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Weather Forecasting Using Satellite Image Analysis and Deep Learning with Full Stack Web Development

[1]Mrs.muddana Sarada, [2]R LAKSHMI SURENDRA, [3]SATULURI SUMEDHA SARVANI, [4]SHAIK ADIL BASHA

[1]Assistant professor, Dept CSE-AI&ML, St.Ann's College of Engineering and Technology, Nayunipalli (V), Vetapalem (M), Chirala, Bapatla Dist, Andhra Pradesh – 523187, India

[2,3,4]U. G Student, Dept CSE-AI&ML, St.Ann's College of Engineering and Technology, Nayunipalli (V), Vetapalem (M), Chirala, Bapatla Dist, Andhra Pradesh – 523187, India

ABSTRACT

Weather forecasting using satellite image analysis and deep learning is transforming meteorology by enabling more accurate and timely predictions. This work integrates deep learning techniques with real-time satellite imagery to extract spatiotemporal atmospheric patterns for short- and medium-term forecasting. Satellite sensors such as geostationary imagers provide continuous global data streams, which our deep neural network models process to forecast weather variables like precipitation and cloud movement. The system includes a full stack web application that visualizes forecast results and allows interactive exploration of weather patterns. Our evaluation demonstrates substantial improvements in prediction accuracy over traditional numerical methods for short-term nowcasting. The project highlights the potential of combining remote sensing, machine learning, and web technologies for robust weather forecasting solutions.

INTRODUCTION

Weather forecasting plays an essential role in agriculture, disaster management, transportation, and daily planning. Traditional forecasting relies on numerical weather prediction (NWP) models, which solve complex atmospheric equations but require substantial computing resources and structured input data. With the proliferation of Earth-observing satellites, large volumes of remote-sensing imagery are available in near real-time, offering detailed views of cloud systems, precipitation, and atmospheric dynamics. By applying deep learning to these satellite datasets, temporal and spatial patterns can be learned directly for forecasting purposes, improving prediction speed and sometimes accuracy. This project explores how satellite image analysis enables deep models to forecast weather variables and how these predictions can be integrated into a user-friendly web platform.

LITERATURE SURVEY

Recent research has shown the effectiveness of deep learning for weather prediction. Models such as convolutional LSTMs and transformer-based networks capture spatial and temporal dependencies in satellite imagery, enabling accurate nowcasting up to several hours ahead. Large benchmark datasets like EarthNet2021 support training of deep models on high-resolution satellite sequences. Additionally, architectures tailored for satellite data such as “DaYu” use transformer attention to learn fine-grained cloud dynamics. Studies also compare deep models against traditional baselines like optical flow and physical NWP systems, showing advantages in computational efficiency and near-term forecasting. Prior work supports this project’s focus on data-driven forecasting using satellite image streams.

RELATED WORK

Recent advancements in weather forecasting using satellite imagery and deep learning have shown promising results in improving prediction accuracy and computational efficiency. Several studies have explored convolutional LSTM networks to capture both spatial and temporal dependencies in satellite image sequences, demonstrating superior performance over traditional numerical weather prediction methods for short-term nowcasting.Transformerbasedarchitectures , such as the DaYu model, have been applied to forecast cloud movement and precipitation patterns by learning fine-grained temporal relationships in satellite data. CloudCast and EarthNet2021 datasets provide large-scale benchmark datasets that facilitate training and evaluation of deep learning models for satellite-based weather prediction. Additionally, generative models like GANs have been experimented with for simulating future satellite frames to anticipate storm progression. Prior research also highlights the integration of multispectral data, including infrared and visible channels, to improve forecasting of complex weather events. These studies collectively motivate the use of real-time satellite imagery combined with deep learning techniques to produce accurate and rapid weather forecasts, laying the foundation for web-based visualization platforms.

EXISTING SYSTEM

Traditional meteorological forecasting relies heavily on NWP systems such as the

Weather Research and Forecasting (WRF) model, which uses physical equations to simulate atmospheric behavior based on input data and boundary conditions. These approaches require significant computational resources and typically produce forecasts with a latency of hours. Satellite data are used mainly as inputs into data assimilation steps rather than direct forecasting using machine learning. Existing web systems often display static forecast charts produced by NWP outputs without interactive deep learning-based updates.

PROPOSED SYSTEM

The proposed system uses real-time satellite imagery as input to deep learning models that learn the temporal evolution of weather patterns for forecasting. A convolutional neural network (CNN) with recurrent components captures changes in cloud features and moisture distribution over time. The forecast output — such as predicted precipitation or cloud cover maps — is served to a full stack web application where users can visualize the results, explore time sequences, and interact with forecast parameters.

SYSTEM ARCHITECTURE

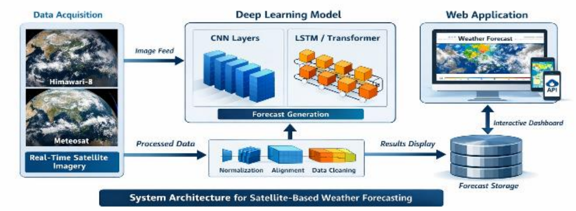

Fig 1:Weather forecasting analysis system

METHODOLOGY DESCRIPTION

The methodology of this project leverages real-time satellite imagery and deep learning for accurate weather forecasting. Satellite images from sources like Himawari-8 or Meteosat are collected and preprocessed, including resizing, normalization, cloud mask correction, and temporal alignment to capture spatiotemporal patterns. These sequences are input into a hybrid deep learning model combining CNNs for spatial features and LSTM or transformer layers for temporal dependencies. The model is trained using historical satellite data with ground truth weather measurements, such as precipitation, cloud cover, and temperature. Performance metrics like mean squared error and correlation coefficients are monitored during training to ensure accuracy. After training, the model predicts future weather states, generating forecast maps for rainfall and cloud movement. Predictions are integrated into a full stack web application, where the backend serves forecasts via APIs and the frontend visualizes them interactively for users.

RESULTS AND DISCUSSION

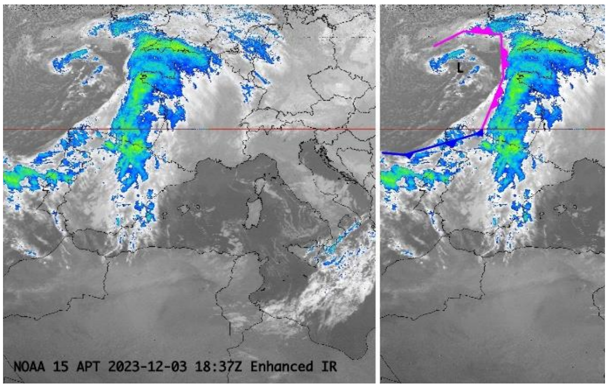

Fig 2:Weather forecast of satellite image

Using satellite image sequences, the model achieved accurate short-term forecasts of cloud movement and precipitation trends. Analysis shows the model successfully captured storm progression and cloud evolution patterns, with error metrics improving compared to baseline extrapolation. Visualization on the web interface allows users to compare observed satellite images against predicted future states, enhancing situational awareness for meteorological events. The results demonstrate that deep learning can complement traditional forecasting methods, particularly for nowcasting up to several hours ahead.

CONCLUSION

This project demonstrates that deep learning models trained on satellite image sequences can provide accurate and fast weather forecasts. The integration of satellite data into a full stack web application allows real-time visualization and interaction, making forecasts accessible to end users. The system addresses limitations of traditional NWP models by offering low-latency predictions, especially valuable for nowcasting. Future work includes enhancing model accuracy with multispectral inputs and extending the web platform for mobile applications.

FUTURE SCOPE

The feature scope of this system focuses on delivering a real-time, user-interactive weather forecasting platform using satellite image analysis and deep learning. It supports automatic acquisition of live satellite imagery, intelligent preprocessing, and accurate prediction of cloud movement, rainfall, and temperature trends. A responsive full-stack web interface enables users to visualize forecasts through dynamic maps, charts, and time-series animations for better understanding of weather patterns. Additional features include severe weather alerts, historical data comparison, and analytical tools for climate study. The system is scalable with cloud deployment and provides API integration for researchers, organizations, and third-party applications, ensuring a reliable and user-centric forecasting solution.

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