Dziula Przemysław

Kołowrocki Krzysztof
Maritime University, Gdynia, Poland

Identification of climate related hazards, the Global Baltic Network of Critical Infrastructure Networks, is exposed to

Keywords

critical infrastructure protection, critical infrastructure network, global network of CI networks

Abstract

The paper presents issues concerning identification of climate related hazards at the Baltic Sea area and their exposure for the Global Baltic Network of Critical Infrastructure Network. As a result, possible natural hazards coming from following climate/weather change are distinguished: sea water temperature changes, change in ice cover, sea level rise/ decrease, coastal erosion, precipitation, storm surges and winds, and air temperature change, for particular critical infrastructure networks operating within the Baltic Sea area.

1. Introduction

The Baltic Sea area is one significantly equipped with various critical infrastructures. Most of them are vulnerable to climate related hazards, as the investigations on actual and predicted climate changes [2] - [4], show their significant importance for the area. Some of critical infrastructure installations show interconnections and interdependencies, that allow to collect them into wider categories, and distinguish as more complex systems. Basing on report [6], they have been identified as critical infrastructure networks, defined as set of interconnected and interdependent critical infrastructures, interacting directly and indirectly at various levels of their complexity and operating activity.

Considering critical infrastructures operating within the Baltic sea area, and specific features of the region, report on Identification of existing infrastructures in the Baltic Sea and its seaside, their scopes, parameters and accidents in terms of climate change impacts [1,7], specified following eight main critical infrastructure networks in the region:

- Baltic Port Critical Infrastructure Network,
- Baltic Shipping Critical Infrastructure Network,
- Baltic Oil Rig Critical Infrastructure Network,
- Baltic Wind Farm Critical Infrastructure Network,
- Baltic Electric Cable Critical Infrastructure Network,
- Baltic Gas Pipelines Critical Infrastructure Network,
- Baltic Oil Pipelines Critical Infrastructure Network,
- Baltic Sip Traffic and Port Operation Information Critical Infrastructure Network.

This article is aiming to identify climate related hazards to particular critical infrastructure networks identified within the Baltic Sea area. At first, principal categories of predicted climate changes, indicated by EU strategy on adaptation to climate change [4], and Climate change in the Baltic Sea Area HELCOM thematic assessment [15], have been specified. Then, for each pointed category of climate change, respective sub-categories of climate related hazards, for particular critical infrastructure networks, have been identified and listed.

2. Climate changes at the Baltic Sea area – actual status and predictions

The Chapter presents results of investigations processed by European Commission and Helsinki Commission, on ongoing climate changes.

European Commission works are mainly concerned with EU strategy on adaptation to climate change [4]. The strategy is showing predicted climate changes for whole Europe, with some particular indications for the Baltic Sea area. There are also indications on adaptation actions, needed to be performed to adapt different sectors, including critical infrastructures, to predicted changes.

The Helsinki Commission investigations have been published in the Baltic Sea Environment Proceedings, No. 137, titled: Climate change in the Baltic Sea Area HELCOM thematic assessment [15]. The document provides recent information on past and projected future climate change in the Baltic Sea Area and their potential impacts on the Baltic Sea area.

Basing on above documents, actual and predicted climate changes have been divided into specified below categories. The categories pointed will allow further to specify climate related hazards for the Global Baltic Network of Critical Infrastructures Networks.

2.1. Sea water temperature changes

Sea surface temperature of Europe's seas rises over the past century are shown in *Figure 1*. The greatest increases in sea surface temperature seem to be in the Baltic Sea and the North Sea, with lower rates identified in the Black Sea and the Mediterranean Sea. Increased sea surface temperature – coupled with changes in precipitation, wind and salinity – influences sea ice coverage as well as the diversity and number of marine species [5].

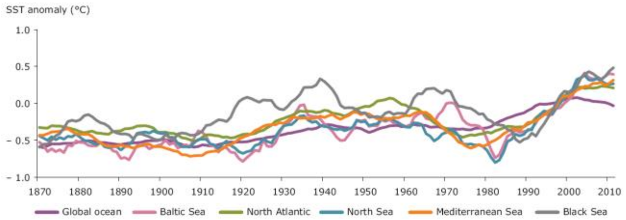

Figure 1. Time series of annual average sea surface temperature (SST), referenced to the average temperature between 1986 and 2010, in each of the European seas [5]

2.2. Change in ice cover

Melting and cracking of ice sheets exposes darker ice as well as sea water. As a result, more solar radiation is absorbed, which causes more ice to melt. Although this is a normal seasonal process in the summer, the increase in the melting of ice associated with climate change will aggravate this feedback loop. Increased sea surface temperature decreases sea ice coverage, as well as the diversity and number of marine species [5].

The length of the ice season at the Baltic Sea is 130 to 200 days in the Bothnian Bay, 80 to 100 days in the Gulf of Finland, and 0 to 60 days in the southern part. There has been a large change in the length of the ice season during the past century. In the Bothnian Bay, which has the longest ice season, the trend is −18 days/century. Larger changes have been observed in the eastern Gulf of Finland, where ice also forms every winter; over the past century, the length of the ice season decreased by 41 days/century, while in the past 50 years, the rate decreased to −62 days/century. In the southern Baltic Sea, the length of the ice season decreases from east to west and from the inner waters toward the sea areas. A weak trend toward a smaller number of days with ice has been found for the last 30-year period analysed [15].

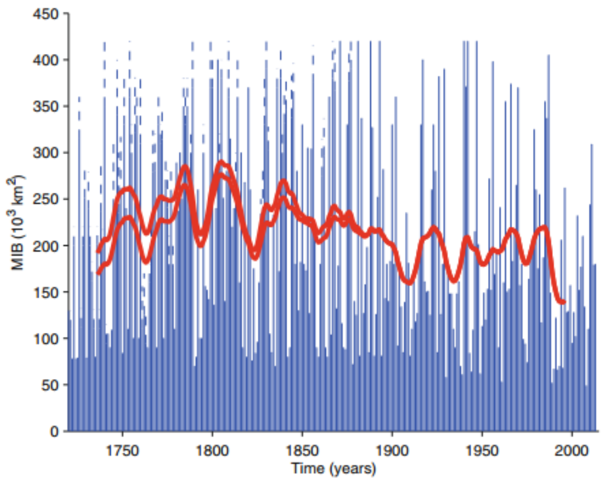

Figure 2. The maximum extent of ice cover in the Baltic Sea 1720 to 2012 [15]

There has also been a significant decreasing trend in the annual maximum ice extent of the Baltic Sea (MIB) observed, which amounted to a decrease of 20% over the past 100 years up to 2011. *Figure 2* shows the MIB from 1720 to 2012, the dashed bars represent the error range of the early estimates. The 30-year moving average is indicated by two lines representing the error range early in the series, converging into one line when high-quality data are available [15].

2.3. Sea level rise/ decrease

Sea-level rise is not constant over Europe but varies regionally. From 1900-2010, sea level rose around 2mm/year in the North Sea, with the southern-most part experiencing greater change. Both, the Mediterranean and the Baltic Sea have experienced increases and decreases in sea level. While in the Mediterranean Sea the range varies regionally from -

4mm/year to +6mm/year, the Sea level of the Baltic is falling in the northern shores and rising to the south. Trends in the Black Sea from 1900-2010 point towards an increase of up to 5mm/year21. On the other hand, parts of the English Channel and the Bay of Biscay show a small decrease in mean sea level [5]. *Figure 3* presents trends in relative sea level at selected European tide-gauge stations.

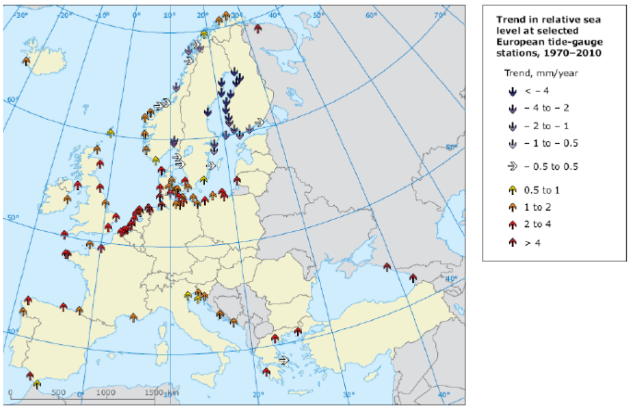

Figure 3. Sea level changes in Europe [5]

The overall mean sea level change at the coasts of the Baltic Sea results from the combined effects of post-glacial rebound, the increase of the global ocean mass largely due to the melting of ice on land, thermal expansion of seawater, and the contributions of regional factors that may cause an overall change in Baltic sea level and/or a redistribution of sea level within the Baltic Sea. The Glacial Isostatic Adjustment exerts a strong influence in the Baltic Sea area, with a maximum uplift of the Earth's crust in the Gulf of Bothnia of approximately 10 mm/year (resulting in a negative trend in relative sea level) and subsidence in parts of the southern Baltic Sea coast of about 1 mm/ year (resulting in a positive trend). Thus, relative sea level is decreasing in the northern Baltic where the continental crust is rising, while sea level is rising in the southern Baltic where the continental crust is sinking. In addition, many climate factors also influence the relative sea level, including changes in water density (temperature and salinity), changes in the total volume of the Baltic Sea, and meteorological factors [15].

Sea-level rise will increase rates of coastal erosion and increase the severity of storm surges. Salt water intrusion into rivers and fresh water aquifers, normally associated with the over exploitation of groundwater resources, could be exacerbated by sea-level rise combined with periods of low river flow, causing salt water intrusion to reach farther points in the river than in times with normal river flow. Salt-water intrusion can threaten freshwater supplies from rivers and coastal aquifers, which not only impacts the drinking water supply but also water for irrigation purposes, and ecosystems in coastal areas [5].

2.4. Coastal erosion

Coastlines are variously subject to shoreline dynamics such as erosion and deposition of sediments depending on the nature of the coast (hard/rocky or softer sediments) and upon the coastal processes of sediment transport and water movements (waves and currents). Natural coastlines have been extensively modified in many places by coastal defences or damming of rivers to prevent erosion and protect urban infrastructure and agricultural land. Wetlands and biodiversity are also affected. About one quarter of the European coastline for which data is available is currently eroding. Climate change can exacerbate coastal erosion, via sea-level rise, increased storminess, higher waves and changes in prevalent wind and waves directions. The impact of storm surges on coastal erosion varies in different regions. Research in Estonia indicates increased beach erosion due to increased storminess in the eastern Baltic Sea, while in France the picture varies: for example the Atlantic region is considered resilient to rising sea levels due to extensive dune systems [5].

The response to climate-related changes differs for the various shore types in the Baltic Sea. Shore types include chalk cliffs, rocky shores, barrier islands with coastal lagoons, sandy beaches, flat clay shores, and esker shores. Each of these shore types has its own erosional and depositional processes that are mediated by various shore-forming forces such as wave energy. Sensitivity to the influence of climate change will also vary by shore type. The impact of wave energy on a shore also depends on the shore openness, which indicates the exposure of a shore to the open sea and thus the potential for wave formation. Shores that face the open sea will receive an increase in average and maximum wave energy due to increasing storminess in the Baltic Sea. The low coasts of the Baltic Sea will be strongly affected by sea-level rise. The Estonian beaches have been shrinking owing to an increase in storm frequency including major storms in 2005 and 2007; the January 2005 storm eroded 15 to 30 m of the gravel and pebble beaches on Saarema Island. The beaches in the Kaliningrad region have also been eroding by from 5 m to up to 40 m in bays. Over the past 20 years, some Lithuanian beaches have disappeared due to westerly storm surges. The average retreat of the Polish coast, mainly formed of sandy sediments, is between 0.5 and 1.5 m/yr. Storm surges in recent years have caused dune erosion and retreat. The beach on the northwest side of the Danish island Anholt has recently been eroding at the rate of 10 m/yr. Rising sea levels are expected to aggravate coastal erosion in these low-lying areas. Soft cliffs in Denmark, Germany, Poland and Latvia are also eroding due to heavy rain and storm surges. The combination of high water levels with strong wind can result in severe damage to soft coastal cliffs. The annual erosion of Polish coastal cliffs is up to 1.3 m/yr [15].

2.5. Precipitation

The temperature of the European land area over the last decade (2002-2011) has been on average 1.3°C above preindustrial level, meaning that the increase in Europe has been faster than the global average. Some extreme weather events have increased, with more frequent heat waves, forest fires and droughts in southern and central Europe. Heavier precipitation and flooding is projected in northern and north-eastern Europe, with an increased risk of coastal flooding and erosion [5].

The amount of precipitation in the Baltic Sea area during the past century has varied between regions and seasons, with both increasing and decreasing precipitation. A tendency of increasing precipitation in winter and spring has been detected during the second half of the 20th century. However, patterns for single seasons were rather different. Precipitation influences river runoff. Analyses of river runoff over the past century have shown that there has been a decrease in annual discharges from southern catchments of the Baltic Sea indicating that the southern regions of the Baltic Sea Basin may become drier with rising air temperatures. In contrast, trends in the north and around the Gulf of Finland indicate increased annual stream flows under warmer temperatures. Model projections indicate that precipitation will increase in the entire Baltic Sea runoff region during winter, while in the summer increases in precipitation are mainly projected only for the northern half of the basin. In a future warmer climate, extremes of precipitation are projected to increase, implying a greater risk of urban flooding, among other impacts [15].

2.6. Storm surges and winds

The wind climate at the Baltic Sea area is generally related to large-scale variations in the atmospheric circulation of the North Atlantic. Overall, reconstructions over the past 200 years show that storminess in Northern Europe is dominated by large multi-decadal variations rather than long-term trends. However, during the second half of the 20th century, large changes were observed in the wind climate over the Northeast Atlantic and Northern Europe. An unusually calm period occurred from 1960 to 1970; this coincided with a period with a very high frequency of Euro-Atlantic blocking in winter, preventing or weakening westerly flow and leading to low wind speeds and fewer storms over Scandinavia. This was followed by a strong increase in annual and winter-to-spring storminess with unprecedented high winter storminess in the early 1990s. In the first decade of the 21st century, wind speeds returned to average values again in the Baltic Sea area. Projections of changes in wind climate are uncertain, both in relation to seasonal mean conditions and extremes. However, there is a slight tendency for an increase particularly over the sea area. Simulations of extremes of wind speed show an even wider spread than those for mean wind speed, but there appear to be small median decreases in winter and small increases in summer over land areas. The results of multi-media ensemble simulations of projected changes in sea-level extremes caused by changes in the regional wind field indicated that at the end of the 21st century the largest changes in mean sea-surface height will occur during spring, amounting to up to 20 cm in coastal areas of the Bothnian Bay. The maximum change in the annual mean sea-surface height will be 10 cm. Another studies show that sea-level rise has a greater potential to increase storm surge levels in the Baltic Sea than does increased wind speed. There are projected large increases of storm surge levels at the entrance to the Baltic Sea, but the relative impact of changing wind speed on sea-level extremes may be even greater for areas in the eastern Baltic, such as St. Petersburg [15].

2.7. Air temperature change

There has been a significant increase in surface air temperatures in the Baltic Sea region since 1871. Linear trends of the annual mean temperature anomalies from 1871 to 2011 were 0.11 °C per decade north of 60°N and 0.08 °C south of 60°N, which is larger than the trend of the global mean temperature of about 0.05 °C per decade for the period 1861 to 2000. All seasonal trends are positive and significant except for winter temperature north of 60°N. The largest trends are observed in spring (and winter in the southern part of the area) and the smallest trends in summer. The seasonal trends are stronger in the northern area compared to the southern area. An analysis of temperature trends from 1970 to 2008 in the Baltic Sea area showed the strongest increase in the Gulf of Bothnia in autumn

and winter (0.5 to 0.6 °C/decade), while significant changes occurred during spring and summer in the central and southern parts of the Baltic Sea area (an increase of 0.2 to 0.3 °C/decade). During the past decade, the warming has continued during spring and summer in the southern parts and during autumn and spring in the northern parts, although the winters of 2009/2010 and 2010/2011 were very cold.
The overall results of different simulations show that temperatures in the Baltic Sea area are anticipated to increase over time and the increase will generally be larger than the corresponding increase in global mean temperature. This is generally the case for the land, which will warm more quickly than the sea. It is also largely a result of the strong increase in winter temperatures resulting from feedback mechanisms associated with the retreating snow and sea-ice cover, which will enhance absorption of sunlight and increase heat storage in the soil, leading to higher temperatures. The strong increase in winter daily mean temperatures is most pronounced in the coldest periods, which is also the case for the more extreme daily maximum and minimum temperatures. Warm extremes in summer are also expected to become more pronounced than at present [15].

3. Identification of climate related hazards for particular critical infrastructure networks operating within the Baltic Sea area

The chapter introduces climate change related hazards to critical infrastructure networks located within the Baltic sea area. The hazards have been determined basing on outcomes of EU, HELCOM, and respective EU-CIRCLE works, indicated in the Bibliography.
Hazards for each particular critical infrastructure network have been specified through the categories of climate changes, pointed in previous chapter.

3.1. Sea water temperature changes

Nevertheless average sea temperature is increasing as mentioned previously, two below parameters regarding this climate feature, can be pointed:
- Sea water temperature below certain value,
- Sea water temperature above certain value.

Mentioned above parameters allow to formulate below mentioned hazards for critical infrastructure networks operating at Baltic Sea area, coming out of both low and high temperatures.

Baltic Port Critical Infrastructure Network:
- Icing of ships operating in port,
- Icing of port installations,
- Problems with cooling of various systems, cooled with sea water,
- Overheating of various port technical equipment.

Baltic Shipping Critical Infrastructure Network:
- Icing of ships,
- Problems with cooling of ship’s engines,
- Overheating of various ship technical equipment.

Baltic Oil Rig Critical Infrastructure Network:
- Icing of various rig’s elements,
- Icing of rig’s installations,
- Problems with cooling of various systems, cooled with sea water,
- Overheating of various rig’s technical equipment.

Baltic Wind Farm Critical Infrastructure Network:
- Icing of various wind turbines components,
- Damages to underwater electric cables caused by thermal expansion of the material,
- Damages to underwater electric cables caused by movements of ice formations.

Baltic Electric Cable Critical Infrastructure Network:
- Damages to cables caused by thermal expansion of the material,
- Damages to cables fittings,
- Damages to cables caused by movements of ice formations.

Baltic Gas Pipelines Critical Infrastructure Network:
- Damages to pipelines caused by thermal expansion of the material,
- Damages to pipelines fittings and gaping,
- Damages to pipelines caused by movements of ice formations.

Baltic Oil Pipelines Critical Infrastructure Network:
- Damages to pipelines caused by thermal expansion of the material,
- Damages to pipelines fittings and gaping,
- Damages to pipelines caused by movements of ice formations.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Icing of overhead system’s components,
- Damages to underwater components caused by thermal expansion of the material,
- Damages to underwater components caused by movements of ice formations.

3.2. Change in ice cover

As indicated earlier, icing periods are going to be shorter in general, however, warm and early winters, followed by a rapid decrease in air temperature, may result in thicker or rougher ice cover formation. Exposure of critical infrastructure networks for ice cover formations can be determined by means of following parameters:
- Ice thickness exceeding certain value,
- Ice formation movement speed exceeding certain value,
- Ice formation movement direction.

Parameters pointed above let to specify following hazards to particular critical infrastructure networks, coming out of ice formations and their movement.

Baltic Port Critical Infrastructure Network:
- Damages to port infrastructure made by emerging and movement of ice,
- Difficulties in ships' berthing operations,
- Occurrence of ice fog.

Baltic Shipping Critical Infrastructure Network:
- Damages to ship's hull,
- Difficulties in ships' berthing operations,
- Occurrence of ice fog.

Baltic Oil Rig Critical Infrastructure Network:
- Damages to rig's components made by emerging and movement of ice,
- Difficulties in supporting ships' operations.

Baltic Wind Farm Critical Infrastructure Network:
- Damages to wind turbines towers and foundations made by emerging and movement of ice,
- Difficulties in service and supervising operations.

Baltic Electric Cable Critical Infrastructure Network:
- Damages to cables made by emerging and movement of ice,
- Difficulties in service and supervising operations.

Baltic Gas Pipelines Critical Infrastructure Network:
- Damages to pipelines made by emerging and movement of ice,
- Damages to pipelines fittings and gaping,
- Difficulties in service and supervising operations.

Baltic Oil Pipelines Critical Infrastructure Network:
- Damages to pipelines made by emerging and movement of ice,
- Damages to pipelines fittings and gaping,
- Difficulties in service and supervising operations.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Damages to information infrastructure installed on aids to navigation made by emerging and movement of ice,
- Damages to other surface information infrastructure made by emerging and movement of ice,
- Difficulties in service and supervising operations.

3.3. Sea level rise/ increase

As pointed before, changes of sea level within the Baltic Sea area vary, from negative trends in northern parts, to positive trends in southern Baltic Sea coast of about 1 mm/ year. Thus, parameters describing critical infrastructure networks exposure for climate changes can be specified as follows:
- sea level decrease,
- sea level rise.

Factors pointed above let to specify following hazards to particular critical infrastructure networks, coming out of sea level rise/ decrease.

Baltic Port Critical Infrastructure Network:
- Damages to port infrastructure,
- Flooding of port infrastructure elements.

Baltic Shipping Critical Infrastructure Network:
- Problems for the passages of bridges.

Baltic Oil Rig Critical Infrastructure Network:
- not applicable.

Baltic Wind Farm Critical Infrastructure Network:
- Damages to wind turbines towers and foundations.

Baltic Electric Cable Critical Infrastructure Network:
- not applicable.

Baltic Gas Pipelines Critical Infrastructure Network:
- not applicable.

Baltic Oil Pipelines Critical Infrastructure Network:
– not applicable.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
– Damages to surface infrastructure.

3.4. Coastal erosion

The coastal erosion intensity, as stated previously, depends on a shore type, and on its openness, which indicates the exposure of a shore to the open sea and thus the potential for wave formation. Shores that face the open sea receive an increase in average and maximum wave energy due to increasing storminess in the Baltic Sea. Also low coasts of the Baltic Sea are strongly affected by sea-level rise. Basic parameter that can describe erosion intensity is average retreat of the coast, that can be measured in meters per year.
Coastal erosion can result with below hazards for particular critical infrastructure networks.

Baltic Port Critical Infrastructure Network:
– Damages to port infrastructure.

Baltic Shipping Critical Infrastructure Network:
– not applicable.

Baltic Oil Rig Critical Infrastructure Network:
– not applicable.

Baltic Wind Farm Critical Infrastructure Network:
– Damages to wind turbines towers and foundations.

Baltic Electric Cable Critical Infrastructure Network:
– Damages to ashore cable legs.

Baltic Gas Pipelines Critical Infrastructure Network:
– Damages to ashore pipeline legs.

Baltic Oil Pipelines Critical Infrastructure Network:
– Damages to ashore pipeline legs.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Damages to ashore infrastructure.

3.5. Precipitation

As indicated earlier, heavier precipitation and flooding is projected in northern and north-eastern Europe, with an increased risk of coastal flooding and erosion. A tendency of increasing precipitation in the Baltic Sea in winter and spring has been detected during the second half of the 20th century. Predictions indicate that precipitation will increase in the entire Baltic Sea runoff region during winter, while in the summer increases in precipitation are mainly projected only for the northern half of the basin. In addition, extremes of precipitation are projected to increase, implying a greater risk of flooding, among other impacts. Parameters concerning critical infrastructure networks exposure for climate changes related to precipitation can be pointed as below:
- rain precipitation exceeding certain level [mm/h],
- snow precipitation exceeding certain level [cm/d].

Above factors allowed to formulate indicated below hazards for particular critical infrastructure networks, related to precipitation events.

Baltic Port Critical Infrastructure Network:
– Damages to port infrastructure due to flooding and landslides,
– Destabilisation of embankments,
– Overload of sewerage systems.

Baltic Shipping Critical Infrastructure Network:
– Icing of ships, if precipitation associated with low temperatures,
– poor, or even unreadable, radar visualisation,
– risk of drifting and collision with other ships or contact with port facilities, if precipitation associated with squalls.

Baltic Oil Rig Critical Infrastructure Network:
– Icing of various rig’s elements, if precipitation associated with low temperatures,
– Icing of rig’s installations, if precipitation associated with low temperatures,
– Scour to structures.

Baltic Wind Farm Critical Infrastructure Network:
– Icing of wind turbines elements, if precipitation associated with low temperatures,
– Scour to structures.

Baltic Electric Cable Critical Infrastructure Network:
– Damages to ashore cable legs caused by mass movements (landslides, mud and debris flows),
– Scour to structures.

Baltic Gas Pipelines Critical Infrastructure Network:
- Damages to ashore pipeline legs caused by mass movements (landslides, mud and debris flows),
- Scour to structures.

Baltic Oil Pipelines Critical Infrastructure Network:
- Damages to ashore pipeline legs caused by mass movements (landslides, mud and debris flows),
- Scour to structures.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Damages to overhead installations,
- poor, or even unreadable, radar visualisation,
- Scour to structures.

3.6. Storm surges and winds

As mentioned before, projections of changes in wind climate are uncertain, both in relation to seasonal mean conditions and extremes. However, there is a slight tendency for an increase particularly over the sea area. Important to point is that predictions for extremes of wind speed show an even wider spread than those for mean wind speed. It should be also noted, that sea-level rise has a greater potential to increase storm surge levels in the Baltic Sea than does increased wind speed. There are projected large increases of storm surge levels at the entrance to the Baltic Sea, but the relative impact of changing wind speed on sea-level extremes may be even greater for areas in the eastern Baltic.
Exposure of critical infrastructure networks for storm surges and winds can be described by following parameters:
- wind speed above certain level,
- wind direction.

Storm surges and winds can cause below pointed hazards for particular critical infrastructure networks.

Baltic Port Critical Infrastructure Network:
- Damages to port infrastructure and installations,
- Collisions of ships with port facilities,
- Difficulties with berthing,
- Unintentional interruptions of cargo handling operations.

Baltic Shipping Critical Infrastructure Network:
- Damages to ship on-deck equipment and installations,
- Collisions of ships with port facilities and with other ships,
- Drifting and listing, that can result with running aground,
- Difficulties with berthing.

Baltic Oil Rig Critical Infrastructure Network:
- Damages to rig's on-deck equipment and installations,
- Unintentional interruptions of operation.

Baltic Wind Farm Critical Infrastructure Network:
- Damages to wind turbines elements, especially rotating ones,
- Damages to wind turbines fittings.

Baltic Electric Cable Critical Infrastructure Network:
- Damages to overhead or not submerged enough, cable legs.

Baltic Gas Pipelines Critical Infrastructure Network:
- Damages to overhead, or not submerged enough, pipeline legs.

Baltic Oil Pipelines Critical Infrastructure Network:
- Damages to overhead, or not submerged enough, pipeline legs.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Damages to overhead installations.

3.7. Air temperature change

As indicated earlier, temperatures in the Baltic Sea area are anticipated to increase over time and the increase is generally going to be larger than the corresponding increase in global mean temperature. The strong increase in winter daily mean temperatures is most pronounced in the coldest periods, which is also the case for the more extreme daily maximum and minimum temperatures. Warm extremes in summer are also expected to become more pronounced than at present.
Exposure of critical infrastructure networks related to air temperature changes can be determined by following parameters:
- air temperature below certain level,
- air temperature above certain level.

Air temperature changes can be associated with below hazards for particular critical infrastructure networks.

Baltic Port Critical Infrastructure Network:
- Overheating of port installations end equipment,
- Increased instability of embankments,
- Reduced life of inner-port road surfaces (pavement deterioration, melting tarmac, buckling of bridges).

Baltic Shipping Critical Infrastructure Network:
- Overheating of various ship technical equipment,
- Problems with cooling of ship's engines.
- Icing of ships at low temperatures.

Baltic Oil Rig Critical Infrastructure Network:
- Overheating of various rig's technical equipment,
- Increased fatigue of rig's installations,
- Icing of various rig's elements at low temperatures,
- Icing of rig's installations at low temperatures.

Baltic Wind Farm Critical Infrastructure Network:
- Icing of various wind turbines components at low temperatures,
- Damages to electric cables and other equipment caused by thermal expansion of the material.

Baltic Electric Cable Critical Infrastructure Network:
- Damages to cables caused by permafrost degradation,
- Damages to cables fittings,
- Damages to cables caused by thermal expansion of the material.

Baltic Gas Pipelines Critical Infrastructure Network:
- Buckling of pipeline legs and material fatigue,
- Damages to pipelines caused by permafrost degradation,
- Reduced throughput capacity in gas pipelines,
- Damages to pipelines caused by thermal expansion of the material.

Baltic Oil Pipelines Critical Infrastructure Network:
- Buckling of pipeline legs and material fatigue,
- Damages to pipelines caused by permafrost degradation,
- Damages to pipelines fittings and gaping,
- Damages to pipelines caused by thermal expansion of the material.

Baltic Ship Traffic and Port Operation Information Critical Infrastructure Network:
- Icing of overhead system's components at low temperatures,
- Damages to system components caused by thermal expansion of the material.

4. Conclusion

The paper has indicated climate related hazards for particular critical infrastructure networks operating within the Baltic sea area. Further evaluation, with use of results of EU-CIRCLE reports [12] – [14], can lead to obtain critical parameters values, representing particular critical infrastructure networks exposure to each of identified hazards. This will allow to process further works aiming to strengthen critical infrastructure networks resilience to predicted climate changes.
Results introduced in the paper will be used for Modelling of operation process of Global Baltic Network of interconnected and interdependent critical infrastructures networks, with use of Critical Infrastructure Operation Process General Model, related to Operating Environment Hazards, and Extreme Weather Events, in its operating environment (EU-CIRCLE Report D2.2-GMU4). The outcomes will be also useful for Global Baltic Network of Critical Infrastructures Networks safety modelling, identification and prediction (without and with climate weather change influence - EU-CIRCLE Report D3.3-GMU11 and D3.3-GMU18).

Acknowledgments

The paper presents the results developed in the scope of the EU-CIRCLE project titled "A pan – European framework for strengthening Critical Infrastructure resilience to climate change" that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653824. http://www.eu-circle.eu/.

References

[1] Blokus-Roszkowska, A., Bogalecka, M. & Kołowrocki, K. (2016) Critical infrastructure networks at Baltic Sea and its seaside, *Journal of Polish Safety and Reliability Association, Summer Safety and Reliability Seminars* 7, 2, 7-14.
[2] Dziula, P. (2015). Selected aspects of acts of law concerning critical infrastructure protection within the Baltic Sea area, *Scientific Journals of the Maritime University of Szczecin* 44, 116, 173-181.
[3] Dziula, P., Kołowrocki, K. & Rosiński, A. (2015). Issues concerning identification of critical infrastructure systems within the Baltic Sea area,

Safety and Reliability of Complex Engineered Systems: ESREL 2015, 119-126.

[4] European Union, European Commission. (2013) Communication from the Commission, *An EU Strategy on adaptation to climate change, COM, 2013, 216 final*, Brussels.

[5] European Union, European Commission. (2013). Commission Staff working document: *Climate change adaptation, coastal and marine issues, SWD(2013)133 final*, Brussels.

[6] EU-CIRCLE Report D1.1-GMU1. (2015), *EU-CIRCLE Taxonomy*.

[7] EU-CIRCLE Report D1.2-GMU1. (2016). *Identification of existing infrastructures in the Baltic Sea and its seaside, their scopes, parameters and accidents in terms of climate change impacts*.

[8] EU-CIRCLE Report D1.3-GMU3. (2015). *Contribution to catalogue of hazards to critical infrastructure reflecting climate changes*.

[9] EU-CIRCLE Report D1.3-GMU4. (2015). *Contributions to generating Questionnaire of End User Needs*.

[10] EU-CIRCLE Report D1.4-GMU3. (2016). *Holistic approach to analysis and identification of critical infrastructures within the Baltic Sea area and its surroundings – Formulating the concept of a global network of critical infrastructures in this region ("network of networks" approach)*.

[11] EU-CIRCLE Report D2.1-GMU3. (2016). *Modelling Climate-Weather Change Process Including Extreme Weather Hazards*.

[12] EU-CIRCLE Report D3.2-GMU1. (2016). *Identification of climate related hazards at the Baltic Sea area and their critical/ extreme event parameters' exposure for port oil piping transportation critical infrastructure*.

[13] EU-CIRCLE Report D3.2-GMU2. (2016). *Identification of climate related hazards at the Baltic Sea area and their critical/ extreme event parameters' exposure for maritime ferry critical infrastructure*.

[14] EU-CIRCLE Report D3.2-GMU3. (2016). *Identification of climate related hazards at the Baltic Sea area and their critical/ extreme event parameters' exposure for port, maritime and information critical infrastructure*.

[15] Helsinki Commission (HELCOM). (2013). *Climate change in the Baltic Sea Area HELCOM thematic assessment in 2013*, Baltic Sea Environment Proceedings No. 137, Helsinki.

[16] Kołowrocki, K. & Soszyńska, J. (2010). Safety and risk optimization of a ferry technical system. *Journal of Polish safety and Reliability Association, Summer Safety and Reliability Seminars* 1, 159-172.

[17] Kołowrocki, K. & Soszyńska-Budny, J. (2011). *Reliability and Safety of Complex Technical Systems and Processes: Modeling-Identification-Prediction-Optimization*. Springer.