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



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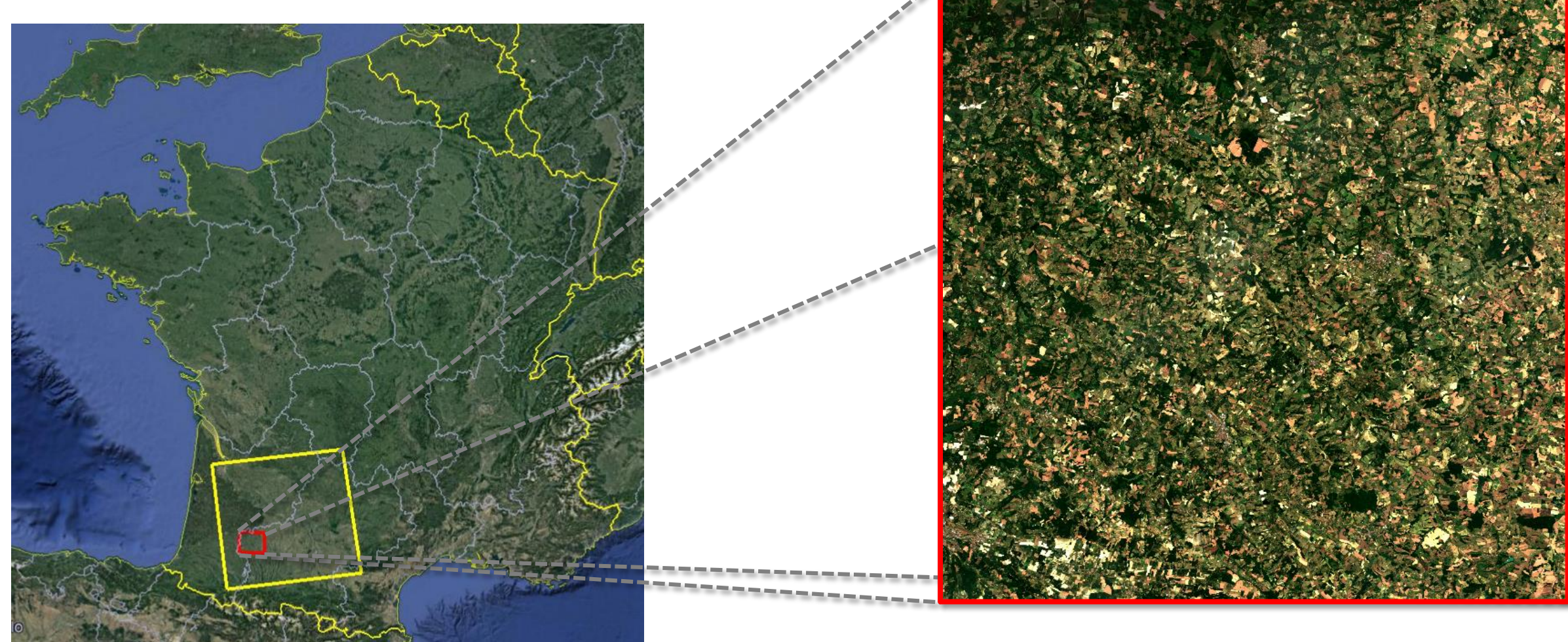
1 INTRODUCTION

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

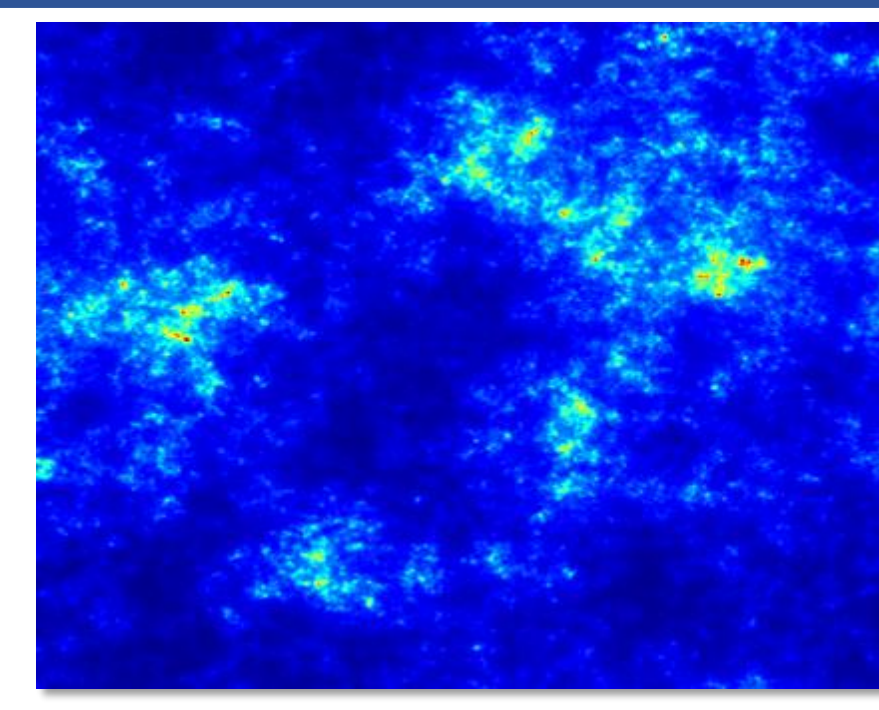
SOUTHWESTERN FRANCE - 2016/2017



Study area: 200x200 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 Régional" - CESBIO
- Work in progress on Landsat-8/MAJA products

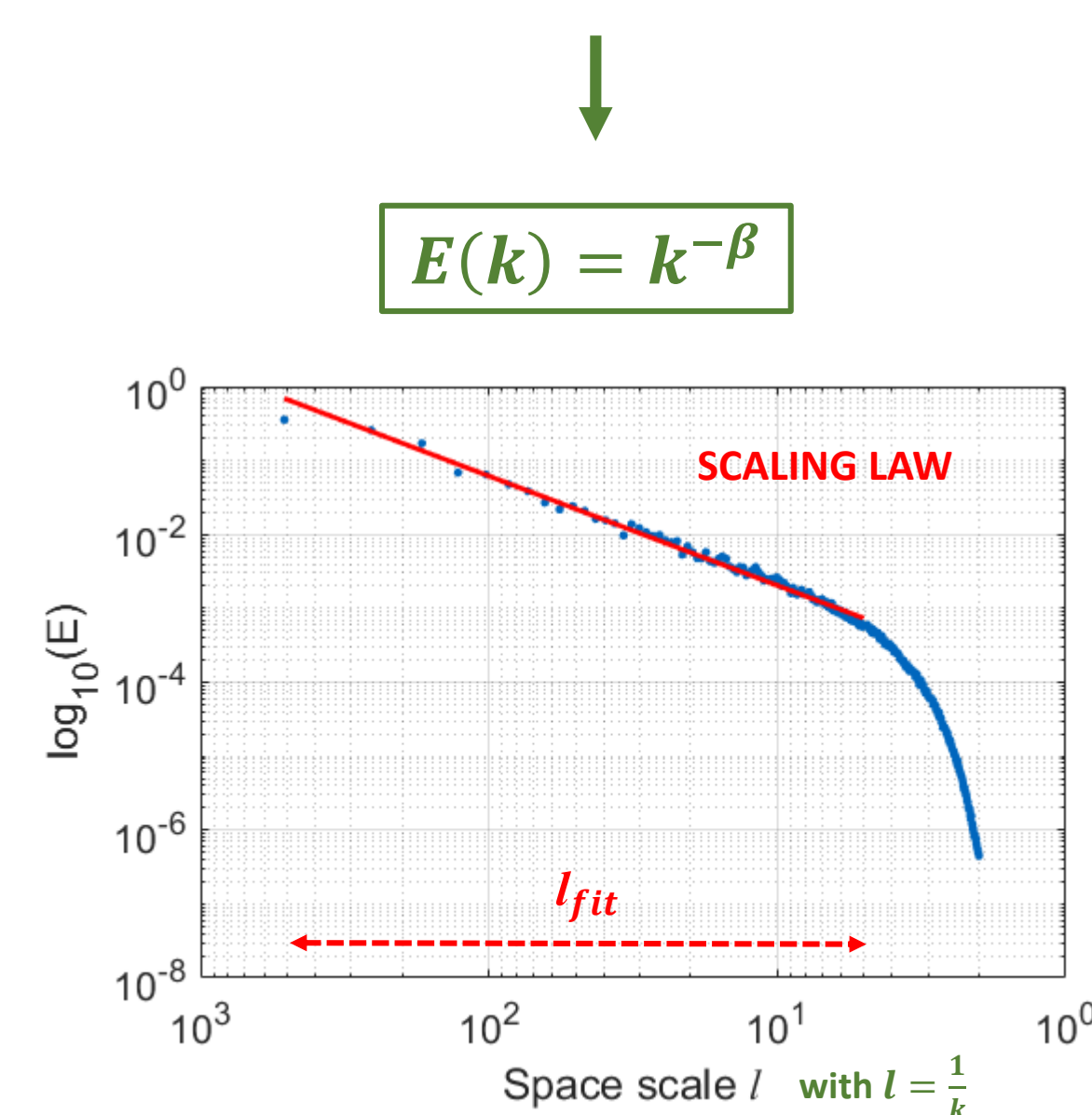
3 METHODOLOGY : Statistical analysis



(Synthetic fractal image)

1. SPECTRAL ANALYSIS

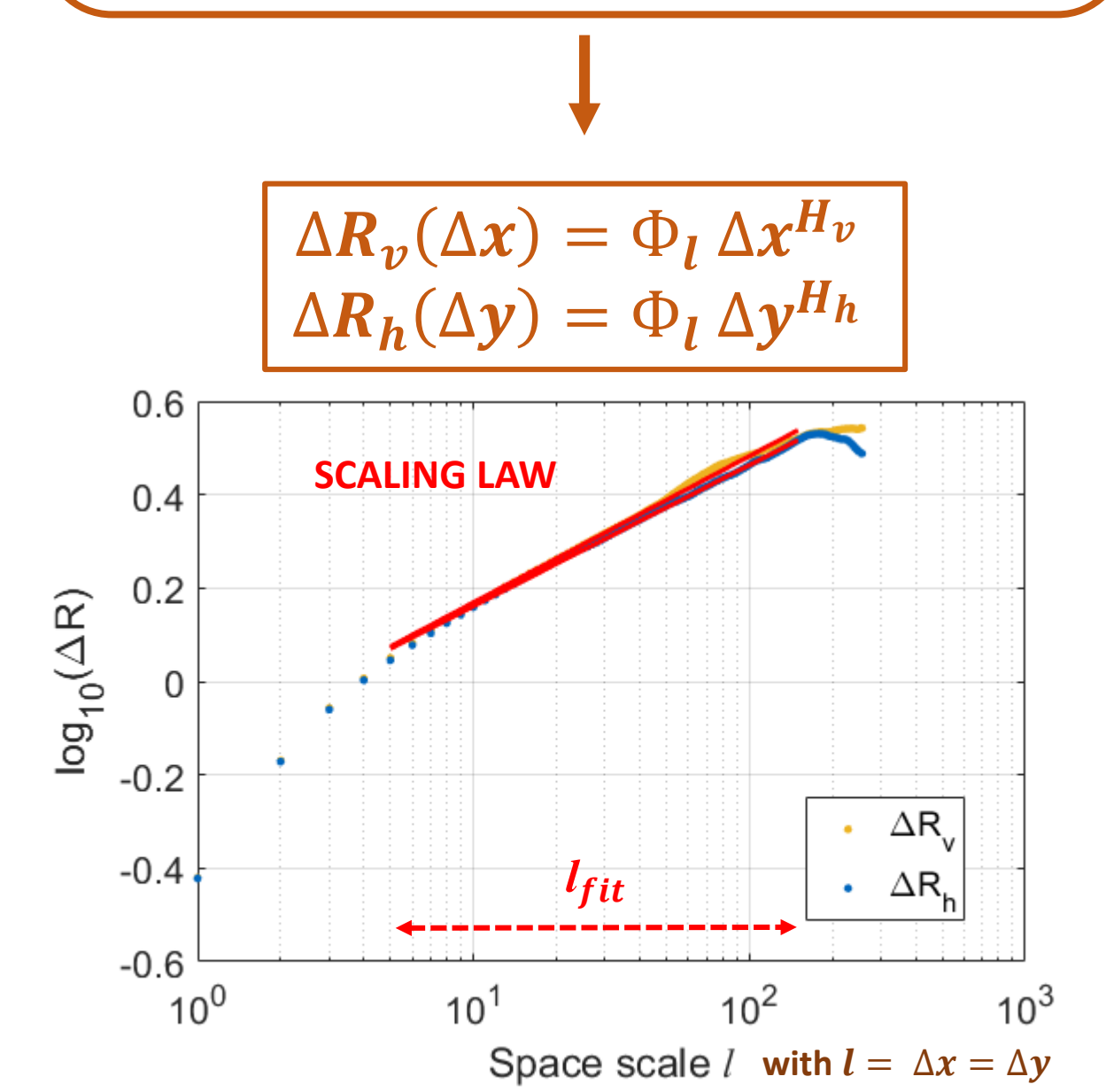
- Computes 2D Fourier power spectrum $P(k_x, k_y) = |FFT(R)|^2$
- Angle integration on x and y axis $E(k) = \int_{\|\vec{k}\|=k} P(\vec{k}) d\vec{k}$



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

2. STRUCTURE FUNCTIONS

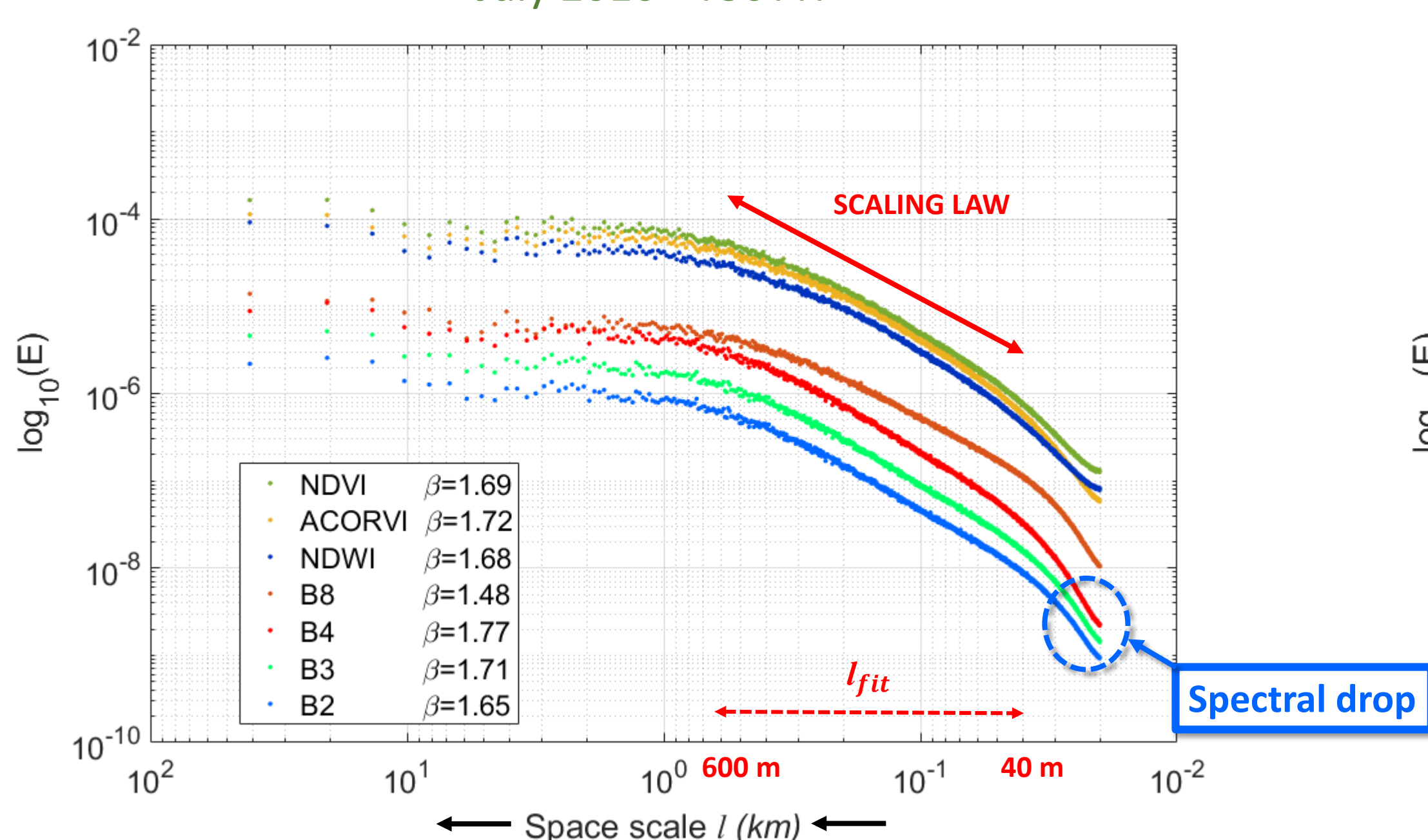
- Computes vertical structure function $\Delta R_v(\Delta x) = \langle |R(x + \Delta x) - R(x)| \rangle$
- Computes horizontal structure function $\Delta R_h(\Delta y) = \langle |R(y + \Delta y) - R(y)| \rangle$



- 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])

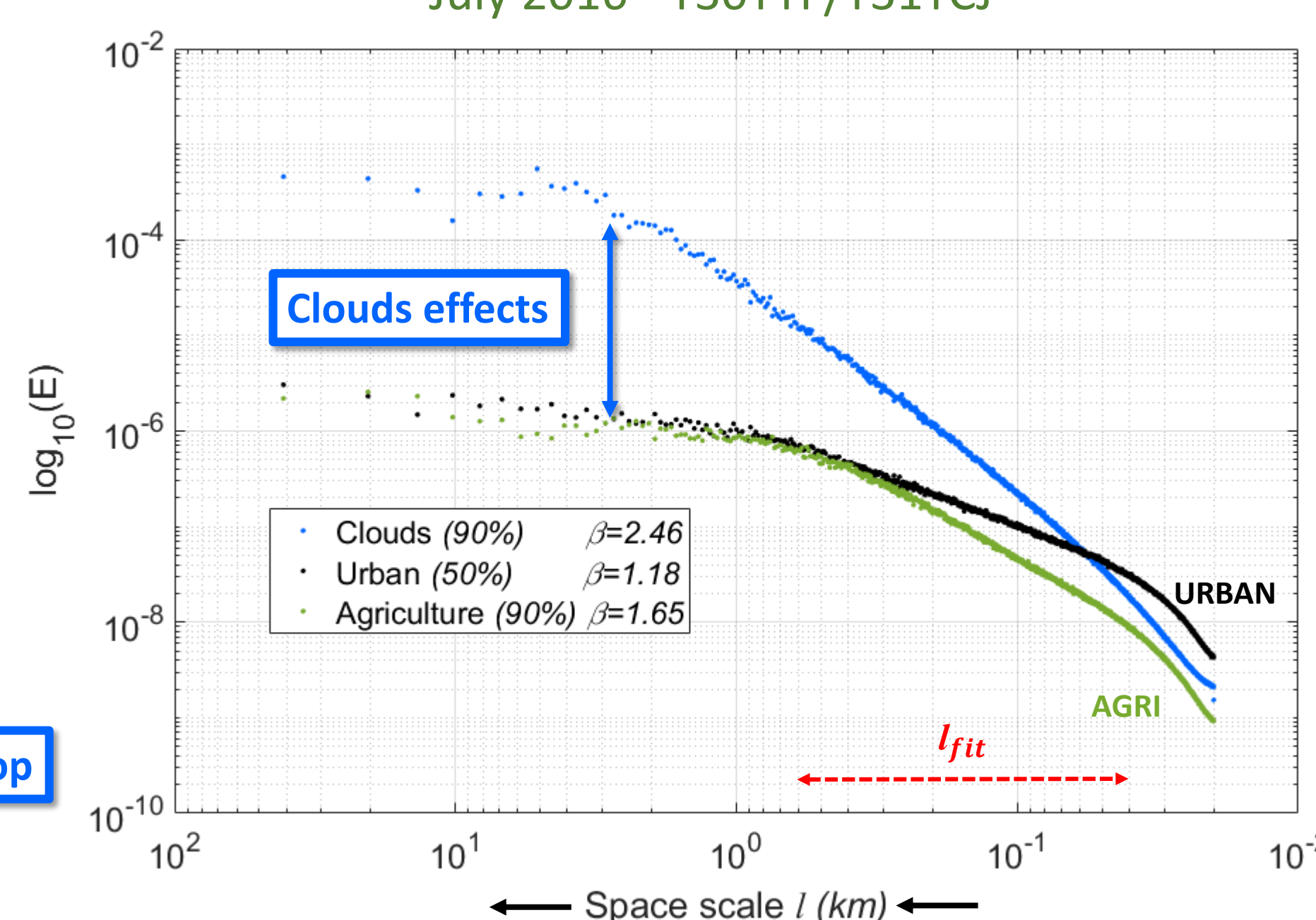
4 RESULTS : 4th February - 10th July 2016

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



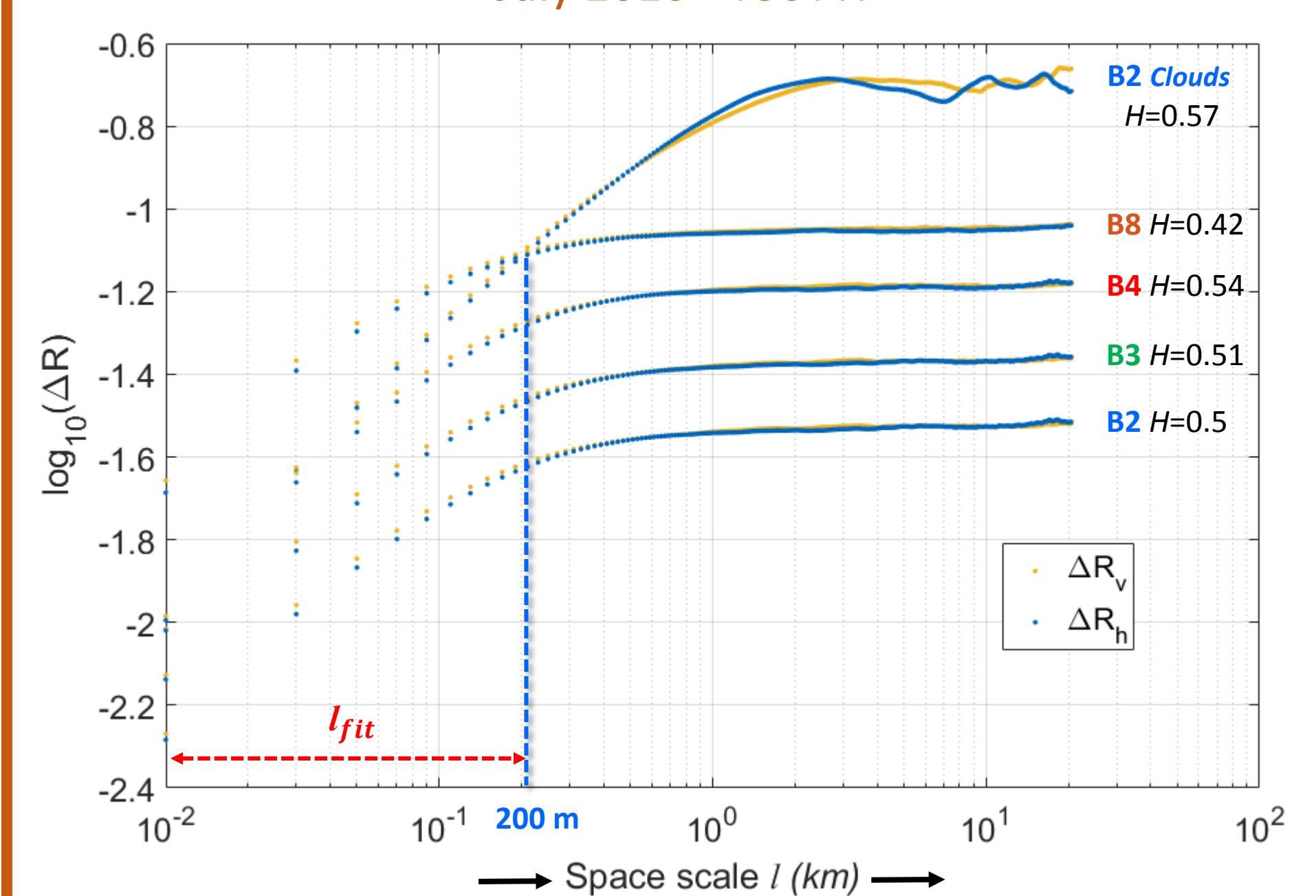
- Impact of acquisition wavelength on the scaling exponent
- Comparison of two vegetation indices NDVI vs ACORVI $\left(\frac{NIR - (R + 0.05)}{NIR + (R + 0.05)}\right)$, [4]:
 - same scaling behavior on most scales
 - better "sensor noise robustness" of ACORVI at smallest scales

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



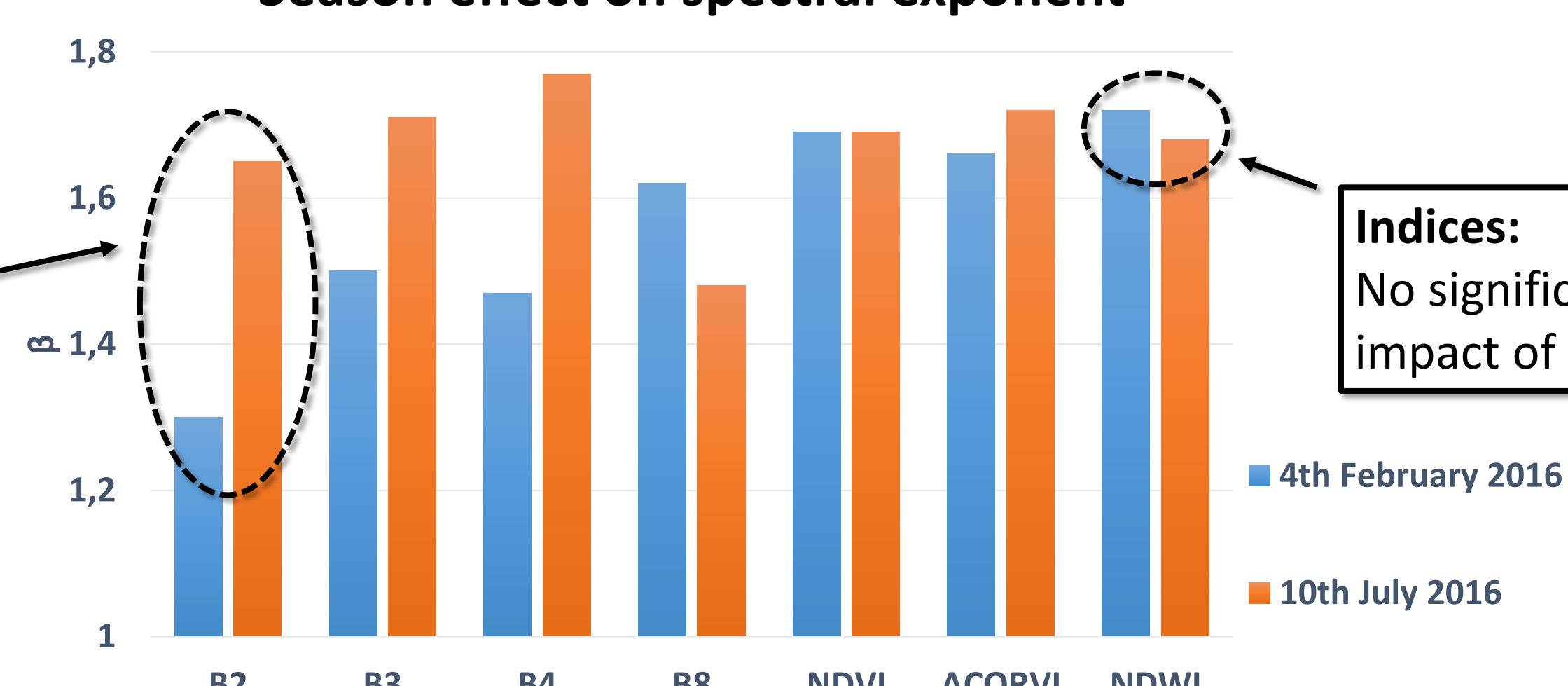
- Cloud impact: increase of spectral slope
- Urban impact: decrease of spectral slope

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>, 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.