Multiscale description of Sentinel-2/MAJA products: a spectral and structure function approach

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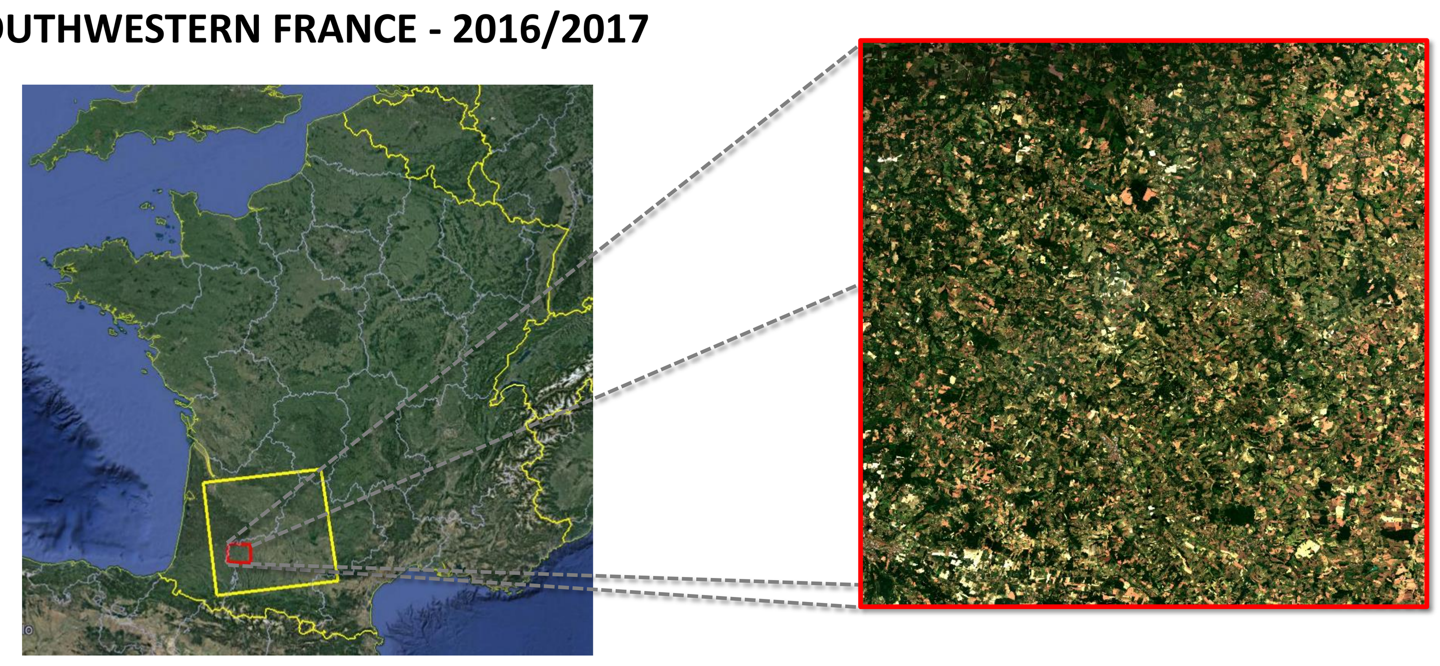
1 INTRODUCTION

Sentinel-2 surface reflectances exhibit a strong spatial variability that is due to both natural variability and strong anthropogenic effects. From an image processing viewpoint, Sentinel-2 products may be seen as images that embed a hierarchy of spatial structures of different sizes and of different energy levels. Many remote-sensing images of natural variables show a fractal structure that can be evidenced by various geometrical and statistical tools [1],[2]. Thus, it is tempting to check if Sentinel-2 images exhibit such scaling features.

Objective: Testing the existence of scaling properties in Sentinel-2/MAJA products based on two main tools: 2D Fourier power spectra and first order structure functions.

2 CASE STUDY AND DATA

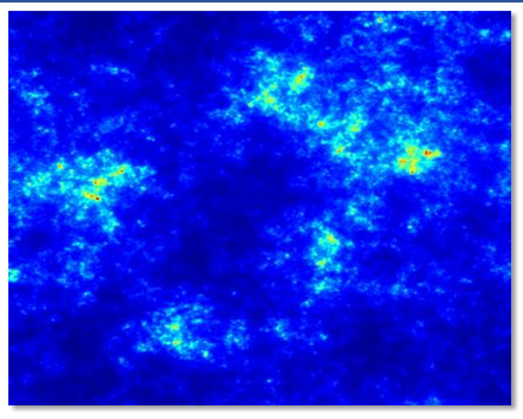
SOUTHWESTERN FRANCE - 2016/2017



Study area: 200x200 km² — Example of analyzed image: 40x40 km²

- **Four S2 tiles** selected on the region: 30TYP, 31TCJ, 31TCK, 30TYQ
- **Chosen dates** with minimum clouds and outliers: 04/02/2016 - 10/07/2016 - 05/07/2017
- **MAJA products** available in this region (atmospheric and slope corrections, clouds detection)
- **Many in-situ campaigns** carried out by "*Observatoire Spatial Regional*" - CESBIO
- **Work in progress** on Landsat-8/MAJA products

3 METHODOLOGY : Statistical analysis

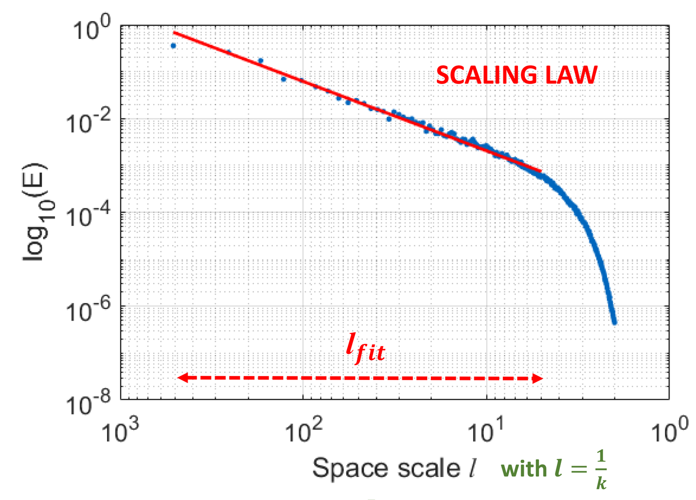


(Synthetic fractal image)

1. SPECTRAL ANALYSIS

- Computes 2D Fourier power spectrum $P(k_x, k_y) = |FFT(R)|^2$
- Angle integration on x and y axis $E(k) = \int_{\|\vec{k}\|=k} P(\vec{k})\, d\vec{k}$

$$E(k) = k^{-\beta}$$

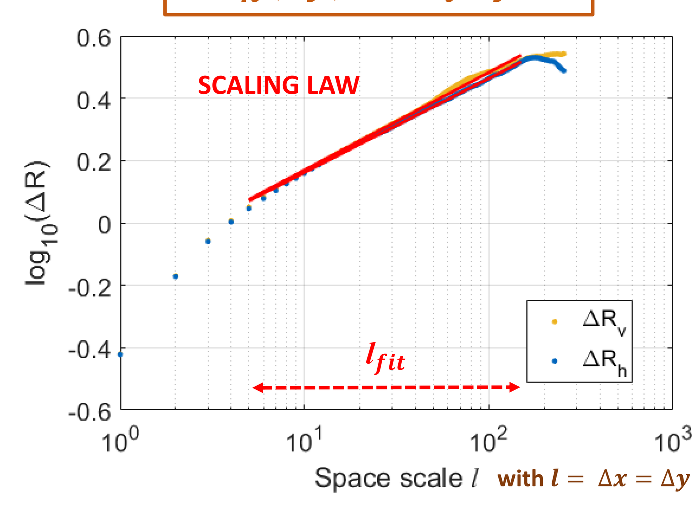


- Range of scales with scaling law: $l_{min} < l_{fit} < l_{max}$
- Scaling exponent β

2. STRUCTURE FUNCTIONS

- Computes vertical structure function $\Delta R_v(\Delta x) = \langle |R(x+\Delta x) - R(x)| \rangle$
- Computes horizontal structure function $\Delta R_h(\Delta y) = \langle |R(y+\Delta y) - R(y)| \rangle$

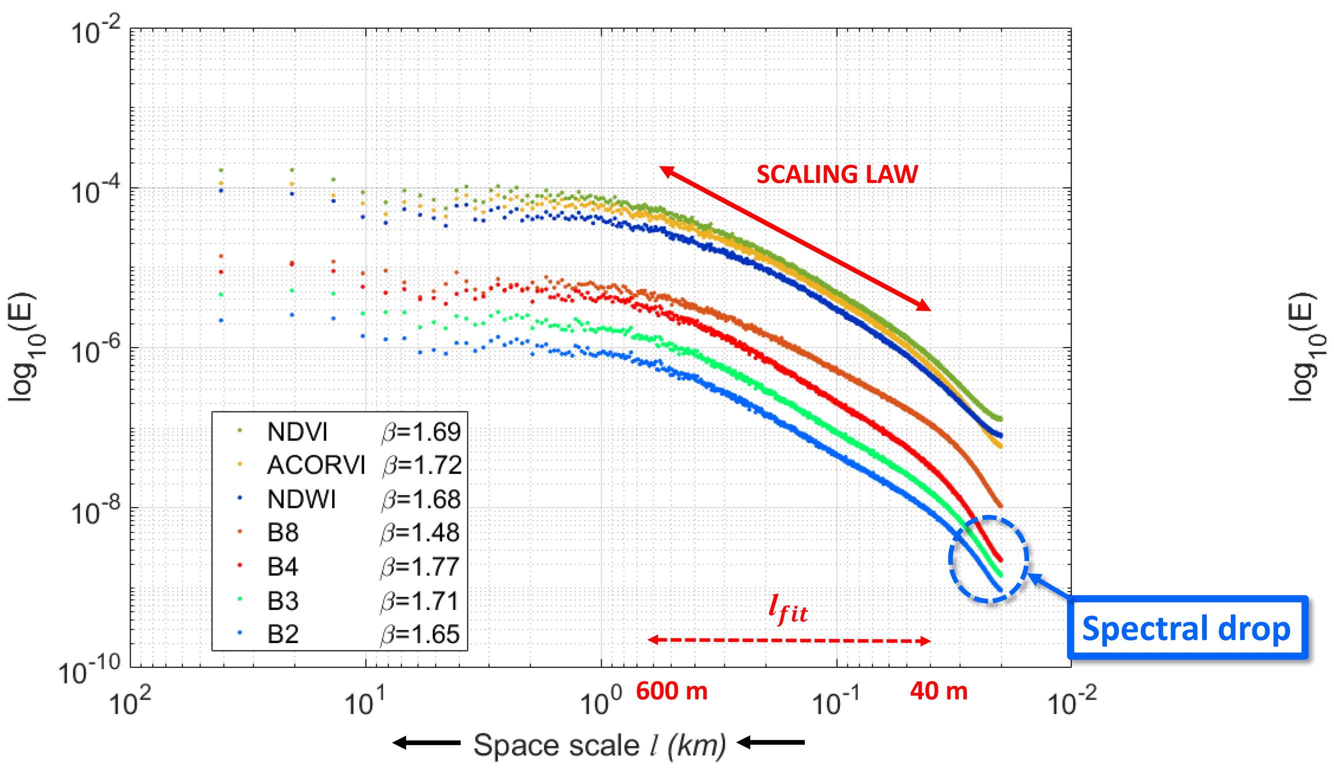
$$\Delta R_v(\Delta x) = \Phi_l\, \Delta x^{H_v}$$
$$\Delta R_h(\Delta y) = \Phi_l\, \Delta y^{H_h}$$



- Fractional integration parameters: H_h and H_v (for each axis)
- Links spectral and multifractal scaling: β = 1 + 2H - K(2) *(with K(2) additional multifractal scaling parameter [3])*

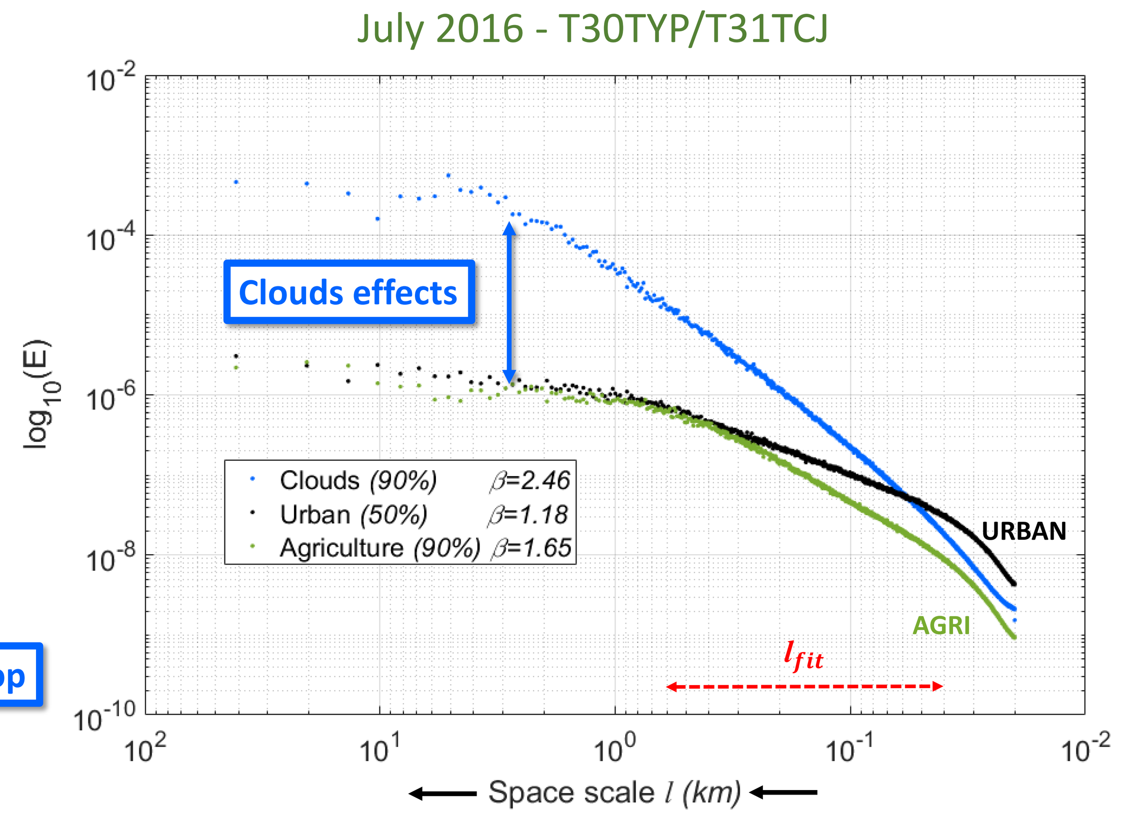
4 RESULTS : 4th February - 10th July 2016

Power spectra of visible, NIR and indices products
July 2016 - T30TYP



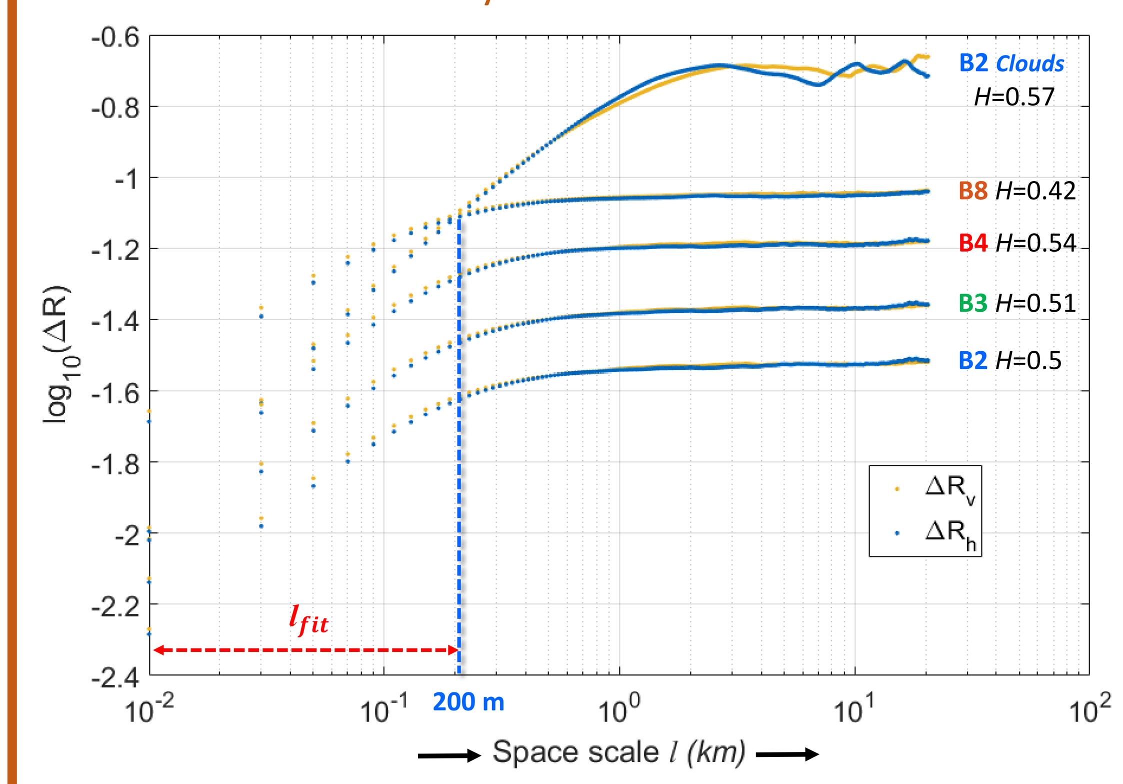
- Impact of acquisition wavelength on the scaling exponent
- Comparison of two vegetation indices NDVI vs ACORVI $\left(\frac{NIR-(R+0.05)}{NIR+(R+0.05)}, [4]\right)$:
  - same scaling behavior on most scales
  - better "sensor noise robustness" of ACORVI at smallest scales

Clouds and land cover effects on blue band spectrum
July 2016 - T30TYP/T31TCJ



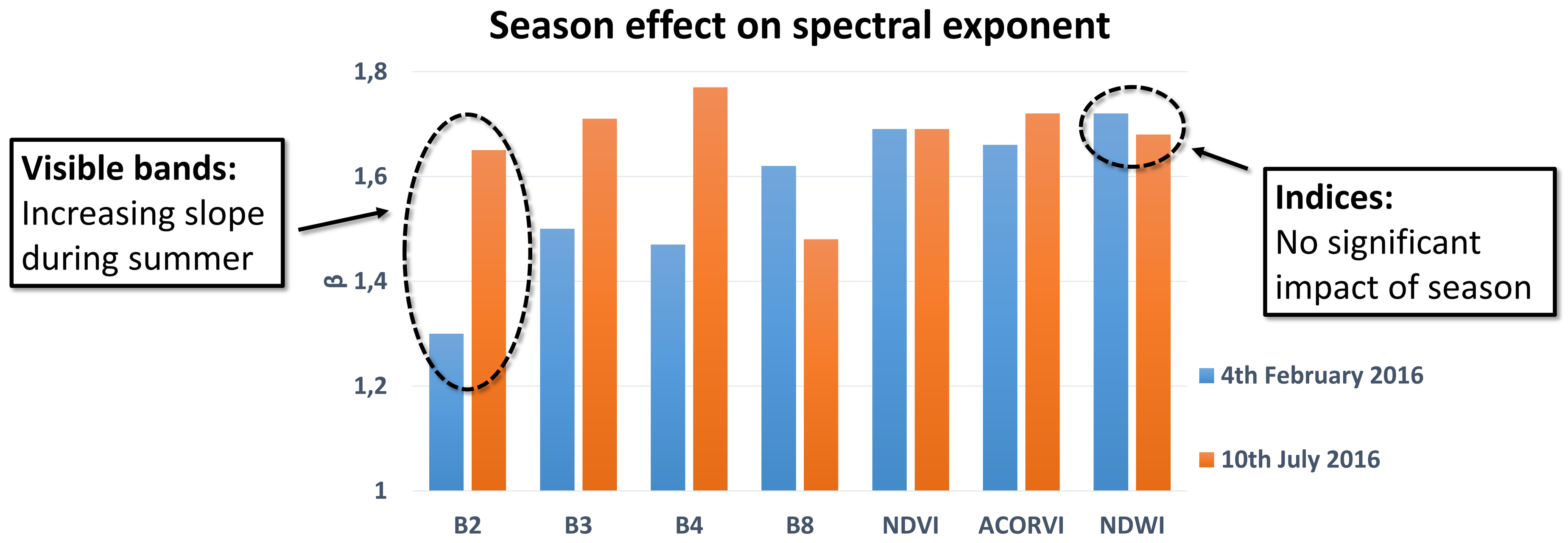
- Cloud impact: increase of spectral slope
- Urban impact: decrease of spectral slope

First order structure functions
July 2016 - T30TYP



- Twofold scaling behavior (scale break at around *200 m*)
- Fractional integration at small scales (*l < 200 m*)
- Possible cloud anisotropy created at scales *l > 1 km*

Season effect on spectral exponent



5 CONCLUSION AND PROSPECTS

- **Identification of fractal scaling features over specific scale ranges:**
  - **Scaling exponents coherent with literature** [1]
  - **Spectral drop** close to satellite resolution: possibly due to optical sensors limitations…
  - **Different scaling behavior according to the acquisition spectral band** (as in [5])
  - **Clouds impacts** scaling properties and anisotropy at least in the blue band
  - **Anthropogenic effects (land cover)** on scaling exponents
- **Further work:**
  - **Apply this analysis on time series of images during 2016-2017**
  - **Comparison to scaling behavior of other optical products:** Landsat-8, SPOT (Take5), Venµs…
  - **Multifractal analysis** [3]: finer characterization of the variability, especially on the extreme
  - **Refine the study on anisotropy**: multiple angles to estimate the structure function

References:

[1] **Lovejoy et al (2008)**, Single-and multiscale remote sensing techniques, multifractals, and MODIS-derived vegetation and soil moisture, *Vadose Zone Journal*, *7*(2), 533–546.
[2] **Neuhauser et al (2018)**, Propriétés statistiques multi-échelles de produits satellitaires SMOS d'humidité du sol désagrégés à la résolution kilométrique, *Rencontre du Non Linéaire*, 55.
[3] **Schertzer and Lovejoy (1987)**, Physical modeling and analysis of rain and clouds by anisotropic scaling multiplicative processes. *Journal of Geophysical Research: Atmospheres*, 92(D8), 9693-9714.
[4] **Olivier Hagolle**, «Using NDVI with atmospherically corrected data", http://www.cesbio.ups-tlse.fr/multitemp/?p=12746, 4th February 2018
[5] **Alonso et al (2017)**, Spatial and radiometric characterization of multi-spectrum satellite images through multi-fractal analysis. *Nonlinear Processes in Geophysics*, *24*(2), 141-155.

THEIA-MAJA Workshop, 13-14th June 2018, Toulouse, France