the 1968 Barbados Experiment

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Abstract

An intensive experiment in tropical meteorology with emphasis upon the interaction of the atmosphere, the ocean and the land will be centered upon the island of Barbados, West Indies, during the summer of 1968. The scientific objectives of this program are outlined, and the means by which these objectives are expected to be attained are described in terms of instrumentation and systems development that has been carried out over the past two years. The role and importance of such experiments in the tropical atmosphere is emphasized.

1. Introduction

One of the most significant lessons that has been learned from investigations of the tropical atmosphere and ocean over the past two decades is that the two fluids are in continual interaction, both with each other and between scales of motion within each fluid. In contrast to mid-latitudes, tropical weather is not dominated by physical processes associated with the synoptic and larger scales of motion to a degree which permits ignoring the influences of smaller scales such as convection and boundary layer turbulent processes. Rather, it has been concluded that an adequate ability to understand and predict tropical weather systems can be developed only by a simultaneous consideration of physical processes over a wide spectrum of spatial and temporal scales ranging from the planetary scales exemplified by subtropical anticyclones, monsoons and trade winds, through the synoptic scale features of equatorial vortices and hurricanes, the convective processes associated with cumulus clouds to the turbulent processes in the boundary layer.

This fundamental principle is most firmly established in the case of hurricanes (typhoons) which have been shown to be the (relatively rare) ultimate stage of development of various synoptic-scale disturbances whose frequency, structure and life-cycle are influenced by the larger scales, and which can form and be maintained only over tropical oceans which provide boundary-layer conditions suitable to provide the necessary sensible and latent heat fluxes to the inflow layer which are subsequently released and transported by convective clouds to maintain these storms (La Seur, 1967). Both the

theoretical and empirical points-of-view have converged upon this model of the hurricane with the result that these storms represent perhaps the only tropical weather system for which an adequate model exists. Similarly, it has been shown (Riehl and Malkus, 1957, 1958) that the energetics of planetary features such as the trades and equatorial trough depend to a large extent upon convective and synoptic scale interaction. It is considered equally probable that these planetary features as well as other systems such as the equatorial vortices and easterly waves can be better understood by incorporating the physical processes associated with smaller scales of motion.

It is apparent that economic considerations preclude the establishment of a data network throughout the tropical atmosphere capable of explicit observation of the meso- and micro-scale motions. Means must be found to parameterize in a meaningful way these smaller scales of motion in terms of observable synoptic and larger scale variables. It follows that emphasis upon observational efforts in the tropics must be directed toward well conceived and executed programs designed to provide information for a variety of combinations of the various scales in order that realistic methods of such parameterization may be developed. In particular, an observational program designed to study one scale of motion, e.g., convection, out of context of other scales is limited from its inception as to the results which may be expected.

Even the scope of a single experiment designed to meet the above objectives taxes the capabilities of a given research group. It is, however, possible to conceive and execute more limited experiments within the framework of the above philosophy. These experiments must not only attempt an implicit inclusion of those scales of motion that cannot be observed directly but must develop the techniques and instrumentation that are necessary precursors to any large scale experiments

The 1968 Barbados Experiment has been designed within the above enunciated framework. The Experiment builds upon two previous field observation programs in the same area (Garstang, 1958; Garstang and La Seur, 1964). These previous experiments were, in turn, largely inspired by the field expeditions carried out by the Woods Hole Oceanographic Institution under the direction of Wyman, Woodcock, Malkus and

others. These experiments clearly revealed that the vertical transports in the layer of constant flux show significant diurnal and inter-diurnal variations (Garstang, 1958; Garstang and La Seur, 1964). Several factors may contribute to the diurnal variations but the inter-diurnal variability is clearly associated with interactions between the boundary layer turbulence and synoptic disturbances in which are embedded convective scales of motion (Garstang, 1967a). One important implication of this work is that computation of such fluxes from climatologically averaged data is subject to considerable error. A second series of problems investigated during these previous experiments were related to interaction between land, sea and air at the boundaries and over a small island (Garstang, Boaz and La Seur, 1965). All of these findings have contributed to the understanding of the structure and behavior of the tropical atmosphere. It is upon this basis that a new set of hypotheses have been formulated and a further experiment designed for their investigation.

2. Scientific objectives of the 1968 Barbados Experiment

The overall scientific objective of the Experiment is the intensive study of the interacting scales of motion within a limited region of the maritime tropics. This objective has been translated into the following inter-related areas:

2.1. Sea-air interaction program

The objectives will be to:

- a) obtain simultaneous quantitative measurements of the flux of momentum, water vapor and sensible heat by a number of independent methods under steady and unsteady atmospheric and oceanic states;
- b) delineate meso (10 to 100 km), convective (1 to 10 km) and turbulent (less than 1 km) scales of motion and place these implicitly within the framework of the synoptic (100 to 1000 km) and planetary (larger than 1000 km) scales of motion;
- c) investigate the interdependence of energy fluxes and the various scales of motion and via the simultaneous measurements of fluxes obtain quantitative intercomparison and determination of absolute magnitudes of the fluxes under these different degrees of organization in the tropical atmosphere;
- d) study variations of oceanographic surface parameters (in particular sea state and wave fields) in relation to meteorological parameters and various fluxes.

2.2. Land-sea-air interaction program

The objectives will be to:

- a) determine differences between oceanic and island conditions leading to intercomparison of frictional and heating effects at sea-land boundaries, intercomparison of land- and sea-based techniques of

flux determination and the representation of oceanic conditions via land-based observations;

- b) examine in detail the effects of an island obstacle and heat-cold source upon the flow of the atmosphere as an example of forced convection and mesoscale organization and the development of a numerical model representing these processes;
- c) examine the radiation balance at the surface of the island and over the open ocean and to determine for the island the radiative flux divergence in the boundary layer.

2.3. Atmospheric program

Directed toward:

- a) a depiction of the vertical structure (kinematic and thermodynamic) of the tropical atmosphere. The relationship between changes in this vertical structure to changes in the energy flux at the lower boundary on the one hand and the changes in the convective, meso- and synoptic-scale organization on the other hand;
- b) the possibility of parameterization of the energy flux in terms other than air-sea property differences, specifically the evaluation of satellite photography of cloud distributions, concurrent aircraft and surface observations (ship and island);
- c) the development of a numerical model to depict the structure of the tropical atmosphere based upon the input at the lower boundary and the vertical and horizontal fluxes;
- d) the interrelationship between the equatorial trough (or inter-tropical convergence zone), the mid-Atlantic trough as planetary features and synoptic and mesoscale organization in tropical atmosphere;
- e) the determination of radiative flux through the atmospheric column and the radiative heating of specific layers with particular emphasis upon the boundary layer and the layer immediately below the tropopause.

3. Choice and instrumentation of the experiment site

During the months of July and August the Barbados region, shown in Fig. 2 (b), experiences many of the atmospheric processes typical of the maritime tropics. Meso- (10 to 100 km) and synoptic- (100 to 1000 km) scale systems in the lower troposphere are associated with the poleward boundary of the equatorial trough. As the Northern Hemisphere summer progresses the trough and associated systems encroach upon the region of proposed investigation. Mid- and high-tropospheric vortices are related to the mid-Atlantic trough. This upper level trough lies across the Leeward Islands during most of the summer. Hurricane generation occasionally occurs east of the Barbados area. During early summer few storms reach full maturity within the immediate vicinity of Barbados; later during the season there is a distinct danger of being subjected to a full

FIG. 1. (a) Cumulus development over the island during undisturbed synoptic conditions. The view is towards the south-west with the north-east coast in the foreground.

(b) Pronounced convective development over the island during a period of low level south-south-westerly flow into hurricane Beulah some 100 miles to the north of Barbados. View toward the east-south-east with the west coast in the foreground.

FIG. 2. The field experiment network on and in the vicinity of Barbados:

(a) Dotted line represents a summer trajectory with six baseline observing stations.

E-1, 100 km east CGSS DISCOVERER:

- (i) salinity, temperature and depth.
- (ii) stable buoy: air temperature, humidity and wind speed at three levels, rainfall, water temperature and wave heights.
- (iii) subcloud layer tethered balloon: temperature, humidity and wind speed at three levels.
- (iv) radar observations of precipitation echo distributions.
- (v) camera observations of cloud fields.
- (vi) radiosondes and upper winds.

E-2, 25 km east, stable buoy:

Temperature, humidity, wind speed and direction at two levels, rainfall, 3-D wave array, water temperature and wave height.

E-3, windward coast:

- (i) 16-m tower: temperature, humidity, wind direction, horizontal and vertical wind speed at four levels, rainfall, direct radiation, albedo, net radiation and cloud photography.
- (ii) subcloud layer system: temperature, humidity, horizontal and vertical wind speed at three levels.

C-1, central station:

- (i) 16-m tower system as for E-3.
- (ii) 10-cm search and 3-cm tracking radar complex.
- (iii) cloud photography.
- (iv) communications center.

W-1, leeward coast station:

- (i) 16-m tower and tethered balloon system as for E-3.
- (ii) wind tunnel, temperature and humidity chambers for calibration.

(iii) data logging and analysis center.

(iv) rawinsonde station.

(v) communications center.

(vi) workshop facilities.

W-2 at 25 km west: stable buoy similar to E-2.

In addition to the baseline stations, three arrays are established:

- (i) indicated by $\circ^{\circ}$, an array of recording anemometers, thermographs and rain gages.
 - (ii) indicated by *II, an array of recording rain gages.
 - (iii) indicated by $\cdot$, an array of ninety-two 12-hr accumulative rain gages.
- (b) Inset showing the relative location of Barbados.

hurricane. Intervening between periods of organized atmospheric disturbances, the weather reverts to a basic trade wind regime.

The island of Barbados (see cover photograph and Fig. 2) is located near 13N, 60W and has the approximate dimensions of 20 mi in the north-south direction and 15 mi in the east-west direction. The maximum elevation is just over 1100 ft and, with the exception of the north-east coast, is of moderate rolling terrain.

The greater part of the island is planted in sugar cane providing generally excellent sites for the exposure of surface instrumentation. The island is large enough to produce significant effects in the atmosphere, as illustrated by Figs. 1 (a) and (b), yet not so large nor with such pronounced relief as to preclude analysis of the island induced effects.

As illustrated, in part, by Fig. 2, five separate areas of instrumentation are envisioned.

- a) *Island.* The baseline stations lie along a mean summer time surface wind trajectory. A 16-m tower, as illustrated in Fig. 3, is erected at each of these baseline stations. Four levels of instrumentation are carried on the 16-m towers: horizontal wind speed and direction, temperature and humidity; at 2 of the 4 levels vertical wind speed is measured.

A network of 13 eight-meter towers of the type shown in Fig. 4 is established over the island (Fig. 2). At each 8-m tower wind speed and direction, temperature and rainfall are recorded.

Two tethered balloons will be flown from the east and west coast baseline stations (E-3 and W-1). A schematic of the tethered balloon system is shown in Fig. 5 and the balloon in Fig. 6. Temperature, humidity and horizontal wind speed will be measured at each level. An attempt will also be made to measure vertical motion.

In addition to the recording rain gages associated with the 8-m towers, 6 recording gages have been maintained on the island since 1959. The recording rain gage network is superimposed upon a dense network of standard gages which are read once every 12 hr (6 a.m. and 6 p.m.). Some 60 of these 92 rainfall stations have a continuous record

FIG. 3. 16-m tower and recording shelter. Four levels of instrumentation at 2, 4, 8 and 16 m will record horizontal wind speed, horizontal wind direction, vertical wind speed, temperature and humidity in digital form on magnetic tape. Digitizers and recorders will be housed in a shelter which will be moved to a location at least 200 ft from the base of the tower.

FIG. 4. 8-m tower and recording rain gage. Wind speed and direction are recorded together with temperature and rainfall on a strip chart recorder housed below the cup anemometer.

exceeding 60 years in length. The length of record at a few stations exceeds 100 years. All of these historical data are on tape and have been subjected to intensive analysis at the Florida State University (e.g., Garstang and Holley, 1968; Garstang and Visvanathan, 1967; La Seur, 1964, 1965 and 1966).

Two U. S. Army M-33 radar systems are located at C-1 at an elevation of 750 ft. The tracking portion of the M-33 will be used to track super-pressure balloons released from an aircraft as shown in Fig. 7. The super-pressure balloon carries a transponder activated by the radar signal. A 403-MHz carrier signal is then used to transmit temperature and humidity from the super-pressure balloon. Azimuth, elevation, range, temperature and humidity are then recorded (system designed by the National Center for Atmospheric Research) on magnetic tape at the radar site. The tracking radar will also be used to track neutrally buoyant balloons released from the island as well as frequent free flight balloons from different locations on the island. The surveillance portion of the radar will be used in multiple balloon flights

FIG. 5. Schematic of tethered balloon subcloud layer sensing system.

as well as for the depiction of precipitation echo distributions. Radar scope cameras (16 mm and Polaroid) will be used to record echo distributions.

Cloud cameras (16 mm time lapse, wide angle and all-sky) will be located at the radar site. Continuous records of cloud distributions over and in the vicinity of the island will be made during daylight hours.

A U. S. Army GMD-1B rawinsonde is located at W-1 and will make four soundings per day during the months of July and August. During synoptic situations of interest eight soundings per day will be carried out. The GMD-1B is equipped with a magnetic tape recording system (designed by the National Center for Atmospheric Research) such that the data retrieval for each sounding can be maximized.

Incident short wave direct and diffuse radiation, long wave radiation and albedo will be measured together with surface temperatures at the central island station (C-1). Net radiation (incoming-outgoing) will also be measured at the west coast site (W-1). Suomi-Kuhn radiometer sondes will be flown at least once per day from W-1. Particulate sampling is being carried out at the surface by the University of Miami (see paper by J. M. Prospero on page 645). Low level aircraft particulate sampling will be carried out by the National Center for Atmospheric Research and arrangements for high level sampling are being made with the U. S. Air Weather Service.

In the island program the Florida State University will work in close conjunction with the McGill University climatology program in Barbados (see paper by B. J. Garnier on page 636). While the total programs of both Universities are of great mutual interest, the measurements made by the McGill University group on evaporation, ground temperatures and heat flux and radiation are of particular significance and interest to the Florida State program. Similarly, the Florida State program will be integrated with the studies being carried out by the Institute of Tropical Meteorology (World Meteorological Organization, United Nations Special Fund Project), the Barbados Meteorological Service, the University of Miami's dust sampling program, the University of the West Indies, and the High Altitude Research Project (see paper by Murphy and Bull on page 640).

- b) *Aircraft.* Two light aircraft (National Center for Atmospheric Research and Weather Science, Incorporated) instrumented for cloud physics work, balloon releases (Fig. 7), radiometric measurements, wind finding and photography will be used over and in the vicinity of the island. U. S. Navy and Air Force reconnaissance aircraft flying at 3 levels (1500, 10,000 and 45,000 ft) have also been requested.

FIG. 6. Dart V-fin 750-cu ft capacity tethered balloon. A sensor package and modulator can be seen being held in hand of technician (checked shirt).

FIG. 7. (a) Super-pressure cylinder balloon being inserted into one of three launching tubes of the Weather Science Incorporated, Norman, Okla., (Dr. Ray Booker) aircraft to be used on Barbados.

(b) The three launching tubes.

- c) *Ship.* An oceanographic ship (CGSS DISCOVERER) will be used to tend a stable buoy carrying three levels of sensors in the atmosphere and one level in the ocean (temperature, humidity, horizontal wind speed, rainfall and pressure in the atmosphere, temperature and wave heights in the ocean). Vertical and horizontal accelerations will also be monitored. The ship will also be used

as a platform for a tethered balloon, pibal/radiosonde and a cloud and radar echo photography program.

In addition to the Florida State program on the DISCOVERER, the Sea-Air Interaction Laboratory of the Environmental Science Services Administration will carry out an independent but closely related investigation in the atmospheric boundary layer using a tethered balloon system. The Sea-Air Interaction Laboratory will provide the support and carry out the radiosonde-pibal program on the ship as well as carry out most of the oceanographic measurements.

- d) *Satellites.* Extensive use is planned of ATS-3 positioned at synchronous altitude over the Amazon mouth, the Environmental Science Services Administration satellites, the NIMBUS satellite from which infrared radiation data will hopefully be obtained and the manned APOLLO flights if they occur during the experiment period. The utilization of ATS-3 is being coordinated by Prof. Verner Suomi, University of Wisconsin and a request detailing the requirements of the 1968 Barbados Experiment has been transmitted through Prof. Suomi to the National Aeronautics and Space Administration at the Goddard Space Flight Center.
- e) *Buoy.* Two stable buoys as illustrated in Fig. 8 will be anchored 15 mi off-shore on the windward and leeward sides of the island in line with the baseline shore stations. The buoys will be instrumented to make dual level measurements in the atmosphere (temperature, humidity, horizontal wind speed and direction, pressure, and rainfall) and a single level of measurements in the ocean (temperature, wave height and on the up-wind buoy the three dimensional wave spectra). The buoy behavior in terms of horizontal and vertical accelerations and pitch and roll will also be monitored. The buoy vehicles have been developed by Dan Clark, Inc., Woods Hole, Mass., in conjunction with Florida State University scientists. The buoy electronics and recording systems have been built by Geodyne Corp., Waltham, Mass. The buoy program at Florida State University has been supported by the Sea-Air Interaction Laboratory.

4. Preliminary test programs

The development phase of the Barbados Experiment began in June 1966. Since that time tests of major pieces of equipment have been carried out.

- a) Radar and rawinsonde digital data acquisition system. Two digital data acquisition systems are being assembled by the National Center for Atmospheric Research for use on the M-33 radar and the GMD-1B rawinsonde system. On the radar the acquisition system will record azimuth, elevation and range signals from the 3-cm track portion of

FIG. 8. 115-foot, 6.25-ton stable buoy TRITON developed for energy flux measurements by the Florida State University. Measurements of rainfall, wind speed and direction, temperature, humidity, 3-dimensional wave field, sea state, sea temperature and the horizontal and vertical acceleration of the buoy are recorded in digital form on magnetic tape and can be transmitted to shore on command.

the radar as well as temperature and humidity from a modulated transponder (see section 4b). Meteorological data and azimuth and elevation angles will be recorded from the GMD-1B. Initial tests of this equipment were carried out in August 1967. Subsequent tests indicate satisfactory performance of the radar recording system and the recording of the wind data from the rawinsonde. Some difficulties have been experienced in recording the thermodynamic variables from the GMD. Further tests will be carried out early in 1968.

- b) Super-pressure balloons and modulated transponder. Super-pressure balloon-borne transponders have been developed by Weather Science, Inc., Norman, Okla., for the Florida State University. These transponders have been tested in conjunction with an M-33 radar and the digital recording system. The transponders performed as designed yielding satisfactory data to determine trajectories but insufficient data are yet available to determine performance characteristics of the temperature and humidity sensors.

- c) Tethered balloon and associated instrumentation. The tethered balloon system was tested in September 1967. An extremely light (less than 1000 g including sensors, packaging and batteries), rugged and high performance modulated transponder has been developed for Florida State University by Weather Science, Inc. The sensor signal is transmitted using a pulse delay modulation scheme which results in a very low power drain. The system has been successfully operated for periods up to 65 hr on a single pair of size D flashlight batteries. Temperatures can be measured within the limits of current thermistors and humidity within the limit of the present carbon strip element. Horizontal and vertical wind speed sensors are currently being evaluated.
- d) Semi-stable buoy. Three field tests of the 115 ft 6.25 ton TRITON buoy built by Dan Clark, Inc., Woods Hole, Mass., have been carried out. The final comprehensive test was carried out in the Gulf of Mexico during October and November 1967. Analysis of the data is not complete but preliminary results of the vehicle performance are most gratifying. Tables 1 and 2 below give vehicle performance data.

A 16-mm camera with a telescopic lens was sited on a "Texas Tower" approximately 400 yd from the buoy. The values listed in Tables 1 and 2 are based upon an analysis of this film as well as upon the digital magnetic tape record from a pair of orthogonal inclinometers, anemometers and pressure transducer (sea state). The extreme values are given in Table 1. These values almost certainly correspond to wave heights well in excess of the mean wave height. From the photographic record it can be seen that in 6 to 8 ft seas:

- 1) the horizontal velocity is $\approx 26 \text{ cm sec}^{-1}$ 62% of the time;
- 2) the vertical velocity is $\approx 17 \text{ cm sec}^{-1}$ 83% of the time.

Values obtained in Table 2 correspond to sea states that range from mean wave heights between 1 to 2 ft to mean wave heights between 6 to 8 ft. Previous results (Garstang, 1967b) on the maximum angular oscillation were obtained from the photographic record only. The results reported in Table 2 are based upon the digital record of the orthogonal inclinometers and are regarded as more reliable than those based upon the photographic record.

The motions described above were obtained in shallow water (~ 100 ft). In deep water, with certain modifications, the above values can be reduced by as much as 50%, reducing errors generated by the buoy motion in the current system of instrumentation to negligible amounts.

5. Time-period and manpower

The field experiment will extend over the months of June, July, August and part of September 1968. The radar complex is to be established in mid-April. Site selection for all towers has been completed and all instrumentation will be set up during the month of June. The intensive observational period will commence in the first week of July and extend through August. All equipment will be dismantled and returned to campus laboratories by mid-September.

About 24 Florida State University scientists, technicians and graduate students will participate in the field program. The Field Observing Facility of the National Center for Atmospheric Research has provided support through the development of recording systems, loan of equipment and instrumentation and the secondment of technicians. National Center for Atmospheric Research scientists are likely to conduct concurrent research as well as take part in aspects of the Florida State University experiment. The Sea-Air Interaction Laboratory of the Environmental Science Services Administration will carry out independent as well as joint experiments aboard the CGSS DISCOVERER. Members of the Experimental Meteorology Branch of the Environmental Science Services Administration will participate in island programs. Scientists and technicians from Weather Science, Inc., will participate on a contractual basis. The Barbados Government, the Barbados

TABLE 1. Displacements, velocity and acceleration of buoy vehicle.

Buoy behavior	Mean sea state 3 to 4 ft seas 15 kt mean wind	Mean sea state 6 to 8 ft seas 20 kt mean wind
Maximum horizontal displacement	6 cm	25 cm
Maximum vertical displacement	6 cm	6 cm
Maximum horizontal velocity	11 cm sec ⁻¹	52 cm sec ⁻¹
Maximum horizontal acceleration	22 m sec ⁻²	110 m sec ⁻²
Maximum vertical velocity	11 cm sec ⁻¹	13 cm sec ⁻¹
Maximum vertical acceleration	22 m sec ⁻²	26 m sec ⁻²

TABLE 2. Pitch and roll of buoy vehicle.

	Wind speed interval at 6 m above the sea						
	<2 m/sec	2.1-4.0 m/sec	4.1-6.0 m/sec	6.1-8.0 m/sec	8.1-10.0 m/sec	10.1-12.0 m/sec	12.1-14.0 m/sec
Pitch in degrees from vertical	± 0.21	± 0.30	± 0.20	± 0.33	± 0.61	± 1.50	± 2.02
Roll in degrees from vertical	± 0.16	± 0.41	± 0.29	± 0.79	± 1.15	± 1.25	± 2.63

Meteorological Service and the Institute for Tropical Meteorology under the sponsorship of the United Nations Development Program and the Caribbean Meteorological Council have each provided extensive assistance in terms of facilities and other invaluable support. During the period of intensive observations, the total staff will be between 40 to 50 scientists and technicians.

6. Concluding remarks

The understanding of the structure and behavior of the tropical atmosphere depends to a great extent upon our ability to provide adequate quantitative description in both time and space of at least a segment of this part of the Earth's atmosphere. As indicated in Section 1 above, the non-linear interaction of a hierarchy of scales of motion means that this is no easy task. Not only is it virtually impossible to observe simultaneously all scales of motion, but we do not possess the requisite tools or experimental techniques to make all of the necessary measurements. Quantitative observations of this nature must be based upon well formulated concepts of the tropical atmosphere. The results of such field programs must provide input into numerical models and must in turn generate mathematically tractable physical models. The 1968 Barbados Experiment is based upon a decade of investigation. Direct preparation for the Experiment extends over two years and has involved a large number of scientific and technical personnel. Yet the Experiment is clearly limited in its scope. If larger scale experiments are to be successfully conducted in the tropical atmosphere and oceans, a great marshalling of scientific and technical capability is called for. If such a large scale experiment is carried out without the concurrent focus of such capability, the scientific return will be small versus a colossal expenditure of funds.

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tional Science Foundation is supporting the radiation study and the U. S. Forest Service has provided funds for the construction of specific instrumentation and the study of certain aspects of the heated island problem of interest to the Forest Service. The support of all these sponsors is gratefully acknowledged. Support of the Field Observing Facility of the National Center for Atmospheric Research has been critical during the development of the program and will be essential in the field. We also are very much indebted to the Government of Barbados and in particular the Prime Minister, the Hon. Errol Barrow, who has taken a personal interest in this research. Without the favorable environment for research established by the Barbados Government this project would not be possible.

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