

Coastal Inundation from Non-Landfalling Tropical Cyclones along the Central Coast of Vietnam

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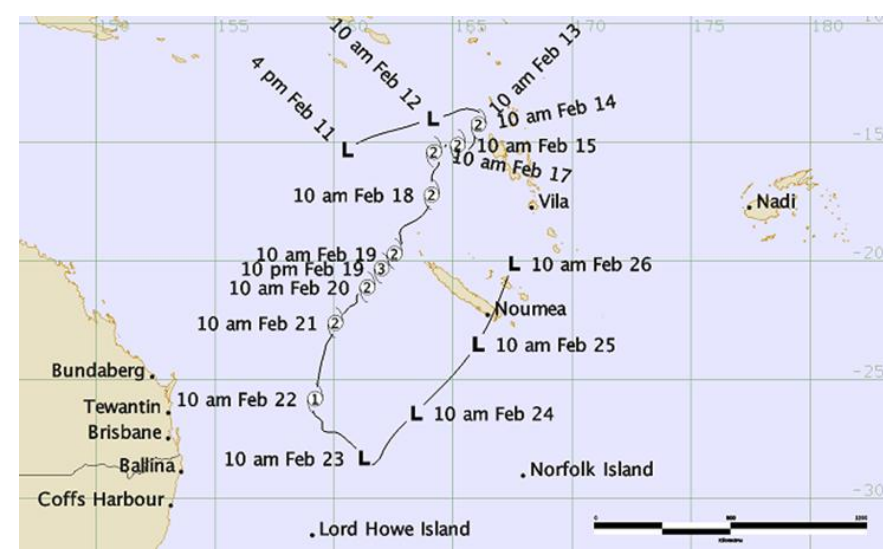
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INTRODUCTION

- Sea-level fluctuations play an important role in disaster prevention, especially regarding storm surges.
- Storm surges, combined with large waves, are the main cause of severe damage in coastal areas, particularly during high tide.
- Major storm surges usually occur when strong storms make direct landfall.
- However, many tropical cyclones remain offshore or have centers far from the coast, yet still produce surges that flood coastal areas.
- Tropical cyclones do not need to make landfall to cause destructive flooding. For example, in Australia, cyclone Oma caused gale-force winds, abnormally high tides, and large surf about the southeast Queensland coast, northern New South Wales coast, and Lord Howe Island.

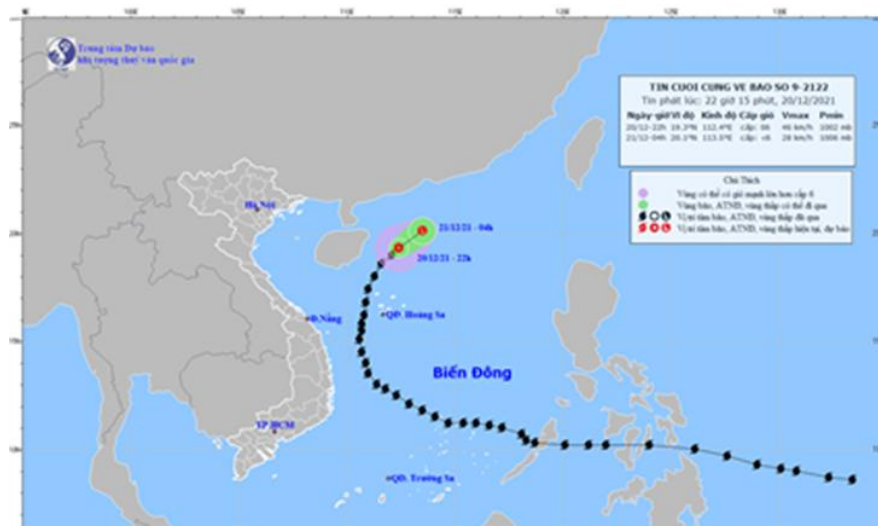


Best track of Cyclone Oma (2/2019)



www.abc.net.au

- In the central coast of Vietnam, Typhoon Rai did not hit land but caused minor flooding along the coastal area of Phu Yen Province.
- Vietnam's central coast is highly vulnerable due to: Narrow continental shelves and Complex coastal topography
- These factors can amplify wave and surge processes during offshore storms.



Best track of Typhoon Rai (12/2021)



https://dantri.com.vn

DATA

- Observed Water Level at Quy Nhon and Vung Tau from 2013 to 2021
- Data obtained from the Vietnam Meteorological and Hydrological Administration, <https://psmsl.org/> and <https://ioc-sealevelmonitoring.org/>

METHODS

- Tidal Harmonic Analysis
- Decomposition of observed sea level to remove tidal signals and extract the non-tidal residual
- 59 to 67 tidal constituents are typically used
- Non-tidal residual = Observed Water level – Astronomical tide – Mean Sea Level

METHODS (cont.)

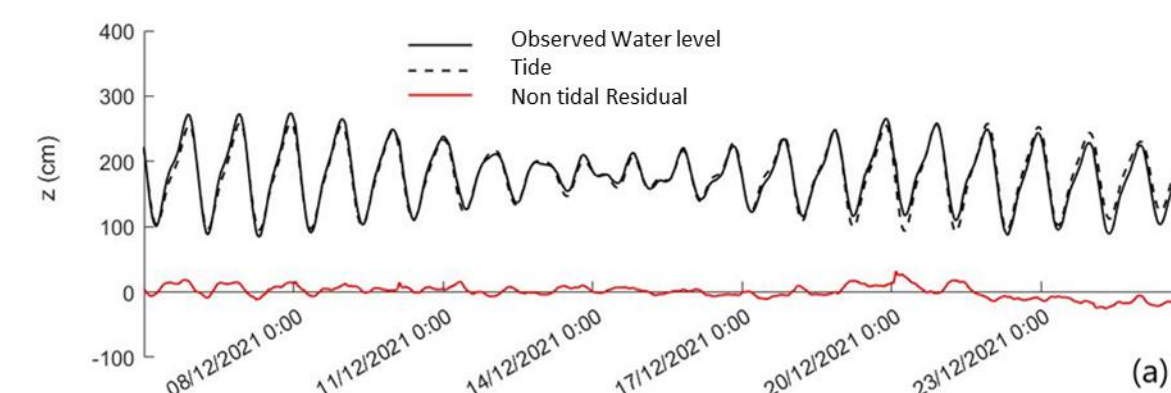
- Low-Frequency Filtering
- Used to detect long-period oscillations
- Filters out high-frequency components
- Investigate sub-tidal oscillations driven by wind stress, pressure gradients, continental shelf resonance, and remote storm-surge propagation



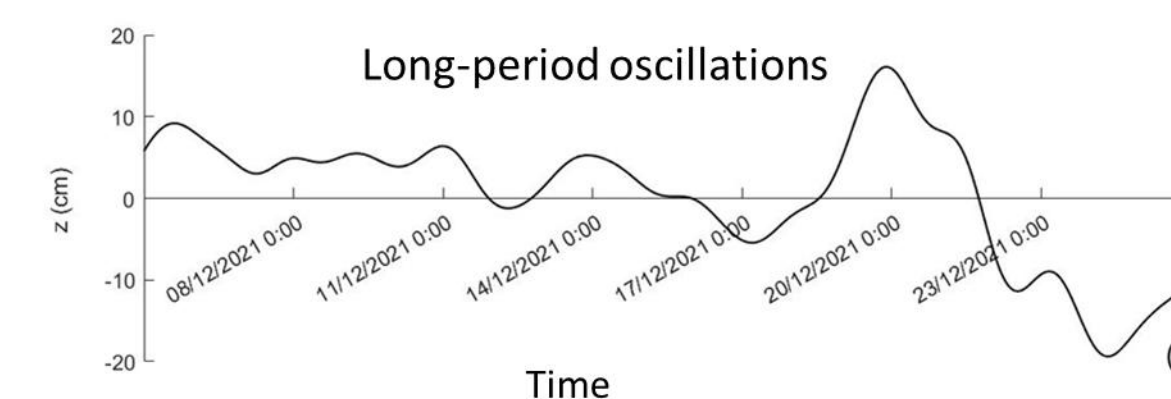
Location of tide gauges along the Vietnam coast

RESULTS AND DISCUSSION

- Typhoon Rai (2021)
- Typhoon center remained far offshore
- Total sea-level anomaly at Quy Nhon: ~32 cm
- Long-wave component: ~22 cm, meaning that long waves contributed ~70% of the coastal sea-level anomaly.



Non-tidal Residual (a) and Long wave oscillation (b) at Quy Nhon during Typhoon Rai (12/ 2021)



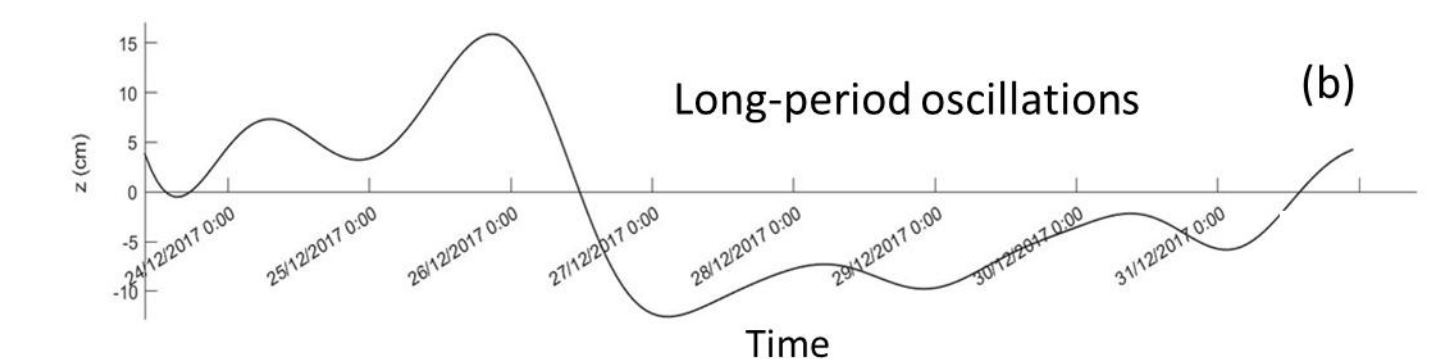
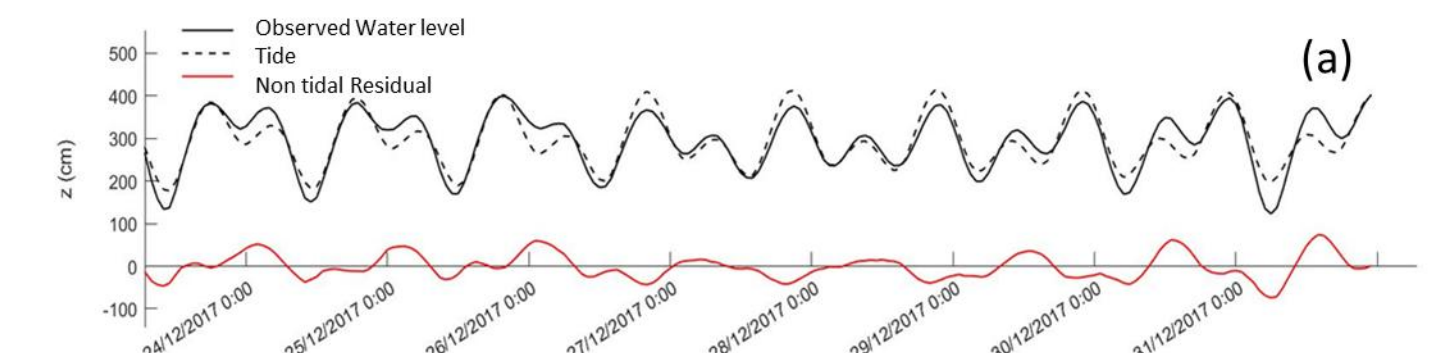
- Discussion: Flooding in Phu Yen Province during Typhoon Rai occurred not because of a landfall typhoon, but due to:
 - Long-wave amplification coincides with peak astronomical tide
 - Coastline shape at Tuy Hoa – Phu Yen Province (river mouth amplification)



Best track of Typhoon Tembin (12/2017)

RESULTS AND DISCUSSION (cont.)

- Typhoon Tembin (2017)
- Maximum long-wave height: ~15 cm.
- Coincided with seasonal high tides in the Southern coast Vietnam
- Areas affected: Vung Tau, Mekong Delta eastern provinces
- Increased risk of flooding despite Tembin not making landfall in the area



Non-tidal Residual (a) and Long wave oscillation (b) at Vung Tau during Typhoon Tembin (12/ 2017)

- Discussion: Southern Vietnam is highly sensitive to even moderate long-wave activity due to low elevation and a broad continental shelf.

CONCLUSIONS

- Offshore tropical cyclones can cause significant sea-level rise in Vietnam, even without making landfall.
- Long-wave oscillations are a major contributor to coastal flooding in the Central Coast of Vietnam.
- Long waves can propagate hundreds of kilometers, creating delayed flooding.
- Combined effects of: Long waves, Astronomical tides, River discharge can cause compound flooding, often underestimated by local forecasting systems.
- Long-wave processes are not represented in many operational storm-surge models.
- Improved monitoring, modeling, and multi-hazard integration are essential for effective warning systems.

FUTURE WORK

- Identify additional historical events to broaden the dataset and strengthen the statistical analysis.
- Integrate ERA5 reanalysis with numerical modeling to simulate the observed phenomena and reveal the underlying driving mechanisms.
- Implement real-time cross-station monitoring to detect and track propagating long-period waves.