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Front page photo: The beach at Międzyzdroje with its steep moraine coast, Island of Wolin, Poland (Marcus Reckermann)

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Preface

It is generally accepted that remarkable progress has been achieved in understanding the climate controlling system on the global scale but also that a spatial downscaling of global processes to the regional scale is required. In a first international conference on climate change in the southern Baltic Sea region, held in 2009 at Szczecin, planning agencies and local authorities expressed the need of future climate change projections which may be used for management and decision making on the regional and local level in order to help mitigate negative effects of climate change to the environment and society. The quality of the answers to the questions depends directly on the data available – records of measurements for the past and future projections as the results of climate modelling.

Increasing research activities are expected regarding the cause-effect relation between greenhouse gas emissions, climate and environmental responses in the Baltic Sea basin. Therefore, and to revive the productive scientific atmosphere of the conference in 2009, it was decided to organize a follow-up conference in 2014, dealing with the climate change effects for the southern Baltic Sea region.

Conference session topics are:

A. Reconstructions of palaeo-environmental change: Geological proxies and numerical modelling
B. Modelling of climate change: How reliable are future projections?
C. Natural dynamics of the coastal zone and the socio-economic response from prehistoric to recent times
D. Climate change and regional planning
E. Changing Baltic Sea coasts and their sustainable protection

Copernicus Symposium

In addition to these scientific topics, a dedicated "Copernicus Symposium" will be part of the conference. This symposium shall honor the 500 years anniversary of Copernicus' pioneering concept of the heliocentric system. This publication caused the "Copernican revolution" as one of the most important events in history of science. Natural scientists, historians, and socio-economists are invited to discuss Copernicus' ingenious work, embedded into the societal environment of his time.

As a result we expect generalizing answers to the question how a productive and fruitful scientific (and societal) atmosphere can be created today. This is getting increasingly relevant when designing the roof of our European house.

This proceedings volume contains all extended abstracts of contributions shown at the conference. The abstracts are colour-coded according to the session, and sorted alphabetically with sessions (oral and poster). The conference is organized in the framework of Baltic Earth, the new research and outreach network in the baltic Sea region, and successor to BALTEX.

The organizers wish to thank Silke Köppen for invaluable help in the preparation of the conference.

Szczecin and Geesthacht, May 2014

Andrzej Witkowski, Jan Harff and Marcus Reckermann, Editors

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Abstracts

Opening Lectures

Late Pleistocene climate change and its impact on palaeogeography of the southern Baltic Sea region

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Late Pleistocene climate change in the southern Baltic Sea region has been significantly influenced by the Eemian Sea, development of which has been interrupted by occasional regressions and transformations into brackish or freshwater reservoirs. A sea environment was considerably dependent both on river discharge from the neighboring land area and on influx of open sea water through passages, mostly in Denmark and northern Germany in the west but also in Karelia in the east.

A transgression of the Eemian sea in the Baltic Basin occurred very rapidly. The sea entered through the Danish straits some 300 hundred years after the beginning of the Eemian that is around 126 ka ago if a terrestrial record of the Eemian is considered. The sea flooded the central southern Baltic region already a few hundred years later (Marks et al., 2014). A contact with the open ocean was wide enough and a salinity in the Gulf of Gdańsk reached 28 psu at 125-124 ka. The salinity has gradually decreased afterwards to about 15 psu but at about 120 ka ago rose again, reachung 23 psu. This second saline episode might indicate more extensive water exchange through the Danish straits, presumably due to rising sea water level after the postulated mid-Eemian cooling, noted both in marine (cf. Knudsen et al., 2002) and terrestrial records (Bińka & Nitychoruk, 2011).

Early glacial of the Vistulian (Weichselian) Glaciation in the southern Baltic region has been indicated by fluvial activity characteristic for temperate climate and expressed by floodplain and ox-bow lake deposition. Such temperate river activity could be interrupted occasionally by deposition of anastomosing rivers, active in a cool climate. The following, more severe climatic conditions with low temperatures and decreased precipitation, most probably connected with aggradation of permafrost, could initiate intensive aeolian processes (Rychel et al., 2014). They were interrupted by more wet episodes and seasonal development of an active layer in a ground when solifluction moved down-slope huge amounts of surficial deposits that had been transformed earlier in a periglacial environment.

In eastern Poland such soliflucted deposits were cut with two generations of ice wedges (Dzierżek & Stańczuk, 2006), characteristic for severe subarctic conditions. Initial sand infilling of the older generation was TL-dated to 49±7 to 43±7 ka (Heinrich event H5). This event could correspond to middle Vistulian (Weichselian) ice sheet advance in northern Poland, expressed by widespread glaciolacustrine deposition (the so-called Chełmno clays) in the Lower Vistula River valley. Sand infilling of the second ice wedge generation was TL-dated to 23±4 ka that fitted to the Last Glacial Maximum (Heinrich event H2). Milder climate during the interval between these two periglacial episodes was represented by a fluvial environment. Final termination of the Late Pleistocene was expressed by aeolian depositon (Rychel et al., 2014).

This abstract is a contribution to research projects (no. 1349/B/P01/2009/37 and 497/N-BIAŁORUŚ/2009/0) funded by the Ministry of Science and Higher Education in Poland.

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Copernicus Dilemma and Contemporary Science

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1. Correctness versus consolidated theory in science

The greatness and meaningful impact of the Copernicus work is not rising any doubts today. However, from a perspective of five centuries, the most important question, although never clearly articulated, thus of decreased significance, is the question, which Copernicus faced through the entire life, and which in today's times we can be stated as follows: is it worthwhile to fight with so called correctness in science? Herein used expression "correctness" can of course be more precisely articulated by other complementary words as: political, ideological, etc. In other words, the same question asked especially among humanists, may be verbalized in more popular manner as: "consolidated theory". Thus the Copernicus dilemma directly concerns with doubt on: what more can harm the revolutionary theory - putting it forward in open way or rather chose a dilatory waiting for more favorable scientific atmosphere? Probably Copernicus was unable to answer both questions, what his hand written manuscript entitled: "Commentariolus" is a best evidence (Mały komentarz-Kopernik, 2012). We might absolve him by giving an examples of Giordano Bruno, Galileo and others (Kokowski, 2009).

In general science, and of course contemporary scientists, faces exactly the same dilemma: to struggle with the widely accepted dogmas or to retreat to safe "hyperborean" hermitage and there, in the sheltered place, work to discover laws ruling the world.

Let us repeat again - the disagreement with the ideological diktat can be manifested in science in two ways:

- as opposing the concept of commonly accepted views (ideologies),
- or through the retreat, most often however connected with abiding own views, although in the limited, that is local environment.

2. Strategy selection

In science, thousands of heroes were annihilated by means of a physical death or a civil one, when fighting with the inertia of strengthened commonly accepted views. But also thousands of them have found a safe niches, trying to store their ideas for so-called better time, facing and accepting the rise of entropy, which proceeds unavoidably.

Strategy selection, that is: to fight or to retreat, is of course a matter conditioned by the personal psychological profile of individual researcher, but more than that, depend upon the current situation, although sometimes the outside conditions are difficult to break. The contemporary science tend to swing into the action requiring from researchers more fighting character, than being rather foggy taboo. Procedures and competitions in modern science are of a good example. Today, probably, even Copernicus will not get any grant, without support from his uncle.

Figure 1. Frombork, Cathedral Hill.

Figure 2. Nicolaus Copernicus monument in Frombork.

3. Why the Copernicus Revolution was not earlier?

How to judge the attitude of the Great Astronomer, who didn't take the fight for the matter, in which rightness he never doubted? How to judge his calculating "merchant" strategy in which, having a good conditions for life as well as - "to do one's job" – he did not rushed into the whirl of actions, eventually providing him power and honors. Thus, one may ask the related question, why the "Copernican Revolution" was not earlier, if Copernicus, instead of settling in Frombork, would had rash to Europe with his vision of the cosmic principles?

Since Copernicus didn't act in a vacuum, and his concept had many predecessors, one should think that, the turning point ripening along with the turn of two epochs, that is the discovery of the proper vision of the Universe, would take place without him, and probably in the same time. However, it doesn't mean, that his escape to Hyperborean Frombork was a pointless resignation. Great ideas are not only forging in the fire of intellectual revolutions, but also are ripening in sheltered places of the hermitage.

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Session A

Reconstructions of palaeo-environmental change: Geological proxies and numerical modelling

A wind direction analysis for the Baltic Sea region: Is it possible to draw conclusions from mean wind statistics on extreme wind statistics?

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1. Motivation

The study of wind fields is of high interest for many different research disciplines. To investigate extremes on decadal timescales homogeneous time series of observed daily wind data are necessary. Unfortunately such data sets are rarely available. Therefore researchers use dynamical modeling approaches to produce regional high-resolution data sets for the recent past such as Reanalysis[1] or Hindcasts[2]. The analysis of these data sets with different statistical methods allow for more robust information. Those analysis can be very useful for different research communities, for instance for the validation of paleoclimate reconstructions from proxy data (e.g. from coastal dunes[3]) or the investigation of changing coastlines due to recent climatic changes and impacts with relevance for regional planning agencies.

A literature research within different research disciplines showed that statistics of mean wind changes are often directly applied to changes in extreme wind statistics. However, in the scientific community there is still low confidence in how observed trends in mean wind speed are related to trends in extreme wind (IPCC-SREX: Seneviratne et al. 2012). In the following we try to verify this issue for the Baltic Sea Region. Furthermore, the predominant extreme wind direction and its temporal changes are analyzed.

2. Data

For our main investigation the reanalysis data set coastdat2 (Geyer 2013) for the time period from 1948 to 2012 is used. This data set is the result of a regional climate simulation (CLM-Community Land Model) conducted with spectral nudging and driven by the boundary forcing of NCEP (National Centers for Atmospheric Prediction) reanalysis to gain a higher temporal and spatial resolution. Hourly data on a 12,8 * 12,8 (km) grid is available for central Europe, but for this study only daily data above the Baltic Sea area was used (Fig. 1).

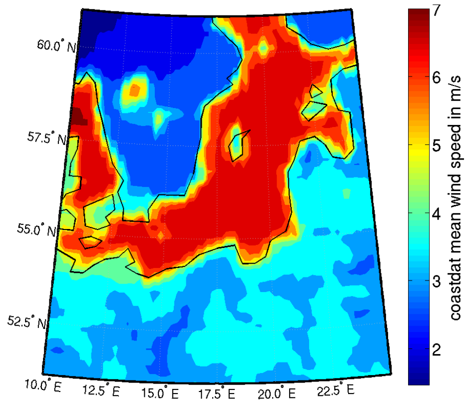

Figure 1. Investigation area as it was used in this study. Colors show the mean wind speed in [m/s] of the coastdat2 data set.

3. Mean vs. Extreme Wind

Differences between both mean and extreme wind direction distributions are detected for all seasons. Main direction for extremes is wind from South-West (SW) whereas for the mean wind all directions can be found (illustrated for winter in Fig. 2).

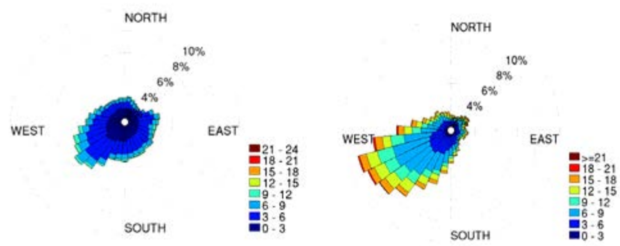

Figure 2. Left: Winter (DJF) wind speed (color) and wind direction (bins) of mean wind (three events per season which are closest to the 50th percentile of wind speed) Right: Wind speed (color) and wind direction (bins) for three strongest wind events per winter (DJF) (from Bierstedt et al. 2013).

The distribution of extreme wind directions shows a limited spread around SW. These distributions are not just different for annual statistics for mean and extreme, but additionally across seasons. The main direction remains SW but deviations from this mean winds in springtime occur as often from SW as from NE. Extreme winds are clearly focused from W, with a stronger influence of SW.

Easterly wind seems to play a minor role in extreme wind statistics. The spatially covariance of wind statistics is further investigated by an Empirical Orthogonal Function (EOF) analysis, which shows

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1 Full 3-dimensional reconstruction of the past evolution of the atmosphere by using a combination of model and available observations.

2 A retrospective prediction of the past with a numerical model.

3 Current project 'Climate Signals in Coastal Deposits' CLISCODE within the REKLIM-Initiative.

seasonally independent patterns of wind direction variability. Extreme winds are mainly westerlies, thus their variability is limited to north-south directions. These variability patterns show no trends in time and are quite homogeneous over the whole region.

As these first results showed a limited distribution for extreme wind directions for SW we continued analyzing changes of wind extremes from W and SW in the Baltic Sea region during winter (DJF).

4. Extreme events from western wind directions.

Extreme winds occur mostly and are strongest in winter season. Although on average all wind directions are quite frequent over the Baltic Sea, extremes are very focused on W and SW directions (Fig. 3).

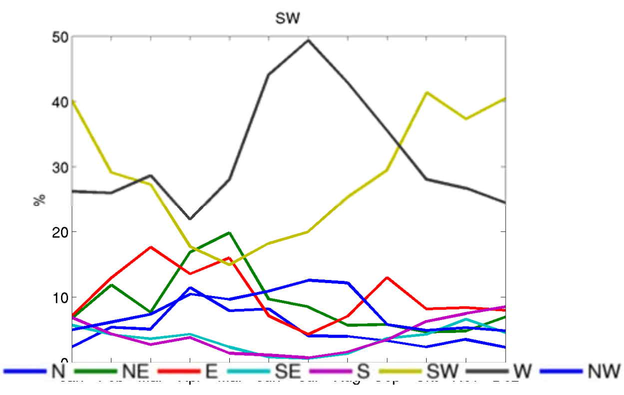

Figure 3. Wind direction frequencies of extreme wind (90th percentile of wind speed) in % per month for 8 wind directions (N, NE, E, SE, S, SW, W, NW) over the south-western Baltic Sea.

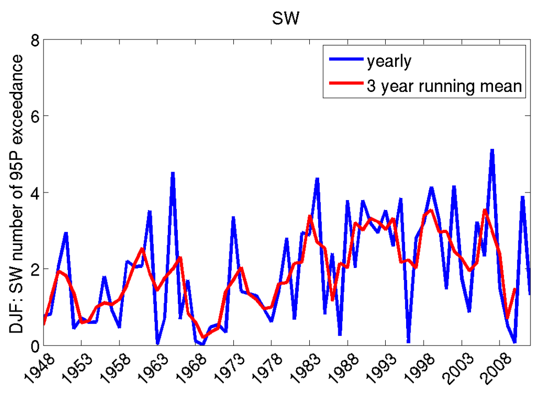

Figure 4. Number of wind events in winter (DJF) from SW which exceeds the 95th winter percentile of wind speed for the south-western Baltic Sea.

Trends in the frequencies of extremes from SW can be detected, namely an increasing trend from 1970 to 1990 and a decreasing trend since then (Fig. 4). A correlation between the sum of W (SW) frequencies and the corresponding intensities shows a statistical significant value of 0.54 (0.25). For the other directions there is no such high correlation (r<0.08). A similar correlation as it was described for wind directions is also visible in a similar but weaker trend for SW wind intensity. This means that years with more (less) W/SW winds show higher (lower) wind velocities. After identifying eight circulation types by cluster analysis, type 4 (type 2) can be related to W (SW) winds and it shows a similar temporal evolution as W (SW) wind frequencies. Type 4 is dominated by low pressure located east of Sweden and for type 2 it lies west of Norway.

5. Summary and conclusion

We investigated whether direction-related statistics of extreme wind events follow statistics of mean wind and thus whether changes in mean wind statistics can be used to approximate extreme wind changes. The results show, that this hypothesis is not valid over the Baltic Sea region.

Temporal changes in frequencies of extreme winds from W and SW have been detected. These changes can be related to changes in the occurrence of special circulation weather types. Further investigations will focus on the influence of large-scale phenomena (e.g. sea level pressure patterns). The analysis of the low frequent variability of extreme winds will be extended to millennium time scales due to millennium regional climate model simulations.

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The cool event about 8.2 ka ago in the Baltic Sea Basin: Proxies data and paleoclimatic reconstructions

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1. Introduction

"The 8.2 ka cold event" was first identified from changes in oxygen-isotope composition in ice cores from the Summit site in Greenland. The decrease in air temperature during this event has been estimated at 6 ± 2°C in central Greenland. An independent method to estimate both air temperature change and the duration of this cold phase, based on the concentrations of $\delta^{15}N$ in N_2 in ice cores (Kobashi et al., 2007; Thomas et al., 2007). Kobashi et al. (2007) from the GISP2 ice core data, with a time resolution of ~10 year, shows a complex time evolution of this event. The duration of the entire cold event was about 160.5 ± 5.5 years, the coldest phase occurring at 69 ± 2 years (Thomas et al., 2007). An air temperature drop of 3 ± 1.1°C occurred within less than 20 years. Independent estimates of changes in air temperature during this cooling event have been obtained from isotope data from four Greenland ice-cores: NGRIP, GRIP, GISP2, and Dye-3 (Thomas et al., 2007).

According to the GRIP core data, the event has been dated to ca. 8,190 ice years ago. The data from GISP2 core revealed two comparatively warm stages: ca. 8,220 and ca. 8,160 ice years ago. The initial stage of cooling is more explicitly recorded in the NGRIP core data.

2. The lake sediments and other proxies data

Independent empirical data, such as marine cores with high resolution, lake sediments, clay varves, speleothem isotope data, pollen diagrams and others, indicate that the cooling was widespread in the entire Baltic Sea Basin, except for the most northern regions north of 70°N (Seppä et al., 2007, 2008; Zubakov, Borzenkova, 1990).

Pollen diagrams from lake and continental sediments provide independent evidence of this cooling. Seppä et al., 2008 clearly identified "the 8.2 ka cold event" across entire West Europe, with the lowest air temperatures in areas adjacent to the North Atlantic. Pollen data from Estonia and southern Fennoscandia indicate about 1°C air temperature drop (Figure 1).

Lake sediments from four sites - the Rõuge lake in Estonia; the Flarken lake in Sweden; the Arapisto and Laihalampi lakes in Finland, all located south of 61°N - indicate that pollen percentage of thermophilous deciduous tree taxa, *Corylus* and *Ulmus,* decreased from 10-15% in the Early Holocene to 5% between 8,250 and 8,050 cal yr BP (Seppä et al., 2007). This implies a temperature drop of 0.5°C to 1.5°C at all these sites. Here, the cold event lasted 200-300 years and ended by a sudden temperature rise. In Estonia, this cold event lasted longer as indicated by a longer period of vegetation re-establishment after a decrease in annual air temperature by at least 1.5-2.0°C (Seppä, Poska, 2004; Veski et al., 2004). "The 8.2 ka cold event" has been identified in pollen diagrams from lake sediments from eastern Latvia (Eini, Malmuta) and Gulf of Riga displaying a decrease of *Alnus*, *Corylus* and also *Ulmus,* and some increase of grass pollen. According the Heikkilä and Seppä (2010) a relatively warm and stable climate was interrupted by cooling at about c. 8,350-8,150 cal yr BP when mean annual air temperatures dropped by 0.9-1.8°C. This was reflected in a change in vegetation composition, characterized by a decrease in broad-leaved tree productivity and pollen increase of boreal species (Heikkilä, Seppä, 2010).

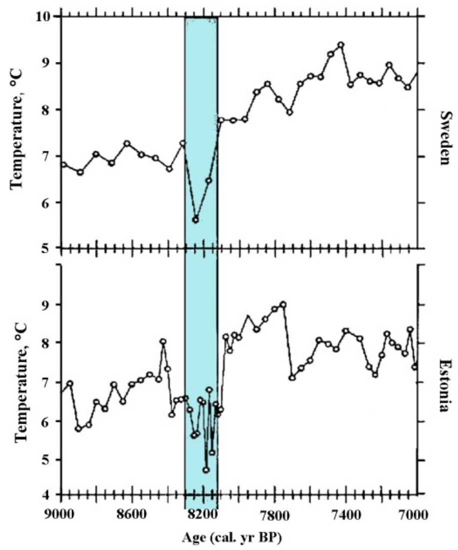

Figure 1. Two climate reconstructions for the cold event 8,200 cal yr BP:pollen-based T_{ann} reconstruction from lake Rõuge, Estonia (Veski et al., 2004), and reconstructed T_{ann} from lake Flarken, Sweden (Seppä et al., 2005). Adopted by authors

During this cold period snow precipitation increased. The estimated duration of the event has been estimated at 150 years (Snowball et al., 2010; Zillén, Snowball, 2009). There are no clear changes in the beetle assemblages from southern or northern Sweden that would indicate a cold spell during this time. This may be due to the insufficient time resolution of the data to identify this change.

In Germany, estimations of the duration of this cold event from changes in isotope composition of ostracod valve carbonate yield about 200 years (von Grafenstein et al., 1998). Almost all data indicate that the decrease in air temperature was significantly larger in winter than in summer. This promoted an earlier freezing and later thawing of sea and lake surfaces.

3. Causes and mechanisms

The causes of the cooling during "the 8.2 ka" event and other cold episodes in the Lateglacial/Early Holocene drew the early interest of researchers (Alley et al., 1997; Alley, Áqústsdóttir, 2005; Clark, 2001;Clarke et al., 2004 Kobashi et al., 2007; Marotzke, 2000; Thomas et al., 2007; Yu et al., 2010). Although some scientists attribute "the 8.2 ka" cold event to changes in the incoming solar radiation (Bos et al., 2007), most of the studies relate this cooling and other cooling events in the past 13,000 years to changes in the circulation of surface and deep water in the North Atlantic driven by melt water from the continental ice sheets.

Clark (2001) and Clark et al. (2002) assumed that freshening of the sea surface layer of the North Atlantic not only disturbed the circulation in the surface layer but also hindered the formation of deep water, thus affecting the intensity and position of the Atlantic "conveyor belt" itself. Drainage of glacial lakes Agassiz and Ojibway as a result of the Laurentide ice sheet melting ca. 8,470 cal yr BP (~ 7,700 ^{14}C yr BP), during which about 2 10^{14} m^3 fresh lake water could have been released within less than 100 years, could have exerted a serious impact on the formation of sea ice, and thus significantly changing the time of their formation in autumn and melting in spring. Sea ice has a higher albedo than open water, and a longer period of sea ice causes an additional cooling (Clark, 2001; Clarke et al., 2004; Fisher et al., 2002; Ganopolski, Rahmstorf, 2001).

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Late Glacial to Holocene environmental changes with special reference to salinity reconstructed from shallow water lagoon sediments of the southern Baltic Sea coast.

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Results of palaeoenvironmental reconstructions from the Baltic Sea coasts might provide important information about processes, which driven development of the Baltic Sea basin since the Last Glacial Maximum. Here, we present results of diatomological analyses from two sediment cores used to reconstruct the environments of the mouth of Rega Valley, Poland. We use a diatom based salinity transfer function for qualitative reconstruction of changes in salinity over the same time period. Results from the two cores correspond, and demonstrate that both basins have experienced a series of marine transgressions, coastal aggradation, and lagoon development over the Late Glacial and Holocene. The results from high-resolution core profiles proves that salinity varied from 2 to 5 psu, through the Late Glacial and from 4 to 7 psu for the most of the Holocene (Boreal through Subatlantic Chronozones), whilst the well-documented mid-Holocene peak in salinities between 6000 and 5000 cal. yr BP was not observed in our records. It is likely that this indicates the buffering of the Baltic waters from freshwaters from the south, and demonstrates the importance of terrestrial-hydrological processes for determining the long-term stability of the salinities in the southern Baltic coastal zone. Quantitative reconstructions of the salinity changes have been based on newly developed calibration set for diatom transfer function. With use of a new data set defining changes in modern diatom assemblages in the salinity gradient occurring in the Baltic Sea (between 2 and 33 psu), there is a potential to test the records from many more studies to provide detailed salinity changes in the Baltic Sea across the entire basin.

Disentangling influences on varve preservation in a 1200-year record of partially varved sediments from Lake Tiefer See (NE Germany) – A multi-proxy approach

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1. Introduction

Annually laminated (varved) lake sediments represent unique archives in continental areas providing both precise chronologies and up to seasonally resolved proxy data. High-resolution multi-proxy analyses on Holocene varved sediments are scarce in NE Germany because of the lack of continuous varved records, so far. Just a few studies from Belauer See and Woseriner See describe varve formation and preservation during the Holocene (Dörfler et al., 2012; Dreibrodt personal communication in Kienel et al., 2013). Varve formation and preservation depend on a range of factors such as seasonality leading to deposition of different sediment layers, anoxic bottom water conditions preventing bioturbation, low lake surface/lake depth ratio minimizing wind induced re-suspension of sediments. These factors are not constant in time because of changing climate, environmental and limnological conditions (Brauer, 2004). Lake Tiefer See (NE Germany) comprises a succession of varved and poorly varved intervals which provides the opportunity to use exactly these variations in varve occurrence in a natural-laboratory as an integral proxy for past climate and environment changes. A combined approach of microfacies analyses using thin sections, µ-XRF analyses on split sediment cores and pollen analyses has been carried out in order to characterize well- and poorly preserved varve intervals during the last 1200 years.

2. Study site and Material

Lake Tiefer See (62m a.s.l., 53°35.5'N, 12°31.8'E, Mecklenburg Vorpommern, NE Germany) is located within the terminal moraine belt of the Weichselian glaciation and is part of the Klocksin Lake Chain which acted as a glacial gully system. The lake has a surface area of ~750 m^2 and a maximum depth of 62 m.

Coring campaigns at the deepest part of the lake provided 7 sediment profiles, 3 of which reached glacial sand deposits at the base. From these individual profiles a ~11 m long continuous composite profile has been performed. The chronology of the core sequence is based on varve counting, AMS ^{14}C dating of terrestrial plant remains and identification of cryptotephras including the Laacher See Tephra ~12,880 yr BP originating from the Eifel region (Brauer et al., 1999). The Laacher See Tephra suggests the onset of lake sedimentation in the late Allerød at about 13,000 yr BP.

3. The sediment record of the last 1200 years

The sediment record of the last 1200 years comprises 250 cm of partially varved sediment (Figure 1). Varves are preserved in three microfacies zones: MZ I 0-40 cm, MZ III 190-213 cm and MZ V 233-250 cm. In MZ V varves are composed of four sub-layers (laminae): (i) a diatom bloom; (ii) a mixed layer of diatoms, plant remains and subordinated siliciclastic and carbonate detritus; (iii) an amorphous organic layer with vivianite crystals in the upper part; and (iv) an additional mixed layer. K, Ti and Ca counts are low indicating sparsely input of clastic detrital matter. MZ III is characterized by increased Ca counts, which is due to the deposition of calcite laminae between the sub-layers (i) and (ii) in the varve cycle. K and Ti counts are also increased compared to MZ V but show a high fluctuation indicating an occasional input of clastic detrital sediment. The uppermost varves in MZ I are characterized by the disappearance of sub-layer (iii) and thicker calcite layers resulting in increased Ca counts in the µ-XRF data (Kienel et al., 2013).

Microfacies zones with poor varve preservation are between: 40 cm and 190 cm (MZ II) and between 213 cm and 233 cm (MZ IV). Both zones are characterized by increased sedimentation rates and higher Ca, K and Ti counts, which could be related to increased influx of clastic detrital material into the lake. First results of pollen data suggest increased human activity and forest opening during these poorly preserved varved intervals.

We propose as working hypothesis that deforestation enhanced soil erosion and surface runoff, which increased the input of detrital sediments triggering lake bottom oxygenation. Furthermore, forest opening favors water mixing by wind bringing additional oxygen to the lake bottom. Both bottom water oxygenation and deeper water mixing likely resulted in an increase of wind-induced sediment mixing and bioturbation and, consequently, to poor varve preservation. Climate change (e.g. increasing wind activity and precipitation) or lake level change probably has amplified these effects.

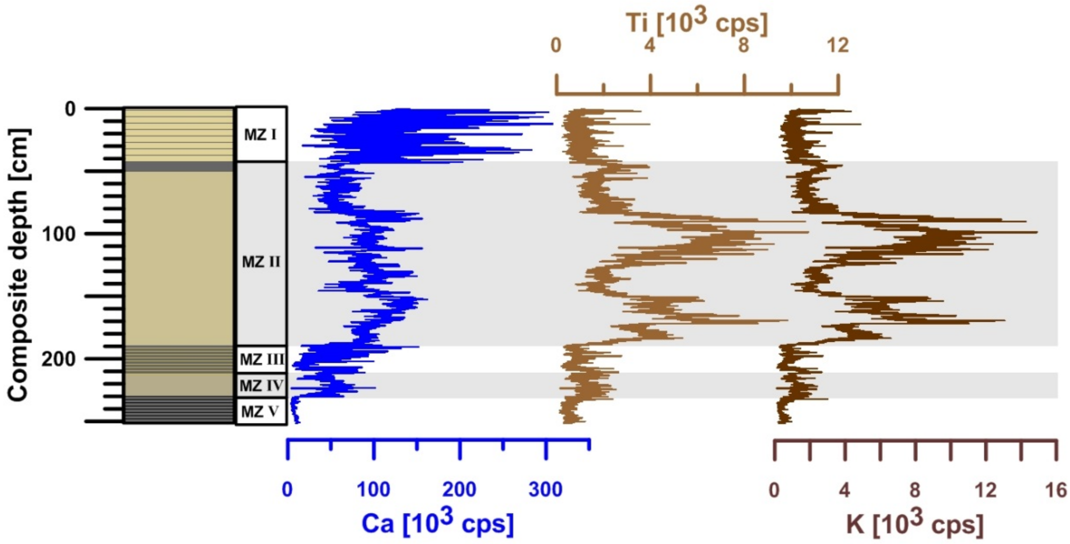

Figure 1. Sediment column, Microfacies zones (MZ) and µ-XRF count rates of calcium (Ca), titanium (Ti) and potassium (K). µ-XRF data is given in counts per second (cps). Grey bars indicate MZ with poor varve preservation.

4. Outlook

In order to test this hypothesis and disentangle the influences of climate and lake level changes on varve preservation, high-resolution analyses of diatom, pollen, macrofossil and cladocera assemblages at the transitions between varved and poorly varved sections is carried out.

This study is carried out within the Helmholtz Virtual Institute ICLEA (Integrated Climate and Landscape Evolution Analysis) and is part of a broader dual-lake approach aiming at a comparison of the sediment records from Lake Tiefer See and Lake Czechowskie, located ca 400 km to the East (central northern Poland) based on independent and high precision chronologies in order to investigate regional differences in lake responses to climatic and environmental changes. The overarching goal of this approach is to test the hypothesis of maritime influences of the North Atlantic decreasing towards more continental regions in the East

4. Acknowledgements

This study is a contribution to the Virtual Institute of Integrated Climate and Landscape Evolution Analysis – ICLEA– of the Helmholtz Association and uses TERENO infrastructure.

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Evolution of the Littorina Sea in the geochemical record of Holocene sediments from western Baltic

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1. Introduction

The Baltic Sea has been formed as result of sea level and salinity fluctuations. These fluctuation were controlled by isostatic uplift of the Fenoscandia and eustatic changes of the ocean level. During the Holocene the connection to the Atlantic were opened and closed that caused marine and lacustrine phases. The last such change had place in early Atlantic period when freshwater Ancylus Lake were inundated by saline waters from the North Atlantic and created Littorina Sea.

The most interesting unresolved problem of evolution of Littorina Sea is the marine transgression pathway. Some studies indicate a possible route of marine transgression via the Great Belt (Rößler et al. 2011). However, other results from investigations in the southern Baltic area report older dates for a marine environment compared with those in the western Baltic Sea, which favours an initial Littorina transgression pathway via the Øresund Strait (Berglund et al. 2005, Witkowski et al. 2005).

The geochemical record of these changes in sediment taken from two adjacent basins of the western Baltic Sea: Arkona Basin and Mecklenburg Bay was helpful in reconstruction of the Littorina Sea paleo-enviroment.

2. Material and methods

The analysed sediment cores were taken from Arkona Basin and Mecklenburg Bay by the Institute for Baltic Sea Research (Warnemünde, Germany) using a gravity corer aboard the research vessels FS "A. v. Humboldt" and FS "Maria S. Merian" during the period 2001–2012.

Geochemical analyses of the cores were conducted to determine the loss on ignition and contents of terrigenous silica, biogenic silica, and the metals: magnesium, calcium, iron and strontium.

Malacofauna shells and bulk sediment samples were dated at the Poznań Radiocarbon Laboratory using 14C accelerator mass spectrometry (AMS).

3. Results and conclusions

The cores from Arkona basin were taken at depth of 40 to 45 m b.s.l.. Holocene sediments of Arkona Basin were built from light olive-grey clay at the bottom, dark olive-grey humus silt and olive-grey mud. The cores from Mecklenburg Bay were taken at depth of 22 to 25 m b.s.l. The sediments of Mecklenburg Bay were represented by light grey clay at the bottom, black peat gyttja, light olive-grey silty sand and olive-grey mud. The bottom clay sediments from both basins were deposited during Baltic Ice lake. While layer of sandy silt and humus silt relates to Ancylus Lake period. The beginning of this period was dated in Mecklenburg Bay at 10 600 cal BP. The upper layer of the mud relates to Littorina and Post-Littorina.

Geochemical record allowed to separate in the marine mud sediments three main stages. The Initial Littorina Sea in Mecklenburg Bay was dated 8900 cal BP and confirmed by increasing content of biogenic silica, loss of ignition, magnesium and strontium. While proper Littorina Sea was confirmed by peaks of biogenic silica, loss of ignition, iron, strontium and magnesium content and dated at around 8000 cal BP in malacofauna shells from Mecklenburg Bay. The Littorina sediments form Arkona Basin characterised by slight signal of the Initial Littorina and pronounced proper Littorina stage that was dated at 8800 cal BP. In respect of the bulk sample of dated material the date should be regarded as about 1000 years older (Rößler et al. 2011).

The accurate age of Littorina Sea in Arkona Basin should supply dating in calcareous fossils.

4. Acknowledgements

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Paleogeographic investigation in the Kaliningrad region, Russia

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1. Introducing

Our paleogeographical investigations started in 2009 and have been based jn studies of sediment cores from peat-bogs and lakes. In 2009 we investigated the peat-bog Velikoe (N 54º 57' 06'', E 22º 20' 28''; 34 m a.s.l.; area ca 2000 ha), it is located in the eastern part of the Kaliningrad region and belongs to the watershed of the River Sheshupe. Part of this results of this research already are published (Arslanov Kh.A et. al., 2010). Lake sediment cores have been recovered in Lake Kamyshovoye (54º22'531''N, 22º42'750''E, 189 m a.s.l.) located on the Vishtynets highland during the 2011-2012.

2. Methods

Within the frame of the research project, which aims at a high-resolution reconstruction of environmental and climatic changes in SE Baltic region since the last glacial maximum, lake sediment sequences have been investigated on the Vishtynets highland during the 2011-2012 by applying a high-resolution sampling strategy. During those expeditions we investigated Lake Kamyshovoye (54º22'531''N, 22º42'750''E, 189 m a.s.l.). This is a small lake with a maximum length ca 1200 m., width – 600 m., depth – 2.2 m. As a result of coring it was taken 9.8 meters of bottom deposits presented from top to bottom by high organic gyttja, brown-grey clay gyttja and dark-grey silty clay with admixture of sand. All deposits were selected by Russian borer diameter of sampler 7 cm and 5 cm, 1 meter length. Total it were taken 28 cores with 1 meter length each other. 9 cores were divided in the laboratory on 10 cm samples for lithological description, loss on ignition and radiocarbon analysis. Other master core was divided on 1cm samples for geochemical analysis. Last master core was divided on 2 cm samples for pollen, diatom and grain-size analysis.

3. Results

At the present we perform pollen, diatom and grain-size analyses and which provided the first data of total organic carbon (TOC). TOC reflects the biological productivity of the reservoir in time, which is directly dependent on climatic parameters, especially on the air temperature. Then higher summer temperatures, the higher the content of TOC in a particular layer of sediment section.

If we investigate changes in the percentage of TOC in time, it is possible to draw conclusions about the dynamics of climatic parameters. Below is a schema of the reconstruction of climate changes based of dynamic of TOC concentration in the sediment of Kamyshovoe lake (fig.1).

4. Discussion

Depending of the dynamics of TOC, we have identified five zones. *Zone 1*: with a TOC content of less than 6 % - it is characterized by the type of allochthonous sedimentation. Waters in the lake were cold. *Zone 2*: with carbon content up to 13 percent. There is a gradual increase in organic material, which may indicate a slight warming. *Zone 3*: allocated to the period 9800-6000 cal. BP High content of TOC let us conclude about strong warming and dominate of biogenic sedimentation. Zone 4: 6000-4100 - it is stagnation zone of dynamics TOC, that can talk about climate stabilization. Zone 5: from the 4100 – to real moment – there is a general degrees concentration of TOC, except for an interval, selected as an zone 4.2 - when the TOC content rapidly degrees, and then rapidly increase. Such a process can`t be associated with the climate and, most likely, it is associated with human activity. Further studies will answer this question, especially result of geochemistry and grain-size analysis.

Based on high-resolution pollen- and diatom stratigraphy, mineral magnetic properties, grain size, organic matter content, radiocarbon measurements performed on the sediments from Lake Kamyshovoye , we attempt a palaeoenvironmental interpretation for the Late Pleistocene and Holocene dynamics of the natural environments in the South-Eastern part of the Baltic region.

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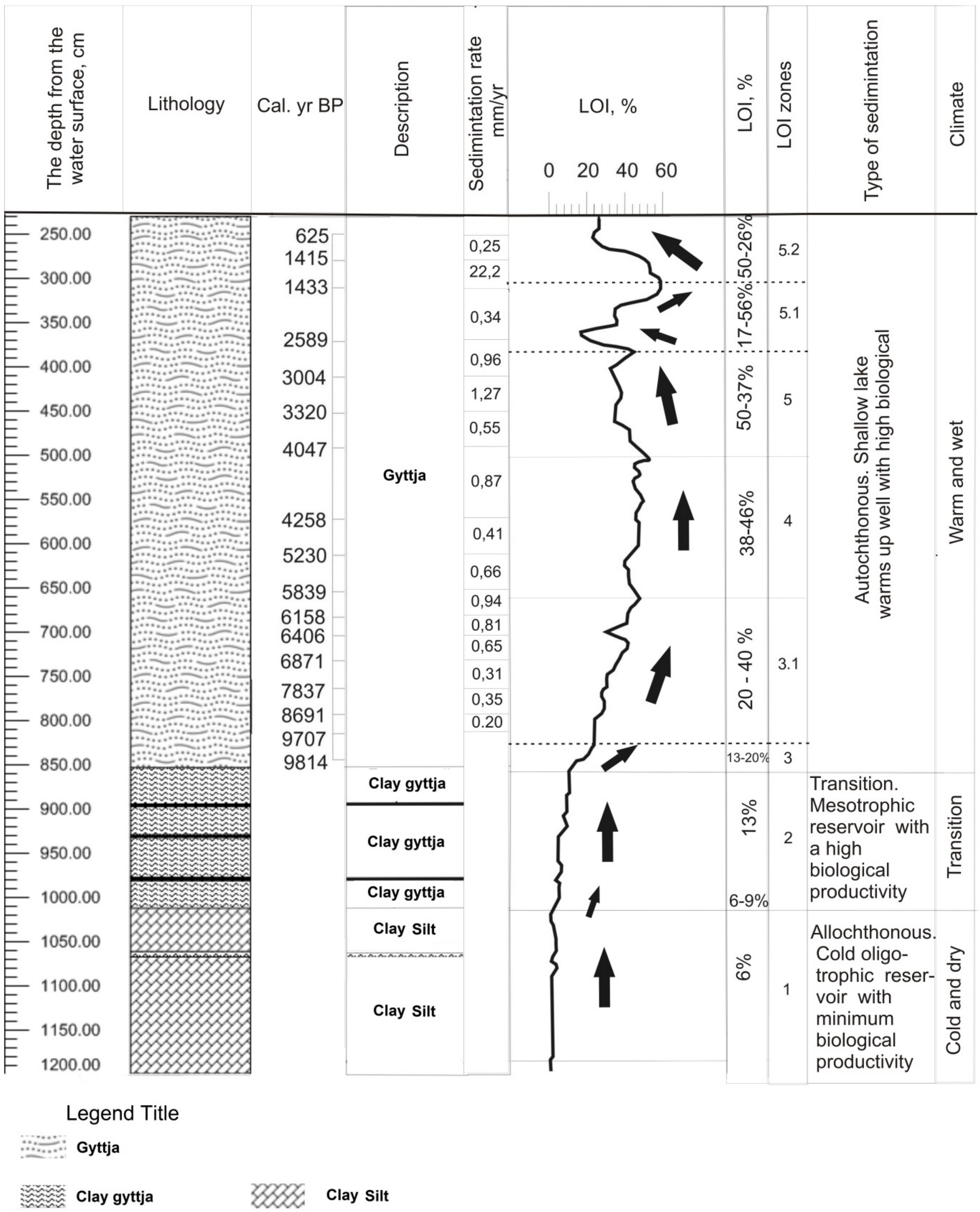
The depth from the water surface, cm
Lithology
Cal. yr BP
Description
Sedimintation rate mm/yr
LOI, %
0 20 40 60
LOI, %
LOI zones
Type of sedimintation
Climate
250.00
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1
Autochthonous. Shallow lake warms up well with high biological
Transition. Mesotrophic reservoir with a high biological productivity
Allochthonous. Cold oligo-trophic reser-voir with minimum biological productivity
Warm and wet
Transition
Cold and dry
Legend Title
Gyttja
Clay gyttja
Clay Silt

The development of lake sedimentation since Older Dryas in Belarus

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1. Introduction

Data on the development of lake sediments are of great importance in the reconstruction of palaeogeographic events. The results of complex examination of lake deposits will enable reconstruction of the history of relief, climate, and vegetation, determination of the development of lakes and their water level, and definition of the character of lake sediment genesis. Respective studies were conducted for separate stages of the Late Glacial and Holocene periods in a wide area of Belarus, where the glaciations might have had very different impact on the development of lakes and sediments. Sediment cores from other lakes in northern district Poozerye (Lozoviki and Krivoe), central district (Mezhuzhol and Sudoble), and southern district Polesye (Bobrovichskoe and Oltushskoe).

2. Regional setting

The territory of Belarus occupied a special position within the East European Plain in the Pleistocene and Holocene. In the Late Glacial (more than 10 000 years ago) arctic (Poozerye) and subarctic (Polesye) conditions prevailed on the territory of Belarus, short-term warming Allerød (AL) periods alternated with cold Younger Dryas (YD) periods. The most typical processes were thawing of frozen soils, glaciokarst (in Poozerye), thermokarst, and solifluction (in periglacial areas) processes, and descent of periglacial water reservoirs (Novik et al. 2010). Aeolian dune-hummocky relief was formed on sandy lowlands, especially in Polesye, and allochthonous clastogenic material accumulated in primary lake reservoirs (Zernitskaya 1997). As seen, environment evolution and climatic conditions in all three areas of Belarus were quite similar in the Holocene (less than 10 000 years ago). This situation was reflected both in the peculiarities of lake sedimentation and in the regularities of lake level fluctuations, proving that regional differences in lake level changes of that period were not caused by the climatic factor.

3. Methods of time scale construction

A wide range of methods has been applied in the study of lake development in Belarus. The data obtained from the best studied reference cores (palynologic, radiocarbon, geochemical and isotope-oxygen data).

4. Discussion and regional comparisons

The old peat of Late Glacial age is found also in other lakes of Belarus. The composition of peat layers shows that low-water periods existed in the development of lakes of Belarus during the second half of the Late Glacial. However, the biostratigraphic data based on pollen analysis show a different age of this peat, according to which continuous accumulation of terrigenous-chemogenic sediments started in the Older Dryas (OD) and Bølling (BÖ) (Zernitskaya 1997). One reason for asynchronous development of lake depressions and their low water level might be glaciokarst and thermokarst processes that took place in the Late Glacial, and synchronous regression of lake levels caused by the warming of climate and final degradation of frozen grounds in the YD and PB.

The cold period during the YD was probably accompanied by increase in the humidity of climate. In the first half of the YD the levels in lakes Lozoviki, Mezhuzhol, Sudoble, and Oltushskoe rose. The tendency towards lake level lowering appeared only in the second half of the YD and the beginning of the Holocene (20 000–11 100 cal yr BP) due to continuing decrease in humidification in that cold epoch and recurrent strengthening of thermokarst processes. Intensive inflow of groundwater during the first half of the YD transported carbonaceous and terrigenous sediments, caused the disappearance of peat and the beginning of the formation of lake sediments in reservoirs of Mezhuzhol and Lozoviki. Owing to the character of sediments, the water level was at that time high also in lakes Sudoble and Oltushskoe.

From the second half of the YD, the prevailing high lake levels were changed to predominantly low ones between ca 12 000 and 11 100 cal yr BP in lakes Lozoviki, Mezhuzhol, and Krivoe. The decrease in water levels after about 12 000 cal yr BP suggests deteriorating climatic conditions similar to those registered globally as the YD cooling (Makhnach et al. 2004).

The beginning of the Holocene is marked by further stabilization or lowering of the water level in lakes of the Poozerye (Lozoviki and Krivoe) and Polesye (Oltushskoe) districts. As a rule, from the end of the PB a slow steady rise in lake levels with no substantial fluctuations is noted. When some balance was achieved between lake levels and subsoil water level, lake sediments were gradually filled with lacustrine sediments (organic and calcareous gyttja). From the second half of the Preboreal (PB), high levels were observed in these lakes, revealed by the substitution of peat sediments by lake deposits (Krivoe and Lozoviki).

Sediment accumulation during the Boreal (BO) and Atlantic (AT) was strongly influenced by climatic and lithologic factors, as well as by the development of water reservoirs, revealed in the increase in their trophicity. The combination of those processes contributed to a gradual change in sediment accumulation in a number of lakes, where by the middle of the AT the carbonate component prevailing since BO time was replaced by the organic-mineral one (Novik et al. 2010).

From the middle of the BO peat formed in L. Bobrovichskoe and the content of organic matter grew substantially in the deposits of L. Oltushskoe, which witnesses to prevalence of low water levels in southern lakes of Belarus. From the end of the BO up to the middle of the AT the content of organic matter in calcareous gyttja of L. Lozoviki rises. At the same time, in lakes Krivoe and Bobrovichskoe, decrease in organic matter in deposits witnesses to increase in water levels.

At the end of the AT the carbonate content of sediments decreased and organic-mineral matter became prevailing in lakes Bobrovichskoe, Oltushskoe, and Lozoviki. The reason for regionally and supraregionally consistent replacement of carbonate sediments by organic gyttja in the vertical section was complex. The change in the type of lake sedimentation was, to a certain degree, determined by exhaustion of carbonate content in the deposits of drainage areas (lixiviation), which entailed decrease in hard water inflow by simultaneous rise in lake levels. Among the factors that determined the cessation or slowdown of lake carbonate formation, the fall of temperature at the end of the AT and climate-induced changes in subsoil waters are mentioned. In many lakes the phenomenon discussed could be connected with the rise in the trophic status as a result of the 'ageing' of the lakes (Makhnach et al. 2004).

In the late AT some increase in organic matter in deposits of L. Bobrovichskoe was recorded, which could be explained by lowering of the water level (Zernitskaya 1997). In the Subboreal (SB), sediment layers with a decreased concentration of organic matter by simultaneous increase in terrigenous matter are noted in bottom deposits of the lakes of the Poozerye district, which could be connected with the rise in the water levels. At the end of the SB and beginning of the Subatlantic (SA) high water levels occurred in lakes Krivoe and Oltushskoe, evidenced by the reduction of organic matter and increase in terrigenous sediments in bottom deposits of these lakes.

At the beginning of the SB peat started to form in sediments of L. Lozoviki. This also serves as an evidence of a low water level. Later on sediments of gyttja in the upper part of the Lozoviki core were covered by SB and SA peat. The formation of peat can be explained by gradual overgrowing of the reservoir and its turning into a peatbog. Detritus gyttja with peat layers of SB age of ca 3890–3565 cal yr BP (about 3.4 ka BP) were discovered in the peat core, which speaks for increase in lake level.

During SA time the levels of most lakes remained stable, indicating homogeneous structure of sediments in the investigated lakes.

5. Conclusion

A number of considerable regularities were recorded in the character of sediment accumulation and, as a result, in water levels of Belarusian lakes during the entire post-glacial epoch. Common patterns and synchronism of lake level changes during the Late Glacial and early Holocene did not reveal significant regional variations. Synchronism in natural-climatic conditions in all three regions studied is first of all connected with the general trend of climate warming at the beginning of the post-glacial epoch and disappearance of permafrost. This led to the increase in infiltration processes, which occurred with similar intensity on the whole territory of Belarus. Radiocarbon dating of organic matter and pollen composition showed that the water level rose in many lakes during the first half of the Younger Dryas (between 12 900 and 12 000 cal yr BP). Regression of the water level in the majority of lakes followed during the second half of the Younger Dryas and the early Holocene (between 12 000 and 11 100 cal yr BP). From the second half of the PB (since about 11 100 cal yr BP), high levels were observed in most of the lakes and several lakes experienced transgressions during the Boreal (about 9000 cal yr BP). Further stagnation of lake levels was promoted by the processes of filling and establishment of hydrostatic balance with the position of subsoil water level. From the latter half of the Holocene (less than 9000 cal yr BP), lake level fluctuations were asynchronous in different regions of Belarus. At that time the general role of the climate decreased and geochemical and lithological differences were mainly caused by other local factors (morphologic structure of the catchment area, lithology of the bedrocks, genesis and shape of lake depressions, intensity of the water cycle, position of the subsoil water level, etc.). It should be noted that the location of the Poozerye lakes in well-defined deep depressions as well as the presence of uplands in their catchment areas created the regime of water level fluctuations most sensitive to climatic changes (decrease in evaporation, increase of precipitation). And vice versa, Polesye lake basins, feebly marked in the relief, have low waterlogged and forest-covered catchment areas that did not provoke sudden rises in water level. It should also be mentioned that in all studied lakes the degree of water infiltration was decreasing as water reservoirs were filling up with lacustrine sediments. First of all it happened in lakes with thick layers of solid carbonate sediments. The Poozerye lakes, where the catchment areas were formed of solid loamy till, were most susceptible to the weakening of infiltration processes.

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Linking terrestrial and marine ecosystems: Holocene land-cover changes and their effect on terrestrial carbon pools and coastal ecosystems along the Swedish Baltic coast

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1. Introduction

Human-induced eutrophication and anoxic bottom waters are of prime concern in Baltic Sea region today. Studies by Zillén et al (2008) and Zillén and Conley (2010) show, that besides natural factors (climate, postglacial land uplift etc.) the past land use may have considerably contributed to the occurrence of hypoxia by influencing nutrient and carbon fluxes and sediment transport between terrestrial and aquatic environments in the Baltic Sea catchment.

One of the major aims of FORMAS financed project "Managing Multiple Stressors in the Baltic Sea" Multistressors is to determine the major driving factors of hypoxia in the Baltic Sea during the late Holocene by using novel cross-disciplinary approach combining experimental hydrology, palaeoecology and ecosystem modelling. As a part of the Multistressors project, we quantitatively reconstructed regional land cover dynamics, modelled related Carbon pools and dissolved organic Carbon (DOC) export for four key areas (Fig. 1), and related the observed changes in terrestrial environment to the dynamics of Baltic coastal marine environment during last 6000 years

2. Land-cover reconstructions

Vegetation composition and land use is reflected in subfossil pollen assemblages from Holocene sedimentary basins. Due to differences between plant species in terms of pollen productivity and dispersal the conversion of pollen percentages to estimates of past vegetation is needed. REVEALS model was developed by Sugita (2007) to overcome these discrepancies and to provide quantitative reconstructions of regional vegetation abundances based on pollen percentage data from large lakes.

Excising pollen records from three key areas: (Umeå, Ångermanland and Blekinge) and new pollen record from Småland were utilised to reconstruct the vegetation and land-use dynamics (see example from Blekinge area: Fig. 2a) during the last 6000 years. The timing, dynamics and extent of human impact on the landscape differs widely between the focus areas, being usually earlier and stronger in the south. However, the land-cover reconstructions show that during last centuries the extent of anthropogenic deforestation of northern Sweden is well comparable with that recorded for southern areas.

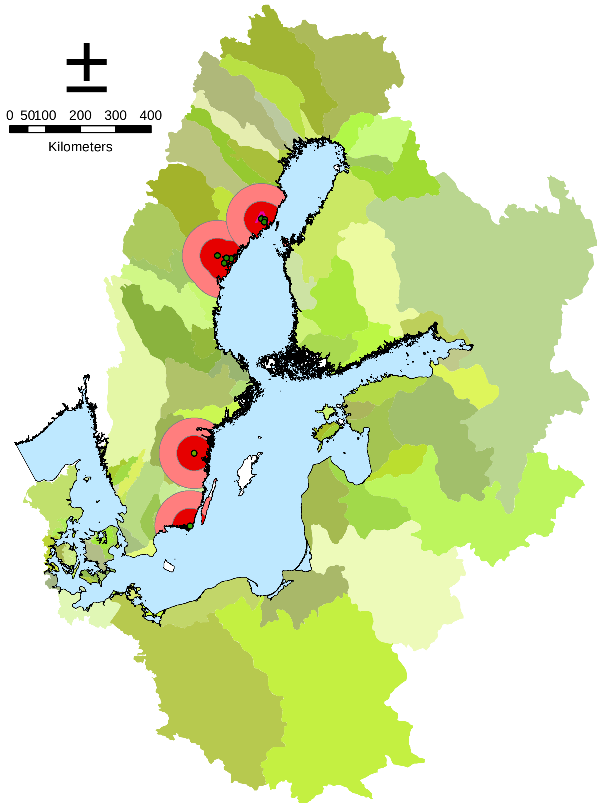

Figure 1. The Baltic Sea catchment. Approximate area covered by REVEALS reconstructions from four key areas is indicated by red (50 km) and pink (100 km) circles.

3. Terrestrial Carbon pool dynamics and DOC export

The dynamic ecosystem model LPJ-GUESS developed by Smith et al (2001) was used to simulate the terrestrial Carbon pools and DOC export using the palaeo-climate data from the GCM (general circulation model) ECHAM5 as an input. The pollen based land cover reconstructions were used to prescribe the portion of anthropogenic deforestation. The applied model utilises litter and soil organic matter dynamics based on CENTURY model developed by Parton et la (1994). Leaching of organic Carbon was expressed as a function of the decay rate for active soil organic matter and the clay content of the soil and only occurs if there is drainage of water.

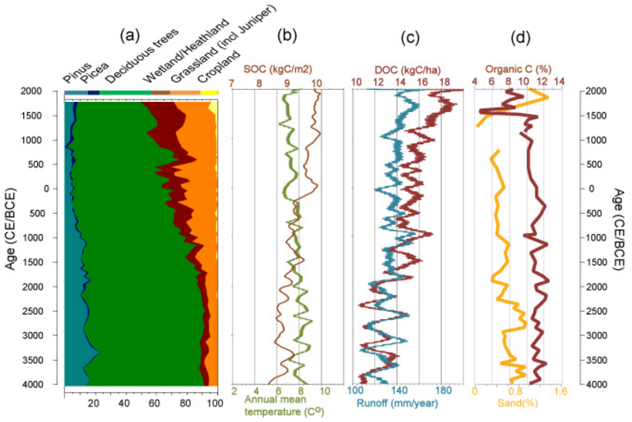

Figure 2: Preliminary results from Blekinge area: (a) regional land-cover reconstruction; (b) simulated soil organic carbon (SOC) content and GCM prescribed annual mean temperature; (c) simulated potential dissolved organic carbon (DOC) production and GCM prescribed runoff during last 6000 years; (d) Percentages of Organic Carbon and Sand in coastal sediments of the Baltic Sea.

The soil organic carbon (SOC) accumulation during last 6000 years was simulated along with potential terrestrial Dissolved Organic Carbon (DOC) production (see example from Blekinge area: Fig. 2b and c) accounting for the reconstructed land-use in area.

Ecosystem modelling results suggest that climate has been major driver determinging the dynamics of terrestrial Carbon pools and DOC export in investigation area. The increase of the SOC accumulation throughout the studied time interval is reflecting the decrease in Carbon decomposition rates due to the overall cooling trend of the late Holocene climate. The DOC export is strongly related to the runoff dynamics. However, disruptions in these relatioships are connected with major human induced deforestation periods.

4. Coastal marine ecosystems

To gain record of the past environmental changes in the Swedish coastal zone of the Baltic Sea we sampled two coastal sites: one from Småland (56°34'23"N; 16°31'26"E) and one from Blekinge, close to the town of Karlskrona (56°7'53"N; 15°32'55"E). The collected sediments were analyzed for a range of proxy variables such as particle size distribution, organic carbon, biogenic silica, XRF elemental analysis as well as dinoflagellate cysts, tintinnids and foraminifera species assemblages.

A poor population of calcareous benthic foraminifera and moderate to high abundances of dinoflagellate cysts and tintinnids were recorded. Together they indicate a lowering of the salinity over the last 6000 years. The nutrient enrichment over time is indicated by the moderate to high values of biogenic silica and organic carbon. The increase of organic carbon and coarser sediment fractions (Fig 2d) during the last 200 years might be related to intensified human activity in the investigated coastal area of Blekinge, where the marine record can tentatively be linked to the development of the city of Karlskrona.

5. Linking the terrestrial and marine environments

Pollen based land-cover reconstructions from four catchment areas along the Swedish east coast confirm the expected differences in timing and extent of anthropogenic deforestation, but also highlight the unanticipated degree of the human related land-cover change in northern Sweden. These major changes in land-cover composition influence the simulated terrestrial Carbon balance and can be associated to observed changes in marine proxies.

However, when linking land and sea in a long term perspective, multiple other factors, such as long term climate and sea level changes or variations in salinity of the Baltic Sea must be taken into account.

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Session B

Modelling of climate change: How reliable are future projections?

Interactions between phytoplankton blooms and environmental conditions in the Baltic Sea – a modelling study

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1. Introduction

Phytoplankton blooms are regular and very important phenomena in the Baltic Sea. Recently, a lot of attention received the cyanobacteria blooms. Abundant blooms can have serious negative biological impacts including potential toxic effects on other algae, invertebrates and fish, impacts on plants and benthic algae due to light shading, thermal stratification of the water column, and impacts on functioning of the food web. Dense blooms of cyanobacteria, accumulation of organic material in sediments and increased bacterial activity may lead to anoxic conditions and fish extinction.

There are a lot of factors influencing the phytoplankton blooms dynamics in the Baltic Sea. These factors include for example: local weather, human activities, fresh water runoff, precipitation/evaporation, solar insolation, and water stratification. The environmental conditions for phytoplankton in the Baltic Sea change with global climate trends. In order to better understand these changes it is important to develop an in-depth understanding of the biological-physical feedbacks in the Baltic Sea.

Some examples of such feedbacks are as follows. The intensity of phytoplankton bloom can significantly affect the radiative transfer in the water column. Abundant blooms impede the light transfer – more energy is absorbed in the upper sea layers. This in turn causes stronger heating at the surface and less effective heating of water at greater depths. Water column becomes stronger stratified. This can also lead to a situation when sea returns to the atmosphere more heat in a shorter time, and the local climate trend can be modified.

Some examples of the interaction between phytoplankton and climate can be found at the following website (Dr Philip Boyd, Phytoplankton and climate change, http://www.niwa.co.nz/video/phytoplankton-andclimate-change).

2. Results

Above described aspects and connections are being presently investigated at the Institute of Oceanology of the Polish Academy of Sciences through numerical modelling validated by in-situ and satellite data.

We use the Princeton Ocean Model, (POM www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/) for the physical – hydrodynamic calculations. This is an Eulerian, sigma coordinate, free surface ocean model, developed by Blumberg and Mellor (Blumberg and Mellor, 1987), that has been also used for ecological studies (e.g., Newberger et al., 2003; Oguz et al., 2001; Zavatarelli et al., 2000).

The biological module in our work has been adapted from the ERGOM Baltic Sea Numerical Model developed by Neumann et al. (2002). The ERGOM model has been successfully validated against empirical data from the Baltic Sea as described in a number of published papers (e.g. Neumann 2000; Neumann et al., 2002; Janssen et al. 2004; Neumann and Schernewski, 2005; Schernewski and Neumann 2005). We have modified this model to include more realistic attenuation of light in the Baltic Sea.

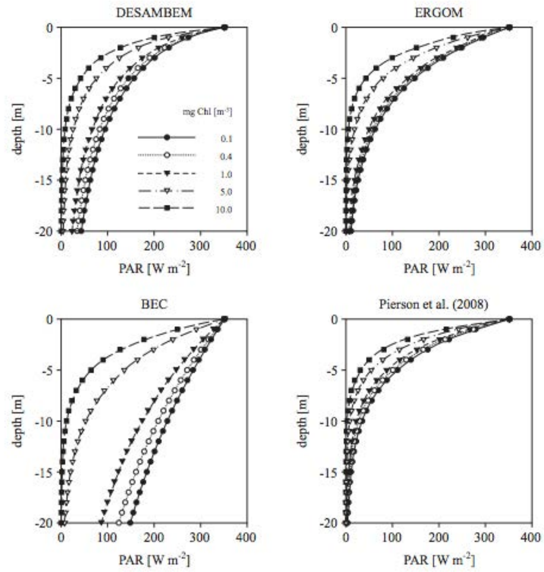

Figure 1. Vertical profiles of downwelling irradiance in the visible spectral range, estimated for a homogenous water column using different parameterizations of the vertical diffuse attenuation coefficient (Stramska and Zuzewicz, 2013)

3. Summary

Our results confirm that phytoplankton-light interactions in the Baltic Sea can have significant influence on sea surface temperature (SST). We are currently continuing model simulations of the phytoplankton/environmental feedback mechanisms and the results will be included in the presentation. This will also include controlled numerical experiments, where trends in the environmental conditions in the Baltic Sea follow up the predicted regional climate trend. Presented issues are crucial to understanding the environmental transformations taking place in the Baltic Sea and will help with developing science based plans for improvements of the regional waters environmental status.

Acknowledgments: Presented research is supported by the National Science Centre in Poland through project number DEC-2012/07/N/ST10/03485, entitled: *Improved understanding of phytoplankton blooms in the Baltic Sea based on numerical models and existing data sets*, awarded to Agata Cieszyńska (Zuzewicz).

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Changes of water balance elements of the Curonian Lagoon in the 21st century

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1. Introduction

The Curonian Lagoon is the biggest fresh water basin in Lithuania influenced by the exchange of the fresh Nemunas and other smaller rivers' water and saline water of the Baltic Sea. The lagoon ecosystem is influenced by fresh, brackish and brackish water masses. A long-term water balance of the Curonian Lagoon was calculated for the period of 1960–2009. The sum river inflow is 21.847 km^3/year, precipitation – 1.194 km^3/year, evaporation – 1.006 km^3/year, inflow of brackish water from the Baltic Sea to the Curonian Lagoon – 6.125 km^3/year, and fresh water runoff from the Curonian Lagoon to the Baltic Sea – 27.655 km^3/year (Jakimavicius and Kriauciuniene, 2013). The lagoon water balance elements have been influenced by climate change. The water balance forecasting has been performed for the period of 2011–2100.

The goal of this article is to forecast the changes of water balance elements in the 21st century according to Global Climate Models (ECHAM5 and HadCM3) and greenhouse gas emission scenarios (A2, A1B and B1).

2. Study area

The Curonian Lagoon is the biggest Baltic lagoon. It lies along the Baltic coast of Lithuania and the Kaliningrad oblast of Russia. The greater part of the Lagoon belongs to Russia (1171 km^2), whereas 413 km^2 is in the territory of Lithuania (Fig. 1). Total volume of water of the Lagoon is approximately 6.2 km^3, and the average depth, about 3.8 m. It is separated from the Baltic by a narrow (~ 1–3 km) sandy spit, the Curonian Spit. The Curonian Lagoon is connected with the Baltic Sea via the narrow Klaipėda Strait. The Lagoon is a terrestrial runoff-dominated system, and its hydrology is strictly related to the discharge from the catchment area (100458 km^2).

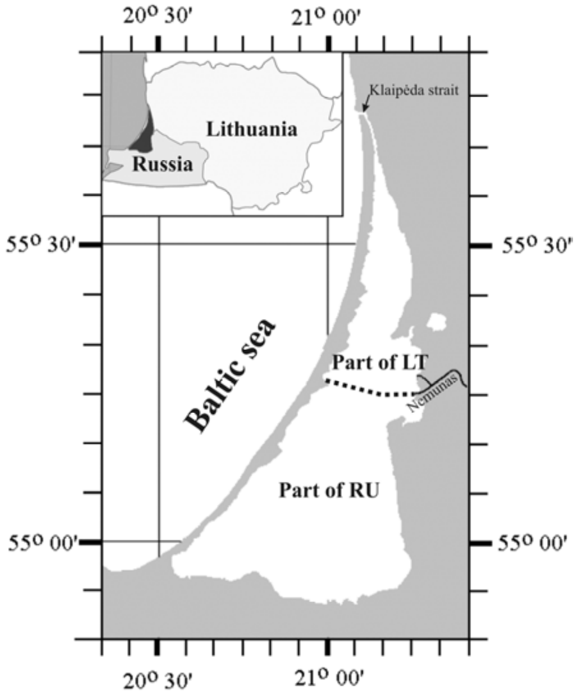

Figure 1. The scheme of the Curonian Lagoon.

3. Methodology

The long-term water balance of the Curonian Lagoon (further referred as Lagoon) has been calculated for the period of 1961–2009 (Jakimavicius and Kriauciuniene, 2013), applying the following equation:

$$(Q_U + P - Z) + (Q_J - Q_M) = \pm\Delta V$$

where Q_U – river inflow to the Lagoon; P – precipitation on the surface of the Lagoon; Z – evaporation from the Lagoon; Q_J – inflow from the Baltic Sea to the Curonian Lagoon; Q_M – outflow from the Lagoon to the Sea; ΔV – change in the volume of the Lagoon.

Climate change impact on the water balance of the Lagoon has been evaluated using Global Climate Models (GCM), greenhouse gas emission scenarios, and hydrological modelling. One scenario was selected for the prediction of the Baltic Sea water level.

The prediction of air temperature and precipitation is essential for the evaluation of changes of the river inflow to the Curonian Lagoon. The changes of meteorological parameters were evaluated according to the global climate models (ECHAM5, HadCM3) and A1B, A2, B1 greenhouse gas emission scenarios output data for the Lithuanian territory.

The predictions of meteorological variables in the 21st century are carried out for 16 meteorological stations across Lithuania. The delta change approach is used for determination of daily meteorological input data to hydrological models.

The semi-distributed conceptual HBV model developed at the Swedish Meteorological and Hydrological Institute was applied for the calculation of the river inflow to the Curonian Lagoon.

During the 21st century, the water level of the Baltic Sea can rise from 9 cm to 88 cm, while according to two models (RCAO-E and RCAO-H) and two emission scenarios (A2 and B2), it can rise up to 48 cm. When the rise of the water level of the Curonian Lagoon during the period of 1961–1990 was evaluated, it was determined that the water level rose averagely 4.02 mm/year. In accordance with this trend, during the period of 2011–2100, the water level of the Curonian Lagoon would rise 36.16 cm. In analysis, only one scenario, in which the water level of the Curonian Lagoon rises averagely 4.02 mm/year, is used.

4. Results

Changes of river inflow to the Curonian Lagoon. The annual air temperature in the territory of the Nemunas catchment will rise intensively in the whole calculated period in comparison with the baseline period: in 2011–2040 – 1.0–1.7°C, in 2041–2070 – 2.0–3.4°C and in 2071–2100 – 2.7–5.3°C. The annual precipitation in the territory of the Nemunas catchment will have positive and negative tendencies in the whole calculated period in comparison with the baseline period (changes are expressed by %): in 2011–2040 – -1.6–2.7%, in 2041–2070 – -0.3–6.6%, and in 2071–2100 – 3.6–7.9%. Modelling of the Nemunas river runoff according to six climate scenarios was done for three periods (2011–2040, 2041–2070, 2071–2100). The annual Nemunas river runoff will decrease in the whole calculated period in comparison with the baseline period: in 2011–2040 – by 9.6–23.1%, in 2041–2070 – by 12.3–31.0% and in 2071–2100 – by 17.8–37.4%. According to all climate change scenarios, the redistribution of the Nemunas river runoff will occur in the 21st century. The spring floods will decrease slightly in 2011–2041 (Fig. 2), whereas the spring floods will disappear in 2071–2100 according to all climate scenarios. The maximal flood discharge values will decrease intensely. The winter season runoff will increase mostly in February, whereas the spring season runoff will decrease mostly in May.

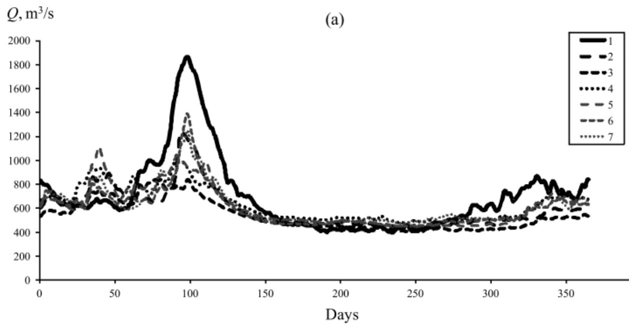

Figure 2. Simulated mean daily discharge of the Nemunas river inflow into the Curonian Lagoon for the period 2011–2040 according to global climate models and emission scenarios: 1 – baseline period, 2 – ECHAM5 A2, 3 – ECHAM5 A1B, 4 – ECHAM5 B1, 5 – HadCM3 A2, 6 – HadCM3 A1B, 7 – HadCM3 B1

Precipitation to the Curonian Lagoon and evaporation from the Lagoon. The smallest part of water balance income is precipitation. In the baseline period, the average precipitation to the Lagoon was 1.157 km^3 per year. According to the six climate change scenarios, the average precipitation amount to the Lagoon will be 1.155 km^3/year in the period of 2011–2040, 1.172 km^3/year – in 2041–2070, and 1.201 km^3/year – in 2071–2100. The amount of precipitation in winter and spring seasons will gradually increase and in summer season will decrease.

Evaporation is the smallest element of water balance losses. In the baseline period, the average evaporation from the surface of the Lagoon was 0.981 km^3 per year. According to six climate change scenarios, the average evaporation from the Curonian Lagoon will be 1.075 km^3/year in the period of 2011–2040, 1.152 km^3 /year – in 2041–2071 and 1.228 km^3/year in 2071–2100. Evaporation is closely tied to weather temperature, as correlation coefficients between them reach 0.97–0.98. In the 21st century air temperature will rise therefore the increase of evaporation is forecasted as well. The most considerable differences of evaporation, in comparison with the baseline period, are identified in winter seasons, while the differences in spring and summer seasons are smaller.

Outflow from the Curonian Lagoon to the Baltic Sea and inflow from the Sea to the Lagoon. Water exchange via the Klaipeda Strait was calculated according to the scenario in which the water level of the Curonian Lagoon will rise 4.02 mm/m in the 21st century. In the periods 2011-2040, 2041–2070 and 2071-2100, the outflow from the Lagoon into the sea decreased respectively 8.9%, 12.5% and 13.7% in comparison with the baseline period. In the periods of 2011–2040, 2041–2070 and 2071–2100, the inflow into the Lagoon will exceed the inflow of the baseline period by 13.1%, 23.2% and 36.2%, respectively. The largest increase of inflow into the Lagoon will be observed during the months of spring and autumn seasons. These changes will be determined by the increase of water level of the Baltic Sea in the 21st century, as well as by the decrease of river inflow into the Curonian Lagoon, particularly in spring season.

5. Conclusions

Considerable changes of the Curonian Lagoon water balance are forecasted in the 21st century. The increase of weather temperature and changes in precipitation will influence the water balance elements of the Lagoon. The inflow of the Nemunas River into the Lagoon will be 20.4% smaller than the inflow of the background period (1961-1990). The distribution of inflow during the years will change considerably: in the winter season, the inflow will increase up to 5.4%, while in the spring, summer and autumn seasons it will decrease up to 40.5%, 1.7% and 21.8%, respectively, in comparison with the baseline period.

Evaporation from the Lagoon will increase up to 25.1% in comparison with baseline period because of increasing weather temperature. The amount of precipitation will increase marginally (up to 3.8%). Outflow from the Lagoon to the Sea will decrease up to 16.6%, while inflow from the Sea into the Lagoon will increase up to 39.7%. These changes appeared as a consequence of climate change, but the increase of inflow from the Sea to the Lagoon can be linked to natural–anthropogenic factors (dredging of the Klaipėda Strait).

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How reliable are future projections of threats from the sea level rise?

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1. Introduction

The aim of the study was the evaluation of the reliability of threats from the sea level rise (storm surge, inundation area). Southern Baltic waters, especially Hel – Karwia region were investigated. The future prediction of climate change was assumed as the 3 climate scenarios of IPPC downscaled to the regional condition of the Polish coastal zone. The threats from the sea level rise were presented by the 100-years flood (1% value of sea level) and inundation area.

2. Data

The case study area Karwia-Hel is located on the central part of Polish coast. The harbor in Hel is located on the head of Hel Peninsula (54°36'N 18°48'E). Entry to the fishing harbor is situated from the side of the Bay of Puck (part of Gdańsk Gulf). There are two basins: - the inner basin with depth of 4 to 5m and other basin with depth of 5 to 8 m, shielded by moles. The tide gauge, operated by IMGW-PIB was build in the harbor. The sea levels used for calculation were observed in this tide gauge.

The observation and measurement data used for the analysis have been produced on the stations of IMGW - PIB from 1950 to 2009. A frequency of data recording at the station are now 10 minutes; anyhow, the mean daily, monthly and annual sea levels were taken for further analyses.

There were established 4 main period of investigation : from 1950 to 2009 as the fundamental period, 1970- 1991 as the reference period and 2011-2030 and 2081-2100 as the future projection periods.
Karwieńska plain is situated on the back of a short dune embankment. For this reason, there is a threat of flooding Piaśnieńskie Meadows reserve. The area of the region is about 20 km2 and is located less than 2.5 meters above sea level. Buildings with low values are within the areas at risk of flooding and storm rising groundwater. From the analysis of the terrain flood risk area Karwia may occur both as a result of the increase of water level in the Channel Karwianka and due to changes abrasive edge of the dune. Infusions of storm water between the dunes may cause local flooding. Dozens of buildings may be flooded.

3. Climate Scenarios

In the climate changes studies, the most often used are 3 following scenarios prepared by IPPC : A2, A1B and B1 (according to the report: "Climate Change 2007 – Summary for Policymakers", 2007, http://www.ipcc.ch). These scenarios are based on the modelling of greenhouse gases emission with prediction of the changes of global temperature. The different scenarios A2, A1B and B1 were created in relation to such parameters, as the forecasted growth of population or economic development of the world and its individual regions (IPCC SRES SPM 2000, Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.B.; Tignor, M.; and Miller, H.L., ed. 2007). Scenario A2 assumed slow rate of global economic development is known as market scenario, scenario A1B (regional scenario) predicts rapid economic development, with ecological priorities, when B1 forecasts sustainable, median economic development with strong ecological priorities. The results of modelling till end of 21 century were published in Special Report on Emissions Scenarios (SRES models of greenhouse gas emission). Downscaling from global conditions to regional (Polish coastal zone) was performed under the **KLIMAT project** in IMGW-PIB (Mietus 2009) with the RegCM model developed by the International Center for Theoretical Physics (ICTP).

4. Threats

The dangerous sea level increase does not only destroy the human lives, but also generate the severe flooding in coastal areas. The changes in the direction and velocity of wind and associated with them sea level changes could be the severe threat for navigation, especially on the fairways of small fishery harbors. The most popular indicator of dangerous sea level is the calculated value of 100-years (return period) flood called 1% sea level. This value is defined as the exceedance probabilities of extreme water levels and is accurately evaluated to inform about risk- flood and erosion management, engineering and for future land-use planning.

Inundation Charts (IC) show the extent of flooding expected spatially over a given area and they are the most important maps in the activity connected with the flood including the spatial planning. The inundation field is defined by EU in Floods Directive defines as area covering by water of land not normally covered by water, in the case of coast by inflow of the sea water/tide. The localization of probably sea water impacts on the roadways, streets, buildings could provide users more knowledge of flood risk in local community ad give the emergency managers and local governments important information to better mitigate the impacts of flooding and build more resilient conditions.

5. Methodology and Results

The 100-years flood (1% sea water – Hel) and floodway zones (Karwia) were calculated according to the rules recommended by the Polish National Water Management Authority (Sztobryn et. all 2010,Kowalska et. all 2012). Inundation maps were being prepared using the latest computer modeling techniques (including ARC GIS) for both local and distant events (Kowalska et. all 2012a). The results of the predicted sea levels by 1% exceedance probability, based on SRES scenarios, are presented on Fig.1. In a scenario during 2011-2030 (scenario A1B), the estimated value of the 100 years water should be maintained at a similar level as in the reference period, the remaining two scenarios predict a slight decline. However, in the period 2081-2100 projected value 100 years water should reach (Scenario A1B and B1) slightly higher than the measurement period.

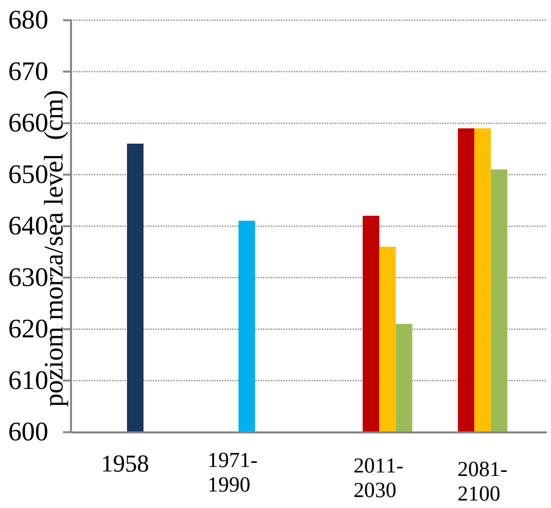

Figure 1. The values with exceedance probability 1% on the basis of calculation in the Hel –main reference and scenario periods 2011-2030 and 2081-2100 for scenarios A1B (red), B1 (yellow) and A2 (green)

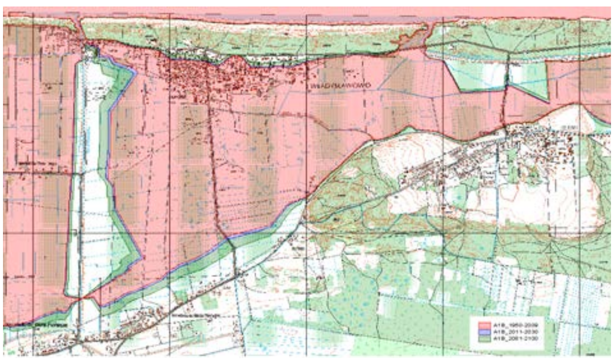

Figure 2. Karwia, map of an inundation area , scenario A1B, 1950-2009, 2011-2030 and 2081-2100

In the case of the Karwia (Fig.2) area is anticipated that the abrasive hazard area will be in the middle class, with a projected change in the shoreline to about -0.59 m assuming an increase in average sea level rise of 0.6 m at 100 years old (Zawadzka - Kahlau E. 2011) .

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Sea level change scenarios in the Polish coast during 21st century

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1. Introduction

Contemporary research focused on sea level variability in the Polish coastal area show positive trends, Wróblewski (1993), Kożuchowski i Boryczka (1997), Miętus (1999), Jakusik et al. (2010). During the second half of 20th century (since 1950) the increase of sea level ranges from 10cm (western part) to over 15cm (eastern part), Marosz et al. (2011). Those changes result from (1) global sea level rise and (2) regional atmospheric circulation i.e. wind-driven level variations, static effect, changes in runoff, changes in precipitation totals and water density. For example, the increase in the intensity of the western air advection results in the transport of the water masses from the North Sea through the Danish Straits towards the Polish coast, Miętus et al. (2004). This results in the increase of the average sea level.

2. Aim of the study and methodology

The aim of the research was to develop the set scenarios of future sea level changes along the Polish coast. The results were prepared with the aid of empirical-statistical downscaling tool – CCA (Canonical Correlation Analysis), von Storch et al. (1993), Miętus (1999). Input data comprised monthly average sea level values at 9 stations (i.e.: Świnoujście - Swin., Kołobrzeg - Kolob., Ustka - Ust., Łeba - Leb., Władysławowo - Wlad., Hel - Hel, Gdynia - Gdy, Gdańsk-Port - GP, Gdańsk-Ujście Wisły - GuW) and monthly means of Sea Level Pressure (SLP) over Euro-Atlantic region (50°W-40°E, 35°N-75°N). SLP values originated from NCEP/NCAR Reanalysis, Kalnay et al. (1996). Model calibration was performed with the reference period 1971-1990. The information about the future variability of atmospheric circulation were derived from MPI - ECHAM5 model, Roeckner et al. (2003). Future sea level variability was established for selected emissions scenarios (ES): B1, A1B, and A2. The resulting sea level changes were calculated as anomalies from reference period 1971-1990. Aside of the atmospheric circulation forced variability (derived from a downscaling model) future global sea level changes were also accounted for to derive absolute values of sea level change. Expected changes of sea level along the polish coast were presented for the time span of 21st century as decadal anomalies from reference period (1971-1990) in annual and seasonal scale.

3. Results

The results (tab. 1, tab. 2, tab. 3) for the beginning of 21st century show relatively small increases with a couple of centimeters in case of B1 scenario. Much greater values are expected for the second part of the 21st century with over 30cm increase in case of A2 scenario. However most of the projected change result from global sea level rise, variations of regional atmospheric circulation is of minor importance.

Tab.1. Average annual sea level change scenarios (cm) in 21st century (B1 ES) along the polish coast. Reference period: 1971-1990.

B1	Swin	Kolob	Ust	Leb	Wlad	Hel	Gdy	GP	GuW
2001-2010	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.3
2011-2020	4.7	4.9	5.0	5.2	5.1	5.1	5.1	5.1	4.9
2021-2030	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.5
2031-2040	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.8
2041-2050	10.4	10.7	10.8	11.0	10.9	10.9	10.9	10.9	10.9
2051-2060	11.5	11.6	11.6	11.7	11.7	11.6	11.6	11.6	11.3
2061-2070	14.0	14.1	14.2	14.3	14.3	14.3	14.3	14.3	13.5
2071-2080	16.0	16.1	16.2	16.3	16.3	16.3	16.3	16.3	15.5
2081-2090	19.5	19.8	20.0	20.2	20.1	20.1	20.1	20.1	19.8
2091-2100	21.1	21.3	21.4	21.5	21.5	21.5	21.5	21.5	20.6

Tab.2. Average annual sea level change scenarios (cm) in 21st century (A1B ES) along the polish coast. Reference period: 1971-1990.

A1B	Swin	Kolob	Ust	Leb	Wlad	Hel	Gdy	GP	GuW
2001-2010	2.8	3.0	3.0	3.1	3.1	3.1	3.1	3.1	2.9
2011-2020	4.2	4.4	4.5	4.6	4.5	4.5	4.5	4.5	4.4
2021-2030	6.4	6.6	6.7	6.8	6.8	6.7	6.7	6.7	7.1
2031-2040	8.2	8.3	8.4	8.5	8.5	8.5	8.5	8.5	8.0
2041-2050	11.5	11.8	12.0	12.2	12.1	12.1	12.1	12.1	11.9
2051-2060	13.6	13.8	13.9	14.1	14.0	14.0	14.0	14.0	13.7
2061-2070	17.0	17.3	17.4	17.6	17.6	17.6	17.6	17.5	16.8
2071-2080	20.1	20.4	20.5	20.7	20.6	20.6	20.6	20.6	20.2
2081-2090	23.9	24.2	24.4	24.6	24.6	24.5	24.5	24.5	24.0
2091-2100	26.5	26.7	26.8	27.0	27.0	27.0	26.9	26.9	26.2

Tab.3. Average annual sea level change scenarios (cm) in 21st century (A2 ES) along the polish coast. Reference period: 1971-1990.

A2	Swin	Kolob	Ust	Leb	Wlad	Hel	Gdy	GP	GuW
2001-2010	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0
2011-2020	4.5	4.7	4.7	4.8	4.8	4.8	4.8	4.8	4.7
2021-2030	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.0
2031-2040	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	6.8
2041-2050	10.5	10.7	10.8	10.9	10.9	10.9	10.9	10.9	10.6
2051-2060	13.1	13.3	13.4	13.5	13.5	13.5	13.4	13.4	13.1
2061-2070	17.3	17.7	17.8	18.1	18.1	18.0	18.0	18.0	17.4
2071-2080	20.6	20.9	21.1	21.3	21.2	21.2	21.2	21.2	20.7
2081-2090	24.9	25.3	25.5	25.8	25.7	25.7	25.7	25.7	25.0
2091-2100	30.4	30.9	31.2	31.5	31.5	31.4	31.4	31.4	30.2

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Session C

Natural dynamics of the coastal zone and the socio-economic response from prehistoric to recent times

The Gulf of Finland: Social and economic problems of St.-Petersburg in conditions of the natural environmental change

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1. Introduction

The water area and coast of the Gulf of Finland (the Baltic Sea) differs uniqueness national, a cultural heritage, including monuments of the world heritage (UNESCO), occupies the important geopolitic position on border of Estonia, Finland and Russia. Within the framework of the declared action «the Year of Gulf of Finland 2014» appears a unique opportunity of development the complete trilateral approach for protection of the sea environment and creation of social and economic values in a zone of the Gulf of Finland and its basin fluvial.

2. Assessment of natural-climatic and anthropogenic changes and their effects on the environment of the Gulf of Finland

Estimations natural, climatic and industrial changes and their influence on a modern ecological condition of water area and coastal zones of Gulf of Finland are resulted. During last decades modern climate change the increase in values of the maximal and minimal temperatures is marked. Sharp temperature drops and pressure of air, storms, etc. more frequently are observed. Fast climate change influences to reduction of a sea ice cover, on sea and coastal ecosystems, bioresources, duration of a season of navigation, etc. On a background of warming in conditions of intensive economic development of water area of the Neva lip and east part of the gulf of Finland, including carrying out of hydraulic engineering works on alluvial sites, construction and operation of a complex of protective constructions of Saint Petersburg from flooding (KZC), new ports and port constructions, pipelines, etc. Technical systems, all this can cause cascade reaction of many natural systems and processes, finally, will aggravate existing and will result in occurrence of new environmental problems.

3. Ecological risks and socio-economic impact of modern changes in the natural and technological environment

The greatest danger represent a technogenic incidents accompanying infringement of conditions of reliable operation of an infrastructure. Ecological risks and social and economic consequences of modern change natural and techno genic environments in territory of a megacity Saint Petersburg and its environs. In result there is an ecological damage and risk for health of the population due to deterioration of environment and the increased danger of infection with infectious diseases. The special attention is given to concrete measures on protection of natural complexes, the basic (superficial) water-currents, channels to water sources on which the water-fence is organized. The special ecological status of these complexes will play an essential role in creation of the conditions favorably influencing health of the person.

4. Forecasting of environmental and sustainable tourism development

Development of all branches of manufacture and financial, and economic activity of Saint Petersburg and suburbs directly or is indirectly connected to forecasting of condition natural and techno genic environments. Each of branches of economy plays a part in sustainable development of region. Such branches of economy, as for example navigation, agriculture, render significant influence on an ecological condition of gulf of Finland, and ecological damage of tourist business, a power industry, etc. is less significant. And tourism, industrial fishery, etc., directly depend on a condition of ecology of region. Tourism is economically important industry in the countries of the Baltic sea. The analysis of the future sustainable development of tourism, shows, that the choice of technology of use of tourist and recreational resources will have serious consequences for economic and social well-being of region.

5. Conclusion

In the conclusion problems of adaptation to climate changing conditions and adaptation of blue and green technologies in the tourist industry are discussed.

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Water and waste management by household in terms of changes in the law

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Waste management is at the forefront of the problems faced by both, the local government and residents. The proposed legislative changes related to the calculation of costs of the waste disposal services provoked much controversy. In this work, basing on the example of selected residential communities, the authors analyze the use of water by households as well as the effectiveness of various methods of calculating waste disposal costs. The study is based on the analysis of costs of housing communities located in Szczecin, but it refers to all possible statutory cost accounting methods, and not only these that are adopted by the Municipality of Szczecin. The research tools applied in the analysis include statistical methods and econometric modeling. The results obtained can be of use for both, local governments and multi-site property managers.

Simulation of the historical ecosystem state as a reference according to the Water Framework Directive

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1. Reconstruction of historical nutrient loads

The EU Water Framework Directive (WFD) has the aim to achieve a good ecological status, which is based on reference conditions with no or very minor disturbance from human activities.

Together with our stakeholders from the local environmental agencies we proposed that the state of 1880 is suitable as reference condition with an area used for agriculture comparable to the present situation, further tile drainage and sewer systems existed.

The German nutrient loads were reconstructed with the catchment model MONERIS by Hirt et al. (2013) and used as model input of our Baltic Sea ecosystem model as well as the reconstruction of Gustafsson et al. (2012) for the non-German rivers.

2. Validation of the historical simulation & comparison with present time

A comparison of the historical simulation with the few existing measurements shows that we are to reproduce them at least qualitatively. Further the decadal variability as well as the climatology are within the range of present simulations.

Unsurprisingly due to the reduced nutrient loads the chlorophyll concentration as well as the nutrient ones are below the present situation. The nutrient limitation shows steps gradients from mainly Phosphorus-limited river outlets to the Nitrogen-limited open sea. These gradients are comparable to the present situation but less strong.

3. Calculation of the WFD`s target values: a combined method of integrated modeling and measurements

The final step from the reconstructed ecosystem state to new WFD targets was to transfer the today measured concentrations to the historical reference situation for several stations along the German coast. Therefore we computed the relative change between the simulations forced with the reference nutrient loads and the one from today and used the relative change as transfer factor (an example is shown in Fig. 1).

Finally we calculated the reference concentration as the median of the shifted values from the last 12 years (to exclude outliers) and the target value by adding 50% to the reference concentration. This approach together with the computed WFD target values are summarized in Schernewski et al. (subm.).

The proposed method has several advantages, especially the bias of the ecosystem model levels out. Further the reference conditions are consistent with the present situation, as they include the gradients from the emission sources to the open sea (in contrast to the actual target values). Finally they can be harmonized easily with HELCOM's targets for the open sea.

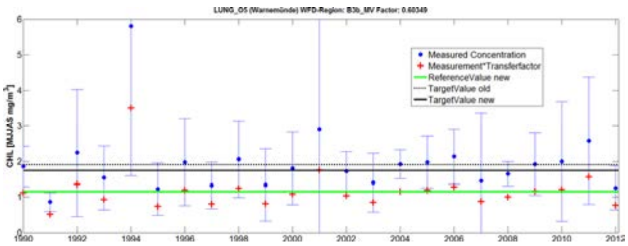

Figure 1. The new reference value of chlorophyll a (averaged for May to September) of station O5 (near Warnemünde) is calculated by first shifting the measured data (blue dots) to the reference conditions by multiplying it with the transfer factor (0.60). Then the median of the shifted values from 2001 to 2012 was computed and used as reference value (green line). The new WFD target value (black solid line) is the reference enhanced by 50% and is with 1.9 a little bit lower than the old one (1.8, dotted line).

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A comparison of selected River mouth systems – Zones of interference between terrestrial, marine and anthropogenic impacts

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River mouth systems play a key role for the generation of source-to-sink models describing the pathway of particulate matter discharged by the rivers to the ocean. The transformation of matter and energy in these zones of transition from the continent to the receiving marine basins depends on the dominance of the interfering main sources of energy governing the sediment dynamics: river (fluvial), tides and waves (Milliman and Farnsworth, 2013). For a comparison, three river mouth systems in high and low latitudes have been selected: 1) Pearl River Estuary (South China Sea) for tide-, 2) Odra River mouths (Baltic Sea) for wave-, 3) Yellow River Delta (Bohai Sea) for river-dominated systems. The position of these rivers within the ternal diagram (Figure 1) of the main influencing natural factors (wave / tide / river) is not stable, but varies on different time scales due to changes of the natural environment and anthropogenic activities such as land claiming, damming of river water, and sand extraction.

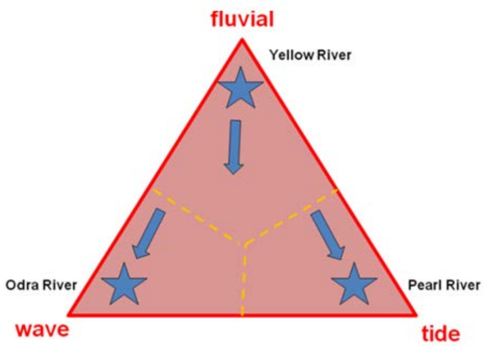

Figure 1. River mouth classification system by acting factors and current positions of Pearl River, Yellow River and Odra River. Arrows mark natural and anthropogenic changes of the environments

The Pearl River mouth has been changing the environment during the Holocene from a river dominated delta to a tide-dominated estuarine environment. Also natural changes in Holocene sea level dynamics and atmospheric circulation have caused a shift of the Odra River mouth from river to wave dominance.The Yellow River mouth starves of sediment load since damming up-streams reduces the discharge of suspended matter to the Bohai Sea. So, the influence of wave and tide dynamics is replacing fluvial influences increasingly. Complex sequence stratigraphic models reflect the influence of sea level change, neotectonics, sediment supply, hydrographic dynamics, and anthropogenic activities and allow not only the reconstruction of paleogeographic developments, but also future projections. These scenarios base on weighted impact factors according to the setting of the river mouth system under investigation and the socio-economic development of the drainage basin and corresponding coastal areas. As a prerequisite, comfortable models of climate change scenarios have to be used for the parameterization of the models. Historical data and proxy-based reconstructions of paleo-geographic environments provide the frame for model validations. Case studies demonstrate the dynamics of the tide dominated Pearl River and the wave dominated Odra River mouth systems as well for historical hindcast as for future scenarios. Scenarios of the development of the increasingly anthropogenically affected Yellow River mouth are discussed.

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The dynamics of the coastline of the Eastern Gulf of Finland: The natural processes and human activities on the natural disasters prevention

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1. Introduction

Reconstruction the dynamics of the coastline Eastern Gulf of Finland, in particular the Kotlin Island and the Neva Bay (coastal part of the Saint-Petersburg agglomeration), based on: the paleogeographic data, the data of long-term instrumental observations over the level of the Baltic Sea, covers the period in 100-200 years, literary and archival data, satellite images of recent decades showing anthropogenic changes.

Shoreline change of the Eastern Gulf of Finland in the post-glacial time associated with a complex combination of vertical glacioisostatic tectonic movements and fluctuations in water level due to the melting of the glacier. Contemporary Gulf coastline generally determined at the end Litorinal time. After lowering the level of Litorinal sea about three thousand years ago, to date, there were only minor fluctuations in the level of 3-5 meters. At the present stage eustatic factors (evaporation, precipitation, river water tributary, water exchange) have a determining influence on the trend level of the Baltic Sea (Kaplin P.A. et. al., 1999, Gordeeva S.M. et. al., 2010).

Due to 300 years of human activity associated with the development of the city of St. Petersburg, construction of embankments and quays the natural features of the coastal zone of the Neva Bay has undergone significant changes. Recent decades building the Complex of protective constructions against floods (giant dam), creating artificial inwashed areas radically change coastline of the Neva Bay.

Periodic fluctuations in sea level (storm surge, seiches), reaching 5-6 meters amplitude (Spiridonov M.A. et. al., 2004) also have an impact on the coast of bay. Therefore, the problem of natural disasters like floods is traditional for St. Petersburg.

2. Conclusions

In the dynamics of changes in the coastline of the Eastern Gulf of Finland on the basis of the relation of natural processes and human activities (in many ways caused by the need to protect against floods) can be distinguished several periods. 1. Formation of natural coastal zone in post-glacial time, the appearance of the main features of the present coastline. 2. Technogenic period (over 300 years), caused by the foundation and the development of St. Petersburg. 3. Intense changes of the coastal zone in recent decades caused by the construction of protective structures against floods (1979-2011) and the creation of artificial dry land in the water area.

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Valuation of environmental damage from the Penglai 19-3 oil spill, China

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The most recent Penglai 19-3 oil spill has not only devastating economic impact on local aquaculture, but also severe consequence of environmental damages in the Chinese Bohai Sea. Nearly 840 km^2 coastal water and 154 km beach were polluted by spilled oil. In this paper, we transferred our previous valuation result in the Bohai Sea coastal waters and beaches to estimate the short-term economic cost for environmental damages. The environmental damages arising from the Penglai 19-3 oil spill was estimated to be ￥$10.6*10^8$ in a conservative way.

Analysis of social response to the threat of flooding , abrasion and methods coastal management, Hel Peninsula, Poland

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1. Introduction

This analysis was done under umbrella Theseus Project “Innovative technologies for safer European coasts in a changing climate”. The Hel Peninsula has an important role in the wave climate in the Gulf, providing shelter for the harbours of Gdynia and Gdansk The peninsula environment has particular value for tourism activities, and the maintenance of high quality recreational resources is an important part of coastal management for the area. The peninsula sand spit, 36 km long is located on the southern Baltic Sea at the western edge of the Gulf of Gdansk. It is mainly fed by longshore drift from the west. The whole peninsula (as well the Puck Bay) is recognized nationally and internationally as important and is designated as the Seaside Landscape Park and part of the NATURA 2000 network. A risk of breaching or other damage by storm surges, raising sea level or waves is an important local issue. The current width of peninsula at the root is 200 m and in the widest section at its head is about 2.6 km.

2. Coastal dynamic

Storm wave inflows and short-term overflows have taken place in the past; regularly occurring breaches were even perceived as an opportunity by local fishermen who used the breaches to operate easily on both sides of the peninsula. A major breach of the peninsula has been a concern for last few decades after several flood events in 70’s and 80’s and recent reports on the consequences of expected sea-level rise. The main concerns for Hel Peninsula are twofold: the erosion of dune system which protects low hinterland against flooding from the open sea, and on the bay side - moving ice banks which are dangerous for buildings, trees and the peninsula’s main road (Basiński, 1995). These issues are especially important for tourism business as the investment in tourism facilities has grown in recent years.

3. Coastal management

The peninsula coast is currently protected against open sea hazards mainly by natural and engineered dunes supplemented by traditional groins and small sections of sea walls and revetments. In the recent years artificial beach nourishment has also been carried out. The coast on the more sheltered Puck Bay side is either natural (very western part with reed bed habitats) or managed with occasionally implemented measures like tony revetments, land reclamation and sections of dikes (protecting the built up areas). The coastal defense system of Hel Peninsula evolved over time. Between 1946 and 1970, along 12.3 km of the Peninsula’s seaward coastline, 161 groins were built and at the root of the peninsula a 420 m concrete seawall was constructed to protect the power plant site. After a catastrophic storm in 1983, the middle part of Hel Peninsula was protected by 1500 m long earthen dyke. In more recent years, the decreasing effectiveness of existing coastal defences has been observed, resulting in the erosion along nearly 80% of the first 23.5 km of the coastline (Boniecka and Zawadzka, 2006). After a pilot stage between 1984 and 1988, which tested different technologies and sources of sediment, since 1989 the beach nourishment is practiced regularly, and by 2010 the volume of sand nourished along the Hel Peninsula reached 15.4 million m^3 (more than 50% of total volume used along the whole Polish coast). The most intensively nourished was the root section of Peninsula coast (first 4km), where 510 m^3/m was placed in the period 1989-1993, and another 250-300 m^3/m in the period 2003 to 2008 (Ostrowski et al. 2011). This restored the shore profile and safety standards were achieved by raising the height of the dune foot to 1.8 m above mean sea level. Differences in the sand sources affected the design of the artificial beach. Grain size parameters for material initially borrowed from Puck Bay indicated that it could be moved relatively quickly during average conditions of wave and current. Since the mid 1990s therefore, a more coarse sand from open sea sites located at 20 m water depth, has been used. A part of sediment was taken from bypass system of the Port of Władysławowo to counteract losing of sediment transported from the western side of the port breakwaters. Although the area still displayed erosive tendencies, the extensive nourishment helped to improve the beach quality and therefore contributes to maintaining of the significant recreational values of protected coast.

4. SPRC model

The SPRC (Source-Pathway-Receptor-Consequence) model was used as the conceptual basis for an initial analysis of the flood system on the Hel Peninsula (Narayan et al., 2011). SOURCE (S): Ultimately the source of the flood events is the climatic condition producing the flood event, but those of interest to the coastal manager are those that directly generate potential flood waters. These have been divided into primary and secondary sources: PATHWAY (P): The pathway for the flood waters is the link between the source and the receptor and provides the route for flood water. This includes consideration of any relevant management infrastructure/regime and geomorphologic response. A pathway must exist for a consequence to exist. RECEPTOR (R): Receptors are what is located on the land that is flooded. This can include people, residential and non-residential properties, local infrastructure and natural habitats. CONSEQUENCES (C): Consequences are the impacts such as economic, social or environmental damage /improvement which may result from a flood. Consequences are the result of the location and magnitude of exposure (i.e. severity of the flood event) and the susceptibility of the receptor (e.g. effectiveness of any engineered management/natural response within the system, ability to „absorb‟ the event). Consequences can be expressed quantitatively (e.g. monetary value), by category (e.g. High, Medium, Low) or descriptively.

Application of SPRC for the whole Hel Peninsula and consideration of historic flood evidence led to the identification of the root of the spit for a detailed SPRC study. This area was further divided into three sub-sections and a detailed SPRC analysis carried out to analyze and understand the linkages between main sources of flooding, the pathways and receptors.

Key Receptors on the peninsula were identified as the recreational beach, green areas (of different types and including valuable habitats), and as most vulnerable elements the road and rail tracks, the camping sites, small urban land use plots, and – last but not least – the Heat&Power plant. The analysis also show that breaching and overflow of water from both sides of Peninsula is possible. Taking into consideration flood risk from Puck Bay side road and railway track could create very good barriers for flooding waters if they could be constructed in adequate way. Before the railway construction, storm surges and waves very often caused the breaking of peninsula during the winter storm. Most serious damage is observed during almost each year during the autumn/ winter storm season. The main benefit of the SPRC conceptual approach was identification of the possible routes of flooding, and the different consequences of flooding at particular Receptors. It also showed which of the Source components required more detailed analysis. Its application was also utilised as a simple method for decision makers to understand the coastal flood system (with its direct and indirect future implications),

5. Local population's attitude to risk and coastal management

For coastal risk management, it is important to understand the local population's attitude to risk, including the way they understand the science and existing management structures. When identifying the sources of risk and therefore the scale of negative consequences, natural processes are perceived as the main cause by the majority of informers, followed by a combination of natural process and human actions (Figure 1.).

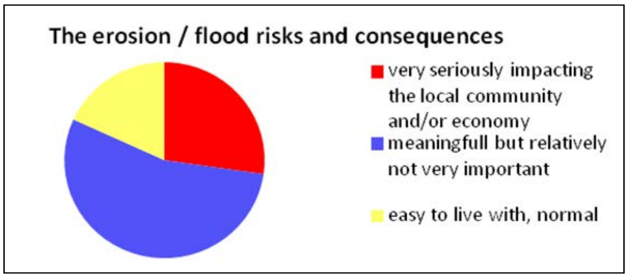

Figure 1. Relative importance of erosion/flood risks and consequences for interviewees (Hel Peninsula)

Only one stressed that humans are most responsible for "risky" image of such phenomena such as coastline fluctuation or different types of inundation.

The key points identified during the interviews for spatial planning and spatial management, are:

Flooding and coastal erosion risk management (FCERM) is relevant to spatial planning regulations at many levels, but there is almost no evidence of good practice – the more experienced in strategic decision making actors denied the consistence of these regulations. FCERM is not used in the current management practices of spatial planning (apart of designation of areas under impact of flood and earth slide). The idea of resilience is not known explicitly and/or not understood properly amongst planning actors, even those involved in the environmental management at decisive level.The spatial planners do not work in partnerships with other FCERM professionals when developing local spatial development plans. There are a few examples of stakeholder engagement in strategic planning process such as Local Agenda 21 or Integrated Coastal Zone Management, but unfortunately not in the framework of spatial planning, including even the quite innovative pilot study of MSP (maritime spatial plan) prepared for the region of Puck Bay. Long term development issues need to be addressed more creatively – including climate adaptation strategies - so far scenario analysis or envisioning have not been used in planning for the case study area.

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Coastal environment monitoring using HF radar system in the Yantai waters, China

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1. Introduction

The coast of Yantai waters have been tremendously changed in the last 30 years due to increasing aquaculture business, coastal tourism and other industries, which subjected to serious problems related to coastal erosion, seawater intrusion, and pollution. The bottom morphology also changed greatly because of continuously artificial reefs construction for the sea cucumbers habitat as a bloomy demand for the sea food, a large amount of stones and cement blocks have been transported to the coast for later dumping to the shallow water sea (Fig.1). The surface cage aquaculture changed the water quality and produce pollutants, structures placed in dynamic coastal waters will affect local hydrodynamics, altering bottom sediment bedforms, and benthic communities.

A sustainable coastal zone management is required by the government to assess the vulnerability and potential of the coastal zone utilization. For this purpose the effectiveness of innovative remote sensing techniques is needed for the long term coastal environment monitoring.

Figure 1. The cement blocks and stones on the coast waiting to be transported to the coastal waters for artificial reefs, the nearby is the HF radar transmit antennas.

2. Data and methodology

The Ocean Radar system is based on over-the-horizon radar technology and provides high resolution current maps for ranges of more than 200 km (Gurgel, et al. 1999). A ground HF WERA radar has been set up in the Yantai coastal waters for a long term coastal environmental monitoring network in the summer of 2013(Fig. 2), 5 months monitoring data provided huge amount of knowledge to the local authorities for sustainable coastal zone management. The radar works in 26.275 MHz and band widths 500k Hz, the detection range for current around 35 km, best detection of currents and waves in a range of 10 kms, which covers most of the coast aquaculture activities. A measuring campaign was done in the Sep/Oct in 2013 using high data sample collection, time step 1 hour and integration period 20 min, an ADCP was deployed in the coverage of the radar with a time period 4 months.

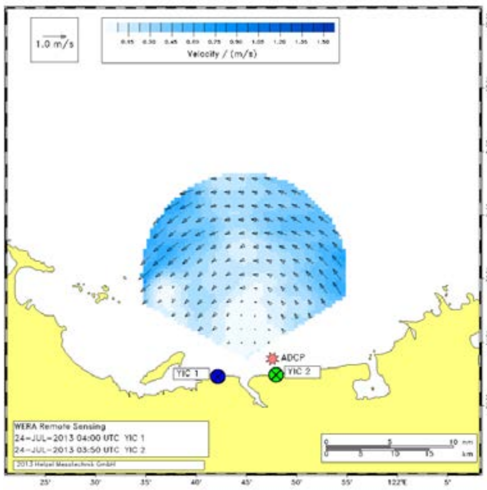

Figure 2. The coast current filed measured by the WERA HF radar in the Yantai waters

3. Result

Figure 2 shows an ocean current map derived from a pair of WERA (26.275 MHz, 12+4 antennas) at the Yantai coast. At about 5 km distance from the coast, an ADCP delivered data for comparison (Fig. 3) which show good accordance with the radar significant wave height data and prove their reliability. These continuous long term land based data offer a sound background for coastal dynamic modeling and later Decision Support System.

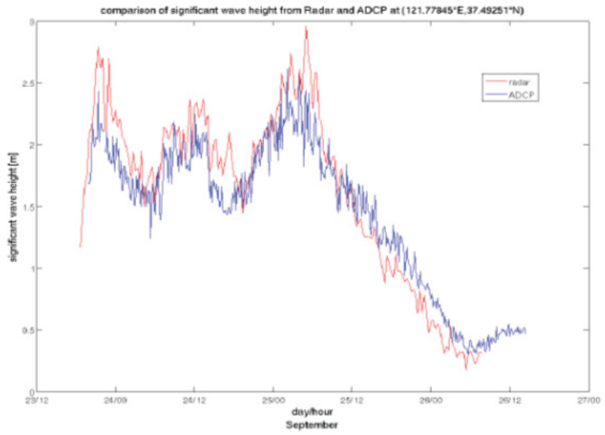

Figure 3. The comparison of significant wave height by the HF rada(red line) and ADCP(blue line)

4. Acknowledgement

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Determination of the snow melting intensity in nowadays climate conditions by example of the Neman river basin

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1. Introduction

Melting rate tends to be one of the main climate change characteristics, applied to the snow cover. This factor is important not only in theory but also has strong practical effect, determining the intensity and scale of snow-melt floods. Estimation of snow storage contributes a lot to the accuracy of flood modeling, taking into account the contemporary warmth, characterized by open winters and frequent thaws, changing steady trend of snow melting and flood formation.

As long as Neman is one of the typical rivers of Europe, revealing its way of flood development should allow to determine formation law of the snow-melting flood for Baltic Sea basin relevant rivers, making it possible to take into account recent climate changes for Baltic region.

Snow storage can be determined by the classical method of snow courses. This routine is time-consuming and therefore is not suitable for quick data acquisition. There is also substantial inequality of snow distribution within the water shed, caused by different formation conditions: different landscapes, anthropomorphic activity, etc. This inequality makes it unviable to spread or interpolate such measurements of snow depth to the whole water shed. The alternative is made by remote sensing of the Earth surface, both in optical and microwave band. Such obvious advantages of microwave diagnostics as possibility to get information in any time, wide weather conditions range, and sunshine independence, have brought a lot of attention of the researchers to it.

Snow storage is estimated using space observations for a long time, particularly based on passive microwave radiation measurements with use of MODIS SSMR and MODIS SSM/I platforms, according to Kitaev et al. (2010). This approach provides general estimation of the snow storage distribution upon a water shed. There is an archive of observations of the water equivalent dynamics for the Northern hemisphere in public access for the 1976-2011 years period (http://www.globsnow.info). These data are combined from on-ground meteorology stations and satellite passive measurements of microwave radiation SMMR and SSM/I. The archive is a set of matrices of 721×721 elements with average value of the snow cower depth water equivalent in millimeters. Thus, one cell is corresponding to 625 km^2 area, which can be practically used only for large water sheds.

While development of the software for flood monitoring and prediction system described by Volchek et al. (2010, 2013), we have tested an approach to determine snow-melting factors on the basis of combined analysis of snow water equivalent values and average daily temperature distribution on the territory of transboundary water shed of the Neman river. Data of the water equivalent distribution where taken from GlobSnow project, while the archive of daily observations of European meteorology stations, accessible through the European Climate Assessment & Dataset project (http://eca.knmi.nl) was used as a source of temperature values.

2. Methodology of the research

188 cells where chosen from the GlobSnow archive, which are covering the specified water shed area. Observations from 29 meteorology stations in Belarus and Lithuania where used to determine average daily temperature. Temperature value for each cell was calculated by interpolation of observed daily average values. To calculate temperature factors of snow cover melting, the gradient of the water equivalent registered value was estimated along with two neighboring axis characterized by positive daily average air temperature. For the cases with decrease of the water equivalent value, the temperature factor of melting was calculated in millimeters of the water equivalent per degree of positive average daily temperature.

Described method demands pairs of water equivalent values, which are acquired with an interval of one day. Due to this reason years from 1979 to 1986 where excluded from consideration, as having only two-day interval values in GlobSnow archive. Therefore values of snow melting temperature factor for the cells of the research-covered territory where accumulated for years 1987 – 2011.

Resulting average values of the snow melting temperature factor for this period are between 0.042 and 597.461 mm of the water equivalent per degree of positive average daily temperature.

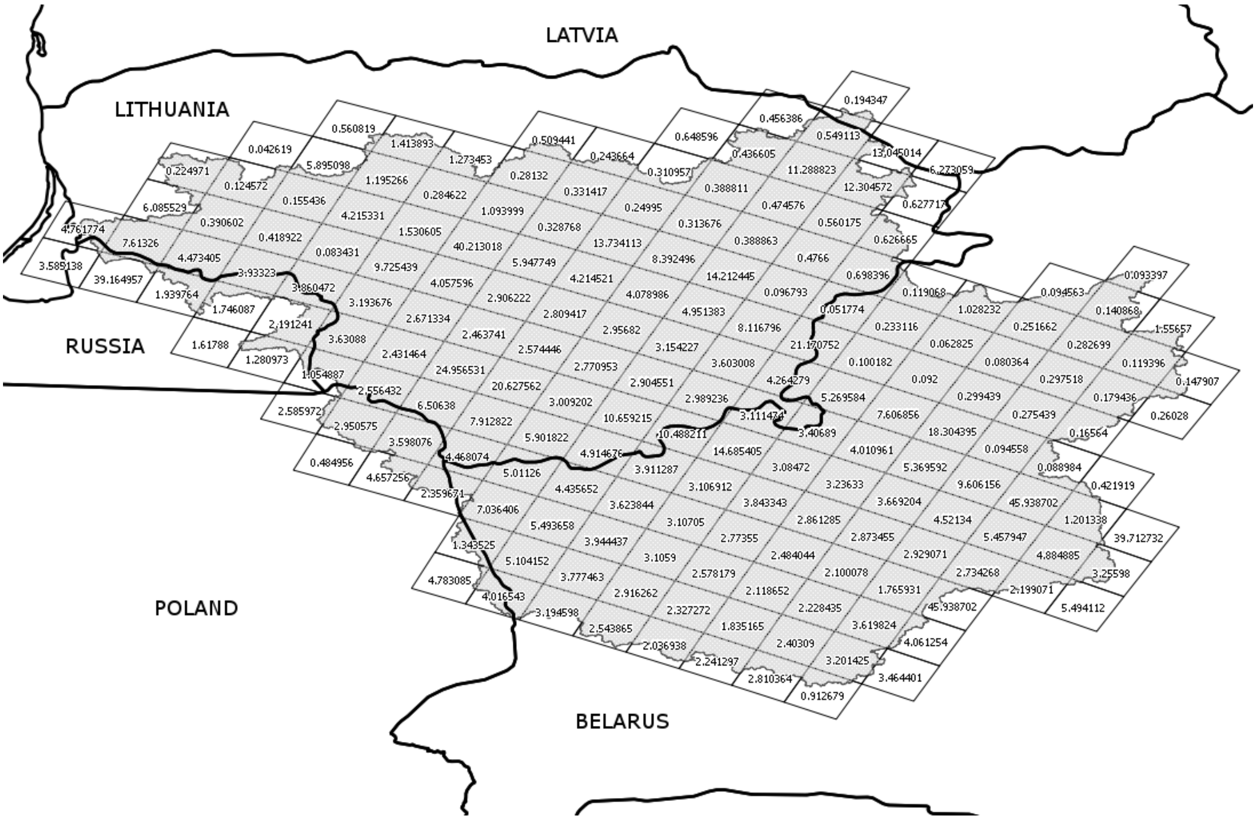

Figure 1. Distribution of average degree-day melting factor for the Neman river water shed area

A clearly anomalous value of 597.461 mm per degree was registered for the cell having center with 53.053°N, 26.549°W coordinates.

3. Verification of the results and final correction

To get primary confidence rating of the estimated average values of the melting factor we have carried out further search of anomalous data. To determine the abnormality of cell values a theoretical maximum of possible snow melting intensity was calculated. Simplified equation of daylight time snow melting, proposed by E.G. Popov was used, as described by N.F. Befani & G.P. Kalinin (1965):

$$h_d = 7.1[(1-\beta)(\theta_{max}-\theta_{daily}-0.2)-0.2(\theta_{daily}-\theta_{min})+ +0.1\omega_d(\theta_d-0.5)] \text{ mm},$$

where β is albedo of snow in unit fraction, θ_{max} and θ_{min} are maximal and minimal air temperatures, θ_d and θ_{daily} are average daylight hours air temperature and average daily air temperature, ω_d is average wind speed on the air vane height for daylight hours. β value was taken equal to 0.1 (0.2, 0.1 are mixture of snow with water and snow covered with a thin water level), θ_d was taken equal to θ_{daily}, and average daily wind speed was taken as ω_d. One can notice that chosen values correspond to maximally possible amount of water produced from melted snow.

Theoretical maximum of possible value for the Neman river water shed equal to 91.877 mm per degree of positive average daily temperature was obtained as a result.

Correction of observed average snow melting factors along with calculated maximal snow melting intensity value was applied only for two cells (53.053°N,26.549°W and 56.262°N,20.760°W with melting factor average values of 597.461 and 111.339). Final distribution of the average snow melting factors can be seen on the figure 1.

Thus we can state that snow melting intensity, calculated on the basis of passive microwave scanning does not generally exceed the theoretically possible one and can be used in combination with snow surveys to apply available data for relatively small territories.

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The dynamic distribution of green tides in Yellow sea and East China Sea and its relations to marine water quality conditions

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The incident of super green tide caused by green macroalgae happened every year in Yellow Sea and East China Sea since 2007. The multi-temporal, multisource and multi spatial resolution remote sensing data were used to analyze the characteristic of temporal and spatial dynamic distribution of the green tide. The conclusions are given below. 1. The Jiangsu Shoal is the source of the large scale green tide; 2. the area influenced by green tide ranges from 29 °N to 37 °N, extending to the east as far as the coast of South Korea, as shown in Fig.1; 3. In late April and early May, driven by the Subei coastal current and Northeast Asia monsoon, the green tide arrives at areas off the Chinese coastline; with the increase of summer monsoon, the green tide moves towards northeast and influences the Yellow Sea; 4. the satellite images of maximum daily instantaneous covered area shows that the most severely influenced area is the offshore of Qingdao in the south of Shandong Peninsula. This influenced area varies in different years and the largest green tide occurred in 2008.

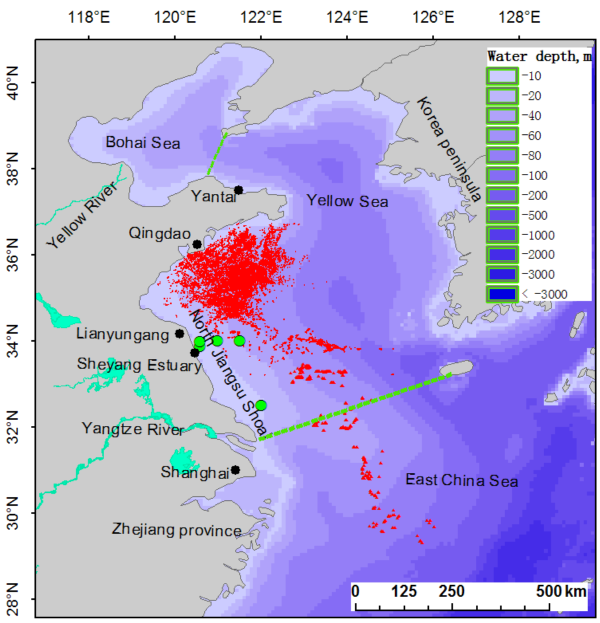

Figure 1 The region impacted by green macroalgae (red patches)

Nutrients have been the dominate pollutants in Chinese coastal waters in the past ten years, controlling the offshore water quality. Based on the water quality levels and corresponding area annually published by State Oceanic Administration of China(example shown in Fig.2), an area-weighted water quality index was devised to denote the nutrient pollution. The results indicate that the nutrient pollution in the great Yellow sea (including the Yellow sea and Bohai Sea) has been increasing since the year 2001. It also shows that the multi-year averaged pollution index in the period of green tide (from 2007 to 2012) was 40% higher than that before the breakout of green tide (2001-2006). Meanwhile, the concentration of nitrogen and Phosphorus in the water off Jiangsu Province, which is the source of green tide, was increasing rapidly; the concentration of PO4-P increased by three times from 2000 to 2011.

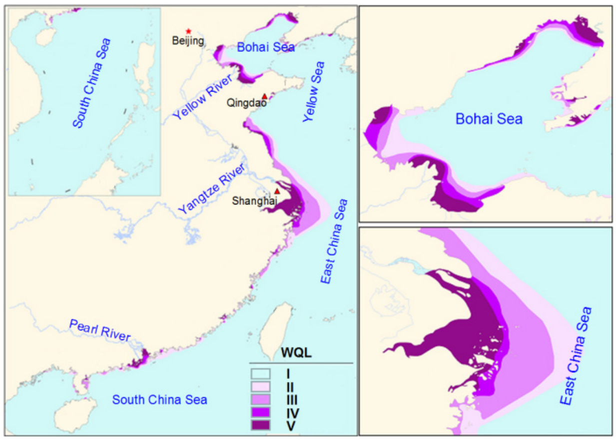

Figure 2 Coastal marine water quality levels in 2007 .

The Chlorophyll concentration derived from satellite remote sensing can be a indication of eutrophication. The analysis demonstrates that the relatively low nutrient sea water (low Chlorophyll concentration) in great Yellow Sea have a trend of remarkable eutrophication; in the severely afflicted areas, the Chlorophyll concentration in the period of large scale green tide (from 2007 to 2012) was much larger than that before outburst of green tide (2001-2006). The Chlorophyll concentration further indicates the eutrophication level in East China Sea and middle Yellow Sea is low, which may be one of the reasons that the macroalgae can reach these areas but not cause a disaster of large scale green tide.

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Session D

Climate change and regional planning

Effects of climate change on atmospheric nitrogen deposition to the Baltic Sea

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1. Introduction

Excess reactive nitrogen (Nr) and Phosphorus input into the Baltic Sea basin is the main reason for eutrophication, probably the most serious environmental problem of this Sea at present (HELCOM, 2009). The Phosphorus input is mainly waterborne, whereas 20-30% of Nr enters the Baltic Sea basin via atmospheric deposition (Bartnicki et al., 2011). Therefore, the monitoring of atmospheric Nr deposition to the Baltic Sea is important for evaluation of the eutrophication status.

Modelling of atmospheric deposition to the Baltic Sea has been a subject of long term cooperation between HELCOM and EMEP. In the frame of this cooperation, annual depositions of Nr to the Baltic have been calculated, using the EMEP MSC-W model (Simpson et al., 2012), every year since 1997 and reported to HELCOM. The latest results are available for the period 1995-2011. Not only information about the past and present Nr deposition is important for HELCOM, but estimation of the future deposition as well. This future deposition is determined by several factors, such as changes in nitrogen emissions and changes in climate conditions.

In the study, we have used the results of the EnsClim project, where four air pollution transport models were used (EMEP MSC-W, MATCH, SILAM and DEHM), with EMEP, MATCH and SILAM driven by downscaled climate meteorology from the Swedish RCA3 model (see Simpson et al., 2014 for details). Here we use the results from one model only, EMEP.

In the frame of the EnsClim project the depositions of many pollutants including Nr were calculated first for the reference year "2000" (average of 1990-2009). Next, depositions were calculated for the year "2050" (average 2040-2059), with projected climate changes taken into account in the meteorological input.

2. Effects of the climate change

Based on the EMEP model results from EnsClim (Simpson et al. 2014), different types of Nr deposition to the Baltic Sea basin and its nine sub-basins were calculated for the reference year 2000 and for the year 2050 with projected climate change. Annual depositions of oxidised dry, oxidised wet, reduced dry, and reduced wet nitrogen were calculated for each model grid belonging to the Baltic Sea basin. In addition, annual deposition to each of nine sub-basins and to the entire basin of the Baltic Sea were calculated for both years. The difference between deposition in the year 2050 and year 2000 is a measure of the climate change effects. The map of annual deposition of total nitrogen to to the Baltic Sea basin is shown in Fig. 1.

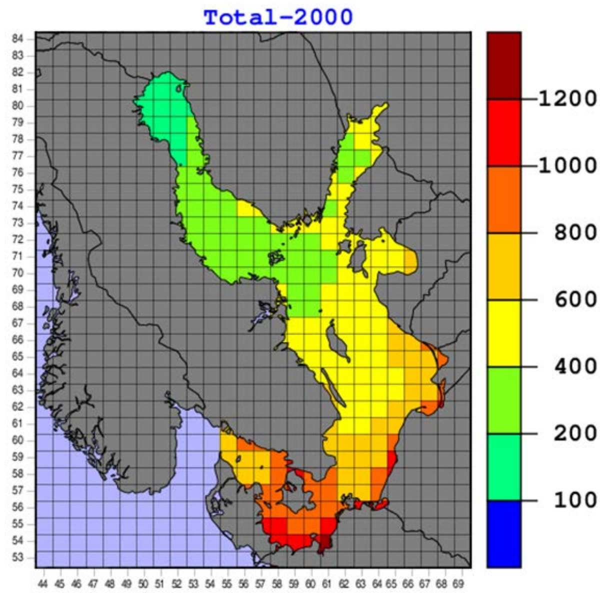

Figure 1. Calculated annual deposition of total nitrogen for the reference year 2000s simulations.

Calculated annual total Nr deposition to the Baltic Sea basin was 213.5 kt N in 2000 and 211.8 kt N in 2050, indicating rather small direct effect of the climate change: -0.8% of 2000 deposition. The changes were slightly larger for individual sub-basins, especially for reduced wet nitrogen deposition to the Gulf of Finland (-6.2%) and (-5.9%) sub-basins.

Generally, the changes in wet deposition were more significant than changes in dry deposition. This is illustrated in Figs. 1 and 2 with the maps of relative differences in dry and wet depositions of reduced nitrogen between the years 2050 and 2000. The increase (4-8%) of both dry and wet deposition as effect of the climate change can be observed in the Northern part of the Baltic basin – in the Bothnian Sea. There is also an increase (2-8%) in the Kattegat sub-basin and fro wet deposition also in Western Baltic sub-basin. Similar increase of wet deposition can be noticed in the Gdansk Bay.

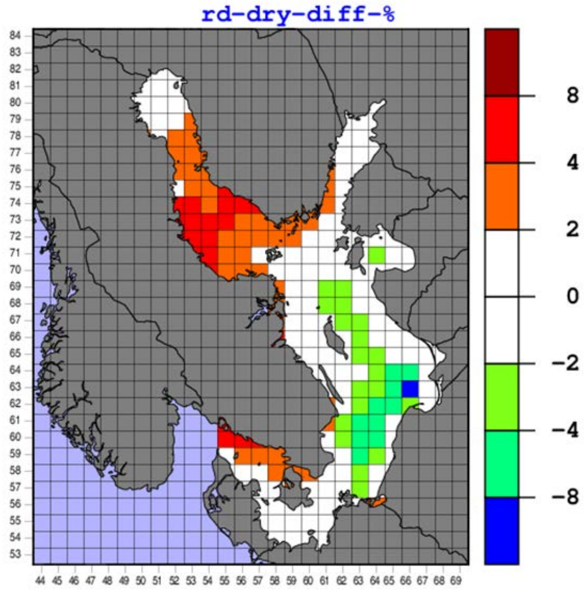

Figure 2. Relative differences between reduced dry nitrogen deposition in the year 2050 and the year 2000, in per cent of 2000 depositions.

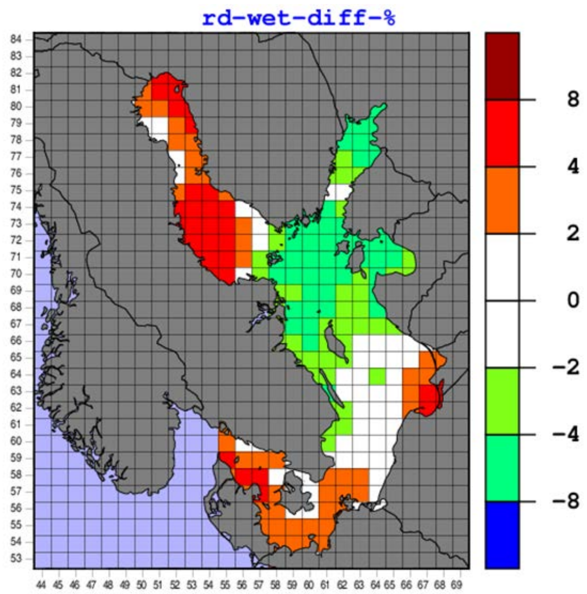

Figure 3. Relative differences between reduced wet nitrogen deposition in the year 2050 and the year 2000, in per cent of 2000 depositions.

The climate change makes the dry deposition of nitrogen lower (2-8%) in large part of the Baltic Proper sub-basin. Wet deposition is lower (also 2-8%) in the Northern Baltic Proper as well as in the Gulf of Finland and Gulf of Riga sub-basins.

The climate effects on total Nr deposition (Fig. 4) indicate the increase (2-4%) in the Bothnian Sea sub-basin and in the Bay of Gdansk. Total nitrogen deposition is lower (2-8%) in the Northern Baltic Proper and in the eastern part of Gulf of Finland sub-basin. There is also a decrease of total deposition in the Gulf of Riga sub-basin.

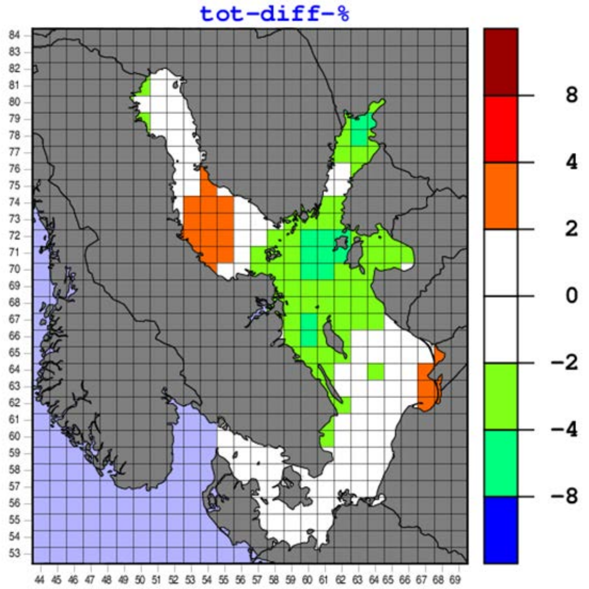

Figure 4. Relative differences between total nitrogen deposition in the year 2050 and the year 2000, in per cent of 2000 depositions.

4. Conclusions

The effects of climate change alone practically do not change the annual amount of reactive nitrogen deposited to the Baltic Sea basin, at least with prescribed emissions. The effects of climate change are mostly visible in reduced wet and oxidised wet deposition of nitrogen. They are much lower than the effects of other factors responsible for changes in future Nr deposition e. g. inter-annual variation of meteorological conditions and especially nitrogen emission changes.

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Multiyear trends and variability in the Baltic Sea level derived from satellite radar altimetry and ocean model

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1. Introduction

Sea-level rise is one of the most direct consequences of climate change. It has been documented that sea level rise is globally subject to considerable spatial heterogeneity. There is an increased awareness of the need to create regional data records and projections of sea level trends, because specific regional processes can cause that the regional trends diverge significantly from the global averages. Sea-level change is an issue of increasing scientific and societal importance, due to its potential impacts and its links to a variety of processes, ranging from climate change to coastal erosion and flooding. Understanding of sea level trends and variations in the Baltic Sea is also important because of the links with the mechanism of exchange of water between the Baltic and the North Seas, which in turn influences stratification and water circulation.

2. Results

Most of the previously published work on sea level variability in the Baltic Sea has been based on the tide gauge data. However, tide gauges are located on the coastline, and these observations always include coastal effects such as land movements, or wave and wind surges. In recent years, the availability of satellite observations has considerably improved the understanding of the main drivers of the global mean sea-level rise and variability. Satellite altimetry permits the avoidance of many of the problems associated with the use of tide gauges (related to tectonic uplift, regional postglacial rebound, storm surges etc.).

In this presentation the available multimission satellite sea level anomaly (SLA) data (from AVISO) were used to estimate multiyear trend in the Baltic Sea level. The estimated trend is about 0.33 cm y-1, similar to the globally averaged sea level trend, but significantly larger than the regional trends estimated in the North Sea and North Atlantic (Stramska and Chudziak, 2013). The decadal scale variability in the sea level trend in the Baltic Sea does not indicate a significant acceleration of the trend in recent years. Our analysis confirms that the interannual variability of sea level in the Baltic Sea in winter is significantly correlated with the North Atlantic Oscillation index. Our results indicate that there is a well-pronounced seasonal cycle in the 20-year averaged sea level and in its standard deviation (Stramska et al. 2013, Stramska 2013). The average annual SLA amplitude in the open Baltic Sea is about 18 cm. The seasonal cycle of the SLA in the Baltic Sea is asymmetric in shape. In the autumn and winter (about 240–260 days per year) the 20-year average daily SLA are higher than the 20-year average SLA. In the spring and summer (about 100–120 days per year), the 20-year average daily SLA are lower than the 20-year average SLA. A similar asymmetry of the seasonal cycle is not observed in the North Sea and North Atlantic SLA data. The annual pattern of the sea level variability in the Baltic Sea is evident if one considers multi-year average time series, but in some years the cycle is not observed.

Figure 1. Map showing the geographical positions corresponding to the time series data used in this study (based on Google Maps).

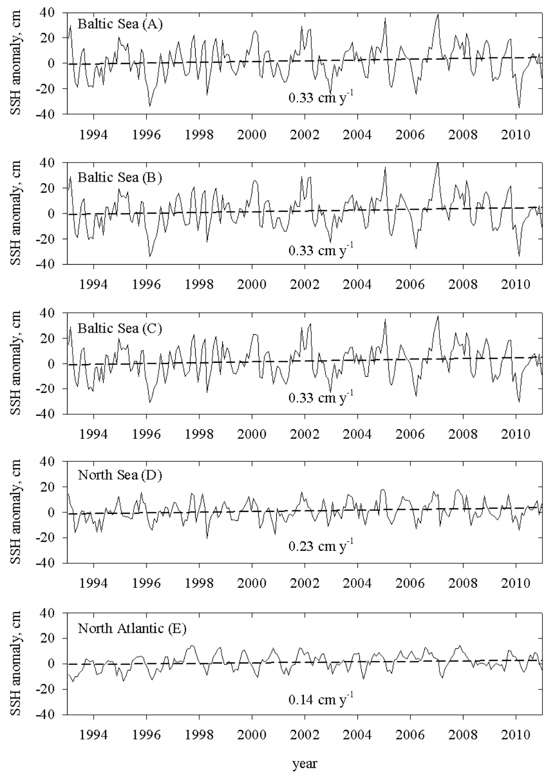

Figure 2. Time series of the monthly averaged sea level anomalies estimated from the merged mission satellite altimetry data in the Baltic Proper (stations A, B, and C in Figure 1) in years 1993-2012. For comparison similar time series in the North Sea (station D) and the North Atlantic (station E) are also shown.

The analyzed satellite data have been compared with the recent simulations with the Community Climate System Model (CCSM) adapted to the Baltic Sea at the Institute of Oceanology of the Polish Academy of Sciences. Although the model seems to underestimate the amplitude of the short-term variations of the SLA, the multiyear trend and the seasonal variability patterns are similar in the model and in the observational data. Presently we are conducting a series of controlled numerical experiments to improve understanding of the mechanism behind the observed sea level variability patterns in the Baltic Sea.

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Acknowledgments

This work was supported through the SatBaltic project funded by the European Union through the European Regional Development Fund, (contract No. POIG.01.01.02-22-011/09 entitled ‘The Satellite Monitoring of the Baltic Sea Environment’). We are grateful to the AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic data, www.aviso.oceanobs.com), for making available the data used in this study.

Influence of climate change on urban surface runoff pollution in the City of Brest, Belarus

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1. Introduction

In temperate climate countries, climate change has been proved to shift spatial and temporal distribution of water in river basins (Kundzewicz et al., 2007) and to have an adverse influence on surface water quality. The increase in concentration of organic matter, micropollutants and pathogens has been detected relatively to more frequent heavy rainfalls and temperature increase (Huntington, 2006; Chang et al., 2010; Delpla et al., 2009). For the Baltic Sea region, variation in water streams quality can have impact on Baltic Sea pollution because significant amount of pollutants arises from river runoff.

In the city of Brest surface runoff from the city territory contributes significantly to the pollution of the receiving river waters. The aim of this paper is to estimate if the pollution that arises from surface water runoff is influenced by climate change in the city of Brest, Belarus.

2. Data and methods

Brest is the city situated at the south-west of Belarus. Brest stands on the river Mukhavets, the river of the Baltic Sea catchment. Mukhavets is the tributary of the Western Bug river, which falls into Narew river near its confluence with Vistula.

Almost all the surface runoff from the city of Brest is discharged to the r. Mukhavets, being only partly treated. Long-term monitoring of quality of Mukhavets river water indicates increased concentrations of several pollutants, which overcome national regulation limits. As Mukhavets is the river of the Baltic Sea catchment pollutants detected in it can be engaged in transboundary element transport and contribute to the pollution of the Baltic Sea.

Climate change in the Baltic Sea region is a subject of thorough study in Europe, as well as quality of urban surface runoff. For water resources management, and especially for adequate treatment of surface runoff it is very important to understand if surface runoff quality is influenced by climate change, because the information can be essential for decision making.

It is quite difficult to estimate how the extent of pollution of runoff is influenced by changing temperatures. For that reason, we analyzed meteorological data of last decades to find changes in meteorological events pattern, which can directly influence the extent of pollution of surface runoff in Brest and as the sequence quality of water of the r. Mukhavets. Runoff quality differs strongly in summer and winter period that is why meteorological events were analyzed separately for summer and winter period. For example, for summer period frequency of precipitation and of extreme weather events were calculated, and for winter period frequency of precipitation and the amount of thaws. Then the trends in meteorological data were analyzed together with surface runoff analyzes data to estimate if the change in meteorological events can have influence on surface runoff quality.

3. Conclusions

On the basis of our analyses we can conclude that climate change has an impact on surface runoff quality in the city of Brest. Climate change trends should be considered for surface runoff treatment and water resources management. There is certain lack of information, especially about pollutants found in surface runoff and their fate after they enter water streams, that is why that issue requires further more detailed investigation. However, obtained results show that any environmental research in XXI century hardly can be completed without assessment of climate change impact.

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The cyclical nature of seasonal precipitation in Pomerania in the period 1951 – 2010

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1. Introduction

The ongoing warming of climate, as the most spectacular expression of the global as well as regional changes of climate, was empirically found in the climatic conditions of Poland. The increase in temperature which is most prominent in the summer months is not accompanied by statistically significant changes in the monthly sums of precipitation. The literature on the subject includes various assessments of multiannual variability of the amount and frequency of precipitation based on multiyear series of data, including the first decade of the 21st century, and concerning various time periods (months, years). The assessments indicate that the pluvial regime in Poland does not show statistically significant changes and the directions of the slight tendencies vary depending on the adopted period of study and region (i.e. Boryczka and Stopa-Boryczka, 2004, Degirmendžić et al., 2004, Kirschenstein and Baranowski, 2005, Żmudzka, 2009). The opinions concerning the increasing variability of precipitation, as well as the weakening of the continental and strengthening of the oceanic features of the pluvial conditions expressed by means of variability and irregularity coefficients and the proportion of total precipitation: warm half-year to cool half-yea, summer to winter, autumn to spring, and July to February (Czarnecka and Nidzgorska-Lencewicz 2012), are not statistically substantiated. The changes in the basic features assessed with the use of linear trend are not statistically significant due to the fact that the changes of the most labile element of the climate can be expressed as irregular fluctuations (Kożuchowski 2004, Ziernicka-Wojtaszek 2006). Therefore, the aim of the present paper is an attempt to detect the recurring fluctuations in seasonal total precipitation in Pomerania with the use of spectral analysis.

2. Materials and Methods

The basic material consisted of monthly sums of atmospheric precipitation obtained from 9 IMGW weather stations from the period 1951 – 2010. The sums of precipitation in four calendar seasons were analysed, namely: spring (March – May), summer (June – August), autumn (September – November), winter (December – February), and the ratio of precipitation sums: warm half-year (April – September) to cool half-year (October – March), summer to winter, autumn to spring, and July to February.

3. Results

The results of the spectral analysis made with the use of a functional series mode revealed a significant cyclical nature of precipitation. The changes in the annual and seasonal total precipitation as for mean values obtained from 9 stations representing the area of Pomerania occurred in the period 1951-2010 in cycles of various length: annually – 10-year-long, in spring – 15-year-long, in summer – 10-year-long, in autumn – 30-year-long, and in winter – approximately 7-year-long (Fig. 1). However, only in the period of calendar autumn the 30-year-long cycle was clearly predominant.

Additionally in spring, apart from the 15-year-long cycle, a 30-year-old cycle was prominent. The cyclic elements varied between stations and their length in individual seasons of a year ranged from 6 to 30 years. The total annual precipitation as recorded in most of the stations changed in 10-year-long periods, yet the cycles of this length were not the most prominent. The same cyclic nature of precipitation was found in all of the stations – 15- and 30-year long. However, depending on the station, the shorter or the longer period was most prominent. The cycles characteristic for autumn precipitation (the longest) and winter precipitation (the shortest), averaged for Pomerania, were found in most of the stations. Summer precipitation was characterised by the greatest diversity in terms of cyclicity. In almost all of the regions represented by meteorological stations taken into consideration, total summer precipitation changed in cycles of 5.5, 6, 7.5, 8.5, 10, 20 and even 30 years. The analysis of periodograms and spectral density charts indicates that every season, apart from clearly predominant cycles, cycles of different length were also present – in most cases the cycles were very short due to very high interannual variability of this element.

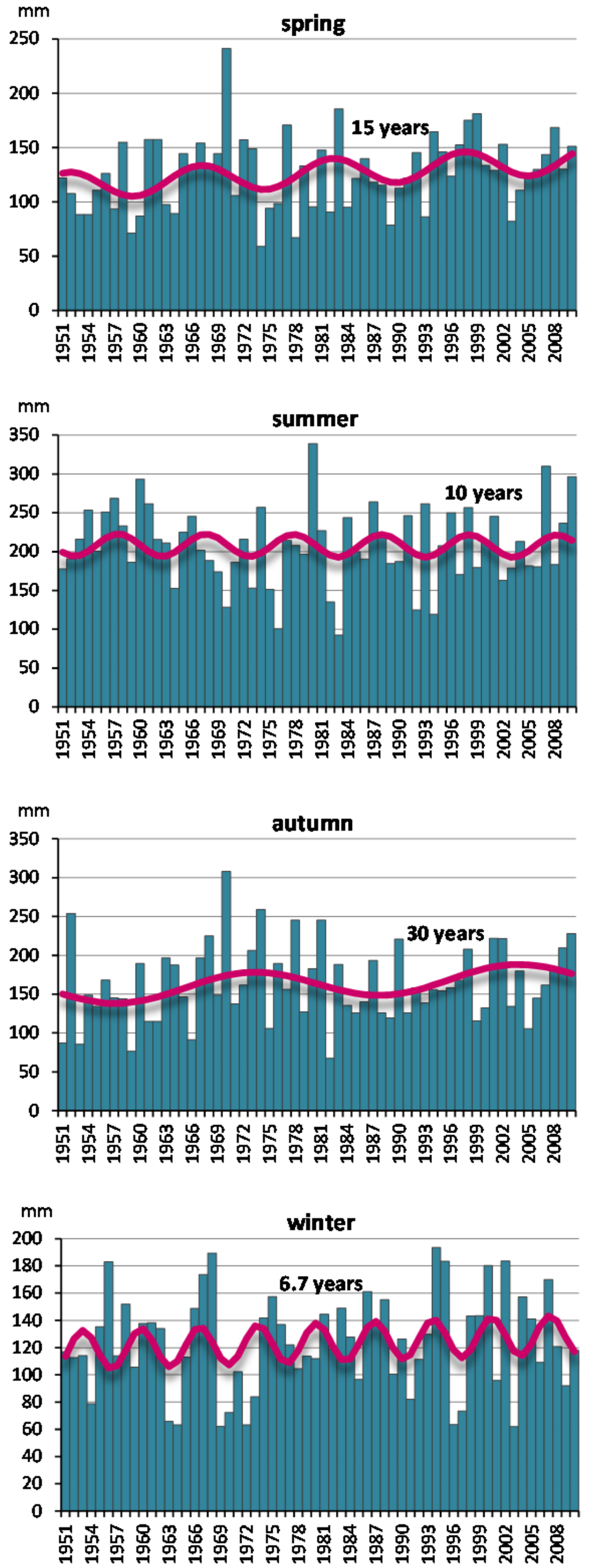

Figure 1. Seasonal sums of precipitations with cycles in Pomerania

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Future Wave Climate Projections at the German Baltic Sea Coast on the Basis of the Regional Climate Model Cosmo-CLM

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1. Introduction

In this study future wave conditions are presented that provide a data basis for a scenario based assessment of the effects of regional climate change on the functional and constructional design of coastal protection structures but also for the assessment of the potential long-term morphological development of the German Baltic Sea coastline.

2. Method

A wave model for the area of the Western Baltic Sea is set up using the 3rd generation spectral wave model SWAN (Booij et al., 1999) with a high temporal and horizontal resolution. The local wave model is nested into a coarse wave model for the whole Baltic Sea. The coarse model is run by the Helmholtz-Zentrum Geesthacht (Groll et al., 2013) using the wave model WAM (Hasselmann et al., 1988).

As input data both wave models use dynamically downscaled near-surface wind (Lautenschlager et al., 2009) from the regional climate model Cosmo-CLM (Rockel et al., 2008) The wave parameters (significant wave height, mean wave direction and different wave periods) are calculated for the future (2001-2100) and actual conditions (1961-2000) on the basis of the SRES emission scenarios A1B and B1 (Nakićenović et al., 2000).

To extract the climate change signal, the relative changes of both annual and seasonal average significant wave heights between two reference periods (1961-1990, 1971-2000) and the future values for the scenarios 2050 (2021-2050) and 2100 (2071-2100) are calculated.

Moreover the relative changes of extreme significant wave heights with a return period of 200 years are calculated and assed for time periods of 40 years at selected locations along the German Baltic Sea coast using methods of extreme value analysis.

3. Results

The results show in general increases of the annual average significant wave heights at locations exposed to westerly winds (cp. Figure 1, top and bottom). The largest increases occur for the SRES emission scenario A1B.

Moreover the changes of the average significant wave heights are depending on the season and are within the range of +1% to +9% compared for the future (2071-2100) with actual conditions (1971-2000). The smallest changes occur during summer and the largest changes occur during winter (cp. Figure 1, bottom).

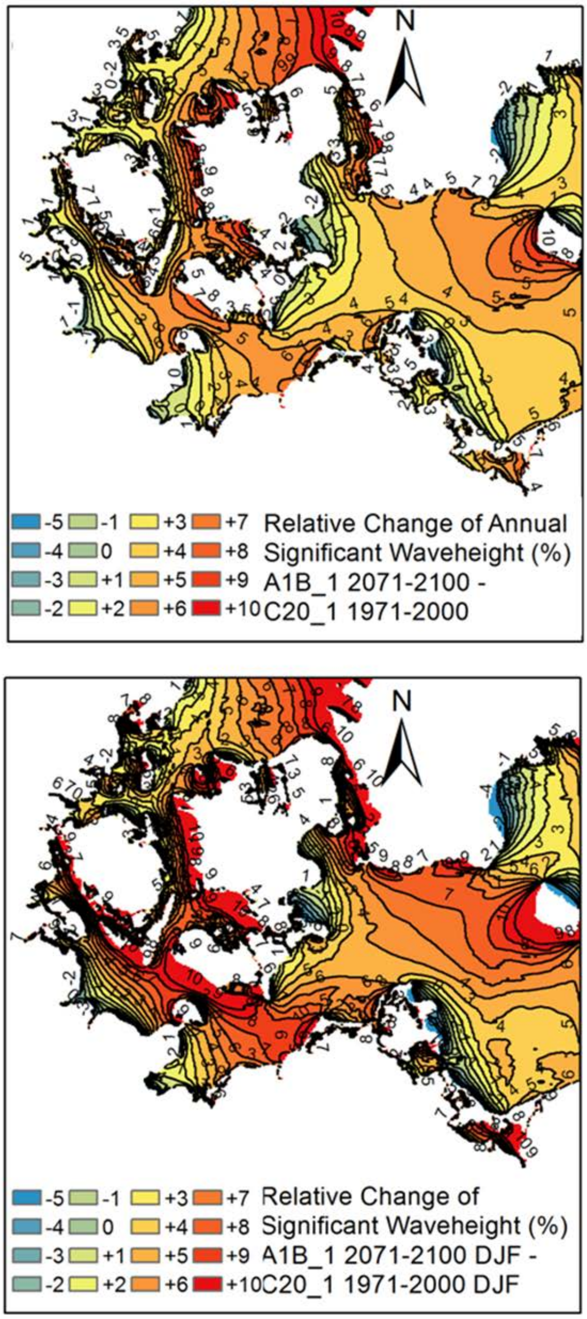

Figure 1. Changes of the annual average significant wave heights (top) in the area of the Western Baltic Sea and changes during winter (bottom) for the first realisation of the SRES emission scenario A1B to the end of the 21st century (2071-2100) compared to actual conditions (1971-2000).

The annual mean wave directions change within the range of 3° to 6° towards more wave westerly directions.

In contrast, at locations exposed to easterly winds, the annual average significant wave heights can change down to -2% and the changes of the annual mean wave directions are within the range of 1° to 2° towards more easterly directions.

The climate change signal for the average wave conditions is more dominant to the end of the 21st century (2071-2100) than compared with other future scenarios (e.g. scenario 2050: 2021-2050).

The results from the local wave model are in good agreement with the results from the coarse wave model for the whole Baltic Sea using the same wind input data (Groll et al., 2013).

The changes of extreme wave events are within the range of -15% to +15% and are depending on the location, emission scenario, realisation and the future time period which is used for the comparison to the actual conditions.

4. Acknowledgements

The work described was conducted within the joint adaptation project RADOST (Regional Adaptation Strategies for the German Baltic Sea Coast). The project is founded by the German Ministry of Education and Research (BMBF, grant nr. 01LR0807F) within the framework of the initiative KLIMZUG (Managing Climate Change in Regions for the Future).

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Response of Lakes Ladoga and Onego - Europe´s largest - to climate change and the influence on the socio-economic development in the region

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The presentation will address the contemporary state of largest lakes of Europe including their watersheds under anthropogenic and climate changes, with a special emphasis given to feed-forward and feedback interactions between aquatic ecosystems, watershed hydrology and economy of the region. The water quality of these lakes affects the water quality of Gulf of Finland. The statistical analysis of multi-year field observations and numerical modeling will be used to investigate the sensitivity of both aquatic systems and their watersheds to the respective counter impacts, as well as regional and global climate change.

It were investigated the regional climate changes and their impact on hydrodynamic and ecosystems of largest lakes of Europe. The water bodies of northwest Russia are very precious source of pristine water and used for many important purposes such as drinking water supply, transportation, hydropower generation, recreation, fisheries and aquaculture like lake trout farming. Though the water availability does not limit the economic development of northwest Russia, there is a growing concern over the water quality due to natural and anthropogenic stressors such as climate change and industrial and municipal wastewater discharges from the residential areas located on the shores and in the catchment areas. Both the understanding of the importance of water recourses in the region and concern over their use and water quality have already drawn the increased attention of both scientists and end-users but will still require better understanding of ecosystem functioning and developing more environmentally friendly and scientifically sound recommendations for the protection and sustainable use of water resources.

Regional changes within the watersheds of these lakes reflect the positive tendencies of air temperature changes in the end of XX – the beginning of XXI centuries.

There were significant positive trends in the mean temperature of the region being 0.10°C/decade. Air temperature annual variation became smoother, amplitudes decreased; marine climate features on the south part of the watersheds became more apparent. It could be related with enlargement of duration on the lakes the period without complete ice cover, when as a result of water mass essentially influence maximal and minimal air temperatures, enhancing winter minimums and declining summer maximums and that results in declining of annual temperature amplitudes. Winter is the season showing the strongest warming in the region for last decade, but in August it observed small cooling in northern and central part of the watershed. The climatic fluctuations in the region are manifest also in the varying length of the period of snow cover in the catchment areas. Long term of observations data and 3-D numerical models developed in Saint-Petersburg Institute for Economics and Mathematics with the results of coupled model of ocean - atmosphere circulation were used to estimate climate changes over the lakes watersheds of Lakes Ladoga and Onego and feedback of water temperatures, ice formation end ecosystems on these climatic changes.. Alteration of thermal regime in the near surface layer in studied region is revealed in ice-free period duration growth. By the end of XX and beginning of XX1 century the number of days free of ice increased on 11-16 days on these lakes. The climatic conditions in the region are manifested also in the varying of chemical and biological parameters. Nowadays the key factor which determines the modern state of these Lakes is the level of anthropogenic loading (Ladoga And Onego, 2010).

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Mean Baltic Sea Level in a changing climate – A review of the observational period

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1. Introduction

The sea surface height (SSH) is an important indicator of climate variability and long-term changes. The understanding of the processes which drive future climatic trends of SSH on global to regional scales presumes the understanding of the multi-year to decadal (long-term) variability in the observational period. This requires an accurate assessment of past and recent global and regional SSH changes, including changes in mean and extreme sea-levels.

Here, we review the studies concerning mean SSH changes in the Baltic region in the observational period (1900-2000) and the main known causes for these changes. We introduce the datasets which are nowadays available for the study of sea level and review the major published findings which can be derived from them for the Baltic Sea region.

This review contribution is part of the BACC II book 'Second Assessment of Climate Change for the Baltic Sea Basin' to be published in 2014 (see also HELCOM 2013).

2. One of the most investigated sea level sites

The Baltic offers a remarkable number of long and high quality densely spaced, tide gauge records with many stations in continuous operation since the late 19th century and some of the oldest sea-level records reporting since 200 years. More than 45 stations with at least 60 years of data have continued until recent times.

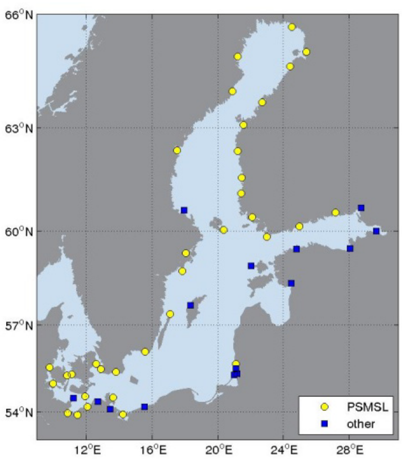

Figure 1 Long Baltic Sea level records with at least 60 years of data and continued until recent times, from PSMSL[1] and other long Baltic sea-level records.

3. Dominated by isostatic land movement effects

The basin-wide pattern of relative sea-level (RSL) trends shows a clear north-south gradient, reflecting the crustal deformations due to the GIA effect with a maximum rate of 8.2 mm/yr in the Gulf of Bothnia (Fig.2 upper panel). Thus, RSL is falling in the northern Baltic (where the continental crust is uplifting at roughly 10 mm/yr) and rising in parts of the Southern Baltic (Fig.2 middle panel). RSL from tide gauges along the Southern Baltic coast yield positive rates with a clear gradient in north-easterly direction (Fig.2 lower panel).

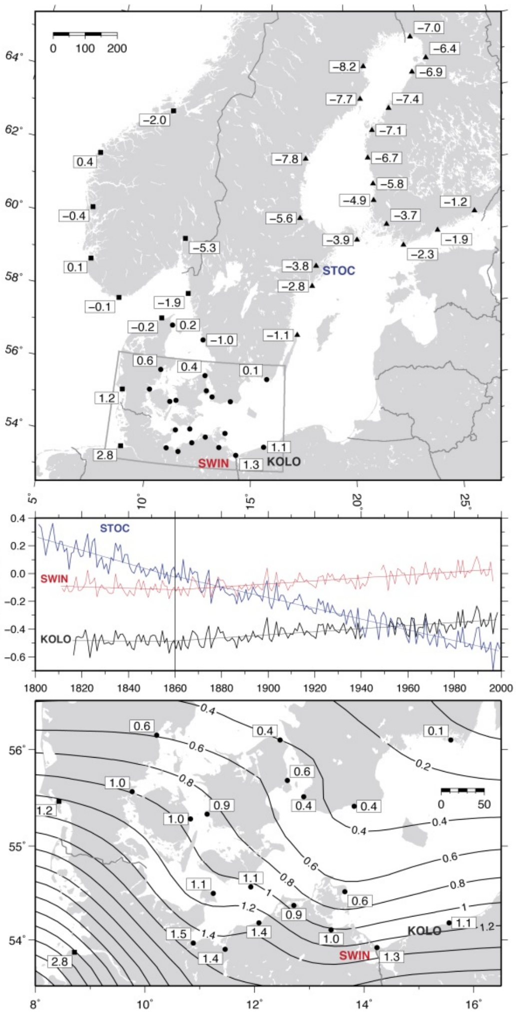

Figure 2 Maps of RSL changes, based on 100-year long tide gauge records for the entire Baltic Sea Region (upper panel) and for the southern Baltic coast (lower panel). Together with changes in linear trends of annual RSL at Stockholm (STOC), Swinoujscie (SWIN) and Kolobrzeg (KOL). The symbols represent the affilation with different reference stations (dots: Warnemünde, triangles: Stockholm, squares: Smögen). (redrawn from Richter et al. 2012).

[1] Permanent Service for Mean Sea Level (www.psmsl.org)

Recent studies indicate a more easterly peak uplift location placed in the middle of the northern Gulf of Bothnia, but consistency in spatial pattern and magnitude with previous studies. The determination of reliable velocity values at the Southern Baltic coast still poses a challenge as uncertainties exceed the amount of the small rates themselves.

4. Affected by sum of global, regional and local effects

This can include thermo- and halosteric effects, general changes in wind, surface pressure and ocean currents and gravitational effects; increasing freshwater input and higher increase in temperatures than in the open ocean.

The SSH decadal variability around the quasi-linear long-term trend (Fig.3) is strongly influenced by westerly winds, closely related to the dominant large-scale sea-level pressure (SLP) pattern of the North Atlantic (NAO).

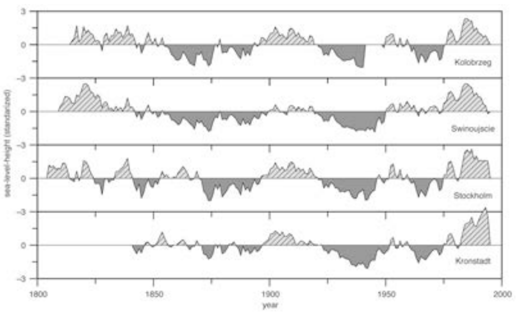

Figure 3 Relative winter mean (December-February) SSH in the Baltic Sea. The series are smoothed by an 11-year running mean to highlight the decadal variations and are standardized by unit standard deviation. The long-term trend was eliminated (redrawn from Hünicke et al. 2008).

The correlations between sea level and SLP is highest in winter, but shows significant changes over time and spatial heterogeneity with low values in southern Baltic parts (Fig.4).

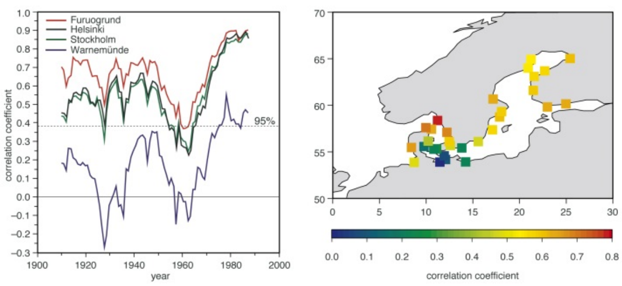

Figure 4 Correlation between winter means of the NAO index and winter mean (linearly detrended) Baltic sea level (1900-2000). Redrawn from Hünicke and Zorita (2006).

The influence of other atmospheric forcing factors (such as temperature and precipitation) on decadal Baltic sea-level variations is found to vary geographically.

5. Increasing amplitude of the annual cycle

The annual cycle in Baltic sea-level displays, in general, higher values during winter and lower values during spring time with an increase in the amplitude (winter-spring sea-level trend) 1800-2000. The magnitude of these increasing trends is found to be basin-wide uniform (except for the Skagerrak area). The precise mechanisms responsible for this have not been completely ascertained, but are very likely not exclusively of regional to local origin (e.g. due to wind-driven changes).

6. Summary

Baltic absolute sea-level (ASL) estimated from recent combined analysis of geodetic (satellite based GPS) measurements, tide gauge observations and geodetic models, show mean values in the range of 1.3 mm/yr to 1.8 mm/yr, dependent on the spatial and time resolution of the observed datasets (1800-2000). This values lie within the range of recent global estimates.

Recent changes in linear 30 yr trends of Baltic tide gauge records (1800-2000) show a positive trend, but similar or even slightly higher rates were observed around 1900 and 1950. The large decadal variability around these positive trends does not allow to establish its statistical significance. Displayed changes in linear 60 yr and 80 yr trends reduce the decadal variability, but also compromise the statistical significance.

7. Outlook

The presented review contributes to the future key scientific issues within the Baltic Earth programme[2] (successor of BALTEX): Understanding sea level dynamics using remote sensing.

Here, suggested key research areas are a compilation of large long-time series from written records, in particular for gauges, the analysis of satellite data sets and comparison with coastal station data in the period of overlap, identification of the locally resolved multi-decadal variability and centennial trends of the rate of sea-level rise, a regionalization of sea-level scenarios by analyses of AR5 CMIP5 scenarios +scenarios of land-ice dynamics, a combination of this information with recent knowledge about land movement, storm surges and wave conditions to evaluate the impact on the coasts, and the identification of the major physical and socio-economic mechanisms that may in the future endanger the stability of the coastlines beyond the range of its natural variability.

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Comparison of the December 2013 storm surge with long-term severe storm events at the Pomeranian Bay coast (the southern Baltic Sea)

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1. Introduction

The storm surges at the Pomeranian Bay coast (the southern Baltic Sea) are induced by strong NW, N or NE winds and changes in atmospheric pressure during passages of low-pressure systems over the Baltic Sea or in its vicinity. They result in the water level changes in the Szczecin Lagoon and the downstream reach of the Odra River. In the study, the December 2013 storm surge generated by the deep low pressure system known as Xaver was compared with all severe storm events recorded in the period 1993-2013.

2. Severe storm surges at the Pomeranian Bay coast

During storm surges in 1993-2013, the level of 100 cm above the mean sea level (msl) at the southern Baltic Sea coast (Świnoujście) was reached or exceeded during 28 events. The highest sea level of 183 cm above msl was recorded on November 4, 1995 (only 13 cm lower than the highest level ever recorded in Świnoujście on February 10, 1874). The number of severe storm surges differed greatly from year to year; in 2007 there were recorded as many as 6 such events (Table 1).

Table 1. The highest storm surges at the Pomeranian Bay coast (Świnoujście) in the period of 1993-2013. Note: msl = 500 cm at the water level gauge with respect to NN Amsterdam 1955.

No.	Date	Maximum sea level (cm)	Maximum sea level above msl (cm)
1	1993-02-21	650	150
2	1995-11-04	683	183
3	2002-02-21	640	140
4	2006-11-01	643	143
5	2012-01-14	642	142

The level of 100 cm above msl was exceeded for 31 hours during the October 2009 storm surge. Although it was not as high as the November 1995 surge case (133 cm above msl in Świnoujście), it induced one of the heaviest storm surge in the last 100 years in the Szczecin Lagoon and the lower Odra channels. In Trzebież the extreme water level of 125 cm above msl was only 12 cm lower than the highest level ever recorded there (on December 31, 1913). Storm surge induced wind-driven water backflow into the lower Odra channels and penetrated as high up the river as Bielinek. The sea level in Świnoujście rose more than 170 cm during 3 surges (November 1995, November 2001, November 2006); it dropped down more than 200 cm only in February 2002. A few surges, one by one, taking place at the Pomeranian Bay coast sometimes transformed into one persisting many days' storm surge in the Szczecin Lagoon and the lower Odra channels (e.g. winter 2007). In some cases increased water volume in the Baltic Sea occurred during snow-melt or rainfall mediated Odra floods. Such cases favored also prolonged duration of high water in the area.

3. The December 6-8, 2013 storm surge description

The December 6-8, 2013 storm surge resulted from a shift of a deep low pressure system from the North Atlantic over the Scandinavia into the central part of Baltic Sea (962 hPa in the centre) and further east. Initially a sea level drop down to 70 cm below msl was recorded at the Pomeranian Bay coast in Świnoujście on December 6. Then a 170-cm rise in the sea level was observed up to the maximum of 100 cm above msl at 3 o'clock am on December 7 (Fig. 1). Later on, the water level dropped down to 14 cm above msl on December 8. During the surge the alarm level (80 cm above msl) lasted 18 hours, while the warning state (60 cm above msl) was exceeded for 37 hours. The highest rate in sea level increase was observed on December 6 morning (up to 50 cm per hour). The maximum drop in the sea level amounted to 17 cm per hour.

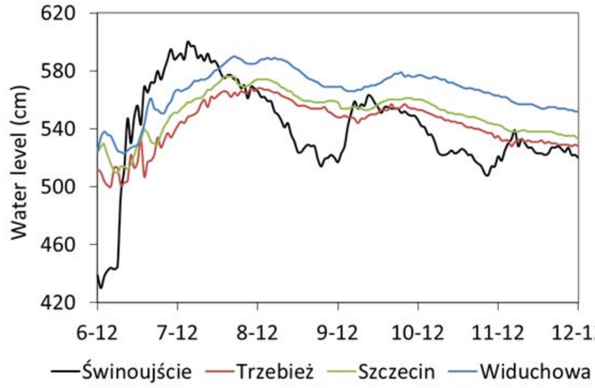

Figure 1. Water level changes in the Odra mouth area during the December 2013 storm surge.

During the storm surge discussed, the Szczecin Lagoon water level fluctuations followed, with a time lag, the sea level changes. On December 6, the water level began to rise up to 68 cm above msl in Trzebież (68-cm rise in water level). The maximum water level was recorded at midnight of December 7. Later on the water level dropped; however, the level was at the warning state until December 10. During the surge, the warning level was exceeded for 91 hours, while the alarm level lasted 26 hours.

The elevated water level was observed in the lower Odra channels. In Szczecin (the West Odra), after the water level rise of 67 cm the maximum of 76 cm above msl occurred on December 7. Similar rises in water level were recorded in the East Odra and in Widuchowa (c. 105 km from the sea). The effects of the storm surge were negligible at Bielinek and Gozdowice.

4. Summary

The December 6-8, 2013 storm surge at the Pomeranian Bay coast was induced by the low atmospheric pressure impact and wind activity during eastward fast passage of deep depression over the Baltic Sea. As a result of a drop in atmospheric pressure by 30 hPa and a change in the wind direction (from SW to NW), 170-cm rise in sea level was recorded. The highest rate in sea level increase amounted to 50 cm per hour. Comparison of this surge with all severe storm events recorded in the period of 1993-2013 allowed to classify it as the one with the fastest rate of hourly sea level increase as well as the highest sea level rise amplitude. Such rise in sea level caused reaching the level of 100 cm above msl, however due to low sea level base from which the storm surge launched, the event was classified as the 28th highest surge in the analyzed period.

The impact of the storm surge in the Szczecin Lagoon and in the lower Odra channels was visible up to Widuchowa (70-cm rise in water level). However moderate duration in the Pomeranian Bay caused the alarm state being exceeded only in the Szczecin Lagoon (Trzebież) and in the East Odra (Podjuchy). It resulted in moderate backflow in the Odra mouth. The effect in the Szczecin Lagoon was strengthened by the following wind-driven backflow observed in the last phase of the storm surge on December 9.

In general, the recent sea level rise, which is 0,17 cm per year in the period of 1961-2010 (Kowalewska-Kalkowska, Marks 2011) increases the sea level base from which storm surge can be launched and decreases the free surface of water in the Odra mouth area, which may cause prolonged duration of surges as well as increase in its maximum values. As a result it may increase the threats, possibly induced floods from storm surges.

5. Acknowledgements

The routinely collected water level data were made available by the Harbour Master's Offices in Świnoujście, in Trzebież and in Szczecin. Data were also drawn from http://monitor.pogodynka.pl.

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Application of hydrodynamic model of the Baltic Sea to the December 2013 storm surge representation along the Polish Baltic coast

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1. Introduction

Storm surges at the southern coast of the Baltic Sea are associated with passages of low-pressure systems over the Baltic Sea. They pose a flood threat for coastal areas and areas adjacent to downstream reaches of rivers. Because of the difficulties involved in investigating complex nature of meteorological factors influencing the storm surges, hydrodynamic models have become an essential tool in flood protection of coastal zone of the southern Baltic Sea. In the study a three-dimensional hydrodynamic model of the Baltic Sea (M3D_UG), developed at the Institute of Oceanography, University of Gdańsk was applied to forecast water level changes along the Polish Baltic coast during the December 6-8, 2013 storm surge.

2. The model study

A hydrodynamic model of the Baltic Sea (M3D_UG), based on the Princeton Ocean Model (Blumberg, Mellor 1987), is a baroclinic model that describes water circulation, with a due consideration to advection and diffusion processes. The model was adapted to the conditions of the Baltic Sea by Kowalewski (1997). Firstly the model was designed for the whole Baltic Sea and the Gulf of Gdańsk. Then the model was developed for the Pomeranian Bay and the Szczecin Lagoon (Kowalewska-Kalkowska, Kowalewski 2006). Evaluation of the model's performance both for the eastern and the western parts of the southern Baltic coast showed the results of the model calculations to be of the same good quality (Jędrasik 2005, Kowalewska-Kalkowska, Kowalewski 2005, Kowalewski, Kowalewska-Kalkowska 2011). The good fit between simulations and readings of water level from gauges located at the southern Baltic coast was an incentive for checking accuracy of water level forecasts during the December 2013 storm surge.

The December 6-8, 2013 storm surge at the coast of the southern Baltic Sea and its adjacent coastal lagoons was induced by the passage of a deep low pressure system over the Baltic Sea (962 hPa in the centre). Initially, a decrease in water level at the coastal stations was observed on December 5-6. Then a rapid rise in sea level was observed up to maximum values recorded on December 7. At the southern coast of the Pomeranian Bay in Świnoujście (Fig. 1) the sea level increased up to 600 cm, i.e. 100 cm above mean sea level (amsl). The highest level was observed in Kołobrzeg – 619 cm, i.e. 119 cm amsl (Fig. 2). At the coast of the Gulf of Gdańsk in Gdynia the level of 599 cm (99 cm amsl) was recorded (Fig. 3). The storm surge caused the wind-driven water back-flow in the Szczecin Lagoon and the channels of the lower Odra River. In Trzebież a 68-cm rise in water level was observed (Fig. 4).

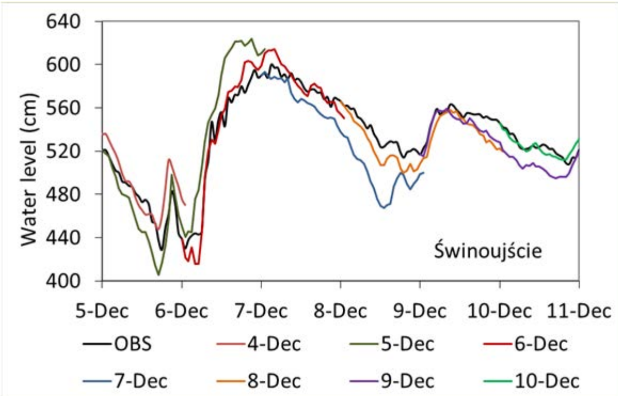

Figure 1. Observed and predicted (48-h forecasts from 4, 5, 6, 7, 8, 9 and 10 December) water level changes in Świnoujście (the Pomeranian Bay) during the December 2013 storm surge. Note: mean sea level (msl) = 500 cm at the water level gauge with respect to NN Amsterdam 1955.

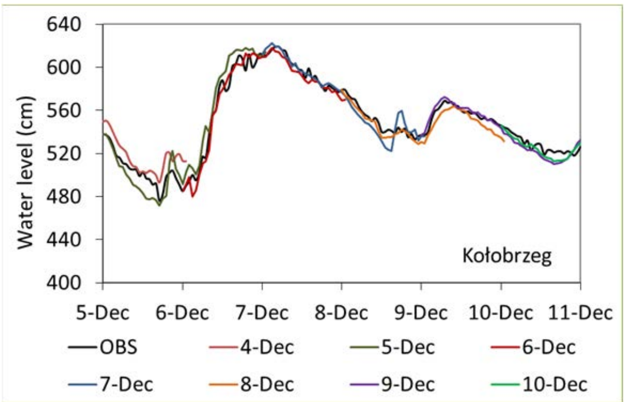

Figure 2. Observed and predicted (48-h forecasts from 4, 5, 6, 7, 8, 9 and 10 December) water level changes in Kołobrzeg (the southern Baltic Sea) during the December 2013 storm surge.

During the storm surge discussed, temporal sea level variations in the region were approximated by the model with a relatively good accuracy. The model properly reflected first a rise, then a drop in sea level at the coastal stations. The agreement between the empirical extremes and the forecasts in the timing and the surge level were also good. The best fit between the numerical calculations and readings from the sea level gauges was obtained for Kołobrzeg, a slightly worse agreement being shown for Świnoujscie and Gdynia. On the Szczecin Lagoon the water level fluctuations followed with a delay to sea level changes and were properly reflected by the model as well.

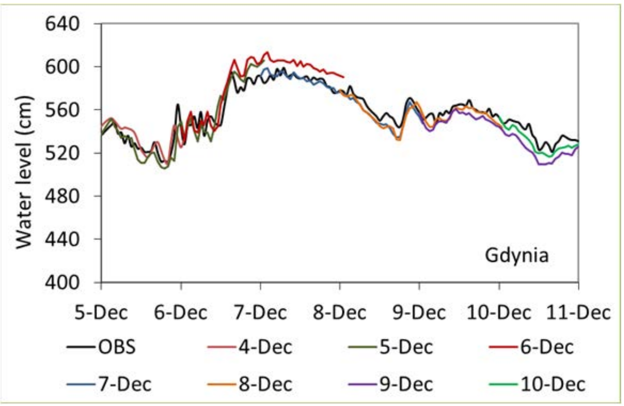

Figure 3. Observed and predicted (48-h forecasts from 4, 5, 6, 7, 8, 9 and 10 December) water level changes in Gdynia (the Gulf of Gdańsk) during the December 2013 storm surge.

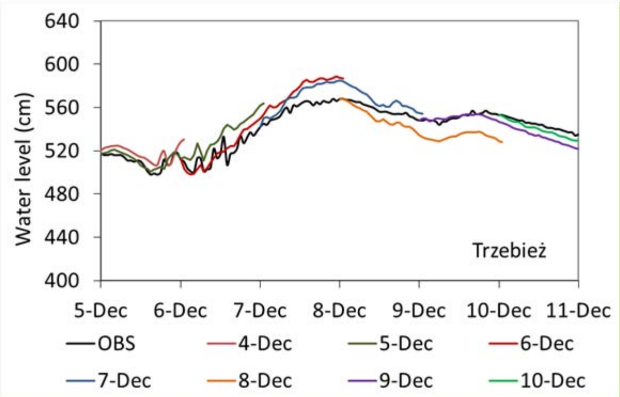

Figure 4. Observed and predicted (48-h forecasts from 4, 5, 6, 7, 8, 9 and 10 December) water level changes in Trzebież (the Szczecin Lagoon) during the December 2013 storm surge.

3. Summary

Evaluation of the M3D_UG model's performance in the case of high-amplitude and rapid water level fluctuations, such as those observed during the December 6-8, 2013 storm surge, showed a good fit between the modelled and observed distributions of water levels.

The relatively good approximation of storm surge-induced sea level variations along the Polish Baltic coast by the hydrodynamic model of the Baltic Sea makes it a reliable flood protection tool. The regularly updated results of the model's application are placed daily on the University of Gdańsk website (http://model.ocean.univ.gda.pl) as maps of 48-hour forecasts of water level for the southern Baltic Sea, the Gulf of Gdańsk and the Pomeranian Bay. It is intended to fine-tune the model to improve its prognostic reliability.

4. Acknowledgements

Water level readings were drawn from http://monitor.pogodynka.pl.

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Influence of climate change on the ice regime of the Belorussian lakes

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1. Introduction

Over the territory of Belarus, there are about 12 thousand lakes. The largest of them are located in the basins of the Zapadnaya Dvina and Neman Rivers.

For the analysis of climate change influence on the ice regime of the lakes of Belarus, we used representative subset of observations at 3 lake posts (Drivyata Lake, Naroch Lake, and Myastro Lake), with the period of observations from 1928 to 2012.

2. Ice regime of the lakes

Due to the increase in air temperature, formation and destruction of the ice phenomena, (first of all, onsets and terminations of the freeze-up) have changed.

The first ice phenomena on these lakes are observed with establishment of negative daily temperatures.

In the last decades, the first ice phenomena on the lakes are observed later than usual by 6-10 days (from the second half of November to early December). This shift is connected with higher autumn surface air temperatures (warming).

Formation of freeze-up also occurred on average two days later (in early December), except the Naroch Lake, where ice cover in the last decades was established on average around the 29th of November, which is 9 days prior to the past mean long-term freeze-up dates.

During the last warming of 1989-2012, spring dates of disappearance of the ice phenomena on these three lakes were observed by 4 to 6 days prior to the past mean long-term dates (usually, in the first decade of April).

Due to later formation of the ice phenomena and their earlier termination, duration of the period with the ice phenomena decreased. Respectively, duration of the period with open ice-free water on considered lakes has increased during the past 25 years .

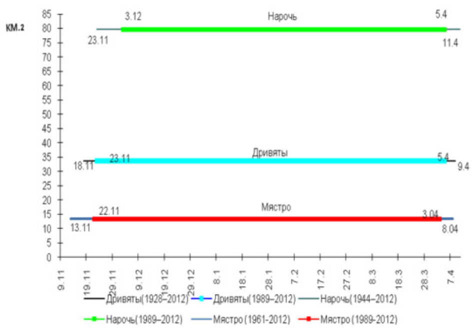

Figure 1. Onset and termination dates of the ice phenomena during the last warm decades and the entire period of observations.

Climate warming impacted the lake ice formation. In the last years. In particular, the mean dates, when the maximum lake ice thickness is reported, shifted to the first decade of March, which is by 6 to 14 days prior to the previous mean long-term dates of these maximums.

Furthermore, the thickness of the lake ice has reduced. Mean values of the maximum lake ice thickness became below mean regional long-term value of 14 cm (in the Drivyata Lake these value is 15 cm, in the Naroch Lake – 18 cm, and in the Myastro Lake – 9 cm). During the past 25 years of warmer temperatures, the maximum ice thickness didn't reach these average values in 80% of the cold seasons It is connected with higher air temperatures and more frequent winter thaws.

At the representative subset of Belorussian lakes (the Drivyata, Naroch, and Myastro Lakes), we found a reduction of the ice cover period (on average by 6 days) and an increase in the ice-free period (on average by 10 days). These changes are well linked with the regional warming in the past 25 years.

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Local climate changes and problems of hydrological division into districts of the territory of Belarus

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1. Introduction

Climatic instability is objective reality nowadays. It is observing for the different parts of the Earth and caused by global processes (Loginow, et, al, 2003). Most likely, along with anthropogenesis factors, the main reason for climate instability are natural factors and, according to some researches they are prevailing under other. Earlier climatic fluctuations in the territory of Belarus and changes in a hydrological regime were connected with water managements (melioration) within their catchments (fig. 1). According to results of our researches one of the main reason of this instability lie in the general circulation of the atmosphere. Published earlier hydrological division into districts of the territory of Belarus in the National atlas and in the educational textbooks correspond to the hydrological division into districts executed in the 60th years by Institute of water problems of Belarus.

The modern climatic instability noted in Belarus since 1989. It is confirmed by 25 year time series of meteorological and hydrological observation. It allows carrying out the analysis in compare with whole period of instrumental observations over climatic and hydrological data (Lopuch, et, al, 2013).

2. Main results

The classical principles of hydrological division into districts realized on the example of Belarus: basin, landscape (physiographic) and hydrological. But the methodological approaches need new interpretation and specification. There is an objective need of specification of existing division into districts of the territory of Belarus taking into account climatic instability which allows take into account basin approach and make hydrological calculations for closing alignments for each river, irrespective of its location and order.

According to existing division into districts there are 6 hydrological regions in Belarus: the Zapadnya Dvina, the Neman, the Viliya, the Upper Dnepr, the Meddle Berezina (Dnepr basin) and the Pripyat regions. Every hydrological region is divided into sub regions. The main shortcoming of existing division into districts is a separation of small rivers (tributaries of 3-5 order) from the main river system. It concern in particular to catchments of the Dnepr, the Pripyat and the Zapadny Bug rivers within Belarus. For example, at division of the basin of the Pripyat river (in the northern and southern parts) and the Zapadny Bug river basins have to be considered all small sub catchments taking into account a climatic factor. In this regard allocation of the Neman hydrological region including a full catchment of the Neman river within the territory of Belarus is correct and objective.

The hydrological regime as a product of climate shouldn't be based artificially only on a regime of the main rivers. Climatic features of first order river catchments reflect local geographical features and define peculiarities of a regime of the main river as a whole, or the hydrological region.

Characteristics of hydrological seasons, quantity of atmospheric precipitation and evaporation, appearance and duration of ice phenomena, thickness of snow cover, size of water equivalent in snow cover and other climatic indicators like (average monthly air temperatures, etc.) are strongly transformed in recent years.

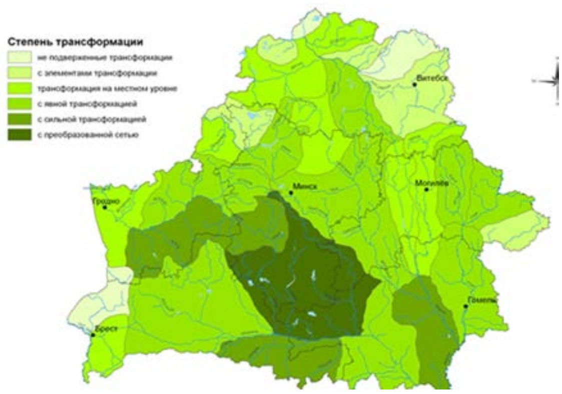

Fig. 1. Scheme of Catchments transphormation of the territory of Belarus

As a result of the our researches and researches of other authors, the analysis of influence of climate instability on a hydrological regime and physiographic division into districts of the territory of Belarus allowed us to offer the new scheme of hydrological division into districts. We offer to allocate the following hydrological regions by analogy to the Neman hydrological region, i.e. regions of the Zapadnaya Dvina, the Neman, the Dnepr, the Berezina (basin of the Dnepr), the Pripyat and the Zapadny Bug rivers. We suggest saving former system of taxonomical units of division into districts (the region – a sub region). It is necessary to keep allocation of sub regions in the Zapadnaya

Dvina, the Berezina, the Dnepr and the Pripyat regions. Allocated earlier the Neman and the Viliya hydrological regions reasonably should be considered as one sub region of the whole Neman hydrological region. Such approach excludes separation of tributaries from the main catchment and their attachment into the neighbor catchments. It is also reflects features of hydrological regime of the transboundary rivers (the Zapadnaya Dvina, the Neman, the Dnepr, etc.)

Climatic features of the Zapadny Bug river catchments and complexity of runoff formation outside the territory of Belarus should be taken into account in the new hydrological division into districts. Within the territory of Belarus in the region of the Zapadny Bug should be allocated two sub regions: Podlyaskopredpolesye and Polesye (Fig.2, Tab.1)

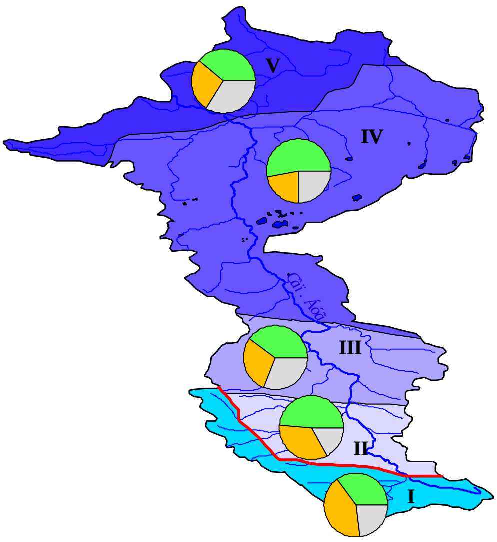

Fig. 2. Division into districts the Zapadny Bug rivers

3. Conclusions

The developed scheme of hydrological division into districts of the territory of Belarus supplements and details the accepted European and national schemes of hydrological division into districts. Results of the research work confirmed the necessity of the analysis of other neighbor territories (Lithuania, Latvia, Russia) for specification of division into districts of the central part of Europe and obtaining authentic and reasonable maps taking into account the general climate change.

Table 1. Seasonal distribution of runoff within the hydrological subdistricts of cross-border basin of Western Bug

Areas	**Hydrological subareas**	**Seasonal flow in% of the annual**		
		Spring (III) - (V)	**summer-fall (VI) - XI**	**Winter (XII) - (II)**
A	(I)Podolsky	32-36	41-45	22-23
B	II. Malopolesskij	41-44	35-37	21-22
B	III. Volyn	36-44	28-30	28-34
B	(IV)Poleski.	47-57	15-27	21-31
B	V. Podlâsko-Predpolessky	33-46	22-36	31-33

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Interrelation between the North Atlantic Oscillation (NAO) and the Discharges of 50 Rivers Located at the Baltic Sea Drainage Basin: A Statistical Sensing Analysis

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1. Introduction

Discharges properties of rivers at the Baltic Sea drainage basin are consider as an indicators of the combined atmospheric processes that are mainly influenced by the North Atlantic Oscillation (NAO). The North Atlantic Oscillation index (henceforth, NAO) is one of the most major teleconnection patterns of intermonthly to interdecadal variability in the Northern Hemisphere. Hurrell (1996) stated that there are two trends captured in the winters of 15-year interval occurred at the mid-latitudes (40 ^{o}N – 70 ^{o}N) since the mid of 1970s. These trends were; towards the positive phase of (NAO) index, and towards warmer northern hemisphere land temperatures. This climate phenomena push to create important questions regarding rivers flows into the Baltic Sea. 1) Is a positive phase of (NAO) index manifesting its impact in winter DJF months and seasons discharge rate over the whole studied rivers? 2) Is a positive phase of (NAO) index manifesting its impact as a unique mechanism responsible of the configured trend in wintertime DJF discharge series over the whole studied rivers?. These questions may be answer by making use of a statistical sense models.

2. Research

The aim of the present work is to detect and model (i.e. predicting and forecasting) the physical interaction between the North Atlantic Oscillation (NAO) index and the river discharge into the Baltic Sea in monthly and seasonal means. Then, inspecting and determining the configured trend in winter DJF (December- January-February) means discharge series. Shorthouse & Arnell (1997) explored a significant winter relationships between interannual climate variability - as measured by the North Atlantic Oscillation Index (NAOI)- and spatial patterns of anomalous flow of 233 rivers between 1961-1990 across Europe, by using Pearson's correlation.

Our result show that the positive phase of (NAO) index is manifested its impact over the related rivers discharges during winter DJF months and seasons, in which, it confirmed that the pressure difference between the Azores high and Icelandic low is higher than normal and westerly winds dominated over Baltic Sea, Scandinavians Peninsula and northern Europe, bringing mild, moist air from the Atlantic Ocean and, consequently, more precipitation and higher temperatures. The environmental conditions (climatic conditions) at the related catchment area are manifested its impacts over the related rivers discharges during winter DJF months and seasons.

Analyses show the winter DJF monthly and seasonal discharges rates are mainly influenced by the following mechanisms; the positive phase of (NAO) index and the environmental conditions. Since the significant response that is revealed by the magnitudes of the trends or the statistical parameters of correlation and regression coefficients are spatially non-uniform, the mechanisms responsible of the trends are the same mechanisms, thus affecting the Baltic basin as a whole. The influence of the North Atlantic Oscillation on the discharge of the Baltic basin rivers is diverse in terms of time and space. Precipitation and air temperature are the main factors impacted the discharge formation.

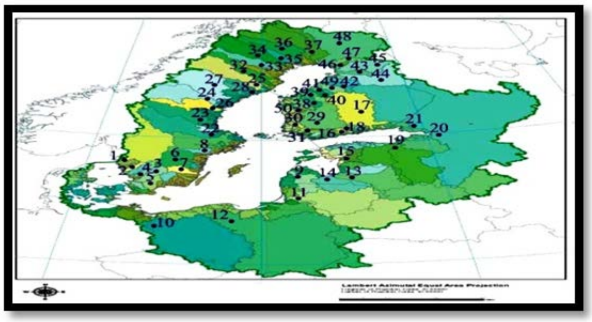

Figure 1. The Baltic Sea catchment area showing rivers basins.

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Variability of bioclimatic conditions in the Polish coastal region of the Baltic Sea

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1. Introduction

The northern part of the Baltic Sea is one of the most substantial area of natural reserves in Poland. The Baltic Sea and shallow shore as well as the broad, sandy beaches and picturesque cliff seacoast only increase the tourist value of the region, and contribute to the fact that tourism and recreation are the predominant elements of the region's economy. In this region tourism and recreation are greatly influenced by the atmospheric conditions. The weather conditions are factors which can both increase as well as decrease the allure of the region causing financial loss (Kamieniecka 2009). It is a well-known fact that the main factor limiting the use of the seaside for the purposes of tourism is the weather, especially the weather conditions which have a direct influence on human. A good understanding of bioclimatic conditions can contribute to better use of the seaside region for the purposes of tourism.

The aim of the paper is the assessment of spatial and temporal bioclimatic conditions in the Polish coastal region of the Baltic Sea from the perspective of tourism development.

2. Material and Methods

The most recent index of thermal stress – Universal Thermal Climate Index (UTCI), was used for the assessment of the bioclimatic conditions (Błażejczyk et al. 2010). The index is based on the analysis of human heat balance determined with the use of a multi-node model of heat transfer. Data obtained with the use of UTCI allows for the objective assessment of the bioclimatic conditions. Respective scales of the UTCI index are based on the objective changes in the physiological parameters of an organism occurring as a result of the environmental conditions and serve as indication of thermal stress (Bröde et al. 2012).

The analysis focuses on the period 2000 – 2013 and is based on the hourly as well as daily values of the UTCI index. The hourly values of the following meteorological elements constituted the input data for the analysis: air temperature, relative air humidity, wind speed and cloudiness. The meteorological data was obtained from the meteorological stations located along the coast of the Baltic Sea: Świnoujście, Kołobrzeg, Ustka, Łeba, Hel, Gdańsk (Fig.1).

The values were calculated using BioKlima software ver. 2.6. Additionally, the results of bioclimatic conditions were correlated with the time periods of the greatest tourist flow. The positive value of weather conditions for tourism and recreational activities in the Polish coastal region of the Baltic Sea was presented using the WSI index (Weather Suitability Index) (Błażejczyk 2007).

Figure 1. Location of meteorological stations along the Polish Baltic coast.

3. Results

The bioclimatic conditions of the Polish coastal region differ from the bioclimatic conditions in other parts of the country, particularly from that of the lowlands. The proximity of the large water reservoir is of primary importance (Koźmiński, Świątek 2012). The localities situated along the coast are characterised by relatively low temperatures during spring and summer, smaller cloudiness and longer sunshine duration time, especially from May to August (Bąkowska, Błażejczyk 2007). The results of the UTCI index for selected months of the warm and cold half-year (January and July) are presented in Figures below. Figure 2 shows that the highest values of UTCI index in January is recorded in the western part of the coast (Świnoujście and Kołobrzeg) and in Gdańsk, whereas the lowest values are recorded in Ustka, followed by Łeba and Hel. The lowest values of the UTCI index in January during the analysed period was recorded in 2010 in Świnoujście -40.6°C. The analysis of the UTCI values in July revealed the fact that the highest values for all localities were recorded in 2006. The results indicate that the differences in values obtained in individual localities in July in consecutive years are smaller and more similar in terms or course than the changes in January. In the course of the maximum values of the UTCI index the west coast of the Baltic Sea was also prominent. The results presented in Figure 3 show that the highest frequency of days with strong and very strong cold stress in January was recorded in Ustka and Łeba. The days with the least thermal stress were recorded mainly in Świnoujście and Kołobrzeg. The frequency of strong and very strong heat stress exhibits a declining tendency from the west coast to the east. Occasionally in July there are days with slight cold stress – most of them are recorded in Ustka and Łeba.

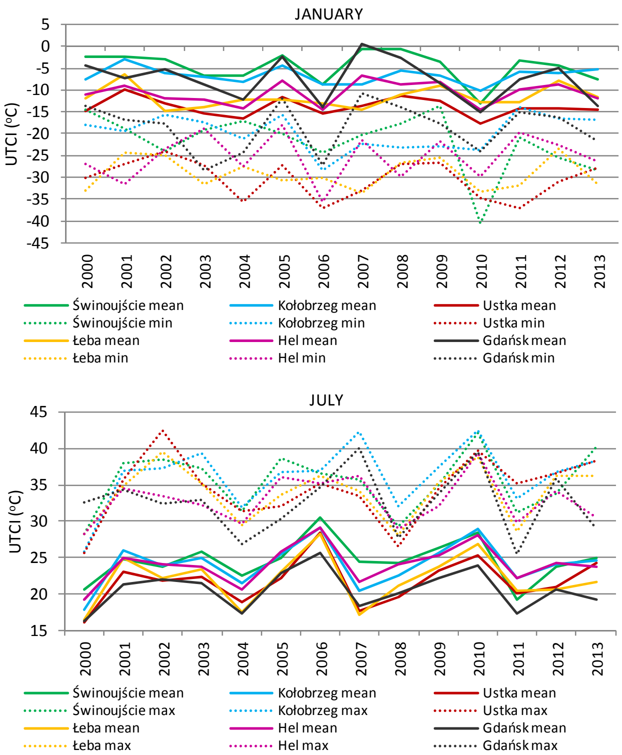

Figure 2 Mean, minimum and maximum UTCI values in January and July in the period 2000-2013 in the Polish coastal region of the Baltic Sea.

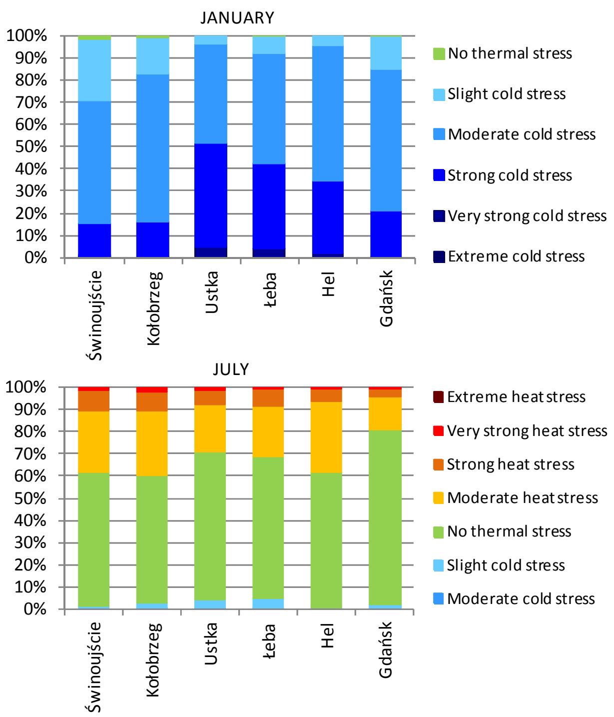

Figure 3 Frequency of thermal stress in January and July in the period 2000-2013 in the seaside localities.

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Climate change and adaptation measures of agriculture in Belarus

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1. Introduction

Researches conducted by the "Republican Hydrometeorological Center" demonstrate that in recent decades, trend of warming has been observed on the territory of Belarus since 1989 year and caused by general trends of climate change. The typical feature of the warming nowadays is not only its unprecedented duration, but also high temperature of air, which in average during 24 years (1989-2013) has exceeded climatic norm in 1.1ºC (Melnik et al, 2010). If to begin with the post-war period (since 1945), all of the 20 warmest years are related to the period 1989-2013 years (Fig 1.)

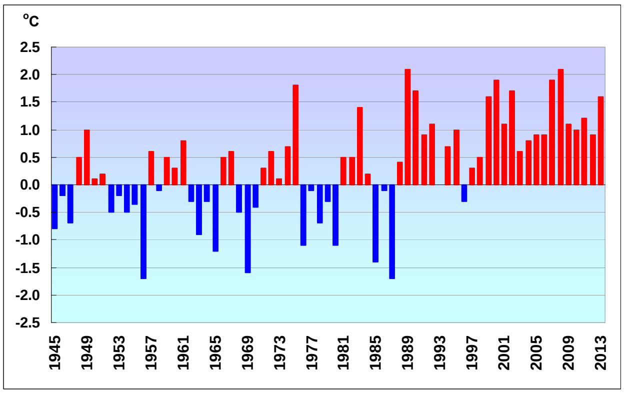

Figure 1. Deviation of the annual air temperature from the climatic norm (+5,9 ° C) for the period 1981-2013 on the territory of Belarus

In general, the second decade of the warming period (1999-2008) has been warmer than first period (1989-1998) by 0,5 º C, at the same time we observe shifting of warming period on summer, autumn months and on December (Melnik and Komarovskaya, 2011) (Table 1).

Table 1 - The average seasonal temperature (º C) for two consecutive decades

Period	Winter (DJF)	Spring (MAM)	Summer (JJA)	Autumn (SON)	Year
1989-1998	-3,1	7,0	17,1	5,9	6,7
1999-2008	-3,3	7,3	18,0	7,1	7,2

2. Main results

Global warming over the period 1989-2013 led to changes in the main agro-climatic indicators, to significant shift (at 60-150 km) of agroclimatic regions borders and the formation of a new, more warm agro-climatic region in the South of Polessye. All this process in complex has changed usual conditions of growth of agricultural crops.

Annually in the Republic of Belarus are registered from 9 to 30 of hazardous hydrometeorological phenomena. World Bank`s experts have found that economy sectors of Belarus have different degrees of economic dependence from hazardous hydro-meteorological phenomena. The most weather-dependent economy sector is agriculture, where damage from hazards is 42%.The total share of weather-dependent sectors in the Republic of Belarus is 41.5 % of GDP output. In accordance with assessments, economy of Belarus nowadays loses annually about 93 million dollars of USA because of damage from adverse and severe weather events and conditions (in prices for 2005).

Positive and negative consequences of climate change for agriculture in Belarus have been identified. Prolongation of frost-free period and the growing season , continuance of warm (> 10 ° C and > 15 ° C) periods, the improvement in heat supply of crops - all these conditions generally are positive factors for agricultural production. Negative consequences are related with increase in aridity in the Southern regions which accompany the global warming and with the observed trend of increasing the probability of adverse and hazardous hydrometeorological phenomena. Conditions have been significantly changed for over-wintering of overwintering crops. In Belarus, in accordance with data of the Ministry of Agriculture and Food, currently being implemented specific measures for adaptation of agriculture due to global climate warming.

Republic Hydrometeorological Center executed a work in terms of aforementioned measures on researches of agroclimatic indices in conditions of climate change in the context of agriculture. On the base of the results of this evaluation, has been made a scientific handbook "Agro-climatic resources of the Republic of Belarus in the context of climate change." Poster “Republic of Belarus in the context of climate change” has been developed and published. In accordance with data of the Ministry of Agriculture and Food, specific measures for adaptation of agriculture due to global climate warming are performed.

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Frequencies of cyclones with different origin within the territory of Belarus and their impact to hydrometeorological conditions

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1. Introduction

Precipitation is a major factor that controls runoff to the Baltic Sea Basins from the territory of Belarus. Its variability defines the national water resources. The intra-annual distribution of precipitation is the most variable component controlling water resources of Belarus being a function of cyclones from the Atlantic Ocean and Mediterranean that bring most of precipitation to the nation. That's why the aim of this investigation was to estimate the extratropical cyclones characteristics and effects of their passing through the Belarus territory on regional water budget and origin of extreme river phenomena (i.e., floods and low water).

2. Data and methods

For this study we used two databases of cyclones. First database consists of cyclone tracking output from NCEP/NCAR reanalysis (Kalnay et.al., 1996). Data are presented from 1949 on 2012. The second database has cyclones from the ECMWF Interim Re-Analysis (ERA-Interim reanalysis) (Simmons et al., 2007) for the period from 1979 to 2012.

Several variants have been suggested concerning the size of study territory for statistical calculations of cyclones. According to the Belarus territory scale and configuration we decided provide calculation of cyclones frequency and their trajectories in the domain 50-56^{o} N and 23-33^{o} E. The domain borders are expanded from the borders of Belarus by 100 km in each direction.

Frequency and intensity of cyclones that influenced hydrometeorological conditions of Belarus have been estimated. We defined the total of cyclones and cyclones of various origin and directions. The most frequent cyclones from the North Atlantic we have conditionally divided into some types depending on their passage through the Belarus. We define these cyclones into: western cyclones which move in zonal direction and enter into Belarus within 51-57^{o} N; northern cyclones which pass also zonal but their way is just north of national borders, but not further 57^{o} N; diving cyclones which move in meridional direction from the north-west of Atlantic to the south-east through the study region. We defined south cyclones (as determined by Gulev et al., 2001), which had formed south of 47^{o} N and east of 0^{o} meridian and entered Belarus from the south.

We took into account number of cyclones which is the number of tracks that pass the region over the same time with multiply entries being ignored. We counted whole cyclones for winter season (December though February) and quantity of cyclones of a various origin. Also we define the same calculations for cyclones with pressure in the centre less than 1000 hPa; sample of the minimum value of pressure in the cyclone centre for a season is made and the estimation of trends is executed.

3. Results and discussion

We have counted number of cyclones with North Atlantic origin but different directions (western, northern, diving) and cyclones with a south origin under two versions of reanalysis. In general, results of calculations on two databases not always coincided; distinctions fluctuated year by year without a regular deviation. Considerably only, that after 1990s these distinguish meet more often. But average values of two databases of cyclones as a whole have identical means.

According to the calculations for the winter period through territory of Belarus pass 11 cyclones, among them are 5 western, 3 southern, 2 northern and 1 diving cyclones. As the greatest interest was represented by consequences of passage of cyclones through territory of Belarus and the possible dangerous phenomena connected with them, we had been defined quantity of cyclones with pressure in the centre less than 1000 hPa by various directions. Thus, in the average for a winter season 4 western, 3 southern, 2 northern and 1 diving cyclone enter to Belarus.

We have been considered long-term dynamics of cyclones of various directions to establish the basic tendencies and to coordinate to change of climatic characteristics in territory of Belarus. Change of the Atlantic western cyclones has shown the slight positive tendency, their quantity (the general number and number of cyclones with pressure in the centre less than 1000 hPa) fluctuated in various years and reached the maximum values (10) in 1986 and 1994. These maximum values marked in the period of climate warming in the Belarus. That is corresponded to the conclusions of Loginov et al. (2002) about the climate warming, connected with increase in air temperature, especially during the winter. During the last decades more frequent zonal air movement in the atmosphere and substantial surface air temperature increase in the winter season provoked the prevalence of winter thaw conditions. The thaws interfered with accumulation of snowpack before the beginning of spring snowmelt and promoted decrease in the number of spring floods on the rivers of Belarus.

Calculation of northern cyclones (as a sort Atlantic cyclones, passing northerly of national borders) has shown the significant tendency of growth. Their maximum quantity is noted in 1965 and 1998 (6). Cyclones of North Atlantic origin bring to the Belarus water vapor from the ocean and precipitation. The increase in quantity of northern cyclones could explain displacement of a trajectory of the Atlantic cyclones to the north and correspond to conclusions (Loginov and Volchek, 2006) about decreasing of precipitation on the north (Baltic sea basin) of Belarus.

Diving cyclones (as a sort of Atlantic cyclones) have no tendency to change of their repeatability. Their greatest quantity has been fixed in 1956 (3) and during the considered period they are observed once per two year.

Dynamics of southern cyclones is characterised by the significant tendency to decrease. In first half of study period the quantity of cyclones was stable and fluctuated within 4-5 cyclones for a season. However, despite the general tendency to decrease, the greatest number of southern cyclones noted in 1986 (8), and in 2009-2011 (7) for a winter season. These cyclones bring considerable precipitation, strengthening of wind, snowstorms and promote formation of high water-accumulation in snowpack before the spring snowmelt (Danilovich et al., 2007).

Thus, calculation of cyclones of various origin show the tendency of slight increase of western and significant growth of northern cyclones during the winter season and decrease of south cyclones. This have led to some precipitation increase during the cold period and to prevalence of thaws. The thaws interfered with accumulation of snowpack before the beginning of a spring snowmelt and promoted decrease in the number of floods on the rivers of Belarus during last decades.

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Signal of wave climate change reflected by wave set-up height

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1. Introduction

Effects of climate change have usually the most significant influence on urban areas where they affect not only existing buildings and infrastructure but also people's safety, new development projects, planning of land use, etc. Many of the related threats are connected with marine-induced coastal hazards. A serious problem for low-lying coastal urban areas is flooding. The properties of it several components such as a high water level of the entire Baltic Sea, local water level increase owing to low atmospheric pressure or wind-driven surge have been studied in detail for the Baltic Sea.

An additional threat for coastal areas exposed to high waves is wave-induced set-up. This phenomenon often provides 30–50 % of the observed maximum water levels in long-term run (Dean and Bender 2006). As large wave set-ups only occur when high waves are incident to the coast, very high total water levels occur infrequently when high surge is accompanied with large waves from a particular direction.

The sensitivity of wave set-up with respect of the match of the wave approach direction and the geometry of the coastline makes this phenomenon a convenient indicator of the intensity of waves from a particular direction. It also offers an option to identify changes in the approach direction of the largest waves in different decades in coastal areas with complicated geometry.

Here we address the changes in "climatology" of set-up height and associated changes in the wave approach direction in the vicinity of the city of Tallinn (Gulf of Finland, Estonia). The changes are highlighted using the timing of the maxima of reconstructed set-up heights over 32 years. These events correspond to the highest waves that approach almost perpendicularly to the single sections of the coast.

2. Data and methods

The study area is substantially expanded compared to the analysis in Soomere et al. (2013) and covers now a section of the southern coast of the Gulf of Finland from the Suurupi Peninsula (west of Naissaar and Tallinn Bay) to the Ihasalu Bay. The coastline has extremely complicated geometry and contains several semi-sheltered bays deeply cut into mainland. As a result, single sections of the coastline are exposed to waves approaching from a variety of directions, from south-west over north to east. The predominant wind direction here is from the south-west but almost equally strong winds from north-north-west and east may occur in the Gulf of Finland (Soomere and Keevallik 2003).

Wave properties were modelled using a simplified scheme of reconstruction of time series of wave properties based on a triple-nested WAM model, with a resolution 3 nautical miles (nm) (about 5.5 km) over the Baltic Sea, 1 nm (about 1.8 km) in the Gulf of Finland and 0.25 nm (about 470 m) in the study area. The model was forced with one-point open-sea wind data from Kalbadagrund for the time interval of 1981–2012.

The coastline of the study area was divided into 174 sections (Fig. 1) with a typical length of 0.5 km. The wave model grid points were chosen as close to the coast as possible but ensuring that waves were still non-breaking. The water depth at these grid points was mostly between 4–10 m. The seabed of these sections was assumed locally homogeneous, with orientation matching the average orientation of the section. Significant wave height and wave approach direction at the breaker line were found from the modelled wave height, period and direction at nearshore grid points by means of fully resolving shoaling and refraction (Soomere et al. 2013).

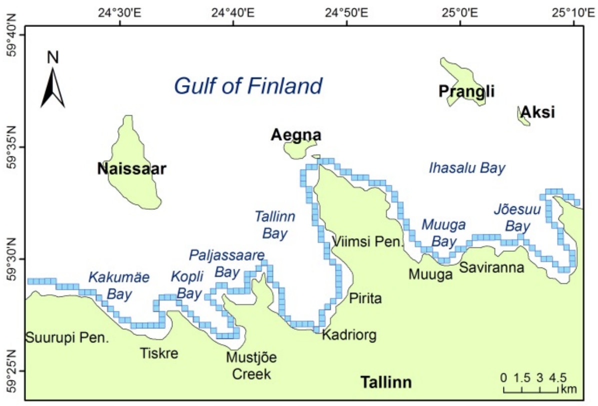

Figure 1. Selected wave model grid points in the study area.

3. Timing of extreme set-up heights

The overall maximum significant wave height in the study area was 5.4 m and thus only slightly exceeded the all-time highest measured value in the Gulf of Finland (5.2 m, Tuomi et al. 2011). The smallest values of the all-time highest waves (1.5 m) were found in sheltered bayheads. All the highest ever waves in the study area occurred in seven storms (Fig. 2). All these storms occurred in the second "half" of the time interval in question, from the year 1995 onwards when a north-eastern storm created high waves in the eastern part of the study area. Note that in the area to the west of the Viimsi Peninsula only four storms in 1998–2006 were responsible for all the highest waves. This may be indicative of an increase in the overall wind speed; however, a more appropriate explanation is that the wind direction in strong storms has changed within the time interval in question.

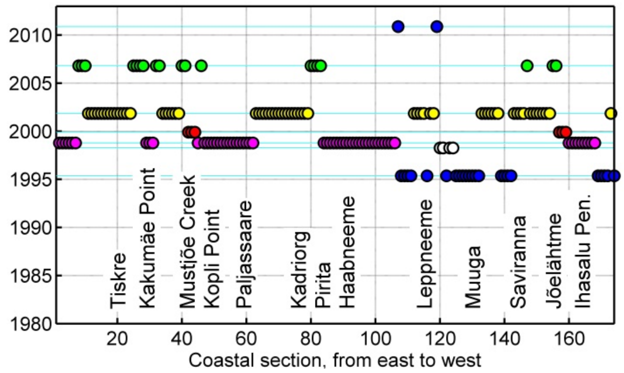

Figure 2. Seven storms that caused highest waves all over the study area in 1981–2012. The horizontal lines indicate storms that produced the highest almost-incident waves at least in one coastal section. Each storm is marked with a single colour. The colours vary cyclically.

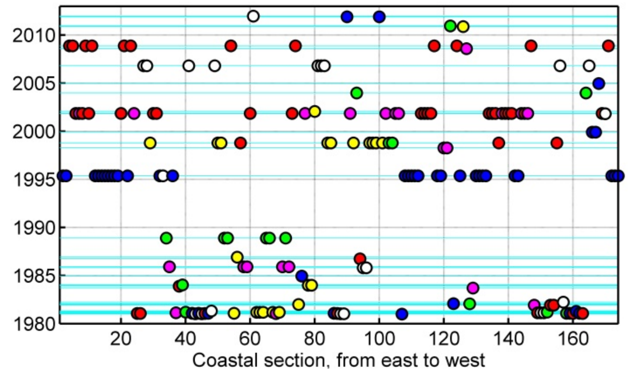

Figure 3. Storms that caused highest waves in particular coastal sections (waves approaching from the direction of ±15° with respect to the normal to the coast). Notations are the same as for Fig. 2.

The extreme values of wave-induced set-up are sensitive with respect to the match of the wave approach direction and orientation of the coastline. The approach angle of the all-time highest waves varies from almost zero up to >90° for several sections located at headlands. Obliquely approaching waves mostly produce longshore current. High set-up only appears when high waves are almost incident to the coast. Therefore in many occasions the all-time highest set-up it is not caused by storms that are responsible for the highest waves all over the study area (Fig. 2).

Similarly to the analysis in Soomere et al. (2013), for almost all coastal sections the highest waves that approach the coast directly (as well as the highest set-up heights) are produced by storms that are not among the strongest ones. While only seven storms were responsible for the all-time highest waves (Fig. 2), 50 different storms produced the all-time highest waves approaching the coast at an angle less than ±15° with respect to the normal to the coast.

Interestingly, apart from the increase in the number of such storms, their distribution over the time interval in question changes radically. The seven storms depicted in Fig. 2 are only responsible for the all-time highest set-up in a small fraction (about 1/3) of the coastal sections. Windstorm Gudrun on 08–09 January 2005 produced the all-time peak water level for many sites in the eastern Baltic Sea (Suursaar et al., 2006) and also very high waves in the Gulf of Finland (Tuomi et al., 2011) but did not produce extreme set-up in any section of the study area. Remarkably, in >50 % of the coastal sections in Fig. 1 the all-time highest set-up was excited before 1995. Moreover, the relevant storms were mostly clustered at the beginning of the 1980s (Fig. 3) while the beginning of the 1990s apparently was relatively calm in this sense.

4. Discussion

The extensive variation of the timing of the all-time highest set-up heights along the study area once more highlights a substantial dependence of the set-up phenomenon on the match of the wave approach direction and the geometry of the coastline.

This feature is accentuated in domains with complex geometry of the coastline where the location and timing of high set-up may substantially vary, depending on the properties of a particular storm.

The performed analysis suggests that the changes to the Baltic Sea wave climate are highly non-trivial and strongly site-specific. The most interesting feature is the evidence of rotation of the wave direction in strongest wave storms from the beginning of the 1980s. This feature mirrors the core property of climate changes in the northern Baltic Sea. Namely, the changes are at times more pronounced in the wind direction (Soomere and Räämet 2014) rather than in the wind speed.

5. Aknowledgements

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The violent mid latitude storm hitting Northern Germany and Denmark, 28 October 2013

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1. The event

A heavy storm passed over all of Northern Europe in late October 2013 (Deutscher Wetterdienst, 2013). We examine this event in some detail with respect to the emergence of record breaking wind speeds in Germany and Denmark on 28 October 2013, and how often such events are to be expected in this part of the world. The analysis makes use of local observations as well as a comparison within the homogeneous "re-analysis" CoastDat (Geyer, 2013).

2. Assessment

At least at one station, the recorded wind gusts were larger than what has been observed earlier. At other locations the winds were also very strong, but not beyond what have been recorded previously. According to CoastDat, the storm was among the 10 strongest since 1958, but not the strongest.

3. Conclusion

We conclude that this storm, which got the name "Christian" in Germany, was a very heavy and rather rare event. Such an event on average may be expected every five years or so. However, such storms show a weak tendency of clustering, so that some storms followed each other within a few years, whereas it happened also that a full decade was free of such strong events.

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Spatial and temporal variability of sea surface temperature in the Baltic Sea based on 30-years of satellite data

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1. Introduction

Sea surface temperature (SST) is a key parameter for constraining the exchange of energy and moisture between the ocean and the atmosphere and is classified as one of the Essential Climate Variables. Satellite SST datasets are based on measuring electromagnetic radiation that left ocean surface and has been transmitted through the atmosphere. Satellite SST measurements are used in many applications as they provide a synoptic view of the dynamic thermal character of the ocean surface. Such data are valuable to agencies and institutions investigating climate variability, providing operational weather and ocean forecasting, for validation and forcing of ocean and atmospheric models, ecosystem studies, tourism and fisheries.

2. Our Research

In this study we have examined the multiyear trends and variability of the Baltic Sea surface temperature (SST) using 30 - years of satellite data. Similar analyses of SST in the Baltic Sea published before have been based on significantly shorter time series (Bradtke et al. 2010, Karagali et al., 2012).

Our results indicate that there is a statistically significant SST trend in most of the Baltic Sea. This trend shows different values depending on the exact geographical location and varies with the month of the year. Higher values of trend are generally present in the summer months. The seasonal cycle of SST in the Baltic Sea is characterized by well-defined winter and summer seasons with relatively short transition periods of spring and fall. The analyzed data show significant interannual variability with extremely high sea surface water temperatures present in the central Baltic in some years.

Our statistical analysis of SST data confirms that the regional climate trend in the Baltic Sea is statistically significant and illustrates some characteristic regional details of these changes.

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Assessment of soil surface water resources from SMOS satellite and in situ measurements in changing climatic conditions

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1. Introduction

Soil moisture is one of 45 Essential Climate Variables (ECV) identified by the United Nations Framework Convention on Climate Change (UNFCCC) to monitor climate variability, recommended for by GCOS (Global Climate Observing System) to observe the effects of climate change.

The information about soil moisture is helping scientists understand more about how water is cycled between the seas, oceans, atmosphere and land – Earth's water cycle. It is also improving weather forecasts and hydrological models. The data are useful for agricultural and environmental evaluations, regional planning, assessments and predictions of droughts and floods by observing water saturation of soil.

In spite of the relevance of soil moisture, there has been a lack of soil moisture observations over the most of the world lands. This is because soil moisture can be very variable, so ground measurements of it need dense network of in situ measurements, which is time consuming and expensive.

The answer for soil moisture data deficiency is SMOS (Soil Moisture and Ocean Salinity) satellite mission. This satellite was launched in November 2009 by European Space Agency (ESA). SMOS carries a novel microwave sensor to capture images of brightness temperature to derive information on soil moisture and ocean salinity. The spatial resolution of SMOS (pixel size) is about 45×45 km and revisit time on every fixed place is approximately 3 days. Precision of soil moisture measurements is claimed to be 0.04 m^3 m^{-3}. Measurements are weather independent, coherent, rapid and conducted globally.

The SMOS mission is the ideal framework to capitalize the often fragmented efforts of the identified experts working in all research areas connected to climate change and regional planning.

Soil moisture (SM in SMOS data) is inherently consistent in time and space, but its validation is still a challenge for further use in the climate and hydrology studies. This is the motivation for the research: to examine soil moisture from SMOS and ground based stations of the SWEX network held over eastern Poland. The presented results are related to changes of the soil moisture on regional scales for Poland in the period 2010-2013.

2. Methods

The SMOS uses observation method of soil moisture and ocean salinity, based on radiometric measurement of the brightness temperature in the spectral range 1.400-1.427 GHz. The brightness temperature in this frequency depends mostly on dielectric constant of soil. Dielectric constant of dry soil is approximately 5, while dielectric constant of water is 80. Because of this significant difference soil moisture can be estimated by measurement of brightness temperature. Another advantage of 1.4 GHz is that this frequency is protected, weakly vulnerable to vegetation cover and not sensible to water vapour, so measurements can be performed in all weather, night and day. The disadvantage is rather poor spatial resolution (45×45 km) of SMOS.

The Institute of Agrophysics participates in the validation of SMOS by conducting ground-based measurements of soil moisture, using the SWEX_POLAND network of automatic ground monitoring stations localized in the Eastern Poland (Fig. 1). These stations are located in the areas representing variety types of land use: meadows, cultivated fields, wetlands and forests. Data series of soil moisture from monitoring stations were compared with time series of the SMOS pixels covering stations' surroundings. Several methods of comparison have been used, for example the Bland-Altman method, concordance correlation coefficient and total deviation index. Using these methods it was confirmed a fair or moderate agreement of SMOS data and network soil moisture observations. This led to the conclusion that SMOS measurements are reliable, so can be used to obtain soil moisture spatial distribution and temporal behaviour.

3. Results

Spatial distributions of surface soil moisture for all Europe are systematically collected since 2010.

The resulting maps of the distribution of soil moisture for the Poland show considerable variation of soil moisture. In the central part moisture values were in the range from about 0.05 to 0.2 m^3 m^{-3}. The high moisture content, of up to 0.4 m^3 m^{-3} was observed in the regions of north-eastern and western borders. In 2011, there was a progressive drought and a significant decrease in soil moisture content below 0.05 m^3 m^{-3}, almost throughout the entire Polish territory.

Figure 1. SWEX_POLAND network of automatic ground monitoring stations

In 2013, Germany, Poland, Czech Republic and Slovakia, as many other countries in Europe, had experienced long and snowy winter. Spring thaw led to soaked soils, which are clearly depicted by SMOS image taken at the end of May 2013 (Fig. 2). Soil moisture in central Germany, reached even up to 0.4 m^3 m^{-3} (the highest ever observed on this area). Then heavy rains occurred which caused catastrophic floods in Germany and Czech Republic. Figure 3 shows surface soil moisture the week after. Soil moisture is lower, which probably depict receding flood in Germany, but on the contrary, some dangerous accumulation of water around Vistula river below Cracow is visible. Fortunately, this accumulation did not cause any severe flood (Fig. 4). The next week (starting from 18.06.2013) was drier, especially in Czech Republic and Slovakia, but some floods on Elbe (Labe) river are still visible (Fig. 4). Weekly averages of spatial distribution of surface soil moisture in the Polesie region (territory of Belarus, Ukraine and Poland) are always bigger than surroundings (Fig. 2-4) because it is flat, marshy land whose half of area is swamp.

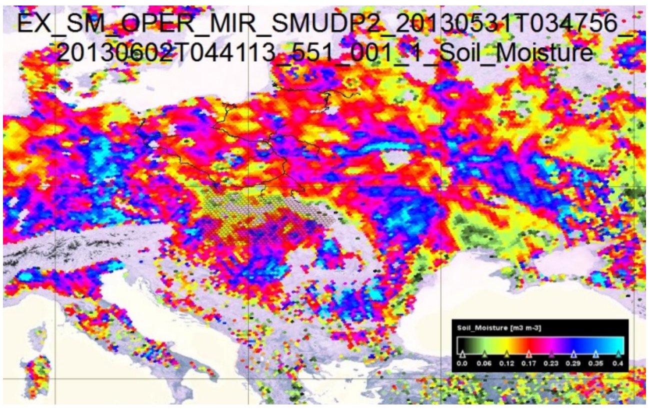

Figure 2. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 31.05.2013)

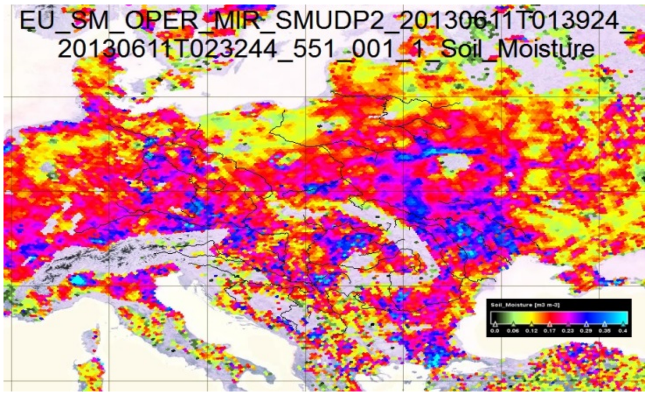

Figure 3. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 11.06.2013)

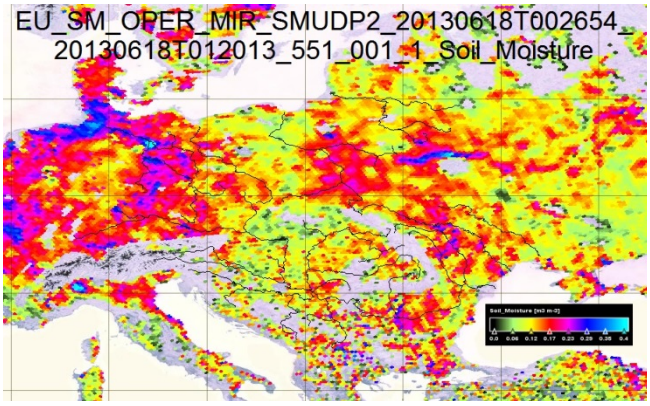

Figure 4. Weekly average of spatial distribution of surface soil moisture in the region of central Europe (starting from 18.06.2013)

4. Summary

Soil moisture measurements taken by the SMOS satellite are more coherent in terms of area and space when compared to other methods. SMOS measurements are reliable and can be used to obtain soil moisture spatial distribution and temporal behaviour. The gathered results are the most representative source of current information of water resources in the soil surface layer. The data are valuable for climate change assessments, hydrological models, and environmental evaluations, assessments of droughts and floods in regional planning.

5. Acknowledgments

The work was partially funded under the ELBARA_PD (Penetration Depth) project No. 4000107897/13/NL/KML. ELBARA_PD project is funded by the Government of Poland through an ESA (European Space Agency) Contract under the PECS (Plan for European Cooperating States).

Influence of climate change on water resources in Belarus

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1. Introduction

The total number of rivers in Belarus is about 20.8 thousand. Approximately 45 % of the rivers belong to the Baltic Sea basin (the rivers of the West Dvina River, the Neman River, and the Bug River basins). The remaining 55 % comes from the Black Sea basin (includes the Dnieper River, the Pripyat River, the Berezina River, and the Sozh River basins), Gosugarstvennyi (2006). The last fundamental researches on water resources in Belarus were published in 1996, Pluzhnikov et al. (1996). The research period ended in the second half of the 1980's, and that work did not include the modern period of climate change. Over the years, the water resources in Belarus were subjected to transformation due to the effects of natural and anthropogenic factors.

The aim of our research was a modern quantitative assessment of surface water resources in the Republic of Belarus. The initial data used materials from the Hydrometeorology Department of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus. We used the data from the current hydrological stations for the period of instrumental observations. The initial data from more than 100 hydrological stations are uniformly located on the territory of Belarus. To obtain comparable results, we selected a single 50-years period since 1962 to 2011. The time series tested for homogeneity, and the missing values were recovered by standard methods to assess their validity.

2. Discussion of the results

The natural water resources in Belarus for the period 1962-2011 years were calculated. Runoff of the main river basins and the administrative regions, and its changes to the data that published in Pluzhnikov et al. (1996), are presented in table 1 and 2.

The total surface water resources have not changed in Belarus. At the same time there was runoff redistribution of the main river basins. There was a runoff increase of the Pripyat River and a slight runoff increase of the West Dvina River. Also a runoff decrease of surface waters for the other rivers in Belarus in recent years was investigated.

Table 1. Runoff of the main river basins in 1962-2011 years (numerator), and its changes to the data that published in Pluzhnikov et al. (1996) (denominator)

River basin	River runoff, km^3/year									
	Local					General				
	Probability, %					Probability, %				
	5	25	50	75	95	5	25	50	75	95
West Dvina	10.6	7.8	6.9	5.5	4.4	22.3	16.4	14.1	11.6	9.0
	0.1	0.1	0.1	0.0	0.1	0.4	0.2	0.2	0.3	0.4
Neman	8.0	6.7	6.2	5.4	4.9	8.1	6.8	6.3	5.5	5.0
	-0.5	-0.4	-0.4	-0.5	-0.3	-0.5	-0.4	-0.4	-0.5	-0.3
Vilia	2.9	2.4	2.1	1.8	1.4	2.9	2.4	2.1	1.8	1.4
	-0.3	-0.3	-0.2	-0.2	-0.4	-0.3	-0.3	-0.2	-0.2	-0.4
Bug	2.8	1.6	1.3	0.9	0.7	2.8	1.6	1.3	0.9	0.7
	-0.2	-0.2	-0.1	-0.2	-0.1	-0.2	-0.2	-0.1	-0.2	-0.1
Pripyat	11.2	7.6	6.6	5.0	3.5	23.9	16.8	14.4	11.0	8.3
	1.3	1.1	1.0	0.6	0.4	1.7	1.5	1.4	0.9	1.3
Dnieper	16.3	11.8	11.0	9.5	7.8	28.2	20.3	18.7	15.6	13.1
	-0.1	0.1	-0.3	0.1	0.2	0.0	0.1	-0.2	-0.1	0.3
including:										
Berezina	6.3	5.0	4.5	4.0	3.4	6.3	5.0	4.5	4.0	3.4
	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Sozh	4.9	3.4	3.0	2.4	1.8	10.6	7.6	6.6	5.4	4.4
	-0.1	-0.1	0.0	-0.1	-0.2	0.0	0.1	0.2	0.2	0.1
Total area	**51.8**	**37.9**	**34.1**	**28.1**	**22.7**	**88.2**	**64.3**	**56.9**	**46.4**	**37.5**
	0.3	**0.4**	**0.1**	**-0.2**	**-0.1**	**1.1**	**0.9**	**0.7**	**0.2**	**1.2**

There was an increase of surface water resources in the Brest and Gomel regions, and for the Grodno region a decrease of water resources due to reduction of water content of the Neman and Vilia Rivers was observed.

The river runoff changes in modern conditions caused mainly by increasing the intensity of the atmosphere general circulation, which is clearly shown in Loginov et al. (2006).

Table 2. Runoff of the administrative regions in 1962-2011 years (numerator), and its changes to the data that published in Pluzhnikov et al. (1996) (denominator)

Administrative region	River runoff, km^3/year				
	Probability, %				
	5	25	50	75	95
Brest	7.5 / 0.3	4.8 / 0.2	4.2 / 0.2	3.3 / 0.1	2.4 / 0.0
Vitebsk	12.4 / 0.1	9.0 / 0.0	8.1 / 0.1	6.6 / 0.0	5.2 / 0.0
Gomel	9.3 / 0.4	6.6 / 0.3	5.9 / 0.3	4.9 / 0.3	3.7 / 0.2
Grodno	5.6 / -0.4	4.7 / -0.3	4.4 / -0.3	3.8 / -0.4	3.6 / -0.2
Minsk	9.9 / -0.1	7.6 / 0.1	6.7 / 0.0	5.4 / -0.2	4.5 / -0.1
Mogilev	7.1 / 0.0	5.2 / 0.1	4.8 / -0.2	4.1 / 0.0	3.3 / 0.0
Total area	**51.8 / 0.3**	**37.9 / 0.4**	**34.1 / 0.1**	**28.1 / -0.2**	**22.7 / -0.1**

Table 3 shows the natural water resources in Belarus taking into account asynchrony of the river runoff that is determined by the genetic characteristics of precipitation. Even for small river basins of Belarus runoff in the whole country is different from runoff of the main river basins due to more significant asynchrony across the country than in some regions. The quite close connection the asynchrony coefficients of probability for the main river basins can be traced.

Table 3. Natural water resources in Belarus taking into account asynchrony of the river runoff

Rivar basin	River runoff, km^3/year							
	Local				General			
	Probability, %				Probability, %			
	5	25	75	95	5	25	75	95
West Dvina	10.2	7.6	5.7	4.8	21.4	16.1	11.9	9.8
Neman	7.6	6.6	5.6	5.2	7.7	6.7	5.7	5.3
Vilia	2.7	2.4	1.9	1.6	2.7	2.4	1.9	1.6
Bug	2.7	1.6	0.9	0.8	2.7	1.6	0.9	0.8
Pripyat	10.5	7.4	5.2	3.8	22.5	16.5	11.4	9.0
Dnieper	15.5	11.6	9.9	8.4	26.8	19.9	16.2	14.1
including:								
Berezina	6.0	4.9	4.1	3.6	6.0	4.9	4.1	3.6
Sozh	4.7	3.3	2.5	1.9	10.1	7.4	5.6	4.8
Total area	**47.7**	**37.1**	**29.8**	**25.2**	**81.1**	**63.0**	**49.2**	**41.6**

3. Conclusion

A quantitative assessment of water resources in Belarus is made. The redistribution runoff of the main river basins and administrative regions was investigated; the total natural water resources have not changed.

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Effects of land management regulations and measures on nitrogen leaching in the German Baltic Sea catchment

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Agricultural production in the German Baltic Sea chatchment is challenged by global and regional regulations on land use management as well as climate change. These challenges need to be addressed in the coming years to maintain a sustainable development of resource utilisiation. We analyse the effects of recent and future agricultural land use and climate change in the German Baltic Sea catchment. An interdisciplinary modeling approach of agricultural and nutrient leaching models is used to evaluate the effects on land use change and nutrient loads on water quality. Nitrogen leaching f. e. is highly dependent upon nutrient inputs due to land use management and also biogeochemical processes in soil. Recently land use patterns and nutrient leaching are changing due to a substantial increase of maize cropping area occurred caused by governmental funding of renewable energy and biomass production. Scienario analysis reveals that until 2021 the effects of climate change are low, instead the trends of nutrient input in the Baltic Sea catchment are controlled by economic and legislative regulations. Especially regulations on agricultural production, agro-environmental measures and renewable energy funding are likely to have an impact on land use management decisions of farmers. We use a socio-economic baseline scenario to evaluate mitigation measures on nutrient input reduction on arable and grassland sites in accordance to the regional land use structures and development trends for the Baltic Sea catchment necessary to achieve the targets of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) targets in the future. Furthermore the regional potentials for growing new crops ore varieties are investigated to test their environmental and economic benefits in the future.

This work is related to an interdisciplinary project on regional adaptation strategies for the German Baltic Sea Coast (RadOst), which aims to assess the effects of climate change, minimize economic, social and environmental harm and develop adaptation strategies.

How reliable are selected methods of projections of future thermal conditions? A case from Poland

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1. Introduction

There is an increasing need for assessment of future climate in specific locations. Global climate models (GCMs) give the projections in the low spatial resolution, with the skillful scale about 1000 km (Grotch and MacCracken, 1991). To get the projection in the local scale it is necessary to downscale GCMs output. There are two conceptually different ways of doing it: regional climate models (RCMs) with model output statistic technics (MOS) or statistical downscaling.

There is a lot of sources of uncertainty of climate predictions. They can appear in the GCM output because of parametrization schemes, uncertainty related to input data: land cover, topography, low quality of meteorological data, uncertainty related to forcing factors, like greenhouse gases and aerosols concentration, and some others. The next source of uncertainty is related to RCMs. They have higher resolution than GCMs, but still quite scarse. The MOS technics also contribute to enhancement of uncertainty.

Due to the chaotic nature of the climate system a small change in initial conditions can cause large difference between model simulations.

In order to make climate projections usefull they should be evaluated.

The aim of this paper is to test a few evaluation methods.

2. Data & methods

Data used in this paper consists of series of daily temperature from different RCMs driven by different GCMs from Central Europe and the period 1951-2010 and series of daily temperature from 20 Polish stations from the period 1951-2010.

The period 1951-2010 is divided into two parts, each lasting 30 years: the reference period 1951-1980 and the evaluation period 1981-2010. Each of analysed projection procedures is calibrated in reference period and then used in the evaluation period. Obtained projections are compared with station data and their quality is assessed.

Different projection methods are to be tested: simple bias correction, distribution based bias correction (Yang et al., 2010; Piani et al., 2010), simple delta change and distribution based delta change.

Series of evaluation measures have to be used, checkin the quality of assessment of the mean value, standard deviation and higher moments as well as distribution consilience.

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Session E

Changing Baltic Sea coasts and their sustainable protection

Dynamics of the Baltic Sea environment under the influence of climate changes (a case study of Lithuanian most famous coastal summer resorts)

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The western boundary of Lithuania is represented by a short (99 km) Baltic Sea coast (Fig.1) famous for its sandy beaches and summer resorts (Fig.2). Similar beaches can be found in Latvia, Poland, and Russia (Kaliningrad Region), i.e. countries which have a gateway to the Baltic Sea.

Figure 1. Study area.

In the last ages, the Baltic Sea environment has been changing under the impact of some factors: the rising Baltic Sea water level (the sea level rose up 14.9 cm beside Klaipeda in the 20th century) (Rimkus et al. 2011), the annual air temperature (wider range of variability of the temperature at the seashore since 1940) and the increasing average wind velocities (deep cyclones became more often from the thirties of the 20th century) (Bukantis et al. 2001).

Intensive recent processes taking place in the Lithuanian coastal area: the budget of continental coastal surface sediments (in 1993-2003) was negative. The annual loss of sediments from the continental coasts is 47930 m³ of sand on the average (Zilinskas & Jarmalavicius 2003). The beach forming processes are entailing by wave action, degradation of the beach foredune ridge, and jamming up with sand of the mouths of the Baltic Sea tributaries, which fall into the Baltic Sea in the most popular recreational beaches. All these processes deteriorate the ecological state of the Baltic Sea.

Especially strongly the Lithuanian coastal zone was transformed by the hurricane "Anatoly" (December 3–4, 1999) which raged along the south-eastern coast of the Baltic Sea. During the hurricane, the wind velocity reached 40 m/s and the sea level rose by 165 cm m (Zilinskas & Jarmalavicius 2003). Another strong hurricane "Ervin" devastated the Lithuanian coast in January 8–9, 2005. The hurricane washed away the beaches, damaged the dunes and transformed the beds of small tributaries. The restoration of the transformed landscape is impossible without huge investments.

The aim of the present article is to evaluate the climate changes in the last thirty years and the associated transformations of the Lithuanian coastal environment.

The study is based on the data for 1961–1990 (Navasinskiene 2003) and next decade (Galvonaite 2007) obtained from the Klaipėda and Nida meteorological stations, comparison of ortophotographs of the studied area in different years, and material collected during the expedition of 2011. A photographic fixation of the territory was performed.

Figure 2. The beach in Sventoji.

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Effect of climate change on ice regime of lagoons of the southern and eastern Baltic Sea

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1. Introduction

Enclosed lagoons are the small continental seas models with a sensitive ecosystem to internal and external pressures. Water temperature appears to be the key factor determining the seasonal and long-term variability of the primary production and abundance of phytoplankton and therefore the level of biological production and trophic status.

This study was to investigate the features of the inter-annual ice cover variations and trends in the south and eastern Baltic Sea lagoons. One of the main aims of this study is to compare tendencies of temporal changes of yearly ice cover season in the lagoons of the South and East Baltic –in the Darss-Zingst Bodden Chain (DZBC) and in the Curonian Lagoon (CL) respectively (Fig. 1).

Lagoons discussed in this study are shallow transitory basins that have only one connection to the Baltic Sea.

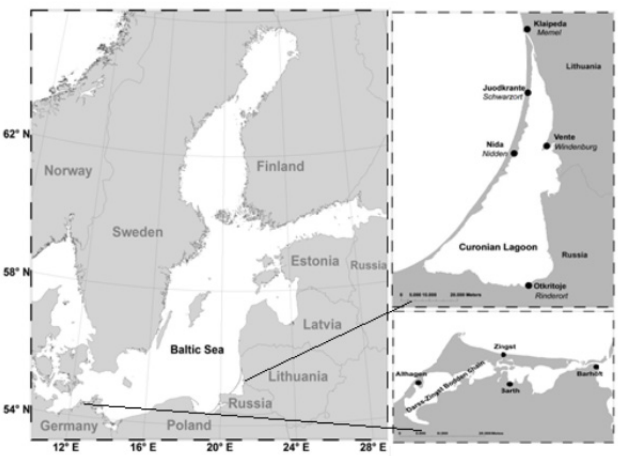

Figure 1. Research area: Locations of Darβ–Zingst Bodden Chain and Curonian Lagoons at the southern and south-eastern Baltic shore.

One of the tasks was to assess the hydrological and meteorological factors affecting the formation of ice cover in the southeastern Baltic. Sea water temperature and salinity was evaluated applying simple and ordinary lognormal kriging. Also we have analyzed time series of some related hydro-climatic factors (Fig. 1).

2. Results

Climate lagoons and ice regime was and still is the most important physic-geographic factor to determine the biological and coastal formation processes.

The study results show that increasing air and water temperature, and decreasing ice cover duration are related to the changes in atmospheric circulation, and more specifically, to the changes in wind regime climate.

Based on the results of Dailidiene et al. (2011) study, the warming trend of the mean surface water temperature in the CL and DZBC lagoons was 0.03 °C year^{-1} in the period 1961-2008 and about 0.05 °C year^{-1} after 1980.

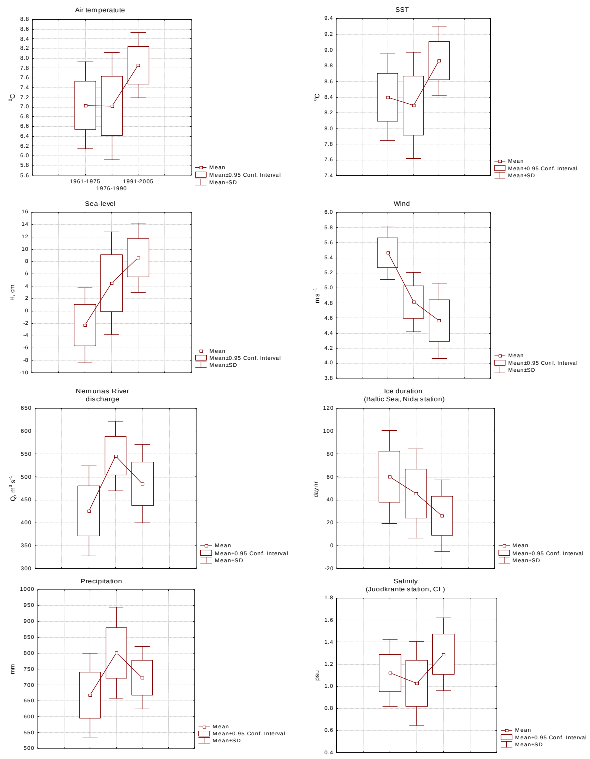

Figure 2. Comparison of the change of hydro-meteorological statistical parameters for the periods 1961-1975, 1976-1990 and 1991-2005 in the South East Baltic Sea area, including Curonian Lagoon, and Nemunas River (Dailidiene et al. 2012).

The estimated increase of the air and sea surface temperature shows up in wintertime in the ice conditions in the South-Eastern (SE) part of Baltic Sea (Fig. 2). The air temperature has risen by 0.9 °C, and the sea surface temperature (SST) in the coastal zone of the Baltic Sea and in the Curonian Lagoon has risen by 0.6 °C during the study period. According to the assessment (from 1991 onwards) the warming trend of the mean air temperature was about 0.06 °C year^{-1}, and the mean surface water temperature - 0.04 °C year^{-1}, respectively (Dailidiene et al. 2012). The correlation coefficients between the numbers of days with ice phenomena per year (ice season), air and sea water temperatures were -0.69 and -0.54 (p<0.001).

The study the Curonian Lagoon hydro-climatic conditions changes indicates increased frequencies of cyclonic circulation. Westerly winds have become more frequent. The atmosphere dynamics and winds most intensively influence the sea-level rise in winter time. Sea level in the CL rose by 18 cm in a period between 1961 and 2008, and at the same time in the DZBC water level increase was three times less - rose by 6 cm (Dailidienė et al. 2011). Maximum rate during the 1961-2008 was ~ 4 mm year ⁻1 for the Curonian Lagoon, and approximately 1 mm year ⁻1 for the DZBC.

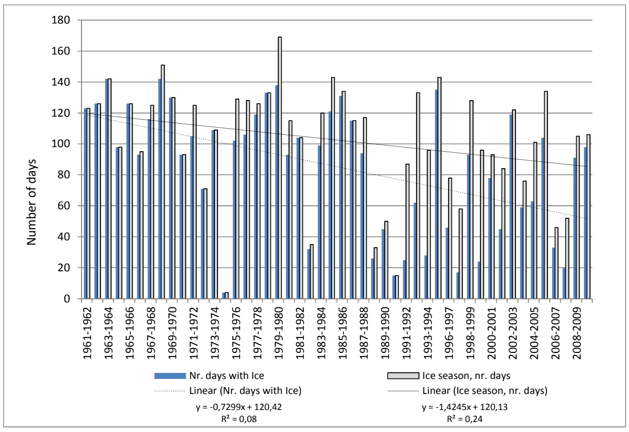

Figure 3. Change the ice season and the number of days with ice in the Curonian Lagoon (Nida station).

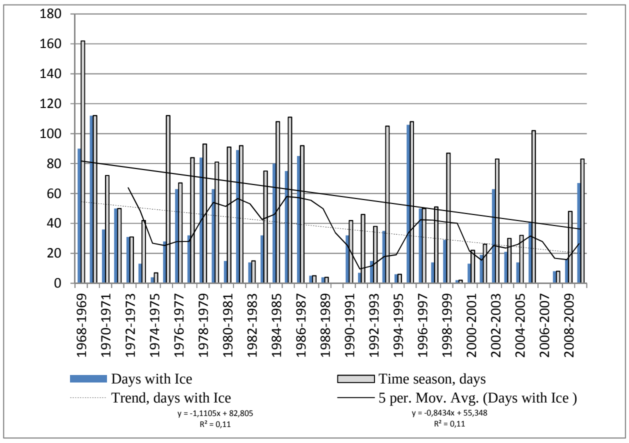

Figure 4. Change the ice season and the number of days with ice in the Darβ–Zingst Bodden Chain (Zingst station).

The ice season duration decreased in the south and eastern part of the Baltic Sea lagoons (Fig. 3 and Fig. 4) and it is associated with climate change in this region, and increase of air and water temperatures. According to Haapala and Leppäranta (1997) the first-order prediction is that an increase of mean atmospheric temperature by 1 °C would delay the freezing date by 5 days, and lead to ice breakup earlier by 5 days in the Baltic Sea.

3. Discussion and conclusions

The ice season duration has shortened in the S and SE Baltic Sea coast. Compared the number of days with ice in the 1991 - 2010 with the period 1968-1990 days with ice in the lagoons became less an average 1 month (29 days) in the CL, and half month (17 days) in DZBC. Obtained results correspond with the atmospheric-ocean models prognosis that was foreseen for the 21th century. According Meier et al. (2004) the length of the ice season could decrease by as much as 1-2 months in northern parts and even 2-3 months in the central Baltic.

The study results show that increasing air and water temperature, and decreasing ice cover duration are related to the changes in mezzo- scale atmospheric circulation, and more specifically, to the changes in wind regime climate. The ice season in the lagoons of south and eastern part of the Baltic Sea is shortening. In such conditions the absence of stable ice cover and domination of pack ice and ice drift will cause severe problems for navigation and coastal stability (Fig. 5). Lagoons climatic changes in ice cover is a good indicator of describing the effects of climate change in the water catchment ecosystem.

Climate change processes, such as the annual air and water temperature, ice periods change, are not expected to be geographically uniform in the Baltic Sea, therefore information about the distribution is needed for the assessment of impact on coastal regions.

In conclusion, the future change in climate system components can have a stronger effect on the Baltic Sea coastal areas, such as lagoons, boddens and hafts.

Figure 5. Ice in the Curonian Lagoon and Klaipeda Strait (Photos by I. Dailidiene and I. Kairyte)

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A method for estimating coastline recession due to sea level rise by assuming stationary wind-wave climate

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1. Motivation

Coastline changes and sea level have been becoming an increasingly important topic of the population living along the edge of the world ocean. An accelerated relative sea level rise can intensify erosion at the unprotected coasts. During the 21st century, an unprecedented rate of sea level rise has been projected (Meehl et al., 2007). Accordingly, there is a vital need for projecting coastline responses to the accelerated sea level rise scenarios.

Recently, there has been a focus on improving the modelling of coastline responses to sea level rise at the equilibrium states (e.g. Woodroffe and Murray, 2012). A more realistic situation is that a coastal profile is always during the process of evolving to the equilibrium states, due to changing external driving forces (e.g., wind waves and sea level changes) and boundary conditions (e.g., sediment input and output). By applying the concept of three-dimensional sediment mass conservation, Deng et al. (2014) have developed a numerical method called Dynamic Equilibrium Shore Model (DESM) to approximate historical coastal morphology. The DESM model is able to account for the dynamic equilibrium evolution of coastal profiles by using the information of historical coastline changes, relative sea level records and modern DEM. This model has shown its potential for future projection of coastline changes due to sea level rise by assuming stationary wind climate in Deng et al. (2014). Here, a complete description of this new method to estimate coastline recession due to sea level rise is presented. The projection of wind climate by 2100 AD is also analysed by using the data of climate modelling.

2. Methods and results

The assumption of stationary wind climate is tested by using climate modelling data covering the time frame from the year 1960 to 2099. These wind data are modelled and adjusted by using gustiness parameterization (Meier et al., 2011). On the basis of these data, the probability density distributions of east-west and north-south wind speed for the periods 1961-2010 AD and 2011-2099 AD are compared. The comparison of probability density distributions at the Pomeranian Bay, southern Baltic Sea shows that there is a noticeably increased frequency of extreme northerly wind, but on average the wind climate can be regarded to be stationary as only insignificant increase of mean wind speed is obtained. Generally speaking, the projection under greenhouse emission scenario A1B shows less increased probability of extreme northerly winds than A2. Intensified coastal erosion due to storm events may be anticipated, as the northerly winds likely generate southward traveling waves attacking the Pomeranian Bay that locates at the southern Baltic Sea.

The predictive mode of the DESM is formulated by 1) deriving the component of sea level rise effect on coastal erosion through the morphodynamic equations, and 2) statistically determining the forward relationship between coastline, sea level changes and the estimated sediment budget by the inverse modelling of the DESM. This new model is also compared with other equilibrium models.

This new method provides a first order (linear function between coastline change and sediment volume change) site-specific projection of future coastline changes based on relative sea level change scenarios. These scenario simulations take the net lateral sediment flux, the net cross-shore sediment flux, and dynamic equilibrium profile into account. The results of the future projection indicate that the impact of the relative sea level rise on the coastline retreat depends on the ratio between the lateral sediment flux and the accommodation space evolving from relative sea level rise.

The effect of increased storm frequency as well as increased wave height may affect the results. This effect needs to be included in the model in future.

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On spatio-temporal variations of the wave energy potential along the eastern Baltic Sea coast

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1. Introduction

Wave energy has one of the largest potential among various renewable energy sources for coastal countries (Previsic et al. 2012). It has high density in many nearshore regions located close to population and industrial centres, and its use is often compatible with existing marine and coastal uses (Kim et al. 2012).

The Baltic Sea has relatively mild wave climate and, consequently, fairly limited wave energy resources. While the onshore wave energy flux often exceeds 50 kW/m in the open ocean, its typical values are a few kW/m in the Baltic Proper. This resource is unevenly distributed. Complicated geometry of the Baltic Sea leads to considerable spatial variation of wave properties and available wave energy. The well-known asymmetry of predominant wind is mirrored in a similar asymmetry of wave energy resources that evidently are the largest along the eastern coast of the Baltic Sea. Extensive seasonal variation in the wind speed results in an even larger variation of wave heights and wave energy flux (wave power). These variations have more or less cyclic character that can be easily accounted for in planning exercises (Kim et al. 2012).

We concentrate on the temporal variability of the wave energy flux along the eastern Baltic Sea coast. Differently from the open ocean coasts (where swells almost continuously provide considerable wave energy supply), highly intermittent nature of the wind and wave properties in the Baltic Sea gives rise to extensive temporal variability of the wave power.

2. Wave energy flux

Onshore wave energy flux at a depth of about 15 m is evaluated using the time series of wave heights, periods and propagation directions calculated using the wave model WAM (horizontal resolution 3 nautical miles) and adjusted geostrophic winds from the database of the Swedish Meteorological and Hydrological Institute. These parameters are evaluated for each of the 222 about 6 km long sections on the eastern coast of the Baltic Sea from the Sambian (Samland) Peninsula (including the Gulf of Riga) to the eastern part of the Gulf of Finland for 1970–2007 based on calculations of Räämet et al. (2010).

The entire coastal stretch receives, on average, about 1.5 GW of wave power. The average wave energy flux reaches its maximum (2.55 kW/m) in the nearshore of Saaremaa and is 1–2 kW/m (Fig. 1) along the rest of the open coast of the Baltic Proper. In Gulf of Finland and Gulf of Riga the typical values of wave power are below 1 kW/m (Soomere and Eelsalu, 2014).

Sea states with the greatest contribution to the annual wave energy in Baltic Proper are represented by waves with the significant wave height of 2–4 m and with peak period of 6–9 s. In Gulf of Riga and Gulf of Finland the greatest part of energy are concentrated in sea states characterised significant wave heights of 1–3 m and periods of 4–8 s. Such wave properties are typical for the strongest autumn storms that occur relatively seldom and the total duration of which is about a week each year. As the relevant waves are very steep, energy extraction from these sea states is complicated.

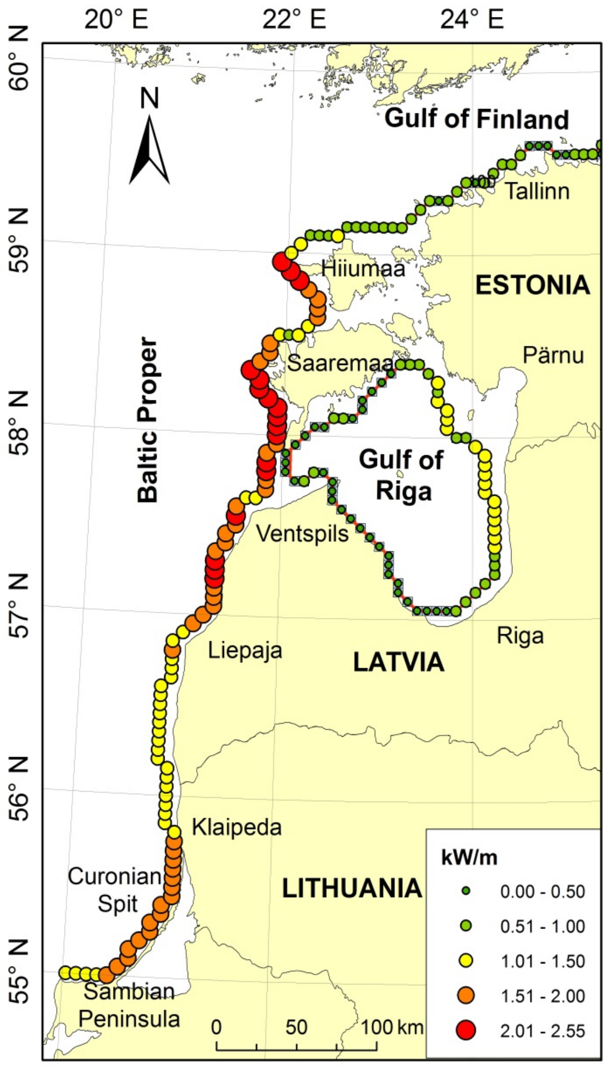

Figure 1. Average wave energy flux along the study area.

The Baltic Sea wave fields relatively rapidly (usually within less than 8 hours) reach a saturated regime. The 'memory' time of the wave fields is only a little longer and normally does not exceed 10–12 hours. The proportion of swells is very low and the majority of wave energy is concentrated in windseas.

These features together with rapid variations in the wind properties give rise to high intermittency of wave energy flux in time. The maximum values of wave power exceed average values in a single coastal section by more than two magnitudes and may reach instantaneous levels of ~700 kW/m during the strongest autumn/winter storms. Although such storms are not very long, they contain a large part of wave energy. More than half of annual energy arrives to the coast only within 18 days (Fig. 2). About 30 % of the annual available energy is brought to the nearshore by 1 % percent of the highest waves of the year, equivalently, by sea states that together cover only 3–4 days each year.

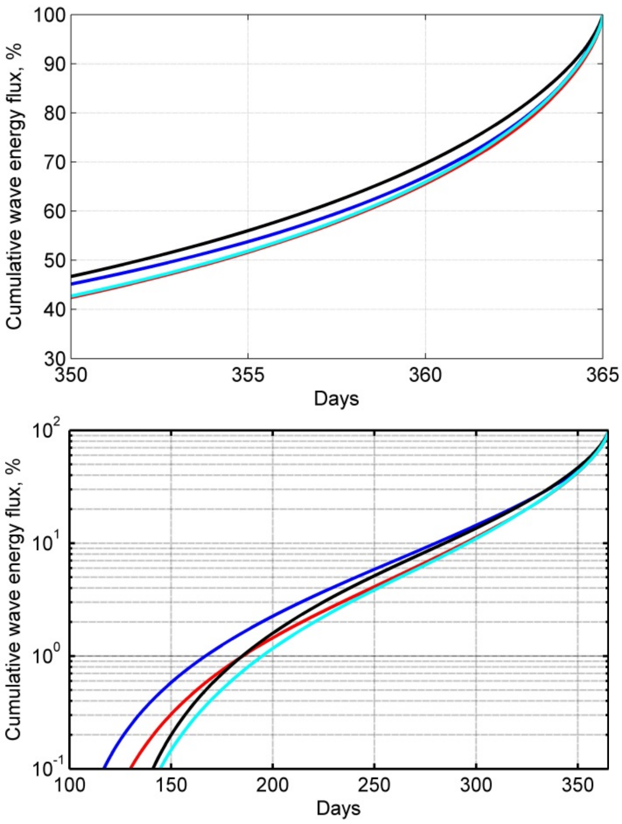

Figure 2 Cumulative energy flux at the border of Latvia and Lithuania (blue), western coast of Saaremaa (red), eastern Gulf of Finland (black) and eastern Gulf of Riga on annual average. The contributions from each 1-hour time interval are sorted in ascending order. Upper panel: contribution of the windiest week; lower panel: contribution of the windier half-year.

Another dimension of such a concentration of large amounts of wave energy into short time intervals is that intervals with very high energy supply are interspersed with extensive gaps in the wave energy flux. On average, the set of the calmest 180 days provides only 1 % of the total annual energy flux. Some intervals can be almost still: the calmest 120 days provide less than 0.1 % of the total annual energy flux.

The described features are common for the entire eastern Baltic Sea. While the problem of energy extraction from high and steep waves can be, in principle resolved, appreciable levels of wave energy are present within less than 1/3 of the days of each year. The resulting gaps in production require either alternative energy sources or possibilities of storage of substantial amounts of energy (e.g. pumping of water into a reservoir, hydrogen production, etc.).

A large part of the coastal areas of the Baltic Sea host existing and planned marine protected areas, incl. the Natura 2000 areas. Such coastal stretches and their immediate vicinity evidently cannot be used for energy production. The existing marine protected areas cover about 46 % of the area in Fig. 1 (Soomere and Eelsalu, 2014). The unprotected areas provide only about 44 % of the bulk theoretically available wave energy.

3. Conclusions

The total wave energy potential in the eastern Baltic Sea is definitely appreciable. It is about 1.5 GW in the entire study area, from which about 1/3 could be provided jointly by the Gulf of Finland and Gulf of Riga.

The major limiter for the industrial and local use of this energy seems to be the combination of strong seasonal variation and high intermittency in the wave properties. These two aspects severely complicate the relevant technical solutions. For example about half of the annual wave energy flux arrives within several strongest storms with a total duration of about two weeks. Another major issue (not considered above) is the regular presence of ice in both the wave generation domain (that reduces the available wave energy) and in the potential locations of wave energy converters. It is therefore not likely that industrial grid energy production from waves in the coastal waters of the Baltic Sea will become economically justified in the conceivable future. However, the presented features of the Baltic Sea wave fields could be interpreted as a challenge for new solutions for wave energy converters.

Acknowledgements

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Effectiveness of coastal and flood protection structures in a changing climate

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Climate change "It is, simply, the greatest collective challenge we face as a human family" said UN Secretary General Ban Ki-moon in 2009.

More than one billion people live in low lying coastal areas, areas that are particularly vulnerable to the impacts of climate change as they are prone to flooding by the sea. To protect these people, efficient coastal and flood protection systems are needed.

In Germany, the Federal Ministry of Education and Research (BMBF) is furthering the development of innovative approaches to climate change adaptation with a funding activity "KLIMZUG". One of the founded project is called RADOST (Regional Adaptation Strategies for the German Baltic Coast). The objective of RAdOst is the development of adaptation strategies for the Baltic coastline of Germany through a dialogue between academics, economists, policy-makers and the public. Other important goals are to minimize the economic, social and environmental harm and to capitalize on development opportunities brought about by climate change.

One goal of RAdOst is the evaluation of present coastal and flood protection strategies and structures under terms of changing climate conditions as a basis for the development of future save strategies. In this scope, the effectiveness and adaption strategies of

- sea dikes,
- dunes,
- flood protection walls,
- revetments,
- (submerged) breakwaters and
- groins

has been systematical evaluated. The investigations has been performed for areas in the Baltic Sea, but the results should be transferable all around the world. Basis for these investigation are different climate change scenarios, as changing mean sea level and changing wave conditions.

In the paper, systematical assessment of the effectiveness of the above coastal and flood protection structures will be presented as well as systematical analyzes of adaptation strategies of these structures. The adaption strategies are generally divided into:

- hold the line,
- fallback,
- business as usual and
- forward defense.

An example for dunes under an so-called climate change "scenario 2050, height" (mean water level increment +40cm, wave height increment +10%, storm flood energy +15%) that roughly describes the today state and future situations for the adaptation strategies "do nothing" and "forward defense" is shown in Fig.1.

The advantages, disadvantages and effectiveness of these strategies for each of the above structure has been evaluated and compared and will be shown in the presentation.

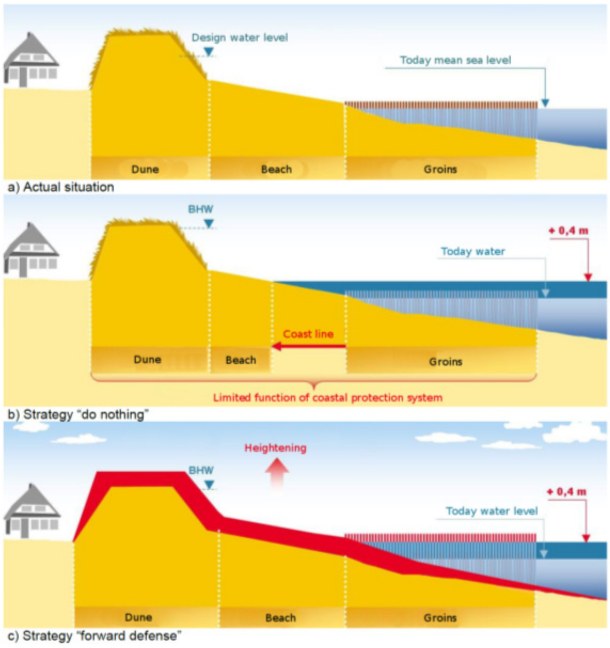

Fig. 1: General example for different strategies for dune-protected coasts for "scenario 2050, height"The headline style is 10pt Calibri, boldface fond. The body text should be typed in Calibri, 10pt, single spaced, two column text, adjusted, as in this example. Please write your extended abstract into it.

Highly persisting patch formation areas in the Gulf of Finland, the Baltic Sea

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1. Introduction

Under normal conditions, the sea surface layer is extremely heterogeneous across a broad range of spatial and temporal scales. The underlying ecosystems may be deeply influenced by variations of any of the natural biogeochemical variables or substances of anthropogenic origin. Such variations in concentrations, referred to as *patches*, may impact the ecosystem in a positive or negative way. Negative impact is often associated with factors of anthropogenic origin and substances released into the environment through e.g. dredging, dumping, aquafarming or discharge of (micro)plastic, chemicals or pollutants.

An important role in the formation of such patches of floating substances may play three-dimensional motions underlaying the two-dimensional surface layer (Lee 2010). The resulting motions in the sea surface often have long-living convergence areas. Items and substances that are either floating or are locked in the surface layer tend to gather in such areas. This property can be quantified in terms of flow compressibility. Such an increase in the concentration may explosively accelerate if the flow compressibility exceeds a certain threshold. Another possible option for substantial increase in surface concentrations is when an area of intense divergence moves synchronously with the Lagrangian transport of the gradually forming patch (Samuelsen et al. 2012).

We explore a simple method for identification of such areas of natural increase in the concentration of items on sea surface by means of the recently developed measure of Finite Time Compressibility (FTC, Giudici et al., 2012; Kalda et al., 2014). With this measure, we illustrate the presence and interannual variability within the timespan 1987–1991 of persistent high-compressibility areas in the test area, the Gulf of Finland, the Baltic Sea. This area has been shown to frequently host regions of high FTC (Kalda et al., 2014). These areas are generally prone to changes in concentrations of floating matter and the associated patch-formation process in the surface layer. Such areas can be detected based on certain properties of surface velocity fields.

2. Methods and data

The analysis in this note relies on the output of the OAAS ocean model (Andrejev and Sokolov, 1989) with a spatial resolution of 1NM. This is a primitive-equation, time-dependent, free-surface, baroclinic model based on hydrostatic approximation. It is fed with meteorological data from a regionalization of the ERA-40 re-analysis over Europe. The idea for quantification of the Finite Time Compressibility (FTC) relies on the tracking of Lagrangian transport of single water parcels that are locked at the water surface and are passively carried by horizontal velocity components. This measure is evaluated in terms of geometrical properties of the triangular elements of triplets of such particles (Fig. 1; see Giudici et al., 2012; Kalda et al., 2014 for details).

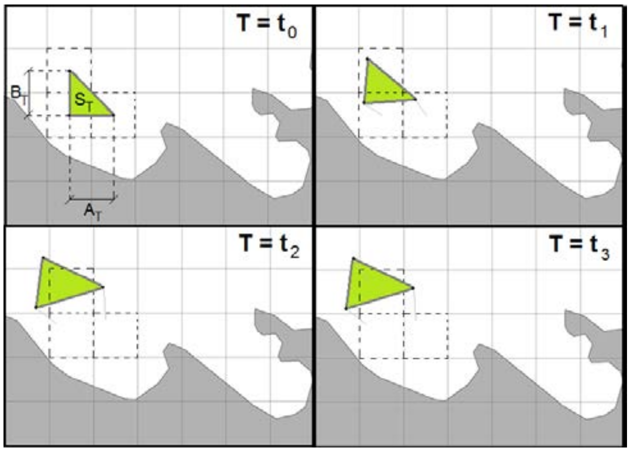

Figure 1. Triplets of simulated floating particles used to calculate Finite Time Compressibility.

The implied calculation scheme involves a division of the simulation period (1987-1991) into fixed length time-windows, over which the tracking of selected parcels is performed. The analysis of changes to the geometry of such triangular elements over each time window gives an estimate of the 2D distribution (map) of the FTC. The properties of this distribution obviously depend on the beginning instant of calculations and the length of the time window (equivalently, the length of the trajectories of selected parcels). The “raw” estimates of the FTC distributions are averaged next over certain time intervals of the beginning instants.

A rapid increase in the concentration only occurs if the FTC exceeds a certain threshold (Giudici et al., 2012; Kalda et al., 2014). In order to evaluate the chances for the FTC calculated for different sea areas to exceed this threshold, the resulting distributions (maps) for different values of the time window length are analysed using a method similar to the peak-over-threshold method. For each wet grid cell, we count the amount of occasions during which the clusterization threshold of FTC = 0.7 is exceeded.

The results are characterized in terms of the frequency of occurrence of high values of FTC, in other words, in terms of time during which the “instantaneous” values of FTC (calculated for a particular start instant and the length of the time window, optionally for certain seasons) exceed the above threshold. The most contrast (that is, highly persistent or frequently occurring) areas of large FTC were manually selected within this set of maps. They were associated with idealised areas, the centroid's position, shape and size did not change by more than ±20% across the entire dataset.

3. Highly persisting patch formation areas

The described process of averaging the instantaneous FTC maps over a long time span allows us to identify and focus only on those areas that systematically show heavy clusterization potential. Averaging over 90 or 180 days long batches of maps smooths out many local features of the FTC that show up on individual maps. More importantly, the resulting distributions demonstrate that several areas of appreciable size steadily (or often) host above-clustering-threshold values of FTC in the Gulf of Finland (Fig. 2). Some of these areas show this property for up to 30 days within the 90 days long batches, that is, during one third of the time. These areas are mostly concentrated on coastal regions, mainly along the southern coast of the gulf. Very few similar areas show up near the northern coast of the gulf where they are also weaker, consequently, indicating lesser chances for the FTC to exceed the above-discussed threshold. Interestingly, one such area is located in the central part of the gulf within the area bounded by the islands of Gogland, Bolshoy Tyuters and Moshchny.

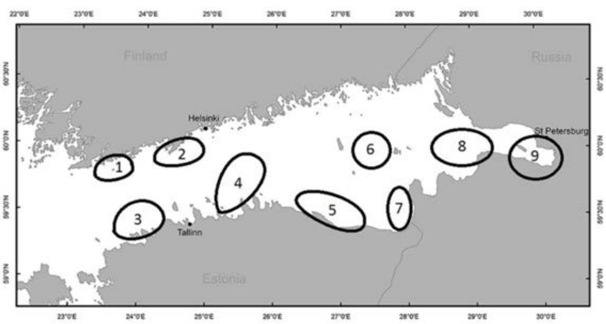

Figure 2. The set of 9 highly-persisting high-FTC areas found in the region of the Gulf of Finland during the timespan 1987-1991.

Vertically averaged profiles of the resulting map of the frequency of occurrence of over-threshold values of the FTC show that this quantity is usually asymmetric in the North-South direction. Namely, the southernmost areas host systematically larger frequencies of occurrence of over-threshold values of the FTC than the northern ones. Therefore, the patch formation processes are more likely to occur in the southern parts of the gulf. Meridionally averaged values of this quantity also reveal that the central part of the gulf is generally less likely to host such areas, while one area (area 8 in Fig. 2) very frequently hosting high FTC values is spotted in the western part of the gulf. Its presence is evidently connected with a persistent area of convergence of the overall cyclonic circulation of the gulf with the voluminous fresh water inflow due to the Neva River.

4. Discussion

The presented approach to the problem of detection of natural patch-formation areas owing to the match of convergence areas and Lagrangian drift of the forming patches in the surface layer highlights a rich pattern of possible patch-formation regions in the Gulf of Finland. The detected areas reveal comparatively low interannual variations of their main properties, even if no evident strong pattern can be seen at this stage. Several of the nine distinguished areas match locations of frequent downwelling regions, while some others are located in the middle of the gulf, possibly indicating long-term convergence areas of surface currents.

Acknowledgement

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Sub aerial beach volume change and sea level rise on decadal time scale in the Lithuanian coasts of the Baltic Sea

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1. Introduction

One of the most important problems in predicting future coastal evolution is determining the impact of potential rise of sea level to coastal systems. However, there are other significant factors which influence coastal dynamics as well, including sand availability, wave climate, storminess, coastal morphology, geologic framework, and human impact. Furthermore, particular factors have different effects in different time scales. In a long-term time scale (decades to centuries), the main aspects which influence the change of sea level are vertical movements of the Earth's crust and sea level eustasy. In a short-term time scale, wind and wave climate influences the change of sea level far more.

Since 2002, a monitoring of yearly changes of coastline position and subaerial beach sand volume took place on the Lithuanian coast of the Baltic Sea. The coastal dynamics for the 2002–2013 period in the coastal systems of different geomorphology was determined according to the obtained data. The aim of this paper is to evaluate the impact of sea level fluctuation and other possible factors on the coastal systems with different geomorphology dynamics on decadal time scale.

2. Study area

The Lithuanian coast consists of two segments of different genesis: the mainland shore (38 km) and the Curonian Spit (51 km) which are separated by the Klaipėda Strait (1.6 km) (Fig. 1). The nearshore of the Curonian Spit has a well-developed bar system consisting of 2 to 5 bars reaching 400–670 m in width. The prevailing 30–80 m wide beaches are composed of fine and medium sand (Jarmalavičius and Žilinskas, 2006). The altitude of the foredune reaches up to 16 meters and the volume of beach sediments is 42–124 m^3/m. The abundance of sand in this section determines the northward longitudinal sand migration. It enables a large amount of sand to reach the Lithuanian territory from the southward part of the spit. Due to the Klaipėda port jetties which block sediment migration flow alongshore, a large part of sand does not reach the mainland coast. For this reason, the mainland coastal sediments are scarcer and the bar system is not well developed. It usually has 1–3 bars, but in some places they do not exist at all. Locally, moraine is exposed at a depth of 1.5–3.0 meters. 20–85 meters wide beaches are mostly composed of fine and medium sand. It should be noted that the shore between Šaipiai and Karklė is dominated by moraine cliffs. The volume of beach sediments there reaches 16–160 m^3/m.

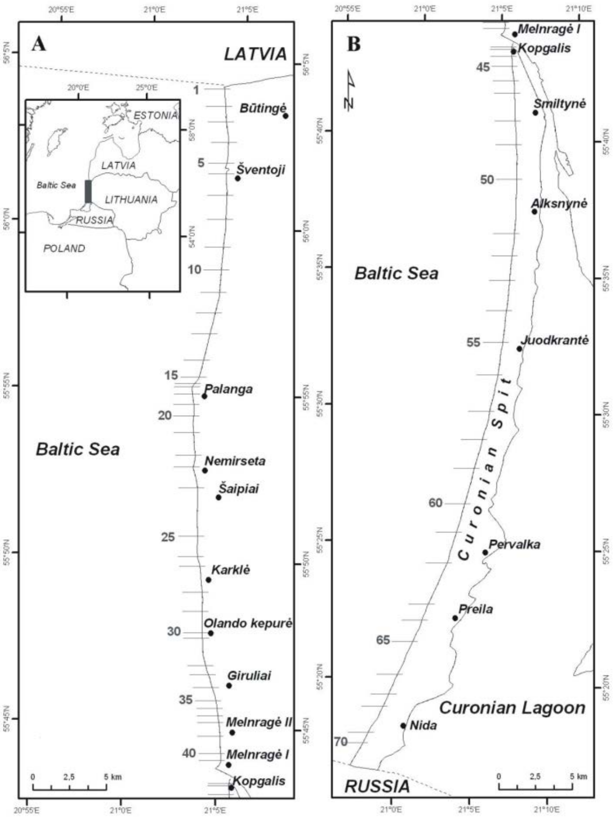

Figure 1. Location map of study area. A – mainland coast, B – Curonian Spit coast.

3. Methodology

In this paper, subaerial beach sand volume was established as the main indicator of coastal dynamics, reflecting both accretion/erosion of coastal system and sand budget. Its volume change comprises of coastal profile volume change from foredune crest to intersection of mean sea level. The data of the shift in sand volume was obtained during the coastal monitoring, when a coastal cross-profile leveling was executed in fixed coastal positions in May each year (Fig. 1). 70 profiles (40 on the mainland coast and 29 on the Curonian Spit coast) were measured in total. This way, the change in amount of coastal deposits and the change of coastline position were determined. The period of observation continued from 2002 to 2013. To evaluate beach volume in different time scales, both decadal change and year-to-year variability were calculated. In the first case, change of subaerial beach volume was calculated over time from the first observation in 2002. In the second case, yearly variations of volume were calculated as the differences between two consecutive years.

The Klaipėda gauging station data (mean monthly sea levels, wind speeds, and wave heights) from 2002 to 2013 was collected from Department of Marine Research of the Environmental Protection Agency. Because coastal monitoring took place in May, the coastline variations reflected the changes from May in one year to April in the next year. Therefore the yearly averages of sea level, wave height, and wind energy were calculated for the same period using monthly means. To avoid random local fluctuations due to rhythmic topography in shoreline position, the data was averaged for sectors of longer coastal length (separately for the mainland coast and the Curonian Spit coast). Because the lengths of distinguished coastal sectors were different (the mainland coast is 38 km, while the Curonian Spit coast is 50 km), the amount of sediment was calculated in cubic meters per meter length of shoreline (m^3/m).

A wind energy indicator which competently reflects both wave climate and general storminess was used in the research. It was calculated according to the formula:

$Ve= \Sigma(-\sin\alpha * V)/n$, where Ve – wind energy; V – wind speed; $-\sin\alpha$ – sinus of wind direction; n – case's number.

4. Results

After the analysis of the sediment volume dynamics in the period of 2002-2013, it is clear that they were differ-rent in the mainland coast and the Curonian Spit coast (Fig. 2). In the mainland coast, an average increase of 0.04 m^3/m per year was identified. Because yearly fluctuations considerably exceeded long-term ones, this trend is not reliable. Therefore the nature of sediment volume dynamics was rather cyclic than linear in the researched period. Sediment accumulation trends were evident on the Curonian Spit coast, where a distinct trend of sediment increase at an average rate of 2.90 m^3/m per year was identified.

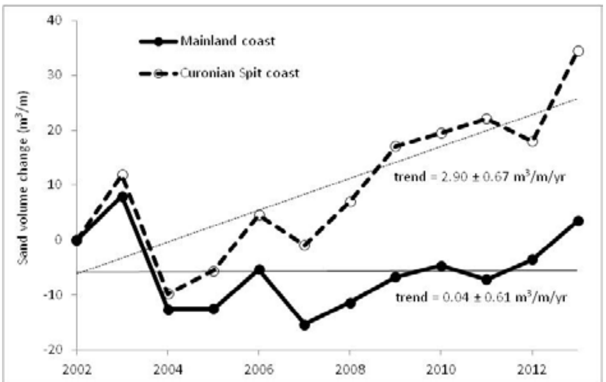

Figure 2. Subaerial beach volume change in mainland coast and in Curonian Spit coast in 2002 - 2013 and their linear trends.

During the 2002-2013 period a trend of rising of sea level changes was identified at a rate of 0.16 cm/yr (Fig. 3). There are no confidential trends for such short time scale due to large inter-annual fluctuations. Nevertheless, general tendencies of changes of the Baltic Sea water level at Klaipėda are seen clearly from the long period time series. A constant increase in sea level takes place from the beginning of the 20th century. In the period of 1898-2013, sea level has been rising at a rate of 0.16 ± 0.02 cm/yr. Therefore the rising trend of the last decade practically corresponds to the rising trend of the last century. Despite the rise of sea level, sand volume was increasing in the Curonian Spit and was stable on the mainland coast.

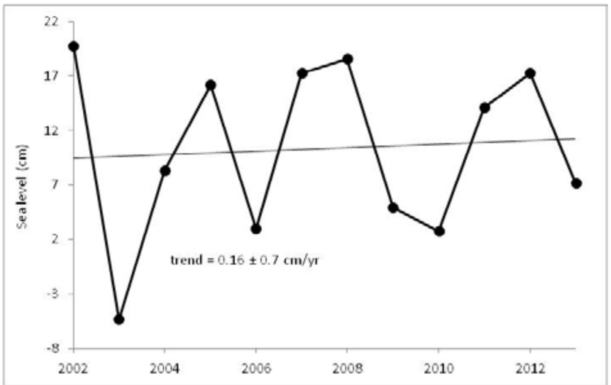

Figure 3. Sea level changes in 2002-2013 and its linear trend.

The dynamics of wind energy during the period of 2002-2013 had a small (0.02 m/s per year) decreasing trend. The wind energy trend, just like the sea level trend, is not reliable. However, a decrease in wind energy at the same rate is observed in the period of 1961-2013. Therefore, wind energy, wave height, and storminess all had a small decreasing trend during the last decade.

In a short time scale (year), there is a reliable connec-tion between relative sea level and changes in beach vo-lume. However, it is difficult to assess the direct effect of changes in sea level which would be isolated from other factors, such as incident wave climate and frequency and intensity of extreme events in a short time scale.

5. Conclusions

After the analysis of sediment amount dynamics for the 2002-2013 period, no significant dependence between subaerial beach volume change and relative sea level rise on decadal time scale was identified. The magnitude of beach volume change is controlled by the sediment supply, storm activity, wave climate, and coastal geomorphology. In addition to that, because sea level, wave height, and magnitude of wind energy are all closely connected in a short time scale, it is difficult to identify the influence of solely the rise of sea level separated from other factors. In a decade time scale, the extent of coast erosion depends more on the frequency and intensity of storms than on the slow rise of sea level. On the other hand, when there are enough sand reserves in the nearshore, a small increase in sea level can stimulate accumulation processes on the coast. A small, up to 0.2 cm/yr rise in sea level does not have any significant influence on the coastal recession.

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Extreme short-term aeolian accumulation on foredunes of west Polish coast caused by hurricane Xavier on December 2013

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1. Introduction

This study analyzes the aeolian accumulation effects caused by extreme hurricane event on foredune – first dune ridge. In paper are resented some main meteorological and hydrological parameters occurring during passage of hurricane Xavier and its influence on aeolian accumulation on foredunes on west Polish coast, that is described in several articles (Łabuz 2013). That hurricane seriously affected not only Polish Baltic coast but also German, the Dutch, Denmark and United Kingdom coasts.

Such studies are important in relation to climate change, causing rapid changes in coastal areas: the destruction of infrastructure, coast rebuilt, erosion and flooding (e.g. Houser et al. 2008).

2. Hurricane parameters affecting coastal change

Severe hurricane Xavier was a strong low-pressure system that formed on North Atlantic on end of October 2013. During the next days it rapidly developed and began to move in an easterly direction. On 5th December 2013 hurricane began in western Poland (Swinoujscie). Polish coast remained under its influence to 8 December. Its presence influenced the rise in sea levels, waves growth up to 10 in Beuafort scale and heavy winds, predominantly from the west and northwest.

In Poland – Świnoujście (first west town and meteo station), the maximum sea level above mean one (amsl) exceeded 1.12 m amsl, in Dziwnow 1.00 m and in Kolobrzeg 1.20 m (last big town of west coast). During Xavier peak wind speeds exceeded 125 km/h, and the average was 75 km/h. The wind gusts measured on Szczecin University coastal station in Miedzyzdroje exceeded 28 m/s, and the average speed was 18 to 21 m/s. The field measurements of wind on 6 and 8 December showed speed up to 23 m/s. The wind was blowing from the west to northwest. On that time huge sand transportation along beach was observed.

3. Data and methods

Data include the west coast of Polish from Swinoujscie to Kolobrzeg (and Mielno). Changes in the relief of the examined coast section were determined based on the analysis of beach and dune profiles established in previous measurements (also in project FoMoBi, www:fomobi.pl, Łabuz 2013). The meteorological and hydrological description of the December 2013 hurricane is based on the routine data provided mainly by the Harbour Master's Office in Swinoujście or Kolobrzeg and field observations.

To quantify the relief changes caused by hurricane discussed were used the profiles surveyed on end of November 2013, few days before phenomenon and on 13 to 15 December after it. These profile were compared for the changes that have taken place in the foredune relief during Xavier hurricane action. In order to asses relief short-term changes, some field surveys based on dune relief fluctuations and aeolian transport regime were conducted on 6 to 8 December (using RTK GPS and wooden piles fixed on the dunes and using sand traps and anemometers for wind speed and sand transportation).

4. Foredune growth

During hurricane storm surge appeared, which reached height up to 2.5 m above mean sea level. On the coast waves destroyed all the beaches less than 2.5 m high and other relief forms (as embryo dunes on beach), and resulted in the erosion of the onshore foredune slopes. Despite such foredune erosion, on each ridge an increase in dune height was observed. This was the result of sand accumulation, that has been blown from adjacent beach. The wider was beach, the more sand was transported onto dune ridge, just before storm surge and beach flooding.

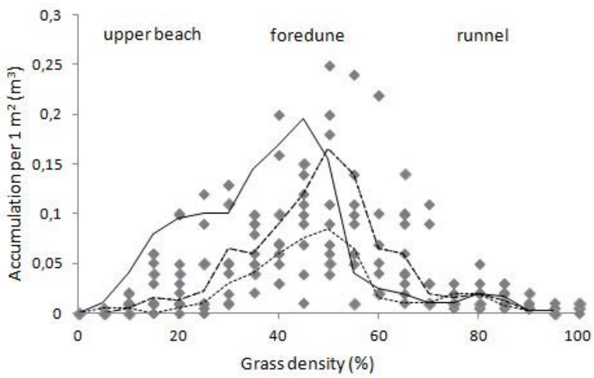

Figure 1. The rate of sand accumulation in relation to grass cover during 3 days of hurricane Xavier on December 2013 on Polish coastal dunes.

It was found that within 3 days of the hurricane the average accumulation on the foredune was 0.1 m^3 / m^2 (per 1 sq. meter of surface). The biggest changes have occurred on the top of dune and on its back leeward slope. The maximum observed accumulation was 0.25 m^3 / m^2 (fig.1). The accumulation of sand was also observed in the gutter-swale behind each foredune - does not exceed 0.05 m per m^2 and on the slope of the second ridge. On the embryo dunes located on upper beach accumulation reached up to 0.2 m. This was permanent and stable increase only in places where embryo dunes were not washed out during storm surge. In places where their height not exceeded 2.5 m, accumulated sand have been washed away and the water eroded slopes of the foredunes. The sand balance on beach of such coast was negative.

It was found that the accumulation was dependent on the density of vegetation cover and the relief of dune coast (beach height and width, embryo dune presence and dune slope angle).

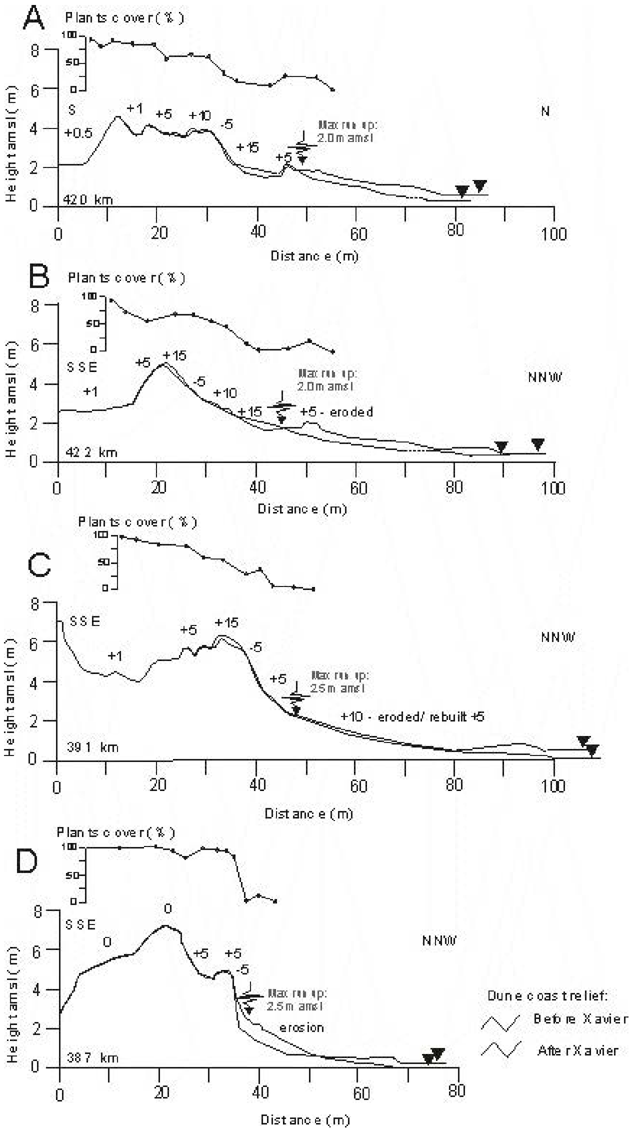

Figure 2. The foredune short-term relief changes (in cm) in each zone related to relief and vegetation cover during Xavier, types A-D, described in text.

4.1. Accumulation related to grass cover

The study compared the accumulation of sand, which occurred on the surface of 1 m^2 to dune cover by grasses (fig.1). These grasses force sand accumulation. This is know from literature (Arens 1996, Houser et al. 2008, and others). It was found that accumulation was greatest in areas where grass cover ranged between 40 and 60%. On the wind exposed slopes, rarely covered with grass deflation was observed. In such areas dunes were lowered about 0.1 to 0.2 m. This zone was most exposed to very strong winds, which results from exposure of the slopes. The foredune zones covered with vegetation to 40% also underwent deflation or a small accumulation, that occurred mostly in dune hollows or in the shade of obstacles (as relief or big grass clumps).

4.2. Accumulation related to coast relief

The study distinguishes four types of coastal dune relief profile in relation to growth during hurricane (fig.2): (1) average accumulation of foredune ridge (0.1 m) and more on the embryo dunes (0.15 m) on coast with wide beach (A), (2) large accumulation of foredune ridge (0.15 m), in the area where the embryo dunes were washed off on coast with wide beach (B), (3) large accumulation of foredune ridge (0.15 m), where there was no embryo dunes and beaches were wide and high (C), (4) small accumulation of of foredune ridge (0.05 m), where the beaches were low and narrow (even with embryo dune – washed off any way), (D).

5. Conclusions

The largest erosion changes during Xavier hurricane, an extreme meteorological event, occurred where, prior to the storm, the beach was lower than the maximum wave runup – 2.5 m amsl, but this is not aim of this study.

The main conclusion is that such events are responsible for the faster development of the dunes on the accumulative part of coast. The biggest changes – aeolian accumulation occurred at the ridge of foredunes exposed in the NW. In neighboring beaches to the east of these sections, the wind took off all available sand before it was eroded by sea. This sand has been accumulated on foredune, and is proving permanent accumulation; will stay there fixed by grasses. All this took place just before the start of beach erosion caused by storm surge. The rate of accumulation was comparable to annual foredune growth during whole year without such extreme event. It should be underlined that such extreme event is destroying some parts of coast but is a force causing accumulation on coast with progradation tendencies.

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Thermal conditioning of seasonal variability of PM10 concentration in Zachodniopomorskie Voivodeship

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1. Introduction

Despite systematic improvements of air quality the excessive concentration of particulate matter is still a problem in Poland. Stationary combustion, the residential sector in particular, are among the main sources of PM10 initial emission. A significant share of PM10 pollution results from an increased volume of vehicular traffic, that is secondary pollution. The issue of overnormative concentration of particulate matter, especially in winter seasons during frosty winter conditions, has been discussed by many authors (Jóźwiak, Wróblewski 2002, Czarnecka, Kalbarczyk 2008). Within the area of the city high PM10 immission values are recorded particularly in districts characterized by scattered and ineffective heating appliances, such as household furnaces or tiled stoves, based on the use of solid fuel, predominantly hard coal of poor quality. High concentrations of particulate matter are recorded not only in the cities of Poland but in most European countries. According to Querol, Alastruey et al. (2004), annual mean PM10 concentration in Berlin ranges from 24 $\mu g \cdot m^{-3}$ to 38 $\mu g \cdot m^{-3}$.

2. Materials and methods

The aim of the research is to determine the thermal conditioning of seasonal variability of PM10 immission as recorded by measuring stations in Zachodniopomorskie Voivodeship. The research is based on data concerning daily PM10 concentration and air temperature obtained from the automatic monitoring stations of the Voivodeship Inspectorate of Environmental Protection in Szczecin for the period: December 2008 – November 2013. The data from three measuring station was used in the analysis of the variability of particulate matter concentration – two stations were located in Szczecin and one in Szczecinek. The influence of temperature on PM10 concentration was determined with the use of correlation analysis method. The variables correlated in this analysis were daily mean values of PM10 concentration and air temperature.

3. Results

In the period of five years under study mean monthly PM10 concentration varied depending on the measuring period and the location of the measuring station – from 10.0 $\mu g \cdot m^{-3}$ to 54.9 $\mu g \cdot m^{-3}$. High concentration of particulate matter, that is from 15.2 $\mu g \cdot m^{-3}$ to 54.9 $\mu g \cdot m^{-3}$, was mostly recorded in the winter seasons during which the temperature was below average. In the analysed period the highest maximum daily PM10 concentration was recorded in Szczecinek (192 $\mu g \cdot m^{-3}$) during the winter of 2010/2011.

The excessive values of a daily standard for PM10 (over 50 $\mu g \cdot m^{-3}$) were recorded predominantly during winter seasons, occasionally in autumn, and rarely in spring. The greatest number of days with excessive PM10 concentration was recorded in Szczecinek in the winter season of 2010/2011 (see Fig. below). The smallest number of excessive values or the lack of overnormative concentrations were recorded in all measuring stations in the summer seasons.

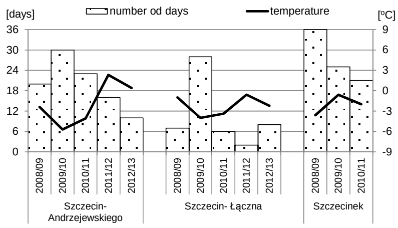

Figure. Number of days with excessive values of PM10 concentration in winter seasons as for seasonal mean air temperature.

According to the results of the regression analysis, PM10 concentrations show a statistically significant relationship with the variability of thermal conditions in most seasons in a year. A decrease in daily mean temperature during winter season brought about a decrease in PM10 immission. A similar direction of the relationship was found also for the spring and autumn seasons. The opposite direction of the relationship in question was characteristic for all summer seasons. The analysis substantiated the fundamental role of thermal conditions in the variability of PM10 concentration in winter seasons. The highest values of correlation coefficient for PM10 concentration and temperature were calculated for the season of 2011/2012. The spring season of 2010 and 2011 showed equally marked influence of thermal conditions on PM10 concentration. A strong influence of temperature on the concentration of the analysed pollutant in 2011 was additionally evident during the period of the calendar autumn, and in both stations located in Szczecin – also in spring (see Table below).

Table. Correlation coefficients for the relationship between PM10 concentration and air temperature. Statistical significance at α=0.005.

	2008–2009	2009–2010	2010–2011	2011–2012	2012–2013
Szczecin – Andrzejewskiego					
winter	-0.400	-0.519	-0.409	-0.879	-0.489
spring	0.062	-0.108	-0.371	-0.143	-0.277
summer	0.576	n.s.	0.689	0.668	0.367
autumn	-0.320	-0.087	-0.680	-0.345	-0.198
Szczecin – Łączna					
winter	-0.196	-0.454	-0.485	-0.822	-0.501
spring	0.120	0.241	-0.226	-0.075	-0.197
summer	0.758	0.375	0.724	0.736	0.532
autumn	-0.399	0.169	-0.572	-0.212	-0.017
Szczecinek					
winter	b.d.	b.d.	-0.600	-0.847	-0.569
spring	b.d.	b.d.	0.010	-0.154	-0.425
summer	b.d.	b.d.	0.705	0.686	0.697
autumn	b.d.	b.d.	-0.553	-0.444	-0.190

b.d. – lack of data; n.s. – not statistically significant

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Sandy beach recurrence to the quasi equilibrium profile after beach replenishment

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1. Introduction

Coastal erosion is a global problem; at least 70% of sandy beaches around the world are recessional (Zhang et al., 2004). In recent decades coastal zones became very important and relevant study object in many parts of the world. Fundamental and applied studies are taken for the sea coast dynamics, coastal zone floor and the entire complex of coastal nature, research (Janukonis, 1999). The coastal zone is a dynamic, complex and vulnerable environment, the changes to which have significant economic and social impact on coastal population. In particular, they may threaten human interests by reducing the recreational area and limiting the development of the coastal infrastructure (Bagdanavičiutė et al., 2012).

Lithuania has a short (only 90.6 km long) stretch of Baltic Sea coast (Žilinskas et al., 2010), part of this Baltic sea coast (38.49 km) belongs to the mainland coast, part (1.14 km) to the Klaipeda straight and Curonian lagoon (51.03 km) (Jarmalavičius et al., 2011). However every coastal section is affected by different anthropogenic impact. Coastal sections that are closer urbanized areas tend to have largest impacts. But the number of holidaymakers and visitors in these regions depends on attractiveness of the beaches for recreational needs. One of such a coastal section is the beach of Palanga city. In the end of 20th century it experienced quite significant shoreline retreat towards the mainland (Bagdanavičiutė et al., 2012).

Therefore the Government of Lithuanian Republic decided to apply the means of coastal management, which have to natural (having the least impact to the natural coastal forming processes). It was decided to apply the "soft" coastal management means – beach nourishment by sand for the damaged section. Generally speaking, beach nourishment involves the placement of sediment on an eroding beach to migrate the shoreline seaward in order to promote storm protection, natural habitat and beach amenity. Due to the widespread use of beach nourishment worldwide (Hamm et al., 2002), it is now important that not only coastal engineers but also geoscientists investigating coastal processes understand the performance of beach replenishment.

Main task of this research was to determine Palanga beach profile transformation in time and space after beach replenishment.

2. Method and data

The paper analyses data of the beach levelling in 2012 – 2013. Study area covered a 3 km section of Palanga coast, which included 30 measurement profiles, distant one from each other by 100 meters (Fig. 1). Profiling was performed using dual-band GPS receiver Leica900. Using this device the height of the Baltic Sea water level and LKS'94 coordinates were recorded into the measurement system. Sand volume (Q) is provided by one meter length of beach shore. Zero value of the Baltic Sea water level was taken as the lowest point for all profile measurements.

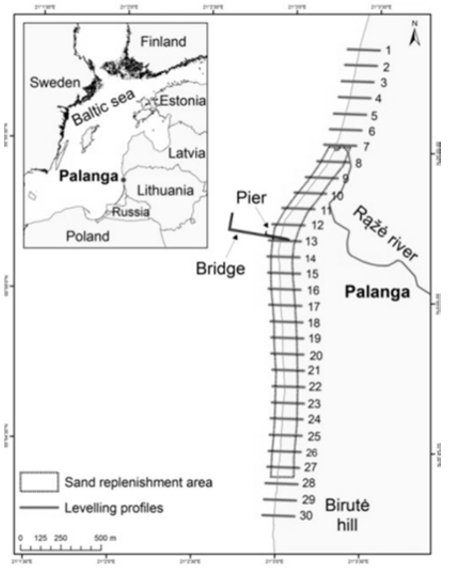

Figure 1. The Location of study area and profile.

For the sand volume change calculations the beach profile was divided into 4 zones: 1st, 2nd, and 3rd zones divide the beach into 3 equal sectors, while the 4th zone exclusively covers only dune ridge area. Calculations were made using ArcMap^{TM} software. The positive values of sand volume changes (ΔQ) show an increase in the volume of sand and negative – decrease.

3. Results

Analyzing the data 1650 sand volume change values were estimated, which illustrates redistribution of sand and migration trends after Palanga beach replenishment with sand in the studied area. Some of the results are presented in figures 2 and 3, showing the intensity and change of trends during the research.

The largest sand volume losses were observed in 9-12 and 18-27 profiles (fig. 3). During the replenishment these profiles received largest amount of sand, therefore their natural balance was damaged the most, resulting in most intensive equilibrium profile adaptation processes. The maximum losses of sand volume occurred at 11 profile (fig. 3). Here one meter of beach length lost more than 100 m^3 of sand per year. Profiles 1-8 and 13-16 stood out in significant increase of sand volume (fig. 3). It also showed a clear eolian transfer, which had impact of sand volume increase for the 3rd and 4th zones (fig. 3).

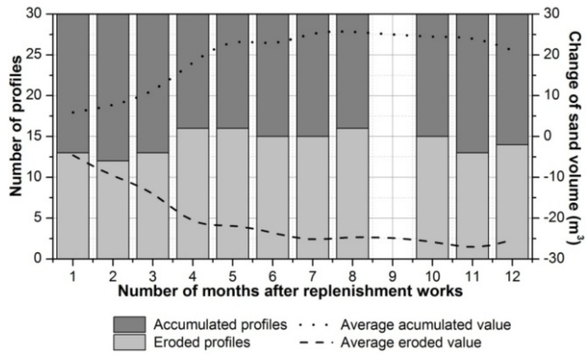

Figure 2. The change of eroded and accumulated profiles and the mean change of sand volume intensity during 2012/06/01-2013/06/01.

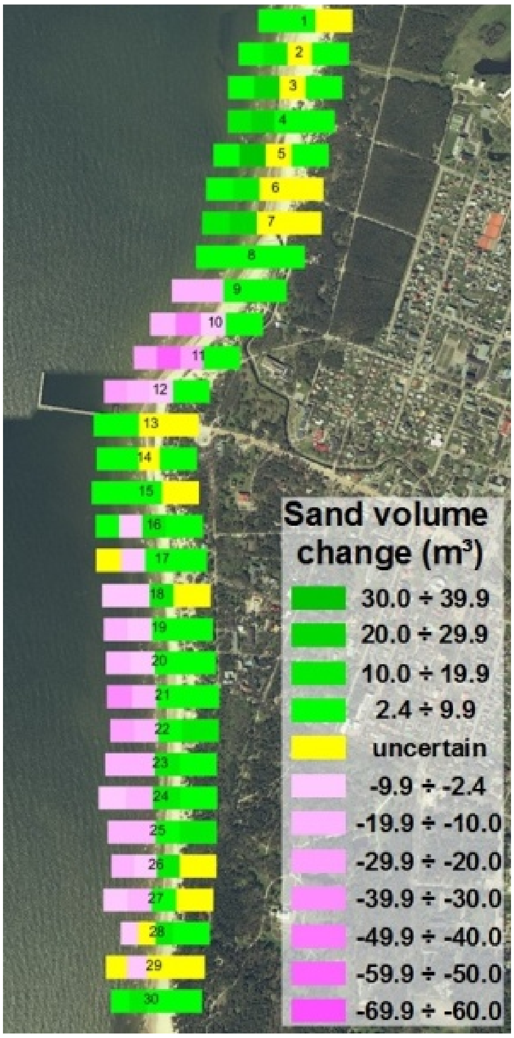

Figure 3.Sand volume changes (ΔQ) in different zones during 2012/06/01-2013/06/01.

The largest intensity of the sand volume change was observed during the first 4 months after Palanga beach replenishment works (Fig. 2). Subsequent changes show relatively stable situation, during it eroded and accumulated profile changes varied in the range of 20 – 30 m^3 on the average every month. Furthermore during the calm season period of 2013 the changes were even less noticeable. The difference between eroded and accumulated profile numbers varied from 0 to 3 during the research.

4. Conclusions

The most active changes of studied profiles were estimated in the sections where the largest injections of sand were made. The most intensive change of beach profiles was on September of 2012, as this month stood out with active hydrometeorological situation. Wave processes reform the area of wet beaches, while areas that are higher are being changed by wind created eolian transfer. Therefore beach profile changes are mainly determined by prevailing hydrometeorological situation.

To the north of eroded areas accumulation areas were formed, their emergence was mostly conditioned by a longitudinal sediment transport, which in the coast of Lithuania prevails from south to north. The emergence of accumulation zone at profiles 13-16 was resulted by the stone pier located near the Palanga Bridge. It formed about 0,5 km length section of accumulation by suspending the longitudinal sediment transportation.

Total change in sand volume on the Palanga beach: + 44 m^3. Largest loss of the sand: near the waterline (1st zone) -130 m^3. Accumulation/erosion processes in the middle of dry beach (2nd zone): highly variable. Main pathways of sand are from S to N, from waterline to dune. The Palanga beach has been almost in equilibrium throughout this year, with very small internal changes. Dune toe area is being filled with sand, small embryonic foredune is being formed.

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On sensitivity of wave-driven alongshore sediment transport patterns with respect to model setup and sediment properties

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1. Introduction

Calculations of wave-driven sediment transport and efforts towards numerical replication of the evolution of sedimentary coasts are extremely sensitive with respect to the input parameters (such as sediment properties, sinks and sources) and driving forces such as wave data and information about the water level (Deng et al. 2013).

Another source of uncertainties is from the methods of quantification the reaction of sediments to the driving forces. For example, the CERC (Coastal Engineering Research Centre) coefficient for the calculations of potential sediment transport varies by several times for different beaches (USACE 2002, Chapter III-2-3). There is evidence that several such semi-empirical methods are not directly applicable in some basins. A potential source of problems is a low level of energy of swells. Although this feature should not affect any express methods used in the coastal engineering, the quality of their output seems to depend on the balance of windsea and swell energy in the Baltic Sea (Soomere et al. 2013).

Calculations of sediment transport along the Baltic Sea coasts using various implementations of the CERC formula (that has been developed for the open ocean coasts) tend to indicate larger values than observations. A part of the bias could stem from a low quality of wave information (e.g. Zemlys et al. 2007; Mėžinė et al. 2013) while another, often larger, contribution to the bias may stem from different interpretations of the wave height in the CERC and similar formulas (Viška and Soomere 2013). Moreover, the Baltic Sea waves often approach the coast under quite large angle. As a result, simplified (but explicit) evaluation of the impact of refraction may lead to considerable overestimation of the breaking wave height and approach angle at breaking and, consequently, to overestimation of the transport rate.

We discuss here the implications of the different choices of the governing parameters (incl. the interpretation of the wave height) in the CERC formula for the net and bulk sediment transport along the eastern Baltic Sea coast.

2. Methods and data

The study area covers the longest interconnected coastal sedimentary system of the Baltic Sea that extends from the Sambian Peninsula to Pärnu Bay in the Gulf of Riga. Estimates of the magnitude and direction of the wave-driven alongshore sediment transport are obtained using the CERC model. The model assumes that the potential sediment transport is proportional to the rate of beaching (per unit of coastline) of the alongshore component of wave energy flux at the breaker line.

For all realistic wave fields it is natural to associate the local wave energy with the root mean square wave height. The group speed of waves at the breaker line is usually linked to the wave height by using so-called breaking index (the ratio of the breaking wave height to the water depth at this location) and the assumption that breaking waves are long waves. Here, different interpretations of the wave height are possible. For regular swells (and coastal stretches that are frequently impacted by high swells) the particular interpretation plays a minor role. However, for windseas (that contain a large number of waves of different height) the largest waves start to break at a much larger distance from the coast compared to the estimates based on the root mean square wave height. As the CERC formula is supposed to describe the transport in the entire surf zone, it is natural to associate the seaward border of the surf zone with the breaking of relatively large waves, the height of which is adequately described by the significant wave height.

The time series of nearshore wave properties (height, period and direction) were extracted from numerical simulations of the Baltic Sea wave climate for 1970–2007 (Soomere and Räämet 2011). Wave properties were simulated using the WAM model driven by adjusted geostrophic winds from the Swedish Meteorological and Hydrological Institute with a spatial resolution of about 5.5 km.

The properties of breaking waves were evaluated using two options: (1) accounting for only refraction under assumption that shoaling is balanced by other processes; (2) fully accounting for both shoaling and refraction in the linear approximation. The wave height was interpreted in three ways: (1) the root mean square wave height was used in all parts of the CERC formula; (2) the significant wave height was used in all parts of the CERC formula; (3) the root mean square wave height was used to evaluate the wave energy at the breaker line but the group speed at the breaker line was calculated from the significant wave height. We also varied the mean grain size from 0.063 mm (that is typical for sheltered parts of the study area such as Pärnu Bay) up to 1.0 mm (that is also found in some sections of the study area).

3. Results

The use of full shoaling and refraction led to a considerable decrease (in places by more than 30 %) in both bulk and net transport along the Sambian Peninsula and at the north-western coast of the Courland (Kurzeme) Peninsula (Fig. 1) compared to the use of only refraction. In these areas the proportion of waves approaching the coast under large angles is substantial and accounting for both shoaling and refraction is obviously necessary. In the rest of the study area the differences compared to the use of only refraction are fairly minor, usually below 10 %. Remarkably, the qualitative patterns of both bulk and net transport are the same for both calculations.

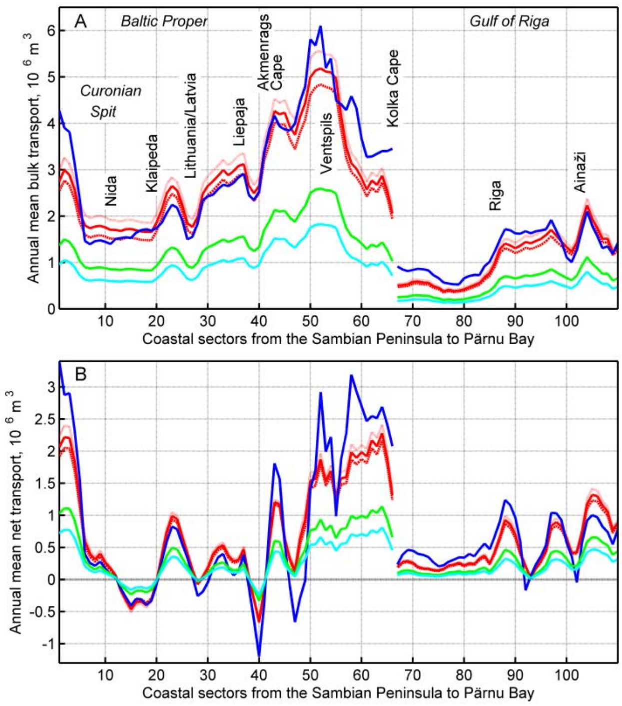

Figure 1. Simulated potential bulk (A) and net transport (B). All lines indicate the moving average over three subsequent coastal sections, calculated as an average over 1970–2007. Blue: d_{50} = 0.17 mm, simplified representation of shoaling, significant wave height as input for the CERC formula (Soomere and Viška 2014). Other colours correspond to the use of full shoaling and refraction. Red: significant wave height as input for the CERC formula; dotted line (upper): d_{50} = 0.063 mm, solid line (middle): d_{50} = 0.17 mm, dashed line (lower): d_{50} = 1.0 mm. Green: d_{50} = 0.17 mm; root mean square wave height as input for the wave energy but group velocity estimated based on the significant wave height. Cyan: d_{50} = 0.17 mm, root mean square wave height as input for the CERC formula (Viška and Soomere 2013).

4. Conclusions

Both the magnitude and spatial patterns of transport are almost insensitive with respect to even radical variations in the grain size (Fig. 1). The use of different interpretations of wave height changes the magnitude of sediment transport but does not affect areas of convergence and divergence of sediment flux. This feature suggests that their pattern (Fig. 2) is invariant with respect to virtually any physically justified method for calculations of sediment transport as well as with respect to certain biases in the driving fields.

The best match with historical estimates of the magnitude of alongshore transport is obtained when the root mean square wave height is used to characterise the wave energy at breaking but the group speed is evaluated using significant wave height at breaking (Viška and Soomere 2013).

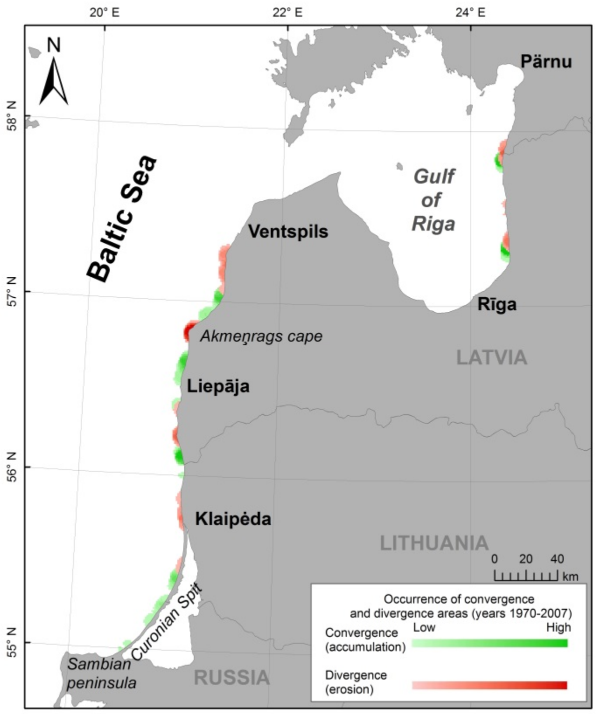

Figure 2. Occurrence of convergence and divergence areas during the 38-year period 1970–2007.

Acknowledgement

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Can we stop erosion by protecting the whole Polish coast?

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1. Introduction

Comprehensive knowledge of natural conditions, in that of variable in time and space dynamic factors, is the basis for decision making in the coastal zone. Investigations and predictions of the variability of processes shaping this specific environment are the basis for determining the methods and techniques of engineering impact into the coastal zone. Determination of the location in the coastal system of stable obstructions/barriers, causing permanent coastal erosion, is one of the most important elements needed for long term planning of coastal protection (Dubrawski, et al. 2006). Analysis of long term changes of the coast, has shown that a hierarchical erosion/accretion coastal system is functioning (Zawadzka-Kahlau 1999). At present, a relatively natural run of dynamic processes occurs along about 50% of the Polish coast. The rest is under influence of various hydrotechnic structures located in the coastal zone. About 70% of the coastline is eroded permanently with varying intensity. Erosion is also extending to previously accumulative coasts.

2. Coastal erosion

During the 19th/20th century, the mean change in the situation of the shoreline, of 0.1 m/year, caused a loss of land area of 36.6 thousand m^2/year, which led to an average diminishing of 80 m^2/year per kilometre of beaches. The deficit of beach sediments caused a gradual decrease in the alimentation of fore-dunes. Considerably larger losses of 0.93 m/year occurred during the intensive shore changes in the years 1971-1983, causing the diminishing of beach area by 753 m^2/km of shore/year (Zawadzka-Kahlau 1999). At the beginning of the 21st century, the losses exceeded 1m/year in many stretches influencing a decrease in deflation area of beaches, constituting a source of sediments for the dune system. Losses of dune sediments occur with a considerable intensity on the shores of the open sea.

The area of dunes destroyed in the years 1960-1983 was recreated in 55%, and in the years 1971-1983 to 47%, which is however not synonymous with a complete reconstruction of their volume and height. The areas where the destruction processes started already at the end of the 19th and beginning of the 20th century, due to a number of hydrometeorological events, are devoid of natural coastal dune. The driving forces, in conditions of intensive storms, related to the run-up of waves during high sea levels, causing rapid shore losses of over 50-100 m^3/m of length, compared to the transporting energy of wind of 21 m/s, indicates no chances of dunes being reconstructed after such an event in less than multi-year periods. A reconstruction of a dune, losing tens of m^3/year, cannot recover its initial parameters. Abrasive changes are not compensated even after 20 years (Zawadzka-Kahlau 2012).

The length of eroded cliff coasts also grows, though more slowly. The very probable growth of cliff coast erosion rates, caused by the predicted sea level rise, will increase the danger of objects located within 150-200 m from the cliff edge. Higher rates of coastal erosion will occur at every predicted rate of sea level rise, as is shown by the effects of the 0.2 m rise during the last 100 years (Dubrawski et al.).

The sequences of significant storms in the 1980s and 90s and in the period 2006/2007 deepened the processes of shore destruction even in accretive sections so far. The beginning of the 21st century involved sea stages and storm frequency exceeding many times the situation of the period 1960-2000. In the light of the factors influencing the intensity of the changes of coastal dunes, the reduction of the space in which eolian processes occur gains considerable significance, being an important cause of a decrease in the chances of the fore-dune foot being reconstructed. This regularity is confirmed by the results of the variability of the system of barriers and dunes of the Southern Baltic, due to the diminishing of the alimentation area, i.e. the beach. The eolian transport occurring with various intensities on the western coast together with small width of beaches and dunes cause a greater threat to their hinterland and infrastructure of the shore zone (Zawadzka 2012).

3. Coastal protection

Technical protection of eroded stretches eliminates for a certain time the danger to the hinterland. However, it does not counteract the durable erosion trends in the near foreshore, which are generated by hydro- and geomorphologic impacts of the far foreshore of the Southern Baltic (Dubrawski, Zawadzka-Kahlau 2006).

In the past, before technical defence works were started, a natural erosion/accretion geomorphologic system existed along the Southern Baltic coast, in which dune coasts took up ~80%, and cliff coasts ~20% of the coastline length. The system was only under the influence of environmental factors, allowing natural reconstruction of coastal forms, but also natural development of erosion phenomena. With the appearance of additional obstructions, generating additional disruptions of sediment transport (port breakwaters, approach channels, coastal defence structures), the erosion/accretion systems became stabilised and erosion of anthropogenic origin increased (Dubrawski, et al. 2006).

Complex coastal defence systems, formed mainly of seawalls and groynes were built along coasts eastwards of port breakwaters. The present progress of erosion forces the construction of hard near-port coastal defences, providing safety of the hinterland at least at a level ensuring resistance to a 100 year return storm situation. On stretches of near-port erosion, various defence techniques were used, aiming at controlling sediment transport, also by means of artificial nourishment. In highly developed regions, coastal defence was carried out permanently, using several, succeeding one after another, methods. During the last 100 years one may distinguish periods with predomination of seawalls, groynes, artificial nourishment and artificial nourishment supplemented by gabion seawalls forming the core of artificial dunes (Dubrawski, et al. 2006).

Coastal defence systems, developed until the end of the 1980ies, did not fulfil the expectations of their designers because of numerous side effects and due to the increasing sediment deficit. Erosion forced increasingly intense coastal defence, but the implemented methods were not able to stop the strengthening processes of erosion, and even often, as a secondary effect, generated additional erosion themselves. The influence of anthropogenic obstructions to sediment transport in the foreshore, dredging works in port regions, additionally increased seaward transport, and limited sediment transport by wind due to strengthening of dunes, made the sediment deficit even larger. All this resulted in growing destruction of the coast and in growing costs of coastal defence. With progressing erosion, some of the coastal defence structures and systems lost, or are losing (depending on the time they were built), their protective potential, requiring an extension of the defence measures and increase of financial outlay (Dubrawski, et al. 2006).

The coastal catastrophe, which occurred in 1989 on the Hel Peninsula, was the cause for the decision to protect the Peninsula by rebuilding the beach, dune and foreshore and improving the sediment balance in the region (Zawadzka 1996, Boniecka et al. 2006). Systematic and long term (1989 -2000) nourishment (>9 million m^3) along a significant stretch of coastline (km H 0.0–23.5) allowed collecting scientific experience, and provided information for the development of a long term coastal protection strategy for the Polish coast.

The developed variant of active coastal protection by means of artificial nourishment and supplementary systems of structures, ensuring flood and erosion safety of the hinterland. The basic assumption of the coastal protection strategy until 2050 is that on selected stretches the coastline of 2000 is to be maintained by nourishing the active part of the shore profile, i.e. dune, beach and foreshore, in order to balance sediment losses. The main objective is to reduce the rates of erosion, and to increase the resistance of the coast and foreshore to the impacts of hydro-meteorological factors, in conditions of sea level rise of 0.6 m/100 years. It is also assumed that significant stretches of cliff coasts and large lengths of dune coasts will be left to retreat freely. Without permanent supplementing of sediment losses, protection of the Southern Baltic coast will not be able to reach its long term goals. Stopping the nourishments would result in quickened erosion, loss of most of the coastal structures, and in increasing numbers of coastal catastrophes, including such as the breaking of the Hel Peninsula and of several spits. Along some stretches, large scale and long term nourishment should be connected with hard defences (Dubrawski, et al. 2006). The basis for its wide and long term use is provided by detailed investigations of the influence of sediments from executed nourishments on the erosion/accretion systems of various parts of the Polish coast and foreshore. A significant advantage of artificial nourishment over other methods of coastal protection is that its positive influence reaches outside the nourished area.

4. Conclusions

At sea level rise of only 0.3 m/100 years nearly 2200 km^2 of coastal land may be flooded. The loss of beaches, foredunes and forward parts of cliffs, flooding of hinterland below +2.5 m msl., destroying of elements of infrastructure and valuable nature, threatened functioning of ports and landing places, towns and recreation and health centres, transformation of land and water biocenosis (coastal lakes), increased penetration of sea water, micro-climatic changes – are only some of the SLR-related dangerous phenomena and processes (Dubrawski, et al. 2006). The best method of protection is beach nourishment. Is also necessary to investigate the composition of coastal sediments, especially on nourished stretches, the resources of sediments suitable for exploitation, and to determine the criterions and standards for nourishing material. All the works, carried out in the framework of the long term coastal protection programme, should be monitored. The aim of the monitoring is to optimise the works and improve the principles of coastal erosion control in the coming decades, in conditions of the 0.6 m/100 years SLR scenario (Dubrawski, at al. 2006). Despite the development of many branches of knowledge, relating to issues of coastal dynamics, a series of activities carried out in this very dynamic area, is performed without the basic principles of ICZM and HELCOM recommendations.

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Copernicus Symposium

Was uns der Augenschein, die Physik und die Bibel lehren – Ein Plädoyer für das geozentrische Weltbild

What intuition, physics and the bible tell us – A plea for the geocentric world view (lecture given in German)

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Dass sich die Erde um die eigene Achse dreht und eine Bahn um die Sonne beschreibt ist heute Teil der Allgemeinbildung. Doch merken wir etwas davon?

Hingegen beschreibt das geozentrische Weltsystem die gesamte Erfahrungswelt der Wissenschaften und des Alltags aus Jahrhunderten und Jahrtausenden. Es war ein geniales Wissenschaftssytem und die ihr zugrunde liegende aristotelische Physik eine bewundernswerte Theorie. Und auch die Bibel hieß die Erde stillzustehen.

Doch es gab Zweifel, die nur langsam durch die Wissenschaftler und die Theologen zu neuer Gewißheit erhoben werden konnte - die Erde bewegt sich. Copernicus stand ganz am Anfang einer langen Entwicklung.

Planet Earth rotates around its own axis and revolves around the sun. This is common knowledge nowadays. But do we really notice?

In contrast, human everyday experience of centuries and millennia is better described by the geocentric world view. It was a brilliant scientific system, and the underlying theory of Aristotelian physics was admirable. Also according to the Bible, the Earth should stand still.

But there were doubts which only gradually were elevated to certainty by scientists and theologists – the Earth moves. Copernicus stood at the outset of a long transformation.

Nicolaus Copernicus – 500 years of experimental science

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1. "Commentariolus" manuscripts written by Nicolaus Copernicus between 1509 and 1514

Exactly 500 years ago Nicolaus Copernicus (Mikołaj Kopernik) (19.02.1473–24.05.1543) doctor of canon law, canon at Frombork Cathedral in Warmia (north of Poland), conducted measurements which leaded to the most important development in modern science; the so called „Copernican Revolution". The experimental observations and research that based upon collected results were completed in several stages. However, the first results and meaningful conclusions have been put together by Copernicus as early as between 1509 and 1514 in form of a few (at least four) hand-written manuscripts, entitled "Commentariolus". It is assumed that Copernicus sent the manuscripts to astronomers in Europe to share the gained knowledge, which was sensational in his time (Dobrzycki and Hajdukiewicz, 1968). Three of four known, original manuscripts were found in Vienna, in Stockholm and in Aberdeen (Marks, 2012).

In the manuscripts Nicolaus Copernicus, experimentally proved the ancient hypothesis of Greek astronomers – Arystotele (384–322 BC) and Arystarchus of Samos (310–230 BC) that the Earth is orbiting around the Sun and is rotating around its own axis (Kokowski, 2009).

In "Commentariolus" the rotational principles of the Solar System configuration and more general indication of the rotational principles of all objects dispersed in the Universe has been properly described. As a consequence the theory of geostationary and geocentricity of the Earth in the Universe, that stopped the development of sciences for almost 2000 years was finally rejected.

2. Copernicus postulates

In "Commentariolus", Copernicus written seven, short but meaningful postulates:

1. Celestial bodies do not all revolve around a single point;
2. The centre of Earth is the centre of the lunar sphere—the orbit of the moon around the Earth;
3. All the spheres rotate around the Sun, which is near the centre of the Universe;
4. The distance between the Earth and the Sun is an insignificant fraction of the distance from the Earth and Sun to the stars, so parallax is not observed in the stars;
5. The stars are immovable; their apparent daily motion is caused by the daily rotation of the Earth;
6. Earth is moved in a sphere around the Sun, causing the apparent annual migration of the Sun; the Earth has more than one motion;
7. Earth's orbital motion around the Sun causes the seeming reverse in direction of the motions of the planets (Mały komentarz-Kopernik, 2012).

Figure 1. Frombork, Cathedral Hill *(photo R. Marks.)*

Figure 2. Nicolaus Copernicus monument in Frombork (photo R. Marks).

3. Copernicus methodological matrix for experimental sciences

It is worth mentioning that the Copernicus approach to observe the motion of planets in cosmos as well as instruments that he constructed and systematically used provided a base for modern experimental sciences. Considering the Nicolaus Copernicus way of performing research, one may conclude that knowledge originates from the sighting phenomenon's correctness or perception of the inaccuracy in commonly accepted theories. Then, first comes the long process of collection data and experimental proof. The scrupulously performed experimental measurements and the verification of results are of great importance in this stage. In the final phase, after an apprehensive perception of the phenomenon’s features comes the stage of the mathematical description of the phenomenon. Experimental verification of new theories and concepts ought to be the essence of development for modern science. Therefore the Nicolaus Copernicus way of doing research can be perceived as the universal methodological matrix.

That is why the Copernicus manuscripts entitled “Commentariolus” can be regarded as the turning point in our civilisation. Therefore, it can be concluded that, the years of 1507-1514, when four copies of “Commentariolus” by Nicolaus Copernicus where written and distributed in Europe (Marks, 2012), are the years when the modern experimental science was grounded.

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Nicolaus Copernicus - 500 years of hand written manuscript entitled "Commentariolus" (The Commentary)

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1. The heliocentric concept

The first meaningful heliocentric concept have been put together by Copernicus as early as between 1509-1514 in form of a few (at least four) hand-written manuscripts, entitled "Commentariolus" (The Commentary).

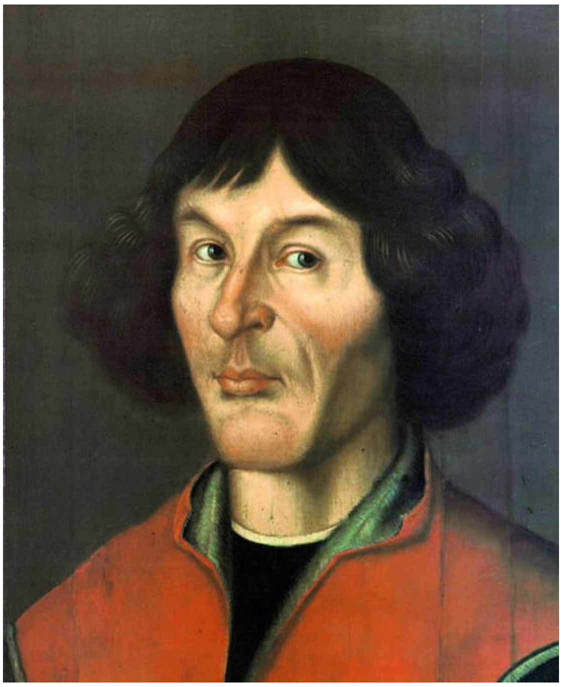

Figure 1. Nicolaus Copernicus (19.02.1473-24.05.1543).

2. Postulates written in "Commentariolus" between 1509 and 1514

1. Celestial bodies do not all revolve around a single point.
2. The centre of Earth is the centre of the lunar sphere—the orbit of the moon around the Earth.
3. All the spheres rotate around the Sun, which is near the centre of the Universe.
4. The distance between the Earth and the Sun is an insignificant fraction of the distance from the Earth and Sun to the stars, so parallax is not observed in the stars.
5. The stars are immovable; their apparent daily motion is caused by the daily rotation of the Earth.
6. Earth is moved in a sphere around the Sun, causing the apparent annual migration of the Sun; the Earth has more than one motion.
7. Earth's orbital motion around the Sun causes the seeming reverse in direction of the motions of the planets (Goddu, 2010).

Figure 2. The Cathedral Hill in Frombork (former Frauenberg), a view from the Vistula Lagoon (photo R. Marks).

3. There are three known hand written manuscripts

Three of four known, original manuscripts were found in Vienna, in Stockholm and in Aberdeen (Marks, 2012). It is assumed that Copernicus sent the manuscripts to astronomers in Europe to share the gained knowledge, which was sensational in his time (Mały komentarz-Kopernik, 2012).

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Figure 3. Copernicus monument in Frombork (photo R. Marks).

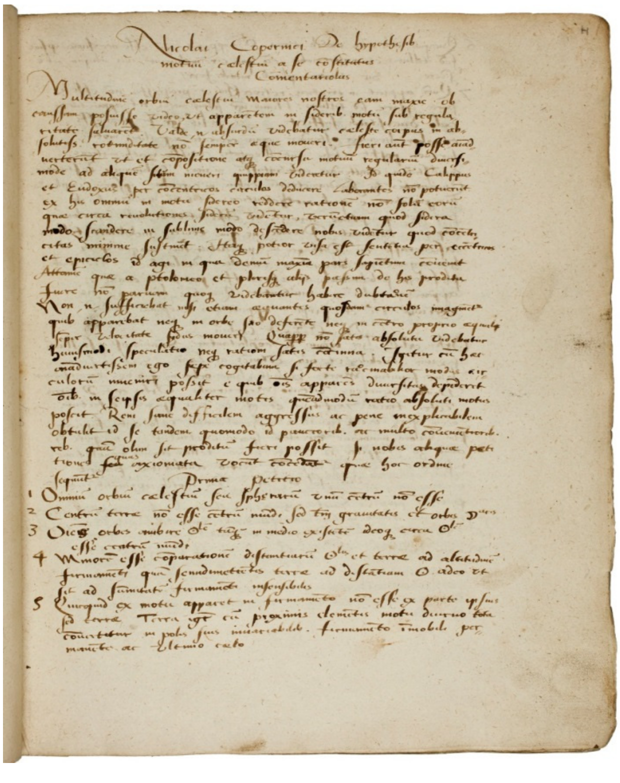
Nicolai Copernici De hypothesib[us] motuum coelestium a se constitutis Commentariolus

Figure 4. The first page of nine pages manuscript known as the Aberdeen copy of "Comentariolus" obtained from the (Sir Dunkan Rice Library of the University of Aberdeen).

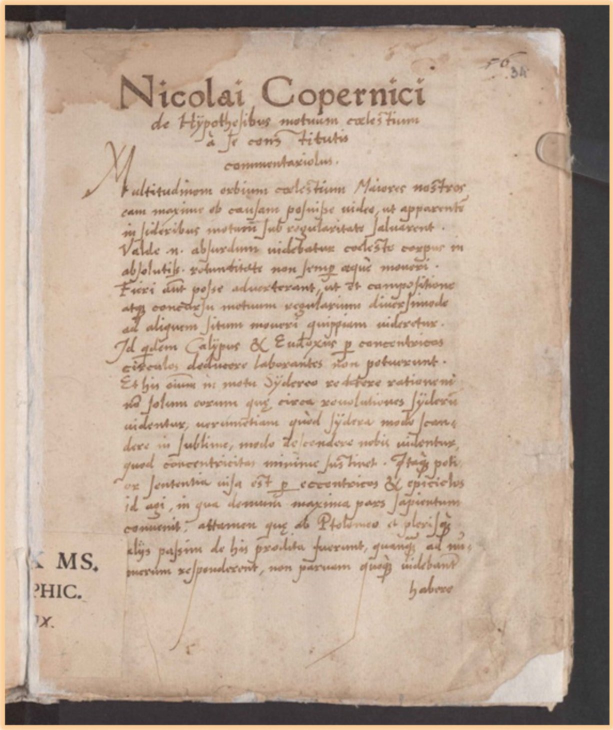
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Figure 5. The first page of nineteen pages manuscript known as the Vienna copy of "Commentariolus" obtained from the (Austrian National Library in Vienna).

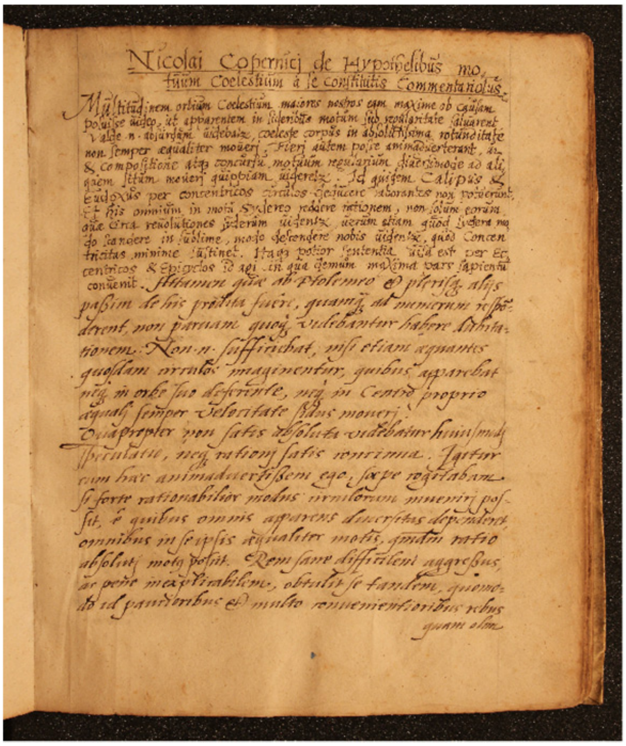
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Figure 6. The first page of sixteen pages manuscript known as the Stockholm copy of "Commentariolus" obtained from the (Centre of History of Science of the Royal Swedish Academy of Science).

Climate change and variability in Poland from Copernicus's time to present

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1. Introduction

In recent years, the issues of climate change and variability, and their consequences for the environment (be it natural or anthropogenic) have become dominant themes in research above all espoused by climatologists and meteorologists. The direct cause of this is global climatic warming observable since the second half of the 1970s, and constituting the so-called second phase to contemporary warming, the first having taken place in the years 1920–1940.

Knowledge on climate change in Poland over the last centuries is fullest in respect of the period of instrumental observations. In the last 25 years it has been possible for various workers to compile, and then engage in the homogenisation of, ten or more air temperature series for Poland. The most important of these are the longest series, which relate to Warsaw (from 1779 on), Wrocław (from 1791) and Cracow (from 1792). Furthermore, high levels of correlation observed for air temperatures across the country allow for the use of these temperature series in characterizing thermal conditions throughout Poland.

In the last several decades there has also been a marked increase in the level of knowledge on the Polish climate from the so-called pre-instrumental period. Nonetheless, this does not extend back before the start of the last millennium (Przybylak et al. (eds), 2010; Przybylak 2011). Relatively better climate information is available since Nicolaus time and onwards.

The main aim of this paper is to sum up the current state of knowledge on changes and variability in Poland's climate from Copernicus's time to present.

2. Results

Information about the climate in Poland in Nicolaus Copernicus's time (1473-1543) is limited, in particular for the end of the 15th century. We have no reconstructed temperatures for particular years, only for certain decades of that time. Additionally, almost nothing is known about the precipitation levels then. Knowledge of the climate becomes markedly better in the first half of the 16th century (see Fig. 1, Limanówka 2001 and Przybylak 2011).

During Copernicus's childhood and in his youth, the climate was either within – or even slightly warmer than – present norms, especially in summer. Reconstructed mean values for air temperature in the January–April period, based on the width of tree rings, also point to the occurrence of a period of cooling at that time (Fig. 1 in Przybylak 2011). More in line with the reconstruction data, based on historical sources, are the newest reconstructions of mean temperatures in February and March obtained on the basis of dendrochronological data from northern Poland (Koprowski et. al. 2010) and southern Poland (Szychowska-Krąpiec 2010). According to Maruszczak (1991), precipitation was probably above normal in this time.

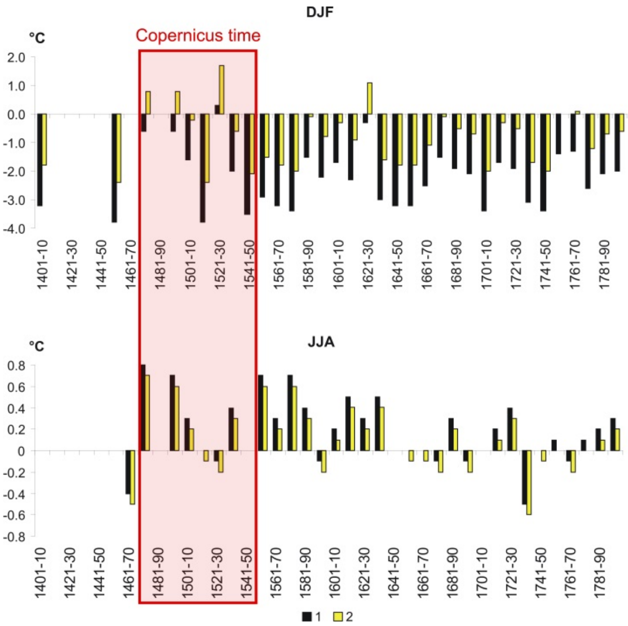

Fig. 1. Reconstructions of mean 10-year air temperatures (°C) in Poland from 1401 to 1800: a) winter (DJF) and b) summer (JJA). 1 and 2 – anomalies with respect to 1901–1960 and 1789–1850 means, respectively (after Przybylak 2011)

The climate during Copernicus's adult years was more continental than in present times. On average, winter temperatures were generally 1-3°C colder than they are today, while summer temperatures were slightly warmer (Fig. 1, see also Limanówka 2001). The coldest winters occurred in the second decade (an anomaly of almost -4°C compared to present times), while the warmest were in the third decade, reaching temperatures even slightly warmer than today. The warmest summers were noted in the fourth decade (an anomaly of about 0.4°C), while the coldest occurred in the second and third decades (Fig. 1). Mean annual values for air and ground-surface temperatures were most probably lower than current values by some 0.9–1.5°C. Ground-surface temperatures were reconstructed for this period using the geothermal method (Majorowicz et al. 2004).

In first two decades of the 16th century, the climate was much wetter than in the following three decades. In particular, the decade of 1531-40 was probably dry, with three extremely dry summers noted (Fig. 2). In contrast, on the basis of an analysis of the numbers of days with precipitation, Limanówka (2001) found that the first half of the 16th century had far less precipitation than it does today. However, it would seem that the notes compiled by the university professors of Kraków did not take account of the lightest precipitation, which they may well have missed altogether.

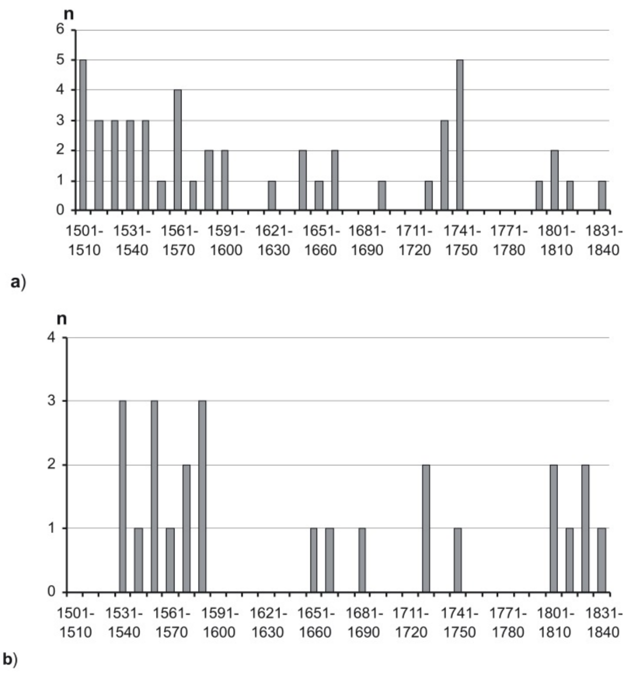

Fig. 2. Decadal frequencies of occurrence of summers (JJA) that were: a) extremely wet and very wet and b) extremely dry and very dry in Poland between 1501 and 1840 (after Przybylak et al. 2004)

According to Przybylak et al.'s (2004) studies, the climate in the first half of the 16th century was most unstable and extreme in the entire analyzed period of 1501-1840.

3. Conclusions

The climate of Nicolaus Copernicus's lifetime can be considered to be transitional between the Medieval Warm Period, which probably ended in Poland at the beginning of the 15th century, and the Little Ice Age, which began in the middle of the 16th century. As a result, extreme situations (including both air temperature and precipitation) were most frequent and most changeable in winter (temperature) and summer (precipitation). The climate in Copernicus's time was more continental than it is today, mainly due to the very severe winters occurring in the later stages of his life (1-3 ^{o}C colder in reference to the mean for 1901-1960). The summers he experienced were slightly warmer and wetter than today, while mean annual air temperatures and surface-ground temperatures were lower, on average, by ca. 1.0-1.5^{o}C than contemporary values

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Evening Lecture

"Energiewende" in Germany - Issues and problems

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1. Introduction

Electricity production from wind and solar radiation is easily possible in a society which agrees to the corresponding use of land, accepts the impact on its cultural landscape, and finances the necessary infrastructure. In Germany, about 70 GW of wind and photo-voltaic power are installed at the end of 2013. The 2012 data of the German load, the on- and offshore and the photo voltaic energy production are used and scaled to the limit of supplying the annual demand (100%-case). The results are analysed. The reference mix of the renewable energy (RE) forms is selected such that the remaining back-up energy is minimised. For the 100%-case the RE power installation has to be about 3 times the present peak load. The back-up system can be reduced by 12% in this case but it cannot be replaced. The surplus energy corresponds to 26% of the demand. The back-up system and more so the grid must be able to cope with large power excursions. All components of the electricity supply system operate at low capacity factors. Large scale storage can hardly be motivated by the effort to further reduce CO2 emission. Demand-side-management will intensify the present periods of high economic activities during the day. Its rigorous implementation will expand the economic activities into the weekends. On the basis of a simple criterion, the increase of periods with negative electricity prices in Germany is assessed. It will be difficult with RE to meet the low CO2 emission factors which characterise those European countries which produce electricity mostly by nuclear and hydro power.

Baltic Earth

Baltic Earth - Earth System Science for the Baltic Sea Region

An open research network to achieve an improved Earth system understanding of the Baltic Sea region

H. E. Markus Meier[1], Anna Rutgersson[2], Marcus Reckermann[3] and the Baltic Earth Interim Science Steering Group

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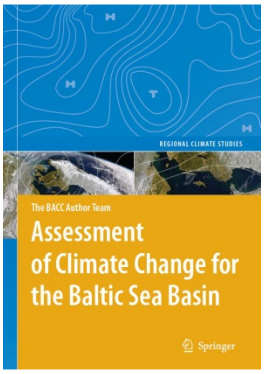
Extending the knowledge of the regional Earth system in the Baltic Sea region

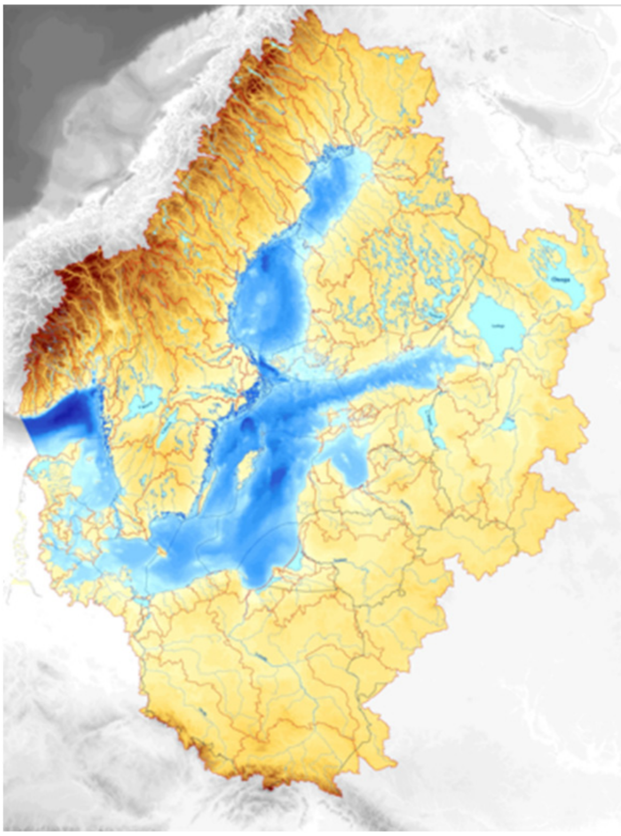
The goal of Baltic Earth is to achieve an improved Earth system understanding of the Baltic Sea region. Baltic Earth is the successor to BALTEX that was terminated in June 2013 after 20 years and two successful phases. The research components of BALTEX continue to be relevant, but now have a more holistic focus encompassing processes in the atmosphere, on land and in the sea, as well as processes and impacts related to the anthroposphere. Specific interdisciplinary research challenges have been formulated by the Baltic Earth Interim Science Steering Group to be approached by the new programme in the coming years. The continuity in basic research fields, structure (secretariat, conferences, publications) and the international network (people and institutions) is symbolized by the logo, which is similar but still distinctly different from the BALTEX logo.

Scientific assessments and Grand Challenges



A major means of achieving the goals of Baltic Earth will be scientific assessments of particular research topics to be prepared by expert groups. Similar to the BACC approach, the assessments shall help to identify gaps and inconsistencies in the current knowledge. A Baltic Earth Science Plan will be established by mid 2014, with a definition of core research questions, so-called "Grand Challenges". They are currently:

1. Salinity dynamics in the Baltic Sea
2. Land-Sea biogeochemical feedbacks in the Baltic Sea region
3. Natural hazards and extreme events in the Baltic Sea region
4. Understanding sea level dynamics in the Baltic Sea
5. Understanding regional variability of water and energy exchanges



The Baltic Sea catchment basin

The Grand Challenges are intended as flexible, regularly updated research topics and will be dealt with by specific working groups. In addition, the BALTEX Working Groups on the "Utility of Regional Climate Models", and "Assessment of Scenario Simulations for the Baltic Sea 1960-2100 " will continue in Baltic Earth. Dedicated working groups have also been established on "Outreach and Communication" and "Education".

The human impact shall be assessed at all levels, wherever possible and reasonable. New Grand Challenges and modifications of existing ones can be implemented by the steering committee and the working groups, by using the assessments of existing research and knowledge, and the open discussions at conferences and workshops. The Grand Challenges are foreseen as research foci for periods of about 3-4 years (then terminated or updated). It is envisaged that Baltic Earth will be internationally embedded in a similar manner as was BALTEX.

Baltic Earth intends to provide a "service to society" in the respect that the assessments may provide an overview of knowledge gaps, and the communication with different stakeholders may help to identify open scientific questions relevant for society, which could be approached by funded research projects.

Baltic Earth will also be committed to educational activities with the establishment of regular Baltic Earth Summer Schools, the first of which is intended to take place in 2015. The first dedicated Baltic Earth Conference is planned for 2016.

"Products" of Baltic Earth will include:

- Conferences
- Workshops
- Assessment Projects
- Research Projects
- Summer Schools

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www.baltic-earth.eu

International Baltic Earth Secretariat Publications

ISSN 2198-4247

No. 1. Programme, Abstracts, Participants. Baltic Earth Workshop on ”Natural hazards and extreme events in the Baltic Sea region”. Finnish Meteorological Institute, Dynamicum, Helsinki, 30-31 January 2014. International Baltic Earth Secretariat Publication No. 1, January 2014.

No. 2. Conference Proceedings of the 2nd International Conference on Climate Change - The environmental and socio-economic response in the Southern Baltic region. Szczecin, Poland, 12-15 May 2014. International Baltic Earth Secretariat Publication No. 2, May 2014.

For a list of International BALTEX Secretariat Publications (ISSN 1681-6471), see www.baltex-research.eu/publications

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