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# SHIPBOARD RADAR WIND PROFILER OBSERVATIONS: NOAA R/V RONALD H. BROWN

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## 1. INTRODUCTION

A newly developed radar wind profiler (RWP) incorporating an electronically stabilized phased-array antenna and real time motion compensation has been operating aboard the NOAA Research Vessel Ronald H. Brown (RHB) since Oct 2000. Observations from several major cruises along with daily rawinsonde flights have provided the opportunity to quantify the performance of this system under shipboard conditions. These include normal ship motions and ship/electronic clutter, as well as varying atmospheric and ocean conditions.

Fig. Electronically stabilized phased-array 915-Mhz antenna: NOAA R/V Ronald H. Brown (arrow).

The RHB system is a low power 915-MHz RWP designed to gather atmospheric data to altitudes of 3-5 km nominally. If precipitating clouds are present, reflections from the water droplets make it possible to obtain data at higher altitudes. The RHB system employs NOAA's Environmental Technology Laboratory's (ETL) advanced multi-peak picking signal-processing system.

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Also incorporated into the signal processing is real time motion compensation. This paper presents results from RWP and rawinsonde comparisons during two research campaigns. Initial results show strong agreement. There is possible interference in the lower range gates (up to 1.0 km) due to sea clutter and the ship's super structure. As expected, the ability to detect the atmospheric signal depends on the meteorological conditions affecting the strength of this signal relative to the other non-atmospheric signals.

## 2. SYSTEM DESCRIPTION

The RHB system is a low power (0.5 kW peak power) 915-MHz RWP (Law et. al., 2002). Figure 1 shows the antenna, with the turtle shell like protective cover, mounted on the aft portside of the RHB. Figure 2 is a schematic of the entire RWP system. This system includes 3 major components: the 90-element phased-array antenna, the motion control and monitoring system (MCM), and the signal processing system (SPS). The electronically stabilized antenna has the capability of compensating for ship motion (roll, pitch, yaw) at 10 Hz through monitoring the ship's motion and computerized control of each element in the phased array antenna. Two sets of RWP operating parameters have been preset in separate parameter files. The RWP operator merely has to select the desired configuration to use best matching the meteorological conditions expected. These two configurations include clear sky and precipitation conditions. Real time displays of motion-corrected winds are available to the on board scientists through the "rb-user" computer. Standard output is 30-min averaged winds.

ETL's SPS software provides meteorological products from RWP averaged-Doppler spectra (Wolfe et. al., 2001; Weber et. al., 1993; Weber and Wuertz, 1991). It differs from the traditional "consensus" signal processing in recognizing that averaged-Doppler spectra may contain multiple spectral peaks, where the atmospheric signal may not be the strongest peak.

## 3. RWP AND RAWINSONDE COMPARISONS

The 2001 Eastern Pacific Investigation of Climate and Pan American Climate Studies (EPIC/PACS) and the 2002 New England Air Quality Study (NEAQS) provided 145 balloon soundings that were compared to RWP 30-min average winds. The EPIC/PACS cruise took place in September and October of 2001 in the eastern Pacific along 90W and 110W of the Inter-Tropical Convergence Zone. The NEAQS cruise took place in July and August of 2002 and monitored the boundary layer winds 10-30 km off the New England coast in support of a regional air pollution study. Rawinsonde launches were made using GPS wind finding systems. The RWP operated in a dual mode measuring winds at both 60 and 100 m

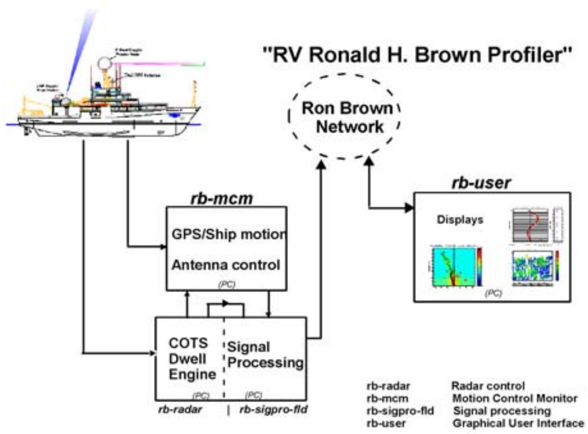


Fig 2. Schematic of the entire radar wind profiler system.

vertical resolutions. Rawinsonde launch times were matched to the nearest 30-min RWP data. Data not within a 30-min window and cases where there were problems with one of the two measurement systems were removed from this comparison. Rawinsonde wind speed and direction data were converted to U and V components and then linearly interpolated to the same wind levels measured by the RWP. This provided both temporal and spatial consistency between the rawinsonde measurements and the RWP winds.

Scatter plots for the rawinsonde and RWP horizontal U and V wind components at all levels for the EPIC/PACS and NEAQS cruises appear in Figs. 3 and 4. Statistics from these inter comparisons are listed in Tables 1 and 2. Both data sets show good agreement with less scatter and better correlation for the 100 m over the 60 m modes. This is not unexpected since there is more transmitted power within a 100 m pulse than a corresponding 60 m pulse providing more returned power from atmospheric signals. Differences between RWP and rawinsonde winds are consistent with previous comparisons (Weber and Wuertz, 1990). Not shown are results from calculations categorizing the data by height to determine if the lowest 0-1.0km is contaminated by interference from the ship's super structure or radar return due to sea clutter. Even though visually there appears to be differences at these lower range gates in the wind profiles, the statistics don't show significant differences. More analysis is needed using ship motion and sea state information to help sort out possible interference periods.

Comparing results from the two different cruises, it is apparent there is less scatter and better correlation during the NEAQS 2002 cruise. Several factors may have contributed to these differences. Though the RWP was technically the same system on both cruises, several of the 90 antenna elements had to be replaced prior to the 2002 NEAQS. Even though GPS wind finding systems were used on both cruises, they were not identical. A newer model rawinsonde system was in place for NEAQS. No allowance is made for different meteorological conditions. Overall winds were stronger for the measurements made just off the New England coast than in the eastern Pacific. Measurements made during NEAQS were affected by not only marine conditions, but by continental air masses. Finally spatial separation between measurements, as always, needs to be considered. This is especially true when taking into account the fact that not only does the balloon drift with the winds, but the ship is also underway during a majority of the launches at speeds reaching a maximum of 12-15 $ms^{-1}$.

Another quantitative measurement of RWP performance is the calculation of the overall height coverage. This parameter was calculated by totaling the number of good data points at each height from the 30 min average winds. Figure 5 presents the results from these calculations for both modes and each cruise. These profiles only contain data for RWP profiles where we have rawinsonde data. Once again, for each cruise we first see the difference between the 60 m and 100 m modes. The greater height coverage is directly correlated to the difference in transmitted power for each radar pulse. Comparing the two cruises there is an obvious improvement in the overall height coverage in NEAQS 2002. As stated above this could be attributed to several different factors. This additional information leads us to believe that the replacement of the antenna elements improved the overall performance of the RWP. The meteorology during the two cruises should not be ruled out as a contributor to these differences.

## 4. CONCLUSIONS

This analysis has provided insight into the performance and operational characteristics of the RHB radar wind profiler. The variability between winds measured by the RWP and rawinsonde are consistent with those measured by land-based radar wind profilers. These results confirm that the electronically stabilized RWP, even in a high-clutter environment, can measure winds accurately and produce real time motion-corrected winds. Differences in the two measurements systems are consistent with results from previous comparisons.

Further detailed analysis of these data are planned to study the overall performance of the RWP within each cruise as well as the differences seen between the two cruises. More analysis is also needed using ship motion and sea state information to help sort out interference periods believed to be contributing to irregularities seen in the lower range gates, especially in the 60 m mode. Wavelet transforms are being tested at ETL (Jordan et. al., 1997) for removing intermittent clutter contamination. These studies should help in the planning of future cruises utilizing the RHB radar wind profiler.

## 4. REFERENCES


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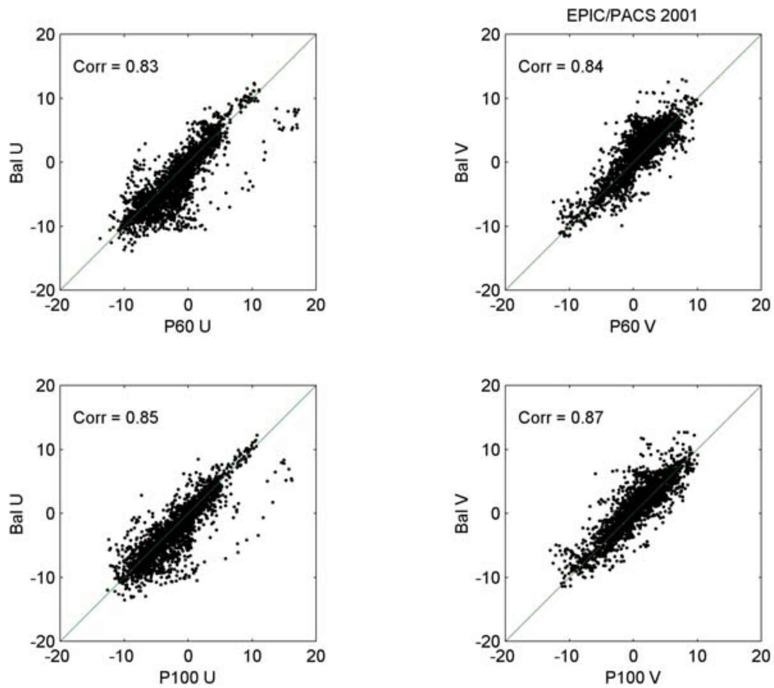


Fig. 3 U/V Horizontal wind component scatter plots EPIC/PACS 2001.
Radar wind profiler vs rawinsonde: 60 and 100 m modes, for all heights.

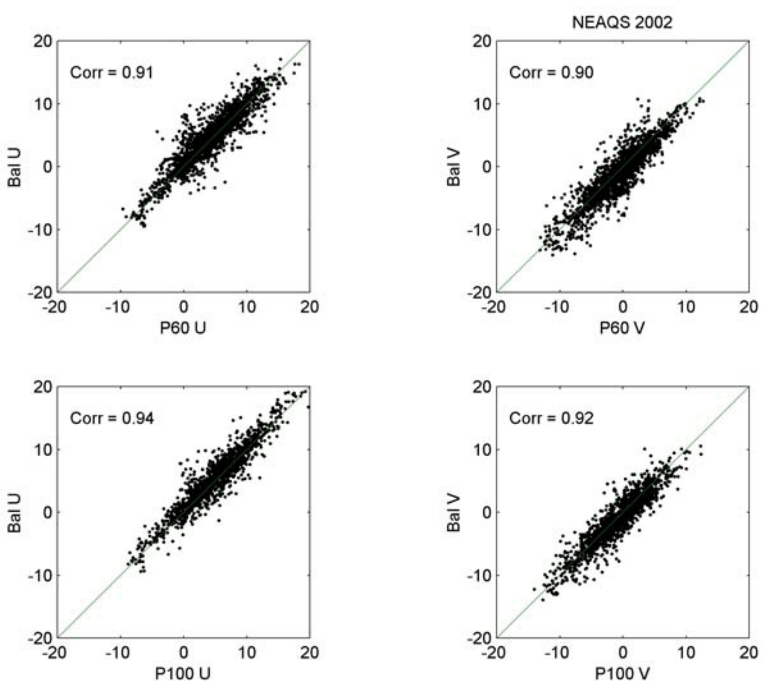


Fig. 4 U/V Horizontal wind component scatter plots NEAQS 2002.
Radar wind profiler vs rawinsonde: 60 and 100 m modes, for all heights.

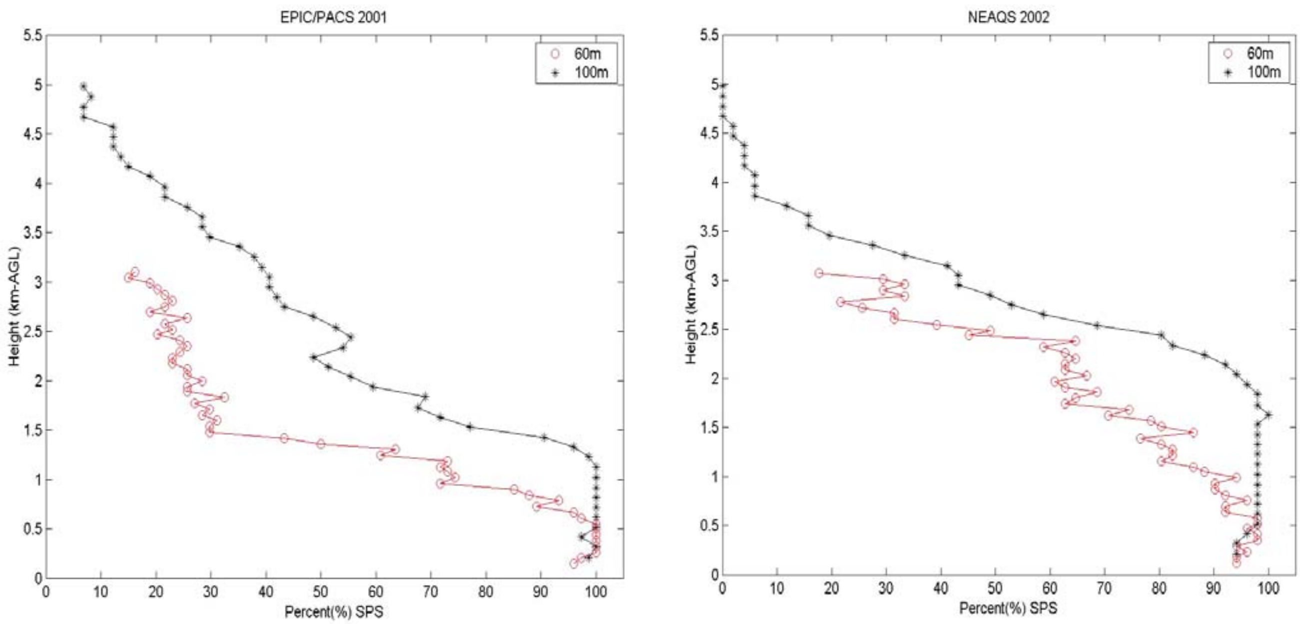


Fig. 5 Number of good radar wind profiler data pts at each height (%):
left EPIC/PACS 2001, right NEAQS 2002.

Table 1. Regression Coefficients for balloon/profiler 60 m and balloon/profiler 100 m: U, V, wind speed and wind direction.

| | EPIC/PACS 2001 | | | NEAQS 2002 | | |
|---|---|---|---|---|---|---|
| | 60m | 100m | Pts 60/100 | 60m | 100m | Pts 60/100 |
| R(u) | .84 | .85 | 2334/2176 | .91 | .94 | 1851/1380 |
| R(v) | .85 | .87 | | .90 | .92 | |
| R(spd) | .64 | .70 | 2334/2176 | .83 | .89 | 1851/1380 |
| R(dir) | .72 | .73 | | .62 | .66 | |

Table 2. Mean and standard deviations of balloon/profiler 60 m and balloon/profiler 100 m: U, V, wind speed and wind direction.

| | EPIC/PACS 2001 | | | | NEAQS 2002 | | | |
|---|---|---|---|---|---|---|---|---|
| | B60 | P60 | B100 | P100 | B60 | P60 | B100 | P100 |
| Mean U $ms^{-1}$ | -2.70 | -1.85 | -2.84 | -2.29 | 4.55 | 4.19 | 5.34 | 4.93 |
| Mean V $ms^{-1}$ | 1.30 | .79 | .74 | .31 | -.86 | -.43 | -1.10 | -.77 |
| Mean spd $ms^{-1}$ | 6.41 | 5.44 | 6.25 | 5.78 | 7.18 | 6.73 | 7.65 | 7.31 |
| Mean dir | 150.1 | 154.4 | 140.1 | 142.0 | 248.9 | 240.7 | 257.8 | 251.1 |
| STD U $ms^{-1}$ | 4.84 | 4.53 | 4.56 | 4.47 | 4.53 | 4.53 | 4.83 | 4.75 |
| STD V $ms^{-1}$ | 4.04 | 3.66 | 4.20 | 4.06 | 4.48 | 4.28 | 4.34 | 4.31 |
| STD spd $ms^{-1}$ | 2.78 | 2.90 | 2.86 | 2.88 | 3.35 | 3.35 | 3.66 | 3.55 |
| STD dir | 84.5 | 87.7 | 87.0 | 90.6 | 83.0 | 84.6 | 75.9 | 78.6 |