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A Boundary-Layer Scaling Analysis Comparing Complex And Flat Terrain

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A comparison of two boundary-layer (at approximately 50m) wind datasets shows the existence of reproducible scaling behaviour in two very topographically different sites. The first test site was in Corsica, an island in the South of France, subject to both orographic and convective effects due to its mountainous terrain and close proximity to the sea respectively. The data recorded in Corsica consisted of 10Hz sonic anemometer velocities measured over a six-month period. The second site consists of measurements from the Growian experiment. The testing site for this experiment was also in close proximity to the sea, however, the surrounding terrain is very flat. The data in this experiment was recorded using propellor anemometers at 2.5Hz. Note the resolution of the sonics was better, however, we found in both cases, using spectral methods, that the quality of the data was unusable below frequencies of one second. The scales that we will discuss therefore are from one second to fourteen hours.

In both cases three scaling subranges are observed. Starting from the lower frequencies, both datasets have a spectral exponent of approximately two from six hours to fourteen hours. Our first scaling analyses were only done on the Corsica dataset and thus we proposed that this change in scaling was due to the orography. The steep slope of the hill on which the mast was positioned was causing the wind's orientation to be directed vertically. This implied that the vertical shears of the horizontal wind may scale as Bogiano-Obhukov's 11/5 power law. Further analysis on the second (Growian) dataset resulted in the same behaviour over the same time-scales. Since the Growian experiment was performed over nearly homogenous terrain our first hypothesis is questionable.

Alternatively we propose that for frequencies above six hours Taylor's hypothesis is no longer valid. This implies that in order to observe the scaling properties of structures with eddy turnover times larger than six hours direct measurements in space are necessary. In again both cases, for time-scales less than six hours up to an hour we observed a scaling power law that resembled something between Kolmogorov's 5/3s and a -1 energy production power law (a spectral exponent of 1.3). Finally from one hour to a second, two very different scaling behaviours occurred. For the Corsica dataset we observe a (close to) purely Kolmogorov 5/3s scaling subrange suggesting surface-layer mixing is the dominant process. For the Growian dataset we observe a scaling subrange that is close to Bolgiano-Obhukov's 11/5s suggesting temperature plays a dominant role. Additionally, for the Growian dataset we found that temperature is an active scaler for time-scales above an hour unlike for the Cosica dataset. This suggests that orographic effects may suppress convective forces over the large scales resulting in different small scale shear profiles in the cascade process.

Given we can reproduce this scaling behaviour within a multifractal framework it will be of great interest to stochastically simulate the corresponding vector fields for the two situations in order to properly understand the physical meaning of our observations.