Status of the KSC 50-MHz Doppler Radar Wind Profiler Operational Acceptance Test

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Outline

- Background
- OAT Criteria
- Data
- Methodology
- Preliminary Results
- Summary and Forward Work
Background

• The new 50-MHz Doppler Radar Wind Profiler (DRWP) shall undergo full certification testing prior to NASA acceptance.
  – Evaluates DRWP performance over multiple seasons.
  – Time-consuming.
• Desire exists amongst the launch vehicle community to use the DRWP before certification is complete.
• Operational Acceptance Test (OAT)
  – Goal: Evaluate the functional performance of the new DRWP so end users can use data during mission operations.
  – Short-term test to verify that the new DRWP’s data quality compares well with the previous DRWP.
• Charts contain the data and methodology that MSFC Natural Environments (NE) is currently using for the OAT.
OAT Criteria

OAT Test Plan Specifications

<table>
<thead>
<tr>
<th>Required Data</th>
<th>Wind Speed and Direction, Altitude, Shear, Radial Velocities, Signal Power, Noise Power, Spectral Width.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Interval</td>
<td>5 min</td>
</tr>
<tr>
<td>Vertical Data Interval</td>
<td>150 m</td>
</tr>
<tr>
<td>Altitude</td>
<td>2-18.6 km</td>
</tr>
<tr>
<td>Wind Accuracy</td>
<td>1.5 m/s RMS component difference</td>
</tr>
<tr>
<td>Effective Vertical Resolution</td>
<td>500 m</td>
</tr>
</tbody>
</table>

- OAT Test Plan specifies expectations of different parameters.
- Root-mean-square (RMS) and effective vertical resolution (EVR) values are baselines for DRWP examination based on results from previous tests (Pinter et al. 2006, Merceret 1999).
- Specifies that MSFC NE will compare simultaneous DRWP and balloon data.
- Does not define specific methodology.
Data

- Automated Meteorological Profiling System (AMPS) balloons.
  - Low-Resolution (LR) and High-Resolution (HR) Flight Element (FE).
  - 30.5-m (100.0 ft) wind components, interpolated from 1-s measurements.
- DRWP
  - Winds and radar parameters reported every 150-m (492 ft) from 1798-19465 m (5899-63862 ft) at ~5-min temporal intervals.
  - Meets the OAT’s “required data”, “time interval”, “altitude”, and “vertical interval” criteria.
  - Signal, Noise, spectral width, first-guess propagations are a function of four-beam system.
- Data collected from 6 Jan 2015 to 19 Feb 2015.
- A total of 5504 concurrent winds from 48 profiles exist.
Methodology-Vertical Matching

- Addresses discrepancies from each source sampling at different altitudes and altitude intervals.
- Extracted balloon data at each DRWP altitude.
- Interpolated balloon wind components to 0.35-m (1.0-ft) intervals.
- Averaged wind component existing within 75 m (246 ft) of each DRWP altitude.
Methodology-Temporal Matching

- Addresses each source's temporal sampling characteristics.
- Extracted DRWP data at timestamp corresponding to balloon's altitude.
- Derived balloon's altitude versus time after release using rise rate.
  - LRFE: Assumed rise rate of 5.2 m/s (17.0 ft/s).
  - HRFE: rise rate exists in data.
- Extracted DRWP data at the closest timestamp to the balloon's timestamp at the given altitude.
- Only used DRWP data if closest timestamp was within 10 minutes of balloon timestamp at the same altitude.
- Accepted concurrent profile if at least 75% of data exist below 15240 m (50000 ft).
Methodology-QC of Concurrent Profiles

- Examined all comparisons, heavily scrutinizing cases with vector wind differences greater than 15 m/s (49 ft/s).
- Manually removed data only within suspect regions of flagged profiles.
- Illustrated case removes winds around 18500 m (60696 ft), but retains V near 12000-13000 m (39370-42651 ft).
Preliminary Results – Wind Differences

From 1798-18288 m (5899-60000 ft), DRWP wind component bias approximates -0.1 m/s (0.3 ft/s) and RMS near 2.0 m/s (6.6 ft/s).

Additional analysis necessary to determine causes of RMS results.
- System noise
- Seasonal effects (downrange drift)
- Sample Size
Summary and Forward Work

- Preliminary results suggest DRWP wind component bias of approximately -0.1 m/s (-0.3 ft/s) and RMS of near 2.0 m/s (6.6 ft/s).
- Forward work
  - Examine DRWP EVR through spectral analysis.
  - Finalize wind difference results.
References


Backup-Initial Processing

• Initial Balloon processing
  – Sorted all balloon data (LRFE and HRFE) chronologically.
  – Balloon must reach at least 15240 m (50000 ft) and report at 30.5-m (100.0-ft) intervals.
  – Balloon release times must be at least five minutes apart.
  – Check that a DRWP file exists for the day of balloon release.
  – A total of 56 balloon profiles are available after this step.

• Initial DRWP processing
  – Read DRWP data for the day(s) of each balloon release.
  – Removed DRWP data during convective events using algorithm from Barbre’ (2012) and synoptic observations provided by the Cape Canaveral Air Force Base Weather Station.

• Implemented a shear check at each individual report.
  – Removed data if vector shear exceeded 0.15 s\(^{-1}\).
  – Retained the rest of the profile.
  – Check removed small amount of balloon and DRWP data, respectively.
A total of 48 profiles are available after aforementioned QC.
Median U approaches 40 m/s (131 ft/s) from 12000-14000 m (39370-45932 ft).
Median V is ranges from 0-5 m/s (0-16 ft/s) throughout profile.
U is as large as 60-70 m/s (197-230 ft/s), which implies significant downrange drift.
Backup: Previous DRWP Study (Pinter et al. 2006)

- Comparisons of DRWP and balloons after DRWP upgrade in 2004.
- Data collected between Oct 2004 and Jan 2005.
- Compared DRWP to HR using DRWP profile 30 minutes after balloon release.
- Negligible bias and wind component root mean square (RMS) of approximately 1.5-2.0 m/s (4.9-6.6 ft/s).
- RMS reduced to roughly 1.6 m/s (5.2 ft/s) after removal of comparisons associated with large horizontal wind gradients.
- LR statistics from simultaneous releases:
  - Bias roughly 1.0 m/s (3.3 ft/s)
  - Standard deviation near 1.5 m/s (4.9 ft/s)
  - Implies RMS of approximately 1.8 m/s (5.9 ft/s).
- Acceptance criteria of 1.0 m/s (3.3 ft/s) mean and 3.0 m/s (9.8 ft/s) RMS component difference.
Backup: Comparison to Previous Study

- Table compares the mean and RMS wind component differences from Pinter et al. (2006) and the OAT at given altitude ranges.
- OAT mean differences are comparable to Pinter et al. (2006), and lower than LRFE mean (~1.0 m/s).
- RMS comparisons are all within 0.7 m/s (2.1 ft/s) of each other.
- OAT RMS differences are lower than Pinter et al. (2006) at altitudes from 2-6 km (6096-18288 ft).

<table>
<thead>
<tr>
<th></th>
<th>mean(du)</th>
<th>mean(dv)</th>
<th>RMS(du)</th>
<th>RMS(dv)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pinter</strong></td>
<td><strong>OAT</strong></td>
<td><strong>Pinter</strong></td>
<td><strong>OAT</strong></td>
<td><strong>Pinter</strong></td>
</tr>
<tr>
<td>All Altitudes</td>
<td>-0.12</td>
<td>-0.05</td>
<td>0.01</td>
<td>-0.12</td>
</tr>
<tr>
<td>2-6 km</td>
<td>N/A</td>
<td>-0.07</td>
<td>N/A</td>
<td>0.03</td>
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<tr>
<td>6-14 km</td>
<td>N/A</td>
<td>-0.19</td>
<td>N/A</td>
<td>-0.25</td>
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<tr>
<td>14-18 km</td>
<td>N/A</td>
<td>0.19</td>
<td>N/A</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

- Notable differences between OAT and Pinter et al. (2006) methodology.
  - Use of LRFE versus HRFE.
  - Maximum wind component magnitudes of ~70 m/s (230 ft/s) versus ~40 m/s (131 ft/s).
  - Temporal and vertical matching differences.
  - Different seasons (winter versus autumn and winter)