1.1 WEATHER FORECASTING

Weather simply refers to the condition of air on the earth at a given place and time. It is a continuous, data-intensive, multidimensional, dynamic and chaotic process. These properties make weather forecasting is a formidable challenge. Forecasting is the process of estimation in unknown situations from the historical data. Weather forecasting is one of the most scientifically and technologically challenging problems around the world in the last century. To make an accurate prediction is indeed, one of the major challenges that meteorologists are facing all over the world. Since ancient times, weather prediction has been one of the most interesting and fascinating domains. Scientists have tried to forecast meteorological characteristics using a number of methods, some of these methods being more accurate than others [MK02].

Knowledge of meteorology forms the basis of scientific weather forecasting, which revolves around predicting the state of the atmosphere for a given location. Weather forecasting as practiced by humans is an example of having to make judgments in the presence of uncertainty. Weather forecasts are often made by collecting quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve in future. Over the last few years the necessity of increasing knowledge about the cognitive process in weather forecasting has been recognized. For human practitioners, forecasting the weather becomes a task for which the details can be uniquely personal, although most human forecasters use approaches based on the science of meteorology in common to deal with the challenges of the task [Do04].

Weather forecasting entails predicting how the present state of the atmosphere will change. Present weather conditions are obtained by ground observations, observations from ships, observation from aircraft, radio sounds, doppler radar and satellites. This information is sent to meteorological centers where the data are collected, analyzed and made into a variety of charts, maps and graphs. Modern high-speed computers transfer the many thousands of observations onto surface and upper-air maps.

Weather forecasts provide critical information about future weather. There are various techniques involved in weather forecasting, from relatively simple observation of the sky to highly complex computerized mathematical models. Weather prediction could be one day/one week or a few months ahead [MK02, D086, AP01]. The accuracy of weather forecasts however, falls significantly beyond a week. Weather forecasting remains a complex business, due to its chaotic and unpredictable nature [KB98, MA94]. It remains a process that is neither wholly science nor wholly art. It is known that persons with little or no formal training can develop considerable forecasting skill [Ge78, KO02]. For example, farmers often are quite capable of making their own short term forecasts of those meteorological factors that directly influence their livelihood, and a similar statement can be made about pilots, fishermen, mountain climbers, etc. Weather phenomena, usually of a complex nature, have a direct impact on the safety and/or economic stability of such persons. Accurate weather forecast models are important to third world countries, where the entire agriculture depends upon weather [CZ97]. It is thus a major concern to identify any trends for weather parameters to deviate from its periodicity, which would disrupt the economy of the country. This fear has been aggravated due to threat by the global warming and green house effect. The impact of extreme weather phenomena on society is growing more and more costly, causing infrastructure damage, injury and the loss of life.

As practiced by the professionally trained meteorologist, weather forecasting today is a highly developed skill that is grounded in scientific principle and method and that makes use of advanced technological tools. The notable improvement in forecast accuracy that has been achieved since 1950 is a direct outgrowth of technological developments, basic and applied research, and the application of new knowledge and methods by weather forecasters. High-speed computers, meteorological satellites, and weather radars are tools that have played major roles in improving weather forecasts [KO02].

Several other factors have contributed significantly to this increase in forecasting accuracy. One is the development of statistical methods for enhancing the scope and accuracy of model predictions. Another is the improved observational capability afforded by meteorological satellites. A third primary reason for the increase in accuracy is the continued improvement of the initial conditions prepared for the forecast models. Statistical methods allow a wider variety of meteorological elements to be predicted than do the models alone, and they tailor the geographically less precise model forecasts to specific locations. Satellites now provide the capability for nearly continuous viewing and remote sensing of the atmosphere on a global scale. The improvement in initial conditions is the result of an increased number of observations and better use of the observations in computational techniques [CZ97].

1.2 TRADITIONAL WEATHER FORECASTING

Weather forecasting is the application of science and technology to predict the state of the atmosphere for a given location. Weather forecasts are made by collecting quantitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve. There are a variety of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property.

In ancient times, forecasting was mostly based on weather pattern observation. Over the years, the study of weather patterns has resulted in various techniques for rainfall forecasting. Present rainfall forecasting embodies a combination of computer models, interpretation, and an acquaintance of weather patterns. The following technique was used for existing weather prediction.

Use of a barometer

Measurements of barometric pressure and the pressure tendency have been used in forecasting since the late 19th century. The larger the change in pressure, the larger the change in weather can be expected. If the pressure drop is rapid, a low pressure system is approaching, and there is a greater chance of rain [TF05].

Looking at the sky

Along with pressure tendency, the condition of the sky is one of the most important parameters used to forecast weather in mountainous areas. Thickening of cloud cover or the invasion of a higher cloud deck is an indication of rain in the near future. At night, high thin clouds can lead to halos around the moon, which indicates the approach of a warm front and its associated rain. Morning fog portends fair conditions, as rainy conditions are preceded by wind or clouds which prevent fog formation [KMQ10].

Nowcasting

The forecasting of the weather within the next six hours is often referred to as nowcasting. In this time range, it is possible to forecast smaller features such as individual showers and thunderstorms with reasonable accuracy, as well as other features too small to be resolved by a computer model. A human, given the latest radar, satellite and observational data will be able to make a better analysis of the small scale features present and so will be able to make a more accurate forecast for the following few hours [RR03].

Analog technique

The analog technique is a complex way of making a forecast, requiring the forecaster to remember a previous weather event which is expected to be mimicked by an upcoming event. It remains a useful method of observing rainfall in places such as oceans, as well as the forecasting of precipitation amounts and distribution in the future. A similar technique is used in medium range forecasting, which is known as teleconnections, when systems in other locations are used to help pin down the location of another system within the surrounding regime[Dj75].

Numerical Weather Prediction model

Numerical Weather Prediction (NWP) is the science of predicting the weather using models of the atmosphere and computational techniques. Current weather conditions are used at the input of the mathematical models of the atmosphere to predict the weather. This model usually provides surrounding point around the wind farm with a spatial resolution of a few kilometers.NWP uses the power of computers to make a forecast. A forecaster examines how the features predicted by the computer will interact to produce the day's weather. The NWP method is flawed in that the equations used by the models to simulate the atmosphere are not precise [Ry02].

A number of weather forecasting agencies operate modeling centers where supercomputers are used to run NWP models that span the entire globe. These include the National Center for Environmental Prediction (NCEP) in the United States, the United Kingdom Meteorological Office (UKMO), and the European Centre for Medium-range Weather Forecasts (ECMWF). Although costly, a global approach to NWP is essential, especially for long-range forecasting. For this reason, achieving accurate forecasts requires an accurate analysis from which to get the model started. This involves a computer-based process called data assimilation, in which the most recent weather observations from around the world are combined with model forecasts to create a global analysis of current conditions. This becomes the starting point for the next run of the NWP model, and is the computer equivalent of the manual analysis cycle that forecasters carry out on an on-going basis. Global models play a key role in modern weather forecasting, and meteorologists at Met Service routinely use the NCEP, UKMO and ECMWF models to assist with day-to-day production of forecasts and weather warnings. These models give insight into the behavior of weather systems on a large scale, without much emphasis on local detail [FS78].

Ensemble Forecasting

To predict the weather forecast meteorologists have developed atmospheric models that approximate the atmosphere by using ensemble forecasting to describe how atmospheric temperature, pressure and moisture will change over time. The equations are programmed into a computer and the data on the present atmospheric conditions are fed into the computer. The computer solves the equations to determine how the different atmospheric variables will change over the next few minutes. The computer repeats this procedure again and again using the output from one cycle as the input for the next cycle. For some desired time in the future, the computer prints its calculated information. It then analyzes the data, drawing the lines for the projected position of the various pressure systems. A forecaster uses the prognostic chart as a guide to predicting the weather. There are many atmospheric models that represent the atmosphere, with each one interpreting the atmosphere in a slightly different way. Weather forecasts made for 12 and 24 hours are typically accurate. Forecasts made for two or three days are usually good. Beyond above five days, forecast accuracy falls off rapidly.

Weather information can also come from remote sensing, particularly radar and satellites.

Radar

Radar stands for Radio Detection and Ranging. In radar, a transmitter sends out radio waves. The radio waves bounce off the nearest object and then return to a receiver. Weather radar can sense many characteristics of precipitation, its location, motion, intensity, and the likelihood of future precipitation. Most weather radar is Doppler radar, which can also track how fast the precipitation falls. Radar can outline the structure of a storm and in doing so estimates the possibility that it will produce severe weather condition [NCW12].

Weather satellites

Weather satellites have been increasingly important sources of weather data since the first one was launched in 1952. Weather satellites are the best way to monitor large scale systems, like storms. Satellites can also monitor the spread of ash from a volcanic eruption, smoke from fires, and pollution. They are able to record long-term changes. Figure 1.1 shows one of the geostationary satellites that monitors conditions over the world. Weather satellites may observe all energy from all wavelengths in the electromagnetic spectrum. Most important are the visible light and infrared (heat) frequencies [ADB12].

Figure 1.1 Geostationary satellites

Weather maps

Weather maps simply and graphically depict meteorological conditions in the atmosphere. Weather maps may display only one feature of the atmosphere or multiple features. They can depict information from computer models or from human observations. Weather maps are found in newspapers, on television, and on the Internet.

On a weather map, each weather station will have important meteorological conditions plotted. These conditions may include temperature, current weather, dew point, cloud cover, sea level air pressure, wind speed and direction. On a weather map, meteorologists use many different symbols. These symbols give them a quick and easy way to put information onto the map [SCO12]. Figure 1.2 shows some of these symbols used for Weather Map.

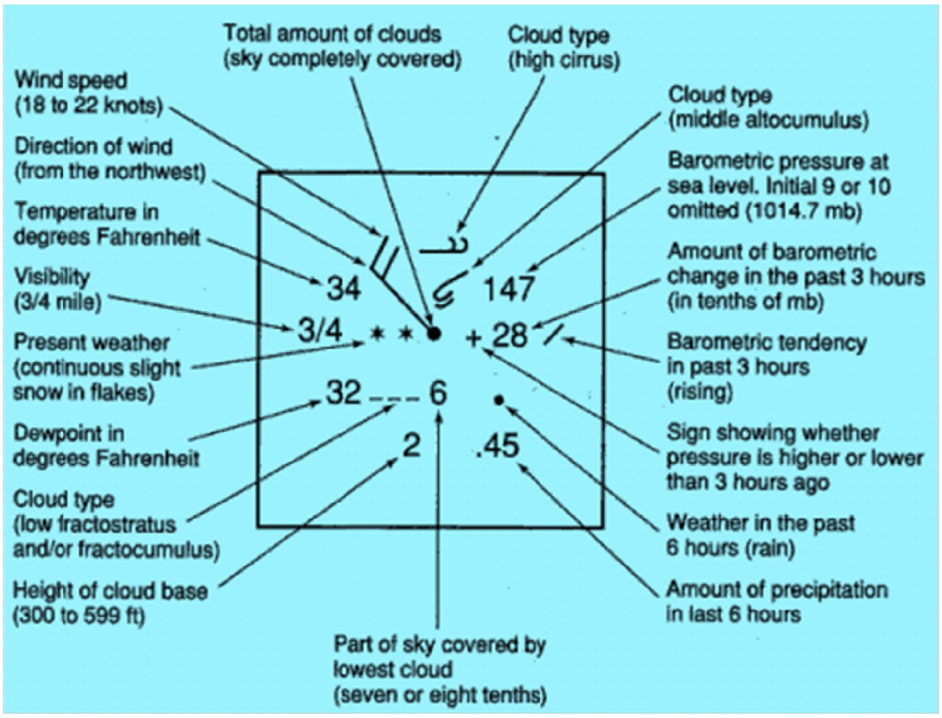

Figure 1.2 Weather Map

Generally, there are two methods used in weather forecasting namely the empirical and dynamical approach [MKA02a, MKA02b]. The empirical approach is based upon the occurrence of analogues and is often referred to by meteorologists as analogue forecasting. This approach normally is useful for predicting local-scale weather if recorded cases are plentiful. Dynamical approach is based upon equation and forward simulations of the atmosphere and is often referred to as computer modeling. This dynamical approach is useful for modeling large-scale weather phenomena and may not predict short-term weather efficiently. Most of the weather forecasting systems combine both empirical and dynamical approaches.

1.3 TYPES OF WEATHER FORECASTING

A daily weather forecast involves the work of thousands of observers and meteorologists all over the world. Modern computers make forecasts more accurate than ever, and weather satellites orbiting the earth take photographs of clouds from space.

Forecasters use the observations from ground and space, along with formulas and rules based on experience of what has happened in the past, and then make their forecast.

Meteorologists actually use a combination of several different methods to come up with their daily weather forecasts [HTTP1]. They are

a) Persistence Forecasting
b) Synoptic Forecasting
c) Statistical Forecasting
d) Computer forecasting

a) Persistence Forecasting

The simplest method of forecasting the weather is persistence forecasting. It relies upon today's conditions to forecast the conditions tomorrow. This can be a valid way of forecasting the weather when it is in a steady state, such as during the summer season in the tropics. This method of forecasting strongly depends upon the presence of a stagnant weather pattern. It can be useful in both short range forecasts and long range forecasts. This assumes that what the weather is doing now is what it will continue to do. To find out what the weather is doing, meteorologists make weather observations.

b) Synoptic Forecasting

This method uses the basic rules for forecasting. Meteorologists take their observations, and apply those rules to make a short-term forecast.

c) Statistical Forecasting

Meteorologists ask themselves, what does it usually do this time of the year? Records of average temperatures, average rainfall and average snowfall over the years give forecasters an idea of what the weather is "supposed to be like" at a certain time of the year.

d) Computer forecasting

Forecasters take their observations and plug the numbers into complicated equations. Several ultra-high-speed computers run these various equations to make computer "models" which give a forecast for the next several days. Often, different equations produce different results, so meteorologists must always use the other forecasting methods along with this one.

Using all the above methods, forecasters come up with their "best guess" as to what weather conditions will be over the next few days.

Weather forecasting now has a wide range of operational products that traditionally are classified under the following groups:

- Very short-range forecast
- Short-range forecast
- Medium-range forecast
- Long-range forecast

Each weather forecast can be defined on the basis of the following criteria:

(a) Dominant technology

(b) Temporal range of validity after emission

(c) Characteristics of input and output time and space resolution

(d) Broadcasting needs

(e) Accuracy

1.4 IMPORTANCE OF WEATHER FORECASTING

Weather forecasting is used in many situations like severe weather alerts and advisories, predicting the behavior of the cloud for air transport, prediction of waterways in a sea, agricultural development and avoiding forest fire.

Severe weather alerts and advisories

A major part of modern weather forecasting is the severe weather alerts and advisories which are the national weather service's issue in anticipation of severe or hazardous weather are expected. This is done to protect life and property. Some of the most commonly known of severe weather advisories are the severe thunderstorm and tornado warning, as well as the severe thunderstorm and tornado watch. Other forms of these advisories include winter weather, high wind, flood, tropical cyclone, and fog. Severe weather advisories and alerts are broadcast through the media, including radio, using emergency systems as the Emergency Alert System which breaks into regular programming [LEB08].

Predicting the behavior of the cloud for Air transport

The aviation industry is especially sensitive to the weather and accurate weather forecasting is essential. Fog or exceptionally low ceilings can prevent many aircraft from landing and taking off. Turbulence and icing are also significant in-flight hazards. Thunderstorms are a problem for all aircrafts because of severe turbulence due to their updrafts and outflow boundaries, icing due to the heavy precipitation, as well as large hail, strong winds, and lightning, all of which can cause severe damage to an aircraft in flight. Volcanic ash is also a significant problem for aviation, as aircraft can lose engine power within ash clouds [JRD06].

Prediction of waterways in a sea

Commercial and recreational use of waterways can be limited significantly by wind direction, speed, wave periodicity, high tides and precipitation. These factors can each influence the safety of marine transit. Consequently, a variety of codes have been established to efficiently transmit detailed marine weather forecasts to vessel pilots via radio, for example marine forecast. Typical weather forecasts can be received at sea through the use of Radio fax.

Agricultural development

Weather plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses and timeliness and effectiveness of prophylactic and cultural operations on crops. Weather aberrations may cause (i) physical damage to crops and (ii) soil erosion. The quality of the crop produced during movement from field to storage and transport to market depends on weather. Bad weather may affect the quality of the produce during transport and viability and vigor of seeds and planting material during storage.

Avoiding Forest fire

Weather forecasting of wind, precipitations and humidity is essential for preventing and controlling wildfires. Different indices, like the Forest fire weather index and the Haines Index, have been developed to predict the areas more at risk to experience fire from natural or human causes. Conditions for the development of harmful insects can also be predicted by weather forecasting.

Military applications

Military weather forecasters present weather conditions to the war fighter community. Military weather forecasters provide pre-flight and in-flight weather briefs to pilots and provide real time resource protection services for military installations. Naval forecasters cover the waters and ship weather forecasts. The Navy provides a special service to both themselves and the rest of the federal government by issuing forecasts for tropical cyclone across the Pacific and Indian Oceans through their Joint Typhoon Warning Center.

Air Force

Air Force Weather provides weather forecasting for the Air Force and the Army. Air Force forecasters cover air operations in both wartime and peacetime operations and provide Army support. Military and civilian forecasters actively cooperate in analyzing and creating weather forecast products.

1.5 DATA COLLECTION

Weather data for ten years (2001-2010) is collected from the Indian Meteorological department of Kanyakumari District, Tamilnadu. The chosen weather data is divided into two groups, the training group, corresponding to 75% of the data, and the test group corresponding to 25% of data. Weather forecasts today depend on collecting and analyzing data and measurements from around the world. Some of the misclassified data are taken from Weather.com and AccuWeather.com. It was supported the meteorologists in analyzing and predicting customized weather forecasts for a city or metropolitan area rather than providing general users with the ability to manipulate and interactively identify possible threats associated with impending weather hazards [HTTP2, HTTP3]. The data set contains fourteen attributes. They are

1. Bar Temperature
2. Bar reading
3. Station level pressure

4. Mean sea level pressure
5. Dry bulb temperature
6. Wet bulb temperature
7. Maximum temperature
8. Minimum temperature
9. Vapor pressure
10. Relative humidity
11. Precipitation
12. Cloudiness
13. Wind speed
14. Wind direction

1.6 OBJECTIVES AND SCOPE

The objectives of this research study are

- ❖ To examine the applicability of Neural Network approach by developing effective and efficient predictive models for weather analysis for Kanyakumari District, TamilNadu, India.
- ❖ To develop an efficient, reliable and effective weather forecasting system based on Back Propagation Neural Network, Radial Basis Function Neural Network, Generalized Regression Neural Network and Fuzzy ARTMAP Neural Network.
- ❖ To compare and evaluate the performance of above models and the programming was carried out using MATLAB as a tool.

The scope of this research work is to evaluate the performance of the above Neural Network models with chosen dataset.

1.7 ORGANIZATION OF THE THESIS

The thesis consists of seven chapters.

The remaining contents of the thesis are organized as follows.

Chapter two reviews the literature about neural network models used in weather forecasting techniques.

Chapter three explains how the Back Propagation Neural Network can be used in weather forecasting, and it also gives an overview of the algorithm and its practical applications.

Chapter four presents the benefits and achievements enabling experimental system of Radial Basis Function Neural Network architecture for weather forecasting.

Chapter five explains the performance analysis of Generalized Regression Neural Network architecture for weather prediction.

Chapter six discusses Fuzzy ARTMAP Neural Network architecture and its experimentation results.

Finally, chapter seven concludes the thesis with a summary of the major findings and implications of the study. The scope for further research is also discussed together with the limitations of the present study.