

PROBABILISTIC ANALYSIS OF WINTER STORM SURGES DEPENDING ON METEOROLOGICAL FEATURES OF EXPLOSIVE CYCLONES

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INTRODUCTION

Explosive cyclones that develop rapidly during winter in the northwest Pacific or Atlantic Oceans have impacted human activities due to extreme wind, waves and precipitation as often reported on the east coasts of the Eurasian and North American continents (Sanders & Gyakum 1980). In 2014 and 2015, energetic explosive cyclones developed in the northwest Pacific Ocean sequentially induced storm surges in Nemuro Bay on the northeast coast of Japan, causing severe flood damages along the bay coast for the second consecutive year (See Fig. 1 b.2). As frequency of intensified explosive cyclones near the Japanese archipelago has increased over the past three decades (Iwao et al. 2012), future disasters are anticipated to occur with greater frequency if the same trend continues.

It is known that the tracks and intensities of explosive cyclones in the northeast Asia highly depends on the baroclinic effects of the monsoon; growth of the Siberian High inducing baroclinicity in the Sea of Japan. Warm ocean currents, such as the Kuroshio, also affect frequencies of the explosive cyclongenesis (Sanders & Gyakum 1980). Yoshida & Asuma (2004) identified three major evolution types of the explosive cyclones of this region: for Type-I, cyclones travel over the Sea of Japan, Type-II cyclones generated on the Sea of Japan and move across the archipelago towards the Pacific Ocean, and Type-III cyclones generated on the Pacific Ocean travel northwards.

In this study, we provide a probabilistic assessment of storm surges on the basis of meteorological features of past explosive cyclones classified in the three evolution types through computational experiments. Three-dimensional ocean current computations were performed to obtain local sea-level rise along the coasts of Japan and Eurasia for cyclones observed in the past two decades. The vulnerability of local coasts and disaster risks are discussed in relation to the calculated probability of sea-level rise due to potential storm surges.

COMPUTATIONAL METHOD

Flows under explosive cyclones were computed using a three-dimensional non-hydrostatic model, MIT general circulation model, in the same manners as Saruwatari et al. (2019). The computed sea level was compared with the tide record during the 2014 Nemuro storm surge to validate our model predicting the major features of the observed sea-level rise.

RESULTS

We found that amplification of local sea level, governed by the relative orientation of coast lines to cyclone tracks, depends on the evolution types of the explosive cyclones rather than the cyclone intensity. Type-I cy-

clones, formed in early and late winter, cause significant sea-level rise over a coast facing the Sea of Okhotsk and northern Sea of Japan (Fig. 1 a). Type-II cyclones, observed in December and February, induce milder sea-level changes for the whole coast of Japan than the other types. Type-III cyclones, which often gain latent heat energy from the Kuroshio and develop in midwinter, provide the highest probability of extreme local amplification of sea level in Nemuro Bay (Fig. 1 b.1). We also found that Nemuro Bay is the most vulnerable site in the northwest Pacific region regardless of the evolution type of cyclones. Sensitivity of the highest sea level at bay coasts to the trajectories and intensities of cyclones is also assessed in this study, leading a conclusion that uncertainties of the surge levels are mostly caused by a wind-induced component of sea-level rise.

The probabilistic evaluation of sea levels depending on the cyclone evolution type, introduced in this analysis, is useful to identify potential risks for storm-surge disasters.

REFERENCES

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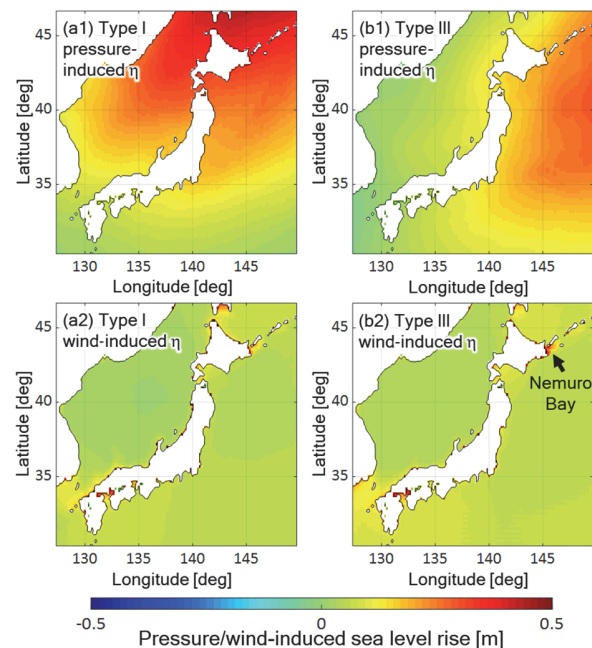


Figure 1 - Pressure-induced (top) and wind-induced (bottom) sea-level rise by Type I (a) and Type III (b) cyclones.