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NOAA Technical Memorandum ERL WPL-13

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Environmental Research Laboratories

Development, Calibration, and Field Tests of Portable Atmospheric Acoustic Echo Sounders Final Progress Report

F. F. HALL, JR.

Wave
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Laboratory
BOULDER,
COLORADO
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DEVELOPMENT, CALIBRATION, AND FIELD TESTS OF PORTABLE ATMOSPHERIC ACOUSTIC ECHO SOUNDERS

FINAL PROGRESS REPORT

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National Oceanic &
Atmospheric Administration
U.S. Dept. of Commerce

F. F. Hall, Jr.

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Wave Propagation Laboratory
Boulder, Colorado
April 1975

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UNITED STATES DEPARTMENT OF COMMERCE
Rogers C.B. Morton, Secretary

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CONTENTS

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FINAL PROGRESS REPORT ROME AIR DEVELOPMENT CENTER PURCHASE ORDER #F30602-73-F-0122

F. F. Hall, Jr.

1. INTRODUCTION

This is the final progress report on the subject purchase order to the Wave Propagation Laboratory, NOAA. The objectives of this investigation were to: (1) measure the backscattering of acoustic energy under field conditions with readily portable acoustic echo sounders, (2) determine how well the acoustic sounding backscattered intensity correlated with in situ measurements of the temperature constant C_T^2, and (3) build and deliver two portable sounders to the U.S. Air Force. These three objectives have all been completed. The following sections of the report provide details on the accomplishment of these objectives.

2. EXPERIMENTAL FIELD MEASUREMENTS OF ACOUSTIC BACKSCATTER

A number of field investigations with the NOAA developed Sounder In A Suitcase first model (SIAS I) and second model (SIAS II or Mark VII design) were performed during the course of this investigation. The SIAS I design is described in NOAA TR ERL 298-WPL 31 by Owens (1974) (Reference I). A listing of these field investigations follows:

Location	Date	Total Number of Days
Miami Beach, Florida	22-23 Jan 1973	2
West Palm Beach, Florida	24-26 Jan 1973	3
Table Mountain, Colorado (Calibration)	15-16 Feb 1973	2
Kirtland AFB Albuquerque, N.M.	19-23 Mar 1973	4
AFCRL experiment site Donaldson, Minnesota	16-18 Aug, 18 Sep 1973	4
Haswell, Colorado	18-29 Mar 1974	11

Location	Date	Total Number of Days
Boulder, Colorado	27 May-21 Jun 1974	20
Jackass Flats, Nevada	17-19 Oct 1974	3
		49 days

Total 49 days or approximately 10 weeks.

3. EVALUATION OF ACOUSTIC ECHO SOUNDING DATA

The tests in Florida were for the purpose of determining C_T^2 structure in a subtropical environment and specifically at the Pratt and Whitney test range in West Palm Beach. During the five days of testing there were significant problems with side lobe echoes from trees and structures that appeared in the lowest 40 m on the facsimile chart. There was very little evidence of convective plume structure, a result not too surprising considering the small temperature contrast between air and surface of the terrain. In addition, at the Pratt and Whitney test site, the local noise level was so high, because of the continuous tests of jet engines, that no quantitative data could be extracted from the magnetic tapes. It was learned in these tests that it would be extremely important to carry with the portable sounder some sort of absorbing cuff to limit side lobe echoes and to improve rejection of background noise levels. Quantitative data could not be obtained from these tests, either by the facsimile recorder or from the magnetic-tape-recorded data (using a single-track cassette, battery-powered Norelco unit).

The Table Mountain calibration tests were designed to compare the sounder returns with <u>in situ</u> measurements of C_T^2. A pair of fine wire temperature sensors was installed on a 20-m pole while the sounder operated at the base of the pole. The two one-half-hour records of recorded data are now believed to be too short to obtain a meaningful average of C_T^2 under convective plume conditions as documented by Neff (1975) (Reference 2). The ringing time of the sounder after a pulse was transmitted was also too long to allow direct comparison at the 20-m height where the <u>in situ</u> sensors were installed. It was planned to extrapolate this calibration on the assumption of C_T^2 decreasing as $z^{-4/3}$.

On the assumption that the Table Mountain calibration was correct, the sounder was taken to the Kirtland Air Force Base . Albuquerque during March 1973. Data were tape recorded on four different days and some facsimile records were obtained on an additional day before bad weather stopped the tests on 23 March. The data recorded on the Norelco cassette tape were analyzed in hope of comparing them with the two sets of in situ C_T^2 sensors on the 30 m tower at the Sandia Optical Range. An analysis of the probability distributions of sounder C_T^2 indicates an obvious saturation of the data at the higher values (probably in the tape recorder). That is, the expected log normal distribution was not obtained, with significant departures in the higher C_T^2 value range. In addition, the data did not behave properly with height, indicating either a high background noise level or excessive ringing of the transducer. Thus, the tower was really too short to be within the minimum range of the sounder because the high noise level prevented an extrapolation downward. An example of the probability distribution of sounder derived C_T^2 data is given in Figure 1 , with the corresponding histogram of these data in Figure 2. When attempts were made to scale these data with the Table Mountain calibration, it was apparent that the gain settings for the two experiments, although noted in the log books as identical, simply could not have been the same. The values of the "similar condition convective plume" C_T^2 differing by several orders of magnitude. Obviously, something was very wrong with either the Table Mountain calibrations or the equipment setup at Albuquerque. However, excellent facsmile recordings were obtained documenting the classes of C_T^2 structure during the Albuquerque tests. Copies of these facsmile records were distributed to both the Sandia Optical Group and to RADC to document the test conditions and the relative frequency of thermal plumes.

At the request of RADC, the sounder was taken to the site of the AFCRL experiment at Donaldson, Minn. during the summer of 1973. Facsimile records were provided to the AFCRL group to document the

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C_T^2 structure during several nights and days of their tower and tethered balloon tests. The cuffed antenna sounder functioned well at this quiet site and the facsimile records showed inversion structures rising with the diurnal heat input.

The SIAS I sounder was carefully recalibrated during a series of tests at Haswell, Colorado in March, 1974. An absolute calibration was provided by a sound source on the tower. Data were recorded on instrumentation quality tape recorders. This calibration information was later supplied with the two SIAS II units for the Air Force.

The SIAS II units were operated at Boulder in May and June of 1974 before delivery to the Air Force. The sounders were operated by AFCRL in Nevada during October, during which time W. D. Neff visited the site and assisted with further calibration and computer program improvements. At the end of these tests, the SIAS II sounder measured values of C_T^2 compared with *in situ* measurements on the Bren tower to within a factor of two. This is in agreement with the carefully documented absolute measurements of C_T^2 documented by Neff in Reference 2.

Data gathered during an experiment in August 1972 at the Haswell, Colorado field site have now been extensively investigated to determine how accurately the measurements of the backscattered acoustic intensity depict C_T^2 structure in the atmosphere. Neff (1975) described in considerable detail the results of this data evaluation. It is concluded that the scattering equation for acoustic energy is essentially correct and that acoustic sounders can measure C_T^2 in the atmosphere within a factor of two during most conditions of static instability or of slight static stability with strong wind shear. During conditions of strong static stability and weak wind shear it is necessary to insure that short enough sounder pulses are used to completely resolve the high C_T^2 in the thin shear layers.

4. CONSTRUCTION OF THE SIAS II SOUNDERS

The Sounder In A Suitcase model II, also known as the NOAA Mark VII Acoustic Echo Sounder, was produced in two copies and delivered to Air

Force Cambridge Research Laboratories, on the instruction of RADC, in June, 1974. The operating manual and the circuit diagrams for the sounder are provided in NOAA Technical Memorandum ERL WPL-12, "NOAA Mark VII Acoustic Echo Sounder." (Reference 3). The Wave Propagation Laboratory has maintained contact with Dr. Haugen's group at AFCRL on their experiences in operating the sounder in Hawaii and in Nevada. As previously mentioned, W. D. Neff visited the Nevada site and aided in the interpretation and processing of the data, to the satisfaction of AFCRL.

5. CONCLUSIONS

It is concluded that light-weight, readily portable atmospheric acoustic echo sounders can be designed, constructed, calibrated, and operated reliably under field conditions. The acoustic echoes received in the monostatic geometry can be taken as a measure of C_T^2 in the atmospheric boundary layer.

6. REFERENCES

1. Owens, E. J., Development of a Portable Acoustic Echo Sounder, NOAA Technical Report ERL 298-WPL 31, Boulder, Colo., May, 1974, 41 pp.
2. Neff, W. D., Quantitative evaluation of acoustic echoes from the planetary boundary layer, NOAA Technical Report ERL 322-WPL 38, Boulder, Colorado, June, 1975, 34 pp.
3. Owens, E. J., NOAA Mark VII Acoustic Echo Sounder, NOAA Technical Memorandum ERL WPL-12, Boulder, Colorado, June, 1975, 71 pp.

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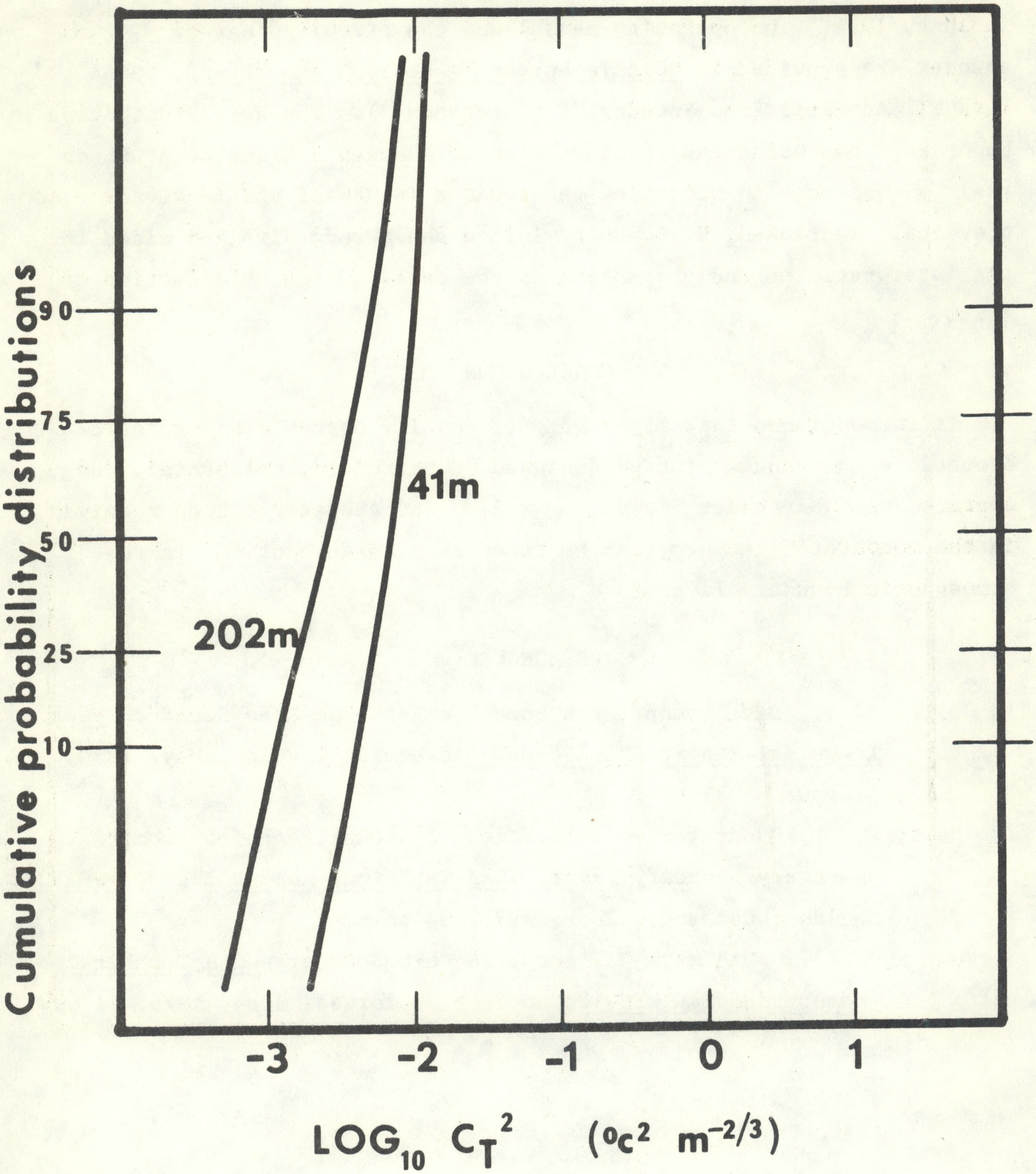

PROBABILITY DISTRIBUTION OF SOUNDER C_T^2

FIG. 1

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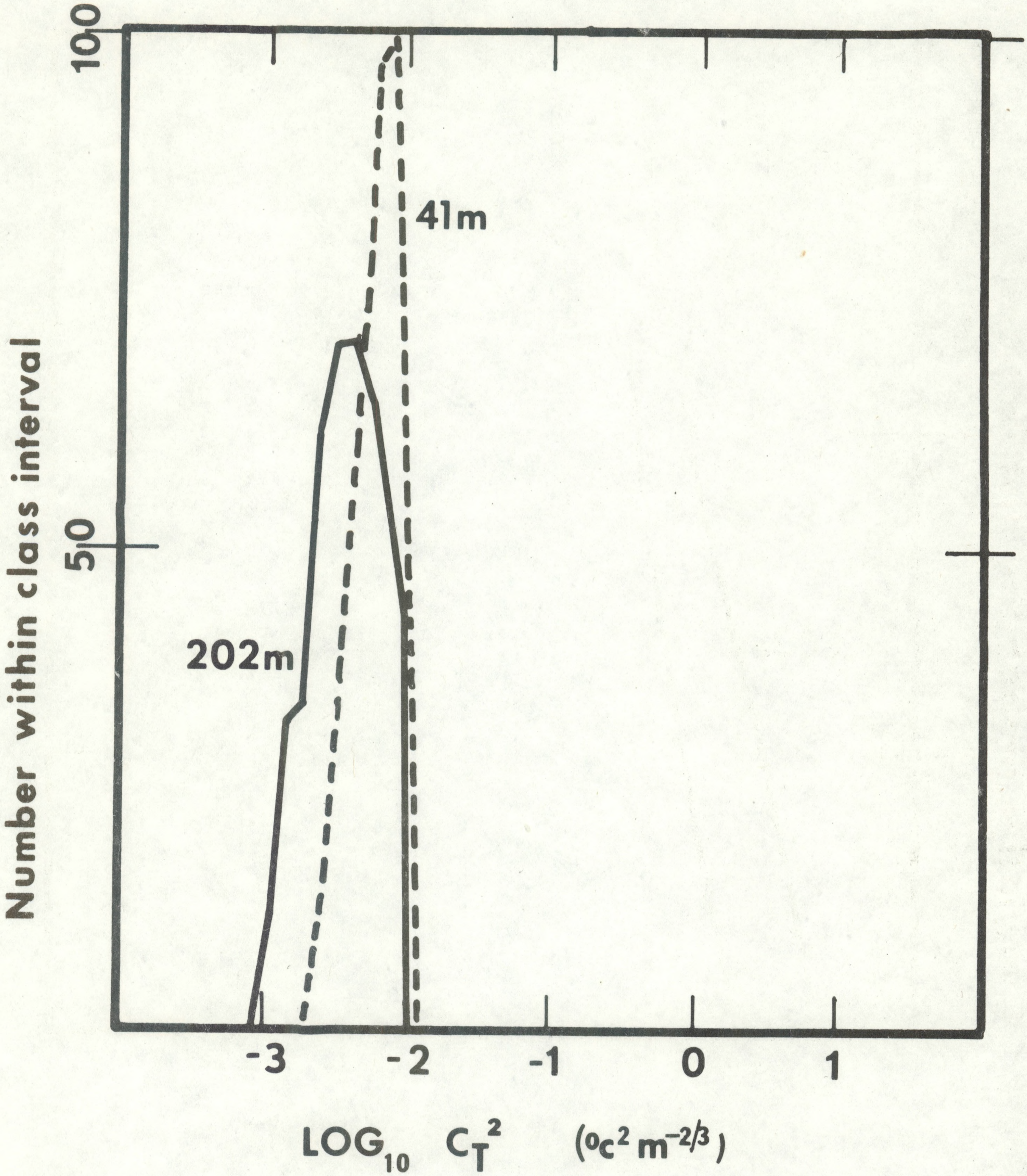

HISTOGRAM OF SOUNDER C_T^2

FIG. 2

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