How is climate change affecting the Baltic Sea?

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HELCOM-Baltic Earth collaboration

BALTEX/Baltic Earth Assessments of Climate Change for the Baltic Sea Basin:

BACC Author Team (2008) - book

BACC II Author Team (2015) - book

BEARs (2022) - special issue in Earth System Dynamics

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Earth System Dynamics Discussions

Climate Change in the Baltic Sea Region: A Summary

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- Knowledge gain since 2013 based upon peer-reviewed papers
- 33 parameters (atmosphere, cryosphere, land, terrestrial biosphere, ocean and sediment, marine biosphere), no anthroposphere
- Past, present and future climate changes
- 47 scientists, 133 pp, 34 figures, 10 tables, > 812 references
- https://esd.copernicus.org/preprints/esd-2021-67/

EN CLIME

Climate Change in the Baltic Sea

2021 Fact Sheet

HELCOM

baltic.earth
Earth System Science for the Baltic Sea Region

https://helcom.fi/media/publications/Baltic-Sea-Climate-Change-Fact-Sheet-2021.pdf

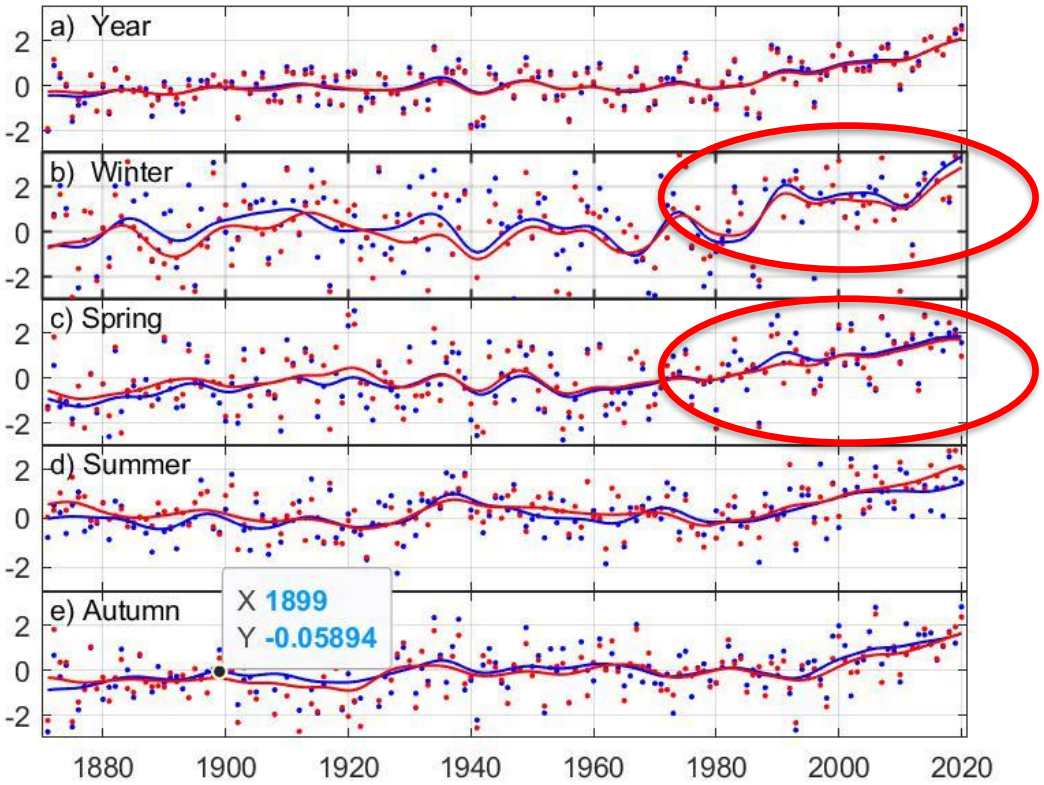
Table 1. Full list of EN CLIME parameters. The asterisk (*) indicates those parameters that include information on extreme events.

Direct parameters	Categorization
Air temperature*	Energy cycle
Water temperature*	Energy cycle
Large scale atmospheric circulation	Energy cycle
Sea ice*	Energy cycle
Solar radiation	Energy cycle
Salinity and saltwater inflows*	Water cycle
Stratification and ocean circulation	Water cycle
Precipitation*	Water cycle
River run-off*	Water cycle
Carbonate chemistry	Carbon and nutrient cycles
Riverine nutrient loads and atmospheric deposition	Carbon and nutrient cycles
Sea level*	Sea level and wind
Wind*	Sea level and wind
Waves*	Sea level and wind
Sediment transportation*	Sea level and wind

Secondary parameters	Categorization
Oxygen	Carbon and nutrient cycles
Microbial community and processes	Biota and ecosystems
Benthic habitats	Biota and ecosystems
Coastal and migratory fish	Biota and ecosystems
Pelagic and demersal fish	Biota and ecosystems
Waterbirds	Biota and ecosystems
Marine mammals	Biota and ecosystems
Non-indigenous species	Biota and ecosystems
Marine protected areas (MPA's)	Biota and ecosystems
Ecosystem function	Biota and ecosystems
Nutrient concentrations and eutrophication	Biota and ecosystems
Coastal protection	Human activities
Offshore wind farms	Human activities
Shipping	Human activities
Tourism	Human activities
Fisheries	Human activities
Aquaculture	Human activities
Blue carbon storage capacity	Services
Marine and coastal ecosystem services	Services

Present climate change

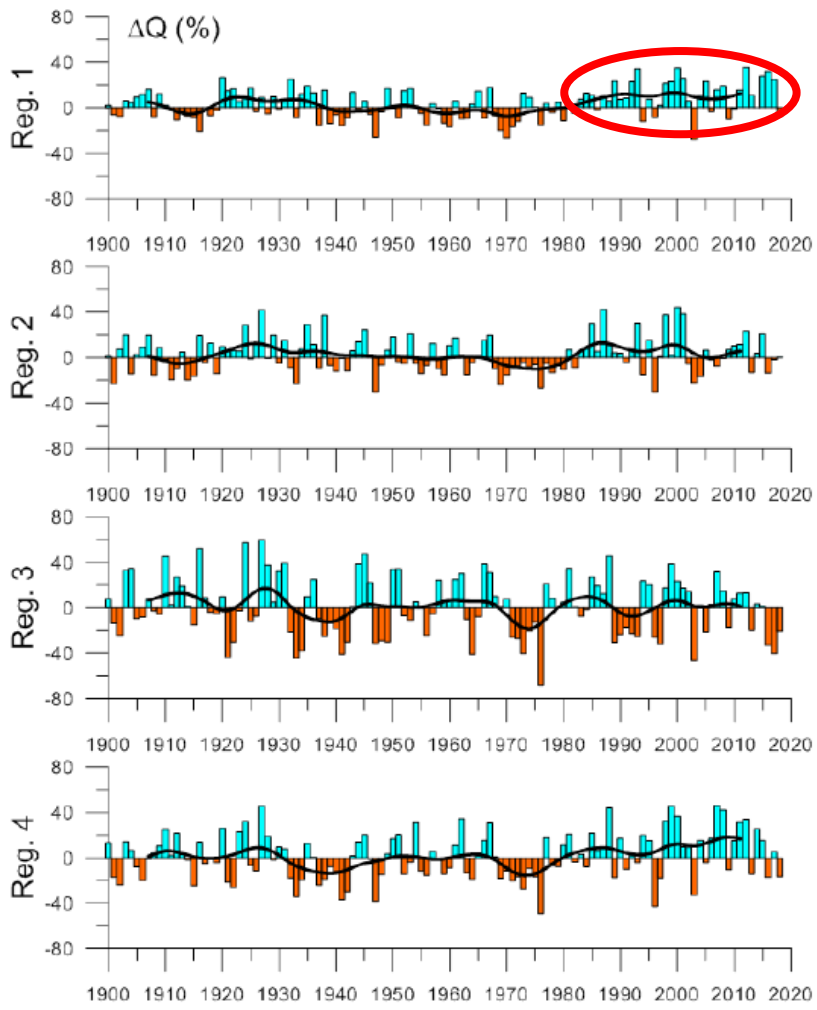
Air temperature over land

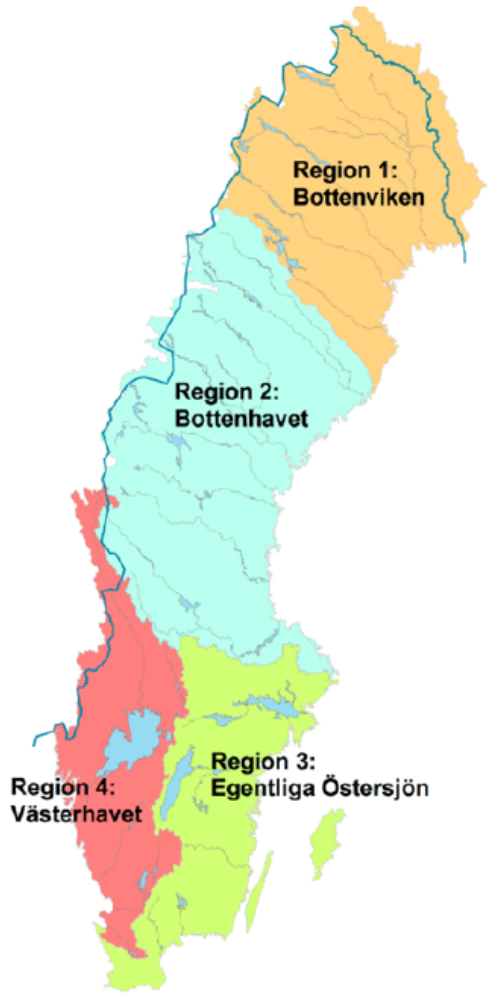


Larger than the global average, slightly larger than estimated earlier

(Source: Anna Rutgersson, Uppsala University)

Blue, red: Baltic Sea basin region north and south, respectively, of 60°N.

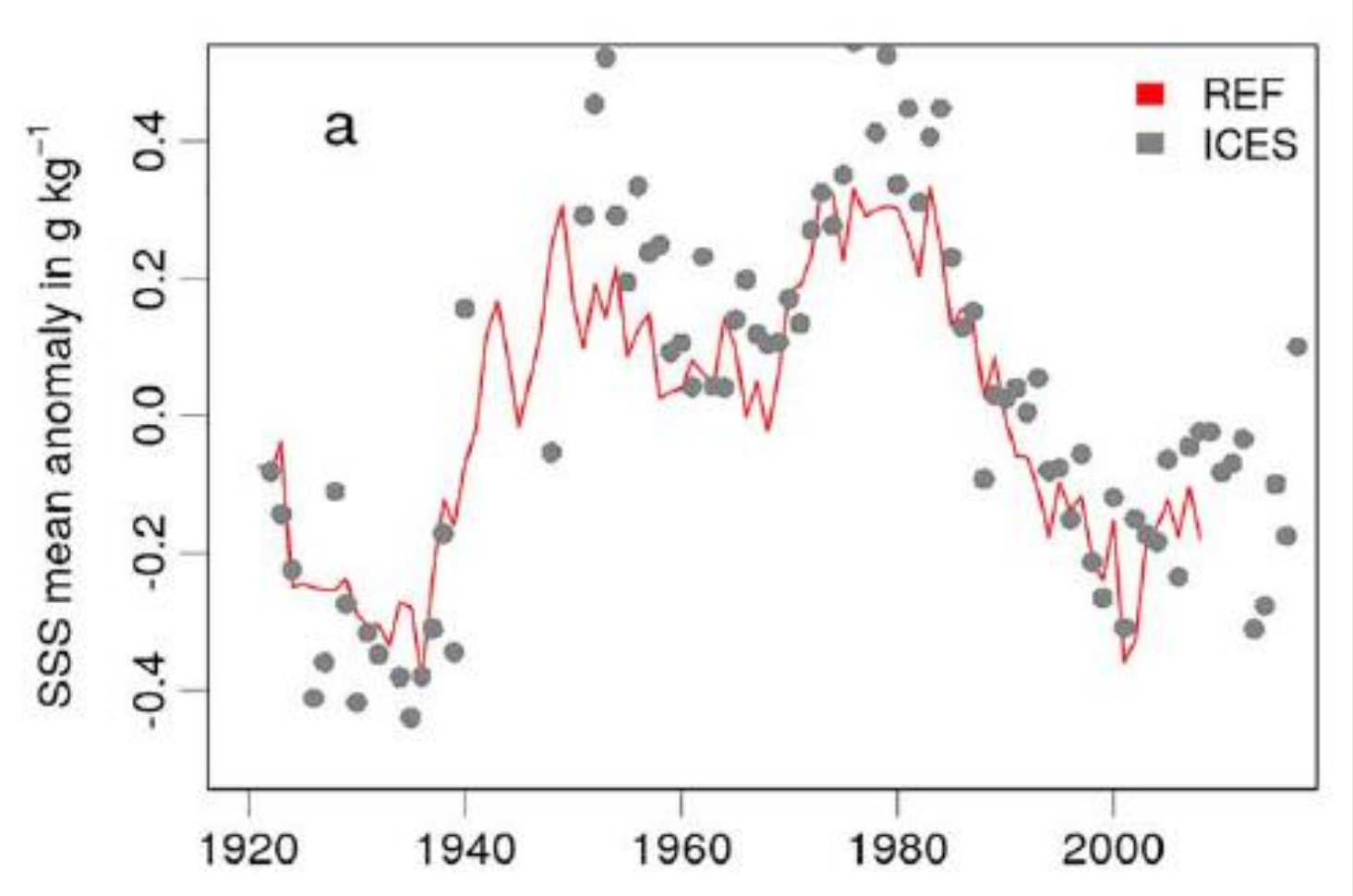




Figur 4. Summerad avrinning för fyra regioner, årsvärden 1900-2018, som avvikelse mot medelvärdet för 1961-1990.

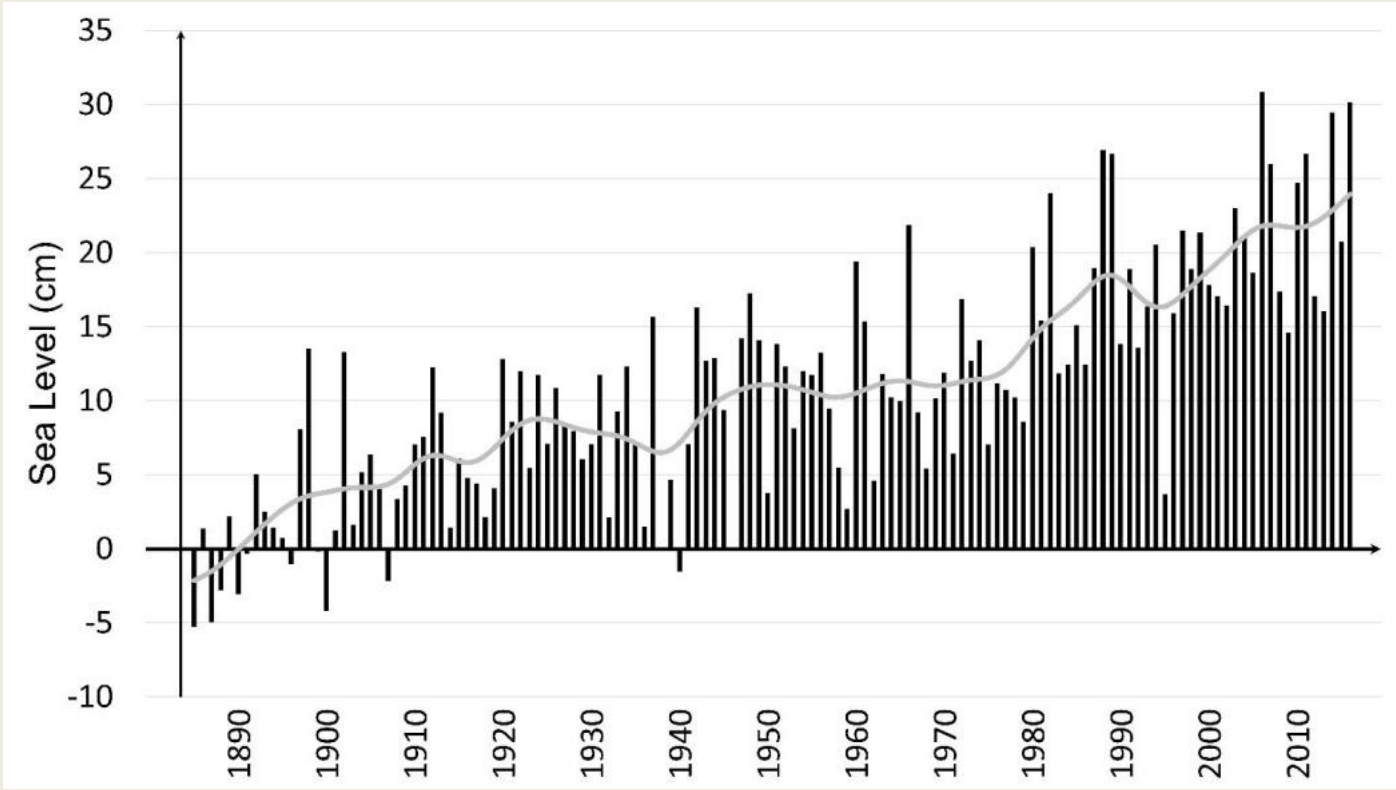
(Source: Lindström, 2019)

Sea surface salinity



(Source : Madline Kniebusch et al., 2019)

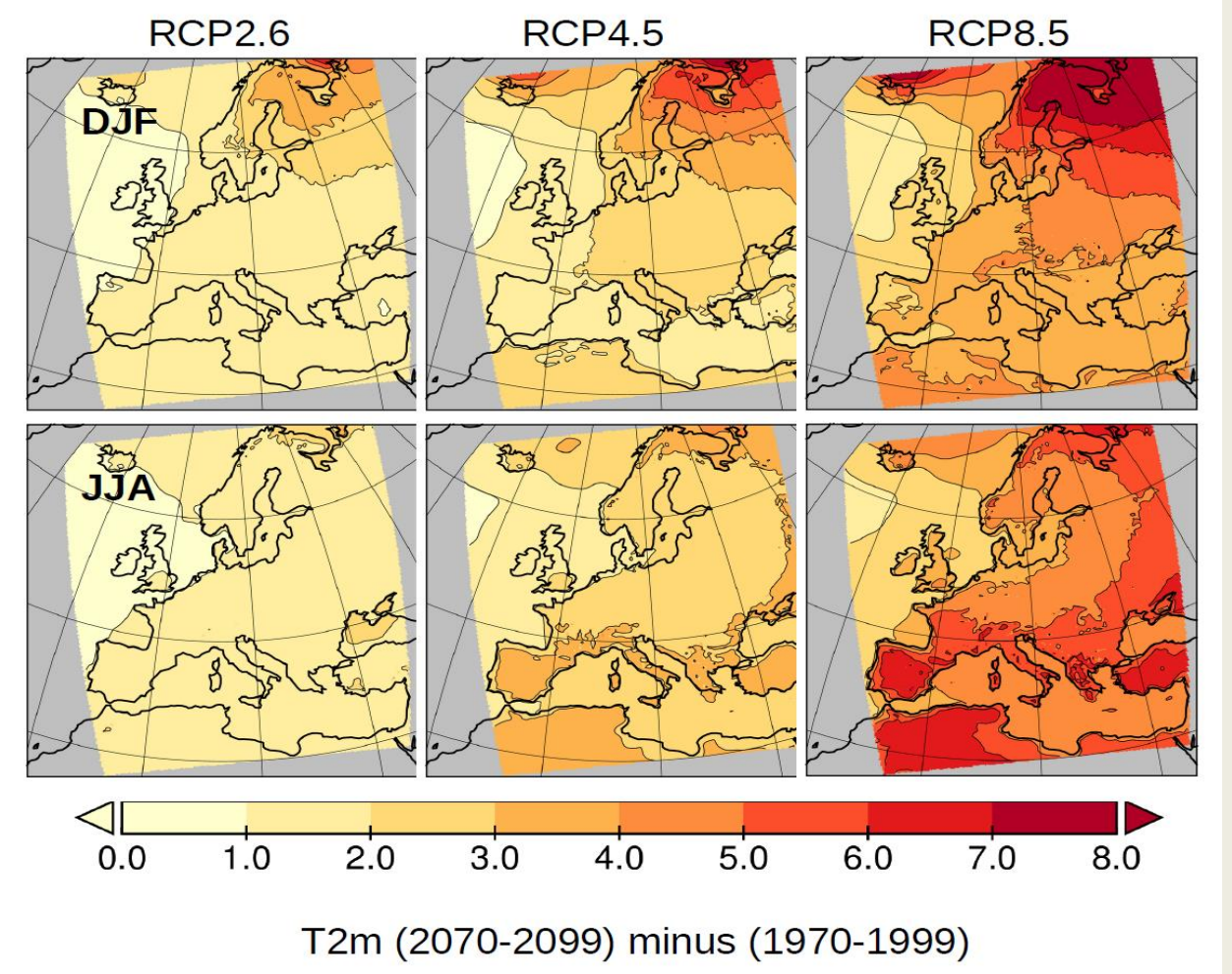
Sea level



Annual mean sea level changes in centimeters for 14 Swedish mareographs since 1886. The data are corrected for land uplift. The grey line shows a smoothed curve. (Source: Swedish Meteorological and Hydrological Institute)

Future climate change

Future air temperature change



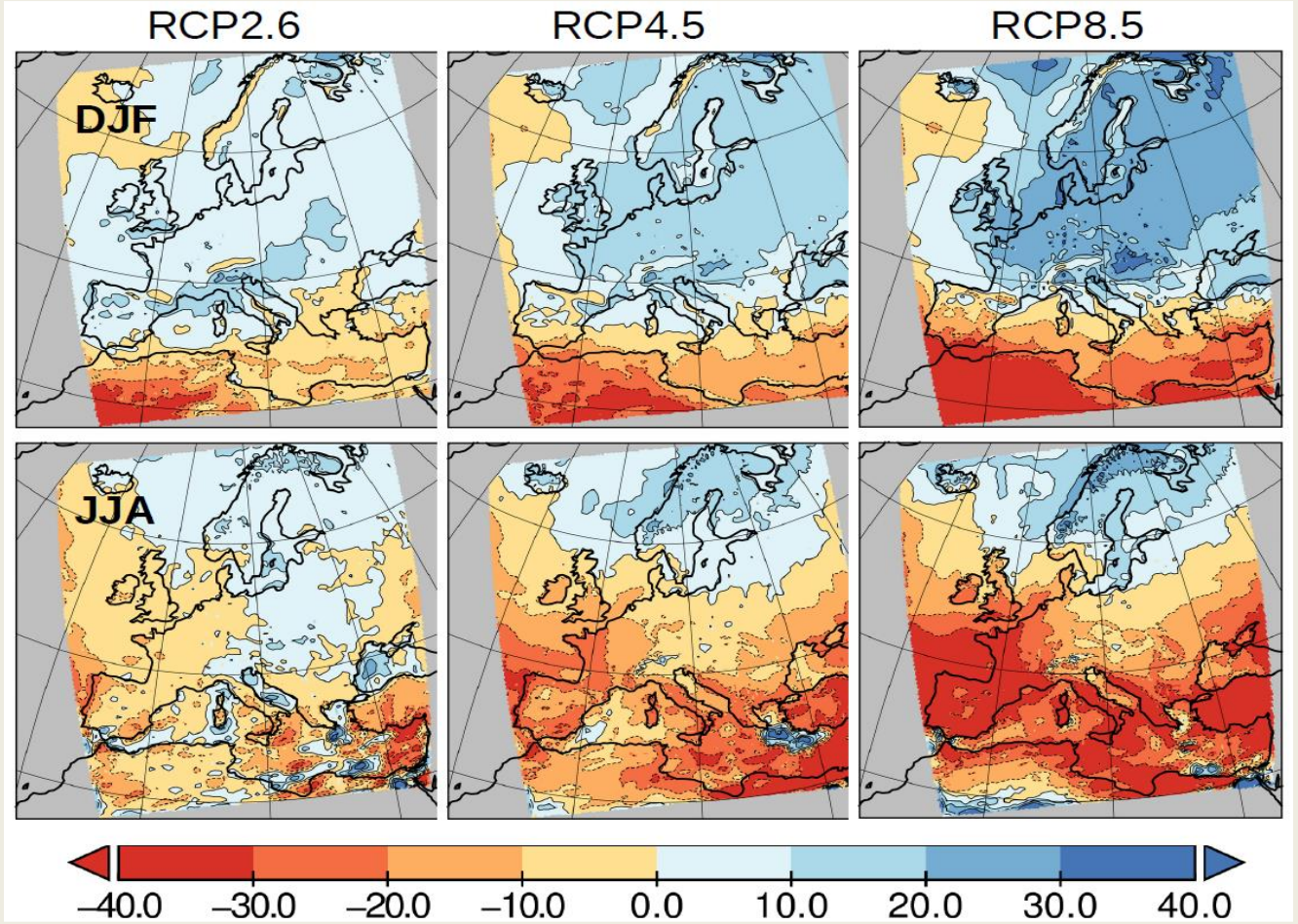
winter

summer

1.5 (RCP2.6) and 4.3°C (RCP8.5)

(Source: Gröger et al., 2021)

Future precipitation change



winter

summer

(Source: Gröger et al., 2021)

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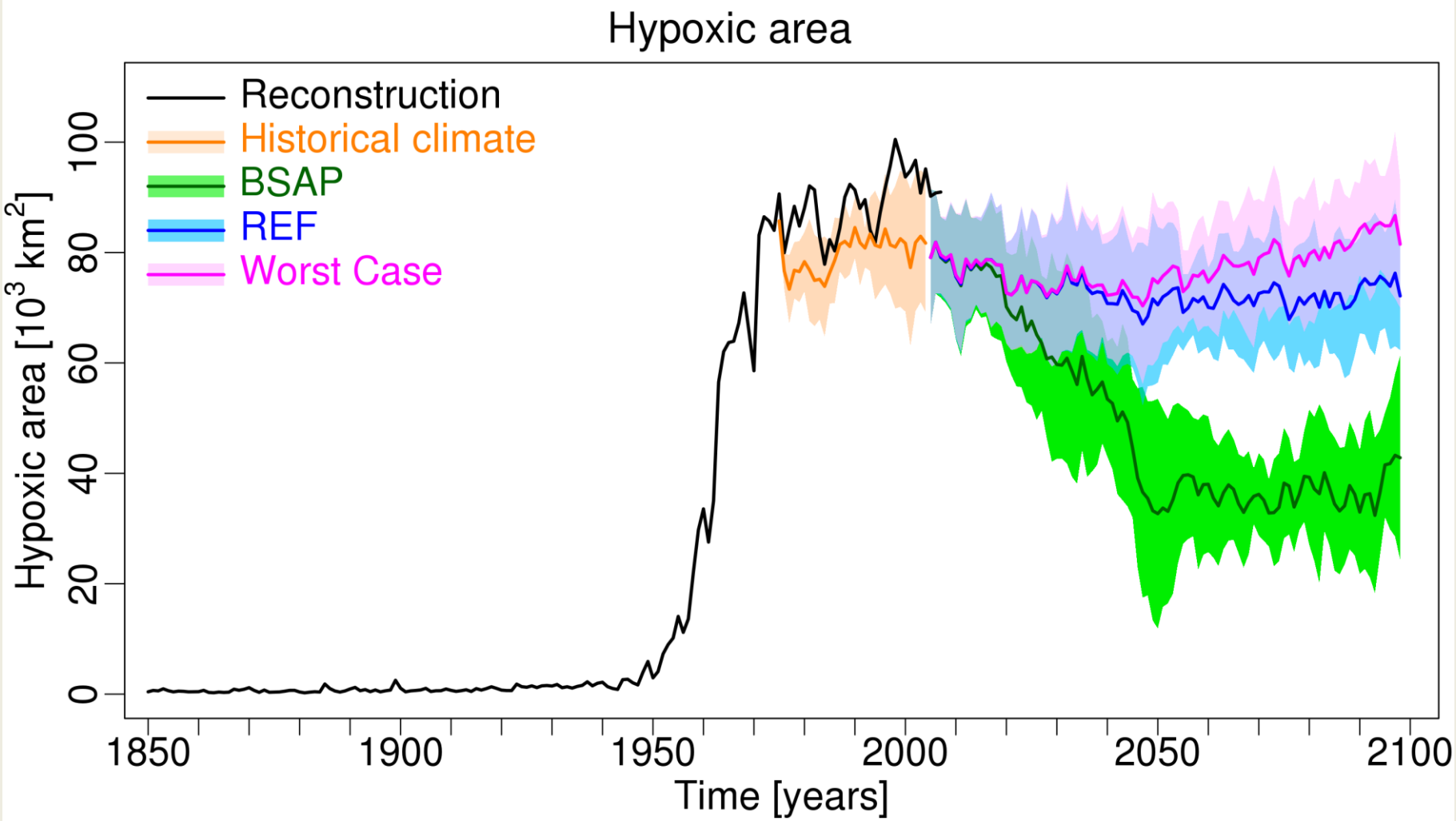


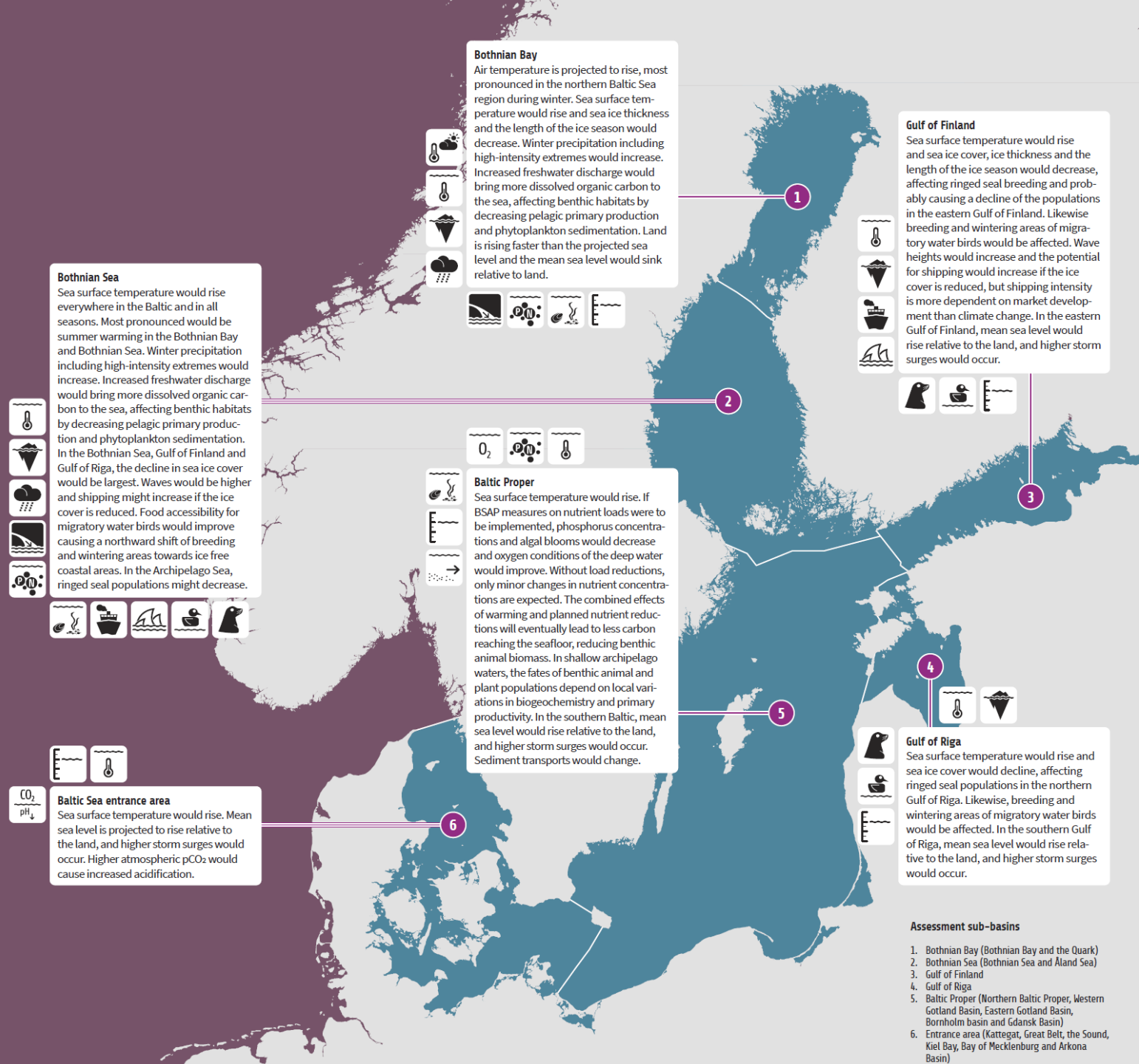
(Source: modified after Meier et al., 2019)

Leibniz Institute for Baltic Sea Research Warnemünde

Climate future of the Baltic Sea

Projections under the RCP4.5 climate scenario

The impact map depicts projected regional changes for some of the most relevant parameters in a particular subbasin of the Baltic Sea under the RCP4.5 scenario. While there is also important information on the other parameters, there was a need to reduce the total 34 parameters to the presented parameters to make the map more legible. The presented parameters have 1) direct societal relevance/experience and/or relevance for other parameters, 2) medium to high confidence of the changes relative to the noise and model/expert judgement uncertainty under the RCP4.5 scenario, and 3) a hotspot sub-region in the Baltic with medium to high confidence of patterns of the regional changes.



Bothnian Bay
Air temperature is projected to rise, most pronounced in the northern Baltic Sea region during winter. Sea surface temperature would rise and sea ice thickness and the length of the ice season would decrease. Winter precipitation including high-intensity extremes would increase. Increased freshwater discharge would bring more dissolved organic carbon to the sea, affecting benthic habitats by decreasing pelagic primary production and phytoplankton sedimentation. Land is rising faster than the projected sea level and the mean sea level would sink relative to land.

Gulf of Finland
Sea surface temperature would rise and sea ice cover, ice thickness and the length of the ice season would decrease, affecting ringed seal breeding and probably causing a decline of the populations in the eastern Gulf of Finland. Likewise breeding and wintering areas of migratory water birds would be affected. Wave heights would increase and the potential for shipping would increase if the ice cover is reduced, but shipping intensity is more dependent on market development than climate change. In the eastern Gulf of Finland, mean sea level would rise relative to the land, and higher storm surges would occur.

Bothnian Sea
Sea surface temperature would rise everywhere in the Baltic and in all seasons. Most pronounced would be summer warming in the Bothnian Bay and Bothnian Sea. Winter precipitation including high-intensity extremes would increase. Increased freshwater discharge would bring more dissolved organic carbon to the sea, affecting benthic habitats by decreasing pelagic primary production and phytoplankton sedimentation. In the Bothnian Sea, Gulf of Finland and Gulf of Riga, the decline in sea ice cover would be largest. Waves would be higher and shipping might increase if the ice cover is reduced. Food accessibility for migratory water birds would improve causing a northward shift of breeding and wintering areas towards ice free coastal areas. In the Archipelago Sea, ringed seal populations might decrease.

Baltic Proper
Sea surface temperature would rise. If BSAP measures on nutrient loads were to be implemented, phosphorus concentrations and algal blooms would decrease and oxygen conditions of the deep water would improve. Without load reductions, only minor changes in nutrient concentrations are expected. The combined effects of warming and planned nutrient reductions will eventually lead to less carbon reaching the seafloor, reducing benthic animal biomass. In shallow archipelago waters, the fates of benthic animal and plant populations depend on local variations in biogeochemistry and primary productivity. In the southern Baltic, mean sea level would rise relative to the land, and higher storm surges would occur. Sediment transports would change.

Gulf of Riga
Sea surface temperature would rise and sea ice cover would decline, affecting ringed seal populations in the northern Gulf of Riga. Likewise, breeding and wintering areas of migratory water birds would be affected. In the southern Gulf of Riga, mean sea level would rise relative to the land, and higher storm surges would occur.

Baltic Sea entrance area
Sea surface temperature would rise. Mean sea level is projected to rise relative to the land, and higher storm surges would occur. Higher atmospheric pCO_2 would cause increased acidification.

Assessment sub-basins

1. Bothnian Bay (Bothnian Bay and the Quark)
2. Bothnian Sea (Bothnian Sea and Åland Sea)
3. Gulf of Finland
4. Gulf of Riga
5. Baltic Proper (Northern Baltic Proper, Western Gotland Basin, Eastern Gotland Basin, Bornholm basin and Gdansk Basin)
6. Entrance area (Kattegat, Great Belt, the Sound, Kiel Bay, Bay of Mecklenburg and Arkona Basin)

Selected results

(1) Scenarios for the Baltic Sea project a **sea surface temperature** increase of 1.1°C (RCP2.6) to 3.2°C (RCP8.5) by the end of this century, compared to 1976-2005.

(2) In the future, it is very likely that the **maximum sea ice extent** will further decrease.

(3) Due to the large uncertainty in projected freshwater supply from the catchment area, wind and global sea level rise, **salinity** projections show a widespread trend, and no robust changes were identified.

(4) Global **sea level** will rise and consequently the Baltic sea level as well, counteracted by land uplift in the northern areas.

(5) Implementation of the BSAP will lead to significantly improved deep water **oxygen** conditions, irrespective of the climate projection.

Baltic Earth
Earth System Science for the Baltic Sea Region

Thank you very much for your attention!