Estimation of Turbulence Kinetic Energy dissipation rate (ε) using High-Resolution Pitot differential pressure sensor onboard a Small Unmanned Aircraft System (sUAS)

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The measurement of Turbulence Kinetic Energy (TKE) dissipation rate (ε) and structure function parameters of temperature {C_{t}}^{2} and refractivity {C_{n}}^{2} have been used as immaculate evidence to confirm the presence of turbulence in the atmosphere. The spatial-temporal variability in the measurements of ε and {C_{t}}^{2} help understand the morphology of atmospheric turbulence. We restrict the discussion to the process of estimation of only ε , simply because of the congruence in the procedures for estimating ε , {C_{t}}^{2} and {C_{n}}^{2}

The estimation of ε requires that the airspeed fluctuations be sampled at sufficiently high temporal resolution to characterize the inertial sub-range in the Power Spectral Density (PSD) of the airspeed fluctuations. The DataHawk sUAS has successfully demonstrated the ability to observe targeted atmospheric columns while employing co-located Hotwire Anemometer and Pitot differential pressure sensor, both with a bandwidth of 800Hz serving as independent measurement sources.

Here, we outline the procedure of estimation and the caveats and limitations in accurately estimating high and low intensity ε using the measurements from the digital Pitot differential pressure sensor exclusively. In doing so, the factors deteriorating the quality of the spectral samples are identified and characterized. The effect of airfoil induced flow acceleration and the motor induced vibrations on the Pitot fluctuation intensity and the resulting spectra are carefully explored. The algorithms used for precisely identifying the frequency range of the inertial sub-range energy cascade in the PSD is also described. The effect of high and low turbulence intensities on the quality of ε estimates are explored. The Pitot derived ε_P is validated using the Hotwire derived ε_{HW} and a model derived ε_m using the estimates of temperature structure function parameter {C_{t}}^{2}

Keywords: Turbulence Kinetic Energy Dissipation , In-Situ measurements, Estimation

