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Comment on esd-2021-67

Donald Boesch (Referee)

Referee comment on "Climate Change in the Baltic Sea Region: A Summary" by H. E. Markus Meier et al., Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2021-67-RC2>, 2021

Answers to reviewer no. 2 (Dr. Donald Boesch) in red

This paper is a *tour de force* compendium on the latest scientific results relevant to understanding recent and future climate change on the Baltic Sea Region. The authors and the Baltic science community are to be commended in taking this on in a way that builds on and updates the two previous BACC assessments. It is particularly effective that the assessment is linked with the efforts of HELCOM. It sets a high standard for climate change assessments for regional seas in other parts of the world.

Thank you very much for the thorough review and excellent comments. We will follow your suggestions and will revise the manuscript accordingly. We are impressed by your review work.

This summary paper brings together and depends on the results of nine specialty papers or BEARs, which I have not reviewed. Nor have I been charged with reviewing the consistency of the summary with the BEARs, but trust the authors to ensure that consistency. The construct wherein each environmental variable is treated under present climate change, future climate change, and knowledge gaps and research needs results in some redundancy. This could be alleviated somewhat by reference to the corresponding previous section without repeating narrative and references. The section on concluding remarks does help bring these all together.

Within Baltic Earth, we performed prior to submission an internal review with two reviewers that were not involved in the BEARs to guarantee consistency.

The list of knowledge gaps and research needs is rather daunting, and rather depressing as it seems that virtually everything uncertain and unknown, and equally so. Clearly, this is not the case. Concluding that section with a brief consideration of the knowledge gaps and research needs that are most critical to determining the future Baltic and are most potentially resolvable with concerted research would be help.

We will add a concluding paragraph.

The words uncertain, uncertainty, and uncertainties are used some 104 times in the paper, and often incautiously. Frequently, there are better terms to describe the nature of these so-called uncertainties. They may be a result of inadequate knowledge rather than inherent uncertainty or they might actually be deep uncertainties. In particular, when future changes depend on steps society might take to limit greenhouse gas emissions, these seem not so much as uncertain but yet to be determined. Some fine-tuning of the uncertainty language would help.

We will fine-tune the uncertainty language.

While, the paper indicated it will follow the terminology used by IPCC concerning degree of confidence in statements, as it does in section on key messages, it is not as very careful when it comes to the use of the term "likely" some 64 times and doesn't seem to differentiate among as-likely-as-not, likely, very likely or virtually certain as per the use of likelihood terms in IPCC parlance. Similarly, the term unknown is used quite a bit, without differentiating among completely unknown, largely unknown, not fully known, or incompletely understood. These might be more accurate descriptors in places.

We will check and possibly be more specific in the revised version. However, for many variables the information about confidence levels does not exist at the regional scale because large ensembles do not exist. We will explain this fact in the introduction and modify the definition of our terminology.

While this paper was developed prior to the release of the IPCC Sixth Assessment in August 2021 it is appearing after this release. Virtually all the literature cited used earlier GCM results, although some results based on CMIP6 models are discussed. It is impossible and unreasonable that this paper attempt to incorporate or compare Sixth Assessment models and conclusions in any great detail, it would be useful if the authors wrote brief comments about the extent to which conclusions might be affected by the new IPCC assessment, perhaps after section 1.5.5. My sense is that they wouldn't dramatically affect the conclusions. Recent literature (e.g. Hausfather and Peters, 2020, as cited in this paper) makes the point that the RCP8.5 pathway and the associated 4°C warming during this century is highly unlikely to occur and, in fact, the IPCC AR6 essentially admits this. Something between RCP7.0 and RCP4.5 is probably the maximum warming without substantial mitigation. Perhaps this point can be made more strongly in this paper. In fact, it would be informative to mention in key places where mitigation measures would affect key climate drivers, if and as society significantly reduces emissions and the use of fossil fuels (e.g. this would affect N deposition, shipping, plastics, etc.).

Following the comments of both reviewers, differences between CMIP5 and CMIP6 and how these differences may affect our results will be discussed.

Specific comments:

What are the current Baltic Earth Grand Challenges, a listing or, at least, a reference (line 128).

We will add the Grand Challenges and a reference.

The regional weather regimes vary (not varies) (line 237)

Will be corrected.

Freshwater (not fresh water) as an adjective (lines 289, 310, 311 1137, 4319, 4325)
Fresh water (not freshwater) as a noun (line 1257)

Thank you. Will be corrected.

Farther (not further) north, as this relates to distance (line 424)

Will be corrected.

analyzed by IPCC (2014b; 2019b) are assessed. (lines 576-577).

Will be corrected.

Were compared by Christensen et al. (2021) (lines 587-588)

Will be corrected.

Regions farther (not further) north as this refers to distance (line 706)

Will be corrected.

Because IPCC AR6 is now out, reference to the last IPCC report is confusing. Should be specific as to what assessment/report/CMIP this refers (lines 736)

Will be specified.

Weak (not weal) effect (line 866)

Will be corrected.

Is this global radiation or radiation at the three sites? (918-919)

It is global radiation as stated in the text.

Not significantly different from what? Does mean there was no trend from 2000 to 2014 or 2000 was not different from 2014? (line 1096)

A trend in the O₃ mean concentration in Northern Europe from 2000 to 2014 could not be identified, given the internal variability. We will rephrase the sentence.

Eutrophication of what, terrestrial ecosystems or surface water? (line 1111)

We will rephrase the sentence "for eutrophication of open water bodies in all European countries".

O₃ (not O3). (line 1125)

Will be corrected.

Kniebusch et al. (2019b) also identified. (line 1155)

Will be corrected.

It is not clear how temperature increases affected stream flow if precipitation increases are unclear, by increased evapotranspiration? (line 1165)

Very good point. We will rephrase the paragraph:

The observed temperature increases have affected stream flow in the northern Baltic Sea region for 1920-2002 in a manner corresponding well to the projected consequences of a continued rise in global temperature in term of increasing winter time discharges (Hisdal et al., 2010). However, the regional impacts of precipitation change on both the observed and projected changes in stream flow are still unclear as the combined effects of changes in precipitation and temperature are still not well known (Stahl et al. 2010).

Should this be 0.18 day (°C)⁻¹ as on the previous line? (line 1287) . .

No, this is correct as it refers to the change in precipitation ("drying"). We will clarify and write "...cm⁻¹ decrease in precipitation"

. Drainage Basin (as defined by Vogt et al, 2007; etc.) (line 1437) as

Will be corrected.

reported by Hock et al. (2019) is . . . (line 1439)

Will be corrected.

Farther (not further) south as this refers to distance (line 1476).

Will be corrected.

Is $139 \cdot 10^3 \text{ km}^2$ correct? (line 1553)

Yes, but we will change to 139,000 km².

Comma after Lehmann et al. (2017). (line 1669)

Will be corrected.

Farthest (not furthest) as this refers to distance. (line 1775)

Will be corrected.

Meaning of "shortening oxygen" is unclear. (line 1902)

Will be rephrased.

It doesn't seem to follow how the less productive coastal zone of the northern Baltic Sea explains why hypoxia is rare along the southern and south-eastern coastline. (lines 1917-1919)

Will be rephrased. "counteracting vertical oxygen supply and natural ventilation by oxygen-rich saltwater intrusions from the North Sea"

Berner et al. (2018) presented further . . . (line 1995)

Will be corrected.

This is a long and complicated sentence, recommending breaking it into two (lines 2195-2199)

Integrated approaches encompassing all of the ecosystem-components discussed above are needed in order to understand and manage the linkages among large-scale and long-term climate effects. These are driven by synergistic interactions of climate change-related physical and chemical drivers with other factors, such as eutrophication or large-scale fisheries, which complicate human adaptation to the changing marine ecosystem (Niiranen et al., 2013; Blenckner et al., 2015; Hyytiäinen et al., 2019; Stenseth et al., 2020; Bonsdorff, 2021).

What about weakening of the polar vortex causing greater meandering of the jet stream? (line 2203)

This is really interesting, but we think that this topic is not within the scope of this paper. To our understanding there is no scientific consensus. No change of the text.

The changes are MORE similar that over the land area. (line 2266)

Will be corrected. It should be "Over the Baltic Sea, the changes are similar to those over the land area"

Projection . . . IS uncertain because . . . (line 2285)

Will be corrected.

Farther (not further) poleward as this refers to distance (line 2290)

Will be corrected.

The future scenarios for shipping do not include a future where the use of hydrocarbon fuels or at least emissions of CO₂ are greatly restricted to meet GHG reduction requirements. Could the authors speculate what this might mean? (lines 2353)

This is a valid point. The current available studies for shipping in the Baltic Sea do not include the strong fossil fuel emission reductions IMO is postulating (i.e. 50% less greenhouse gas emissions by 2050). The IMO secretary-general states in the foreword of the Fourth IMO Greenhouse Gas Study: "The Study demonstrates that whilst further improvement of the carbon intensity of shipping can be achieved, it will be difficult to achieve IMO's 2050 GHG reduction ambition only through energy-saving technologies and speed reduction of ships."

New synthetic fuels are needed or alternative propulsion. We are just running our CTM for scenarios addressing those requirements. Results will be available in spring next year, earliest.

In a synthesis paper for Shipping in the Baltic Sea, we will show that under current legislation and quite strong energy efficiency assumptions (stronger than the EEDI from IMO), CO₂ emissions in the BS will drop down to only about 78% in 2040 compared to the value in 2014. Other measures are needed, while the use of LNG as fuel is a good solution for reducing air pollutants like NO_x, SO₂ and PM, CO₂ emissions remain considerable. Methane slip during transport and operation can even compensate for the reduced CO₂ emissions. This paper will not be published in time for this summary.

We will close the paragraph with a more general remark (line 2369):

"The pollutant concentrations reported in this section may drop to yet not known lower values if the shipping sector is (partly) successful in meeting the IMO target in greenhouse gas emission reduction of 50% by 2050. This reduction is only possible if low-carbon alternative fuels will be introduced, employing a high energy efficiency as it is already considered in scenarios used in Karl et al. (2019a) will not be sufficient. The new fuels will also lead to altered emissions of pollutants."

In this section, is the use of "likely" versus "very likely" consistent with IPCC? (line 2372)

We will change "may have an influence" because it is difficult to state this cause-and-effect relationship for all systems of the hydrosphere.

This paragraph refers to both mitigation measures and adaptation measures. This is confusing in light of the way those terms are used in climate change assessments. (lines 2439-2444)

We agree and we will use "anthropogenic measures".

Here again adaptation and mitigation are both used in a somewhat confusing way (lines 2450-2464)

We will rephrase the paragraphs.

This sentence is unclear. (line 2556-2557)

We suggest the following alternative formulation: "*The authors argued that a more comprehensive assessment of forest management as a strategy to achieve the goals of the Paris Agreement should go beyond the reduction of atmospheric CO₂ and, thus, the reduction of the radiative imbalance at the top of the atmosphere. They suggested...*"

To which models are you referring? Do you mean under both RCP2.6 and RCP8.5 emissions pathways? (line 2568-2569)

We will rephrase the first paragraph to clarify the changes under the various RCPs.

Shouldn't this be median -25 cm? (line 2756)

Yes, will be corrected.

Is this also assuming a RCP8.5 pathway? (lines 2762-2763)

Yes, we will clarify.

There is a need for a reference for this paragraph, I assume it is BACC II Author Team (2015). These conclusions about decreased pH are contradicted somewhat by the previous discussion in section 3.2.5.7.2. (lines 2878-2883)

We will add the BACC II Author Team 2015 reference and clarify the apparent contradiction.

Aberle et al. (2015) showed . . . (lines 3009-3010)

Will be corrected.

The concept of retreat of marine **species** may not be clear for readers unfamiliar with the Baltic Sea, perhaps this can be more accurately stated as reduced penetration of marine species into the Baltic Sea. (line 3024)

We will add new text in line 3024

... many species in the Baltic Sea. Because of the projected decline in salinity, a reduced penetration of marine species, such as bladderwrack, eelgrass and blue mussel, into the Baltic Sea has been predicted (Vuorinen et al., 2015). A large number of other species is affiliated with such keystone species, and species distribution modelling has indicated that, e.g., a decrease of bladderwrack will have large effects...

Here again, it seems to be assumed that shipping will continue to depend on the use of fossil fuels. (lines 3236-3237)

New text: The efficiency of SOx scrubbing depends on the temperature, salinity and pH of the seawater, and eventually ends up contaminating the Baltic Sea (Turner et al., 2018). Shipping itself affects climate through combusting fossil fuels, although the emissions can be expected to be reduced with the expected increase of renewable energy within the European Union (EC, 2021)

EC, 2021. Directive of the European parliament and of the council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament.

Isn't it more accurate to state that how these practices will change in response to climate change is yet to be determined? (line 3245-3246)

We will rephrase this sentence to emphasize the research needs in this respect.

Perhaps state that there is YET little direct evidence THAT THIS IS OCCURRING? (lines 3261-3262)

Thank you, as for the previous comment, we will rephrase the sentence.

It is mentioned earlier that warmer temperatures should allow the establishment of more nonindigenous species. This bears repeating here. (line 3263).

We will add the information.

Won't microplastics also be greatly affected by societal decisions about the use of plastics, in part influenced by efforts to decarbonize? (line 3283-3285)

Thank you, that is a good point; changes in the use of plastics and regulations in response to the problem can be expected but the effects are uncertain. We will add a short sentence in this respect.

Should the authors continue to use Celsius rather than Kelvin here? (line 3399)

Yes, we decided to use Celsius in the entire manuscript will change here.

. . . strongly affected by whether warming is allowed to proceed to the point of destabilizing Antarctic ice sheets. (line 3605)

We will rephrase the sentence.

What does it mean to have low confidence in a statement that changes could not be detected? (line 3750)

The confidence level refers to our knowledge about the change in large-scale circulation and not to the specific statement. We will explain the confidence levels better.

If this trend is almost statistically significant, why isn't it medium confidence, just less than a 95% threshold for high confidence? (line 3829)

We agree and change to medium confidence.

Why is there only low confidence in the statement that larger runoff would lead to larger nutrient inputs? (lines 3920-3921)

We agree and change to medium confidence.