Holocene oscillatory sea level: literature review and implications for imminent anthropogenic multi-metre transgression

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Abstract

The famous 1961 'Fairbridge Curve' of Holocene sea level (SL) shows metre-scale (up to ~5m) oscillations, based on a worldwide compilation of carbon-dated geological data-points. Dozens of later authors found further evidence for such fluctuations; while dozens of others, including the Intergovernmental Panel on Climate Change (IPCC), deny oscillations >50cm. The debate is settled here by (1) a review of the Holocene SL literature, exposing flaws in the techniques and assumptions used in constructing smooth SL curves, and (2) an exhaustive review (companion study by the author) of copious published English coastal archaeology, proving a ~4-metre SL rise in only ~70 years (~430-500AD, early 'Dark Ages'), equating to Fairbridge's global 'Rottnest transgression', but much more precisely dated (dendrochronology, coins, pottery). Thus, the IPCC's opinion that global mean SL has risen faster since 1900 than over any preceding century in at least the last 3,000 years is incorrect. This vindication of Fairbridge implies that IPCC's 'worst-case' predicted SL rise of 1.75m by 2100 is, in fact, unexceptional. Another companion study argues that 'Fairbridge-type' SL rises must be due to Antarctic ice-cliff-collapse events, attributable to warming by solar grand maxima, apart from the next collapse (anthropogenic), predicted to raise SL at least 3m by 2100.

1. Introduction

The following abbreviations are used throughout this article: C = Century AD; mm = millimetres; cm = centimetres; m = metres; y = years; ky = thousand years; ka =

thousand years B.P. ('Before Present', i.e. before 1950, by convention); SL = sea level; O.D. = United Kingdom Ordnance Datum, 1915 to 1921 mean SL at Newlyn Tidal Observatory.

The Intergovernmental Panel on Climate Change (IPCC) is confident that, due to anthropogenic global warming, sea level (SL) will rise >0.5 and <1m by 2100, with a "Low-likelihood, high-impact" worst case of 1.75m (IPCC, 2021a, Fig. SPM.8d). IPCC believes that no SL oscillation in the last 2.5ky exceeded 25cm, based on a global SL curve by Kemp et al. (2018; republished in IPCC 2021b, Fig. 2.28b), constructed using a selective assemblage of published SL proxies (updated from Kopp et al., 2016). However, the chosen proxies are defective (see Section 3). As a result, it is argued here that NASA's (2025) assertion that the present-day rate of global sea level rise, 3mm/y (101mm rise from January 1993 to October 2024; NASA, 2025) is "unprecedented over the past 2,500-plus years" is incorrect. Rates an order of magnitude higher are indicated for several Holocene-interglacial (began 11.7ka; Walker et al., 2009) marine transgressions on the global oscillatory 'Fairbridge Curve' (see Section 2), e.g. ~2m rise in ~50y (= average 4cm/y) at ~4.2ka (Fairbridge, 1976, fig. 3). The following our other publications similarly indicate rapid Holocene SL rises. Schofield (1960, p. 479) doubted his own New Zealand evidence for "an extraordinary rapid rise in sea level of 5 ft in less than 50 years" (>3cm/y) about 2.5ka (his fig. 8d), stating (p. 479) that the key data-point "is more happily placed if considered to be 100 years younger" (i.e. 5-foot rise in 150y). In France, the "Saint Firmin Submergence ... appears to have been extremely fast" (Ters, 1987, p. 227). Ters' SL curve (her fig. 12.2) depicts the Saint Firmin as a ~2.5m rise in ~300y (~0.8cm/y) but, given the long time-gap (~300y) between the two defining data-points, the rise could have lasted <100y (i.e. >2.5cm/y). On the Florida (USA) Gulf of Mexico coast, the "Wulfert sea-level rise" (Walker et al., 1995, p. 208), based on archaeology, amounted to ~2m in ~150y (~1.3cm/y; their fig. 8). The Brazilian SL curve of Martin et al. (2003, fig. 7B) shows a SL rise of ~3.5m in ~200y (~2cm/y) at ~3.6ka. However, given the wide error-bars (typically 150-300y), the rise may have lasted <100y (i.e. >3.5cm/y). A glacio-eustatic SL rise of 2-3m in <100y (i.e. average of 2-3cm/y or more) was proven for the previous interglacial, MIS5e (Blanchon et al. 2009; Blanchon, 2011).

Many subsequent authors agreed with Fairbridge that m-scale oscillations characterised Holocene SL, but many others disagreed (see Section 2). The debate is settled by an exhaustive review (Higgs, 2024, 2025a) of copious English coastal archaeology literature, of hitherto underappreciated SL significance, proving a ~4-metre sea-level rise lasting only ~70 years (~430-500AD, early 'Dark Ages'), equating to the "Rottnest transgression" of Fairbridge (1961, p. 171; "Rottnest Submergence" in table 2 and fig. 15).

2. Holocene global sea level: oscillatory or smooth?

Based on a global compilation of published age-and-elevation data for dozens of geological markers of former SL, such as raised or drowned beaches, wave-cut benches and salt-marsh-peat beds, Fairbridge (1961, fig. 15) produced his renowned Holocene-interglacial SL curve. (A precursor, showing none of the data, appeared in Fairbridge [1960, p. 76].) The 1961 curve was updated by Fairbridge (1976), who referred to his 1961 original as the "Fairbridge Curve" (p. 358); and was updated again by Fairbridge and Hillaire-Marcel (1977). All three versions show repeated, m-scale, rapid (<300y) rises interspersed with m-scale falls during the last 6ky. Recognising the supra-regional extent of his SL oscillations, Fairbridge (1961) interpreted them as global, i.e. eustatic, specifically glacio-eustatic, stating "Every recorded glacial advance of the last 5000 years is matched by a eustatic lowering" (p. 173).

Many subsequent authors ("wigglers" of Bungenstock and Weerts, 2010) published similar oscillatory SL curves based on geological markers in various individual countries around the globe (Table 1); the timing of their oscillations varies substantially, reflecting limited data points and the inherent inaccuracy of radiocarbon dating (typically +/- 200y). Some of the wigglers' SL curves closely resemble Fairbridge's in showing, since 5ka, three or more m-scale (<5m) oscillations whose amplitude and maximum elevation generally diminish with time, and which mostly straddle the present-day mean SL, e.g. in Table 1, Geng et al. (1987, eastern China), Korotkii et al. (1980, eastern Russia), Martin et al. (1985, Brazil), Razjigaeva et al. 2004 (eastern Russia), and Tjia (1996, Malaysia). Few, if any, of these authors ventured to suggest that the oscillations were eustatic. On the other hand, in Alaska, Hume (1965), though lacking enough data-points to justify producing a SL curve, nevertheless found evidence for a ~1m SL rise and ~2m fall, both occurring between ~250 and 500AD (see Higgs, 2025b, table 1), which " supports Fairbridge's ... suggestion that sea level has fluctuated slightly above and below the present sea level during the last few thousand years" (p. 1166).

The Brazilian research group of Martin, Suguio, Bezerra and others emphatically dismissed eustasy; their alternative interpretation evolved in three successive articles, as follows. Referring to their Brazilian oscillatory SL curve, Martin et al. (1985, fig. 2a and p. 87) said: "the relative sea level has clearly been above the present level, with a maximum elevation having occurred about 5,150 years B.P. This is not, however, a worldwide trend and thus can not [sic] be explained by glacial eustasy and, in this case, hardly by crustal movements. ... Moreover, two quick fluctuations of relative sea level occurred" between 5ka and 2ka. This description quite closely matches the Fairbridge Curve, whose peak elevation is similarly at ~5ka and a few m above modern SL; and which likewise between 5ka and 2ka shows two complete oscillations of a few m. Citing none of Fairbridge's papers, Martin et al. (1985) continued (p. 87): "These fluctuations are too important to be related to glacial eustasy and they cannot be of crustal origin". Suguio et al. (1988) republished the same SL curve and mentioned (p. 206) "two rapid oscillations of relative sea level of 2 to 3 m, too large to be glacio-eustatic." Highstand variation by ~2m along ~2,000km of coastline was ascribed to geoidal changes. The authors also opined (p. 207) that "depression of the geoid, followed by uplift on a scale of centuries, can explain the rapid oscillations" and therefore (p. 203) "so-called eustatic curves, such as that of Fairbridge (1961), cannot be used as models of relative sea-level variations over recent millennia". This assessment is doubly erroneous: 1) on the 1976 and 1977 updates of Fairbridge's SL curve, glacio-eustatic oscillations in the interval 5ka to 2ka are likewise of m-scale (~1-5m), and curve steepness indicates rates of rise up to ~4cm/y (see Section 1), while the fastest rise on the Martin et al. (1985, fig. 2a) curve is ~3.5m in ~200y, i.e. ~2cm/y average; and (2) geoid-related SL changes are *much* slower, <1m/ky (cf. Mörner, 1976b, fig. 9). Of their slightly different oscillating SL curve for Brazil, Bezerra et al. (2003, p. 73) said: "in general, this ... curve fits" the non-oscillating SL curve predicted by Peltier (1998; based on glacio-isostatic modelling), except for a pronounced deviation of ~+2m at ~1.8ka (their fig. 12b), which they ascribed to local tectonism (rather than eustasy or a geoidal effect), stating "the assumption that the Brazilian coast is a highly stable region [passive margin] has been scarcely questioned" (p. 85).

Unlike the wigglers, many other authors (Table 2) are "smooth-curve believers" (Mörner, 1987, p. 342) or "smoothers" (Bungenstock and Weerts, 2010, p. 1687), who argue that SL oscillations, if any, in the last 5ky were <50cm (<30cm in many cases). Pirazzoli's (1991) important 'World Atlas of Holocene Sea-Level Changes', a compilation of published SL curves, contains roughly equal numbers of wigglers and smoothers. (The same applies to Tables 1 and 2.) Pirazzoli was a smoother (Table 2) but admitted (his p. 21) that "a linear sea-level curve is constructed not only from data, but also from subjective ideas, and in some cases preconceived theories of their author. How can we explain otherwise that some authors find oscillating sea-level curves everywhere, while others only obtain curves showing regular trends?".

One possible reason for smoothers finding no large (>1m) post-5ka SL oscillations is non-discovery of crucial data-points recording high- or lowstands. For example, raised markers of former highstands might be overlooked (e.g. poorly developed due to highstand brevity, or largely eroded by storm waves or rain); or might lack associated carbon-datable shell or wood. Conversely, lowstand markers currently below modern mean SL might be either unsought (cf. SL curve of Martin et al. [1985, fig. 2a], which is 'downwardly truncated' at modern mean SL) or missed (e.g. obscured by coral overgrowth, or destroyed by subsequent transgression). Such cases would result in SL curves with multi-century data-gaps.

In many studies with sparse data-points, age-gaps are long enough (0.3->1.0ky) to 'hide' an entire Fairbridge-type oscillation, yet the authors chose to *assume* smoothness across the gaps for no stated reason, fitting either an 'eyeballed'- or a calculated (least-squares) straight line or smooth curve. An extreme example is Bloom (1970), who opted for two straight lines meeting at a dog-leg (his fig. 1), based on just three post-5ka data-points, only one of which plots on the lines; the "submergence curve ... has been drawn as a straight line from the clearly established trend between 6500 and 5500 radiocarbon years ago to the position of sample 005, then as another straight line from the position of sample 005 to the origin" (p. 1901).

Eminent marine geologist Francis Shepard (1963) compiled data from "relatively stable areas" around the world (his fig. 1) and applied an eyeballed(?) "average curve" of smoothly decelerating SL rise from ~-4m at 5ka (his fig. 2), despite numerous samples plotting 1-3m above or below the curve, and sample-gaps of up to 0.5ky. The same data and curve were republished by Shepard 1964 (figs 1, 2). Three outliers

(Australia, shells) 3-7m above the curve, an "enigma" (Shepard, 1963, p. 5), were dismissed as possible kitchen middens (Shepard, 1961, 1964). Earlier, Shepard (1961) plotted the same data on a graph (his fig. 1), superimposing an early version of Fairbridge's curve (slightly different from that of Fairbridge [1960, p. 76]). Taking into account the inherent inaccuracy of carbon-dating, Fairbridge's oscillating curve fits the plotted data better than Shepard's (1963, 1964) own smooth curve.

In Vietnam, despite wide data-gaps (centuries to >1ky) and large sample-elevation uncertainty (commonly 1.5m or more), a smooth SL curve was interpolated by Stattegger et al. (2013, fig. 4). Similarly, in each of nine regions along the W- and NW coasts of France, Stéphan and Goslin (2014) invoked "no significant sea-level oscillations during the Holocene" (p. 296; contrast Ters, 1987 in Table 1, same region), despite wide data-gaps and large elevation uncertainties (their fig. 10).

In later studies, similarly with data-gaps large enough (0.3-1.0ky) to hide entire 'Fairbridge-type' (m-scale, multi-C) SL oscillations, a 'best-fit' straight line or curve was calculated mathematically (least-square regression). For example, Bondevik et al. (1995), some of whose data-gaps exceed 1ky (their figs 11-14), fitted a polynomial, concave-up, smooth curve, admitting: "The weakness of this method is that the constructed sea-level curve is probably smoother than the real curve because short-lived variations in the rate of eustatic sea level rise must have occurred. However, these variations could hardly have been detected with the available dating accuracy" (p. 170), or with the large age-gaps.

Baker et al. (2001a, b, 2005) applied 5th- and 8th-order polynomial curves to Brazilian and Australian SL data with multi-century (to ~1.5ky) age-gaps. The curves trend downward (toward modern SL), with one or more steps, none of which shows a reversal exceeding 15cm, hence their inclusion in Table 2 rather than 1. Baker et al. (2005, fig. 7 caption) noted that "the smoothing in the regression could be concealing larger and more rapid fluctuations", and (p. 3) the "synchronicity of ... oscillations" in Australia, Brazil and SE Asia "is not inconsistent with FAIRBRIDGE's (1961) basic thesis of world-wide eustatic Holocene sea-level change".

A notable case of pre-conceived smoothness is that of Chappell (1983, fig. 1), concerning NE Australian microatolls. Chappell stated (p. 408): "A minimum hypothesis is that these data fall on a straight line. Fig. 1 shows the least-squares linear regression ... I conclude that the straight line is the simplest model fitting these results".

This begs the question: why is the "simplest" more likely to be correct? The elevation-error bars of ten of Chappell's twenty-four post-5ka data-points are entirely off (above and below) his fig. 1 SL line. The ten points were presumably dismissed as spurious. Chappell confessed (p. 408): "The smoothly falling sea level suggested by the straight line may not be the only interpretation, in the light of careful work performed elsewhere in the world. A strong case has been made for alternating transgressive and regressive tendencies of sea level of amplitudes around 1m or more, superimposed on the general post-glacial trend in each region of interest, for example by Tooley from many studies in the United Kingdom, by Morner [sic] from Sweden, by Martin et al. from South American sites, and from Oceania by Schofield. Despite the finding that the microatoll results conform to the straight line in Fig. 1, two factors suggest that sea-level oscillations may not be recorded by this form of evidence. (1) Evidence for regressions may be buried within the reef flats by subsequent transgressional effects. (2) Regressional phases may be sandwiched in the gaps between the dating results. For example, the two outliers above the line in Fig. 1, at 3,600 BP, may correspond with the Calais IV-B transgression in the Netherlands, although their radiocarbon ages are rather younger. Note that the Netherlands results show fluctuations of ~0.5m about the mean trend, which may not be visible in the microatoll sequences".

Similarly, despite poor alignment of South Australian data-points of the last 6ky, Chappell (1987) dismissed the non-linear SL curve of Belperio et al. (1984, p. 313) as "unproven", preferring "the linear falling curve of Byrne [sic] (1982) as the simplest approximation to the data". Chappell admitted (p. 314): "It will be apparent to the reader that the writer is prejudiced in favour of the simple falling sea-level model illustrated in Figs 10.5 to 10.8, and it must be left to later workers to demonstrate unequivocal oscillations".

In another example of assumed SL smoothness, Lambeck et al. (2014) adopted a complex four-stage procedure: (i) compile a database of dozens of published post-5ka SL markers (and hundreds of older ones) from tectonically stable locations remote from former ice-sheet margins (including microatolls on Kiritimati atoll; see Section 3.2). Throughout the last 5ky, data-point elevations are scattered up to ~3m above and below modern SL (NB comparable oscillation amplitudes on Fairbridge Curve); uncertainty in each point's interpreted SL is +/- 0.1 to 2m (their table S1); (ii) adjust each point's elevation for modelled glacio-hydro-isostatic subsidence (requiring assumptions about ice-volume evolution, mantle rheology, etc.); (iii) fit a smooth SL curve to the "corrected" (p. 15301) data using a Markov chain Monte Carlo smoothing algorithm, said to reveal the "underlying signal in the ... noisy time series" (p. 15300). This "ice-volume equivalent" SL curve (their fig. 4A) "is taken as an objective estimate of the underlying 'denoised' time series" (p. 15300); and finally (iv) conclude that in the interval "4.2ka to ~0.15ka, there is no evidence for oscillations in global-mean sea level of amplitudes exceeding 15–20 cm" (p. 15302) despite, throughout this interval, many data-points plotting 1-2m above or below the calculated smooth SL curve and, in some cases, their SL-error-bars not even intersecting the curve.

Equally questionable is the technique of 'smoothers' Angulo et al. (2006): (i) compile two datasets of dozens of published SL markers (intertidal encrusting vermetid gastropods) from the northern and southern sectors of Brazil's east coast; (ii) recognise eight "outliers [which] plot outside the 2 standard deviation envelope around the MSL [mean SL] trend for their respective regions, calculated by a 5th-order polynomial ... With the removal of these outliers from the data set a new trend is then drawn for both regions" (p. 500); and (iii) interpret two of the highest outliers as "possibly due to ... high wave action at the site" (p. 495). This treatment begs the question of why, in the light of the (global) Fairbridge Curve's numerous exceptional high- and lowstands, Angulo et al. dismissed the Brazilian outliers as spurious. Mentioning Fairbridge just once, Angulo et al. (2006, p. 488) said "Bigarella (1965, 1971) compared the paleo-sea-level data from Brazil with Fairbridge's (1961) curve, which was understood at that time as a representation of the eustatic sea-level behavior". The two Bigarella articles, uncited by Pirazzoli (1991), are in Brazilian publications of doubtful availability online.

Several authors apparently *expected* SL smoothness because this is what glacio-isostatic models published (by others) for their study area show. For example, for various regions in western Canada, Clague et al. (1982) assumed smooth SL curves (their figs 3-6, 10, 12), despite several large data-gaps (to >1ky) and up to m-scale elevation-scatter of data-points (e.g. figs 3, 10). The chosen curves were likened (in fig. 12) to the relative SL curve modelled by Clark et al. (1978), which *assumes* that "no change in eustatic sea level has occurred since 5000 B.P. (i.e. the ocean volume has not changed since that time)" (fig. 13). This example of circularity is not unique. In a study of 917 data-points in the western Mediterranean, Vacchi et al. (2016, p. 172) stated: "We assessed the spatial variability of RSL [relative SL] histories for 22 regions and compared these with the ICE-5G (VM2) GIA model" of Peltier (2004; co-author in Clark et al., 1978). The authors claimed that "a generally good qualitative agreement between the predicted [smooth] and the observed RSL changes" (p. 191) indicated "a continuous rise [i.e. no oscillations] in RSL during the Holocene" (p. 192), in accordance with the model-predicted SL curve for each region (their figs 6 to 11). Yet the data-points in all regions (same figs) commonly have wide spacing (to >2ky), large age-uncertainty bars (to >1ky) and large elevation uncertainty (+/-~1m), permissive of oscillations. This is another case of greater weight being given to a preconceived model than to the actual data.

The expectation of smooth SL is illogical. The deglaciation that preceded the Holocene interglacial included three brief (300-500y) ice-sheet-melt events ('Meltwater pulses') coinciding with accentuated warmings and accelerated SL rise (Blanchon, 2011). Thus, there is no reason why such events should not also have occurred in Holocene time, when polar ice was (is) still plentiful. Indeed, nine brief (multi-century) ice-rafting episodes have been recognised (Bond et al., 2001; see 'Bond event', Wikipedia), likely linked to warmings and, possibly, m-scale global SL rises. Unfortunately, Fairbridge-type transgressions and Bond events are too loosely (carbon-) dated to prove that they correlate.

Strong support for the "wigglers" comes from two studies based on techniques very different from the usual method involving SL markers (i.e. age/elevation of index-points). Somoza et al. (1998) produced a Holocene relative SL curve (their fig. 6) based on sequence-stratigraphic analysis of architectural stacking patterns interpreted from seismic profiles and borehole logs from the Ebro Delta in Spain. The curve shows oscillations of ~0.5 to 1m amplitude in the last 5ky; the amplitude is greater (~1-2m) after detrending the curve (steeply inclined due to the delta's high subsidence rate). The oscillations were interpreted as eustatic. The authors listed (p.12) many deltas around the world whose architectures are interpreted in the literature as controlled by 5th- and 6th-order eustatic oscillations, the latter typically of ~200-300y periodicity (Lowrie and Hamiter, 1995). Secondly, an interpreted global SL curve by Siddall et al. (2003, fig. 1), based on oxygen isotopes in foraminifera in a Red Sea core, indicates oscillations of ~2-8m in the last 5ky; paleobathymetric error-bars are very large (+/-12m), permissive of even larger (or smaller) oscillations.

Several published SL curves are unrealistic 'join-the-dots' zig-zag lines connecting successive widely spaced (centuries to >1ka) data-points. This procedure yields oscillations >0.5m in some cases (e.g. in Table 1, Schofield [1960, 1977], Ward [1971], Tjia et al. [1983] and Compton [2001]), and <0.5m in others (e.g. in Table 2, Kaland [1984] and Galili et al. [1988]).

The smooth-vs-oscillatory debate applies equally to archaeological data. Concerning western Mediterranean archaeology of the last 2ky, Flemming (1969, p. 1) remarked: "A survey of the literature on archaeological evidence for eustatic change reveals that selections from the field data have been used to prove everything from eustatic constancy to oscillations of 25 ft every 600 years".

3. Problems with sea-level proxies favoured by IPCC

The Fairbridge Curve was rejected by Lambeck et al. (2010) and by IPCC (2013, Lambeck co-lead-author). Both publications instead claimed that no SL rise or fall between 1AD and 1800AD exceeded 25cm or reached higher than today (IPCC, 2013, fig. 5.17f from Lambeck et al., 2010, fig. 4.14), based on Earth-ice glacio-isostatic modelling by Lambeck and colleagues (many references in Lambeck et al., 2010) and on five particular classes of SL proxy data selected from various regions around the world. Lambeck is co-author in four of these five cases, and senior author in two of them. Three of the five cases are from Mediterranean coasts prone to earthquake up/down jolts. All five have other weaknesses, as follows.

3.1. Problematic proxy 1: Cosquer sea-flooded cave

In Cosquer Cave, near Marseille on the French Mediterranean coast, Paleolithic wall paintings and engravings ~25ky old are visible above the water surface (= SL). Cave access is via an offshore tunnel-mouth 37m below SL. The tunnel is 120m long and ascends parallel to bedding (~30°), terminating in two human-decorated chambers (Clottes and Courtin, 1996, fig. 23 and p. 48). The entire tunnel and lower parts of the chambers are flooded due to post-glacial SL rise. The paintings include two horses interpreted by Lambeck and Bard (2000, fig. 11 photo caption) as "partly destroyed by the rising sea level in post-glacial time but the horse's legs have been damaged only up to a height of 0.5m above present mean sea level. This value represents the maximum range of modern fluctuations in sea level due to tides and meteorological forcing of the ocean surface" (Marseille modern spring-tide range is ~30cm), from which Lambeck and Bard concluded that Holocene SL was never higher than at present (contrast the Fairbridge Curve's six Holocene SL highstands 1 to 3m above modern mean SL). However, Lambeck and Bard did not discuss why the supposed "damage" (erasure) limit is *not horizontal*. In fact, each horse is only a 'head-and-shoulders' depiction whose lower limit slants ~30° leftward (their fig. 11; enlargement in Clottes and Courtin, 1996, fig. 61; close-ups in Clottes et al., 2005, figs 87, 90). Similarly, most of the dozens of other paintings and engravings of quadrupeds (horses, bison, antelopes, deer) higher on the cave walls and ceilings are likewise only partial (Clottes et al., 2005, figs 92, 97, 108, 115). Moreover, the implication of Lambeck and Bard (2000) that any raised SL would have erased (limestone corrosion by seawater?) all paintings up to that level conflicts with the observation that Cosquer paintings and engravings, including the two Lambeck and Bard horses, "frequently" have a protective veneer, a "thin layer of calcite" (Clottes and Courtin, 1996, p. 17).

Lack of encrusting marine fauna on the cave walls does not negate higher-than-now Holocene SL, because an inevitable 'fresh-water lid' (percolated rainwater) floating on the sea-water in the cave would have precluded encrustation by marine fauna throughout the cap's thickness. Encrusting serpulids, sponges and bryozoa do occur in the Cosquer access-tunnel (Clottes and Courtin, 1996, p. 48). Only the serpulids persist into the cave's flooded lower chambers, but they are reportedly dead, presumably having colonised the rock surface while the SL was higher, followed by death in the fresh-water lid when SL fell. Alternatively, these serpulids may correspond to the *previous* interglacial (MIS5e) SL highstand. Based on SL markers in geologically stable areas, the latter was several metres above modern SL (Hearty et al., 2007; Blanchon et al., 2009). Similarly, an MIS5e SL marker only ~50km from Cosquer indicates that SL was 3 +/- 1.4m above modern (Cerrone et al., 2021 citing Provansal et al., 1995). Thus, the cave's MIS5e water level was probably a few metres above today's, in which case the dead serpulids would imply that the fresh-water lid was at least this thick. Low salinity also explains the lack of any raised bioerosional notch (formed by marine borers, e.g. molluscs, sponges; Murray-Wallace and Woodroffe [2014]); nor is there any modern notch (e.g. Lambeck and Bard, 2000, Fig. 11). Lack of higher-SL algal coatings on the cave walls is attributable to 24-hour darkness.

The fresh-water lid, saturated with calcium carbonate (hence the cave's abundant stalagmites and stalactites) and therefore incapable of corroding the limestone of the cave-walls, may instead have precipitated calcite, forming the veneer mentioned above, when SL was higher.

3.2. Problematic proxy 2: microatolls on Kiritimati Atoll

On Kiritimati Atoll (Pacific Ocean), the "adjusted" elevations of >100 fossil coral microatolls (individual lifespan decades to centuries) ranging from ~5ky to ~90y old are <25cm above and below their living counterparts (Woodroffe, Lambeck et al., 2012, fig. 2B), "precluding global sea-level oscillations of one or more metres inferred from less stable locations" (their p. 951). However, the claim of a 5-ky "*near-continuous* record" (italics added here) is an exaggeration. In fact, the 100+ radiometric (mostly radiocarbon) ages are notably clustered (their fig. 2) and error-bars are wide (typically 200-400y; some >1ky), raising the possibility of unsampled multi-century time-gaps. One potential time-gap spans as much as 600y (400-1000AD in Woodroffe et al., 2012, fig. 2). Tan et al. (2023) reassessed the Woodroffe data more conservatively and added 23 data-points from another study. "The new database contests the view that RSL had remained within 0.25 m of present day levels over the past ~5 ka" (Tan et al., p. 14). Between 1AD and 1,000AD (containing the ~3m "Rottnest Submergence" of Fairbridge [1961, fig. 15 and table 2]), the combined Woodroffe et al. and Tan et al. data allow one or more SL oscillations reaching up to ~1m above and below modern mean SL (Tan et al., 2023, fig. 3c), i.e. amplitude up to ~2m.

3.3. Problematic proxy 3: coastal fish tanks in Italy

Italian coastal fish tanks of 1stC age, built at SL, are now drowned by 1 to 2m, varying from place to place (Lambeck et al., 2004). This observation is consistent with GPS data indicating 1-2mm/y steady subsidence for these regions (Serpelloni et al., 2013, fig. 10). Prior to the publication of these GPS data, Lambeck et al. (2004) measured the fish-tank elevations, "corrected" (e.g. their p. 1588 and fig. 6a) each elevation by removing the isostatic contribution *predicted* by global glacio-hydro-isostatic *modelling* (italics added here; ten publications by Lambeck, eight of them with co-authors, were cited), then applied a further correction for local tectonism, and concluded that "the change in eustatic sea level since the Roman Period is –0.13 +/- 0.09 m", i.e. 1stC eustatic SL was somewhere between 22cm and 4cm lower than today, so the change between that time and now is very small, <22cm. However, this value is the *net* SL change between ~2ka and today. The analysis does not preclude intervening dm- or m-scale SL oscillations.

3.4. Problematic proxy 4: coastal water-wells, Caesarea, Israel

In Israel's Caesarea port city on the Mediterranean coast, 64 water-wells attributed to successive Roman to Crusader cultures have similar bottom-elevations, said to indicate that SL (governing the water-table) fluctuations did not exceed a few dm between 1AD and 1100AD (Sivan, Lambeck et al., 2004, fig. 6). However, dating is loose, based on archaeological stratigraphy adjacent to each well or (even looser) typology of the youngest pottery fragments found at the excavated well bottom, thought to "establish the time the well ... reverted to a household garbage container. When stratigraphic data is not available, the cultural material from the bottom of the well (mainly fragments of pottery vessels) has been used to establish the date of use". However, this reasoning is unsound: the bottom-fill may instead be an attempt by the inhabitants to counter salt-water intrusion into the well by SL (water-table) rise, using broken residual pottery of a previous culture. Moreover, for most wells, each well's age-uncertainty is admitted to be high (typically 200-500y, their table 1) and is permissive of multi-century age-gaps between wells (see their fig. 6 error-bars). A well-digging pause as long as ~600y is possible, i.e. the collective life-span of two Roman aqueducts (i.e. wells probably superfluous) built in the 1st C and ~400AD (Porath, 2002), the earlier one functioning longer, until the 640/641 Islamic conquest (Porath and 'Ad, 2015). (According to Porath and 'Ad [p. 124*], "The Roman–Byzantine-era metropolis of Caesarea Maritima ... enjoyed a plentiful water supply from external sources, conveyed by three aqueducts: the High Aqueduct, the Low Aqueduct and the Southern Pipe".) Thus, the ages of 18 of the studied wells (numbers 4 to 21, supposedly Late Roman and Byzantine, post-200/pre-640AD; Sivan et al., fig. 2 and table 1) are likely incorrect and might be younger, 640-750AD (Umayid time), like Wells 22 and 23. This putative ~600y gap between wells is long enough to have missed the ~4m Rottnest SL rise and most of the ensuing fall (Higgs 2024, 2025a).

3.5. Problematic proxy 5: Atlantic coastal salt-marshes

In salt marshes of Iceland and eastern North America (Newfoundland to Florida), a surface peat layer 1 to 3m thick started accumulating between ~2.8 and ~1.6ka (varying from place-to-place), based on carbon-dated plant fragments sampled in cores, trenches, and tidal-creek banks (Gehrels et al., 2006; Kemp et al., 2011, 2013, 2014, 2015, 2017a, b, 2018; Gerlach et al., 2017). Supposed continuity of peat accumulation (lack of evident intra-peat hiatuses) is said to preclude any SL oscillation >25cm between 800BC and 1800AD (e.g. Kemp et al., 2018, fig. 9), negating the *metre*-scale Abrolhos and Rottnest transgressions and ensuing regressions on the Fairbridge Curve, and implying that the 30cm SL rise *measured* by tide-gauges since 1800AD (Jevrejeva et al., 2008) is unprecedented in at least 2.8ky, and fostering the opinion that "Global mean sea level has risen faster since 1900 than over any preceding century in at least the last 3000 years (high confidence)" (IPCC 2021a). However, three problems with the peat studies are as follows.

Firstly, in a peat marsh, any thin (cm) sand or mud layer corresponding to a brief (decades) SL rise and ensuing fall would become partly to entirely homogenized with the enclosing peat by bioturbation, e.g. by plant roots, crabs, etc.. Such camouflaging or erasure of evidence may have misled eminent SL researcher Shepard (1963, p. 3): "If during the past 6,000 years the sea had fluctuated up and down to the extent of 10 feet or more, it would seem almost certain that the high stands would have covered the peat marshes and thus there should be gaps in the record". However, if the SL excursions were very brief, such "gaps" would probably take the form of thin (cm) sand or mud layers, prone to homogenisation. A possible example occurs in the Late Holocene of Newfoundland: "Within the high salt-marsh peat are thin (<5 cm) and discontinuous horizons containing increased fine-grained clastic sediment" (Kemp et al., 2018, p. 97). (The interpretation was tenuous: "The discontinuous nature of these units likely indicates that they are the result of a process operating intermittently and on metre-scales, such as delivery of ice-rafted sediment".) Conversely, "if sea levels fall ... vertical accretion ... slows or stops, and if the regression is sharp enough, existing marsh substrates can oxidize and degrade, producing gaps in the paleoenvironmental record that may be difficult to detect" (Kearney, 1996 p. 182). Two other examples of easily missed indicators of SL change in a South Carolina salt-marsh peat, from Scott et al. (1995), are: (a) an intercalation of *fresh-water* peat, attributed (their fig. 3) to a ~2m SL fall from ~4.4 until ~3.7ka followed by a poorly constrained SL rise to the present day; and (b) "lithological breaks where burrows from the layer above can be observed into the underlying peat", interpreted as "unconformities" (p. 618).

Secondly, the combination of (a) wide spacing of samples (plant fragments) and (b) large uncertainty in their calibrated radiocarbon ages (2-sigma confidence range 50-250y) allow inter-sample time-gaps of up to ~700y (e.g. Kemp et al., 2014, table 2 and fig. 3; Gerlach et al., 2017, table 2 and fig. 6B). Thus, entire Fairbridge-type SL excursions, amounting to 1 to 3m upward or downward (Fairbridge, 1961, fig. 15), might be missed.

Thirdly, there is evidence that peat carbon-ages worldwide are exaggerated by an overlooked salt-water effect, such that none of the sampled peats (references above) pre-dates ~400AD. In Iceland, a rare cross-check on salt-marsh-peat carbon ages is provided by a horse-bone, found 15cm above a 1cm volcanic-tephra bed within a 1.6m peat profile exposed in a tidal-creek bank (Gehrels et al., 2006, fig. 2A, logged-section 2A). The bone was separately carbon-dated 1578AD (median calibrated age; 1-sigma confidence range 1520-1636AD; their table 1), exposing the following flaw in the peat's modelled age-depth curve (their fig. 4, corresponding to lookalike logged-section 3A, 800m away). The curve comprises two sectors: (i) a deeper, older sector (100BC-1880AD), largely linear (cf. all of the above Kemp et al. papers), based on 9 carbon-dated plant fragments; and (ii) a steeper, post-1880 sector (too young for reliable carbon-dating) whose trend was determined from marker horizons (elemental, isotopic, magnetic) relating to known events (e.g. nuclear bomb testing). The 'kink' between the two sectors is attributed by all authors to 19thC acceleration of SL rise. Crucially, extrapolation of the horse-bone onto the age-depth curve at the appropriate elevation (15cm above the same tephra bed) indicates an age of ~1200AD, *~400y older than the bone's independently measured, calibrated-radiocarbon median age of 1578AD*. Moreover, the bone has practically the same age and elevation (only 5cm higher, relative to the tephra) as plant-fragment AAR-8035 (1549AD +/- 59y), *rejected* by Gehrels et al. (2006) for being out of stratigraphic order, i.e. younger than two shallower carbon-dated samples (their fig. 4). The close age- and depth agreement of the two 'anomalous' data-points (bone and AAR-8035) suggests that the carbon ages of the other 9 sampled plant fragments are exaggerated. If so, a corrected, steepened, older sector of the age-depth curve can be drawn, connecting the kink and Sample AAR-8035 and projecting downward. (This procedure greatly reduces the kink angle.) Extending the new sector linearly downward indicates a much younger corrected age for the base of the studied Iceland peat, ~800AD instead of ~100BC, i.e. ~1.15ky old instead of ~2.05ky. Applying the same age-correction factor of 0.55 would mean the supposedly 2.80ky-old earliest studied peat (Kemp et al., 2018, fig. 3B) is, in fact, only ~1.55ky old, i.e. ~400AD.

The above age correction negates the assumption, based on the (erroneous) bracketing carbon-ages, that the above-mentioned 1cm tephra is the Landnám Tephra (previously dated 875AD +/- 6y; references in Gehrels et al., 2006). Supporting this suggestion: (a) the study area (their fig. 1 inset) is ~50km *outside* the Landnám Tephra's 0.5cm isopach (Schmid et al., 2017, fig. 4B); and (b) if the tephra really is the 875AD Landnám, the 15cm separating it from the ~1578AD horse bone must have accumulated in ~700y (average 0.2mm/y), versus ~240y for the 28cm (1.2mm/y) between the kink (at 39cm and 1820AD in their fig. 4) and the bone's extrapolated position below it, a six-fold discrepancy in accumulation rate.

The corrected age-depth sector is steeper than the original, i.e. the 'false' curve's divergence increases with age, implying that the cause of carbon-age exaggeration operated continuously since plant death. A likely cause is salt-water chemoautotrophic bacteria living on decomposing plant fragments and fixing 'old' organic carbon from marsh-water CO2 (Peterson et al., 1980). The delicacy of the dated "fragile, horizontally embedded, detrital plant fragments" (Gehrels et al., 2006, p. 951), deliberately selected to maximise the likelihood that the parent plants were indigenous to the salt marsh, is consistent with infestation by chemoautotrophic bacteria. Thus, coastal-peat researchers may have unwittingly measured the *composite* carbon age of bacterial carbon *plus* original plant carbon (whose proportions respectively increase and decrease with time). This justifies the opinion that "dark carbon fixation by chemoautotrophic bacteria is a major process in the carbon cycle of coastal sediments, and should therefore receive more attention in future studies on sediment biogeochemistry and microbial ecology" (Boschker et al., 2014).

Regarding 'anomalous' AAR-8035, which, in fact, yielded the only correct carbon age (apart from the bone), this sample, described as "Detrital brown-red (woody) material" (Gehrels et al., 2006, table 1; sixteen other samples' colour unmentioned; only one other described as woody) is probably an allochthonous tree fragment, non-metabolizable by salt-marsh bacteria.

4. Cause of 'Fairbridge-type' sea-level rises

A companion study by the author (Higgs, 2025b) argues that large (m), brief (decades), 'Fairbridge-type' sea-level rises can only be caused by Antarctic ice-cliff-collapse events, attributable to warming by solar grand maxima except the (anthropogenic) next one, likely to raise sea level at least 3m by 2100.

References

Angulo, R.J. and Lessa, G.C., 1997. The Brazilian sea-level curves: a critical review with emphasis on the curves from the Paranaguá and Cananéia regions. Marine Geology, 140, 141-166.

Angulo, R.J.; Lessa, G.C., and de Souza, M.C., 2006. A critical review of mid- to late-Holocene sea-level fluctuations on the eastern Brazilian coastline. *Quaternary Science Reviews*, 25, 486–506.

Baeteman, C., 2008. Radiocarbon-dated sediment sequences from the Belgian coastal plain: testing the hypothesis of fluctuating or smooth late-Holocene relative sea-level rise. *The Holocene*, 18(8), 1219-1228.

Baker, R.G.V. and Haworth, R.J., 2000. Smooth or oscillating late Holocene sea-level curve? Evidence from the palaeo-zoology of fixed biological indicators in east Australia and beyond. *Marine Geology*, 163, 367–386.

Baker, R.G.V.; Haworth, R.J., and Flood, P.G., 2001a. Warmer or cooler late Holocene palaeoenvironments?: interpreting southeast Australian and Brazilian sea-level changes using fixed biological indicators and their $\delta^{18}O$ composition. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 168, 249-272.

Baker, R.G.V.; Haworth, R.J., and Flood, P.G., 2001b. Inter-tidal fixed indicators of former Holocene sea levels in Australia: a summary of sites and a review of methods and models. *Quaternary International*, 83–85, 257–273

Baker, R.G.V.; Haworth, R.J., and Flood, P.G., 2005. An oscillating Holocene sea level? Revisiting Rottnest Island, Western Australia and the Fairbridge eustatic hypothesis. *In:* Finkl, C.W. (ed.), *The Sun, Earth and Moon: A Tribute to Rhodes W. Fairbridge. Journal of Coastal Research*, Special Issue No. 42, pp. 3-14.

Balsillie, J.H. and Donoghue, J.F., 2004. High resolution sea-level history for the Gulf of Mexico since the Last Glacial Maximum. *Florida Geological Survey, Report of Investigations*, No. 103, 65p.

Baxter, A.J. and Meadows, M.E., 1999. Evidence for Holocene sea level change at Verlorenvlei, Western Cape, South Africa. *Quaternary International*, 56, 65-79.

Behre, K.E., 2007. A new Holocene sea-level curve for the southern North Sea. *Boreas*, 36, 82-102.

Bennema, J., 1954. Holocene movements of land and sea-level in the coastal area of the Netherlands. *Geologie en Mijnbouw*, 16(6), 254-264.

Bezerra, F.H.R.; Barreto, A.M.F., and Suguio, K., 2003. Holocene sea-level history on the Rio Grande do Norte State coast, Brazil. *Marine Geology, 196, 73-89.*

Blanchon, P., 2011. Meltwater pulses. *In:* Hopley, D. (ed.), *Encyclopedia of Modern Coral Reefs*. Dordrecht, The Netherlands: Springer, pp. 683-690.

Blanchon, P.; Eisenhauer, A.; Fietzke, J., and Liebetrau, V., 2009. Rapid sea-level rise and reef back-stepping at the close of the last interglacial highstand. *Nature*, 458, 881–884.

Bloch, M.R., 1963. The social influence of salt. *Scientific American*, 209(1), 88-98.

Bloom, A.L., 1970. Paludal stratigraphy of Truk, Ponape, and Kusaie, eastern Caroline Islands. *Geological Society of America Bulletin*, 81, 1895-1904.

Bond, G.; Kromer, B.; Beer, J.; Muscheler, R.; Evans, M.N.; Showers, W., et al., 2001. Persistent solar influence on North Atlantic climate during the Holocene. *Science*, 294, 2130-2136.

Bondevik, S.; Mangerud, J.; Ronnert., L., and Salvigsen, O., 1995. Postglacial sea-level history of Edgeøya and Barentsøya, eastern Svalbard. *Polar Research,* 14 (2), 153-80.

Boomer, I. and Horton, B.P., 2006. Holocene relative sea-level movements along the North Norfolk Coast, UK. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 230, 32– 51.

Boschker, H.T.S.; Vasquez-Cardenas, D.; Bolhuis, H.; Moerdijk-Poortvliet, T.W.C., and Moodley, L., 2014. Chemoautotrophic carbon fixation rates and active bacterial communities in intertidal marine sediments. *PLoS ONE*, 9(7), e101443.

Brooks, M.J.; Colquhoun, D.J; Pardi, R.R.; Newman, W.S., and Abbott, W.H., 1979. Preliminary archaeological and geological evidence for Holocene sea level fluctuations in the lower Cooper River Valley, South Carolina. *The Florida Anthropologist*, 32, 85- 103.

Bungenstock, F. and Weerts, H.J.T., 2010. The high-resolution Holocene sea-level curve for Northwest Germany: global signals, local effects or data-artefacts? *International Journal of Earth Sciences (Geologische Rundschau)*, 99, 1687-1706.

Burne, R.V., 1982. Relative fall of Holocene sea level and coastal progradation, northeastern Spencer Gulf, South Australia. *BMR Journal of Australian Geology & Geophysics*, 7, 35-45.

Caldas, L.H.O.; Stattegger, K., and Vital, H., 2006. Holocene sea-level history: evidence from coastal sediments of the northern Rio Grande do Norte coast, NE Brazil. *Marine Geology*, 228(1–4), 39-53.

Cerrone, C.; Vacchi, M.; Fontana, A., and Rovere, A., 2021. Last Interglacial sea-level proxies in the western Mediterranean. *Earth System Science Data*, 13, 4485–4527.

Chappell, J., 1983. Evidence for smoothly falling sea level relative to north Queensland, Australia, during the past 6,000 yr. *Nature*, 302, 406-408.

Chappell, J., 1987. Late Quaternary sea-level changes in the Australian region. In: Tooley, M.J. and Shennan, I. (eds.), *Sea-Level Changes*. Oxford: Blackwell, pp. 296-331.

Clague, J.; Harper, J.R.; Hebda, R.J., and Howes, D.E., 1982. Late Quaternary sea levels and crustal movements, coastal British Columbia. *Canadian Journal of Earth Sciences*, 19(3), 597-618.

Clark, J.A.; Farrell, W.E., and Peltier, W.R., 1978. Global changes in postglacial sea level: a numerical calculation. *Quaternary Research*, 9, 265-287.

Clottes, J. and Courtin, J., 1996. *The Cave Beneath the Sea: Paleolithic Images at Cosquer*. New York: Abrams, 200p.

Clottes, J.; Courtin, J., and Vanrell, L., 2005. *Cosquer Redécouvert*. Paris: Seuil, 255p.

Colquhoun, D.J. and Brooks, M.J., 1986. New evidence from the southeastern U.S. for eustatic components in the Late Holocene sea levels. *Geoarchaeology: An International Journal*, 1(3), 275-291.

Compton, J.S., 2001. Holocene sea-level fluctuations inferred from the evolution of depositional environments of the southern Langebaan Lagoon salt marsh, South Africa. *The Holocene,* 11(4), 395–405.

Compton, J.S., 2006. The mid-Holocene sea-level highstand at Bogenfels Pan on the southwest coast of Namibia. *Quaternary Research*, 66, 303–310.

Cooper, J.A.G.; Green, A.N., and Compton, J.S., 2018. Sea-level change in southern Africa since the Last Glacial Maximum. *Quaternary Science Reviews*, 201, 303-318.

Curray, J.R., 1965. Late Quaternary history, continental shelves of the United States. *In:* Wright, H.E. and Frey, D.G. (eds.), *The Quaternary of the United States*. Princeton: Princeton University Press, pp. 723-735.

Dean, S.; Horton, B.P.; Evelpidou, N.; Cahill, N.; Spada, G., and Sivan, D., 2019. Can we detect centennial sea-level variations over the last three thousand years in Israeli archaeological records? *Quaternary Science Reviews*, 210, 125-135.

Devoy, R.J.N., 1977. Flandrian sealevel changes in the Thames Estuary and the implications for land subsidence in England and Wales. *Nature,* 270, 712-715.

Devoy, R.J.N., 1979. Flandrian sea level changes and vegetational history of the lower Thames Estuary. *Philosophical Transactions of the Royal Society of London, Series B*, 285, 355-407.

Einsele, G.; Herm, D., and Schwarz, H.U., 1974**.** Sea level fluctuation during the past 6000 yr at the coast of Mauritania**.** *Quaternary Research,* 4, 282-289.

Fairbanks, R.G., 1989. A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature*, 342, 637-641.

Fairbridge, R.W., 1960. The changing level of the sea. *Scientific American*, 202(5), 70-79.

Fairbridge, R.W., 1961. Eustatic changes in sea level. *In:* Ahrens, L.H.; Press, F.; Rankama, K., and Runcorn, S.K. (eds.). *Physics and Chemistry of the Earth, volume 4*, London: Pergamon, pp. 99–185.

Fairbridge, R.W., 1976. Shellfish-eating Preceramic Indians in coastal Brazil. *Science*, 191, 353-359.

Fairbridge, R.W. and Hillaire-Marcel, C., 1977. An 8,000-yr palaeoclimatic record of the 'Double-Hale' 45-yr solar cycle. *Nature*, 268, 413-416.

Fedorov, P.V., 1971. Postglacial transgression of the Black Sea. *International Geology Review*, 14(2), 160-164.

Flemming, N.C., 1969. *Archaeological Evidence for Eustatic Change of Sea Level and Earth Movements in the Western Mediterranean During the Last 2,000 years*. Geological Society of America, *Special Paper 109*, 98p.

Flemming, N.C.; Czartoryska, N.M.G., and Hunter, P.M., 1973. Archaeological evidence for eustatic and tectonic components of relative sea-level changes in the South Aegean. *In:* Blackman, D.J. (ed.), *Marine Archaeology*. London: Butterworths, pp. 1-63.

Galili, E.; Weinstein-Evron, M., and A. Ronen, A., 1988. Holocene sea-level changes based on submerged archaeological sites off the northern Carmel coast in Israel. *Quaternary Research*, 29, 36-42.

Gayes, P.T.; Scott, D.B.; Collins, E.S., and Nelson, D.D., 1992. A late Holocene sea level fluctuation in South Carolina. *In:* Fletcher, III, C.H. and Wehmiller, J.F. (eds.), *Quaternary Coasts of the United States: Marine and Lacustrine Systems*. SEPM Society for Sedimentary Geology Special Publication, 48, 155-160

Gehrels, W.R.; Marshall, W.A.; Gehrels, M.J.; Larsen, G.; Kirby, J.R.; Eiríksson, J., et al., 2006. Rapid sea-level rise in the North Atlantic Ocean since the first half of the nineteenth century. *The Holocene*, 16, 949-965.

Gerlach, M.J.; Engelhart, S.E.; Kemp, A.C.; Moyer, R.P.; Smoak, J.M.; Bernhardt, C.E., and Cahill, N., 2017. Reconstructing Common Era relative sea-level change on the Gulf Coast of Florida. *Marine Geology*, 390, 254-269.

Geyh, M.A.; Kudrass, H.-R., and Streiff, H., 1979. Sea-level changes during the late Pleistocene and Holocene in the Strait of Malacca. *Nature*, 278, 441-443.

Gibb, J.G., 1986. A New Zealand regional Holocene eustatic sea-level curve and its application to determination of vertical tectonic movements. *Royal Society of New Zealand Bulletin*, 24, 377-395.

Godwin, H., 1940. Post-glacial changes of relative land- and sea-level in the English Fenland. *Philosophical Transactions of the Royal Society of London, Series B*, 230, 285-303.

Godwin, H., 1978. *Fenland: its Ancient Past and Uncertain Future*. Cambridge: Cambridge University Press, 196p.

Greensmith, J.T. and Tucker, E.V., 1973. Holocene transgressions and regressions on the Essex coast outer Thames Estuary. *Geologie en Mijnbouw*, 52(4), 193-202.

Hall, B.L.; Baroni, C., and Denton, G.H., 2004. Holocene relative sea-level history of the Southern Victoria Land Coast, Antarctica. *Global and Planetary Change*, 42, 241–263.

Hallmann, N.; Camoin, G.; Eisenhauer, A.; Botella, A.; Milne, G.A.; Vella, C., et al., 2018. Ice volume and climate changes from a 6000 year sea-level record in French Polynesia. *Nature Communications*, 9(285). doi: 10.1038/s41467-017-02695-7

Hearty, P.J.; Hollin, J.T.; Neumann, A.C.; O'Leary, M.J., and McCulloch, M., 2007. Global sea-level fluctuations during the Last Interglaciation (MIS 5e). *Quaternary Science Reviews*, 26, 2090–2112.

Heyworth, A., and Kidson, C., 1982. Sea-level changes in southwest England and Wales. *Proceedings of the Geologists' Association*, 93(1), 91-111.

Higgs, R., 2024. British archaeology verifies 5th-Century rapid multi-metre sea-level rise and portends another before 2100. European Geosciences Union, 2024 General Assembly, Vienna, https://doi.org/10.5194/egusphere-egu24-1322 (abstract and downloadable poster).

Higgs, R., 2025a. Geological review of English coastal archaeological evidence portending multi-metre sea-level rise by 2100. *Non-peer-reviewed preprint at EarthArXiv,* DOI: XX

Higgs, R., 2025b. Holocene rapid (decades) multi-metre marine transgressions by climatically driven Antarctic ice-collapse events. Another event imminent? *Non-peer-reviewed preprint at EarthArXiv*, DOI: XX

Horton, B.P.; Gibbard, P.L.; Milne, G.M.; Morley, R. J., and Purintavaragul, C., 2005. Holocene sea levels and palaeoenvironments, Malay-Thai Peninsula, southeast Asia. *The Holocene,* 15(8), 1199-1213.

Hume, J.D., 1965. Sea-level changes during the last 2000 years at Point Barrow, Alaska. *Science*, 150(3700), 1165-1166.

IPCC, 2013. Chapter 5: Information from paleoclimate archives. *In:* Climate Change 2013: The Physical Science Basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 383-464.

IPCC, 2021a. Summary for policymakers. *In:* Climate Change 2021: The Physical Science Basis. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 3-31.

IPCC, 2021b. Chapter 2: Changing state of the climate system. *In:* Climate Change 2021: The Physical Science Basis. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 287-422.

Jelgersma, S., 1971. Sea-level changes during the last 10,000 years. *In:* Steers, J.A. (ed.). *Introduction to Coastline Development.* London: Macmillan and Co Ltd, pp. 25-48.

Jelgersma, S., 1980. Late Cenozoic sea level changes in the Netherlands and the adjacent North Sea Basin. *In:* Mörner, N.-A. (ed.). *Earth Rheology, Isostasy and Eustasy*. Chichester: John Wiley & Sons, pp. 435-447.

Jerardino, A., 1995. Late Holocene Neoglacial episodes on southern South-America and southern Africa – a comparison. *The Holocene*, 5, 361-368.

Jevrejeva, S.; Moore, J.C.; Grinsted, A., and Woodworth, P.L., 2008. Recent global sea level acceleration started over 200 years ago? *Geophysical Research Letters*, 35(L08715). doi: 10.1029/2008GL033611

Kaland, P.E., 1984. Holocene shore displacement and shorelines in Hordaland, western Norway. *Boreas*, 13, 203-242.

Kearney, M. S., 1996. Sea-level change during the last thousand years in Chesapeake Bay. *Journal of Coastal Research*, 12(4), 977-983.

Kemp, A.C.; Horton, B.P.; Donnelly, J.P.; Mann, M.E.; Vermeer, M., and Rahmstorf, S., 2011. Climate related sea-level variations over the past two millennia. *PNAS*, 108, 11017-11022.

Kemp, A.C.; Horton, B.P.; Vane, C.H.; Bernhardt, C.E.; Corbett, D.R.; Engelhart, S.E., et al., 2013. Sea-level change during the last 2500 years in New Jersey, USA. *Quaternary Science Reviews*, 81, 90-104.

Kemp, A.C.; Bernhardt, C.E.; Horton, B.P.; Kopp, R.E.; Vane, C.H.; Peltier, W.R., et al., 2014. Late Holocene sea- and land-level change on the U.S. southeastern Atlantic coast. *Marine Geology*, 357, 90–100.

Kemp, A.C.; Hawkes, A.D.; Donnelly, J.P.; Vane, C.H.; Horton, B.P.; Hill, T.D., et al., 2015. Relative sea-level change in Connecticut (USA) during the last 2200 yrs. *Earth and Planetary Science Letters*, 428, 217-229.

Kemp, A.C.; Hill, T.D.; Vane, C.H.; Cahill, N.; Orton, P.M.; Talke, S.A., et al., 2017a. Relative sea-level trends in New York City during the past 1500 years. *The Holocene*, 27, 1169-1186.

Kemp, A.C.; Kegel, J.J.; Culver, S.J.; Barber, D.C.; Mallinson, D.J.; Leorri, E., et al., 2017b. Extended late Holocene relative sea-level histories for North Carolina, USA. *Quaternary Science Reviews*, 160, 13-30.

Kemp, A.C.; Wright, A.J.; Edwards, R.J.; Barnett, R.L.; Brain, M.J.; Kopp, R.E., et al., 2018. Relative sea-level change in Newfoundland, Canada during the past ~3000 years. *Quaternary Science Reviews*, 201, 89-110.

Kennedy, D.M., 2008. Recent and future higher sea levels in New Zealand: a review. *New Zealand Geographer*, 64, 105–116.

Khan, N.S.; Ashe, E.; Horton, B.P.; Dutton, A.; Kopp, R.E.; Brocard, G., et al., 2017. Drivers of Holocene sea-level change in the Caribbean. *Quaternary Science Reviews,* 155, 13-36.

Kidson, C. and Heyworth, A., 1978, Holocene eustatic sea level change. *Nature*, 273, 748-750.

Kirby, J.R.; Garrett, E., and Gehrels, W.R., 2023. Holocene relative sea-level changes in northwest Ireland: an empirical test for glacial isostatic adjustment models. *The Holocene*, 33(8), 926-938.

Kopp, R.E., Kemp, A.C.; Bittermann, K.; Horton, B.P.; Donnelly, J.P.; Gehrels, W.R., Hay, C.C.; Mitrovica, J.X.; Morrow, E.D., and Rahmstorf, S., 2016. Temperature-driven global sea-level variability in the Common Era. *PNAS*, 113 (11), E1434-E1441, doi: 10.1073/pnas.1517056113

Lambeck, K. and Bard, E., 2000. Sea-level change along the French Mediterranean coast for the past 30 000 years. *Earth and Planetary Science Letters*, 175, 203-222.

Lambeck, K.; Anzidei, M.; Antonioli, F.; Benini, A., and Esposito, A., 2004. Sea level in Roman time in the Central Mediterranean and implications for recent change. *Earth and Planetary Science Letters*, 224, 563-575.

Lambeck, K.; Woodroffe, C.D.; Antonioli, F.; Anzidei, M.; Gehrels, W.R.; Laborel, J., and Wright, A.J., 2010. Paleoenvironmental records, geophysical modeling, and reconstruction of sea-level trends and variability on centennial and longer timescales. *In:* Church, J.A.; Aarup, T.; Woodworth, P.L., and Wilson, W.S. (eds.). *Understanding Sea-Level Rise and Variability*. Oxford: Wiley-Blackwell, pp. 61-121.

Lambeck, K.; Rouby, H.; Purcell, A.; Sun, Y., and Sambridge, M., 2014. Sea level and global ice volumes from the Last Glacial Maximum to the Holocene. *PNAS*, 111(43), 15296–15303.

Lewis, S.E.; Wüst, R.A.J.; Webster, J.M., and Shields, G.A., 2008. Mid-late Holocene sea-level variability in eastern Australia. *Terra Nova*, 20, 74–81.

Lighty, R.G.; Macintyre, I.G., and R. Stuckenrath, R., 1982. *Acropora palmata* reef framework: a reliable indicator of sea level in the western Atlantic for the past 10,000 years. *Coral Reefs*, 1, 125-130.

Loewe Kooijmans, L.P., 1974. *The Rhine/Meuse Delta: Four Studies on its Prehistoric Occupation and Holocene Geology*. Leiden, The Netherlands: E.J. Brill, 421p.

Loewe Kooijmans, L.P., 1980. Archaeology and coastal change in the Netherlands. *In:* Thompson, F.H. (ed.). *Archaeology and Coastal Change*. London: Society of Antiquaries, pp. 106-133.

Lowrie, A. and Hamiter, R., 1995. Fifth and sixth order eustatic events during Holocene (fourth order) highstand influencing Mississippi delta-lobe switching. *Journal of Coastal Research*, Special Issue No. 17: Holocene Cycles: Climate, Sea Levels, And Sedimentation, pp. 225-229

Martin, L. 1985; Flexor, J.-M; Blitzkow, D., and Suguio, K., 1985. Geoid change indications along the Brazilian coast during the last 7,000 years. *Proceedings of the Fifth International Coral Reef Congress* (Tahiti), 3, pp. 85-90.

Martin, L.; Dominguez, J.M.L., and Bittencourt, A.C.S.P., 2003. Fluctuating Holocene sea levels in eastern and southeastern Brazil: evidence from multiple fossil and geometric indicators. *Journal of Coastal Research*, 19(1), 101-124.

Mason, O.K. and Jordan, J.W., 2002. Minimal late Holocene sea level rise in the Chukchi Sea: Arctic insensitivity to global change? *Global and Planetary Change*, 32, 13– 23.

McFarlan, E., 1961. Radiocarbon dating of Late Quaternary deposits, south Louisiana. *Geological Society of America Bulletin*, 72(1), 129-158.

Meier, D., 2008. The historical geography of the German North-Sea coast: a changing landscape. *Die Küste,* 74, 18-30.

Meijles, E.W.; Kiden, P.; Streurman, H.-J.; Van Der Plicht, J.; Vos, P.C.; Gehrels, W.R., and Kopp, R.E., 2018. Holocene relative mean sea-level changes in the Wadden Sea area, northern Netherlands. *Journal Of Quaternary Science*, 33, 905–923.

Miller, D.E.; Yates, R.J.; Jerardino, A., and Parkington, J.E., 1995. Late Holocene coastal change in the southwestern Cape, South Africa. *Quaternary International*, 29-30, 3-10.

Milliman, J.D. and Emery, K.O., 1968. Sea levels during the past 35,000 years. *Science*, 162(3858), 1121-1123.

Moore, G.W., 1960. Recent eustatic sea-level fluctuations recorded by Arctic beach ridges. In: *Geological Survey Professional Paper 400-B*. Washington: U.S. Government Printing Office, pp. 335-337.

Moriwaki, H.; Chikamori, M.; Okuno, M., and Nakamura, T., 2006. Holocene changes in sea level and coastal environments on Rarotonga, Cook Islands, South Pacific Ocean. *The Holocene,* 16(6), 839-848.

Mörner, N.-A., 1976a. Eustatic changes during the last 8,000 years in view of radiocarbon calibration and new information from the Kattegatt region and other northwestern European coastal areas. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 19, 63-85.

Mörner, N.-A., 1976b. Eustacy and geoid changes. *The Journal of Geology*, 84, 123-151.

Mörner, N.-A., 1980. The northwest European "sea-level laboratory" and regional Holocene eustasy. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 29, 281-300.

Mörner, N.-A., 1987. Models of global sea-level changes. *In:* Tooley, M.J. and Shennan, I. (eds.), *Sea-Level Changes*. Oxford: Blackwell, pp. 332-355.

Mörner, N.-A., 2007. Sea level changes and tsunamis, environmental stress and migration overseas: the case of the Maldives and Sri Lanka. *Internationales Asienforum*, 38(3–4), 353–374.

Morton, R.A.; Paine, J.G., and Blum, M.D., 2000. Responses of stable bay-margin and barrier-island systems to Holocene sea-level highstands, western Gulf of Mexico. *Journal of Sedimentary Research*, 70(3), 478–490.

Moslow, T.F. and Colquhoun, D.J., 1981. Influence of sea level change on barrier island evolution. *Oceanis*, 7, 439-454.

Murray-Wallace, C.V. and Woodroffe, C.D., 2014. *Quaternary Sea-Level Changes: A Global Perspective*. Cambridge: Cambridge University Press, 484p.

NASA, 2025. *Sea Level*. Webpage, accessed 31st January 2025, https://climate.nasa.gov/vital-signs/sea-level/?intent=121

Oliver, G.J.H. and Terry, J.P., 2019. Relative sea-level highstands in Thailand since the Mid-Holocene based on ^{14}C rock oyster chronology. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 517, 30–38.

Pascucci, V.; De Falco, G.; Del Vais, C.; Sanna, I.; Melis, R.T., and Andreucci, S., 2018. Climate changes and human impact on the Mistras coastal barrier system (W Sardinia, Italy). *Marine Geology*, 395, 271–284.

Peltier, W.R., 1998. Global glacial isostatic adjustment and coastal tectonics. *In:* Stewart, I.S. and Vita-Finzi, C. (eds.). *Coastal Tectonics*. Geological Society London, Special Publication, 146, 1-29.

Peltier, W.R., 2004. Global glacial isostasy and the surface of the ice-age earth: the Ice-5G (VM2) model and Grace. *Annual Review of Earth and Planetary Sciences*, 32, 111–149.

Peterson, B.J.; Howarth, R.W.; Lipschultz, F., and Ashendorf, D., 1980. Salt marsh detritus: an alternative interpretation of stable carbon isotope ratios and the fate of *Spartina alterniflora*. *Oikos*, 34, 173-177.

Pirazzoli, P.A., 1991. *World Atlas of Holocene Sea-Level Changes*. Amsterdam: Elsevier, 300p.

Pirazzoli, P.A. and Montaggioni, L.F., 1986. Late Holocene Sea-Level Changes in the Northwest Tuamotu Islands, French Polynesia. *Quaternary Research*, 25, 350-368.

Pirazzoli, P.A. and Montaggioni, L.F., 1988. Holocene sea-level changes in French Polynesia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 68: 153-175.

Pirazzoli, P.A.; Montaggioni, L.F.; Salvat, B., and Faure, G., 1988. Late Holocene sea level indicators from twelve atolls in the central and eastern Tuamotus (Pacific Ocean). *Coral Reefs*, 7, 57-68.

Porath, Y., 2002. The water-supply to Caesarea: a re-assessment. *In:* Amit, D.; Hirschfeld, Y., and Patrich, J. (eds.). The Aqueducts of Israel, Journal of Roman Archaeology Supplementary Series, no. 46, 104-129.

Porath, Y. and 'Ad, U., 2015. Excavations along the high level aqueduct to Caesarea Maritima. *'Atiqot*, 81, 107-149 (in Hebrew; English summary p. 124*-126*).

Porter, S.C.; Stuiver, M., and Heusser, C.J., 1984. Holocene sea-level changes along the Strait of Magellan and Beagle Channel, southernmost South America. *Quaternary Research*, 22(1), 59-67.

Raban, A. and Galili, E., 1985. Recent maritime archaeological research in Israel – a preliminary report. *The International Journal of Nautical Archaeology and Underwater Exploration*, 14(4), 321-356.

Ramsay, P.J., 1995. 9000 years of sea-level change along the southern African coastline. *Quaternary International*, 31, 71-75.

Razjigaeva, N.G.; Grebennikova, T.A; Ganzey, L.A.; Mokhova, L.M., and Bazarova V.B. 2004. The role of global and local factors in determining the middle to late Holocene environmental history of the South Kurile and Komandar islands, northwestern Pacific. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 209, 313– 333.

Redfield, A.C., 1967. Postglacial change in sea level in the western north Atlantic Ocean. *Science*, 157(3789), 687-692.

Reynolds, L.C. and Simms, A.R., 2015. Late Quaternary relative sea level in Southern California and Monterey Bay. *Quaternary Science Reviews*, 126, 57-66.

Schmid, M.M.E.; Dugmore, A.J., Vésteinsson, O., and Anthony J. Newton, A.J., 2017. Tephra isochrons and chronologies of colonisation. *Quaternary Geochronology*, 40, 56-66.

Schofield, J.C., 1960. Sea level fluctuations during the last 4,000 years as recorded by a chenier plain, Firth of Thames, New Zealand. *New Zealand Journal of Geology and Geophysics,* 3, 467-485.

Schofield, J.C., 1977. Late Holocene sea level, Gilbert and Ellice Islands, west central Pacific Ocean. *New Zealand Journal of Geology and Geophysics*, 20(3), 503-529.

Scholl, D.M.; Craighead, F.C., Sr., and Stuiver, M., 1969. Florida submergence curve revised: its relation to coastal sedimentation rates. *Science*, 163(3867), 562-564.

Scott, D.B.; Gayes, P.T., and Collins, E.S., 1995. Mid-Holocene precedent for a future rise in sea-level along the Atlantic coast of North America. *Journal of Coastal Research,* 11(3), 615-622.

Searle, D.J. and Woods, P.J., 1986. Detailed documentation of a Holocene sea-level record in the Perth region, southern Western Australia. *Quaternary Research*, 26(3), 299-308.

Selivanov, A.O. and Stepanov, V.P. 1985. Geoarcheological investigations on the Soviet Primorye coast: their application to interpretations of paleoclimates and former sea levels. *Journal of Coastal Research*, 1(2), 141-149.

Serpelloni, E.; Faccenna, C.; Spada, G.; Dong, D., and Williams, S.D.P., 2013. Vertical GPS ground motion rates in the Euro-Mediterranean region: new evidence of velocity gradients at different spatial scales along the Nubia-Eurasia plate boundary. *Journal of Geophysical Research: Solid Earth*, 118(11), 6003-6024.

Shepard, F.P., 1961. Sea level rise during the past 20,000 years. *In:* Russell, R.J. (convenor). *Pacific Island Terraces: Eustatic? Zeitschrift für Geomorphologie*, Supp. 3, 30-35.

Shepard, F.P., 1963. Thirty-five thousand years of sea level. *In: Essays in Marine Geology in Honor of K.O. Emery*. Los Angeles: University of Southern California Press, pp. 1-10.

Shepard, F.P., 1964. Sea level changes in the past 6000 years: possible archeological significance. *Science*, 143(3606), 574-576.

Shepard, F.P. and Curray, J.R., 1967. Carbon-14 determination of sea level changes in stable areas. *Progress in Oceanography*, 4, 283-291.

Siddall, M.; Rohling, E.J.; Almogi-Labin, A.; Hemleben, Ch.; Meischner, D.; Schmelzer, I., and Smeed, D.A., 2003. Sea-level fluctuations during the last glacial cycle. *Nature*, 423, 853-858.

Sivan, D.; Lambeck, K.; Toueg, R.; Raban, A.; Porath, Y. and Shirman, B., 2004. Ancient coastal wells of Caesarea Maritima, Israel, an indicator for relative sea level changes during the last 2000 years. *Earth and Planetary Science Letters*, 222, 315-330.

Sloss, C.R.; Murray-Wallace, C.V., and Jones, B.G., 2007. Holocene sea-level change on the southeast coast of Australia: a review. *The Holocene*, 17(7), 999-1014

Sloss, C.R.; Nothdurft, L.; Quan Hua, Q.; O'Connor, S.G.; Moss, P.T., Rosendahl, D., et al., 2018. Holocene sea-level change and coastal landscape evolution in the southern Gulf of Carpentaria, Australia. *The Holocene*, 28(9), 1411-1430.

Sneh, Y. and Klein, M., 1984. Holocene sea level changes at the coast of Dor, southeast Mediterranean. *Science*, 226(4676), 831-832.

Somoza, L.; Barnolas, A.; Arasa, A.; Maestro, A.; Rees, J.G., and Hernandez-Molina, F.J., 1998. Architectural stacking patterns of the Ebro delta controlled by Holocene high-frequency eustatic fluctuations, delta-lobe switching and subsidence processes. *Sedimentary Geology*, 117, 11-32

Stapor, F.W; Mathews, T.D., and Lindfors-Kearns, F.E., 1991. Barrier-island progradation and Holocene sea-level history in southwest Florida. *Journal of Coastal Research*, 7(3), 815-838.

Stattegger, K.; Tjallingii, R.; Saito, Y.; Michelli, M.; Nguyen Trung Thanh, N.T., and Wetzel, A., 2013. Mid to late Holocene sea-level reconstruction of Southeast Vietnam using beachrock and beach-ridge deposits. *Global and Planetary Change,* 110, 214–222.

Stéphan, P. and Goslin, J., 2014. Évolution du niveau marin relatif à l'Holocène le long des côtes françaises de l'Atlantique et de la Manche : réactualisation des données par la méthode des "sea-level index points". *Quaternaire*, 25(4), 295-312.

Suguio, K.; Martin, L., and Flexor, J-M., 1980. Sea-level fluctuations during the past 6000 years along the coast of the State of São Paulo, Brazil. *In:* Mörner, N.-A. (ed.). *Earth Rheology, Isostasy and Eustasy*. Chichester: John Wiley & Sons, pp. 471-486.

Suguio, K.; Martin, L., and Flexor, J.-M., 1988. Quaternary sea levels of the Brazilian Coast. *Episodes*, 11(3), 203-208.

Tan, F.; Khan, N.S.; Li, T.; Meltzner, A.J.; Majewski, J.; Chan, N., et al., 2023. Holocene relative sea-level histories of far-field islands in the mid-Pacific. *Quaternary Science Reviews,* 310, 107995, doi: 10.1016/j.quascirev.2023.107995

Tanabe, S.; Hori, K.; Saito, Y.; Haruyamad, S.; Vue, V.P., and Kitamura, A., 2003. Song Hong (Red River) delta evolution related to millennium-scale Holocene sea-level changes. *Quaternary Science Reviews*, 22(21-22), 2345–2361.

Tavernier, R. and Moormann, F., 1954. Les changements du niveau de la mer dans la plaine maritime flamande pendant l'Holocène. *Geologie en Mijnbouw,* 16(6), 201-206.

Ters, M., 1987. Variations in Holocene sea level on the French Atlantic coast and their climatic significance. *In:* Rampino, M.R.; Sanders, J.E.; Newman, W.S., and Königsson, L.K. (eds). *Climate: History, Periodicity, and Predictability*. New York: Van Nostrand Reinhold, pp. 204-237.

Tjia, H.D., 1996. Sea-level changes in the tectonically stable Malay-Thai Peninsula. *Quaternary International*, 31, 95-101.

Tjia, H.D.; Fujii, S., and Kigoshi, K., 1983. Holocene shorelines of Tioman island in the South China Sea. *Geologie en Mijnbouw*, 62, 599-604.

Toniolo, T.D.F.; Giannini, P.C.F.; Angulo, R.J.; de Souza, M.C.; Pessenda, L.C.R., and Spotorno-Oliveira, P., 2020. Sea-level fall and coastal water cooling during the Late Holocene in Southeastern Brazil based on vermetid bioconstructions. *Marine Geology*, 428 (106281), doi: 10.1016/j.margeo.2020.106281

Tooley, M.J., 1974. Sea-level changes during the last 9000 years in north-west England. *The Geographical Journal*, 140(1), 18-42.

Vacchi, M.; Marriner, N.; Morhange, C.; Spada, G.; Fontana, A., and Rovere, A., 2016.

Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean: sea-level variability and improvements in the definition of the isostatic signal. *Earth-Science Reviews*, 155, 172-197.

van Andel, T.H. and Lianos, N., 1984. High-resolution seismic reflection profiles for the reconstruction of postglacial transgressive shorelines: an example from Greece. *Quaternary Research*, 22(1), 31 - 45.

van Straaten, L.M.J.U., 1954. Radiocarbon datings and changes of sea level at Velzen (Netherlands). *Geologie en Mijnbouw*, 16(6), 247-253.

Walker, K.J.; Stapor, F.W., and Marquardt, W.H., 1995. Archaeological evidence for a 1750-1450 BP higher-than-present sea level along Florida's Gulf Coast. *In: Holocene Cycles: Climate, Sea Levels, and Sedimentation. Journal of Coastal Research*, Special Issue No. 17, pp. 205-218.

Walker, M., and 18 others, 2009. Formal definition and dating of the GSSP (Global Stratotype Section and Point) for the base of the Holocene using the Greenland NGRIP ice core, and selected auxiliary records. *Journal of Quaternary Science*, 24, 3–17.

Ward, W.T., 1971. Postglacial changes in level of land and sea. *Geologie en Mijnbouw*, 50(5), 703-718.

Woodroffe, C.D.; McGregor, H.V.; Lambeck, K.; Smithers, S.G., and Fink, D., 2012. Mid-Pacific microatolls record sea-level stability over the past 5000 yr. *Geology*, 40(10), 951-954.

Woodroffe, S.A., 2009. Testing models of mid to late Holocene sea-level change, North Queensland, Australia. *Quaternary Science Reviews, 28(23-24)*, 2474–2488.

Zeuner, F.E., 1946. *Dating the Past: An Introduction to Geochronology*. London: Methuen, 444p.

Zhao, X; Tang L.; Wang, S, and Shen, C. 1995. Holocene climatic and sea-level changes in Qingfeng Section, Jianhu County, Jiangsu Province: a typical example along the coastal areas in China. *In: Holocene Cycles: Climate, Sea Levels, and Sedimentation. Journal of Coastal Research*, Special Issue No. 17, pp. 155-162.

Zong, Y., 1992. Postglacial stratigraphy and sea-level changes in the Han River Delta, China. *Journal of Coastal Research*, 8(1), 1-28.

Tables 1 and 2 (no figures) ....

Table 1. List of published sea-level (SL) curves invoking oscillations of at least 0.5m in the last 5ky, based on SL benchmarks (geological data-points, except where indicated "Archaeo./geol." or "Archaeo."). Column header "Ampl. (m)" = amplitude of oscillations, in metres, estimated from each published SL curve. The list only includes curves showing more than one complete oscillation (up-down or down-up) since 5ka. Includes two areas of strong isostatic uplift (i.e. Sweden-Denmark, Hudson's Bay) and a few tectonically unstable regions (e.g. Aegean, Japan, Mediterranean, New Zealand, Red Sea). Most curves are *relative* SL, i.e. uncorrected for tectonic or glacio-isostatic uplift or subsidence. "In Pirazzoli" generally refers to articles originally published in sources now of doubtful availability online. C = century AD; GoM = Gulf of Mexico; ky = thousand years (duration); ka = thousand years B.P. ('Before Present', i.e., 1950).

Reference (& fig. no.)	Study area	Ampl. (m)	Remarks
Badyukov 1982	Pacific atolls	~0.5-3	In Pirazzoli 1991, pl. 44.
Badyukov & Kaplin 1979	Russia (Arctic)	>0.5, <1.0	In Pirazzoli 1991, pl. 36.
Badyukov & Kaplin 1979	Russia (Jap. Sea)	~1.0	In Pirazzoli 1991, pl. 36.
Balsillie & Donoghue 2004 (7)	USA (GoM)	~0.5-2.5	Compilation of other authors' data. SL curve is a 7-pt moving average.
Baxter & Meadows 1999 (11)	South Africa	~1-2	Archaeo./geol.
Behre 2007 (1,3)	Germany (North Sea)	~0.5-2	Archaeo./geol.. Data compilation. Data- -point elevation- & age uncertainty since 3ka mostly small (+/- 20cm, +/- 50y).
Berzin 1967	Latvia (E Baltic)	~4-9 (sic)	In Pirazzoli 1991, pl. 13. Curve ends 1.2ka. Oscillations diminish with time (cf. Fairbridge Curve).
Bezerra et al. 2003 (11,12)	Brazil	>1.5	Own data. Error-band demands SL oscillations of at least 1.5m & allows up to 5m. Co-author Suguio (see below).
Bloch 1963 (p. 98)	Israel? (cf. Bloch 1981)	~1-2.5	SL curve since 4ka inferred from "tracing old shore lines, from carbon-dating of plant and animal remains and from historical records" (p. 95). Omitted by Pirazzoli 1991. "In the past 4,000 years there have been small [sic] but important oscillations" (p. 98).

Bloch 1981	Israel?	~1.5-3	"Bloch, 1981, fig. 10" SL curve coplotted in Raban & Galili 1985, fig. 26, beside their own near-identical curve (for Israel; see below). Bloch uncited in bibliography. Curve differs slightly from Bloch 1963. Omitted by Pirazzoli 1991.
Boomer & Horton 2006 (10)	England (Norfolk)	~1	No data after 2.3ka. "possible 1 m oscillation ... between 4000 and 2000 cal. BP", defined by a cluster of data points.
Bungenstock & Weerts 2010 (5)	Germany (North Sea)	>1	Reevaluated Behre 2003 data. Error-band demands SL oscillations of at least 1m & allows up to 3m; larger ones permitted by two multi-C sample gaps. Interprets most of Behre's oscillations as "data-artefacts or local effects".
Colquhoun & Brooks 1986 (1)	USA (S Carol.)	~0.5-3	Archaeo./geol.
Compton 2001 (5)	South Africa	~1-1.5	'Join-the-dots' SL curve links mid-points of elevation-error bars. Bars demand an oscillation of at least 0.5m.
Compton 2006 (6)	Namibia & South Africa	~1-1.5	New data & that of Compton 2001. 'Join-the-dots' SL curve, generally linking mid-points of elevation-error bars.
Cooper et al. 2018 (4)	Southern Africa (Namibia, S Afr., Mozambique)	~0.5-1	Own data & of others. Elevation-error bars overlap (fig. 3), compatible with zero oscillation.
Dalongeville & Sanlaville 1989	Kuwait (Persian Gulf)	~0.5-1	In Pirazzoli 1991, pl. 30. Archaeo./geol.. Two data-gaps of ~1ky.
Devoy 1977 (2)	UK (Thames Estuary)	~1	Curves 1 & 2. Only 4 data points.
Devoy 1979 (29)	UK (Thames Estuary)	~1	Modified (dotted sectors added) from Devoy 1977.
Devoy 1979 (32)	UK (Bristol Channel)	~1.5-3	SL curve plotted from published data (app. 2), including Kidson & Heyworth 1973, 1976. No data after 2.4ka.
Dolukhanov 1979	Russia (eastern Baltic)	~2-5	In Pirazzoli 1991, pl. 13. Four post-5ka oscillations. Like Fairbridge Curve.
Einsele et al. 1974 (3)	Mauritania	1-5	Own & others' data. Curve ends at 2ka.
Fairbridge 1960 (p. 76)	Global comp.	~1-5	Data not shown.
Fairbridge 1961 (15)	Global compilation	~1-6	Error bars not shown. Called "Fairbridge Curve" by Fairbridge (1976, p. 358).
Fairbridge 1976 (3)	Global comp.	~0.5-4	Update of his 1961 SL curve, adding Brazil archaeo. data. Error bars not shown. Omitted by Pirazzoli 1991.
Fairbridge & Hillaire-Marcel 1977 (2)	Global comp.	~0.5-4	Update of Fairbridge 1976 SL curve, adding Hudson's Bay geological data. Omitted by Pirazzoli 1991.
Fedorov 1971 (1)	Black Sea	1-6	Co-plotted with Fairbridge Curve (very similar).
Fletcher, Fairbridge et al. 1990	Norway	~1-2	In Pirazzoli 1991, pl. 3.
Fontaine & Delibrias 1974	Vietnam	~0.5-2	In Pirazzoli 1991, pl. 32. SL curve "inspired by Fairbridge" (Pirazzoli p. 118).
Gayes et al. 1992 (6)	USA (South Carolina)	~2	Multi-C data-gaps & wide error-bars. Shows 1.5 oscillations.
Geng et al. 1987	Eastern China	~1-3	In Pirazzoli 1991, pl. 34. Archaeo./geol.. Cited by Zong 1992. Resembles Fairbridge Curve.
Gibb 1983	New Zealand	0.5-1	In Pirazzoli 1991, pl.47 (curve J).

Gibb 1986	New Zealand	~0.5-1	Republ. by Kennedy 2008, fig. 1.
Godwin 1940 (31)	E England	~3-5	Archaeo./geol.. Dating by varves & pollen. Relative *land*-level curve. Re-plotted as rel. SL curve (inverted) by Zeuner 1946, fig. 34.
Godwin 1978 (33)	E England	~2-4	Archaeo./geol.
Greensmith & Tucker 1973 (6)	SE England	~1-4	Archaeo./geol.
Gudelis 1979	Lith. (E Baltic)	~2-4	In Pirazzoli 1991, pl. 13.
Hirai 1987	Japan	~4	In Pirazzoli 1991, pl. 37.
Huang 1986, 1987	S China	~2-4	In Pirazzoli 1991, pl. 32.
Jerardino 1995 (6b)	South Africa	~0.5-2	Archaeo.. Data from Jerardino 1993. Curve ends at 1.1ka.
Johnson et al. 2022 (4b)	South Shetland Islands	~1	See dashed curve. Data compiled from other authors.
Kerfourn 1974	France (Atl.)	~4	In Pirazzoli 1991, pl. 22.
Klug 1980	Germ. (Baltic)	>0.5, <1	In Pirazzoli 1991, pl. 14.
Korotkii et al. 1980	Russia (Japan Sea)	~1-5	In Pirazzoli 1991, pl. 36; also in Selivanov & Stepanov 1985, fig. 1. Resembles Fairbridge Curve.
Lewis et al. 2008 (4)	Australia (Gt Barrier Reef)	~0.5-1	Data compilation & a few new data-points. Data envelope allows oscillations to be as small as ~0.5m or as large as ~1m. Noncommittal on origin.
L'Homer et al. 1981	France (Rhone)	~1-2	In Pirazzoli 1991, pl. 24.
Martin et al. 1985 (2a)	Brazil	max. 3+	Archaeo./geol.. Also in Pirazzoli 1991, pl. 56 (curve L) & fig. 2-35. Resembles Fairbridge Curve, especially update by Fairbridge & Hillaire-Marcel 1977. cf. Suguio below (same research group).
Martin et al. 2003 (7B)	Brazil	max. 3+	Same SL curve as Martin et al. 1985, with sample ages reservoir-corrected & calibrated. Rises "very rapid"; falls too (fig. 7B). Age error-bars allow multi-C data-gaps, possibly hiding other m-scale SL excursions. Cause of oscillations not discussed. No mention of geoid, eustasy or Fairbridge.
Meier 2008 (5)	Germ. (N Sea)	~0.5-1	Archaeo./geol.. Last 3ky only.
Miller et al. 1995 (7)	South Africa	~0.5-2	Archaeo.. No data after 1.1ka.
Moore 1960	USA (N Alaska)	1-2	No SL curve. Invoked "minor fluctuat-ions with an amplitude of 1 to 2 m"; "small eustatic changes".
Mörner 1976a (7)	Sweden-Denmark	0.8-1.2	"eustatic curve"; data not plotted. Curve ends at 0.6ka.
Mörner 1980 (8)	Sweden-Denmark	~1	"eustatic ... low-amplitude oscillating curve"; data not plotted.
Mörner 2007 (2)	Maldives	~0.5-1.5	Archaeo./geol.
Morton et al. 2000	USA (Texas)	1-2	No SL curve given. Plots of published data-points (figs 16, 17) suggest "rapid water-level oscillations of 1 to 2 m". Glacio-eustasy preferred over hydro-isostasy.
Morzadec-Kerfourn 1974	France (Atlantic)	~3	In Pirazzoli 1991, pl. 22 (curve k). SL curve ends ~1.6ka.
Moslow & Colquhoun 1981 (7)	USA (South Carolina)	1-2	Archaeo./geol.. SL curve (of Brooks et al. 1979?) spans 4.5-1.9ka. A "very rapid" 2-3m rise between 4.5 & 4ka, possibly in <100y (allowed by error-bars).

Omoto 1979	Japan	~1	In Pirazzoli 1991, pl. 37.
Pascoff & Sanlaville 1983	Tunisia	>0.5, <1	In Pirazzoli 1991, pl. 24.
Pascucci et al. 2018 (7)	Sardinia	~1-5	Archaeo./geol.. "eustatic fluctuations".
Pomel 1979	West Africa	~1-3	Thesis cited in Pirazzoli 1991, pl. 29.
Qiu 1986	S China (Hainan Is.)	~0.5-1.5	In Pirazzoli 1991, pl. 32.
Raban & Galili 1985	Israel (Medit.)	~1-2	Archaeo.. Eustasy invoked. SL curve co-plotted with near-identical curve of Bloch 1981.
Ramsay 1995 (2)	South Africa & Mozambique	min.~2	Own data & of others. Data gap 3-1.6ka. No data after 0.8ka.
Razjigaeva et al. 2004 (6b)	Russia (Pacific)	~0.3-3	Island arc. "small ... fluctuations"; two "minor transgressions" of 4m (min.) & 2.5m. Resembles Fairbridge Curve.
Sanlaville 1989	Iraq (Per. Gulf)	~1-3	Archaeo./geol.. In Pirazzoli 1991, pl. 30.
Schofield 1960 (8d)	New Zealand	~0.5-1.5	Last 4ka only. 'Join-the-dots' curve.
Schofield 1977 (7)	New Zealand	~0.5-1	Last 4ka only. Adjusted data of Schofield 1960. 'Join-the-dots' curve.
Schofield 1977 (7)	C Pacific atolls	~1-3	'Join-the-dots' curve.
Schütte 1939	Germ. (N Sea)	~3-5	In Pirazzoli 1991, pl. 15.
Scott et al. 1995 (3)	USA (South Carolina)	~2	Same SL curve as Gayes et al. 1992; some error-bars changed.
Selivanov & Stepanov 1985 (1)	Russia (Japan Sea)	1.5+	Archaeo.. Max. amplitude >1.5m (low-stands unseen).
Siddall et al. 2003 (1)	Red Sea	~2-8	Based on foram oxygen isotopes in core. Decadal resolution. Paleobathymetry error-bars very large (+/-12m). SL curve is 5-point running mean.
Sneh & Klein 1984 (1)	Israel (Medit.)	~1-2	Archaeo./geol.. Last 4ky only. Multi-C sample-gaps.
Somoza et al. 1998 (6)	Spain (Medit.)	~1-2	Based on sequence stratigraphy (seismic & borehole data).
Stapor et al. 1991(14)	USA (GoM)	~0.5-1.5	Beach-ridge elevations. Last 3ky only. Co-author of Walker et al. 1995 (below).
Suguio et al. 1980 (4a,b)	Brazil	max. 3+	Archaeo./geol.. After ~5ka highstand, an oscillation of at least 3m (lowstand elevation unknown, below modern SL) spanned ~4.1 to 3.3ka. Post 3.3ka multi-C (to >2ky) sample gaps. Omitted by Pirazzoli 1991.
Suguio et al. 1988 (4A,B)	Brazil	max. 3+	Same SL curves as Martin et al. 1985, except data-points not plotted. Co-author of Bezerra et al. (above).
Taira 1980	Japan	1-4	In Pirazzoli 1991, pl. 38. Archaeol. (shell middens). No data after 2.3ka.
Tan et al. 2023 (3c)	Kiritimati (Pacific)	>0.5	Woodroffe et al. 2012 smooth SL interpretation (see Table 2) reassessed, using extra data-points (see Section 3.2). Elevation-error bars allow 1 or more oscillations reaching up to ~1m above & below modern mean SL, i.e. ampl. up to ~2m.
Ters 1987 (12-2)	France (W & NW)	~0.5-3	Data-point spacing (to 250y) & error-bars (typically 200-400y; table 12-1) allow higher amplitudes & 200-300y(?) flexibility in high-/lowstand timing.
Tjia 1996 (3)	Malay-Thai Peninsula	~2?	From 5m highstand ~5ka, SL fell in a "series of fluctuations ... amplitudes of 2m and periods of about 2000 years".

			Resembles Fairbridge Curve.
Tjia et al. 1977	Pen. Malaysia	~1.5	In Pirazzoli 1991, pl. 31 (curve C).
Tjia et al. 1983 (3)	Malaysia (Tioman)	~1	No data after 1.9ka. Zigzag 'join-the-dots' (only 8 samples) "eustatic" SL curve; multi-C (to 1ky) sample-gaps. No age/elevation error-bars given.
Tjia et al. 1983 (3)	Pen. Malaysia	~1.5-3	Zigzag "eustatic" curve (Tjia et al. 1977 data). Samples not plotted. >40 samples, yet curve has only 5 inflections.
Tooley 1974 (10)	NW England	~1-1.5	SL curve poorly constrained (only 10 samples after 4.7ka).
Toyoshima 1978	Japan	~2-4	In Pirazzoli 1991, pl. 40. Pirazzoli implies oscillations may be artifact of blocks with distinct tectonic histories.
van Andel & Lianos 1984	Greece(Aegean)	~1.5	Archaeo.. In Pirazzoli 1991, pl. 25.
van Straaten 1954 (4)	Holland	~0.5-1	From his preferred SL curve (version 3). Only 4 data-points; large elevation uncertainty (2-3m) would also allow no oscillations. No data after 2ka.
Walker et al. 1995 (8)	USA (GoM)	1.9	Archaeo.. Co-author Stapor. 50BC to 750AD only. Single SL oscillation, younger/ briefer than shown by Stapor et al. 1991.
Ward 1971 (2)	New Zealand	~1-1.5	Based on "corrected" data of Schofield 1960, 1964. 'Join-the-dots' curve.
Weinsberg 1974	Latvia (Baltic)	~0.5-4	In Pirazzoli 1991, pl. 13.
Wellman 1962	New Zealand	~0.5-1	In Pirazzoli 1991, pl. 47.
Xie et al. 1986	Southern China	~1-2	In Pirazzoli 1991, pl. 33; "similar to Fairbridge's curve".
Yang and Xie 1984	Eastern China	~1-5	In Pirazzoli 1991, pl. 34.
Zhao et al. 1995 (5B)	Eastern China	~0.5-1.5	Local. Based on forams. Dense sampling (spacing <200y; calibrated by 3 carbon-ages). No data after 1ka.
Zong 1992 (12)	Southern China	~1-2?	Multi-C sample gaps. Error band demands SL oscillations of at least 0.5-1m; allows oscillations up to 3.5m.

Table 2. List of published sea-level (SL) curves invoking smooth SL (no oscillations >0.5m) in the last 5ky, based on geological data-points, except where indicated "Archaeo./geol." or "Archaeo.". Includes some tectonically unstable regions, e.g. Aegean, Israel, Jamaica, Japan, Mediterranean, Panama. Most curves are relative SL, i.e. uncorrected for tectonic or glacio-isostatic uplift or subsidence. C = century; GoM = Gulf of Mexico; ky = thousand years (duration); ka = thousand years B.P. ('Before Present', i.e., 1950); m = meter. "In Pirazzoli" generally refers to articles originally published in sources now hard to locate (non-digitised).

Reference (& fig. no.)	Study area	Remarks
Angulo & Lessa 1997 (11)	Brazil	Compilation of published vermetid data. Chosen best-fit SL curve (4th-order polynomial) shows slightly undulating SL fall from ~+3m at 5ka. But data-points are widely dispersed, up to ~1.5m above and below the curve.
Angulo et al. 2006 (18)	Brazil, E coast (N & S sectors)	Literature review. Chosen SL curves (5th-order polyno-mials) show, since 5ka, (i) continuous fall at varying rate (N sector) & (ii) overall fall with a superimposed oscillation of <0.5m & >1ky. "It cannot be ruled out ... that the late Holocene sea-level fall ...

		underwent small-scale (few decimeters) oscillations." Wide age- & elevation error bars allow brief (<300y each), m-scale, 'hidden' oscillations. Of 6 "outliers" in the N data-set, 3 are 'over-high' (fig. 18); the highest, at 400AD (+/-300y; Rottnest-highstand?), is ~3m (+/-1m) above the N-sector SL curve.
Baeteman 2008 (1)	Belgium	No data for last 1.3ky; "fluctuating sea-level rise can not [sic] be considered as realistic."
Baker et al. 2001a (8a)	SE Australia	Data of Baker & Haworth 2000. Chosen best-fit curve (5th-order polynomial) shows stepped SL fall starting ~4.5ka. Multi-C sample gaps. No data after 1.3ka.
Baker et al. 2001a (9a)	Brazil	Data of Angulo et al. 1999. Chosen best-fit curve (5th-order polynomial) shows one minor rise (~10cm) superimposed on overall fall starting ~4.7ka; very like SE Australia curve (same article). One 1.5-ky sample gap.
Baker et al. 2001b (6b)	SE, SW & S Australia (incl. (Rottnest Is.)	Own data & of others. Chosen best-fit curve (5th-order polynomial) shows one minor rise (~10cm), superimposed on overall fall from ~4.5ka. Multi-C data-gaps. No data after 1.3ka.
Baker et al. 2005 (7)	W Australia (incl. Rottnest)	Chosen best-fit curve (8th-order polynomial) shows stepped SL fall from ~5.8ka, with a superimposed very minor rise (~5cm) in 1st Millennium AD.
Baroni & Hall 2004	Antarctica	In Johnson et al. 2022, fig. 4a.
Belperio 1979	NE Australia	In Pirazzoli 1991, pl. 50.
Belperio et al. 1983	S Australia	In Pirazzoli 1991, pl. 48.
Bennema 1954 (1)	Holland	Smoothly decelerating SL rise, with superimposed "likely ... slight rises" & falls since 4ka.
Berger 1983	Panama(Carib.)	In Pirazzoli 1991, pl. 58.
Bloom 1970 (2)	Caroline Is. (Pacific)	Continuous SL rise. Only 3 samples.
Bloom & Stuiver 1963	USA (Connec.)	In Pirazzoli 1991, pl. 62. Smoothly decelerating SL rise.
Bondevik et al. 1995 (11-14)	Svalbard	Least-squares curve, shows continuous (decelerating) SL rise. Data-gaps of up to 2.5ky.
Braddock et al. 2022 (3a)	Antarctica	Relative SL curve smooth. Error-bars, 2-sigma uncertainty band, & sample gaps collectively allow m-scale oscillations.
Burne 1982	S Australia	Straight line assumed. In Chappell 1987, fig.10.8c (misspelled Byrne).
Caldas et al. 2006 (8)	Brazil	Chosen (eyeballed?) SL curve shows linear fall from ~+1m at ~5ka. Multi-C data gaps. No data after 1.7ka. "Beachrock positions with their error bars are all within the tidal-range envelope. Therefore, no secondary oscillations during the sea level fall can be confirmed."
Chappell 1983 (1)	NE Australia	Own data & of others. Assumed linear fall (least-squares regression), from ~1m above modern, since 6ka. Multi-C sample gaps. Error-bars of several data-points fall entirely off the line (dismissed as spurious?).
Clague et al. 1982 (3-6, 10,12)	W Canada (various regions)	Smooth curves assumed, despite data-gaps to >1ky & elevation--scatter to m-scale (e.g. figs 3, 10). Chosen curves likened to that predicted by Clark et al. 1978 glacio-isostatic *model*.
Cornen et al. 1977	West Africa	In Pirazzoli 1991, pl. 29.
Curray 1965	USA (GoM shelf)	In Pirazzoli 1991, pl. 59.
Dean et al. 2019	Israel	Archaeo.. Last 4ky only; only 4 data-points before 2ka. SL rise 0.9m 800BC-350AD; then 40cm fall & rise 350AD to present.
Delibrias 1974	West Africa	In Pirazzoli 1991, pl. 28.
Digerfeldt & Enell 1984	Jamaica	In Pirazzoli 1991, pl. 57.
Fairbanks 1989 (2)	Barbados	Based on Lighty et al. 1982 data from 4 other Caribbean islands.
Flemming 1969	W Mediterr. (multi-nation)	Archaeo.. 179 cities. Literature review. "no net eustatic change in the last 2000 years". No SL curve given.

Flemming et al. 1973 (57)	E Mediterr. (Aegean)	Archaeo.. 70 sites. Own data & of others. Last 4ky only. "eustatic sea level change has not exceeded 30 cm in the last 3,000 years."
Galili et al. 1988 (3)	Israel (Mediterr.)	Archaeo.. Only 3 samples in last 5ky. Sample gaps up to 2ky. Smoothly decelerating SL rise assumed ('join-the-dots' curve).
Gehrels et al. 2006 (7)	Iceland	Salt-marsh forams. Last 2ky only. Continuous SL rise.
Gerlach et al., 2017 (8b)	Florida (GoM)	Salt-marsh forams. Last 2.5ky only. ~20cm SL fall until ~2.1ka; then ~1.1m unsteady continuous rise to present-day.
Geyh et al. 1979 (2)	Malaysia (Str. of Malacca)	1.8-ky data gap. Steady SL fall assumed, from ~+5m at 4.5ka to ~0m at 1ka.
Gibb 1986	New Zealand	SL curve reproduced by Kennedy 2008, fig. 1a. SL reached present level ~6.5ka. No ensuing oscillations >0.5m.
Giresse 1975	West Africa	In Pirazzoli 1991, pl. 29.
Grant 1975	E Canada	In Pirazzoli 1991, pl. 66.
Hall et al. 2004 (5)	Antarctica	Raised beach ridges. Carbon-dated seaweed, sealskin, shells, penguin bones/guano. SL-*limiting* points only, allowing m-scale oscillations, but a non-oscillating "best fit" curve is applied.
Hallmann et al. 2018 (5)	French Polynesia	Atolls & high islands. No data after 1.2ka. Multi-C sample gaps. Unsteady SL fall of ~0.8m between ~4 & 1.2ka.
Hawkins 1971	SW Britain	In Pirazzoli 1991, pl. 21. Slowly decelerating SL rise since 5ka.
Heyworth & Kidson 1982 (5)	Wales & SW England	Continuous SL rise since 5ka.
Hine et al. 1979	USA (Carolina)	In Pirazzoli 1991, pl. 57.
Hoppe et al. 1969	Svalbard	In Bondevijk et al. 1995, fig. 18.
Horton et al. 2005 (2)	Malay-Thai Peninsula (both flanks)	Own data & (mostly) of others. No data from 5.1 to 4.3ka. Invokes +5m highstand ~4.5ka, then steady fall.
Iseki et al. 1982	Japan	In Pirazzoli 1991, pl. 39.
Jaritz et al. 1977	Mozambique	In Pirazzoli 1991, pl. 30.
Jelgersma 1971 (1.6)	Holland	Only 1 data-point after 3ka. 'Curve III (mean sea-level)' assumes continual rise to present-day, with no oscillations.
Jelgersma 1980 (5)	Holland	Only 1 data-point after 2.9ka. Smoothly slowing rise assumed.
Kaland 1984 (18)	Norway	Only 3 samples after 5ka; none after 1.9ka. Assumed SL curve ('join-the-dots') shows gradually slowing rise.
Kale & Rajaguru 1985	W India	In Pirazzoli 1991, pl. 30.
Katto & Akojima 1980	Japan	In Pirazzoli 1991, pl. 40.
Kemp et al. 2011 (2B)	USA (N Carol.)	Salt-marsh forams. Last 2.1ky only. Unsteady continuous SL rise.
Kemp et al. 2013 (7B)	USA (N. Jersey)	Salt-marsh forams. Last 2.5ky only. Unsteady continuous SL rise.
Kemp et al. 2014 (5B)	USA (NE Flor.)	Salt-marsh forams. Last 2.5ky only. Unsteady continuous SL rise.
Kemp et al. 2015 (6B)	USA (Connec.)	Salt-marsh forams. Last 2.2ky only. Unsteady continuous SL rise.
Kemp et al. 2017b (5A,B)	USA (North Carolina)	Salt-marsh forams. Last 3.2ky only. Unsteady continuous SL rise.
Kemp et al. 2018 (9)	Newfoundland	Salt-marsh forams. Last 2.8ky only. Unsteady (stepped) SL rise.
Kemp et al. 2018 (10a)	Global	Eustatic curve for last 2.8ky derived via method of Kopp 2016 (see below). Curve shows: (i) cm-scale oscillations; & (ii) eustatic SL varied only ~+/-10cm between 2.8ka & 1850AD. **Last 2.5ky of this SL curve was adopted by IPCC 2021b fig. 2.28b.**
Khan et al. 2017 (5-8)	Caribbean (20 regions)	Data compilation. Spatio-temporal model applied to data (procedure unclear) yielded a SL curve for each region, showing no post-5ka oscillations >0.5m. Good match to data-points in some cases (e.g. figs 4, 10); in others, elevation uncertainty is commonly m-scale; error bars may even plot entirely off the curve (e.g. fig. 9). Also, many sample-gaps are multi-C or larger, possibly 'hiding' m-scale oscillations.
Kidson & Heyworth 1978 (1)	England (N Somerset)	Curve interpreted as eustatic. Smoothly slowing ~4m rise in high-tide level since 5ka; no oscillations. Multi-C sample gaps. No data after 2.3ka. "There seems little reason to invoke oscillations in sea level".
Kidson & Heyworth	Wales	Curve interpreted as eustatic. Smoothy slowing ~3m rise in

1978 (1)	(Cardigan Bay, Irish Sea)	high-tide level since 5ka; no oscillations. Multi-C (to >1ky) data-gaps. No data after 1.1ka?
Kirby et al. 2023 (6b)	NW Ireland	Salt-marsh forams. Last 2.6ky only. Unsteady continuous SL rise.
Kopp et al. 2016 (1a)	Global	Last 2.5ky only. Supposed eustatic curve, derived by analysing a global database of SL data-points using "a spatiotemporal empirical hierarchical model ... that distinguishes ... sea-level changes that are common across the database", shows: (i) cm-scale fluctuations; (ii) eustatic SL varied only ~+/-6cm between 2.5ka & 1850.
Labeyrie et al. 1976	French Medit.	In Pirazzoli 1991, pl. 24.
Lambeck et al. 2010 (4.14)	Global	Archaeo./geol. Compilation of published data. "there is no convincing evidence for oscillations in global ocean volume ... during the past 6000–7000 years". **SL curve adopted by IPCC 2013, fig. 5.17f.**
Lambeck et al. 2014 (4a, inset)	Global	Non-undulating SL curve fitted to compilation of published data using a complex smoothing function (see Section 2); shows smoothly slowing SL rise from ~-2m at 5ka; "no evidence of oscillations exceeding ~15–20 cm in time intervals ≥200 y" between 6 & 0.15ka. Error-bars of many data-points plot entirely off the calculated curve.
Lighty et al. 1982 (2)	Tropical west Atlantic	Compilation of published data. Multi-C to >1ky sample gaps. Chosen SL curve (interpreted as eustatic) shows smoothly slowing rise from ~-5m at 5ka.
Loewe Kooijmans 1974 (14, curve E; 16)	W Holland	Archaeo.. Compilation of published data. Stepped 4m rise in mean-high-water level since 5ka (fig. 16). Most steps decimetric.
Loewe Kooijmans 1980 (50)	W Holland	Archaeo.. Compilation of published data. Multi-C sample gaps. No data after 1.9ka. Chosen SL curve shows smoothly slowing 4m rise in mean-high-water level since 5ka.
Mason & Jordan 2002 (2)	N Alaska	Marsh peat. Own data & of others. Multi-C sample gaps. No data 5 to 4ka. Chosen least-squares linear SL curve shows 1.4m rise in high-water level since 5ka.
McFarlan 1961 (9)	USA (Louisiana)	Shells, wood, peat, etc. Own data & of others. SL curve interpreted as eustatic; shows SL reached present level ~4ka; no change since then; but some samples come "from 2 to 30 feet" below SL ... "adjustments ... made for environment and subsidence and ... local compaction".
Meijles et al. 2018 (6)	N Holland	Published-data compilation. Basal peats. Multi-C to >1ky sample gaps. No data after 0.6ka. Modelled curve fitted to data shows 3.5m unsteady continual SL rise from 5 to 1ka, then ~0.2m fall in 300y, but modelled error-band varies from +/-0.3 to 1.6m (depending on sample spacing), i.e. C-scale oscillation(s) of up to 3m possible.
Milliman & Emery 1968	E USA shelf	In Pirazzoli 1991, pl. 59.
Moriwaki et al. 2006 (7)	Cook Islands (Pacific)	Only ~10 samples, i.e. wide data-gaps. Two alternative SL curves given: (i) essentially stable SL at ~+1.5m from ~4.5 to ~0.5ka; (ii) ~1m smooth SL fall & rise in that time.
Mörner 1989	Tierra Fuego	In Pirazzoli 1991, pl. 54.
Neumann 1971	Bermuda	In Pirazzoli 1991, pl. 57.
Oliver & Terry 2019 (12)	Thailand (Andaman Sea)	Raised oysters. Own data. Multi-C sample gaps. Individual curves for 3 sites show ~6ka SL at ~+2.5m to ~+4m, then continual fall.
Pirazzoli et al. 1985	Tahiti & Moor.	In Pirazzoli 1991, pl. 44.
Pirazzoli & Montaggioni 1986 (11)	NW Tuamotu Is. (Fr. Polyn.)	6 atolls. SL curve interpreted as eustatic. Sample gaps multi-C to >1ky; no data after~0.7ka. Curve shows SL essentially stable at ~+0.8m from 5 to ~1.7ka; then continuous fall to today.
Pirazzoli & Montaggioni 1988 (11)	Fr. Polynesia	28 atolls, 10 high islands. Curve shows 2 oscillations of ~10cm & 20cm between ~5 & 1ka, then ~1m SL fall to present-day.

		Samples numerous, but carbon-dating uncertainty makes multi-C data-gaps likely.
Pirazzoli et al. 1988 (12)	SW Tuamotu Is. (Fr. Polyn.)	12 atolls. SL curve, said to be same as Pirazzoli & Montaggioni 1986 (above), in fact differs subtly.
Porter et al. 1984	Chile (Fuego, Magel., Beagle)	In Pirazzoli 1991, pl. 54. Only 5 samples. Curve shows ~3m steady SL fall since 5ka.
Rabassa et al. 1987	Argentina (Fuego, Beagle)	In Pirazzoli 1991, pl. 54. Curve shows ~8m steady SL fall since 5ka.
Redfield 1967	Bermuda	In Pirazzoli 1991, pl. 57. Steady rise of ~3m from ~4.5 to ~0.5ka.
Reynolds & Simms 2015(2)	USA (S Calif.)	Visual(?) best-fit curve shows ~3m steady rise, 4-0ka. Multi-C data-gaps.
Reynolds & Simms 2015(3)	USA (C Calif.)	Multi-C data gaps. Visual(?) best-fit curve shows ~5m steady rise, 4-0ka.
Scholl et al. 1969 (2)	USA (S Florida)	Multi-C data-gaps. Visual(?) best-fit curve, interpreted as eustatic, shows smoothly slowing SL rise from ~-2.5m at 5ka. Elevation uncertainty allows oscillations up to ~30cm.
Searle & Woods 1986	W Australia	In Pirazzoli 1991, pl. 48. Smoothly slowing SL fall from ~+2m at 5ka.
Shepard 1963 (1,2)	Global	Compilation, "relatively stable areas" (fig. 1). "Average curve" (fig. 2) shows smoothly slowing SL rise from ~-5m at 5ka. Data & curve republished in Shepard 1964 (figs 1,2). Three outliers (Australia, shells) 3-8m above the curve, an "enigma" (1963), dismissed as possible kitchen middens (Shepard 1961, 1964).
Shepard & Curray 1967 (3)	USA (GoM coast, Holland)	Compilation from "stable areas" (excl. Miss. Delta). Interpolated eyeballed(?) "proposed eustatic curve" (also fig. 5) shows smoothly slowing SL rise from ~-4m at 5ka. Multi-C (to ~1.2ky) data-gaps.
Sloss et al. 2007 (5,6)	SE Australia	Own data & of others. "minor ... oscillations in relative sea level during the mid to late Holocene ... most likely represent intertidal species adjustment to variations in coastal exposure and/or variable wave and climate conditions".
?Sloss et al. 2018 (7)	NE Australia (Carpentaria)	Own data & of others. Non-oscillating SL "curve representing line of best fit through the data points". Multi-C data-gaps & large "averaged vertical error of sea-level proxies" (shaded band, +/-1.5m) allow 'hidden' oscillations >0.5m. Sample ages have multi-C uncertainty (tables 3-5).
Stattegger et al. 2013 (4)	Vietnam (S China Sea)	Non-oscillating curve proposed, despite multi-C (to ~1.5ky) data-gaps & most samples' ~+/-1m vertical uncertainty. SL "fell almost linearly" from ~+1.4m at 5ka, with "small-scale climatically induced oscillations (Kemp et al., 2011)". Fall ascribed to continental levering & ocean siphoning.
Stéphan & Goslin 2014	France (W & NW)	Reassessment of published data. Fig. 10 shows Holocene SL data-points separately plotted for 9 coastal sectors. "Despite the high number of sea-level records available, the number of reliable data is still low". Many multi-C (to >1ky) data gaps. Data-point vertical uncertainty typically high (>1.5m), yet authors invoke "no significant sea-level oscillations during the Holocene" (contrast Ters 1987 [same region]; see Table 1). Fairbridge unmentioned.
Takahashi et al. 1988	Japan (Ryukyu Is.)	In Pirazzoli 1991, pl. 41.
?Tanabe et al. 2003 (8,9)	Vietnam (S China Sea)	Archaeo./geol. Data of others. No data after 1.9ka. Multi-C (to ~1.3ky) sample-gaps. Elevation uncertainty (shaded band) ~+/-0.5m, i.e. dm-scale oscillations not disproved.
?Tavernier & Moormann 1954	Belgium	No SL curve given. Discusses three post 2.2ka "Dunquerquienne" transgressions. No mention(?) of intervening regressions, i.e. SL may have either oscillated or risen step-wise.

Toniolo et al. 2020 (2A)	Brazil	Own data. Last 4ky only. No data for last 0.8ky. Chosen best-fit SL curve (4th-degree polynomial) shows continuous fall, at variable rate, from ~+2.5m at 4ka. Wide data-gaps (multi-C to 1.1ky) & large age- & elevation uncertainties (~+/-100y & ~+/-0.5m) allow brief (<300y), m-scale, 'hidden' oscillations. Conspicuously "over elevated" (p. 3) sample F6.2, ~1.3m (+/-~0.5m) above the curve & dated ~1400BP (~550AD) +/-~100y, ascribed to wave run-up.
Vacchi et al. 2016 (6-11)	W Medit. & Adriatic (various nations)	Archaeo./geol. Literature synthesis for 22 separate regions. Based on SL curves predicted by glacio-isostatic modeling (figs 6-11), the authors concluded that SL "rose continuously for the whole Holocene", i.e. assumed no oscillations, despite data-points commonly having wide (to >2ky) spacing, large age-uncertainty bars (to >+/-500y) & large elevation uncertainty (+/-~1m).
Woodroffe 2009 (8)	NE Australia	Own data & of others. "no evidence for ... fluctuations ... although they cannot be entirely ruled out". But oscillations >0.5m are indicated by large (2-4m) elevation scatter of data-points of small (<1m) elevation uncertainty. Multi-C sample gaps; one may span 400BC to 700AD (allowed by error-bars).
Woodroffe et al. 2012 (2)	Kiritimati (Pacific)	Own data. 100+ microatolls, "an almost continuous sequence spanning the past 5 k.y.", indicating SL was constantly "within 0.25 m of its present position". But wide error-bars (typically 200-400y; some >1ky) allow multi-C data-gaps; one may span 400-1000AD. Reassessed by Tan et al. 2023 (see Table 1 & Sect. 3.2).
Zale & Brydsten 1993	Svalbard	In Bondevijk et al. 1995, fig. 18.