LABORATÓRIO NACIONAL
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A forecast system based on OPENCoastS

REPORT 42/**2021 – DHA/NEC**

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An EOSC-hub report

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R&D HYDRAULICS AND ENVIRONMENT

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Title

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A forecast system based on OPENCoastS

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TIDES AND STORM SURGES IN THE COAST OF TAIWAN

A forecast system based on OPENCoasts

Abstract

This report describes the implementation and validation of a forecast system to predict sea water levels in the coast of Taiwan. The forecast system was generated using the OPENCoastS platform, in the scope of the EOSC-hub Early Adopters Program.

Keywords: Forecasts / OPENCoastS / SCHISM

MARÉS E SOBRELEVAÇÕES NA COSTA DE TAIWAN

Um sistema de previsão baseado no OPENCoastS

Resumo

O presente relatório descreve a implementação e a validação de um sistema de previsão oceanográfico, para marés e sobrelevações, para a costa de Taiwan. O sistema de previsão foi desenvolvido com a plataforma OPENCoastS, no âmbito do EOSC-hub Early Adopters Program.

Palavras-chave: Previsões / OPENCoastS / SCHISM

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1 | Introduction

The island of Taiwan is jeopardized by typhoons that can have devastating effects. In the scope of the EOSC-hub Early Adoption Program, a forecast system was created to predict storm surges in the coast of Taiwan using the OPENCoastS service (Oliveira et al., 2020). This forecast system is used to demonstrate the applicability of OPENCoastS for worldwide applications. The present report briefly describes the generation and validation of this forecast system.

2 | Model setup

2.1 Data

Three types of data were used to setup and validate the model.

The coastline was defined based on the global Self-consistent, Hierarchical, High-resolution Shoreline (GSHHS) database (available at https://gnome.orr.noaa.gov/goods/tools/GSHHS/coast_subset). The data used to define the model domain are shown in Figure 2.1.

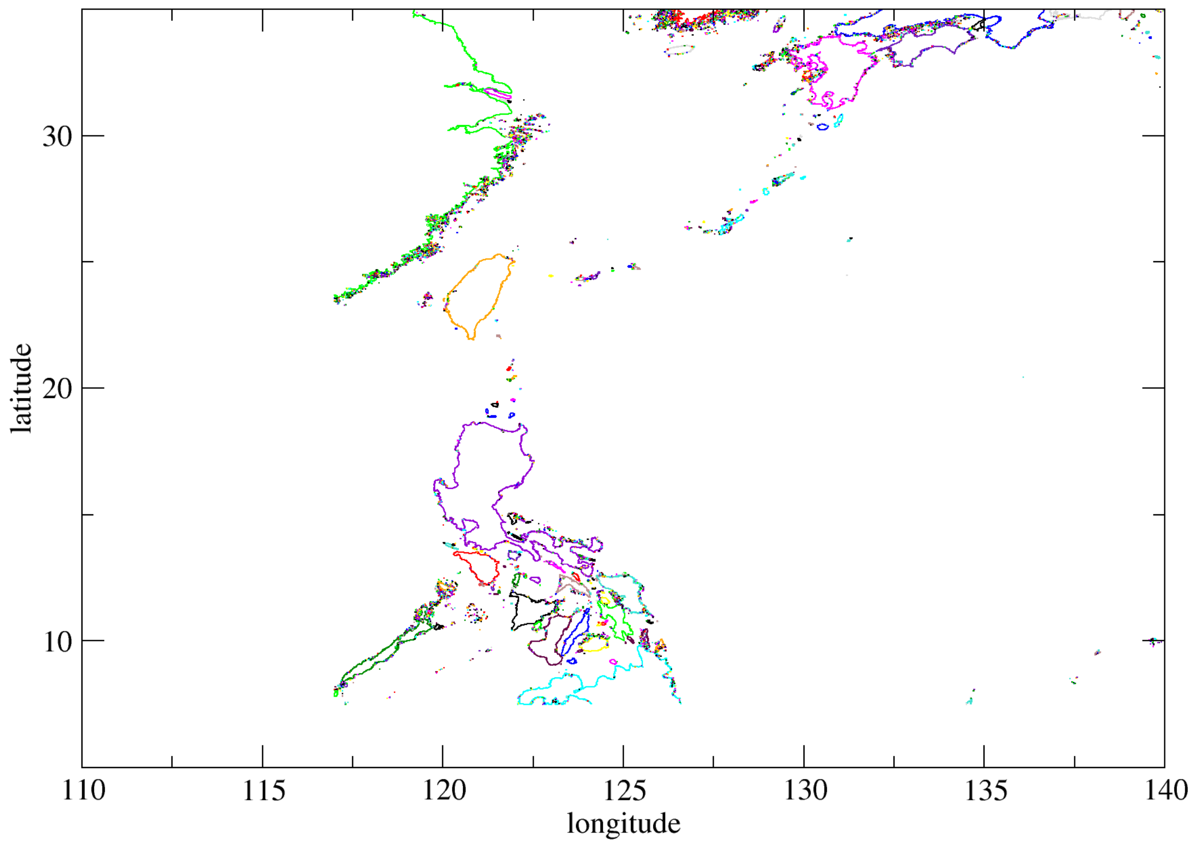

Figure 2.1 – Land boundaries from the World Vector Shoreline

The bathymetry was extracted from the General Bathymetric Chart of the Oceans (GEBCO, available at https://download.gebco.net). The bathymetry interpolated on the model grid is shown in Figure 2.2.

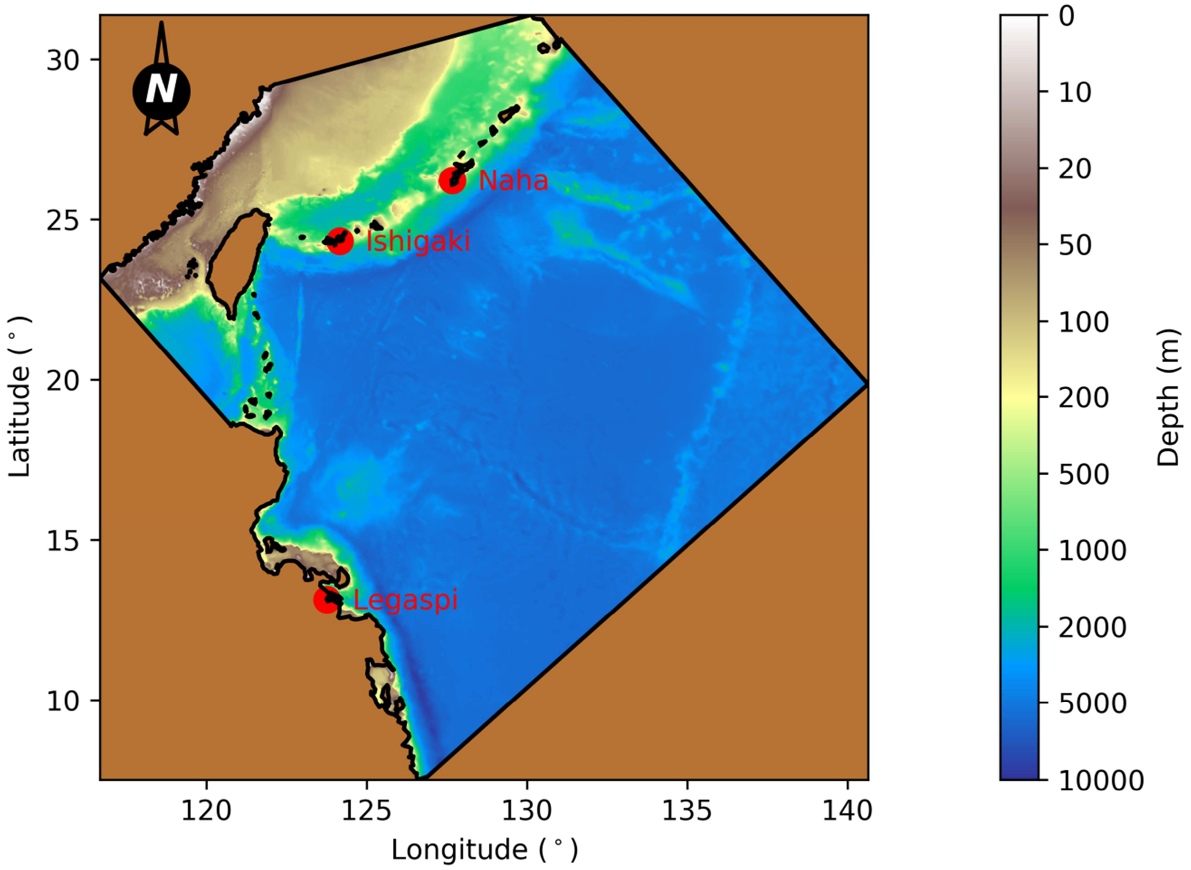

Figure 2.2 – Bathymetry interpolated on the model grid. The red circles indicate the tide gauges used for model validation

The tide gauge data available at EMODNET (http://www.emodnet-physics.eu) within the model domain were used for model validation. Data at the coast of Taiwan are not available. Data are available at three stations, shown in Figure 2.2. Tide gauge data was treated as follows:

- Data from May 2020 on was downloaded from EMODNET;
- Outliers were removed;
- Short-scale oscillations were filtered to remove seiches (Figure 2.3);
- A local mean sea level was estimated by averaging all the available data at each station and subtracted from the data.

The subtraction of the mean sea level from the time series was necessary because EMODNET does not indicate the vertical datum of the time series. Ideally, a full year of data should have been used to determine the mean sea level. However, only data from May to September could be downloaded from EMODNET, and these data contain numerous gaps. The data are shown in Figure 2.4.

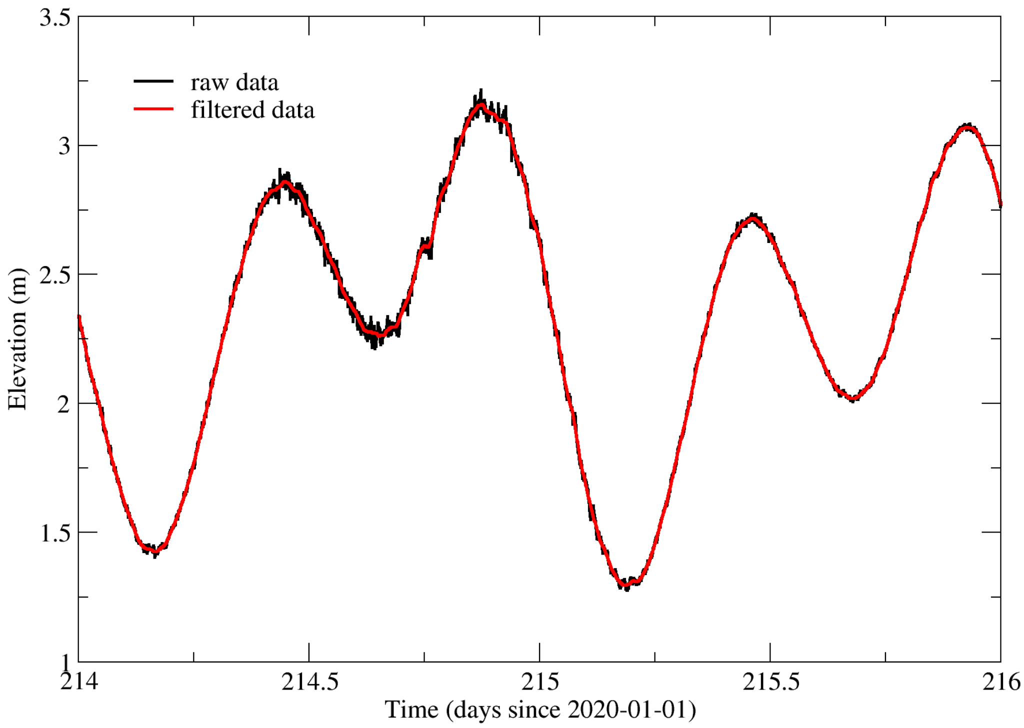

Figure 2.3 – Example of the application of the filter

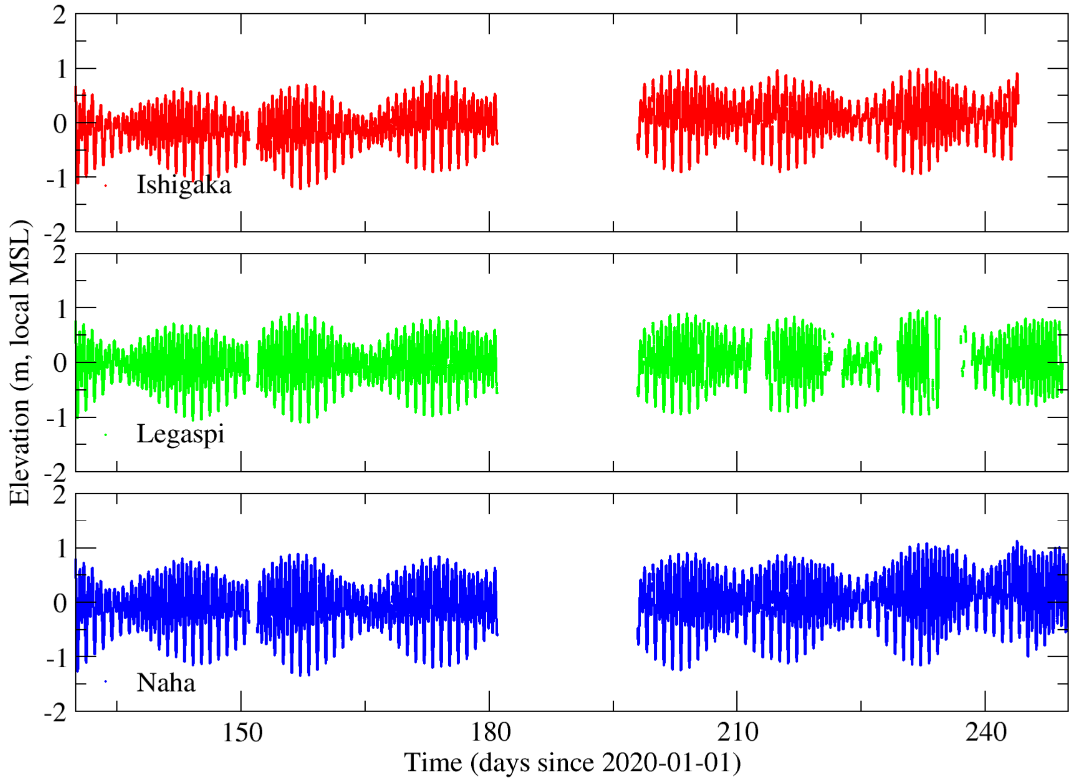

Figure 2.4 – Time series of water levels used for model validation

2.2 Grid generation

The model domain is limited by China and the South China Sea in the north-west, the Philippines in the south-west, the East China Sea in the north-east, and the Philippine Sea to the west (Figure 2.5). Considering the most frequent typhoons tracks in the region, typhoons are expected to enter the domain from south-east boundary and develop mostly inside the model domain.

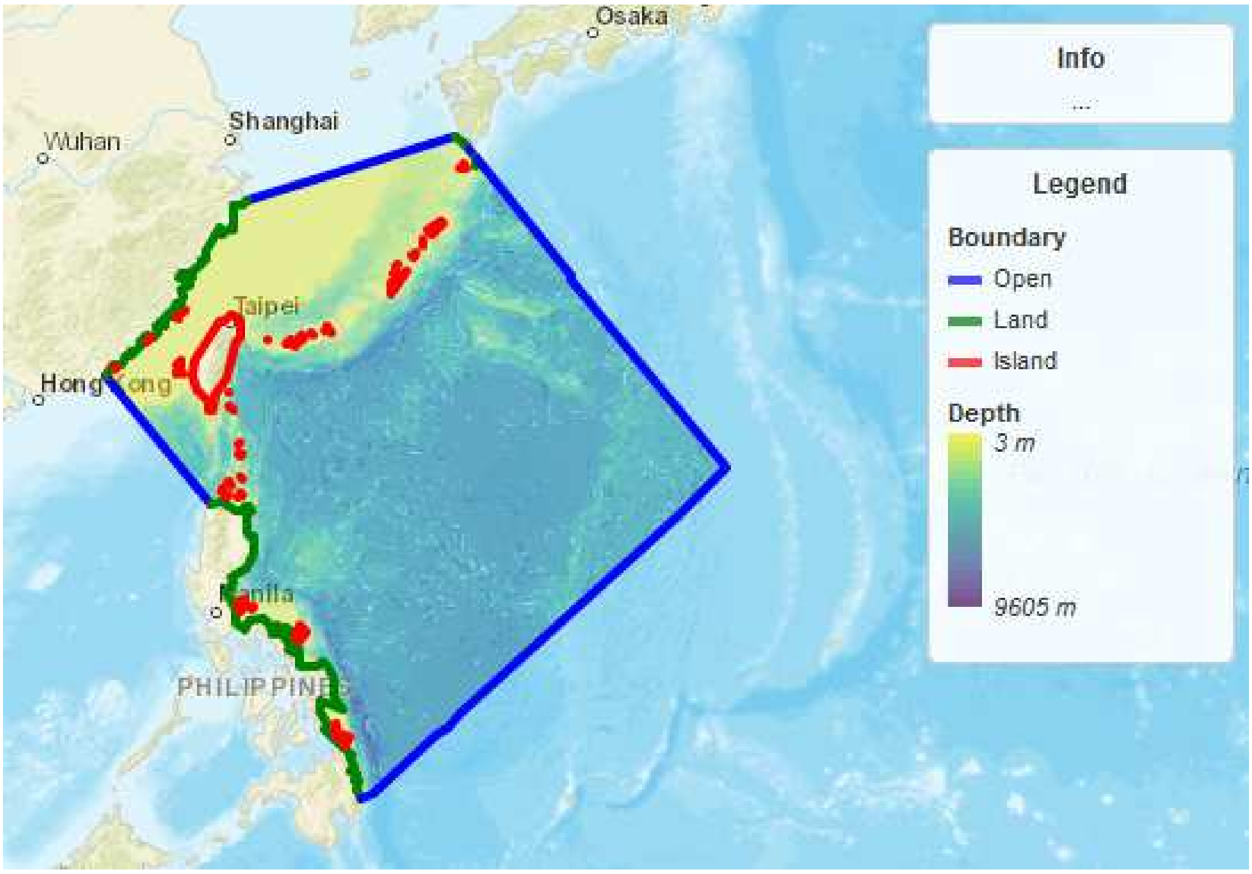

Figure 2.5 – Model domain and boundaries

The grid was generated with the programs xmgredit (Turner and Baptista, 1993) and nicegrid (Fortunato et al., 2011). The grid resolution varies between 1-2 km around Taiwan and 10-16 km in the deep ocean (Figure 2.6). The number of elements per node varies between 5 and 7 to ensure a smooth transition between element sizes.

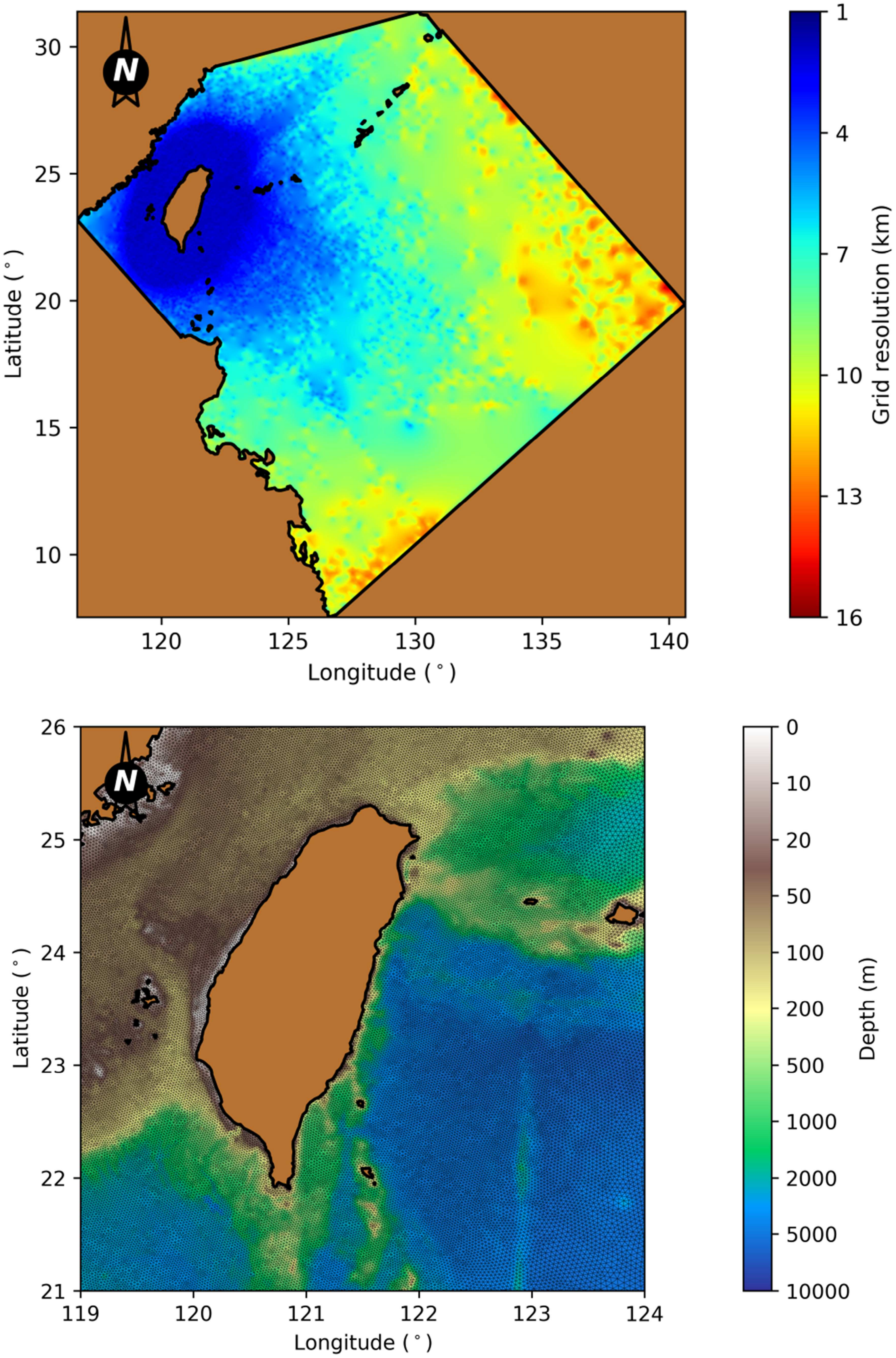

Figure 2.6 – Taiwan grid: grid resolution, given by the equivalent element diameter (top) and detail of the grid around Taiwan (bottom)

2.3 Model configuration

The model SCHISM was run in depth-averaged barotropic mode without waves. Although waves can be important in the generation of storm surges in Taiwan (Liu and Huang, 2020), the present version of OPENCoastS only allows the simulation of waves in the North Atlantic Ocean. The model was forced by tides from FES2014 and the inverse barometer effect at the four open boundaries, and by wind and atmospheric pressure from NOAA/GFS at the surface. The time step was set to 240 s. The Manning friction coefficient was set to 0.022 $m^{1/3}/s$, without any calibration. Considering the exceptionally large depths in the Philippine Sea, the model results at the three available tide gauges are expected to be fairly insensitive to the friction coefficient.

3 | Validation

The model forecast was launched on 2020-07-04. Results between 2020-07-05 and 2020-09-30 are used for model validation. Note that this period coincides with the typhoon season in the region, which goes from July to September. According to the Wikipedia (https://en.wikipedia.org/wiki/2020_Pacific_typhoon_season, accessed on October 20, 2020), the following events occurred in this period:

- Tropical Depression Carina (July 11 – July 15)
- Tropical Storm Sinlaku (July 31 – August 3)
- Typhoon Hagupit (July 31 – August 5)
- Tropical Storm Jangmi (August 7 – August 11)
- Tropical Depression 06W (August 9 – August 13)
- Severe Tropical Storm Mekkhala (August 9 – August 11)
- Severe Tropical Storm Higos (August 16 – August 20)
- Typhoon Bavi (August 21 – August 27)
- Typhoon Maysak (August 27 – Saptember 3)
- Typhoon Haishen (August 31 – September 9)
- Tropical Depression 12W (September 10 – September 12)
- Tropical Storm Noul (September 14 – September 19)
- Severe Tropical Storm Dolphin (September 19 – September 24)
- Severe Tropical Storm Kujira (September 26 – September 30)

While not all these events passed close to Taiwan, it is clear that the water levels in the model domain must have been significantly affected by storm surges during this period.

Data/model comparisons, root mean square errors and maximum errors are shown in Figure 3.1. The RMS errors, between 5 and 12 cm, compare favorably with a recent application to the same area (Liu and Huang, 2020). Chen et al. (2017) modeled typhoon-induced surges in the coast of Taiwan using the model SELFE, SCHISM's predecessor. These authors found the effect of wind waves on the storm surge to be spatially variable: it could reach over half a meter in some stations, and be negligible in others. This conclusion suggests that the good accuracy obtained at the three stations used herein for validation does not necessarily extend throughout the domain, since waves were not considered.

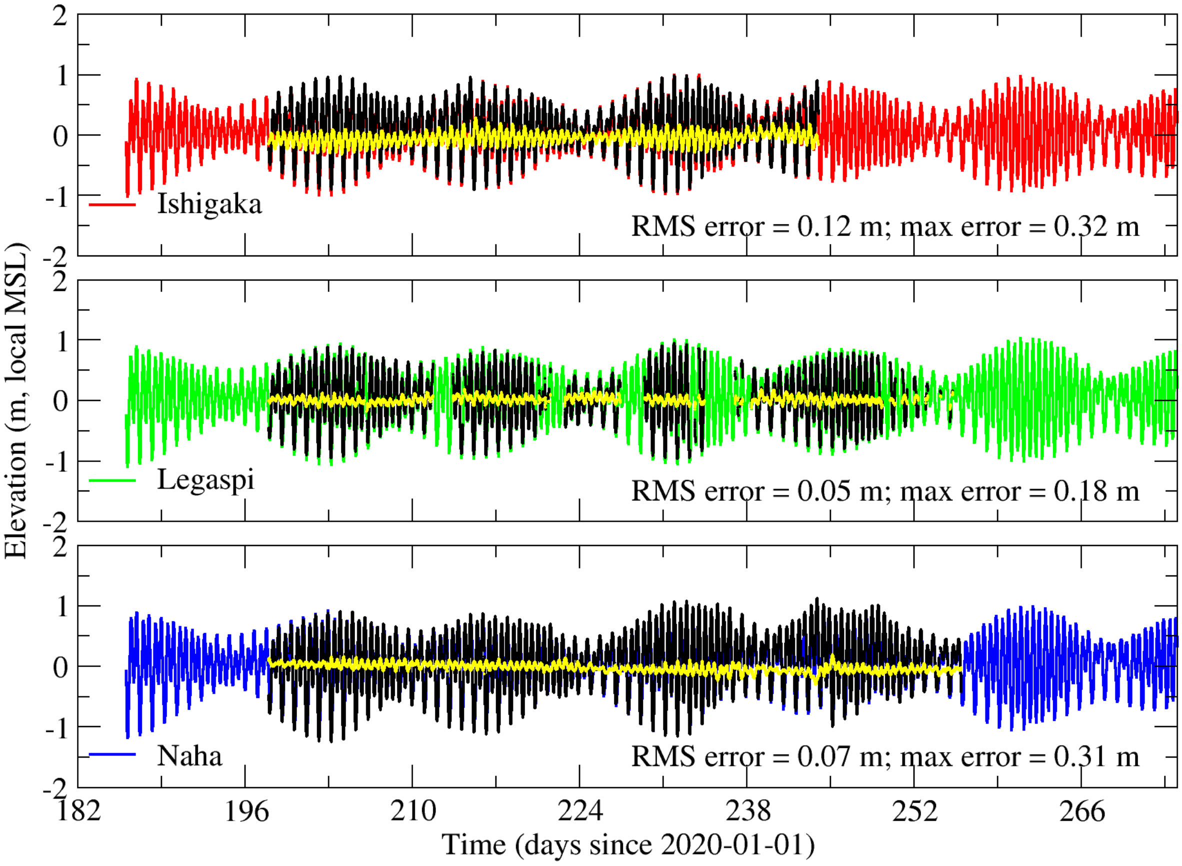

Figure 3.1 – Model validation: comparison of data and model results at the three stations, for the months of July through September 2020. The data are represented in black, and the differences between the model and the data in yellow

4 | Summary and conclusions

A forecast system for storm surges in Taiwan was generated with the OPENCoastS platform (Oliveira et al., 2020). Only open data available in the internet was used for both the model setup and the model validation. Validation results are considered very good, especially considering the absence of calibration.

In spite of the good results achieved, the forecasts could probably be improved through:

- Better bathymetries: the GEBCO bathymetry, used herein, is not always accurate. There is some concern on the accuracy of these data, in particular in the South China Sea.
- Better coastlines: comparisons between the coastline used herein and the satellite images suggest that this dataset is coarse and probably outdated in some areas.
- Better wind and pressure fields: the resolution of the NOAA/GFS atmospheric forecasts is relatively coarse. A higher resolution regional atmospheric forecast would possibly improve the storm surge forecasts.
- Including the effect of wind waves. Previous studies in the Taiwan area indicate that the wave setup can contribute significantly to the surge in some areas.

Also, none of the stations used for validation is in Taiwan itself, since there are no Taiwanese tide gauge data in EMODNET. It is recommended that the forecast system is validated with data from Taiwanese tide gauges.

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APPROVED

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