Large-Eddy Simulations of Coherent Structures in the Atmospheric Surface Layer

Seminar at the Institute of Geophysics,
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ABSTRACT

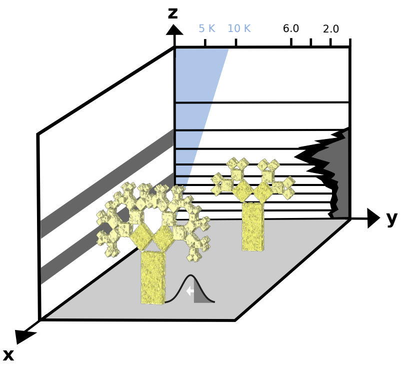

Figure 1: **Pythagoras grove**

Since the pioneering large-eddy simulation (LES) of Shaw and Schumann [1], the forest stands have been treated as a porous body of horizontally uniform (leaf) area density LAD(z) with constant drag coefficient C_D. This approach is sometimes called *field-scale* approach. Current finer scale applications and field campaigns consider the heterogeneity of the canopies at the *plant-scale*.

Here, we investigate the turbulence structure of a heterogeneous forest stand by high-resolution numerical modeling using EULAG (Eulerian/semi-Lagrangian geophysical fluid solver) [2, 3]. For this purpose, the forest elements in the numerical simulation are mimicked with immersed boundaries, representing fractal Pythagoras trees (Fig. 1). This approach was recently used to model neutrally and stably stratified air flow past buildings [2].

With our fractal approach [3], we simulate a wide range of scales (5 cm - 100 m). Vortex shedding behind individual branches or trunks is resolved as well as the integrated response of the Pythagoras grove on the flow. Our neutral reference run produces results in the turbulence statistics, that are quantitatively comparable to former field-scale LES and wind tunnel experiments.

A focus of our study is the investigation of the turbulence structure due to different thermal background stratification and heating/cooling of the crown space. Besides statistical quantities (e.g. turbulent kinetic energy or momentum flux), onset and formation of coherent structures are investigated.

The urban sprawl around cities like London exhibits a fractal structure (Fig. 2) as documented by [5]. The geometrical properties, as the fractal dimension ($D \approx 1.3$ – 1.7 for London), can be represented by fractals as Sierpinski triangles ($D \approx 1.58$). We investigate if there is an analogue to Darcy's law for flow through the fractal structure, as a porous medium, at high Reynolds numbers [4].

Currently, the dynamics of a wind mill wake is studied above complex topography as, e.g., forests. In a first approach, the wake is studied as a vortex in shear flow [6]. Linear analysis and idealized large-eddy simulations reveal an instability of the wind mill wake vortex.

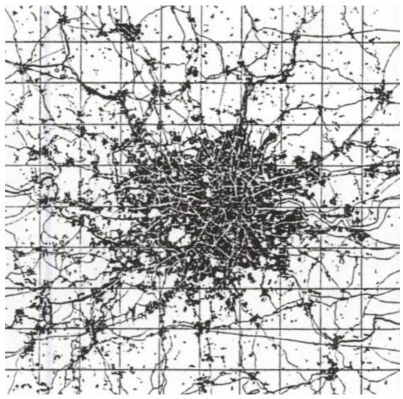

Figure 2: **London** – urban sprawl exhibits a fractal structure.

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