13.7 USE OF THE NCEP MESOETA DATA IN A WATER LEVEL PREDICTING NEURAL NETWORK

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1. INTRODUCTION

Accurate water level forecasts are of vital importance along the Texas coast as the waterways of the northern Gulf of Mexico play a critical economic role for a number of industries including shipping, oil and gas, tourism, and fisheries. Astronomical forcing or tides are well tabulated. However water level changes along the Gulf coast are often dominated by meteorological factors which impact is often larger than the tidal range itself (e.g. Cox et al. 2002) and unaccounted for in present forecasts. A comparison between water level forecasted by the tidal charts and actual measurements is presented for Port Aransas, Texas in Figure 1. The National Oceanic and Atmospheric Administration (NOAA) stated that “presently published predictions do not meet working standards” when assessing the performance of current predictions, a parameter closely related to water levels, for regular weather conditions in Aransas Pass and Corpus Christi Bay (NOAA 1991, NOAA 1994). A prototype model based on the use of Artificial Neural Networks (ANN) (Tissot et al. 2002) is presently developed at Texas A&M University-Corpus Christi (TAMUCC) Conrad Blucher Institute (CBI) in collaboration with the Corpus Christi National Weather Service (NWS) Weather Forecast Office (WFO). The model takes into account weather forcing and produces short to medium term up to 48 hours water level forecasts. Inputs to the model include recent measurements of water levels, wind speeds, wind directions, and barometric pressures collected by the Texas Coastal Ocean Observation Network (TCOON), which consists of 60 weather platforms from Brownsville to the Louisiana border (Michaud et al. 2001). An important input to the model is a set of weather forecasts including forecasted wind speeds and wind directions extracted from the National Center for Environmental Predictions (NCEP) Eta-12 model. The Eta-12 model and the application of its forecasts to the ANN based water level forecasting model is the focus of this work and is described in the later sections.

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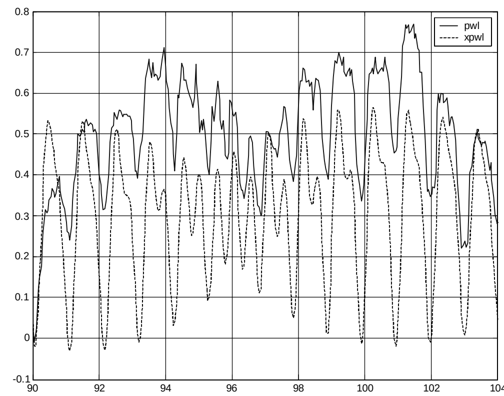

Figure 1. Comparison of water levels at the TCOON Port Aransas station as measured (—) and as forecasted by the tidal charts (---). The y-axis represents the water elevation in meters relative to Mean Lower Low Water and the x-axis represents 1998 Julian days.

2. NCEP MESOETA MODEL AND ITS APPLICATION TO THE TEXAS COAST

The NOAA NCEP/Environmental Modeling Center (EMC) developed the Eta-12 model (herein the Eta), which is a limited-area, numerical atmospheric model. It integrates the primitive hydrostatic equations in three dimensions. The model uses spherical coordinates in the horizontal. The vertical coordinate is known as the “eta”, which is achieved by modifying the terrain following sigma coordinate. The advantage of the eta coordinate is that the surfaces are quasi-horizontal, thus avoiding errors associated with steep slopes of the coordinate surfaces (Mesinger 1984) and hence improving the solution over highly variable topography such as over the Western United States. It uses the Arakawa E-grid in the horizontal to minimize errors associated with geostrophic adjustment and forcing due to topography and the Lorenz grid in the vertical. The resolution is 12 km in the horizontal with 60 layers in the vertical. The domain is 106 x 80 of latitude x longitude, centered over the central United States.

Each Eta forecast model run is initialized by the Eta Data Assimilation System (EDAS), a continuous process whereby short-term (3-hour) Eta runs are performed within a longer pre-forecast data assimilation period. At the end of each short-term run, the 3-

Dimensional Variational Analysis (3DVAR) (Parrish et al. 1996) technique is used to create an analysis. In creating the analysis, 3DVAR assimilates a myriad of high-frequency observations within 1.5 hours of the analysis time. EDAS is fully cycled, thus atmospheric variables (temperature, wind, moisture), soil parameters, turbulent kinetic energy, and cloud water are obtained from the analysis of the previous EDAS. The lateral boundary condition involves extrapolation or prescription along a single outer boundary line, followed by a "buffer" row of points of four-point averaging, with no relaxation or diffusion (Messinger 1977). The surface is parameterized with topography and a multi-layer land surface model (e.g. Mitchell et al. 1999). For the Planetary Boundary Layer, the Mellor-Yamada level 2.5 turbulence closure (Mellor and Yamada 1982) is used. This is a local scheme which improves the emulation of sub-grid scale vertical mixing. The Betts-Miller-Janic scheme is used for cumulus parameterization (Betts 1986; Betts and Miller 1986; Janjic 1994). Radiation is provided by the GFDL radiation scheme (i.e. Fels and Schwarzkopf 1975). The grid-scale microphysical scheme is the relatively new Eta grid-scale cloud and precipitation scheme released on 2001 or EGCP01 (Rogers et al. 2001) which predicts changes in six species of water. In February 2002, a change was made to the treatment of thermal conductivity of snow cover in the model to reduce cold bias in the 2-m air temperature over areas with snow cover. Otherwise, no changes were made to the Eta since November 2001. NCEP plans to make the next change to the EDAS/Eta in November 2002, with an Eta 3DVAR and assimilation upgrade.

Each day, NCEP conducts four separate EDAS/Eta modeling system runs. For each run, the output is transmitted to National Weather Service (NWS) Weather Forecast Offices (WFOs) via the AWIPS (Advanced Weather Interactive Processing System) Satellite Broadcast Network (SBN), in the GRIB (GRIdded Binary) file format. This gridded model data is then written into netCDF-formatted files where the data is also mapped into several numeric grids of varying spatial resolution and domain size. Every six hours surface data is sent to TAMUCC-CBI from the netCDF files containing Eta output mapped to AWIPS Grid 215 (Dey 1998) with a horizontal grid spacing of 20 km. Eta surface output contained on grid 215 is referred to as the "MesoEta" output. A set of about 40 locations on the Gulf coast, in the Gulf of Mexico and inland were selected. The locations of the selected stations are displayed in Figure 4. 10-meter MesoEta forecasts are used as the inputs to the ANN based water level forecasting model.

3. ANN MODEL FOR WATER LEVEL FORECASTS

The concept of neural networks was developed in the sixties by scientists attempting to emulate the functioning of the brain. Neural networks became an effective artificial intelligence technique in the late eighties and early nineties with the development of efficient training techniques. The application of neural networks to water level forecasting consists in designing and training a network that, given a time series of water levels, weather observations and forecasts (wind and tidal forecasts), accurately predicts the next water levels for a period of one, six, twelve, twenty four hours or more (Tissot et al. 2002). The typical structure of the neural networks used in this work is illustrated in Figure 2 and includes one hidden layer and one output layer.

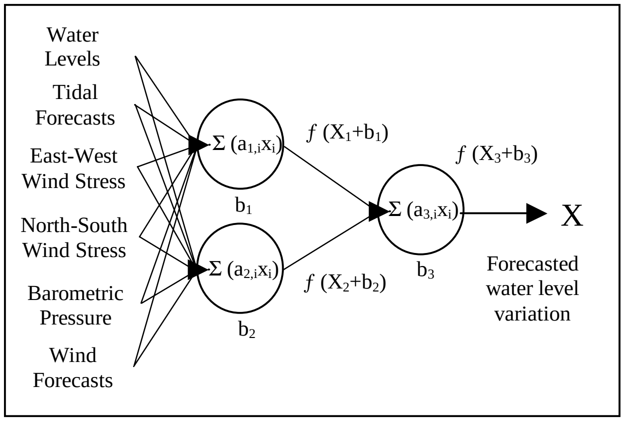

Figure 2. Schematic of the type of neural network model applied to the problem of water level forecasting including inputs, outputs, and neural network topology.

The elements of the input decks are chosen to track the variation of the main forcing functions to the changes in water levels. They consist of time series of previous water levels, barometric pressures, wind speeds, and wind directions. Also included as part of the input decks are tidal forecasts presently computed using Xtide 2 (Hopper 2000). A software to compute tidal coefficients and make tidal forecasts for all TCOON stations with enough water level history is presently under development (Mostella et al. 2002). The tidal forcing is included in the model by using water level differences between measured and forecasted water levels and the water levels predicted by the tide tables. The changes in the resulting water level differences are then a direct function of the meteorological forcing. Also this methodology allows for the implicit inclusion of long-term effects such as steric effects as part of the input to each short-term forecast. The neural network models are trained using a backpropagation algorithm and all computations are performed within the MATLAB 5.3/version 3 of the Neural Network Toolbox (The Math Works Inc. 1998) computational environment running on a Pentium IV PC. The real-time model will be implemented as part of TCOON with its forecast automatically updated on the World Wide Web and possibly other communication media to facilitate access to the forecasts.

4. INITIAL ANN MODEL RESULTS

The ANN model has been initially developed in hindcast mode using previous measurements to replace the MesoEta forecasts (Cox et al. 2002 and Tissot et al. 2002). It was shown (Cox et al. 2002) that the model is not overly sensitive to the accuracy of the wind forecasts. In operational mode historical wind measurements will be replaced by the actual MesoEta wind forecasts. Another paper presented at this conference shows generally good agreement between MesoEta forecasted winds and measured winds (Stearns et al. 2002). The model was tested in hindcast mode for Galveston, Texas (Cox et al. 2002, and Tissot et al. 2002) as well as Port Aransas, Texas. Figure 3 displays a comparison between measured water levels and water levels forecasted by the tidal charts and the ANN model (24 hour forecasts) (Drikitis 2002). The model was trained over a full year of data (1997) and applied to the 1998 data set. As can be seen in the figure, the ANN model is able to capture the future effect of frontal passages and greatly improve the accuracy of the water level forecasts for a 24-hour forecast.

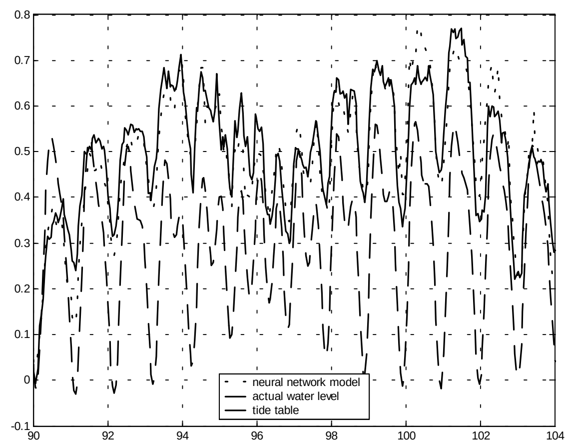

Figure 3. Comparison of water levels at the TCOON Port Aransas station as measured (—), as forecasted by the NN model (24 hr forecasts, …) and as forecasted by the tidal charts (**---**). The y-axis represents the water elevation in meters relative to Mean Lower Low Water and the x-axis represents 1998 Julian days.

5. CONCLUSION

NCEP MesoEta forecasts for Texas and the Gulf of Mexico are combined with TCOON measurements to form the input of a model forecasting water levels along the Gulf Coast. The model is based on the use of Artificial Neural Networks and has shown good results up to 48 hours in hindcast mode using previous wind measurements as part of the input to the model. Given the good overall correlation between MesoEta Forecasts and TCOON measurements the model is expected to perform well in real time and provide accurate short to medium term water level forecasts up to 48 hours for coastal users.

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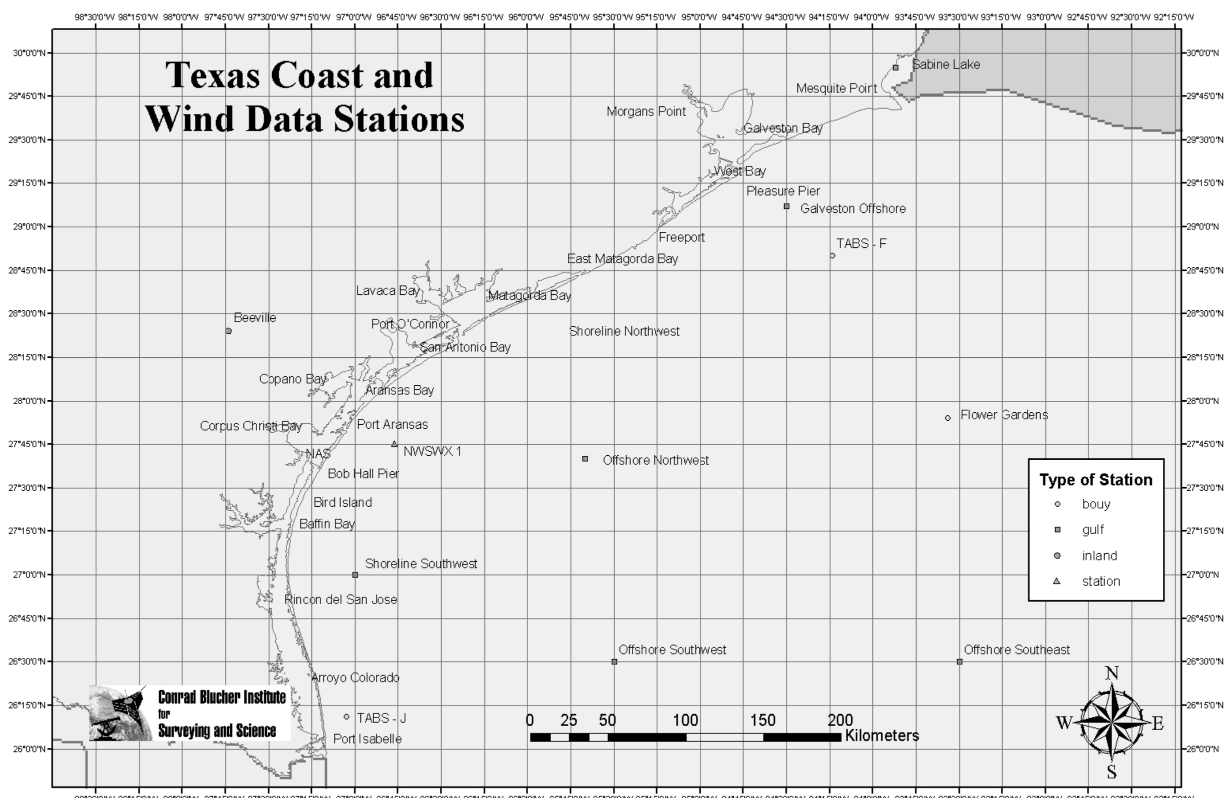

Figure 4. Locations for which MesoEta forecasts are extracted by CCNWS and sent to TAMUCC-CBI be part of the input to the ANN model forecasting future water levels.