Severe Storms and Blow-down Disturbances in the Amazon Forest

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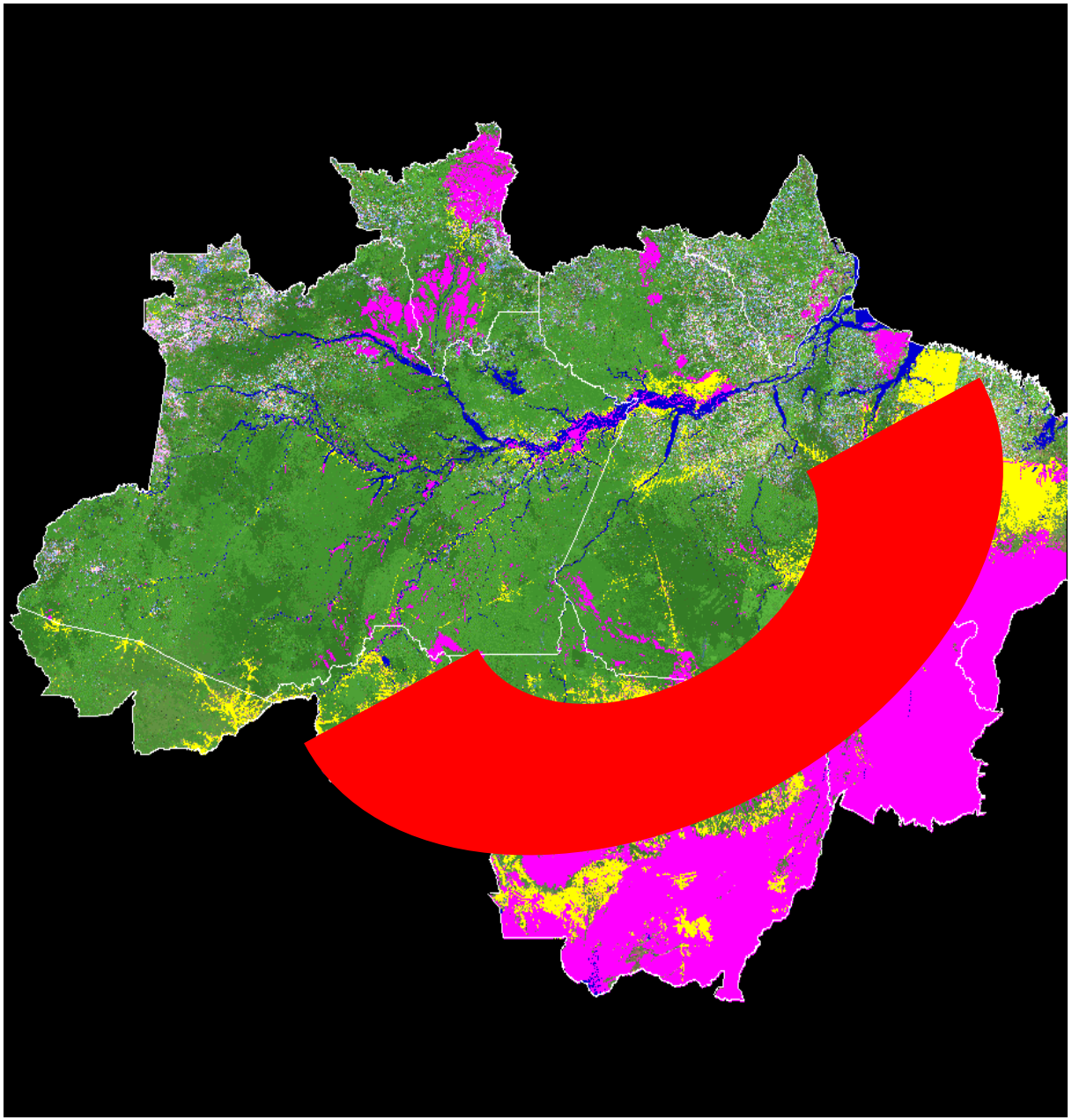
1. Background

The amount of carbon in the tropical ecosystems varies spatially and temporally as a result of natural and human activities;

Human-induced changes in the vegetation cover of the Amazon:
- deforestation (Skole and Tucker, 1993);
- selective logging (Souza and Barreto, 2000; Asner et al., 2005);
- fire (Cochrane, 2003);
- gold mining;
- urbanization



Deforestation

Selective Logging

Fire

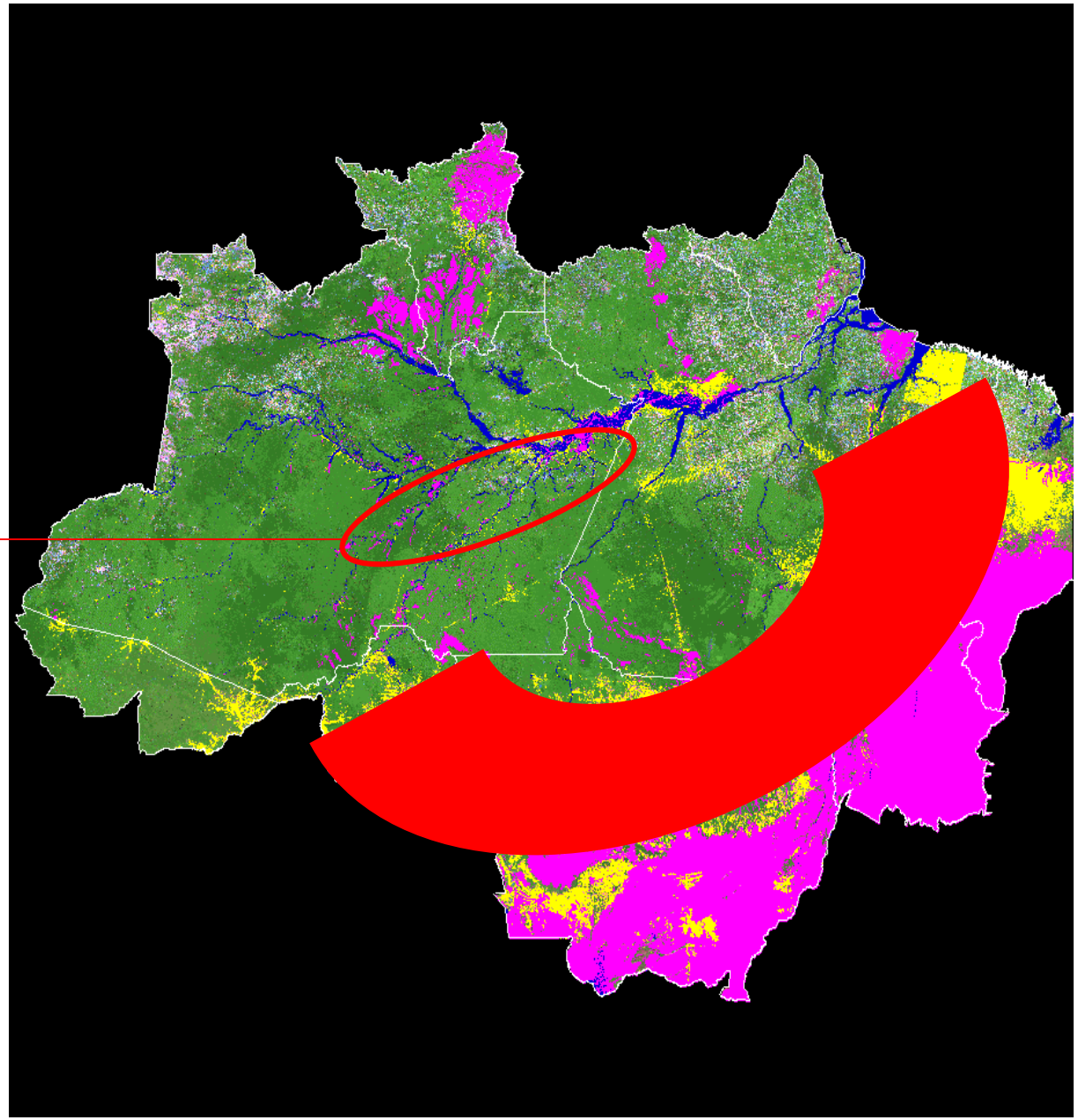
Gold Mining

Urbanization

INPE (2006)

1. Background

However… NATURAL DISTURBANCE IS ALSO IMPORTANT!

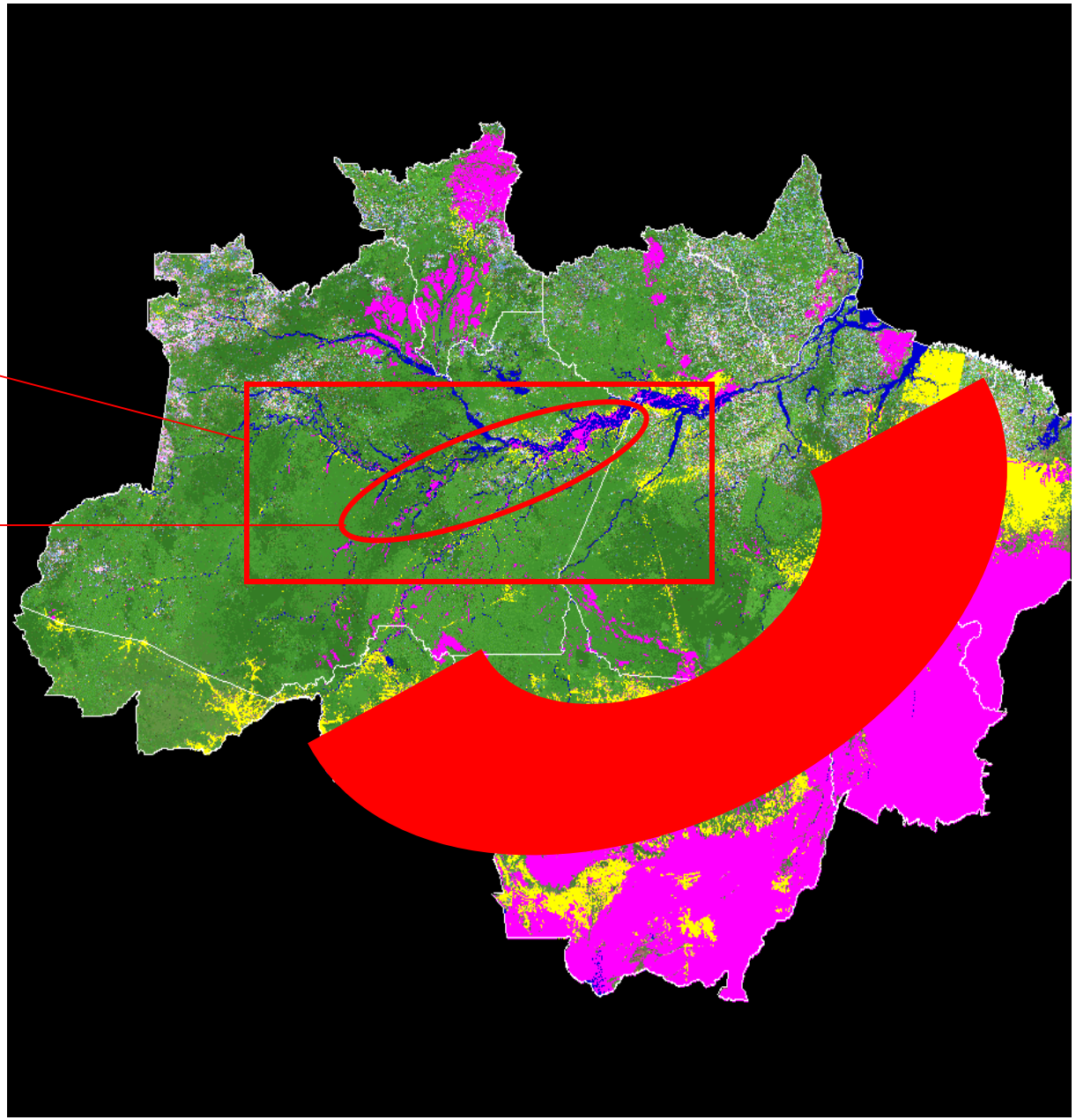

Flooding
Deforestation
Selective Logging
Fire
Gold Mining
Urbanization

INPE (2006)


2 meters of flooding

Larde
Disturbances
Blow-downs

Flooding



Deforestation

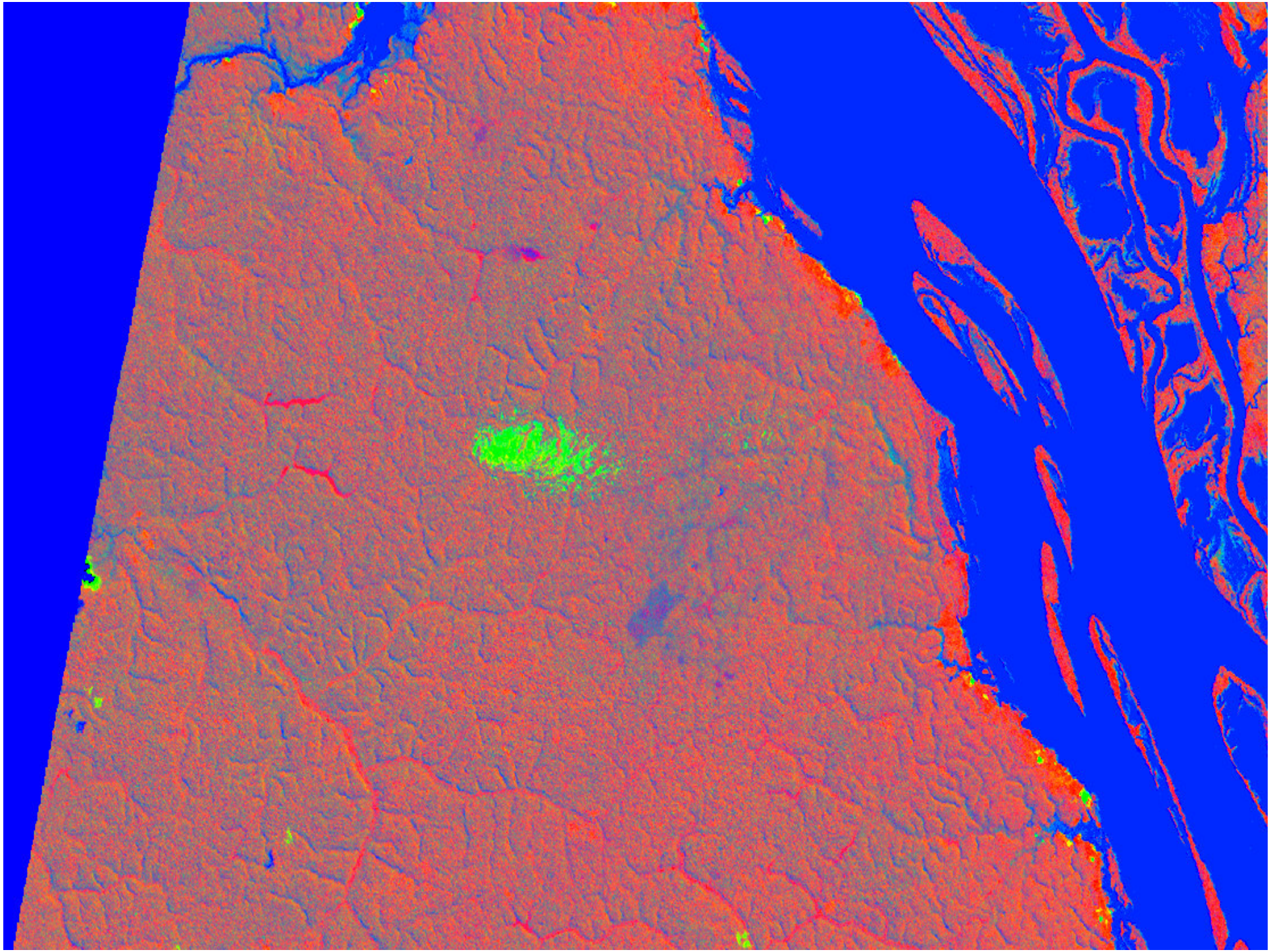
Selective Logging

Fire

Gold Mining

Urbanization

INPE (2006)



Back to the history…

Ecology, 75(3), 1994, pp. 853–858

FOREST DISTURBANCE BY LARGE BLOWDOWNS IN THE BRAZILIAN AMAZON

Bruce W. Nelson,[1] Valerie Kapos,[2] John B. Adams,[3,5] Wilson J. Oliveira,[4] Oscar P. G. Braun,[4] and Iêda L. do Amaral[1]

Wind defoliation and large blowdowns are important and frequent disturbances for tropical forests of islands and coastal areas in the hurricane belts 10°–20° north and south of the equator (Sousa 1984, Whitmore 1984). In the Caribbean, hurricane repeat cycles may be ≤15–20 yr and effects on the forest can range from

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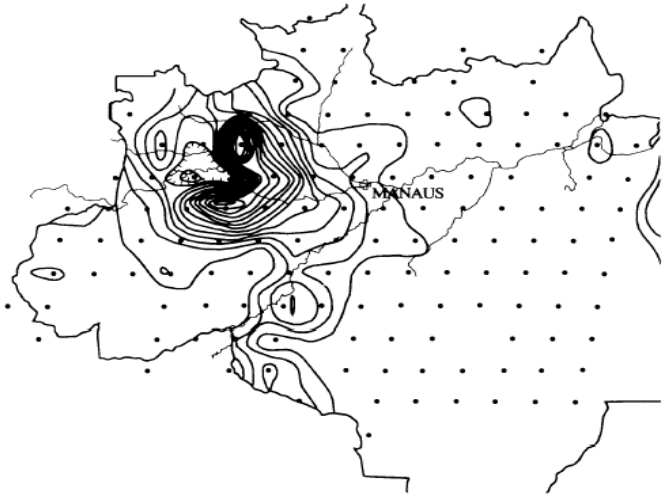
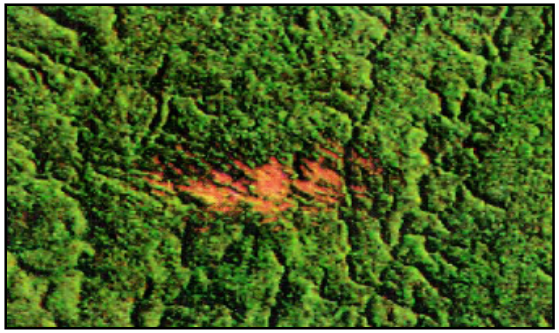
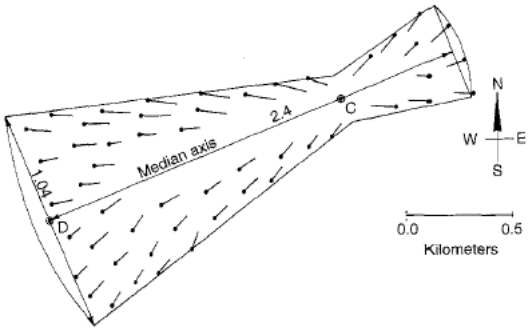


- ✓ Using 137 TM Landsat images, Nelson *et al.* (1994) found 330 that were identified from their geometry and spectral pattern as blow-downs.
- ✓ The 330 observed blow-down covered a total of 90,000 ha. The TM scene with the greatest total blow-down-affected area had 16 blow-down totaling 8.600 ha or 0.31% of the scene area.
- ✓ The largest single blow-down covered 3370 ha, with the most frequent size classes falling between 30 and 100 ha.



(a)



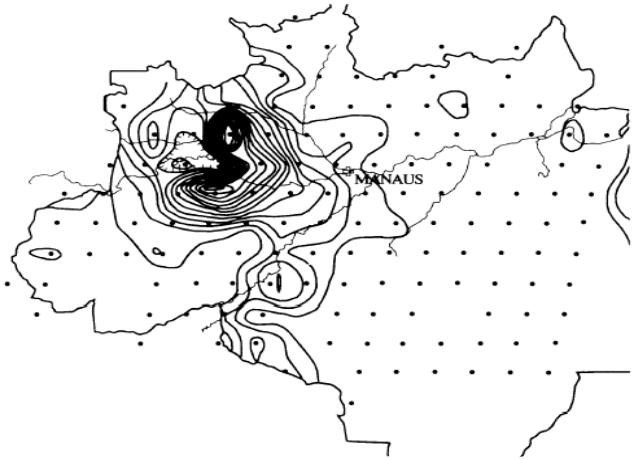
(b)

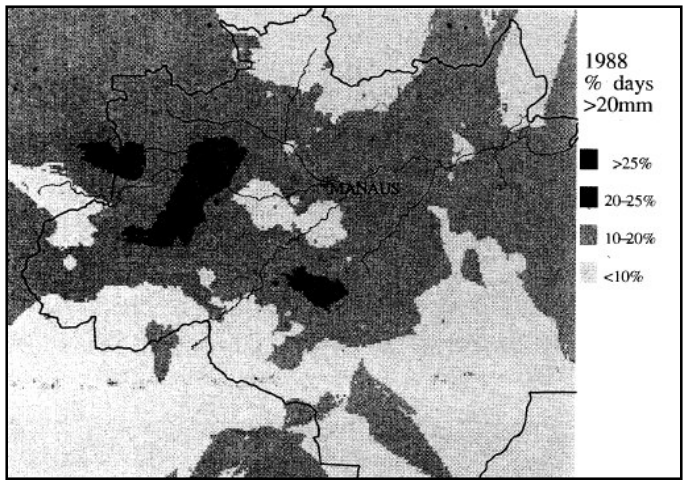
Figures:

(a) Blow-down area with fan-shaped patches observed by Nelson *et al.* (1994) in Landsat TM image (1990).

(b) Schematic diagram of mean blow-down characteristics (size, shape and tree-fall orientation) reported by Garstang et al. (1998).

- ✓ Nelson *et al.* (1994) observed an apparent coincidence between the frequency of blow-down and heavy precipitation. Large blow-downs area due to downbursts produced by traveling convective storms.



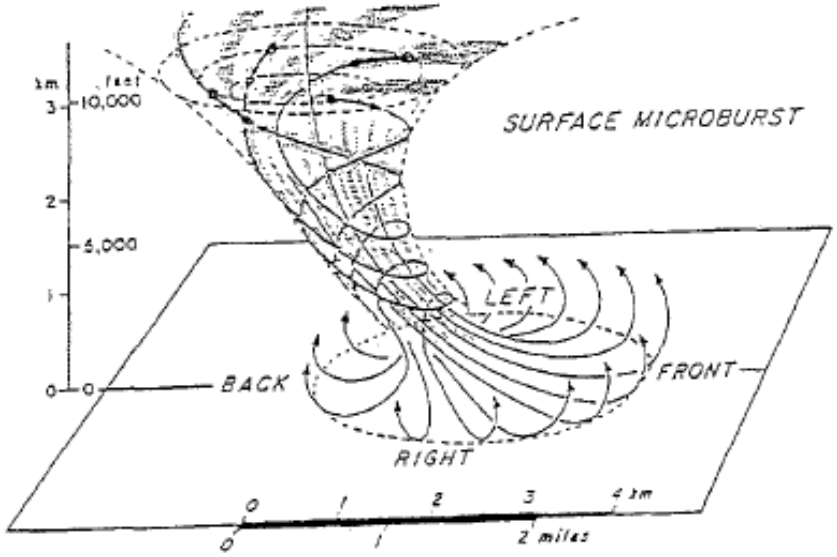


- ✓ In the Amazon, conditions of instability considered necessary for convective storm to produce “downdrafts” with magnitude ranging from 25 to 50 m/s are not common (Gartang *et al.*,1998);
- ✓ A wet <u>microburst reaching 25 m/s</u> and lasting less than 1 min could destroy trees over a linear distance of 1.25 km requiring a swath width of only 0.25 km to produce the lower range of the observed blow-downs of 0.3 km^2 (Gartang *et al.*,1998);

Figures:

(a) Model of the descent of a microburst from cloud base (Garstang *et al.,* 1998).

(b) Illustrative picture of a microburst (or tornado?) observed in Manaus, Brazil (October 21 of 2005).



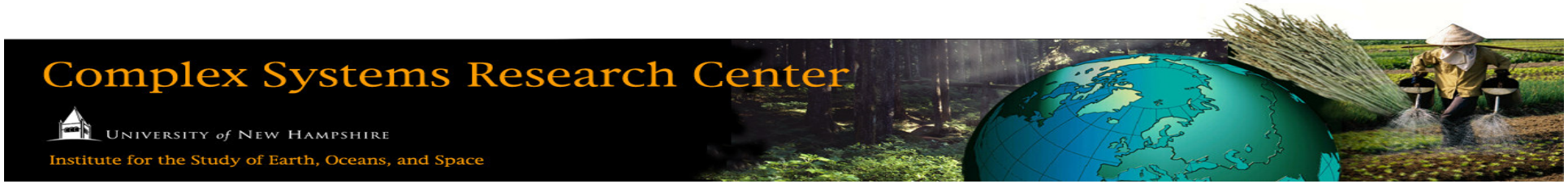
(a)

(b)

Courtesy: Alessandro Palmeiras (IPAM)

Research Questions

- ✓ What is the turnover of these events vary across the Amazon landscape?
- ✓ Is there some mechanistic process that can explain the variation and the intensity of these disturbances at local and regional scales?
- ✓ What is the effect of blow-downs on carbon flux in Western and Eastern Amazon, respectively?
- ✓ Do the blow-down events have effect on forest structure in the Amazon landscape?
- ✓ What is the relative importance of large disturbances (blow-downs) at the regional landscape scale versus small disturbances (tree mortality) at the local scale to the forest dynamic processes?



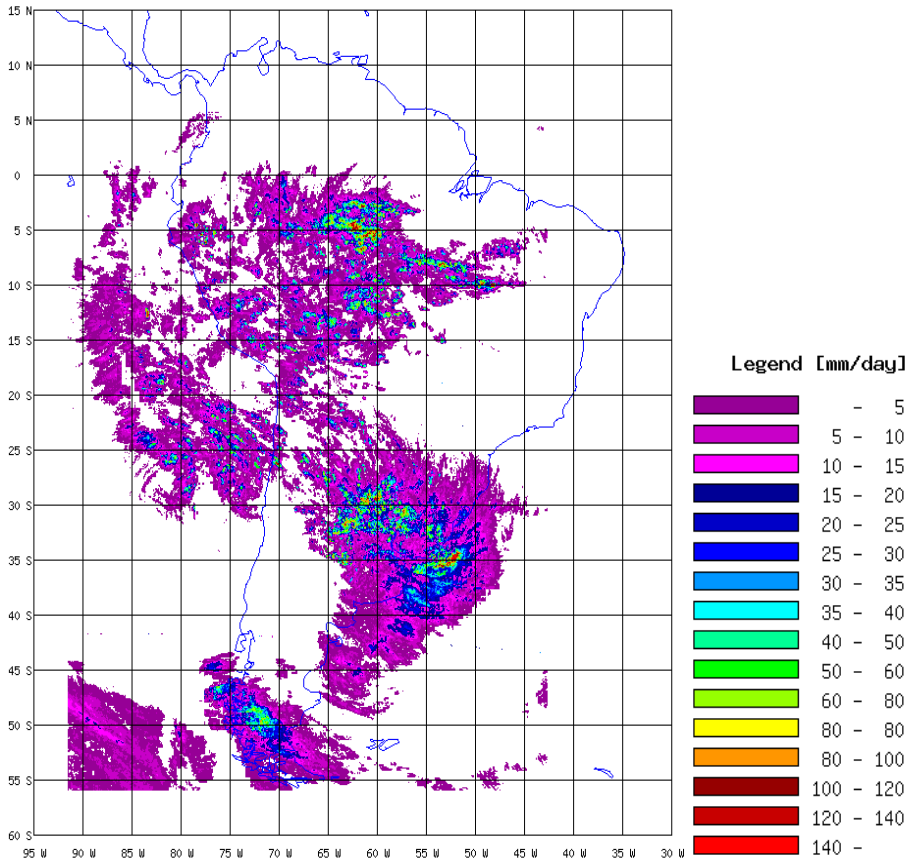
2. Objective

The goal of this study is to quantify the dynamic processes of large forest disturbances in the Brazilian Amazon by use of land cover and weather remote sensing data.

3. Methods

We analyzed the pattern of large forest disturbances apparently caused by severe winds (blow-downs) in a mostly unmanaged portion of the Brazilian Amazon using a longitudinal transect of Landsat images (27 scenes between 6º43'W 68º50'S and 2º16'W 51º51'S) and daily precipitation estimates based on NOAA satellite data.

Weather Satellite Data



GOES Infrared Estimated Daily Rainfall

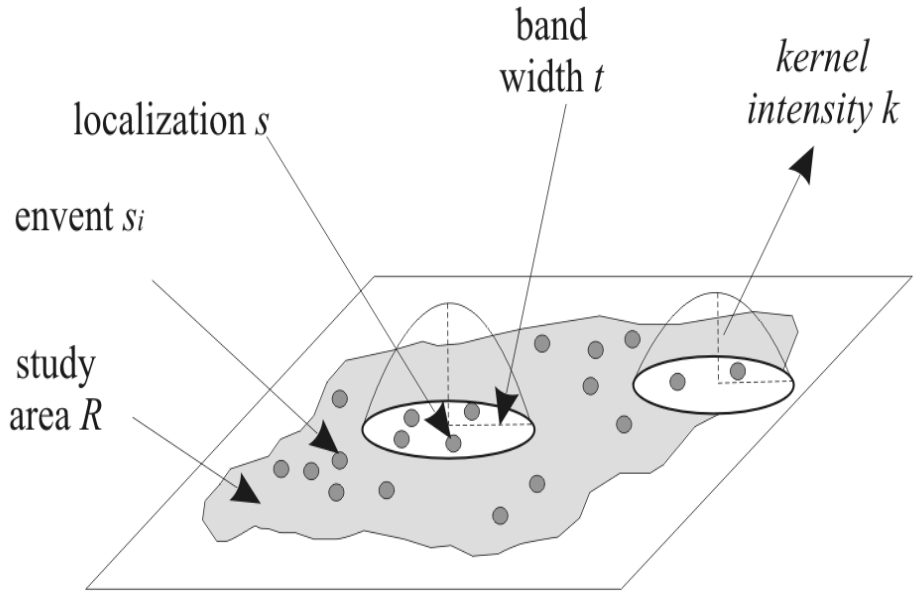
- ✓ RTR daily image were obtained from a compilation of the *auto-estimator using the NOAA 8 and -9 in the infrared (IR) 10.7- mm band* to compute real-time precipitation amounts based on a power-law regression algorithm.
- ✓ This regression is derived from a statistical analysis between surface radar–derived instantaneous rainfall estimates and satellite-derived IR cloud-top temperatures collocated in time and space.
- ✓ The rainfall rate estimates are adjusted for different moisture regimes using the most recent fields of precipitable water and relative humidity generated by the National Centers for Environmental Prediction Eta Model (Vicente *et al.*, 1998).

Land Cover Satellite Data

Orthorectified ETM+ Landsat images

- ✓ ETM+ Landsat images ranging from 1999 to 2001;
- ✓ Low cloud cover (~10%), spatial resolution of ~30 m and it was acquired already orthorectified with a spatial accuracy of 10 m (Tropical Rain Forest Information Center, 2000).

Spatial analysis



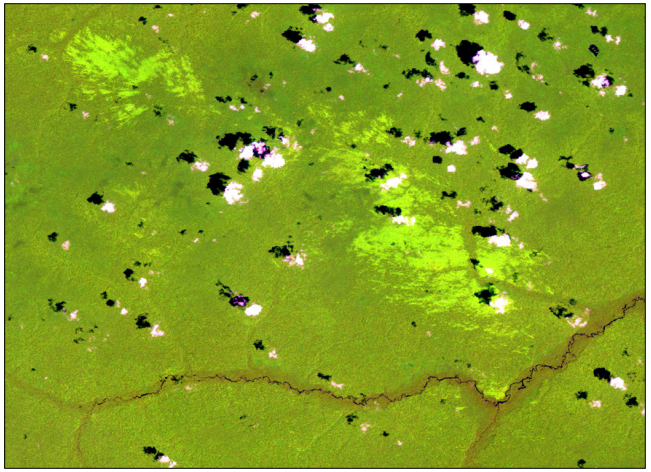
- ✓ Spatial patterns of blow-dows areas in the Brazilian Amazon were carried out by use of a mobile frequency wind named kernel (Bailey and Gatrell, 1995).
- ✓ The goal is to observe if these events exhibit some aggregation (cluster) in the space.

$$\lambda(s) = \lim_{ds \to 0} \left\{ \frac{E(Y(ds))}{ds} \right\}$$

Points (frequency) can be estimated by use of their median *E* (Y(*A*)), and covariance *COV* (Y(*A*i), Y(*A*i)), given that Y is the event number in A and that it depend clearly of the size area used. In a stationary process, the limit of a small area tends to be zero. Thus, is zero into of *R* and *E*(Y(*A*)) = *B*, were *B* is an area of *A*.

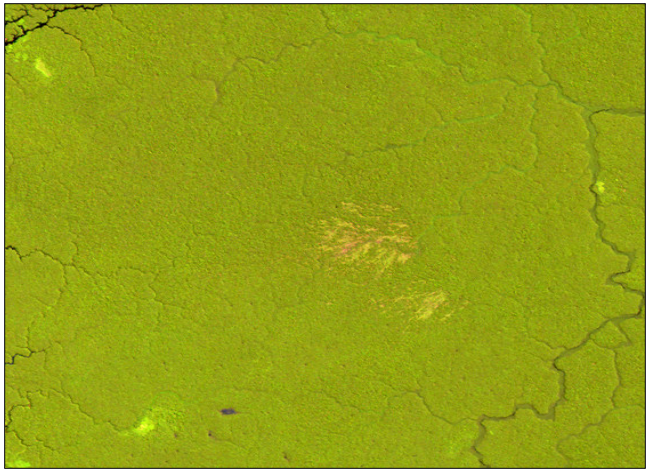
Classification by Unmixing Images

New Blowdown



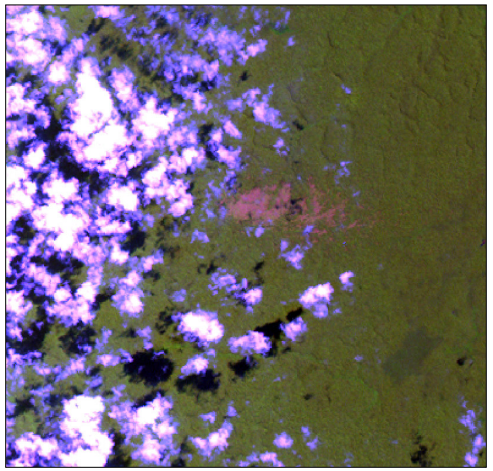
- ✓ Low soil fraction
- ✓ High veg fraction
- ✓ High red band
- ✓ Low infrared band

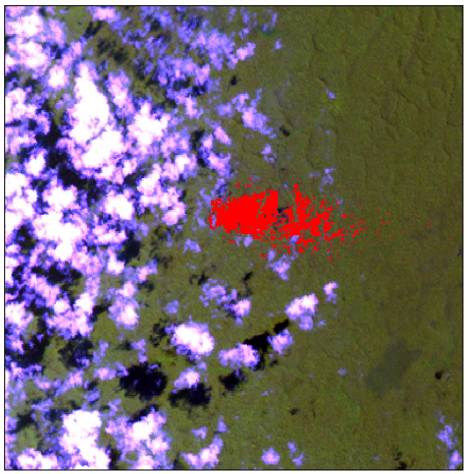
Old Blowdown



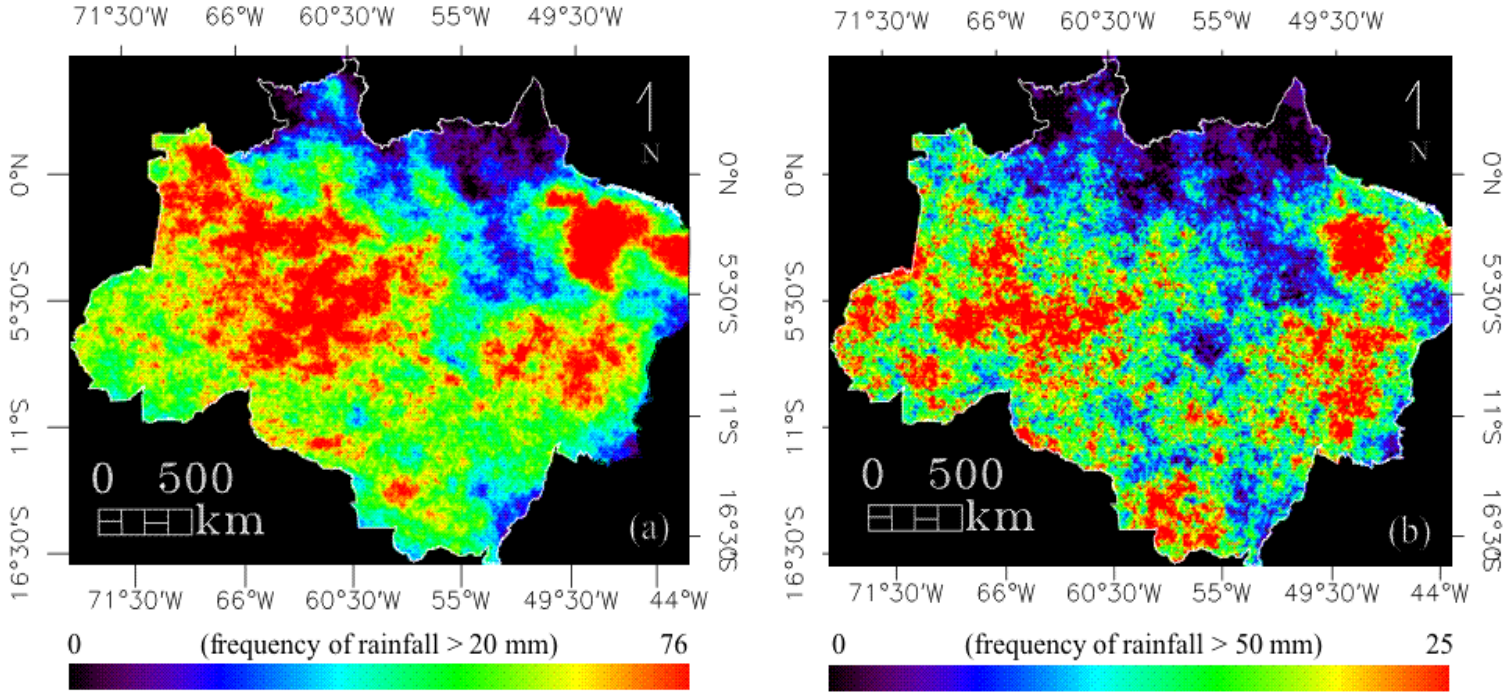
- ✓ High soil fraction
- ✓ Low veg fraction
- ✓ Low red band
- ✓ High infrared band

"Fan-Shape patches"



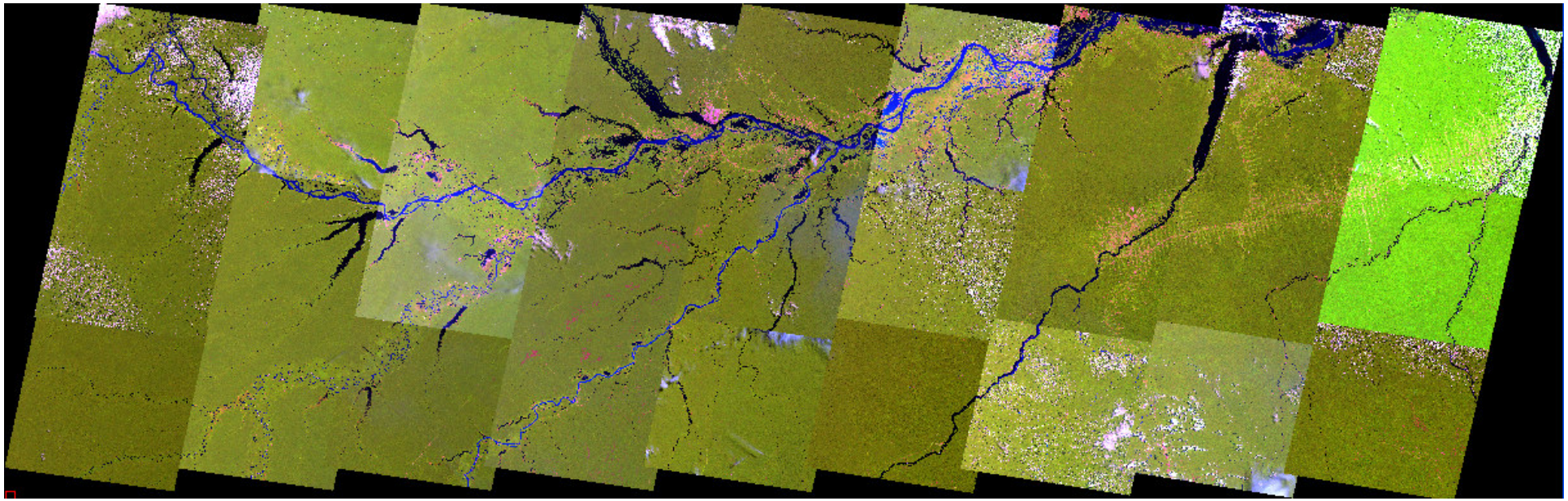


4. Results

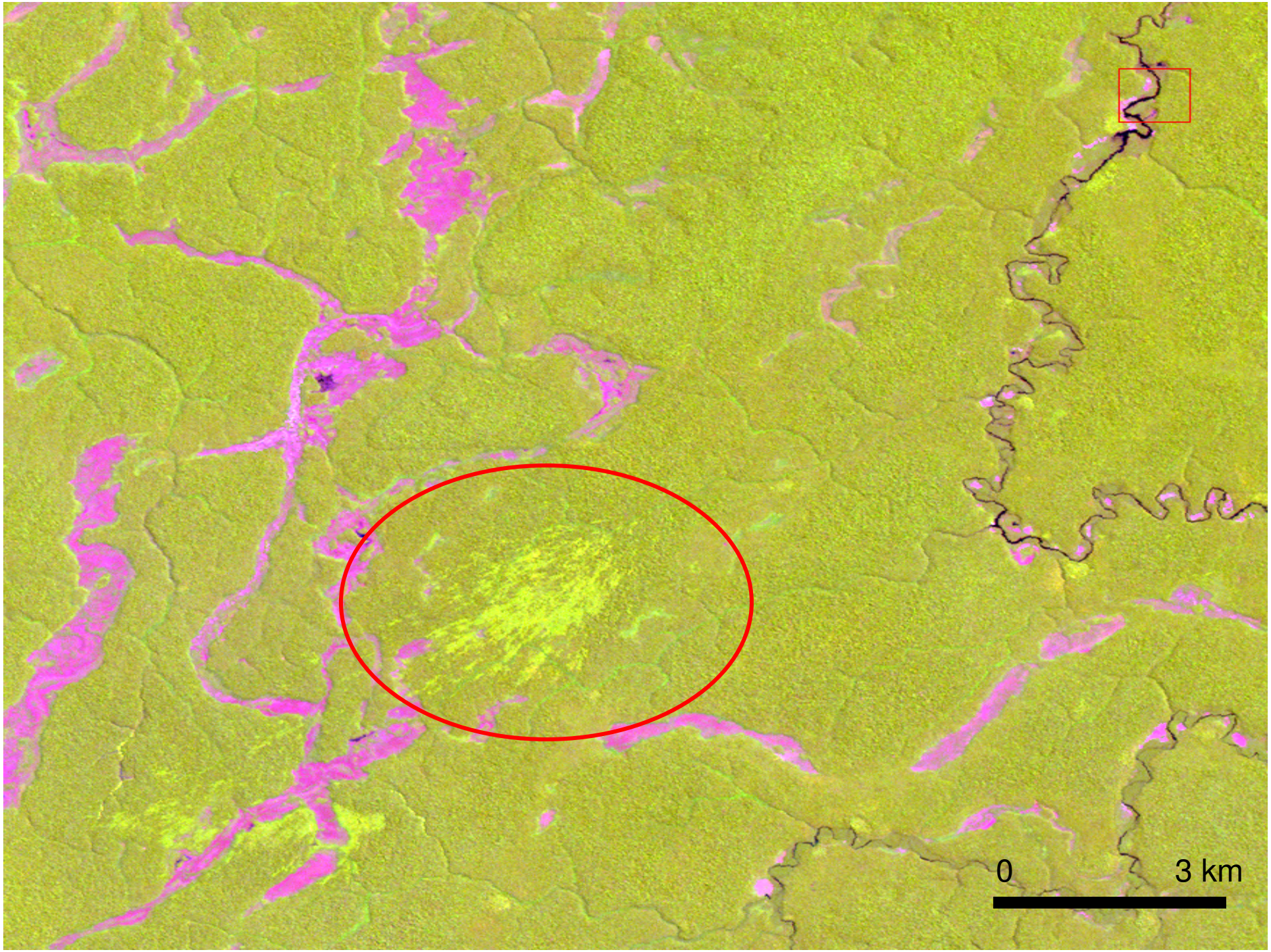


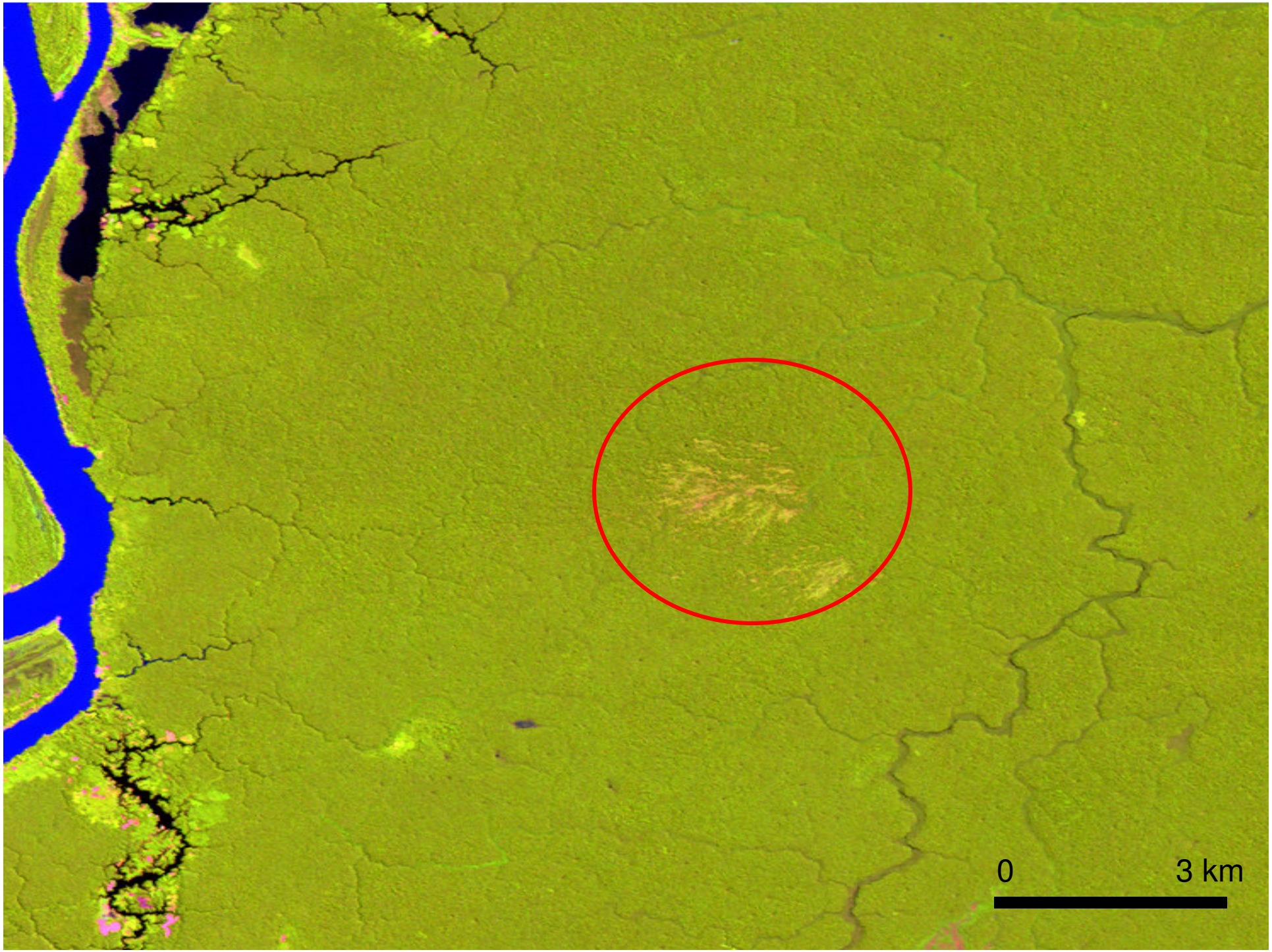
- ✓ Using 313 Real-Time Rainfall daily images (~ 1 year) of geosynchronous NOAA satellite (Vicente *et al.*, 1998) we produced two frequency images of precipitation ≥ 20 mm and ≥ 50 mm of rainfall.
- ✓ The maximum precipitation frequency of heavy rainfall ≥ 20 mm and ≥ 50 mm were 75 (Figure *a*) and 26 (Figure *b*).
- ✓ The central area located around of ~ 63º longitude and area between 0º and 8º of latitude (close of Manaus) showed the most heavy rainfall.

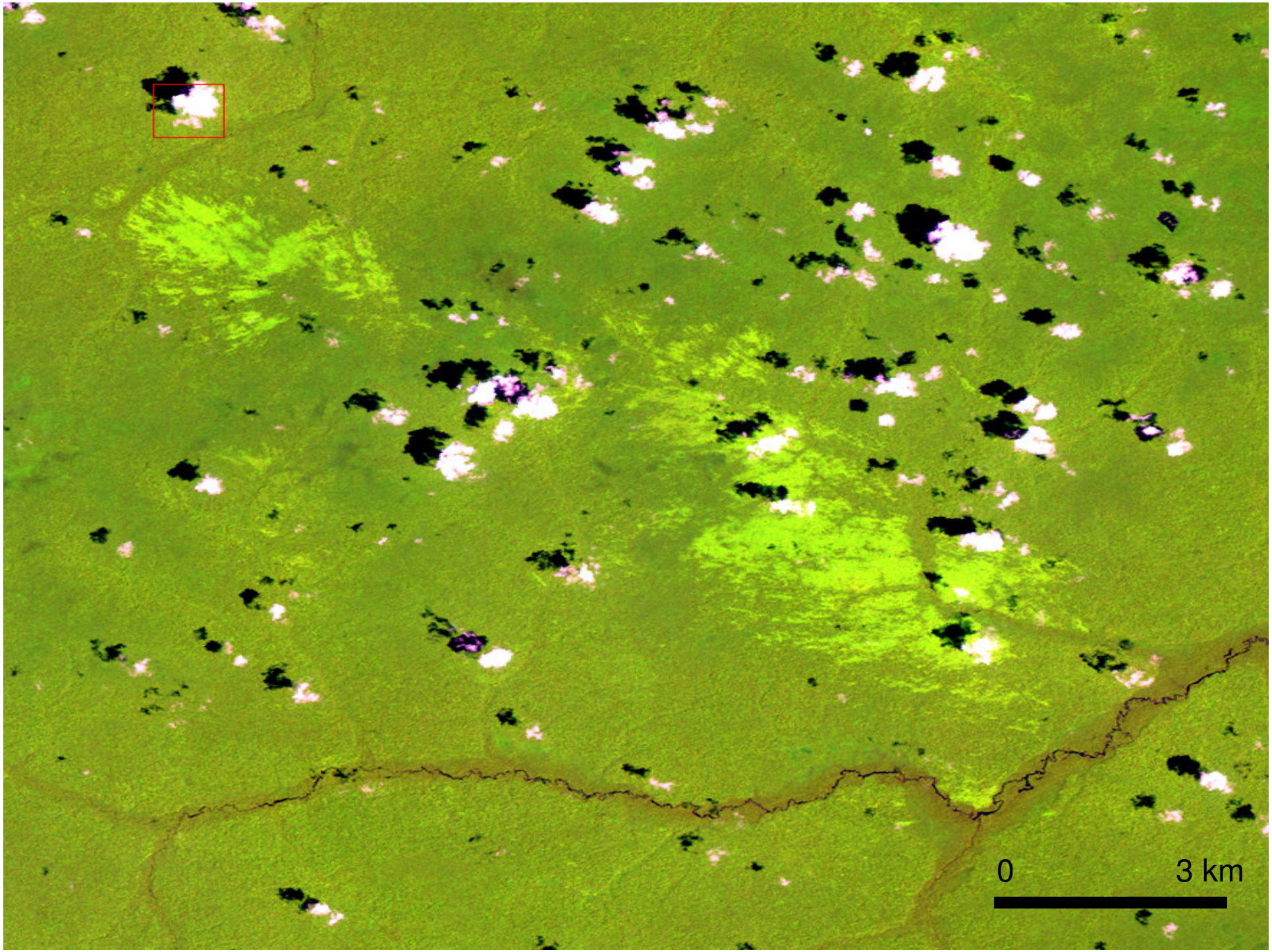
ETM+ Landsat Mosaic Image

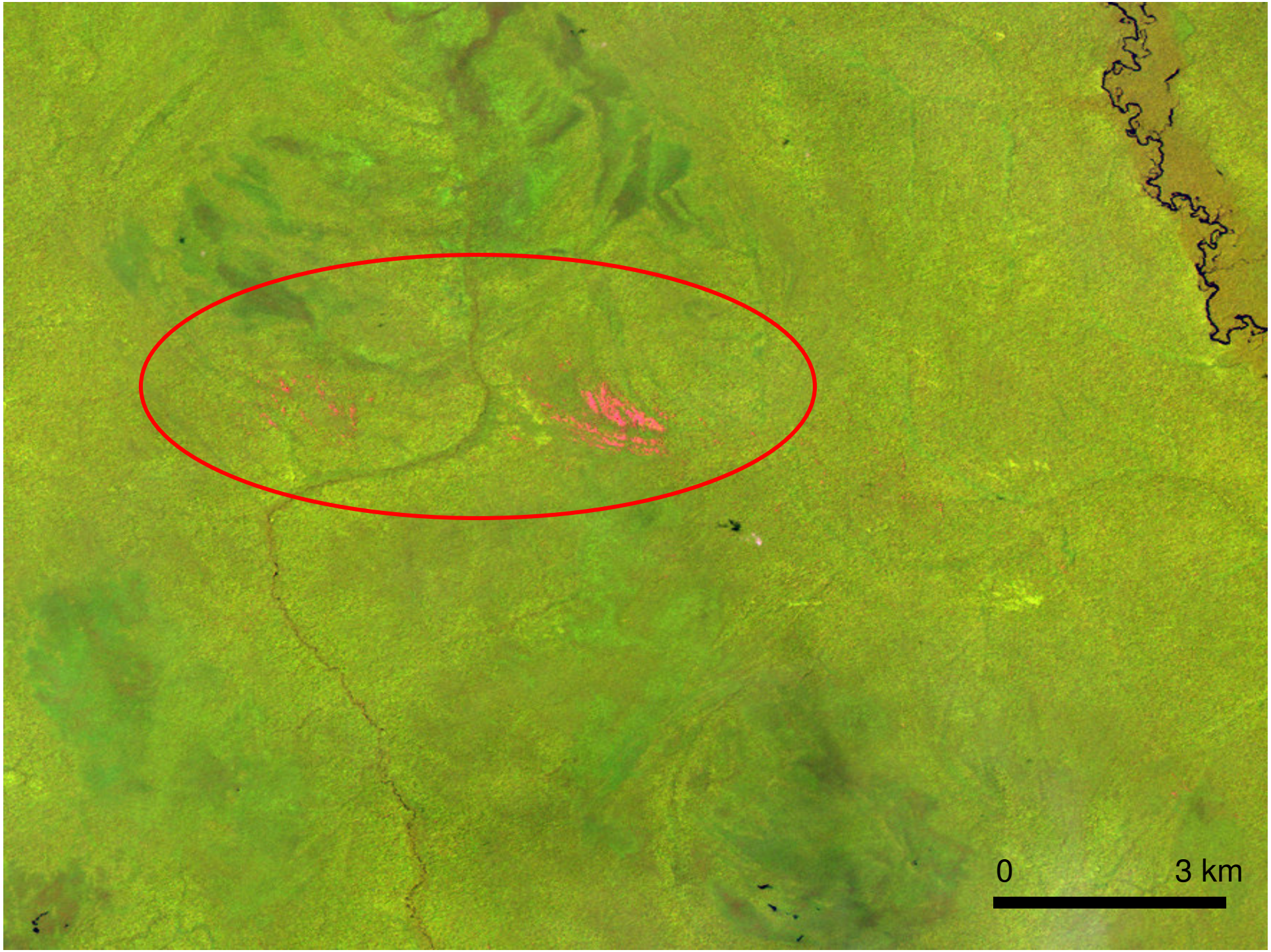


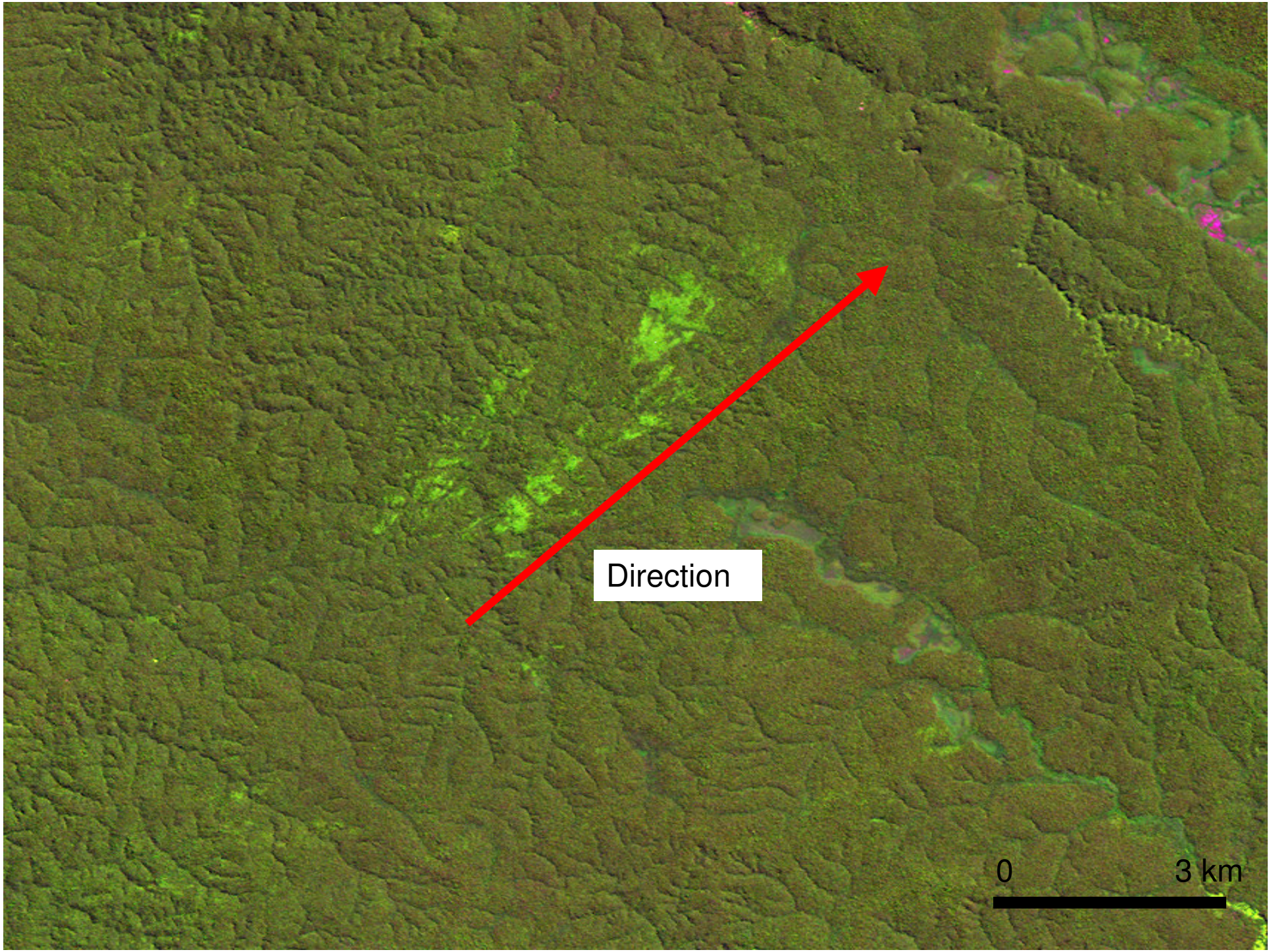
- 27 ETM+ Landsat images were analyzed;
- Color compositions 5,4, and 3 and false color 4,5, and 3 were used;

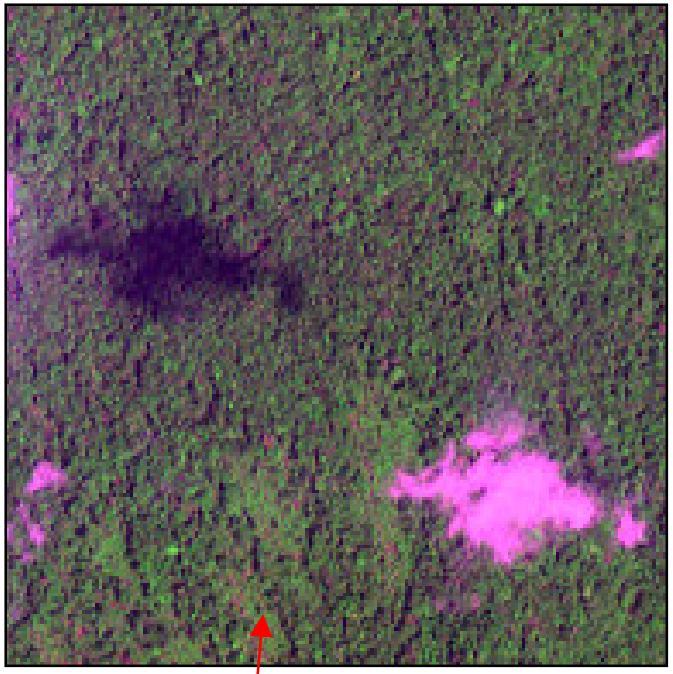

0
3 km

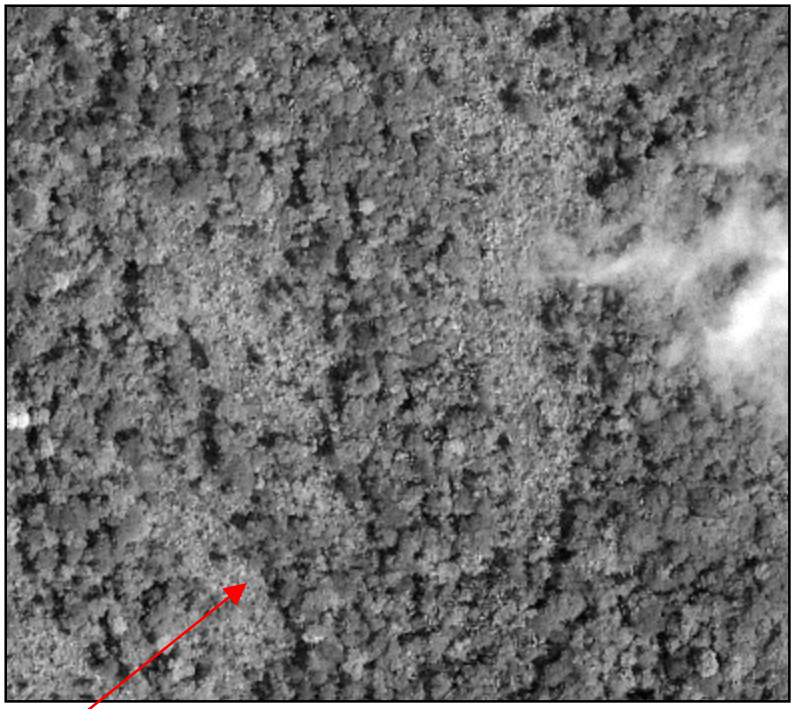

0
3 km

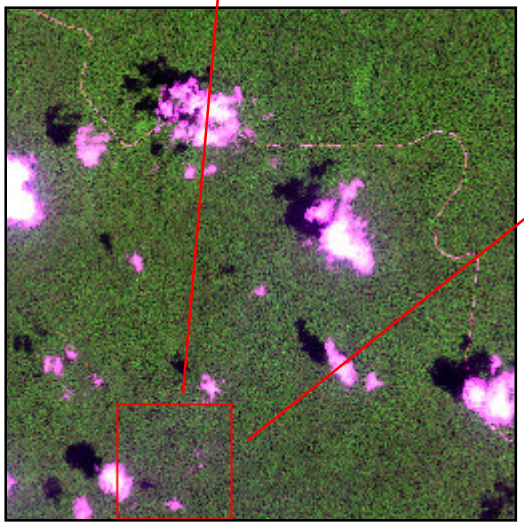

0
3 km


0
3 km


Direction
0
3 km

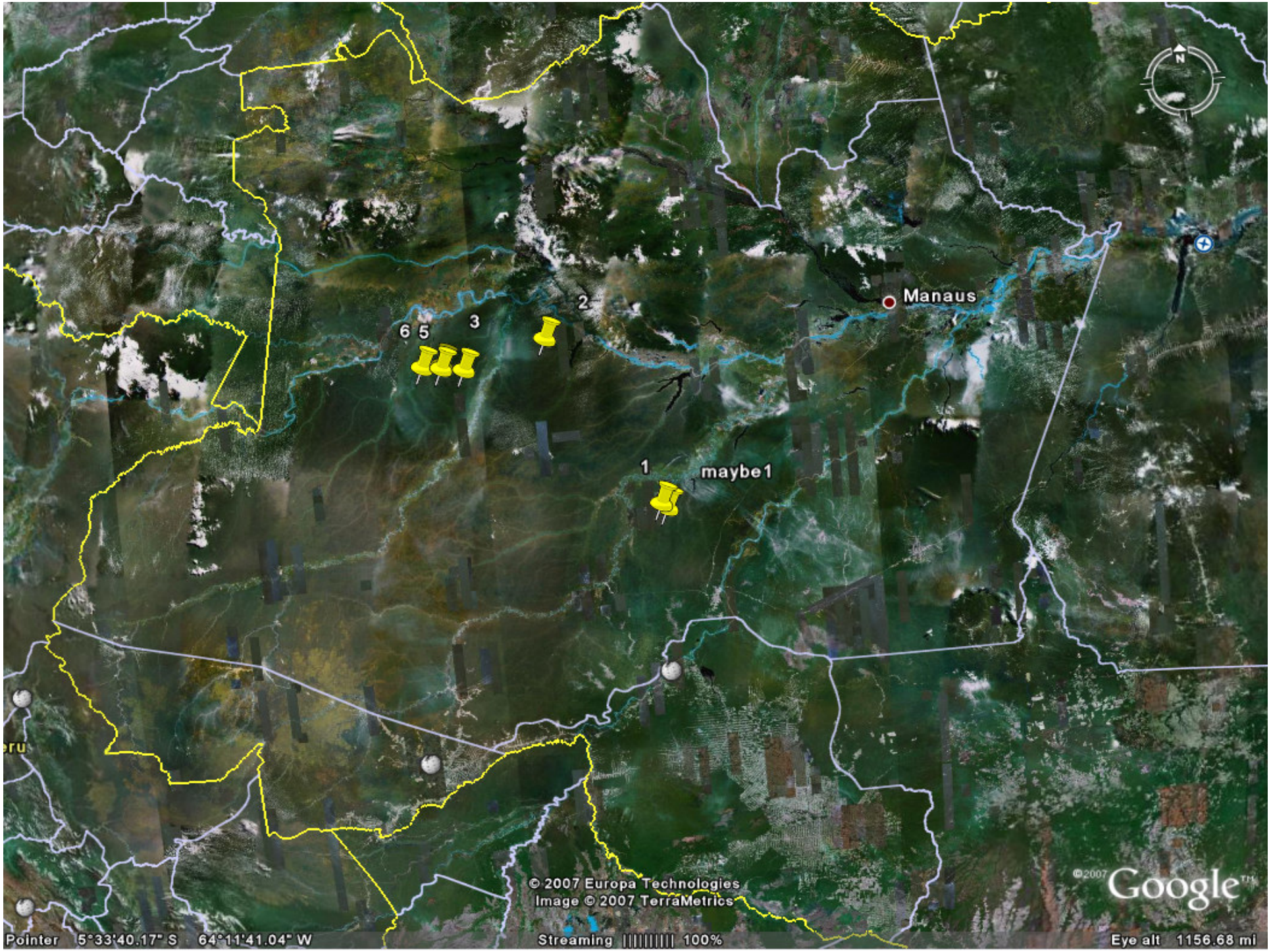






Blowdown in Ikonos 2000

0 2 km

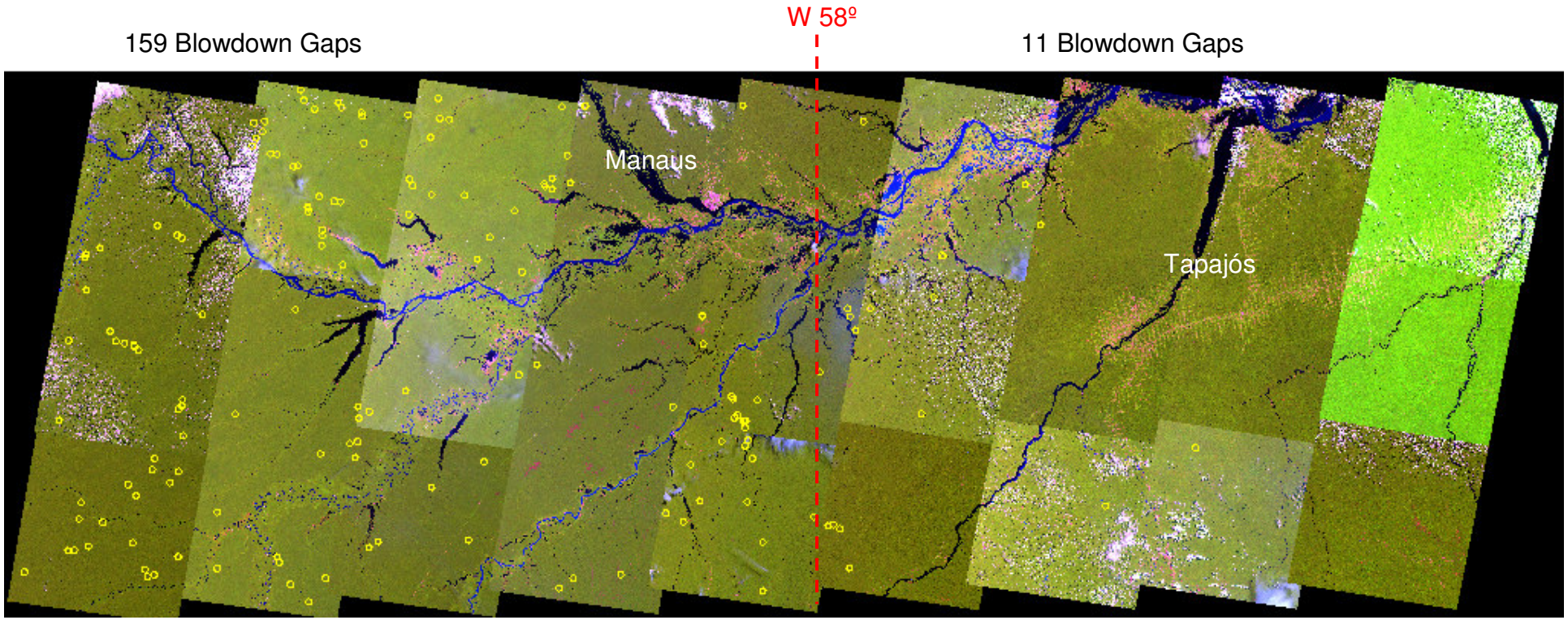

Manaus
1
maybe1
2
3
5
6
© 2007 Europa Technologies
Image © 2007 TerraMetrics
©2007 Google™
Pointer 5°33'40.17" S 64°11'41.04" W
Streaming 100%
Eye alt 1156.68 mi


N
4
5
Image © 2007 TerraMetrics
©2007 Google™
Pointer 3°32'06.54" S 66°54'02.05" W elev 308 ft
Streaming 100%
Eye alt 20.48 mi


N
1
Image © 2007 DigitalGlobe
©2007 Google™
'53.85" S 63°46'26.51" W elev 239 ft
Streaming 100%
Eye alt 2831 ft

Geographic Distribution

- 170 new and old blowdowns were found;



Geographic Distribution

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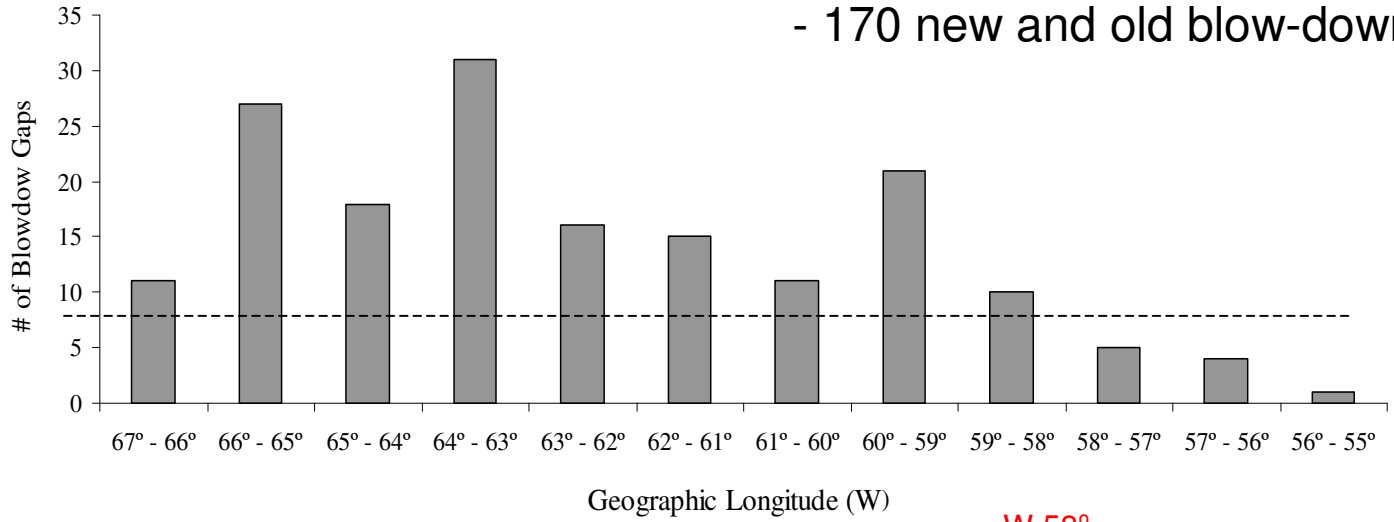
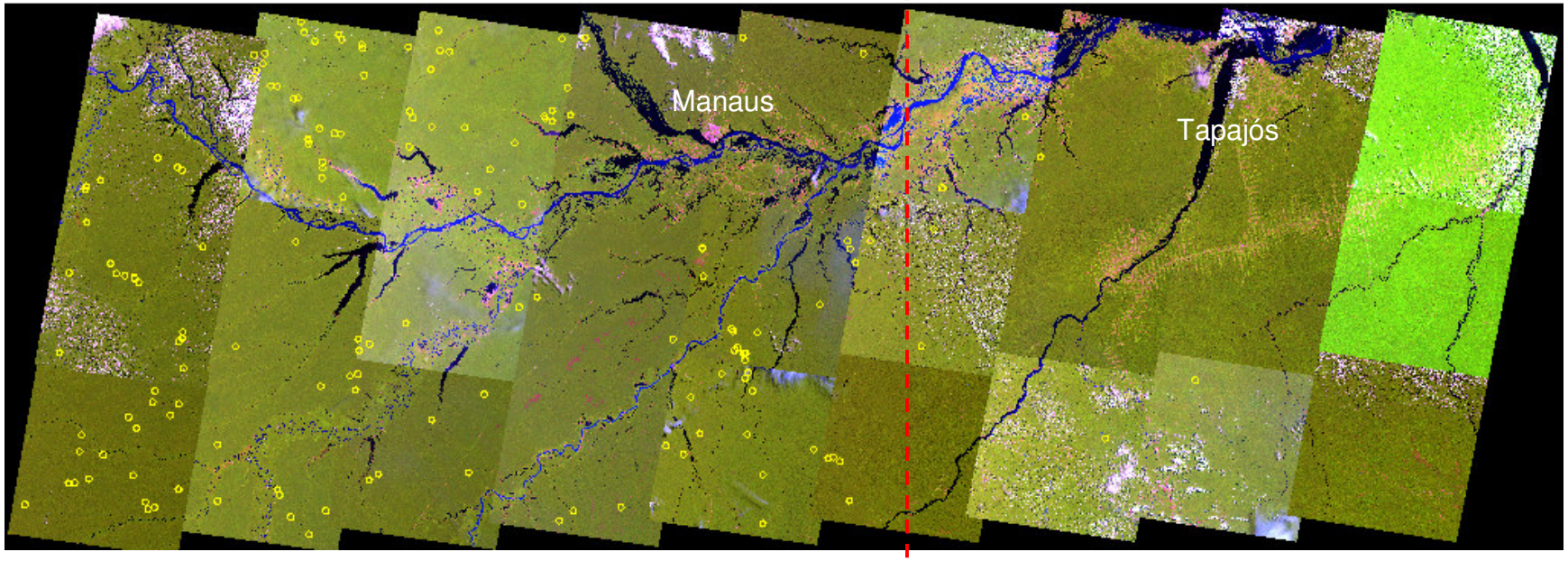


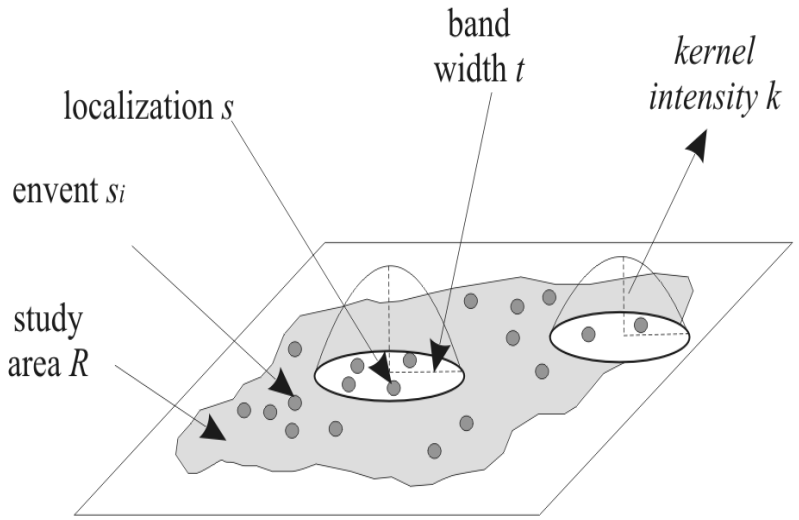
159 Blow-down

W 58º

11 Blow-down



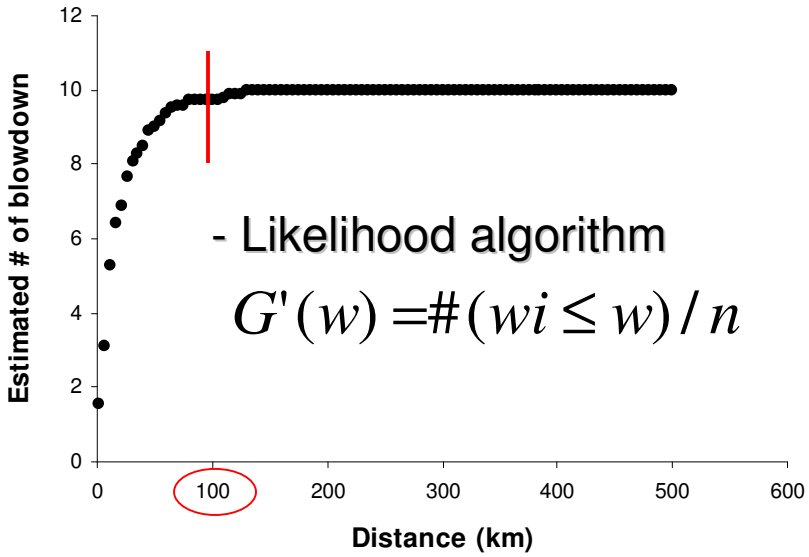
Spatial analysis



Event intensity

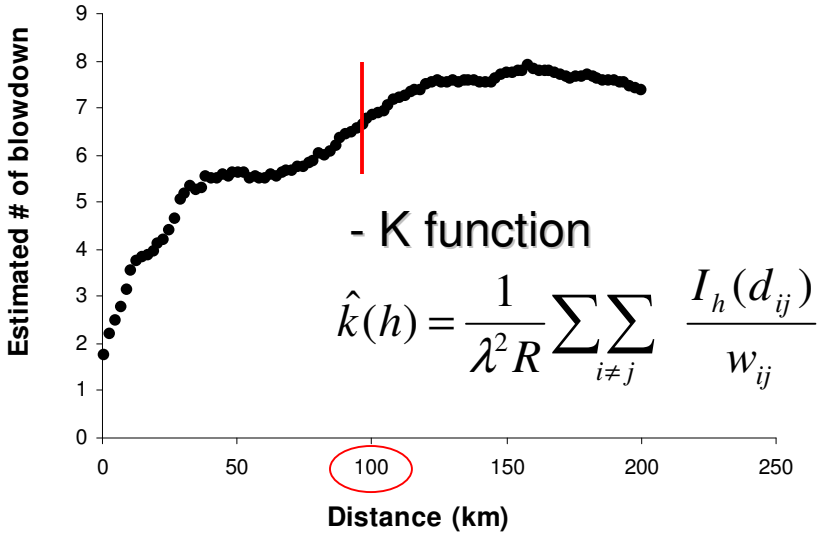
$$\hat{\lambda}_\tau(s) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{(s - s_i)}{\tau}\right)$$

$$k(h) = \frac{3}{\pi}(1 - h^2)$$



- Likelihood algorithm

$$G'(w) = \#(wi \le w)/n$$



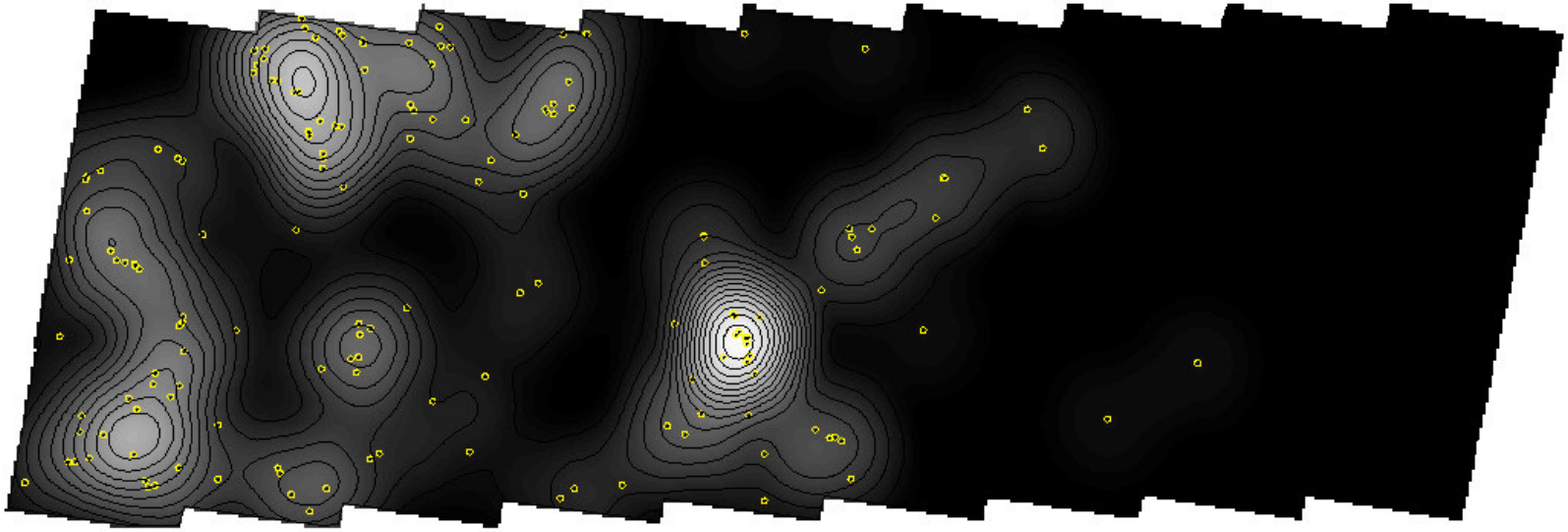
- K function

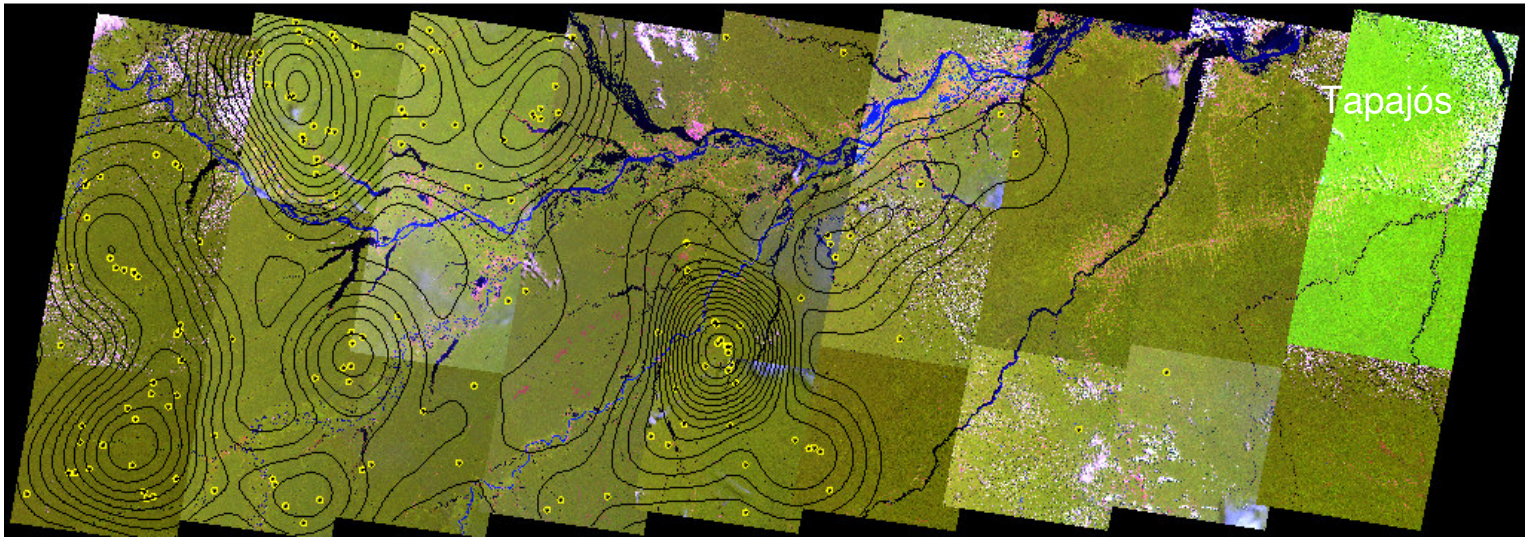
$$\hat{k}(h) = \frac{1}{\lambda^2 R} \sum\sum_{i \neq j} \frac{I_h(d_{ij})}{w_{ij}}$$

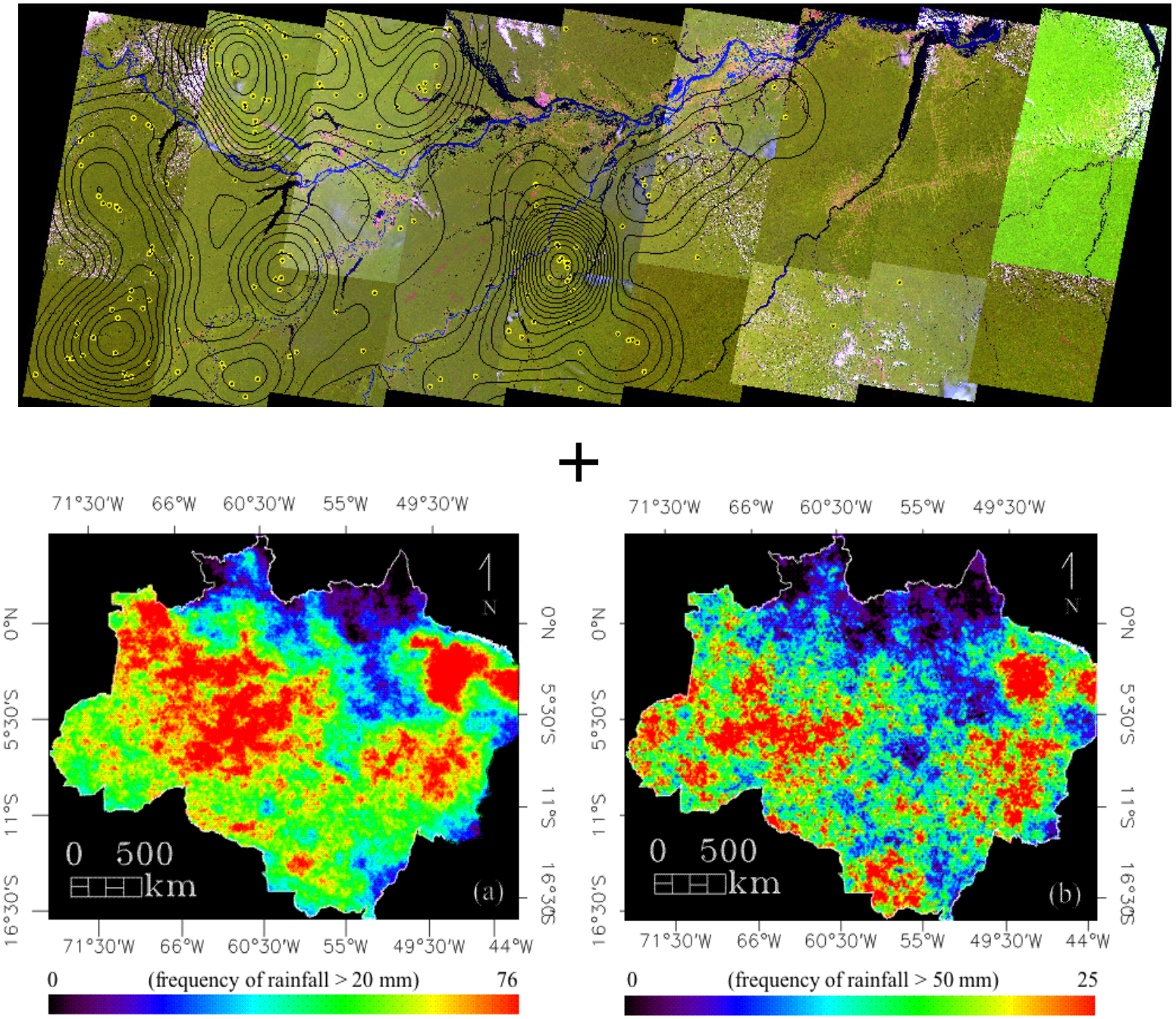
Cluster Analysis

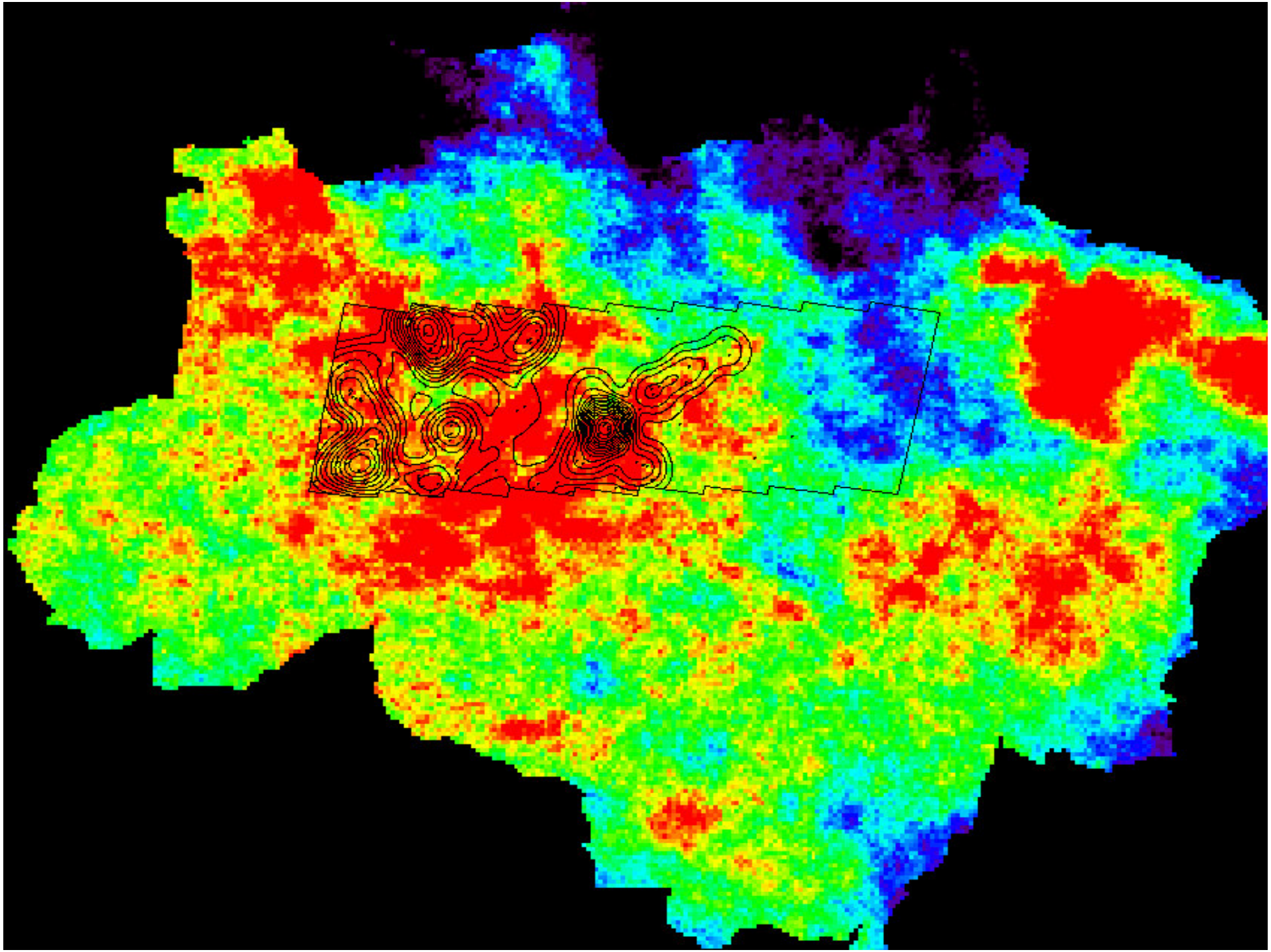
- 8 clusters;

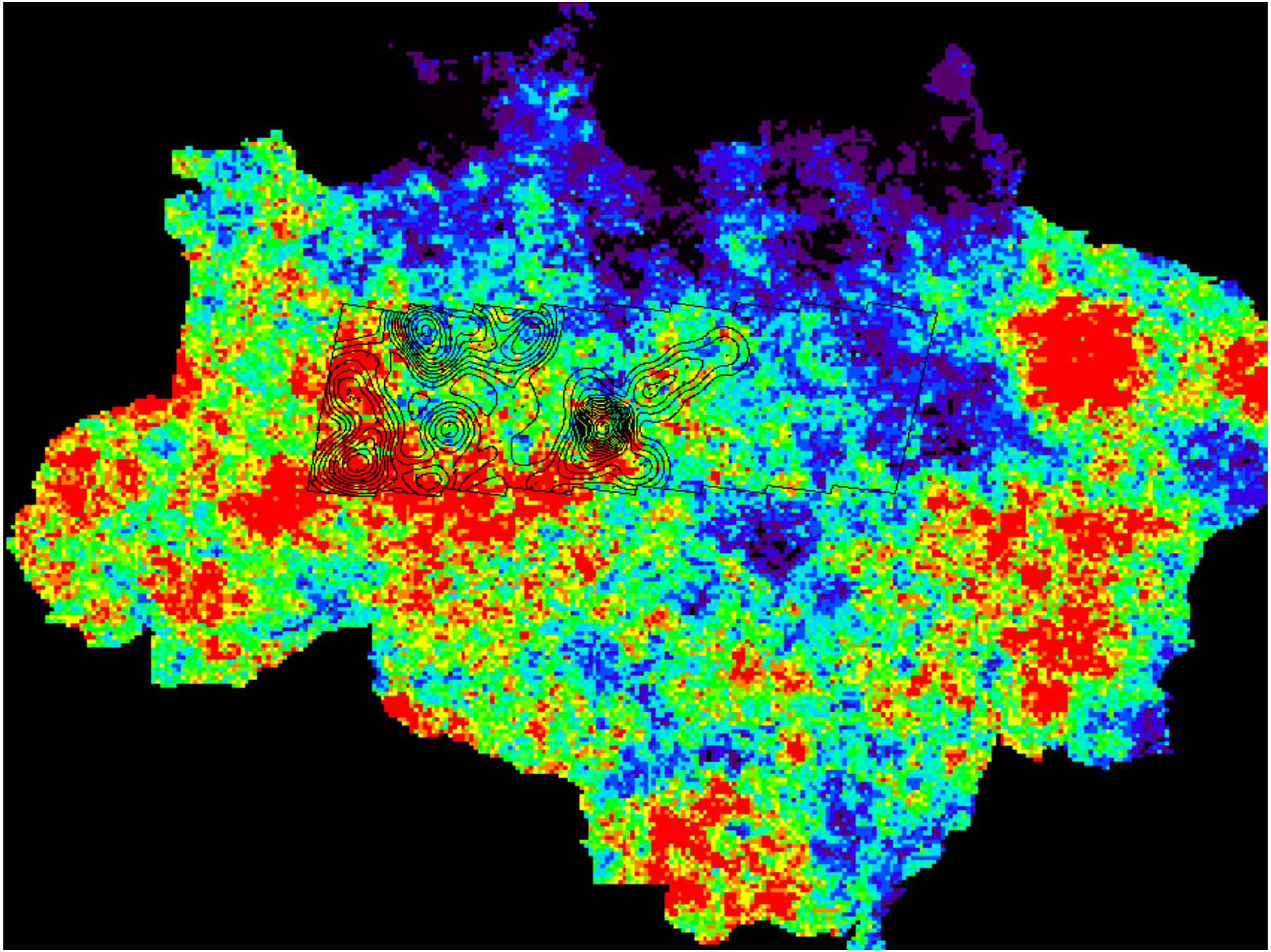
- 100 km was used into a spatial dependency process

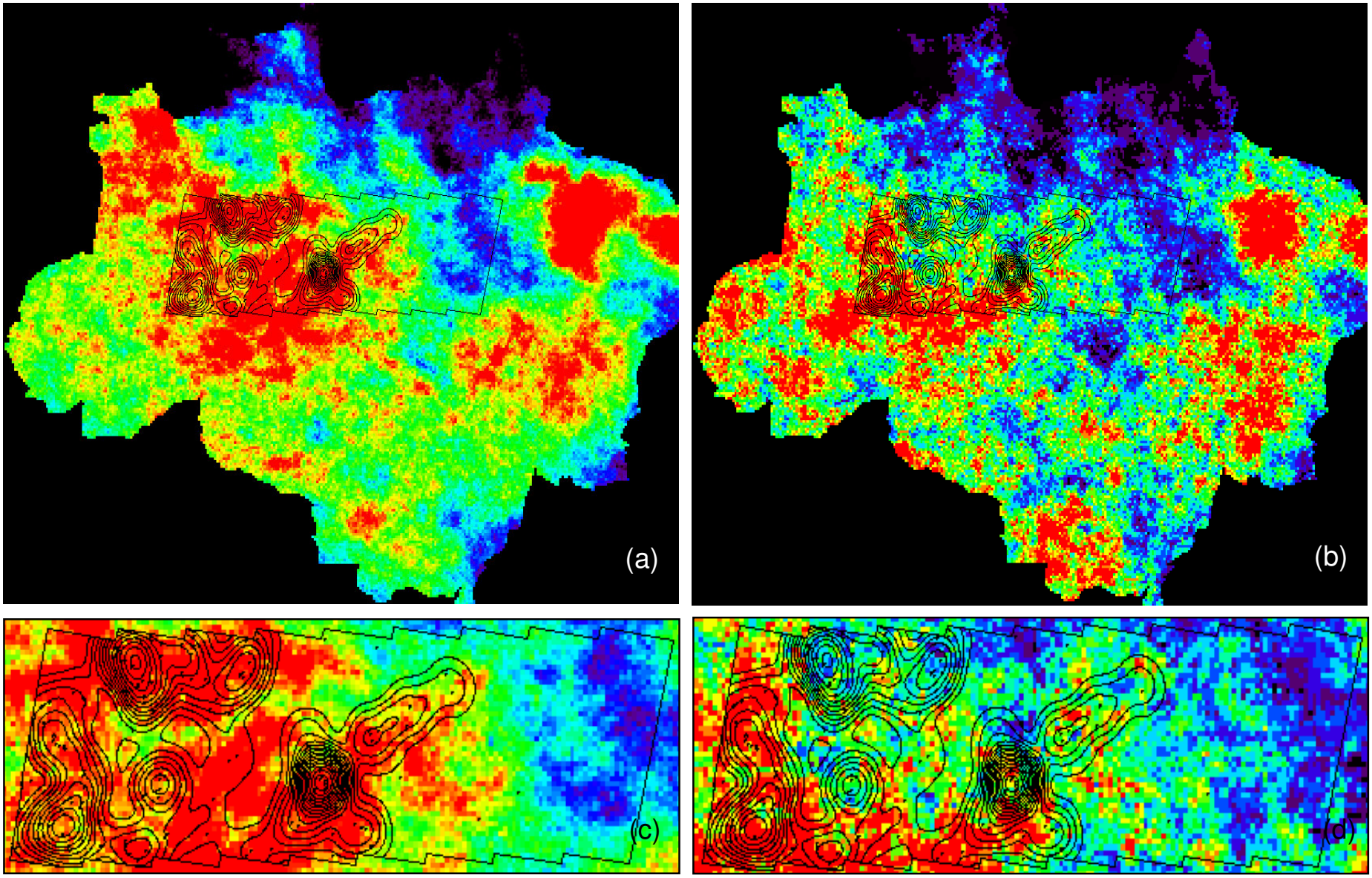


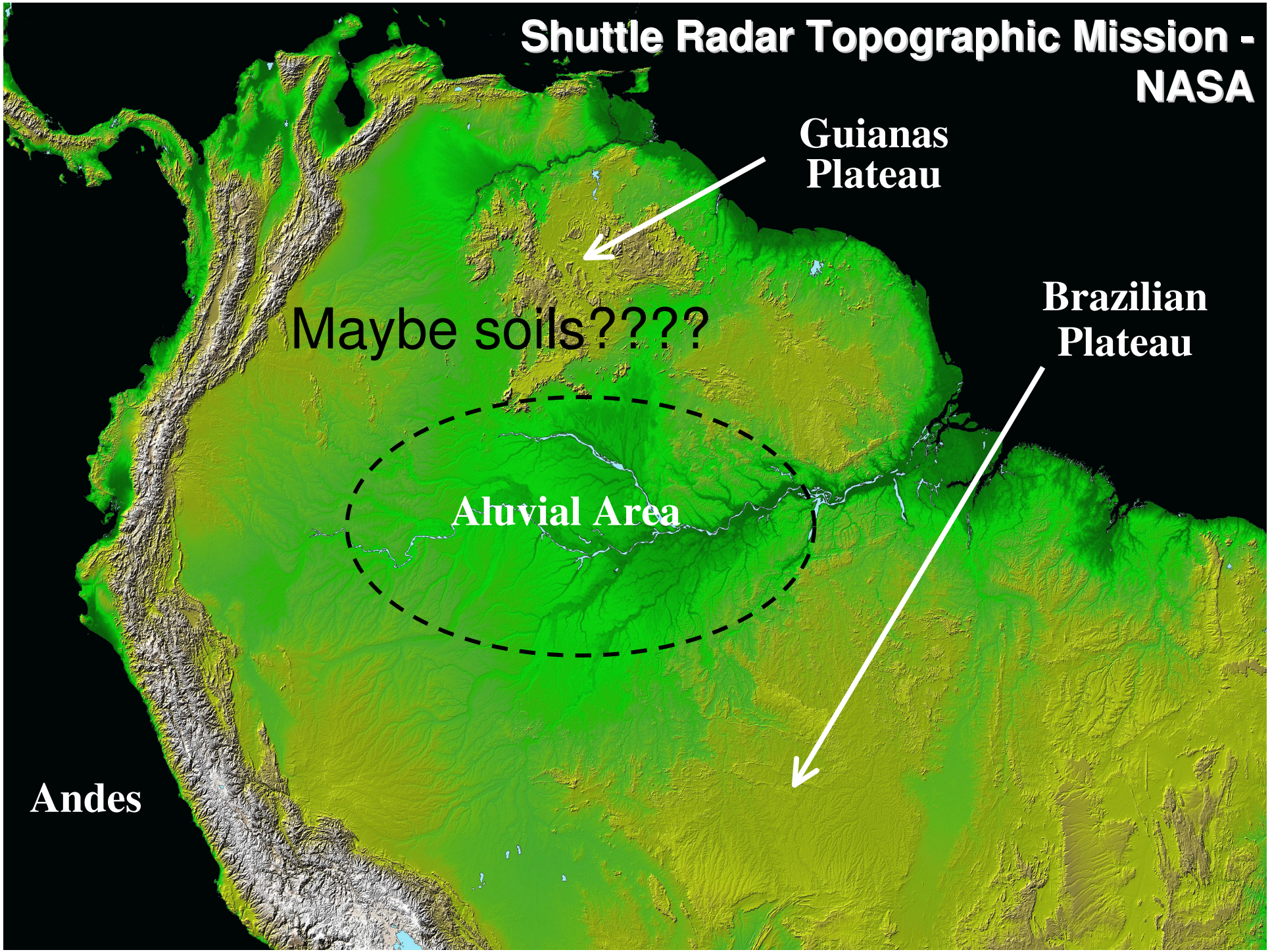


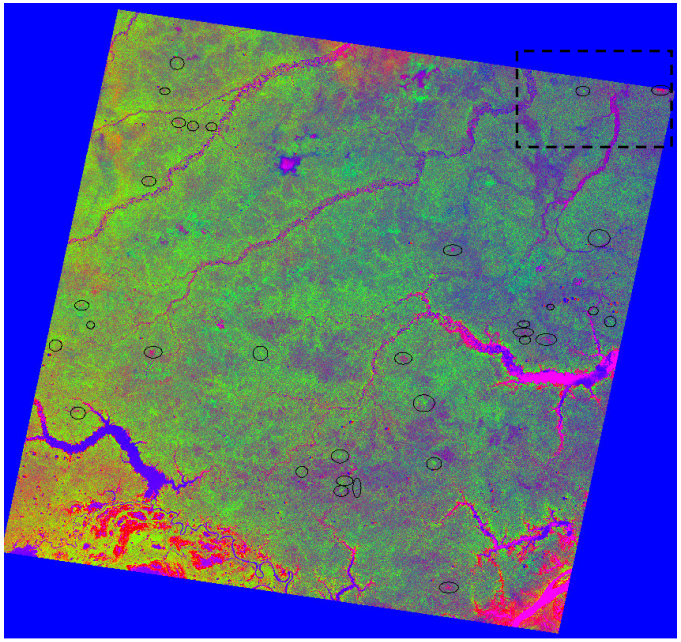

71°30'W
66°W
60°30'W
55°W
49°30'W
44°W
0°N
5°30'S
11°S
16°30'S
N
0 500
km
(a)
(b)
0
(frequency of rainfall > 20 mm)
76
(frequency of rainfall > 50 mm)
25

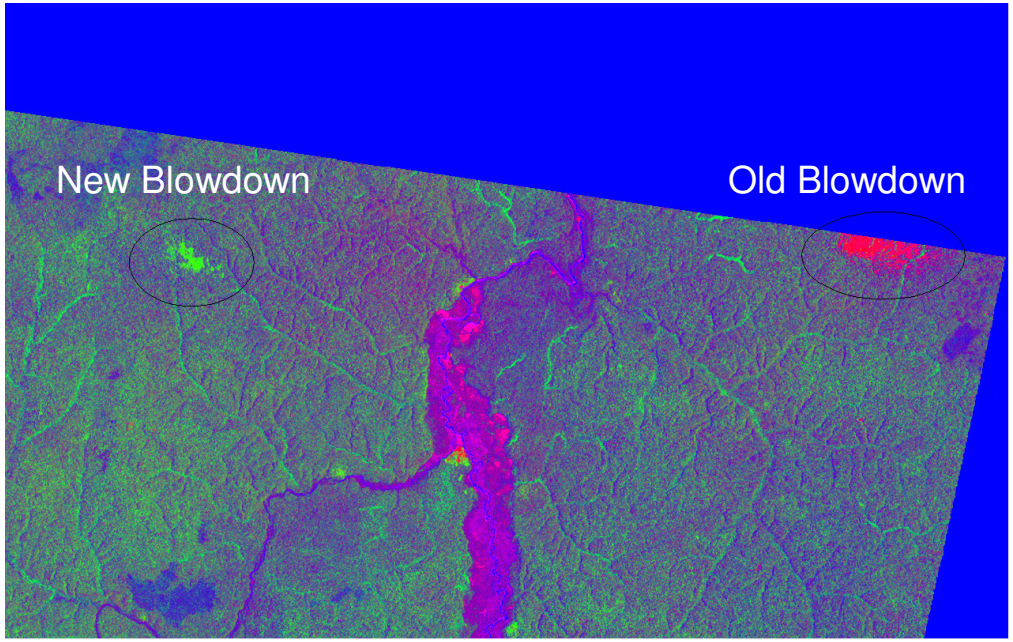





(a)
(b)
(c)
(d)


Shuttle Radar Topographic Mission - NASA
Guianas Plateau
Maybe soils????
Brazilian Plateau
Aluvial Area
Andes

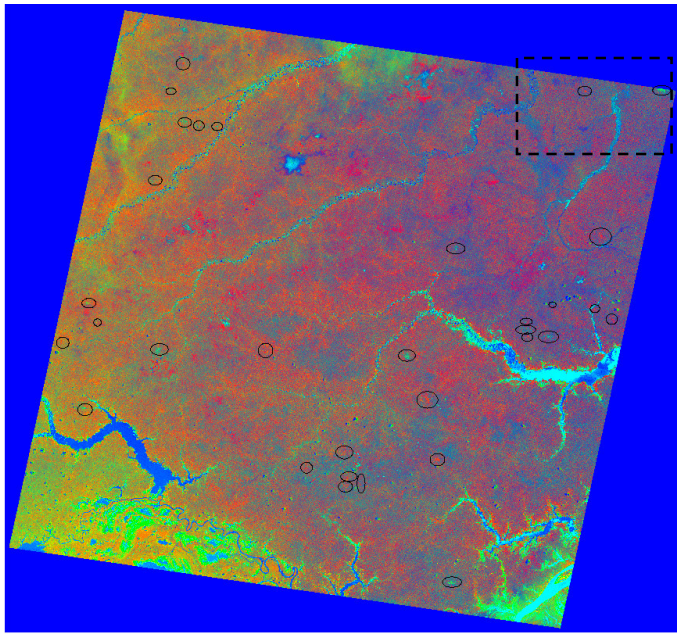


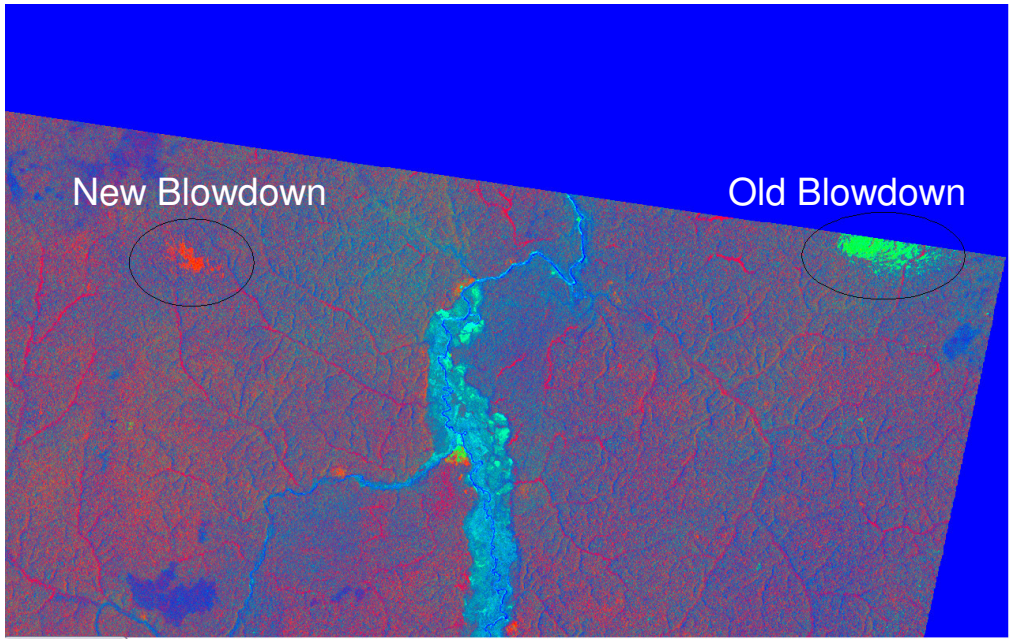


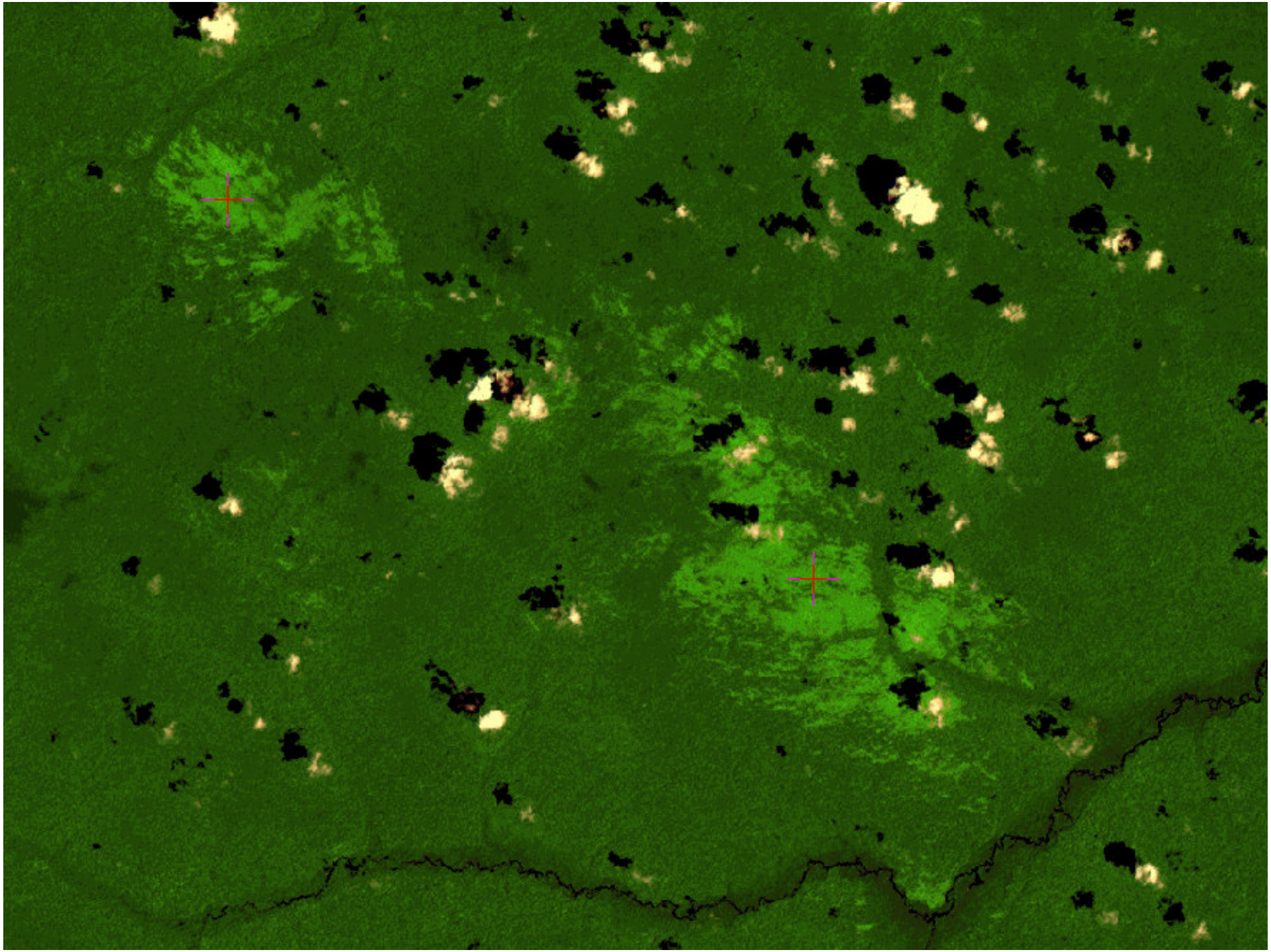
Vegetation (R), Soil (G) and Shade (B)

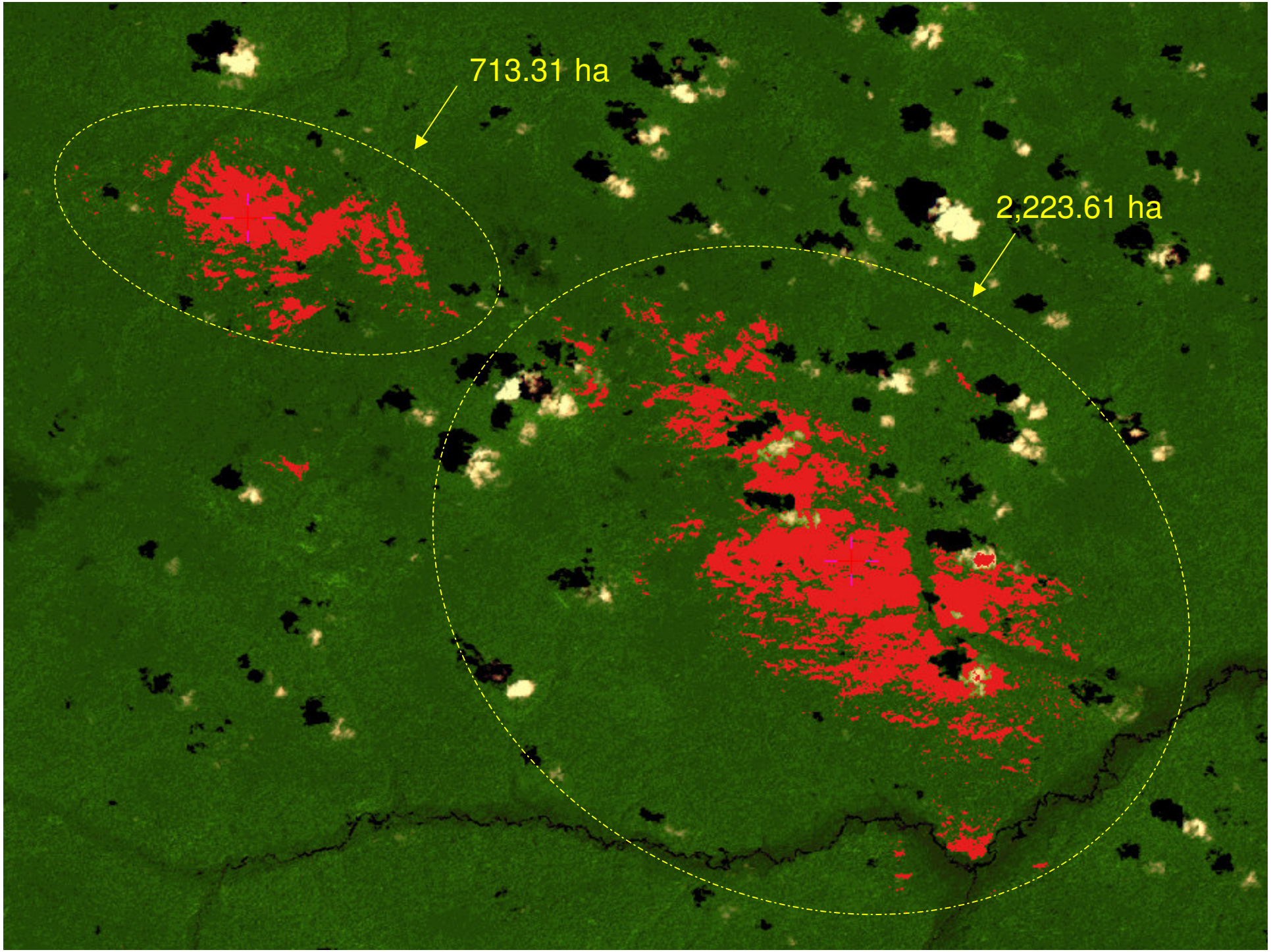
Unmixing images showing new and old blowdowns

Soil (R), Vegetation (G) and Shade (B)

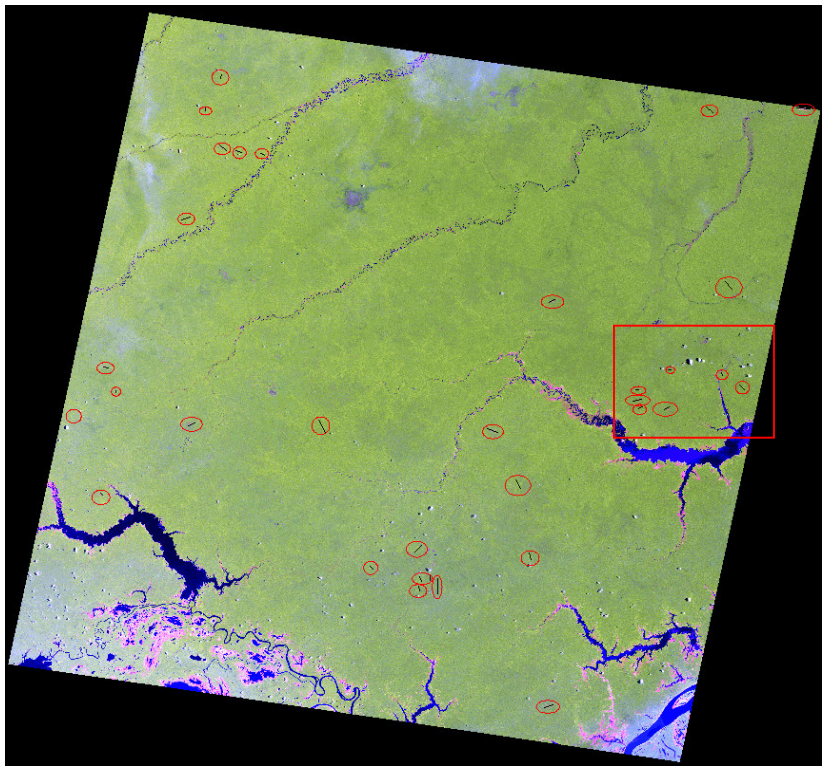


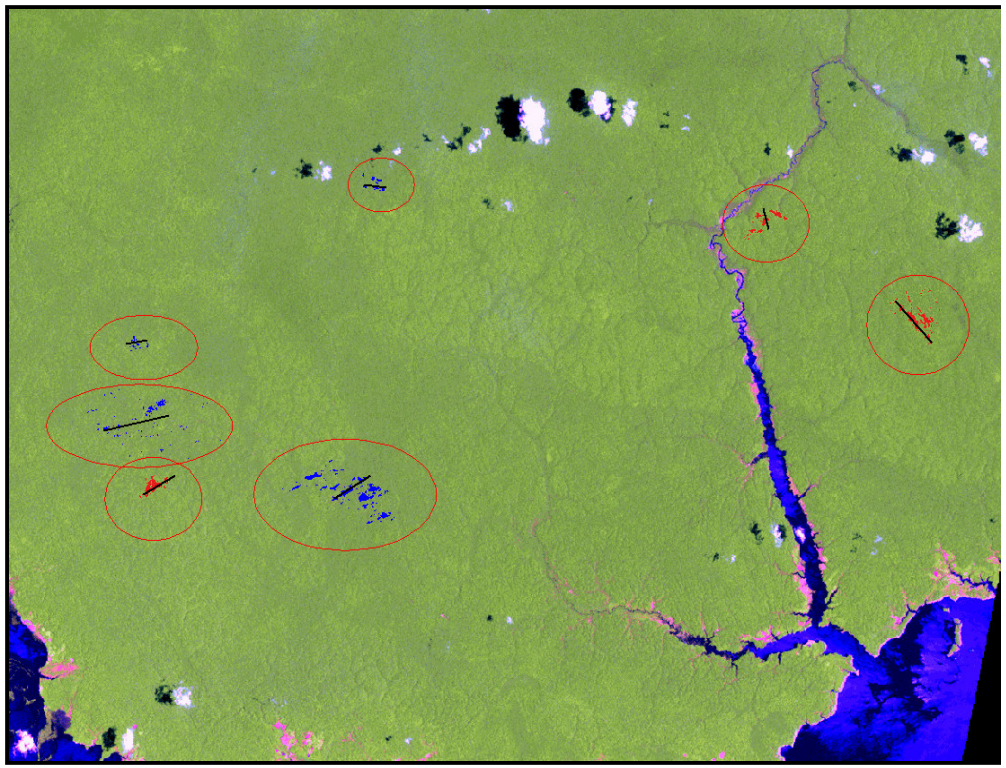





713.31 ha
2,223.61 ha

Type, area, length, width and DIRECTION for each blowdown



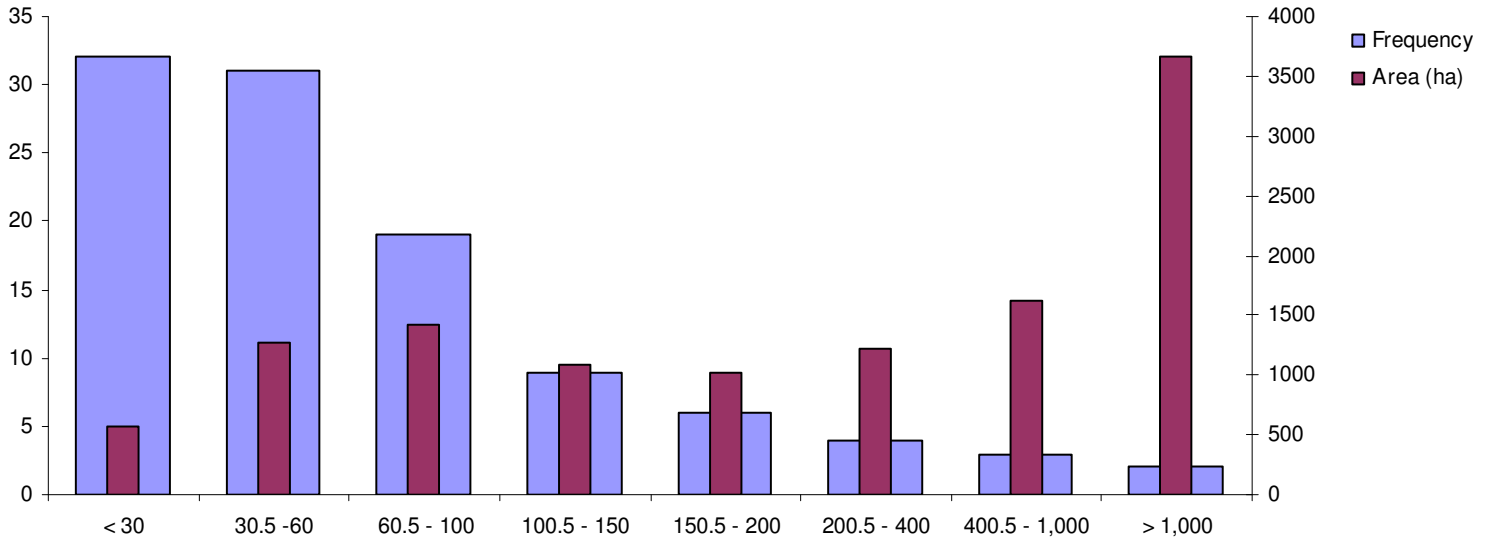


	A	B	C	D	E	F	G	H	I	J	K	M
1	Calculation of disturbance area for 27 Landsat Scenes											
2												
3	scenes (path/row)	Image date	X	Y	Blowdowns #	Type (Unmixing)	Area (ha)	Length (Km)	Wild (Km)	Angulo (º)	Frequency	Observation
16	001/63	8/1/2001	o 66 11 37	s 4 13 45	00163_20010801_01	new	28.75	3.18	0.29	140.709371	1	
17	001/63	8/1/2001	o 65 39 27	s 4 15 38	00163_20010801_02	new	11.29	0.7	0.2	221.69547	2	
18	001/63	8/1/2001	o 64 54 18	s 4 1 10	00163_20010801_03	old	498.39	4.08	2.82	238.047942	3	
19	001/63	8/1/2001	o 65 59 10	s 4 2 50	00163_20010801_04	old	409.21	3.9	2.4	159.41	4	
20	001/63	8/1/2001	o 66 1 0	s 3 47 21	00163_20010801_05	old	63.35	1.16	0.97	124.71744	5	
21	001/63	8/1/2001	o 65 44 21	s 4 14 25	00163_20010801_06	old	15.43	0.76	0.32	244.421498	6	
22	001/63	8/1/2001	o 65 47 38	s 4 9 7	00163_20010801_07	old	349.75	2.12	1.94	234.64089	7	
23	001/63	8/1/2001	o 65 31 18	s 4 19 16	00163_20010801_08	old	29.49	1.26	0.22	160.574903	8	
24	001/63	8/1/2001	o 65 33 34	s 4 17 19	00163_20010801_09	old	70.5	1.56	1.24	230.687256	9	
25	001/63	8/1/2001	o 65 33 55	s 4 16 35	00163_20010801_10	old	43.04	1.9	0.7	199.701624	10	
26	001/63	8/1/2001	o 65 13 39	s 4 29 43	00163_20010801_11	old	25.34	1.31	17	?	11	
27	001/63	8/1/2001	o 65 18 35	s 4 26 19	00163_20010801_12	old	28.34	0.76	0.42	186.73	12	
28	001/63	8/1/2001	o 65 8 42	s 4 50 39	00163_20010801_13	old	31.51	1.08	0.86	156.874401	13	
29	001/63	8/1/2001	o 65 6 48	s 4 48 52	00163_20010801_14	old	174.63	1.78	2.21	172.049	14	
30	001/63	8/1/2001	o 65 6 22	s 4 45 35	00163_20010801_15	old	18.6	0.81	0.35	?	15	
31	001/63	8/1/2001	o 65 50 52	s 3 52 49	00163_20010801_16	old	92.51	2.84	1.22	201.21	16	
32	001/63	8/1/2001	o 65 55 19	s 3 54 4	00163_20010801_17	old	70.17	2.36	2.49	172.08	17	
33	001/63	8/1/2001	o 65 51 10	s 3 45 45	00163_20010801_18	old	155.46	2.83	1.36	163.799379	18	
34	001/63	8/1/2001	o 65 47 12	s 3 41 26	00163_20010801_19	old	15.59	0.83	0.23	195.40996	19	
35												
36	001/64	6/10/2001	o 65 24 25	s 5 22 1	00164_20000610_01	new	64.33	1.038	1.2	?	1	
37	001/64	6/10/2001	o 65 22 53	s 5 16 17	00164_20000610_02	new	18.35	?	?	141.689822	2	there is not any clear pa

4. Discussion

Calculation for 6 Landsat images

Blowdow size class (ha)	Frequency	Area (ha)	
< 30	32	575.72	
30.5 -60	31	1265.21	
60.5 - 100	19	1425.39	
100.5 - 150	9	1079.84	
150.5 - 200	6	1026.08	
200.5 - 400	4	1227.78	
400.5 - 1,000	3	1620.91	
> 1,000	2	3671.85	
		11892.78	total



Sceneries (first approximation)

Calculation of Forest Turnover Time (years) considering 3 cases. Cases differ by number of scenes. Case 1 for all 27 Scenes; Case 2 for Eastern 11 Scenes; and Case 3 for Western 159 Scenes. We used 3 km^2 as an average are for this first approximation.

		Case1 (All)	Case2 (East)	Case3 (West)
a	Blowdowns	170	11	159
b	km^2	3	3	3
c	km^2	510	33	477
d	Area per Scene km^2	32400	32400	32400
e	Number of Scenes	27	9	18
f	Total Area	874800	291600	583200
g	Turnover Time (f/c) years	1715	8836	1223
	Distubance Fraction	0.00058299	0.000113169	0.000817901
	Aparence of these events (years)	15	15	15
	Fraction of Disturbance in 1 year	3.8866E-05	7.54458E-06	5.45267E-05
	Turnover Time years	25729	132545	18340

5. Conclusion

- ✓ We found a close relationship between the frequency of heavy storms and the occurrence of blow-down disturbances events;
- ✓ This, in turns, suggests a close connection between severe weather and the rate of forest turnover caused by blow-down disturbances;
- ✓ The forest turnover time calculated for these disturbances within 9 Eastern Landsat scenes studied was almost 9000 years whereas for the 18 scenes in the Western Amazon, turnover time was closer to 1200 year;
- ✓ Large disturbances may have a significant influence on the spatial pattern of forest dynamics and productivity of the Amazon.