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BACKGROUND: In the late 1980s, a climatology of a limited number of oceanographic features in the Gulf of Mexico (GOM) was created that was based on satellite remote sensing and in-situ data. Other aspects of the climatology of features in the GOM have been subsequently reported in the literature over the years. Among the features included in those studies were the frequency of Loop Current (LC) water in the eastern GOM, LC eddy separation periods, cold core rings (CCRs) on the LC boundary, and warm core ring (WCR) water in the GOM. Up to 28 years of data were used in at least one of those studies. Most, however, used datasets that had much smaller periods (i.e., about 10-15 years, on average). The data set that is available to develop a climatology of oceanographic features in the GOM now span up to 32 years, which would lend greater statistical significance to a climatology. Furthermore, it is possible to develop additional statistics that were previously unattainable because the required data were not available.

OBJECTIVE: The objective of this project is to develop a climatology of certain ocean features in the GOM using data sets that span long time periods (i.e., as long as 32

years in some cases) to create the statistics. Twelve (12) separate statistics were created, some of which described characteristics of the LC, while others were involved with WCRs that separate from the Loop Current and CCRs. It is expected that these statistics will be useful in planning field programs, to marine biologists and oceanographers, as background information for environmental impact statements (EISs), in evaluating and directing improvements for models that calculate the ocean dynamics, and for oil and gas exploration and exploitation in the GOM.

DESCRIPTION: The study area encompassed the entire GOM. The data resources used to create the climatology included analyzed in-situ data from ships of opportunity, from MMS field programs in the GOM, and from GOM projects managed by the various oil and gas companies. The bulk of the information was, however, obtained from satellite remote sensing data. These data included sea-surface temperature (SST) data from radiometers aboard TIROS-M, HCMM, SEASAT, GOES, and the numerous NOAA polar orbiting satellites; ocean color data from the CZCS, which was aboard the Nimbus polar orbiting satellite, and from the SeaWiFS and MODIS systems; and altimeter data from the TOPEX/Poseidon and the ERS systems. These data were used to develop monthly ocean front analyses in the GOM from which many of the statistics were derived. In the periods 1976 through 1978 and 1986 through 1991, only SST data were available to create the ocean front analysis in the GOM. Most of the SST data were obtained from the NOAA/AVHRR, though significant use was also made of GOES SST and SST data from the HCMM. As a result of using only SST data in the periods mentioned above, the frontal analyses could only be determined for as little as 5 months and as many as 8 months in a year, depending on when the mixed layer developed in the summer and was removed in the autumn. However, in those periods when satellite SST data were not useful, significant use was made of “ship-of opportunity” data to fill data gaps in climatological data sets for certain ocean features. In the period 1979 through 1985, CZCS ocean color data were used to supplement the SST data, which were used to detect ocean features in the warm season when SST data were of little use. After 1991, TOPEX/ERS sea-surface height (SSH) data were available and the frontal analyses for most features could be developed for each month in the year. After 1997, SeaWiFS ocean color data were also used to supplement the SST data in the warm season to detect features that could not be detected in the SSH data (e.g., intrusions of LC water on the WFS).

SIGNIFICANT CONCLUSIONS: In the EGOM, CCRs, which are very persistent and/or numerous in that region, play an important role in redistributing heat and salt. They account for a significant portion of the development of isolated pools LC water in the EGOM and for all intrusions of LC water onto the WFS through transport associated with their circulation. Iit has been previously shown that in the WGOM, WCRs play an important role in the heat and salt balance. The results from this study indicate that WCRS have their most significant effect on the heat and salt balance in that region north of 24˚ N. A region of relatively high frequency of WCRs was found near the western wall of the WGOM between 22˚ N and 25˚ N. This region supports the notion that WCRs may be major contributors to the transport in the WGOM and the maintenance of an anticyclonic cell along the western boundary of the GOM.

STUDY RESULTS: The LC front reached 28˚ N latitude in the EGOM only about 5% of the time. It reached 27˚ N about 20% of the time. About 80% of the LC's orientation angles were between 0˚ (a north-south orientation) and 30˚ (a north-northwest to south-southeast orientation), which characterize the stable orientation for the LC and ring separation is not expected anytime soon. Less than 20% of the LC's orientation angles were greater than 30˚, which characterize the unstable mode for the LC and ring separation is usually expected soon. Isolated warm pools of LC water were found throughout the region north of 26˚ N in the EGOM with frequencies as high as 14% near 27˚ N and 85˚ W. This center was created, for the most part, as a result of many cases in which there was transport of warm LC water by the circulation associated with CCRs located on the boundary of the LC. Intrusions of LC water onto the WFS are, for the most part, due to transport associated with a CCR located on the eastern boundary of the LC, with a maximum frequency of about 12%.

The frequency distribution for the separation period of major WCRs from the LC had a bi-model distribution with modes at 6 and 11 months and a range of 5 to 19 months. The average period was 11 months and the standard deviation was ± 4 months. The average period did not change substantially over the 10-year period 1994-2003, remaining at about 11 months. A high frequency of ring separation was found in March, and no rings were observed to separate from the LC in December. The most significant period in the variance-preserved spectrum of the LC northern boundary variations was 12 months. The most significant variance showed a one-month variation over the last ten years (1994-2003), presumably a result of the year-to-year variability in the eddy-shedding period.

The path that WCRs take through the WGOM most often is the Central Path The Northern Path had the next highest frequency, and the least likely trajectory for the WCRs was the Southern Path. The average speed of the WCRs through the WGOM was 4.4 km/day with a standard deviation of ± 2.9 km/day. As the WCRs moved through the WGOM, they decayed, on average, to about 55% of their initial size in about 8 months.

The maximum frequency of WCR water in the WGOM occurred near 25˚N and 90˚ W and was 24%. The frequency contours for WCR water ridged into the northwest corner of the WGOM where major WCRs are often observed. An east-west zone of relatively high frequency of WCRs was found in the WGOM in the 25-26˚ N latitude belt from 88˚ W to 94˚ W in which the maximum frequency was about 12%. Another region of relatively high frequency of WCRs was found near the western wall of the WGOM between 22˚ N and 25˚ N, in which the maximum frequency was also about 12%.

In the EGOM, a northwest-southeast oriented zone of relatively high frequency for CCR centers was found in the EGOM, having two centers of maximum. The northwestern center was located at around 27.5˚ N and 88.5˚ W, which is in an area where CCRs have been previously found to intensify and/or develop, and the maximum frequency in this area was about 30% (the highest frequency noted for any kind of ring—warm or

cold). The southeastern center (maximum frequency ~17%) was located at around 25.5˚ N and 85.5˚ W, which is in the Dry Tortugas region where CCRs have been previously noted. In the WGOM, four region of relatively high frequency for CCR centers were found. The maximum frequency in these regions varied from 16-20%.

STUDY PRODUCTS: Vukovich, F.M., 2005. Climatology of Ocean Features in the Gulf of Mexico: Technical Report. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2005-031 58 pp.

Vukovich, F.M., 2005. Climatology of ocean features in the Gulf of Mexico using satellite remote sensing data. Paper to be submitted to the Journal of Physical Oceanography.