Procedia Computer Science
Volume 66, 2015, Pages 184–190
YSC 2015. 4th International Young Scientists Conference on Computational Science

Special aspects of wind wave simulations for surge flood forecasting and prevention

Sergey S. Kosukhin[1*], Anna V. Kalyuzhnaya[1], Anna. V. Nikishova[1], Alexander V. Boukhanovsky[1]
[1]*ITMO University, Saint-Petersburg, Russia*
skosukhin@gmail.com, kalyuzhnaya.ann@gmail.com, annanikishova@gmail.com, avb_mail@mail.ru

Abstract
The paper is focused on several issues of wind wave simulations with SWAN model for the tasks related to prevention of surge floods in St. Petersburg. It introduces main objectives that are pursued through the use of the model as well as covers problems of computational mesh generation and model parameter calibration. We also examined several assumptions on the necessity to take ice fraction and sea level rise into account in wind wave simulations.

Keywords: wind waves, storm surges, model calibration, grid generation

1 Introduction

Storm surges is a common hazard for many coastal cities. However, a solution to flood protection in each case is almost unique, mostly due to geographical features and operational requirements. The most well-known flood protection systems are in Amsterdam [1], Rotterdam [2], Venice [3], London [4], New Orleans [5], and St. Petersburg [6]. There are also several new dams and barriers in the world that are being designed or constructed, e.g. New York barriers.

In St. Petersburg, storm surges are caused by deep cyclones that cross the Baltic Sea along its center line from south-west to north-east. Such cyclone rises water level by its low-pressure center and initiates the propagation of a long progressive wave. The height of the wave increases as it travels through shallow and narrow water area of the Gulf of Finland. Additionally intensified by the wind, that wave leads to fast sea level rise in St. Petersburg. In 2011, Saint Petersburg Flood Prevention Facility Complex (the Barrier) [6] was introduced into services and became a reliable protection from inundations. The barrier consists of dams which are equipped with floodgates for ship passage and water exchange (Fig. 1). As storm surges are irregular and complex events, the Barrier is aided by

* Corresponding author. Tel.: +7-921-639-76-68

Selection and peer-review under responsibility of the Scientific Programme Committee of YSC 2015

doi:10.1016/j.procs.2015.11.022

simulation-based Flood Warning System (FWS) intended to support optimal decision making on floodgate operations [7, 8].

The FWS is based on a complex of various numerical models and data sources, which are combined to form an operational workflow [9]. The essential elements of the complex are hydrodynamic models parameterized with sea wave prognostic fields according to the wind-over-waves coupled (WOWC) approach [10]. Following that approach, sea surface roughness, induced by wind waves, can be taken into account to produce more precise water level forecast. Moreover, wind wave forecasts are necessary to estimate potential wave-impact loads on floodgates during maneuvering operations. It is considered that the safety of the flood barrier is assured if wind wave parameters (e.g. significant wave height, spectrum peak period, etc.) in its immediate vicinity fit into the predetermined limits. Thus, the functional purpose of wind wave simulations in surge flood forecasting and prevention tasks is to provide two types of forecasts:

- Large-scale forecasts that cover potential areas of storm surge initiation and propagation, and that are terms of forcing in hydrodynamic models;
- Fine-grained forecasts that cover the local area of flood protection constructions, and that are necessary to predict possible floodgates malfunctions due to heavy wave-impact loads.

Calculations of subsequent wind wave forecasts are initiated regularly upon receipt of corresponding meteorological forecasts, and must finish over a fixed, relatively short period.

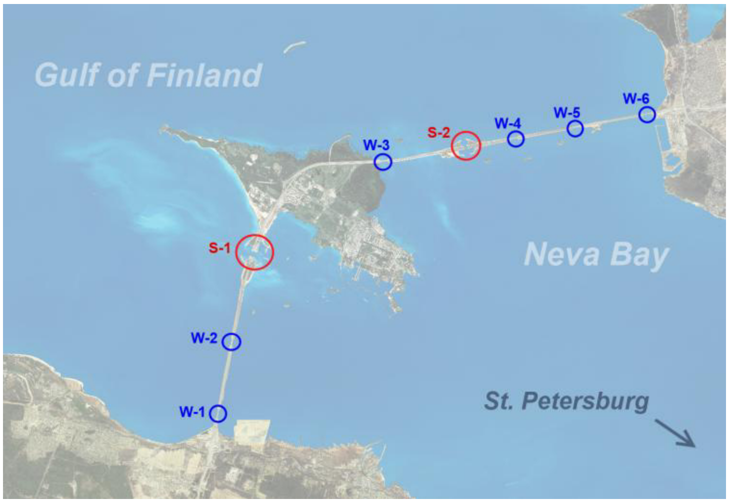

Figure 1: Saint Petersburg Flood Prevention Facility Complex scheme

In modern applied research studies, third-generation spectral wave models are a common choice for sea wave forecasting and hindcasting. The most widely used models are WAVEWATCH III [11] and SWAN [12]. The later is used in the current version of the FWS, as it contains additional formulations for shallow water.

SWAN is used in a wide range of applications: from spectral wave climate simulations [13] to freak wave occurrence probability studies [14]. The model is based on the wave action balance equation (1) with sources and sinks (e.g. in [15]).

$$\frac{dN}{dt} = S_{in} + S_d + S_b + S_{nl} \qquad (1)$$

Here $S = \sum_i S_i$ is a source and sink function, which defines sea waves formation, propagation and dissipation. Principal members of this sum are wind energy transmission (S_{in}), wave energy dissipation (S_d), bottom interaction with waves (S_b) and nonlinear wave interactions (S_{nl}). Parameters for wind energy transmission, wave energy dissipation, bottom interaction with waves were used for model calibration (section 3).