Earth 436B Thesis

? Calculating

~~Obtaining~~ rates of glacial isostatic adjustment from unequally spaced data

John Lawson

→ Font is too small

→ please space lines at 1.5 spacing

Contents

2 Introduction

The Earths crust rests on top of the mantle, its elevation rising and falling with the amount of mass weighing on it. During glacial periods, a significant portion of the water on earth is transferred in form from water in the oceans to glacial ice, weighing down the continental crust. This causes the crust to ride lower in elevation, a change which is quickly reversed when the weight is removed as the ice sheets melt. This vertical motion of the crust while returning to its previous position is known as glacial isostatic adjustment (GIA).

This process of isostatic rebound has implications for the routes that the flow of water on the Earths surface takes; the "tilting" of the surface caused by uneven rates of GIA in different locations may open or close locations along basins, causing some rivers and lake outlets to close, while potentially opening others. Additionally, the change in "tilt" has potential to change shorelines of existing basins, which has implications for property assessment and long term engineering projections for structures such as locks and dams.

sheets
and causing the mantle to dynamically adjust.
relative
of ice sheet
relative
attempting to
GIA
what locations? Do you mean drainage by outlets
other what?
so they do not drain? OR just change outlet location
? which one's? Needs explanation
Need to mention highest rates in areas where glacial ice was thickest & longest lasting.
Low so?
Long-term relative movement of the ground surface due to GIA is much longer than property assessments.
Yes, but are built to last over several decades (i.e. 20-50 years)
Impact - location & maintenance of infrastructure.

Need to add something about the LGL's → Laurentide ice sheet oscillated across LGL's many times helping to sculpt the lake basins through (erosion & deposition) ...

Use references:

Karrow & Calkin (1985) Geological Association of Canada Special Paper

Larson & Schaetzl (2001) Journal of Great Lakes Research, 27 518-546.

And mention - GIA has been identified as one of the top 3 factors contributing to water level change but long term rates of GIA are difficult to estimate without long term data.

International Upper Great Lakes Study (International Joint Commission) (2009 & 2012) Reference.

1 Abstract

The ground surface underlying the Laurentian Great Lakes is currently undergoing vertical adjustment after being depressed by the weight of an ice sheet formed in the most recent glacial period. The rate of glacial isostatic adjustment (GIA) varies by location, and exerts ~~a significant control~~ on the flow of water in the Laurentian Great Lakes as the inclination of the ground surface changes. In order to predict the future movement in ~~this area~~, the rate of GIA must be inferred from measurements of the water level ~~in~~ the geological record. These measurements are made by measuring the elevation of a subsurface sedimentary contact relating to past lake levels,which are then age dated with optically stimulated luminescence (OSL) to provide an age ~~value~~ of sediments. Elevation and age data are then compiled to create site paleohydrographs per lake basin.

The ~~focus~~ of this paper is to analyze this data by ~~measuring~~ subtracting the relative difference in water levels between study sites, ~~comparing differences in relative water levels~~ to create a plot of relative elevation over time. Once this is done, ~~the rate of change~~ per unit time is obtained from a linear regression, representing an estimate ~~of the value~~ of GIA between each pair of sites. This is done for all possible ~~combinations of the~~ four sites ~~used~~, Grand Traverse Bay (GTB), Au Train Bay (ATB), Batchawana Bay (BATB), and Tahquamenon Bay (TAHB).

The results of this process were ~~a strong~~ in agreement of 95p confidence intervals on GIA rates obtained from forward and reverse regressions for the combination of ATB-BATB (23.5 to 31 cm/century) and BATB-TAHB (11 to 17 cm/century). Agreement was also seen for GTB-TAHB (anywhere from -3 to 8.5 cm/century), ATB-GTB (9 to 13 cm/century), ATB-TAHB (19.5 to 29 cm/-century), and BATB-TAHB (11 to 17 cm/century).

(LGL), the Wisconsinan.

an influence

the LGL

What about water level gauges? (Add please) Also please add context, require long term data to best record long term process.

interpreted from sediments that formed at similar time periods

difference in

surrounding Lake Superior, namely

~~for one study site~~

Add text to explain what "This" is referring to.

write out the

repeat

95p? or something different?

not the same?

This part needs clarification. Please describe better.

Have to add description that includes "unequally spaced data" – in your title. You propose a method to calculate GIA between study sites using measured and interpolated data between linearly data points.

2.1 Previous Work

Mainville & Craymer (2005) used water gauge data collected around the Great Lakes over the past 150 years to create monthly means of water level. Differences in these values between sites would then be plotted against time to get a rate of elevation change between sites over time (ie GIA). However, combinations of sites were shown to produce inconsistent results, so a second method using a least squares adjustment process was used, iteratively removing some monthly mean outliers which fell some arbitrary residual distance or farther from the linear regression line until none remained "too far away" from the final regression. A third, and ultimately best method was developed by Mainville & Craymer by using the original method of directly comparing monthly water level means, but applying adjustments for the epoch, site, and month of each monthly water mean when subtracting between sites. Their findings showed better agreement with the ICE-3G global model of GIA than ICE-4G (Mainville & Craymer, 2005).

Johnston et al. (2012) attempted to refine previous estimates made using water gauge data by using data over a much longer timescale. In this method, water levels were inferred from the elevation of beach deposits from the late Holocene sediment record around Lake Superior, the ages for each data point measured by dating samples from these beach deposits (known as strandplain sequences) with Optically Stimulated Luminescence (OSL) age dating. This data differed from that used by Mainville & Craymer in that data collected did not have elevations sampled at the same points in time for calculation of relative rates. As a result, the elevation vs time data was modelled with a linear regression for each site, the difference in slopes representing the GIA rate between sites (Johnston et al, 2012). In a later 2014 paper, Johnston et al. attempted to refine the method by adjusting the model of each site upward or downwards with common lake level lows and highs observed in the other sites (Johnston et al, 2014).

In order to project the future impact of this process on the Great Lakes Basin, an estimate of the historical rate of GIA is needed. This estimate is obtained by comparing the elevation of the water mark at two different locations around a basin, and observing how this difference changes over time. The elevation of the water can be inferred by a variety of indicators in the sediment record, in this case, beach deposits known as strandplain sequences are used, their ages determined by optically stimulated luminescence (OSL) dating. This raw data is presented in Figure 1.

Need to show figures < individual gauge data in map, merged gauge & model data
And describe these → pattern & rates? < General for GLs And then pattern & rates for Lake Superior.

This calculated value is interpreted to represent GIA, a long-term process

Calculate or adjustment of the crust and mantle from the weight of the Laurentide Ice Sheet

GGL

were?

Poor grammar - please reword.

To calculate GIA

Need to improve explanation

post glacial

at that time

used relict shorelines in beach ridge strandplains to estimate rates of GIA

→ 5000 years in Lake Superior,

inferred from using of these beach deposits

Now, Need to state the numbers that Johnston et al. (2012) report

Please improve grammar, use

(2005)

Modelled linear rate in 4 time periods or phases:
- Sault
- Algoma (most data)
- Sub-Sault
- Nipissing

Calc. Difference between linear rates between sites. Explain.

GIA - long term GGL

? Like what?

Paragraph is out of place. Some is a repeat of above and some text should be used to improve explanations above. Please revise.

But you are focusing on Lake Superior.

GIA relative to outlet at Sault Ste. Marie (SSM)

BATB 6 cm/cent

SSM 0 cm/cent

TAIB -3 cm/cent

GTB -9 cm/cent

ATB -17 cm/cent.

All rates of GIA were similar to Mainville & Craymer (2005) except between (SSM-outlet) & (ATB)

Johnston et al (2012) = -17 cm/cent
Mainville & Craymer (2005) = -12 cm/cent

Differs

No, Johnston et al (2014) summarized more than two decades of research creating paleohydrographs & preliminarily compared data in wide basin paleohydrographs from lakes Michigan and Superior (Johnston et al. 2012).

Baedke & Thompson (2000) Journal of Great Lakes Research 26(4): 416-426.

Did you get close to these?

↳ Explain in Discussion section but present here.

No title in figure → include in caption.

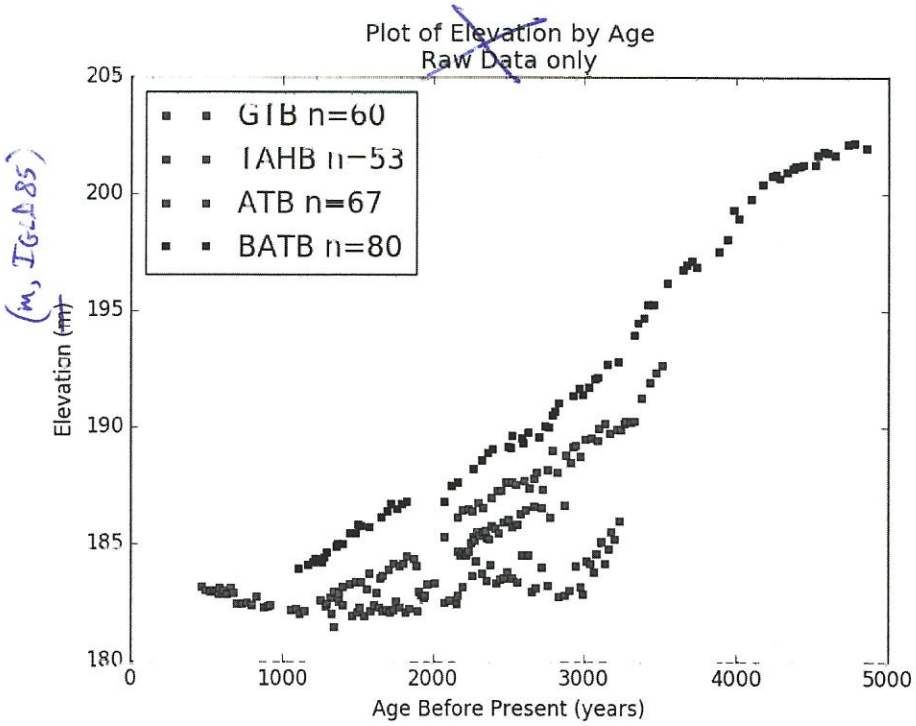
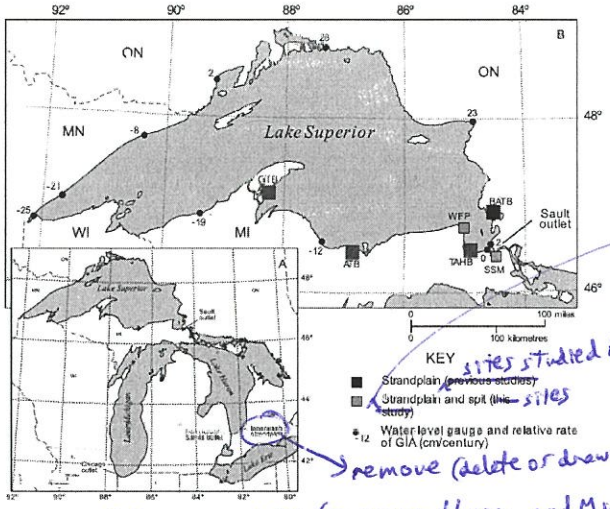


Figure 1: Current day elevation of ~~where the~~ shoreline ~~was~~ with respect to time before present over the last 5000 years. relict shorelines for four strandplains of each ridges surrounding Lake Superior.

↑ part of last paragraph?

The data was sampled from four separate locations around Lake Superior, namely Au Train Bay, Michigan (~~known in this paper as~~ ATB), Grand Traverse Bay, Michigan (~~known as~~ GTB), Batchawana Bay, Ontario (~~known as~~ BATB), and Tahquamenon Bay, Michigan (TAHB).



Additional.

sites studied in this Thesis

remove (delete or draw white box over top this label) Not relevant in your Thesis.

Map of the upper LGL (Superior, Huron, and Michigan) showing location of strandplains.

showing location of modern (Sault and Port Huron/Sarnia) and ancient (Chicago) outlets.

Figure 2: ~~Geographic~~ Map of Lake Superior & surrounding regions. ~~Note that the colour of each site marker will remain constant throughout the rest of this paper for convenience.~~ ~~Reproduced~~ Modified from Johnston et al, ~~2014~~ (2012).

(Can keep) (in brackets)

Part of last paragraph?

These datasets were previously ~~created by~~ published in Johnston et al, ~~2014, but were analyzed using a different method.~~ 2012. From observing the graph, it can be seen that all four datasets follow somewhat linear trends, increasing in elevation as the time before present increases. This is because the crust underlying the ~~Great~~ LGL ~~Lakes~~ has been rebounding upwards over the time period in question, implying that areas that were at the elevation of the water surface in the past have been shifted up in elevation above the current water surface elevation. The rate of this ~~upward~~ trend varies by site, generally increasing for sites closest to the north and east ~~extremes~~. (this is due to the rate of rebound increasing with closeness to the center of the Laurentide Ice Sheet, roughly near current day James Bay in Northern Ontario). ← This should be included in intro – GIA explanation. Between the four study sites, the most common feature is good data coverage between approx. 1000 and 3500 years before present, with a common gap in coverage around 2000 years before present. This ~~was due to conditions which worked against the formation of strandplain sequences during the~~ Algoma lake level fluctuation (Johnston et al, 2014), ~~thus causing most of our datasets to have interrupted records of lake level elevation at this time.~~ While some of the datasets have coverage extending ~~far~~ beyond this range, the only dataset which does not fol-

Refer to fig #. The general cross-strandplain trend in elevations follow

Geologists describe old to young. Please reverse

moved

general cross-strandplain linear

over 5,000 years...

No, interpreted by Johnston et al, (2012) to represent.

part of Lake Superior that is closer to the centre of the Laurentide Ice Sheet.

gap in data between the Sault high water level phases of Lake Superior.

explain which site extends <1000 & >3500...

State which ones. Help the reader by adding ~~site~~ which sites and then referencing the figure.

Need to add comment about TAHB earlier, after mention of 4 sites. But all sites have data between ~2000 and 3200 ? generally

which pattern?

low this pattern of data coverage is TAHB, which will be discussed later in this section.

Have to first explain that data from sites have different coverage ... Then most data between

In order to measure a relative rate of GIA between sites, the rate at which these trends diverge must be measured. In the previous work done on this dataset, this was accomplished by representing the trend of increasing elevation with age as a straight line using a linear regression (Johnston et al, 2012). This was an effective first approximation, but failed to take into account that large gaps exist the ranges of time before present where no data is available for some sites. For example, the TAIIB dataset has a large gap between 600 and 2100 years before present in which no data is available. A linear regression of this dataset would imply a similar rate of change connecting these two disconnected ranges, during which there is no actual evidence that the sites actual elevation was anywhere near the linear regression line. which it is represented by in calculations for producing a GIA rate.

within each lake phase (Sub-Sault, Sault Algoma, Nipissing)

Incorrect - Please remove or reword. Johnston et al (2012) divided the datasets into 4 lake phases, calculated a linear regression for each lake phase for each study site. Then calculated the difference between linear regression rates to derive GIA between study sites.

In order to produce an estimate of GIA which better reflects the inconsistent coverage of the data over time, a better strategy would be to simply subtract the differences in elevation between sites, and plot these differences with respect to time. Unfortunately however, none of the datasets have elevations sampled at the same times, an estimate of elevation being needed for times where one dataset has a data point present, but the other does not. In this paper, this estimate (the modelled elevation) is created by using linear interpolation between datapoints, represented as a solid line between points as seen in Figure 3.

individual ← refer to in methods.

Then develop a relationship with TDS data to derive GIA, similar to the method of Manville & Gayner (2005) and with water level gauge data.

and values of GIA were calculated using a difference calculated between modeled and measured data between study sites.

The objective of this study is to develop a new method of calculating GIA from shorelines of beach ridges surrounding Lake Superior over the last 5,000 years and compare with rates calculated in Johnston et al (2012) and Manville & Gayner (2005). Something like that ...

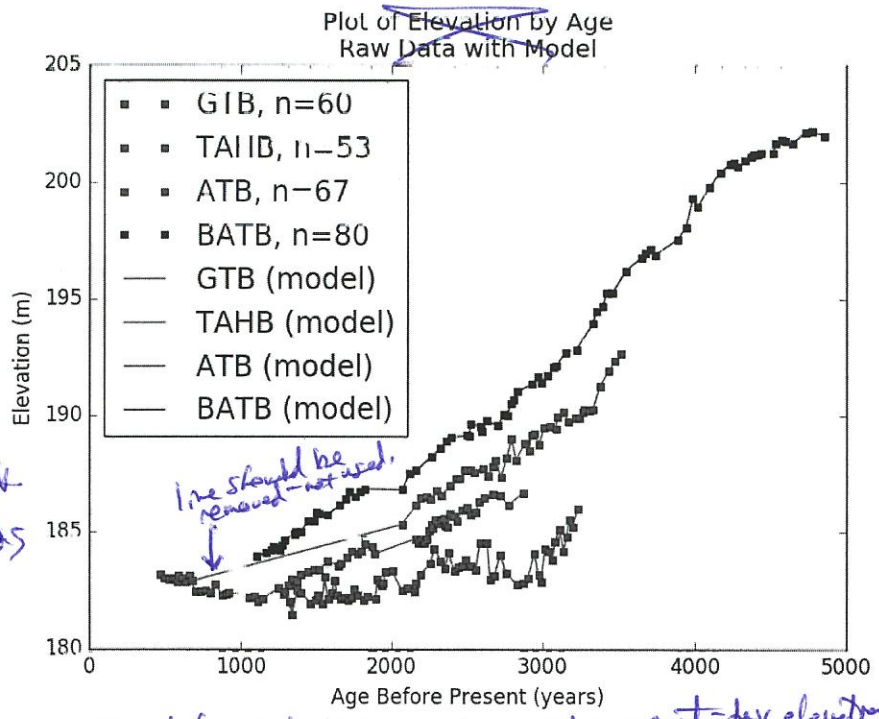


Figure 3: ~~Water surface elevation with respect to time before present, modelled~~ Standardized paleohydrographs including present-day elevation and age of formation for four study sites in Lake Superior. Linear interpolation is used between data points and described as modelled data

2.2 Methods

Once this estimate of elevation for times between sampled datapoints at a site is created, the difference in GIA between sites can be created by subtracting the elevation of a measured data point from the modelled elevation of another dataset at that point in time, this difference is the dashed line shown in Figure 4: To avoid making comparisons between data in one dataset and a model for another in areas where the model stretched over long distances between measured data (such as the 1500 year gap in TAHB), the data was grouped into a series of bins starting at 450 years before present with width of 200 years. ~~(ie the error bounds on the age values reported in the original data)~~. If any bin had no data available for one site or the other in a comparison, none of the datapoints in that bin range were used to make comparisons, thus ensuring that areas like the gap in TAHB were ~~avoided~~ not included when making comparisons. In addition, a second rule ~~that~~ the counts for the bins needed to be within 75% of one another was used, which cleared up a few areas where the datasets for both bins compared poorly, but produced valid comparison windows (see the small zone of GTB-TAHB overlap at 600 years before present).

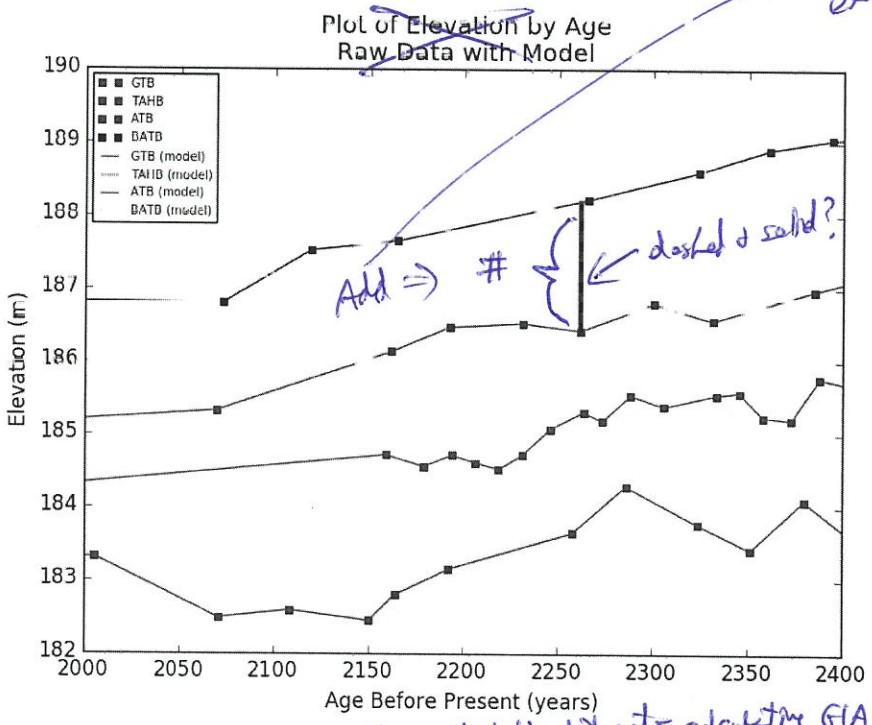


Figure 4: Example GIA comparison from a data point to a linear interpolation (model) represented by an alternating dashed line

Section 4

Results

8 ~~GIA Graphs~~

Using comparisons from measured data points to the linear interpolation model, a pair of graphs of the relative difference over time was created for each pair of sites, two graphs ~~being needed to~~ represent the comparison ~~both ways~~. (ie for the site combination of ATB & BATB, ATB needs to be compared to BATB, and BATB needs to be compared to ATB). The rates of GIA produced by these comparisons should be of opposite signs, but similar magnitudes.

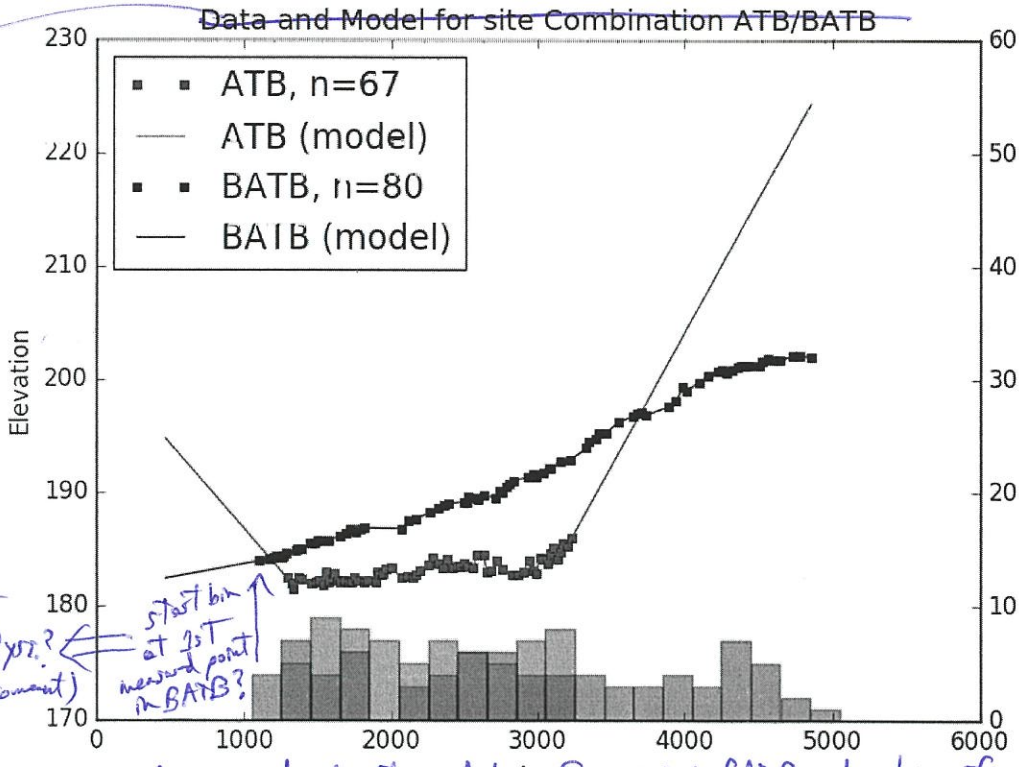
(methods) Please integrate into methods section.

Listed in ~~this section~~ are the results of the six possible combinations of sites. The GIA rates are determined by applying a Linear Regression to each comparison, the slope of each regression representing the relative rate of GIA between sites

lower case.

<- Need to explain this step generally in 'The methods Section.

~~Data and Model for site Combination ATB/BATB~~



No titles (in caption)

Or start bin at 450 yrs? (See Page 9 comment)

Start bin at 1st measured point in BATB?

Measured and modelled elevation data (and age) for ATB & BATB. Number of data points or counts in 200 year bins ~~for~~, one each for ATB, BATB, and both ATB & BATB.

Figure 5: ATB-BATB raw data with linear interpolation model

Need to add detailed description in captions. Please fix all

In this section prepare the reader for what you have include in the results section and describe in detail each.

Potential sequence:
- 6 combos
- ~~2 for each site~~
- create table showing all combos (measured/modelled)
- Explain - show data for each combo = measured and modelled data for each site and 200 year bins for each site and data used between site to calc. GIA...

The data available for sites ATB and BATB shows two of the most common trends in the data used in this paper; Data is available for both sites from

The reader does not know what you are referring to → please explain in detail, or state what you see in graph first and then relate to what you previously talked about.

approximately 1000 years before present to ~~roughly~~ 3300 years before present, with a gap in the record at around 2000 years before present ~~(caused by a low water level period preferentially not forming beach deposits during this time)~~ (~~Johnston et al, 2014~~). With the data divided up into bins of 200 years width starting at 1050 years before present, the data from every bin between 1250 and 3250 was used in calculating a rate of GIA, save for the previously mentioned gap from 1850-2050 years before present (where comparisons between data in the ATB dataset would be subtracting against a modelled value for BATB that is likely unreliable given the distance to the nearest datapoint in BATB). The regressions derived from this pair of data sets, seen in Figures 6 & 7, are well constrained and produce a moderately well constrained value on relative GIA between ATB and BATB of 23.5-31 cm/century. A plot of the confidence intervals for the slopes obtained from each linear regression can be seen in Figure 23

This is the results section. Just describe results

Need to tell readers general method you used to bin data in methods.

Tell reader total # of bins used.

What "previously mentioned"? Please start new sentence & explain.

New sentence, improve explanation

Have to explain

Fig 6 = Compare ___ to ___ (sites)
= Diff. calculated between ___ & ___
= Describe data
↳ elev. Difference range?
= Regression created through all data (linear)
(r^2 = good fit?)
= Describe confidence intervals
- range? wide? narrow? & range
- +ve or -ve slope
- slope value = # ? ± ___

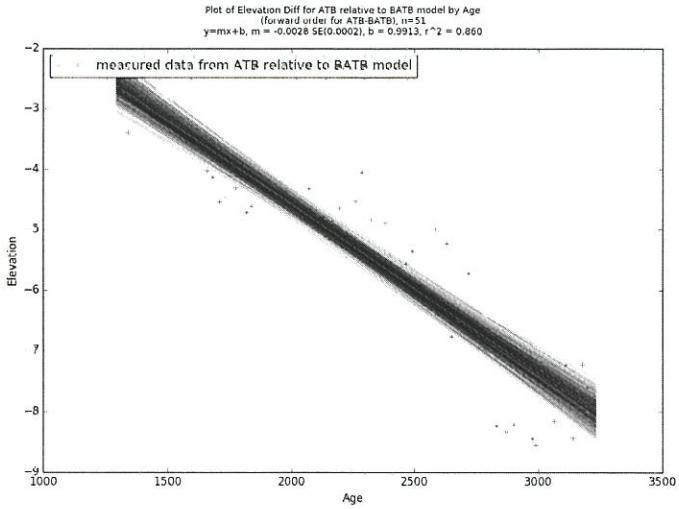
Need to describe.
Cannot just state this → present r^2 & confidence to demonstrate this & slope ± ___ value

Does that include both combos of these two sites?
Please first ~~state~~ ~~range~~ state value & range for one combo & then the other combo and then a combined value & range accounting for both combos for two sites.

Please present each combination like this. You can also combine 2 from one site, but describe each first and then compare between the two.

After you describe each combo & plot then you can summarize in a chart and describe the data using the chart in a paragraph or two or more. So, please move this sentence until after each plot in a summary section of the results.

You could make subsections with titles to help the reader see the 6 combos. (i.e. Comparison (& find) of ATB & BATB),



Can you increase the size of the plot so the reader can view it better? (You could rotate & place on one page)

Figure 6: Differences in elevation measured from the ATB data to the ATB model. Add sentence to describe what else is shown in plot = confidence interval? ...

Please revise all plot captions & increase size.

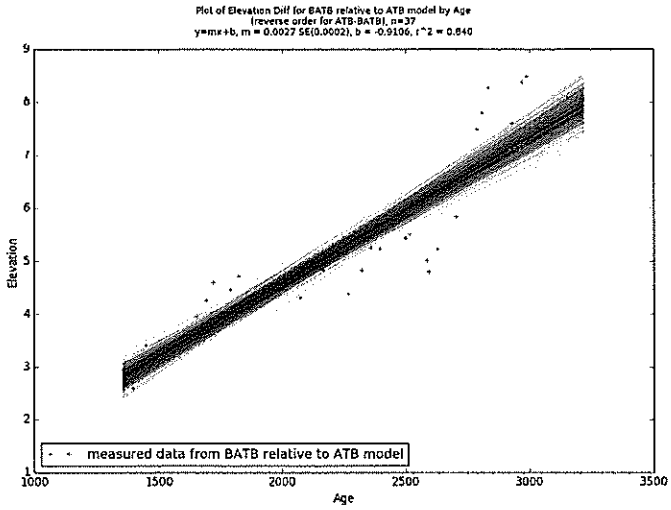


Figure 7: Differences in elevation measured from the BATB data to the ATB model

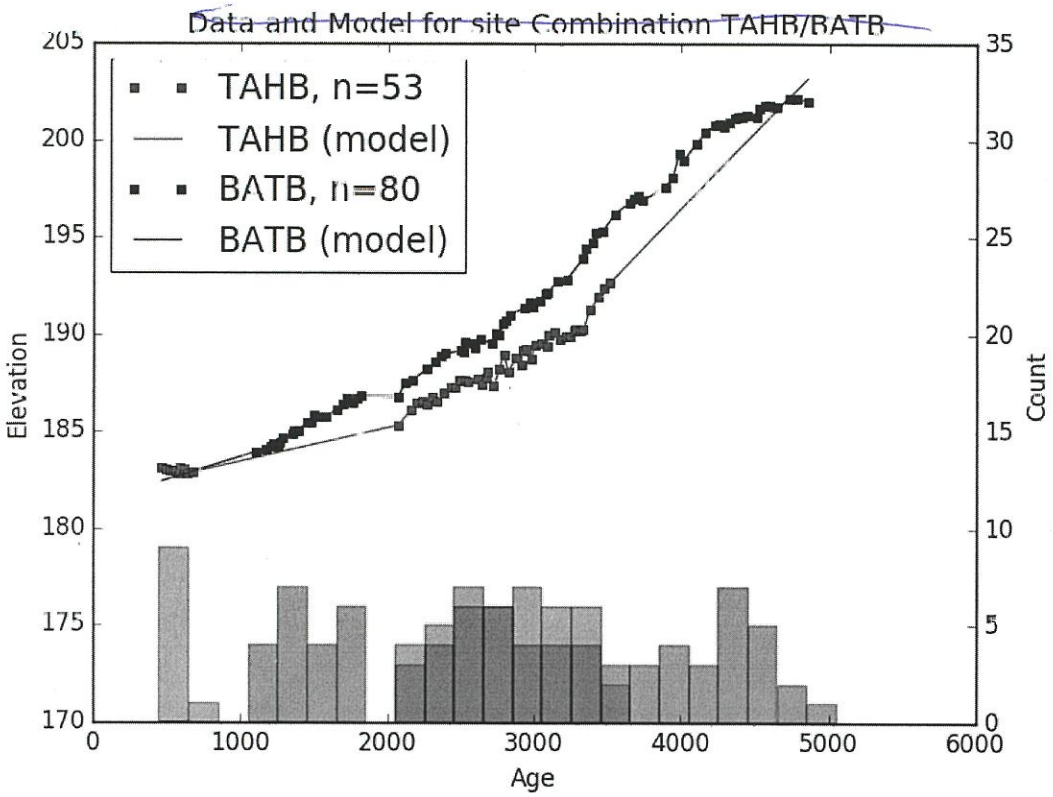


Figure 8: TAHB-BATB raw data with linear interpolation model

The data plot for the site combination of TAHB and BATB shows a common issue with comparing datasets, as the data with ages more recent than the 2000 year before present gap is unsable. This is because the regions where data ~~is~~ are available for one dataset are empty of datapoints for the other, making the modelled prediction of the other dataset ~~highly~~ unreliable. As a result, a filter is applied to the data to prevent this, grouping data points into bins 200 years wide, and ignoring the data points from bins in which either data set had no datapoints, as well as any which had bin counts differing by more than 75% for that bin. As a result, only the data from 2050 to 3650 years before present were used in creating the GIA comparisons.
The linear regressions produced from this dataset seen in Figures 9 & 10, are well constrained, and report a value for relative GIA of between 11-16.7 cm/century.

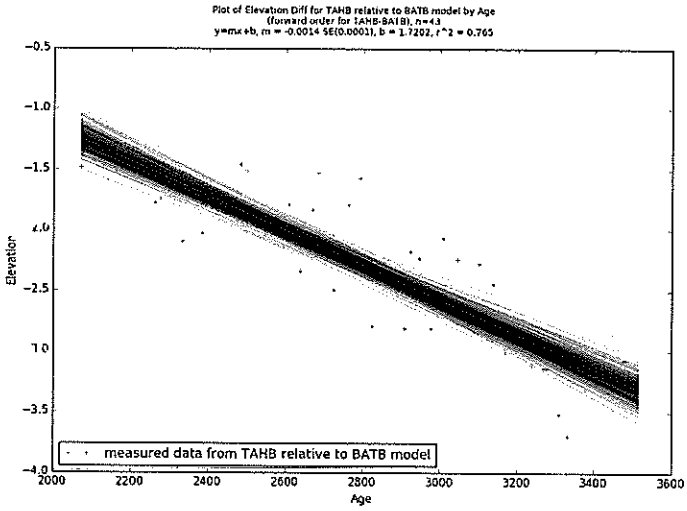


Figure 9: Differences in elevation measured from the TAHB data to the BATB model

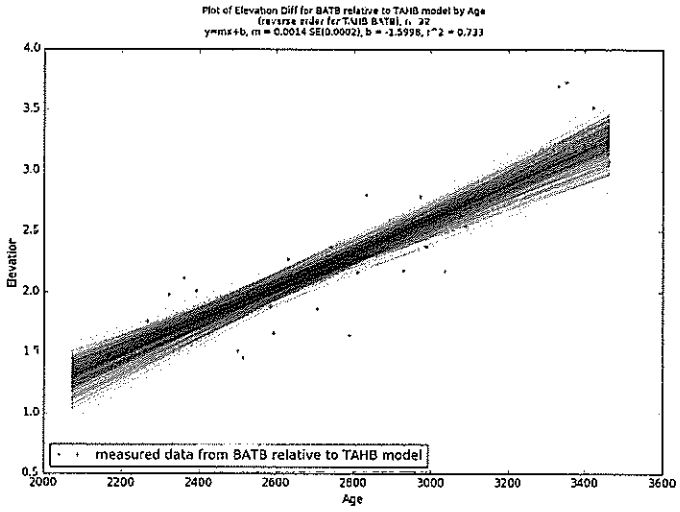


Figure 10: Differences in elevation measured from the BATB data to the TAHB model

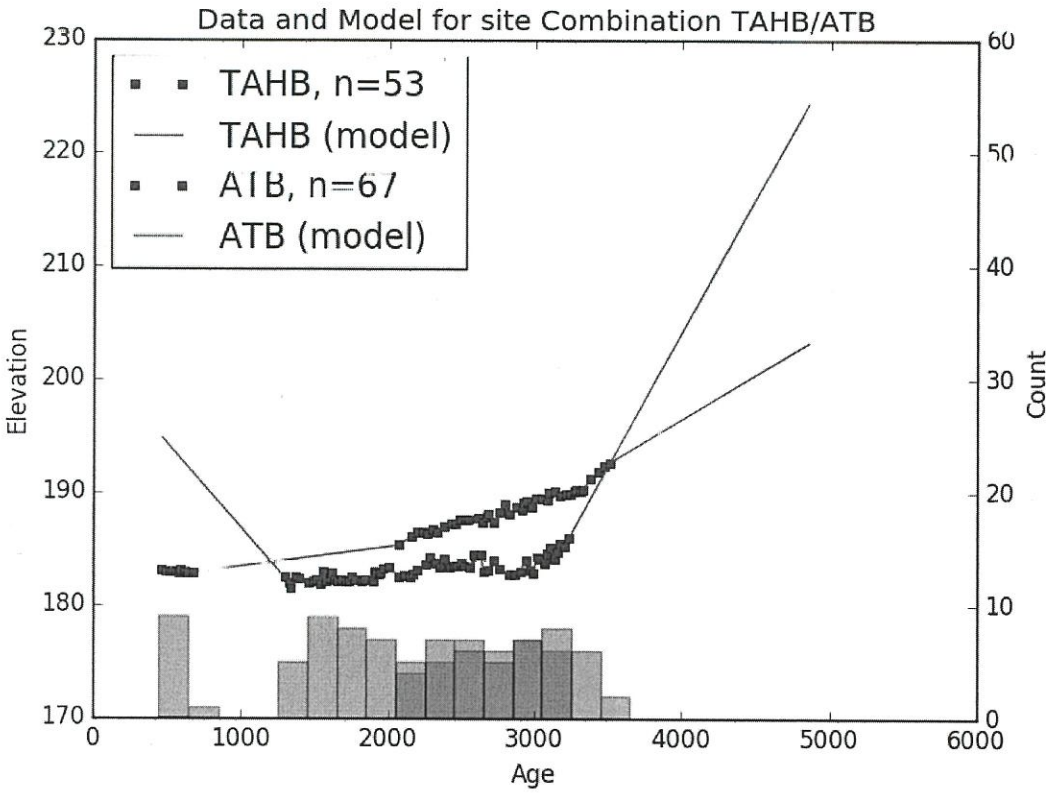


Figure 11: TAHB-ATB raw data with linear interpolation model

Similar to previous datasets, the combination of TAHB and ATB are constrained to ages older than 2050 years before present ~~by the Algoma gap,~~ but also have a much shorter range of age values that can be ~~considered~~ for GIA calculation, ending at around 3100 years before present. This is due to TAHB having no data available between 1250-2050 ~~yBp~~, while ATB has a great deal of data in this range that can not be considered for this comparison. Using only datapoints between 2050 and 3250 years before present results in relatively poor regressions that are not as well constrained, giving a wide range for relative GIA of between 19.4-29 cm/century.

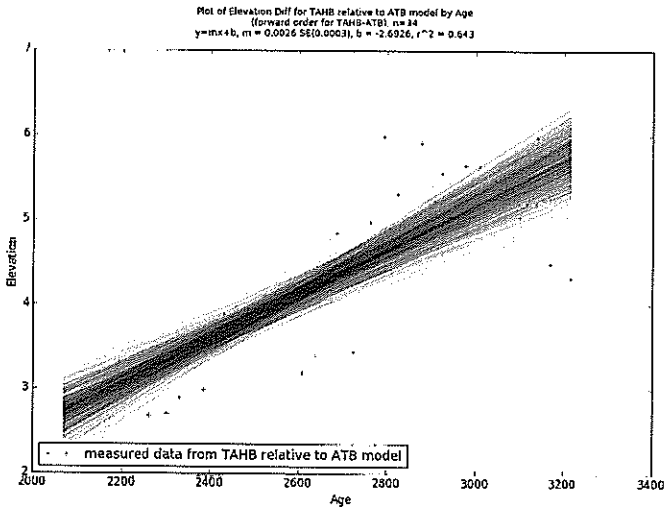


Figure 12: Differences in elevation measured from the TAIIB data to the ATB model

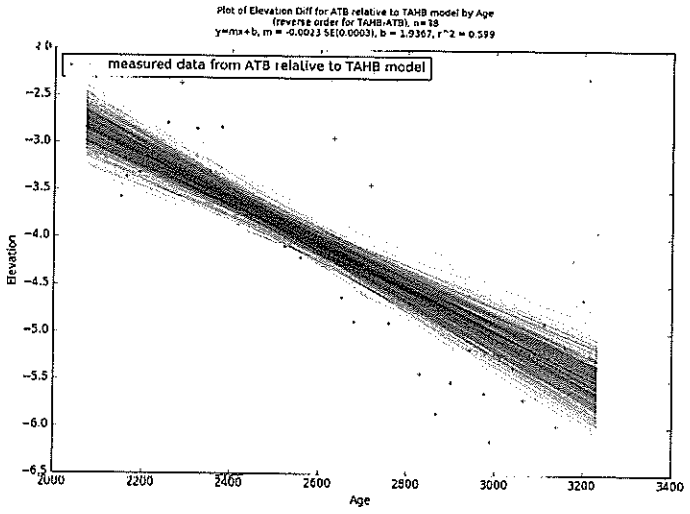


Figure 13: Differences in elevation measured from the ATB data to the TAHB model

Please improve text below - not well described and many places where you are using slang.

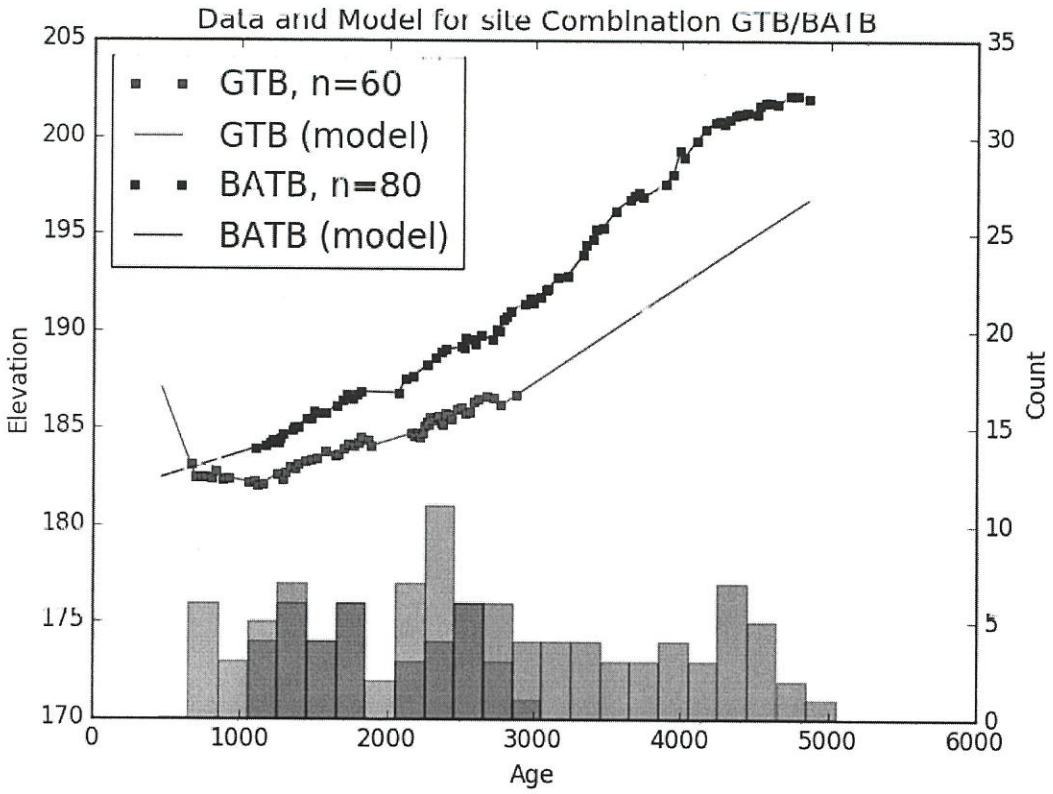


Figure 14: GTB-BATB raw data with linear interpolation model

Need to first describe GTB & BA, Then afterwards you can compare, (At end with chart)

The GTB BATB combination has a data spread similar to that of ATB & BATB, with data available for both datasets from 1050 to 3050 years before present with an ~~Algoma related~~ gap from 1850 to 2050 years before present. The first case of the 75% difference cutoff has its first appearance here as the oldest shoreline available from GTB just falls inside of the 2850-3000 ybp window, causing the entire window to be used if the only criteria was both dataset counts within that window being non-zero. The 75% cutoff prevents this window from being used in this case, as the counts for the 2850-3000 ybp window differ by 120%. This rule is useful in identifying areas of the dataset where both sites have data available, but the density of one of the datasets in that region is low enough to cause ~~issues with the models ability to make~~ accurate predictions ~~in~~ between measured datapoints. The regressions in Figures 15 & 16 bear this out, producing one of the better constrained values at 10.4-12 cm/century.

and

?

reword. slang - does not literally "fall" Please reword.

Good example of rule

potentially

& modelled

slang - please reword.

better than what? First need to report each & Then compare.

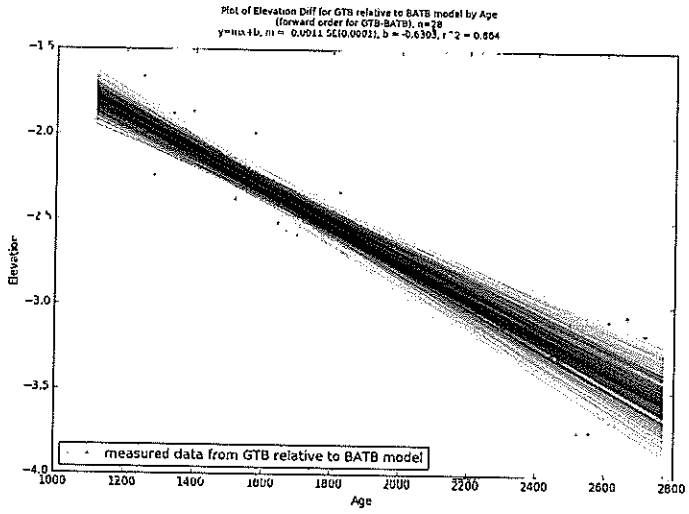


Figure 15: Differences in elevation measured from the GTB data to the BATB model

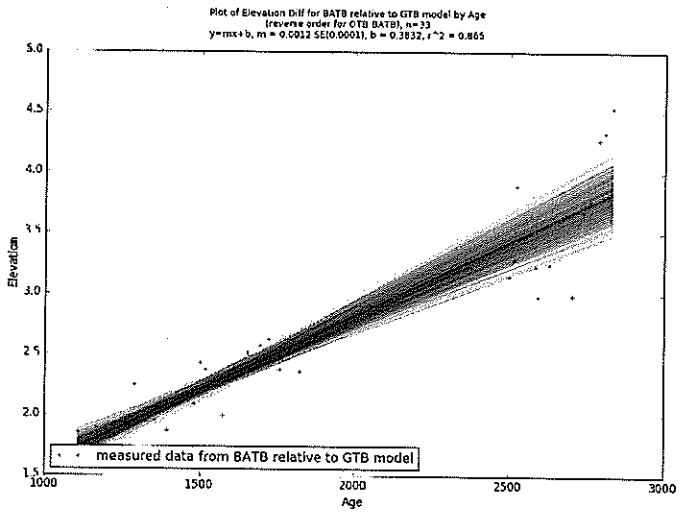


Figure 16: Differences in elevation measured from the BATB data to the GTB model

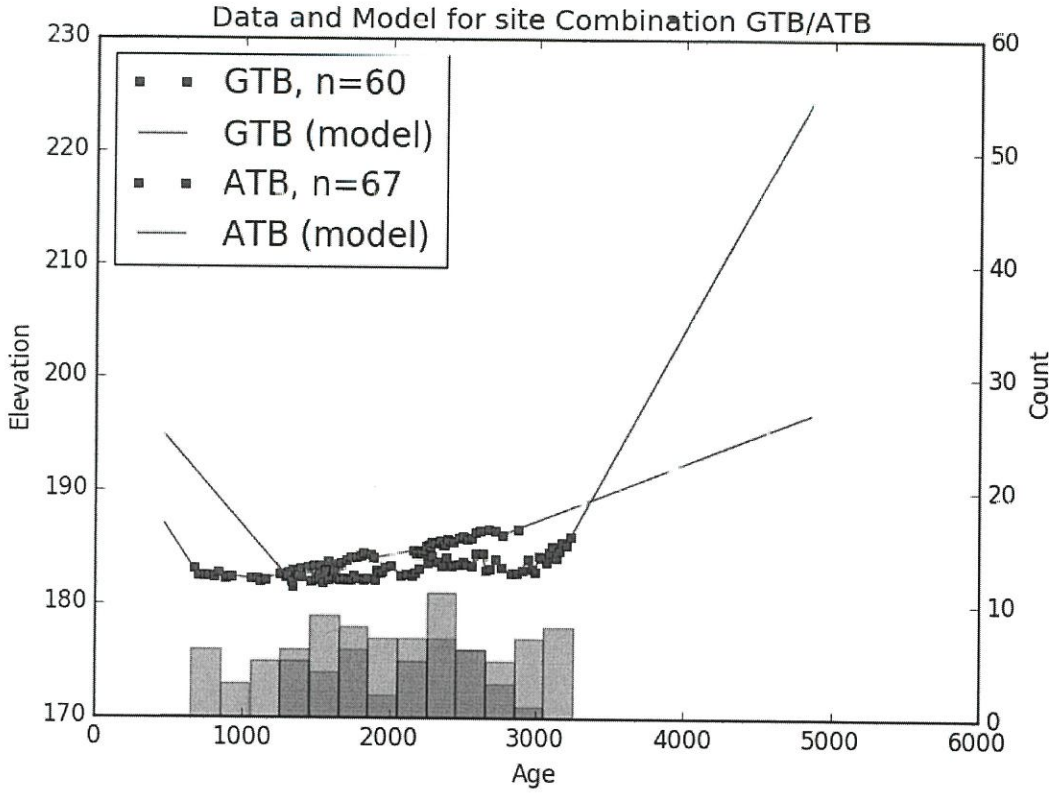


Figure 17: GTB-ATB raw data with linear interpolation model

The GTB-ATB combination is similar to most of the combinations looked at so far, windows from 1250 to 3050 ybp containing data for both sites. Two of these windows fail to qualify for use under the filter due to the site counts differing by more than 75%, one from 1850-2050 ybp, and a second one from 2850 to 3050 ybp. Looking at the graph, it can be seen that both of these windows coincide with ranges of time where GTB has sparse data, making the GTB models predictions unreliable. Possibly due to this, the regressions in Figures 18 & 19 are not the best constrained constrained, giving a rate of GIA of 9-13.4 cm/century.

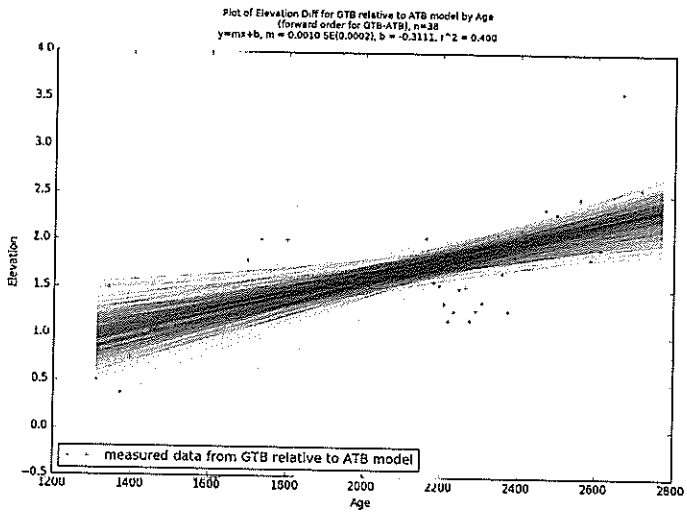


Figure 18: Differences in elevation measured from the GTB data to the ATB model

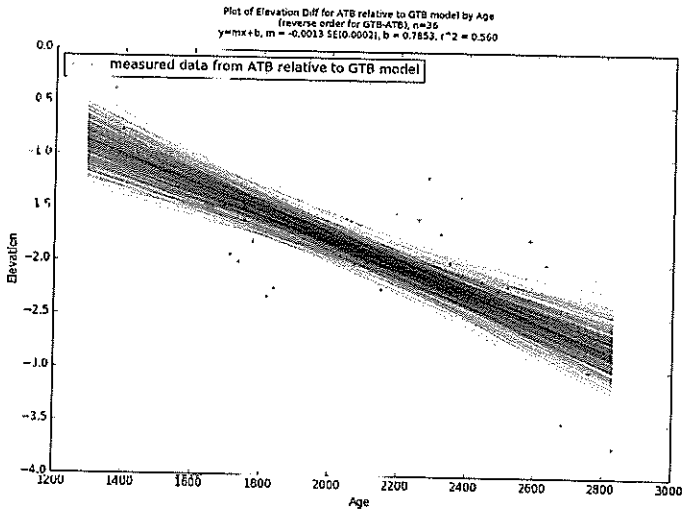


Figure 19: Differences in elevation measured from the ATB data to the GTB model

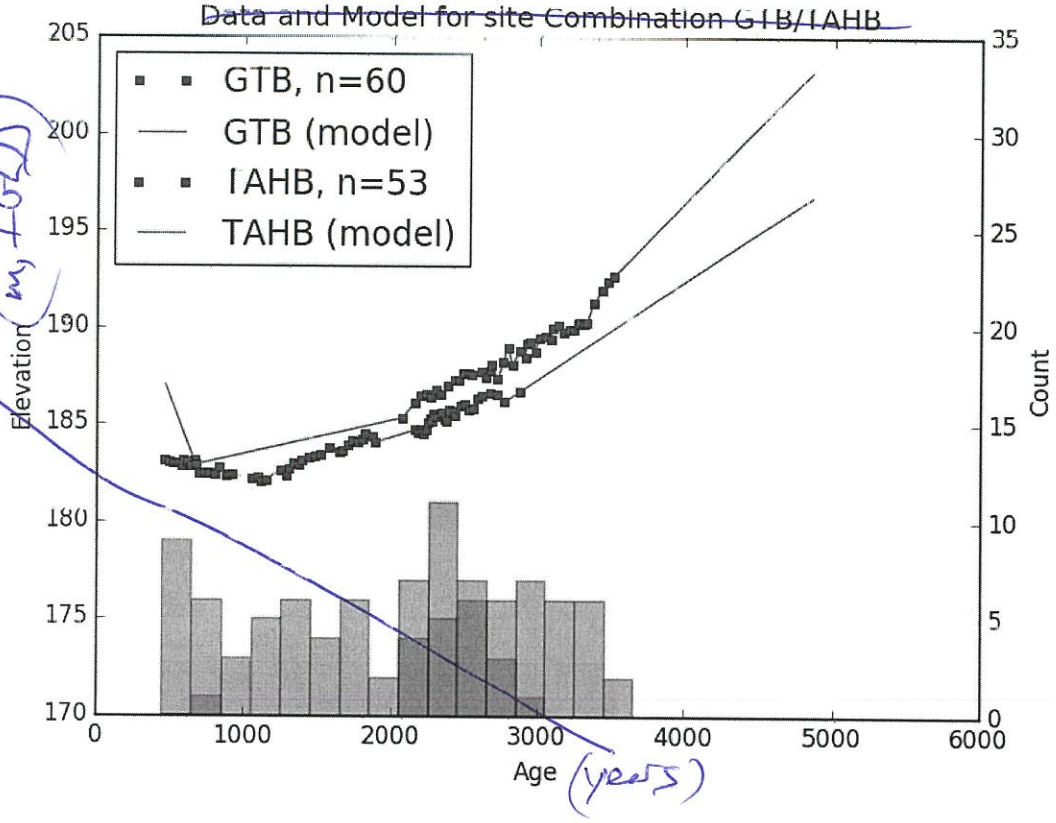


Figure 20: GTB-TAHB raw data with linear interpolation model

~~The final pair of sites.~~GTB and TAHB has by far the most poorly constrained set of regressions, likely due to the alignment of most of both datasets only giving sample sizes of n=22 (Figure 22) and n=27 (Figure 21). This was due to the ~~valid~~ range of data extending only from 2050 to 2850 ybp. Two potential windows at 650-850 ybp and 2850-3050 ybp were thrown out due to not meeting the 75% rule, as bothwould have produced comparisons between areas of data in one dataset and a poorly constrained model in the other. This resulted in an estimate of GIA ~~that~~ ranges ~~anywhere~~ from -2.8-8.6 cm/century, ~~possibly~~ implying that there may be no difference in vertical adjustment rates between ~~the TAHB and GTB sites.~~ This range interestingly includes a potential ~~value~~ of zero ~~or~~ or no GIA between GTB & TAHB.

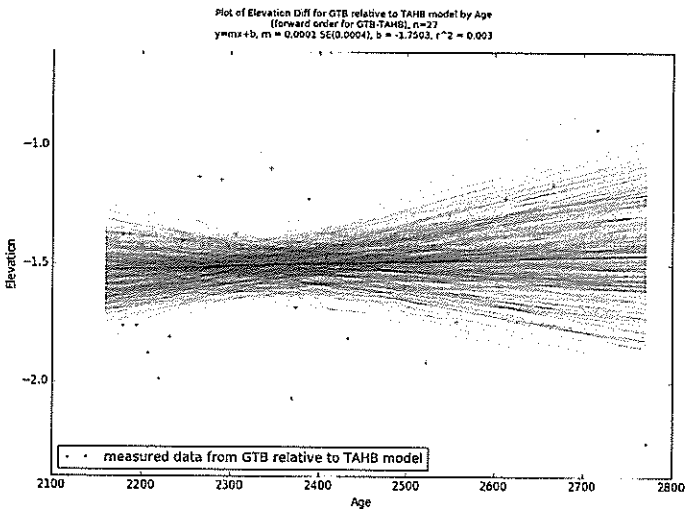


Figure 21: Differences in elevation measured from the GTB data to the TAHB model

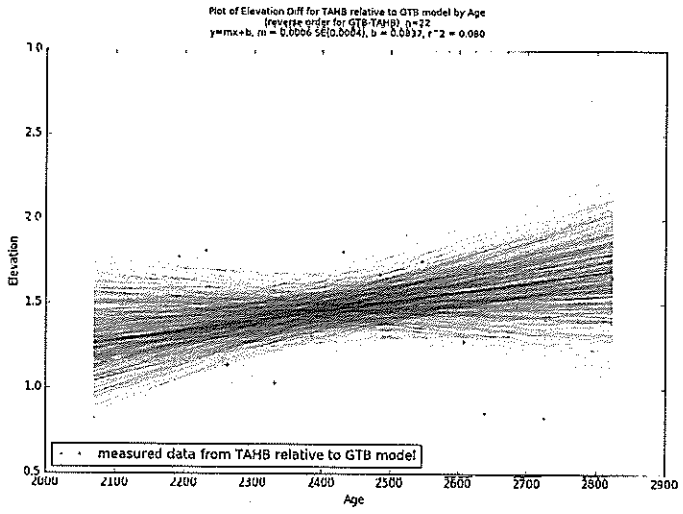
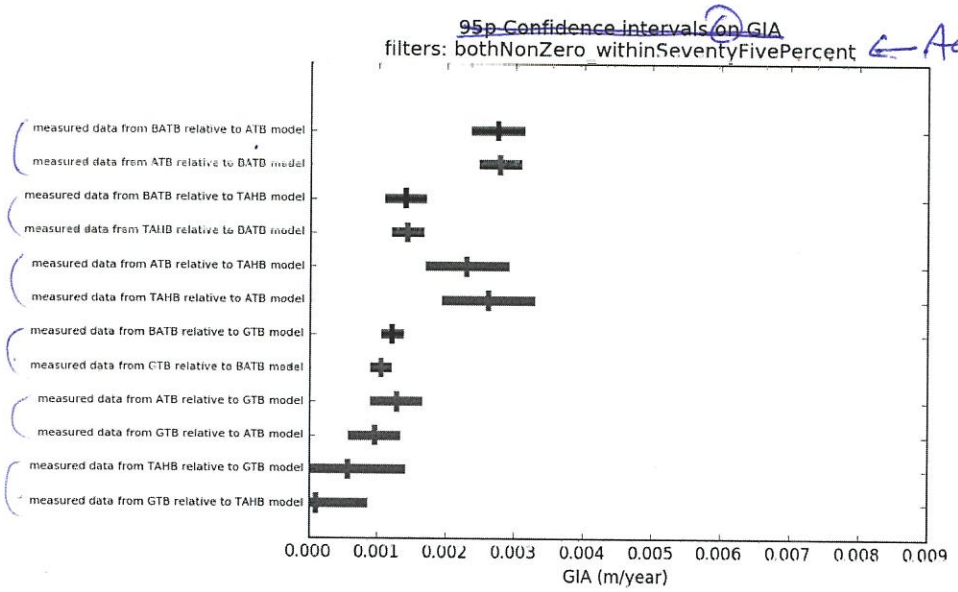


Figure 22· Differences in elevation measured from the TAHB data to the GTB model

Add subtitle before The (sub) section?

Potentially: Summary of site Comparisons



← Add sentence in caption below.

← Have to add table with values as well.

Figure 23: 95p Confidence intervals on GIA rates obtained from site comparisons

↳ write out ↳ calculated

6? combos? between 4 study sites? Please tell reader.

Need to add several paragraphs describing the chart above.

- 6 combos (12 total) - Describe Data
- ~~Stats~~
- Paired sets similar? - Describe 95p value between sites (i.e. ATB & BATB / BATB & ATB)
- Overlap between combos? - Describe if all are the same or similar statistically.
- Describe most well constrained & least well constrained...

~~4~~ ~~Results~~

In the following section, ~~the~~ values for relative GIA produced by this paper are contrasted with ~~those~~ previously obtained by Mainville & Craymer by plotting the difference between each site as a line between sites with the corresponding value next to it on a map.

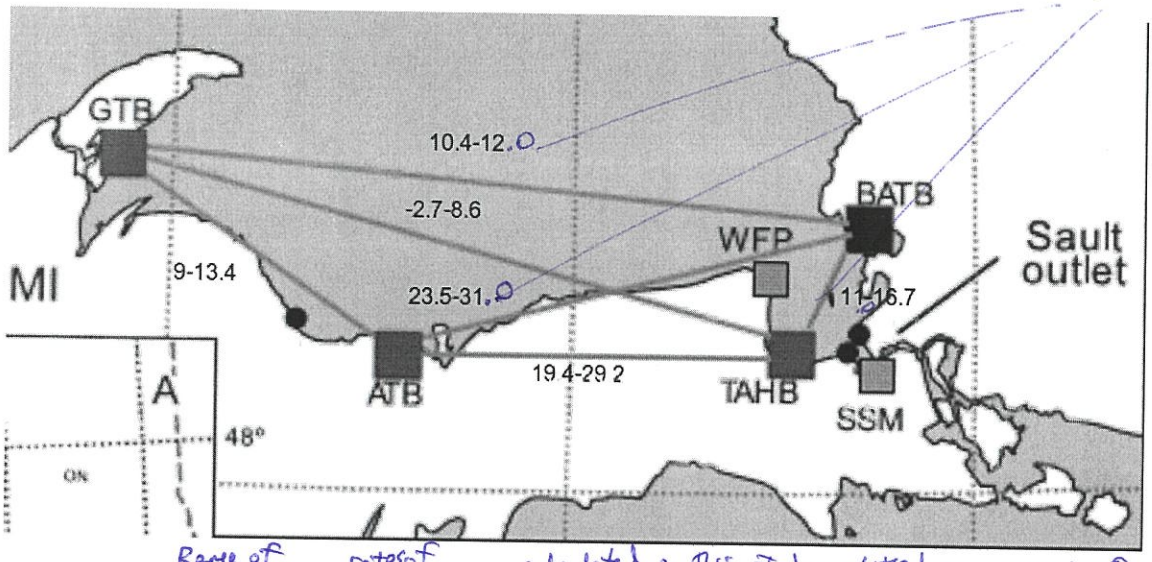


Figure 24: ~~Relative~~ GIA ~~Rates produced by this paper's method~~, all values are reported in cm/century

Then after you summarize your new results Then compare it To M+C(2005) ... but describe M+C(2005) in text first.

— M+C (2005) — water level gauged data? ...
— diff in equally-spaced data over several decades? ...
— surrounded with postglacial model to produce rates of GIA for the entire LGL's.
— for Lake Superior → closest gauge to each study site & value reported? And is it similar to yours?

Discuss & write out in text.

Only 3 close gauges

Marquette -12.2 ± 0.3 / 2 ± 0.9

Point Iroquois 0 / 0

Gros Cap 1.6 ± 0.7 / -8 ± 1.0

↑ Table 3 (M&C 2005)

Not many to compare to your sites.

Need to paraphrase and not plagerize.

Data from M+C(2005) Fig. 7. (tell the reader in text)

BATB — 27
TAHB — 18
GTB — 12
ATB — 9

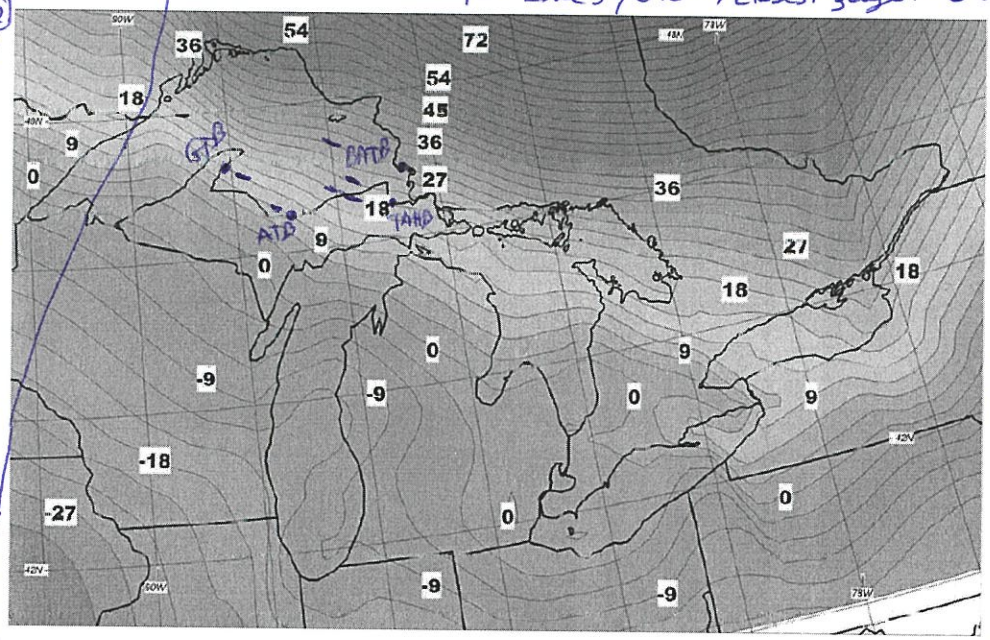


Figure 7. Contour map of vertical velocities derived from water level gauges over the Great Lakes surrounded with ICE-3G–derived velocities. Contour interval—3 cm/century.

Have to discuss values on figure relative to the ~~Port~~ Port Huron / Sarnia outlet (0 $\frac{cm}{cent}$)

Then subtract between these numbers ~~to~~ and add to figure 26.

↑ (correct these #'s)

Figure 25: Relative GIA Rates produced by Mainville & Craymer, all values reported in cm/century (reproduced from Mainville & Craymer, 2005)

The equivalent values for rates between sites as produced by Mainville & Craymer are inferred from subtracting the difference in contour between sites as shown in Figure 25, and are presented in Figure 26.

Place in Table:
- your values
- M+C (2005) values

So, the reader can compare.

And Then plot both on one map.

Then write a paragraph or two describing whether they ~~are~~ are similar or not.

And if they differ by a common pattern (i.e. All your data are greater than M+C(2005) → may suggest ~~your long term data~~ WL gauge data (shorter term data) underestimate rate of GIA?).

→ Johnston et al. (2012) reported rates of GIA: (Adjusted to SSM outlet as 0 $\frac{cm}{cent}$)

BATB = 6 cm/cent.
SSM = 0 cm/cent. (outlet.)
TAHB = −3 —"—
GTB = −9 —"—
ATB = −17 —"—

Johnston et al. (2012) report all rates calculated from straddlers compare except for ATB.

M+C(2005) = −12 $\frac{cm}{cent}$ from SSM to ATB.

Your data supports higher #'s of GIA?

Point Iroquois ≈ TAHB (closest but slightly off)

Marquette ≈ ATB (closest but slightly off)

−12 $\frac{cm}{cent}$ / 19.4–29.2 cm/cent.

Historical water level gauges seem to underestimate rate of GIA.

But lets evaluate rate of GIA between sites using WL gauge & postglacial model of GIA in LGL created by Mainville & Craymer (2005),

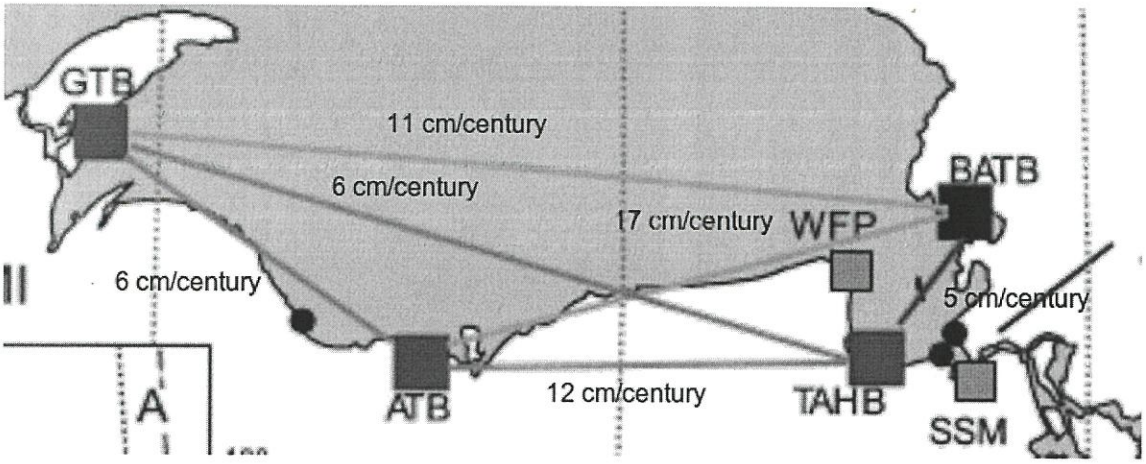


Figure 26: Relative GIA Rates produced by Mainville & Craymer

You have to tell the readers which ones and provide reference to numbers, charts, figs, and sites.

While most of the site comparisons agree reasonably well between the method employed by Mainville & Craymer and this paper, one area where significant disagreement is seen is between sites ATB, BATB, and TAHB, especially in the much larger values produced by this paper between ATB-BATB and ATB-TAHB. Given that both of these site combinations are separated by an East-West line, this could imply that the location of the center of the Laurentide Ice Sheet during the last glaciation being to the north and west of Lake Superior had a stronger effect on the overall process of rebound than the simple fact that areas to the north were more likely to be depressed by the weight of ice sheets than areas further south.

Basis for this claim? Need to reason out argument in logical steps so the reader ~~can see~~ knows the evidence for this interpretation.

Need to guide the reader by explaining the disagreement using numbers, ranges & figures.

All larger? Consistently? And by how much? Provide #'s. Twice or three-times larger? All larger by 10 or different?

Need to reword & create a concluding paragraph while referencing figures.