

Application of Remote Sensing to Assess the Impact of Short Term Climate Variability on Coastal Sedimentation

First Year Progress Report for NASA Grant NAG5-9688
covering the period June 15, 2000 – June 14, 2001

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1. Introduction

The University of Wisconsin and Louisiana State University have teamed to study the forcing of winter season cold frontal wind systems on sediment distribution patterns and geomorphology in the Louisiana coastal zone. Wind systems associated with cold fronts have been shown to modify coastal circulation and resuspend sediments along the microtidal Louisiana coast (Roberts et al. 1987, Moeller et al. 1993). The assessment includes quantifying the influence of cumulative winter season atmospheric forcing (through surface wind observations) from year to year in response to short term climate variability, such as El Nino events. A correlation between winter cyclone frequency and the strength of El Nino events has been suggested (Noel and Changnon, 1998). The atmospheric forcing data are being correlated to geomorphic measurements along western Louisiana's prograding muddy coast. Remote sensing data is being used to map and track sediment distribution patterns for various wind conditions. Transferring a suspended sediment concentration (SSC) algorithm to EOS MODIS observations will enable estimates of SSC in case 2 waters over the global domain.

Progress in Year 1 of this study has included data collection and analysis of wind observations for atmospheric forcing characterization, a field activity (TX-2001) to collect in situ water samples with co-incident remote sensing measurements from the NASA ER-2 based MODIS Airborne Simulator (MAS) and the EOS Terra based MODERate resolution Imaging Spectroradiometer (MODIS) instruments, aerial photography and of sediment burial pipe field measurements along the prograding muddy Chenier Plain coast of western Louisiana for documenting coastal change in that dynamic region, and routine collection of MODIS 250 m resolution data for monitoring coastal sediment patterns. The data sets are being used in a process to transfer an SSC estimation algorithm to the MODIS platform. Work is underway on assessing coastal transport for the winter 2000-01 season. Water level data for use in a Geomorphic Impact Index, which relates wind energy, water level conditions, and geomorphic change along the microtidal western Louisiana coastline is being assembled.

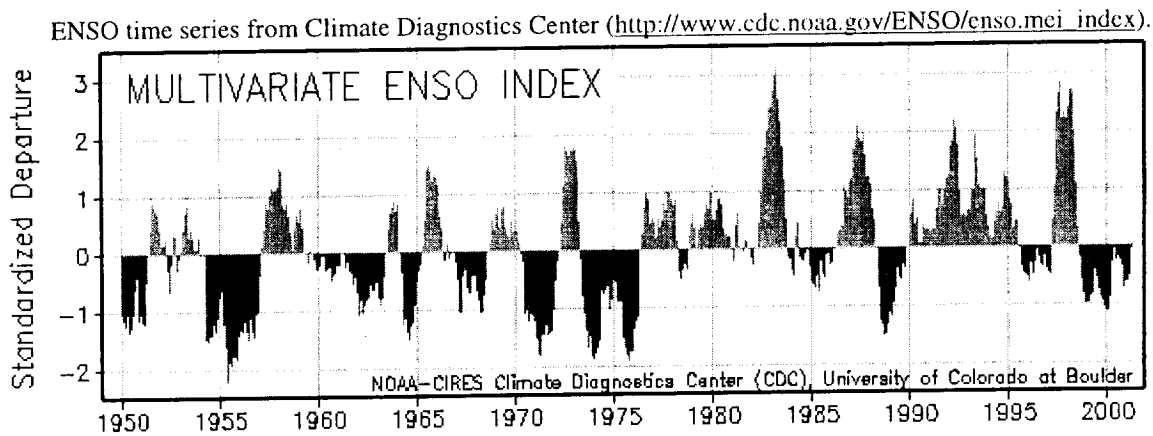
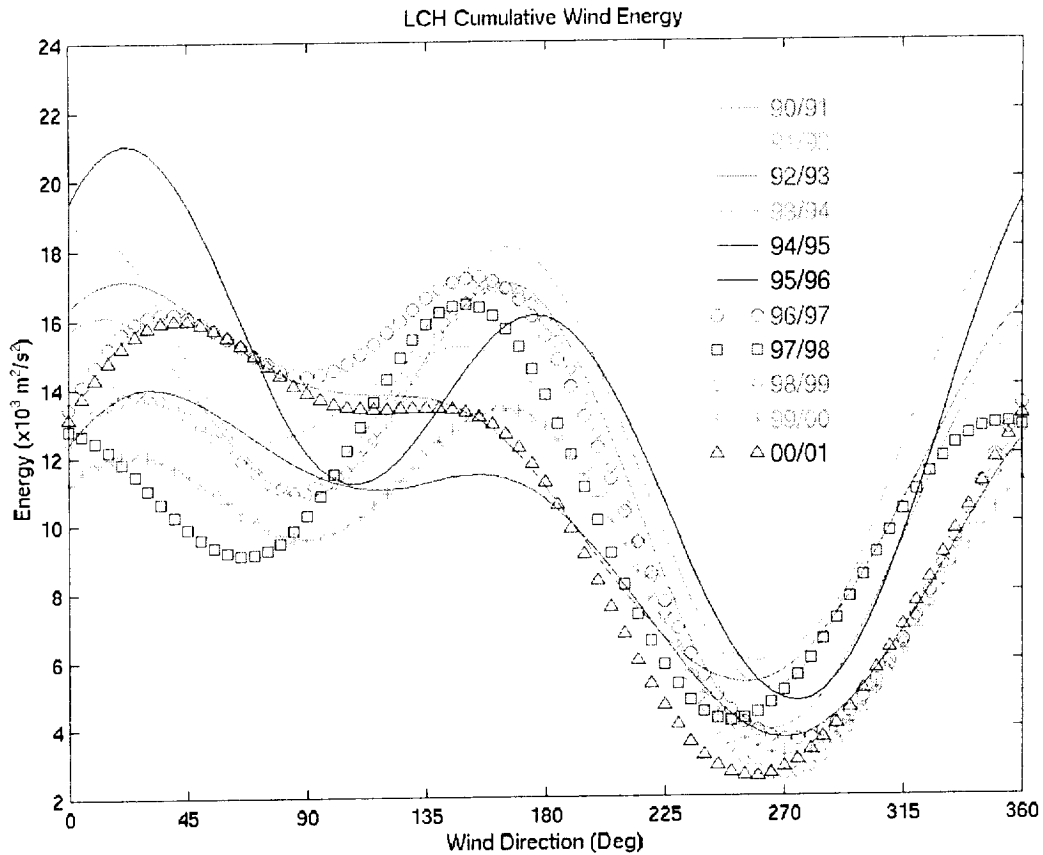


Figure 1. Variation in surface wind energy (top) at Lake Charles, LA for the cold front seasons of the last decade demonstrate that atmospheric forcing has changed markedly from year to year in the Gulf of Mexico coast region. Atmospheric forcing impacts sediment transport in the microtidal coastal zone of Louisiana by driving up and setting down water levels in coastal bays and estuaries, and influencing nearshore circulation. Time series of El Niño – Southern Oscillation (ENSO) Index (bottom) suggest a correlation between Gulf coastal wind energy and short term climate variation associated with El Niño events. The strong El Niño years (red) of 1991-92 and 1997-98 both show wind energy peaks shifted more towards the southeast than the south. In general these years show lower wind energy from the north, suggesting that frontal boundaries are not pushing as far southward.

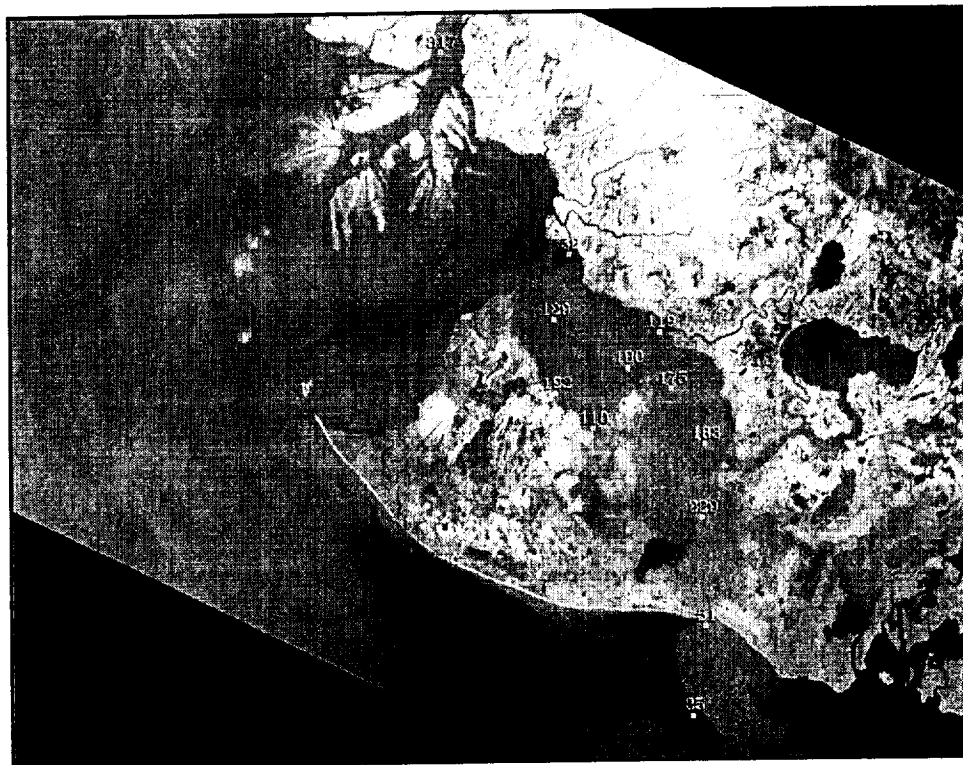
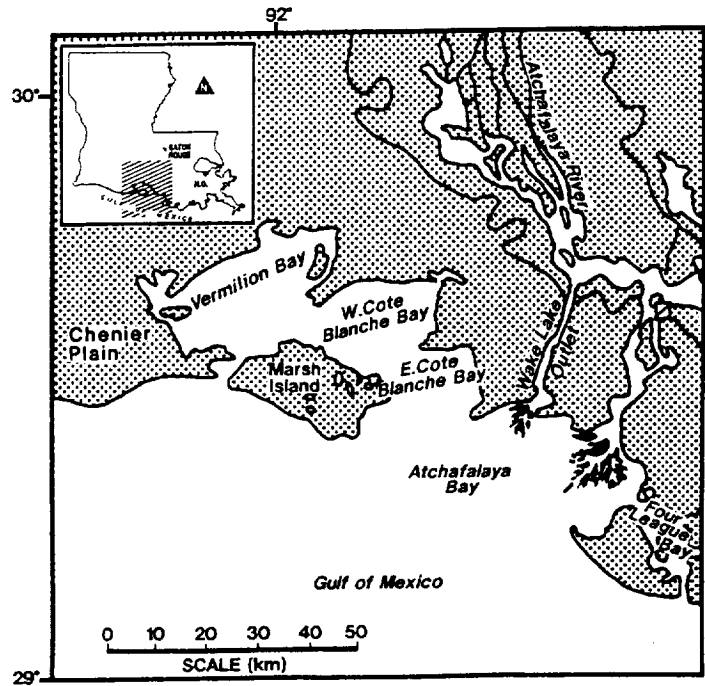


Figure 2. MAS 50 m resolution near infrared (750 nm) image of Atchafalaya Bay region on March 21, 2001 with in situ SSC (mg/l) data plotted at sampling locations. The in situ data will be used with MAS reflectances to develop coefficients for a suspended sediment concentration estimation algorithm. The algorithm will be transferred to MODIS observations on Terra to extend its application to other case 2 waters. Coupled sediment concentration and water motion information is useful for estimating sediment transport.

2. Year 1 Activities

- A. Wind energy is based on hourly National Weather Service (NWS) surface wind observations separated into onshore and offshore components. As cold front systems approach and move downstream through the Gulf Coast of Louisiana, the coastal zone experiences pre-frontal southerly (blowing onshore) winds followed by a switch to northerlies after frontal passage. During each cycle of this wind pattern, sediment resuspension and transport results (Walker et al. 1997; Walker and Hammack, 2000). Offshore transport in the post-frontal phase exposes suspended sediment to longshore currents, resulting in downdrift transport. Surface wind data for the 2000 – 2001 cold front season (October – April) have been collected. Wind measurements from 1998-1999, and 1999-2000 have also been analyzed. These wind measurements extend the wind measurement record to 15 years (1987 – 2001). Figure 1 demonstrates variability of wind energy from year to year during the cold front season (Oct. – April) in the Gulf coast region. Year to year wind energy for northerly and southerly wind directions varies by almost a factor of two over the decade shown. In the microtidal Gulf coast, these winds have an important influence on existing water levels and circulation (Moeller et al. 1996). The wind energy data are used with water level data in a seasonal transport prediction, referred to as a Geomorphic Impact Index (see Item 2.D). The variation of wind energy on a year to year basis is considered a signature of short term climate change. Association of the wind energy behavior with the El Nino – Southern Oscillation (ENSO) Index has been reviewed as a mechanism by which short term climate change may be directly influencing sediment transport along the Louisiana coast. A suggestion of some influence is present however further analysis is required.
- B. A NASA ER-2 aircraft was flown along the Atchafalaya Bay region of the Louisiana coast in spring 2001 during the Terra eXperiment –2001 (TX-2001). On March 21 the ER-2 flew multiple overpasses of the Atchafalaya Bay region of the central Louisiana coast while a boat team from LSU collected in situ water samples and the Terra satellite (with MODIS) passed overhead (1654 UTC). The boat team measurements included suspended sediment concentration (SSC; figure 2), bulk temperature, salinity, secchi depth, and VNIR radiometer measurements of the upwelling reflectance out of the water column. The ER-2 data set included the MODIS Airborne Simulator (MAS) 50 m spatial resolution data and high resolution (< 5 m) false color IR photography. The MAS data depicting the post-frontal conditions will be coupled with the in situ suspended sediment samples to produce an SSC estimation algorithm. The MAS relationship will then be transferred to co-incident MODIS 250 m resolution observations for transfer of the SSC algorithm to MODIS. The multiple overpasses of the Atchafalaya Bay region will be used to derive water motion vectors. Coupling these vectors with SSC estimates will provide a sediment transport snapshot for the March 21 flight day, providing insight on the influence of the wind pattern on transport.
- C. An X-band direct broadcast receiving station at the University of Wisconsin provides daily near real time MODIS imagery, including coverage of the Louisiana coast. MODIS data provides a source of relatively high resolution (250 m) well calibrated imagery over the global domain, a valuable resource for extending tools and findings to analysis of estuaries and deltas around the world. MODIS 250 m resolution data has been collected on a routine basis for clear sky overpasses of the Louisiana coast. The images provide snapshots of the coastal sediment distribution pattern under the prevailing wind

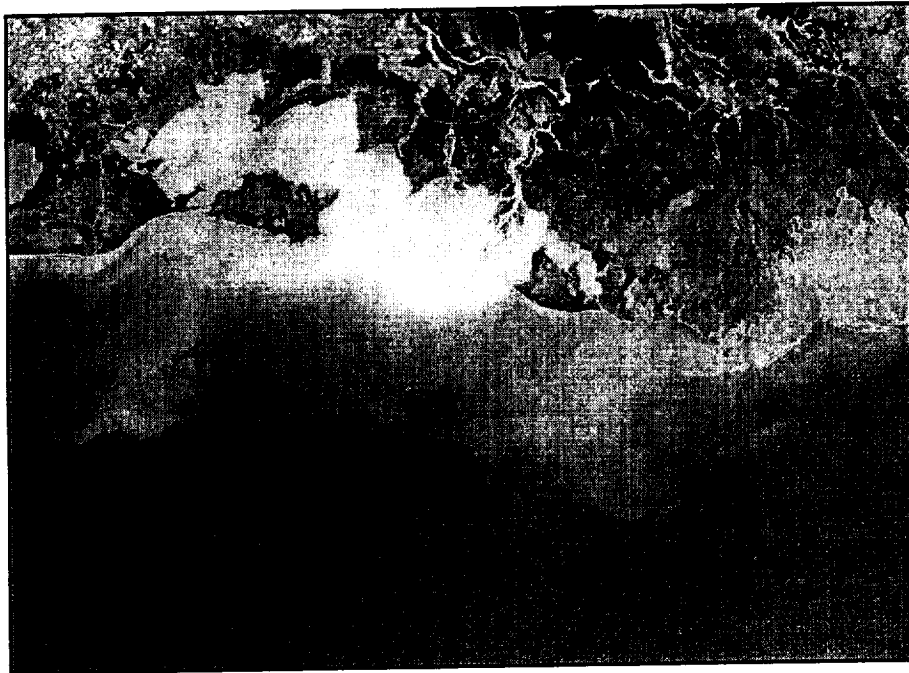
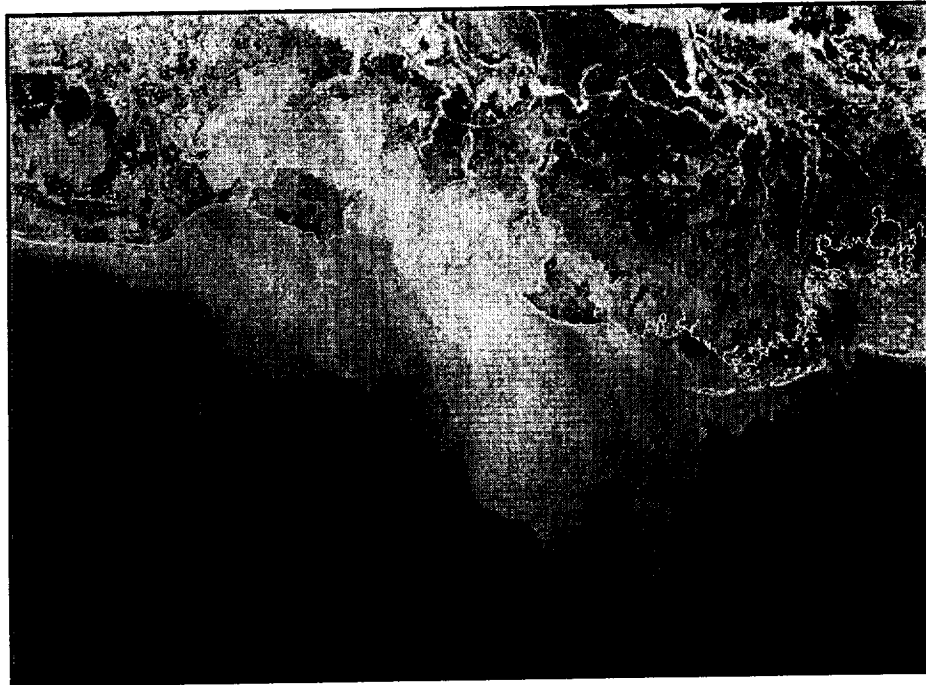


Figure 3. MODIS 250 m resolution band 1 (650 nm) imagery on March 21 (top) and March 26, 2001 (bottom). The sediment plume from the Atchafalaya Bay (center of each image) is extended to the south and east on March 21, in keeping with the low level wind flow from the northwest (see Figure 4). On March 26, winds had turned from the northeast pushing the sediment plume towards the southwest. These images are typical of sediment plume response to surface wind influence. With MODIS 250 m resolution data, it is now possible to monitor sediment plume behavior on a daily basis (clouds permitting) through the annual cycle; a capability that will advance understanding of plume interaction with various regimes of surface winds and water level.

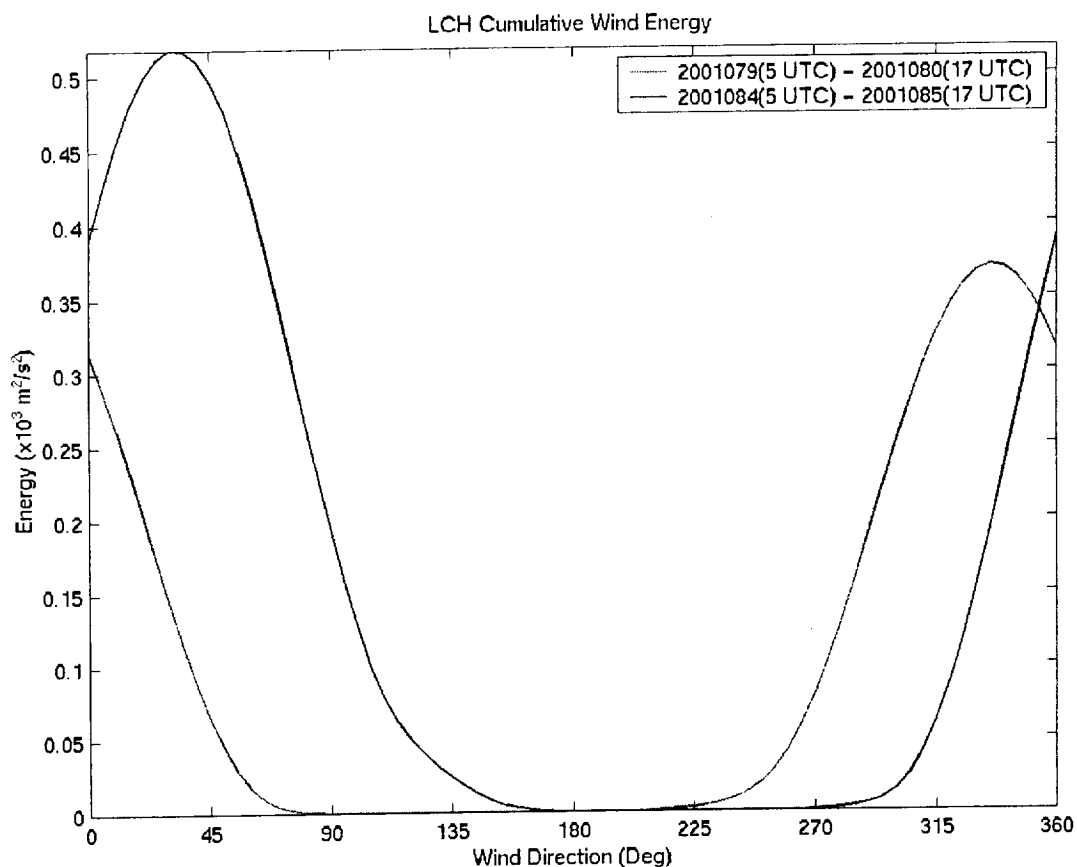


Figure 4. Cumulative surface wind energy for March 21 (red) and 26 (blue), 2001 from National Weather Service observations at Lake Charles, LA. Each profile is based on 36 hours of observations leading up to the time of MODIS overpass (about 1700 UTC on each day). March 21 is dominated by winds from the northwest while prevailing wind direction on March 26 is from the northeast. MODIS imagery in figure 3 shows the sediment plume response to these winds.

conditions. The MODIS 2300 km crosstrack swath in its sun-synchronous polar orbit provides coverage of the Louisiana coast about two out of every three days. The two 250 m resolution reflectance bands (650 nm and 860 nm) are providing new monitoring capability and insight on the spatial variability and temporal change of sediment distribution in the coastal zone. Figure 3 shows examples of sediment plume behavior on March 21 and 26, 2001. Winds from the northwest on March 21 (figure 4) drove the sediment plume towards the southeast out over the continental shelf. On March 26, winds from the northeast allowed the sediment plume to orient towards the west-southwest, the prevailing direction of longshore currents off the Louisiana coast.

D. Sediment accumulation along the prograding Chenier Plain coast of western Louisiana is useful as an indicator of sediment transport in the westward longshore current off Louisiana's Atchafalaya Bay region. The hypothesis that active cold front seasons (based

on wind energy) result in larger sediment transport downdrift is being tested. Measurements of shoreface accumulation (vertically measured at sediment burial pipes, horizontally measured using aerial photography) are correlated to a combination of wind energy and water level in a Geomorphic Impact Index, designed to predict coastal change along the western Louisiana muddy coast. Early efforts suggest the hypothesis has merit (figure 5); analysis of additional measurements is underway. Sediment pipe measurements suggest that vertical accumulation at the prograding coast is small once landform has been established. Gradual colonization of the new landform by vegetation fortifies the coastal progradation.

3. Year 2 Plans

- A. NWS surface wind observations and Army Corp of Engineers (ACOE) water level data will continue to be collected. These will be used for ongoing assessment of year to year variability in atmospheric forcing, and used to investigate the Geomorphic Impact Index as an indicator of sediment transport to the muddy western Louisiana coast.
- B. The spring 2001 LSU boat team in situ measurements will be co-registered with the MAS data and analyzed for SSC estimation coefficients. MAS imagery will be atmospherically corrected for this procedure. The MAS SSC estimates will be co-located with MODIS data for transfer of the algorithm to MODIS data. MODIS SSC estimates will be compared to new in situ measurements collected in year 2 for testing the algorithm.
- C. The MAS multiple pass imagery of March 21, 2000 will be co-registered and animated to estimate water motion vectors. With the SSC estimates, these will be turned into sediment transport estimates for the wind regime of that day. The sediment transport estimates will be compared to those of previous MAS overflights for insight on wind forcing and sediment transport.
- D. Knowledge of the sediments in the Atchafalaya Bay region will be used to estimate water leaving reflectance based on an existing forward model. The forward model calculation includes dependence on particle size, shape, and elemental content to predict the water leaving radiance. This investigation will be used to gain insight on the sensitivity of water leaving reflectance to the characteristics of suspended sediment. It is expected to provide insight on the sediment characteristics of river effluents around the world, a step towards expanding the MODIS sediment estimation capability to the global domain.
- E. Opportunistic ER-2 overflights of the Louisiana coast with MAS will be sought (at no cost to this project) for testing the SSC estimation algorithm using MAS and MODIS data. Repeat overflights will be sought for water motion and sediment transport estimation. Other ongoing activities with the NASA Airborne Science Program may provide these opportunities. If feasible, in situ ground truth by the LSU team will be collected during any overflights.

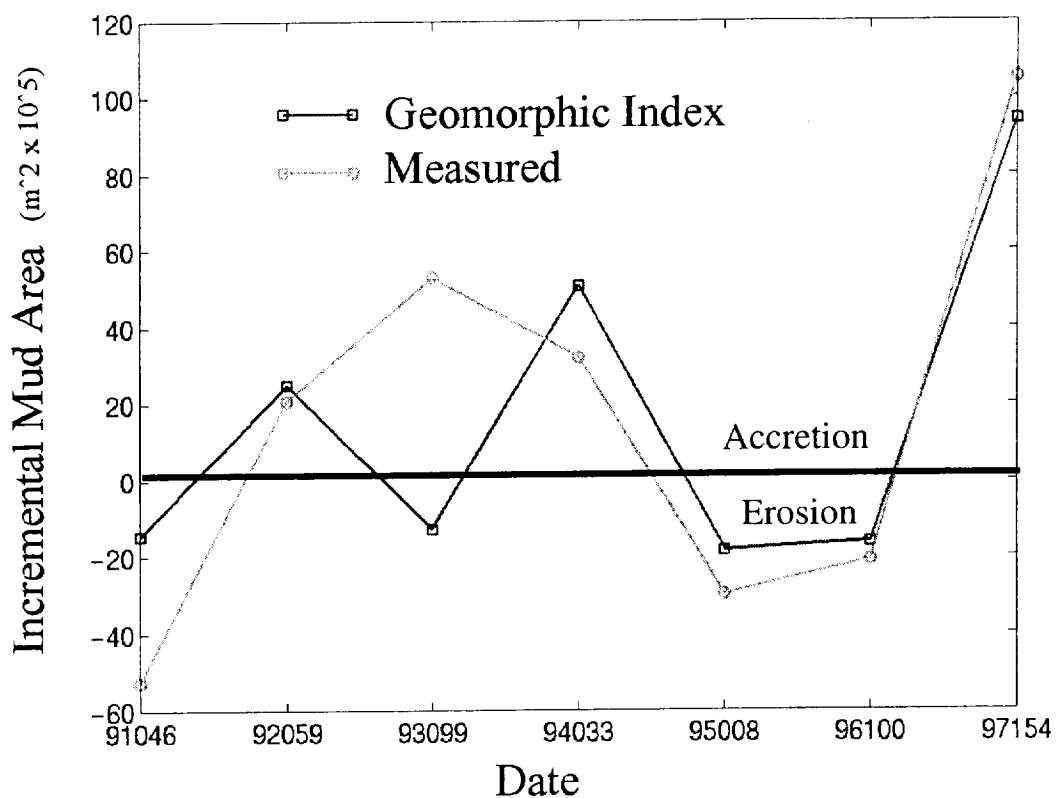
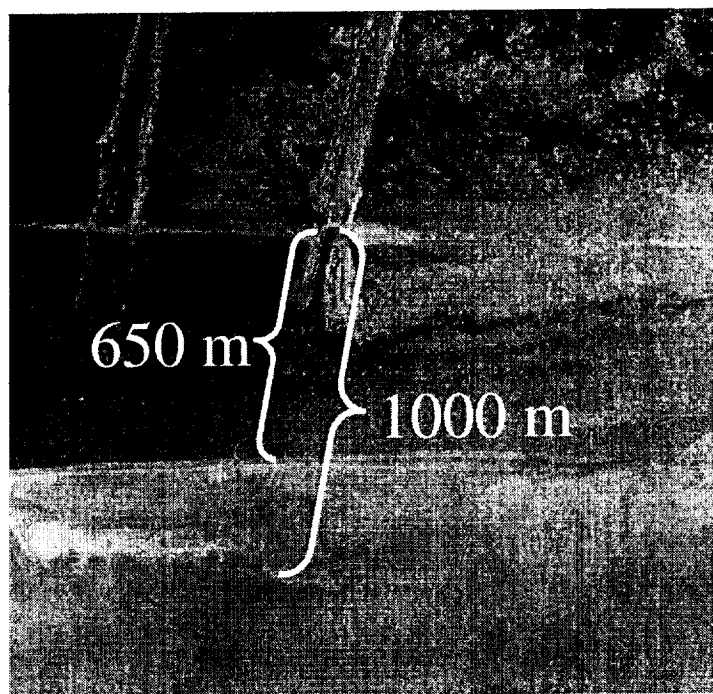


Figure 5. Surface wind energy and water level data are used with geomorphic measurements (e.g. false color IR aerial photography at top) to relate atmospheric forcing to coastal progradation of the western Louisiana coast (a “Geomorphic Impact Index”). The coupled wind and water level data are compared to land growth (or loss) measurements. It has been found that large southerly wind energy in the presence of high water levels shows skill in predicting geomorphic evolution (bottom).

- F. MODIS data sets will continue to be collected in clear sky conditions for monitoring sediment plume behavior. Estimates of SSC will be made on an ongoing basis to provide further insight into the annual cycle. Louisiana coast imagery will be staged on the CLAGEO web page at <http://cimss.ssec.wisc.edu/clageo/>.
- G. The University of Wisconsin and Louisiana State University investigators will meet for strategizing and collaborating on project activities and publications.

4. Publications

- Huh, O. K., N. D. Walker, and C. C. Moeller, 2001. Sedimentation along the Eastern Chenier Plain Coast: downdrift impact of delta complex shift. *J. Coastal Res.*, V17, No. 1, pp. 72-81.
- Moeller, C. C., M. M. Gunshor, O. K. Huh, N. D. Walker, W. P. Menzel, and L. D. Rouse, 2001. Recent monitoring of suspended sediment patterns along Louisiana's coastal zone using ER-2 based MAS data and Terra based MODIS data. Poster presentation at the 11th Conference on Satellite Meteorology and Oceanography, AMS, Oct 15-18, 2001, Madison, WI.

5. References

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- Noel, J., and D. Changnon, "A pilot study examining U.S. winter cyclone frequency patterns associated with three ENSO parameters". *J. of Climate*, 11, pp. 2152-2159, 1998.
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- Walker, N. D., and A. B. Hammack, "Impacts of winter storms on circulation and sediment transport: Atchafalaya-Vermillion Bay region, Louisiana, USA". *J. Coastal Res.*, Vol. 16, No. 4, pp. 996-1010, Fall, 2000.