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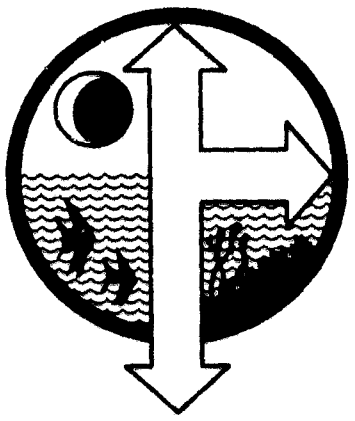

BOMEX BULLETIN NO. 7

JULY 1970

Prepared by
THE BOMAP OFFICE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
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I. INTRODUCTION

BOMEX Bulletin No. 7 brings together published abstracts of BOMEX-related papers presented at scientific meetings during early 1970; sample products from the cloud photography and radar surveillance data collected during BOMEX; and a status report of BOMEX data processing and reduction.

II. ABSTRACTS OF BOMEX-RELATED PAPERS

Preliminary results and analyses from BOMEX, and methods and techniques used to collect data, were described in papers presented at three scientific meetings during early 1970. Abstracts of the papers are brought together in this bulletin. Permission to publish these abstracts, which appeared in the cited publications of the Institute of Electrical and Electronics Engineers, Inc.,1/ the American Geophysical Union,2/ and the American Meteorological Society,3/ is gratefully acknowledged. Numbers in parentheses after author's names identify BOMEX experiments. Experiment numbers 1 through 87 are described in BOMEX Bulletin No. 4, pages A-6 through A-34, May 1969, and experiment numbers 88 through 100 in BOMEX Bulletin No. 5, pages 7 through 11, November 1969.

A. Second Annual International Geoscience Electronics Symposium, The Institute of Electrical and Electronics Engineers, Inc., April 14-17, 1970, Washington, D.C.

Title: Airborne signal processing in an ocean heat flow radiometer

McAlister, E.D. (61), Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92037
McLeish, W., ESSA Atlantic Oceanographic and Meteorological Laboratories, Sea-Air Interaction Laboratory, 901 S.Miami Avenue, Miami, Fla. 33130

An airborne two-wavelength infrared radiometer has been developed to measure the total heat flow to the ocean surface. This quantity represents the total energy available to the marine atmosphere from below and is of value for meteorological predictions. The instrument records mean temperature at two shallow depths in the water, both within the surface conductive sublayer, through measurement of the emitted radiation intensity in two narrow infrared wavebands. Accuracies in the temperature difference on the order of 0.003°C appear to have been obtained at sea, but there has not been a standard against which this value may be verified. Such accuracies have been attained, in part, as a result of the signal processing scheme developed for this instrument.

1/ IEEE Second International Geoscience Electronics Symposium Digest of Technical Papers, Washington, D.C., April 14-17, 1970.

2/ EOS, Transactions, American Geophysical Union, vol.51, no.4, April 1970.

3/ Bulletin of the American Meteorological Society, vol.51, no.3, March 1970.

The field of view of the detectors scans in a circle through a rapidly rotating mirror. During each rotation, the detectors view below, above, and two reference targets at slightly different temperatures, so that the infrared signal is recalibrated continually. The electrical signal passes through a filter whose characteristics are determined by the rotation speed and the geometrical arrangement of the targets. Then an airborne data system converts the readings to digital form and averages a number of readings of each target before recording. The recalibrations are applied and further averaging is performed ashore. The effectiveness of noise reduction derives largely from the reshaping of the noise power spectrum through recalibration before averaging.

A correction is required for the slight reflectivity of the water surface, and each scan provides a measurement of the downwelling radiation for this purpose. Atmospheric interference is reduced by extrapolating readings from different altitudes to the surface. The resulting heat flow values have an accuracy probably equivalent to the best in situ measurements and have the further advantage of airborne mobility so that large regions can be surveyed.

Title: Airborne turbulent flux measurement technique

Miyake, M. (63), and Donelan, M., Institute of Oceanography, University of British Columbia, Vancouver 8, Canada

With set of fast response turbulence sensors for vertical velocity, downwind velocity, temperature and humidity on a boom of a twin engine aircraft together with air raft motion sensor surface transport of momentum, heat and humidity can be determined. The result is presented with experimental result and error analysis.

B. American Geophysical Union Fifty-First Annual Meeting, April 20-24, 1970, Washington, D.C.

Title: The BOMEX core experiment

Holland, Joshua Z. (37,38), The BOMAP Office, Environmental Science Services Administration, 6010 Executive Blvd., Rockville, Md. 20852

During May and June 1969, the BOMEX ship and aircraft arrays and observation schedules were dictated by the Sea-Air Interaction "Core Experiment" consisting of a systematic attempt to measure all major terms of the energy budgets for an atmospheric volume and an underlying oceanic volume. These terms include (1) in the ocean: (a) net radiation, (b) horizontal heat flux divergence, (c) upward eddy heat flux, and (d) change in heat storage; and (2) in the atmospheric volume: (a) latent and (b) sensible heat input at the interface, (c) horizontal flux divergence of latent and (d) sensible heat, (e) net condensation, and (f) net radiative cooling. Other terms may sometimes exceed some of the above. Tests will include comparison of: (1) point vertical fluxes by aerodynamic profile and eddy covariance methods; (2) interface fluxes from point measurements with those obtained by line, area, and volume integral methods; (3) interface fluxes estimated from atmospheric and oceanographic data; (4) estimates obtained by different platform and sensor subsystems (e.g., aircraft vs. ravinsonde line integrals); and (5) observations with estimates from parameterization models.

Title: Surface wave spectra in the deep ocean

Grose, P.L., Warsh, K.L., and Garstang, M. (31), Department of Oceanography, Florida State University, Tallahassee, Fla. 32306

During the summers of 1968 and 1969 numerous sets of meteorological and wave data were acquired in the open tropical Atlantic east of Barbados, West Indies. These sets of data were collected under the various meteorological conditions which are typical of the trade wind regime. Spectra calculated from these observations are presented. Relationships between these spectra and the prevailing meteorological conditions in the tropical Atlantic are deduced.

Title: Air flow characteristics near waves and momentum of fluxes measured from FLIP

Portman, Donald J. (71), and Davidson, Kenneth L., University of Michigan, Ann Arbor, Mich. 48104

Simultaneous measurements of wave heights and of temperature fluctuations and wind velocity component fluctuations at different heights (one to 8 m) show prominent spectral characteristics that agree, substantially, with existing wave generation theories. At frequencies corresponding to the dominant surface wave, streamlines and cospectrum (uw) estimates in the lowest layer show a Bernoulli flow compatible with the general pressure distribution greatest over troughs and least over crests. However, above this layer, but beneath the critical level, and at the same frequencies, stream line deformation and phase relationships between velocity components and the surface waves indicate an adjustment of the velocity field due to vorticity perturbations at a higher level. Cospectra in the latter case consistently reflect enhanced downward transport of horizontal momentum at the wave frequency. Phase shifts place the extremes of the horizontal velocity at the wave nodes.

Title: Momentum fluxes determined from time and space structure-functions (BOMEX/FLIP)

Franceschini, Guy A. (24,25), and Cain, Jimmy D., Department of Meteorology, Texas A & M University, College Station, Tex. 77843

Structure-functions at the 10-meter level were determined from wind speed differences between two hot-film anemometers positioned 1 meter apart, normal to the mean flow, $D(1)$, and also from each single probe, $D(\sigma)$, at corresponding time lags, σ . At a time lag of $1/\bar{u}$ seconds, the two structure-functions have the same horizontal separation. In the analysis, averaging periods of five minutes were used with a sampling rate of 12 points sec^{-1}. It was found that $D(1/\bar{u})/D(1)$ consistently fell in the range 0.4 to 0.8. This seems to imply an elongation of the eddies in the downstream direction. Structure-function values obtained for mean wind speeds near 5 m/sec were about one-third as large as the values for mean wind speeds near 10 m/sec. Structure-functions were related to energy dissipation, skewness, and separation distance. Values of skewness were found to be less than 0.33 in absolute value for all runs. Estimates of shearing stress were then made from the structure-functions, assuming adiabatic conditions and that energy dissipation equaled energy production.

For the lower wind speeds, shearing stress was on the order of 0.6 dyne/cm^2 and, for the higher wind speeds, values ranged from 1.3 to 1.7 dyne/cm^{-2}. Calculated drag coefficients were found to fall in the range 0.0012 to 0.0017 at all wind speeds.

Title: Turbulent velocity and temperature measurements in the marine boundary layer (BOMEX/FLIP)

Gibson, C.H. (33), University of California at San Diego, La Jolla, Calif., 92037

Vertical and horizontal components of velocities were measured from FLIP at positions from 2 to 30 meters above mean sea level using hot wire anemometers. Preliminary spectral measurements appear to confirm the rather slow approach to local isotropy discovered by previous investigations at lower Reynolds numbers. Various statistical parameters of the turbulent velocities and velocity derivatives as well as temperature and temperature derivatives have been calculated. Dissipation rates are compared with log normality predicted by Kolmogoroff's third hypotheses and the influence of such "intermittency" on the turbulent parameters is examined.

Title: Airborne turbulence and water vapor flux measurements

Lappe, U.O., Turbulence Consultants, Inc., Pleasantville, New York

Preliminary power spectrum analyses of turbulence and water vapor density data are presented. The data were obtained from DC-6B measurements made by the Research Flight Facility of ESSA during the BOMEX program. Vertical velocity, water vapor, and moisture flux spectra are presented for altitudes of approximately 100, 500, and 1000 ft. General spectral characteristics and the relative importance of the small- and large-wavelengths in the momentum and moisture transport processes are also discussed.

Title: Turbulent flux measurement from aircraft in the BOMEX grid

Miyake, M. (63), and Donelan, M., Institute of Oceanography, University of British Columbia, Vancouver 8, British Columbia, Canada

Information from fast response turbulence sensors for vertical velocity, downwind velocity temperature, and humidity on the NCAR Beechcraft Queenair was combined with the information from the aircraft motion sensors. The fluxes of momentum, heat, and water vapor were computed using the cospectra in the energy containing frequency region from the data gathered in BOMEX. These results were compared with the estimates from other methods.

Title: The BOMEX spectral albedo measurement program

Drummond, A.J. (18), and Hickey, J.R., Eppley Laboratory, Newport, R.I. 02840

This paper describes part of the BOMEX radiation project, which was carried out in July 1969 on the NASA CV-990 jet research aircraft. Integral and spectral wavelength incoming solar and outgoing reflected fluxes were recorded on two parallel automatic data logging systems. Sensor outputs were essentially independent of ambient temperature and referred to

the wavelength intervals λ >200, 200-530, 530-685, and >685 nm. There was participation in 11 flights with altitude varying from near ocean level to about 12 km. Vertical profile results are presented and the analysis extended to the separation of atmospheric scattering and absorption and, hence, the distinction of true surface albedo from path length influence. Also of special interest are the derived transmittance of high-level cirrus cloud and the absorptance of solar radiation by dust layers.

Title: Preliminary results of the Florida State University radiation program during pre-BOMEX and BOMEX observational periods

Gille, John C. (32), and Ellingson, Robert G., Florida State University, Tallahassee, Fla. 32306

The goals of the experiment were: (1) The measurement of short and long wave fluxes at the surface on Barbados, for use with other data in determining the island's energy budget; (2) the comparison of heating rates measured by radiometersonde with detailed calculations, with a view to determining aerosol effects; and (3) the measurement of radiative flux divergence in the lowest 8 meters and comparison with calculation. The instrumentation and results to-date will be discussed. In particular, flux divergence measurements in the lowest 2 meters over Barbados show a mean IR cooling rate of 40°C/day. All cooling rates in the lowest 8 meters show changes by a factor of 3 over periods of several days.

Title: Radon-222 in the North Atlantic trade winds: a tracer for African air parcels

Prospero , Joseph M. (10), Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, Florida
Carlson, Toby N. (10), National Hurricane Research Lab., ESSA, Miami, Fla.

The concentration of radon-222 ($t_{\frac{1}{2}}$ = 3.82 days) in the NE trade winds was measured during May, June, and July 1969, as a part of the Barbados Oceanographic and Meteorological Experiment (BOMEX); these measurements were made during flights at altitudes ranging from 30 meters to 6000 meters over the BOMEX array and in weather systems in the western equatorial Atlantic Ocean. The radon-222 concentrations (determined from the daughter product concentrations) ranged from about 1×10^{-12} curies m^{-3} to 40×10^{-12} curies m^{-3} and tended to be higher in areas of dense haze which is attributed to dust originating from the arid regions of western Africa. Thr radon concentration often varied markedly with geographical location and with altitude during flights; the largest variation and the highest concentration was associated with the passage of an easterly wave on July 14. These studies suggest that radon-222 may be useful as a tracer for African air parcels over the equatorial Atlantic Ocean.

Title: Concentration of trace gases in a marine environment

Decker, Clifford E., and Smith, James R. (78), Research Triangle Institute, Research Triangle Park, North Carolina 27709
Ortman, Gordon G., National Air Pollution Control Administration, Raleigh, North Carolina

During BOMEX in 1969, RTI conducted a research cruise from Wilmington, North Carolina to the vicinity of the equator and return. Ozone, total oxidant, oxides of nitrogen, sulfur dioxide, carbon monoxide, and methane concentrations were measured in a relatively unpolluted marine environment. The mean concentration of ozone was found to be 0.5 pphm. The mean total oxidant concentration was approximately 0.9 pphm. Oxide of nitrogen (NO, NO_2) concentrations ranged from 1 to 30 ppb. No detectable amount of SO_2 was observed at any time. The average measured concentrations of methane and carbon monoxide were 1.36 and 0.18 ppm respectively. The data does not reveal a diurnal trend in ozone or total oxidant concentration, such as that observed in continental areas. This suggests that photochemical reactions and vertical transport near the surface of the sea were at a minimum. A feasible explanation for the low level of photochemical activity would be the absence of ozone and oxidant precursors. The data are representative only of the early summer season. No significant evidence of urban pollution from the United States or other continents was detected at sea during this cruise. The mean values presented for ozone, total oxidant, carbon monoxide, and methane are considered representative of the geophysical background levels for the region during early summer.

Title: W.H.O.I. Solar radiation experiments

Bunker, Andrew F. (9), and Payne, Richard E. (73), Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

For three weeks in July, 1969, emergent upwelling irradiance, U, and total downwelling irradiance, D, were measured at 13°54'N 54°W. The ratio U/D varied from 0.2 to 0.6% and was correlated with cloudiness as well as increasing markedly toward the ends of the day. The relation between U/D and cloudiness is expressed by the following equation,

$$U/D = 0.574 - 0.165\ D,$$

a least squares linear fit of the data with a correlation coefficient of 0.8. Data from a shaded pyranometer at Seawell Airport were combined with Dr. Kuhn's total downwelling irradiance data from the same location to determine the relationship between the total downwelling irradiance and its diffuse component. Measurements of the short wave-length solar radiation were measured from the W.H.O.I. C-54Q aircraft during the latter part of BOMEX. Mean charts of the solar radiation have been compiled. Insolation has been correlated to the amounts and types of clouds present at the time of observation.

Title: Interaction of radiation and climate -- BOMEX experiment

Kuhn, Peter M. (46), and Stearns, Lois P., Atmospheric Physics & Chemistry Laboratory, ESSA Research Laboratories Boulder, Colorado 80302

The BOMEX radiation experiment was a direct probe of the three dimensional structure of the radiation budget of a fixed environmental volume from the surface to 31 km. Surface, aircraft, and balloon platforms carried infrared and solar detectors. The heat budget of the environment is a function of solar and infrared radiative exchange and transport of latent and sensible heat. Here we are concerned with radiative transfer and its effects on climate. The objective is to determine the interaction of radiant transfer in defining a sub-tropical climate and changes in this climate by analyzing the radiation budget in both disturbed and undisturbed conditions. Our results demonstrate that after determining the typical unperturbed radiation climate of the Barbados area the following phenomena were instrumental in altering the normal regime: (a) African haze layer (Harmattan haze), (b) Inverted "V" systems, and (c) High cirrus shields. Such phenomena produced marked changes in the radiation budget. They resulted in, respectively, stronger cooling and possible instability at 3 to 4 km; horizontal discontinuities in the infrared cooling; greatly reduced radiant transfer and resulting atmospheric heat loss. The presence or absence of a high cirrus layer was the most dominant factor in controlling radiational heat loss and could reduce the available thermal power at the surface by up to 20 percent.

Title: Ocean structure and circulation east of Barbados during the BOMEX Project (Preliminary results)

Mazeika, Paul (60), U.S. Naval Oceanographic Office, Washington D.C.
Smith, J.R., Research Triangle Institute, Research Triangle Park, North Carolina 27709

General distribution of flow in the BOMEX and surrounding area is presented by geopotential topography of the surface and of the 125 decibar surface. A vertical section of geostrophic currents across 55°30' west meridian indicate approximate mean velocities of zonal components at various depths. Computed geostrophic velocities are compared with measured current velocities at some depths of current meter arrays. Horizontal distribution of maximum salinities and depth contours of maximum salinities complements interpretation of flow at 125 decibar surface.

Title: A preliminary report on meteorological conditions during BOMEX, fourth phase (July 11-28, 1969)

Partagas, Jose J. Fernandez, and Estoque, Mariano A. (19), Division of Atmospheric Science, School of Marine & Atmospheric Sciences, University of Miami, Coral Gables, Florida 33124

Meteorological conditions which prevailed over the BOMEX-Lesser Antilles network during the BOMEX Fourth Phase (July 11-28) are analyzed. The characteristics of both the mean circulation and the individual disturbances are investigated. The method of investigation is based on an analysis of the conventional meteorological variables and their perturbations from suitably defined averages. The mean position of the Intertropical Convergence Zone was found to be near normal. Pressure oscillations larger than

synoptic scale were observed. Six synoptic disturbances were studied. Five out of the six disturbances showed characteristics of cyclonic circulations at the high or middle troposphere. At levels below, these circulations are reflected as wave-type perturbations. The sixth disturbance was a well-developed tropical depression. This preliminary study leads to the conclusion that interactions among upper-level conditions, the Intertropical Convergence Zone, and the Trades are significant.

Title: The ESSA airborne water vapor flux measurement system

McFadden, James D., and Travis, Charles W., ESSA Research Flight Facility, Miami, Florida
Gilmer, Richard O., and McGavin, Raymond E; ESSA Wave Propagation Laboratory, Boulder, Colorado

Water vapor flux measurements were made from a DC-6 A/B aircraft during the Barbados Oceanographic and Meteorological Experiment (BOMEX) utilizing a system developed jointly by ESSA's Research Flight Facility and the Wave Propagation Laboratory. Basically the system consists of a Lockheed gust (angle of attack) probe and a Litton LN-3 inertial platform, both used to measure the necessary parameters for the computation of the vertical component of the wind, and a refractometer system which is used to measure the parameters necessary for computing the absolute humidity. This paper presents the basic theory of measurement, a detailed description of the system and its operation, its method of employment during BOMEX and the procedures being used in digitizing and processing the data.

Title: Observations of tropospheric water vapor contrasts near the ITC from aircraft and NIMBUS III during BOMEX

Conaway, J. (12), Conrath, Barney J., Brennan, Barbara (6), and Nordberg, William (20), Goddard Space Flight Center, Greenbelt, Md. 20771

Near simultaneous measurements of upwelling radiation were obtained in the BOMEX area on 11 and 13 July 1969 by the microwave and infrared radiometers carried on a NASA aircraft at an altitude of 11 km and by the infrared interferometer spectrometer (IRIS) carried on the NIMBUS III satellite. The 1.55 cm brightness temperatures were found to be 12°K higher south of the intertropical convergence (ITC) than to the north while the 11μ brightness temperatures measured by both IRIS and the aircraft radiometer were approximately 2°K lower south of the ITC. Temperature profiles derived from IRIS measurements were essentially the same north and south of the ITC, but humidity profiles derived from IRIS measurements were drastically different. On 13 July the total precipitable water vapor 300 km south of the ITC was about 4.6 gm/cm^2 with 1.1 gm/cm^2 above 700 mb. 300 km north of the ITC the total precipitable water was 2.6 gm/cm^2 with only 0.2 gm/cm^2 above 700 mb. This dry zone appears to be limited to a 1000 km wide region just north of the ITC since IRIS measurements, 1200 km north of the ITC, indicate the total water was 3.4 gm/cm^2 with 0.6 gm/cm^2 above 700 mb. Due to cloudiness, measurements of water vapor could not be made directly over the ITC with either the microwave or infrared instruments.

Title: Preliminary divergence computations from BOMEX aircraft data

Reeves, Robert W. (95), The BOMAP Office, Environmental Science Services Administration, Rockville, Maryland 20852

On the aircraft flights flown in support of the line integral mission of BOMEX, much of the time was spent in performing soundings and "calibration boxes." Soundings were performed by flying a series of straight level flights on opposite headings at several altitudes. The calibration boxes consisted of a series of right angle turns between which were flown 2-minute straight legs. The soundings and boxes were used as internal calibration of the winds. Sample divergences were computed for the array from the Navy hand-tabulated on-board computer winds. Systematic use of the reciprocal heading soundings as calibrations improved the accuracy of the divergence measurements by an order of magnitude.

Title: Validation of ESSA Research Flight Facility BOMEX data

Davis, Harlan W., and Conrad, Gerald, ESSA Research Flight Facility, Miami, Florida

The accurate description of the pressure, temperature, humidity and wind fields is basic to the problems of atmospheric research. The ESSA Research Flight Facility considers as its primary task the ability to provide these data to the scientist. All RFF instruments are calibrated in the laboratory. However, errors develop on the aircraft from sources such as instrument position and drift, and it is necessary to have programs to eliminate these also. While it may not be possible to provide an absolute calibration, it is possible to construct a set of data that is compatible within itself and minimize the effect of any residual error. The BOMEX flight patterns were designed with the inclusion of formation flying, soundings and ship overflights in such a manner as to allow the development of a comprehensive validation program. This paper presents the procedures used and the results from this program.

C. Symposium on Tropical Meteorology,
June 2-11, 1970, Honolulu, Hawaii -- cosponsored by the American Meteorological Society and the World Meteorological Organization

Title: Results from a comprehensive tropical field experiment

Garstang, M. (31,32), and La Seur, Noel E., Department of Oceanography, Florida State University, Tallahassee, Florida 32306

In design and execution, the Florida State University Barbados Field Program was based upon the growing conviction, that the structure and behavior of the tropical atmosphere are not dominated by processes on a single scale, and that increased understanding and improved predictions of tropical weather must be based upon consideration of a hierarchy of scales ranging from boundary-layer turbulence to planetary waves. Furthermore, new observational efforts designed to yield simultaneous, coordinated data on as many scales as possible are needed.

After two years devoted largely to design and acquisition of observing-recording systems for boundary layer, sub-cloud layer and lower cloud layer processes, the first observations were made during June-September 1969 over Barbados and its immediate oceanographic environment.

The observational program was repeated during April-August 1969 within the framework of the Barbados Meteorological and Oceanographic Experiment (BOMEX).

Selected results will be presented, emphasizing interdependence among various scales of motion.

Title: Use of ESSA Research Flight Facility's instrumented aircraft for major meteorological experiments in the tropics

Friedman, Howard A., ESSA Research Flight Facility, Miami, Florida

Instrumented aircraft of the ESSA Research Flight Facility (RFF) have supported major meteorological research efforts for more than a decade. A prime example of the RFF's participation in world-wide tropical meteorological research is the Barbados Oceanographic and Meteorological Experiment (BOMEX) of May, June, and July 1969. On flights prior to the field experiment, operational patterns were developed and aircraft sensor-derived data were tested, calibrated, and compared.

The aircraft flew 146 missions totaling 1138 hours and obtained: approximately 3 million digital recorded meteorological observations; numerous sea-surface temperature and water vapor flux measurements; 2 million cloud and radar photographs; special measurements of incoming and reflected solar radiation; dust concentrations; and, Aitken nuclei counts.

A brief description of the scientific objectives of the program, aircraft and instrumentation systems employed, sample tracks, data collected and subsequent procedures are presented. In addition, with a view toward future RFF participation in the tropics in support of the Global Atmospheric Research Program (GARP), the aircraft, sensors and related recording systems capabilities are described.

Title: Water vapor flux measurements from ESSA aircraft

McFadden, James D., and Travis, Charles W., ESSA Research Flight Facility, Miami, Florida
Gilmer, Richard O., and McGavin, Raymond E., Wave Propagation Laboratory, Boulder, Colorado 80302

A system for measuring water vapor flux directly from aircraft was recently developed jointly by ESSA's Research Flight Facility and Wave Propagation Laboratory. The system consists of a Lockheed gust (angle of attack) probe and a Litton LN-3 inertial platform to measure the parameters necessary for the computation of the vertical component of the wind, and a refractometer system to measure the parameters necessary for computing absolute humidity. The system is installed on an ESSA DC-6 A/B aircraft which during the Barbados Oceanographic and Meteorological Experiment flew 16 missions devoted specifically to water vapor flux measurements, many of them in conjunction with the FLIP program. Measurements were also made at various times during 11 other missions supporting other objectives. This paper will present the basic theory of measurement, a detailed description of the system and its operation in a tropical environment, and procedures for digitizing and processing the data.

Title: Altering the tropical radiation norm

Kuhn, Peter M. (46), ESSA Research Laboratories, Boulder, Colorado 80302

Direct observations over the tropical Atlantic during BOMEX demonstrate that the single most important factor in changing the "average" radiation budget of the tropics is the incidence of high cirrus. The changes are abrupt and sharply bounded. Reductions of from 25 to 50% in the available thermal power from cloudless to cirrus shielded areas can perturb the mean trade circulation. Jet aircraft penetrations and numerous long-range high altitude traverses with sensitive radiometric detectors in addition to routine blanket radiometersonde ascents provide the research information.

Title: Progress report on BOMEX core experiment

Holland, Joshua Z. (37,38), The BOMAP Office, Environmental Science Services Administration, Rockville, Md. 20852

The Sea-Air Interaction Program or "Core Experiment" of BOMEX is a systematic determination of the energy and momentum transfer from sea to air by analysis of a carefully planned series of observations in both fluids over a 500 km square near Barbados during May and June 1969. Direct observations of vertical fluxes of heat, moisture and momentum at points near the interface were made on FLIP and other platforms. Horizontal flux divergences in the atmosphere are derived from concentrated series of rawinsondes from ships at the corners of the square and numerous "line integral" aircraft flights along the perimeter of the square. Dropsondes from aircraft inside the square and rawinsondes from a ship at the center provide additional data for determining volume integrals ("storage" terms) and their time derivatives. Salinity, temperature, and depth measurements from the ships give data on storage terms and geostrophic fluxes of mass, heat and salt in the ocean. Radiometers on ships, aircraft, balloons and satellites, together with satellite and aircraft cloud pictures, provide information on the short- and long-wave radiative flux divergence. Net conversion of latent to sensible heat by precipitation is estimated from the cloud pictures, radar, rain gages and ocean salinity measurements. Best estimates of the various energy budget terms are made by least squares methods taking into account the instrumental and sampling error variances associated with the different data acquisition subsystems.

Title: Structure of air flow over ocean waves

Portman, Donald J. (71), and Davidson, Kenneth L., Department of Meteorology and Oceanography, University of Michigan, Ann Arbor, Mich. 48104

The influence of ocean waves on air flow over them and on momentum and sensible heat exchanges are shown by spectral and cross-spectral analyses of simultaneous measurements of wave heights, wind velocity component fluctuations and temperature fluctuations. During BOMEX with equipment mounted on FLIP, about 200 miles east of Barbados, velocity component and temperature fluctuations were measured simultaneously at two heights, from 2 to 8 m above the water and analyzed over a frequency range of 0.01 to 50 Hz.

Title: Cloud streets over the tropical oceans

Kuettner, Joachim P. (47,48), ESSA Research Labs., Boulder, Colorado

Observations on tropical cloud streets made during the BOMEX project are presented and compared to a theory of organized convection which expand Rayleigh's classical convection theory to the case of convection in a moving medium.

Title: Maintenance of the ITCZ

Charney, Jule G. (11), Massachusetts Institute of Technology, Cambridge, Mass.

From observations of the ITCZ made during the Line Islands Experiment and during the BOMEX Fourth Period, theoretical results relating to the dynamics of the ITCZ will be discussed.

Title: Lidar observations of the lower troposphere during BOMEX

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A lidar (laser radar) was flown on a U.S. Air Force WC-130B aircraft over the BOMEX area during the third experimental period (20 June to 3 July 1969). Detailed observations of lower atmospheric aerosol relative density distributions were used in the study of factors influencing aerosol vertical transport. The lidar instrument used a neodymium laser (1.06 wavelength) and had a firing rate of approximately one pulse per 3.5 sec. Most of over 5000 lidar signatures collected during eight flight missions were obtained over the eastern portion of the BOMEX area at 10,000 ft and at a speed of 100 m sec^{-1}, with the lidar pointing 60^{o} below the horizon.

The data are sufficient to allow presentation of several vertical cross sections of optical density covering "slices" of the lower atmosphere 3000 m deep and tens of kilometers long.

The first data analyzed clearly reveal well-defined haze layers associated with the subcloud layer and with the trade-wind inversion. There may be a dust layer above extensive lower clouds. Within cloud layers, clear air between clouds typically gives less signal return, indicating cleaner or drier air. Experimental runs indicate increasing turbidity above the clean layer associated with the trade-wind inversion.

III. HIGH-LEVEL CLOUD PHOTOGRAPHY SAMPLES

A quantitative assessment of clouds -- the visual evidence of many meteorological processes, including the response of water content of air to air motions and microphysical processes -- was an integral part of BOMEX. Thousands of cloud photographs were taken during BOMEX from aircraft at various altitudes. High-level cloud photography, from 50,000 or 60,000 ft, was the responsibility of the U.S. Air Force. These photographic missions were flown daily by the 53rd Weather Reconnaissance Squadron, 9th Weather Wing, with RB-57 photo-equipped aircraft, operating from Ramey Air Force Base, Puerto Rico. Lower-level photographic missions were flown by other organizations. BOMEX aerial cloud photography is summarized in Table 2 of BOMEX Bulletin No. 3. Only Air Force RB-57 high-level cloud photography is described here.

A. Description of High-level Cloud Photographs

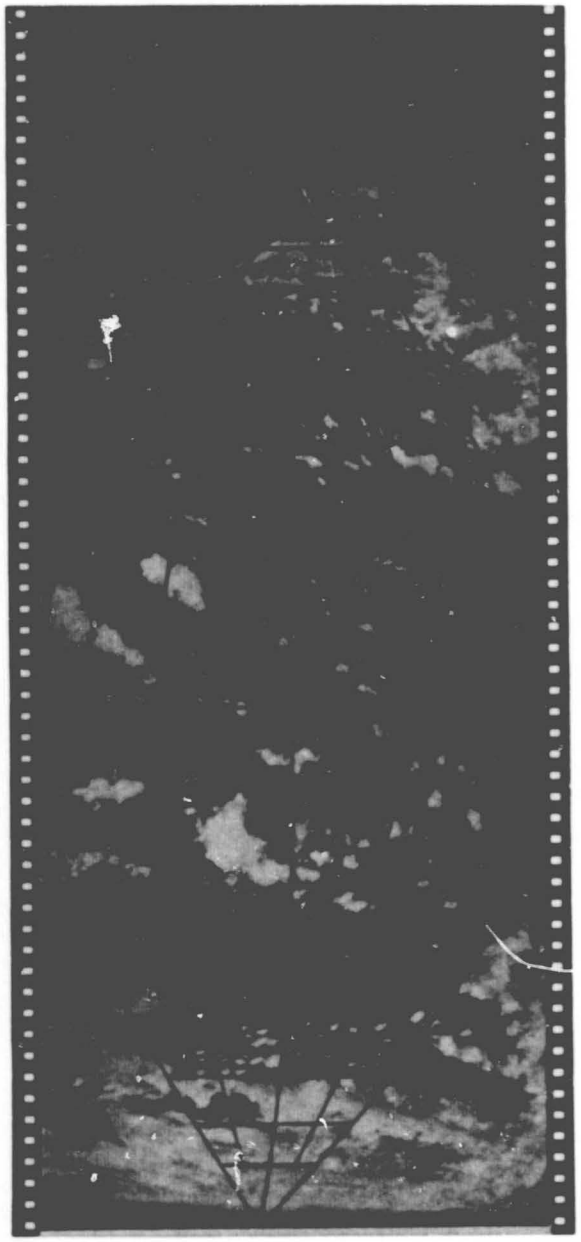
The high-level cloud photographs are panoramic color transparencies taken by a camera pointed vertically downward. From the flight path, each picture extends from left horizon to right horizon, and, in flight direction, forward a distance 76 percent of flight altitude and aft the same distance. The scan from left to right horizon is accomplished by a rotating mirror system within the camera. Figure 1 shows a sample cloud photograph taken from 50,000 ft (in black and white and reduced to one-half original size) and the coordinate grid for interpreting distances on the photograph. Distances are expressed in percent of flight altitude. The flight altitude of 50,000 ft is equal to 8.5 nautical miles (n.mi.). Hence, for lines parallel to the flight path, the 100-percent lines indicate sea surface positions 8.5 n.mi. to the left and right of the flight track, and 200-percent lines are at distances 17 n.mi. to the left and right of the flight track. In the flight direction, the distance along the flight track (at the center of the grid) is approximately 13 n.mi.

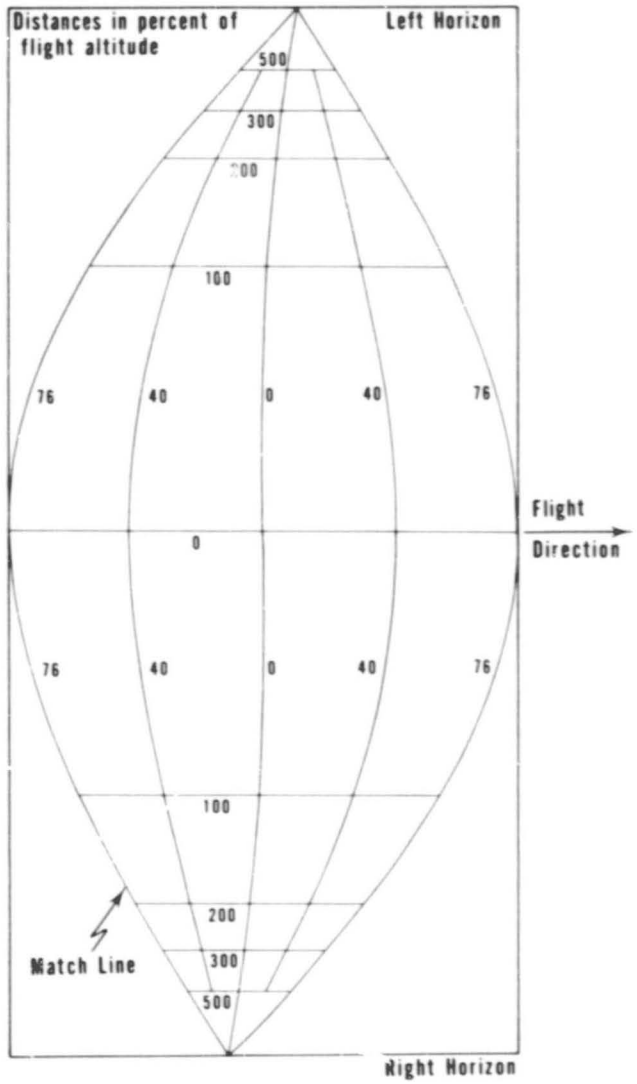
The overlap of approximately 50 percent in the outer part of successive photographs was controlled by an automatic timing device which operated the camera at pre-established time intervals of about one minute. Along the left and right horizons the same clouds appear in several successive photographs. Each daily flight secured about 100 pictures on a 100-ft roll of aerial Ektachrome film. The margin of each photograph includes a view of a clock and a frame counter.

B. Flight Tracks for High-Level Cloud Photography

Air-sea interaction investigation

During the air-sea interaction investigation, Periods I, II, and III of BOMEX, a standard flight track was flown parallel to and 35 n.mi. inside the south, east, and north sides of the BOMEX square. This flight pattern was designed to provide the maximum possible coverage of the BOMEX area within the available operating time for one flight and the film capacity of the camera which was preloaded before the flight. Each of these missions also collected air samples at 40,000 and 50,000 ft at the four corners of the BOMEX square. The camera was turned off during transit from the cloud photography flight track to the adjacent corner of the BOMEX square and return. The flight track for June 28, 1969, is shown in figure 2. Positions of all photographs and times of every fifth photograph are indicated.





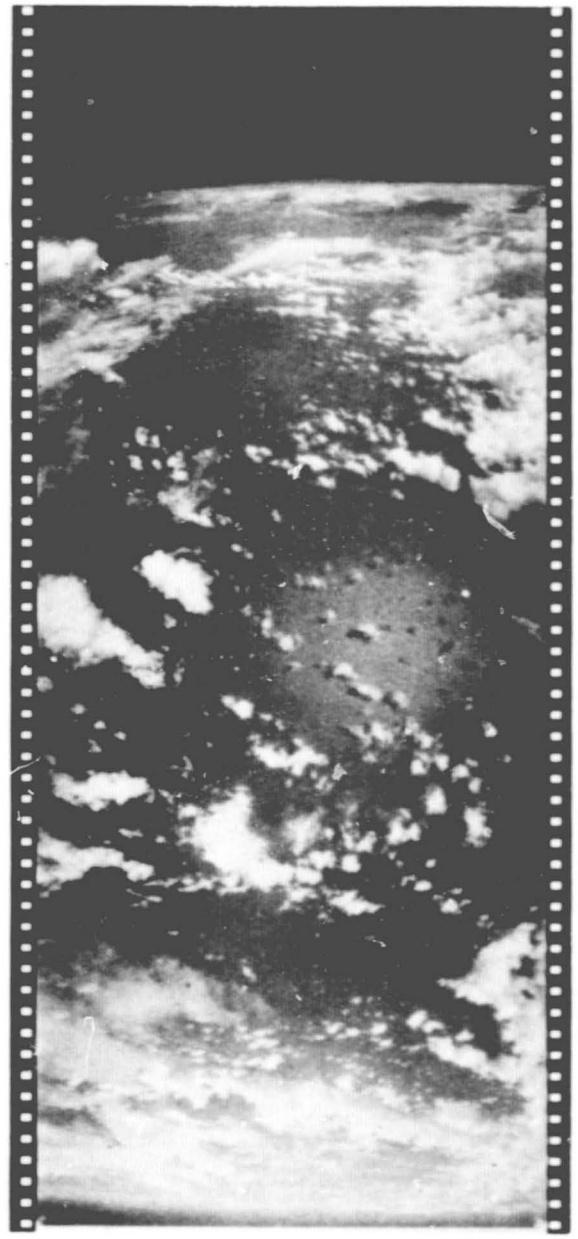


Figure 1.--Panoramic cloud photograph from 50,000 ft, reduced to one-half original size. Coordinate grid distances in percent of flight altitudes.

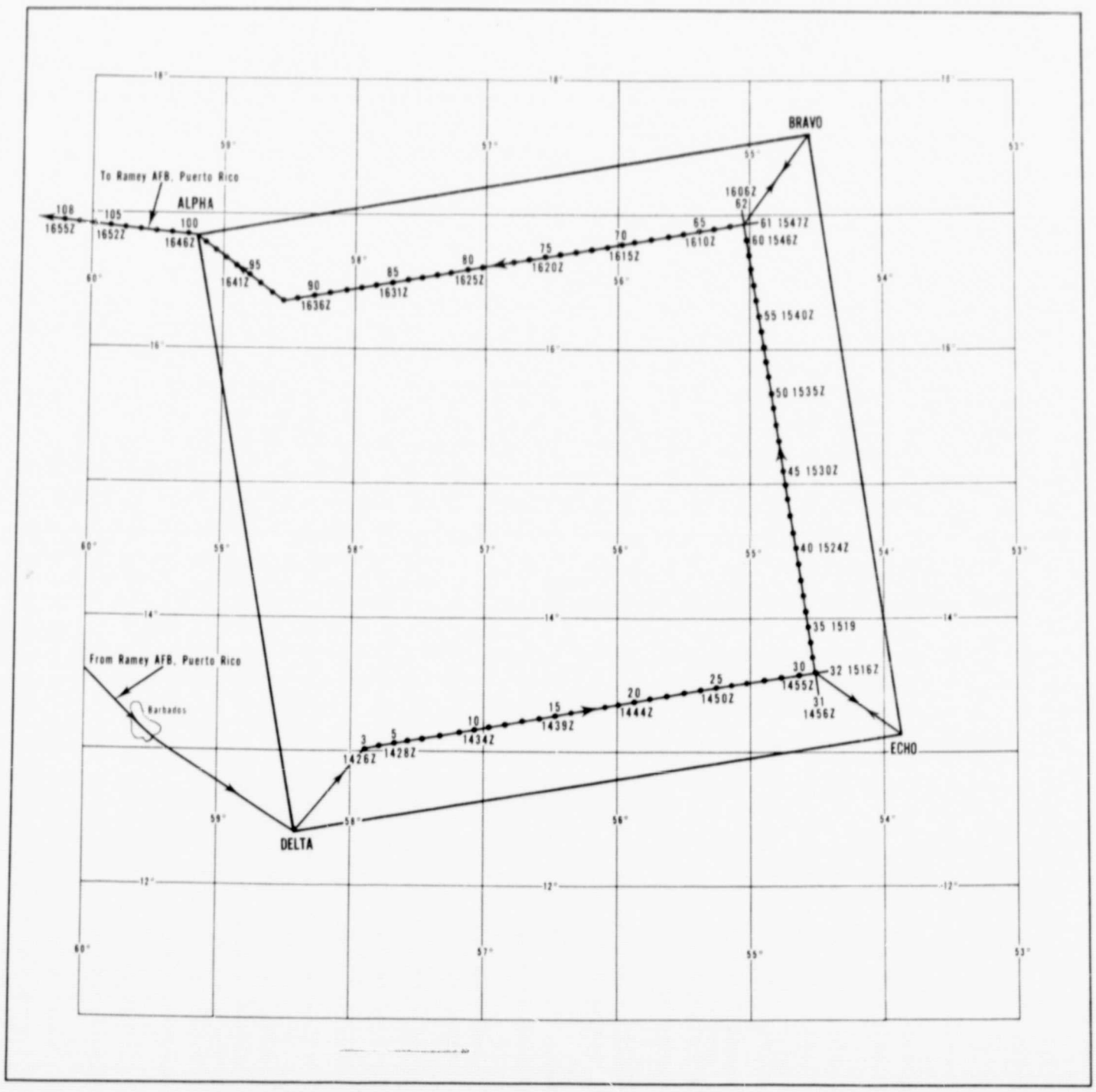


Figure 2.--BOMEX Period III high-level cloud photography flight track.

Exploration of tropical convective systems

During the exploration of tropical convective systems, Period IV of BOMEX, high-level cloud photography missions were flown daily along tracks selected to provide optimum coverage of prominent convective systems. Figure 3 shows a typical flight track for Period IV on July 18, 1969.

C. Cloud Data Processing and Publication

Flight tracks for BOMEX Periods III and IV have been reconstructed and positions of photographs marked on these tracks by the BOMAP staff. Figures 2 and 3 are examples of this work. The tracks are based on navigator's pre-flight and in-flight logs and notes and on evidence of orientation from the photographs. All pictures for the 12 flights of Period III have been reduced to half-size black and white prints and are being assembled as photo-composites for publication in atlas form. Figure 4 is an example of a typical page in the atlas. Each page of photographs covers one-half of the track flown along one side of the BOMEX square. Hence, six pages are required to cover each daily flight. The odd-numbered pictures are along one line and even-numbered pictures are along another line, together with a map showing the flight track and positions and times of the photographs.

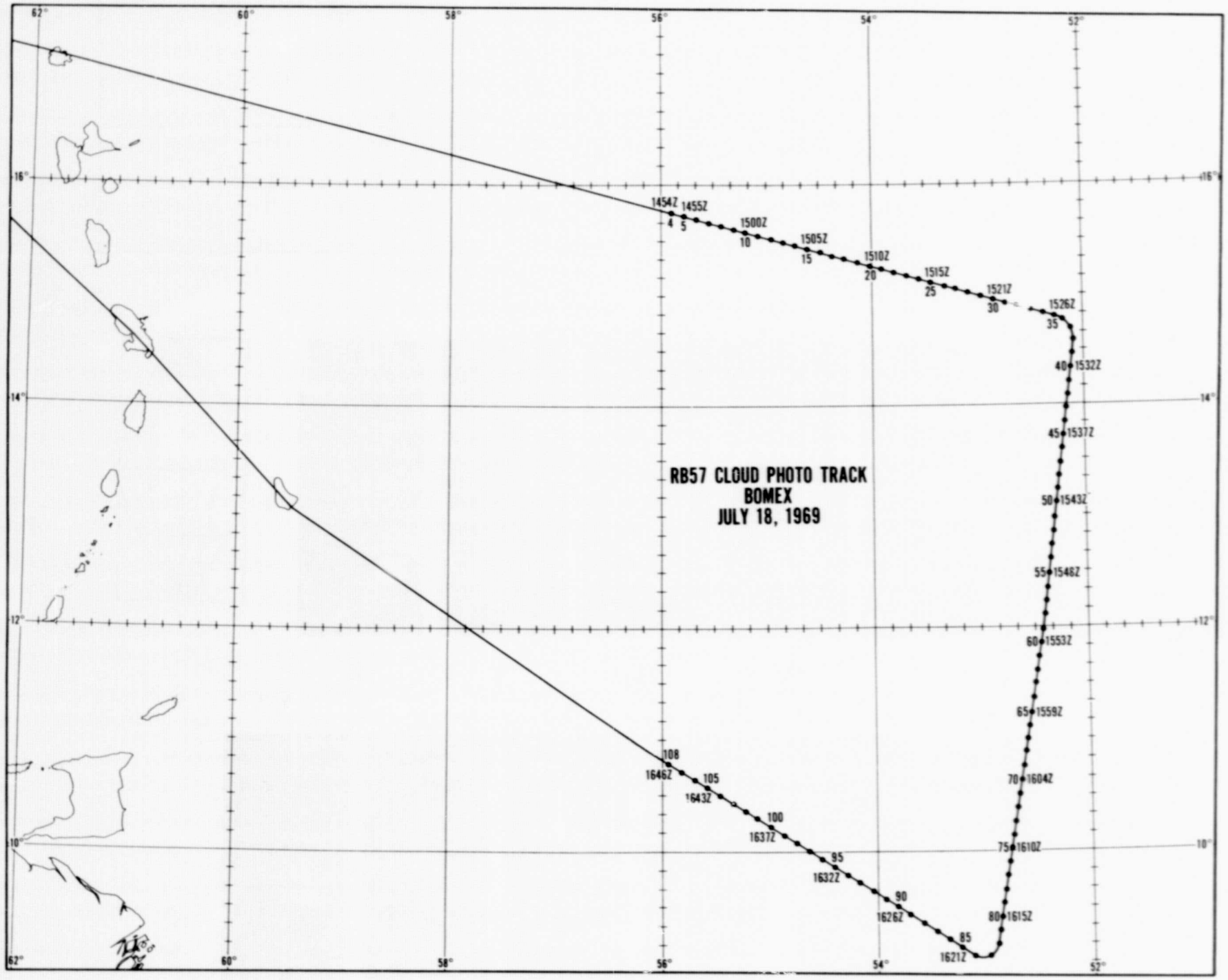
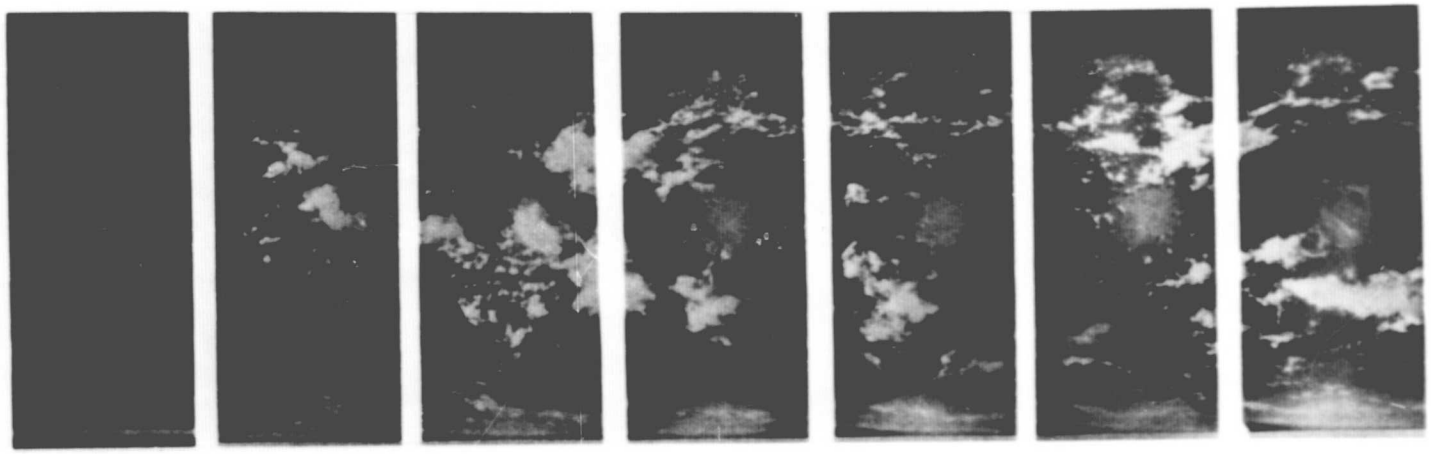
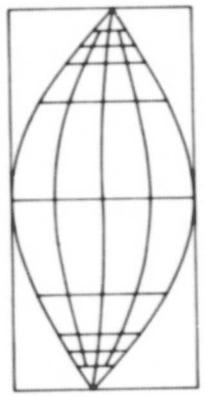


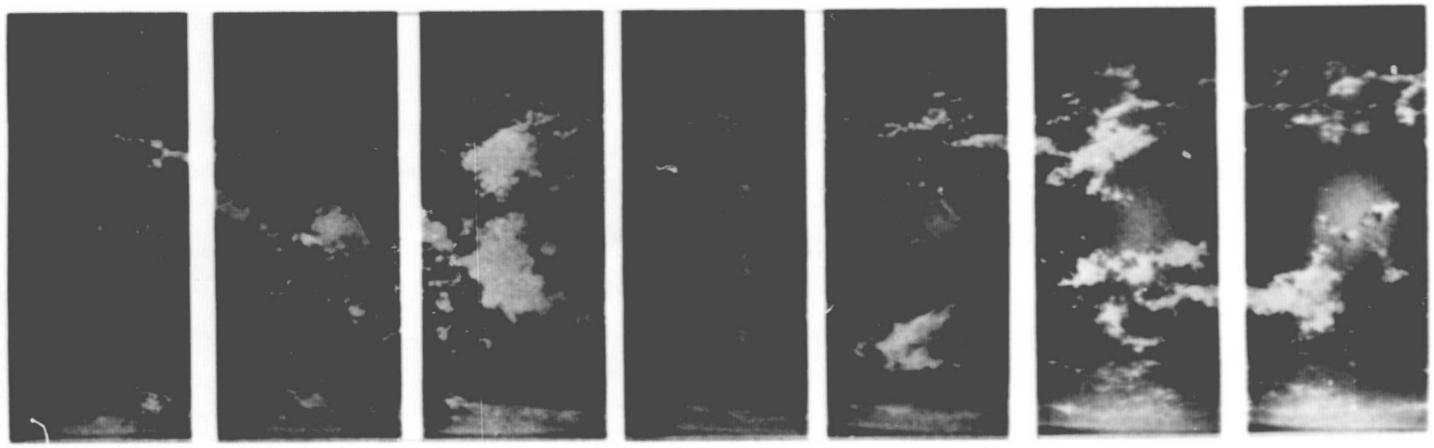
Figure 3.--Example of a BOMEX Period IV high-level cloud photography flight track.



5 7 9 11 13 15 17

6 8 10 12 14 16 18





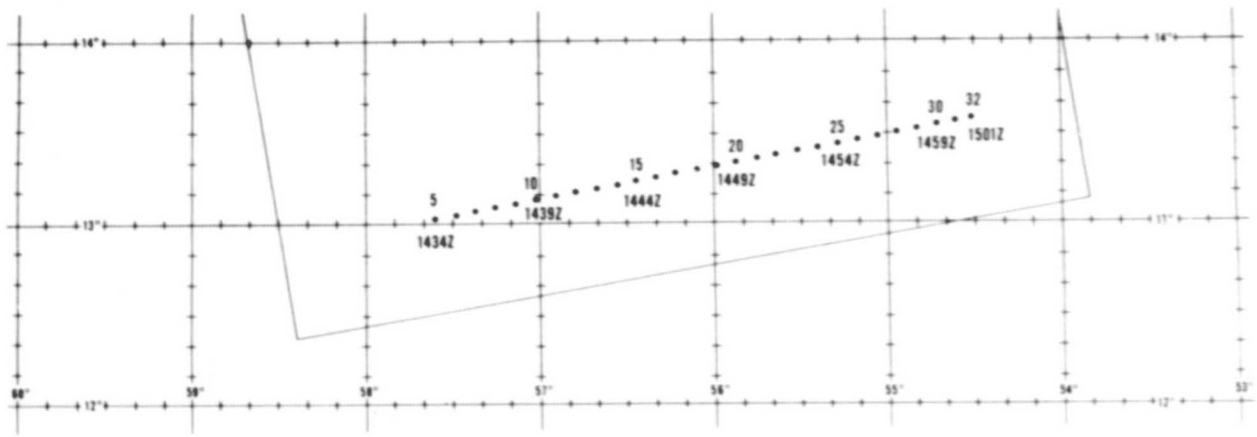


Figure 4.--Example of atlas page showing B-57 cloud photography from 50,000 ft on June 25, 1969. Photographs 19 through 32 of same sequence are pictured on facing page of atlas.

IV. RADAR DATA SAMPLE PRODUCTS

During BOMEX weather radar data were collected by aircraft, shipboard, and land-based radars. A U.S. Army radar (MPS-34) was stationed on the island of Barbados (fig. 5). An ESSA radar (METEOR-200) was aboard the U.S. Coast and Geodetic Survey ship Discoverer at the southeast corner of the BOMEX array -- position ECHO (fig. 5). An Air Force B-47 aircraft was used to collect radar photographs along the flight path shown in figure 5. Aircraft radar data also were collected by ESSA's Research Flight Facility and by a VW-4 Navy squadron. Only the surface-based and Air Force aircraft radar data are considered here.

The reduction of radar data collected during Periods I, II, and III of BOMEX comprises both qualitative and quantitative analyses as follows:

1. Qualitative Analyses -- Consist of assembling radar photographs into composite form to depict radar echo distributions over the entire BOMEX array in a synoptic time frame.
2. Quantitative Analyses -- Consist of digitizing radar photographs so that computer analyses can be performed. Information on the quantitative intensity and statistical character of radar echoes and their temporal and spatial distributions can be derived from the digitized data.

As part of the qualitative analysis, an atlas of radar and satellite cloud photographs is being assembled for publication in late 1970. The atlas will contain mosaics of the aircraft radar films, composites of surface radar photographs, and enlargements of satellite photographs of the BOMEX area. The atlas will display these products, when available, four times daily. The times are selected to correspond with:

1. Time One -- the nighttime Nimbus 3, HRIR.
2. Time Two -- an early morning ATS-3 photograph.
3. Time Three -- the mid-flight time for the AF B-47.
4. Time Four -- a late afternoon ATS-3 photograph.

Figures 6, 7, and 8 are sample atlas products for time three on June 29, 1969. All data are reproduced at a scale of approximately $1:8.125 \times 10^6$. Superimposed on each picture is an outline of the BOMEX area. The east and west sides of this square are oriented 10 degrees west of grid north. Figure 6 is a composite of radar photographs from the U.S. Army MPS-34 radar on Barbados and ESSA's METEOR-200 radar on the Discoverer for June 29, 1969. Figure 8 is a mosaic of the AF B-47 radar data collected on June 29, 1969. The approximate aircraft positions and times for 16 locations are shown on the flight path schematic below the mosaic.

As illustrated in figure 6, the BOMEX square is not completely surveyed by the two surface-based radars. Aircraft radar data are usually available only during mid-daylight hours. Therefore, to assess the distribution of clouds and precipitation for those times and areas not covered by surface and aircraft radar data requires the use of satellite data. Figure 7 is an enlarged portion of an ATS-3 satellite photograph of the BOMEX area.

A comparison of surface and aircraft radar data with ATS-3 satellite photography for June 29 (figs. 6, 7 and 8) shows that radar echoes are associated with some areas of cloud patterns on the satellite photograph but not with other areas of cloud patterns. In the southwest sector of the BOMEX square a line of radar echoes is associated with the cloud pattern shown on the satellite photograph. However, in the northeast sector of the square, radar echoes were not observed, while the satellite photograph shows clouds covering the northeast quadrant. The value of aircraft radar data in assessing regions of convection and precipitation is demonstrated by these comparisons. A knowledge of cloud types also is important in interpreting satellite cloud photographs and assessing areas of precipitation. For example, in the northeast sector of the BOMEX square, where radar echoes were not recorded within the area of satellite-observed cloud pattern, the clouds apparently were of cirrostratus type. The high-level cloud photography collected by the Air Force B-57 (see section III) provides a means of assessing the areal distribution of cloud types.

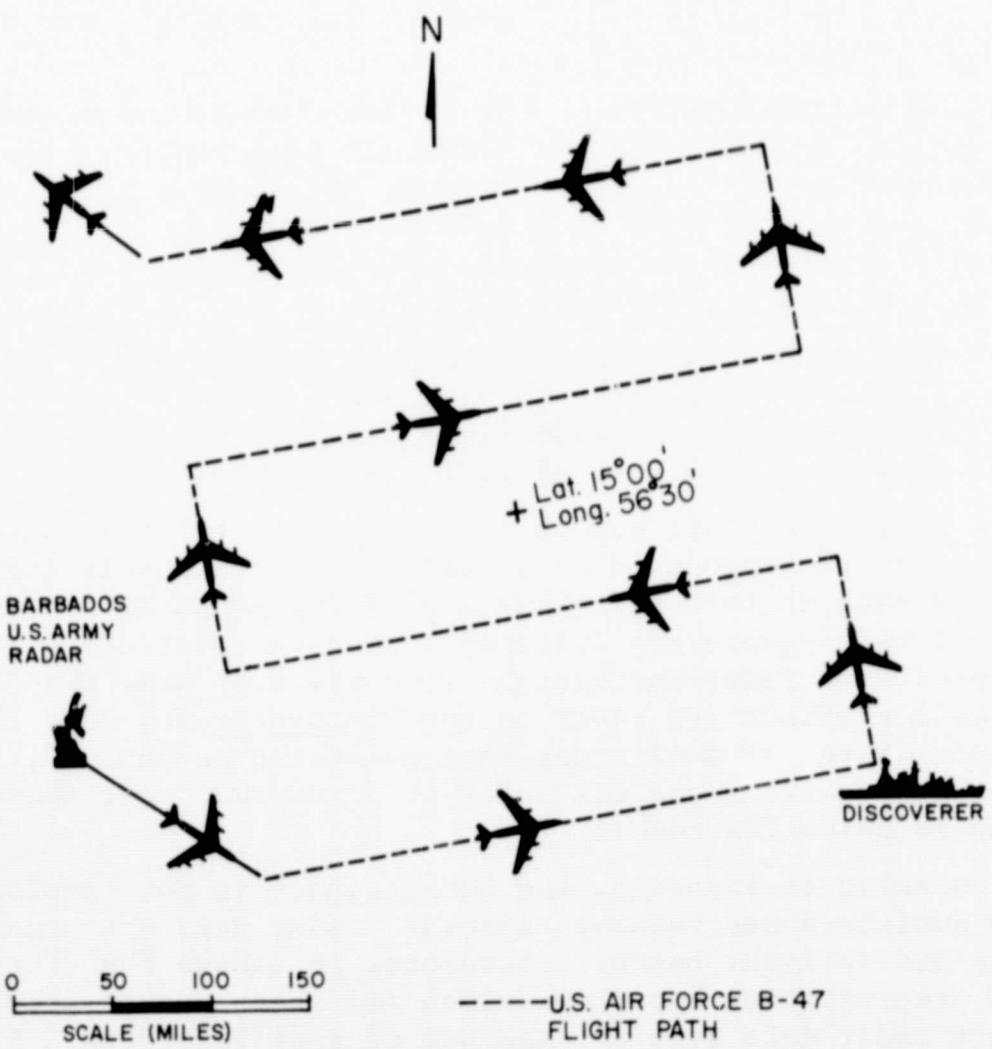


Figure 5.--Aircraft and surface-based radar coverage during BOMEX Periods I, II, and III.

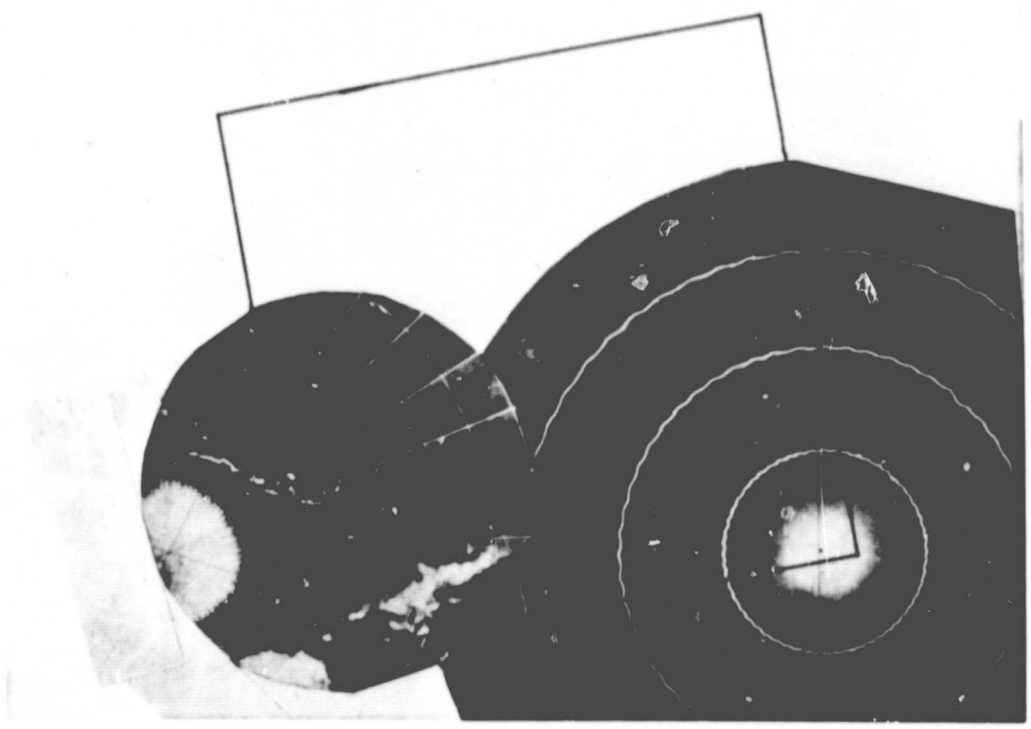


Figure 6.--Composite of surface-based radar photographs for June 29, 1969, 1555Z -- Barbados radar USC&GS ship Discoverer radar.

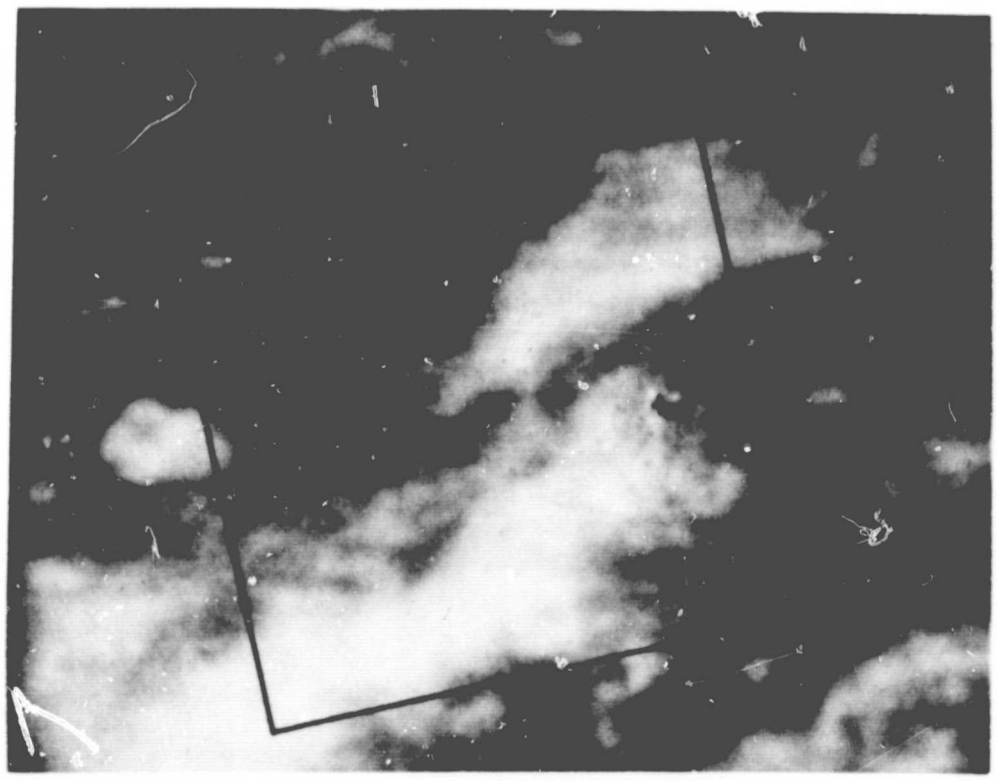
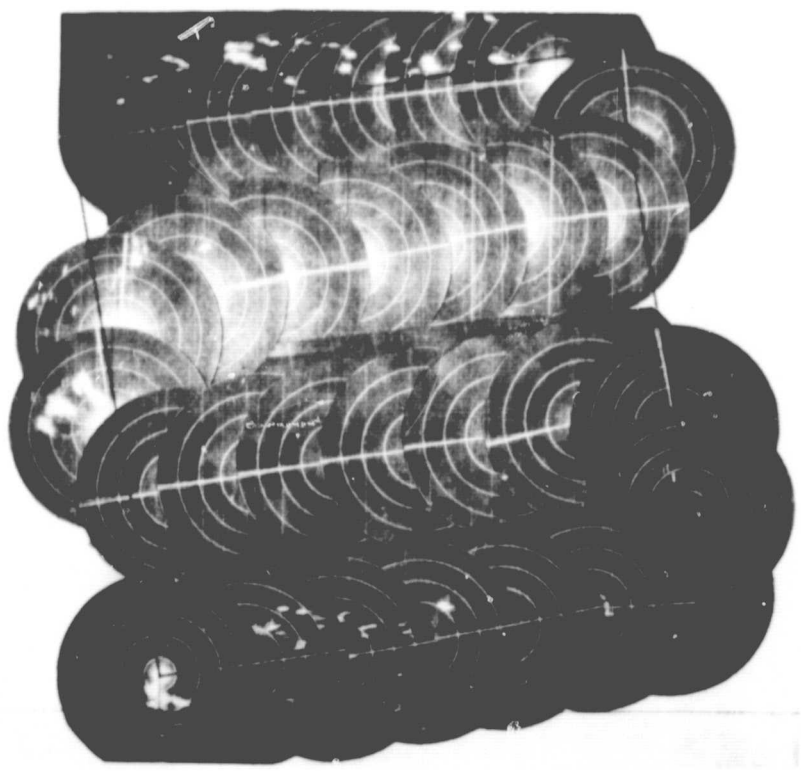
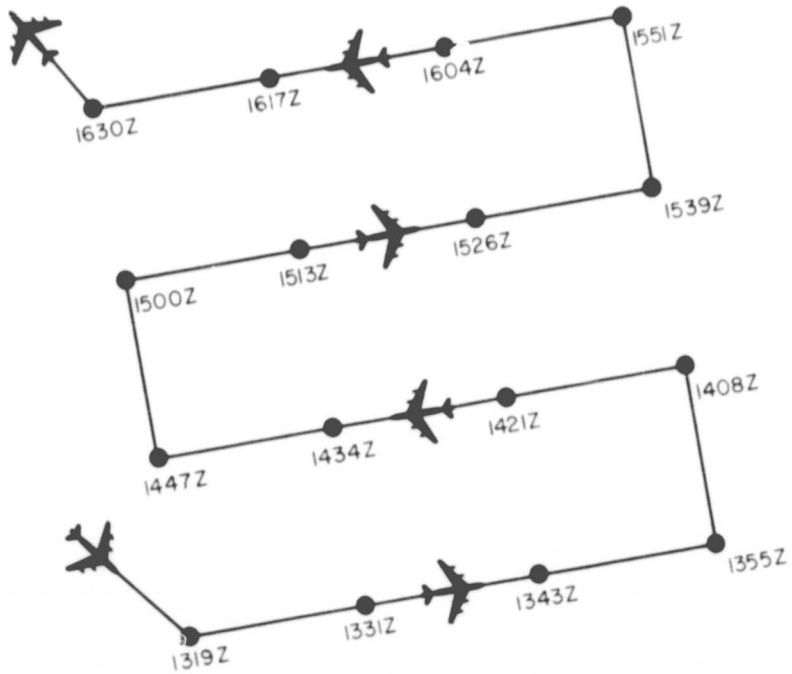


Figure 7.--Enlargement of ATS-3 satellite photograph for June 29, 1969, 1549Z.



(a)



(b)

Figure 8.--(a) Mosaic of Air Force B-47 radar photographs for June 29, 1969 -- flight altitude approximately 30,000 ft. (b) Flight path showing aircraft position and time for 16 locations.

The quantitative analyses include the digitization of approximately 5,000 radar photographs collected by the surface-based radars. A coordinate digitizer with magnetic tape storage is used for digitization. Figure 9 is a computer printout of a magnetic tape record of digitized radar data, displayed in plan position indicator (PPI) format. The digitized radar data make possible the study of the quantity and character of radar precipitation echoes. Echo statistical analyses will be performed using computer algorithms. Quantitative precipitation estimates also will be derived from the radar data. The surface-based radars were equipped with "gain-step" equipment.

The digitized radar data will be stored in binary mode on magnetic tape. Also, plans are underway to archive digitized computer PPI plots on microfilm. Computer plots similar to figure 9 will be output for each radar photograph and receiver gain. Composites corresponding to an entire gain-step sequence also will be assembled for plotting by computer program. For the composites, an integer representing the highest attainable gain-setting will be printed in the appropriate grid.

Figure 9.--Computer printout of digitized radar data from off-center PPI scope display -- island of Barbados. Grid north is at top of display.

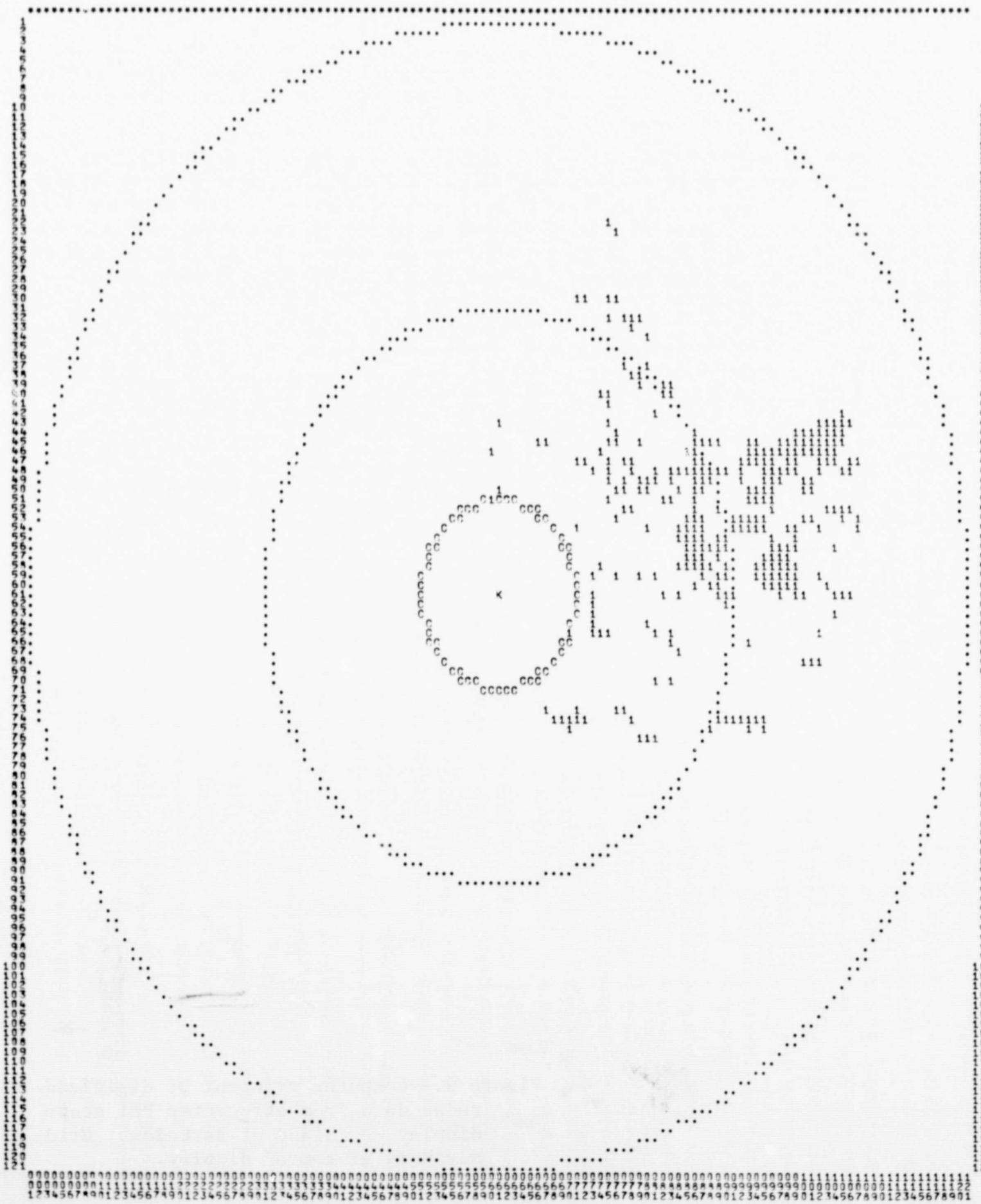
ROMEX DIGITIZED RADAR DATA

DATE 6/29/69 START TIME 30453 END TIME 30453 .

RADAR (1) ANTENNA TILT ANGLE 0 DEG.

SCALE FACTOR= 4.0540 MI/GRID.

CODE (4) GROUND CLUTTER EXTENT = 40 MILES RANGE MARKER INTERVAL = 121.6200 MILES.



V. STATUS OF DATA PROCESSING AND REDUCTION (June 15, 1970)

A. Fixed-Ship Computer Data Reduction

Digitization and initial or "A_o" fixed-ship computer data processing (see fig. 30, BOMEX Bulletin No. 6) at the NASA Computer Operations Office Slidell Facility, Slidell, La., and NASA Mississippi Test Facility (MTF), Bay St. Louis, Miss., are progressing as follows.

1. SCARD (Signal Conditioning and Recording Device). The SCARD analog data is converted to 10 samples per second (sps) digital data, edited for gross noise elimination, and averaged to 2 sps. Progress is reported as follows.

(a) Periods III and IV are completed and delivered to MTF.
(b) Period II is 96 percent completed and delivered to MTF.
(c) Period I is 92 percent completed and delivered to MTF.

The remaining tapes for Periods I and II should be delivered to MTF in July.

2. 2-sps data review. Rawinsonde start-and-stop times have been selected by BOMAP/MTF for the Discoverer, Rainier, and Rockaway for Period IV. All necessary data to complete the Period IV 2-sps has been received by BOMAP/MTF.

3. Rawinsonde software and data processing status. The initial fully-automated reduction process ("A_o") output for BOMEX Period III rawinsondes taken on the Mt. Mitchell, Oceanographer, and Rainier have been received and reviewed by BOMAP/MTF. Rawinsonde "A_o" output consists of a listing of the 5-sec "raw" input values (temperature frequencies, temperature low reference frequencies, azimuth 20, azimuth 360, voltage in digital counts, slant range voltage in counts, etc.) used in the rawinsonde computations, separate plots of temperature and humidity, and "u" and "v" wind components versus the natural log of pressure (along with log pressure-height curves), and a listing of 5-sec values of rawinsonde temperature, humidity, pressure, and wind component outputs in scientific units. An examination of the "A_o" rawinsonde output shows that the use of data points every 5 seconds is a better choice than the significant levels. Sample sounding based on 5-sec data show a finer detail of the stratification of temperature and humidity with each stratum readily traceable in a time series and the major strata identifiable from one ship to another.

Results of the preliminary "A_o" review, in terms of the amount of data that could be automatically processed when given the manually derived rawin start time, follow.

The Oceanographer took 106 rawin observations during Period III. Of the 106 soundings, 98 were selected for processing; 8 were either aborted or had relative humidity data missing.

(a) 39 were processed to normal termination of data (400 mb).
(b) 16 were terminated early or before 400 mb due to loss of relative humidity signal.
(c) 3 were terminated early due to loss of time in 2-sps data.
(d) 34 were terminated early due to the following reference recognition problems:

5 were not processed due to noise or missing references at the surface.
3 lost signal during the flight causing 2 or more missing low references.
26 were reference recognition problems -- of these, 87 percent of the available data for the average flight was processed.

(e) 4 were not processed due to operational computer problems.
(f) 2 were not processed due to various input data problems.

A preliminary estimate of data yield for the Oceanographer is that 40 percent of 98 soundings contained processed data to 400 mb or higher and 64 percent of 98 soundings contained processed data to at least 550 mb.

The Mt. Mitchell took 130 rawin observations during Period III. Of the 130 soundings, 105 were selected for processing; 25 were either aborted, had time missing from the 2-sps data, or had relative humidity data missing.

(a) 69 soundings were processed to 400 mb or higher.
(b) 6 were terminated before 400 mb due to loss of relative humidity or temperature signal.
(c) 3 were terminated early due to time missing from 2-sps data.
(d) 5 were terminated because first pressure contact was higher than surface pressure.
(e) 22 were terminated prior to 400 mb because of reference recognition problems. Of these:

2 were terminated due to unrecognized reference at surface.
2 were terminated during flight due to loss of two or more references in signal noise.
18 were terminated prior to 400 mb due to unrecognized references which were present. At the termination point of these 18 flights, 76 percent of the available data was processed.

A preliminary estimate of data yield for the Mt. Mitchell is that 66 percent of 105 soundings contained processed data to 400 mb or higher and 83 percent of 105 soundings contained processed data up to at least 550 mb.

The Rainier took 124 rawin observations during Period III. Of the 124 soundings, 118 were selected for processing; 6 were either aborted, had time missing from edited 2-sps tapes, or had humidity data missing.

(a) 51 soundings were processed to 400 mb or higher.
(b) 1 was not processed due to excessive signal dropout or loss.
(c) 6 were not processed due to time gaps.
(d) 1 was not processed due to erroneous start time.
(e) 1 was not processed due to erroneous baroswitch calibration data.
(f) 58 were not processed to termination due to reference recognition problems. Of these:

8 soundings were terminated at the surface due to noise.
1 was terminated in flight due to loss of 2 or more references.
49 were terminated prior to 400 mb due to reference recognition problems. Of these 49, the average sounding in this category contained 64 percent of the available data.

A preliminary estimate of data yield for the Rainier is that 43 percent of 118 soundings contained processed data to 400 mb and 85 percent of 118 soundings contained processed data up to at least 600 mb.

In order to improve the yield from "A_o" to 400 mb or higher, Period III rawinsondes will be reprocessed with "A_o" software modifications to solve some of the reference recognition problems. The software modifications are planned for testing during July. Recent figures for SCARD rawinsonde processing time reveals that approximately 22 hours of computer time are required to process the rawin data for 1 ship for Period III. By using these figures as a guide, it is anticipated that Periods III and IV will be completed in August and Periods I and II by early October.

Since production of automatically reduced rawin data to support the design of the next level of data reduction ("A" process) was one of the "A_o" process objectives, the following corrections (to be applied at the "A" process level) have been defined thus far during the course of the preliminary "A_o" and 2-sps review by BOMAP/MTF and BOMAP/Rockville.

1. Correct wind speed and direction data for ship motion.
2. Improve rawin reference and temperature/humidity data recognition.
3. Improve pressure contact handling and calculation of rawin surface pressure correction using the Rosemont pressure data for its surface value.
4. Provide flexible process of manual addition, deletion, and/or forced interpolation of data.
5. Provide manual forcing of temperature reference recognition where "A_o" has failed and complete "A_o" data analysis proves that an improved reference recognition and pressure contact handling is not feasible.
6. Insert low pass filter, nonlinear interpolation across references and gaps, and provide lag correction of temperatures. Target is meaningful 0.1-Hz data sampled each 5 sec.
7. Provide manual identification and computer assisted correction of humidity frequency "doubling" problems.
8. Provide thermal lag correction to humidity data.

9. Provide insolation correction to humidity data.
10. Provide software filtering of Scanwell slant range. The significant vertical resolution availbale in the temperature and humidity makes it very desirable to try for maximum resolution in wind data without aliasing high frequency oscillations or excursions present in slant range and azimuth data.
11. Provide software filtering of Scanwell azimuth data (see 10 above).
12. Manual entry of azimuth angular bias.
13. Potentiometer loading correction to the slant range and course (360) azimuth.
14. Modified wind computation procedure that is compatible with 10 and 11 above.
15. Filter Discoverer Selenia wind data in a manner compatible with the Scanwell equipped ships Oceanographer, Mt. Mitchell, and Rainier.
16. Provide graphical output in skew-T and time series formats.

4. Boom/surface data processing. The boom and other surface data for all of Period III has been completed and delivered to BOMAP for preliminary review. A detailed analysis of boom/surface data will be accomplished at BOMAP/Rockville with some analysis support from BOMAP/MTF personnel. Although the analysis effort has not been completed, the following corrections to the boom/surface data (which were not a part of the "A_o" process) will be accomplished in Rockville.

(a) Removal of bias from data and provide capability to use time varying coefficients for transfer equations.
(b) Removal of ship motion from wind speed and direction data.
(c) Identification and flagging of periods of time when sensors were inoperative or out of calibration.

5. STD (Salinity-Temperature-Depth) sensor digitization at MTF Data Acquisition Facility. Digitization of SCARD analog data is progressing at approximately 8 samples per second. Periods I through IV of the Discoverer and Oceanographer STD data are complete. Period I of the Mt. Mitchell STD data is complete and Periods II, III, and IV are being digitized.

6. STD Data Processing at BOMAP/Rockville. The first pass STD data reduction software is in the final stages of checkout at BOMAP/Rockville, using the ESSA CDC-6600 computer in Suitland. This program reads the digitized data tapes from MTF and produces the following:

(a) Time series at 8 sps from just below the surface to 1000 meters.
(b) A file of surface STD data cards.
(c) A file of 1000-meter STD data cards.
(d) Air/sea interface records consisting of 100 cards, at least 40 of which are on each side of the interface.
(e) Zero corrections for the depth measurements.
(f) Sample data will soon be available with processing of all periods of the Discoverer data to start shortly after that.

BOMAP/Rockville has received 20 tapes of 8-sps data from MTF for all periods for the Discoverer. If the test run for these tapes proves successful, the computer program will be used on all 20 tapes.

7. Boundary Layer Instrumentation Package (BLIP) digitization and "A_o" process. Status of this work is as follows.

(a) Digitization of BLIP data (Oceanographer and Mt. Mitchell is completed.
(b) Processing of the BLIP "A_o" wind speed and relative wind direction data has begun.
(c) Software is being written to convert the BLIP dry bulb and wet bulb temperature to scientific units. Pressure data will not be converted to scientific units during BLIP "A_o" processing.
(d) BLIP "A_o" microfilm displays are being designed.

B. Manual Rawinsonde Data Reduction

A format has been designed for the output from the rawinsonde computation program. One format has been designed for use in the Mesoscale Analysis Project and the other for validating the "A_o" process and use in the Core Experiment. The output will consist of temperature, humidity, and wind at all significant levels; height of pressure surfaces (meters), temperature (^oC) (actual and virtual), dewpoint, relative humidity, specific humidity, wind speed and direction, and potential temperature (^oK) at both significant and mandatory levels or other set of levels. The basic input tape will include all punched cards from rawinsonde observations, surface observations, ship operation forms, baroswitch calibration cards, temperature, humidity, and wind data from rawinsonde reduction.

Rawinsonde data for the period of June 23, 1200Z through June 24, 1200Z has been transcribed from strip charts to code forms. The transcription of the Scanwell strip charts for period IV on the Oceanographer, Rainier, and Mt. Mitchell has been completed.

A deck of input cards has been punched for all rawinsondes between June 23, 1200Z and June 24, 1200Z to be used as input for a test run of the Core Experiment.

C. Aircraft Data Peduction

1. Most of the RFF DC-6 flights are now ready for processing by NHRL (National Hurricane Research Laboratory) at the Suitland computer using the Miami terminal.

2. Processed (renavigated) data from RFF DC-6 39C flights for June 23, July 14, and July 25, and RFF DC-6 40C flights for June 9, June 23, June 25, July 18, and July 20 have been received at BOMAP after being checked by NHRL.

3. Gross errors in hand-tabulated Navy aircraft wind data have been corrected and a new working tape has been written. The task of editing Navy punched paper tape is progressing. Garbled sections of data are being eliminated and backward reading records are being reversed. Separate observations are being identified and arranged in chronological order for preparation of a suitable working tape.

4. Dropsonde records have been examined for superadiabatic lapse rates. The transcription forms, adiabatic chart plots, baseline checks and strip charts are being used manually to validate questionable portions of the dropsonde records case by case.

Work has continued to edit and correct the dropsonde data for obvious errors, and to compute means and variances from a card deck and a data tape which was prepared.

Mean soundings have been computed and found to be in agreement with climatological data for the temperature and humidity during the first three periods. Standard statistics have been computed for day and night runs, for individual aircraft, and for various quadrants of the BOMEX box. Joint probabilities for temperature and dew point depression have been computed at 50-mb intervals for the first three periods.

Dropsondes for all four periods have been worked up. Final detailed individual dropsonde results will probably have to be adjusted slightly during subsequent intercomparison with aircraft and radiosonde data.

D. Background Weather Analysis

It is now planned to prepare a final set of synoptic-scale analyses and a set of mesoscale analyses in BOMAP/Rockville for the first three periods of BOMEX to assist in the interpretation of the Core Experiment data. Work has begun on plotting surface data from the observation cards for the mesoscale analysis project. These will be plotted on $1:2\times10^6$ base maps which include the area from 10^{o} to 19^{o}N and from 50^{o} to 64^{o}W.

E. Turbulent Flux Analysis

The reduction of RFF DC-6 gust probe/refractometer data for approximately 200 5- or 10-min runs has been completed by Rinaldi Data Processing Associates under contract with BOMAP. These include tabulations or plots of cross covariances, power spectra, cospectra, coherence spectra, and phase angle spectra of vertical velocity and humidity. Reduced time series of humidity and vertical velocity at 10 samples per second for all runs are also recorded on magnetic tape. These data are being analyzed by the Radio Meteorology Group, Wave Propagation Laboratory, Research Laboratories (ESSA), Boulder, Colo.

F. Radiation Analysis

The first NASA sample of High Resolution Infrared grid printout from Nimbus 3 satellite data has been received. The radiation equivalent temperature is printed on a Mercator projection map.

G. Cloud Data Reduction

Cloud photographs taken by the Air Force RB-57 at 60,000 ft during BOMEX Period IV have been prepared as 35-mm slides. The adjustment of flight tracks and preparation of descriptive material to accompany these slides is nearing completion. Cloud photographs taken by the RB-57 at 50,000 and 60,000 ft during BOMEX Period III have been reduced to half-size black and white prints and are being prepared as photo-composites for publication in atlas form (see section III, High-Level Cloud Photography Samples).

H. Radar Data Reduction

Sample products of the radar data reduction are shown and discussed in section IV of this bulletin.

I. Satellite Data Reduction

The BOMAP Office is preparing an atlas-type publication to show the distribution of clouds during BOMEX as observed from earth-orbiting satellites. Most of the pictures will be enlargements of satellite cloud photographs, will cover an area extending from 0 to 25°N and from 40 to 70°W, and will have grid points and an outline of the BOMEX area superimposed upon them. The NASA ATS-3 satellite provided the most frequent pictures and these will be used as source material for this publication. Four pictures will be shown for each BOMEX day -- enlargements of satellite photographs for shortly after sunrise, midday, and shortly before sunset, and a full earth disk photograph for midday to provide a view of the clouds over the Atlantic Ocean. The tasks of enlarging the photographs and adding the grid points are complete. These tasks were performed to BOMAP Office specifications by Allied Research, Inc., a contractor to NASA, at the request of NASA.

Three principal satellites recorded pictures during BOMEX -- May through July 1969:

ESSA 9 -- an ESSA operational satellite which provided coverage in the visual range; passed over the BOMEX area in the early afternoon, local time.

Nimbus 3 -- a NASA experimental satellite which provided infrared and visual range pictures at approximately local noon over BOMEX and infrared at approximately midnight.

ATS 3 -- a scientific NASA satellite in synchronous orbit above the equator which provided visual range pictures of the entire earth disc or the northern half at 15- or 30-minute intervals during daylight on most BOMEX days.

A listing of currently available publications, prospective publication dates, archive addresses, and ordering instructions for satellite photographs taken during BOMEX follows:

ESSA-9 data catalog and archives

Published catalog. "Catalog of Meteorological Satellite Data, ESSA-9 Television Cloud Photography April 1 - June 30, 1969" is in preparation by ESSA's Environmental Data Service and will be out in a few months. This catalog will be identical to previous volumes in this series, presently in most university and laboratory libraries, and will show the Northern Hemisphere and Southern Hemisphere in polar stereographic projection with a gridded map background, produced from digitized signals,

When completed this volume will be for sale by the Superintendent of Documents (current price $2.00) or can be obtained for cooperators by the BOMAP Office.

The catalog for July 1 - September 30, 1969, will follow the above and is expected to be identical in format.

Microfilm archive. ESSA-9 data are archived at the National Weather Records Center on microfilm in the following forms, all currently available for the BOMEX period.

(a) Hand-drawn nephanalyses.

(b) Strip mosaics, from the Advanced Vidicon Camera System (AVCS) television photos.

(c) Hemispheric pictures, from digitized data, identical to those published in data catalogs.

(d) Mercator presentation of tropical area from digitized data.

These can be furnished by the National Weather Records Center, Federal Building, Asheville, North Carolina, 28801, at cost. Only complete reels of positive or negative duplicate 35 mm film, covering one-half month are furnished. The strip mosaics are on separate reels by tracks. Tracks 2 and 3 cover the BOMEX area. The hemispheric and Mercator presentations are worldwide, contained on a single reel for a half month. Current cost of all reels is $8.50 each.

These should be ordered direct from NWRC. BOMAP has no facilities for handling these orders.

Enlargements. A few enlargements for particular days and locations if requirements are urgent can be obtained by BOMAP for cooperating investigators direct from the National Environmental Satellite Center, by courtesy of the Center.

Print archive. A file of the Mercator presentation of ESSA-9 photos from digitized data (see (d) under "microfilm archive") is at the BOMAP Office and may be studied here.

Nimbus-3 data catalogs and archives

Published catalogs. The following have been published by the Goddard Space Flight Center and distributed to many libraries:

(a) "The Nimbus III User's Guide."

(b) "The Nimbus III Data Catalog, Volume 1, Part I. -- 14 April through 31 May 1969."

(c) Contains IDCS (Image Disector Camera System) Visual range daytime strip mosaics and HRIR (High Resolution Infrared) day and night strip mosaics. Nimbus III overflies BOMEX area at approximately local noon and midnight, 0.7 - 1.2 micron channel by day and 3.4 - 4.2 micron channel by night.

(c) "The Nimbus III Data Catalog, Volume 1, Part II. -- 14 April through 31 May 1969."

Contains MRIR (Medium Resolution Infrared) streps in five channels. Little detail over BOMEX area.

(d) "The Nimbus III Data Catalog, Volume 2, June 1969."

Contains the same information as (b) and (c) for June.

These can be ordered from: Mr. John Linstrom, Manager, NADUC, Code 460, Goddard Space Flight Center, Greenbelt, Maryland 20771. An additional volume covering July 1969 will be issued shortly.

Microfilm archive. The MRIR, HRIR, and IDCS pictures published in data catalogs are archived at NWRC on 70 mm microfilm. These can be duplicated at cost by NWRC, either as complete positive or negative reels or as selected contact prints. Place orders to National Weather Records Center, Federal Building, Asheville, North Carolina, 28801. BOMAP has no facilities for processing these orders. BOMEX period film is now available at Asheville.

ATS-3 data catalogs and archives

Published Catalogs. The following are published and distributed by the Goddard Space Flight Center:

(a) "Meteorological Data Catalog for the Applications Technology Satellites, Volume I."

(b) Part I is User's Guide to ATS-3 Meteorological Data. Other parts give ATS 1, 2, and 3 data for portions of 1967 and 1968.

(b) "Meteorological Data Catalog for the Applications Technology Satellites, Volume III."

Covers ATS 1 and ATS 3 for period February through December 1968. Includes one picture per day of disc of earth from ATS 3 and illustrates type of material that will be published in the subsequent catalog covering BOMEX period.

(c) Catalog for January - July 1969 is in press, similar to (b).

The above may be ordered from the same address as the Nimbus catalogs, see above.

Film archive. Earth disc photos are archived at NWRC on 5-inch film. Each reel of film includes overlay grids needed for that reel as separate images. Place orders for complete positive or negative reels or selected contact prints with National Weather Records Center, Federal Building, Asheville, North Carolina, 28801. Recipient pays cost. BOMEX period film is now available.

Print archive. All ATS 3-earth disc pictures during BOMEX are on file at the BOMAP Office in the form of 8x10-inch glossy prints, and may be studied or inspected here.

Enlargements of BOMEX area. The BOMAP Office expects to assemble enlarged ATS-3 photos for the BOMEX area on BOMEX observation days, a selection of two or three pictures per day, and publish these in a report.

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