Gulf Stream and Middle Atlantic Bight: Complex Thermal Structure as Seen from an Environmental Satellite

Abstract. *High-resolution infrared imagery from the ITOS 1 satellite demonstrates the utility of synoptic sea-surface temperature information. The northern edge of the Gulf Stream, the slope waters, and the shelf waters display complex thermal characteristics with distinct temperature gradients separating these three water masses. This type of information can be very useful for increasing our understanding of many physical phenomena that occur over Earth's oceans.*

Comprehensive and repeated survey of the world's sea-surface temperature distribution could be of great benefit to atmospheric and marine scientists. This information could be of considerable economic value to fisheries, naval operations, and other shipping interests because of the relationship between the ocean's thermal field and fish concentrations, oceanic circulation features, sea state, and weather.

The data obtained from the high-resolution infrared radiometer on the Nimbus satellites have been used to determine the sea-surface temperature distribution in the Gulf Stream region (*1*). In spite of system noise in the data, it was demonstrated that the boundary of the Gulf Stream could be located and that the magnitude of the gradient could be determined within 1° to 2°C of the available surface information. Because of noisy data, cloud contamination of the scene, and image display techniques designed for meteorological rather than oceanographic investigations, it was not possible in previous studies to detect any of the fine detail of the structure in the complex surface thermal field associated with the Gulf Stream, slope, and shelf-water circulations. The launching of several environmental satellites with better quality radiometers has now made possible the more precise measurement of temperatures under relatively clear-sky conditions. In addition, the direct readout capability of recent satellite systems enables use of the data with minimum delay.

The information presented here is derived from the scanning radiometer measurements of the Improved TIROS Operational Satellite 1 (ITOS 1). This environmental satellite, launched on 23 January 1970, is equipped with several television cameras and radiometers. The satellite is an Earth-oriented spacecraft with three-axis stabilization. It is designed to provide full day-and-night coverage of the entire surface of Earth. The orbit is circular at 790 nautical miles (1463 km), sun-synchronous, and nearly polar in inclination. The scanning radiometer has two channels, one of which measures the radiation emitted from Earth in the 10.5- to 12.5-μm wavelength region. When the radiometer is looking straight down at Earth's surface, the area instantaneously in view is about 4 nautical miles (7.4 km) in diameter. The orbiting motion of the satellite, together with the day-night capability of the scanner, provides complete Earth coverage every 12 hours (*2*).

The global infrared measurements are stored temporarily on tape on board the satellite for later transmission to the ground and subsequent computer processing. The scanning radiometer also transmits infrared radiation data in real time directly to APT (automatic picture transmission) stations for local use. These transmissions, known as the DRIR (direct readout infrared) data, can be displayed on a photofacsimile recorder, which produces a continuous strip image. The cover photograph is an example of this imagery; it shows radiation data acquired over the eastern United States and the Atlantic Ocean. This type of pictorial display is invaluable for qualitative interpretation of the environmental data; it was designed to make visible the relatively small horizontal temperature gradients associated with the ocean surface. The display is arranged so that the relatively cold clouds, snow, and ice are shown as light areas (less radiant energy reaching the radiometer) and warmer regions are shown as darker areas (more energy reaching the radiometer). A calibrated gray-scale wedge can be generated and compared with the picture data to derive quantitative values. In this example, each gray-scale step over the warmer ocean surface represents a temperature range of 1.5°C.

The cover photograph shows nighttime DRIR imagery obtained on 19 October 1970. Some of the prominent features that can be identified because of the thermal contrast between the relatively cool land and the warmer sea surface are Long Island, Delaware Bay, Chesapeake Bay, and the Delmarva Peninsula. This is one of the best thermal images of the region ever obtained from an environmental satellite. The most striking features are the main thermal front on the northern

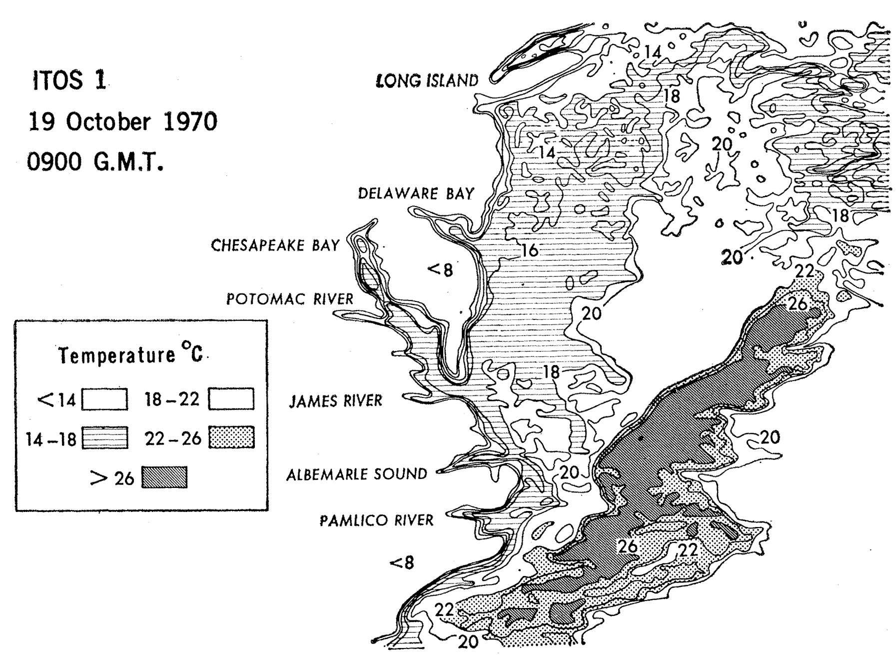

Fig. 1. Analysis of the Middle Atlantic Bight surface temperatures from the cover photograph. Clouds (cooler) obscure the Gulf Stream to the south and east of the main thermal front. Three water masses are depicted by the shadings indicated: (i) Gulf Stream, 22°C; (ii) slope water, 18° to 22°C; and (iii) shelf water 18°C.

edge of the Gulf Stream and the secondary structure to the north. The three distinct gray shades that are visible indicate the presence of three definite thermal regions. The dark region to the east and south corresponds to the Gulf Stream; clouds (bright areas) obscure the warm waters of the stream farther seaward. The light gray area just east of the coast represents the cool (shelf) water mass, and the intermediate area represents the intermediate temperature of the slope water mass. Meanders in the Gulf Stream north wall (main boundary) are quite visible. These features have been observed from aircraft on previous occasions but only over very limited areas and never in a completely synoptic sense such as the satellite provides. Tongues of cool water penetrating into the intermediate slope water can also be noticed along the secondary thermal boundary. Pictures like this one can be received at any APT station and can be used operationally.

For quantitative work the digitized radiation information is more useful. When used for such studies the infrared radiation measurements should be corrected for any atmospheric contamination of the observed surface values. In the 10.5- to 12.5-μm region, atmospheric water vapor and carbon dioxide are absorbing constituents. Corrections vary with the viewing angle of observation, cloud conditions, and the amounts of these atmospheric constituents. The data presented in Fig. 1 have been corrected for these factors.

Figure 1 shows an analysis of the digitized infrared radiation data displayed on the cover. Isotherms have been drawn at intervals of 2°C. The 8°C isotherm traces, in gross fashion, the east coast of the United States, and a strong temperature gradient appears along the coastline. Over the Gulf Stream area the surface temperature was greater than 26°C, over the intermediate slope water about 20°C, and over the shelf waters about 17°C. The satellite-derived temperatures were compared with aircraft radiometric observations obtained over the same area on 17 October 1970 from the U.S. Naval Oceanographic Office. Differences were less than 1.0°C over the three principal water mass regions. The strong temperature gradient and the meanders along the main thermal boundary are very dramatic. Several interesting coastal water intrusions visible at various points on the cover are even more noticeable in Fig. 1. Two intrusions of cool shelf water penetrate the intermediate slope water just east of the James River and Chesapeake Bay. On each side of these cool tongues, a compensating intrusion of warmer water into the shelf waters toward the northwest is noticeable. Similar thermal features over the same area have been noticed on other days in the infrared radiation data from the satellite. A detailed analysis and interpretation of the satellite data and supporting surface information for these cases will be published at a later date.

Synoptic sea-surface temperature information from environmental satellites, together with supporting information from other observation platforms, can be very useful for increasing our understanding of the physical phenomena occurring over Earth's oceans. It is almost impossible to get an instantaneous and complete thermal picture of surface features with dimensions as large or larger than the Gulf Stream without use of environmental satellites equipped with infrared radiometers. Utilizing the satellite's capability to provide a synoptic overview of large portions of the ocean surface ties together the vertical soundings beneath the surface, possibly only from in situ measurements, for a more complete three-dimensional understanding of our marine environment.

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Rifting in Iceland: New Geodetic Data

Abstract. *Small but measurable lengthening of several survey lines within the eastern rift zone of Iceland occurred between 1967 and 1970. The changes can be interpreted as a widening of the rift by 6 to 7 centimeters, possibly during the 1970 eruption of Hekla volcano.*

Fifty-eight survey lines averaging 2.7 km in length were measured with a model 6 Geodimeter in Iceland during 1967. Most of the lines were joined end to end to form two segmented profiles across the rift zones and were designed primarily to detect horizontal movements perpendicular to the rift axes (*1*). Resurvey of these lines was planned for 1972, but the May and June 1970 eruption of Mount Hekla, 15 km south of the eastern profile, prompted a resurvey of 17 line segments during September 1970 with a model 8 Geodimeter (Fig. 1).

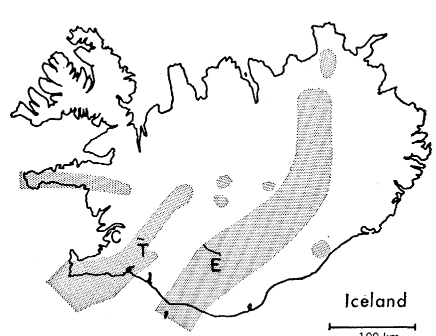

Fig. 1. Index map of Iceland showing the postglacial volcanic zones in gray (*12*) and three groups of survey lines: *C*, calibration lines; *T*, Thingvellir lines; *E*, eastern rift lines near Hekla volcano.

From Table 1 it can be seen that all the line segments show an apparent increase in length from 6 to 45 mm. These apparent increases are in part a problem of inaccuracy between the two different Geodimeters, which can fortunately be resolved. Two calibration lines were located in an aseismic area of Tertiary volcanics outside the rift zones and parallel to the northeast-southwest Tertiary dike trends. Therefore, for both geological and geophysical reasons, these lines can be considered relatively stable. An 18-mm correction is derived from the calibration data (Table 1); this correction can be subtracted from the 1970 values or added to the 1967 values. Statistical analysis of the 29 line differences ex-