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## **A new Holocene relative sea-level curve for western Brittany (France): Insights on isostatic dynamics along the Atlantic coasts of north-western Europe**

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1 **A new Holocene relative sea-level curve for western Brittany (France): insights**  
2 **on isostatic dynamics along the Atlantic coasts of north-western Europe**

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17 **Abstract**

18 This study presents new Relative Sea Level (RSL) data that were obtained in the Finistère region  
19 (Western tip of Brittany, France) and the implications those data have for the understanding of the  
20 isostatic dynamics at the scale of north-western Europe, and more specifically along the Atlantic and  
21 Channel coasts. New stratigraphic sequences were obtained and analyzed to derive 24 new Sea-level  
22 Index Points, in which 6 are basal. These new data considerably increase the knowledge we have of  
23 the RSL evolution along the coasts of Western Brittany since the last 8 kyr B.P. From this new dataset,  
24 RSL was estimated to rise continuously over the last 8 kyr with a major inflection at ca. 6 kyr cal. BP.  
25 Our results show large vertical discrepancies between the RSL records of Brittany and South-western  
26 UK, with the latter plotting several meters below the new data. From this comparison we suggest that  
27 the two regions underwent a very different pattern/amplitude of subsidence during the last 8 kyr which

28 has implications for the spatial and temporal pattern of the peripheral bulge of the European ice  
29 sheets. We compared our data against predictions of Glacio-Isostatic Adjustment models (GIA  
30 models). There are large misfits between RSL observations and the predictions of the global (ICE-5G  
31 (VM2a) - Peltier *et al.*, 2004, GLAC1-b - Tarasov & Peltier, 2002; Tarasov *et al.*, 2012, Briggs *et al.*,  
32 2014) and regional UK models ("BIIS" -Bradley, 2009; Bradley *et al.*, 2011-, model of "Kuchar"- Kuchar  
33 *et al.*, 2012), which can't be resolved through significant changes to the deglaciation history and size  
34 of the British-Irish Ice sheet. Paleo-tidal modelling corrections indicate regional changes in the tidal  
35 ranges played a negligible role in the data-model misfits. Hence, we propose that the misfits are due to  
36 some combination of: (i) unaccounted mass-loss of far-field ice-sheets (Antarctic ice-Sheet or  
37 Laurentide Ice-Sheet) or, more likely, (ii) significant lateral variations in the Earth's structure across the  
38 English Channel.

39 **Key words:** Relative sea-level; Holocene; isostasy; GIA models; Tidal-range modeling; Earth  
40 structure; Brittany.

#### 41 **Introduction**

42 During the last decades, there has been extensive effort to reconstruct Holocene relative sea-level  
43 (RSL) histories, with a clear revival of interest in more recent years, due to concerns relating to future  
44 global climate change. Reconstructions of past RSL have proved to be of prime interest to  
45 understanding present-day and possible near future sea-level variations (Bindoff *et al.*, 2007; Church  
46 and White, 2011; Church *et al.*, 2008; Engelhart *et al.*, 2009; Leorri *et al.*, 2012; Gehrels and  
47 Woodworth, 2013). This contributes to understanding the behaviour of coastal sedimentary systems  
48 during periods of RSL rise and provides improved constraints of the vertical movements of the **solid**  
49 **Earth** which have taken place since the Late Glacial Maximum (LGM). During the Holocene, the main  
50 processes driving regional RSL changes are (i) eustatic sea-level rise (ESL) (i.e. the increase of the  
51 volume of the oceans induced by the retreat of the continental ice-sheets, **regional glaciers** and steric  
52 changes), (ii) isostatic dynamics (commonly referred to as GIA ; Glacio-Isostatic Adjustments), i.e.  
53 changes in the topography of the solid Earth induced by the decrease of the ice load following the  
54 retreat of the major land based ice-sheets ("glacio-isostasy") and from the increase of the water-  
55 loading of the continental shelves ("hydro-isostasy") and (iii) tectonic movements, **the relative**  
56 **importance of all these parameters in RSL evolution being variable during the Holocene.** At mid- to

57 high-latitudes, the northern hemisphere was covered by large land-based ice-sheets (e.g. Laurentide,  
58 British-Irish and Fennoscandian Ice-Sheets, noted LIS, BIIS and FIS, respectively, but also the  
59 Innuitian, Cordilleran, Greenland and Kara-Barents ice-sheets) and as such glacio-isostatic dynamics  
60 have been the predominant processes in RSL evolution since the middle Holocene.

61 Glacio-Isostatic Adjustment (GIA) resulting from the melting of these northern hemisphere ice-  
62 sheets is still ongoing, and will play a major role in present-day and near-future RSL changes along  
63 the coasts of the northern hemisphere. The Holocene RSL signal across NW Europe is mainly driven  
64 by the GIA resulting from the regional ice sheets (i.e. the “Fennoscandian Ice-Sheet” and the “British  
65 Irish Ice-sheet”, respectively noted FIS and BIIS hereafter). Therefore, recent sea-level observations  
66 from tide gauges and satellites contain remnant GIA signals that must be taken into account when  
67 isolating eustatic and steric signals (e.g. Peltier, 2001; Tamisiea and Mitrovica, 2011, Wöppelmann &  
68 Marcos, 2012). Understanding the regional GIA dynamics is hence crucial before reliable scenarios of  
69 future regional RSL rise can be proposed. To address this problem, numerical geophysical models  
70 (termed Glacio-Isostatic Adjustment models or “GIA models”) have been developed since the early  
71 seventies. These models provide RSL predictions for any particular location on the surface of the  
72 Earth by solving a unified set of equations (the Sea-Level Equation, “SLE”, Farrell and Clark, 1976)  
73 that merges (i) an “Ice model”, which defines the history of the major land-based ice sheets and (ii) a  
74 rheological model (“Earth model”) describing the behaviour of the Earth’s surface in response to  
75 surface load changes, and (iii) the changes in gravitational field induced by the redistribution of the  
76 mass at the Earth’s surface (melting of the ice-sheets) and within the Earth’s interior (displacement of  
77 mantle material due to isostatic adjustment) (e.g. Mitrovica and Peltier, 1991; Peltier, 1998; Mitrovica  
78 and Milne, 2003; Spada *et al.*, 2012). Significant regional misfits continue to exist between predicted  
79 and observed RSL (e.g. Engelhart *et al.*, 2012; Oostanciaux *et al.*, 2012), which suggest errors and/or  
80 simplifications in the ice history and/or earth rheology components of the GIA models. Hence, precise  
81 and reliable RSL observations are still needed in many places to better constraint GIA models.

82 In Northwestern Europe, sea-level reconstructions have been produced since the seventies. The  
83 most intensive research efforts were conducted around the British Isles, especially along the northern  
84 and eastern coasts of the UK. The dense RSL dataset obtained in Great Britain served as a basis for  
85 the development and the fine-tuning of regional GIA models (Shennan *et al.*, 2006; Bradley *et al.*,  
86 2011; Kuchar *et al.*, 2012). Results recently published by Bradley *et al.* (2011) and by Shennan *et al.*

87 (2012) agree for present-day land subsidence rates of ca. 0.5 to 0.8 mm/yr<sup>-1</sup> in Devon and Cornwall.  
88 However, Bradley *et al.* (2011) and Kuchar *et al.* (2012) note misfits of several meters between  
89 geological reconstructions and regional model predictions for the Southwest UK. In this study, we  
90 propose to push the comparison between Holocene RSL and GIA model predictions a few hundred  
91 kilometers south on the other side of the English Channel.

92 Within the framework of a coastal risk assessment research program (ANR COCORISCO, French  
93 National Research Agency), extensive fieldwork has been conducted during the past four years  
94 around the Finistère peninsula (Western Brittany, France). Along with the study of Holocene paleo-  
95 storminess, which was the prime objective of the research program (Van Vliet *et al.*, 2014a, 2014b),  
96 many of the sampled sedimentary sequences could also be successfully analyzed to derive RSL data.

97 The first objective of this study is to obtain new precise and reliable sea-level index points (SLIPs)  
98 for the Western Brittany region with a particular emphasis placed on recovering compaction-free basal  
99 SLIPs. The second objective is to explore the implications of these new RSL data for the isostatic  
100 dynamics of the coasts of Western Europe, following a two-step approach. First, we perform a regional  
101 comparison of our data with the RSL history proposed for the closest region for which a well-  
102 constrained Holocene RSL record is available (Southwest UK). We thereby evaluate if isostatic  
103 gradients can be identified on the basis of RSL data alone. Second, we compare our new data against  
104 predicted RSL from both global and regional published GIA models. We also discuss the origin of the  
105 misfits between our data and model predictions, with a particular emphasis on local- to regional-scale  
106 factors which can potentially influence paleo-RSL.

### 107 **1. Relative sea-level histories of the French Atlantic and Channel coasts: previous studies**

108 Despite the several RSL studies that have been conducted since the seventies along the  
109 French Channel and Atlantic coasts (Delibrias and Guillier, 1971; Ters, 1973; Morzadec-Kerfourn,  
110 1974; Ters, 1986, Van de Plassche, 1991; Goslin *et al.*, 2013; Stéphan *et al.*, 2014), there remains a  
111 lack of reliable and high-quality Holocene basal SLIPs (Stéphan and Goslin, 2014). For the Finistère  
112 region (western tip of Brittany), only two studies achieved a sufficient data density to derive Holocene  
113 RSL reconstructions (Morzadec-Kerfourn, 1974; Stéphan *et al.*, 2014). However, none of these studies  
114 included data prior to 6000 yr B.P., nor sufficient basal data to provide reliable conclusions on the  
115 Holocene RSL evolution in Western Brittany. Additionally, Goslin *et al.* (2013) showed that a re-

116 assessment of the oldest data from the region, extracted by state-of-the-art methods, leads to a further  
117 reduction by up to two thirds of the number of SLIPs which can be considered reliable. At a larger  
118 scale, the data from Delibrias and Guillier (1971), Ters (1973, 1986), Morzadec-Kerfourn (1974) and  
119 Van de Plassche (1991) formed the main constraint for modeling work of Lambeck (1997) and Leorri  
120 *et al.* (2012). These studies aimed to quantify the contributions of the glacio- and hydro-isostatic  
121 components in the RSL histories of the Atlantic coasts of Europe. Both studies proposed that a North-  
122 South trending glacio-isostatic gradient could have influenced the European Atlantic coasts, due to the  
123 influence of the north-western European peripheral bulge that formed in response to the combined  
124 influence of the BIIS and FIS ice loads. This gradient would have extended from the southern coasts  
125 of UK to the south of the Bay of Biscay (Lambeck, 1997) or even as far as South Portugal (Leorri *et*  
126 *al.*, 2012). However, as Goslin *et al.* (2013) recently suggested, the field-data used by Lambeck (1997)  
127 and by Leorri *et al.* (2012) for the Brittany region should not be considered reliable enough to  
128 conclusively validate the outputs of their GIA models. Hence, the proposed isostatic gradients along  
129 the western Atlantic coasts of France and Spain are still to be ascertained. In northwest Europe, Vink  
130 *et al.* (2007) evidenced for a continuous heightening of the RSL records when progressing from  
131 northern France to southern Denmark that illustrated a progressive damping of the FIS peripheral  
132 bulge isostatic subsidence towards its tail. Unfortunately, the lack of basal data along both sides of the  
133 English Channel coasts has up to now prevented from following this trend further west, while the  
134 signal becomes more and more complex as it sums up with the isostatic signal induced by the BIIS  
135 loading and hydro-isostasy. Finally, offsets between tide-gauge records at Brest and Newlyn  
136 (Cornwall, Southwestern UK) (ca. 1.41 mm/year and 1.74 mm/year, respectively) hint for different  
137 recent RSL rise rates between the two locations (Woodworth *et al.*, 1987; Douglas, 2001, Haigh *et al.*,  
138 2009). Considering the proximity of the two stations, located ca. 200 km apart, and the absence of any  
139 tectonic active process which could account for such a ca. 0.3mm.yr<sup>-1</sup> differential in vertical land-  
140 movement, this difference is still unexplained (Douglas, 2008; Wöppelmann *et al.*, 2008, Haigh *et al.*,  
141 2009).

142 In this context, obtaining new high-quality RSL data in the Finistère (Western Brittany) region was  
143 critical to improving the understanding of Holocene isostatic dynamics and the RSL history along the  
144 Atlantic coasts of Europe. Located ca. 200 kilometers directly south of Cornwall, Brittany also  
145 remained ice-free during the Late Pleistocene. It can be considered, together with Southwest UK

146 (Massey *et al.*, 2008), as a key area to constrain the extent, amplitude and dynamics of the north-  
147 western European peripheral bulge and the ESL signal over this period.

## 148 **2. Regional settings and study sites**

### 149 2.1 Geological, geodynamic and physiographic settings

150 The Finistère region is situated at the western end of the Armorican massif, which is bounded on  
151 this northern termination by the North-Armorican scarp marking the entrance of the English Channel  
152 geological system. The latter is characterized by a system of grabens, delimited by a dense network of  
153 multi-kilometric deep crustal faults (up to 7 to 10 kilometers, Evans, 1990; Lericolais, 1997; Lagarde *et*  
154 *al.*, 2003). The northern and southern parts of the Finistère region are composed of granitic batholiths  
155 domains that were emplaced during the Cadomian and Variscan orogenies. In those regions, the  
156 basement is mainly composed of endogenous granites and metamorphic rocks (gneisses and  
157 amphibolites). In between those plutons, a synclinal deformation hosts sandstones and shale  
158 formations of Palaeozoic age. Brittany is considered to have undergone a long step-wise passive  
159 margin subsidence since the opening of the Bay of Biscay between the Jurassic and the Late and  
160 Early Cretaceous (Evans, 1990; Van Vliet *et al.*, 1997; Bonnet *et al.*, 2000). The Finistère region is  
161 currently undergoing compression due to the ongoing northward motion of the Iberian plate (Wyns,  
162 1991; Bonnet *et al.*, 2000). This dynamic results into a low-intensity and diffuse seismicity that remains  
163 concentrated along two majors faults (the *North-* and *South-Armorican Shear Zones*, Lagarde *et al.*,  
164 2003). Large earthquakes (of magnitudes equal to or greater than 5.5) are unusual (centennial) and  
165 mainly concentrated within the Cotentin region, in the central part of the English Channel. Seismic  
166 activity can be considered to have been of equal magnitude and frequency during the Holocene, and  
167 thus to have had none or insensible impacts on the sedimentary sequences of this period.

### 168 2.2 Rationale for study sites selection

169 The Finistère peninsula is exposed to macro- to meso-tidal conditions, with spring tidal ranges  
170 decreasing from up to 7.5 m in the north to ca. 4 m in the south of our study area (table 1). Present-  
171 day local tide data were obtained either from the nearest tide station(s) (SHOM, 2012, French Navy  
172 Oceanographic Agency) or by interpolation between the two nearest tide stations.



173 New stratigraphic data were collected from six sites (Guissény, Landéda, Porsmilin, Treffiagat,  
174 Kermor-Tudy and Guidel) which covered the entire study area (Fig.1), and sampled a range of very  
175 diverse morphological configurations: open embayments, inner rias, open coast and estuarine back-  
176 barrier sites (classification after Allen, 2000). The spatial spread of the study sites was chosen to  
177 improve the regional representation of the reconstructed RSLs. Finally, the extended north-south  
178 spread of the study sites allowed (i) the differences in tidal ranges to be assessed and (ii) investigation  
179 of the RSL signal from sites located at variable distances from the former centres of the paleo-ice-  
180 sheets (and thus situated in different positions along the glacio-isostatic gradient).

### 181 3. Material and Methods

#### 182 3.1 New data

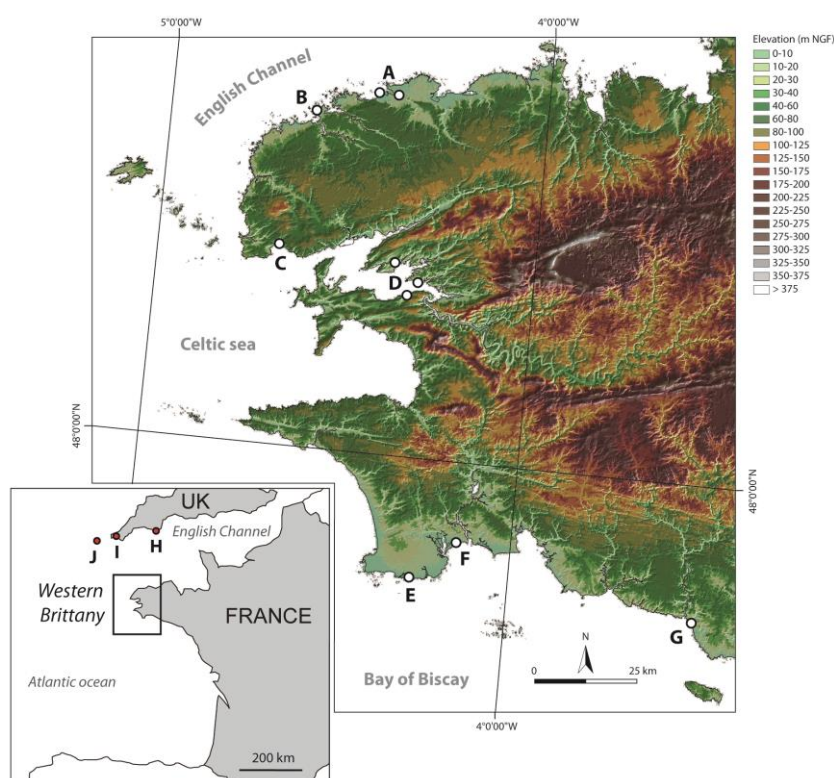
##### 183 3.1.1 Sampling and surveying

184 Most of the sampling was from coring (using an Eijkelkamp 60-mm diam., hand-held motor-driven  
185 percussion corer that extracts 1m sections in plastic tubes). For some sequences that comprised thick  
186 layers of sand and a thick water table (Kermor and Guidel sites, see fig.1 and section 4.1), buoyancy  
187 problems prevent us from using percussion corers. The BRGM's (French Research Agency for  
188 Geology and Mines) sedidrill mounted-rig was then used. Extreme precautions were taken to identify  
189 and sample undisturbed sediment and drillings were cross-checked in order to ensure the stratigraphic  
190 continuity. This latter is also ensured by the high-resolution paleo-environmental studies that have  
191 been made on the same sequences (Fernane *et al.*, 2014, 2015). Finally, some short sequences were  
192 retrieved from the foreshore using a hand-gouge prior to this study. All sites were positioned using a  
193 Trimble 5800 DGPS and tied to IGN (French National Geographic Institute) benchmarks. Elevations  
194 were determined with respect to the NGF datum (French levelling datum).

##### 195 3.1.2 Sedimentary analyses and dating

196 All sedimentary sequences were described in the laboratory in terms of grain size, colour, organic  
197 and macrofossil contents. Particular attention was paid to identify possible reworked levels or  
198 erosional surfaces. Radiocarbon AMS dating was performed after the material was washed, dried and  
199 carefully selected under the microscope. Whenever possible, plant remains were preferred as their  
200 fragility reduces the risk of re-deposition (Gehrels *et al.*, 1996; Törnqvist *et al.*, 1998; Gehrels, 1999).

201 Potentially reworked material such as drift wood or charcoal was dated only when no other material  
202 was sufficiently available. Marine shells were dated only if found complete and in living position within  
203 the deposits. AMS radiocarbon measurements were performed at the “*Laboratoire de Mesure du*  
204 *Carbone 14*” (Gif-S/Yvette) and at the Poznan Radiocarbon Laboratory (Poland). Dates were  
205 calibrated after correction for isotopic fractionation using Calib 7.0 with the IntCal13 and the Marine13  
206 calibration curves for the terrestrial and marine material, respectively (Reimer *et al.*, 2013). Dates are  
207 reported with a  $2\sigma$  (95%) confidence interval.



208  
209 **Figure 1 - Location map of the study area and of the study sites.** A) Guissény -Tressény (inner dot) &  
210 Guissény-Vougot (outer dot), B) Landéda, C) Porsmilin, D) Bay of Brest, E) Treffiagat, F) Kernor-Tudy, G) Guidel  
211 Loc'h. (H, I, J) are the locations of the SW England Holocene RSL records to which we compare our data to  
212 (section 4.4).

### 213 3.1.3 Paleo-RSL elevation reconstruction

214 We follow the SLIP methodology (Shennan, 1986; Van de Plassche, 1986) to reconstruct RSL  
215 changes. For a general view on RSL reconstruction methods and on the SLIP methodology, readers

216 are referred to Shennan *et al.* (2015). In short, a valid index point requires the following information: (i)  
217 the latitude and longitude of the site, (ii) the altitude (and associated uncertainties) of the surface, (iii)  
218 an age and (iv) an Indicative Meaning (IM). The IM of a sample is the altitude of the original deposition  
219 tied to a paleo-tidal reference level (e.g. Mean High Water Spring Tide MHWST or Mean tide Level  
220 MTL). In this study, the elevation of each SLIP was calculated according to the following formula:

$$SLIP = H - D - I + T + A$$

221 where  $H$  is the elevation of the top of the core in meters relative to the reference water level;  $D$ , the  
222 depth of the sample in the core in meters;  $I$ , the Indicative Meaning in meters (in this study the IM was  
223 taken relative to the Mean High Water Spring Tide of each site),  $T$  the correction brought to  $I$  to include  
224 changes in paleo-tidal ranges and  $A$  the potential post depositional autocompaction undergone by the  
225 studied intercalated layer since deposition (uncorrected within this study).

226 SLIPs are then weighted with  $E_s$  the sum of altitudinal error terms potentially introduced at each  
227 stage of the reconstruction. For each index-point,  $E_s$  can be calculated from the following expression  
228 (Horton *et al.*, 2000):

$$E_s = \sqrt{E_1^2 + E_2^2 + E_n^2}$$

229 where  $E_1 \dots E_n$  are the elevation uncertainties affecting the given sample. For example (i) the possible  
230 deformation of the sequences during the coring (e.g., compaction induced by the percussion); (ii) the  
231 non-verticality of the core that can lead to an under-estimation of the sample depth; (iii) the potential  
232 flexure of the rods during hand-augurings; (iv) the potential “twirl” effect on the intercalated samples  
233 retrieved with the screw-drilling rig; (v) the leveling uncertainties inherent to DGPS measurements; (vi)  
234 the error in tying the station altitude to the IGN benchmark, and finally (vii) the uncertainty inherent to  
235 the calculation of the IM, which is defined as the “Indicative Range” (IR). This later uncertainty  
236 depends on the methodology used to determine the Indicative Meaning and on the specific tidal  
237 parameters of each site. The various terms used to calculate the elevation uncertainties are  
238 summarized in table 2.

239 Changes in tidal regimes during the Holocene are an additional, and significant, source of error in  
240 RSL reconstructions. Indeed, paleo RSL positions are most often derived from indicators which were  
241 emplaced within the high-tide domains. Therefore, changes in the tidal ranges through time can result

242 in paleo-RSL positions that differ from the “true” Mean Sea Level (MSL) signal that represents  
243 “allogenic” RSL change (as termed by Gehrels, 1995). Estimating the paleo changes in local tidal  
244 ranges is even more crucial when observational data are to be compared with RSL predictions  
245 produced by GIA models, which are defined relative to the MSL. In this study, the effects on RSL  
246 reconstructions of possible changes in the tidal range in our study area have been obtained following  
247 a modelling approach, described in section 3.3.2. **This is one of the few studies to date where paleo-**  
248 **tidal corrections have been applied in the reconstruction of RSL histories in NW Europe (Shennan *et***  
249 ***al.*, 2000; Shennan and Horton, 2002, Neill *et al.*, 2010).**

250 Indicative meanings are traditionally determined through the use of micro-fauna assemblages (e.g.  
251 Horton *et al.*, 2006; Massey *et al.*, 2008; Kemp *et al.*, 2009, Kemp *et al.*, 2013, Stéphan *et al.*, 2014).  
252 Within most of our sedimentary sequences, foraminifera were scarce or totally absent while diatoms  
253 were rare and limited to some particular layers. To overcome this difficulty, we determined indicative  
254 meanings using salt-marsh surface sediment stable carbon isotope ratios ( $\delta^{13}\text{C}$ ) and bulk  
255 geochemistry (TOC, TN, C/N ratio). The latter is an alternative RSL reconstruction approach whose  
256 usability in micro-fauna poor saltmarsh environments has been recently highlighted (Engelhart *et al.*,  
257 2013; Goslin, 2014). We used the modern geochemical reference constructed for our study region by  
258 Goslin (2014). **Complete details on the development and use of this reference, along with the**  
259 **protocols followed and the obtained results can be found in Supplementary Online Material (SOM,**  
260 **appendix S1).** In short,  $\delta^{13}\text{C}$ , TOC and TN measurements were made on modern sediments sampled  
261 at the surface of three saltmarshes located in Brittany. Samples were taken along transects running  
262 from the low marsh to the high-marsh brackish to freshwater transitional domain. We combined the  
263 results obtained from the surfaces of the three marshes to build a modern geochemical regional  
264 training set. Clustering statistical analyses (Partitioning Around Medoids, PAM) were then made on  
265 the whole dataset to decipher whether groups of comparable  $\delta^{13}\text{C}$ , TOC and TN values could be  
266 identified along the tidal frame. This way, we identified four elevational groups characterized by  
267 specific values of  $\delta^{13}\text{C}$ , TOC and TN and altitudinally bounded. Palaeo salt marsh elevations (and *i.e.*  
268 palaeo RSL positions) were then reconstructed from Holocene cores using Linear Discriminant  
269 Functions, that allow to determine the probability for palaeo observations (core samples) to be  
270 allocated to one of pre-specified classes (here, to one of the biozones obtained above by PAM from  
271 modern samples and characterized by specific values of  $\delta^{13}\text{C}$ , TOC, and TN). Palynological data were

272 also used when available (Morzadec-Kerfourn, 1974; Fernane *et al.*, 2014). Deposits that could not be  
273 directly related to the reference water level were used to provide limiting points: terrestrial freshwater  
274 deposits gave high-limiting points; and marine deposits, low-limiting points (Shennan *et al.*, 2015).  
275 **Indicative meanings that were used are summarized in table 3.**

276 As proposed by Engelhart *et al.*, (2012), we classified our SLIPs into three categories (see  
277 Engelhart *et al.*, 2012 for a full description of these categories): (1) Base of Basal deposits (noted  
278 “BB”), considered to provide compaction-free index-points (thus of prime reliability for RSL  
279 reconstruction); (2) Basal deposits (noted “B”, possible but limited autocompaction); finally (3) the  
280 SLIPs derived from Intercalated deposits (noted “I”, prone to autocompaction, non-corrected within this  
281 study).

### 282 3.2 Additional data

283 RSL data previously produced by Morzadec-Kerfourn (1974) in the North Finistère region were  
284 thoroughly re-assessed (recalibration of the dates, new determination of the indicative meaning,  
285 assignation of error terms) before they were incorporated into our dataset. The details of these re-  
286 assessments can be found in Goslin *et al.* (2013). This included reassessment of the salinity regime of  
287 some of the basal peat from these previous studies using a mixed palynological and geochemical  
288 approach (Goslin *et al.*, 2013). When it could be ascertained that these basal peats were deposited  
289 within a brackish environment, it was considered that they formed between the Mean High Water  
290 Neap Tide (MHWNT) and the Highest Astronomical Tide (HAT) levels (Goslin *et al.*, 2013). Recent  
291 RSL data published by Stéphan *et al.* (2014), mostly obtained from salt-marshes of the Bay of Brest,  
292 were incorporated as published. Data we retained from previously published studies of Goslin *et al.*  
293 (2013) and Stéphan *et al.* (2014) are summarized in table 5, with their original error terms.

### 294 3.3 Modelling

#### 295 3.3.1 Geophysical glacio-isostatic adjustment modelling

296 We compared the RSL predictions of five GIA models (five different ice and Earth models  
297 combinations) against the new RSL data obtained in this study. We utilised two global ice models. **The**  
298 **“ICE-5G” model, developed by Peltier (2004) is a non-glaciological ice-loading model that has been**  
299 **hand-tuned to provide best-fit predictions to an extensive global database of RSL and GPS records.**

300 The second global (“Glac1-b”) model is a set of interim results for an ongoing large ensemble  
301 Bayesian calibration of the Glacial Systems Model (GSM) which includes a 3D thermomechanically  
302 coupled ice sheet component (Tarasov *et al.*, 2012; Tarasov, 2013). The constraint data set for the  
303 calibration includes most of the same data use to tune ICE-5G along with additional ice sheet specific  
304 data such as strandline records of pro-glacial lake levels and marine limits for North America and the  
305 dynamic model fit to present-day observed ice topography and thickness for Antarctica and  
306 Greenland. Glac1-b contains components from Tarasov & Peltier, 2002 (Greenland); Tarasov *et al.*,  
307 2012 (North America), Briggs *et al.*, 2014 (Antarctica), and a yet unpublished component for Europe  
308 (that has been validated for the Barents/Kara region against GRACE observations in Root *et al.*,  
309 2015). We also utilized two regional models which were combined with the global ice model “Brad15”,  
310 an extension of the global model of Bassett *et al.* (2005) constrained with new Holocene RSL data  
311 from China and Malay-Thailand (Bradley, 2009; Bradley, 2011; Bradley *et al.*, submit.). The “BIIS”  
312 model was originally published in Bradley *et al.*, (2011). It was developed by combining Brad15 with a  
313 UK-Ireland ice sheet model (Brooks *et al.*, 2008). The latter was developed to fit the UK  
314 geomorphological data and fine-tuned to fit the British-Irish RSL database and GPS data (Bradley *et al.*,  
315 2009, Bradley, 2011). The second regional (“Kuchar”) model (Kuchar *et al.*, 2012) was derived  
316 from output of a glaciological three-dimensional thermomechanical ice sheet model for the BIIS  
317 (Hubbard *et al.*, 2009). The ICE-5G and GLAC1-b models respectively use the VM2a and VM5a Earth-  
318 models for the European region. These Earth-models were tuned to provide the best-fit solution to  
319 near-field Hudson Bay and Angerman River (Sweden) RSL records (Peltier, 2004). Conversely, we  
320 ran the “BIIS” and the “Kuchar” models with Earth-models whose parameters were fine-tuned against  
321 near- and intermediate-field RSL data from the British Isles and present-day GPS land vertical motion  
322 data (Bradley, 2011; Bradley *et al.*, 2011). All these GIA models are based on the self-consistent SLE  
323 theory first introduced by Farrell and Clark (1976). The ICE-5G (VM2a) model of Peltier (2004) was  
324 originally developed with a lithosphere thickness of 90 km. We ran it with upper mantle viscosities of  
325  $0.5 \times 10^{21}$  Pa.s, and lower-mantle viscosities of  $2.7 \times 10^{21}$  Pa.s. GLAC1-b uses Peltier’s VM5a Earth  
326 model. VM5a is a variant of VM2a, with lithospheric thickness reduced to 60 km and an additional 40  
327 km thick low viscosity layer directly below the lithosphere ( $1.0 \times 10^{21}$  Pa.s). It has upper mantle  
328 viscosities of  $0.5 \times 10^{21}$  Pa.s and lower-mantle viscosities of  $1.6 \times 10^{21}$  Pa.s (upper 500 kms) and  
329  $3.2 \times 10^{21}$  Pa.s (rest of lower mantle). “BIIS” (Bradley, 2009, Bradley *et al.*, 2011, Bradley *et al.*, submit.)

330 and Kuchar *et al.*'s (2012) regional models adopt a lithosphere thickness of 71 km, upper- and lower-  
331 mantle viscosities of  $0.5 \times 10^{20}$  Pa.s and  $3 \times 10^{22}$  Pa.s for the former and of  $0.3 \times 10^{20}$  Pa.s and  $2 \times 10^{22}$   
332 Pa.s for the latter, respectively.

### 333 3.3.2 Paleo-tidal modelling

334 We computed changes in tidal ranges for our study sites using the 3D tidal model of Neill *et al.*  
335 (2010). The reader is referred to Neill *et al.* (2010) for greater details about model parameters and  
336 calculations. In summary, the evolution of the principal semi-diurnal ( $M_2$ ) and solar ( $S_2$ ) tidal  
337 constituents were simulated to describe "mean" spring and neap ranges and interpolated initially by  
338 running the outer coarser global tidal model of Uehara *et al.* (2006), modified to account for the  
339 updated ICE-5G (VM2a) GIA model (Neill *et al.*, 2010). A  $1/24^{\text{th}}$  degree resolution grid was used for  
340 the tidal range computations (Neill *et al.*, 2010). Due to negligible differences at the scale of the shelf  
341 after 6ky B.P., we did not performed calculations after this date (Neill *et al.*, 2010). Thus, we obtained  
342 tidal ranges for 5 kyr, 4 kyr, 3 kyr, 2 kyr and 1 kyr B.P by linear interpolation between model output  
343 values. We corrected and recalculated the Indicative Meanings and the Indicative Ranges of our  
344 modern regional tidal zones to account for the tidal conditions that prevailed at each site at the time of  
345 deposition of the various sedimentary layers. The output figures of the model runs are provided as  
346 supplementary information in SOM (appendix S2), for each study site.

## 347 4. Results and discussion

### 348 4.1 Stratigraphies

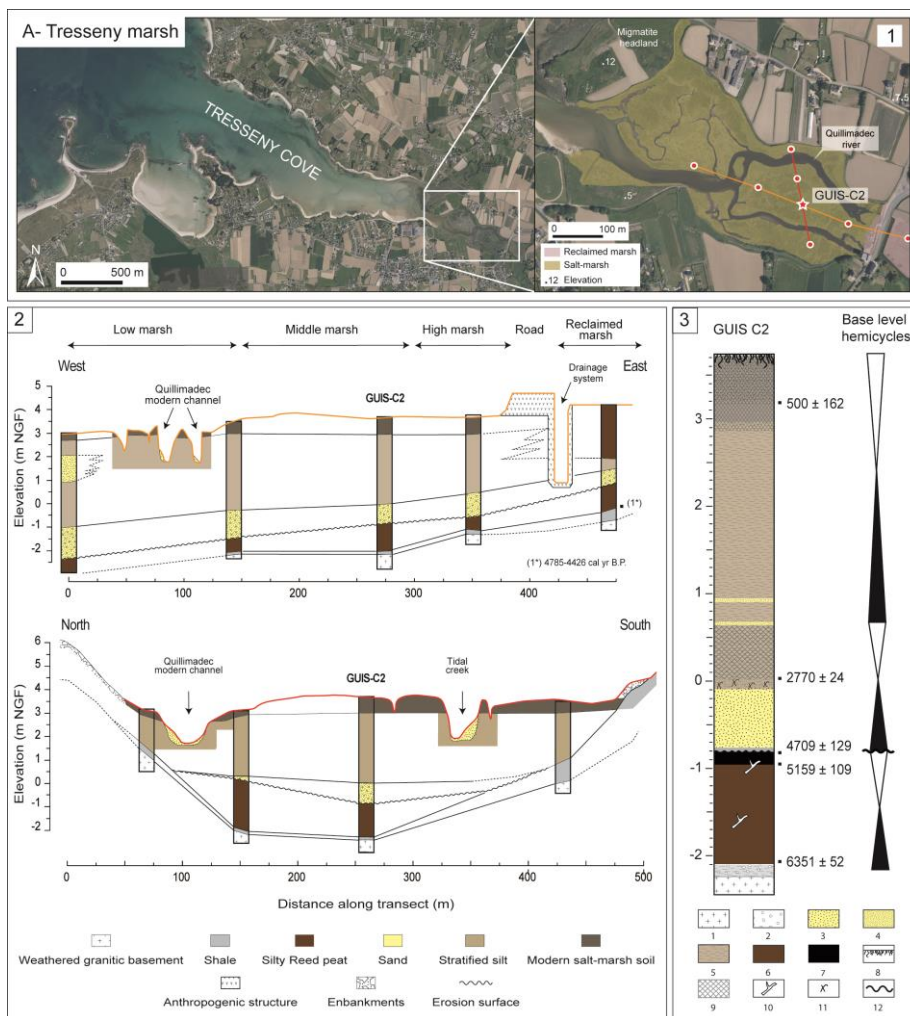
349 Complete information regarding the data presented below (e.g. datings, depth, geochemical  
350 measurements, IM, IR) is summarized in table 4.

351 Kerlouan – Guissény (A. North Finistère)

#### 352 *Tressény marsh*

353 Core GUI5-C2 was retrieved from the central part of the inner cove salt-marsh of Tressény (fig. 2-  
354 1). The sequence sampled by the GUI5-C2 core consists in 0.4 m of Pleistocene material,  
355 progressively topped with ~0.6 m of a highly organic stratified silty peat, containing rare foraminifera  
356 and *Phragmites australis* macroremains (fig.2-3), indicating its brackish character. The base of the  
357 basal peat layer yielded geochemical values characteristic of high-marsh deposits (index n° 17, table

358 4). This basal deposit evolves into a 0.15 m thick black-peat layer that denotes the onset of slightly  
 359 regressive conditions towards highest marsh deposit environments on the site around 5.1 kyr B.P. and  
 360 4.7 kyr B.P.



361  
 362 **Figure 2 - 1)** Map of the Tressény marsh (noted A on Fig.1) showing the location of the coring transects. The red  
 363 star locates the GUIs-C2 sampled core. 2) Detailed stratigraphy from coring transects taken through the marsh  
 364 (adapted from Stéphan *et al.*, 2014), (1\*) is an informative dating taken from Stéphan *et al.* (2014) and unused in  
 365 this study. 3) Complete stratigraphic log of the GUIs-C2 core. 1- Weathered granitic basement, 2- Angular gravels  
 366 and pebbles, 3- Coarse sand, 4- Fine sand, 5- Laminated silt dominated minerogenic deposit, 6- Silty Reed peat,  
 367 7- Black peat, 8- Humic soil horizon, 10- wood fragments, 11- fragmented shells, 12- Erosion surface.

**Commentaire [BVVL1]:** NEW FIGURE ADDED

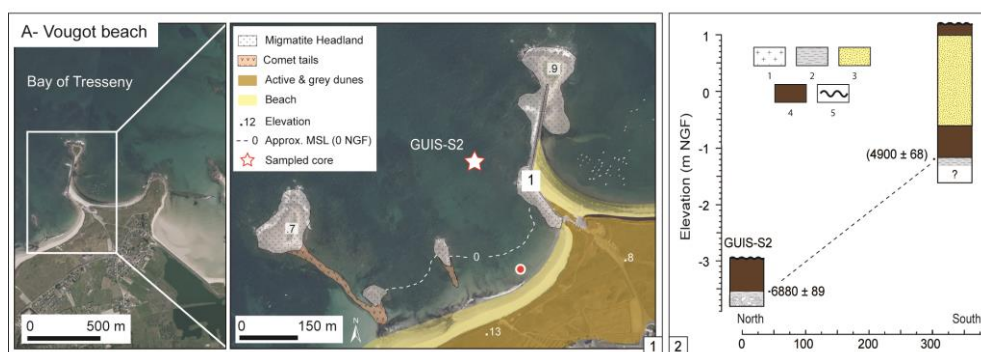
368 The black peat layer is abruptly eroded at its top. A 0.6 m thick sand layer rests above the peat layer,  
 369 showing high energy granulometric characteristics and evolving upward from terrestrial material at its



370 base towards coarser shell-rich marine sand. The top of the sequence is composed of alternating  
 371 layers of organic silty layers and some sand enriched layers, progressively increasing in organic  
 372 content before reaching the contemporaneous salt-marsh soil (3.75 m NGF, Fig. 2). The silty layers in  
 373 the top of the sequence show evidence of deposition within a channel environment and contain signs  
 374 of allochthonous material embedded in the sediment (in particular, very low  $\delta^{13}\text{C}$  and C/N values).  
 375 Therefore these layers were not considered reliable for RSL reconstruction. The roof of the infill, dated  
 376 ca. 500 yr B.P., displays all the geochemical characteristics of middle to high marsh environment  
 377 (index n°1, table 3).

378 *Vougot Beach*

379 The sequence preserved at the bottom of the Vougot beach at Guisseny was investigated by one  
 380 hand-auguring (see sequence Guis-S2, Fig.3). Within the Guis-S2 sequence, 0.65 m of brown peat  
 381 was retrieved before reaching the underlying loess formation. The base of the basal peat layer (-1.15  
 382 m NGF) shows signs of brackish environment deposition (embedded reed fragments).

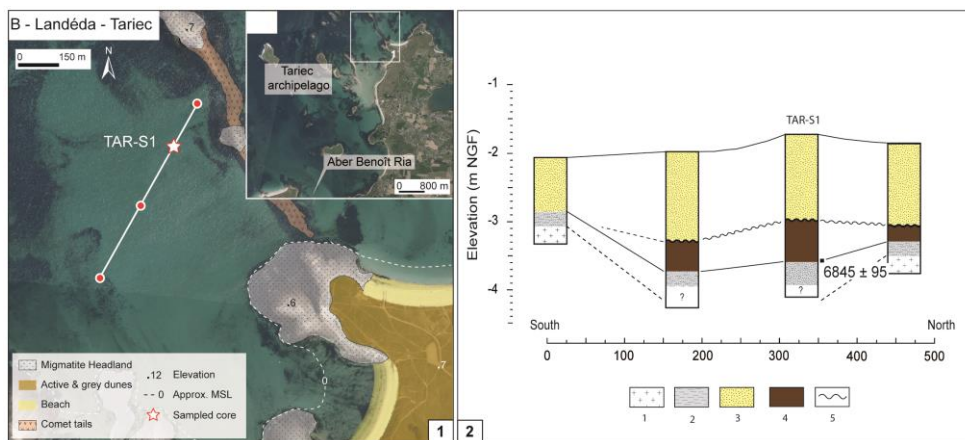


383 **Figure 3** - 1) Map of the Vougot beach (noted A on Fig.1) showing the location of the cores. The red star locates  
 384 the GUI-S2 sampled core. 2) Detailed stratigraphy from coring transects taken through the marsh. Dating in  
 385 brackets is given for informative purposes and in not used in this study. 1- Weathered granite basement, 2- Silt, 3-  
 386 Medium sand, 4- Reed peat, 5- Erosion surface.

Commentaire [BVVL2]: NEW FIGURE ADDED

388 Landéda – Tariec (B. North Finistère)

389 In core 'TAR-S1', an approximately 0.6 m-thick highly fibrous peat was reached at -3 m NGF  
 390 (Fig.4), It is principally composed of embedded reed-leaves fragments and directly overlaid the  
 391 Pleistocene loessy silt level. It is topped by a ca.1 m-thick sand layer. The blended *Phragmites*  
 392 *australis* and *Juncus maritimus* macro-remains suggest a brackish highest high marsh environment.



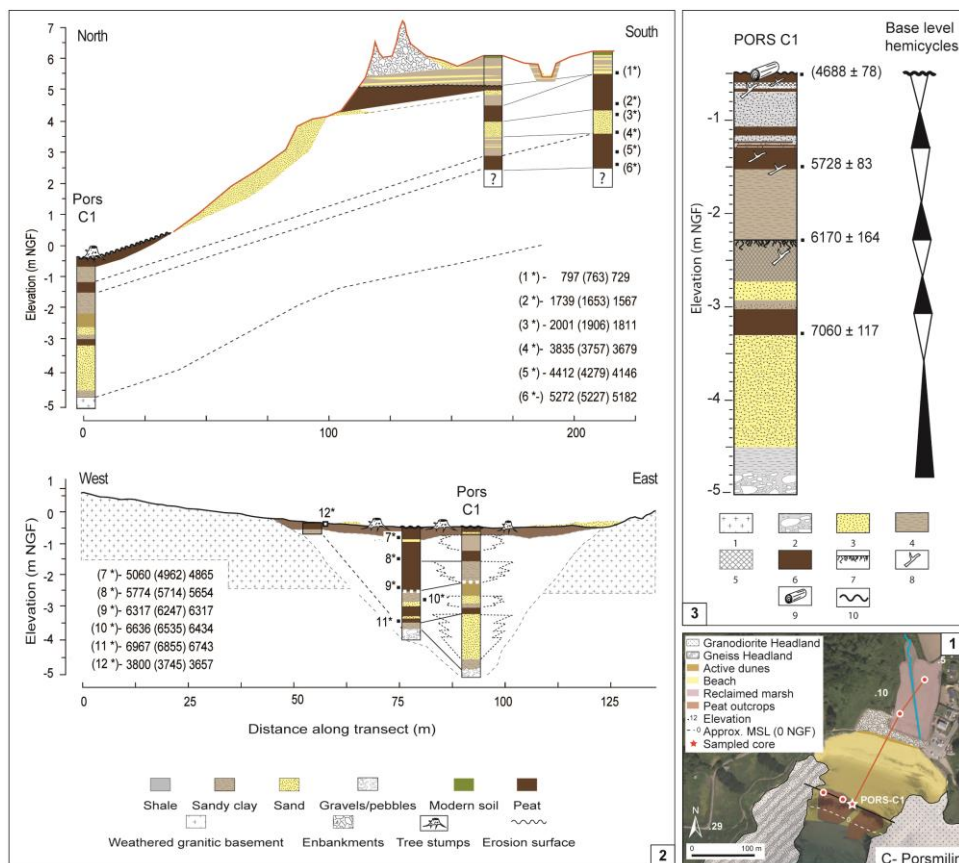
393

394 **Figure 4** - 1) Map of the Tariec foreshore (noted B on Fig.1) showing the location of the coring transect. The red  
 395 star locates the TAR-S1 sampled core. 2) Detailed stratigraphy from the coring transect taken through the site. 1-  
 396 Granite basement, 2- Silt, 3- Medium sand, 4- Reed peat, 5- Erosion surface.

**Commentaire [BVVL3]:** NEW FIGURE  
 ADDED

397 Porsmilin (C. West Finistère)

398 Five piston cores were retrieved from the foreshore to the bottom of the back-barrier swamp (Fig. 5).  
 399 Only core PorsC1, which was retrieved at the bottom of the beach, could successfully be interpreted  
 400 for RSL reconstruction purposes as the cores retrieved from the inner areas of the marsh only  
 401 contained freshwater deposits that delivered non informative limiting points (Fig.5). In PorsC1, the roof  
 402 of the weathered basement was reached at -5 m NGF. Over this basement lays ca. 0.3 m of gravel-  
 403 rich clay, topped with around 2 m of slightly clayey sand of probable channel origin. Above this layer,  
 404 the upper half of the sequence is characterised by a shift towards organic and stratified silt deposits,  
 405 intercalated with woody peat layers (Fig.2). The base of the basal peat (-3.3 m NGF) was dated at 7 ky  
 406 cal. B.P. A high marsh depositional environment can be inferred from the geochemical values obtained  
 407 on this deposit. This is in accordance with the palynological assemblages described by Fernane *et al.*  
 408 (2014) that show dominating *Poacea* and *Cyperacea* pollen spores (which can correspond to plant  
 409 species adapted to a brackish environment, such as *Spartina alterniflora*, *Phragmites australis* and  
 410 *Juncus roemarianus*). The upper half of the sequence shows constant signs of pyritisation embedded



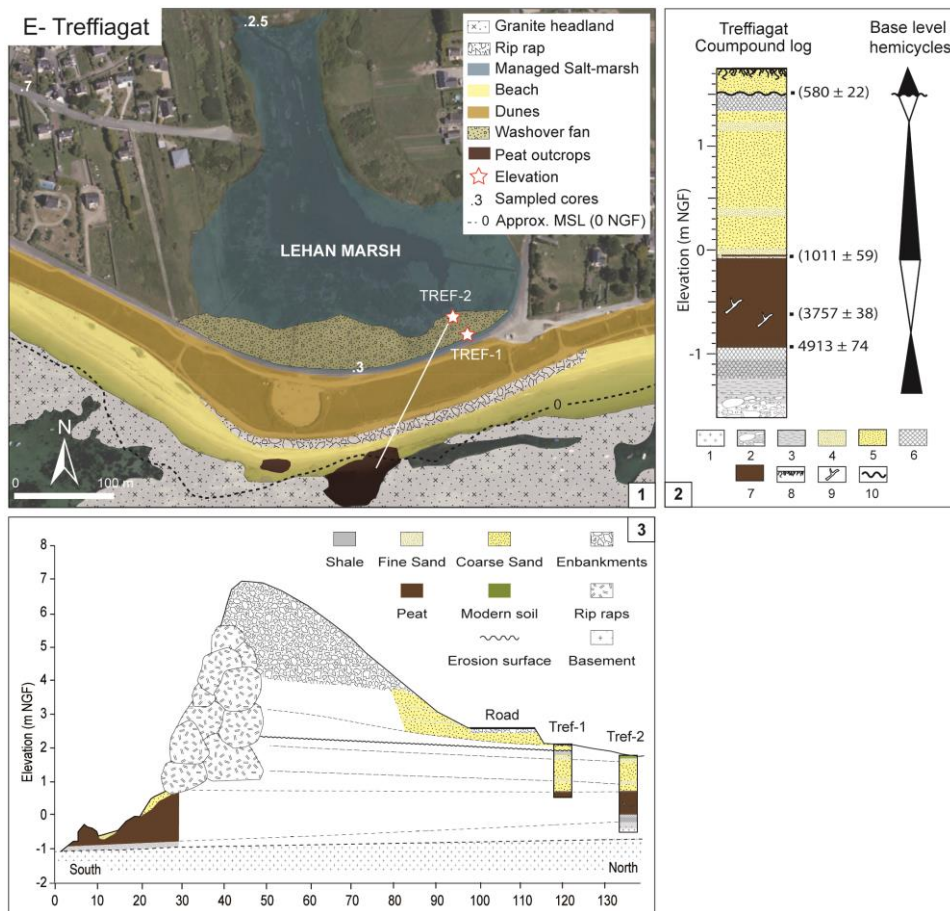
412  
 413 **Figure 4 - 1)** Map of the Porsmilin site (noted C on Fig.1) showing the location of the coring transects and of the  
 414 sampled core. The red star locates the PORS-C1 sampled core. 2) Detailed stratigraphy from coring transects  
 415 taken through the marsh and the foreshore. Datings in brackets (Fernane *et al.*, 2014) are given for informative  
 416 purposes and are not used in this study. 3) Complete stratigraphic log of the PORS-C1 core: 1- Weathered granite  
 417 basement, 2- Angular gravels and pebbles, 3- Sand, 4- Stratified silt deposit, 5- Highly organic layer, 6- Peat, 7-  
 418 Humic soil horizon, 8- wood fragments, 9- Tree stump, 10- Erosion surface.

Commentaire [BVVL4]: NEW FIGURE ADDED

419  
 420 Treffiagat (D. South Finistère)

421 Two cores were taken near the swamp in the back-barrier zone, respectively at 2.2 m NGF and  
 422 1.75 m NGF, that were merged to build a compound complete sequence (Fig.6). The observed  
 423 sequence begins at -1.25 m NGF with a ~0.3-m thick Pleistocene silty-mud complex (traces of  
 424 oxidation and several roots remains attest of its aerial exposure) overlaying the weathered basement.  
 425 Over this first layer, a 30-cm thick organic silty peat layer is found, progressively turning into a wood-  
 426 rich black peat above ca. -0.75 m NGF (Fig.6). This peat layer is capped by ~1.70 m medium to

427 coarse sand layer, of sand-barrier origin, whose onset was dated ca 1000 cal. B.P.  
 428 Micromorphological analyses revealed an extensive presence of pyrite within the matrix of the basal  
 429 Holocene silty peat layer, along with *Chrysophyceae* fragments (unspecified species). Geochemical  
 430 data from this basal deposit imply deposition in a mid- to low marsh environment. In contrast, no direct  
 431 evidence for brackish influences could be obtained from the overlying peat deposit.



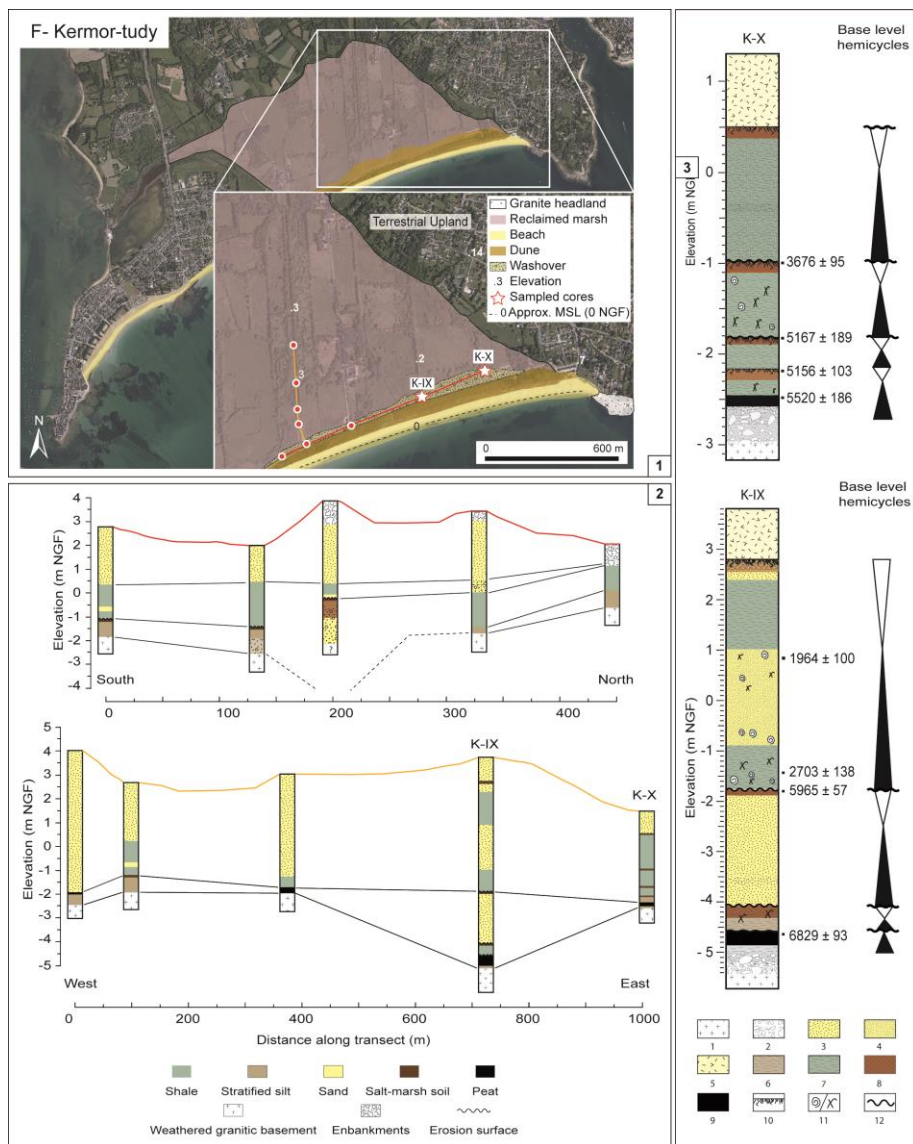
432  
 433 **Figure 6** - 1) Map of the Treffiogat site (noted E on Fig.1) showing the location of the TREF-1 and TREF-2  
 434 sampled cores (red stars). 2) Detailed stratigraphy from coring transects and trenches/outcrops observations. 3)  
 435 Compound stratigraphic log of back-barrier sedimentary sequence: 1- Weathered granite basement, 2- gravels  
 436 and pebbles, 3- Clayey/silt deposit, 4- Medium sand, 5- Coarse sand, 6- Highly organic layer, 7- Peat, 8-Humic  
 437 soil horizon, 9- wood fragments, 10- Erosion surface.

Commentaire [BVVL5]: NEW FIGURE ADDED

438 Kermor - Tudy (F. South Finistère)

439 Two cores were taken in the eastern part of the Kermor site, near the root of the barrier. Core K-IX  
 440 (3.8 m NF) passed through nine meters of sediments before encountering the weathered basement at

441 -5.6 m NGF (Fig.7). The base of the sequence consists of a ca. 0.2-m thick silty-peat layer, containing  
 442 several *Phragmites australis* and *Juncus sp.* remains. The peat is truncated by a sharp erosive surface  
 443 on top of which lays ca. 0.5 m of sandy-silt.



444  
 445 **Figure 7 - 1)** Map of the Kermor-Tudy site (noted F on Fig.1) showing the location of the coring transects and of  
 446 the sampled cores (red stars). 2) Detailed stratigraphy from coring transects. 3) Stratigraphic log of the K-IX and  
 447 K-X sampled: 1- Weathered granitic basement, 2- gravels and pebbles, 3- Medium sand, 4- Fine sand, 5- Fine  
 448 Aeolian dune sand, 6- Organic sandy clay, 7- Sandy clay, 8- Salt-marsh soil horizon, 9- Peat, 10- Humic soil  
 449 horizon, 11- Shell in living position / fragmented shells, 12- Erosion surface.

Commentaire [BVVL6]: NEW FIGURE ADDED

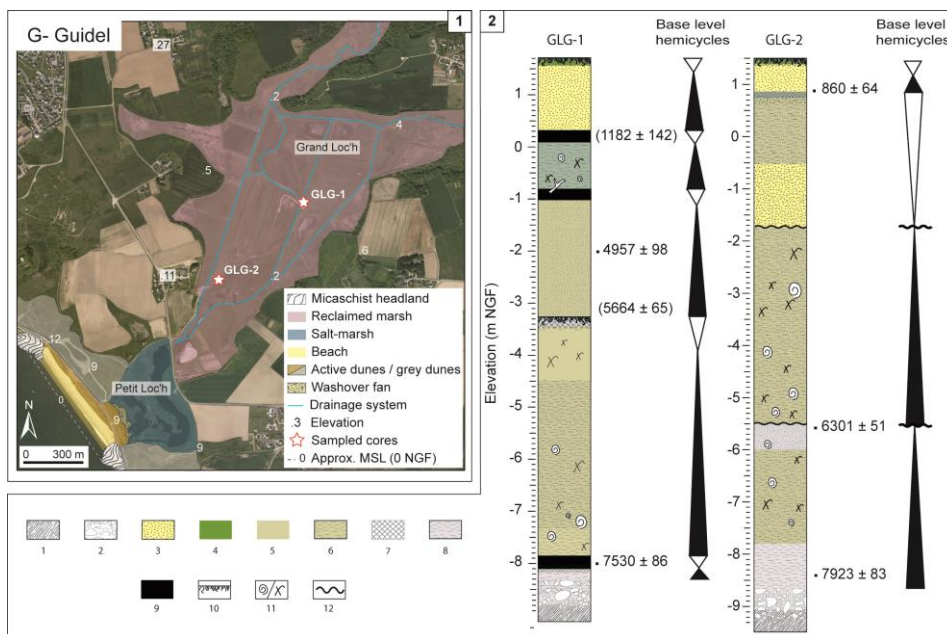
450 The top of this latter unit is itself eroded at -4 m NGF and is overlaid by ca. 2 m of slightly shelly  
451 coarse sand, topped with a 0.1 m sandy peat layer at -1.8 m NGF. The sequence continues with ca. 3-  
452 m thick very-shelly (*Scrobicularia*) sandy-silt infilling.

453 Above 1-m NGF and up to 2.3m NGF, clay becomes dominant, where it is topped by a 1.5-m thick  
454 sand upper layer. Foraminiferas were observed throughout the sequence, but were too scarce to  
455 permit representative counting. Assemblages are dominated by *Elphidium williamsoni*,  
456 *Haplophragmoides wilberti* and *Haynesina germanica*, which characterize a low-salt-marsh to mudflat  
457 depositional environment (Perez-Belmonte, 2008; Stéphan *et al.*, 2014). All dated layers gave  
458 geochemical values that are characteristic of the low marsh environment, with populations dominated  
459 by *Elphidium williamsoni* and *Haynesina germanica*. Geochemical indicators yielded a heavy  $\delta^{13}\text{C}$   
460 value of -19.95‰ and very low TOC and TN values (1.17% and 0.11%, respectively) in accordance  
461 with a low-marsh environment. Using these latter geochemical values, we obtained a RSL position of -  
462  $0.67 \pm 0.76\text{m}$  on the same layer (index n°3, Table 4).

463 Core K-X (1.3 m NGF) reached the weathered rocky substrate at -2.7 m NGF (Fig.7). The  
464 sequence is composed of a ca. 0.1-m thick sandy silt layer at its base, progressively turning into a  
465 black peat until ca. -2.45 m NGF (Fig.2). The basal peat was dated using organic content to give an  
466 age of ca. 5.5ky cal. B.P. at a depth of  $-2.49 \pm 0.22$  m NGF (i.e. ~10 cm above the basal contact).  
467 Over the peat lays 0.8 m of very organic stratified silt horizons (Fig.2) cut by a sharp erosion surface.  
468 Above this rests a very shelly marine mud layer (*Hydrobia ulvae*), dated from ca. 5.1 kyr cal. B.P. This  
469 layer becomes progressively more organic and loses its shell content towards the top, until ca. -1 m  
470 NGF where a thin soil horizon is observed. The uppermost part of the core is composed of 1.3 m of  
471 brown to green clay, on which rests a dune sand level. The basal peat layer provided geochemical  
472 values characteristic of the high-marsh domain. Other samples yielded geochemical signatures  
473 characteristic of the low-marsh-to mudflat environment, in accordance with the domination of  
474 *Elphidium williamsoni*, *Haplophragmoides wilberti* and *Haynesina germanica* within the foraminifera  
475 assemblages. No other indicator bears out a deposition within a brackish environment.

476 Guidel (E. South Finistère)

477 Two drillings were completed along a SW/NE transect across the Guidel-Loc'h pond (Fig.8): GLG-1  
478 was drilled in the center of the pond, and GLG-2 was drilled about 500 m seaward of GLG-1.



479

480 **Figure 8 - 1)** Map of the Guidel site (noted G on Fig.1) showing the location of the sampled cores (red stars). 2)  
 481 Stratigraphic log of the GLG-1 and GLG-2 cores: 1- Weathered granite basement, 2- gravels and pebbles, 3-  
 482 Medium sand, 4- Fine sand, 5- Fine Aeolian dune sand, 6- Organic sandy clay, 7- Sandy clay, 8-Salt-marsh soil  
 483 horizon, 9- Peat, 10- Humic soil horizon, 11- Shell in living position / fragmented shells, 12- Erosion surface.

Commentaire [BVVL7]: NEW FIGURE ADDED

484 GLG-1 is an 11-m deep drilling that reached the micaschist weathered basement at -8.3 m NGF.  
 485 The base of the sequence consists of ca. 0.2 m of lacustrine clay encroaching the basement on which  
 486 lays a 0.2m thick silty-peat layer. From -7.9 m NGF, the sequence is a 7-m thick succession of sand  
 487 and muddy-silty layers, interrupted by several salt-marsh soils. The top of the sequence consists of  
 488 clay-dominated deposits, the uppermost 1.4 m being coarse sand (Fig.8). Except for the basal peat  
 489 layers, the whole sequence contains foraminifera, the assemblages being dominated by *Haynesina*  
 490 *gemanica*, *Amonia becarii* and *Elphidium williamsoni*. At -2m NGF, *Scrobicularia plana* in living  
 491 position gave an age of 4.9 kyr cal. B.P. Geochemical values infer deposition within a low-marsh to  
 492 mudflat environment.

493 The GLG-2 sequence is somewhat equivalent to the GLG-1 sequence, only lacking the basal peat  
 494 layer (Fig.8). As for GLG-1, the whole sequence is characterized by the extensive presence of shells  
 495 (*Hydrobia ulvae* especially) within the deposits and by the domination of low-marsh to mudflat  
 496 foraminifera species.

497 4.2 Holocene Relative Sea Level variations and responses of the coastal systems

498 This study has resulted in 24 new dates for the coastal Holocene sedimentary infillings in Western  
499 Brittany (table 4). This new RSL record, containing five new base-of-basal SLIPs, considerably  
500 improves the precision of the regional RSL history between 8 kyr and 5 kyr cal. B.P. Specifically, (i)  
501 this new dataset extends the previous available data by ca.1.5 kyr to 8 kyr cal. B.P.; and (ii) the basal  
502 SLIPs provide new critical constraints on RSL inflections around 6 kyr cal. B.P. No reliable basal  
503 indexes could be retrieved for dates younger than 4 kyr cal. B.P. so the RSL evolution for the Late  
504 Holocene remains less precise (Fig.9). Our new data show an overall continuous 6.5 m RSL rise since  
505 7 kyr cal. B.P. Following an initial rapid rise between 8-6kyr B.P. from ca. -8m to -5m below present-  
506 day level, there is a marked slowdown in the RSL rise around 6kyr cal. B.P., after which the rate of  
507 RSL rise progressively decreases towards present day values.

#### 508 4.2.1. RSL evolution from 8 kyr cal. B.P. to 6 kyr cal. B.P.

509 The two oldest samples (index n° 23 and 24) obtained are intercalated SLIPs and provide for the first  
510 time an indication of the RSL history between 8 kyr and 7.5 kyr BP. However, the lack of base of basal  
511 peats (Fig.9) limits the reliability of the RSL chronology over this period (Fig.9) These two samples  
512 (index n°23 and 24) were obtained from deposits taken at the base of the sequences cored at the  
513 Guidel sites but were not sampled directly at the contact with the underlying bedrock. Thus, a  
514 compaction-induced artefact cannot be ruled out, and we suspect that true RSL positions may have  
515 been slightly higher than drawn by these SLIPs. Therefore, we suggest that the RSL positions given  
516 by these two indexes should be taken as indicative of minimum values.

517 Around 7000 cal. B.P., basal peats formations were emplaced along most of Western Brittany  
518 coasts. These basal deposits record a RSL situated between  $-6.74 \pm 1.22\text{m}$  (index n°22) and  $-6.95 \pm$   
519  $1.22\text{m}$  (index n°20) below present day between ca. 7 kyr and 6.8 kyr cal B.P (Fig.3). A limiting date,  
520 obtained from a basal freshwater peat deposit sampled in the Porsmilin sequence (index n°21) further  
521 constrains that the RSL was situated *at least* -6.47 m below present-day ca. 7 kyr cal. B.P.

522 Between 6.5 kyr and 6 kyr cal. B.P., where some SLIPs are derived from incompressible basal peat  
523 deposits, there is a continuous RSL rise reaching ca.  $-3.27 \pm 0.76\text{ m}$  at around 5.9 kyr cal B.P. On top  
524 of these basal peat deposits, where an erosive hiatuses (wave ravinement surfaces) did not erode the  
525 previously-deposited sediments, a widespread onset of silty deposits mostly showing back-barrier  
526 lagoonal facies formed. These formations are, in turn, topped by humic layers (maximum- flood



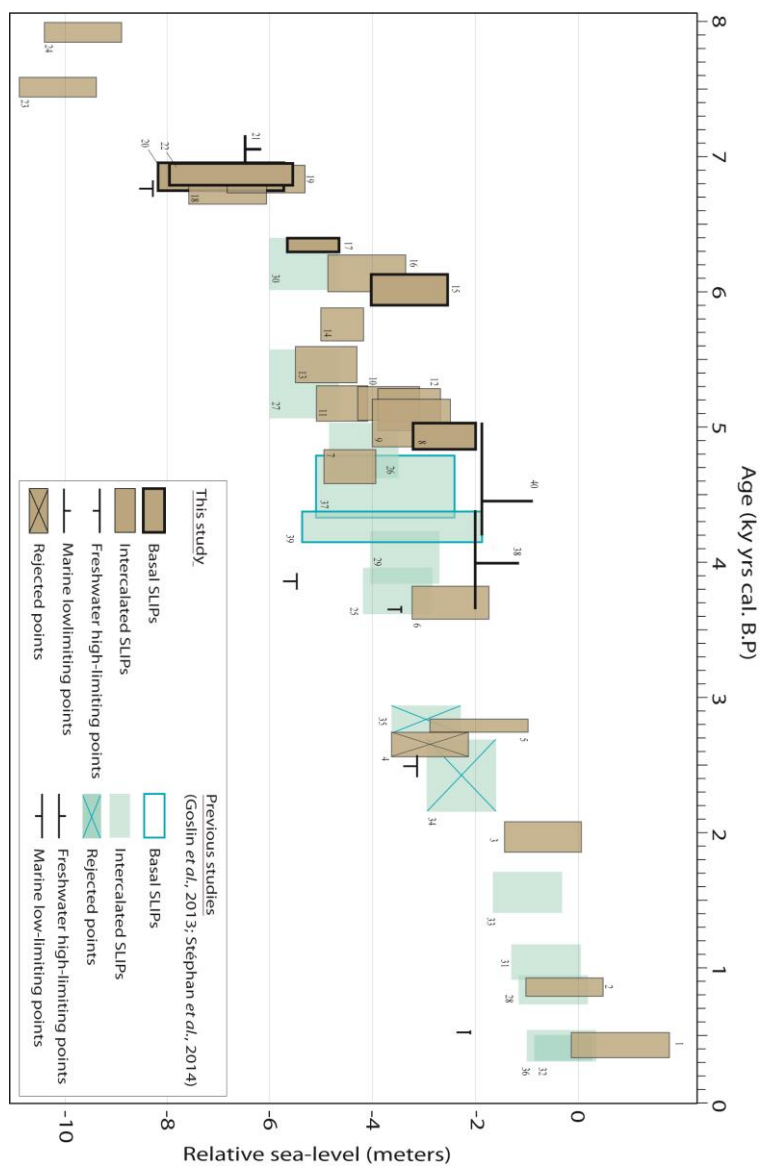
527 surfaces) which suggest a widespread heightening of lagoonal marsh surfaces and evidence for  
528 regressive conditions in the back barrier environments. They record the shift from the transgressive  
529 system tract towards the mid-Holocene highstand system tract, where deposition most probably  
530 occurred in the context of a deceleration of the RSL rise and with a large amount of sedimentary  
531 material available within the foreshore domain.

532 The RSL rise rates we obtained in Brittany between 7ky B.P and 6ky B.P. are closely comparable  
533 to those observed for the same period in South-Western UK (Massey *et al.*, 2008, Gehrels *et al.*, 2011;  
534 Gehrels and Anderson, 2014), in the North of France (Gandouin, 2003) and in the west of the  
535 Netherlands (Hijma and Cohen, 2010), suggesting the eustatic component still played the dominant  
536 role in RSL evolution during this period. However, as stated above, due to a lack of basal SLIPs, large  
537 uncertainties remain in the RSL rise rates observed in Western Brittany for the older periods.

#### 538 4.2.2. RSL evolution from 6 kyr cal. B.P. to 4 kyr cal. B.P

539 From 6 kyr cal. B.P., there is a pronounced slowdown in the rate of RSL rise in Finistère region (Fig.9).  
540 Around 5000 yr cal. B.P., basal SLIP n°8 records the RSL at  $-2.6 \pm 0.6$  m below the present level,  
541 while the high-limiting point n°38 constrains the RSL to lay at least  $2 \pm 0.55$  m below its present  
542 position between 4.4 - 3.8 kyr cal. B.P. While the new basal SLIPs clearly suggest a decrease in the  
543 RSL rise rate between 6 and 4 kyr cal. B.P., denser and more precise basal data are still necessary to  
544 provide a detailed description of this RSL rise deceleration. From a more regional viewpoint, it is  
545 interesting to note that, as the rate of RSL rise slowed down, some of our study sites (Porsmilin,  
546 Kermor, Guidel) clearly returned to transgressive conditions, as shown by silty-sandy deposits. This  
547 stratigraphic evidence implies the local creation of accommodation space between 6 kyr and 5 kyr cal.  
548 B.P. driven by (i) the persistent and continuous, even if slow, RSL rise and probably (ii) the possible  
549 compaction of the underlying sequences. Indeed, there is a clear spread (up to 3 meters for SLIPs of  
550 approximately the same age) of the intercalated SLIPs between 6 kyr and 5 kyr cal. B.P. which is  
551 similar to what was observed by Massey *et al.* (2008) in Southwestern UK and by Gandouin (2003) in  
552 the St Omer marsh (Northern France). This process may be caused by (i) the onset of coastal barriers  
553 due to both a slowing-down in the rate of RSL rise and the large amount of available sediment (ca.  
554 5000 yr cal. B.P.; Van-Vliet *et al.*, 2014a), (ii) by the subsequent landward migration of these barriers,  
555 as they rolled-over the back-barrier marsh sequences and (iii) by the shifting of tidal inlets, potentially

556 fostered by barrier breaching (Stéphan *et al.*, 2014).



557

558 **Figure 9 - New Holocene relative sea-level evolution for western Brittany for the last 8 ky cal. B.P.** Sea-  
 559 level indexes are numbered accordingly to table 3 and 4.

560

561 4.2.3. RSL evolution from 4 kyr cal. B.P. to present

562 No basal index-point could be obtained younger than 4 kyr cal. B.P. This, when combined with the  
 563 lack of SLIPs between 4kyr and 2kyr cal. B.P. (Fig.9), prevents a precise constraint on the RSL

564 evolution during the late Holocene. Several SLIPs that were dated around 3 kyr cal. B.P. (either during  
565 this work or by Stéphan *et al.*, 2014) were rejected due to the anomalously low elevation which  
566 resulted from a massive reorganization and disruption of the sedimentary system during formation  
567 (Goslin *et al.*, 2013, Stéphan *et al.*, 2014), e.g. as illustrated by the widening of the river channel in the  
568 Guissey site.

569 From 2 kyr cal B.P. onwards, RSL reached a position very close to the present-day. Index n°3  
570 which was obtained from the top of a thick sandy sequence (Kermor KIX) is likely to have undergone  
571 only a small amount of post-depositional compaction and hence can be considered as fairly reliable.  
572 From this data point, the rate of RSL rise is estimated to have been reached a maximum of 0.71  
573 mm.yr<sup>-1</sup> during the last ca. 2 kyr cal. B.P. Assuming that the ESL over the last 2 kyr was small, we  
574 estimate that Western Brittany underwent a maximum subsidence of ca. 0.7 mm.yr<sup>-1</sup> for the last 2000  
575 years, as a consequence of the post-glacial isostatic response of the lithosphere. Yet, this value is  
576 calculated on the basis of only one point that carries some uncertainty due to its stratigraphical  
577 position. Hence, this latter result must be considered as only indicative at this stage of the study and it  
578 would require basal SLIPs for the Brittany region over the last two millenaries to be conclusive on this  
579 latter point.

#### 580 4.4 Comparison of Holocene RSL geological records along the English Channel: evidencing for 581 a particular behavior of south-western UK (Devon, Cornwall and Scillies).

582 Vink *et al.* (2007) gave clear evidences for the glacio-isostatic subsidence induced by the collapsing of  
583 the northern Europe peripheral bulge to progressively decrease along a NE - SW gradient running from  
584 Germany to Belgium (as mainly driven by the loading of the FIS). In order to explore the glacio-  
585 isostatic gradients and subsidence patterns induced by the loading of the north-European ice-sheet  
586 complex and the collapse of associated peripheral bulge, we compared the RSL data from this study  
587 to the high-quality RSL records available along the English Channel, either produced by the study of  
588 Holocene sedimentary successions in Southwest UK (Devon, Cornwall and Scillies, Healy, 1993;  
589 Healy, 1995; Massey *et al.*, 2008; Gehrels *et al.*, 2011, Gehrels and Anderson, 2014), southern UK  
590 (Hampshire region; Long and Tooley, 1995), Northern France (Seine Estuary, Huault, 1980; Frouin *et al.*,  
591 *et al.*, 2007; Stéphan and Goslin, 2014) and Belgium (Izjer valley, Denys and Baetman, 1995). The main

**Commentaire [BVVL8]:** RSL RISE RATES FIGURE DELETED TO FREE SOME SPACE FOR THE FIGURES REQUESTED BY THE REVIEWERS IN THE MODELLING SECTION

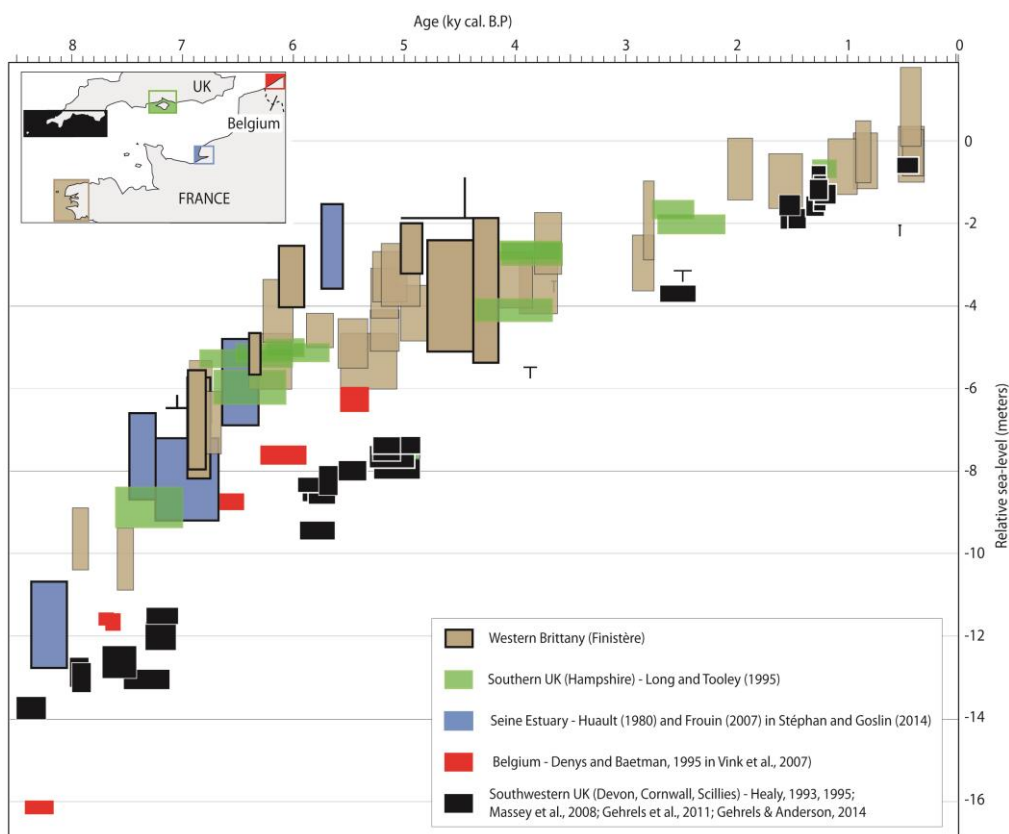
**Commentaire [BVVL9]:** COMPLETELY REWRITTEN SECTION

592 aim of this comparison was to broadly evaluate if the glacio-isostatic subsidence gradient identified by  
593 Vink *et al.* (2007) from northern Germany to Belgium could be followed further eastward.

594 As far as the data allowed it, only the basal SLIPs were compared. Before the data could be  
595 compared, adjustments had to be made to fix vertical differences between the datums of the different  
596 countries and/or the RSL datum used within the different studies. Indeed, the French data are  
597 referenced to the NGF system (Nivellement Général de la France) at Marseilles (IGN69 datum), the  
598 UK data we used are related to the Ordnance Datum of Newlyn (ODN) while the Belgian data is  
599 related to the DNG system (Deuxième Nivellement Général) at Ukkle. Yet, the ODN is higher than the  
600 NGF of ca.  $40 \pm 2$  cm (Greaves *et al.*, 2008), while the Belgian DNG lies 1.75m above the NGF  
601 (Craetes de Paulet, 2013). Hence, before comparing the different RSL datasets, we applied a  
602 consistent altitudinal correction to the depths of the samples to resolve this altitudinal discrepancy: a  
603 ca. -40 cm shift was applied to the UK RSL data prior to their comparison with our RSL records, while  
604 the Belgian data were lowered by 1.75m. However, as for the ODN correction it must be noted that  
605 this offset is a somewhat crude estimate and is likely to slightly overestimate the real difference  
606 between both datum's. Nonetheless, considering the fact that leveling errors are globally east-west  
607 conservative both in UK and in France (Rebischung *et al.*, 2009), this correction can be considered as  
608 a sufficient first approach (P. Woodworth, *comm. pers.*). In some of the UK studies we took data from  
609 (Massey *et al.*, 2008), RSL positions were expressed relative to MTL, and not to ODN. In order to  
610 relate these data to ODN and prior to the correction for the vertical difference between the ODN and  
611 NGF datum, these were applied them a vertical shift corresponding to the local tidal heights relative to  
612 ODN (Massey *et al.*, 2008): -0.11m, -0.09m, -0.12, -0.11 for the SLIPs obtained at Bantham Sand,  
613 North Sands, Slapton Sands and Blackpool Sands sites, respectively.

614 This comparison clearly shows that all studied regions undergone very comparable RSL histories  
615 during the 8.5 - 5 ky B.P. period, in great accordance with the one of Western Brittany. While all  
616 regions seem to have experienced slightly different RSL variations over the considered period (that is  
617 notably observable via slight differences in the RSL rise rates prior to 5 kyr cal. B.P.), a general  
618 synchronicity is clearly observable between the RSL trends estimated from the records. In all regions,  
619 there is an obvious inflection in the rate of RSL rise at ca. 6 kyr cal. B.P. (Fig.10) that most probably  
620 reflect a decrease in meltwater production from the melting of the global ice sheets (Vink *et al.*, 2007).

621 The synchronicity of the global RSL trends between Brittany and sites located eastward (Hampshire,  
 622 UK; Seine Estuary, Northern France) in the English Channel and at its eastern termination (Izjer  
 623 Valley, Belgium) suggests that all considered regions have been subjected to major synchronous RSL  
 624 forcing agents.



625  
 626 **Figure 10 - Inter-regional comparison of RSL records from Western Brittany (brown boxes), South-**  
 627 **western UK (Devon, Cornwall - black boxes), Central UK (Hampshire - green boxes), Seine estuary (Blue**  
 628 **boxes) and Western Belgium (red boxes) during the last 8 ky B.P.** Mind that all represented data basal  
 629 SLIPs, excepted thin contoured brown boxes and SLIPs from Hampshire. These latter may thus have been  
 630 lowered by some post-depositional compaction and hence potentially underestimate RSL position.

Commentaire [BVVL10]: NEW  
 FIGURE ADDED

632 The RSL record from Belgium plots several meters under the ones from the Seine, Hampshire and  
 633 Brittany regions (Fig.10). This undoubtedly illustrates the greater subsidence undergone by the  
 634 Belgium coastal plain, in relation to the collapse of the peripheral bulge situated at the south of the  
 635 North Sea (Vink et al., 2007). Indeed, this latter region has most probably been subjected to the  
 636 conjunction of two subsiding dynamics, coming both from the north (glacio-isostatic gradient linked to

637 the collapse of the peripheral bulge south of the BIIS, as evidenced by Horton and Shennan, 2009)  
638 and from the north east, induced by the deflation of the peripheral bulge southwest of the FIS (Vink et  
639 *al.*, 2007). Progressing westward, we note that the Hampshire and Seine regions show very lookalike  
640 RSL records. Being located both in the middle part of the English Channel and in very comparable in  
641 regard to the North Sea and Atlantic basins, these two regions must have been subjected to a  
642 somewhat equivalent hydro-isostatic component, yet difficult to evaluate at this stage of the study. This  
643 high variability in the hydro-isostatic component associated with the relatively large error margins the  
644 SLIPs are weighted with makes it difficult to precisely identify a glacio-isostatic gradient that potentially  
645 progressively damps westward along the English Channel.

646 However, a spectacular result emerges from the visual comparison of the RSL records that shows the  
647 RSL data from SW UK to plot consistently several meters below the data of all studied regions during  
648 the last 8 kyr B.P. Indeed, before 5 kyr cal. B.P. the basal SLIPs retrieved from SW UK sedimentary  
649 sequences SLIPs plot ca. 4 meters below the ones we obtained in Brittany (Fig. 10). It is interesting to  
650 note that the offset seems to reach a maximum ca. 6-5 ky B.P., while it appears to decrease towards  
651 the older and younger times. To the first order, and assuming a constant decrease of the isostatic  
652 component, Brittany would have subsided at an average rate between 0.42 and 0.67 mm.yr<sup>-1</sup> since 6  
653 kyr cal. B.P., while the subsidence over the same period reached 1.3 to 1.5 mm.yr<sup>-1</sup> in Devon (a lack of  
654 basal data for Brittany after 6 kyr cal. B.P. precludes a similar comparison for the late Holocene  
655 period). This result is especially revealing if we consider that Brittany and SW UK have subsided partly  
656 in response to the loading of the continental platform: the hydro-isostatic component accounts for ca. -  
657 2 to -3 m since ca. 7 kyr cal. B.P. and is considered commensurate between the two regions (e.g.  
658 Leorri *et al.*, 2012) as these latter share comparable peninsula configurations and almost identical  
659 geological histories and features. Investigations on the gravitational and solid Earth changes from 10  
660 kyr cal. B.P. show the geoid being less than 0.5m higher for Brittany than for Devon/Cornwall at 8 ky  
661 cal. B.P. Therefore, the influence of differing hydro-isostatic components seems unlikely to explain the  
662 large vertical discrepancies observed between UK and Brittany RSL levels.

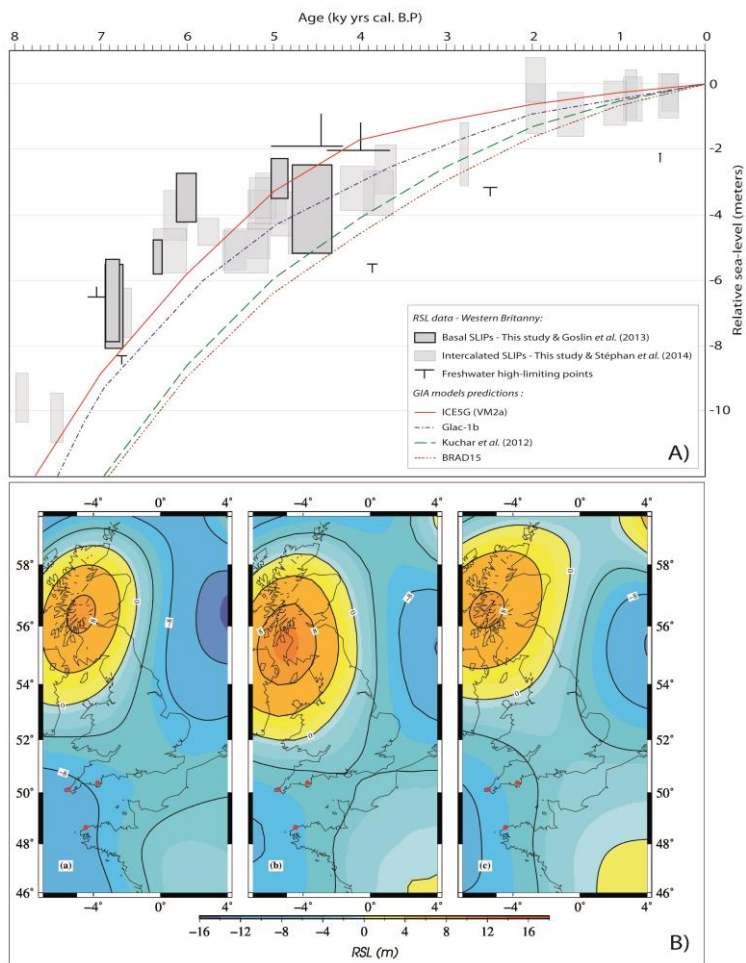
663 In spite of the larger uncertainties concerning the most ancient and the most recent periods, this result  
664 nonetheless confirm that a time-dependent north-south subsidence gradient seems well to exist along  
665 the Atlantic coasts of Europe. This gradient would result from the collapse of the peripheral bulge of  
666 the European ice complex (British-Irish and Fennoscandian Ice-Sheets). SW UK and Brittany being

667 located at equivalent distances from the centers of glaciations, it could be awaited from glacio-isostatic  
668 component to be broadly equivalent in the two regions and RSL histories to be quite close. As it is not  
669 the case, we believe that two main hypotheses can be put forward. One hand, our new findings may  
670 challenge the inferences previously made on the amplitude and extent of the peripheral bulge of the  
671 north-European Ice-sheet complex south of the BIIS. The amplitude of the vertical offsets observed  
672 between Western Brittany and Southwest UK RSL records could imply that Devon was much closer to  
673 the apex of the bulge than Western Brittany was. If this is the case, our new findings challenge the  
674 inferences previously made on the amplitude and extent of this bulge. The offset amplitude in the  
675 isostatic subsidence between Brittany and Devon, regions which are close to one another, would  
676 suggest some combination of (i) a shorter wavelength of the bulge than was previously inferred by  
677 Lambeck (1997) and Leorri *et al.* (2012) and of (ii) a more northern position of the bulge apex than  
678 was previously considered. One another hand, differences in the Earth response are also likely to be  
679 invoked to explain such an offset. These results are in favor of a geological origin for the still  
680 unexplained differences in the land-subsidence rates obtained from tide-gauges records between  
681 Brest and Newlyn, as already suggested by Woodworth (1987). Indeed, recent tide-gauge based  
682 modern RSL studies (Wöppelmann *et al.*, 2006, Douglas *et al.*, 2008, Haigh *et al.*, 2009) suggest that  
683 RSL rises at a rate of  $1.74 \text{ mm.yr}^{-1}$  at Newlyn against  $1.41 \text{ mm.yr}^{-1}$  at Brest, thus advocating for a  
684 greater subsidence in SW UK.

685  
686 4.5 Comparison between predictions from GIA Models and RSL observations in Western  
687 Brittany.

688 To investigate more in depth the origins of the vertical discrepancies we identified between  
689 Brittany's and south-western's UK RSL records, we compared the new RSL data obtained in Western  
690 Brittany (this work) and GIA model RSL predictions. As no significant differences could be identified  
691 between the data records from the northern and southern part of our study area, we chose the location  
692 of Guisseny (the northernmost site of our study area;  $48^{\circ}65'$  lat,  $-4^{\circ}45'$  long.) as the reference location  
693 for data-model comparison. This choice pertains to the fact that most of the basal SLIPs we obtained  
694 come from the northern coast of Brittany. It is also justified by the fact that all sites that produced basal  
695 SLIPs are seen to have been concerned by an equivalent hydro-isostatic component during the last  
696 millenaries.

Commentaire [BVVL11]: RE WRITTEN  
SECTION WITH SUPPLEMENTARY FIGURES :  
1) RSL SPATIAL PLOTS



697

698 **Figure 11 – A) Data-model comparison between Holocene RSL observational data for western Brittany**  
 699 **(this study - grey boxes) and RSL predictions produced by GIA models of global and regional significance**  
 700 **(color lines), B) Spatial plots of the RSL evolution as predicted by the BRAD15, GLAC-1B and ICE-5G**  
 701 **VM2a GIA models, respectively.** Here is shown only the RSL plot at 6 ky B.P. Plots for 7, 5 and 4 ky B.P.  
 702 periods can be found in the SOM (Appendix 3).

703 **From the data-model comparison there are some key points (Fig.11):**

704 - The patterns of the RSL predictions from the various models are, in general, consistent with our  
 705 observations. The predicted RSL trends approximately capture the inflections in the observed rate of  
 706 RSL rise at ca. 7, 6, 5-4 and 2 kyr cal. B.P. (Fig.11)

707 **This synchronism validates *a posteriori* the global pertinence of both the ICE-5G, BRAD15 and GLAC-**  
 708 **1b multiple ice models chronologies used as inputs for GIA models.**

**Commentaire [BVVL12]:** NEW  
 FIGURE : RSL Spatila plots to illustrates the spatial differences between the different models' predictions



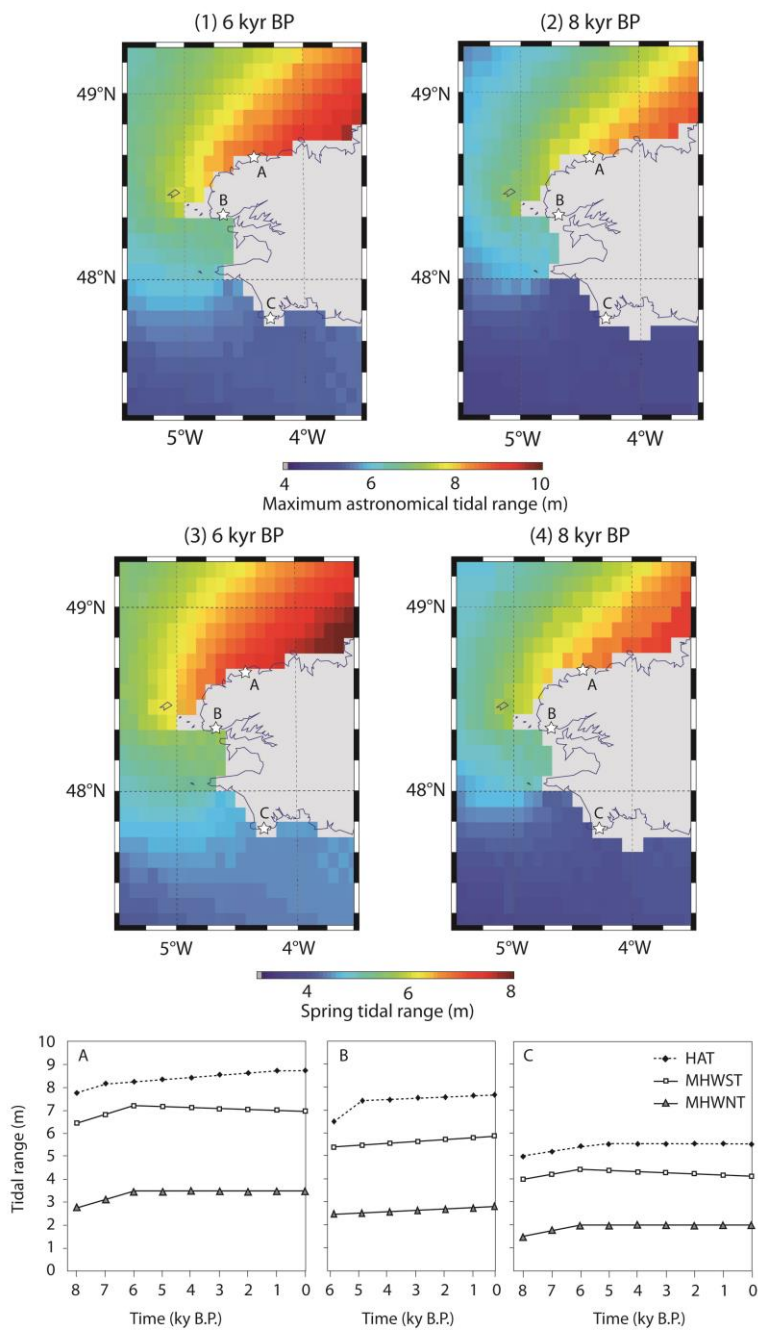
709 - However, none of the models, whether “global” or “regional”, was able to fit accurately our new RSL  
710 observations in Brittany. All models under-estimate observed RSLs by up to several meters for the last  
711 8 kyr and thus either (i) infer inaccuracies in the timing and amount of melt from the global ice sheets  
712 or (ii) over-estimate the peripheral bulge subsidence. For example, the predictions of the ICE-5G  
713 (VM2a) and GLAC1-b models lay up to 3 m below the mean RSL position obtained from our basal  
714 SLIPs at 7 kyr cal. B.P. (Fig.11). When the “regional” “BIIS” and Kuchar *et al.* (2012) models are  
715 compared to our new data, the misfits are even larger, ca. 6 m around 7 kyr cal. B.P. and more than  
716 ca. 2 meters around 4 kyr cal. B.P. (Fig.11). The global ICE-5G (VM2a) model, which is the most  
717 highly tuned (of the models sampled) to fit global RSL data, is the one that produced the best fit to our  
718 observations. Conversely, the best-fit UK regional models fail to fit our new RSL data. These latter  
719 models produce RSLs for Brittany which plot slightly below those they produce for Devon. It was  
720 previously proposed (Lambeck *et al.*, 1997; Leorri *et al.*, 2012) that the two regions would have  
721 undergone comparable amounts of glacio- and hydro-isostatic subsidence, with Devon subject to a  
722 slightly stronger glacio-isostatic signal. Our new data reinforce this idea but suggests a more abrupt  
723 damping of this component across the Channel.

#### 724 4.6. Evaluating the influence of local process: changes in the paleo-tidal ranges

725 As stated before, we investigated changes in regional tidal ranges so that our RSL data,  
726 constructed from high-tide indicators, could be directly compared to the RSL predictions from the GIA  
727 models. For each of our sites, changes in the neap, spring and maximum annual tidal ranges are  
728 shown in appendix S2 as height values and percentages of the present-day ranges. Graphical  
729 representations of the results are presented in figure 7. The results of the paleo-tidal modeling indicate  
730 that there were only very slight changes in the tidal range at our study sites during the last 8 kyr. The  
731 maximum changes occurred between 8 and 6 kyr cal. B.P. and are mainly driven by changes in the  
732 neap tidal ranges. For these latter, maximum changes were observed for the southern sites of our  
733 study area (Treffiagat, Guidel), where neap tidal ranges increased by up to 30% of the present-day  
734 value between 8 and 6 kyr cal. B.P. before reaching their present day values ca. 6 kyr cal. B.P.

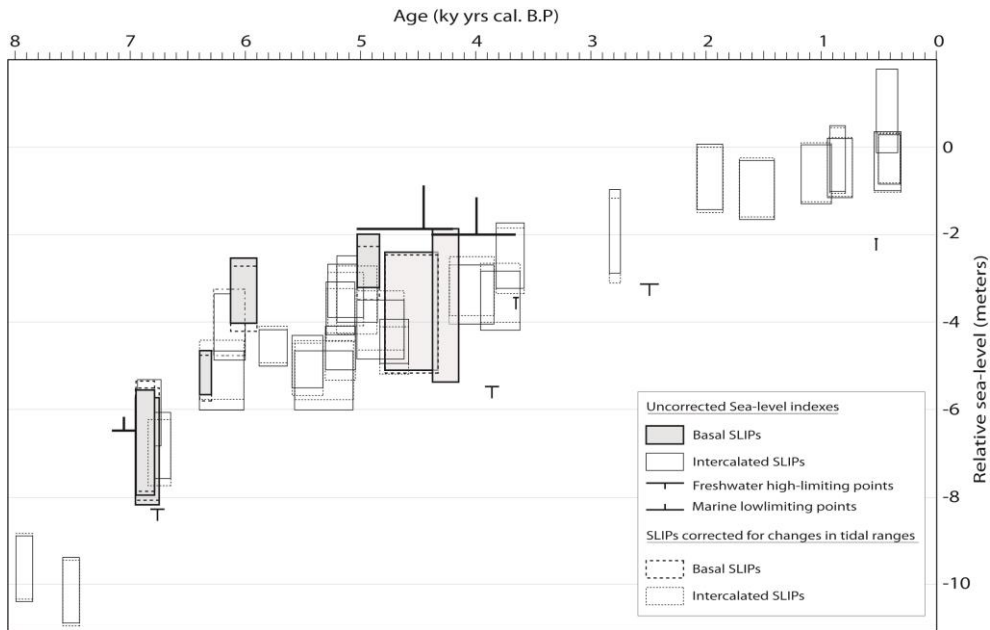
735 However, considering the reduced amplitude of the tidal ranges at these sites, these tidal increases  
736 only represent ca. 50 cm changes in height values (25 cm in half tidal ranges). Different evolutions  
737 were observed for the spring tidal ranges. Indeed, for most of the sites situated on the outer coasts of

738 our study region (i.e. Bay of Brest and entrance excluded), model runs suggest that spring ranges  
739 reached a maximum at 6 kyr cal. B.P., with values greater than present-day by up to 3 to 6%. This  
740 only translates into minor changes in the height values (max. 0.3 m). More importantly, the  
741 relationships between neap, spring and astronomical tidal ranges have remained very constant  
742 through time on all our study sites (see SOM, appendix S2). As a consequence, only minor changes in  
743 indicative ranges are applied to most of the extracted SLIPs (Figure 14). Additionally, the model  
744 results show differences between neap and maximum tidal ranges to have continuously increased  
745 since 8 kyr cal. B.P., the most important rise being observed for Guisseny (0.7m). These changes  
746 required the indicative ranges of SLIPs derived from undifferentiated high-marsh brackish peat  
747 deposits (see section 3.1.3, indexes n°20, 22 and 39) to be slightly adjusted (reduced by 0.09m). As a  
748 main result, we can state that our HWST-related indicators lead to only slightly over-estimate the MSL  
749 evolution. Yet, it must be noted that the paleo tidal models we used were developed at a regional  
750 scale (continental shelf) and thus are most probably unable to catch the changes in tidal ranges that  
751 may have occurred at site-scales due e.g. to reorganizations of the foreshore sedimentary wedges.  
752 These local changes in tidal ranges may have potentially been higher than those we modelled at the  
753 shelf-scale.



754  
 755  
 756 **Figure 13 - Paleo tidal model outputs of the maximum annual tidal range (maps 1 & 2) and Spring tidal**  
 757 **ranges (maps 3 & 4) for the study region for 8 ky and 6 ky cal. B.P. Stars show the locations of the**  
 758 **Guisseny-Tressény (A), Porsmilin (B) and Treffiagat (C) sites. Example plots of the 8ky to present-day**  
 759 **evolution of the local max. annual, spring and neap tidal ranges are shown. Plots for the other sites are**  
 760 **given in SOM (appendix S2). Complete model outputs values can be found as supplementary material in**  
 761 **SOM (appendix S2).**

762



763

764 **Figure 14 - Sea-level index points uncorrected (plain boxes) and corrected (dotted boxes) for paleo tidal**  
 765 **range changes through the last 8 ky cal. B.P.**

766

767 4.7. Regional to global causes of the data-models misfits: North-western Europe Ice-  
 768 sheet complex history, lateral variations in the earth structure and meltwater  
 769 contributions

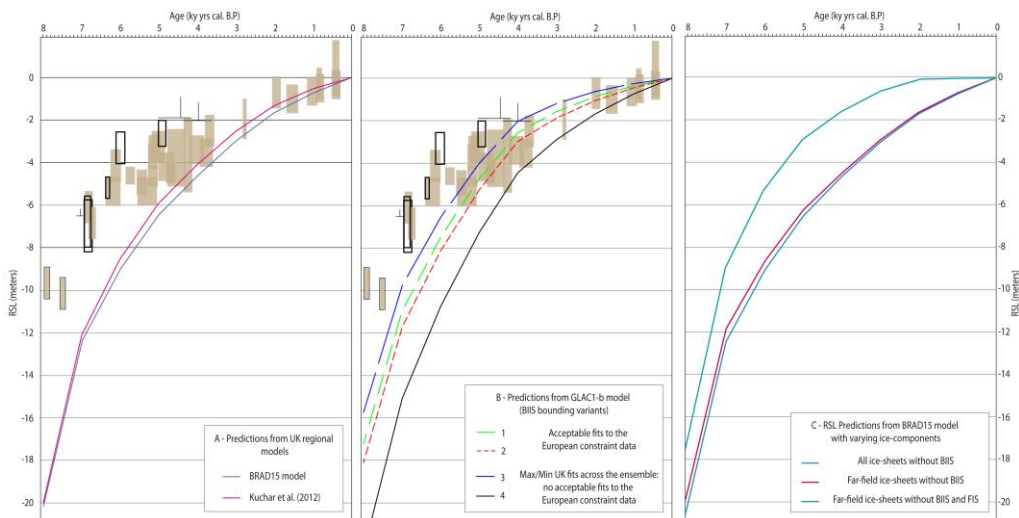
770 As demonstrated above (section 4.4), the effects of regional changes in the tidal-ranges remained  
 771 negligible during the Holocene in our study region and are largely insufficient to explain the plurimetric  
 772 offsets observed between our observational RSL data and GIA models RSL predictions (Fig.11,  
 773 Fig.14). As such, hypotheses other than local to regional changes in the tidal ranges are required to  
 774 explain the large data-models misfits we observe. In this section, we explore several agents that may  
 775 play a role in the data-models misfits we observe between the RSL predictions of the GIA models and  
 776 our RSL reconstruction based on geological indicators.

777 **We propose that the misfits could mainly be due to an over-estimation of the glacio-isostatic**  
 778 **component, which can be explained by an over-estimation of the spatial extent and amplitude of the**  
 779 **European peripheral bulge and/or to temporal inaccuracies. This is partially corroborated by the**

**Commentaire [BVVL13]:** RE WRITTEN SECTION WITH SUPPLEMENTARY FIGURES : 1) PLOT OF SPLIT RSL SIGNALS BETWEEN REGIONAL AND FAR-FIELD ICE-SHEETS ADDED TO FIG.9, 2) PLOTS OF SENSITIVITY ANALYSES TO EARTH-MODEL PARAMETERS

780 increases in model/data misfits with time. The easiest solution to resolve such under-predictions could  
781 be to lower the vertical amplitude of the peripheral bulge, e.g. by reducing the ice-thicknesses - and  
782 hence ice-loads - over the British Isles. Yet, a thinner BIIS would considerably increase the model-data  
783 discrepancies in near-field areas (such as Scotland) and would be contrary to the recent reevaluations  
784 of Scottish trimline data. Indeed, these latter studies suggest that BIIS ice-thickness would have  
785 conversely been thicker than what is accounted in the models we used (e.g. Ballantyne *et al.*, 2008,  
786 Ballantyne, 2010; Ballantyne and Stone, 2015). To investigate the sensitivity of the RSL predictions to  
787 the size of the BIIS, we generated RSL predictions for the Brittany region with bounding variants of  
788 BIIS ice models (i.e., various ice-thicknesses for the BIIS, figure 9a and 9b). For example, the revised  
789 ice-model used by Kuchar *et al.* (2012) which is up to two-three times thicker than the BRAD15 ice  
790 model (Bradley *et al.*, 2011) only results in a maximum 0.5 m vertical difference in the RSL predictions  
791 produced by the two models (Figure 9a). This statement is also supported by figure 9b, where RSL  
792 predictions generated by the GLAC1-b model with extremal bounding BIIS variants (bounding with  
793 respect to regional Holocene RSL). These results illustrate that diverging scenarios of the BIIS and  
794 ice-thicknesses over the British-Isles would only be responsible for slight changes in the RSL  
795 predictions for ice-distal locations such as the Brittany region. As we illustrated in figure 9 and already  
796 suggested by Bradley *et al.* (2011) and Kuchar *et al.* (2012), the RSL signal at these distal southern  
797 sites is primarily driven by eustasy and the collapse of the peripheral bulges from all the major  
798 Northern Hemispheric ice-sheets, and most prominently that of the Fennoscandian ice sheet that  
799 accounts for much of the loading within our study region (about 50% at 6 ky cal. B.P., Fig.9 and  
800 Fig.10). This advocates for the data-model misfits observed for Brittany, if such misfits are well driven  
801 by problems at the level of the architecture and deglaciation histories of the ice-sheets, to be rather  
802 linked to FIS than to BIIS. GIA response being non-linear, it must be noted that the separation  
803 between ice-sheets would be fully appropriate only neglecting the migration of shorelines. The results  
804 of such a separation are only approximations. Yet, uncertainties linked to this phenomenon are likely  
805 to be very small, causing changes in the RSL trends of an order of  $2 \times 10^{-6}$  mm.yr<sup>-1</sup> (G.Spada, *comm.*  
806 *pers.*) Finally, the complex trade-off between regional and global signals must be accounted that  
807 makes that straightforward relationships between ice-thicknesses and RSL history of distal regions  
808 remain hard to establish (Kuchar *et al.*, 2012).

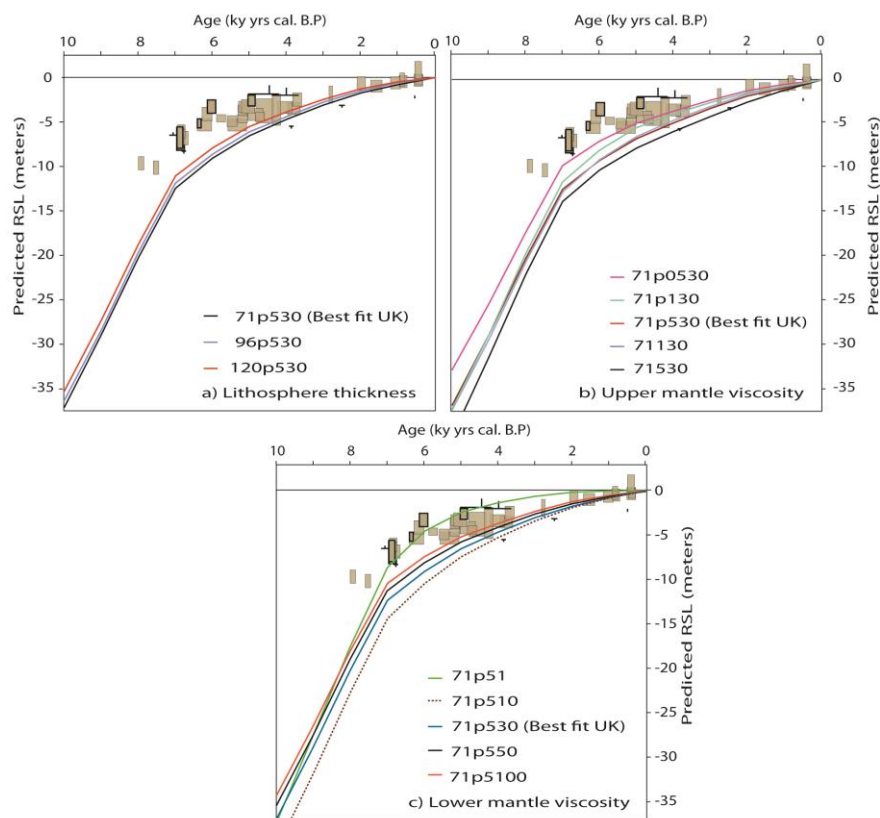
809 On the basis of such statements, we suggest that the possible origin for the data-model  
 810 discrepancies are related to some combination of: (i) errors in the regional earth structure in the  
 811 adopted Earth model, (ii) inaccuracies in the pattern of ESL due to potential issues related to the  
 812 amplitude, provenance and timing of farfield meltwater contributions and (iii) issues relating to the  
 813 spatial and temporal pattern of deglaciation of the FIS and LIS and the resultant peripheral bulges.



814  
 815 **Figure 9 - (A), (B) Plots showing the effects of varying the British Irish Ice-Sheet on the RSL predictions**  
 816 **from the regional and global GIA models, respectively (refer to the text for further explanation). (C) Plot of**  
 817 **the RSL signal induced by the different ice-sheet loadings as predicted by the “BIIS” model, showing the**  
 818 **relative responsibility of far-field ice-sheets, BIIS and FIS within the total Holocene RSL signal for the**  
 819 **Brittany region. (A) Predictions from the regional models fine-tuned for the British-Isles. “BIIS” and Kuchar**  
 820 **models ran with a unique earth model (lithosphere thickness of 71 km, upper- and lower-mantle viscosity of**  
 821  **$0.3 \times 10^{20}$  and of  $2 \times 10^{20}$  Pa.s, respectively). Note that the BIIS in the Kuchar model is 2-3 times than in the “BIIS”**  
 822 **model (B) Predictions of the Glac1-b model for BIIS bounding variants (after 9087 full model runs): Inner curves**  
 823 **(red and green lines, respectively) do have weakly acceptable European Ice-sheets. Conversely, outer curves**  
 824 **(black and blue lines, respectively) show max/min UK fits across the ensemble and do not have acceptable fits to**  
 825 **the European constraint data.**

826 With regards to rheological issues, the data-model discrepancies we observe may originate from the  
 827 fact that most GIA models use radially-varying one dimensional Earth models that assume a  
 828 spherically symmetric Earth rheology. Yet, such earth models have been shown to be inaccurate (e.g.  
 829 Spada *et al.*, 2006; Whitehouse *et al.*, 2006) as they disregard lateral variations in the Earth structure.  
 830 The VM2 and VM5a earth models, which were combined with the ICE-5G and Glac-1b global models

831 were developed on the basis of the fit to RSL data from old-cratons regions of north-American  
 832 (Hudson Bay, Canada) and Northern-Europe (Angerman River, Sweden). Hence, these models do not  
 833 consider the large-scale variations in the earth structure that were identified at the scale of Western  
 834 Europe (Spada *et al.*, 2006; Whitehouse *et al.*, 2006) and also may not be appropriate to use at  
 835 locations distant from the reference regions to which they were tuned.



836

837 **Figure 10 - Plots of “BIIS” model RSL predictions for a range of (a) varying lithosphere thicknesses, (b)**  
 838 **varying upper mantle viscosities and (c) varying lower mantle viscosities.** In (a), 120p530, 96p530 and  
 839 71p530 are model predictions for lithosphere thicknesses of 120 km, 90 km and 71 km, respectively and fixed  
 840 upper- and lower-mantle viscosities of  $5 \times 10^{20}$  Pa.s and  $3 \times 10^{22}$  Pa.s (parameters of the best fit model for the  
 841 British Isles, Bradley *et al.*, 2011), In (b) 71p0530, 71p130, 71p530, 71130 and 71530 are predictions for fixed  
 842 lithosphere thickness and lower mantle viscosity values of 71 km and  $3 \times 10^{22}$  Pa.s, and upper-mantle viscosities  
 843 values of  $5 \times 10^{19}$  Pa.s,  $1 \times 10^{20}$  Pa.s,  $5 \times 10^{20}$  Pa.s,  $1 \times 10^{21}$  Pa.s and  $5 \times 10^{21}$  Pa.s, respectively. In (c) 71p51,  
 844 71p510, 71p530, 71p550 and 71p5100 are predictions for fixed lithosphere thickness and upper- mantle viscosity values of  
 845 71 km and  $5 \times 10^{20}$  Pa.s, and lower-mantle viscosities values of  $1 \times 10^{21}$  Pa.s,  $1 \times 10^{22}$  Pa.s,  $3 \times 10^{22}$  Pa.s,  $5 \times 10^{22}$  Pa.s  
 846 and  $10 \times 10^{22}$  Pa.s, respectively.

Commentaire [BVVL14]: NEW  
 FIGURE

847 The best-fit UK regional models ("BIIS" and Kuchar) were also combined with Earth-models that adopt  
848 only a spherically symmetric Earth rheology (Bradley *et al.*, 2011, Kuchar *et al.*, 2012). However, these  
849 Earth model parameters were fine-tuned to provide adequate regional solutions fitting UK RSL data  
850 and UK GPS data. In this context, the very large misfits we observe in Brittany between the data and  
851 the UK regional models are even more surprising and we propose three possible explanations.

852 First, regional models were tuned to an older, relatively poorly constrained FIS component (modified  
853 from ICE-3G model, see Shennan *et al.*, 2006), which would in turn affect the amplitude and/or  
854 position of the European peripheral bulges. Yet, as stated before, FIS would drive most of the RSL  
855 signal for the NW Europe sites. Another explanation could be that adopted regional earth model  
856 parameters are biased towards the RSL data from the northern rather than southern site (see Fig.7c  
857 and Fig.4c in Bradley *et al.*, 2011 and Kuchar 2012). Indeed, these studies showed a clear distinction  
858 in the sensitivity of the RSL data to the adopted Earth model parameters between the northern and  
859 southern UK RSL data. Finally, an explanation could be related to the lateral heterogeneities in the  
860 lithospheric structure and mantle viscosity profile across the English Channel that are not included  
861 within the earth models. We made some tests to evaluate the dependency of the data-model misfits to  
862 changes in the Earth parameters (Fig.10). Several combinations of lithosphere thicknesses and upper-  
863 / lower-mantle viscosities were ran within the BRAD15 model. Slight variations in the RSL predictions  
864 are with the different lithosphere thicknesses, in accordance with the suggestions of Watts (2001) and  
865 Whitehouse *et al.* (2006). One another hand, our results show RSL predictions from BRAD15 model to  
866 be particularly sensitive to changes upper- and lower-mantle viscosities. The best fits with RSL data  
867 from Brittany are obtained with low upper- and lower-mantle viscosities of  $5 \times 10^{19}$  Pa.s and  $1 \times 10^{21}$   
868 Pa.s, respectively. Those viscosities are significantly lower than those of the best-fit model for the  
869 British Isles (Bradley *et al.*, 2011; Kuchar *et al.*, 2012), thus possibly highlighting for large lateral  
870 variations in the Earth structure across the Western termination of the English Channel. Such  
871 variations seem supported by seismic tomography studies which find evidence for differences in the  
872 lower upper-mantle shear wave velocities between France and south-western UK at 410 and 585 km  
873 depths (Legendre *et al.*, 2012; Zhu *et al.*, 2012). Particularly, contrasts in the S-wave speeds of up to  
874 4% are observed in the Western and Irish Sea regions, which can be converted into variations in the  
875 upper mantle viscosity of up to four orders of magnitude (Wu *et al.*; 1998) between Cornwall-Devon  
876 and Brittany. This evidence supports the theory that significant variations exist in the near-field lateral



877 structure of the shallow earth below the study regions, which are not resolved by the GIA earth  
878 models. This said, a caveat must be that such low upper-mantle viscosities values are inconsistent  
879 with Angerman river decay time constraints (Nordman *et al.*, 2015) (Can you develop, LEV??).  
880 Finally, the presence of a deep relic crustal suture zone (Rheic suture) along the southern coast of  
881 England (Legendre *et al.*, 2012) also raises the question of the likelihood for the elastic response of  
882 the lithosphere to get mitigated in the vicinity of deep faulted suture zones.

Commentaire [BVVL15]: NEED SOME  
HELP HERE TO WRITE SOMETHING SUBTLE  
AND PRECISE.

883 Also, As all GIA models considered under-estimate the RSL during the older Holocene (pre 8 kyr  
884 cal. BP), this would be consistent with an under-estimation of the ESL resulting from the far-fields ice  
885 sheets, such as Antarctic, Iceland, Patagonia and Eastern Siberia / Arctic sea during this period (Clark  
886 & Tarasov, 2012; Niessen *et al.*, 2013). As originally proposed by Milne and Peros (2013) from  
887 comparisons with RSL data from circum-Caribbean far-field regions, the fact that the predictions of  
888 Bradley's and Kuchar's models fall far below our observational data may imply that the EUST3 global  
889 model (part of the BRAD15 model; Bradley, 2011, Bradley *et al.*, submit.) used by these models  
890 involves too much melting after 8 kyr B.P., in turn causing the "eustatic" component to be over-  
891 deepened during Mid- to Late-Holocene. However, an increase in the melt from 8 kyr BP was required  
892 in the EUST3 model to reduce the over prediction in the height of the Holocene high stand at the UK  
893 and Ireland RSL data.

## 894 **Conclusion**

895 This new RSL dataset developed for the Finistère region (Western Brittany, France) significantly  
896 improves our knowledge of the Holocene RSL history in this region. We observe a general ca. 7-m  
897 RSL rise over the last seven thousand years. The six new basal SLIPs, free from possible vertical  
898 displacement induced by post-depositional compaction, now enable the extraction of reliable RSL  
899 trends for the 8 kyr to 4 kyr B.P. interval. These new SLIPs points more precisely constrain the  
900 decrease in the rates of RSL rise during the Mid-Holocene, with inflections centered around 7 kyr, 6  
901 kyr and ca. 5-4 kyr cal. B.P. During Late Holocene (post 4 kyr cal. B.P. period), the lack of basal data  
902 still precludes the reconstruction of a precise reliable RSL history. This study, for the first time applies  
903 paleo-tidal modeling corrections to SLIP reconstructions for data sites from France. The results of our  
904 paleo-tidal modelling confirm those previously published by Uheara *et al.* (2006) and Neill *et al.* (2010),  
905 showing (i) that tidal ranges only underwent slight changes since 8 kyr cal. B.P. (max. 0.7m increase)

906 and (ii) that the relationships between neap, spring and astronomical tidal ranges remained very  
907 constant through time.

908 This revisited Holocene RSL evolution for Western Brittany has significant implications for the  
909 understanding of isostatic dynamics along the Atlantic coasts of Western Europe and, particularly, of  
910 its glacio-isostatic component, linked to the collapse of the European peripheral bulge south of the  
911 British Isles. A large time-dependent vertical offset between the RSL records of the two regions  
912 suggests that Southwestern UK experienced a greater subsidence than Western Brittany during the  
913 last thousand years. We propose, that this offset probably indicates that Southwestern UK was located  
914 closer to the apex of the bulge than Brittany was.

915 At a larger scale, our results challenge the hypotheses that were previously proposed on the  
916 amplitude and the extent of the glacio-isostatic peripheral bulge subsidence along the Atlantic coasts  
917 of Northwestern Europe. Comparisons of our data with RSL predictions from both global ICE-5G  
918 (VM2a) and GLAC1-b (Tarasov & Peltier, 2002; Tarasov *et al.*, 2012; Briggs *et al.*, 2014) and regional  
919 (“BIIS” model of Bradley *et al.*, 2011, model of Kuchar *et al.*, 2012) GIA models show that none of the  
920 models fit our observations satisfactorily. The regional models under-estimate the observed RSLs by  
921 several meters and thus probably over-estimate the subsidence that Brittany underwent during the  
922 Holocene. This misfit could not be resolved with significant changes to the size and deglaciation  
923 histories of the BIIS, suggesting the source of the misfit may be related to (i) errors in the pattern and  
924 amounts of meltwater production from the far-field ice sheets, (Antarctic, Iceland, Patagonia and Arctic  
925 sea) which are predominately driving the RSL rise across the study region and to (ii) lateral variations  
926 in the Earth’s structure across the English Channel, especially in the upper-mantle viscosity, which  
927 occur over relatively short-scale lateral distances and (iii) potential misfits in the adopted FIS history.  
928 More generally, this work highlights the importance for future work to consider the potential role played  
929 by such lateral heterogeneities in the RSL signal across this region. Generally, this work again  
930 identifies the importance of developing three-dimensional earth models and of further considering the  
931 potential roles played by tectonic features in isostatic adjustment dynamics.

932 Several questions, pertaining to the isostatic dynamics at the scale of Northwestern Europe are still  
933 to be resolved. Providing reliable answers to these questions will allow a better prediction of future  
934 regional RSL variations. Our work emphasizes the need for more new reliable index points along the

935 coasts of Eastern North Atlantic and of the English Channel, in order to estimate more precisely the  
936 relative contribution of the hydro- and glacio-isostatic components of the RSL rise, as well as to better  
937 constraint three-dimensional lateral and vertical variations in the Earth structure across the English  
938 Channel. Such work is already underway. Furthermore, as such distal regions can be shown to the  
939 highly sensitive to changes in the far-field eustatic signal, such new data could provide new  
940 information for the rates of ESL rise over the Holocene.

941 The results of this study insist on the fact that GIA models are still unable to provide a reliable  
942 evaluation of the subsidence history for the Brittany region. Yet, recent RSL rise rates are calculated  
943 from modern tide-gauge records corrected from land-movements by using GIA predictions.  
944 Considering the inconsistency of the GIA prediction with the geological RSL records, it is likely that  
945 modern RSL rise rates obtained from Brest tide-gauge record are under-evaluated.

#### 946 **Supporting information (Supplementary Online Material)**

947 Additional supporting information can be found as Supplementary Online Material in the online version  
948 of this article:

950 S1- Building of the salt-marsh surface sediments geochemical modern referential and application to  
951 Holocene cores

952 S2- Numerical outputs of the paleo tidal modelling at our study sites.

953 S3- RSL spatial plots from "BIIS", Glac-1B and ICE-5G (VM2a) GIA model predictions for the 7 ky,  
954 6ky, 5ky and 4ky B.P periods.

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SOME MORE SUPPLEMENTARY ONLINE  
MATERIAL

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Site	Reference tide-gauge(s) location	Spring Tidal range	HAT (m NGF)	MHWST (m NGF)	MHWNT (m NGF)	MTL (m NGF)	MLWNT (m NGF)	MLWST (m NGF)	LAT (m NGF)
Guissény	Brignogan / Aber Wrac'h	7.52	4.74	4.06	2.36	0.62	-1.07	-3.46	-4.37
Landéda	Aber Wrac'h	7.52	4.45	3.73	2.08	0.39	-1.17	-3	-3.95
Porsmilin	Le Trez-Hir	5.55	4	3.17	1.67	0.39	-0.93	-2.38	-3.21
Treffogat	Le Guilvinec	4.2	3.16	2.66	1.56	0.50	-0.44	-1.54	-2.38
Kermor-Tudy	Loctudy	4.20	3.09	2.45	1.35	0.41	-0.65	-1.75	-2.40
Guidel	Le Pouldu	4.15	2.78	2.23	1.18	0.17	-0.82	-1.92	-2.65

1241 **Table 1 - Present-day tidal levels on the studied sites (from SHOM, 2013).** Levels are given related to the French ordnance datum (m NGF). HAT (Highest  
1242 Astronomical Tide), MHWST (Mean High Water Spring Tides), MHWNT (Mean High Water Neap Tides), MTL (Mean Tide Level), MLWNT (Mean Low Water  
1243 Neap Tides) MLWST (Mean Low Water Spring Tides), LAT (Lowest Astronomical Tide)  
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Source of vertical uncertainties	Amplitude
Coring process	Hand-auguring : - 0.02m / meter depth Percussion-coring: null Screw-drilling: ± 0.5 m
Levelling	DGPS measurement : ± 0.02m Geodetic benchmark accuracy : ± 0.1 m
Sampling	± 0.02 m
Tidal levels	± 0.05 m when estimated from distant stations

1245 **Table 2 - Errors terms used in RSL reconstruction.**

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Deposit environment	$\delta^{13}\text{C}$ (‰)	TOC (%)	TN (%)	Pollen	Plant macro-remains	Foraminifera (if present)	Pyrite	Indicative meaning
Biozone 2	-28 / -26.4	1 - 8	0.1 - 0.85	Presence of halophilous species	E.g. Halimione sp., Triglochin sp., Limonium vulgare	Mid to low marsh species	Embedded within the sedimentary matrix	(SWLI 179 – SWLI 129) /2
Biozone 3	-28 / - 25.5	>4.95	>0.9	Presence of halophilous species	E.g. Juncus maritimus, Scirpus maritimus, Halimione portulacoides	high marsh species	Embedded within the sedimentary matrix	(SWLI 212 – SWLI 183) /2
Undifferentiated brackish peat deposit	n/a	n/a	n/a	Presence of halophilous species	E.g. Phragmites australis, Juncus roemerianus, Juncus maritimus	Present	Embedded within the sedimentary matrix	(HAT – MHWNT) /2
Freshwater peat deposit	n/a	n/a	n/a	Absence of halophilous species	Freshwater reed species	absent	absent	High limiting (> MHWST)

1247 **Table 3 – Indicative meanings used to reconstruct RSL from foraminifera poor sedimentary sequences.** Reader is invited to refer to Supplementary

1248 Online Material S1 for further explanations on the building of the modern geochemical reference.



Index n°	Core	14C Lab code	Age B.P. conv.	Cal. a BP (2σ)		Elevation		Position	δ <sup>13</sup> C ‰	TOC %	TO N %	C/N	Indicative meaning (m)	Vertical uncertainties (m)					RSL (m relative to present-day MHWST)	RSL corrected for regional changes in paleo tidal ranges		
				min (med. Prob.)	max	(m NGF)	Relative to local HWST							Indicative range	Coring	Sampling	Levelling	Distant tidal station		Total	RSL position (m relative to present-day MHWST)	Indicative range (m)
1	GUIS-C2	UBA-15681	431 ± 28	527 (500)	338	3.2	-0.8	I	-27.63	4.35	0.33	13.09	-1.65	0.94	0	0.02	0.12	0.05	0.94	0.85 ± 0.94	0	0
2	GL2	Poz-48807	970 ± 30	933 (860)	796	1	-1.226	I	-26.40	4.74	0.36	13.30	-0.99	0.56	0.5	0.02	0.12	0.05	0.76	-0.23 ± 0.76	-0.04	0
3	KIX-1	SacA-23976	2305 ± 30	2084 (1964)	1864	0.8	-1.65	I	-19.95	1.17	0.11	11.09	-0.98	0.56	0.5	0.02	0.12	0	0.76	-0.67 ± 0.76	-0.07	0
4	KIX-3	SacA-23976	2875 ± 30	2774 (2703)	2565	-1.4	-3.85	I	-22.40	3.03	0.28	10.70	-0.98	0.56	0.5	0.02	0.12	0	0.76	-2.87±0.76 (*)	n/d	n/d
5	GUIS-C2	UBA-15685	2 666 ± 25	2844 (2770)	2746	0.05	-3.63	I	-27.76	2.35	0.18	12.86	-1.65	0.94	0	0.02	0.12	0.05	0.95	-1.98 ± 0.94	-0.20	0.02
6	KX1	Poz-42852	3425 ± 35	3825 (3676)	3581	-1	-3.45	I	-20.82	5.60	0.46	12.27	-0.98	0.56	0.5	0.02	0.12	0	0.76	-2.47 ± 0.76	-0.12	0
7	GUIS-C2	Poz-49796	4165±/35	4830 (4709)	4580	-0.8	-4.48	I	-28.01	36.92	1.50	24.60	-0.07	0.48	0	0.02	0.12	0.05	0.50	-4.41 ± 0.50	-0.19	0.02
8	TREF	Poz-45390	4340 ± 40	5035 (4913)	4839	-0.95	-3.61	BB	-25.27	5.56	0.44	12.66	-1.035	0.59	0.09	0.02	0.12	0.05	0.61	-2.58 ± 0.61	-0.28	0.01
9	GL1	Poz-49806	4395 ± 35	5212 (4957)	4859	-2	-4.226	I	-25.24	0.20	0.02	10.24	-0.99	0.56	0.5	0.02	0.12	0.05	0.76	-3.23 ± 0.76	-0.26	0.04
10	KX-3	Poz-36731	4530 ± 30	5309 (5156)	5053	-2.2	-4.65	I	-23.67	12.15	0.64	19.02	-0.98	0.56	0.5	0.02	0.12	0	0.76	-3.67±0.61	-0.17	0
11	GUIS-C2	Poz-49798	4530±/35	5311 (5159)	5050	-0.95	-4.63	I	-27.90	16.89	1.04	16.22	-0.07	0.48	0	0.02	0.12	0.05	0.50	-4.56 ± 0.5	-0.20	0.02
12	KX-2	Poz-42853	4480 ± 35	5292 (5167)	4978	-1.8	-4.25	I	-22.07	3.60	0.32	11.38	-0.98	0.56	0.5	0.02	0.12	0	0.76	-3.27±0.61	-0.17	0
13	KX-4	Poz-42854	4800 ± 40	5606 (5520)	5334	-2.49	-4.94	I	-26.62	23.51	1.21	19.51	-0.04	0.3	0.5	0.02	0.12	0	0.60	-4.9 ± 0.60	-0.19	0
14	PM1	Poz-42858	5000 ± 35	5891 (5728)	5645	-1.5	-4.67	I	-28.61	23.92	1.26	19.00	-0.1	0.4	0	0.02	0.12	0.05	0.42	-4.57 ± 0.42	0.09	0
15	KIX-4	Poz-42850	5215 ± 35	6129 (5965)	5908	-1.8	-4.25	BB	-21.96	0.28	0.04	8.07	-0.98	0.56	0.5	0.02	0.12	0	0.76	-3.27±0.76	-0.21	0
16	PM1	Poz-42860	5365 ± 35	6277 (6170)	6006	-2.27	-5.44	I	-28.00	13.56	0.65	20.82	-1.3	0.76	0	0.02	0.12	0.05	0.77	-4.1 ± 0.77	0.10	-0.01
17	GUIS-C2	UBA-15686	5 563 ± 31	6403 (6351)	6299	-1.52	-5.2	BB	-27.52	9.66	0.64	15.13	-0.07	0.48	0	0.02	0.12	0.05	0.50	-5.13 ± 0.5	-0.13	0.02
18	GL2	Poz-48773	5910 ± 40	6846 (6730)	6651	-5.59	-7.816	I	-24.59	1.16	0.10	11.25	-0.99	0.56	0.5	0.02	0.12	0.05	0.76	-6.81 ± 0.76	-0.13	0
19	KIX-5	Poz-42851	5990 ± 40	6939 (6829)	6736	-4.6	-7.05	B	-22.31	3.22	0.21	15.51	-0.98	0.56	0.5	0.02	0.12	0	0.76	-6.07 ± 0.76	n/a	n/a
20	TAR-S2	UBA-15458	6 001 ± 28	6927 (6845)	6750	-3.6	-7.38	BB	-26.9	-	-	-	-0.44	1.21	0.06	0.02	0.12	0.05	1.22	-6.95 ± 1.22	0.13	0.03
21	PM1	Poz-42861	6150 ± 40	7164 (7060)	6943	-3.3	-6.47	BB / HL	-	-	-	-	-	-	-	-	-	-	-	< - 6.47	n/a	n/a
22	GUIS-S2	UBA-15460	6 033 ± 29	6951 (6880)	6791	-3.5	-7.18	BB	-	-	-	-	-0.44	1.21	0.02	0.02	0.12	0.05	1.22	-6.74 ± 1.22	0.13	0.03
23	GL1	Poz-47039	6650 ± 40	7587 (7530)	7444	-8	-10.226	B	-26.38	15.51	0.77	20.08	-0.04	0.30	0.5	0.02	0.12	0.05	0.60	-10.18 ± 0.60	-0.04	0
24	GL2	Poz-49808	7090 ± 40	7996 (7923)	7840	-8.39	-10.616	B	-24.84	1.40	0.13	10.61	-0.98	0.56	0.5	0.02	0.12	0.05	0.76	-9.63±0.76	0.05	0

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**Table 4 - Details of the new Holocene RSL data obtained in this study.** (\*) indicates rejected dates (see text). The last two columns on the right show the correction applied to raw RSL data for changes in paleo tidal ranges. "I" stands for "intercalated" deposits" (uncorrected for compaction), "B" for "basal" deposits and "BB" for "base-of-basal" deposits, "HL" stands for "High Limiting" indexes.

Index n°	Location	Core	14C Lab code	Age B.P. conv.	Cal. a BP (2σ)		Position	Type	RSL (m relative to present-day MHWST)	Source	Correction for regional changes in paleo tidal ranges (This study)
				min (med. Prob.)	max	(m)					
25	Bay of Brest	P-C2	Erl-10678	3500±60	3957 (3773)	3615	I	SLIP	-3.49 ± 0.67	Stéphan <i>et al.</i> (2014)	0.17
26	Bay of Brest	P-C2	Erl-10679	4280±60	5036 (4852)	4625	I	SLIP	-4.17 ± 0.67	Stéphan <i>et al.</i> (2014)	0.21
27	Bay of Brest	P-C2	Erl-10680	4640±60	5581 (5394)	5071	I	SLIP	-5.32 ± 0.67	Stéphan <i>et al.</i> (2014)	0.21
28	Bay of Brest	T-C2	Erl-10682	940±56	952 (850)	734	I	SLIP	-0.48 ± 0.67	Stéphan <i>et al.</i> (2014)	0.04
29	Bay of Brest	T-C2	Erl-10683	3690±70	4235 (4031)	3843	I	SLIP	-3.35 ± 0.67	Stéphan <i>et al.</i> (2014)	0.17
30	Bay of Brest	T-C2	Erl-10686	5450±70	6399 (6242)	6015	I	SLIP	-5.32 ± 0.67	Stéphan <i>et al.</i> (2014)	0.25
31	Bay of Brest	A-C10	Erl-11753	1081±56	1174 (999)	916	I	SLIP	-0.61 ± 0.67	Stéphan <i>et al.</i> (2014)	0.04
32	Bay of Brest	A-C14	Erl-11749	436±55	546 (483)	316	I	SLIP	-0.30 ± 0.67	Stéphan <i>et al.</i> (2014)	0.02
33	Bay of Brest	A-C14	Erl-11750	1686±56	1720 (1597)	1415	I	SLIP	-0.97 ± 0.67	Stéphan <i>et al.</i> (2014)	0.06
34	Bay of Brest	A-C14	Erl-11751	2340±54	2691 (2372)	2159	I	SLIP	-2.26 ± 0.67 (*)	Stéphan <i>et al.</i> (2014)	0.08
35	Bay of Brest	A-C14	Erl-11752	2716±55	2941 (2822)	2748	B	SLIP	-2.96 ± 0.67 (*)	Stéphan <i>et al.</i> (2014)	0.13
36	Tresseny	G-C2	UBA 15681	431±28	527 (500)	338	I	SLIP	-0.28 ± 0.55	Stéphan <i>et al.</i> (2014)	-0.02
37	Tresseny	G-C3	UBA 15459	4054±32	4785 (4530)	4426	B	SLIP	-3.75 ± 1.35	Stéphan <i>et al.</i> (2014)	-0.09
38	Trezien	/	GIF-714	3660 ± 115	4385(3994)	3648	BB / HL	SLIP	<2 ± 0,55	Goslin <i>et al.</i> (2013) Morzadec-Kerfourn (1974)	n/a
39	Arg.- Gwen.	/	GIF-816	3970 ± 35	4525 (4453)	4297	BB	HL	-3.61 ± 1,75	Goslin <i>et al.</i> (2013) Morzadec-Kerfourn (1974)	n/a
40	Plou.-Pors.	/	GIF-711	4120 ± 140	5031 (4605)	4184	BB	SLIP	< -1,86 ± 0,55	Goslin <i>et al.</i> (2013) Morzadec-Kerfourn (1974)	n/a

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**Table 5 - Holocene RSL data from previous studies** (Morzadec-Kerfourn, 1974; Goslin *et al.*, 2013; Stéphan *et al.*, 2014) incorporated to our dataset. (\*) indicates rejected dates (see text). The last column on the right show the correction applied to raw RSL data for changes in regional paleo tidal ranges. "I" stands for "intercalated" deposits" (uncorrected for compaction), "B" for "basal" deposits and "BB" for "base-of-basal" deposits, "HL" stands for "High Limiting" indexes.

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**Supplementary Online Material 2 (Appendix S2): Numerical outputs of the paleo tidal modelling at our study sites.**

Time	Site	Guissény		Porsmilin		Bay of Brest		Treffiagat		Kermor-Tudy		Guidel	
		Range (m)	%	Range (m)	%	Range (m)	%	Range (m)	%	Range (m)	%	Range (m)	%
<b>NEAP TIDAL RANGES</b>													
0 (control)		3,50	100	2,6	100,0	2,79	100,0	2	100	2	100	2	100
1 Ky B.P		3,50	100	2,59	99,6	2,74	98,2	2	100	2	100	2	100
2 Ky B.P		3,50	100	2,57	98,8	2,69	96,4	2	100	2	100	2,01	100,5
3 Ky B.P		3,50	100	2,56	98,5	2,64	94,6	2,01	100,5	2	100	2,01	100,5
4 Ky B.P		3,50	100	2,55	98,1	2,6	93,2	2,01	100,5	1,99	99,5	2,01	100,5
5 Ky B.P		3,50	100	2,53	97,3	2,55	91,4	2,01	100,5	1,99	99,5	2,02	101
6 Ky B.P		3,50	100	2,52	96,9	2,5	89,6	2,01	100,5	1,99	99,5	2,02	101
7 Ky B.P		3,16	90,3	no data	no data	no data	no data	1,77	88,36	no data	no data	1,78	89
8 Ky B.P		2,82	80,6	no data	no data	no data	no data	1,52	76,02	no data	no data	1,54	77
<b>SPRING TIDAL RANGES</b>													
0 (control)		6,97	100	5,55	100	5,9	100	4,15	100	4,2	100	4,15	100
1 Ky B.P		7,01	100,6	5,53	99,6	5,82	98,6	4,2	101,2	4,23	100,7	4,2	101,2
2 Ky B.P		7,05	101,1	5,52	99,5	5,74	97,3	4,24	102,2	4,27	101,7	4,26	102,7
3 Ky B.P		7,09	101,7	5,5	99,1	5,65	95,8	4,29	103,4	4,3	102,4	4,31	103,9
4 Ky B.P		7,13	102,3	5,48	98,7	5,57	94,4	4,34	104,6	4,34	103,3	4,36	105,1
5 Ky B.P		7,17	102,9	5,46	98,4	5,49	93,1	4,39	105,8	4,37	104,0	4,41	106,3
6 Ky B.P		7,21	103,4	5,45	98,2	5,41	91,7	4,43	106,7	4,41	105,0	4,47	107,7
7 Ky B.P		6,84	98,1	no data	no data	no data	no data	4,22	101,7	no data	no data	4,28	103,1
8 Ky B.P		6,48	93,0	no data	no data	no data	no data	4,01	96,6	no data	no data	4,1	98,8
<b>MAX ANNUAL TIDAL RANGES</b>													
0 (control)		8,73	100	7,2	100	7,68	100	5,54	100	5,49	100	5,43	100,0
1 Ky B.P		8,73	100	7,19	99,9	7,63	99,3	5,54	100	5,49	100	5,43	100,0
2 Ky B.P		8,64	98,9	7,17	99,6	7,58	98,7	5,54	100	5,49	100	5,44	100,2
3 Ky B.P		8,54	97,8	7,16	99,4	7,53	98,0	5,55	100,2	5,49	100	5,44	100,2
4 Ky B.P		8,45	96,7	7,15	99,3	7,49	97,5	5,55	100,2	5,48	99,82	5,44	100,2
5 Ky B.P		8,35	95,6	7,13	99,0	7,44	96,9	5,55	100,2	5,48	99,82	5,45	100,4
6 Ky B.P		8,26	94,6	6,57	91,3	6,53	85,0	5,43	98,0	5,41	98,54	5,49	101,1
7 Ky B.P		8,16	93,5	no data	no data	no data	no data	5,22	94,2	no data	no data	5,31	97,8
8 Ky B.P		7,77	89,0	no data	no data	no data	no data	5,01	90,4	no data	no data	5,13	94,5