Implications of Accelerated Sea-Level Rise (ASLR) for Lithuania:

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General overview

Total land area of the Republic of Lithuania is 65,300 km^2, and total length of the coastline is 99 km (Counties of Lithuania, 1999). The total national population of Lithuania is 3,698,536 and the national population growth rate is -0.08 % (Counties of Lithuania, 1999). The coastal zone is under the administration of the Klaipeda County. The total coastal zone population is 415,591. 11.5 % of Lithuania GDP is produced in the coastal area. The largest coastal city and coastal Harbour is Klaipeda (total population of the city is 204,300). Two health-resort cities Neringa (2,713 habitants) and Palanga (19,550 habitants) belong to the coastal infrastructure too. The total length of protected coastline is 99 km (Republic of Lithuania. Law I-1105, 1995). Hard-protected coastline runs along 52 km (Neringa National Park), but soft protection measures are applied to 47 km (Pajurio Regional Park) (Republic of Lithuania. Government Decision No. 78, 1996). The total length of Harbour-protected coastline is 12 km.

The coastal ecosystem is situated on the southeastern side of the Baltic Sea. The length of the open Baltic Sea coastline, *i.e.,* wave exposed, is also 99 km (Grigelis, 1991). Sandy beaches representing accumulation environments stretch for a 98 km, but rocky coast only occur over 1 km (*i.e.,* 16 m cliff Olando Kepure with 400 m bench) (Fig. 1). The Curonian Lagoon (Kursiu Marios) is separated from the sea by the Curonian Spit (this is a candidate to the UNESCO Heritage Site list), and is also significant in the coastal zone of the Lithuanian Baltic Sea basin (Gelumbauskaite, 1997). The Curonian Lagoon is a shallow, fresh, bell-shaped estuary with a narrow neck in the north. It opens to the Baltic Sea via the Klaipeda Strait. The total area of the lagoon is 1,584 km^2, average depth is 3.7 m, and the length of the western (inward) coastline is 52 km. The Nemunas River, which is over 1,000 km long, drains into the Curonian Lagoon. The Nemunas drainage basin area is *c.* 100,000 km^2; and total river discharge 632 m^3/s (23 km^3/year). Fluvial supply of thin dispersed sedimentary matter into the lagoon varies seasonally with total input of up 437,200 ton/year. Lagoon bottom sediments are entirely terrigenous, with fine-grained sandy sediments prevailing, although muddy sediments are locally deposited for example in some bays (Curonian Lagoon, 1998). The length of Nemunas Delta (south to north direction) is 12 km, and the total delta area is 2,000 km^2 (Digital Satellite Image Maps, 1998). The Klaipeda Harbour is situated on the Klaipeda Strait. Harbour gates and embankments extend over 12 km, and the depth of harbour and inlet channel is artificially deepened to 14 m. The coastal plain is not visibly affected by floods because of the low oscillation of the Baltic Sea level are restricted to a few tens of centimetres.

Coastal Ecosystems

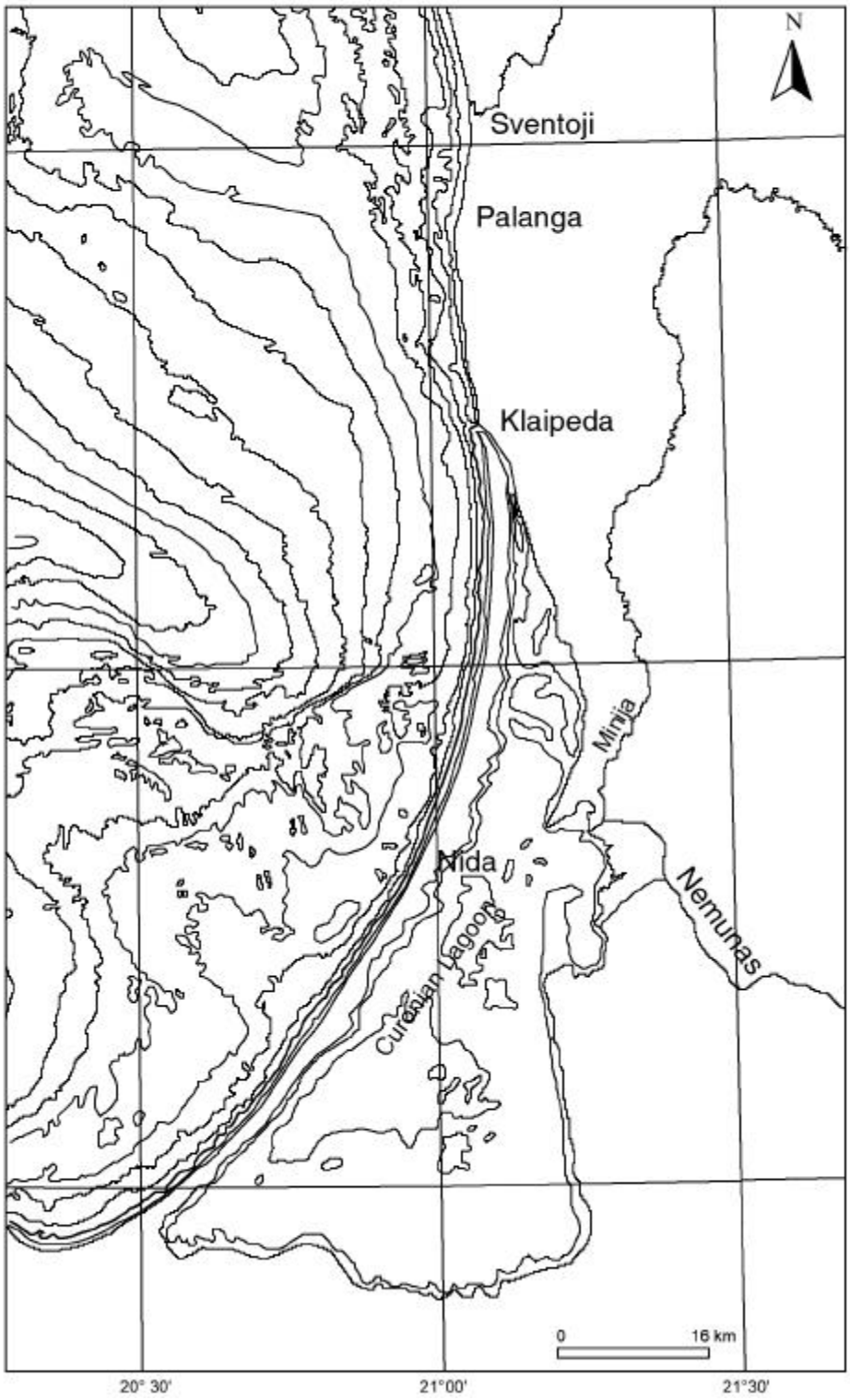
The Lithuanian Baltic Sea coastal lowland belongs to the area affected by the last Quaternary Glaciation and is covered by glacial and glaciofluvial deposits. These are overlain by Holocene marine sandy-silt sediments (Gelumbauskaite, 1997). Land use is mainly agricultural; with forests covering *c*. 32% of the coastal lowlands. The climate is characterised by maritime influences. Annual precipitation in the lagoon amounts to 700-760 mm/year. West to southwest winds are predominant (Dubra and Dubra, 1999). The coastal environment is characterised by a negligible tidal range, but is strongly variable due to the high hydrodynamics of near-shore currents and seasonal storms.
The following coastal ecosystems exist on the Lithuanian Baltic Sea coast:

- Temperate wetlands - represented by Blowaway Plain (Palve) on the Curonian Spit.
- Beaches - represented by a narrow sandy belt along the whole Lithuanian coast of first ten meters width.
- Dunes - represented by foredunes and main dune ridges mostly covered by either coniferous forest or bush, but there are also bare dune chains on the Curonian Spit (the highest bare dune is Parnidzio Kopa and lies 66 m high).
- Meadows - about 57,000 ha of the Nemunas Delta Plain belongs to flood meadows; the area is a coastal RAMSAR site (Svazas *et al.*, 1999).

Sea-level rise data

According to recent data (Bukantis *et al.*, 1999), air temperature and precipitation are the main climatic factors related to sea-level conditions on the Lithuanian coast. Average annual temperature was 6.2^{o}C in 1990. This is expected to rise to 7.8^{o}C by 2050, and 9.6^{o}C by 2100 (Fig. 2). This could result in increasing instability of the snow cover. Average annual precipitation could increase from 670 mm in 1990 to 770 mm in 2100 (Fig. 3). These changing trends should result in increasing maritime influences. Accelerated sea-level rise (ASRL), as forecasted, could reach +60±35 cm in global terms by the end of the 21st century. At present, ASLR is fixed for Klaipeda area at +6.5 mm/year (Jarmalavicius and Zilinskas, 1996). Consequently, ASLR could increase approximately by 65 cm in 2100. One scenario, *i.e.*, a sea-level rise of 30 cm (1 cm/year) by the year 2030 is discussed regarding the potential impacts of ASLR on the Lithuanian coastal ecosystem (Bukantis *et al.,* 1999).

Figure 1: Situation of the Lithuanian Baltic Sea nearshore area.
Isobathes on the seashore are drawn at 5 m, and on the Curonian Lagoon at 2 and 5m
(after L.Z. Gelumbauskaite *et al.*, 1998)



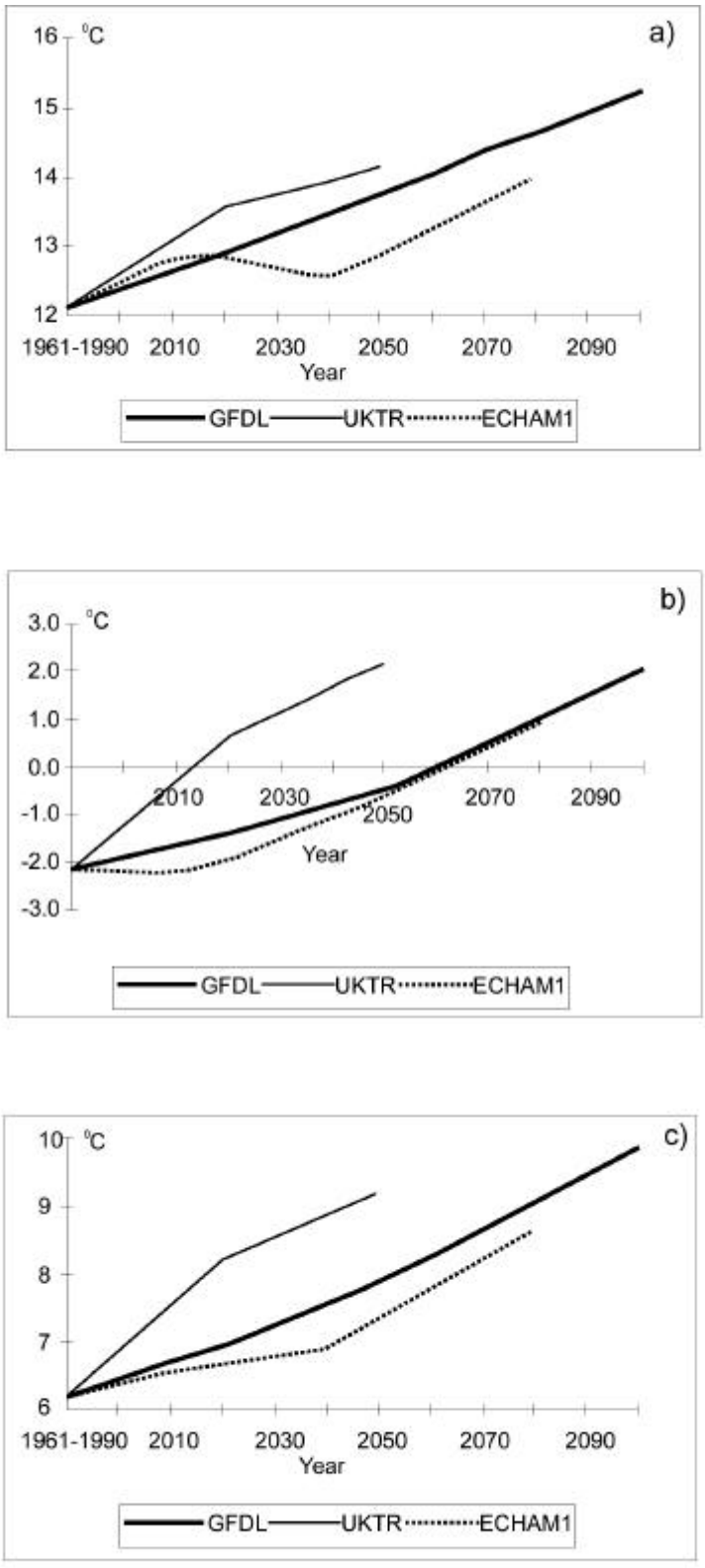


Fig. 2. Regional models of air temperature alteration for Lithuania by year 2100:
a) warm period (April-October), b) cold period (November-March),
c) annual data (after Bukantis in Bukantis, Kilkus, Zaromskis et al., 1999)

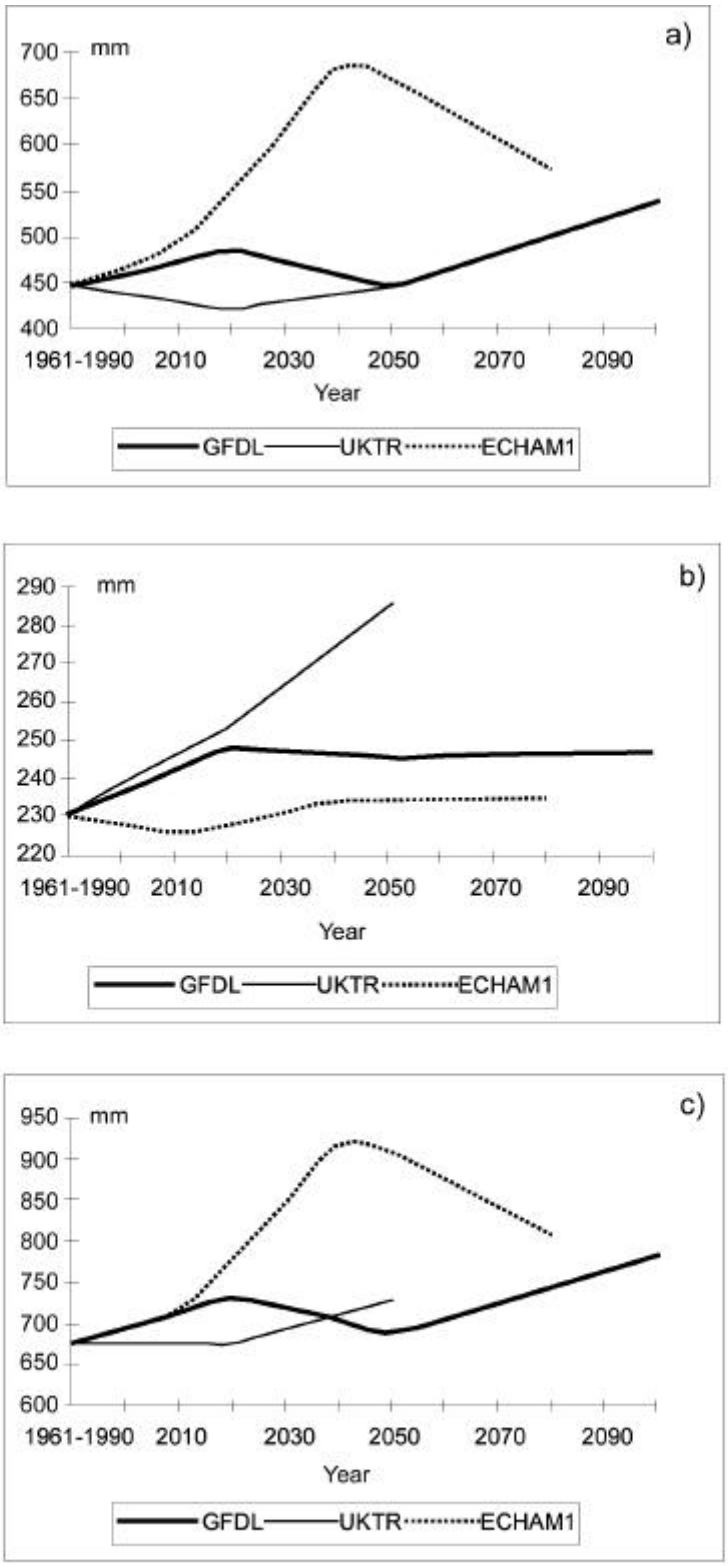


Fig. 3. Regional models of precipitation alteration for Lithuania by year 2100:
a) warm period (April-October), b) cold period (November-March),
c) annual data (after Bukantis in Bukantis, Kilkus, Zaromskis et al., 1999)

Primary Impacts

Erosion: At present, an erosional sandy coast is stretching in several sections south of Klaipeda. Otherwise, the coast is retreating in the area between Sventoji settlement and Lithuanian/Latvian border. It is estimates that every 10 years 8-9 ha of upland is lost. ASLR will increase the rate of coastal erosion and will cause an overall retreat of the coastline to the East (Zaromskis and Zilinskas, 1996).
Flooding: This process is inactive at present time. ASRL scenario, 30 cm by the year 2030, shows that flooding is anticipated in separate coastal areas, namely in Palanga city and between Sventoji and Butinge settlements (Bukantis *et al.*, 1999).
Inundation: No effect on coastal ecosystems in reality because of extremely low tidal range.
River flooding: It occurs seasonally every year in the Lower Nemunas meadows. 4,800 habitants and 978 farms are at risk of flooding. There is an old polder system but 49,950 ha of agricultural land is in the hazard zone. The maximum area at risk embraces 57,000 ha. If ASLR causes lagoon water flooding, the river defences, dam and road network would have to be rebuilt. Capital value at risk for <5 years life is estimated at 6,55 million. US$ (Klaipeda County prevention, 2000).
Salinisation: No effect in reality; no data.
Coastal surge: A strengthening of westerly to southwesterly winds and increasing number of extreme storms (Jarmalavicius and Zilinskas, 1996) is likely. As a result, the south to north near-shore current and sediment transport would become stronger. The increasingly negative effect of seasonal storms has to be mentioned. For example, the ANATOLY hurricane (03-04 December 1999) washed down *c*. 100,000 m^3 sand from the coast, the foredune ridge was seriously destroyed, and a steep cliff was formed up to 10 m high in many places.

Conclusions

No satisfactory ASRL/climate change or socio-economic scenarios have been produced for the Lithuania coastal zone. The proposed implications of sea-level rise for Lithuania are based on past and on-going academic research. An expert ASRL scenario of 30 cm by the year 2030 has been proposed, however, by Bukantis *et al.* (1999). In view of the latter scenario the following conclusions are proposed:

- the south side of the Baltic Sea is vulnerable to impacts of ASRL;
- the coastline will actively retreat to the East;
- the coastal zone will be affected by increasing risk of flooding;
- the harbours will need serious regulation by technical means;
- the existing national impact assessment should be improved;
- the coastal system, *i.e.,* comprising both natural subsystem and socio-economic subsystem, should be considered as an area of national priority.

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