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3.1.3 TROPOSPHERIC TURBULENCE PARAMETERS MEASURED BY USING THE MU RADAR

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INTRODUCTION

The spectral width of the Doppler radar echo has been used to estimate the atmospheric turbulence parameters (CUNNOLD, 1975; SATO and WOODMAN, 1982; HOCKING, 1983a), because it is directly related to the kinetic energy contained in the turbulence. However, sufficient care must be taken in deriving the turbulence parameters since the measured spectral width can be easily affected by undesired factors such as beam broadening, shear broadening, and the temporal variation of the wind field (SATO and WOODMAN, 1982; HOCKING, 1983b).

Here we examine these factors in the case of the MU radar observation of the upper troposphere, and present preliminary results obtained so far.

METHOD AND DATA

The MU radar has a relatively broad antenna beam among existing radars (see FUKAO, et al., 1985 for details of the system), thus suffers mainly from the beam broadening effect. The shear broadening does not cause any trouble because the antenna beam can be pointed to the zenith. It is even possible to estimate the strength of the shear inside the turbulent layers by comparing the spectral width in the vertical and off-vertical directions. The temporal variation of the wind field may add to some error, but it is not the major factor since the time resolution is as good as 1 min. The magnitude of rms fluctuation within 1 min is estimated to be about 0.2 m/s based on the record-to-record valiability of the radial wind velocity.

In order to estimate and correct the effect of the beam broadening, it is important to measure the horizontal wind accurately. We used five antenna beams in the present observation; one pointing vertically, and remaining four toward north, east, south, and west at a zenith angle of 10°. The zonal and meridional wind components derived from the line-of-sight velocity in these directions are used to correct the beam broadening effect.

The solid line in Figure 1 shows the result of a numerical simulation which relates the true and observed spectral width σ and the horizontal wind velocity V_h. The broken line shows the case where the antenna beam pattern is approximated by a Gaussian. In this case, the effect of the beam broadening is expressed simply as

$$\sigma_{obs}^2 = \sigma_{true}^2 + C^2 V_h^2 \qquad (1)$$

where C = 0.044 is a constant determined for the MU radar antenna. Thus, it can be easily removed if the horizontal wind velocity is known. This approximation is used in the following. The spectral width and the mean Doppler shift are determined by fitting a Gaussian to the observed spectra.

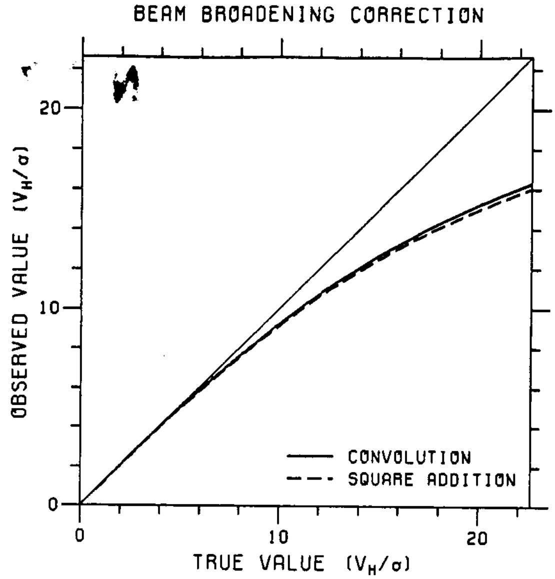

Figure 1. Numerical calculation showing the effect of the beam broadening.

After subtracting the beam broadening effect, the energy dissipation rate k and the eddy thermal diffusivity k_h can be estimated as (SATO and WOODMAN, 1982; HOCKING, 1983b)

$$\varepsilon = 0.49\ \sigma^3 k_o \tag{2}$$

$$k_h = \varepsilon / 3\omega_b^{\ 2} \tag{3}$$

where $k_o = \omega_b/\sigma$ is the outer scale wave number of the turbulence (WEINSTOCK, 1981), and ω_b is the Brunt-Vaisala frequency.

The data were taken for four days in July, 1985, when the stratospheric jet was weak. The time and height resolutions are 1 min and 150 m, respectively, and the height range in which the meaningful data are obtained was 4.8-16 km.

RESULTS

Figure 2 shows a 24-hour mean observed spectral width at 5 beam directions and the beam broadening factor obtained from the horizontal wind velocity. An interesting feature is that no appreciable difference exists between the spectral width in the vertical and off-vertical directions, which means that no shear broadening effect is observed. This is probably due to the convective structure of the troposphere where large shear cannot last for a long duration over a large vertical dimension.

Figure 3 is the resultant 24-hour mean profiles of the derived parameters. The Brunt-Vaisala frequency is estimated from nine temperature profiles obtained by rawinsondes launched at Hamamatsu, about 150 km east of the MU radar. The values are slightly larger than those obtained at Arecibo, Puerto Rico (SATO and WOODMAN, 1982).

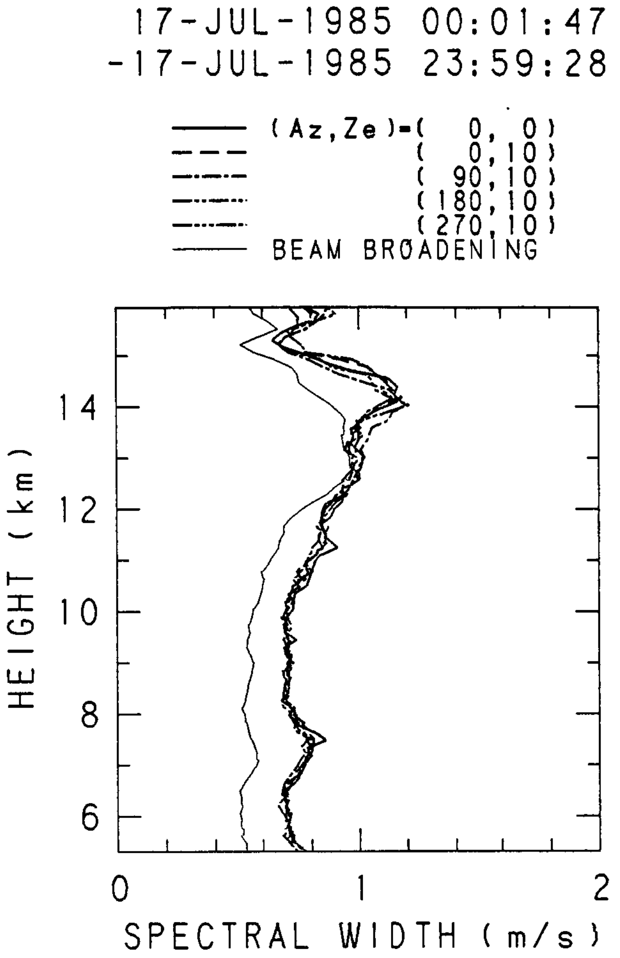

Figure 2. Observed spectral width at 5 beam directions, and the beam broadening factor estimated from the horizontal wind.

The fairly large outer scale of turbulence, which is close to the height resolution of 150 m, seems to be consistent with the macroscopic behavior of the layers found in the time-height variability of the echo power structure. However, the turbulence parameters obtained here must be treated with care, because the temperature profiles observed by rawinsondes do not reflect local structures, although the radar itself has a high resolution.

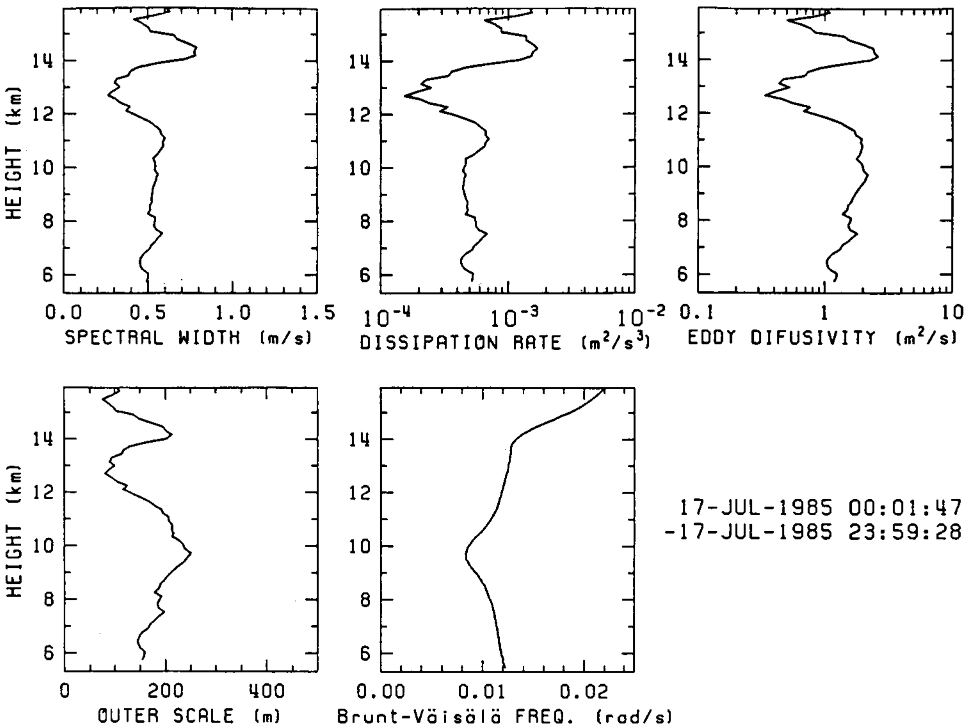

Figure 3. A 24-hour mean profile of the corrected spectral width, the energy dissipation rate, the eddy thermal diffusivity, the outer scale of turbulence, and the Brunt-Vaisala frequency.

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