# JP3.1 EIGHT STABLE URBAN ENVIRONMENT CHARACTERISTICS

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**ABSTRACT**

Urban stability is generally defined as either neutral or unstable. Stable conditions do occur in small urban complexes. These atypical environments have been the topic of investigation by the Army Research Laboratory (ARL) since the first of three independent urban field studies sampled the atmospheric conditions around and above a single building in southern New Mexico. By inter-comparing the stable patterns from each of the three March field studies, repeated attributes were observed, extracted and analyzed. The intended goal of this effort was to empirically define an urban diurnal stability cycle for forecasting purposes.

Measurements from the first two studies revealed atmospheric conditions that included long periods of typical spring New Mexico strong winds (winds sustained at 10 meters per second [m/s] or greater). The latest study contained long periods of light winds. The contrasting weather scenarios were critical in identifying the six spatial characteristics of the urban stable environments. The two temporal urban stable characteristics appeared to be independent of the seasonal effects.

In this paper, a brief overview of the three Urban Studies is followed by a discussion of the eight stable urban environmental characteristics. A consolidated outline of these urban stable characteristics concludes the paper.

## 1. BACKGROUND

Urban atmospheric stability patterns impact health, industry, and various outdoor activities. By identifying repeatable urban stability patterns, improvements to each impact area can be achieved.

Since 2000, the Army Research Laboratory (ARL) has been enhancing their current understanding of the urban atmosphere through three progressively more complex urban field studies conducted in southern New Mexico. One of the goals for these urban *Studies* was to develop a tool that will help define and inform persons of least hazardous areas, or "safe" zones, around a building. Two atmospheric elements that make critical contributions to the definition of an urban "least hazardous location" are atmospheric stability (which impacts airborne chemical/biological concentrations) and airflow (which impacts airborne chemical/biological dissemination). This article will focus on the urban atmospheric stability research. For information regarding the urban airflow research see Vaucher et al. (2008).

## 2. OVERVIEW OF THREE SOUTHERN NEW MEXICO URBAN STUDIES

The research objectives for the three southern New Mexico urban field studies covered a range of scientific, technical, and application areas. The scientific objective linking all three *Studies* was to characterize the stability and airflow patterns around and above a single urban building. All three *Studies* shared a common New Mexico sampling location, as well as, the same time of year for data acquisition and baseline sensor layout/design. Regarding the sampling period, the equinox month of March was selected to minimize systematic effects from the diurnal heating/cooling cycle. The field site layout and design were described in earlier publications (see Vaucher et al., 2008; Vaucher, 2008; Vaucher, 2007). In short, the subject building was a single, rectangular, two-story office building. The meteorological sensors and data were grouped according to their primary application of thermodynamic or dynamic characterizations. The stability research sensors, labeled "thermodynamic sensors," were mounted on the east side of the 10 or 12 meter (m) towers. The airflow sensors, labeled "dynamic sensors," were mounted on the tower's west (windward) side.

The towers supporting the thermodynamic data acquisition were strategically positioned on all four sides of the building. The initial two field studies, *White Sands Missile Range (WSMR) 2003 Urban Study (W03US)* and *WSMR 2005 Urban Study (W05US)* utilized identical thermodynamic sensors. The *WSMR 2007 Urban Study (W07US)* added three Net Radiometers to the original sensor selection. The sensors operated during each *Study* are shown in table 1. The tower placements surrounding the building are displayed in figure 1.

Each tower was referenced by its compass position relative to the single subject building. For example, the North tower was the 10 m tower placed on the north side of the subject building. The South tower was the tower placed on the south side of the building. The towers to the west and east of the subject building

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were skewed into a southwest to northeast location in all field studies, to accommodate prevailing wind direction.

The dynamic characterization of *W03US* utilized the same tower configuration as the thermodynamic characterization with an additional tower on the roof. In *W05US*, three more tripods were added to the leeside, to accommodate the expanded wind flow research objectives. The *W07US* field layout required a total of 7 towers and 5 tripods, to accomplish the detailed airflow characterization. For details on each field study, see Vaucher et al. (2007).

Sections 2.1–2.3 presents a chronological summary of the stable data analysis results for each field study.

| Sensors | Variable | *W03US* | *W05US* | *W07US* |
|---|---|---|---|---|
| Vaisala PTB-101B | Pressure (mb) | Yes | Yes | Yes |
| Campbell T107 | Temperature (C) | Yes | Yes | Yes |
| Vaisala HMP45AC | Temperature (C) / Relative Humidity (%) | Yes | Yes | Yes |
| RM Young 05103 | Wind Speed (m/s) / Wind Direction (deg) | Yes | Yes | Yes |
| Kipp/Zonen CM3 | Pyranometer (W/m$^2$) | Yes | Yes | Yes |
| Kipp/Zonen NR-Lite | Net Radiometer (W/m$^2$) | No | No | Yes |

**Table 1. Thermodynamic sensors used in each of the WSMR Urban Studies.**

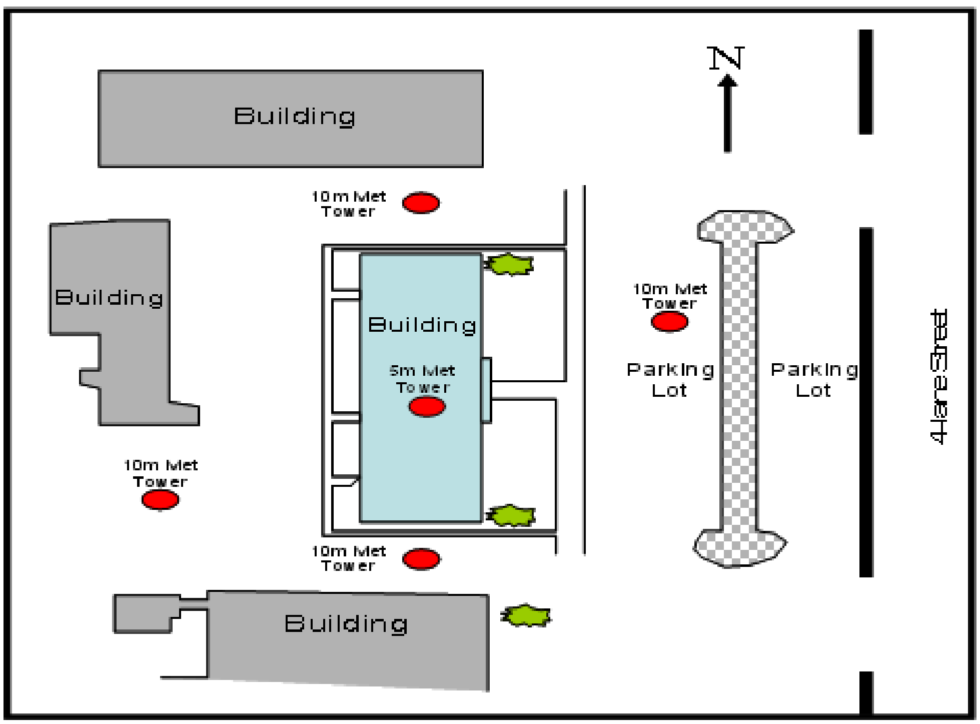


**Figure 1. Thermodynamic sensors were mounted on towers surrounding the subject building. Gray areas represent buildings, with the subject building as blue. The red filled circles represent the Towers. Green jagged circles are trees. The trees on the leeside of the subject building were removed just prior to *W07US*.**

## 2.1 WSMR 2003 Urban Study

The initial *W03US* stability analysis searched for general diurnal urban cycles to contrast with the rural environment. When both rural and urban-city stability patterns were found, a re-analysis of the *W03US* data was conducted that focused on just the atypical stable environments. As explained in Vaucher (2007), the following results for *W03US* were found:

- The total *W03US* days sampled per tower ranged from 7 and 9 days. On average, the tower data reported stable conditions occurring in 65% of these days sampled. The tower reporting the greatest number of minutes in a stable environment was the East tower. The second greatest number of stable condition minutes was recorded from the South tower. The least amount of stable minutes was reported by the North tower sensors. Note: The North tower sensors also sampled the fewest days (7 days).

- The average number of stable minutes ranged from 12–40 minutes per day (min/day), with large standard deviations. Coupling these statistics with a timeline perspective, a grouping of stable environmental conditions was observed. The maximum number of stable condition minutes in a single day paralleled the breakdown of overall total stable condition minutes for *W03US*: the East tower reported a maximum period of 236 min in a single day, followed by the South tower (151 min), the West tower (75 min), and the North tower (47 min).
- Grouping consecutive stable minutes together into cases, the longest duration for a case was 60 min, which occurred at the East tower. The South and West towers each showed 37 min for their longest case. The North tower reported the longest case to be 14 min. On average, a case was between 5–11 min in length (±4–14 min).

The temporal distribution of the stable conditions was evaluated by subdividing the 24-h clock into four consecutive periods: 0300–0859 Local Time (LT) (Sunrise), 0900–1459 LT (Daytime), 1500–2059 LT (Sunset), and 2100–0259 LT (Nighttime). The stable minutes from all towers were then tallied by period.

The stable patterns over the 24-hour (h) clock showed the period of greatest occurrence was between 2100 and 0259 LT (Nighttime), followed by 0300–0859 LT (Sunrise). As expected, no stable conditions were reported from 0900–1459 LT (Daytime). No stable conditions were observed between 1500–2059 LT (Sunset).

Table 2 summarizes the *W03US* stable atmosphere statistics.

### 2.2 WSMR 2005 Urban Study

The *W05US* stable environment data analysis results were described in Vaucher (2007) as the following:

- *W05US* acquired data for approximately 19 days. Approximately 50% of these days sampled reported stable conditions from each side of the building. The total stable minutes observed during *W05US* was greatest in the East tower (663 min). The North tower reported about half as many minutes in a stable status. The South (195 min) and West towers (150 min) reported the least frequent occurrences.
- The average period for stable minutes ranged from about 8–35 min, but these numbers only showed a partial picture. One needed to consider the standard deviation to see that there was significant clustering in portions of the stability timeline.
- Defining consecutive minutes of stable conditions into units of a "case," the average case duration statistically ranged from 4–10 min. However, the longest stable case duration was 54 min and was observed in the East tower data.
- Using a 24-h timescale, the time period with the greatest number of stable vertical profiles was between 2100 and 0259 LT (Nighttime). The second most populated time period was between 0300 and 0859 LT (Sunrise), followed by 1500–2059 LT (Sunset). As expected, no stable samples were observed between 0900–1459 LT (Daytime). Subtle to these numerical observations was the presence of a mini-heat island effect surrounding the building.

Table 3 provides a statistical summary of the *W05US* stable conditions.

### 2.3 WSMR 2007 Urban Study

All statistics reported in this section include the roof stability data. Prior to *W07US*, roof stability data were unavailable. The following *W07US* summary is taken from Vaucher (2008):

The *W07US* stability data were acquired over a period of approximately 19 days. On average, about 74% of these days reported stable conditions in one or more towers. The total number of stable condition minutes from all the towers was 6,430 min.

The spatial distribution for the observed stable environments was the following: The greatest number of stable minutes was observed in the West tower (1,724 min), followed by the Roof tower (1,510 min), the East tower (1,344 min) and the South tower (1,138 min). The least number of stable minutes was reported by the North tower (714 min). The average stable minutes per day ranged from about 38 min (North tower) to 91 min (West tower). All towers reported an exceptionally large standard deviation, implying strong clustering of stable events.

Converting the consecutive stable minutes into "cases," the average case duration was 8.6 min. The longest stable case occurred in the West tower and lasted 312 min, or 5 h and 12 min. Table 4 provides a statistical summary of the spatial *W07US* stable conditions.

Examining the temporal patterns for *W07US* stable conditions, the most populated stable period was from 2100–0259 LT (Nighttime). All towers reported this period as having the greatest occurrence. Approximately two-thirds, or 67%, of the total *W07US* stable minutes fell within this time interval. The second greatest occurrence was from 0300-0859 LT (Sunrise). All towers consistently reported about 26% of their stable data within this time period. No stable conditions were reported from 0900–1459 LT (Daytime). From 1500–2059 LT (Sunset), the average occurrence in all towers was 7%.

| ***W03US*** **Stable Conditions** | **West** | **South** | **North** | **East** |
|---|---|---|---|---|
| Julian Day number sampled | 83–90 | 71, 83–90 | 84–90 | 83–90 |
| Percentage of days sampled in which stable conditions were reported | 62% | 67% | 57% | 75% |
| | | | | |
| Total minutes in stable conditions | 197 | 267 | 84 | 320 |
| Average stable minutes per day | 25 (±29) | 30(±49) | 12(±18) | 40(±80) |
| Maximum number of stable minutes per day | 75 | 151 | 47 | 236 |
| | | | | |
| Maximum number of cases per day | 26 | 37 | 16 | 30 |
| Average case duration (min) | 7.6(±8.9) | 7.2(±6.8) | 5.3(±4.2) | 10.7(±14.5) |
| Longest case duration (min) | 37 | 37 | 14 | 60 |

**Table 2. Statistical summary of *W03US* stable conditions.**

| **W05US Stable Conditions** | **West** | **South** | **North** | **East** |
|---|---|---|---|---|
| Julian Day number sampled | 76–94 | 76–94 | 76–94 | 76–94 |
| Percentage of days sampled in which stable conditions were reported (number of days) | 58% (11) | 53% (10) | 47% (9) | 47% (9) |
| | | | | |
| Total minutes in stable conditions | 150 | 195 | 352 | 663 |
| Average stable minutes per day | 7.9 [±11] | 10[±14] | 18[±27] | 35[±62] |
| Maximum number of stable minutes per day | 36 | 52 | 86 | 238 |
| | | | | |
| Number of cases | 41 | 44 | 58 | 83 |
| Average case duration (min) | 3.7 [±3.5] | 4.4 [±3.4] | 6.1 [±3.9] | 8.0 [±10.7] |
| Longest case duration (min) | 20 | 16 | 17 | 54 |

**Table 3. Statistical summary of W05US stable conditions.**

| ***W07US*** **Stable Conditions** | **West** | **South** | **North** | **East** | **Roof** |
|---|---|---|---|---|---|
| Julian Day number sampled | 75–93 | 75–93 | 75–93 | 75–93 | 75–93 |
| Percentage of days sampled in which stable conditions were reported (number of days) | 84% (16) | 58% (11) | 63% (12) | 84% (16) | 79% (15) |
| | | | | | |
| Total minutes in stable conditions | 1724 | 1138 | 714 | 1344 | 1510 |
| Average stable minutes per day | 91[±106] | 60[±80] | 38[±61] | 71[±90] | 80[±101] |
| Maximum number of stable min/day | 371 | 280 | 233 | 282 | 332 |
| | | | | | |
| Number of cases | 159 | 136 | 111 | 166 | 175 |
| Average case duration (min) | 10.8[±26.9] | 8.4 [±11.4] | 6.4 [±5.9] | 8.1 [±8.1] | 8.6 [±17.0] |
| Longest case duration (min) | 312 | 79 | 37 | 52 | 205 |

**Table 4. *W07US* statistical summary of stable conditions.**

## 3. STABILITY CHARACTERIZATION GLEANED FROM INTER-STUDY COMPARISONS

Comparing the stable character found within the three field studies required some systematic adjustments. For example, *W03US* acquired thermodynamic data over a 9-day period, whereas *W05US* and *W07US* acquired thermodynamic data over an approximately 19-day period. For this reason, when investigating "how often a stable environment was present," the results were put into proportions with respect to the total number of days sampled. The results were:

- Approximately 50% of the *W03US* days sampled reported stable conditions.
- Approximately 65% of the *W05US* days sampled reported stable conditions.
- Approximately 75% of the *W07US* days sampled reported stable conditions.

Another systematic difference impacting inter-*Study* comparisons was the following: The first two *Studies* utilized thermodynamic data from four towers surrounding the subject building, whereas the *W07US* added a fifth thermodynamic data resource on the roof. Thus, the influences of this fifth resource (the Roof tower) on the statistical comparisons will be flagged where appropriate.

The inter-*Study* analyses were subdivided into two distinct perspectives: the spatial and the temporal stable condition characteristics. The ultimate goal of these comparisons is to extract a repeatable pattern useful in defining an urban diurnal stability cycle.

### 3.1 Spatial Comparisons

The spatial aspects of the urban stable characterization effort will be described through the use of four questions:

(1) Is there a preferred side of a building for stable atmospheric conditions?

(2) Why would the *W07US* Roof data rank second, after the west side, with regard to the greatest percentage of stable minutes sampled?

(3) What is the average number of stable minutes per day?

(4) How often do consecutive stable conditions occur in a day and what is the average duration for these consecutive stable conditions?

Each question will be addressed in the following subsections.

#### 3.1.1 "Is there a preferred side of a building for stable atmospheric conditions?"

The three field studies sampled stability data around a north-south aligned subject building during the vernal equinox time period. Theoretically, this arrangement would minimize any systematic solar heating/cooling influences. Comparing the spatial distribution of stable conditions across the field studies, there were no fully consistent patterns. In table 5, the tower table-cell with the greatest percentage of stable minutes during each field study is filled with red. The second greatest is filled with orange, third with yellow, fourth with green, and finally, the last is filled with blue (following the longer to shorter wavelength color spectrum). If the first two field studies were evaluated without the third, a natural observation would be that the East tower was the preferred stable side. The open parking lot and a multi-lane street to the subject building's east would certainly support this observation, with its potential for radiative cooling overnight.

The *W07US* results show the east side as ranking second without the Roof data, and third, when the Roof data is included. One possible explanation for the discontinuity between field studies involves the overall atmospheric conditions exhibited during the *Studies*. During *W03US* and *W05US*, the field site experienced typical climatologically windy conditions. That is, long periods of sustained strong winds were observed. With strong winds, the atmosphere tended to be well mixed. During *W07US*, the strong wind episodes occurred but were not as frequent as the previous *Studies*. Without these strong winds, the opportunity for a stratified vertical profile would have increased. The less dynamic and more buoyant atmosphere around the building would have subsequently integrated the building's heat into the local environment. Therefore, the potential for a stable atmosphere would have decreased around and downwind from the building. For *W07US*, this latter condition would have been on the north, south, and east of the subject building. The only side not injected with the subject building's heat would have been the upwind or Fetch side. The Fetch for *W07US* was on the west, which reported the greatest occurrence of stable conditions.

| Percentage of Stable Min by Tower | *W03US* | *W05US* | *W07US* No Roof Data Included | *W07US* Roof Data Included |
|---|---|---|---|---|
| East | 36 | 49 | 27 | 21 |
| South | 31 | 14 | 23 | 18 |
| West | 23 | 11 | 35 | 27 |
| North | 10 | 26 | 15 | 11 |
| Roof | N/A | N/A | Not Included | 23 |

**Table 5. Inter-*Study* Comparison: Percentage of stable minutes reported by tower. If the entire field study reported stable conditions, the number entered would be 100%.**

### 3.1.2 "Why would the *W07US* Roof data rank second, after the west side, with regard to the greatest percentage of stable minutes sampled?"

One possible explanation draws from the observation that on the northwest corner of the Roof was a building heating vent. Since neither dismantling nor turning off the building's heating system were options, the Roof tower placement was such that under normal climatological conditions, the heating vent's exhaust would be carried away from the building along a path well removed from the Roof tower. Typical climatological winds for the area are strong, westerly winds. Coupling the seasonal (regional) westerly winds with local forcing, the net prevailing flow over the roof was expected to be southwesterly winds. As discussed earlier, *W07US* did not experience the typical strong, seasonal New Mexico winds. The regional wind direction was, however, still westerly. Without the anticipated air velocities to carry the heat away from the building, the atmosphere over the roof may have gained a pocket of warm air that could have been picked up by the Roof's upper level sampler. The net result would have shown the lower level Roof sensor as relatively cooler than the upper level. Thus, a stable roof environment would have been reported.

### 3.1.3 "What is the average number of stable minutes per day?

Table 6 shows the average number of stable minutes per day by tower and field study. Once again, the results were color coded from most to least frequent using the sequence of red, orange, yellow, green, and blue. Unfortunately, no consistent patterns are apparent between the three field studies.

Comparing the relative order of average magnitudes, *W03US* and *W05US* showed the highest average in the East tower, but didn't agree with the rest of the order. They also showed a consistent 5 min/day drop in the greatest and least average values. *W07US* (without the Roof data) had a unique preference for the highest average (West tower) and the second place average (East tower), but then agreed with the *W05US* that the South tower ranked third place (South tower) and with *W03US*'s reporting of the fourth place (North tower). No significant correlations could be made when including the Roof data.

Regarding the distribution of average consecutive stable values, the top three positions in *W03US* and *W07US* (no Roof data) showed a clustering of values with a sharp drop in magnitude for the lowest average. Even when the roof was included; the pattern of clustered values with a sharp drop in the last location remained intact.

Table 7 shows the maximum number of stable min/day by tower and field study. These followed the same ordering as the averages presented in the preceding table.

### 3.1.4 "How often do consecutive stable conditions occur in a day and what is the average duration for these consecutive stable conditions?"

To address these questions, the consecutive stable minutes were grouped together into "cases." The number of stable cases per day was tabulated in table 8. Before drawing conclusion, the reader is reminded that the *W03US* data acquisition period was for only 9 days and the other two studies were roughly 19 days in length. This observation helps to explain why the number of cases per day for *W05US* was about twice the magnitude as *W03US*. The larger jump in number of cases between *W05US* and *W07US* was explained earlier in the discussion about the climatologically typical windy conditions for the first two studies and the atypical climatological conditions (less wind events) observed during *W07US*. These statistical results reinforced the influential nature of dichotomous seasonal environments. They also suggest that running this same field study under purposefully buoyant conditions could greatly enrich our understanding of the urban environment.

| Average Stable Min/Day | *W03US* | *W05US* | *W07US* No Roof Data | *W07US* Roof Data Included |
|---|---|---|---|---|
| West | 25 | 8 | 90 | 90 |
| South | 30 | 10 | 60 | 60 |
| North | 12 | 18 | 38 | 38 |
| East | 40 | 35 | 71 | 71 |
| Roof | N/A | N/A | Not included | 80 |

**Table 6. Inter-*Study* Comparison: Average stable minutes per day.**

| Maximum number of Stable Min/Day | *W03US* | *W05US* | *W07US* No Roof Data | *W07US* Roof Data Included |
|---|---|---|---|---|
| West | 75 | 36 | 371 | 371 |
| South | 151 | 52 | 280 | 280 |
| North | 47 | 86 | 233 | 233 |
| East | 236 | 238 | 282 | 282 |
| Roof | N/A | N/A | Not included | 332 |

**Table 7. Inter-*Study* Comparison: Maximum number of stable minutes per day.**

| Number of Cases/Day | *W03US* | *W05US* | *W07US No Roof Data* | *W07US Roof Data Included* |
|---|---|---|---|---|
| West | 26 | 41 | 159 | 159 |
| South | 37 | 44 | 136 | 136 |
| North | 16 | 58 | 111 | 111 |
| East | 30 | 83 | 166 | 166 |
| Roof | N/A | N/A | Not included | 175 |

**Table 8. Inter-*Study* Comparison: Number of stable cases per day; a "case" is comprised of two or more consecutive minutes of stable conditions.**

Before addressing "how often the stable conditions occur," a look at the average case duration is useful. Table 9 summarizes the average case duration by tower and field study. The intriguing observation here was that despite the contrasting climatological conditions between field studies, the overall average case duration was fairly consistent between all field studies. *W05US* reported the average duration to be about 6 min, and both *W03US* and *W07US* showed their averages to be about 8 min (with and without the Roof data).

Assessing the outer extremes in the stable condition occurrence, the longest stable case durations by tower and field study are summarized in table 10. Across the three *Studies*, there were no truly consistent preferences. Grouping the first two field *Studies* together, the highest duration was reported in the East tower. This was not surprising in light of the previous tables. The ranking of the second longest duration was also equivalent between the first two *Studies*, though the magnitudes were not very close.

The North tower consistently reported a low magnitude of minutes in this longest case duration table (with and without the Roof data). These results remain a puzzle, considering that one would expect the north side of a building to favor cooler and therefore, stable air. Perhaps the fact that the subject buildings north side was also a canyon flow area (accelerated flow through a narrowed passageway) may explain the lack of stable preference over the other subject building sides. That is, an accelerated flow through a narrowed passageway would tend to generate a transitory and well-mixed (non-stable) atmosphere.

### 3.2 Temporal Comparisons

Amazing consistency between the three *Studies* was found in the temporal character of the stable environments. Using the four-quadrants of a 24-h clock, all field studies reported the most populated period of stable minutes to be during the Nighttime, between 2100–0259 LT. The second most populated time period was consistently reported as during the Sunrise Period (0300–0859 LT). The percentages tabulated in table 11 were calculated with respect to the total number of stable minutes observed for each particular field study. The consistency of proportions for each of the time quadrants was most encouraging, especially in the context of unveiling an urban diurnal stability pattern. Based on this consistency, the time quadrants were subdivided into hourly divisions and statistical totals were generated using all available tower data.

For the 9-day *W03US*, the refined (hourly) stable period preference was between 2300-0500 LT. Modest values were still present in the hour preceding, and the two hours following, this favored period. The MOST populated period was 0100-0159 LT, with a close second during the 0200-0259 LT hours.

The approximately 19-day *W05US* showed the hourly periods with 50 or more cumulative (all towers) minutes to be between 2000–0600 LT. The times in which 100 or more minutes occurred were during two periods: the single hour of 2100 LT and the period of 0100–0400 LT. The over 150 min totals were found between 0200–0400 LT. The MOST populated hour was during the 0300 LT hour.

| Average Case Duration (min) | *W03US* | *W05US* | *W07US No Roof Data* | *W07US Roof Data Included* |
|---|---|---|---|---|
| West | 8 | 4 | 11 | 11 |
| South | 7 | 4 | 8 | 8 |
| North | 5 | 6 | 6 | 6 |
| East | 11 | 8 | 8 | 8 |
| Roof | N/A | N/A | Not included | 9 |

**Table 9. Inter-*Study* Comparison: Average stable case duration in minutes.**

| Longest Case Duration (min) | *W03US* | *W05US* | *W07US No Roof Data* | *W07US Roof Data Included* |
|---|---|---|---|---|
| West | 37 | 20 | 312 | 312 |
| South | 37 | 16 | 79 | 79 |
| North | 14 | 17 | 37 | 37 |
| East | 60 | 54 | 52 | 52 |
| Roof | N/A | N/A | Not included | 205 |

**Table 10. Inter-*Study* Comparison: Longest stable case duration by tower.**

| Field Study | Sunrise 0300–0859 LT | Daytime 0900–1459 LT | Sunset 1500–2059 LT | Night Time 2100–0259 LT | Total (%) |
|---|---|---|---|---|---|
| *W03US* | 44 | 0 | 0 | 56 | 100 |
| *W05US* | 44 | 0 | 6 | 50 | 100 |
| *W07US* | 28 | 0 | 6 | 66 | 100 |

**Table 11. Inter-*Study* Comparison: Temporal distribution, in percentage, of stable conditions around the subject building.**

Finally, the tallies for *W07US* showed the following: Even without the Roof data, the cumulative stable minutes reported were four times the earlier studies. With the Roof data, those hours in which over 100 min of stable conditions were present around and over the building ranged from 1900–0600 LT. The most favored period (greater than 600 cumulative minutes) was between 2300–0300 LT. Preceding this highly populated period, was a gradual, consistent increase from 1900–2200 LT. After the highly populated period, there is a sharp drop for two hours and a curious increase in occurrence during the 0600 LT hour. The 0600 and 2200 hours were similar in magnitudes. For *W07US,* the MOST populated hour was 0100 LT.

This higher temporal resolution analysis is still in progress. However, the current results would seem to imply that the previous strong preference for 2100–0259 LT can be refined. Based on the hourly results and a subjective opinion, the new period favoring stable conditions might be defined as between 0000–0300 LT.

## 4. SUMMARY

Urban atmospheric stability patterns impact military and civilian health, tools, operations, and strategic planning. By identifying repeatable urban stability patterns, improvements to each area of impact can be achieved.

In this paper, the stability conditions for each of the three *WSMR Urban Studies* were reviewed, with a focus on characterizing the atypical stable urban environments.

While no spatial patterns proved consistent among all three field studies, there was consistency between seasonally similar field study atmospheric environments. For example, the spatial distribution during the climatologically windy field studies showed a preference of stable conditions on the leeside (east) of the subject building. One possible explanation for this preference: the open environment on the leeside suggests an increased potential for radiative cooling with respect to the other “enclosed” building sides.

The climatologically atypical conditions (light winds) of the *W07US* favored the windward (west) or Fetch side of the building. The proposed explanation for these contrasting results suggested that the heat from the radiating building lacked the airflow necessary to send the heat away from the building. Therefore, all sides but the Fetch integrated the added heat into the vertical profiles and reported less stable conditions than the non-building-influenced Fetch side.

The inter-*Study* stable case evaluations showed an amazing consistency in the average case length. On average, the consecutive minutes of a stable environment were between 6–8 min in length. The maximum case durations between towers and field studies varied greatly, ranging from 14–312 min.

The temporal distribution of the stable environment was extremely consistent between the three field studies! The first preferred time period for occurrence was 2100–0259 LT (Nighttime). The second preferred was 0300–0859 LT (Sunrise). In two of the *Studies*, there was a third preferred of 1500–2059 LT (Sunset). No *Study* reported stable conditions during the Daytime period (0900–1459 LT).

In short, after inter-comparing the results of the three *Studies*, there were eight stable environment characteristics observed. These included:

1. The most populated period for stable environment occurrence was midnight, ±3 h.*

* Preliminary findings from subsequent research indicate That the most populated period may be refined to 0000–0300 LT.

2. The second most populated period for stable environment occurrence was sunrise, ±3 h.
3. During windy conditions, the building leeside was favored for a stable environment.
4. During non-windy conditions, the building windward (Fetch) side was favored for a stable environment.
5. The average duration of consecutive minutes for stable conditions was 6–8 min.
6. The extreme durations for consecutive stable minutes ranged from 14–312 min (312 min = 5 h 12 min).
7. Extreme stable case durations favored the non-windy environments.
8. The roof with a heating vent generated a stable environment.

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