Engineering Notes (Marine Systems)

An Oceanographic Aircraft

J. J. Schule Jr.* and J. C. Wilkerson†
U. S. Naval Oceanographic Office, Washington, D. C.

CONTRIBUTIONS of classical cruise techniques to our understanding of the ocean's physical behavior are becoming less important, because they do not permit separation of space and time variations. Considerable thought has been given to increasing the number and simultaneity of oceanographic observations on a continuing basis by means of two major possibilities: 1) increase the number of platforms, probably by use of moored arrays; or 2) increase the speed of a single platform, i.e., use of aircraft or, possibly, satellites.

Figure 1 shows a Super Constellation aircraft chosen for the purpose and indicates the techniques for remote measurement of gravity waves and sea temperature. This aircraft cruises at a speed of 370 km/hr and has an operating range of about 7500 km with a maximum flight time of about 20 hr. Measurements have been made at altitudes varying from 30 to 6000 m, depending on the purpose of the experiment. A number of modifications to the aircraft were necessary, not only to provide aperture and lauching mechanisms for sensors, but also to provide recording, analysis, and communication facilities in the aircraft itself. The aircraft is equipped with radioteletype capability, so that data may be transmitted immediately ashore.

Although a wide variety of experiments have been conducted with the Super Constellation, three instrument systems are of special interest. Figure 2 shows a sample recording taken with an airborne radiation thermometer, a device that employs passive infrared techniques in the 8 to 13 region to sense sea surface temperature. The instrument, normally flown at an altitude of 300 m, averages the signal over a 6m² spot on the sea surface and computes surface temperature by comparing the amount of incoming radiation with that from an accurate temperature-controlled black body source. Accuracies of ±0.2°C are achieved in the laboratory; field accuracies are ±0.4°C 95% of the time when corrected for atmospheric effects.[1] Horizontal thermal gradients, however, are measured more accurately than this by an order of magnitude.

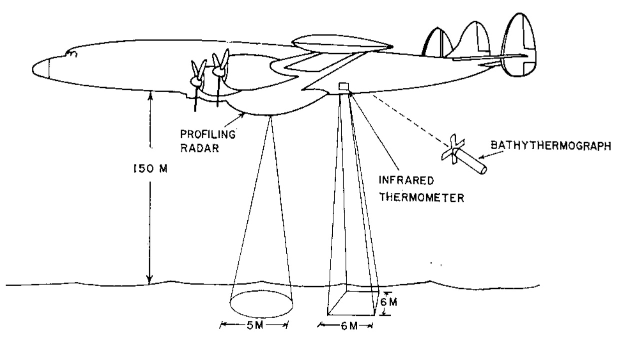

Fig. 1 Schematic of super constellation aircraft installation.

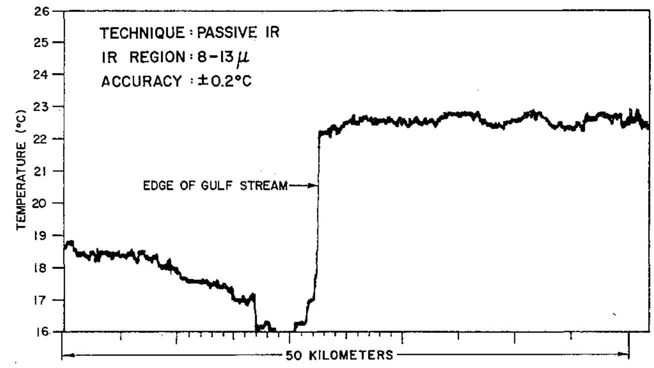

Fig. 2 Sample record from airborne radiation thermometer.

Figure 3 outlines the characteristics of the airborne wave meter and shows a sample wave record taken from the aircraft. The wave meter is an FM-continuous wave radar device operating at a frequency of 4.3 GHz with frequency modulation of 25 MHz. This instrument, regularly flown at 150 m, develops a narrow vertical beam to illuminate a spot on the sea surface 5 m in diameter. This limits the information obtained to waves of about 3-sec or greater periods. The output is a profile of the sea surface in one dimension; approximately a $2\frac{1}{2}$-min sample is required to provide data statistically adequate for spectral analysis. Of course, to obtain information compatible with point spectra generally employed in wave prediction studies, the computed spectrum must be mapped from the space to the time domain and also corrected for the speed of the aircraft. An interesting feature of the instrument is the recording of the aircraft motion sensed by an accelerometer system; this motion is automatically removed from the sea surface profile by the instrument.

A third instrument is the expendable airborne bathythermograph, pictorially described in Fig. 4. This instrument consists of an expendable buoy with a transmitter capable of sending a varying frequency signal to the aircraft where it is recorded on an XY plotter. The sensor is a free-falling thermistor probe designed to fall at a constant rate and is attached to the buoy by 600 m of special conducting cable.

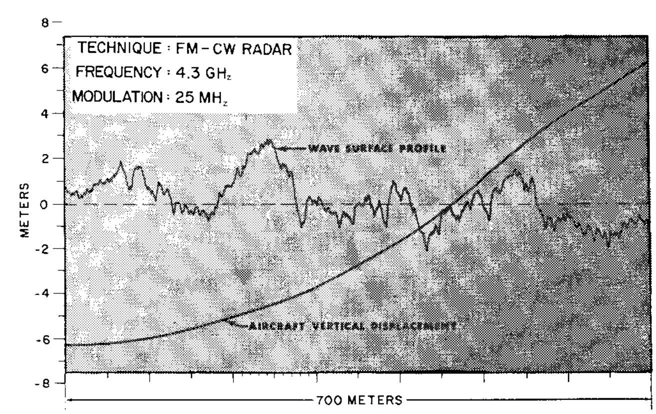

Fig. 3 Airborne wave meter characteristics.

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* Supervisory Oceanographer, Research & Development Department.
† Oceanographer, Oceanographic Prediction Division, Systems Integration Branch.

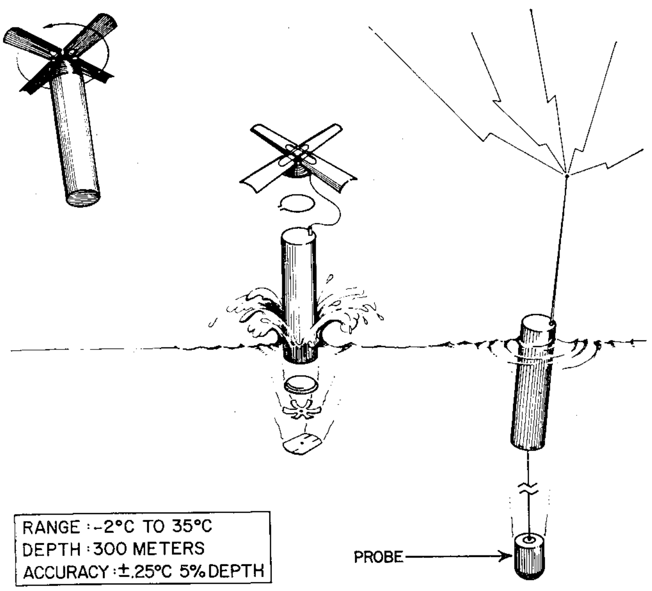

Fig. 4 Airborne expendable bathythermograph.

Sea temperature soundings are accurate to ±0.25°C and 5% of depth.

The equipment described previously, along with other devices capable of providing information on meteorology, solar radiation, and underwater acoustics, has permitted a wide variety of oceanographic experiments. Time will permit the description of only three. Of special interest in the exployment of the Airborne Radiation Thermometer is the continuing surveillance of the extremely complicated surface temperature conditions associated with the Gulf Stream system. Although sea surface temperature charts for this area have been constructed from the aircraft data, an interesting technique has been developed to track the movement of the sharp boundary between the Gulf stream and colder water masses by intersecting the strong gradient zone of the boundary often 10°C in less than 100 m. This is accomplished by using a readout device which enables the pilot to follow the boundary. Figure 5 shows three consecutive positions of the temperature front obtained in this manner over a period of about 2 weeks. A considerable amount of data of this type has been collected; its study will enable scientists to devise more meaningful hypotheses on the behavior of the Gulf Stream system.

In another experiment, the airborne wave-profiling radar was used to study the growth characteristics of the surface

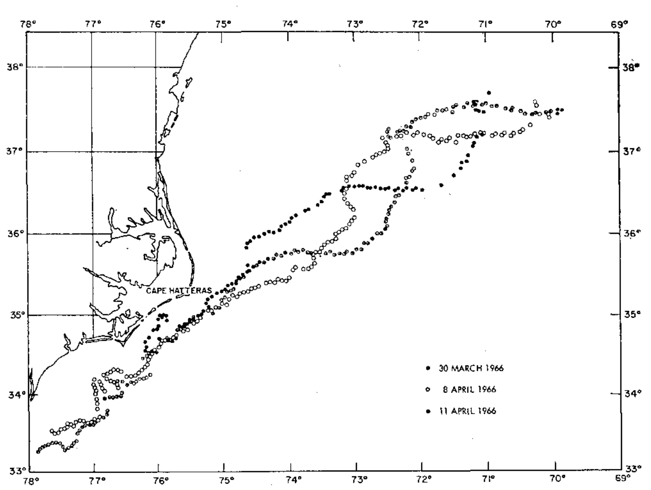

Fig. 5 Locations of strong thermal discontinuity during March-April 1966.

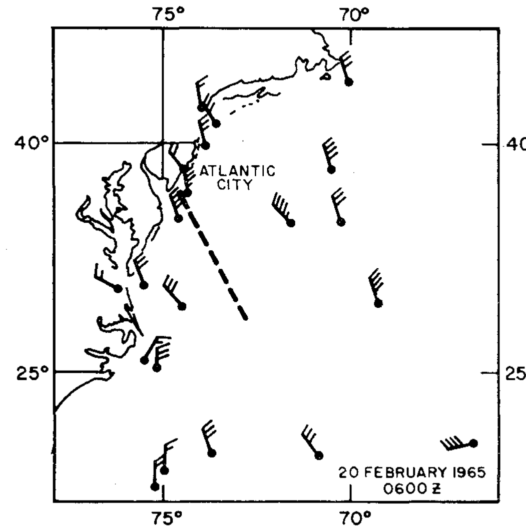

Fig. 6 Observed wind field on February 20, 1965.

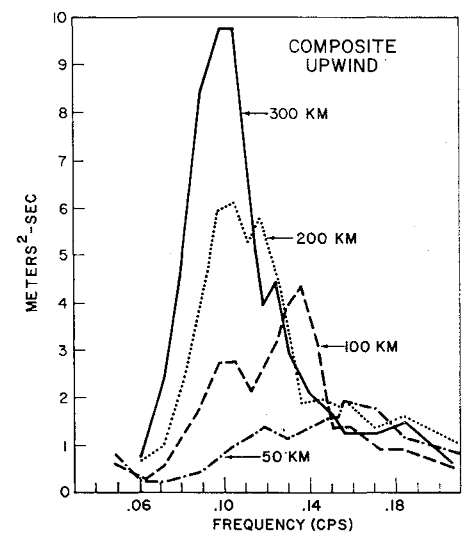

Fig. 7 Surface wave spectra as a function of fetch on February 20, 1965.

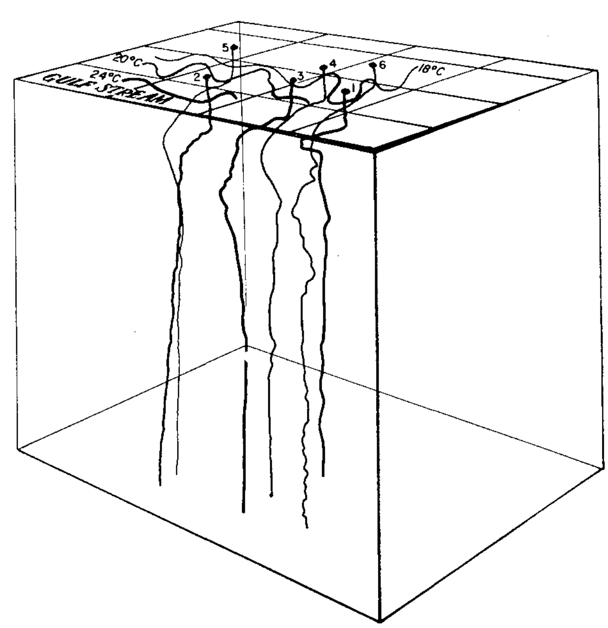

Fig. 8 Airborne expendable bathythermograph observations in a limited area.

gravity wave spectrum. Although our ability to measure time changes of the deep water wave spectrum at a point has been limited, the measurement of the fetch-limited steady-state condition in the presence of a strong offshore wind has been impossible. In this case, the aircraft was flown downwind from the coast out to a distance of 300 km. Figure 6 indicates the observed wind conditions during the experiment and the flight path of the aircraft. Energy spectra were computed at 50-km intervals; a representative sample is shown in Fig. 7. This experiment has not only provided a clear insight into the effect of fetch on the rate of wave growth as a function of frequency, but has revealed several interesting special features of the wave spectrum as well. For instance, the progressively consistent attenuation of high frequency content as fetch becomes longer appears to be significant; the problem is now being studied, and results will be presented in a forthcoming report by Barnett and Wilkerson.

Figure 8 outlines a study of the thermal structure of a limited ocean area conducted entirely from the air over a period of 6 hr. The surface isolines are sea surface temperature obtained with the Airborne Radiation Thermometer. Six observations of temperature vs depth were obtained with the expendable airborne bathythermograph. The rather dense surface information, combined with the somewhat sparse subsurface measurements, will generally provide a fair approximation to the true three-dimensional thermal structure.

It has been possible to describe only a few of many oceanographic experiments being conducted from fixed-wing aircraft. We believe that many more applications of aircraft technology are possible for furthering our knowledge of the oceans. Previous accomplishments, however, prove that the aircraft is a valuable oceanographic platform and that its usefulness will progressively increase.

Reference

[1] Pickett, R. L., "Accuracy of an airborne infrared radiation thermometer," U. S. Naval Oceanographic Office, Informal Manuscript Rept. 0-1-66 (April 1966).