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STUDY TITLE: Gulf of Mexico University Initiative: Studies of Long-Term Effects of Oil and Gas Production

REPORT TITLE: Satellite Based Assessment of the Mississippi River Discharge Plume's Spatial Structure and Temporal Variability

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KEY WORDS: Mississippi River; sediment; plume; satellite oceanography; river discharge; shelf circulation; sediment transport; atmospheric forcing; Loop Current

BACKGROUND: The Mississippi River is the major contributor of freshwater, sediments, pollutants, and nutrients to the northern Gulf of Mexico continental shelf and slope. These river inputs have important impacts on all aspects of continental shelf oceanography in the northern Gulf of Mexico. This study utilized five years of satellite information obtained by the NOAA Advanced Very High Resolution Radiometer (AVHRR) to quantify which areas of the continental shelf and slope of the Gulf of Mexico are subjected to discharges emanating from the Mississippi River on various time scales ranging from days to years. Correlation and multiple regression techniques were employed to identify the environmental forcing factors which most affect plume variability. Results of this study provide important information concerning suspended sediment distribution on the continental shelf, potential fate of riverborne contaminants, and circulation processes in the vicinity of the delta.

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OBJECTIVES: (1) To determine which areas of the continental shelf and slope in the Gulf of Mexico are most influenced by riverborne sediments and pollutants of the Mississippi River through the Balize delta; (2) to gain a better understanding of the environmental forcing factors controlling the distribution of river water and sediments in the northern Gulf of Mexico.

DESCRIPTION: Five years of digital data acquired by the Advanced Very High Resolution Radiometer (AVHRR) of the NOAA environmental satellites were used in this study. Reflectance information, derived from the visible channels, provided a quantitative means of defining the Mississippi River plume and was used as the primary database for this investigation. Sea surface temperatures, computed from the thermal infrared channels, were helpful in identifying the maximum spatial extent of plume waters and for the detection of Loop Current eddies and filaments.

The study area included much of the Gulf of Mexico, including but not limited to the area 25° to 31° N latitude, 86° to 98° W longitude. In year 1, a calibration algorithm, relating satellite reflectances to suspended sediment concentrations, was developed. The satellite image database was comprised of 113 NOAA-11 afternoon images, hand selected from over 3000 images obtained at the Earth Scan Laboratory (ESL), Coastal Studies Institute, Louisiana State University between July 1988 and October 1993. The image database was used to investigate the spatial and temporal variabilities of plume morphology on various time scales. The environmental variables included in the study were river discharge, hourly wind data from the Burrwood C-man station, tidal phase and tidal range. The relationships between five plume measurements and these environmental variables were explored using correlation and multiple regression techniques.

SIGNIFICANT CONCLUSIONS: Individual satellite images revealed that the Mississippi River sediment plume ranged in size from 822 km^2 under low discharge conditions to 7699 km^2 under high discharge conditions. The sediment plume exhibited annual variability which was related to the annual river discharge cycle. The average plume for October 1989, a low discharge month, measured 2058 km^2, less than 1/2 the area of the average plume for March/April 1989, during the spring flood. Although the time-averaged plume was found to be closely related to large variations in river discharge, tremendous day-to-day variability was observed which was unrelated to discharge.

The correlation and multiple regression analyses, revealed wind forcing to be the most important environmental forcing factor, after river discharge. Southeasterly winds confined the plume to the continental shelf and nearshore zone. The presence of westerly winds maximized the areal extent of the sediment plume west of the Balize delta throughout the year. During winter, northerly winds associated with eastward-moving winter storms, increased the areal extent of the Mississippi plume and maximized the offshore dispersal of the suspended sediments. The presence of southerly and westerly winds increased the areal extent of the plume east of the delta as well as the extreme eastward extent of the plume.

This study has demonstrated the all-important role of wind forcing to the fate of river sediments from the Mississippi River delta in the northern Gulf of Mexico. In most cases, the plume's response to wind forcing was maximized after 12 hours. The multiple regression model results were encouraging and demonstrate that the plume's areal extent and surface morphology are somewhat predictable from readily accessible environmental variables.

STUDY RESULTS: The Mississippi River sediment plume was found to range in size from 822 km^2 under low discharge conditions to 7700 km^2 under high discharge conditions. An investigation of the variability of the sediment plume on the annual and interannual time-scales revealed that the time-averaged plume varied in size with large changes in river discharge. However, tremendous short-term variability in plume area and morphology occurred over a time span of days.

Results of the statistical analyses revealed that the size and morphology of the Mississippi River sediment plume is influenced by several environmental forcing factors. The most important factors determining plume area were found to be river discharge, prevailing winds 12 hours prior to image acquisition, and wind speed. Tidal phase and range explained very little of the variability in plume area or morphology.

Multiple regression techniques were employed in an attempt to use the relationships observed between the plume parameters and the environmental variables to help establish predictive models for plume variability. More success was obtained in predicting plume area than plume length. The best model was obtained for the eastern area from May through September when 70% of plume variability was explained by river discharge and local wind behavior. Plume area was found to increase in size under conditions of high river discharge and southerly or westerly winds. The largest sediment plumes east of the delta were observed after exposure to at least 12 hours of strong southwesterly wind forcing (8-10 $m\ s^{-1}$) when river discharge was high. In predicting the eastern extent of the sediment plume, local wind behavior was found to be more important than river discharge. The enormous sediment plume observed east of the delta on August 1993, subsequent to the Great Flood of 1993, provides an excellent example of how efficiently the surface sediment is dispersed towards the east under prolonged exposure to southerly and southwesterly winds. In this extreme case, so much Mississippi River water flowed onto the continental shelf east of the delta that a detectable amount reached the Florida Keys and the east coast of the United States, entrained by southward-flowing currents associated with the eastern edge of the Loop Current.

The second best predictive model was obtained for the western plume area during the summer months. In this case, 64% of plume variability was explained by river discharge, wind speed, and the east-west wind component. The western plume area was maximized during summer under conditions of high river discharge and weak to moderate westerly winds. During winter, a prevalence of northerly or westerly winds maximized sediment dispersal west of the delta. Strong northerly winds, associated with eastward moving winter storms, maximized the offshore transport and dispersal of plume water and sediments.

STUDY PRODUCTS: Walker, N.D., G. Fargion, L.J. Rouse, and D. Biggs, 1994. Circulation of Mississippi River water discharged into the northern Gulf of Mexico by the Great Flood of Summer 1993. EOS, Transactions, American Geophysical Union, V. 75, no. 36, 409-415.

Walker, N.D., O.K. Huh, and L.J. Rouse, Jr., 1994. Satellite detection of high velocity shelf/slope currents in the northern Gulf of Mexico and interactions with two anticyclonic Loop eddies. Journal of Geophysical Research. Submitted.

Walker, N.D. 1994. Satellite based assessment of the Mississippi River discharge plume's spatial structure and temporal variability. OCS Study MMS 94-0053, Dept of the Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans, La.

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