Sea level changes and coastal evolution in the south-eastern Baltic Sea

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The studying object is south-eastern Baltic Sea and its coasts including three countries – Lithuania, Russia (Kaliningrad district) and Poland. Aim of the work is possible to separate into three parts:

1. Creation of 4D (space/time) geological model for south-eastern Baltic Sea in Late-Glacial - Holocene (last 13 500 years);
2. Comparison of long term and short term (Postlitorina) relative sea level changes;
3. Prognostic scenarios of the south-eastern Baltic Sea (about 700 years).

The 4D model includes three main components. First, a digital elevation model (DEM_0) describing the recent state of coastlines and the elevation of adjacent areas is needed. This structural model has to include both bathymetry and land relief. Second data describing the eustatic component of sea level variations have to be provided by climate modellers. Third, vertical movements of the earth's crust have to be taken into account (Meyer 2003, Meyer et al. 2005) (Fig. 1).

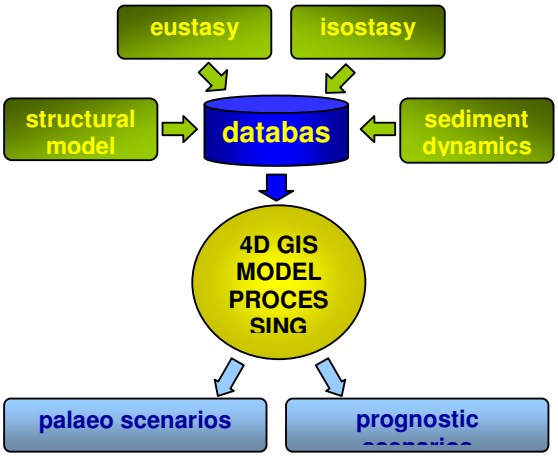

Fig. 1. *Scheme of geological modelling (after Meyer, M.).*

It is possible to describe the elevation model in time using formula (in case of t<0):

$$DEM_t = DEM_0 + SED_{E/D} + RSL_t$$

DEM_t – elevation model in time;
$SED_{E/D}$ – sediments affected by erosion/deposition;
RSL_t – relative sea level changes.

Relative sea level changes can be described:

$$RSL_t = EC_t + IC_t$$

EC_t – Eustatic component (mainly caused by climatic factor);
IC_t – Isostatic component (mainly caused by tectonic movements of earth crust).

For future scenarios formula will be used (in case of t>0):

$$DEM_t = DEM_0 + SED_{E/D} + EC_t + IC_t$$

Digital Elevation Model (DEM)

Digital Elevation Model for the south-eastern Baltic Sea area is compiled using various data sources: Elevation data of Lithuania mainland up to 21°30'E (GIS Centre data, Vilnius); Bathymetry of Baltic Sea (Gelumbauskaitė 1996); GTOPO30 (United States Geological Survey 1996). Digital elevation model is created using *krigging* interpolation method in Surfer program, where horizontal resolution is 50 m and vertical - 1,0 m (Fig. 2).

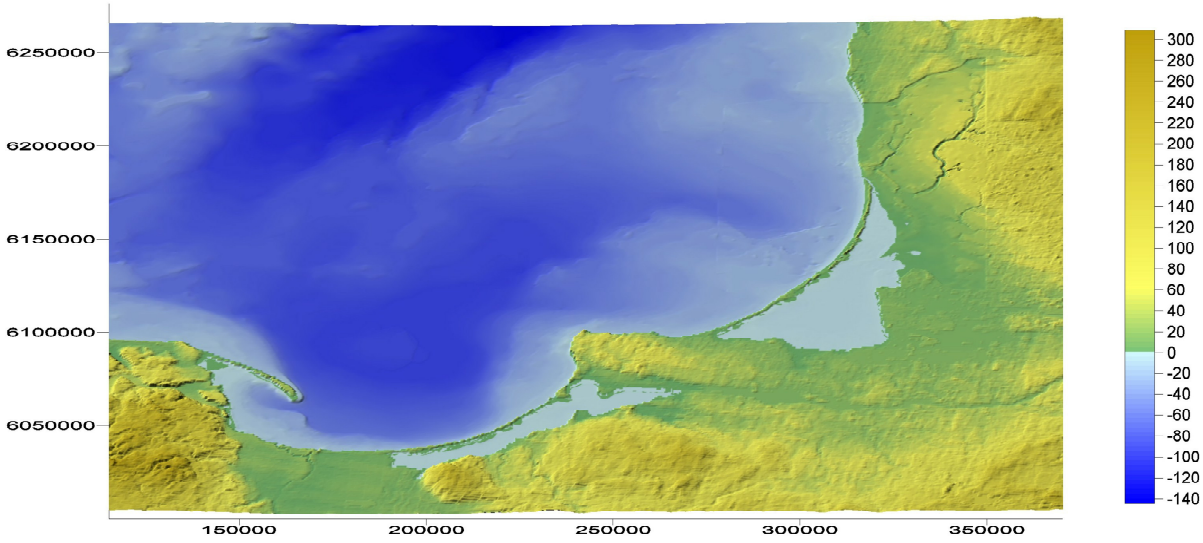

Fig. 2. *Digital elevation model of south-eastern part of the Baltic Sea.*

Data about erosion/deposition processes ($SED_{E/D}$)

Geophysical (echosounding, seismoacoustic, etc.) and geological data were collected in 1983-2003 within national marine-maritime geological mapping programs at a scale 1:200,000-50,000 and several international projects. Geoseismic units were interpreted as geological units via interpretation of cores and boreholes where spore and pollen analysis, lithostratigraphical, radiocarbon and OSL dating were performed by different authors.

Geoseismic profile offshore and geological profile onshore were compiled together and was got seismogeological profile stretching from West to East through Baltic Sea – Curonian Spit - Curonian Lagoon - Lithuanian onshore (about 100 km). The horizontal scale of the profile is at 1:150 000 and vertical - 1:500 (Fig. 3).

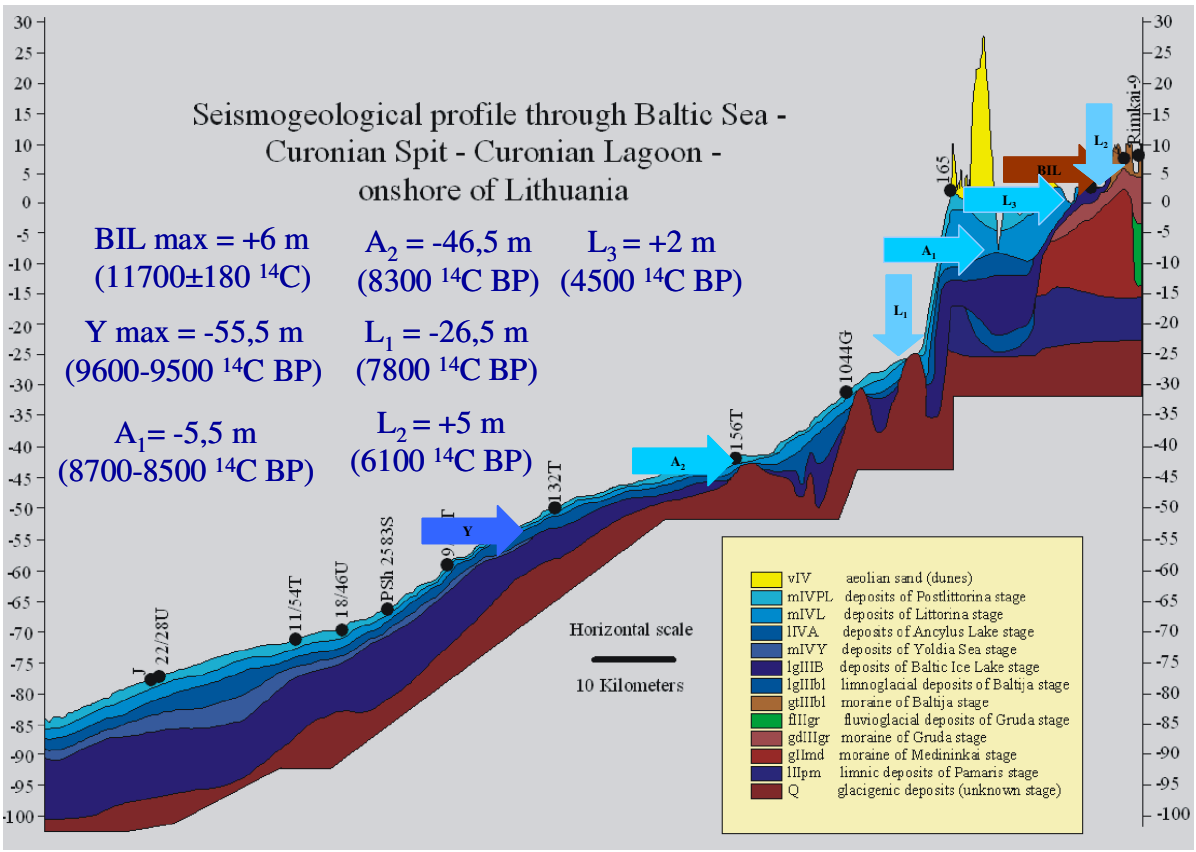

Fig. 3. *Seismogeological profile showing transgression-regression peaks (marked by arrows) of different Baltic Sea stages (Gelumbauskaitė et. al. 2005a).*

Using gyttja and peat dating (Andren 1999, Kabailienė 1997, 1999, Blazhchishin et al. 1974, 1989, Bitinas et al. 2001, 2002) as well as remnants of wood dating (Bitinas et al. 2003, 2004) and geomorphological method of ancient shore formations (Lukosevicius et al. 1974, Blazhchishin et al. 1982, Gelumbauskaitė 1982, 2000, 2002) it has been done curve of relative sea level changes.

Relative Sea Level changes (RSL_t)

According to the traced geoseismic section, the ancient shore levels of the transgression-regression peaks have been constituted: Baltic Ice Lake maximum transgression (11,700±180 ^{14}C BP) refers to +6 m NN, Y max. transgression (10,000-9,500 ^{14}C BP) to –55.5 m NN, A_1 max. transgression

(8,800 ^{14}C BP) to –5.5 m; A_2 regression peak (8,300 ^{14}C BP) to –46.5 m, L_{1-} (8,000-7,800 ^{14}C BP) to –26.5 m, L_2 max. (6,100±125 ^{14}C BP) to +5.0 m, L_3 (4,500–4,415±45 ^{14}C BP) to +2.0, PL (4,000–3,500-3,295±50 ^{14}C BP) (Gelumbauskaitė et al. 2005a, b) (Fig. 4).

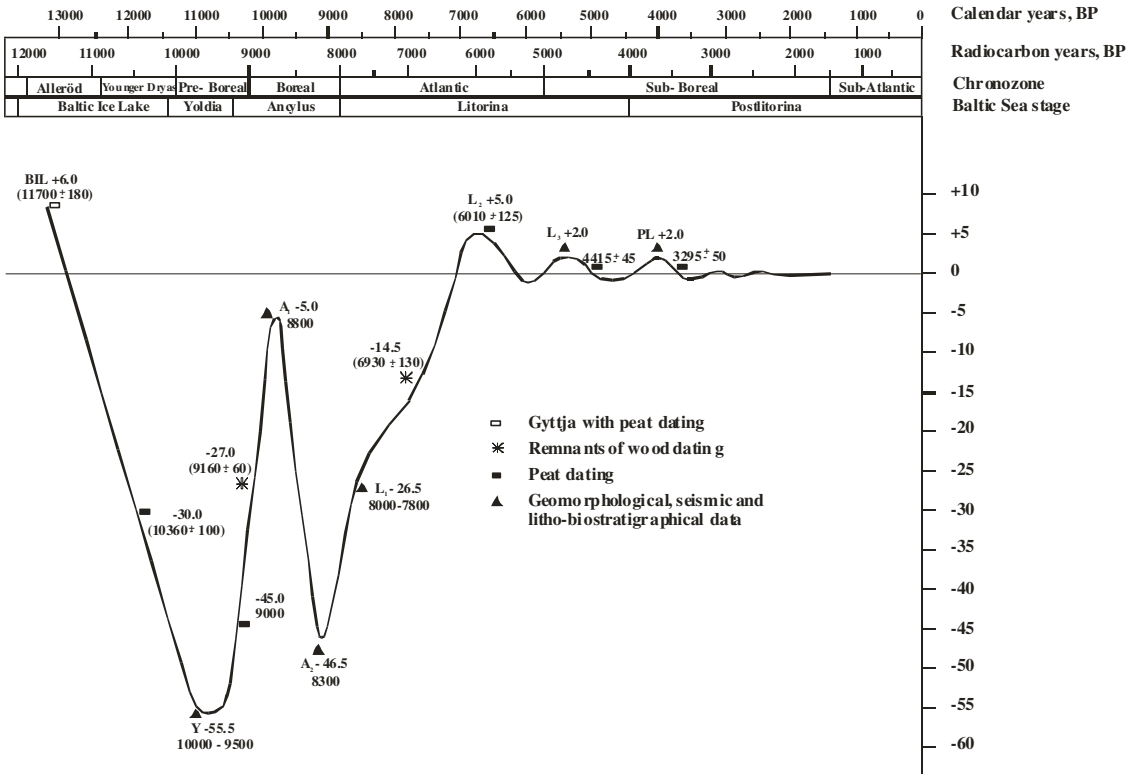

Fig. 4. *Relative sea level changes in the south-eastern Baltic Sea (Klaipėda traverse), isostatic factor is not separated (Gelumbauskaitė et al. 2005a).*

Relative sea level curve was compared with other curves compiled by other authors in Lithuania (Kabailienė 1997, Bitinas et al. 2004) (Fig. 5).
We found direct correlation of the curves presented in this presentation with curves of the eustatic changes in the North-West Europe and Atlantic Caribbean region (Fairbanks 1989, Mörner 1980) (Fig. 6).

Data on short term climate changes

Data on short term water level changes in Curonian Lagoon and Lithuanian coast are playing special interest and will help to create prognosis scenarios for coastline changes. South-eastern part of the Baltic Sea belongs to the passive tectonic zone (fixed near Klaipėda, Gudelis 1961, 1982, Frischbutter et al. 1995, Harff et al, 2001), where value of movement amplitude is near 0. Therefore, geodynamic model created in this part of Baltic Sea can be standard to investigate sea level rises caused by climatic factors. Several data sources will be used for modelling: curves of climate changes from Swinoujscie (Poland) to Liepaja (Latvia) (Jarmalavičius et al. 2001) (Fig. 7); content of spores-pollen (Pustelnikovas et al. 1996); chemical composition of sediments (Pustelnikovas et al. 1996).

First results

According to our investigations full marine and lacustrine deposition complex prevailed only offshore, until 50m b.s.l., in the existed BIL, Y,A_{1-2} and L_{1-2-3} propers on the Lithuanian coast.
On the shallow, nearshore and onshore, Late-Glacial and Holocene depositional complex is more variable, truncated, caused by fluvial processes.
The palaeogeographical conditions and depositional–erosional activity of the fresh water basins during Alleröd-Boreal periods have been investigated using created GIS database of the stratigraphical units. Palaeotopography of the till loam top, IL-BIL and A_{1-2} Baltic Sea stages is reconstructed and exposed on 3D schemes, revealed deformations and dimension of the morpho-lithogenetic processes during Late-Glacial and Postglacial time.
The curve of the relative sea level changes on the traverse Klaipeda-Dreverna and its correlation with other long-term-short term curves of the eustatic changes revealed conformities and discrepancies in the eustatic mechanism at the latitude Klaipeda on the the Lithuanian coast.

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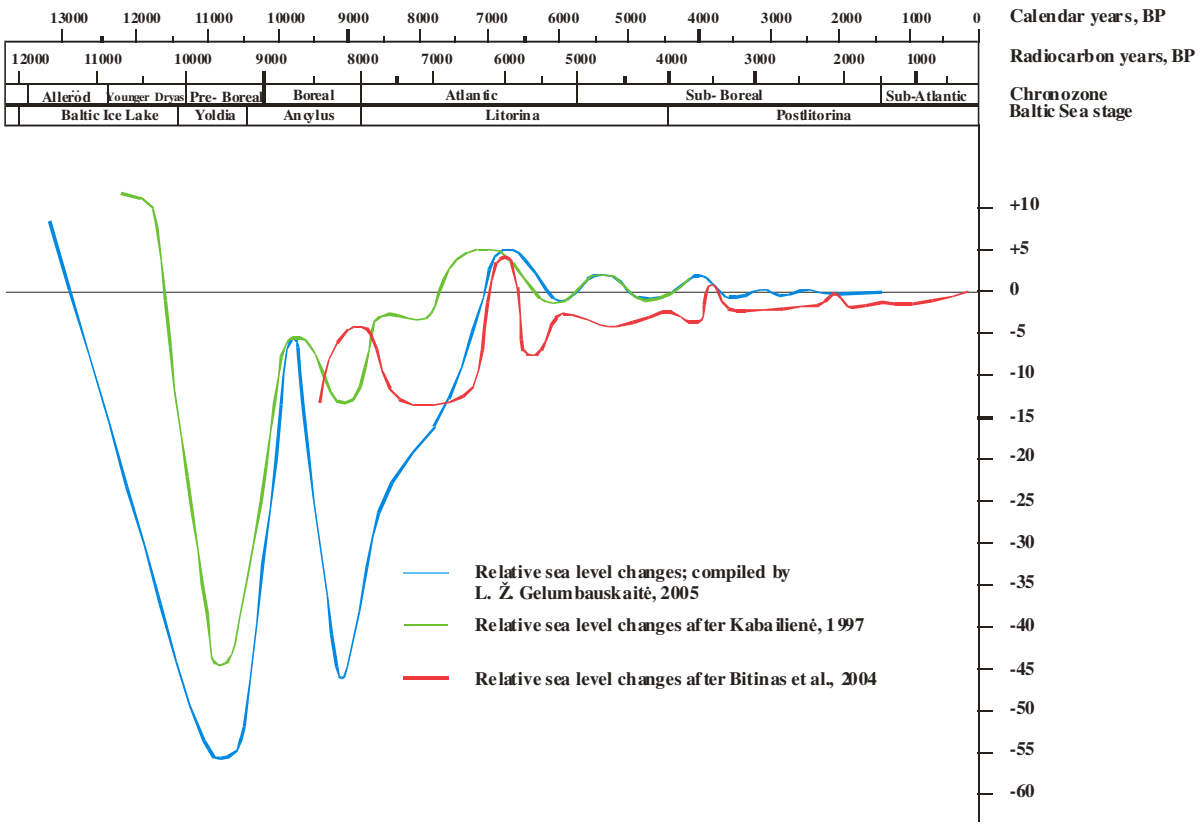

Fig. 5. *Shoreline displacement curves in the south-eastern Baltic according to different authors (Gelumbauskaitė et al. 2005a).*

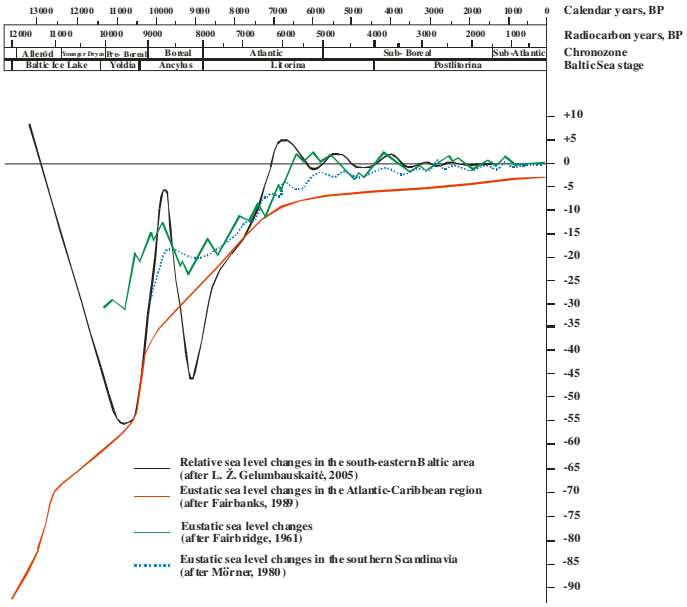

Fig. 6. *Comparison of relative sea level changes in the south-eastern Baltic and eustatic changes in the North-West Europe and Atlantic-Caribbean region.*

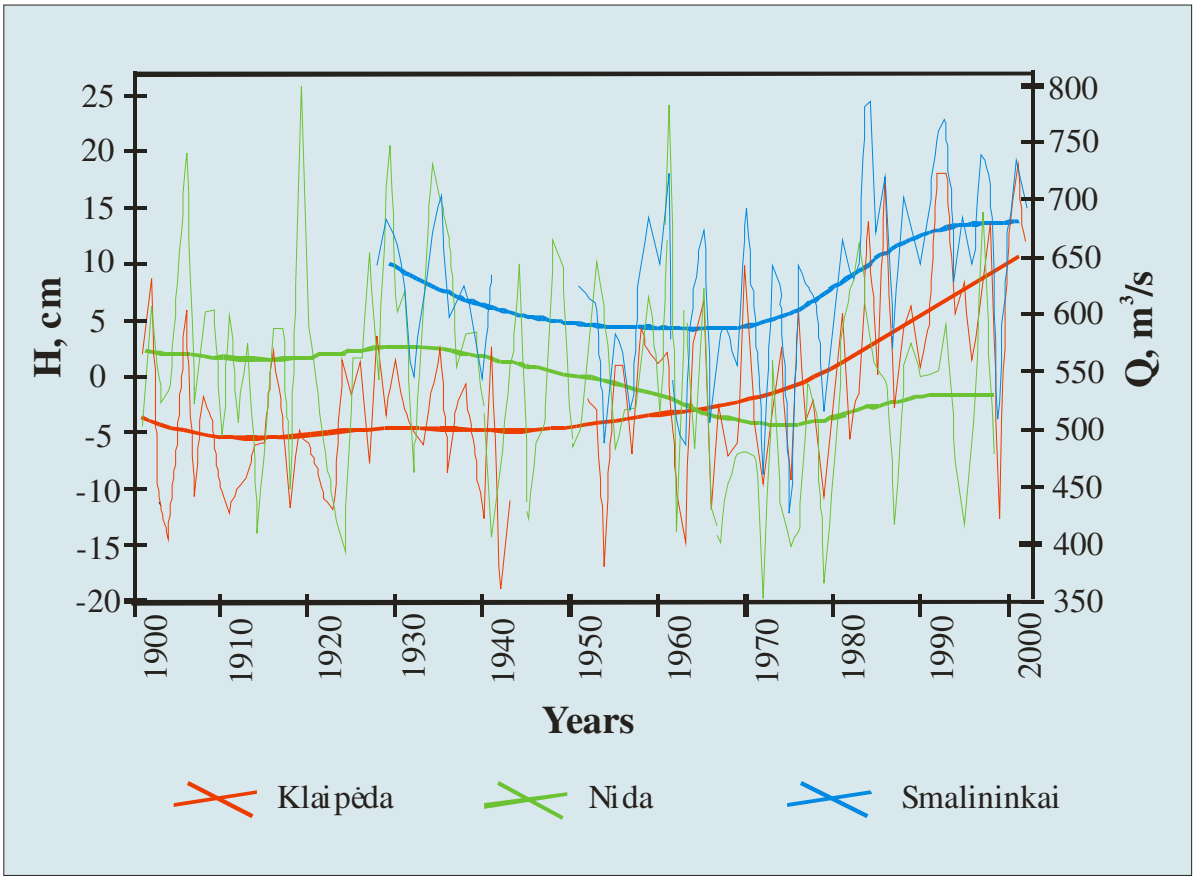

Fig. 7. *Short term fluctuations in the mean water leveli n the Baltic Sea (at Klaipėda) and Curonian Lagoon (at Nida) and those in the Nemunas river runoff (at Smalininkai) (Jarmalavičius et al. 2001).*