Baltic Earth

Baltic - C

SEVENTH FRAMEWORK PROGRAMME

Scenarios developed in the Baltic-C program

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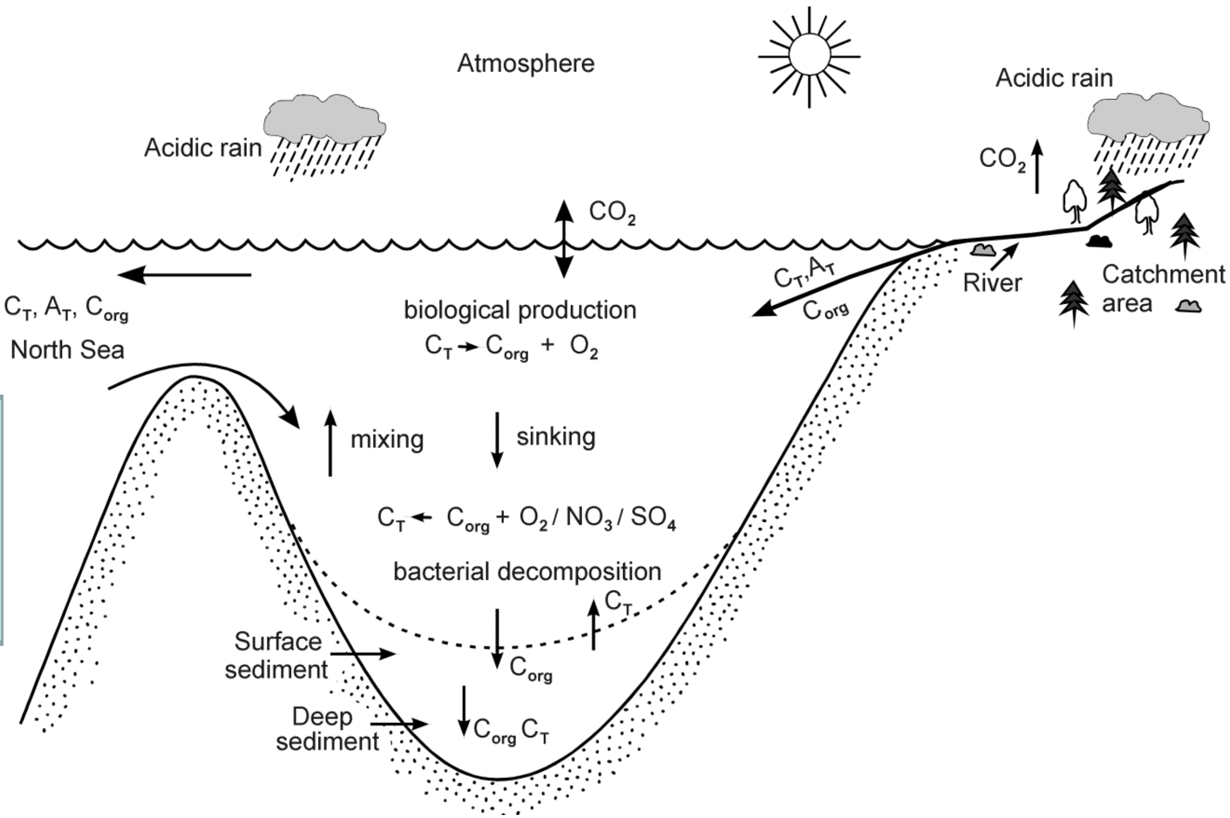
Aim to present some results from:

Omstedt, A., Humborg, C., Pempkowiak, J., Pertillä, M., Rutgersson, A., Schneider, B., and Smith, B. (2014). Biogeochemical Control of the Coupled CO_2–O_2 System of the Baltic Sea: A review of the results of Baltic-C. Ambio,43: 49-59. DOI 10.1007/s13280-013-0485-4

Edman, M., and A., Omstedt (2013). Modeling the dissolved CO_2 system in the redox environment of the Baltic Sea. Limnol. Oceanogr., 58(1), 2013, 74-92

Omstedt, A., Edman, M., Claremar, B., Frodin, P., Gustafsson, E., Humborg, C., Mörth, M., Rutgersson, A., Schurgers, G., Smith, B., Wällstedt, T., and Yurova, A. (2012). Future changes of the Baltic Sea acid-base (pH) and oxygen balances. Tellus B, 64, 19586, http://dx.doi.org/10.3402/tellusb.v64i0,19586.

Modelling the Baltic Sea CO_2 - O_2 system



The Baltic Sea CO_2 - O_2 system needs to be considered when studying multiple threats due to eutrophication, acidification and climate change on the marine system.

pH and alkalinity change in the redox environment of the Baltic Sea

Alkalinity generation due to anoxic water needs to be considered in modelling otherwise the models will overestimate acidification

Dissolved CO_2 system and redox reactions

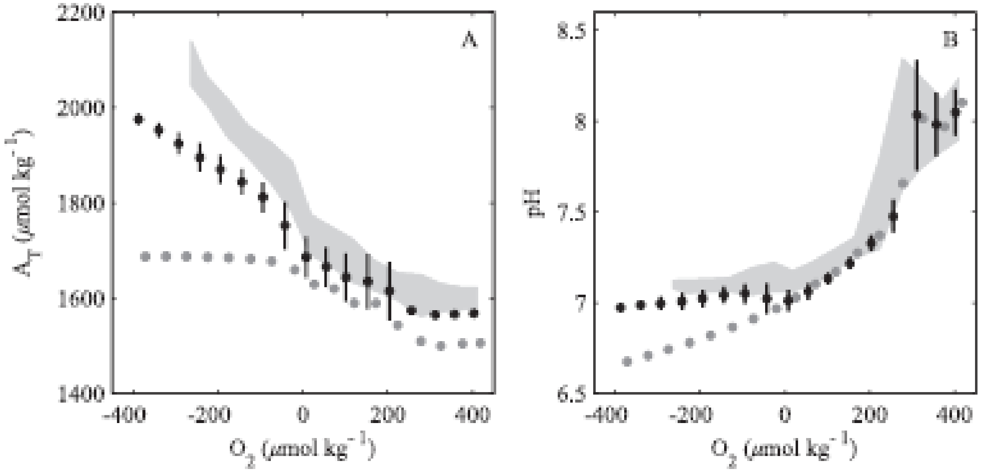


Fig. 7. (A) Total alkalinity (A_T [μmol kg^{-1}]) and (B) pH as functions of oxygen concentration (O_2 [μmol kg^{-1}]) for 0–250 m at Sta. BY15, the Gotland Deep. The observational data (1995–2004) are indicated by ± 1 standard deviation of the mean (light gray area), and the mean model results (1995–2004) are indicated by gray or black markers with ± 1 standard deviation indicated by lines of the same color. The black markers and lines represent a model run including internal generation of A_T, and the gray markers represent a model run excluding internal generation of A_T.

Edman and Omstedt (2013)

Modelled and observed partial CO_2 pressure in the central Baltic Sea

Reasonable modelled Baltic Sea CO_2 partial pressure but mid-summer minimum missing due to lack of phosphorus. A source missing?

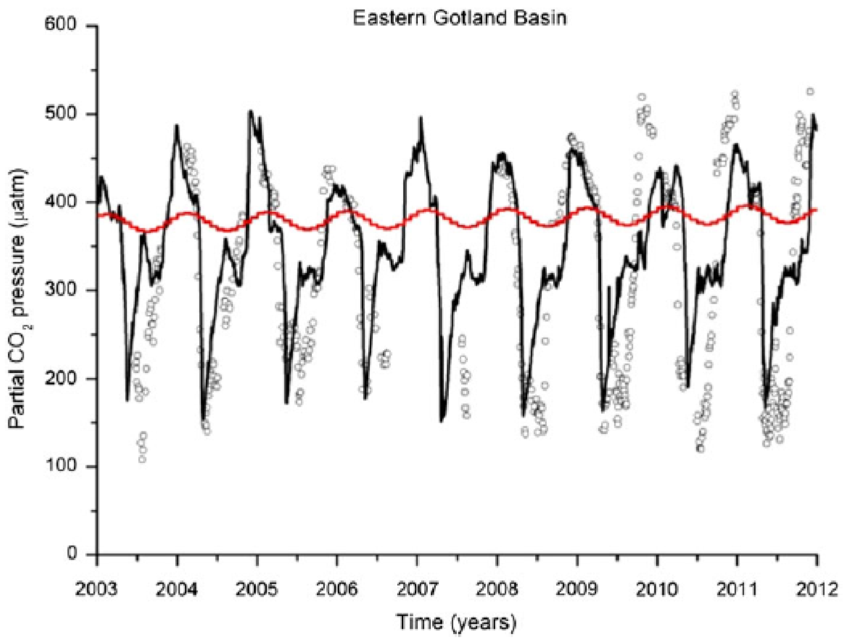
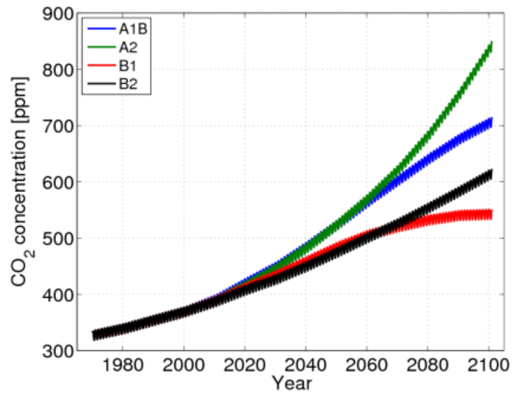
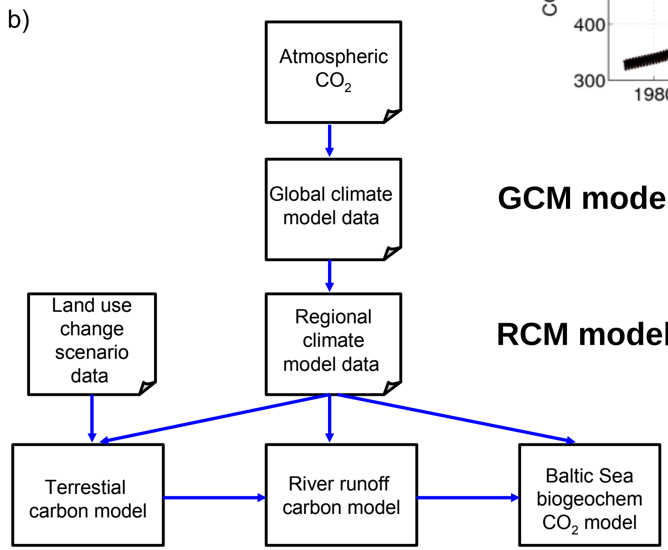


Fig. 5 Surface water partial CO_2 pressure from observations (*circles*) and from the model calculations (*line*, PROBE-Baltic version 3.0, Omstedt et al. 2012). The observations represent measurements from VOS Finnpartner-Finnmaid also illustrated in Fig. 2a. The *red curve* indicates the partial pressure in the atmosphere

Omstedt et al (2014)

Baltic-C modelling system and scenario design





GCM models: ECHAM5, HADCM3, CCSM3

RCM model: RCA3

Terrestrial model: LPG-GUESS

River runoff model: CSIM

Baltic Sea model: PROBE-Baltic

Omstedt et al. (2012).

Table 1. Scenarios and sensitivity studies in Baltic-C.

Number	**GCM**	**SRES narrative**	**Ensemble member**	**Land cover**	**Nutrient loads**	**GCM bias correction**	**Factor addressed**
1, 13*)	ECHAM	A1B	#1	present-day	present-day	none	baseline scenario,
2, 14*)	ECHAM	A1B	#2	present-day	present-day	none	natural variability
3, 15*)	ECHAM	A1B	#3	present-day	present-day	none	natural variability
4, 16*)	HadCM	A1B		present-day	present-day	none	climate system
5, 17*)	CCSM	A1B		present-day	present-day	none	climate system
6, 18*)	ECHAM	A2		present-day	present-day	none	emissions (higher)
7, 19*)	ECHAM	B1		present-day	present-day	none	emissions (lower)
8, 20*)	ECHAM	A1B	#1	GRAS	present-day	none	land cover change
9, 21*)	ECHAM	A1B	#1	present-day	"medium"	none	nutrient loads change
10, 22*)	ECHAM	A2		BAMBU	"business as usual"	none	multi-factor, "business as usual"
11, 23*)	ECHAM	A1B	#1	GRAS	"medium"	none	multi-factor, "balanced policy"
12, 24*)	ECHAM	B1		SEDG	Baltic Sea action plan	none	multi-factor, "environmental"
25	20th century	A2		20th century	20th century	none	-
26	20th century	A1B	#1	20th century	20th century	none	-
27	20th century	B1		20th century	20th century	none	-
28	20th century	SC_85		20th century	20th century	none	-
29	ECHAM	A2		20th century	20th century	yes	bias-corrected version of Scenario 10
30	ECHAM	A1B	#1	20th century	20th century	yes	bias-corrected version of Scenario 11
31	ECHAM	B1		20th century	20th century	yes	bias-corrected version of Scenario 12

*) with bias corrections

Omstedt et al. (2012).

The use of dimensionless skill metrics

The correlation coefficient: ***r***

→ Do the model results and observations co vary?

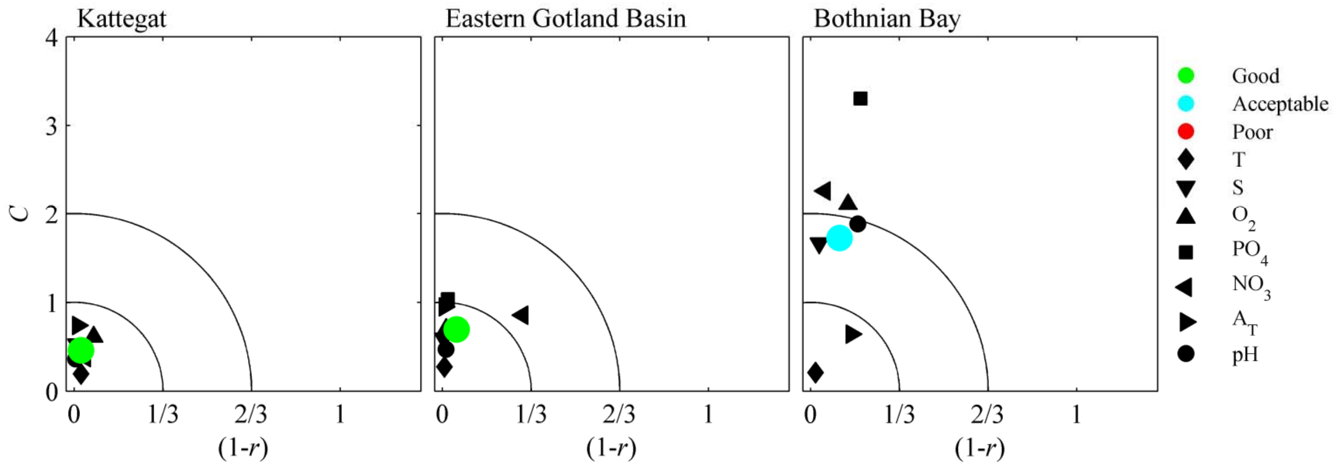
The cost function : ***C***

→ Are the model results within the std of observed data?

Omstedt et al. (2012).

Statistical evaluation of present climate conditions (1995-2009)

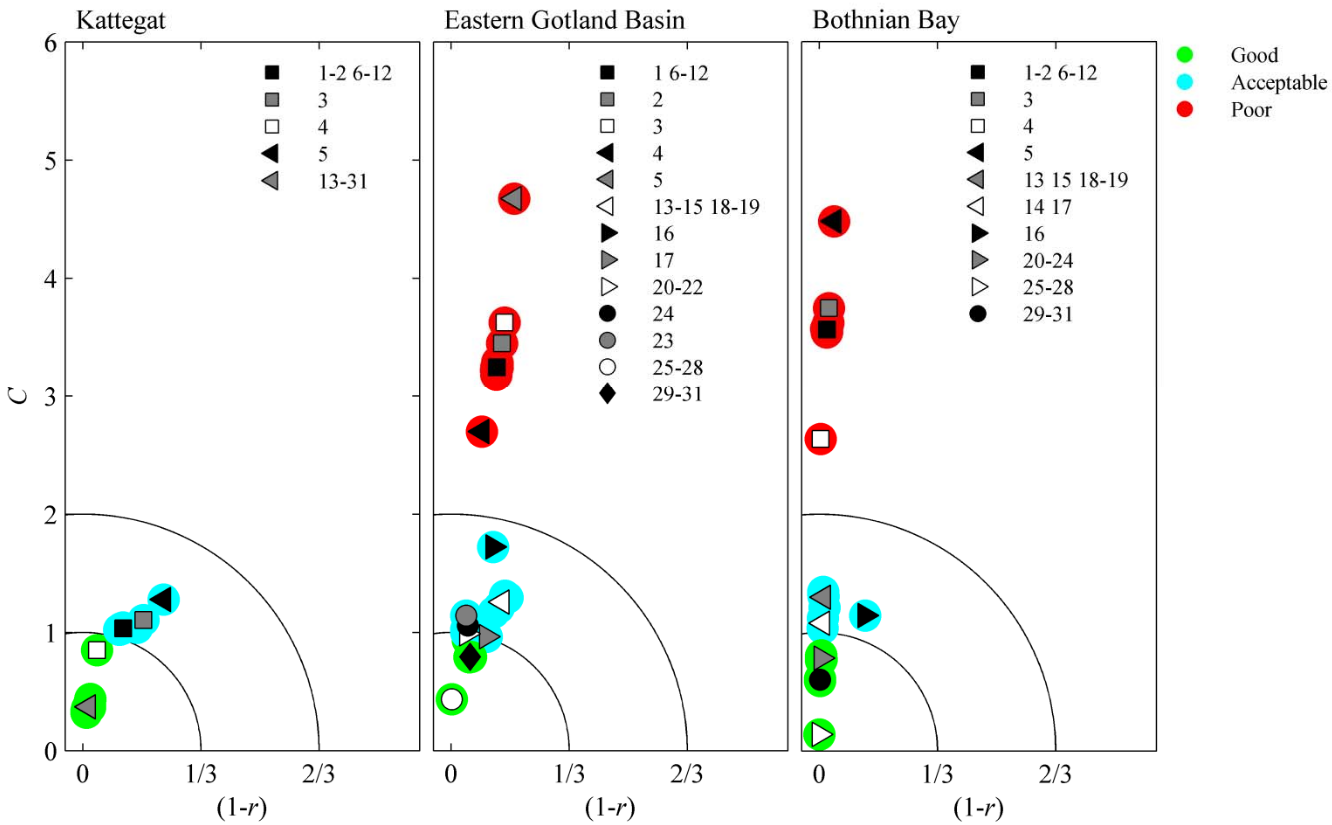
Present climate mean properties good to acceptable



Omstedt et al. (2012).

Statistical evaluation of climate forcing during control period (1971-2000)

Run 1-12 poor,
Run 13-31 good to acceptable
Delta change needed !



Modelled pH sensitivity due to:
- Different climate model initial conditions (run 13, 14, 15)
- Different GCM but the same emission (run 13, 16, 17)

These sensitivities are one order of magnitude less than the modelled change

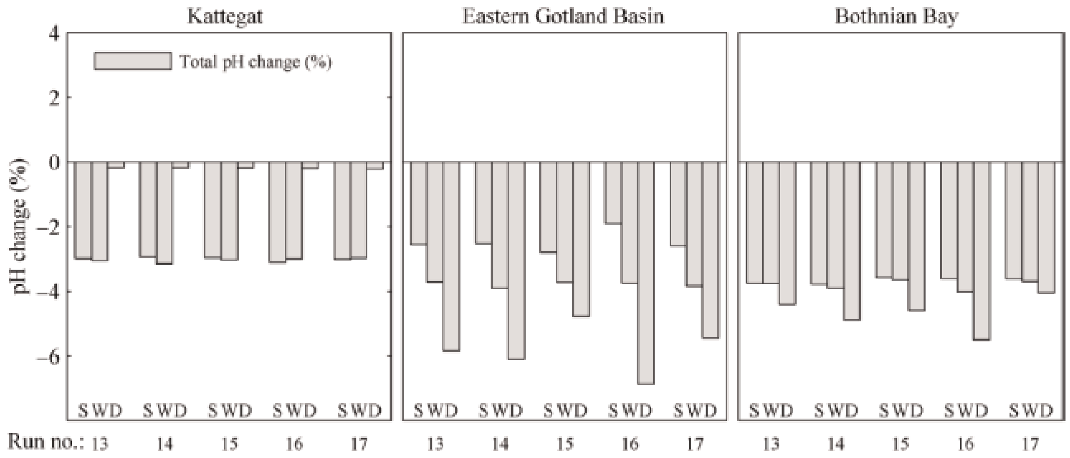


Fig. 6. The Baltic Sea model sensitivity in pH with regard to climate model set-up, comparing 30-yr means from 1971–2000 and 2069–2098. The total pH change is shown in relation to present pH (means for 1971–2000). S and W indicate summer and winter surface means (upper 5 m), respectively, and D indicates depth water mean (from halocline to bottom).

Modelled pH sensitivity due to the same emissions but increasing model complexity:

Run 26 the same climate as today but emissions as A1B
Run 13 ECHAM +A1B no change in land-cover
Run 21 as run 13 + Nutrient load change
Run 23 as run 21 + Land cover change

CO2 emission sets the scene. Climate change increases water temp. and the mineralization rates

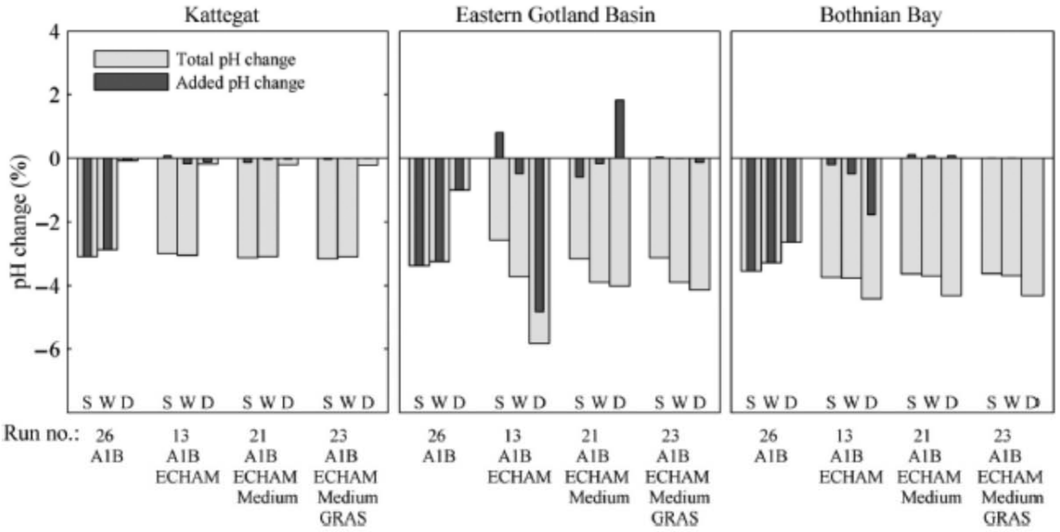
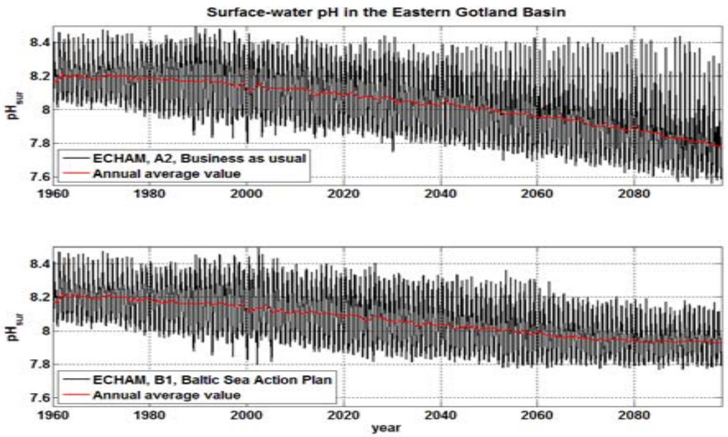
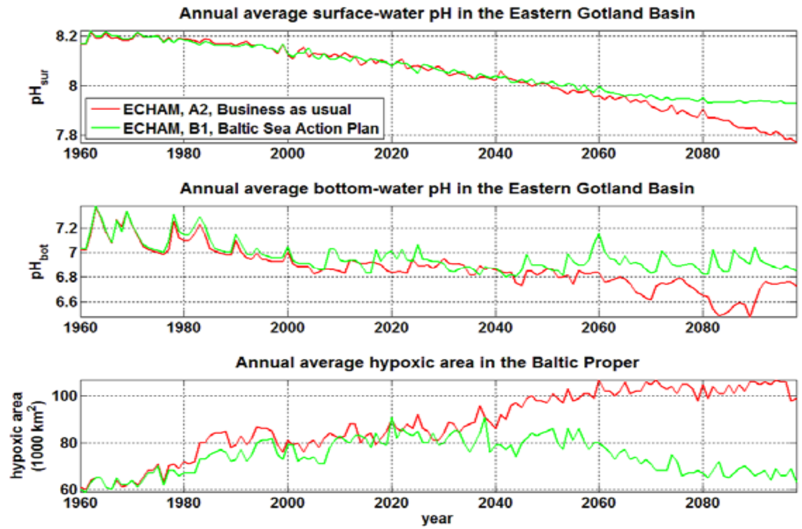


Fig. 7. The Baltic Sea model's pH response to different forcing components, comparing 30-yr means from 1971–2000 and 2069–2098. The added pH change is the deviation from the total pH change that is caused by the added forcing. S and W indicate summer and winter surface means (upper 5 m), respectively, and D indicates depth water mean (from halocline to bottom).

Management options: Marine acidification and hypoxia or?

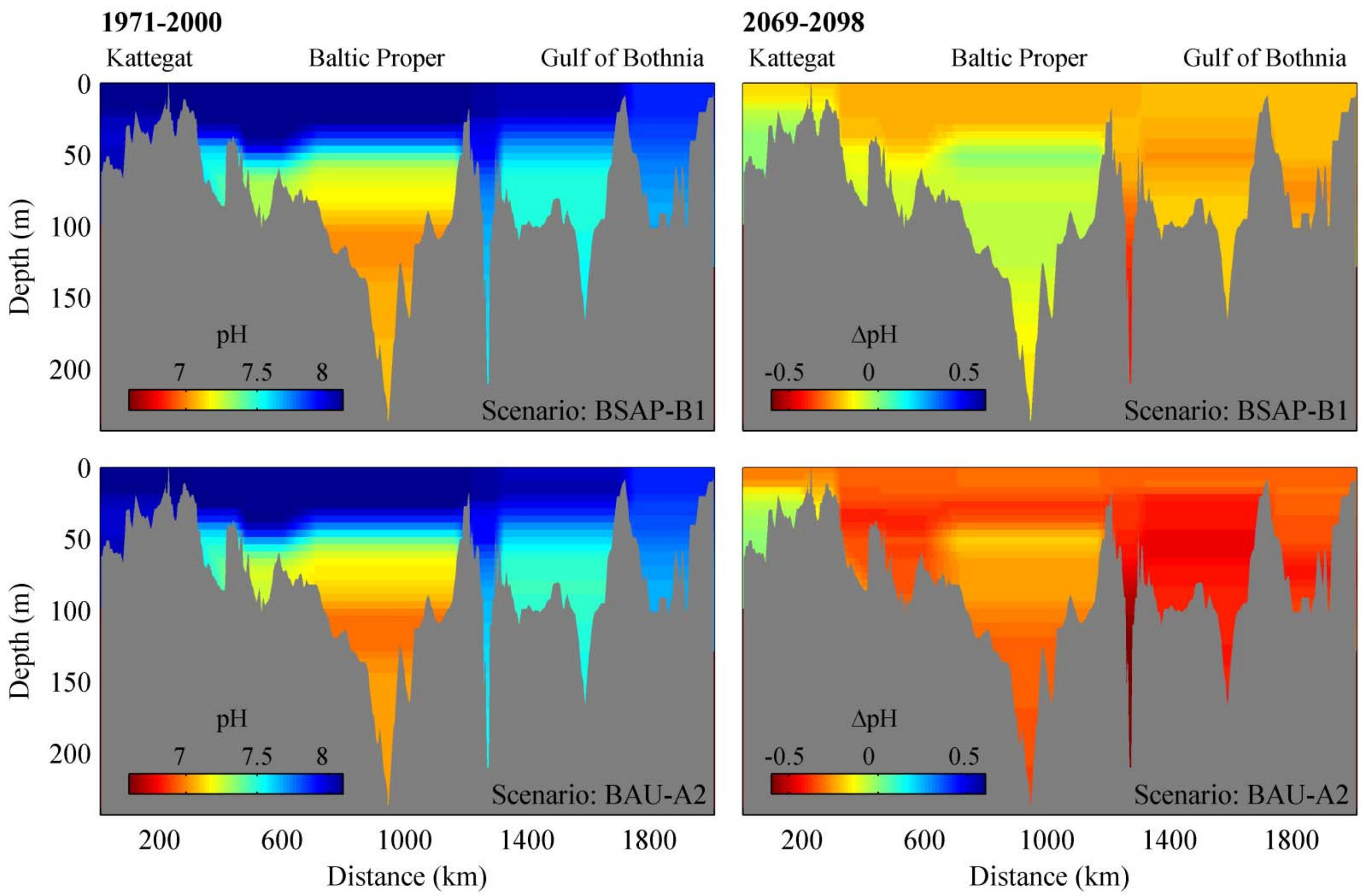




Baltic Sea will most likely become more acid in the future. Reduction needs in both nutrient loads and CO2 emissions.

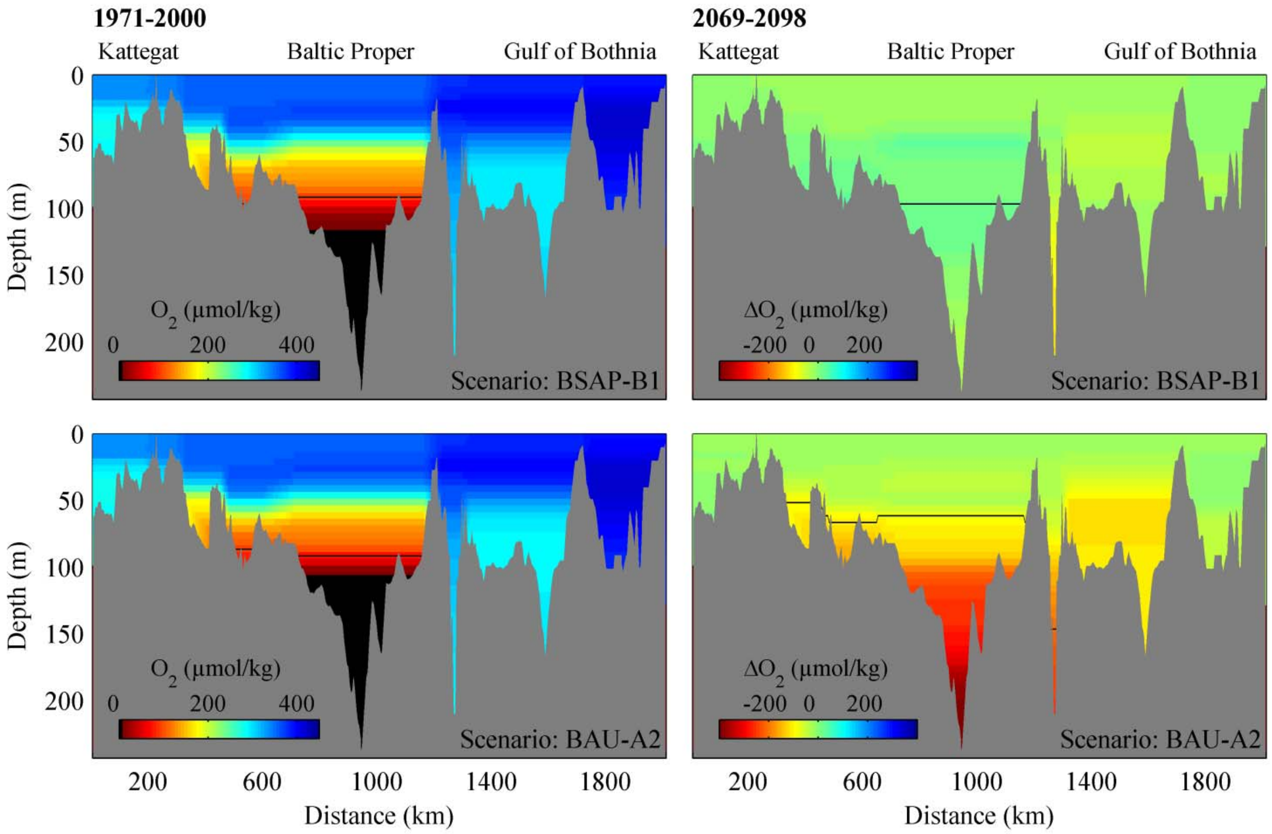
Omstedt et al. (2012).

Two possible developments: BSAP-A2 and BAU-B1?
pH distribution



Omstedt et al. (2012).

Two possible developments: BSAP-A2 and BAU-B1?
Oxygen distribution



Omstedt et al. (2012).

Summary and conclusions

- Marine acidification is influenced by increasing atmospheric CO_2, eutrophication, changes in alkalinity from rivers, changes in redox state and indirectly climate change.
- The acidification is not sensitive to GCM used or GCM initial conditions. Instead the main factor is the CO_2 emissions. On that climate and river changes add modifications. Changes in hydrology may considerable change the Baltic Sea alkalinity distribution.
- Increased nutrient load will not inhibit future acidification in the Baltic Sea, but the seasonal pH cycle will become amplified due to increased biological production and mineralization. All examined scenarios indicate future acidification of the whole Baltic Sea and at all depth.
- Apart from decreasing pH, we also project a decreasing saturation state of calcium carbonate, a decreasing respiration index, and increasing hypoxic and anoxic waters, all of which will further threaten the marine ecosystem.
- The Baltic Sea will most probably become more acid in the future. Substantial reductions in fossil-fuel burning are needed and are not in conflict with the nutrient reductions suggested in the Baltic Sea Action plan.

Thanks for your interest!