OCEANOGRAPHIC AND METEOROLOGICAL OBSERVATIONS DURING EXTREME EVENTS ON THE LOUISIANA INNER SHELF

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ABSTRACT

The response of the Louisiana inner shelf to four different types of storms was recorded by current meters, wave gages, and water level gages mounted on bottom-resting instrument platforms; meteorological data were obtained on nearby oil production platforms. Data were obtained during Tropical Storm DEBRA, an extratropical cyclone, northers following polar front passages, and pre-frontal spring winds. Characteristics of each type of storm are described.

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1. Introduction

During the 12-month period ending June 1979, the National Ocean Survey (NOS) conducted physical oceanographic studies at two sites on the Louisiana inner shelf; supporting meteorological data were also collected. These studies were carried out under a cooperative agreement between the National Oceanic and Atmospheric Administration (NOAA) and the Department of Energy (DOE) Strategic Petroleum Reserve (SPR) Program. DOE is implementing the SPR by storing crude oil in underground salt domes beneath Texas and Louisiana. The existing caverns in the salt domes are insufficient for the large volume of oil to be stored; additional salt must be dissolved and the resulting brine solution discharged through pipeline diffusers into the nearby Gulf of Mexico. A companion study to characterize the chemical and biological features of the two sites was completed by the NOAA National Marine Fisheries Service. The NOAA Environmental Data and Information Service is synthesizing all of the data collected at the two sites into environmental assessments of brine disposal.

The locations of the study sites, known as West Hackberry and Weeks Island after the inland locations of the salt domes, are shown in Figure 1. The Louisiana coastline between 91°W and 94°W longitude is arcuate with an approximate west-

Figure 1. Brine disposal sites.

northwest/east-southeast trend. The topography adjacent to the coast is composed of gradual elevations; the inner shelf is bathymetrically simple with a slope of about 50 cm/km at the West Hackberry site and 70 cm/km at the Weeks Island site. The nominal water depth at Gulf Coast Low Water (GCLW) is 10 m at the West Hackberry site and 8 m at the Weeks Island site. The West Hackberry site is 11 km south of Holly Beach, between the Sabine Pass and the Calcasieu Pass. The Weeks Island site is 42 km due south of Marsh Island.

2. Measurements

Five subsurface instrument platforms (Figure 2)

Figure 2. Platform/mooring system.

were initially deployed at each site; the number of platforms in the water at any particular time varied during the study, depending on instrument malfunctions and losses. The subsurface platforms were equipped with two Grundy Model 9021 current meters positioned 1 m and 3 m above the bottom. The platforms positioned at the center of each site were also equipped with Aanderaa WLR-5 water level gages and Applied Microsystems Model 750A wave gages. Aanderaa weather stations were mounted on nearby oil production platforms. In addition to data collected by these in situ time-series recording instruments, monthly CTD casts were made and water samples were collected to determine dissolved oxygen levels.

Measurements made during the NOS SPR Support Project are traceable to laboratory standards. Error sources were identified and analyzed to develop uncertainty statements, and a total measurement uncertainty (TMU) was computed for each measurement. The TMU includes an estimated calibration uncertainty, sensor measurement uncertainty, and environmental error sources; the TMU's bound errors for 95 percent of the typical field measurements. The methodology and results are described by Frey and Appel (1981).

3. Tropical Storm DEBRA

DEBRA was one of 11 tropical storms during the Atlantic hurricane season of 1978. Three of the tropical storms made landfall in the western Gulf of Mexico. AMELIA and BESS made landfall south of Corpus Christi and near Nautala, Mexico, respectively. DEBRA's track crossed the West Hackberry study site and made landfall at 0130 GMT on August 29, 1978 (Figure 3). Meteorological data were obtained by NOS on an oil production platform, and by the NOAA Ship MT.

Figure 3. Track of Tropical Storm DEBRA

MITCHELL which was in the area to perform a cooperative hydrographic survey for DOE. A NOAA WP-3D aircraft made observations in the storm; SEASAT made an overpass; the GOES 2 satellite obtained imagery; data were also obtained 50 km inland of the study site at Lake Charles Airport. The meteorological data set obtained at the West Hackberry study site is rich indeed.

DEBRA was not a particularly well-defined cloud system; it was not a well-organized storm which is why, as shown in Figure 3, the official track given in the preliminary report of the National Hurricane Center differs from the least squares 3rd order fit produced by Powell (1979). The maximum wind speed measured 19.5 km above the GCLW datum was 17 m/s as shown in Figure 4. The backing wind (counterclockwise rotation) subsided to 10 m/s as the eye of the storm passed and the surface air pressure dropped to 998 mbar. The MT. MITCHELL observed a minimum pressure of 1001 mbar while about 15 km south-east of the site, and the NOAA WP-3D observed a minimum pressure of 1000 mbar in the storm.

Figure 4. Meteorological data during DEBRA.

Time-series current meter data obtained 3 m above the bottom at the West Hackberry site are shown in Figure 5. The decrease in directional scatter as the storm approached and passed indicates that the wind drift current exceeded the wave-induced oscillatory motions; this is also shown for another storm described in section 5. The maximum current speed at the 3-m level associated with the leading edge of DEBRA was 67 cm/s; the speed associated with the trailing edge was 77 cm/s; both were nearly due westward, parallel to the local isobaths. The average scalar speed prior to the effects of DEBRA was about 8 cm/s. In comparison with DEBRA, Smith (1978) found alongshore currents during Hurricane ANITA, 21.5 km off the central

Figure 5. Current data 3 m above bottom during Tropical Storm DEBRA

Texas Gulf Coast, reaching speeds of approximately 70 cm/s and 80 cm/s at 2 m and 10 m above the bottom, respectively; the station depth was 17 m.

Wave data obtained at the center of the West Hackberry site (where the water depth is 9.8 m at GCLW) are shown in Figure 6. The data indicate a maximum wave height of 3.47 m and a significant wave height of 2.49 m at 1555 GMT, August 28, 1978. The storm winds rotated counterclockwise, changing fetch and creating opposing seas. The fetch was limited to 11 km as the winds became northerly.

Figure 6. Wave heights during Tropical Storm DEBRA

4. Extratropical Cyclone and Northers

The effects of an extratropical cyclone were observed at the West Hackberry site on January 12 to 14, 1979. The cyclone developed over New Mexico, moved off the Texas coast by midday (GMT) on January 11, and tracked eastward across the northern Gulf of Mexico and into the Atlantic Ocean. Meteorological data obtained during this period on an oil platform at the site are shown in Figure 7. Air pressure dropped monotonically to 1000 mbar at 0700 GMT on January 13, a decrease of 24 mbar. The maximum wind speed (averaged during 10-minute intervals) was 16.5 m/s from 320° True at 2300 GMT, January 13.

Figure 7. Meteorological data during extratropical cyclone and northers.

Current meter data obtained 1 m above the bottom are shown in Figure 8; data obtained at the 3-m level could not be validated. The current at the 1-m level was persistently westward through midday (GMT) on January 12. Azimuthal rotation of the current on January 13 responded closely to backing and then veering of the wind. The current decelerated sharply as the wind backed through northerly and it remained less than 10 cm/s through the cyclone. Scatter in the current direction data (Figure 8) indicate a noisy signal; this is consistent with relatively meager current speeds in a storm sea.

Figure 8. Current data 1 m above the bottom during an extratropical cyclone.

Wave data obtained at the West Hackberry site during the extratropical cyclone indicate a significant wave height of 1.45 m, maximum wave height of 2.51 m, and period of peak energy of 7 s at 1800 GMT on January 11. The leading edge of the storm traversed the site at this time and the wind was east-northeasterly. Backing of the wind from northerly to southerly resulted in a substantially greater fetch; spectral growth with the longer fetch produced periods of peak energy ranging between 9 s and 10 s from 1400 GMT on January 12 to 1000 GMT on January 13, while significant wave heights ranged between 26 cm and 43 cm. After this time, periods of peak energy at the West Hackberry site were 6 s or less. Data obtained at the Weeks Island site indicate a significant wave height of 1.74 m, maximum wave height at 2.40 m, and period of peak energy of 5 s at 2000 GMT on January 11. Periods of peak energy ranging between 9 s and 10 s occurred between 0800 GMT on January 12 and 0000 GMT on January 13.

The effects of northers following frontal passages were substantially greater than those of the extratropical cyclone. Meteorological observations at both study sites, together with an analysis of daily weather maps, indicate that the number of frontal passages per month compared exactly with an 8-year average (1965 to 1972) reported by DiMego et al (1976), except in February when the number of passages was 3.5 less than 8-year average. Wind and air pressure data obtained at the West Hackberry site during three January northers are shown in Figure 7, and wave and current data are shown in Figure 9.

Figure 9. Current data 1 m above bottom and wave data during northers.

Polar front passages occurred on January 20, 23, and 26 (Figure 7); corresponding air pressure minimums were 993 mbar, 995 mbar and 998 mbar; maximum wind speeds were 19.7 m/s, 17.7 m/s, and 11.8 m/s; highest significant wave heights were 1.90 m, 1.57 m, and 1.65 m; and maximum wave heights were 2.32 m, 2.93 m, and 2.82 m. The maximum current speed observed 1 m above the bottom was 43 cm/s toward 100° True; this eastward current persisted about 24 hours in response to westerly winds. The persistently westward currents on January 23 and 26 were in response to the generally east-southeasterly winds that accompanied the approaching fronts. Corresponding measurements at the Weeks Island site indicate significant wave heights of 2.19 m, 1.53 m, and 1.11 m; maximum wave heights of 2.78 m, 2.39 m, and 1.71 m; and periods of peak energy of 6 s, 7 s, and 6 s. Both maximum and significant wave heights observed during the northers were greater than those found during the extratropical cyclone, but less than those observed during Tropical Storm DEBRA. The periods of peak energy remained 5 s or less during the northers; the fetch at the West Hackberry site is reduced to 11 km when winds are northerly, impeding spectral growth of wind waves. Evidence of Langmuir mixing was found during overflights of the study areas (Frey et al, 1981).

5. Spring Storm

A special 32-day experiment was conducted at the West Hackberry site beginning April 5, 1979 (Frey and Appell, 1981). The experiment included current meter measurements at four levels above the bottom and, using acoustic and electromagnetic current meters, burst-sampled data to observe wave-induced current fluctuations. Time series data are shown in Figure 10 for winds at 15.8 m above GCLW, de-meaned currents at the 3-m level, and wave heights; data are shown for the first 20 days of the experiment. The weather system that produced persistent south-southeasterly winds was a stalled front on the outer shelf. This system dominated from midday (GMT) on April 10 to midday on April 11, and winds that peaked at 15 m/s drove the most pronounced westward drift observed during the 12-month study.

Data collected at the 3-m level with a Grundy current meter are shown in Figure 11. The maximum current observed during the storm was 80 cm/s, slightly faster (by 3 cm/s) than the maximum current observed during DEBRA at the same location. Figure 12 shows signal-to-noise (S/N) values determined from a burst-sampling Neil Brown Instrument Systems acoustic current meter. The S/N ratio is defined here as the ratio of the mean flow to the standard deviation of fluctuations in each 1-minute burst; there are 60 instantaneous values in each 1-minute burst. When the S/N is less than 1.4, fluctuations exceed the mean, and wave-induced reversing flow occurs. Measurement errors induced by wave motions increase sharply when $S/N < 1.4$. The S/N time series in Figure 12 shows

Figure 10. Wind data, de-meant current data and wave data during April 1979.

Figure 11. Current data 3 m above the bottom during April 1979.

typical values greater than 1.4 during the storm. Low values are associated with low current speeds, less than about 10 cm/s.

The vertical shear of the alongshore and transverse components of currents is shown in Figure 13. The profile was still developing at 1800 GMT on April 11 when the wind had begun to subside. The profile at 0000 GMT resembles that of fully developed turbulence with strong shear occurring

in the bottom boundary layer. The offshore flow in the near-bottom water is consistent with onshore flow in upper layer caused by southerly winds over the shallow inner shelf. The three

Figure 12. Signal-to-noise time series at 3 m above bottom during April 1979.

Figure 13. Vertical profiles of currents at West Hackberry site center.

profiles later in the day (0600 GMT, 1200 GMT, and 1800 GMT) on April 12 show the effect of

decreasing southerly wind speed, ranging from about 2 m/s to 6 m/s.

6. Summary and Conclusions

The northers that follow polar frontal passages occur often enough to compose a significant part of the climatology on the Louisiana shelf (average of 68 per year), but the most locally energetic and potentially destructive storm observed during the NOS SPR Support Project was a tropical cyclone. Extratropical cyclones, such as the one observed during January 1979, tend to be much larger scale disturbances and, through conservation of angular momentum, less severe than tropical cyclones. Persistent southeasterly winds that accompanied a stalled front during April 1979 produced an alongshore drift slightly faster than the one observed during Tropical Storm DEBRA. Current measurements made during DEBRA compared closely with those reported by Smith (1978) during Hurricane ANITA under similar circumstances. DEBRA produced significant wave heights of 2.49 m and a period of peak energy of 9 s where the water depth is only 9.8 m at GCLW. The highest significant wave heights observed during northers ranged from 1.21 m to 1.90 m, with periods of peak energy ranging from 5 s to 8 s. The vertical profile of currents within the 4-m layer above the bottom during 15 m/s persistent southeasterly winds suggests fully developed turbulence and slab-like motion on the shallow inner shelf.

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