Gulf Stream Meanders and Eddies as Seen in Satellite Infrared Imagery

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With the launching of several earth-orbiting satellites carrying infrared (IR) radiometers, it has now become possible to detect structure in sea surface temperature distributions under relatively clear sky conditions. A number of studies (Rao, 1968; Curtis and Rao, 1969; Smith *et al.*, 1970; Warnecke *et al.*, 1971; Rao *et al.*, 1971) have shown sea surface temperature distributions over both small and large areas by means of satellite IR information. This brief report shows two informative examples of surface temperature distributions over the western Atlantic which were detected by means of data from the scanning radiometer on the Improved TIROS Operational Satellite-1 (ITOS-1). This satellite series, replacing the ESSA series, became operational with NOAA's environmental satellite NOAA-1, launched in December 1970.

ITOS-1, launched 23 January 1970, was designed to provide 12-hr coverage (day and night) of the entire surface of the earth, principally for meteorological purposes. The scanning radiometer (SR) has a visible and an IR channel, the latter measuring radiation in the 10.5–12.5 μm wavelength region. When the radiometer is looking straight down at the earth's surface, the area instantaneously viewed is about 7.5 km in diameter. For additional information on the ITOS system see the TOS Project Report (1970).

These radiation measurements are temporarily stored on board the satellite for later transmission to the ground and for subsequent global mapping. For the convenience of those within transmission range of the satellite, the SR also transmits data for immediate local use directly to Automatic Picture Transmission (APT) ground stations. The IR transmission is known as Direct Readout Infrared (DRIR). Data obtained from the DRIR can be displayed on a photofacsimile recorder to produce a continuous strip image of infrared radiance over the local area. When used properly this pictorial display can be very useful for immediate qualitative interpretation of thermal conditions. The two examples presented here have been processed to make visible the horizontal temperature gradients on the ocean surface. The gray-scale representation chosen encompasses only temperatures ranging from 0 to 30C. All cooler surfaces, such as clouds, snow and ice and

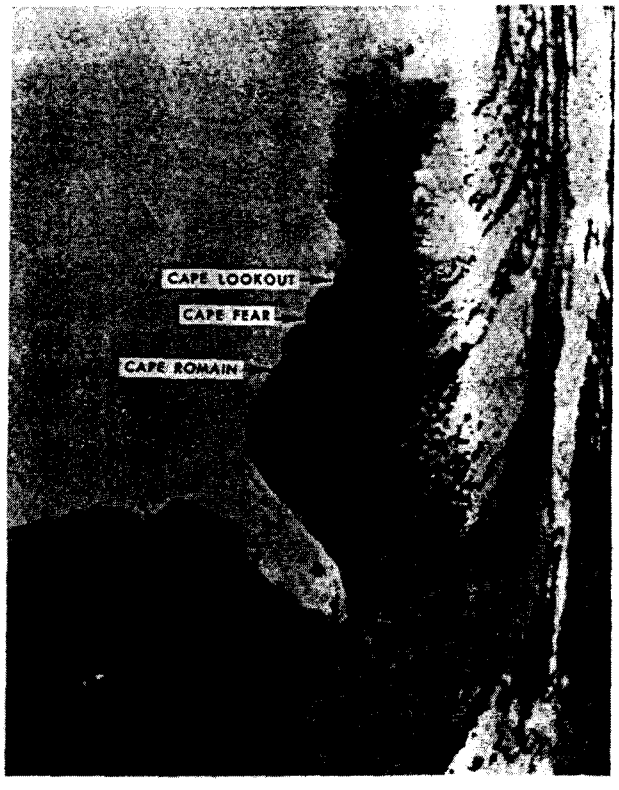

FIG. 1. Portion of an infrared image from the ITOS-1 satellite taken about 0900 GMT 15 February 1971. Darker tones represent warmer areas.

much of the land surface, appear white (less radiant energy reaching the satellite), while warmer surfaces appear progressively darker. Quantitative values can be obtained by generating a calibrated gray scale wedge and comparing it with the picture, or by using a computer printout of the calibrated temperature values at grid points. In the two examples presented here, each gray scale interval represents a temperature change of approximately 1C.

Fig. 1 is a DRIR image obtained about 0900 GMT 15 February 1971 from ITOS-1. Some of the prominent features of this thermal image are the Florida Peninsula and the Gulf Stream. The main thermal front on the northern edge of the Gulf Stream, and the meanders along the thermal front between Charleston, S. C., and Cape Hatteras are dramatic. Three distinct gray shades, indicative of three thermal regions, can be seen as far south as the coast of Georgia. Farther south only two such regions are discernable. A similar separation in the Middle Atlantic bight region, showing three different water masses, has been shown by Rao *et al.* (1971), using October 1970 ITOS-1 DRIR data. The near-black area corresponds to the Gulf Stream, and the dark gray and light gray areas, just north of the Stream, correspond to the intermediate slope water mass and the cooler shelf water mass, respectively. Clouds obscure the warm waters of the Stream in the Florida Straits. Meanders in the Gulf Stream boundary are evident just east of Cape Romain and Cape Lookout. The same features, seen in the ITOS-1 DRIR data on the following day, persisted until late February.

Two weeks later a dramatic change occurred in the meander region of the Gulf Stream. Through breaks in overlying clouds, it was noticed in the satellite pictures that a cold eddy had started to detach from the colder water. Following the passage of a cold front the area became free of clouds on 5 March 1971. Fig. 2 shows the ITOS-1 DRIR image for this day. Three break-off eddies are visible along the northern edge of the Gulf Stream. Two, immediately east of Cape Romain and Cape Fear, are very well defined; the northernmost eddy is small and barely visible.

Because of general overcast conditions in the area, it was not possible to establish a good history on the development of these eddies during the 18-day period between the days on which these two DRIR images were acquired. Continued monitoring of ITOS-1 IR data indicated no evidence of these eddies in the same general area during a 10-day period subsequent to 5 March.

These eddies along the Gulf Stream boundary occur in a region of strong shearing action between the rela-

FIG. 2. Portion of an infrared image from the ITOS-1 satellite taken about 0900 GMT 5 March 1971. Darker tones represent warmer areas. Notice the eddies along the Gulf Stream boundary.

tively slow moving slope water and the fast moving main Gulf Stream. It is possible that they are related in some way to the bottom topography or the coastline configuration. Strong, 50-kt westerly winds, associated with an intense storm that crossed the region on 4 March 1971, were reported by two ships in the vicinity of these eddies. It seems likely that these winds caused extreme stress on the ocean surface and so played a major role in the thermal structure shown in Fig. 2. The occurrence of these eddies downwind of the Carolina Capes may be more than just coincidence.

At present no other "surface truth" data are available to study the structure of the water on these days. Digitized satellite IR data are being analyzed. As soon as supporting data are available, the structure of these eddies will be studied in greater detail.

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