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General Peculiarities of Long-term Fluctuations of the Baltic Sea and the Curonian Lagoon Water Level in the Region of Lithuania

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Water level is one of the indicators of the climate change. The reasons of the rise in water level are related with more frequent advection of warm and wet water masses during the cold period, with global atmospheric changes in circulation, with stronger air movement from the west, with rising air temperature, which causes rising water temperature. Rapid rise in water level observed during the last decades of the 20th century is directly associated with the problems of shore destruction, land flooding, violation of ecological balance. It is a matter of great concern. This study aims to investigate water level variability in the region of Lithuania during the last 100 years.

Key words: *water level, regime, fluctuations, Curonian Lagoon, Klaipėda Strait, the Baltic Sea.*

1. Introduction

Information about the changes in water level is necessary for harbor reconstructions, building settlements, towns, and enterprises next to water bodies. It is necessary for navigation and to guarantee the security. Therefore, systematic water level observations have been performed in the Curonian Lagoon as all over Europe since the beginning of the 19th century.

A matter of great concern is the rise in water level stated by scientists from the various countries [1, 6, 12, 13, 14, 17, 20].

The long-term change of climate has cyclic fluctuations. At present, we live during the warming period (IPCC, 1992, 2001). It is known that this warming process to a large extent is influenced by astronomic, climatic factors; although anthropogenic factors are getting more and more active. According to the data of various authors, water level in the world ocean rises with the speed from 1mm to 1.9 mm per year [3, 8, 14, 16, 18, 19]. The World Meteorological Organization (WMO) has established an intergovernmental group of climate change (IPCC), where scientists from various countries pay great attention to the studies of water level change as one of the main indicators of climate change. Water level will rise during the next century according to the conclusions made by scientists from the climate change group about general climate warming. Scenarios based on various forecast calculations which state that due to the warming climate and at the same time warming water temperature, due to melting glaciers water level may rise from 8 cm to 25 cm till 2025 and from 31 cm to 110 cm till 2100 depending on physical geographical conditions have been made [8, 18].

The mentioned problems are relevant in Lithuania as well. Therefore, the aim of this paper is to analyze the long-term tendency in changes of water and lagoon water level in our region.

2. The object of research, materials, and methods

The paper analyzes general peculiarities of long-term fluctuations of water level in the southeastern part of the Baltic Sea and the Curonian Lagoon, which belongs to Lithuania.

The area of the Curonian Lagoon is about 1 584 km^2, the length of the shores – about 324.3 km, the

water volume – 6.2 km^3, the mean depth – about 3.8 m. The northern part of the lagoon (413 km^2), i.e. about 26 % of the area of the lagoon and about 150 km of the shoreline, belongs to the territory of Lithuania [21]. Other part of the lagoon belongs to Russian Federation. Lithuanian coastal of the Baltic Sea is about 92 km.

Analyzing the regularity of the long-term water level changes in the southeastern part of the Baltic Sea and the Curonian Lagoon, the paper refers to everyday and hourly historic data and the data presented by the near-shore water level stations, which belong to the Center of Marine Research of the Ministry of the Environment.

Table 1 presents the water level observation stations and periods of their activity. The approximate locations of stations are seen in Fig. 1.

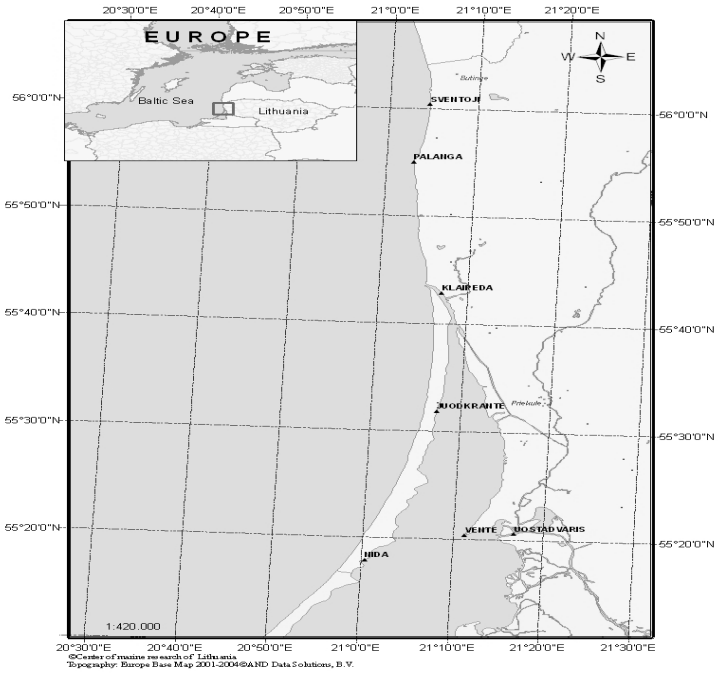

Fig. 1. The scheme of water level stations

Table 1. Water level hydrometric stations and periods of their activity

Stations	Observation period
Klaipėda	1898-1940, 1949-2002
Juodkrantė	1901-1915,1925-1938,1955-2002
Nida	1925-1938, 1948-2002
Ventė	1925-1942, 1955-2002
Uostadvaris	1901-1915, 1925-1932, 1961-1965, 1973-1985, 1997-2002

The long-term change of water level is outlined by series of data from the Klaipėda Strait, Juodkrantė, Ventė, and Nida hydrometric stations.

Long-term data of wind and air temperature were used to analyze the influence of meteorological conditions on water level dynamics and changes in water temperature. We have compared the curves and trends of yearly meanings of water level with air temperatures, with surface water temperatures, and have calculated correlation coefficients.

Graphs and trends of water level changes are made according to mean of monthly and yearly meanings of water levels, which are calculated using hourly and 1 - 3 times per day water levels data. Bigger attention is paid to analyze water level changes in the Klaipėda Strait as the series of data involve a period of more than 100 years (1898 - 2002).

The speed of water level rise (mm per year) in various stations of the Klaipėda Strait and the Curonian lagoon is evaluated using the equation of linear regression, which expresses unidirectional tendency of water level rise in respect to time.

3. Results

The day regime of water level is determined by a short change of atmospheric processes. The regime of a mean monthly water level change during a year depends on seasonal changes in hydrological and meteorological conditions. The regime of long-term water level is affected by the entirety of climatic, geological, eustatic, and astronomic factors.

Long-term fluctuations in water level are rather chaotic. The components of 3, 9, and 100 year periodicity are clearly distinguished in the data series

(Fig. 2) of yearly fluctuations in mean water level of the Klaipėda Strait [5] during the period of one hundred years (1898 - 1998).

Table 2 presents the statistical mean long-term water levels, which are regarded as standard. The highest absolute yearly water level in the region of Lithuania is observed in the Klaipėda Strait. Bigger amplitude of water level fluctuation in the northern part of the lagoon is formed due to the shore exposition in the Curonian Lagoon, which has a form of a funnel and a comparatively narrow Klaipėda Strait. The total effect of the changes in the hydrological regime of the Nemunas catchment area is reflected in the Curonian lagoon, the water of which flows into the Baltic Sea. The long term of mean water level is generally higher at the stations located in the river mouth area and Kurshiu Marios lagoon (Tables 1, Table 2).

As it is seen from Fig. 3, in different years both the amplitude of fluctuation and mean yearly water level are different in regard to climatic conditions. The amplitude of fluctuation and its frequency more often change in extreme cases increased at the end of the 20th century.

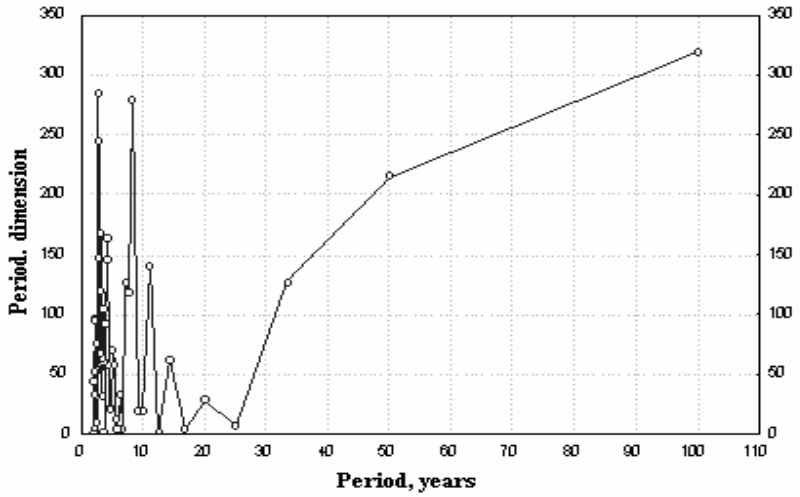

Fig. 2. Periodogram of mean water level fluctuations in the Klaipėda Strait during the period from 1898 to 1998

Table 2. Mean, maximal, and minimal long-term water levels calculated from data of water level stations

Stations	Mean water levels, (cm)	STD	Max (cm)	Min. (cm)
Klaipėda	-1,22	7,90	185	-91
Juodkrantė	5,83	7,41	149	-70
Nida	8,33	7,43	154	-70
Ventė	4,76 (+5,5*=10,26**)	8,04	164	-72
Uostadvaris	21,30	8,33	146	-49

**The correction for water level of Vente (cm) calculated from levelings according heights of benchmarks*
***The revised value of long term mean water level [5]*

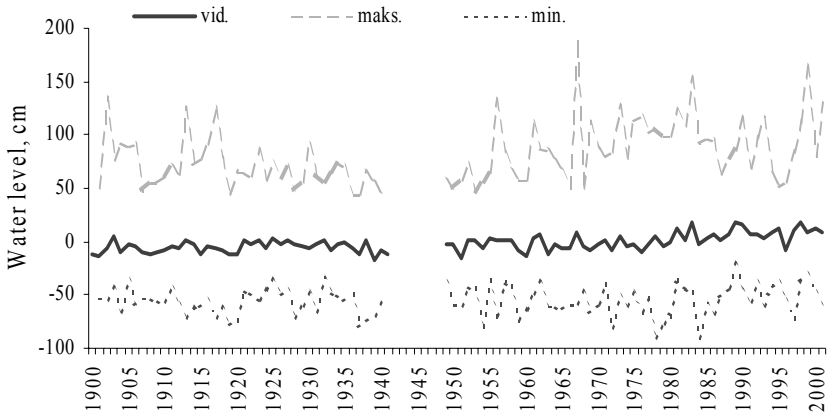

Fig. 3. The long term change of water level in the Klaipėda Strait, 1900 – 2002

After the performance of the filtration of the longest available data series in sliding decades it can be seen that the water level at the beginning of the 20th century decreased by nearly 5 cm. (Fig. 4). It remained stable during the second decade. A slight water level rise was observed in the third decade. A stronger tendency of a positive trend was observed at the end of the 20th century from the eight decade (Fig. 5).

The regime of water level change in the Klaipeda Strait and the Curonian Lagoon had a slight rising tendency till the eighth decade of the 20th century. A more sudden rise was observed in 8th and 9th decades. During this period water level raised about 10 cm. (Fig. 6).

The speed of long-term water level rise is unequal in separate periods. The annual mean water level had been rising with the approximate rate of 3,0 mm per year since 1960. Water level during 100 years (1981 - 2001) in the region of the Klaipėda Strait rose about 13.5 centimetres (Dailidiene et. al., 2004). More rapid rise of water level is unfavourable for the perspective of shore destruction in Lithuania. A bigger part of the shore will be open to the destructive impact of waves when the water level rises.

Correlation coefficient between annual mean of water level and annual mean of surface temperature in Klaipėda strait station in 1991 – 2002 period was 0.60, in Juodkrantė station it was 0.41, in Nida station it was 0.44, in Ventė station it was 0.24, in Uostadvaris it was 0.25. The correlation was stronger where the Baltic Sea waters influence Curonian Lagoon. It can be seen that the tendencies of change are similar if the decades of mean air temperatures (Fig. 7), sea surface water temperature (Fig. 8), and water level change (Fig. 9) in the coast of the Baltic Sea near Klaipėda were compared. A more sudden rise of all mentioned parameters was observed during the last decades of the 20th century.

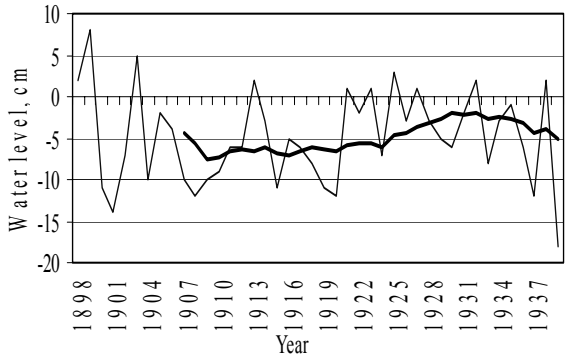

Fig. 4. The annual mean water level in the Klaipėda Strait and the curve of sliding decades from 1898 to 1939)

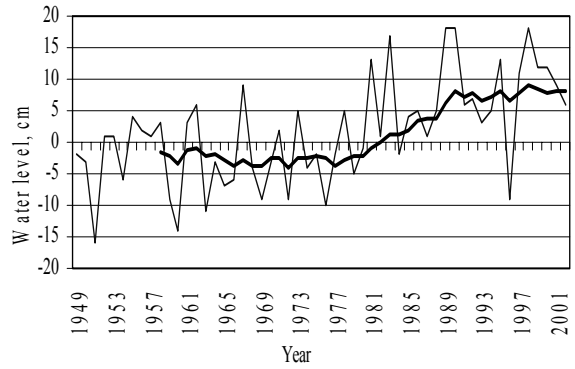

Fig. 5. The change of annual mean water level in the Klaipėda Strait and the curve of sliding decades (from 1949 to 2002)

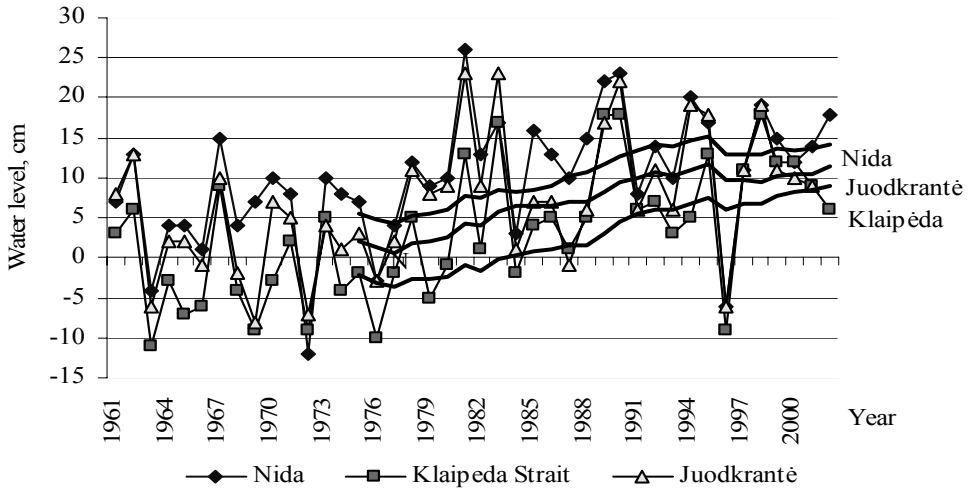

Fig. 6. The mean year annual water level at selected Lithuanian water stations, and the 15 year moving averages

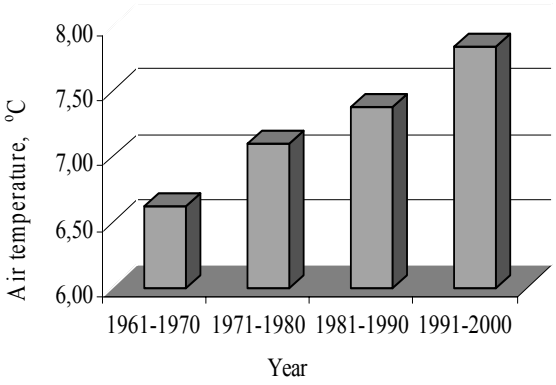

Fig. 7. The decades of mean air temperature in Klaipėda

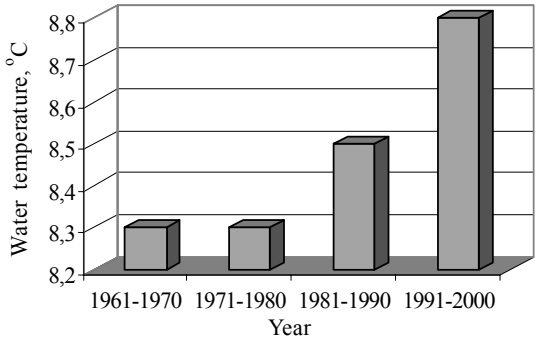

Fig. 8. The decades of mean sea surface water temperature in the coast of the Baltic Sea near Klaipėda

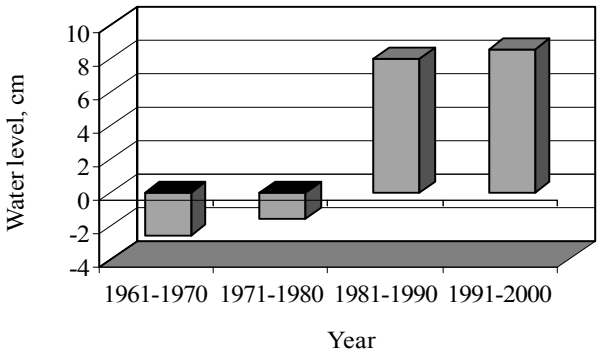

Fig. 9. The decades of mean water level in the coast of the Baltic Sea near Klaipėda

Analyzing the annual mean of water level change during different periods of a year, the stronger tendency of water level rise is distinguished during the cold period (from October to March) of a year than during the warm period from April to September (Fig. 10, Fig. 11). Much more precipitation fall during warm winters which cause winter flooding and higher water level in the Curonian lagoon. The rise in water level in recent decades is related with more frequent advection of warm and wet air masses during the cold period, stronger movement of air from the west.

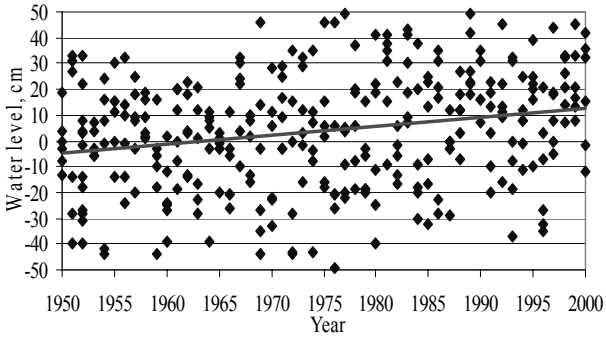

Fig. 10. The trend of mean monthly change of water level during the warm period of a year (April - September), 1950 – 2000

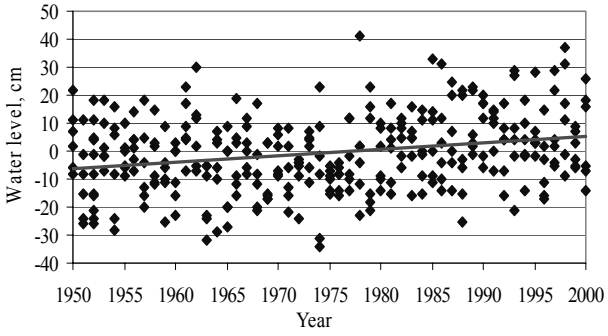

Fig. 11. The trend of mean monthly change of water level during the cold period of a year. (October - March), 1950 – 2000

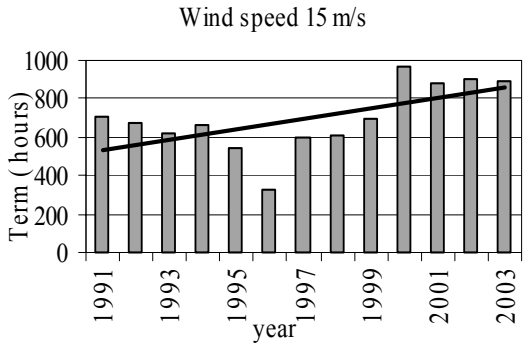

Fig. 12. The rate hours and trend of western directions winds of 15 m/s

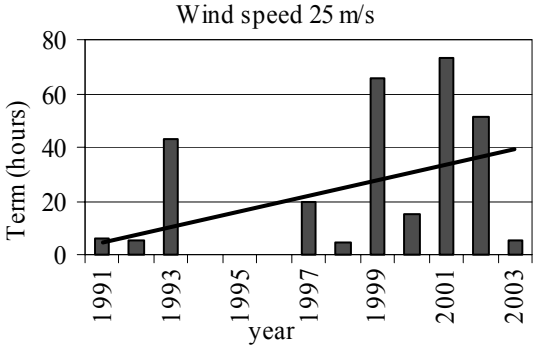

Fig. 13. The rate hours and trend of western directions winds of 25 m/s

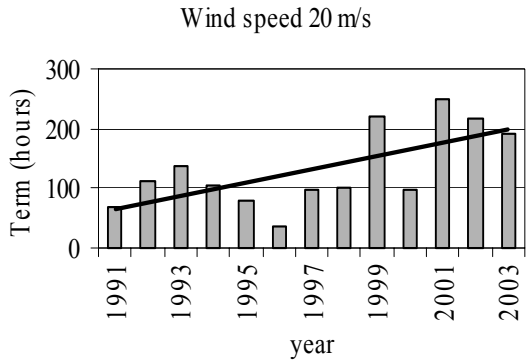

Fig. 14. The rate hours and trend of western directions winds of 20 m/s

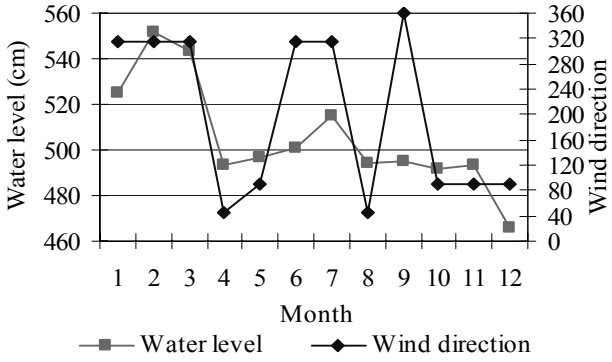

Fig. 15. The change of water level regarding to dominant directions of wind

Generally western wind blows most often in the Lithuanian coast of the Baltic Sea. We can see that the hours of western winds of 15 m/s, 20 m/s, and 25 m/s velocity have been rated (Fig. 12. 13, 14). The rise and lowering of water level directly depend on the direction of wind in the respect of coast line. Higher water levels in the southeastern part of the Baltic Sea are observed when the affluent wind of southwestern, western, northwestern, and western directions blows, and lower levels when northeastern, eastern, southeastern and southern winds prevail (Fig. 15). Therefore strong western wind forms the water level rise in the Baltic Sea coast.

4. Conclusions

1. The water level near Lithuanian shore has risen by 13.5 cm since the beginning of the 20th century according to the long term (1898-2001) water level data from the Klaipėda Strait water level measurement station.
2. The speed of water level rise is unequal during separate periods. A stronger rise tendency in the long-term water level change of the Curonian Lagoon and of the Baltic Sea coasts became evident at the end of the 20th century. Water level has risen about 3 mm per year since 1961.
3. Water level rise is distinguished during the cold period of a year than during the warm period.
4. The long term rising of water level with extreme meanings of water level will flood bigger land areas and they will be effected by destructive activity of waves, shore lines will change, sea water invasion to the fresh Curonian lagoon will increase, danger to ecosystems and coastal environment will occur.
5. Water level rise is related to changes in atmospheric circulation with more intense air movement from the west, having influence on positive changes in air temperature in cold period and surface water temperature as well.
6. The regional analysis of the long-term change in water level is necessary for the research of climate change. Water level may be analyzed as one of the indices of a regional atmospheric circulation change.

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Baltijos jūros ir Kuršių marių vandens lygio daugiamečių svyravimų bendrosios ypatybės Lietuvos regione

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(gauta 2004 m. lapkričio mėn.; atiduota spaudai 2004 m. gruodžio mėn.)

Straipsnyje, analizuojant daugiametį vandens lygio kaitos režimą pietrytinėje Baltijos jūros dalyje ir Kuršių mariose, remtasi Aplinkos ministerijos Jūrinių tyrimų centro pakrantės stočių hidrologinių duomenų sekomis. Nagrinėjant hidrometeorologinių sąlygų sąveiką su vandens lygio dinamika, naudoti Lietuvos hidrometeorologinės tarnybos Klaipėdos skyriaus oro temperatūros ir vėjo parametrų duomenys.

Remiantis daugiamečiais Klaipėdos sąsiaurio (1898 – 2001 m.) vandens lygio tyrimo duomenimis, vandens lygis ties Lietuvos krantais per šimtmetį pakilo 13,5 cm. Nuo 20 a. vidurio jūros lygio kilimas spartėja, o nuo 1960 metų vidutinis vandens lygis per metus pakyla maždaug 3,0 mm. Vandens lygis analizuotinas kaip vienas iš regioninės atmosferos cirkuliacijos kaitos, klimato šiltėjimo indikatorių. Daugiamečio vandens lygio vandens lygio kilimas sietinas su stiprėjančia vakarų pernaša, dažnėjančia šiltų ir drėgnų jūrinių oro masių advekcija šaltuoju periodu.

Susirūpinimą kelia pastaraisiais dešimtmečiais pasireiškęs spartesnis vandens lygio kilimas, kuris tiesiogiai susijęs su krantų ardymo, hidrotechninių įrenginių saugumo, sausumos užliejimo bei ekologinės pusiausvyros pažeidimo problemomis. Esant tokiems vandens lygio kilimo tempams, jau dabar reikėtų imtis atitinkamų priemonių, nes, pakilus vandens lygiui, pakis ekstremalios vandens lygio vertės, vis didesni sausumų plotai bus veikiami ardomosios bangų veiklos, keisis krantų linijos, iškils grėsmė pakrančių aplinkai bei socioekonominėms infrastruktūroms.