

WOODS HOLE OCEANOGRAPHIC INSTITUTION
Woods Hole, Massachusetts

REFERENCE NO. 68-8

AIR-SEA INTERACTION FOR THE INTERNATIONAL
INDIAN OCEAN EXPEDITION

by

Andrew F. Bunker

February 1968

TECHNICAL REPORT

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Nick P. Fofonoff
Department Chairman

Air-Sea Interaction for the International
Indian Ocean Expedition

Final Report

by

Andrew F. Bunker
Woods Hole Oceanographic Institution

I. Observational Flights of the C-54Q Research Aircraft to the
Indian Ocean

A C-54Q aircraft was bailed to the Woods Hole Oceanographic Institution to participate in the International Indian Ocean Expedition and other research projects in the fields of meteorology and oceanography. With the joint support of the Office of Naval Research and the National Science Foundation, the aircraft was modified and instrumented for meteorological research. When the modification was completed in June 1963, the aircraft was flown to Bombay to cooperate in the meteorological program of the Indian Ocean Expedition. Ten observational flights were made between 18 June and 8 July 1963, during the active phase of the southwest monsoon. On these flights records were taken of the temperature and humidity of the air, dropsondes were released, time-lapse motion pictures of the clouds were taken, Doppler radar records of the flight speed and drift were taken to compute the winds, turbulence records were taken, and the solar radiation and the albedo were measured.

A second flight was made to the Indian Ocean in February 1964

to study the conditions during the northeast monsoon season. Twelve research flights were made out of Bombay and the RAF base at Gan Island. The same basic observations were made during flights plus measurements of CO₂ and tritium by Drs. Bischoff and Rooth. The third and last flight to the Indian Ocean was made in August 1964. Thirteen observational flights were flown out of Bombay, India and Aden, Arabia. The flights spanned the active and waning phase of the southwest monsoon season.

II. Processing and Distribution of Data

The records obtained during the flights of the C-54Q have been processed to yield meteorological quantities and distributed to meteorologists interested in their analysis. Copies of all reduced data have been placed in the IIOE files at the University of Hawaii. These data have been used in a study of the monsoon structure by F. Miller, a study of the sea-breeze by J. Nicholson, and a study of air-sea interactions by R. Fleagle.

The following list itemizes the data obtained and the form in which they have been distributed.

A. Aircraft Psychrograph Records

The signals from a dry- and a wet- thermistor were recorded alternately each 5 seconds on an L & N strip recorder. The records were read each 5 minutes, put on punched cards and fed into a GE 225 computer. The printed output of the computer gave the dry-bulb temperature, wet-bulb temperature, mixing ratio, potential temperature, virtual temperature, potential virtual temperature, equivalent potential temperature, density, and relative humidity. Additional information such as time, latitude, longitude, altitude,

and pressure are printed on the same sheet.

B. Winds from Doppler Radar Records

Ground speed, drift, heading and true air speed were indicated on a panel in the cabin of the aircraft and were photographed each twenty seconds. Readings were read from the photographs each five minutes, and the winds computed. The data from the 1963 flights were tabulated on a separate printout. The wind data for the 1964 flights were incorporated in the psychrograph printout.

C. Solar Radiation and Albedo

Signals from Eppley pyranometers mounted on the top and the bottom of the aircraft were alternately recorded on an L & N strip-chart recorder. These values were read, punched on cards and fed into the computer. The printout gave time, latitude, longitude, hour angle, solar altitude, aircraft height, short-wavelength solar and sky radiation, reflected radiation, radiation falling on a surface perpendicular to the sun's rays, daily total of radiation, albedo and the average albedo over the flight leg. The daily total of radiation was computed from the instantaneous observed value at a given time assuming that value to be characteristic of that time of day at that latitude and longitude on that day of the year. This computed summation was chosen as the only meaningful value that could be presented for records taken during aircraft flights that sometimes lasted from dawn to sunset and covered up to 20 degrees of latitude.

D. Dropsonde Releases

During the three trips to the Indian Ocean, 109 dropsondes were released which functioned satisfactorily. Values

of the pressure, temperature and relative humidity obtained from the records were fed into the computer to give all the thermodynamic quantities computed for the psychrograph data.

E. Turbulence and Turbulent Fluxes

Rapid fluctuations of the temperature, humidity, airspeed, vertical acceleration, and aircraft altitude were recorded during the flights over the Indian Ocean. From these records, 405 one-minute sections were read and the data fed into the computer. The values computed were: root-mean-square values of the horizontal and vertical components of the turbulent wind, temperatures and humidities; the shearing stress, and the turbulent fluxes of the heat and water vapor.

F. Cloud Photographs

Cloud photographs were taken during all flights with time-lapse cameras on color film at 2-second intervals. In all, over 15,000 feet of film was exposed during the three trips. The cloud images have been projected onto a gridded screen and many measurements of position made. From these measurements, heights of the cloud bases and tops were made. Cloud types were noted, and sky coverage was estimated. Vertical cross-sections along the flight paths were constructed from these data.

III. Papers Published

The following papers have been published under Grant G22389:

1. Bunker, Andrew F., 1965: A low-level jet produced by air, sea, and land interactions. Proc. of Sea-Air Interaction Conf. Tech. Note 9-SAIL-1., ESSA, Weather Bureau. 225-238.

2. Bunker, Andrew F., 1965: Improvements on the Ronne system of cloud measurements from aircraft motion picture films. Unpub. Ms. WHOI Ref. No. 65-17, 11 pp.
3. Bunker, Andrew F., 1965: Interaction of the summer monsoon air with the Arabian Sea. Proc. Sym. on Met. Results of the Int. Ind. Ocean Exp., WMO and UNESCO. Bombay. 3-16.
4. Srivastava, R. C. and C. Ronne, 1966: Salt particles and haze in the Indian monsoon air. Ind. Journ. Met. and Geophys. Vol. 17, No. 4. 587-590.
5. Srivastava, R. C., 1967: A study of the effect of precipitation on cumulus dynamics. Journ. Atm. Sci. Vol. 24, No. 1, 36-45.
6. Srivastava, R. C., 1967: On the role of coalescence between raindrops in shaping their size distribution. Journ. Atm. Sci. Vol. 24, No. 3, 287-292.
7. Bunker, Andrew F., 1967: Cloud formations leeward of India during the northeast monsoon. Journ. Atm. Sci. Vol. 24, No. 5. 497-507.
8. Bunker, Andrew F. and Margaret Chaffee, 1968: Tropical Indian Ocean Clouds. Int. Ind. Ocean Exp.: Met. Monogr., 5, East-West Center Press, Honolulu. (In preparation).

Woods Hole Oceanographic Institution
Reference No. 68-8

AIR-SEA INTERACTION FOR THE INTERNATIONAL INDIAN OCEAN EXPEDITION
by Andrew F. Bunker. 5 pp.
February 1968. Contract No. NSF 22389

A report is given of 3 flights of the WHOI C54Q aircraft
to the Indian Ocean in 1963 and 1964. The type of observations
that were made, their processing and distribution are given.
Publications are listed.

1. International Indian Ocean Expedition
 2. Aircraft meteorological observations
- I. Bunker, Andrew F.
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