Flow across a step change in roughness: turbulence statistics estimation via interpretable network-based modelling

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This study aims to deliver an interpretable and robust data-driven methodology for the estimation of the statistics of velocity fields in atmospheric turbulent flows. The capability to estimate flow statistics, namely, to infer flow information for untrained configurations, is particularly relevant for several atmospheric flow applications such as, among others, dispersion problems or to evaluate wind loading on buildings. This work builds upon the success in modelling complex dynamical systems through cluster-based network models, where these are used to estimate time traces from a turbulent boundary layer developing over a step-change in surface roughness. Data were collected from laboratory experiments performed in the EnFlo wind tunnel at the University of Surrey, specifically the vertical profiles of the three velocity components were acquired using a three-component Laser-Doppler Anemometer (LDA) at various streamwise locations across the step-change in roughness. These data were partially used to train our model and the remaining data were used for validation purposes. Our results show that our cluster-based network model is able to estimate the vertical profiles of first and second moments (mean and variance), as well as higher-order statistics, with good accuracy (comparable with experimental uncertainty, say 10%), even when the specific validation location (x, y, z) in the domain was not considered for training. We show that the proposed data-driven method can complement existing measurement tools (e.g., LDA), allowing one to significantly reduce measurement times, while retaining an acceptable level of accuracy. Based on present findings, we believe our framework can be effectively employed for wind engineering applications, particularly for the estimation of extreme events in the atmosphere.