Synoptic Drivers of Tropical Cyclone Senyar and Long-term Change in Near-Equatorial Tropical Cyclones over the Maritime Continent

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Abstract

Tropical Cyclone (TC) Senyar was a rare near-equatorial TC that formed in the narrow Malacca Strait and severely impacted the western Maritime Continent (MC). Its development was driven by the convergence of cold-surge easterlies and westerlies enhanced by a negative Indian Ocean Dipole (IOD) around a background vorticity center. Over the past 60 years, near-equatorial TC activity has increased in the northwestern and southeastern MC.

Keyword: tropical cyclone, Maritime Continent, extreme weather, synoptic variability, climate change

Introduction

In November 2025, TC Senyar hit northern Sumatra, causing 1,204 deaths, the worst TC impact in Indonesia since TC Flores (1973), and an economic loss of IDR 68.7 trillion. Near-equatorial cyclogenesis is rare (e.g., Typhoon Vamei, 2001), and its long-term trends over the MC are unexplored. This study aims to:

- Identify the synoptic drivers of TC Senyar;
- Quantify long-term (1966–2025) changes in near-equatorial TCs over the MC.

Research Method

Data: BMKG/IBTrACS tracks; station and gridded rainfall; ERA5 reanalysis; DMI and RMM indices.

Vorticity budget (850 hPa): $\zeta_t \approx \zeta_t^{AR} + \zeta_t^{AP} + \zeta_t^{SR} + \zeta_t^{SP}$ (advection and stretching of relative and planetary vorticity).

Cold surges & waves: SCS northerly and mid-/high-latitude MSLP indices; Wheeler–Kiladis filtering.

Long-term change: 1966–1995 vs 1996–2025 TC tracks and genesis, 5-year linear trends, and TC hazard maps (frequency and duration within 500 km).

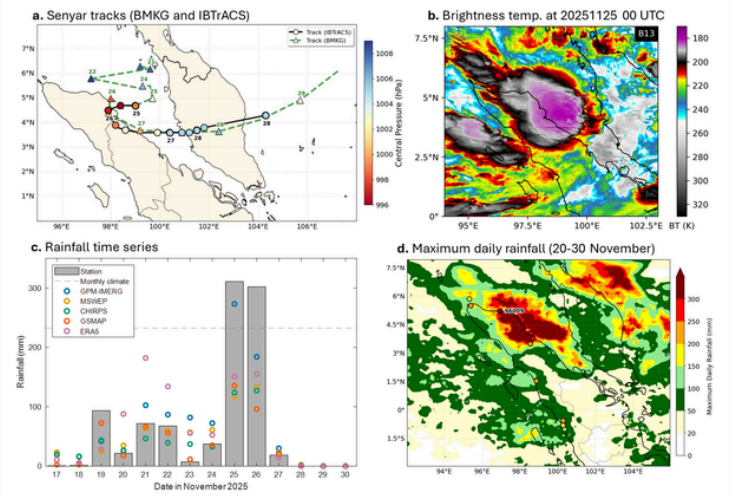


Fig. 1. (a) Senyar tracks; (b) Himawari-9 brightness temperature, 25 Nov 00 UTC; (c) daily rainfall, station 96009 and gridded data; (d) max daily rainfall, 20–30 Nov.

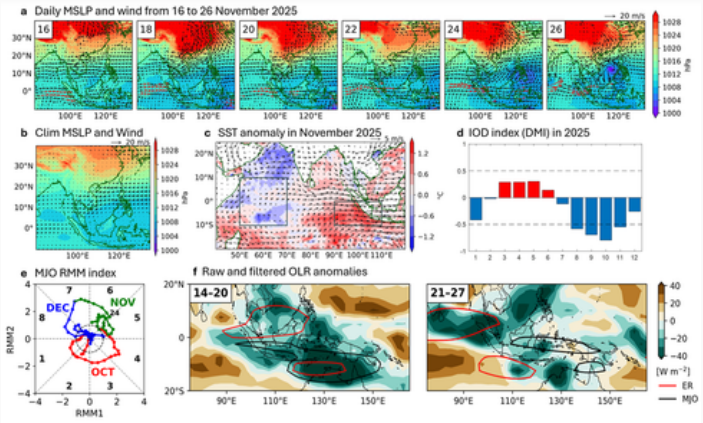


Fig. 2. (a) MSLP and 850-hPa wind, 16–26 Nov; (b) climatology; (c) Nov 2025 wind/SST anomalies; (d) DMI; (e) MJO RMM; (f) filtered OLR.

Discussion & Result

Disturbance 95B (21 Nov 2025) became TC Senyar on 25 Nov (998 hPa), made landfall in Sumatra, then moved east into the South China Sea (SCS). An Aceh station recorded 310.8 and 302.2 mm/day on 25–26 Nov, exceeding its November monthly climatology of 232.3 mm (Fig. 1).

- **Easterlies:** SCS easterlies strengthened to ~3× climatology from 17 Nov, driven by two cold surges (18–21 and 24–27 Nov) from Siberia and the Tibetan Plateau (Fig. 2).
- **Westerlies:** eastern Indian Ocean westerlies were enhanced by a negative IOD (Jul–Nov 2025); an equatorial Rossby wave played a secondary role (Fig. 2).
- **Vortex growth:** convergence-driven stretching of relative vorticity (ζ_t^{SR}) amplified a pre-existing vorticity center and steered its propagation; planetary terms were weak (Fig. 3).
- **Long-term change:** near-equatorial TC genesis increased significantly in the northwestern ($p = 0.023$) and southeastern MC ($p = 0.018$), while subtropical western North Pacific TCs declined (Figs. 4–5).

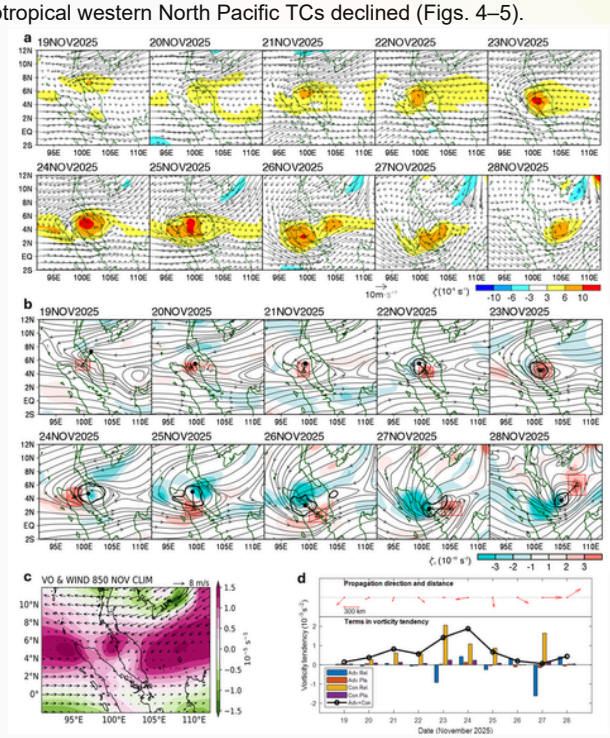


Fig. 3. (a) 850-hPa wind and vorticity, 19–28 Nov 2025; (b) streamlines and vorticity tendency; (c) November climatology; (d) vorticity budget terms.

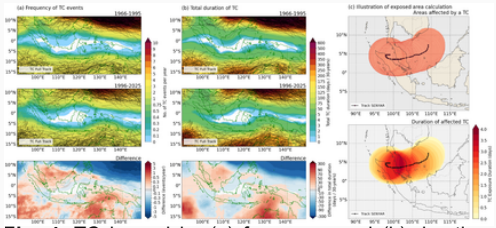


Fig. 4. TC hazard by (a) frequency and (b) duration: 1966–1995, 1996–2025, and difference.

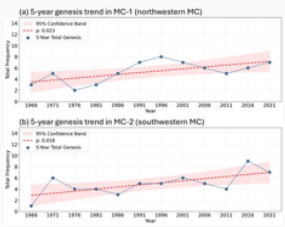


Fig. 5. 5-year TC genesis in (a) NW and (b) SE MC.

Conclusion

TC Senyar formed where cold-surge northeasterlies converged with IOD-enhanced westerlies over a pre-existing vorticity center. Rising near-equatorial TC activity implies a growing TC hazard for Indonesia.

- **Implications:** reassess hazard maps for risk-informed spatial planning; strengthen monitoring, impact-based forecasting, and coordination with local authorities and communities.
- **Future work:** IOD-sensitivity simulations, mesoscale dynamics, climate projections, and machine-learning TC prediction.