

Conferência  
Científica  
Internacional

Amazônia  
Ciência Integrada

LBA  
GEOMA  
PPBio

em Perspectiva  
para um Futuro Sustentável

17 a 20 de novembro de 2008

# Validation of fire pixels detected by satellites with small format aerial photos

*(Validação de focos de queima detectados por satélites  
com fotos aéreas de pequeno formato)*

Alberto Setzer<sup>1</sup>

Demerval Aparecido Gonçalves<sup>2</sup>

Fabiano Morelli<sup>1</sup>

asetzer@cptec.inpe.br

demerval@ita.br

fmorelli@cptec.inpe.br

<sup>1</sup>INPE - Instituto Nacional de Pesquisas Espaciais

<sup>2</sup>ITA - Instituto Tecnológico de Aeronáutica

## **Objective.**

To validate the detection of fire pixels from different satellites in the INPE operational monitoring system using small format aerial photographs as field data.

## **Why ?**

The INPE fire pixels are used by more than 3000 registered users for different purposes: fire fighting, fire statistics, estimates of emissions, etc.

Firemen, scientists, decision makers and scientists use the data regularly, and its reliability must be estimated.

# Background: dozens of products using fire pixels. Is the info real?

Fire Monitoring - Mozilla Firefox

Ministry of Science & Technology and Ministry of the Environment

## Vegetation Fires Fire Monitoring

Português English Español

Cptec Weather Climate Numer. Forecast Satellites Waves Energy Observ. Data Res. & Develop.

Map of Fires - With Clouds Fire: 2008/11/19 00 GMT - 2008/11/20 - 07:30 GMT

Home With Clouds With Fire Risk With Smoke With Veget. Modis Img. TM Img.

Clippings Clippings Regions of Brazil North Northeast Southeast South Central-West Clippings For Countries Argentina Bolivia Brazil Cuba Paraguay Peru Venezuela Africa (MSG2)

Bata Basis Fire GIS Fires, Conservation Units Fires at Google Earth & RSS Others Tables & Graphs, current Reports on line My Reports by e-mail Previous Data Ibama Report Monthly Texts

INPE/CPTEC/DISA - Contact queimadas@cptec.inpe.br - Acessos: 291192

IBAMA  
MMA  
Instituto Brasileiro de Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA/MMA  
http://www.ibama.gov.br

### Boletim de Monitoramento de Focos de Calor UNIDADES DE CONSERVAÇÃO

Nº. 224 UC/2008  
Data: 19/11/08

#### Satélites NOAA-15 e TERRA/AQUA - Sensor MODIS

- As imagens do satélite NOAA-15 em 18/11/08 recobriram o país. Não foram detectados focos de calor em unidade de conservação do país.
- As imagens do satélite TERRA/AQUA - Sensor MODIS (passagens - INPE) 19/11/08 recobriram o país. Não foram detectados focos de calor em unidades de conservação do país.

#### Unidades de Conservação em estado de ALERTA VERMELHO

- Parque Nacional da Chapada Diamantina BA continua em estado de **ALERTA VERMELHO**. De acordo com a Nota PREVFOGO nº 233 de 19/11/2008, há três grandes incêndios ocorrendo na PARNA: Paty, Beco da Sinhá e Mandassaia. Nos dois primeiros focos estão atuando as brigadas voluntárias do Vale do Capão e Guiné, no último foco estão atuando as brigadas de Lençóis e Palmeiras. Os combates do Mandassaia estão sendo auxiliados pelos Bombeiros e um helicóptero. Segundo informações repassadas hoje pelo Chefe da Unidade, na parte norte da Unidade há fogo na região conhecida como Capivara e em Lençóis há fogo na região do Remanso. A logística continua a mesma, mas agora está sendo priorizando o Vale do Rio Preto no Paty e os Bombeiros de Brasília estão terminando o combate no sul de Mucugê. Está prevista a chegada de reforço do Rio de Janeiro para hoje ao meio-dia, no aeroporto de Lençóis. Esse contingente está sendo deslocado por meio do avião da FAB e é composto por 40 Brigadistas (voluntários e contratados do Prevfogo que atuam em UCs do estado do RJ), Coordenador Estadual do Prevfogo/RJ, Gerente do Fogo do PARNA de Itaitiaia, ex-Gerente do Fogo do PARNA da Chapada Diamantina. Além disso, a Coordenação Nacional do Prevfogo solicitou à Defesa Civil Nacional que preste apoio à base de Mucugê.

#### Unidades de Conservação em estado de ALERTA AMARELO

Estado do Amapá

Monitoramento de Queimadas - Mozilla Firefox

Home Queimadas Home Inpe

Tabelas - Focos de Queimadas - Ainda em aperfeiçoamento

CONFIGURAR BDQ BDQUCs BDQMCs

Total de focos acumulados no período de: 2008/11/19 (00:00 GMT) a 2008/11/20 (07:30 GMT), para todos os satélites.

País	Focos
Argentina	256
Bolivia	146
Brasil	3883
Chile	13
Ecuador	2
Guyana	1
Guyana Francesa	1
Paraguay	373
Peru	5
Suriname	5
Uruguay	25
Venezuela	6
	4716.0

Países

Monitoramento de Queimadas - Mozilla Firefox

Estado	Focos
MA	1529
CE	698
PA	487
PI	435
SP	292
BA	90
PE	86
PB	79
AP	50
AL	31
MS	31
PR	23
TO	19
MG	8
MT	8
GO	7
RN	7
SE	2
AM	1
	3883.0

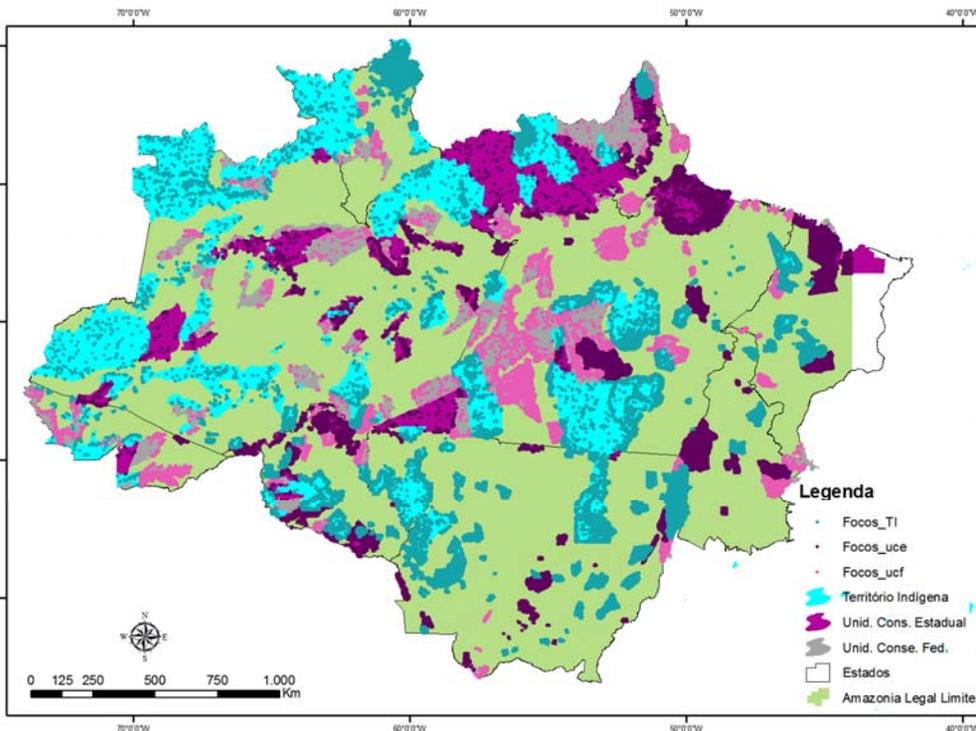
Estados



For instance, is it really true that in the **Brazilian Amazonia**,  
“For the **~674 Protected Areas**, 473 of them, or **~70%**, were affected by fire when using just the detections made with the more consistent AVHRR/NOAA-12 series. Using data from all satellites, these values rise to **617 areas with fires**, or **~92% of them.**”  
as reported in this conference by [Poster # 567](#) based on fire pixels?

## Example of an application using INPE's fire pixels with serious environmental consequences

The Brazilian Amazonia with ~5 million km<sup>2</sup> and its Protected Areas:  
137 Federal Conservation Units with 585.3 x 10<sup>3</sup> km<sup>2</sup>; 159 State Conservation Units with 559.8 x 10<sup>3</sup> km<sup>2</sup>, and; 378 Indian Territories with 1,077.9 x 10<sup>3</sup> km<sup>2</sup>.  
(Source: ISA, July/2007)



### Conclusions (From Poster # 567, this Conference)

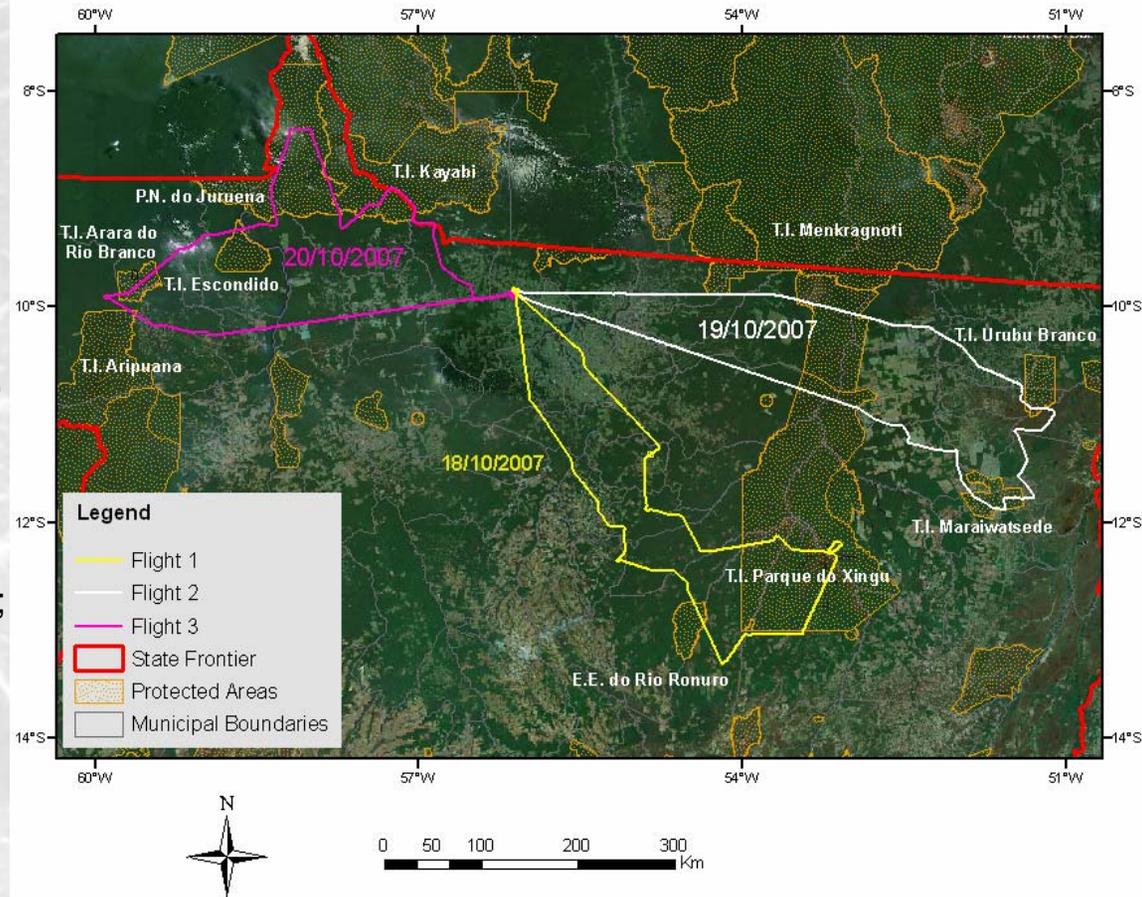
- Occurrences of man-caused vegetation fires inside the Protected Areas of the Brazilian Amazonia were analyzed for the first time. The period of interest was 2000-2007. The results show that all types of Protected Areas, in all Amazon states, and in all main vegetation ecosystems are affected by fire.
  - For the 674 Protected Areas, 473 of them, or **70.2%**, were affected by fire when using just the detections made with the more consistent AVHRR/NOAA-12 series. With data from all satellites, these values rise to 617 areas with fires, or **91.5%** of them.
  - For the percentage of the areas with fire occurrences inside them, the 137 Federal Conservation Units showed the highest value, **80%**, followed by the 159 State Conservation Units with **77%**, and by the 378 Indian Territories with **64%**.
  - The extent of the fire effect in the Protected Areas affected varies widely, from cases when over 70% of the area shows fires almost every year, to those when only isolated fires are identified at the boundary of the area.
  - The Protected Areas of the Brazilian Amazonia comprise about 2.1 million km<sup>2</sup>, or ~42% of the region. In general, these Protected Areas have no practical means to prevent or combat fires.
- Occurrences of illegal man-caused fires in the Protected Areas of Amazonia present a definite case for scientific, environmental, ecological and administrative concern.

# Location of the 3 flights made for validating INPE fire pixels

Base: Alta Floresta, MT

1. Indian Territory Parque do Xingu; 577 photos over 1250 km, Oct/18/2007.
2. Indian Territories Maraiwatsede and Urubu Branco; 392 photos over 1350 km, Oct/19/2007.
3. Indian Territories Kayabi, Arara do Rio Branco and Juruena Nat. Park; 404 photos over 1.150 km, Oct/20/2007.

## Aerophotographical Survey Flights on October 18, 19 and 20, 2007



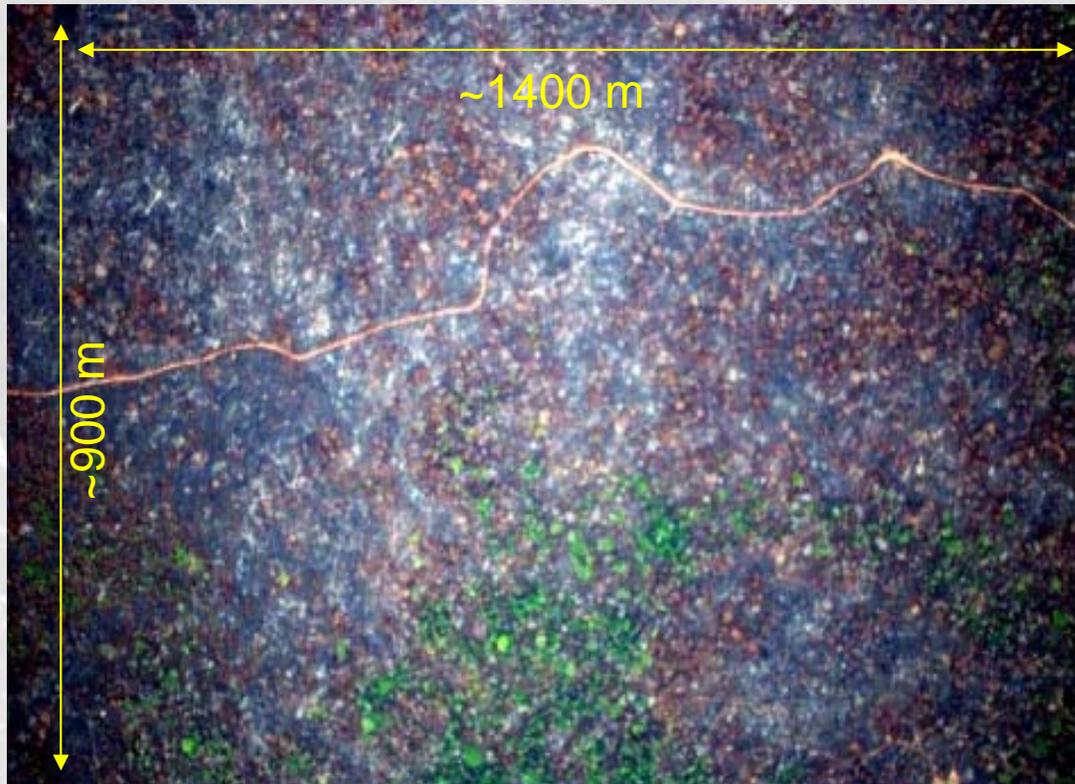
# Main characteristics of the aerial photos

- ❖ Digital camera: Nikon D1x.
- ❖ Imaging angle:  $63^\circ$  centered at the aircraft's nadir.
- ❖ Flight level: 1200 to 1500 meters.
- ❖ Aircraft model: Embraer EMB110.
- ❖ Time interval: manual operation.
- ❖ Coordinates recorded by the camera log and flight tracking.



# Main characteristics of the aerial photos

- ❖ Digital photos: 3008 x 1960 pixels (5,6 megapixels).
- ❖ Ground imaging dimensions: 900 x 1400 meters, average; transversal.
- ❖ Number of photos: 1373, total.



# Catalog of the aerial photos

All photos were manually interpreted for different types of land cover and individual spacial features.



## Attributes of the aerial photos

- PHOTO
- LAT
- LONG
- LATITUDE
- LONGITUDE
- GPS
- ALTITUDE
- DATE
- HR
- EXPOSITION
- FOREST\_SCAR
- DEFOREST\_SCAR
- POLYGON
- ANTHR\_FOREST\_SCAR
- ANTHR\_DEFOREST\_SCAR
- FIRE
- BUILDINGS
- COAL-PIT
- CLOUD
- WATER
- FOREST
- ANTHROPICAL
- BARESOIL
- CHANGEDFOREST
- OBS
- RELIEF
- FLIGHTHEIGHT
- LENGHT
- WIDTH
- QUICKLOOK
- LOCAL
- QTPOINTBUFF
- QTPOINT

Microsoft Excel - fapef-planilha.xls [Somente leitura]

Arquivo Editar Exibir Inserir Formatar Ferramentas Dados Janela Ajuda Adobe PDF

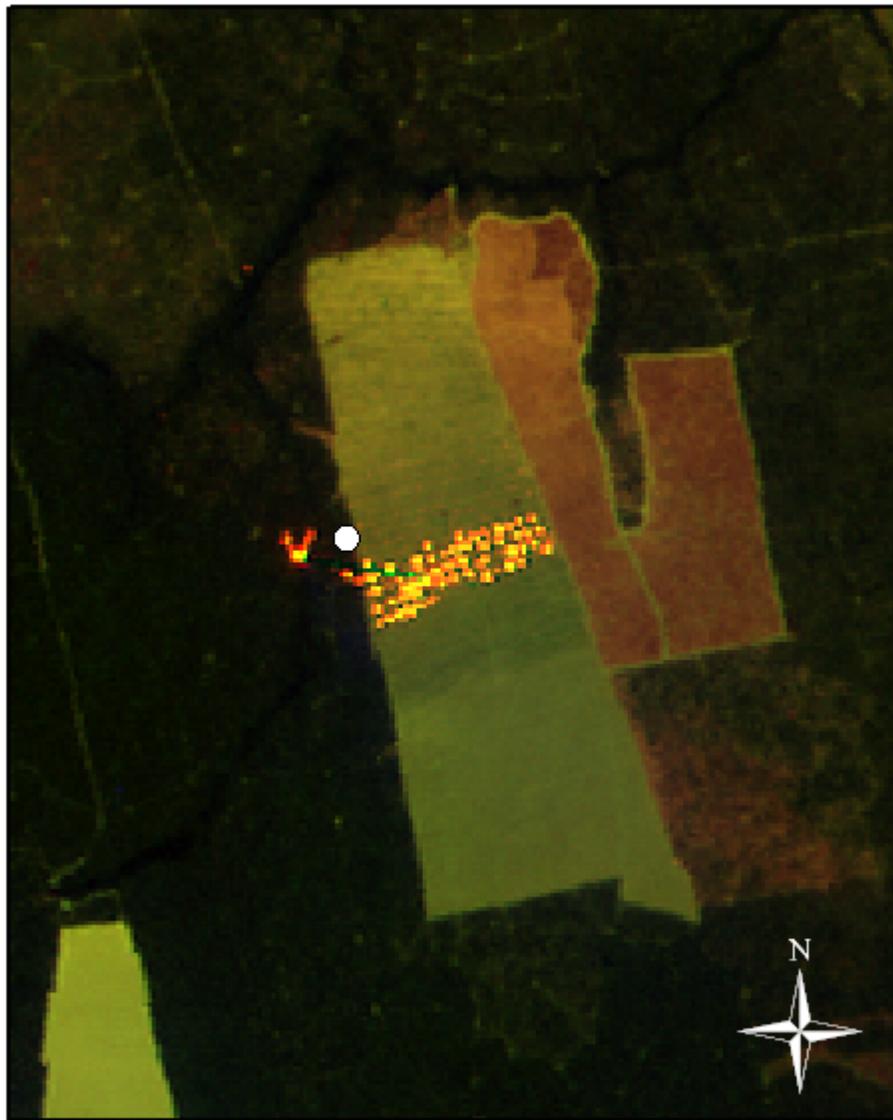
Digitale uma pergunta

Arial 10

Responder com alterações... Finalizar revisão...

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
FOTO	LAT	LONG	LATITUDE	LONGITUDE	GPS	ALTITUDE	DATA	HORA	EXPOSICAO	CICLOFREST	CICDESMA	CICFLOAM	CICDESAM	FOGO	CONSTRUCAC	CARYOAR	NUVEM	AGUA	VEGALT	DESMRECENT	OBS
1	dsc_380.nf	10 40 34.2	55 59 39.6	-10.676166670	-55.994333333	camera	1739	18/10/07	0:20:48.0	500	0	0	0	15	Não	Não	Não	Não	0	0	
2	dsc_381.nf	10 57 10.2	55 54 2.4	-10.952833330	-55.900666667	camera	1748	18/10/07	0:27:55.2	250	0	5	0	0	sim	Não	Não	Não	0	250	15
3	dsc_382.nf	10 57 35.4	55 53 44.4	-10.958833330	-55.895666667	camera	1751	18/10/07	08:28:07	250	0	0	0	20	Não	Não	Não	Não	0	0	10
4	dsc_383.nf	10 58	55 53 26.4	-10.968666670	-55.890666667	camera	1752	18/10/07	8:28:18.3	250	5	0	0	0	Não	sim	Não	Não	0	0	0
5	dsc_384.nf	11 6 21.6	55 47 46.2	-11.106000000	-55.796166667	camera	1759	18/10/07	8:32:19.4	1600	10	0	0	0	Não	Não	Não	Não	0	0	0
6	dsc_385.nf	11 12 43.8	55 46 12	-11.185333330	-55.767000000	camera	1757	18/10/07	8:33:21.1	1250	20	0	0	0	Não	Não	Não	Não	0	0	0
7	dsc_386.nf	11 12 43.8	55 43 25.2	-11.212166670	-55.723666667	camera	1746	18/10/07	8:35:17.5	1000	20	0	0	0	Não	Não	Não	Não	15	0	0
8	dsc_387.nf	11 13 18.6	55 43 12	-11.221833330	-55.717000000	camera	1747	18/10/07	8:35:33.5	1000	0	5	0	0	Não	Não	Não	Não	5	0	0
9	dsc_388.nf	11 13 45	55 42 43.2	-11.239166670	-55.712000000	camera	1747	18/10/07	8:35:45.5	1000	15	5	0	15	Não	Não	Não	Não	0	0	0
10	dsc_389.nf	11 14 6.6	55 42 28.2	-11.239166670	-55.707833333	camera	1747	18/10/07	8:35:55.0	1000	10	0	0	10	Não	Não	Não	Não	10	0	0
11	dsc_390.nf	11 14 29.4	55 42 12	-11.241500000	-55.703666667	camera	1747	18/10/07	8:36:4.4	1000	35	10	0	0	Não	Não	Não	Não	0	0	0
12	dsc_391.nf	11 14 47.4	55 42 12	-11.245000000	-55.703333333	camera	1747	18/10/07	8:36:14.0	1000	5	20	0	0	Não	Não	Não	Não	0	5	0
13	dsc_392.nf	11 15 9	55 41 6.8	-11.262500000	-55.696333333	camera	1747	18/10/07	8:36:23.5	1000	0	15	0	0	Não	Não	Não	Não	0	20	0
14	dsc_393.nf	11 15 36	55 41 28.2	-11.261000000	-55.691666667	camera	1746	18/10/07	8:36:34.2	1000	5	40	0	0	Não	Não	Não	Não	0	95	0
15	dsc_394.nf	11 15 53.4	55 41 16.2	-11.264833330	-55.687833333	camera	1745	18/10/07	8:36:43.3	1000	10	20	0	0	Não	Não	Não	Não	0	55	0
16	dsc_395.nf	11 16 15	55 41 12	-11.270833330	-55.683666667	camera	1745	18/10/07	8:36:52.1	1000	5	5	0	0	Não	Não	Não	Não	0	0	0
17	dsc_396.nf	11 16 54	55 40 34.8	-11.281666670	-55.678333333	camera	1745	18/10/07	8:37:11.5	1000	5	35	10	0	Não	Não	Não	Não	20	0	0
18	dsc_397.nf	11 17 11.4	55 40 23.4	-11.286500000	-55.673166667	camera	1746	18/10/07	8:37:19.3	1000	5	30	0	0	Não	Não	Não	Não	15	0	0
19	dsc_398.nf	11 17 32.4	55 40 9	-11.292333330	-55.670294000	aeronave	1746	18/10/07	8:37:28.2	1000	5	5	0	5	Não	Não	Não	Não	0	85	0
20	dsc_399.nf	11 18 6	55 39 45.8	-11.309333330	-55.662666667	camera	1745	18/10/07	8:37:45.2	500	20	0	0	0	Não	Não	Não	Não	10	20	0
21	dsc_399.nf	11 18 23.4	55 39 34.2	-11.309500000	-55.659000000	camera	1746	18/10/07	08:37:54	500	15	70	0	0	Não	Não	Não	Não	10	0	0
22	dsc_399.nf	11 18 45	55 39 18.2	-11.312000000	-55.655333333	camera	1746	18/10/07	08:38:03	500	5	85	0	0	Não	Não	Não	Não	10	0	0
23	dsc_399.nf	11 18 45	55 39 4.8	-11.313333330	-55.651333333	aeronave	1746	18/10/07	8:38:13.1	500	10	80	0	0	Não	Não	Não	Não	10	0	0
24	dsc_399.nf	11 18 6	55 39 48	-11.324861000	-55.644825000	aeronave	1746	18/10/07	8:38:21.5	500	20	75	0	0	Não	Não	Não	Não	10	0	0
25	dsc_399.nf	11 18 6	55 39 48	-11.330388000	-55.644623000	aeronave	1746	18/10/07	8:38:32	500	45	40	0	0	Não	Não	Não	Não	40	0	0
26	dsc_399.nf	11 18 6	55 39 3.4	-11.336538000	-55.640797000	aeronave	1746	18/10/07	8:38:41.5	500	40	35	0	0	Não	Não	Não	Não	30	0	0
27	dsc_399.nf	11 18 6	55 39 4.8	-11.342358000	-55.639240000	aeronave	1746	18/10/07	8:39:12	500	5	70	0	0	Não	sim	Não	Não	5	0	0
28	dsc_399.nf	11 18 6	55 39 48	-11.346270000	-55.632596000	aeronave	1746	18/10/07	8:39:02.2	500	5	75	0	0	Não	sim	Não	Não	5	0	0
29	dsc_399.nf	11 18 6	55 39 48	-11.353205000	-55.629453000	aeronave	1746	18/10/07	8:39:10.1	500	10	80	0	0	Não	Não	Não	Não	5	0	0

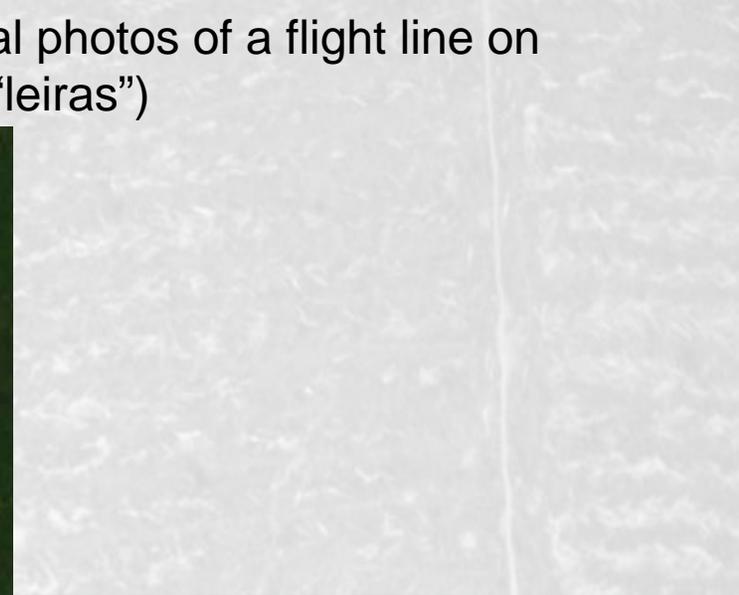
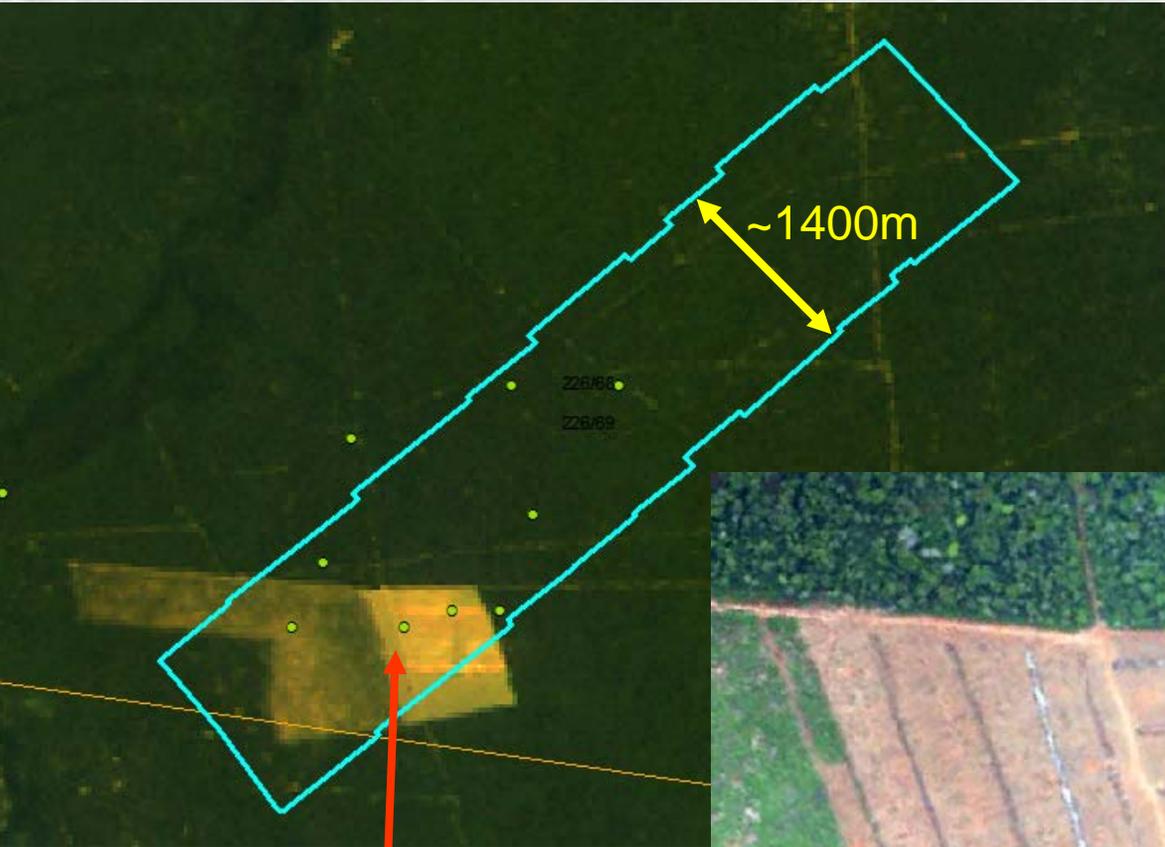
Pronto



TM / Landsat Images were used to extend the analysis of fire pixels and burned areas to the vicinity of the areas covered by the aerial photos.

Patterns of linear burning are common and easily noticed in TM images, as in this scene of Oct/04/2007.

TM Scene of Oct/04/2007 and the sequence of aerial photos of a flight line on Oct/18/2007, confirming the fires in linear patterns (“leiras”)



GOES, AQUA and  
TERRA fire pixels  
detected by INPE from  
Sep/23-28/2007

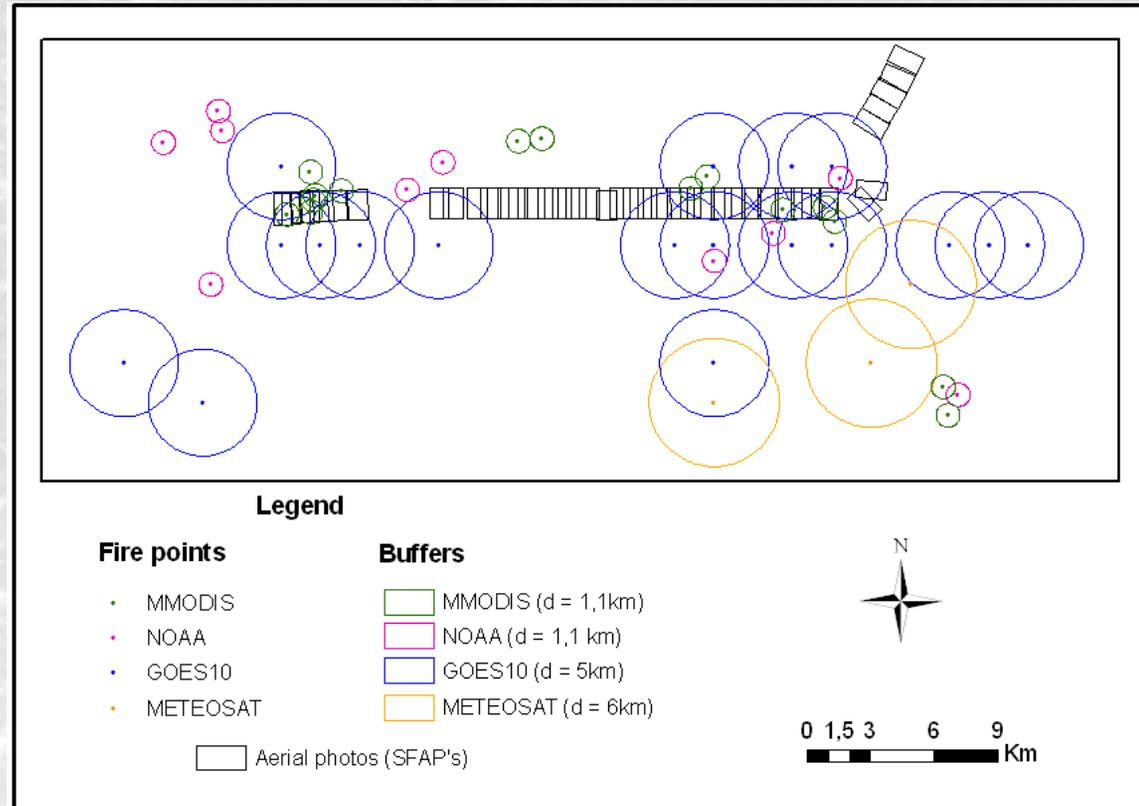
# Analysis of the individual photos

The coordinates of the individual fire pixels detected in the period of 15/Sept to 19/Oct/07 were used to define circular buffers of potential fire occurrences, depending on the spatial resolution of the satellite sensors.

## Buffer size for the fire coordinates:

- ❖ 1.1 km for NOAA and MODIS.
- ❖ 5 km for GOES
- ❖ 6 km for METEOSAT

The aerial photos were classified according to the attributes defined in the catalog, in order to relate their spatial analysis with the fire pixels.



# Summary analysis of the individual photos, Flight 1

## Results

Using only the aerial photos, the potential Commission Cases amounted to 19% and the potential Omission Cases, 13%.

These values were greatly reduced after examining the TM / Landsat images for the region, where the spatial buffers were used to account for expected navigation errors in the location of the fire pixels.

Sep 15 to Oct 19, 2007 fire pixels



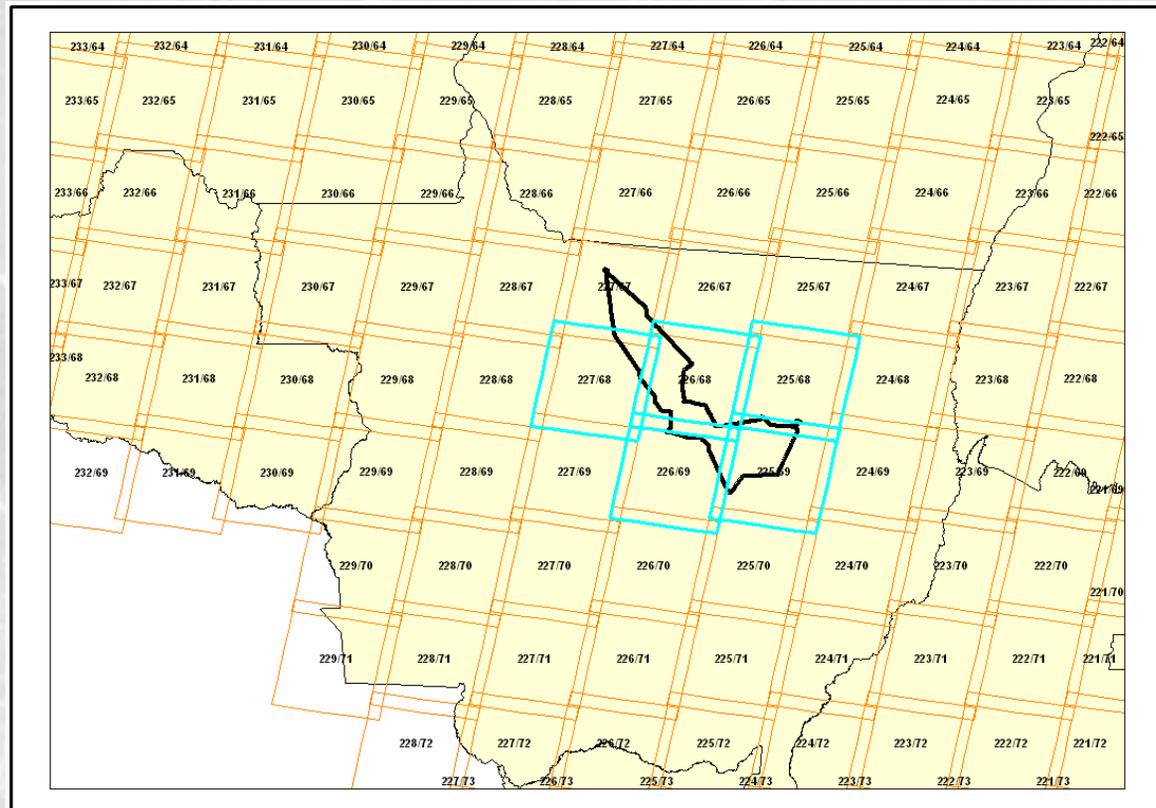
# Validation of fire pixels using the aerial photo mosaics

TM / Landsat scenes of different dates were used for the contextual analysis

Dates:

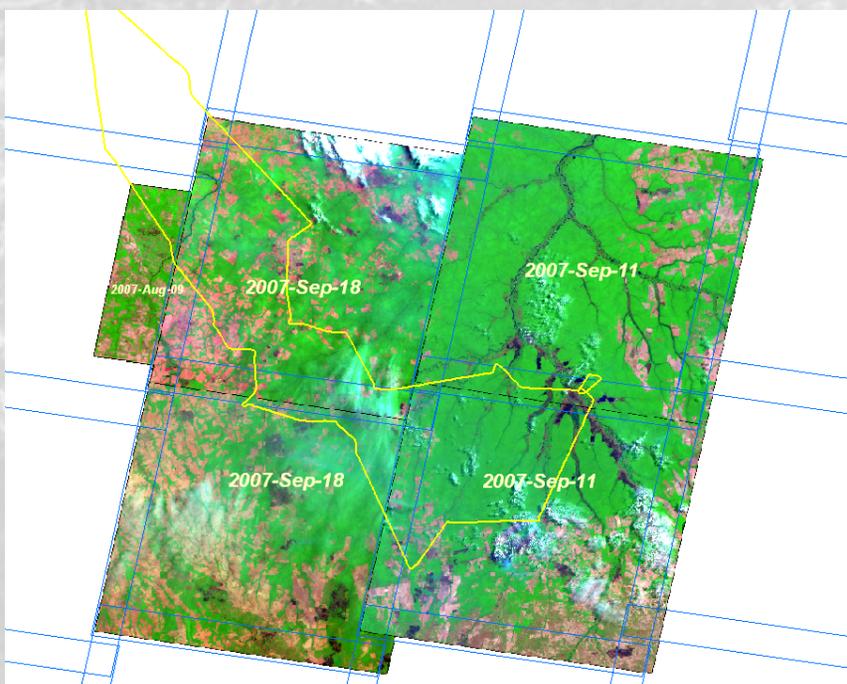
- ❖ 18/Oct/07: Flight 1
- ❖ 15/Sep/2007: fire pixels, start date
- ❖ 19/Oct/2007: fire pixels, final date

Flight 1 covered an area of 5 TM / Landsat scenes.

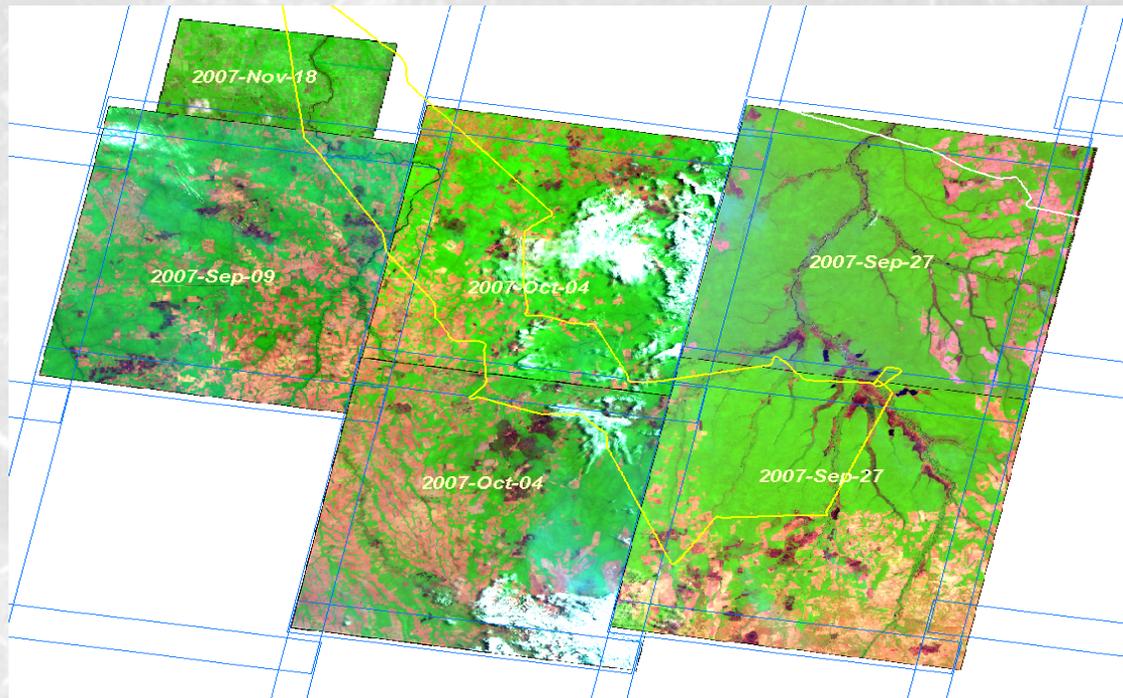


## Scenes for the start date

Landsat / TM scenes used for the “start” and “end” dates in the contextual analysis to validate the fire pixels in the areas outside (but near) the aerial photos.



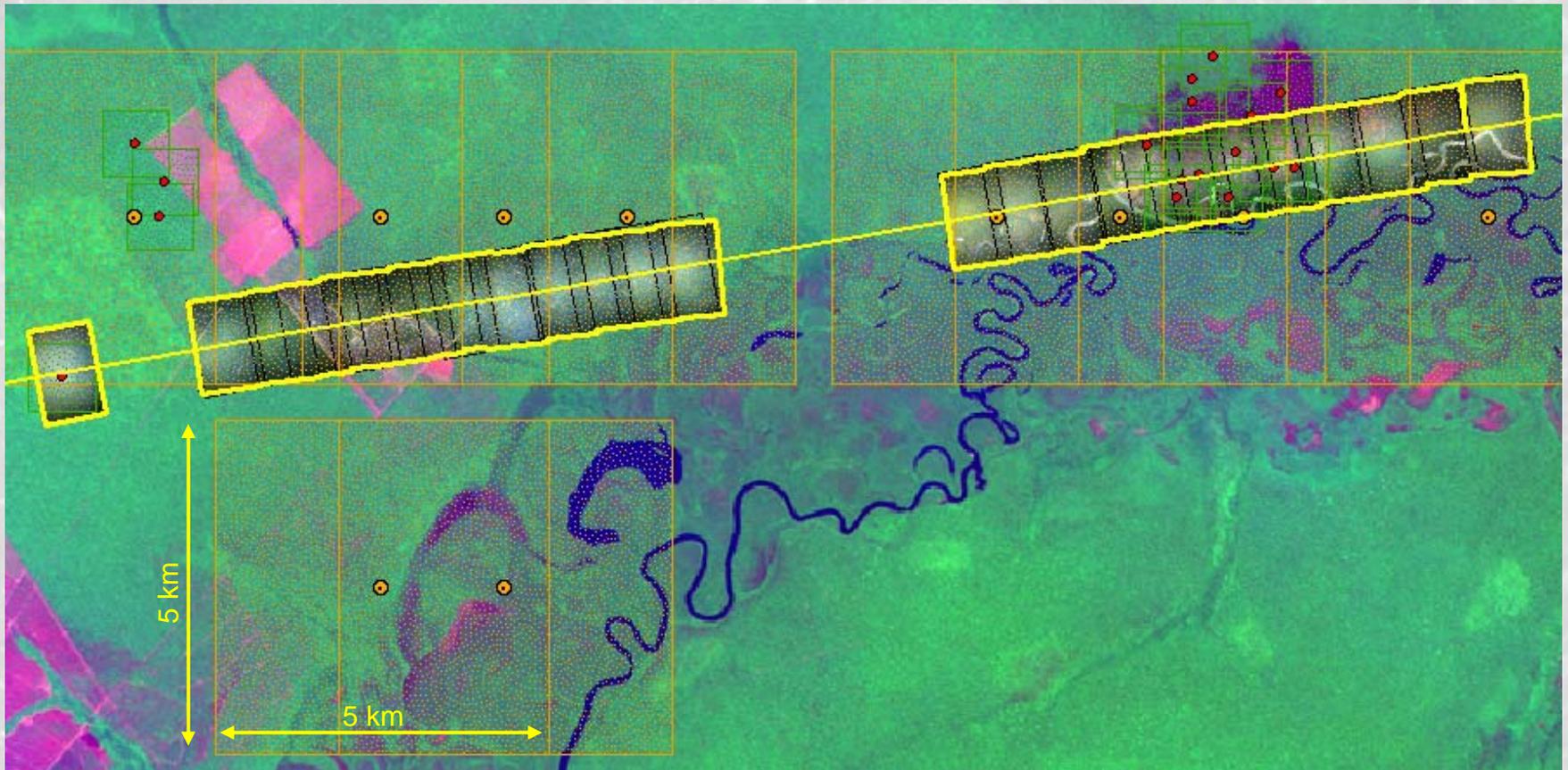
## Scenes for the end date



# Validation of the fire pixels using the aerial photo mosaics together with Landsat/TM scenes

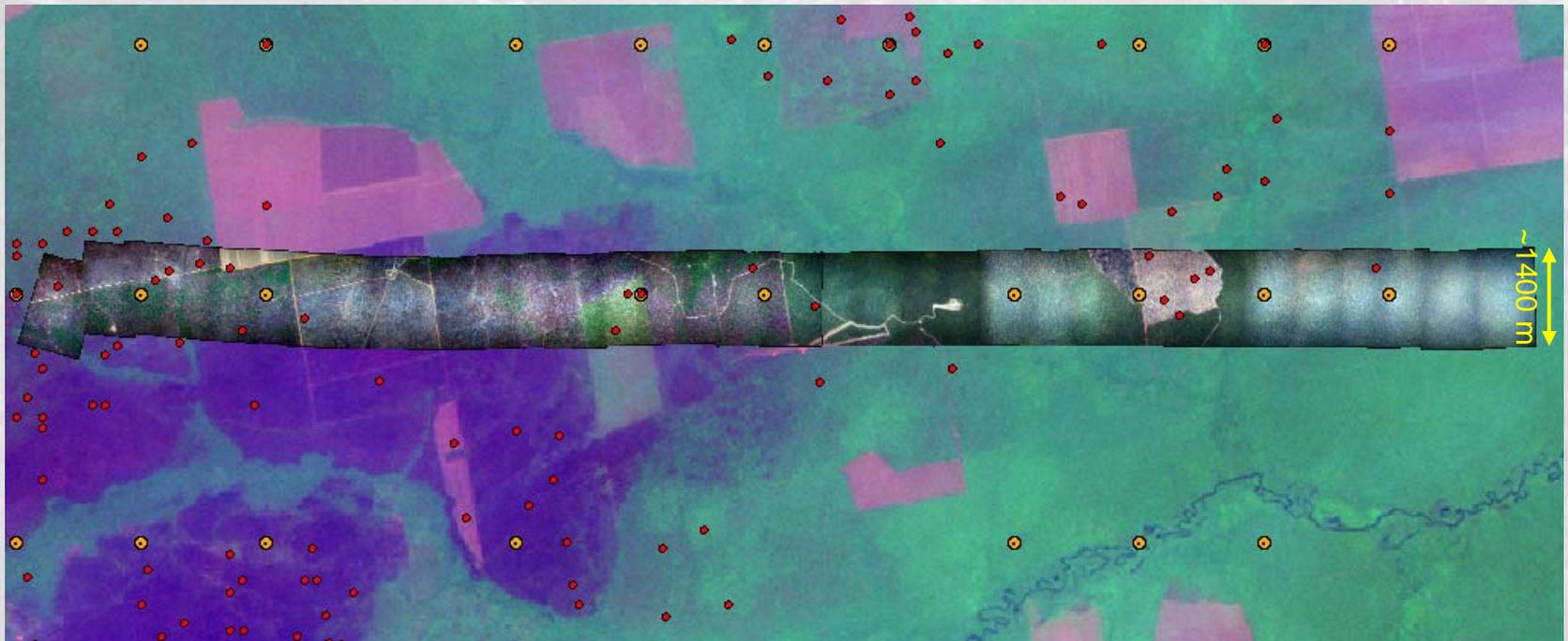
**Square buffers centered at the coordinates of the fire pixels along a flight line, :**

- ❖ 1 x 1 km for AQUA, Terra, MMODIS-01D, NOAAs-15A/15D/17D/18A/18D.
- ❖ 5 x 5 Km for GOES
- ❖ 6 x 6 km for METEOSAT



# Validation of the fire pixels using the aerial photo mosaics together with the Landsat/TM scenes

- ❖ Number of photos: 336 aerial photos in 61 mosaics from Flight 1.
- ❖ Area covered: 36.885 ha.
- ❖ Amount of fire pixels, Sep/15 to Oct/19/2007: 485 (201 GOES; 24 METEOSAT; and 260 other satellites).
- ❖ Potential Commission cases: **1,23%**, 6 fire pixels.
- ❖ Omission cases: **5%**, totaling 1.855 há.



Mosaic of aerial photos, Oct/18/2007

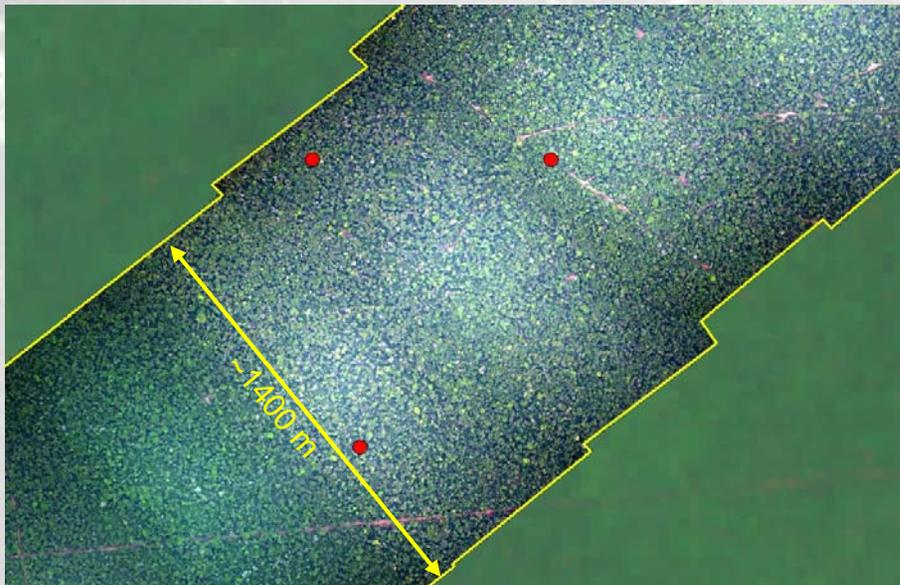
# Validation of the fire pixels using the aerial photo mosaics together with the Landsat/TM scenes - Commission Errors

Classification of 6 fire pixels with **potential** commission errors:

Unlikely: 4 fire pixels  
Inconclusive: 2 fire pixels

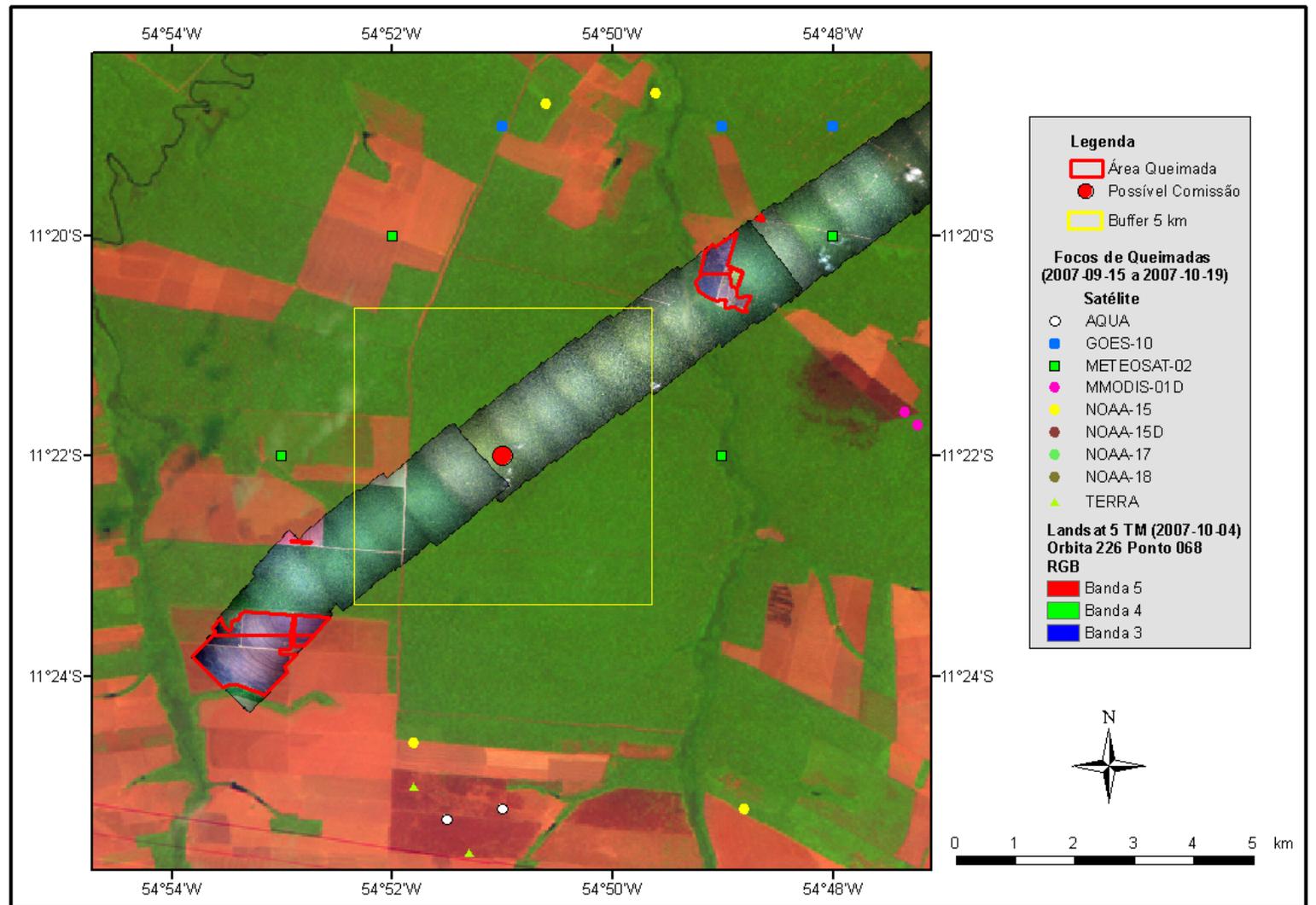
It is difficult to corroborate Commission Errors because of:

- ❖ Existence of roads in the forested region imaged in the aerial photo, indicating human presence and intense logging activities;
- ❖ Possibility of at least 1 pixel displacement in the fire pixel data (misregistration) and presence of other fires in the surroundings;
- ❖ Strong anthropic evidence in the region.

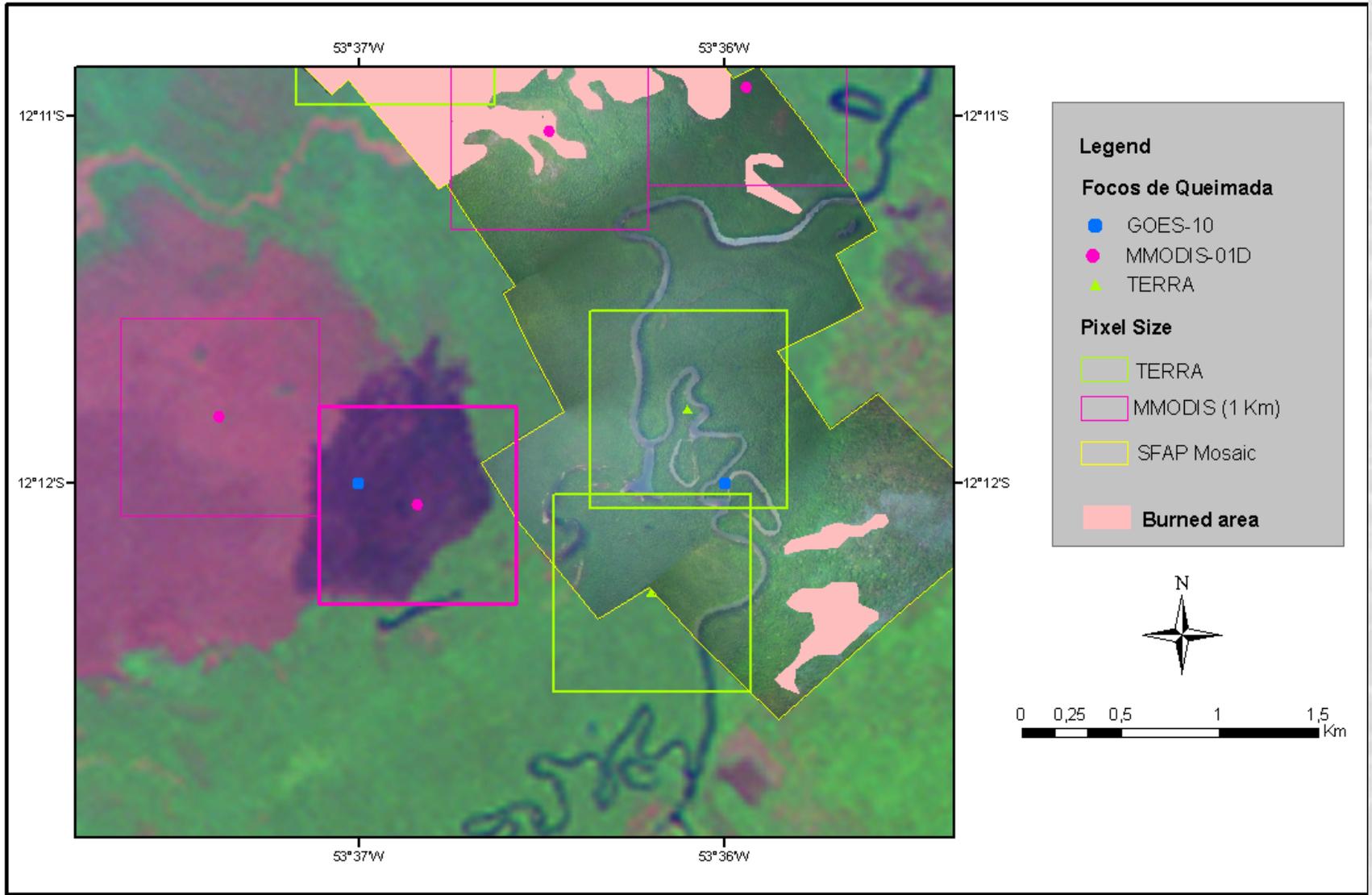


Mosaic of aerial photos, Oct/18/2007

Example of a potential commission error for a GOES fire pixel. No fire scars are visible in the 5km x 5km square centered on the GOES fire detection, but nearby burned areas exist to SW and NE, and the whole area is undergoing forest conversion. Navigation errors of 01 km are expected in satellite images, and in this case would explain the commission error.



Example of a potential commission error for a MODIS fire pixel. The MMODIS fire pixel (purple dot) at the center of the figure is ~2.5 km from the burned areas mapped in the aerial photo mosaic. Considering only the mosaic it seems a commission error, but examining the surroundings in the TM image, a fire scar is noticed at the pixel location.



# Conclusions (Flight 1)

- ❖ ~3% of **Potential Commission Errors** in the Fire Pixels
- ❖ 5% of the areas burned were not detected - **Omission Errors**





# Acknowledgments



MCT/INPE (CPTEC, OBT, DSA, DPI)



MMA/IBAMA (Proarco, Prevfogo, PPA/Ação Queimadas)



MCT/CNPq Bolsa AP



MCT/CNPq Projeto Milênio 2 (Prof. P.E.Artaxo)



MCT/LBA

LBA Conference, Manaus



Silvia C. de Jesus, Queimadas Project, INPE