N72-25382

PRECEDING PAGE BLANK NOT FILMED

FIELD TESTS OF THE OPTICAL CROSS-BEAM SYSTEM

V. A. Sandborn

Colorado State University

ABSTRACT

Recent detailed evaluation of the use of an optical cross-beam system to measure convective wind velocities are reported. Low level measurements, where the optical system is looking at either the earth surface or cloud banks, are demonstrated. Further information on the nature and scale of the light fluctuations is reviewed.

1. INTRODUCTION

The measurement of convective wind speeds with the optical cross-beam system is demonstrated by Montgomery (1969). These preliminary measurements were limited to clear skies at elevations of 61 meters or greater. Operation of the optical system under cloudy skies had proven difficult, due to the extreme large variation in light intensity. In recent experiments it has been found that sufficient light fluctuations are present at low levels to allow operation even against distant cloud backgrounds. The present paper demonstrates the operation of the optical system during the cloud conditions.

2. FIELD TESTS

Field tests of the ground based cross-beam system were conducted at a Colorado State University meteorological field site on the St. Vrain Creek in northeastern Colorado. The general location is in the North Platte River Valley. It is located approximately 15 miles east of the first pressure rise of the Rocky Mountains. A 61 meter high tower is set up at the site.

The optical instruments and general arrangement of the equipment are reported by Montgomery (1969). (See first paper, Section 8, this volume)

2.1 Measurements with Ground and Cloud Backgrounds - The report of Montgomery (1969) has demonstrated the operation of the cross-beam system for ideal sky conditions. Current measurements are presently being conducted to evaluate the system operation during adverse light conditions. Two conditions; one looking at distant hills and the other looking at distant cloud banks, have been investigated. At low levels the amount of light fluctuation due to scattering is much greater than at high levels. Thus, the cross-beam system is found to give good results for these two adverse conditions.

The magnitude and frequency of light fluctuations are found to change with time and from day to day. However, at no time are the fluctuations found to be absent. Figure 1 shows a typical trace of the fluctuations in light seen by a telescope. Figure 1 is from a telescope looking in a south direction at an elevation of 52° 12' above the horizon. The light fluctuations are from a band of 4500 to 6500 Å in optical wave length. Figure 2 shows the energy spectra of the light fluctuations measured both for the trace shown in Figure 1 (noted as Unit No. 1 on Figure 2) and for the second telescope that was looking into the north sky. The spectral function is defined as

$$\int_0^\infty F(f)\, df = 1 \quad . \tag{1}$$

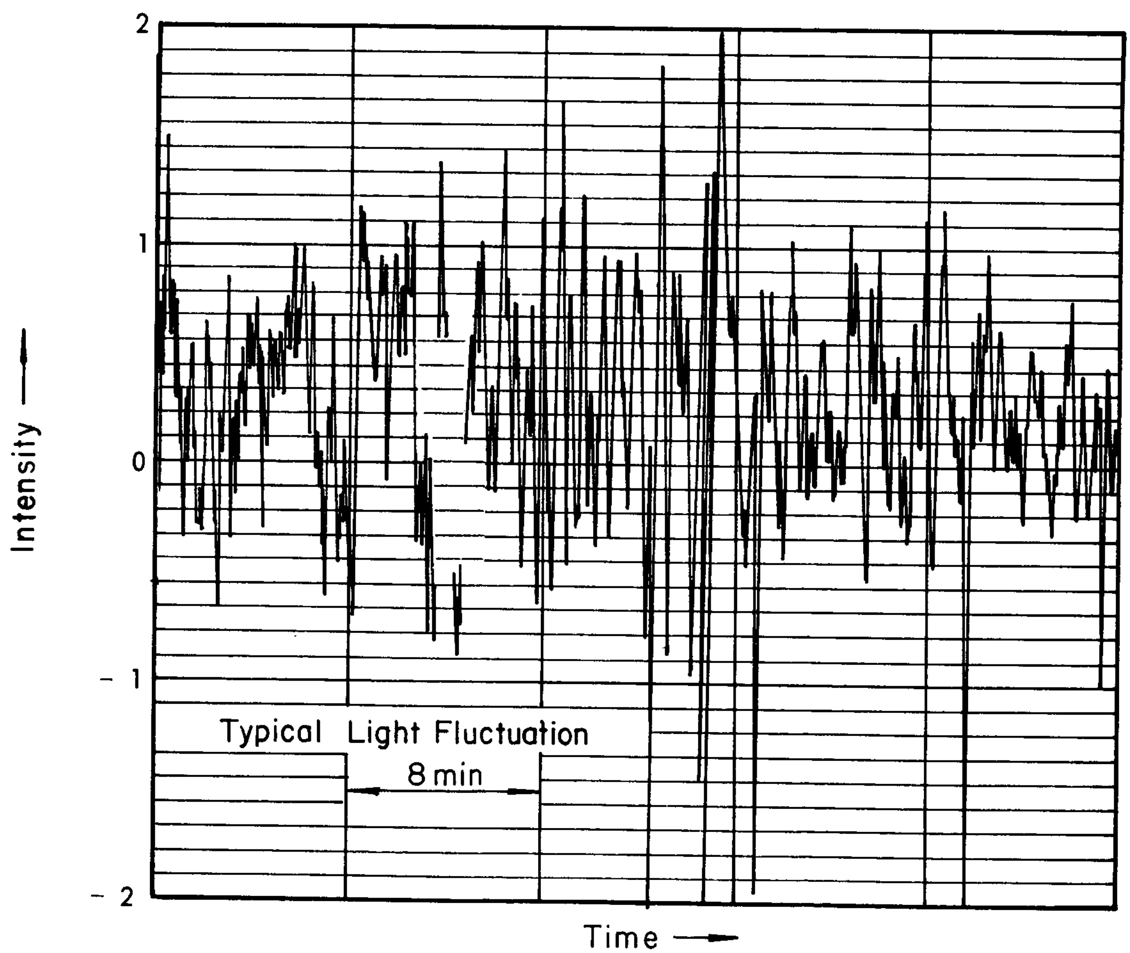

Figure 1. Typical light intensity fluctuations.

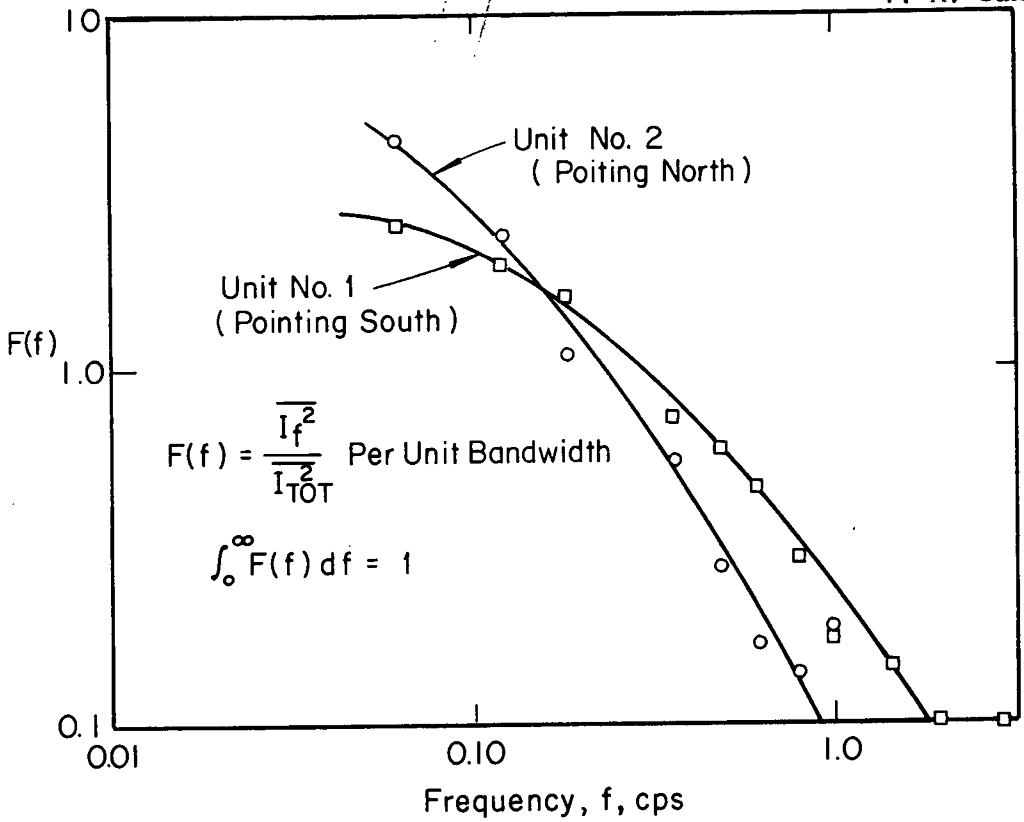

Figure 2. Spectra of light fluctuations.

Using the Taylor turbulent scale definition

$$L_x = \int_0^\infty R_x \, dx \tag{2}$$

together with the Fourier transformation

$$F(f) = \frac{4}{U} \int_0^\infty R_x \cos \frac{2\pi f x}{U} \, dx \tag{3}$$

where R_x is the x-distance correlation and U is the wind velocity, the turbulent scale may be written as

$$L_x = \frac{F(o)U}{4} \tag{4}$$

where $F(o)$ is the value of $F(f)$ at zero frequency. The spectrum curve of Figure 2 does not go to zero frequency; however as a first approximation the maximum value of $F(f)$ might be used. For Unit No. 1 $F(f)_{max} \simeq F(o) \simeq 3$. For a wind velocity of approximately 15 meters/sec measured with cup anemometers at the time the recording was taken, equation (4) gives a scale length of 11.2 meters. This indicates that the fluctuations that dominate the record of Figure 1 come from heights of the same order of magnitude as the turbulent scale. Thus, the major part of the fluctuations most likely come from the first 10 or 20 meters in the atmosphere.

Figure 3 shows an autocorrelation curve for the signals of Figure 1. Using the transformation, Ut = x, the autocorrelation is equivalent to the space correlation R_x. Evaluation of L_x from equation (2) and the autocorrelation curve give a scale of 10.8 meters, which is in good agreement with the spectrum measurements. The autocorrelation curve falls to zero correlation after 5 seconds, indicating information on scales as great as (5 x 15) 75 meters are contributing to the signal. Thus, there is information in the light fluctuations from high elevations as well as from the lower levels.

Figure 4 shows a cross-correlation curve for the two light beams operating parallel to the ground. Both beams are looking at the distant hills beyond the river valley. The cross-correlation was obtained with a Princeton Research Associates time correlator. The two beams are separated by a distance of 67.8 meters. The common volume of the two beams is 209.8 meters. This is a very large volume of common intersection; however, the cross-correlation coefficient reaches a maximum of 0.10. The small correlation coefficient is due to the large magnitude of background fluctuations which are not correlated. The delay time to peak correlation agrees well with the observed wind velocity of approximately 10 meters per second. This run shown in Figure 4 was taken on a very cloudy day. If the overall light level were fluctuating along with the local levels seen by the beam, a peak in the correlation curve would also be observed at zero time delay. Zero time delay peaks have been observed for runs such as shown in Figure 4.

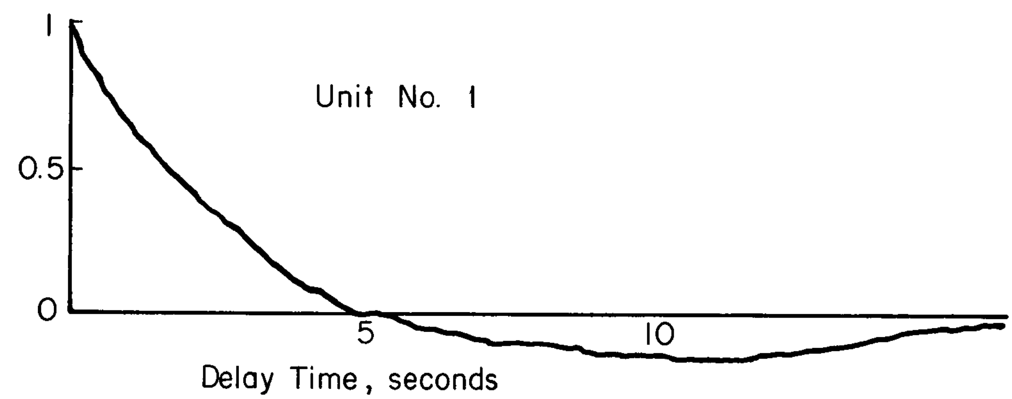

Figure 3. Autocorrelation of the light fluctuation.

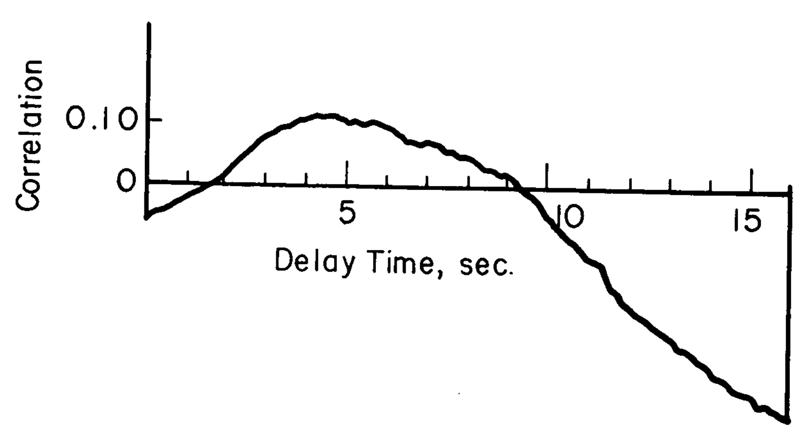

Figure 4. Cross correlation for two beams separated by 67.8 meters and parallel to the ground at a height of approximately 3 meters.

Figure 5 shows a cross-correlation curve for the two light beams operating at a low level of elevation (No. 1 Unit 6^{o} 28', No. 2 Unit 7^{o} 54'). The height of their common intersection point is 13.1 meters. The two beams are separated by 67.8 meters. Both beams are looking into clouds. Although the light fluctuations were very large for this particular test run, the peak of the cross-correlation curve is at the right time for a wind velocity of approximately 5 meters per second. One of the major difficulties encountered with the cross beam application to the atmosphere has been the large dynamic range of the light fluctuations. The present electronic operation of the photodiodes is not adequate to handle large fluctuations caused by clouds. Only near the surface, where there are large local light fluctuations, can the instruments be operated in the presence of clouds. Modification of the electronic circuits should improve the operation of the system in the presence of clouds.

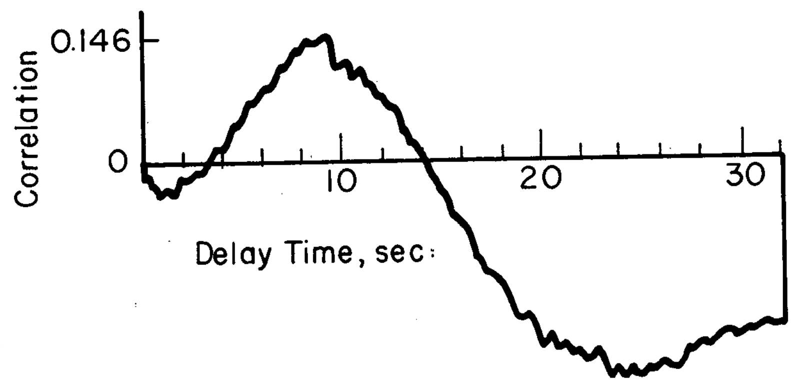

Figure 5. Cross correlation for two beams separated by 67.8 meters at a height of 13.1 meters.

3. RECOMMENDATIONS

The cross-beam technique has been demonstrated to measure convective velocities of the wind under specific conditions. It is important to keep in mind the fact that this technique may be employed with almost any atmospheric sensing instrument. The correlation technique could produce a convective velocity for any tracer that can be sensed by optical, infrared, or micro-wave techniques.

3.1 Continuing Studies - The optical cross beam system is presently being compared with cup anemometers. The system will be developed and evaluated by a means of measuring local velocity distributions above the surface.

3.2 Future Studies - The optical cross beam system should be able to evaluate a great deal of information about the turbulent structure of the atmosphere. Further studies of the measurement of the scale of turbulence from cross correlation data will be undertaken. The cross beam measurements are to be compared with turbulence evaluated from hot-wire anemometer data.

3.3 Special Facilities - The field tests are being run through the joint cooperation of NASA and ESSA. Further studies will be conducted at the ESSA Gun Barrel hill site. A special digital converter system is being developed to improve the evaluation of the measurements.

4. CONCLUSIONS

The cross beam optical system has been proven as a technique to measure convective winds in the atmosphere. It is also demonstrated that low level winds can be measured using either surface or cloud backgrounds. Further development of the instruments should make it a very flexible measuring tool.

ACKNOWLEDGMENTS:

The field tests reported in this paper were conducted under NASA Contract DCN 1-7-75-20042 (IF) for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The work is administrated under the technical direction of the Aero-Astrodynamics Laboratory with Dr. Fritz Krause acting as project manager.

REFERENCE

Montgomery, A. J., 1969: Remote sensing of winds and atmospheric turbulence by cross correlation of passive optical signals, Atmospheric Exploration by Remote Probes, Vol. 2, National Academy of Science - National Research Council, Washington, D. C.