

# The Weather Analysis Display (WAND) Tool: Developing a Meteorological Data Display Tool for Situational Awareness during Day of Launch of Space Launch Vehicles Using Python

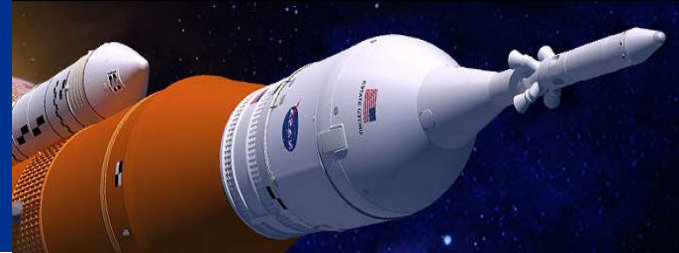
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Phoenix, AZ*

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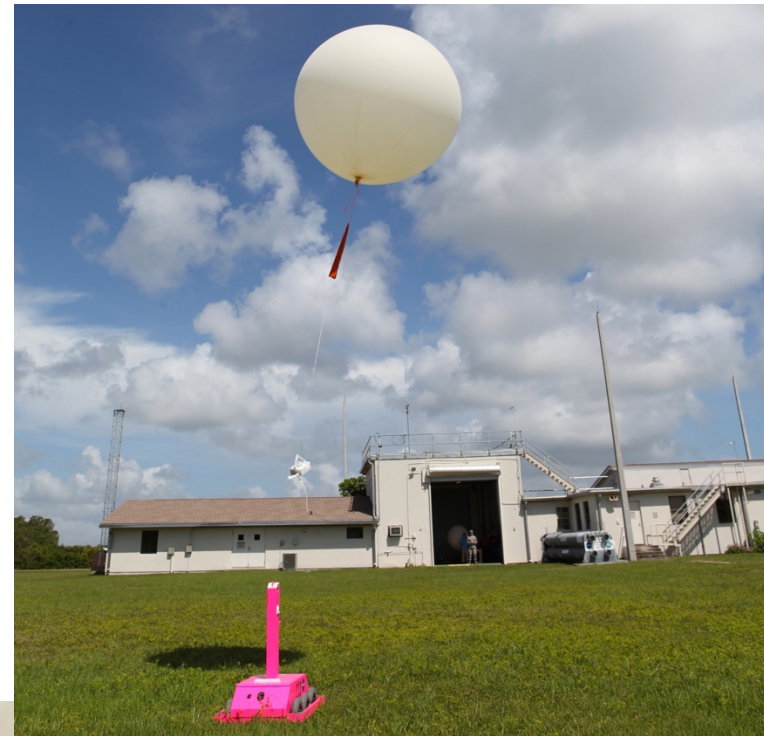


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# Background

- Atmospheric environments are an important element in day-of-launch (DOL) operations of space launch vehicles.
- NASA Marshall Space Flight Center Natural Environments Branch provides multiple functions supporting DOL operations.
  - Generates a vertically complete profiles for trajectory and load calculations using the Profile Envision and Splicing Tool (Orcutt et al.; 2017)
  - Monitors atmospheric conditions for situational awareness

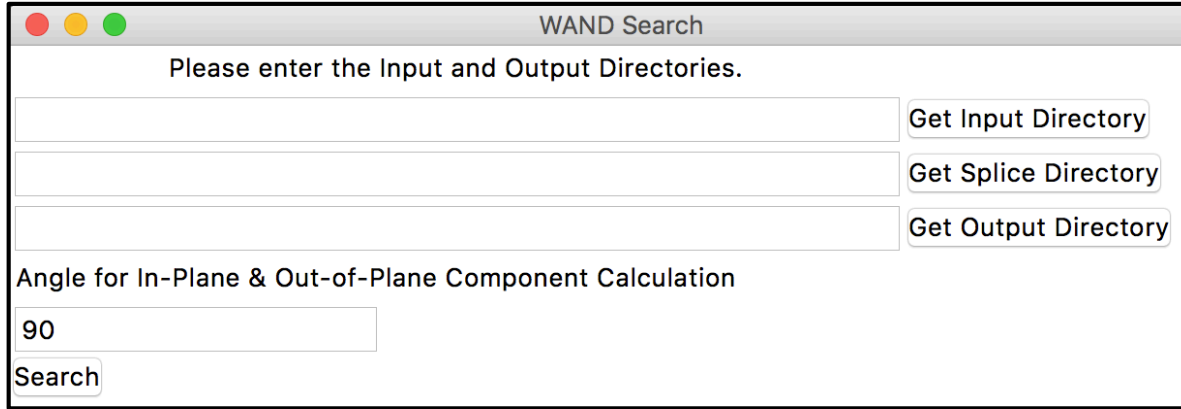


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# Weather Analysis Display (WAND) Introduction

- The USAF's Eastern Range contains of a highly dense network of weather instrumentation.
  - A network of weather towers
  - Weather balloons
  - A network of Doppler Radar Wind Profiling (DRWP) systems
    - Tropospheric DRWP at ~48-MHz
    - Boundary Layer Profilers at 915-MHz
- WAND was developed by MSFC NE to provide MSFC NE DOL operators situational awareness capability by presenting data in a multitude of ways.
  - Observations
  - Climatology
- Designed to operate within the “highly secured” environment at the Huntsville Operations Support Center.
  - WAND was coded using Python 3
  - Has few dependencies
    - Numpy – array handling
    - Scipy – mathematical functions
    - Matplotlib – data visualization
    - Tkinter – create and execute the Graphical User Interface (GUI)

# WAND Design

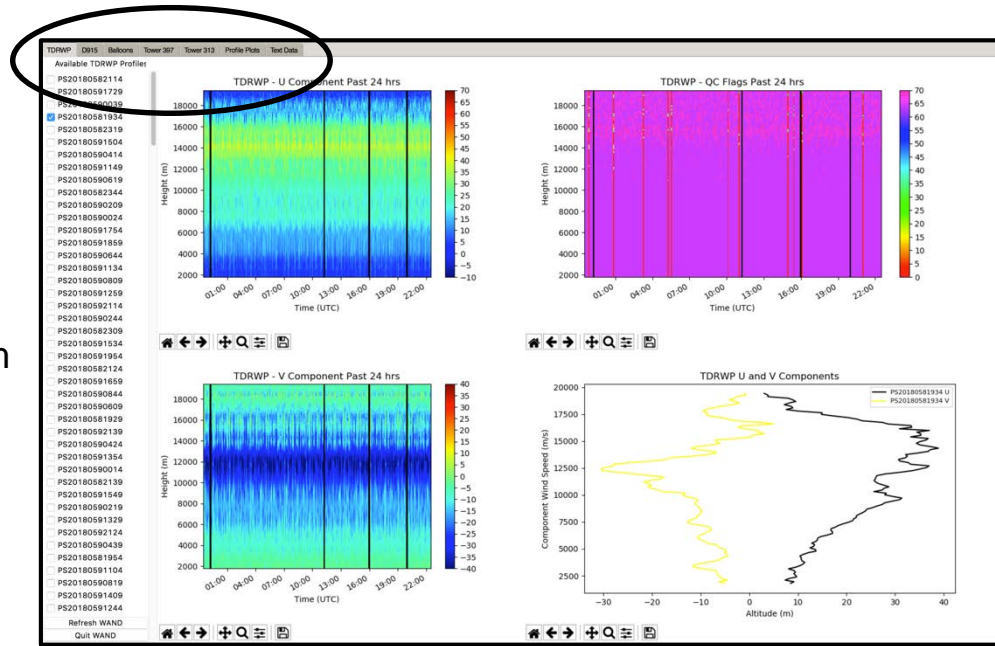


The screenshot shows a window titled "WAND Search" with a standard macOS-style title bar (red, yellow, green buttons). The main content area contains the text "Please enter the Input and Output Directories." followed by three text input fields. To the right of each field is a button: "Get Input Directory", "Get Splice Directory", and "Get Output Directory". Below these fields is the text "Angle for In-Plane & Out-of-Plane Component Calculation" followed by a text input field containing the value "90". At the bottom left of the window is a "Search" button.

- This window is the initial window that appears when WAND is started.
- Allows the operator to select the desired input and output directories as well as set the desired angle for in-plane and out-of-plane wind component calculations.
- Clicking the “Search” button once all directories are supplied will get WAND to search for any data from the past 24 hours.

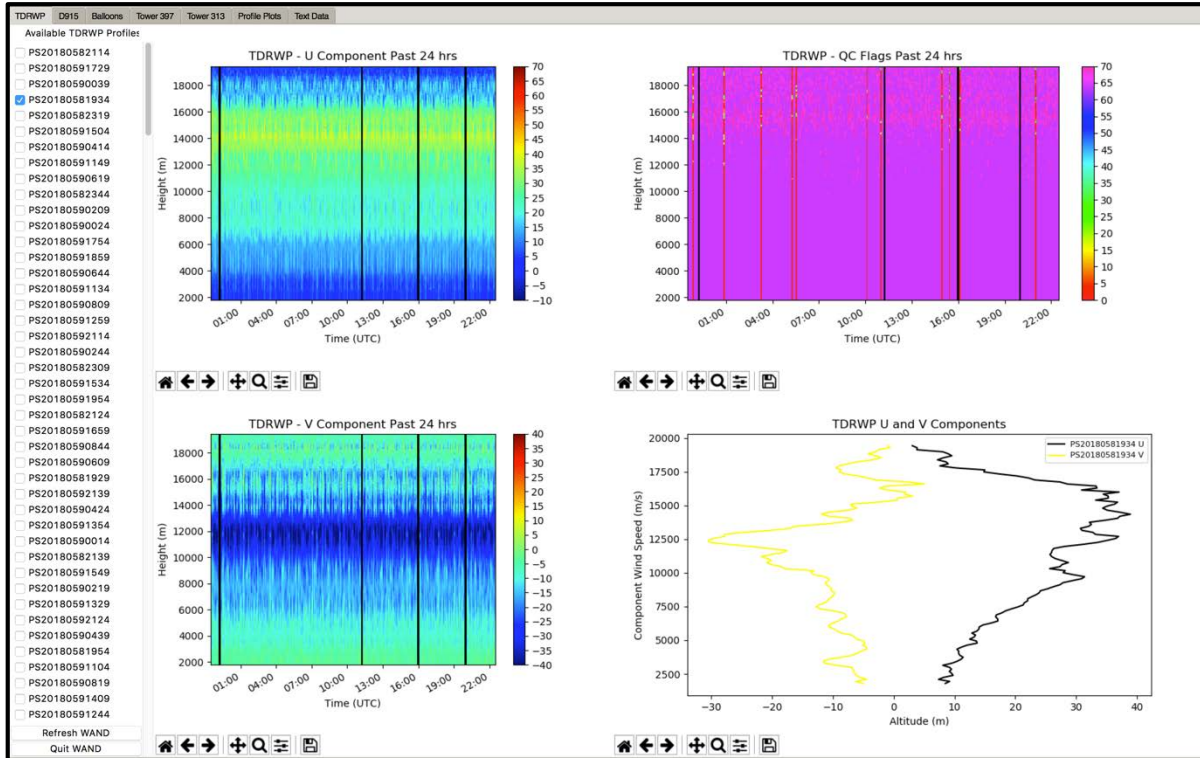
# WAND Design

- WAND uses tabs to control which system is being displayed.
  - Tropospheric DRWP (TDRWP)
  - 915-MHz DRWP (D915)
  - Balloons
  - Tower 397 (located at the launch pad)
  - Tower 313 (located approximately 5 km from the launch pad)
  - Profile Plots
  - Text Data



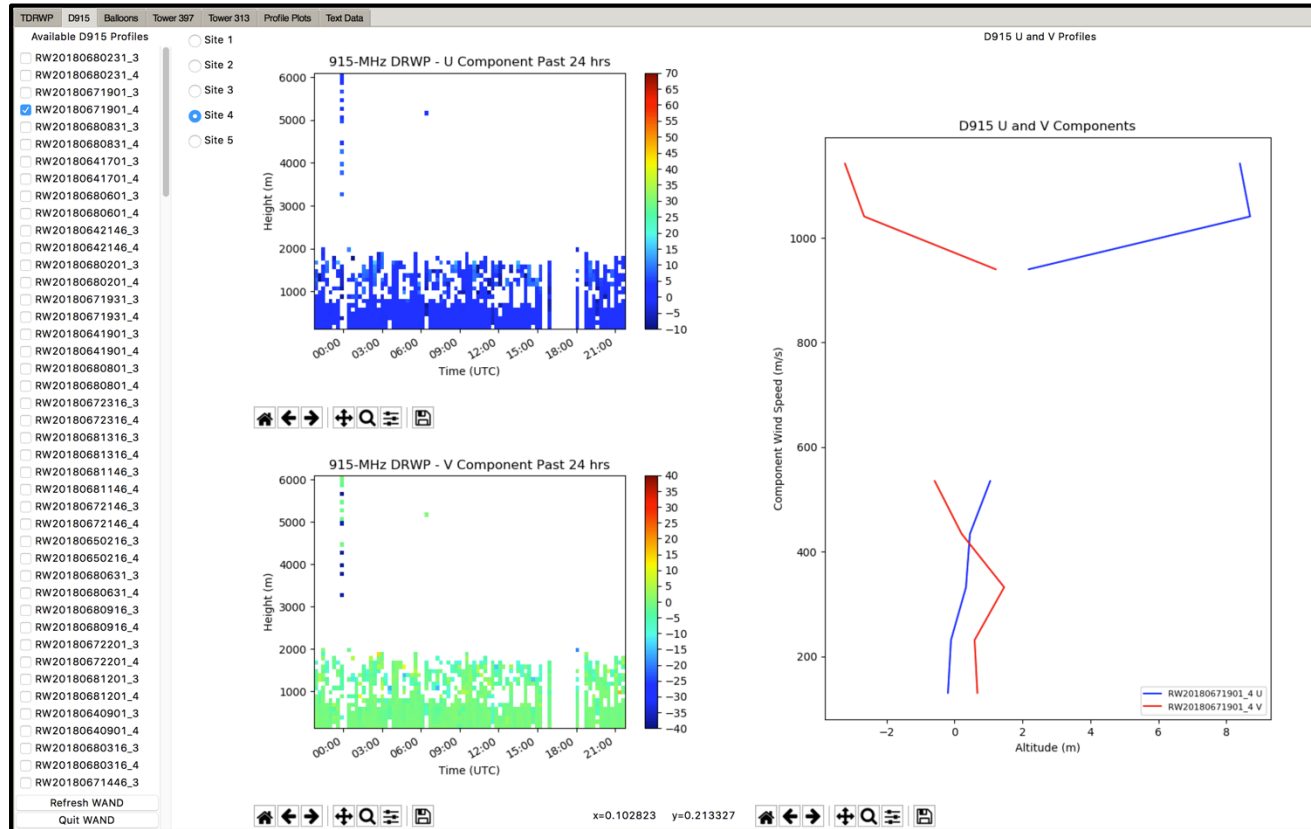
# WAND Design

- WAND opens to the TDRWP tab.
- The TDRWP tab contains time-height cross-sections of the U and V wind components, the TDRWP's QC flags, and profile plots of U and V.



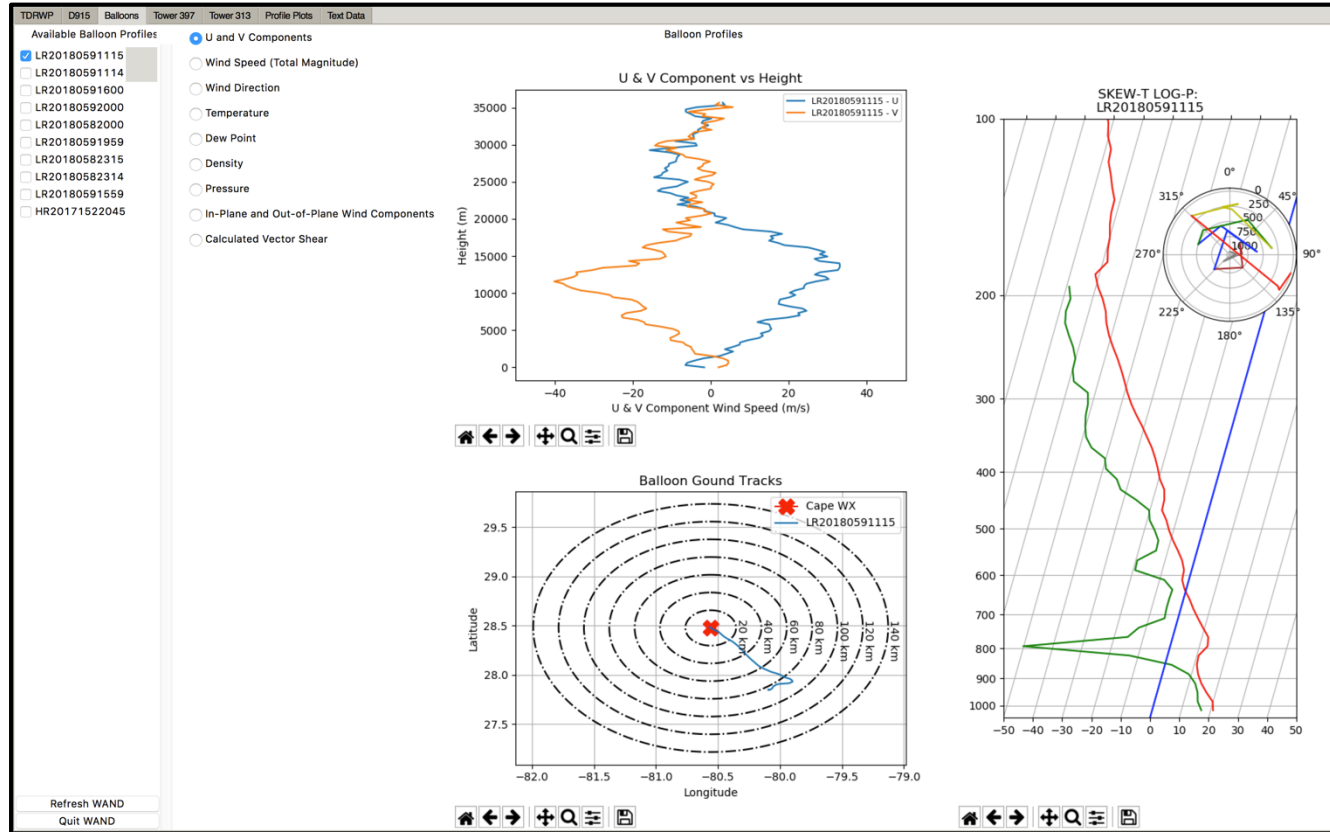
# WAND Design

- The D915 tab is nearly identical to the TDRWP tab, but does not have a QC flag time-height cross-section plot.



# WAND Design

- The Balloons tab displays the vertical profile of all variables reported by the balloon systems, ground tracks of the balloons, and Skew-T Log-P.





# WAND Design

- The Tower 397 tab displays a time series of any variable that is measured by the towers, a table of the current conditions from all sensors, and a table of time series of the past 10 minutes of data from the up-wind tower (Orcutt et al., 2016).

TDRWP D915 Balloons Tower 397 Tower 313 Profile Plots Text Data

Mean U Component  
 Mean V Component  
 Mean Wind Speed  
 Mean Wind Direction  
 Peak U Component  
 Peak V Component  
 Peak Wind Speed  
 Peak Wind Direction  
 Temperature  
 Dew Point  
 Relative Humidity  
 Pressure  
 Mean In-Plane Wind Component  
 Mean Out-of-Plane Wind Component  
 Peak In-Plane Wind Component  
 Peak Out-of-Plane Wind Component

Select the LPS Tower

Tower 1  
 Tower 2  
 Tower 3  
 Up-Wind Tower

Pad 39-B LPS Towers

Tower 397 Mean Wind Speed and Direction 059/2018 22:31

	132 Ft	257 Ft	382 Ft	457 Ft
T1	6.69/142.0	6.69/143.0	7.72/148.0	7.72/141.0
T2	7.72/137.0	7.72/134.0	8.23/134.0	8.23/135.0
T3	4.12/148.0	3.09/133.0	2.57/131.0	1.54/100.0
UWT	4.12/148.0	3.09/133.0	2.57/131.0	1.54/100.0

Wind Speed (m/s) / Wind Direction (Degrees)

Tower 397 Up-Wind Tower Mean Wind Speed and Direction

	22:21	22:22	22:23	22:24	22:25	22:26	22:27	22:28	22:29	22:30	22:31
132 Ft	3.09/146.0	2.57/133.0	3.09/138.0	3.09/146.0	nan/nan	3.09/145.0	3.09/146.0	2.57/139.0	3.6/129.0	nan/nan	4.12/148.0
257 Ft	2.57/127.0	2.57/132.0	3.09/136.0	3.09/145.0	nan/nan	3.6/140.0	3.09/144.0	2.57/135.0	2.57/127.0	nan/nan	3.09/133.0
382 Ft	3.09/128.0	3.6/128.0	3.09/137.0	2.57/139.0	nan/nan	2.57/142.0	2.57/134.0	3.09/129.0	3.09/131.0	nan/nan	2.57/131.0
457 Ft	1.54/103.0	1.54/100.0	1.05/112.0	0.51/121.0	nan/nan	0.51/96.0	1.03/101.0	1.54/100.0	1.03/110.0	nan/nan	1.54/100.0

Wind Speed (m/s) / Wind Direction (Degrees)

Refresh WAND  
 Quit WAND

# WAND Design

- The Tower 313 tab is identical in layout to the Tower 397 tab.

TDRWP D915 Balloons Tower 397 Tower 313 Profile Plots Text Data

Mean U Component

Mean V Component

Mean Wind Speed

Mean Wind Direction

Peak U Component

Peak V Component

Peak Wind Speed

Peak Wind Direction

Temperature

Dew Point

Relative Humidity

Pressure

Mean In-Plane Wind Component

Mean Out-of-Plane Wind Component

Peak In-Plane Wind Component

Peak Out-of-Plane Wind Component

Select Tower 313 Sensor

NE Sensors

SW Sensors

Up-Wind Sensor

Tower 313

Tower 313 Mean Wind Speed and Direction 059/2018 22:31

	6 Ft	12 Ft	54 Ft	162 Ft	204 Ft	295 Ft	394 Ft	492 Ft
NE	nan/nan	2.37/141.0	4.63/140.0	6.17/139.0	7.2/136.0	nan/nan	7.72/144.0	7.72/140.0
SW	nan/nan	2.37/184.0	4.63/127.0	4.68/134.0	7.2/139.0	7.2/137.0	nan/nan	7.72/139.0
LWS	nan/nan	nan/nan	nan/nan	7.2/137.0	nan/nan	nan/nan	nan/nan	nan/nan

Wind Speed (m/s) / Wind Direction (Degrees)

Tower 313 Up-Wind Tower Mean Wind Speed and Direction

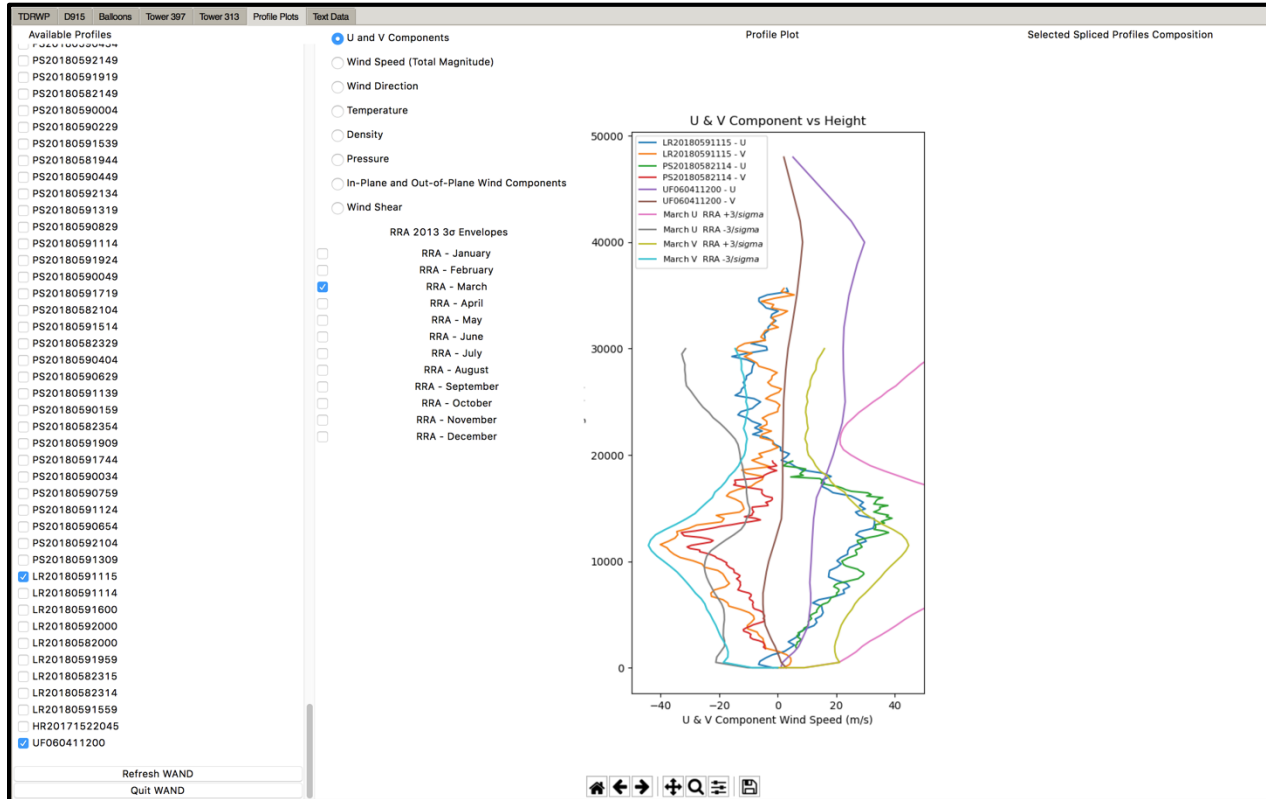
	22:21	22:22	22:23	22:24	22:25	22:26	22:27	22:28	22:29	22:30	22:31
12 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan
54 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan
162 Ft	6.69/139.0	6.17/137.0	nan/nan	nan/nan	nan/nan	7.2/136.0	7.2/136.0	6.69/136.0	nan/nan	nan/nan	7.2/137.0
204 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan
295 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan
394 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan
492 Ft	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan	nan/nan

Wind Speed (m/s) / Wind Direction (Degrees)

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# WAND Design

- The Profile Plots tab displays vertical profiles of any measurement from all of the DRWPs, balloons, Profile Envision and Splicing Tool (PRESTO) spliced profiles, upper level profiles, and statistical envelopes.



# WAND Design

- The Text Data tab displays the selected data file as text.

The screenshot shows the WAND software interface. The 'Text Data' tab is active, displaying a list of available profiles on the left and a data table on the right. The data table contains columns for ALT, DIR, SPD, SHR, WW, S1, S2, S3, N1, N2, N3, WID1, WID2, WID3, G, G, QC, GEOM, DEG, M/S, /SEC, M/S, DB, DB, DB, DB, DB, DB, M/S, M/S, M/S, 1, 2, NN.

ALT	DIR	SPD	SHR	WW	S1	S2	S3	N1	N2	N3	WID1	WID2	WID3	G	G	QC	GEOM	DEG	M/S	/SEC	M/S	DB	DB	DB	DB	DB	DB	M/S	M/S	M/S	1	2	NN
1795	303	7.7	.000	-0.09118	.9117	.0118	0	57.9	58.3	58.1	0.7	0.5	0.62	0	0	64																	
1944	308	7.9	.004	-0.05116	.2117	.1116	6	57.8	58.2	58.0	0.8	0.5	0.65	0	0	64																	
2093	306	7.6	.002	-0.11120	.6122	.4121	6	57.4	57.7	57.6	0.6	0.5	0.56	0	0	64																	
2243	305	8.1	.004	-0.09123	.8121	.9123	0	57.9	58.3	58.1	0.8	0.5	0.64	0	0	64																	
2392	307	8.3	.003	-0.06119	.6122	.6121	4	58.7	59.1	58.9	0.6	0.5	0.53	0	0	64																	
2542	310	9.9	.011	-0.08114	.2115	.8115	1	59.2	59.4	59.3	0.4	0.5	0.46	0	0	64																	
2691	317	11.6	.015	-0.15102	.8103	.5103	2	59.9	60.2	60.1	0.6	0.7	0.66	0	0	64																	
2841	323	11.7	.008	-0.14106	.3106	.2106	3	60.1	60.2	60.2	0.6	0.7	0.65	0	0	64																	
2990	325	11.4	.004	-0.13103	.7104	.7104	3	60.1	60.2	60.2	0.7	0.6	0.65	0	0	64																	
3140	322	11.6	.003	-0.11100	.5100	.4100	5	60.1	60.2	60.2	1.1	0.6	0.87	0	0	64																	
3289	325	12.2	.006	-0.01	98	.8100	0	99.4	60.0	60.1	1.0	0.8	0.88	0	0	64																	
3439	324	14.3	.014	0.01111	.6113	.2112	5	60.1	60.2	60.2	0.5	0.6	0.56	0	0	64																	
3588	323	14.7	.003	0.04114	.0115	.1114	6	60.1	60.3	60.2	0.5	0.6	0.56	0	0	64																	
3737	320	14.1	.006	-0.02110	.0108	.1109	2	60.1	60.3	60.2	0.5	0.8	0.66	0	0	64																	
3887	313	13.9	.011	-0.04112	.1110	.6111	4	60.1	60.2	60.1	0.5	0.7	0.58	0	0	64																	
4036	309	13.3	.008	-0.05109	.5109	.2109	4	60.1	60.2	60.1	0.6	0.7	0.63	0	0	64																	
4186	302	12.4	.011	-0.04107	.2108	.7108	0	60.0	60.1	60.1	0.6	0.5	0.55	0	0	64																	
4335	295	11.5	.012	-0.01110	.0108	.7109	4	60.1	60.2	60.1	0.5	0.5	0.52	0	0	64																	
4485	292	11.9	.005	-0.05109	.9109	.3109	6	60.0	60.2	60.1	0.5	0.4	0.45	0	0	64																	
4634	293	12.6	.004	-0.09106	.8105	.2106	1	60.1	60.1	60.1	0.5	0.4	0.43	0	0	64																	
4784	292	12.1	.004	-0.12111	.7109	.4110	7	60.0	60.1	60.1	0.6	0.4	0.46	0	0	64																	
4933	292	12.1	.000	-0.13110	.7111	.9111	3	60.1	60.1	60.1	0.6	0.3	0.49	0	0	64																	
5083	292	13.1	.007	-0.10102	.5103	.0102	7	60.0	60.1	60.1	0.8	0.5	0.65	0	0	64																	
5232	291	14.3	.008	-0.07106	.8106	.7106	7	60.1	60.1	60.1	0.6	0.6	0.61	0	0	64																	
5381	295	14.7	.007	-0.04108	.8109	.2109	0	60.0	60.1	60.1	0.5	0.7	0.61	0	0	64																	
5531	300	15.8	.012	-0.04107	.0106	.0106	5	60.0	60.0	60.0	0.6	0.6	0.60	0	0	64																	
5680	301	16.4	.004	-0.11104	.2100	.8102	8	60.0	60.1	60.1	0.5	0.6	0.58	0	0	64																	
5830	300	16.9	.004	-0.09	99.3	97.7	98.5	60.0	60.1	60.0	0.6	0.6	0.62	0	0	64																	
6079	290	17.7	.007	-0.10	00.7	04.0	00.1	60.1	60.1	60.1	0.6	0.6	0.63	0	0	64																	

# Summary

- MSFC NE developed a tool, WAND, using Python to provide DOL personnel with displays of the meteorological conditions at and around the launch site for situational awareness.
- WAND can display data from all systems at Kennedy Space Center and Cape Canaveral Air Force Station, as well as upper level wind forecasts and statistical envelopes.
- Forward work
  - Finish Formal Acceptance Testing

# References

Orcutt, J. M., J.C. Brenton. (2016) The Quality Control Algorithms Used in the Process of Creating the NASA Kennedy Space Center Lightning Protection System Towers Meteorological Database. Fifth Aviation, Range, and Aerospace Meteorology Special Symposium. New Orleans, LA, Amer. Meteor. Soc. P828.

Orcutt, J. M., R.E. Barbré, J.C. Brenton, R.K. Decker. (2017) The Profile Envision and Splicing Tool (PRESTO): Developing an Atmospheric Wind Analysis Tool for Space Launch Vehicles Using Python. Seventh Symposium on Advances in Modeling and Analysis Using Python. Seattle, WA, Amer. Meteor. Soc.

# Questions?

