Literature Review on Tropical Cyclone Intensity and Track Prediction

# Paper 1: Sridevi et al., 2022

Citation: Sridevi, Ch., Pattanaik, D.R., Das, A.K., Srivastava, A., Durai, V.R., Johny, C.J., Deshpande, M., Suneetha, P., Kanase, R. (2022). Tropical cyclone track and intensity prediction skill of GFS model over NIO during 2019 & 2020. Tropical Cyclone Research and Review, 11(1), 36–49. DOI:10.1016/j.tcrr.2022.04.002

## PICO Summary

Problem: Tropical cyclones in the North Indian Ocean cause severe damage. Accurate prediction of track and intensity is essential for early warning. IMD uses the GFS model, but its skill over the NIO needed evaluation for recent years (2019–2020).

Intervention: Verified the skill of the GFS (T1534, ~12.5 km resolution) for 13 cyclones using the GFDL Vortex Tracker. Compared GFS forecasts with IMD’s best-track data. Measured Direct Position Error (DPE), Along-Track Error (ATE), Cross-Track Error (CTE), Maximum Sustained Winds (MaxWS), and Minimum Sea Level Pressure (MSLP).

Comparison: Benchmarked with earlier global and regional studies (Chen, Hamill, Hazelton, Deshpande, Routray, Kotal, Malakar). Findings align that GFS is useful for track but tends to underpredict intensity.

Outcome: Track forecast reliable up to 2–3 days; DPE ~51–331 km (2019) and 82–359 km (2020). Forecasts biased towards faster and slightly rightward tracks. Intensity underestimated, especially in 2020, with MaxWS errors up to 26 kt. Errors larger in Arabian Sea and weaker storms.

## Simple Summary

GFS performs reasonably well for cyclone track forecasts up to 2–3 days but underestimates cyclone intensity, especially in weaker systems. Forecast accuracy varied between 2019 and 2020. Compared to earlier works, ensembles, higher resolution models, and hybrid statistical methods provide better results.

# Paper 2: ML-based Intensity Prediction, 2023

Citation: Cyclone Intensity Prediction over North Indian Ocean using Machine Learning Models. Environmental Modelling & Software, 2023. DOI:10.1016/j.envsoft.2023.105612

## PICO Summary

Problem: Forecasting cyclone intensity in the NIO is difficult, and traditional methods like NWP or Dvorak often mispredict intensity.

Intervention: Used Machine Learning models (Random Forest, Gradient Boosting, XGBoost) with IMD best-track data (2001–2020). Input features included cyclone location, pressure, wind speed, and distance from land.

Comparison: Benchmarked against IMD statistical model (SCIP), Dvorak, and GFS. Earlier ML works showed 88–99% accuracy with RMSE ~4–5 kt.

Outcome: ML models achieved much smaller errors (RMSE ~4–5 kt, high classification accuracy 88–99%), outperforming GFS and SCIP.

## Simple Summary

ML models significantly improve cyclone intensity prediction over NIO compared to NWP and statistical models. They show very small errors and high accuracy, making them strong candidates for operational use.

# Paper 3: Gupta & Arthur, 2025

Citation: Gupta, D., Arthur, M.P. (2025). Ensemble deep learning models for tropical cyclone intensity prediction using heterogeneous datasets. Tropical Cyclone Research and Review, 14, 1–12. DOI:10.1016/j.tcrr.2025.02.001

## PICO Summary

Problem: Cyclone intensity remains harder to predict than track, especially maximum sustained winds.

Intervention: Ensemble CNN models combining satellite imagery (GridSat, CMORPH) with numerical features (wind, SLP, size, location). Tested standalone CNN, RNN, AlexNet, VGG16, and ensemble fusion models.

Comparison: Compared against prior DL models like ConvGRU, ConvLSTM, as well as standalone CNNs.

Outcome: Ensemble fusion achieved best results (MSE 194, execution time 1229s). Outperformed AlexNet, VGG16, RNN, and prior DL models.

## Simple Summary

By combining both images and numerical cyclone data, ensemble deep learning reduced prediction errors significantly compared to single models. It also trained more efficiently, making it promising for operational use.

# Paper 4: Lee et al., 2024

Citation: Lee, J., Im, J., Shin, Y. (2024). Enhancing tropical cyclone intensity forecasting with explainable deep learning integrating satellite observations and numerical model outputs. iScience, 2024. DOI:10.1016/j.isci.2024.109905

## PICO Summary

Problem: Intensity forecasts are less accurate than track forecasts. Rapid intensification events are especially difficult.

Intervention: Hybrid CNN model fusing COMS satellite imagery (IR, WV channels) with CFSv2 outputs. Applied Explainable AI (XAI). Predictions made for 24h, 48h, and 72h lead times.

Comparison: Compared with KMA operational forecasts and deep learning models using single data sources (COMS-CNN, CFSv2-CNN, Intensity-LSTM).

Outcome: Hybrid-CNN improved skill scores: +22% (24h), +110% (48h), +7% (72h). Rapid intensification: +62% (24h), +87% (48h), +50% (72h). MAE ~15–23 kt, strong performance gains vs. KMA.

## Simple Summary

Hybrid-CNN with fused data sources shows significant improvements over operational forecasts, especially in rapid intensification cases. Explainable AI provides interpretability, helping forecasters trust the model in operational systems.

# Paper 5: Hybrid-CNN for TC Intensity Forecasting

Citation: (Assumed from context, Hybrid CNN Deep Learning study description provided).

## PICO Summary

Problem: Accurate prediction of TC intensity is crucial for disaster preparedness, yet traditional models underperform for intensity.

Intervention: Proposed a hybrid CNN approach combining satellite observations with numerical model outputs to forecast intensity at multiple lead times. Incorporated explainable AI to identify key factors driving predictions.

Comparison: Benchmarked against operational forecasts and other DL models using individual data sources.

Outcome: Demonstrated strong improvements in skill scores and MAE across 24–72h lead times, particularly for high-intensity and rapid intensification cases.

## Simple Summary

Hybrid-CNN successfully combines multiple data sources for better accuracy in intensity prediction. With explainable AI, the approach offers both improved accuracy and transparency, making it suitable for integration into real-time warning systems.