J5.3 DETAILING SINGLE BUILDING STABILITY AND AIR FLOW PATTERNS (PHASE II)

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ABSTRACT

Detailing the stability and airflow character around a single building was the objective for the 2005 Army Research Laboratory [ARL] Phase II-*Urban Study: Flow and Stability around a Single Building*. The Study's design was based on Snyder and Lawson's 1994 wind tunnel study, as well as, the 2003 ARL Phase I-*Urban Study* (a mean parameter characterization). Mean and turbulence measurements were acquired over a 2 week period using four 10m towers located along the North, East, South and West building sides, a 5m Roof tower and 3 Tripods. To minimize the heating/cooling bias, the equinox time period was selected for both field study executions.

Preliminary results reaffirmed the presence of a bi-level accelerated flow, a velocity deficit, and a cavity flow. They also quantitatively demonstrated the location of the reattachment zone and two building leeside side eddies. Stability results portrayed a mini-heat island effect, as well as, a traditional desert rural pattern. Details regarding stable conditions occurring around a single building have been summarized in this paper, as well as, a visual sample of the horizontal building leeside eddy. We conclude the paper with a Summary, Lessons Learned and Recommendations for Future Urban Measurements.

1. Introduction.

In 2005 March, the Army Research Laboratory executed the second of two urban field studies at White Sands, New Mexico. Unlike the Phase I Urban Study (March 2003) which sought to characterize mean airflow and surface layer stability transition patterns, this recent investigation was focused on characterizing turbulent conditions. Starting with the original design of four 10m meteorological towers on each side of a two-story rectangular office building and a 5m tower on the building's flat roof, 3 tripods were added and strategically placed to quantitatively map the leeside building reattachment zone and 2 leeside horizontal side eddies (See Figure 1). The 1994 Snyder and Lawson wind tunnel study (Snyder and Lawson) was again utilized as the main guidance for the field study design.

On the 10m Towers, 1-minute average sampling was acquired by Campbell-T107 and Vaisala-HMP45AC temperature probes at 10m and 2m AGL, respectively. Mean pressure (Vaisala PTB-101B), solar radiation (Kipp/Zonen-CM3 Pyranometer) and relative humidity (Vaisala-HMP45AC) were also acquired at approximately 2m AGL. Mean winds at 5m AGL were captured by a wind monitor (RM Young-05103). Turbulence measurements (20Hz) were taken by RM Young Model 81000 ultrasonic anemometers (sonics) mounted at 10m, 5m, 2.5m AGL. The roof tower acquired sonic data at 5m AGL. Three independent tripods sampled sonic data at 2m AGL.

The selected concrete-block building had single story buildings to the south and west sides. To the north was a matching two-story building. Nearly level gravel and dirt surfaces were between these buildings. East of the building were a grassy area, a sidewalk and a paved 4-row parking lot. During the acquisition period, automobiles were confined to the farthest two parking lot rows and no vehicle traffic was permitted near the towers.

The weather pattern during acquisition ranged from calm clear skies to typical New Mexico spring windstorms (winds sustained at greater than 10 m/s) due to tight pressure gradients aloft.

1.1 Stability Characterization.

The stability characterization was limited to the available mean temperature and solar radiation measurements. The influence of the diurnal heating-cooling cycle was minimized by selecting a 2-week period near the equinox (when equal heating-cooling occurs within a-24 hour period). From the 2003 Phase I Study, we expected both rural (stable nights; unstable days) and urban (neutral/unstable) diurnal patterns. The actual results will be presented in Section 2.

1.2 Air Flow Characterization.

Phase I of this Study validated the presence of 4 gross features noted in the Snyder and Lawson wind tunnel experiments. These features included the reference fetch flow upwind on the building's windward side, an accelerated flow over the building's roof, a velocity deficit on the building leeside, and a flow reversal (cavity flow) also on the leeside. Phase I Study data also reported flow acceleration between buildings whether the neighboring building was the same height or half the size. Consistent in all 10m tower datasets was the fact that the higher level winds (10m AGL) were of a greater magnitude than

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the 2m level, independent of wind direction. In a subtler manner, an oscillation in the leeside cavity flow prompted a more detailed airflow inspection. For 2005 Phase II Urban Study Results, see Section 3.

2. Stability Characterization Results

Phase I rural and urban diurnal stability cycles were validated by the Phase II data. Examining the Phase II stability data by tower, each side of the building reported approximately 50% of the 19 days sampled as having stable conditions. Table 1 summarizes some of the ongoing details being extracted from the 2005 data set. With an area of green lawn and a parking lot to the building's East, the magnitude increase from 150 (West) to 663 (East) Total Stable Minutes observed during the field Study is reasonable. The Average Stable Minutes/Day only shows a partial picture. One needs to review the Longest Stable Case Duration and the case clustering viewed in the stability cases timeline, first. A Stable Case is defined as when the vertical (10m minus 2m) temperature differential is greater than 1 degree C. From the Table 1 values, the dominance of a mini-heat island effect for all building sides becomes most evident. The consecutive 54 minutes of stable atmosphere from the East Tower, however, is noteworthy. The Average Case Duration follows the increasing Total Stable Minutes per Tower. Whether this is a statistical property or physically explainable is still being investigated.

Table 1. Stable Condition Statistical Summary. Summary of Stable Conditions occurring during the 19 days of *Phase II: WSMR 2005 Urban Study*. Each 10m Tower is presented by its position relative to the single subject building. A 'case' is defined as when the vertical temperature differential is greater than 1C.

Stable Conditions	West	South	North	East
Days with…	11	10	9	9
Total Stable Min for Study	150	195	352	663
Avg min/day	7.9	10.3	18.5	34.9
Max cases/day	36	52	86	238
Longest case duration (min)	20	16	17	54
Avg case duration (min)	3.7	4.4	6.1	8.0

3. Air Flow around a Single Building Results

The 2005 Urban Study re-enforced the Phase I Study initial validation of the 4 gross wind tunnel features (fetch flow, over-the-roof acceleration, velocity deficit, cavity flow). With the tripod data from the building leeside, the 2005 data also confirmed the presence of the Reattachment Zone, and the two horizontal building side eddies. A limited number of Sonics lead to the use of fence posts with yellow caution0tape tell tails tied to their tops, to map the horizontal eddies curling around the leeside building edge (See Figure 2). Data from a tripod-mounted sonic anchored the horizontal eddy flow feature at the position of the flow reversal. For additional details on the Airflow Results, see paper number J6.4 [Cionco et al, 2006], which is also published in these proceedings.

4. Summary

The ongoing Phase II data analysis has reaffirmed the presence of a bi-level accelerated flow, a velocity deficit, and a cavity flow. They also quantitatively demonstrated the location of the reattachment zone (leeside) and two building leeside side eddies. Stability results portrayed a mini-heat island effect, as well as, a desert rural pattern. The East side of the building reported the greatest total number of Stable condition minutes and the longest duration time period for these stable conditions. This could be explained, in part, by the terrain surrounding the building.

5. Lessons Learned and Recommendations for Future Urban Measurements

Stability has been characterized during relatively equal diurnal heating/cooling cycles. There is a need to repeat this experiment during the heating/cooling cycle extremes (the solstices). This would help develop a more complete picture of the building-atmosphere effects.

One of the focuses of the *WSMR 2005 Urban Study* was the building leeside horizontal eddy flow. While the existence of the side eddies were established by the 2005 data acquired, the vertical extent of these eddies remains unknown. Several methods for quantitatively documenting these structures have been proposed. For now, however, there are trees at the building corners, which have already mapped some of the vertical structure in their growth patterns due to wind streamlining.

Resolving the interaction between the building's horizontal side eddies and the cavity flow (a vertical rotor) coming over the building top and flowing back to the center leeside, is another area for future study.

Finally, we hope to enhance our understanding through the release of non-toxic tracer smoke during a data acquisition period. Using digital imaging, the flow could be mapped. This would correlate well with modeling results and greatly assist with the construction of empirically-derived airflow algorithms.

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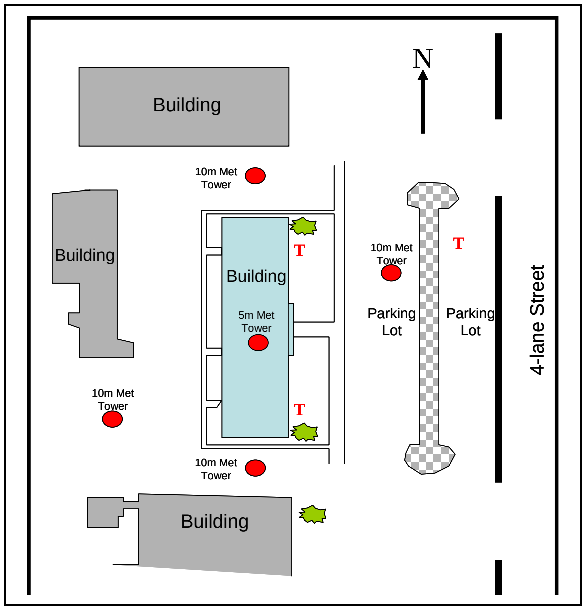

Figure 1. Phase I (2003) and II (2005) Urban Study Tower Configuration. Gray areas represent buildings, with the subject building as blue. Green jagged circles are trees. Red filled circles represent the 10m Towers. Tower orientation with respect to the building was skewed to accommodate prevailing wind direction. The Phase II *Urban Study* field layout added 3 tripods represented by a 'T'.

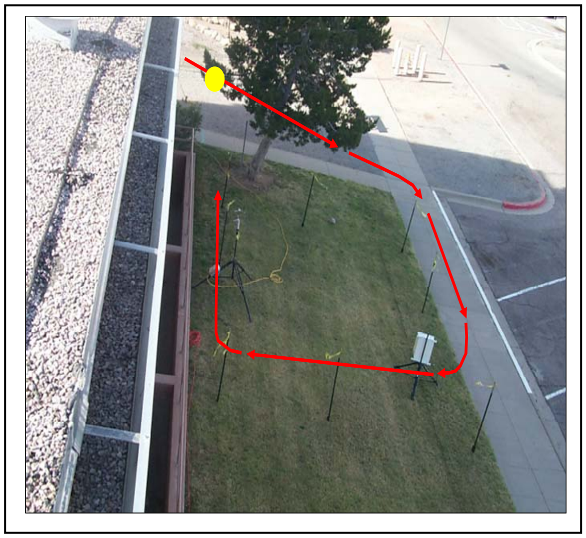

Figure 2. Building Horizontal Side Eddy. A top down picture of the building horizontal side eddy as mapped by yellow telltales and a sonic anemometer. The yellow dot flags the flow origin. The red arrows show the eddy path.