Building a QC Database of Meteorological Data from NASA KSC and the United States Air Force's Eastern Range

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Abstract

The National Aeronautics and Space Administration's (NASA) Marshall Space Flight Center (MSFC) Natural Environments Branch (EV44) provides atmospheric databases and analysis in support of space vehicle design and day-of-launch operations for NASA and commercial launch vehicle programs launching from the NASA Kennedy Space Center (KSC), co-located on the United States Air Force's Eastern Range (ER) at the Cape Canaveral Air Force Station. The ER complex is one of the most heavily instrumented sites in the United States with over 31 towers measuring various atmospheric parameters on a continuous basis. An inherent challenge with large datasets consists of ensuring erroneous data are removed from databases, and thus excluded from launch vehicle design analyses. EV44 has put forth great effort in developing quality control (QC) procedures for individual meteorological instruments, however no standard QC procedures for all databases currently exists resulting in QC databases that have inconsistencies in variables, development methodologies, and periods of record. The goal of this activity is to use the previous efforts to develop a standardized set of QC procedures from which to build meteorological databases from KSC and the ER, while maintaining open communication with end users from the launch community to develop ways to improve, adapt and grow the QC database. Details of the QC procedures will be described. As the rate of launches increases with additional launch vehicle programs, it is becoming more important that weather databases are continually updated and checked for data quality before use in launch vehicle design and certification analyses.

Current and Future Work

- The efforts outlined here are still a work in progress. The QC checks for wind towers are written. The remaining QC checks are based upon the previously developed databases by EV44.
- These checks will flag data, allowing analysts to search for specific flagged sets of data.
- These efforts will be revisited as new instrumentation is introduced at KSC/ER.
- These efforts will need to be modified as the format of the data may be altered

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Wind Towers

- Data from 31 different towers at KSC and the ER are archived at MSFC.
- Several towers are associated with launch complexes (LC) such as Tower 397 at LC39-B (SLS), Tower 40 at LC40 (Falcon 9), and Tower 41 at LC41 (Atlas V).
- The towers vary in height and meteorological measurement capabilities, but almost all towers measure wind speed, wind direction, temperature, and relative humidity at various heights. From these values dew point, mean winds, and peak winds are derived.

Left: The three wind towers at LC39-B

Wind Towers QC [4]

- Check that derived T_d has supporting measured T and RH values.
- Calculate T_d if T and RH are both provided, but T_d isn't available.

$$T_d = 243.04 * \frac{\ln\left(\frac{RH}{100}\right) + \left(\frac{17.625 + T}{243.04 + T}\right)}{17.625 - \ln\frac{RH}{100} - \frac{17.625 * T}{243.04 + T}}$$

- Realistic value check for T, T_d, RH, WS_{mean}, WD_{mean}, WS_{peak}, WD_{peak}.
- Check for instances where dew point was greater than temperature.
- Check for instances where $WS_{mean} > WS_{peak}$
- Check for instances where the difference between a value and the surrounding hourly mean exceed a threshold.
- Check for values that exceed daily variability thresholds.
- Light wind check:

$$(WS_{mean} == WS_{peak}) \geq 1.0\ m/s$$

- Check vector difference for mean and peak winds:

$$\Delta u_i = {}^1\!/_2\,(u_{i-1} + u_{i+1}) - u_i$$
$$\Delta v_i = {}^1\!/_2\,(v_{i-1} + v_{i+1}) - v_i$$
$$\Delta V_i = [(\Delta u_i)^2 + (\Delta v_i)^2]^{\frac{1}{2}}$$

- Checks against data from surrounding vertical sensors:

$$|T_{adjacent} - T| > Tower\ defined\ threshold$$
$$|\Delta V_{mean\ adjacent} - \Delta V_{mean}| > 3.0\ m/s$$
$$|\Delta V_{peak\ adjacent} - \Delta V_{peak}| > 3.0\ m/s$$
$$45^o < |WD_{mean\ adjacent} - WD_{mean}| < 315^o$$

Missing wind report from adjacent sensor

- Checks against multiple instruments at a given height:
  - Data reporting a constant value for greater than 30 minutes.
  - Differences of a given parameter at the same height that exceeded daily climatological thresholds.
  - For the three towers at LC39-B, a horizontal check comparing each value to the other two values at a given height is performed to flag data where:

|ΔT|, |ΔTd| < 4.0 ºC
|ΔRH| < 10 %
|ΔMean Wind Speed| < 5.0 m/s

Balloons

- Two types of Automated Meteorological Profiling System (AMPS) flight elements are used at the ER; low resolution flight elements (LRFE) and high resolution flight elements (HRFE).

Left: LRFE balloon

Right: HRFE balloon

Balloons QC [3]

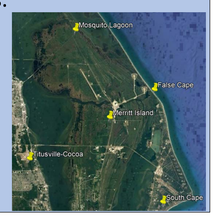
- Maximum height of at least 10 km.
- Realistic value check for T, Td, RH, WS, WD, P, D, I/R, V/S, VPS, PW, and the rise rate.
- Values that exceed the six σ values above or below the annual mean.
- Check for instances where data goes to zero above surface level.
- Check that the absolute value of the lapse rate does not exceed 150º C/km.
- Check that pressure decreases with altitude.
- Calculate density if not provided but other thermodynamic values are available.
- At least 50% of the profile is available.
- All altitudes are in ascending order.
- Check for gaps larger than 5 km.

915 MHz Doppler Radar Wind Profiler

- Five 915-MHz Doppler Radar Wind Profilers (DRWP) report wind speed and wind direction from 130 to 6,100 meters.
- Profiles are generated every 15 minutes and contain 60 range gates spaced by approximately 100 meters.

Left: South Cape 915 MHz DRWP

Right: Map of 915 MHz DRWP



915 MHz Doppler Radar Wind Profiler QC [2]

- Vertical beam contains an adequate number of consensus records.
- Vertical beam SNR is greater than -20 dB.
- Consensus averaging time period is at least six minutes for all beams.
- Consensus records do not exceed the number of required consensus records.
- Oblique beams SNR are greater than -20 dB.
- Oblique beam radial velocity does not exceed the Nyquist velocity.
- Wind direction is within a range of 0 to 360 degrees.
- Vertical wind velocity does not exceed 10 m/s.
- Shear values exceed 0.1 s^{-1}.
- Check if at least 50% of the data up to 3 km are available.

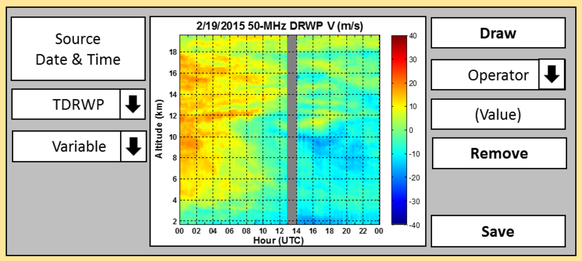
Tropospheric Doppler Radar Wind Profiler

- The KSC Tropospheric Doppler Radar Wind Profiler (TDRWP) measures wind speed and wind direction from 1,795 – 19,430 meters. The TDRWP is located near the Space Shuttle Landing facility.
- The TDRWP uses a four beam configuration and operates at 48 MHz. Profiles are generated every 5 minutes, and each profile contains 119 range gates spaced by approximately 150 meters.
- In addition to wind speed and direction, the data file contains signal power, spectral width, number of first guess propagations, and quality control flags at each range gate.

TDRWP at KSC

Tropospheric Doppler Radar Wind Profiler QC [1] [2]

- Check for QC flag in file. Flag for failing SNR, Shear, and First Guess Propagations.
- Convection check based on vertical velocity and spectral width.
- Vertical wind speeds exceeding 2 m/s.
- Median value of surrounding values that exceed thresholds.
- Visual QC through GUI.



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