We would like to thank the two Anonymous Referees for their comments that improved the quality of the manuscript. The detailed responses to each comment can be found further on in this document.

Anonymous Referee #1

Received and published: 22 November 2019

General Comments: This manuscript provides a lake and mire isolation data set for the estination of post-glacial land uplift,the data sets focuses on the lake and mire isolation data set and archaeological data set. although the data set can forms the main data set used in the modeling, the manuscript should be not publicated the ESSD, I have three points to reject it. (1) the manuscript only collect the data, it is short of originality of the study. (2) the dataset is at small spatial extent, they will not attract the wide readers of the world. (3) the authors should added the detailed the description of the method in producing the data set

- We thank Referee #1 for the comments. Here are detailed responses for the comments:
  (1) This is true, but the combination and unification of two different data sets including lot of data from different sources producing a usable data set for the estimation of the land uplift in Scandinavia makes it worthwhile to present the manuscript and the data in our opinion.
  (2) The land uplift is a phenomenon that is notably present at only few locations in earth and the studies concerning it have been mainly done in Scandinavia so this makes the study focused around the Baltic Sea area.
  (3) Some details of the method in producing the data set have been added to chapters 1 (page 2, lines 10-20) and 3 (page 6, lines 4-6).

Anonymous Referee #2

Received and published: 19 December 2019

The article ‘Lake and mire isolation dataset for the estimation of post-glacial land uplift in Fennoscandia’ of Pohjola et al. presents a collection of data, drawn from existing, both archaeological and palaeoenvironmental sources. It has been made available on the PANGAEA database. The data covers the complete Holocene and provides information about the ages of the earliest radiocarbon dates from mires and lakes, supposed to be representing their earliest stages after being isolated from the Gulf of Bothnia. Combined with spatial information (location and elevation), this is useful to build or validate and optimise land uplift models for Fennoscandia. Some potential pitfalls or deficiencies in the use of this data are pointed out. However, certain parts need some more critical discussion while others need clarification in order not to confuse or misguide readers and potential data users. Most of it concerns radiocarbon dating. Furthermore, the dataset uploaded to PANGAEA could benefit from certain additions, especially for the case that inconsistent results need to be evaluated critically. It would also get more interesting for disciplines apart from postglacial uplift modelling. The conclusion seems to devaluate the dataset, as it suggests that it should not be published yet by saying that the search for additional (already existing) data is ongoing. All relevant studies that are already published should already be in the PANGAEA data of this manuscript. I suggest revision and a re-evaluation. Detailed comments can be found below.

We thank Referee #2 for the constructive comments. They have improved the quality of the manuscript greatly. Also, the data set uploaded to PANGAEA will be updated based on the comments. The conclusion has been rewritten to give more basis for the study. Here are detailed responses for the comments.

Detailed comments:

Page 1

l. 20: Add more references if there are any or put an 'e.g.' before the two given citations or mention that these two are the most important (if so).

- e.g. has been put before the citations and the citation style has been corrected

l. 21: Not a complete sentence ('the most important source of information is that describing the shoreline displacement'). Please rephrase to make clear what was intended to be said.

- Corrected as 'the most important sources of information are the ones describing the shoreline displacement'

Page 2

ll. 5-7: This needs to be discussed in further detail. Consequently, ages that are from the first organic layers of ponds or mires are rather indicating the age of the ice retreat but cannot safely be used to infer uplift or isolation from marine influence.

- This has been discussed in more detail: 'Generally, the organic matter accumulated to the bottom sediments of the basins indicates ice retreat. The basins collected to the data set are from the time period of the Ancylus Lake, so it can be assumed that the ice had melted before the accumulation of organic matter. Although the timing might not be exact, it is an indication of the isolation contact. In addition, there are geological interpretations of the retreat of the Ancylus Lake and the Baltic Ice Lake in mire studies and references'.

l. 27: define the kind of laboratory analysis or rephrase. For example, simply to: 'The isolation is defined by the transition from marine or brackish water algae to fresh-water algae.'

- Corrected as suggested

Page 3

ll. 1-2: Bog and mire? Above, it was pond and mire. As a bog is also a mire, but a mire is not always a bog, please correct. See also page 2, l. 31.

- For clarification, the manuscript has been modified to use lakes, ponds and mires throughout the text.

l. 4: Having information on the material that was sampled in both PANGAEA data files would be very good. It would allow the reader to assess the reliability of the radiocarbon age. Depending on the type of macrofossil or sediment dated, the discrepancies can be large.

- A column for the dated material will be added to both data files.

Page 4

Figure 2: Why is the term height used, instead of elevation? The unit of Age is given in cal year instead of years BP, as in the text. Be consistent throughout manuscript and dataset.

- The figure has been corrected with term elevation instead of height and the unit of age has been changed to years BP

ll. 7-8: Do you mean older than expected? Something in this sentence is wrong: 'the radiocarbon dated burial remains seem to be younger than expected from the radiocarbon datings.' Expected from which datings? Did you want to say that the burial remains should be younger than the radiocarbon dating suggests?

- Yes, older than expected was meant and it has been corrected.

l. 9: Do you mean 'from a time period stretching over thousands of years' or 'from thousands of years ago'? Consider revising to be more precise.

- Corrected as 'from a time period stretching over thousands of years'

ll. 10-12: What about an old wood effect of the dated material? Depending on what type of archaeological material was dated, the marine reservoir effect is unlikely to have altered the sample. What about the possibility that bones of humans were dated, which were eating a lot of fish or molluscs. And: also, freshwater lakes have varying reservoir effects (e.g. Philippsen 2013). Again, the type of material dated (bulk sediment, plant macrofossils, wood, bones, etc.) would be valuable to add directly to the data files provided on PANGAEA.

- The old wood effect and the freshwater reservoir effect on radiocarbon dated samples have now been discussed: 'Also, the 'Old wood effect' (Olsen et al., 2013) might have had affected the samples. It is concluded in Olsen et al. (2013) that the dating of cremated human bone could have an inaccuracy of approximately 50-100 ^{14}C years. In addition, the freshwater reservoir effect (Philippsen, 2013) is one aspect that could be considered with the time and elevation discrepancies.' The material issue with the data files was discussed in a previous response.

Page 5

ll. 19-22: The term 14C age is normally used for uncalibrated radiocarbon ages (also concerns the 14C-error). In addition, the terminology is different in the .tab data files, where only Age and error are used. Furthermore, the ages given in the .tab file appear to be uncalibrated (for example Hel-146 in archaeological data). It is not only confusing but also dangerous if the data is used wrongly by users who believe to have calibrated ages at hand. This needs to be resolved by clear terminology in manuscript and both data files, and maybe with a comment for readers who are less experienced with radiocarbon dating. It needs to be clear if the age is calibrated or not. Right now, the text suggests that calibrated ages are provided, which is not the case in the data.

- This has been corrected in manuscript, the ages given are indeed uncalibrated. The column headers of the data-files will also be corrected.

ll. 21-22: Links/URLs to a database or report in lake/mire data file are not existing. Why not?

- URLs have been added where it has been possible

ll. 25-26.: The Bronk Ramsey citation should be put behind 'Oxcal program' in l. 24. The IntCal 13 calibration curve should be cited properly with Reimer et al. (2013). The Reimer reference also appears on Figure 3, so it needs to be in the full references anyway.

- The Bronk Ramsey citation has been put to its appropriate place and the IntCal13 reference (Reimer et al. 2013) has been added to the reference list.

ll. 25ff.: Does this paragraph relate to the data handling to produce for example Figure 2? It comes a bit out of nowhere as long as the previous lines are saying, that the data is already calibrated. As the radiocarbon data in the data files is not calibrated, consider introducing this paragraph in a different way to put it more into the context of how to handle the data. Right now it says, that "the calibration was done using [. . .]", but where was it done then?

- This has been clarified linking this paper to our previous works.

ll. 30-31: 'certain areas' and deferring to Fig. 1 is a bit vague. This should have been at least briefly discussed earlier in the text. For example, it is said in the beginning, that the lake/mire isolation data is the most important for modelling, but the data points are concentrated mostly on the eastern coast of the Gulf of Bothnia.

- This has been written in more detail: 'The collected data set in this paper covers the coastal area of Finland and Sweden reasonably well, especially the extent of the Ancylus Lake. There is always room for improvement, because lake and mire data points are missing from e.g. Hälsingland and Västerbotten areas in Sweden. However, the archaeological data points cover sufficiently almost all of the Swedish - Finnish coastal area. Also in the Estonian side, more archaeological and geological data are needed.'

Page 6

Figure 3.: In the example for a calibration, the scale is set to calBC, which is not mentioned before. See comment above concerning the consistent use of units.

- The scale in the figure has been changed to years BP

Comments on the files uploaded to PANGAEA ('Fennoscandia_lake_mire_isolation.tab' and 'Fennoscandia_archaeological_data.tab')

- The archaeological data provides URLs to the original radiocarbon data. Unfortunately, this is not the case for the lake/mire isolation data. Why are no URLs or further information provided?

- URLs will be added where it is possible.

- Referring to the problem of using pond/mire data (page 2, ll. 5-7), how can the data user distinguish between lake radiocarbon data and pond/mire radiocarbon data?

  - A column will be added to the data file to identify the basin type.

- The whole dataset would greatly benefit from adding the material that was used for radiocarbon dating. By this, the reliability of the ages could be assessed better. Furthermore, disciplines aside from uplift modelling would get attracted to the data collection.

  - The material will be added to the data files.

Technical comments:

Page 1

l. 3: its instead of it's

l.14: see previous comment

- Both were corrected as suggested

ll. 16-17: Correct citation style '. . .can be found in Tikkanen and Oksanen (2002), Björck (1995), Punning (1987) and Ojala et al. (2013).

- The citation style has been corrected

l. 22: 'Nowadays, land uplift. . .' or 'Ongoing land uplift...' or 'Today's land uplift..'

- Nowadays land uplift was changed to Ongoing land uplift

l. 24: citation style

- The citation style has been corrected

l. 25: citation style ('Eronen et al. (2001) and Cato (1992) examined the isolation of several lakes. . .')

- The citation style and the sentence have been corrected as suggested

Page 2

l. 5: ‘on top of’

- corrected as suggested

l. 19: remove ‘timing’, put ‘age’ information

- timing changed to age

l. 28: ‘In Finland, the main data. . ..’

- corrected as suggested

ll. 30-31: Citation style (brackets). Consider rephrasing:’ Mäkila et al. (2013) present a collection of . . .’

- corrected as suggested and the sentence has been rephrased

Page 3

Figure 1: consider highlighting the Baltic Ice Lake better, as the contrast of the mild blue to the background is partly not high enough. Also think about the graphic being printed in black and white.

- The Baltic Ice Lake has been highlighted better, the figure has also been made more suitable for black and white print.

Page 5

l. 1: I would use British English (organisation), as you are also using ‘archaeology’ and not ‘archeology’.

- organization has been changed to organisation

ll. 20-21: Something is wrong with the structure and the brackets here:’. . .the name of the place, the reference (14C) Laboratory Identification, if available),. . .’

- the extra) has been removed

l. 32: citation style (see above)

- The citation style has been corrected

Lake and mire isolation data set for the estimation of post-glacial land uplift in Fennoscandia

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Abstract. Postglacial land uplift is a complex process related to the continental ice retreat that took place about 10,000 years ago and thus started the viscoelastic response of the Earth's crust to rebound back to it's its equilibrium state. To empirically model the land uplift process based on past behavior of shoreline displacement, data points of known spatial location, elevation and dating are needed. Such data can be obtained by studying the isolation of lakes and mires from the sea. Archaeological data on human settlements (i.e., human remains, fireplaces etc.) are also very useful as the settlements were indeed situated on dry land and were often located close to the coast. This information can be used to validate and update the postglacial land uplift model. In this paper, a collection of data underlying empirical land uplift modeling in Fennoscandia is presented. The data set is available at https://doi.pangaea.de/10.1594/PANGAEA.905352 (Pohjola et al., 2019).

1 Introduction

Holocene land uplift has been known to people living along the shores of the northern Baltic Sea for centuries. Land uplift is a consequence of the Weichselian stadial and the massive ice layer that covered the Northern Europe from the British Isles to the proximity of Ural mountains in Russia. Heavy ice load pressed the Earth's crust down during the Weichselian period and when the ice started to melt at the beginning of the post-Weichselian or the Holocene period, the crust began to rebound to it's its equilibrium state. During the Holocene land uplift, the area of the current Baltic Sea experienced several lake and sea phases before finally settling to the present form of the Baltic Sea. More detailed review of the history of the Baltic Sea and the changes in the sea level can be found in (Tikkanen and Oksanen, 2002; Björck, 1995), (Punning, 1987) and (Ojala et al., 2013) Tikkanen and Oksanen (2002), Björck (1995), Punning (1987) and Ojala et al. (2013).

The timing of the ice retreat phases is also important in land uplift modeling. The estimated time of withdrawal of the edge of the ice sheet from a certain location marks the phase when subsidence turned into land uplift at that particular location. Several studies are available considering the timing of ice retreat(Hughes et al., 2016; Stroeven et al., 2016)., e.g. Hughes et al. (2016) and Stroeven et al. (2016).

In empirical land uplift modeling, the most important source of information is that sources of information are the ones describing the shoreline displacement. Nowadays Ongoing land uplift can be monitored using precise GPS station networks and gravimetric measurements from satellites described, for example, in (Lidberg et al., 2010; Müller et al., 2012; Poutanen et al., 2010; Timme Lidberg et al. (2010), Müller et al. (2012), Poutanen et al. (2010) and Timmen et al. (2004). Unfortunately, the GPS-based time series are relatively brief compared to other, less accurate data. The historical land uplift rate in Fennoscandia has been studied using information on lake isolation from the sea. ~~In (Eronen et al., 2001; Cato, 1992)~~ Eronen et al. (2001) and Cato (1992) examined the isolation of several lakes ~~was examined~~ using sediment samples taken from the bottom of the lakes. The samples were dated using the ^{14}C radiocarbon dating method and the age and depth of the layer where saltwater algae changed into freshwater algae were determined. The resulting shoreline displacement curves show that the land uplift rate has not been steady and there have also been local variations in the uplift. The same technique has been used with the ponds and mires by dating the first organic layer ~~in~~ on top of the inorganic clay layer. ~~This method cannot be directly compared to the dating of lakes, because ponds and mires are usually missing the algae samples. On the other hand,~~ Generally, the organic matter accumulated to the bottom sediments of the ~~bottom organic layer may have formed very rapidly in the ponds and mires after the continental ice retreat~~ basins indicates ice retreat. The basins collected to the data set are from the time period of the Ancylus Lake, so it can be assumed that the ice had melted before the accumulation of organic matter. Although the timing might not be exact, it is an indication of the isolation contact. In addition, there are geological interpretations of the retreat of the Ancylus Lake and the Baltic Ice Lake in mire studies and references.

Archaeological findings are useful in cases where the sea level can be checked against the location and age of human settlements. In Fennoscandia it can be safely assumed that people during the Holocene lived on dry land and, therefore, the location and elevation of these settlements ~~sets~~ set an upper bound for the sea level at the time the settlements are dated to.

In this paper we present a data set underlying our efforts in developing empirical land uplift models (Pohjola et al., 2014). The data set consists of lake isolation data, data ~~on the oldest dated layers of peat bogs~~ based on expert judgement on the sediment layers of mires as well as relevant archaeological findings. In the next chapters we describe the data and the data cleaning procedure and present the data collectors and the owners of the data repositories.

2 The data sets

2.1 Data description

The data set presented in this paper is a collection of ~~1918~~ 2335 data points and it can be divided into two subsets: lake/mire isolation data (~~669~~ 1086 data points) and archaeological data (1249 data points). Lake/mire isolation data are represented by ~~black~~ red circles and archaeological data by ~~red circles~~ black triangles in Figure 1. Each data point has a spatial location, elevation and ~~timing~~ age information that is preferably obtained using the ^{14}C dating and calibration. In most cases, the uncertainties in the ^{14}C dating are also taken into account, but the user of this data set must be aware of the uncertainties in spatial coordinates and elevation values (explained in more detail in the 'Data Handling' section). In the following sections, the sources of the two data subsets are presented. An example of the data from both data sets can be seen in Figure 2.

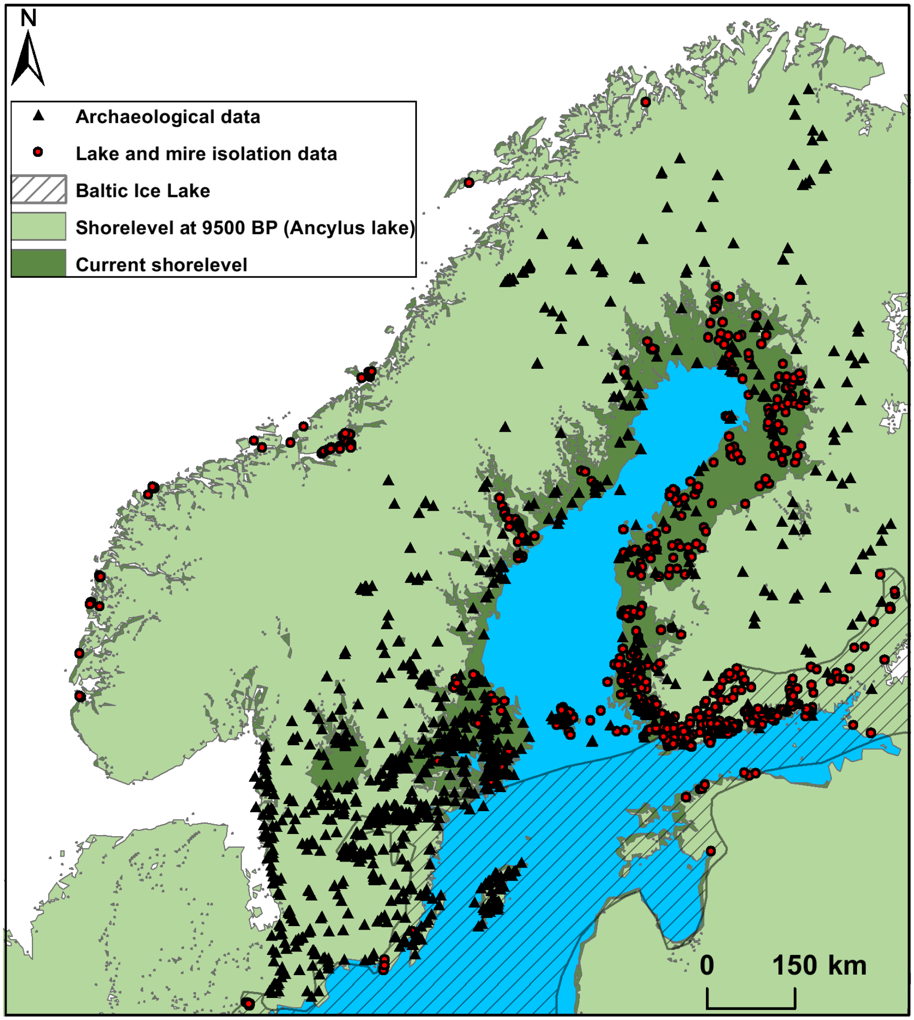

Figure 1. Spatial location of source data points. Maximum extent of the Ancylus lake phase is indicated in dark green color and the Baltic Ice Lake area is marked ~~in mild blue color~~by a hatched area. *Data points: (Pohjola et al., 2019). Background map: Esri. Historical shorelines: Geological Survey of Finland.*

2.2 Lake and mire isolation data set

The lake/mire isolation data forms the main data set used in the modeling. The basic idea behind these type of data is the determination of the freshwater/saltwater ecosystem boundary from a core drilled sample from a lake or mire bottom sediment. The ~~layer where the~~ isolation is defined by the transition from marine or brackish water algae ~~change~~ to fresh-water algae~~is determined in laboratory analysis~~. These kinds of samples have been collected especially in the area of Finland and Sweden. In Finland, the main data contributors have been Matti Eronen and Gunnar Glückert (Eronen et al., 2001). Arto Vuorela collected additional data points and included the data set of Matti Eronen and Gunnar Glückert into his own data set, published

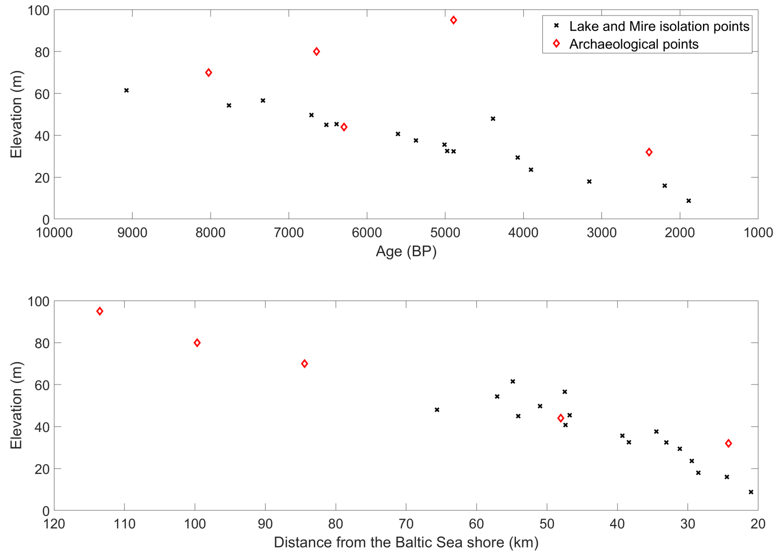

Figure 2. A sample of the data set containing data points along the line from (61° 0' 0,0", 21° 6' 0,0") to (61° 0' 0,0", 24° 0' 0,0") in WGS84 coordinate system. The distribution of the data points in the height – age and height – distance domains is presented in the upper and lower panel, respectively. Black ~~circles~~ cross markers denote the lake/mire isolation data and red ~~circles~~ diamond markers the archaeological data. *Background map: Esri.*

in (Vuorela et al., 2009). ~~(Mäkilä et al., 2013) is~~ Mäkilä et al. (2013) present a collection of mire ~~and bog~~ evolution and isolation datings in Finland. The collection of data points presented in this paper is sampled selectively from these sources and complemented with data points gathered from other scientific sources. ~~Bog~~ Pond and mire data sets are based on core drillings and in some cases the layers of different datings are close to one another in the core. In some rare cases the datings do not fully correspond to the depth of the dated sample along the core for some unknown reasons. In these cases the oldest sample was considered even if it is not the deepest one near the clay sediment in the drilling core. Some Norwegian shoreline points experienced several oscillatory rebound and retreat phases. The same issue can be seen in Finland and Sweden, where the same spatial location may have shore markings of the Baltic Ice Lake, the Litorina Sea and possibly the Ancylus Lake. Fortunately, in most cases the elevation is different and this allows to use all the available elevation/dating information of the point in question.

2.3 Archaeological data set

There are plenty of archaeological data available, but our main focus is to acquire samples that have an existing ^{14}C dating. For example, if there were coal remains from different time periods in dwelling site fireplaces, the oldest dated sample was included in the data set. The oldest sample is also an evidence of the site in question being above the water level at that time. However, there are issues of which the user of this data set must be aware. For example in Kolmhaara, Eura in southern Satakunta, Finland, the radiocarbon dated burial remains seem to be ~~younger~~ older than expected from the radiocarbon datings. Kolmhaara is a famous place, because it contains human remains (graves, fireplaces etc.) from a time period ~~of~~ stretching over thousands of years. The site has been located near the Baltic Sea shoreline. However, when using shoreline modeling, these burials appear to be several meters below the sea level at the time the remains are dated to. Either the shoreline displacement model is incorrect or the 'Marine reservoir effect' ~~(Dettman et al., 2015; Philippsen, 2013; Reimer and Reimer, 2006)~~ (Dettman et al., 2015; Reimer and Reimer, 2006) has had an influence on the samples. Also, the 'Old wood effect' (Olsen et al., 2013) might have had affected the samples. It is concluded in Olsen et al. (2013) that the dating of cremated human bone could have an inaccuracy of approximately 50-100 ^{14}C years. In addition, the freshwater reservoir effect (Philippsen, 2013) is one aspect that could be considered with the time and elevation discrepancies.

Main sources of the archaeological findings are the Finnish Heritage Agency archives (http://www.kyppi.fi) and the Swedish National Heritage Board archives (http://www.raa.se). ^{14}CARHU database consists of the radiocarbon data collected by Helsinki University (Junno et al., 2015). More detailed references are included in the data sets.

3 Data handling and organisation

Various different coordinate systems were used in the original data sets. The data were reprojected to the WGS84 coordinate system and the elevation is presented as meters above the sea level corresponding to the average sea level datum. Some of the archaeological point locations were described verbally like *"half a kilometer west from the main building..."* and some of the site locations were drawn manually illustrating the significant landmarks in the area. All these data points were checked using the National Land Survey of Finland (NLS) maps as some of the archaeological sites are included in the NLS base maps. If they were not included in the base maps, the best estimates, based on the verbal clues and possible hand drawings, were determined using the NLS maps. In some cases the elevation information was also checked from the NLS base maps or NLS digital elevation maps and refined if possible. In the cases where elevation was known, it was possible to check the location using elevation information. The maximum error in the spatial location of the data points can be estimated to be about 100 meters, however, as a single data point usually represents a larger area of several kilometers' radius when estimating the land uplift behavior, the exact location of the data points is not critical. As an example, a part of this data set was used in the study by Pohjola et al. (2018).

The vertical error in the lake/mire isolation and archaeological data sets is assumed to be ± 0.5 m. Defining the altitude is sometimes very challenging, especially in villages situated at hill slopes. In these cases the lowest altitude is used and it is assumed that the lowest point of the village has existed during the oldest period. This is somewhat questionable, because the village might have expanded during the centuries around the oldest settlement. As said before, the archaeological data set is used only for validation purposes when modeling land uplift.

In all cases concerning both the archaeological and the lake/mire isolation data, latitude (WGS84), longitude (WGS84), altitude (meters above sea level), ^{14}C age (~~calibrated~~ uncalibrated years BP), ^{14}C error (years), the name of the place, the reference (^{14}C laboratory identification, if available), URL of the database (if available), dated material (if available) and

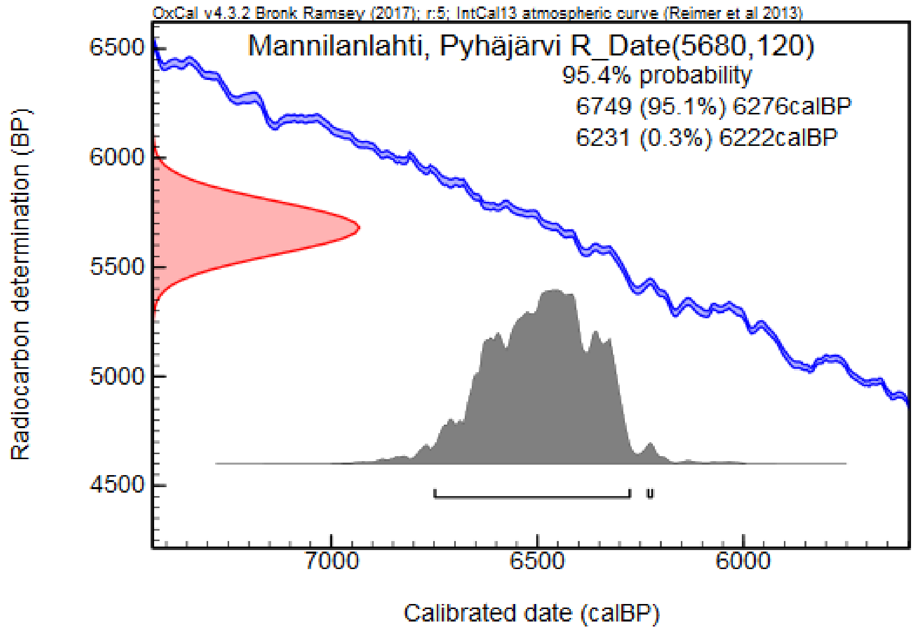

Figure 3. The calibration curve and the error distribution from OxCal program (Bronk Ramsey, 2009).

possible additional information are provided. The reference field will contain the ^{14}C laboratory report or a link to a database. In some cases the samples are collected as a side product of other work and in these cases the laboratory number is the link to digital site report (in Finnish) or some commonly referred article, where the finding is mentioned.

~~The~~ In our studies, e.g. (Pohjola et al., 2014, 2018) the calibration for the ^{14}C radiocarbon dated data points was done using the Oxcal program (Bronk Ramsey, 2009) containing Oxford radiocarbon acceleration unit calibration curve (IntCal 13) ~~(Bronk Ramsey, 2009)~~(Reimer et al., 2013). An example of the calibration curve is presented in Figure 3.

4 Conclusions

This data set is intended to be used for ~~modeling~~ modelling the postglacial land uplift in Fennoscandia between 12,500 and 0 years BP. The collected data set in this paper covers the coastal area of Finland and Sweden reasonably well, ~~but the data set is still too sparse in certain areas (see Figure 1). Also, the work for searching additional data is currently going on and other data sets such as the lake tilting data set presented in (Påsse, 1996) is worth studying~~especially the extent of the Ancylus Lake. There is always room for improvement, because lake and mire data points are missing from e.g. Hälsingland and Västerbotten areas in Sweden. However, the archaeological data points cover sufficiently almost all the Swedish - Finnish coastal area. Also in the Estonian side, more archaeological and geological data are needed.

The data set introduced in this paper can also be used to estimate the flooding risk due to the rising seawater. In Bothnian Bay the land uplift estimates (6-9 mm / year) (Poutanen et al., 2010) are higher than the predicted seawater rise (2.5 - 5.5 mm

/ year) (Church et al., 2013) but for example in the Gulf of Finland the land uplift rise is 0-5 mm / year (Poutanen et al., 2010). Also future housing development planning in the northern Baltic Sea coastal areas could benefit from this data set for assessing the flooding probability.

5 Data availability

Both datasets are available at https://doi.pangaea.de/10.1594/PANGAEA.905352 (Pohjola et al., 2019).

Author contributions. J.P. and J.T. performed the data collection and handling. The manuscript was written by J.P., J.T. and T.L. in collaboration.

Competing interests. The authors declare that they have no conflict of interest.

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