Modeling and Theoretical Investigation of multi-scale Interactions between Convection and Land-Surface Heterogeneity

Zahra Parsakhoo*, Cedrick Ansorge, Yaping Shao
Institute for Meteorology and Geophysics, University of Cologne
*z.parsakhoo@uni-koeln.de

1. Introduction

Land-surface heterogeneity has different scales, and its effect on atmosphere and surface-fluxes is not fully resolved in models. It is specially interesting to understand the interaction of different surface pattern (**SP**) scales on development of atmosphere boundary layer. However definition of patterns is an open question.

In our study, we first defined **SP**s by the dominant pattern scale and pattern persistence. Then we replace the surface boundary condition with SPs generated by a multi-fractal spectral approach and let model run with the new surface boundary condition to answer the following questions:

Research Questions:

- If land surface heterogeneity is to be parameterized, which heterogeneity should be considered as the primary parameter?
- For a given run, which land surface pattern is the most important (in terms of producing more/less convective rain and changing rain pattern)?
- Which combination is most critical to boundary layer development?
- Which combination is most important for shallow convection?

2. Model

➢ **Model Setup:**

To study the interaction between land-surface and atmosphere, we run the WRF model in its meso-scale mode forced by ERA-INTERIM reanalyses for a time period covered by the HOPE campaign.

WRF (real simulation)

Forcing data: ERA-INTERIM reanalyses
Spatial resolution: 10km
Temporal resolution: 6h

One-way nesting:
d01: 3km
d02: 1km

Baseline run: original geodata from USGS WPS

Duration: 23-27 of April 2013
23rd → Spin-up time
24th → Clear sky
25th → PBL clouds
26th → Frontal clouds, precipitation
27th → Clear sky

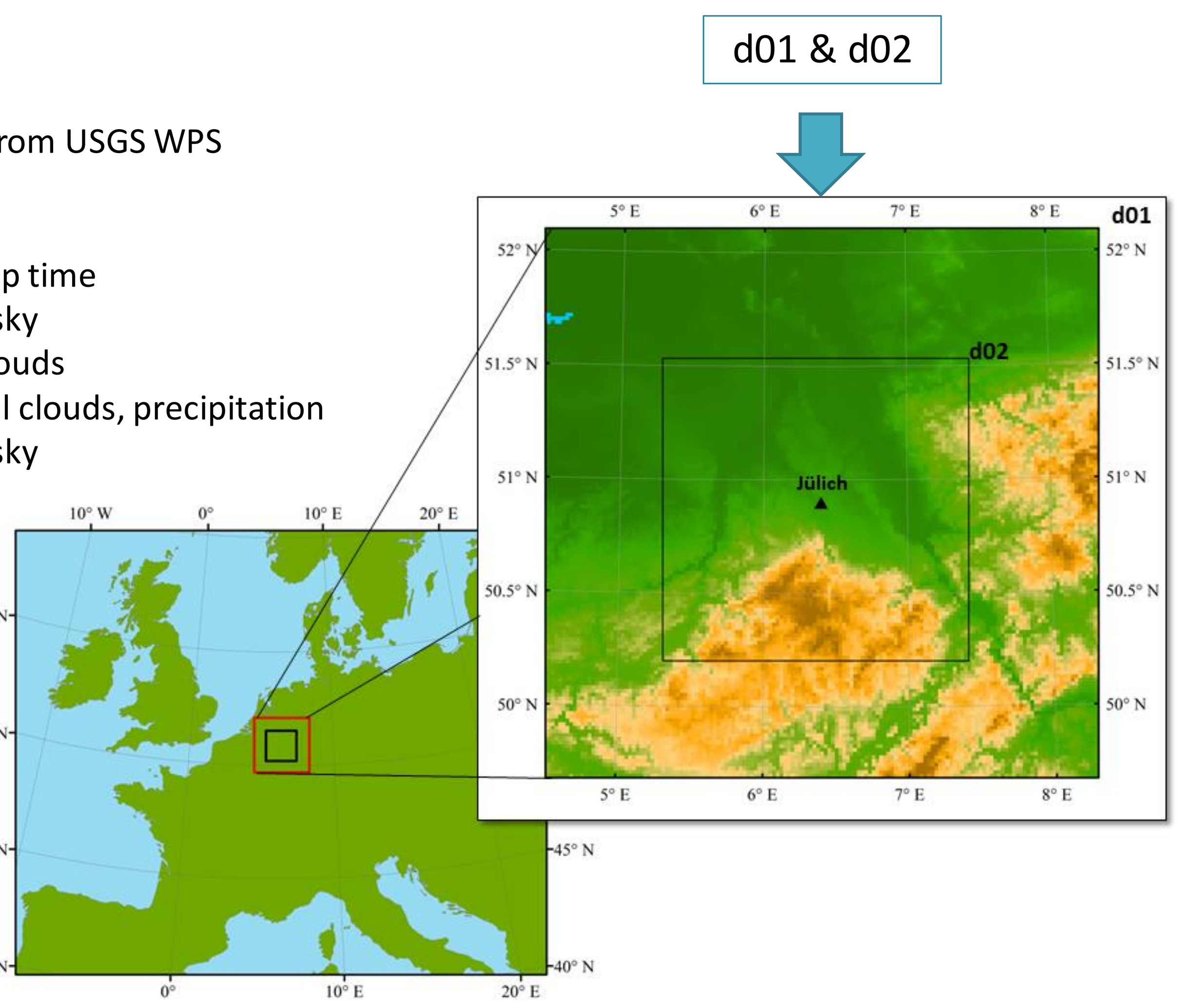
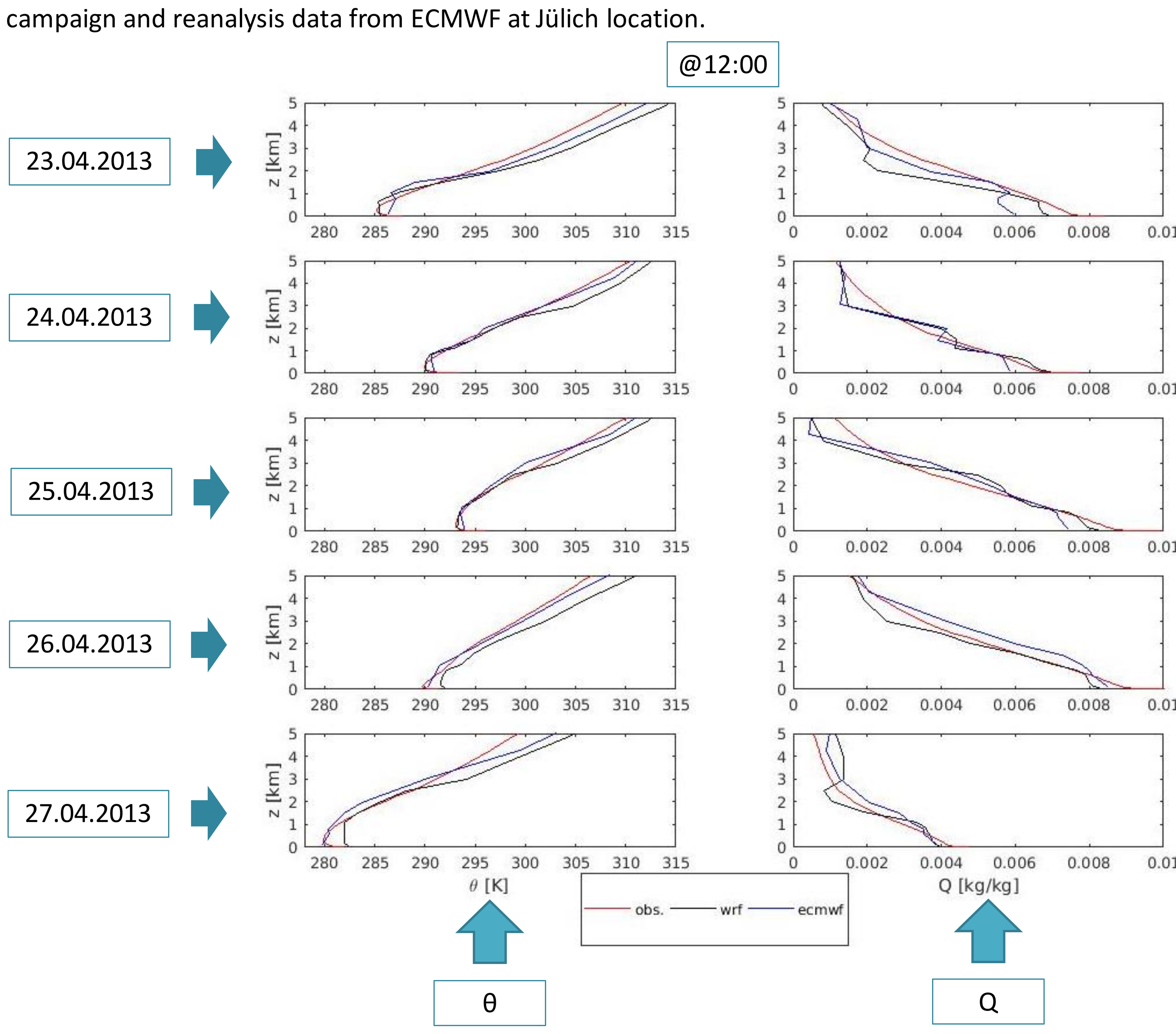


Figure 1: A map of model domains. The two model domains are centered around Jülich research center.

➢ **Model Evaluation:**

To evaluate model baseline run, we compare two model output variables with observations from Hope campaign and reanalysis data from ECMWF at Jülich location.



3. Method

➢ **Theory:** A *multi-fractal approach* comes into use because we would like to have many randomly generated SPs with specific properties which are under control. We want to have different scales of fractals in two-dimension (2D) and/or the combination of small and large scale fractals.

$$P(k) = N \times \frac{k^{s1}}{(1+k)^{s1+s2}}$$

P : spectral density function
k : wave number (k/k0)
N : normalization factor
s1 & s2: slopes of desired spectral density curve

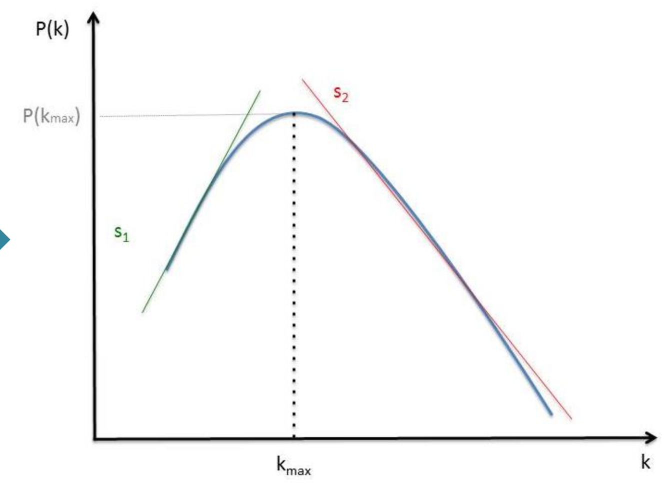


Figure 3: Schematic of the desired curve for the spectral density of the multi-fractal fields.

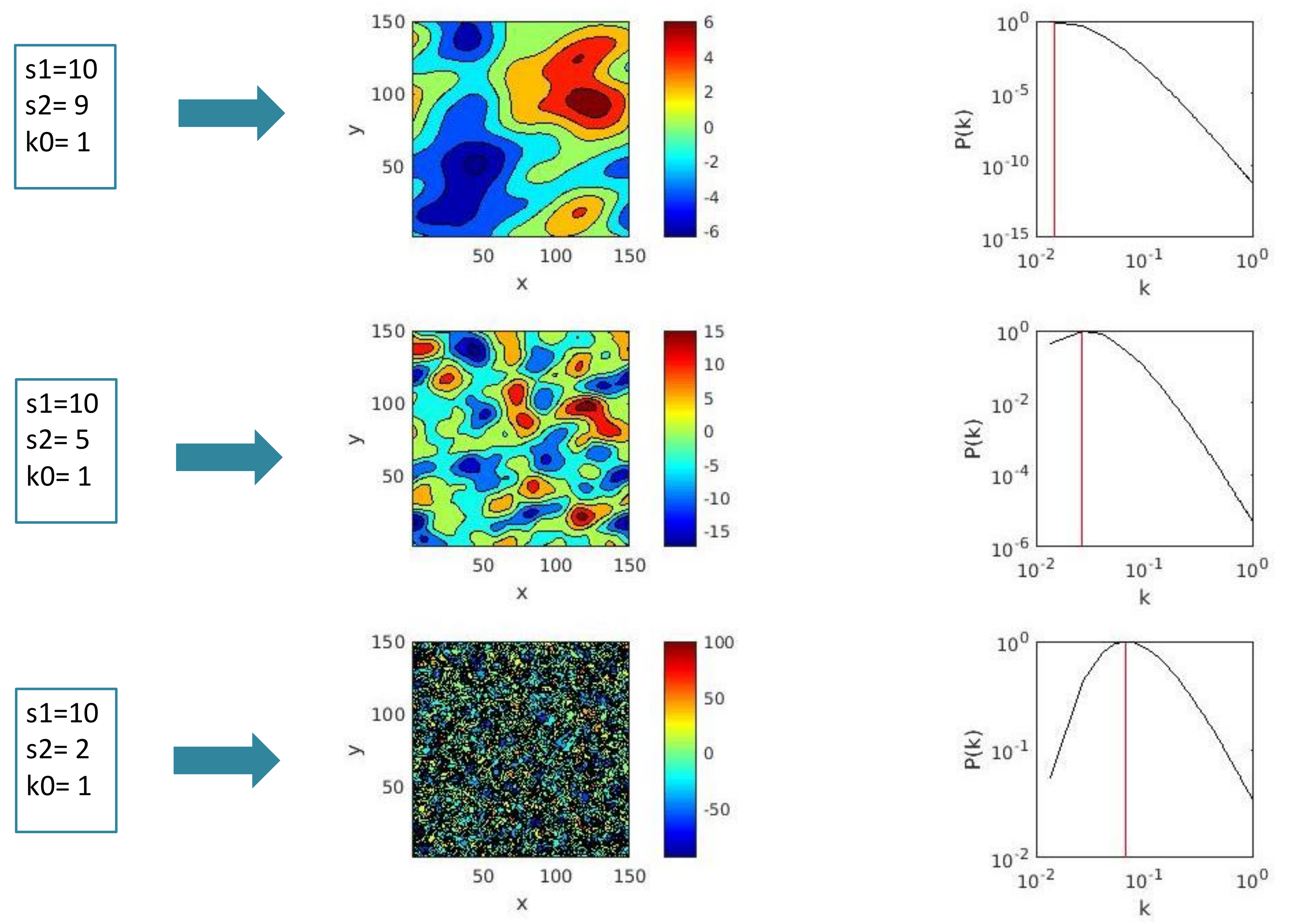


Figure 4: Three examples of using the above equation for generating SPs (right column). Left column shows the corresponding power spectrum.

➢ **Design of ensemble runs:**

To study more precisely the interaction between land-surface scheme properties and atmosphere, we focus on three surface parameters which categorize as below:

Hydraulic properties →	Soil type →	ISLTYP
Aerodynamic properties →	Roughness length →	z0
Thermal/radiative properties →	Albedo →	ALBBCK

To estimate kmax and slopes for each surface property, we calculate power spectrum of original ISLTYP and z0 fields for the d02 and some other fields which have the same size as d02 and are surrounding d02.

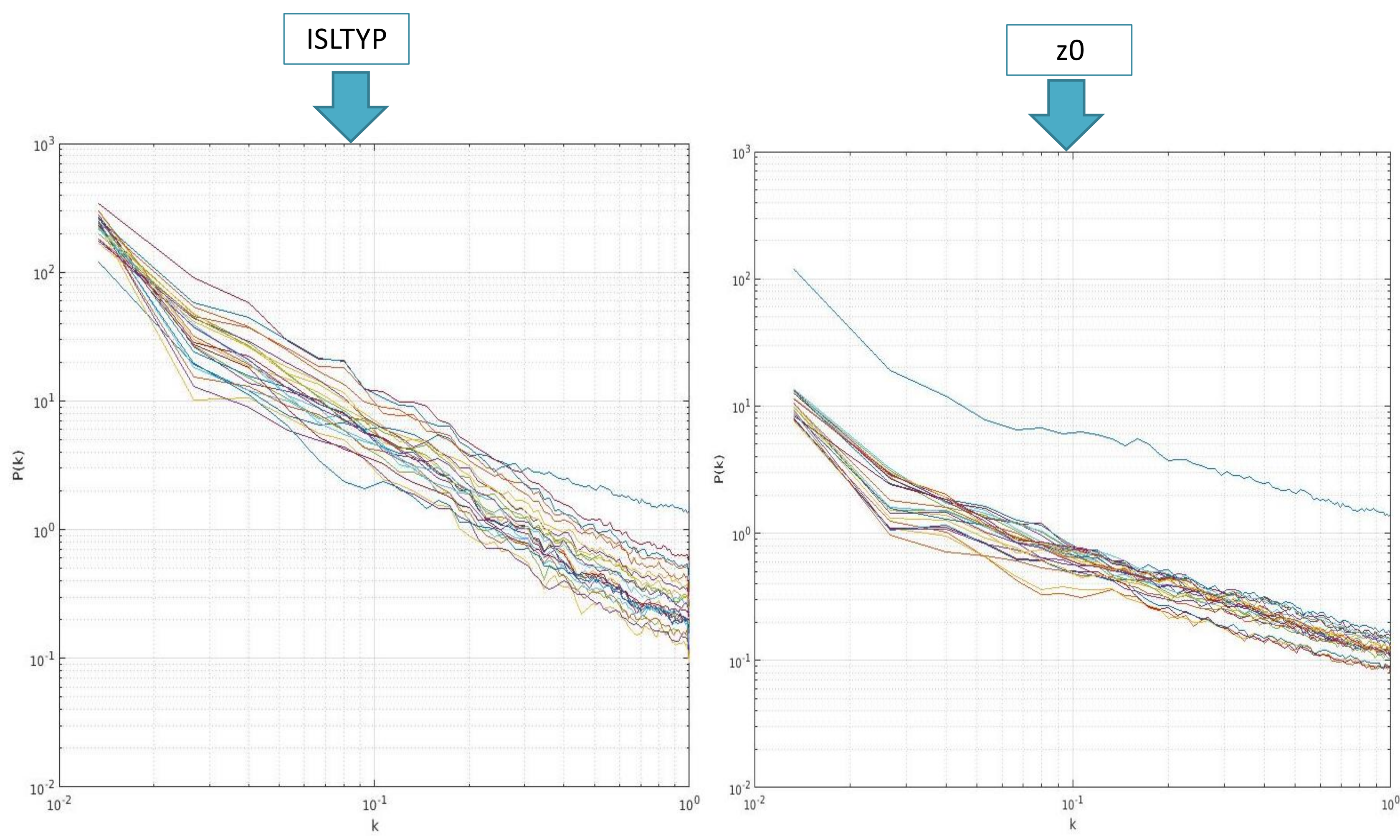


Figure 5: Power spectrum of the original ISLTYP(left) and z0 (right) for different domains. Different colors indicate different domains around d02.

4. Outlook

It is planned to generate an ensemble of a size of the order of 1000 varying the surface pattern parameters. In this ensemble, we will analyze the sensitivity of bulk parameters of the atmosphere to the parameters describing the surface pattern.

Summary of the next steps:

- Random Realization
- Ensemble Runs on Supercomputers
- ANOVA decomposition for the pattern identification and analysis of the model outputs