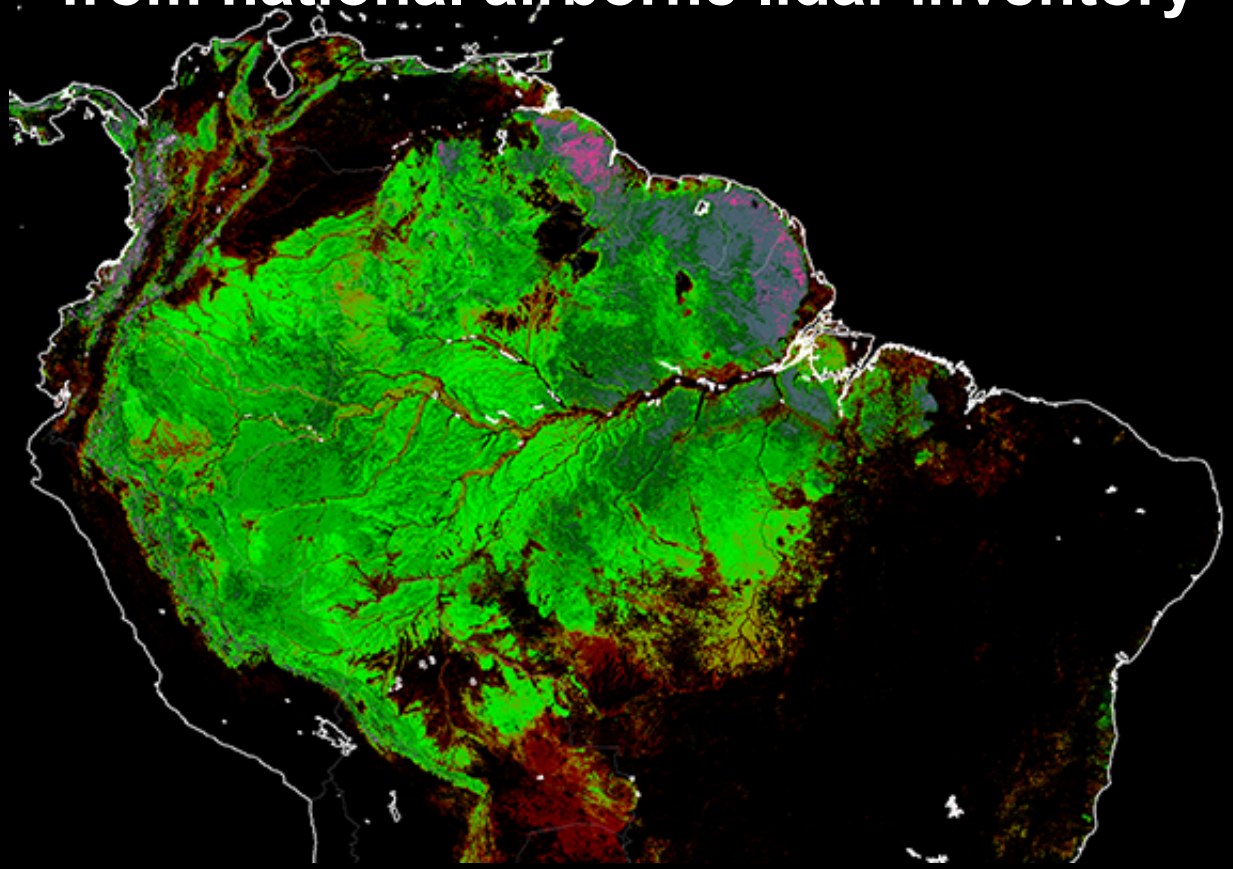
# Diversity of forest structure and patterns of aboveground biomass in the Brazilian Amazon from national airborne lidar inventory



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April, 2019

# Carbon Emissions and Removals from Deforestation, Degradation, Regeneration

deforestation

degradation

Regeneration

$$\Delta C = \sum \Delta A \cdot B \cdot E_{def} + \sum A \cdot \Delta B \cdot E_{\deg} + \sum A \cdot \Delta B \cdot R_{reg}$$

*where A is the area of forest type, with biomass B, emission efficiency factor E, and removal efficiency R*

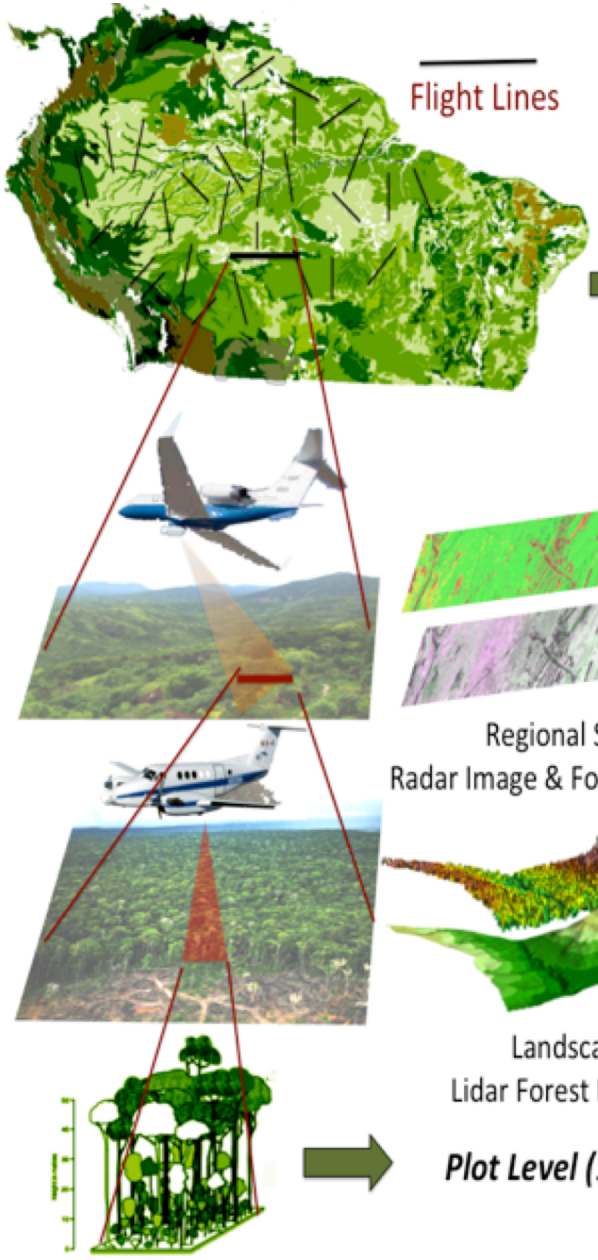
# How do we approach the problem?

1. Develop National Inventory Plots

2. Use Direct Remote Sensing Techniques from Space

3. Use a combination of remote sensing sampling and ground measurements

# Forest Biomass Inventory and Mapping from Space

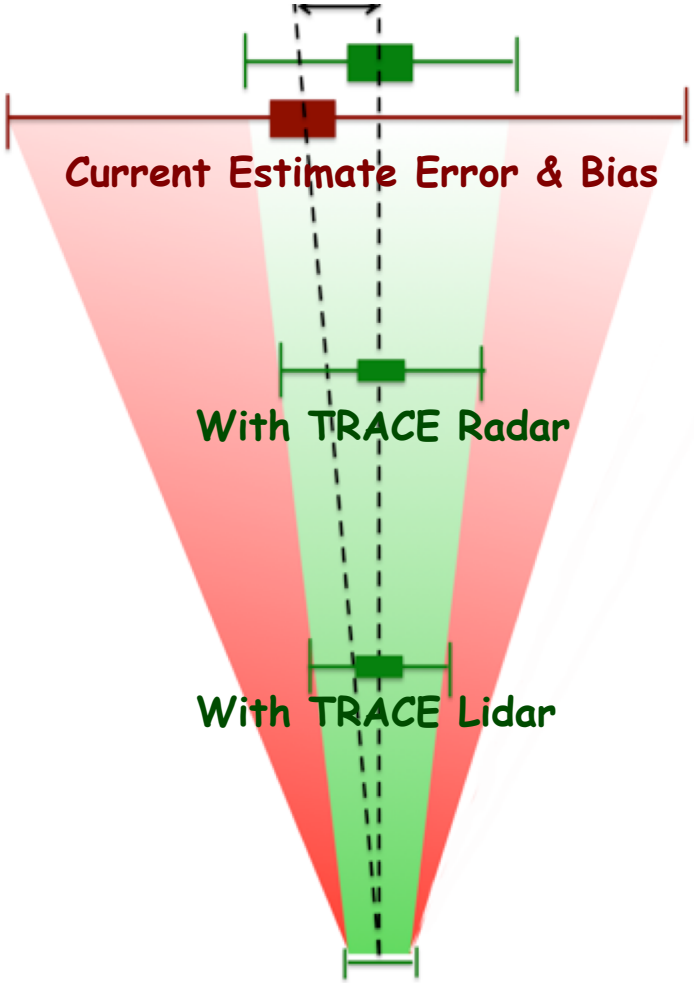


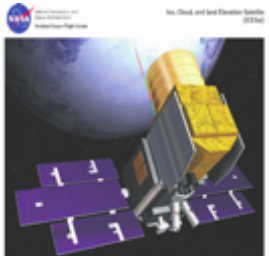

**Regional Scale Carbon Fluxes**

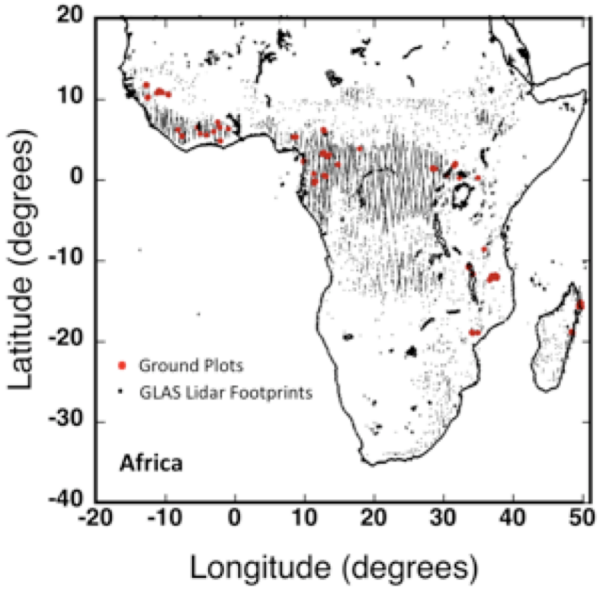
**Regional sampling 100-100,000 km²**

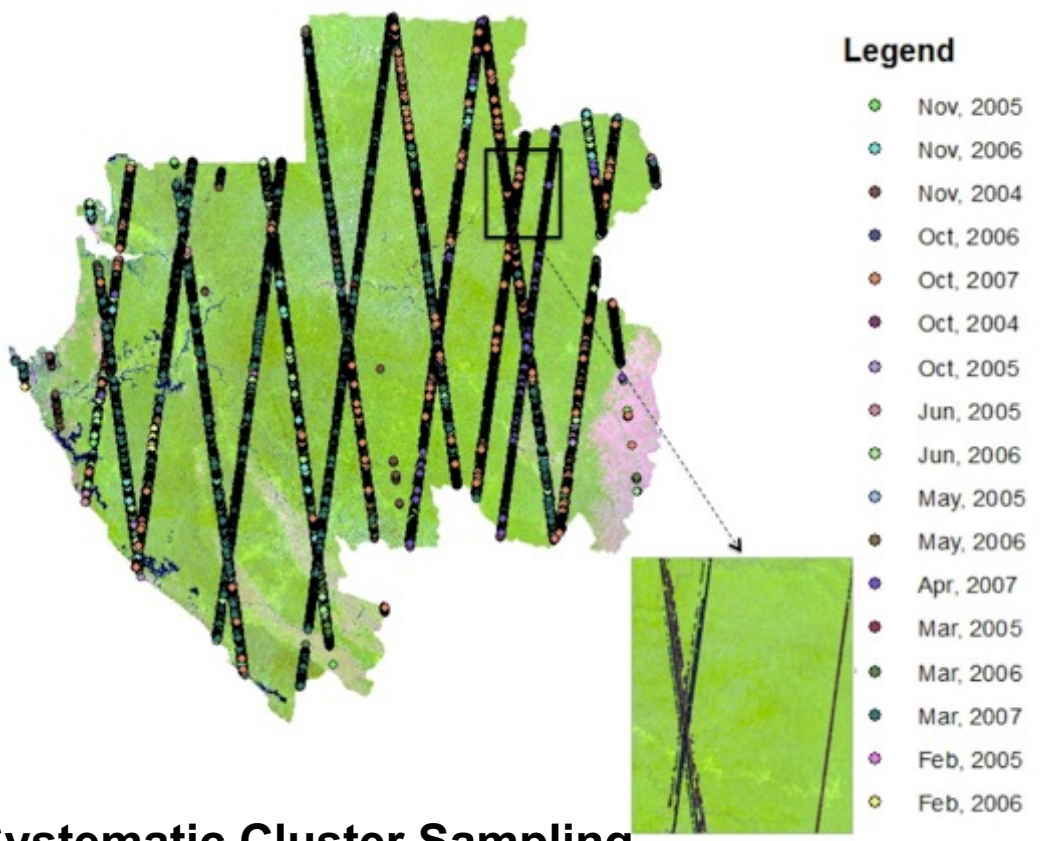
**Landscape Scale sampling 10-100 km²**

**Uncertainty in estimating regional scale carbon stock and changes**





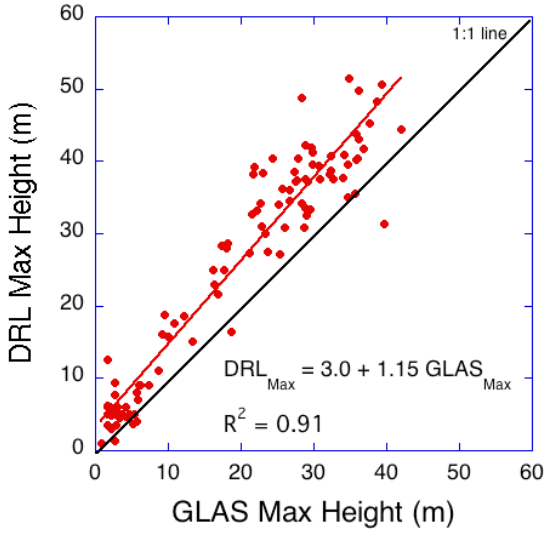



**Systematic Cluster Sampling**

## Density of Lidar Samples

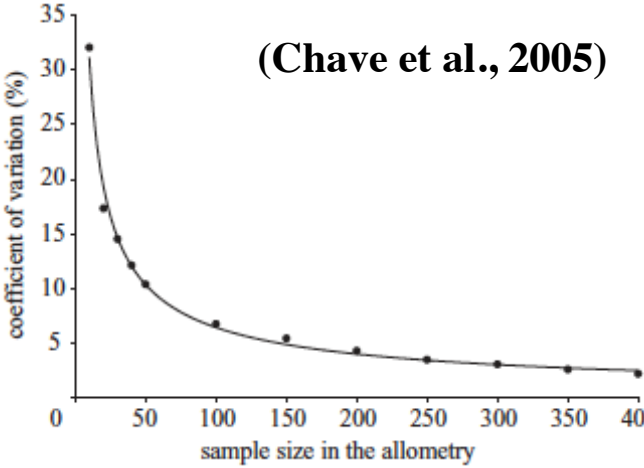
### Sample GLAS Shots Over Old Growth Forests (~0.25 ha)



# Lidar/Plot Level Allometry

$$AGB = \sum_{i=1}^{N} 0.0509 \times \rho_i \times (D_i^2) \times H_i$$

$$AGB = \bar{\rho} \sum_{i=1}^{N} 0.0509 \times (D_i^2) \times H_i$$




**(Chave et al., 2005)**

$\bar{\rho}$ : mean plot wood density is adequate for AGB estimation.

H-D allometry is regionally variables and may depend on environmental variables (Temperature Seasonality, Rainfall Seasonality, MWD)

Plot Level Allometry

$$AGB = a\bar{\rho}B^{\alpha}h^{\beta}$$

$$h_{lidar} = g(B,h)$$

Spatial pattern of AGB is controlled by spatial pattern of h and $\bar{\rho}$

$$h = \frac{\sum_{i=1}^{N} H_i \times BA_i}{\sum_{i=1}^{N} BA_i} \cong \frac{\sum_{i=1}^{N} H_i \times CA_i}{\sum_{i=1}^{N} CA_i}, \qquad h = MCH, \qquad h = \text{ other height metrics}$$

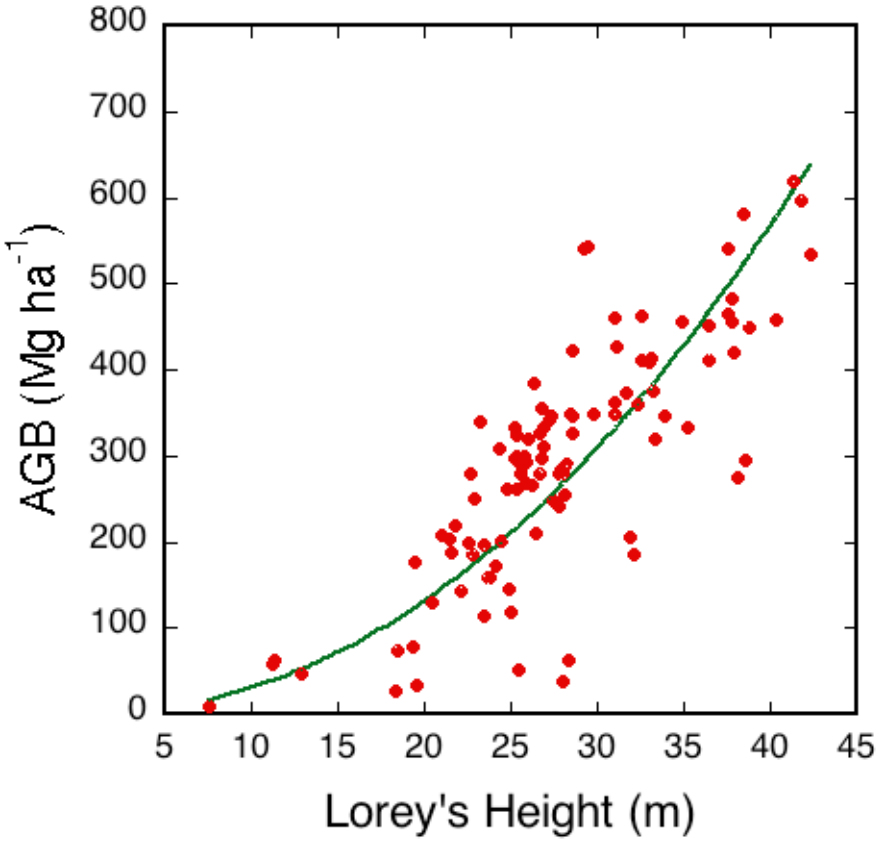
# Height Biomass Allometry

$$AGB = a\bar{\rho}h_{GLAS}^{b}$$

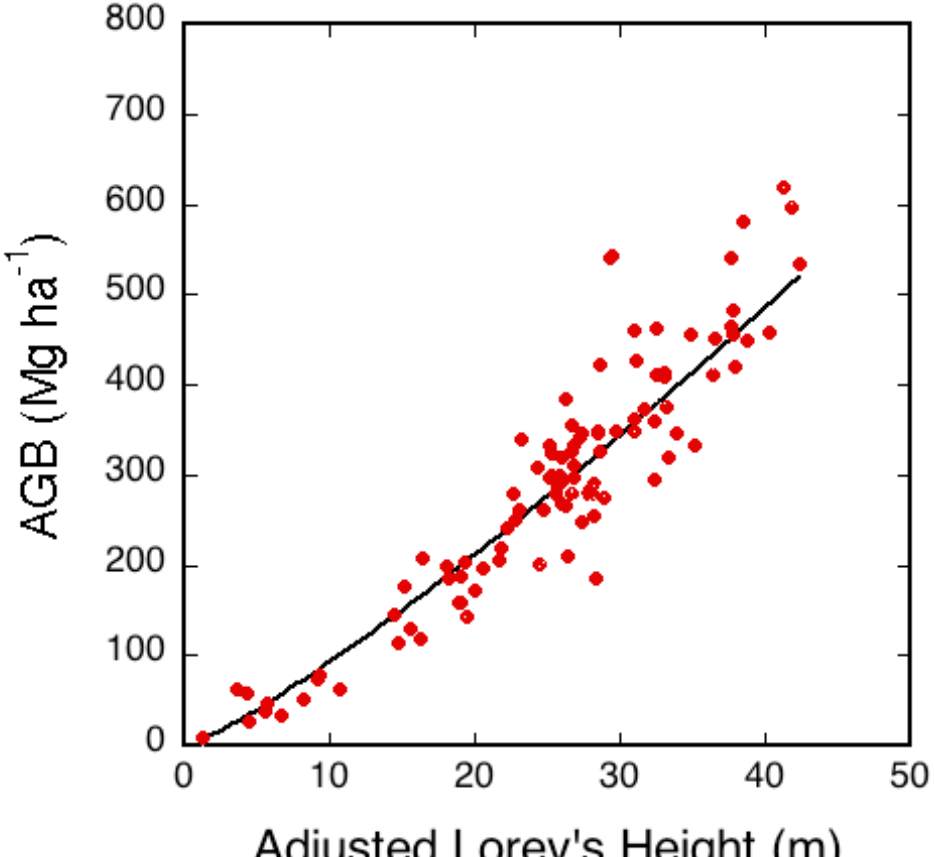
$$h_{GLAS} = f \times h_{Ground}$$

$f$ : Canopy Cover

**Ground Height Biomass Model**

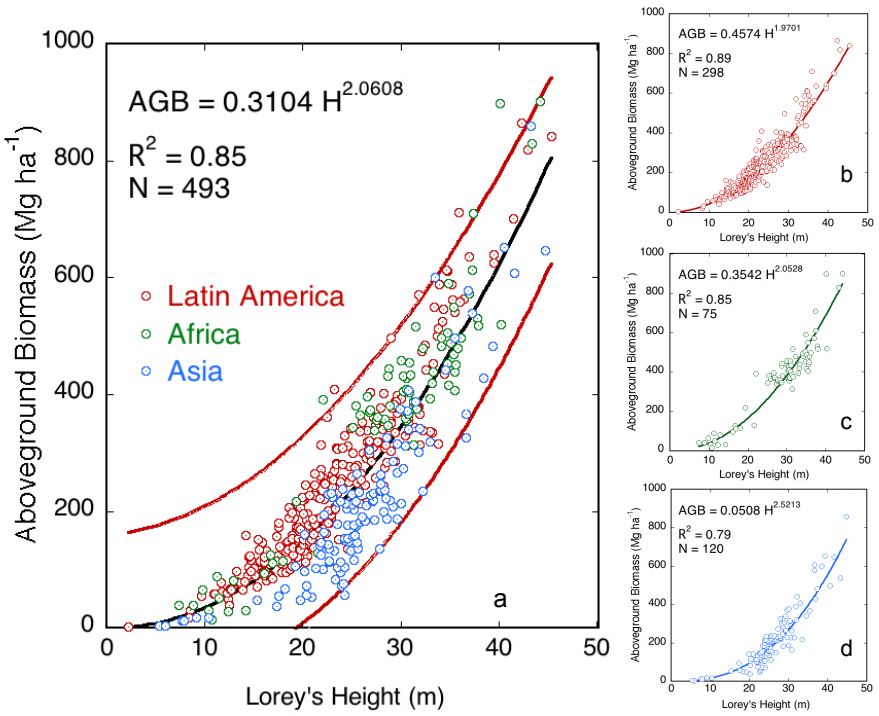


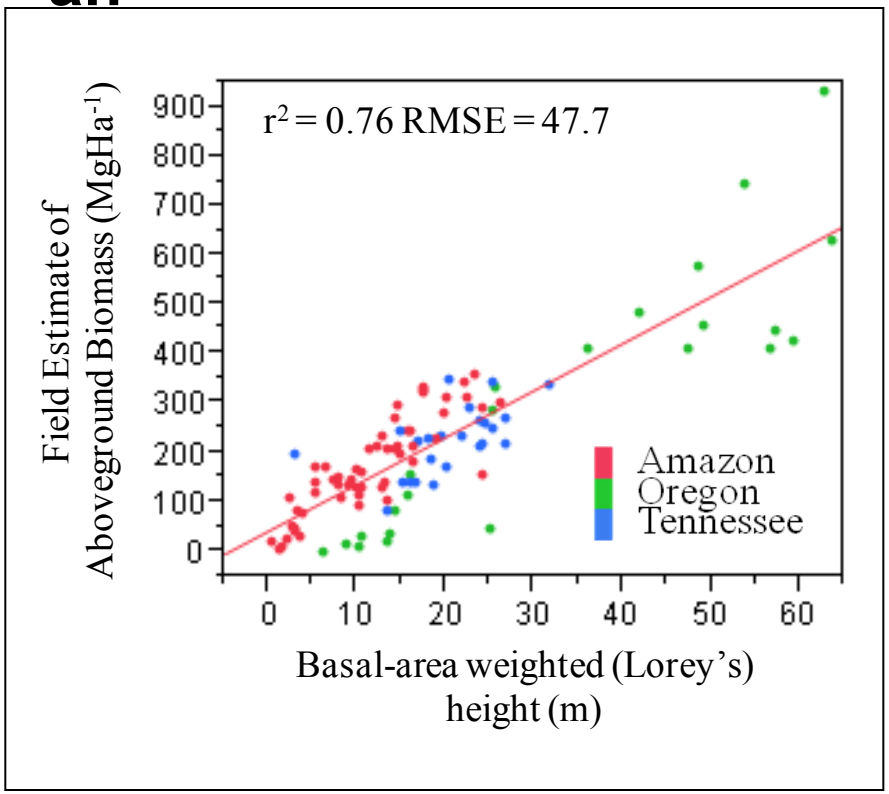

**GLAS Height Biomass Model**



# Forest Height Bioamss Allometry

## $AGB = ah^b$




$$AGB = 0.3H^{2.061}$$

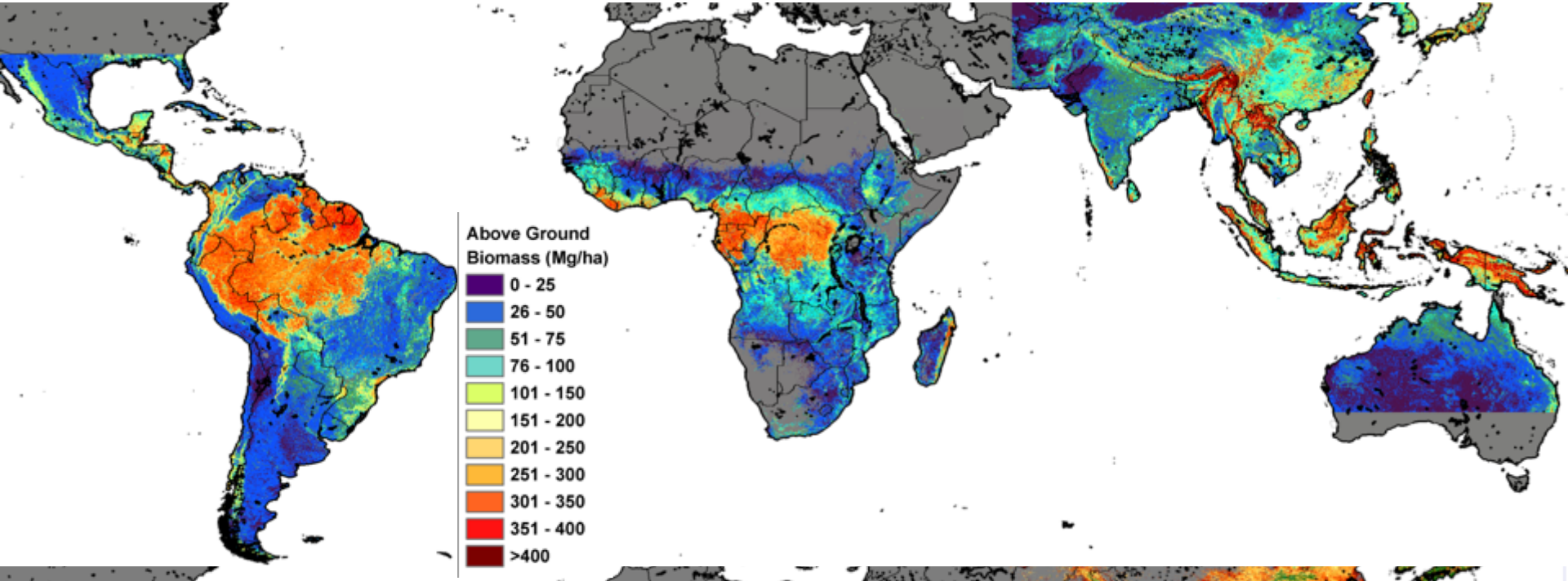
$$\varepsilon_{allometry} = 21.0\%$$

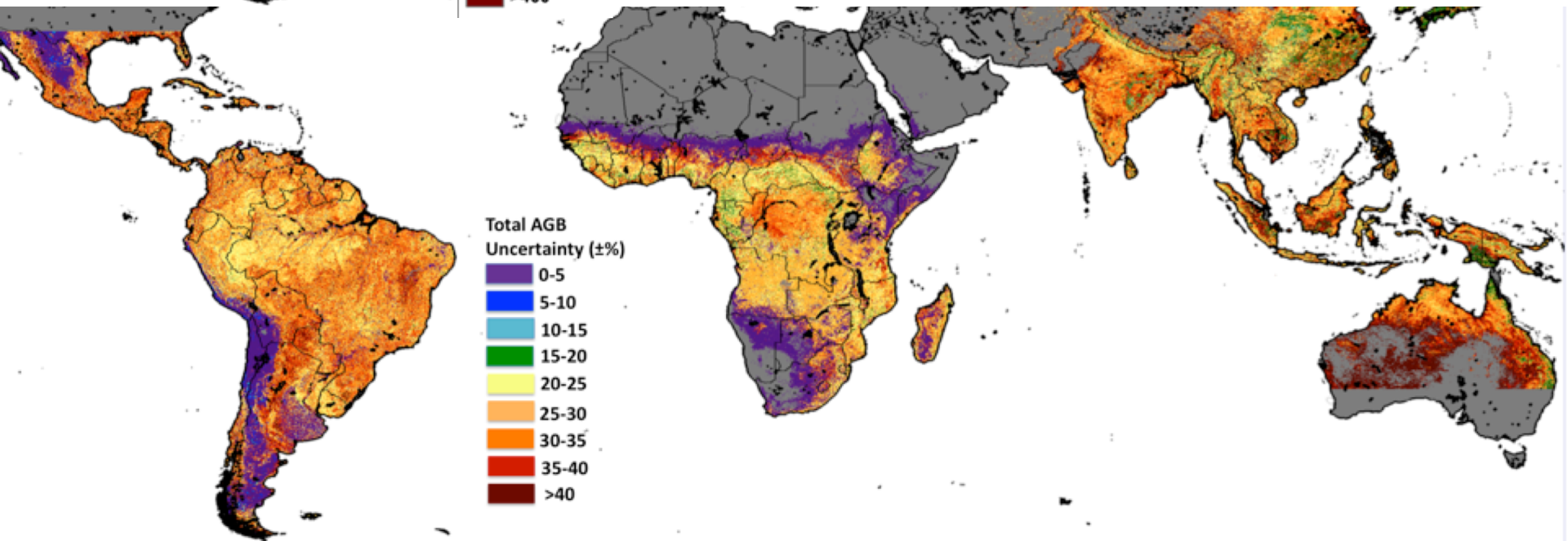
$$\varepsilon_{AGB} = [\varepsilon_{allometry}^2 + (2.061\varepsilon_H)^2]^{1/2} = 35.2\%$$

**Lorey's Height Error: 3.3 m (13.7% Lefsky, 2010)**

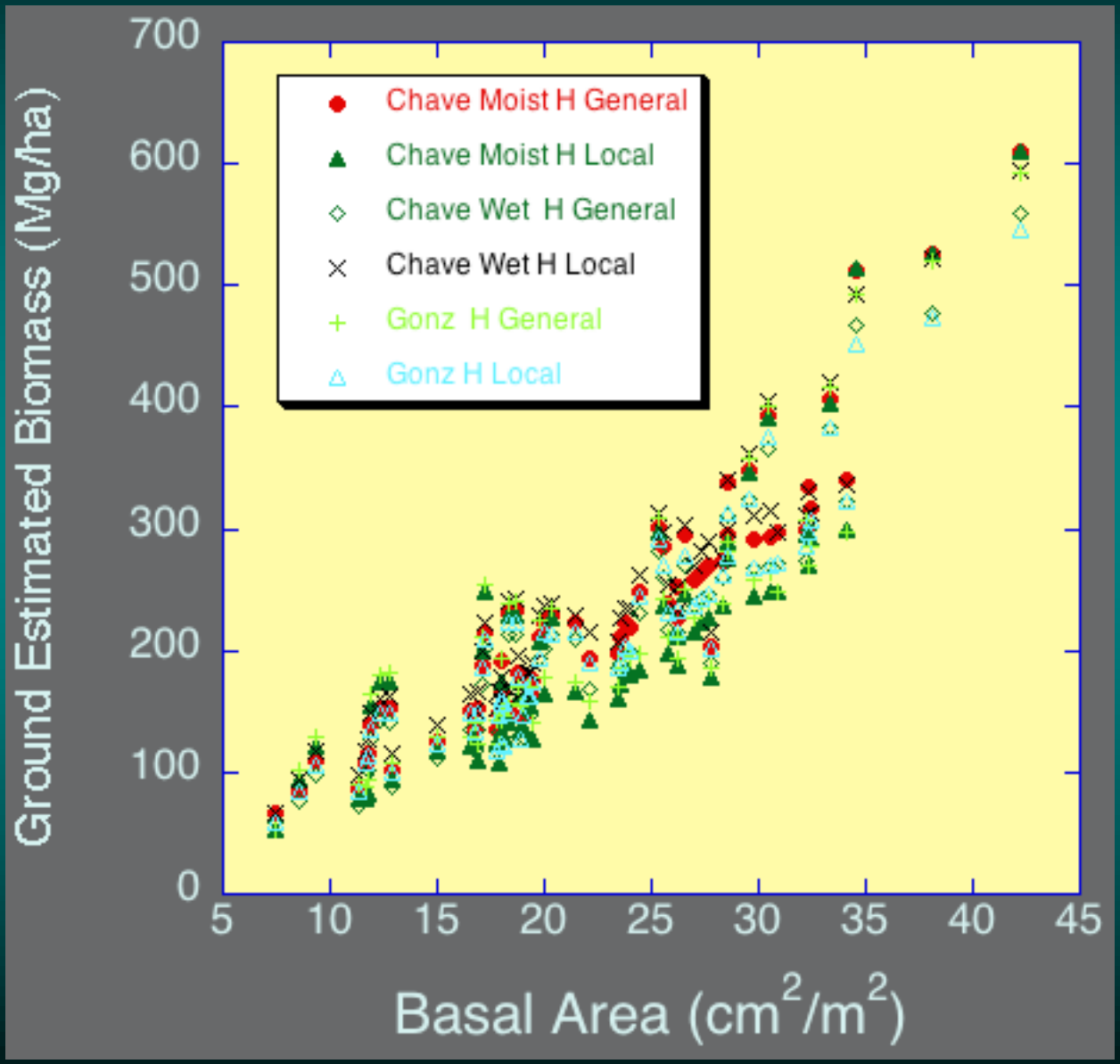
**Assuming Errors are independent and there is no bias in any step of the process except allometry.**

# Pan Tropical Map



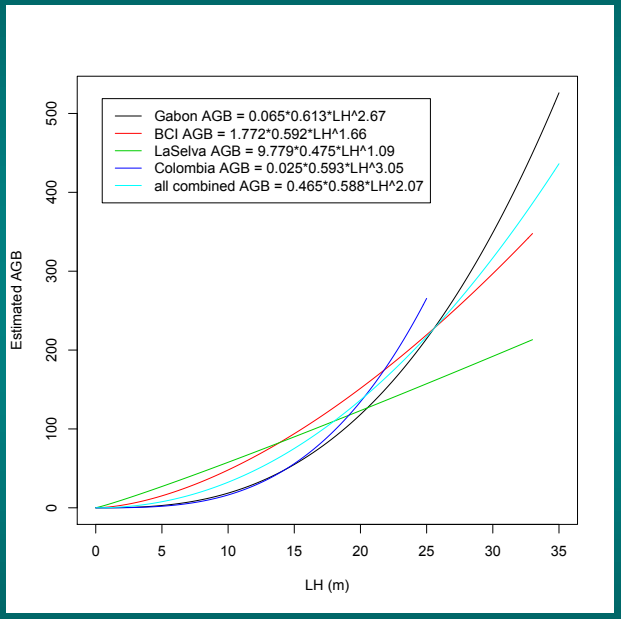



# Available Allometry



# Lidar Biomass Allometry

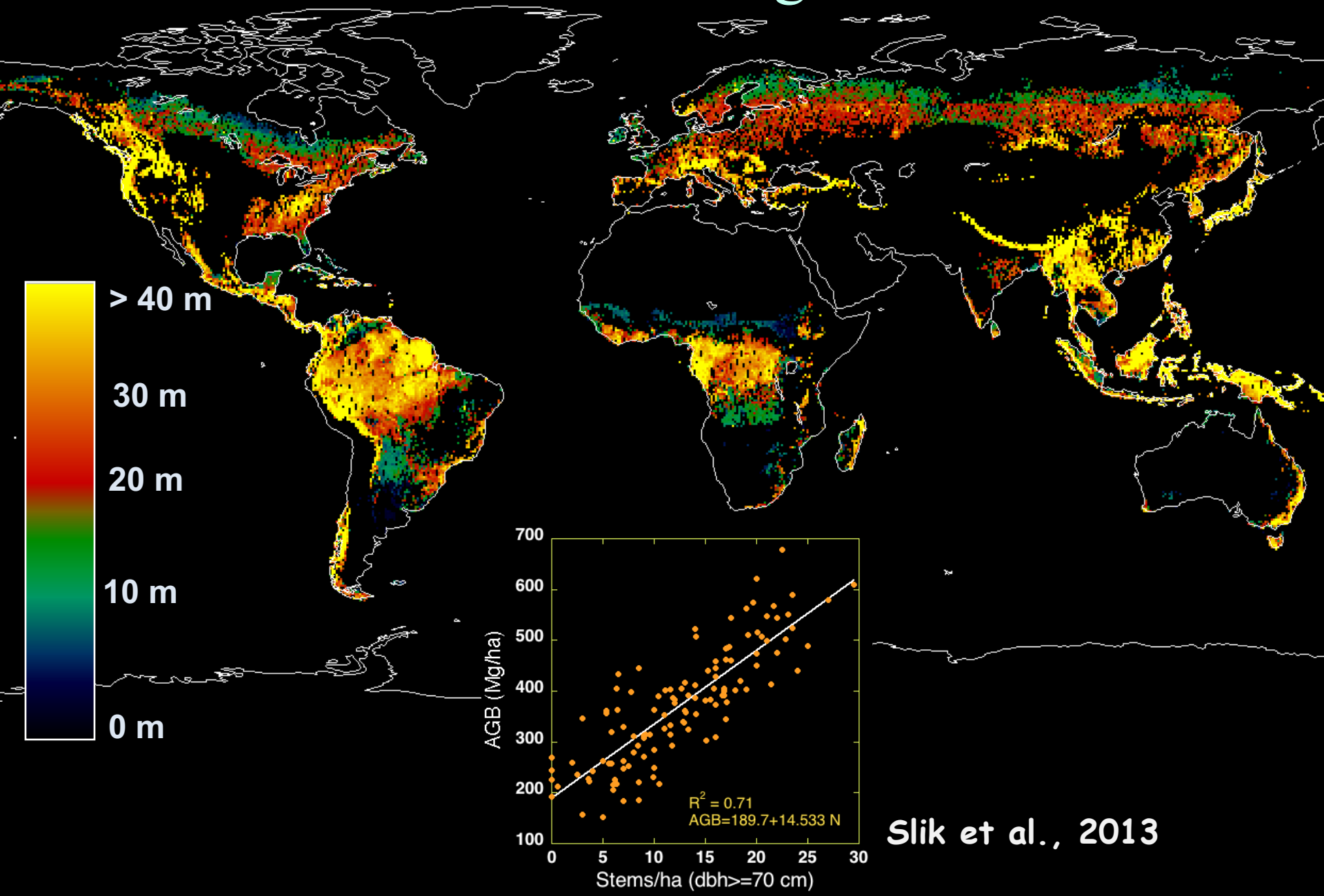
$$AGB = a\bar{\rho}h_{GLAS}^{b}$$




Pattern of AGB is defined by:

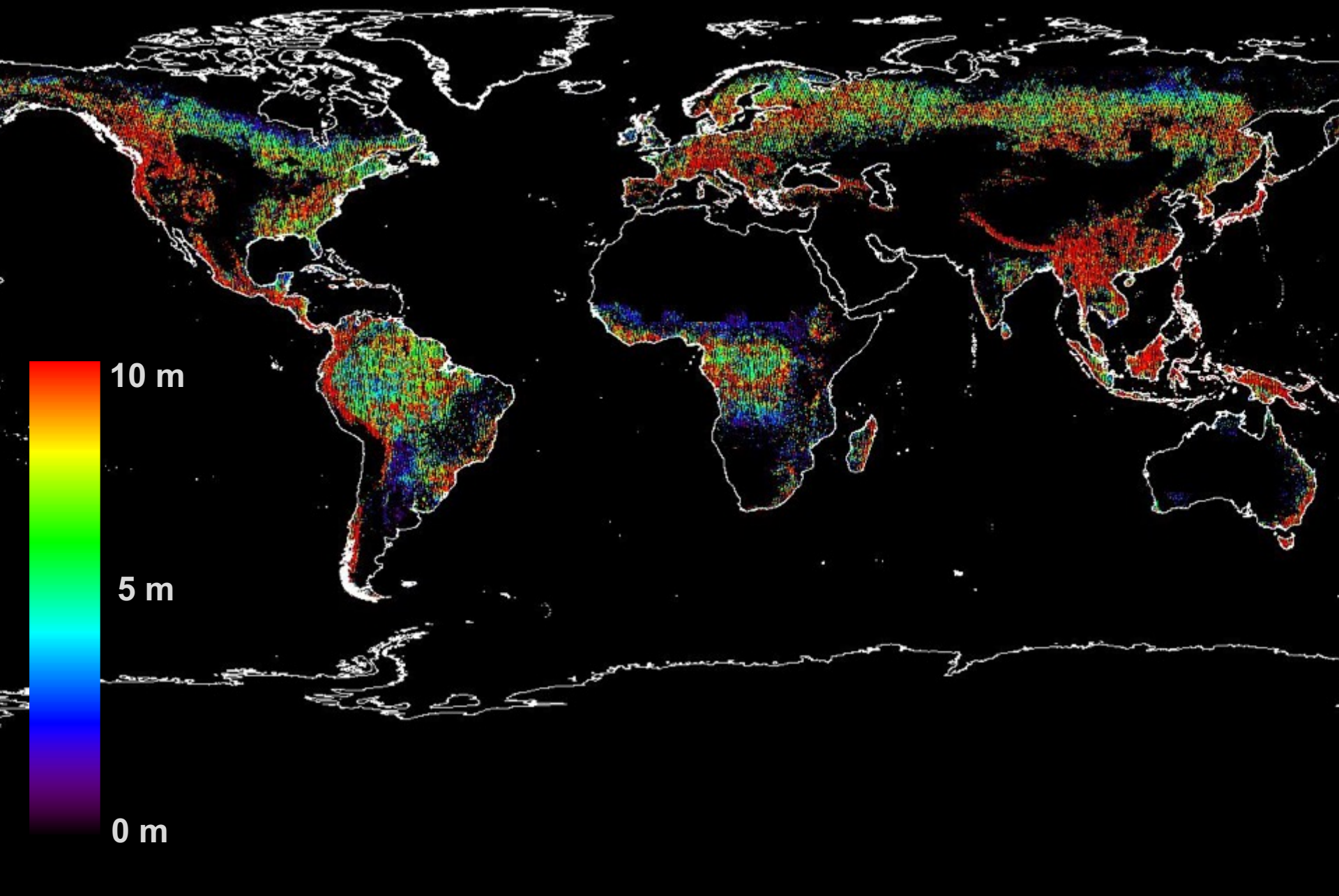
1. Pattern of large trees
2. Pattern of high wood density trees
3. a and b may be dependent on environmental variables

# Where are the large trees?

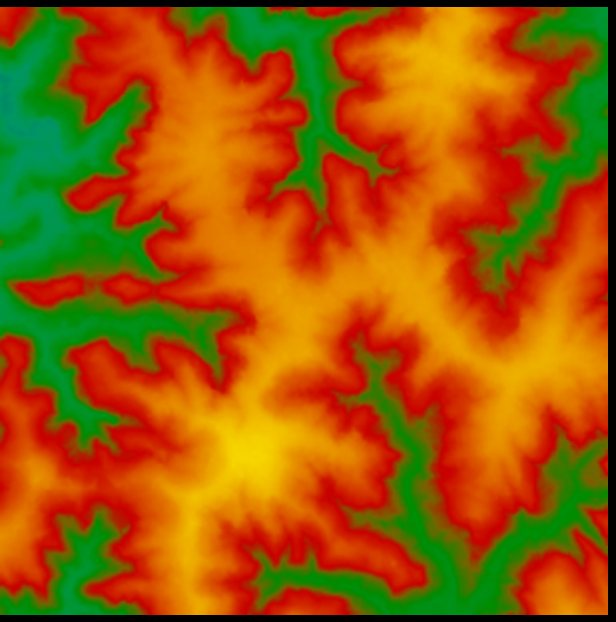



Slik et al., 2013

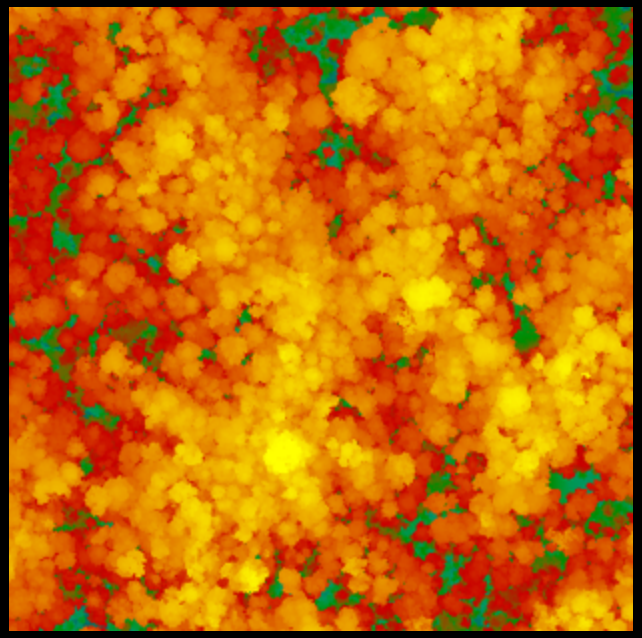
# Global Variations of Forest Structure



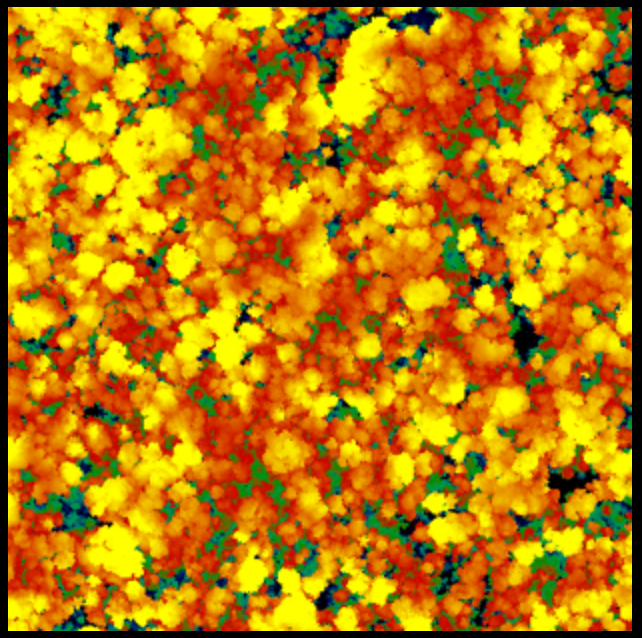
# Landscape Scale Distribution of Forest Structure



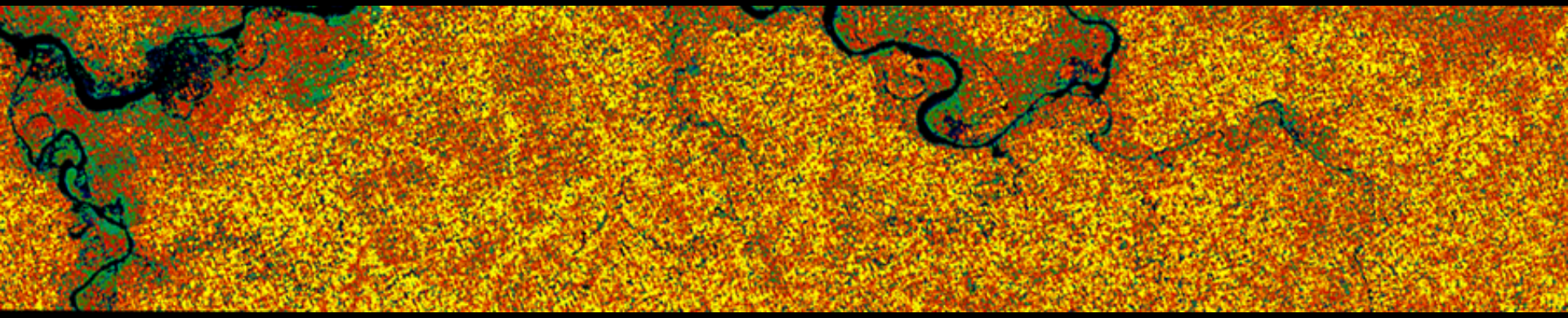
0 m 90 m



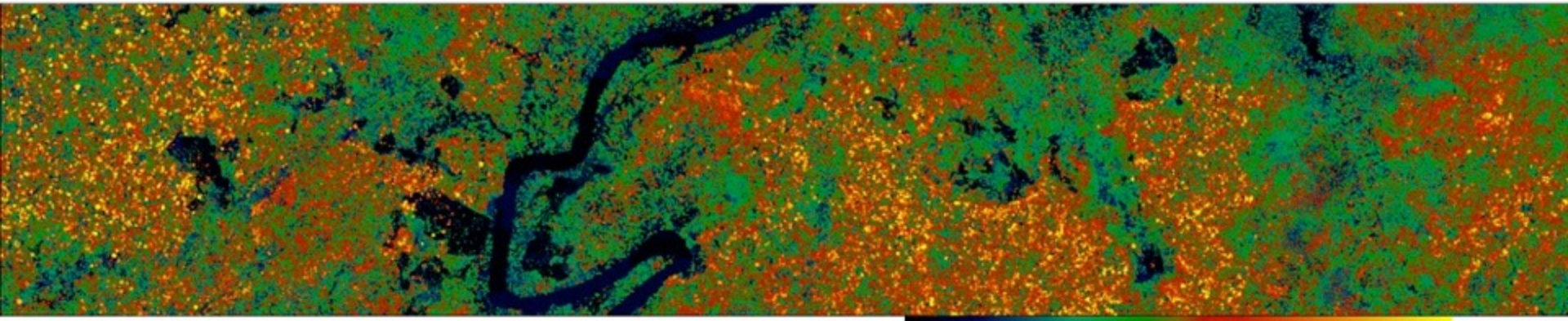
0 m 125 m



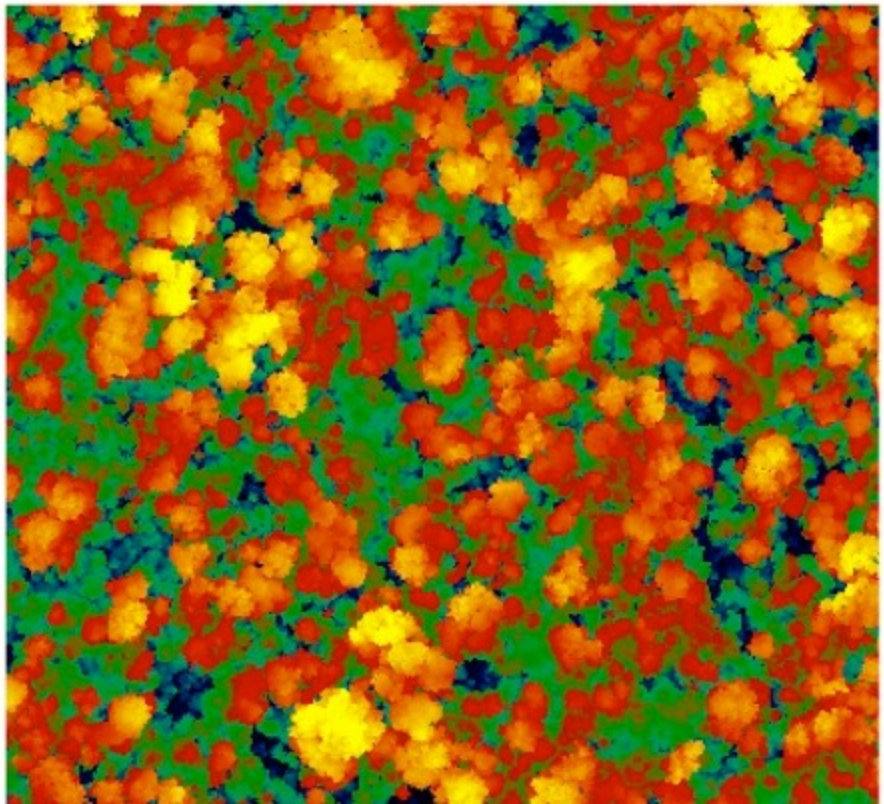
0 m 56 m

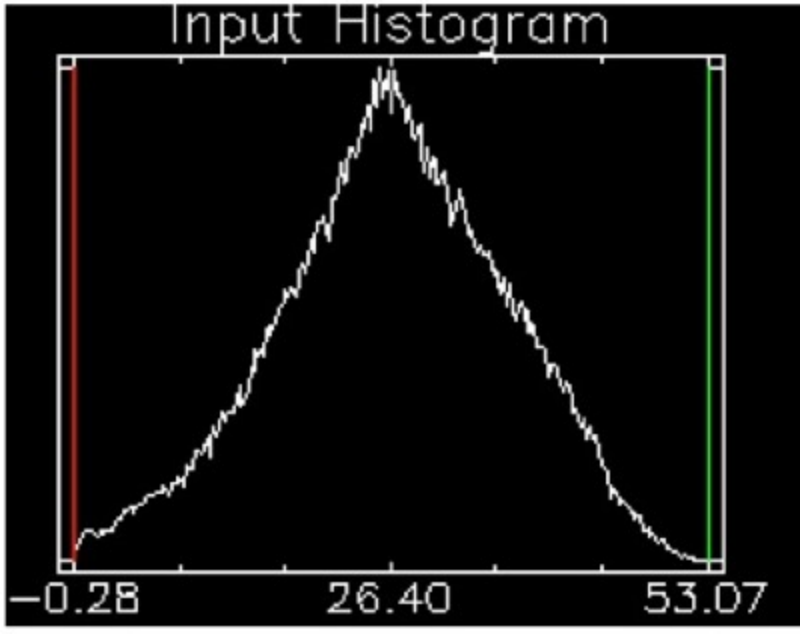


# Lidar Transect (2000 ha)

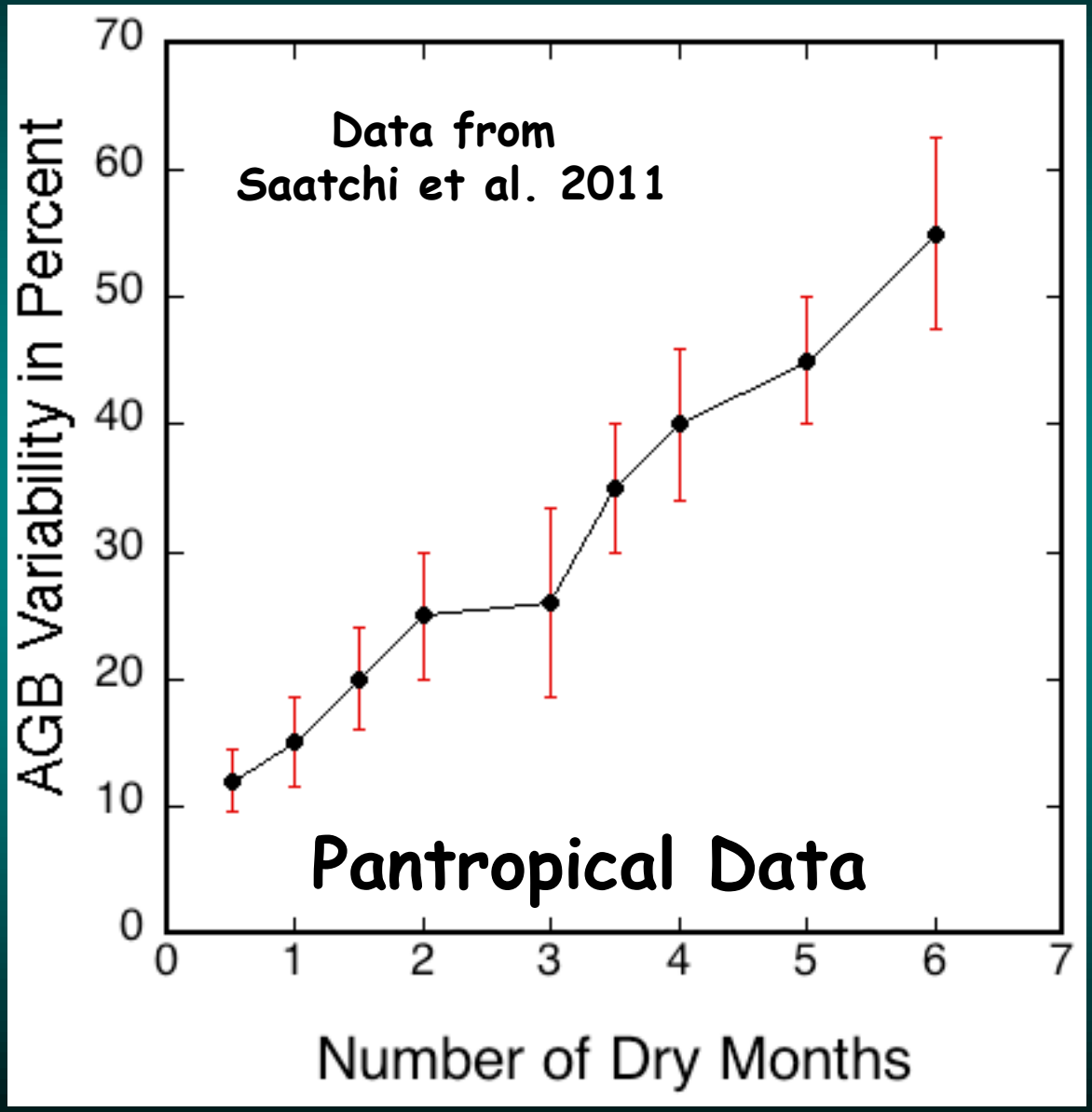


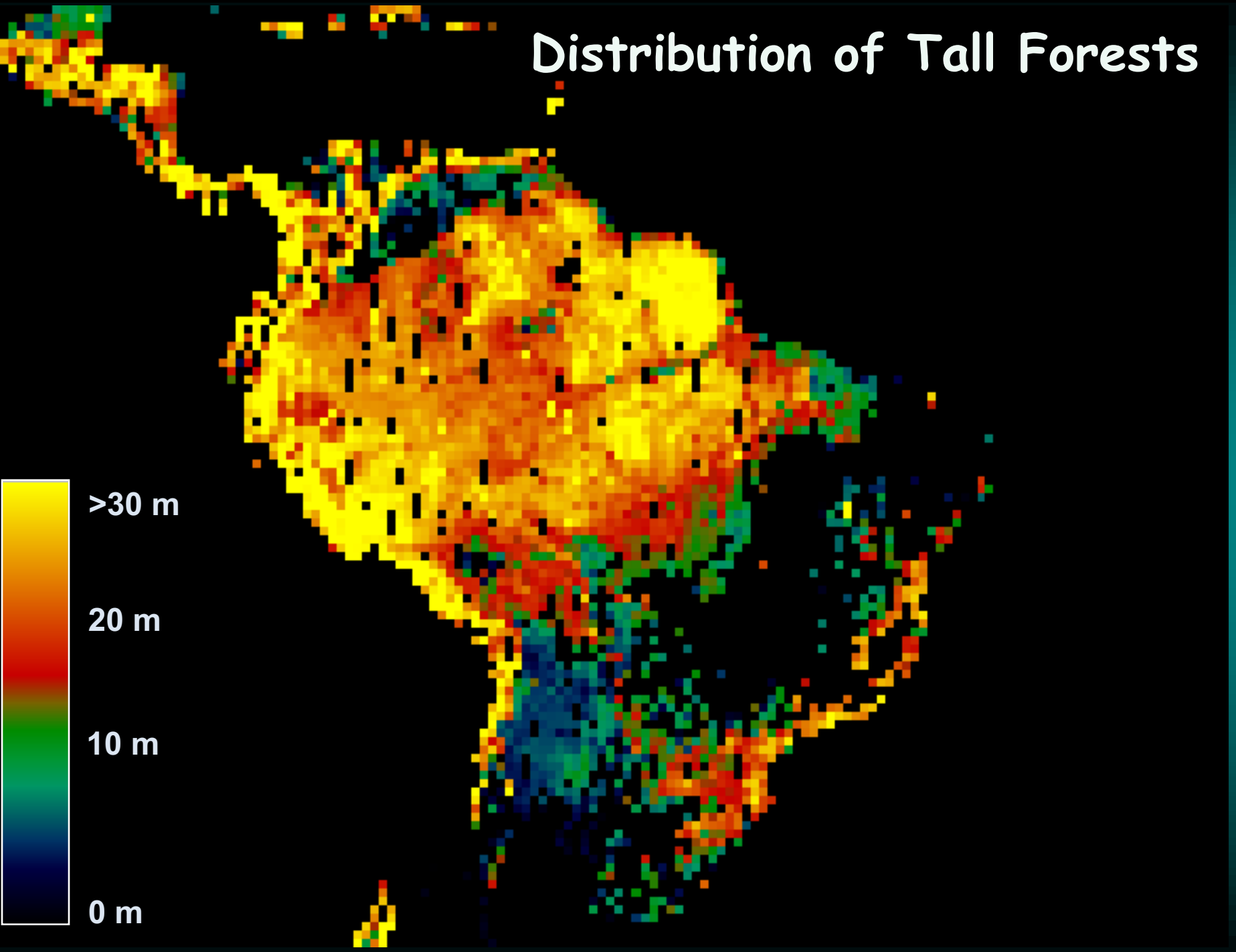

Height profile over landscape



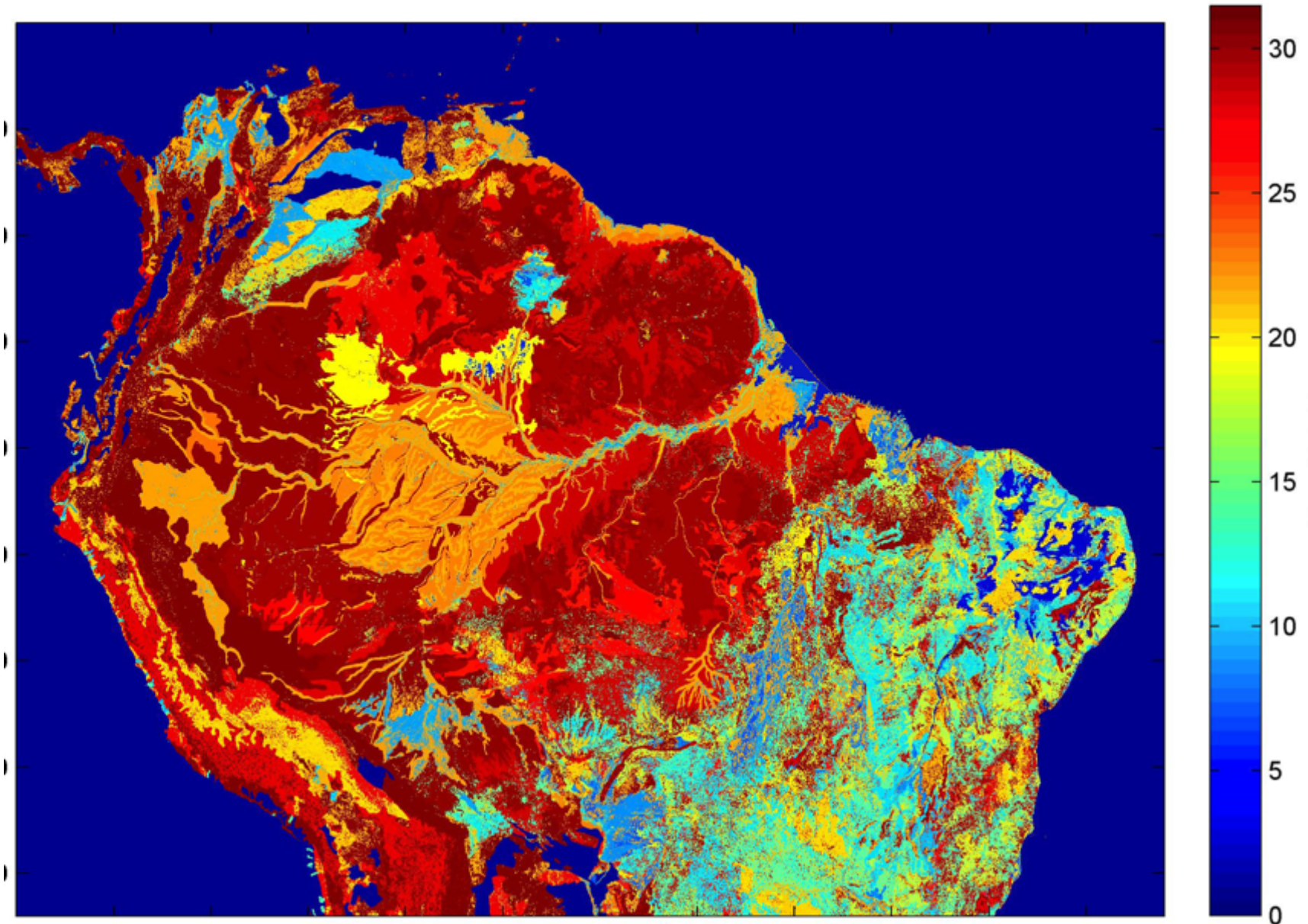


# Environmental Variability



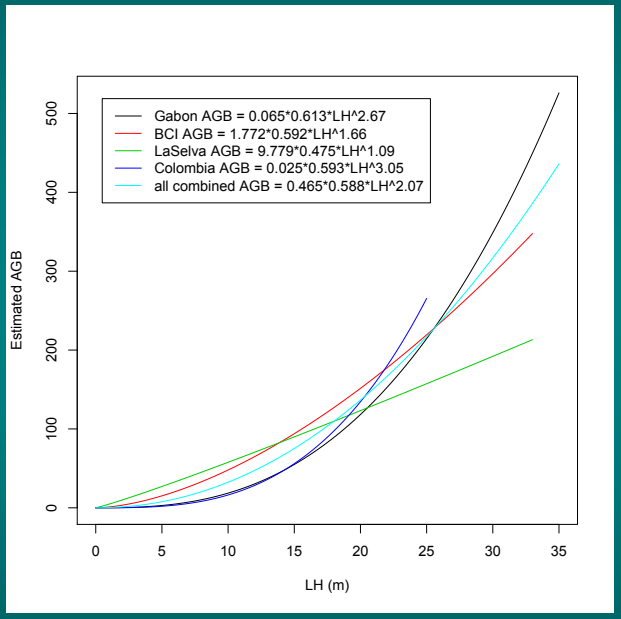

Distribution of Tall Forests
>30 m
20 m
10 m
0 m

# GLAS Lidar Mean Top Canopy Height Estimate of Amazon Basin



# Lidar Biomass Allometry

$$AGB = a\bar{\rho}h_{GLAS}^{b}$$

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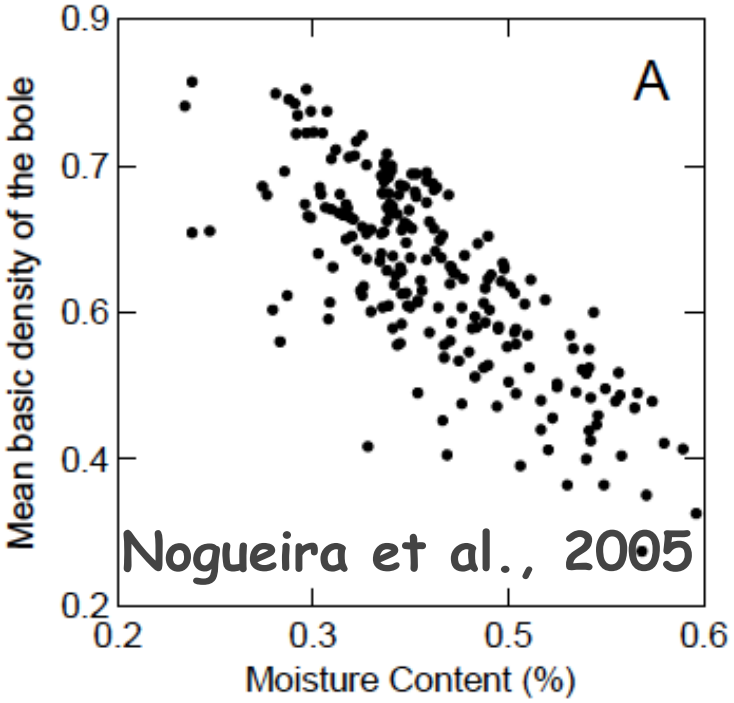
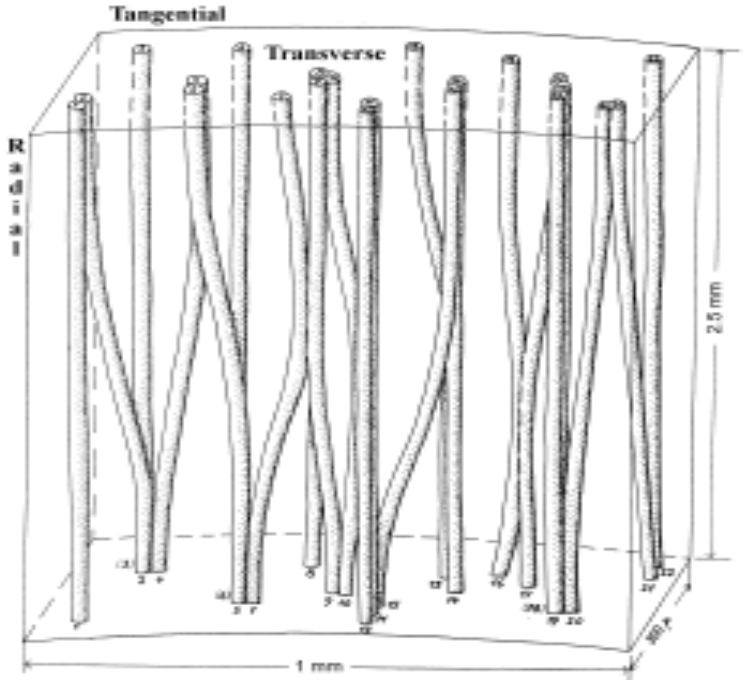
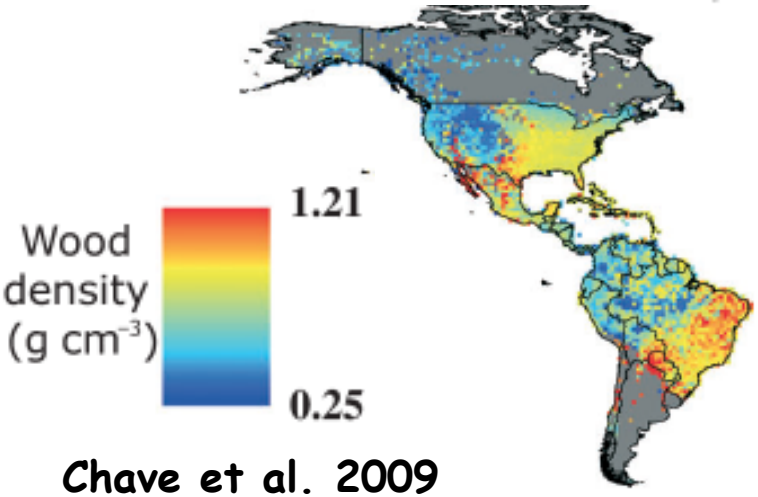
# Wood Density




Chave et al. 2009

# QSCAT Sensitivity to Canopy Water Content


$$\sigma_p^0 = \gamma_p [\frac{1 - \exp(-\alpha_p W_c \sec\theta)}{\sqrt{W_c}}]$$

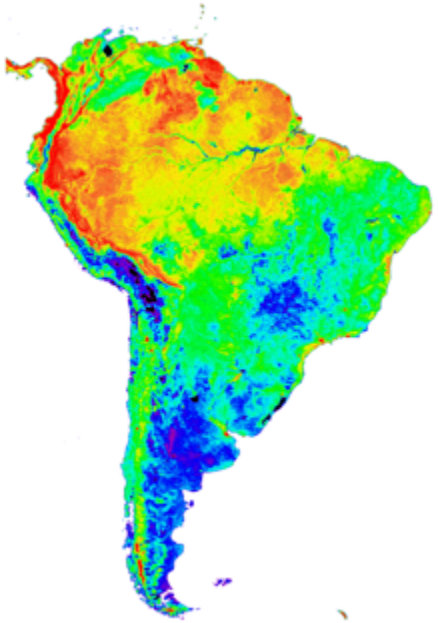
$W_c$ = canopy water content

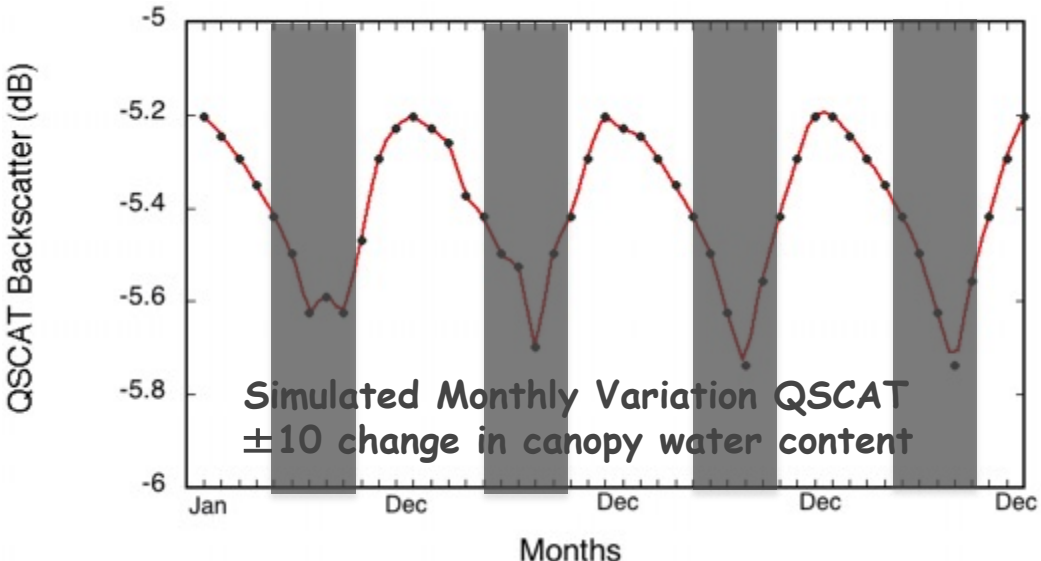
$\gamma_p$ and $\alpha_p$ : forest type calibration parameters

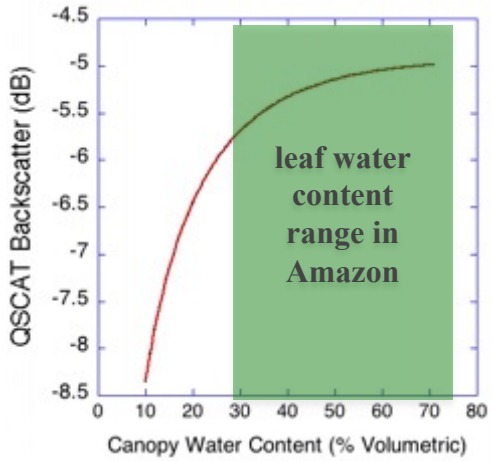
$p$ : polarization (H,V)

$d_c$ : canopy penetration depth

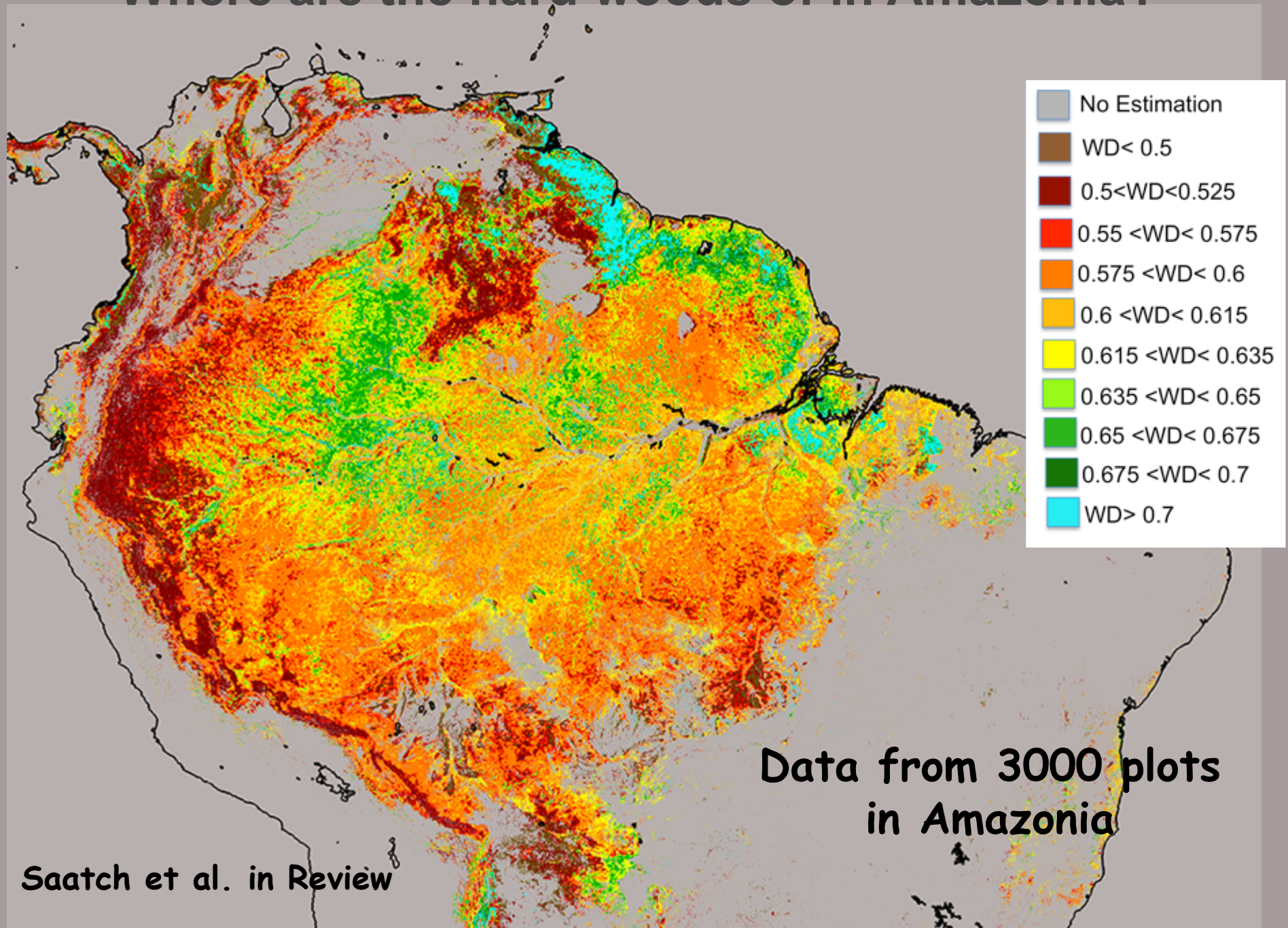


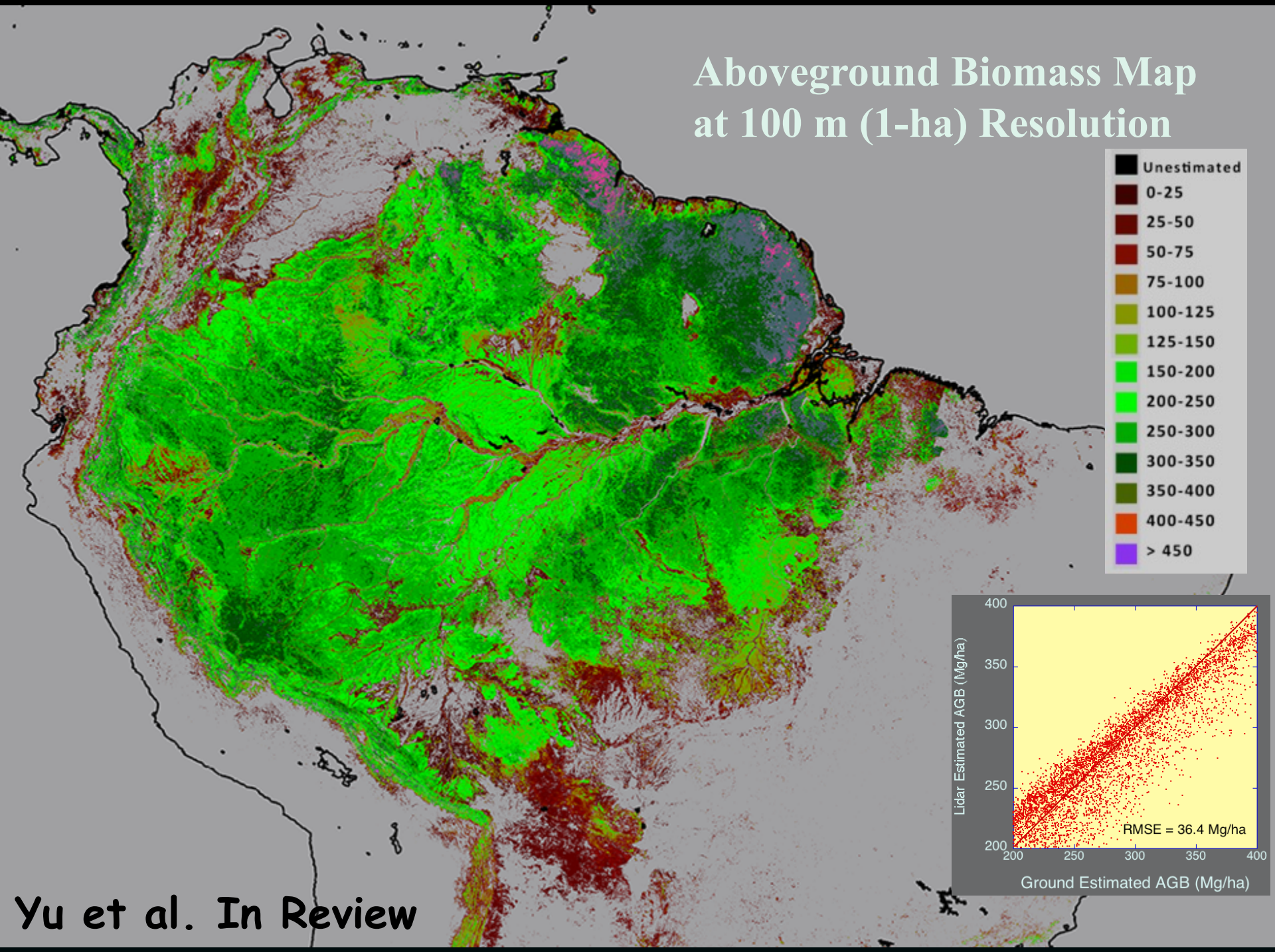



# Where are the hard woods of in Amazonia?



# Aboveground Biomass Map at 100 m (1-ha) Resolution




Yu et al. In Review