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VARIATION OF FLOW WITHIN THE MUST BUILDING ARRAY

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1. INTRODUCTION

The Mock Urban Setting Test (MUST) was intended to gain greater insight into airflow and plume transport around building arrays and to produce a database for the validation of transport and dispersion models (Biltoft, 2001). MUST was designed to be a near full-scale model of a built-up area, more realistic than wind tunnel experiments but idealized compared to a real city. MUST provided researchers an opportunity to instrument an idealized urban terrain under real atmospheric conditions, but without the logistical problems encountered in a real city. In this paper, we intend to better understand the development of flow structure within the urban canopy as a function of downstream fetch by evaluating measurements from 2D and 3D sonic anemometers that were placed throughout the array. The results found are surprising and do not agree with earlier wind tunnel and flume experiments.

Figure 1. Photograph of the MUST array as seen from the southeast (courtesy of C. A. Biltoft, DPG ret.).

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2. EXPERIMENTAL DETAILS

The MUST experiment was conducted at the US Army's Dugway Proving Ground (DPG) located in Utah's West Desert during the month of September 2001. The MUST array consisted of a 10 by 12 array of aligned shipping containers each 12.2 m long, 2.42 m wide, and 2.54 m high (H). Figure 1 is photograph of the MUST array taken from the southeast corner of the array. The terrain in the area is relatively flat and surrounded by low bushes.

The array had a plan area density of 0.096 and frontal area densities of 0.10 and 0.03 for the length and width respectively (Yee and Biltoft 2004). Various 2D and 3D sonic anemometers were located in a line perpendicular to the length of the shipping containers in a street channel near the center of the array as seen in Figure 2. The yellow diamonds and aqua circle represent the locations of 2D sonic anemometers operated by LANL (Los Alamos National Laboratory) and DPG respectively; the purple circle, purple triangle, green cross, and black square represent the locations of 3D sonic anemometers on towers operated by ASU (Arizona State University), DSTL (Defense Science Technology Laboratory), ARL (Army Research

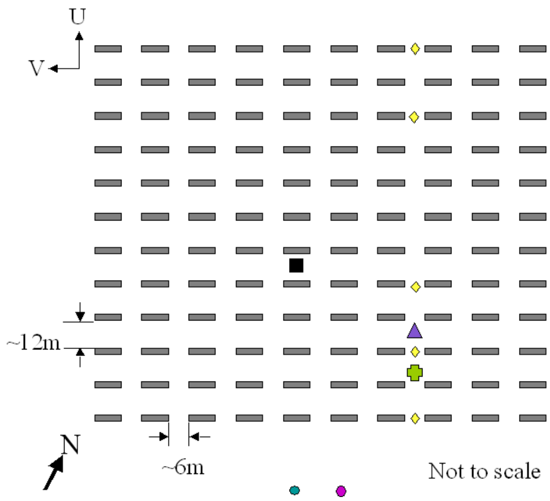

Figure 2. Schematic of the MUST array with relative locations of sonic anemometers. See text for definition of symbols.

Laboratory), and DPG respectively. Most of the experiments were conducted at night with prevailing south-easterly winds and wind speeds at building height <3 m/s.

3. PRELIMINARY RESULTS

Figure 3 depicts some unusual behavior of the mean flow as it travels down the street channel through the MUST building array. Instead of a monotonic decrease in wind speed as a function of distance down the street channel, the flow is found to gradually accelerate after an initial deceleration as it enters the array. Wind tunnel, flume, and reduced-scale field experiments on flows through building arrays have shown a monotonic decrease in wind speed with increasing distance into the building array (e.g., Davidson et. al. (1995), Davidson et. al. (1996), MacDonald et. al. (1997)). Although we have not yet determined the reasons for the different behavior, the disparity may be a result of different wind sensor locations, different building spacing, the effect of low-level jets, wind direction shear, and/or atmospheric stratification.

Figure 3 also shows another interesting feature. As the flow enters the array two different regimes were found distinguished by the upstream wind speed at the reference height. Upstream reference wind speeds greater than 1 m/s (shown in blue) generally exhibited the largest amount of deceleration after the first row of the array, while upstream reference wind speeds less than 1 m/s (shown in red) generally exhibited the largest deceleration before the first row of the array. It is unclear what the cause of this behavior may be, however, it is hypothesized that the formation of circulations associated with the buildings (e.g., side wall recirculation, upstream rotor) may vary based on an inflow wind speed criterion and that this could impact the magnitude of the initial deceleration. It is certainly necessary to determine if the five-minute averaging time is sufficient to achieve statistical convergence. This analysis should be completed shortly.

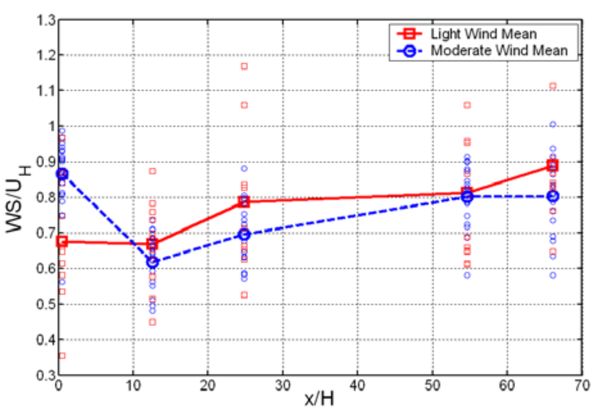

Figure 3. 5-minute average normalized wind speed below building height versus normalized downstream distance into the array.

Figure 4 shows how the standard deviation of the streamwise velocity fluctuations (σ_u) normalized by the upstream friction velocity (U_*) changes through the array. Due to the fact that this data was collected using 2D sonic anemometers the local values of U_* are unknown, which is unfortunate since normalizing by the local values would probably prove more insightful. However, the magnitude of the velocity fluctuations can be seen to increase as the flow enters the array and come to a fully developed value at *x/H*~25. The values measured in this region are much larger than those typically reported for the neutral surface layer ($\sigma_u/U^* = 2.5$). The larger values found for the light wind cases may be an indication that the statistics may not have converged for some of the observation periods.

4. CONCLUSIONS

2D sonic wind measurements collected along a street channel below building height within the MUST array contradict similar measurements obtained in wind tunnel, flume, and reduced-scale field experiments. Instead of the wind speed decreasing with downwind distance, there was a gradual increase in the wind speed after an initial deceleration. While the data has been checked to ensure that the unusual trends are not due to faulty sensors, the causes of this unusual behavior have not yet been determined. Computational fluid dynamics studies may help to provide answers. Additionally, we found that the measurements of σ_u/U^* are significantly larger within the building array as compared to values typically measured in neutral surface layers.

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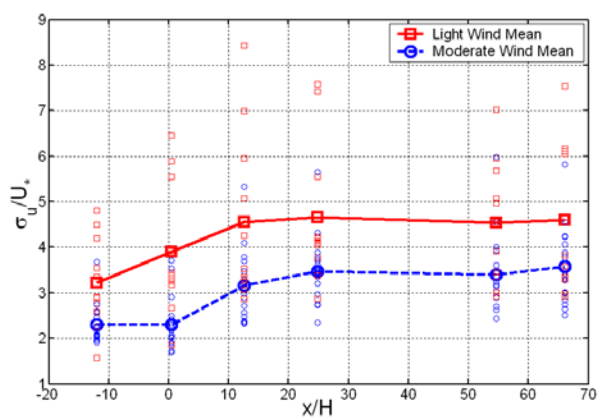

Figure 4. Normalized streamwise velocity fluctuations (σ_u) below building height versus normalized distance into the array.

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