A Simplified Laboratory Model Flow for the Turbulence Structure of Atmospheric Low Level Jets – PART II: Scaling Gross Parameters

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CAIPEEX Phase IV

LLJ occurrence in and around Solapur: CAIPEEX IV Radiosonde Measurements

The ground site of CAIPEEX – IV campaign is located at NBNSCoE (Sinhgad College), Solapur (17.6599° N, 75.9064° E) with the ground height being 480 m above the mean sea level. Radiosonde balloons are launched from the top of the Civil Engineering Building (height from ground being 20 m) every day at 11:00 hrs. IST except for few exceptions largely attributed to ATC permission issues. During Monsoon (JJAS 2018), a second Radiosonde flight is conducted around 14:30 hrs IST on some days depending on the requirements of the IOPs during the seeding experiments; in this poster we shall consider data from 11:00 hrs flights only. The Radiosonde system being used is MW31 DigiCORA system from Vaisala, Finland with RS-92 SGPL being the Radiosonde payload model. Figure 1 shows the contours of horizontal wind speed U on the time-height plane for the Radiosonde data for the period JJAS 2018; start of the month of June is set as zero. It is clear that the LLJ flow strengthens from the end of June and is quite strong and persistent through July and August with peak wind speeds reaching up to 20 m/s in the jet core located between 1.5 to 2 km height from the surface. Active and break spells of the Monsoon over Solapur region can also be identified as the strong and weak jet activity in the contour plot. The jet in and around Solapur is seen to significantly weaken down in the month of September. Figure 2 shows typical LLJ profiles of the zonal wind speed (u) and horizontal wind speed (U) for the sounding on 21st July 2018. For the present analysis, vertical extent of the LLJ flow is defined as the height from ground where the zonal wind speed flips its sign for the first time.

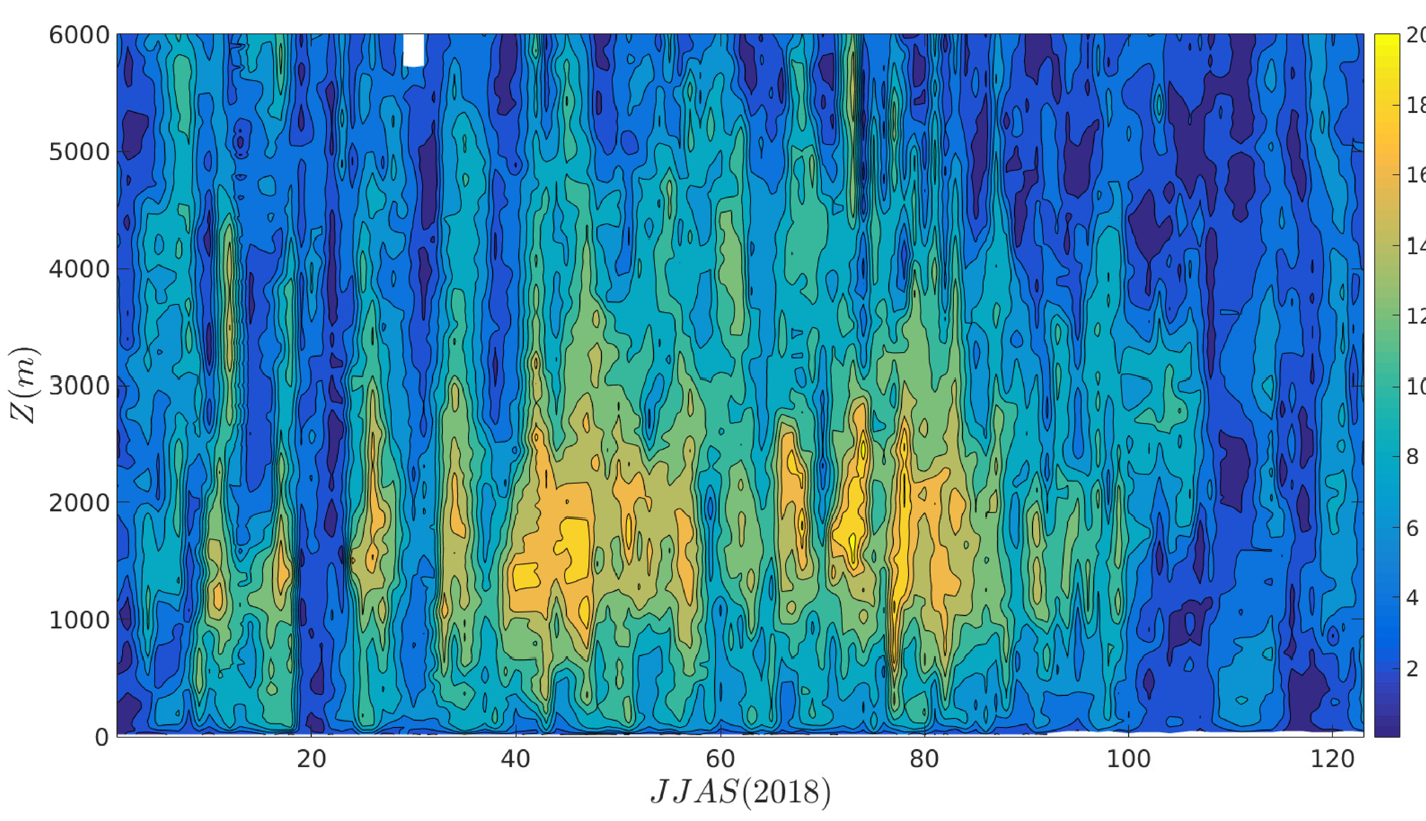

FIG. 1. Contours of horizontal wind speed U (m/s) on the time-height plane for the Radiosonde data for the period JJAS 2018

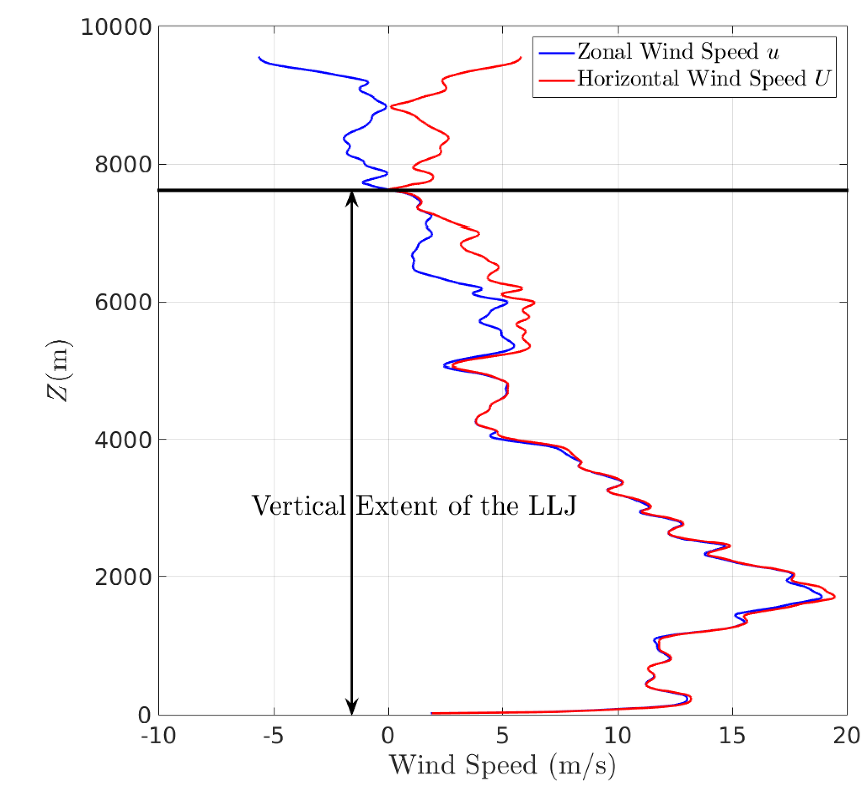

FIG. 2. Typical LLJ profiles of the zonal wind speed (u) and horizontal wind speed (U) for the sounding on 21st July 2018

Local Momentum Flux Scaling for Gross Parameters in Laboratory Wall Jets

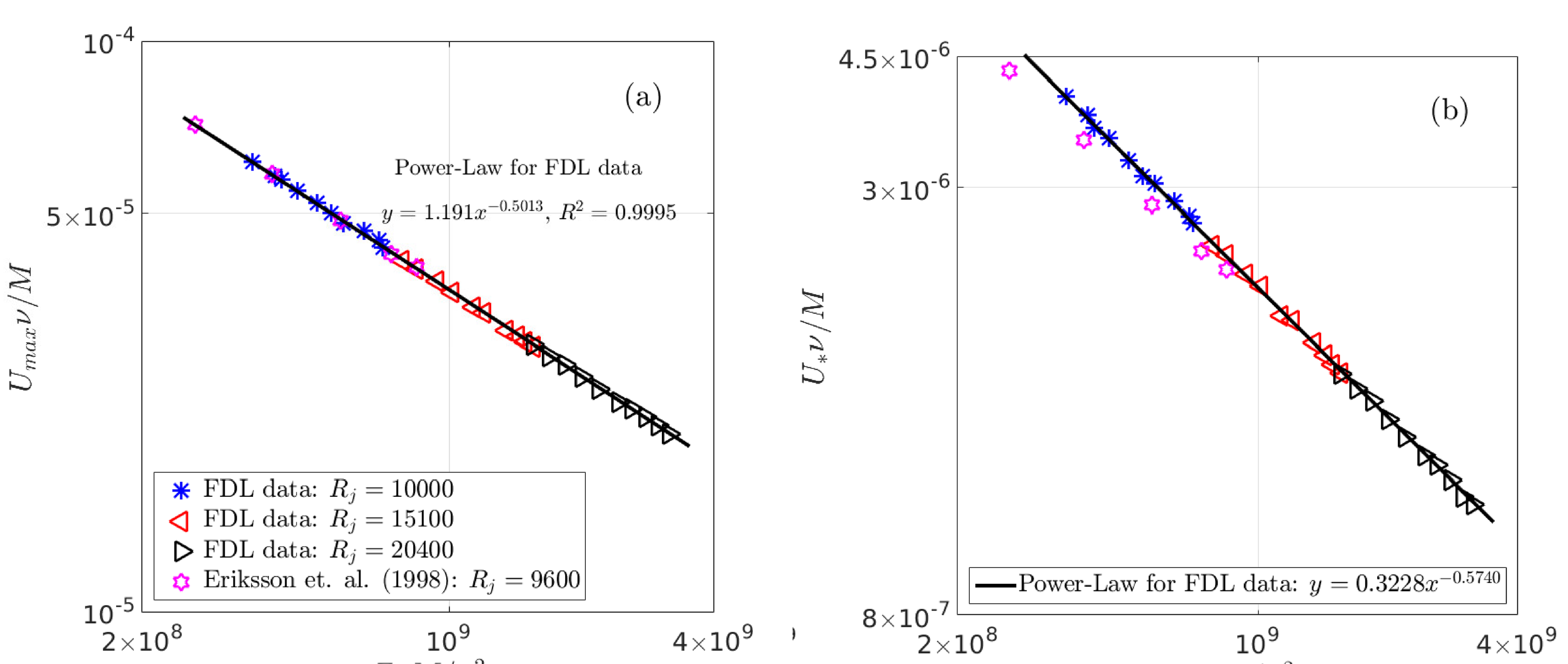

FIG. 3. Plot of (a) U_{max} versus Z_T and (b) U_* versus Z_T f or laboratory wall jets in the present M -ν scaling.

As mentioned in PART – I of this poster, a laboratory wall-jet flow is a turbulent flow where a jet is blown along a flat solid surface. Wall-jets have been the subject of interest for laboratory fluid dynamics researchers over the past few decades [1-10] and one major reason for this interest is that this flow is considered to be a combination of a jet - a free shear flow - and a boundary layer - a wall-bounded flow. As a result, the flow exhibits scaling properties peculiar to jets in the outer part and boundary layers in the inner part. Scaling approaches for mean quantities in wall-jets can be broadly classified into two distinct but related categories: (i) scaling of gross parameters with respect to their variations in the streamwise (x) direction and (ii) scaling of profiles of various mean quantities measured at different streamwise stations. Here we focus on the scaling of gross parameters namely the mean velocity maximum U_{max} in the mean velocity profile and height Z_T of the location in the outer region where mean velocity $U(z)$ equals $U_{max}/2$; z is the wall-normal coordinate and Z_T is a measure of the overall thickness of the flow. Traditionally, U_{max} and Z_T have been scaled using two major approaches: the first uses nozzle exit velocity U_j and nozzle exit slot height b [1,2] while the second uses nozzle momentum flux $M_j \sim b*U_j$ ^2 (instead of using U_j and b separately) and fluid kinematic viscosity ν [4,6] as scaling parameters. Both these approaches underscore continued influence of the initial conditions (ICs) at nozzle exit on the downstream development of a wall-jet flow even in the fully-developed regime. We have proposed a new scaling based on the *local* momentum flux M and ν (to reported in detail elsewhere) that collapses data from different laboratory experiments remarkably well as shown in Fig. 3 (a,b). The conceptual advantage of the present M -ν over the M_j -ν scaling is that the former eliminates the influence of nozzle ICs and allows for self-similar development. Due to its local nature, this approach can be readily applied to the Monsoon LLJ.

Scaling Gross Parameters in Monsoon LLJs

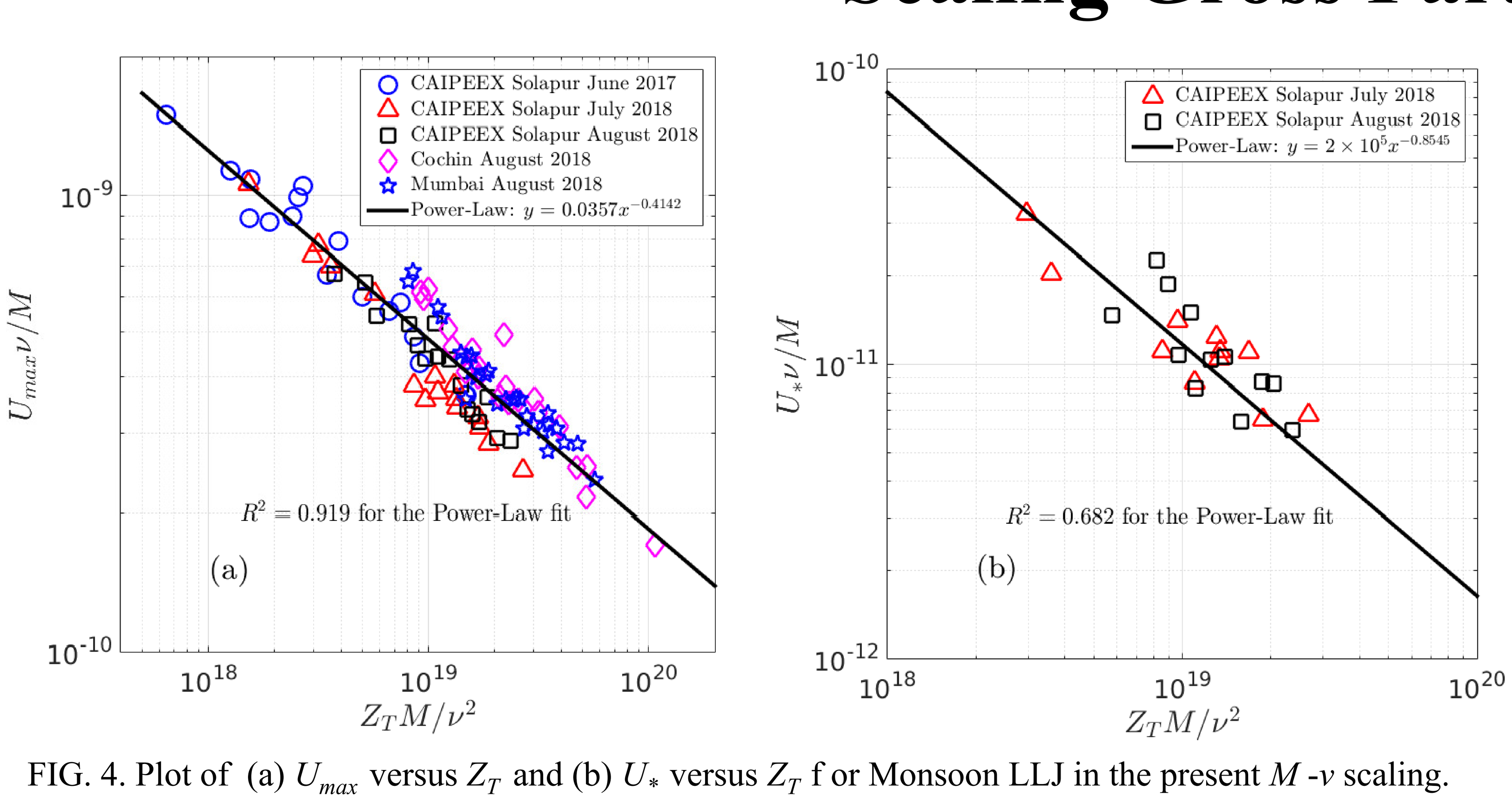

FIG. 4. Plot of (a) U_{max} versus Z_T and (b) U_* versus Z_T f or Monsoon LLJ in the present M -ν scaling.

Figure 4(a,b) shows the local M -ν scaling applied to the Monsoon LLJ data. LLJ profiles are all from Radiosonde measurements; CAIPEEX measurements in Solapur during 2017 and 2018 as well as Cochin and Mumbai profiles during 2018 (obtained from http://weather.uwyo.edu/upperair/sounding.html). From these profiles, U_{max}, Z_T and M are computed. Friction velocity U_* in Fig. 4(b) is obtained during the sounding flight from the sonic anemometer mounted in the surface layer (4 m from the ground) on the micrometeorological tower located at the ground site in Solapur. Figures 4(a) and 4(b) indicate that the data cluster around a power-law fit quite well even when no attempt is made to scrutinize the data points based on stability; this could be due to the strong shear and overcast conditions present during the Monsoon LLJs. The clustering of data around a preferred curve implies that random combinations of U_{max}, Z_T and U_* are not allowed and there is a self-similarity constraint that regulates these parameters.

Figure 5 shows the laboratory wall jet data of Fig. 3 plotted along with the Monsoon LLJ data of Fig. 4. It is clear that the present local M -ν scaling holds remarkably well over a huge range of local Reynolds number R=$U_{max}Z_T/\nu$ (O(10^4) for laboratory wall jets to O(10^9) in the Monsoon LLJ). Such scaling is very unlikely to be fortuitous and underscores structural similarity between these seemingly related but vastly disparate flow archetypes. This is a very strong indication that the hypothesis presented earlier in PART – I of this poster is very likely to be true and therefore there is indeed merit in studying laboratory wall jets in detail to enhance our understanding of the vertical structure of turbulence in LLJs and associated mixing. We consider that Figs. 4(b) and 5(b), after sufficient population, hold the key to obtain surface layer momentum flux simply from the sounding profiles. However more data is required to critically evaluate this proposal.

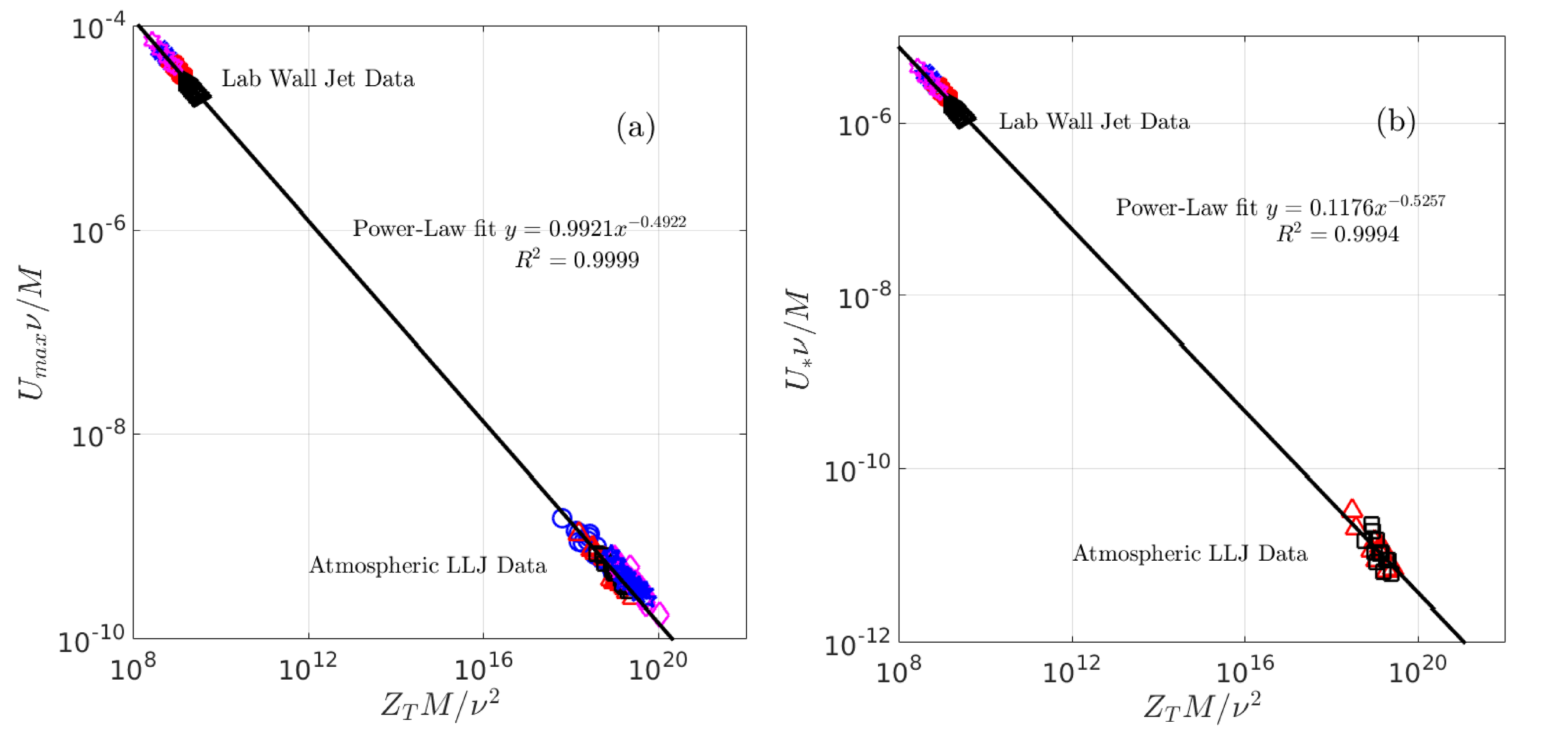

FIG. 5. Scaling Laboratory Wall Jets together with the Monsoon LLJ over a remarkable five decades range in local Reynolds number.

Acknowledgements

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