Monitoring and Predictive Modeling of Water Temperatures in the Laguna Madre

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November 9, 2007

Executive Summary

The study focuses on the measurement and predictability of cold water events in the Laguna Madre. These events have previously resulted in significant fish mortality. This study seeks to better understand the dynamic and forcings of the water column temperatures during these events as well as to develop a predictive model that could help implement possible preventive action ahead and during the cold water events. The objective of the study were to (1) install water temperature profiling stations in and around the 'land cut' area of the Upper Laguna Madre, Texas, (2) test, monitor, maintain, and analyze the data from the water temperature profiling stations, (3) develop a water temperature predictive model particularly for the prediction of cold water events i.e. events resulting in water temperatures at or below 45F and (4) implement the model on the world wide web to make its predictions accessible to decision makers.

Two measuring stations were installed at existing platforms to leverage existing infrastructure of the Texas A&M University-Corpus Christi (TAMUCC) Division of Nearshore Research (DNR) and the Texas Coastal Ocean Observation Network (TCOON). One set of instruments was installed at the TCOON Rincon station and the other set of instruments was installed at the former TCOON El Toro Island station. Water temperatures at approximately 3', 6', 9' and 12' within the water column were measured hourly starting respectively on February 27, 2006 and December 13, 2005. The temperature time series are available on the World Wide Web through the DNR website (http://lighthouse.tamucc.edu).

Data quality was excellent at the Rincon station and is the main data set used for the analysis. Problems were encountered at the Land Cut station. This later data set is discussed in the report and mostly used to complement the data collected at the Rincon station. Several cold water events were monitored during the study including a January 2007 event with water temperatures decreasing from 22.5°C down to 4.6°C in 60 hours. Throughout the study period the water temperatures were found to be mostly homogenous, i.e. temperatures within a 0.5°C range throughout the water column. A small moderating effect at the bottom of the channel, i.e. for the 12' sensor, was observed during sharp temperature rises. Bottom temperatures during these events stayed cooler by 1°C to 2°C up to 5°C but the temperature gradients always rapidly disappeared at the most within 8 hours. This moderating effect at the bottom of the Laguna Madre was

however not observed during the sharp temperature decreases associated with frontal passages. The results of this study indicate a homogeneous temperature throughout the water column during cold water events. Further monitoring could attempt to measure temperatures in the muddy bottom of the Laguna Madre to confirm that there is indeed no location within the water column where marine life may seek warmer temperatures during cold water events. Temperatures in shallow waters could also be recorded to investigate if significantly lower temperatures are reached at such locations. Comparing temperature records at both project stations and other DNR stations show a mostly homogeneous temperature distribution throughout the Laguna Madre with variability observed in the deeper waters of Corpus Christi Bay northward the Brownsville ship channel southward and at the Mansfield station which is linked to the Gulf of Mexico by a smaller ship channel.

The water temperature predictive model was designed and implemented using Artificial Neural Network (ANN) methodology. The methodology had been previously used for the modeling of water levels along the Texas Coast and is particularly well suited to model non linear systems when large data sets are available. The performance of the ANN model was also compared with a multi linear regression approach to confirm the advantage of the selected methodology. The model was developed for the Bird Island Station in the northern portion of the Laguna Madre because of the considerably longer time series and number of cold events available for that station. Small modifications were made to adapt the model to the project stations (described later in this summary). A statistical analysis highlighted that air temperature is by far the main forcing for water temperatures in the Laguna Madre away from ship channels. The statistical analysis also identified the relative importance and time lags for the other forcings to the system. Given the importance of the air temperature forcing, air temperature predictions were included in the model. The model was first designed using measurements as forecasts (perfect prog approach) and then tested with actual predictions provided by the Corpus Christi Weather Forecasting Office (CCWFO). For the present operational model air temperature predictions are being sent 4 times a day as part of a broader collaboration with CCWFO. The predictions are presently extracted from the National Centers for Environmental Prediction (NCEP) Nonhydrostatic Mesoscale Model (NMM) recently integrated within the Weather Research and Forecasting (WRF) framework from the North American Model (NAM-WRF). The NAM-WRF air temperature predictions are adjusted with a linear transformation for air temperatures below 18°C to improve model performance for the project stations (MOS approach).

A short term model was designed for 3 and 12 hour forecasts and a longer term model was constructed for 24 and 48 hour forecasts. The models were designed following a stepwise method, consecutively adding possible inputs and then comparing the average absolute error of the models. Both models included the previous 26 hours of water temperature at Bird Island and air temperature forecasts. The short term model inputs also consisted of the previous 22 hours of air temperature measurements and the past 16 hours of a 24 hour time stamp. Long term model inputs included the previous 16 hours of air temperature measurements along with the most recent available water temperature measurement at the nearby Gulf of Mexico station of Bob Hall Pier.

Performance was analyzed for both the perfect prog approach for several test years and using a historical data base of actual WRF-NAM predictions for a shorter time span. Using the perfect prog approach yearly average absolute error ranged from about 0.3°C for 3 hour predictions to about 0.7°C for 12 hour predictions, to about 1.0°C for 24 hour predictions and 1.7°C for 24 hour predictions. Year to year variability increased from up to 0.2°C for 3 hour predictions to up to 0.6°C, 0.14°C and 0.23°C for respectively 12 hour, 24 hour and 48 hour predictions. Cold water performance was analyzed for four events between 2003 and 2007 during which cold water temperature reached 8°C or below. The performance during these events was computed using past WRF-NAM predictions. During the cold events the mean average absolute error was lower than 1°C for all predictions increasing from 0.1°C for 3 hour predictions to 0.9°C for the longer prediction times. While the number of cold events with WFR-NAM predictions available is still small a mean average absolute error of 1°C is likely a good estimate of the average performance of the model for cold events. The cold event performance was homogeneous across the temperature range with variability and performance dominated by the accuracy of the WRF-NAM atmospheric predictions, i.e. the performance of the model will mostly depend on how well the atmospheric models capture the future dynamic of the cold fronts.

While the model was developed for the Bird Island TCOON station because of the considerably longer time series available, the study shows no significant biases or lags between that station and the project stations. Consequently the Bird Island model can be considered valid for the Upper Laguna Madre, at least for the Intracoastal Water Way and nearby waters. Water temperatures near the ship channels in the northern and southern ends of the Laguna Madre as well as the Port Mansfield station are affected by the link with the Gulf of Mexico and higher temperature lows are observed. Water temperatures in the very shallow portions of the Laguna Madre are also expected to exhibit differences.

The performance of the model for cold water event was also evaluated based on its accuracy to detect an event. Based on the available data if a cold event is not predicted by the model, the chances of such event taking place are virtually nil. Once an event is predicted, the chances that the event will indeed take place varies depending on the extent of the forecast from 90% for 3 hour predictions to 85%, 83% and 64% for 12, 24 and 40 hour predictions. If an event is not observed the chances that one was predicted are virtually nil and if a cold water event takes place there is a 70% to 80% chance that the event was indeed predicted. The operational model was implemented as part of the DNR/TCOON website (http://lighthouse.tamucc.edu/) Forecasts portion and is presently available at the following link: http://lighthouse.tamucc.edu/Forecasts/HomePage.

Continuous monitoring of the water temperature gradient at the station locations is highly desirable particularly to capture more cold water events. Additional events, particularly colder events would be helpful to better define the performance of the model during these conditions and confirm the absence of a vertical temperature gradient. Other recommendations for possible other locations south of the present locations, in shallower waters or in the muddy Laguna Madre bottom are included in the report. The use of other machine learning based techniques such as random forest modeling could prove helpful in improving predictions specifically during cold events.