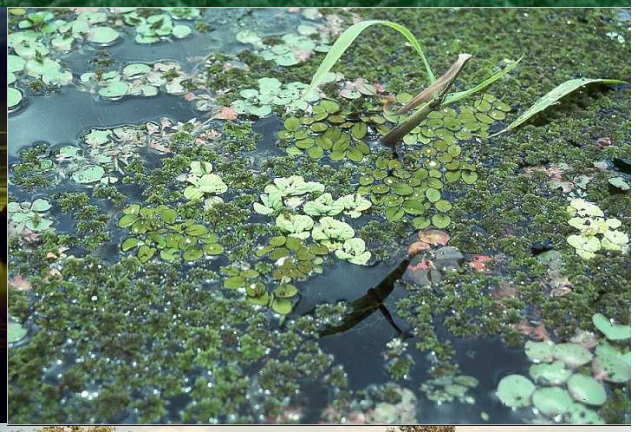



Water circulation dynamics in Amazon river/Curuai floodplain system through remote sensing






Cláudio Barbosa

Evlyn Novo

J. Melack

FAPESP

LBA-LC-07

Presentation sequence

Objective

Study area, initial data available and

Preliminary analysis

Processing, analysis and integration of results

- limnologic;
- Spectral;
- Orbital images
- Bathymetric

- Conceptual Model proposed

Objective

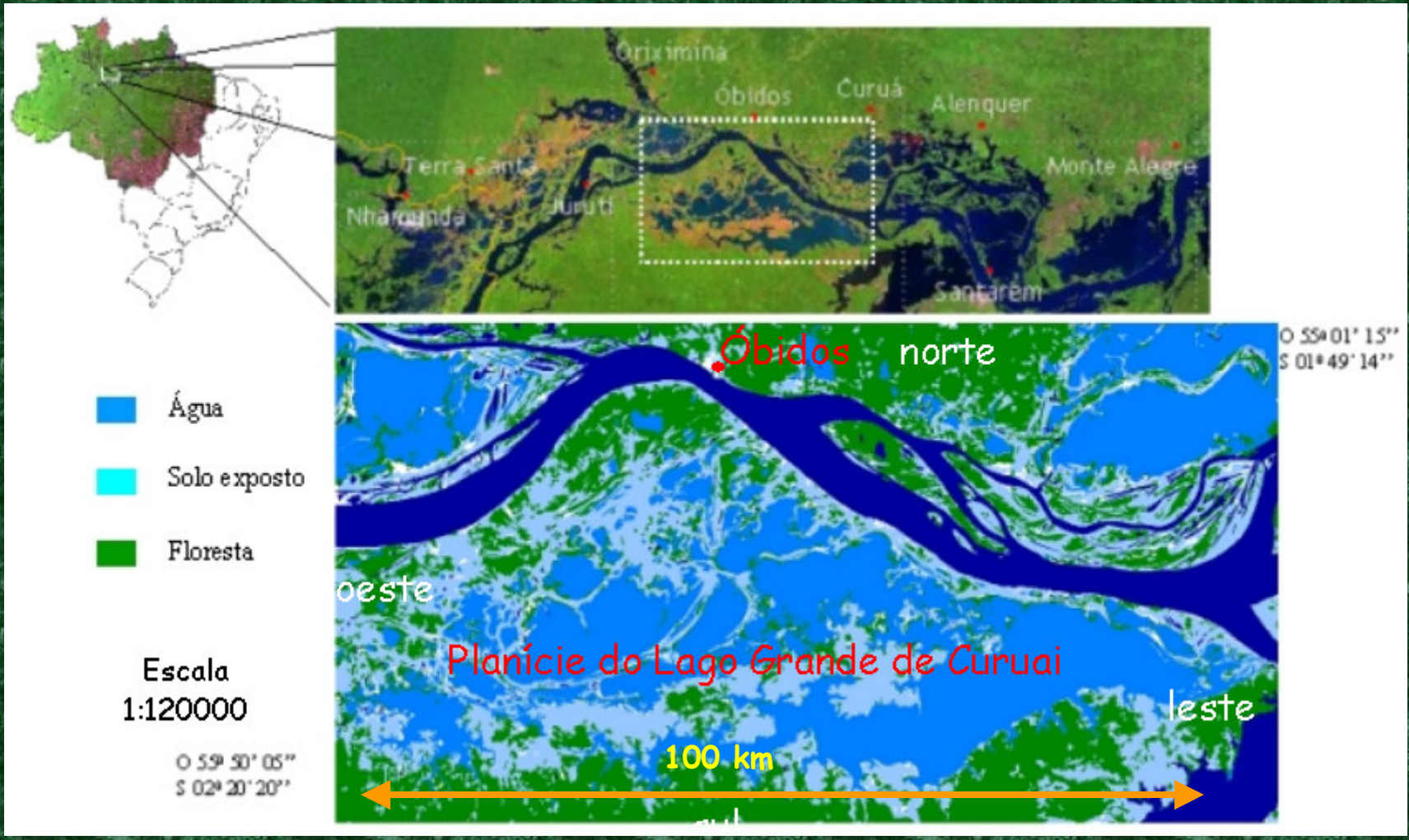
Propose and test a methodology based on remote sensing to understand the water circulation dynamics (composition and volume) driven by flooding pulse in the Amazon basin.

Study area

Lago Grande de Curuai (LGC) floodplain

area ~3500 Km^2

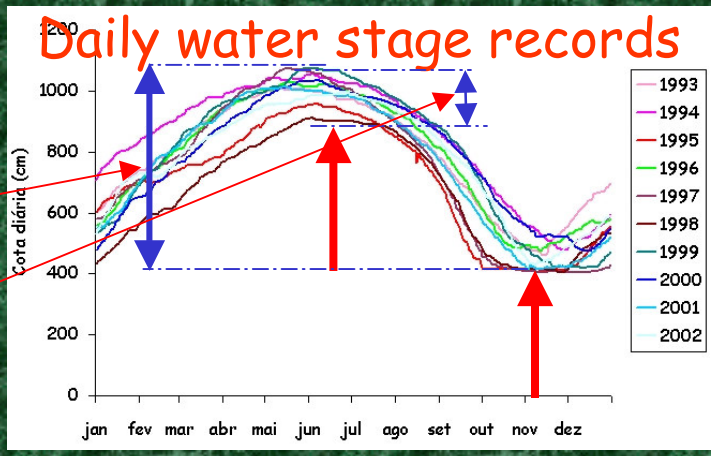
+20 interconnected lakes.



Dynamics of flooding in terms of water level fluctuation

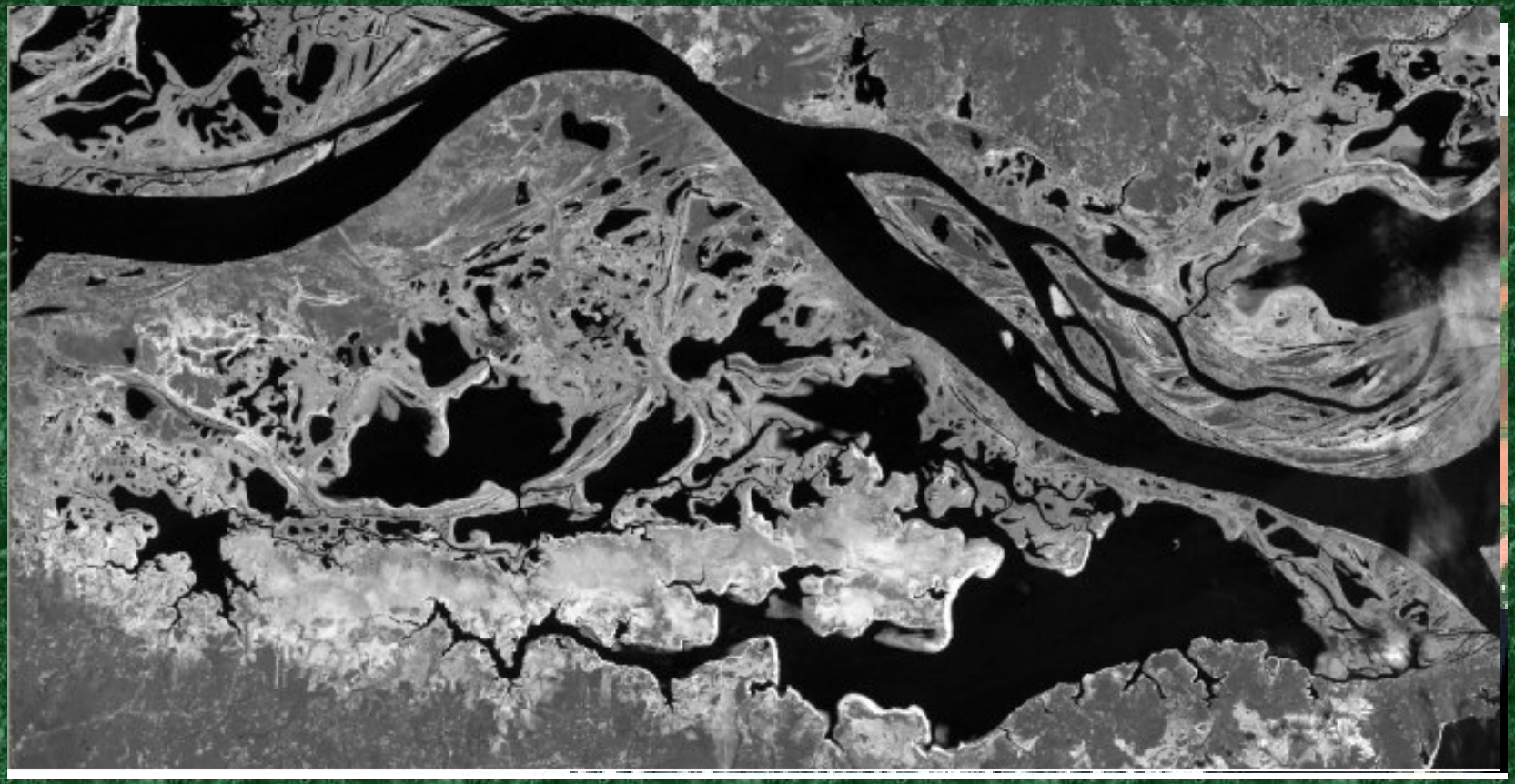
Annual flood amplitude about 7 meters

inter-annual fluctuations about 2 meters

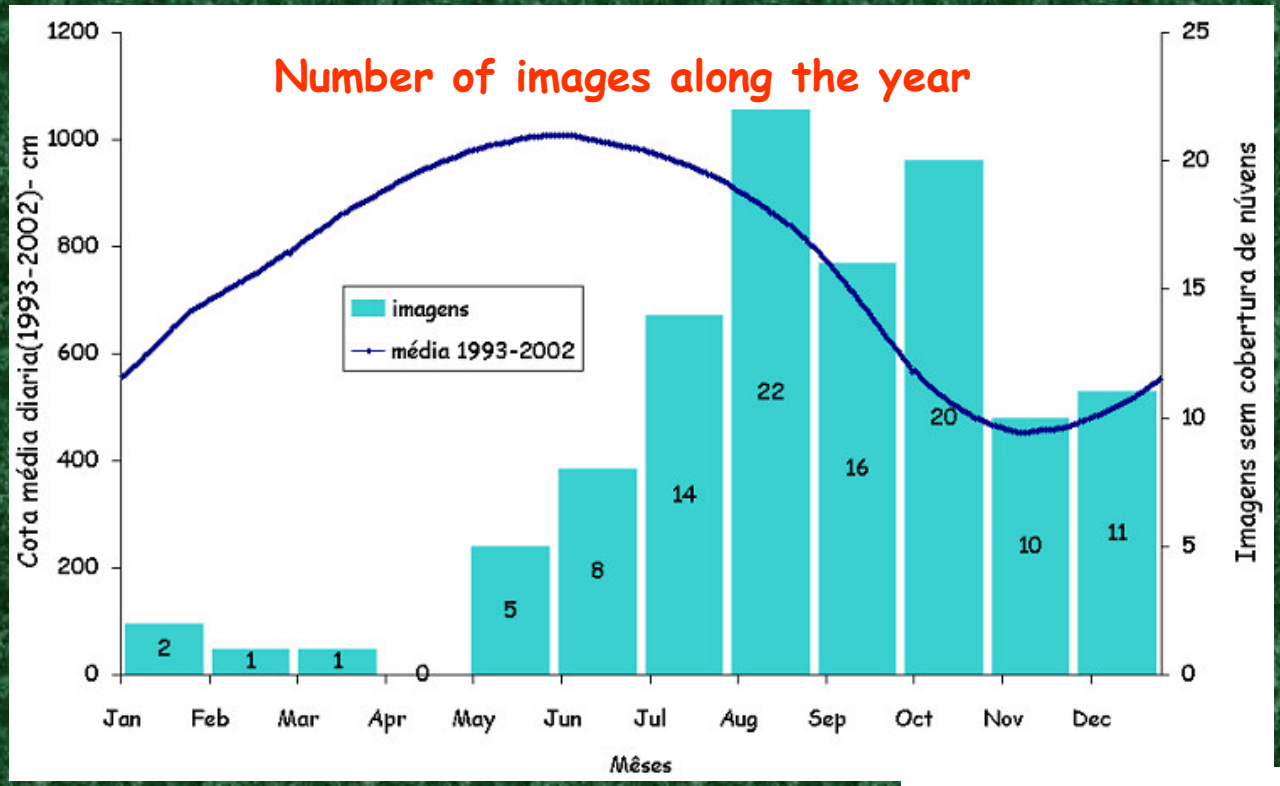


high water stage Image

Low water stage Image

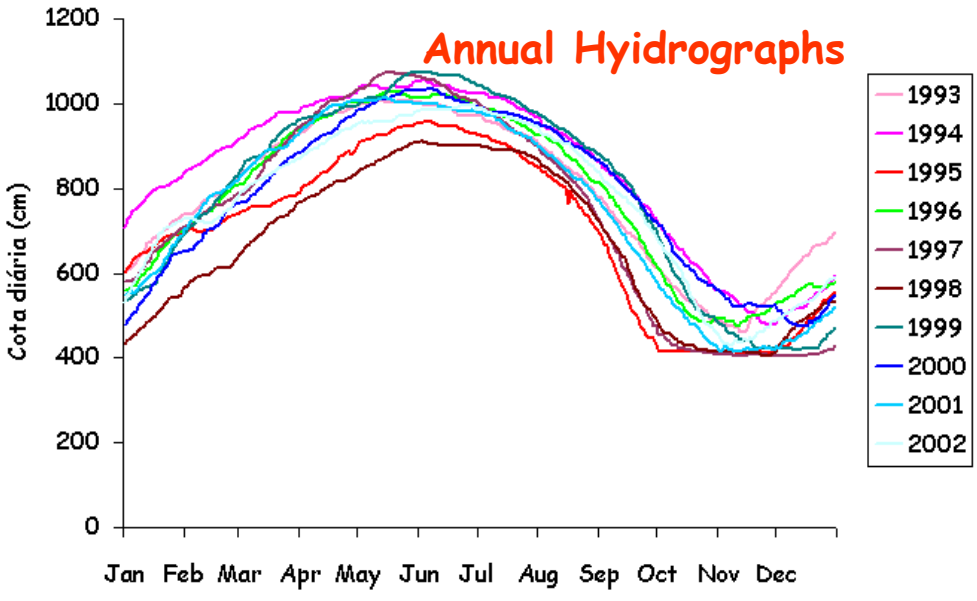


Initial data available



110 TM/Landsat images without cloud cover (30 years)

Records of historical daily of water stage (1993 a 2002)

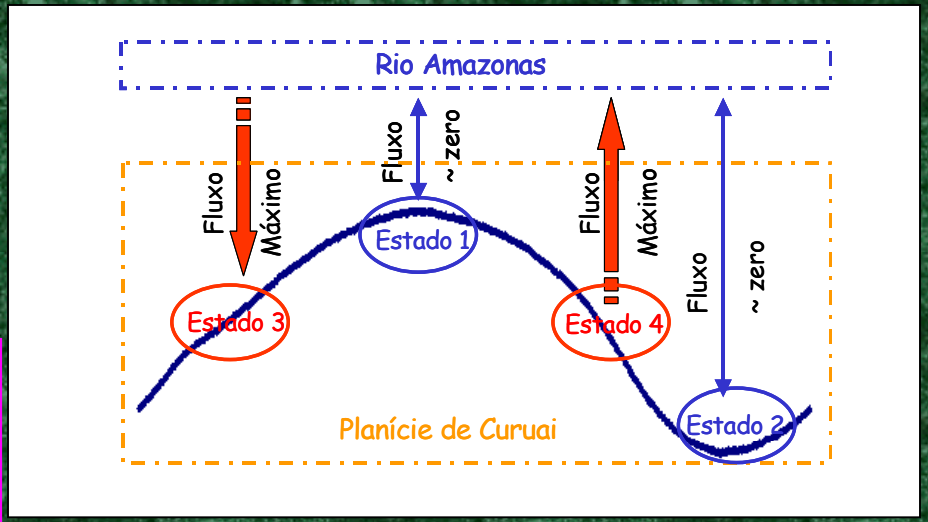


Exploratory analysis on the initial data available

Approach used: treat the river/floodplain as a 4 states system characterized by water level dynamic:

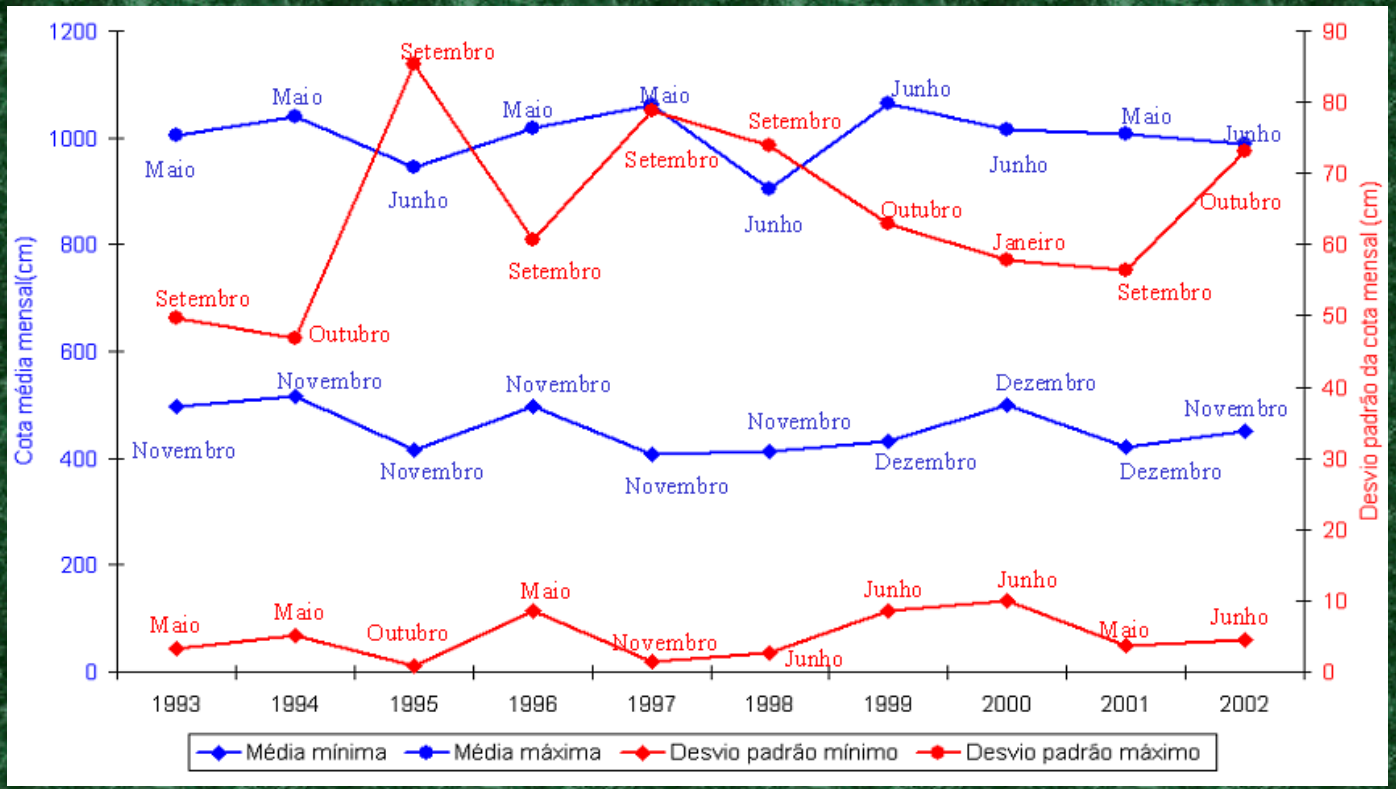
States 1 e 2 **Stability**

States 3 e 4 **Instability**



Mean and standard deviation analysis

- month of **maximum** and **minimum** occurrences
- month of major **standard deviation**-> instability



First indicatives

State 1 (high)
May/June

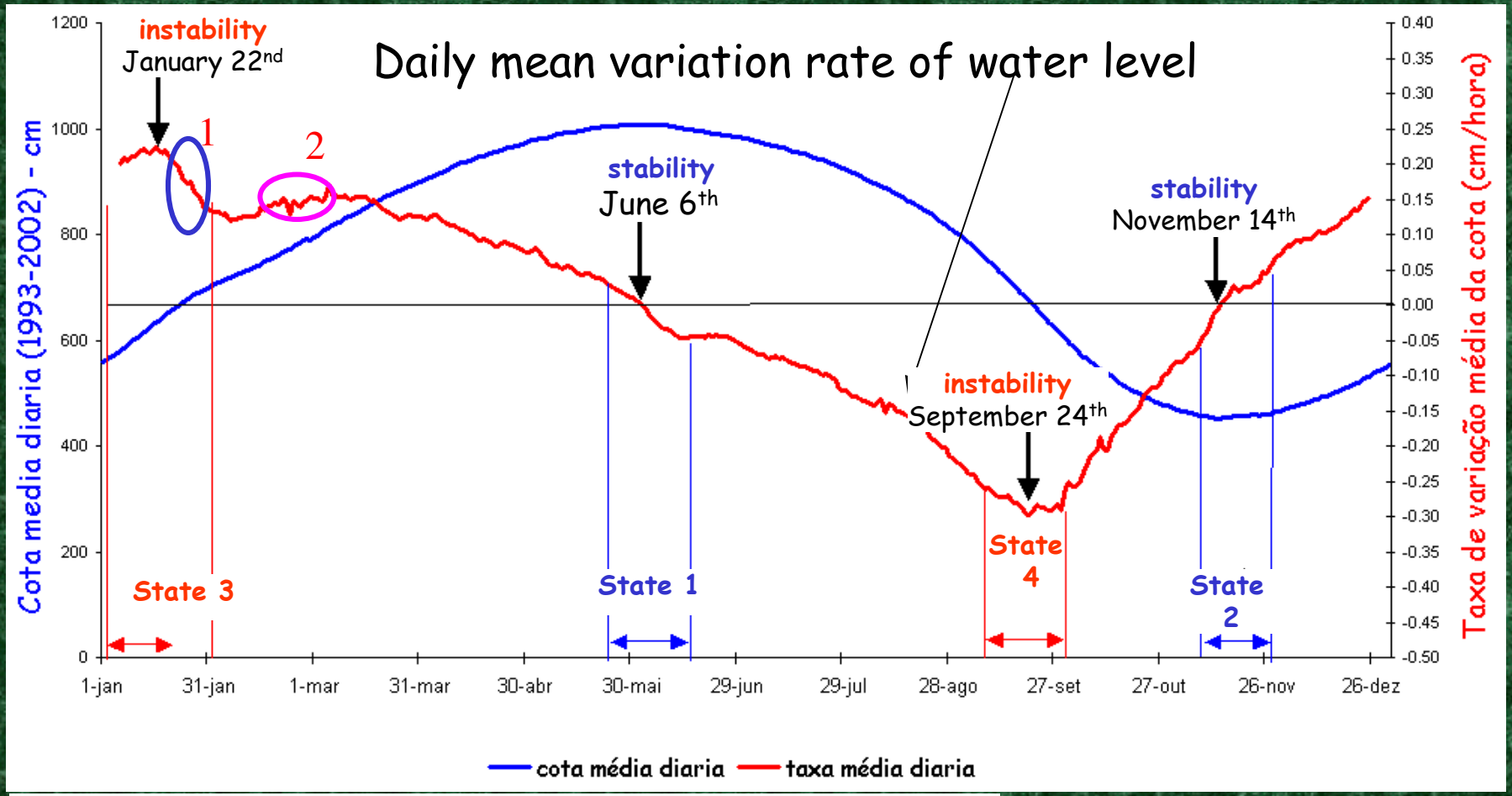
State 2 (low)
November

State 3 (rising)
January

State 4 (decline)
September

The most representative period of each state for sampling

(Refining the first indicatives)



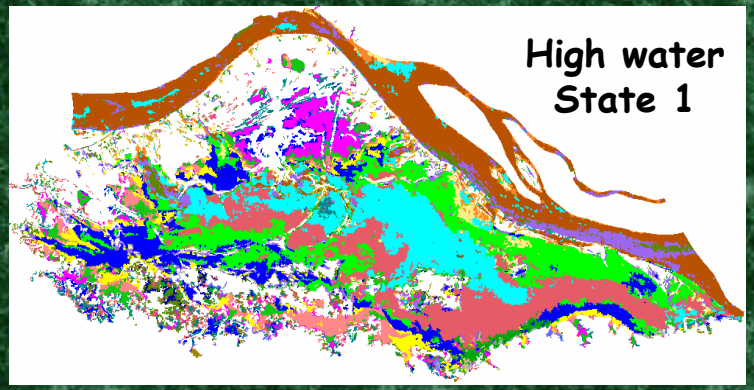
Estado do sistema rio/planície	*Estado 1* (cheia)	*Estado 2* (baixa)	*Estado 3* (enchente)	*Estado 4* (Vazante)
Períodos adequados	27/05 a 16/06	04/11 a 24/11	12/01 a 01/02	14/09 a 04/10

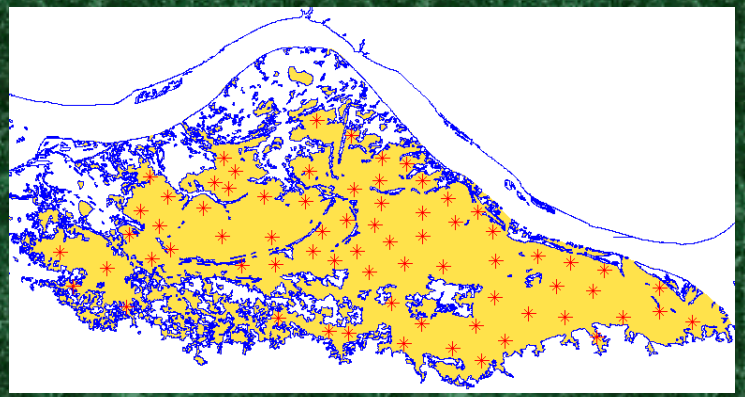
Adjust to include image acquisition day

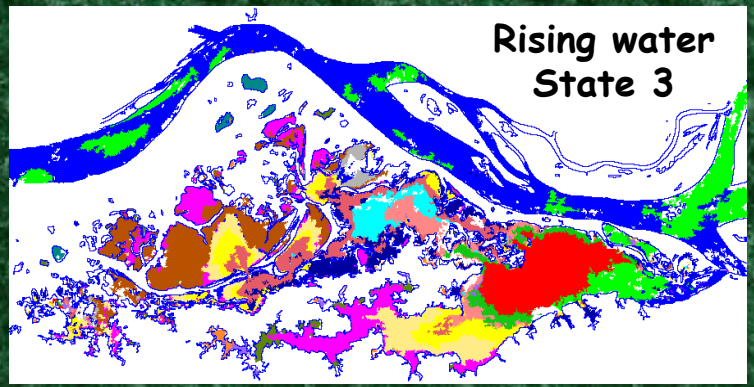
Number and location of sampling points

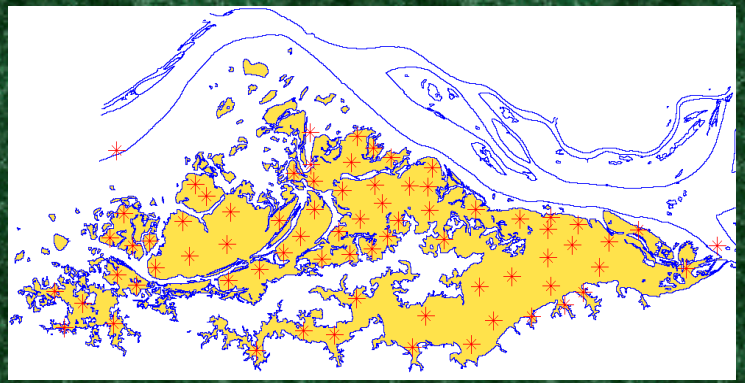
Homogeneous water masses were delimitated through the automatic classification of historical images.

Purpose: ➔ avoid both: over-sampling in some water masses and under-sampling in others

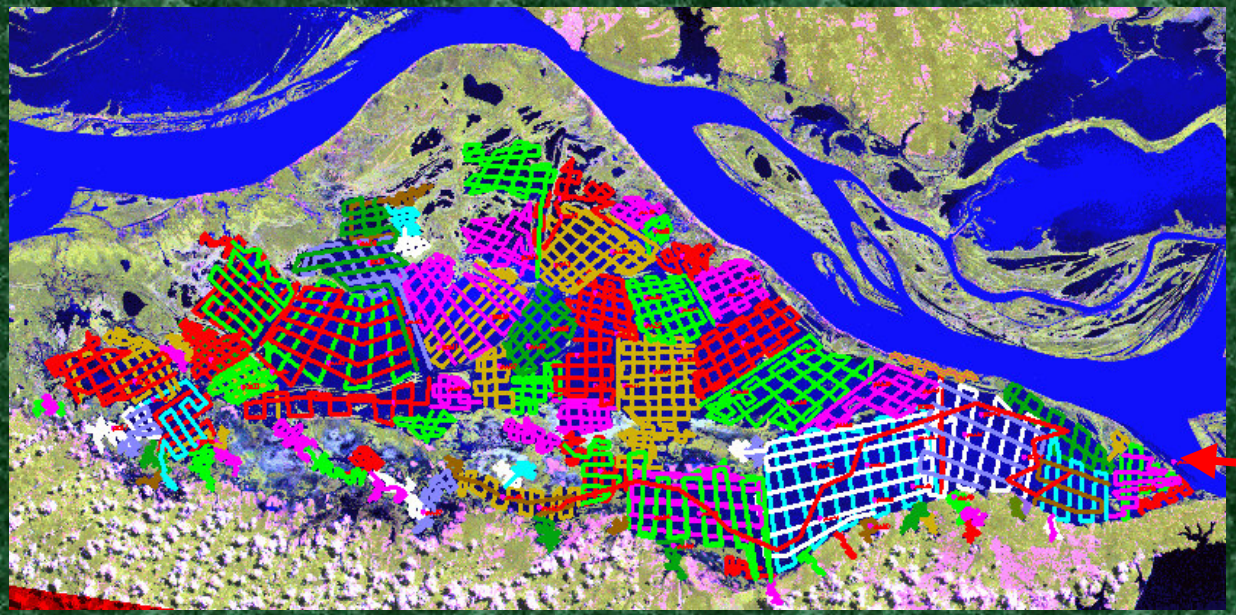




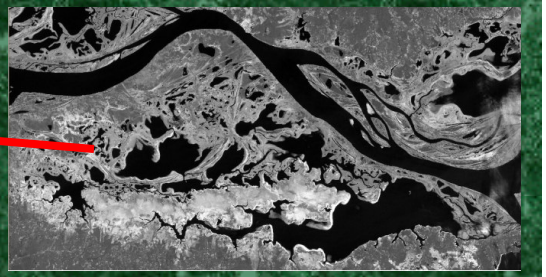




bathymetric plan and available infra-structure



The density of transects was based on floodplain relief



Infra-structure

A large boat and 3 small

crew 5

Research team : 5 persons

Summary of the parameters collected

	CAMPANHAS DE CAMPO			
	Vazante *(Estado 4)*	Baixa *(Estado 2)*	Enchente *(Estado 3)*	Cheia *(Estado 1)*
Período adequado	14/09 a 04/10	04/11 a 24/11	12/01 a 01/02	27/05 a 16/06
Período de execução	23/09 a 09/10/03	19/11 a 01/12/03	01/02 a 14/02/04	31/05 a 21/06/04
Medidas	In Situ			
Condutividade	208 pontos	202 pontos	221 pontos	256 pontos
Oxigênio Dissolvido				
Turbidez				
pH				
Profundidade Secchi				
Profundidade Total				
Temperatura da água				
Curva espectral				
Análises	Laboratório			
Clorofila	72 pontos	73 pontos	74 pontos	76 pontos
DOC				
DIC				
M. Total suspensão				
M. Inorg. Suspensão				
M. Org. suspensão				
Nitrogênio Total			29 pontos	32 pontos
Fósforo Total				

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- Spectral;
- Orbital images
- Bathymetric

- Conceptual Model proposed

Processing and analysis of four distinct data types

limnologic : In order to understand the spatiotemporal changes on water composition, an exploratory analyses had been applied on limnological data, using ordinary kriging
Purpose: identify spatial patterns in water composition related to flooding pulse

Spectral: observe changes in water spectral response due to changes in water composition. (how the dynamic of water composition affects water spectral response)
Purpose: Get insights to better interpret the multi-spectral images.
The reults was used as a link between water composition and multi-spectral images

Multi-spectral images : used to delimit homogeneous water mass in terms of spectral response
Purpose: delimitate, characterize and quantify homogeneous water masses in different phases of hydrological cycle.(multi-temporal analysis)

Bathymetric : quantify volume and flooded area.
Purpose: analysis of volume and flooded area inundated dynamics

Synthesis of spatiotemporal dynamics of TSS
for the hydrological cycle in with data were gathered

depth ↓ wind ↑

resuspension => High TSS

smooth variation (homogeneity)

Controlling factors

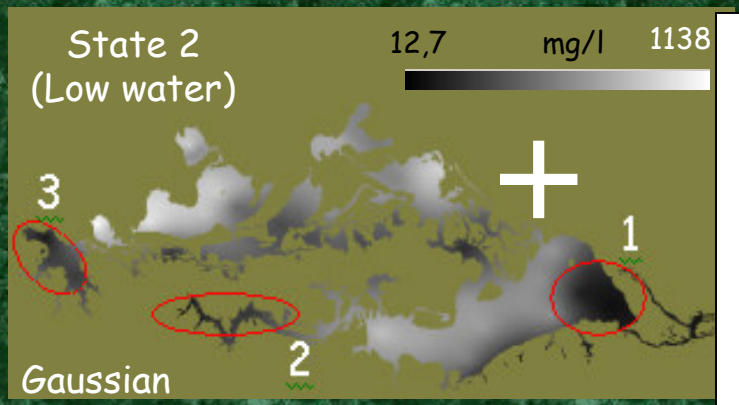
Depth and Wind

Entering water

Dominant pattern

> 50% (M ± 1DP)

Well defined transition



what the mathematic model fitted means?

Gaussian: The data have smooth spatial variation pattern, with no abrupt transitions (High spatial continuity).

Exponential: suggest that there is gradual transition between patterns

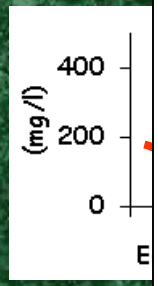
spherical: evidence of a dominant spatial pattern with clear transition point.

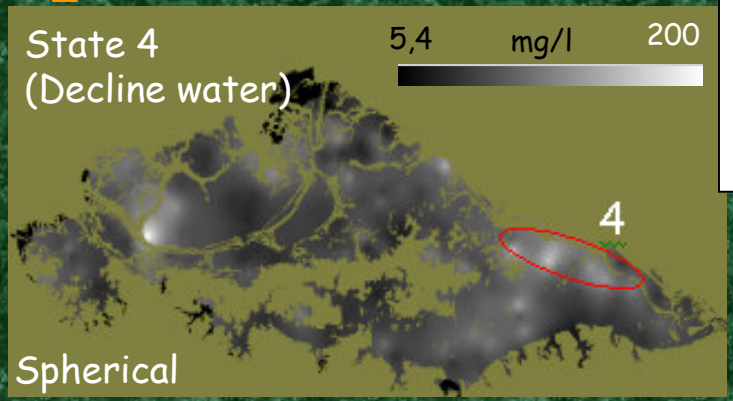
+7 times

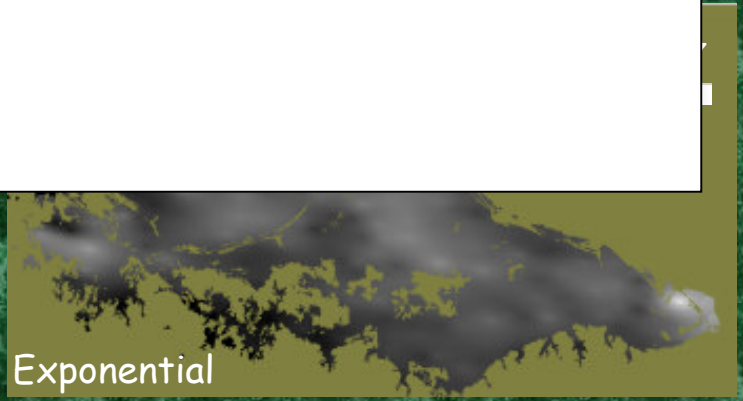
depth ↓ wind ↑

resuspension =>

Gradual transition

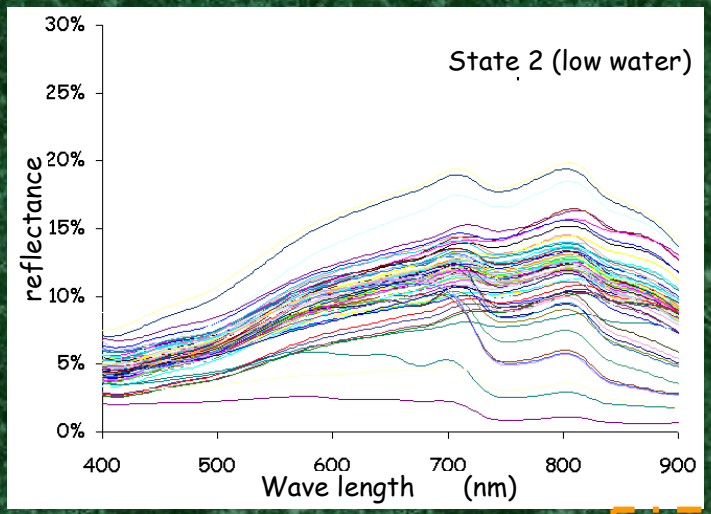






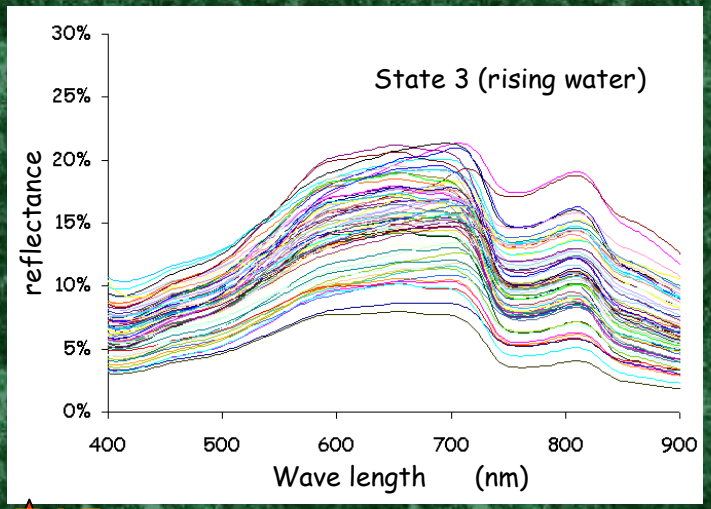
In situ radiometric measures processing:

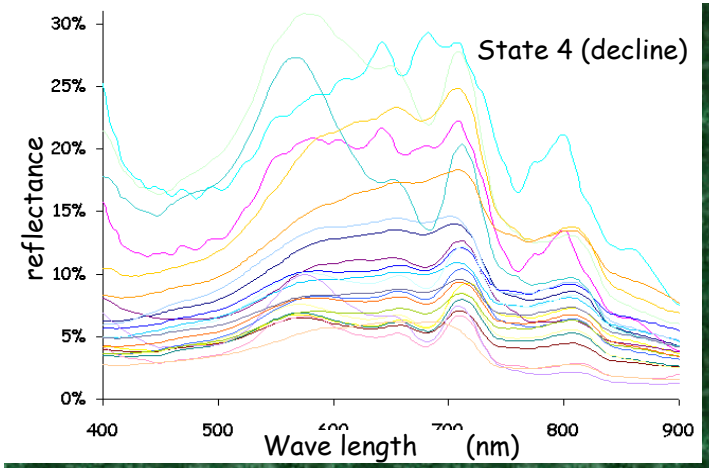
Effect of dynamics composition on water spectral response

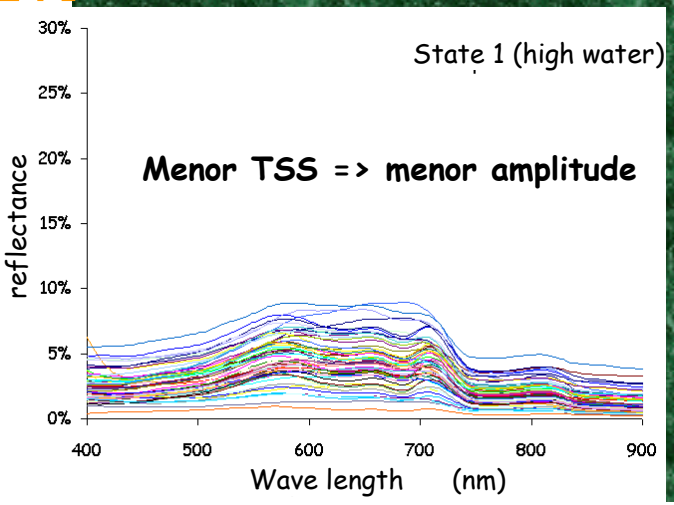


How changes on water composition affect both:

Amplitude and Shape of the spectra

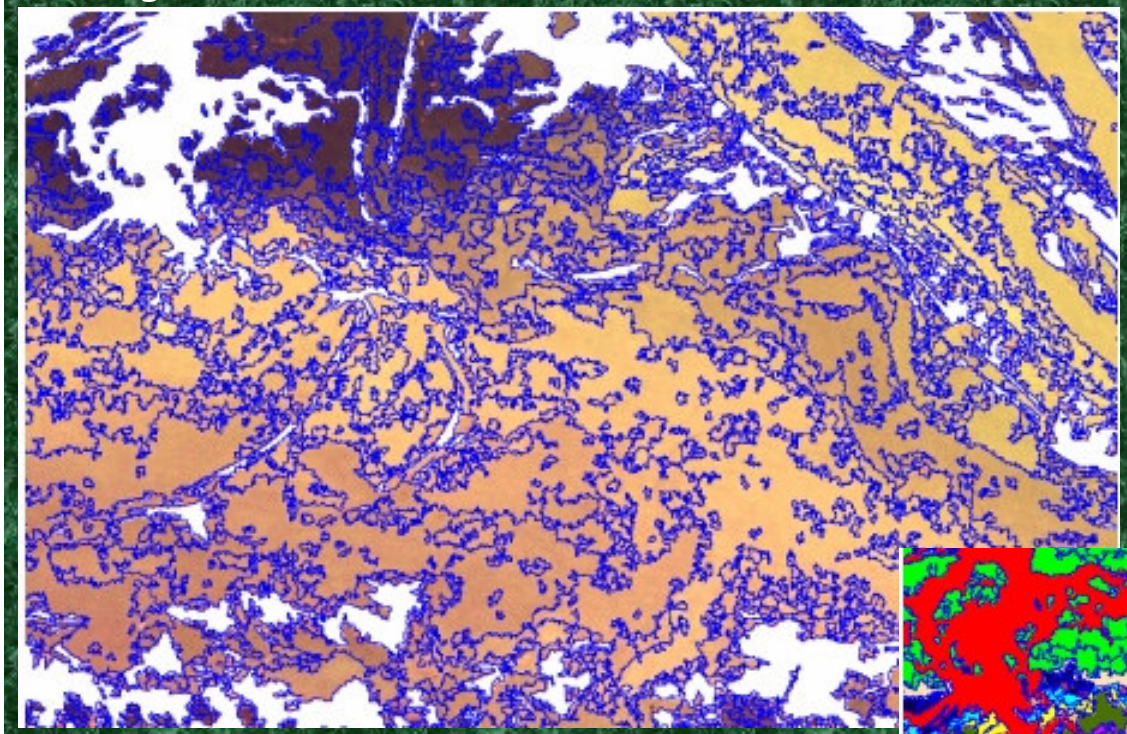






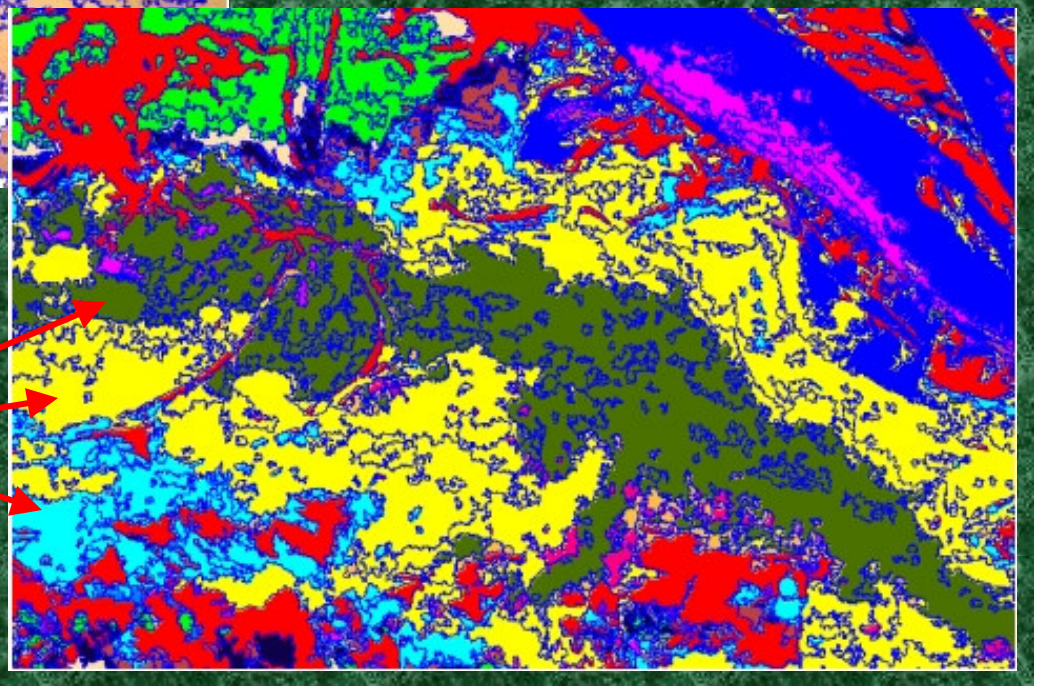
Multi-spectral images processing: spatial delimitation of homogeneous water masses

Segmentation



Homogeneous water masses were delimitated submitting TM/Landsat Images to segmentation and unsupervised classification

Unsupervised classification



homogeneous water masses with diferent spectral response

Mapping criterion

1 - high chlorophyll concentration

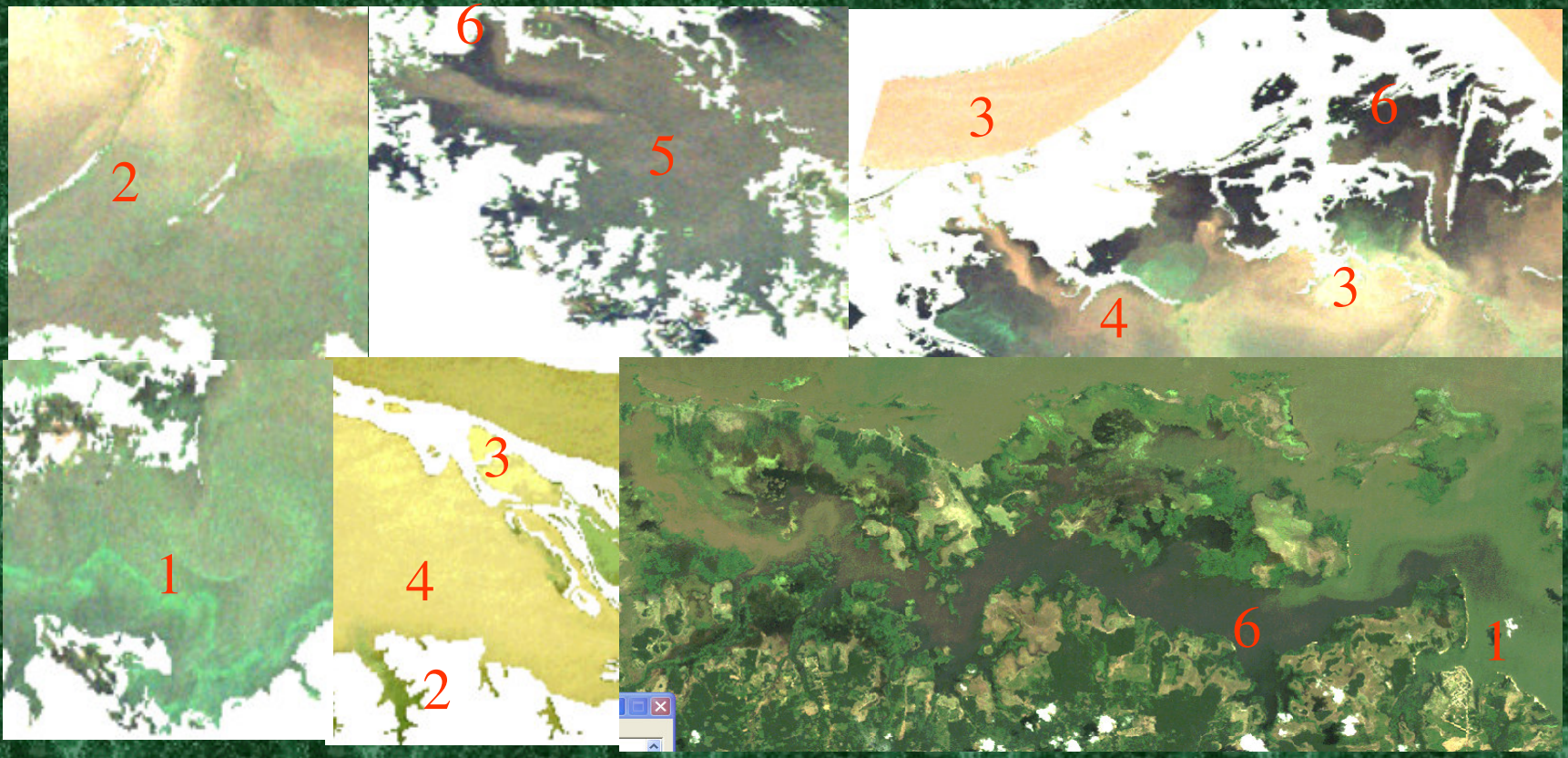
2 - medium chlorophyll concentration

3 - high inorganic particle concentration

4 - medium inorganic particle concentration

5 - medium organic matter concentration or low inorganic particle

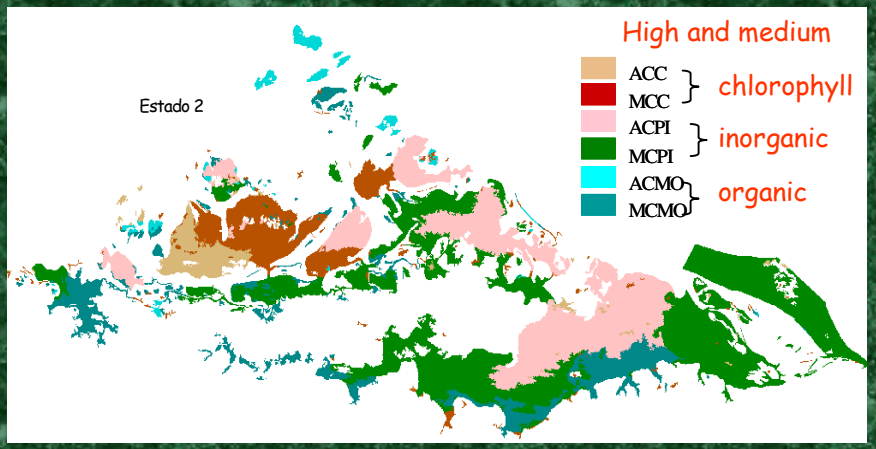
6 - high organic matter concentration

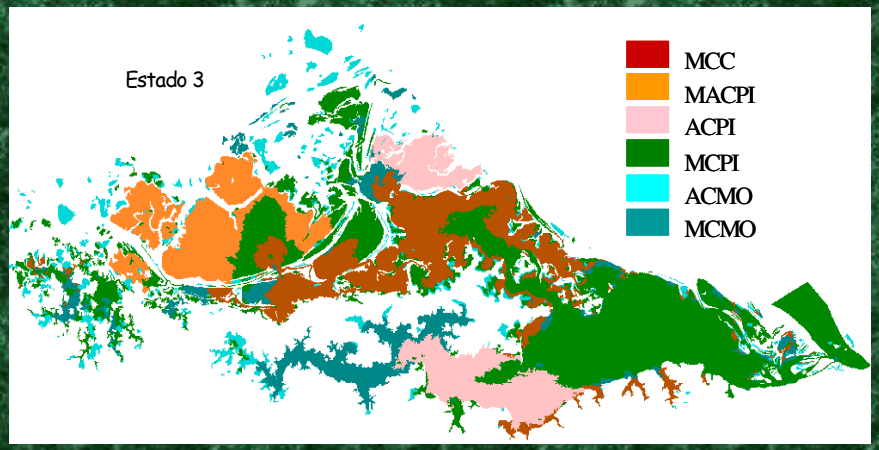


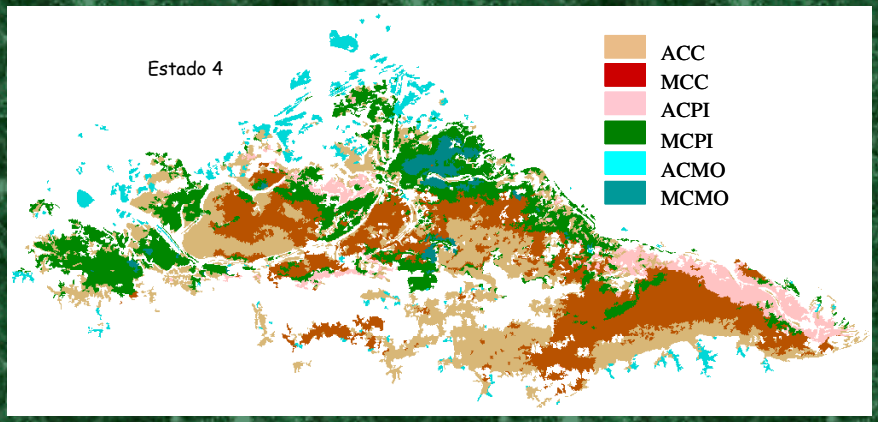
(TM 1-> Blue, TM 2 -> Green, TM 3-> Red)

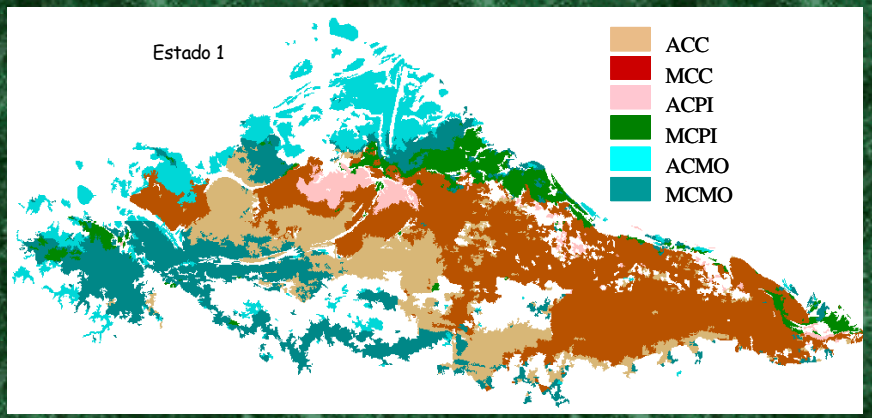
Thematic maps

(results of mapping processing based on the previous criterion)





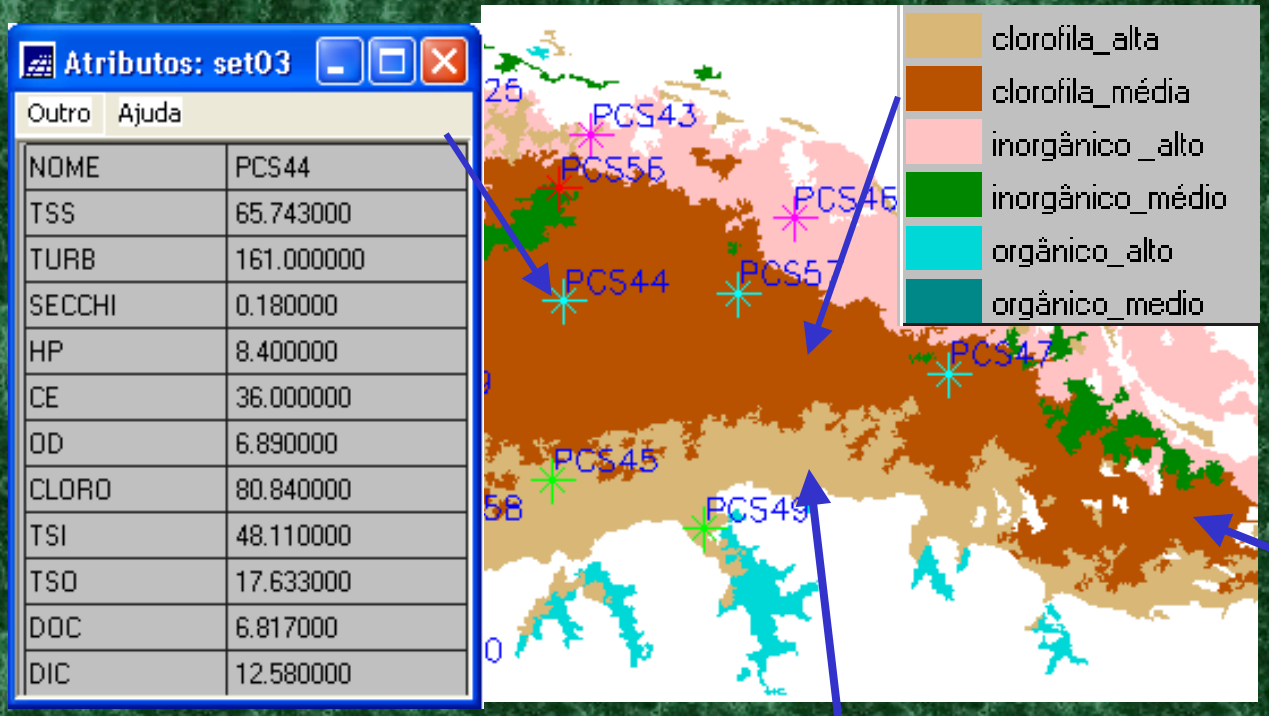




Classes characterization in terms of parameter concentration

Fieldwork samples overlaped the classes delimitation and the mean concentration value for each class was estimated.

mean values of chlorophyll for high and medium chlorophyll classes was estimated. The same were done for inorganic and organic matter classes

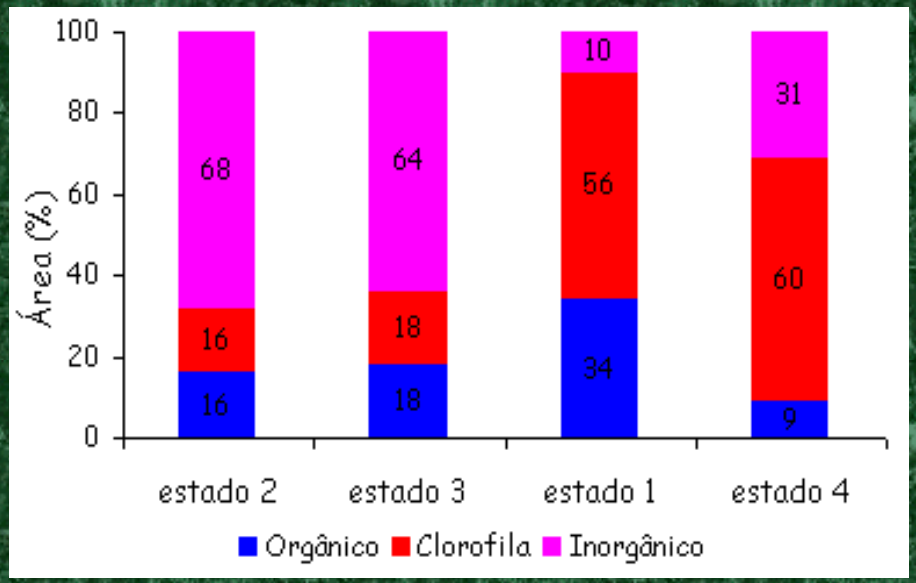


medium chlorophyll

high chlorophyll

Dominant component : responsible for spectral response

This approach allowed to quantify the percentage of area occupied by each theme during each state of the system



Fieldwork campaigns

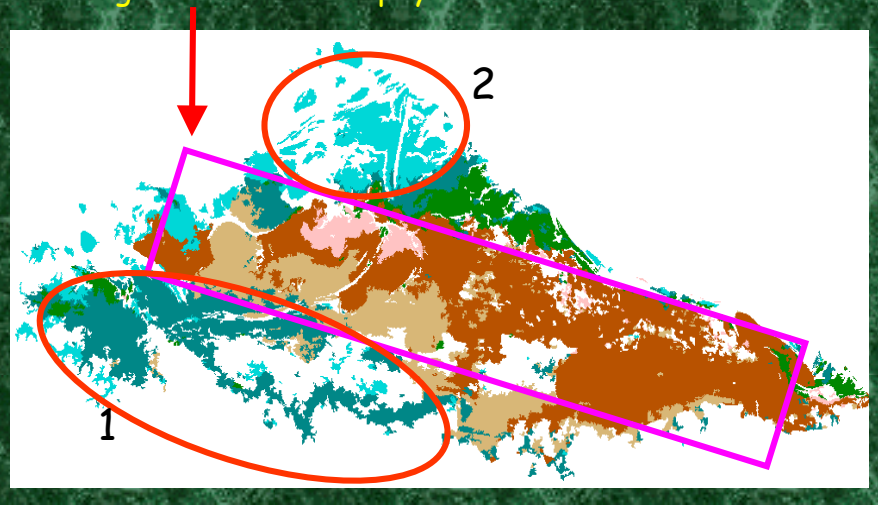
Inorganic: states 2 e 3 (~66%)

(458 e 94 mg /l)

Chlorophyll: states 1 e 4 (~58%)

(28 e 68 µg/l)

Region where chlorophyll concentration dominates



State 2 = low state 3 rising
State 1 = high state 4 decline

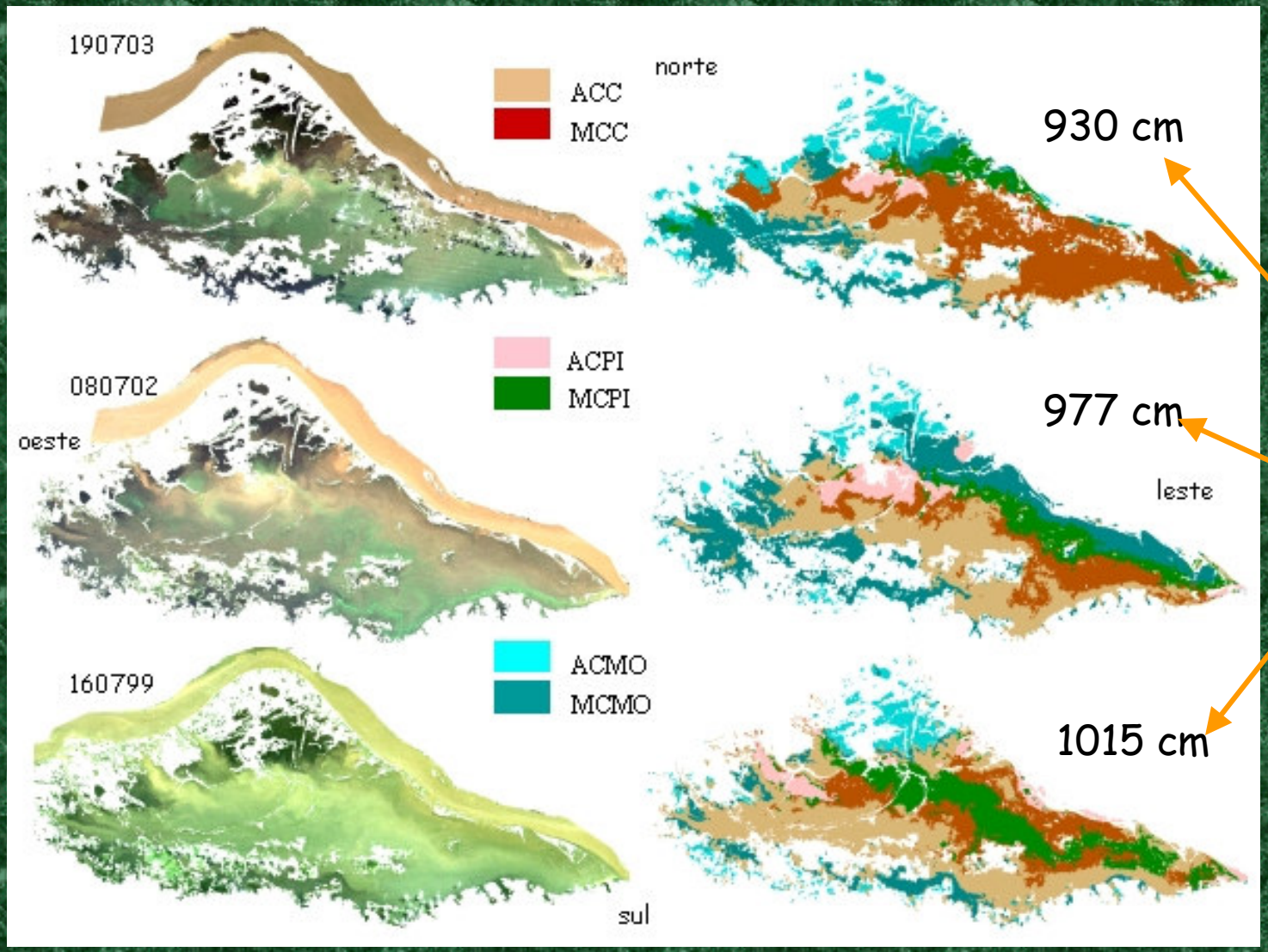
Multi-temporal analyze

Just a reminder:

Everything that was presented up to now, was related to a single hydrological cycle.

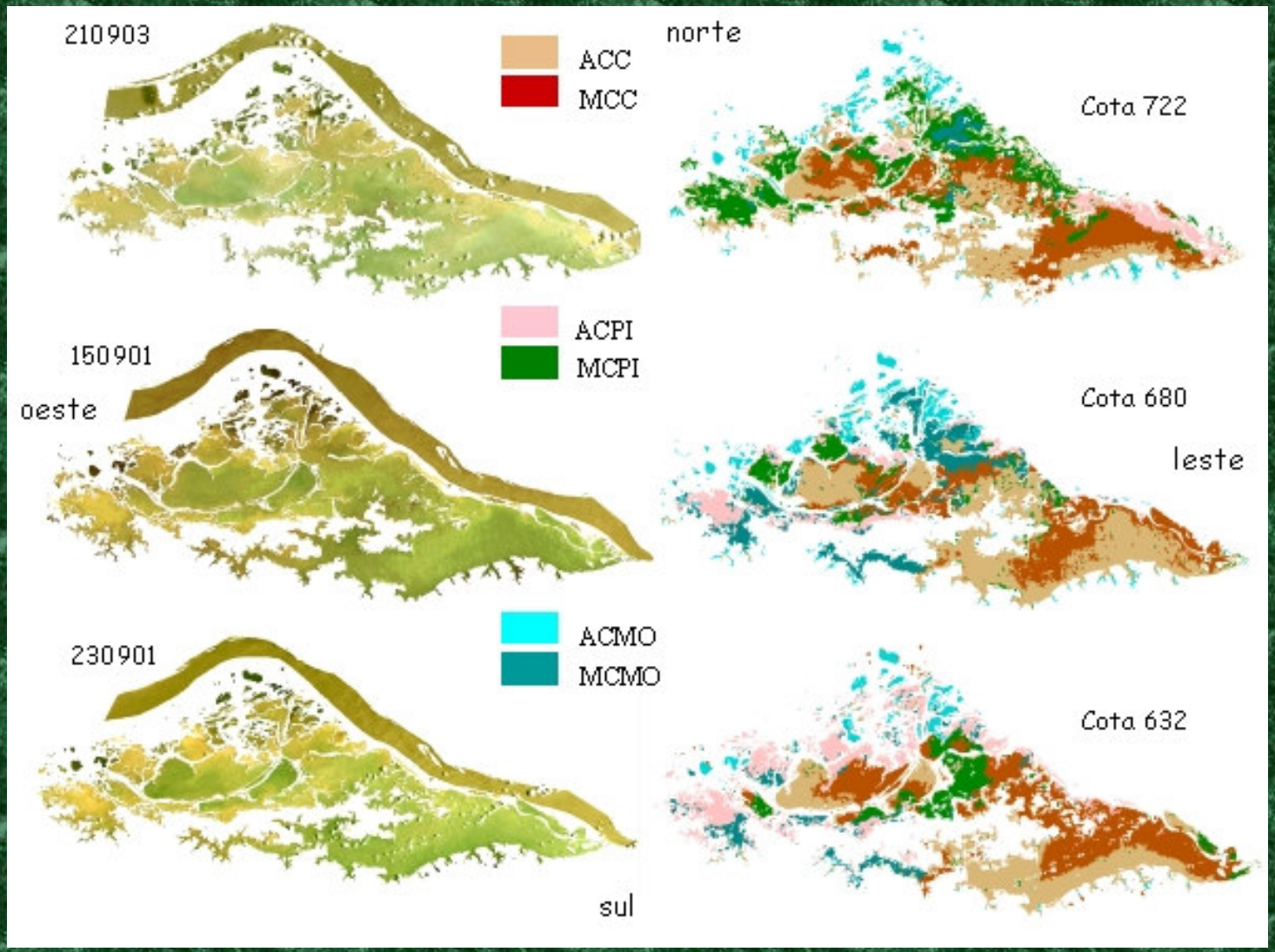
To confirm if the process observed is recurrent, images from previous hydrological cycle were processed.

Multi-temporal Sequence – high water



Predominance of chlorophyll is recurrent in high water

Multi-temporal Sequence – decline stage



Predominance of chlorophyll is recurrent in decline stage

Synthesis of the effect of flooding pulse on water composition

Predominance of inorganic and Chlorophyll is a characteristic of **white water**

occupied on average

fieldworks

80% of white water

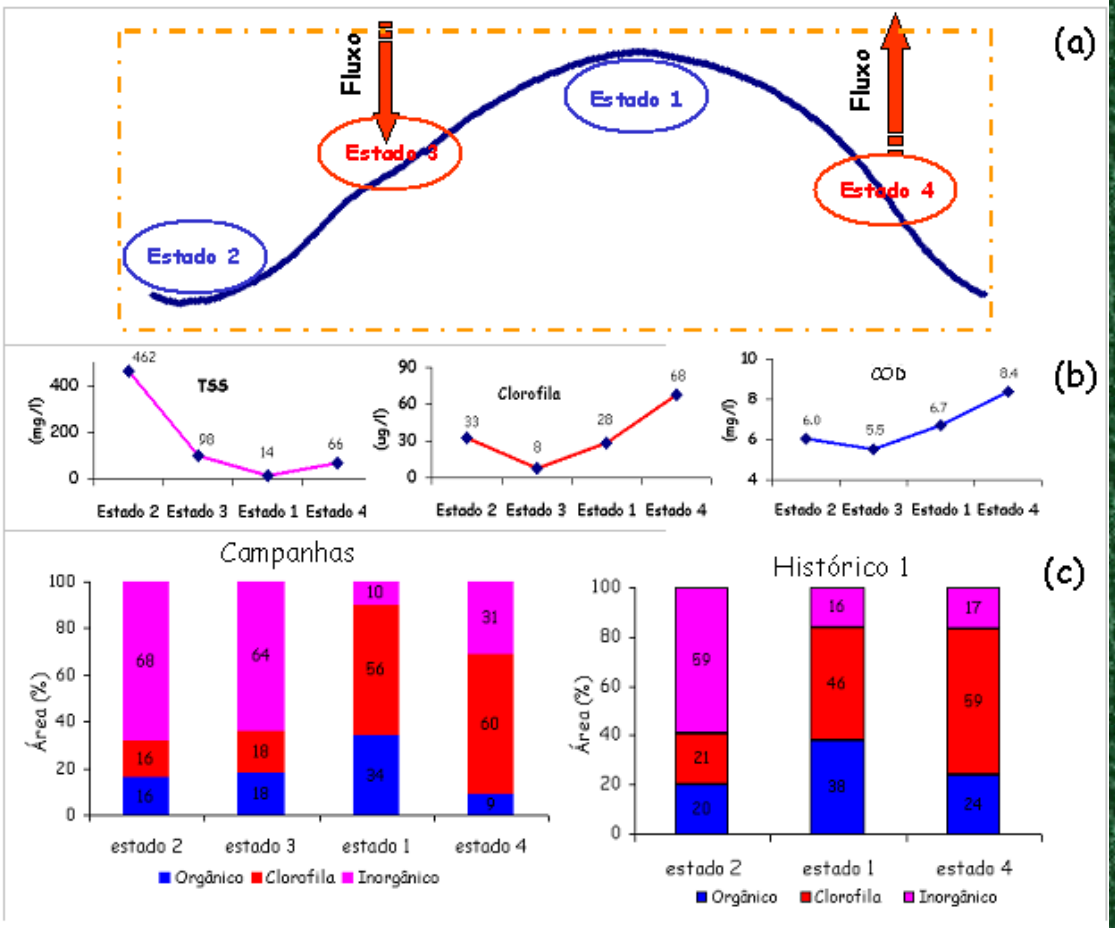
Results also show recurrence

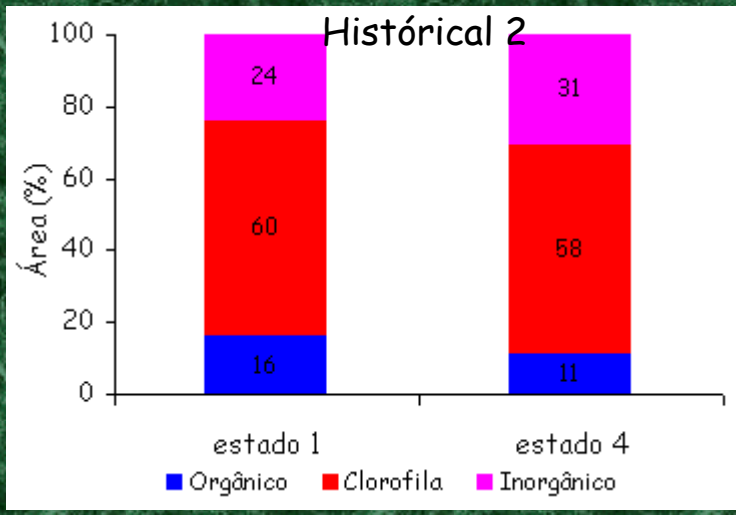
Historical 1

73 % of white water

Historical 2

86 % of white water





The dynamics of flooding pulse affects both: composition and spatial distribution water masses

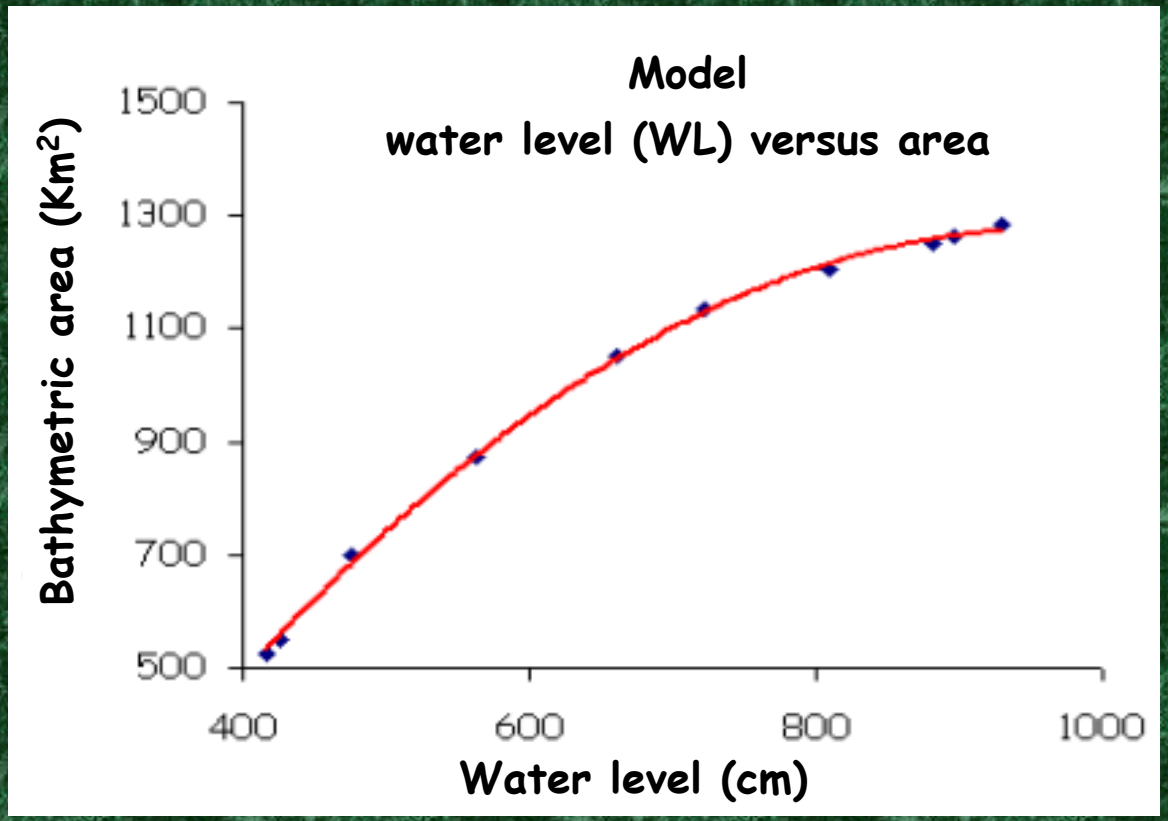
Synthesis of *Bathymetric data* processing

Bathymetric Model for Curuai floodplain (bottom relief)

➔ *that was used to quantify volume and flooded area.*

Assessing the dynamics of flooded area (open water)

(regression model to estimate flooded area from water level)



Flooded area = $-25\ 10^{-4} \times WL^2 + 4{,}75 \times WL - 1020{,}5$

open water area

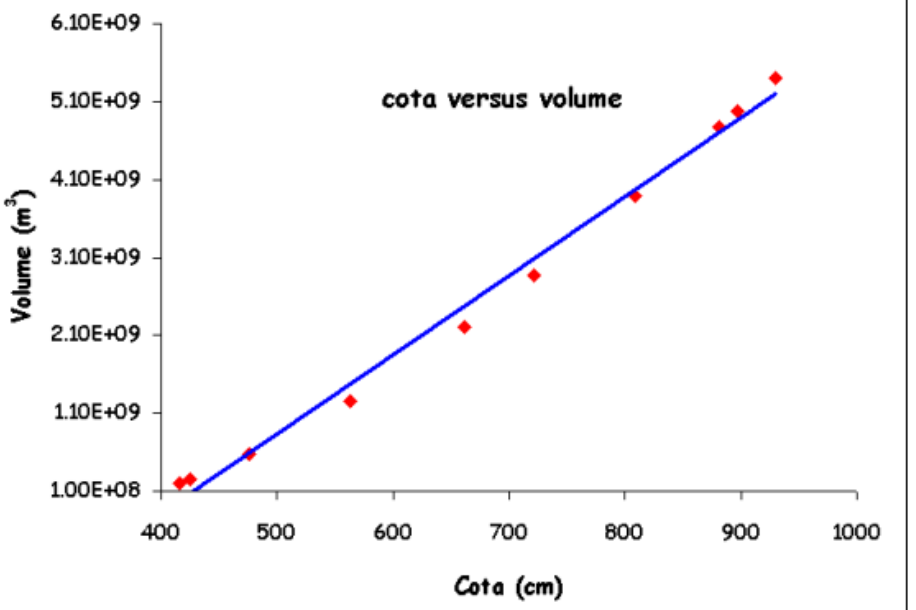
minimum area = 706 km²

maximum area = 1590 km²

Assessing the dynamics of volume (open water)

(regression model to estimate water volume from water level)

Cota (cm)	Volume (10^6 m^3)
416	209,3
425	256,2
476	575,0
563	1.258,1
662	2.213,3
722	2.870,5
809	3.889,9
881	4.775,1
897	4.976,5
930	5.396,6



Model WL versus volume

Volume = 10^7 WL – 4,0 x 10^9

average volume variation

per hydrological cycle 5,1 x 10^9 m^3

Presentations sequence

Purpose and study area

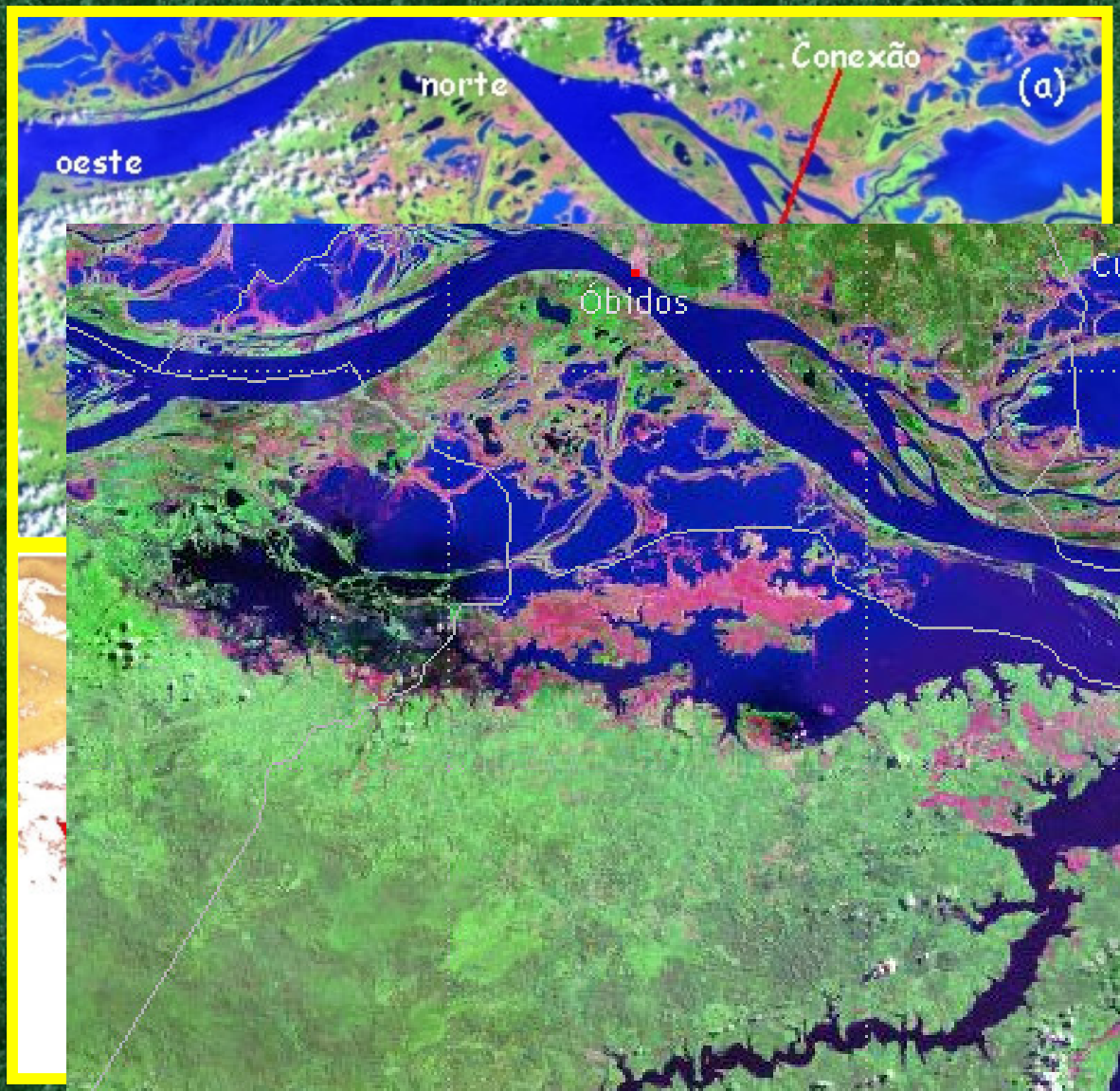
Initial data available preliminary analysis

Processing analysis and integration of results

limnologic;
Spectral;
Orbital images
Bathymetric

- Conceptual Model proposed

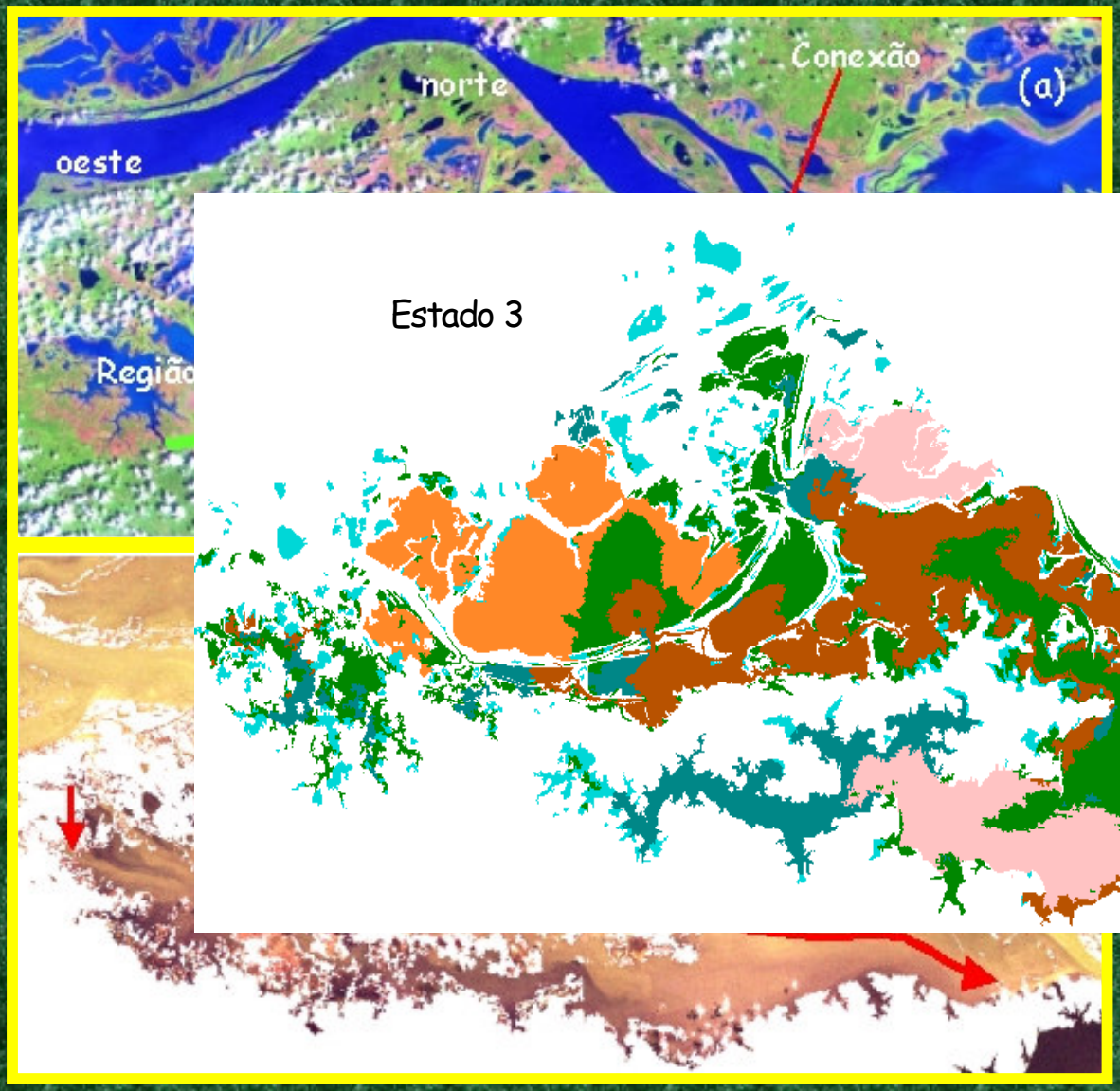
Conceptual Model to describe water circulation in Curuai floodplain



1- Tapajós river reaches high level

2 – increase water level at east of Curuai floodplain

Conceptual Model of water circulation in Curuai floodplain



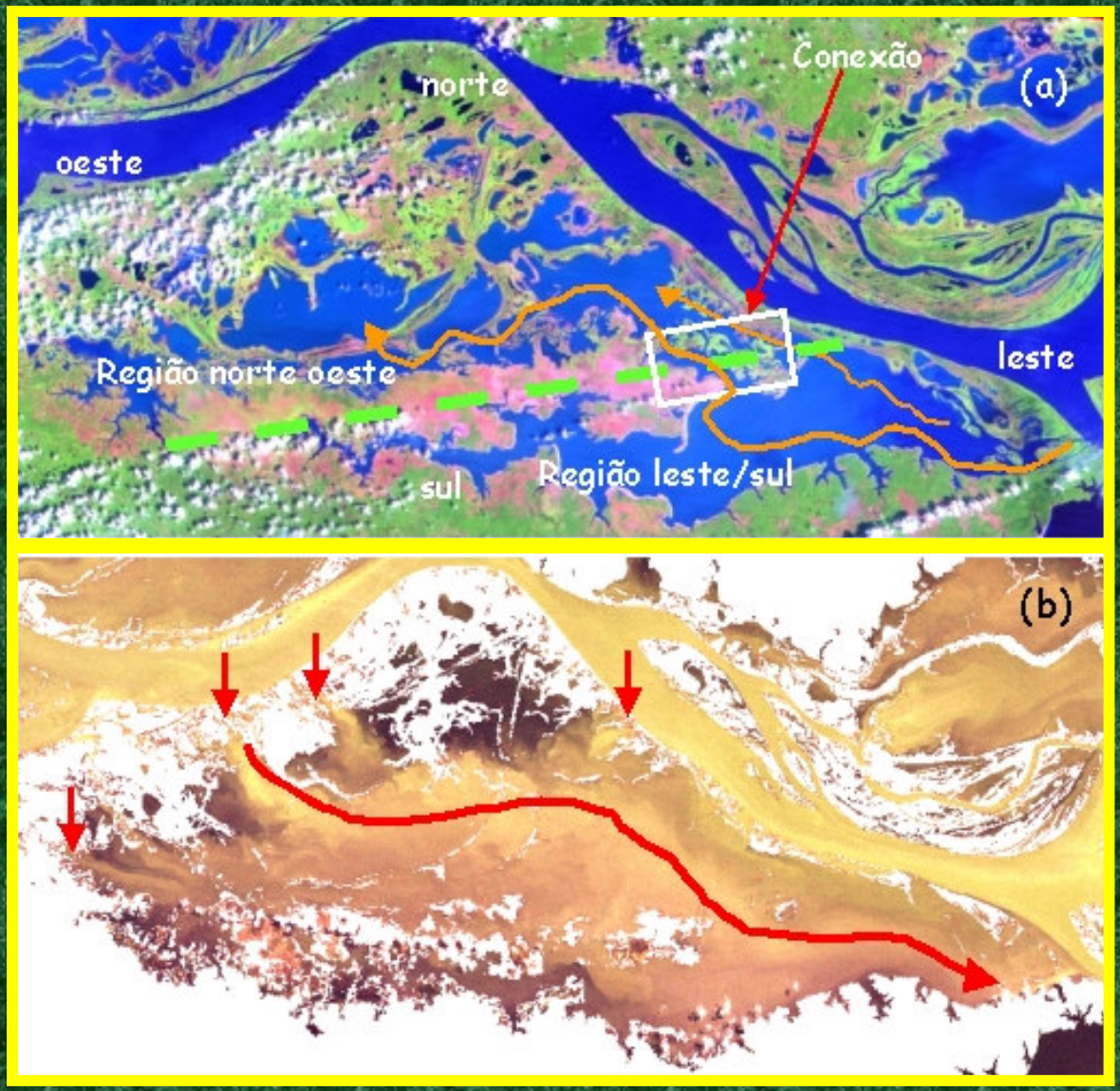
1- Tapajós river reach high level

2 – increase water level at east of

High and decline (1 e 4)

TSS + CLO (dominate)

Conceptual Model of water circulation in Curuai floodplain



1- Tapajós river reach high level

2 -water level increases at east of Curuai floodplain

3 – east-west flux begins

4 – at 720 cm water level, inputs from igarapés (northern/western borders) are dominants

5 – the system reach equilibrium (may/June)

6 – the water movement is driven by natural barrier. (two distinct regions)

Water composition

Low and rising (2 e 3)

TSS (dominate)

High and decline (1 e 4)

TSS + CLO (dominate)

CONCLUSION

✓The results of this research confirm that is possible to delimit and characterize the spatiotemporal variation of distinct water masses resident in the Amazon floodplain, using optical images, independent of their acquisition year.

✓The results also confirm the importance of the Amazon flooding pulse as the main function force that driven the spatiotemporal variation of water masses in the Amazon floodplain.

✓It was also possible to confirm that there is a spatial pattern of water circulation in the Amazon floodplain, and that this pattern is recurrent

✓It is possible to use optical images with spatial and temporal resolution similar to TM/Landsat acquired in distinct hydrological cycles.


Thanks