The Vertical Resolution of the Kennedy Space Center 50-MHz Wind Profiler

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ABSTRACT

The effective vertical resolution of the Kennedy Space Center 50-MHz Doppler radar wind profiler is determined using vertical wavenumber spectra and temporal coherence. The resolution ranges from being Nyquist limited at 300 m to as coarse as 900 m. The average resolution is about 500 m.

1. Introduction

The utility of wind profilers compared to balloons to support space launch operations depends in part on the relative vertical resolution of the two measurement systems. High-resolution wind sounding balloons (‘‘Jimspheres’’) were characterized by Wilfong et al. (1997) using spectral and coherence techniques. This note reports results of applying the same techniques to the Kennedy Space Center (KSC) 50-MHz Doppler radar wind profiler (DRWP). The DRWP and its measurement characteristics are described in detail by Schumann et al. (1999), but that paper does not address the question of its vertical resolution.

2. Data processing and methodology

A subset of the data prepared by Merceret (1997) for the study of wind change probabilities was used for this analysis. The extensive quality control to which those data had been subjected and their ready availability to the author governed the selection. Of the 117 days available, 93 were accepted. The remaining days had too many missing soundings for the generation of acceptable coherence spectra. A full day would have profiles every 5 min for 24 h, or 288 profiles. DRWP outages and quality control procedures reduced this on many days. If fewer than 100 consecutive profiles were available, the day was discarded.

Each profile contains wind speed and direction at each of 112 adjacent levels or ‘‘gates’’ spaced 150 m apart beginning at an altitude of 2011 m. For this study, the u and v wind components were computed for gates 33–96 in each profile. The resulting 64 gates covered most of the region (gates 27–100) used in the previous study. For each profile, a fast Fourier transform (FFT) was applied separately to the u and v components. Profiles were processed in pairs spaced 5 min apart (consecutive profiles). From the FFTs, the power spectrum and cross spectrum between the current profile and the time-lagged profile were computed for both components. Before taking transforms, the mean and linear trend were removed from each set of data and a triangular Parzen window was applied. This is identical to the data processing used by Wilfong et al. (1997), which facilitates direct comparison of their work with the results presented here.

For each day in the sample, the average power spectra of u and v plus the coherence spectra of u and v with respect to the time-lagged profiles was computed and stored as an ASCII text file along with the sample size and other information about the sample. The ASCII format was chosen to facilitate further analysis and to import it into a spreadsheet for generation of graphics. Data from multiple days was combined by sample-size-weighted averaging of the power and coherence spectra. Averages of the full dataset plus selected subsets were created.

Wilfong et al. (1997) used the coherence between two simultaneous radar measurements of the same balloon to estimate the vertical resolution of Jimspheres. We only have one 50-MHz profiler and it can only make one measurement at a time. If the atmosphere remains unchanged between profiles, then coherence between adjacent profiles can perform the same function. Since no alternative is available, this study assumes no change in the atmosphere in a 5-min period. This is a conservative assumption since any atmospheric change will reduce the coherence and thus make it appear that the DRWP resolution is coarser than it actually is. The results suggest that the instrument is usually not Nyquist

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limited, so the inaccuracy introduced by the deviation of the atmosphere from the assumption could be of consequence.

In regard to nomenclature, the term ‘‘coherence’’ is sometimes used to mean the cross spectrum divided by the square root of the product of the power spectra, and sometimes to mean the square of that quantity. The latter definition is preferred by the author and is used here. Thus the quantity called ‘‘coherence’’ in this paper is called ‘‘coherence squared’’ by Wilfong et al. (1997). Whatever its name, when it falls below 0.5, the convention is that the data are dominated by noise. At or above 0.5, the data are dominated by signal.

3. Results

Figure 1 shows the average coherence and power spectra for the full dataset. The anisotropy results from the presence of 45 days for which the u and v components behave quite differently. An example is presented in Fig. 2. When these anomalous records are excluded, Fig. 3 results. Figure 4 shows a single day typical of this ‘‘normal’’ group. The cause of this anisotropy is unknown, but similar phenomena have been reported in the literature; for example, see Reiter and Burns (1966). One cause might be spectral leakage, which is discussed below.

The power spectra in Fig. 4 begin to make a transition from the steep slope characteristic of the atmosphere in this spectral region to the flatter spectrum characteristic of noise at wavenumbers above about 3×10^{-3} m^{-1}. The coherence remains above 0.5 to 2.08×10^{-3} m^{-1}. These equate to scales of 333 and 481 m, respectively. The coherence scales for the full dataset as shown in Fig. 1 are 426 m for the u component and 565 m for the v component. Thus, it appears that the DRWP is noise limited on average to length scales of about 500 m.

The poorest resolution in the entire dataset was day 95 287, shown in Fig. 5. The u-component coherence decays below 0.5 at about 1.12×10^{-3} m^{-1}. This equates to a resolution of 890 m. The v component remains coherent to a wavelength of 780 m. In general, the lowest signal-to-noise ratios tend to occur in light and variable winds. Eight light and variable days were in the sample, including 95 287. The composite of these days is shown in Fig. 6. The u component becomes incoherent at scales smaller than about 610 m. The v-component coherence scale is 740 m. The best resolution in the dataset included some days that were Nyquist limited.

4. Discussion

One potential cause for anomalous spectral behavior is spectral leakage from longer wavelengths to shorter ones due to the behavior of the data window used in processing. To examine this possibility, the entire dataset was processed four different ways.

1) No preprocessing, rectangular window with mean and trend not removed;
2) rectangular window, mean and linear trend removed;
3) high-pass filtered, rectangular window (some cases tried with and without detrending); and
4) mean and trend removed, Parzen window (some cases tried with Hamming, Hanning, and Bartlett windows, but no significant difference observed).

All of these methods produced a large number of cases with asymmetries. Method 4, selected for comparability with the Jimsphere results, produced the smallest coherences at a given scale in the high wavenumber range and thus was the most conservative. The high-pass filtered data was the next most conservative, suggesting that leakage could be responsible for some of the observed behavior.

It is important to keep in mind that the interpretation of decoherence as an indication of the limiting resolution of the instrument depends on the assumption that the atmosphere is perfectly coherent at all scales over 5-min intervals. In reality, this is probably not true at the smaller scales; hence the results above are conservative. That is, the DRWP resolution is at least as fine as the numbers presented indicate and may be somewhat finer. Since the indicated resolution is coarser than the Nyquist limit, this could be significant in some cases. The worst-case data are biased and the worst-case resolution is certainly finer than 900 m, but one cannot infer by how much from these data. The indicated average resolution of 500 m is also biased to larger scales; again, one cannot tell from these data how much bias there is.

A reviewer suggested that similar considerations of bias might apply to the Jimsphere results of Wilfong et al. (1997). In that case, single balloons were simultaneously tracked by two radars thus eliminating temporal and spatial decoherence of the atmosphere. Any decoherence due to the radars themselves is an inherent part of the Jimsphere sensor system and thus is properly considered in assessing its resolution. Thus these considerations should not be a factor for those measurements.

5. Summary

The resolution of the KSC DRWP is generally noise limited at about 500 m, but in some cases may be noise limited at larger or smaller scales down to and including the Nyquist limit of 300 m. The largest scale seen in this study was 900 m, although the actual instrument resolution was probably finer due to the bias introduced by the assumption of perfect atmospheric coherence. This range is two to three times larger than the 150–300-m resolution range for Jimspheres reported by Wilfong et al. (1997).

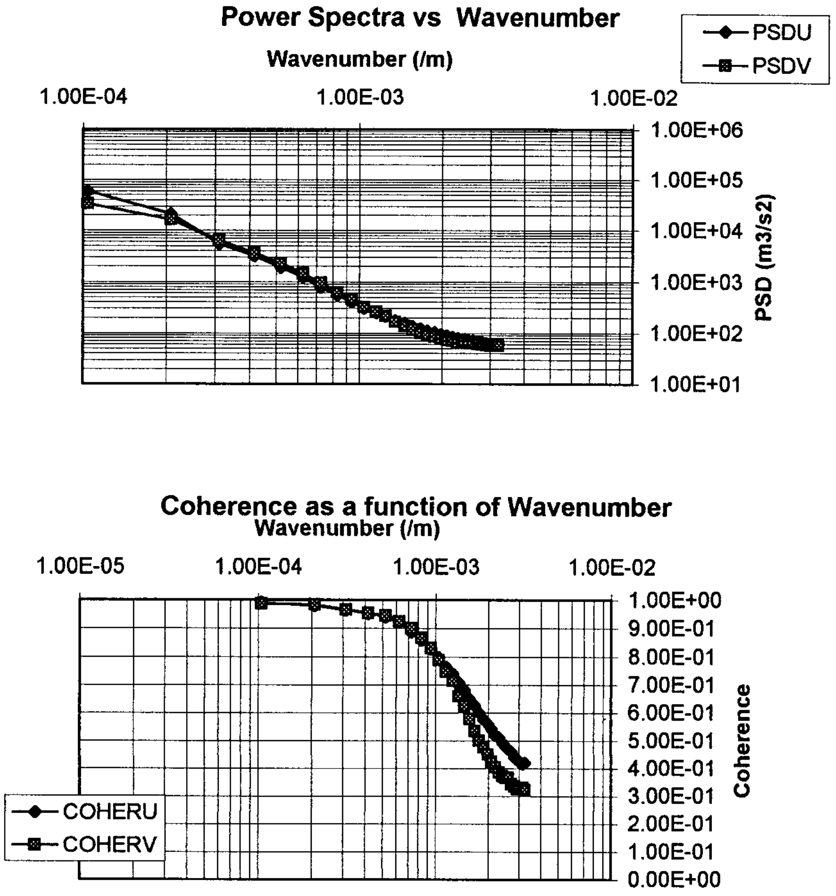

FIG. 1. Average power spectra and coherences with 5-min time lag for all 93 days. This is an average of 93 files containing a total of 23 045 profiles.

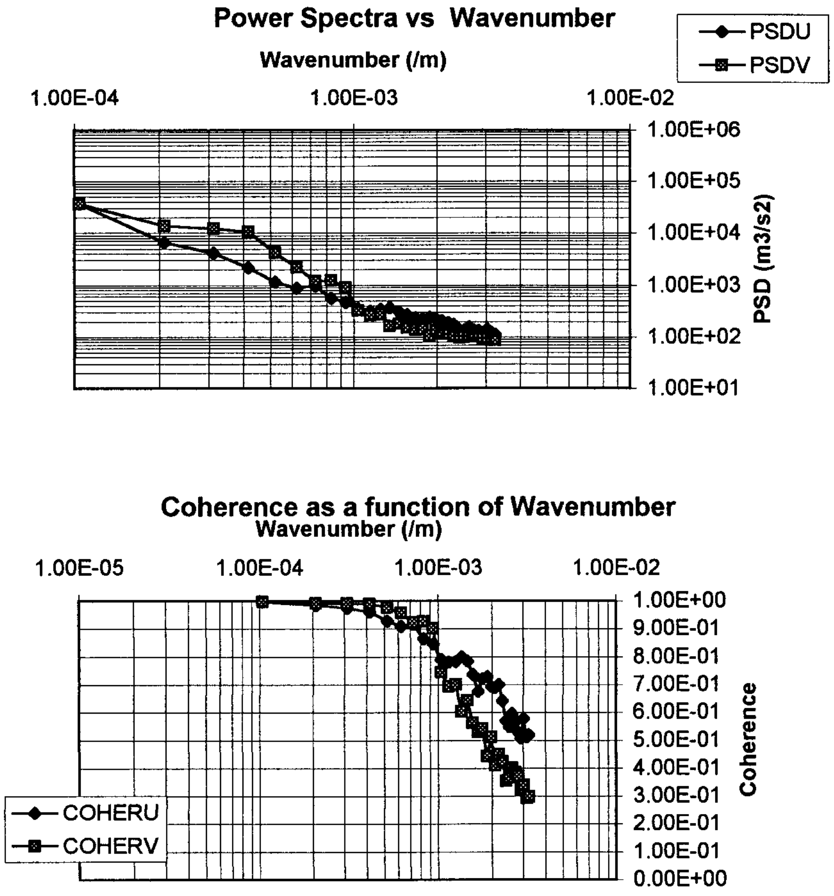

FIG. 2. An example of anisotropic spectra (one file averaging 282 profiles).

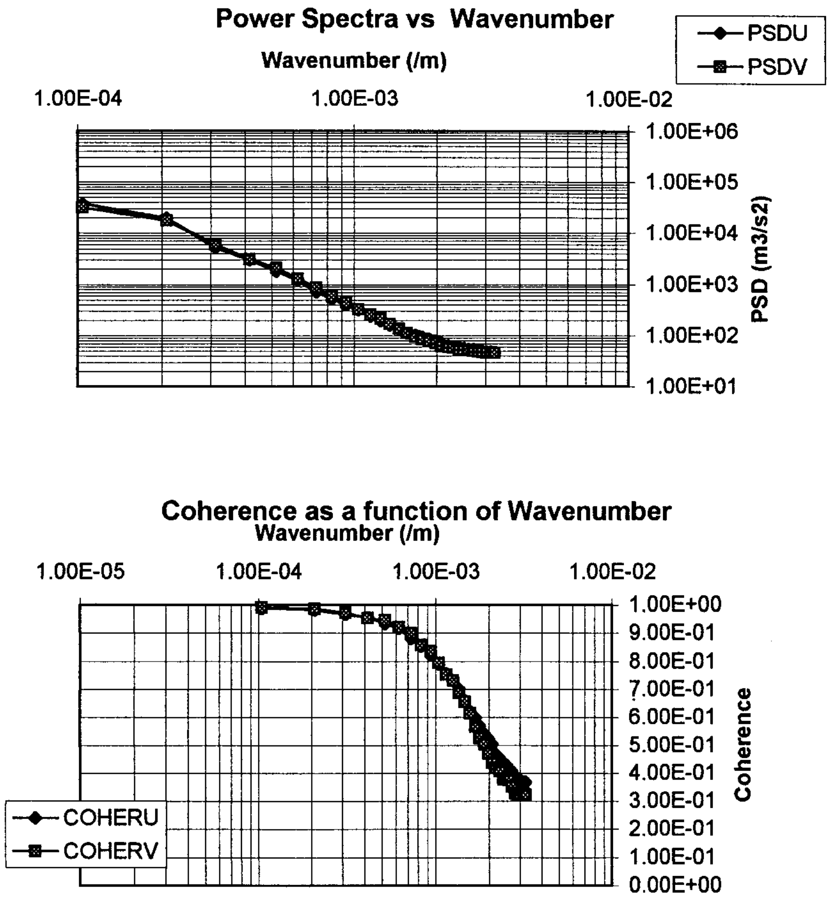

FIG. 3. Power and coherence spectra with obviously anisotropic days removed. Some residual anisotropy is evident in the coherence spectra. The average is based on 44 files containing 10 727 profiles.

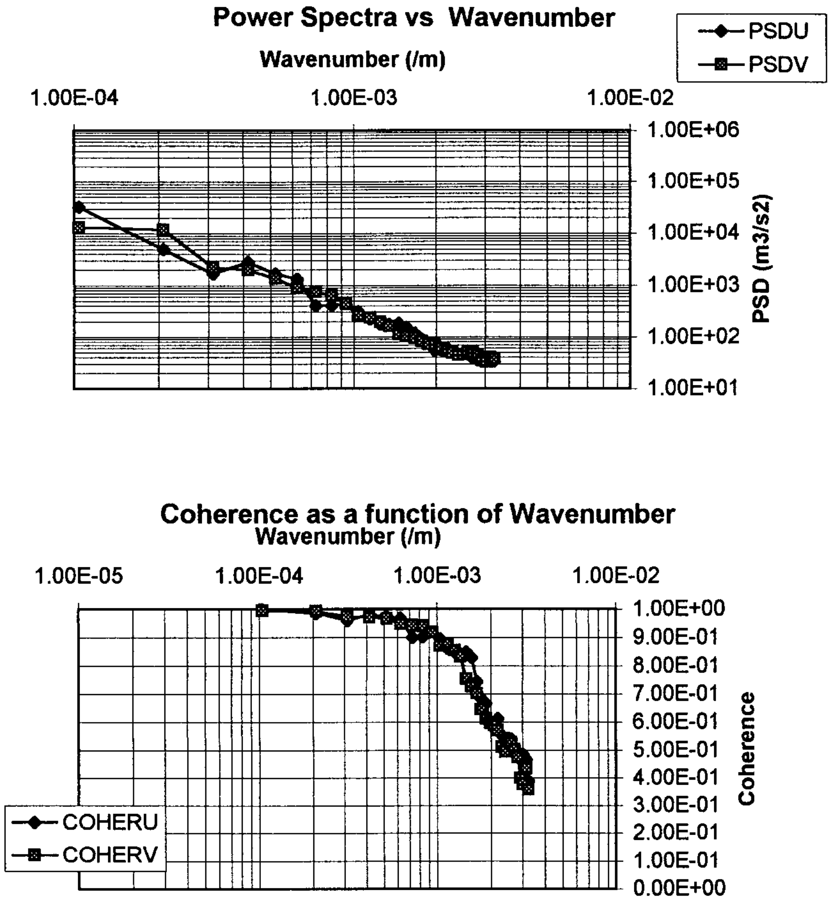

FIG 4. An example of an isotropic day (one file, 280 profiles).

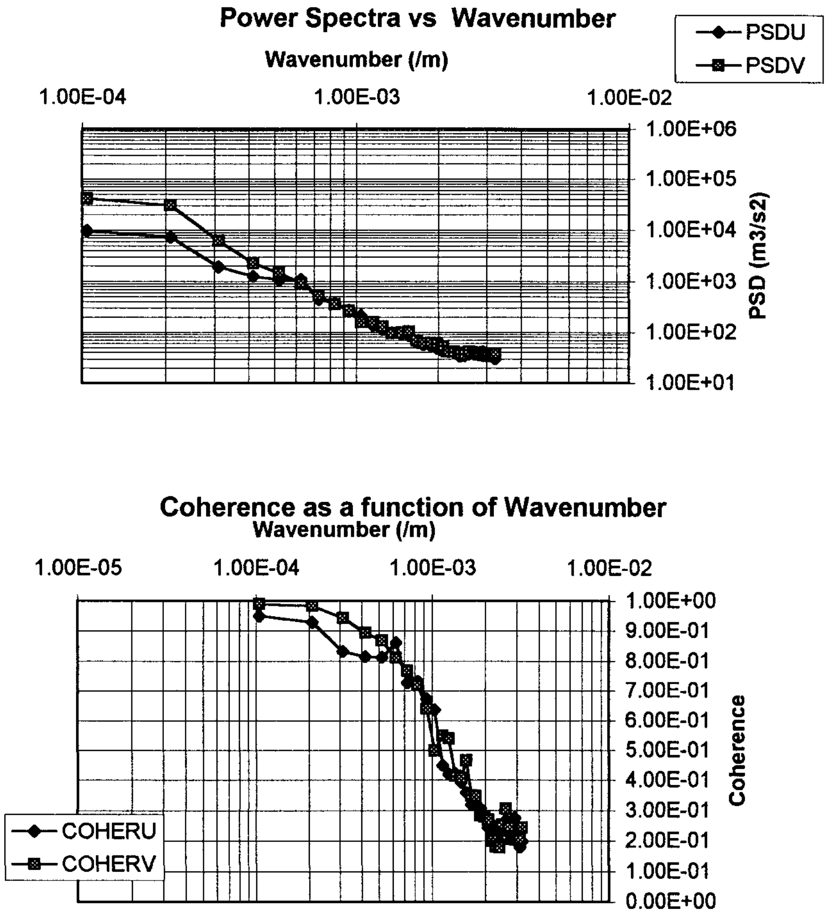

FIG. 5. Spectra of the sample day with poorest resolution (one file, 284 profiles).

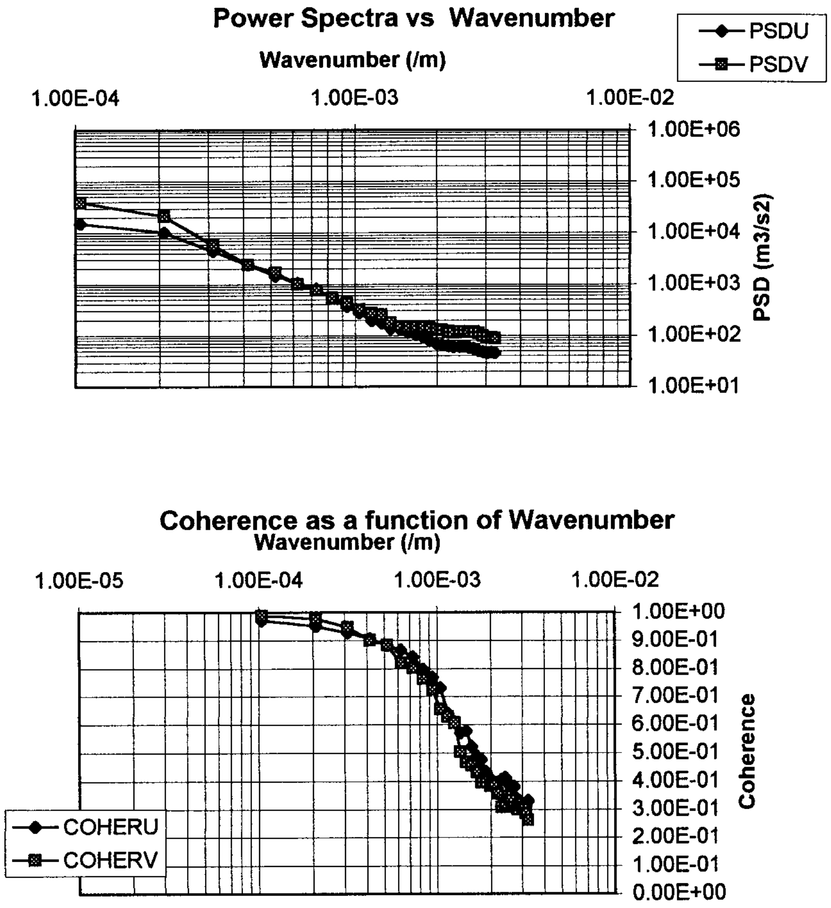

FIG. 6. Composite spectra from the eight light and variable days in the sample. This is an average of eight files containing 1664 profiles.

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REFERENCES

Merceret, F. J., 1997: Rapid temporal changes of midtropospheric winds. *J. Appl. Meteor.,* **36,** 1567–1575.

Reiter, E. R., and A. Burns, 1966: The structure of clear-air turbulence derived from ''TOPCAT'' aircraft measurements. *J. Atmos. Sci.,* **23,** 206–212.

Schumann, R. S., G. E. Taylor, F. J. Merceret, and T. L. Wilfong, 1999: Performance characteristics of the Kennedy Space Center 50-MHz Doppler radar wind profiler using the median/filter first-guess data reduction algorithm. *J. Atmos. Oceanic Technol.,* **16,** 532–549.

Wilfong, T. L., S. A. Smith, and C. L. Crosiar, 1997: Characteristics of high-resolution wind profiles derived from radar-tracked Jimspheres and the Rose processing program. *J. Atmos. Oceanic Technol.,* **14,** 318–325.