A Comparison of Velocity Spectra from Hot-Film Anemometer and Gust-Probe Measurements

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ABSTRACT

Velocity spectra obtained from a hot-film anemometer and a gust probe on board the NOAA DC-6 (39C) during a research mission into Hurricane Eloise 1975 are compared at common frequencies. The spectra compare reasonably well, thus justifying some confidence in measurements acquired from the individual instruments.

1. Introduction

Recently Moss and Merceret (1976) presented results from a low-layer NOAA DC-6 (39C) aircraft research mission along the periphery of Hurricane Eloise on 17 September 1975. The mission included four legs in the well-mixed layer that alternated either directly with or against the mean horizontal wind. The mean wind speed averaged 20 m s^{-1}. In addition to the relatively slow-response instruments used in determining the mean profiles, the aircraft was equipped with a hot-film anemometer (HFA) and a gust-probe (GP). The HFA provided high-frequency measurements of fluctuation in the streamwise component of the wind (u'). The GP was configured to measure relatively high-frequency fluctuations in the three velocity components. Unfortunately, the streamwise-component GP measurements were unusable at the frequencies considered here due to the presence of liquid water which accumulated in the gust probe's pitot tube, but reliable measurements of the lateral (v') and vertical (w') components were obtained. Detailed discussions of the HFA and GP systems are presented elsewhere by Merceret (1976a) and Grossman and Bean (1973), respectively. In this note we compare power spectral densities obtained from the two instruments in a frequency interval common to the working regions of both.

2. Discussion and results

The analog recording bandwidth of the hot-film system is 2500 Hz and the sampling rate for the GP, recorded on digital tape, is 40 s^{-1}. The total length of record chosen for this study was 160 s from a nearly horizontal flight leg whose height averaged 362 m above the sea surface. For the HFA, spectra were generated in a Spectral Dynamics Real Time Analyzer model SD 330A.[1] Sixty-four individual spectra were generated from consecutive records of 2.5 s duration each, stored by the analyzer in an auxiliary memory and then averaged. From the gust-probe data, 100 individual spectra were computed (using the fast Fourier transform algorithm) from consecutive records of 1.6 s duration each. These spectra were then averaged to obtain a composite spectrum. The above Bartlett smoothing procedures resulted in 192 degrees of freedom for the u' spectrum and 300 degrees of freedom for the v' and w' spectra (Jenkins and Watts, 1968).

Fig. 1 presents the u', v', w' spectra obtained from the various instruments for the frequency range from 0.5 to 40 Hz. For the most part the spectra show an inertial subrange in which the power spectral densities ($E_{u',v',w'}$) decrease with the 5/3 power of the frequency (f). The discrepancies from inertial subrange behavior in the low-frequency end of the u' spectrum (<3 Hz) and the high-frequency end of the v', w' spectra (>10 Hz) are attributable to the response characteristics of the HFA and GP, respectively. All the spectra demonstrate inertial subrange behavior in the frequency range 4–10 Hz. Following Tennekes and Lumley (1972) the following relationship should be valid in this isotropic region:

$$E_{v',w'}(f) = \tfrac{4}{3} E_{u'}(f). \quad (1)$$

Therefore, in a qualitative sense, the spectra behave as expected although $E_{v',w'}$ are roughly a factor of 2 (rather than $\frac{4}{3}$) larger than $E_{u'}$.

[1] Mention of a proprietary product does not constitute an endorsement thereof by the authors or the National Hurricane and Experimental Meteorology Laboratory, and no reference implying such endorsement shall be made to this paper in any promotion or advertisement.

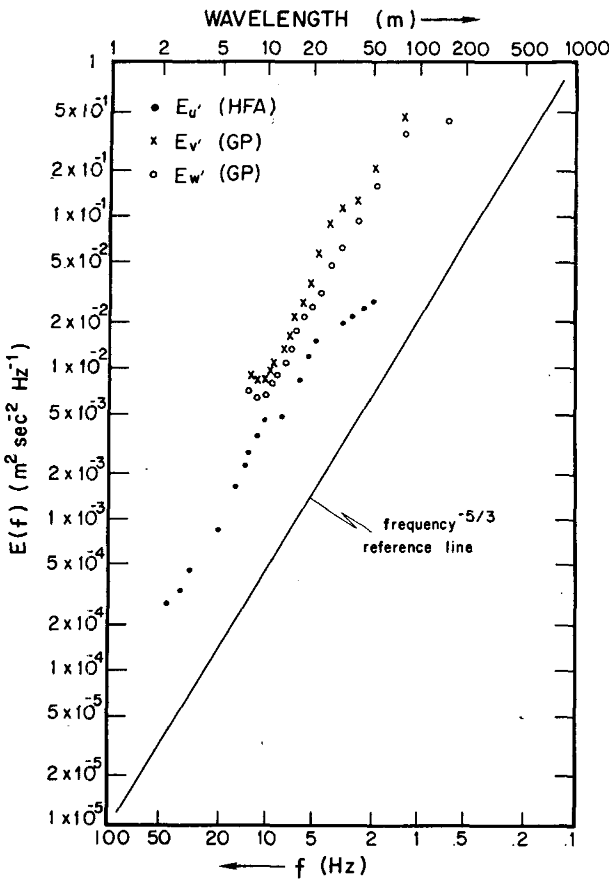

FIG. 1. Velocity spectra obtained from the HFA and GP.

3. Conclusions

Considering the differences in the instrument design and frequency response characteristics, spectra from HFA and GP measurements agree very well. As a quantitative check on the spectral estimates, we computed dissipation rates (ϵ) via the relations

$$\bar{\epsilon}=\frac{2\pi}{\bar{U}}\overline{[2.2f^{5/3}E_{u'}(f)]^{3/2}}$$
$$=\frac{2\pi}{\bar{U}}\overline{\{2.2f^{5/3}[\tfrac{3}{4}E_{v',w'}(f)]\}^{3/2}}, \quad (2)$$

where the overbar denotes an average over all frequencies in the inertial subrange, $\bar{U}$ is the true airspeed, and we have chosen a value of $\alpha=0.45$ ($1/\alpha=2.2$) for Kolmogorov's constant (Boston and Burling, 1972). The dissipation rates computed via (2) are $\bar{\epsilon}=1.66\times10^{-2}$ m^2 s^{-3} for the u' spectrum and 3.22×10^{-2} m^2 s^{-3} for the v' and w' spectra. These values fall within the range computed by Merceret (1976b) for 1975 Hurricane Caroline, which, in turn, agreed reasonably well with the bulk budget study estimates of Riehl and Malkus (1961) and Miller (1962) for 1958 Hurricanes Daisy and Helene, respectively.

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