Simulating the dispersal of marine plastic during tropical cyclones

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SEAmap
South East Asia MArine Plastics: Solutions and Integrated Strategies for the Reduction, Control and Mitigation of Marine Plastic Pollution in the Philippines

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Introduction

Tropical cyclones can rapidly transfer large volumes of terrestrial plastic debris into the ocean and disperse them[1]. The timing, extent, and mechanisms of ocean plastic transport during these events is poorly understood[2] (Fig.1).

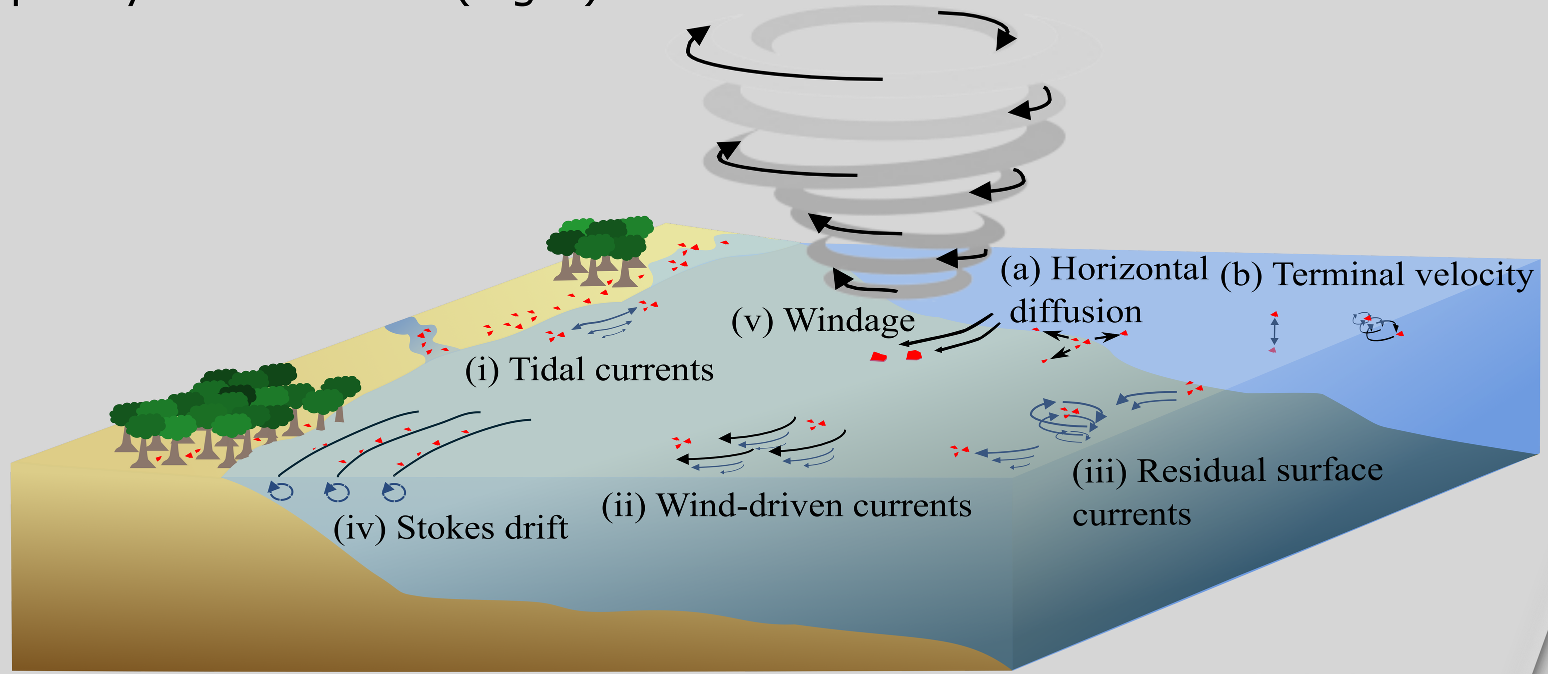

Figure 1. Key processes, which drive marine plastic transport, included in our model.

Case Study

Super Typhoon Rai passed over the Philippines Archipelago in December 2021 (Fig. 2). The event was characterised by storm surges ~2m in height, and large waves ~12m in height. More than 1.1 million homes were damaged[3], affecting 47% of the population.

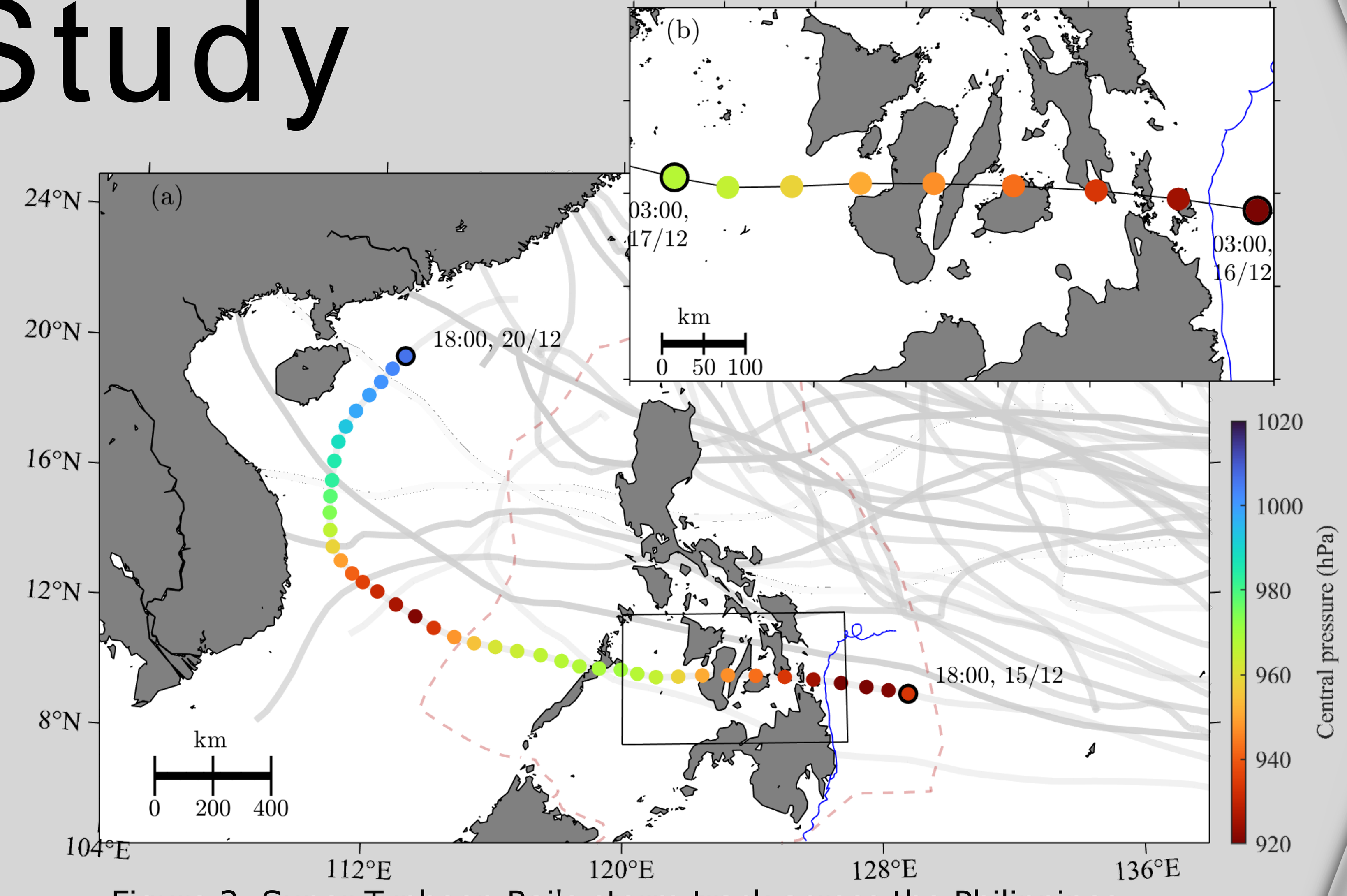

Figure 2. Super Typhoon Rai's storm track across the Philippines.

Model Setup

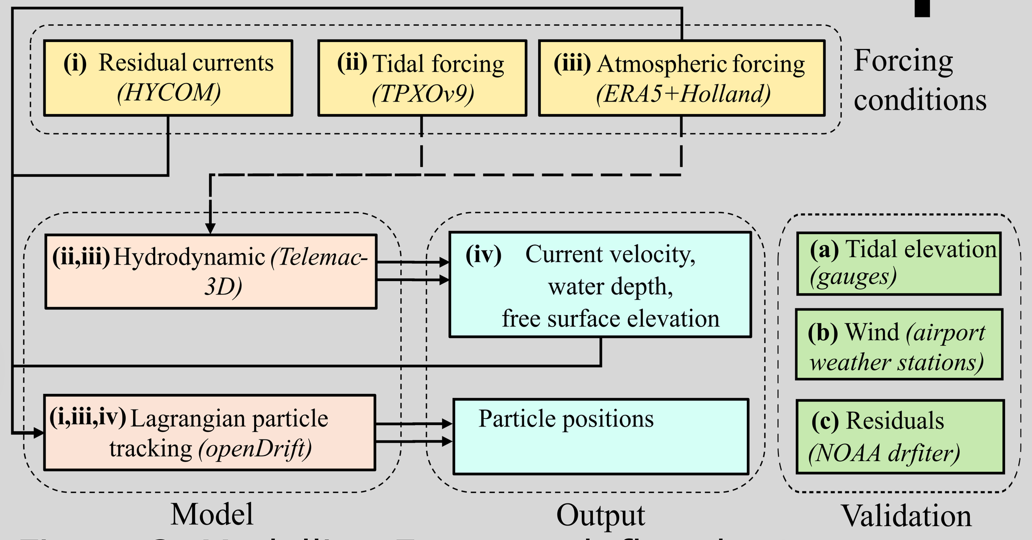

Figure 3. Modelling Framework flowchart.

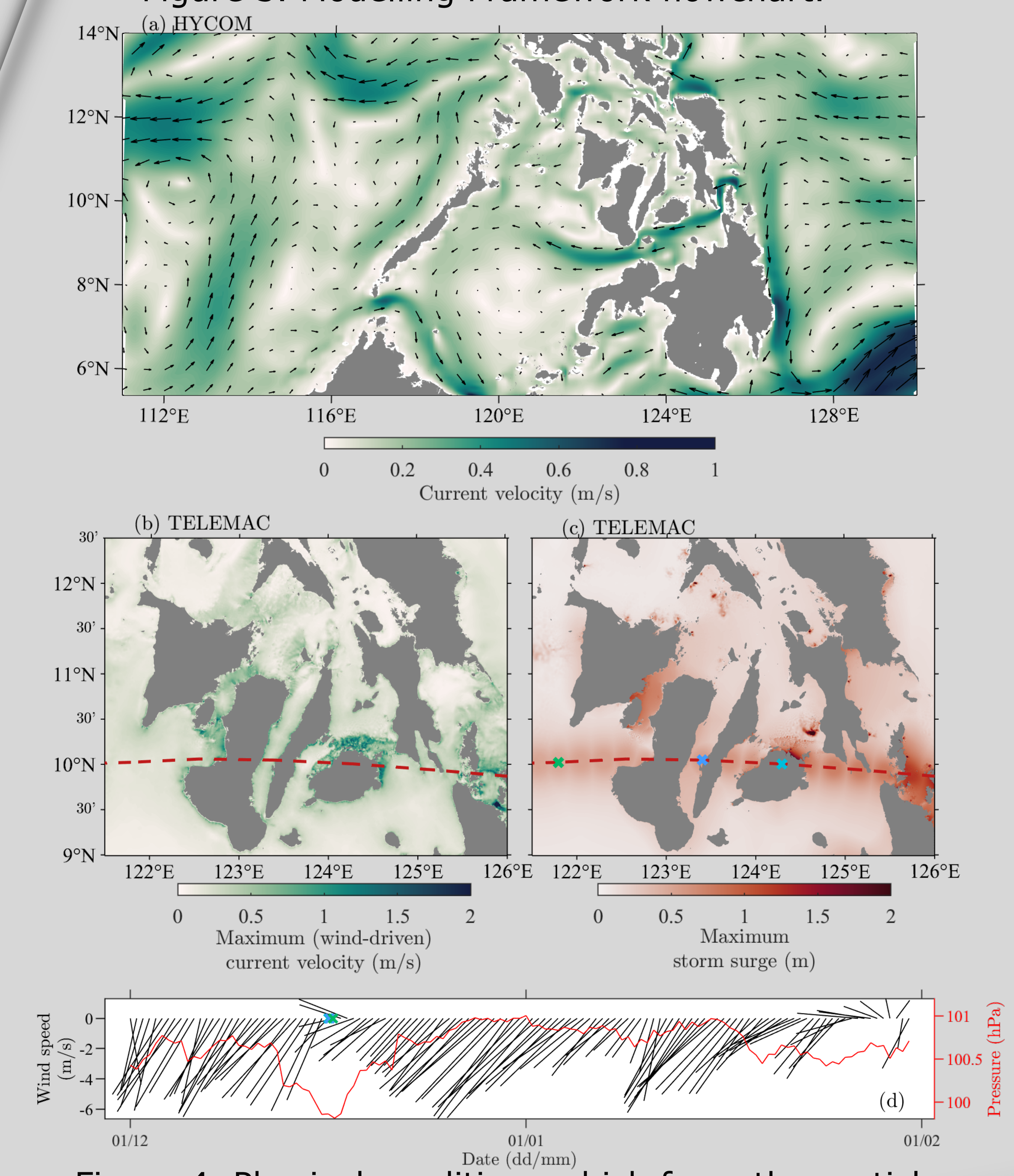

Figure 4. Physical conditions which force the particle tracking model

Conclusions

(1) The onshore transport rate increased (i.e., beaching occurs faster due to the typhoon). This supports many reports of extreme coastal plastic pollution following tropical cyclones.

(2) Eastward facing coastlines experienced the highest beaching rates, owing to Super Typhoon Rai's direction of travel (east to west) realtive to seasonal monsoon wind direction.

Key Message: Our findings reveal patterns in tropical cyclone-driven plastic distributions. By combining storm tracks with monsoon wind direction, we suspect that the distribution of marine plastic can be predicted in the days following the event.

References

[1] Lo, H.S., Lee, Y.K., Po, B.H.K., Wong, L.C., Xu, X., Wong, C.F., Wong, C.Y., Tam, N.F.Y. and Cheung, S.G., 2020. Impacts of Typhoon Mangkhut in 2018 on the deposition of marine debris and microplastics on beaches in Hong Kong. Science of the total environment, 716, p.137172.
[2] Nakajima, R., Miyama, T., Kitahashi, T., Isobe, N., Nagano, Y., Ikuta, T., Oguri, K., Tsuchiya, M., Yoshida, T., Aoki, K. and Maeda, Y., 2022. Plastic after an extreme storm: the typhoon-induced response of micro-and mesoplastics in coastal waters. Frontiers in Marine Science, 8, p.806952.
[3] Cahigas, M.M.L., Prasetyo, Y.T., Persada, S.F. and Nadlifatin, R., 2023. Examining Filipinos' intention to revisit Siargao after Super Typhoon Rai 2021 (Odette): An extension of the theory of planned behavior approach. International Journal of Disaster Risk Reduction, 84, p.103455.

Results

(a) When particles are released pre-typhoon (S1; Fig.5ai), their fate is highly dependant on their position relative to the storm track. Evident by the S-shaped particle distribution in the Cebu and Tanon Strait. In Fig. bi, particles are more diffuse.

(b) Super Typhoon Rai increases mean plastic transport speed by 4x (from ~0.1 to ~0.4 m/s; Fig. 5aii/bii), albeit the magnitude of the event is shortlived.

(c) The typoon drives an east to west transfer of particles (south of the storm track), this is especially evident in the Tanon Strait.

(d) 5-10% more particles are beached in the typhoon scenario compared to the 'typical conditions' scenario (Fig. 6d).

(e) When released post-typhoon, particles on south/west facing coastlines are less likely to be beached and are transported offshore.

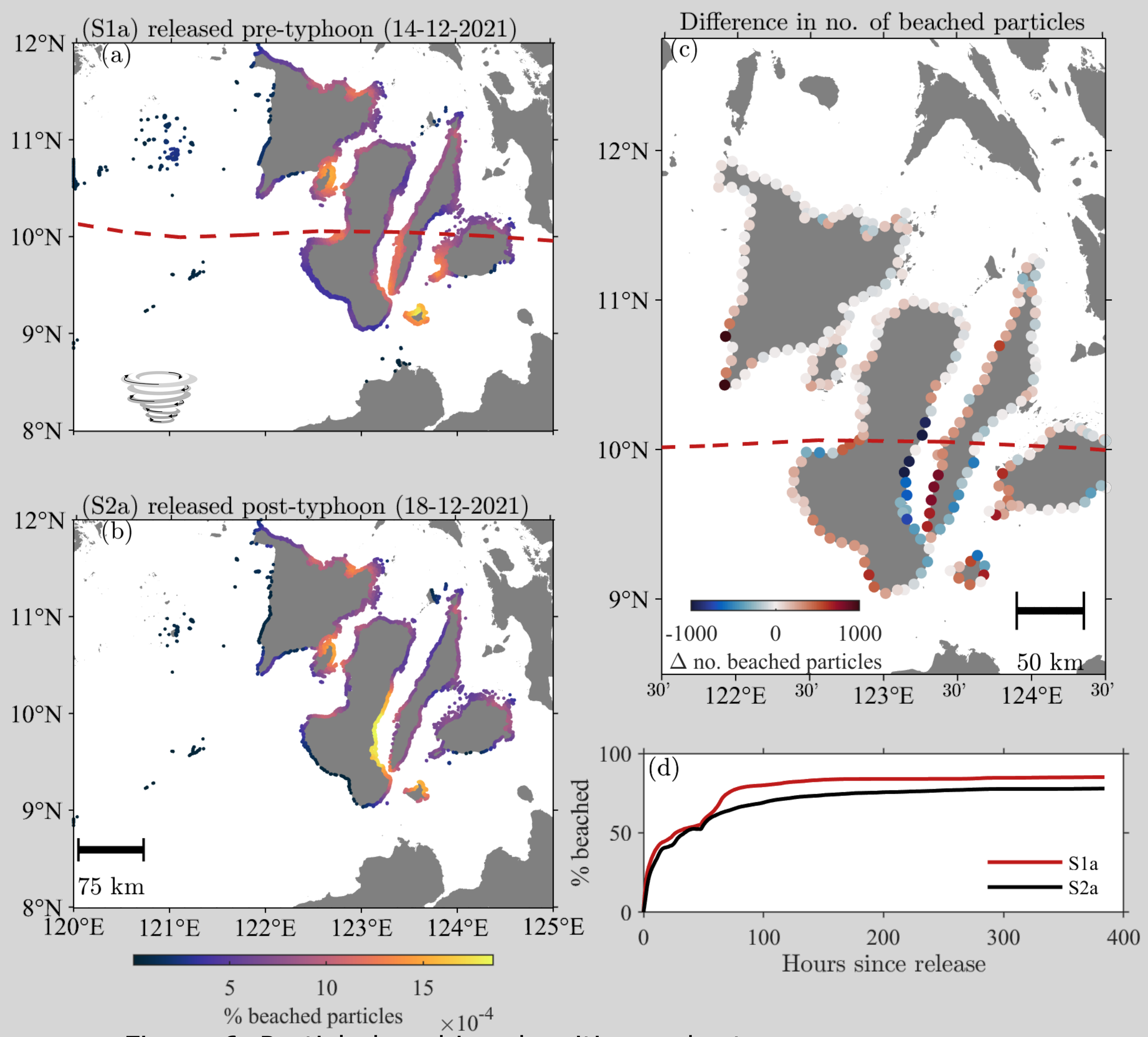

Figure 6. Particle beaching densities and rates.

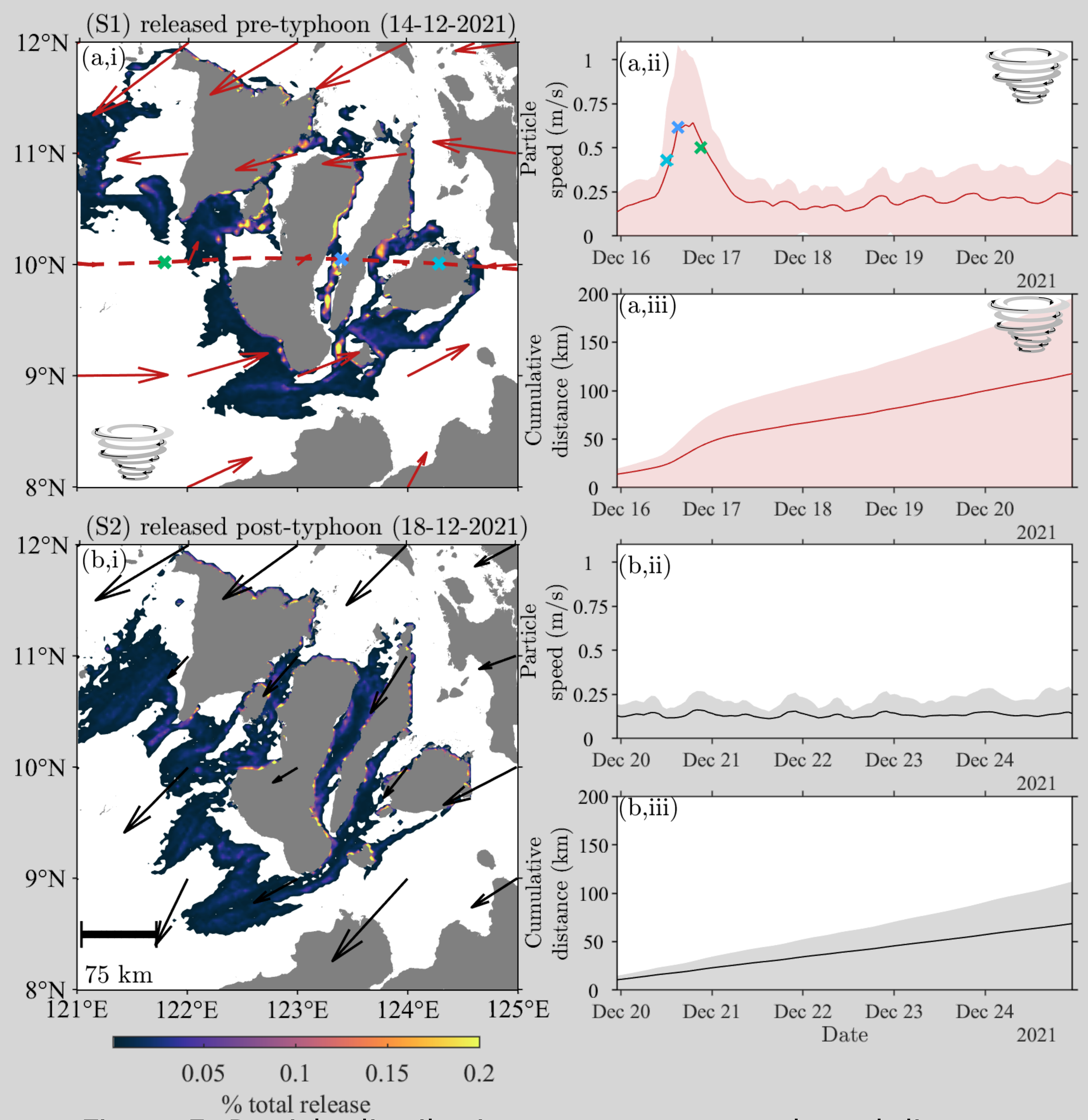

Figure 5. Particle distributions, transport speeds and distances.