Mapping tropical biodiversity using high resolution spectroscopic imaging : from experimental acquisition to physical modeling

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Outline

I. Introduction

II. Illustration of the potential of imaging spectroscopy for mapping tropical biodiversity

III. 3D radiative transfer modeling for a physical interpretation of experimental results

IV. Conclusion & perspectives

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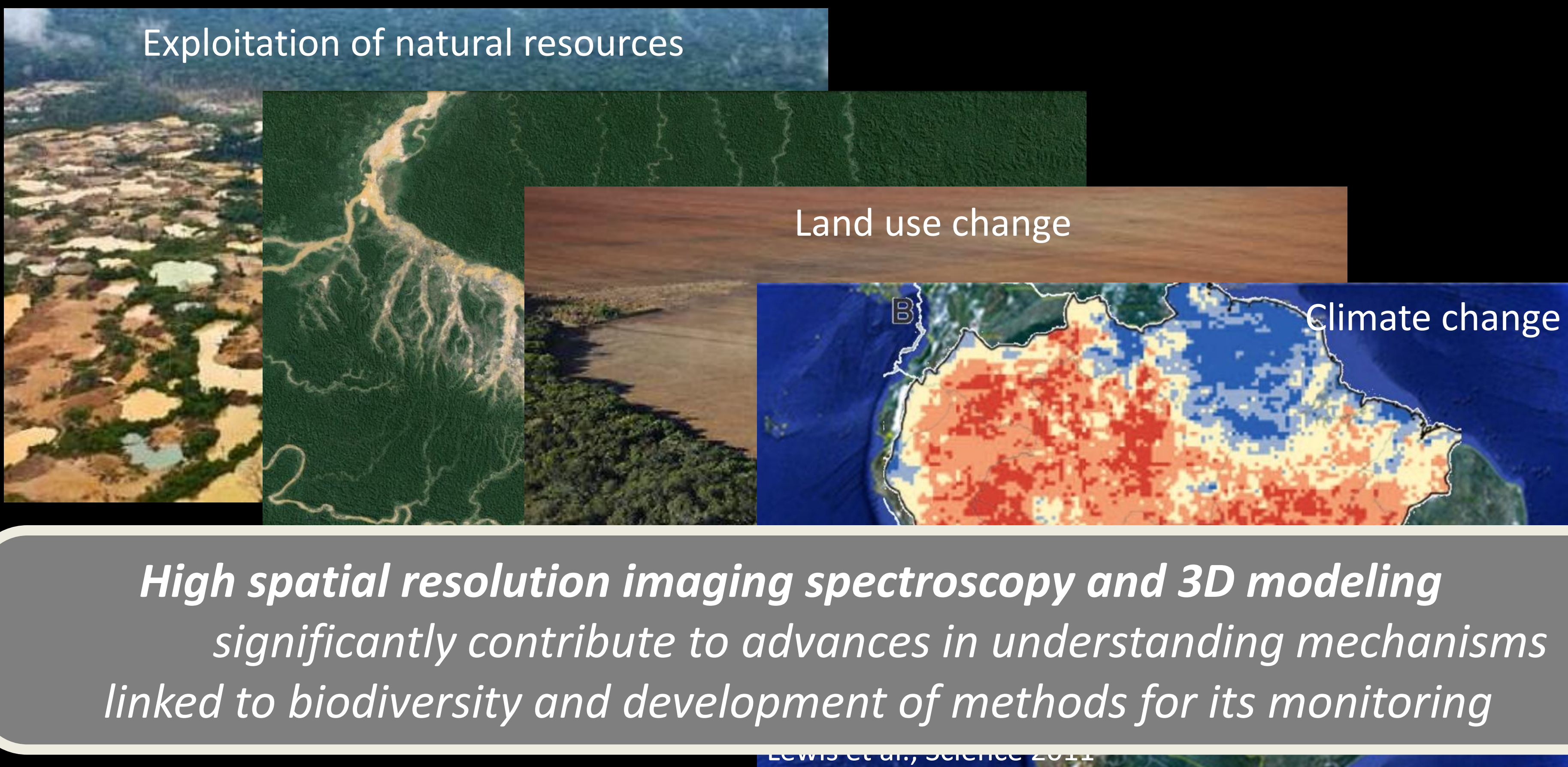
1. **Introduction**
2. Illustration of the potential of imaging spectroscopy for mapping tropical biodiversity
3. 3D radiative transfer modeling for a physical interpretation of experimental results
4. Conclusion & perspectives

Introduction : Context

Tropical forests contain most of the terrestrial biodiversity

The increasing rate of biodiversity erosion needs to be monitored and controlled



High spatial resolution imaging spectroscopy and 3D modeling
significantly contribute to advances in understanding mechanisms linked to biodiversity and development of methods for its monitoring

Introduction : Context

Many aspects of biodiversity may interest ecologists, depending on the goal and scale of applications :

- Presence / absence of particular species :

  → *Invasive / threatened / indicator species*

- Richness and abundance in species at local scale :

  → *α diversity*

- Spatial distribution of species communities :

  → *β diversity*

Fine scale mapping of these information allow comparison with other spatial and environmental information.

I. Objectives of this presentation

- Introduction of an unsupervised method for mapping of biodiversity in tropical forests using airborne imaging spectroscopy

__HyperTropik : preparation of the vegetation applications for HYPXIM satellite mission (CNES)__

- Physical interpretation of information used to map biodiversity
- Determination of limit conditions for the estimation of biodiversity
- Refinement of instrumental specifications for HYPXIM mission

→ Radiative transfer 3D-modeling performed with DART

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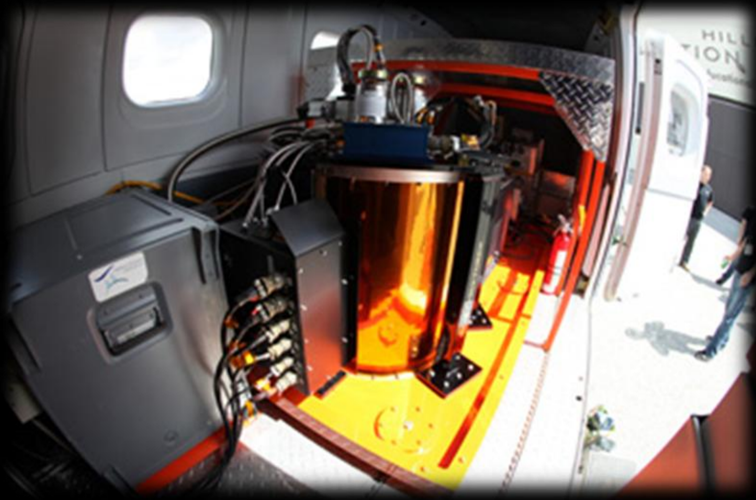
<u>*AToMS*</u>

(Airborne Taxonomic Mapping System)



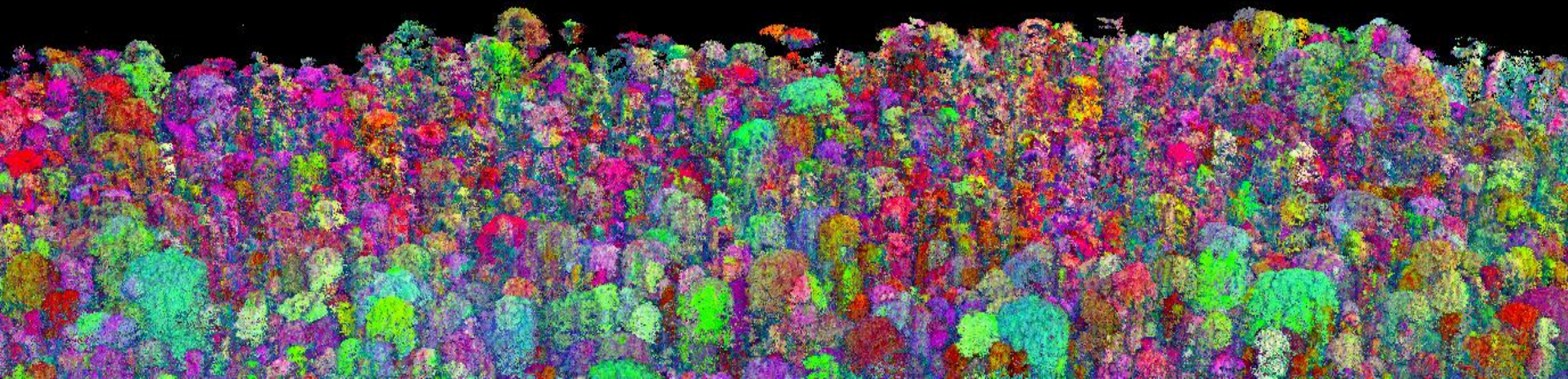
Carbon mapping

Canopy chemistry

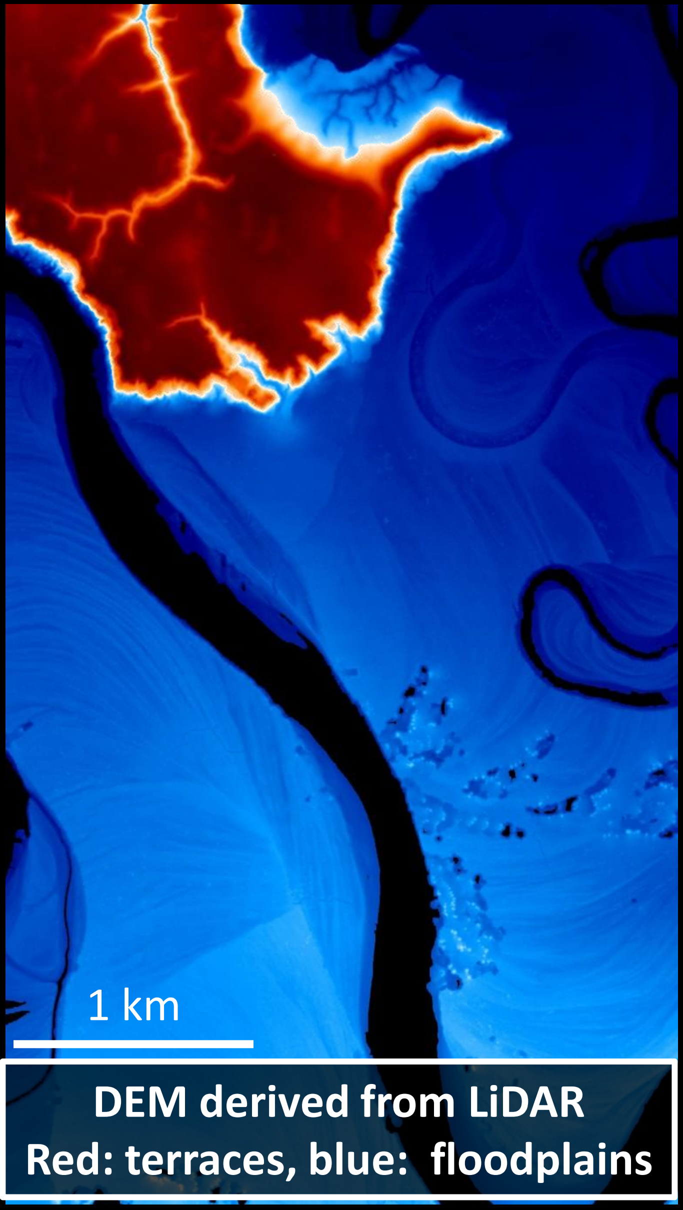
Species identification

Canopy structure

…



Spectroscopic imaging to map tropical biodiversity



Spectroscopic imaging to map tropical biodiversity

Material :

- Airborne acquisition over Amazonian Peruvian forest :

→ spectroscopic imaging + LiDAR

- Field plot network :

→ 100 + plots (0.14 ha) inventoried (DBH>10cm) in different forest types (floodplains to mountainous areas)

Methods :

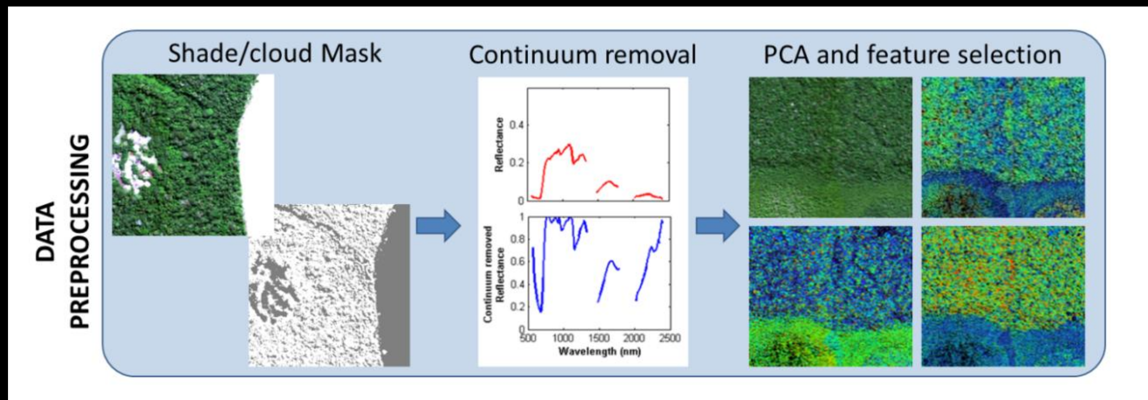
- Based on Spectral Variation Hypothesis (Palmer et al., 2002)
- Define "**spectral species**" based on segmentation of landscape's spectral space

Mapping products :

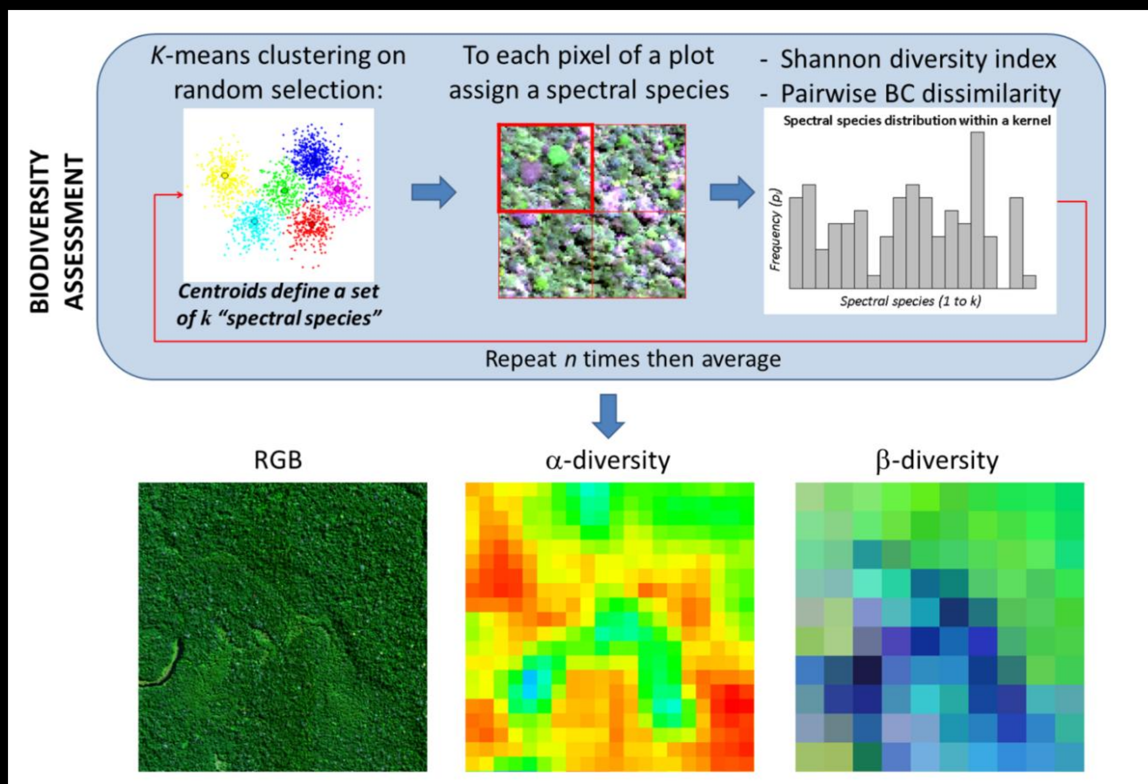
→ α ***diversity :*** Shannon index → β ***diversity :*** Bray-Curtis dissimilarity

Spectroscopic imaging to map tropical biodiversity : Spectral Species Distribution (SSD)

PREPROCESSING



ESTIMATION of BIODIVERSITY INDICES

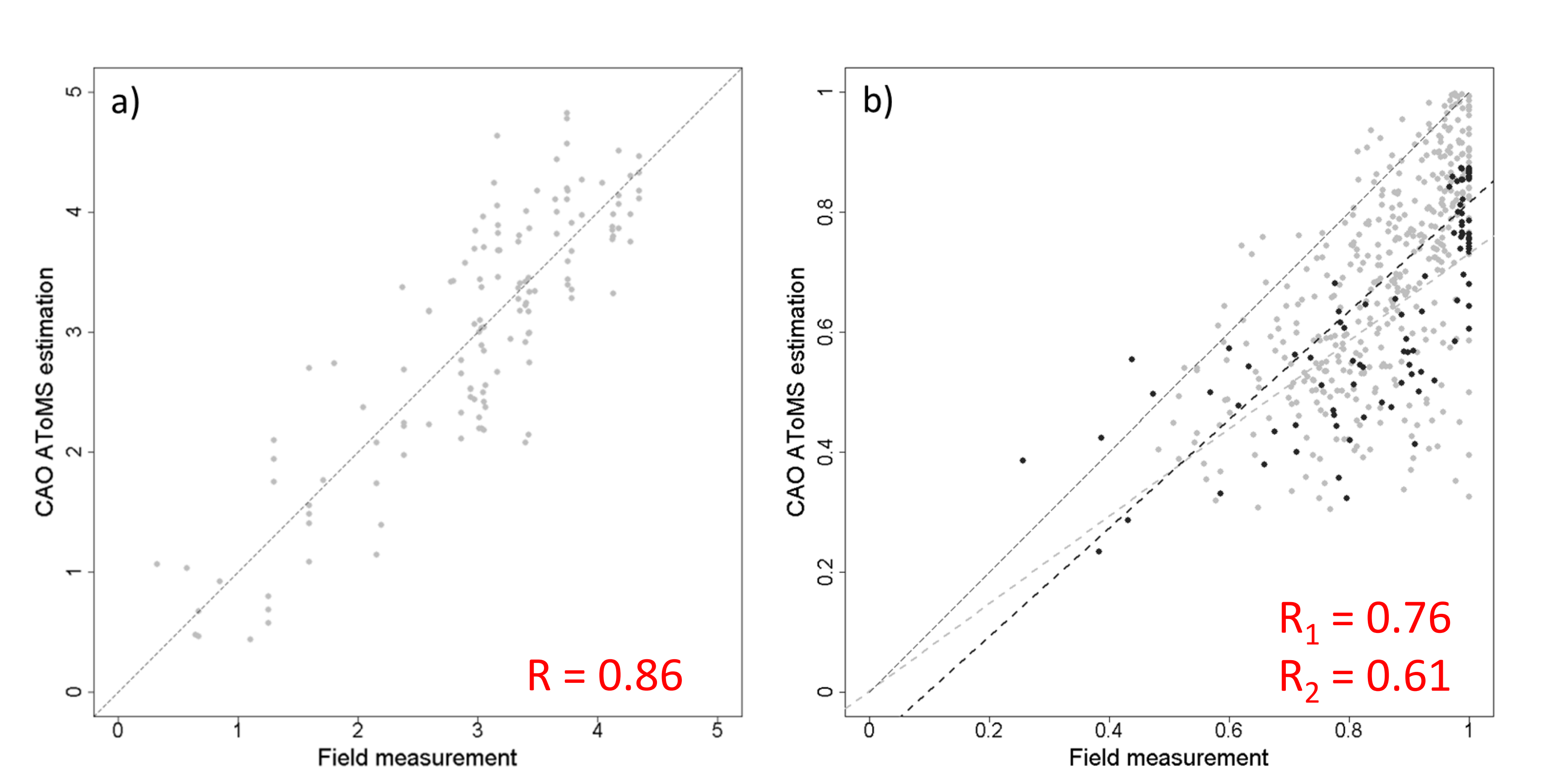


Féret & Asner, 2014 (Ecological Applications)

Spectroscopic imaging to map tropical biodiversity : Validation of the method

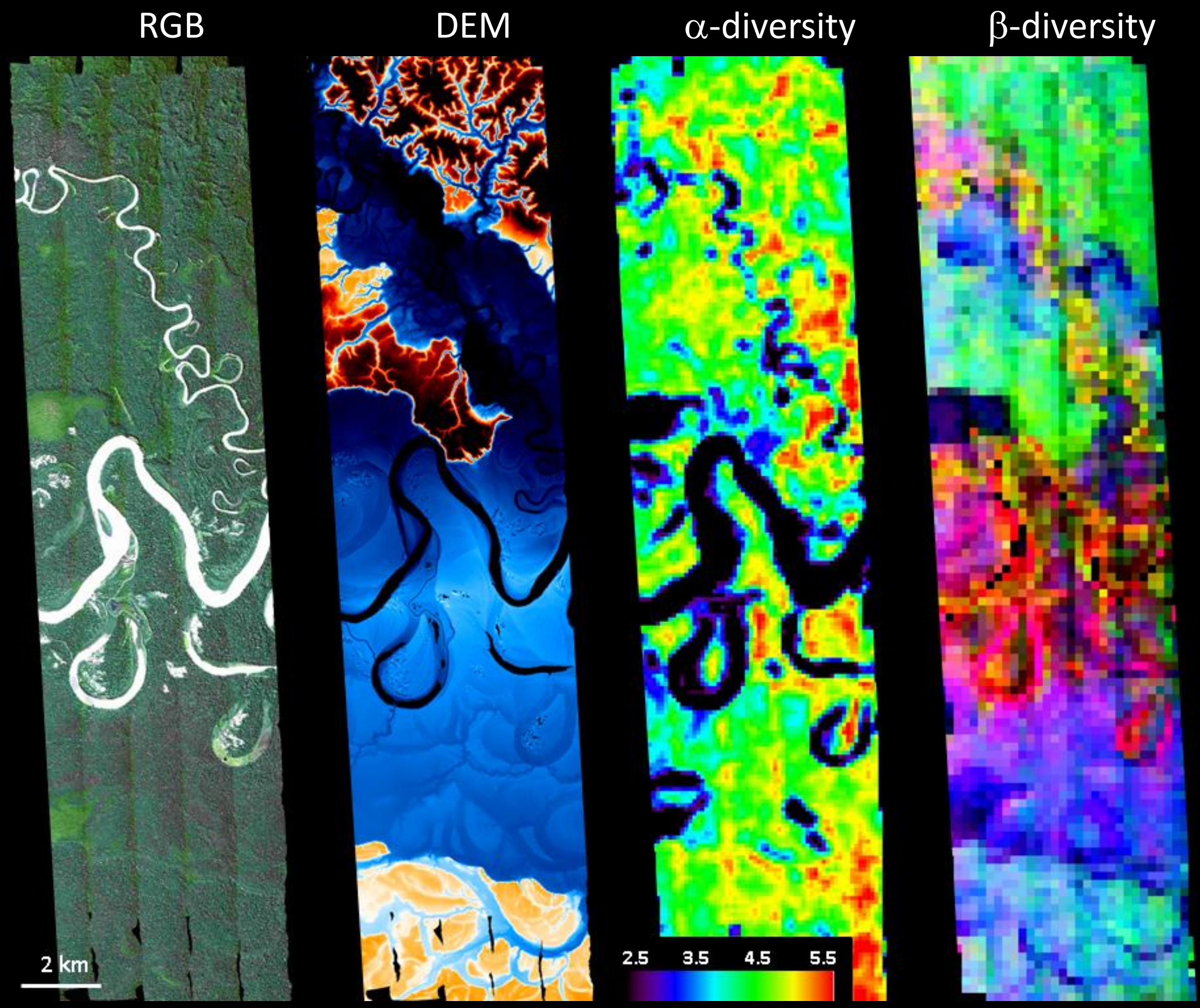
α diversity (Shannon index)
153 plots

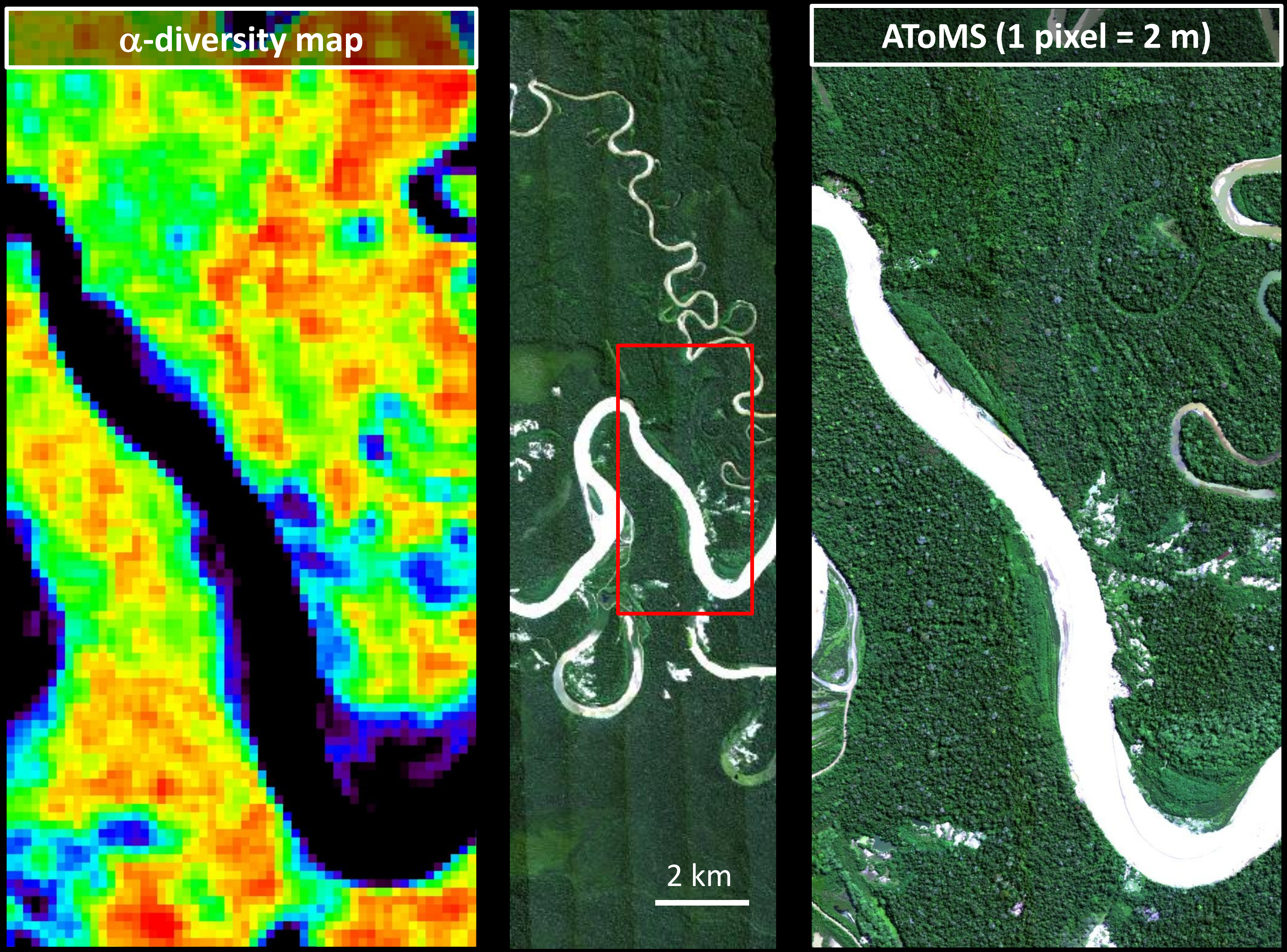
β diversity (Bray-Curtis dissimilarity)
91 + 496 pairs of plots (2 sites)



→ **Outperforms other existing methods**

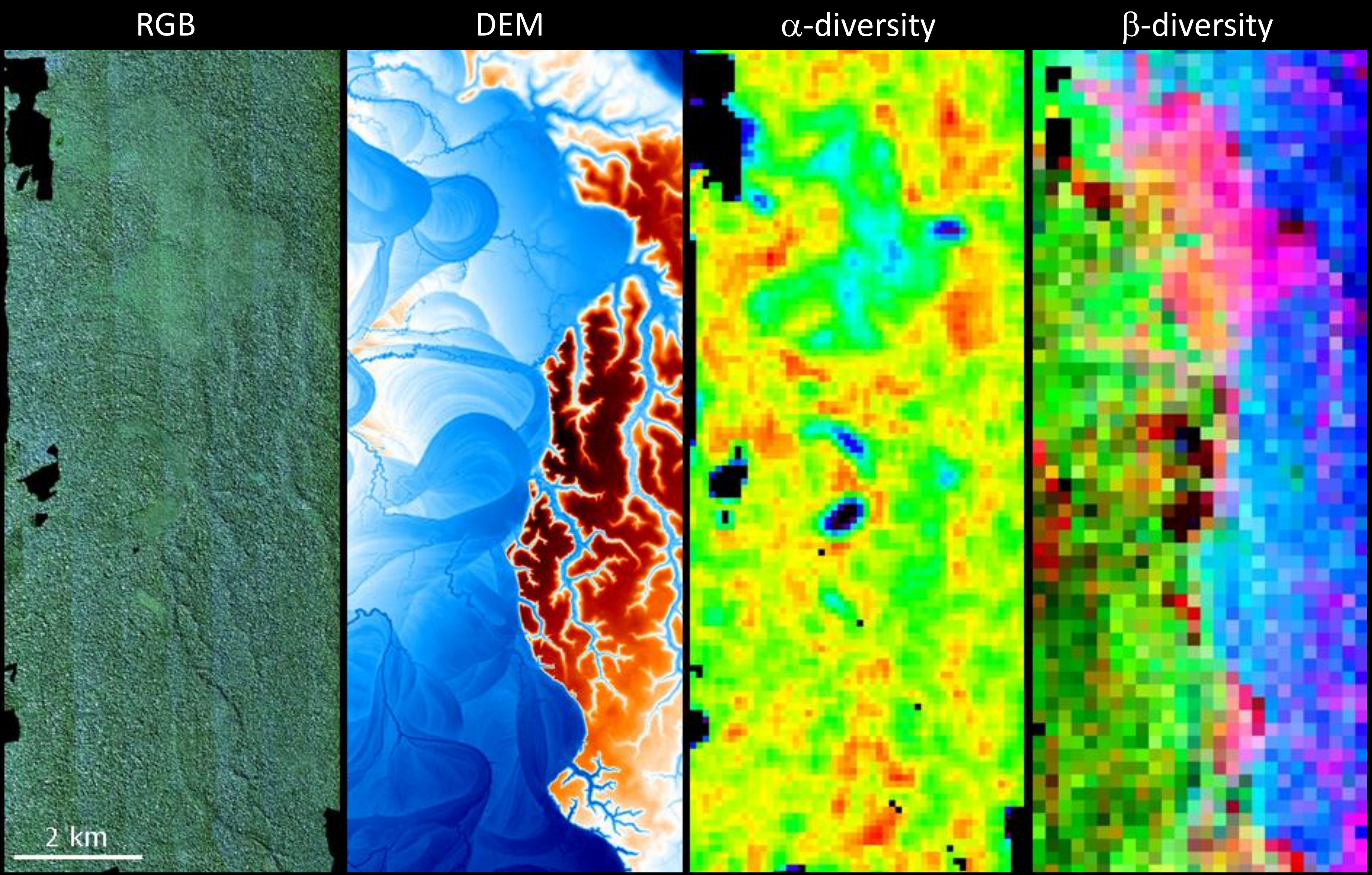
Application to experimental data: CICRA





α-diversity map
2 km
AToMS (1 pixel = 2 m)

Application to experimental data: Chuncho



Details about the site: Asner & Martin, 2011 (New Phytol.)

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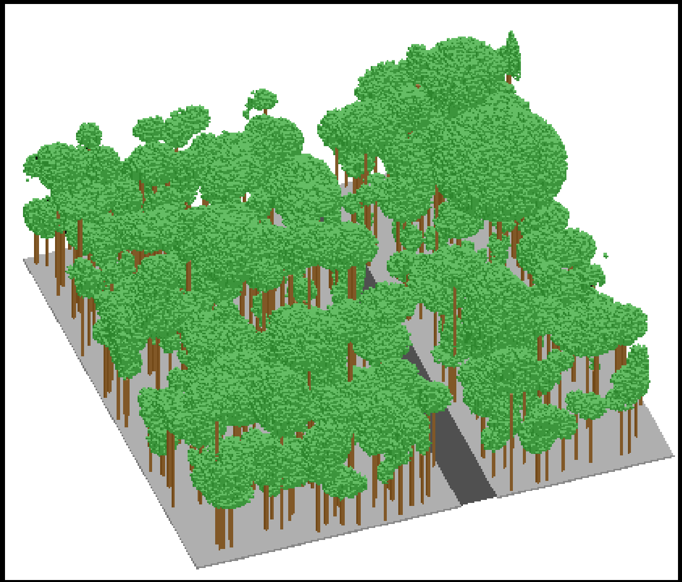
3D radiative transfer modeling of tropical biodiversity



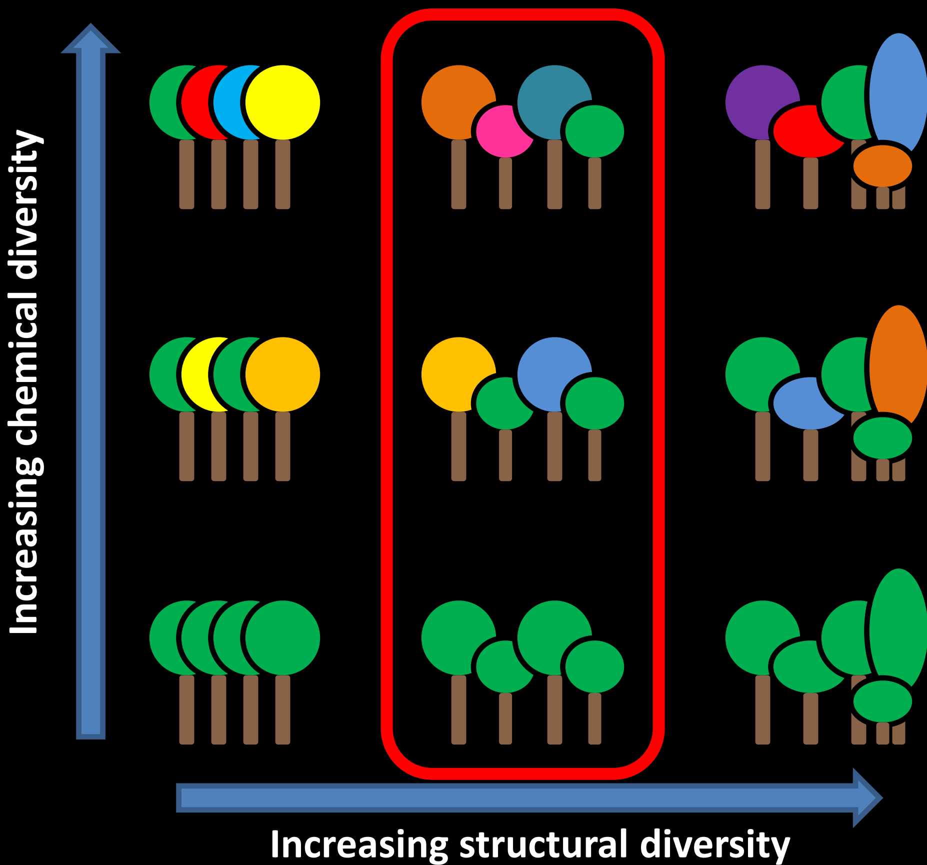
Maquette

Simulation

- Better understanding and interpretation of vegetation / light interactions
- Methodological improvement
- Test limit conditions of developed methods
- Test robustness to experimental conditions (sun direction, topography, atmosphere, biodiversity)
- Test robustness to instrumental characteristics (spatial & spectral resolution, spectral sampling, viewing direction)

3D radiative transfer modeling of tropical biodiversity

Sensitivity study of the relative contribution of biophysical canopy variables (leaf chemistry and density, individual tree structure) :



At first, within individual variability is not taken into account

Application of existing methods :

- Segmentation
- Classification
- Statistical regressions
- Inversion

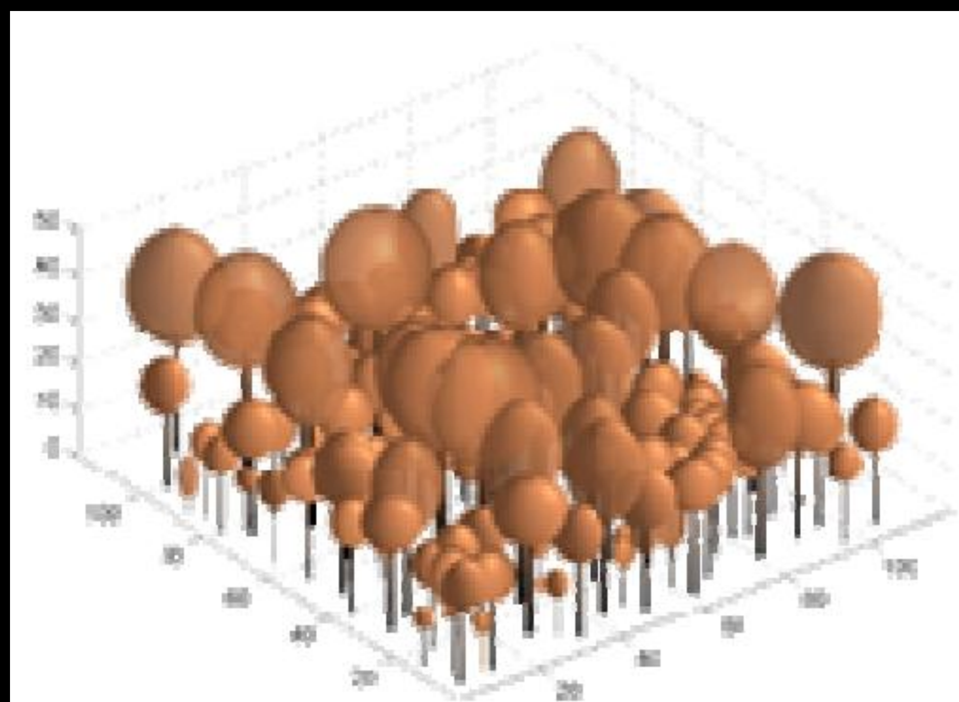
Then :

- introduction of within-individual variability
- Addition of new diversity gradients (topography, conditions of acquisition, …)
- Integration of available field data

3D radiative transfer modeling of tropical biodiversity

Maquette used during our sensitivity study :

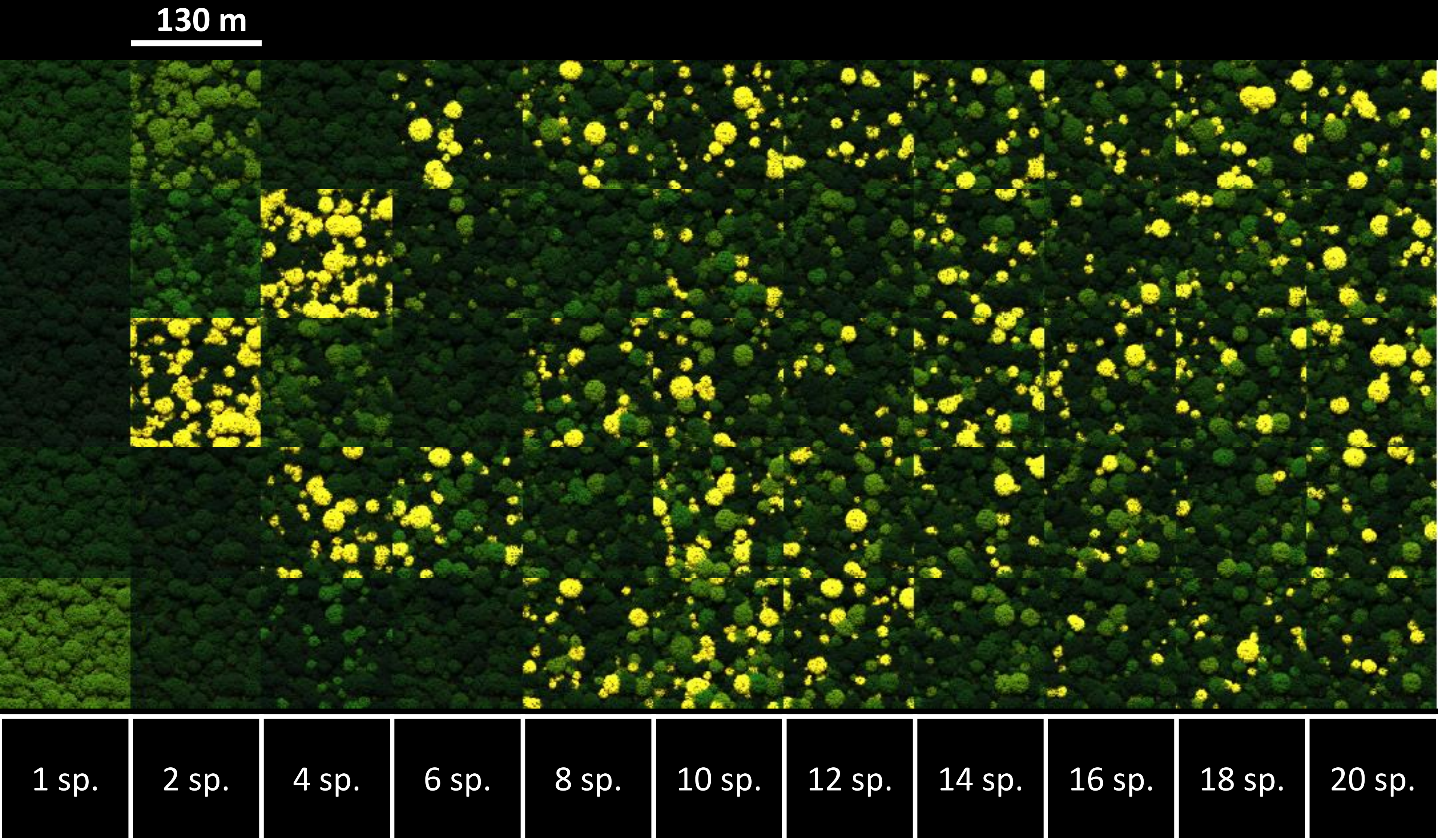
- Spatial and structural distribution of trees common to all simulations
- Each species is defined based on its optical properties
- Leaf optical properties simulated using PROSPECT-5 based on leaf chemistry derived from experimental data
- Biodiversity : 1 to 20 species per simulation, randomly distributed



Proisy et al. (2012) : Biomass Prediction in Tropical Forests: The Canopy Grain Approach

3D radiative transfer modeling of tropical biodiversity

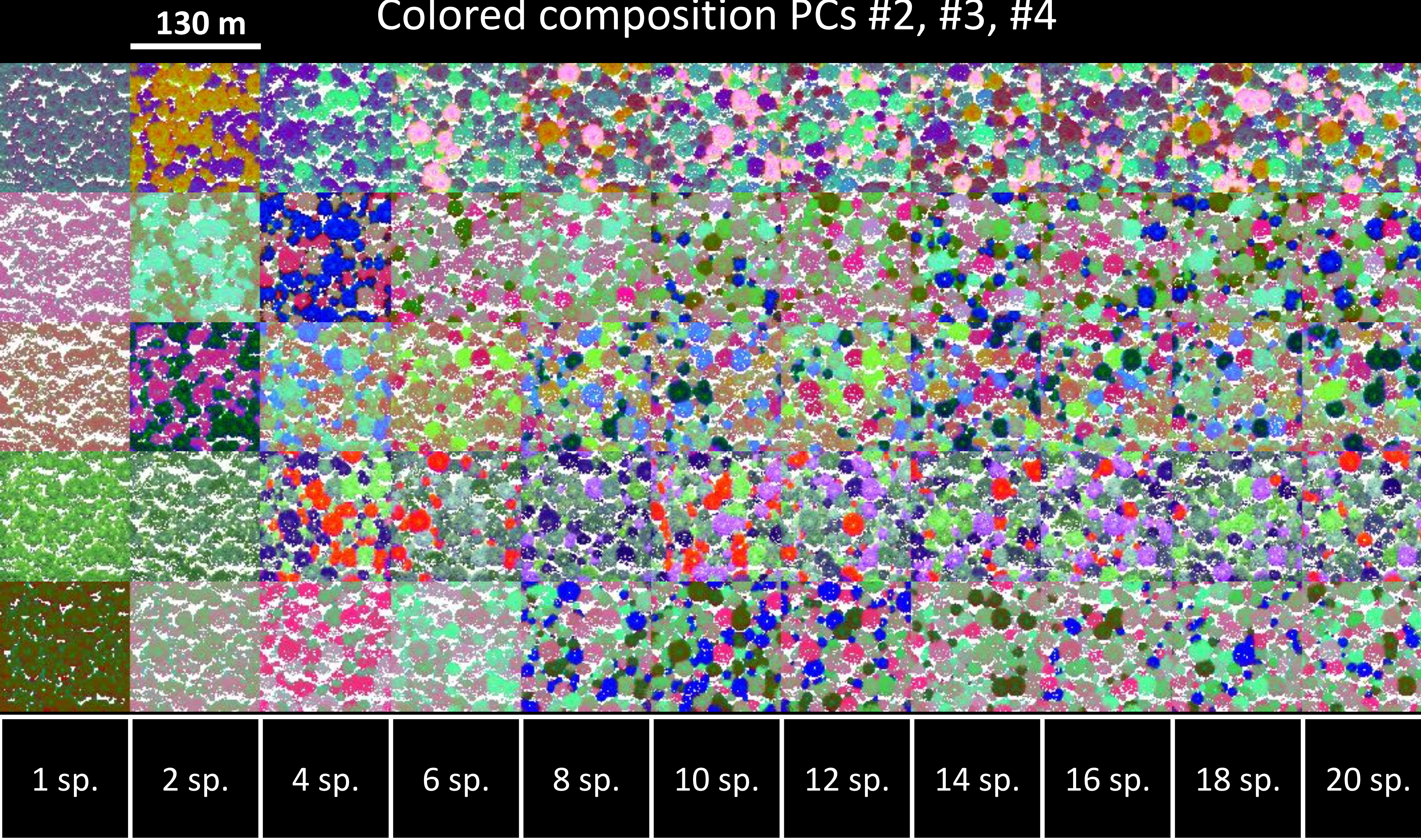
Bottom Of Atmosphere



3D radiative transfer modeling of tropical biodiversity

Bottom Of Atmosphere

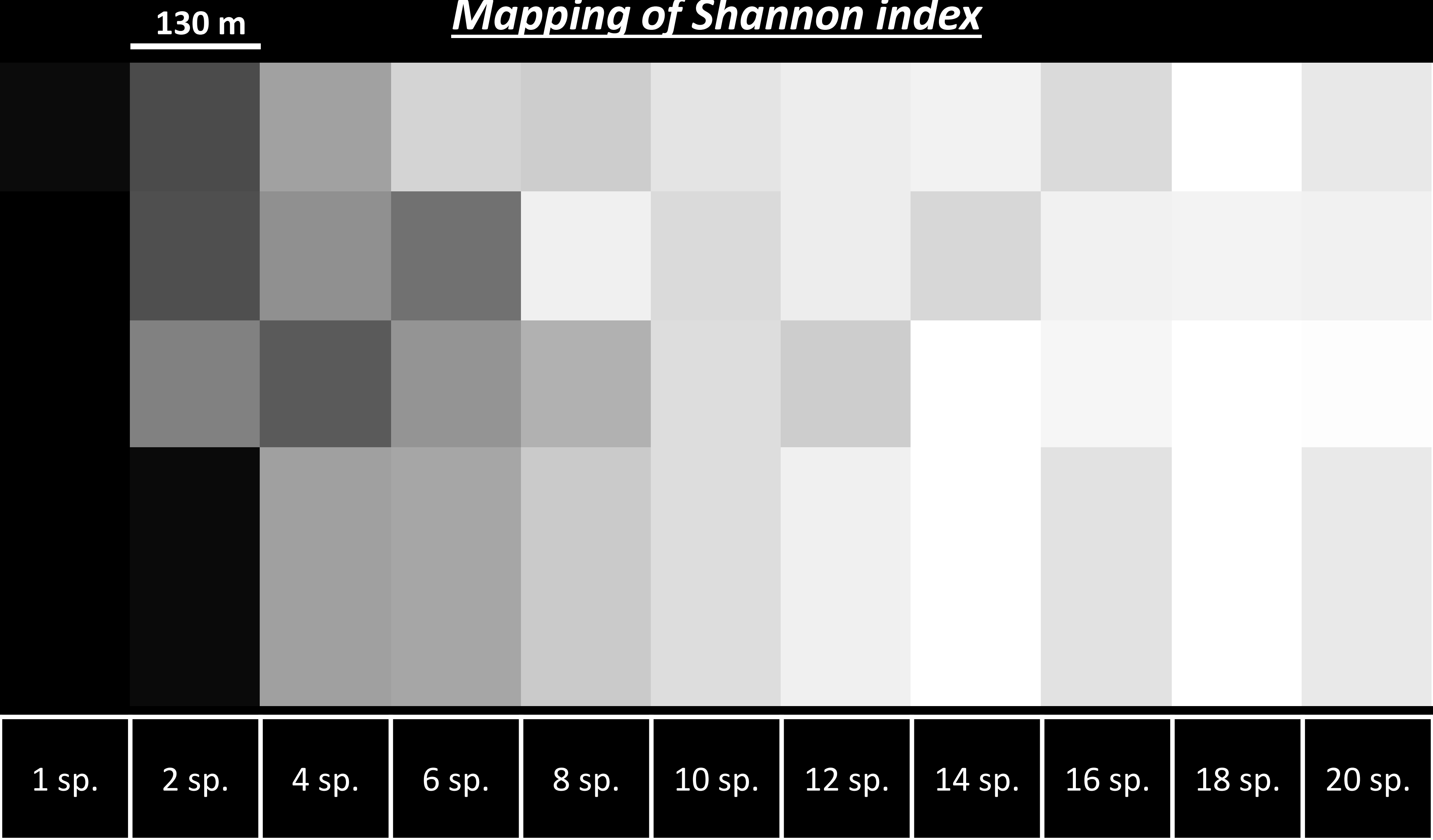
Colored composition PCs #2, #3, #4



3D radiative transfer modeling of tropical biodiversity

Bottom Of Atmosphere

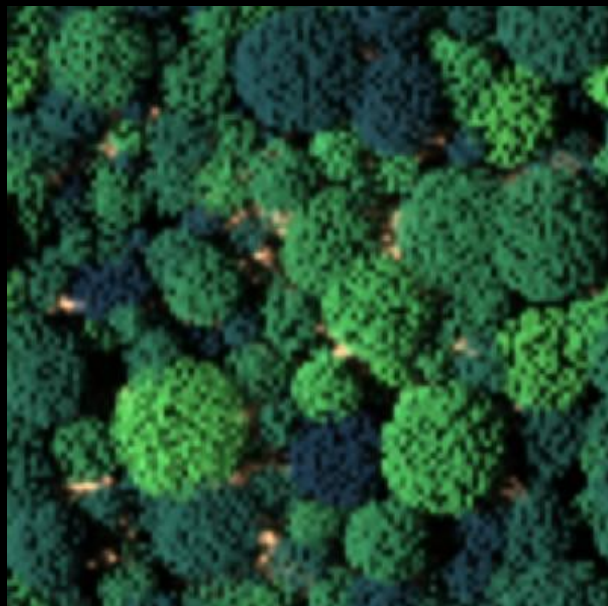
Mapping of Shannon index

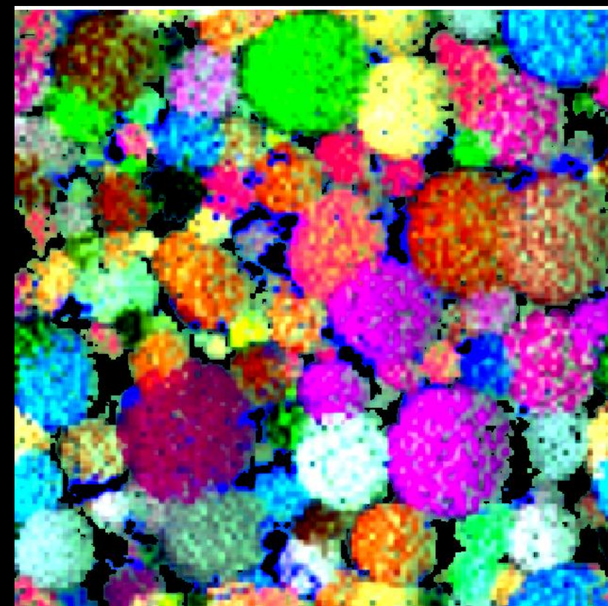


Unraveling spectral characteristics

RGB composition | PCA (comp #2, 3, 4)

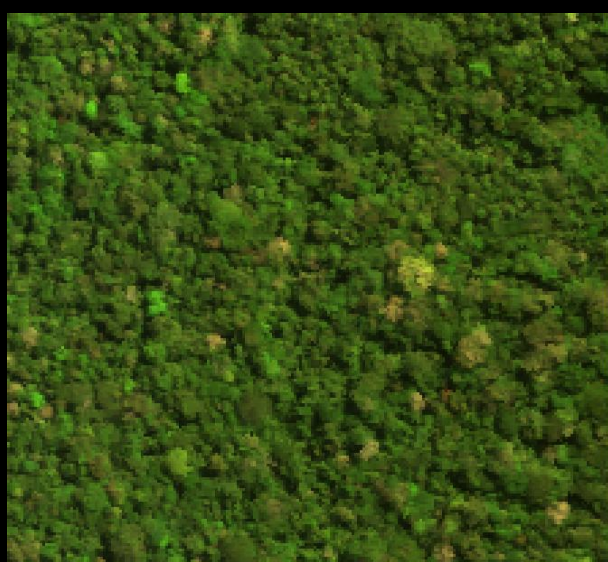
DART simulation

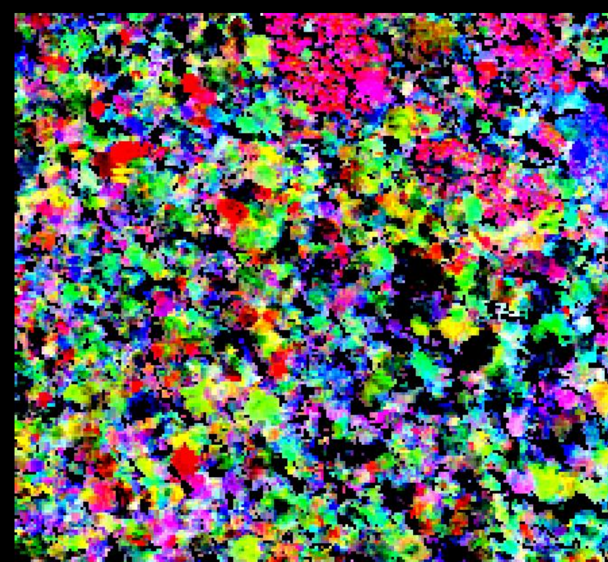




1 ha,
25 cm
spatial
resolution

CAO data



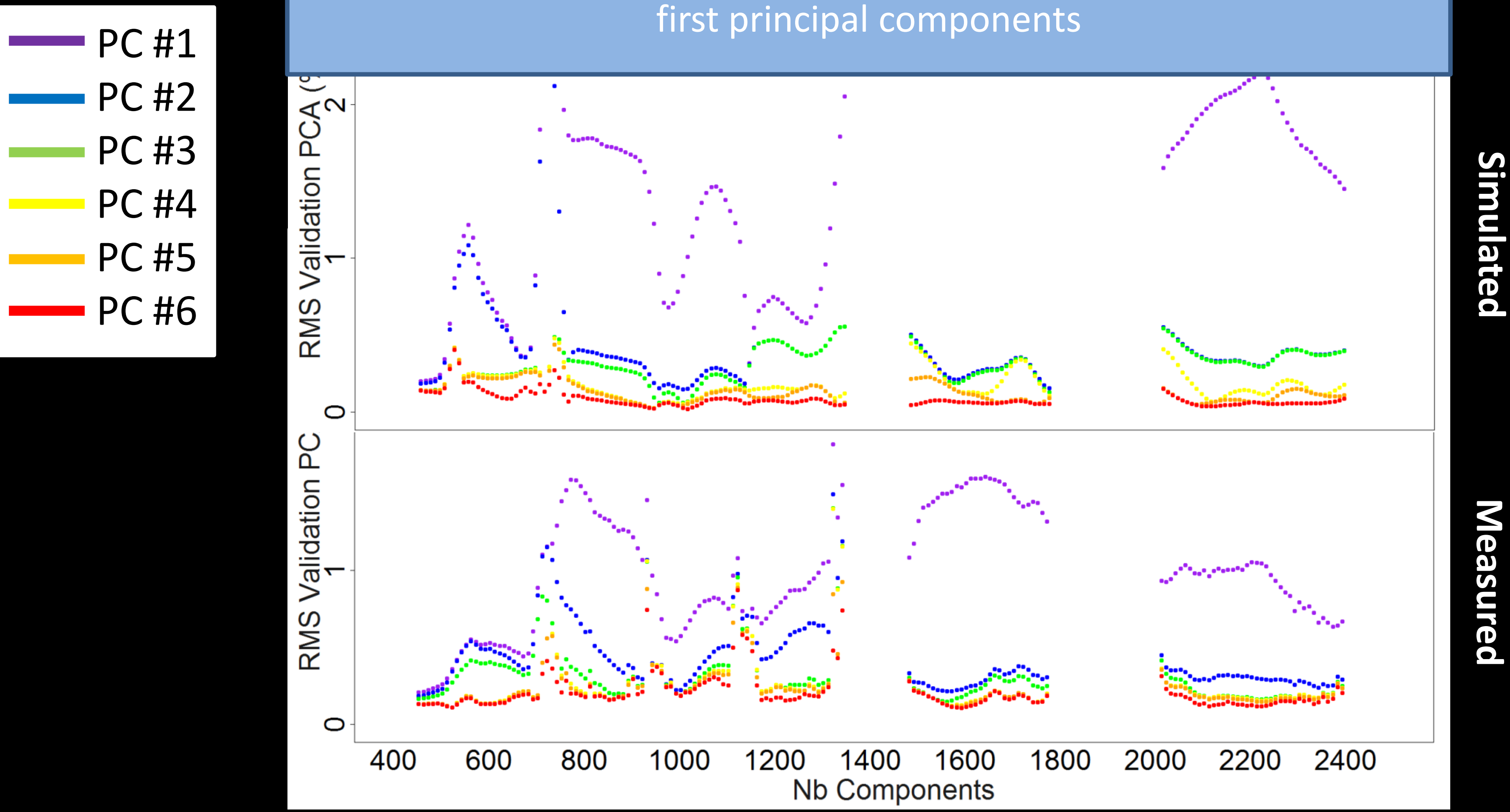


25 ha,
2 m spatial
resolution

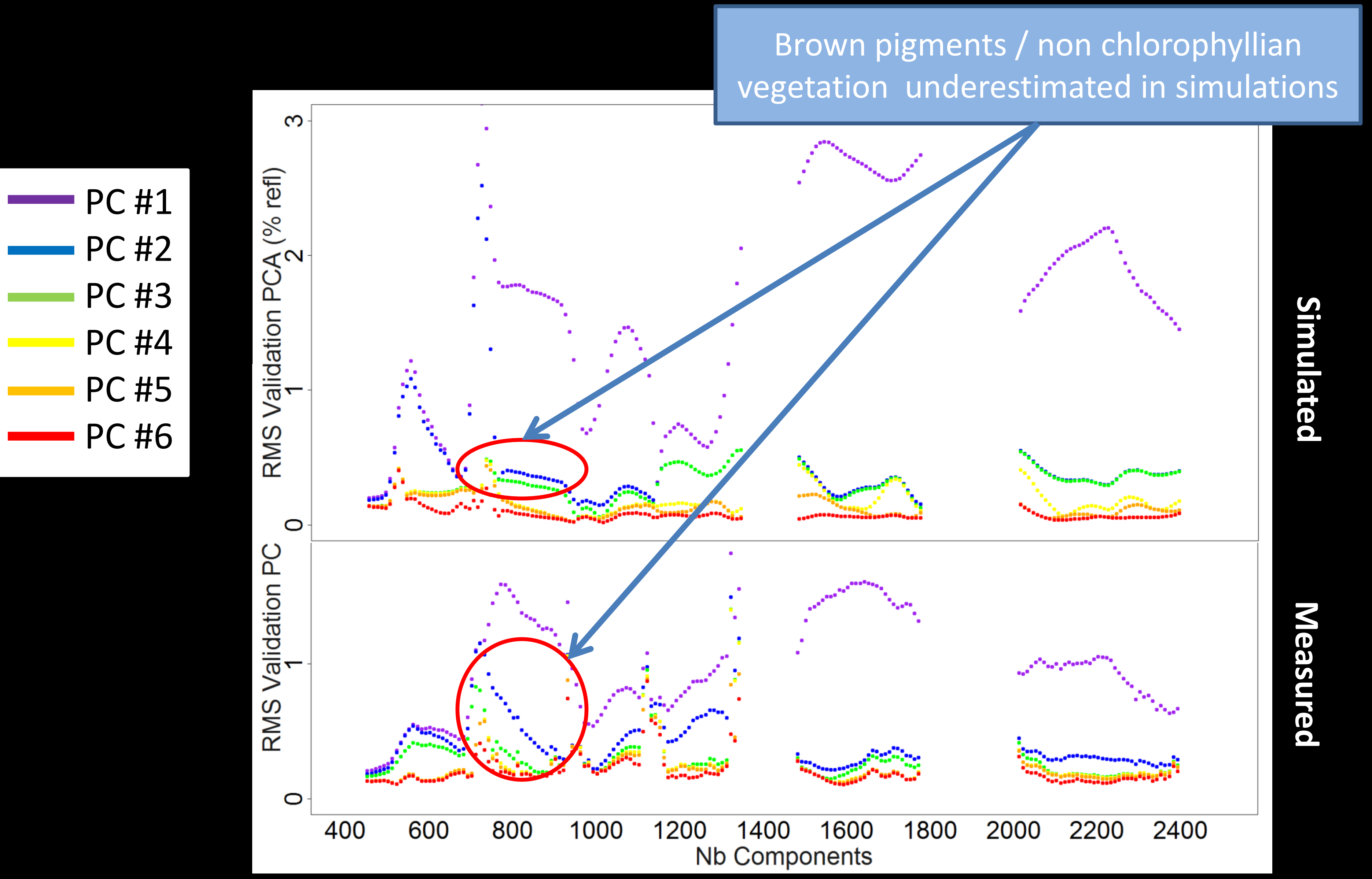
Unraveling spectral characteristics

Validation of PCA model (compare simulated / experimental data)

Spectrum reconstruction of an independent dataset based on 1 to 6 first principal components

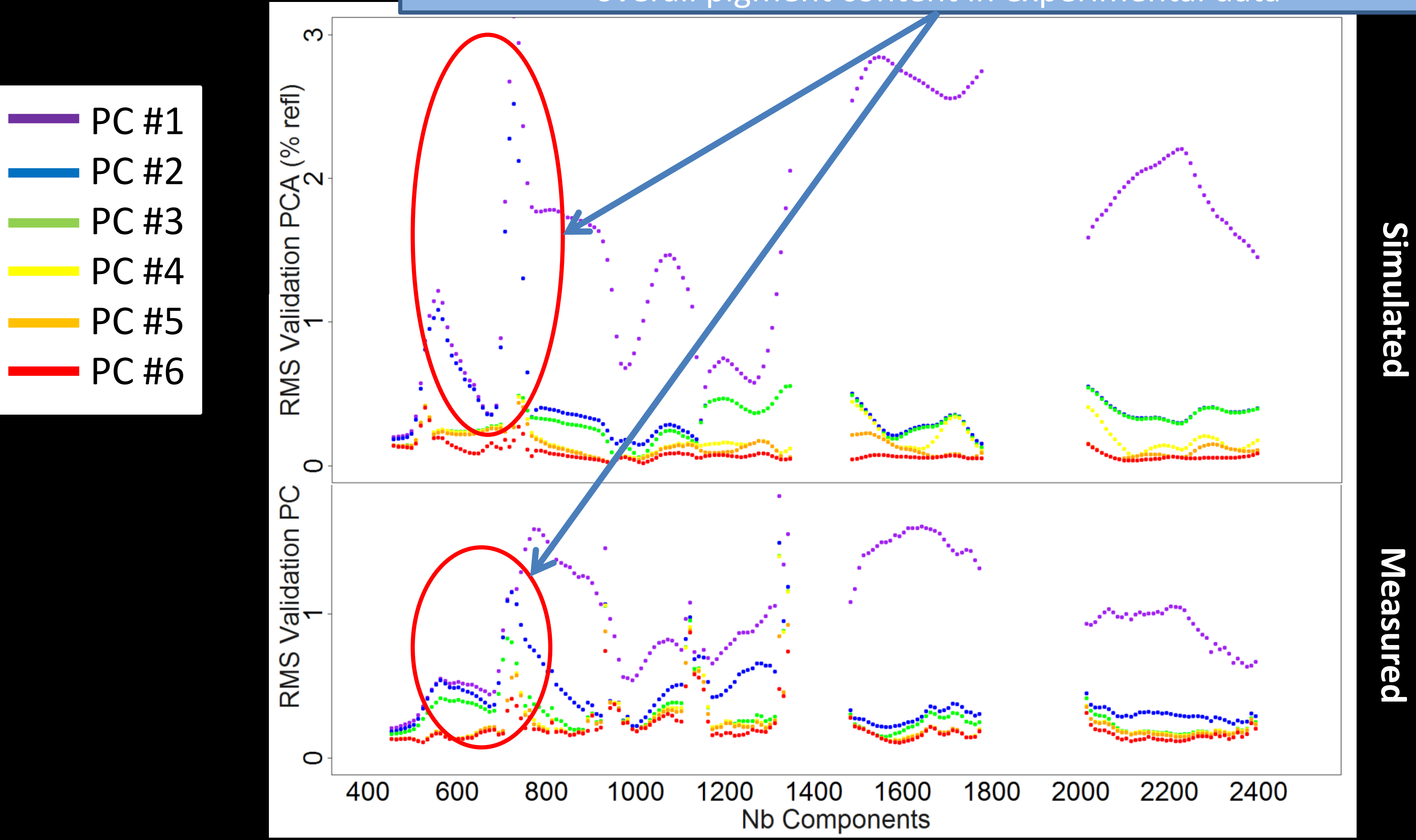


Unraveling spectral characteristics



Unraveling spectral characteristics

Lower variability of Red Edge and VIS domain in experimental data.
Possible explanation: either lower range of variation or higher overall pigment content in experimental data



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Conclusions and perspectives

- Validation of biodiversity mapping with experimental data shows that our method outperforms other existing methods

However :

- Low availability of experimental data and validation plots makes extensive sensitivity studies complicated or impossible
- The preparation of the spatial mission ***HYPXIM*** *(study of tropical biodiversity)* requires :

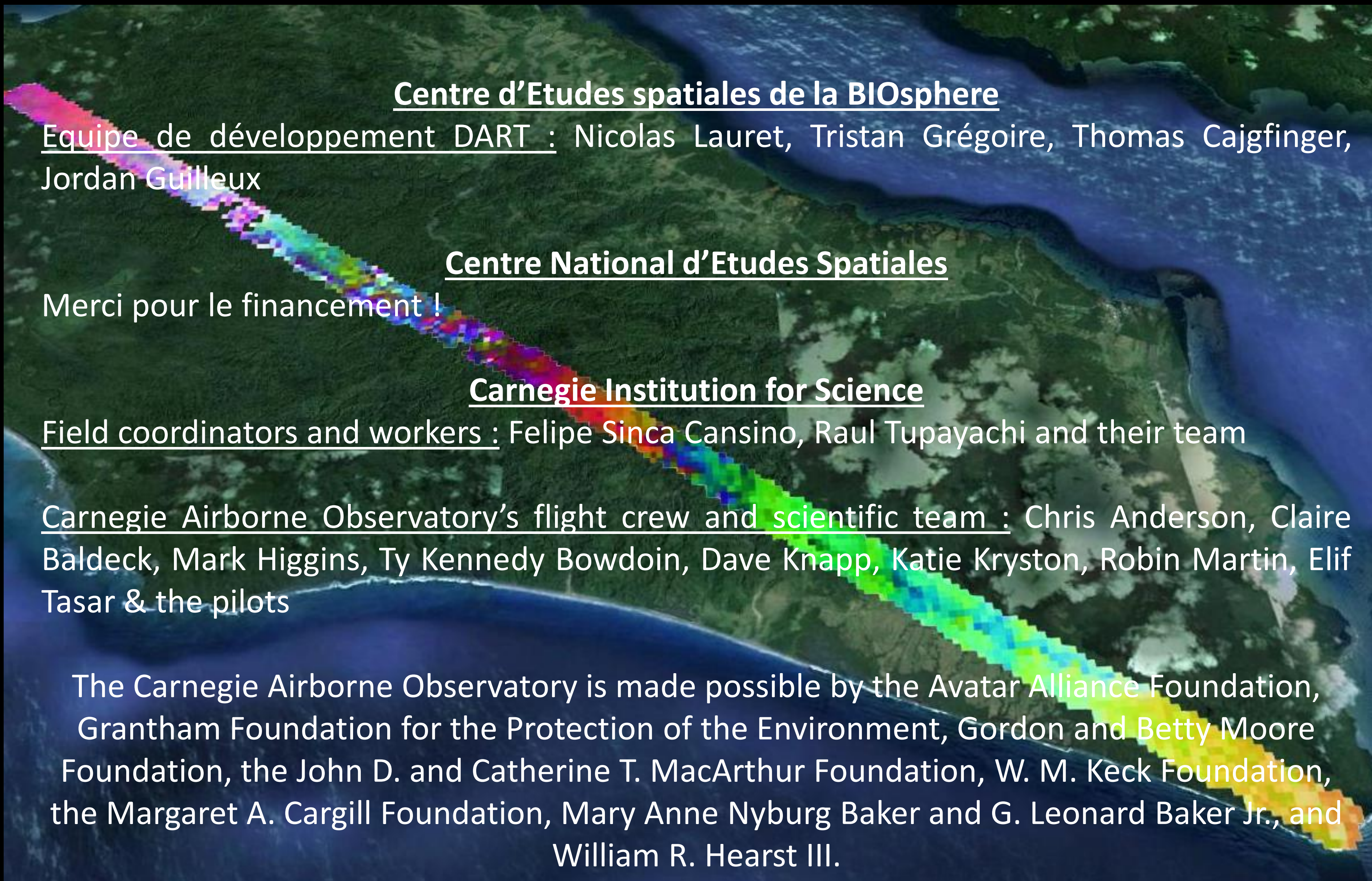
i) Better definition of factors linking biodiversity and radiometric measurements to improve preprocessing : ***physical interpretation***

ii) Intensive sensitivity studies to prepare spatial acquisitions

Conclusions and perspectives

- First results show good qualitative agreement between experimental acquisitions and modeling, however efforts are required to produce more realistic / detailed maquettes
- TOSCA (2014) funded the development of DART and field data collection to improve maquettes
- Need to explore potential of other data sources (Sentinel 1 & 2, Spot) for the mapping of tropical biodiversity

Acknowledgements



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