

Experiments on Landsat scene 227-062 in Brazil

- Multiple image registration
- Forest / non forest mapping
- Forest change detection

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Purpose

Grant by Norwegian Space Centre to **evaluate appropriateness** of methods developed by the Norwegian Computing Center, applied on time series of satellite images of **tropical forest**

- ▶ **Multiple image registration:**
 - Automatic **co-registration** of images down to sub pixel accuracy
 - Essential for subsequent **change detection**
 - Images from the same (or similar) sensor.
 - Model-based **georeferencing** based on satellite parameters **has already been done**
- ▶ **Forest / non-forest mapping:**
 - Yearly forest inventory
 - Handle **missing data** due to clouds and Landsat 7 SLC-off
- ▶ **Forest change detection:**
 - **Eliminate errors** introduced by simple comparisons of yearly inventories
 - Handle **missing data** due to clouds and Landsat 7 SLC-off

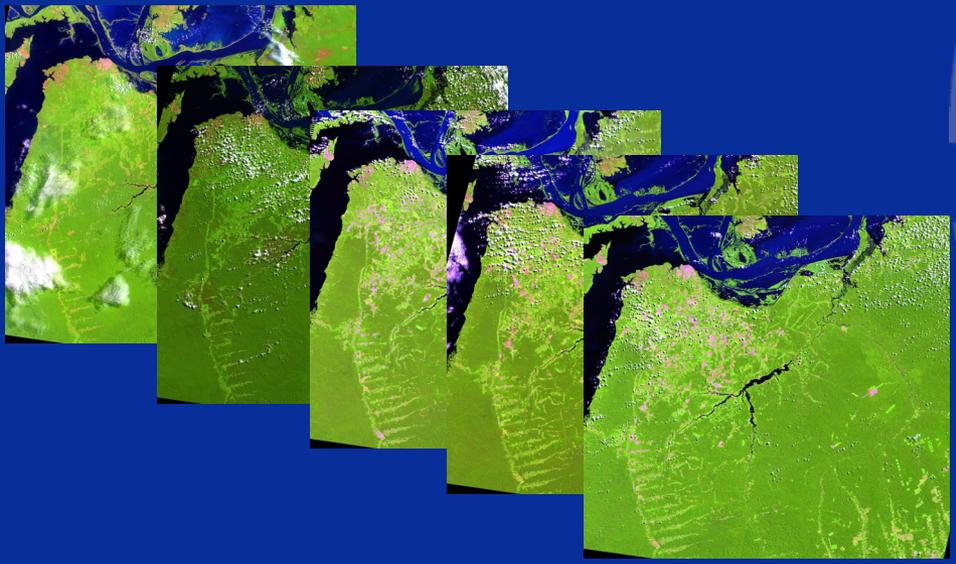


Conclusions

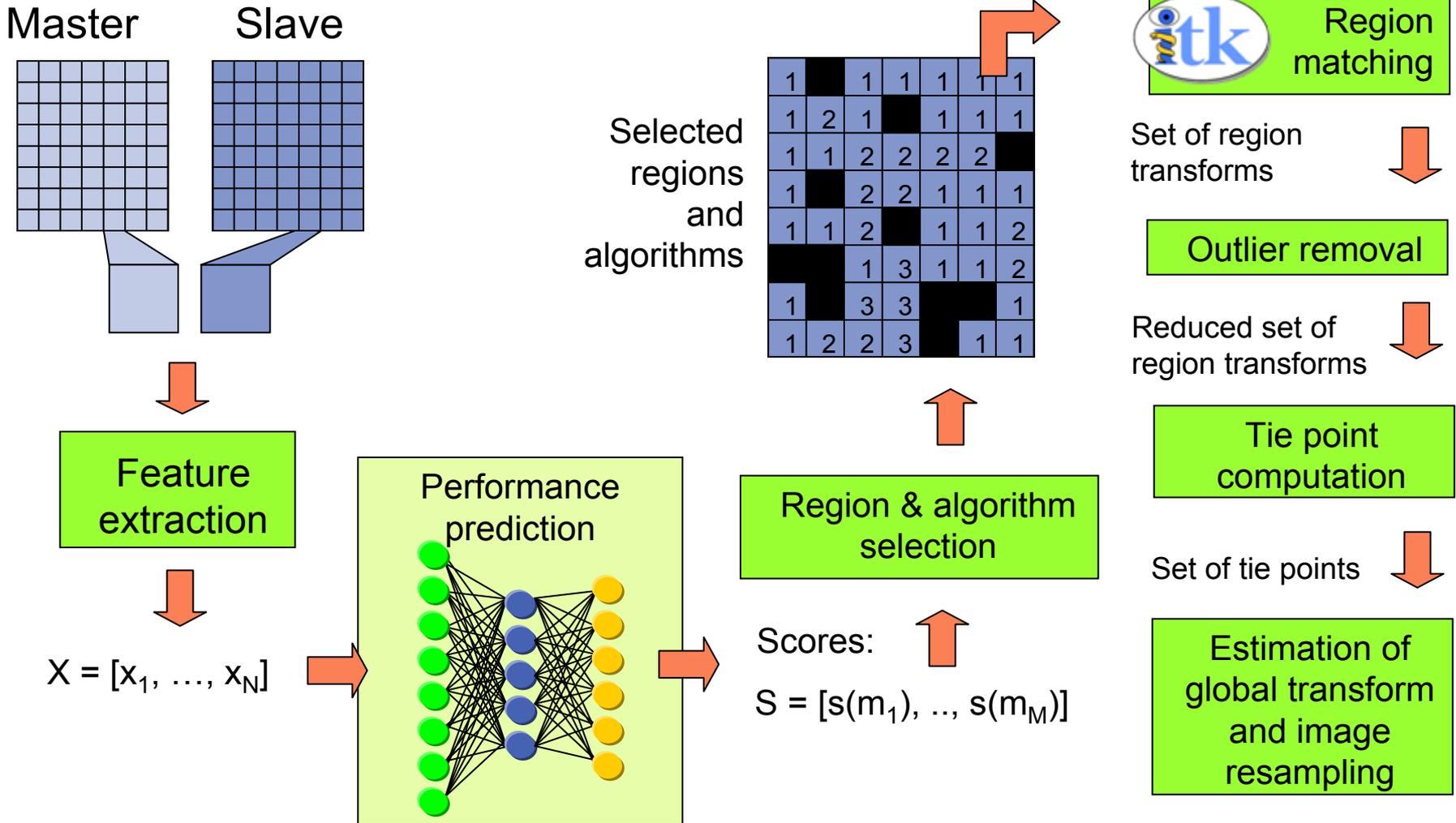
- ▶ **Evaluated on Landsat 5 TM scene 227-062 from Brazil**
- ▶ **Multiple image registration**
 - Performs well on all test images; subpixel accuracy on 12 of 14 images
- ▶ **Forest / non-forest mapping and forest change detection**
 - Snapshot from a work in progress
 - Lack of calibration and verification data
 - Promising results



Multiple image registration



Multiple image registration

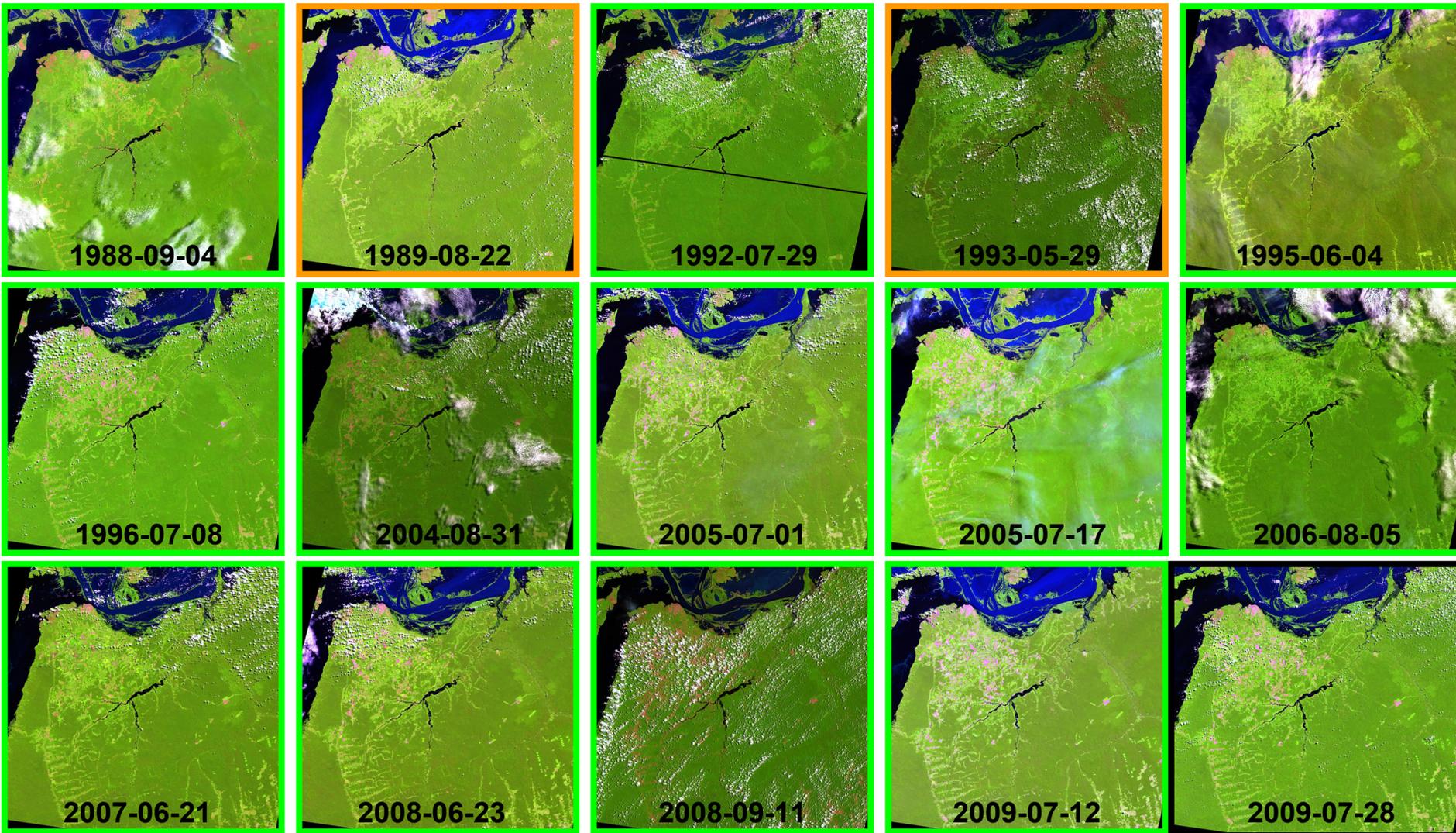


Experiments: Landsat 5, Brazil

- ▶ Co-registration of 14 images from 1988-2009 of scene 227-062
- ▶ Reference image from 2009
- ▶ Approximate relative displacements in x, y:
 - x: 10 .. 140, y: -25 .. 60
- ▶ Results evaluated by manual inspection.
- ▶ Results:
 - 12 of 14: sub-pixel accuracy
 - 2 of 14: errors within 1-2 pixels



Landsat 5 TM scene 227-062, Brazil



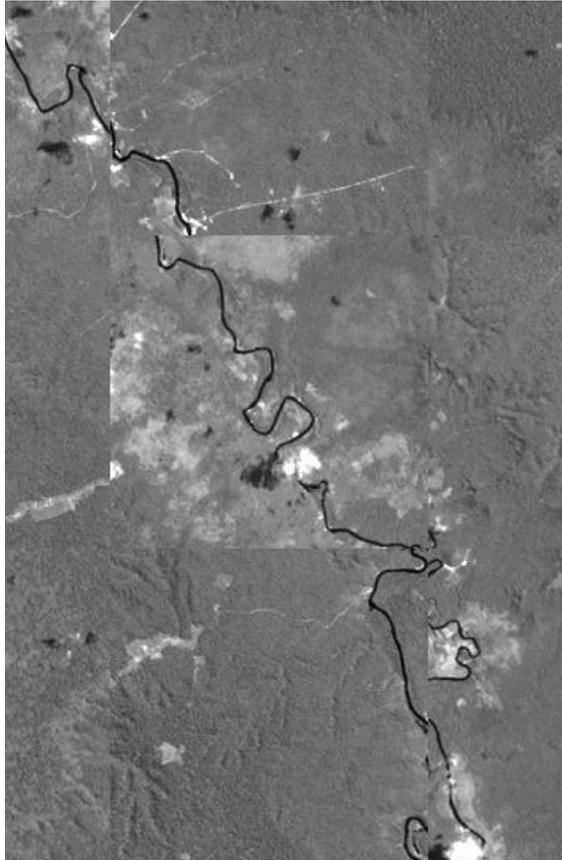
Landsat 5 TM scene 227-062

IMAGES	Approximate displacements	Results
▶ 1988-09-04	(28, 64)	< 1 pixel
▶ 1989-08-22	(141, -17)	1-2 pixels
▶ 1992-07-29	(31, 48)	< 1 pixel
▶ 1993-05-29	(19, -13)	1 pixel
▶ 1995-06-04	(40, -10)	< 1 pixel
▶ 1996-07-08	(16, -37)	< 1 pixel
▶ 2004-08-31	(-44, 33)	< 1 pixel
▶ 2005-07-01	(21, 13)	< 1 pixel
▶ 2005-07-17	(22, 7)	< 1 pixel
▶ 2006-08-05	(49, 7)	< 1 pixel
▶ 2007-06-21	(83, -13)	< 1 pixel
▶ 2008-06-23	(54, -24)	< 1 pixel
▶ 2008-09-11	(55, -22)	< 1 pixel
▶ 2009-07-12	(11, 8)	< 1 pixel
▶ 2009-07-28	Reference	Reference

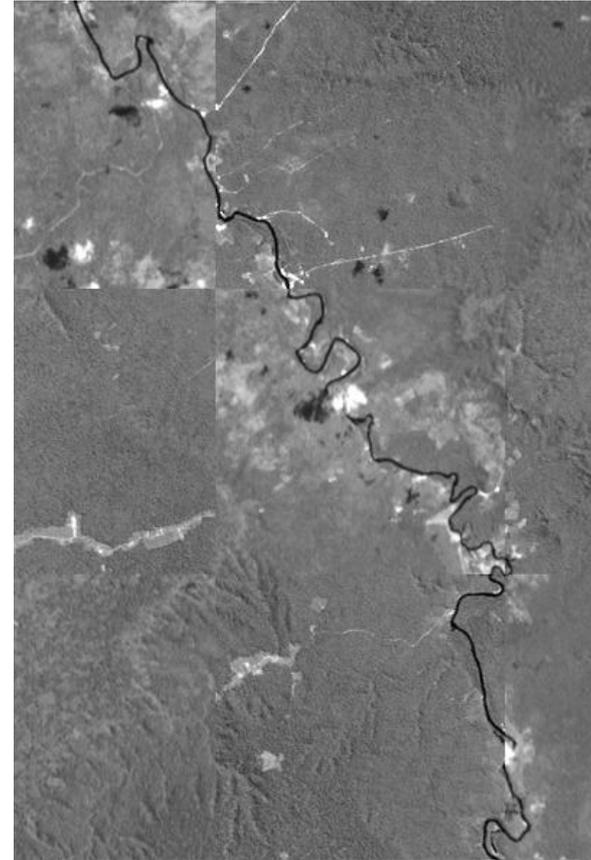


Example: Accuracies I

Mosaic of reference (2009-07-28) and slave image (1988-09-04)



Before co-registration



After co-registration



Example: Accuracies II

Mosaic of reference (2009-07-28) and slave image (2004-08-31)



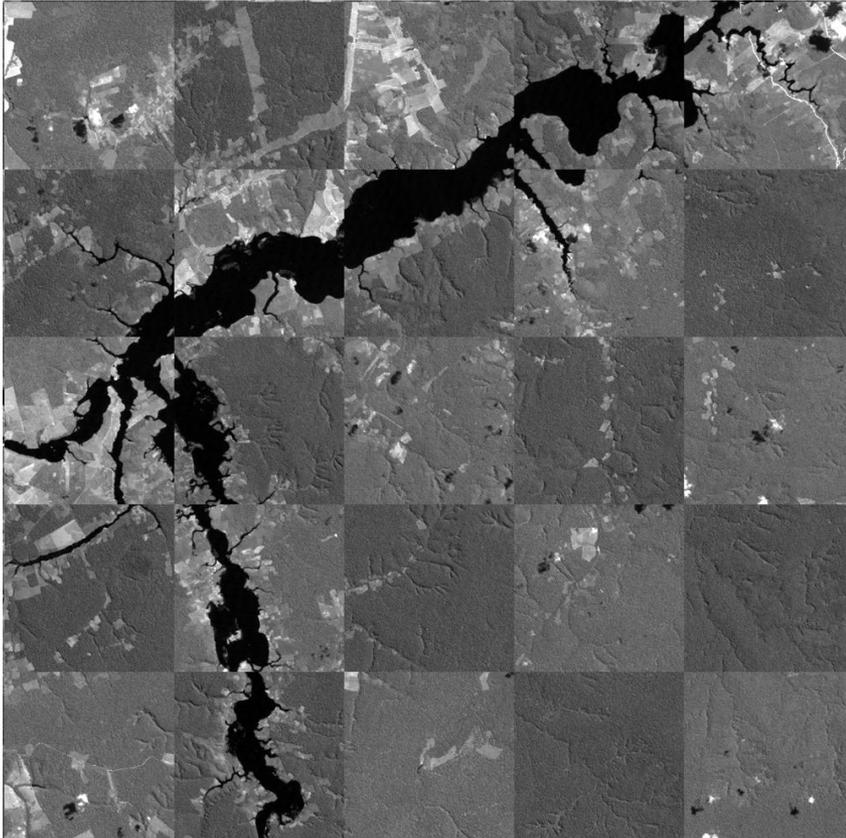
Before co-registration



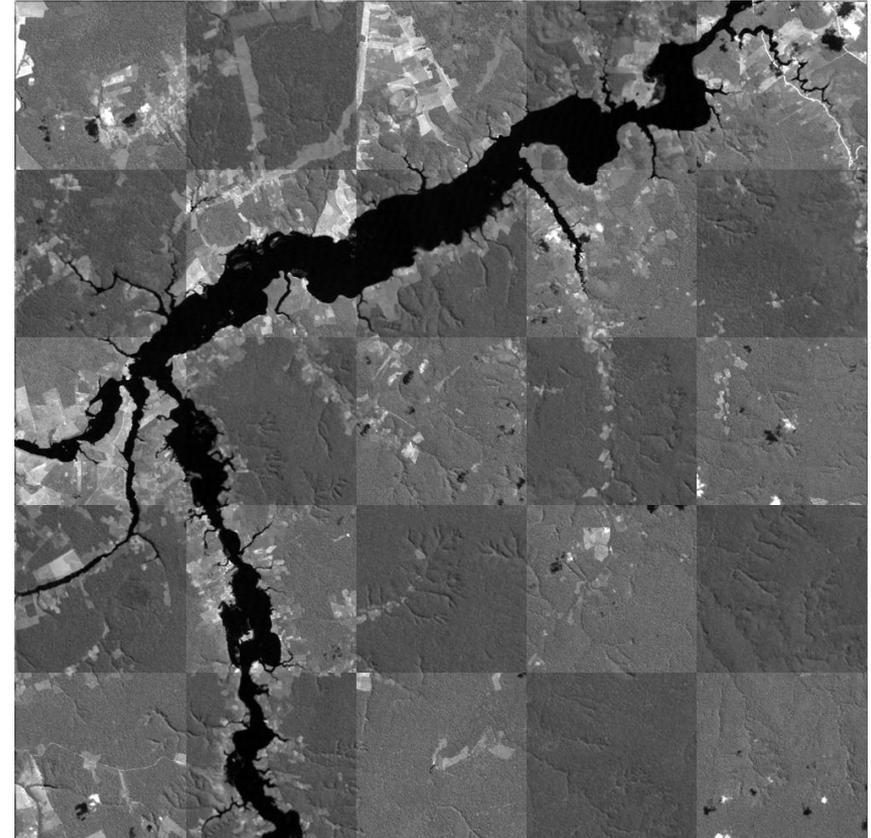
After co-registration

Examples: Accuracies III

Mosaic of reference (2009-07-28) and slave image (1996-07-08)

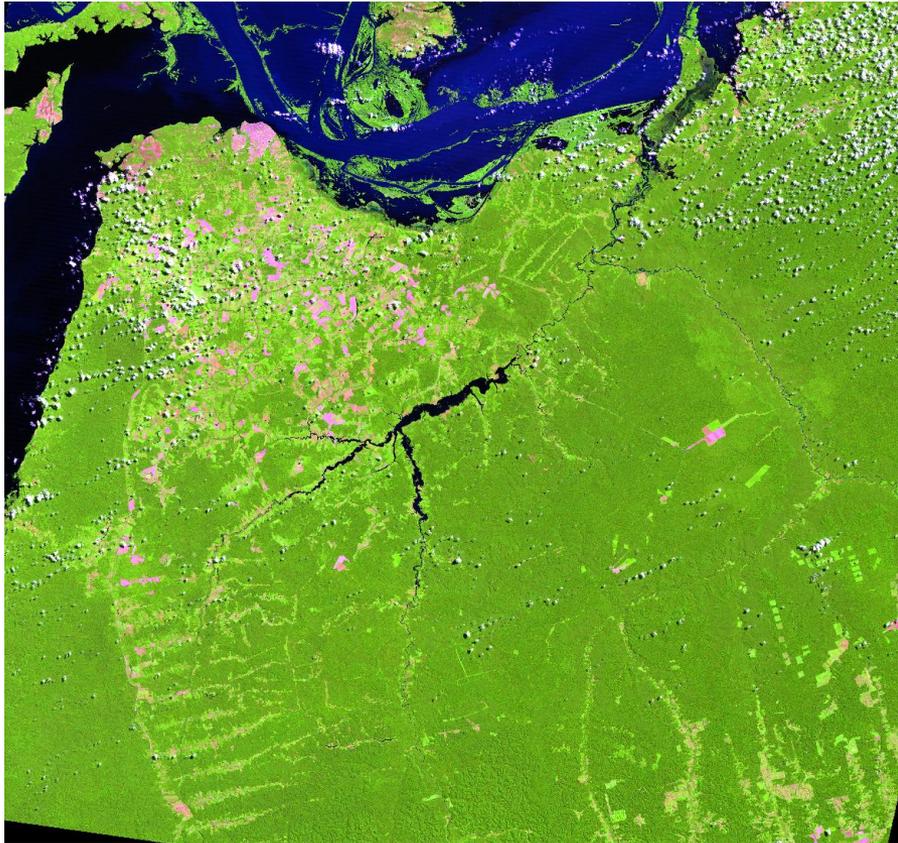


Before co-registration

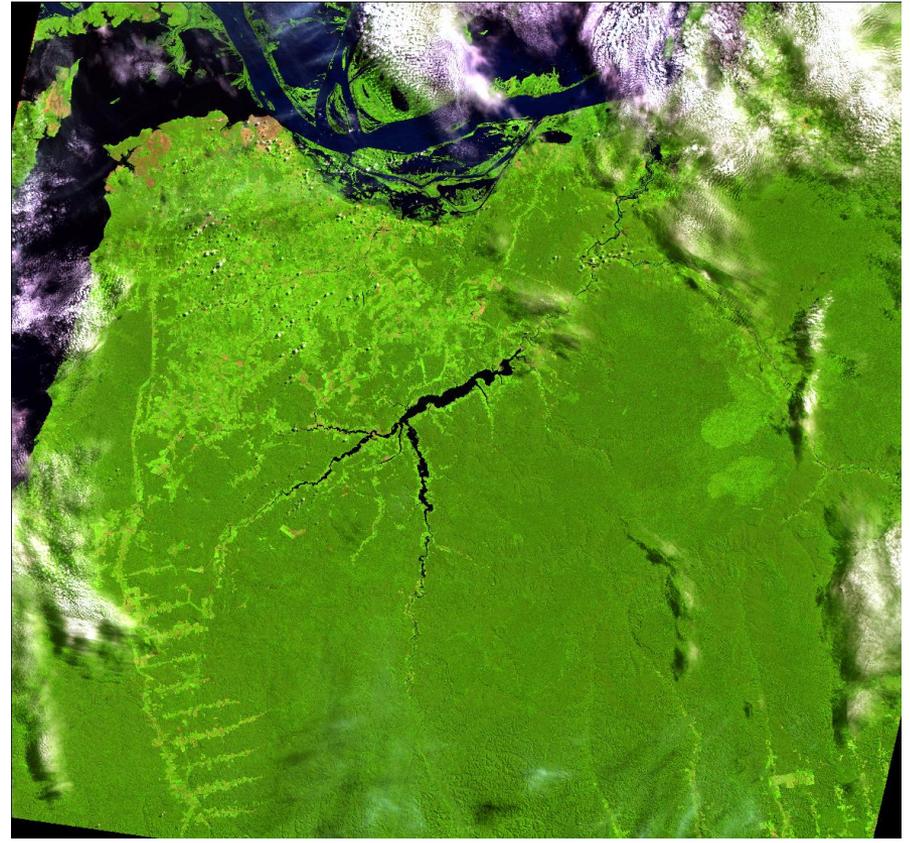


After co-registration

How the method works



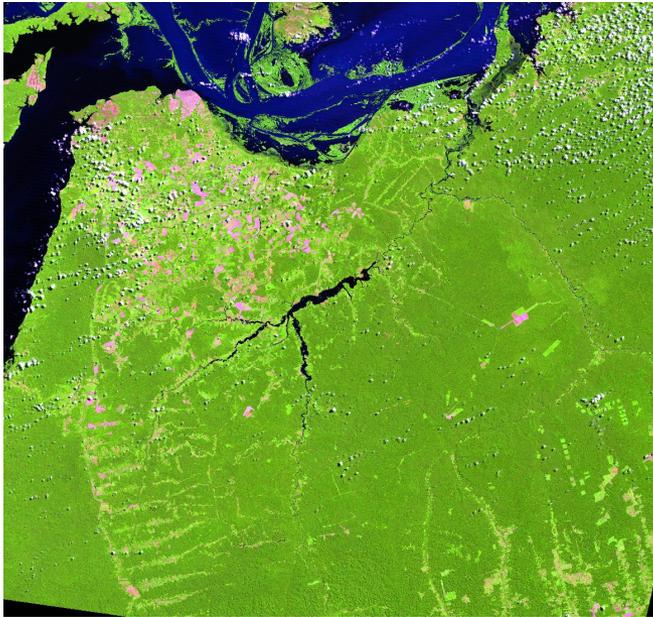
Reference: 2009-07-28



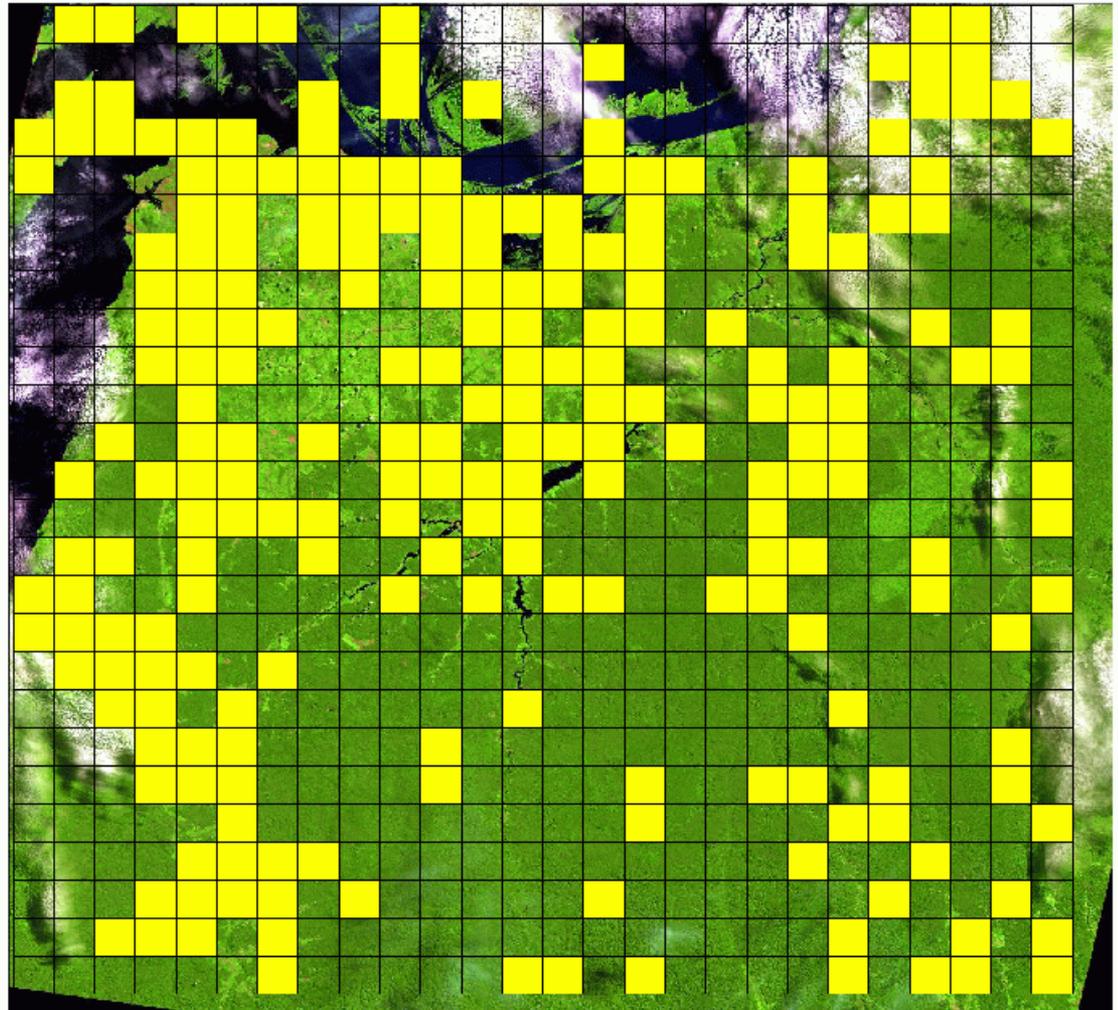
1996-07-08



Region & method selection



Reference: 2009-07-28



1996-07-08

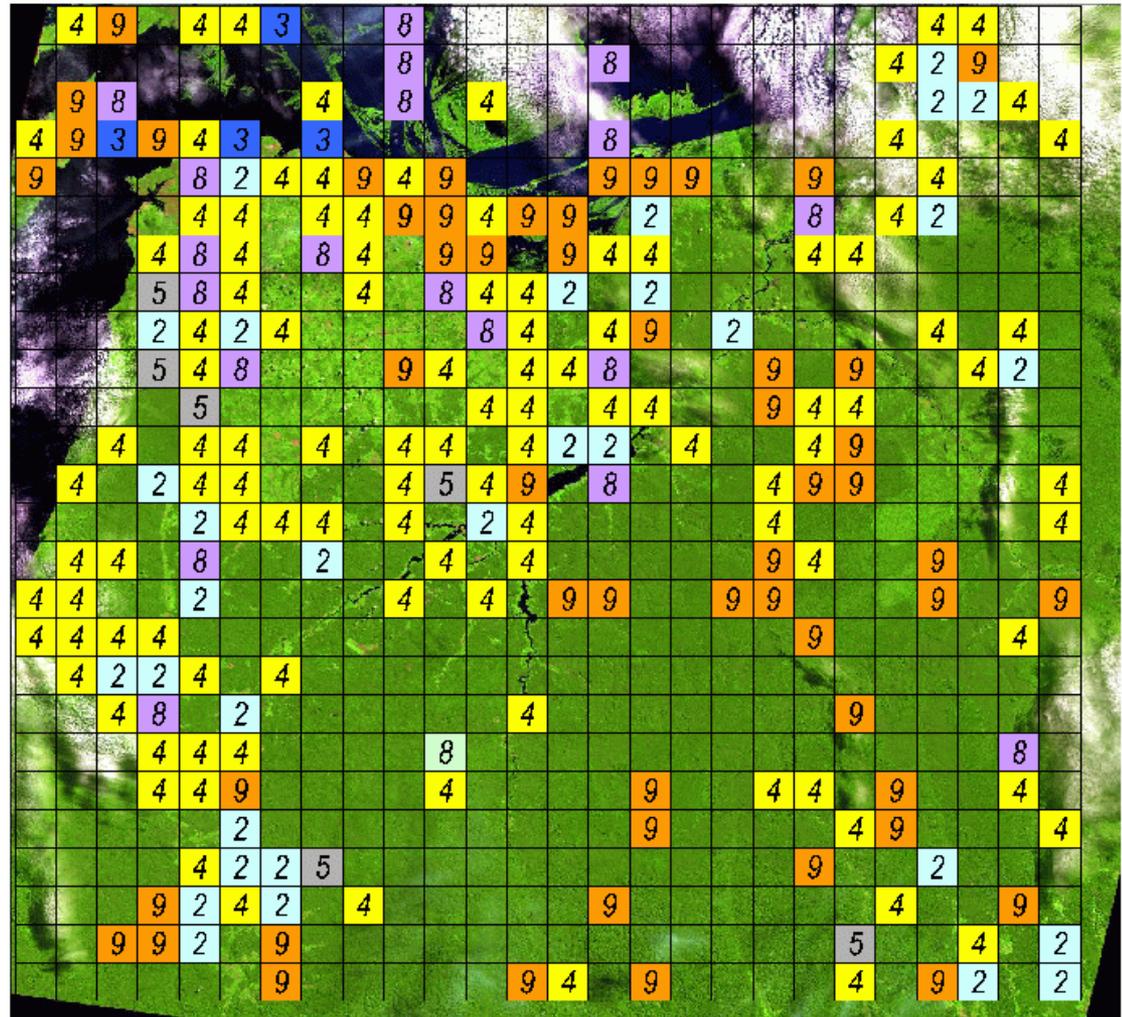


Region & method selection

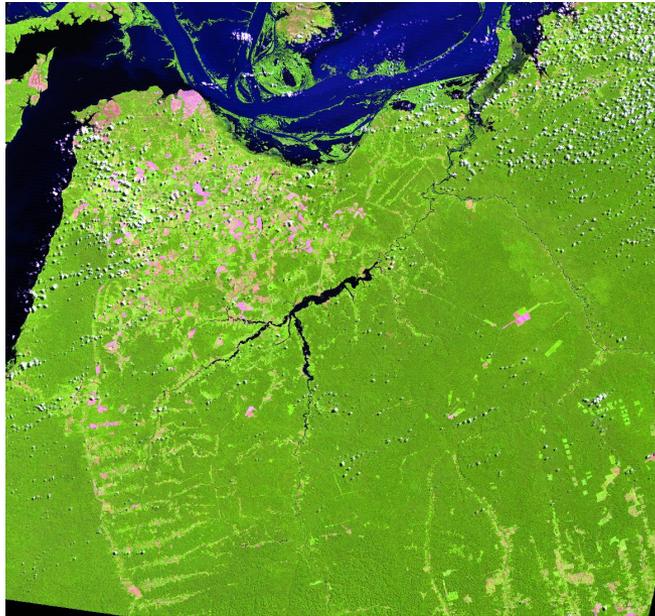


Reference: 2009-07-28

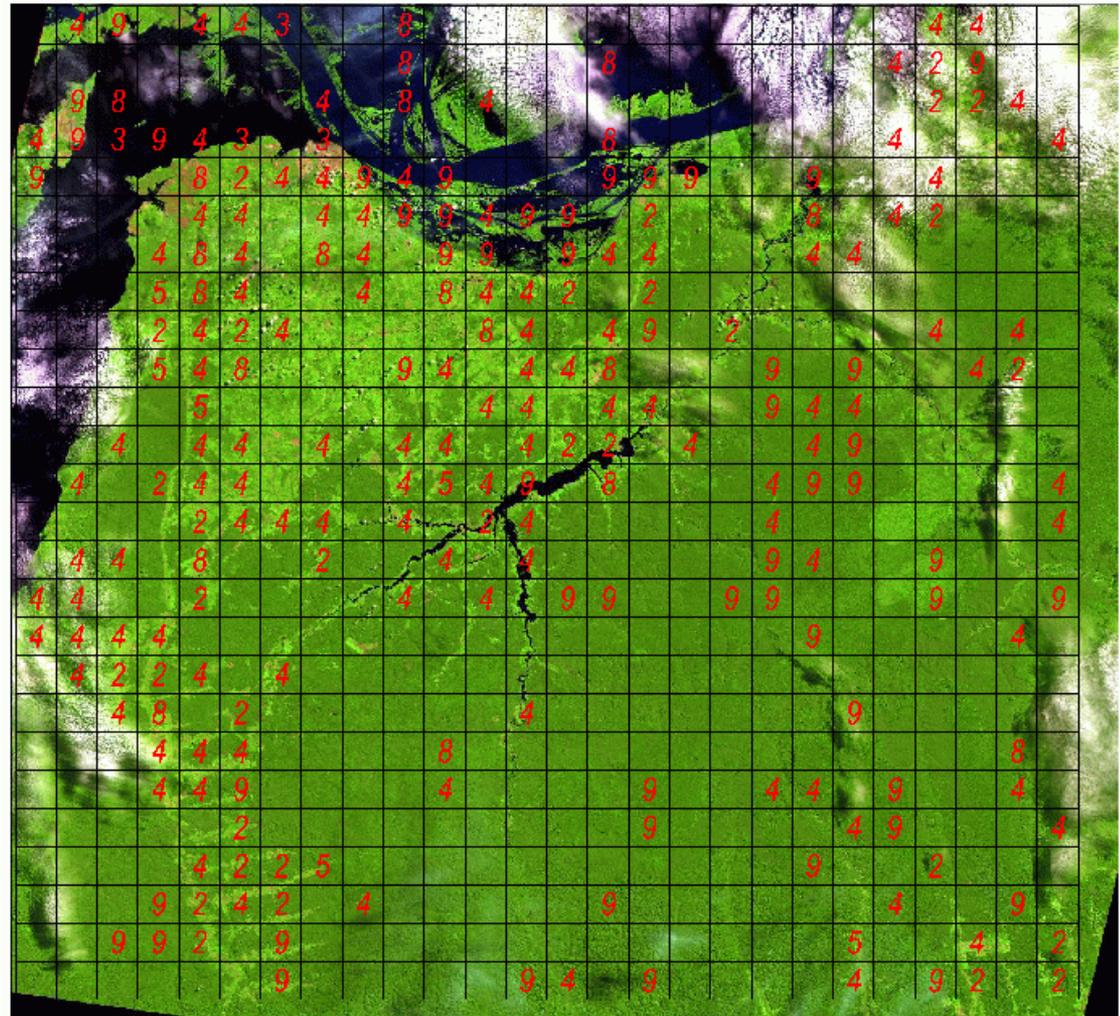
1996-07-08



Region & method selection



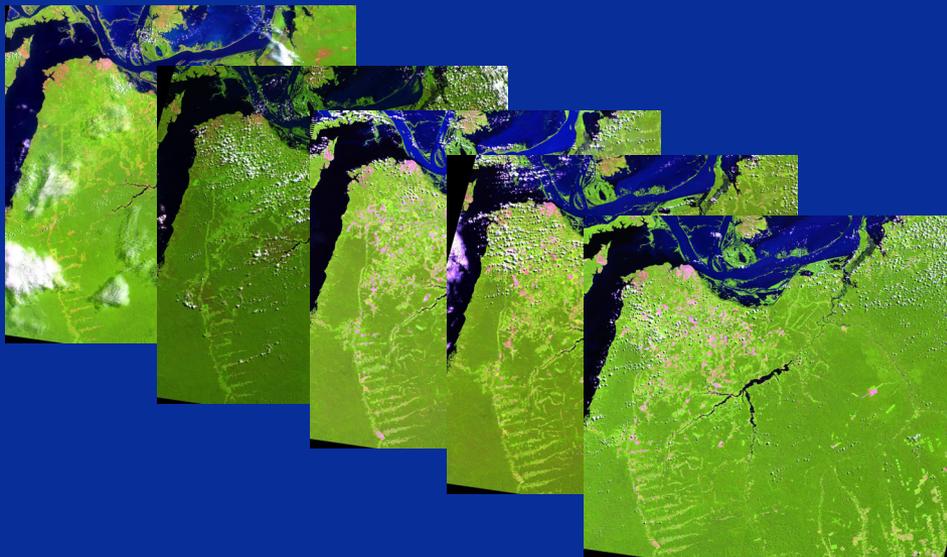
Reference: 2009-07-28



1996-07-08



Forest / non-forest mapping



Forest / non-forest mapping

- ▶ Algorithm that handles **missing data**
 - Clouds
 - Cloud shadows
 - Stripes in Landsat 7 ETM+ SLC-off images
- ▶ Support vector machines (SVM) classifier
- ▶ Two stages
 - Missing data detection
 - Land cover classification



Two-stage classifier

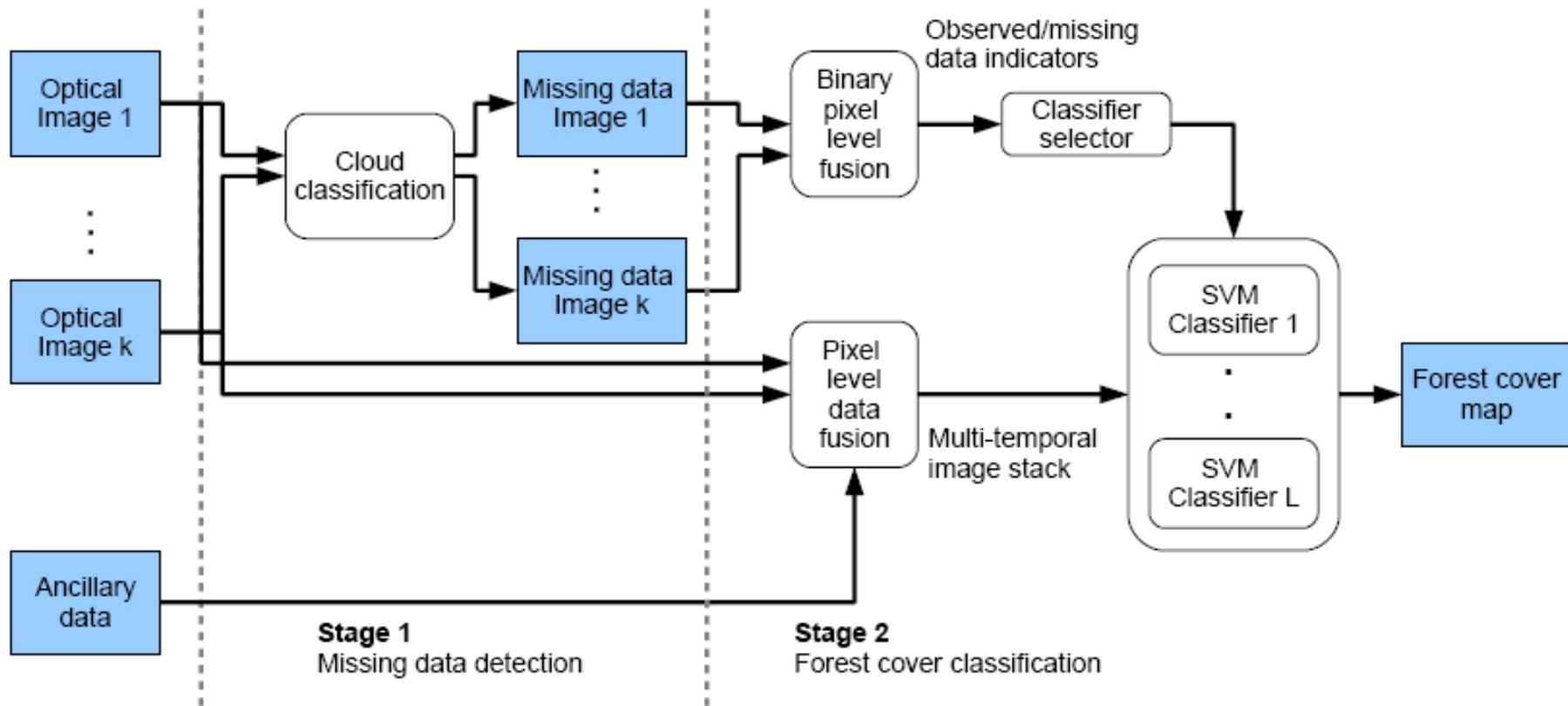
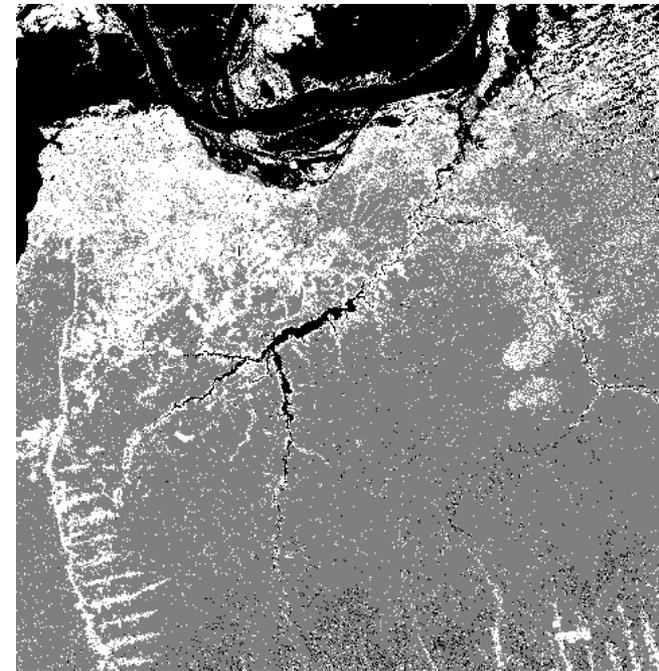
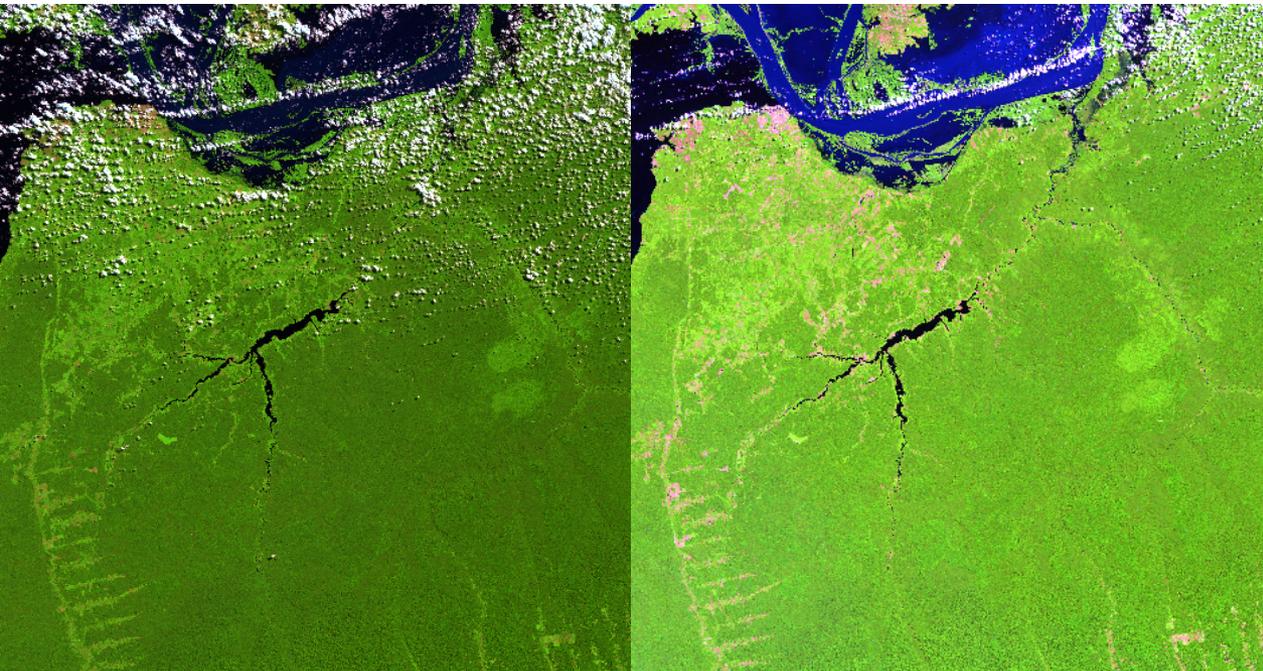


Image 1												
Image 2												
Image 3												
Pixel number	1	2	3	4	5	6	7	8	9	10	11	12



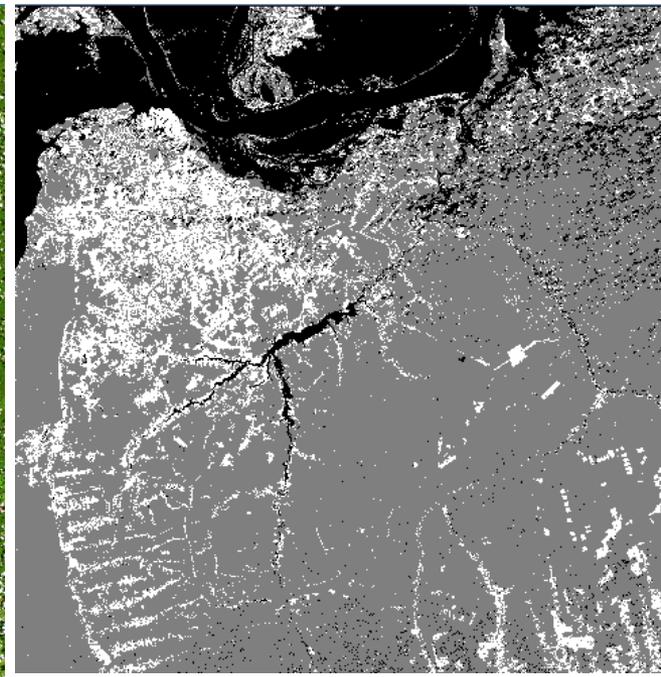
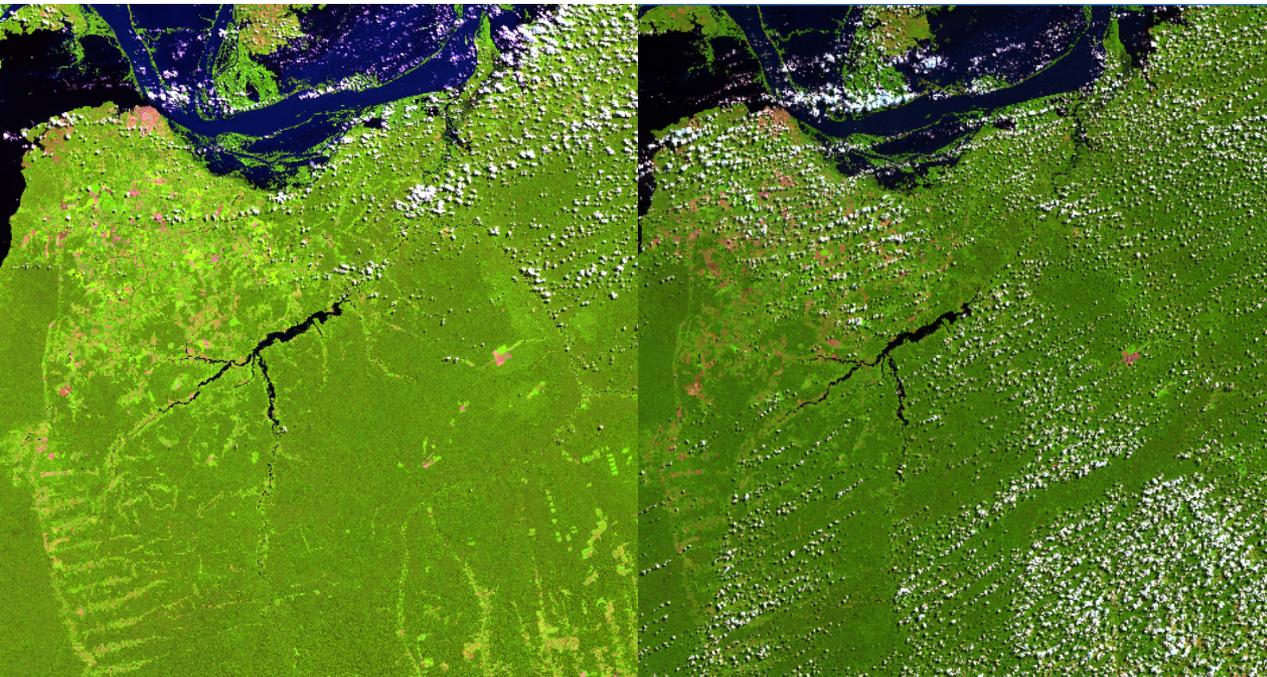
Forest cover map 1997

► 25 June 1997 + 27 July 1997

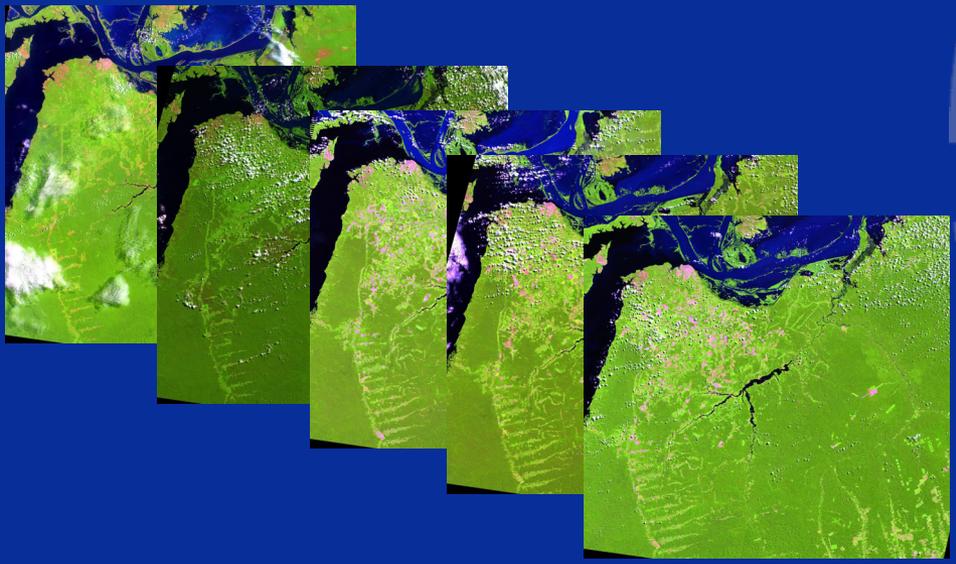


Forest cover map 2007

► 21 June 2007 + 23 July 2007



Forest change detection



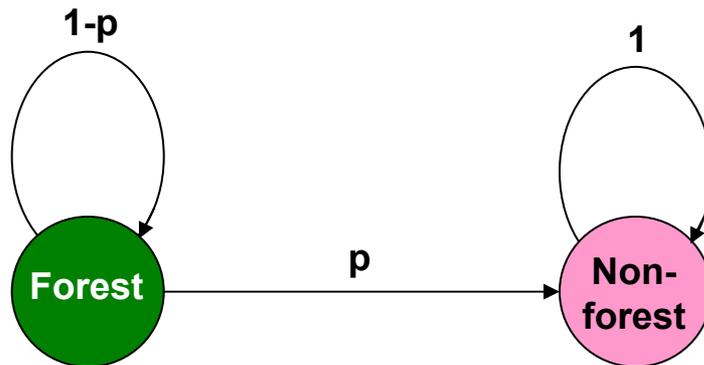
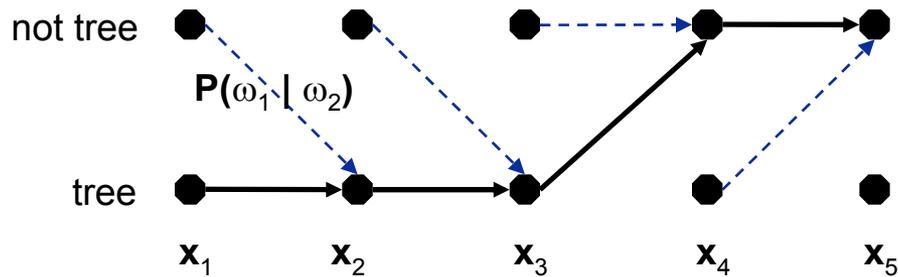
Forest change detection

- ▶ For each pixel, the state is either forest or non-forest
- ▶ The state may change from forest to non-forest over time, but not the other way (in our dataset)
- ▶ A Markov-chain model is used
- ▶ Given the observed data, compute the optimum chain of states for each pixel
- ▶ The result is a forest change image product, with dates for state changes from forest to non forest

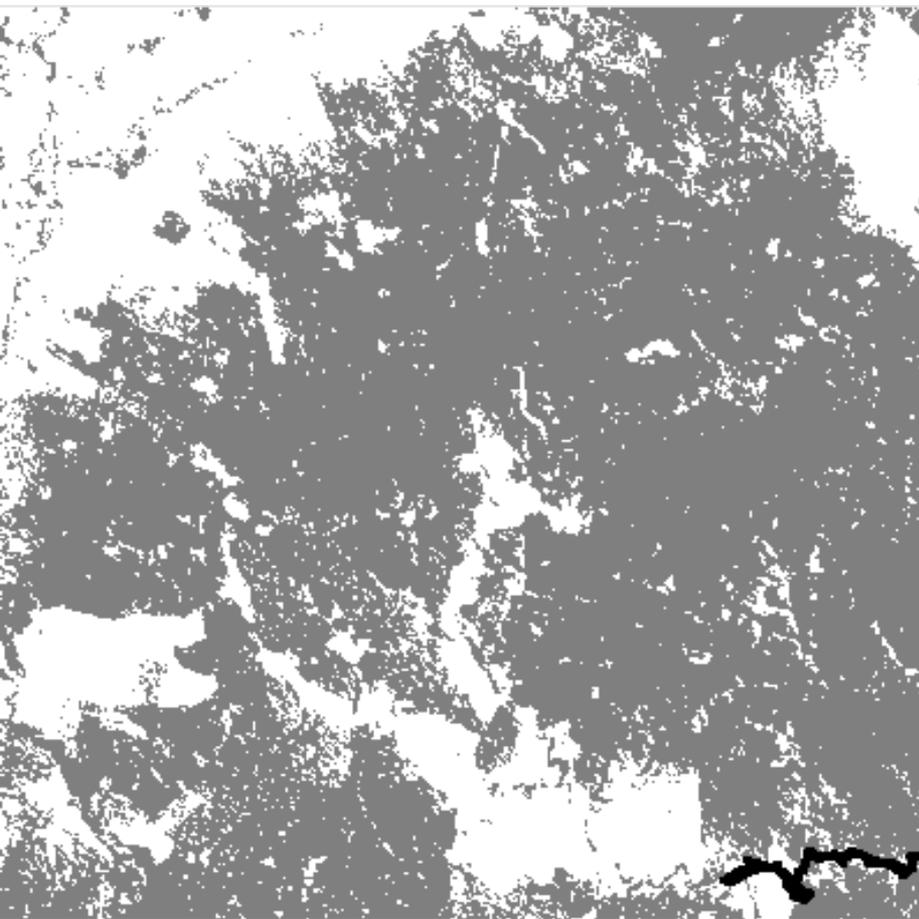


Markov chain model

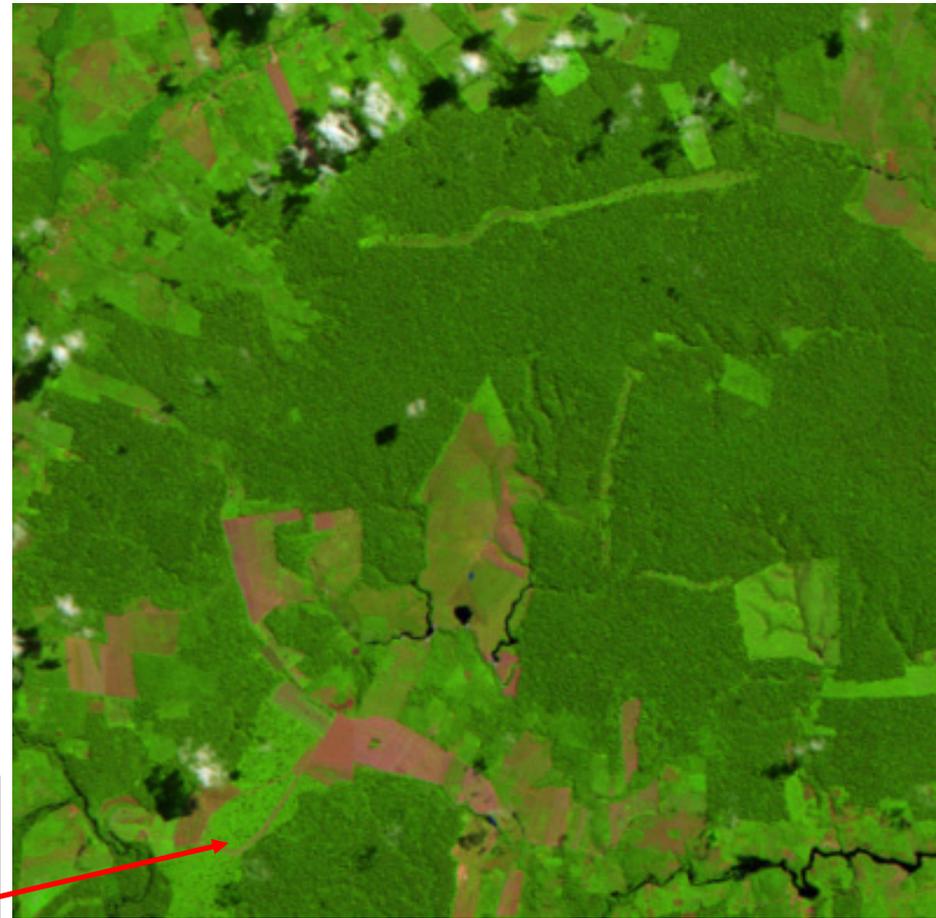
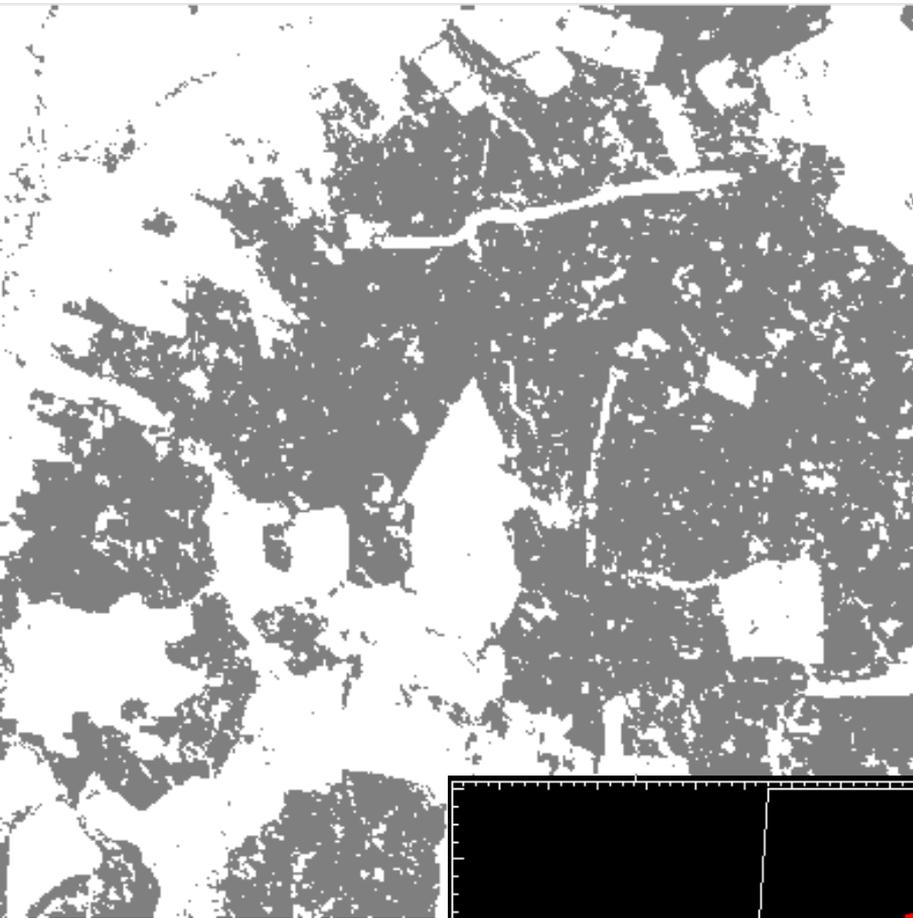
- ▶ Optimum sequence found using the Viterbi algorithm



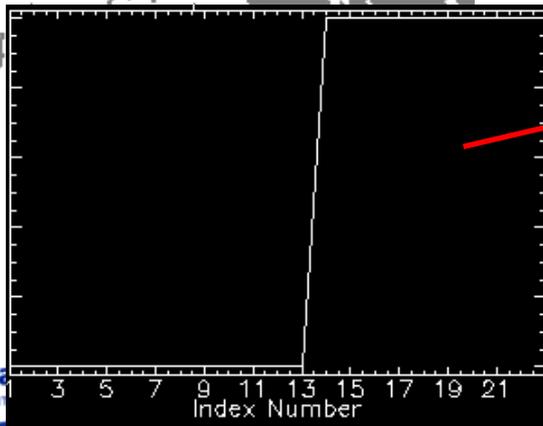
Forest cover map July 29, 1986



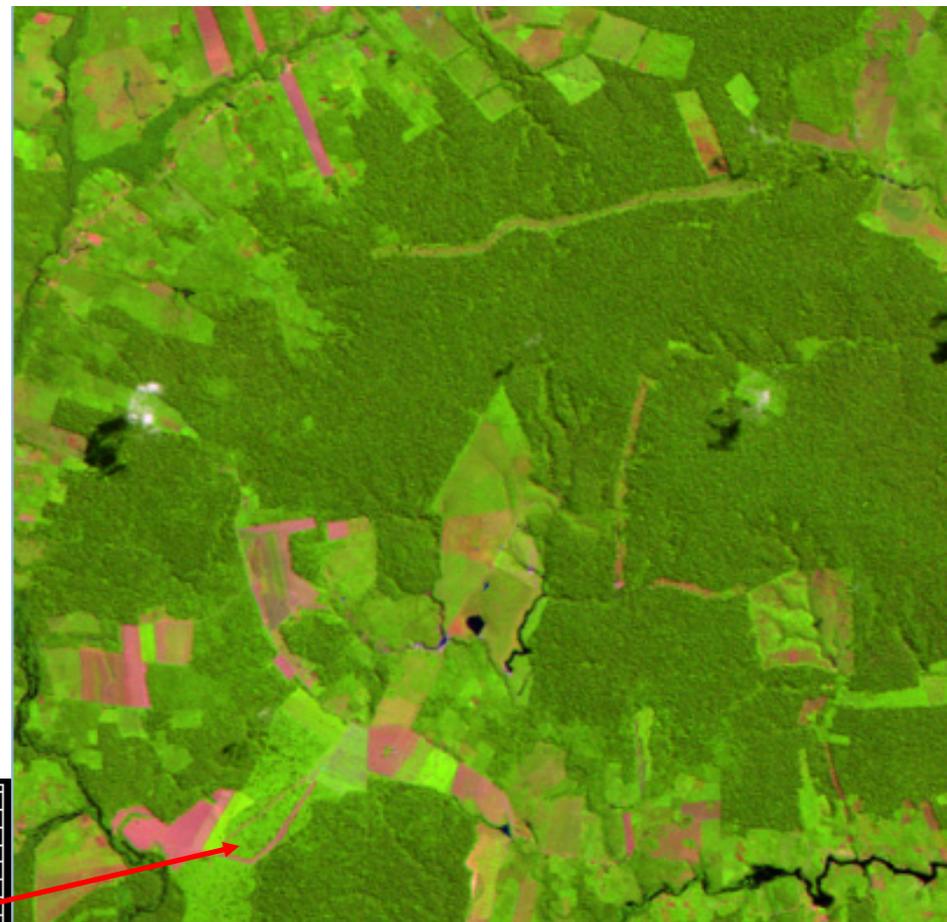
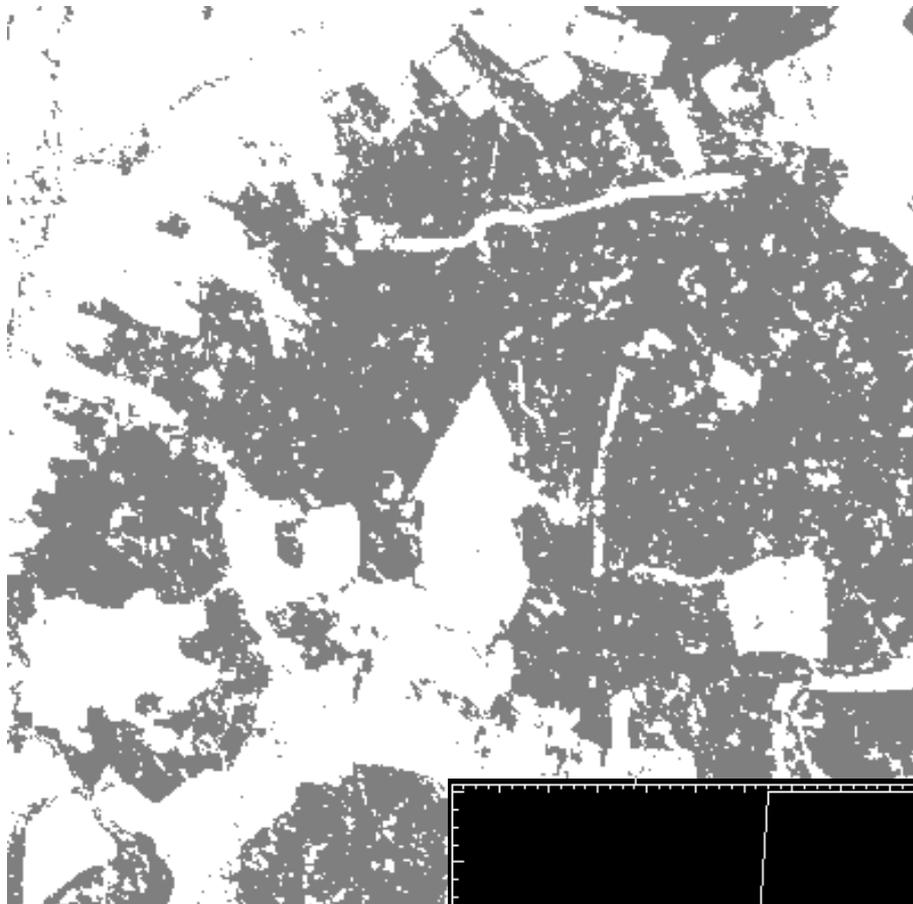
Forest cover map July 23, 2007



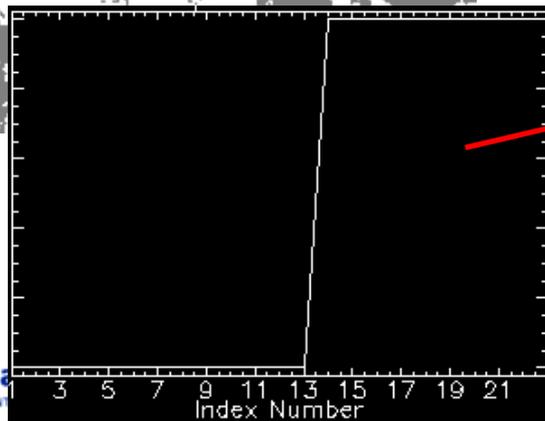
Change in 2004



Forest cover map June 23, 2008



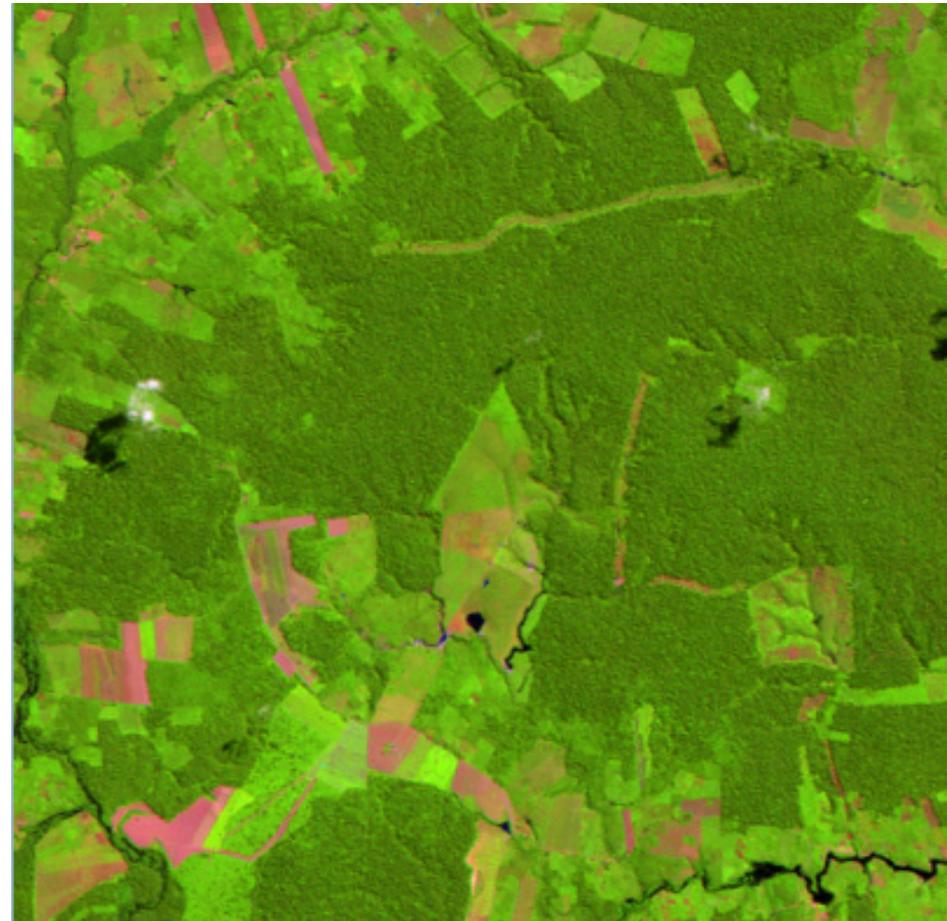
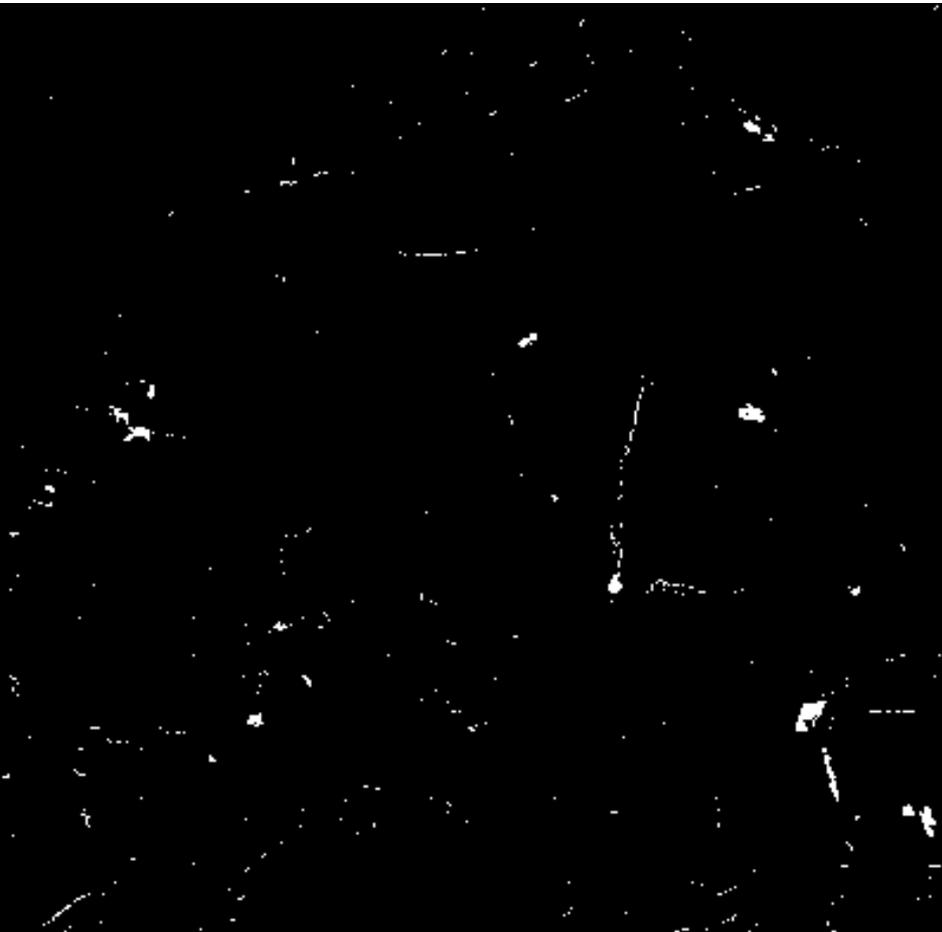
Change in 2004



Forest cover **change** map July 29 1986 – June 23, 2008



Forest cover **change** map July 23 2007 – June 23, 2008



Further work

- ▶ Combine the SVM classifier with Markov chain to improve forest change detection
- ▶ Combine with spatial information from neighboring pixels (e.g., Markov random fields)
- ▶ We need calibration and verification data:
 - Very-high resolution, visible + near infrared, satellite data, e.g., Ikonos, Geoeye, Quickbird, Worldview-2.
 - Quicklooks without NIR could not be used



References

- Eikvil, L., Holden, M., Huseby, R. B., 2009. Adaptive registration of remote sensing images using supervised learning. *Photogrammetric Engineering & Remote Sensing* 75 (11); 1297-1306.
- A. B. Salberg, “Land cover classification of cloud-contaminated multi-temporal high-resolution images”, Revised version submitted to *IEEE Transactions on Geoscience and Remote Sensing*.
- A. B. Salberg and R. Jenssen, “Land cover classification of partly missing data using support vector machines”, *In preparation*.

