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2024 JULY EXTREME WEATHER EVENT RECORDS IN THE GULF OF RIGA LATVIAN COAST IN THE LONGSHORE SEDIMENT TRANSPORT MODEL IN HYWASPORT SYSTEM AND DAUGAVA RIVER

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Abstract. The longshore sediment transport process has been defining the coastline and bathymetry dynamics in the coastal areas in Latvia. Numerical models had been applied and the sediment load transport - characterizing the seabed disturbance above the selected threshold, its integral value since 1st of July in the recent year and its climatic mean are recorded and virtually monitored in the system HywasPort. Seabed disturbance indicators are calculated from the outputs of University of Latvia coastal oceanographic model which uses two Copernicus Marine products as boundary conditions (wave and ocean currents). The highest sediment transport intensity correlates with the storm conditions. It threatens the vegetation cover in two different situations – complete destruction of the algae attachment to the solid substrate or reduction in available light due to sediment allocation. The study records and analyses the sediment load transport in the Gulf of Riga, Latvia in the particular storm event, July 2024. The study emphasizes the most impacted localities and dominating direction of the sediment load transport – leftward along the coast in the most impacted localities along the shore of the Gulf of Riga. The highest intensity of sediment transport had been in Daugavgrīva – located on the left from the Daugava River estuary in the Gulf of Riga in Latvia. It also provides climatic means of the sediment loading in both directions along the shore and its total. Total sediment load indicator may be better applicable (than the maximum sediment load transport in positive or negative direction alone) in further vegetation distribution modelling. It may illustrate total vegetation disturbance values in the coastal locations.

Keywords: sediment load transport modelling, the Gulf of Riga

1 INTRODUCTION

Sandy beaches are a valuable treasure of Latvia's land and seascape. The major part of the seashore and coastal seabed is sand sediments in Latvian coast of the Gulf of Riga. Beach sand grain-size analysis in 15 beaches on the shore of the Gulf of Riga in Latvia is given in Dimante – Deimantovica et. al. 2023. Gravel, coarse, and/or very coarse sand were dominant at only a few sites along the shoreline of the Gulf of Riga in Latvia. Fine sand is dominant mostly.

Wave exposure is one of the main structuring forces in the marine environment and availability of quantitative physical models data layers serve species modeling and management as mentioned by. G. Sundblad. 2014. Jönsson et. al. 2005 states that almost the entire Baltic Sea down to around 80 m depth is affected by wave-induced resuspension at least once every year.

There is a scarce narrow and vulnerable vegetation belt built of algae species *Fucus vesiculosus* and *Fucus lumbricalis* attached to solid substrate – boulders, pebbles and gravel along the Gulf of Riga Baltic Sea Latvian coast. Light is reaching the substrate in sufficient amount in the coastal area which is also severely impacted by waves. Bäck and Ruuskanen (2000) showed that the maximum growth depth of *F. vesiculosus* – correlates with light intensity.

Longshore sediment transport can disturb the vegetation cover by reducing the light and damaging the attachment permanently in case of the extreme sand allocation and wave exposure.

Storms in the Baltic Sea had been described by Suursaar, Ü., et al. 2018. Leszczyńska et. al. 2025. Regional waterlevels for potential estimates of worst-case scenarios of coastal erosion as well as for the design of coastal engineering structures outlined by Männikus and Soomere, 2023. General extreme hazard risk diversity and current research status in the region had been characterized by Rutgersson et. al. 2022.

Longshore sediment transport impacting the shore had been studied in detail and reported by Soomere and Viska, 2014. It is evident that dominating sediment transport direction is rightwards along the coast in the most part along the shoreline. Storms approaching the coast causing conditions resulting in leftwards along the coast direction of the sediment load transport are also possible.

2 MATERIALS AND METHODS

2.1 Study area

Study area – the Gulf of Riga is semi-enclosed subbasin of the Baltic Sea with the maximal depth 54 m in its central part, Figure 1. Straits connect it to the Eastern Gotland basin in the west and north. It is characterized by a microtidal regime, relatively shallow bathymetry and a highly anisotropic wave climate. Recent studies have demonstrated that the sedimentary shores of the Gulf of Riga are organized into a set of partially isolated sedimentary compartments, within which wave-driven longshore transport dominates coastal sediment dynamics (Soomere et al., 2025). Sediment transport integral characteristics along the Gulf of Riga coastline in Latvia had been decomposed into five naturally almost isolated compartments based on the analysis of wave-driven sediment flux. Authors agree that the individual storms that drive the sediment flux cross the compartments are possible.

While long-term mean transport patterns reflect the prevailing wave climate, individual storm events may temporarily modify transport directions and intensities and induce sediment exchange across compartment boundaries. These features make the Gulf of Riga a suitable natural laboratory for investigating storm-induced variability of longshore sediment transport in semi-enclosed basins.

2.2 Sediment transport model in Hywasport system

Recent development of high-performance computing and web service opportunities allowed introducing of new service by modelling and offering seabed disturbance indicators calculated from the outputs of the coastal oceanographic model operationaly. It uses two Copernicus Marine products as boundary conditions (wave and ocean currents). It provides sediment load transport operational monitoring. Web service Hywas-port had been developed recently, Center of processes´ analysis and research Ltd. (2022). It allows virtual observations of operational sediment load model results along the Latvian shore. Integral sediment load parameters in selected locations along the coast are displayed since 1st of July 2024 in the system, Figure 1. It includes the operational map of seabed disturbance in the coastal zone of Latvia; the operational map of sediment flux and direction and cumulative indicator – sediment load transport since 1st of July - characterizing the seabed

disturbance above the selected threshold in the recent year. Comparison with the climatic value of the indicator is given in the system.

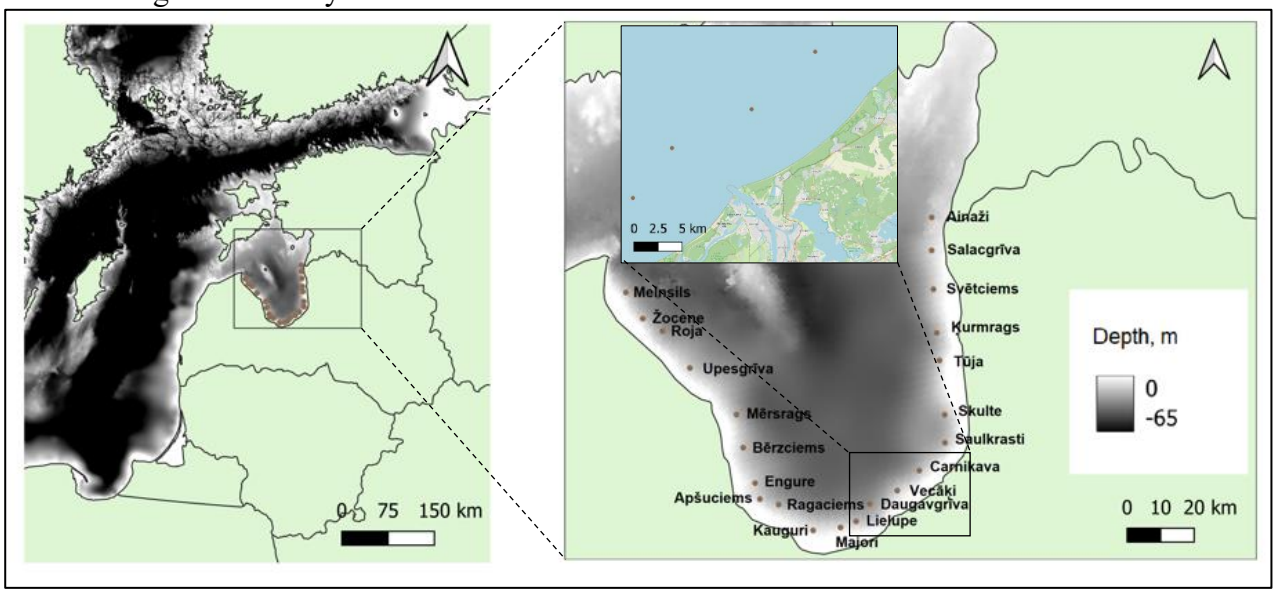

Figure 1. The Gulf of Riga, Baltic Sea and the locations of longshore sediment load transport virtual monitoring in Hywasport system along the Gulf of Riga, Latvia. Bathymetry shaded. Daugava river delta outlined

Timing of the sediment load transport operational service offers the possibility to analyse a particular extreme weather event in July 2024 in the southern part of the Gulf of Riga, Latvia. The extreme weather event – storm approaching the southern part of the Gulf of Riga as well as extreme rainfall intensities in Lielupe and Daugava basins occured during last days in July 2024. The present study pays attention to the sediment loads virtually recorded in the Hywasport system during the storm. Main applications of the sediment load transport model incoporated in Hywasport system: providing information on sediment load transport intensities around navigation channels in the ports; might support long term monitoring of coastal erosion, accumulation characteristics and sediment accumulation probability in sites where valuable aquatic vegetation attached to rocky seabed resides or going to be restored. In particular study sediment load transport climatic means obtained are presented. It is worth outlining the localities having high total integral sediment transport values – those may not be among accumulation or erosion hotspots and may not be fruitful area for vegetation due to intense sediment transport disturbance by the total sediment load transport there. Total integral sediment transport value as an indicator could be tested for species distribution modelling in future.

Seabed disturbance indicators are calculated from the outputs of the coastal oceanographic model which uses two Copernicus Marine products as boundary conditions (wave and ocean currents) from the regional Domain: Baltic Sea: physical state of the Baltic Sea near real time (003_006); modelled near real time wave data (003_010).

The system has been enhanced using Copernicus Marine services as the boundary conditions for a HirombBOOS (HBM) oceanographic coastal model in an operational setup by University of Latvia: 7 levels of nesting with the resolution of 36 m for inner ports, and 72/100 m for the port approaches; module of HBM and energetic model of longshore transport for sediment flux calculation; in-house wave model for port approaches and aquatories. It offers higher spatial resolution and uses localized boundary conditions.

As a first step, stationary wave amplitudes in port regions under a monochromatic wave assumption had been computed. This approach yields spatial fields of wave amplitude corresponding to various combinations of input parameters, including wave direction, amplitude, and period.

Assuming the incident wave energy spectrum follows the JONSWAP (Joint North Sea Wave Project) distribution Hasselmann, K. et al. 1973, we decompose the incoming wave field into a superposition of monochromatic components. Each component is assigned a weight derived from

the spectral energy density. The resulting linear combination of monochromatic wave fields approximates the total wave state and serves as the target variable for wave field visualization.
The longshore sediment load transport is estimated using the CERC (Coastal Engineering Research Center) formula, U.S. Army Corps of Engineers 1984, which relates wave energy flux and angle of incidence to the volumetric transport rate of sediments along the shoreline.

The calculated longshore sediment load transport is divided into positive and negative components. The positive component corresponds to sediment transport directed rightwards from the selected coastal profile, while the negative component represents transport directed to the left from the coastal profile.

Both annual and seasonal potential longshore sediment transport rates are computed and their long - term averages, calculated over a 20-year reference period.

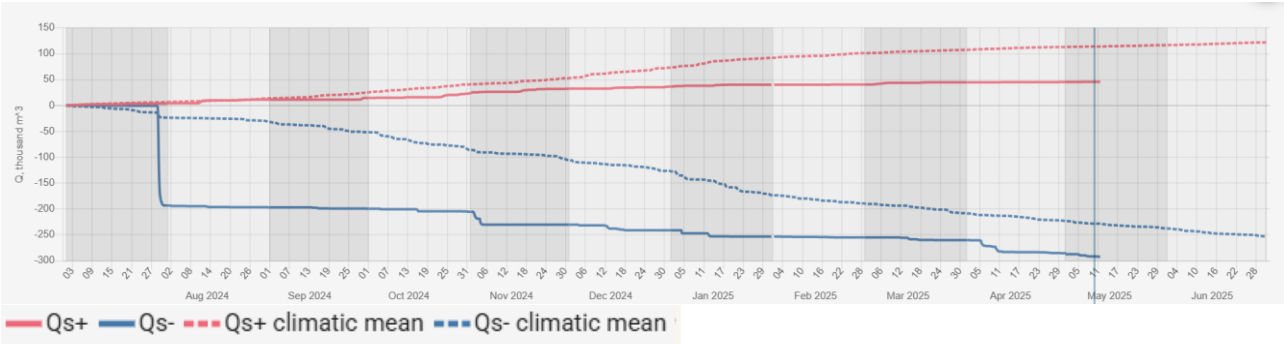

Figure 2. Longshore sediment load transport characterisation in Hywasport system. Daugavgrīva, Riga city Figure 1d – integral sediment load transport since 1st of July 2024. Dashed line – climatic average, solid line – current year

2.3 Abbreviations used

Sediment loads are expressed in t. m^3/year - thousand cubic meters per year. Qs- and Qs+ are used for the load in leftward and rightward direction along the coast respectively. Values since 1st of July displayed. Total sediment load transport in the location n from the set of all given locations is calculated according to formula:

$$Qst_n = |Qs+|_n + |Qs-|_n.$$

Sediment accumulation and loses in the coastal segments joining the adjacent locations from the set had been characterised: Lnt – total sediment accumulation (total sediment loss in case of negative value) in the segment n.

J2024 has been used as indication that parameter value had been calculated for July 2024.

3 RESULTS AND DISCUSSION

3.1 Extreme conditions July 2024

Total precipitation amount in 3rd decade in July 2024 had been the highest in the central region of Latvia - 228.2 mm recorded in Kalnciems station. Total percipitation had been considerably smaller in parishes along the coast of the Baltic Sea in Latvia and eastern region of Latvia (35.4 mm total precipitation only - had been observed in Rēzekne city). The highest precipitation amound in Kalnciems had been acquired during 2 days – 199.6 mm of precipitation in total – twice as much as the total precipitation climatic average in the station in July 1991-2020, Latvian Environment, Geology and Meteorology Centre provided data archive.

Storm damage and flooding had been mainly observed in Jurmala, Jelgava and Riga cities on the shore of Daugava and Lielupe river estuaries in the Gulf of Riga.

3.2 Sediment transport characterisation

Figure 3 shows that in the most part of locations Qs+ climatic mean exceeds the absolute value of Qs- climatic mean and the net sediment load is rightwards oriented along the coast there. There are several locations with Qs+ climatic mean close to the absolute value of Qs- climatic mean (Mērsrags, Ragaciems, Carnikava, Saulkrasti). The absolute value of Qs- climatic mean is considerably higher than Qs+ climatic mean in Melnsils, Daugavgrīva and Skulte according to the climatic sediment load assessment – meaning that the net sediment load is leftwards oriented along the coast there.

When the absolute values are analised: the highest potential sediment load transport Qs+ climatic mean occurs in Ainaži – 619 t. m3/year; the highest potential sediment load transport Qs- climatic means occurs in Skulte – 432 t. m3/year; the highest total sediment load |Qs+| + |Qs-| occurs in locations on the eastern shore of the Gulf of Riga. The maximum total sediment load – 939 t. m3/year in Svētciems, Figure 3.

Figure 3 and 4 also outlines the average balance of the sediment load for the segments of the analysed locations (in red and green). Climatic annual mean balance in Figure 3 shows that 3 segments with the highest sediment loss are Daugavgrīva - Vecāķi, Svētciems - Salacgrīva and Skulte -Tūja. Similarily – 3 segments with the most intense sediment accumulation: Saulkrasti - Skulte, Lielupe - Daugavgrīva and Vecāķi - Carnikava. In case the sediment loads induced by July 2024 storm are considered: the highest sediment load directed leftwards along the coastline had been in Daugavgrīva. This has been the storm with the highest intensity until May 2025 and exceeds Qs- climatic mean of 8 month (July to March) in Figure 2. Sediment loads and directions give additional information about integral amount of sand that is added or left the coastal segment between two suceeding locations. Figure 4 illustrate potential sediment lost volume in the storm July 2024.

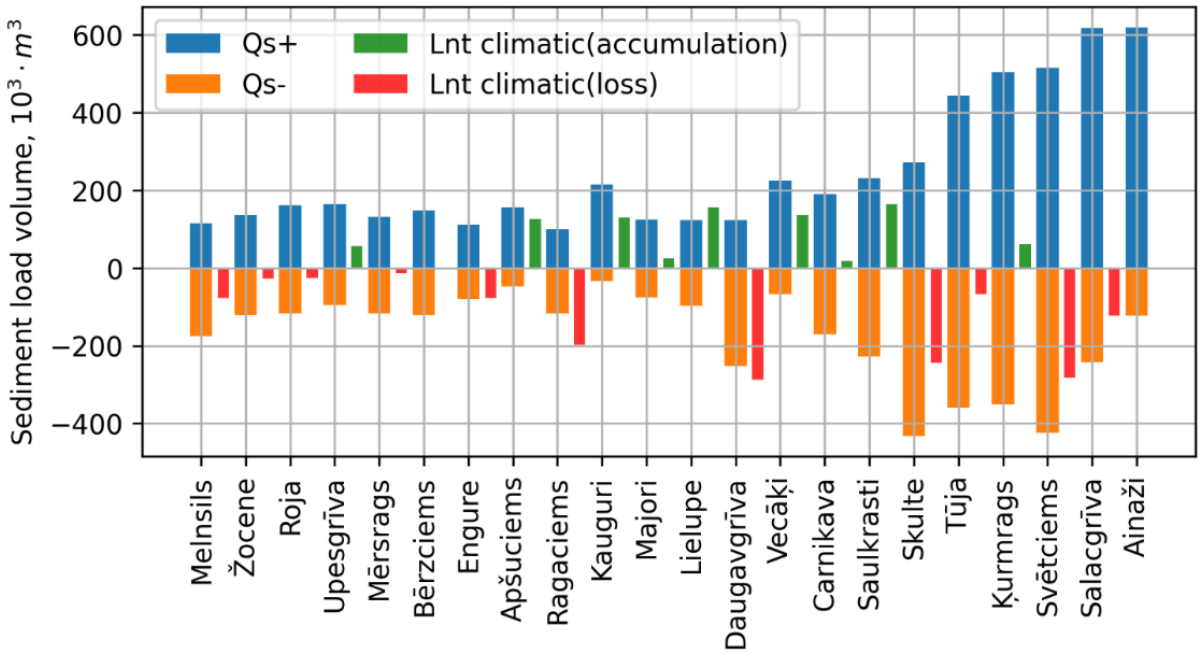

Figure 3. Climatic mean sediment load volume per year and sediment volume lost/accumulated in compartment between locations

Particular storm that hit the region in July 2024 could caused the highest sediment loss in Daugavgrīva - Vecāķi, Ragaciems - Kauguri, Engure – Apšuciems, Figure 4. The highest storm induced sediment accumulation could be expected in Lielupe -Daugavgrīva, Apšuciems - Ragaciems and Vecāķi - Carnikava. It can be seen that despite being noticeable – this extreme event had not reached the full annual level of sediment transport load in none of the outlined segments. The segment Engure - Bērzciems that on average loses 4 t. m3 per year had received 35 t. m3 during storm in July 2024, Figure 3-4.

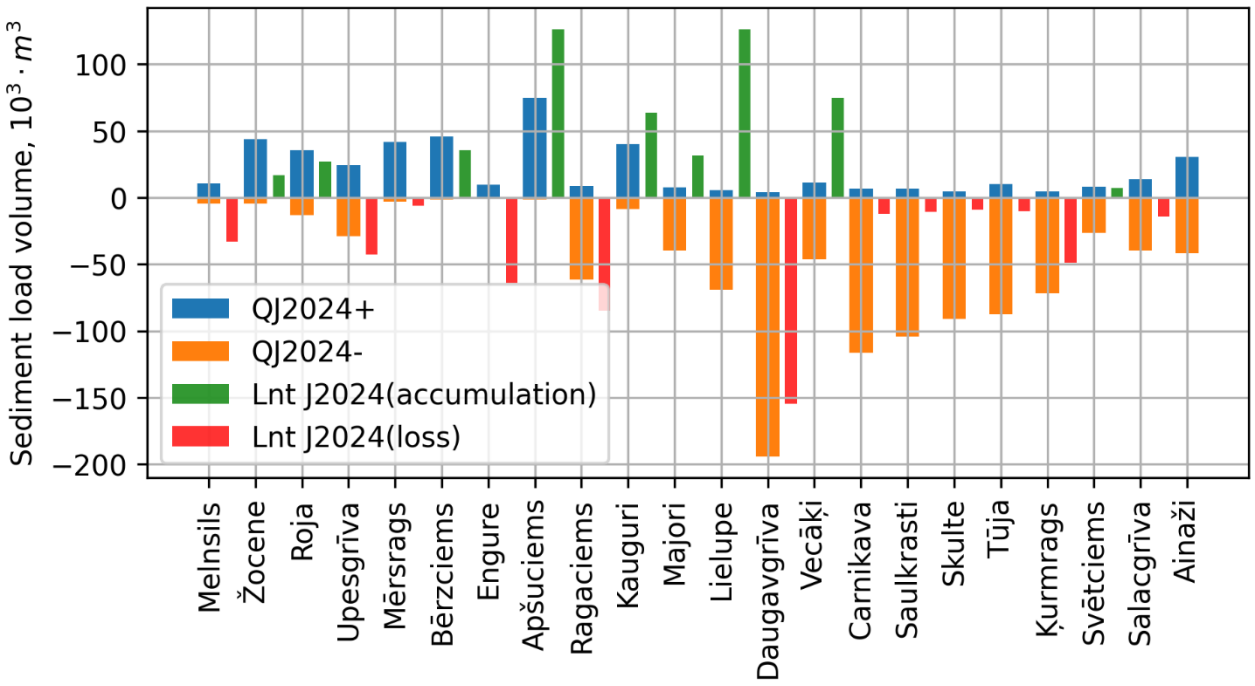

Figure 4. Sediment transport load components and volumes lost/accumulated in compartment between locations during 1st July-1st August 2024 according to Hywasport system

4 CONCLUSIONS

Results illustrate the sediment loading character along the Gulf of Riga shoreline in Latvia climatically and during the particular weather event - July 2024 storm. The largest sediment loads had been observed in Daugavgrīva – located closely to the the Daugava river delta (on the left from it). The direction of the sediment load had been leftward along the coast there.
Other sites with the highest sediment load transport during the particular storm had been outlined. It should be noted that obtained quantity of the sediment load transport in July 2024 does not exceed annual average of the sediment load in the location.

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