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Prepared by
Center for Experiment Design and Data Analysis
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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PREFACE

This is the last issue in the BOMEX Bulletin series. The delay in getting it out has been considerable, but it was thought desirable to wait with publication until most of the other BOMEX tasks for which the Center for Experiment Design and Data Analysis (CEDDA) has been responsible had been completed. The major one among these has been, of course, the validation and archiving of the BOMEX data, which are now available from the National Climatic Center (NCC) in Asheville, N.C. Descriptions of the processing methods, and inventories of the archived data, are contained in NOAA Technical Report EDS 12, issued in May 1975.

It seems appropriate to publish in this last issue, as a matter of "historical interest," the Final Report of the BOMAP Advisory Panel, dated May 1973. In the first part of that report, the Panel members correctly anticipated that the experience gained by CEDDA--the "EX" in BOMEX--would yield benefits later. This has been true in the case of both the 1972-73 International Field Year for the Great Lakes (IFYGL) and the 1974 GARP Atlantic Tropical Experiment (GATE). The data from the major U.S. IFYGL collection systems have been fully processed and placed in the IFYGL Archive at NCC. CEDDA's close involvement in the planning and in the field phase of GATE, as well as in the data processing, has paid off in terms of a much more demanding (yet attainable) data processing schedule than was true of BOMEX. Practically all our resources are now being applied to meeting that schedule.

In Part B of the BOMAP Advisory Panel report, I reviewed the history of BOMEX and BOMAP (the Barbados Oceanographic and Meteorological Analysis Project). One question I raised at the time dealt with the responsibility for providing a comprehensive scientific synthesis of BOMEX. This question I am now personally addressing in a technical report which will review the major findings as reflected in the more than 200 BOMEX-related papers that have, so far, appeared. A second question, concerning the lack of focus in the analysis of the Tropical Convection Program during the fourth BOMEX observation period, is being ameliorated in a wave of current work including that by Martin and Sikdar at the University of Wisconsin, Bluestein at MIT, and Zipser and his coworkers at the National Center for Atmospheric Research.

The last three of the BOMEX atlas publications are currently in press: BOMEX Period III Radar-Satellite Atlas, BOMEX Rawinsonde Atlas, and BOMEX Atlas of Low-Level Atmospheric Data. The radar precipitation analysis was published recently in NOAA Technical Report EDS 13, and another technical report is forthcoming on the BOMEX Core Experiment analysis, for which the budget calculations are complete. With these things done, BOMAP will be behind us. However, the analytical work being continued elsewhere, particularly in the testing of convection parameterization models by Nitta and Esbensen at UCLA, Ogura, Cho, and Soong at the University of Illinois, Betts and his coworkers at Colorado State University, and others, testifies to the usefulness of the BOMEX data. This usefulness may even increase as GATE data become available for comparative studies of the atmospheric and oceanic processes over the eastern and western tropical Atlantic Ocean.

Joshua Z. Holland
Director, CEDDA

NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING

2101 CONSTITUTION AVENUE WASHINGTON, D.C. 20418

U.S. COMMITTEE FOR THE
GLOBAL ATMOSPHERIC RESEARCH PROGRAM
DIVISION OF PHYSICAL SCIENCES

October 11, 1973

Dr. Robert M. White
Administrator
National Oceanic and Atmospheric Administration
Department of Commerce, Room 5130
Washington, D.C. 20230

Dear Bob:

It is with pleasure that I informally transmit the final report of the BOMAP Advisory Panel which reported to the U.S. Committee for the Global Atmospheric Research Program (USC-GARP) at its September meeting.

With the approval of the officers and members of the Committee, this report is being provided for the further assistance and guidance it will provide you for the completion of the BOMAP activity, and to the subsequent and related activities of NOAA and others in the developing plans for U.S. participation in the Global Atmospheric Research Program.

I believe the BOMAP Advisory Panel has proved very helpful during the course of the BOMAP activities and has carried out its responsibilities with a high degree of dedication, purpose and achievement. This is an area of crucial importance to the science, which you have long recognized. Further, it is the primary responsibility of the government to assure the excellence of its continuing work in data processing and management. Many lessons have been learned as a result of this activity. The job required to execute it well has proved to be bigger and of longer duration than anyone had earlier contemplated. And there is still a significant way to go before it gets fully in hand.

You will note that the Panel's report has identified several tasks that remain for the BOMAP to be truly effective and complete in its activities, and which, no doubt, will become basic tenets for the continuing work and role of CEDDA in its future activities. The work still before CEDDA is clearly identified, and these and our earlier recommendations should be given deliberate and careful attention.

As you will note, copies of this report are being provided other appropriate offices in NOAA, as well as to those in NSF and NASA, whose cooperation and assistance can also contribute to the excellence of the execution of this federal task.

The support of NOAA and NSF during the work of the BOMAP Advisory Panel is fully appreciated, as was the prompt, attentive and positive response of the personnel at CEDDA and NOAA management to the evolving suggestions and recommendations of the Panel over the past several years.

Sincerely yours,

Verner E. Suomi

Verner E. Suomi
Chairman, U.S. Committee for the Global Atmospheric Research Program

Enclosure

cc: Prof. Robert G. Fleagle
GATE Project Office, NOAA
CEDDA, NOAA
GARP Project Office, NASA
GARP Project Office, NSF

FINAL REPORT OF THE BOMAP ADVISORY PANEL

U.S. COMMITTEE FOR THE GLOBAL ATMOSPHERIC RESEARCH PROGRAM

National Academy of Sciences
National Research Council
Washington, D. C.

July 1973

BOMAP Advisory Panel Members

Robert G. Fleagle, Chairman, University of Washington

Alfred K. Blackadar, Pennsylvania State University

Charles S. Cox, Scripps Institution of Oceanography

Thomas O. Haig, University of Wisconsin

Noel E. LaSeur, Florida State University

John M. Wallace, University of Washington

Edward J. Zipser, National Center for Atmospheric Research

Final Report of the BOMAP Advisory Panel

Part A: Report of the Panel

Part B: Report of the Director, BOMAP

PART A

Report of the BOMAP Advisory Panel

Membership

Robert G. Fleagle, Chairman
Alfred K. Blackadar
Charles S. Cox
Thomas O. Haig
Noel E. LaSeur
John M. Wallace
Edward J. Zipser

PART A

Contents

I. Introduction

Upon initiation of the Barbados Oceanographic and Meteorological Analysis Project (BOMAP) in August 1969 the objectives were identified as follows:

(1) To reduce all data collected in BOMEX under BOMEX Project Office direction and make it available to all investigators.

(2) To complete analysis of the BOMEX "Core Experiment" (comparison of estimates of sea-air exchange of energy by the line integral, budget, and aerodynamic methods with direct measurements by eddy-convariance methods), for which ESSA, through the BOMEX Project Office, provided the Principal Investigators, and for which the ship and aircraft arrays and operating schedules during the first three operational periods of BOMEX were designed.

(3) To provide a central contact point and information exchange for all BOMEX investigators during the data reduction and immediate analysis period, and to provide a channel for unified publication of BOMEX experimental methods and results.

The BOMAP Advisory Panel was appointed by J.G. Charney, Chairman of the USC/GARP, in November 1969 to (1) review the program of analysis, and (2) facilitate exchange of all BOMEX data.

The Panel has met on five occasions for two days each and has reported after each meeting its findings and recommendations for insuring that the BOMAP objectives are achieved. These reports were transmitted to the Director of BOMAP, the Administrator of NOAA, and to the Chairman of the USC/GARP.* The Panel has been concerned especially with two issues: manpower quality, and carry-over of BOMAP capabilities to subsequent national programs. We are now satisfied that these issues have been adequately and properly cared for. Our over-all assessment at this time is that the objectives can be achieved under the program now in progress and nearing completion, and that the Center for Experimental Design and Data Analysis (CEDDA), which was created from BOMAP in 1971, is a strong, well-organized unit which should be invaluable in planning and data processing for GATE.

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*1. Memo to Director, BOMAP, January 19, 1970
2. Memo to Director, BOMAP, September 30, 1970
3. Memo to Director, BOMAP, July 7,1971
4. Letter to Administrator, NOAA, June 5, 1972
(with cc to Director, BOMAP; and Chairman, USC-GARP)
5. Letter to Chairman, USC-GARP, July 24, 1973 (transmittal of final report of Panel)

Analysis of BOMEX data is still in progress by CEDDA and by many of the individual principal investigators in other institutions. It is too early to attempt a final assessment of results of the whole experiment. On the other hand, completion of the central CEDDA tasks of data archiving and calculation of surface fluxes from the Core Experiment are in sight, and the outlines of the major results of BOMEX probably can be seen. However, completion of the Core Experiment calculations based on budget equations must await final processing of the rawinsonde data. Arrays of technical memoranda, atlases, and scientific papers have been published by CEDDA, and others are in progress. An appraisal of BOMEX results has been published by Fleagle (1972), and Hidy (1972) has included comments on BOMEX in his review of air-sea interaction research. CEDDA plans a final BOMAP report for completion by mid-1974.

Organizational aspects of BOMAP and later of CEDDA have presented difficulties. The unit was organized and objectives assigned after the field experiment, initial staffing was carried out largely by transfers from other NOAA units, the staff was not familiar with many aspects of the observing procedures, and the staff required considerable training and experience in data processing techniques. A great many corrections to data had to be made by hand, and correction techniques had to be devised and perfected.

BOMAP was assigned responsibility both for data processing and archiving and for analysis of Core Experiment data. This dual responsibility has constituted a problem for management, and the effectiveness of this organization has been a subject of discussion at Panel meetings. The Panel's view is that coupling of the two responsibilities has been necessary and valuable in BOMAP. It has contributed substantially to staff morale and has helped to insure a high level of quality control. It is doubtful if the Core Experiment analysis could have been carried out in any other way.

CEDDA is now organized into a division of data processing and a division of analysis with clearly defined responsibilities and schedules for completion of tasks. This organization should enable CEDDA to carry to completion its BOMAP responsiblities over the next year while undertaking increasing responsibilities for other major field programs. Further evolution of the structure of CEDDA may be appropriate in order to carry out data processing for GATE.

The Summary Report by J. Z Holland, which accompanies this report, reviews the history of BOMAP and its present status from the perspective of BOMAP.

II. Functions of BOMAP: Achievements and Work Remaining

2.1 Archiving

Among the principal objectives of BOMAP has been to:

"Reduce all observations taken under BOMEX Project Office scientific direction, consisting of data taken from:

(a) Ship's holding station in the array;

(b) Aircraft flights in support of the Core Experiment and the BOMEX Tropical Exploration Program;

(c) Island stations operating under BOMEX Project Office direction.

....

"To archive all BOMEX data for the benefit of the general scientific community so as to insure proper:

(a) Storage with minimal degradation of information content;

(b) Prompt retrieval;

(c) Dissemination.

Reduction and archiving of the ship STD and boom data, BLIP, aircraft, dropsonde, radar, and satellite data are essentially completed. All four periods of rawinsonde data will be processed by September 30, 1973, and this will conclude the archiving task. Data not processed as part of BOMAP are in the hands of the several responsible investigators, and the status of these data varies from case to case. Certain problems associated with these data are discussed later in this report.

In reviewing the BOMAP archiving effort, several important points should be mentioned:

(1) CEDDA has developed excellent formats for data archiving, Most data can be retrieved in either graphical or tabular form.

(2) The magnitude of the archiving task was not fully appreciated at any time during planning. All estimates of resources or time required to complete the archiving task have been exceeded. The amount of hand work required to reduce and validate data has been much greater than expected.

(3) The archiving task was complicated because the personnel, the software, and the procedures needed to examine, test and qualify the data had to be assembled or invented. If the same data set were presented to the present CEDDA organization, it would take only a few months to reach the same level of archive achievement.

2.2. Atlases and Data Summaries

Preparation of atlases and data summaries has proceeded at a steady and impressive rate. The following atlases have been published:

BOMEX Field Observations and Basic Data Inventory. March 1971.

BOMEX Period III High-Level Cloud Photography Atlas. May 1971.

BOMEX Atlas of Satellite Cloud Photographs, V.A. Myers. July 1971.

BOMEX Period III Upper Ocean Soundings, V.E. Delnore. In Press.

The technical quality of these publications is high, and they should be of great value to later investigations of the tropical ocean. Their appearance within about two years of BOMEX is especially noteworthy. The following atlases are in preparation:

BOMEX Period III Radar-Satellite Atlas

Boom and BLIP Time Series

Synoptic Scale Weather Maps

Radiosonde Time Cross Sections

The data available in the BOMEX Temporary Archive were documented in January 1972 as NOAA Technical Report EDS 10 (ed. Terry de la Moriniere). The BOMEX Permanent Archive will be described in a publication planned for mid-1974.

2.3 Core Experiment Analysis

Calculation of mean fluxes for the BOMEX area during the months of May and June from the budget equations for water vapor, heat, and momentum has been one of the major responsibilities of BOMAP. The associated data processing task has proved to be enormous, and it appears that observational failures and errors will limit calculations to about 19 days. Some of the lessons learned from this experience are reviewed later in this report.

Trial calculations using the A_0 (preliminary) data have been completed for a period of 5 undisturbed days (virtually no precipitation) and a period of 2 disturbed days (precipitation at an average rate of 3.7 mm/day over the area). Calculated values of average vapor flux at the sea surface for these two periods are considered accurate to within 20 percent. Calculations have yielded vertical profiles of horizontal velocity divergence, vertical transfer of horizontal momentum (horizontal stress), and other quantities which are not directly measurable. These calculations have served to validate the procedures for correcting and processing data and for performing calculations. Upon completion of the A data set for all valid data, anticipated by September 1973, budget calculations can be carried out in a matter of a few days.

Rawinsonde observations have provided the primary data used in the budget calculations. Aircraft data have been useful in determining that horizontal eddy flux terms were negligible for the periods analyzed, and cloud photographs from aircraft have been valuable in verifying data and in describing and defining mesoscale features. Dropsondes have not been useful to the budget calculations.

A scheme has been developed for carrying out budget calculations using base data distributed nonuniformly in space and time. This scheme fits linear combinations of analytic base functions to the data; and it yields space-time derivatives, integrals, estimated variances, and confidence limits. The scheme has been tested successfully using the 7 days of budget calculations. It should be very valuable in coping with the variety of data expected in GATE.

The Panel is assured, that, even though the major portion of the budget calculations remain for the future, they will be carried out expeditiously upon completion of the A (final) data set.

2.4 Coordination and Data Exchange

Expecially since the establishment of the Temporary Archive in February 1971, BOMAP has succeeded to a rather high degree in making the data from BOMEX available to the community at large. Prior to that time, despite a fully cooperative attitude on the part of the BOMAP staff, information exchange was hampered by the need for personal service to outside users. The Temporary Archive, combined with the invitations to students to visit, resulted in more widespread use of the data, and the personal involvement of the BOMAP staff in helping others was very important to the success of many of these users in getting worthwhile results.

The maintenance of a directory of all participants and projects and the regular appearance of the BOMEX Bulletins and Technical Memoranda was an important and successful step in information exchange. In serving as a clearinghouse for information, BOMAP has consistently given service when asked. In the possibly competitive situation between "in-house" and "out-house" research, the evidence is strong that there was, if anything, preference given to outside scientists.

Upon completion of the data archive and publication of the atlases which are planned, access of the scientific community to BOMEX data should be easy and straightforward. However, maintenance of a "mailing address," and someone to answer the mail, will be essential. Use of BOMEX data may well increase when the archive is completed. New customers especially will require a certain amount of personal service.

2.5 Development of Data Handling Capabilities

It is clear that the data processing capability of CEDDA represents a national resource which has long been needed to support large-scale environmental observation programs, and that CEDDA will be used for data processing for IFYGL, GATE, DST, FGGE, and in all probability, a continuing series of such programs. The data processing costs for these later programs should be reduced significantly, both because CEDDA need not be duplicated and because CEDDA personnel can improve data processing efficiency by participating in early program planning.

III. Critical Issues and Recommendations

3.1 Completion of Core Analysis

Processing of data for the Core Experiment analysis has absorbed a large fraction of BOMAP energies, and successful completion of this task has been a major focal point of Panel interest. The Panel is disbanding before BOMAP has completed the Core Experiment analysis. We are assured that the calculations will be carried out as soon as the A data set is completed and that this elusive milestone is in sight. Despite some concern on this matter, we are impressed with CEDDA's capability and its determination to see this through. We believe that the Core Experiment must continue to receive the attention of the scientific staff until all budget calculations are completed.

Upon completion, we recommend that a small conference be convened under auspices of the USC/GARP to discuss the results of the Core Experiment.

3.2 Processing, Archiving, and Access to Non-BOMAP Data

The issue addressed here stems from the fact that the Core Experiment was one of approximately 100 experiments carried out in BOMEX under different principal investigators. Data processing for the 99 other experiments has been the responsibility of the individual principal investigators; included here are the data recorded on FLIP, the NCAR Queen-Air, and NASA Convair 990, the FSU tethered balloon and buoy, and the surface observations made on Barbados. BOMAP has not had the resources or the authority to coordinate these efforts or to incorporate all BOMEX data in the Permanent Archive.

Many of the data sets are highly specialized and are in non-standard formats. In some cases processing and interpretation can be done only by the individual principal investigators. For these reasons, it is not feasible to include all BOMEX data in the Permanent Archive. However, as much as possible of these data should be accessible to the scientific community. The Panel believes that in accepting public support for a scientific program, each scientist should recognize his obligation to provide processed data on a reasonable schedule. This is a matter that was never adequately resolved in BOMEX.

The Panel believes that it is essential to determine what data exist, and to provide an efficient method for accessing all the data. To that end, the Panel recommends that CEDDA contact each principal investigator responsible for BOMEX data not already archived at NOAA; and

(a) Identify the data sets, their current status, format, degree of documentation, users, etc.

(b) Document the data so that anyone examining the files to be established can determine what was collected, where it is, what form it is in, and how to access it.

(c) Maintain an index of BOMEX data for use by interested persons.

On the basis of this information CEDDA should decide which data sets, if any, should become part of the Permanent Archive and should take steps necessary to archive the data in appropriate format. At appropriate periods CEDDA should issue a brief updated index of BOMEX data to advise users of the status and accessibility.

3.3 Continuing Responsibilities Beyond BOMAP

With completion of the data processing and transfer of data to the National Weather Records Center, and upon completion of Core Experiment data analysis and reporting, the primary BOMAP program will be completed. Data archives will be managed by other units within the Environmental Data Service. However, there is a need for a focal point to continue to exist to receive, to coordinate, and to respond to queries and requests concerning BOMEX and the BOMEX data. Also, as noted, a continuing pressure to move BOMEX data from the several individual investigators into the archives appears to be needed.

It seems clear that only CEDDA provides the right combination of complete program comprehension, organizational permanence, and motivation required to meet this on-going need. The work load should be small, but it should be recognized as an important portion of the CEDDA mission.

IV. Value to Future Programs: Lessons Learned

4.1 Planning

In addition to the intrinsic results of BOMEX-BOMAP efforts, the experience gained can be of great value to the planning of future observational programs, especially GATE. Some of the lessons learned have been presented in detail by Holland and Williams (1971) and Fleagle (1972). The following are especially important.

(1) Large-scale efforts require several years of planning, funding, organization, execution, and analysis of results; it is essential to have continuity of key personnel throughout all phases of the effort.

(2) Scientific input to the experimental design should be provided early enough that effective operational plans can be developed which will insure the collection of the required data in the required form. This requires redundancy of sensors and of physical principles.

(3) Supervisors for each discrete activity should be appointed who understand the objectives and are able to exercise options to the best interest of the overall objectives.

(4) Preparation for the field program should include: adequate field testing of observational systems and procedures, especially inter-comparison and calibration of different sensor systems; complete and careful documentation of calibrations, inter-comparisons and operating procedures. Real-time processing of some data should be provided in order to detect malfunctions and to insure that the experimental objec-

tives are being met. Carefully written standard operating procedures should be provided, and complete documentation of unanticipated, non-routine events should be required.

(5) A detailed plan for data processing, archiving, and dissemination should be developed. This should reflect the needs of various groups engaged in the analysis of scientific results.

4.2 Data Processing System

CEDDA is now organized in two sections, one concerned with data processing and archiving under Mr. Mitchell, the other concerned with data analysis and the preparation of scientific papers under Dr. Rasmusson. The data processing section represents a unique capability not duplicated elsewhere in NOAA, nor available to the atmospheric research programs from any other organization. The value of the analysis section to the CEDDA function is found in the guidance which the scientists who are involved in using data can give to the data processors.

In planning for processing of the GATE data by CEDDA, careful consideration should be given to systematizing as many processes as possible and to capitalizing on the BOMAP experience in all respects. However, processing of data for GATE will present a new challenge to CEDDA. CEDDA's procedures will have to be developed in phase with requirements of scientific groups coordinated with USC/GARP and the GATE Project Office. Data will have to be processed simultaneously for several scientific programs of equal importance, and parallel scientific inputs will be needed from appropriate groups of scientists. CEDDA activities will constitute part of the international data management program, so that procedures for effective coordination and data transfer on the international level will be essential. For these reasons, the structure of CEDDA, which evolved through experience with BOMEX, may require further changes to be fully effective in GATE.

4.3 Key Measurement Capabilities

The "EX" of BOMEX might well be applied to the experience gained in making crucial measurements in the hostile environment of the ocean--experience that will be invaluable for the planning and execution of future oceanic field experiments. Much of this experience has been recorded in a recent article by Holland and Williams (1971).

Through inter-comparisons of redundant observations and experiments in BOMEX, we know that atmospheric budget analyses of rawinsonde data can give acceptable determinations of sea-air fluxes of water vapor, latent heat, sensible heat, momentum, and kinetic energy over a 500 km square surface averaged for a 5-day period. It has also be demonstrated that over a similar 5-day period, evaporation rates can be measured consistently (though in this case not for identical areas and times) by six different methods: water-vapor budget (rawinsondes), ocean heat budget, aircraft covariance measurements, surface based (FLIP) covariance measurements, mean profiles, and bulk aerodynamic method. Perhaps the most important demonstration is the enormous advantage gained by maximizing the redundancy of observations and experiments.

Any of these methods could have been executed alone, with far less planning and effort. Had they not been done in BOMEX, most of these experiments could have and probably would have been carried out at different times and places at a total aggregate cost that would have been roughly comparable to their share of the BOMEX costs. The fact that they were done as part of the coordinated field program makes possible inter-comparisons that permit far-reaching conclusions that would have been impossible otherwise. Such knowledge should prove useful in future experiments to provide both for adequate redundancy of observations and for the most effective deployment of observational resources.

Finally, mention should be made of new techniques that were given the first real shakedown in BOMEX. A notable accomplishment was the deployment of a tethered Boundary Layer Instrument Package (BLIP) and the recording of about 700 hours of data. The need for a balloon-borne wind and turbulence profile measuring technique was recognized several years earlier (Panofsky et al., 1964). Although a number of serious difficulties were encountered in BOMEX, the limited success of this instrument system must be rated as an important contribution to future measurement capabilities.

4.4 Inter-agency Coordination

Although BOMEX was endorsed by the Interdepartmental Committee for Atmospheric Sciences (ICAS) and was intended as an inter-agency research program, planning was done largely by ESSA (Department of Commerce), and the individual agency programs were budgeted and managed separately. A number of very serious consequences resulted from lack of an effective inter-agency mechanism for planning, budgeting, and management.

(1) FLIP was the primary base for surface flux measurements. However, it was available only for the first month of BOMEX, when other BOMEX units were least reliable. Scheduling of research teams during this time was based largely on accommodating ONR contractors rather than on providing coherent sets of high quality data for flux comparisons. In consequence, comparison of independent surface flux measurements has been severely limited.

(2) Individual investigations were funded independently by NSF and other agencies, analysis has proceeded in a largely uncoordinated manner, and there is no means for insuring that all data are processed or for developing a coherent synthesis from all relevant data.

(3) Meso-scale oceanographic data taken by two Navy ships are not available to the scientific community or to BOMAP.

Despite these serious deficiencies, BOMEX exhibited a higher degree of inter-agency cooperation than had been achieved in prior programs. Navy aircraft operated effectively under BOMEX Project Office management. Valuable capability in data processing was provided by NASA. Coordination and communication among NSF- and ONR-supported programs and the BOMEX Project Office was generally good.

4.5 Government-University Coordination

BOMEX included about 45 investigations carried out essentially independently by scientists from universities and research institutes. Several Ph.D. theses have been based on BOMEX data, and the number of papers in the scientific literature is growing steadily. This broad participation properly can be considered one of the highlights of the program.

The chief means for coordinating the individual investigations has been through scientific meetings with special emphases. Although these meetings have been productive and a considerable number of papers have resulted, there remains need for introducing discipline into data processing and reporting. It seems reasonable to the Panel that in future programs of this type recipients of research grants should be responsible for processing and reporting all data, or representative samples of data where this is more appropriate, on a reasonable but specific schedule. We recognize that the issue or proprietary data is controversial, but in the case of a coordinated program where major facilities are provided by government we believe that the individual investigator's priority is adequately protected by his intense scientific interest which presumably motivated his proposal and by his initial familiarity with the data.

This problem will be more serious in GATE than it has been in BOMEX, and the Panel proposes that NOAA and NSF, with USC/GARP review, develop guidelines and procedures to insure prompt processing and access to GATE data.

4.6 Training and Experience

The systems engineering and programming expertise which have been developed in BOMAP should be very valuable to subsequent large field programs. Individuals who gained experience in BOMEX and BOMAP are now playing important roles in GATE, and CEDDA provides an essential competence in planning and data processing. Without the training and experience of BOMEX and BOMAP it is difficult to see how GATE could be carried out successfully.

V. Summary of Recommendations

1. Upon CEDDA's completion of the Core Experiment analysis, a small conference should be convened under the auspices of the USC/GARP to discuss the results.

2. CEDDA should communicate with each principal investigator who is responsible for BOMEX data not already archived at NOAA, and

   (a) Identify the data sets, their current status, format, degree of documentation, users, etc.

   (b) Document the data so that anyone examining the files to be established can determine what was collected, where it is, what form it is in, and how to access it.

   (c) Maintain an index of BOMEX data for use by interested persons.

On the basis of this information CEDDA should decide which data sets, if any, should become part of the Permanent Archive and should take steps necessary to archive the data in appropriate format. At appropriate periods CEDDA should issue a brief updated index of BOMEX data to advise users of the status and accessibility.

3. CEDDA should continue to serve as the focal point for information concerning BOMEX data.

4. NOAA and NSF, with USC/GARP review, should develop guidelines and procedures to insure prompt processing and access to field data taken by scientists and agencies participating in future cooperative programs.

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PART B

Report of the Director, BOMAP

Director, BOMAP

Joshua Z. Holland

PART B

Contents

July 30, 1973

Summary Report to the BOMAP Advisory Panel

by Joshua Z. Holland

Director, BOMAP

1. History

The idea of the limited-area experimental investigation of air-sea energy exchange was included in the recommendations to the Government by a joint panel of the NAS/NRC Committees on Atmospheric Sciences and Oceanography in 1962 (Benton, 1962). A Federal interagency panel responded by recommending a Federal Air-Sea Interaction program with the Department of Commerce as lead agency. Subsequently the new Environmental Science Services Administration (ESSA) assigned responsibility for developing the program to its Institutes for Environmental Research under George Benton and, within the Institute of Oceanography, to the Sea-Air Interaction Laboratory (SAIL) under Feodor Ostapoff.

The proposal for the Barbados Oceanographic and Meteorological Experiment (BOMEX) was first presented in two documents dated March 1967, prepared by SAIL. One was addressed to the Joint ICO/ICAS Panel on Air-Sea Interaction and essentially presented ESSA's objectives and plans for BOMEX. The second reviewed the overall scientific and technical background, plans, and status, of the Federal air-sea interaction program, the available experimental techniques, and preliminary design consideration for BOMEX. These plans drew heavily on earlier studies by the Florida State University group (Garstang and La Seur, 1968), and on experience gained in the International Indian Ocean Expedition (Fleagle, Badgley, and Hsueh, 1968). The scale and approach followed closely the recommendations of the NAS/NRC Panel on International Meteorological Cooperation (Charney, 1966).

Emphasis in BOMEX was to be placed on determining the air-sea exchange of energy, momentum, and water vapor by the "line integral" and "trajectory" techniques. In addition to these two, four other techniques were listed for comparative evaluation: the aerodynamic, eddy correlation, energy dissipation, and geostrophic departure techiques. Problem areas singled out were:

> "The magnitude of the space and time scales for which estimates of average flux are needed,
>
> "The parameterization of turbulent and convective exchange processes appropriate for the various space and time scales,
>
> "The present levels of understanding of the basic physics of the turbulent exchange of energy, momentum, and water vapor."

The basic plan was intended to be both self-sufficient as a field experiment and within the in-house capability of ESSA to execute. During 1967, William Barney was appointed as Project Manager and Ben Davidson as Scientific Director of BOMEX (Dr. Davidson worked part-time until mid-1968).

Subsequently six other agencies responded to ESSA's invitation to join and enlarge the project and the four ESSA ships were augumented by three Coast Guard ships and one Navy ship by February 1968 (BOMEX Bulletin No. 1). By that time the basic data array configuration for the Core Experiment had been established. It was also planned to have five Odessa buoys in a meso-scale array, three meteorological buoys of the Triton type, and a roving ship to obtain oceanographic data at higher spatial resolution within the array.

In the spring of 1968 the U. S. National Committee for GARP, at its first meeting, reviewed the plans for BOMEX, adopted BOMEX as a U. S. contribution to GARP, and established the BOMEX Advisory Panel under the chairmanship of Prof. Fleagle. Dr. Ben Davidson had by that time developed the basic design for the experiment. There was considerable uncertainty regarding adequacy of the available aircraft or ballon-borne sensors for measurement of humidity and of the upper air winds for the determination of the horizontal flux divergences of mass and water vapor.

During mid-1968 NASA offered the resources of its Mississippi Test Facility to provide data acquisition systems for the ships and to take responsibility for BOMEX data management. Dr. Davidson then began to spell out in briefings and informal notes the scientific computations which would be required, the observational inputs to these computations, the accuracy requirements and expectations, and the averaging which would be required.

Field tests with the ESSA research ship Discoverer, one RFF DC-6 aircraft, the NCAR Queen-Air and the Triton buoy were carried out east of Barbados in the summer of 1968. These were closely integrated with an extensive Florida State University observation program on the Island under the direction of Michael Garstang, and were designed to provide necessary information on random and systematic errors and a test of equipment and procedures. In fact, extensive comparative data were obtained on: Boom vs. Triton wind, temperature and humidity data; aircraft vs. rawinsonde temperature and humidity measurements; overland vs. oversea aircraft doppler winds, etc.

Dr. Davidson became very ill during the fall of 1968 and died in December. In the last months he was very heavily occupied with difficult decisions and shifting options regarding hardware procurement, and regarding deployment and scheduling of platforms, instruments, and people. Could the Odessa buoys be made ready in time? The BLIP? The gust probe? Would the Navy's FLIP be available or not? Should the Discoverer, with the only available shipboard precipitation radar, be moved from the center to a corner of the square to replace the Rockaway whose wind finding radar was inadequate? This decision, one of his last, was a wise and important one, assuring the feasibility of the divergence and water budget computations.

Less urgent demands for his attention were presented by the need for careful analysis of the 1968 field test data, and for specification of scientific requirements for data processing. The development of plans for the analysis of the data was pushed even farther into the background.

Following Dr. Davidson's death, Dr. Joachim Kuettner was appointed as the new Director of BOMEX, and in February 1969 I was loaned to ESSA by the Atomic Energy Commission to become Chief Scientist for the Sea-Air Interaction Program.

By March 1969 (BOMEX Press Kit) the Odessa buoys had been cancelled, and the three Triton buoys had been reduced to one. After strenuous interagency negotiations, the participation of FLIP had been secured, but only for the first month of BOMEX. Meso-scale oceanographic coverage was to be accomplished through two traverses of the array by the Advance II and the Gilliss, and by the Navy current meter and temperature arrays. The number of aircraft equipped with turbulent flux instruments had grown from one to four. It had been decided to limit the Sea-Air Interaction Program to the first three of the four 2-week observation periods planned, and to devote the fourth period to the "Tropical Convection" program under the direction of Dr. Jule Charney. Arrangements had been made for directly receiving data from the ATS-3 satellite at Barbados during the fourth period. At that time (March 1969) it was stated: "It is planned that all BOMEX basic core recorded data will be available to all interested parties not later than 6 months after the end of the observation period."

In the BOMEX field operations, May-July 1969, most of the planned data collection was accomplished successfully. The first period served as a shakedown period, during which many systems were marginally operative, and numerous repairs and adjustments were carried out. The BLIP systems were assembled for the first time. Two of the deep-sea moorings failed. A vital replacement part for the Discoverer radar antenna was late in arriving. Much effort was given to solving a variety of problems which cropped up in the shipboard rawinsonde system.

By the middle of the first period all ships were on station, observation schedules were being largely met, the FLIP direct flux instruments were working satisfactorily, and many FLIP intercomparisons were flown by the NCAR Queen-Air and RFF DC-6 flux-measuring aircraft.

In the second period the aircraft line integral flight patterns were changed from a mode designed to supply spatial interpolation data for the ship rawinsonde array to one which could be used alone to compute the atmospheric water vapor budget in the event the rawinsonde data should prove to be inadequate. But basically, Dr. Davidson's design proved to be very sound. Both the aircraft and rawinsonde systems appeared to be producing data of adequate quality and quantity, while the radar data assured that the precipitation amounts were low enough to permit closure of the water vapor budget.

In the fourth period the climatological prediction continued to hold up. From predominantly undisturbed trade-wind weather in May and June, the frequency and intensity of disturbances increased, presenting a variety of types for investigation. Much useful experience was gained in executing multi-aircraft reconnaissance of cloud features appearing on the ATS-3 pictures.

The decision by the Administrator of ESSA to establish BOMAP as a provisional organization within the Research Laboratories was made in Barbados in July 1969, ending the uncertainty about who would supervise reduction of the ESSA data, complete the Core Experiment analysis, and serve as a contact point for the BOMEX investigations after the field phase. The process of acquiring staff (on a temporary basis) to augment the small group of BOMEX hold-overs (Holland, Glaser, Williams, de la Moriniere, Reeves) began in Rockville in August.

Meanwhile, at the MTF, it was becoming evident that the data would require considerable manual inspection and editing in order to be put in suitable condition for scientific computations or analysis. It began to be realized too, that the digitization of ship data alone would take up at least the 6 months allowed for processing all the data, and that the data reduction software sill needed extensive debugging and further development work.

The devastation of hurricane Camille further set back the effort at MTF. It was estimated that the data processing and Core Experiment analysis would be completed in 3 years (by June 1972).

It was decided during the fall of 1969 that a first, automated reduction ("A_o") of the shipboard data would be done at MTF, and that BOMAP would carry out a manual review, make necessary changes in the software, and reprocess the data to final form. A BOMAP detachment of six people (borrowed from the Environmental Data Service) was stationed at MTF. It was planned to complete the data processing, archiving and documentation by the summer of 1971 and the analysis and reporting by the summer of 1972 (BOMEX Bulletin No. 6).

The ship boom and rawinsonde data were digitized, reduced and reviewed for satisfactory program operation by the fall of 1970. The rawinsonde data, in addition, were carefully reviewed for various hardware and software defects to be addressed in the development of the final process. Completion of the BLIP data took several months longer. The STD data were digitized separately and reduced by BOMAP at Rockville.

Arrangements were made with the National Hurricane Research Laboratory to do the initial processing of the RFF aircraft data, using existing software. For various reasons including software and computer turnaround problems, an underestimate of the magnitude of the data preparation tasks, and competition from a very productive STORMFURY season, this task also took more than a year, about twice as long as expected. Similar factors affected the other data types.

Following the second review by the BOMAP Advisory Panel in September 1970, it was decided to make the preliminary, unvalidated reduced data available to the scientific community through a temporary archive. All preliminary reduced data tapes were copied and reformatted as necessary. Documentation and graphical data were microfilmed, films were copied, and the temporary archive was in operation by February 1971, 19 months after the completion of the field program. A subsidy for visits by graduate students was established, and word was gotten out through BOMEX Bulletins, The Bulletin of the AMS, EOS, and letters to all known University Departments of Meteorology or Oceanography in the United States. About a dozen graduate students have taken advantage of this offer and visited the BOMAP office. Some 200 data requests have been filled.

Atomospheric mass and water vapor budget calculations were begun in early 1971 for a 5-day undisturbed period in June 1969 based on rawinsonde data. Aircraft data were checked and divergence computations by various methods attempted. Precipitation estimation methods using the radar scope photographs were tested and correlations were developed between the ship and island radar, and between radar and satellite. The analysis of the heat budget of the oceanic mixed layer was begun based on STD data.

Results of all these preliminary analyses of the preliminary data were encouraging. However, it was thought that the additional accuracy, time resolution and reliability to be gained by a careful reprocessing of the rawinsonde, aircraft and radar data would more than justify the added effort. Furthermore, in early 1971 it appeared to us that this added effort would not require slippage of the completion date for the archive beyond June 1972.

As the Panel was told at some length in the spring 1972 review, this final processing stage again has taken longer than had been expected. Much effort of the scientific staff has gone into the analysis of data quality and errors, and development of editing, reduction and correction procedures. Analysis has been delayed by this slippage in processing of data. Some of the problems will be mentioned in a later section.

Substantial progress has nevertheless been made during the past year in several areas of scientific analysis, such as: the analysis of radar and aircraft data; the examination of time and height variations in observed and derived quantities; the application of simplified forms of the vorticity equation to the estimation of vertical velocity at the top of the boundary layer; the use of BOMEX data for testing more generalized objective analysis schemes for the derivation of vertical velocities and other quantities, which are not directly measurable, from arbitrary observation grids; and the analysis of the oceanic energy, mass and salt budgets.

BOMAP has also served as a communication point and clearinghouse for information about BOMEX, i.e., what "the other 99" investigators are doing as well as what they may want to know about the status of BOMAP's data reduction and analysis. This has been accomplished through the BOMEX Bulletin series, the latest of which (No.11) contains abstracts of BOMEX related publications; through correspondence, visits to BOMAP by many of the participating scientists; and through presentation of informal seminars and briefings on BOMEX at various universities, research laboratories, scientific conferences, committee meetings, etc.

In mid-1971 the temporary BOMAP organization was given permanent status as the Center for Experiment Design and Data Analysis (CEDDA) and began to build a broader capability for data management and software development to support the International Field Year for the Great Lakes (IFYGL) and GATE. In mid-1972 CEDDA was transferred from the Environmental Research Laboratories to the Environmental Data Service (EDS) where CEDDA has continued to have responsibility for BOMAP.

BOMEX and BOMAP have enjoyed a very high priority and strong top-management support in the competition for ESSA and NOAA resources. NSF support has also been available for those BOMEX investigators who have sought it.

2. Chief Accomplishments

Some of the major BOMEX accomplishments, in both technological and scientific areas, will be listed. Some of these can be credited in part to BOMAP (see Appendix I).

The technological contributions of BOMEX are quite impressive but will only be touched upon here.

In the field operation phase the percentage of planned observations accomplished, the adherence to schedules and budgets, the accomodation of a large number of participants, and the overall safety, efficiency, and effectiveness of the operation were highly noteworthy and gratifying.

In the data management area, NASA's Mississippi Test Facility made an important contribution to the technology for automated recording and processing of a wide variety of shipboard observations. Their initial processing of the data, carried out under very difficult circumstances, resulted in the availability of a unique and valuable data set for researchers about a year and a half after the experiment.

The following are examples of instrument systems which were used successfully for the first time in a tropical marine environment; some were operational for the very first time:

- o Tethered balloon system (BLIP) for profiles and time series of wind, temperature, and humidity up to 600 m;
- o Aircraft (DC-6) gust probe/refractometer for turbulent water vapor flux down to 18-m altitude;
- o Lyman-alpha "humidiometer" for fast-response humidity measurements on FLIP and Queen-Air;
- o Hot-film anemometers for space and time structure-function measurements on FLIP;
- o Sonic anemometer on Queen-Air aircraft;

- o Scanwell "wind-finding-at-sea" system;
- o Wave height and velocity spectrum by land-based radar;
- o Lidar profiling of aerosols;
- o Twin-wave radiometer for remote measurement of sea-air energy flux from aircraft;
- o ATS-3 satellite pictures for real-time operations planning and control.

A new deep-sea mooring system for the five stationary ships was thoroughly tested. Two of the moorings survived for about 50 days.

Among the scientific accomplishments of BOMEX are:

- o For the first time in the tropics, the surface fluxes of heat, water vapor and momentum were thoroughly documented in BOMEX by covariance and energy (variance) dissipation techniques as well as by profile, bulk aerodynamic and volume integral techniques in the atmosphere. At the same time the radiative input to the sea and detailed oceanic mixed-layer temperature profiles were obtained. The intercomparisons provide necessary guidance for the selection of techniques to be used in future field programs. The sensible heat flux in the surface layer turned out not to be proportional to the very small air-sea temperature difference, but more nearly to the water vapor saturation deficit. For momentum and water vapor flux, the bulk aerodynamic technique was well validated under undisturbed tradewind conditions.
- o The radiative role of dust and marine aerosols was made quantitative by aircraft and balloon-borne radiometry. It was found that the absorption of solar radiation by atmospheric aerosols over the ocean was much more important than previously thought. The implications for the diurnal variation of temperature deduced from the new semi-empirical radiative flux estimates were borne out by the 1 1/2-hourly shipboard rawinsondes, which show a maximum amplitude at 1-2 km altitude.
- o The computation of horizontal divergence on the 500-km scale from the preliminary rawinsonde data was shown to be feasible with sufficient accuracy to determine the water vapor budget within 20% or better over averaging periods of 5 days or less, and to determine the diurnal variation of vertical velocity over a similar period. This diurnal variation is consistent with the diurnal temperature wave at and above the level of maximum solar heating and, at lower levels, is consistent with the diurnal variation of radar echoes.

- o Divergence computed from aircraft data on this same scale was shown to be closely comparable to the rawinsonde results with resolution equivalent to about 6 hours in time and about 50 mb vertically. The kinematically computed vertical velocities at the top of a 500-mb box were found to agree well with those estimated from thermodynamic considerations. Those at the top of the frictional boundary layer were found to be reasonably well estimated from the curl of the surface stress, confirming the "boundary layer pumping" part of CISK, but only when development or advection of disturbances was not involved.

- o The depth of the frictional boundary layer and the stress profile were well defined for the first time in the trade-wind zone by momentum budget analysis. It was found that application of the geostrophic departure technique was precluded by errors of a few tenths mb in the surface pressure measurements but the assumption of negligible acceleration, on which the technique is based, was confirmed for the conditions of the experiment.

- o The previously suspected absence of an "Ekman" layer on the equatorward side of the ITCZ has been confirmed in BOMEX, posing problems regarding the boundary layer pumping mechanism in relation to the CISK hypothesis.

- o The vertical profiles of heat and moisture sources and sinks, derived for moderately disturbed as well as undisturbed conditions, show important extrema in the trade inversion layer in undisturbed conditions and in a higher stable layer in the disturbed case. The analyses by BOMAP have been independently confirmed, using the same data, by Yanai's group at UCLA, and are very similar to results obtained from ATEX.

- o The eddy flux convergence of sensible heat in the boundary layer was found to compensate the radiative heat sink, but the mechanism by which this is accomplished turned out to be somewhat different from what was previously assumed. The boundary-layer scale eddy energy is supplied primarily by water vapor bouyancy, augmented by thermal buoyancy only in the surface layer, and opposed by thermal buoyancy in the upper part of the boundary layer (cumulus layer). Detailed information on along-wind and cross-wind spectra of vertical velocity, temperature and humidity and their cross-spectra from FLIP have provided a wealth of documentation of the structure and interactions of the eddies and their roles in the transport processes.

- o A complete chain of evidence was obtained linking the Sahara dust streams, seen on satellite pictures over the Atlantic, to dust samples collected on aircraft, to radon content reflecting recent contact with a continental surface, and to a potential temperature and mixing ratio structure seen on shipboard rawinsondes at the altitude of the dust layer and identifiable with that observed over Africa and over the Cape Verde Islands.

- A preliminary analysis underway of geostrophic mass, heat, and salt transport in the ocean has already demonstrated the suitability of long, detailed series of oceanographic temperature and salinity soundings, taken on a synoptic grid, for this purpose.

- Some of the BOMEX observations have already attained nearly "classical" status: for example, the FLIP temperature and humidity spectra, and the vertical profile of horizontal divergence. These have been re-appearing in various publications. The latter was used as one of the illustrations in the ISMG GATE Proposal. The July 14, 1969, disturbance east of Barbados was probably the most completely observed and analyzed tropical cloud cluster to date.

- If imitation is the sincerest form of flattery, the Soviet TROPEX-72 project, employing a BOMEX-type five-ship square array in the eastern tropical Atlantic, attests to the value of BOMEX as perceived by the Soviet scientific community. Dr. Petrosyants, scientific director of the expedition, had been put on the BOMEX Bulletin mailing list, at his own request, a year or so earlier.

- BOMEX experience has been deliberately integrated into GATE at the interanational level through assignment of key roles to BOMEX/BOMAP veterans, for example: the appointment of Dr. Kuettner as Director of the International Scientific and Management Group (ISMG); the use of Terry de la Moriniere as ISMG staff member for international data management planning; my own role on the ISMG Boundary Layer Advisory Group.

- Published contributions by BOMAP are listed in Appendix I.

Of course the greatest effort of BOMAP has been invested in the processing of the BOMEX data. This is just now coming to an end. Appendix II contains descriptions and examples of the principal archive products. The interest in BOMEX as a source of experimental material for trying out ideas for GATE may well be increasing rather than diminishing in the scientific community. The future scientific contributions of BOMEX may be as important as those already behind us.

3. Chief Problems

Problems resulting from inadequate lead time, inadequate planning effort, and inadequate command of resources by the project director, associated with the loosely coordinated interagency management structure, have been pointed out by Fleagle (1972) and are evident in the history of the project as reviewed in an earlier section.

Of particular current and future importance are the following two problems which were not solved satisfactorily in BOMEX:

(a) how to get the data processed promptly; and

(b) how to keep an adequate analysis effort focused on the central scientific objectives of the project.

It now seems fairly certain that the time required for reduction and analysis of the data might have been significantly shortened, and the scientific value of the results increased, if half a dozen reasonably well-trained scientific assistants, supported by a dozen technicians and programmers, had been available to the Scientific Director during the critical final year of preparation. A few of the most urgent tasks of test data analysis, procedure and process specification and testing could then have been receiving sustained and concentrated attention concurrently. And, of course, if Dr. Davidson had lived to put the pieces together.

It seems reasonable to conclude, also, that it could have made a big difference if a few qualified and experienced atmospheric scientists had been assigned to the BOMEX data management effort at the MTF in order to communicate effectively with the BOMEX Scientific Director, to become fully knowledgeable regarding the scientific requirements, to translate them into more detailed processing specifications, and generally to provide scientific guidance and review of the work at the MTF. This might have increased significantly the effectiveness of NASA's multimillion dollar investment in data acquisition hardware, computer programming, and data processing.

The lack of experience with any previous project of this type and magnitude was undoubtedly a factor in the consistent underestimates of time and effort required. BOMEX was a large step up from the Indian Ocean Expedition and Line Islands Experiment. It had to be done when it was in order to have value for the further development of GARP, and possibly, as Fleagle (1972) has suggested, if it was to be done at all. The trade of BOMEX lead time and resources (including experience) for GATE lead time and resources was thus, in a sense, deliberate and well justified.

Some of the lessons we had learned by 1971 were published by Holland and Williams (1971).

In mid-1971 the problems remaining were, unfortunately, the most difficult ones: manual reduction of the second period GMD-1 wind observations aboard the Oceanographer (when the automated Scanwell system was out of action); development of a satisfactory correction for radiative heating and thermal lag of the humidity elements in the radiosondes and dropsondes; renavigation of the ships to determine ship-motion corrections for the surface and upper air winds after the moorings had failed; development of software which would follow the radiosonde temperature and reference frequencies through their crossing; and generally dealing with a great number and variety of irregularities in the boom, BLIP, and rawinsonde data.

The delays in processing have caused delay in scientific analyses by BOMAP as well by other BOMEX participants whose studies required that they wait for the final ship and aircraft data.

The second problem, which has been pointed out by Hidy (1972), is the lack of a coordinated and comprehensive interpretation of the data gathered in the experiment. This may be related to the deficiency of federal inter-agency coordination of funding and management pointed out by Fleagle (1972).

BOMAP has not had the mission to provide a comprehensive scientific synthesis of BOMEX, nor have we had the resources, the skills, or the authority to coordinate and integrate even the data processing efforts, much less the analytical efforts of the "other 99" of the "100 experiments" of BOMEX. Does this responsibility reside anywhere? If so, where? I believe this is a question which should be addressed by the BOMAP Advisory Panel. In the case of GATE the need has been recognized in advance and effort is now underway to define the analysis plan and to identify those responsible.

In retrospect, one glaring gap in the 1968-69 final planning period was the lack of a continuing, working non-governmental (e.g., NAS or UCAR) scientific "presence": a group of scientists dedicated to BOMEX who would share the responsibility for defining the necessary analyses, and would secure commitments from the individuals who would do these. Such a coordinating group, continuing after the field phase, could have helped to assure the fulfillment of these commitments by scheduling meetings for exchange of results, developing plans for joint, integrative reports, etc.

Communication has been dependent on the willingness of the other BOMEX investigators, as well as on the energy invested by BOMAP, and has been incomplete. We have the impression that continuity of effort by the "other 99" on BOMEX data reduction and analysis has been hampered by graduate degree research cycles, funding lapses, transfers of key investigators from one institution to another, and pressures or attractions of other projects.

A great deal of data of considerable potential value seems not to have been analyzed, reported or archived, and no effective mechanism seems to exist for making this happen. Examples are: large fractions of FLIP and Queen-Air turbulence data, Gilliss and Advance II oceanographic data (except for Vukovich, 1971), Navy temperature array data.

The "Tropical Convection Program" to which the fourth period was devoted, has lacked focus in the analysis phase. Can anyone say whether the objectives of this program were attained?

In summary, the difficulties and delays in processing the bulk of the BOMEX data have aggravated but have not been the sole cause of the diffuseness and fragmented character seen by some in the scientific results which have been coming out.

4. Where do Things Stand?

Clearly more analysis of BOMEX data is needed in order to fulfill the expectations of the proposers, planners, and supporters of the experiment. At least more syntheses and more comprehensive pulling together of results are needed. Considering the impressive "fragments" already reported, such a synthesis might be enough to establish "successful completion."

As to the potential for further findings, we are now at the beginning of the hard part of the work. The easy, obvious, first-order results have been published. These tend to be descriptive and particular. What are their general implications? To what extent do they reflect local, transitory conditions? What can be gleaned about the next order of relationships, such as: the variation of the drag coefficient; the interaction of the vertical profile of radiative energy flux divergence with the cloud field and dynamics; the interdependence of the observed time-varying 500-km bulk quantities with the larger scale systems in which they are observed; the scales within the 500-km grid at which the sub-grid-scale processes are occurring?

While there has continued to be an expectation by some scientific participants that BOMEX would contribute new information about the contribution of meso-scale atmospheric flow features to energy and water vapor transports and conversions, and to the problem of parameterizing such contributions, the actual experimental layout for the first three periods of BOMEX provided data essentially on the 500-km scale and on the microscale. The aircraft and BLIP data certainly contain information on the intermediate scales which might be useful, but no one (including BOMAP) has given this topic a high priority because, compared to other topics, it is ill-defined in terms of objectives and methods, it is open-ended in terms of the amount of time and effort which could be invested in it, and it is now well served by the BOMEX data grid. Available are time-height sections from rawinsondes, single-station time series from BLIP along-wind and across-wind horizontal line samples at several levels (at different times) from aircraft; but never 3-dimensional or 4-dimensional meso-scale sampling. Nevertheless, the observations which exist are of high quality, unique, and rich in scientific potential. They might lend themselves to a variety of case studies by graduate students with particular hypotheses in mind regarding structures or mechanisms.

The data are available or will be within a few months. (Appendix III gives the status of the various data sets.) BOMAP as a mechanism for carrying forward the analysis, and as a focal point for information exchange, is scheduled to be phased out in about a year. Its task will have been completed and the first crop of scientific results will have been harvested. The opportunity for further research, making use of the unique national asset which has been created in the BOMEX data archive, continues and should be exploited in the future.

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APPENDIX I

BOMAP PUBLICATIONS

Status as of May 3, 1973

Center for Experiment Design and Data Analysis
National Oceanic and Atmospheric Administration
Washington, D. C. 20235

ATLAS PUBLICATIONS

Published

BOMEX Field Observations and Basic Data Inventory. March 1971.

BOMEX Period III High-Level Cloud Photography Atlas. May 1971.

BOMEX Atlas of Satellite Cloud Photographs. V. A. Myers. July 1971.

BOMEX Period III Upper Ocean Soundings. V. E. Delnore. In Press.

In Preparation

BOMEX Period III Radar-Satellite Atlas.

Boom and BLIP Time Series.

Synoptic Scale Weather Maps.

Radiosonde Time Cross Sections.

TECHNICAL REPORTS

Published

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BOMEX Temporary Archive: Description of Available Data. Terry de la Moriniere. NOAA Technical Report EDS 10. January 1972.

In Preparation

Trial Integral Calculations. Eugene M. Rasmusson.

Radar-Satellite Precipitation Analysis of a Five-Day BOMEX Data sample. Michael D. Hudlow.

Planned

BOMEX Permanent Archieve: Description of Available Data.

BOMEX Core Analysis: Final Report. Eugene M. Rasmusson.

A Detailed Study of the Structure of the Trade Inversion During BOMEX. Robert W. Reeves.

TECHNICAL MEMORANDA

Published

High-Level Cloud Photography Inventory, BOMEX Period IV. Vance A. Myers. NOAA Technical Memorandum ERLTM-BOMAP 1. September 1970.

A Statistical Data Plan for BOMEX. T.W. Horner. NOAA Technical Memorandum ERL BOMAP-2. December 1970.

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In Preparation

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Estimate of Precipitation From Salinity Measurements During BOMEX. Garry W. Elliott.

A Technique for Deriving Precipitation Estimates for a Tropical Atmosphere. Wolfgang D. Sherer and Michael D. Hudlow.

Time Series of Fluxes for BOMEX Period II. Jason K.S. Ching.

Estimating Vertical Velocity Using the Vorticity Equation. Jason K. S. Ching.

BLIP Profiles of Temperature and Humidity. James A. Almazan.

RFF Aircraft Sensor Performance During BOMEX. Donald T. Acheson.

BOMEX Radiosonde Humidity Errors and Correction Procedures. Leslie D. Sanders.

BOMEX Dropsonde Reduction Procedures. Leslie D. Sanders.

An Algorithm for Direct Computation of Wet-Bulb Temperature From Dry-Bulb Temperature and Relative Humidity. Leslie D. Sanders.

Moisture and Heat Flux Through Top of BOMEX Volume as Function of Precipitation Rate. Vance A. Myers.

Planned

Radar-Satellite Precipitation Analysis for BOMEX Period II. Wolfgang D. Scherer.

A Comparison of BOMEX Temperature Soundings During Disturbed and Undisturbed Conditions. Jason K.S. Ching and Wolfgang D. Scherer.

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Published or in Press

The BOMEX Project. Joachim P. Kuettner and Joshua Z. Holland. Bulletin of the American Meteorological Society, Vol. 50, No. 6, June 1969, pp. 304-402.

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In Preparation

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Radar Echo Climatology East of Barbados Derived From Data Collected During BOMEX. Michael D. Hudlow. Preprints of Papers Presented at the 14th Radar Meteorology Conference, Tucson, Ariz., November 17-20, 1970, American Meteorological Society, pp. 432-437.

APPENDIX II

BOMEX Archive Products

Description and Samples:

Ship Systems

- STD
- Boom
- Ship Renavigation
- BLIP
- Rawinsonde

Radar

Aircraft Systems

- Photographs
- Aircraft Meteorological Data
- Dropsonde

May 3, 1973

Preparation of STD Data for BOMEX Archive

On April 2, 1973, CEDDA placed the last deposit of salinity-temperature-depth (STD) data, taken during the Barbados Oceanographic and Meteorological Experiment during the summer of 1969, into the final archive at the National Oceanographic Data Center. Beginning in October 1970, this massive array of STD data from 1,650 STD soundings taken on five ships over a 3-month period was carefully reduced and edited, producing 53 clean time series STD tapes, which were placed in the archive in August 1972. To increase the immediate useability of BOMEX STD data and to provide a convenient synopsis of each STD sounding, salinity and temperature were sorted by depth into decibar-interval, 1,000-point arrays for each sounding, which were then recorded on tape and plotted on microfilm. All BOMEX STD data, on 53 time-series tapes, three depth-sorted data tapes, and four reels of microfilm, are immediately available to the scientific community.

STATUS OF PREPARATION OF STD DATA FOR THE BOMEX ARCHIVE

Period	Magnetic Tape, Nine-Channel			Microfilm	
	Time series binary	Time series BCD	Depth-sorted	Depth-sorted plots	Support data
I	Completed	Completed	Completed	Completed	Completed
II	Completed	Completed	Completed	Completed	Completed
III	Completed	Completed	Completed	Completed	Completed
IV	Completed	Completed	Completed	Completed	Completed

```
1BOMEX STD OCEANOGRAPHER YEAR 1969 DAY 151 TIME 10+56[redacted]MT LAT.17+36N L[redacted]054+38W
0 POINTS ARE IN TRIPLES OF (P,S,T). TIME BETWEEN TRIPLES IS 0.120 SECONDS
0FORMAT IS GIVEN BELOW . RECORDS CONTAIN 100 TRIPLES. LAST RECORD ZERO FILLED.
 FORMAT(5(F6.2,2F5.3))
0SENSOR INFORMATION  STD MODEL 9006 SERIAL   01  PARAMETER=(FREQUENCY-Z)*S+C
0SALINITY      SN=2323  Z= 4995.   S= .00343   C= 28.0    PARTS PER THOUSAND
 TEMPERATURE   SN=2253  Z= 2127.   S= .0179    C= -2.0    DEGREES CENTIGRADE
 PRESSURE2     SN=2297  Z= 9712.   S=-1.279    C=  0.0    DECIBARS
0SURFACE REGION STD OBSERVATION.
0SENSOR DESCENDS FROM SURFACE TO 63 DECIBARS.
```

```
 16373467527467  16353467427467  16323467527463  16323457227463  16283467327461
 16253467327463  16253467527464  16233467527465  16163457627463  16063467327461
 16773468327468  16783468127468  16753468227467  16703458327466  16653468027454
```

Time-Series STD Data. Dump of header record and first few card images from data records.

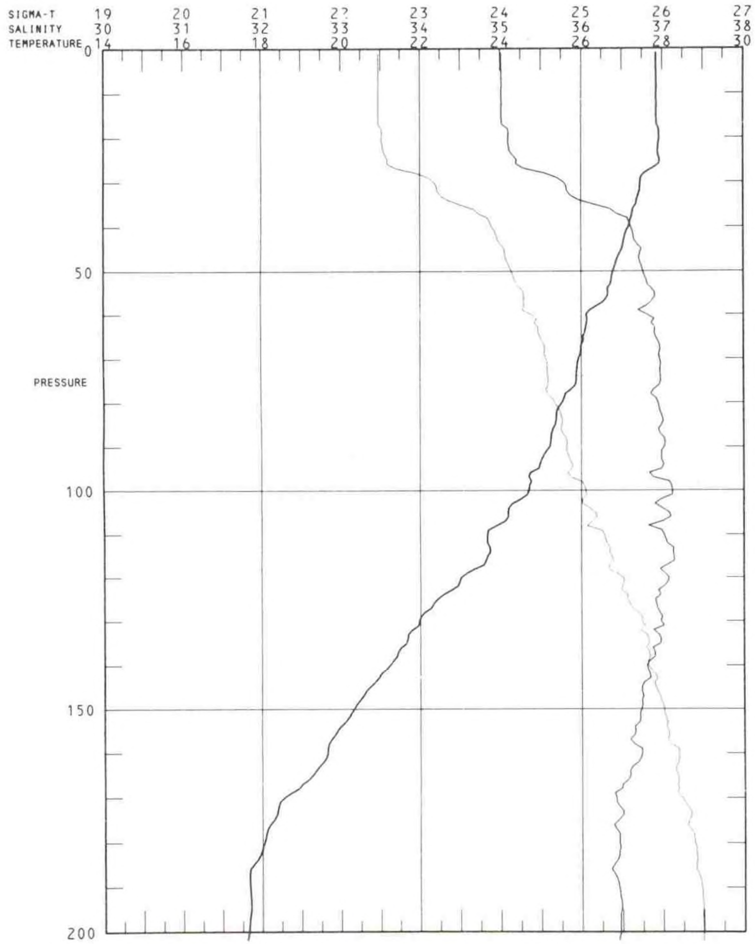
```
POINTS ARE IN TRIPLES OF (S,T,SIGMA-T) PRESSURE CAN BE DETERMINED AS FOLLOWS
P(N)=F+(N-1)*D WHERE F=  1.00 (FIRST POINT).  D=  1.00 (PRESSURE INTERVAL).
N=INDEX OF POINT. INDICES   8 THROUGH   63 HAVE VALID DATA. OTHERS SET TO ZERO.

FIVE TRIPLES PER 80 CHARACTERS. FORMAT  (5(1X,3F5.3)). 20*80 CHARACTERS/RECORD.

BOMEX STD OCEANOGRAPHER YEAR 1969 DAY 151 TIME 10+56 GMT LAT.17+36N LON.054+38W

SENSOR INFORMATION  STD MODEL 9006 SERIAL   01  PARAMETER=(FREQUENCY-Z)*S+C

SALINITY     SN=2323  Z= 4995.0    .00343    28.45    PARTS PER THOUSAND
TEMPERATURE  SN=2253  Z= 2127.0    .01790    -2.00    DEGREES CENTIGRADE
PRESSURE2    SN=2297  Z= 9712.0   1.27900     0.00    DECIBARS

SURFACE REGION STD OBSERVATION.

SENSOR DESCENDS FROM SURFACE TO 63 DECIBARS.
```

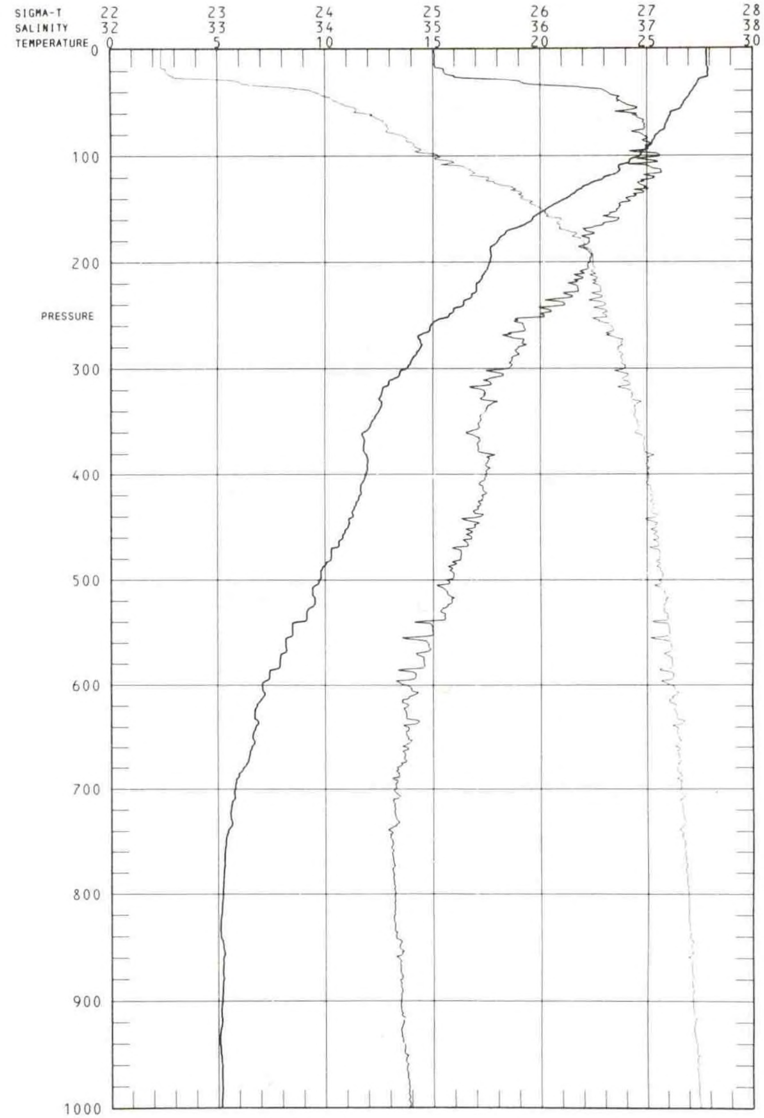
```
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0 35113274632675 35116274662676 35117274682677
35119274682678 35118274682678 35118274662678 35118274682677 35120274712678
35119274712677 35119274702677 35119274702677 35119274702577 35127274712683
35155274702704 35252274472784 35430273292957 35540272882053 35543272662062
```

Depth-Sorted STD Data. Dump of header record and first few card images from data record.

DISCOVERER YEAR 1969 DAY 127 TIME 109 GMT LAT.13°10N LON.053°54W
PRESSURE CORRECTION OF 4.1 DECIBARS ADDED THROUGHOUT CAST.

STD Depth-Sorted Plots
Vertical Axis: Pressure, decibars
Horizontal Axis: Top Line - Sigma-t, units
2nd Line - Salinity, parts per thousand
3rd Line - Temperature, °C





Depth-sorted STD data. Print of STD profile from microfilm.

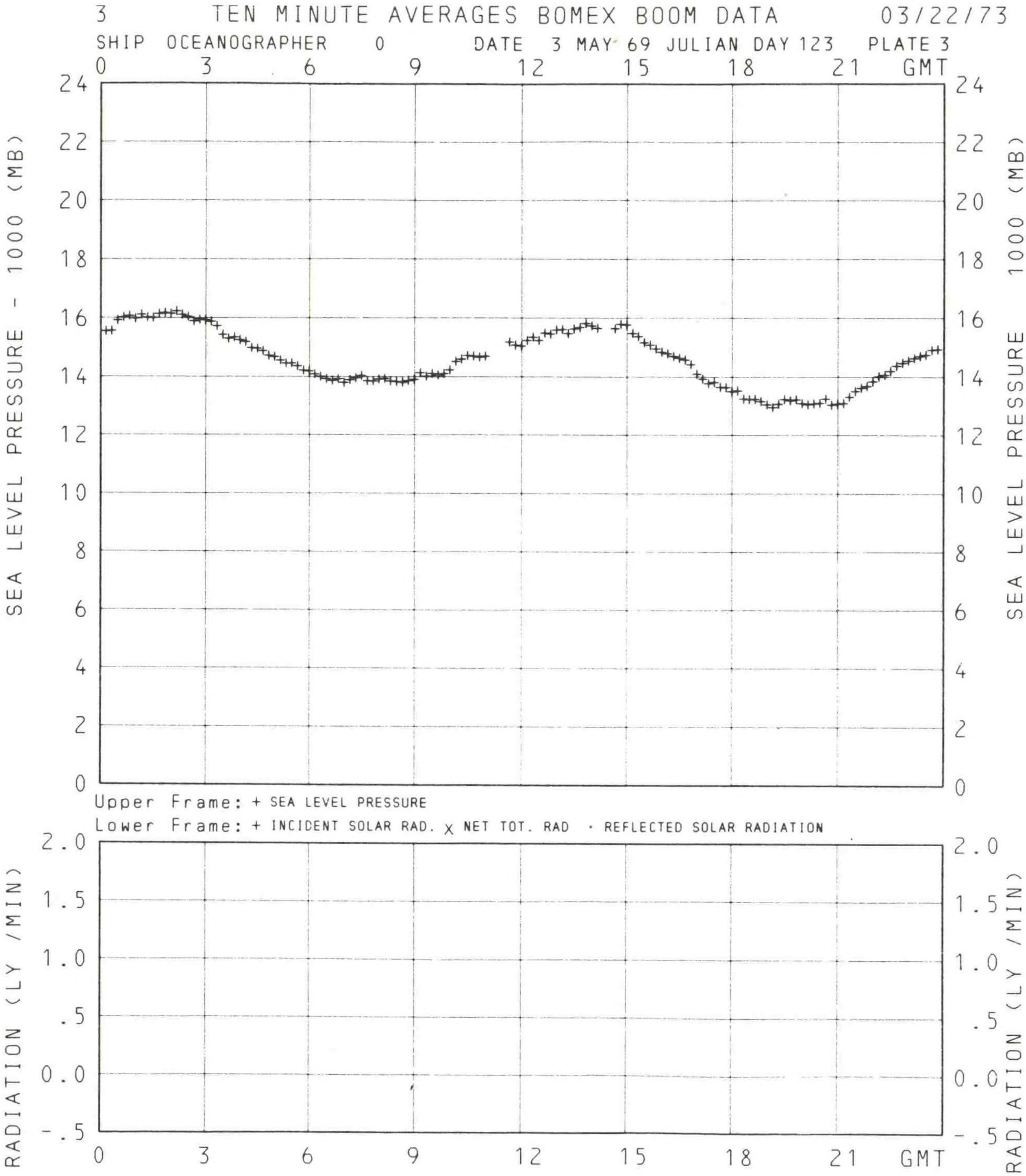
Preparation of Boom Data for the BOMEX Archive

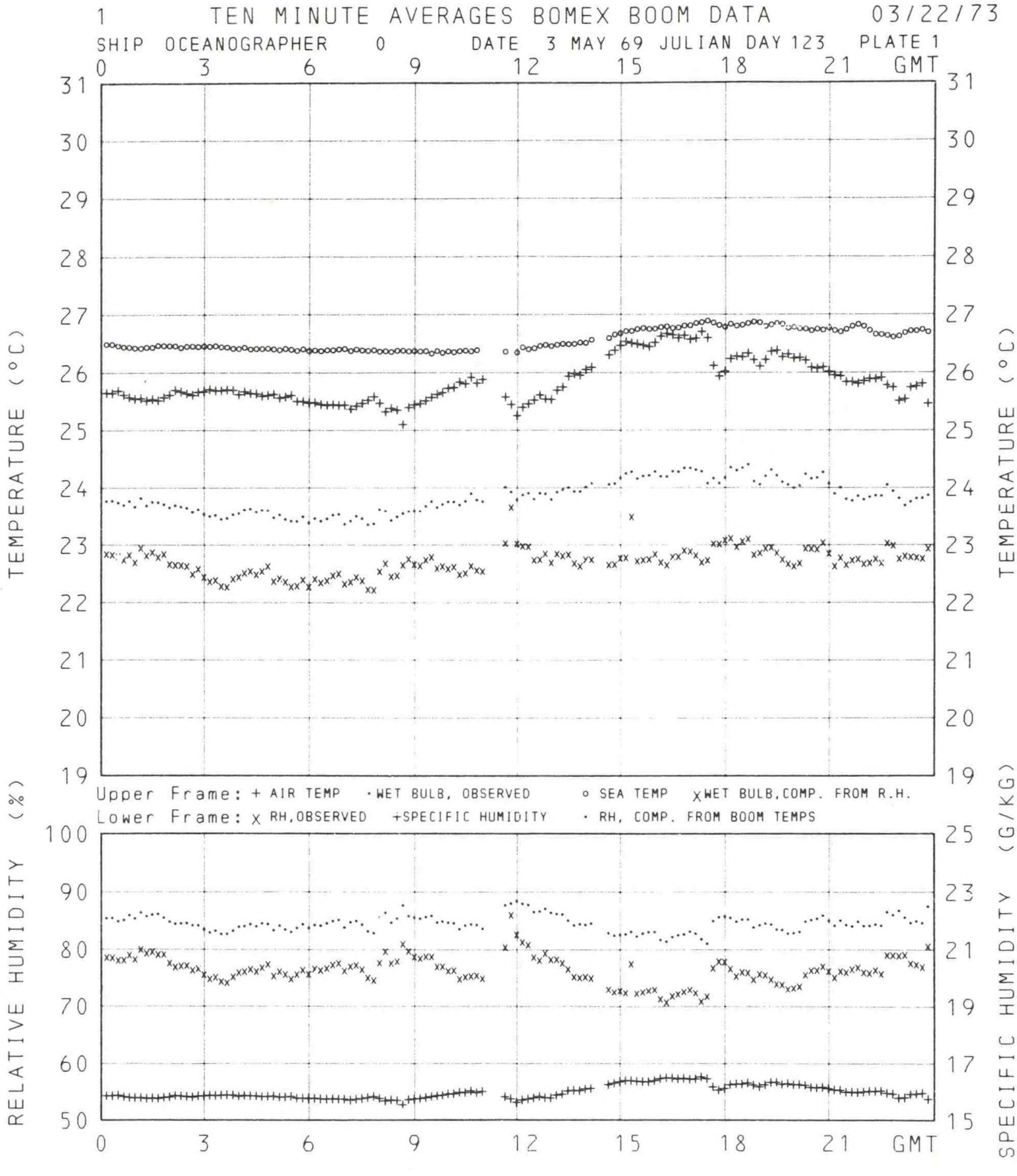
Final BOMEX shipboard boom data are now available for shipment to NCC. These data are in two forms: one in 10- and 30-minute averages on magnetic tapes in BCD format; the second as time-series plots of the 10-minute averages.

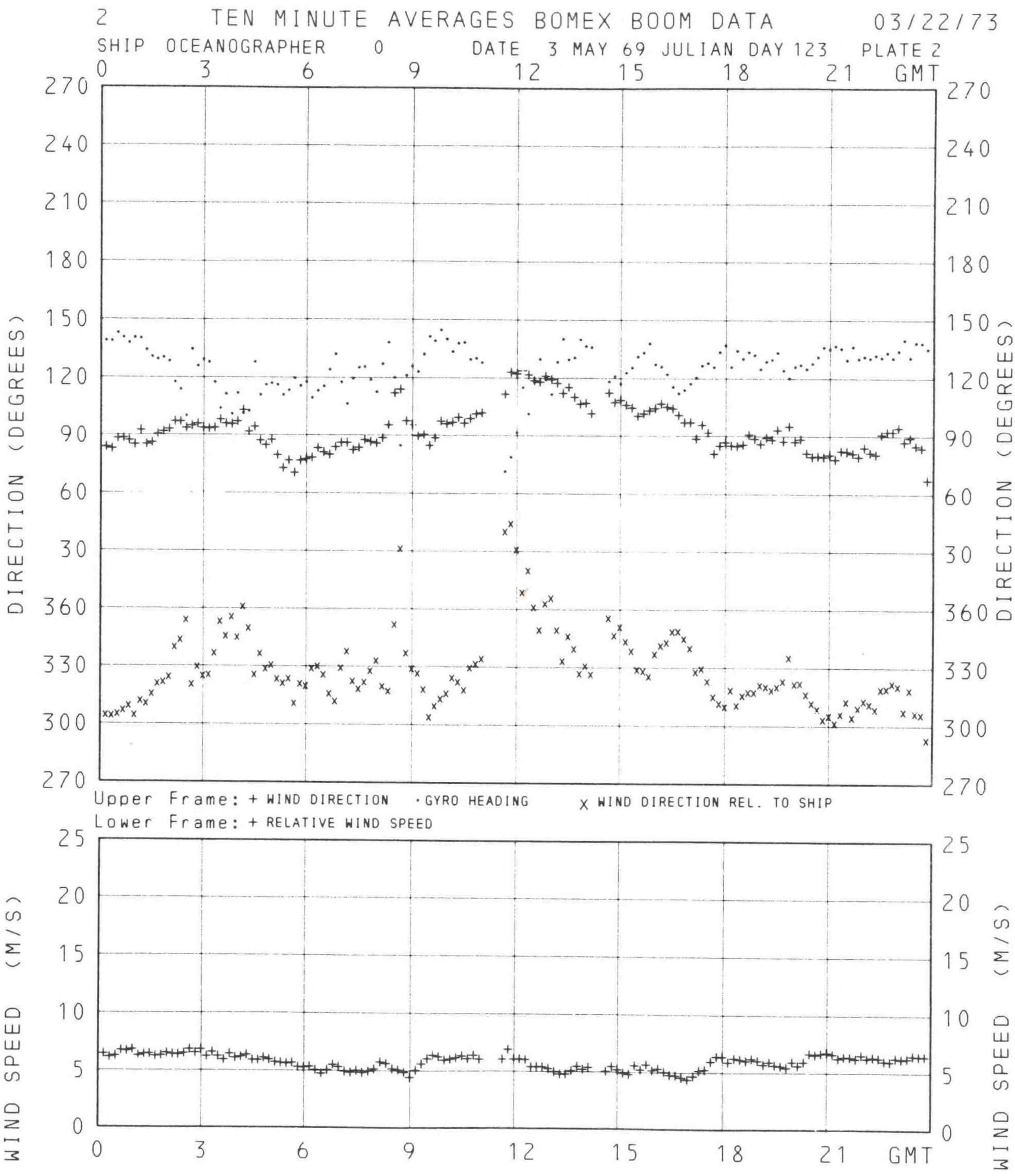
A third set of data in the form of the original 2 samples per minute will also be available this month on magnetic tapes in BCD format. This set is a byproduct of the 10- and 30-minute average product.

STATUS OF PREPARATION OF BOOM DATA FOR THE BOMEX ARCHIVE; ALL SHIPS

Period	"A" Boom Edit	Binary Tapes	BCD Archive Tapes	Micro-film	Copy BCD Tapes	Archive Tapes and Microfilm for NCC
			10- and 30-minute averages			
I	9/15/72	10/15/72	3/15/73	4/18/73	5/1/73	5/2/73
II	9/15/72	10/15/72	3/15/73	4/18/73	5/1/73	5/2/73
III	9/1/572	10/15/72	3/15/73	4/18/73	5/1/73	5/2/73
IV	9/15/72	10/15/72	3/15/73	4/18/73	5/1/73	5/2/73
			2 samples per minute			
I	9/15/72	10/15/72	5/15/73		5/31/73	6/15/73
II	9/15/72	10/15/72	Sample listings being checked	None planned	5/31/73	6/15/73
III	9/15/72	10/15/72			5/31/73	6/15/73
IV	9/15/72	10/15/72			5/31/73	6/15/73


3 TEN MINUTE AVERAGES BOMEX BOOM DATA 03/22/73
SHIP OCEANOGRAPHER 0 DATE 3 MAY 69 JULIAN DAY 123 PLATE 3
0 3 6 9 12 15 18 21 GMT
SEA LEVEL PRESSURE - 1000 (MB)
24 22 20 18 16 14 12 10 8 6 4 2 0
Upper Frame: + SEA LEVEL PRESSURE
Lower Frame: + INCIDENT SOLAR RAD. x NET TOT. RAD · REFLECTED SOLAR RADIATION
RADIATION (LY /MIN)
2.0 1.5 1.0 .5 0.0 -.5


1 TEN MINUTE AVERAGES BOMEX BOOM DATA 03/22/73
SHIP OCEANOGRAPHER 0 DATE 3 MAY 69 JULIAN DAY 123 PLATE 1
0 3 6 9 12 15 18 21 GMT
31 30 29 28 27 26 25 24 23 22 21 20 19
TEMPERATURE (°C)
Upper Frame: + AIR TEMP · WET BULB, OBSERVED ○ SEA TEMP x WET BULB, COMP. FROM R.H.
Lower Frame: x RH, OBSERVED + SPECIFIC HUMIDITY · RH, COMP. FROM BOOM TEMPS
100 90 80 70 60 50
RELATIVE HUMIDITY (%)
25 23 21 19 17 15
SPECIFIC HUMIDITY (G/KG)


2 TEN MINUTE AVERAGES BOMEX BOOM DATA 03/22/73
SHIP OCEANOGRAPHER 0 DATE 3 MAY 69 JULIAN DAY 123 PLATE 2
GMT
DIRECTION (DEGREES)
Upper Frame: + WIND DIRECTION · GYRO HEADING x WIND DIRECTION REL. TO SHIP
Lower Frame: + RELATIVE WIND SPEED
WIND SPEED (M/S)

Preparation of Ship Renavigation for BOMEX Archive

Adjusted hourly ship position data in terms of latitude and longitude for Observation Periods II and III have been completed for each of the five ships in the BOMEX fixed-ship array. These data are available in tabular form on microfilm; they are also reproduced in digital form and available on magnetic tape. Ship motion data for the same periods are available in terms of u and v components (Cartesian geometry) by operational mode (drift or steam). The data have been compiled by using drift motion calculated on the basis of 6-hour increments. The motion data are available in the same form as the ship position data.

STATUS OF PREPARATION OF SHIP MOTION AND POSITION DATA FOR BOMEX ARCHIVE

Ship	Period I	Period II	Period III	Period IV
Oceanographer	u	u	c	x
Rainier	x	c	c	x
Mt. Mitchell	x	c	c	x
Discoverer	u	u	c	x
Rockaway	u	c	c	x

u = ship moored.

c = motion and position data completed.

x = no attempt made to determine motion and position data.

Hourly Ship Positions, the Rainier, BOMEX Period II

Day (Julian)	Date (May 69)	Time (GMT)	Navigation Fix Latitude (deg)	Navigation Fix Latitude (min)	Navigation Fix Longitude (deg)	Navigation Fix Longitude (min)	Adjusted Position Latitude (deg)	Adjusted Position Latitude (min)	Adjusted Position Longitude (deg)	Adjusted Position Longitude (min)
147	27	2000	16	52	59	16	16	50	59	18
147	27	2100	16	53	59	14	16	50	59	18
147	27	2200	16	53	59	15	16	50	59	18
147	27	2300	16	55	59	14	16	50	59	19
148	28	0000	16	56	59	16	16	50	59	19
148	28	0100	16	55	59	16	16	49	59	18
148	28	0200	16	56	59	16	16	50	59	19
148	28	0300	16	55	59	17	16	49	59	19
148	28	0400	16	54	59	16	16	49	59	18
148	28	0500	16	53	59	16	16	48	59	17
148	28	0600	16	52	59	9	16	48	59	17
148	28	0700	16	51	59	14	16	48	59	17
148	28	0800	16	49	59	15	16	48	59	16
148	28	0900	16	49	59	14	16	47	59	15
148	28	1000	16	45	59	15	16	46	59	15
148	28	1100	16	44	59	15	16	46	59	15
148	28	1200	16	44	59	15	16	46	59	15
148	28	1300	16	45	59	16	16	47	59	16
148	28	1400	16	43	59	15	16	47	59	16
148	28	1500	16	49	59	14	16	47	59	16
148	28	1600	16	49	59	12	16	47	59	16
148	28	1700	16	49	59	12	16	47	59	17
148	28	1800	16	49	59	12	16	48	59	17
148	28	1900	16	49	59	12	16	48	59	17
148	28	2000	16	48	59	14	16	47	59	17
148	28	2100	16	46	59	15	16	46	59	17
148	28	2200	16	46	59	17	16	45	59	17
148	28	2300	16	45	59	15	16	46	59	16
149	29	0000	16	45	59	15	16	46	59	15

Ship Motion, the Rainier, BOMEX Period II

Day (Julian)	Date (May 69)	Time Start(GMT)	Time Duration(min)	Operational mode *	Motion(m/s) u comp.	Motion(m/s) v comp.
144	24	0022	38	0	-.19	.05
144	24	0100	96	0	-.13	.04
144	24	0236	54	1	.02	-.01
144	24	0330	50	1	.35	-.13
144	24	0420	72	1	.26	-.29
144	24	0532	31	0	-.13	.04
144	24	0603	15	0	-.13	.04
144	24	0618	42	0	-.13	.04
144	24	0700	38	0	-.13	.05
144	24	0738	30	0	-.13	.05
144	24	0808	42	0	-.13	.05
144	24	0850	46	1	.24	-.31
144	24	0936	125	0	-.13	.05
144	24	1141	56	0	-.13	.05
144	24	1237	23	0	-.13	.05
144	24	1300	3	0	-.12	.07
144	24	1303	87	0	-.12	.07
144	24	1430	60	0	-.12	.07
144	24	1530	120	0	-.12	.07
144	24	1730	60	0	-.12	.07
144	24	1830	30	0	-.12	.07
144	24	1900	60	0	-.12	.09
144	24	2000	40	0	-.12	.09
144	24	2045	200	0	-.12	.09
145	25	0000	28	0	-.12	.09
145	25	0028	32	0	-.12	.09
145	25	0100	6	0	-.12	.10
145	25	0106	61	0	-.12	.10
145	25	0257	53	1	.25	-.26
145	25	0300	30	1	.13	-.36
145	25	0330	90	1	.21	-.63
145	25	0500	30	1	.29	-.56
145	25	0530	24	1	.41	-.78
145	25	0554	46	0	-.12	.10
145	25	0640	20	0	-.12	.10
145	25	0700	7	0	-.11	.11
145	25	0707	60	0	-.11	.11
145	25	0807	86	1	.31	-.19
145	25	0933	57	0	-.11	.11
145	25	1030	38	0	-.11	.11
145	25	1108	22	0	-.11	.11
145	25	1130	33	0	-.11	.11
145	25	1203	46	0	-.11	.11
145	25	1249	11	0	-.11	.11
145	25	1300	36	0	-.10	.13

* 0 = drifting; 1 = steaming

BOMEX Boundary Layer Instrument Package (BLIP)

The final processing of the BLIP data for the permanent archive will be completed in June. The data set consists of time series of one-sample-per-second data of wet- and dry-bulb temperatures, wind speed and direction, and pressure or relative humidity. These will be in BCD format on magnetic tape and continuous plots on 35-mm microfilm.

Manual editing has been performed on the entire A_0 data set; erroneous data have been deleted and doubtful data flagged. Over 750 hours of data will be placed in the archive. This includes all of the BLIP data collected during BOMEX, except for the Discoverer Period II data, which could not be processed.

BOMEX BLIP DATA FOR PERMANENT ARCHIVE

Ship	Period II (No. of runs)	Period III (No. of runs)	Period IV (No. of runs
Mt. Mitchell	22	25	30
Oceanographer	24	20	38
Discoverer	--	10	--
Rainier	2	5	--

Total data: Approximately 750 hours.

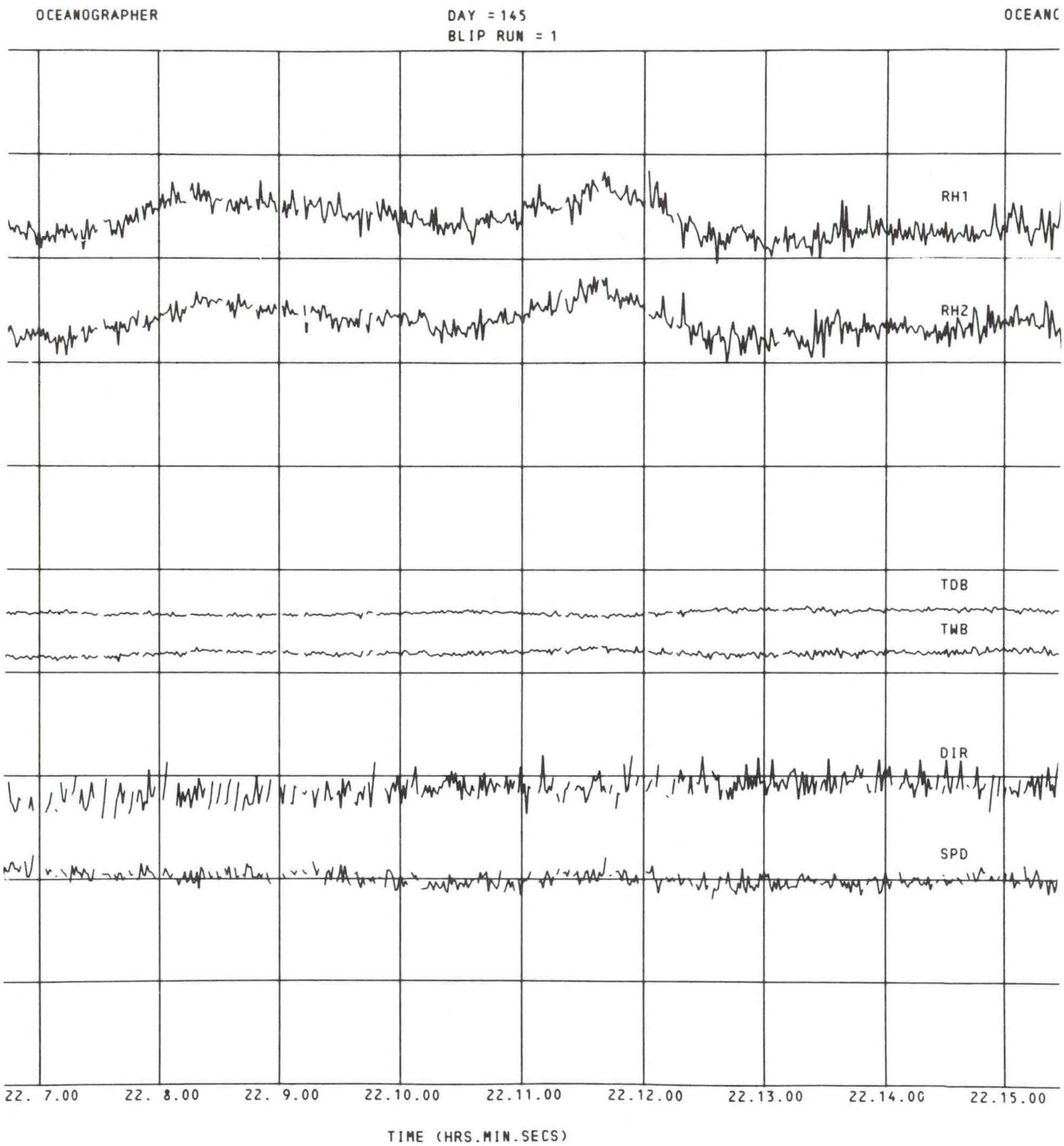
Format: 1 sample-per-second data on magnetic tape (30 tapes);
1 sample-per-second data plots on 35-mm microfilm.

Date: June 30, 1973.

TAPE FORMAT OF BLIP DATA

OCEANOGRAPHER 2 1 145 0

TIME SECS	A	SPEED MPS	B	DIREC DEG	C	U MPS	V MPS	N	TDB DEG C	D	TWB DEG C	E	PR/RHI LVL/PC	F	RH2 PC	G	N
71671		8.35		81.34		-8.25	-1.26	5	26.59		23.99		75.16	1	80.8		3
71672		8.63		86.45		-8.62	- .54	2	26.63		23.94		75.61	1	80.2		3
71673		8.44		88.22		-8.44	- .26	3	25.56		23.95		75.16	1	80.7		2
71674		8.12		91.91		-8.11	.27	3	26.61		24.12		75.37	1	81.6		1



Example of BLIP data plots

Status of BOMEX Rawinsonde Processing as of May 1, 1973

All necessary programming for processing the five BOMEX ship rawinsondes has been completed and checked out. Computer runs are going on.

Almost all computer runs for Period III have been completed, and that phase is in final inspection stage. This is a stage of selecting which version of a sounding, "automatic" or "manual," is of archive quality.

We expect to have magnetic tapes and microfilm assembled for the archive of Period III by May 31. Remaining periods will be completed in the order of II, I, IV. An estimated 75% of necessary computer runs have been completed for Period II. Runs for Periods I and IV will be started within May. We expect to complete Period II by June 30, Period I by July 31 and Period IV by August 31, 1973.

The entire automatic processing is divided into 7 stages:

I. Convert from 2-sample-per-second data to 5-second averages of temperature, humidity, slant-range and azimuth.

II. Merge auxiliary data (surface pressure, pressure calibrations, ship position, etc.) with data from Stage I.

III. Compute the sounding into meteorological units (pressure, temperature, moisture, winds).

IV. Microfilm pseudo-adiabatic and wind (u and v component) plots from data of Stage III.

V. Compute similar output as in Stages II, III, and IV for data introduced by manual means.

VI. Inspect microfilm outputs of Stages IV and V to determine which soundings are of archiveable quality, including a choice between "automatic" and "manual" if both are available.

VII. Assemble soundings chosen for archive in Stage VI onto magnetic tape and microfilm in time sequence for each ship.

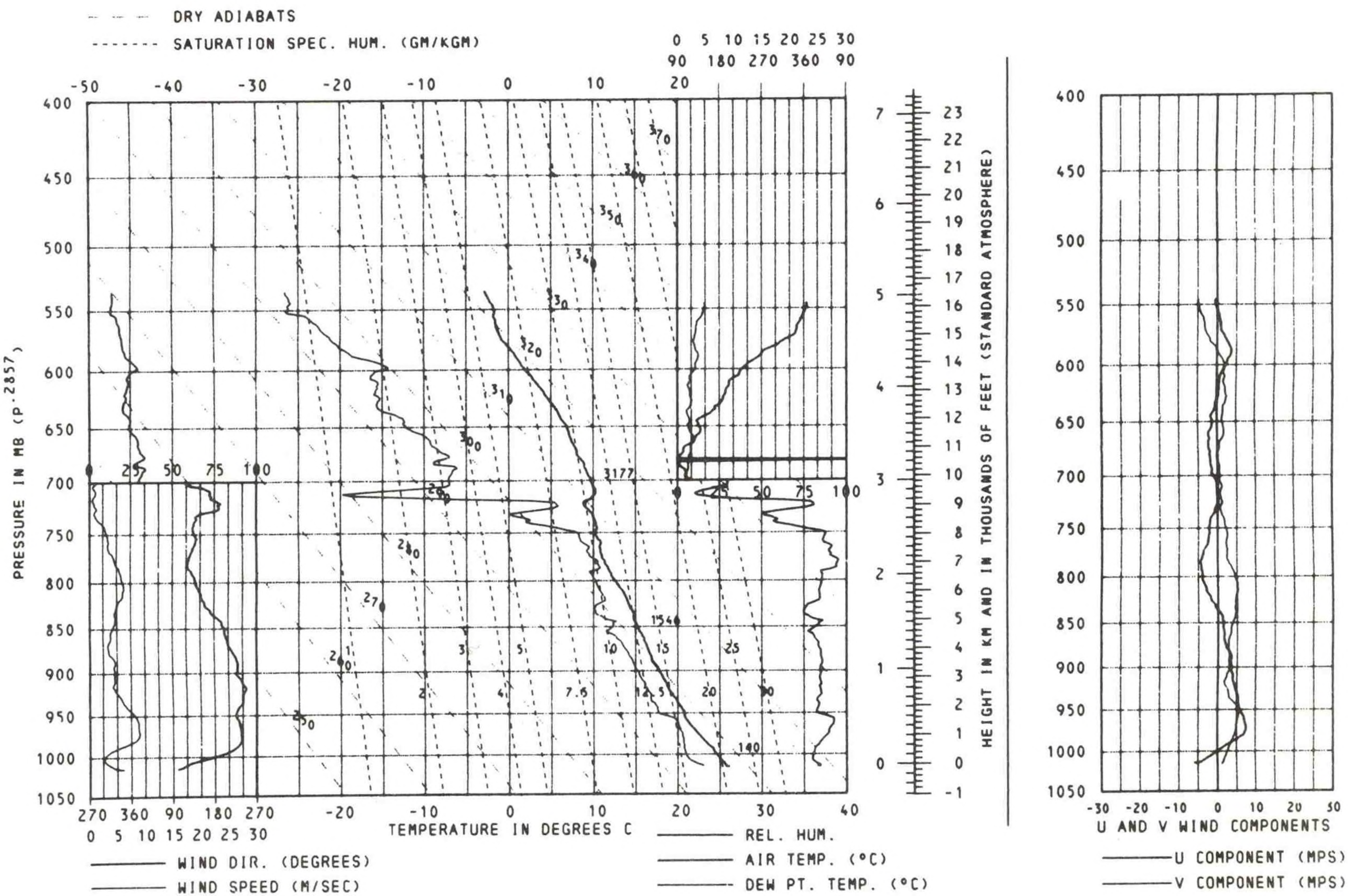
STATUS OF BOMEX RAWINSONDE DATA PROCESSING

Program runs	BOMEX Period I Percent complete	BOMEX Period I Date of completion	BOMEX Period II Percent complete	BOMEX Period II Date of completion	BOMEX Period III Percent complete	BOMEX Period III Date of completion	BOMEX Period IV Percent complete	BOMEX Period IV Date of completion
Automatic								
Temperature, humidity	0	May 25	100		100		0	June 15
Slant range, azimuth	0	May 25	100		100		0	June 15
Merging all data	0	May 31	93	May 3	100		0	June 20
Soundings computations	0	June 12	80	May 10	100		0	July 15
Microfilming	0	June 15	0	May 15	100		0	July 20
Manual	75	May 31	75	May 25	75	May 11	75	June 15
Assembly for Archive	0	July 31	0	June 30	0	May 31	0	August 31
Overall	20	July 31	50	June 30	70	May 31	20	August 31

OUTPUT FOR FLIGHT NO. 1644 PROCESSED ON 08/14/73
JULIAN DAY 175 PHASE NO. 3 TEMP-HUM MANUAL WINDS MANUAL
DATE 7/25/69 NOMINAL LAUNCH TIME 0Z ACTUAL LAUNCH JD 175 0. 0.0Z
SHIP NO. 1, RAINIER LATITUDE 16.54N, LONGITUDE 59.11W

TIME (SEC)	PRESS (MB)	TEMP (C.)	NOT LAGGED RELTV HUMID (PCT)	NOT LAGGED SPEC HUM (G/K)	NOT LAGGED DEW PNT (C.)	LAGGED HYGRISTOR RELTV HUMID (PCT)	LAGGED HYGRISTOR SAT V-PR (MB)	LAGGED HYGRISTOR VAP PRES (MB)	LAGGED HYGRISTOR SPEC HUM (G/K)	LAGGED HYGRISTOR DEW PNT (C.)	VIRT TEMP (K.)	THICK (M)	GEOPOT HEIGHT (M)	GEOMET HEIGHT (M)	POT TEMP (K.)	WIND U (M/S)	COMP V (M/S)	WIND DIR (DEG)	WIND SPD (M/S)	SHIP MOTION (M/S)	SHIP MOTION (M/S)
0.0	1014.6	27.3	84.0	18.9	24.4	84.0	36.3	30.5	18.9	24.4	303.9	999.0	9.1	9.1	299.2	-3.9	1.4	110.0	4.1	.2	-.2
5.0	1014.6	27.3	81.8	18.4	23.9	84.0	36.3	30.5	18.9	24.4	303.9	0.0	9.1	9.1	299.2	-3.9	1.3	108.0	4.1	.2	-.2
18.8	1008.2	27.2	75.6	17.0	22.5	77.3	36.0	27.9	17.4	22.9	303.5	56.3	65.4	65.5	299.6	-7.1	1.7	103.6	7.3	.2	-.2
65.0	986.5	25.6	80.1	16.7	21.9	84.6	32.8	27.7	17.7	22.8	301.9	192.9	258.3	258.8	299.9	-8.0	1.6	101.3	8.2	.2	-.2
106.4	969.2	24.2	85.5	16.7	21.6	90.9	30.2	27.4	17.8	22.6	300.5	156.1	414.4	415.1	300.0	-8.0	1.9	103.3	8.2	.2	-.2
125.0	960.7	22.4	88.0	15.6	20.3	98.5	27.1	26.7	17.5	22.2	298.7	76.9	491.3	492.2	299.0	-8.3	2.1	104.4	8.6	.2	-.2
126.8	959.9	22.4	88.2	15.6	20.4	98.2	27.1	26.6	17.4	22.1	298.7	7.3	498.6	499.5	299.0	-8.4	2.2	104.5	8.6	.2	-.2
156.8	947.8	21.8	94.4	16.4	20.9	100.0	26.1	26.1	17.3	21.8	298.1	111.4	610.1	611.1	299.5	-8.9	2.7	107.0	9.3	.2	-.2
185.0	935.6	21.1	83.7	14.0	18.2	88.5	25.0	22.2	14.9	19.1	296.9	112.5	722.5	723.8	299.9	-8.7	3.6	112.4	9.4	.2	-.2
198.2	929.7	20.8	80.0	13.2	17.2	84.2	24.5	20.7	14.0	18.0	296.4	55.4	778.0	779.3	300.1	-8.7	4.0	114.8	9.5	.2	-.2
245.0	909.8	19.7	78.2	12.3	15.8	82.1	22.9	18.8	13.0	16.5	295.1	187.5	965.5	967.2	300.8	-8.7	3.3	110.9	9.3	.2	-.2
284.0	894.8	18.8	76.8	11.6	14.6	80.6	21.6	17.4	12.2	15.3	294.1	143.1	1108.6	1110.6	301.3	-8.7	2.1	103.6	8.9	.2	-.2
305.0	887.2	18.3	81.6	12.1	15.1	85.6	21.0	18.0	12.7	15.8	293.7	73.1	1181.8	1183.9	301.6	-8.4	2.6	107.0	8.8	.2	-.2
318.2	882.2	18.0	85.4	12.5	15.5	89.5	20.6	18.5	13.1	16.2	293.4	49.1	1230.9	1233.1	301.7	-8.2	2.9	109.3	8.7	.2	-.2
339.8	873.7	17.5	83.4	12.0	14.6	87.4	20.0	17.5	12.5	15.4	292.8	82.5	1313.4	1315.8	302.1	-7.7	3.2	112.7	8.4	.2	-.2
354.2	867.7	17.6	82.2	12.0	14.6	84.1	20.2	17.0	12.2	14.9	292.9	59.2	1372.6	1375.2	302.8	-7.5	3.1	112.5	8.1	.2	-.2
365.0	863.1	17.6	77.2	11.3	13.5	78.6	20.1	15.8	11.5	13.8	292.8	45.5	1418.1	1420.8	303.2	-7.3	3.0	112.2	7.8	.2	-.2
422.6	841.5	17.6	37.3	5.6	2.9	37.4	20.2	7.5	5.6	2.9	291.8	217.2	1635.4	1638.5	305.5	-6.1	2.2	110.2	6.5	.2	-.2
425.0	840.7	17.6	37.3	5.6	2.9	37.3	20.2	7.5	5.6	2.9	291.8	8.3	1643.7	1646.8	305.6	-6.0	2.2	110.2	6.4	.2	-.2
484.4	820.5	17.7	36.6	5.6	2.7	36.5	20.2	7.4	5.6	2.7	291.8	208.0	1851.7	1855.3	307.8	-5.2	1.5	106.1	5.5	.2	-.2
485.0	820.3	17.7	36.6	5.6	2.7	36.5	20.2	7.4	5.6	2.7	291.8	1.7	1853.4	1857.0	307.8	-5.2	1.5	106.1	5.5	.2	-.2
545.0	802.7	16.6	35.9	5.3	1.4	37.1	18.9	7.0	5.4	1.9	290.7	185.5	2038.9	2042.9	308.5	-5.3	1.4	104.6	5.5	[illegible]	-.2
605.0	785.3	15.6	35.1	5.0	.3	36.5	17.7	6.5	5.1	.8	289.7	185.5	2224.4	2228.9	309.4	-5.5	.7	97.4	5.6	[illegible]	-.2
660.2	770.5	14.7	34.5	4.7	-.8	35.9	16.7	6.0	4.9	-.2	288.7	161.8	2386.2	2391.1	310.1	-5.1	-.2	88.3	5.1	.2	-.2
665.0	769.2	14.6	34.4	4.6	-.9	35.9	16.6	6.0	4.8	-.3	288.6	13.7	2399.9	2404.8	310.2	-5.0	-.2	88.2	5.0	.2	-.2
725.0	754.1	13.4	33.6	4.3	-2.2	35.3	15.4	5.4	4.5	-1.6	287.4	167.7	2567.6	2572.9	310.7	-4.1	.4	95.3	4.1	.2	-.2
785.0	737.6	12.3	32.8	4.0	-3.6	34.4	14.3	4.9	4.2	-2.9	286.2	186.0	2753.6	2759.4	311.4	-3.7	1.0	105.4	3.8	.2	-.2
798.8	733.5	12.0	32.6	3.9	-3.9	34.2	14.1	4.8	4.1	-3.3	285.9	46.2	2799.8	2805.7	311.6	-3.6	1.1	106.5	3.8	.2	-.2
845.0	721.7	11.0	31.9	3.6	-5.1	33.6	13.1	4.4	3.8	-4.4	284.8	135.8	2935.5	2941.8	311.9	-4.0	.6	98.0	4.0	.2	-.2
905.0	706.4	9.7	30.9	3.3	-6.6	32.6	12.1	3.9	3.5	-5.9	283.5	178.9	3114.5	3121.2	312.5	-4.1	1.5	109.8	4.3	.2	-.2
927.8	700.5	9.3	30.5	3.2	-7.2	32.2	11.7	3.8	3.4	-6.5	283.0	68.8	3183.3	3190.1	312.7	-3.8	2.6	124.9	4.6	.2	-.2
936.8	698.0	9.0	30.4	3.1	-7.5	32.2	11.5	3.7	3.3	-6.7	282.7	30.3	3213.5	3220.5	312.7	-3.7	2.8	127.6	4.7	.2	-.2
965.0	690.0	8.3	31.5	3.1	-7.6	33.5	10.9	3.7	3.3	-6.8	282.0	95.5	3309.0	3316.3	312.9	-4.3	.6	97.6	4.4	.2	-.2
1025.0	671.9	6.7	33.7	3.1	-8.1	35.9	9.8	3.5	3.3	-7.3	280.4	218.2	3527.3	3535.1	313.6	-4.4	-.2	88.0	4.4	.2	-.2
1085.0	655.1	5.2	35.4	3.0	-8.9	37.8	8.8	3.3	3.2	-8.0	278.9	207.9	3735.1	3743.5	314.1	-3.5	2.2	122.3	4.1	.2	-.2
1145.0	639.8	3.7	36.9	2.9	-9.7	39.5	8.0	3.1	3.1	-8.8	277.3	191.8	3927.0	3935.9	314.5	-4.0	-.2	86.8	4.0	.2	-.2
1185.8	627.5	2.7	37.8	2.8	-10.3	40.4	7.4	3.0	3.0	-9.4	276.3	157.3	4084.3	4093.7	315.1	-4.6	-2.7	59.8	5.4	.2	-.2
1205.0	622.0	2.2	40.4	2.9	-9.8	43.1	7.2	3.1	3.1	-9.0	275.9	71.8	4156.1	4165.7	315.4	-4.5	-1.5	71.9	4.7	.2	-.2
1265.0	606.5	.7	47.2	3.1	-9.2	50.5	6.4	3.3	3.3	-8.4	274.4	203.3	4359.4	4369.6	316.0	-4.9	.7	98.0	5.0	.2	-.2
1268.6	605.6	.7	47.6	3.2	-9.1	50.6	6.4	3.3	3.4	-8.3	274.4	12.3	4371.7	4382.0	316.1	-5.0	.7	98.1	5.1	.2	-.2
1325.0	589.6	-.9	52.4	3.2	-9.4	56.4	5.7	3.2	3.4	-8.4	272.8	214.5	4586.2	4597.1	316.7	-4.7	-1.7	69.8	5.0	.2	-.2
1361.0	578.5	-1.8	54.8	3.2	-9.7	58.8	5.4	3.2	3.4	-8.8	271.9	151.6	4737.7	4749.1	317.3	-3.7	-4.4	40.4	5.7	.2	-.2
1385.0	570.8	-2.4	47.9	2.7	-11.9	51.3	5.1	2.6	2.9	-11.1	271.2	106.4	4844.1	4855.8	317.8	-4.1	-4.6	42.1	6.2	.2	-.2
1399.4	567.0	-2.8	42.2	2.3	-13.8	45.3	5.0	2.3	2.5	-13.0	270.8	52.8	4896.9	4908.8	318.0	-4.4	-4.7	43.2	6.4	.2	-.2
1428.8	558.8	-3.5	75.4	4.0	-7.2	80.9	4.7	3.8	4.2	-6.3	270.3	116.2	5013.1	5025.4	318.4	-4.2	-4.3	44.1	6.0	.2	-.2
1445.0	554.0	-3.9	77.4	4.0	-7.3	83.0	4.6	3.8	4.3	-6.4	269.9	67.3	5080.4	5092.9	318.7	-3.7	-3.7	45.1	5.2	.2	-.2
1497.8	540.1	-5.3	86.1	4.1	-7.2	92.5	4.1	3.8	4.4	-6.3	268.6	200.2	5280.7	5293.8	319.5	-1.8	-3.0	31.3	3.5	.2	-.2
1505.0	538.2	-5.4	84.9	4.0	-7.6	91.3	4.1	3.7	4.3	-6.6	268.4	27.6	5308.3	5321.5	319.6	-1.5	-3.2	25.3	3.5	.2	-.2
1511.6	536.5	-5.6	83.9	3.9	-7.9	90.2	4.0	3.6	4.2	-6.9	268.2	25.4	5333.7	5347.0	319.7	-1.2	-3.3	19.8	3.5	.2	-.2
1512.8	536.2	-5.6	83.8	3.9	-7.9	89.9	4.0	3.6	4.2	-7.0	268.2	4.1	5337.7	5351.1	319.7	-1.1	-3.3	18.8	3.5	.2	-.2
1551.8	526.2	-6.3	59.5	2.7	-12.8	63.0	3.8	2.4	2.9	-12.1	267.4	147.5	5485.2	5499.1	320.7	-.5	-4.3	6.4	4.4	.2	-.2

RAWINSONDE PSEUDO-ADIABATIC CHART (1050 TO 400 MB)
OUTPUT FOR FLIGHT NO. 2 PROCESSED ON 08/18/73
JULIAN DAY 123 PHASE NO. 1
DATE 5/ 3/69 NOMINAL LAUNCH TIME 300Z ACTUAL LAUNCH JD 123 305
SHIP NO. 0, OCEAO LATITUDE 17.37N, LONGITUDE 54.34W



BOMEX Radar Data Reduction

During BOMEX 74 rolls of 35-mm film of surface radar data were collected and these were placed in the archive. Out of these, 2,200 individual PPI frames were manually digitized for Period III and 3,200 frames were digitized for Period II. The manually digitized PPI photographs consist of gain step sequences. For Periods II and III the digitized sequences are compressed into PPI composites showing for each data point the highest gain step level observed. The composite data will be archived on both magnetic tape and microfilm.

BOMEX RADAR DATA REDUCTION

Period	PPI photos; No. of rolls of microfilm	No. of manually digitized PPI photographs	No. of magnetic tapes of composite gain sequences	No. of rolls of microfilm composite PPI displays
I	6 Island 0 Discoverer	--------	--------	--------
II	22 Island 5 Discoverer	1,600 Island 1,600 Discoverer	2 Island 1 Discoverer	1 Island 1 Discoverer
III	11 Island 5 Discoverer	1,500 Island 700 Discoverer	1 Island 1 Discoverer	1 Island 1 Discoverer
IV	19 Island 7 Discoverer	--------	--------	--------

Process complete for Period III.

Manual digitization 80% complete for Period II.

Estimated completion of Period II processing: June 30, 1973.

BOMEX DIGITIZED RADAR DATA

DATE 150 START TIME123602 END TIME 124832 RADAR 1

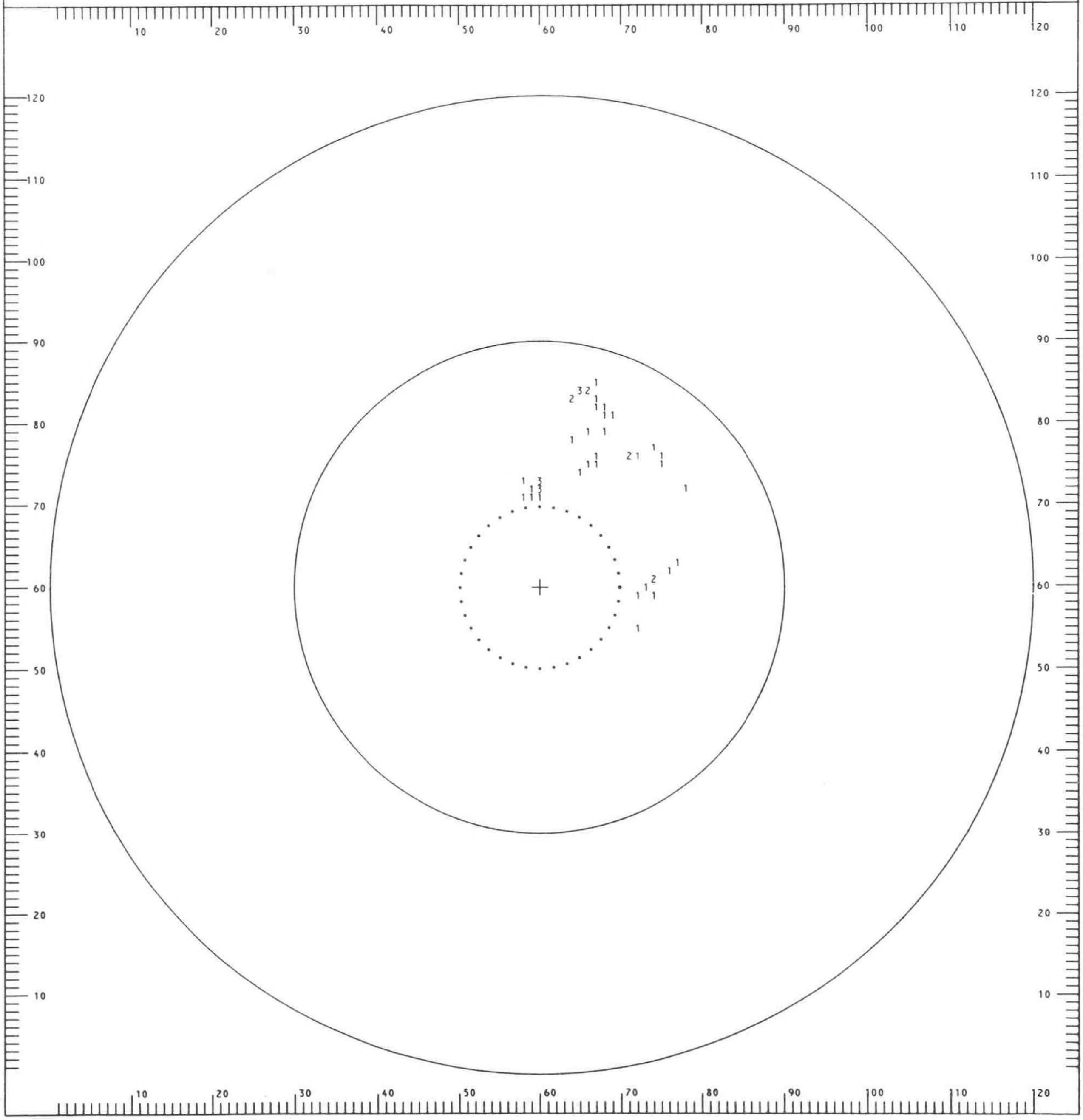
FIRST PIC 3000 LAST PIC 3004 LAST PIC CODE 2 ANT. TILT 0

LAT 0 LON 0 CLTR 40 FID ANG. 70 FID.DIST.300 SCALE 406 STC 0

COMPOSITE POINTS 36 PER CENT ACC. 95

GAIN STEP POWERS	1	2	3	4	5	6
	82	64	58	48	40	0

RANGE MARKER INTERVAL 121.80



BOMEX DIGITIZED RADAR DATA

DATE 150 START TIME152515 END TIME 152630 RADAR 2

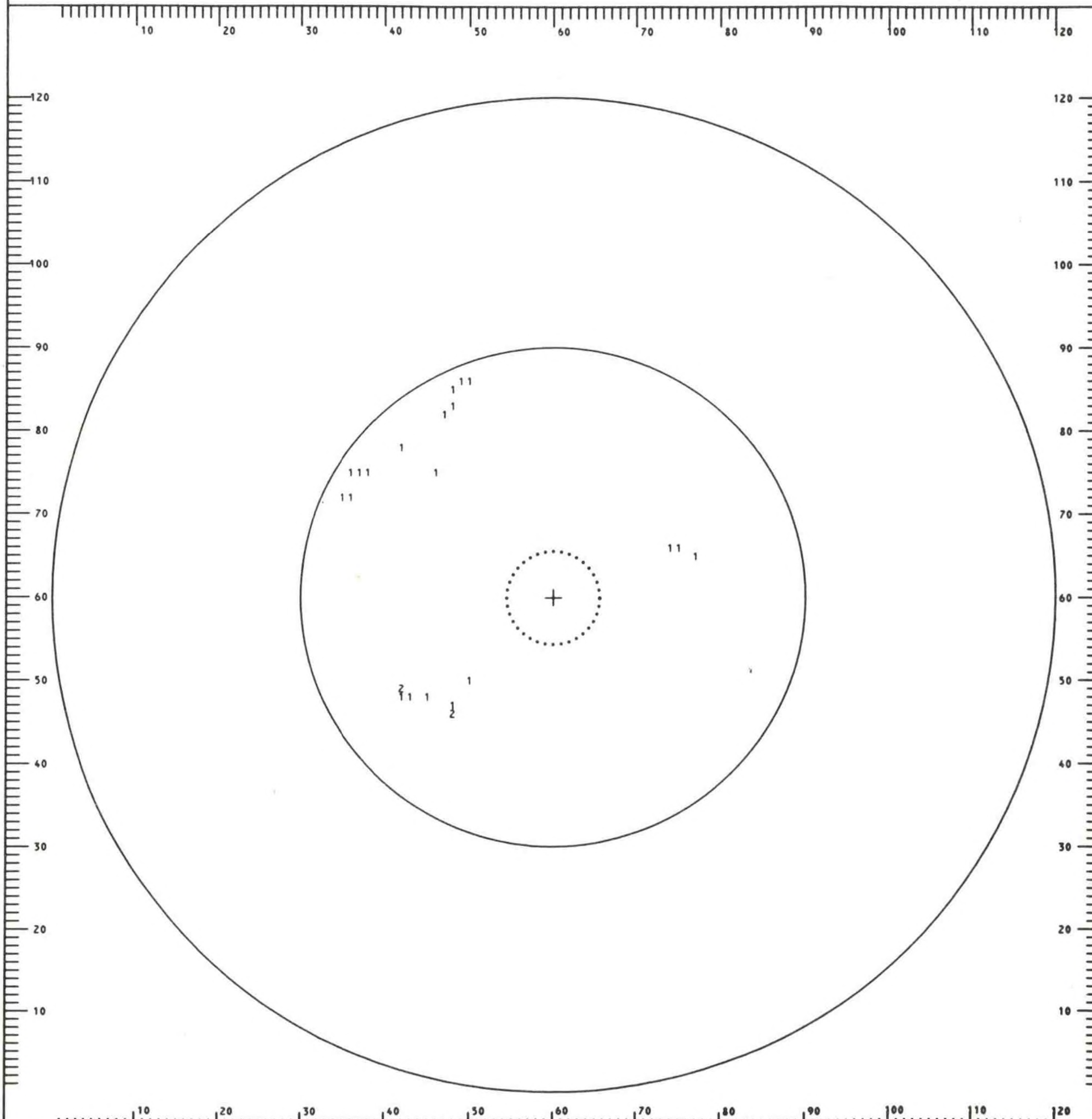
FIRST PIC 5000 LAST PIC 5002 LAST PIC CODE 1 ANT. TILT 0

LAT 0 LON 0 CLTR 25 FID ANG. 0 FID.DIST.345 SCALE 448 STC 1

COMPOSITE POINTS 22 PER CENT ACC. 95

GAIN STEP POWERS	1	2	3	4	5	6
	91	76	70	0	0	0

RANGE MARKER INTERVAL 134.40



Preparation of RFF Cloud Photographs and Instrument Panel Photographs for BOMEX Archive

During the course of the RFF flights, a series of photographs of clouds were taken and have been presented in moving picture form. Those taken from the nose of the aircraft are 16-mm color photographs, while those taken from the right and left sides of the nose of the aircraft are 35-mm black and white pictures.

In addition to the cloud photographs, pictures were also taken of the instrument panel on the aircraft. These are presented either in 35-mm black and white moving pictures or as microfilm.

STATUS OF PREPARATION OF RFF CLOUD PHOTOGRAPHS AND AIRCRAFT PANEL PHOTOS FOR BOMEX ARCHIVE

Period	16-mm Color Movie Nose Camera	35-mm Black and White Movie Left	35-mm Black and White Movie Right	35-mm Black and White Movie of Panel	35-mm Microfilm of Panel
I	Completed	Completed	Completed	Completed	Completed
II	Completed	Completed	Completed	Completed	Completed
III	Completed	Completed	Completed	Completed	Completed
IV	Completed	Completed	Completed	Completed	Completed

Preparation of Aircraft Data for BOMEX Archive

RFF

Status: All input tapes have been prepared and machine and manual edits completed. Archiving program is complete and debugged.

Outputs and Schedule - All Periods: 1 sample-per-second archive tape generation began May 1, 1973. The data format is shown on the next page. The archive program generates a statistical summary which will be used to correct (by addition or deletion of edit cards) any serious discrepancies noted. Completion by June 15.

1 sample-per-second tapes will be condensed to 30-second average time series and microfilm plots of these generated and archived by October 1, 1973.

Navy and Air Force

Status: All data have been cross-checked and corrected for assignment to proper flight and ordered in correct time sequence. A program (modified from RFF processing) is being written to compute wind box corrections.

Outputs and Schedule - All Periods: All data will be archived as originally tabulated with the addition of best estimates of u, v, t and q at selected times. Since the bulk of the original data consists of bursts of 10 readings each 5 minutes, the values of u, v, t and q noted above will be archived at approximately these times. Completion scheduled for June 30, 1973.

ARCHIVE TAPE DESCRIPTION

Header - appropriate descriptive material

Density - 556 or 800 BPI

Mode - BCD

Record Length - 2,080 (16 x 130) characters

Record Contents

Word	Field	Data		Format
1	1-6	AP	(Notes 1,2,3)	F6.0
2	7-12	RA	"	F6.0
3	13-17	HDh	"	F5.0
4	18-24	DTC	"	F7.0
5	25-28	DA82	"	F4.0
6	29-33	TVOR	"	F5.0
7	34-38	IRH	"	F5.0
8	39-43	DP	"	F5.0
9	44-47	GS153	"	F4.0
10	48-51	DA153	"	F4.0
11	52-56	TROS	"	F5.0
12	57-61	CSI	"	F5.0
13	62-66	LIOW	"	F5.0
14	67-68	MEM	"	F2.0
15	69-71	JD		F3.0
16	72-73	HR		F2.0
17	74-75	MN		F2.0
18	76-77	SC		F2.0
19	78-81	U		F4.1
20	82-85	V		F4.1
21	86-89	T		F4.1
22	90-93	Q		F4.1
23	94-97	LW	(Note 4)	F4.1
24	98-102	P		F5.1
25	103-107	Z		F5.0
26	108-114	LAT		F7.4
27	115-121	LON		F7.4
28	122-125	GS?		F4.1
29	126-129	TH?		F4.1

Note 1. If denoted missing on input tapes (-1) denote missing on archive tape (-1).

Note 2. If corrected by correction card, word = -data.

Note 3. Units of "counts" as originally recorded by RFF with exceptions as noted in 1 and 2 above.

Note 4. If data missing on input tape, LW is set to 0 on archive tape.

Preparation of Dropsonde Data for BOMEX Archive

Dropsonde data from the four BOMEX observational periods have been completely re-evaluated from the original recorder strip charts using closer tolerances than required by standard Air Weather Service procedures. A total of 436 of the 488 soundings (89%) provided useable data and have been processed. Tabular output data on magnetic tape include: (1) uncorrected significant level data; (2) significant level data corrected for sea-level pressure error, and for temperature and humidity lag errors; (3) corrected data at 10-millibar intervals of p*; and (4) corrected data at 50-millibar mandatory pressure levels. Microfilm of these four tabular outputs plus a pseudo-adiabatic plot of each sounding will also be available.

STATUS OF PREPARATION OF DROPSONDE DATA FOR BOMEX ARCHIVE

BOMEX Period	No. of Soundings	No. of Tapes	Reels of Microfilm	Completion Schedule	
				Archive tape	Microfilm
I	87	1	1	Completed	5/15/73
II	140	2	1	5/4/73	5/15/73
III	107	1	1	Completed	5/4/73
IV	64	1	1	5/31/73	5/31/73
*	38	1	1	5/4/73	5/15/73
Totals	436	6	5		

* Comparative soundings over the ship Mt. Mitchell in Periods i, II, III.

THIS IS THE SIGNIFICANT LEVEL CORRECTED DATA

OUTPUT FOR DROP NO. 1 POSITION 2 COORDINATES 14.3N LAT., 57.0W LONG.
JULIAN DATE 123 DATE 5/ 3/69 TIME(GMT) 1322
FLIGHT PRESSURE 462 (MB.) FLIGHT ALTITUDE 6169 (METERS)

PRESS (MB)	TEMP DEG C	RELTIV HUMID (PCT)	SATUR VAPOR (MB)	VAPOR PRESS (MB)	SPEC HUMID (G/KG)	DEW POINT DEG C	POT TEMP DEG K	VIRT TEMP DEG K	MEAN VIRT DEG K	THICK (GPM)	GEOPOT HEIGHT (GPM)	GEOMET HEIGHT (M)
1014.10	27.05	80.83	35.77	28.91	17.93	23.47	299.01	303.48	303.48	0.00	0.00	0.00
963.81	22.61	93.94	27.44	25.78	16.81	21.58	298.90	298.79	301.13	448.61	448.61	449.39
927.69	20.58	87.03	24.24	21.09	14.27	18.34	300.11	296.28	297.53	332.93	781.55	782.94
862.06	16.67	99.11	18.98	18.81	13.68	16.53	302.40	292.24	294.26	632.41	1413.96	1416.61
828.42	16.72	61.75	19.04	11.75	8.87	9.35	305.91	291.44	291.84	340.28	1754.23	1757.62
818.42	16.22	45.18	18.45	8.33	6.36	4.34	306.45	290.50	290.97	103.51	1857.74	1861.36
808.65	15.90	37.56	18.07	6.79	5.24	1.45	307.16	289.98	290.24	102.11	1959.85	1963.70
789.42	14.60	32.97	16.62	5.48	4.33	-1.48	307.89	288.52	289.25	203.90	2163.75	2168.07
778.42	14.11	38.63	16.10	6.22	4.98	.24	308.60	288.14	288.33	118.51	2282.26	2286.86
769.87	13.63	60.11	15.61	9.38	7.62	6.05	309.06	288.12	288.13	93.12	2375.38	2380.20
760.87	13.16	63.57	15.14	9.62	7.90	6.41	309.59	287.69	287.91	99.16	2474.54	2479.61
711.60	9.16	36.34	11.61	4.22	3.69	-4.99	311.17	282.95	285.32	559.50	3034.05	3040.53
685.10	7.18	16.75	10.15	1.70	1.54	-16.37	312.37	280.61	281.78	313.23	3347.28	3354.59
663.00	5.11	17.71	8.79	1.56	1.46	-17.41	312.98	278.52	279.56	268.50	3615.78	3623.84
659.94	5.94	16.09	9.31	1.50	1.41	-17.86	314.33	279.34	278.93	37.80	3653.58	3661.74
617.33	4.12	14.74	8.20	1.21	1.22	-20.35	318.29	277.48	278.41	544.31	4197.89	4207.63
578.06	1.58	13.57	6.85	.93	1.00	-23.33	321.36	274.91	276.19	531.73	4729.62	4740.99
539.79	-1.04	12.51	5.66	.71	.82	-26.32	324.60	272.25	273.58	548.91	5278.54	5291.68
492.47	-3.95	9.98	4.56	.46	.58	-31.01	329.67	269.31	270.78	727.79	6006.32	6021.98
462.00	-9.40	9.98	3.00	.30	.40	-35.29	328.94	263.82	266.57	498.62	6504.94	6522.41

THIS IS THE SIGNIFICANT LEVEL UNCORRECTED DATA

OUTPUT FOR DROP NO. 1 POSITION 2 COORDINATES 14.3N LAT., 57.0W LONG.
JULIAN DATE 123 DATE 5/ 3/69 TIME(GMT) 1322
FLIGHT PRESSURE 462 (MB.) FLIGHT ALTITUDE 6169 (METERS)

PRESS (MB)	TEMP DEG C	RELTIV HUMID (PCT)	SATUR VAPOR (MB)	VAPOR PRESS (MB)	SPEC HUMID (G/KG)	DEW POINT DEG C	POT TEMP DEG K	VIRT TEMP DEG K	MEAN VIRT DEG K	THICK (GPM)	GEOPOT HEIGHT (GPM)	GEOMET HEIGHT (M)
1019.60	26.81	88.32	35.26	31.14	19.22	24.71	298.31	303.47	303.47	0.00	0.00	0.00
970.00	22.42	99.66	27.12	27.03	17.52	22.36	298.16	298.72	301.10	439.82	439.82	440.58
932.50	20.42	92.54	24.01	22.22	14.95	19.17	299.51	296.25	297.49	343.56	783.38	784.77
867.10	16.61	99.68	18.91	18.85	13.64	16.56	301.84	292.18	294.21	626.65	1410.02	1412.67
833.00	16.61	65.09	18.91	12.31	9.25	10.03	305.32	291.40	291.79	342.90	1752.93	1756.31
823.00	16.11	47.64	18.32	8.73	6.62	5.00	305.85	290.44	290.92	102.92	1855.84	1859.46
813.00	15.78	40.17	17.93	7.20	5.53	2.29	306.56	289.91	290.17	103.91	1959.75	1963.60
794.00	14.46	34.94	16.48	5.76	4.52	-.81	307.24	288.41	289.16	200.29	2160.04	2164.36
783.00	13.97	41.34	15.96	6.60	5.26	1.06	307.94	288.05	288.23	117.78	2277.82	2282.41
774.00	13.49	64.70	15.47	10.01	8.08	6.98	308.44	288.06	288.06	97.54	2375.37	2380.19
765.00	13.01	69.29	14.99	10.39	8.49	7.52	308.96	287.65	287.85	98.62	2473.98	2479.05
715.50	8.97	39.36	11.46	4.51	3.93	-4.10	310.47	282.80	285.22	558.87	3032.85	3039.33
689.00	7.02	18.04	10.04	1.81	1.64	-15.61	311.68	280.46	281.63	311.33	3344.18	3351.49
666.90	5.70	17.49	9.16	1.60	1.50	-17.07	313.12	279.11	279.79	267.17	3611.36	3619.40
663.84	6.58	16.88	9.74	1.64	1.54	-16.77	314.52	280.00	279.56	37.66	3649.01	3657.16
621.00	3.97	15.82	8.12	1.28	1.29	-19.66	317.58	277.34	278.67	544.53	4193.54	4203.27
581.50	1.43	14.62	6.77	.99	1.06	-22.62	320.64	274.76	276.05	531.41	4724.95	4736.31
543.00	-1.19	13.39	5.60	.75	.86	-25.70	323.87	272.11	273.44	548.65	5273.61	5286.74
495.33	-4.15	10.68	4.49	.48	.60	-30.46	328.88	269.11	270.61	728.33	6001.94	6017.58
462.00	-9.40	10.68	3.00	.32	.43	-34.61	328.94	263.83	266.47	543.71	6545.65	6563.27

THIS IS THE PSTAR 10 MB. LEVEL CORRECTED DATA

OUTPUT FOR DROP NO. 1 POSITION 2 COORDINATES 14.3N LAT., 57.0W LONG.
JULIAN DATE 123 DATE 5/ 3/69 TIME(GMT) 1322
FLIGHT PRESSURE 462 (MB.) FLIGHT ALTITUDE 6169 (METERS)

PRESS (MB)	TEMP DEG C	RELTIV HUMID (PCT)	SATUR VAPOR (MB)	VAPOR PRESS (MB)	SPEC HUMID (G/KG)	DEW POINT DEG C	POT TEMP DEG K	VIRT TEMP DEG K	MEAN VIRT DEG K	THICK (GPM)	GEOPOT HEIGHT (GPM)	GEOMET HEIGHT (M)
0.00	27.05	80.83	35.77	28.91	17.93	23.47	299.01	303.48	303.48	0.00	0.00	0.00
10.00	26.17	83.44	33.95	28.33	17.74	23.13	298.98	302.55	303.02	87.96	87.96	88.10
20.00	25.28	86.05	32.22	27.73	17.53	22.78	298.95	301.62	302.09	88.57	176.52	176.82
30.00	24.40	88.65	30.57	27.10	17.31	22.40	298.93	300.69	301.16	89.18	265.71	266.16
40.00	23.52	91.26	28.99	26.46	17.07	22.01	298.91	299.75	300.22	89.82	355.52	356.13
50.00	22.63	93.87	27.48	25.80	16.81	21.59	298.90	298.81	299.28	90.46	445.98	446.75
60.00	22.06	92.09	26.54	24.44	16.09	20.71	299.21	298.11	298.46	91.15	537.13	538.07
70.00	21.50	90.17	25.65	23.13	15.38	19.82	299.55	297.41	297.76	91.90	629.03	630.13
80.00	20.94	88.26	24.78	21.87	14.69	18.92	299.89	296.72	297.07	92.66	721.69	722.96
90.00	20.36	87.69	23.92	20.98	14.24	18.25	300.22	296.06	296.39	93.44	815.13	816.58
100.00	19.77	89.53	23.05	20.64	14.17	18.00	300.55	295.45	295.76	94.26	909.39	911.02
110.00	19.17	91.37	22.22	20.30	14.09	17.73	300.88	294.83	295.14	95.10	1004.48	1006.30
120.00	18.58	93.21	21.41	19.95	14.00	17.46	301.23	294.22	294.53	95.95	1100.43	1102.45
130.00	17.98	95.05	20.62	19.60	13.91	17.18	301.58	293.60	293.91	96.83	1197.26	1199.47
140.00	17.39	96.89	19.86	19.24	13.81	16.89	301.94	292.98	293.29	97.72	1294.99	1297.40
150.00	16.79	98.73	19.13	18.88	13.71	16.59	302.32	292.37	292.67	98.64	1393.63	1396.24
160.00	16.68	90.27	18.99	17.14	12.58	15.08	303.21	292.06	292.21	99.63	1493.26	1496.08
170.00	16.69	79.16	19.01	15.05	11.16	13.07	304.25	291.82	291.94	100.71	1593.97	1597.01
180.00	16.71	68.06	19.03	12.95	9.71	10.79	305.30	291.58	291.70	101.83	1695.79	1699.06
190.00	16.50	54.59	18.78	10.25	7.78	7.33	306.14	291.03	291.31	102.92	1798.71	1802.20
200.00	16.08	41.81	18.28	7.64	5.86	3.12	306.76	290.27	290.65	103.94	1902.65	1906.37
210.00	15.59	36.47	17.72	6.46	5.01	.77	307.33	289.63	289.95	104.97	2007.62	2011.58
220.00	14.92	34.09	16.97	5.78	4.54	-.75	307.71	288.87	289.25	106.03	2113.64	2117.85
230.00	14.36	35.71	16.37	5.84	4.65	-.61	308.23	288.33	288.60	107.13	2220.77	2225.23
240.00	13.87	49.48	15.85	7.84	6.33	3.48	308.83	288.13	288.23	108.37	2329.14	2333.85
250.00	13.33	62.33	15.31	9.54	7.80	6.28	309.40	287.84	287.99	109.68	2438.82	2443.80
260.00	12.61	59.82	14.60	8.73	7.24	5.01	309.79	287.02	287.43	110.91	2549.73	2554.98
270.00	11.79	54.30	13.84	7.52	6.31	2.88	310.09	286.05	286.53	112.04	2661.77	2667.30
280.00	10.98	48.77	13.12	6.40	5.44	.63	310.41	285.08	285.56	113.17	2774.95	2780.76
290.00	10.17	43.24	12.43	5.37	4.63	-1.75	310.74	284.13	284.61	114.34	2889.29	2895.39
300.00	9.36	37.72	11.77	4.44	3.87	-4.31	311.08	283.18	283.66	115.54	3004.83	3011.23
310.00	8.60	30.79	11.18	3.44	3.05	-7.63	311.50	282.28	282.73	116.79	3121.62	3128.33
320.00	7.85	23.40	10.62	2.49	2.23	-11.74	311.95	281.39	281.84	118.09	3239.71	3246.73
330.00	7.09	16.80	10.08	1.69	1.54	-16.41	312.39	280.51	280.95	119.42	3359.13	3366.48
340.00	6.15	17.23	9.45	1.63	1.50	-16.88	312.66	279.57	280.04	120.79	3479.92	3487.60
350.00	5.21	17.66	8.86	1.56	1.47	-17.35	312.94	278.62	279.09	122.18	3602.10	3610.12
360.00	5.69	15.90	9.15	1.46	1.39	-18.20	314.84	279.08	278.85	123.93	3726.03	3734.39
370.00	5.26	15.58	8.89	1.38	1.34	-18.78	315.75	278.65	278.87	125.84	3851.87	3860.60
380.00	4.83	15.27	8.62	1.32	1.29	-19.37	316.68	278.21	278.43	127.61	3979.48	3988.58
390.00	4.41	14.95	8.37	1.25	1.25	-19.95	317.63	277.78	277.99	129.44	4108.92	4118.40
400.00	3.91	14.64	8.08	1.18	1.20	-20.60	318.53	277.27	277.52	131.31	4240.23	4250.09
410.00	3.26	14.34	7.72	1.11	1.14	-21.35	319.28	276.61	276.94	133.18	4373.41	4383.68
420.00	2.62	14.05	7.38	1.04	1.09	-22.11	320.06	275.96	276.29	135.08	4508.49	4519.17
430.00	1.97	13.75	7.04	.97	1.03	-22.87	320.87	275.30	275.63	137.05	4645.54	4656.65
440.00	1.31	13.46	6.72	.90	.98	-23.64	321.68	274.63	274.97	139.08	4784.63	4796.17
450.00	.62	13.18	6.39	.84	.93	-24.42	322.49	273.94	274.29	141.18	4925.80	4937.80
460.00	-.06	12.91	6.08	.79	.88	-25.20	323.34	273.25	273.59	143.34	5069.14	5081.60
470.00	-.75	12.63	5.79	.73	.84	-25.98	324.21	272.55	272.90	145.58	5214.72	5227.66
480.00	-1.39	12.21	5.52	.67	.79	-26.86	325.16	271.90	272.23	147.91	5362.64	5376.07
490.00	-2.00	11.67	5.27	.62	.73	-27.83	326.19	271.28	271.59	150.36	5512.99	5526.93
500.00	-2.62	11.14	5.04	.56	.68	-28.82	327.25	270.65	270.97	152.90	5665.89	5680.36

THIS IS MANDATORY PRESSURE LEVEL CORRECTED DATA

OUTPUT FOR DROP NO. 1 POSITION 2 COORDINATES 14.3N LAT., 57.0W LONG.
JULIAN DATE 123 DATE 5/ 3/69 TIME(GMT) 1322
FLIGHT PRESSURE 462 (MB.) FLIGHT ALTITUDE 6169 (METERS)

PRESS (MB)	TEMP DEG C	RELTIV HUMID (PCT)	SATUR VAPOR (MB)	VAPOR PRESS (MB)	SPEC HUMID (G/KG)	DEW POINT DEG C	POT TEMP DEG K	VIRT TEMP DEG K	MEAN VIRT DEG K	THICK (GPM)	GEOPOT HEIGHT (GPM)	GEOMET HEIGHT (M)
1000.00	25.80	84.51	33.23	28.09	17.66	22.99	298.96	302.17	302.83	124.19	124.19	124.40
950.00	21.83	91.30	26.17	23.90	15.80	20.35	299.35	297.82	300.00	450.73	574.92	575.92
900.00	18.93	92.13	21.88	20.16	14.05	17.62	301.02	294.58	296.20	469.09	1044.01	1045.91
850.00	16.69	85.72	19.00	16.29	12.00	14.28	303.64	291.96	293.27	491.00	1535.02	1537.93
800.00	15.31	35.49	17.41	6.18	4.82	.15	307.48	289.32	290.64	516.11	2051.12	2055.18
750.00	12.27	57.56	14.28	8.22	6.85	4.15	309.91	286.62	287.97	544.38	2595.50	2600.86
700.00	8.29	27.76	10.95	3.04	2.70	-9.22	311.68	281.92	284.27	574.47	3169.97	3176.81
650.00	5.51	15.77	9.04	1.43	1.37	-18.44	315.21	278.91	280.41	608.69	3778.66	3787.17
600.00	3.00	14.22	7.58	1.08	1.12	-21.66	319.60	276.34	277.62	650.90	4429.56	4440.00
550.00	-.34	12.80	5.96	.76	.86	-25.52	323.69	272.96	274.65	700.00	5129.56	5142.22
500.00	-3.48	10.39	4.72	.49	.61	-30.24	328.81	269.78	271.37	757.59	5887.15	5902.39

DROPSONDE

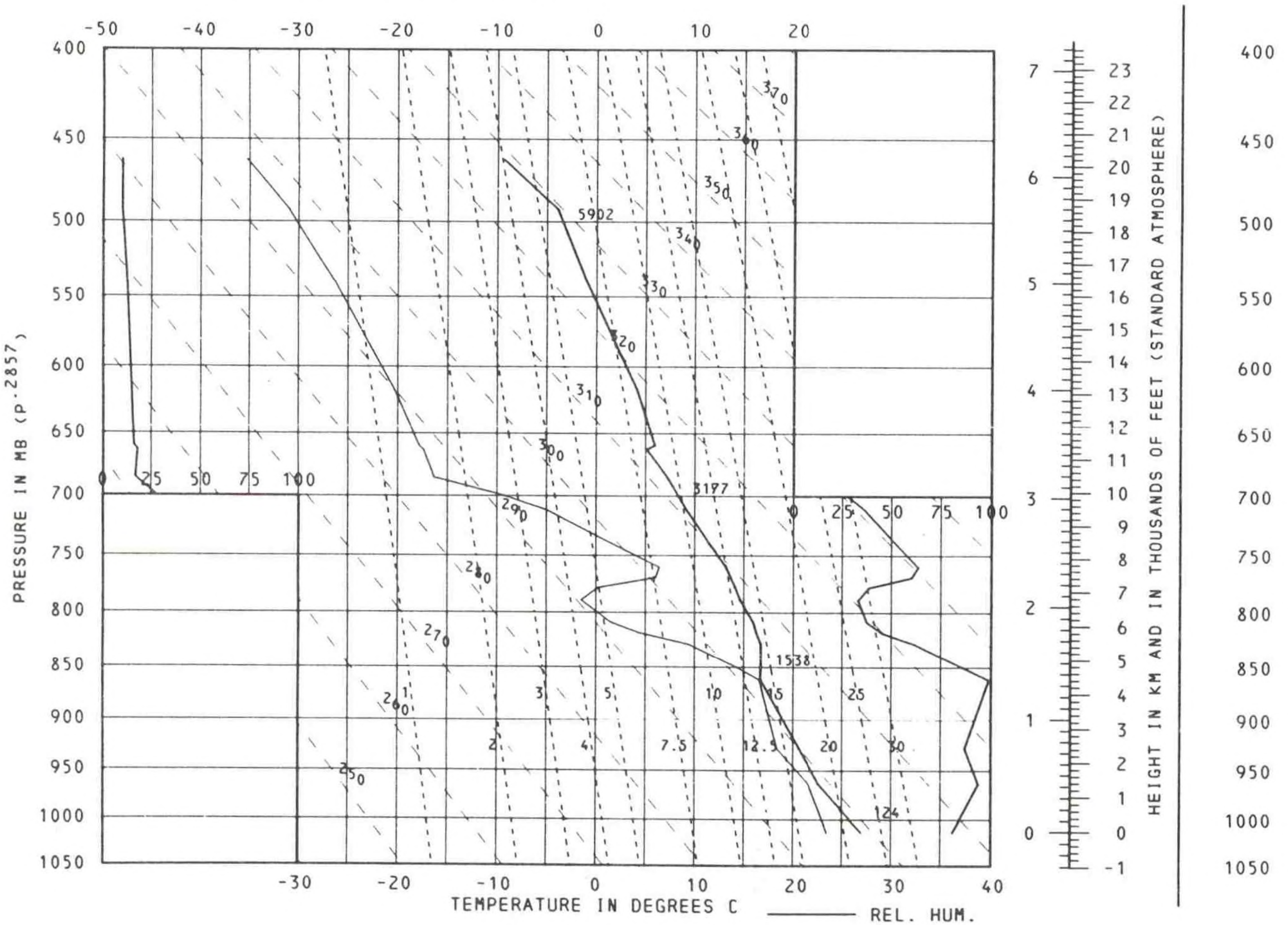
PSEUDO-ADIABATIC CHART (1050 TO 400 MB)

THIS IS THE SIGNIFICANT LEVEL CORRECTED DATA

OUTPUT FOR DROP NO. 1 POSITION 2 COORDINATES 14.3N LAT., 57.0W LONG.
JULIAN DATE 123 DATE 5/ 3/69 TIME(GMT) 1322

— — — DRY ADIABATS

------- SATURATION SPEC. HUM. (GM/KGM)



——— REL. HUM.

——— AIR TEMP. (°C)

——— DEW PT. TEMP. (°C)

APPENDIX III

Status of BOMAP Data Sets, August 8, 1973

Fixed Ship STD Data:	Completed.
Ship Boom Data:	Completed.
BLIP Data:	Tapes completed, microfilm in process, expected completion 9/1/73.
Rawinsonde Data :	Period III completed. Periods I, II, and IV expected complete 10/30/73.
Aircraft Data:	Expected completion 9/15/73.
Dropsonde Data:	Completed.
Radar Data:	Expected completion 9/15/73.
Aircraft and Satellite Photography:	Completed.

WIND STRESS AND TURBULENT ENERGY BUDGET MEASUREMENTS IN THE UNDISTURBED SURFACE BOUNDARY LAYER OVER THE SEA; THE TERN BUOY EXPERIMENT *

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Introduction

In the closing hours of BOMEX, the lightweight spar-buoy Tern[1], equipped with low-inertia cup anemometers at three levels, was launched from the USCGS Rainier, stationed at the northernmost position of the modified ship array during Period IV. This last of the point-flux experiments carried out an investigation of the undisturbed mean and turbulent wind structure in the surface boundary layer by placing a suitably instrumented mast of minimal cross section in the open sea. The comparatively fragile Tern was launched successfully only twice in six attempts. This note summarizes the more complete experiment of July 28; in an earlier run on July 20, data at only two levels were obtained, and therefore budget calculations could not be made.

As reported at the early BOMEX Symposium (Frenzen, 1969), the first analysis of these observations appeared to indicate that turbulent kinetic energy did not dissipate locally; calculated dissipation rates failed to balance rates of energy production by as much as 40 percent. This was attributed to vertical divergence terms, and it was speculated that large departures from local dissipation might be characteristic of wind flow over waves. This note tempers these speculations, for the energy budget discrepancies are greatly reduced when new values, independently suggested, are used for the Kolmogorov and von Karman constants. Here we use $\alpha_1 = 0.55$ (instead of the former 0.49) and $k = 0.35$ (instead of 0.41). Other observations supporting these values appear in a number of articles (Businger et al., 1971; Pond et al., 1971; Frenzen, 1972).

Equipment

As shown in figure 1, the buoy is quite slender. At the water line, the Tern is 10 cm in diameter; at 2 m the mast narrows to 5 cm, while above 4 m it is only 2.5 cm wide. In this final BOMEX experiment, the top sensor stood 6.5 m above the water. The damping disc and ballast were 11 m below the surface. In the 1-m waves of July 28, the Tern buoy was observed to pitch $\pm$ 5° and to heave an estimated $\pm$ 25 cm. During launching, the data cable fouled the pickup line and caused a cross-wind list of about 15°, while excess ballast lowered the buoy an extra 10 cm in the water. These changes in

* Work performed under the auspicies of the U.S. Atomic Energy Commission.

[1] Constructed for this project by the Division of Meteorological Physics, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia, during the principal author's temporary assignment to that organization; the name "Tern" refers to the small sea bird which migrates between the southern and northern hemispheres.

geometry were determined from real-time observations and subsequent analysis of photographs; sensor heights were corrected accordingly.

The anemometers used were low-inertia, "staggered-six" types of Argonne National Laboratory design, featuring cosine response and a distance constant of 35 cm (Frenzen, 1967a). For measurements based on a semi-stable platform at sea, these instruments were adjusted for flat rather than cosine response by mounting the two three-cup rotors slightly closer together. In this configuration, the outputs remain within 0.5 percent of the true wind speed when the sensors are tilted up to 10° in the direction of the wind; note that a cross-wind tilt does not affect the calibration of the anemometers. Wind signals (70 Hz per m s^{-1}) were mixed and transmitted to the ship through a single, 1,000-ft coaxial cable supported by floats. On board, the signals were demodulated and simultaneously recorded by a multichannel electronic counter for mean values, by a special-purpose digital structure function computer for real-time flux estimates, and by a tape recorder for subsequent computation of turbulence spectra. All sensors were recalibrated in the Argonne wind tunnel immediately after the equipment had been returned to the laboratory.

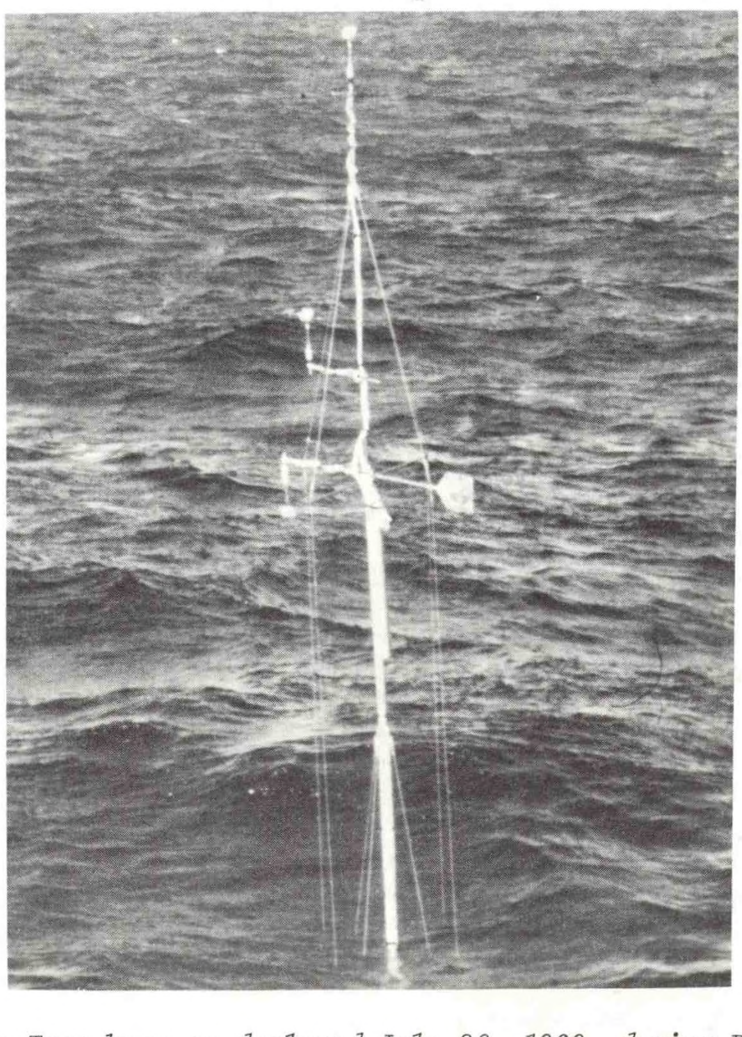

Figure 1.--The Tern buoy as deployed July 28, 1969, during BOMEX Period IV.

Results

Mean profile observations are summarized in table 1. Steady winds during the first four observation periods of 20 min each made it possible to combine these data into two runs of 40-min duration. Midway through the fifth run, the wind increased sufficiently to require termination of the experiment, because the ship had increasing difficulty maintaining station within the prescribed distance from the buoy. The Tern was recovered in winds approaching 10 m s^{-1}, and shortly thereafter, the observation phase of BOMEX as well as that of the Tern buoy experiment having been completed, the ship headed for Barbados.

The profile of run E is very nearly logarithmic (corrected sensor heights being essentially logarithmically spaced). Note that in this case the u_*'s derived from adjacent levels are within $\pm$ 1 percent of the value derived from the overall velocity difference. Profiles $\overline{AB}$ and $\overline{CD}$ appear to be slightly stable, but increases in the winds at the middle level of only 0.2 percent would make both wind distributions logarithmic. At any rate, the recorded sequence of very slightly stable profiles with somewhat reduced drag coefficients, becoming neutral or slightly unstable when increased winds and an associated increase in sensible and latent heat flux occur, is not an unreasonable one. The magnitudes of C_{10} observed for near-neutral to slightly unstable profiles (1.26 - 1.35 x 10^{-3}) are also quite reasonable in view of values obtained in the extensive measurements summarized by Brocks and Krügermeyer (1970).

Table 1.--Wind profiles on July 28, 1969, observed at indicated local standard times, plus implied values of u_* and C_{10}; figures in parentheses are (u_2 - u_1) or (u_*) calculated from adjacent levels; $\bar{U}_{10}$ is extrapolated and surface drift relative to the drifting buoy is assumed negligible; heights (z) are in cm and all velocities are in cm s^{-1}.

z	$\bar{U}_z$ and $(u_2 - u_1)$				$u_* = k\Delta u(\phi_m \cdot \ln z_2/z_1)^{-1}$		
	$\overline{AB}$ 1536-1616	$\overline{CD}$ 1619-59	E 1702-12		$\overline{AB}$	$\overline{CD}$	E
650	754.7	751.1	821.1				
	(28.2)	(29.9)	(30.7)		(29.5)	(30.2)	(31.7)
446	726.5	721.2	790.4				
	(26.1)	(26.7)	(31.4)		(26.2)	(26.1)	(31.2)
305	700.4	694.5	759.0	u_*:	27.8	28.1	31.4
$\bar{U}_{10}$:	784	782	854	C_{10}:	1.26	1.29	1.35x10^{-3}

Table 2 lists bulk aerodynamic estimates of the sensible (H) and latent heat flux (L_wE) determined from the winds at the buoy, psychrometer measurements on the ship, and bucket sea temperatures less a surface correction of 0.5°. These data were used to compute stability corrections in accordance with the empirical relation for the non-dimensional shear:

$$(kz/u_*) \cdot (du/dz) \equiv \phi_m = (1 - 15\ z/L)^{-1/4} .$$

In all runs the Obukhov length L was between -100 and -200 m; at the 4.5-m level the corresponding shear factor ϕ_m was therefore between 0.90 and 0.93. The absence of unstable wind profiles throughout the experiment must be attributed either to small calibration errors of a few tenths of 1 percent, or, with less likelihood, to comparatively large errors in sensor height measurements.

Table 2.--Flux estimates, turbulent energy production rates due to buoyancy (π_B), and the Obukhov length parameter (L) estimated by bulk aerodynamic methods, using $C_H = C_E \sim 1.3 \times 10^{-3}$.

	$\overline{AB}$	$\overline{CD}$	E
H (mW cm^{-2})	0.1	-0.4	0.2
L_wE (mW cm^{-2})	17.3	19.2	21.0
π_B ($cm^2\ s^{-3}$)	3.7	2.6	4.7
L (m)	-130.0	-204.0	-154.0

Values of u_* and C_{10} derived from dissipation measurements are summarized in table 3. As shown in the first half of the table, when the stability factor ϕ_m and the energy production rate by buoyancy π_B are known (and provided local dissipation obtains), u_* can be computed from single dissipation measurements. Thus, from the turbulent energy equation

$$\varepsilon = \phi_m(u_*^3/kz) + \pi_B - D ,$$

in which the divergence terms are written as -D and

$$\pi_B \equiv [(H + 0.07\ L_wE)/(\rho\ c_p)]\ (g/\bar{\theta}) \text{ and } D \simeq 0 ,$$

we can write

$$u_* = [(\varepsilon - \pi_B)\ kz/\phi_m]^{1/3} .$$

Table 3.--Dissipation rates (cm^2 s^{-3}) derived from spectra for July 28, 1969, plus implied values of u_* and (C_{10}) computed by single- and double-dissipation methods; spectra integrated over half octaves, $f \simeq U/z$ to $1.5\ \bar{U}/z$ Hz

z (cm)	$\overline{AB}$	$\overline{CD}$	E	$\overline{AB}$	$\overline{CD}$	E
	$\varepsilon_z - \pi_B$:			$u_* = [(\varepsilon_z - \pi_B) kz\ \phi_m^{-1}]^{1/3}$; ($C_{10}$)		
650	80.9	76.4	103.5	27.7 (1.25)	26.8 (1.17)	29.9 (1.23)
305	177.9	169.5	215.0	27.4 (1.22)	26.7 (1.17)	29.0 (1.15×10^{-3})
	ε; ($\varepsilon \cdot z$):			$u_* = [(N/N-1) \Delta\varepsilon kz_1\ \phi_m^{-1}]^{1/3}$		
650	84.6 (54990)	79.0 (51350)	108.2 (70330)	27.9 (1.27)	27.2 (1.21)	29.1 (1.16×10^{-3})
305	181.6 (55388)	172.1 (52490)	219.7 (67008)			

Table 4.--Kinetic energy budgets based on ε values from spectra, u_* values from profiles, and π_B estimates from bulk aerodynamic fluxes derived from shipboard temperature and humidity measurements; apparent divergence contributions D derived as residuals, $\varepsilon - (\phi_m\ u_*^{\ 3}/kz) - (\pi_B)$

	z = 650			z = 305		
	$\overline{AB}$	$\overline{CD}$	E	$\overline{AB}$	$\overline{CD}$	E
ε_z	84.6	79.0	108.2	181.6	172.1	219.7
$\phi_m\ u_*^{\ 3}/kz$	82.1	88.5	120.4	186.6	197.7	271.7
π_B	3.7	2.6	4.7	3.7	2.6	4.7
D	-1.2	-12.1	-16.9	-8.7	-28.2	-56.7

Alternatively, when H and L_WE are not known, π_B can be eliminated between two expressions for ε at two levels in the constant flux layer. This results in the double-dissipation relation for u_* used in the second half of table 3:

$$u_* = [(N/N-1)\ (\varepsilon_1 - \varepsilon_2)\ kz_1/\phi_m]^{1/3};\ N \equiv z_2/z_1 .$$

Note that this partly compensates for divergence, retaining only $[D(z_1) - D(z_2)]^{1/3}$.

The C_{10} values determined by dissipation methods and listed in table 3 are fairly uniform, being within $\pm$ 5 percent of 1.20×10^{-3}. The fact that these estimates are somewhat smaller than those obtained from profiles suggests the presence of small contributions by divergence terms, as confirmed in table 4. The $\varepsilon \cdot z$ products shown in the lower half of table 3 lend some support to the profile indications of slight stability in runs $\overline{AB}$ and $\overline{CD}$, because these decrease with height; but this behavior could also be effected by the distribution of divergence in the vertical. Run E is evidently unstable to a significant degree since here $\varepsilon \cdot z$ clearly increases with height.

Energy budgets implied by wind profile u_*'s and ε's derived from spectra at two levels are shown in table 4. Residual divergence contributions will be seen to be of significant magnitude, markedly exceeding π_B in every case but one. Summed over the 80 min of $\overline{AB}$ and $\overline{CD}$ taken together, the divergence terms average $-6.6\ cm^2\ s^{-3}$ at 6.5 m and $-18.4\ cm^2\ s^{-3}$ at 3.0 m. These values constitute about 8 and 10 percent of the average dissipation rates observed at the two levels. Note that the mean divergence decreases with height, roughly in inverse proportion to z. In run E the residual divergence increases to 16 and 26 percent of ε at the upper and lower levels, evidently in response to the accelerating wind velocities.

Provided the divergence terms are either negligible or inversely proportional to the height, it can be shown that the derivative $d(\varepsilon \cdot z)/dz$ can be used to estimate π_B from anemometer measurements (Frenzen, 1967b). This method of estimating the buoyancy-effective heat flux would appear to be particularly attractive for application to observations over the open sea. The sensors are comparatively dependable, their outputs in the frequencies of interest are unaffected by the motions of a spar-buoy, and methods are available to compute the required statistics either in real time aboard a nearby ship or aboard the buoy itself for storage and subsequent retrieval. If systematic instrumental errors limit the absolute accuracies of flux estimates obtained in this way, relative accuracies could be sufficient to detect the hour-to-hour changes in the turbulent exchange that are central to many air-sea interaction problems. However, further investigation of the vertical variation of the divergence terms will be required in order to assess the potential value of this procedures.

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Epilogue

In the years since these observations were made, no new information (in addition to the new values of k and α_1) sufficient to further modify the conclusions of this analysis has come to our attention. On our part, we have attempted to repeat the experiment on several occasions, but as yet without success. Mean and turbulent wind speeds recorded at three levels from an off-shore tower in Lake Michigan invariably showed interference effects caused by the supporting structure; a slender spar-buoy deployed from a taut mooring off the Lake Michigan tower and designed to avoid the tower interference was capsized by a storm before an adequate set of measurements could be obtained; and just recently, in September of this year, much of the equipment we installed on Brookhaven National Laboratory's spar-buoy in the Atlantic off Long Island was lost or damaged in Hurricane Eloise, again before the requisite data set of observations at three levels could be recorded.

Aside from the quantitative results presented in this note, two additional conclusions can be brought to the reader's attention. First, the degree of internal consistency evident in these data and in the surface boundary layer characteristics inferred from them, lend indirect support to the values of the Kolmogorov and von Karman constants used in the analysis, namely $\alpha_1 = 0.55$ and $k = 0.35$. And second, the obvious sensitivity of these results to very small errors in the experimental measurements emphasize the fact that, in order to examine these phenomena in the comparatively weak flux regimes of boundary layers over the sea, extreme care must be taken to insure that the sensors and the platform upon which they are mounted do not disturb the flow.

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