Title: A Hybrid HYSPLIT-LSTM approach for predicting radioactive material dispersion from the Zaporizhzhia nuclear power plant

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Abstract: This study presents a predictive framework for modeling the dispersion of radioactive materials following a hypothetical incident at the Zaporizhzhia Nuclear Power Plant. Leveraging meteorological data from the National Oceanic and Atmospheric Administration (NOAA) and simulations via the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, key environmental variables such as altitude, temperature, and humidity were forecasted for the period of February 1 to 7, 2024. These forecasts were extended using a Long Short-Term Memory (LSTM) neural network, enabling trajectory predictions for the following week, which were then compared against actual observations. To quantify the accuracy of the predictions, statistical indicators including Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Relative Error (MRE), and Mean Bias Error (MBE) were applied. The LSTM network demonstrated superior precision in longitude estimation (MAE: 0.0837, RMSE: 0.1241, MAPE: 0.1779 %) compared to the Recurrent Neural Network (RNN), which showed higher error margins. Similarly, for latitude prediction, the LSTM model maintained lower deviation values (MAE: 0.2019, RMSE: 0.3845) than its RNN counterpart. These findings highlight the LSTM's advantage in handling long-term sequential data, particularly in scenarios where traditional RNNs struggle with vanishing gradients and loss of temporal dependencies. The proposed approach offers a reliable tool for enhancing nuclear emergency preparedness, supporting early warning systems, and informing strategic countermeasures in the face of radiological threats.

https://doi.org/10.1016/j.radphyschem.2025.113424

https://www.sciencedirect.com/science/article/abs/pii/S0969806X25009168