International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Weather Prediction Models: A Comparison

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ABSTRACT

The weather refers to a temporary condition of atmosphere which is the layer of air surrounding the earth. Weather is a condition of the environment at a specific place and time ascertained through different parameters viz. air pressure, humidity, temperature, precipitation, sun radiation, wind and so forth, which continues to change on every day. In this work we have compared various existing models of weather predictions on various factors.

Keywords: Weather prediction, models, weather models, models of weather prediction.

1. Weather

1.1 Weather

The weather refers to a temporary condition of atmosphere which is the layer of air surrounding the earth. Weather is a condition of the environment at a specific place and time ascertained through different parameters viz. air pressure, humidity, temperature, precipitation, sun radiation, wind and so forth, which continues to change on every day. Weather conditions forecasting is the act of foreseeing the condition of the environment for a given area in light of various climate boundaries. Weather conditions figures are made by getting together information about the present status of the climate. Estimating precise weather conditions is a difficult job for meteorologists and scientists. Climate data is fundamental in each aspect of life like farming, the travel industry, air transport, mining industry, and electrical power system. In agriculture, prior information about weather helps farmers to take necessary decisions to improve their crop yields. Airport or naval systems require continuous weather data to know if there is a sudden change in climatic conditions. Accurate wind speed prediction is critical for wind farms to control the working of wind turbine during wind power generation. Mining industries require precise weather information to monitor the Earth‘s crust continually. Weather conditions prediction on a day to day, week by week, month to month, or yearly basis becomes fundamental as it can more readily reflect the changing pattern of environment and furthermore give productive ecological data-sets for making decisions at the micro-management level (Salman et al., 2015).

Aristotle (340 B.C.) was one among the first to have documented work about weather analysis and forecasting methods. Meteorologica is a formal set of documents compiled in a form of book by him, where he wrote extensively about observed weather and distinguished fire, air, water, and earth as four elements that caused "events in this world". Ancient weather forecasting methods relied on observed patterns of events. It was not until the invention of electric telegraph in 1835 that the modern age of weather forecasting began. Since then, the weather prediction has come a long way from simply observing the sky and earth.

The data of present status of climate and its changes in imminent future is vital as it fundamentally affects different areas of society, for example, farming, chances of flood, water asset management, sports, transport, air traffic, travel and tourism, military applications and so on. (Frisinger, 1977; Moran and Michael, 1994). This multitude of above areas require estimates at various lead times for example different time degrees of the estimates. These weather conditions conjectures at various lead times, utilized in various areas, are profoundly significant for giving alerts to safeguard life and property and for the preparation and readiness against serious climate. Contingent upon the expectation lead times, weather conditions gauges are sorted into various gatherings (Ahrens, 2009). A weather conditions conjecture under 12 hours is known as now cast, which are utilized in advance notice of dangerous climate, for flying purposes, satellite send-offs and so on. Estimate past 12 hours and as long as 72 hours is known as a short-range figure; 72 hours to 240 hours (3-10 Days) is called medium-range conjecture; 10 to 30 days is named as broadened range endlessly gauge that reaches out past 30 days is called long-range gauge.

Weather forecasting requires lot of computing power and generates huge data sets and now has entered the paradigm of Big Data. Advances in observation systems for climate like satellite meteorological observation, data reception, analysis and also prediction have contributed actively in expanding the volumes of data. Conventional computational intelligence models are not adequate to predict the weather accurately.

Moreover, with the advancement of deep learning techniques and appropriate data visualization methods, weather forecasting and climate prediction can be made more effectively and accurately. Hence it is rational to use deep learning approaches to process such huge datasets that can learn themselves and make weather predictions more effectively based on past data. Deep learning techniques use layers of neural networks to identify and extract meaningful patterns from the datasets. A neural network with deep architectures can extract high-level abstract features of Big Data accurately (Gheisari et al., 2017).

The effective implementation of deep learning in various domains has motivated its use in weather forecasting and is a significant development for the weather industry. The deep learning architectures like Recurrent Neural Networks, and Long Short Term Memory Networks are proved to be reliable models for weather forecasting tasks.

Forecasting models can be categorized as temperature prediction models, wind speed prediction models, rainfall prediction models, dew point prediction models, and so on depending upon the parameter to be predicted. Each prediction model forecasts a particular parameter based on previous observations. Temperature forecasting models aim at predicting the minimum, maximum, or average temperature of a location, based on various weather parameters. The maximum temperature forecast depends on sunshine during day time, whereas the minimum temperature forecast relies on cloud conditions at night.

Temperature prediction plays a vital role in agriculture. Prior information about weather helps farmers to take necessary decisions to enrich their crop cultivation. The extreme temperature will cause severe damages to plants and animals, and it is always a great concern for farmers. The temperature should be optimal for the growth of plants. Low temperatures may cause injury to crops. So, the prediction based on temperature is essential in agriculture.

Likewise, wind speed prediction models are intended for forecasting wind speed. Wind speed prediction is an important activity as the wind has applications in various domains such as power generation, agriculture, Industry, Naval Systems, and the marine world. The wind is the process of moving air from high pressure to low pressure, and wind speed is calculated by taking into account the difference between them. As the difference increases, the wind speed also increases. Wind energy is one of the most efficient renewable energy sources. Greenhouse gases originating from conventional energy sources like fossil fuels are the ultimate reason for global warming. Unlike traditional energy sources, renewable energy sources are pollution free, economic, inexhaustible, and environment-friendly. The effective use of wind energy contributes to sustainable development. Urbanization, population growth, and industrialization are the key reasons for the high demand for renewable energy sources. Wind power generation witnessed a significant increase from 2001 to 2018. Wind power production can be enhanced if the available wind speed is higher than the wind turbine‘s cut-in speed. Since wind power and wind speed are cubic proportional, a small change in wind speed will produce higher wind power. Therefore, continuous monitoring of wind speed is a necessity in wind farms. Wind speed forecasting is essential for the proper functioning of the wind turbine as well as for optimum wind power generation.

Quantitative rainfall is the amount of rainfall received over a period of time in a given area. Rain forecasting is essential for the agricultural industry and the flood monitoring system. Precipitation is frozen water or liquid that forms in the atmosphere and drops to the Earth. This weather parameter will help farmers to make decisions on activities like irrigation, spraying, and harvesting.

Atmospheric air pressure is the weight exerted by the air on the surface of the Earth, and it varies with altitude. Atmospheric pressure decreases with increasing altitude. Dew point specifies how much water is present in the air, and it will get a high value when there is more water vapor in the air. Dew point is essential for the growth of desert plants and also for plants growing in areas with moderate rainfall. The quantity of moisture contained in the air of the lower atmosphere is termed as humidity, which is essential for leaf growth, photosynthesis, pollination, and economic yield. Ozone is one of the hazardous pollutants in the lower atmosphere. The concentration of ozone in the atmosphere discloses its impact on plants, humans, and other organisms. Predicting and controlling ozone concentrations can reduce the effects of tropospheric ozone on human health and the environment.

Weather in the tropical regions, like India, has very diverse and complex characteristics due to the unique geographical features with complex topography. This diversity in weather systems of tropical region is partly due to the presence of much weaker horizontal pressure and temperature gradients and higher humidity in this region in comparison to extratropics (Charney, 1963, 1969). Due to sparse network of surface and upper air observations in the tropics and weak geostropic balances, prediction of weather in the tropical region is difficult in comparison to extra tropics (Holton, 2004, Boer, 1995; Shukla, 1989).

2. Models of Weather Predictions

Circulation Models (GCMS)

They are systems of differential equations based on the basic laws of physics viz., conservation of mass, momentum, state equation and conservation of energy. These equations are solved in GCM by considering the earth as a three dimensional array of grids. This gives a 3-dimensional representation of the circulation of the atmosphere and oceans as shown in the figure 1.

Hybrid models are devised by combining two or more models, where linear or nonlinear models can be combined. These are the most recent models which yield better performance. Analysis of studies confirms that hybrid models deliver better forecasting accuracy than individual models.

Random forest is one of the reliable ensemble classifiers for high dimensional data and is proved to be better for weather prediction. Singh et al. (2019) offered a weather prediction system using a random forest algorithm. A model for forecasting the likelihood of rain, average temperature, and maximum wind for a given day is developed by Ahmed (2015).

DL model

Deep learning (DL) is the use of machine learning methods based on artificial neural networks with representation learning. Deep learning models are trained using a neural network architecture or a set of labeled data that contains multiple layers. It easily exceeds the human way of learning. Its use in weather prediction is relatively new.

ML model

A machine learning model is an expression of an algorithm that combs through mountains of data to find patterns or make predictions. Fueled by data, machine learning (ML) models are the mathematical engines of artificial intelligence. Machine learning algorithms are being widely used for predicting weather.

Statistical model

This is the oldest model of weather prediction, where statistical analysis of data is done to analyse the previous weather conditions and predict the same about the future.

3. Illustrations

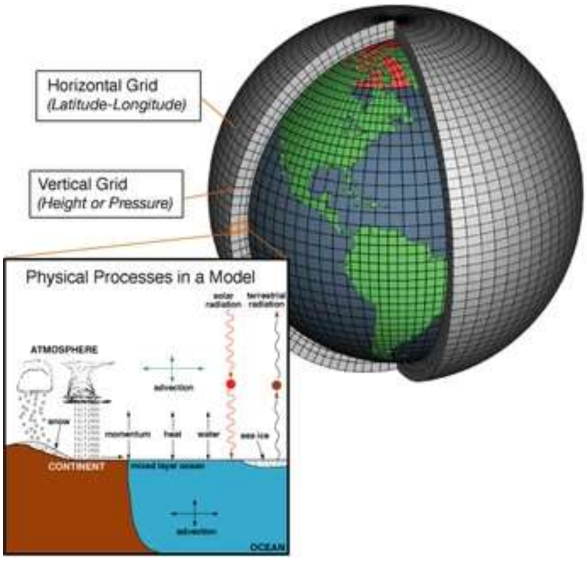

Fig. 1 -Schematic diagram for three dimensional General Circulation Model (GCM)

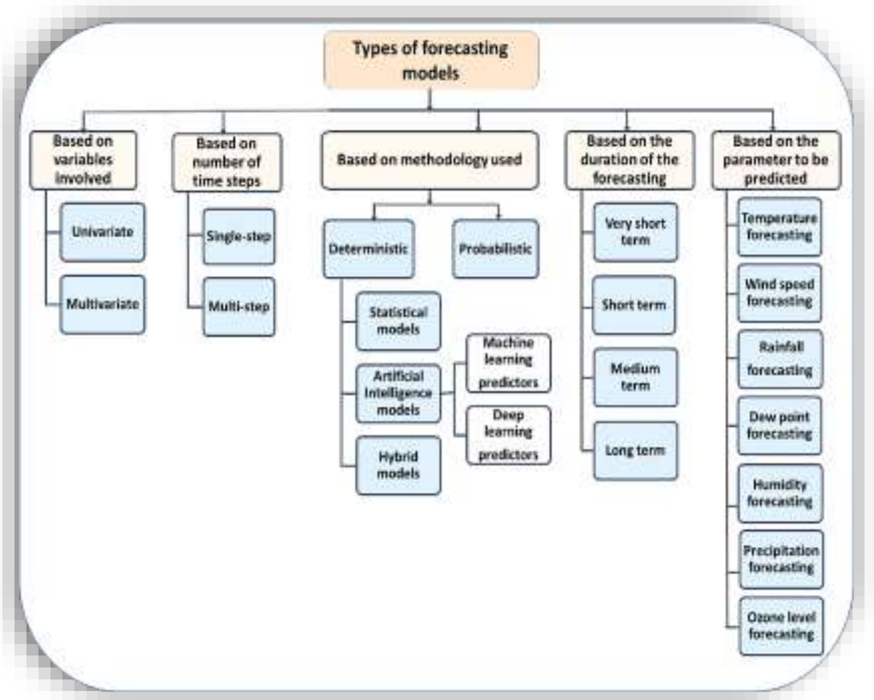

Fig. 2 Types of forecasting models

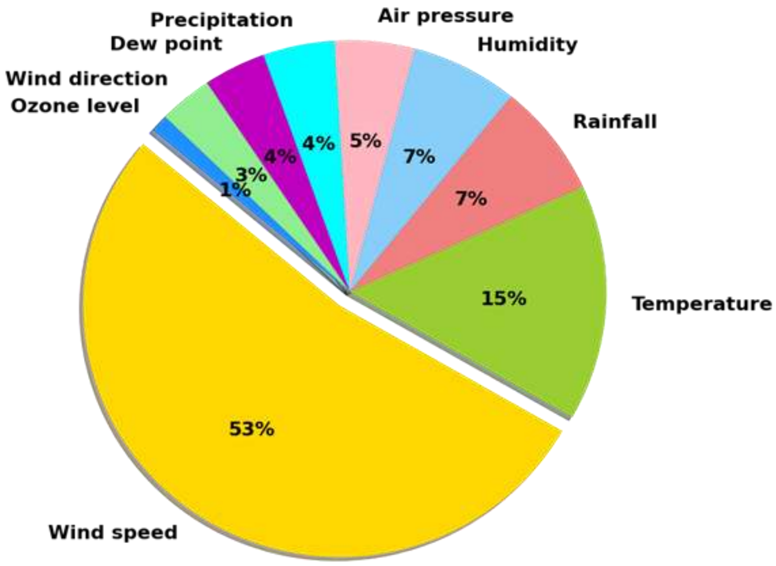

Fig. 3 Details of various forecasting models based on parameters

4. Comparison of weather models

Sl. No.	Parameter predicted	References
1	Ozone level	(Flores-Vergara et al., 2019; Ghoneim and Manjunatha, 2017)
2	Pressure	(Khajure and Mohod, 2016; Suryanarayana et al., 2019)
3	Dew point	(Khajure and Mohod, 2016; Hasan et al., 2016; Mohammadi et al., 2015; Saba et al., 2017)
4	Precipitation	(Du et al., 2017; Hernández et al., 2016; Zhang et al., 2017)
5	Temperature	(Rasp and Lerch, 2018; Nayak et al., 2012; Liu et al., 2018c; Abhishek et al., 2012; Khajure and Mohod, 2016; Suksri and Kimpan, 2016; Narvekar and Fargose, 2015; Yu et al., 2016; Rasel et al., 2017; Singh et al., 2019; Ahmed, 2015; Mohammadi et al., 2015; Ismail et al., 2016; Jayanthi and Sumathi, 2017; Suryanarayana et al., 2019; Hossain et al., 2015; Liu et al., 2015; Aghelpour et al., 2019; Chouksey et al., 2017; Zaytar and El Amrani, 2016; James et al., 2015)
6	Rainfall	(Reddy and Babu, 2017; Tran Anh et al., 2019; Zaw and Naing, 2009; Suhartono et al., 2012; Hung et al., 2009; Kashiwao et al., 2017; Mislan et al., 2015; Narvekar and Fargose, 2015; Rasel et al., 2017; Lu and Wang, 2011; Shabariram et al., 2016; Ahmed, 2015; Navadia et al., 2017; Hernández et al., 2016; Zhang et al., 2017; Saba et al., 2017)
7	Wind speed	(Tarade and Katti, 2011; Kulkarni et al., 2008; Kavasseri and Seetharaman, 2009; Erdem and Shi, 2011; Liu et al., 2011; Liu et al., 2012; Chen et al., 2009; Cadenas et al., 2016; Filik and Filik, 2017; Hou et al., 2019; Liang et al., 2018; Khodayar and Teshnehlab, 2015; Su et al., 2018; Yu et al., 2017; Liu et al., 2013; Liu et al., 2015; Sergio and Ludermir, 2015; Wu et al., 2019; Mi et al., 2017; Qu et al., 2019; Carrillo et al., 2017; Dhiman et al., 2019; Zhang et al., 2019; Mi et al., 2019; Qolipour et al., 2019; Chen et al., 2019b; Liu et al., 2020; Holmstrom et al., 2016; Kushwa et al., 2020; Ramasamy et al.. 2015; Ghorbani et al., 2016; Senthil, 2019; Blanchard et al., 2019; Liu et al., 2017; He and Xu, 2019; Ranganayaki et al., 2019; Li et al., 2018b; Adnan et al., 2019; Cai et al., 2020; Han et al., 2019; Zhao et al., 2020; James et al., 2015; Jaseena and Binsu, 2019; Chen et al., 2018; Zhu et al., 2019; Wang and Wang, 2017; Yu et al., 2018a; Hong et al., 2019; Chu et al., 2019; Wang et al., 2020)

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