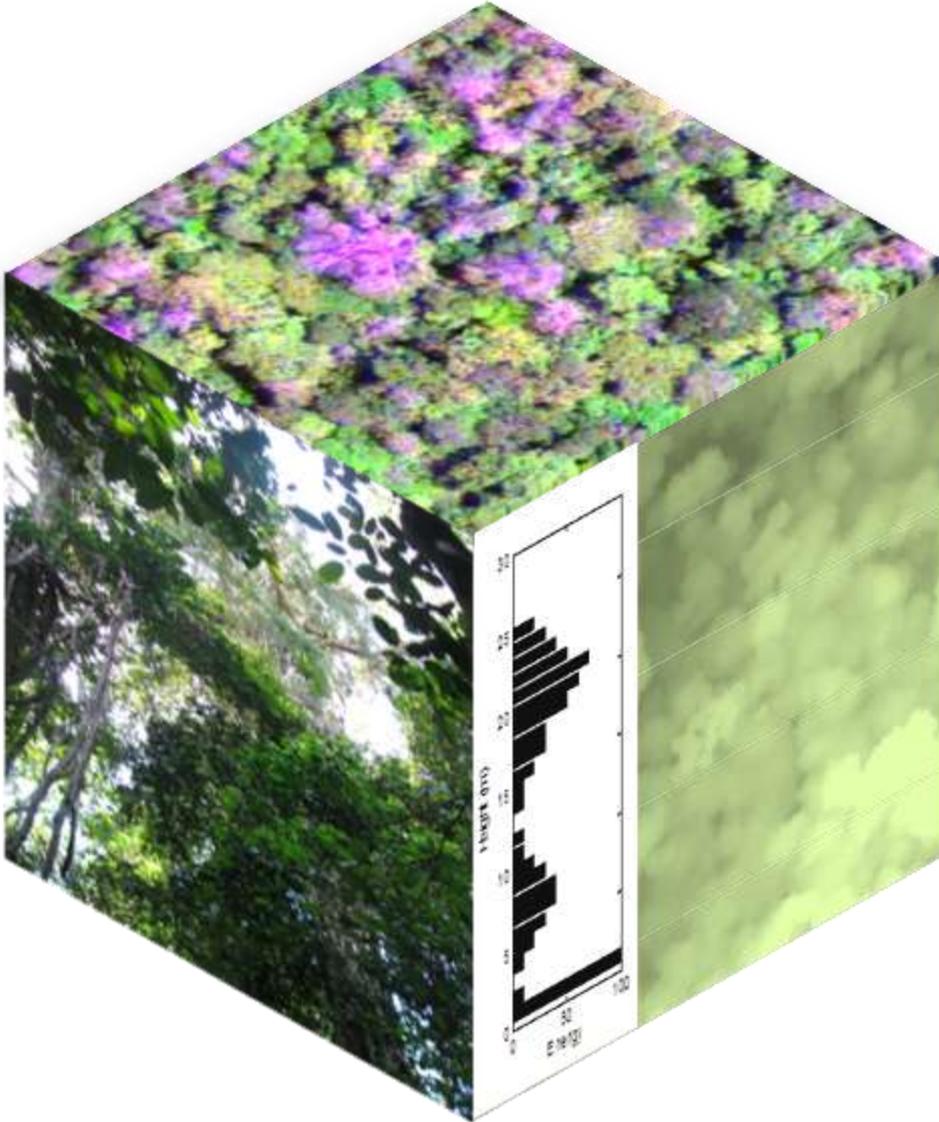


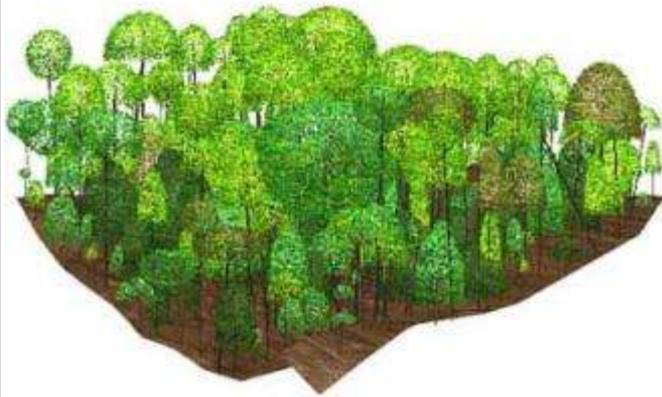
Prospects

- Combine (nested):
 - Regional: **Hypertemporal**;
 - Local:
 - **Hyperspatial**,
 - Penetrating signals (Radar/Lidar);
 - **Very local**: detailed Ground data (incl. 3D, e.g. TLiDAR).
- Need of Biological & Physical models



A biological / physical modelling framework

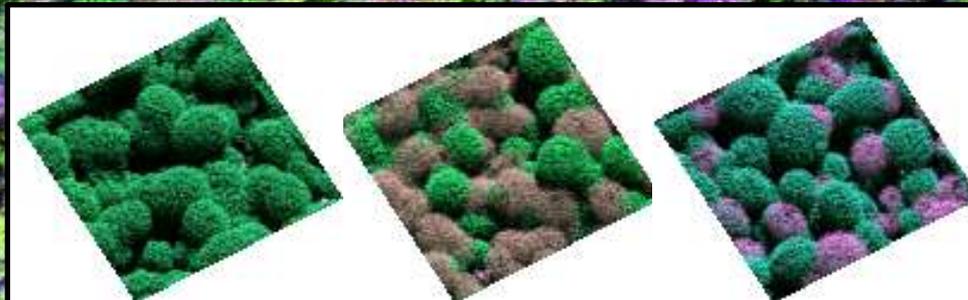
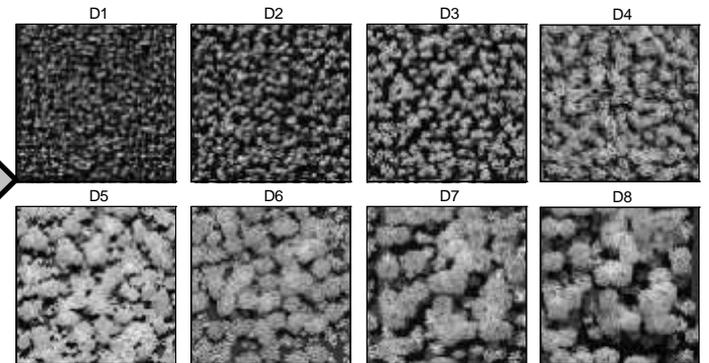
3D stand models



Radiative transfer
(DART)

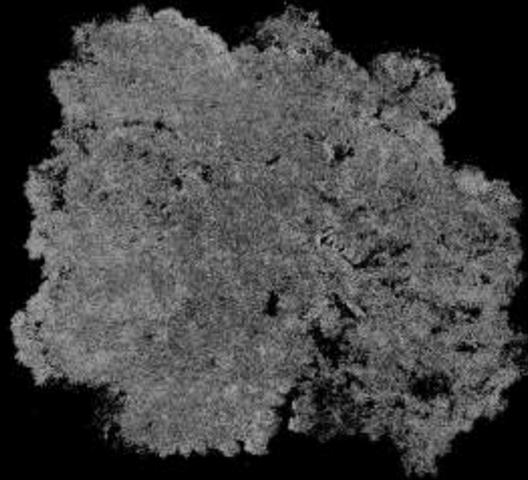


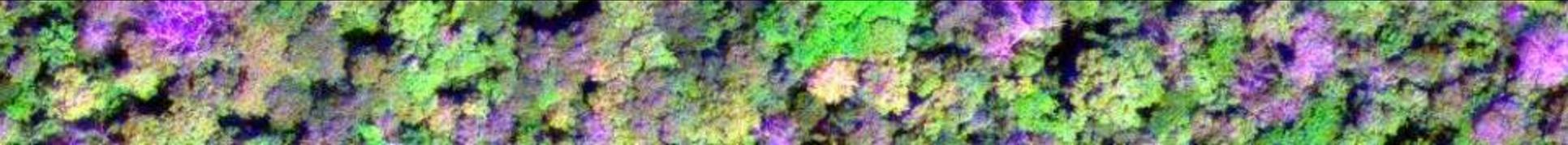
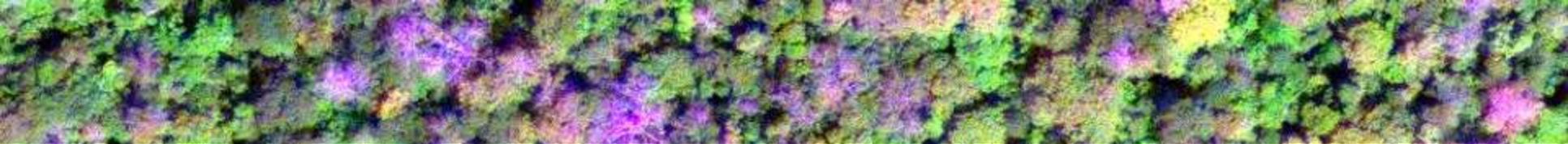
Canopy images



Tree architecture: Towards better scene modelling

- [Stereophotogrammetry](#)
- TLiDAR





Quantifying structure

- Approaches in spatial statistics for grid data (e.g. Images or regular series) :
 - **Structure**: delineate patches and analyse their shape properties.
e.g. size, area, perimeter,...
 - **Texture**: Quantify spatial correlation.
e.g. auto-correlation, variography, spectral analysis.

Quantifying structure

Spectral analysis

Partition of variance into frequencies using periodic (sine/cosine) functions

Particularly appropriate for periodic patterns

Quantify dominant wavelengths (regularity) and orientations (symmetry)

Powerful, well known properties yet rarely used in Ecology

A gridded series of values (quantitative)

$$X(j)$$

$$Y(j) = X(j) - \bar{X}$$

$$Y(j) = y_1, y_2, \dots, y_j, \dots, y_n$$

Fourier transform (1D):

$$F(\omega) = \sum_j^n y_j \cos(\omega j) + iy_j \sin(\omega j) \equiv a(\omega) + b(\omega)i$$

$$\omega = 2\pi p/n \quad (p=1, 2, \dots, n/2)$$

Amplitude and phase

$$A(\omega) = \sqrt{a(\omega)^2 + b(\omega)^2}$$

$$\theta(\omega) = \tan^{-1}(b(\omega)/a(\omega))$$

Periodogram

$$I(\omega) = n^{-1} A(\omega)^2 = n^{-1} (a(\omega)^2 + b(\omega)^2)$$

$$E[I(\omega)] = \sigma^2$$

$$I(\omega) \sim \sigma^2 \chi_2^2 / 2$$

Fourier transform (2D):

$$F(\omega, \varphi) = \sum_k^m \sum_j^n y_{kj} \cos(\omega j + \varphi k) + iy_{kj} \sin(\omega j + \varphi k) \equiv a(\omega, \varphi) + b(\omega, \varphi)i$$

$$\omega = 2\pi p/n \text{ et } \varphi = 2\pi q/m$$

$$p=1, 2, \dots, n/2 \text{ et } q=1, 2, \dots, m/2.$$

Amplitude and periodogram

$$A(\omega, \varphi) = \sqrt{a(\omega, \varphi)^2 + b(\omega, \varphi)^2}$$

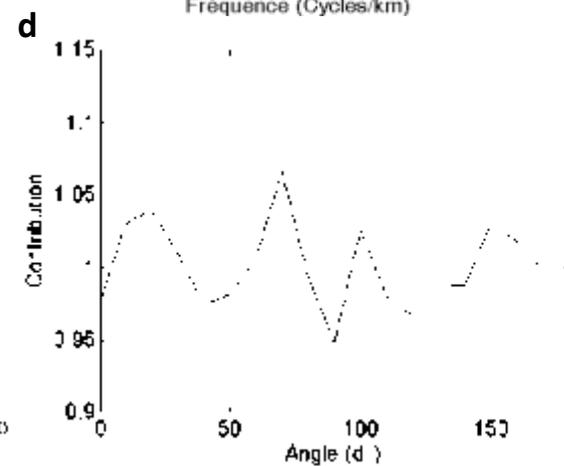
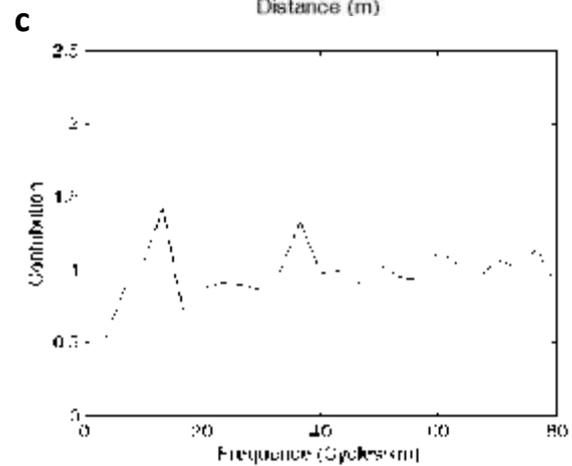
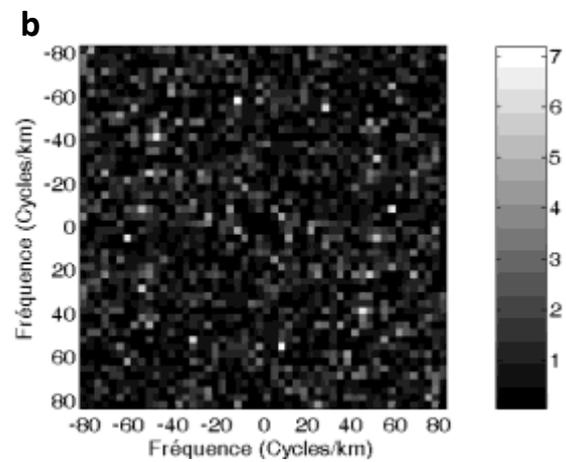
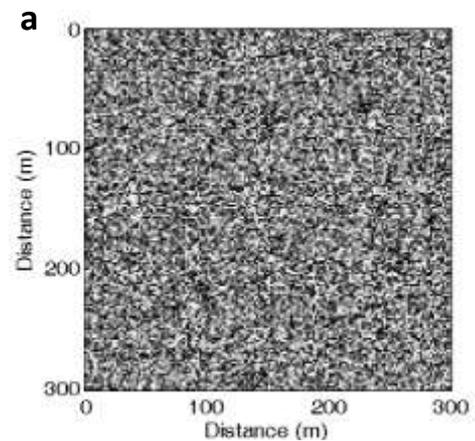
$$I(\omega, \varphi) = I(p, q) = nm^{-1} A(\omega, \varphi)^2$$

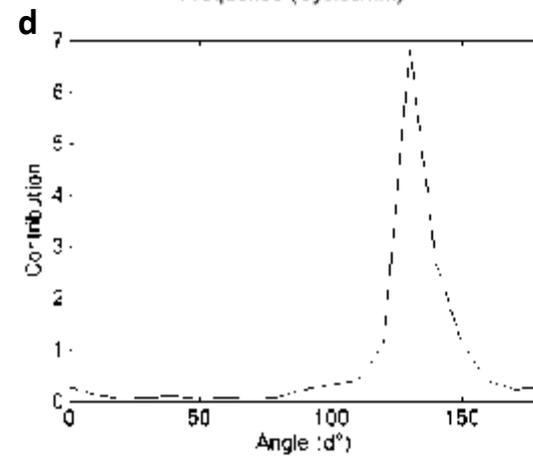
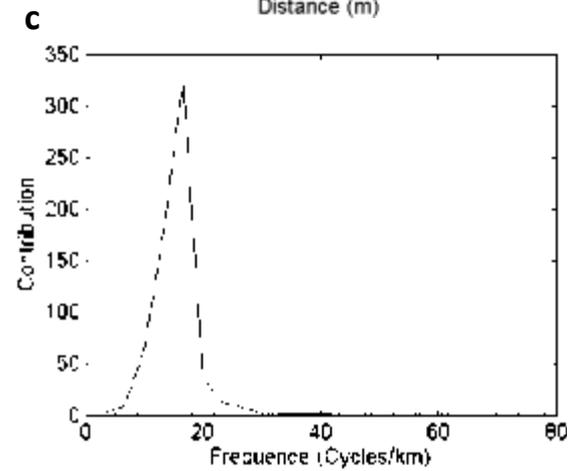
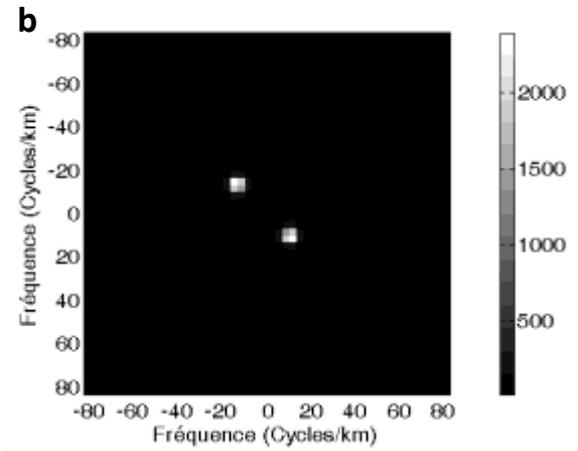
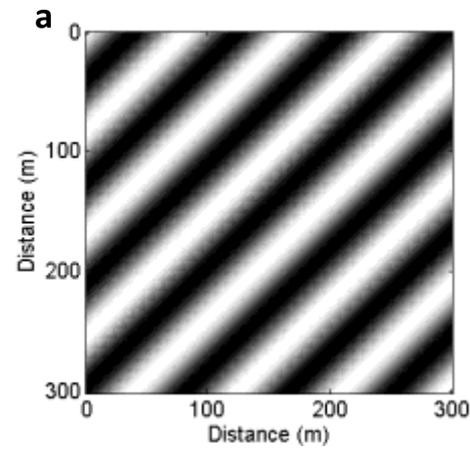
Polar coordinates

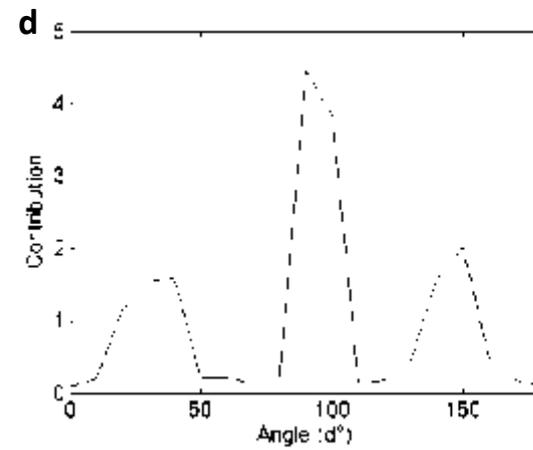
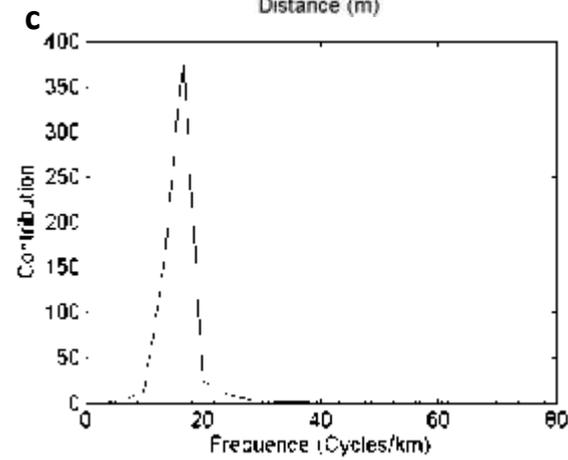
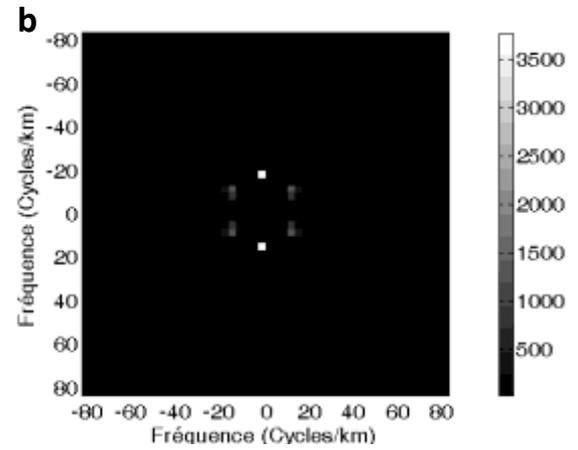
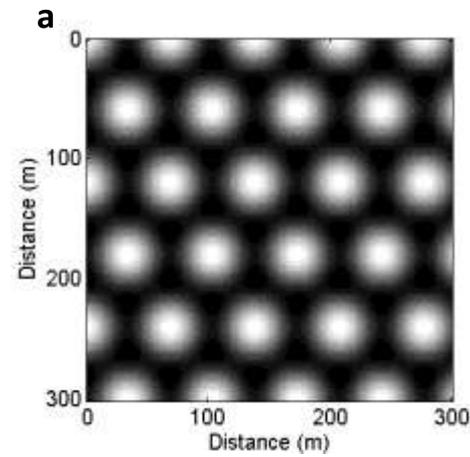
$$r = \sqrt{p^2 + q^2}$$

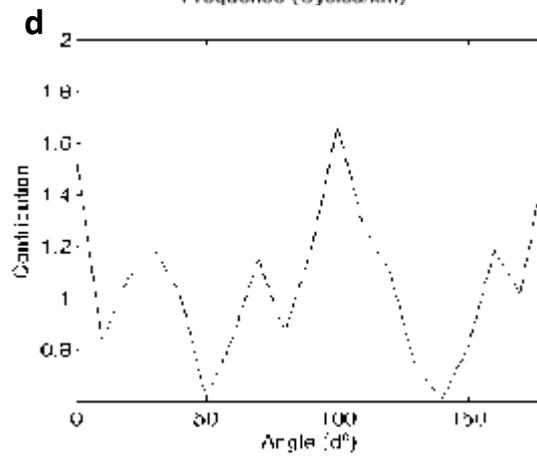
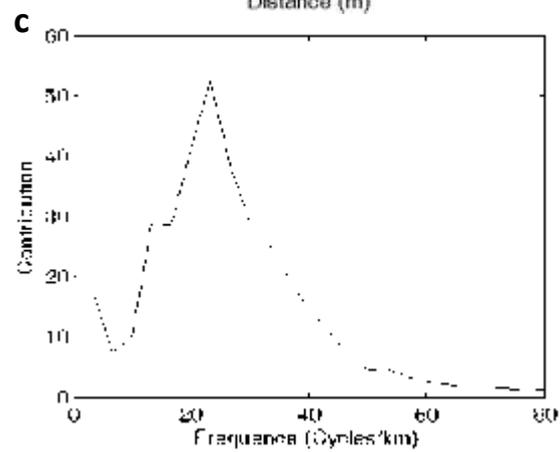
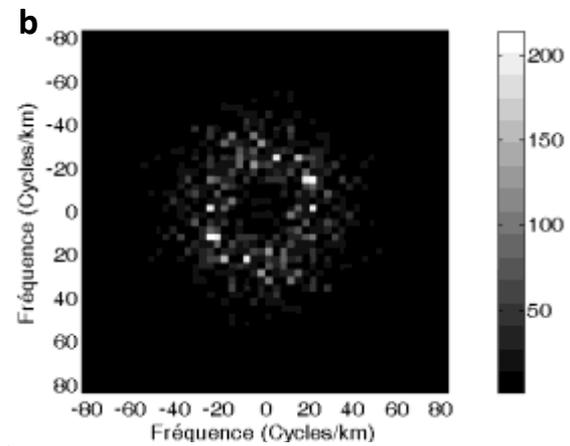
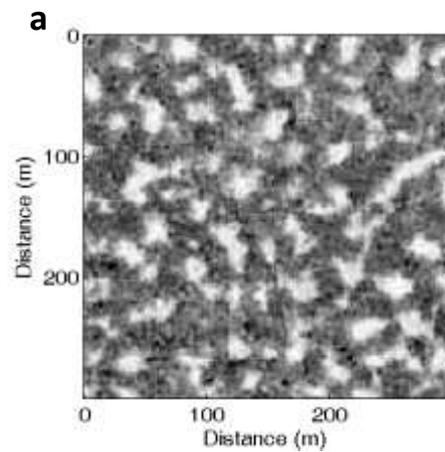
$$\theta = \tan^{-1}(q/p)$$

=> Simplification to r-spectrum and θ -spectrum



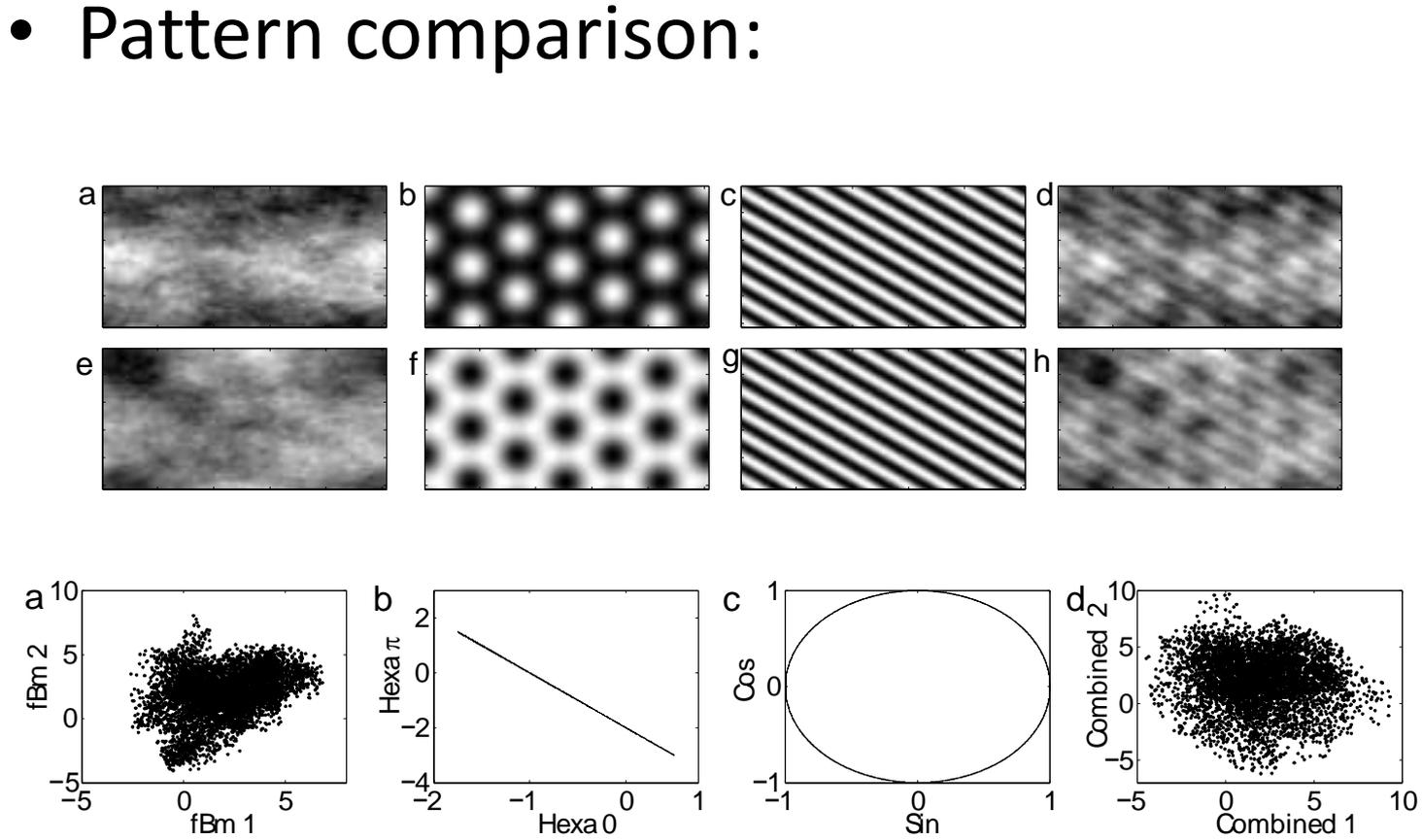






Multiscale comparison of spatial patterns using two-dimensional cross-spectral analysis: application to a semi-arid (gapped) landscape

Nicolas Barbier · Pierre Coutron · Olivier Planchon · Abdoulaye Diouf



$$F_x(\omega) = \sum_j^n x_j \cos(\omega j) + i x_j \sin(\omega j) \equiv a_x(\omega) + b_x(\omega)i$$

$$F_y(\omega) = \sum_j^n y_j \cos(\omega j) + i y_j \sin(\omega j) \equiv a_y(\omega) + b_y(\omega)i$$

Cross-periodogram

$$I_{xy}(\omega) = n^{-1}(a_x(\omega)a_y(\omega) + b_x(\omega)b_y(\omega)) - n^{-1}i(b_x(\omega)a_y(\omega) + a_x(\omega)b_y(\omega)) : \\ \equiv c_{xy}(\omega) + iq_{xy}(\omega)$$

Cross-amplitude

$$a_{xy}(\omega) = \sqrt{c_{xy}(\omega)^2 + q_{xy}(\omega)^2}$$

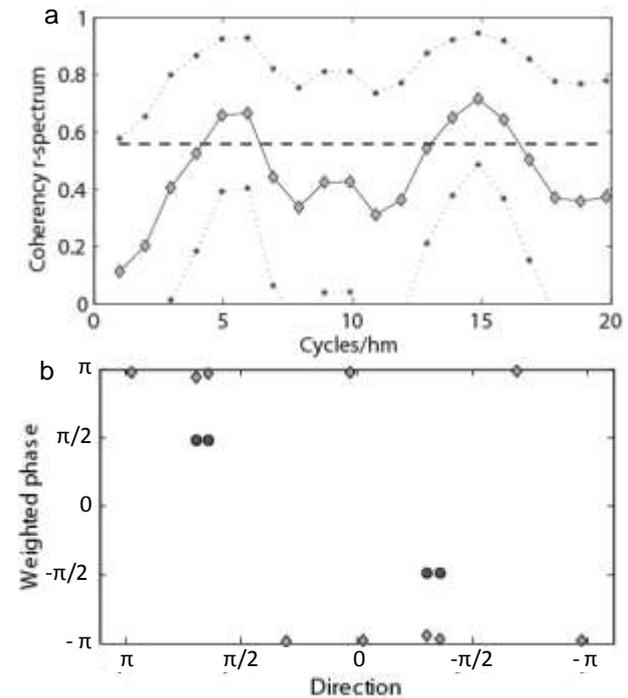
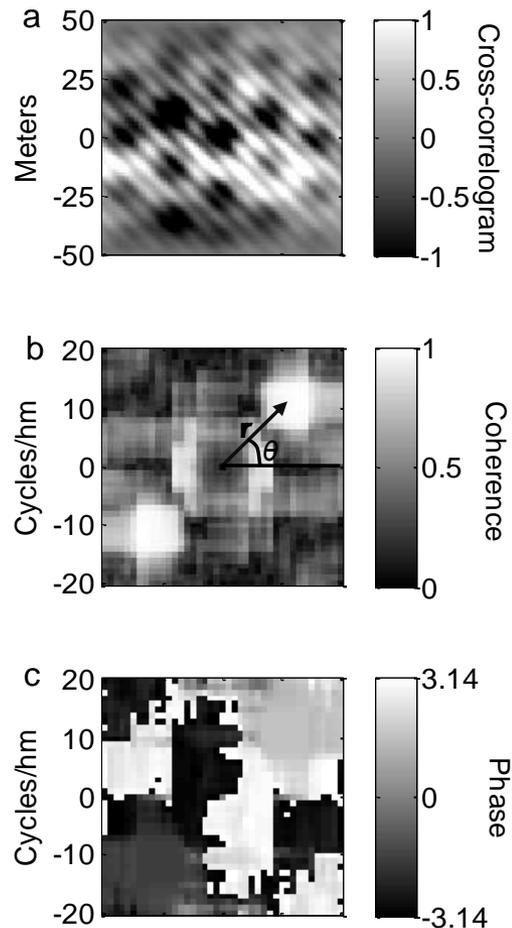
Phase spectrum

$$\phi_{xy}(\omega) = \tan^{-1}[q_{xy}(\omega)/c_{xy}(\omega)]$$

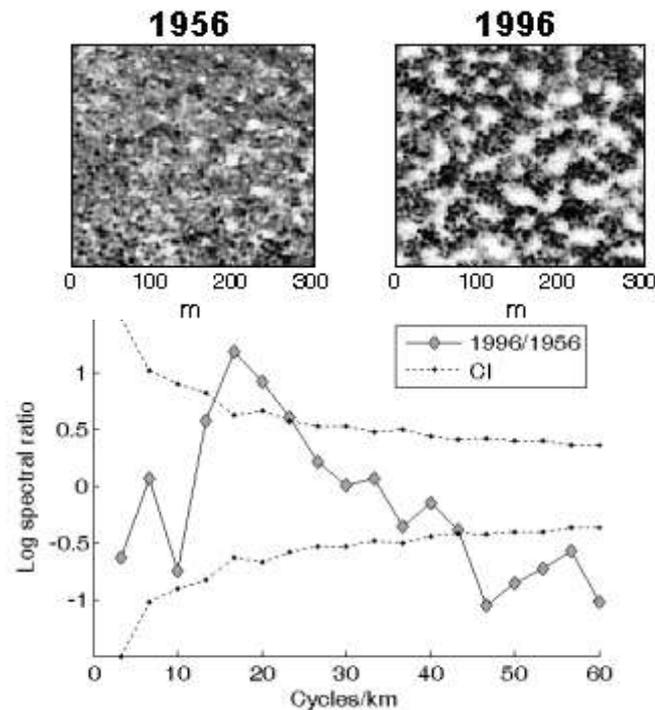
Coherency spectrum [0,1] ~ scale specific correlation

$$b_{xy}(\omega) = a_{xy}(\omega) / \sqrt{I_x(\omega)I_y(\omega)}$$

- Pattern comparison: Cross-spectral analysis
 - Scale specific correlation analysis
 - Coherency = correlation coeff. between frequencies
 - Phase = shift between coherent frequencies

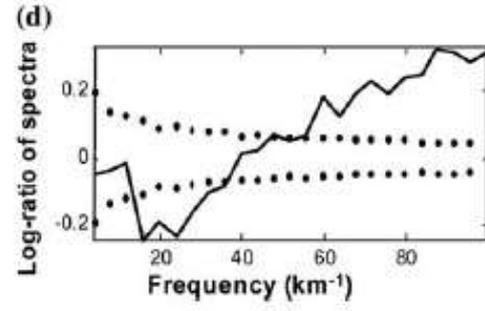
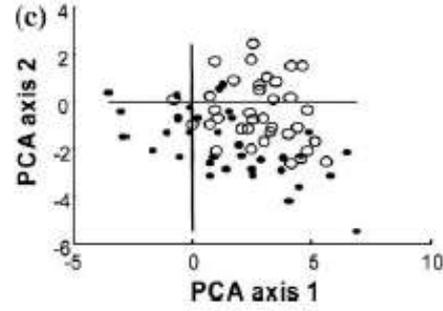
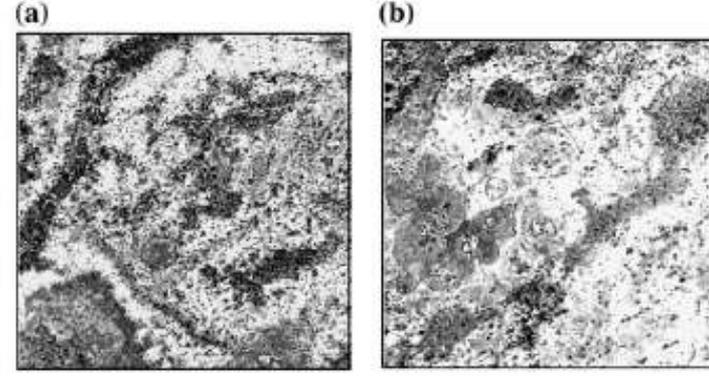
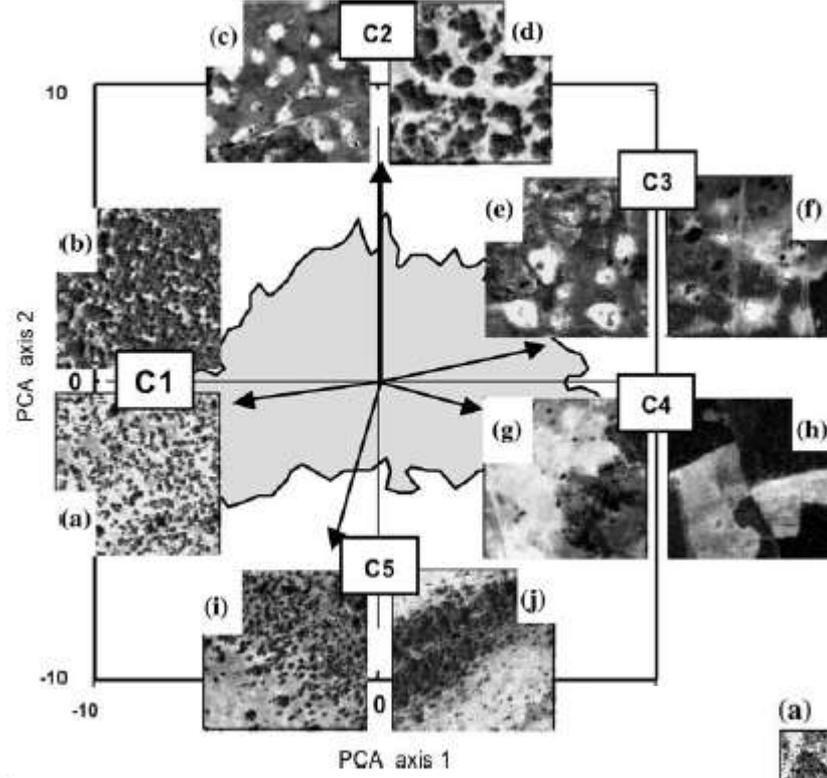


- Pattern comparison using r-spectra
 - Values for different frequencies are independent
 - They follow a χ^2 distribution
 - Spectral ratio follows a F distribution
 - Ordination - Classification

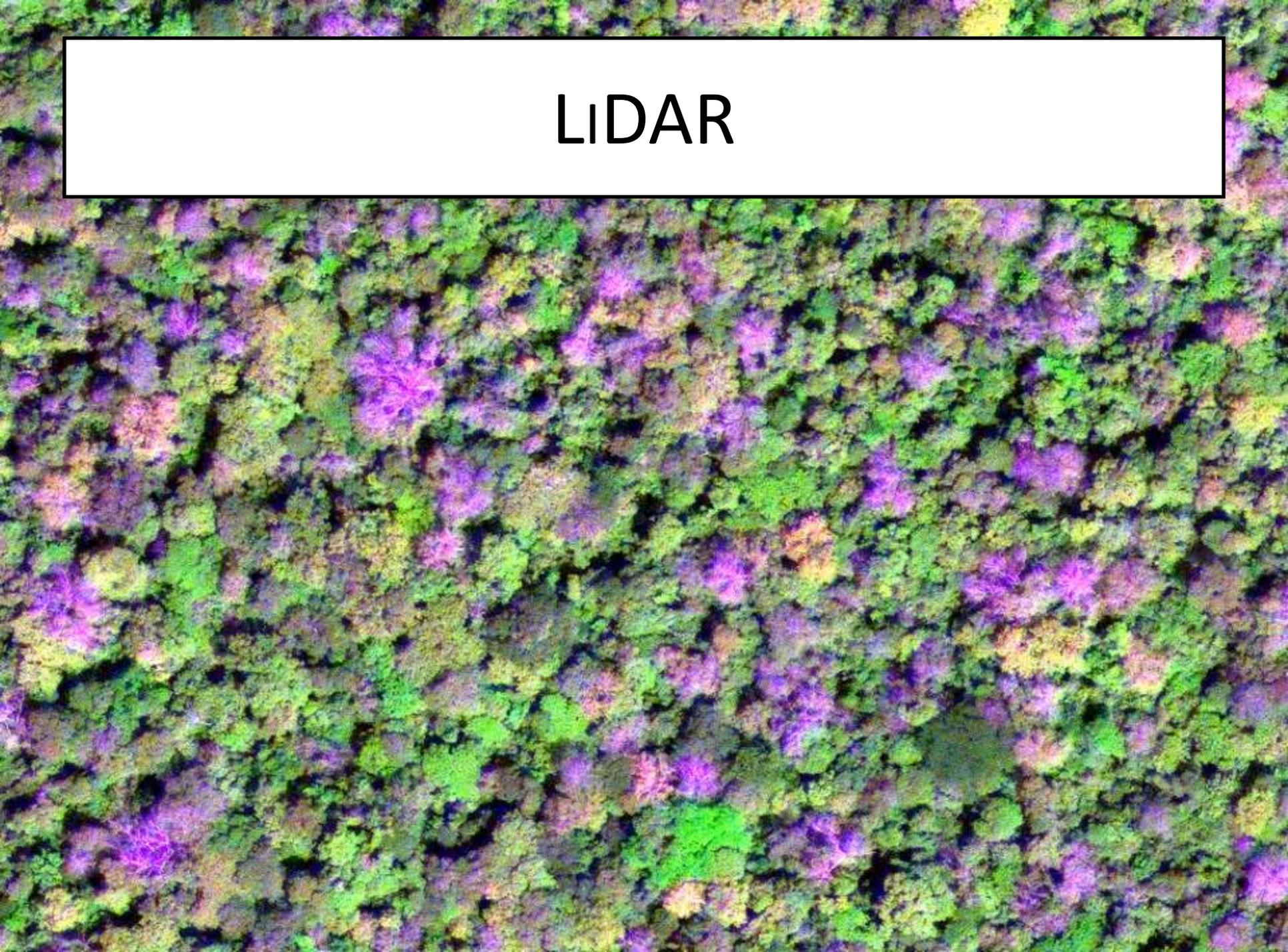


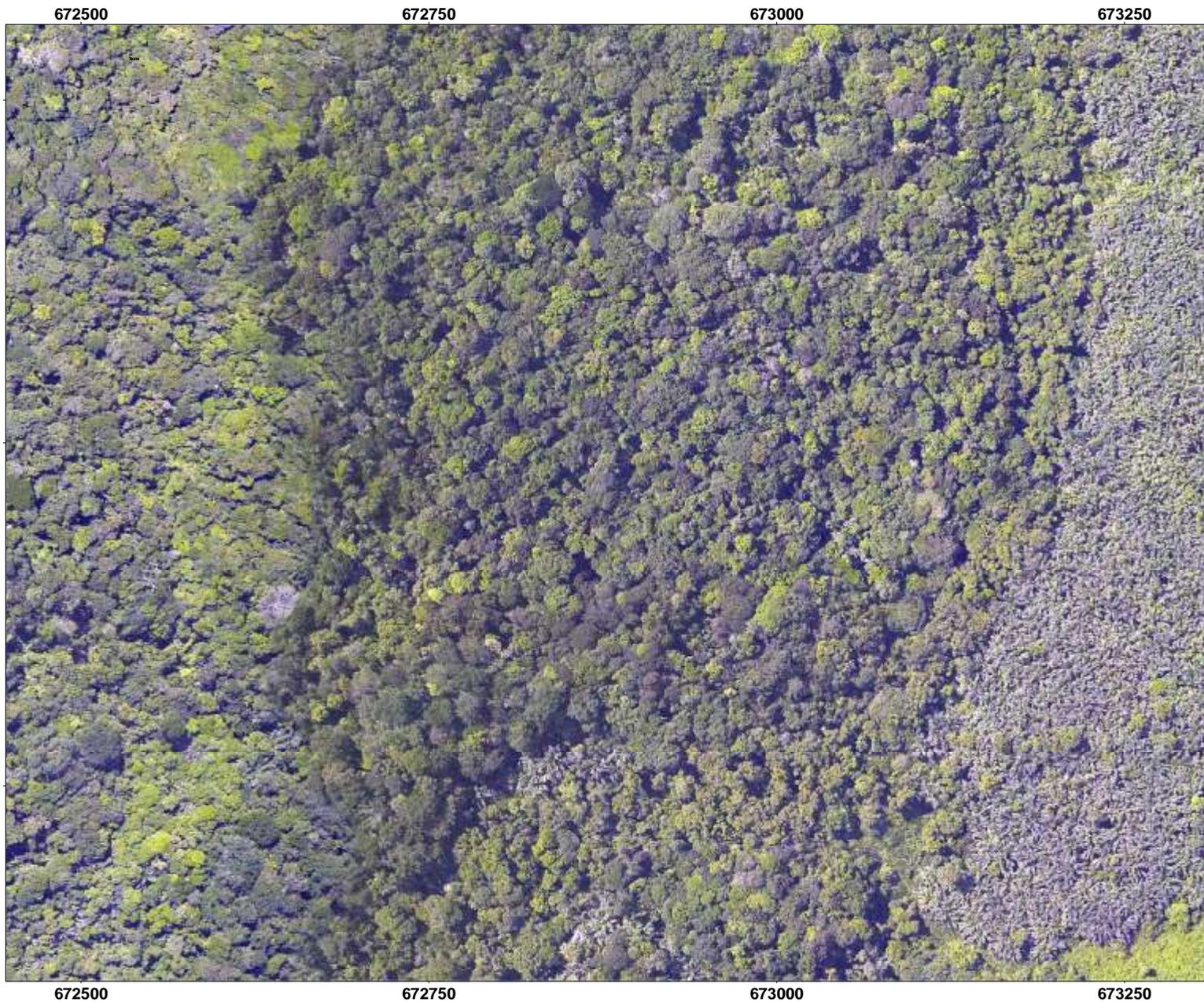
Textural ordination based on Fourier spectral decomposition: a method to analyze and compare landscape patterns

Pierre Couteron^{1,2,*}, Nicolas Barbier³ and Denis Gautier⁴



LIDAR





67250

67275

67300

67325

991775

991775

991750

991750

991725

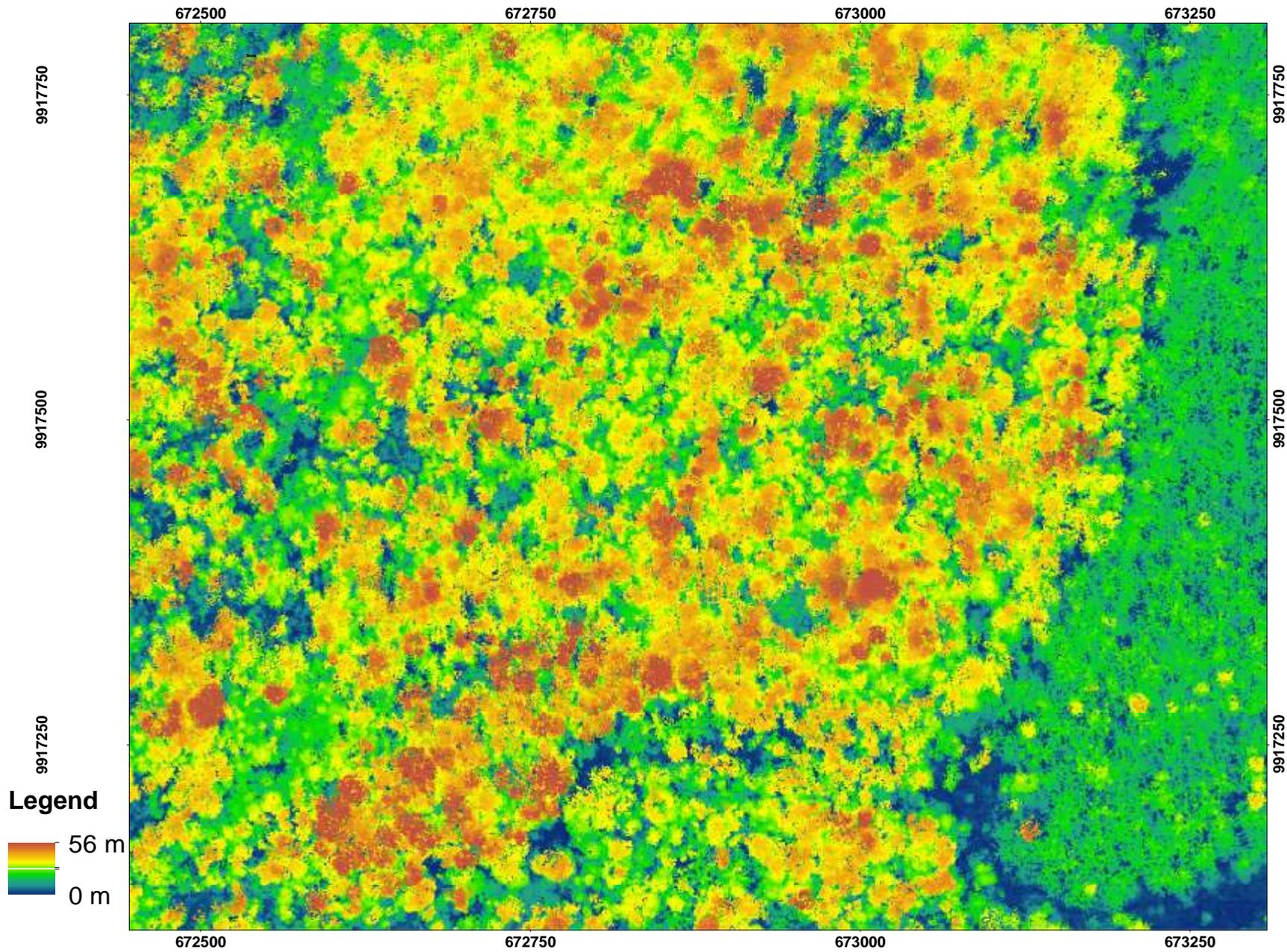
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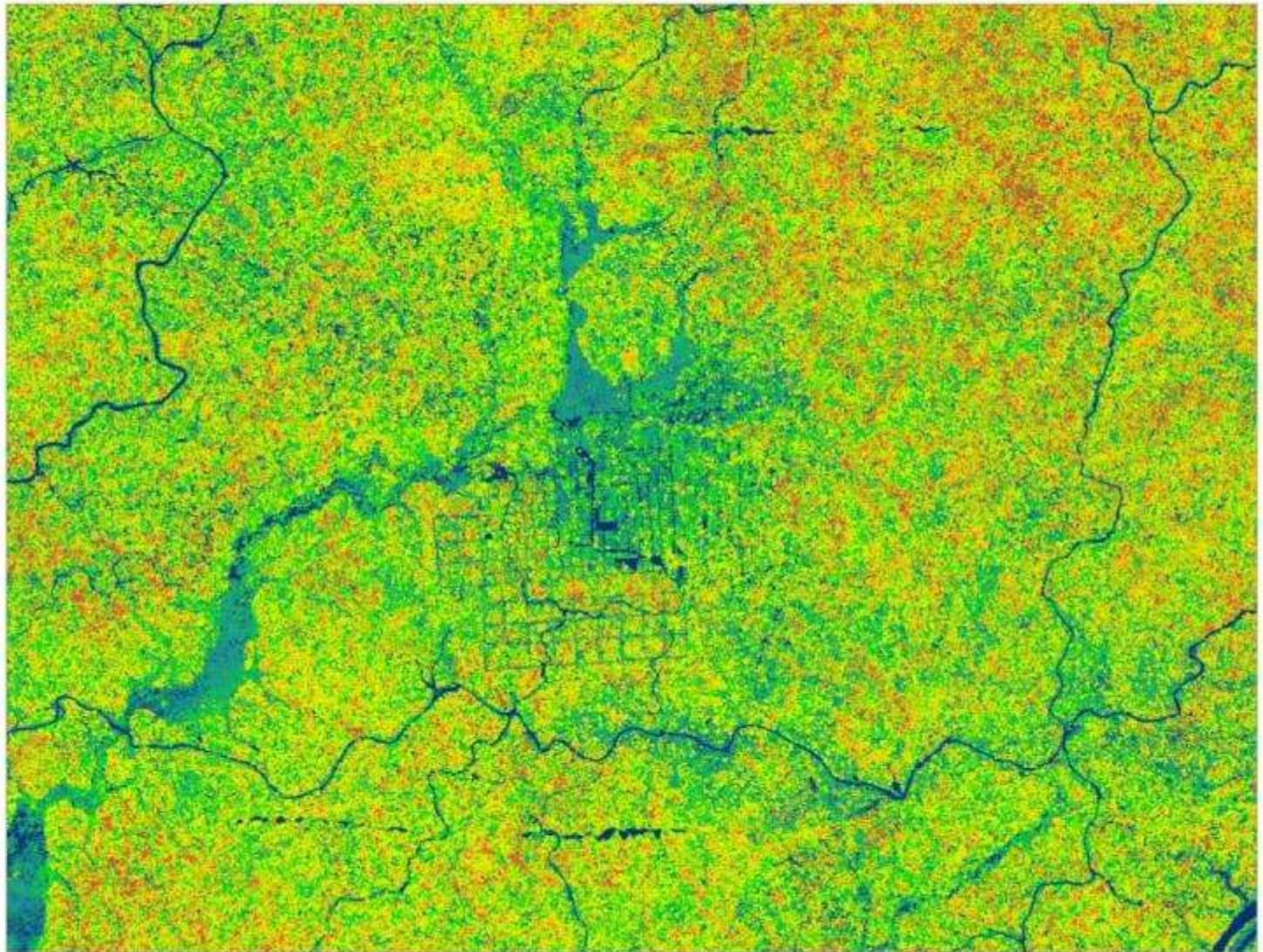
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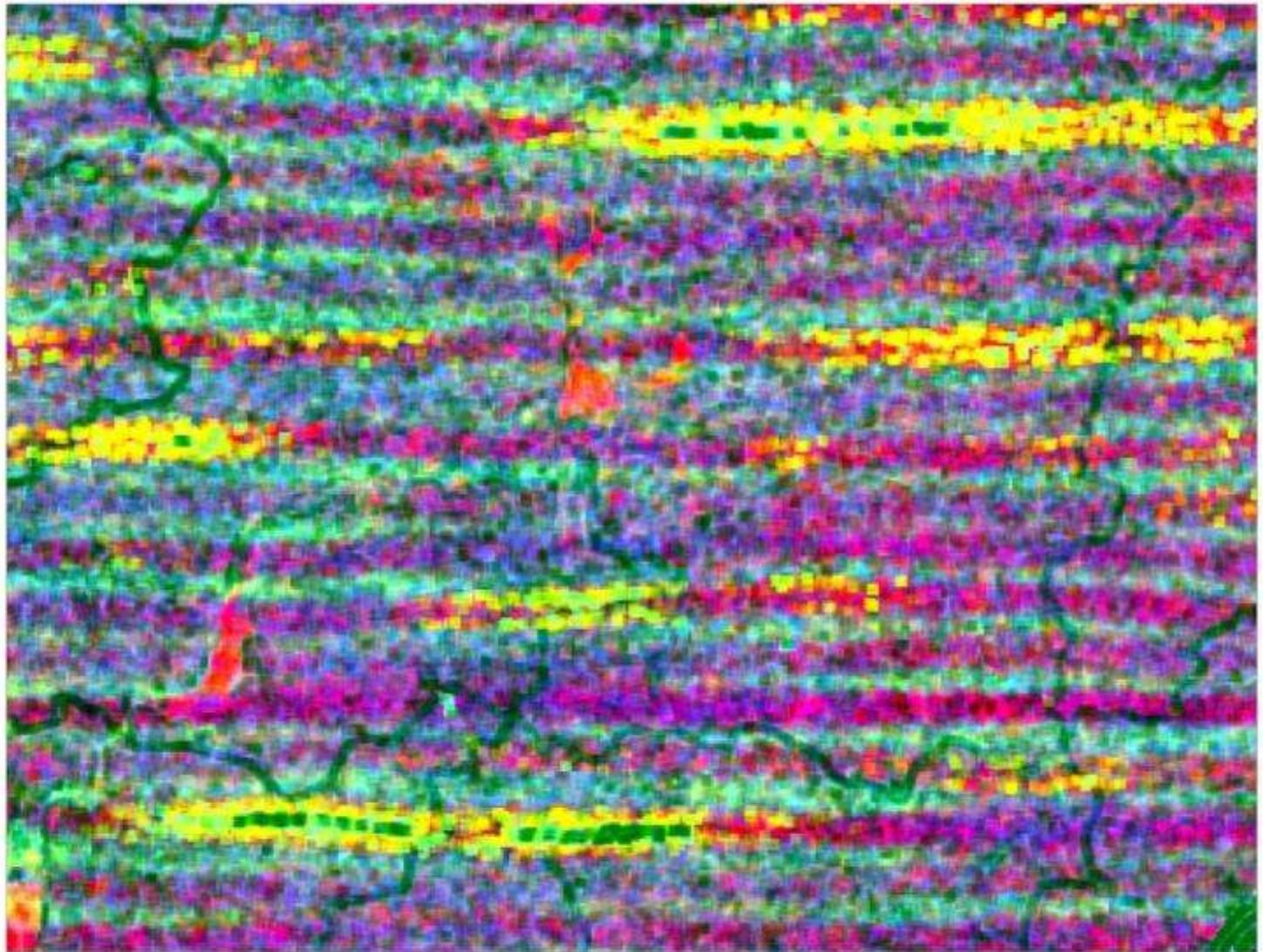
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67325

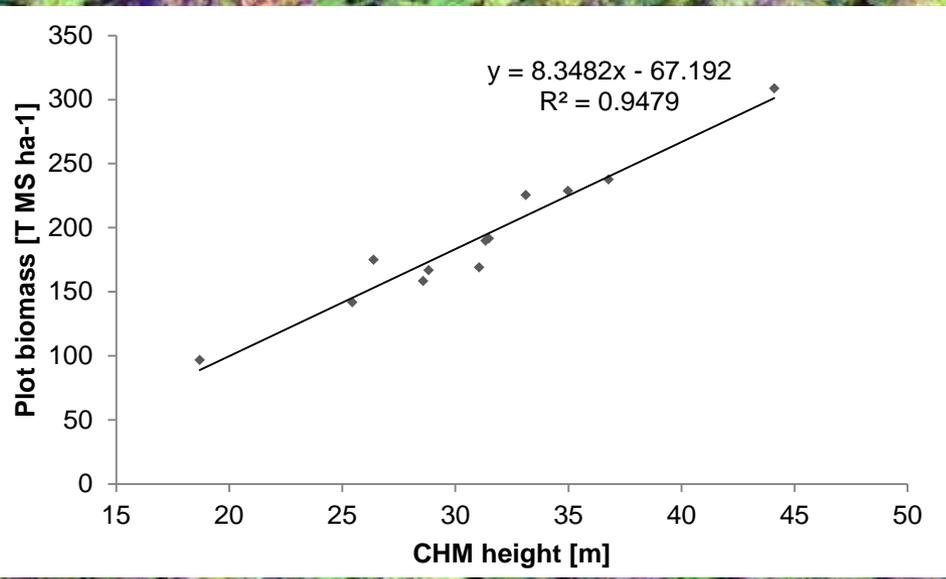
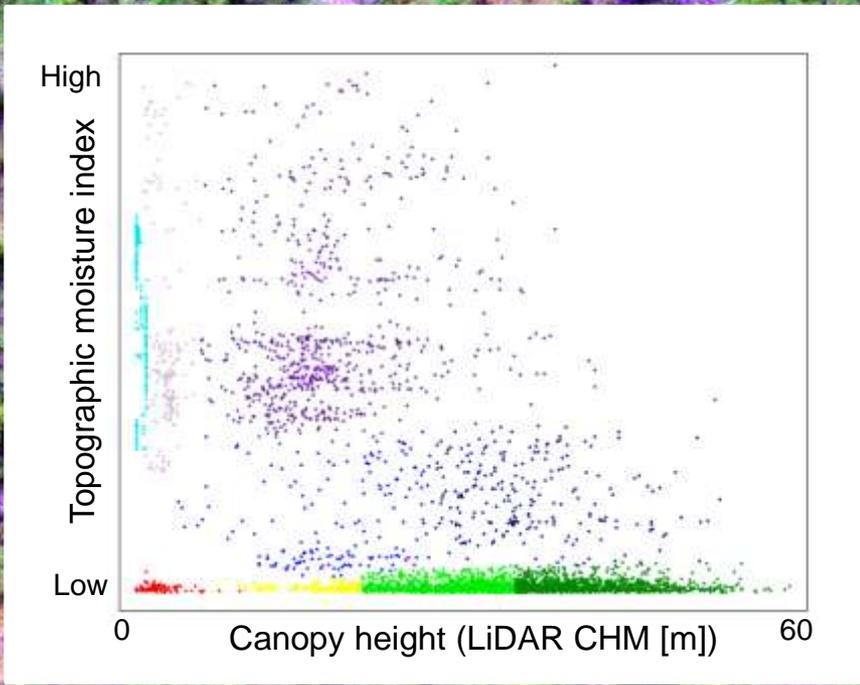




0 0.5 1 2 3 Kilometers



0 0.5 1 2 3 Kilometers



Terra Firme forest aboveground biomass map

Mabounie - Gabon

Submission:
Jan. 2013

PI:
Tarsq Sévart (MBG)

Mapping:
Nicolas Barbier (IRD - AMAP)

Data collection:
N. Barbier, P. Ploton, V. Douissart (IRD AMAP)
Y. Isenbe, J.-N. Bosserien (CENAREST)
K. Stark, S. Griffith, A. Bonafot (Golder Assoc.)
Vincent, Yves, Kauro,
John, Petit Jean and co. (Field assistants)

Base data:
1 ha plots
LiDAR acquisition Aerodata 2007
Canopy height model
& topographic moisture index

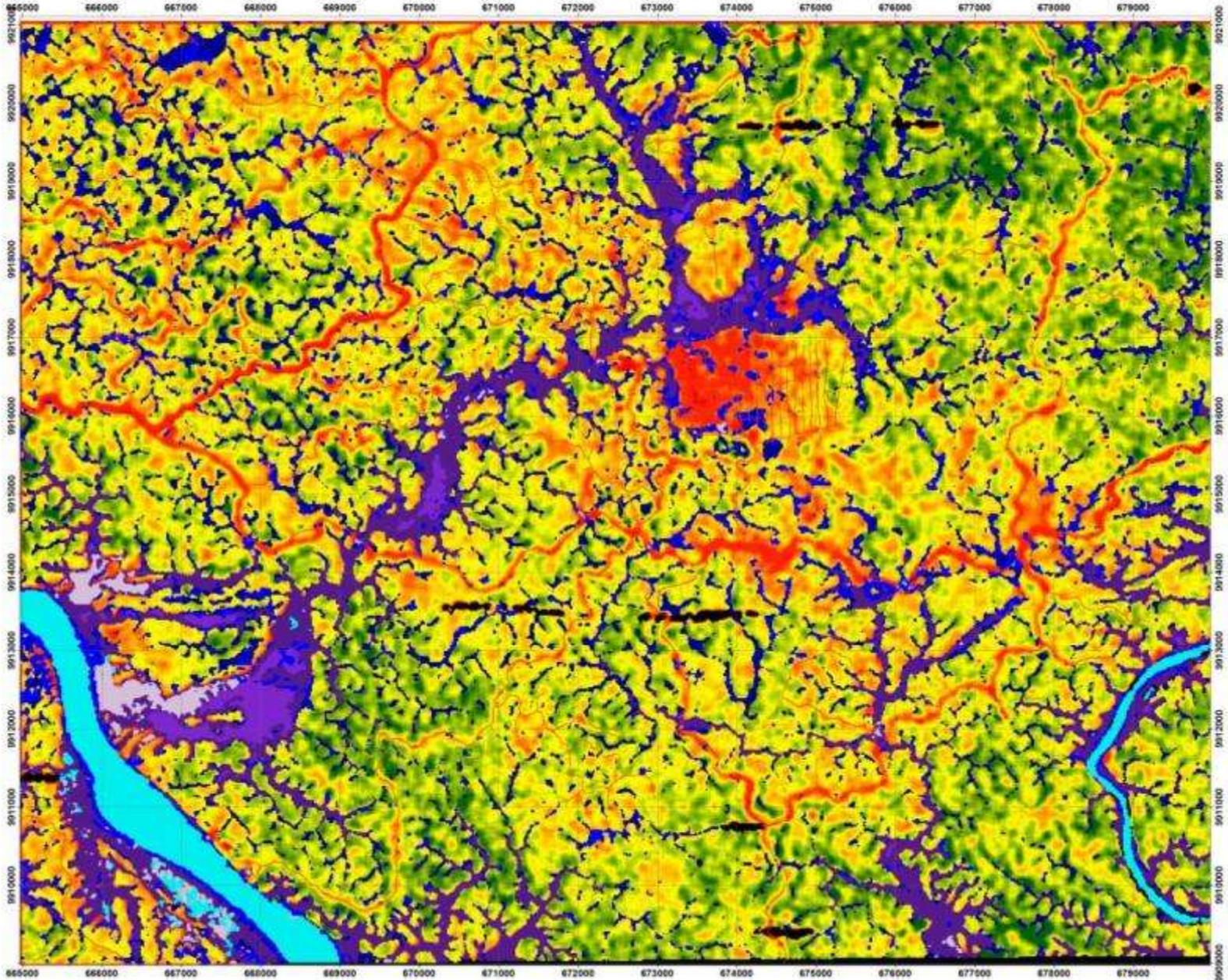
Projection:
WGS 84 - UTM 32N



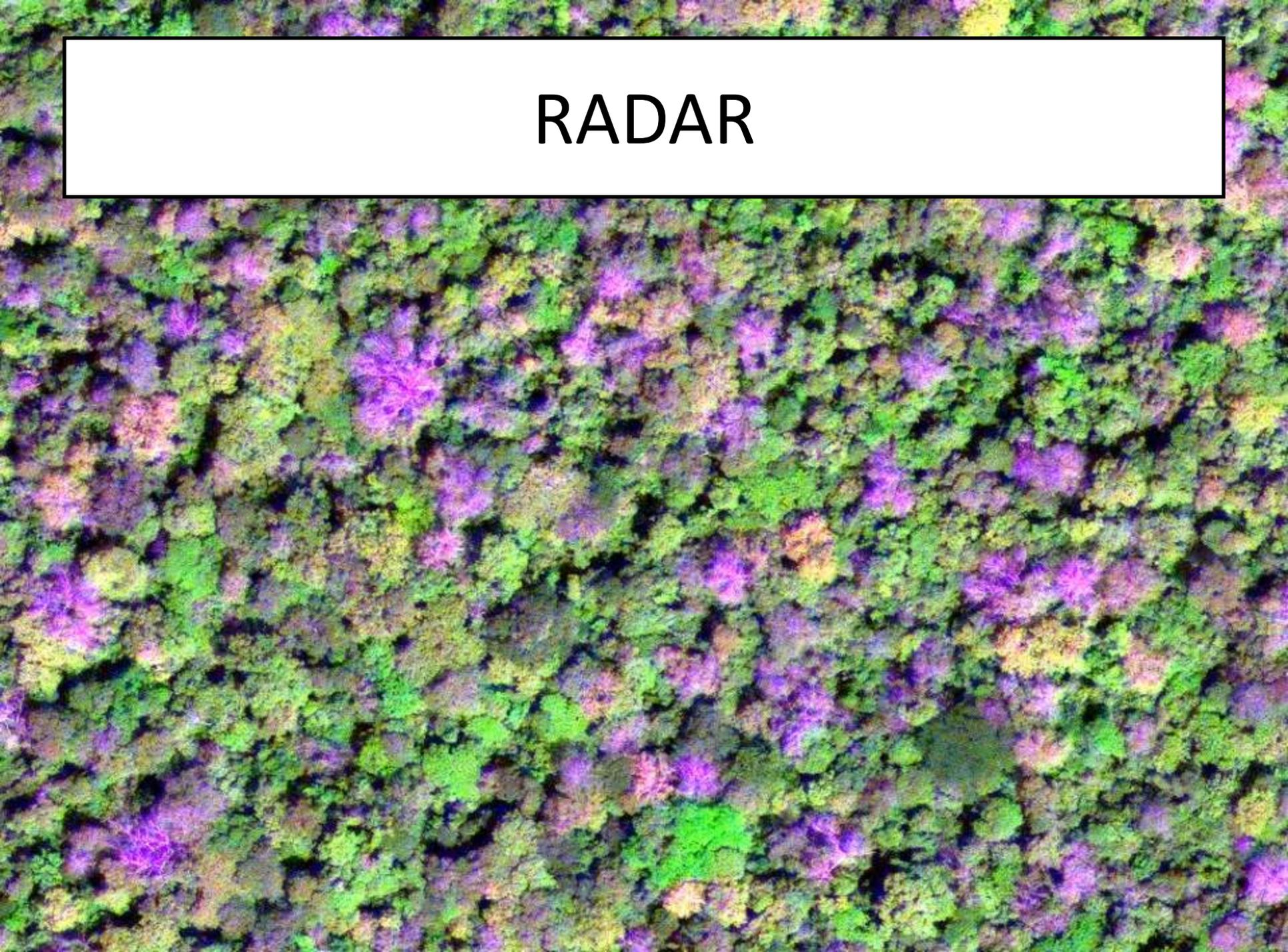
AGB Biomass [T DM/ha]

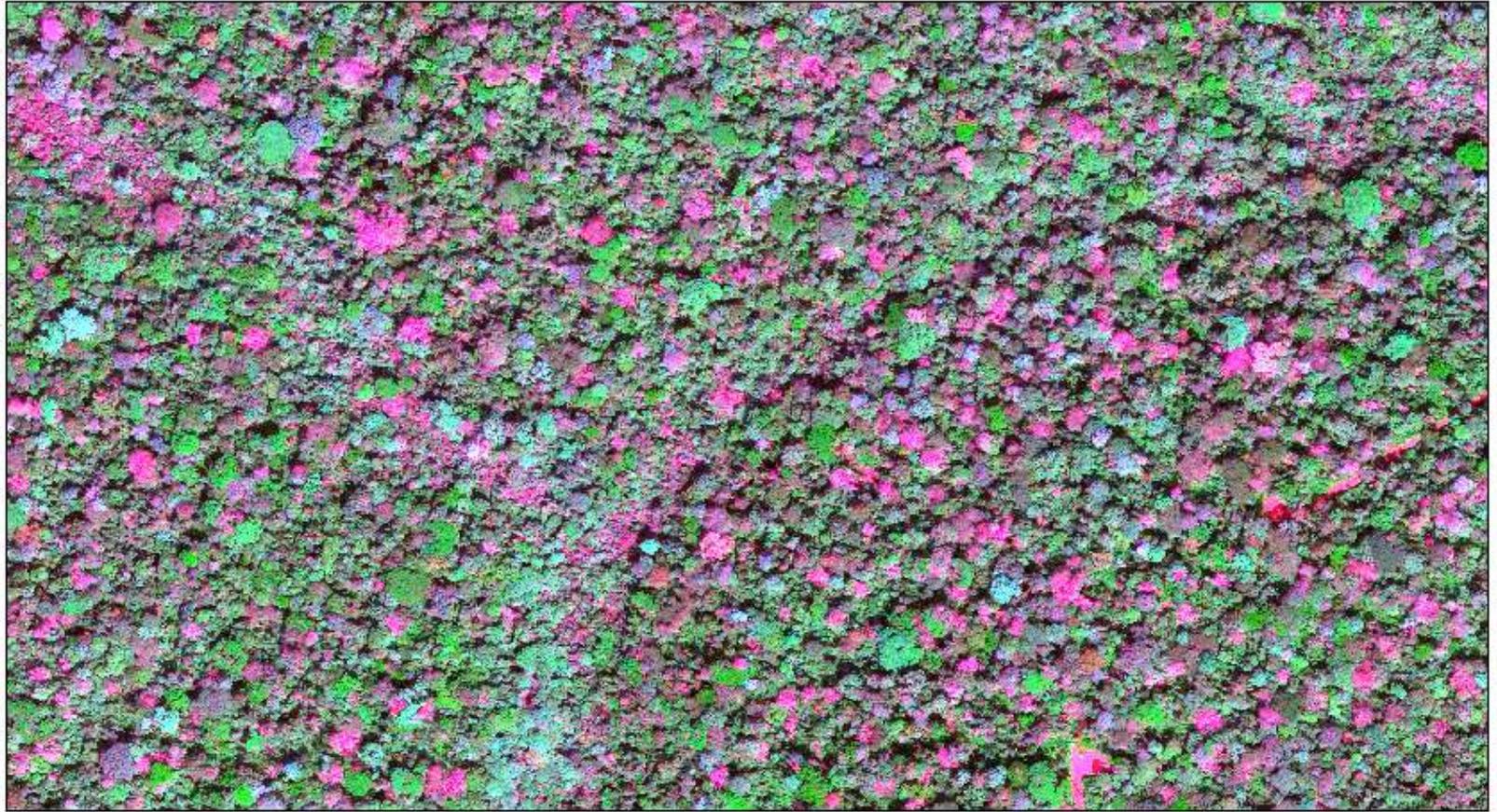


- Unclassified - No data
- Built up - Bare
- Open Water
- Swamp grassland
- Pure Raphia stands
- Mixed swamp forests
- Low flooded forest
- High flooded forest



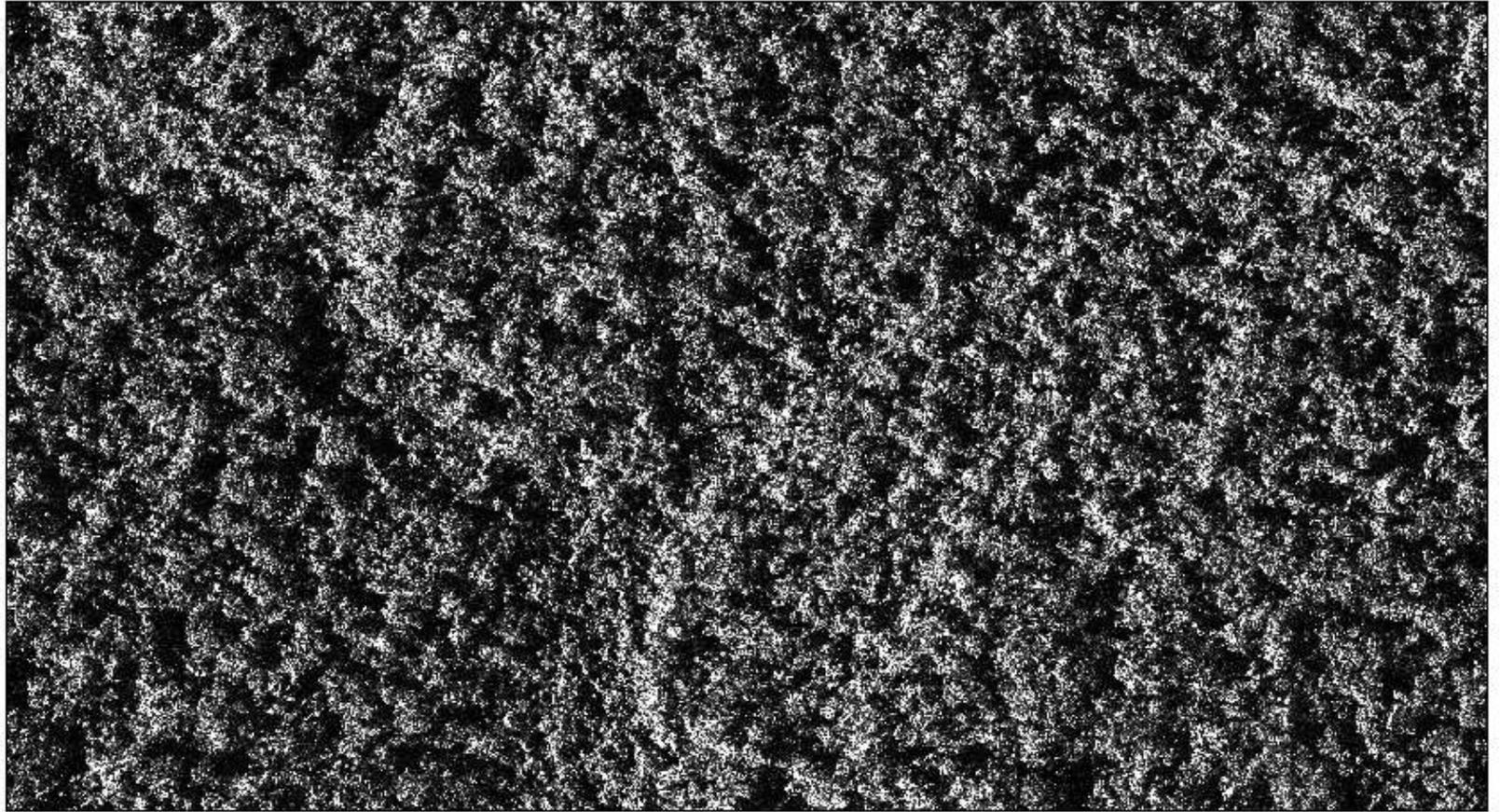
RADAR





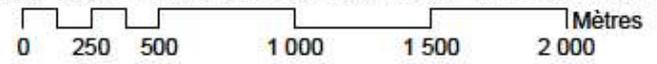
0 62.5 125 250 375 500 Mètres

GeoEye 3-4-2



TerraSar X HS

0 62.5 125 250 375 500 Mètres



TerraSar X HS

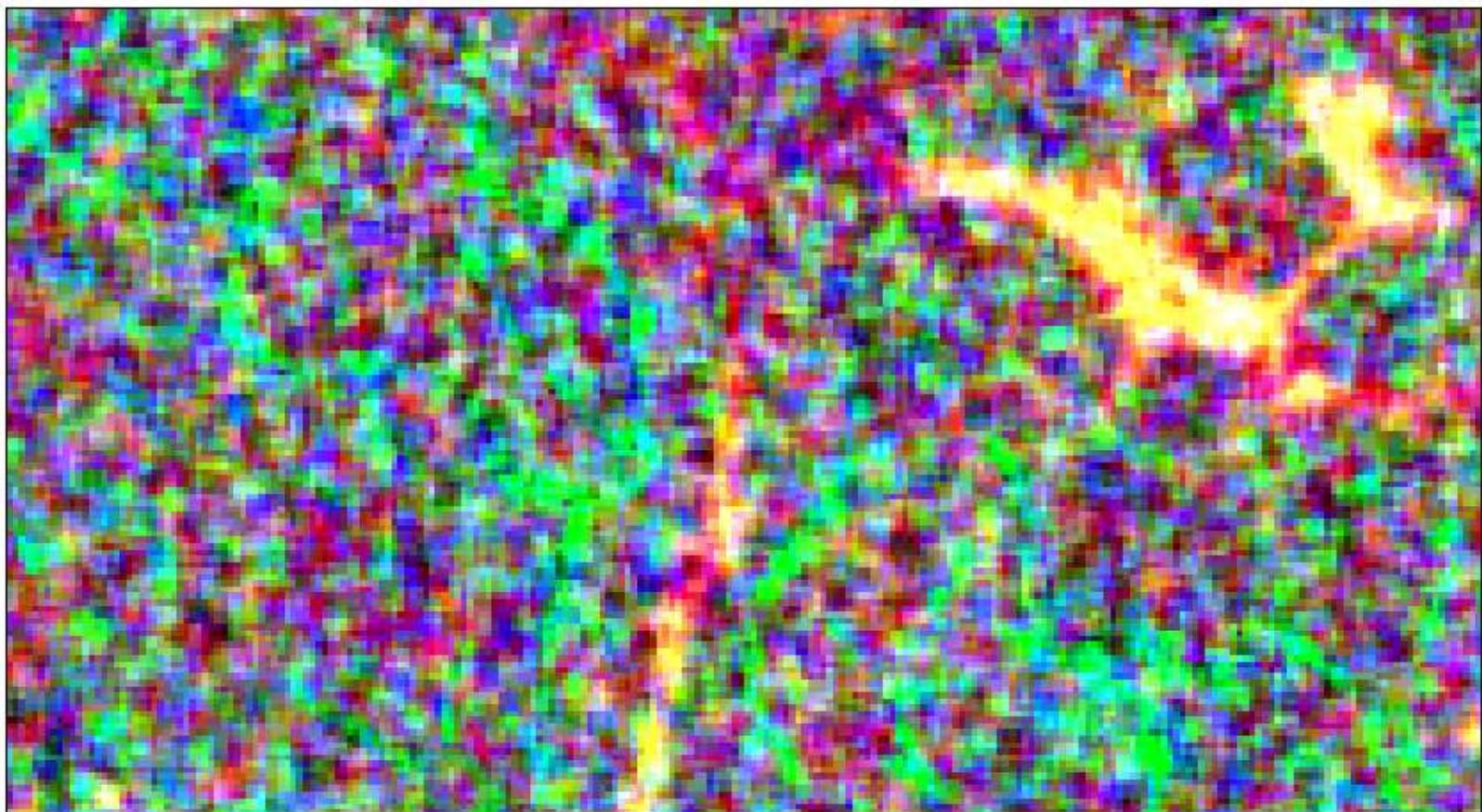


FOTO texture PCA1-2-3