CHARACTERIZATION OF ATMOSPHERIC SURFACE LAYER STRUCTURE IN PERSIAN GULF

Arindam Singha[*, a)], Reza Sadr[**]
[*]Department of Mechanical Engineering, Texas A and M University at Qatar, Qatar
[**]Department of Mechanical Engineering, Texas A and M University at Qatar, Qatar

Summary The characteristic of the atmospheric surface layer in Persian Gulf is reported based on tower based instrument measurement during June, 2011 in coastal area of Qatar. The micrometeorological characteristics of atmospheric surface layer (ASL) are reported within the framework of the Monin-Obukhov similarity theory. This is the first ever investigation of similar nature not only in Qatar, but in entire Middle East, and is expected to provide important micrometeorological information about Qatar. The normalized variances of three components of velocity and temperature for different stability regimes of ASL are estimated and compared with similar investigations carried out in different parts of the world. The result indicates that the characteristic of ASL in Qatar is comparable with data from around the world, except the variance of vertical velocity, which exhibits a lower magnitude. However, the growth rates of the variances are comparable with other investigations. The normalized variance of temperature attains a higher magnitude for stable regime of ASL, which may be indicative of the signature of atmospheric surface layer in Qatar.

INTRODUCTION

Atmospheric surface layer (ASL) plays an important role in transport of pollutants and heat from the surface and therefore accurate characterisation of the ASL is important. The increased importance of Middle-East in world economy and industrialization is well recognized, but so far no atmospheric study has been carried out to explore the nature of ASL in Middle-East. The present investigation reports the micrometeorological information of ASL measured at a pier in the approach light area in New Doha International Airport in Qatar, during June, 2011. The characterization is presented within the framework of Monin-Obukhov similarity theory.

Monin-Obukhov similarity theory states that the normalized variances of velocity components and temperature would be a universal function of a suitably constructed stability parameter, as

$$\frac{\sigma_i}{u_*} = A_i\left[1 + B_i\left(\frac{z}{L}\right)\right]^{c_i};\ \ i = u, v, w; \tag{1}$$

where, u,v and w are the streamwise, transverse and vertical velocity components; u_* is the friction velocity; z is the vertical height, and L is the Monin-Obukhov length scale, defined as;

$$L = -\frac{1}{k}\frac{u_*^3}{\left(\frac{g}{\overline{T}}\right)\overline{w'T'}}. \tag{2}$$

In the above expressions, overbar denotes averaging, and dash denotes fluctuating components. Also, T is the potential temperature, and k is the Von -Karman constant (= 4.1).
The non-dimensional variance of temperature variation can be modelled as

$$\sigma_T / T_* = C(-z/L)^{-1/3}; \tag{3}$$

where $T_* = -\overline{w'T'}/u_*$.

EXPERIMENTS

Experiments are conducted in the coastal region in Doha, Qatar, (25.25N, 51.62E) in a pier located into 500 m into the Persian Gulf. Three sonic anemometers (CSAT3) were mounted at a nominal height of z= 4.5, 8.2 and 10 m from the ocean surface, and acquire data at 20 Hz frequency simultaneously. Figure 1 shows an image of the experimental setup. The experiment is performed during June, 2011, and the nominal temperature was around 33^{0}C, and humidity 45%. The wind velocity was always more than 4 m/s.

RESULTS

a) Corresponding author. Email: arindam.singha@tamu.edu.

Table 1 compares the value of σ_u / u_*, σ_v / u_* and σ_w / u_* at near-neutral condition and compare them with the similar values reported from around the world. While the value of σ_u / u_*, σ_v / u_* matches closely with other investigation, the value of σ_w / u_* is comparatively lower in Qatar. This is probably because of the lower aerodynamic roughness length of the present site.

Figure 1: An image of the experimental setup.

Site detail	σ_u / u_*	σ_v / u_*	σ_w / u_*
Qatar	1.72±0.38	1.27±0.53	0.89±0.17
North Beijing, China [1]	1.75	1.60	1.22
Penang, Malaysia [2]	2.08	2.00	1.44
Harscheidweg, Germany [3]	1.86	1.96	1.29
Lucknow, India [4]	2.67	2.14	1.01
Kansas, USA [5]	2.39	1.92	1.25

Table 1: Normalized variance of the wind velocity components at near-neutral condition.

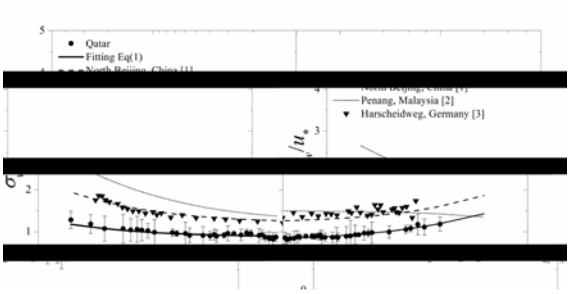

Figure 2: Variation of σ_u / u_* with *z*/*L*

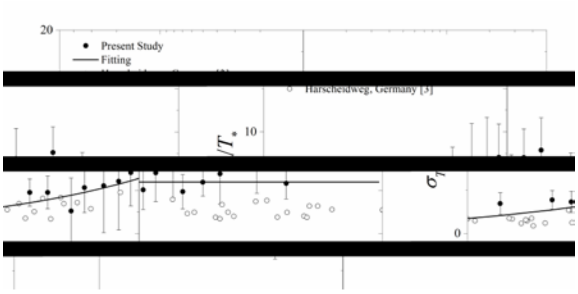

Figure 3: Variation of σ_T / T_* with *z*/*L*.

Figure 2 shows the variation of σ_w / u_* with *z*/*L*, and it can be seen that σ_w / u_* remains low all ranges of *z*/*L*. However, the growth rate of σ_w / u_* is consistent with past investigations. The points were fitted with Equation 1 and the modelling parameters are estimated as [*A B c*] = [0.88 0.45 0.33] for unstable regime, and [*A B c*]=[0.79 1.40 0.33] for stable regime, respectively.

Figure 3 depicts the variation of σ_T / T_* with *z*/*L*, for unstable and stable regime, respectively. For the unstable regime, the points are fitted with function in Equation 3, and C was estimated to be $C \approx -2.23$. This is comparable with the value $C \approx -2.99$ reported by Wyngaard et al. [6]. In the stable regime, σ_T / T_* attains a constant value of 3.1, slightly higher than the value reported by Al-Jiboori et al. [3].

CONCLUSIONS

Experiments are conducted in coastal area of Qatar in Persian Gulf to explore the micrometeorological properties of atmospheric surface layer within Monin-Obukhov similarity theory framework. To best of our knowledge, this is the first ever study of this kind in the entire Middle-East region, and it is expected to be a forerunner towards successful modeling of pollutant dispersion and mixing in Qatar. The site in Qatar is characterized by lower vertical velocity variance, but comparable growth rate compared to other investigations around the world. The normalized variance of temperature is found to be higher for stable regime of atmospheric surface layer.

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