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STUDY TITLE: Pressure Gauge and Moored CTD Array along the Louisiana Coastal Current

REPORT TITLE: Investigation of Pressure and Pressure Gradients along the LA/TX Inner Shelf and their Relationships to Wind Forcing and Current Variability.

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PROJECT MANAGERS: S.P. Murray, N.D. Walker

AFFILIATION: Coastal Studies Institute, Louisiana State University

ADDRESS: Howe-Russell Geoscience Complex, Louisiana State University, Baton Rouge, LA 70803.

PRINCIPAL INVESTIGATORS*: S.P. Murray, N.D. Walker

KEY WORDS: physical oceanography, Louisiana Coastal Current, shelf circulation, water level changes, pressure gradients, air-sea interaction, coastal set-up, coastal trapped waves, coastal processes.

BACKGROUND: The northwestern rim of the Gulf of Mexico is characterized by a broad, shallow shelf dominated by North American continental drainage, including the Mississippi and Atchafalaya Rivers and an array of smaller rivers and bays. The Mississippi/Atchafalaya River outflow produces buoyant, turbid plumes along the Louisiana coastline. This current exhibits intense spatial and temporal variability related to the volume of river discharge and nature of the wind forcing. Although circulation over the Louisiana/Texas shelf is complex and can vary rapidly, certain general circulation patterns have emerged from previous studies. On the inner shelf west of Atchafalaya Bay, surface circulation is primarily wind-driven and coherence has been found between alongshore wind-stress and alongshore currents for coastal locations. The wind-current relationship results in downcoast flow (westward/southward) along the Louisiana/Texas coast for much of the year with a coastal-type jet on the inner shelf. The predominant east to west flow on the inner shelf is enhanced by the Atchafalaya and Mississippi River discharges. Short-lived flow reversals occur when winds blow from the west, as occurs with the passage of winter storms with recurrence frequencies of 3-10 days. Longer-lived flow reversals occur during summer when strong southerly winds prevail along the south Texas coast and weak southerly and southwesterly winds blow along the Louisiana coast. In this study, six pressure gauges were installed along the Louisiana/Texas inner shelf to enable a detailed investigation of the alongshore pressure and pressure gradients and their relationships to wind forcing and coastal circulation along the Louisiana/Texas coast. Lessons learned from observations, in the LCC and other studies suggest that alongshore variation in the pressure (water level) and pressure gradients may be of great importance in understanding the mechanisms controlling the Louisiana/Texas coastal current.

OBJECTIVES: The primary objectives of this study were:

1. To deploy an alongshore near coastal pressure gauge array in order to understand the role of sea level slopes in the dynamics controlling the Louisiana Coastal Current.
2. To quantify the relationships between coastal wind stress and (1) sub-surface pressure (water level) and (2) alongshore pressure gradients.
3. To obtain a better understanding of the role of alongshore pressure gradients in coastal circulation changes.
4. To produce a data set of near coastal sea level and sea level slopes suitable for calibration and validation of numerical models of the Louisiana/Texas coastal current.

DESCRIPTION: To analyze the sub-tidal temporal and spatial variability of sub-surface pressure and pressure gradients along the Louisiana-Texas coastline, six sub-surface pressure gauges were deployed in very shallow water (< 20m). These gauges were either SD 635 or SBE Seagauge instruments and they were set to record data with a 15-minute sampling interval. Most of the instruments were attached to offshore oil and gas platforms. The gauges became operational in July 1994 and were kept in the specified locations until August 1995. Inspection of the recorded pressure time-series from this initial deployment revealed several periods of time with questionable or bad data that occurred mostly as a result of instrument malfunction. Faulty instrumentation was repaired and, for the most part, the sub-surface pressure gauges were returned to the same locations. The second recording period began in May 1996 and lasted through January 1998. To improve the spatial coverage of the pressure and pressure gradient changes along the Louisiana-Texas coast, four water level stations from the Texas coast were included in the analyses. Hourly wind measurements from the same CMAN stations, an airport at Brownsville, and an anemometer at Freshwater Bayou (see Table 1 and Figure 1 for their locations) were also analyzed together with the sub-surface pressure time-series to investigate pressure and pressure gradient responses to wind stress components. To investigate time series variability and interdependence, the following statistical analyses were employed: spectra estimation, multiple, partial and ordinary coherence.

SIGNIFICANT CONCLUSIONS: A semi-annual cycle in sub-surface pressure/water level was detected in the monthly mean pressure data along the Louisiana and Texas inner shelves. Mean monthly pressure maxima were measured in October of each year with secondary maxima in April/May. The pressure minima were observed in January/February with secondary minima in July/June. These seasonal pressure changes were closely associated with seasonal changes in alongshore wind forcing. Pressure minima coincided with relatively strong upcoast wind stress and pressure maxima coincided with relatively strong downcoast wind stress. Strong westward wind stresses were measured in October. A more detailed analysis of the water level fluctuations on the synoptic scale revealed that the highs and lows in water levels were attributed to one or more distinct wind events within each month. Statistical analyses of the relationships between pressure and wind stress revealed that at all stations and in both summer and winter seasons, highest coherences were observed between the alongshore wind stress and sub-surface pressure variations. Along the Louisiana coast, coherences of 0.7-0.8 were found between pressure and alongshore wind stress at frequencies between 2 and 20 days. No large seasonal differences were observed in the levels of coherence between pressure and alongshore wind stress along the LA coast. Along the Texas coast, coherences between pressure and alongshore wind stress were also much higher than those with cross-shore wind stress. Coherences between alongshore wind stress and pressure were 0.7 to 0.8 during winter and 0.48 to 0.70 during summer. Current meter measurements on the inner shelf near Cameron were compared with the pressure gradients along the Louisiana-Texas continental shelf. Visual inspection of graphical outputs revealed similarities between pressure gradients along the Texas coast and flow off Cameron. Further statistical investigation demonstrated the existence of significant relationships only during summer. This is an important result as it indicates that inner shelf currents along at least a portion of the Louisiana shelf during summer may be driven by pressure gradients and currents generated along the Texas coast. In general, however, the computed pressure gradients were consistent with gradients that would result from the wind stress forcing. Based on this study, we conclude that the barotropic pressure gradients along the coast do not provide a major control on current variability except in the west portion of the study region during the summer. Long period oscillations in pressure/water level were detected along the Louisiana-Texas coastline during the 1996 summer. They exhibited periods of about 10 days and amplitudes of at least 10 mb. Similar long-period oscillations were evident in the corresponding atmospheric pressure and alongshore component of the wind stress. The spatial vastness of the pressure events and the time lag between stations may suggest that these are long coastal-trapped waves.

STUDY RESULTS: A detailed analysis of the water level fluctuations on the synoptic scale revealed that the highs and lows in water levels were attributed to one or more distinct wind events within each month. Westward (Louisiana) and southwestward (Texas) wind stress events produced the highest coastal water levels. Lowest water levels along the Texas coast were produced by northward wind stress. Along the Louisiana coast, lowest water levels occurred in close association with strong eastward wind stress. Although similarity in water level responses was observable in the water level records, there were events for which the coastal water levels across the region responded differently to a wind event. The change in coastline orientation from Louisiana to Texas in relationship to wind stress produced interesting differences in water level responses on the synoptic scale. For example, a strong wind blowing towards the east along the Louisiana coast produced alongshore wind stress, upwelling and a reduction in coastal water levels due to Ekman set-down. This same wind stress along the Texas coast resulted in cross-shelf offshore wind and little water level change. A detailed analysis of pressure/water level fluctuations along the Louisiana/Texas coastline was performed for January 1997. This analysis demonstrated that water levels only fall when winds blow upcoast. Thus, the presence of strong winter winds from the northeast does not reduce coastal water levels, but increases them. Thus, all frontal passages do not have the same effect on coastal water levels. Winter storms that blow upcoast (west winds) have a much stronger flushing effect in coastal Louisiana than winds blowing downcoast (east winds).

STUDY PRODUCTS: Walker, N.D. 2001, E. Jarosz and S. P. Murray.2001. An investigation of pressure and pressure gradients along the Louisiana/Texas inner shelf and their relationships to wind forcing and current variability. OCS Study MMS 2001-057. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, 52 pp.

P.I.'s affiliation may be different than that listed for Project Manager(s).