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Low Level Jet Development – Investigating the Interaction of Different Scale Physical Processes with the use of the Hilbert – Huang Transform

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The Low Level Jet (LLJ) is a common feature of the vertical structure of the Atmospheric Boundary Layer (ABL) that affects the meteorology and the local climate of an area, while it is important for aviation safety, wind energy and air quality applications. Low Level Jets have been associated mainly with the local topography and/or a large scale horizontal temperature contrast causing baroclinicity in the ABL, the diurnal heating cycle over sloping terrain, the mid-latitude fronts, the frontogenesis, the baroclinicity near coastal regions and the frictional decoupling.

The purpose of this work is to investigate the interaction of the physical processes characterized by different time scales and identify the way they affect the characteristics and the evolution of the LLJ. The complex topographic features of the experimental area (Messogia Plain in Attica, Greece) and the vicinity with the sea, introduces, under favorable synoptic conditions, a variety of local circulations like land – sea breezes, katabatic and anabatic flows, phenomena that could provide a strong imprint on the wind components and affect the shape and behavior of LLJs. The selected event is a representative case of a post-frontal LLJ mainly observed during spring, summer and early autumn days at this area, characterized by clear skies or scattered cloudiness and strong diurnal temperature ranges. It is shown that these LLJ events are a result of the interaction of the synoptic scale with the local diurnal circulations which produces an oscillating core and highly fluxionary depth within the period of the diurnal cycle.

In order to reveal the character of the observed wind variations during the LLJ event, the Hilbert–Huang Transform (HHT) algorithm is applied to SODAR wind speed data, at different levels. The HHT algorithm is an adaptive and empirically based data analysis method, well-suited for the study of intermittent and non-stationary processes that take place within the ABL. It consists of two steps of analysis. The first step, the Empirical Mode Decomposition (EMD), decomposes the original time series into a finite number of Intrinsic Mode Function (IMF) components, which represent the timescales that comprise the dataset. Then, the Hilbert transform (second step) is applied to each IMF to extract the instantaneous frequencies and amplitudes, as a function of time. The instantaneous frequency calculated by the Hilbert transform, should be understood as the frequency of a sine wave that locally fits the signal, rather than the frequency of a sine wave that is present throughout the entire time series signal.

The analysis of this LLJ case showed that the moderate horizontal pressure gradient, the absence of cloudiness and the strong solar radiation provided a favorable environment for the development of the local flows. These flows interacted with the prevailing large scale wind field and significantly altered the shape of the synoptic LLJ introducing an oscillating core and variable depth. The use of the HHT algorithm provided a quantitative picture of the contribution of the various involved mechanisms. Inertial motions were mainly observed during the passage of the weak front, having a quite coherent vertical structure, while during the rest of the experimental period they exhibited much weaker amplitudes with an intermittent character. The diurnal cycle was found to be imprinted at the east – west wind component (u component) which is nearly parallel to the direction of the developed local flows, while the northerly component (v component) showed very weak diurnal variations. This was confirmed by the spectrum of the northerly component which was dominated by the synoptic forcing with periods from 4 to 8 days. The synoptic forcing is the physical process that controls the variations of the v component, while the u component was mainly affected by the inertial – diurnal cycle (frontal passage – local flows).