Weather Forecasting Models, Methods and Applications

Iseh. A. J.[1]* Woma. T. Y.[1,2]

1. Department of Pure & Applied Physics, Federal University Wukari, Taraba State. P. M. B. 1020 Wukari, Taraba State.
2. Department of Pure & Applied Physics, Federal University Wukari, Taraba State. P. M. B. 1020 Wukari, Taraba State.

ABSTRACT

Weather forecasting modelling is a computer program that provides meteorological information for future times at given locations. In modern forecasting models, Numerical Weather Prediction is mostly applied and this means, "a set of simplified equations used to calculate changes in atmospheric conditions". The act of writing these equations, imposing the boundary conditions and solving them using super computers, is known as numerical modelling. An example of such equations is the Hypsometric equation given as $P_I = P_O \exp{-gz/RT}$. Computerized numerical models are designed for different intervals which are known as global models under which we have long range forecast and medium range forecast, and regional models under which we have the short range forecast. The methods include persistence, climatologic, looking at the sky, use of barometer, nowcasting, use of forecasting models, analogue and ensemble forecasting. Forecasting could be applied in air traffic, severe weather alerts, marine, agriculture, utility companies, private sector and military application. Weather forecasting is a complex and challenging science that depends on the efficient interplay of weather observation, data analysis by meteorologist and computers, and rapid communication system.

Key words: *Weather, weather prediction, forecast, forecasting models, weather data, forecasting methods and applications.*

1.0 INTRODUCTION

Modern society's ever-increasing demand for more accurate weather forecasts is evident to most people. The spectrum of needs for weather predictions ranges from the general public's desire to know if for instance, the weekend will permit an outing at the beach, or an organization's rally, or an outdoor wedding reception. Such diverse industries as airlines and fruit growers depend heavily on accurate weather forecasts to have an idea of what their next schedule of flight would appear to be or if the weather will be suitable for harvesting. In addition, in developed countries, the designs of buildings, and many industrial facilities rely heavily on a sound knowledge of the atmosphere.

Weather forecasting can be defined as the act of predicting future weather conditions or an attempt to indicate the weather conditions which are likely to occur.

Weather forecasting is the application of Science and Technology to predict the state of the atmosphere for a future time and a given location. Human beings have attempted to predict the weather informally for millennia, and formally since at least the nineteenth century. Weather forecasts are made by collecting qualitative data about the current state of the atmosphere and using scientific understanding of atmospheric processes to project how the atmosphere will evolve within the next few hours.

Once, an all-human endeavour based mainly upon changes in barometric pressure, current weather conditions and sky conditions, forecast models are now used to determine future conditions. A model, in this context, is a computer program that produces meteorological information for future times at given positions and altitudes. The horizontal domain of a model is either global, covering the entire earth, or regional, covering only part of the earth. Regional models also are known as limited area models. Human input is still required to pick the best possible forecast model to base the forecast upon, which involves pattern recognition skills, knowledge of model performance and knowledge of model biases. The chaotic nature of the atmosphere, error involved in measuring the initial conditions, an incomplete understanding of atmospheric processes mean that forecast become less accurate as the difference in current time and the time for which the forecast is being made increases.

There are a variety of end users to weather forecasts. Weather warnings are important forecasts because they are used to protect life and property. Forecasts based on temperature and precipitation are important to agriculture, and therefore to commodity traders within stock markets. Temperature forecasts are also used by utility companies to estimate demand over coming days. On an everyday basis people use weather forecasts to determine what to wear on a given day. Since in recent time in Uyo – Nigeria for example, outdoor activities are severely curtailed by heavy rains, forecasts can be used to plan activities around these events, and to plan ahead and survive them.

2.0 HOW MODELS CREATE FORECASTS

2.1 Data collection

Since invention of the first weather instruments in the seventeenth century weather observation has undergone considerable refinement. Denser monitoring networks, more sophisticated instruments and communication systems, and better-trained weather observers, have produced an increasingly detailed, reliable and representative record of weather and climate. In weather forecasting, data collection has been divided into two categories namely:

i. Surface weather observations
ii. Upper-air weather observations.

Surface Weather Observations

Surface weather observations are the fundamental data used for safety as well as climatological reasons to forecast weather and issue warnings worldwide. They can be taken manually by a weather observer, by computer through observers to augment the otherwise automated weather station.

Referring to Lutgens and TarBuck (1989), a vast network of weather stations required to produce a weather chart will encompass enough to be useful for short-range forecasts. On a global scale, the World meteorological organization, which consists of over 130 nations, is responsible for gathering the needed data and producing some general prognostic charts.

Surface weather observations of atmospheric pressure, temperature, wind speed and direction, humidity, precipitations are made near the earth's surface by trained observers or automatic weather stations. The World meteorological Organization acts to standardize the instrumentation, observing practices and timing of those observations worldwide. By international agreement, the regular synoptic observations are made every six hours beginning at midnight

Greenwish Mean Time (0000GMT, 0600GMT, 1200GMT and 1800GMT) each day. In addition, observations for aviation purposes are made at many airports every hour, or more often if the weather is changing rapidly. Specialized observations may also be made under certain conditions for agricultural, industrial, research, or other purposes (Miller and Thompson, 1975).

Upper-air weather observations

Measurements of temperature, humidity and wind above the surface are found by launching radiosondes on weather balloons. Radiosonde is a unit for use in weather balloons that measures various atmospheric parameters and transits them to a fixed receiver. Radiosondes may operate at a radio frequency of 403MHz or 1680MHz and both types may be adjusted slightly higher or lower as required. Mohan and Morgan (1991) states that, the instrument transmits to the ground station vertical profiles of air temperature, pressure, and relative humidity up to an altitude of about 30km. In addition, winds at various levels are computed by tracking the balloons with a radio direction finding antenna.

Upper-air weather data are also obtained by aircraft, dropwind sondes, radar, and satellites. Increasingly, data from weather satellites are being used because of their almost global coverage. Although their visible light images are very useful for forecasters to see development of clouds, little of this information can be used by numerical weather prediction models. The infrared data however, can be used as it gives information on the temperature at the surface and cloud tops. Individual clouds can also be tracked from one time to the next to provide information on wind direction and strength at the clouds steering level.

Miller and Thompson (1975) agrees that, the observations are collected at a number of points where there are processed by a Central weather analysis organization. Three locations have been designated by the World Meteorological Organization as World Meteorological Centers, these are located in Melbourne, Australia; Moscow, Russia; and Washington, D.C. U.S.A. In addition, most countries maintain national centers, where the basic weather needs of the domestic economy are met. In Nigeria, the National Meteorological Center is located in Abuja.

2.1.1 Data assimilation and analysis

In order to do their work, most numerical models look at the atmosphere as a series of boxes. In the middle of each box is a point for which the model actually calculates weather variables and makes forecasts. The result of this three dimensional boxing up of the atmosphere is known as the grid; the point in the middle is the grid point, and the distance between one point and another is called the grid spacing (Ackerman and Knox, 2003).

Grid point models of the atmosphere can get fussy when the data in the initial conditions is not obtained at exactly the location of the grid point. Also, the process of creating an evenly spaced data set from irregularly spaced observations is called interpolation.

Ackerman and Knox (2003) then say that, the multiple jobs of interpolating and smoothing the data for use in numerical models are collectively called data assimilation.

During the data assimilation process, information gained from the observations is used in conjunction with a numerical model's most recent forecast for the time that observations were made, since this contains information from previous observations. This is used to produce a three-dimensional representation of the temperature, moisture and wind called a meteorological analysis. This is the models estimate of the current state of the atmosphere. Data assimilation proceeds by analysis cycles. In each analysis cycle, observations of the current (and possibly, past) state of a system are combined with the result from and mathematical model (the forecast) to produce an analysis, which is considered as "the best" estimate of the current state of the system. This is called the analysis step. Essentially, the analysis step tries to balance the uncertainty in the data and in the forecast. The model is then advanced in time and its result becomes the forecast in the next analysis cycle.

2.1.2 Numerical weather prediction

Linacre and Geerts (1997) define Numerical Weather prediction (NWP) as a simplified set of equations called the primitive equation used to calculate changes of conditions. Modern weather forecasting relies heavily on numerical weather prediction.

According to Lutgens and TarBuck (1989), the word "numerical" is misleading, for all types of weather forecasting are based on some quantitative data and therefore could fit under this heading. Numerical weather prediction is based on the fact that the gases of the atmosphere obey a number of known physical principles. Ideally, these physical laws can be used to predict the future state of the atmosphere, given the current conditions. This situation is analogues to predicting future position of the moon based on physical laws and the knowledge of its current position. Still, the large number of variables that must be included when considering the dynamic atmosphere makes this task extremely difficult.

Manipulating the huge data sets and performing the complex calculations necessary to do this (weather prediction) on resolution fine enough to make the result useful requires the use of some of the most powerful supercomputers.

Referring to the work of Houghton (1986), the task of writing the equations and the boundary conditions in a suitable form and then of solving them with high speed digital computers is known as numerical modeling. By comparing the behaviour of the model with that of the real atmosphere, the validity of the procedures employed by the model is tested. The most important application of numerical modeling is the development of methods sufficiently reliable and sufficiently fast to be used in routine weather forecasting.

There are numerous equations employed in this work of forecasting models one of which is the hypsometric equation which can be derived from the hydrostatic equation written as

$$dP = -P\frac{g}{RT}dZ \qquad - \qquad (1)$$

We can simplify equation (1) by dividing through with P to have

$$\frac{dP}{P} = \frac{-g}{RT}dZ \qquad - \qquad (2)$$

Integrating the right hand side of equation (2) from P_0 to P_1 and the left hand side from Z_0 to Z_1, we have:

$$\int_{P_0}^{P_1}\frac{dP}{P} = \frac{-g}{RT}\int_{Z_0}^{Z_1} dZ \quad + \quad C$$

Let C = 0

$$[\text{InP}]_{P_0}^{P_1} = \frac{-g}{RT}[Z]_{Z_0}^{Z_1}$$

$$\rightarrow \text{InP}_1 - \text{InP}_0 = \frac{-g}{RT}(Z_1 - Z_0)$$

$$\rightarrow \text{In}\,(P_1/P_0) = \frac{-g}{RT}(Z_1 - Z_0) \; - \qquad (3)$$

Taking the exponent of both sides of equation (3), we have:

$$e^{\text{In}\,(P_1/P_0)} = e^{[-g/_{RT}(Z_1 - Z_0)]}$$

$$P_1/P_0 = e^{[-g/_{RT}(Z_1 - Z_0)]}$$

$$\rightarrow P_1 = P_0 e^{[-g/_{RT}(Z_1 - Z_0)]}$$

At sea level, $Z_0 = 0$. Thus,

$$P_1 = P_0 e^{[-g\,Z_1/_{RT}]} \quad - \quad (4)$$

Equation (4) is the Hypsometric equation, which gives the pressure P_I of the atmosphere at a particular height Z_1,

Where P_0 is the pressure at the sea level,

g is acceleration due to gravity.

R is the molar gas constant and

T is the temperature at the surface

Mohan and Morgan (1991) agree with Barry and Chorley (1992) that, some computerized numerical models of the atmosphere are designed to operate over different spatial scales depending on the forecast range. For medium range forecasts (up to 10 days), observational data are fed into the computer from all over the globe, since within that forecast range a weather system may travel long distances. On the other hand, for short-range forecasts (up to 3 days), the model utilizes data drawn from a more restricted region of the globe. Compared to a global model, a regional model offers the advantage of greater resolution of data over a smaller area of interest.

As it is, there are basically three types of numerical weather prediction models namely: short-range forecasts, medium range forecast (as briefly discussed by Mohan and Morgan, 1991; and Barry and Chorley, 1992 above), and long range forecast.

Thus, Linacre and Geerts(1997) describes long range forecasts as descriptive forecasts which are made for times of ten to thirty days or one to four months (a seasonal outlook). Also, use is made of a dynamical numerical weather prediction model which allows for oceanic processes, which are too slow to be important in short range weather forecasting.

Meteorological bureaux now regularly provide seasonal outlook, with an accuracy notably enhanced by increased understanding of the relevance of the southern oscillation, indicated by the sea surface temperatures, the strength of the trade winds, the location of areas of day convention across the tropical Pacific Ocean, and the depth of themocline.

But of all these three types of numerical weather prediction, Mohan and Morgan (1991) say that actually, when viewed with the objectivity of statistical analysis, short-range weather forecasting is surprisingly more accurate probably because of the short range of time within which this forecast is made for.

The most modern models of weather data processing systems for the two categories of numerical models are as follows:

Global models: Some of the better-known global numerical models are:

1. Global Forecast System (GFS) – Developed by the National Organization for the Atmosphere in America. Output is freely available.
2. NOGAPS – Developed by the US Navy to compare with the GFS
3. Global Environmental Multi-scale Model (GEM) – Developed by the meteorological service of Canada
4. European Centre for Medium Range Weather Forecasts (ECMWF) – a model run by the Europeans with limited availability
5. UKMO – Developed by the United Kingdom Meteorological Office. Limited availability, but is hand corrected by professional forecasters.
6. GME – developed by the German Weather Service

7. ARPEGE – developed by the French Weather Service, Meteo France.
8. Intermediate General Circulation model (IGCM) – developed by members of the Department of Meteorology at the University of Reading.

Regional models: Some of the better-known regional numerical models are:

1. The Weather Research and Forecasting (WRF) Model was developed co-operatively by NCEP and the meteorological research community. WRF has several configurations including:
    a. WRF – NMM: The ERF Non-hydrostatic Mesoscale Model is the primary short-term weather forecast model for the United State,
    b. AR-WRF: Advanced Research WRF developed primarily at the United State National Center for Atmospheric Research (NCAR)
2. The North American Mesocale Model (NAM)
3. Colorado State University for numerical simulations of atmospheric meteorology and other environmental phenomena on scales from metres to hundreds of kilometres
4. MMS – The fifth Generation mesoscale model
5. The Advanced Region Prediction System (ARPS) – developed at the University of Oklahoma. It is a comprehensive multi-scale non-hydrostatic simulation and prediction system that can be used for regional scale weather prediction up to the tornadscale simulation and prediction.
6. High Resolution Limited Area Model (HIRLAM)
7. GEM – LAM – Global Environmental Multi-scale Limited Area Model
8. Aladin: The high resolution limited area hydrostatic and non-hydrostatic model developed operated by several European and North African countries under the leadership of Meteo-France.
9. COSMO: The COSMO Model, formerly known as LM, aLMD or LAMI, is a limited area non-hydrostatic model developed within the framework of the consortium for small scale modelling (Germany, Switzerland, Italy, Poland and Greece). www.wikipedia.com.

According to Linacre and Geerts (1997), the advantage of numerical weather prediction is that it avoids errors of human judgment in deriving the prognosis, and can be steadily improved by enlarging the amount and reliability of input data, by new understanding of the Physics of atmospheric change, and by faster, larger computers.

2.1.3 Model Output Post Processing

The raw output is often modified before being presented as the forecast. This can be in the form of statistical techniques to remove known biases (a term used to describe a tendency or preference towards a particular perspective, ideology or result) in the model, or its adjustment to take into account consensus among other numerical weather forecast. MOS or Model Output Statistics is a technique used to interpret numerical model output and produce site-specific guidance. This guidance is presented in coded numerical form, and can be obtained for nearly all National Weather Service reporting stations.

3.0 FORECASTING PROBLEMS

An important goal of all scientific endeavour is to make accurate predictions. The physicist or chemist who conducts an experiment in the laboratory does so in the hope of discovering certain fundamental principles that can be used to predict the outcome of other experiments based on those principles. In fact, most of the laws of science are merely very accurate predictions concerning the outcome of certain kinds of experiments. But few physical scientists are faced with more complex or challenging prediction problems than the meteorologist.

In the first place, the meteorological laboratory covers the entire globe, so that even the problem of measuring the present state of the atmosphere is tremendous. Furthermore, the surface of the earth is an irregular combination of land and water, each responding in a different way to the energy source – the sun. Then, too, the atmosphere itself is a mixture of gaseous, liquid, and solid constituents, many of which affect the energy balance of the earth, one of them, water, is continually changing its state. Also, the circulations of the atmosphere range in size from extremely large ones, which may persist for weeks or months, to minute whirls, with life spans of only a few seconds.

According to Miller and Thompson (1975) and Ayado and Burt (2001) the problem of forecasting then, involves an attempt to observe, analyze and predict the many interrelationships between the solar energy source, the physical feature of the earth, and the properties and motions of the atmosphere. This is the basis on which weather forecasts still go wrong today.

Ackerman and Knox (2003) points out reasons why forecasts still go wrong today by stating that the limitations which directly relates to today's numerical forecast models are as follows:

i. **Imperfect data:** The data of today's numerical models still includes a large helping of radiosonde observations. However, the number of radiosonde sites in the World over has actually declined over the past few decades. Developed countries in the world today, spend more money in launching weather satellites than for boring weather balloons. Satellite data are global in average, but researchers in data assimilation are still trying to figure out how this data can be "digested" properly by the models. In addition, important meteorological features still evade detection, especially over the oceans. The model results are only as good as the data in its initial conditions.

ii. **Faulty "vision" and "fudges":** Today's forecasts also involve an inevitable trade-off between horizontal resolution and the length of the forecast. This is because fine resolution means lots of point at which to make calculations. This requires a lot of computer time. A forecast well into the future also requires millions or billions more calculations. If fine resolution is combined with a long range forecast, the task would choke the fastest supercomputers today. One would not get forecasts for weeks. Future improvement in computing will help speed things up.

In the meantime, however, some models are still not able to pick or "see" small-scale phenomena such a clouds, raindrops, and snowflakes. To compensate for this fuzzy "vision" of models, the computer code includes crude approximations of what is not being seen. These are called parameterizations. Even though much science goes into them, these approximations are nowhere close to capturing the complicated reality of the phenomena. This is because; the smallest scale phenomena are often the most daunting to understand. Therefore, it is not an insult to meteorologists' abilities to say that parameterizations are "fudges" of the actual phenomena.

iii. Chaos: It will be surprising to note that, even if a supercomputer which could do quadrillions of calculations each second were to be invented, no better forecasting result would still be gotten. Brute force numerical weather forecasting with extremely fine resolution has its limits.

The reason for these limits is a curious property of complex, evolving systems like the atmosphere. It is called "Sensitive dependence on initial conditions", and is a hallmark of what is popularly known as chaos theory. Chaos in the atmosphere does not mean that everything is a mess; instead, it means that the atmosphere both in real life and in a computer model may read very differently to initial conditions that are only slightly different.

Because we do not know the atmospheric conditions perfectly at any time, chaos means that the resemblance between a model's forecast and reality will be less and less with each passing day.

4.0 METHODS OF WEATHER FORECASTING

Of course for weather forecast to exist there must be methods on which it is done. These methods are as follows:

4.1 Persistence forecasting

Persistence forecasting is the easiest method of forecasting which assumes a continuation of the present. It relies upon today's conditions to forecast the weather when it is 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.

Persistence forecasts are used by local forecasters in determining such events as the time of the arrival of a thunderstorm that is moving toward their region. Persistence forecasts do not account for changes that might occur in the intensity or in the path of a weather system, and they do not predict the formation. Because of these limitations and the rapidity with which weather system change in most geographical regions, persistence forecasts break down after twelve hours, or a day at most.

4.2 Climatology forecasting

Whereas persistence forecasting is most accurate over short periods (before factors for change have had time to operate), the best estimate of the weather a long time ahead is the average value of past measurements there at that time of day and year.

Climatology forecast relies on the observation that weather for a particular day at a location does not change much from one year to the next. As a result, a long term average of weather on a certain day or month should be a good guess as the weather for that day or month. The most obvious climatology forecast in this part of the world (Nigeria) is, "Cold in December, warm in July (the popular July break)". One does not need to be a meteorologist to make that forecast.

Today's numerical forecast methods still use climatological statistics as a "reality check". There make sure that the computer models are not going off the deep end, climatologically speaking.

4.3 Looking at the sky

Along with pressure tendency, use of the sky condition is one of more important weather parameters that can be used to forecast weather in mountainous areas. Thickening of cloud cover or the invasion of a higher cloud deck is indicative of rain in the near future. Morning fog portends fair conditions, as rainy conditions are preceded by wind or clouds, which prevent fog formation. The approach of a line of thunderstorm could indicate the approach of a cold front. Cloud free skies are indicative of fair weather for the near future. The use of sky cover in weather prediction has led to various weather lore over the centuries.

4.4 Use of a barometer

Using barometric pressure and the pressure tendency (xthe change of pressure over time) has been used in forecasting since the late 19th century. The larger the change in pressure, especially, if more than 2.54mmHg, 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. Rapid pressure rises are associated with improving weather conditions, such as clearing skies.

4.5 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.

Severe weather is typically short-lived (less than two hours) and, due to its mesoscale character (less than one hundred kilometers), it affects local/regional areas necessitating site-specific forecasts. Included in this category are thunderstorms, gust fronts, tornadoes, high winds especially along coasts, over lakes and mountains, heavy snow and freezing precipitation. The development of radar networks, new instruments and high speed communication links has provided a means of issuing warnings of such phenomena.

Several countries including Nigeria have recently developed integrated satellite and radar systems to provide information on the horizontal and vertical extent of thunderstorms, for example. Such data are, supplemented by networks of automatic weather stations that measure wind, temperature and humidity.

Nowcasting methods use highly automated computers and image analysis systems to integrate data from a variety of sources rapidly. Interpretation of the data displays requires skilled personnel and or extensive software to provide appropriate information. The prompt forecasting of wind shear and downburst hazards at airports is one example of the importance of nowcasting procedures.

4.6 Use of Forecasting Models

In the past, the human forecasters were responsible for generating the entire weather forecast based upon available observation. Today, human input is generally confined to choosing a model based on various parameters, such as model biases and performance. Using a consensus of forecast models, as well as ensemble members of the various models, can help reduce forecast error. However, regardless how small the average error becomes with any individual system, large errors within any particular piece of guidance are still possible on any given model run. Humans can use knowledge of local effects, which may be too small in size to be resolved by the model to add information to the forecast.

4.7 Analogue Forecasting

The analogue method 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. The analogue forecaster's task is to locate the date in history when the weather is a perfect match, or analogue, to today's weather. Then the forecast for tomorrow is simple – whatever happened in the day after the analogue will be the weather for tomorrow. The forecast for the day after tomorrow is whatever happened in the second day after the analogue, and so forth.

What makes it a difficult method to use is that, there is rarely a perfect analogue for an event in the future. In fact, no two patterns or sequences of weather are ever identical. There may, for example, be five reasonable analogues for a particular month, but examination of the succeeding weather sequences might show mild, rainy weather in two cases and cold spells in the other three. In the preparation of the forecast therefore, many factors, which can affect the weather trends, such as sea temperature and the extent or amount of rainfall, have to be taken into consideration.

Some call this type of forecasting pattern recognition. It remains a useful method of observing rainfall over data voids such as oceans, as well as the forecasting of precipitation amounts and distribution in the future. A similar method 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. Teleconnections are used by forecasters today to make general forecasts months into the future. While in short term forecasting, the pattern recognition is still used by weather forecasters to supplement today's computerized methods. But in the end the complexities of weather, like human personalities, defy simple categorization.

The main problem with this method may well be the lack of complete enough information, which also of course, limits the usefulness of numerical weather predictions.

4.8 Ensemble Forecasting

Although a forecast model will predict weather features evolving realistically into the distant future, the errors in a forecast will inevitably grow with time due to the chaotic nature of the atmosphere and the inexactness of the initial observations. The detail that can be given in a forecast therefore decreases with time as these errors increase. These become a point when the errors are so large that the forecast has no correlation with the actual state of the atmosphere.

However, looking at a single forecast gives no indication of how likely that forecast is to be correct. Ensemble forecasting entails the production of many forecasts in order to reflect the uncertainty into the initial state of the atmosphere (due to the errors in the observations and insufficient sampling). The uncertainty in the forecast can then be assessed by the range of different forecasts produced. However, the simple logic behind ensemble forecasting is that two runs of a model are not enough to base a forecast upon.

Ensemble forecasts are increasingly being used for operational weather forecasting. Ensemble forecasting requires a sophisticated understanding of the atmosphere and computer models.

5.0 APPLICATIONS OF WEATHER FORECAST

The importance of accurate weather forecasts cannot be over emphasized as the needs for them are always craved for in virtually every aspect of life. These forecasts can be applied in the following areas:

5.1 Severe weather alerts and advisories

A major part of modern weather forecasting is the severe weather alerts and advisories, which the national weather services issue in the case that severe or hazardous weather is expected. This is done to protect life and property. Some of the most commonly known severe weather advisories are the severe thunderstorm and tornado warnings, as well as the recent warnings about areas that are prone to flood in some part of Nigeria by the National Meteorological Agency. 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 break into regular programming.

5.2 Air Traffic

Because the aviation industry is especially sensitive to the weather, accurate weather forecasting is essential considering the fact that a greater number of plane crashes recorded the world over have weather related causes. Just as turbulence and icing are significant in flight hazards, thunderstorms are a major 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 lightening, all of which can cause severe damage to an aircrafts in-flight. Volcanic ash is also a significant problem for aviation, as aircrafts can lose engine power with ash clouds. On a day-to-day basis, airliners are routed to take advantage of the jet stream tailwind to improve fuel efficiency. Aircrews are briefed prior to takeoff on the conditions to expect enroute and at their destination. Additionally, airports often change which runway is being used to take advantage of a headwind. This reduces the distance required for takeoff, and to eliminate potential crosswinds.

5.3 Marine

Commercial and recreational use of waterways can be limited significantly by wind direction and speed, wave periodicity and heights, 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 through radio, for example the MAFOR (Marine forecast).

5.4 Agriculture

Farmers rely on weather forecasts to decide what work to do on any particular day. For example, drying hay is only feasible in dry weather. Prolonged periods of dryness can ruin cotton, wheat, and corn crops. While crops can be ruined by drought, their dried remains can be used as a cattle feed substitute in the form of silage. Frosts and freezes play havoc with crops both during the spring and fall. For example, peach tree in full bloom can have their potential peach crop decimated by a spring freeze. Orange groves can suffer significant damage during frosts and freezes, regardless of their timing.

5.5 Utility companies

Electricity and gas companies rely on weather forecasts to anticipate demand, which can be strongly affected by the weather. They use the quantity termed the degree-day to determine how strong of a use there will be for heating (heating degree day) or cooling (cooling degree day). These quantities are based on a daily average temperature of 65^0F (18^0C). Cooler temperatures force heating degree-days (one per degree Fahrenheit), while warmer temperatures force cooling degree-days. In winter, severe cold weather can cause a surge in demand as people turn up their heating. Similarly, in summer or dry season a surge in demand can be linked with the increased use of air conditioning systems in hot weather. By anticipating a surge in demand, utility companies can produce additional supplies of power or natural gas before the price increases, or in some circumstances, supplies are restricted through the use of brown outs and blackouts.

5.6 Private Sector

Increasingly, private companies pay for weather forecasts tailored to their needs so that they can increase their profits or avoid large losses. For example, supermarket chains may change the stocks on their shelves in anticipation of different, consumer spending habits in different weather conditions. Weather forecasts can be used to invest in the commodity market, such as futures in oranges, corn, soybeans and oil. Also, members of the public use knowledge of future weather conditions to determine what to put on, on a daily basis.

5.7 Military applications

Similarly to the private sector, military weather forecasters present weather conditions to the war fighters, community. Military weather forecasters provide pre-flight weather briefs to pilots and provide real time resource protection services for military installations.

6.0 CONCLUSION

Weather forecasting is a complex and challenging science that depends on the efficient interplay of weather observation, data analysis by meteorologists and computers, and rapid communication systems. Meteorologists have achieved a very respectable level of skill for short-range weather forecasting. Further improvement is expected with denser surface and upper air observational networks, more precise numerical models of the atmosphere, larger and faster computers and more are to be realized. However, continued international co-operation is essential, for the atmosphere is a continuous fluid that knows no political boundaries.

So far, the accuracy of long range forecasting has been minimal, but the short range forecasting has been of imı help and advantage to the world at today.

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