Modeling of sediment resuspension in Neva Bay during strong wind events

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INTRODUCTION

Resuspension is the process of sediment particles entrainment into the water due to the flow moving over the bed. Resuspension starts when the total bed-shear stress exceeds some critical threshold value which varies considerably for different types of bottom sediments.

In the present study a second model calibration was carried out with making use not only meteorological data at weather station St. Petersburg, but also from weather stations Kronshtadt and Ozerki with appropriate interpolation. First of all it was done to get more correct wind field over Neva Bay because wind properties at the station St. Petersburg are distorted by the influence of buildings and other constructions.

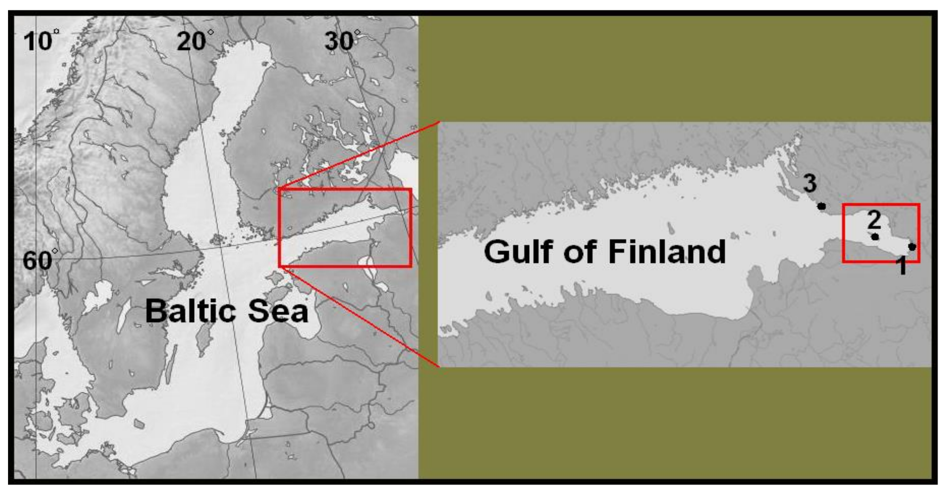

Fig. 1. Neva Bay location in the eastern part of the Gulf of Finland. Points mark the location of weather stations St. Petersburg (1), Kronshtadt (2) and Ozerki (3)

METHODS

A 3D hydrodynamical model of the Neva Bay is based upon the circulation model of Princeton University[1].

-7 uniform vertical sigma-levels;
-350x182 horizontal curvilinear grid;
-min (dx, dy) is 60-70 m, max (dx, dy) is 1 km.

To calculate the characteristics of wind waves a spectral model SWAN[2] was used.

The model formulations for resuspension process are those proposed by van Rijn (2007)[3,4].

Main features of the resuspension model:

- Two different main bottom sediment fractions: sand and silt;
- The bottom of the Neva Bay was divided into areas with predominance of either sand or silt sediments (Fig. 2);
- Density and mean diameter of sediment particles were set according to observations;
- Resuspension model takes into account the influence of suspended particles density upon the water density stratification;
- Particles settling velocity depends on suspended sediments concentration;
- Calculation of total bed shear stress takes into account non-linear interaction of currents and wind waves;
- Calculation of the critical bed shear stress for both sand and silt particles takes into account the cohesion of bottom sediments and the possible presence of clay fraction in the sediments.

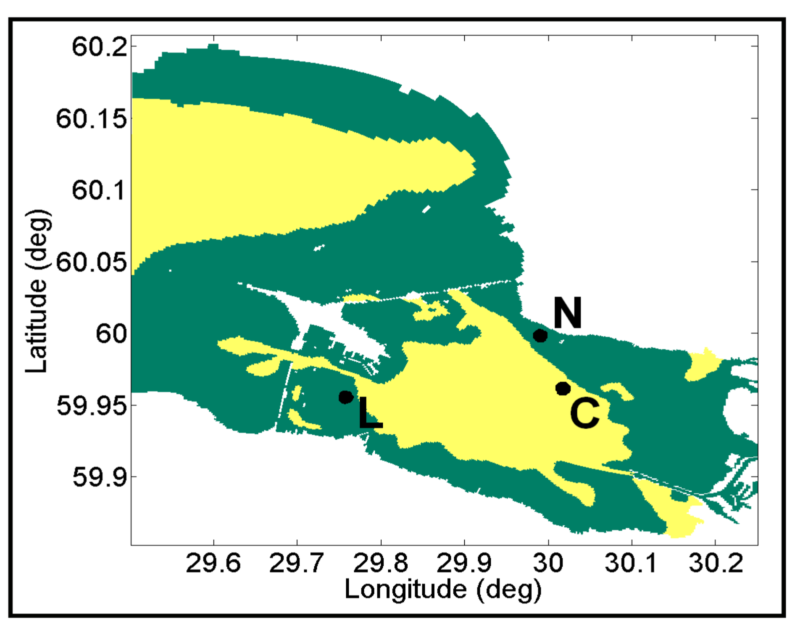

Fig. 2. Scheme of bottom sediments location in the model domain. Yellow – silt, green – sand

Table 1. Bottom sediments parameters in the Neva Bay based on the geological surveys

	Particle diameter, μm	Density, kg/m^3
Sand	110	2370
Silt	9	2000

In previous studies related to resuspension modeling in Neva Bay it was shown that values of empirical coefficients controlling the cohesion effects for silt sediments and proportion of clay fraction is of great importance to correctly simulate suspended sediments distribution.

RESULTS

1. Calibration

To take into account the inflow of suspended material with river water but not being resuspended from the bottom in Neva Bay, the third fraction of suspended particles was added into the model. Its inflow was set only at the eastern boundary with the Neva river discharge and equal to 3 mg/L. This third fraction, called wash load, is considered to be almost passive, with very small fall velocity.

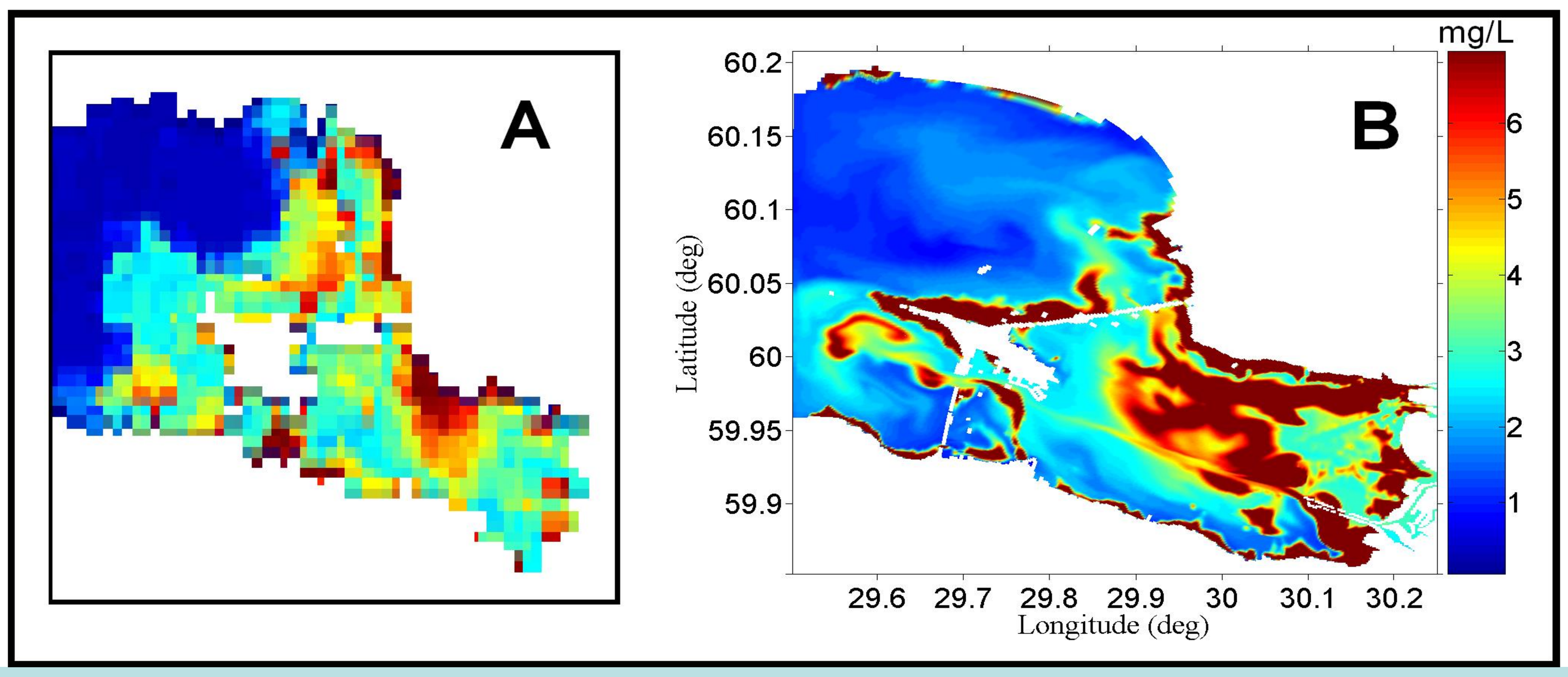

Fig. 3. Left: Spatial distribution of TSM in the Neva Bay on 15 June 2004 (MODIS data). Right: Modeled surface SSC at the same moment.

2. Modeling of sediment resuspension during strong wind events

The model runs were carried out for the ice-free time period 01.05 – 30.11 2008, the year which is characterized by strong winds over the Neva Bay.

In 2008 the highest surface modeled SSC occurred during the period from October until the end of November due to strong western and south-western winds 10–13 m/s. Spring and summer periods were relatively calm and most of the time SSC was sometimes high only in coastal areas (points L and N) while central part of Neva Bay (point C) was almost free of suspended sediments.

It is interesting to note that resuspension at point L is more intense than at points N and C. It is explained by the additional influence of current-related bed-shear stress upon the total bed-shear stress at that location. While resuspension at points N and C is caused predominantly by wind waves, resuspension in point L is also controlled by currents, generated by storm surges coming from the Gulf of Finland.

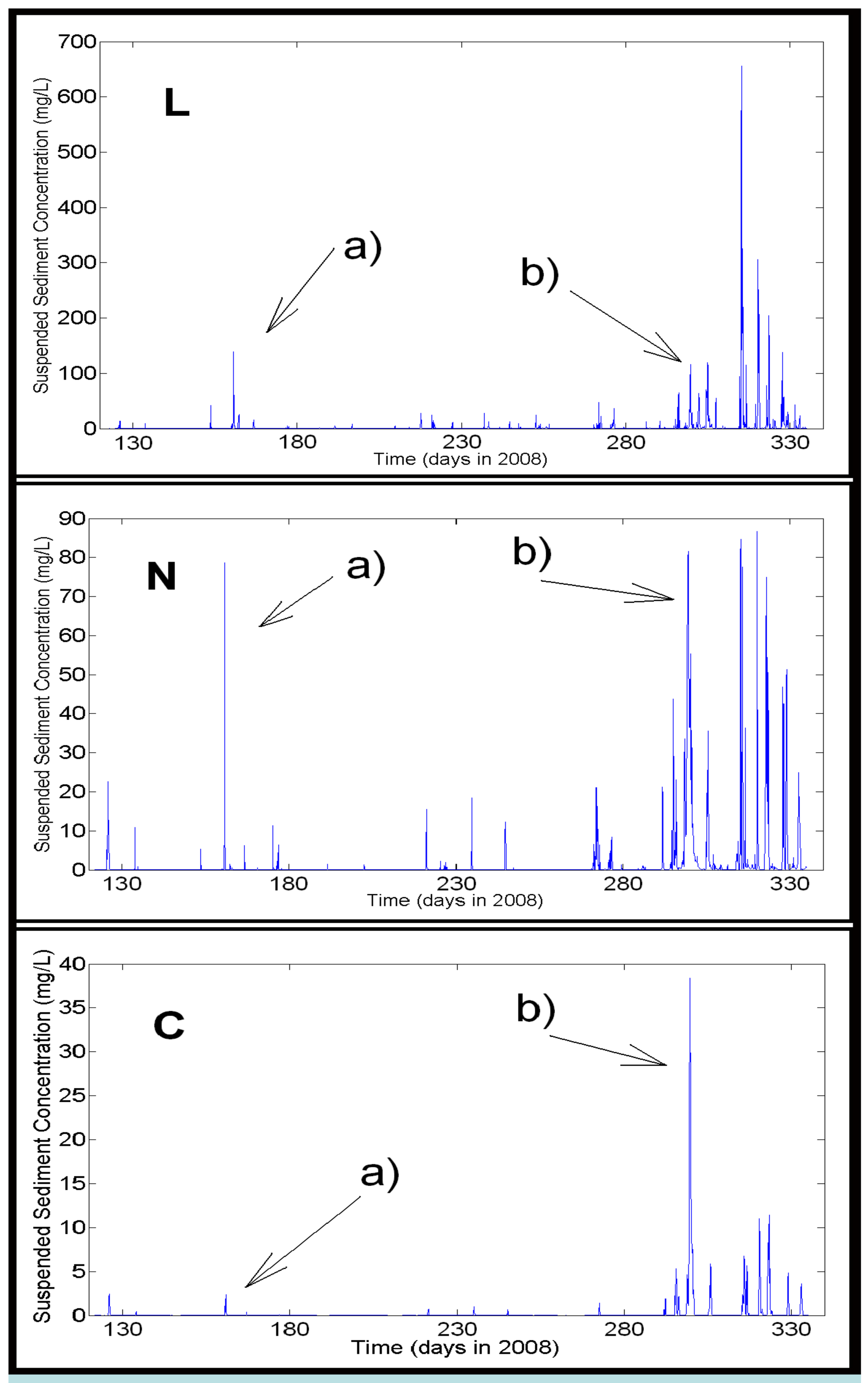

Fig. 4. Surface modeled suspended sediment concentration at points L, N and C in Neva Bay 01.05 – 30.11 in 2008. Location of points is shown on Fig. 2

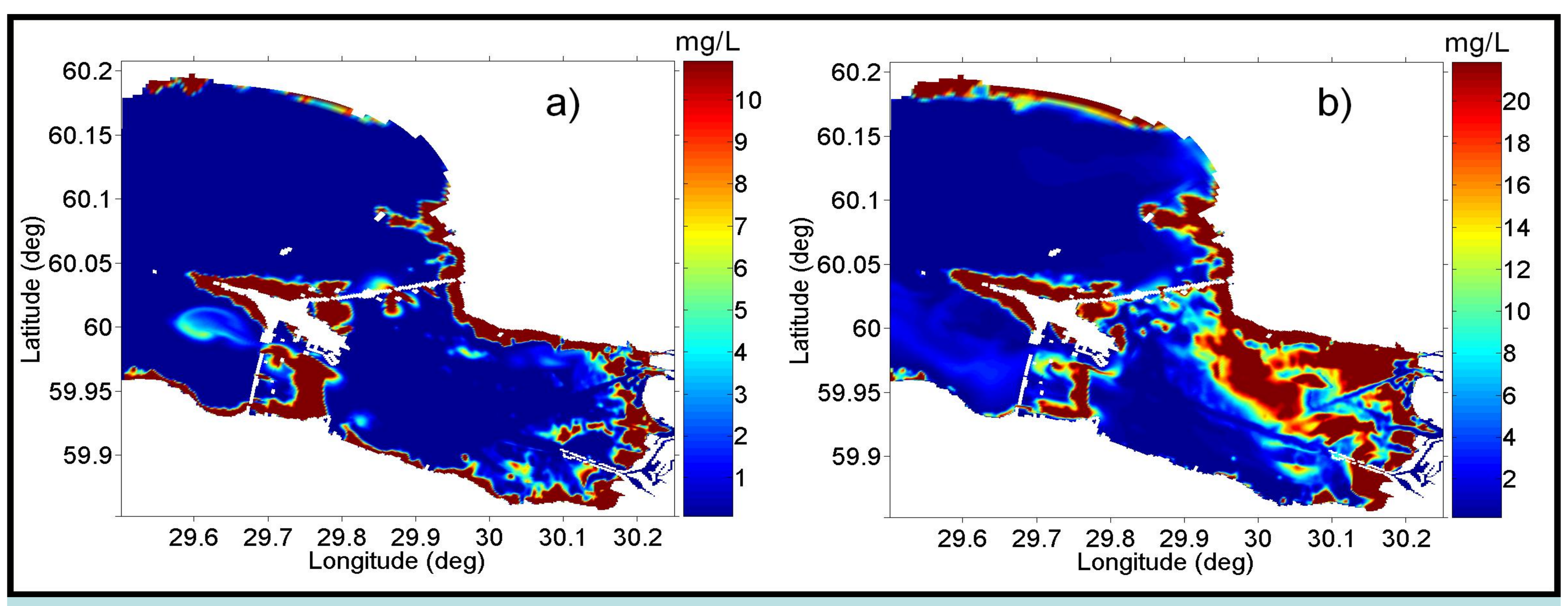

Fig. 5. Spatial distribution of modeled Suspended Sediment Concentration for the moments a) 2008-06-09 16:00 and b) 2008-10-26 13:00, as shown on Fig. 4 with arrows

References

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