



# balt adapt

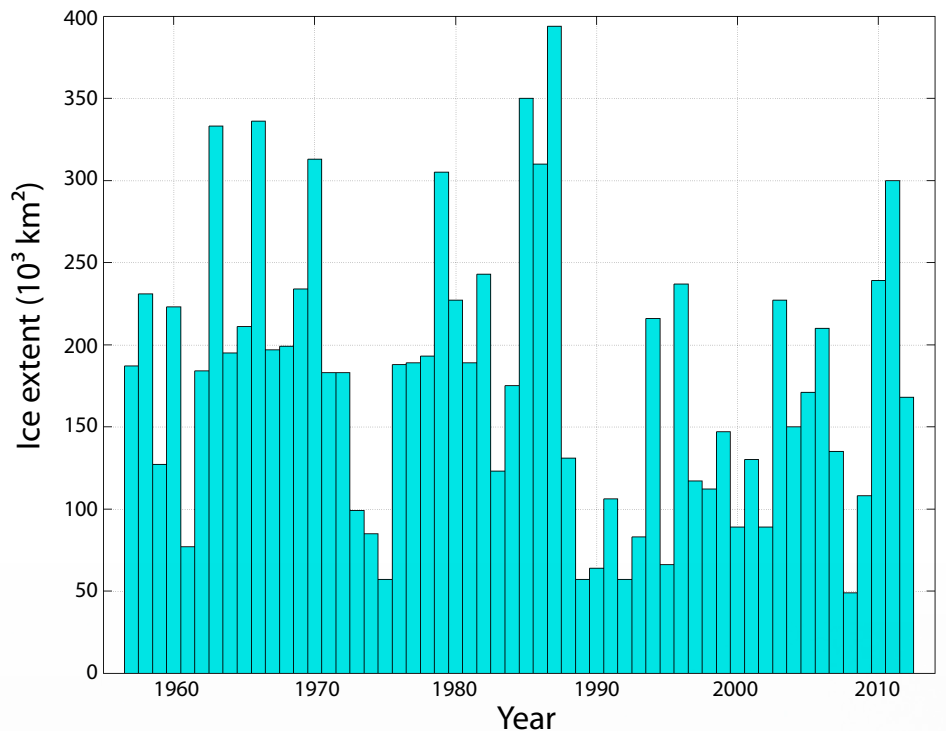
Baltic Sea Region  
Climate Change Adaptation Strategy

## Climate Change in the Baltic Sea Region: Sea Ice

### BALTADAPT CLIMATE INFO # 14

#### Climatological sea ice conditions in the Baltic Sea

The Baltic Sea is partly covered by ice in the winter season. Sea ice usually starts forming along the coasts in the northernmost parts of the Bothnian Bay in October/November. Depending on how cold the winter gets the ice gradually gets more and more extensive until the maximum is reached sometimes during February/March. In spring and early summer gradual melting takes place so that the sea is generally ice free in May/June. Depending on the severity of the winter the growth and areal extent varies significantly from year to year. Historic observations reveal that the maximum sea ice extent varies between 50,000 and 400,000 km<sup>2</sup> during the last 50 years (Figure 1). The most prominent ice winters include the three cold winters in the mid 1980ies. Ice winters have generally been less severe during the last two decades compared to the preceding two even if single years show extensive ice cover, as 2011.



**Figure 1:** Maximum sea ice extent in the Baltic Sea and Kattegat (in total ca. 420,000 km<sup>2</sup>). The area is defined by analysing the ice extent in a large number of small grid squares. If the ice cover in such a grid square exceeds 15% the grid box is considered to be ice covered. The data that covers 1957–2012 is taken from SMHI.



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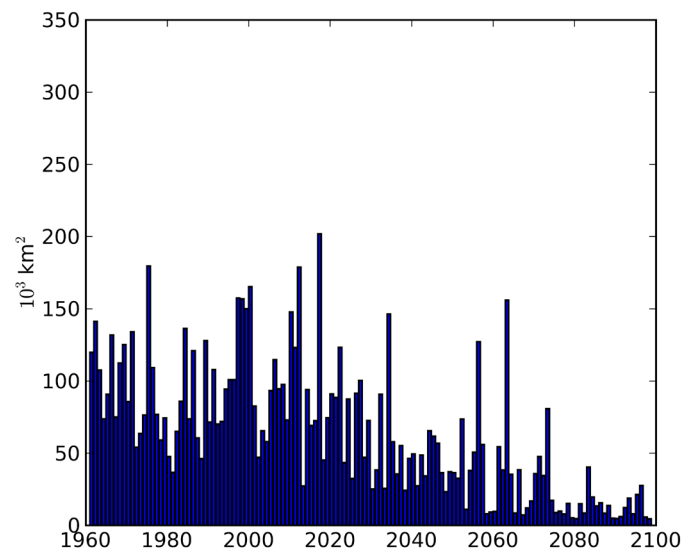
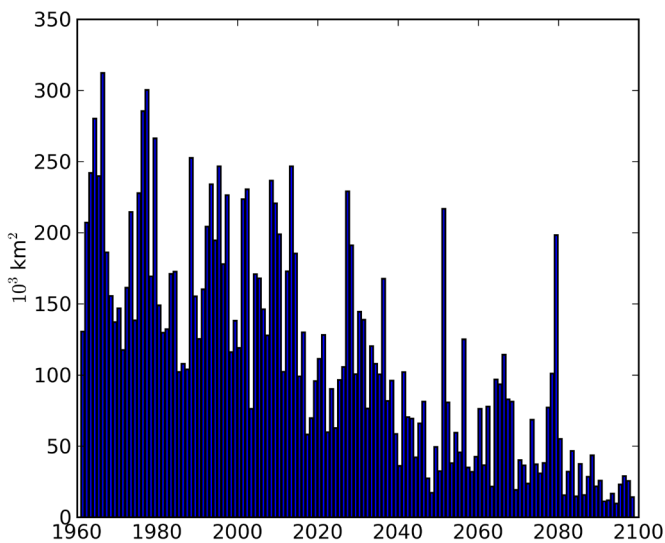
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SEA REGION



## Simulated Climate Change signal

Climate change scenarios shows the largest changes in temperature in this region during winter. This amplified warming is to a large extent a result of declining snow and sea ice extent in the area. As the extent of these highly reflective white areas decreases a larger fraction of the incoming solar radiation can be taken up by ground and sea water and thus further act to increase the temperature. Sea Ice in the Baltic Sea area is expected to decrease with time as the temperature in the region increases. The two regional climate scenarios presented in Figure 2 (from Meier et al. 2011) show large inter-annual variability. This is in agreement to

the observations while the absolute maximum in the models do not reflect the maximum observed sea-ice extent, especially in one of the integrations. Both scenarios project a gradual decrease in the maximum sea ice extent with time. At the end of the century there is still a large inter-annual variability spanning between almost ice free winters and those reaching a few 10,000 km<sup>2</sup>. We note here that not even the most severe ice winters at the end of the 21<sup>st</sup> century show a maximum sea ice extent reaching 50,000 km<sup>2</sup> that is what the least severe winters show during the last half a century.

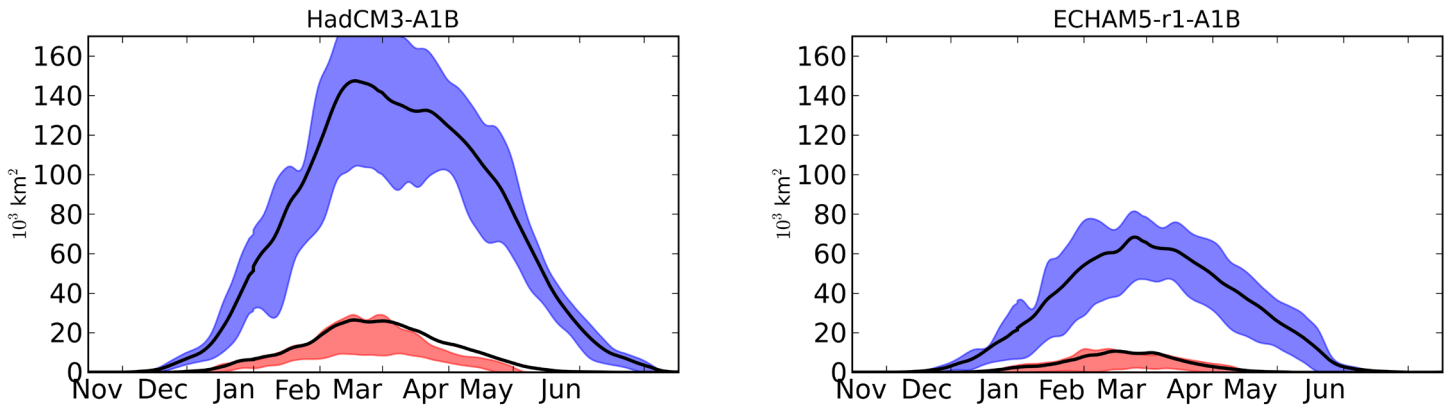


**Figure 2:** Maximum sea ice extent in the Baltic Sea and Kattegat (in total ca. 420,000km<sup>2</sup>). The area is defined by analysing the ice extent in a large number of small grid squares. If the ice cover in such a grid square exceeds 15% the grid box is considered to be ice covered. Data are taken from two climate change scenarios with the coupled atmosphere-ocean regional climate model RCAO with boundary conditions from the global climate models HadCM3 (left) and ECHAM5 (right). Both simulations represent conditions following the SRES A1B emission scenario.



In addition to a very large reduction in the sea ice extent also the ice season changes. Figure 3 shows the mean monthly sea ice extent in the two scenarios both at the end of the 20<sup>th</sup> century and at the end of the 21<sup>st</sup> century. From the figure it is clear that the areal extent gets much smaller for all months in the future. Apart from the very large decrease as outlined above there is also a shortening of the ice season. The shortening is manifested both through a later onset in fall and an earlier melting in spring. It is noted that the mean (thick black line) sometimes falls outside of the interval defined by the 25<sup>th</sup> and 75<sup>th</sup> percentiles. This is a result of the small ice cover in future which allows for occasional winters with relatively extensive ice to show up in the average.

Climate change on the regional scale is highly uncertain and as the results presented above stem from only two regional climate model scenarios they certainly do not represent the full range of uncertainties. A major problem in this context is the lack of high-resolution climate model results for this area. Global climate mod-



**Figure 3:** Mean annual cycle of the monthly mean sea ice area in the Baltic Sea and Kattegat as calculated by multiplying the ice concentration with the area of the grid squares in the region. The thick line represents the long term average while the shaded area shows the data between the 25<sup>th</sup> and the 75<sup>th</sup> percentiles. The blue shading and upper thick line represents the control period (1961–1990) and the red shading and the lower thick line 2071–2100 under the SRES A1B emission scenario. Data are taken from two simulations with the coupled atmosphere-ocean regional climate model RCAO with boundary conditions from the global climate models HadCM3 (left) and ECHAM5 (right).

els are generally too coarse to provide realistic sea-ice conditions in the Baltic Sea. Regional climate models including both atmosphere and ocean as presented above can help as it has been shown that such combinations can simulate the sea-ice cover in the Baltic Sea in a more realistic way. However, only very few scenarios with coupled regional climate models exist (e.g. Meier et al., 2004; Meier et al., 2011). Common to them is that they all project a decrease in sea ice in the future. A further problem with the regional climate model scenarios is that biases in the large-scale climate features in the global climate model will also show up in the regional climate model. This implies that the results are sensitive to which global model that is used for providing boundary data and it stresses the fact that it is important to set the regional climate model results in a larger context. Based on an ensemble of 19 global climate models Luomaranta et al. (2010) shows that severe ice winters will become very rare by 2050 and that the sea ice that may form will be much thinner than observed now. This finding lends more confidence in the regional climate model scenarios presented above as the results appear to be robust over the larger ensemble.

### Summary and outlook

Climate change scenarios reveal strong changes in sea ice in the Baltic Sea region. The projections show a gradual decrease in the sea ice extent over time and a general shortening of the ice season. A large inter-annual variability is seen in the future scenarios as well as in the observed climate. However, the most severe ice winters in the future may even become less severe than the mildest winters in the climate of the 20<sup>th</sup> century.



## Climate scenario data

Results on future changes in sea ice presented in this Fact Sheet are taken from numerical climate models. Here, results from coupled atmosphere-ocean regional climate model (RCM) simulations have been used (Meier et al., 2011). These are performed on a domain covering most of Europe with an ocean model explicitly added for the Baltic Sea and Kattegat. The RCMs downscale results from global climate models (GCMs) to a higher spatial resolution: typically 25–50 km, compared to the GCM resolution of 100–300 km. The finer spatial scale in the RCMs implies that impact on climate from land-sea contrasts and altitude of mountains can be described in more detail than in the GCMs. Further, the climate change signal can be studied in finer detail more representative in terms of climate change impacts and adaptation work. We note that even if RCMs have high spatial resolution they preserve many features of the GCM simulations. This implies that uncertainties related to e.g. large-scale atmospheric circulation patterns, climate sensitivity, and/or emission scenarios exist also in the RCM results.

The climate model simulations make use of a series of emission scenarios representing different story lines for the future (Nakićenović et al., 2000). These, so called SRES scenarios describe the evolution of the world in the 21<sup>st</sup> century. Altogether 40 different SRES emission scenarios were constructed based on assumptions about world population, economic development, technological changes etc. Six of these (A1B, A1T, A1FI, A2, B1 and B2) were chosen by the IPCC as marker scenarios. Most climate model simulations are forced by the A2, A1B and B1 emission scenarios representing: high (A2), intermediate (A1B) and relatively low (B1) increases in greenhouse gas concentrations during the 21<sup>st</sup> century. RCM simulations for Europe mostly involve the A2, A1B and B2 scenarios.

Presently, autumn 2012, a large number of new global and regional climate model integrations with a set of new emission scenarios are being produced by the international climate modelling community. These will serve as input for the next IPCC assessment report in 2013/2014. A novelty compared to the SRES scenarios is that some of the new scenarios take mitigation into account.

## References

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Nakićenović, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grübler, A., et al., 2000. Emission scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, 599 pp.

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## The Baltadapt project in a nutshell

The Baltic Sea and its coastlines face challenges due to climate change. The projected increase in precipitation amounts and temperature will jeopardize the integrity of the ecosystem and increase risks caused by natural disasters. Adaptation strategies are needed to cope with the inevitable consequences of climate change. Baltadapt is developing a transnational climate change adaptation strategy for the Baltic Sea Region. This will help decision makers all over the region to tackle the consequences of climate change.

The project was approved under the Baltic Sea Region Programme 2007–2013 and has a total budget of € 2.86 m. Its partner consortium is led by the Danish Meteorological Institute. Baltadapt is a flagship project under the EU Strategy for the Baltic Sea Region and has been awarded the Baltic 21 Lighthouse Project quality label.

