11.4 STUDY OF NEAR-BUILDING AIRFLOW AND TURBULENT EDDIES

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1. INTRODUCTION

Understanding and modeling meteorological and diffusion processes within and about urbanized areas have come to the forefront of DOD research. In the midst of pending urban warfare, chemical and biological terrorism, as well as, our preparations to participate in the Joint Urban 2003 field study (JU2003), a field study was designed and executed by USARL personnel at White Sands Missile Range, NM. In that micro- meteorological modelers have been addressing airflow and diffusion in rural and urban domains for several years, this study provides more insight into ongoing research.

Based upon guidance derived from a wind tunnel study completed by NOAA-ARL (Snyder and Lawson, 1994) in the EPA Wind Tunnel Facility, five micrometeorological masts were located with respect to four side walls of our Laboratory building and its roof top. The arrangement of the masts upwind, laterally, downwind, and rooftop was established to be optimum for our springtime, southwest flow regime. In particular, the downwind mast in the lee of the building per wind tunnel results was positioned to detect a reversal of flow in the cavity region. This paper addresses only the resultant data set.

2. OBJECTIVES

Two objectives of our field study were: a) to field test our micro-meteorological system from end to end prior to JU2003; and b.) to measure airflow about our Laboratory building – in essence, CARPE DIEM.

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3. FIELD SITE

Our Laboratory building is located amongst other buildings on the White Sands Missile Range, NM. The building is on slightly sloping terrain with adjacent areas of bare soil, some cement, a few trees, and asphalt-covered parking lots. See Figure 1 for building locations. It is clear that this array of buildings does not conform to the wind tunnel's orthogonal design. However, skewing the orientation of the masts for an upwind southwest flow field does allow the same major flow features to be observed and quantified.

4. DESIGN OF MEASUREMENTS LAYOUT

The placement of micrometeorological masts and sensors was based upon guidance derived from wind tunnel studies reported by Snyder and Lawson (1994) specifically for flow about a single building. Snyder and Lawson repeated their airflow study for model buildings of different widths and lengths referenced to the model's fixed height. See Figure 2 for their resultant streamline fields for buildings of different width/height ratios (2 to 10). The width/height ratio of our building is 6. Their wind tunnel results clearly show separation points about the buildings edges as well as cavity flow where the flow field reverses direction with height in the lee of the model building. Placement of our micro-meteorological masts was designed to capture the upwind reference flow field, the lee side cavity flow, and flow over the building. Figure 3 shows the locations of our along wind masts upwind, downwind and atop our 'model' building for an optimum data set during our springtime flow regime. Figure 4 provides a plan view of the five masts.

5. SENSORS AND EQUIPMENT

The ground-based masts each had two levels of Campbell sensors with RM Young 05301 wind birds and CR22X data logging units. Wind, air temperature, relative humidity, barometric pressure, and solar radiation sensors were installed at the two meter level. A second wind vane with propeller along with a temperature sensor was located at the ten meter level. In addition to these levels, a soil heat flux sensor was placed near the base of three of the four ground-based masts. The fourth mast was located on the asphalt parking lot surface, thereby negating the installation of the soil probe. All sensors were sampled at five second intervals and averaged over a one minute period. The wind bird was specifically placed at a distance 2.5 times the diameter of the mast's cross section to minimize shadowing effects. The rooftop mast had only one level of sensors located a 5 meters. For obvious reasons, a soil probe was not inserted into the roof's surface. Our original design included a combination of sonic anemometer-thermometers and Campbell-type surface stations. This study is being repeated using the roof mast and four masts of three levels of RM Young sonic anemometers.

6. DATA COLLECTION CONDITIONS

Springtime conditions of at least moderate wind speeds, 8 to 19 m/s, prevailed with limited periods of near calm. Optimal wind directions of southwest and west also occurred with some excursions through northeast as well as through southeast with fair weather and clear skies dominating. A time history for a short period of time is given of wind speed in Figure 5 and of wind direction in Figure 6 for the upwind reference mast.

7. ANALYSES

Conditional sampling on wind direction and stability focused our detection and analysis of airflow features exhibited in the wind tunnel studies. By example, Table 1 lists a set of common values occurring simultaneously upwind, downwind, adjacent to, and atop our 'model' building at the 2m and 10m levels (only 5m on the roof) when wind directions are perpendicular or near perpendicular to the building's west facing wall.

At the upwind mast, the wind speeds (also noted in Figure 5) are greater at the 10m level than the 2m level, while the wind directions (also noted in Figure 6) are virtually the same at both levels. Over the building, the wind speed is accelerated versus the upwind speed value at 10m. Downwind of the building, the wind speed value at 10m exhibits deceleration while the 2m level speed decreased significantly as the flow reverses in the cavity zone.

Figures 6, 7, and 8 show wind direction variability, similarities, and differences occurring with time as well at locations upwind, at rooftop, and downwind of our building. Take note of the upwind westerly wind producing the flow reversal (to be easterlies) downwind at the 2m level. The rooftop winds at 5m also remain westerly even though the speeds are enhanced (see Table 1). In regard to flow around the 'model' building, Figures 9 and 10 show that the adjacent buildings serve to straighten the flow thereby channeling the flow as well as causing speed enhancements at the 2m and 10m levels as noted in Table 1.

Even with this limited set of measurements, many of the wind tunnel flow features are observed. Detection and documentation of the reversal of flow downwind of our building, however, is the most significant feature measured (See Figure 11). Our placement of each mast proved to be optimum as we documented reference conditions, rooftop enhancements, cavity flow, and channeling downwind simultaneously. Some minor influences also occurred that match our pre-conceived notions.

8. SUMMARY

For this field test, all sensors and equipment worked properly. It is clear that one building sufficiently disturbs the flow field. We observed and documented that: a.) wind directions are altered; b.) channeling can occur between adjacent buildings; c.) wind speed accelerations and decelerations are detected; d.) velocity deficits occur along wind; and e.) cavity flow

develops in the lee of the building. Our detection of cavity flow / flow reversal supports our experimental design. This study also validates the guidance derived from Snyder and Lawson's physical modeling studies in the wind tunnel. At the time of this writing, the execution of the second field study with three levels of sonic anemometers at 2, 5, and 10m AGL at the same five mast locations to further examine the behavior of turbulence about our 'model' building had not been completed.

9. REFERENCES

Snyder, W. H. and R. E. Lawson, 1994: Wind Tunnel Measurements of Flow Fields in the Vicinity of Buildings. Proceedings of 8th AMS Conf. on Appl. Air Poll. Meteorol., Boston, MA.

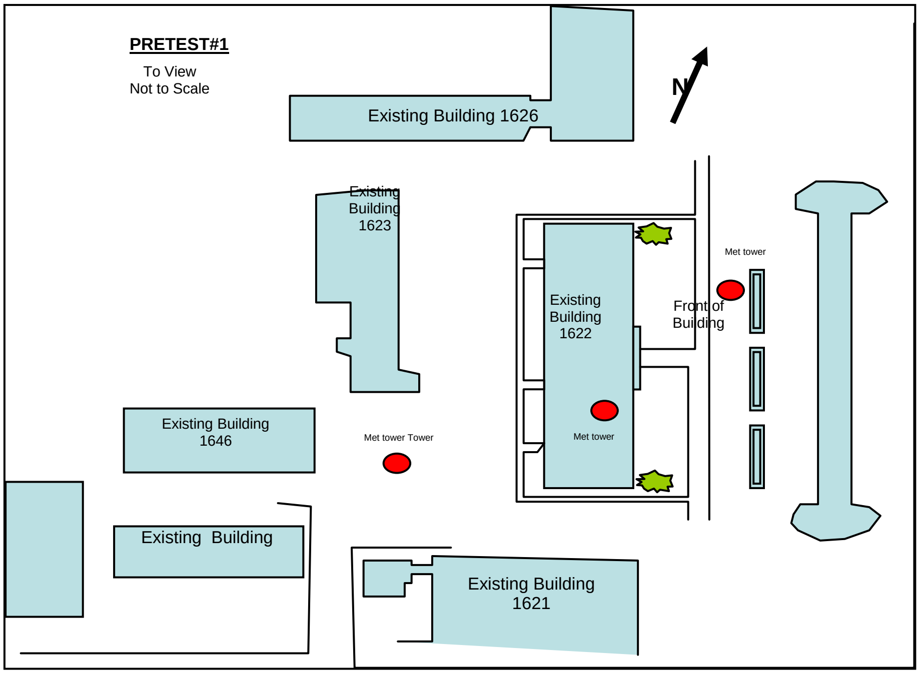

Figure 1. Plan view of our building (1622) and adjacent buildings.

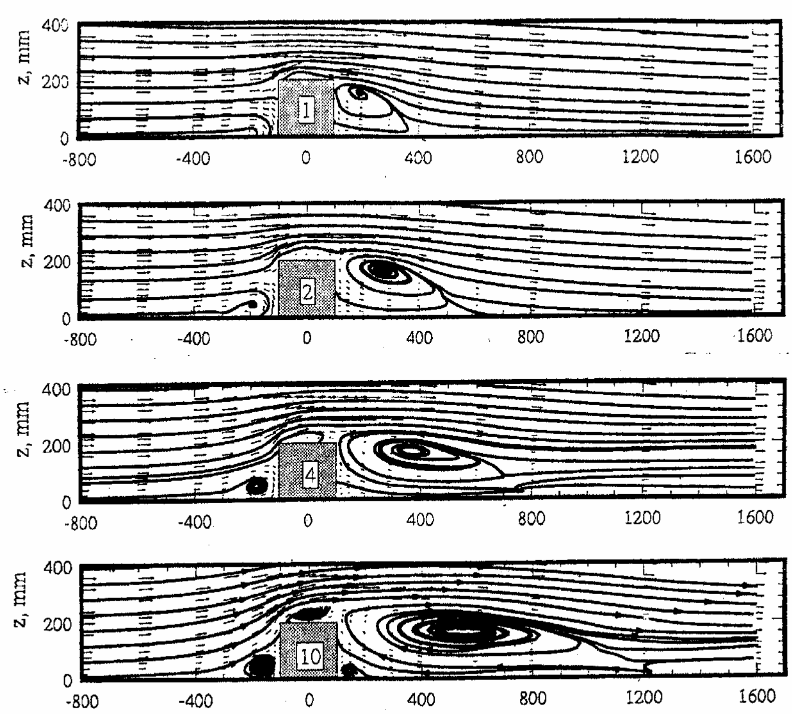

Figure 2. Wind tunnel study streamline field for four W/H ratios shown in the building cross-section.

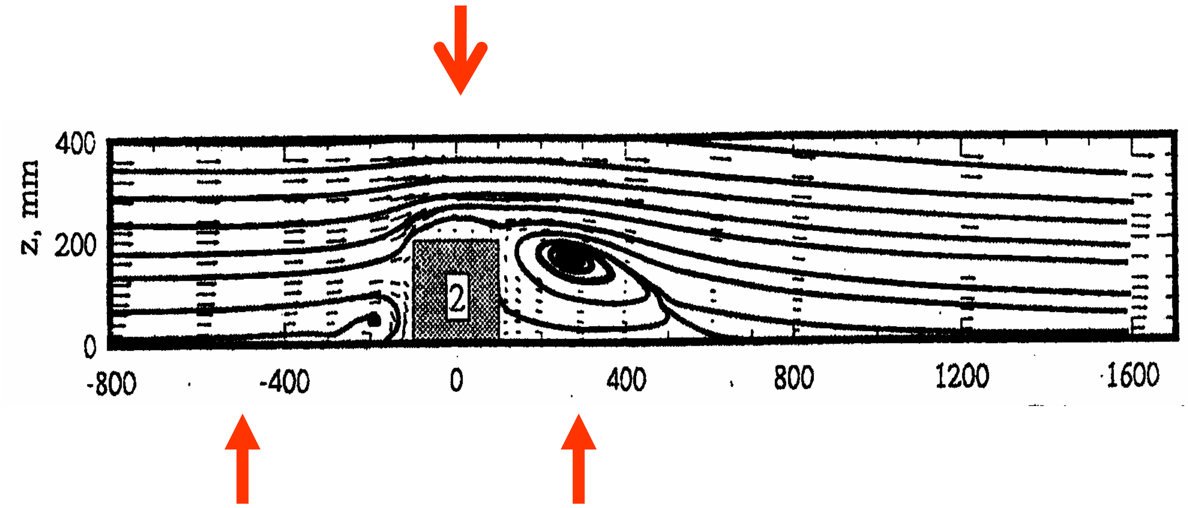

Figure 3. Relative locations of wind masts (upwind, rooftop, downwind).

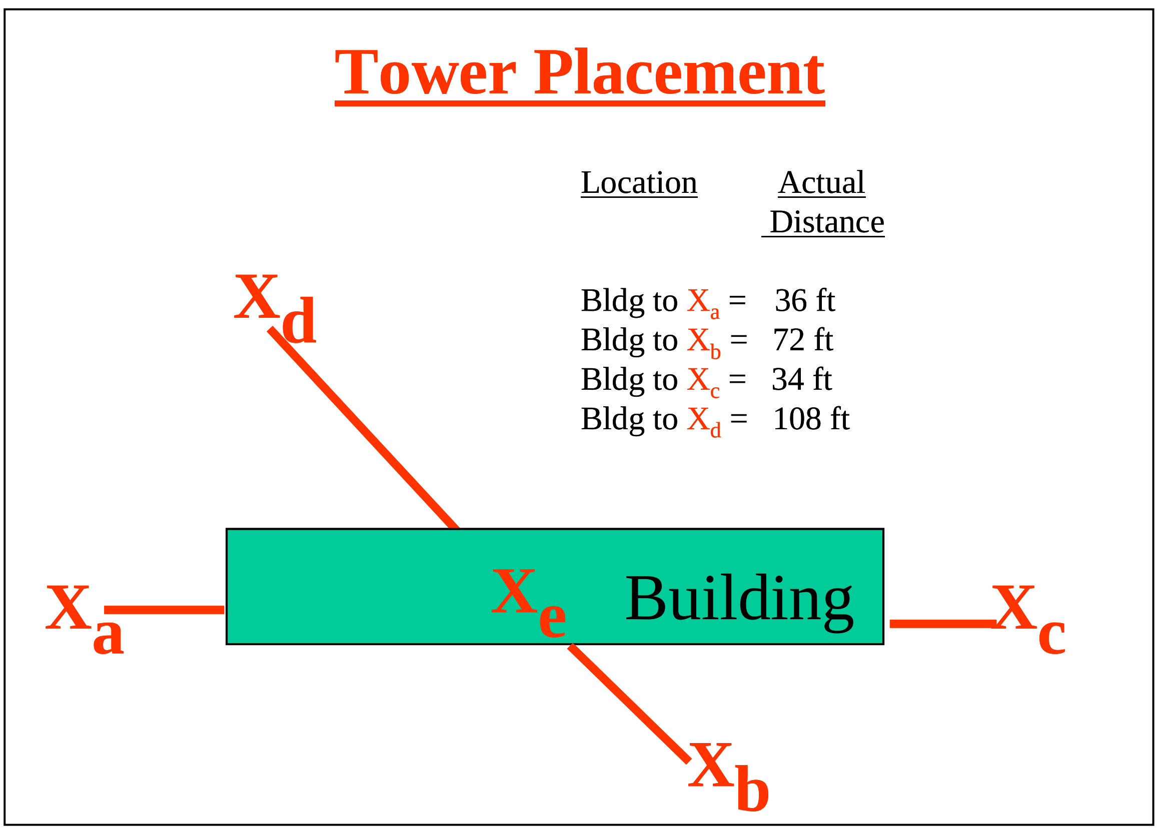

Figure 4. Plan view of all mast locations for Building 1622.

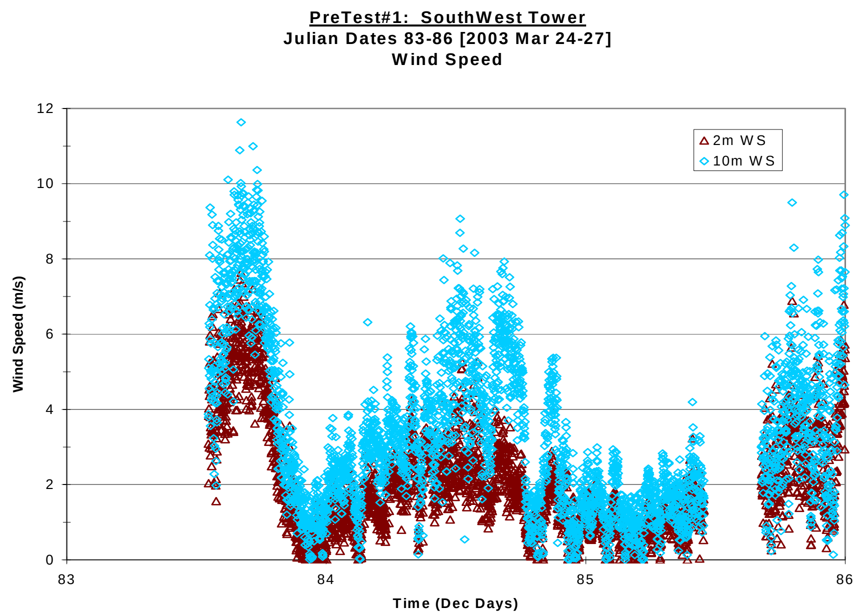

Figure 5. Time history of wind speeds at the upwind mast at the 2m (brown) and 10m (blue) levels.

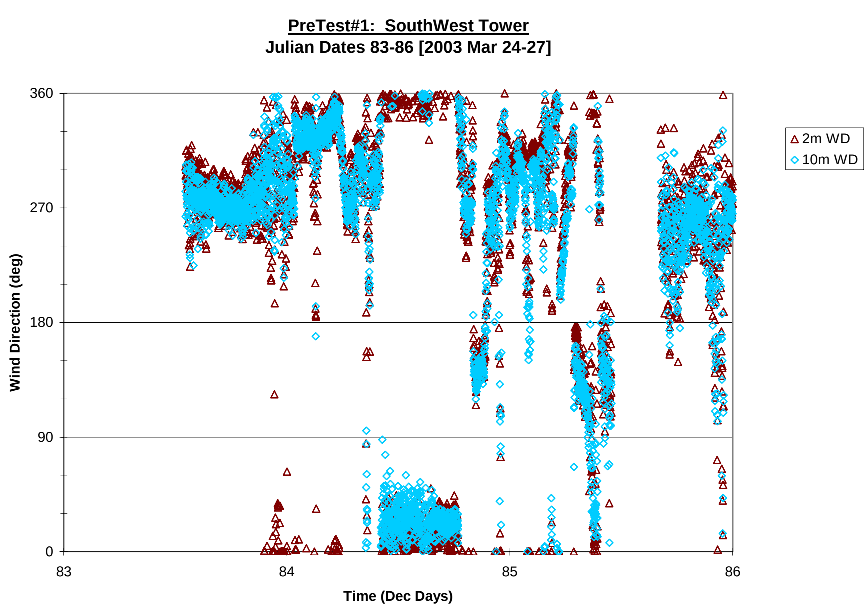

Figure 6. Upwind mast wind directions at 2m (brown) and 10m (blue).

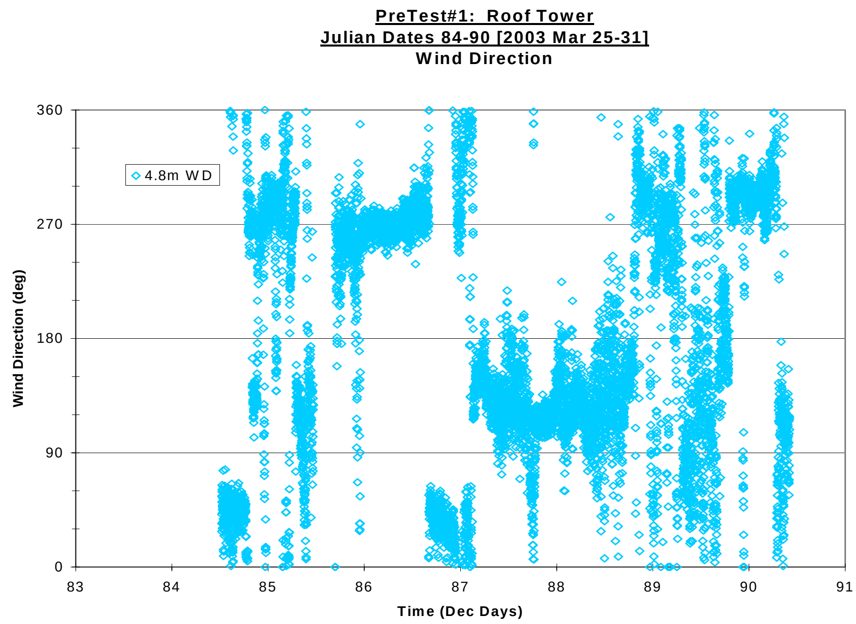

Figure 7. Rooftop mast wind directions at 5m.

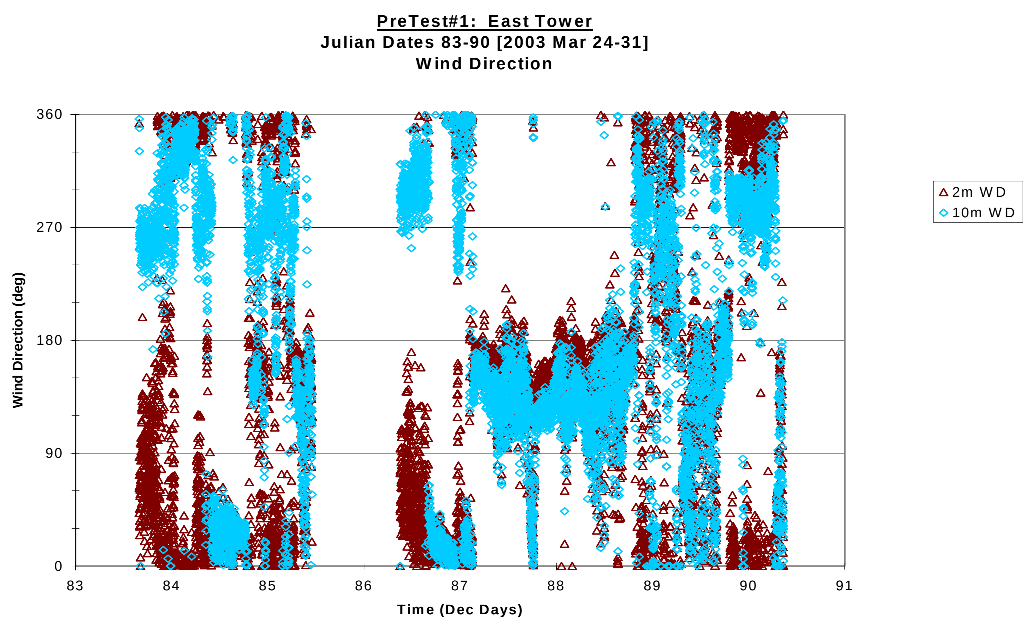

Figure 8. Downwind mast wind directions at 2m (brown) and 10m (blue).

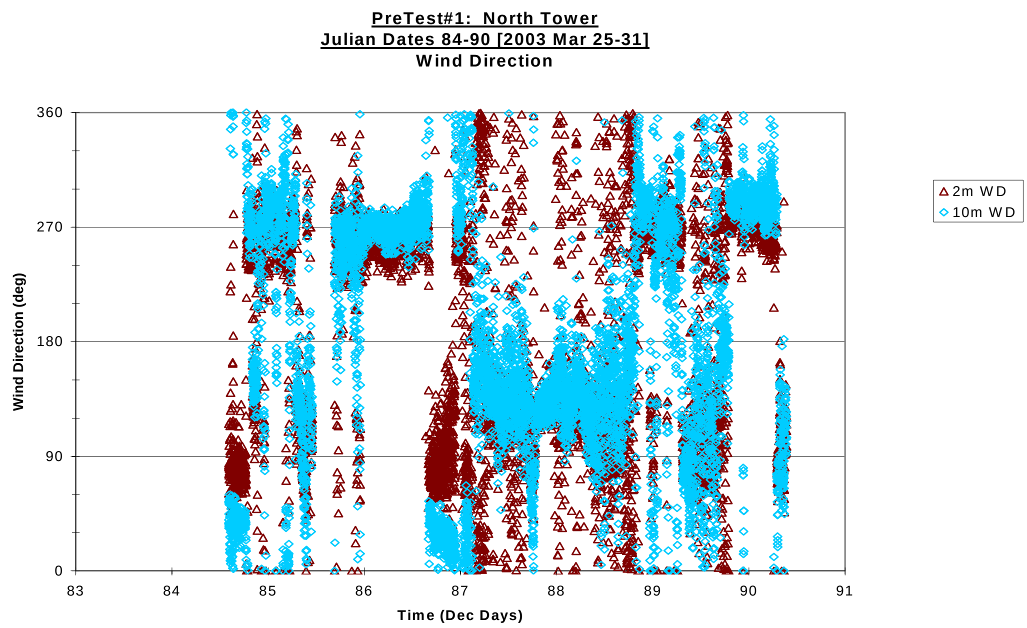

Figure 9. Flow around north side of our building at 2m and 10m.

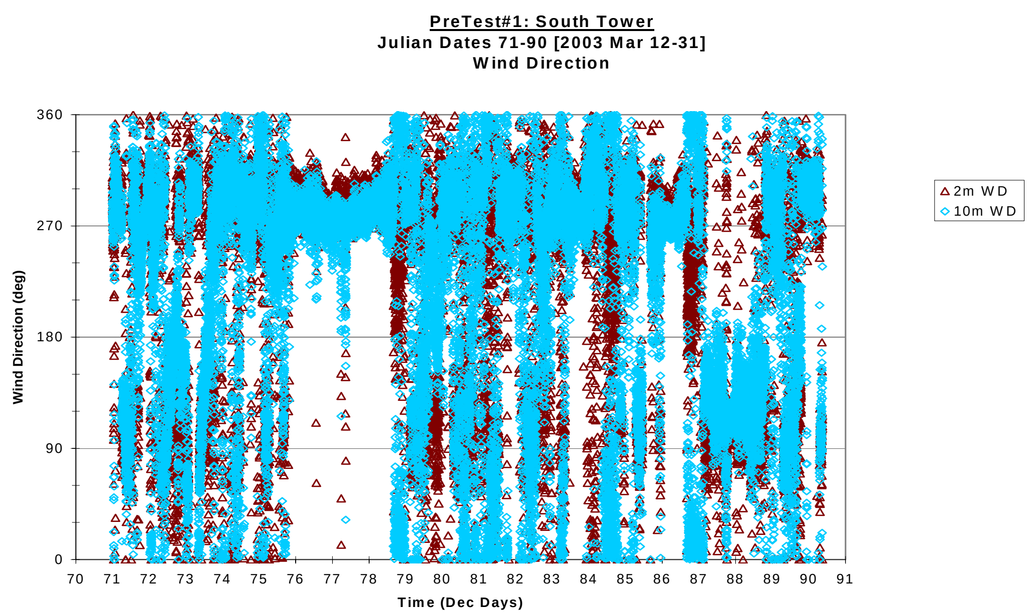

Figure 10. Flow around south side of our building at 2m and 10m.

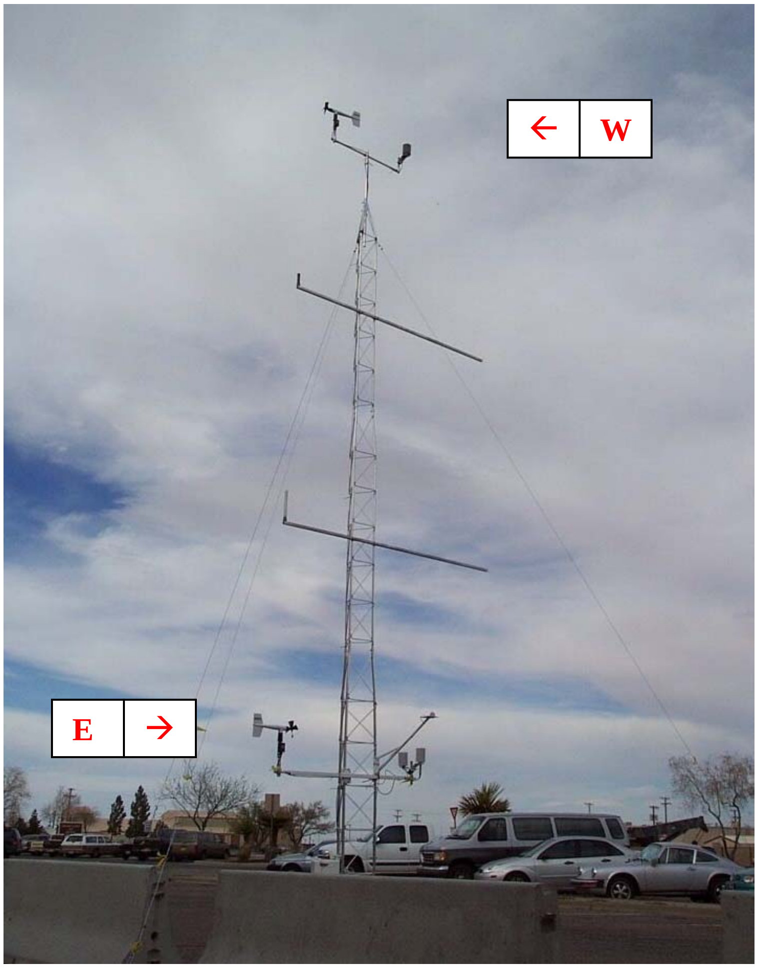

Figure 11. Photo of 10m and 2m wind birds documenting flow reversal.

Table 1. Common wind values simultaneously sampled at all masts.
Case of strong westerly winds for JD 86.422:

Tower	SW	Roof	East	North	South
10m	13.64 m/s	14.54 m/s	Westerly 8.4 m/s	14.6 m/s	15.4 m/s
2m	7.1 m/s	….	Easterly 2.8 m/s	9.22 m/s	11.7 m/s