Response to referees' and Phil Woodworth's comments on the manuscript "MISELA: High-frequency sea-level analysis global dataset" by Zemunik et al., submitted to Earth System Science Data (essd-2021-134)

We sincerely thank to comments and suggestions raised by two anonymous referees and Phil Woodworth, which greatly improved the quality of the manuscript.

Reply to RC1: 'Comment on essd-2021-134' by Anonymous Referee #1:

This paper describes the derivation of a global sea level dataset that is purpose-built for the study of non-seismic extreme events that act on very short timescales. The authors rightly point out that, for the most part, historical tide gauge datasets do not offer the temporal resolution that is required to study such events. This is largely due to the past limitations on data storage and telecommunications of earlier tide gauge technology and the lower computational power of data-processing systems that were available at that time. Faster sampling technology and near real time telecommunications systems, together with increased back-office computational power have meant that higher frequency data are now more prevalent. Even so, many of these high frequency datasets are only used for operational early warning purposes and there is certainly a need for high frequency research quality data. The MISELA dataset therefore will address a gap that exists amongst global data portals.

- We thank the reviewer, appreciate the positive attitude and have made changes in the manuscript following his/her comments.

However, I can't help wondering why the authors tailored (and thereby restricted) the use of the dataset to studying only atmospherically-induced sea level oscillations? At some stage, prior to removing tsunamis from the dataset, the authors would have possessed a quality-controlled high frequency sea level dataset that could have multiple scientific applications, including the study of tides, tsunamis and meteotsunamis, seiches, storm surges etc. Sadly, that gap remains unaddressed.

- We agree with the reviewer that restricting the dataset to the atmospherically-induced high-frequency sea-level oscillations sets limitations and that the dataset would have multiple applications if it would contain also the data of tides, seiches, storm surges, etc. However, as we stated in the manuscript, raw data contain numerous problems, including shifts and drifts and spurious signals, which cannot be – in our opinion – treated properly, ending in a potentially unreliable dataset. Therefore, we chose to keep a portion of the signal for which the reliability is presumably high and that is not part of any existing global sea-level dataset. For that reason, we referred the MISELA dataset as the analysis (research product) dataset, focused on specific sea-level analyses.

  Further, the MISELA dataset can be conjoined with other high-quality datasets that have a lower sampling frequency and contain longer-period oscillations (e.g. GESLA, UHSLC), and in this way research of other sea-level processes can be performed.

That is the reason why we set up filter cut-off period at 2 h, which is Nyquist frequency for hourly data.

Another drawback is that the dataset only uses tide gauges that afford 1 min sampling, as those that offer faster sampling are disregarded. A means of sub-sampling or averaging these data to one minute intervals would be desirable.

- We agree with the reviewer that expanding the dataset with stations that have a higher frequency of sampling would be a way forward. However, at this stage, we have decided to select only stations with a minute resolution, so that all the stations are equally processed with the same steps of quality control procedure, resulting in a homogeneous dataset. Hopefully, the future versions of the MISELA dataset will expand the dataset, yet still keeping the focus on the applications related to high-frequency sea-level phenomena.

Nevertheless, this dataset is undoubtedly an improvement on current data provision and the allocation of a DOI is excellent. In addition, the processing methodology appears sensible. I recommend publication, subject to correction of a few discrepancies which are listed below:

Page 1, Line 20, The reference is missing from the list of references on page 15

- The reference is added in the list of references.

Page 1, line 25, replace 'processes' with 'phenomena'
Page 1, Line 28, 'no quality-checked global ….an hour'. This isn't quite true – BODC and GESLA datasets do offer some data at higher frequency than an hour. I'd rephrase to say 'no quality-checked global sea-level datasets afford sufficiently high temporal resolution to cover periods at which ….'

- Replaced.

Page 2, line 45, BODC supplies data at the resolution provided by tide gauge operators, which is sometimes hourly intervals, but is generally higher, e.g. 15 minute for the UK and 6 minute for the USA. Also, BODC provides sea level data for a vast number of locations. The authors should be clear about which BODC dataset they are referring to. Is it the GLOSS Core Network or another?

- Here we referred to section "International sea-level data" (i.e. GLOSS/WOCE/CLIVAR data) as hosted by BODC. This issue is clarified and the description is expanded.

Page 2, line 57 'with a minute resolution' should read 'with a minute or higher resolution'
Page 3, line 78, remove 'with'

- Corrected.

Page 3, Line 79, The meaning of 'not completely operational…facility' is not clear. Are the authors saying that many stations do not afford high enough frequency data? Or are many stations offline i.e. in disrepair?

- Clarified – we meant that some stations are offline i.e. in disrepair.

Page 3, line 84, use 'displaying' rather than 'controlling'

Page 3, line 89, use inverted commas for ‘as received’
Page 3, line 90, should read ‘quality control’ not ‘quality’
Page 3, line 95, should read ‘each of the stations’
Page 3, line 96, replace ‘and other’ with ‘etc’

- Corrected.

Page 13, line 215, I don’t think it is fair to say that the hazard has been underrated. Instead, the ability to study this hazard has until recently, been restricted by technological and computational limitations (as I described above).

- Replaced.

Page 13, line 226. It is a bit of a ‘leap’ to suggest that the MISELA dataset might encourage operators to increase their sampling resolution or to install more tide gauges in observationally sparse regions. The determining factor for both of those issues is more likely to be financial.

- It is rephrased in the text that increasing of the sampling resolution and installing new tide gauges are future perspective in research of the high-frequency phenomena.

Page 13, line 230, use ‘enabled’ instead of ‘allowed for’
Page 13, line 234, should read ‘The recent manual …’
Page 13, various uses of ‘quality-check’ should really be ‘quality control’ or ‘quality-checking’
Page 13, line 238, ‘procedures’ should be singular
Page 13, line 241, ‘automatized’ should be ‘automated’
Page 14, line 248, ‘’with as much quality-check….’ Is a bit clumsy. Maybe rephrase to ‘to report, so far as possible, near real-time quality-controlled data.’
Page 14, line 2501 ‘evolution’ not ‘evolving’

- Corrected.

Reply to RC2: 'Comment on essd-2021-134' by Anonymous Referee #2:

The authors propose a global dataset (331 stations) of high temporal sampling (1-min.) data recorded by tide gauges over the period 2004-2019. Their primary source of data (95%) is the IOC Sea level station monitoring facility (SLSMF) at VLIZ in Belgium, supplemented with data from two national agencies (17 stations), which do not contribute to this data assembly centre of the global sea level observing system (GLOSS) of IOC/UNESCO. The major added-value of the derived dataset is thus the quality control of the SLSMF data, and this is really a major outcome.

- We thank the reviewer for the constructive comments. Our responses to all comments are provided below.

Indeed, many users have misunderstood what is the goal of SLSMF data assembly centre, whose goal has never been delivering high-frequency data, but informing about the station real-time operational status (Is the station operational, or not). This status reporting goal has been achieved via the collection of the stations real-time data. It should be made a little

clearer in the manuscript to underline the originality of what the authors propose. They can also quote one of the comments published by the GLOSS programme directors in J. Coastal Research in response to a clear misuse of the IOC SLSMF dataset for science or technology assessment (Aarup et al. 2019).

- We emphasized in the text that IOC SLSMF is strictly focused on reporting of the station availability and performance and that any research use of this data require additional processing (e.g. quality control). Aarup et al. (2019) is cited.

Many discussions have taken place within the GLOSS group of experts regarding its SLSMF dataset, in particular to take actions towards a data quality control, hence addressing the needs of scientific applications investigating high-frequency sea level phenomena. In this regard, the work undertaken by the authors is relevant, and clearly fills a gap. However, it raises several issues that need to be clarified: how this action and dataset articulates with GLOSS? What are the perspectives in terms of update and maintenance? Indeed, if the dataset is not meant for update and maintenance, its scope becomes rather limited (2004-2019 and ca 300 stations).

- All of these questions are relevant, as it would be the worst-case scenario that our efforts will not be updated and expanded in the future. Still, this is beyond this paper and our efforts, which are largely the part of the PhD research of the first author. Our idea here was – similarly to the creation of the GESLA dataset (which is a project that "grew out of the interests of several people in learning more about the changes in the frequency and magnitude of extreme sea levels") – to allow for better research on high-frequency phenomena, which is an emerging topic in the sea-level research nowadays. So, we hope that our efforts will be recognized by GLOSS and sea-level data centres, which may invest more man power and resources to continue our work. Regardless of that, we plan to update the MISELA dataset in the future, to which students might be of a great help (one of co-authors here was engaged as master's degree student). We added a few sentences on that in Section 5.

It is further limited by the filtering choice, which is clearly an application dependent restrictive feature. (In this respect the title is misleading.) In my opinion, this aspect should be left out to the scientists (what filter they want to apply, and why). The most invaluable aspect achieved here is the 1-minute sea level quality-controlled data. Filters are application-oriented, and often have pros- and cons (here, these are not discussed). In terms of quality-control, the manuscript does not develop the details of the datum and clock shifts. How are these flaws handled? Why the multiple sensor locations are not exploited to fill gaps, instead of using interpolation? Several other technical issues are commented below.

- For the choice of filter, please also refer to the response to the similar comment from Anonymous Referee #1. We chose Kaiser-Bessel filter because it is often use to obtain high-frequency sea-level signal. We added references in the text in which the filter is described and in which it is used for obtaining high-frequency signal.
- Datum and clock shifts have not been treated, as requiring information which is not available at IOC SLSMF. Indeed, IOC SLSMF contain no levelling information as designed for operational purposes only, while clock shifts are hard to detect at a minute timescale. We are aware that these problems are present in the data, but we

consider that they occur in a small percentage of the overall data (as coming from visual quality control, when going through all the data records).

- We chose not filling the gaps with other sensors at a station (where multiple exist, which is minority of stations) as it appeared (at some stations) that high-frequency sea-level signal is different between the sensors (at a minute timescale), due to the technology behind the sensors, and that may influence the statistics.
- We changed the title to ”MISELA: High-frequency sea-level analysis global dataset”.
- All above is added and clarified in the text to highlight the limitations of the dataset. However, as both anonymous referees and Philip Woodworth (https://doi.org/10.5194/essd-2021-134-CC1) emphasized, despite to these shortcomings, the dataset might become an invaluable tool for the science of sea level at high frequencies and is filling the gap in available sea-level products. We hope that the future versions of the dataset will handle at least some of these problems.

To wrap up, the manuscript is overall well written, and organized. It can represent an invaluable contribution to the international sea level community and science, provided its current limitations are addressed (filtering, interpolation) and perspectives clarified (update, maintenance).

p.2, L43-44: The PSMSL requests their updated reference to be quoted. This data assembly centre has substantially extended its contents since 2003 with many useful developments

- It is updated with reference Holgate et al. (2013, https://doi.org/10.2112/jcoastres-d-12-00175.1)

p.3, L82-83: To my understanding, the goal of the IOC SLSMF has never been delivering high-frequency data, but informing about the station real-time operational status (Is the station operational, or not). This goal is achieved via the successful collection (or not) of the real-time data. This aspect should be made crystal clear (see Aarup et al.) for the full appraisal of the added-value provided by MISELA. See general comment above.

- We removed the first part of the sentence and changed to: “The main objective of the facility is to inform users about the status of station availability and performance (Aarup et al., 2019). This includes displaying the tide gauge station metadata and regularly checking the operational status of all stations, as well as contacting operators regarding non-operating stations. Another important objective is a display service through which one can undertake quick visual inspection of the raw data in a selected half-daily, daily, weekly or monthly period during which the chosen station was operational (IOC, 2012). It is also possible to download the data for the whole operational period. However, any research use of these data would require additional processing (e.g. quality control), in order to properly prepare and involve data in statistical analyses and avoid misleading results and conclusions (Aarup et al., 2019).”

p.4, Fig.1: What are the problems illustrated here? I suggest to state them in the figure caption so that the reader makes a direct association.

- The illustrated problems are stated in the figure caption: “… a) gaps, b) spikes, c) shifts, and d) spurious oscillations …”

p.5, L109: The rationale for the criteria (2-year long) should be developed, if there is any.

- MISELA is a research product for statistical analyses of high-frequency sea-level oscillations. For that reason, short series are not of use for any statistical analysis there. We clarified this in the text as: “As the dataset is intended to be applicable for statistical analyses of high-frequency sea-level processes, we choose a length of 1.4 year (70% of 2 years) as a threshold, because short time series or those overly intermitted with data gaps would not significantly contribute to the research.”

L111: what is “too many”? “incorrect records”? Need for objective criteria.

- “too many spikes, incorrect records” is replaced with “spikes that are distributed throughout most of the time series and appear on an hourly or multi-hourly basis, obvious incorrect records like spurious oscillations produced by malfunctions of instruments”. As is written, these are spotted by visual checking, therefore do not have an exact numerical threshold. Later in the text we also explain that the visual control is subjective to a certain extent.

p.5, L117-118: I do not understand what it means: “or 30 cm differing from both neighbouring values (20 and 15 cm, respectively”. Please, clarify.

- The sentence is rephrased: “The automatic quality-control procedures included removing of out-of-range values, i.e. values 50 cm differing from one neighbouring value or 30 cm differing from both neighbouring values (in case of the FMI stations 20 cm differing from one or 15 cm differing from both neighbouring values).”.

p.5, L119: how much is “deviate”? Needs clarification.

- Three standard deviations. It is added in the text.

p.5, L128: “Not all problems” Can you give an example?

- E.g. spikes, artificial oscillations, stucks of instruments. It is added in the text.

L130-131: How many users have expressed their interest within this atmospheric community? Did the authors make a survey, for instance within international programmes like GLOSS?

- No, we didn’t perform any survey, but just coming from recent research activities on high-frequency sea-level phenomena (e.g. being spotted by the meteotsunami community at the First World Conference on Meteotsunamis, www.izor.hr/mts2019). We added a few words and references on that: “The next step in creating the MISELA dataset was to exclude sea-level records observed during seismic tsunamis, since the applications are directed towards research on atmospherically-induced sea-level oscillations, which has been an emerging field during last decades (e.g. Pattiaratchi and Wijeratne, 2015; Vilibić et al., 2021).

p.6, L138: what is the interpolation rationale behind the duration of “one week”?

- We filled these gaps to simplify our filtering procedure. However, interpolated data are, of course, non-reliable, and are thus marked with a flag.

p.8, Table: Is the 0.01-degree precision sufficient? At this spatial resolution gravity waves can be rather different in terms of amplitude and impact. For instance, in terms of exposure along a protected coastline (harbour, estuary…).

- Majority of stations in the MISELA dataset have higher precision (0.001- or 0.0001-degree), yet some stations provide 0.01-degree precision at the IOC SLSMF portal, e.g. Japanese stations.

p.9, L139: “acceptable”? Needs clarification. I suggest to remove this subjective term.

- It is changed with a sentence: “Figure 4 shows that stations included in the MISELA dataset cover many of the World’s coasts”.

p.9, Last line: “excellent”: the regions in c) d) and f) have large gaps along long parts of the coastline; in other words, far from “excellent” in my opinion.

- “Excellent” is replaced with “satisfactory”.

p.11, L203: June 2018 at the latest in a SLSMF? Needs explanation in the context of a real-time facility, something sounds weird (objectives, misunderstanding…).

- We clarified in the text that we have obtained records from the IOC stations for the period from as early as 1 January 2006, when the portal started operating, up to 14 June 2018 at the latest, when we have last downloaded the data. Unfortunately, we have not downloaded sea-level time series after this date due to extensive time needed for performing quality control of the data. To emphasize, this work has largely been done as a part of the PhD research, with limited human resources, thus cannot provide up-to-date research-quality data in an operational way. We hope that the future developments of the MISELA dataset will be taken over by data centres, with much higher human capacities and resources to perform such a work.

Reply to CC1: 'Comment on essd-2021-134' by Philip Woodworth:

I have a few extra comments on this paper to add to those of the reviewers. First, I have to say that this data set of high-frequency variability is to be welcomed, and it fills a gap in a type of data provision by the other sea level data sets. It is also good to see use being made of the data in the IOC SLSMF, even though that is not what the SLSMF was primarily designed for.

- We really appreciate the positive comments and the attitude towards our research.

On this topic, reviewer 2 end of first para, refers to an article by Aarup et al. (2019) which commented on an earlier paper which had made use of SLSMF data somewhat inappropriately. That paper, if we are talking about the same one, and the paper it was commenting on were in a journal called Measurement and not in Journal of Coastal Research. The Aarup et al. reference is:
Aarup, T., Wöppelmann, G., Woodworth, P.L., Hernandez, F., Vanhoorne, B., Schöne, T. and Thompson, P.R. 2019. Comments on the article "Uncertainty and bias in electronic tide-gauge records: evidence from collocated sensors" by Stella Pytharouli, Spyros Chaikalis, Stathis C. Stiros in Measurement (Volume 125, September 2018). Measurement, 135, 616-619, doi:10.1016/j.measurement.2018.12.007.

- This reference is included in the text.

Other remarks:
somewhere - as reviewer 2 mentions it would be good to see a statement that you plan to update this data set every few years

- A statement on the updating of the dataset is in last paragraph of the conclusion – we expanded it a bit. However, we don't firmly say that it will be updated every few years, as the presented dataset is largely developed as a part of the PhD study and a work of a small group of scientists with limited resources. Any interest and contribution of external scientists or sea-level data centres is highly desirable and we hope that our work will attract such an attention.

page 2, top - one could add the Caribbean to this list e.g.
Woodworth, P.L. 2017. Seiches in the eastern Caribbean. Pure and Applied Geophysics, 174(12), 4283-4312, doi:10.1007/s00024-017-1715-7.
This paper also used SLSMF data as you did.

- Added.

line 37 – others
line 48 - GESLA (by which you mean GESLA-2) is not an hourly data set. I realise you say 'at the majority' but that gives a wrong impression. I would change that to 'containing global sea-level data with hourly or higher (e.g. 10 or 15-min) resolution at 1355 ...
GESLA-3 will be appearing later this year by the way.
76 - dataset is the
82 - Besides giving access to the data - see above. I suggest you say something like:
Besides giving access to the data (although that is not the main priority of the SLSMF, see strong comments on this aspect in Aarup et al. (2019)), the main
84 - station
96 - others

- Corrected.

Fig.1 caption. Please expand the caption to say what you are trying to show in each of the four example plots. You don't even explain that in the text.

- The problems of the time series that we are pointing to are added in the caption of the figure.

103 - IOF needs an http or https
121 - least-squares
124 - what does gap-denser mean? jargon. please reword
128 - drop the comma after approach
136. …timescales. However,

- Corrected.

138 - does the allowing of large gaps introduce Gibbs-type oscillations in the use of the filter?

- We didn't find Gibbs-type oscillations in the MISELA dataset. However, we are aware that digital filters may create some spurious oscillations at the edge of a series (e.g.

between data gaps and real data). For that reason, in the forthcoming statistical analysis based on the MISELA dataset (to be submitted in a month) we didn't take into account the data (close to data-to-gap transitions) that can be affected by gaps.

140 - define QC

- It is defined in the text (quality control).

Fig 5 - the caption needs expanding to say that a,b,e,f are sea level before and after, whereas c,d are Non-Tidal Residuals (NTR presumably). Does Wake really have a small tide as in (z)? In b and f presumably despiking and filtering is after detiding?

- The definition of NTR (non-tidal residual) is added in the caption of the figure. Wake has tidal range up to ~1.2 m which can be seen on both panels (left and right). "filtering" is replaced with "detiding and filtering" at Charleston station. It is clarified in the caption which panels are before and which are after processing.

150 - attributes including the station
152 - 'abas'
154 - drop 'the'
sentence 'The FMI' would be better coming before sentence 'The variable time'

- Corrected.

Fig 4 - there are too many lat/lon annotations

- Reduced.

193 - some of the longest individual records .. shorter time-series on average
I can see in Fig 6(b) that ASWA has shorter records than global on average but CSP looks about the same as global

- We excluded CSP from the sentence.

Fig 6(b) - what is the meaning of the size of the box and the outer error bars? Box-Whiskers is just jargon, I suggest you drop that.

- We clarified the meaning of the boxplot in the caption of the figure and dropped the "Box-Whiskers".

255 - IOC (1997), which is the GLOSS Implementation Plan is ok to mention. But I would also refer to for example:
Woodworth, P.L., Aman, A. and Aarup, T. 2007. Sea level monitoring in Africa. African Journal of Marine Science, 29(3), 321-330. doi:10.2989/AJMS.2007.29.3.2.332.

- The reference is added.

257 - contains a

- Corrected.

371 - you could refer to Woodworth and Player (2003) as well for the PSMSL if you want but a later reference is:
Holgate, S.J., Matthews, A., Woodworth, P.L., Rickards, L.J., Tamisiea, M.E., Bradshaw, E., Foden, P.R., Gordon, K.M., Jevrejeva, S. and Pugh, J. 2013. New data systems and products

at the Permanent Service for Mean Sea Level. Journal of Coastal Research, 29, 493-504, doi:10.2112/JCOASTRES-D-12-00175.1.
which is what the PSMSL web site now asks you to refer to.

- The reference is replaced with the proposed reference.