Quality Control of Wind Data from 50-MHz Doppler Radar Wind Profiler

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Abstract

Upper-level wind profiles obtained from a 50-MHz Doppler Radar Wind Profiler (DRWP) instrument at Kennedy Space Center are incorporated in space launch vehicle design and day-of-launch operations to assess wind effects on the vehicle during ascent. Automated and manual quality control (QC) techniques are implemented to remove spurious data in the upper-level wind profiles caused from atmospheric and non-atmospheric artifacts over the 2010-2012 period of record (POR). By adding the new quality controlled profiles with older profiles from 1997-2009, a robust database will be constructed of upper-level wind characteristics. Statistical analysis will determine the maximum, minimum, and 95th percentile of the wind components from the DRWP profiles over recent POR and compare against the older database. Additionally, this study identifies specific QC flags triggered during the QC process to understand how much data is retained and removed from the profiles.

Background

- The DRWP is a vertically pointing radar which transmits radio pulses in three beams (vertical, and two 15° off zenith at azimuths of 45° and 135° East from North) to determine vertical and horizontal winds.
- Return signal is converted to a power spectra using a Fast Fourier Transform.
- Radial velocity is then obtained from Doppler Shift.
- Using triangulation, U (east-west) and V (north-south) components are calculated from the radial velocity assuming a homogeneous atmosphere.
- Wind data are reported at 111 gates in 150m increments from 2,666 to 18,166m.
- Advantages over traditionally used weather balloons:
  - Continuously produces profiles every 3-5 minutes vs. 1 hour for weather balloons.
  - Measures wind above DRWP eliminating effects of balloon drift.
- Provides an important asset for NASA to understand the effects of the wind environment on the structural integrity of launch vehicles during ascent. NASA's Space Launch System program is currently using wind data from the DRWP in vehicle trajectory design analyses.

Image 1: DRWP surrounded by a fairly flat terrain.

Methodology

Automated QC Process

- Fills data gaps if greater than six minutes exist between timestamps with the missing data flag.
- Evaluates vertical beam measurements to avoid flagging a valid wind calculation.
- Series of threshold checks include:
  - unrealistic wind, isolated data, small median test, oblique beam spectrum width (SW), meteorological shear, vertical velocity, first-guess propagation (FGP), oblique beam signal power, and convection.

Manual QC Process

- Flag contaminated data that pass automated QC check.
- Data that appears to be contaminated by convection or ground clutter are assigned own QC flag.
- Wind components from time correlated weather balloons are compared with DRWP profiles as a third-party check.

Statistical Analysis

- Calculate the total number of QC flags that occur.
- Determine the number of complete vertical profiles that exist.
- Construct maximum, minimum, and 95th percentile profiles and compare against previous QC data.

Analysis

Example Day of QC Process:

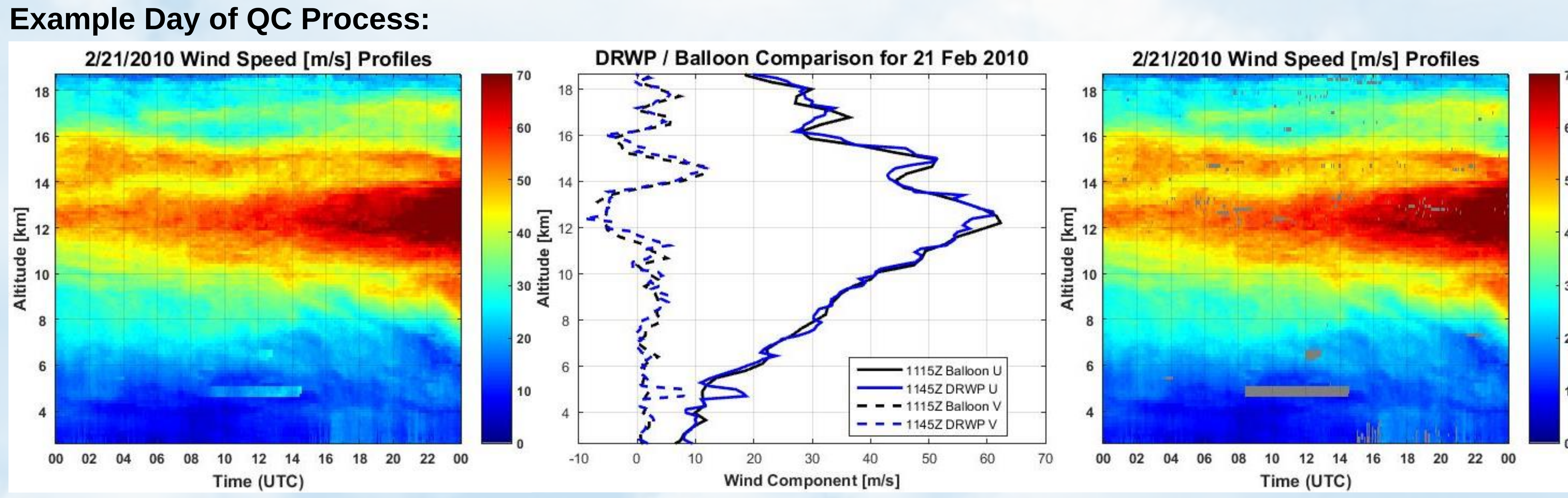

Figure 1: Example of the graphical user interface demonstrating before (left) and after (right) of the automated and manual QC process on daily profiles. The range of wind speeds (m s^{-1}) are displayed in the color bar. A third-party (middle) shows the corresponding wind components at a particular time during the analyzed day.

Effects of QC Data:

Number of Gates	No Flag	Vertical QC	Convection Flag	Missing	Unreal	SW	DRWP Shear	Vertical Speed	FGP	Met Shear	Median	Ground Clutter	No Signal	Isolated	Manual	Convection	Removed	Retained	Total
Jan	3046386	34475	114276	685314	0	0	839	0	39795	10	47	20077	9829	786	105228	231	862156	3195137	4057293
Feb	2901333	42885	246986	449550	0	0	2163	0	10555	12	37	22488	6597	24	55218	965	547609	3191204	3738813
Mar	3302175	39304	23054	522477	0	0	3883	0	6466	9	63	23490	4619	15	142223	1593	704838	3364533	4069371
Apr	2314385	31799	177378	1254189	0	0	1229	0	10753	6	275	16327	5638	27	115905	1156	1405505	2523562	3929067
May	2996030	79613	386268	479742	0	0	1113	0	5980	10	73	14988	4953	10	145299	8686	660854	3461911	4122765
Jun	2045408	81695	103700	1520922	0	7	2367	0	1227	4	191	13157	1947	4	172644	3887	1716357	2230803	3947160
Jul	2267312	92309	23650	1510155	0	0	1097	0	9768	1	125	11075	7007	46	175242	3219	1717735	2383271	4101006
Aug	2849659	157111	149053	566766	0	0	2033	0	14319	0	2022	17124	7466	206	300396	10764	921096	3155823	4076919
Sep	1747478	71319	188268	426573	0	0	2659	0	2806	3	132	11563	3356	13	142332	676	590113	2007065	2597178
Oct	1822815	21063	212986	484404	0	0	1950	0	9514	1	142	14426	5272	108	122430	968	639215	2056864	2696079
Nov	2249990	22131	91580	65601	0	0	3200	0	7391	8	117	18446	4492	60	78980	0	178295	2363701	2541996
Dec	1622551	9861	108622	961482	0	0	35	0	7451	2	28	10708	5078	17	695457	0	1680258	1741034	3421292
Tot	29165522	683565	1825821	8927175	0	7	22568	0	126025	66	3252	193869	66254	1316	2251354	32145	11624031	31674908	43298939

Table 1: Number of data affected by each QC check during each month.

Percentage of Gates	No Flag	Vertical QC	Convection Flag	Missing	Unreal	SW	DRWP Shear	Vertical Speed	FGP	Met Shear	Median	Ground Clutter	No Signal	Isolated	Manual	Convection	Removed	Retained
Jan	75.1	0.8	2.8	16.9	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.2	0.0	2.6	0.0	21.2	78.8
Feb	77.6	1.1	6.6	12.0	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.6	0.2	0.0	1.5	0.0	14.6	85.4
Mar	81.1	1.0	0.6	12.8	0.0	0.0	0.1	0.0	0.2	0.0	0.0	0.6	0.1	0.0	3.5	0.0	17.3	82.7
Apr	58.9	0.8	4.5	31.9	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.1	0.0	2.9	0.0	35.8	64.2
May	72.7	1.9	9.4	11.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.1	0.0	3.5	0.2	16.0	84.0
Jun	51.8	2.1	2.6	38.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	4.4	0.1	43.5	56.5
Jul	55.3	2.3	0.6	36.8	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.2	0.0	4.3	0.1	41.9	58.1
Aug	69.9	3.9	3.7	13.9	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4	0.2	0.0	7.4	0.3	22.6	77.4
Sep	67.3	2.7	7.2	16.4	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.4	0.1	0.0	5.5	0.0	22.7	77.3
Oct	67.6	0.8	7.9	18.0	0.0	0.0	0.1	0.0	0.4	0.0	0.0	0.5	0.2	0.0	4.5	0.0	23.7	76.3
Nov	88.5	0.9	3.6	2.6	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.7	0.2	0.0	3.1	0.0	7.0	93.0
Dec	47.4	0.3	3.2	28.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.0	20.3	0.0	49.1	50.9
Tot	67.4	1.6	4.2	20.6	0.0	0.0	0.1	0.0	0.3	0.0	0.0	0.4	0.2	0.0	5.2	0.1	26.8	73.2

Table 2: Percentage of data affected by each QC check during each month.

Comparison of Complete Profiles:

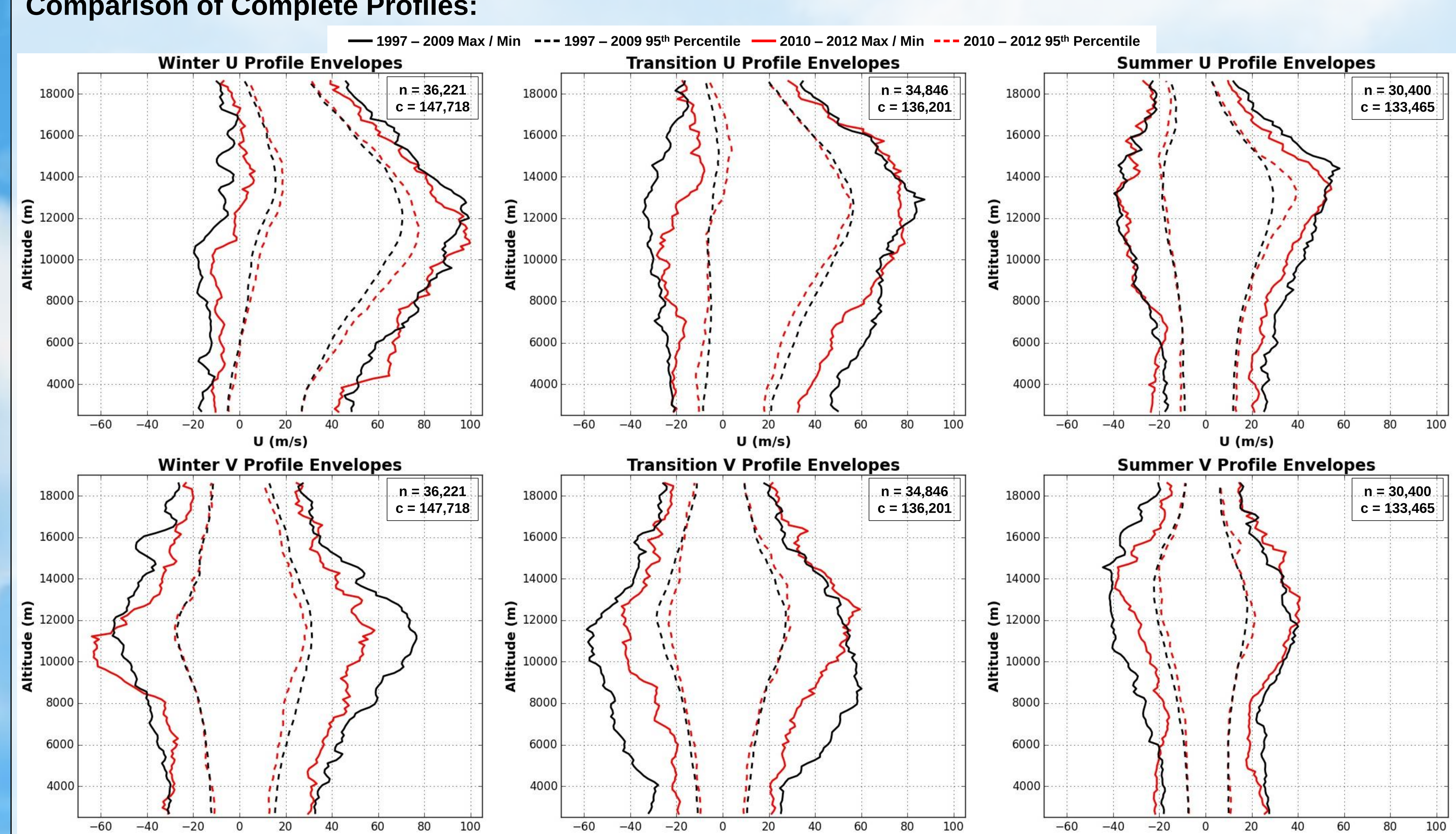

Figure 2: Comparisons of U and V profiles from the DRWP. Wind components (m s^{-1}) are along the x-axis and altitude (m) is along the y-axis. 1997 – 2009 Max/Min (solid black lines) and 95th percentile (dashed black lines), 2010 – 2012 Max/Min (solid red lines) and 95th percentile (dashed red lines), number of new complete profiles per season (n), and number of current complete profiles per season (c) are shown.

Results

QC Data

- Interference signals from sidelobes (non-meteorological artifacts, radio-frequency interference, ground clutter) are removed from daily profiles. Figure 1 shows a sidelobe feature being removed from the daily profile at 5 km between the times of 8 to 14 UTC.
- The January 2010 to August 2012 data set contained 43.3 million gates with a given month containing 2.5 – 4.1 million gates.
- A total of 136 days existed that contained no data.
- The missing data flag was tallied most accounting for 20.6% of the total gates.
- The new QCed database retained 73.2% of the possible wind observations.

Complete Profiles

- A total of 101,467 complete profiles exist in the new QCed database. The Winter season contains the most complete profiles (36,221), while the Summer season contained the least complete profiles (30,400).
- An average of 3,171 profiles exist per month, ranging from 80 profiles (June 2010) to 5,072 profiles (May 2012).
- By adding the new QCed data to the current database, the number of complete profiles increased by 24.3%.

Weather Patterns

- Larger values of easterly winds are noticeable during the Transition and Summer seasons due to sea breezes developing off the Florida coast.
- Slightly larger northerly winds can be observed during the Summer season as the Azores High intensifies over the Atlantic Ocean.
- Westerly winds are more predominant during the Winter season as the jet stream develops trough patterns in the lower part of the United States.

Conclusions

- Third-party comparisons also display sidelobe characteristics which can be used to assist with the manual QC process.
- Manual QC is essential to ensure that only valid profiles are used for the database.
- A larger sample size of wind measurements better represents the atmosphere that could be experienced by launch vehicles.
- Adding new maximum and minimum wind observations assists on the development of structural integrity that the launch vehicle may experience during ascent.
- New database will be implemented in design assessments of the Space Launch System and future launch vehicle designs.

Future Work

- Continue the QC process and recalculate the number of gates and complete profiles with the remaining unfinished QC data of September 2012 until the end of the POR.
- Determine the number of pairs for each month for multiple temporal separation that correspond with the profiles.

Acknowledgements

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