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DIRECT MEASUREMENT OF VORTICITY NEAR THE GROUND

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Abstract

A new method of direct measurement of vorticity near the ground is proposed. And the results of the observation by use of the new sensor are shown.

1. Introduction

Nature of vorticity and its transport near the ground has been often disussed in detail from theoretical point of view. But verification of theories by experiments has not been done because of the difficulties in measuring vorticity. The sonic anemometer, which has developed recently, measures the line averaged value of wind velocity component along the sound path of the sensor.. This is recognized as the fundamental limitation of the sonic anemometer in measuring point characteristics of wind turbulence. But a good use of this deficiency can be made in direct measurement of vorticity or circulation on a small closed curve made of sonic sound paths. The results of the test experiment of direct measurement of vorticity by sonic anemometers are presented in this paper.

2. Details of Observation

The observation was made by the use of three sonic anemometers designed by the present author [1966] at the height of 1.5 meters over flat bare soil surface in the Uji Campus of Kyoto University as a part of a project for developement of sonic anemometry.

Three sonic anemometers were placed as trianglar form as shown in Fig. 1. The dimension of the triangle is 70 cm on vertical side and 65 cm on reclining sides. The effective sound path lengths of sonic anemometers are 60 cm for verical and 50 cm for reclining sides. The integrated wind velocity component on one side can easily obtained by multiplying the length of the side with the anemometer indication, because the line averaged value of wind

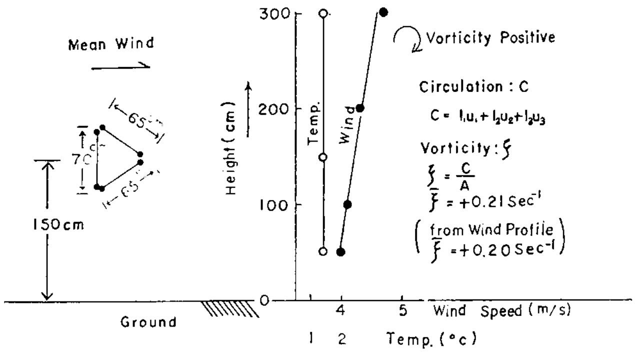

Fig. 1. Observation scheme of vorticity and mean profiles, (at Uji 17h15m Feb. 2, 1965: Run U-33).

velocity component is measured by the sonic anemometer. And by adding three of these values in cyclic sense, the circulation over this triangle is obtained. The average vorticity on this triangle is then derived by dividing the circulation by the area.

The trianglar vorticity sensor was placed in the vertical and to the mean wind direction. Mean profiles of wind speed and air tempersture are also measured at the nearby point. The observation was started at 1715 on the 2nd of February, 1965.

3. Results

The data were sampled for 1 min in duration and 1/4 sec in averaging time. The sampling duration was rather short but for the convenience of data handling this time length was chosen for this test experiment. Mean profiles of wind and temperature are shown in Fig. 1. The stability condition was neutral and mean wind speed at the observational height of 1.5 m was about 4.2 m/sec. The vorticity expected from mean wind profile or wind shear was about 0.20 sec^{-1}.

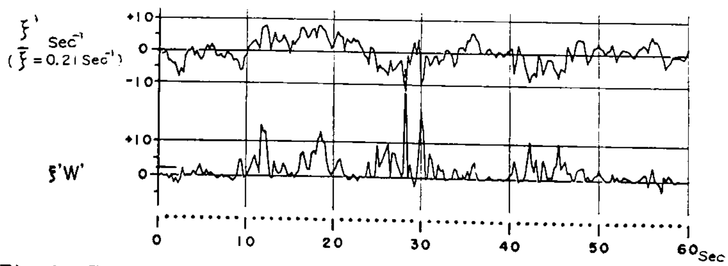

Fig. 2. Time changes of vorticity and its transport near the ground, (Transport is shown in arbitrary unit).

The time change of vorticity obtained by the method described in the previous section is shown in Fig. 2. The mean value of vorticity measured by the new sonic sensor is 0.21 sec^{-1}, which shows good agreement with the result from mean wind profile. Fluctuations of vorticity are very large compared to the mean value.

The power spectrum of the vorticity fluctuations was calculated by the simplified method of Bushnell & Huss [1958], and the result is shown in Fig. 3. The reliability of the results is not so good because of short sampling duration and simple method. But it may be concluded that high frequency fluctuation of vorticity shows quite rapid decreasing with increasing frequency. This character is not in quite agreement with the anticipation from the theory. This point should be studied in future. The attenuation of short period fluctuation component caused from the dimension of the sensor is not so large because equivalent averaging time is about 0.15 sec and is smaller than avraging time of 1/4 sec used in this analysis. (The equivalent averaging time can be estimated as (dimention)/(mean wind speed).)

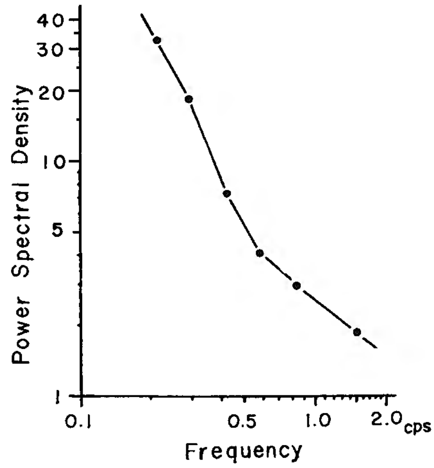

Fig. 3. Power spectrum of vorticity near the ground, (Shown in arbitrary unit).

The vorticity transport was also computed from the data and time change of the cross term is shown in Fig. 2. The mean transport was about 37 cm/ sec^{-2}. (The cross term is shown in arbitrary unit in the figure.) The values of cross term are positive (upward flux) at almost every moment. This is in quite different condition from the feature of momentum transport. In case of momentum transport the instantaneous value of $u'w'$ shows large fluctuations around the zero line and the mean value is only a small residue of it.

4. Conclusion

The direct measurement of vorticity by the sonic anemometers is proved to be sucessful by the test observation. This method will be useful technique of the studies on atmospheric turbulence. And this method can be also applied to the vorticity measurement in the horizontal plane.

References

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