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Estimating future sea level changes from past records

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Abstract

In the last 5000 years, global mean sea level has been dominated by the redistribution of water masses over the globe. In the last 300 years, sea level has been oscillation close to the present with peak rates in the period 1890–1930. Between 1930 and 1950, sea fell. The late 20th century lack any sign of acceleration. Satellite altimetry indicates virtually no changes in the last decade. Therefore, observationally based predictions of future sea level in the year 2100 will give a value of $+10 \pm 10$ cm (or $+5 \pm 15$ cm), by this discarding model outputs by IPCC as well as global loading models. This implies that there is no fear of any massive future flooding as claimed in most global warming scenarios.

Keywords: Sea level changes; Past records; Future predictions; Models versus observations

1. Introduction

The recording and understanding of past changes in sea level, and its relation to other changes (climate, glacial volume, gravity potential variations, rotational changes, ocean current variability, evaporation/precipitation changes, etc.) is the key to a sound estimation of future changes in sea level.

In previous papers, I have discussed the separation of the eustatic and isostatic factors in paleo-shoreline data (Mörner, 1969, 1971a, 1979), the eustatic factor (Mörner 1971b, 1986), geoid changes (Mörner, 1976), the effects of changes in Earth's rate of rotation (Mörner, 1988, 1995a, 1996a), the multiple interaction of parameters (Mörner, 1987, 1996b, 2000a,b) and the rates and amplitudes of different variables (Mörner, 1996b,c, 2000a). All this material (together with the rich literature by other researchers; e.g. Jelgersma, 1961; Tooley, 1974; Shennan, 1987; Newman et al., 1980; Pirazzoli, 1991; Grossman et al., 1998) form the base for the present paper where I try to apply all this observational material and theoretical consideration for a sound estimation of the sea level changes to be expected in the near future.

2. The Late Holocene

Prior to 5000–6000 BP, all sea level curves are dominated by a general rise in sea level in true glacial eustatic response to the melting of continental ice caps. The general rise in sea level from ~20,000 to ~5000 BP implied a corresponding increase in the radius of the Earth. This radial increase (by basic laws in physics) must be compensated by a general deceleration. In the last 30,000 years, Earth passed through three main eustatic-rotational modes (Table 1).

After 5000–6000 BP, the Earth came into another mode (Mörner, 1996b, Fig. 2). The glacial eustatic rise

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Table 1
Relations among sea level changes and Earth's rate of rotation implying that the Earth has passed through three main modes in the last 30,000 years, the last 5000 years being characterised by an irregular redistribution of the water masses over the globe and the interchange of angular momentum between the solid Earth and the hydrosphere (and the atmosphere and core, too) as further discussed elsewhere (Mörner, 1995a, 1996a,b)

Main modes	I	II	III
Sea level	Fall	Rise	Redistribution of water masses
Rotation	Acceleration	Deceleration	Interchange of angular momentum
Time in BP	30,000–20,000	20,000–5000	From 5000–6000 BP onwards

had ended because there were no more ice to melt and, consequently, the rotational deceleration ended, too. The sea level records are now dominated by the irregular redistribution of water masses over the globe. This redistribution of water masses is primarily driven by variations in ocean current intensity (ocean circulation) and in the atmospheric circulation system (monsoonal regime, evaporation/precipitation, etc.) and maybe even in some deformation of the gravitational potential surface.

The irregular changes in sea level set the character of sea level changes in the Late Holocene. On a global scale, they seem rather to be of a compensational nature, lacking signs of any general trend.

These sea level changes have set the character of the changes in sea level in the last century as well as in the last decades and years. Therefore, they are also assumed to come to set the dominant character in the near-future.

3. The near-past and present

When we go from Late Holocene sea level records to last centuries' records, we also change predominant

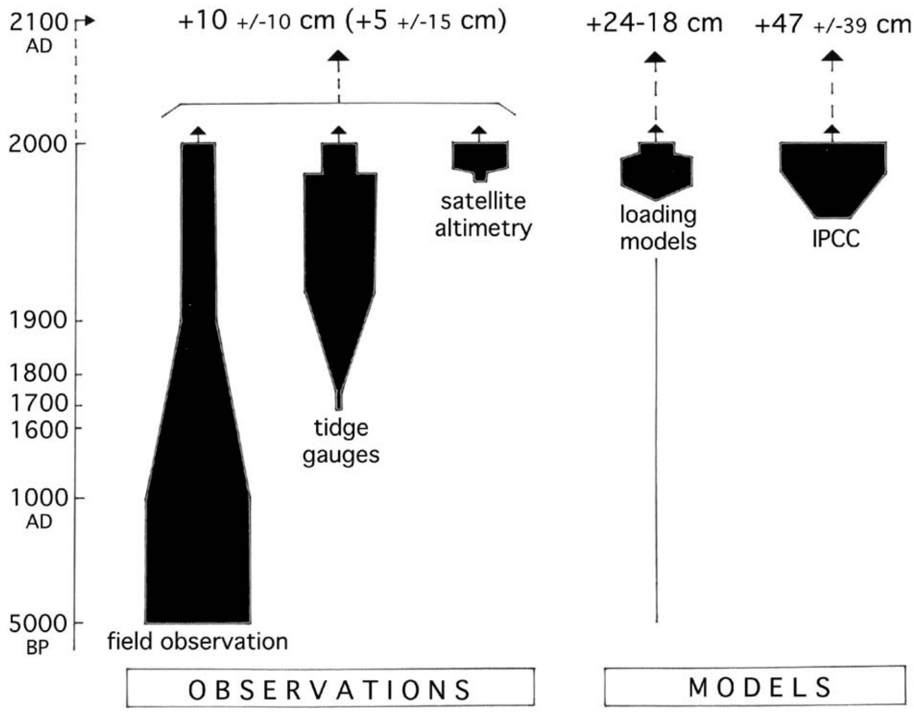

Fig. 1. Means and techniques of recording or estimating sea level changes and make predictions for the next century (AD 2100). Multiple field observations (i.e. classical sea level research), tide gauges and satellite altimetry are all based on true observational data. They give a uniform prospect for the future. The model-based outputs form the loading models and the scenario-based outputs of IPCC give higher to much higher predictions values (cf. Fig. 4). The observational-based value of + 10 ± 10 cm (+ 5 ± 15 cm) for year 2100 is strongly advocated as more realistic than the model outputs.

Table 2
Recent, present and possible future changes in sea level as recorded or calculated from different observational records

Time period	Rates (mm/yr)	Source of information	Reference
1682–1940	1.1	mean of tide gauges	1
1860–1960	1.2	mean of tide gauges	2
1830–1930	1.1	NW Europe tide gauge data	3
1830–1930	1.1	past uplift vs. present uplift and eustasy	3
1830–1930	max. 1.1	Earth's rotation vs. tide gauge	4
Last 100 years	1.0	UK–North Sea tide gauges	5
Last 100 years	1.1	Fennoscandian tide gauges	6
1910–1990	0.9	estimates of all water sources	7
1992–1996	0.0	Satellite altimetry	8
1997–1998	ENSO	Satellite altimetry	8
1999–2000	< 0.5	Satellite altimetry	8

References: (1) Gutenberg (1941), (2) Fairbridge and Krebs (1962), (3) Mörner (1973), (4) Mörner (1992), (5) Shennan and Woodworth (1992), (6) Lambeck et al. (1998), (7) IPCC (2001) (TAR-3), (8) Fig. 2.

technique and date base. We change from stratigraphic proxy data (based on geology, stratigraphy, morphology, archaeology, biology, ecology and radiocarbon dating) to instrumental records from water-marks, tide gauges and mareographs and, in the last decade, to satellite altimetry (Fig. 1).

From the geophysical loading models, Peltier and Tushinghan (1989) arrived at a present mean global rise in sea level of 2.4 mm/year (this value was adopted by IGBP, 1992; later revised at 1.8 mm/year, IPCC, 2001). This rate—if realistic—would imply a total reversal of old observational records. So, for example, would the North Sea region and the Dutch coasts, known for their long-term subsidence, be going up at a rate of about 1.2 mm/year. This was unrealistic. To test the case, Mörner (1992) used the recorded rate in rotation and showed that any global rise component, if real, can, at the most, amount to 1.1 mm/year. This value fits very well with a number of observational records as illustrated in Table 2.

We therefore conclude that the mean eustatic rise in sea level for the period 1850–1930 was in the order of 1.0–1.1 mm/year.

After 1930–1940, this rise seems to have stopped (Pirazzoli et al., 1989; Mörner, 1973, 2000b). This lasted, at least, up to the mid-60s.

During the 1970s and 1980s, our data are not really clear enough for a proper evaluation of any general trend in sea level. The first satellite altimetry recording (Geosat) ranges over 1986–1988. There is hardly any trend to be recognised. At the same time, the technical precision was not good enough.

With the TOPEX/POSEIDON mission, the situation changed. We now have a very good cover of the global mean sea level changes over the areas covered by the satellite. The record (Fig. 2) can be

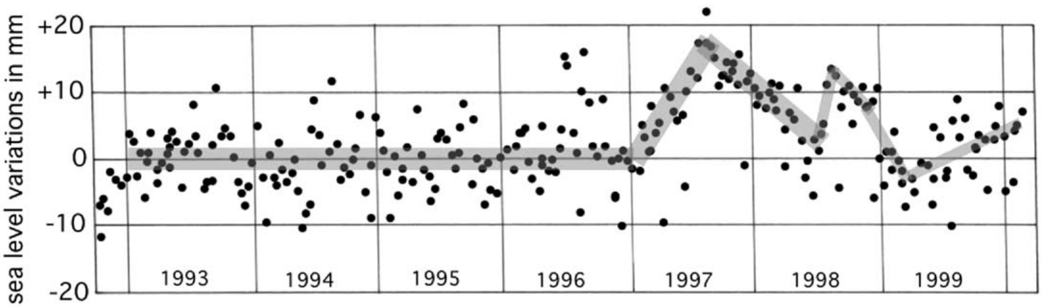

Fig. 2. Sea level changes in mm as recorded by TOPEX/POSEIDON between October 1992 and April 2000: raw data before any filtering or sliding mean average. The variability is high, in the order of ± 5–10 mm. From 1993 to 1996, no trend is recorded, just a noisy record around zero. In 1997, something happens. High-amplitude oscillations are recorded; a rapid rise in early 1997 at a rate in the order of 2.5 mm/year, followed by a rapid fall in late 1997 and early 1998 at a rate in the order of 1.5 mm/year, and finally, in late 1998 and 1999, a noisy record with unclear trends. The new factor introduced in 1997 and responsible for the high-amplitude oscillations, no doubt, is the global ENSO event, implying rapid redistribution of oceanic water masses (characteristic for mode III in Table 1). This means that this data set does not record any general trend (rising or falling) in sea level, just variability around zero plus the temporary ENSO perturbations.

divided into three parts: (1) 1993–1996 with a clear trend of total stability (and a noise of ± 0.5 cm), (2) 1997–1998 with a high-amplitude rise and fall recording the ENSO event of these years and (3) 1998–2000 with an irregular record of no clear tendency (but possibly with a small rise of < 0.5 cm/year in years 1999–2000). But most important, there is a total absence of any recent "acceleration in sea level rise" as often claimed by IPCC and related groups.

IPCC (2001) made an estimate of all variables and their possible contribution to sea level rise. They arrived at a mean value of 0.9 mm/year. This value is in harmony with the records of the present and near-past given in Table 2.

Still—and this is remarkable —IPCC compared their own value with a model value of 1.8 mm/year (cf. above), which they termed "observed", and discarded their own estimate as unrealistic. The mean value 0.9 mm/year is close to the truly observed value of 1.0–1.1 mm/year for 1850–1930 and, consequently, quite reasonable.

Fig. 3 gives a summary of available data for the last 300 years, the 0.9 mm/year volume-estimate by IPCC (though discarded as unrealistic), the long-term trends as given by the geophysical models of Peltier and Lambeck (2.4 and 1.8 mm/year), and, to the right, the future estimated by the INQUA Commission on Sea Level Changes and Coastal Evolution (INQUA, 2000) and the scenario output values of IPCC (2001).

4. Models versus observation

Fig. 4 illustrates the three different ways of handling sea level data and predictions of the future. The way of INQUA (Commission on Sea Level changes and Coastal Evolution) and IGCP (their sea level projects) is to consider all available data, make quality estimates, and regional and global syntheses. The output of this analysis is a possible future sea level rise in the order of 10 cm, or maximum 20 cm, in the next century (Mörner, 1995b, 1996b; INQUA, 2001).

The global loading models (by Peltier, Lambeck and others) make a highly personal selection of input data (rather from model-fit, than from data quality). The output is a present-to-future rise of 24–18 cm in a century.

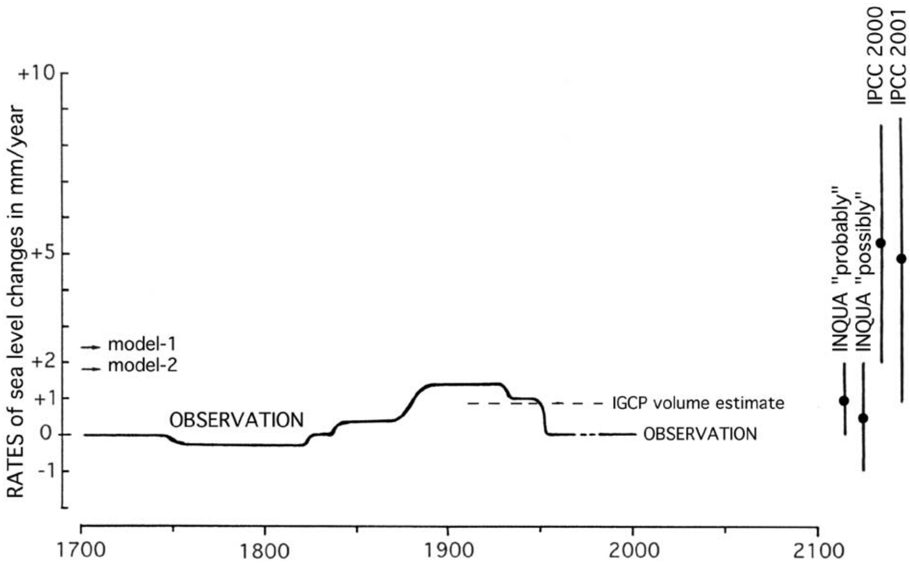

Fig. 3. Rates of sea level changes from 1700 to 2100 AD as given by (1) observed records (solid line), (2) volume estimates by IPCC (dashed line) and (3) predictions (vertical bars) by INQUA and IPCC, respectively. Arrows to the right refer to loading model outputs.

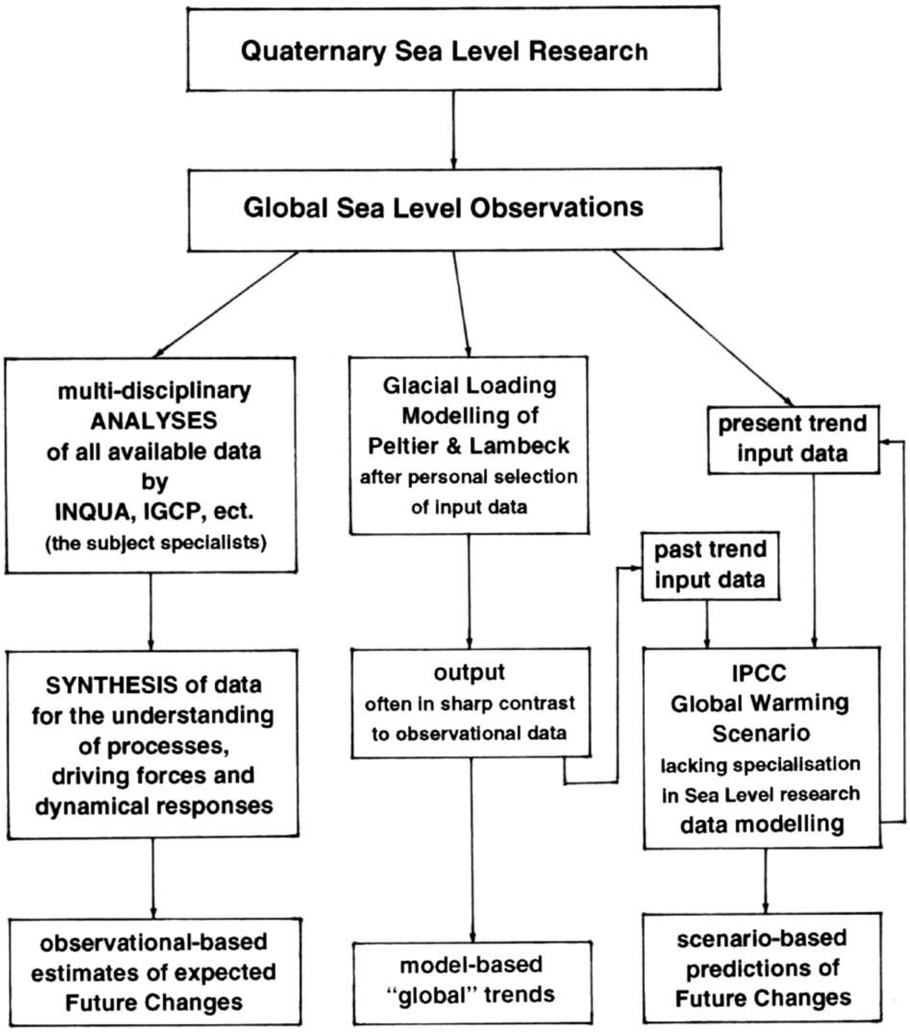

Fig. 4. The three different ways of handling sea level data: (1) that of INQUA and IGCP leading to observational-based predictions, (2) that of the glacial loading models leading to model-based predictions and (3) that of IPCC leading to scenario-based predictions. The predictions values for year 2100 are given in Fig. 1.

IPCC uses loading-model values, some present-day records and recycled model-output data as input-data and arrives at a number of scenarios with a mean sea level rise in the order of 47 ± 39 cm (i.e. 8–86 cm) in a century (with higher values in previous estimates by IPCC). From this value, IPCC launched their hypothesis of a disastrous flooding of coastal low-lands and low islands (like the Maldives) in the next century (e.g. Hoffman et al., 1983).

When we (the INQUA Commision on Sea Level Changes and Coastal Evolution) consider past records, recorded variability, causational processes involved and the last centuries' data (Figs. 1, 2 and 4), our best estimate of possible future sea level changes is + 10 ± 10 cm in a century or, maybe, even + 5 ± 15 cm.

Therefore, we have to discard the model output of IPCC (2001) as untenable, not to say impossible (Mörner, 1995b; INQUA, 2000), and we cite the Gilgamesh Epos from about 5000 BP saying: *Lay upon the sinner his sin. Lay upon the transgressioner his transgression*.

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