

# Spatial and Temporal Patterns of Aquatic Biogeography in the Amazon

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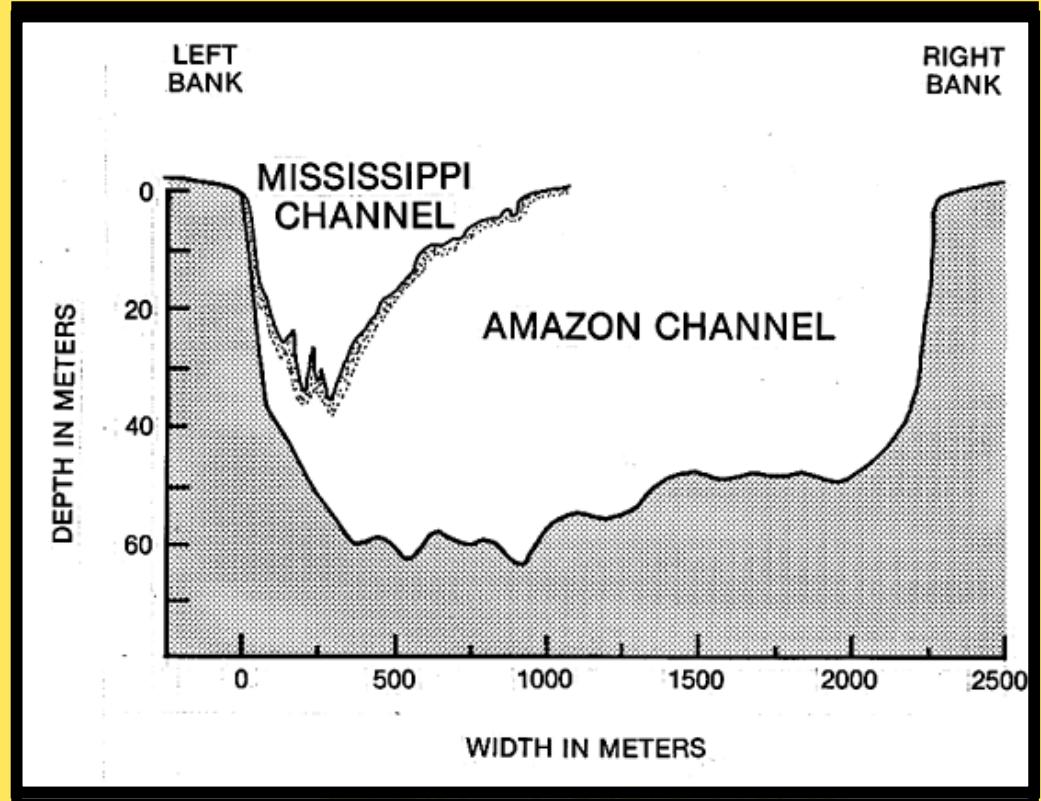
<sup>3</sup>Universidade Federal de Viçosa, Brazil

**Thanks also to Laura Hess and John Melack**

*LBA-ECO Science Team Meeting, Brasilia, Brazil October 2006*

- Heavy seasonal flooding:
  - 400,000 km<sup>2</sup>,  
*or 6-8% of the Basin*  
~ *size of California*
- Floodplains of Amazon River and large trib only:
  - 350,000 km<sup>2</sup>,  
*or 20% of central Amazonia*

## Flooded areas



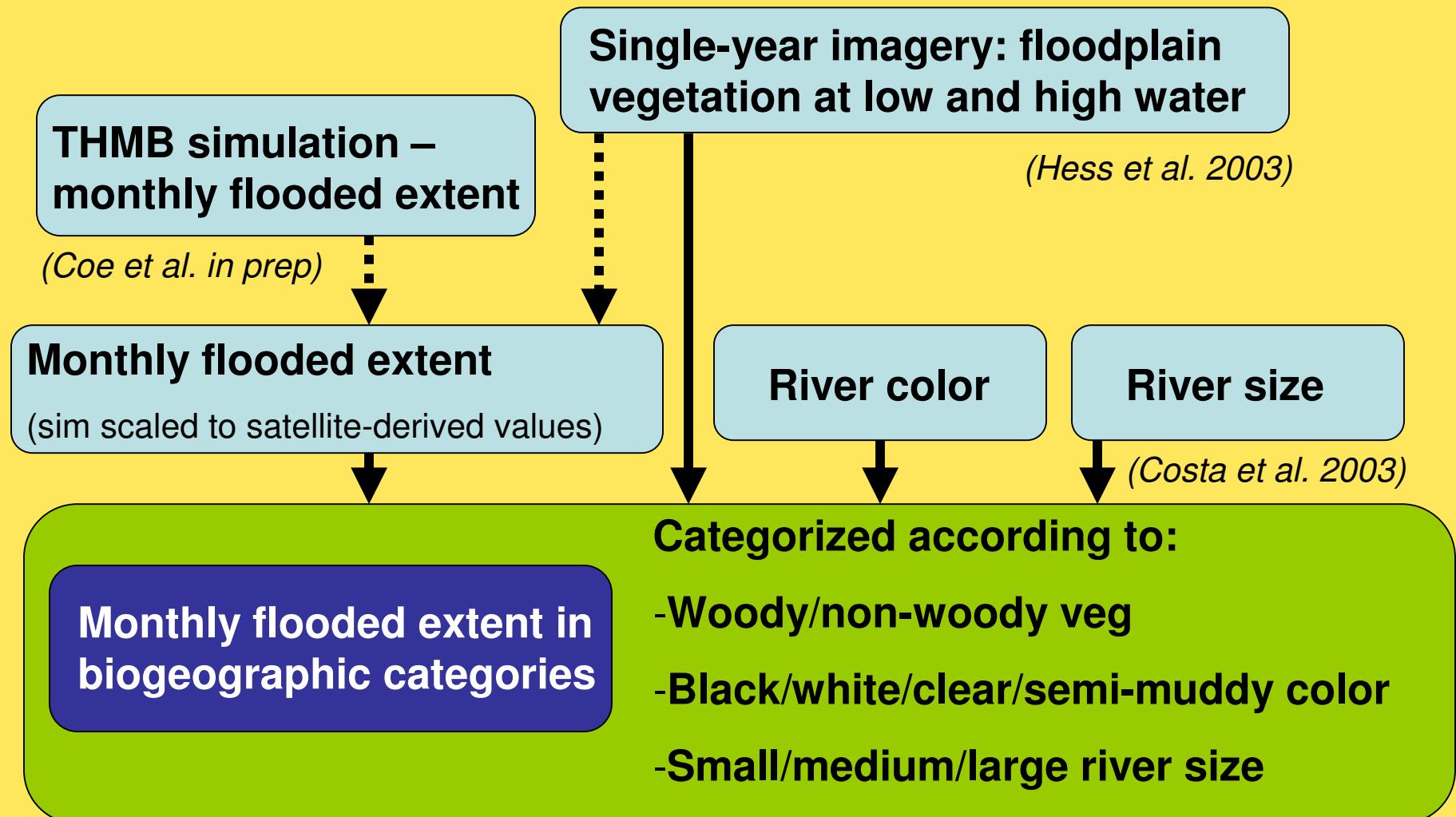
# What does this mean for Amazonians?



## Driving question

**How do changes in hydrology  
affect the distributions of different  
aquatic ecosystems in the Amazon  
Basin over space and time?**

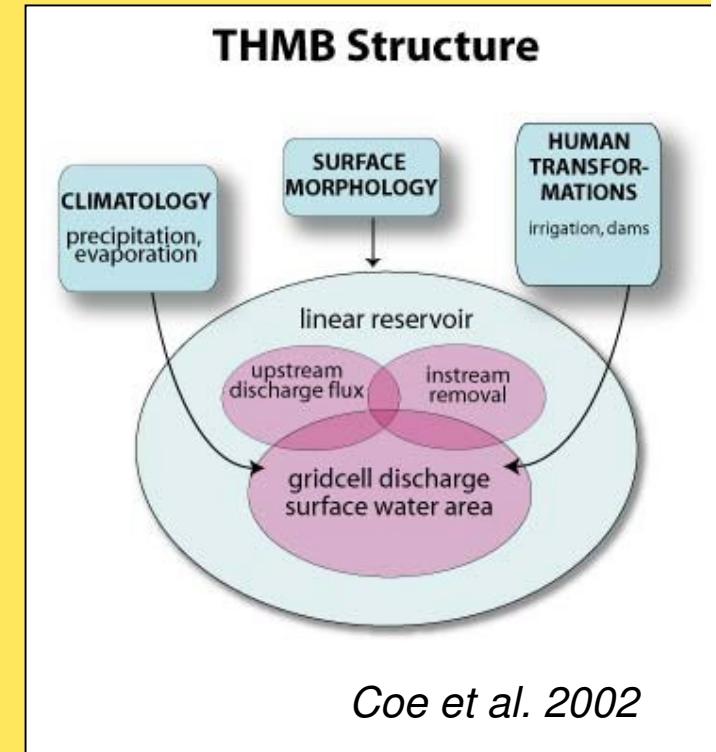
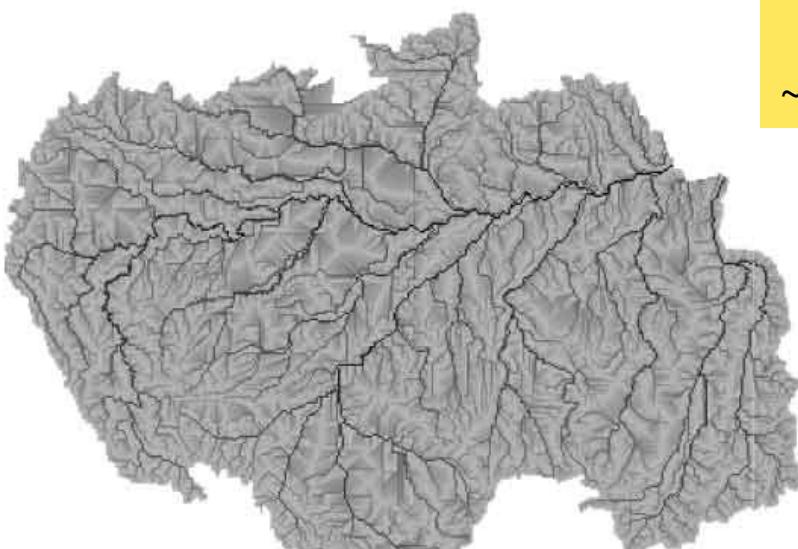
# Deriving wetland biogeographic categories



# Terrestrial Hydrology Model with Biogeochemistry (THMB)

## *Land surface hydrology*

- *5-min spatial resolution (~ 9 km)*
- *River transport*
- *Water storage in wetlands and reservoirs*
- *Seasonal inundation of floodplain*

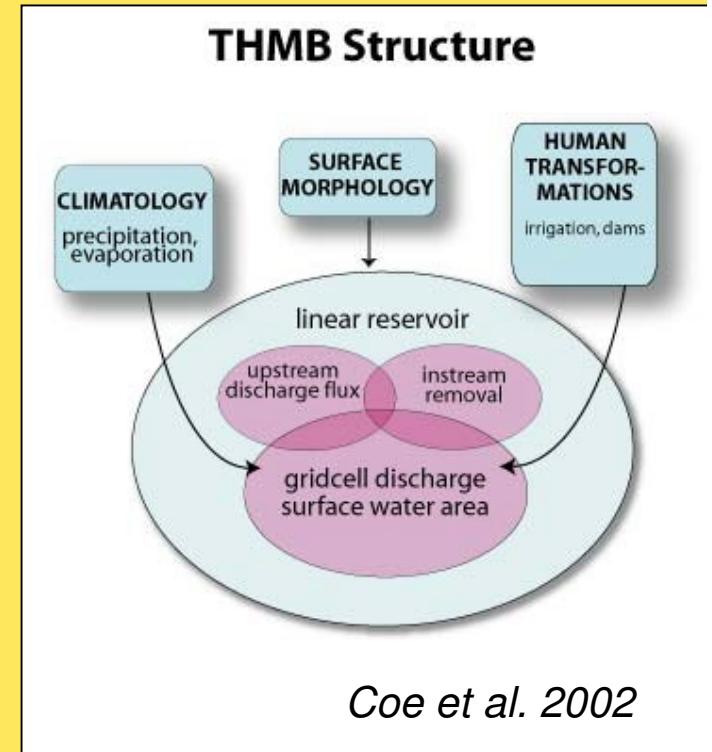
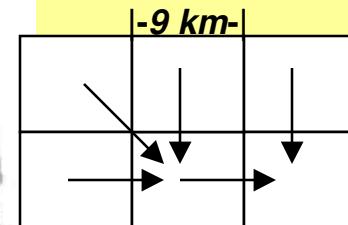
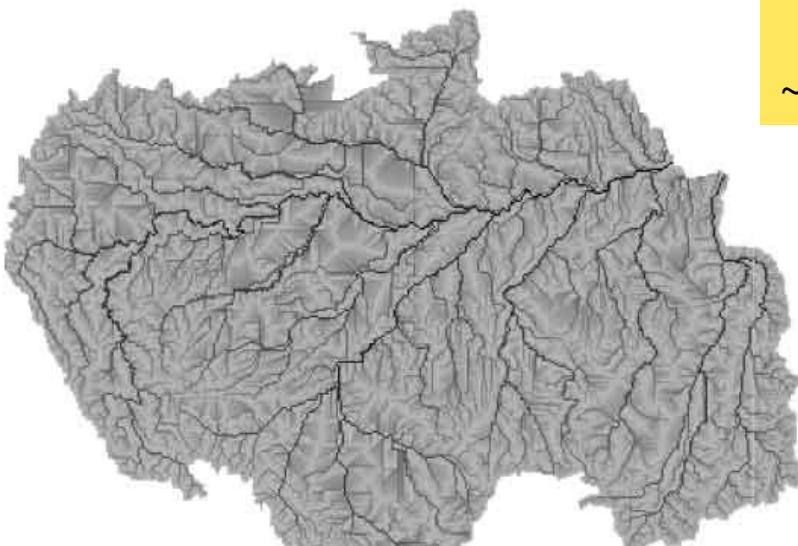


**Model Framework**

# Terrestrial Hydrology Model with Biogeochemistry (THMB)

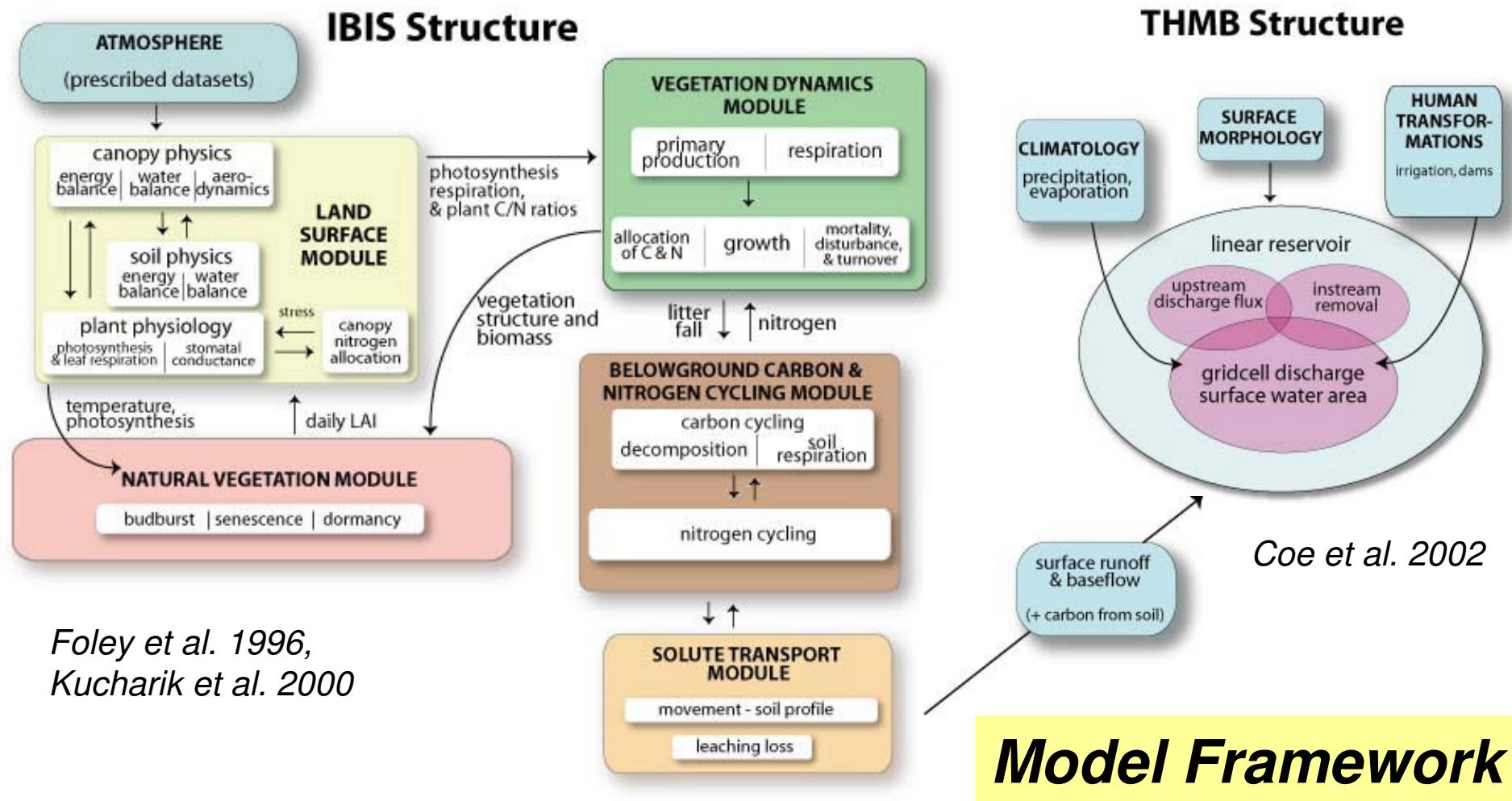
## Inputs:

- *Climate data*
- *Topography at 1-km (SRTM and GTOPO30)*
- *Empirically-derived river directions*
- *Surface and sub-surface runoff*



**Model Framework**

# Surface runoff and baseflow from IBIS

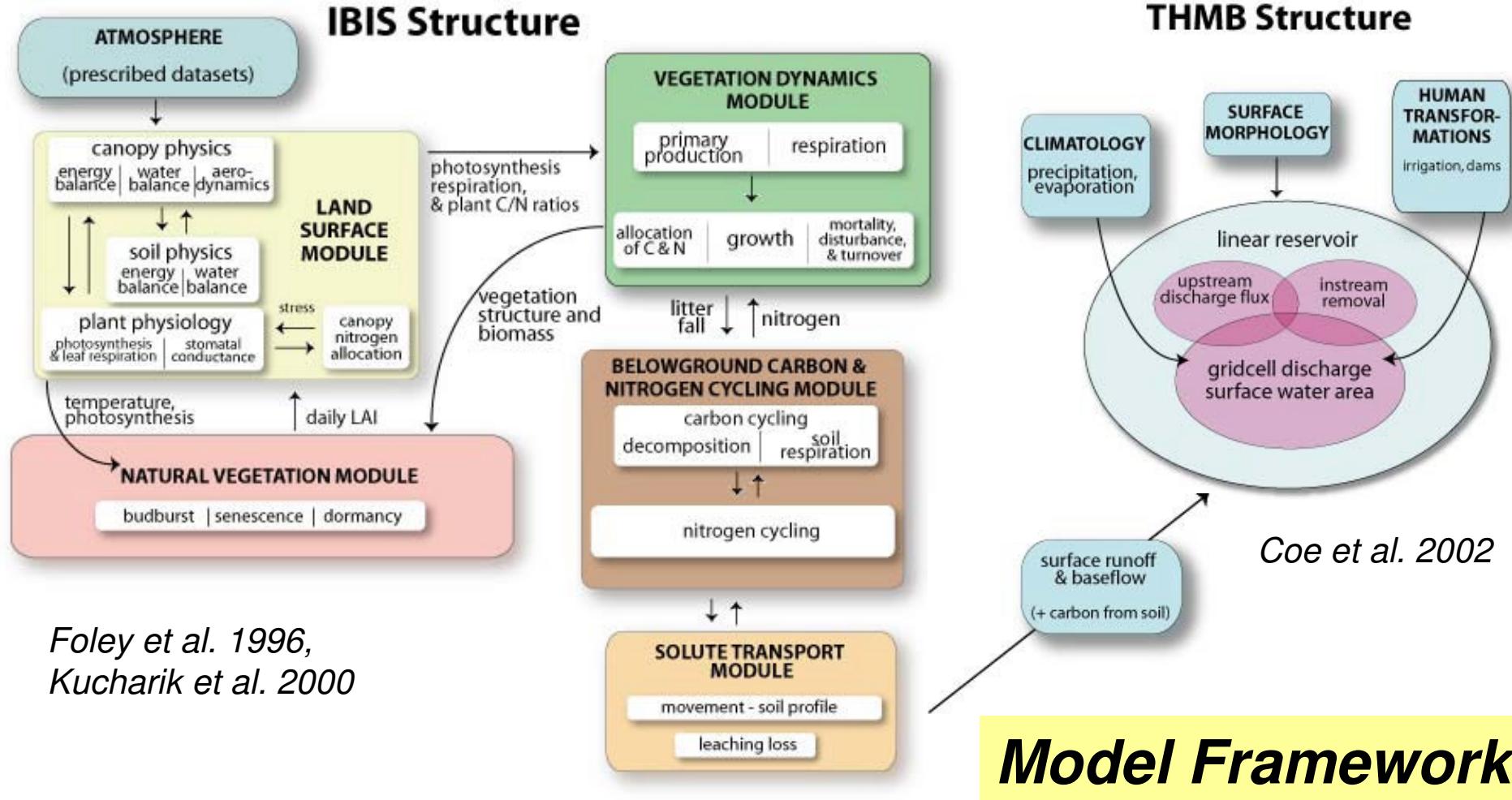


# Water, carbon & energy balance validated against Amazon flux tower measurements

Foley et al. 2002; Botta & Foley 2002

Flooding and height validated against discharge meas'ts and satellite data

Coe et al. 2002; Costa et al. 2003



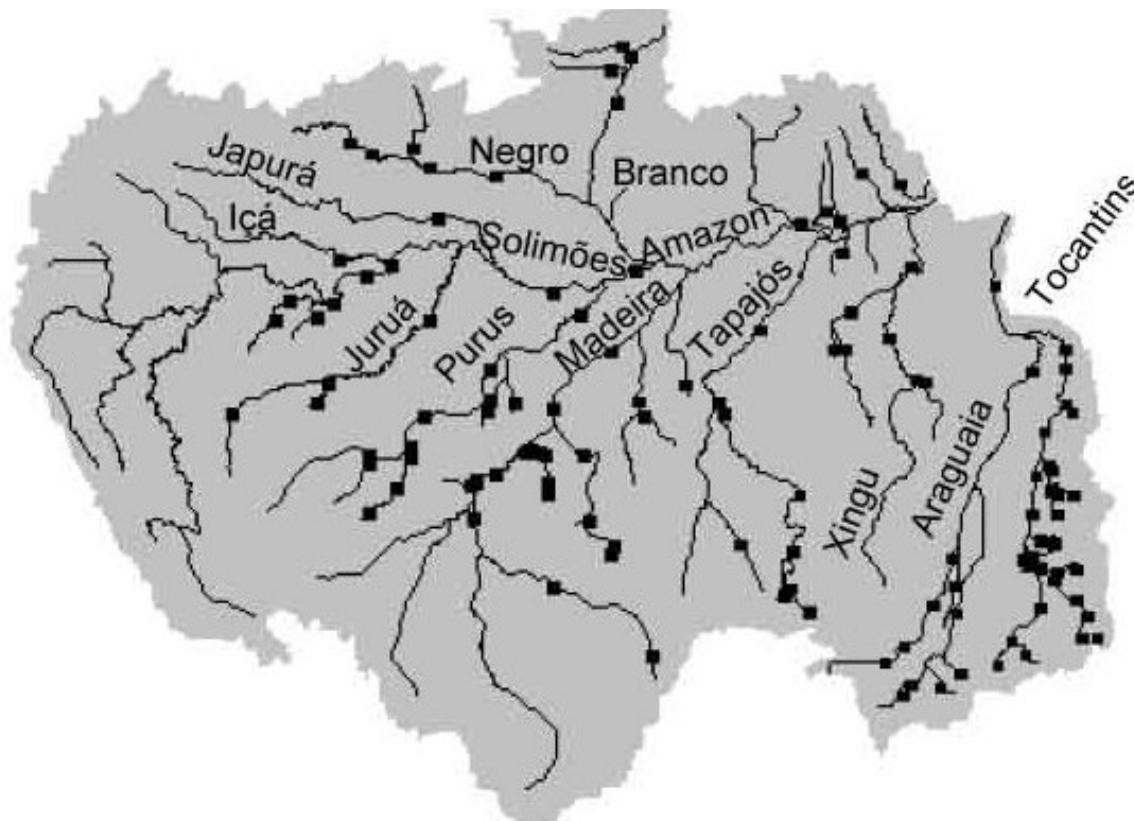
Foley et al. 1996,  
Kucharik et al. 2000

Water, carbon & energy balance  
validated against Amazon flux  
tower measurements

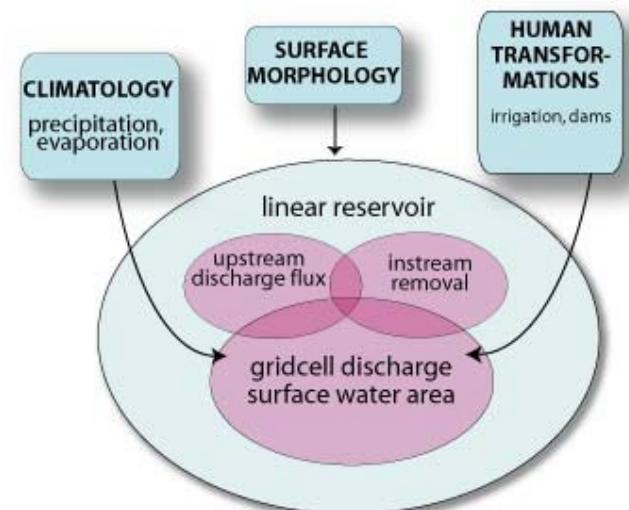
*Foley et al. 2002; Botta & Foley 2002*

Flooding and height  
validated against  
discharge meas'ts and  
satellite data

*Coe et al. 2002; Costa et al. 2003*



### THMB Structure

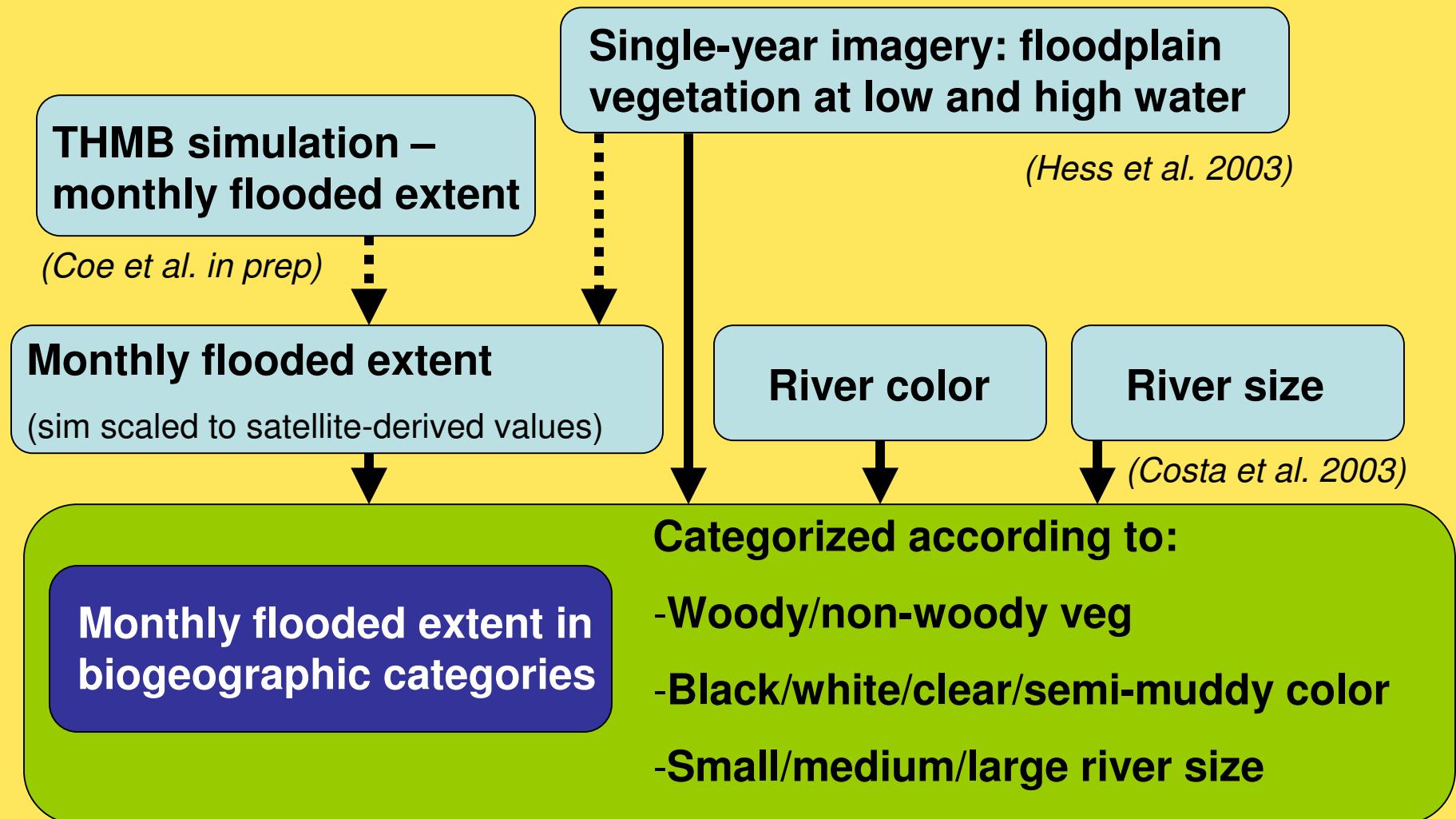


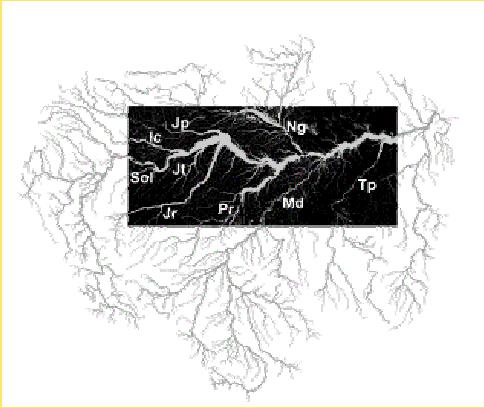
*Coe et al. 2002*

***Model Framework***



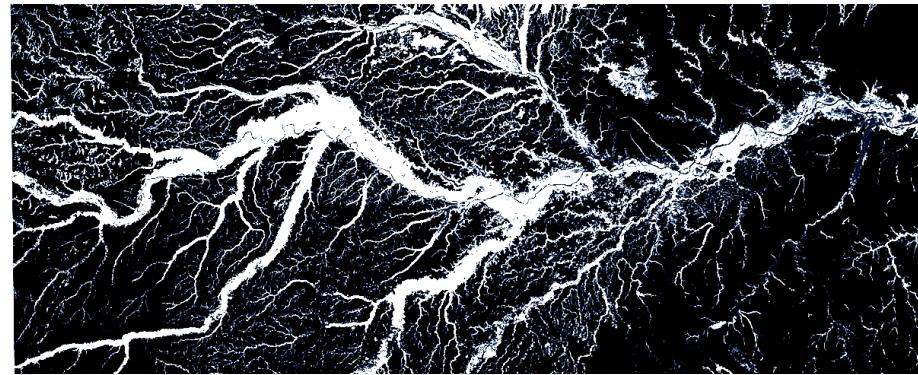
# Deriving wetland biogeographic categories



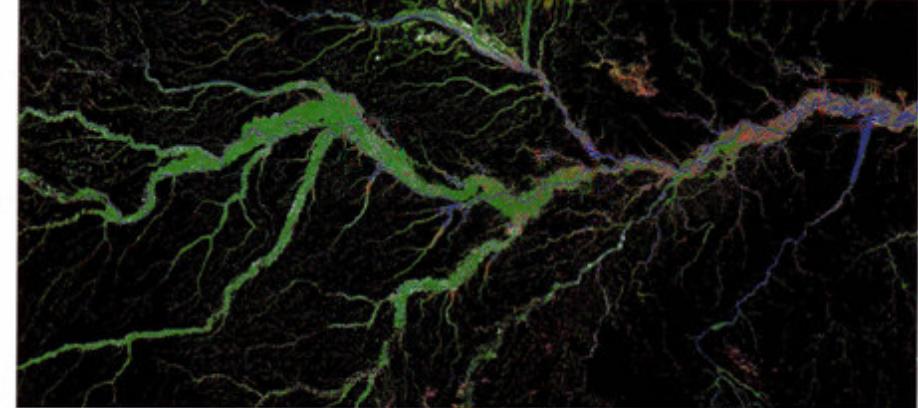


(From Hess et al. 2003)

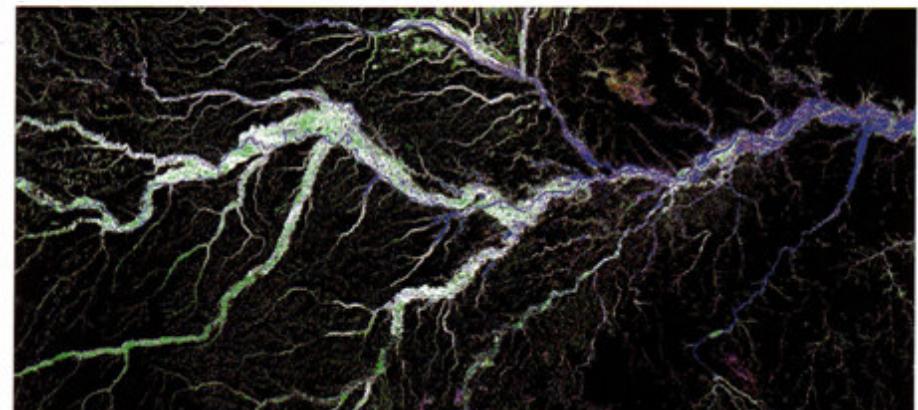
- █ Water
- █ Bare or herbaceous, nonflooded
- █ Herbaceous, flooded
- █ Shrub, nonflooded
- █ Shrub, flooded
- █ Woodland, flooded
- █ Forest, nonflooded
- █ Forest, flooded



**Wetland  
mask**



**Low  
water  
habitats**

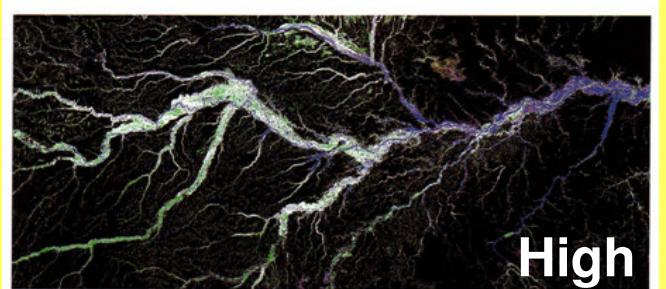
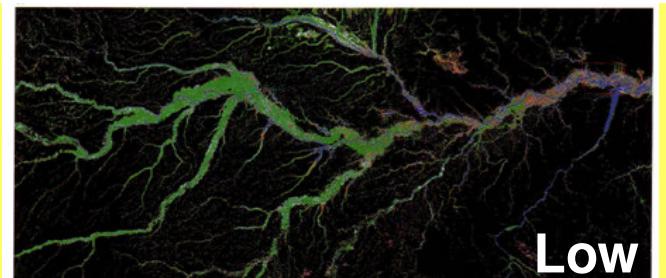


**High  
water  
habitats**

**Monthly  
flooded  
area  
from  
THMB  
1939-1998**

+

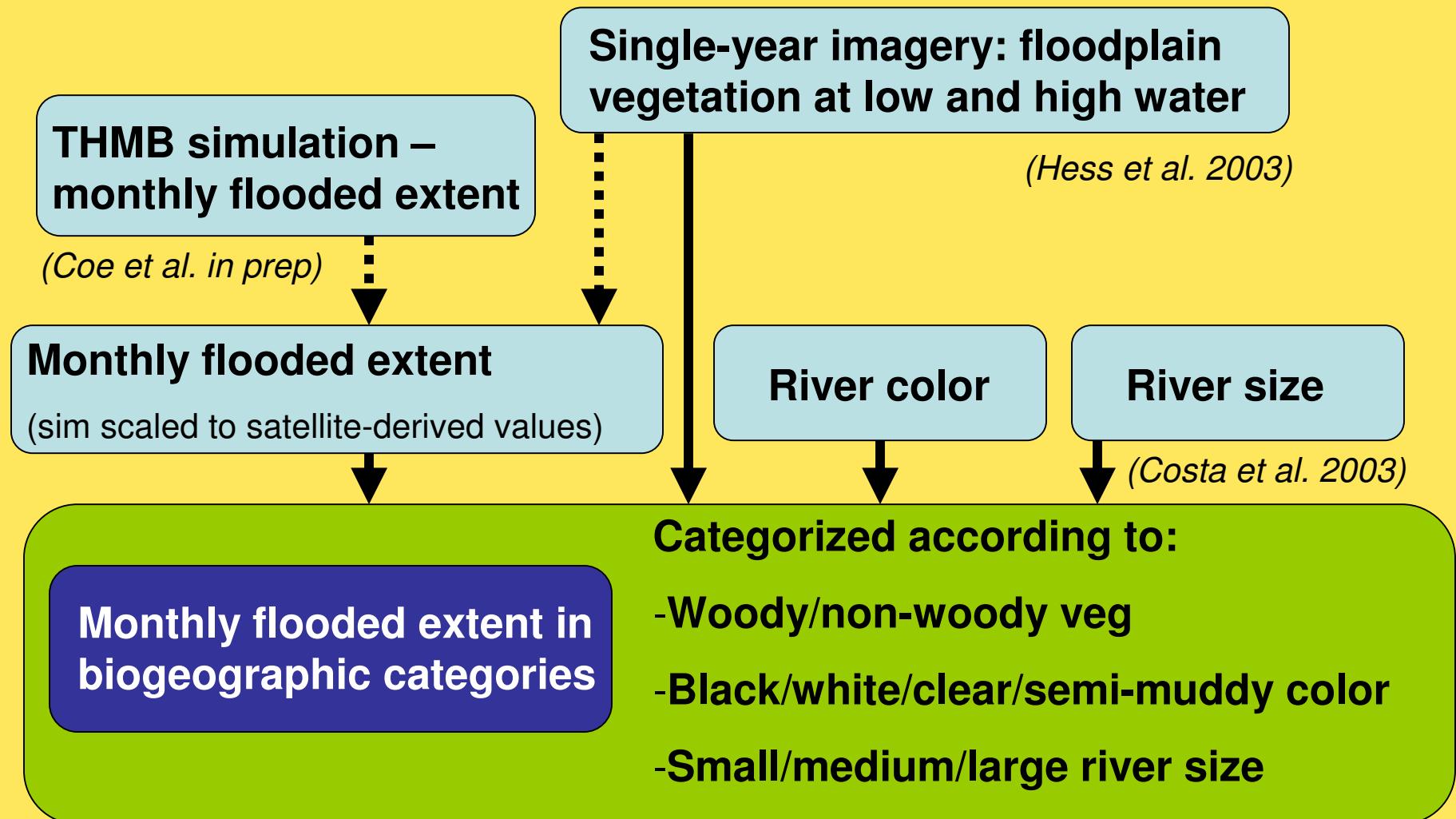
**1995-1996**



=

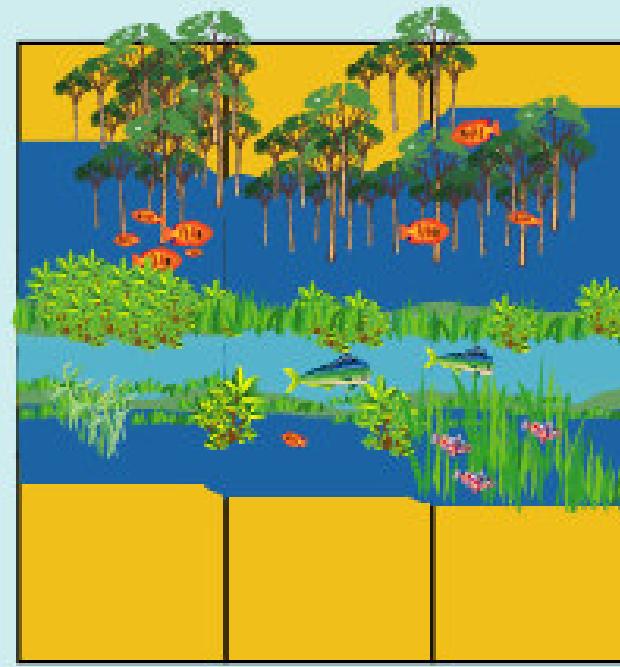
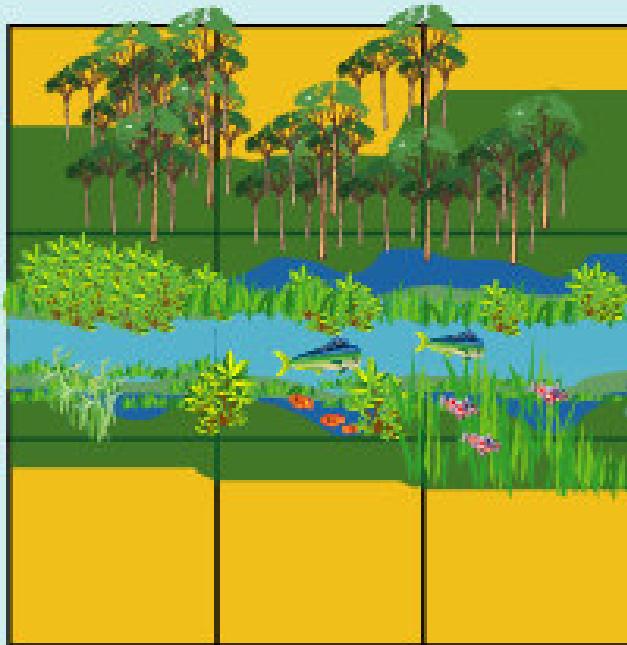
**Calibrated  
monthly  
flooded  
area & area  
of woody,  
non-woody  
vegetation  
1939-1998**

# Deriving wetland biogeographic categories

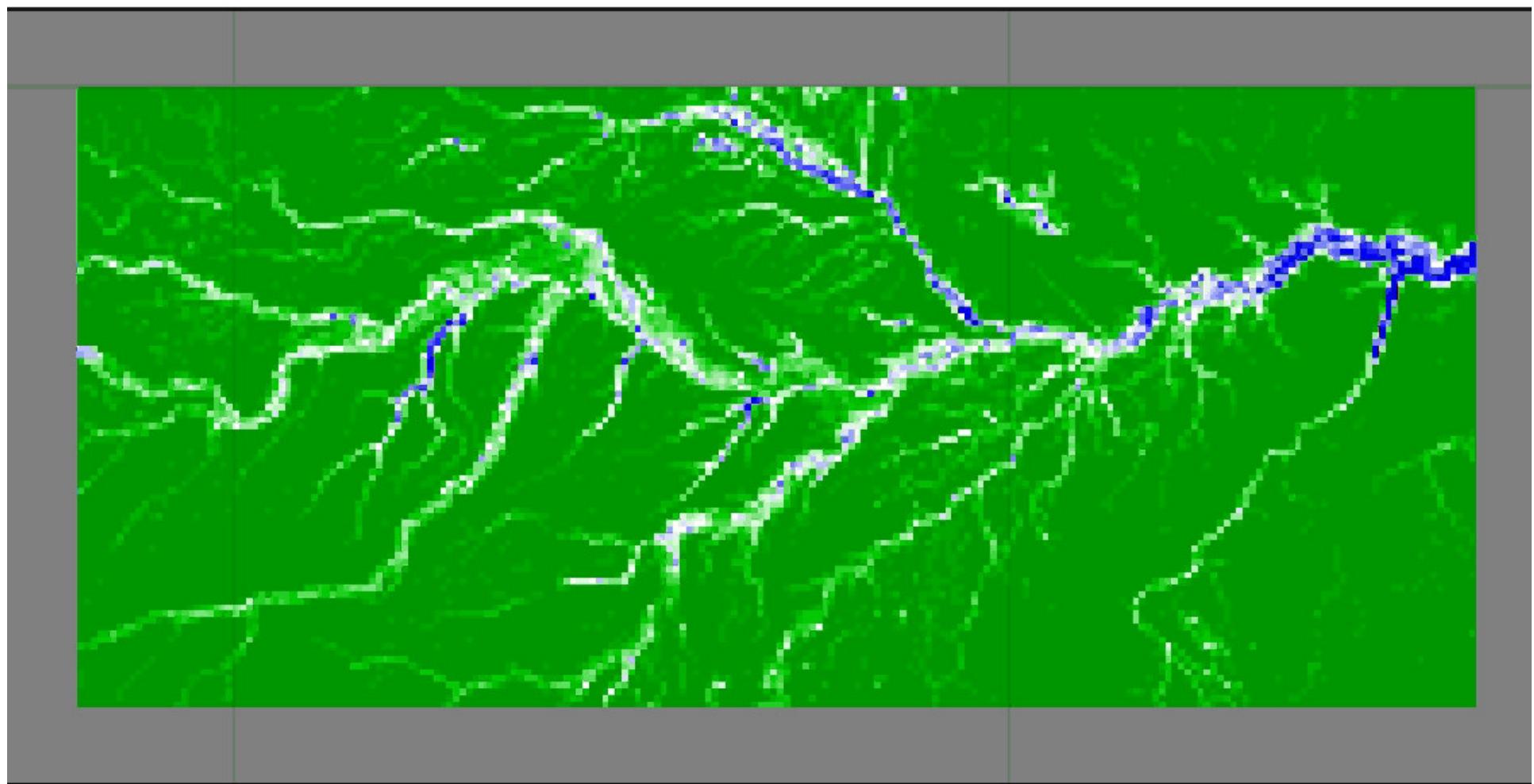


## Driving question

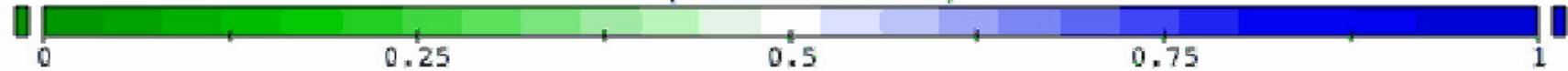
**How do changes in hydrology affect the distributions of different aquatic ecosystems in the Amazon Basin over space and time?**



JANUARY / JANEIRO



- (fraction of 1)



Region bounded by -73.0°E, 1.0°W, -53.0°E, -9.0°W

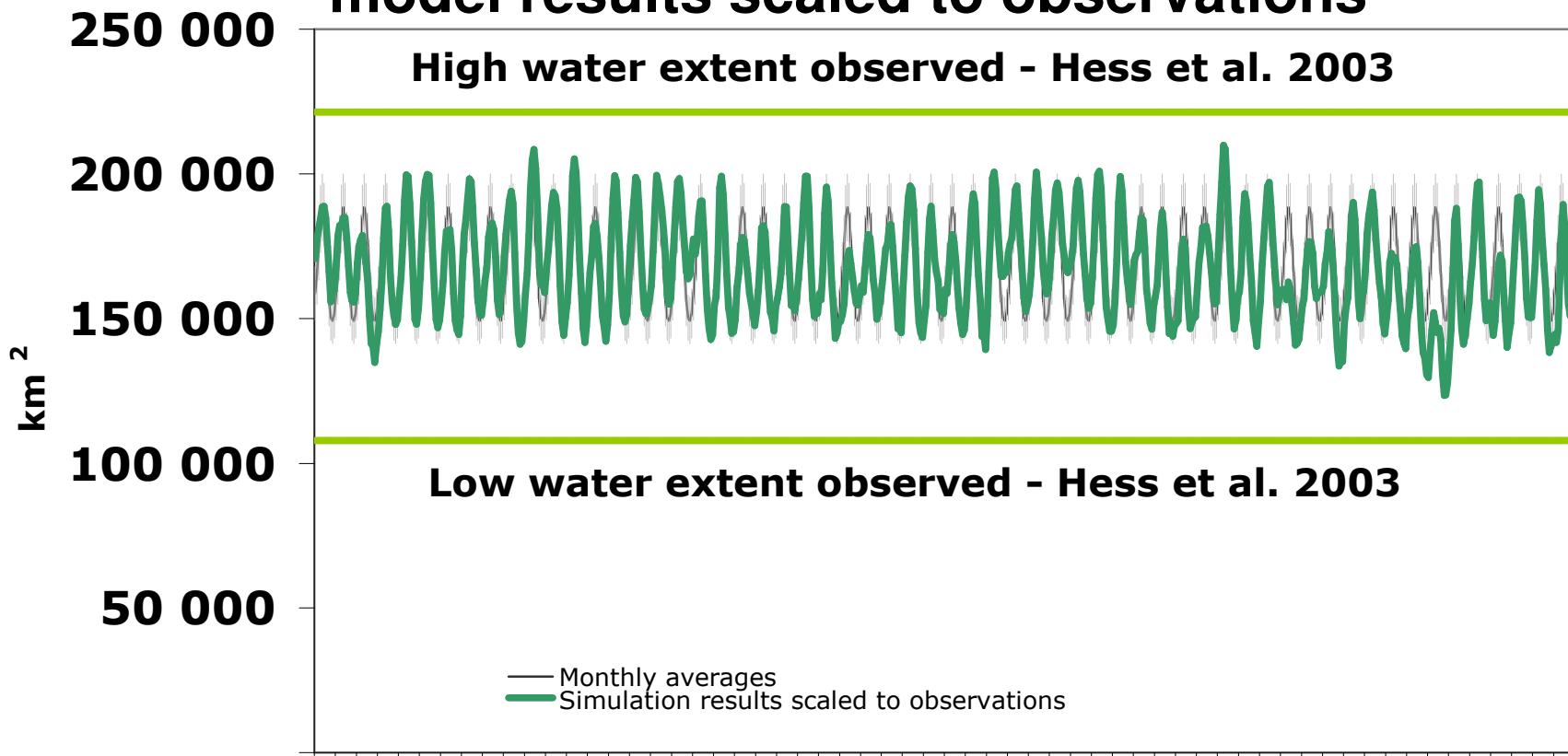
Data Min = 0, Max

**All flooded ecosystems**

- 17 -

**Model Results**

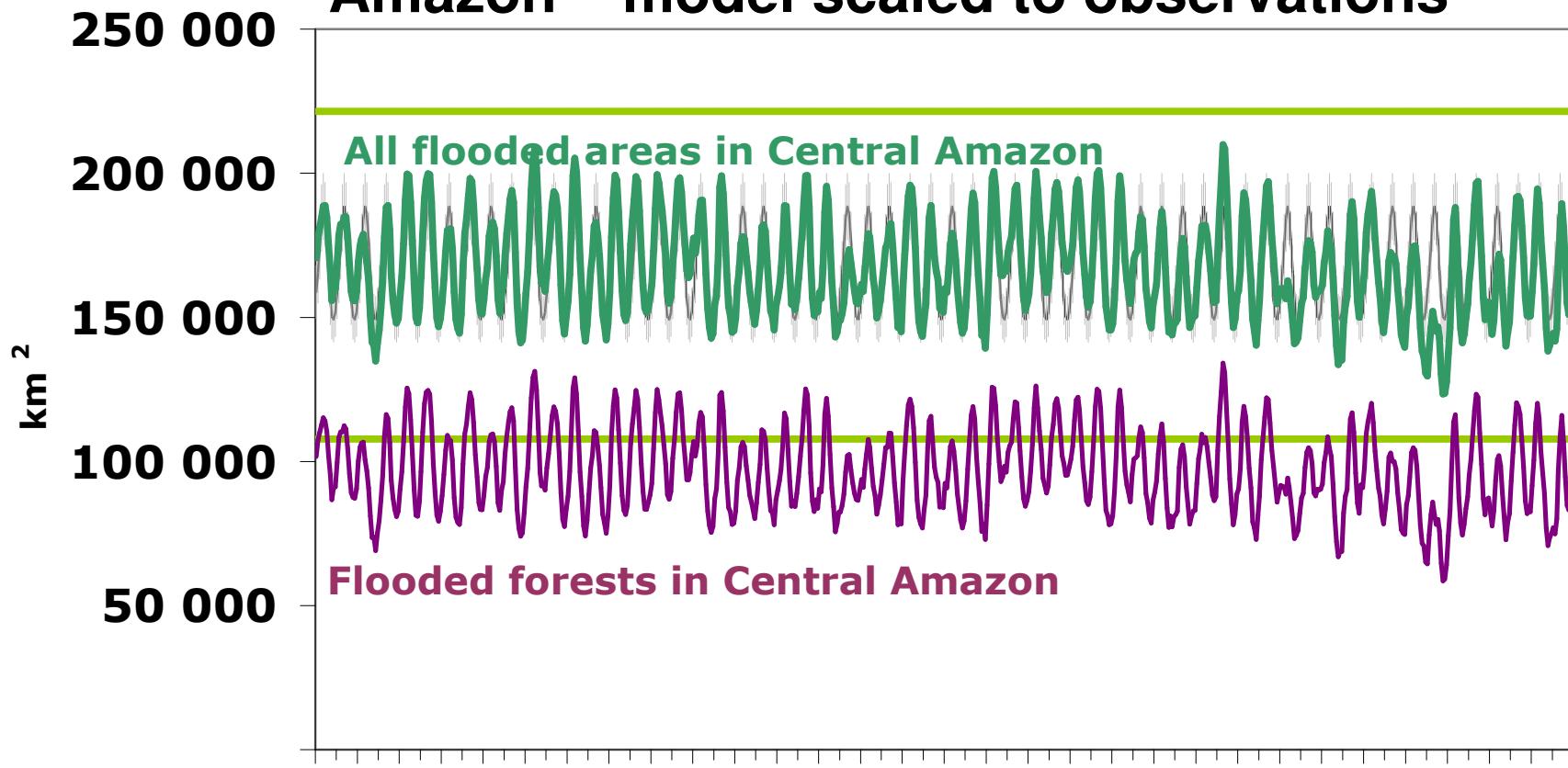
# Annual flooded area in Central Amazon – model results scaled to observations



1939  
1941  
1943  
1945  
1947  
1949  
1951  
1953  
1955  
1957  
1959  
1961  
1963  
1965  
1967  
1969  
1971  
1973  
1975  
1977  
1979  
1981  
1983  
1985  
1987  
1989  
1991  
1993  
1995  
1997

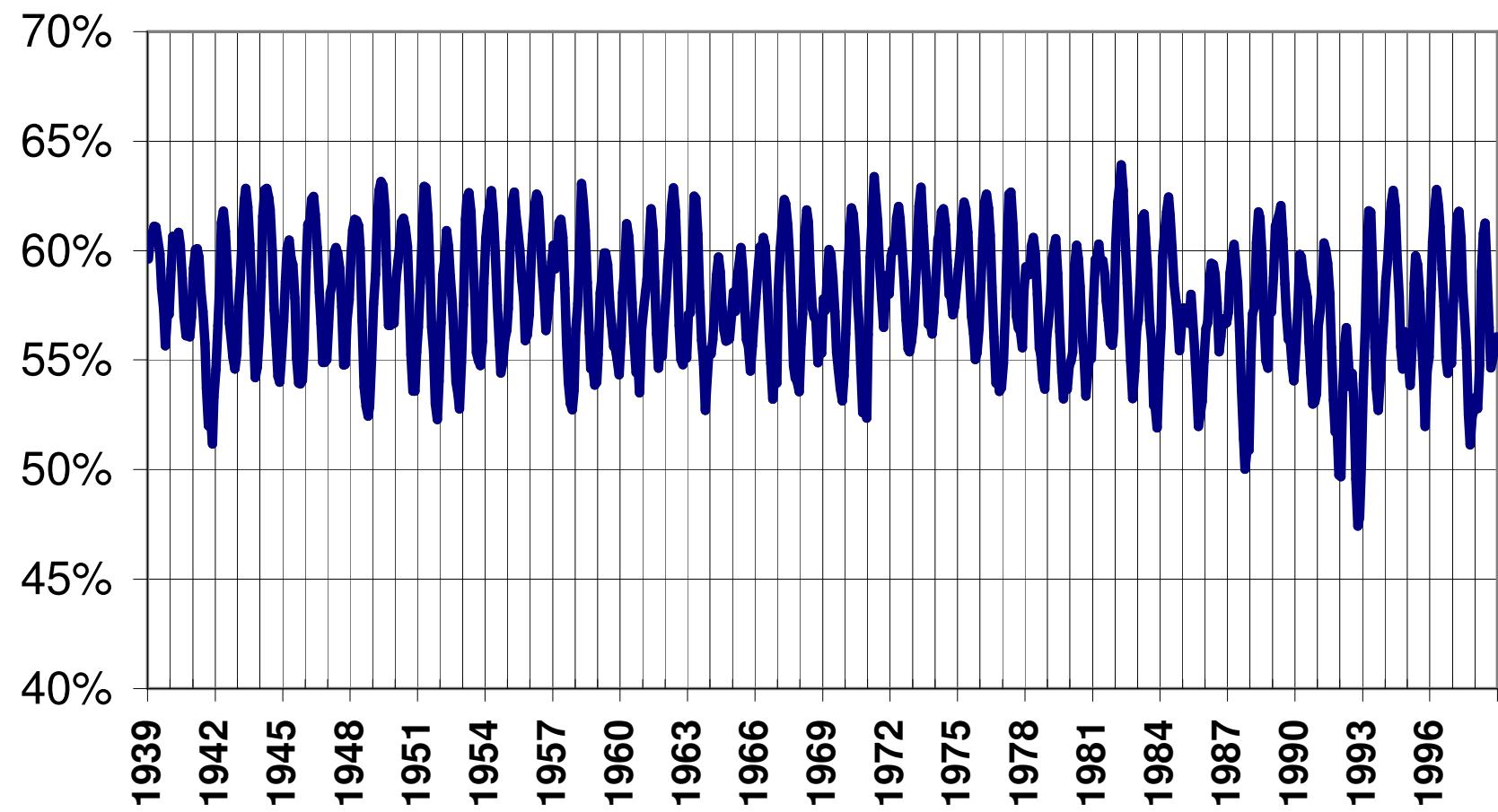
***Model Results***

## Annual flooded FOREST area in Central Amazon – model scaled to observations



**Model Results**

## Ratio of flooded forests to all flooded lands

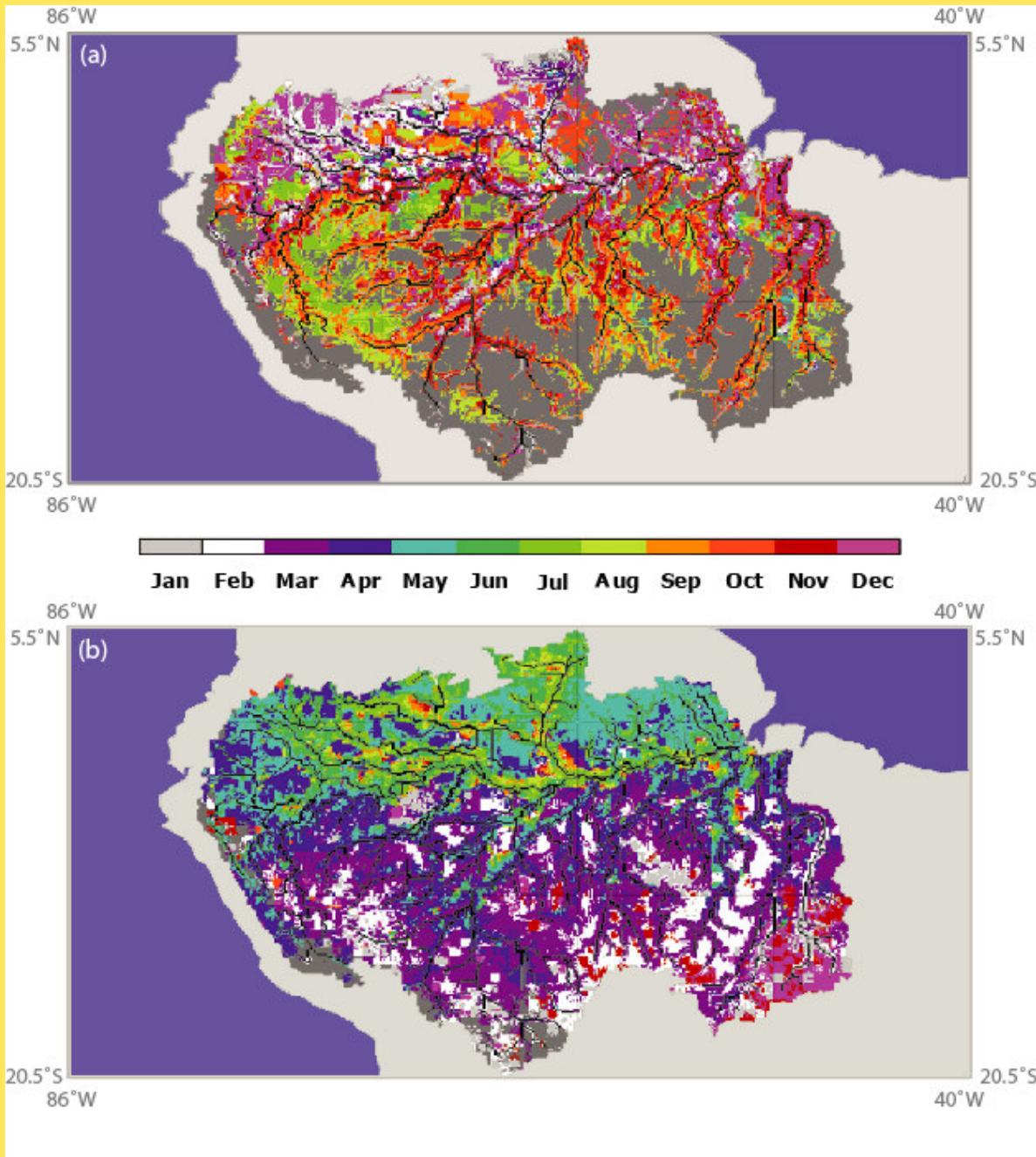


**When  
is low  
water**

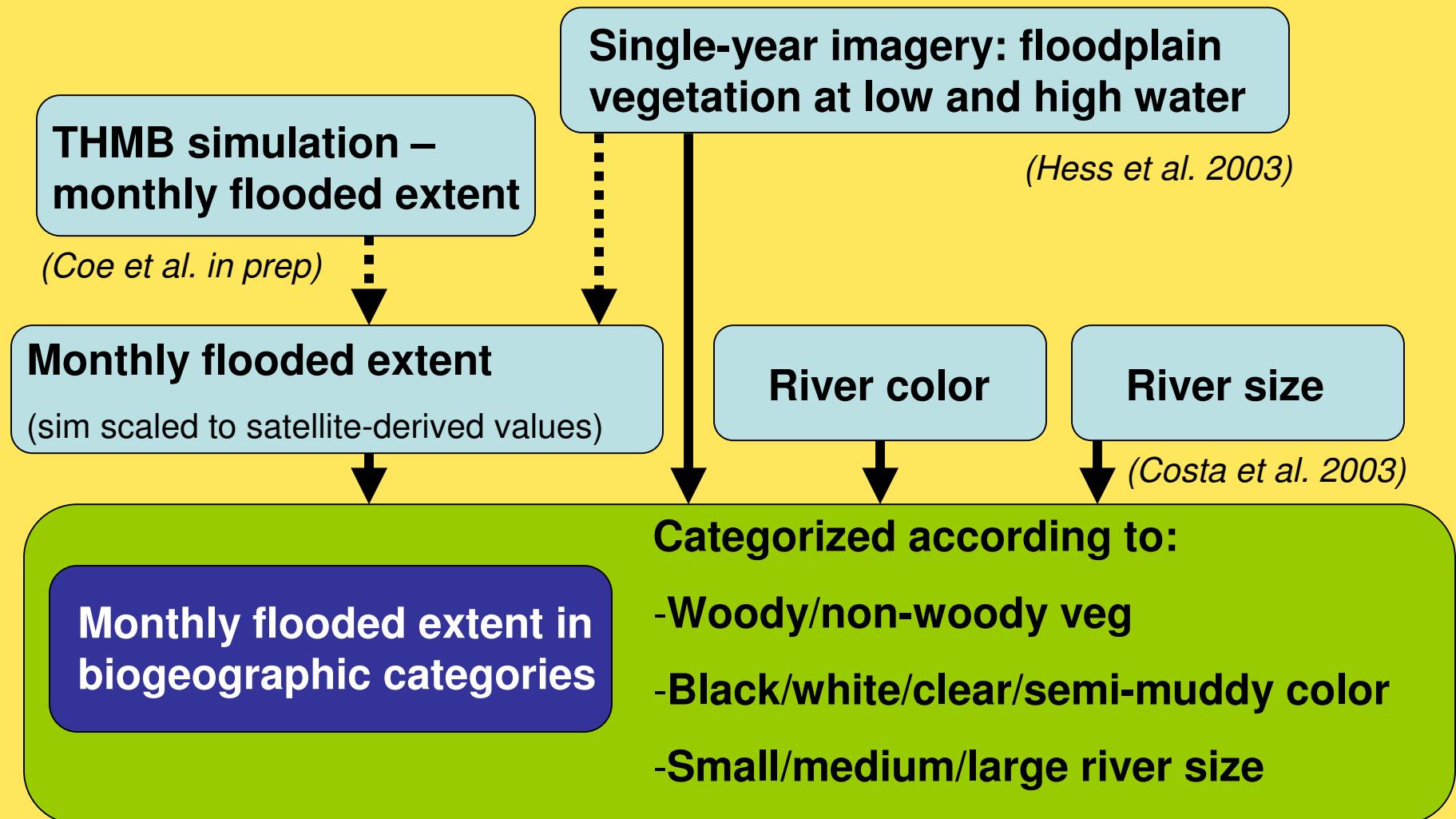
?

**When  
is high  
water**

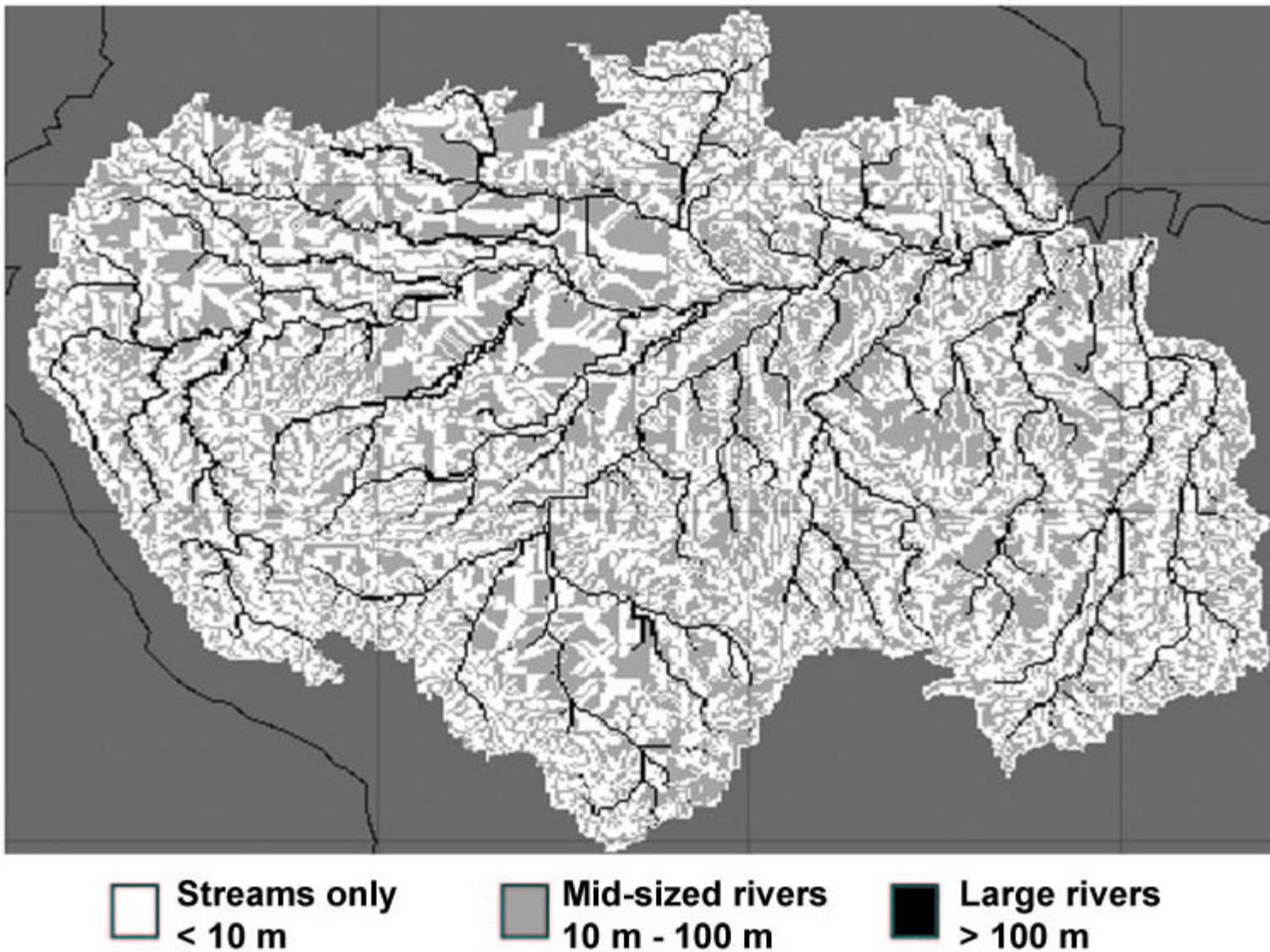
?



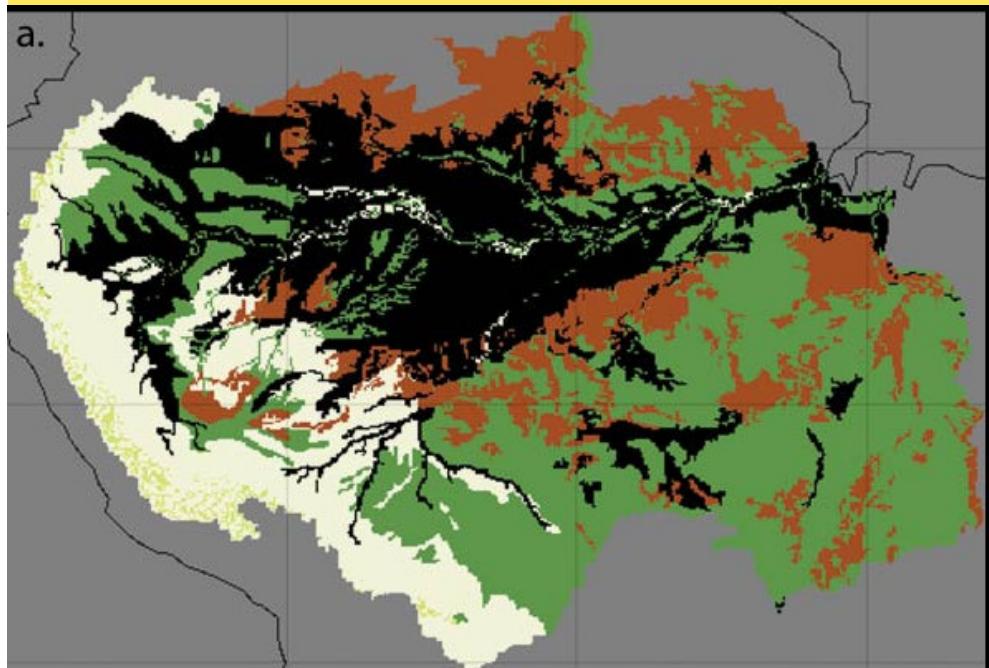
# Deriving wetland biogeographic categories



# River size

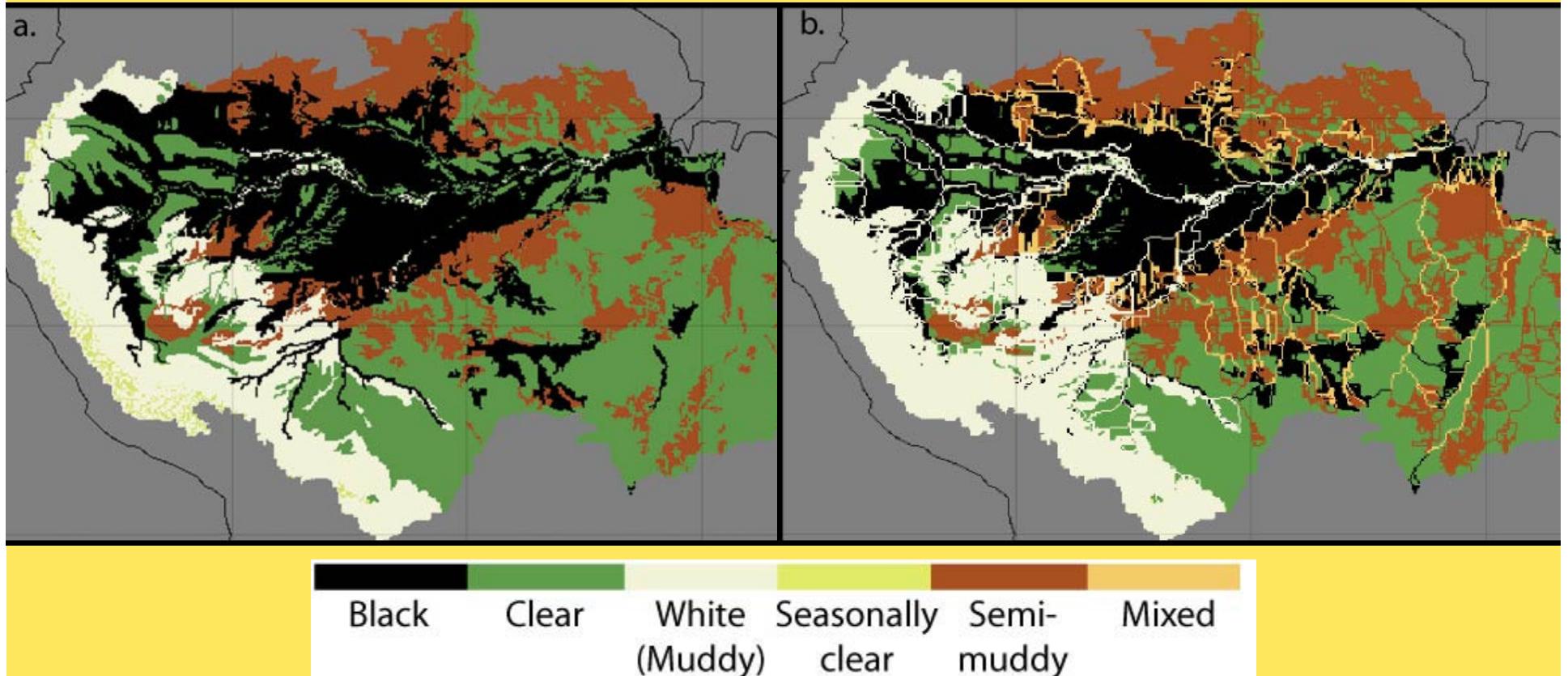


# River color



Black	Clear	White (Muddy)	Seasonally clear	Semi- muddy	Mixed
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# River color



# Amazon Basin biogeography

Small

Medium

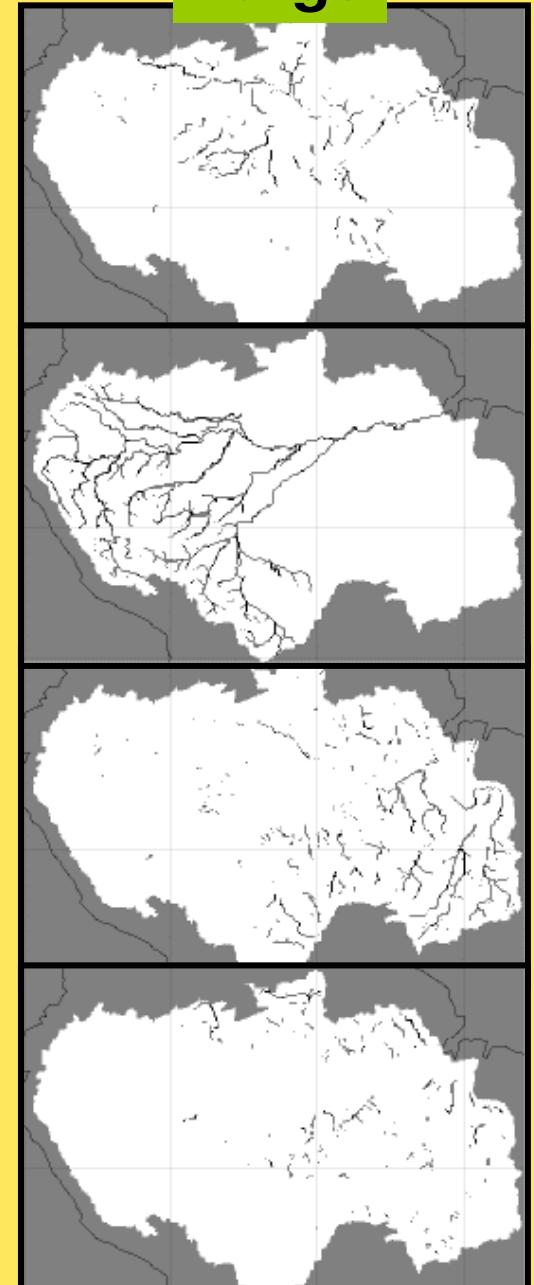
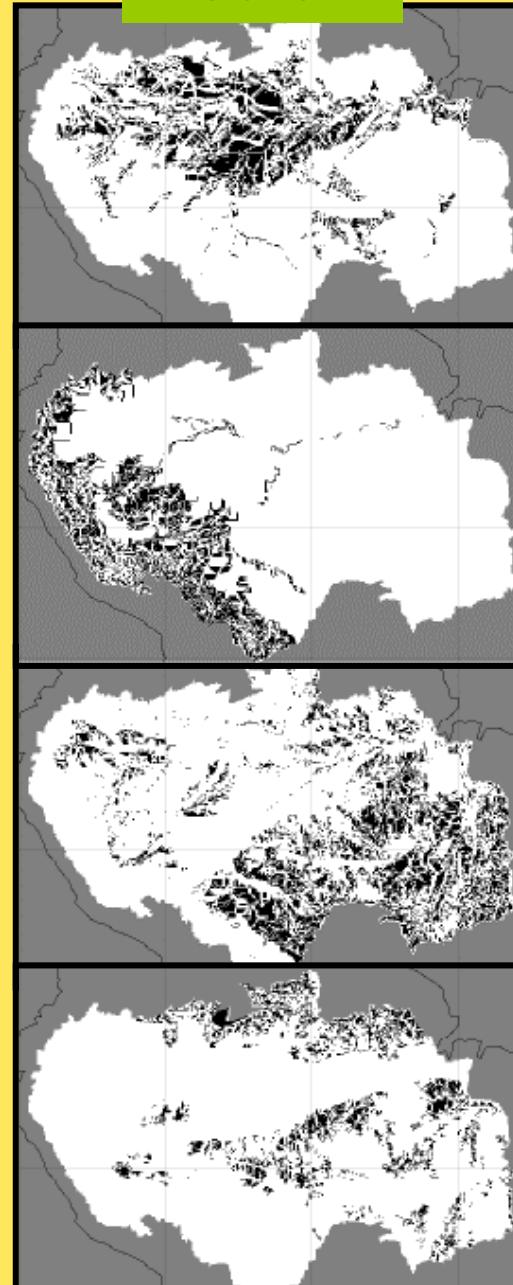
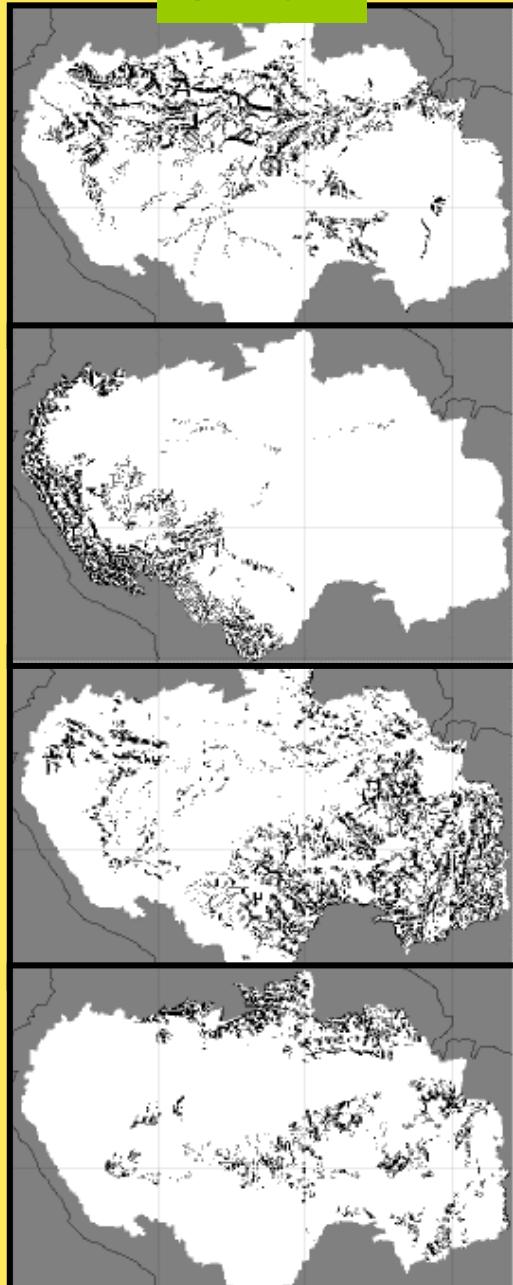
Large

Black

White

Clear

Semi-muddy



# Seasonally flooded, woody vegetation

**Small**

**Medium**

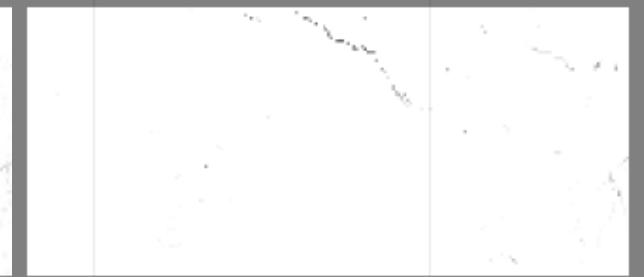
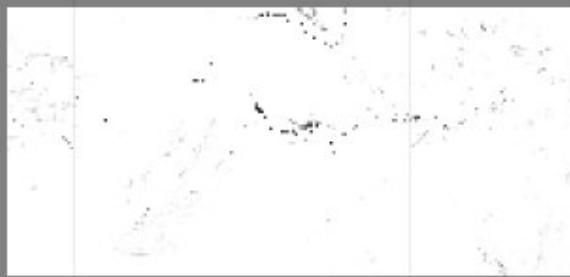
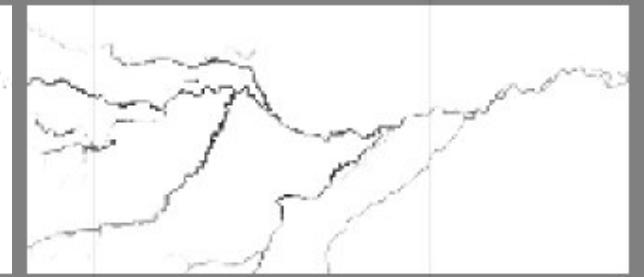
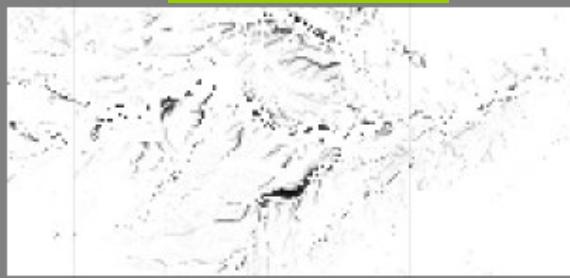
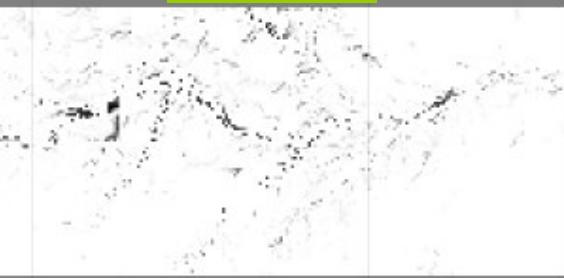
**Large**

**Black**

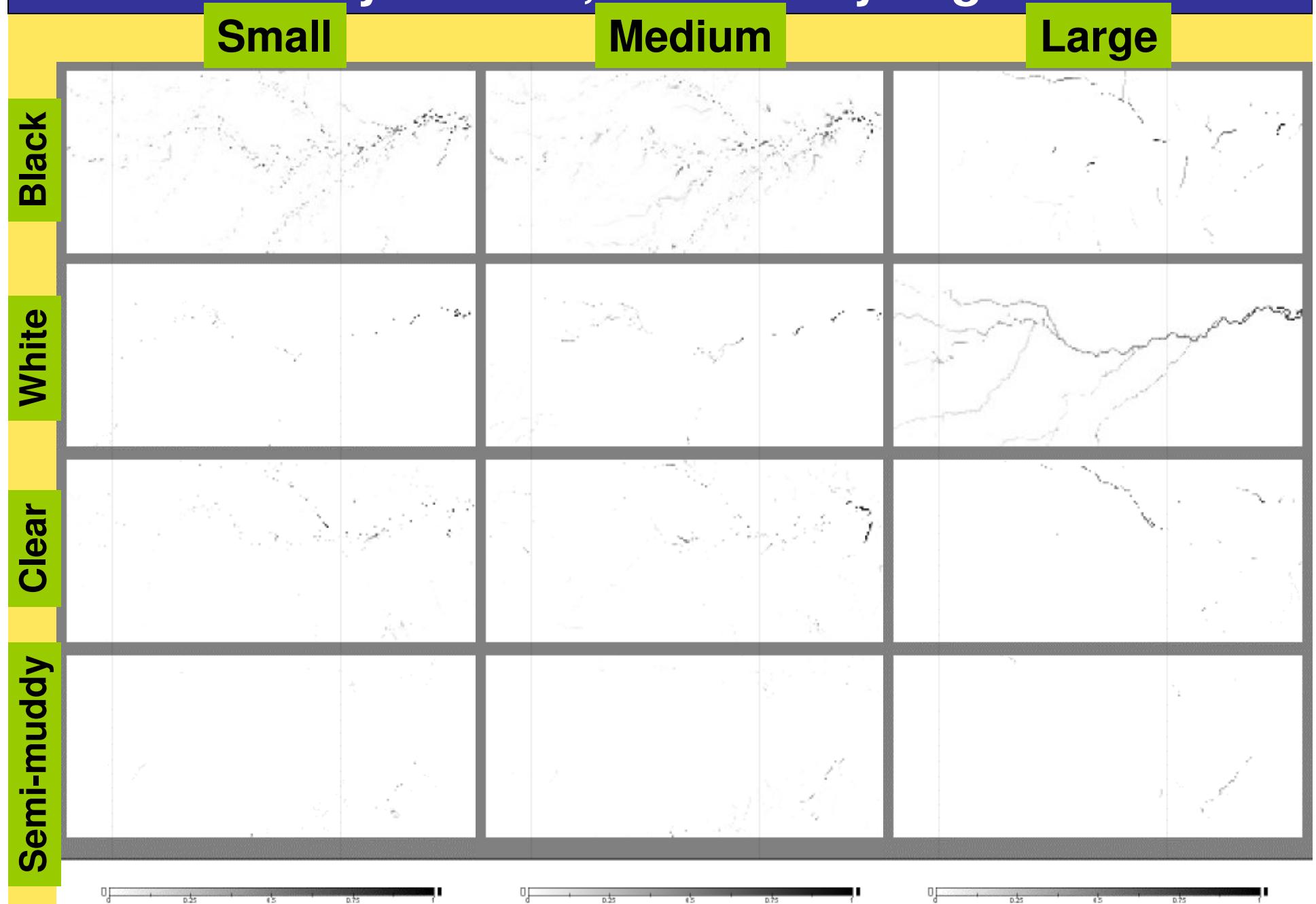
**White**

**Clear**

**Semi-muddy**



# Seasonally flooded, non-woody vegetation



# Potentially floodable, woody vegetation

**Small**

**Medium**

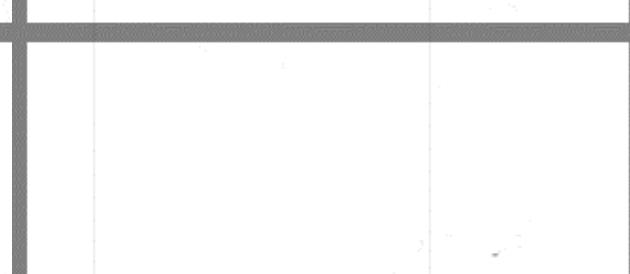
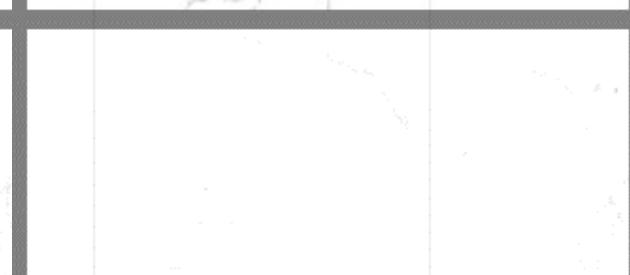
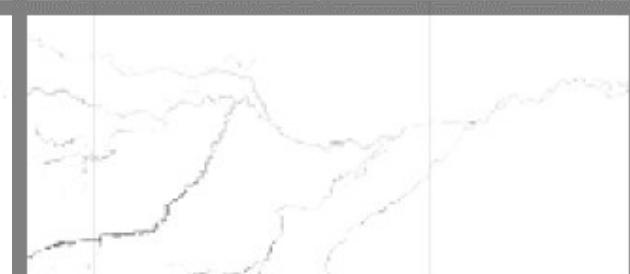
**Large**

**Black**

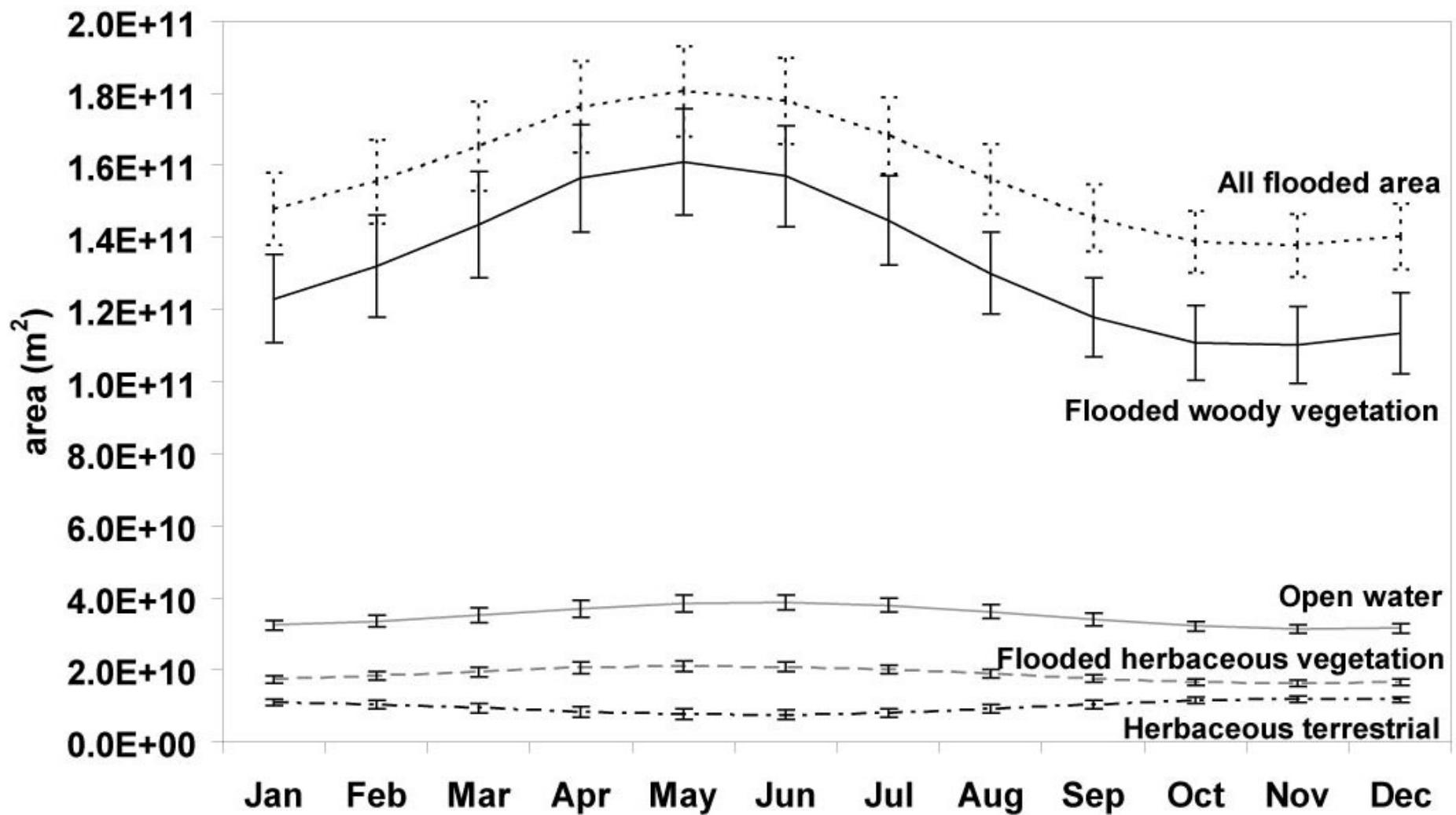
**White**

**Clear**

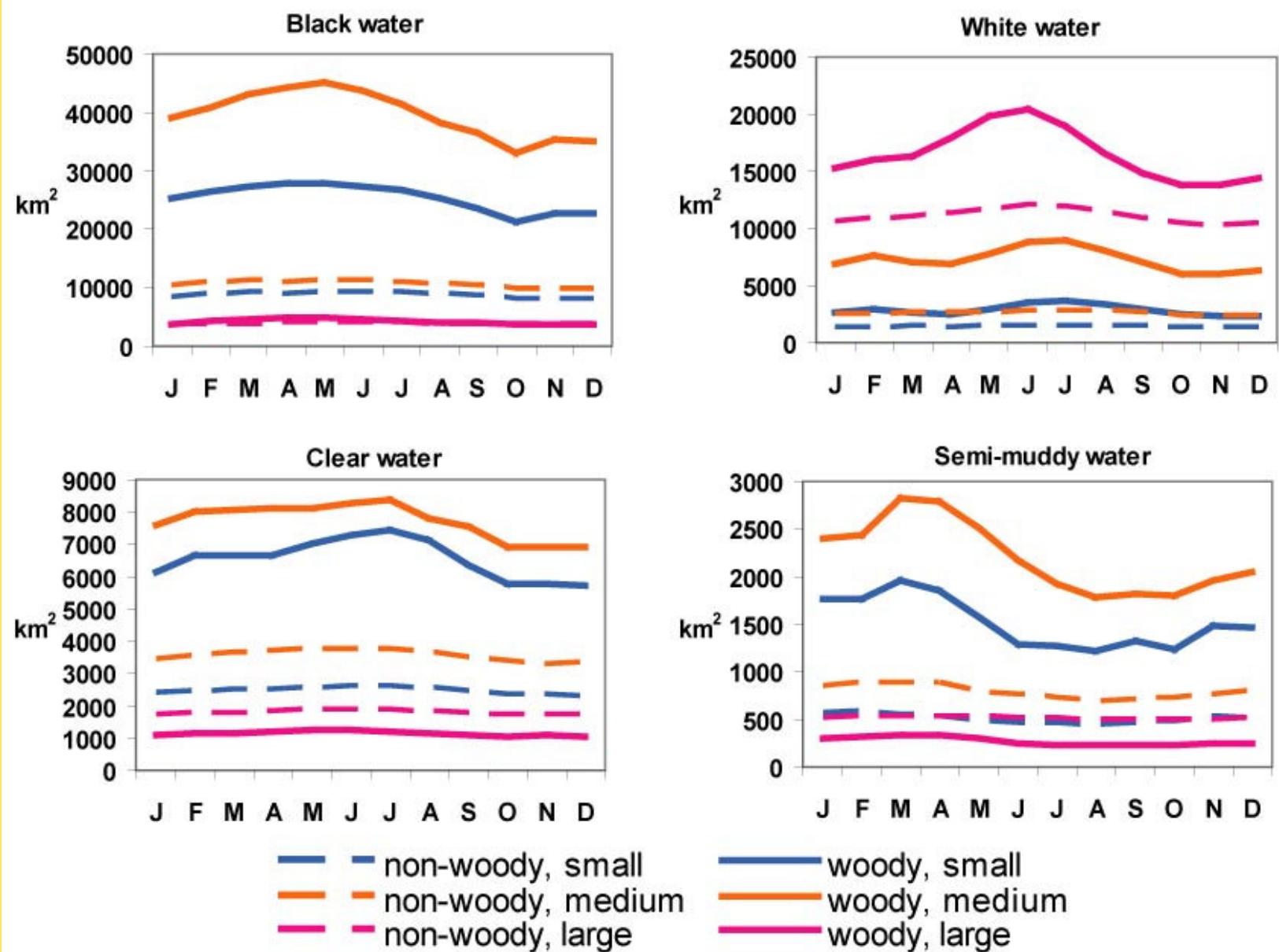
**Semi-muddy**



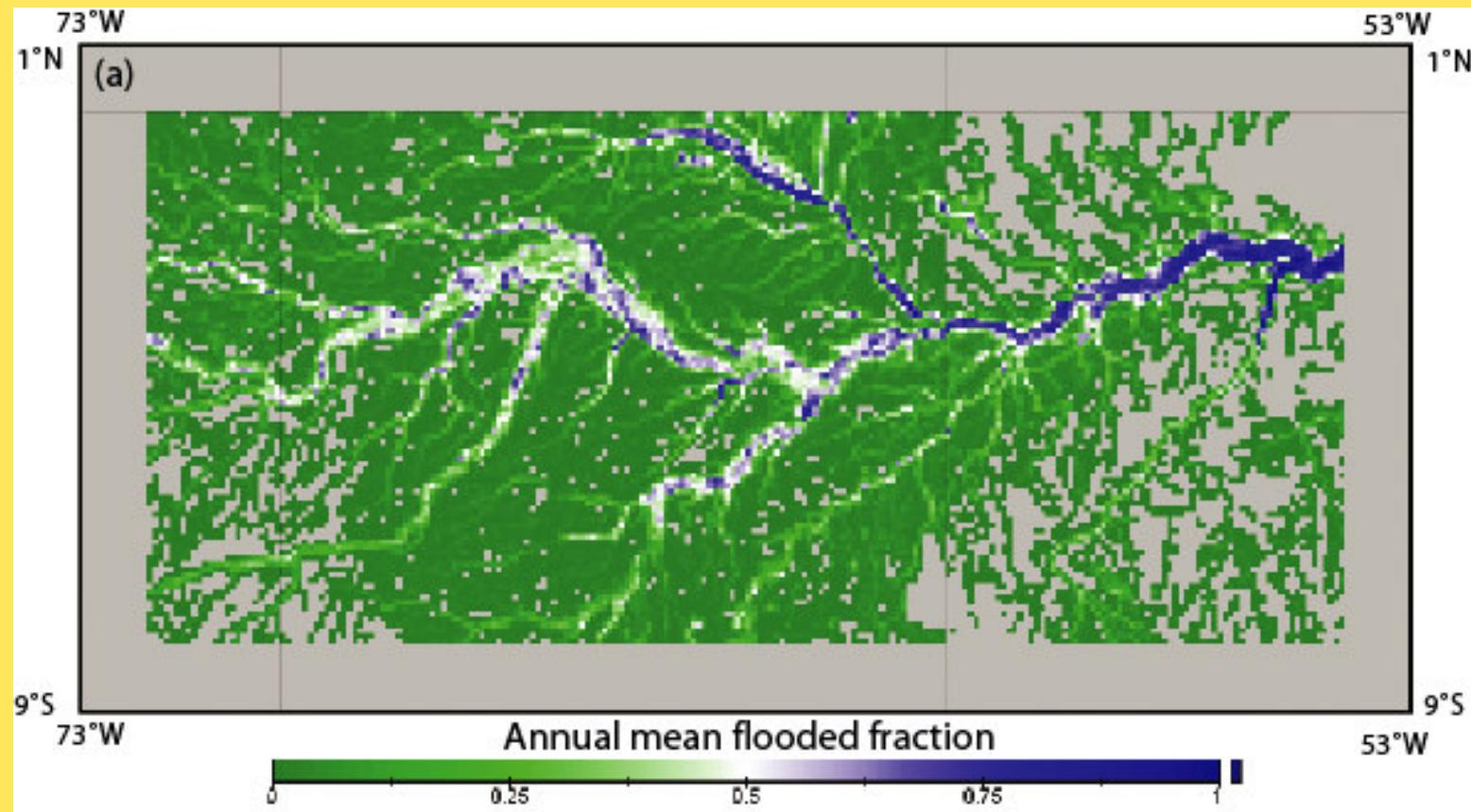
# Flooding seasonality



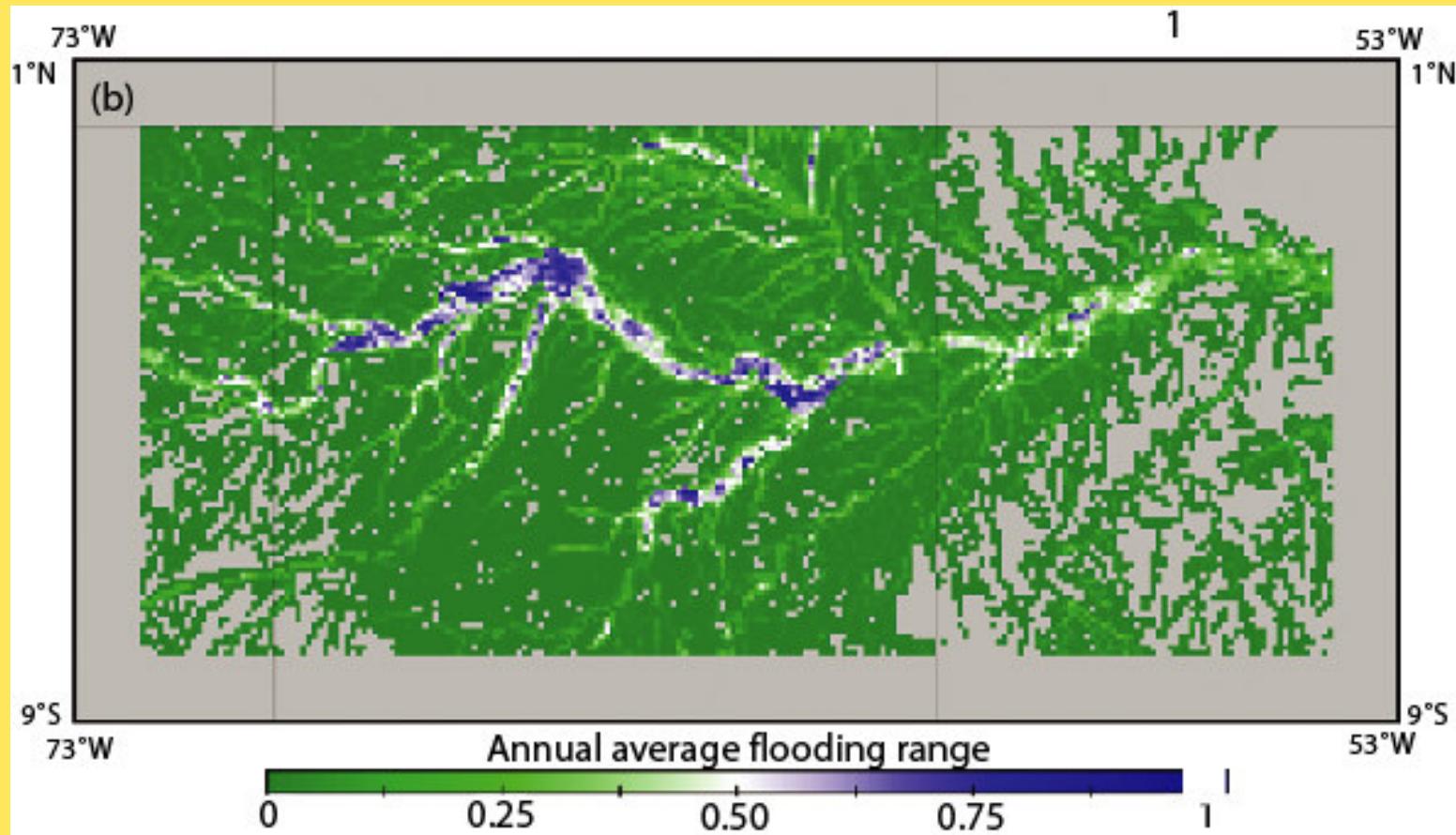
# Flooding seasonality



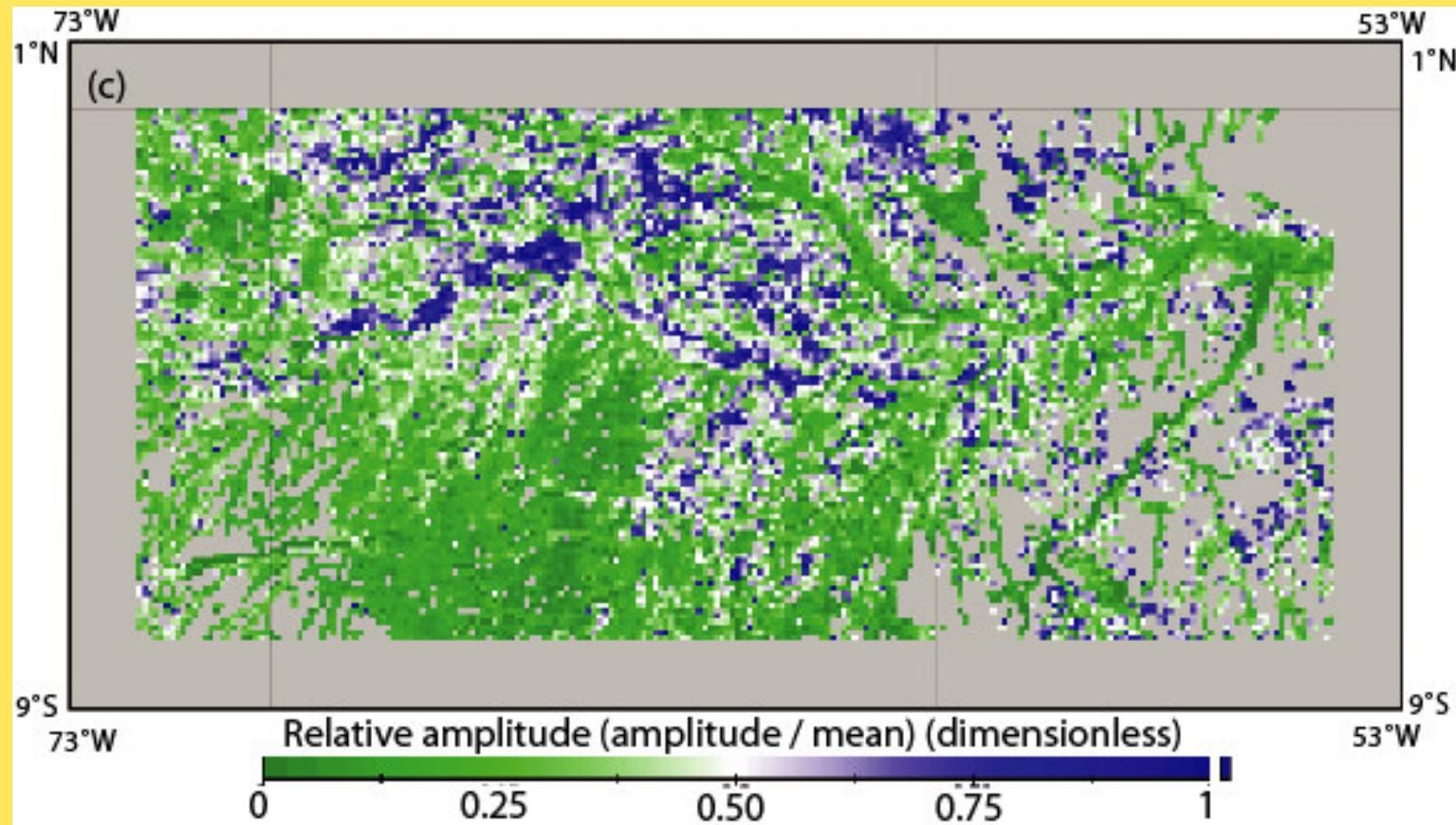
# Annual mean flooding



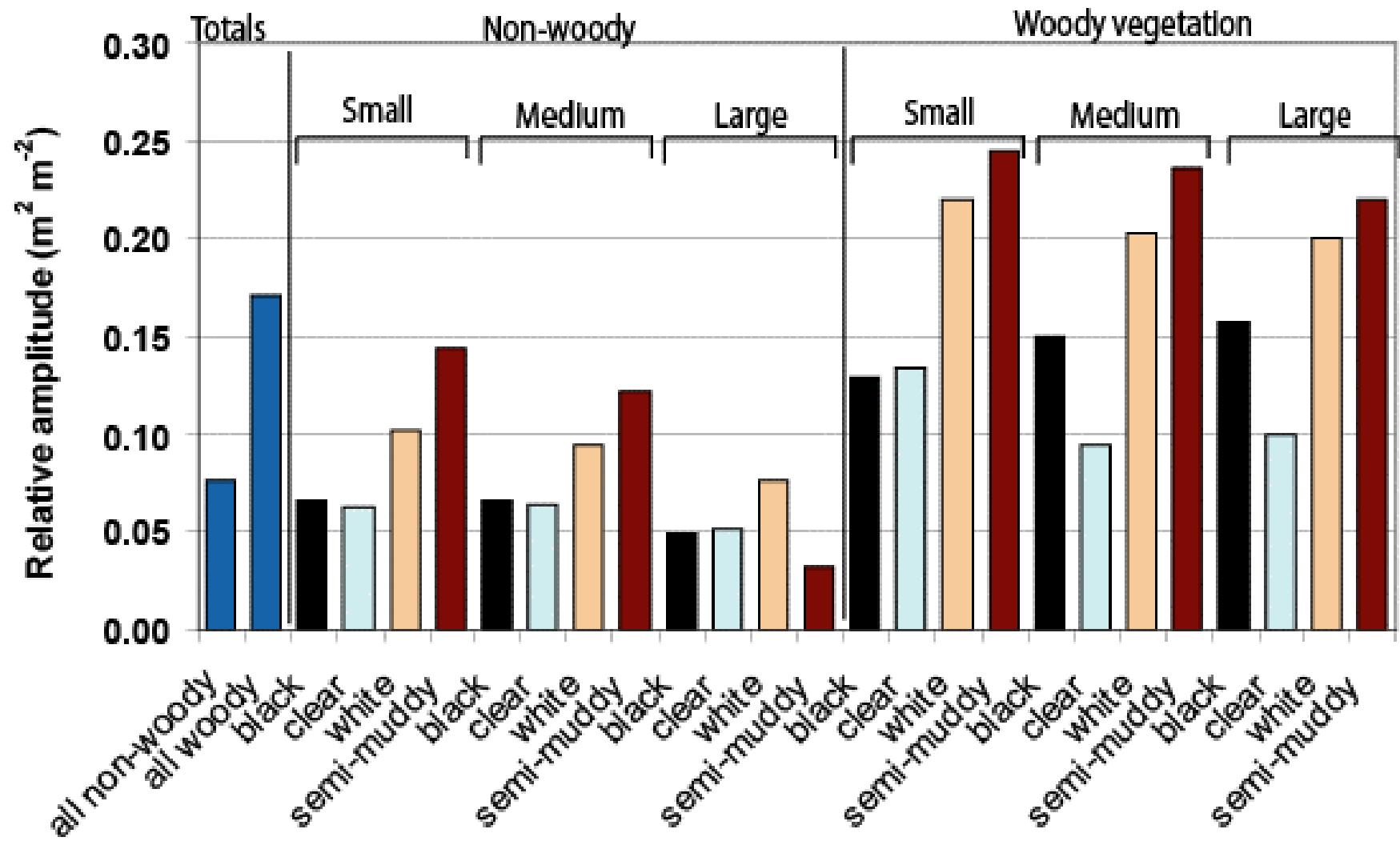
# Annual range of flooding



# Seasonal sensitivity to flooding



# Seasonal sensitivity to flooding



# Conclusions

- Quantifies variability in wetland ecosystem extent
- Great seasonal and inter-annual variability in flood extent and timing
- Regional flooding variability may have disproportionate effects on different ecosystem types (e.g., woody vs. non-woody)

*Persistent changes to flooding regimes may have long-lasting consequences for floodplain vegetation, carbon cycling, wildlife, and human residents.*

# What does this mean for Amazonians?



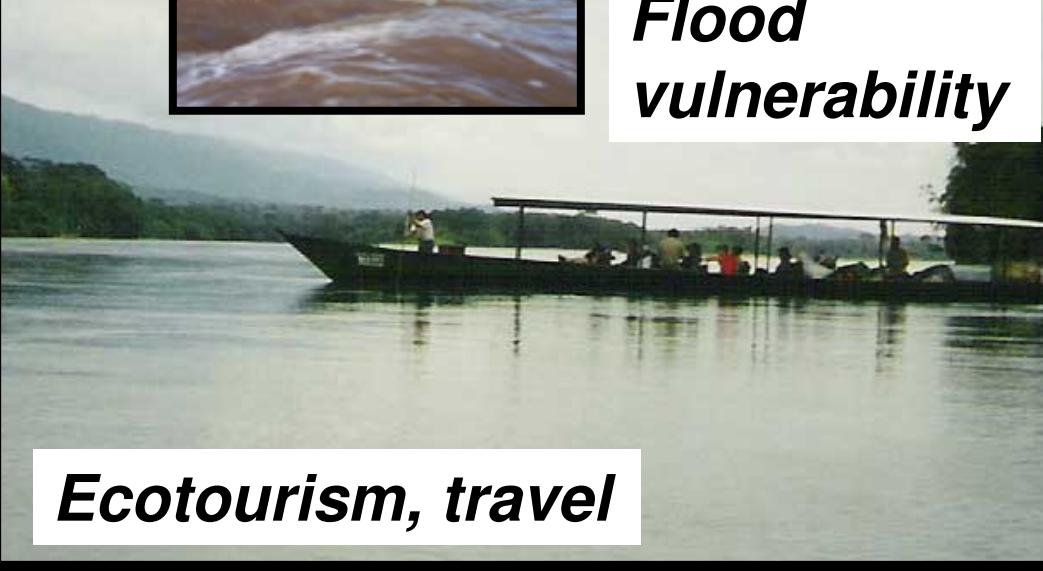
***Commerce***



***Fisheries***



***Flood vulnerability***



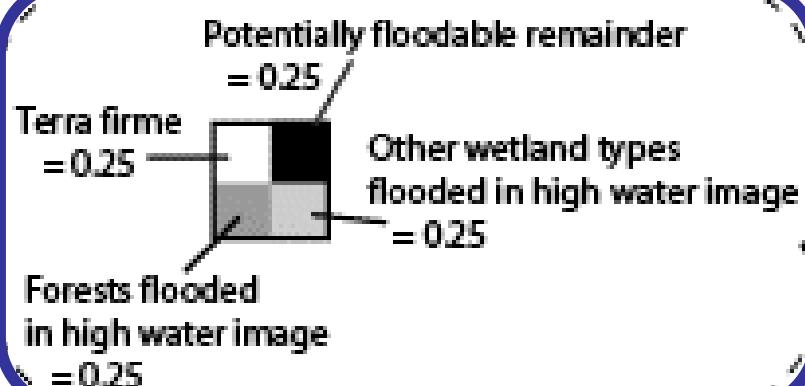
***Ecotourism, travel***

*Thank you!!*

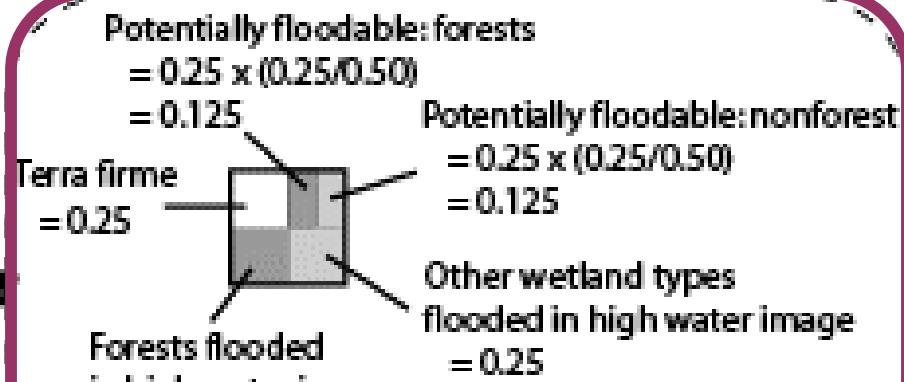
**[eahoward@wisc.edu](mailto:eahoward@wisc.edu)**



*On the Rio Tapajos, an Amazon tributary*



### Visual schematic: method for scaling simulated flooded forest fraction to observations:



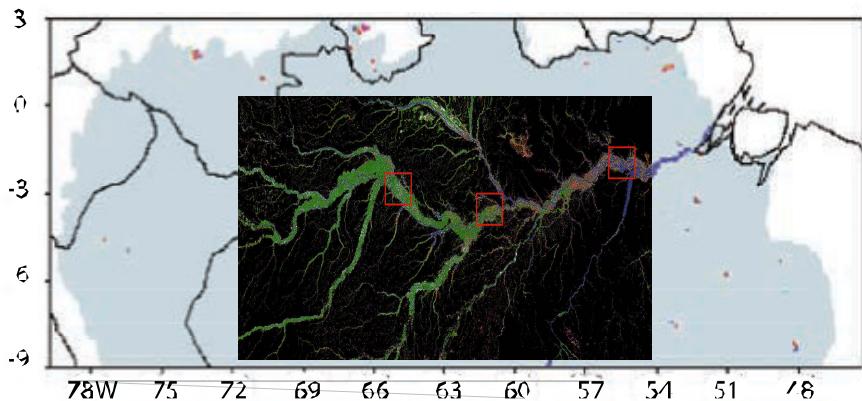
$$\text{Simulated maximum extent of flooded forests} = \left[ (\text{Potentially floodable remainder}) \times \left( \frac{\text{Ratio of observed flooded forest to total observed flooded fraction at high water}}{\text{observed flooded forest fraction at high water}} \right) \right] + \text{(observed flooded forest fraction at high water)}$$

# Model / Satellite Comparison

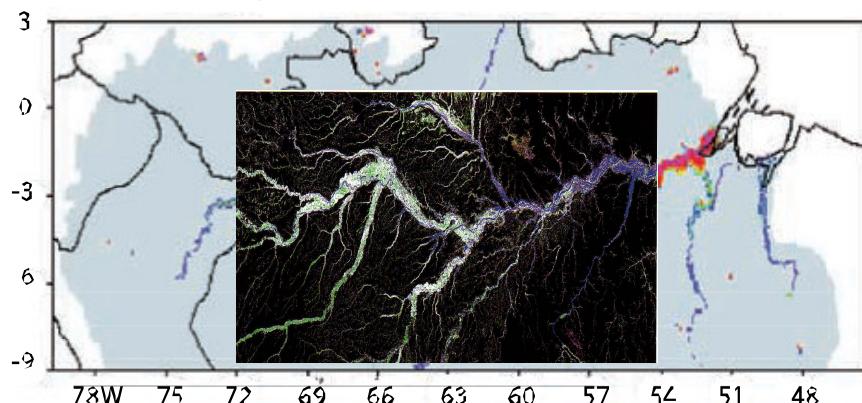
# Model / Satellite Comparison

Hess *et al.* 2003

Low water - 1995-1996



High water - 1995-1996



Water  
Bare or herbaceous, nonflooded  
Herbaceous, flooded  
Shrub, nonflooded

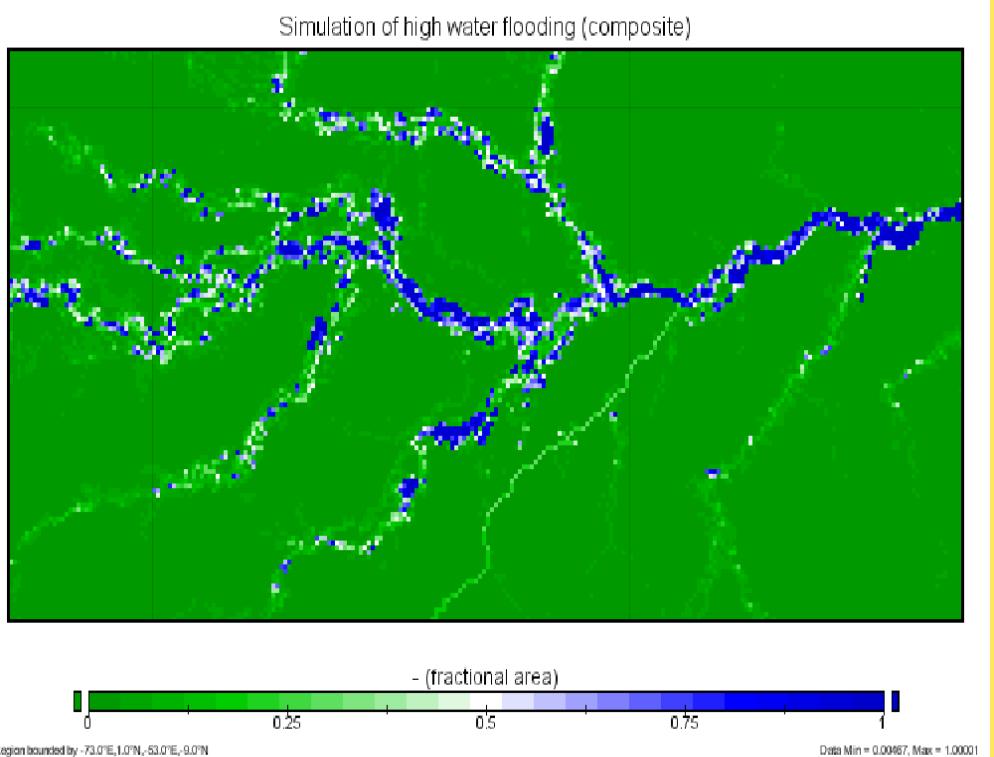
Shrub, flooded  
Woodland, flooded  
Forest, nonflooded  
Forest, flooded

Composite images:

- Low & high water only
- 1995 & 1996
- Central Amazon only

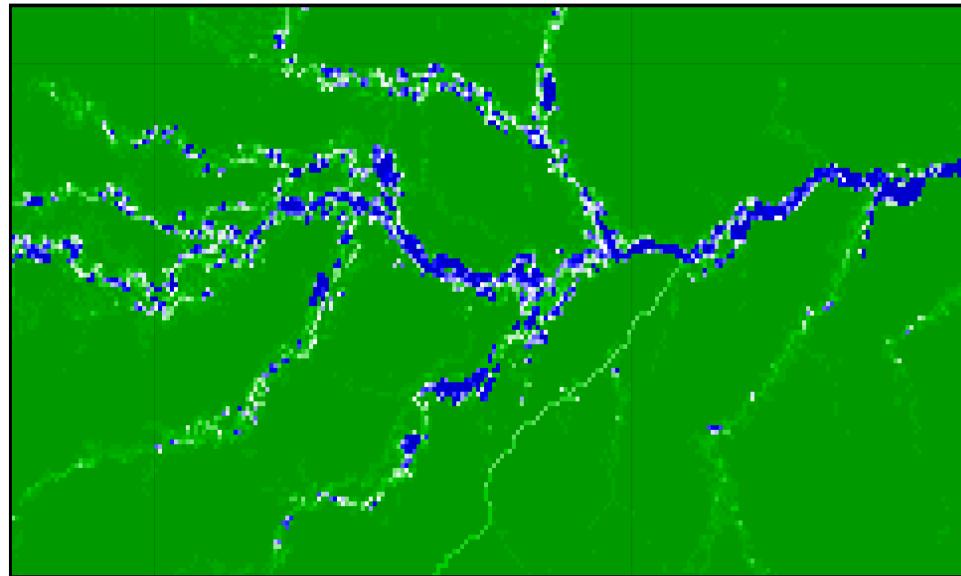
Identified wetland pixels:

- Fine scale: 3 arc-sec
- Classified by habitat type
- Validated against other remote sensing and ground meas'ts

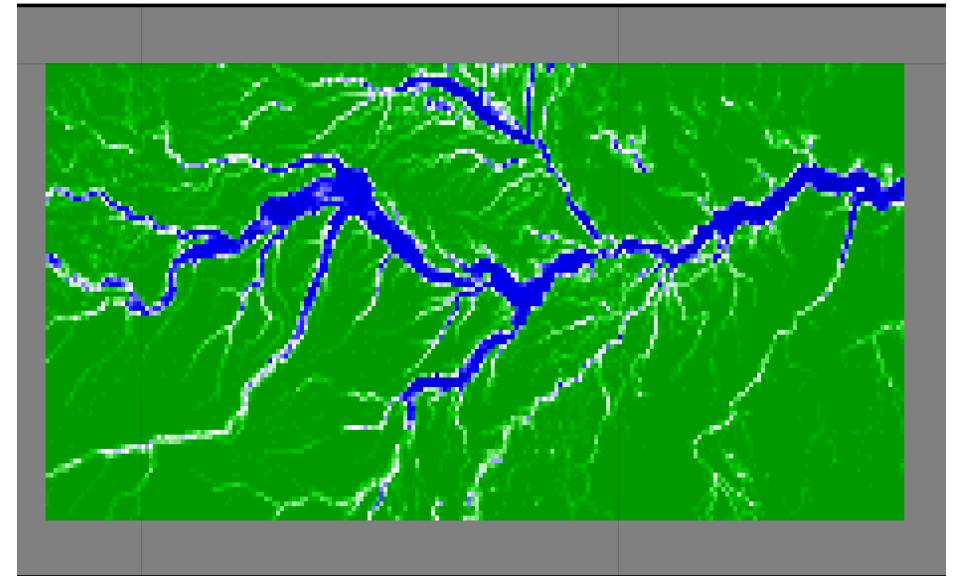


High  
water

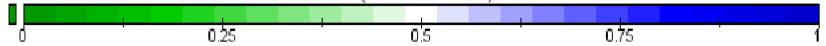
Simulation of high water flooding (composite)



High water composite - All flooded ecosystem types



- (fractional area)



Region bounded by -73.0°E, 1.0°N, -53.0°E, 9.0°N

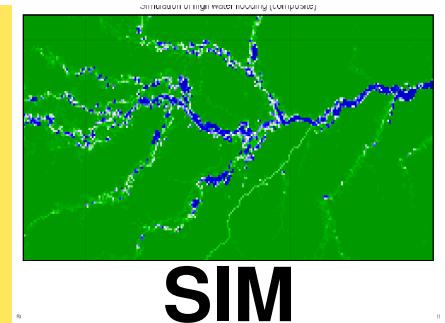
- (fractional\_flooded\_area)



Data Min = 0, Max = 1  
Region bounded by -73.0°E, 1.0°N, -53.0°E, 9.0°N

**Correlation in flooding pattern:  $r = 0.54$**   
**% difference in area flooded = -26%**

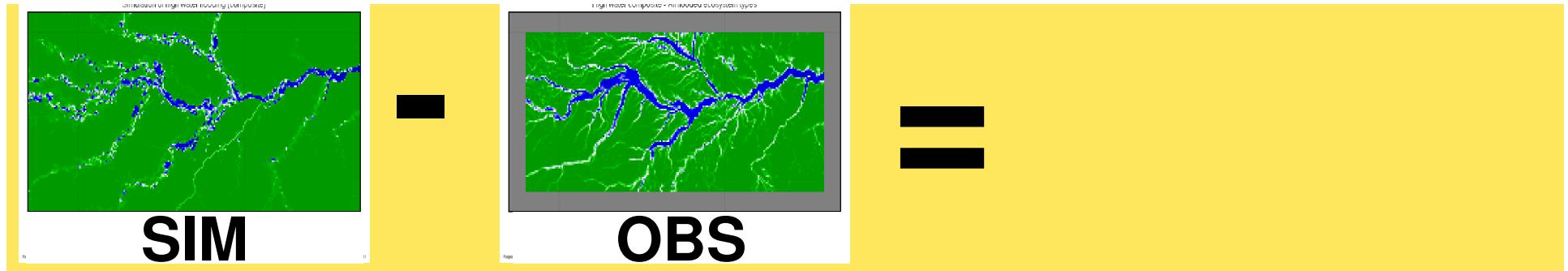
**High  
water**



=

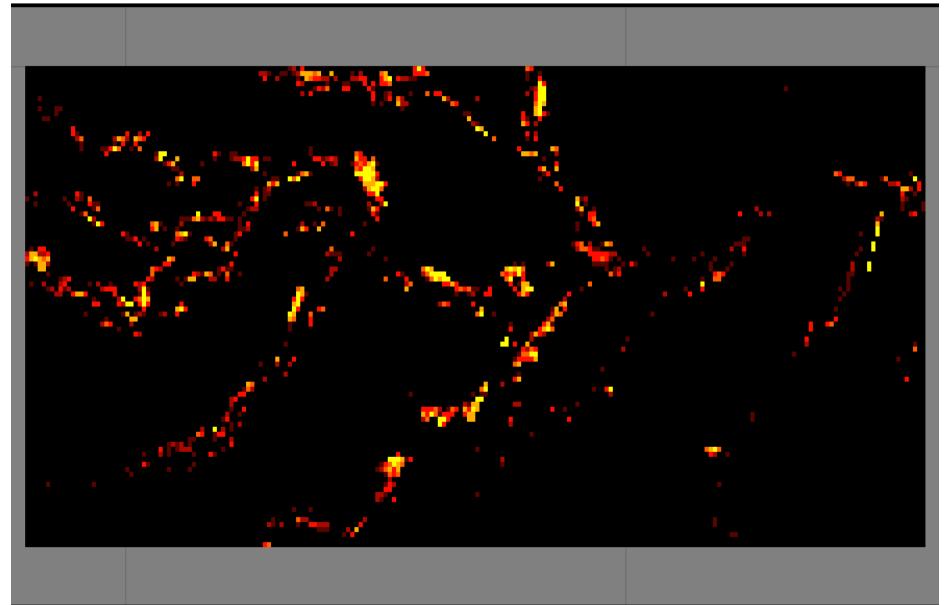
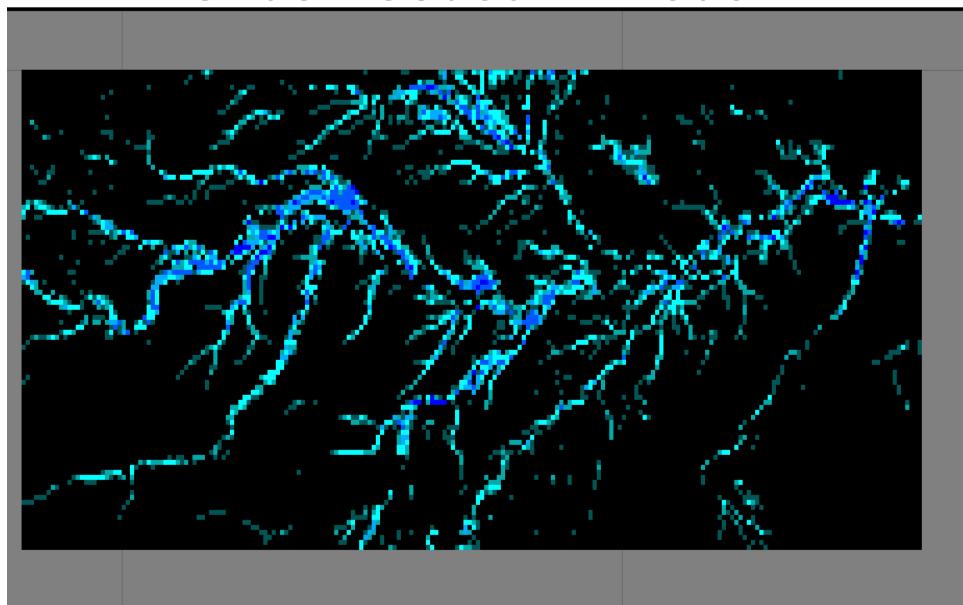
**Correlation in flooding pattern:  $r = 0.54$**   
**% difference in area flooded = -26%**

**High  
water**



**Underflooded in model**

**Overflowed in model**

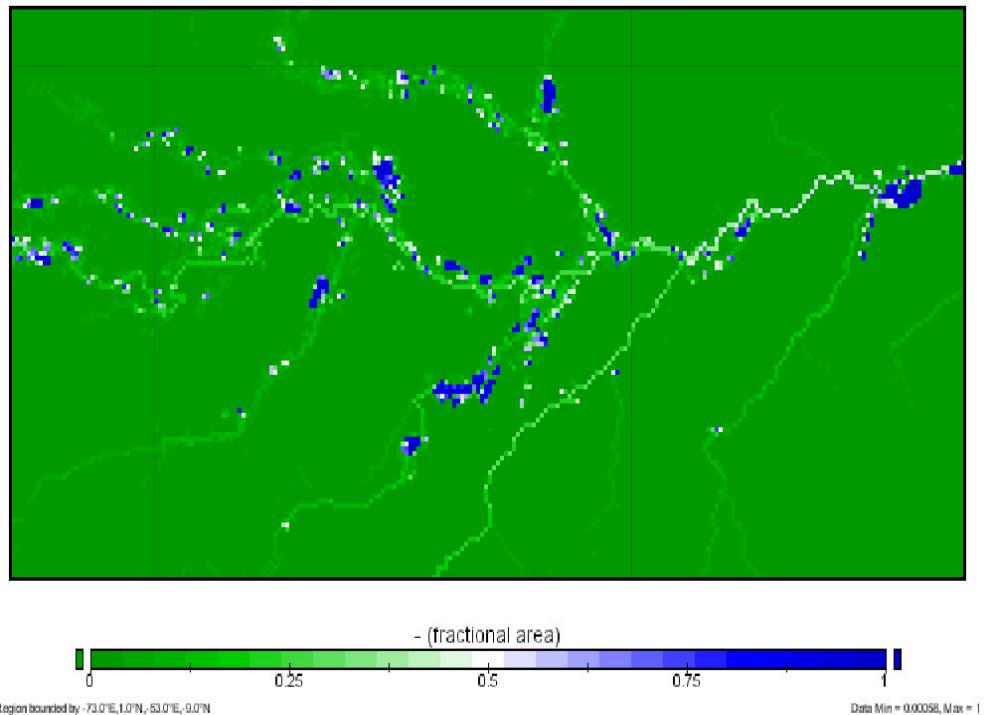


**Correlation in flooding pattern:  $r = 0.54$**

**% difference in area flooded = -26%**

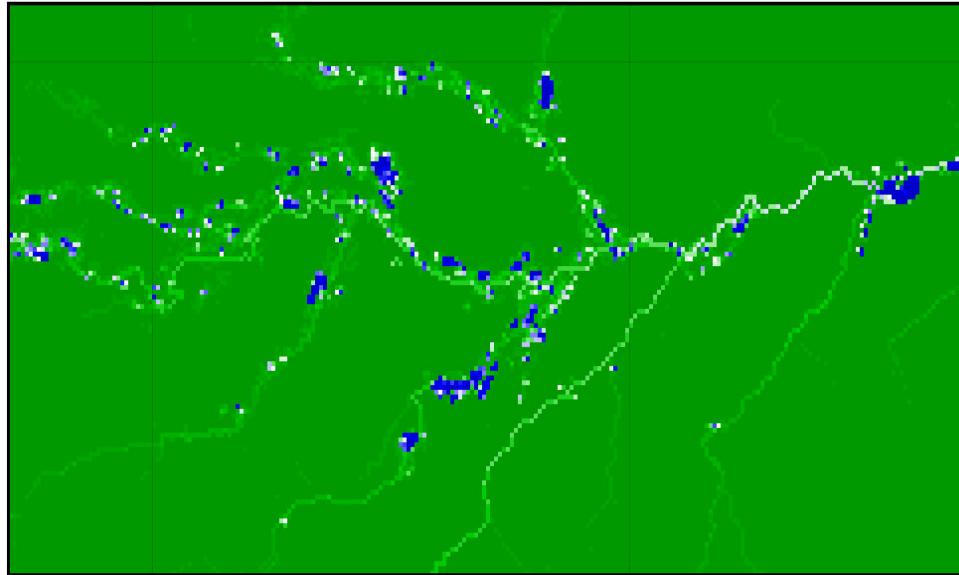
**High water**

Simulation of low water flooding (composite)

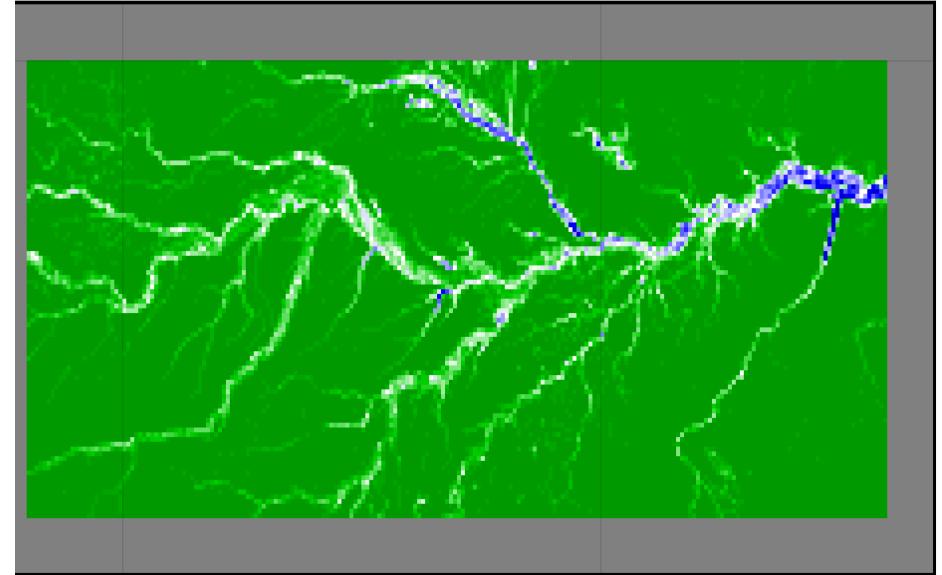


**Low  
water**

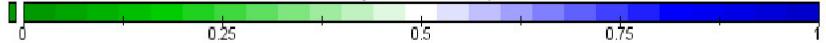
Simulation of low water flooding (composite)



Low water composite - All flooded ecosystem types

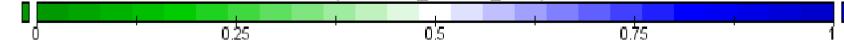


- (fractional area)



Region bounded by -73.0°E, 1.0°N, 53.0°E, 9.0°N

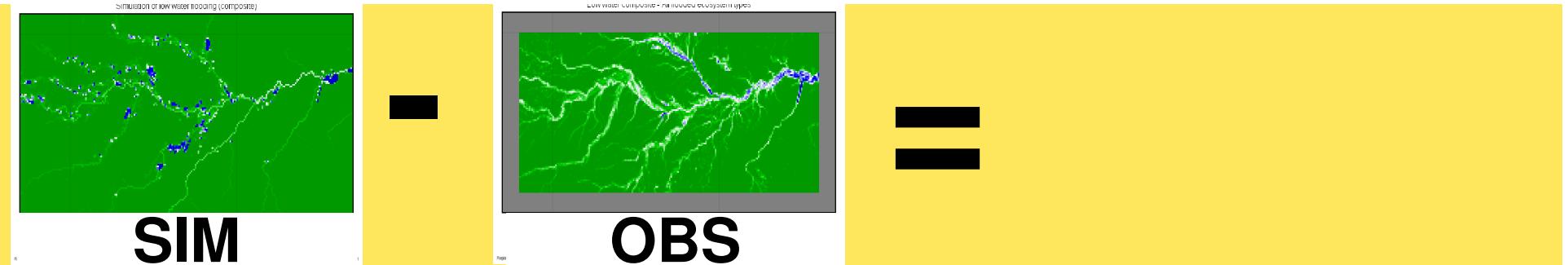
- (fractional\_flooded\_area)



Data Min = 0.00098, Max = 1  
Region bounded by -73.0°E, 1.0°N, 53.0°E, 9.0°N

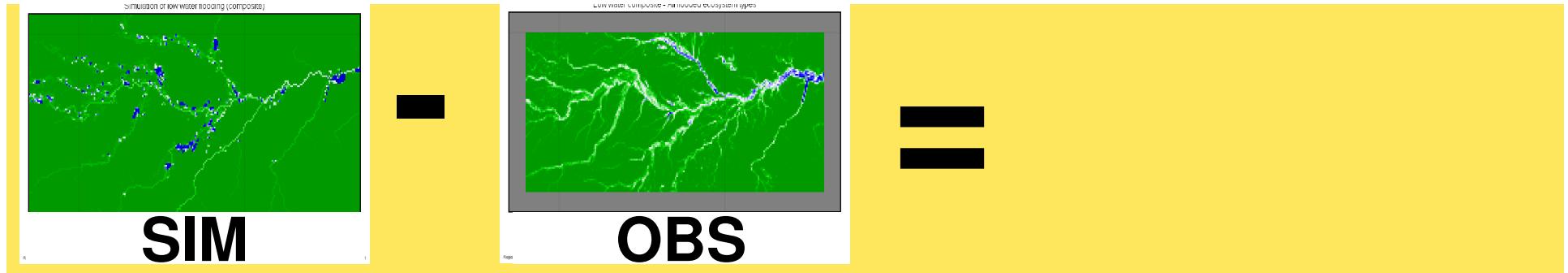
**Correlation in flooding pattern:  $r = 0.35$**   
**% difference in area flooded = -25%**

**Low  
water**



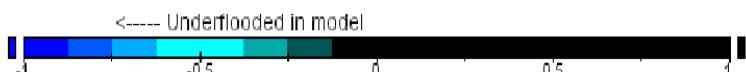
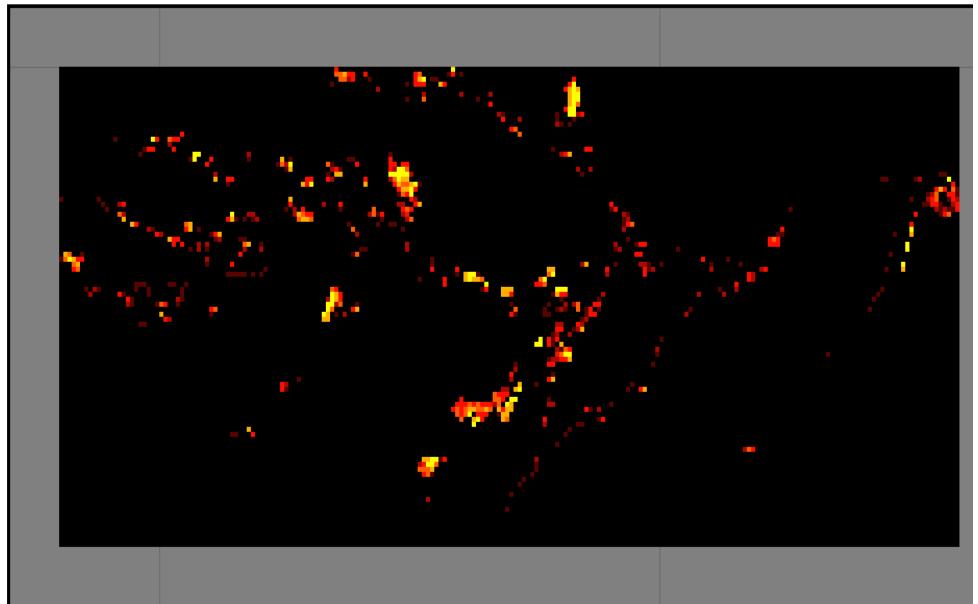
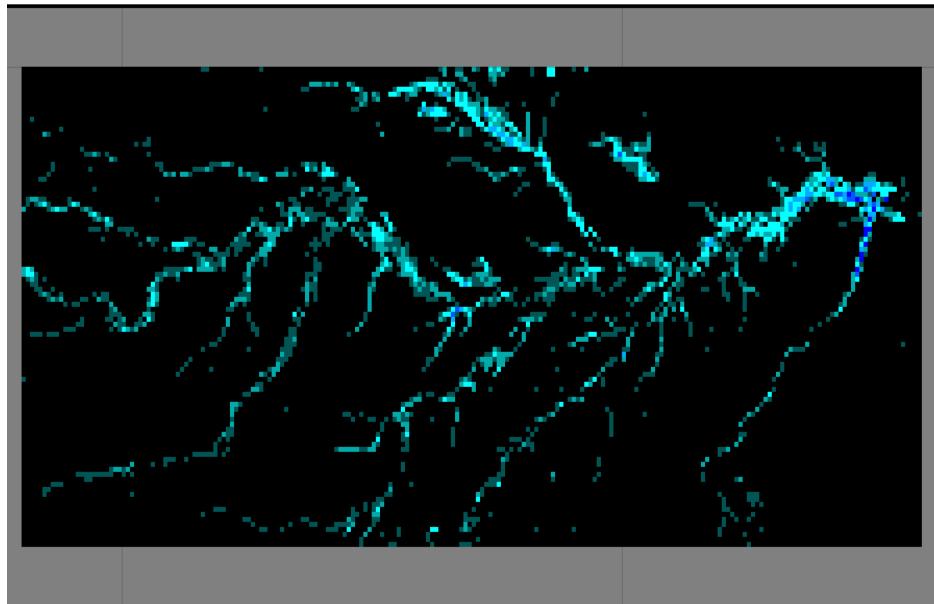
**Correlation in flooding pattern:  $r = 0.35$**   
**% difference in area flooded = -25%**

**Low  
water**



**Underflooded in model**

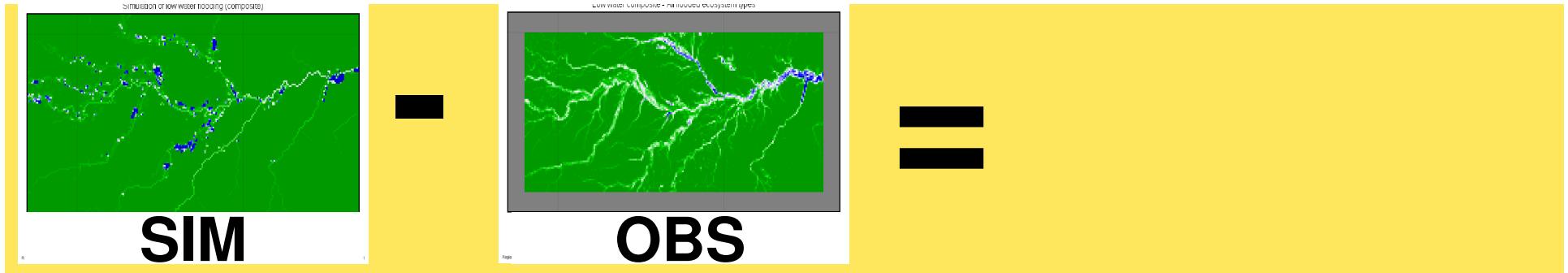
**Overflowed in model**



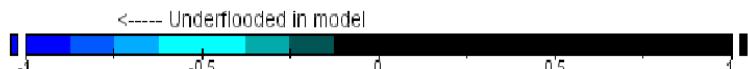
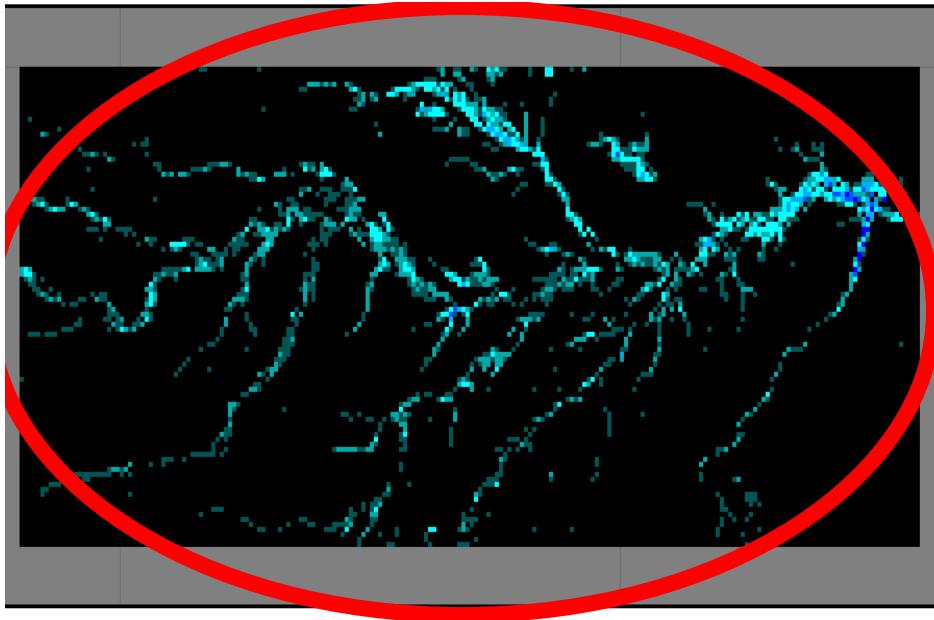
**Correlation in flooding pattern:  $r = 0.35$**

**% difference in area flooded = -25%**

**Low water**

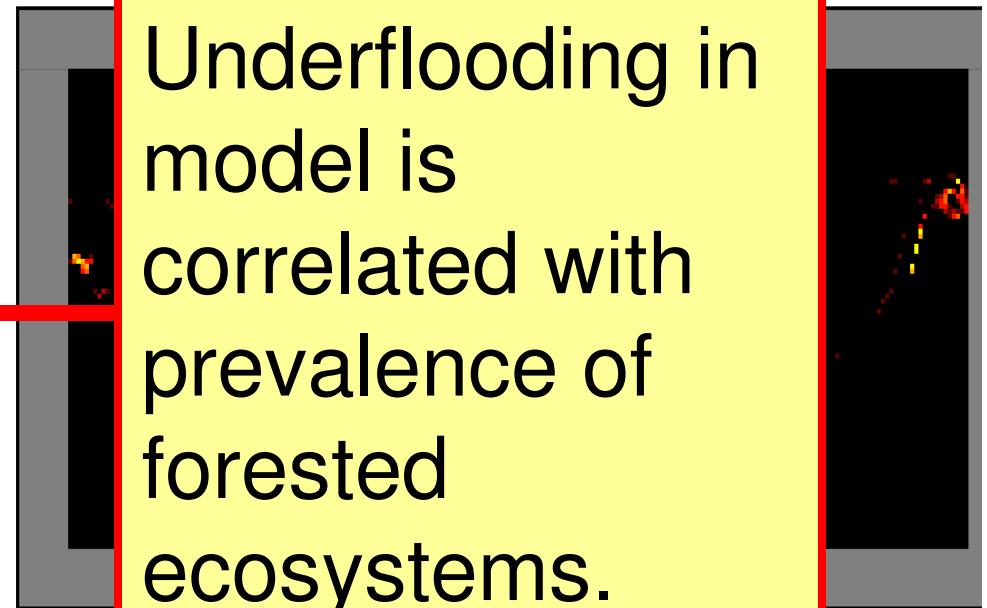


**Underflooded in model**



**Overflowed in model**

Underflooding in model is correlated with prevalence of forested ecosystems.



**Correlation in flooding pattern:  $r = 0.35$**

**% difference in area flooded = -25%**

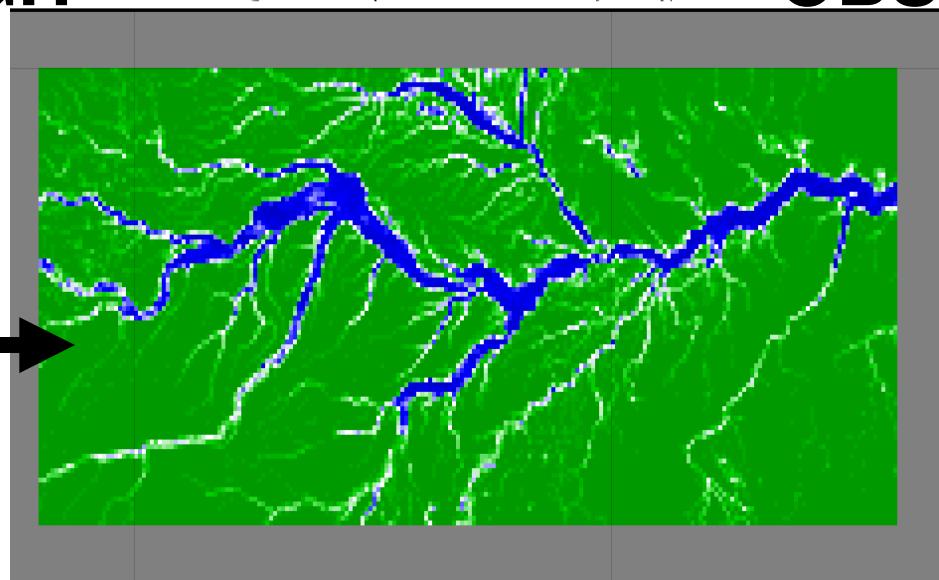
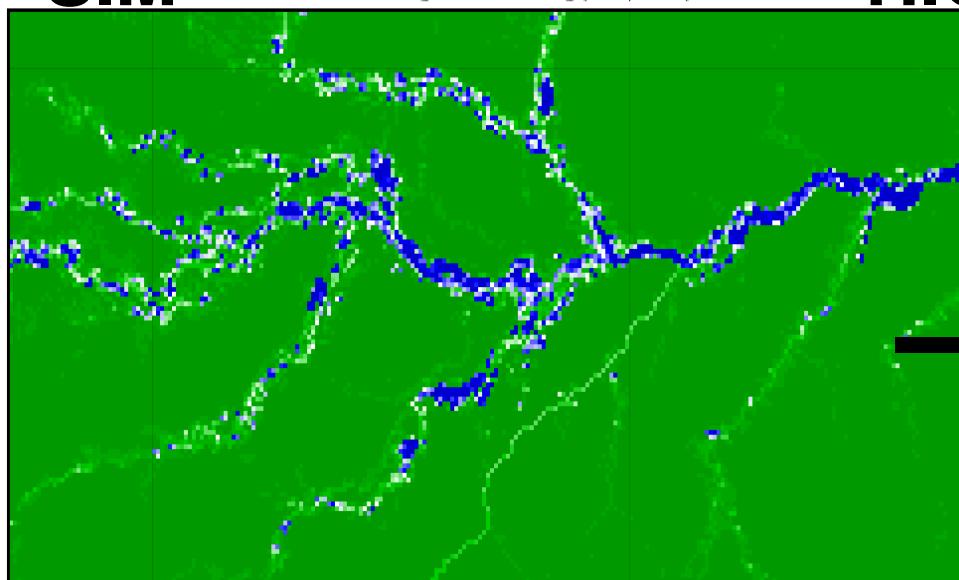
**Low water**

**SIM**

Simulation of high water flooding (composite)

**HIGH**

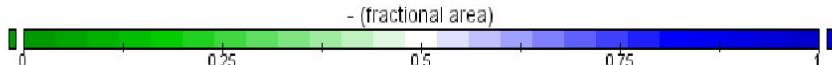
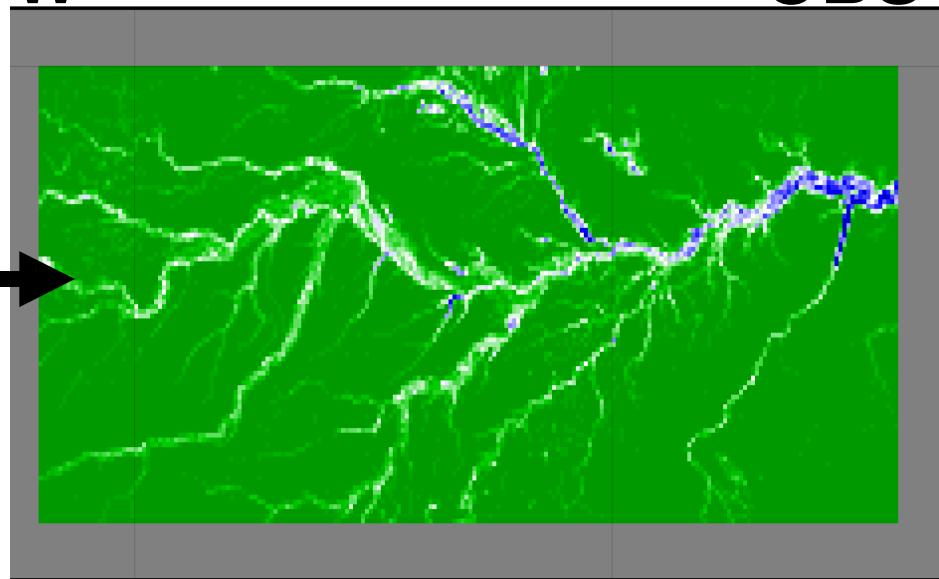
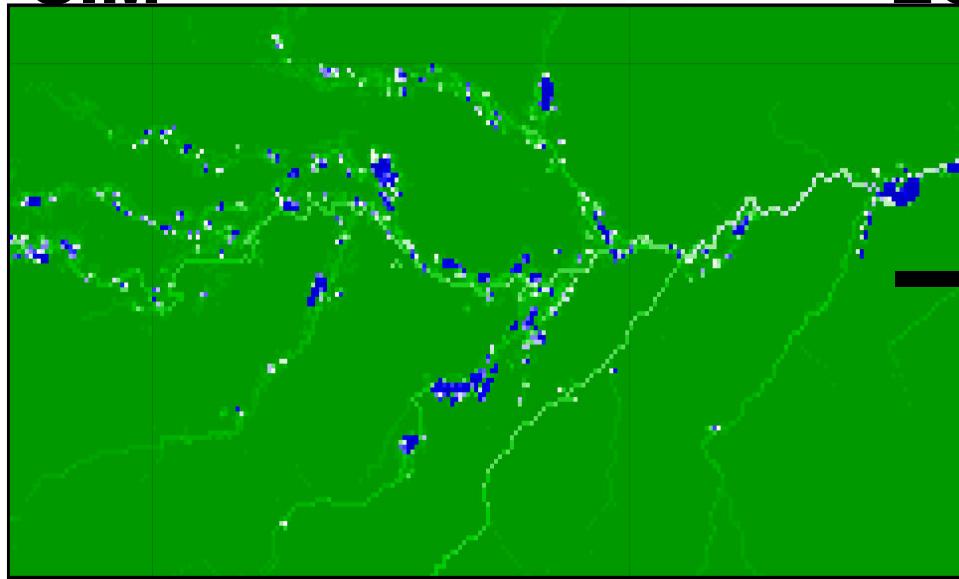
High water composite - All flooded ecosystem types

**OBS****SIM**

Simulation of low water flooding (composite)

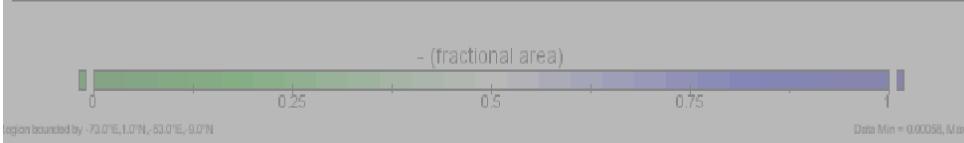
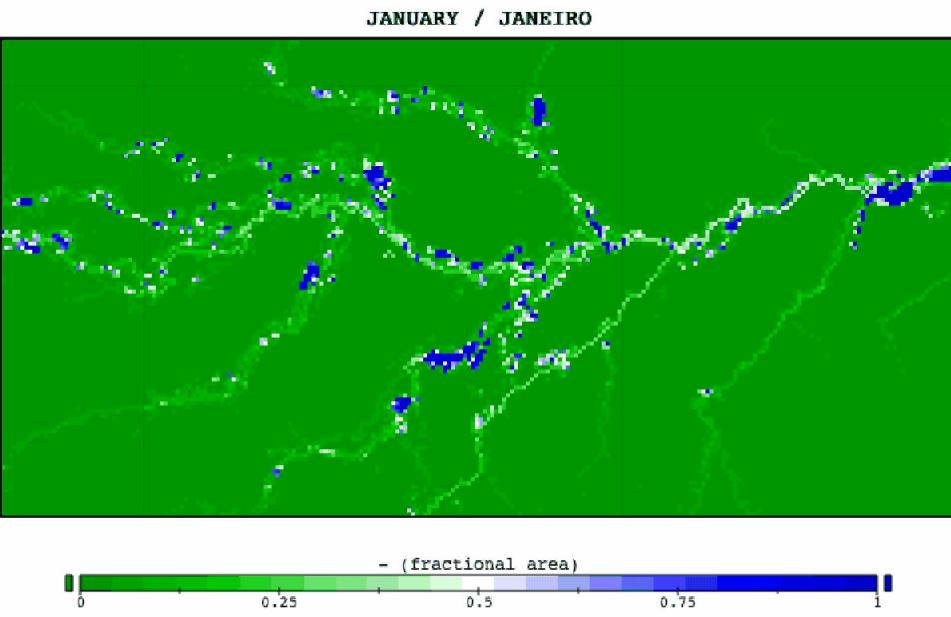
**LOW**

Low water composite - All flooded ecosystem types

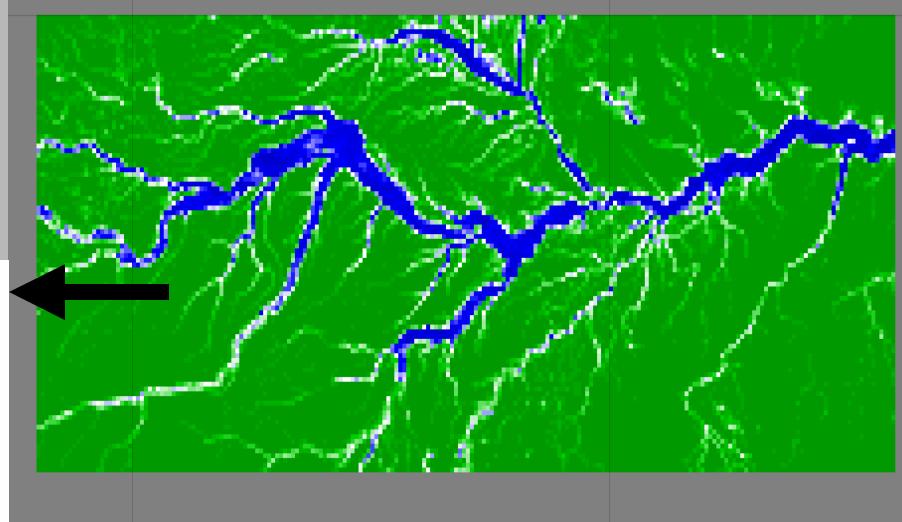
**OBS**

**SIM**

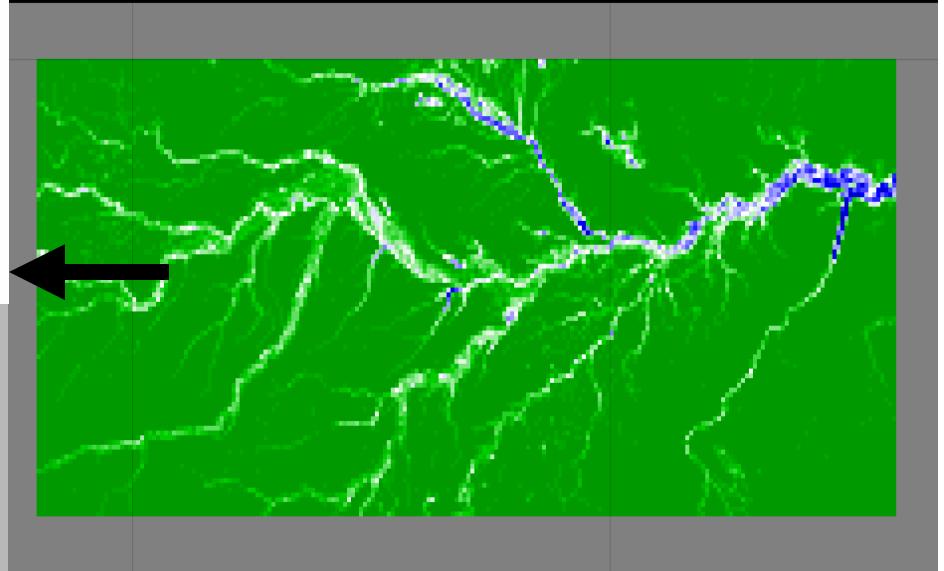
Simulation of high water flooding (composite)

**OBS**

High water composite - All flooded ecosystem types

**OBS**

Low water composite - All flooded ecosystem types



Data Min = 0, Ma