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

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.

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.

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.

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 that 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.

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.

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.).

Specific comments:

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

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

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

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

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

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

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

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)

Weak (not weal) effect (line 866)

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

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

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

O₃ (not O3). (line 1125)

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

It is not clear how temperature increases affected stream flow if precipitation increases are unclear, by increased evapotraspiration? (line 1165)
Should this be 0.18 day \( (\degree C)^{-1} \) as on the previous line? (line 1287)

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

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

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

Is \( 139 \times 10^3 \) km\(^2\) correct? (line 1553)

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

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

Meaning of “shortening oxygen” is unclear. (line 1902)

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)

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

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

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

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

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

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

The future scenarios for shipping do not include a future where the use of hydrocarbon fuels or at least emissions of CO\(_2\) are greatly restricted to meet GHG reduction requirements. Could the authors speculate what this might mean? (lines 2353)

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

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)

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

This sentence is unclear. (line 2556-2557)

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

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

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

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

The concept of retreat of marine sciences 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)

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

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)

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

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

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)

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

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

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

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

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