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Artificial Neural Network Model for Prediction of Latent Heat Flux over Bay of Bengal

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Abstract**—** Latent Heat Flux is the flux of heat from the Earth's surface to the atmosphere that is associated with evaporation of water at the surface and subsequent condensation of water vapour in the troposphere. It is key component of global water and energy cycles. It also responsible for to maintain the salinity budget of the ocean surface. Prediction of Latent Heat Flux is essential for understanding ocean-atmospheric interaction process which helps to explore the climate change condition, global warming conditions and also monitor the atmospheric conditions. Ocean and atmosphere data is a non-linear type of data to extract the more information from non-linear data, Artificial Neural Network gives a better solution. Among the Indian Ocean only Bay of Bengal having a numerous significant features. Changes in a Bay of Bengal responsible for climate change condition, precipitation and cyclone formation etc., In present analysis used an ocean parameters such as Wind Speed at 10m above sea surface and Sea Surface Temperature for the prediction of Latent Heat Flux over the latitude 80°E: 100°E and longitude 0-25°N for Bay of Bengal from 2011 to 2015. To achieve the objective use a Feed-forward Neural Network model with Levenberg-Marquardt training algorithm. Performance of model is calculate using performance analysis parameters such as Correlation Coefficient and Room Mean Square Error. The result of Correlation Coefficient and Root Mean Square Error indicates that proposed neural network model gives a better prediction of Latent Heat Flux.

Keywords**—**Latent Heat Flux, Bay of Bengal, Sea Surface Temperature, Wind Speed, Artificial Neural Network

I. INTRODUCTION

Climate prediction is one of the most essential and challenging task approved by weather-related services in all over the world. Ocean is a one of the major parameter which is responsible of climate change conditions. Among the three major oceans of the world i.e. Pacific, Arctic and Atlantic, Indian Ocean (IO) is a physically more complex. It divided into two major oceans i.e., Arabian Sea (AS) and Bay of Bengal (BoB) which shares same longitude (i.e. 0-25°N) but having different latitude (i.e. 45°E: 80°E for AS and 80°E: 100°E for BoB). Among these only BoB having a various significant features which are responsible not only for climate change condition but also the rainfall pattern and cyclone formation. Because of its unique characteristics most of the oceanographic and meteorologist people pay attention towards BoB to extract more information about ocean atmospheric interaction and also monitor climate change condition. Oceanographical and meteorological data such as Latent Heat Flux (LHF), Wind Speed (WS), horizontal and meridional wind component (u-v component) and Sea Surface Temperature (SST), etc. are very complex and non-linear type of data. Small changes in SST and WS affects the atmosphere. LHF over ocean is a key component in a global water and energy cycles which play major role in salinity budget of the ocean surface. Artificial Neural Network (ANN) is an advanced computing technique which play a crucial role for solving oceanic and atmospheric problems such as prediction, forecasting and climate modelling etc. Here the major objective of present analysis is to predict the Latent Heat Flux (LHF) over BoB using SST and WS over BoB. To achieve the objective use a Feed-Forward Neural Network (FFNN) model for prediction and also compute the correlation coefficient and Root mean square error to measure the performance of proposed neural network model. This study is presented in a following manner, section II represent related work, section III & IV represents Methodology & Results and discussion respectively and lastly conclusion & future scope gives in a section V.

II. RELATED WORK

From previous studies it observed that many scientist pay attention towards the ANN to examine the climate conditions. Karmakar, Choubey and Mishra [1] reviews the past 50 years to find out the appropriateness of ANN in climate prediction and observed that backpropagation neural network and basis function neural network this two models which have been used by most of the researchers and the result of their test found to be satisfactory. Gandhi, D'Souza and Arjun [2] used a feed-forward neural network model with Quasi-Newton Back-Propagation algorithm to predict SST a day in advance using current day's SST using satellite oceanographic data for three years period, results show that more than 75% of the time the model error is ≤ ± 0.5 ◦C. Amender, Chattopadhyay, Mishra and Jain [3] used a NN model for prediction of evaporation they used a multilayer perceptron (MLP) architecture with two training function i.e. Backpropagation and Conjugate gradient descent using various meteorological parameters such as maximum and minimum of temperature, relative humidity in the morning and evening, wind speed for different location. They observed that MLP with backpropagation gives a better prediction rate in most of the cases along with that they also conclude that with larger number of input variables are performed better for prediction of evaporation. Narvekar and Fargose [4] used an ANN for daily weather forecasting they conclude that ANN with backpropagation algorithm gives better prediction rate with minimal error. Erdil and Arcaklioglue [5] analyzed the prediction of meteorological variables using ANN they found that used of ANN increases the calculation rate in a minimum time. Litta, Idicula and Mohanty [6] predict the meteorological parameters during Premonsoon Thunderstorms using ANN with different training algorithms they observed that ANN with Levenberg-Marquardt algorithm well predict the thunderstorm. Bodri and Cermak [7] developed an ANN model to predict monthly and yearly precipitation using 38 years precipitation data for a different locations in Czech Republic. Luk, Ball and Sharma [8] used an ANN model for short-term precipitation prediction using spatial and temporal data of rainfall. Maqsood, Khan and Abraham [9] developed ANN model to prediction of air temperature, wind speed and humidity before 24 hrs over Canada. Chaudhuri and Chattopadhyay [10] developed a feed-forward neural network model for prediction of relative humidy and maximum surface temperature. ANN techniques used in a number of hydrological modelling [11], [12], [13], [14]. From previous studies it observed that ANN modelling positively implemented in several of weather, climate and atmospheric studies but less attention pay towards for ocean studies or ocean atmospheric interaction process. The main objective of present study is use an ANN technique for LHF using ocean parameters over ocean. Traditionally LHF is calculating using following bulk formula. As a progress in an ANN modelling in many complex real word problem, here we attempt to predict LHF over BoB using daily SST and WS data over BoB.

$$LHF = \rho L_E C_L U_{10}(q_s - q_a) \quad (1)$$

Where,
L_E = Latent Heat of Evaporation,
C_L = Latent Heat Transfer Coefficient,
U_{10} = Wind speed at 10m above sea surface,
q_s/q_a = Specific humidity at sea-surface and 10m above

III. METHODOLOGY

Figure 1. Shows a location of BoB (latitude 80°E-100°E and longitude 0-25°N) which is consider for present work. Ocean parameters such as SST, WS and LHF are extracted from TropFlux [15],[16] daily Data for the year 2011 to 2015. The TropFlux project started in the year of 2008 as combined research association among National Institute of Oceanography, Goa, India and Institute Pierre Simon Laplace, Paris, France. This project purposes to deliver timely estimates of both momentum and net heat flux and their components. The data available on a 1°x1° degree grid for the whole 30°N-30°S area. TropFlux is basically developed from a grouping of European Centre for Medium-Range Weather Forecasts reanalysis data interim version (ERA-I) and long wave fluxes and International Satellite Cloud Climatology Project (ISCCP) surface radiation data for shortwave flux. Daily 1°x1° degree grid data has been used for present study.

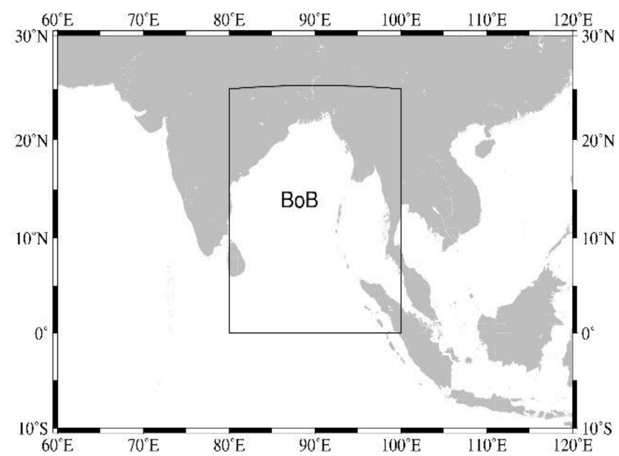

Figure 1. Location of Bay of Bengal (80°E-100°E and 0-25°N)

TropFlux Data are available in netcdf format (Network Common Data Form) extension of netcdf data file is .nc. It is a machine independent data format which support to create, share and access array-oriented scientific data. TropFlux data available in Monthly and Daily time interval. For present analysis consider a daily data from the year 2011-2015. Fig. 2. Represents the proposed methodology

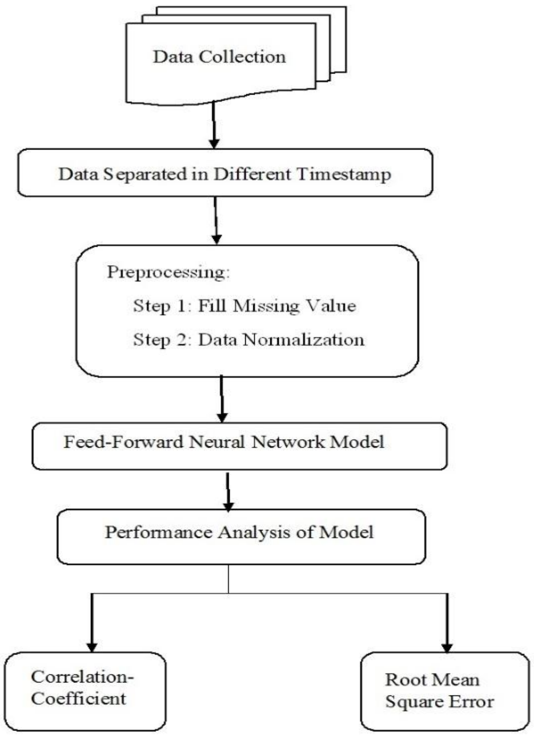

Figure 2. Proposed Methodology

Data Separation

After data collection data separated in 365 days (1-January to 31-December) and create a single .nc file for each day using a Ferret. Ferret it is data visualization and analysis tool for complex gridded Ocean and meteorological data.

Pre-Processing

Two preprocessing techniques used to improve performance of model

a) Missing Value

Netcdf data contains the missing value to solve these problem and increase the performance of model have use a spline (piecewise cubic spline interpolation) and linear (linear interpolation of neighboring, non-missing values) method in step 1.

b) Data Normalization

After solving missing values problem data is normalized i.e. data is convert between 0 to 1 using following formula

$$Norm_{(i)} = \frac{i - \min(i)}{\max(i) - \min(i)} \quad (2)$$

Where, *i* is ocean variable

Feed- Forward Neural Network Model with Backpropagation (FFNNB)

After preprocessing create a three layer (input layer, hidden layer, and output layer) Feed Forward Neural Network with backpropagation (FFNNB) model. In first layer i.e. in input layer use a SST and WS as an input neuron, second layer i.e. hidden layer with 10 neuron and third layer i.e. output neuron use LHF as an output neuron. Lavenberg - Marquardt, Gradient descent with momentum weight & bias and hyperbolic tangent sigmoid use as training algorithm, learning function and transfer function respectively. Data is divided into 70%, 15% and 15% for training, testing and validation respectively.

Performance Analysis

Performance of model is calculated using following performance analysis parameters.

Correlation Coefficient (Cc): It is computed using following formula

$$Cc = \frac{n\sum O_{lhf}P_{lhf} - (\sum O_{lhf})(\sum P_{lhf})}{\sqrt{n\left(\sum O_{lhf}^2\right) - (\sum O_{lhf})^2}\sqrt{n\left(\sum P_{lhf}^2\right) - (\sum P_{lhf})^2}} \quad (3)$$

Where *n* the total number of days for a particular year is, O_{lhf} and P_{lhf} are the observed and predicted values of latent heat flux for particular year.

Root Mean Square Error (RMSE): RMSE evaluated using following formula

$$RMSE = \sqrt{\frac{\sum (O_{lhf} - \hat{P}_{lhf})^2}{N}} \quad (4)$$

Where O_{lhf} are the observed values and P_{lhf} are the predicted values of LHF for a particular year, *N* is the number of observations.

IV. Results and Discussion

Figure. 3 Shows the prediction of LHF from 1-January to 31-December for years 2011-2015. Interesting result observed in a prediction. When we look into month wise prediction rate for year 2011 it gives good prediction from May to June and also from July to September. In case of 2012 less difference observed in target predicted LHF in moth from May to July and from August to September and in December. While moving from 2013 to 2015 same result observed it gives better prediction in month of July, March and December respectively. From Analysis it found that proposed model gives a better results for some time duration but also gives major difference in target and predicted LHF for other months, which indicates using SST and WS can predict the LHF over Ocean but if want to predict better prediction may be other ocean parameters also responsible such as specific humidy, latent heat of evaporation and latent heat transfer coefficient. These is the parameters which is used in bulk formula for calculation of LHF. If we consider these parameters for as an input parameters for neural network model may it gives the better prediction rate.

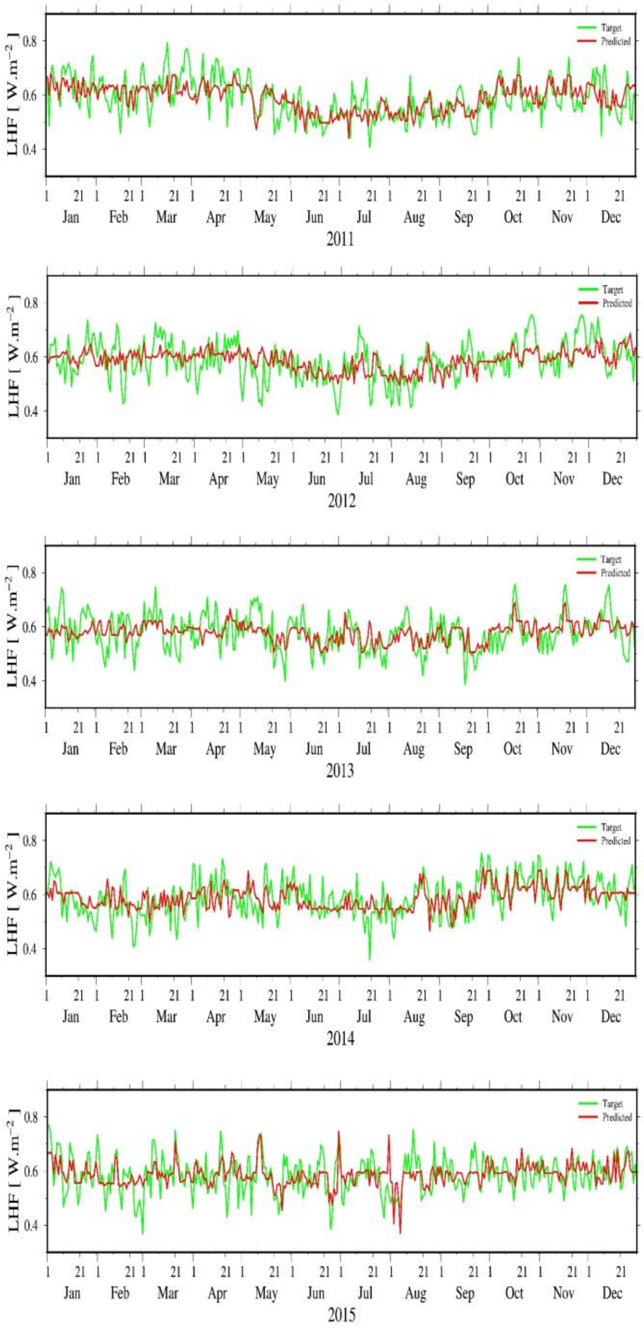

Figure 3. Result of FFBNN model for prediction of LHF, Target Value (Green) and Predicted Value (Red)

Figure 4. Represents the performance of proposed model in terms of correlation coefficient and RMSE. Higher correlation i.e. 0.62 and lower RMSE i.e. 0.056 observed in the year 2011which indicates better prediction. While considering other year i.e. 2012, 2013, 2014 and 2015 correlation is 0.48, 0.50, 0.56 and 0.50 respectively. These Correlation-coefficient values indicates that it predict well with minor difference. Also RMSE values for year 2012, 2013, 2014 and 2015 is 0.063, 0.058, 0.057 and 0.059 respectively which satisfy the correlation coefficient results. From Analysis it observed that ANN computing technology also gives a better solution in ocean and atmospheric studies.

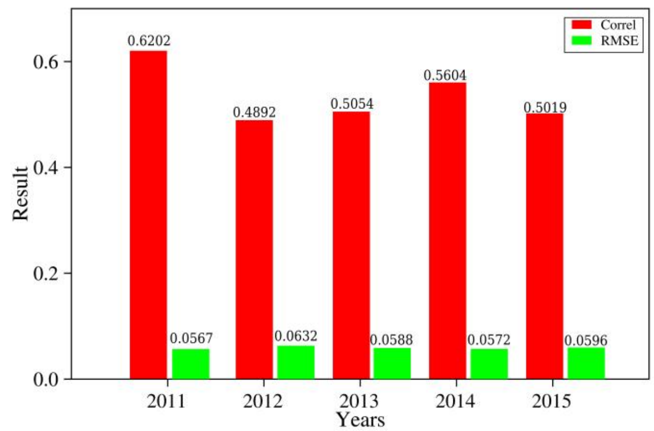

Figure 4. Performance of Proposed Mode

V. CONCLUSION AND FUTURE SCOPE

One of the power of the ANN computing modelling is its simplicity and its less requirement. ANN actively play important role in real-world problems. The beauty of ANN is it doesn't require the previous knowledge about data. From present analysis it found that use of ANN modelling is a better choice in ocean and meteorology studies which increase the prediction rate in less time. Feed-Forward Neural Network with backpropagation algorithm it is a good solution for time-series data analysis. Prediction of LHF using SST and WS over ocean play an active role in ocean-atmospheric interaction process and climate change conditions. From analysis it observed that using wind speed and Sea surface temperature play a vital role for prediction of latent heat flux over ocean surface. But from performance analysis parameters i.e. from correlation coefficient and root mean square error it observed that prediction rate needs to increase to increase performance of proposed model.

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