Estimation of Hurricane Parameters using Artificial Neural Network

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Abstract

In this study, an Artificial Neural Network (ANN) model has been developed and applied to estimate hurricane central pressure CP and Radius to Maximum Winds (R_{Max}). The network has been trained and verified using historical dataset collected from the National Hurricane Centre (NHC). Promising correlation has been observed in data during model training and validation. The successful application of the neural network provides an efficient tool to estimate important hurricane parameters typically used in storm surge calculations. For the application and demonstration of the model, the historical hurricanes which influenced on the Gulf of Mexico (GOM) coast have been used. However, this methodology can be adopted easily to study storm surge in other area also.

1. Introduction

Hurricane intensity or pressure scale deficit (CP) is generally modelled as a function of the relative intensity and thermodynamic and atmospheric environmental variables including sea surface temperature, tropopause temperature, and vertical wind shear [1]. Several models are available to quantify this hurricane intensity. Most of these models are based on regression and probabilistic characterization, which include SHIFOR [2], GFDL [3] and SHIPS [4] [5] [6]. Law & Hobgood [7] suggested that different models should be used to consider different hurricane intensity and different stages during a hurricane life cycle rather than using one regression model for a particular forecast interval. They presented a new statistical model to consider multiple regression equations to forecast future 24-h wind speed and central pressure changes. Su et al. [8] developed a data mining model to forecast hurricane intensities using a generic algorithm (GA). It showed that the model gives better prediction than that of SHIPS.

Radius to Maximum Winds (R_{Max}) is an important parameter for hurricane risk prediction, particularly for storm surge and wave modelling [1] [9][10]. In order to estimate the R_{Max}, several studies have been conducted. Vickery & Wadhera [10] developed two statistical models for the Gulf of Mexico and Atlantic Ocean hurricanes, respectively, which are a function of hurricane intensity and latitude. Other statistical models are also available which do not capture well nonlinear behaviours [11].

In order to overcome the inherent limitations of the statistic models, the neural networks have been introduced in various areas dealing with time series forecasting. Use of neural network has several advantages. First, field recoded data can be directly used without simplification because neural networks are less sensitive to the error term assumptions and can tolerate noise and chaotic components [12]. Most importantly, it can simulate nonlinear behaviours.

In this study, an Artificial Neural Network (ANN) model has been developed and applied to estimate hurricane central pressure CP and Radius to Maximum Winds (R_{Max}). The network has been trained and verified using historical dataset collected from the National Hurricane Centre (NHC). The successful application of the neural network provides an efficient tool to estimate important hurricane parameters typically used in storm surge calculations.

2. Data

For neural network's training and verification, the historical best track data from 2001 to 2008 were collected from National Hurricane Center (ftp://ftp.nhc.noaa.gov/atcf/archive/). During this period, total 130 tropical storms were issued in North Atlantic Ocean, 63 tropical storms of them were strengthened to hurricanes. Figure 1 shows a sample of the storms used for training the neural network. For the neural network training and verification, 130 dataset were used. Among them 27 dataset were used for validation, and 27 dataset for the testing.

The estimated CP and R_{Max} values for all dataset are compared with target data using statistical correlation (R^2 and RMSE). Figure 2 shows the comparison between estimated and observed CP. Very good correlation in CP is observed in data during model training and validation. Figure 3 shows the comparison between estimated and observed R_{Max}. Again satisfactory correlation in R_{Max} is observed in the trained ANN model.

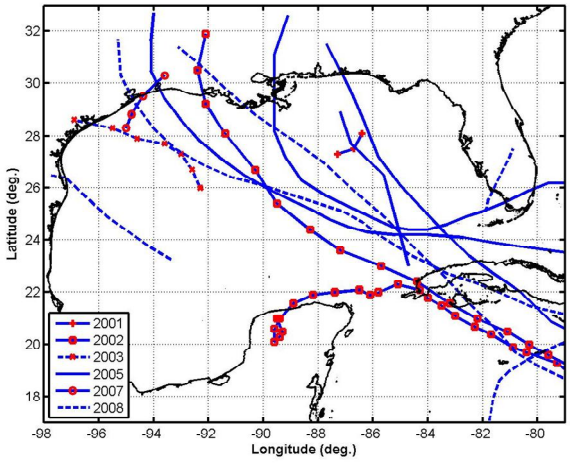

Figure 1: Data used in this study for Neural Network testing, training and verification.

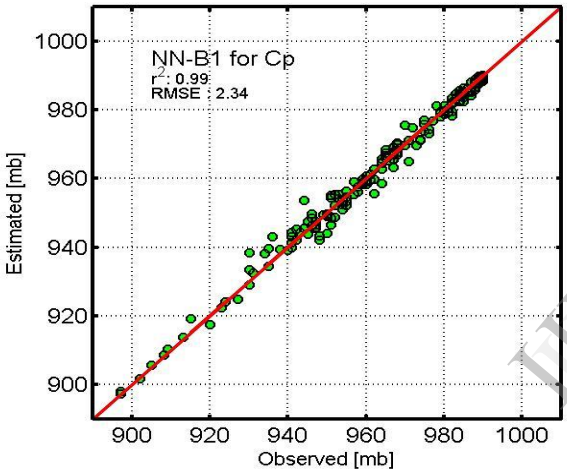

Figure 2: Correlation between observed and estimated central pressure (CP).

3. Application of ANN

To test the neural network model, four historical hurricanes which influenced on the Gulf Coastal areas were chosen: Dennis (2005), Katrina (2005), Rita (2005), and Gustav (2008). From the best track data of each hurricane, input data for the neural network (CP and R_{Max}) are used and later estimated outputs are compared with the observed data. Figures 4 and 5 show results for hurricane Dennis and Katrina. These figures demonstrate model performance in predicting Cp and R_{Max} values in real time using neural network. Overall, the results look very promising for application in storm surge models.

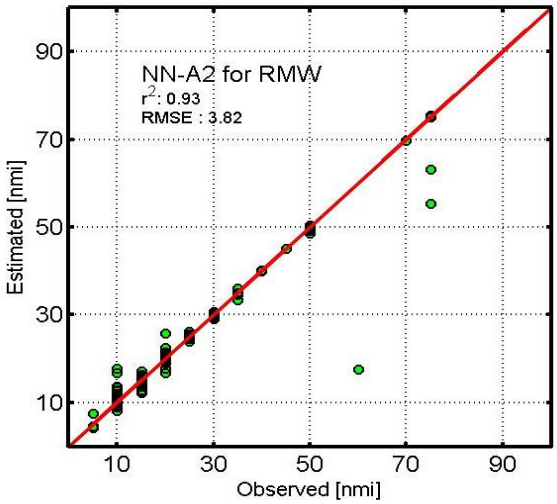

Figure 3: Correlation between observed and estimated Radius to Maximum Winds (R_{Max}).

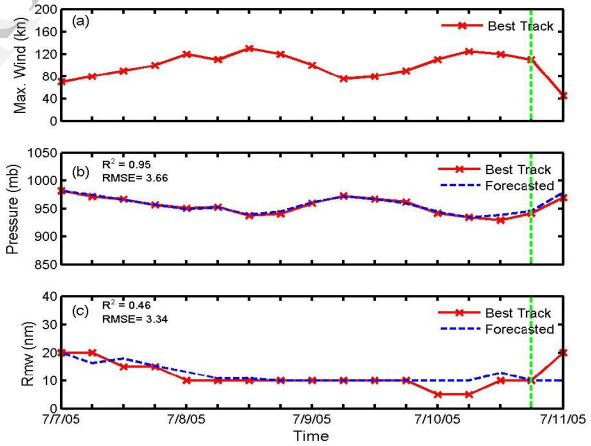

Figure 4: Comparison between observed and forecasted CP and R_{Max} for Hurricane Dennis. Model was run from 7/7/2005

00:00 to 7/11/2005 00:00. The green vertical line indicates the hurricane's landfall time

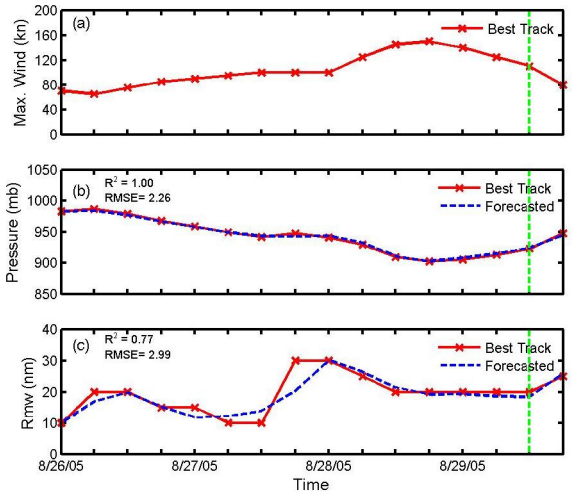

Figure 5: Comparison between observed and forecasted CP and R_{Max} for Hurricane Katrina. Model was run from 8/26/2005 00:00 to 8/29/2005 18:00. The green vertical line indicates the hurricane's landfall time

4. Discussion

A neural network model has been developed to estimate key hurricane parameters such as, CP and R_{Max} values using advisory data from the National Hurricane centre (NHC). Results show that this approach can be efficiently applied to estimate these storm parameters to be applicable to any hydrodynamic models for prediction of storm surge and inundation. These estimated parameters along with other advisory data available from NHC (e.g., forecasted track, current CP and wind speed) are useful in accurate prediction of storm surge for hazard mitigation and planning. Although this methodology is applied to the Gulf of Mexico, but can be easily adapted to other geographical area such as, Bay of Bengal, to study storm surge in developing countries like Bangladesh, India or Myanmar.

5. References

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