Wide-area monitoring of tropical forest and land cover

Case study: Borneo 2007

Dirk Hoekman

K&C 12 Meeting, 16 June 2009

Presentation outline

1. Introduction: wide-area radar mapping objectives
2. Operational wide-area radar mapping methodology
3. Example: Borneo PALSAR LULC map 2007 and comparison
4. Interoperability (with MODIS, ENVISAT ASAR)
5. Conclusions

Introduction

Objective: design and validate operational methodology for wide-area wall-to-wall monitoring using ALOS PALSAR:

- Using **currently available** operational radar techniques
- Using **consistent approaches** with consolidated methods
- Allowing **interoperability** with complementary optical data sources

Applications include:

- National Carbon Accounting System Indonesia (NCASI)
- GEO Forest Carbon Tracking Task
- Sustainable biomass production EU Renewable Energy Directive

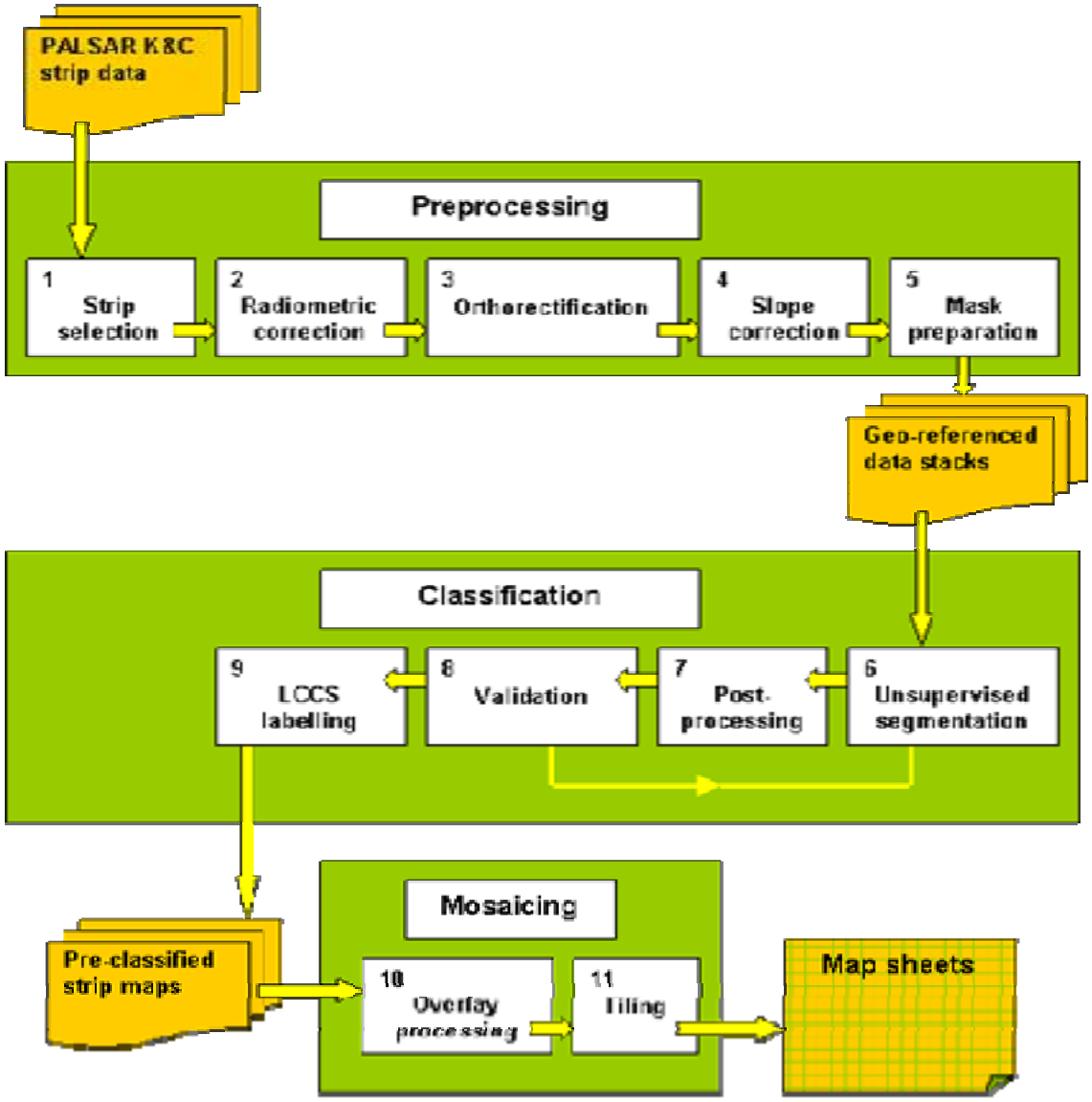
Work is NL contribution to GEO Forest Carbon Tracking Task

Wide area SAR mapping methodology: processing chain

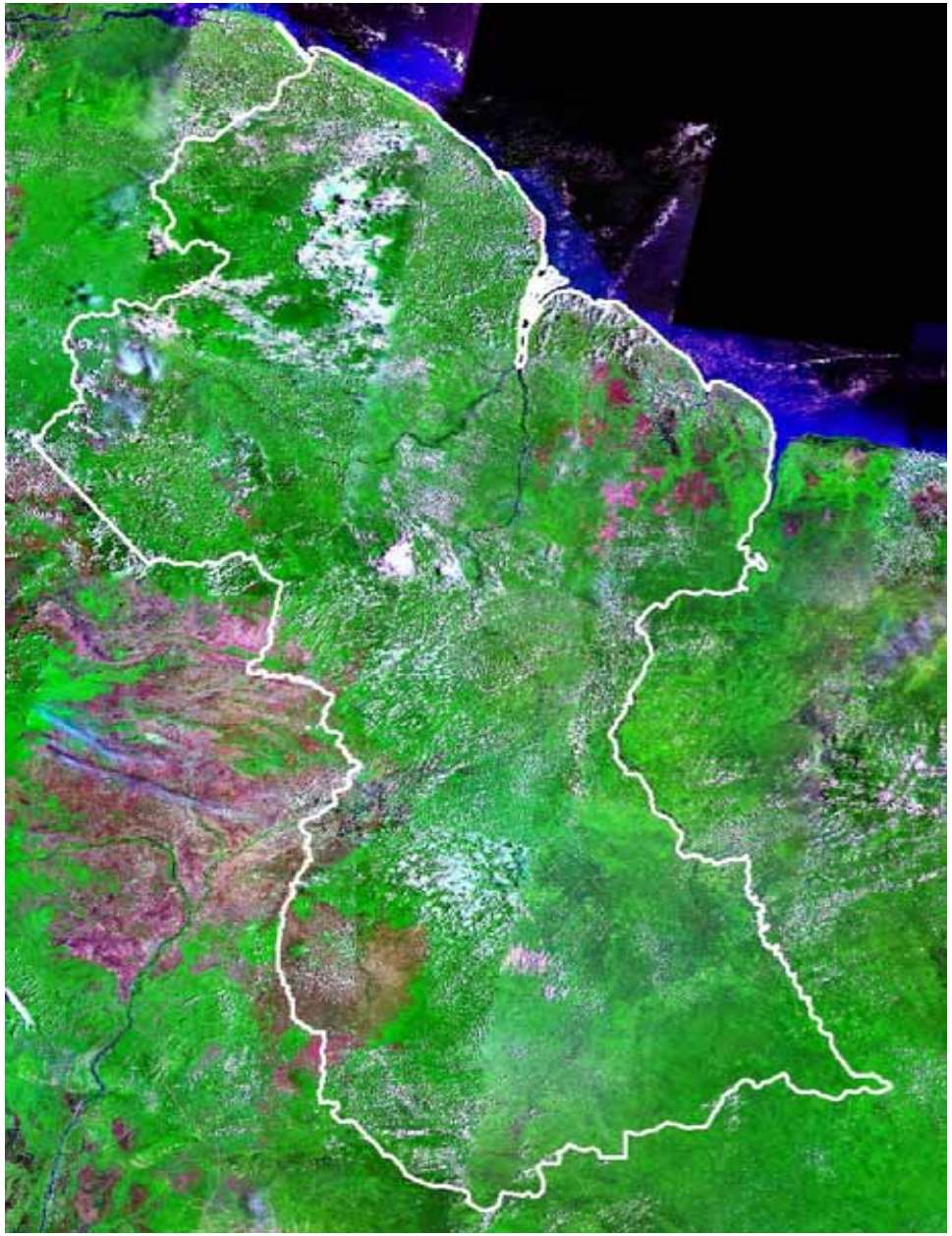
<u>Operational</u> processing chain has been developed for systematic mapping of:

- Forest - non-forest
- Land cover (LCCS)

using ALOS PALSAR FBS and FBD strip data



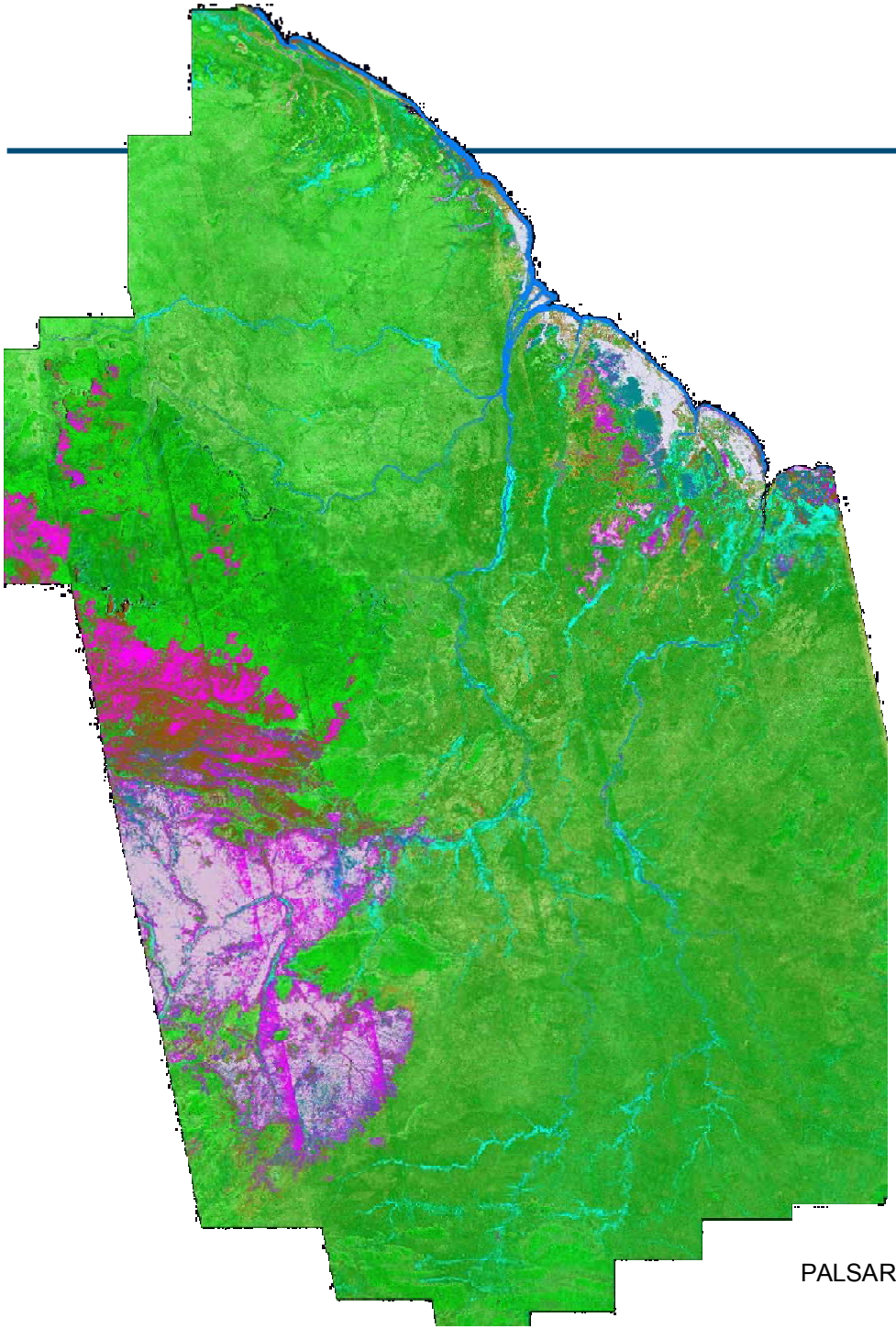
Example Guyana



The best available national satellite data coverage for Guyana is **Geocover 2000 30m Landsat**…

Cloud cover limits its use

Note: boundaries from FAO geonetwork



Example Guyana

Vegetation Map of Guyana: Huber *et al*. 1995

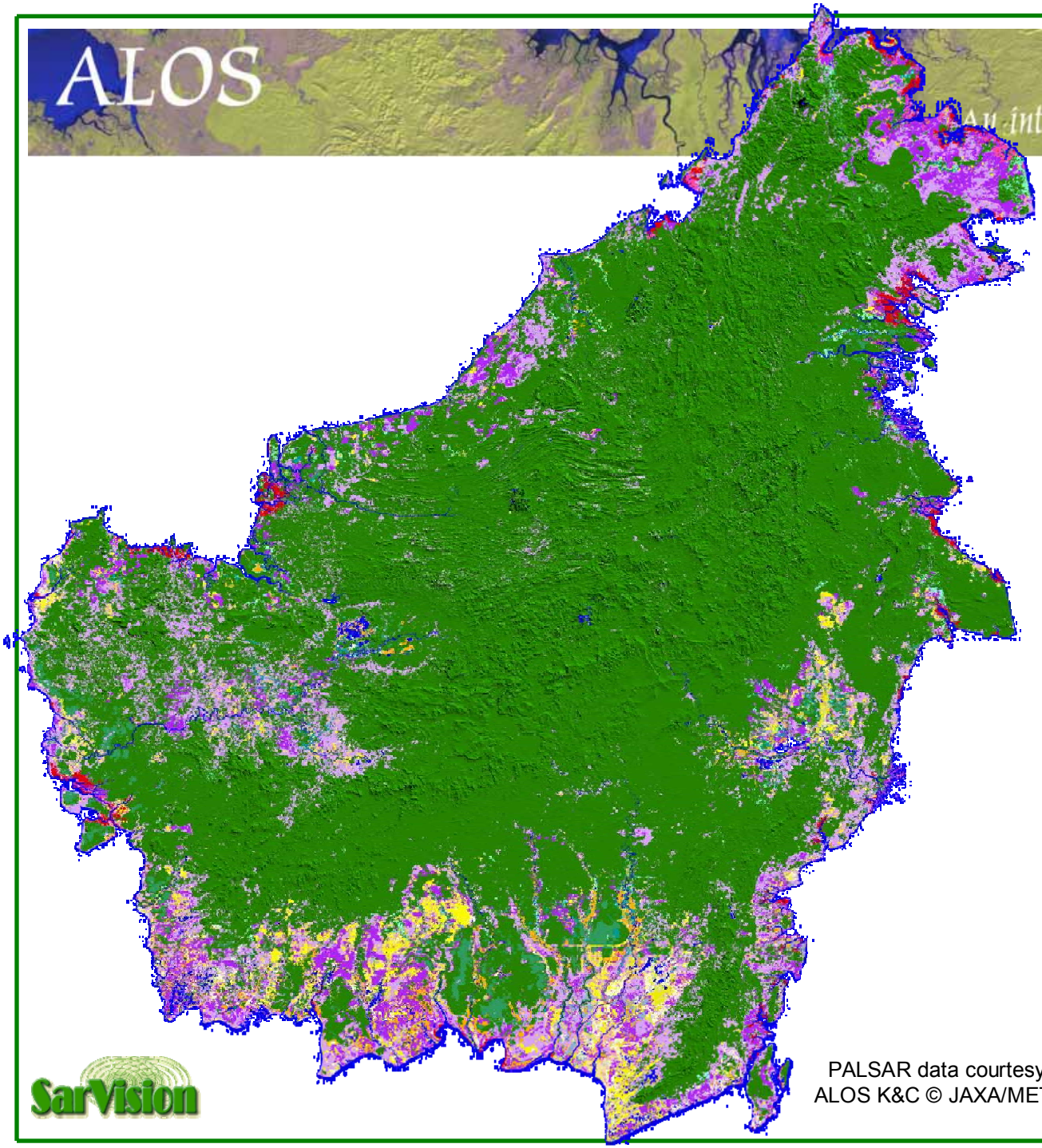
PALSAR data courtesy: ALOS K&C © JAXA/METI.

ALOS

K&C Initiative

An international science collaboration led by JAXA

Example Borneo



PALSAR data courtesy:
ALOS K&C © JAXA/METI.

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Guyana: ~ 215,000 km^2

FBD 2007 dry season

ScanSAR 2008 wet season

Borneo: ~ 750,000 km^2

FBD 2007 dry season

FBS 2007 wet season

Problems Borneo (as compared to Guyana):

1) No good reference maps available

2) Highly dynamic low biomass areas, transitional phases

3) Local differences in run-off regimes >

Additional wetland cycles would improve ambiguities

General problem: Radiometric errors in strip data

Wide area SAR mapping methodology: processing chain

Key features of the PALSAR methodology developed:

1) Data required: **two observations per year**, **dual polarised** data required for best results (exploit extra information due to differences in **wet and dry season** for identification of wetlands and cropland classes);

2) **Slope correction** is critical for deriving reliable classification results;

3) Optimal classification: use **probabilistic method** based on finite mixture modelling and Markov Random Fields classification.

References:

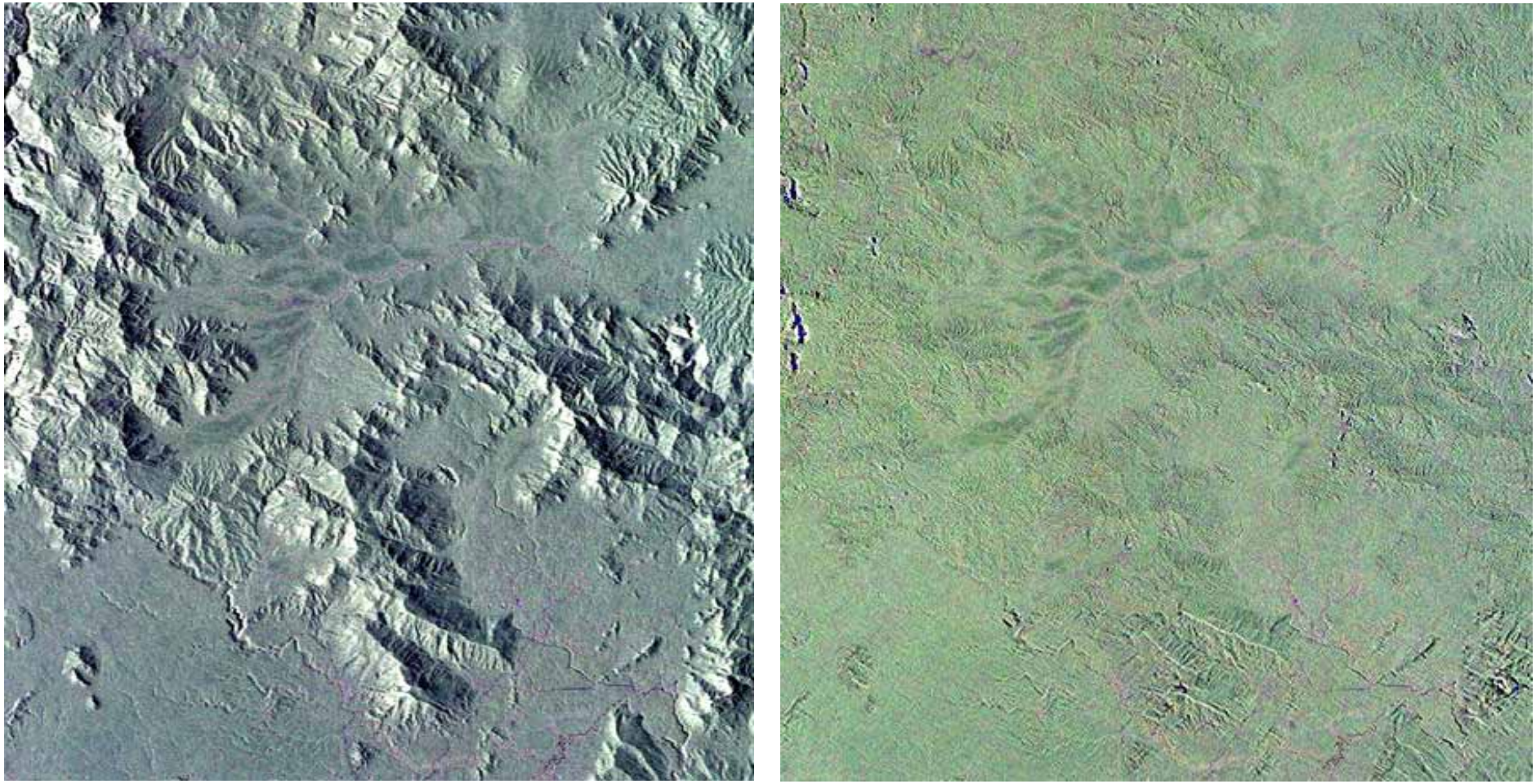
- Hoekman, D.H., T. Tran, and M.A.M. Vissers, 2007, Unsupervised full-polarimetric segmentation for evaluation of backscatter mechanisms of agricultural crops, Proc. of POLinSAR 2007 Workshop, ESA SP-644, 22-26 Jan 2007, Frascati , Italy.
- Hoekman et al,. 2009, Unsupervised full-polarimetric multi-temporal SAR data segmentation of agricultural areas, IEEE J-STARS (*subm.*)

Wide area SAR mapping methodology: input data

Two observations per year (one in dry season and one in wet season)
Two polarisations (FBD: HH+HV, FBS: HH) at 50m spatial resolution

	FBD			FBS		
RSP	Date	Cycle	Shift	Date	Cycle	Shift
RSP410	20070804	13	+12	20070201	09	+12
RSP411	20070821	13	+29	20070218	09	+29
RSP412	20070723	13	0	20070120	09	0
RSP413	20070809	13	+17	20070206	09	+17
RSP414	20070826	13	+34	20070223	09	+34
RSP415	20070728	13	+5	20070125	09	+5
RSP416	20070814	13	+22	20070211	09	+22
RSP417	20070831	13	+39	20070228	09	+39
RSP418	20070802	13	+10	20070130	09	+10
RSP419	20070704	12	-19	20070216	09	+27
RSP420	20070905	13	+44	20070305	09	+44
RSP421	20070807	13	+15	20070204	09	+15
RSP422	20070824	13	+32	20070221	09	+32
RSP423	20070726	13	+3	20080126	17	+369
RSP424	20070812	13	+20	20070209	09	+20
RSP425	20070829	13	+37	20070226	09	+37
RSP426	20070915	14	+54	20070128	09	+8
RSP427	20070817	13	+25	20070214	09	+25
RSP428	20070903	13	+42	20070303	09	+42
RSP429	20070805	13	+13	20080205	17	+379
RSP430	20070707	12	-16	20080408	18	+442
RSP431	20070608	12	-45	20070121	09	+1

Slope correction/mitigation example



FBS/FBD composite before and after slope correction (same backscatter scale)

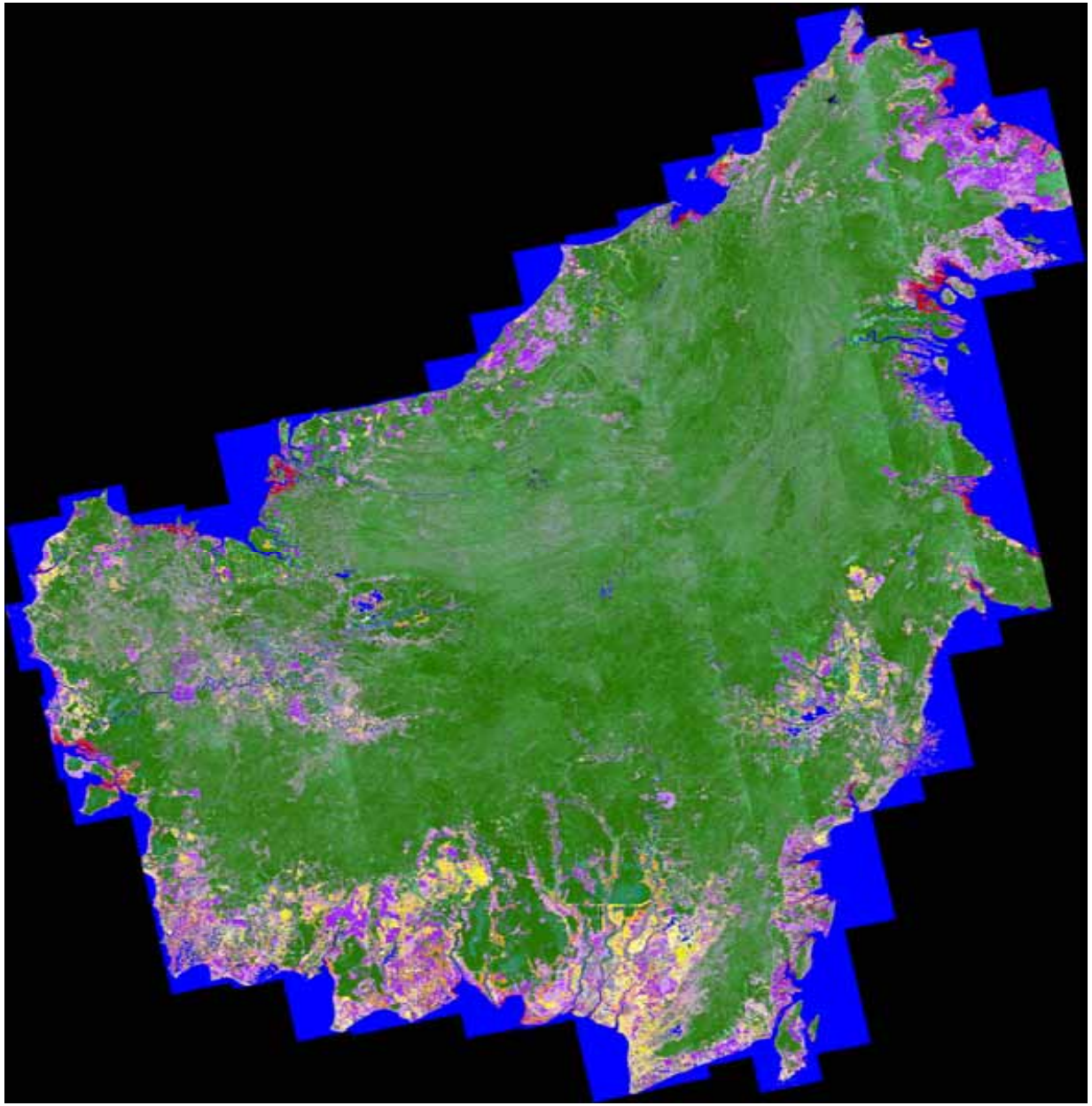
Wide area SAR mapping methodology: classification

Results: overview

ALOS PALSAR 2007

Land cover classification Borneo

Legend: next slides



PALSAR data courtesy:
ALOS K&C © JAXA/METI.

Wide area SAR mapping methodology: classification

Class legend development and work to harmonize classes to enable inter-comparison with other maps, e.g. Globcover

With a single protocol and a single set of statistics all strips can be classified directly over wide areas.

Key types of forest, shrubs, deforestation can be differentiated, legend development according to LCCS ongoing.

A validation study is ongoing, revealing a proper legend (i.e. what the radar can differentiate well) and associated accuracies.

- Bare area(s)
- Grassland
- Rainfed croplands
- Mosaic Forest/Croplands
- Shrubland (cover 10-40%)
- Open broadleaved evergreen forest
- Closed broadleaved evergreen forest
- Water bodies
- Rice paddy fields - Graminoid crops
- Riparian forest - Broadleaved evergreen high trees temporarily flooded (fresh-brackish)
- Peat swamp forest - Closed to open broadleaved forest regularly flooded (fresh-brackish water)
- Nipah - Broadleaved evergreen medium high trees permanently flooded (saline-brackish)
- Mangrove - Closed broadleaved forest permanently flooded (saline-brackish water)

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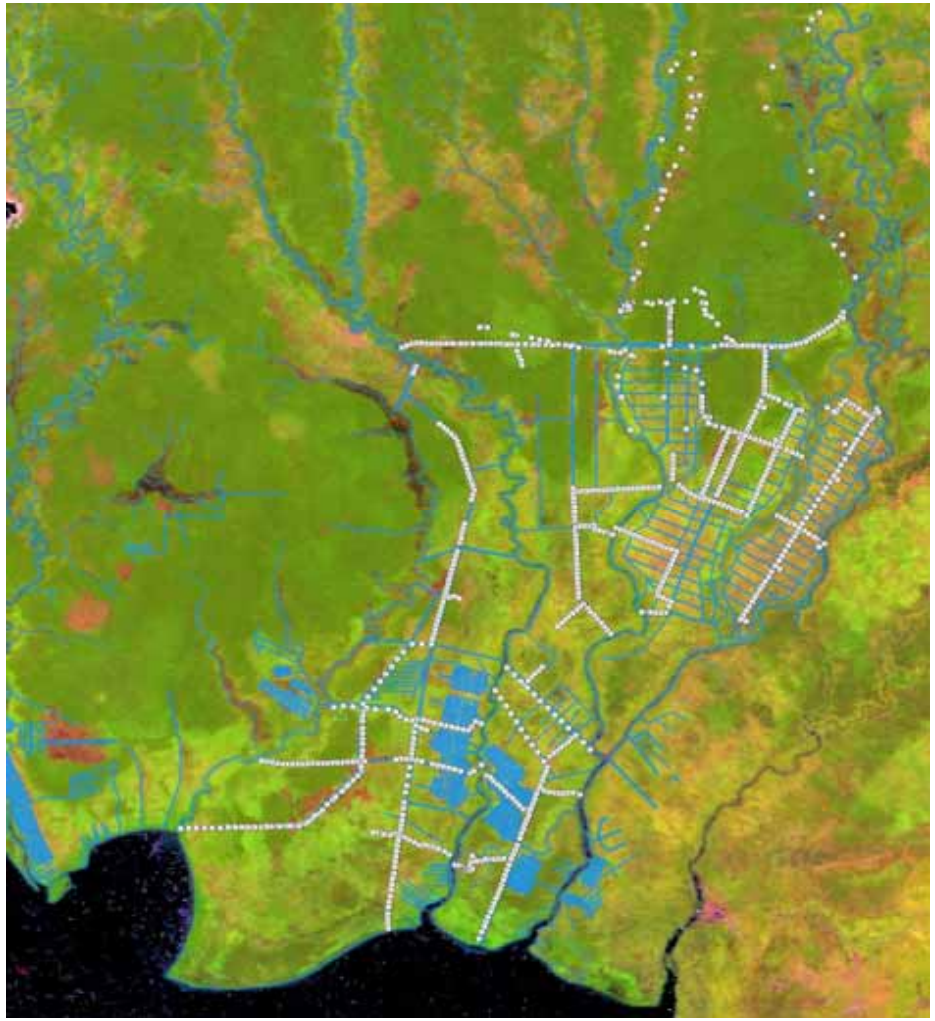
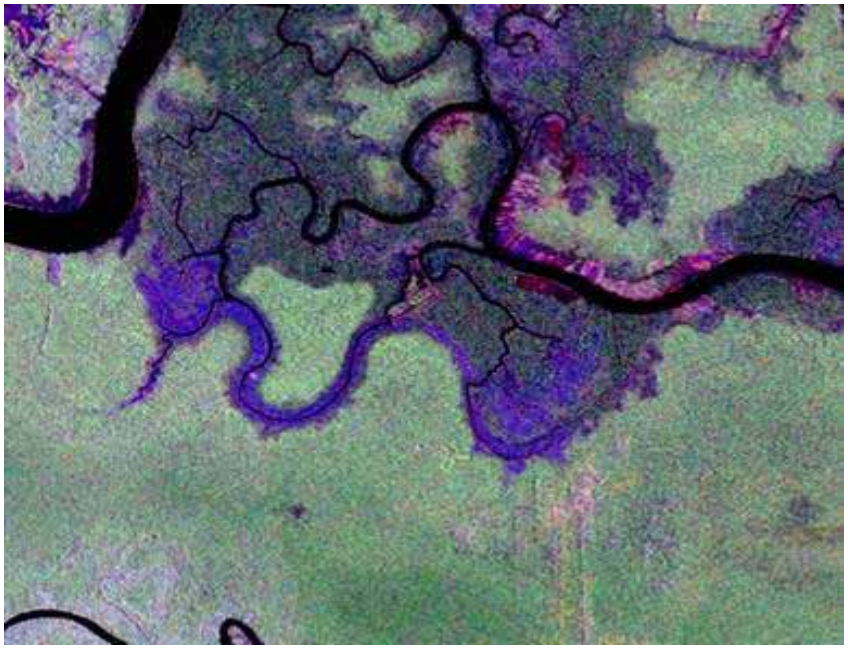
Land cover mapping at 50 m: Central Kalimantan

Ground reference data collection (*white dots*):

Geo-referenced photos and field notes at > 892 locations

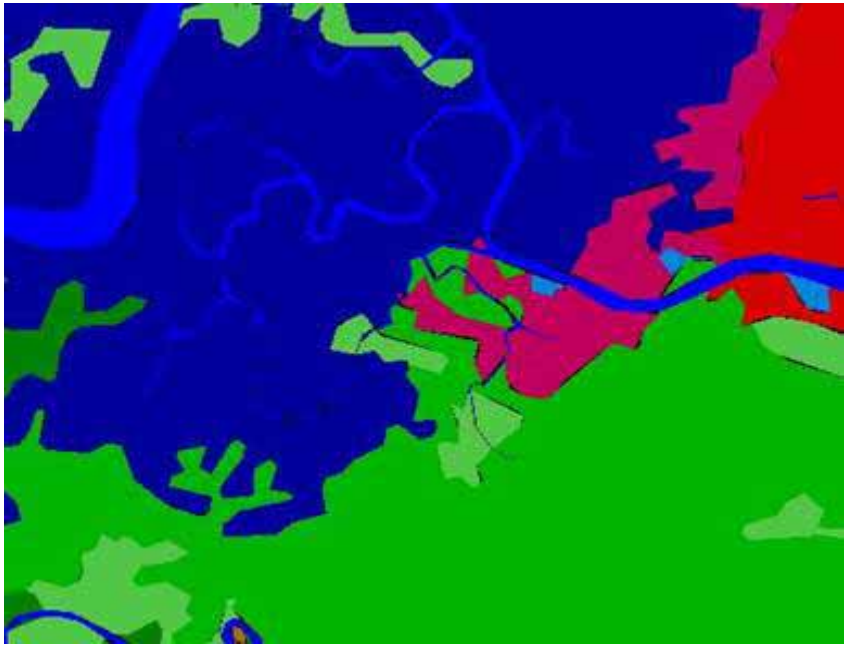


Comparison Mangrove

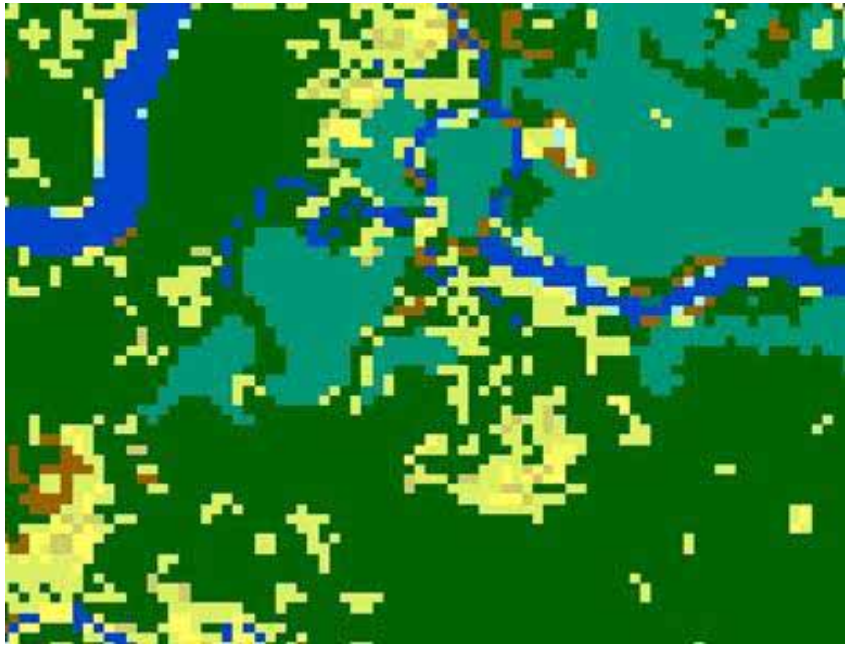


PALSAR 2007

PALSAR 2007 classes

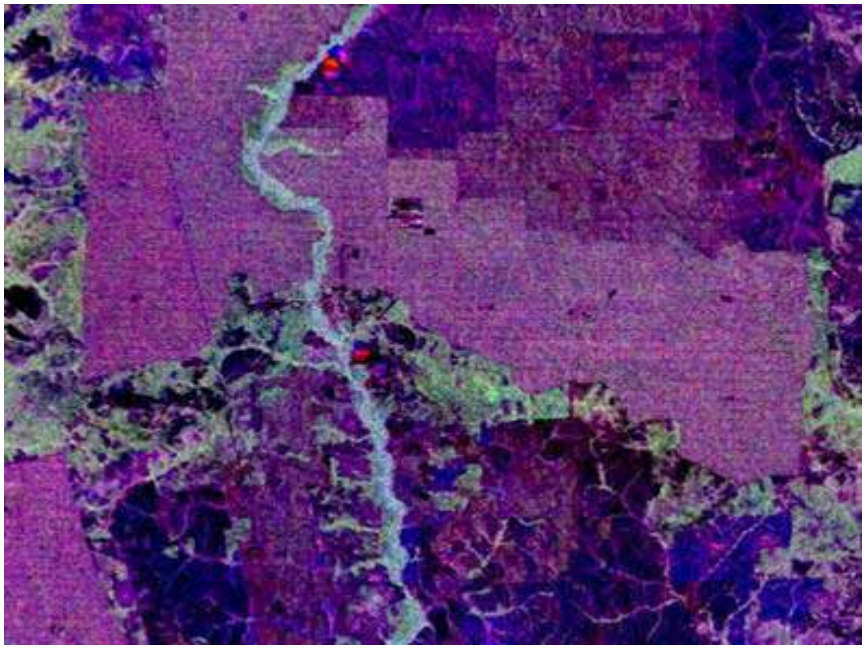


MOF ≤2005 classes

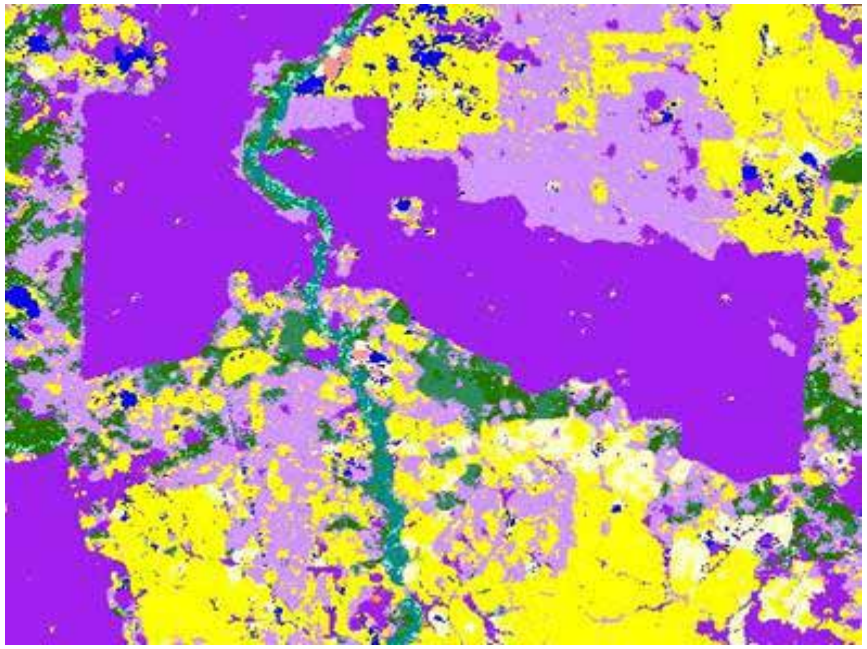


GlobCover 2006

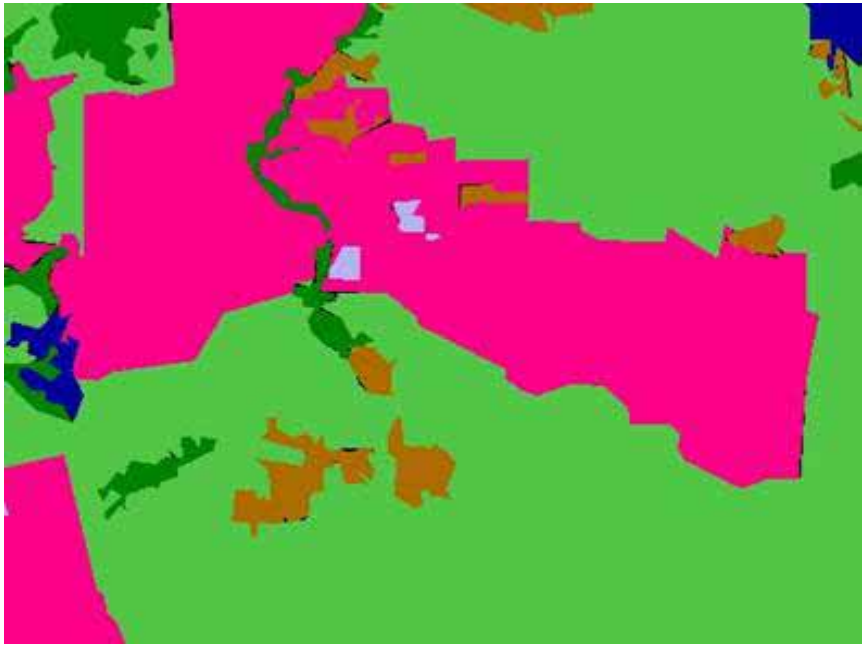
Comparison
Oil Palm



PALSAR 2007



PALSAR 2007 classes



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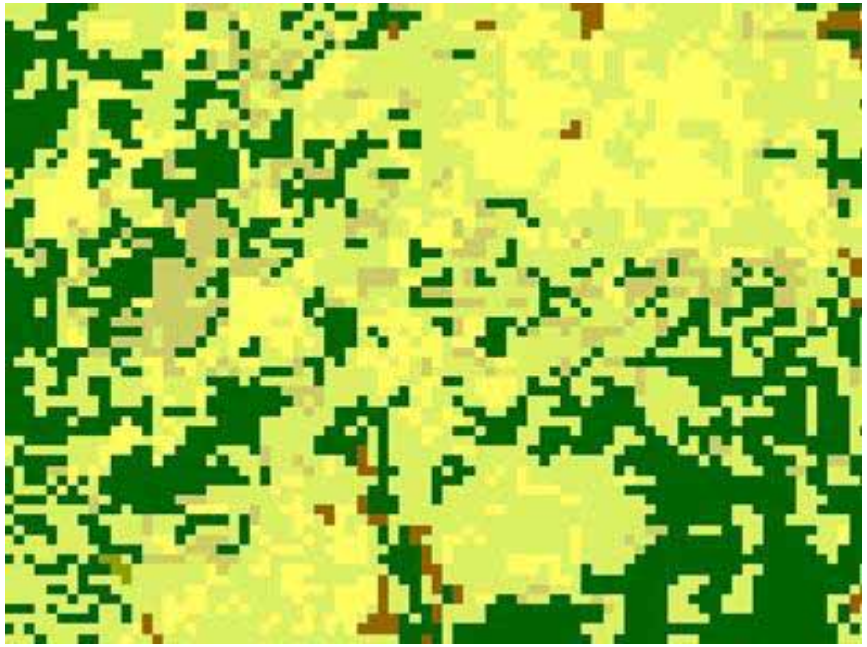
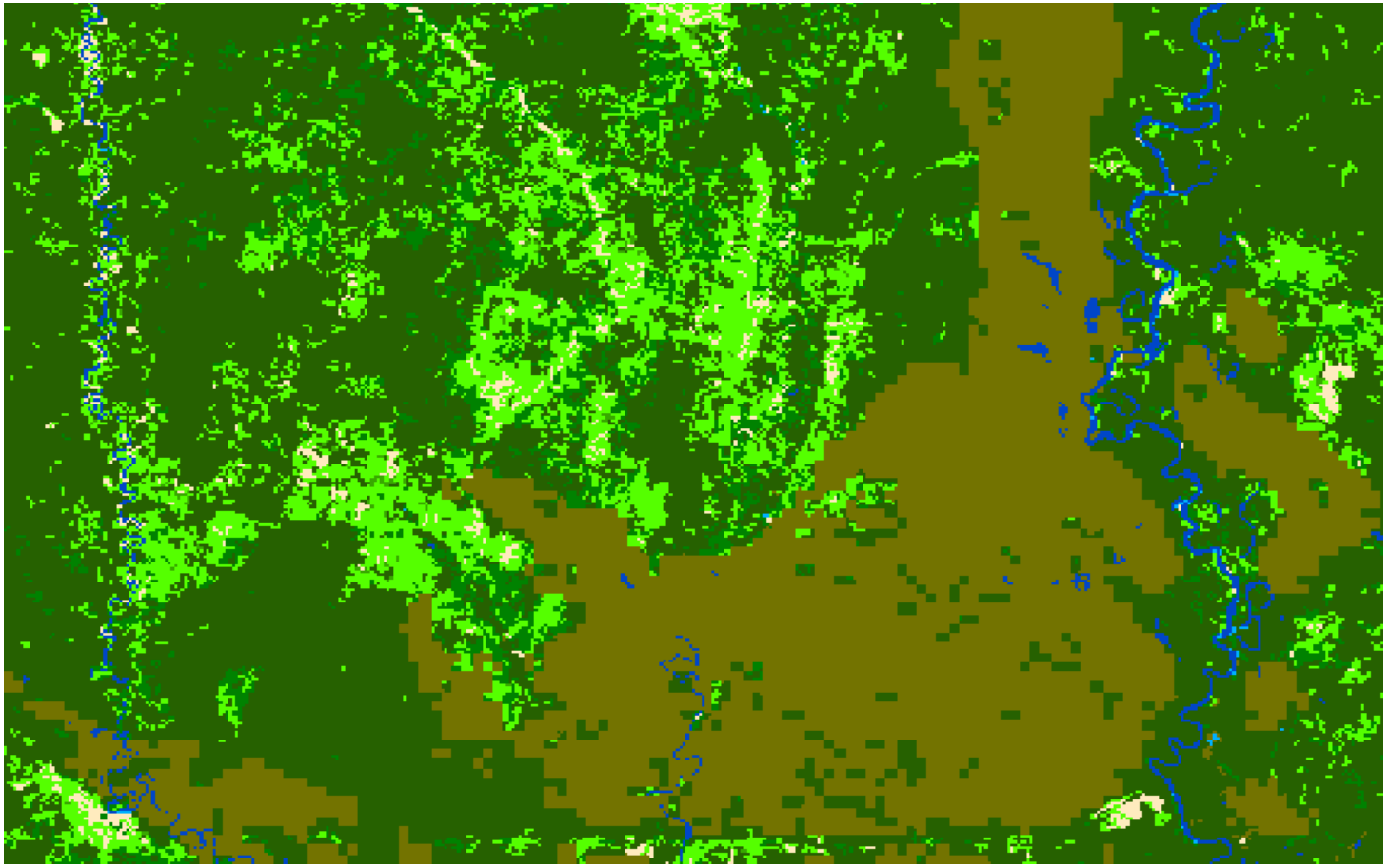


GlobCover 2006

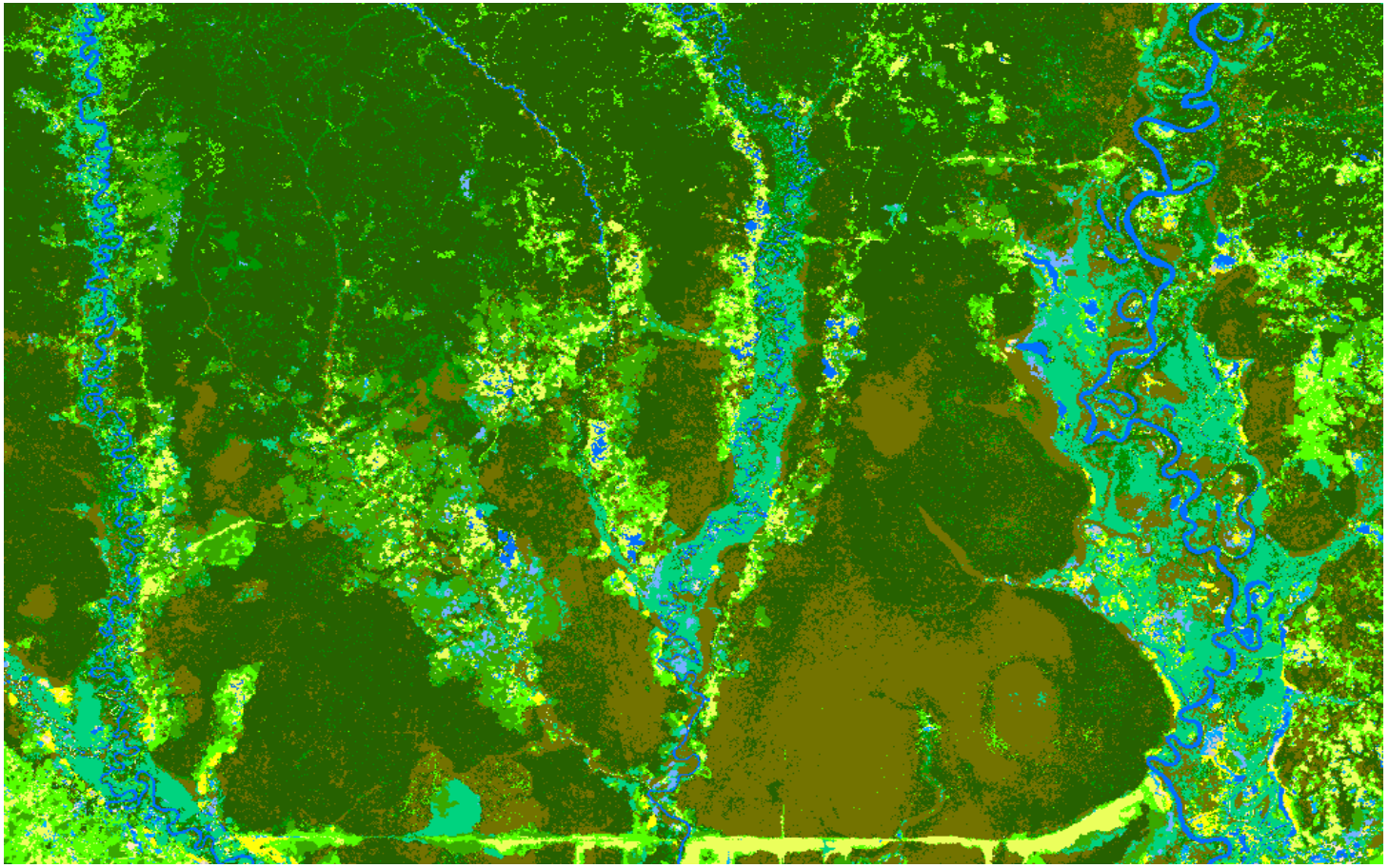
Example: Borneo LULC 2007 comparison



2005/2006 Globcover 300m

25 km

Example: Borneo LULC 2007 comparison

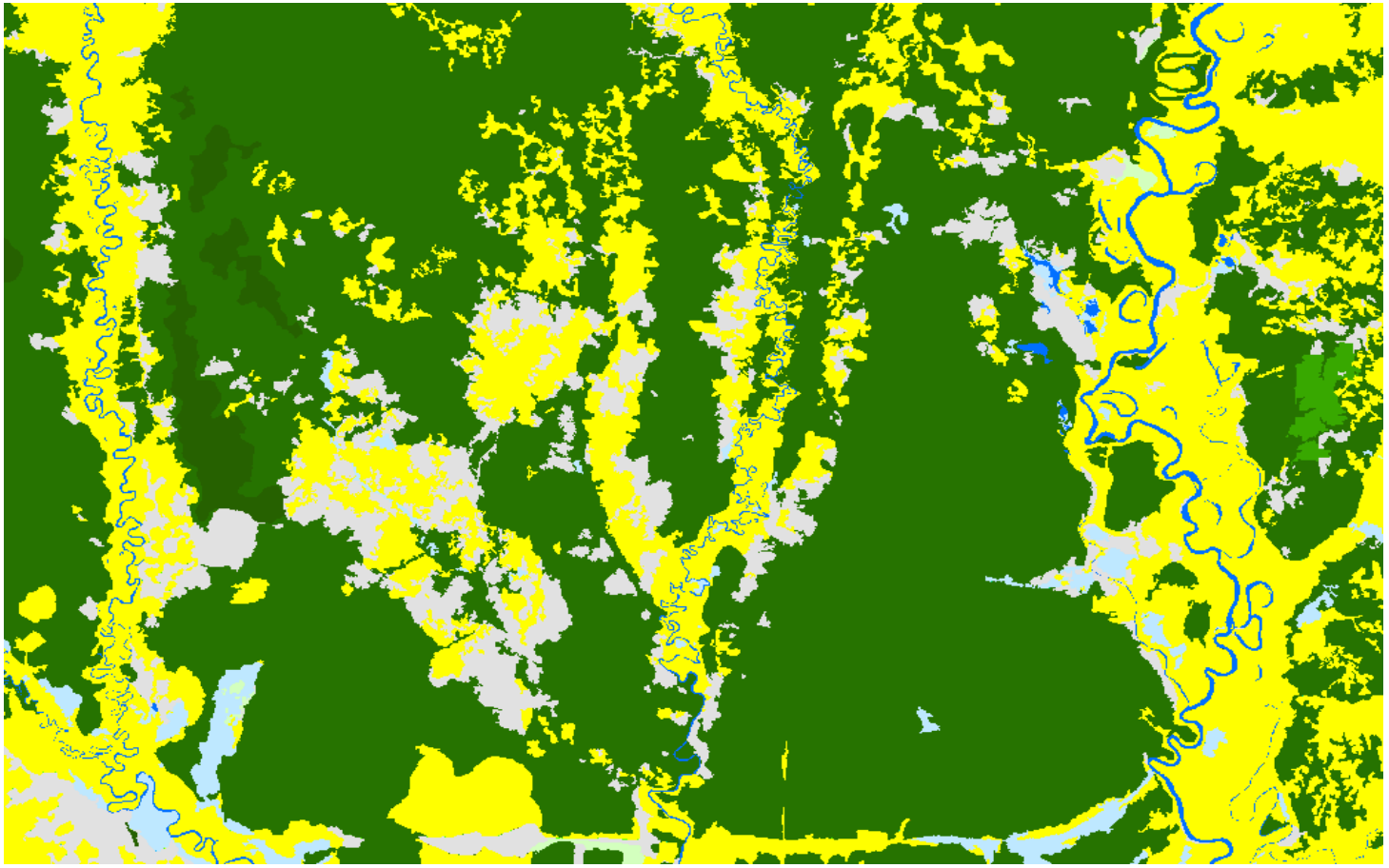


2007 PALSAR 50m classification

25 km

PALSAR data courtesy:
ALOS K&C © JAXA/METI.

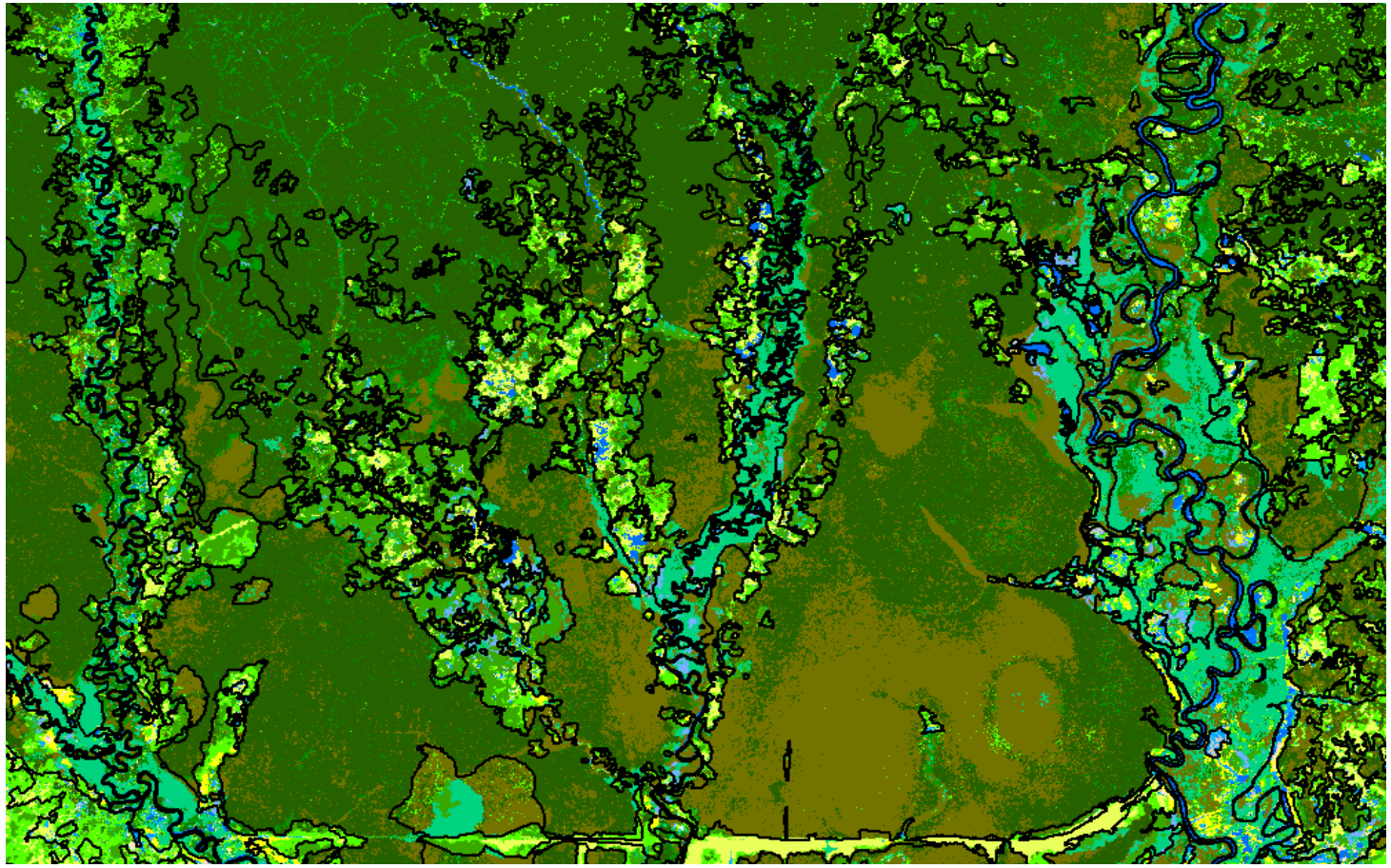
Example: Borneo LULC 2007 comparison



2005 visual interpretation Landsat
Indonesian Ministry of Forestry

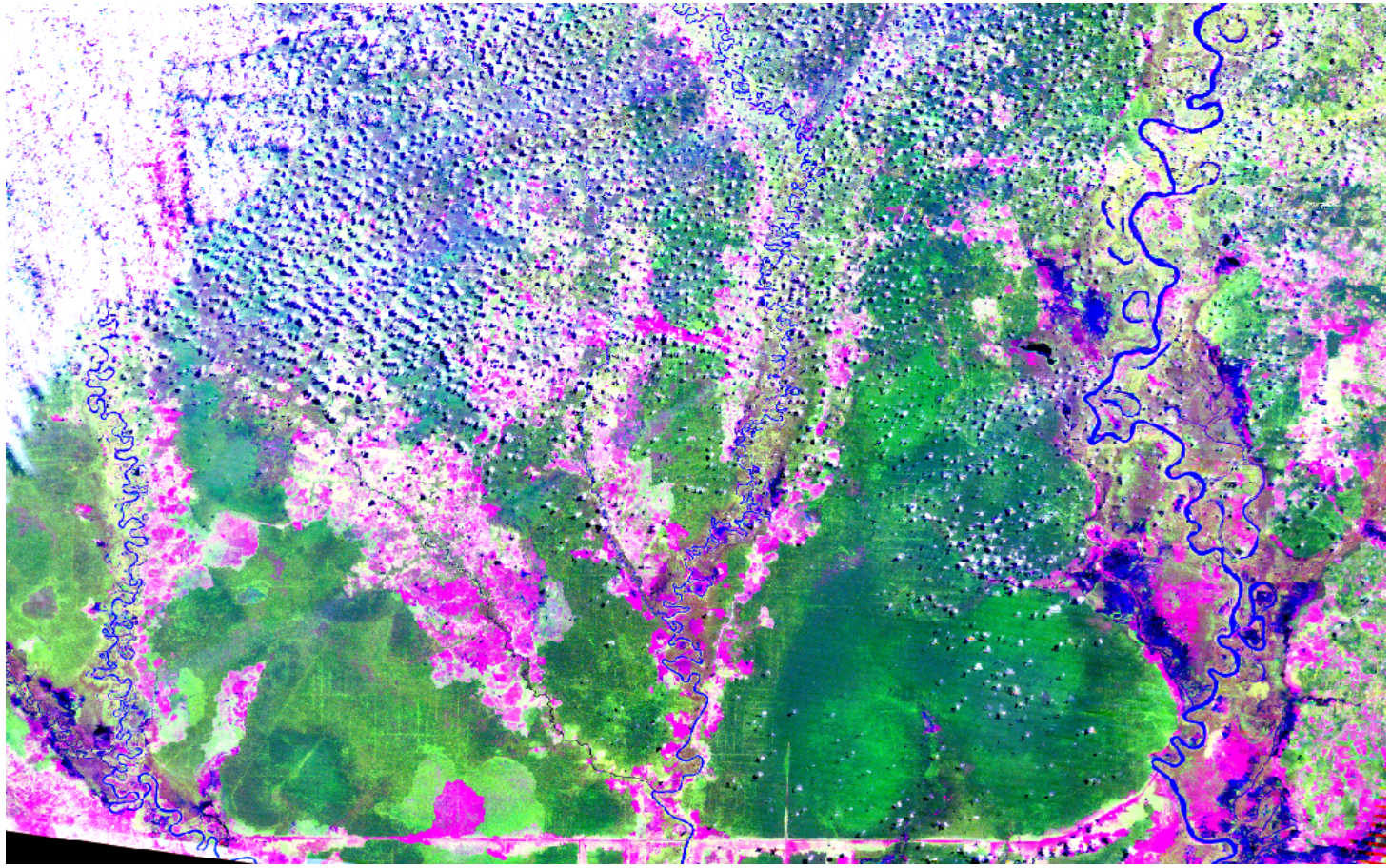
25 km

Example: Borneo LULC 2007 comparison



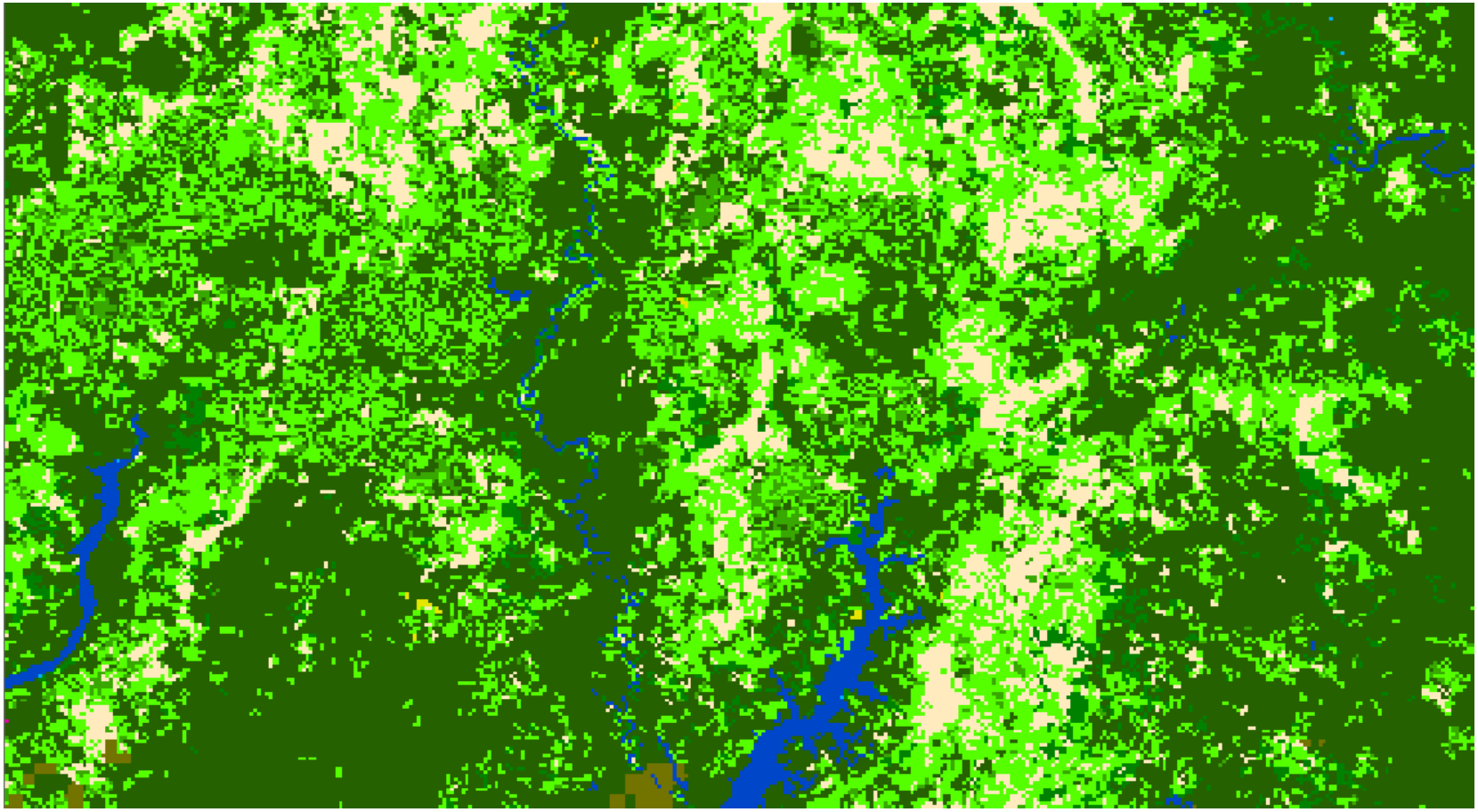
2007 PALSAR 50m + 2005 visual interpretation Landsat

Example: Borneo LULC 2007 comparison



2007 Landsat ETM+ 30m reference

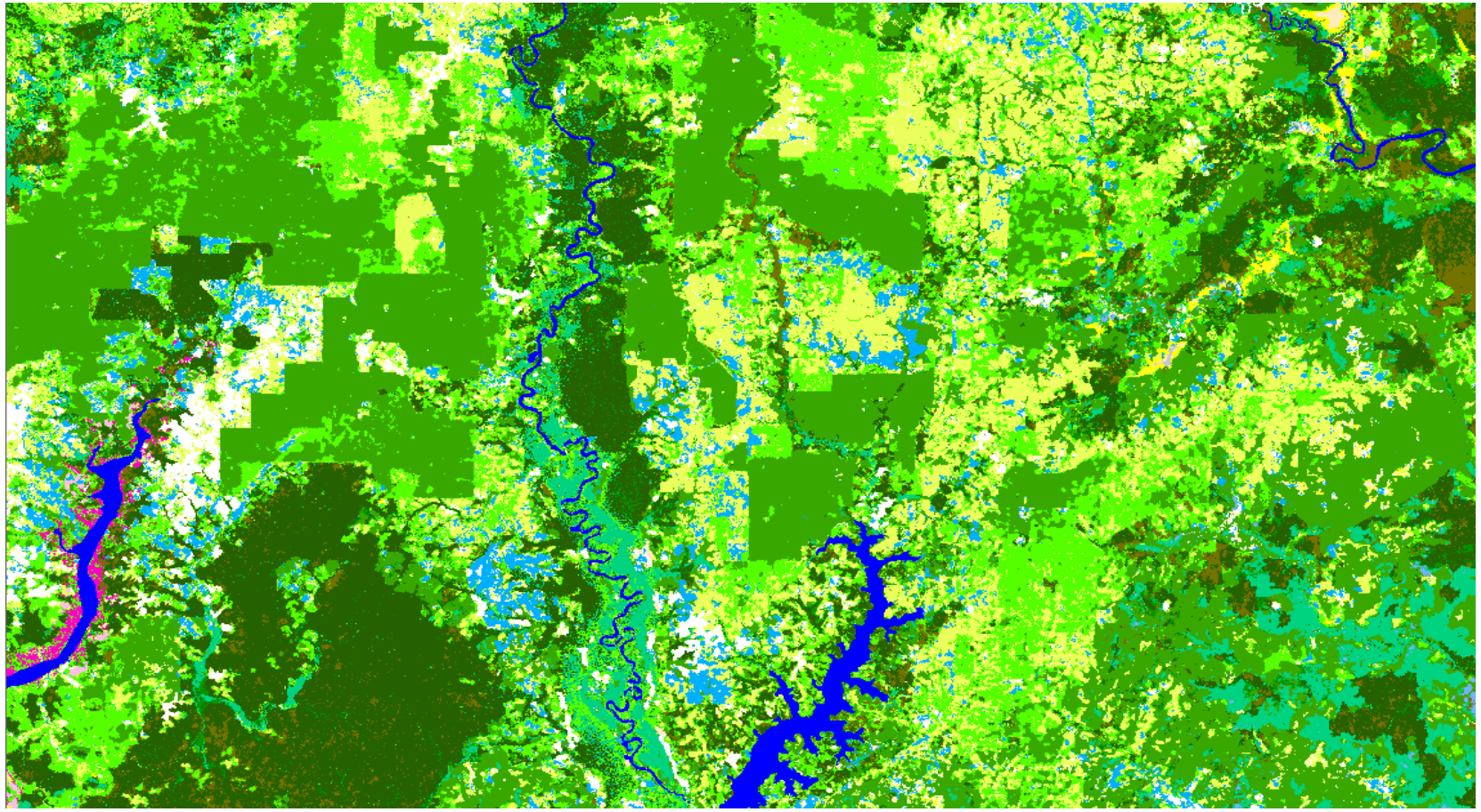
Example: Borneo LULC 2007 comparison



2005/2006 Globcover 300m

35 km

Example: Borneo LULC 2007 comparison



2007 PALSAR 50m classification

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PALSAR data courtesy:
ALOS K&C © JAXA/METI.

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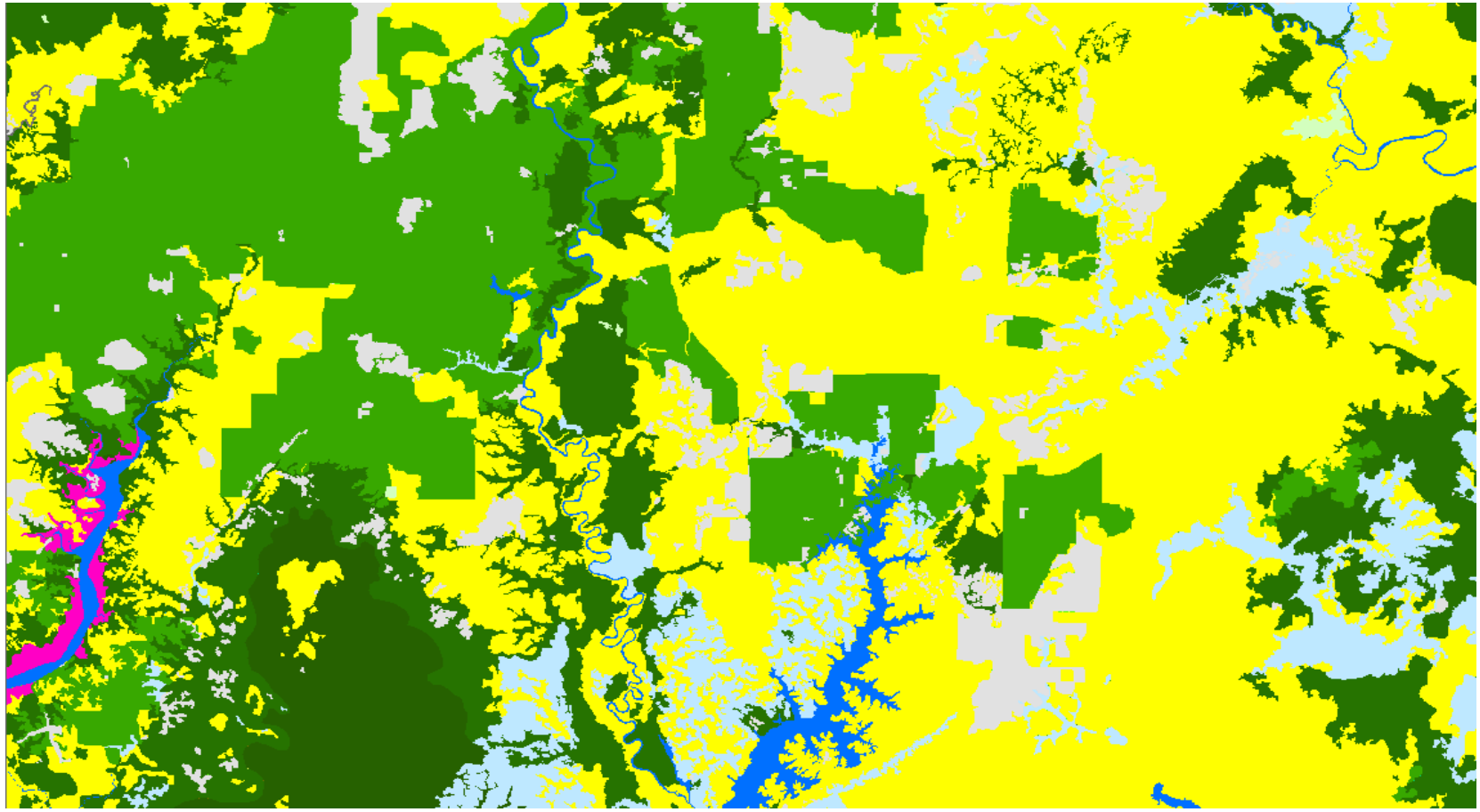

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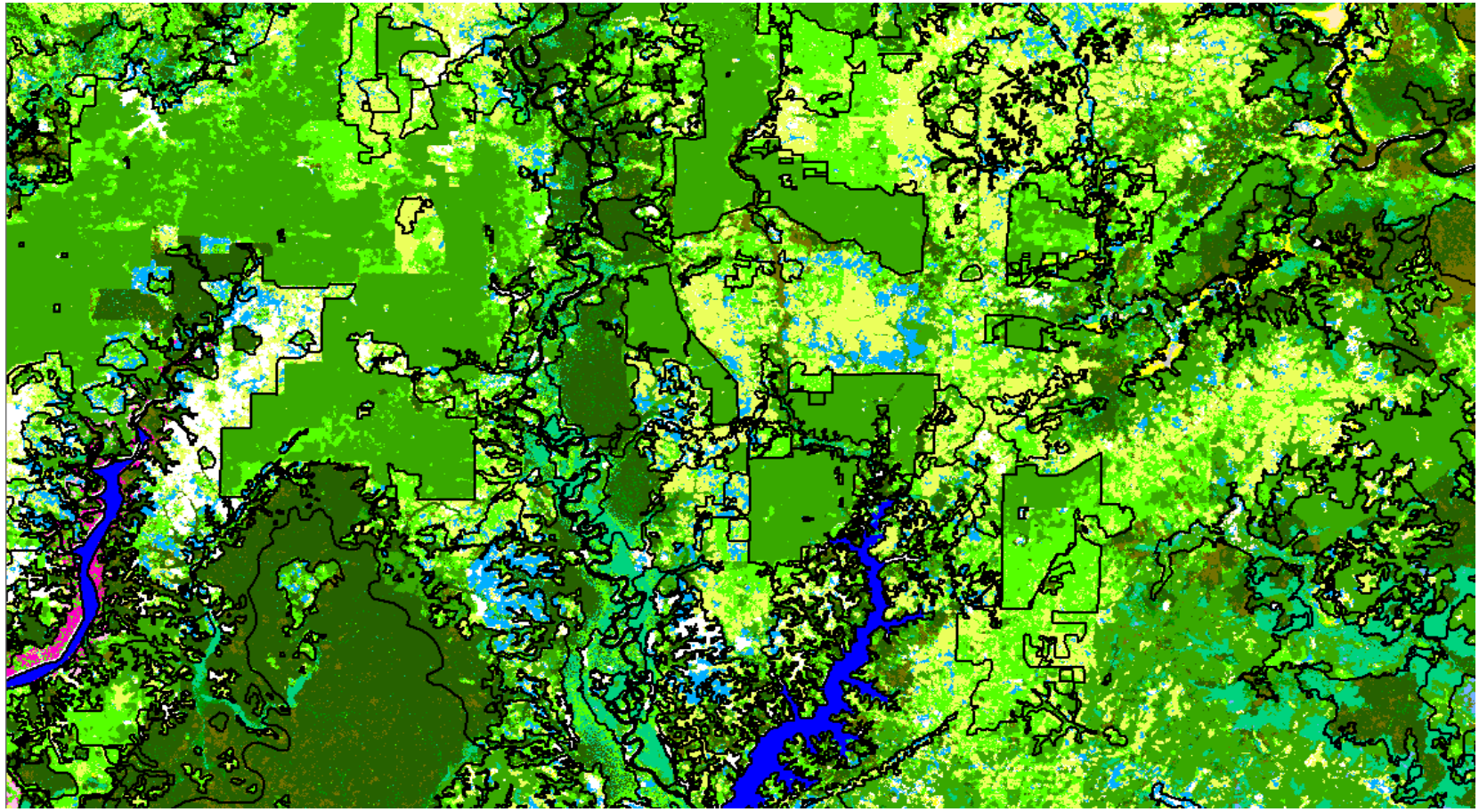
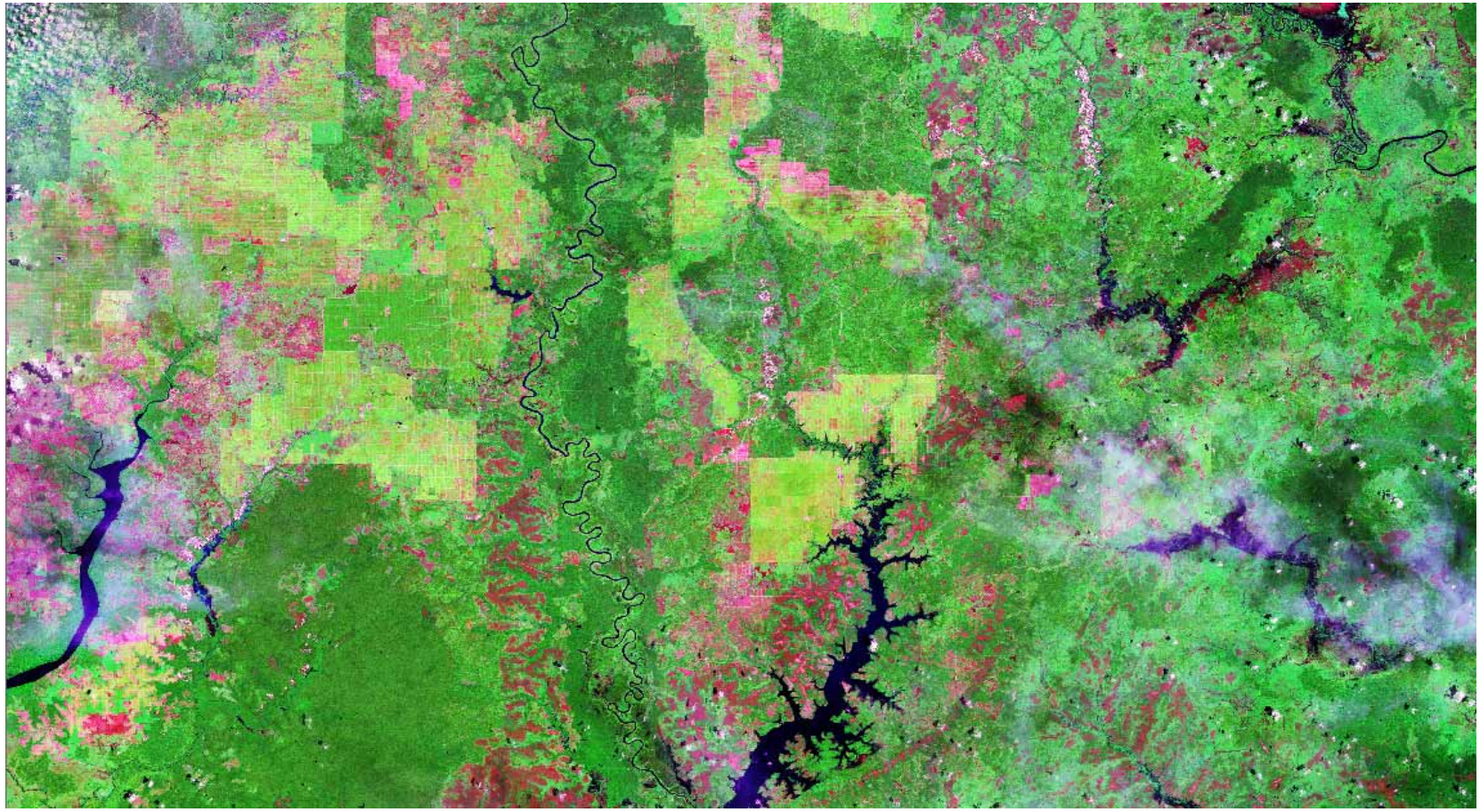


2007 PALSAR 50m + 2005 visual interpretation Landsat

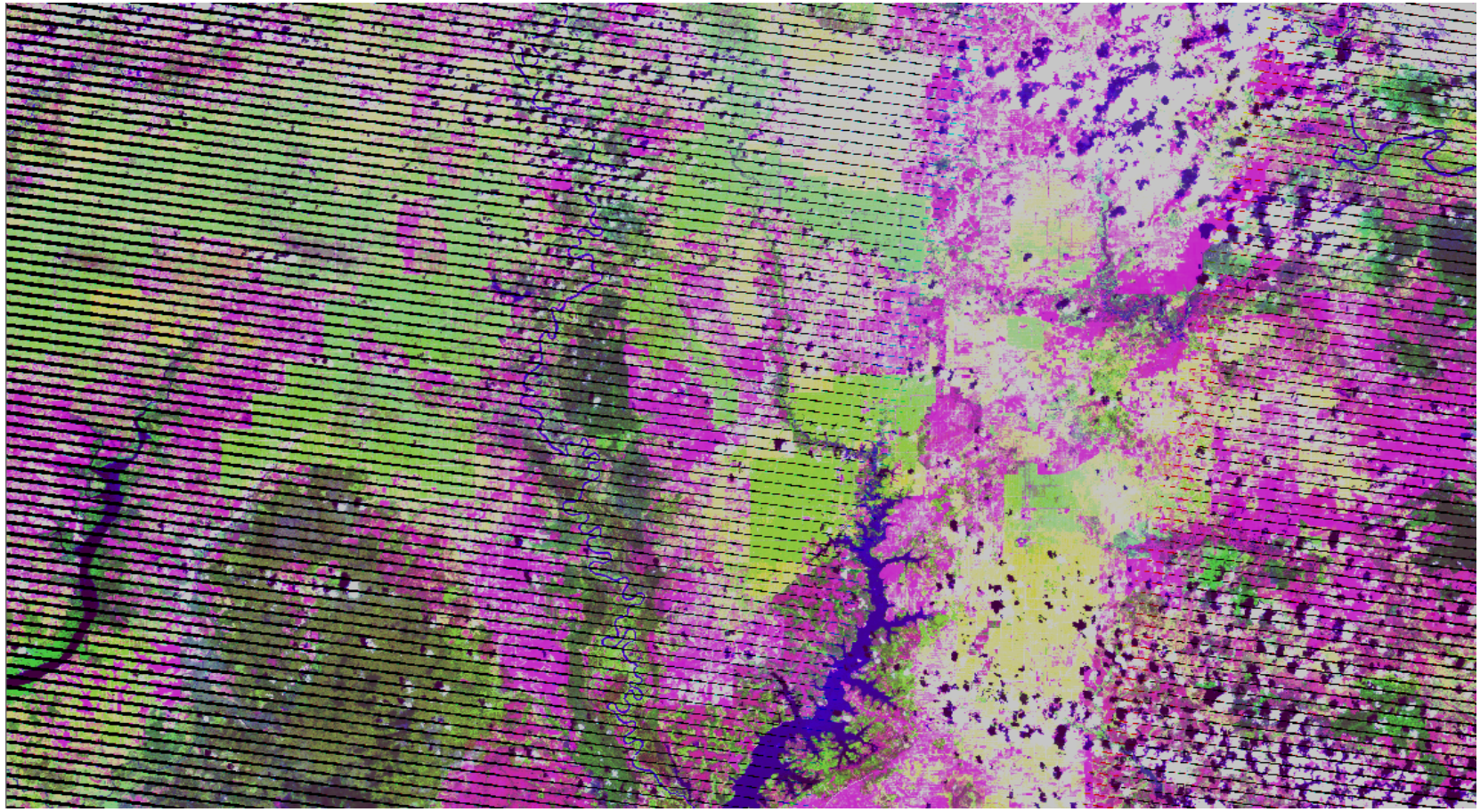
Example: Borneo LULC 2007 comparison



2000 Landsat ETM+ 30m (Geocover) reference

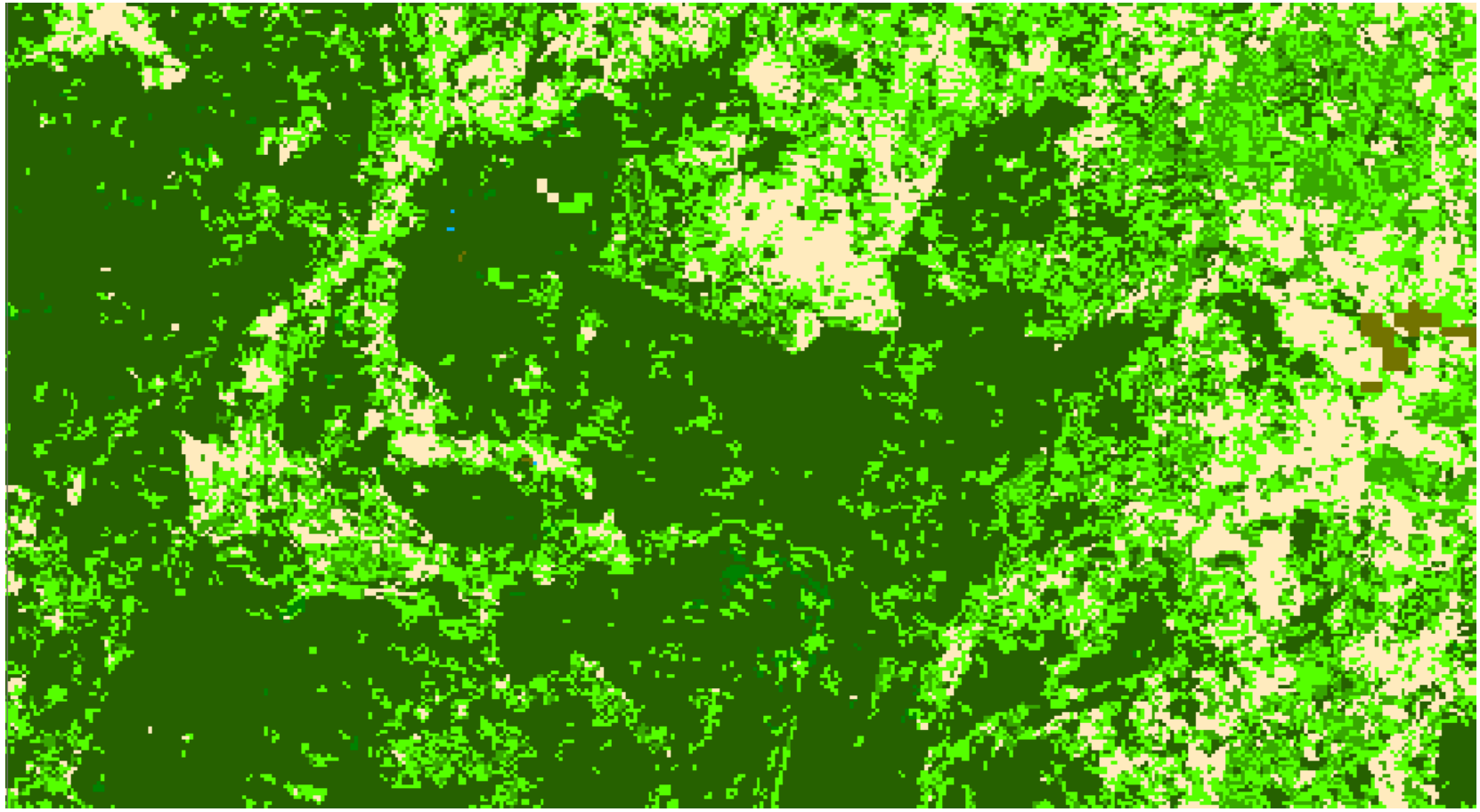
35 km

Example: Borneo LULC 2007 comparison



2008 Landsat ETM+ 30m reference

Example: Borneo LULC 2007 comparison



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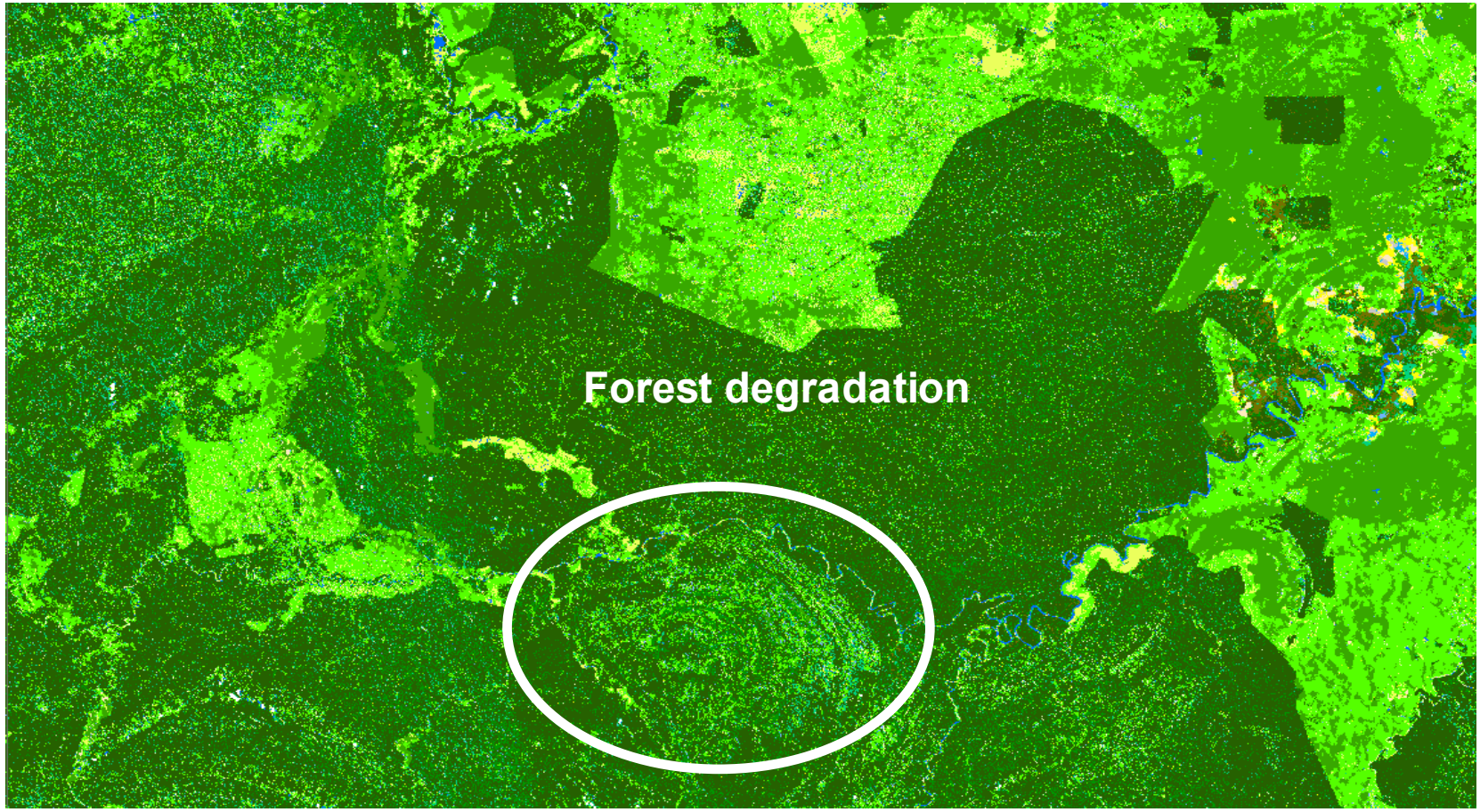

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PALSAR data courtesy:
ALOS K&C © JAXA/METI.

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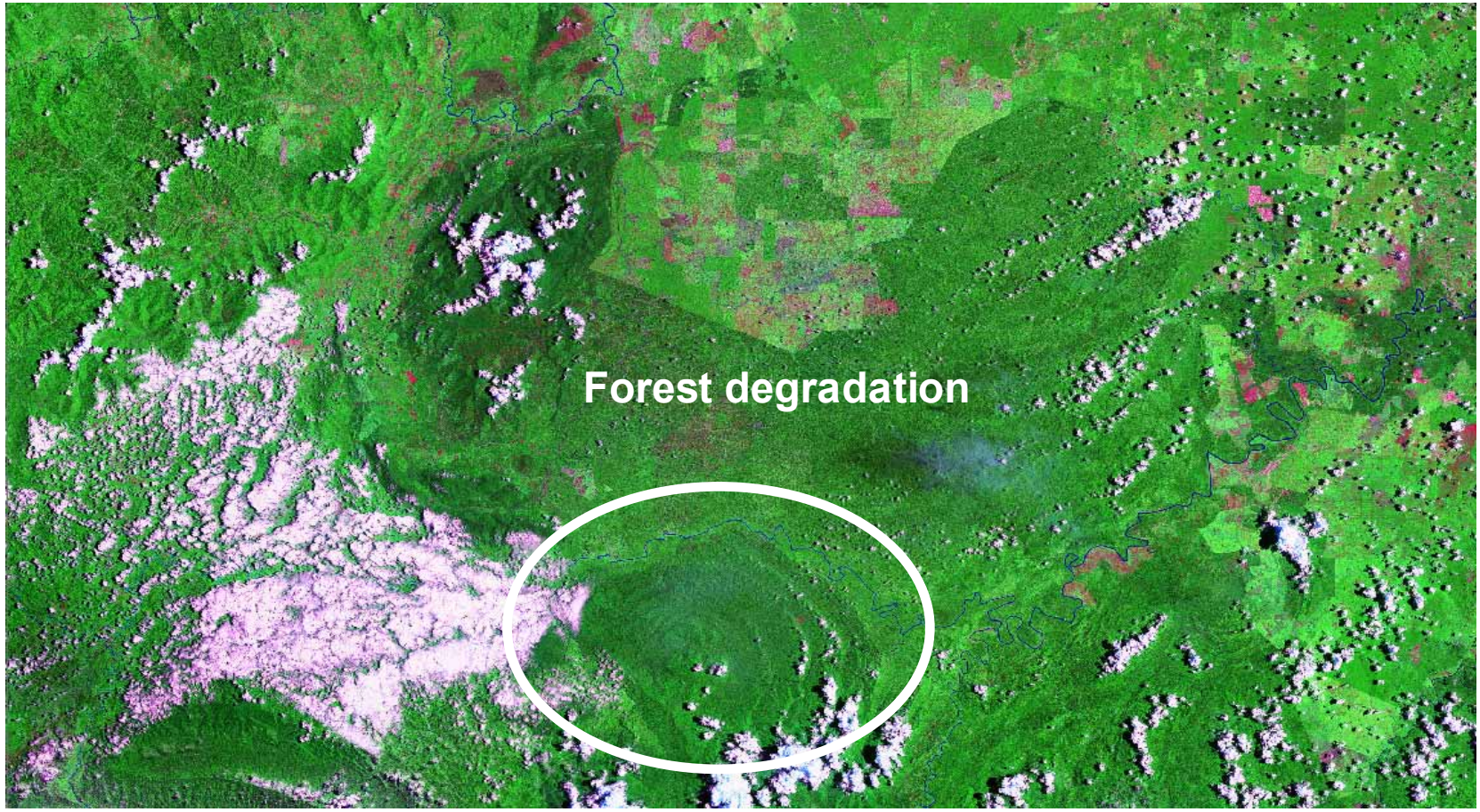

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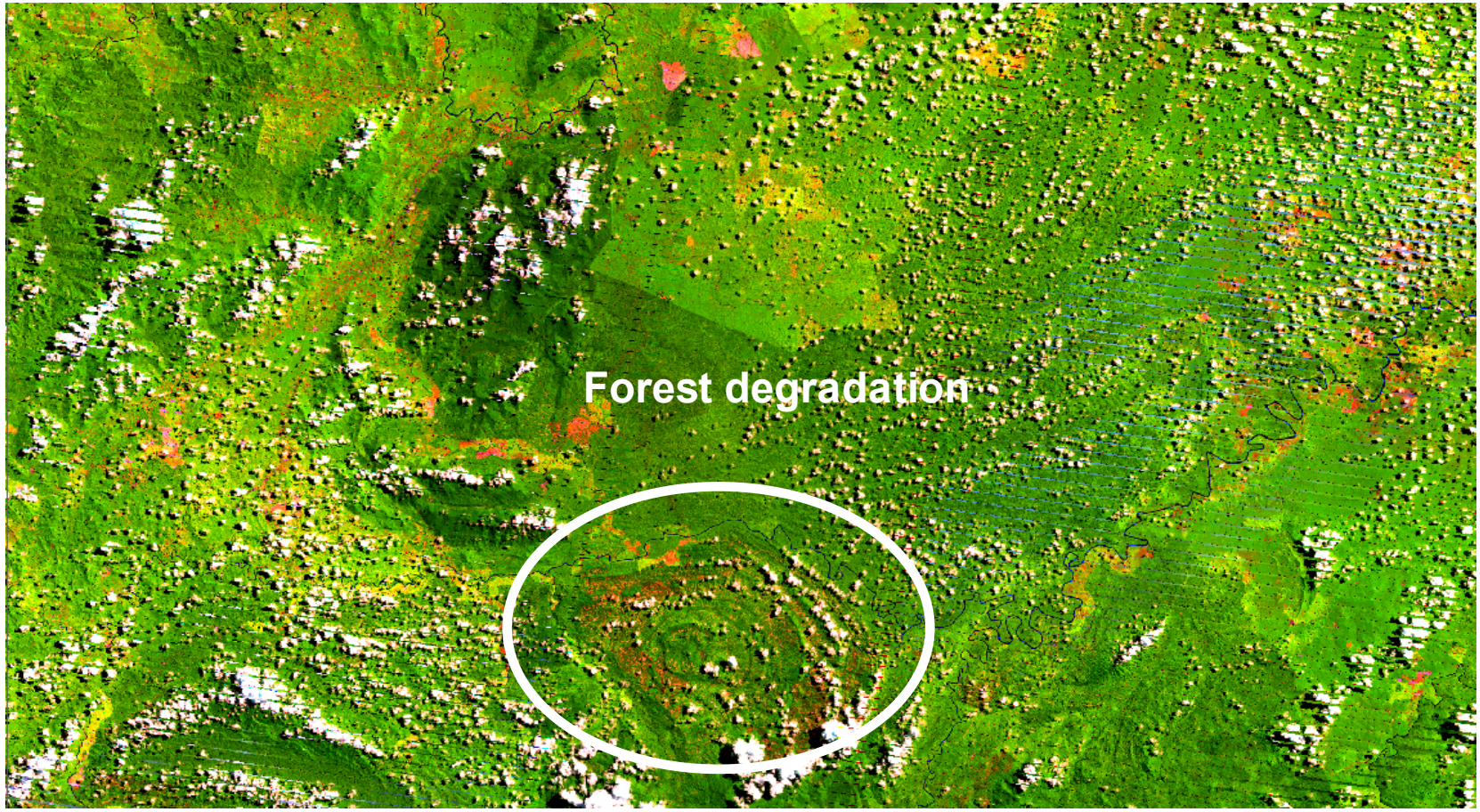

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Quantitative accuracy assessment ongoing following GOFC GOLD best practice guidance:

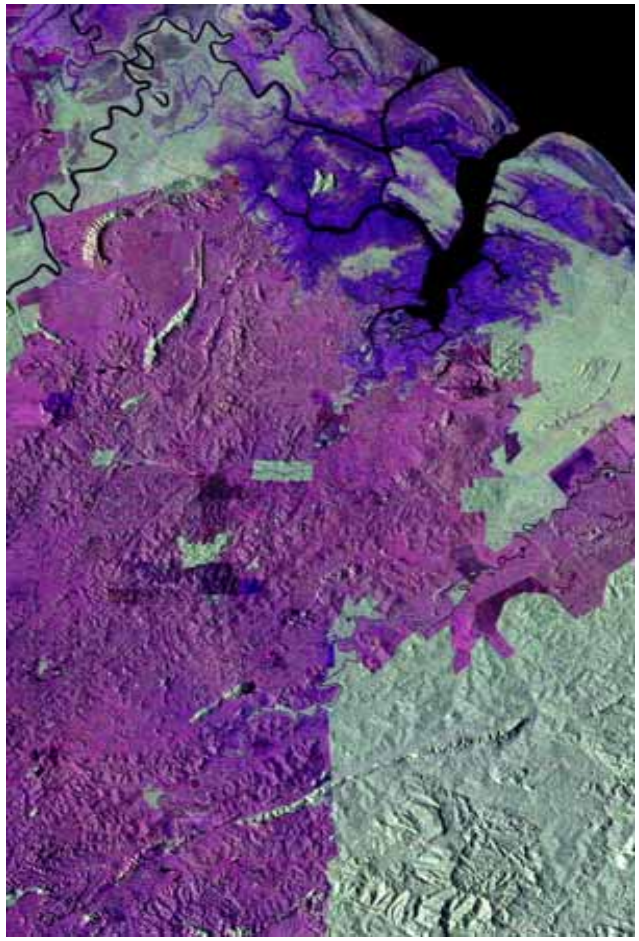
1. Quantitative assessment similar approach as Globcover validation: experts determine LCCS classifiers for large number of validation points

2. Probabilistic classification approach enables production of confidence images: maps showing how well pixels do belong to the assigned class

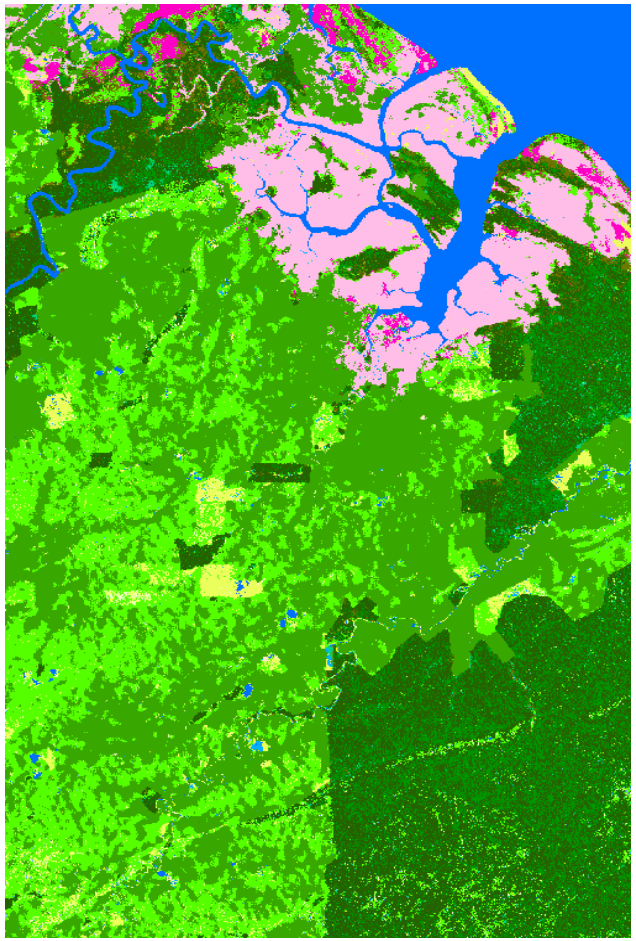
3. Comparison with IKONOS & Quickbird image show disagreement for low biomass / dynamic areas. The reasons are: (a) thematic differences caused by observation techniques, (2) exact timing is critical.

4. These points are now accounted for in the validation procedure.

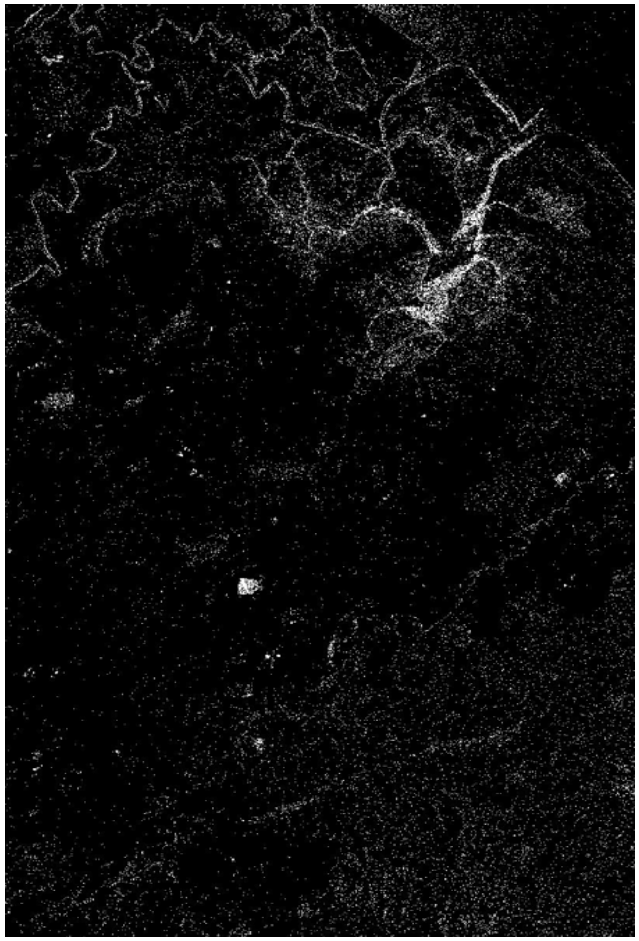
Example: Borneo LULC 2007 comparison



Radar input data



Thematic classification



80% confidence level image

Outliers systematically detected: **isolated pixels**, fuzzy features (such as **mixed pixels** along rivers), and **distinct objects** (potentially resulting from change between dry-wet observations);

For single-year PALSAR-derived thematic maps as produced, the following issues have to be addressed:

1) **Secondary forest and regrowth, dense shrubs misclassified as forest**
-> Solution: using longer term PALSAR time-series, and/or (time series of) optical data;

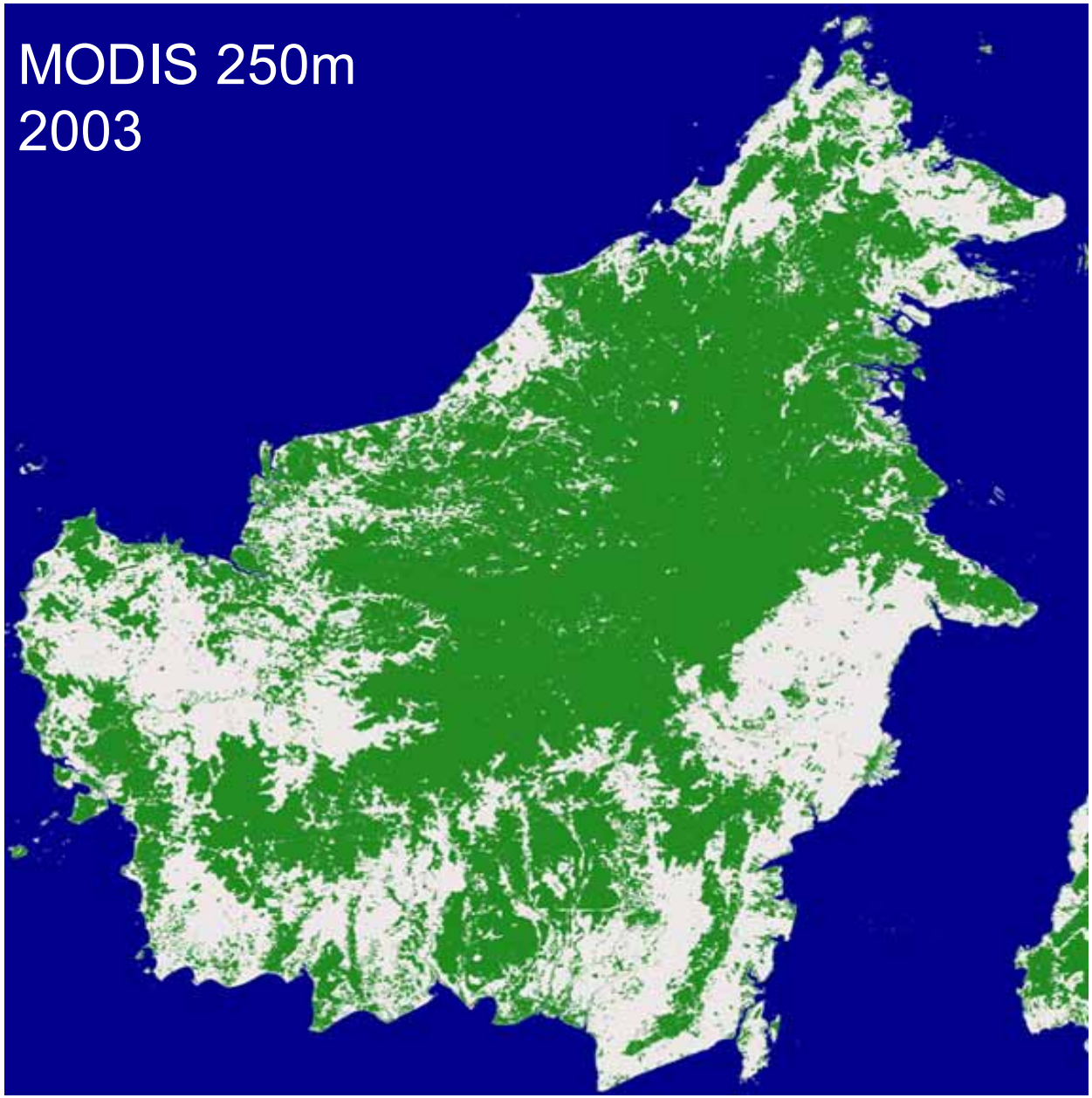
2) **Plantations are often a gradient of growth stages** (i.e. herbaceous to shrub-tree cover)
-> Solution: seperation high biomass shrubs and palms using higher resolution standard PALSAR data (10-15m), further discuss LCCS class definitions (no confusion biophysically);

3) **Burnt forest is confused with shrubs in the floodplain**
-> Solution: e.g. using MODIS hotspots or ASAR APP forest change;

4) **Urban areas are poorly detected**
-> Solution: e.g. using optical and/or ASAR APP

5) **Locally relevant class Nipah (palm-mangrove) is confused with early regrowth**
-> Solution: using longer term PALSAR time-series.

Interoperability (with MODIS, ENVISAT ASAR)

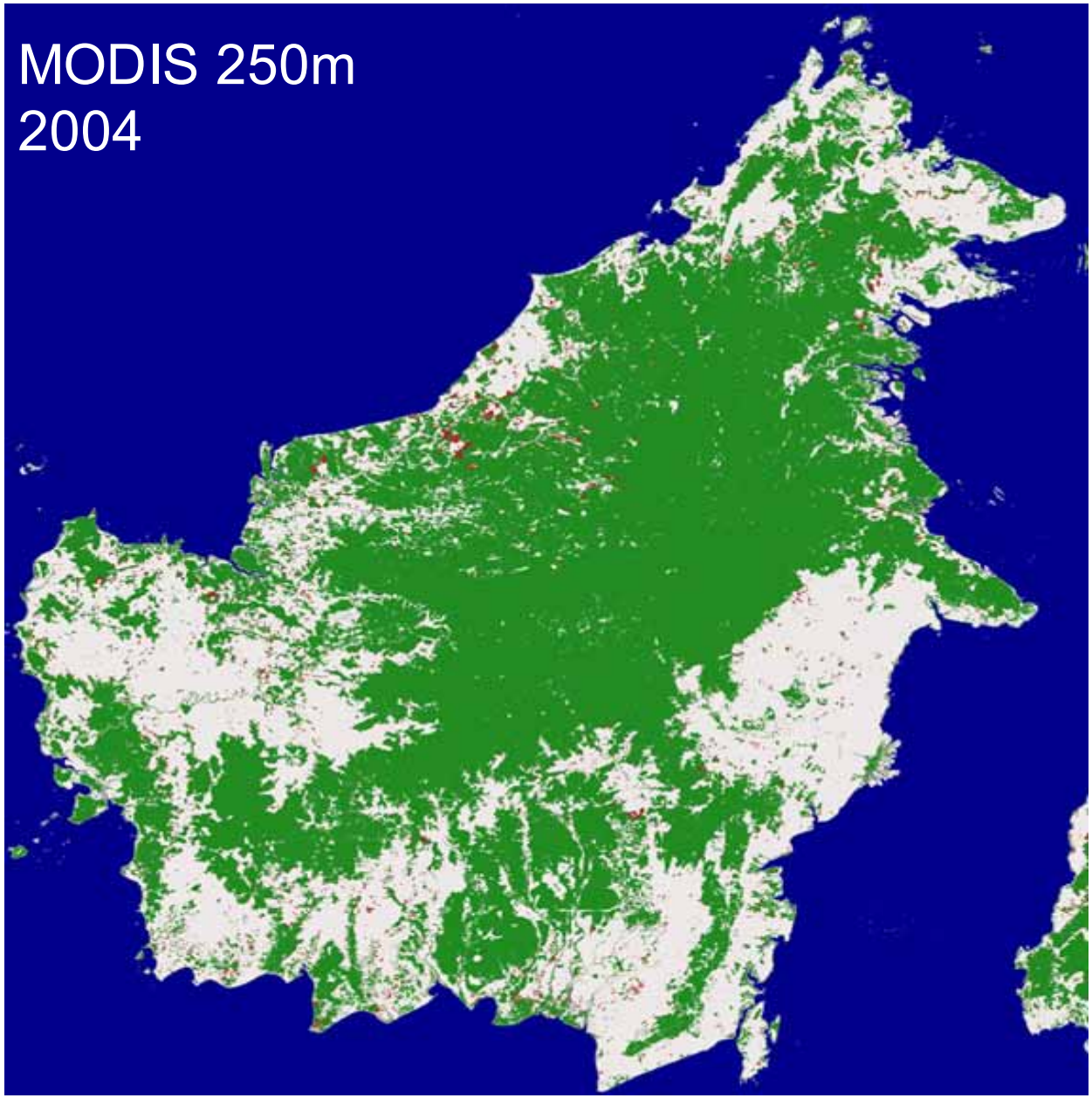


Example: use MODIS time-series since 2000/2001:

Identify deforestation hotspot areas, areas of secondary forest (regrowth)

Forest; non-forest;
new deforestation;
old deforestation

Interoperability (with MODIS, ENVISAT ASAR)



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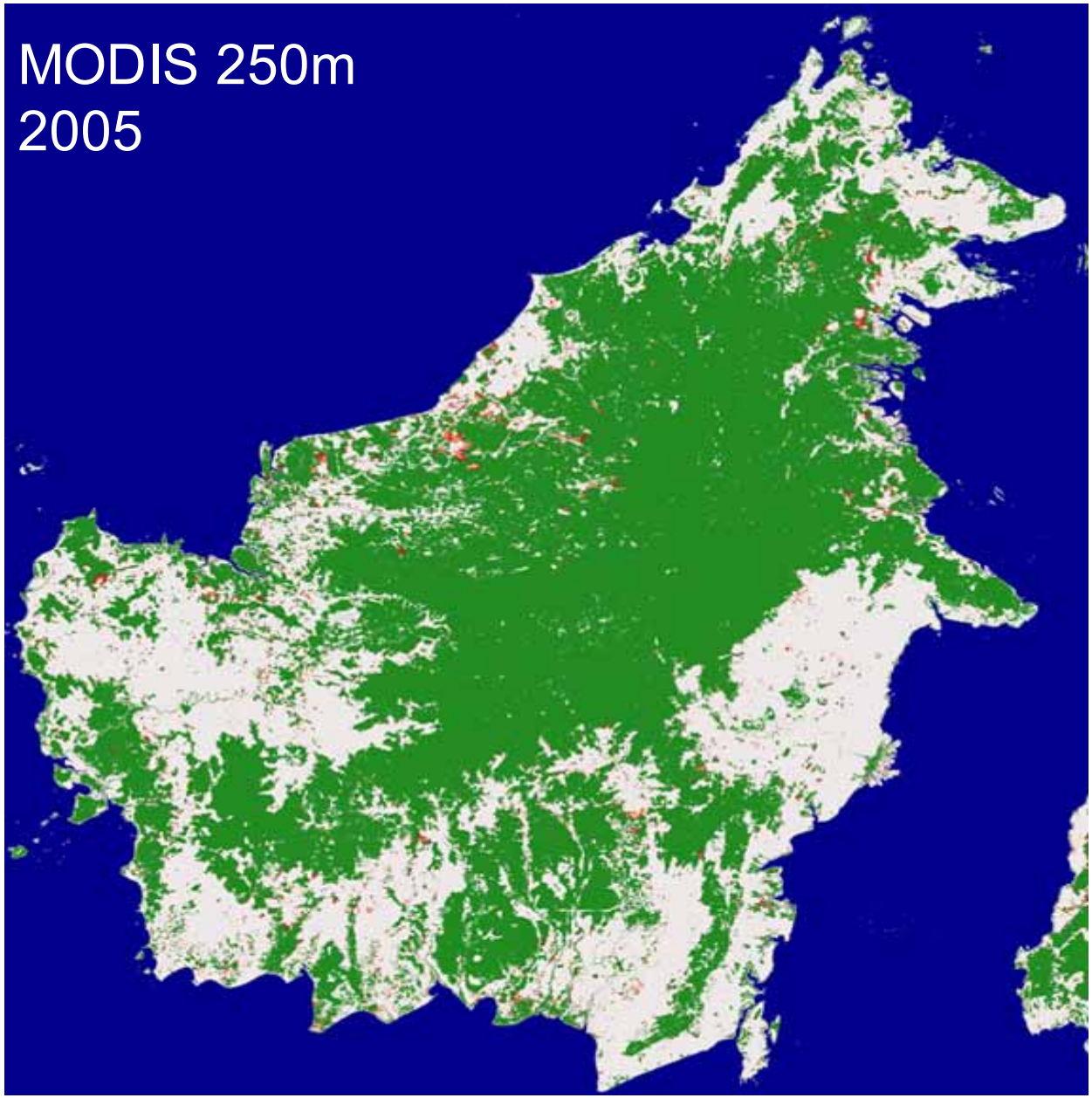

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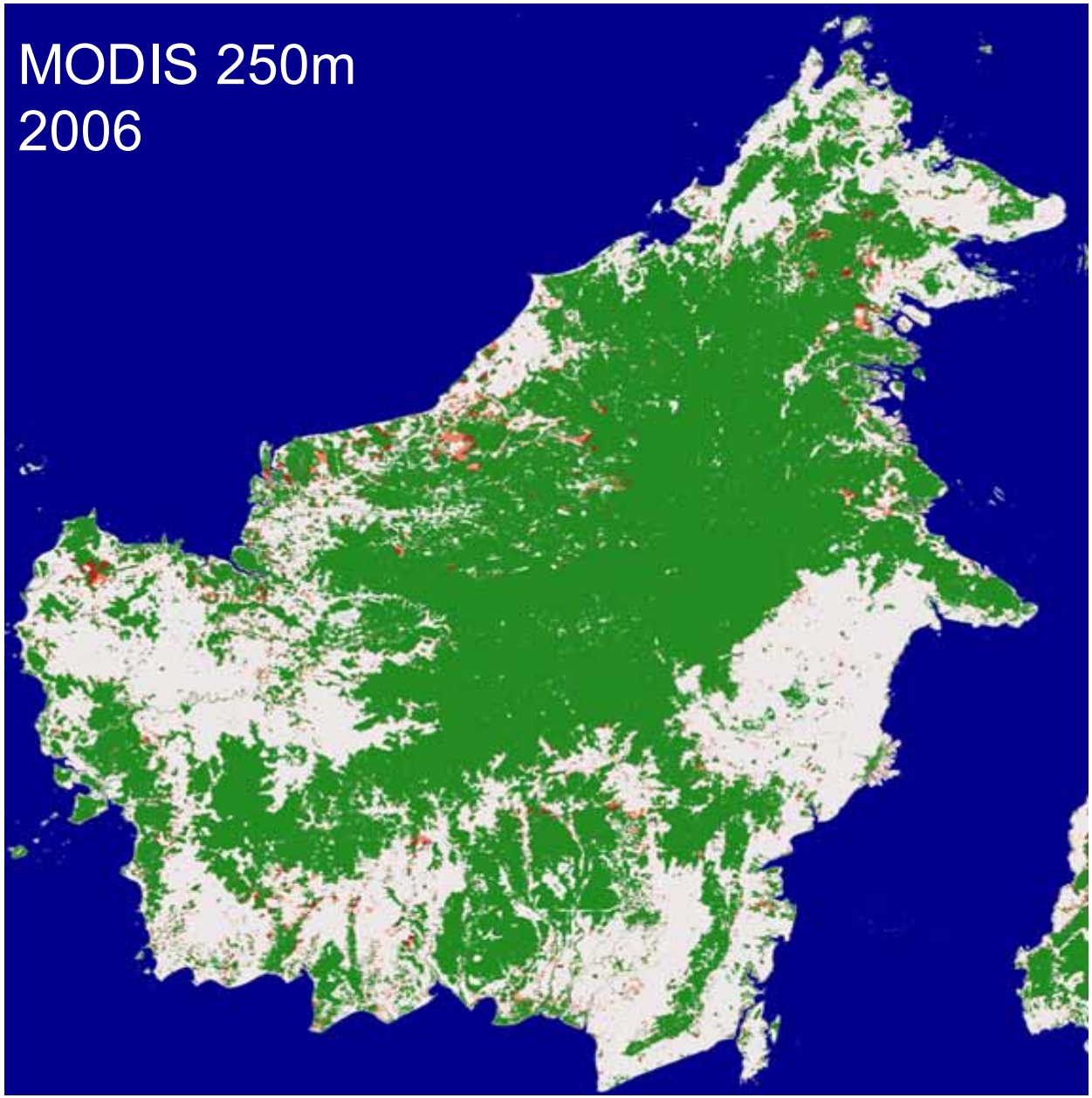

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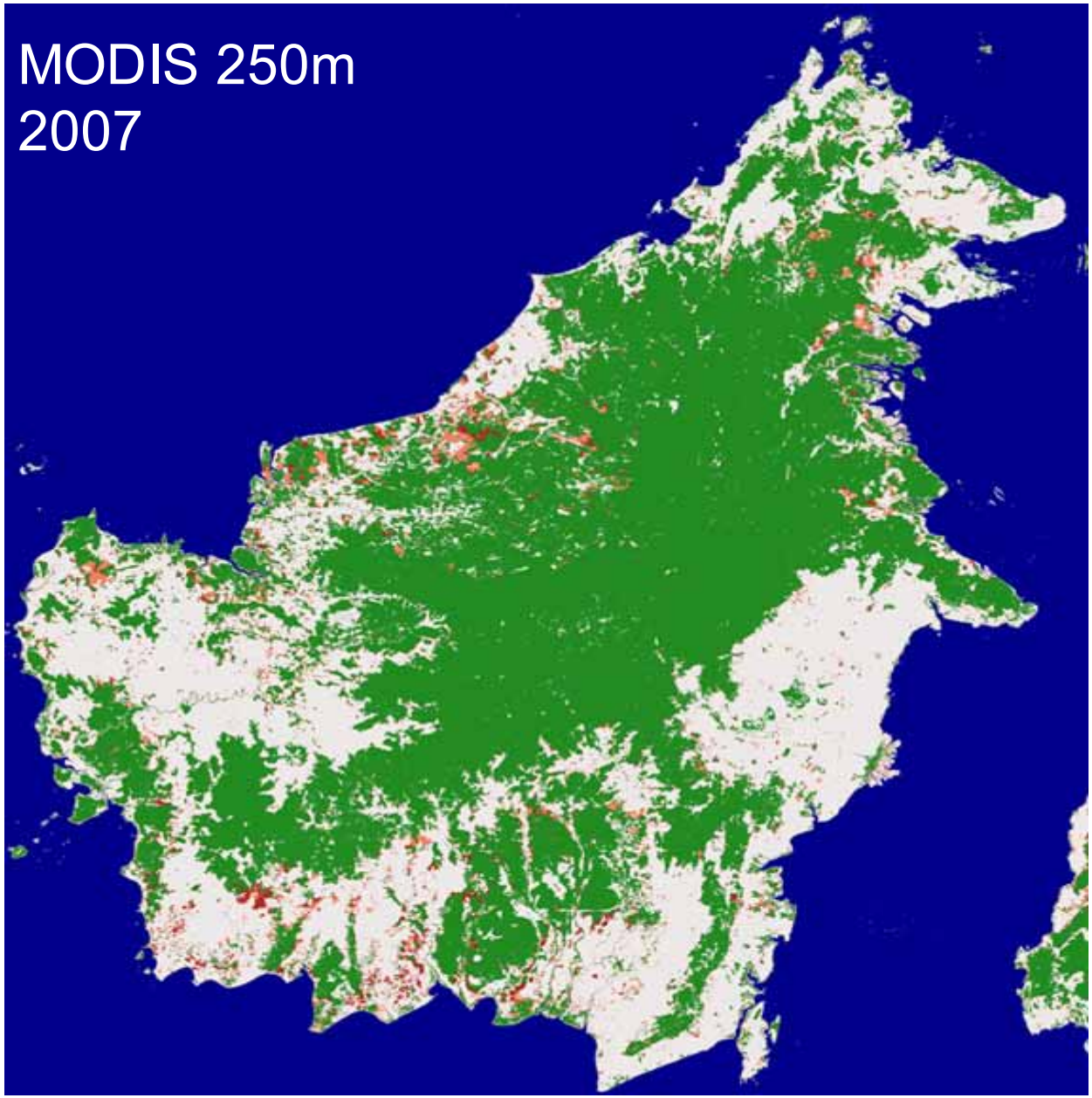

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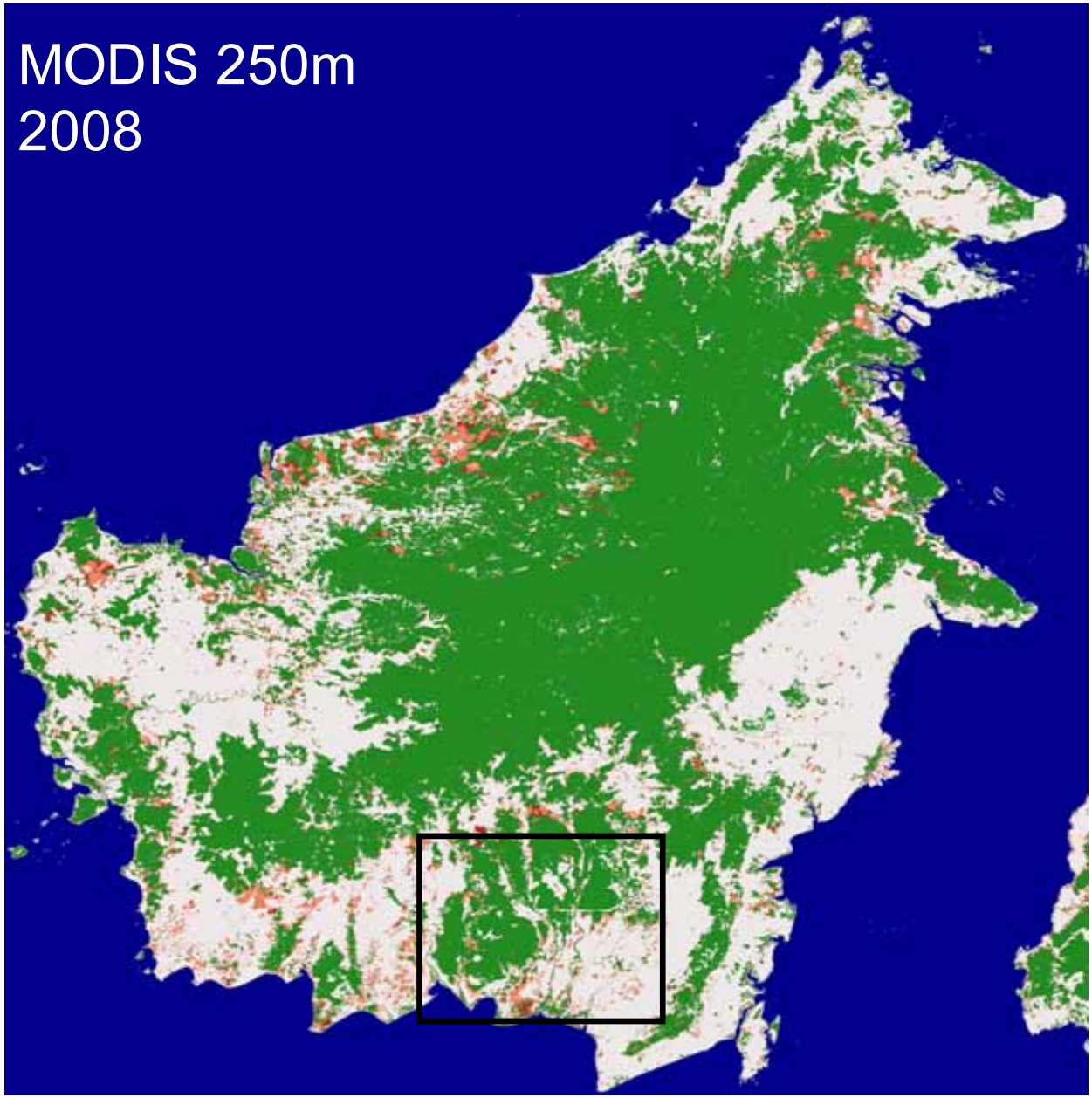

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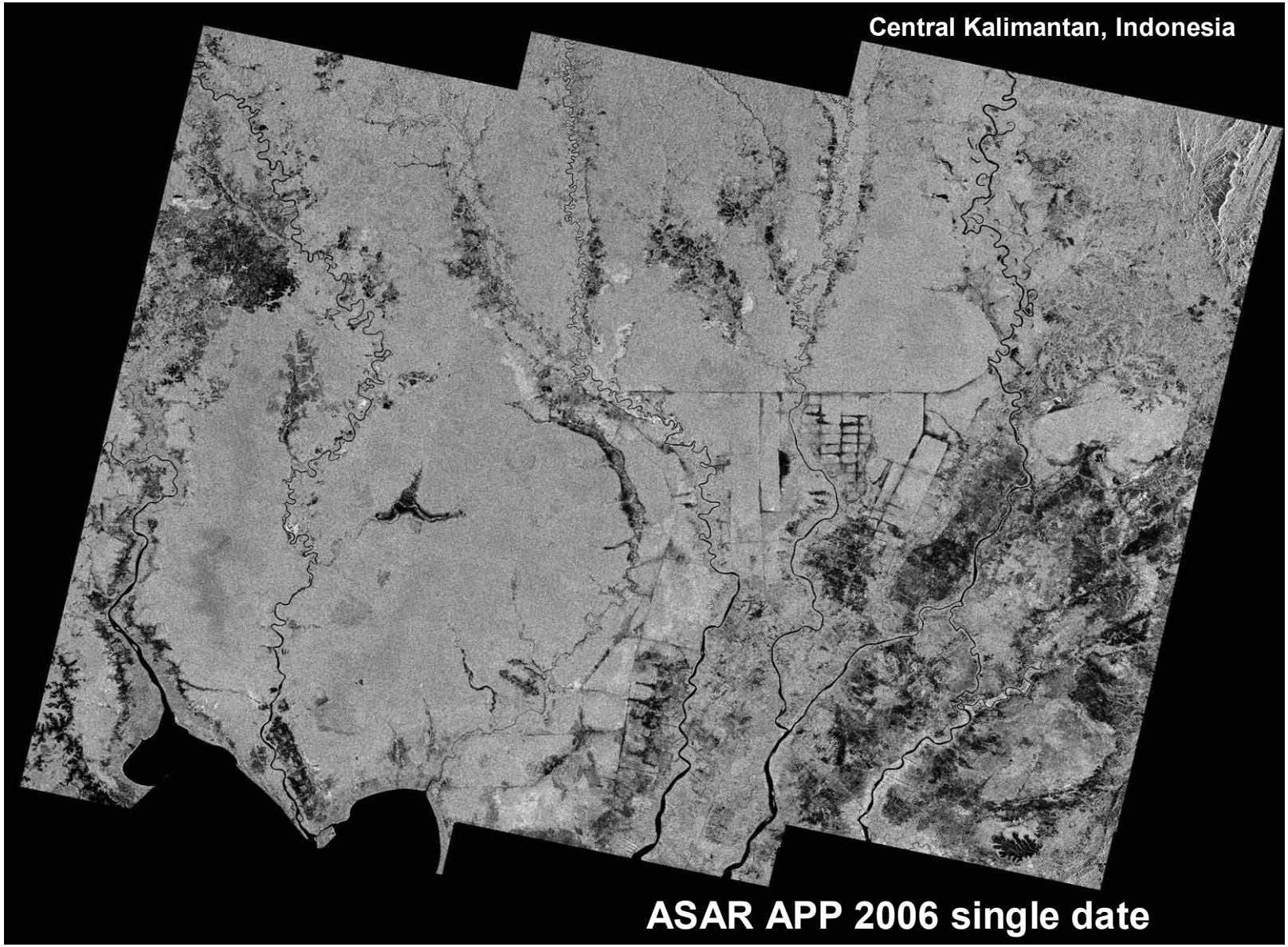
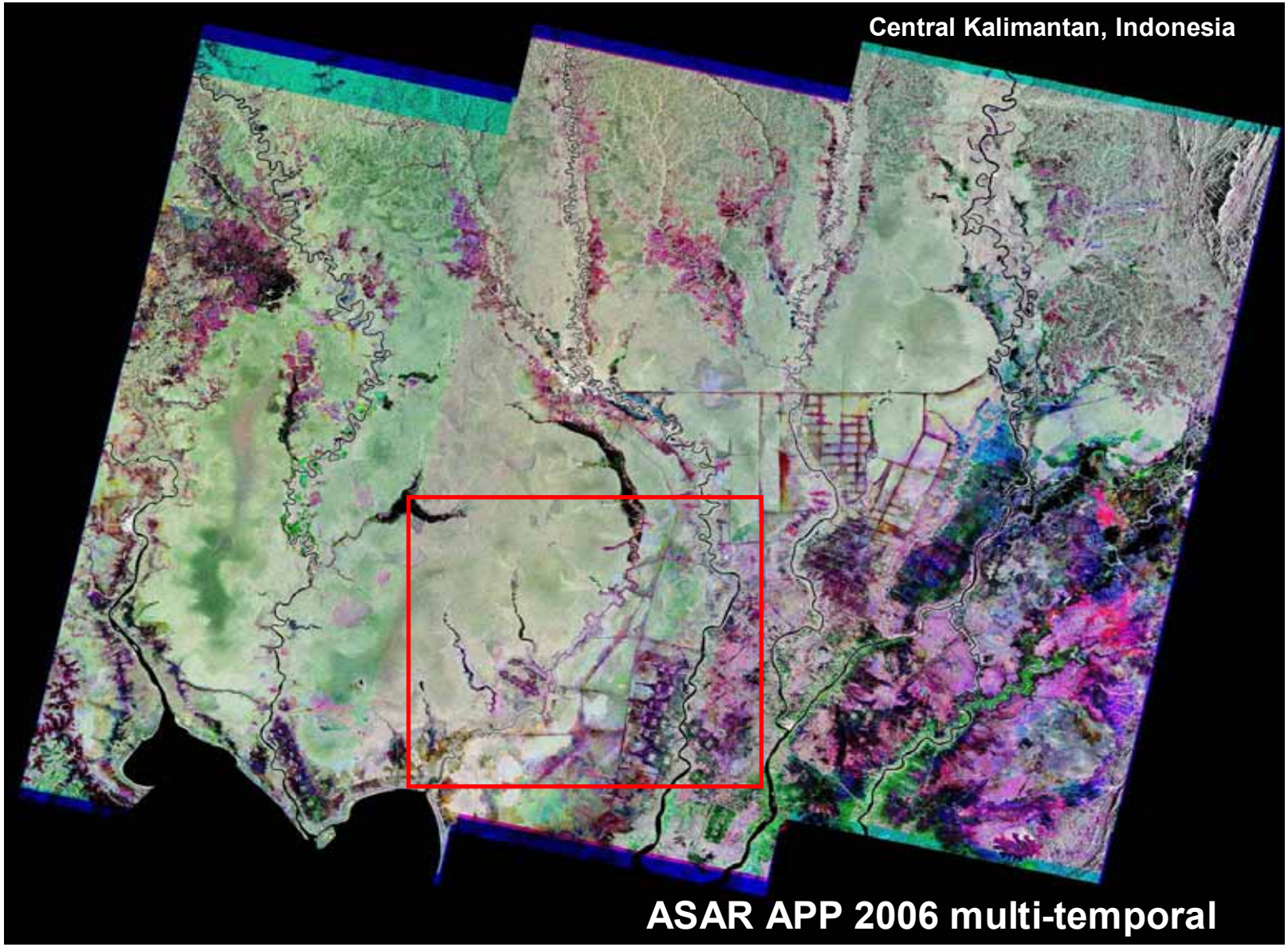
old deforestation

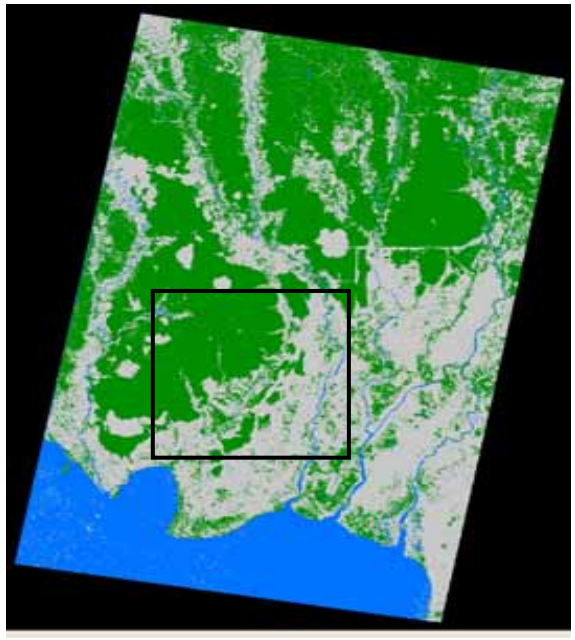
Interoperability (with MODIS, ENVISAT ASAR)



Interoperability (with MODIS, ENVISAT ASAR)



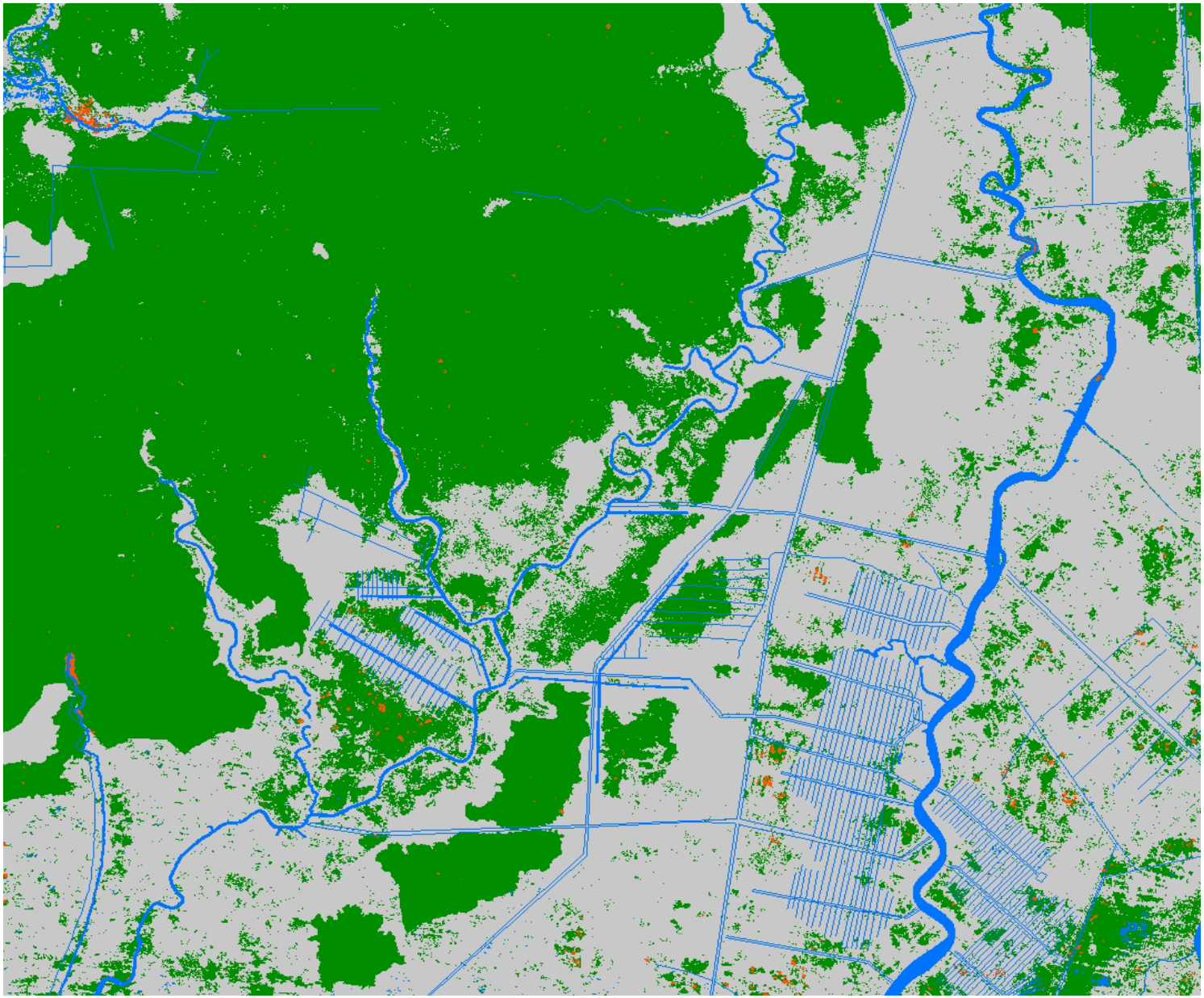
Interoperability

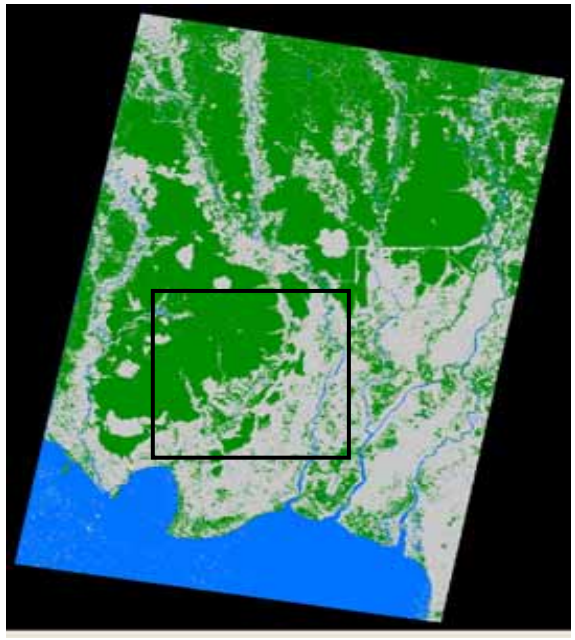


Forest mask

2005 base year

Interoperability



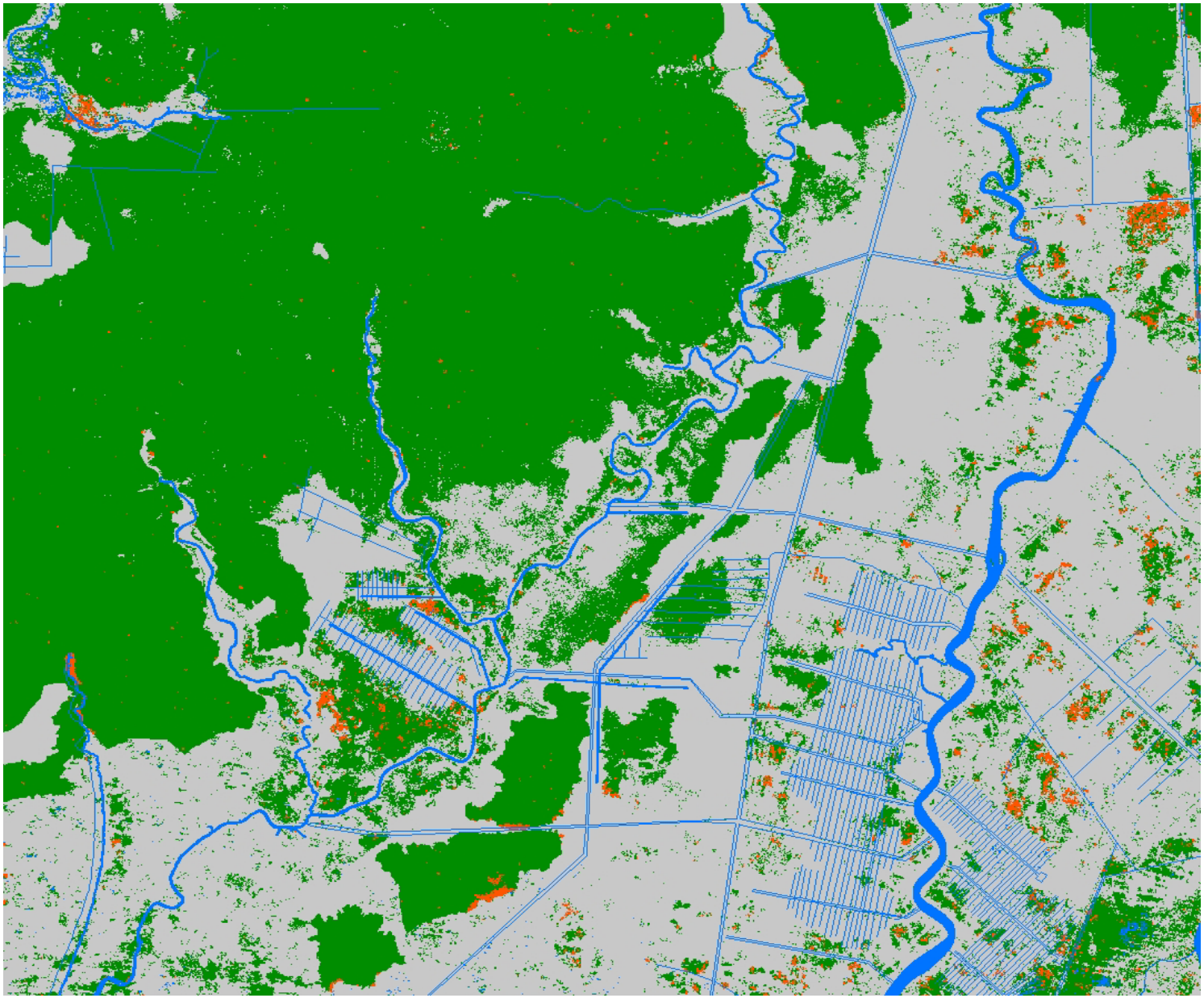


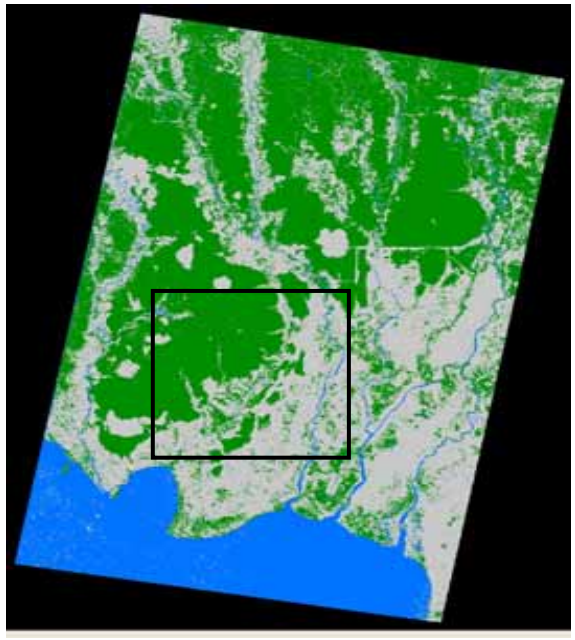
Orange – forest change

Radar changes

2006 Jan- Mar

Interoperability



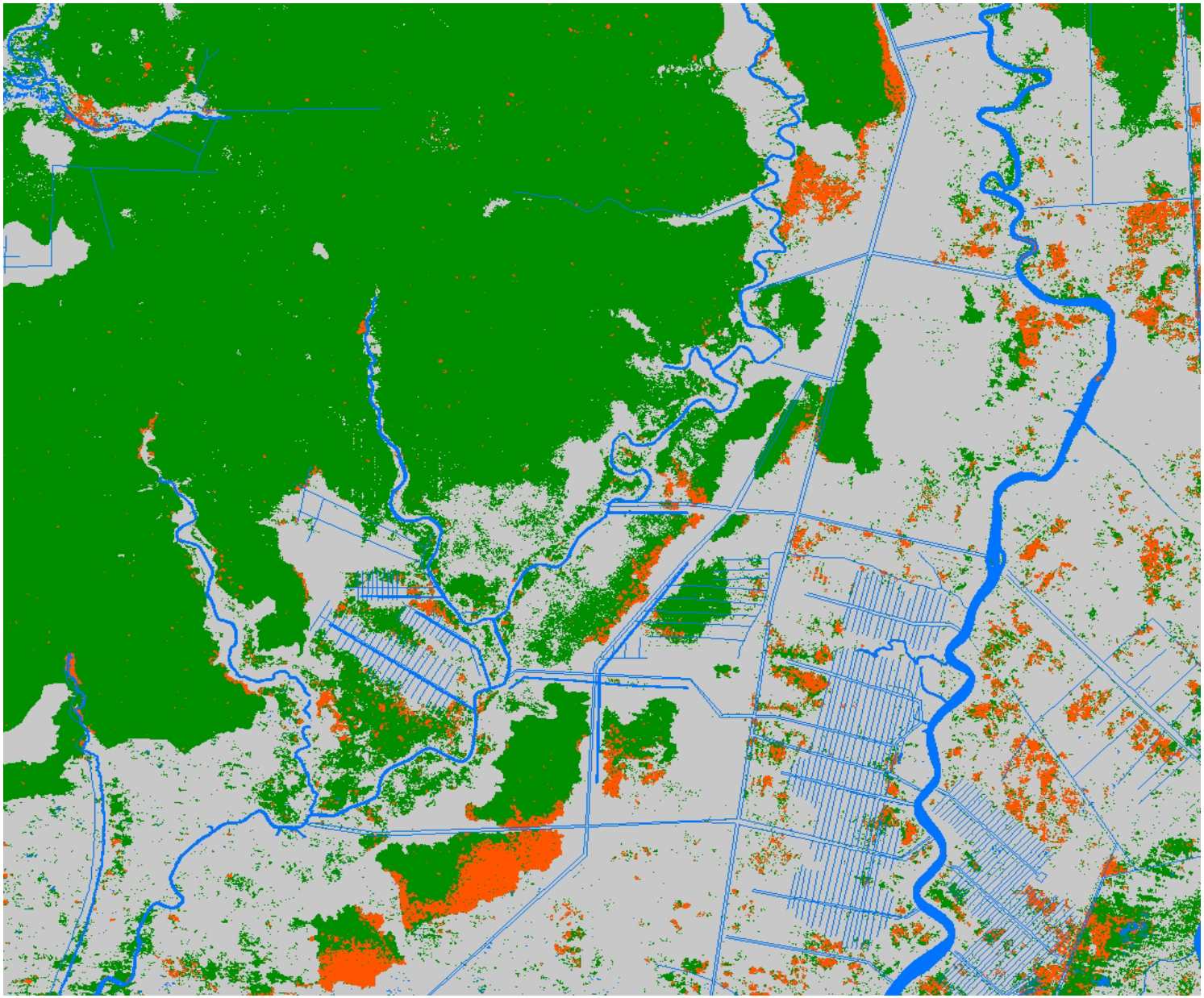


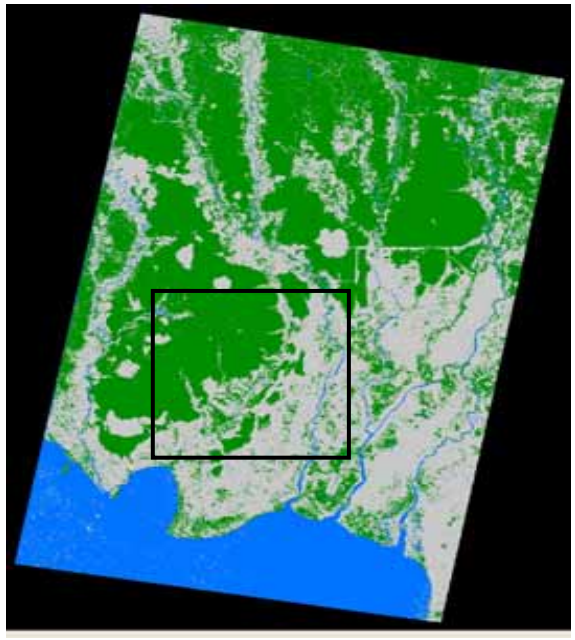
Orange – forest change

Radar changes

2006 Apr- Jun

Interoperability



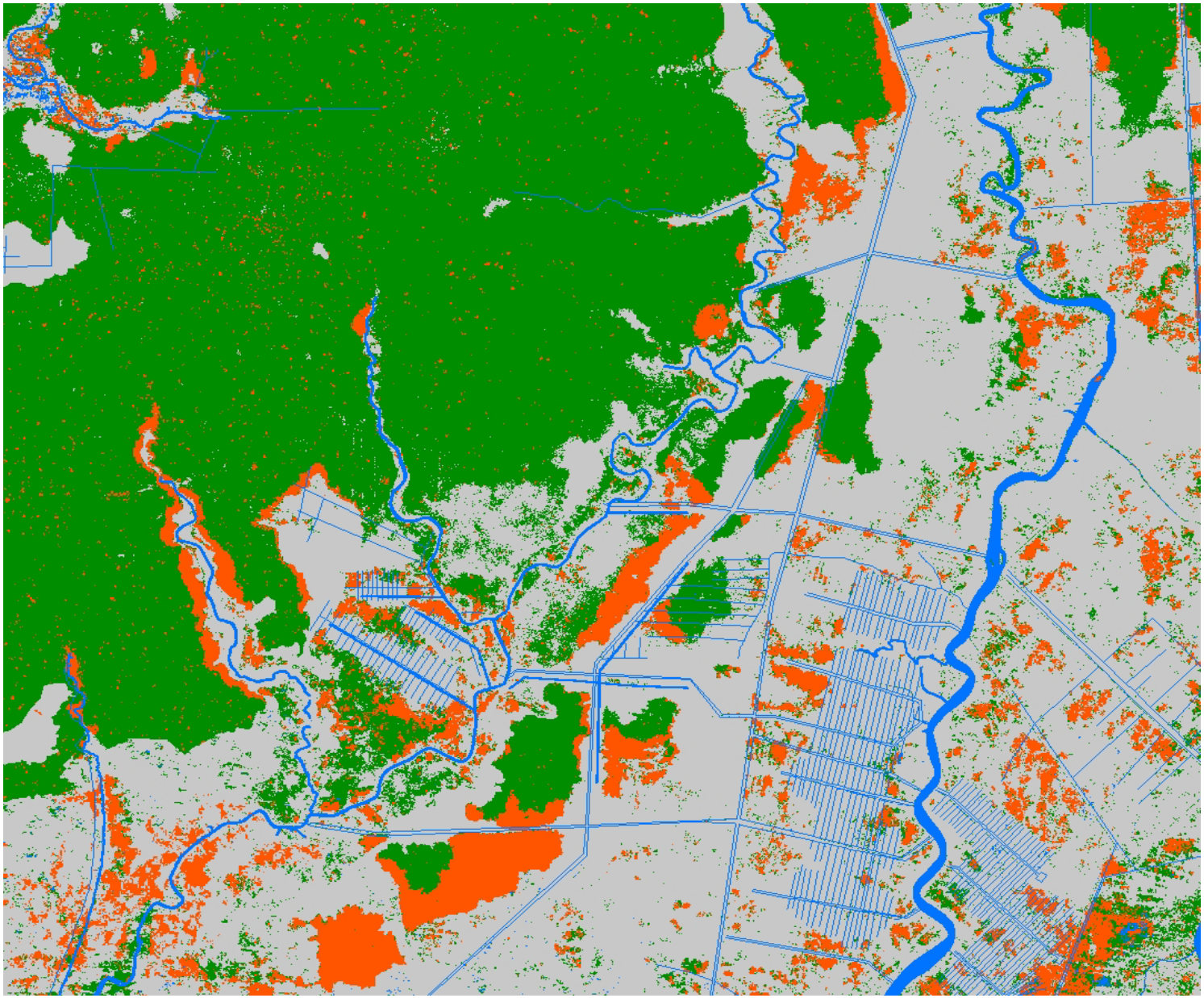


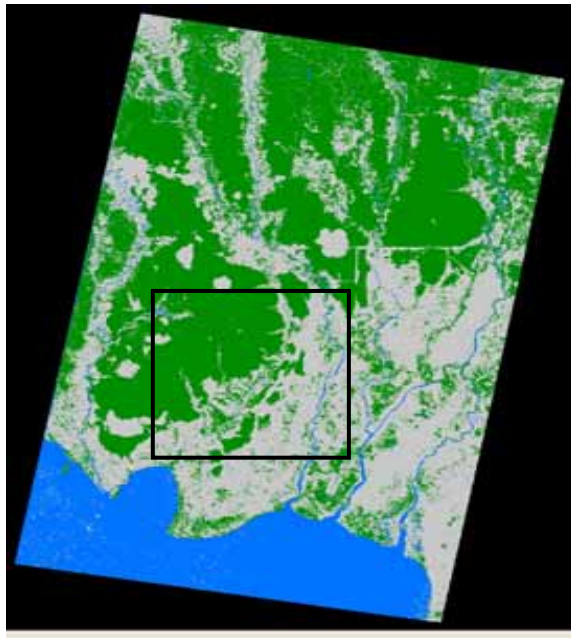
Orange – forest change

Radar changes

2006 Jul- Sep

Interoperability



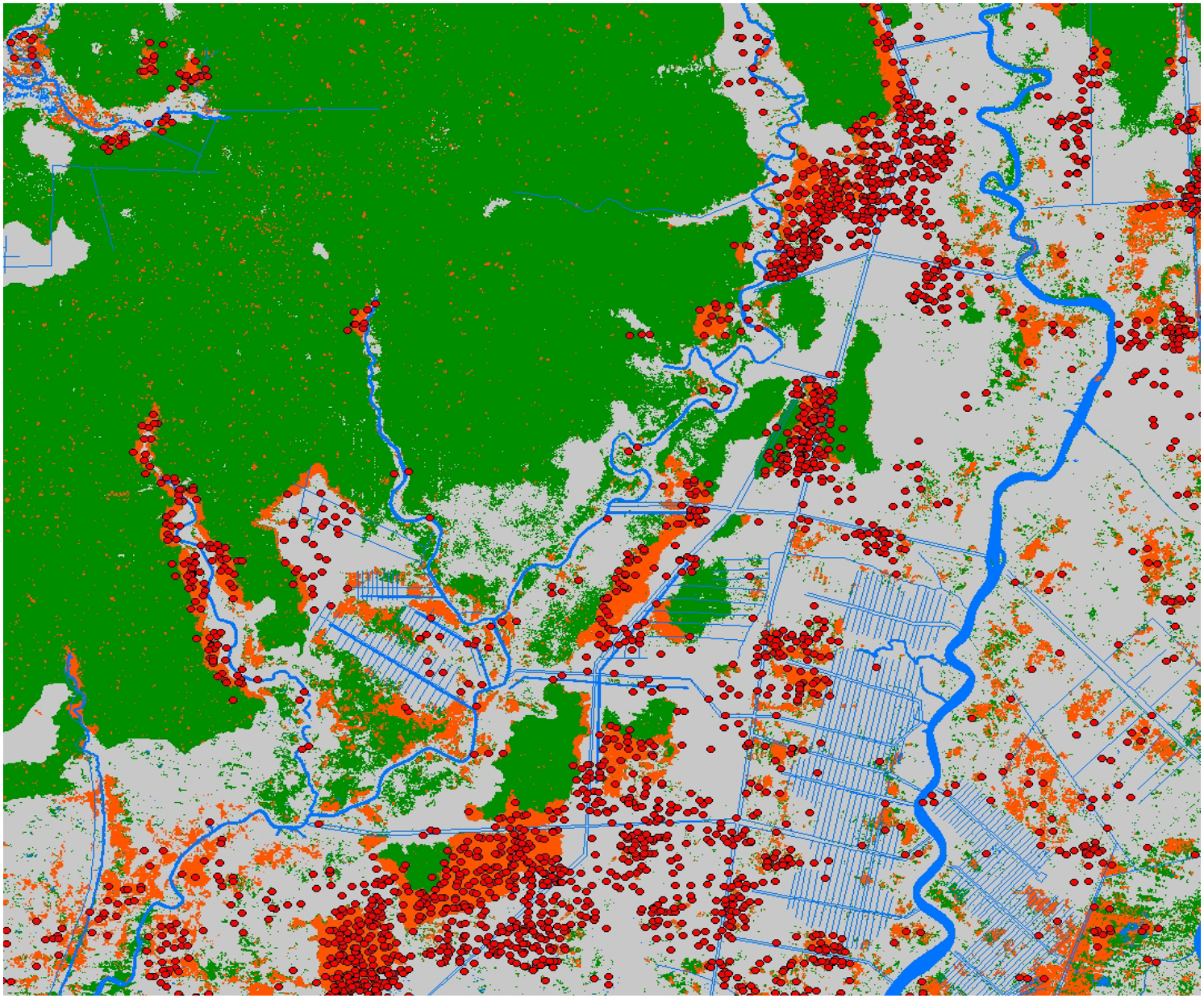


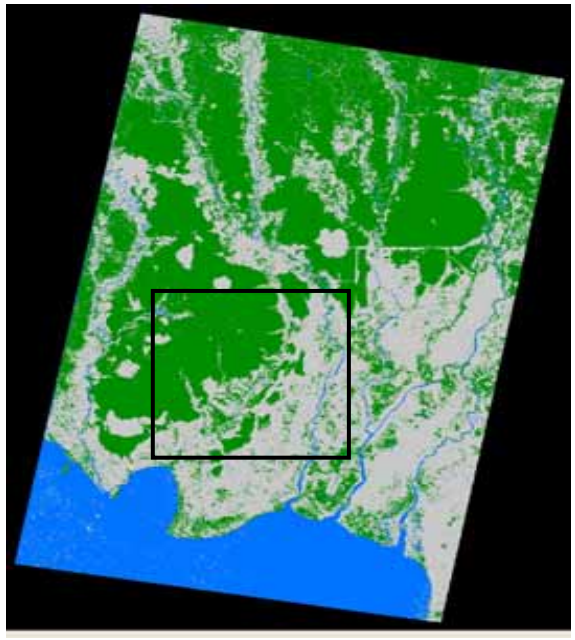
Orange – forest change

Radar changes

2006 Oct- Dec

Interoperability



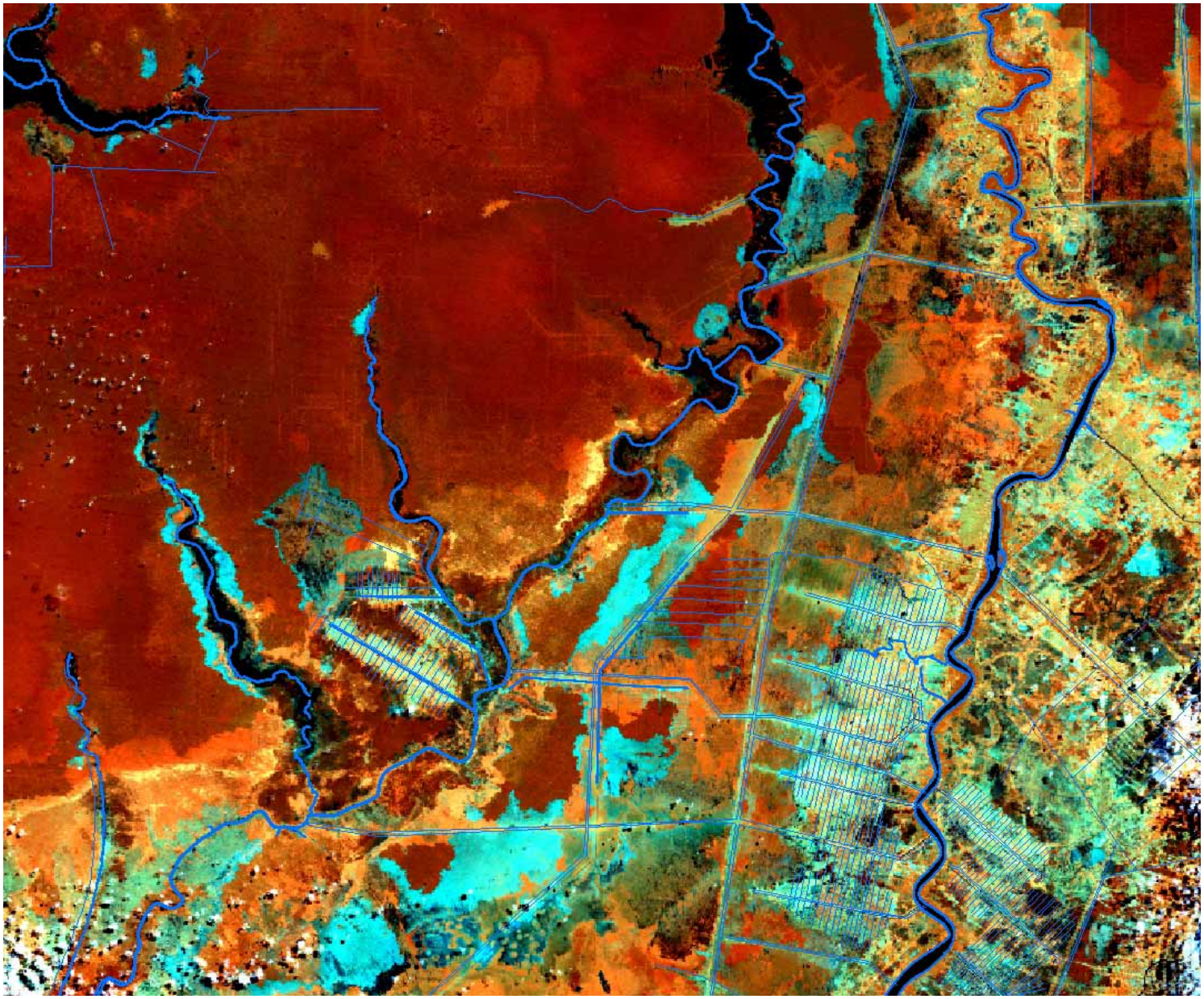


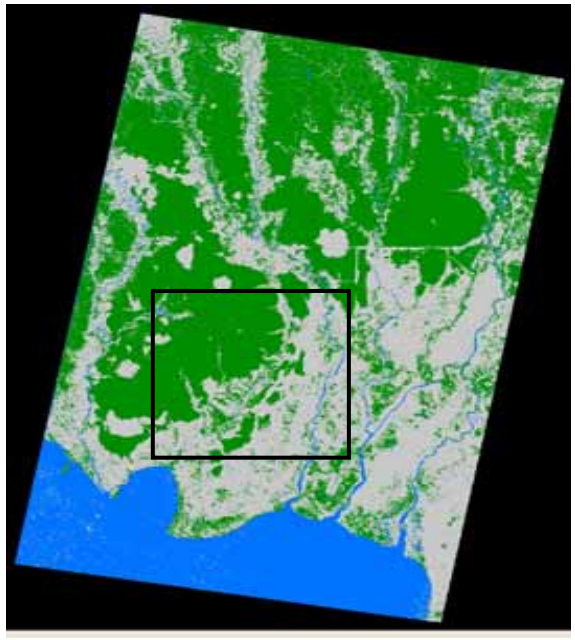
Orange – forest change

● – fire detection

2006 fire detections

Interoperability

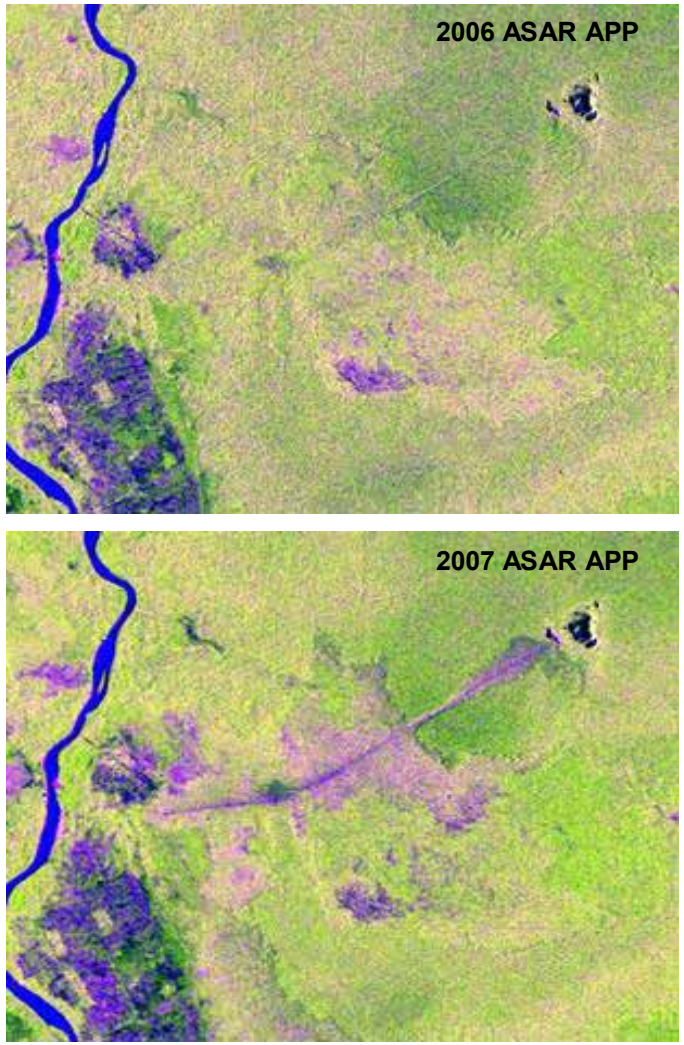




Landsat 457

2007 control

Interoperability

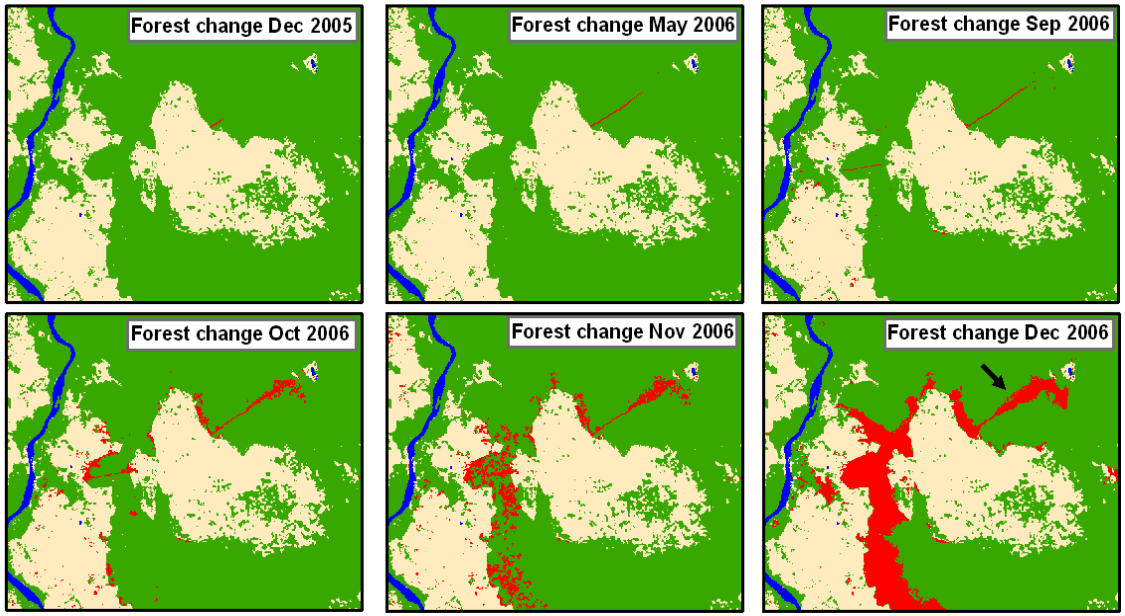


Satellite data courtesy ESA, processed by SarVision

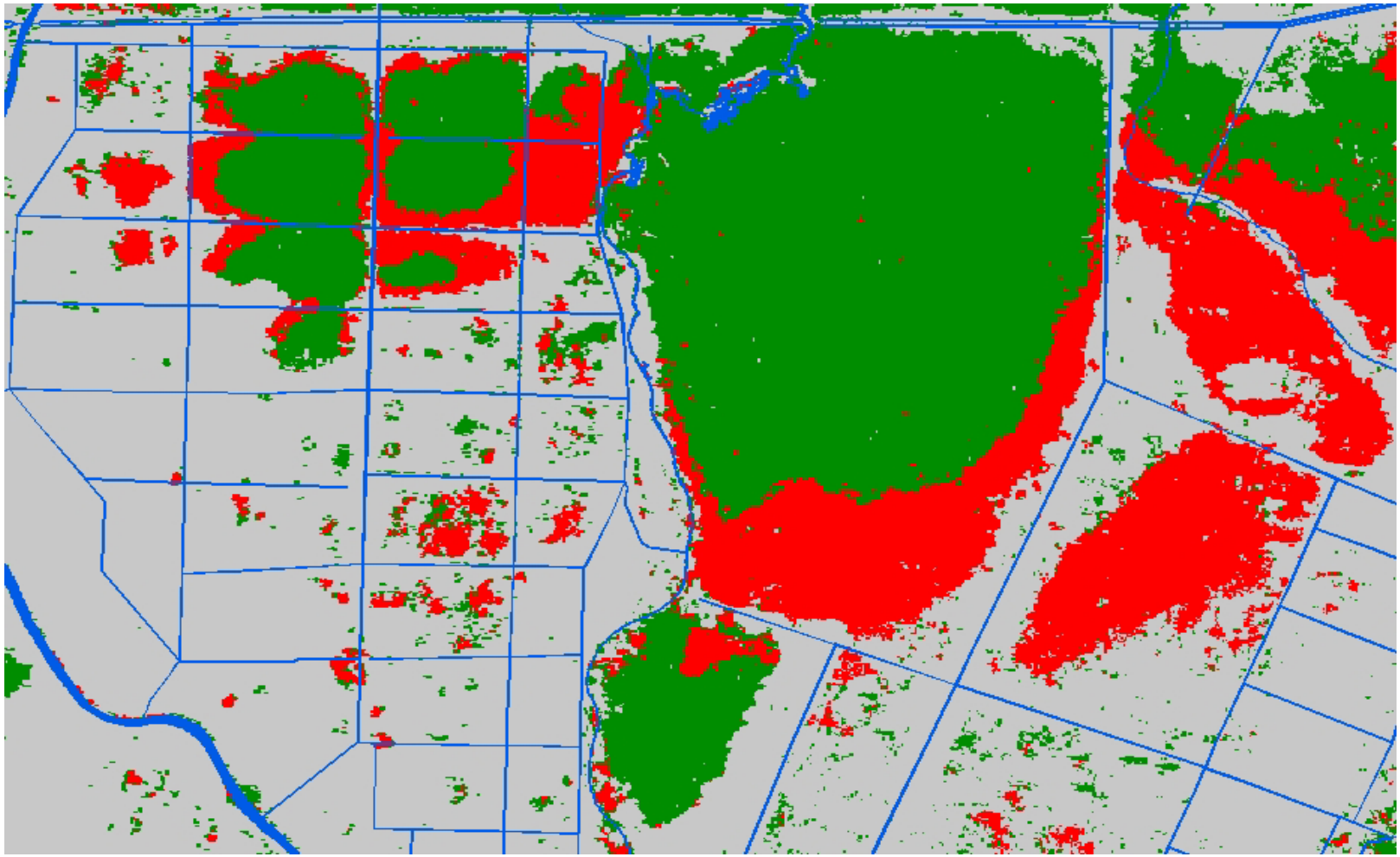
Zoom in to 25x27km area

ENVISAT ASAR APP has been demonstrated in a 200x300km area in Borneo as a unique, fast and reliable tool for operational deforestation monitoring

We propose to use PALSAR to map forest and add SENTINEL-1 to monitor tropical deforestation

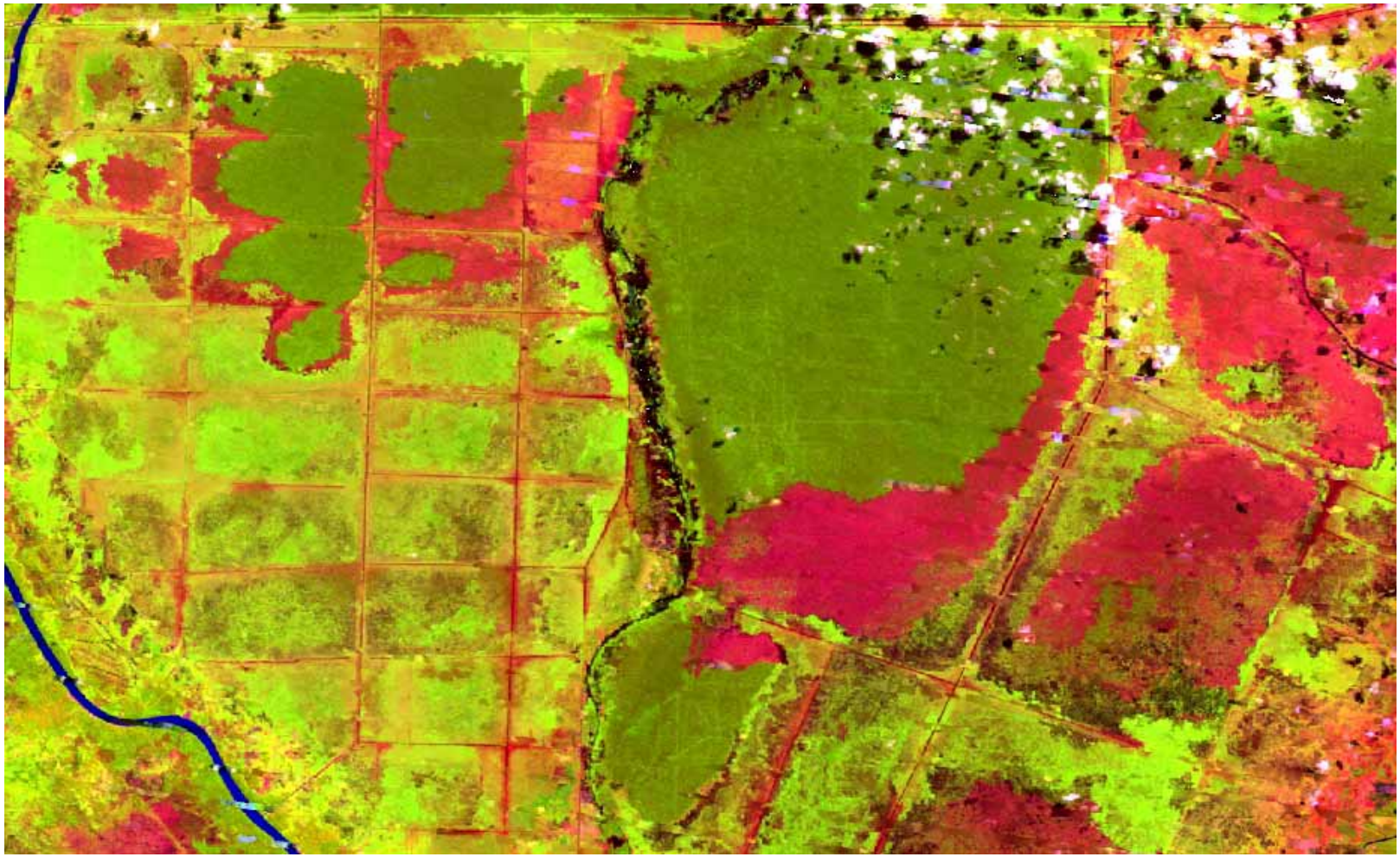


Interoperability



2005 – Dec 2006 ASAR forest change (red: change)

Interoperability



2007 July : first good Landsat image (10 months later)

Conclusions

- Wide-area operational radar mapping is feasible, yielding spatially consistent and timely wall-to-wall coverage of key vegetation types required
- Use of radar can help address known flaws of Globcover in tropical forest areas
- Time-series and interoperability with other optical and radar sensors are recommended
- Achieving comparable results using different sensors will help to achieve the confidence required for operational monitoring

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Thank you