ANALYSIS OF PEAK WINDS IN THE KENNEDY SPACE CENTER-CAPE CANAVERAL AIR FORCE STATION WIND TOWER NETWORK

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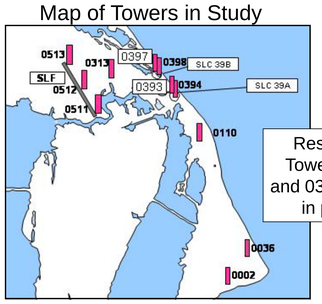
BACKGROUND

- The peak winds near the surface are an important forecast element for vehicle launch and landing operations. There are defined peak wind thresholds that cannot be exceeded in order to ensure the safety of personnel and equipment during these operations.
- The 45th Weather Squadron (45 WS) and the Spaceflight Meteorology Group (SMG) indicate that peak winds are a challenging parameter to forecast.
- *The AMU was tasked to develop short-range peak-wind forecast tools to use in support of launch and landing operations.*

DATA

- 5-minute average and peak wind speed and direction observations from the Kennedy Space Center/Cape Canaveral Air Force Station (KSC/CCAFS) wind tower network
- Data were from wind sensors at the 7 towers used to make operational decisions for the 4 main spacelift programs at KSC/CCAFS: Shuttle, Atlas, Delta, Titan
- Period of Record: January 1995 – December 2001, 7 years
  Over 700,000 observations per sensor

Map of Towers in Study



Results for Towers 0393 and 0397 shown in poster

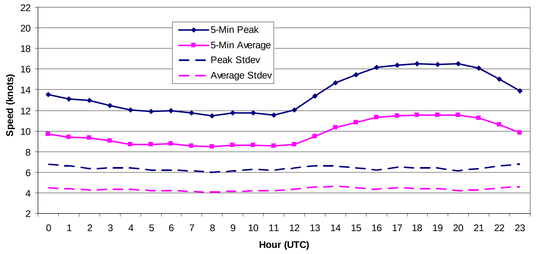
QUALITY CONTROL

- 5 data quality control routines were used to flag questionable data:
  - Impossible value check
  - Within 10 standard deviations of mean
  - Peak-to-average wind speed ratio limit
  - Vertical consistency between sensors at same tower/different levels
  - Temporal consistency at individual sensors
- *Only 0.6 – 2.1% of data per sensor flagged by the routines, most data good and available for analysis*

CLIMATOLOGY

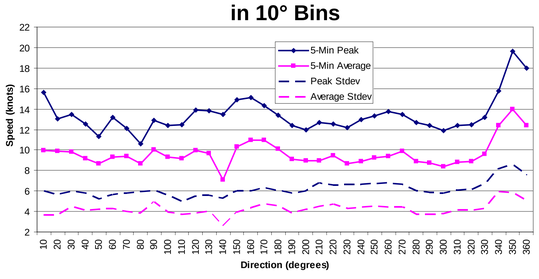
- Data first stratified by tower/height combination and month
- Stratified in 3 ways to calculate climatologies:
  Hour
  Direction in 10° bins
  Direction in 45° bins, then hour
  (Bins narrower than 45° produced stratifications with too few observations for reliable calculations)
- Calculated means and standard deviations
- Number of observations in calculations recorded
- Images shown are the March climatologies for Tower 0393 at 60', located 1250' NW of Shuttle Launch Pad 39A

Hourly Means and Standard Deviations



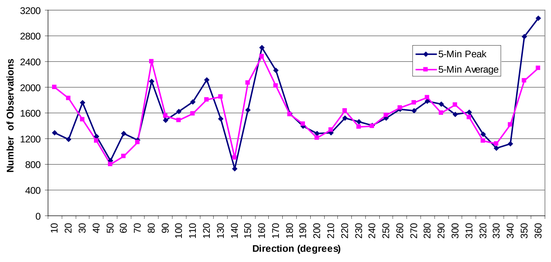
- Means show a diurnal pattern, speed increase in daytime (*Local noon: 1700 UTC)*
- Standard deviations indicate large variability, little diurnal change

Directional Means and Standard Deviations in 10° Bins



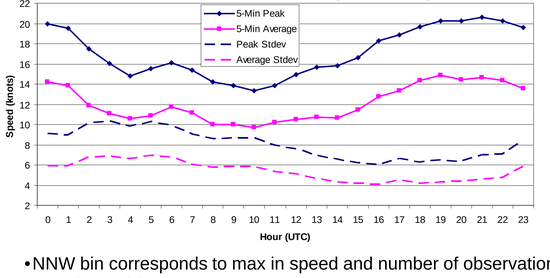
- Value on axis is upper limit of bin
- No noticeable pattern with direction, speed max from NW (330-360°)
- Drop in speeds and standard deviations at 140° likely due to obstruction of flow around launch pad SE of tower

Number of Observations in each 10° Bin



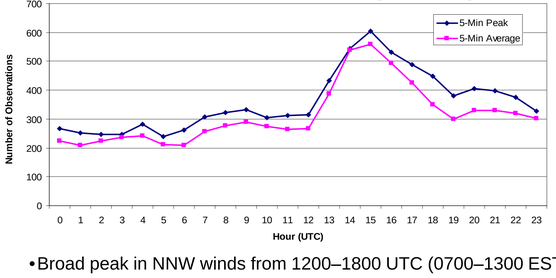
- 2 maxima in the number of observations from S-SE (150-180°) and NW (340-360°)
- Large oscillation in number of observations from S-SE (130-170°) likely due to obstruction of flow around launch pad SE of tower

Hourly Means and Standard Deviations in NNW Direction Bin (315-360°)



- NNW bin corresponds to max in speed and number of observations seen in 10° bins
- Diurnal trend in both means and standard deviations
- Values generally higher than in hourly stratification

Number of Observations for each Hour in the NNW Direction Bin (315-360°)

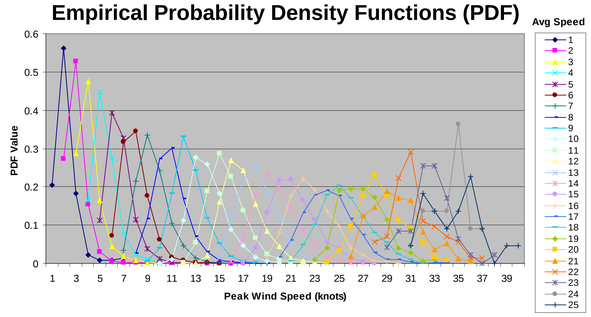


- Broad peak in NNW winds from 1200–1800 UTC (0700–1300 EST)
- Same peak seen with other towers in March
- Conclusion: Max speeds and greatest number of observations at Tower 0393/60' in March 1995-2001 were from the NNW

PROBABILITY DISTRIBUTIONS

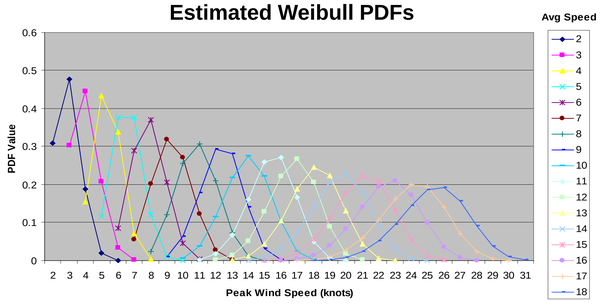
- Probabilities of meeting/exceeding specific operational wind speed thresholds were calculated to:
  -Yield a greater understanding of peak speed behavior with average speed, and
  -Produce a method for forecasters to determine probability of meeting/exceeding a specific 5-minute peak speed given a 5-minute average speed
- Empirical PDFs of peak speed with average speed created
- Tests conducted to fit a theoretical distribution to the empirical PDFs
- Images shown are the January PDFs for Tower 0397 at 60', located 1250' NW of Shuttle Launch Pad 39B

Empirical Probability Density Functions (PDF)



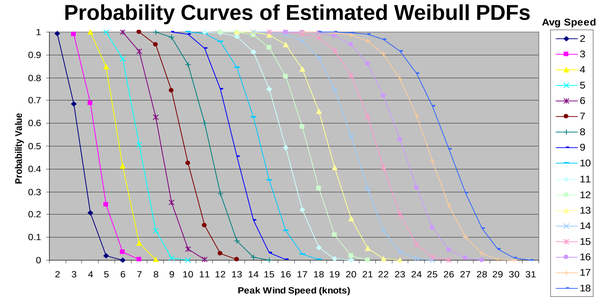
- Height/width of PDFs decrease/increase with average speed
- PDFs become irregularly-shaped beyond 18 kts average speed
- Number of average speed observations < 600 above 18 kts

Estimated Weibull PDFs



- Theoretical distribution sought in order to
  - Smooth/interpolate over variations in empirical PDFs due to undersampling
  - Estimate probabilities for peak gusts not yet observed
- Tests indicated the PDFs were Weibull distributed
- Weibull parameters for each empirical PDF estimated, then used to create the estimated PDFs above

Probability Curves of Estimated Weibull PDFs



- Curves above show probability of meeting/exceeding peak speed values based on average speed
- Not able to fit a theoretical distribution to average speeds with < approximately 600 observations (in example, 1 kt and > 18 kts)
- May be due to too few observations
- May be that different, or combination of, theoretical distributions fit the data for higher wind speeds

RESULTS AND CONCLUSIONS

Parameter Estimation for Higher Average Speeds

- Average speeds with < 600 observations in the POR were ~ > 20 kts for most sensors – but are operationally significant
- Tests were conducted to estimate Weibull parameters for the average speeds with < 600 observations
- Results indicated that the estimates may not be accurate
- *Final decision:*
  -Peak speed PDFs for average speeds with at least 600 observations could be produced with confidence, but
  -Do not estimate parameters for higher speeds since final product could not be proven reliable for operations

Final Products for Operations

- Microsoft® Excel Pivot Charts of
  -Climatologies
  -Empirical peak speed PDFs for ALL average speeds observed at sensor
  -Estimated Weibull peak speed PDFs for average speeds with > 600 observations in the POR
- These products will provide forecasters with information about the past behavior of peak and average winds, and may be a helpful tool in forecasting peak winds for operations