Multi-Hazard Mapping over the Indonesian Maritime Continent: Tropical Cyclone-Induced Wind, Rainfall, and Wave Height Extremes

PPMI FITB ITB 2026:
Pengembangan Sistem Pengukuran Kecepatan Arus Permukaan Berbasis *Large Scale Particle Image Velocimetry* Menggunakan Video Drone dan CCTV

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1. Background & Research Gap

TCs were long thought unlikely within ~10° of the equator. Yet **Vamei (2001)**, **Seroja (2021)** and **Senyar (2025)** caused severe impacts. Senyar, the first TC formed over the Malacca Strait, left **1,207 people dead** and **>184,000 houses** damaged.

TC is **not a hazard category** in Indonesian risk assessments. Its impacts are recorded as floods, landslides or extreme weather, and hazards are assessed **one by one**.

Research gap: no study has mapped multiple TC-induced hazards (rainfall, wind, waves) over Indonesia.

Keywords: near-equatorial tropical cyclone · multi-hazard · quasi-Lagrangian · population exposure · ship traffic

2. Objectives & Novelty

1. Attribute extreme **rainfall, wind gust and wave height** to individual TCs, 1979–2025.
2. Map event **frequency and duration** on a 0.1° grid, on land and at sea.
3. Overlay **population and ship traffic** in an exploratory hazard–exposure index.

Novelty: first **TC-specific multi-hazard baseline** for near-equatorial Indonesia, covering land and sea.

Study Area & TC Tracks (1979–2025)

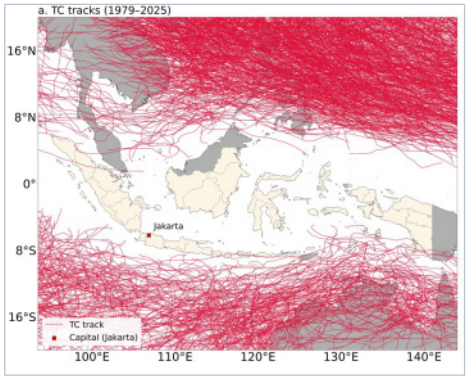


Figure 1. TC tracks (IBTrACS) over the Indonesian Maritime Continent (90–147°E, 15°S–12°N). 461 systems came within 500 km of Indonesian land.

Data

TC tracks	IBTrACS v4r01, 1979–2025 (incl. depressions)
Rainfall	MSWEP v2.8 (1979–2020), GPM IMERG (2021–25)
Gust, waves	ERA5 reanalysis (3-hourly maxima)
Exposure	WorldPop 2020, DEGURBA, AIS ship density

3. Research Method

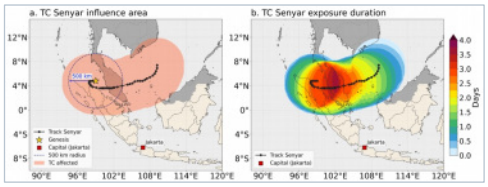


Figure 2. Quasi-Lagrangian method, illustrated by TC Senyar (25–28 Nov 2025): (a) influence area, (b) exposure duration (days).

TC influence area
500 km circle around the TC centre at every 3-hourly step

↓

Extreme events
Rain ≥ 12.7 mm/3 h · Gust ≥ 12.86 m/s · SWH ≥ 2 m

↓

Frequency & duration
Events/year and hours/year in each 0.1° cell

↓

Hazard × Exposure
$R = H^{0.5} \cdot E^{0.5}$, five Fisher–Jenks classes

4. Results & Discussion

TC-Induced Hazards

79% of land reached by a TC

33 | 40% extreme rain | gust

71% of sea cells: extreme waves

- **East Nusa Tenggara** is the all-hazard hotspot: up to 0.6 rain and 1.3 gust events/yr (30.7 gust h/yr). Gusts dominate South Papua & Maluku; rain lasts longest in Aceh.
- At sea, **IFMA 573** peaks: 1.15 extreme-wave events and 38 h per year.

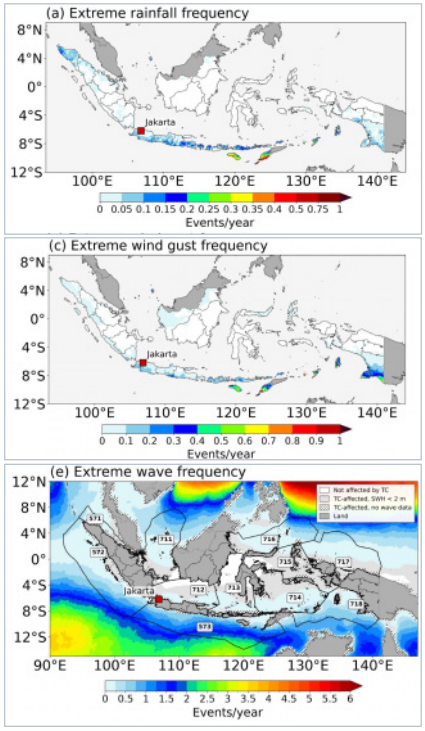


Figure 3. TC-induced extreme (a) extreme rainfall (c) wind-gust and (e) wave frequency, 1979–2025. Numbered polygons are Indonesia's Fisheries Management Areas (IFMAs).

Population Exposure

92% of people (≈260 M) reached by a TC

72% (≈200 M) met an extreme event

75% of those reached are urban

- **Exposure is an urban issue:** >80% of urban residents reached by a TC also met an extreme (rural: 50–55%).
- High + Very high risk classes cover only **10% of land cells** but hold **59% of the population**. Java holds 67% of Very high cells; Bali–Nusa Tenggara 32%.

Hazard–Exposure Risk Index

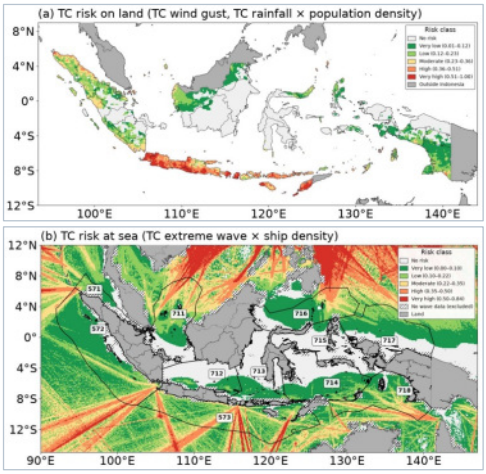


Figure 4. Exploratory TC risk, R = H^0.5·E^0.5: (a) land (wind & rain × population); (b) sea (extreme waves × ship density).

5. Conclusion

Influence ≠ extremes: recurrent extremes concentrate in **East Nusa Tenggara** and **IFMA 573**.

Risk follows people: Java is exposure-driven, East Nusa Tenggara hazard-driven.

At sea, the busiest IFMAs (712, 713) lie in low-hazard waters; **573, 572, 711** are more exposed.

Recommendation: include **TC as a distinct hazard** in regional contingency plans (East Nusa Tenggara, Java, IFMA 573).

Limitations: exploratory index; no vulnerability or storm surge; not yet validated against BNPB loss records; 47-year record may miss the rarest events.

Outputs

1. Manuscript "Multi-Hazard Mapping of Near-Equatorial Tropical Cyclone-Induced Wind, Rainfall, and Wave Height Extremes over the Indonesian Maritime Continent" **submitted** to ***International Journal of Disaster Risk Science*** on November 17, 2026.
2. Manuscript "Dynamical Interaction between Marine Heatwaves and Indonesian Throughflow Variability in the Lombok Strait during the 1998 and 2016 Extreme Events" **submitted** to ***Estuarine, Coastal and Shelf Science*** on November 14, 2026.

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