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

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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 of Florida's population during its movement over the state (Stein, 2017). An overview of the TDRWP system configuration, brief summary of Hurricanes Irma and Matthew storm track in proximity to KSC, characteristics of the tropospheric wind observations from the TDRWP during both events, and discussion of the dissemination of TDRWP data during the event will be presented.

KSC TDRWP

- Multi-Beam, Multi-Mode capability (McLaughlin, 2017)
- Transmit Frequency: 48.0 MHz
- Pulse Length: 2 micro sec
- Antenna field: 640 Yagi elements over 5 acres
- Peak Power: 250 kW
- Altitude Range: 1.8-19.4 km
- Altitude Intervals: 150 m
- Profile Cycle Time: 5 min

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

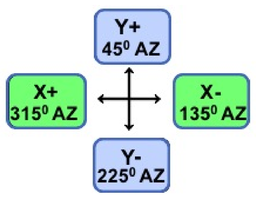

Figure 2. Four beam pointing azimuths with a 'lug nut' scan strategy transmitted by the TDRWP

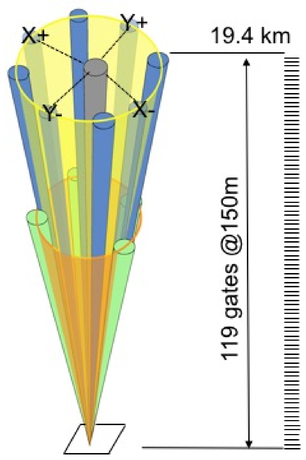

Figure 3. Four beam pointing strategy over altitude range coverage by TDRWP. System capable of steering in any direction but does not transmit vertical beam (gray) in current scan configuration.

Hurricanes Irma & Matthew

Hurricane Irma

- 30 Aug-12 Sept 2017
- 2nd landfall near Marco Island, FL at 1935 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)

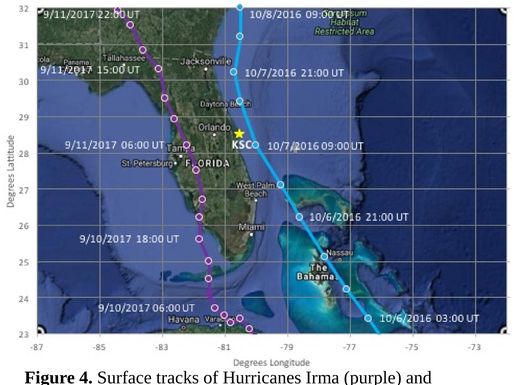

Figure 4. Surface tracks of Hurricanes Irma (purple) and Matthew (Blue) in proximity to the KSC TDRWP site (yellow star).

Hurricane Irma TDRWP Observations

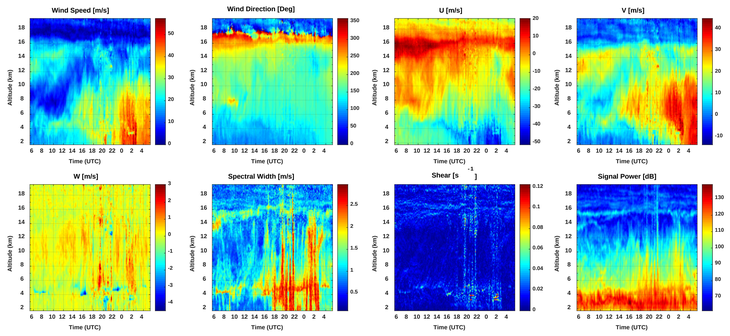

Figure 5. TDRWP output from 0524 UTC on 10 Sept 2017 to 0524 UTC on 11 Sept 2017. TDRWP experienced power outage at ~0530 UTC on 11 Sept 2017.

- The vertical extent of winds associated with Hurricane Irma over this 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 0-2 UTC in the layer from 2-4 km
- As the system tracked northward, the southerly wind (V component) peaked to 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

Hurricane Matthew TDRWP Observations

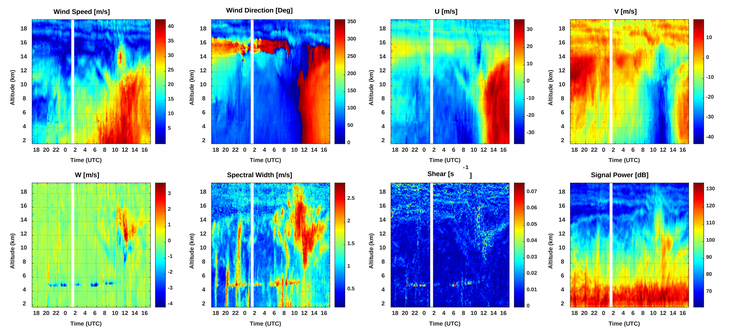

Figure 6. TDRWP output from 1659 UTC on 6 October 2016 to 1659 UTC on 7 October 2016. Vertical white column at ~0130 UTC indication of missing or removed data. TDRWP experienced power outage at 1700 UTC on 7 October 2016 .

- 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 (Reed, 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

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), and Quality Control Flag

Figure 7. TDRWP description page on the Spaceport Weather Archive site.

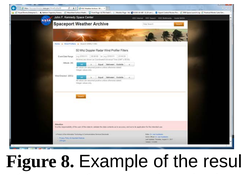

Figure 8. Example of the results of query after entering desired date, time span and applying filters.

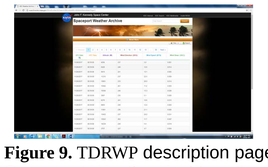

Figure 9. TDRWP description page on the Spaceport Weather Archive site.

References

- Huddleston, L., Smith K., Winters, K. and Sharp, D. (2017). *Hurricane Irma and Comparison with Hurricanes Impacting the NASA Kennedy Space Center*. NASA/USAF/NOAA Internal report: unpublished.
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- Reed, K., T. Wilfong, L. Huddleston, and T. Brauer, 2017: A Unique Look in Hurricane Matthew: High-Resolution Wind and Precipitation Observations using the NASA Tropospheric Doppler Radar Wind Profiler and other Mulit-Frequency Weather Surveillance Radars. 38th Conf on Radar Meteorology. Chicago, IL, Amer. Meteor Soc, Boston MA.
- Stein, P, "Irma weakens to a tropical storm after knocking out power to millions in Florida." *The Washington Post* 11 September 2017. Web. 15 Oct 2017.

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