RESEARCH TRIANGLE INSTITUTE

MARINE APPLICATIONS OF HCMM SATELLITE DATA

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FOREWORD

This report by the Office of Geosciences Programs of the Research Triangle Institute, Research Triangle Park, North Carolina, presents the results of the analysis of HCMM infrared data in the Nantucket Shoals region and in an anticyclonic warm ring. The report was prepared for the National Aeronautics and Space Administration, Goddard Space Flight Center under Contract No. S97807-B.

PREFACE

The results of a limited comparison of HCMM sea-surface temperature data with *in situ* data suggested that the HCMM data can provide a rather accurate representation of the sea-surface temperature and temperature pattern. In the Nantucket Shoals region, the HCMM analyses provided data on the surface heating, and on transport south of Nantucket Island and in Nantucket Sound. They also provided data on the sea-surface temperature structure of an anticyclonic warm ring.

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1.0 Introduction

The heat capacity mapping mission (HCMM) satellite was the first of a planned series of applications explorer missions that involve the placement of a small, dedicated spacecraft in special orbits to satisfy mission-unique data acquisition requirements. The satellite was specifically designed to support exploratory scientific investigations to determine the feasibility of utilizing thermal infrared remote-sensing measurements of the earth's surface to estimate the thermal inertia. The satellite was launched on April 26, 1978, and completed over 6500 orbits before the experiment was terminated in October 1980. The spacecraft orbit was sun-synchronous with a nominal ascending equator crossing time of 1400 Local Standard Time (LST), in order to provide north mid-latitude crossing times of 1330 and 0230 LST.

The satellite had a two-channel scanning radiometer; one channel was in the visible band from 0.5 to 1.1 micrometers, and the other channel viewed the thermal infrared band from 10.5 to 12.5 micrometers. The measurement accuracy of the two channels was limited by the analog telemetry system to 0.2 mW cm^{-2} power in the visible band and to 0.4 K at 200 K in the infrared band. The orbital altitude of the satellite was 620 kilometers, and the angular resolution was 0.83 milliradians which yielded a resolution surface of the earth at nadir of 600 m x 600 m in the infrared channel and 500 m x 500 m in the visible channel.

Though the principal purpose of the HCMM satellite data was to develop estimates of the thermal inertia, the high resolution data offered a potential to examine in detail the sea-surface temperature distribution. This paper offers examples of the utilization of the HCMM data describing the sea-surface temperature distribution associated with the cold lens over the Nantucket Shoals and the sea-surface temperature pattern associated with a warm ring.

2.0 Comparative Studies

Before presenting the analysis of the sea-surface temperature patterns, the results of a brief study on the accuracy of the HCMM data are presented. Figure 1 shows the positions of stations along which sea-surface temperature data were collected by the Woods Hole Oceanographic Institution (Limeburner, Beardsley, and Esaias, 1980). The stations in the figure oriented in a north-south direction will hereafter be referred to as N-S transect and those stations oriented in a west-east direction will hereafter be referred to as W-E transect. Figures 2 and 3 show the comparison of the Woods Hole sea-surface temperature data with the HCMM sea-surface temperature data along the two transects for a period in July 1978 and one in September 1978. The HCMM data, which were corrected for atmospheric attenuation and were calibrated, show strong agreement with the *in situ* data both in the absolute and relative reference frame. A comparison of 57 distinct observations produced a root-mean-square difference of ± 1.0°C and a linear correlation coefficient of 0.97 (Figure 4).

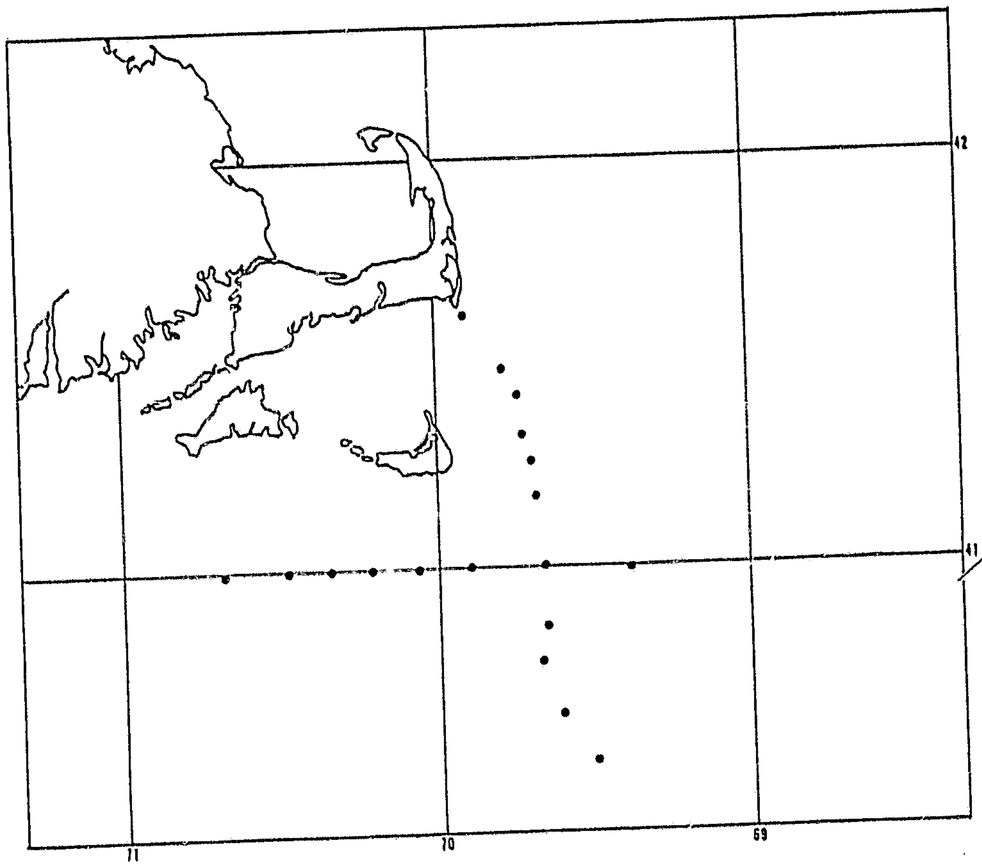

Figure 1. Map showing positions where _in situ_ sea-surface temperatures were obtained in the Nantucket Shoals.

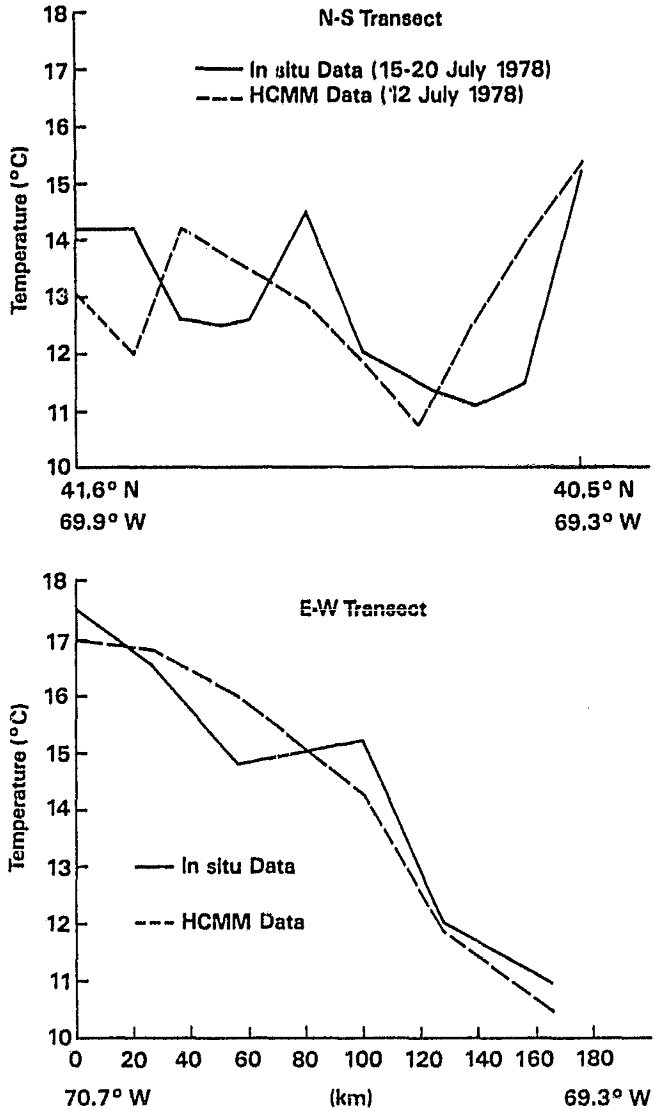

Figure 2. Comparison of in situ and HCMM sea-surface temperatures along the transects in Figure 1 for the July 1978 case.

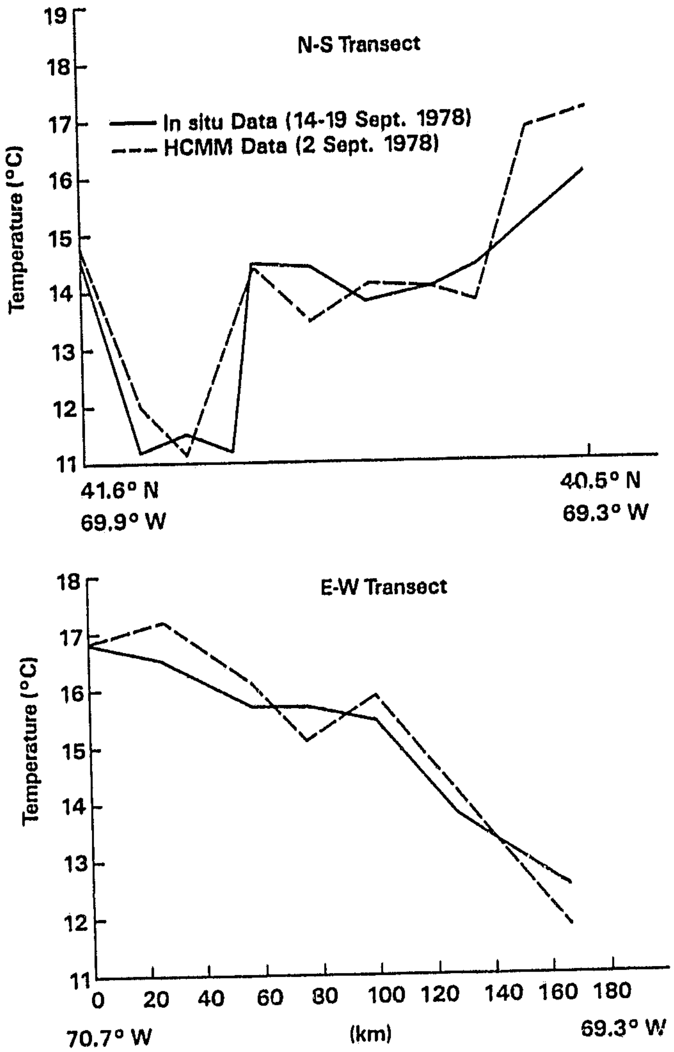

Figure 3. Comparison of in situ and HCMM sea-surface temperatures along the transects in Figure 1 for the September 1978 case.

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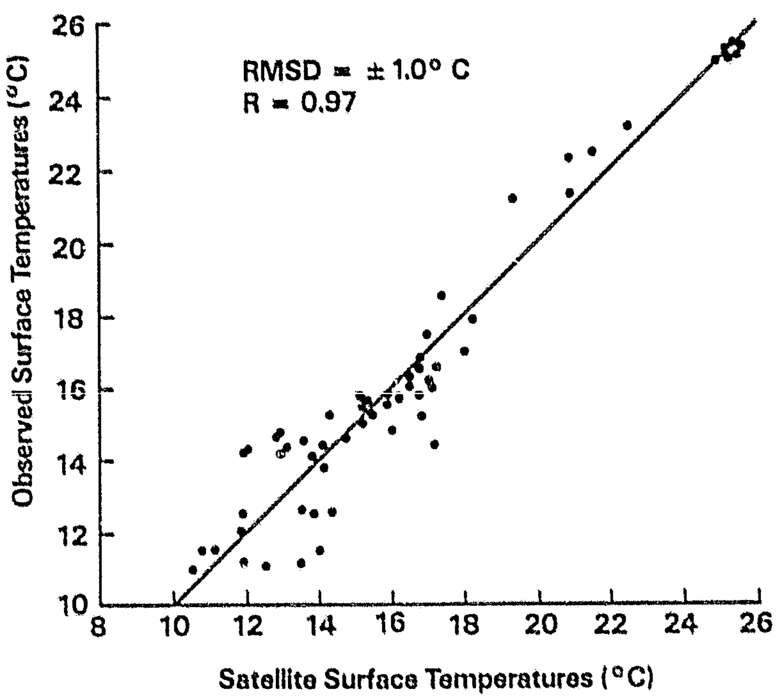

Figure 4. An overall comparison of in situ and HCMM sea-surface temperatures.

3.0 Nantucket Shoals Analyses

Figures 5 through 8 show the analyses of the HCMM sea-surface temperature data in the Nantucket Shoals region for the period of June-September, 1978. The data presents a time history of a cold lens formed immediately south of Cape Cod over the Shoals which is produced by tidal mixing. The mixing phenomena occurs the year round, but the cold lens is most distinct from about May-September. In the winter, the water in this region is uniformly mixed in the vertical. Though tidal mixing turns over the water, little or no horizontal temperature contrasts are developed. In the late spring and early summer, the surface water is heated and the mixed layer is developed. The tidal mixing brings cooler subsurface water to the surface, and a strong horizontal contrast is developed.

Nantucket Shoals region is a major fish spawning area off the northeast coast of the United States. A strong signal indicating the presence of the cold lens is important because primary production of chlorophyll biomass is directly associated with development of an identifiable cold feature. The cold feature in some years develops in early May; and in other years, in late May. The timing for the production of the cold lens relative to spawning is important because it may have pronounced effects on the success of an entire colony of larvae. Limeburner *et al*. (1980) found that on about 1 June 1978 the central temperature in the cold lens over the Nantucket Shoals was about 7°C. Combining their results with these indicates that the central temperature in the cold lens increased about 3°C between 1 June and 1 July 1978, and only 1°C between 1 June and 2 September 1978. Whereas, in the waters to the north of the Nantucket Shoals, the surface temperatures increased approximately 4°C in the period of 1 June to 1 July 1978; and remained relatively unchanged in the period of 1 July to 2 September 1978.

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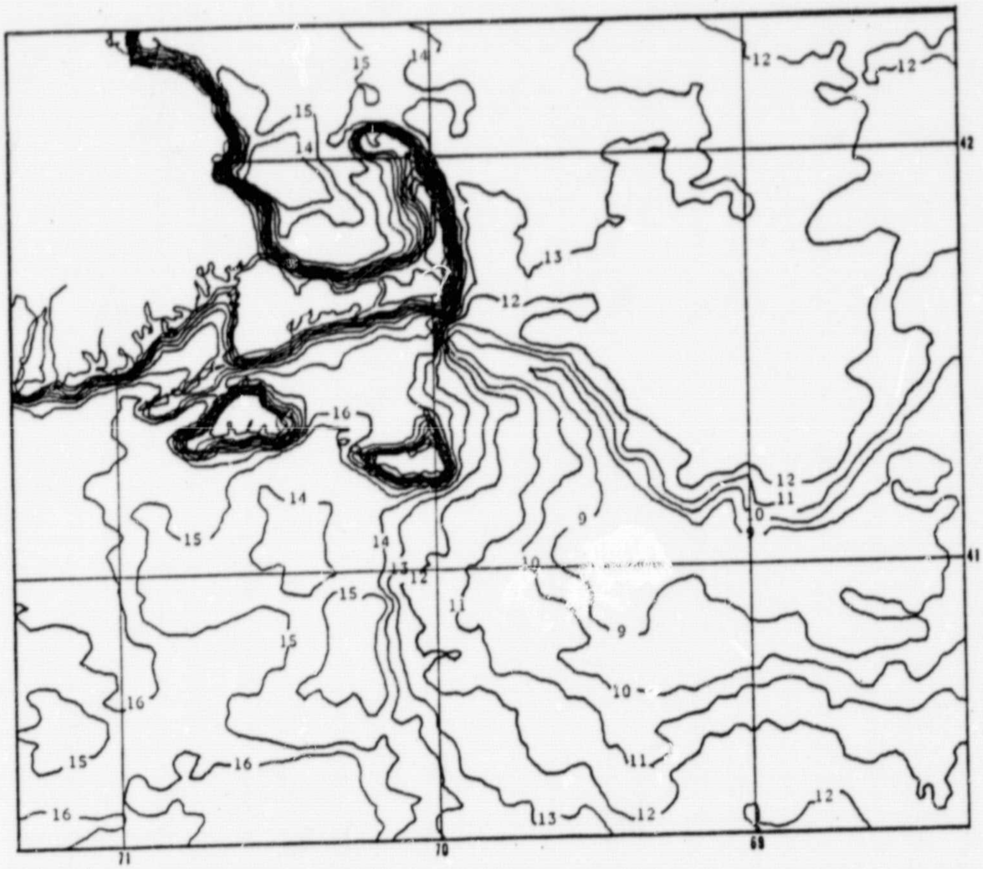

Figure 5. HCMM sea-surface (°C) temperature analysis for 10 June 1978 in the Nantucket Shoals region.

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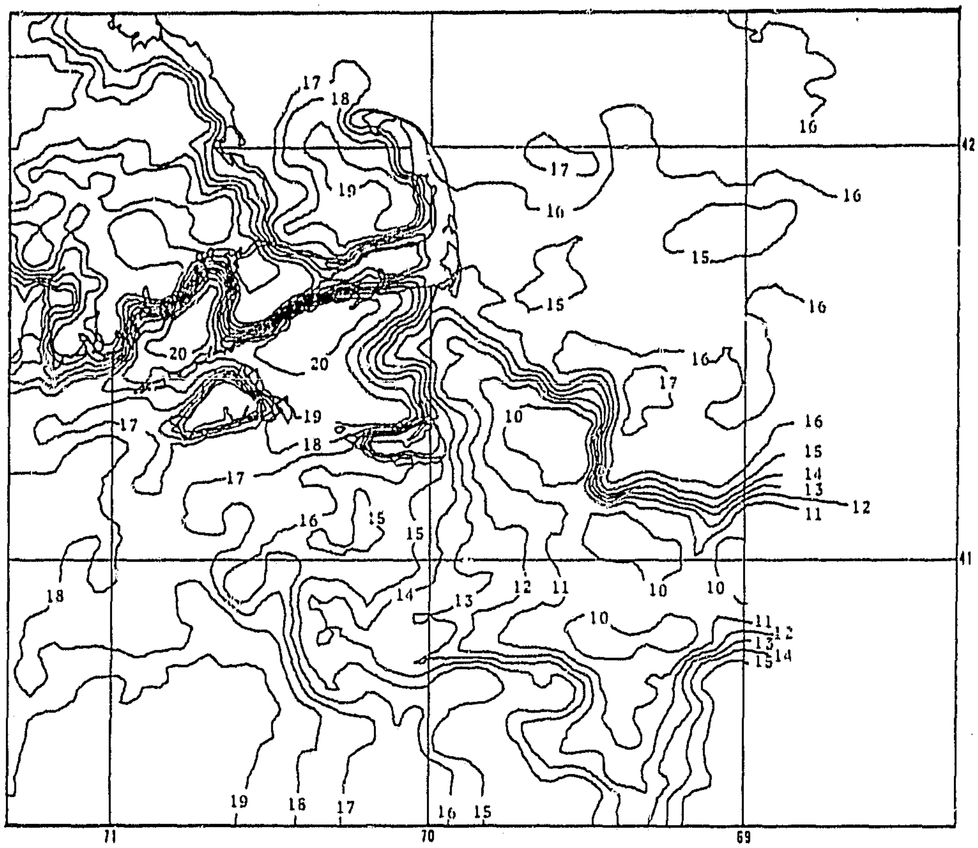

Figure 6. HCMM sea-surface (°C) temperature analysis for 1 July 1978 in the Nantucket Shoals region.

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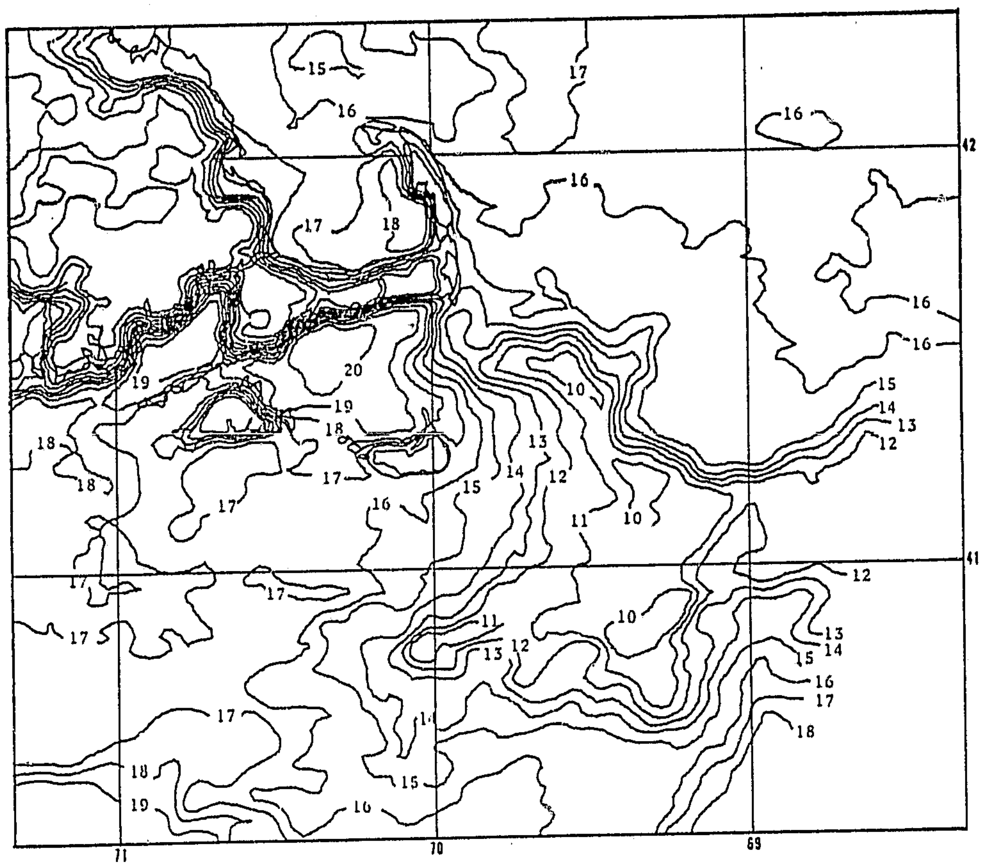

Figure 7. HCMM sea-surface (°C) temperature analysis for 12 July 1978 in the Nantucket Shoals region.

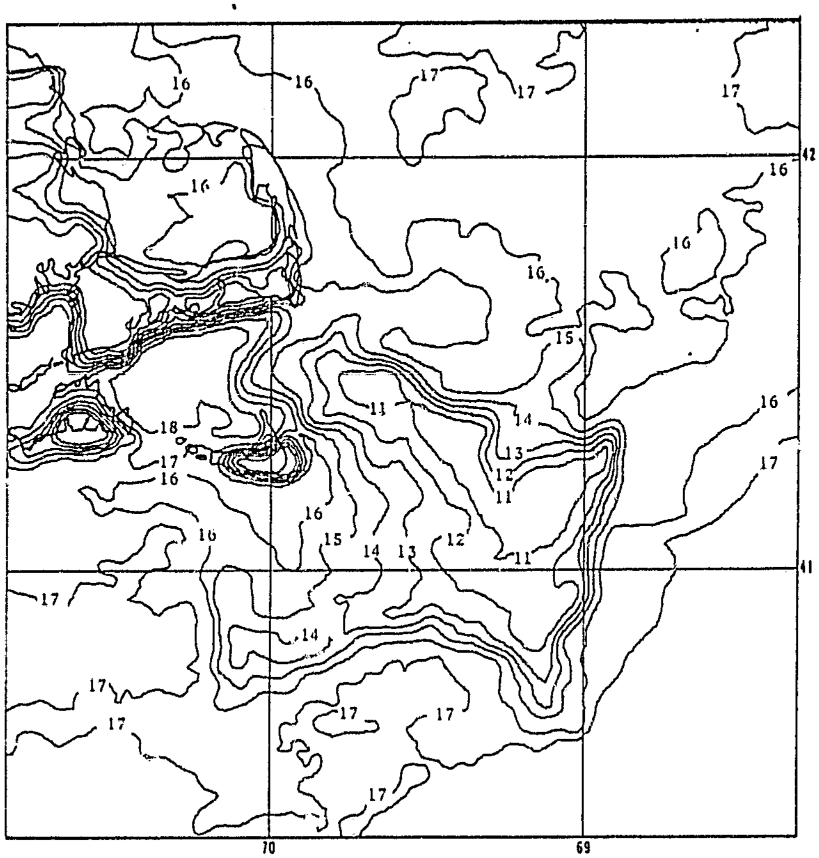

Figure 8. HCMM sea-surface (°C) temperature analysis for 2 September 1978 in the Nantucket Shoals region.

An interesting feature to note is the intrusion of cold surface water south of Nantucket Island in the period of 10 June to 2 September 1978. Initially, the intrusion is manifested as the westward bulge of cold water south of the Island. In time, it evolves into a narrow tongue of cold water that moves eastward and then turns to the northwest. Average currents in the cold tongue were estimated to be about 8 cm s^{-1}. It is in the area of this cold intrusion that Limeburner et al. found relatively high concentrations of chlorophyll A.

Another interesting feature is the penetration of the front associated with the cold lens into Nantucket Sound (the region immediately north of Nantucket Island). The penetration is most pronounced on 1 July and 2 September 1978. These penetrations are believed to be due to transports produced by currents associated with the tide.

4.0 The Warm Ring Analysis

The warm ring depicted in Figure 9 began to develop on 7 June 1978. The ring broke off and became independent of the Gulf Stream around the 9 or 10 June 1978. At the time of the analysis (10 June 1978), the ring was drifting westward at a speed of about 5 km per day. The warm ring is centered at 39.4°N and 68.6°W. It is almost circular, having a diameter of approximately 200 km. The warm region centered at roughly 38°N and 67.5°W is the Gulf Stream. Relatively cold surface water (22°C) is found at the center of the ring. The warmest water (24°C) in the ring is located to the southeast of the center. Strong surface temperature gradients are noted in the ring to the north, east, and south. The weakest gradient is on the western side.

Probably the most distinct feature in the analysis associated with the warm ring is the narrow, cold tongue which has its origin on the eastern side of the warm ring and which extends through the southern portion of the ring. The temperature in the cold tongue is as low as 19°C. There appears to be an extension of this cold tongue made up of isolated cold lenses, having a temperature of 23°C which appeared to spiral around the ring in an anticlyclonic manner, converging to the center of the ring and the mass of cold surface water in that region. Immediately south of the cold tongue, is a narrow warm zone having surface water temperatures greater than 23°C with lenses imbedded in this area having temperatures as large as 24°C. The width of the warm zone is approximately 15 km. Another interesting feature in the analysis is the rather sharp angles made by the 22° isotherm south of the cold tongue and the 18° isotherm inside the cold tongue. Maintenance of these features could suggest either the absence of horizontal mixing at the surface or the definition of a zone characterized by differences in vertical mixing. However, since the analysis is an instantaneous picture of the sea-surface temperature

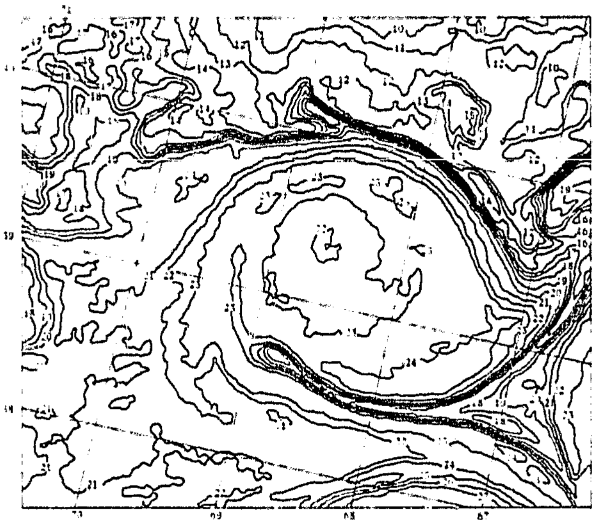

Figure 9. HCMM sea-surface (°C) temperature analysis in a warm ring.

distribution associated with the warm ring, it is not clear how long this isotherm configuration is maintained.

5.0 Discussion of Results

Though this study is limited in scale, the results indicate that HCMM sea-surface temperature data can provide rather accurate representation of the sea-surface temperature and detailed sea-surface temperature patterns. The analyses in the Nantucket Shoals region provide a quantitative information on the effect of heating in the cold lens and in the surrounding water mass over the period of interest, and on water movements in the Nantucket Sound and in the region south of Nantucket Island. They also provided information on the structure of the surface temperature in a warm ring. The analysis in the warm ring suggested that cold water, which has its origin from a cold tongue located to the south of the center of the ring, spirals in an anticyclonic manner around the ring and converges to the center of the ring. The source of the cold water to the south of the center of ring may be through upwelling or through advection of cold slope water north of the ring around the ring to the southern part of the ring.