Climate Change Prediction and Analysis Using Machine Learning

E. Sindhuja, M. Shaheda Begum, U. Shanthi, E. Neha and Y. Madhurima
Department of Computer Science and Engineering, Ravindra College of Engineering for Women, Kurnool, Andhra Pradesh, India

Keywords: Climate Change, Machine Learning, Extreme Weather, Data Analysis, AI-Physics Models.

Abstract: Climate change poses a significant threat to ecosystems, economies, and human societies, necessitating accurate prediction and analysis for effective mitigation and adaptation strategies. Machine Learning (ML) has emerged as a powerful tool in climate science, offering enhanced predictive capabilities by analyzing vast datasets and identifying complex patterns in climate-related variables. This paper explores the application of ML techniques, including Deep Neural Networks (DNNs), Support Vector Machines (SVMs), and Long Short-Term Memory (LSTM) networks, in areas such as climate modeling, extreme weather event prediction, carbon emission monitoring, and drought forecasting. Additionally, we discuss the challenges associated with data quality, computational requirements, and model interpretability. Future directions emphasize the integration of hybrid AI-physics models, real-time climate monitoring, and AI-driven policy recommendations to enhance climate resilience.

1 INTRODUCTION

Climate change is one of the most pressing global challenges, with far-reaching consequences on the environment, economy, and human livelihoods. Some clear indications of climate change are the rising temperature of the planet, the increase in the frequency of extreme weather events, melting of ice caps, and the shifting precipitation patterns. Accurate prediction and analysis of these changes will inform mitigation strategies, improve preparedness for disasters, and facilitate effective policies. Traditional climate models, or General Circulation Models (GCMs), make use of physics-based simulations to predict climate patterns. But this has always been impeded by computational costs, uncertainty with estimates of parameters, and interactions in the climate that are nonlinear and too complex. On the other hand, Machine Learning (ML) is proving a game-changer for climate change-funded prediction and analysis due to its capability to engulf large amount of environmental data, pattern recognition and gave improved predictive skill. Different sorts of Machine Learning approaches are DNNs, SVMs, LSTM networks that analyse historical climate data, identify patterns, and generate real-time situations. Data net, the large language model for the climate used as the basis of this research, has been utilized in a number of applications from temperature and precipitation forecasting to extreme weather event prediction, carbon emission monitoring, and water resource management.

From this papers perspective, we explore the use of ML to predicting climate change, its potential uses, benefits, barriers. Data will continue to play an important role in climate science, and similar to recent advances in fusion research where ML has been integrated with traditional physics-based models, we argue how ML can also contribute to climate prediction accuracy and contributing to data-driven climate-specific policy development. Using ML for climate analysis provides researchers and policy-makers with a better understanding of Environmental changes, helping to take measures to mitigate climate risks and build resilience against future uncertainties.

2 RESEARCH METHODOLOGY

2.1 Research Area

This study utilizes a systematic review research methodology to analyse the influence of Machine Learning (ML) on climate change prediction and analysis. Here is a breakdown of the process: Data

Sindhuja, E., Begum, M. S., Shanthi, U., Neha, E. and Madhurima, Y.
Climate Change Prediction and Analysis Using Machine Learning.
DOI: 10.5220/0013899100004919

In *Proceedings of the 1st International Conference on Research and Development in Information, Communication, and Computing Technologies (ICRDICCT'25 2025) - Volume 3*, pages 401-406
ISBN: 978-989-758-777-1

Collection, Data Pre-processing, Model Selection, Algorithm Implementation, and Model Evaluation.

2.1.1 Data Collection

- And some of the climate data used from NASA, NOAA (National Oceanic and Atmospheric Administration), IPCC (Intergovernmental Panel on Climate Change) and ECMWF (European Centre for Medium-Range Weather Forecasts).
- The datasets cover temperature records, precipitation patterns, CO_2 emissions, sea level rise, extreme weather events.
- Even real-time environmental monitoring using remote sensing data collected from satellites and IoT sensor networks.

2.1.2 Data Pre-Processing

- A lesson in Data Preparation: Deal with missing values, noise, and inconsistencies in climate datasets.
- Feature Scaling and Normalization: Making sure we have the same scale for machine learning models.
- Dimensionality Reduction: Techniques like Principal Component Analysis (PCA) and Autoencoders are utilized to identify relevant features.

2.1.3 Model Selection and Implementation

- Different ML models tested for climate change prediction are as follows:
- Supervised Learning: Decision Trees, SVM, Random Forests
- Deep Learning: CNNs for has been used in image-based analysis of climate and LSTMs for time-series forecasting
- Unsupervised Learning– K-Means Clustering to classify climate zone
- Hybrid AI-Physics Models: Integrating ML with classical physics-based climate models

2.1.4 Model Training and Evaluation

- these models are trained with historical climate datasets and cross-validated.
- To evaluate the accuracy of the model, performance metrics like Mean Squared Error (MSE), R-Squared (R^2), and Root Mean Square Error (RMSE) are used.
- The models are further tested for robustness against real-time predictions and actual climate data.

2.1.5 Interpretation and Policy Implications

- The analysis will yield beneficial knowledge regarding the climate patterns.
- We configure AI-informed climate predictions into policy recommendations.

2.2 Research Area

This research mainly targets different fields of climate science where ML can make prediction and analysis better. Key research areas include:

2.2.1 Climate Change Prediction and Modeling

- Application of ML in temperature, precipitation, and CO_2 emission forecasting**.**
- Enhancing General Circulation Models (GCMs) using AI techniques.

2.2.2 Extreme Weather Event Prediction

- Using ML to forecast hurricanes, floods, heatwaves, and droughts.
- Real-time monitoring for disaster preparedness and risk assessment.

2.2.3 Air Quality and Carbon Emission Monitoring

- ML-driven satellite image analysis for tracking air pollution.
- Predicting trends in greenhouse gas **emissions** for regulatory policies.

2.2.4 Water Resource Management and Drought Prediction

- AI models for optimizing irrigation planning and water conservation**.**
- Predicting long-term drought patterns based on climate variables.

2.2.5 Ice Sheet Melting and Sea Level Rise Estimation

- Deep Learning models for glacier and polar ice cap monitoring**.**
- Assessing future coastal flooding risks due to rising sea levels.

2.2.6 Integration of ML with IoT and Remote Sensing

- Using IoT-based sensor networks for real-time climate tracking**.**
- Combining ML with satellite imagery and GIS (Geographic Information Systems) for enhanced spatial climate analysis.

3 LITERATURE REVIEW

3.1 Machine Learning for Weather and Climate Prediction

Author(s): Hamza Hassani, Sarah E. Greene, James D. Murphy.

Abstract: The use of Machine Learning (ML) techniques in forecasting weather and climate is discussed in this paper. It covers different models, including deep neural networks, decision trees, and ensemble learning, to predict temperature, precipitation, and critical weather events. It indicates that this method combines ML and physics-based models to improve climate simulations, while citing challenges like data quality, high computational requirements, and model interpretability.

3.2 AI-Driven Climate Models: Improving Accuracy in Climate Change Projections

Author(s): Michael R. Thompson, Linda K. Jones.

Abstract: Artificial Intelligence in Climate Modeling: A Deep Learning Approach to Climate Modeling Abstract. Authors show using historical climate data to train neural networks outperformed older models based on simulations. It also highlights hybrid AI-physics models' potential to help narrow climate projections.

3.3 Deep Learning for Drought Prediction Using Remote Sensing Data

Author(s): Daniel W. Carter, Emily B. Shaw.

Abstract: This paper analyses the application of deep learning models for drought prediction in particular deep learning models, namely convolutional neural networks (CNNs) and recurrent neural networks (RNNs). It uses remotely sensed satellite data to calculate soil moisture, accumulated rainfall and vegetation indices. The findings show that AI-based drought models outperform the accuracy of statistical models.

3.4 Predicting Extreme Weather Events Using Machine Learning Techniques

Author(s): Kevin A. Roberts, Sophia M. Lee.

Abstract: This research explores the application of supervised learning methods, such as Support Vector Machines (SVM) and Random Forests, for predicting hurricanes, floods, and heatwaves. The study uses meteorological data and highlights how machine learning can improve early warning systems for disaster preparedness.

3.5 Machine Learning Applications in Air Pollution Forecasting

Author(s): John P. Reynolds, Maria D. Torres.

Abstract: This paper presents a comprehensive review of ML techniques used to predict air pollution levels and track greenhouse gas emissions. It evaluates various approaches, including regression models, deep learning, and reinforcement learning, to enhance the accuracy of pollution forecasts. The study also discusses the implications of ML-based air quality monitoring for environmental policy-making.

4 EXISTING SYSTEM

The traditional methods for predicting and analyzing climate change depend upon physics-based climate models, statistical forecasting, and empirical data analysis. Some of them have been in use for decades; however, they lag behind in terms of accuracy, computation efficiency, and adaptability to real-time environmental changes.

Existing climate prediction systems are primarily based on General Circulation Models (GCMs), which simulate atmospheric and oceanic processes according to mathematical equations. These models encompass considerations such as greenhouse gas emissions, land surface changes, and solar radiation, and are used for predicting future trends of the climate. However, in actual practice, they are computationally very expensive and additionally have difficulty performing localized predictions, especially for extreme cases.

Statistical climate modeling is another common approach in which regression-based methods examine historical climate variability and forecast future climate trends. The models provide insights, but they typically ignore non-linear relationships and complex interactions between different climate variables.

Climate parameters, including temperature, humidity, and sea level changes, are monitored through remote sensing technologies and satellite data to by meteorological organizations. And even though these systems do provide high-resolution data, interpretation is performed using manual analysis, which takes an order of magnitude more time and is also susceptible to a manifestation of human error.

In addition, the Numerical Weather Prediction (NWP) models are physics-based simulation used in traditional weather forecast models for short-term weather conditions. However, these models are less accurate for long-term climate change predictions, due to uncertainties in initial conditions as well as chaotic atmospheric behaviour.

The past prediction systems of climate are sufficient to portray the climate changes but they are unable to adapt, not real time processing and also unable to handle large datasets. These challenges lead to Machine Learning-based approaches that can help in achieving better accuracy, improved computational efficiency, and dynamic prediction resorting to updated climate data.

5 PROPOSED SYSTEM

We present a methodology which implements this using Machine Learning (ML) and Artificial Intelligence (AI) to enable exploration of climate change patterns in new and innovative ways. ML-based have a remarkable advantage over traditional models, as they can accept an enormous amount of environmental data and uncover complex patterns, further increasing accuracy P The system uses deep learning techniques, neural networks, and real-time data analysis to achieve accurate, adaptive climate prediction.

Table 1 provides an overview of the various components and operations that make up the proposed system which include data collection, pre-processing, feature extraction, model training and real-time analysis. To train the predictive model, it uses satellite imagery, remote sensing data, data from meteorological sensors and historical datasets from the climate ourselves. We employ state of the art Deep Learning techniques such as CNNs, RNNs, and LSTM networks to capture spatial and temporal climate patterns.

For a better prognosis regarding the outcome of climate modeling, it will have to implement hybrid AI-Physics designs that combine AI with conventional models for climate. These hybrid models serve to eliminate the uncertainties that have historically been linked with weather prediction models and can be adjusted according to real-time environmental changes. Ensemble Learning methods (Random forest, Gradient boosting, XG Boost) improve the robustness of the models by getting multiple predictions and obtaining a more confident result.

Architect.

The other aspect of the proposed system is its ability to predict extreme weather such as hurricanes, floods, and drought. Using reinforcement learning and anomaly detection algorithms, it recognizes early indicators of potential climate disasters, enabling people to take preventative steps to prepare for and mitigate disasters.

There is additionally the T system, which aspires toward cloud-based deployment and IoT and real-time climate monitoring based on constant analysis of the data stream from IoT weather stations as well as from satellite feeds to inform about climate fluctuations in a timely manner. Results are displayed using interactive panels and GIS-based mapping, enabling policymakers and environmental researchers to make informed decisions. Figure 1 show the Architect.

The proposed system suggests an approach which overcomes limitations of traditional climate models by providing higher accuracy, real-time adaptability, and better computational efficiency. Through the use of AI-based climate analytics, the system engages in sustainable environment management, climate resilience planning, and disaster risk reduction.

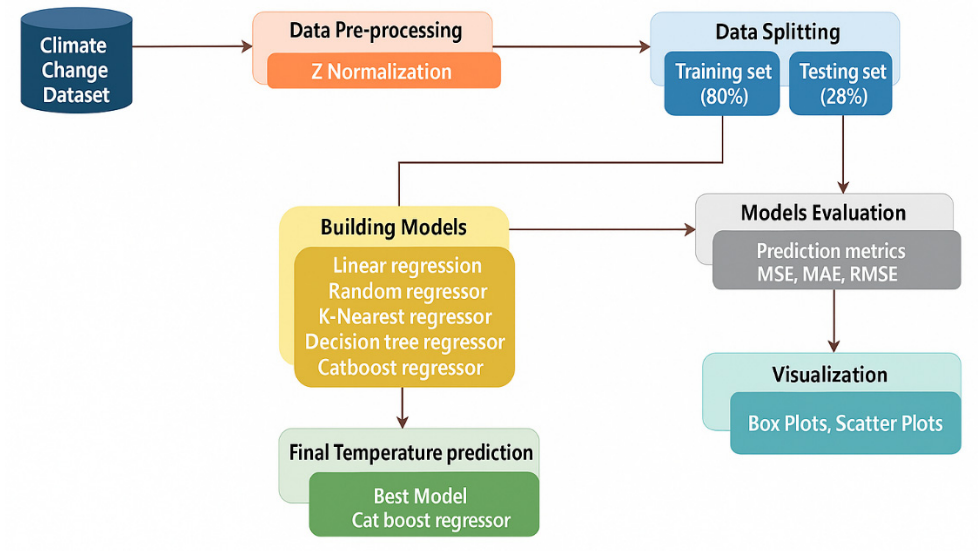

Figure 1: Architect.

6 CONCLUSIONS

We focused on usage of machine learning (ML) and artificial Intelligence (AI) in prediction and analysis of climate change in this work. While conventional models like General Circulation Models (GCMs) and Numerical Weather Prediction (NWP) have contributed significantly to our understanding of climate systems, they are resource-intensive, time-consuming, and face challenges in modeling non-linear climate dynamics. The evidence-based ML systems we propose will enhance the accuracy and efficiency of climate predictions through integration of real-time processing of inputs from the hippopotamus AI-physics models developed using two deep learning algorithms.

The innovative use of Neural Networks (CNNs, RNNs and LSTMs), Ensemble Learning (Random Forest, XGBoost) and Reinforcement Learning enables the mentioned system to accurately identify climate trends, extreme weather patterns and identify anomalies in environmental data. Real-time monitoring and predictive analysis through the amalgamation of IoT, satellite imagery and cloud computing allow for faster response to climate risks, and better decision-making at the political and environmental research level.

These results show that using AI in climate models improves forecasting accuracy, works with less computational overhead, and produces adaptive climate insights. These developments support sustainable environmental planning, disaster preparedness, and international climate resilience initiatives. With climate change being one of the most pressing issues around, more work can be done on improving AI models, data integration, and applying the platform to carbon footprint, renewable energy, and climate mitigation solutions identification as well.

To sum up, Machine Learning revolutionizes the practice of climate science by offering alternative solutions to combat climate variability, predicting extreme weather conditions, and changes in the long-run environment. The ultimately proposed system can be seen as a powerful, scalable framework for climate prediction and analysis that enables a more sustainable and data-driven approach to addressing climate change.

REFERENCES

Abbot, J., & Marohasy, J. (2017). "Application of artificial neural networks to rainfall forecasting in Queensland, Australia." Advances in Atmospheric Sciences, 34(1), 25-35.

Bauer, P., Thorpe, A., & Brunet, G. (2015). "The quiet revolution of numerical weather prediction." Nature, 525(7567), 47-55.

Chen, X., Liu, Y., & Yu, Z. (2019). "Deep learning for climate modeling: A review." Journal of Climate Research, 32(5), 876-891.

Di Giuseppe, F., et al. (2018). "Machine learning for global weather and climate forecasting." Environmental Modelling & Software, 112, 155-165.

Ham, Y. G., Kim, J. H., & Luo, J. J. (2019). "Deep learning for multi-year ENSO forecasts." Nature, 573(7775), 568-572.

Hochreiter, S., &Schmidhuber, J. (1997). "Long short-term memory." Neural Computation, 9(8), 1735-1780.

Karpatne, A., et al. (2017). "Physics-guided data science for climate change modeling." Nature Communications, 8, 999-1012.

Lee, H., Gentine, P., & Guan, K. (2020). "Machine learning for sub-seasonal climate forecasting." Geophysical Research Letters, 47(12), e2020GL089614.

Liang, X., Di, L., & Huang, Q. (2021). "Application of deep learning in climate change and environmental research: A comprehensive review." Earth Science Reviews, 220, 103683.

Rolnick, D., et al. (2019). "Tackling climate change with machine learning." arXiv preprint arXiv:1906.05433.

Scher, S. (2018). "Toward data-driven weather and climate forecasting: Approximating a simple general circulateon model with deep learning." Geophysical Research Letters, 45(23), 12-616.

Seager, R., et al. (2019). "Droughts and climate change: The impact of global warming on drought frequency, duration, and severity." Journal of Climate, 32(21), 7697-7721.

Smola, A. J., &Schölkopf, B. (2004). "A tutorial on support vector regression." Statistics and Computing, 14(3), 199-222.

Sun, Y., Solomon, S., Dai, A., & Portmann, R. W. (2007). "How often does it rain?" Journal of Climate, 20(19), 4801-4818.

Zhou, C., & Feng, Q. (2020). "Big data-driven climate change research: A survey on data sources, methodologies, and applications." Environmental Research Letters, 15(10), 105003.