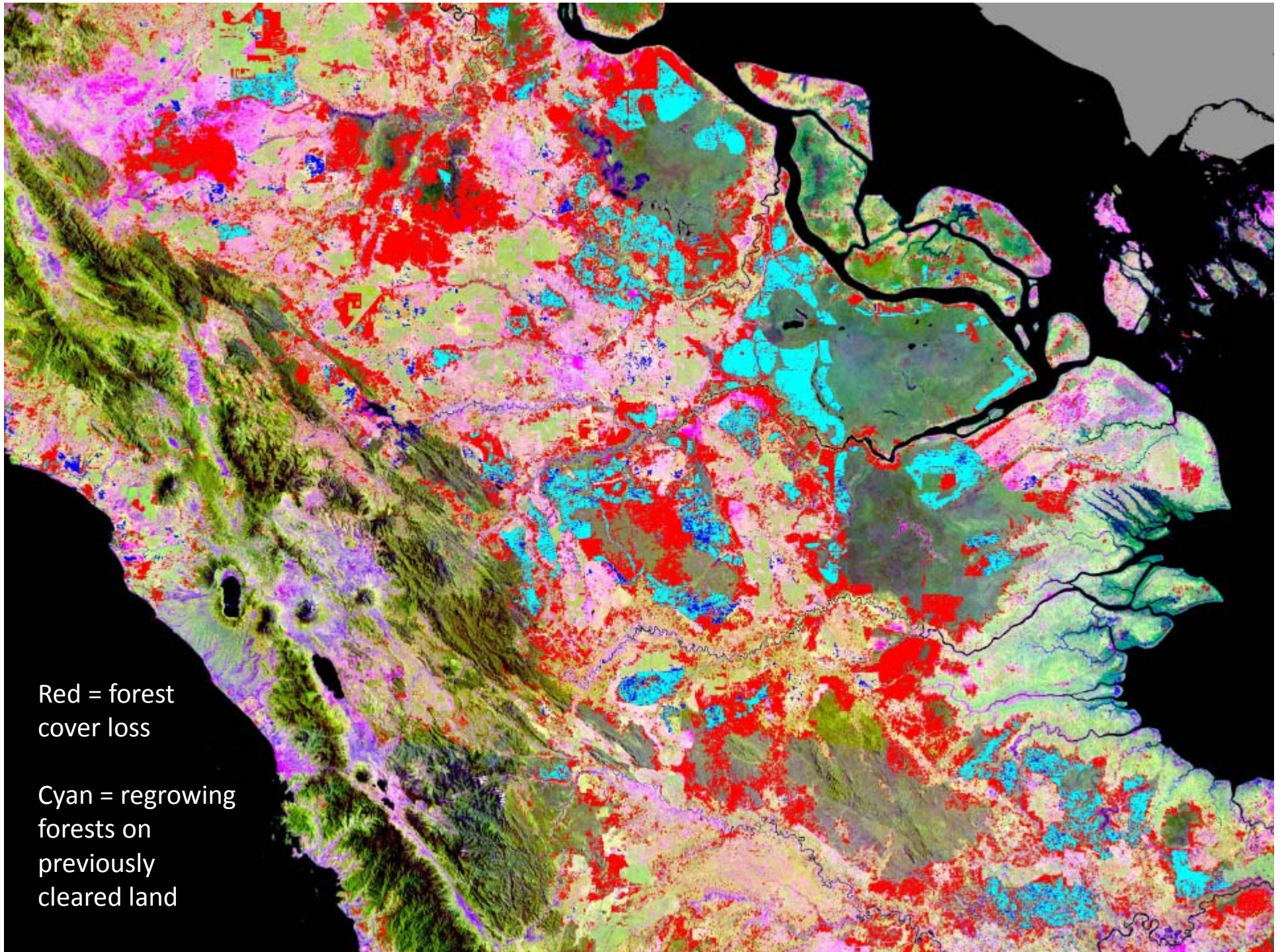
Forest land use zones



Indonesian Ministry of Forestry (2000)

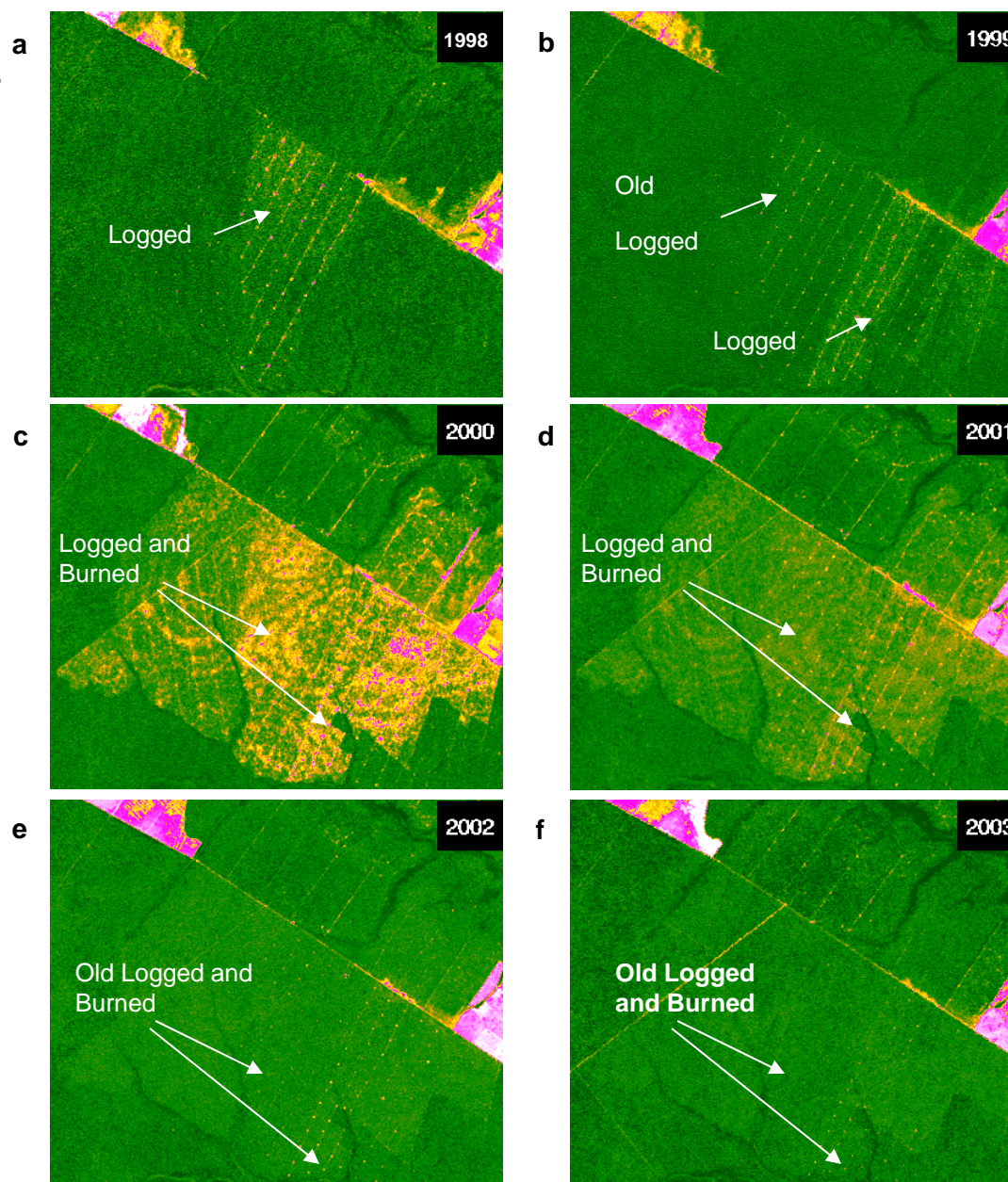
Forest cover loss trends per forest land use zone





Forest Degradation – example from Brazil

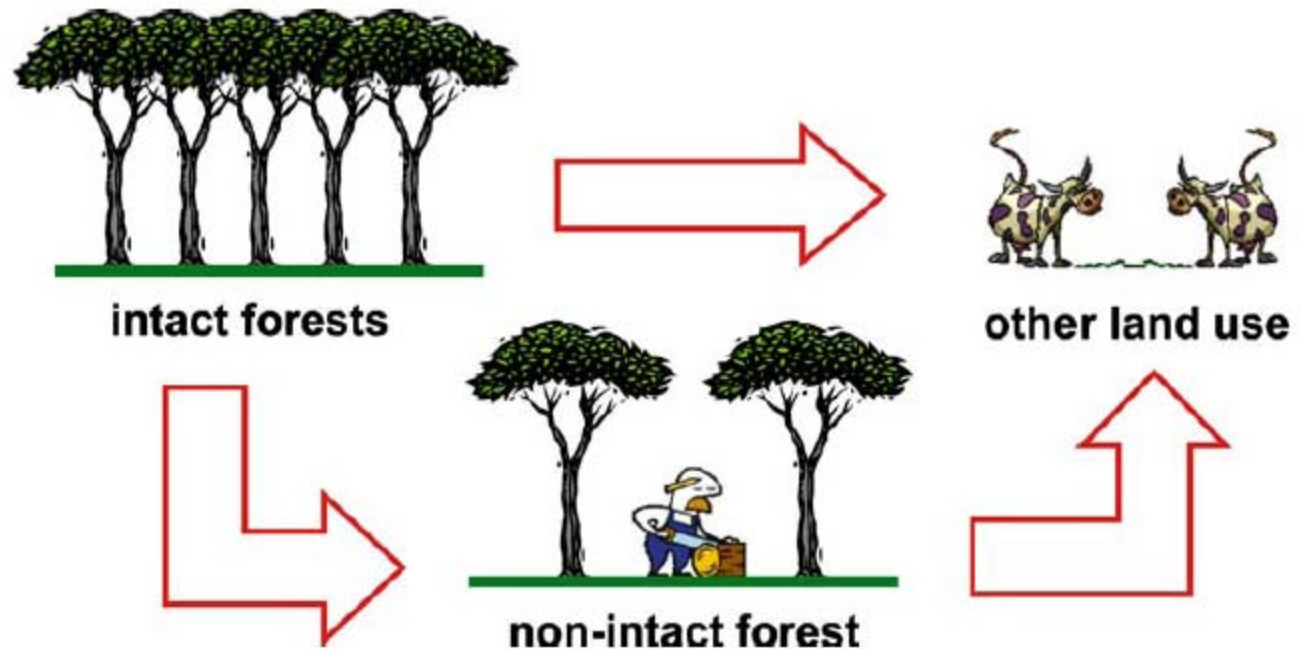
- Degradation signal is ephemeral, its detection requires regular cloud free acquisitions
- Annual monitoring is required to keep track of the forest degradation process (correlation of Landsat-quantified degradation and biomass ‘collapses’ one year after degradation event)
- Degradation must be significant, on the order of $\geq 30\%$ canopy removal for reliable detection



Courtesy of Carlos Souza, Imazon

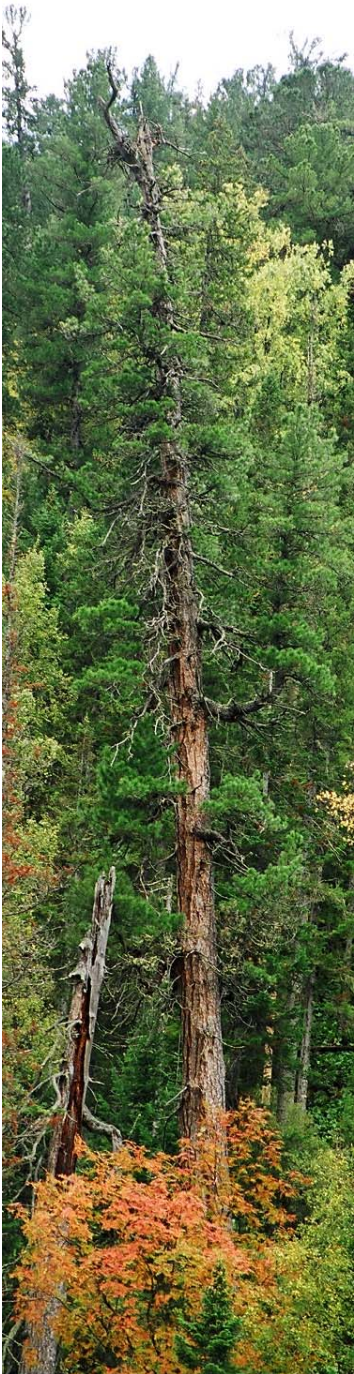
Intact Forest Landscapes (IFL) concept

Forest degradation monitoring is important for carbon accounting

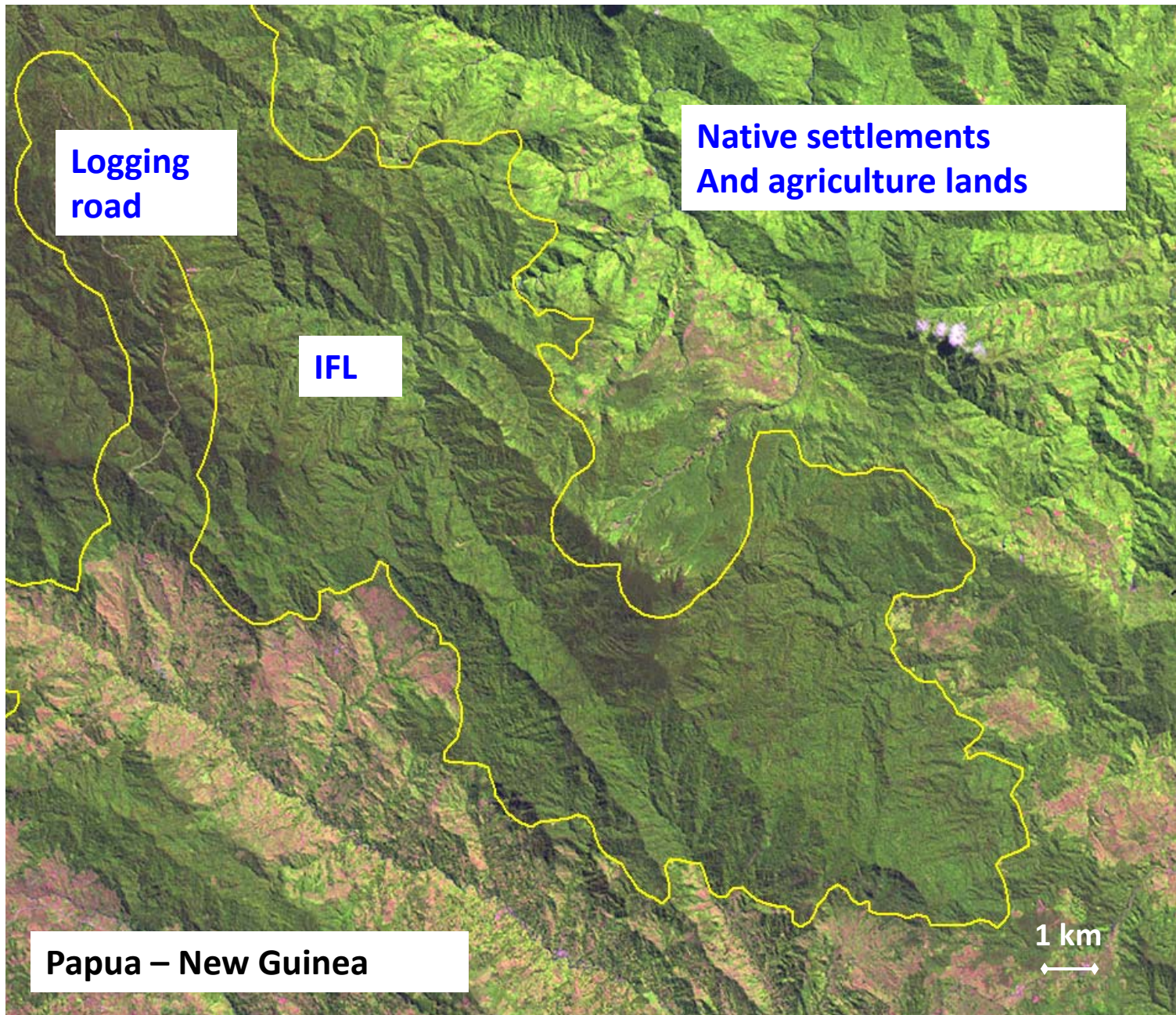


Under current UNFCCC definitions a forest can contain anything from 10 to 100% tree cover; it is only when cover falls below 10% that land is classified as non-forest. But the degradation of fully-stocked forests (leading to the reduction of tree canopy cover to as low as 10%) could cause a larger loss of carbon than the conversion of already degraded forests.

D. Mollicone et al. An incentive mechanism for reducing emissions from conversion of intact and non-intact forests // *Climatic Change* (2007) 83:477–493





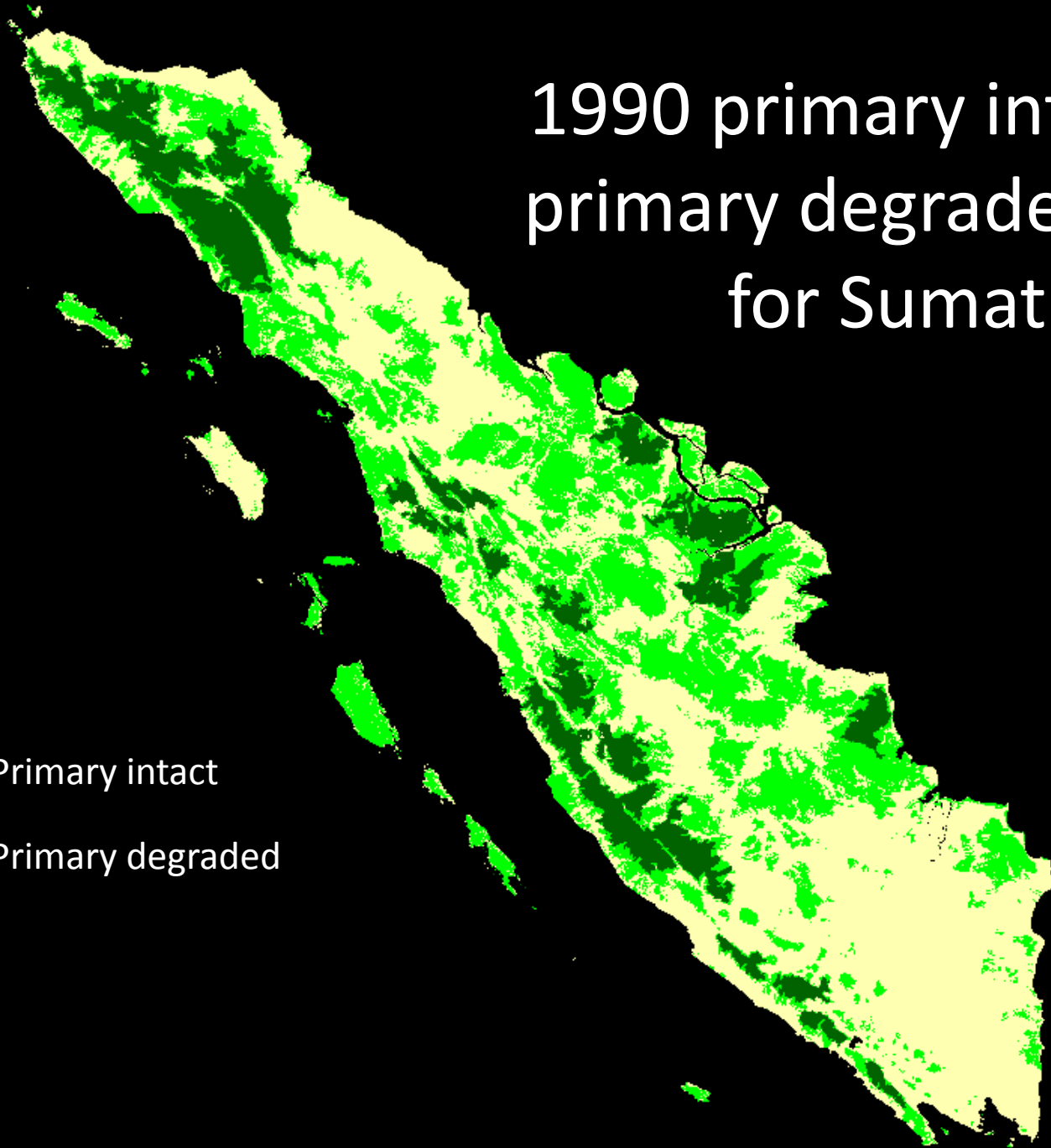
Intact Forest Landscapes (IFL) mapping







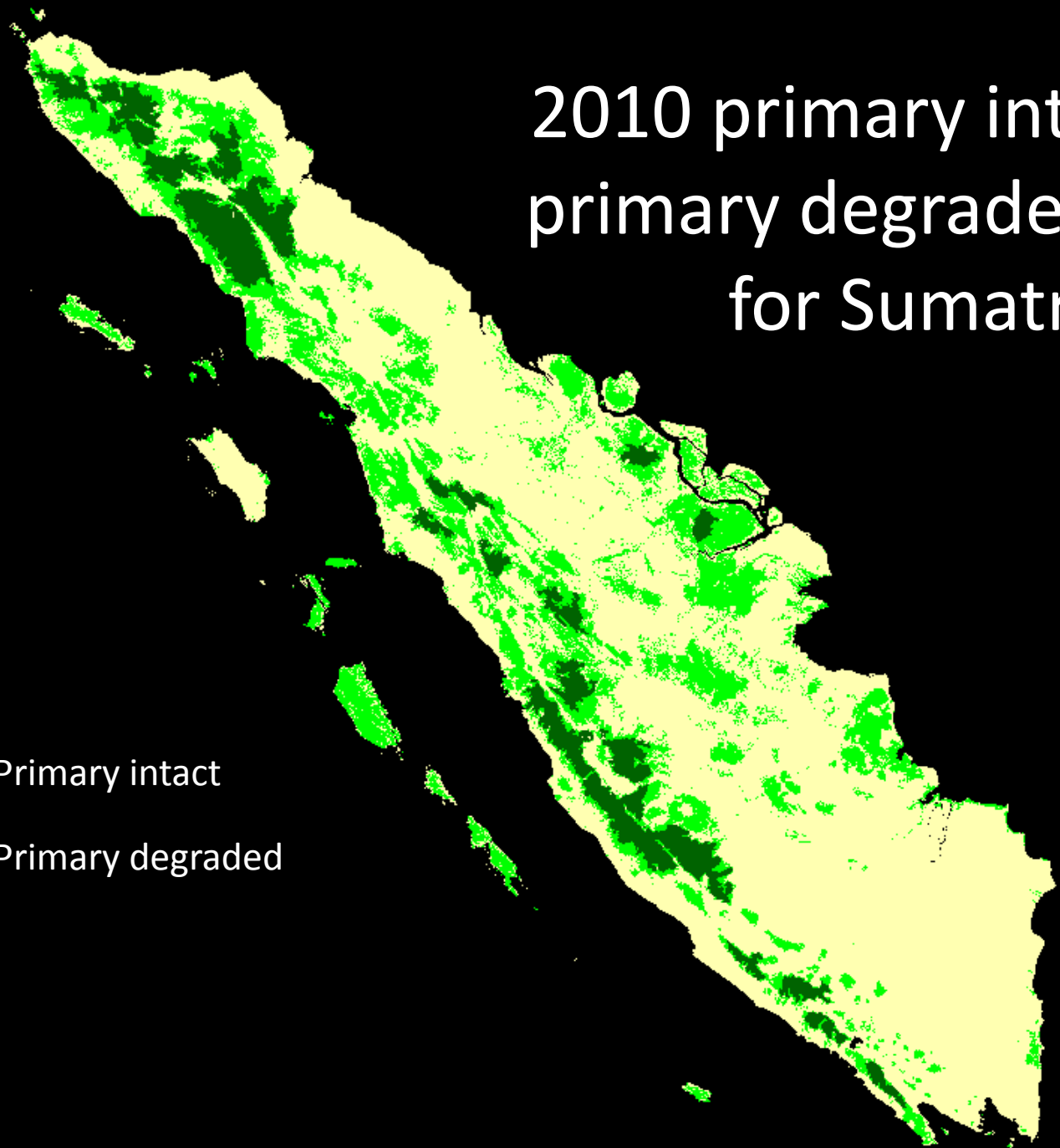
1990 primary intact and primary degraded forest for Sumatra

-  Primary intact
-  Primary degraded

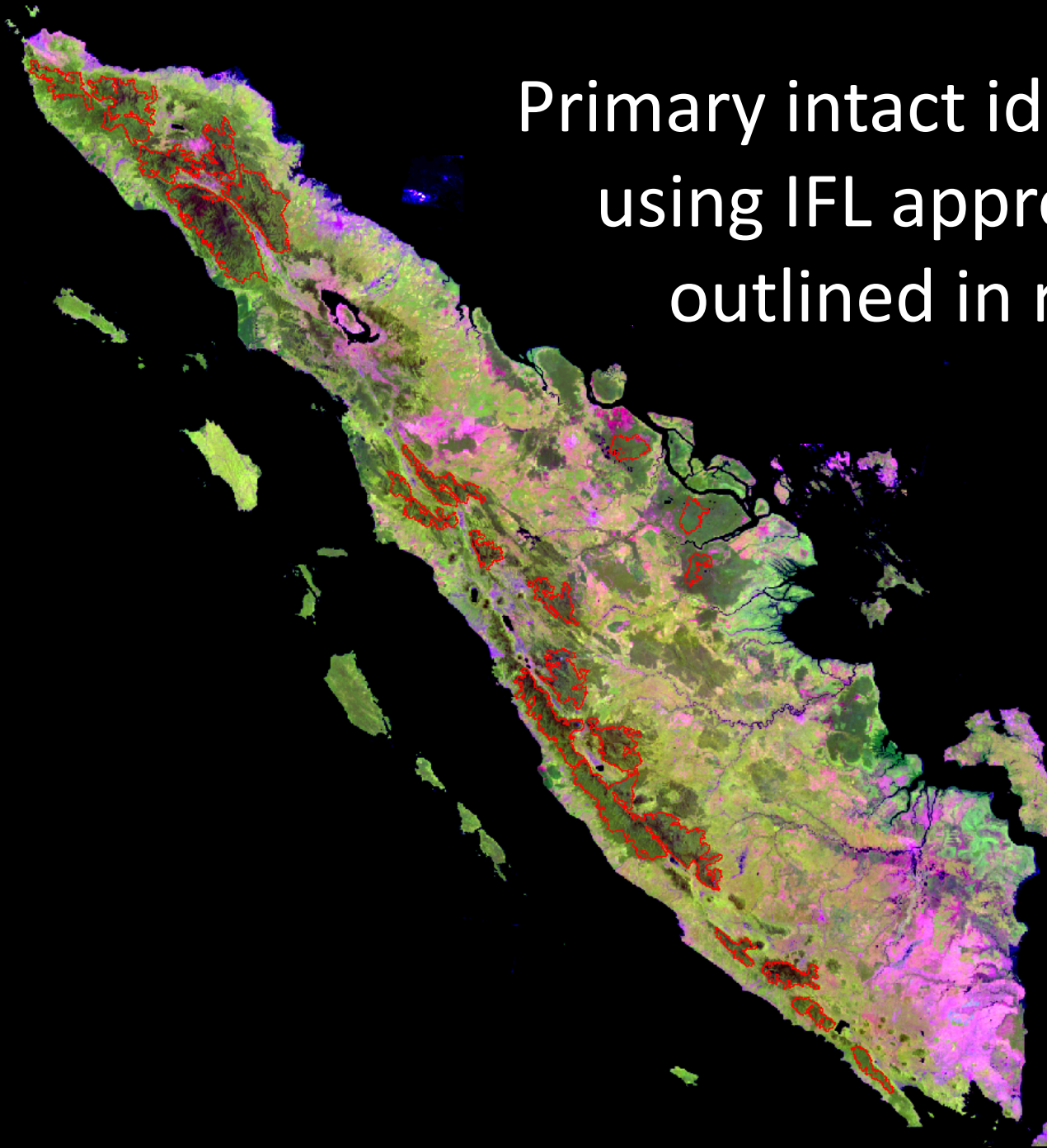


2010 primary intact and primary degraded forest for Sumatra

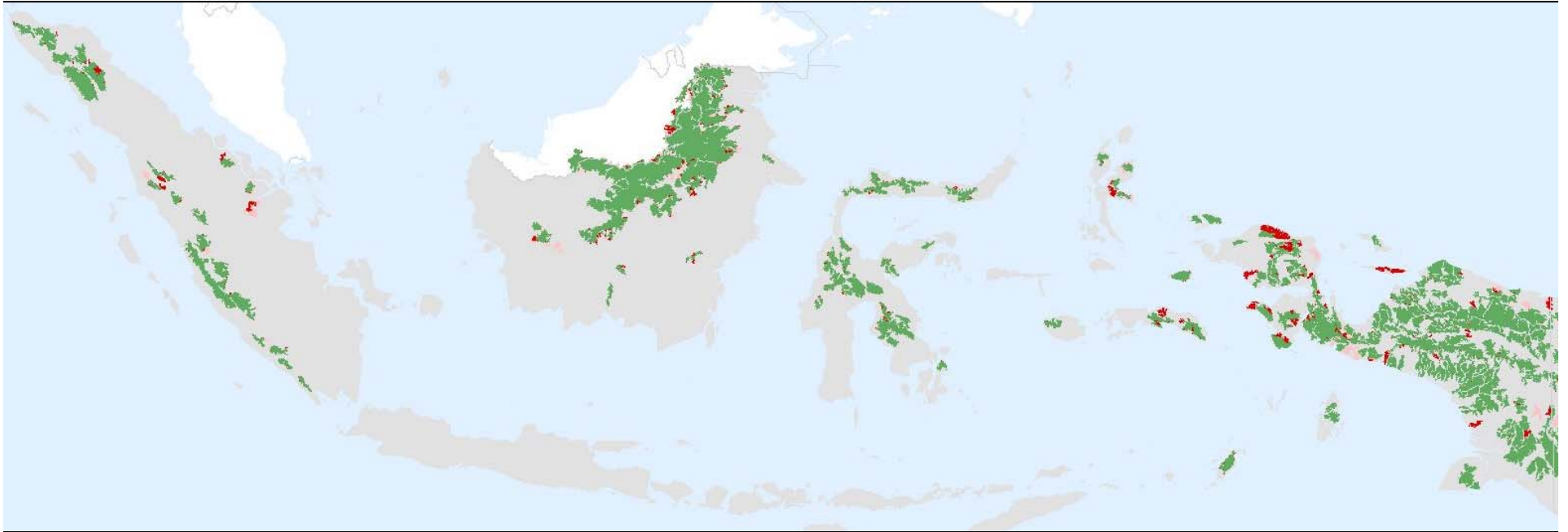
-  Primary intact
-  Primary degraded





Primary intact identified
using IFL approach,
outlined in red



IFL Loss in the Tropics: Indonesian Forests

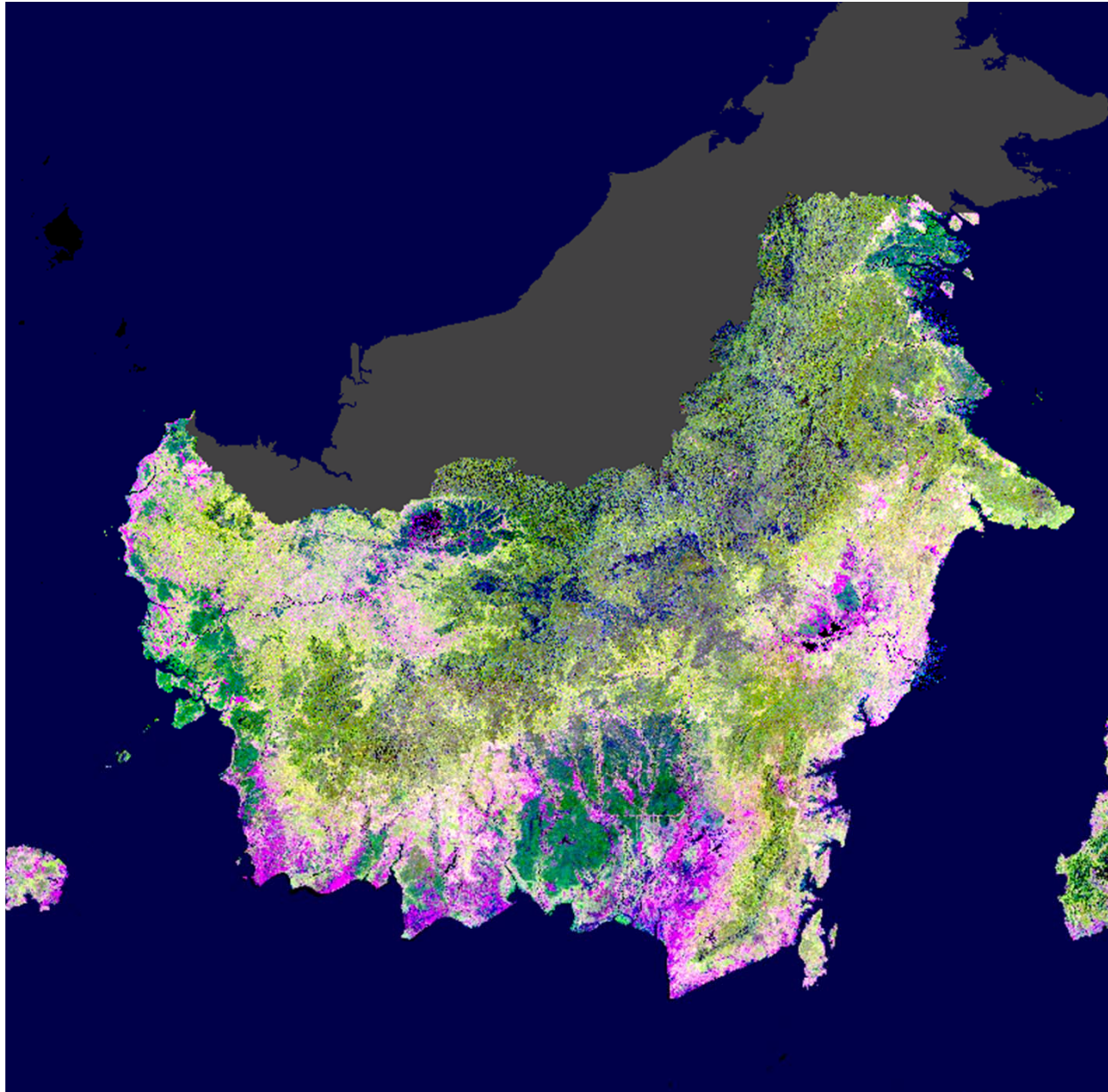


 - IFL loss (deforestation or degradation) in 2000-2005

 - IFL loss (deforestation or degradation) in 2005-2010

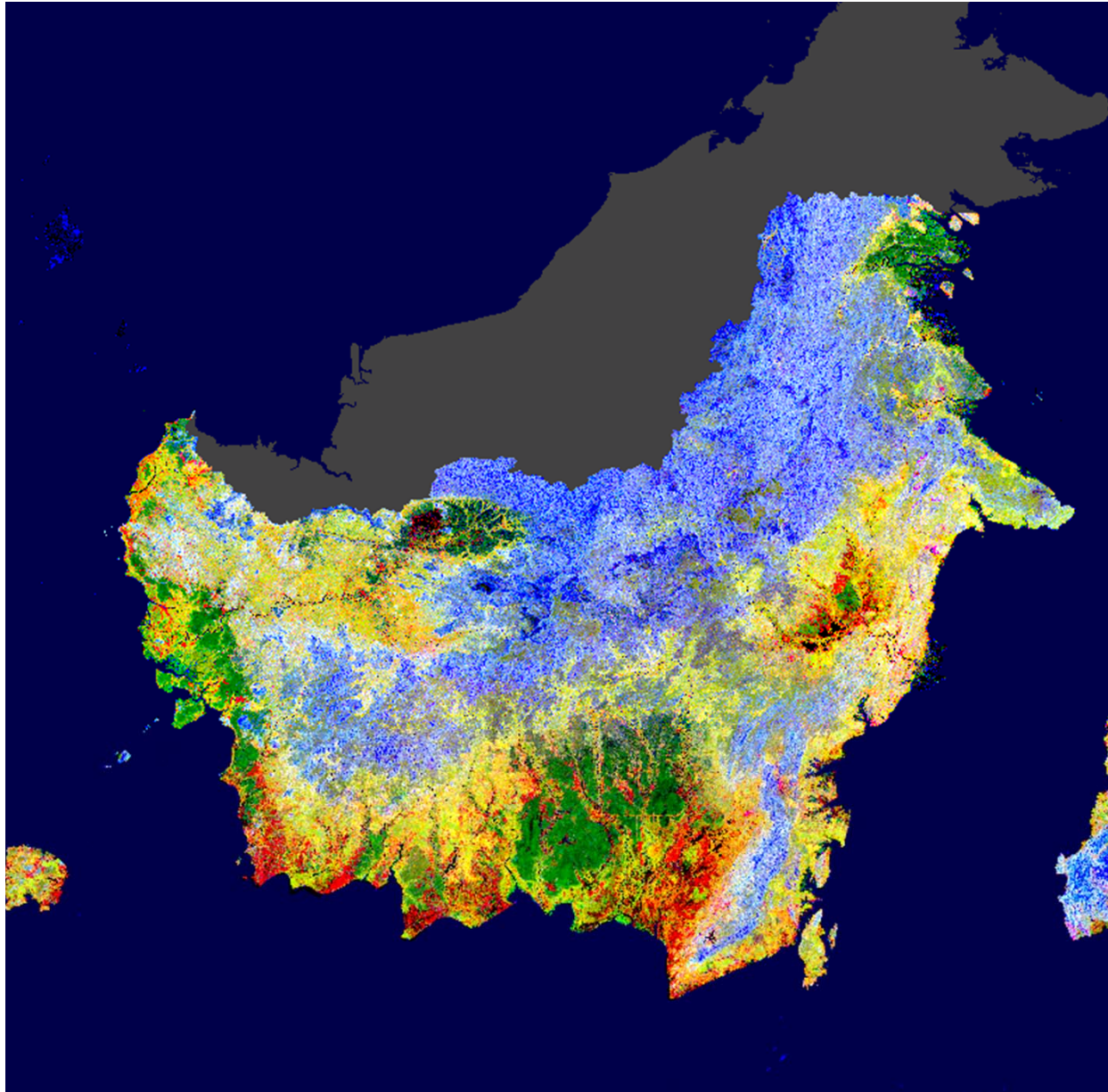
 - IFL area 2010

Landsat composite imagery – cloud free



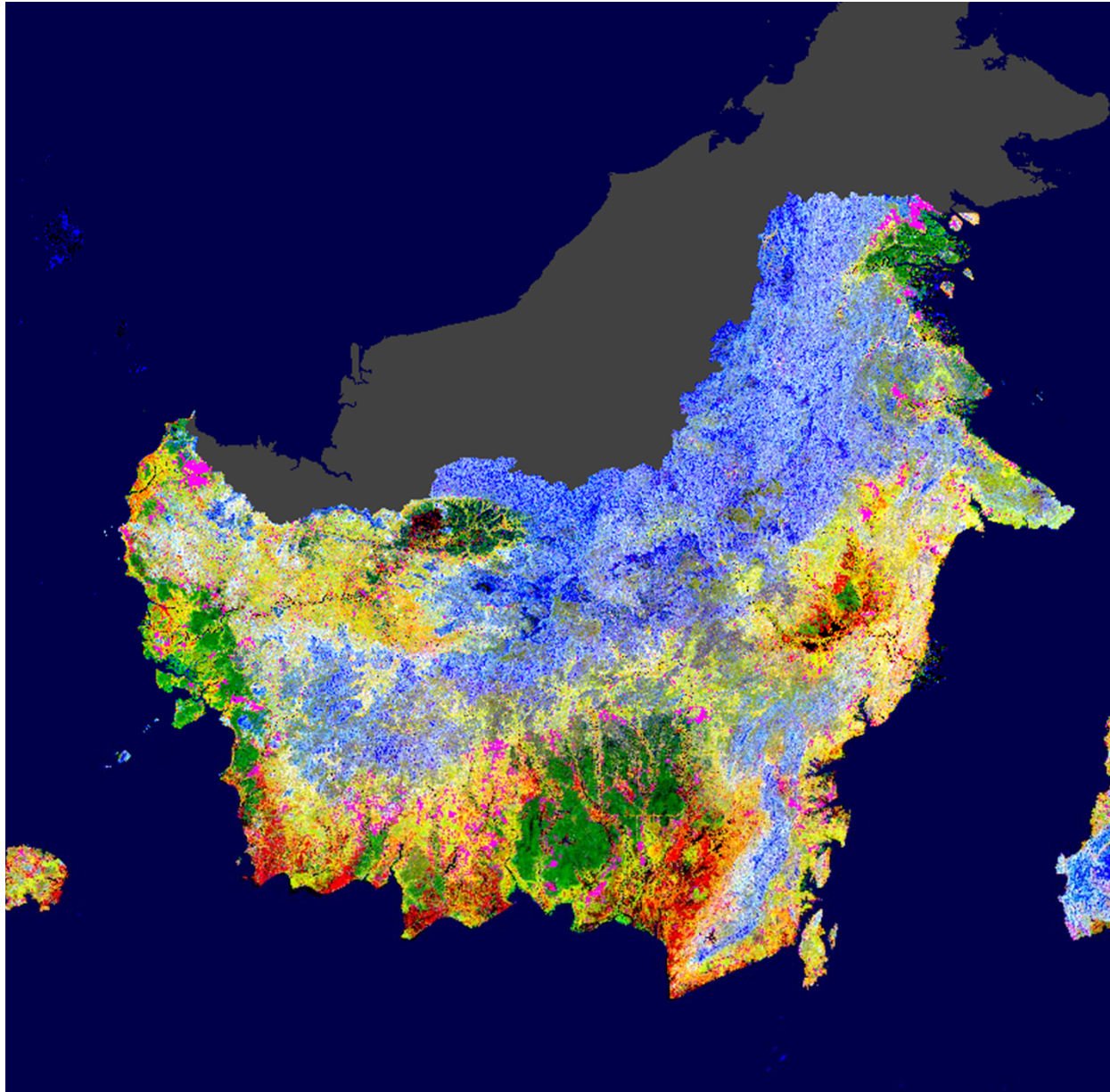
Dark green = wetland forests for 2010

Landsat / SRTM



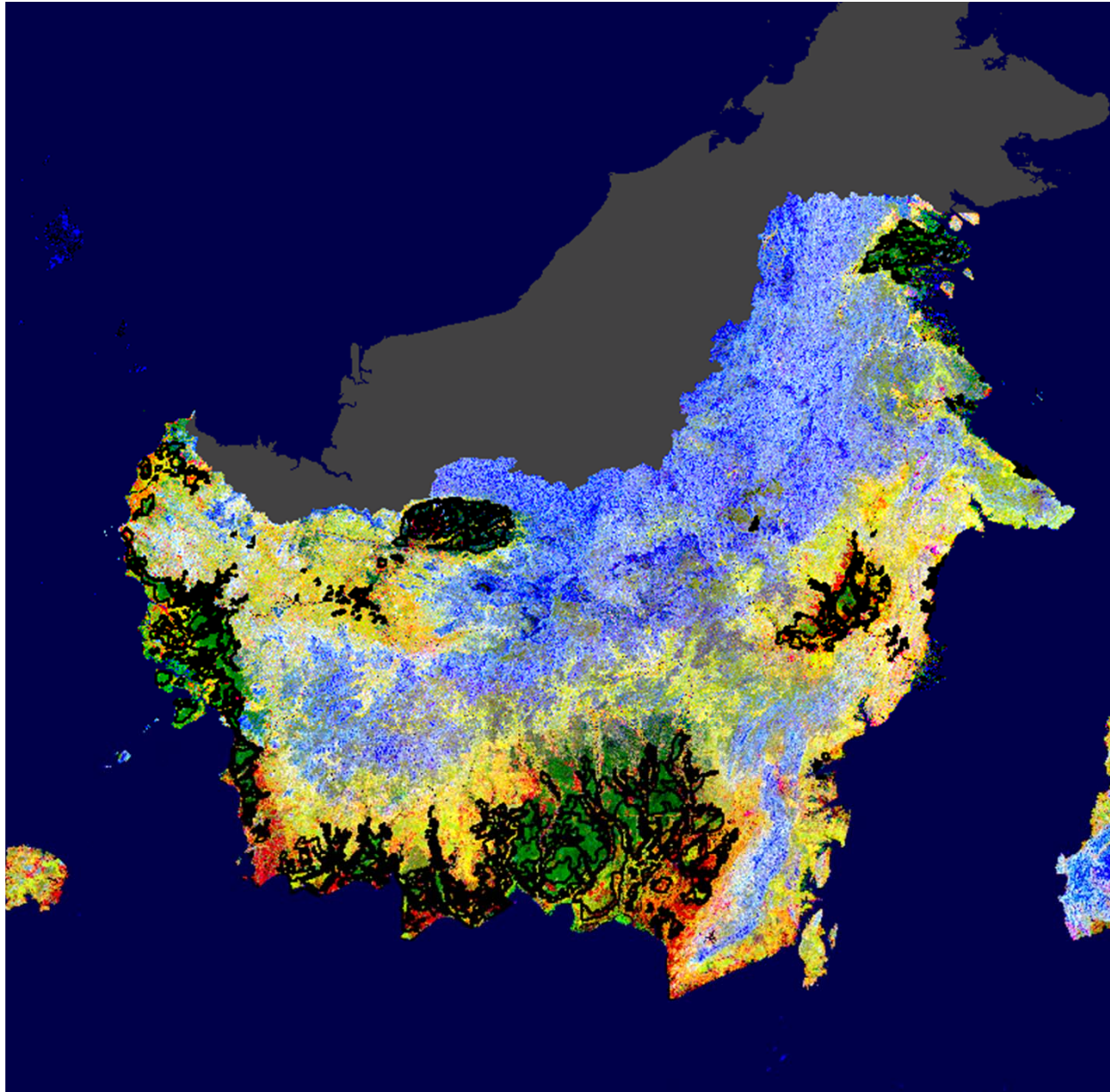
Blue = high slopes

Landsat / SRTM

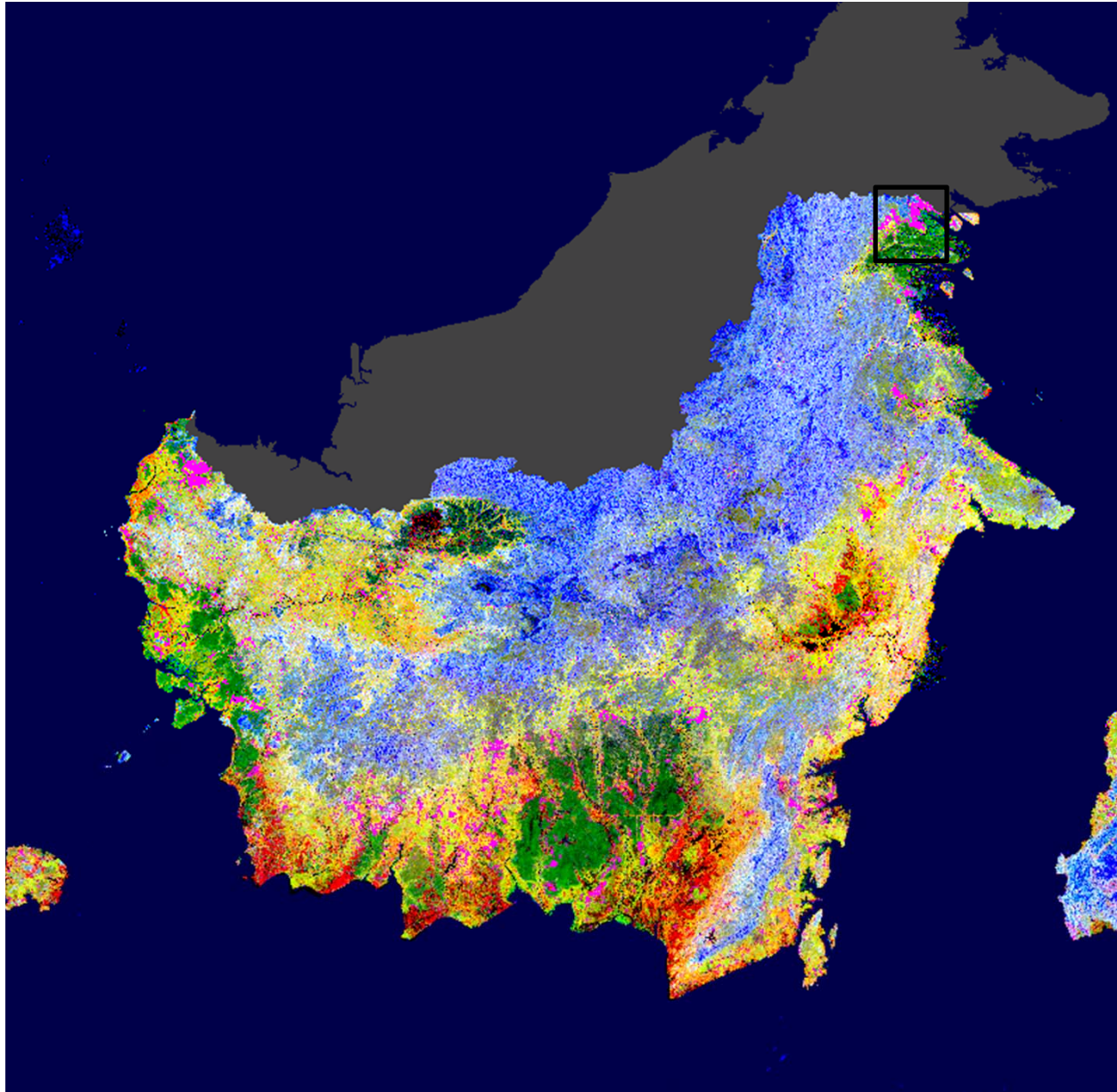


Magenta = forest cover loss, 2000 to 2010

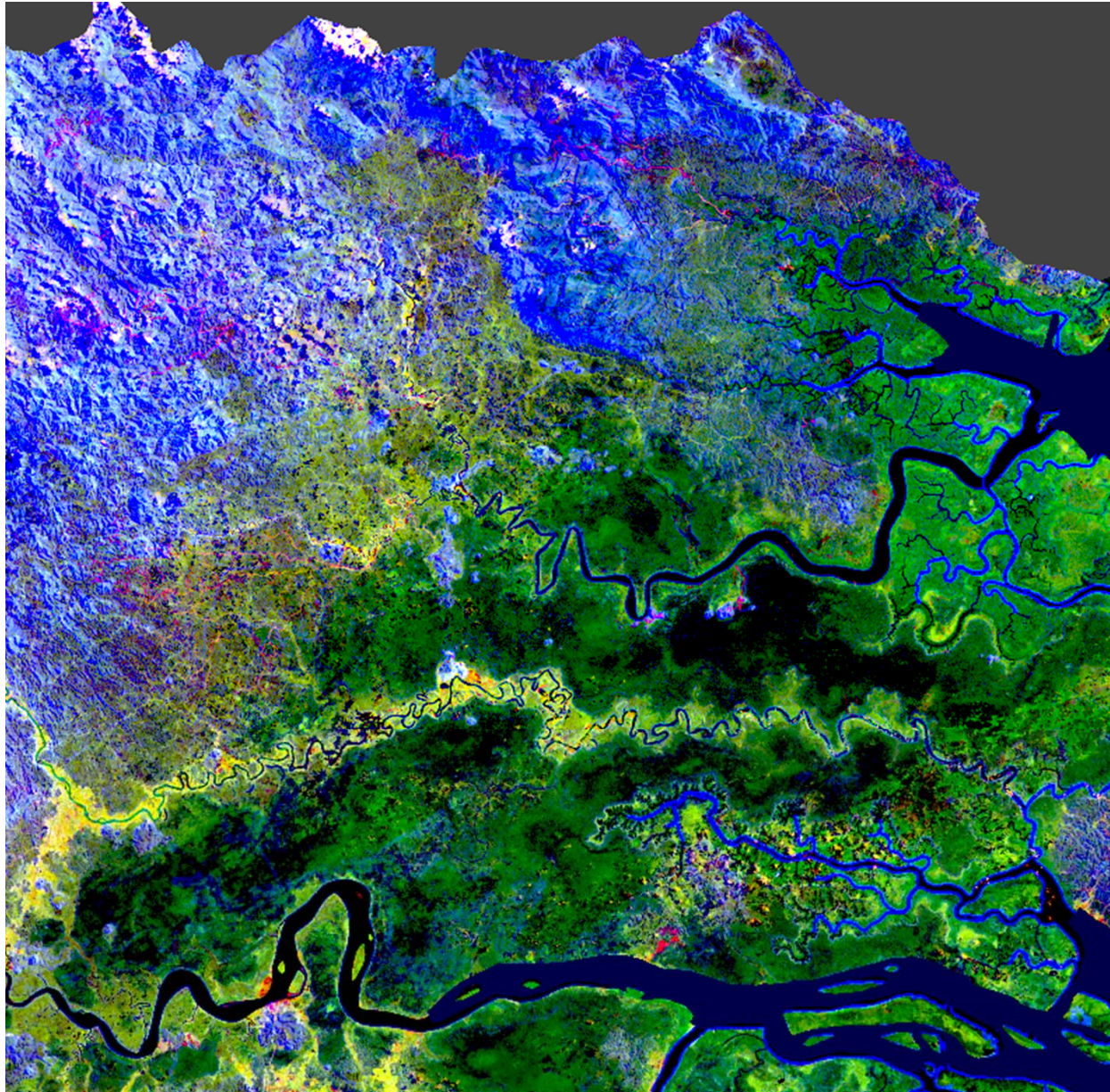
Landsat / SRTM



Black = Wetlands International

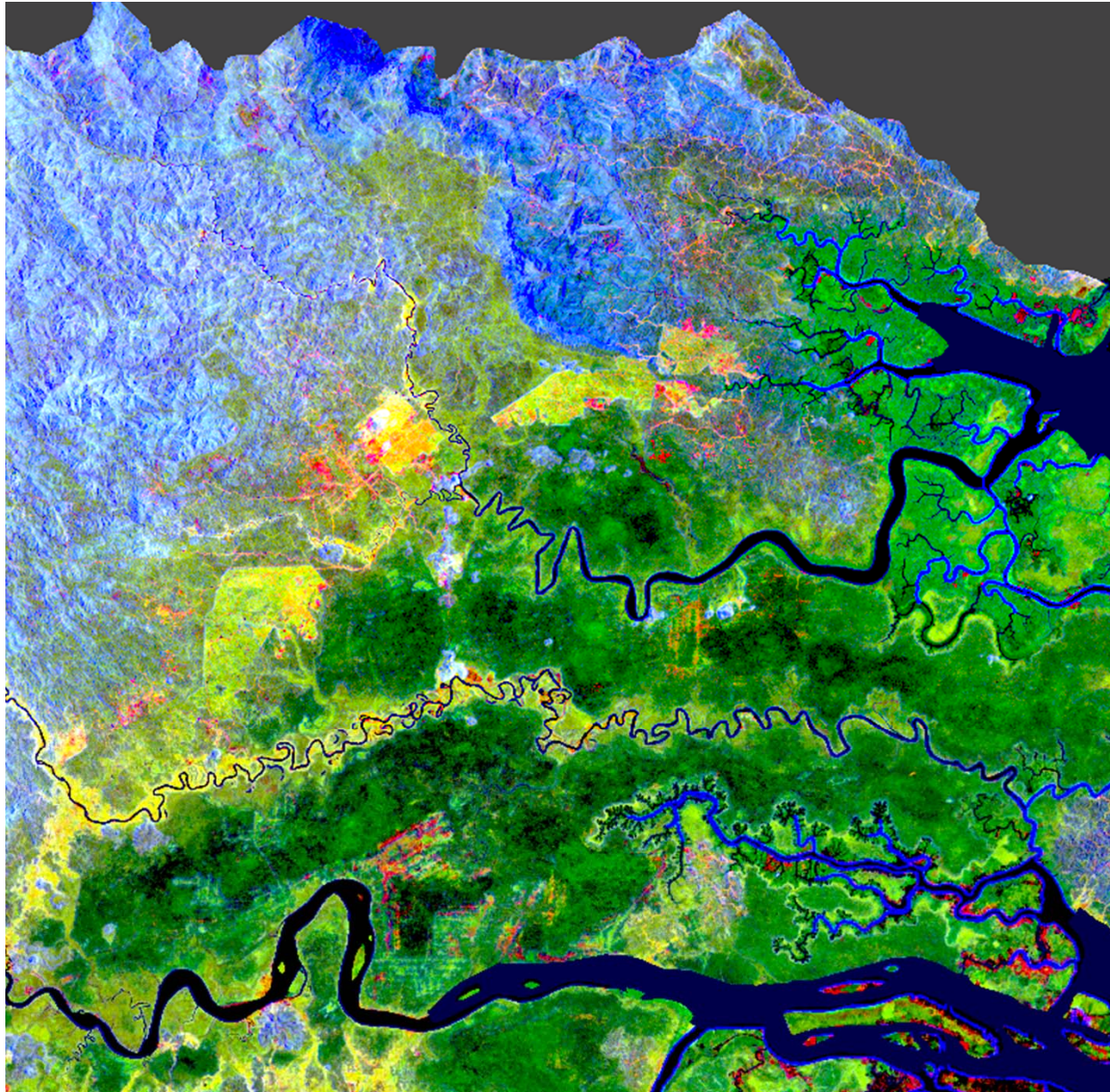


1990



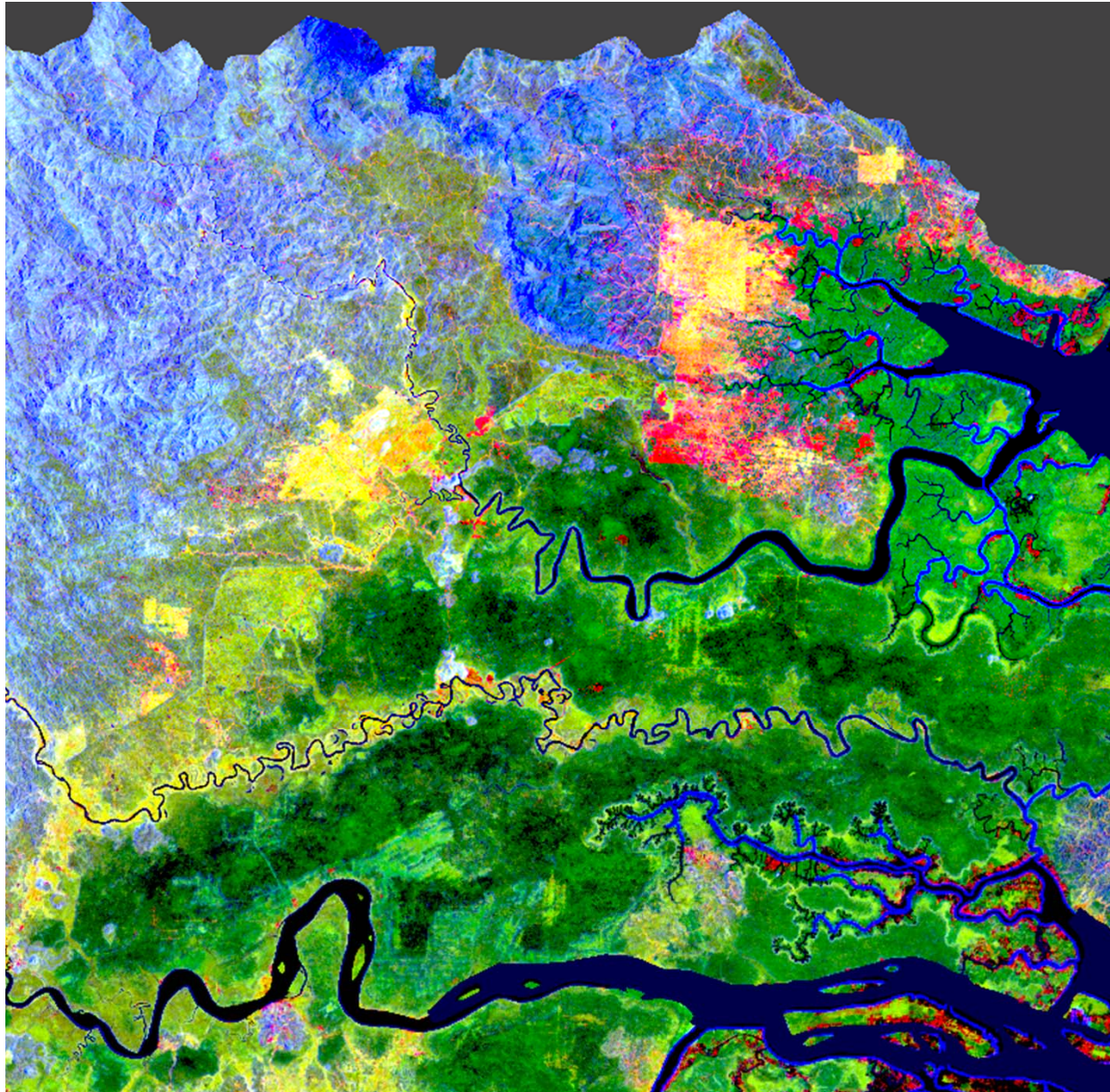
100km x 100km

2000



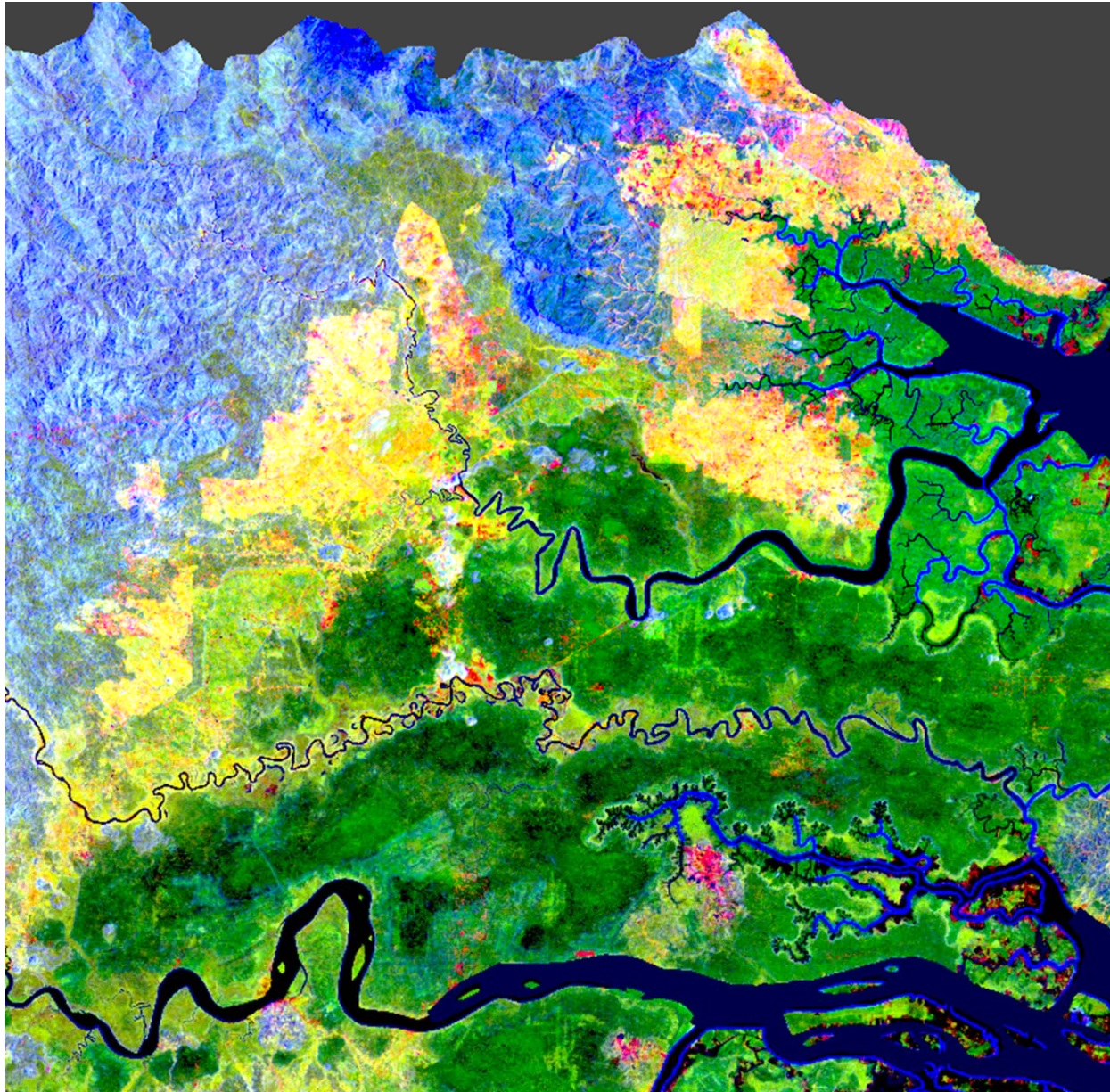
100km x 100km

2005



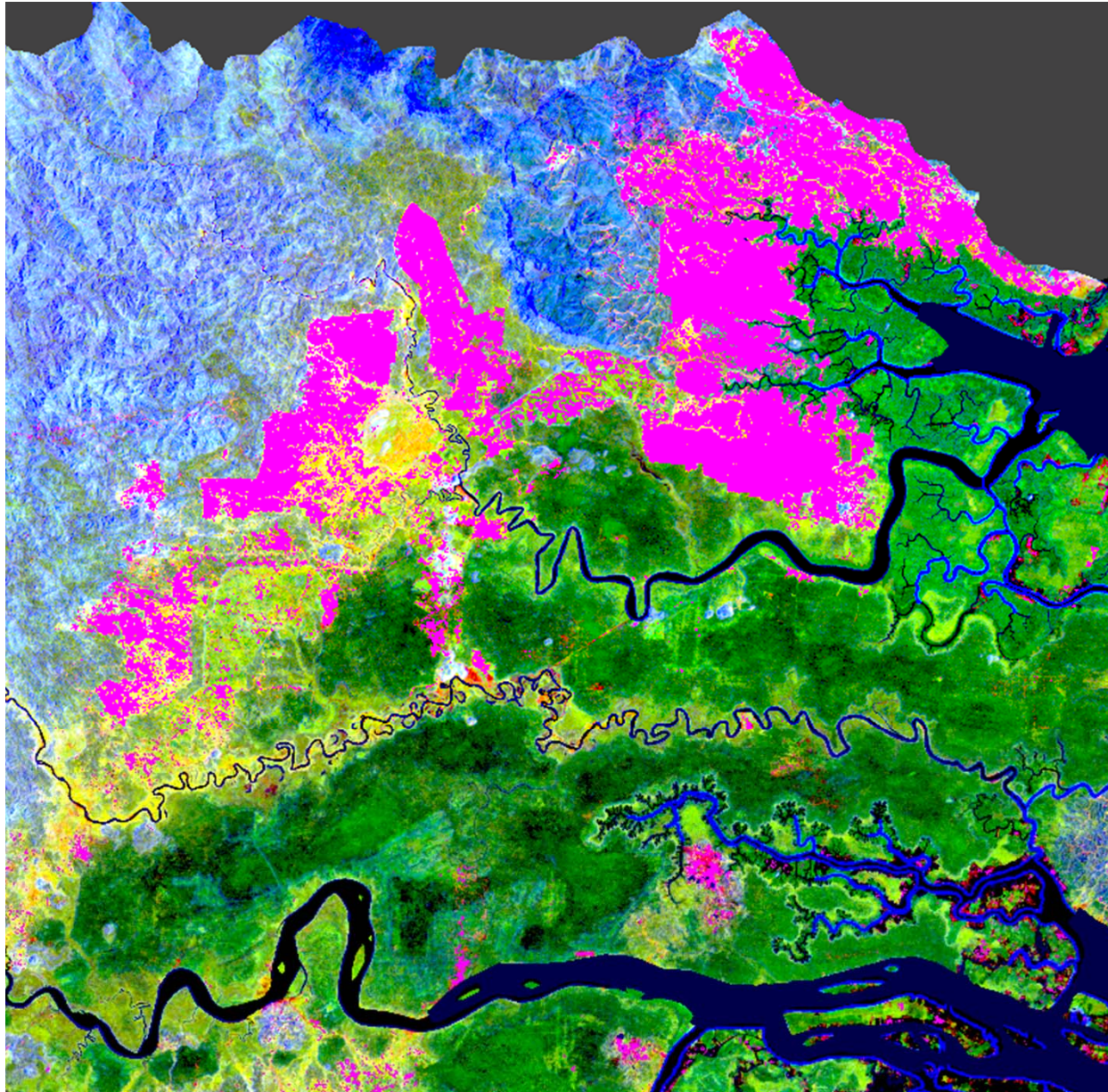
100km x 100km

2010

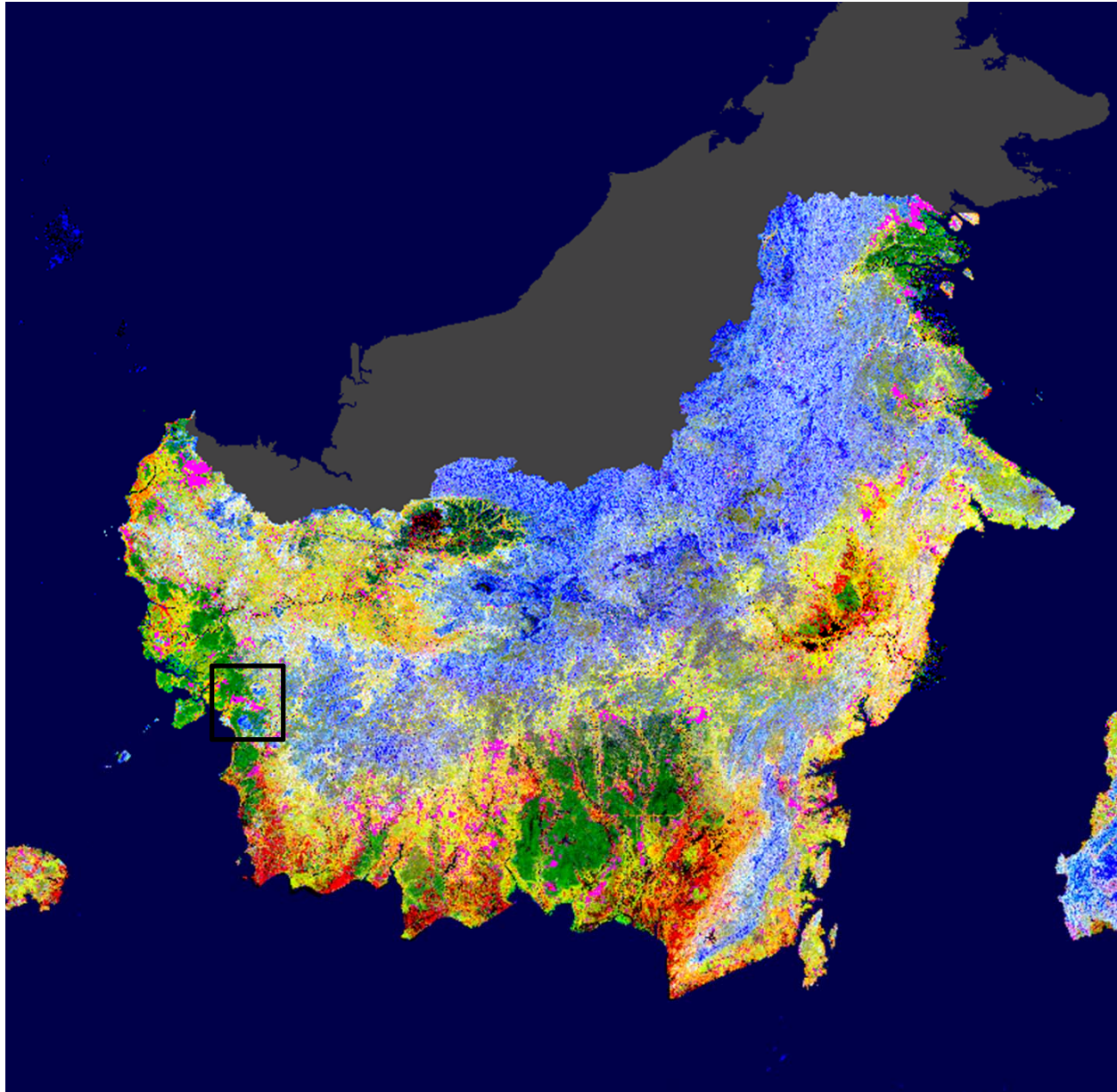


100km x 100km

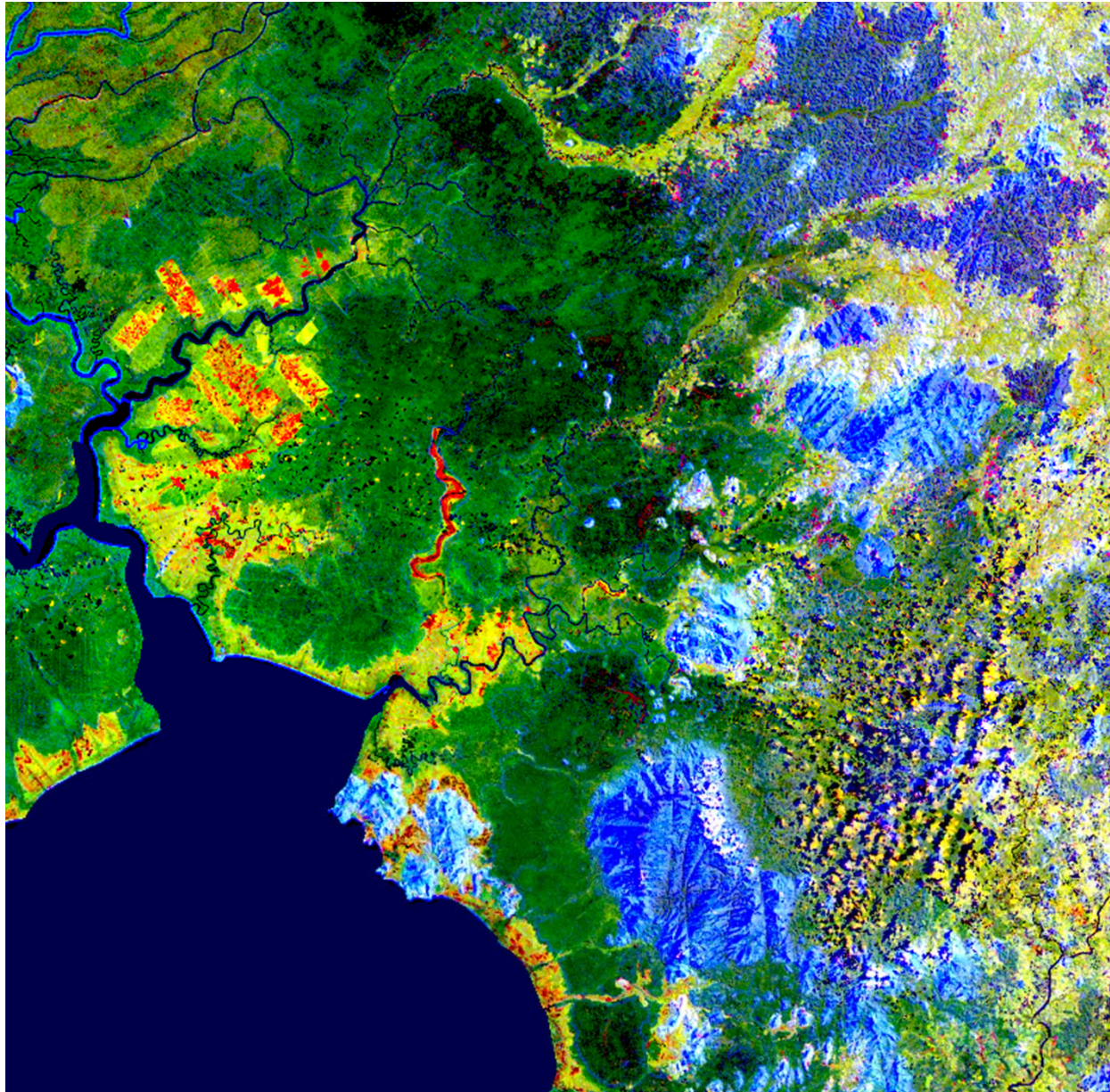
Magenta = forest cover loss, 2000 to 2010



100km x 100km

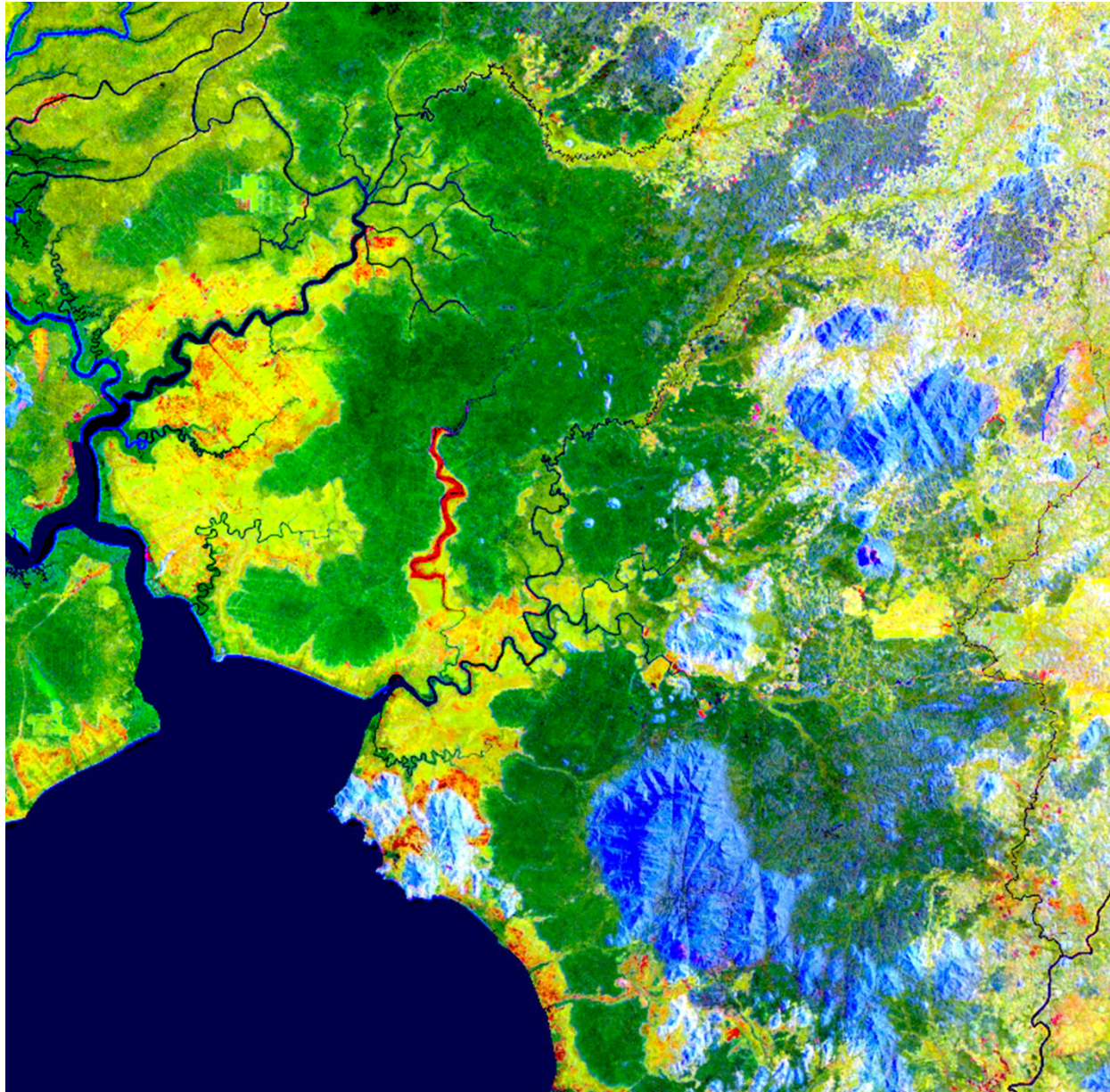


1990



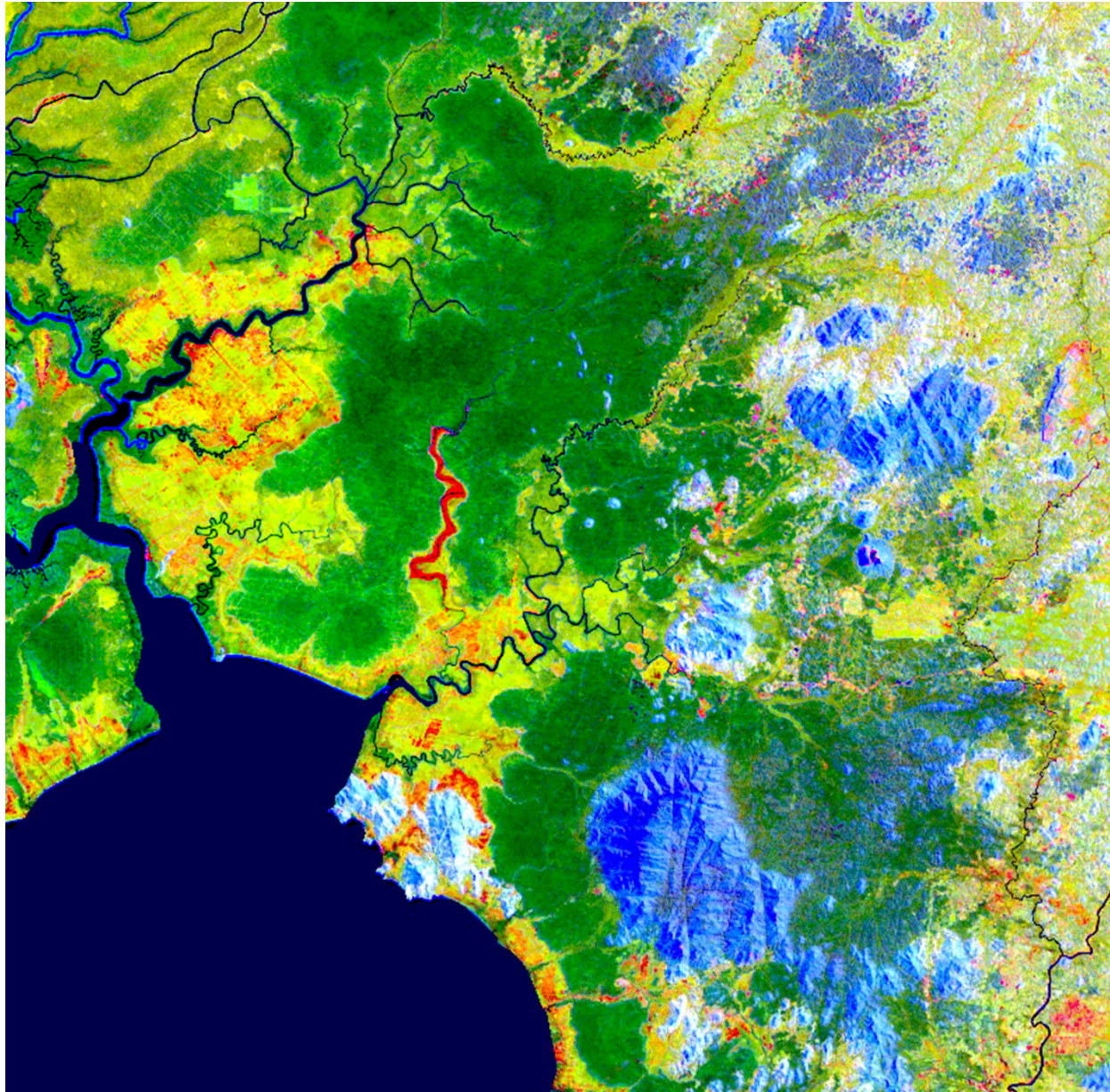
100km x 100km

2000



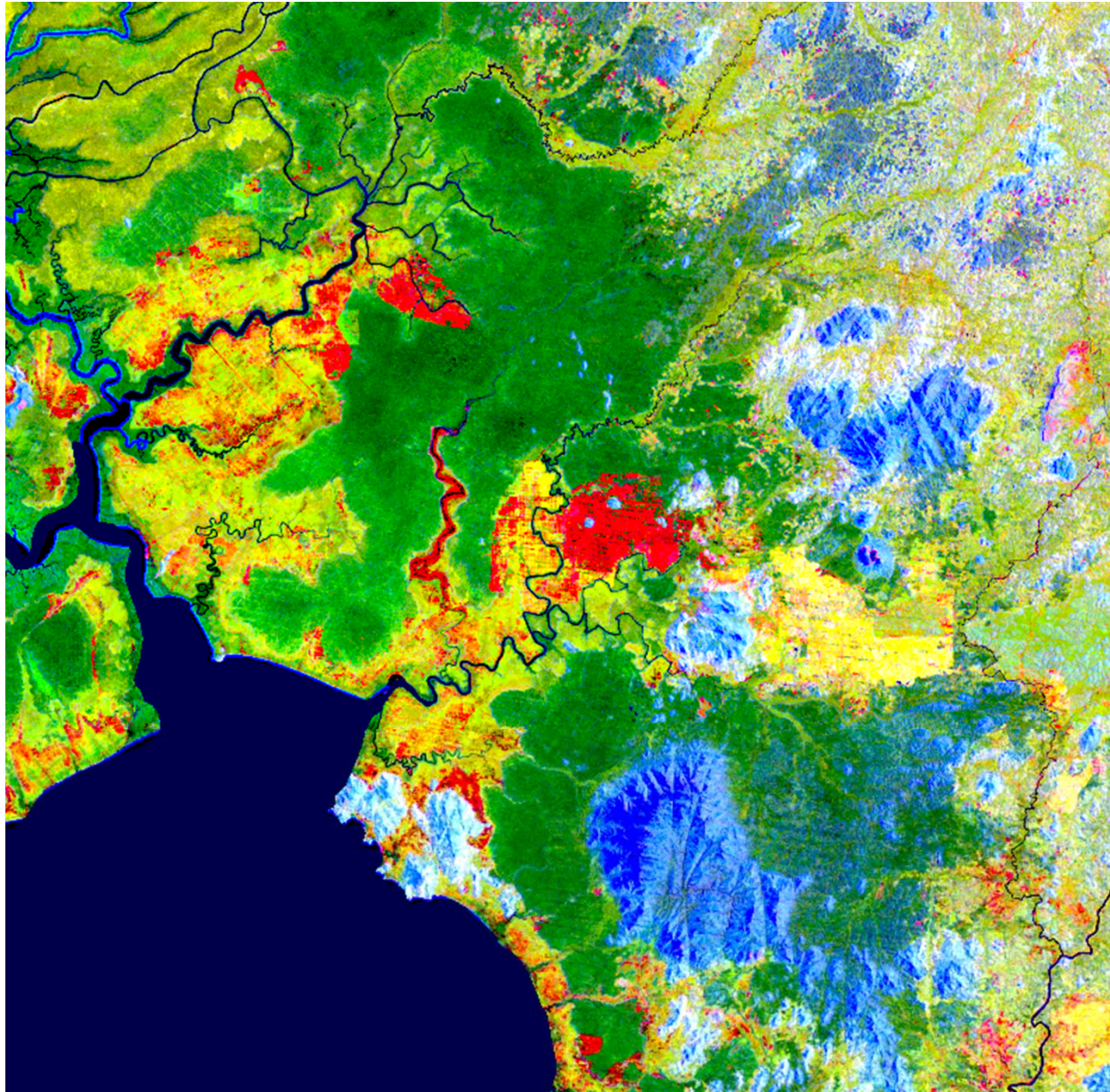
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2005



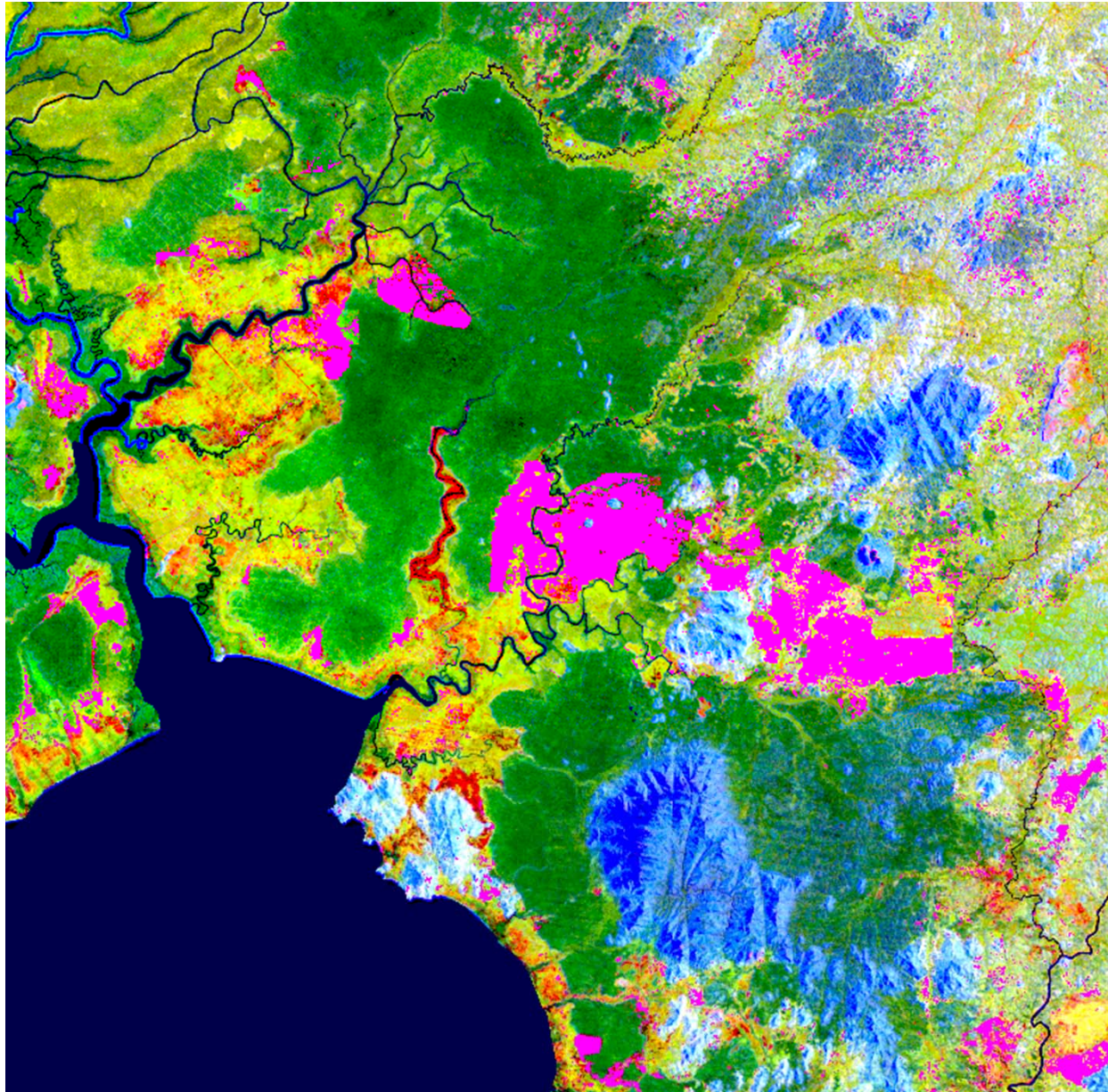
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2010

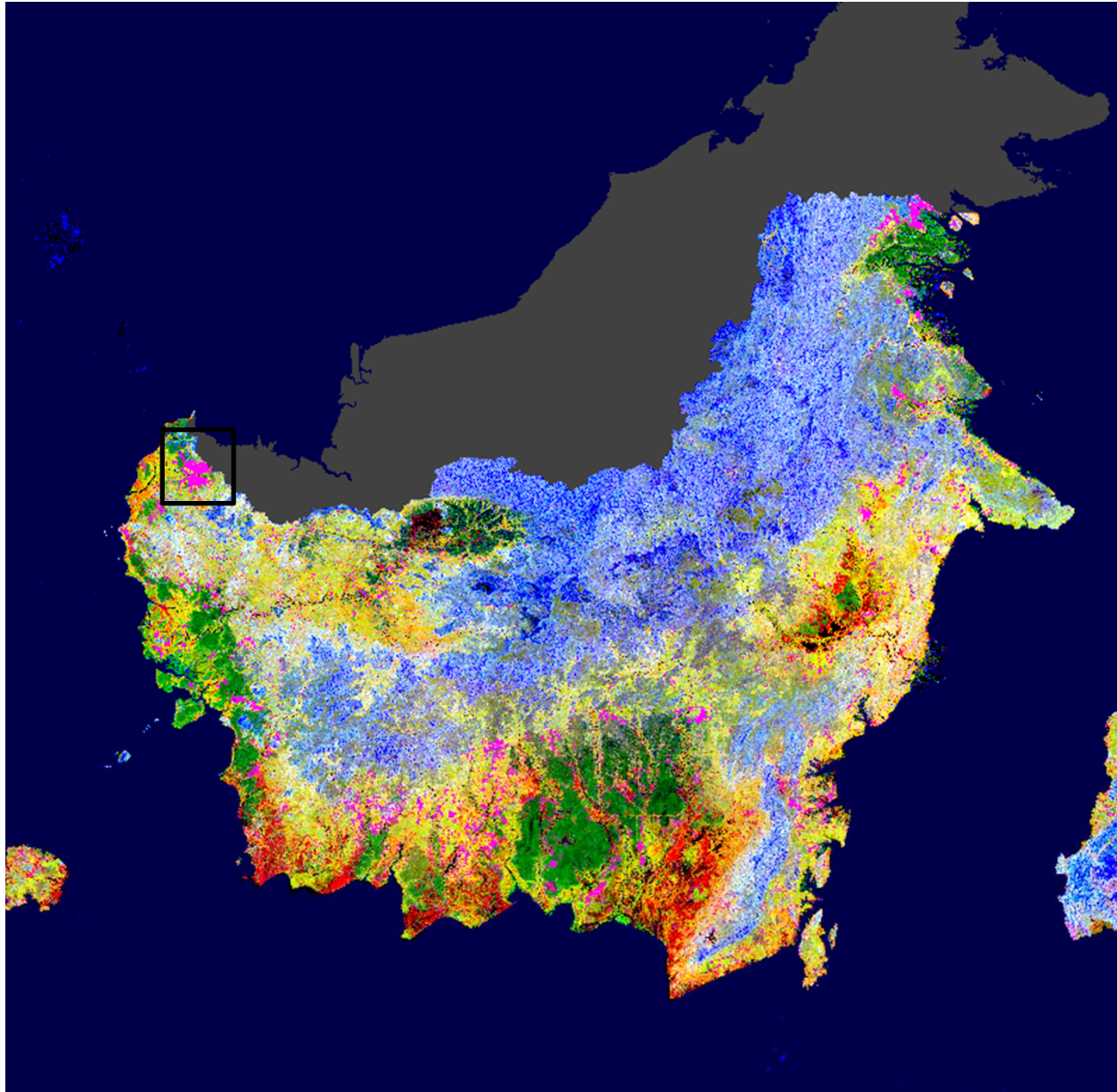


100km x 100km

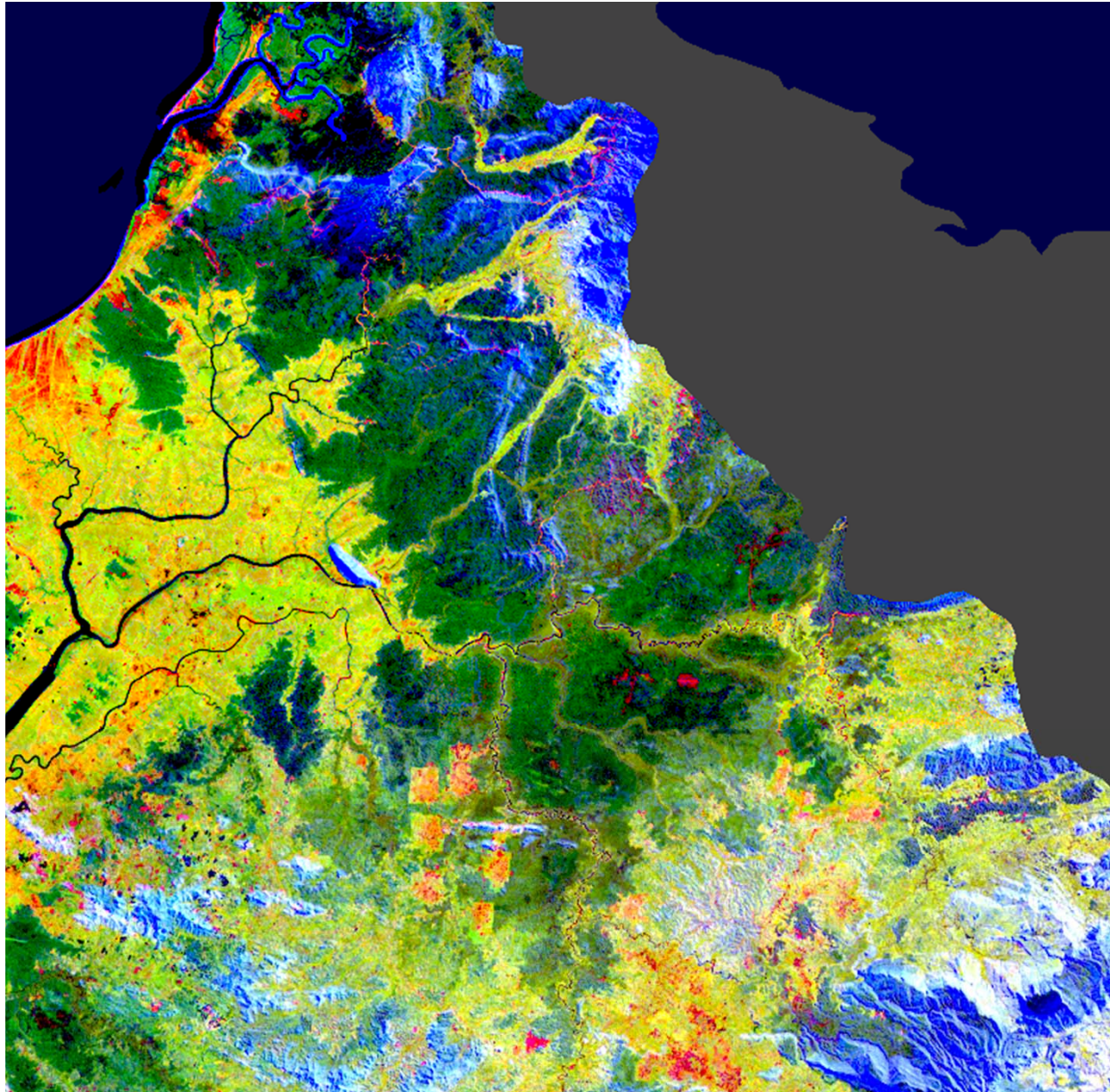
Magenta = forest cover loss, 2000 to 2010



100km x 100km

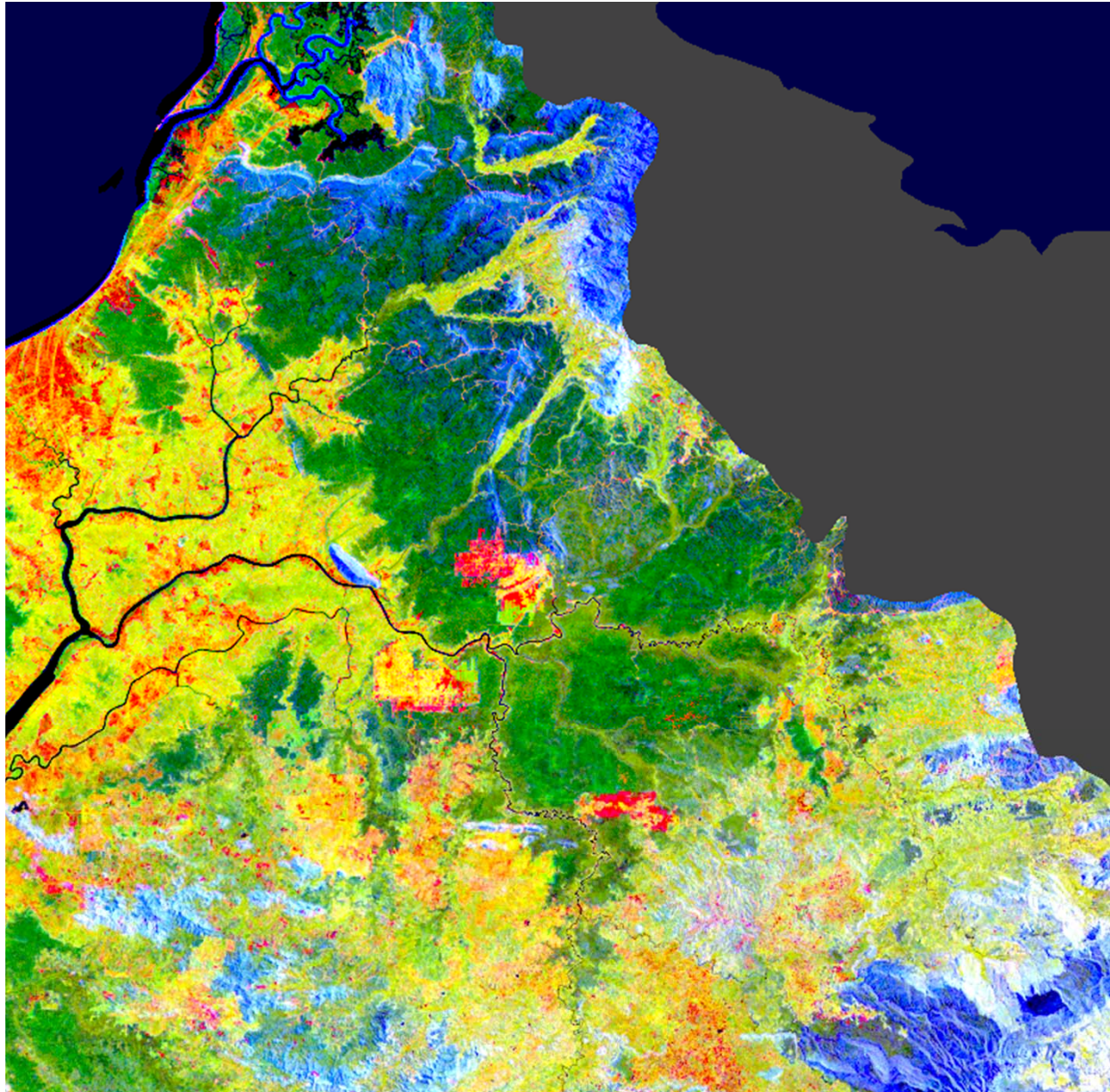


1990



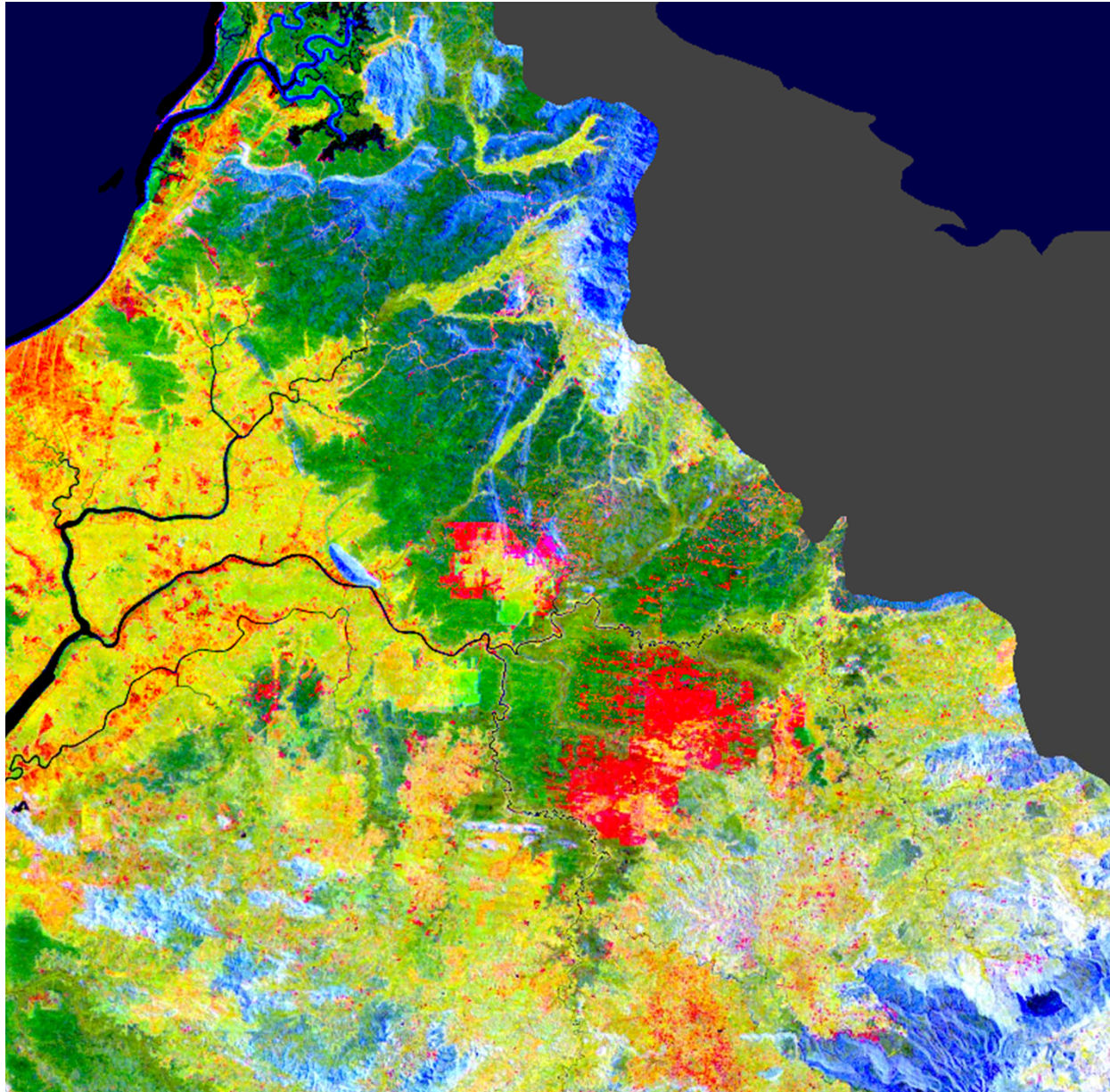
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2000



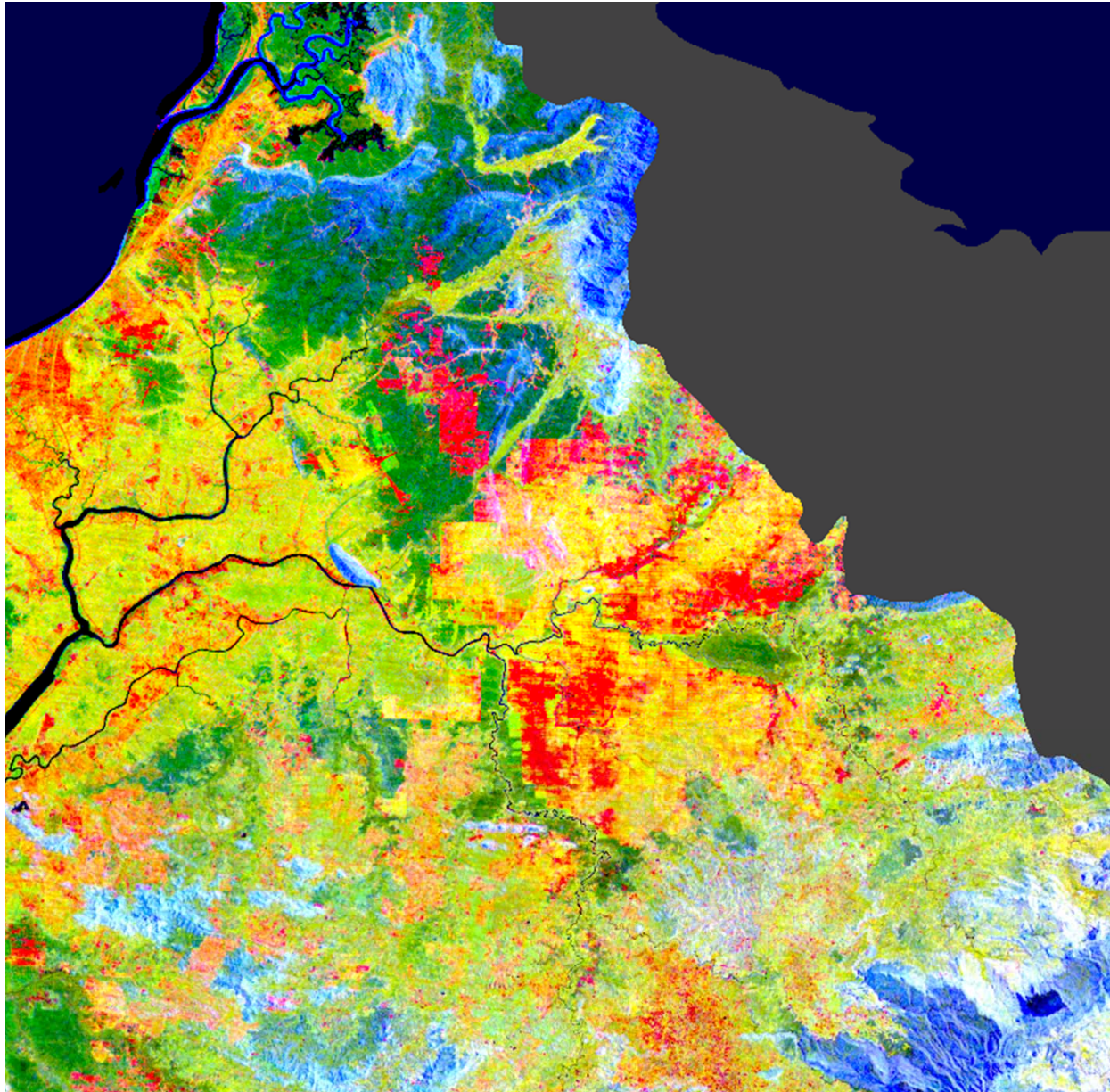
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2005



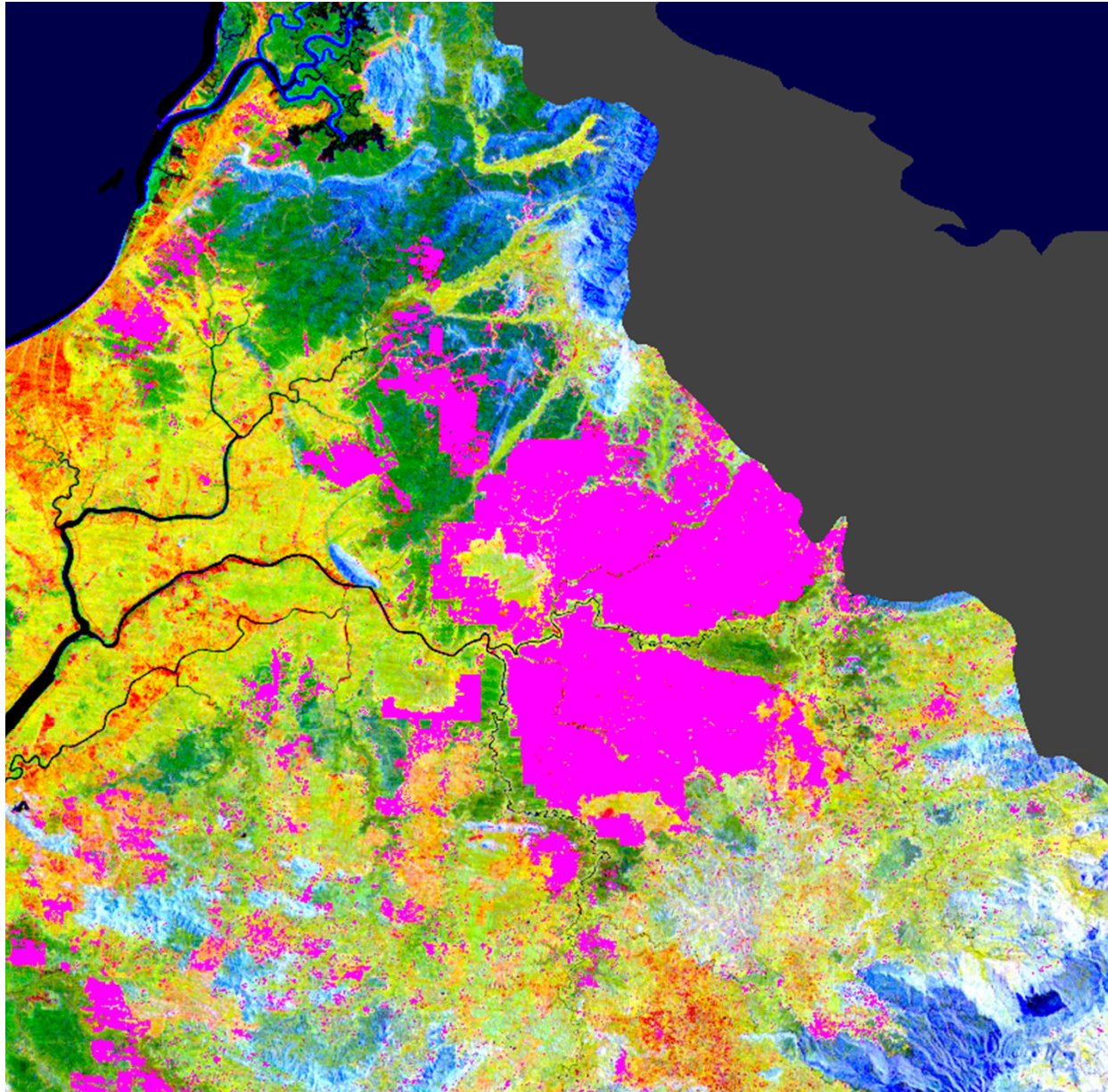
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2010



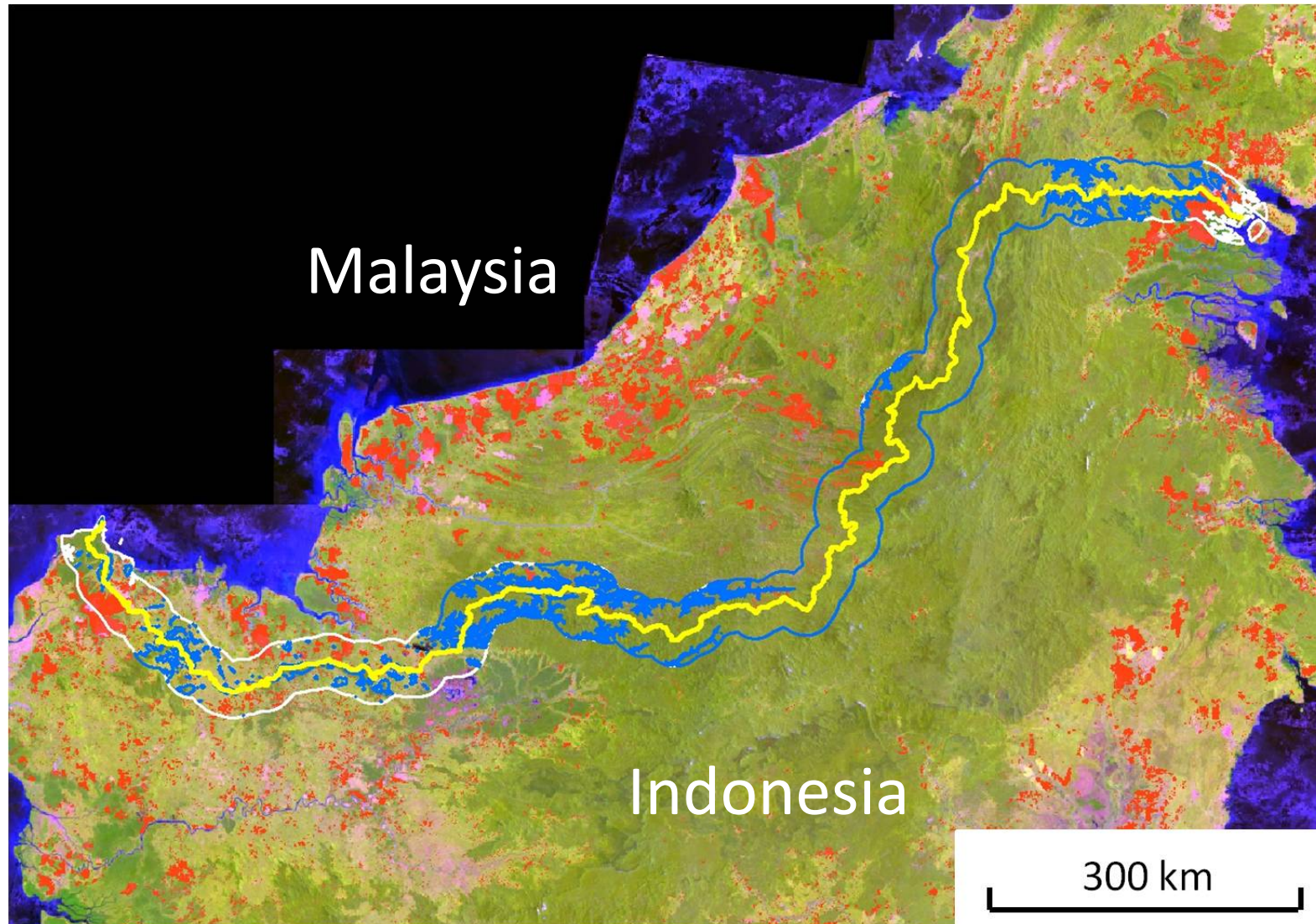
100km x 100km

Magenta = forest cover loss, 2000 to 2010

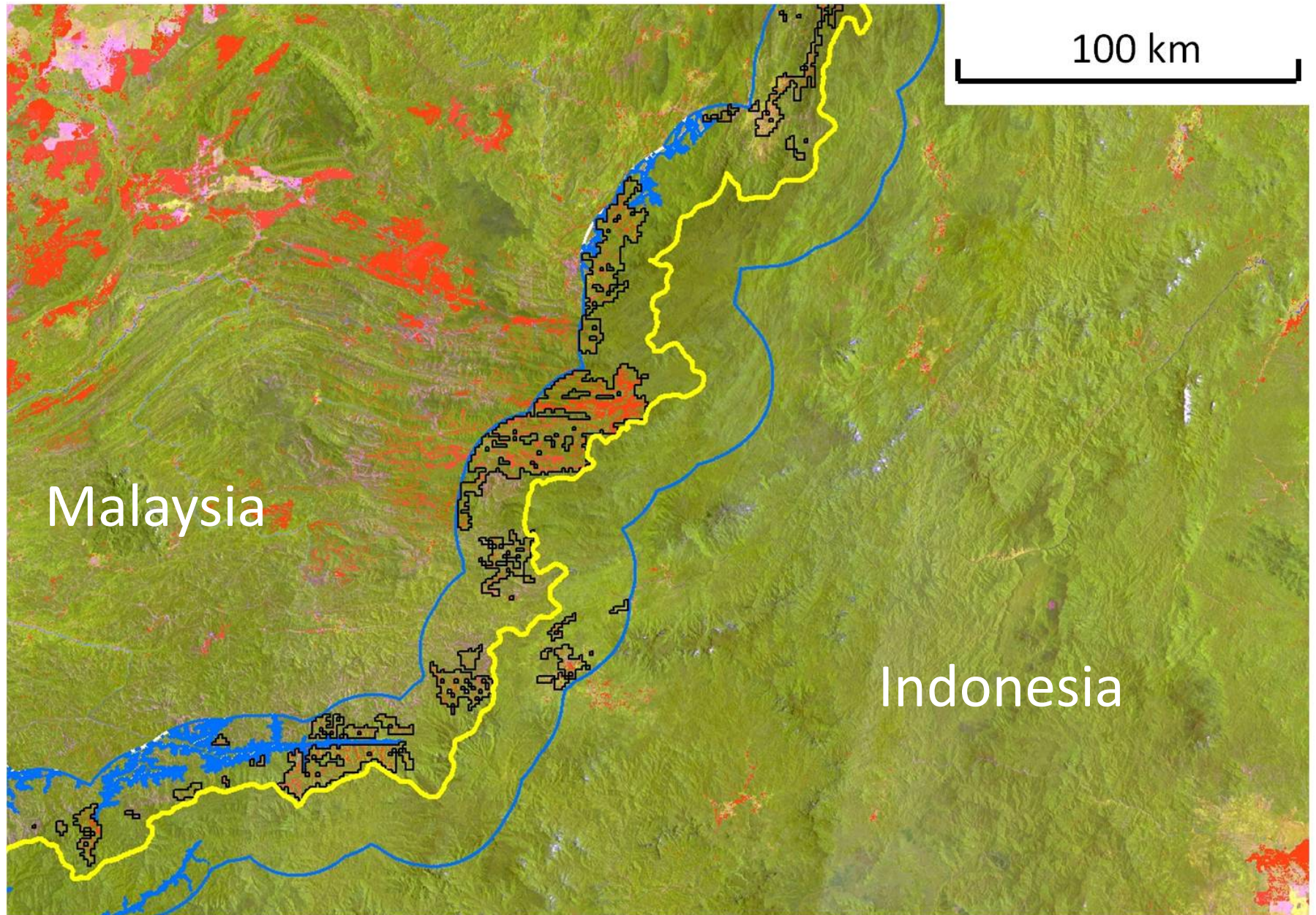


100km x 100km

Trans-boundary effects



Trans-boundary effects



Next steps

- Complete national-scale forest type maps
 - Primary intact
 - Primary degraded
 - Wetland / peatland forest
 - Timber plantations
 - Palm estates
- Establish rates of change within and between these forest categories

Conclusions

- MODIS/Landsat processing enables large area cover extent and change characterization
- Automated pre-processing of large volumes of image inputs is a requirement for most humid tropical areas
- Themes can be characterized in a hierarchical manner to quantify change dynamics in support of national monitoring objectives
- As methods mature, implementation by responsible agencies should be enabled to advance policy-driven monitoring objectives, such as REDD (research to operations)

Landsat is unique among medium resolution sensors

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

