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### ► To cite this version:

Mathis Neuhauser, Sébastien Verrier, Sylvain Mangiarotti. Multiscale description of Sentinel-2/MAJA products: a spectral and structure function approach. THEIA-MAJA Workshop, Jun 2018, Toulouse, France. , 2018. hal-04464086

**HAL Id: hal-04464086**

**<https://hal.science/hal-04464086v1>**

Submitted on 18 Feb 2024

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# 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

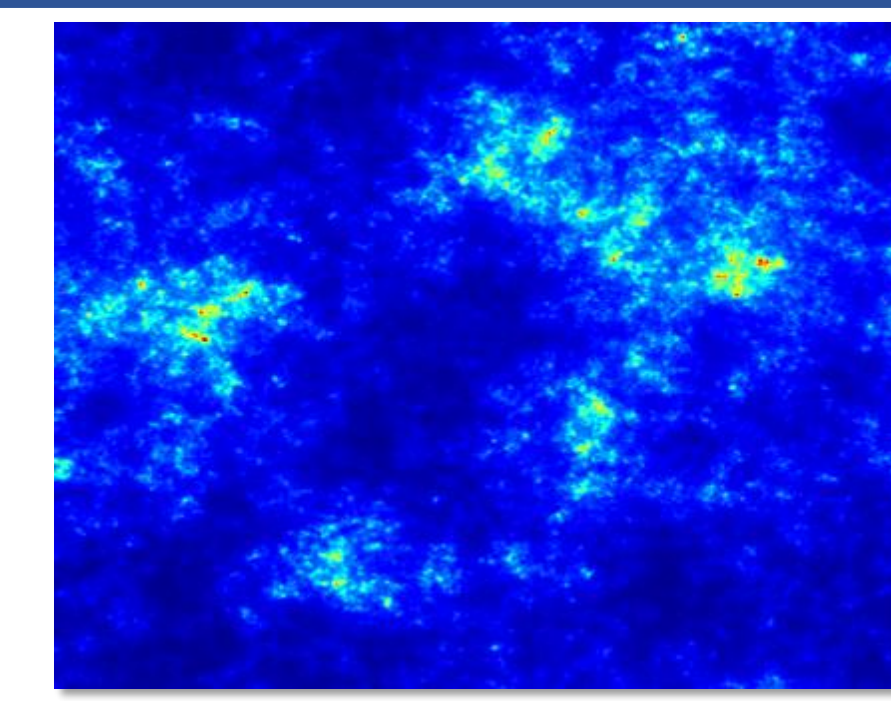
SOUTHWESTERN FRANCE - 2016/2017



Study area: 200x200 km<sup>2</sup> Example of analyzed image: 40x40 km<sup>2</sup>

- 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 Régional" - CESBIO
- Work in progress on Landsat-8/MAJA products

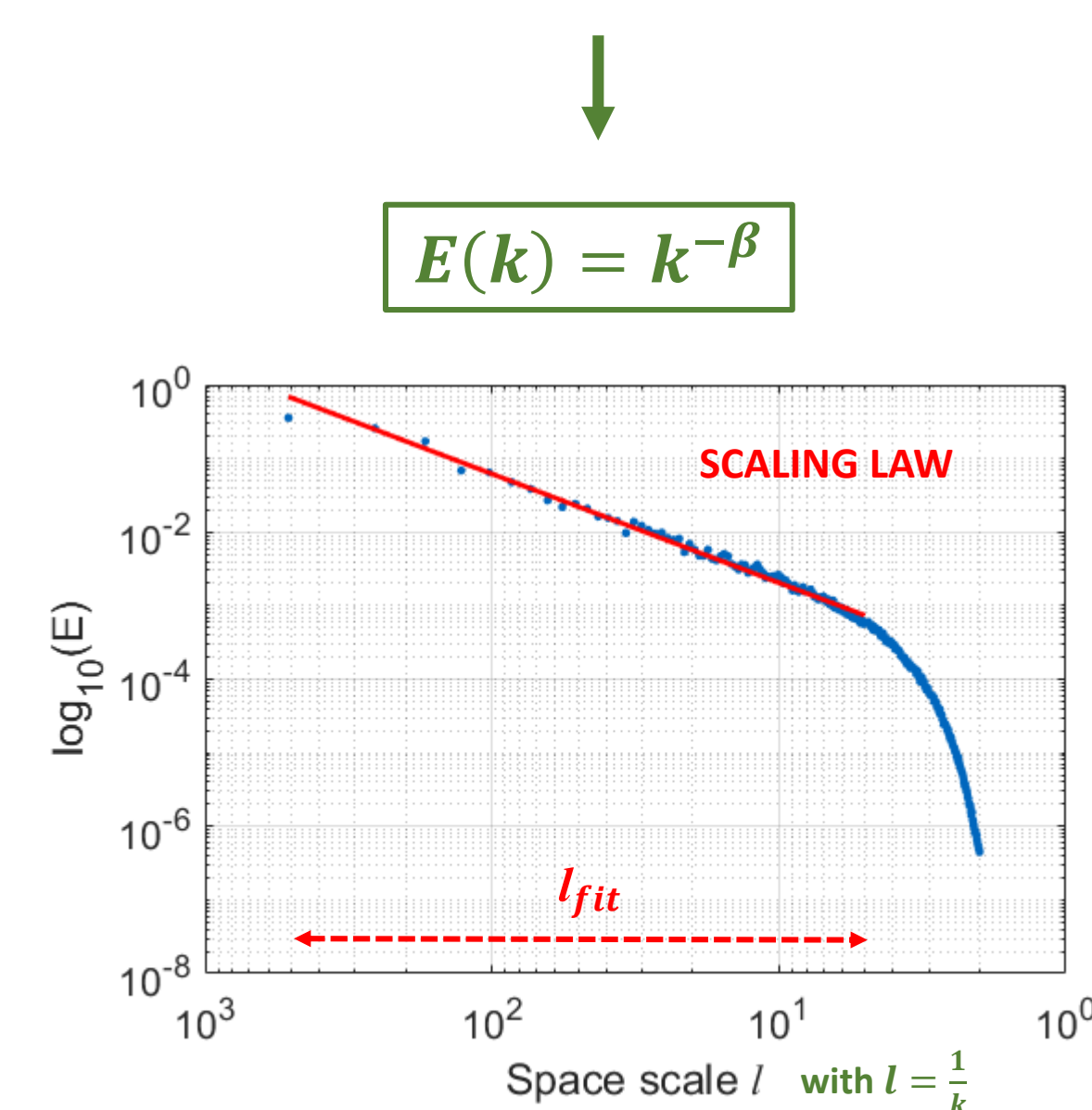
## 3 METHODOLOGY : Statistical analysis



(Synthetic fractal image)

### 1. SPECTRAL ANALYSIS

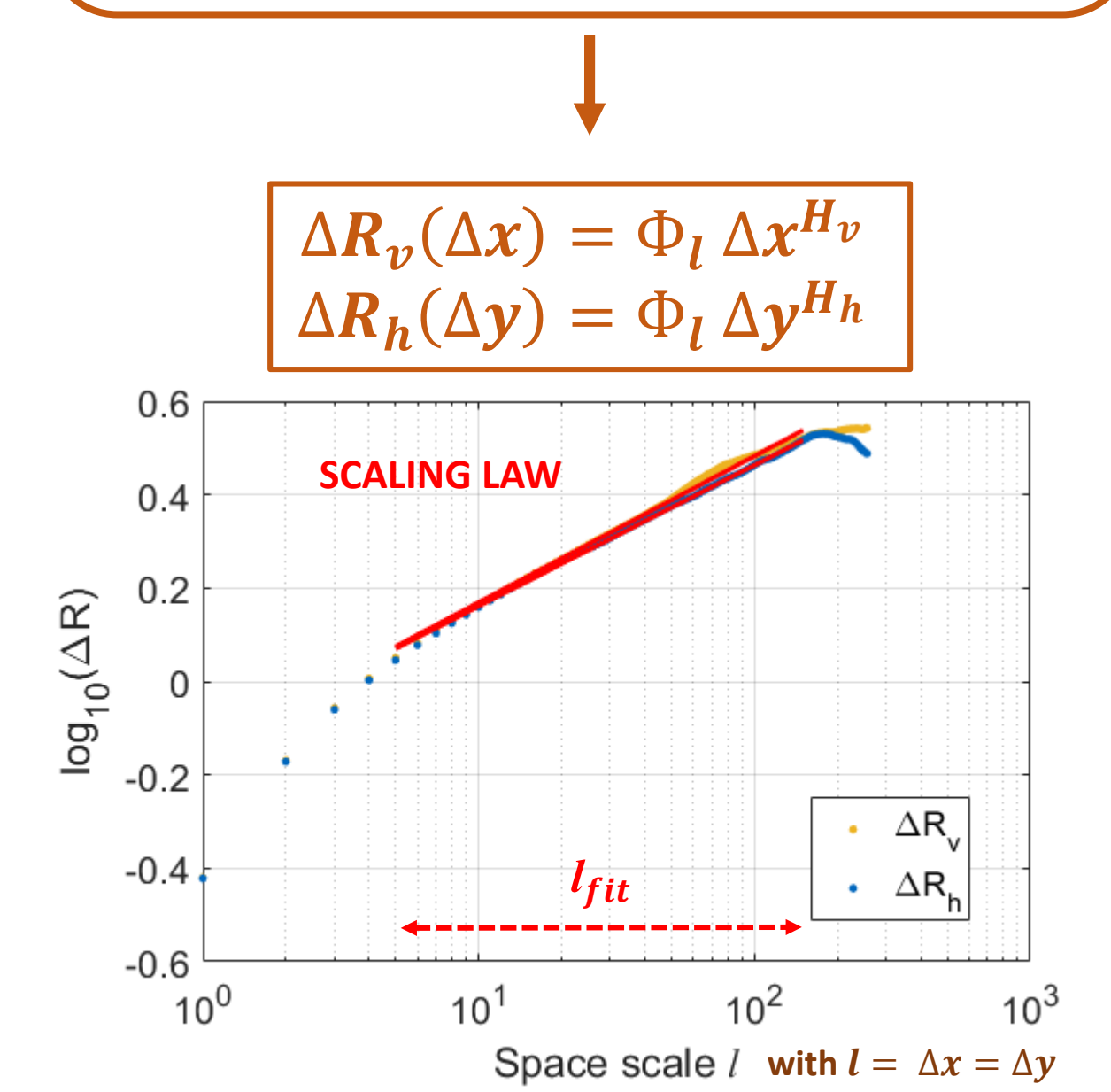
- Computes 2D Fourier power spectrum  $P(k_x, k_y) = |FFT(R)|^2$
- Angle integration on x and y axis  $E(k) = \int_{\|\vec{k}\|=k} P(\vec{k}) d\vec{k}$



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

### 2. STRUCTURE FUNCTIONS

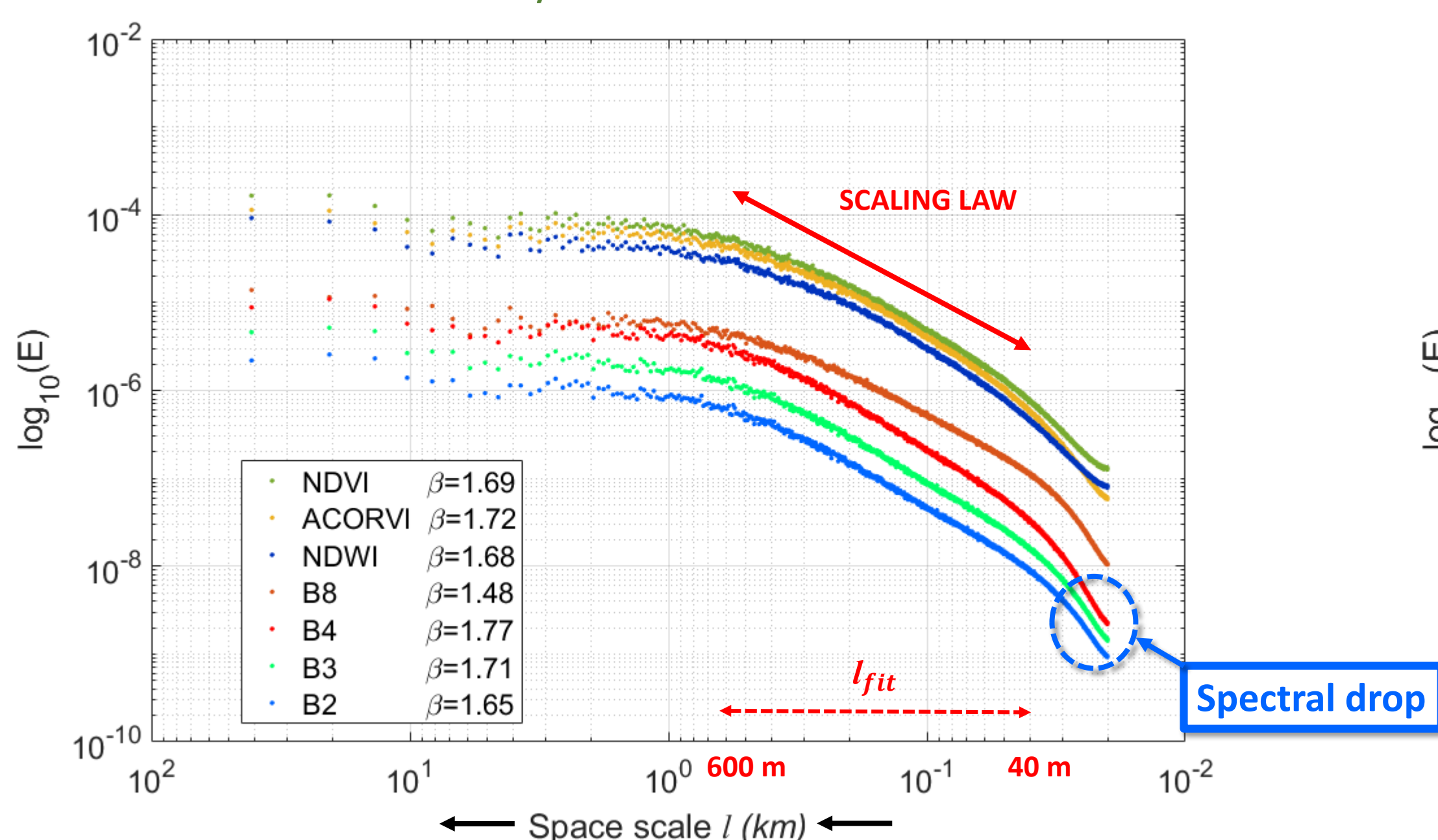
- Computes vertical structure function  $\Delta R_v(\Delta x) = \langle |R(x + \Delta x) - R(x)| \rangle$
- Computes horizontal structure function  $\Delta R_h(\Delta y) = \langle |R(y + \Delta y) - R(y)| \rangle$



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

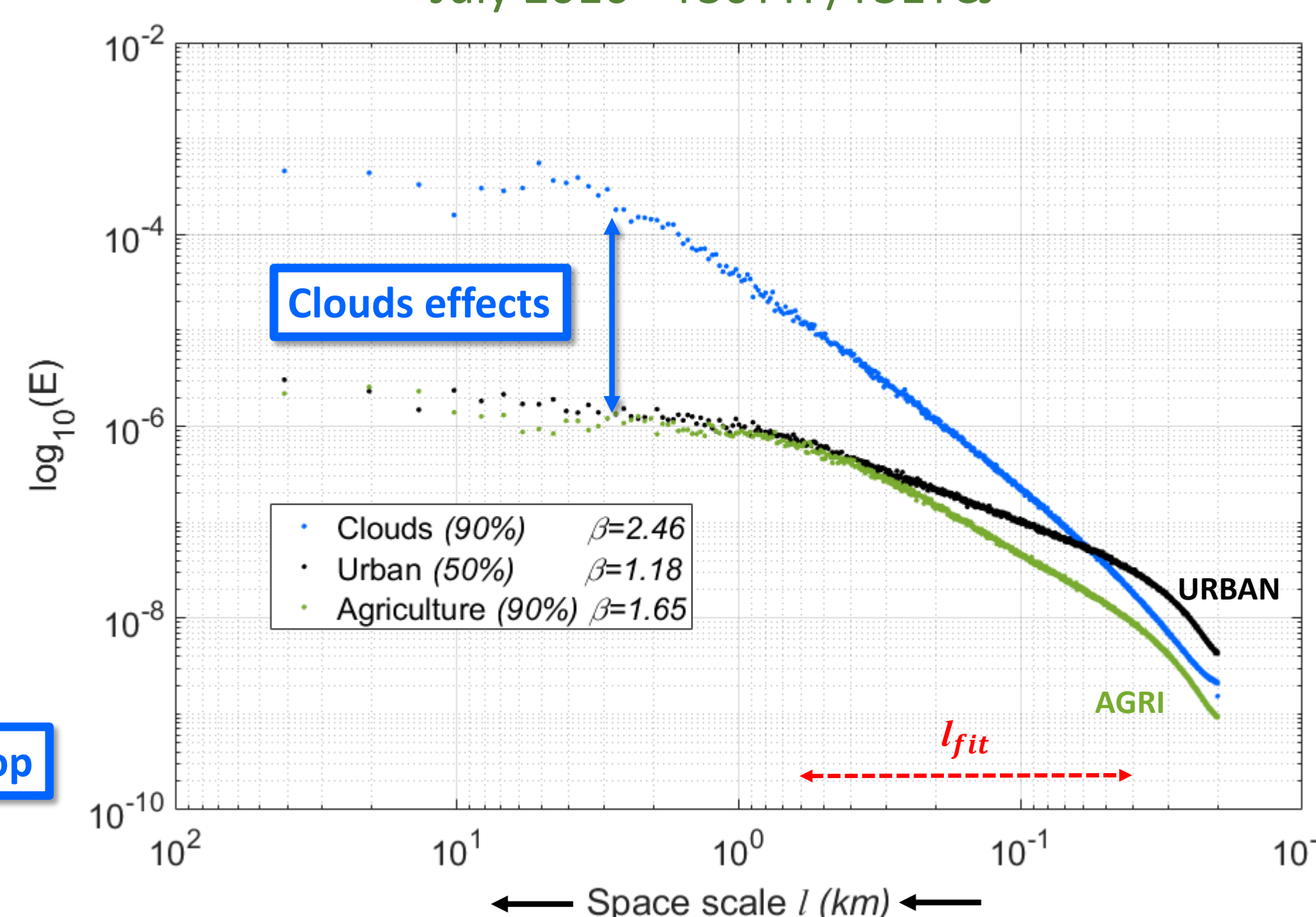
## 4 RESULTS : 4<sup>th</sup> February - 10<sup>th</sup> July 2016

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



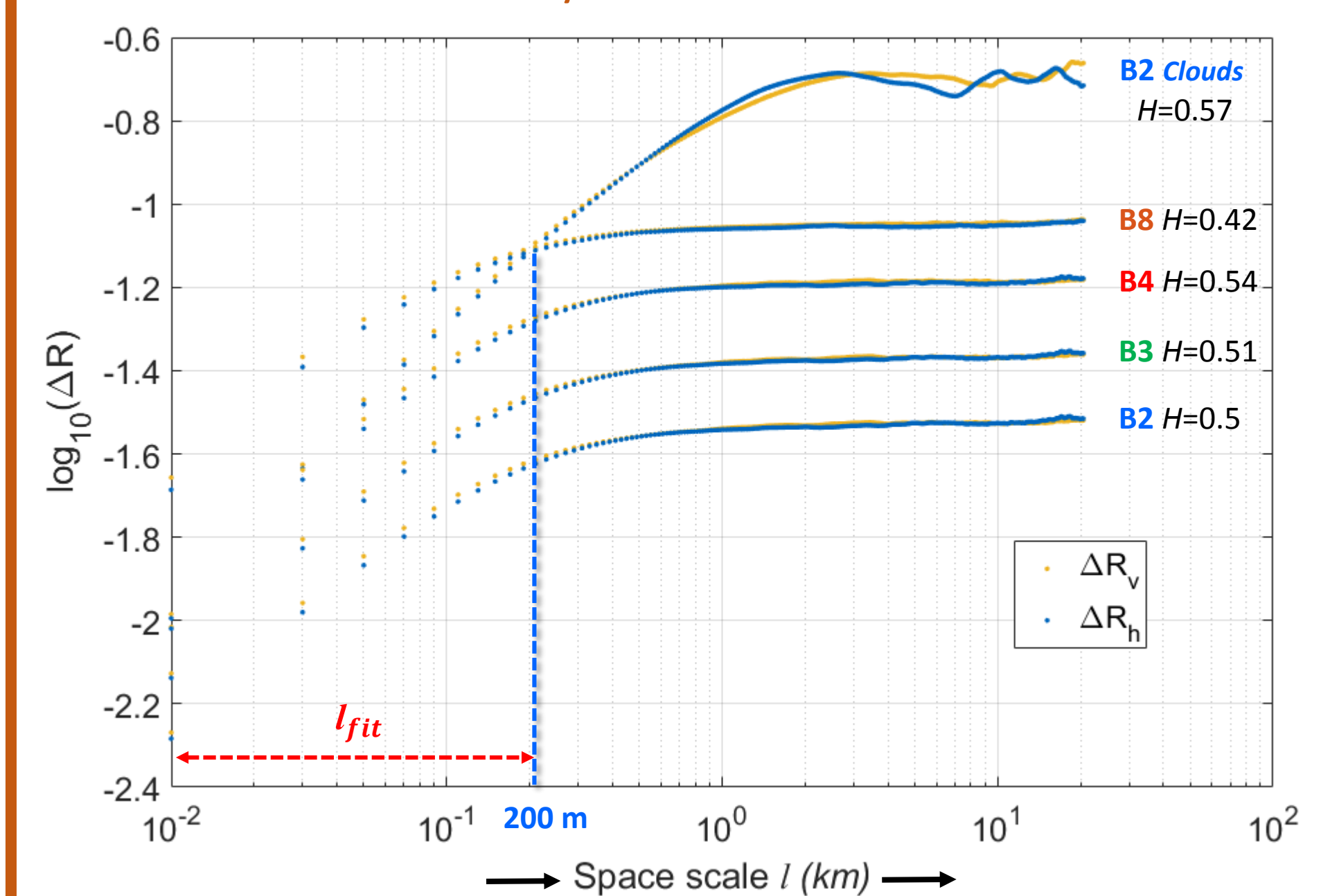
- Impact of acquisition wavelength on the scaling exponent
- Comparison of two vegetation indices NDVI vs ACORVI  $\left( \frac{NIR - (R + 0.05)}{NIR + (R + 0.05)} \right)$ , [4]:
  - same scaling behavior on most scales
  - better "sensor noise robustness" of ACORVI at smallest scales

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



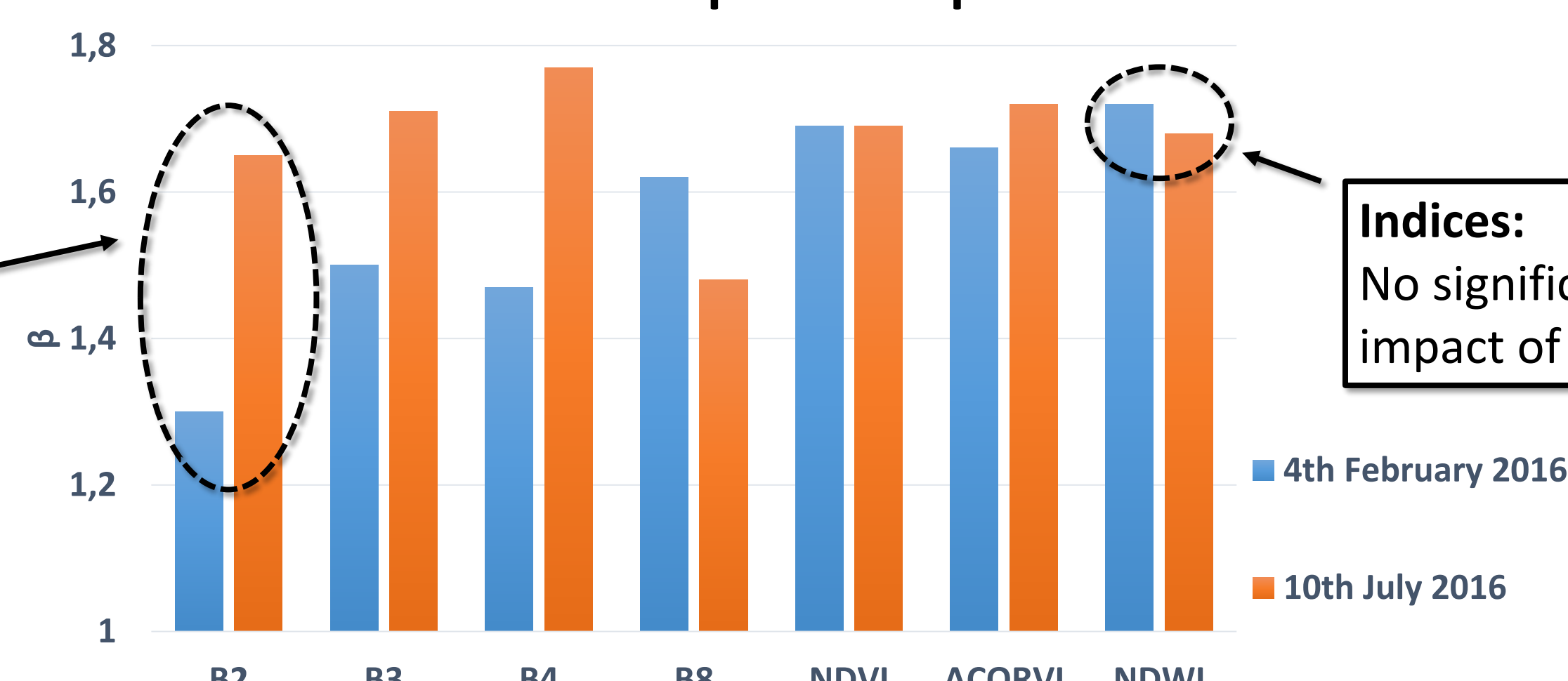
- Cloud impact: increase of spectral slope
- Urban impact: decrease of spectral slope

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



Visible bands:  
Increasing slope during summer

Indices:  
No significant impact of season

## 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>, 4<sup>th</sup> 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.