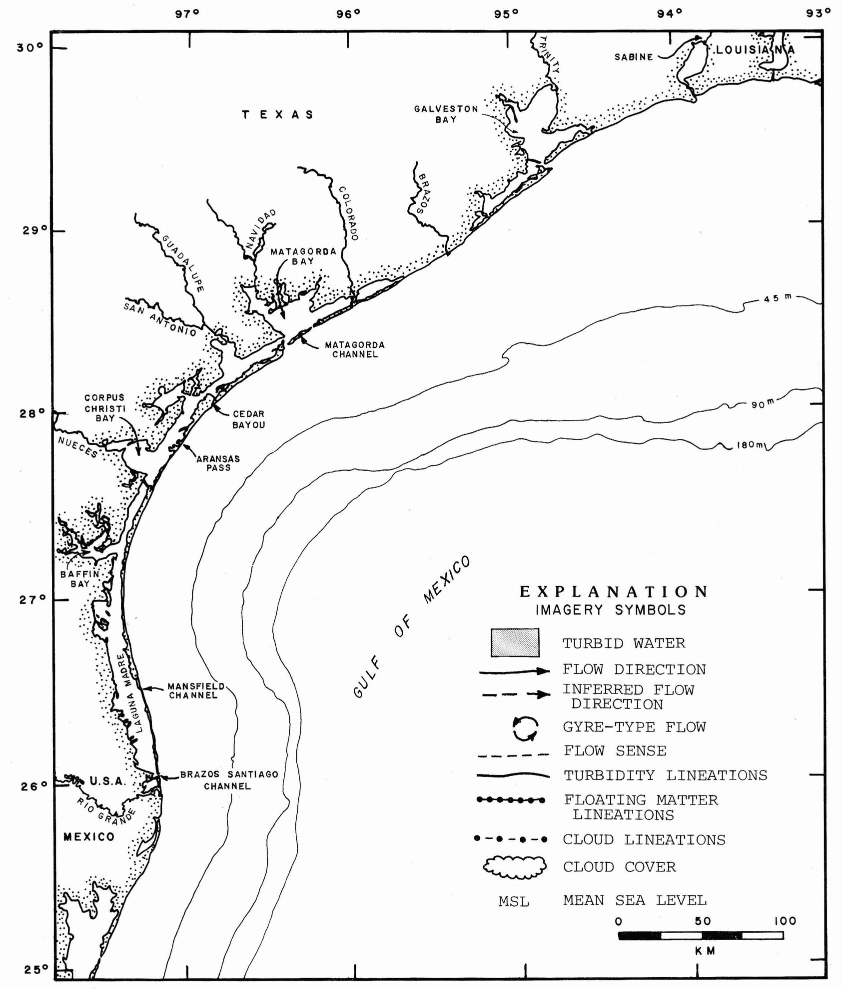

Figure 1A.--Map showing region of Landsat imagery coverage on the Texas inner Continental Shelf, and explanation of observed features shown in figures 2-11.

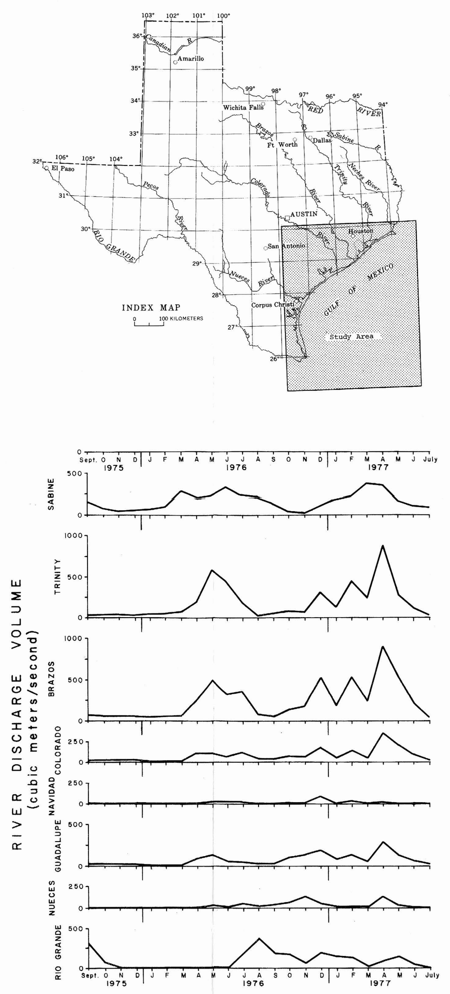

Figure 1B.--Graphs showing monthly discharge volume of major rivers in proximity to the Texas Continental Shelf.

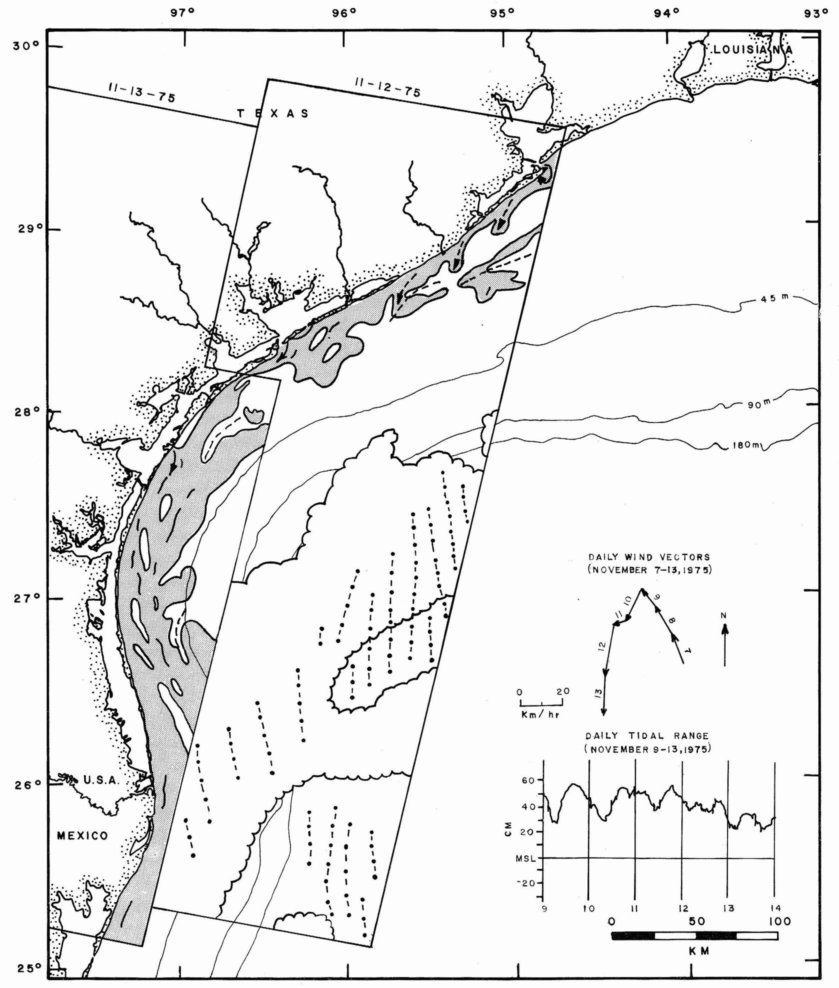

Figure 2.--Map showing imagery patterns and associated wind and tidal conditions during the November 12-13, 1975, overpass.

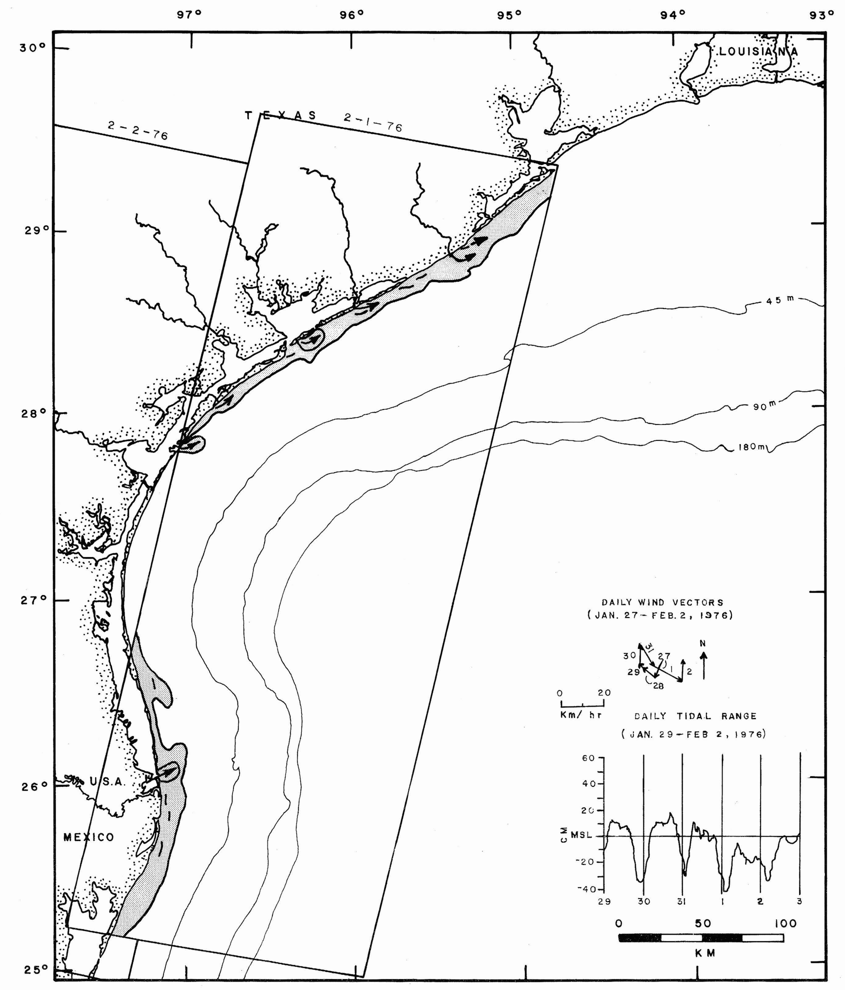

Figure 3.--Map showing imagery patterns and associated wind and tidal conditions during the February 1-2, 1976, overpass.

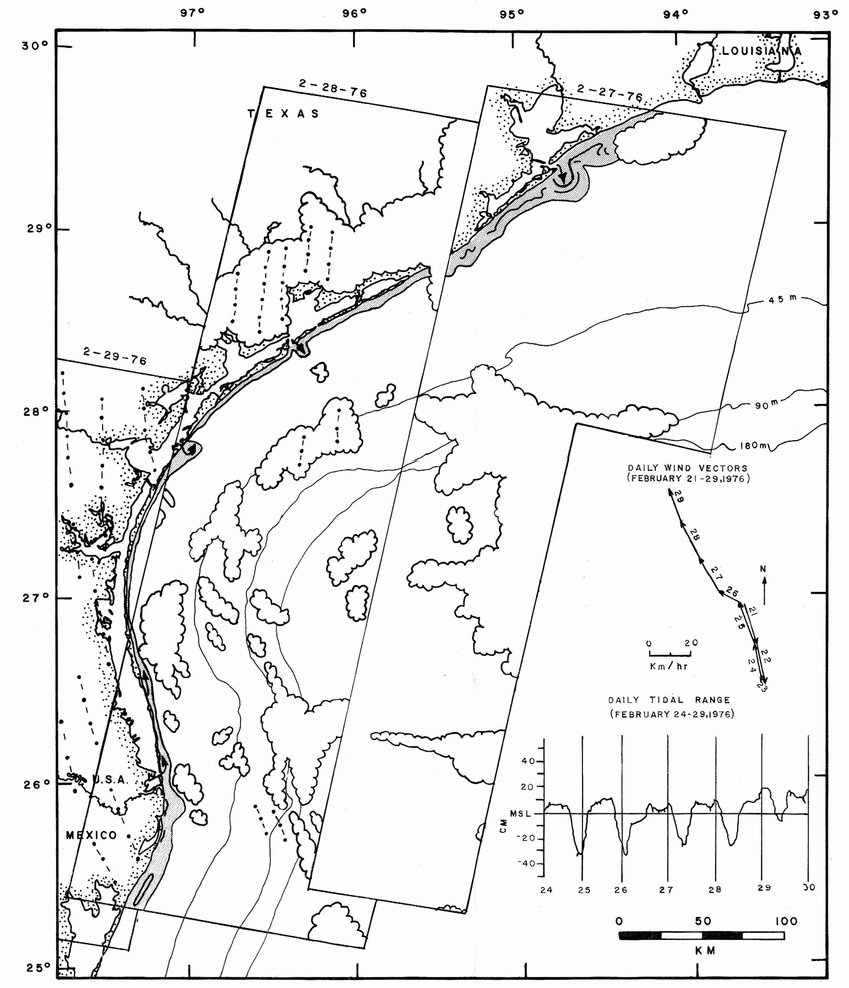

Figure 4.--Map showing imagery patterns and associated wind and tidal conditions during the February 27-29, 1976, overpass.

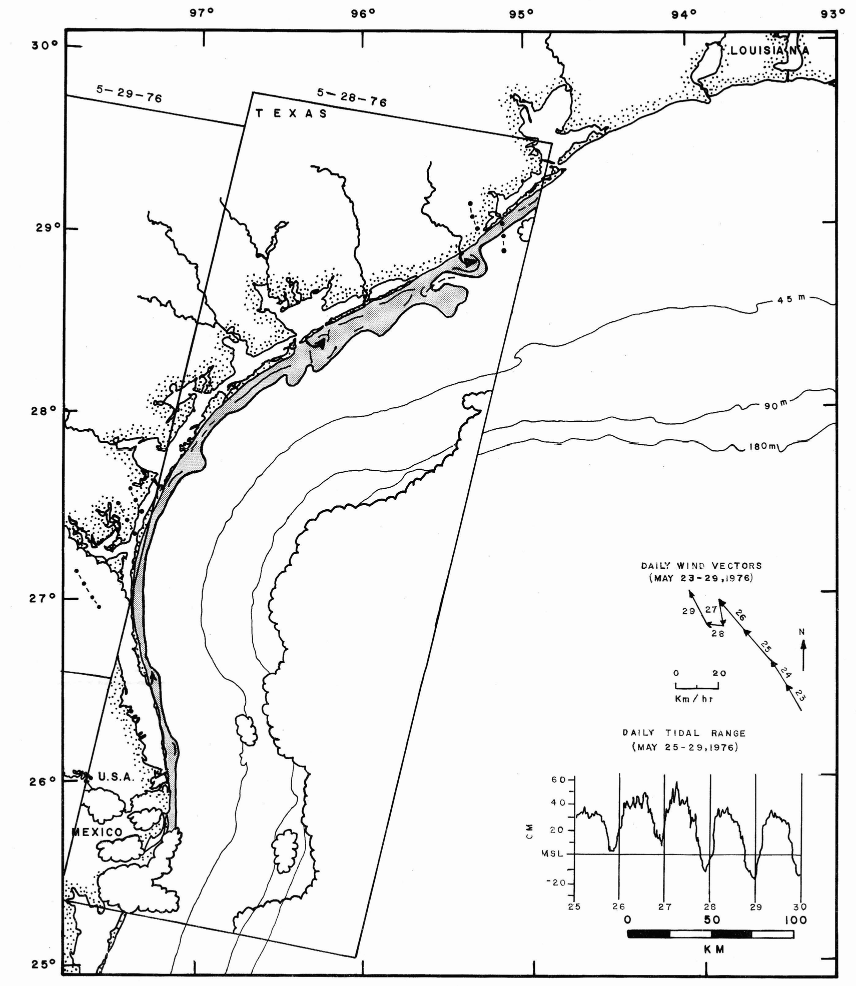

Figure 5.--Map showing imagery patterns and associated wind and tidal conditions during the May 28-29, 1976, overpass.

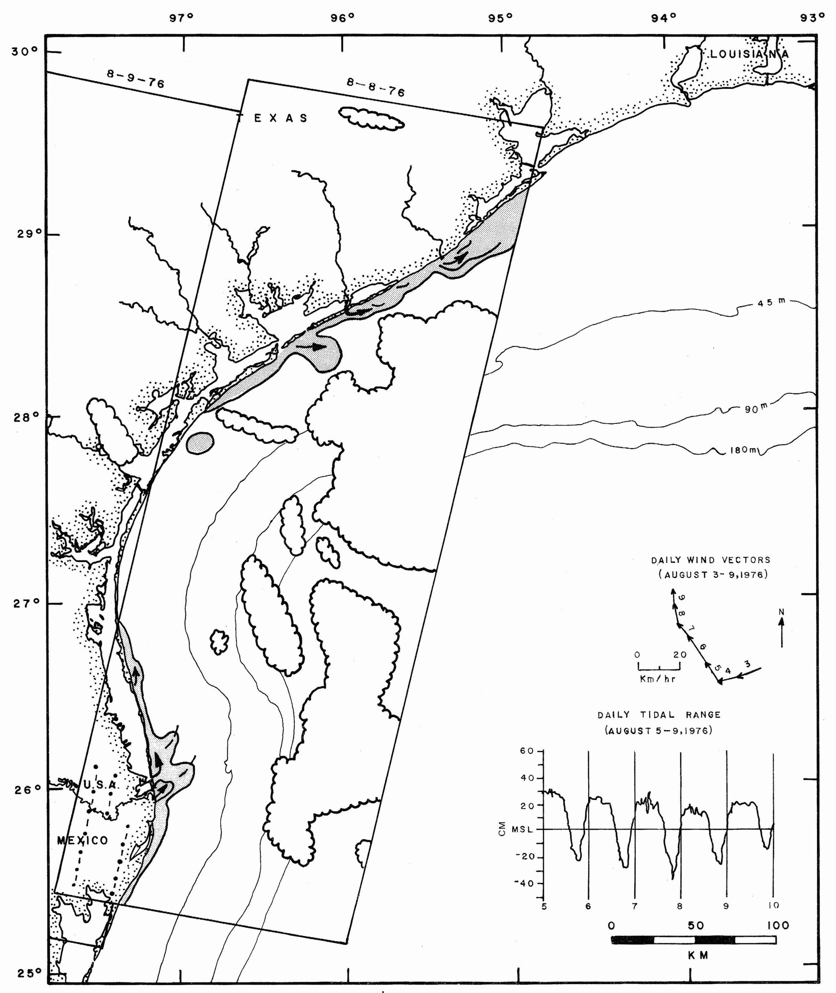

Figure 6.--Map showing imagery patterns and associated wind and tidal conditions during the August 8-9, 1976, overpass.

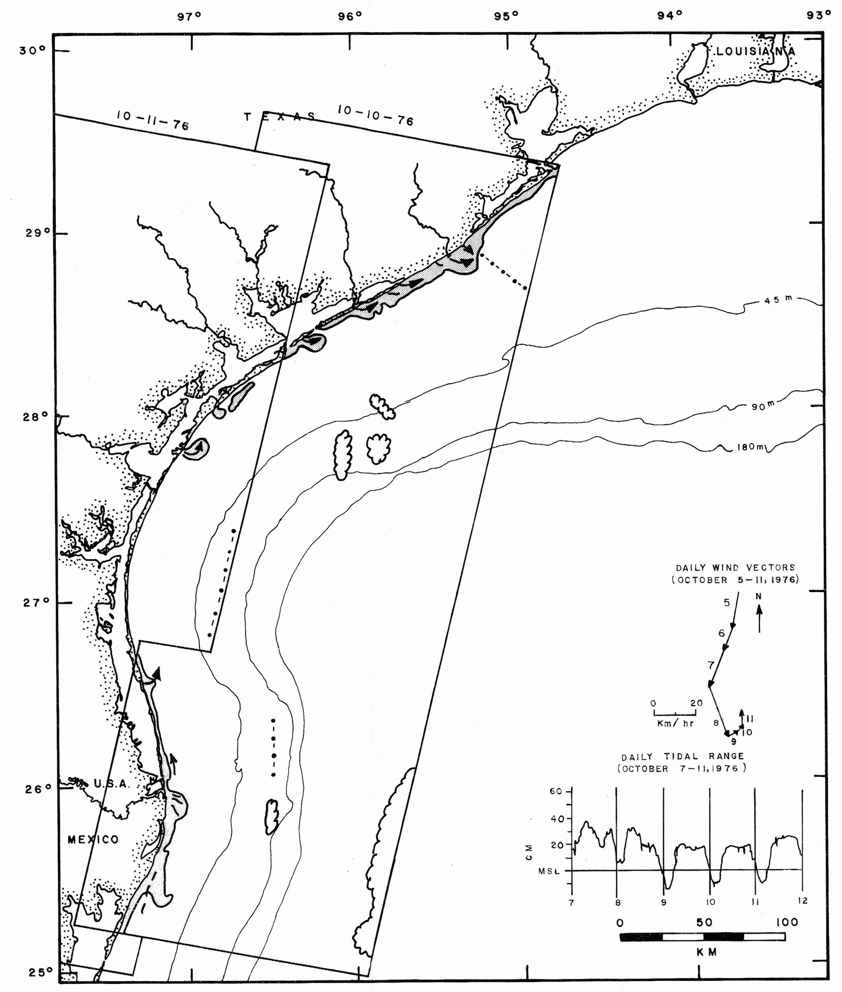

Figure 7.--Map showing imagery patterns and associated wind and tidal conditions during the October 10-11, 1976, overpass.

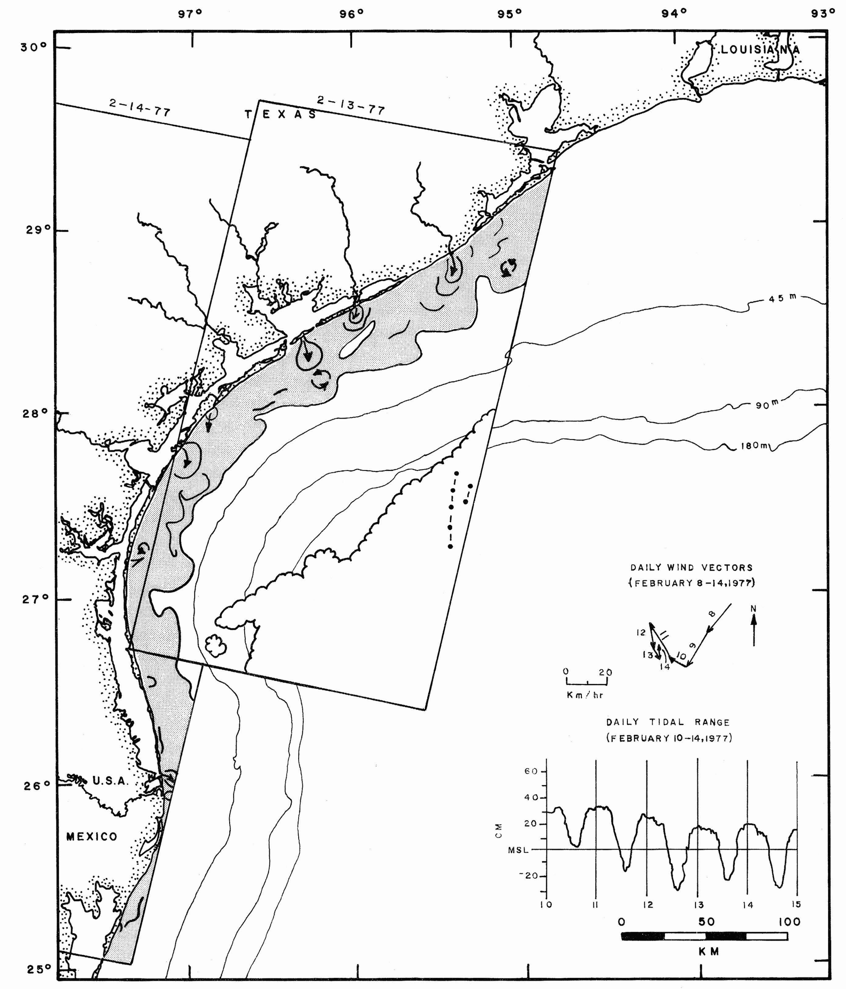

Figure 8.--Map showing imagery patterns and associated wind and tidal conditions during the February 13-14, 1977, overpass.

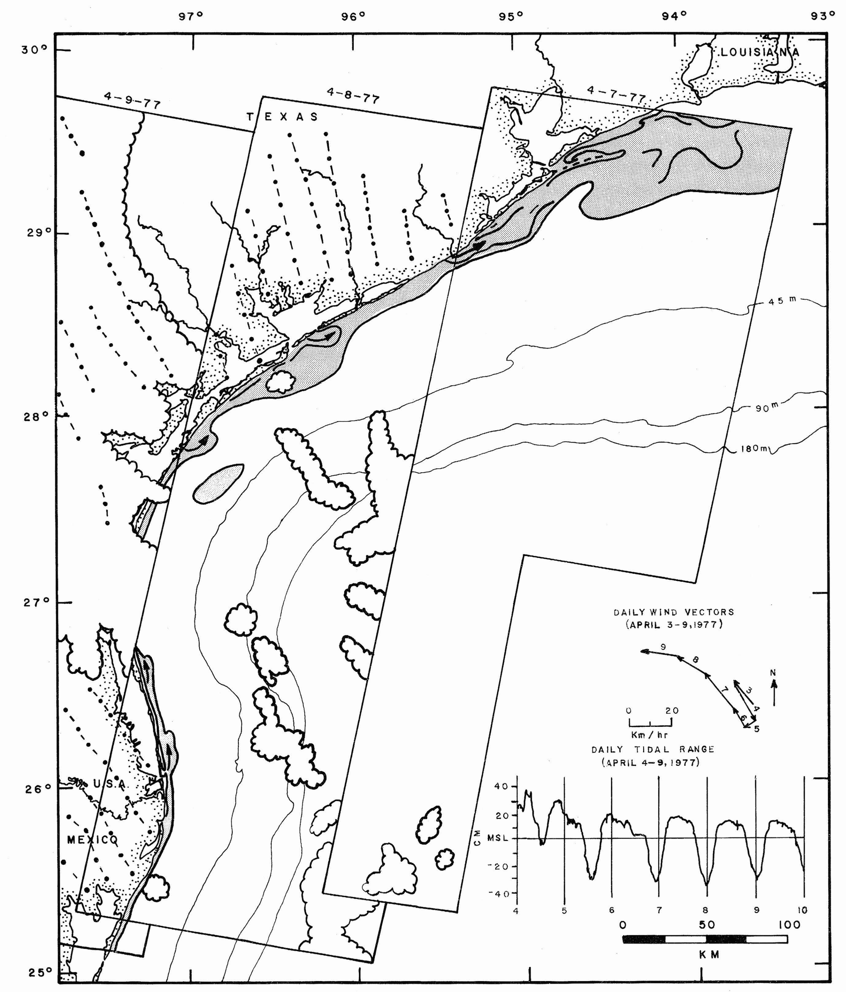

Figure 9.--Map showing imagery patterns and associated wind and tidal conditions during the April 7-9, 1977, overpass.

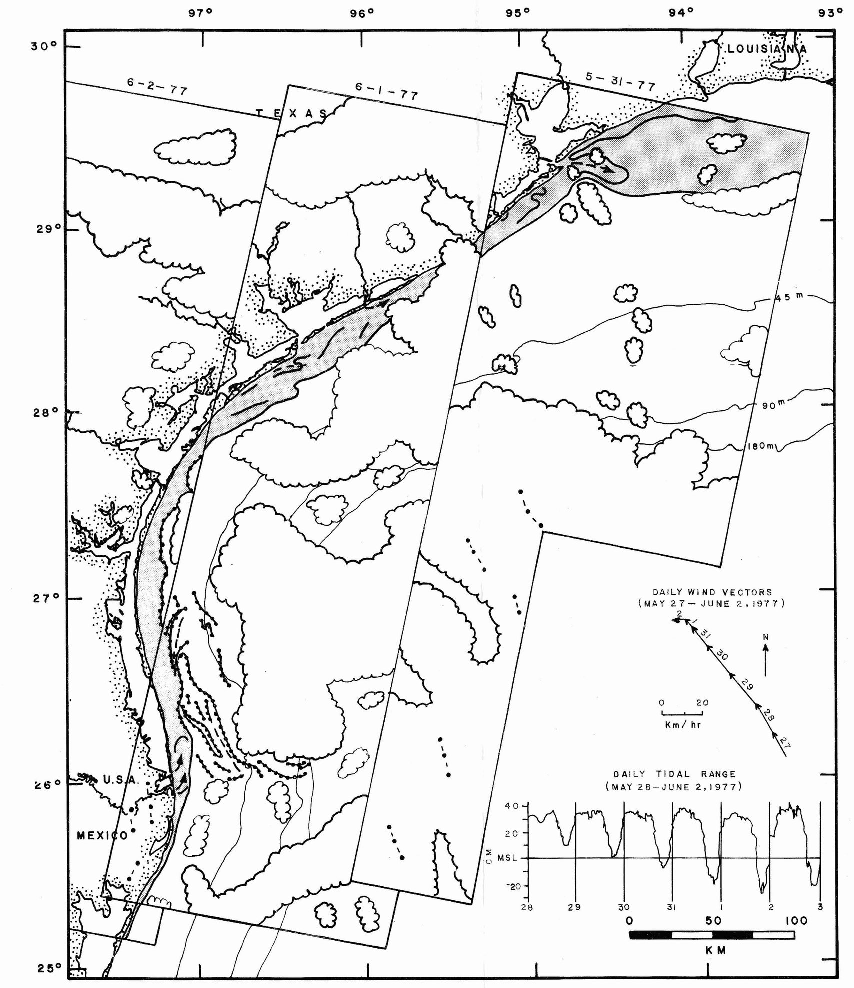

Figure 10.--Map showing imagery patterns and associated wind and tidal conditions during the May 31-June 2, 1977, overpass.

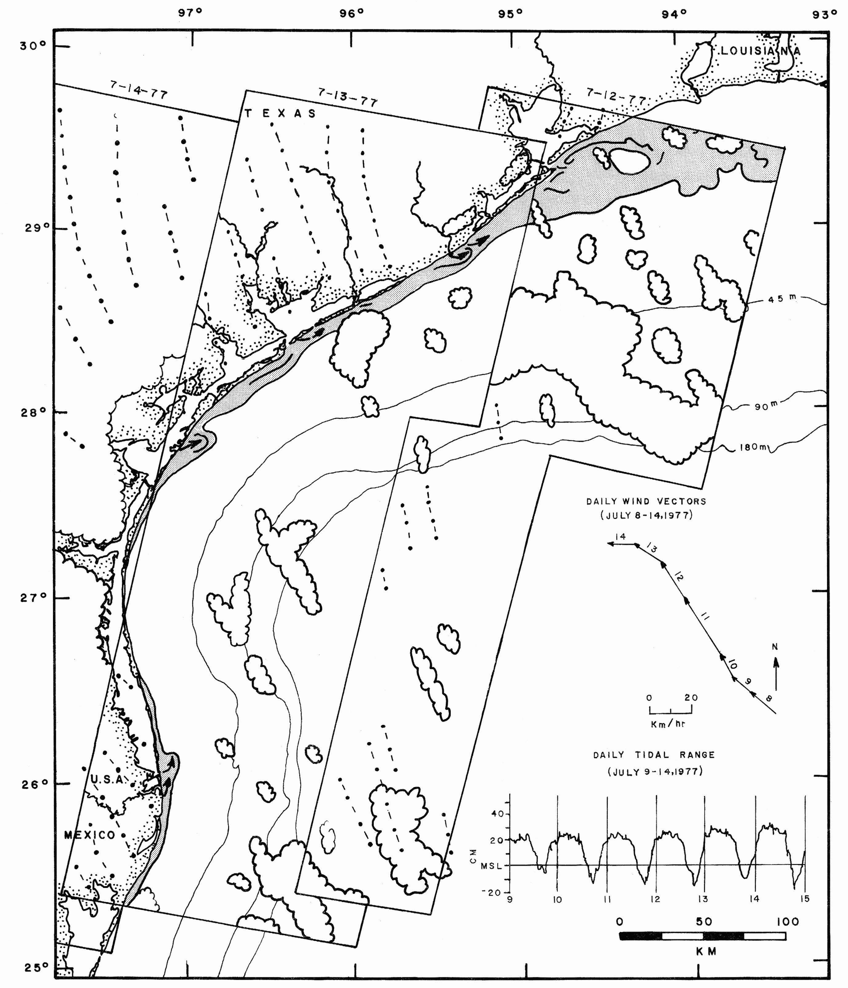

Figure 11.--Map showing imagery patterns and associated wind and tidal conditions during the July 12-14, 1977, overpass.

INTRODUCTION

This study of surface turbidity from Landsat imagery was conducted as part of a regional investigation of suspended sediment transport on the Texas Continental Shelf within the northwest Gulf of Mexico. The objective was to examine a seasonal time sequence of imagery from November 1975 to July 1977, in an effort to delineate nearshore sediment-dispersal patterns and their relationship to ambient meteorological conditions. This work was conducted under the auspices of the U.S. Bureau of Land Management as part of the South Texas Outer Continental Shelf (OCS) environmental studies program associated with offshore petroleum lease sales. Some previous observations of turbidity patterns off the Texas coast using Landsat imagery have been reported by Hunter (1973, 1976). In addition, ground measurements of surface turbidity on the Texas shelf also have been reported previously (Manheim and others, 1972; Shideler, 1976, 1978).

METHODS

Selected Landsat imagery was obtained from the U.S. Geological Survey's EROS Data Center. Imagery from a total of ten Landsat overpasses was qualitatively analyzed for turbidity patterns and sediment-dispersal directions. Imagery was selected so as to provide complete seasonal coverage; specific overpasses were selected on the basis of imagery quality, acceptable cloud cover, and the availability of sufficient images to form a composite mosaic map of the study region (fig. 1*A*). The Landsat imagery consisted of multispectral scanner (MSS) black and white film negatives at a 1:1 million scale. The spectral band used was the red band 5 (0.6-0.7 micrometers); this band provided the optimum resolution of turbidity patterns along the shallower inner shelf, the sector which was judged to be the most informative. A composite mosaic map was prepared for the images from each overpass to illustrate turbidity and flow patterns (figs. 2-11). Wind and tidal conditions associated with the overpass period also were plotted on each map, in an effort to relate the imagery patterns to meteorological conditions. The wind and tidal data were obtained, respectively, from the National Weather Service facility and the U.S. Army Corps of Engineers tide gauges within the Corpus Christi Bay area, which was considered to be representative of the region. In addition, discharge characteristics of major rivers in proximity to the Texas Continental Shelf were determined over the monitored period to assess the possible influence of coastal runoff on shelf turbidity (fig. 1*B*).

SEDIMENT-DISPERSAL PATTERNS

Imagery from the first fall overpass (November 12-13, 1975) showed turbid water masses throughout much of the inner-shelf (<45-m depth) sector (fig. 2). The turbid zone extended seaward from the coastline and increased in width southward. Several features were indicative of sediment-dispersal directions. A regional alongshore transport component throughout the inner shelf was suggested both by turbidity lineations and by the trends of shear structures developed between turbid and nonturbid water masses. The alongshore transport was southward, as indicated by ebb-tide sediment plumes emanating from Matagorda ship channel and Aransas Pass (fig. 1*A*). Regional southward transport was further indicated by a series of oblique south-trending tongues of turbid coastal water northeast of the Colorado River, as well as by clockwise gyre-type flow at Galveston Bay inlet, which appears to reflect the interaction of ebb tidal currents with south-flowing littoral currents.

During the following winter overpass (February 1-2, 1976), the imagery showed a relatively narrow zone of turbid nearshore water that diminished in width from the north and south toward the central sector (fig. 3). No significant turbidity was observed within the central sector (Corpus Christi Bay to Baffin Bay), which is the area of maximum coastal curvature. Sediment plumes were associated with most principal rivers and inlets, and they generally indicated regional alongshore transport northeastward. The only exception was the plume of the Brazos Santiago Channel, which suggested more radial dispersion without any strong alongshore component.

The imagery from the subsequent winter overpass (February 27-29, 1976) showed that turbid water was confined to the nearshore area of the inner shelf, and that the turbid zone decreased in width toward the central sector (fig. 4). The largest ebb-sediment plume was from Galveston Bay inlet, which indicated a radial seaward dispersal pattern with no dominant alongshore component. Radial dispersal also was indicated by a plume from Matagorda ship channel, but, in contrast, the plumes from inlets within the southern half of the region (Aransas Pass, Mansfield Channel, Brazos Santiago Channel) indicated sediment dispersal northward.

During the following spring overpass (May 28-29, 1976), the turbid water zone was restricted to the nearshore area, and it decreased in width southward (fig. 5). Sediment plumes emanating from the Brazos River, Matagorda ship channel, and Mansfield Channel all indicated regional north-northeastward alongshore drift.

Imagery from the subsequent summer overpass (August 8-9, 1976) showed that turbid water was localized within the nearshore area (fig. 6). The width of the turbid zone decreased from the northern and southern sectors toward the central sector; no significant coastal turbidity was observed within the central sector. Regional sediment dispersal to the north-northeast was indicated by all sediment plumes. Plumes were associated with the Brazos and Colorado Rivers, the Matagorda ship channel, the Mansfield Channel, the Brazos Santiago Channel, and the Rio Grande. However, no plume was associated with Aransas Pass within the nonturbid central sector.

The following fall overpass imagery (October 10-11, 1976) showed that inner-shelf turbidity was very low, the turbidity being confined to the immediate nearshore zone (fig. 7). The turbid zone decreased in width toward the central sector, where no observable turbidity was present. Sediment plumes were associated with all principal rivers and inlets. Except for the Rio Grande plume, which did not indicate a dominant alongshore transport component, all other plumes indicated regional sediment dispersal to the north-northeast.

Imagery from the subsequent winter overpass (February 13-14, 1977) showed that turbidity was relatively high (fig. 8). The turbid water zone extended seaward across most of the inner shelf and was widest within the northern sector. Sediment plumes were well developed and were associated with most principal rivers and inlets; all plumes indicated regional alongshore transport to the south. Time-lapse coverage of the plumes associated with Aransas Pass and Cedar Bayou during both overpass dates illustrated a reduction in southward orientation on February 14.

During the next early spring overpass (April 7-9, 1977), the available imagery was somewhat more extensive and provided additional inner-shelf coverage east of Galveston Bay (fig. 9). Inner-shelf turbidity was highly variable throughout the region. The lateral extent of the turbid water zone was minimal within the central sector and widest within the northernmost sector. The turbid zone was of maximum width east of Galveston Bay, where the zone extended from the shoreline to 33 km offshore. All coastal sediment plumes indicated regional alongshore transport to the north-northeast. The Brazos River exhibited an unusually strong plume. Time-lapse imagery indicated that the Brazos plume persisted at least two days (April 7-8), with decreasing intensity on the second day; this plume was associated with a period of maximum discharge volume from the Brazos River (fig. 1*B*). Moderate plumes were associated with Matagorda ship channel and Aransas Pass, and small plumes were developed at the Mansfield and Brazos Santiago Channels.

Imagery from the following late spring overpass (May 31-June 2, 1977) showed that the coastal turbid-water zone was of minimal width within the central sector and increased in width northward (fig. 10). Similar to the earlier spring overpass (April 7-9), the turbid zone was widest (37 km) east of Galveston Bay. Sediment plumes associated with the Rio Grande and Brazos Santiago Channel in the southern sector indicated northward alongshore transport. A substantial alongshore component within the northern half of the region also was suggested by the northeasterly trending of narrow bands of floating matter; these appeared to be spring plankton bands alined along the direction of flow. A weak plume from the Colorado River suggested northeasterly transport, whereas a plume at Galveston Bay inlet indicated mainly eastward transport.

During the subsequent summer overpass (July 12-14, 1977), the imagery showed that the width of the coastal turbid-water zone was minimal within the central sector south of Baffin Bay and widest (58 km) within the northern sector east of Galveston Bay (fig. 11). The presence of the wide turbid zone east of Galveston Bay during this period of relatively low river discharge (fig. 1*B*) suggests that it is a persistent feature which is not produced by coastal runoff. The turbid zone is concordant with bathymetry, for the zone occurs where the shelf widens and shoals substantially; this relationship suggests that it is probably attributed largely to bottom-sediment resuspension by wave surge. Sediment plumes were associated with the Brazos River and an adjacent stream northeast of it, and with the Matagorda ship channel, Aransas Pass, the Brazos Santiago Channel, and the Rio Grande. All plumes indicated regional alongshore transport to the north-northeast.

DISCUSSION

A comparison of the Landsat imagery time sequence and the associated meteorological conditions indicates that inner-shelf surface turbidity patterns and sediment-dispersal directions are highly regulated by wind direction. This is in agreement with previous drifter studies (for example, Watson and Behrens, 1970; Hunter and others, 1974; Hill and others, 1975), which indicated that seasonal winds were highly influential in establishing the circulation patterns of the Texas shelf. The alongshore transport of sediment, resulting both from littoral currents produced by locally generated wavetrains and from wind-driven shelf currents, is restricted by the curvature of the Texas coastline to either a north-northeast or a south-southwest trend. Within this framework, the imagery indicated that alongshore transport was to the south-southwest when ambient winds had strong northerly components, a condition most common during the winter months. In contrast, alongshore transport was to the north-northeast when winds had strong southerly components, a prevalent condition during summer months.

The imagery further suggested that the offshore transport component also may be influenced mainly by wind direction. The widest coastal turbid zones, which presumably reflected the most extensive seaward dispersal of sediment, occurred during the only two overpasses when northerly winds were active and regional alongshore drift was southward (figs. 2, 8). As the two overpasses occurred during periods of contrasting wind velocities, coastal runoff, and tidal conditions (spring tides versus neap tides), the only apparent common factor was a northerly wind direction. In contrast, the narrowest coastal turbid zone occurred during a period of average tides and coastal runoff, when winds were southerly and alongshore drift was northward (fig. 7).

Regional coastal runoff did not appear to have a systematic influence on offshore sediment transport (fig. 1*B*). Although the wide coastal turbid zone during the February 13-14, 1977, overpass (fig. 8) did coincide with a period of relatively high river discharge, the wide turbid zone during the November 12-13, 1975, overpass (fig. 2) was associated with a period of low river discharge. In addition, the narrowest coastal turbid zone that occurred during the October 10-11, 1976, overpass (fig. 7) was associated with a period of average runoff. Furthermore, turbid zones of only average width occurred during spring overpasses that were associated with the periods of greatest regional runoff (figs. 5, 9). These inconsistent relationships suggest that the short-term shelf turbidity patterns observed on the imagery were more greatly influenced by wind direction rather than by regional runoff conditions. The majority of Texas coastal rivers flow into an extensive lagoonal-estuarine system which probably serves as an effective runoff reservoir and buffer zone between fluvial discharge and shelf response. The maximum seaward dispersal of coastal sediment during periods of northerly offshore winds may largely reflect the more efficient ebb-tide flushing of turbid lagoonal-estuarine waters through tidal inlets, as compared to the periods of southerly onshore winds.

Tidal amplitudes did not appear to have a major influence on regional turbidity patterns. However, the strongest development of ebb-sediment plumes did occur during periods of spring tides. This could reflect periods of higher tidal current velocities, resulting in generally more efficient water exchange between the shelf and the adjacent intracoastal sources of suspended sediment.

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MAP SHOWING TURBIDITY PATTERNS FROM LANDSAT IMAGERY ON THE TEXAS INNER CONTINENTAL SHELF

By
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1979

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1979

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