High temporal resolution tropospheric wind profile observations at NASA Kennedy Space Center during Hurricane Irma

The NASA Kennedy Space Center (KSC) operates a 48-MHz Tropospheric/Stratospheric Doppler Radar Wind Profiler (TDRWP) on a continual basis generating wind profiles between 2-19 km in the support of space launch vehicle operations. A benefit of the continual operability of the system is the ability to provide unique observations of severe weather events such as hurricanes. Over the past two Atlantic Hurricane seasons the TDRWP has made high temporal resolution wind profile observations of Hurricane Irma in 2017 and Hurricane Matthew in 2016. Hurricane Irma was responsible for power outages to approximately 2.3 million people in Florida’s population during its movement over the state (Stein, 2017). An overview of the TDRWP system and the detailed observations during Hurricane Irma and Matthew are presented below.

KSC TDRWP

- Multi-Beam, Multi-Mode capability (McLaughlin, 2017)
- Transmit Frequency: 48.0 MHz
- Transmit Power: 250 kW
- Closest distance to KSC was 43.9 km (23.7 nmi) at 1150 UTC on 10 Sept 2017
- Altitude Range: 1.8-19.4 km
- Altitude Intervals: 150 m
- Profile Cycle Time: 5 min
- Profile Field: 640 Yagi elements over 5 acres
- Signal Power (dBs) S1 (dBs) Signal power (average of E-W pair of beams), S2 (dBs) Signal power (average of N-S pair of beams), N1 (dBs) Noise power (average of all 4 oblique beams), N2 (dBs) Noise power (average of N-S pair of beams), N3 (dBs) Noise level (average of all 4 oblique beams), WID1 (m/s) Spectral width (average of E-W pair of beams), WID2 (m/s) Spectral width (average of N-S pair of beams), WID3 (m/s) Spectral width (average of all 4 oblique beams), G1 First Guess Propagation (max value for the E-W pair of beams), G2 First Guess Propagation (max value for the N-S pair of beams), Quality Control Flag
- Altitude (km)
- Wind Direction [Deg]
- Time (UTC)
- Transmit Beam

Hurricane Irma & Matthew

Hurricane Irma

- 30 Aug-12 Sept 2017
- 2nd landfall near Marco Island, FL at 0321 UTC on 10 September as a Saffir-Simpson Scale Category 3 hurricane
- Closest distance to KSC was 161.3 km (87.1 nmi) at 0540 UTC on 11 Sept 2017 (Huddleston, 2017)
- Maximum 5-min average 10-m derived winds at KSC were 27.3 m/s at 0210 UTC on 11 Sept 2017 (Huddleston, 2017)

Hurricane Matthew

- 28 Sept-9 Oct 2016
- Tracked parallel to FL coast over 24-hr period from 2100 UTC on 6 Oct 2016 to 2100 UTC on 7 Oct 2016 as a Saffir-Simpson Scale Category 3 hurricane
- Closest distance to KSC was 43.9 km (23.7 nmi) at 1150 UTC on 7 Oct 2016 (Huddleston, 2017)
- Maximum 5-min average 10-m derived winds at KSC were 23.9 m/s at 1135 UTC on 7 Oct 2016 (Huddleston, 2017)

KSC Spaceport Weather Archive

- Public Facing Website (https://kscwxarchive.ksc.nasa.gov/)
- TDRWP data, as well as other meteorological data from KSC and Cape Canaveral Air Force Station (CCAFS) available
- Default TDRWP fields: UTC date, UTC time, Altitude (m), Wind Direction (degrees), Wind Speed (kts), and Wind Shear (sec)
- Additional TDRWP fields: WW (m/s, vertical velocity, positive up), S1 (dBs) Signal power (average of E-W pair of beams), S2 (dBs) Signal power (average of N-S pair of beams), S3 (dBs) Signal power (average of all 4 oblique beams), N1 (dBs) Noise level (average of E-W pair of beams), N2 (dBs) Noise level (average of N-S pair of beams), N3 (dBs) Noise level (average of all 4 oblique beams), WID1 (m/s) Spectral width (average of E-W pair of beams), WID2 (m/s) Spectral width (average of N-S pair of beams), WID3 (m/s) Spectral width (average of all 4 oblique beams), G1 First Guess Propagation (max value for the E-W pair of beams), G2 First Guess Propagation (max value for the N-S pair of beams), Quality Control Flag

References


Figure 1. Aerial view of KSC TDRWP. System electronics are housed in trailer.

Figure 2. Four beam pointing azimuths with a “big red” scan strategy transmitted by the TDRWP.

Figure 3. Four beam pointing strategy over altitude range coverage by TDRWP. System capable of steering in any direction but does not transmit vertical beam (gray) in current scan configuration.

Figure 4. Surface tracks of Hurricanes Irma (purple) and Matthew (blue) plotting to the KSC TDRWP site (yellow star).

Figure 5. Hurricane Irma TDRWP Observations

- The vertical extent of winds associated with Hurricane Irma over the period were observed up to 12 km
- The onset of easterly winds (U component) over KSC in the mid-troposphere began early on 10 September and gradually increased to the maximum of ~45-50 m/s on the 11th around 9-2 UTC in the layer from 2-4 km
- As the system tracked northward, the southerly (V component) peaked near 40 m/s below 8 km on the 11th from roughly 0-5 UTC
- Vertical velocity magnitudes (W component) exceeded +/- 3 m/s
- Expansive storm footprint associated with duration of vertical velocity variations/structure over period
- Increased turbulence (spectral width) in mid-troposphere from 18 UTC 10 Sept until 4 UTC 11 Sept correlated with increased signal power return

Figure 6. Hurricane Matthew TDRWP Observations

- Wind features associated with the storm reached about 14 km altitude as storm approached
- Easterly winds near 35 m/s around 6-10 UTC below 4 km, and quickly shifted to westerly winds, which dominated after eyewall passed the site. The westerly winds reached 30-35 m/s
- Elevated vertical velocities, resulting from deep convection near eyewall, from 10-14 UTC between 10-14 km correlated well to increased spectral width and signal power return (Read, 2017). Both quantities represent the average value from all four beams.
- Wind shift at ~12 UTC as eye moved north of KSC had decreased turbulence (low spectral width) and little horizontal shear (shear) from 2-8 km

Figure 7. Example of the results of query after entering desired data, time span and applying filters.