Forecasting of hurricanes using weather buoy data

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***Abstract*—This project is an attempt to predict the occurrence of a hurricane over the seas using both recent and historical data obtained from the National Oceanic and Atmospheric Administration web pages. National Oceanic and Atmospheric Administration stores and manages a very extensively detailed database of all the buoy data. It keeps a check on the condition of the Oceans, major waterways and the atmosphere. This project mainly focuses on Hurricane Irene. Hurricane Irene was a large and destructive tropical cyclone that hit the US coast in August 2011. To predict the occurrence of a hurricane, we use attributes such as wave period, wave direction, wave height, latitude, longitude, wind direction, wind direction, wind speed and pressure.**

I. Introduction

Hurricanes are a type of tropical cyclone, which form over the Atlantic Ocean and Northeastern Pacific Ocean. The creation of tropical cyclones is a subject of extensive research and is still not understood precisely. The few key factors that affect hurricanes are atmospheric pressures, warm sea surface temperatures, light winds aloft, and rotation or spin. This project deals with the prediction of hurricane formation or occurrence by evaluating such factors. Data for our project consists of buoy data which is available on the NOAA's website separately for each buoy. All buoy stations measure wind speed, direction, atmospheric pressure and air temperature. In addition, they also measure sea surface temperature and wave height and wave period. In this project, the spotlight is given to the hurricane "Irene". Using the historical data of 2011, we are developing a model, which predicts the occurrence of a hurricane.

II. Importance

The most critical reason to predict hurricanes is to minimise loss of life and property. Hurricanes are one of the most destructive natural calamities. Governments in areas prone to hurricanes develop contingency plans to help people take actions such as boarding up windows, moving in land, sheltering in safe locations etc. By predicting hurricanes, people can be directed to take action that minimises chaos and loss of life. Hurricane predictions and the probability that a hurricane will hit a specific area has a great deal of relevance to the flood risk of an area. Flooding from a hurricane can be caused by excessive quantities of rain, broken and breached levees, and storm surges from the ocean or a major lake. Many of the government operated hurricane management centres like THE NATIONAL HURRICANE CENTRE and the CENTRAL PACIFIC HURRICANE CENTRE give an accurate prediction about the formation and trajectory of hurricanes using satellite imaging upto 48 hours before they occur. In most of the cases, 2 to 5 days are not enough for entire cities to prepare themselves for a hurricane. This is why an early and accurate prediction of such calamities is very important.

III. Current Approaches

A. Summary

Hurricane forecasts have traditionally focused on predicting a storm's track and intensity. The track and size of the storm determine which areas may be hit. To do so, forecasters use models – essentially software programs, often run on large computers. Unfortunately, no single forecast model is consistently better than other models at making these predictions. Sometimes these forecasts show dramatically different paths, diverging by hundreds of miles. Other times, the models are in close agreement. In some cases, even when models are in close agreement, the small differences in track have very large differences in storm surge, winds and other factors that impact damage and evacuations. So, forecasters use a collection of models to determine a likely range of tracks and intensities. Such models include the NOAA's Global Forecast System and European Centre for Medium-Range Weather Forecasts global models. The FSU Superensemble was developed by a group at our university, led by meteorologist T.N. Krishnamurti, in the early 2000s. The Superensemble combines output from a collection of models, giving more weight to the models that showed better predicted past weather events, such as Atlantic tropical cyclone events.

B. GFDL Model

The GFDL hurricane prediction system originated as a research model in the 1970s. Since 1995, the GFDL Hurricane Prediction System has been used operationally by the National Hurricane Center and has consistently been one of the top-performing models utilized by NHC. The current GFDL hurricane model is a gridpoint model that consists of three computational meshes which are nested together with increasingly finer grid-point spacing in each mesh.This area of fine resolution moves with the hurricane, keeping the storm centered in the middle of the innermost computational grid.

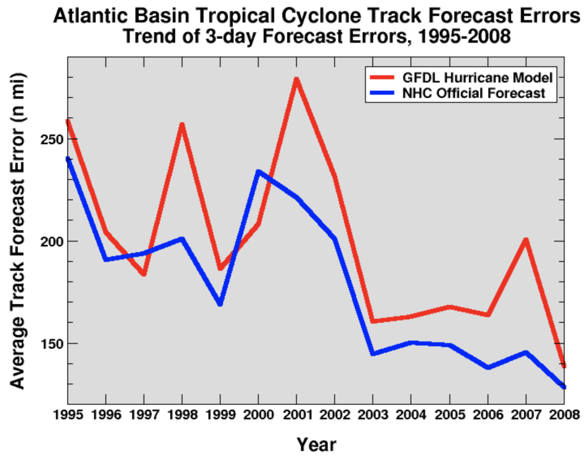

Fig. 1. The figure above shows the trend of hurricane intensity forecast errors over the last nine seasons and even indicates that in 2006, for the first time ever, the GFDL hurricane model produced intensity forecasts that had smaller average errors than those from the National Hurricane Center's official forecasts.

C. Current findings

The National Hurricane Center (NHC) made their all-time best track forecasts during the 2017 Atlantic hurricane season, setting new records for track forecast accuracy at all forecast times. According to their annual forecast verification report released on May 9, the 2017 NHC track forecasts were up to 15 percent better than the previous record-best forecasts. Over the past fifteen years, 1- to 5-day NHC track forecast errors have declined by about a factor of two—an extraordinary accomplishment that has undoubtedly led to a huge savings in lives, damage, and emotional angst for the people living in Hurricane Alley.

D. Limitations

Over the past decade, track forecasts have steadily improved. A plethora of observations – from satellites, buoys and aircraft flown into the developing storm – allow scientists to better understand the environment around a storm, and in turn improve their models. Some models have improved by as much as 40 percent for some storms. However, it's extremely difficult for a model to estimate the occurence and maximum wind speed of a tropical cyclone at any given future time. Models are inexact in their descriptions of the entire state of the atmosphere and ocean at the start time of the model. Small-scale features of tropical cyclones – like sharp gradients in rainfall, surface winds and wave heights within and outside of the tropical cyclones – are not as reliably captured in the forecast models. There have been great strides forward made in the science of forecasting hurricanes, but there is still a lot to do. One major problem is accuracy. The National Hurricane Center has been forecasting the paths of hurricanes since the early 1950's. They issue 120 hour, 96 hour, 72 hour, 48 hour, 24 hour, and 12 hour forecasts. The error decreases as the time before landfall decreases. The error has also decreased over the years as models become more accurate (NOAA, 2004). Despite becoming more accurate, the error is still relatively large.

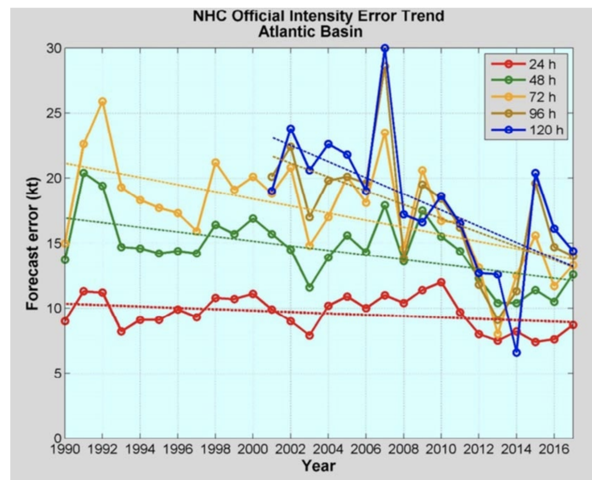

Fig. 2. Verification of official NHC hurricane intensity forecasts for the Atlantic, 1990 - 2017. Intensity forecasts have shown little improvement over the past five years, but some modest improvement over the past fifteen years. Image credit: 2017 National Hurricane Center Forecast Verification Report.

IV. Problem Statement

Through our model, we are trying to predict the occurrence of a hurricane over the seas using both recent and historical data obtained from the National Oceanic and Atmospheric Administration's sea buoy data at least 7-10 days in advance. Forecasting right and forecasting early will be the goal as time is a very crucial factor which plays a vital role while taking appropriate preventive measures.

V. Our approach

Our aim is to predict formation of hurricane accurately as early as possible. Since hurricane Irene was one of the largest and most destructive hurricanes, the aim is to observe the changes in weather data around the time when it occurred and fit an appropriate model to predict future occurrences in the surrounding areas. Our approach involves using the data obtained from the buoys affected by hurricane Irene and analyse the data leading up to the event. The major focus would be to understand pressure patterns which are observed during the formation of a hurricane. Multiple such pressure patterns will be analysed and used, through which we intend to "train" our model and use it to make informed decisions about future occurences of such events.

A. Data

Our project data consists of historical and realtime buoy data.The data is available on the NOAA's website. Each buoy data consist of the attributes wave period, wave direction, wave height, latitude, longitude, wind direction, wind direction, wind speed and pressure. We are making our data model on the basis of data from Hurricane Irene. Hurricane Irene was a large and destructive tropical cyclone which affected much of the Caribbean and East Coast of the United States during late August 2011. Atlantic hurricane season, Irene originated from a well-defined Atlantic tropical wave that began showing signs of organisation east of the Lesser Antilles. Due to development of atmospheric convection and a closed centre off circulation, the system was designated as Tropical Storm Irene on August 20,2011. We have a list of all the buoys which were in the trajectory of this particular hurricane. Using the historical data of 2011, we want to develop a model, which predicts the occurrence of a hurricane.

B. Pressure Patterns

Inside a hurricane, the barometric pressure at the ocean's surface drops to extremely low levels. As air is pulled into the eye of the hurricane, it draws moisture from the ocean and rises rapidly before condensing, cooling and releasing large amounts of heat into the atmosphere before falling and begins the cycle again. This refuels the hurricane, lowering the barometric pressure on the ocean surface. The lower the barometric pressure at the center of the storm, the stronger the hurricane, and vice versa. The Saffir-Simpson scale ranges from Category 1 hurricanes with a barometric pressure of greater than 980 millibars that cause minimal damage, to Category 5 hurricanes with a central pressure of less than 920 millibars.

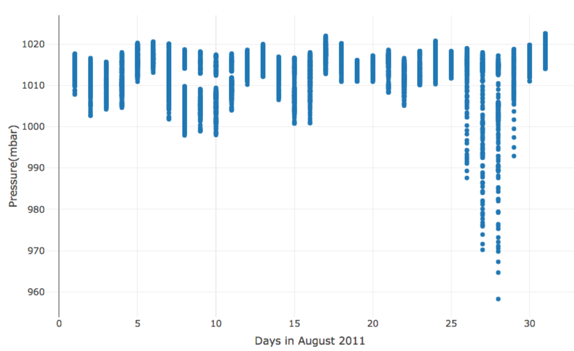

Fig. 3. Pressure readings for the month of August,2011(according to our data). A clear pressure drop can be observed around the time hurricane Irene occured.

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