Dear Pohjola et al.,

Thank you for reacting to the comments of my first review by incorporating the suggested changes into the written part and figures of your manuscript. Beside a few minor comments (see below), the revision with the implemented corrections, additional information and discussion has improved its quality and readability.

Having checked the two datasets/files with the archaeological and mire/lake isolation data accessible

on PANGAEA, I was not able to find changes or additional data yet. This concerns the requests for:

⬚ changing of headers (age unit terminology, see first reviewer comment, it needs to be clear

that the ages in the data files are uncalibrated)

⬚ providing a separate column for the type of dated material (wood, bone, bulk peat,

macrofossils, charcoal, etc.) in both files

⬚ providing a separate column for the dated archive/basin type (lake, mire or pond)

⬚ adding URLs to the radiocarbon reports of the lake/mire isolation data, where available (like

in the archaeological data file).

Although there is a lot of dry work involved, I strongly suggest adding this information to raise the

quality of the data and increase the impact of this publication. If changes were already made and the

changes are just not visible because the files are in review on the PANGAEA website, just ascertain

again, that the adjustments were correct.

Please find a few minor comments and technical issues below. Please excuse me that I might have

overseen some of them in the first review:

We thank Referee #2 again for the constructive comments. The previous comments and the comments after the first revision have improved the quality of the manuscript significantly.

The updated data sets have been uploaded to PANGAEA and the data sets are now visible there. All the requests have been addressed. Here are detailed responses for the other comments. At the end of the document is the marked-up version of the manuscript.

Page 1

l. 17: Instead of 'timing', the term 'chronological order' should be used.

l. 21: comma after satellites

Both were corrected as suggested.

Page 2

l. 4: 'on the bottom sediments' instead of 'in'

Corrected as suggested.

l. 5: to the 'time period of Ancylus Lake', the time period should be given in numbers, with a reference.

Time period in numbers and two references were added to the text.

l. 6: isolation and contact contradict each other. You could remove 'contact'.

Corrected as suggested.

ll. 7-8: '…in mire studies and references…', technically, these mire studies are among the references. You can write that there are interpretations of the retreat drawn from mire studies and then put a few literature references behind, which are specifically evidencing it. In other words, if you already use 'references', then also name a few.

Corrected as suggested with references.

l. 10: comma after 'In Fennoscandia'

Corrected as suggested.

l. 13: 'data based on expert judgement on the sediment layers of mires…' sounds weird, as if it is unclear what "expert judgement" is or who these experts are. It would sound more serious if you just

write: 'data based on the initial layers of mire development as well as …'

Corrected as suggested.

ll. 20-21: put 'method' behind 14C.

Corrected as suggested.

'Each data point has a spatial location, elevation and age information that is preferably obtained using the 14C dating and calibration.' Because the chapter is called data description, the sentence suggests or may be misinterpreted, that the ages provided in the files are calibrated already. It should be made clear that the data user still needs to calibrate the 14C-dates. The (raw) 14C-dates are already there, but the calibration still needs to be done, which is not differentiated here yet.

The need to calibrate the 14C dates was emphasized.

Page 3

I. 3: It is not completely clear what is meant by the statement that 'in some cases the layers of different datings are close to one another in the core.' Does it mean that there are big age discrepancies between samples that are almost in the same layer/depth or very close to each other?

That was the intention and it has been clarified.

II. 3-4: You could give some hint to the reader for possible reasons for these age reversals. For example, roots that were accidentally dated and give ages that are less old than a layer above, redeposited older material from outside the catchment.... Possibly with a few references. At least, remove the 'for some unknown reasons'. Otherwise, it may sound slightly unprofessional.

An example with a reference was added as well as possible reasons for these age reversals.

Page 4

In Figure 2, the figure caption still says height instead of elevation. Consider using m a.s.l. (above sea level).

The figure and the figure caption were corrected to use elevation m a.s.l.

Page 5

II. 20-21: Again the pointer to the two datasets and the need to apply the changes concerning terminology, units and additional columns on sample type, links to the reports where missing, etc. (see first review).

The PANGAEA data sets have been updated addressing these remarks.

I. 25: Put citation/syntax in order/rephrase to: 'In earlier studies (e.g. Pohjola et al., 2014, 2018), the calibration.....'

Corrected as suggested.

Page 6 (mind that the line numbers are not displayed correctly)

I. 33: on the Estonian side

ll. 1-5: To streamline the conclusion slightly, consider ending the sentence after the Church et al. reference and then: 'In contrast, the land uplift in the Gulf of Finland is 0-5 mm / year (Poutanen et al., 2010). Therefore, future housing development planning in the northern Baltic Sea coastal areas can benefit from this data set as a tool to assess the flooding probability.'

Page 8 (References)

ll. 2-3: DOI is missing for this reference.

All pages:

'modeling' is American English. Change to British 'modelling'. Check for consistency throughout the manuscript.

Page 1, lines 7, 17, 20, Page 2, l. 26., Page 4, l. 10, Page 5, l. 18

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 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~~ modelling 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 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).

The ~~timing~~ chronological order of the ice retreat phases is also important in land uplift ~~modeling~~modelling. 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, e.g. Hughes et al. (2016) and Stroeven et al. (2016).

In empirical land uplift ~~modeling~~modelling, the most important sources of information are the ones describing the shoreline displacement. 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) 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. Eronen et al. (2001) and Cato (1992)

examined the isolation of several lakes 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

5 organic layer on top of the inorganic clay layer. Generally, the organic matter accumulated ~~to~~ on 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 (9500-8000 BP (Björck, 1995; Tikkanen and Oksanen, 2002)), 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 studiesand references.~~drawn from mire

10 studies, e.g. (Eronen et al., 2001; Mäkilä et al., 2013).

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 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).

15 The data set consists of lake isolation data, data based on ~~expert judgement on the sediment layers of mires~~ the initial layers of mire development 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

20 The data set presented in this paper is a collection of 2335 data points and it can be divided into two subsets: lake/mire isolation data (1086 data points) and archaeological data (1249 data points). Lake/mire isolation data are represented by red circles and archaeological data by black triangles in Figure 1. Each data point has a spatial location, elevation and age information that ~~is preferably~~ has been obtained using the ^{14}C dating ~~and calibration.~~ method. The ^{14}C dates in the data sets are uncalibrated so they need to be calibrated in order to convert them to calendar ages. In most cases, the uncertainties in the ^{14}C dating method

25 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.

2.2 Lake and mire isolation data set

The lake/mire isolation data forms the main data set used in the ~~modeling~~modelling. The basic idea behind these type of data

30 is the determination of the freshwater/saltwater ecosystem boundary from a core drilled sample from a lake or mire bottom sediment. The isolation is defined by the transition from marine or brackish water algae to fresh-water algae. These kinds of
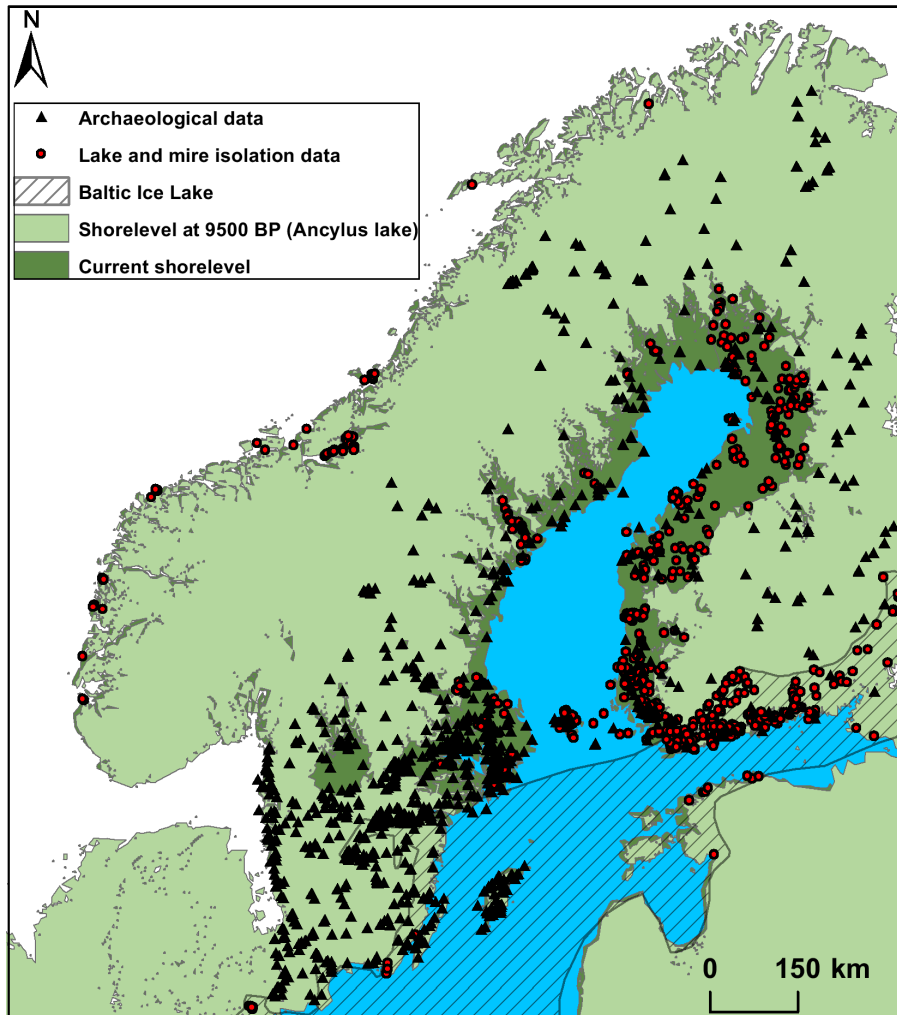
Figure 1. Spatial location of source data points. Maximum extent of the Ancylus lake phase is indicated in dark green color and the Baltic Ice Lake area is marked by a hatched area. *Data points: (Pohjola et al., 2019). Background map: Esri. Historical shorelines: Geological Survey of Finland.*

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 in (Vuorela et al., 2009). Mäkilä et al. (2013) present a collection of mire 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. Pond and mire data sets are based on core drillings and in some cases ~~the layers of different datings are close to one another~~ there are large age discrepancies between samples that are close to each other in the core ~~. In~~ so the interpretation of the results is important.
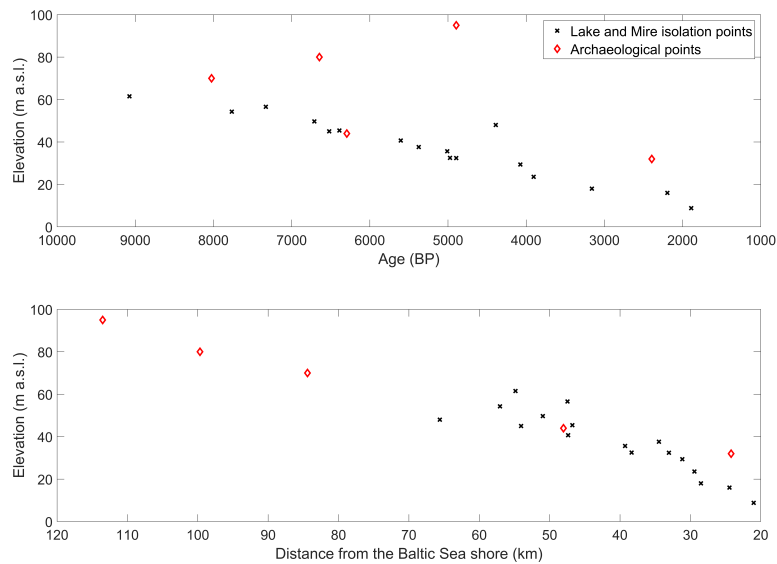
3

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~~ elevation – age and ~~height~~ elevation – distance domains is presented in the upper and lower panel, respectively. Black cross markers denote the lake/mire isolation data and red diamond markers the archaeological data. *Background map: Esri.*

In addition, in some rare cases the datings do not fully correspond to the depth of the dated sample along the core~~for some unknown reasons.~~. An example of this kind age reversal are the samples belonging to the Nälköönsuo series (Jungner, 1979). The younger sample HEL-103 has been taken from a deeper layer than the older sample HEL-104. These kind of discrepancies can result from e.g. redeposited older material from outside the catchment or roots that were inadvertently dated giving ages that are younger than than the layer above. 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,

4

Finland, the radiocarbon dated burial remains seem to be older than expected from the radiocarbon datings. Kolmhaara is a famous place, because it contains human remains (graves, fireplaces etc.) from a time period stretching over thousands of years. The site has been located near the Baltic Sea shoreline. However, when using shoreline ~~modeling~~modelling, 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; Reimer and Reimer, 2006) has had an influence on the samples.

5 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

10 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

15 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

20 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

25 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~~ modelling land uplift.

In all cases concerning both the archaeological and the lake/mire isolation data, latitude (WGS84), longitude (WGS84),

30 altitude (meters above sea level), ^{14}C age (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 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
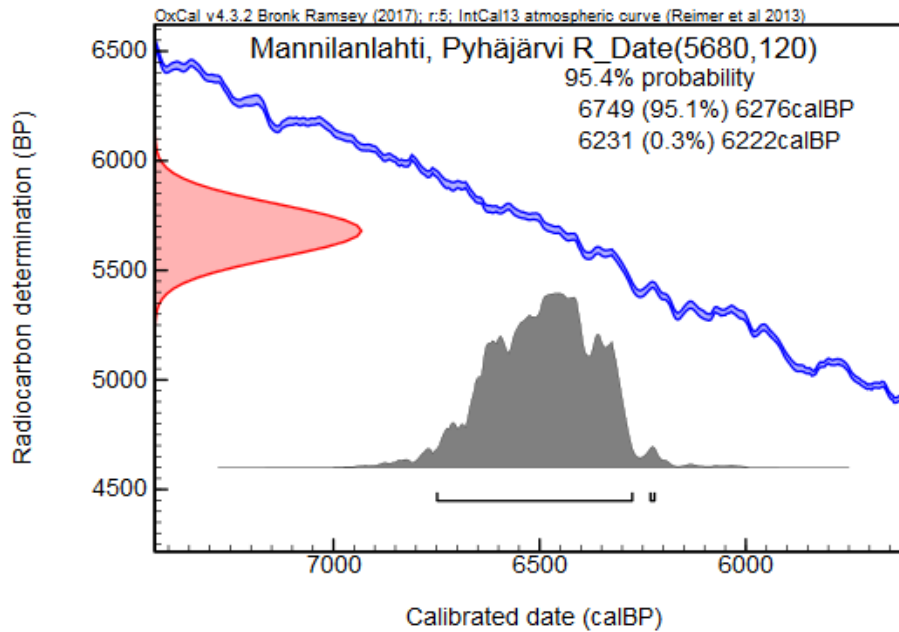
Figure 3. The calibration curve and the error distribution from OxCal program (Bronk Ramsey, 2009).

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.

In ~~our studies,~~ earlier studies, (e.g. ~~(Pohjola et al., 2014, 2018)~~ Pohjola et al. (2014, 2018)) the calibration for the ^{14}C radio-
5 carbon dated data points was done using the Oxcal program (Bronk Ramsey, 2009) containing Oxford radiocarbon acceleration unit calibration curve (IntCal 13) (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 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, especially the extent of the
10 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~~ on 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 contrast, the land uplift in the Gulf of Finland ~~the land uplift rise~~ is 0-5 mm / year (Poutanen et al., 2010). ~~Also~~ Therefore, future housing development planning in the northern Baltic Sea coastal areas ~~could~~ can benefit from this data set ~~for assessing~~ as a tool to assess 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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