

AI-Baesda Prediction of Tropical Cyclones over the Arabian Sea: A Comparative Evaluation of GraphCast, Pangu-Weather, Aurora, and FourcastNet



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Abstract

The increasing intensity and frequency of tropical cyclones over the Arabian Sea pose substantial socio-economic and environmental risks to the surrounding coastal regions. Recent advances in artificial intelligence (AI)-based numerical weather prediction have provided new opportunities for improving tropical cyclone forecasting skill. In this study, we evaluate the performance of four state-of-the-art AI weather forecasting models namely GraphCast, PanguWeather, Aurora and FourCastNet in predicting the tropical cyclone Shakhti over the Arabian Sea. The model's potential are assessed in terms of track, intensity, and associated synopticscale atmospheric fields across different forecast lead times and initialization conditions. Results indicate that all AI-based models demonstrate considerable skill in forecasting cyclone characteristics, particularly within the first 24 hours of prediction. However, forecast accuracy varies substantially with lead time, initialization time, and the choice of initial conditions. Among the models, GraphCast exhibits superior skill in predicting cyclone intensity, whereas Pangu-Weather provides comparatively better track forecasts, especially at longer lead times. In general, forecasts initialized using IFS data outperform those driven by GFS initial conditions. The findings highlight the growing potential of AI-driven forecasting systems for operational tropical cyclone prediction and disaster preparedness over the North Indian Ocean region.

Introduction or Motivation

- The increasing intensity of tropical cyclones poses a significant threat of widespread devastation. A pronounced rise in sea surface temperatures over the Arabian Sea (AS) has made it a more active region for cyclogenesis.
- Tropical cyclones (TCs) forming over the AS impact Indian region, bringing intense rainfall, flash floods, and substantial socio-economic losses, particularly to communities living in coastal areas.
- Recent advancements in Artificial Intelligence (AI) have revolutionized global weather forecasting by significantly outperforming traditional models in accuracy and reliability. Leveraging complex algorithms and vast datasets, AI-based forecasting represents a transformative shift in meteorological practices, enabling more precise predictions of weather phenomena, including tropical cyclones.
- In this study, we demonstrated four AI-based weather forecasting models Pangu-Weather(Bi, et al. 2023), GrapCast(Lam, et al. 2023), Aurora(Bodnar, C., et al. 2025), FourCastNet(Pathak, et al. 2022) in predicting Tropical Cyclone Shakhti over the Arabian Sea.

MODEL, DATA AND METHODOLOGY

Pangu-Weather Model: The PW model is based on a spatial 3D Earth-specific transformer with hierarchical temporal aggregation approach (Bi et al. 2023). The model is run at a horizontal resolution of 0.25° and uses selected surface variables and standard upper-air variables on 13 pressure levels (50 hPa, 100 hPa, 150 hPa, 200 hPa, 250 hPa, 300 hPa, 400 hPa, 500 hPa, 600 hPa, 700 hPa, 850 hPa, 925 hPa, and 1000 hPa) as input. The model was trained using the hourly ERA5 reanalysis data, which provides the most reliable estimates of atmospheric variables over a period of 39 years (1979-2017). A set of four pre-trained models are generated i.e. 1, 3, 6, and 24 hour models. These models are subsequently tested and validated with data from 2018 and 2019 (Bi et al., 2023). The AI Weather Prediction (AIWP) Model Reforecasts dataset was obtained from the Registry of Open Data on AWS, provided by the AI Weather Prediction (AIWP) team (Radford et al., 2025).

GraphCast Model: GraphCast is implemented using GNNs in an "encode-process-decode" configuration, where the encoder maps (surface and atmospheric) features on the input latitude-longitude grid to a multi-mesh, the processor performs many rounds of message-passing on the multi-mesh, and the decoder maps the multi-mesh features back to the output latitude-longitude grid. GraphCast takes as input the two most recent states of Earth's weather, the current time and six hours earlier and predicts the next state of the weather six hours ahead. A single weather state is represented by a 0.25° latitude/longitude grid (721×1440), which corresponds to roughly 28×28 kilometer resolution at the equator, where each grid point represents a set of surface and atmospheric variables.

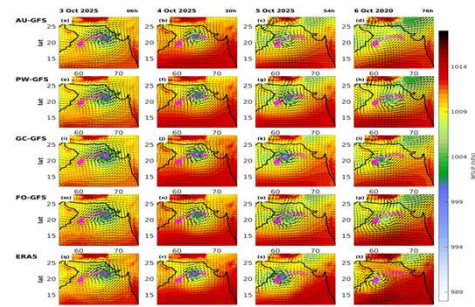
Aurora Model: Aurora is a machine learning model that produces forecasts for any collection of Earth system variables at any desired resolution. The model consists of three parts: (1) an encoder that converts heterogeneous inputs into a universal latent three-dimensional (3D) representation; (2) a processor that evolves the representation forward in time; and (3) a decoder that translates the standard 3D representation back into physical predictions. The processor is implemented as a 3D Swin Transformer and both the encoder and the decoder as Perceiver-based modules.

FourCastNet Model: FourCastNet, short for Fourier ForeCasting Neural Network, is a global data-driven weather forecasting model that provides accurate short to medium-range global predictions at 0.25° resolution. FourCastNet accurately forecasts high-resolution, fast-timescale variables such as the surface wind speed, precipitation, and atmospheric water vapor.

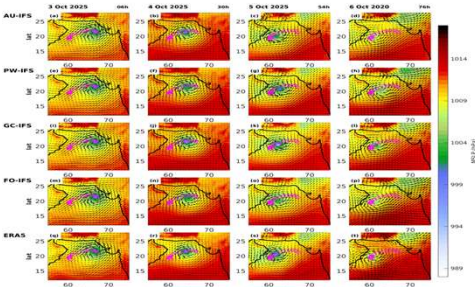
TRACK AND TRACK COMPUTATION

In this study, the storm centre was identified as the location of the local minimum in mean sea level pressure (MSLP). To ensure that the identified system represents a cyclonic circulation, the relative vorticity at 850 hPa (hereafter 850RV) was required to exceed a threshold of 1.0×10^{-4} . However, during the early development stages (depression and deep depression), the closed circulation criterion was not strictly applied, as the vortex may not be well organized at these stages. Relative vorticity at 850 hPa (hereafter 850RV) was computed from zonal and meridional wind components using central finite differences on a $0.25^\circ \times 0.25^\circ$ grid.

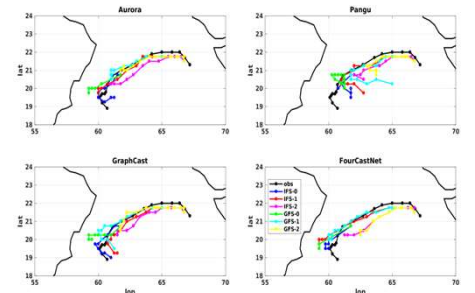
Results



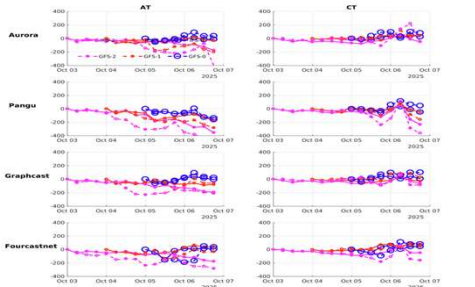
MSLP(shading) and wind (vectors), initialized on 03 October 2025 and driven by GFS initial conditions level pressure (shaded).



MSLP(shading) and wind (vectors), initialized on 03 October 2025 and driven by IFS initial conditions level pressure (shaded).



Paths of cyclone Shakhti for all the predictions along with observation



Along-track error and cross-track error for cyclone Shakhti up to 48 hours against corresponding values for the reference-track data

Discussion and Conclusions

- All models demonstrate good forecasting skill, particularly within the first 24 hours; however, forecast accuracy decreases with increasing lead time and varies with initialization time and dataset.
- GraphCast and Aurora consistently outperform the other models, especially with IFS initialization, and more accurately capture the cyclone's recurring track.
- The results demonstrate that the choice of AI model and the initialization dataset substantially influence forecast skill, particularly during the mature and recurring stages of the cyclone.
- These findings highlight the potential of AI-based weather forecasting systems to improve operational tropical cyclone prediction and disaster preparedness over the North Indian Ocean.
- The accuracy of cyclone track prediction depends on the forecasting model and quality of the initialization dataset.
- Track deviations increase with forecast lead time, whoever the AI-based models retain good directional accuracy throughout the cyclone lifecycle, with track forecast errors being dominated primarily by along-track rather than cross-track uncertainties.

Acknowledgements & References

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References

- Radford, J. T., Ebert-Uphoff, I., Stewart, J. Q., Musgrave, K. D., DeMaria, R., Tourville, N., & Hilburn, K. (2025). Accelerating community-wide evaluation of AI models for global weather prediction by facilitating access to model output. *Bulletin of the American Meteorological Society*, 106(1), E68-E76.
- Pathak, J., Subramanian, S., Harrington, P., Raja, S., Chattopadhyay, A., Mardani, M., ... & Anandkumar, A. (2022). Fourcastnet: A global data-driven high-resolution weather model using adaptive fourier neural operators. *arXiv preprint arXiv:2202.11214*.
- Bodnar, C., Bruinsma, W.P., Lucic, A. et al. A foundation model for the Earth system. *Nature* 641, 1180–1187 (2025). <https://doi.org/10.1038/s41586-025-09005-y>
- Sanchez-Gonzalez, A. (2024). GraphCast: Learning skillful medium-range global weather forecasting. *European Geosciences Union General Assembly 2024 (EGU24)*, 11381.
- Bi, K., L. Xie, H. Zhang, X. Chen, X. Gu, and Q. Tian, 2023: Accurate medium-range global weather forecasting with 3D neural networks. *Nature*, 619, 533–538

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