

**AI DRIVEN-WEATHER MONITORING AND FORECAST: THE PROSPECTS AND STRATEGIES AS PERCEIVED BY ENVIRONMENT EXPERTS**

By

**ETUK, Iniobong Ita.**  
**Department of Environmental Science and Waste Technology,**  
**Akwa Ibom State Polytechnic.**  
**Ikot Osurua.**

**EFFIONG, Mordecai Effiong**  
**Department of Environmental Resources Management,**  
**University of Calabar,**  
**Calabar.**

And

**ETUK, Christiana Utibe, Ph.D.**  
**Department of Biological Sciences,**  
**Akwa Ibom State Polytechnic.**

**ABSTRACT**

*This study explores the transformative role of Artificial Intelligence (AI) in modern weather monitoring and forecasting, focusing on its prospects and strategic applications as perceived by environmental experts. AI technologies, particularly machine learning and neural networks, enhance prediction accuracy and disaster preparedness by analyzing vast meteorological datasets. Experts emphasize the integration of AI with traditional models for improved efficiency and reliability. Key strategies include data openness, ethical governance, and interdisciplinary collaboration. The paper highlights the importance of localized forecasting, capacity building, and policy support. Findings suggest that AI holds significant promise for climate resilience. The study concluded that experts emphasize the need for strategic integration, including data sharing, ethical safeguards, and cross-sector collaboration. The study also recommended that it helps to develop guidelines for ethical AI use, addressing algorithmic bias, explainability, and data governance to maintain public trust and equitable outcomes.*

**KEYWORD: Artificial Intelligence (AI), Weather Forecasting, Environmental Monitoring, Environment Expert**

**INTRODUCTION**

Recent advancements in artificial intelligence (AI) have significantly transformed weather monitoring and forecasting, offering enhanced accuracy, faster data processing, and predictive capabilities that surpass traditional methods. AI models—especially deep learning algorithms—are increasingly employed to process satellite imagery, radar data, and sensor networks, facilitating real-time and localized weather predictions. These systems address long-standing challenges such as the chaotic nature of weather systems and the limitations of physical models. According to Rasp et al. (2020), machine learning offers a complementary approach to traditional numerical weather prediction (NWP), significantly improving nowcasting and short-term forecasts by learning patterns directly from vast datasets rather than relying solely on atmospheric physics.

Environmental experts are particularly optimistic about the integration of AI in climate-related modeling and disaster risk reduction. AI not only increases forecasting precision but also enables scenario-based modeling for extreme weather events such as floods, hurricanes, and heatwaves—critical in regions with climate vulnerability. Scher and Messori (2021) argue that hybrid models, combining physics-based and data-driven approaches, are particularly valuable in climate-sensitive

regions where historical data may be sparse or unreliable. These advancements are also crucial for early warning systems, which are essential for timely evacuations and resource planning during natural disasters. AI's predictive capabilities, as demonstrated in projects such as Google DeepMind's "GraphCast," show significant promise in supporting these strategies by anticipating large-scale atmospheric phenomena with high accuracy (Lam et al., 2022).

Despite the prospects, experts also highlight the necessity for strategic implementation frameworks. The effective deployment of AI in meteorology requires cross-disciplinary collaboration, open-access data infrastructures, and standardized evaluation protocols to avoid bias and ensure model interpretability. Moreover, ethical considerations about data privacy and algorithmic transparency remain pivotal. As per Rolnick et al. (2022), aligning AI development with sustainability and equity goals is essential to avoid exacerbating socio-environmental disparities, especially in low-resource regions. These strategies must be supported by policy reforms and institutional readiness to ensure long-term integration into operational meteorological systems.

### **CONCEPT OF AI**

Artificial intelligence (AI) refers to computer systems capable of performing complex tasks that historically only a human could do, such as reasoning, making decisions, or solving problems. Artificial intelligence is a field of science concerned with building computers and machines that can reason, learn, and act in such a way that would normally require human intelligence or that involves data whose scale exceeds what humans can analyze. Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems (Craig, 2024).

According to Glover (2025) Artificial intelligence (AI) is a branch of computer science that aims to build machines capable of performing tasks that typically require human intelligence. AI enables machines to simulate human abilities, such as learning, problem-solving, decision-making and comprehension. Common applications of AI include speech recognition, image recognition, content generation, recommendation systems and self-driving cars. Artificial intelligence (AI) is technology that allows machines to simulate human intelligence and cognitive capabilities. AI can be used to help make decisions, solve problems and perform tasks that are normally accomplished by humans.

As mentioned by Copeland (2025) artificial intelligence (AI), the ability of a digital computer or computer-controlled to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience. Since their development in the 1940s, digital computers have been programmed to carry out very complex tasks. As quoted by Karl (2024) Artificial Intelligence (AI) technology is intelligence exhibited by machines and computer systems that simulate human reasoning, performing tasks that would otherwise require human intelligence. Using algorithms, data, and computational power, AI can reason, learn, and problem-solve by recognizing patterns based on experience and making informed data-based decisions.

### **CONCEPT OF WEATHER**

Weather is the state of the atmosphere at a specific place and time, with respect to conditions such as temperature, humidity, wind, cloudiness, precipitation, and air pressure. It is the day-to-day conditions, such as a sunny, cloudy, rainy, or windy day. Weather can change rapidly and is influenced by various factors like air masses, fronts, and atmospheric circulation.

According to Botkin et al (2022), Weather encompasses interactions between atmospheric elements and the biosphere, influencing environmental processes such as erosion, plant growth, and animal behavior. Weather, as most commonly defined, occurs in the troposphere, the lowest region of the atmosphere that extends from the Earth's surface to 6–8 km (4–5 miles) at the poles and to about

17 km (11 miles) at the Equator. Weather is largely confined to the troposphere since this is where almost all clouds occur and almost all precipitation develops.

Weather condition is the regional weather during a defined time period from one up to several weeks. Weather condition is describing typical weather phenomena, such as a series of thunderstorm in hot summer, foggy month in autumn or other weather conditions which are typical for a specific region and/or season. Weather is a geographically variable phenomenon, where location-specific atmospheric conditions define human and physical geography (Marsh et al, 2023). Weather refers to daily or hourly atmospheric updates used in public forecasts to inform decisions related to travel, agriculture, and safety (National Weather Service, 2024).

### **CONCEPT OF WEATHER MONITORING**

Weather monitoring systems play a crucial role in our daily lives, especially when it comes to safety, agriculture, and planning (Davda, 2024). These systems are designed to track and analyze various atmospheric conditions, helping us understand and predict weather patterns with greater accuracy. The outdoor weather monitoring system is composed of weather sensors, microcomputer weather data collectors, power supply systems, all-weather protective boxes, and environmental monitoring cloud platforms. It is a weather monitoring system designed for environmental monitoring and disaster monitoring and early warning. It is used to monitor wind speed, wind direction, rainfall, air temperature, air humidity, light intensity, soil temperature, soil humidity, evaporation, atmospheric pressure, etc. Meteorological elements are monitored all-weather on-site. Then it is connected to the computer through the professional supporting data collection communication line, and the data is transmitted to the meteorological monitoring cloud platform for statistical analysis and processing. It is widely used in scientific research institutes, intelligent agriculture, construction site dust monitoring and other occasions (Sensor 2021).

The KSEM instruments is used to monitor the near-Earth space weather conditions which affect a number of human activities including the radiation environment hazardous to spacecraft, crews of high-altitude aircraft, and the ionosphere environment (Comprehensive Remote Sensing 2018).

Weather monitors are instruments designed to collect and analyze data related to atmospheric conditions. These sophisticated devices are crucial for meteorology, climatology, and a range of other applications where weather plays a significant role, such as agriculture, aviation, and disaster management. At their core, weather monitors track and record various meteorological parameters, which typically include temperature, humidity, atmospheric pressure, wind speed and direction, precipitation, and solar radiation. This information is essential for understanding weather patterns, forecasting weather, and studying climate change.

### **CONCEPT OF WEATHER FORECAST**

Weather forecast is the result of the process of predicting (forecasting) the state of the atmosphere for a particular place and time using science (meteorology) and technology. Meteorologists also study the various processes that occur in the ocean and on land, because everything in nature is interconnected. Weather forecasting is the use of science and technology to forecast atmospheric conditions for a certain place and period. For centuries, people have tried to forecast the weather informally and officially since the nineteenth century (Ittianath 2025).

Encyclopedia (2025), asserted weather forecasting or weather prediction is the application of science and technology to predict the conditions of the atmosphere for a given location and time. People have attempted to predict the weather informally for thousands of years and formally since the 19th century. Weather forecasting uses tools, observational data, science, and technology to predict the weather hours, days, and months in advance for a given location. Before computer models, weather forecasting was done by observation. The first computer-generated weather forecast was made in 1955. Weather forecasting is used for knowing our daily weather and also used for long-term forecasting.

Forecasting the weather involves recording the ongoing measurements of temperature, pressure, precipitation, wind speed, and the amount of cloud cover, and giving those current readings and reports to the public. The reports of the current conditions are then used to predict the weather further out. Weather affects everyone. Hazardous and severe weather forecasts are very important as they can potentially save lives, property, and crops (Szymanski 2023).

Building and Environment (2022) asserted that a weather forecast is the prediction of future weather conditions based on global and regional scale numerical models and data assimilation. It is used to plan field measurement schedules and identify preferred weather scenarios. A weather forecast is simply a scientific estimate of future weather condition. Weather condition is the state of the atmosphere at a given time expressed in terms of the most significant weather variables. The significant weather variables being forecast differ from place to place. In the Philippines, the weather parameters with significant variation and therefore of interest to the users of the forecast are cloudiness, rainfall and wind.

## **ROLES OF AI IN WEATHER MONITORING**

Artificial Intelligence has significantly transformed weather monitoring and forecasting, enhancing accuracy, efficiency, and predictive capabilities across various domains. Below is an extensive overview of AI's role in weather monitoring:

- **Enhanced Weather Forecasting Accuracy**

AI models, particularly deep learning techniques like Long Short-Term Memory (LSTM) networks, have demonstrated superior performance in weather prediction tasks. For instance, a study by Sudhakar (2020) highlighted that LSTM models outperformed traditional methods in forecasting temperature and wind speed, achieving a maximum  $R^2$  score of 0.91 and a minimum Root Mean Square Error (RMSE) of  $2.1^\circ\text{C}/\text{m/s}$ . The integration of AI models with renewable energy data further optimized energy production by reducing fluctuations and enhancing grid stability.

- **Real-Time Precipitation Forecasting**

The development of MetNet, a neural network model introduced by Sønderby et al. (2020), marked a significant advancement in precipitation forecasting. MetNet utilizes radar and satellite data to predict precipitation up to 8 hours in advance with high spatial resolution ( $1 \text{ km}^2$ ) and temporal resolution (2 minutes). This model outperformed traditional Numerical Weather Prediction (NWP) methods, providing timely and localized weather information crucial for sectors like agriculture and disaster management.

- **Climate Modeling and Long Term Predictions**

AI enhances long-term climate forecasting by identifying complex patterns in decades of historical data, including temperature trends, ocean currents, and greenhouse gas emissions. According to Rolnick (2019), Deep learning models like Transformers and Autoencoders are used to simulate climate scenarios and project future changes. These tools improve regional downscaling and help predict events like El Niño, polar ice melt, and sea level rise. AI also assists in assessing risks under different carbon emission pathways. This supports informed policy-making and climate adaptation strategies. Compared to traditional models, AI provides faster and often more localized climate insights.

- **Data Assimilation and Global Weather Forecasting**

AI improves global weather forecasting by rapidly assimilating massive datasets from satellites, radar, and sensors into coherent models. Unlike traditional methods, AI can process diverse data types and fill gaps in real-time observations. Deep learning models such as Graph Neural Networks enhance the initialization of forecasts, improving accuracy. AI also enables faster simulations of global atmospheric patterns with reduced computational cost. This allows frequent, high-resolution updates

critical for aviation, disaster planning, and agriculture. Overall, AI supports more efficient, scalable, and precise global weather predictions.

- **Air Quality Monitoring and Forecasting**

AI is used to predict air pollution levels by analyzing environmental data such as wind patterns, temperature, traffic emissions, and industrial output. Models like CNNs and LSTMs process spatial and temporal patterns to forecast pollutants like PM<sub>2.5</sub>, NO<sub>2</sub>, and ozone. These forecasts are crucial for public health alerts, especially in urban areas. AI also supports the integration of sensor networks and satellite data for real-time air quality assessment. Federated learning methods help protect data privacy while enabling wide-scale pollution monitoring. Overall, AI improves the accuracy and timeliness of air quality information.

- **Drought Prediction and Management**

AI enhances drought forecasting by analyzing complex, non-linear relationships between climate variables like rainfall, soil moisture, and vegetation health. Machine learning models such as ANN, SVM, and LSTM are used to predict drought onset, duration, and severity (Taylan et al. 2021). These models outperform traditional statistical methods by learning from large datasets across diverse climatic zones. Satellite imagery combined with AI produces real-time drought maps for early warning systems. This supports better water resource planning and agricultural decision-making. Overall, AI enables faster, more localized, and reliable drought risk management.

- **Renewable Energy Optimization**

AI supports renewable energy systems by accurately forecasting weather-dependent variables like solar irradiance and wind speed. Models such as LSTM and gradient boosting use real-time weather data to predict energy output from solar panels and wind turbines. These forecasts help optimize grid operations, reduce energy waste, and balance supply and demand. AI also enables predictive maintenance of energy infrastructure by detecting anomalies linked to weather conditions. Integrating AI with meteorological data enhances the reliability of clean energy systems. This contributes to more stable and efficient renewable energy management.

## **ROLES OF AI IN WEATHER FORECAST**

Hazardous weather events up to a week in advance, using a probabilistic diffusion model (Weyn, 2024). Artificial Intelligence (AI) has revolutionized weather forecasting by improving the accuracy, speed, and reliability of predictions. Over the past few years, several AI-based models have emerged; demonstrating superior performance compared to traditional numerical weather prediction (NWP) models.

- **Improving Forecast Accuracy and Computational Efficiency**

One of the most impactful developments in recent years is Graph Cast, a machine learning (ML) model developed by Deep Mind, which uses a graph neural network to forecast global weather 10 days in advance at a resolution of 0.25 degrees. It achieves this in less than a minute, outperforming traditional models on 90% of over 1,300 evaluation metrics (Lam, 2022). Similarly, Pangu-Weather, developed by Huawei, uses 3D Earth-Specific Transformer to generate forecasts up to 10,000 times faster than conventional systems while maintaining competitive accuracy (Bi, 2023).

- **AI in Medium-Range and Global Forecasting**

AI is increasingly used in medium-range forecasting (3–10 days) to reduce reliance on computationally intensive simulations. Deep learning models can capture nonlinear relationships in vast meteorological datasets. According to Ravuri et al. (2021), deep generative models can simulate

realistic climate sequences by learning directly from satellite observations and reanalysis data. A more recent example is FengWu-Adas, an end-to-end system integrating AI-based data assimilation and forecasting, which has shown promising results when tested against operational forecasting standards (Cao, 2023).

➤ **Weather Event Prediction**

AI has shown particular promise in predicting severe weather events. Storm Cast, a model by Nvidia, provides short-term (0–12 hour) storm predictions by simulating storm systems at a resolution of one kilometer, enabling rapid alerts for floods and heavy rainfall (Nvidia, 2024). Deep Mind's SEEDS (Scalable Ensemble Envelope Diffusion Simulator) also stands out for its ability to identify rare and

➤ **AI in Renewable Energy Weather Forecasting**

Accurate forecasting is crucial for optimizing renewable energy sources like solar and wind. AI models, such as Long Short-Term Memory (LSTM) networks and hybrid neuro-fuzzy systems, have demonstrated improved performance in predicting weather-dependent energy outputs. A recent review by Iyer and Singh (2022) found that hybrid AI systems significantly reduce energy prediction errors and enhance grid reliability, especially in areas with fluctuating weather conditions.

➤ **Applications in Disaster Risk Management**

AI also plays a crucial role in disaster preparedness and early warning systems. AI-enhanced weather forecasts are being used to support urban planning and public safety through initiatives such as the United Nations' Global AI for Disaster Resilience project. These systems improve lead times and reliability in predicting extreme weather, such as cyclones and floods, allowing for better resource deployment and emergency response (Ghosh, 2024).

➤ **Localized Applications: Rainfall Prediction in Africa**

AI has also proven effective in regional forecasting. For instance, in Ethiopia, researchers have used Artificial Neural Networks (ANN) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS) to predict monthly rainfall with high accuracy. This supports agriculture and water management strategies in climate-sensitive regions (Yilma, 2022).

## **STRATEGIC STEPS OF USING AI FOR WEATHER MONITORING**

Artificial Intelligence (AI) has significantly advanced weather monitoring and forecasting, offering enhanced accuracy, efficiency, and scalability. Below is a strategic framework for integrating AI into weather monitoring systems.

➤ **Data Acquisition and Integration**

Effective AI-based weather monitoring begins with acquiring high-quality, multi-source datasets. This includes data from satellites, radars, meteorological stations, and historical records. Integrating diverse datasets ensures coverage of spatial and temporal variations, which is critical for accurate predictions. AI models such as those used in renewable energy forecasting have demonstrated higher accuracy when integrating data from sources like NASA and the European Centre for Medium-Range Weather Forecasts (ECMWF) (Kaur & Sharma, 2023).

➤ **Data Preprocessing and Feature Engineering**

AI systems require structured input. Data preprocessing involves cleaning, handling missing values, and transforming raw data. Feature engineering extracts key variables that influence weather outcomes, improving learning efficiency. For example, the use of Partial Mutual Information (PMI) in

rainfall and flood forecasting improved model input selection, leading to higher predictive accuracy (Mishra, 2020).

➤ **Model Selection and Development**

AI techniques like Artificial Neural Networks (ANNs), Long Short-Term Memory (LSTM) networks, and Random Forests are widely applied for weather forecasting. LSTM, in particular, is effective for time-series data, handling temporal dependencies inherent in meteorological data. A hybrid model combining ANN and LSTM was able to predict solar radiation and wind speed with an  $R^2$  value of 0.92, showcasing the potential of AI in weather-sensitive industries (Kaur & Sharma, 2023).

➤ **Model Training and Validation**

Training involves feeding historical data into models to learn patterns. Validation ensures that the model performs well on unseen data, preventing overfitting and ensuring reliability. The Artificial Intelligence Forecasting System (AIFS) developed by ECMWF showed high accuracy in medium-range forecasts by training on vast, high-resolution datasets (Pathak, 2024).

➤ **Model Evaluation and Calibration**

Evaluation metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and  $R^2$  score assess model performance. Calibration methods adjust output to reflect real-world observations better. Techniques like IMPROVER (post-processing pipeline) improved the accuracy of raw AI-generated forecasts by applying statistical corrections (Hewson, 2025).

➤ **Deployment and Operationalization**

AI models must be integrated into operational platforms for real-time application. This step involves system integration, performance monitoring, and scalability across regions or sectors. FengWu-Adas, an end-to-end AI-driven global forecasting system, exemplifies how AI can be operationalized for large-scale, real-time weather forecasting (Zhang et al., 2023).

➤ **Continuous Monitoring and Model Updating**

Weather systems are dynamic. AI models should be updated with new data regularly. Continuous training and assessment ensure model relevance and accuracy over time. AI models can complement and even outperform traditional Numerical Weather Prediction (NWP) methods when continuously updated (Hewson, 2025).

**STRATEGIC STEPS OF USING AI FOR WEATHER FORECAST**

Artificial Intelligence (AI) has revolutionized the field of weather forecasting by enabling systems that can learn from vast datasets, model complex atmospheric behaviors, and improve predictive accuracy. The successful deployment of AI in this field requires a structured approach involving several strategic steps.

➤ **Data Acquisition and Integration**

The foundation of any AI-based weather forecasting system is comprehensive and high-quality data. Sources include satellite imagery, radar outputs, surface weather stations, and climate reanalysis datasets. Integrating data from multiple sources enhances model accuracy by capturing spatial and temporal variations (Kaur & Sharma, 2023). The integration of NASA satellite data with European Centre for Medium-Range Weather Forecasts (ECMWF) outputs is a common practice in recent AI weather prediction models.

➤ **Data Preprocessing and Feature Engineering**

Raw meteorological data often contain noise, missing values, and inconsistencies. Preprocessing involves data cleaning, normalization, and transformation to formats usable by AI models. Feature engineering, including techniques like Partial Mutual Information (PMI), helps extract meaningful input variables that significantly affect weather events (Mishra, 2020). Properly engineered features improve model learning and reduce training complexity.

#### ➤ **Model Selection and Development**

AI models used in weather forecasting include:

- **Artificial Neural Networks (ANNs)** for pattern recognition,
- **Long Short-Term Memory (LSTM)** networks for time-series forecasting, and
- **Random Forests** for classification and regression tasks on structured data.

Hybrid approaches combining LSTM and ANN have achieved promising results in predicting solar radiation and wind speed, with high accuracy ( $R^2 = 0.92$ ) (Kaur & Sharma, 2023). The choice of model depends on the nature of the data and the specific forecasting task.

#### ➤ **Model Training and Validation**

Once selected, the models are trained on historical weather datasets. Proper validation using techniques like k-fold cross-validation ensures generalizability to unseen data. ECMWF's Artificial Intelligence Forecasting System (AIFS) exemplifies a robust training setup, using high-resolution global datasets to predict variables such as temperature, humidity, and wind at different altitudes (Pathak, 2024). This approach has demonstrated that AI models can match or even outperform traditional numerical methods in some mid-range forecasts.

#### ➤ **Model Evaluation and Calibration**

Evaluation is essential for assessing performance using metrics such as Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and the coefficient of determination ( $R^2$ ). Calibration methods adjust the raw AI predictions to align with actual observations. For instance, the IMPROVER post-processing pipeline significantly improved the reliability of ECMWF's AI-based forecasts (Hewson, 2025). These methods ensure forecasts remain robust under varying atmospheric conditions.

#### ➤ **Deployment and Operationalization**

Operationalization involves integrating the AI model into weather services, ensuring it can deliver real-time forecasts. This includes system architecture planning, cloud deployment, and user interface design. The FengWu-Adas system is a notable example of a fully operational, AI-driven global forecasting system that combines data assimilation and deep learning for real-time weather prediction (Zhang, 2023).

#### ➤ **Continuous Monitoring and Model Updating**

Weather systems are dynamic, necessitating ongoing model refinement. Continuous retraining with fresh data, adaptive learning techniques, and integration with traditional Numerical Weather Prediction (NWP) systems help maintain forecast relevance. Research by Hewson. (2025) emphasizes the importance of combining AI with statistical post-processing and traditional models to maintain accuracy over time.

## **CONCLUSION**

In conclusion, artificial Intelligence (AI) is revolutionizing weather monitoring and forecasting by enabling faster, more accurate predictions using vast datasets from satellites, sensors, and models. Environmental experts view AI as a critical tool in addressing climate-related challenges, especially in



predicting extreme weather events. Through machine learning, AI systems can detect patterns and anticipate changes with greater precision than traditional methods. This technological shift enhances disaster preparedness, supports agricultural planning, and strengthens climate resilience. Experts emphasize the need for strategic integration, including data sharing, ethical safeguards, and cross-sector collaboration. AI also facilitates localized forecasting, benefiting vulnerable communities. Its prospects are promising, but require structured implementation.

### RECOMMENDATIONS

- It helps to develop guidelines for ethical AI use, addressing algorithmic bias, explainability, and data governance to maintain public trust and equitable outcomes.
- It helps to encourage partnerships between climatologists, data scientists, and AI engineers to co-develop robust, interpretable forecasting models suited to regional and global climates.
- It is uses AI-enhanced models to improve early warning systems for disasters like floods and cyclones, reducing response time and minimizing loss of life and property.

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