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An analysis of peak wind speed data from collocated mechanical and ultrasonic anemometers

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This study compared peak wind speeds reported by mechanical and ultrasonic anemometers at Cape Canaveral Air Force Station and Kennedy Space Center (CCAFS/KSC) on the east central coast of Florida and Vandenberg Air Force Base (VAFB) on the central coast of California. Launch Weather Officers, forecasters, and Range Safety analysts need to understand the performance of wind sensors at CCAFS/KSC and VAFB for weather warnings, watches, advisories, special ground processing operations, launch pad exposure forecasts, user Launch Commit Criteria (LCC) forecasts and evaluations, and toxic dispersion support. The legacy CCAFS/KSC and VAFB weather tower wind instruments are being changed from propeller-and-vane (CCAFS/KSC) and cup-and-vane (VAFB) sensors to ultrasonic sensors under the Range Standardization and Automation (RSA) program.

Mechanical and ultrasonic wind measuring techniques are known to cause differences in the statistics of peak wind speed as shown in previous studies. The 45th Weather Squadron (45 WS) and the 30th Weather Squadron (30 WS) requested the Applied Meteorology Unit (AMU) to compare data between the RSA ultrasonic and legacy mechanical sensors to determine if there are significant differences. Note that the instruments were sited outdoors under naturally varying conditions and that this comparison was not designed to verify either technology.

Approximately 3 weeks of mechanical and ultrasonic wind data from each range from May and June 2005 were used in this study. The CCAFS/KSC data spanned the full diurnal cycle, while the VAFB data were confined to 1000-1600 local time. The sample of 1-minute data from numerous levels on five different towers on each range totaled more than 500,000 minutes of data (482,979 minutes of data after quality control). The ten towers were instrumented at several levels, ranging from 12 ft to 492 ft above ground level. The ultrasonic sensors were collocated at the same vertical levels as the mechanical sensors and typically within 15 ft horizontally of each another. Data from a total of 53 RSA ultrasonic sensors, collocated with mechanical sensors were compared. The 1-minute average wind speed/direction and the 1-second peak wind speed/direction were compared.

The overall results for the peak wind speed comparison follow:

Overall Peak Wind Speed:

Mechanical 10.72 kt, Ultrasonic 11.78 kt, Ultrasonic - Mechanical = 1.06 kt

The AMU also examined each mechanical/ultrasonic pairing for consistency in wind speed and wind direction. The most consistent sensors were used to define a composite average-mechanical/ultrasonic comparison. Comparisons of the consistent composite were slightly different than the overall comparison cited above

Composite Peak Speed:

Mechanical 10.95 kt, Ultrasonic 11.93 kt, Ultrasonic - Mechanical = 0.98 kt

The average difference in the composite peak wind speed is statistically significant because of the large sample size and relatively small standard deviation of differences in the minute-by-minute data, +/- 1.10 kts.

The observed differences in peak wind speeds can be approximated by a Monte Carlo process in which a simulated mechanical system has a smaller variance in 1-second wind speeds than the simulated ultrasonic system. The effective difference in variance of about 10% may be due to an effective temporal smoothing by the mechanical system or a greater sensitivity of the ultrasonic system to small scale turbulence. Small differences in average wind speeds were also noted and are reported in detail under final reports at http://science.ksc.nasa.gov/amu/home.html. From an operational point of view, the differences in peak wind speeds are important, indicating that the change to ultrasonic sensors can be expected to result in an increase in reported peak wind speeds. An increase in peak wind speeds would result in a decrease of launch availability, depending on the LCC threshold wind speed. For example, the probability of peak wind speeds at 20 kt or less using the CCFAS/KSC mechanical data was 95.2%. For the same 20 kt threshold, the CCFAS/KSC ultrasonic data showed a probability of 92.3%, a potential loss of launch availability of up to 2.9%. Since a launch scrub costs hundreds of thousands to over a million dollars, depending on the launch vehicle, a change in launch opportunity of only a few percent can be costly.