Referee comment on the MS "Sea Level Dynamics and Coastal Erosion in the Baltic Sea Region" https://doi.org/10.5194/esd-2021-6

The MS is intended to constitute one of the "review papers summarizing and updating the knowledge around the major Baltic Earth science topics. Being part of the series, this study concentrates on sea level dynamics and coastal erosion in the Baltic Sea region." Knowledge on sea level dynamics and coastal erosion has been significantly advanced during the recent 5-10 years and a well readable summarizing paper is highly needed. Besides the scientific importance, the topic is of very high societal significance due to the (not yet well-known) impacts of climate change and the need for appropriate mitigation measures.

The authors are prominent scientists in the field. Extensive list of up-to-date scientific literature is referred. Therefore, the expectations for the MS are high.

Reading the MS further with high interest, I found that different parts are not equally reader-friendly. There is excellent sub-chapter "2.3 Coastal erosion and sedimentation", which is fluent to read, and the sentences contain important findings (including numerical estimates) that are backed by references. Contrary to this, the Abstract and several of the sub-chapters contain occasionally long phrases which information content is not clear. For example, the Abstract begins with: "There are a large number of geophysical processes affecting sea level dynamics and coastal erosion in the Baltic Sea region. These processes operate on a large range of spatial and temporal scales and are observed in many other coastal regions worldwide." I am not able to learn very much out of this very general formulation. Among "large number of processes", a few most important processes could be outlined. Similar problems are in "4 Conclusions and key messages", which ends with "This is primarily because of the large number of processes contributing to Baltic Sea level variation and change, which makes interpretation difficult."

The readers might be interested to find the conclusive statements easily, instead of going through the extensive list of references. Considering the mean sea level and its trends, including their regional characteristics, inclusion of a figure could be useful, for example, Fig. 9 by Madsen et al. (2019). Regarding absolute SLR, a good candidate could also be https://www.eea.europa.eu/data-and-maps/figures/sea-level-changes-in-europe-october-1992-may-1 (given also at the end of this comment). The sub-chapter on extreme sea levels lacks the numerical estimates about sea level, although there is good description of wind waves that contribute to the run-up in the coastal areas. For clarity, the issues of wind waves could be moved to a separate sub-chapter. Regarding sea level extremes, again some figures could be useful. A candidate could be Fig. 2 by Wolski et al. (2014). Decadal variations of mean and extremes of sea level are missing in the result sections and are considered mainly in the "Gaps of knowledge" section, although publications on identified variations are available and referenced. Baltic Sea Chart Datum 2000 – a common reference level for nautical charts and sea level information in the Baltic Sea – has been or is being established in the riparian countries. Datum corrections of about several tens of cm are introduced. The MS does not reflect this development.

The sub-chapter 3.3 name "Knowledge gaps" is often used in the case when there are policy-driven goals determined beforehand. Such goals are missing for the present review MS; therefore appropriate approach could be to develop something like "further research challenges" or similar. Within this, breakthrough issues could be defined and elaborated, based on new emerging research techniques. It seems that the drivers for new results are remote sensing (including altimetry), modelling at very high resolution, and, perhaps machine learning. I expect the whole sub-chapter 3.3 recomposed, therefore specific remarks are not given.

The MS should be revised in order to make the text more concise and coherent. The Abstract and Conclusions should be elaborated to include distinct findings.

Specific remarks

L40: Baltic Sea area and volume numbers could be referenced by original study, not the overview publication. The newest scientific publication is by Jakobsson et al., 2019.

L42: Perhaps it is not good to start the specific aims with the phrase "may appear irrelevant" but point out what is relevant. The logical structure of the whole sentence is not very clear: "considerable attention over the last centuries" is not related to the global perspective of sea level change as noted in the beginning of the sentence.

L51: "short distances", the scale of distances could be specified.

L52-53: "to study a wide range of phenomena with larger and global relevance" could be specified.

L79: "dynamical consideration", it is interesting to remind that already Svansson (1980) estimated the time scale of Baltic volume change about 12 days, using the analytical model of Helmholz resonator.

L84-85: "About 75% of the basin-average mean sea level change externally enters the Baltic Sea as a mass signal from the adjacent North Sea". It could be clarified what are the processes making the rest 25% of the mean sea level change. The next sentence presents already the sea level variations occurring within the sea (not affecting the mean). From the list of this sentence, mean wind and precipitation affect the mean sea level as well. Freshwater discharge (rivers, P-E) and issues related to ice dynamics are not mentioned in the text. It could be useful to introduce briefly the concept of water budget of semi-enclosed basin. Around Fig. 2, basic principles could be explained in a few sentences. The subsequent paragraph of sediment dynamics is very good and can serve as an example to elaborate the sea level part.

L127-144: The question of different reference levels could be addressed in more detail. The references are rather old. The publication by Bogdanov et al., 2000 (L140) deals specifically with the Kronstadt time series, not with uncertainty of coastal sea level observations in general. Baltic Sea Chart Datum 2000 should be introduced.

L129: The publication by Kowalewska-Kalkowska and Marks, 2011 cannot be found on the web. It could be uploaded to ResearchGate, Academia or some other platform.

L158-160: Introductory sentences could be reformulated to be more informative. For example, I doubt that variations in ocean currents have direct significant effect on Baltic Sea level, compared to the meteorological changes they induce, and to the thermal expansion of seawater.

L165-166: "tide gauge data are more representative for coastal changes", why to say "more", is there a substantial number of historical offshore tidal gauges anywhere?

L187: Nice that comparison has been made, but what are the results?

L196: "Stronger than normal westerly winds push water masses into the Baltic Sea, raising overall sea level". Here, the mechanism of barotropic water exchange through the Danish Straits could be briefly outlined (e.g Stigebrandt, 1983; Mattsson, 1996).

L197-204: The part of the text presenting salinity and its influence should be placed in the logical order. I think the basic driver for salinity is along-basin separation of main saltwater source (Danish Straits) and freshwater sources (largest rivers in the Bothnian Sea and Gulf of Finland), that creates along-basin (estuarine) salinity gradient. Then it could be explained, how this persistent salinity gradient affects sea level via seawater density and what are the mean sea level differences. Further, all the sentences should be checked if there is any result included. For example: "Any changes in the hydrological cycle, either in the long term or in the form of

episodes associated with strongly increased or decreased river runoff or precipitation/evaporation over the Baltic Sea, have the potential to substantially modify this salinity gradient (Kniebusch et al., 2019) and thus the distribution of sea level anomalies and their variability in space and time."

L205-212: From these eight lines, I was able to understand only that several studies have been made on relations between the NAO and Baltic sea level. What are the results?

L212-217: Did I understood correct: Karabil et al. (2018) have shown that atmospheric pressure difference between Bay of Biscay and Northern Norway near Tromsø (termed BANOS index) explains Baltic mean sea level variations better than NAO, due to the proper account of the inverse barometer effect.

L233: "point to slightly higher sea level rise", what is the range?

L237: "Future changes in the Baltic Sea freshwater budget may further affect the regional distribution of Baltic mean sea level". What is the direction of budget change (I guess the full budget is zero due to mass conservation, but the components are changing) and corresponding sea level change? How much?

L266: The sub-chapter "2.2.1 Sources of data" from the "2.2 Extreme sea levels" deals with wave measurements. The title and the text should match each other.

L277-279: In this introductory part, wave set-up has been put on the first place in the extreme sea levels. This view is biased. In the whole sub-chapter, the wave part could be compressed, giving more elaboration to the storm surges, including their occurrence frequency (Wolski and Wiśniewski, 2020).

L284: "preconditioning" should be written without quotation marks, but it needs to be more specified. One type of preconditioning is lower mean sea level before strong westerly winds (Lass and Matthäus, 1996), that favors inflow of highly-saline water (Major Baltic Inflows). We are considering here the basic type of preconditioning, when mean sea level is prior to storm already high (Suursaar et al., 2006; Madsen et al., 2015) and storm surge creates wind sloping and long gravitational waves on top of that.

L288: There is a reference to the publication that is already a review book. I think reviews should refer to the original study results, whenever possible.

L296: For the Gulf of Riga, a reference to the 2005 flood should be added (Suursaar et al., 2006).

L297: The statement that storm surges "are primarily caused by strong onshore winds during storms": the effect of preconditioning from the previous paragraph must be mentioned as well. Important storm surge components are also long gravitational waves, including seiches, and wave set-up.

L337: The height of seiche is more important for the extreme sea level than its period. The heights have been discussed by Wolski and Wiśniewski (2020). When Jönsson et al. (2008) have proposed the seiche period 17 h in the Gulf of Riga, then Suursaar et al. (2002) have presented the period 5 h. This should be mentioned, because the time series plots of sea level frequently reveal such oscillations after sudden changes of wind.

L345-347: The same comment as for L288.

L401-405: Very general wording, key points cannot be found.

L487-492: One effect of sea ice is also land-ocean interaction in the form of shore ride-up and pile-up of ice, see Omstedt et al. (2014) and the references therein.

L552-734: Specific comment on sub-chapter 3.3 were omitted, see the general comments.

L736-741: Is the key message "Research of Baltic sea level and coastal issues is well developed and is societally important".

L742-745: The paper by Reusch et al. (2018) is very interesting, but there is no clue with the present MS so far.

L745-754: The text starting with "We argue that…" belongs rather to the discussion.

Technical remarks

Regarding the style, there is occasionally rather high uncertainty in the text. For example, the word "may" is counted 48 times. (This broke to my eye, therefore I checked some other similar review papers, usually this word is used several times less).

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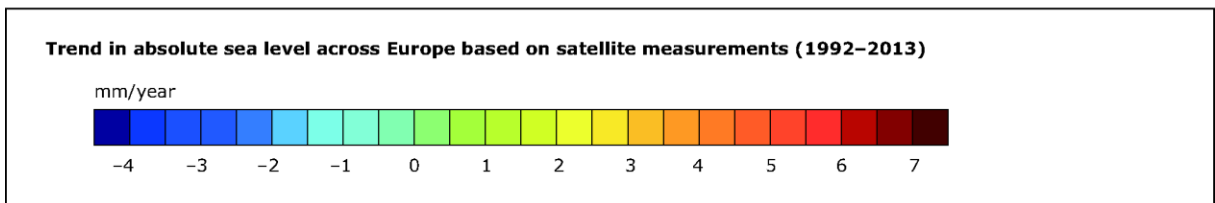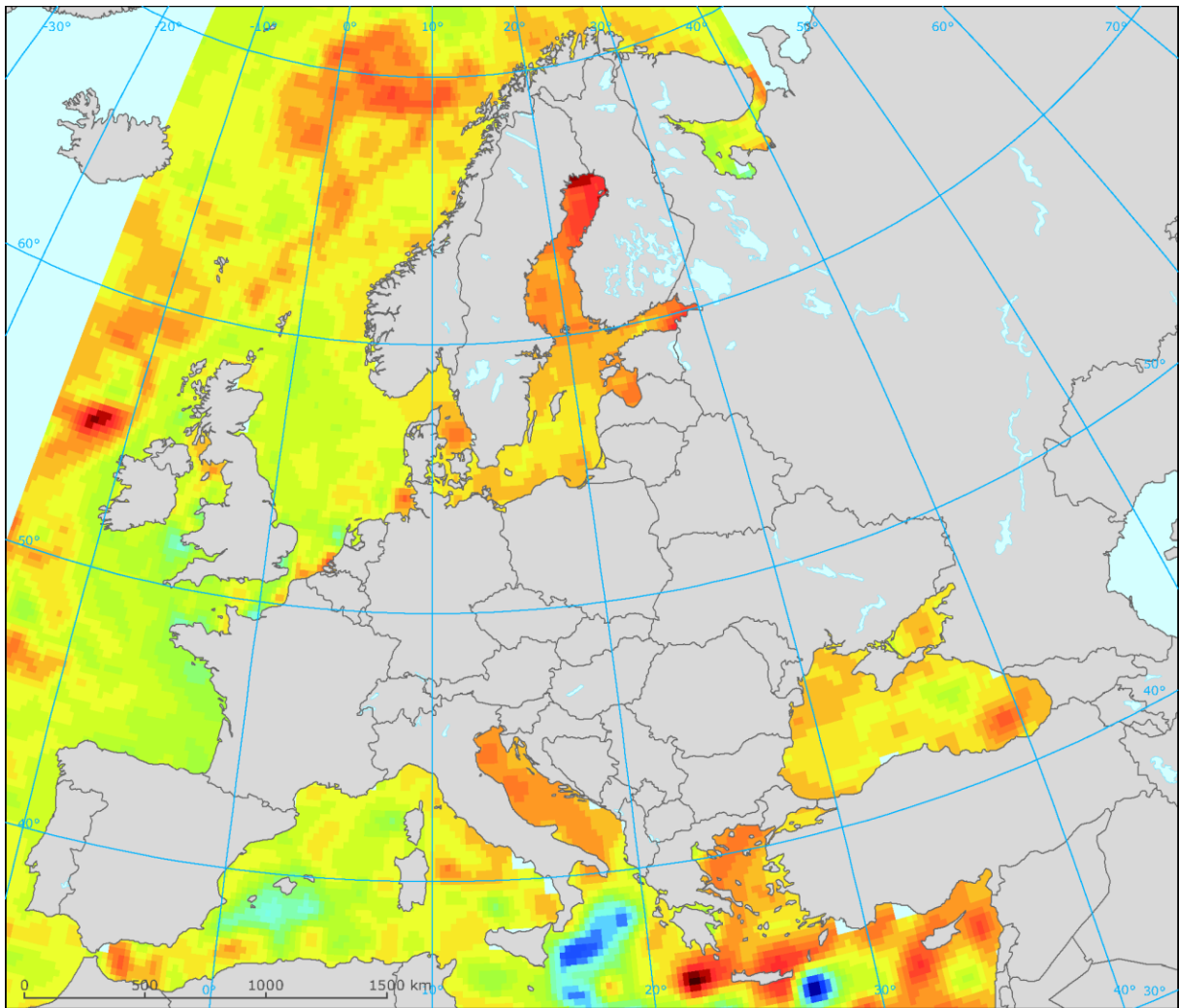
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Trend in absolute sea level across Europe based on satellite measurements (1992–2013)

mm/year

−4 −3 −2 −1 0 1 2 3 4 5 6 7