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Sea Level Changes as recorded in nature itself

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Abstract
The science of sea level changes is quite multi-facetted. The level of the oceans is always changing, both vertically and horizontally. We have documented these changes quite carefully. After the last glaciation maximum, sea level has risen in the order of 120 m. This rise has been oscillatory. We can set frames on the maximum rate of a sea level rise; at the most rapid ice-melting after the Last Ice Age, sea level rose at about 10 ±1 mm/yr. The thermal expansion of water is, of course, a function of the water column heated; hence the effect is zero at the shore where there is no water to expand. The claim by the IPCC on a present sea level rise is greatly exaggerated. Coastal tide gauges give relative rates in the order of 0-2 mm/yr. The value of the absolute rise in sea level varies between 0.0 and 1.1 mm/yr. There are firm reasons to downgrade, even neglect,the fear of a disastrous coastal flooding in the present century.
Keywords: Sea level changes, oscillations, absolute sea level, no disastrous flooding.

I. INTRODUCTION

Sea level changes are important because they shape and control the coastal habitat. If sea level would rapidly rise, the coastal environment would, indeed, be threatened – as proposed by the IPCC (*e.g.* 2007). If climate gets warmer, there are both pros and cons for local environment, but if sea level would rise, there are only cons to expect. There are no true scientific observational reasons, however, for advocating any rapid sea level rise.

II. SETTING FRAMES

In recent years we have unfortunately ended up in dialectics between scientists basing their studies on field observations, accumulated scientific knowledge and physical laws (*e.g.* Mörner, 2011, 2013a), and IPCC affiliated groups (*e.g.* Horton et al., 2014) that confine their work to models and statistical analyses of time-series.

I will here address two fundamental factors where we in fact are able to apply physical frames to what is possible and what is outside the frames of reality (Mörner, *e.g.* 2011, 2013a).

1. The maximum rate of sea level rise

No sea level rise at any time can beat the rate at the maximum melting of the continental ice caps of the Last Ice Age. At about 11,000 years ago, the Holocene warm period commenced with a very strong rise in temperature and a very rapid ice melting. At Stockholm I Sweden, ice receded by 300 m/yr. Because ice flow outwards at the same time at a speed of about 500 m/yr, the actual melting was about 800 m/yr (Mörner, 2011, Fig. 3). Still, global sea level did not rise by more than 10 mm/yr. This value sets the absolute ultimate theoretical value for a sea level rise (Mörner, 2011, Fig. 5), as a fact any present sea level rise must be significantly less. This means that we can safely discard all those claims of a rise by 1 m or more by year 2100 as sheer nonsense.

2. The expansion of ocean water by heating

Like a railway track, also water expands when heated. The expansion is, of course, a direct function of the length (in this case water depth) of the column heated. Ocean heating is normally confined to the uppermost 700 m or so (Mörner, 2011, Fig. 4). Furthermore, heating in nature is never linear with time (only in models); it goes up and down in response to various forcing functions. Mid-ocean warming is likely to be less than 10 cm over a century. Towards the shore, the expansion must continually decrease with respect to the decreasing water depth, and at the shore it will be zero (±0.0 mm) because there is no water to expand (Mörner, 2011, 2013). This fact provides another fundamental frame in present to future sea level research.

III. SEA LEVEL RESEARCH

Sea level research has gone through a quite revolutionary evolution over the last 50 years (as reviewed in, for example, Mörner, 1987, 2013). One outcome was that the term eustasy had to be redefined (Mörner, 1986).

It seems to be vital for sound sea level research that it is firmly based on observational facts in the field (*i.e.* controllable) and well fixed as to age. Results based on models are inferior and very often directly misleading.

1. An old controversy: solved

In the 60s, there was a vigorous debate whether the postglacial sea level rise occurred as a smooth rise (Shepard, 1963) or an oscillatory rise (Fairbridge, 1961). My own low-amplitude oscillations sea level curve (Mörner, 1969) came as some sort of intermediate solution (Fig. 1). It was derived by the isolations of the isostatic and eustatic component in the spectrum of 40 individual shorelines recorded over 300 km in the direction of tilting in the periphery of the Fennoscandian uplift and dated by numerous C14-dates (Mörner, 1969, 1971). Numerous subsequent records from places scattered all over the world indicate that, indeed, the postglacial rise in sea level occurred in a mode of low-amplitude oscillations (e.g. Pirrazoli, 1991). This is even true for the Late Holocene and the last millennium (e.g. Mörner, 1980; van de Plassche, 2000; Hansen et al., 2012).

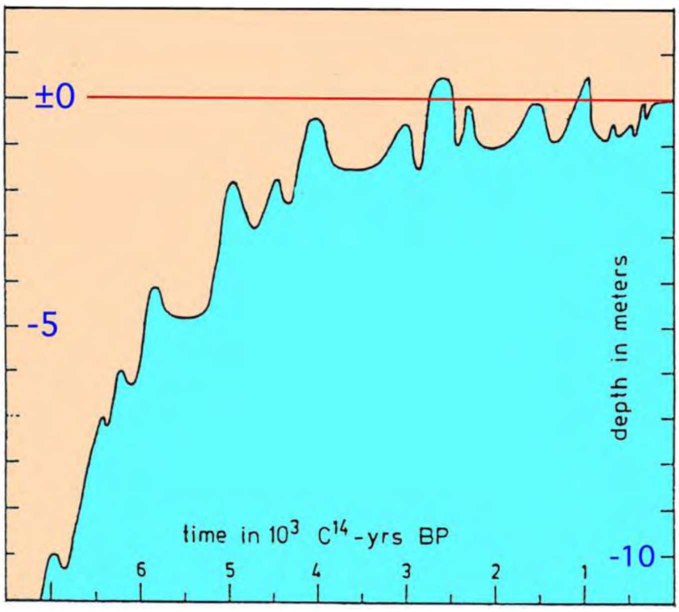

Fig. 1. Regional eustatic curve for northwest Europe according to Mörner (1980).

2. A recent step back in the debate

In a recent paper, Lambeck et al. (2014) claim – with respect to the Holocene to present sea level changes – *"a progressive decrease in the rate of rise from 8.2 ka to ~2.5 ka BP, after which ocean volumes remained nearly constant until the renewed sea-level rise at 100–150 y ago, with no evidence of oscillations exceeding 15– 20 cm in time intervals ≥200 y from 6 to 0.15 ka BP"*.

This is a grave insult to painstaking sea level research and observational facts presented by numerous sea level specialists from sites all over the world (Mörner, 2014a).

3. Back to observational facts

Oscillations in sea level are very well recorded throughout the hole of the Holocene (Fig. 1). Below follows a few examples (which I happen to know well).

(1) In the Maldives, there were 7 sea level oscillations in the last 5000 years, as illustrated in Fig. 2 (from Mörner, 2007).

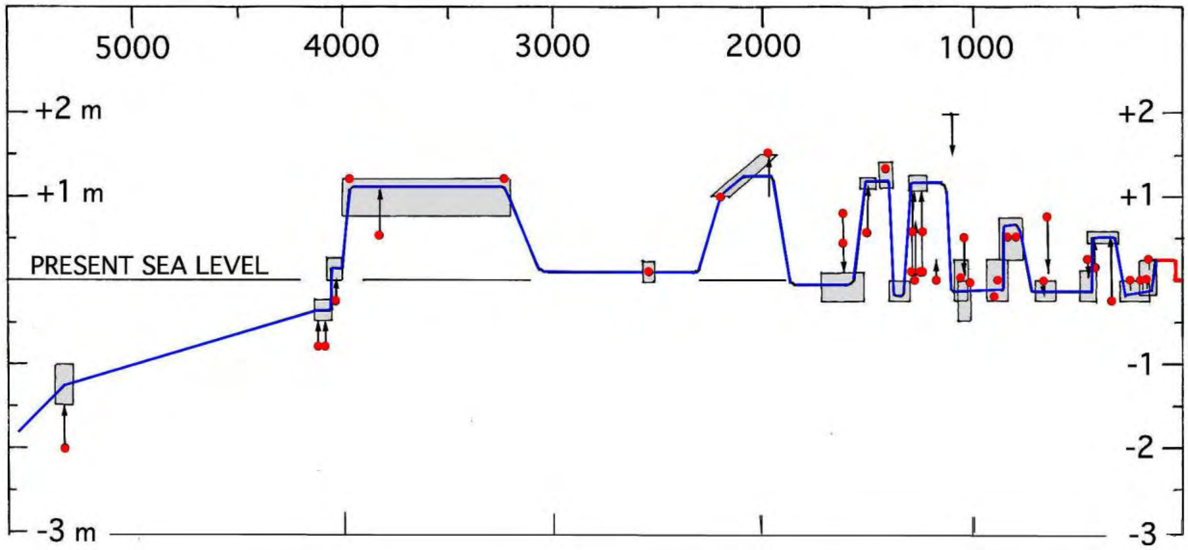

Fig. 2. The Late Holocene sea level changes in the Maldives (Mörner, 2007)including 7 transgression peaks in the last 4000 years with 3 peaks in the last millennium.

(2) In Connecticut, there were 3 sea level oscillations in the last 1500 years (van de Plassche, 2000) as illustrated in Fig. 3a.

(3) In the SW Sweden – Kattegatt Sea region there were 16 oscillations in the last 10,000 years (Mörner, 1971, 1980) with 4 oscillations in the last 3000 year (Fig. 3b).

(4) In the Kattegatt and the Baltic, sea level oscillations are recorded in response to the Medieval Warm Optimum and the subsequent Little Ice Ages (Åse, 1970; Mörner, 1980, 1999; Ambrosiani, 1984; Hansen et al., 2012).

(5) The world is full of other records indicating the presence of Late Holocene sea level oscillations (e.g. Pirazzoli, 1991).

These examples provide a quite solid platform for a statement that sea level oscillations are, indeed, a characteristic for sea level changes on a local as well as on a regional to global basis. What detailed field observations indicate cannot be cancelled by model outputs.

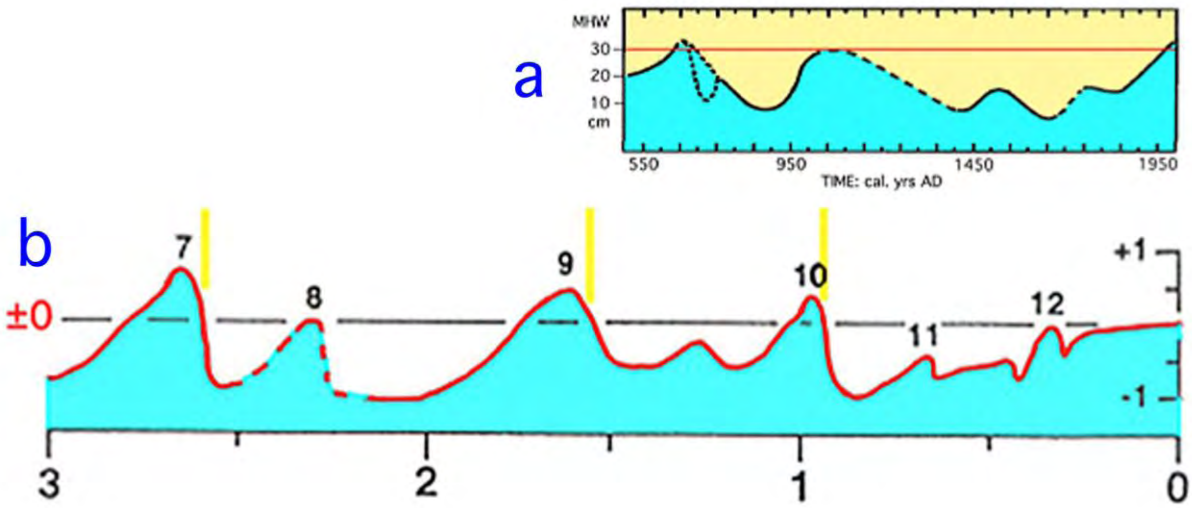

Fig. 3. Late Holocene sea level fluctuation:*(a) from Connecticut* by van de Plassche (2000) with removal of 1.0 mm/yr subsidence.Note that the AD 1000 peak was larger and faster than today's rise.*(b) from Stockholm*, Sweden, by Mörner (1980, 1999) with removal of 4.9 mm/yr uplift.Note the rates and peaks of previous eustatic peaks.Both curves show ups and downs (as usual) and nothing unique at present.It is a grave insult to claim that there is an absence of oscillations prior to 1800.What detailed field observations indicate cannot be cancelled by model outputs.

IV. THE PRESENT

The understanding of present sea level changes in founded in the reconstruction of past sea level records as observed in the field. Estimations of future sea level changes have to grew out of sophisticated analyses of past and present sea level changes (Mörner, 2004). Models may guide, but can never be elevated to substitute actual observations.

In Fig. 3, we can see that the present sea level changes, by no means, are exceptional to the past. The records invalidate not only the claim by Lambeck et al. (2014) but also the basic claim by the IPCC (2007).

1. Illusive hockey sticks

There are two ways of obtaining an illusive view of "a hockey stick rise in sea level".

One way is by combining sedimentary proxy data with tide gauge records; *i.e.* the combination of two methods that have totally different correction factors and hence is a *no-no* in physics. Such studies should not even be accepted in seriously peer-reviewed literature. Still, this way of establishing trends has become increasingly more common, not least for the American East Coast (*e.g.* Kemp et al., 2009; Engelhart et al., 2011; Ezer and Atkinson, 2014). Furthermore, it completely contradicts the Connecticut curve by van de Plassche (Fig. 3a), which must be held as the very best curve established in Eastern USA.

The other way is not to adjust for the un-compacted upper parts of sedimentary records (as discussed by Mörner, 2010, Fig. 7). Not dealing with this factor will immediately lead to an illusive acceleration towards the top. Whilst this is a well-known factor in geology, it is hardly known in biology, from where many scientist working with the fossil records of sediment cores originates.

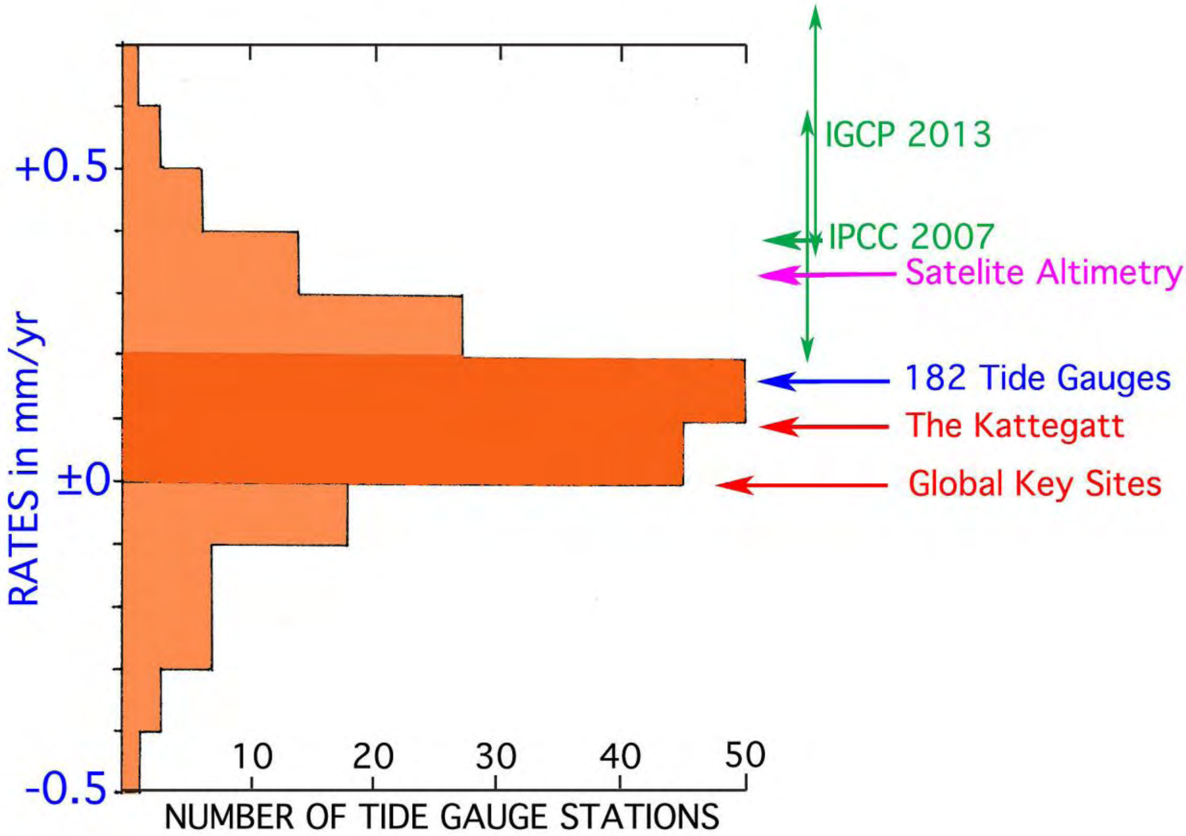

Fig. 4. Spectrum of sea level rate estimates (from Mörner, 2013, 2014b, 2014c): observations at global key sites (±0.0), the Kattegatt (+0.9), mean of 182 global tide gauges (+1.6), satellite altimetry (+3.2) and IPCC model estimates. The big differences indicate errors and mistakes.

2. Subjective "corrections"

Fig. 4 gives the spectrum of relative sea level changes in 182 tide gauge stations scattered all over the globe. The mean is at +1.6 mm/year, implying that the absolute sea level value must be even lower or in the zone of ±0.0 to +1.0 mm/yr (Mörner, 2014b, 2014c).

The absolute sea level changes can be pinpointed in the Kattegatt Sea at +0.9 mm/yr (Mörner, 2014b) and in the North Sea at +1.1 mm/yr (Mörner, 2014c). These values are very important because the absolute crustal component (uplift in the Kattegatt and subsidence in the North Sea) is very firmly known. Advocating higher rates of eustatic sea level rise would violate the very well-established crustal components (*e.g.* 4.9 mm/yr uplift in Stockholm, +2.3 mm/yr uplift in Gothenburg, +0.3 mm/yr uplift in Malmö, ±0.0 stability in 8000 years at Korsör, -1.6 mm/yr subsidence at Cuxhaven, and -0.4 mm subsidence in Amsterdam; Mörner. 2014c).

At many global key sites in the Indian Ocean, the Pacific, Guyana and Venice (Mörner, 2014c) provide stable sea level conditions; i.e. ±0.0 mm/yr (summarized in Mörner, 2014c).

The satellite altimetry value of +3.2 mm/yrfalls far above the above-mentioned values. This indicates that something must be wrong. It is absolutely clear what is wrong with the satellite altimetry value: it is established after significant "calibration" of a strongly biased and subjective nature (Mörner, 2004, 2013a) and must hence be discarded as a true measure of sea level changes (Mörner, 2014c).

V. ACKNOWLEDGEMENTS

The present paper represents a summing up of intensive sea level research during a period of about 50 years and including some 200 peer-reviewed papers in sea level changes and related problems. I was president of the INQUA Commission on "Sea level changes and coastal evolution" 1999-2003, organizer of the Maldives Sea Level Research project 2000-2007, and co-ordinator of the INTAS project on "Climate and Magnetism" 1997-2003. Most of the work was performed when I was head of Paleogeophysics & Geodynamics at Stockholm University in 1991-2005.

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