RW-Turb kick off meeting

Jerry Jose

Ángel García Gago

Universal Multifractal framework

- Wind power (available and produced) shows a highly non-Gaussian distribution, where intensity depends upon the scale of measurement.

- The framework of Universal Multifractals (UM) enables to characterize the extreme variability of geophysical fields across scales, with the help of a limited number of parameters with physical meaning (Schertzer and Lovejoy (1987)).

$$p(\varepsilon_\lambda \geq \lambda^\gamma) \approx \lambda^{-c(\gamma)}$$

Statistical moments (q) of a scale invariant field (ε) scale with resolution (λ)

$$\langle {\varepsilon_\lambda}^q \rangle \approx \lambda^{K(q)}$$

Moment scaling function (K(q)) characterized using only two parameters,

$$K_c(q) = \frac{C_1}{\alpha - 1}(q^\alpha - q)$$

multi-fractality index α and mean intermittency co-dimension C_1.

- Using UM, we try to characterize variability of wind power and its correlation with other highly variable geophysical fields such as wind velocity, rainfall rate and air density.

Data analysis: inputs and methods

Available wind power

$$P_w = \frac{1}{2}\rho A v^3 C_p$$

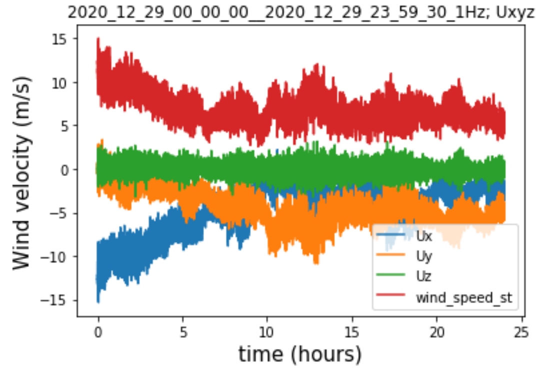
where, ρ - air density (kg/m^3)
A - rotor swept area (6,362 m^2 for Vestas-90)
V - wind velocity (m/s; from Anemometers)
C_p - Betz coefficient

Air density of moist air, CIPM-2007

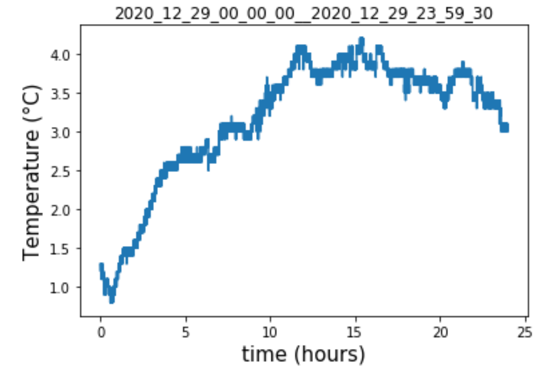
$$\rho(t,p,h) = \frac{pM_a}{Z(t,p,h)RT(t)}\left\{1 - x_v(t,p,h)\left[1 - \frac{M_v}{M_a}\right]\right\}$$

t is temperature ($°C$; from Meteorological station)
p is pressure (Pa; from Meteorological station)
h is humidity ($0 \le h \le 1$; from Meteorological station)
$T(t)$ is air temperature (K; from t)

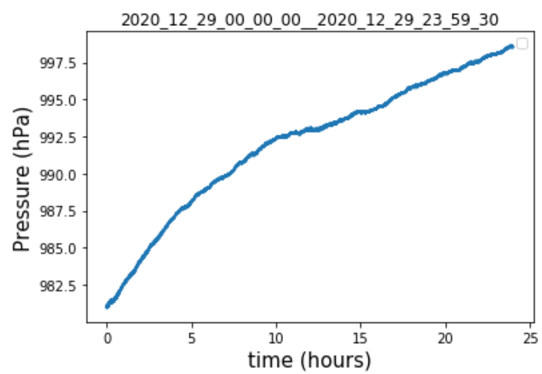
Z is compressibility factor
R is molar gas constant $(Jmol^{-1}K^{-1})$
x_v is mole fraction of water vapour
M_a is molar mass of dry air $(gmol^{-1})$
M_v is molar mass of water $(gmol^{-1})$



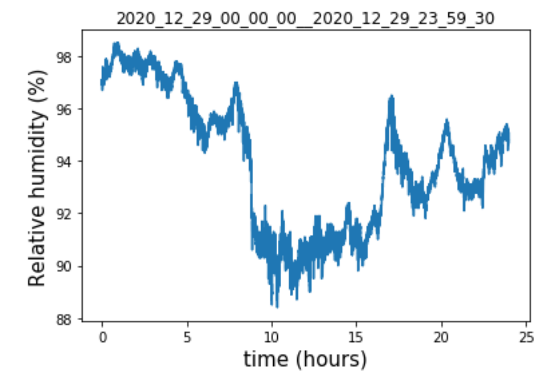
Wind velocity; Anemometer1 & Station 1



Temperature; Station 1

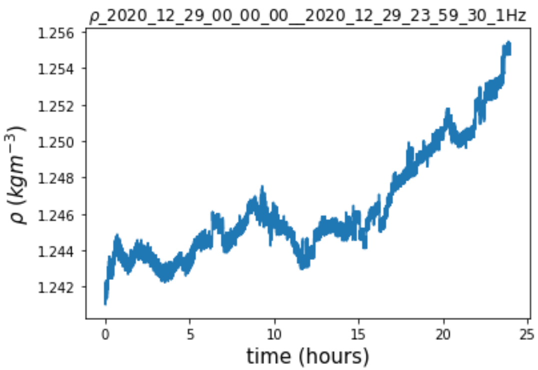


Pressure; Station 1

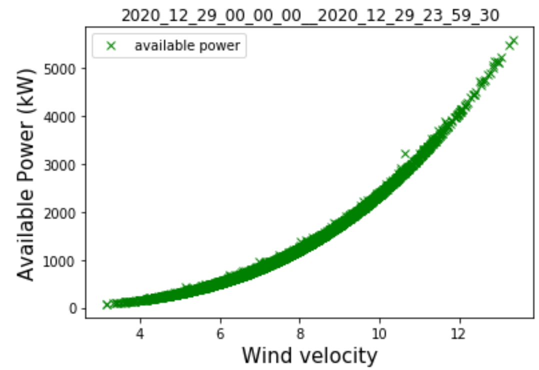


Relative humidity; Station 1

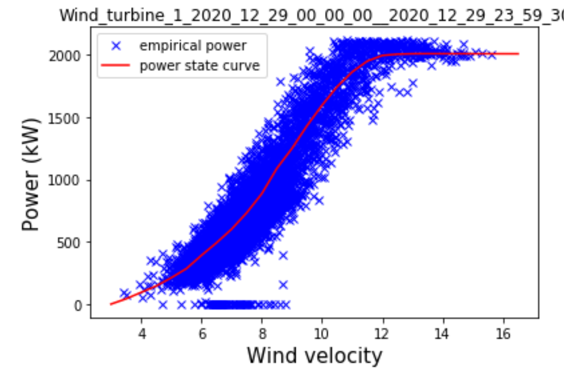
Data analysis: outputs



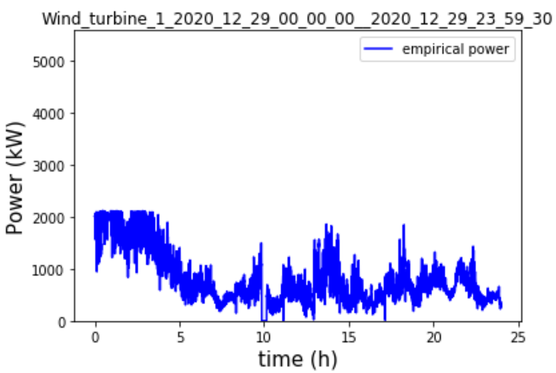
Air density; from Anemometer1 & Station 1 data



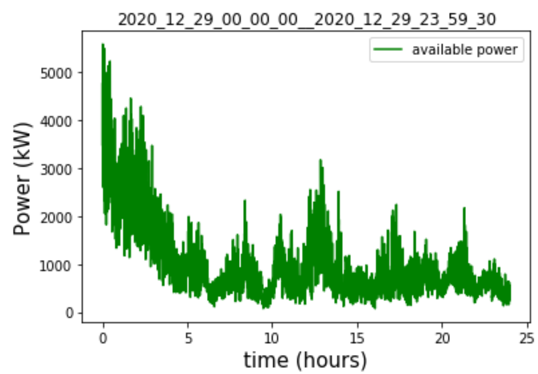
Available wind power



Turbine wind power



Power produced by Turbine, time series

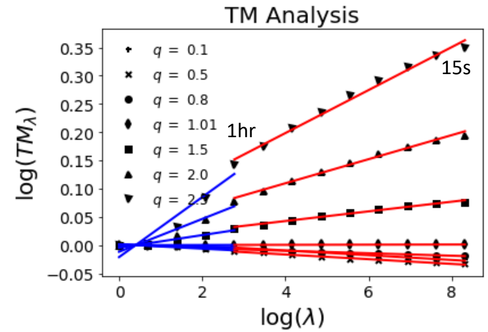


Available wind power, time series

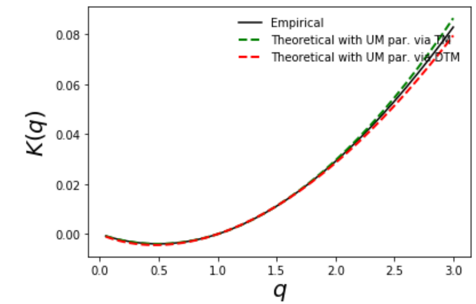
Initial MF analysis

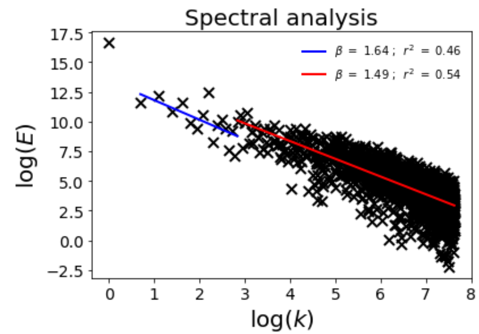
Ensemble analysis of Power produced:

- Ensemble analysis using the longest available time data to have an idea on average behaviour of field
- Negative wind power values were set to 0
- Wind turbine power time series shows 2 scaling regimes, whether its needed should be investigated
- Effect of upper threshold (2000kW) might create some bias (needs investigation)
- Analysis need to be refined according to rainfall conditions, will be repeated based on rainfall



$$\langle {\varepsilon_\lambda}^q \rangle \approx \lambda^{K(q)}$$





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

	Scale 1	Scale 2
R2_TM	0,905	0,986
alpha_DTM	1,713	1,713
C1_DTM	0,016	0,012
beta	1,648	1,493
H	0,338	0,261

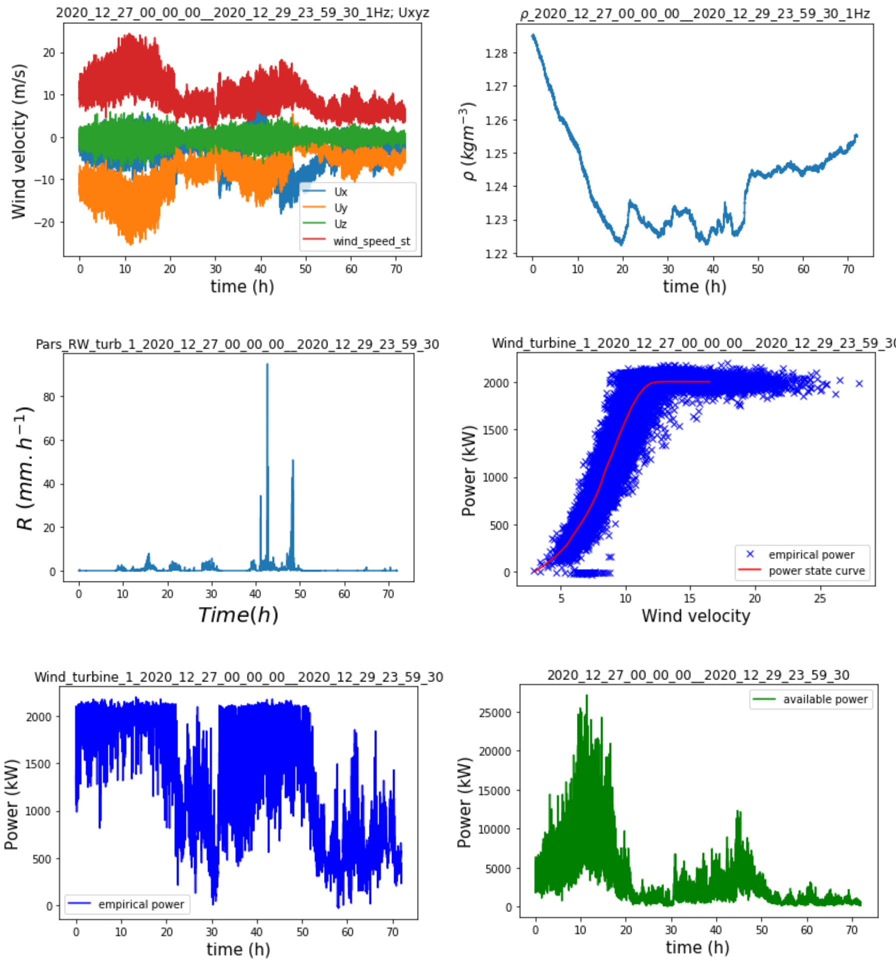
Time period – 12 Dec 2020 to 14 Feb 2021

Data – Wind turbine #1

Sample length – 4096 (close to 1 day)

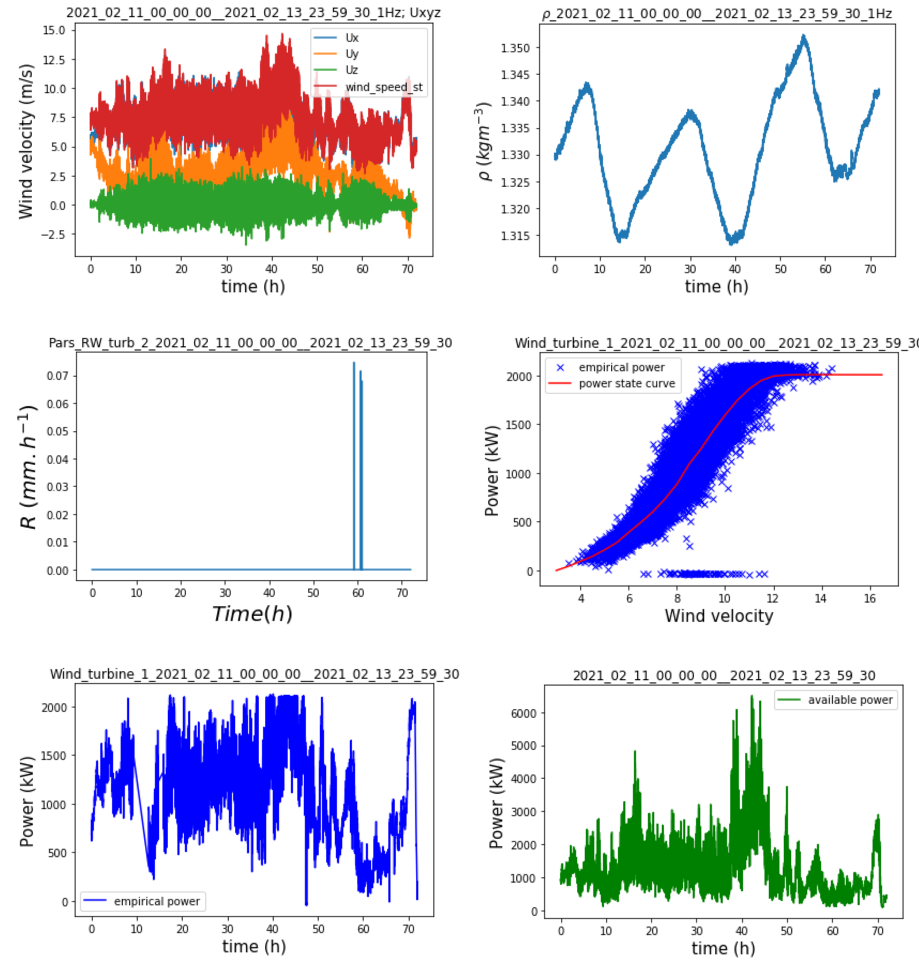
No. of samples – 67

Rainy days



Rainy days: 27 to 29 Dec 2020;

Dry days

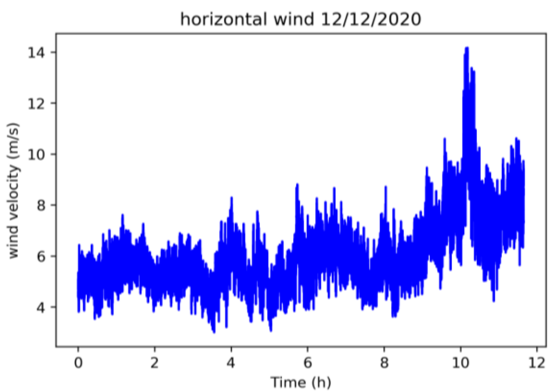


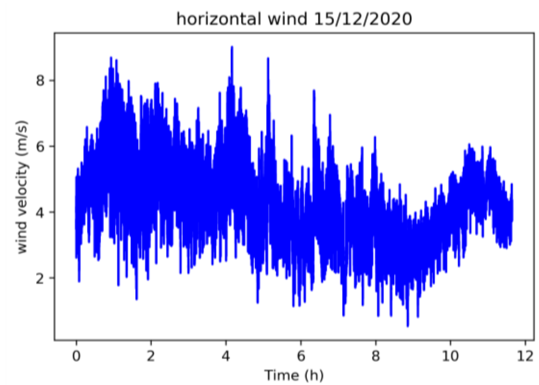
Dry days: 11 to 13 Feb 2021

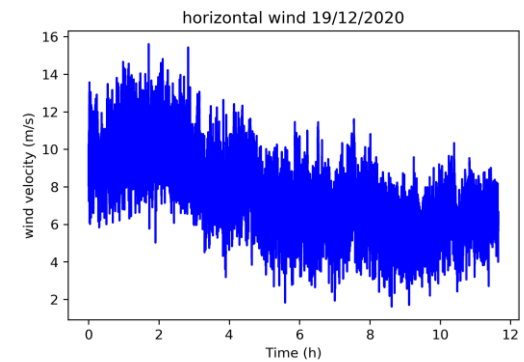
Outline

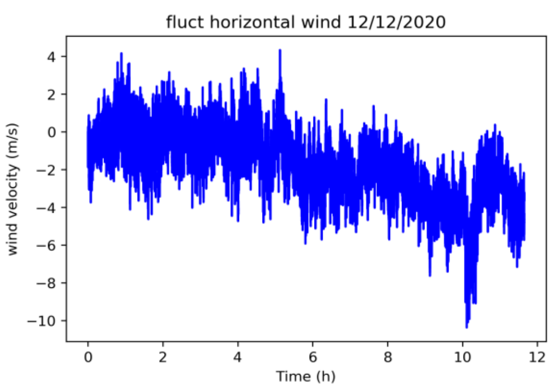
- Main purpose, develop modelling chain
- Bibliography to understand universal multifractal (UM) framework
- Analysis of atmospheric fields
- Compute simulations

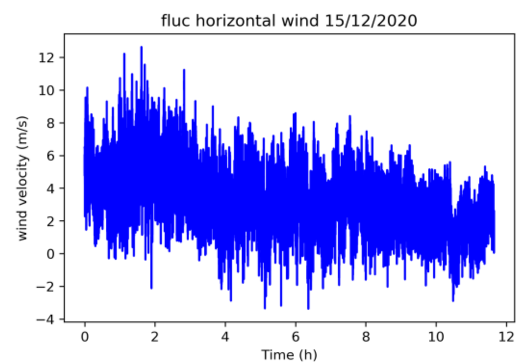
Data 100hz Anemometer

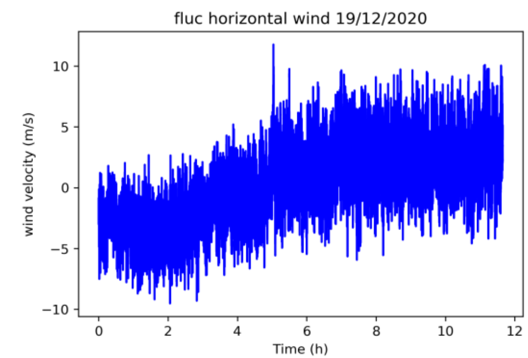






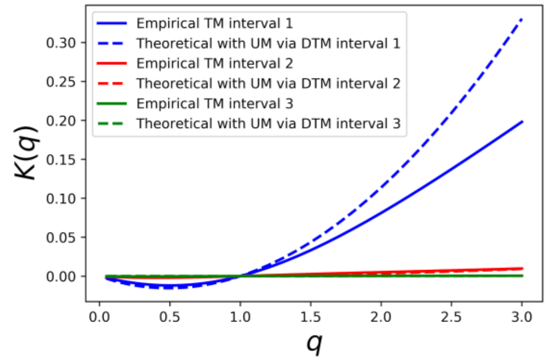




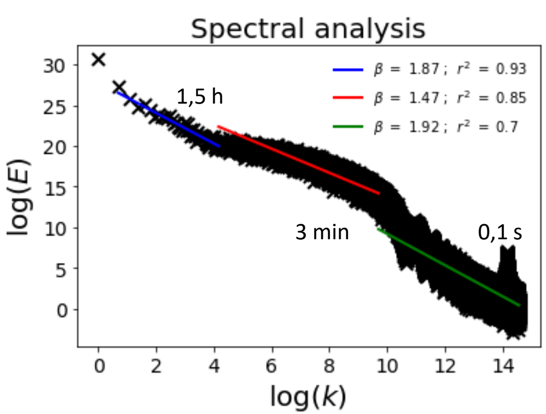


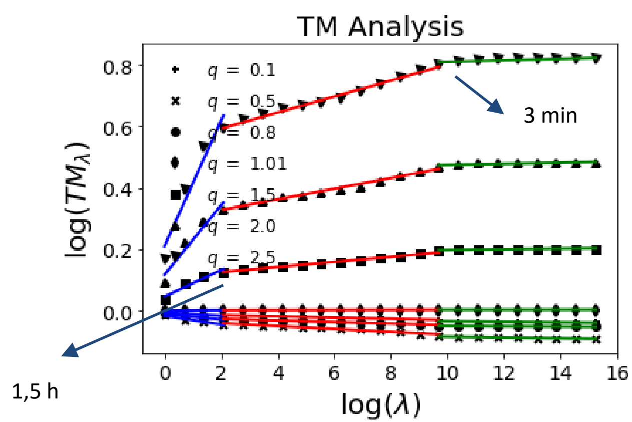
Preliminary Analysis

- Ensemble of 7 rainy days
- Spectral Analysis in horizontal wind
- High values of H
- UM analysis in fluctuations



	Blue interval	red interval	green interval
alpha	1.30	1.75	1.84
c1	0.003	0.02	0.03
beta	2.05	1.33	1.51
H	0.52	0.19	0.28

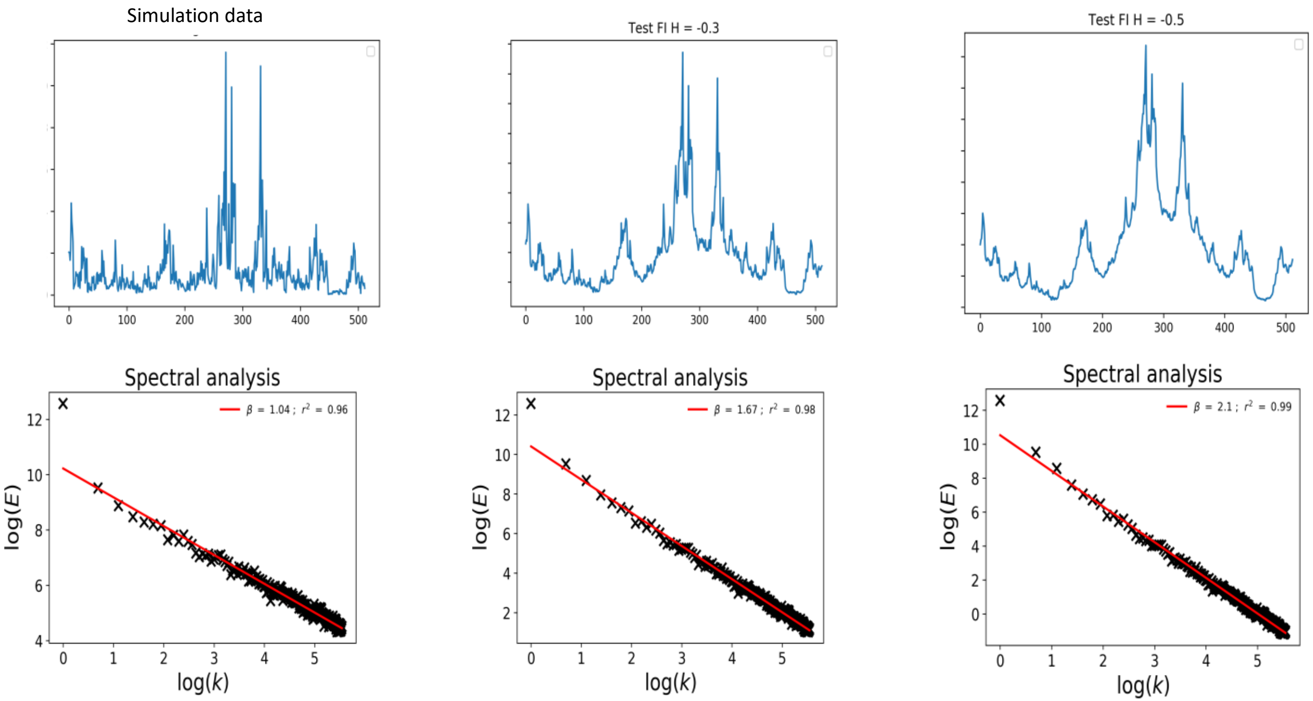




	r2		
q	blue interval	red interval	green interval
1,5	0.57	0.98	0.98

Fractional Integration/Differentiation

Simulation inputs n=9 alpha=1.89 c1=0.07 Samples=100

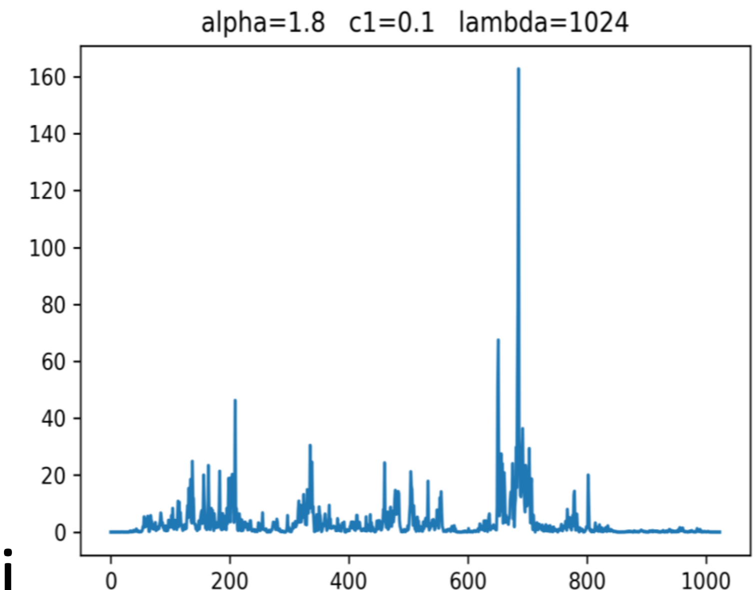


$$E(k) \approx k^{-\beta}$$

$$\beta = 1 + 2H - K(2)$$

Simulation, UM continuous cascades

1. Create a levy noise
2. Fractional Integration
    a. Fitton's script
3. Take the exponential
4. Renormalization of the fi



Simulations

How to manage negative fields

$$Data = RE\left(e^{\log X + (\log Y) j}\right)$$

Replicate analysis results

Using parameters recovered in analysis

Improve the simulations

Vector fields

Different rainfall conditions