STUDY TITLE: Coastal Marine Environmental Modeling: Part III

REPORT TITLE: High-Resolution Integrated Hydrology-Hydrodynamic Model: Development and Application to Barataria Basin, Louisiana

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BACKGROUND: The Barataria Basin, a bar-built estuarine system located directly west of the Mississippi Delta, has been experiencing a significant land loss, especially since the leveeing of the Mississippi River for flood control purposes in early 20th century. Recent efforts to alleviate the land loss problem includes the construction of man-made freshwater diversion structure in order to divert river water as well as its associated suspended sediments from the Mississippi River into the Barataria Basin. A major consequence of man-made freshwater diversions in estuarine environments such as Barataria Basin is its impact on salinity distribution. Salinity gradients, such as those within Barataria and Terrebonne estuaries have a significant influence on the distribution of estuarine flora and fauna. In order to establish modeling capability usable for responsible management purposes, an integrated hydrology-hydrodynamic model, that simulates local runoff and circulation inside the bay, is needed.

OBJECTIVES: To establish an integrated hydrology-hydrodynamic model of Barataria Basin that can be useful for management purposes. The model should; 1) account for local hydrological cycle including evaporation and precipitation, in particular local runoff from the surrounding drainage basins; 2) be high-resolution in order to simulate very accurately salinity changes in the complex network of channels and bayous within the basin; 3) be thoroughly tested and calibrated against real observed data to be useful. The direct contribution of this project would be to demonstrate feasibility of an integrated hydrology-hydrodynamic model that can be used to simulate anticipated changes in bay salinity distribution in response to various diversion scenarios within the framework of various local weather and climatic conditions.

DESCRIPTION: Development of a high-resolution integrated hydrology-hydrodynamic model of Barataria Basin is presented. First, a hydrology model that explicitly accounts for the local hydrological cycle over the surrounding drainage basins for the Barataria Basin is developed. Using observed precipitation and estimated evaporation over the surrounding drainage basins, the hydrology model provides estimates of local runoff. The hydrology model is coupled to a high-resolution (O (100m)) two-dimensional depth-integrated hydrodynamic model of the Barataria Basin in order to simulate the hydrodynamic response of Barataria Basin to hydrological, tidal, and wind forcing. The coupled model was used to simulate the flood event during tropical storm Allison in June 2001 that resulted in significant rise in sea-level heights especially in the upstream region of the basin, thus, providing a rare opportunity to test the model. The integrated model was also used to simulate a typical dry summer condition, namely the 30-day period during the summer of 1999. The model was then used to simulate potential impact of freshwater diversions at Naomi, West Pointe à la Hache, and Davis Pond.

SIGNIFICANT CONCLUSIONS: A high-resolution (O (100m)), integrated hydrology-hydrodynamic model of the Barataria Basin can be developed to simulate explicitly local hydrological cycle over the surrounding drainage basin and hydrodynamics within the basin in response to hydrological, tidal and wind forcing. The integrated model appears to be able to simulate the observed sea-level variations during the flood event due to the tropical storm Allison in June 2001. The model appears to do reasonable job of simulating time evolution of salinity fields inside the bay during a typical dry summer condition, namely the 30-day period during the summer of 1999. Model simulations to depict potential impact of freshwater diversions at Naomi, West Pointe à la Hache and at Davis Pond suggest that even at reasonable diversion rates, notable impacts on water level and salinity should be observable. The results of this study highlight the need to use high model resolution, sufficiently high enough to resolve many of the important complex morphological features of the basin in order to achieve reasonable simulation capability of salinity distribution for morphologically complex basins such as Barataria Basin.

STUDY RESULTS: First, a hydrology model that explicitly accounts for the local hydrological cycle over the surrounding drainage basins for the Barataria Basin is developed. Using observed precipitation and estimated evaporation over the surrounding drainage basins, the hydrology model provides estimates of local runoff.

The hydrology model is coupled to a high-resolution (O (100m)) two-dimensional depth-integrated hydrodynamic model of the Barataria Basin in order to simulate the hydrodynamic response of Barataria Basin to hydrological, tidal, and wind forcing. A flood event during tropical storm Allison in June 2001 resulted in significant rise in sea-level heights especially in the upstream region of the basin, thus, providing a rare opportunity to test the model. It is shown that the integrated model is capable of capturing a significant portion of the observed sea-level variations during the flood. The integrated model was also used to simulate a typical dry summer condition, namely the 30-day period during the summer of 1999. Despite the relatively crude salinity initial condition used (based on only eight observations), the model appears to do reasonable job of simulating time evolution of salinity fields inside the bay. The model was then used to simulate potential impact of freshwater diversions at Naomi, West Pointe à la Hache, and Davis Pond. Those simulation runs suggest that even at reasonable diversion rates, notable impacts on water level and salinity should be observable in the multiply connected channels through the marsh in the vicinity of operating diversion structures within several days of freshwater release, and after 15 days or so even in the downstream regions of the basin. The largest impact of diversions should be felt in the mid-bay region where the ambient salinity gradients are the steepest. It is notable that the diversion signal propagates at shallow-water wave speed, like a tidal bore, due to its mass flux, that is much faster than the diffusion time-scale suggested for mixing of two water masses in estuaries (e. g., Elliot and Reid, 1976). It is interesting to note that even after day 30, some isolated areas still remain without noticeable influence of the diversion. Those observations highlight the need to use high model resolution, sufficiently high enough to resolve many of the important complex morphological features of the basin in order to achieve reasonable simulation capability for morphologically complex basins such as Barataria Basin.

STUDY PRODUCTS: Inoue, M. and W. J. Wiseman, Jr. 2000. Transport, stirring and mixing process in a Louisiana estuary: A model study. Estuarine. Coastal and Shelf Science, 50:449-466.

Park, D., M. Inoue, and W. J. Wiseman, Jr., 2000. Wind, tide, and buoyancy-driven flow in Barataria Bay, LA. Extended abstracts proceedings volume, edited by C. T. Friedrichs and A. Valle-Levinson, the 10th International Biennial Conference on Physics of Estuaries and Coastal Seas. 7-11 October 2000, Norfolk, Virginia, SRAMSOE Report No. 366, Virginia Institute of Marine Science, Gloucester Point, VA, U. S. A.

Park, D., M. Inoue, and W. J. Wiseman, Jr., 2001. Hydrodynamics and freshwater dispersion within Barataria Basin. ERF2001: An Estuarine Odyssey, Conference Abstracts, 106.

Park, D. H. 2002. Hydrodynamics and freshwater dispersion within Barataria Basin. Ph.D. dissertation, Louisiana State University, Baton Rouge, Louisiana. 107 pp.

Park, D., M. Inoue and W. J. Wiseman, Jr., 2002. Salinity effects of riverine diversions to Barataria Basin, a bar-built estuary. Abstract submitted to the 11th International Biennial Conference on Physics of Estuaries and Coastal Seas in Hamburg, Germany.

Park, D., M. Inoue and W. J. Wiseman, Jr., 2002. A high-resolution integrated hydrology-hydrodynamic model of the Barataria Basin system. Abstract submitted to OCEANS 2002 MTS/IEEE meeting held in Biloxi, Mississippi, October, 2002.

Inoue, M., D. Park, D. Justic, and W. J. Wiseman, Jr., 2004. A High-Resolution Integrated Hydrology-Hydrodynamic Model of the Barataria Basin System. Abstract submitted to 7th International Marine Environmental Modeling Seminar to be held in Washington, DC, October 19-21, 2004.