NAVAL RESEARCH

REVIEWS

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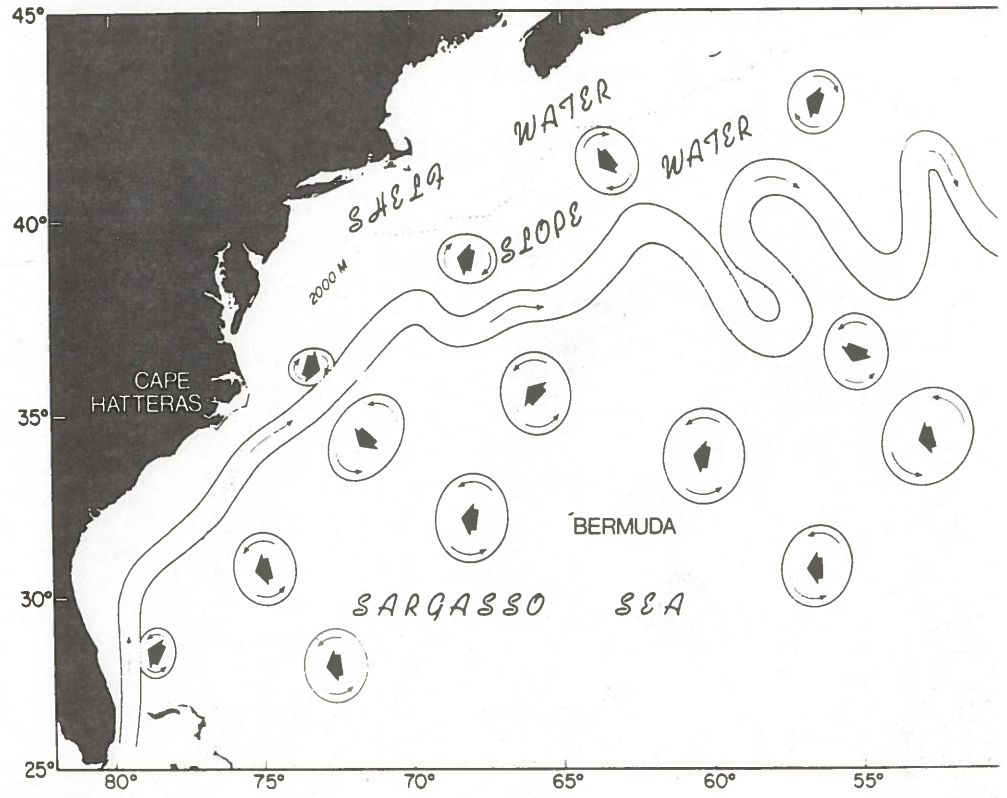

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

Gulf Stream Cyclonic Rings

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Gulf Stream Rings

The physical structure and dynamic evolution of cyclonic rings generated by the Gulf Stream is a subject of active research by a group of Navy-sponsored scientists. The origin of our knowledge of these mesoscale oceanic features can be easily traced to pioneer work by Columbus Iselin at Woods Hole Oceanographic Institution (WHOI) in 1936 (1). Iselin's work showed that rings (then referred to as eddies) existed as large, vertical perturbations of the main thermocline in the Sargasso Sea (Figure 1). A cyclonic ring appears as a dome of cold water in a temperature section along a diameter. A cold central region corresponds to a mass of North American Slope Water which is trapped as a deep cyclonic meander of the Gulf Stream separates from the main flow. The region of large temperature gradient surrounding the cold core is indicative of an encircling remnant or "ring" of the Stream. The area of the core can be approximated as that of a one-degree square at mid-latitudes, although the overall size is considerably larger. The generation and evolution of a ring was first examined during a series of cruises conducted from WHOI in 1951 (2). The first data on the longevity and evolution of the spatial structure of a ring was determined during 1967 by following a single cyclonic ring for a nine-month period. A study of the potential energy distribution as a function of time yielded a projected three to five year lifetime for this ring (3). The implications of the data became clear; cyclonic rings were the most energetic of ocean eddies. They provide a dynamic means for the shedding of cyclonic vorticity by the parent Gulf Stream, and they provided a mechanism for altering the physical structure of the Sargasso Sea.

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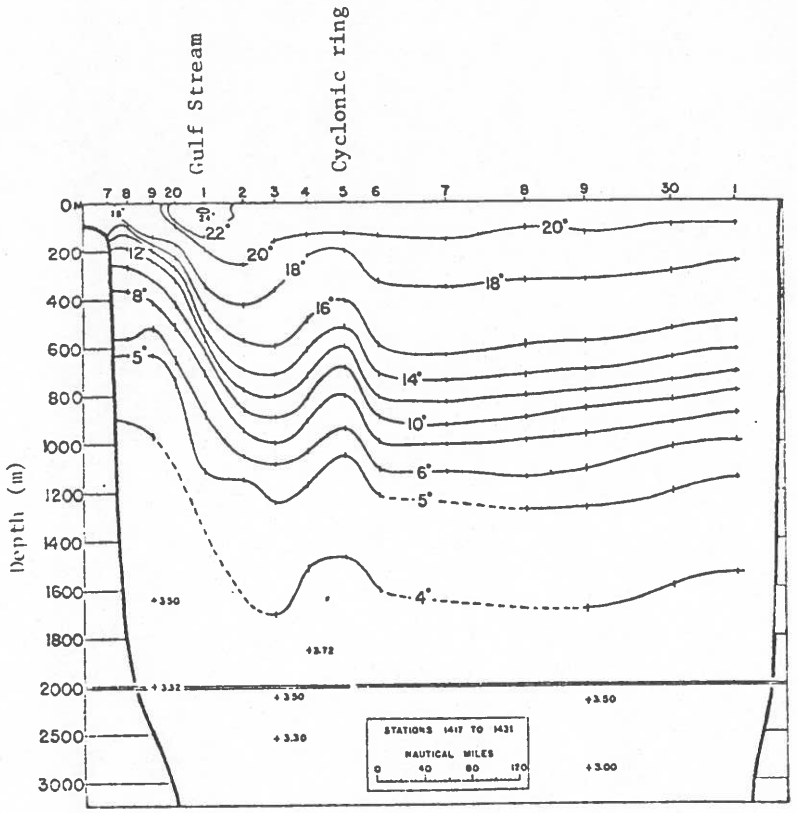

Figure 1 — Temperature section showing a cyclonic ring (Iselin, 1936).

The distribution and number of cyclonic rings in the Sargasso Sea is important as an indication of their potential effect on the Gulf Stream system and on the dynamics and physical structure of the Sargasso Sea. The results of a survey of the Bathythermograph (BT) file at WHOI detailed a number of actual sightings of rings, either intentional or by chance, during the period 1932 to 1970 (4). The distribution, shown in Figure 2, indicates a western ring region curiously separated from a possible eastern ring region by an area possessing no rings. However, an analysis of data since 1970 and several cruises during the last year to the region between 50-60°W have indicated that rings are found there, although their near surface expression is reduced from that of the western region (5). The discovery of several large rings, roughly 200 km in diameter, and a meander sufficiently large to form them indicates rings form in this region as well as the western area. The analyses of historical data plus the repeated observations of a few rings suggest that on the average they move in the west and southwest

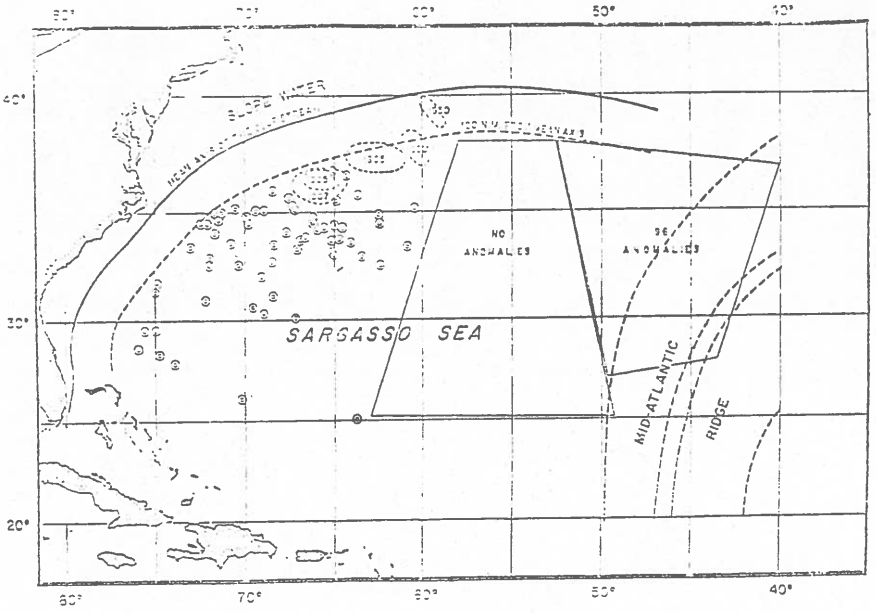

Figure 2 — Observations of rings 1932-1970 (Parker, 1971)

directions. A fourteen month survey of a ring indicated it moved from east of Cape Hatteras southwest and parallel to the average Gulf Stream path to the Blake Plateau off Florida where the ring was thought to have coalesced with the Gulf Stream (6). The observed westward component of ring movement is in agreement with the theoretical analysis given by B. A. Warren (7) and, also, with the mean currents in the Sargasso Sea.

The physical structure of cyclonic rings varies during the ring lifetime as the ring slowly decays. Surface velocity and serial temperature and salinity observations have shown a horizontal shrinking and shrinking of the thermocline in rings. The decay of a ring is shown in Figure 3 (8). Changes in the oxygen and temperature distribution have been examined and a tentative picture of the radial movement of water has been developed utilizing field observations (Figure 4) (9,10). A numerical study of the spin-down process was carried out which predicted a longevity for the 1967 ring that was roughly half that given by Barrett and more in accord with later data (11). Recent work has shown analytically that the horizontal flow pattern in a cyclonic ring varies with depth and that a region in the upper water is carried along with the ring as it moves through the ocean and that deeper water can pass through the ring (12). Subsurface floats set by NAVOCEANO and WHOI in a cyclonic ring support this picture. A long range acoustic

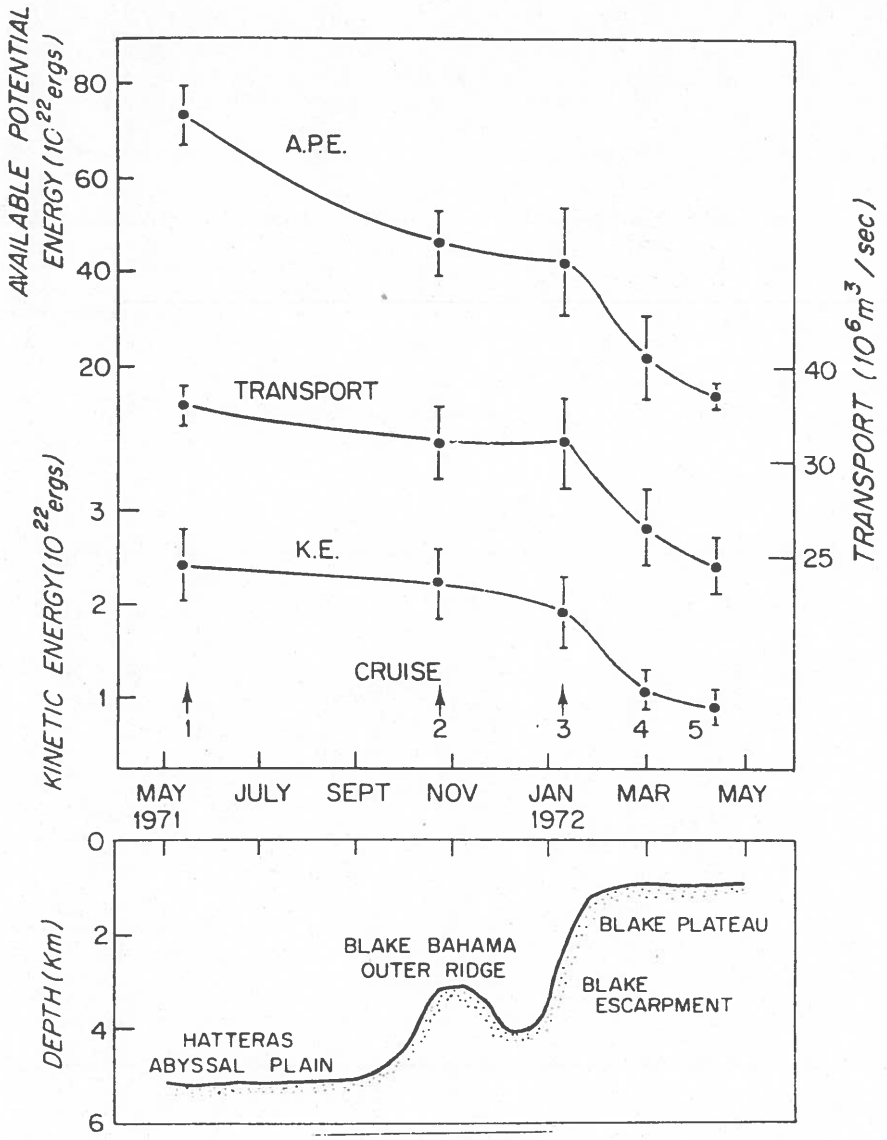

Figure 3 – Decay of available potential energy, transport, and kinetic energy relative to 1000 m. Variation of depth under the center of the ring is shown below. (Cheney and Richardson, 1975)

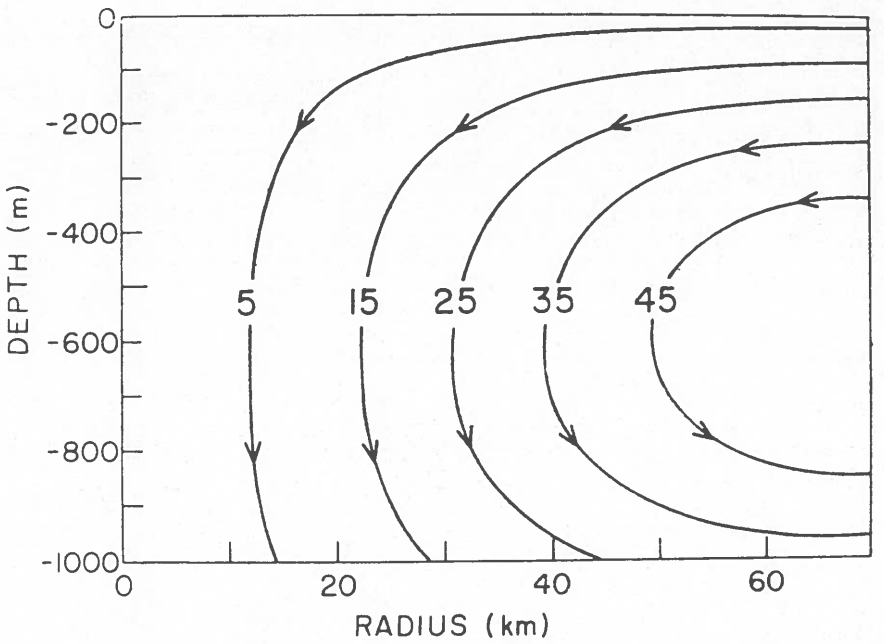

Figure 4 — Field of streamlines (10^8 cm^3/sec^{-1} rad^{-1}) (Schmitz and Vastano, 1975). Maximum vertical speed at the center is 10^{-3}cm/sec and maximum radial speeds are approximately 10^{-2}cm/sec.

effect of cyclonic rings has been theoretically demonstrated (13). The low sound velocity region in the core of the 1967 ring was studied with ray trace techniques and showed a pronounced tendency to focus shallow water sound energy at lower depths, outside the ring, on the Sargasso Sea sound channel axis.

Research Goals

The analysis of data on file at NODC and Fleet Numerical Weather Facility suggest that at least ten rings are present at a given time. Although satellite measurements provide intermittent views of the surface temperature field and are valuable in occasionally identifying rings from their generation time to an age of a few months, it is quite probable that the majority of rings present in the Sargasso Sea will be found by deep temperature measurements by ship survey. A census over the entire region and subsequent tracking of rings found will provide data permitting a logical attack on problems of origins and alternative fates of cyclonic rings. As yet, a complete quasi-synoptic survey has not been carried out and is a primary goal of present research.

The aging process in a cyclonic ring has been numerically modelled with limited success. The current area of investigation centers on the acquisition of serial field measurements in a single ring with the goal of defining the dependence of critical coefficients in the governing equations of motion. In addition, several researchers are focusing on the idea that rings provide *in-situ* laboratories for investigating a number of biological and chemical problems. A ring provides a traceable water mass and represents a microcosm of the ocean. By understanding how a ring evolves, we will understand more about the ocean in general.

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