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During Sea-Level Highstands:
A Global Synthesis with implications
for management of future coastal change

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Sea Level Changes in the Past, at Present and in the Near-Future Global Aspects Observations versus Modells

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Abstract

Sea level rose for glacial eustatic reasons up to about 5000 BP. After that, global sea level has been dominated by the redistribution of ocean water masses (and by that ocean-stored heat). This redistribution of water masses is driven by the interchange of angular momentum between the solid earth and the hydrosphere (in feedback coupling) primarily expressed as changes in the oceanic surface current systems. In view of this, it is very hard to define a true global eustatic signal. This is where and why a dialectic between models and observations enter the sea level debate. According to the glacial loading models, global sea level is now rising by 2.4 mm/year or 1.8 mm/year. The IPCC models have hypothesised of a very rapid rise in the near future, ranging for original wild estimates of 1-3 m in a century to the presently advocated value of 47±37 mm in a century.

The INQUA Commission on Sea Level Changes and Coastal Evolution (www.pog.su.se/sea) hosts the true world specialists on sea level research. This commission has presented an observationally based analysis of the present sea level changes and the changes to be expected in the next century. Both the glacial loading models and the ICPP scenarios are strongly contradicted by observational data for the last 100-150 years that cannot have exceeded a mean rate of 1.0-1.1 mm/year. In the last 300 years, sea level has been oscillation close to the present with peak rates in the period 1890-1930. Sea level fell between 1930 and 1950. The late 20th century lacks 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 ±10 cm or, rather, +5 ±15 cm, by this discarding model out-puts by IPCC as well as global loading models. The INQUA Maldives research project has revealed that there, on a regional scale, are absolutely no signs what so ever on any on-going flooding of the Maldives. On the contrary, a distinct sea level fall is recorded at around 1970.

In conclusions, there are firm observationally based reasons to free the world from the condemnation to become extensively flooded in the 21st century AD.

The Holocene

The multiple interaction of different sea level variables are discussed elsewhere (Mörner, 1996, 2000a, 2000b).

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. After 5000-6000 BP, the Earth came into another mode (Mörner, 1996, Fig. 2).

The glacial eustatic rise had ended because there was 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 the Late Holocene. On a global scale, they seem rather to be of a compensational nature, lacking signs of any general trend.

The Last Centuries and the Present

When we go from Late Holocene sea level records to last centuries' records, we also change predominant 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 (Mörner, 2003). From the geophysical loading models, Peltier and Tushinghan (1989) arrived at a present mean global rise in sea level of 2.4 mm per year (this value was adopted by IGBP, 1992; later revised at 1.8 mm per 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 per 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 per year. This value fits very well with a number of observational

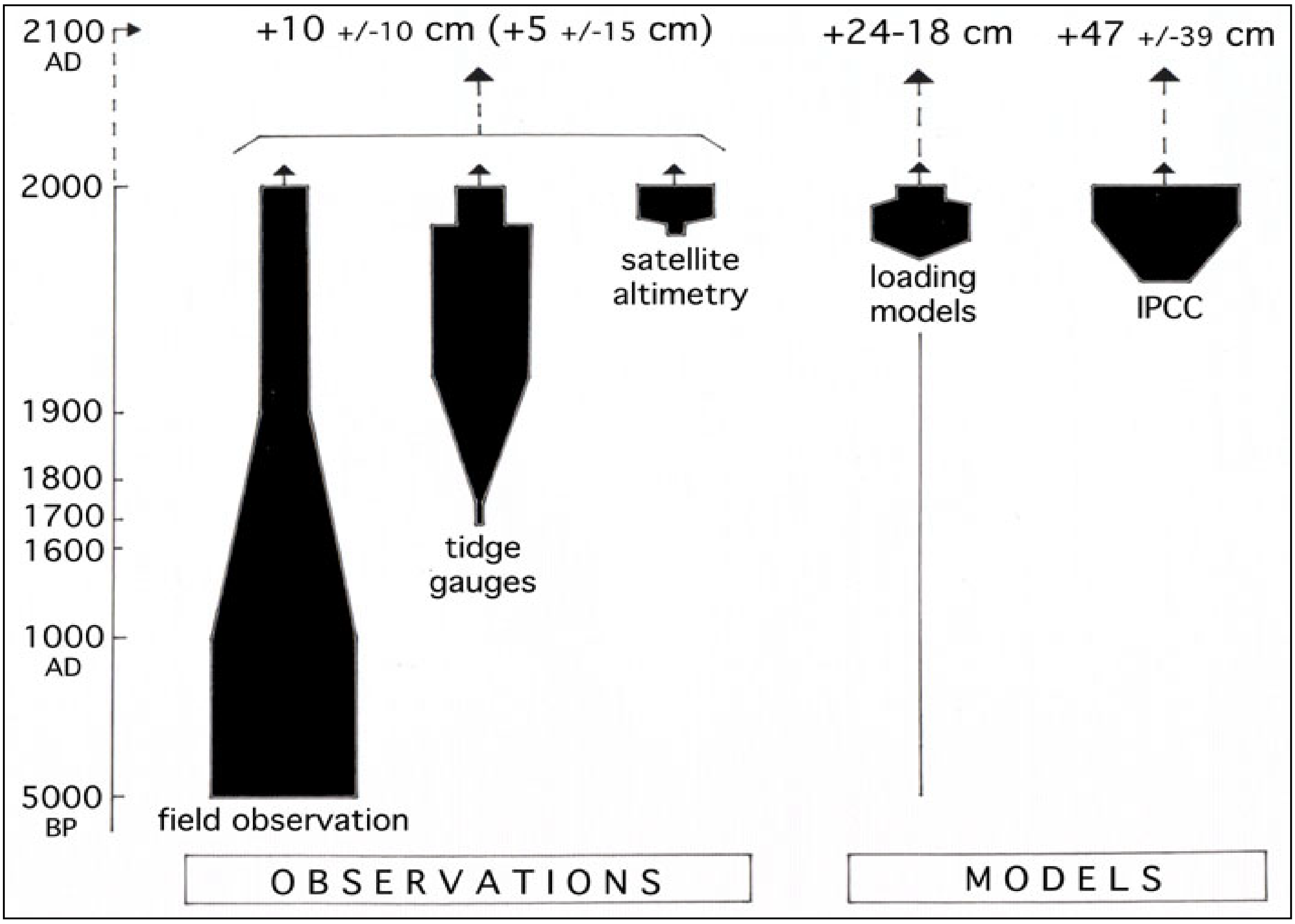

Figure 1. Means and techniques of recording or estimating sea level changes, and make predictions for the next century (AD 2100). Multiple field observations (i.e. classical sea level research), tide gauges and satellite altimetry are all based on true observational data. They give a uniform prospect for the future. The model-based out-puts form the loading models and the scenario-based out-puts 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 out-puts.

records. 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 per 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 60:ies. During the 1970:ies and 1980:ies, 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 1) can be 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 per year in years 1999-2000).

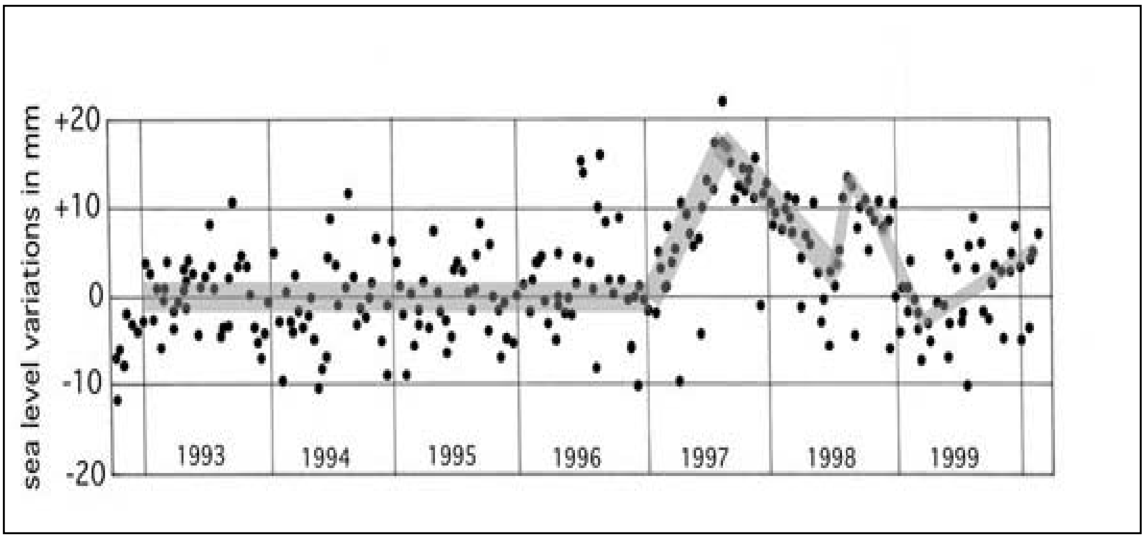

Figure 2. Sea level changes in mm as recorded by TOPEX/POSEIDON between October 1992 and April 2000. The variability is high, in the order of ±5-10 mm. From 1993 to 1996, no trend is recorded, just a noisy record around zero. In 1997 something happens. High-amplitude oscillations are recorded; a rapid rise in early 1997 at a rate in the order of 2.5 mm/yr, followed by a rapid fall in late 1997 and early 1998 at a rate in the order of 1.5 mm/yr, 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. 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.

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 per year. This value is in harmony with the records of the present and near-past (Mörner, 1996; 2000b). Still – and this is remarkable – IPCC compared their own value with a model value of 1.8 mm per year (cf. above), which they termed "observed", and discarded their own estimate as unrealistic.

The mean value 0.9 mm per year is close to the truly observed value of 1.0–1.1 mm per 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 per 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).

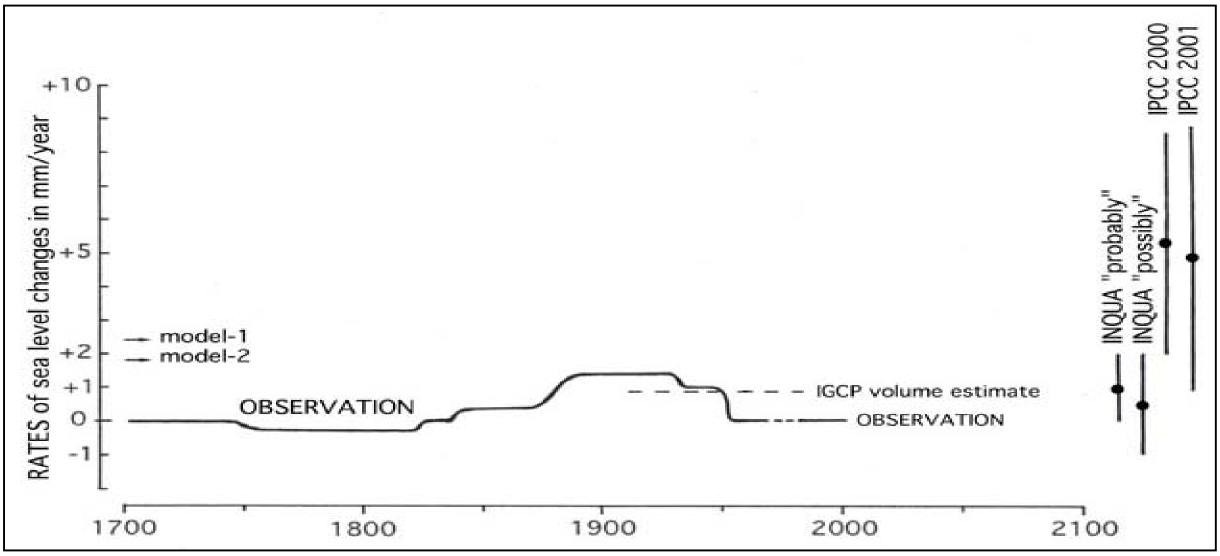

Figure 3. Rates of sea level changes from 1700 to 2100 AD as given by (1) observed records (solid line), (2) volume estimates by IPCC (dashed line) and (3) predictions (vertical bars) by INQUA and IPCC, respectively. Arrows to the right refer to loading model outputs.

The Maldives Project of the INQUA Commission on Sea Level Changes and Coastal Evolution has presented strong observational records indicating that there is no on-going sea level rise and that the flooding scenario of IPCC fails when tested in the field.

The Future: observations versus models

There are the three different ways of handling sea level data and predictions of the future (Fig. 4). 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, 1995; 1996; 2002; 2003; INQUA, 2000).

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 to 18 cm in a century. IPCC uses loading-model values, some present-day records and re-cycled model-output data as input-data, and arrives at a number of scenarios with a mean sea level rise in the order of 47 cm $\pm$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).

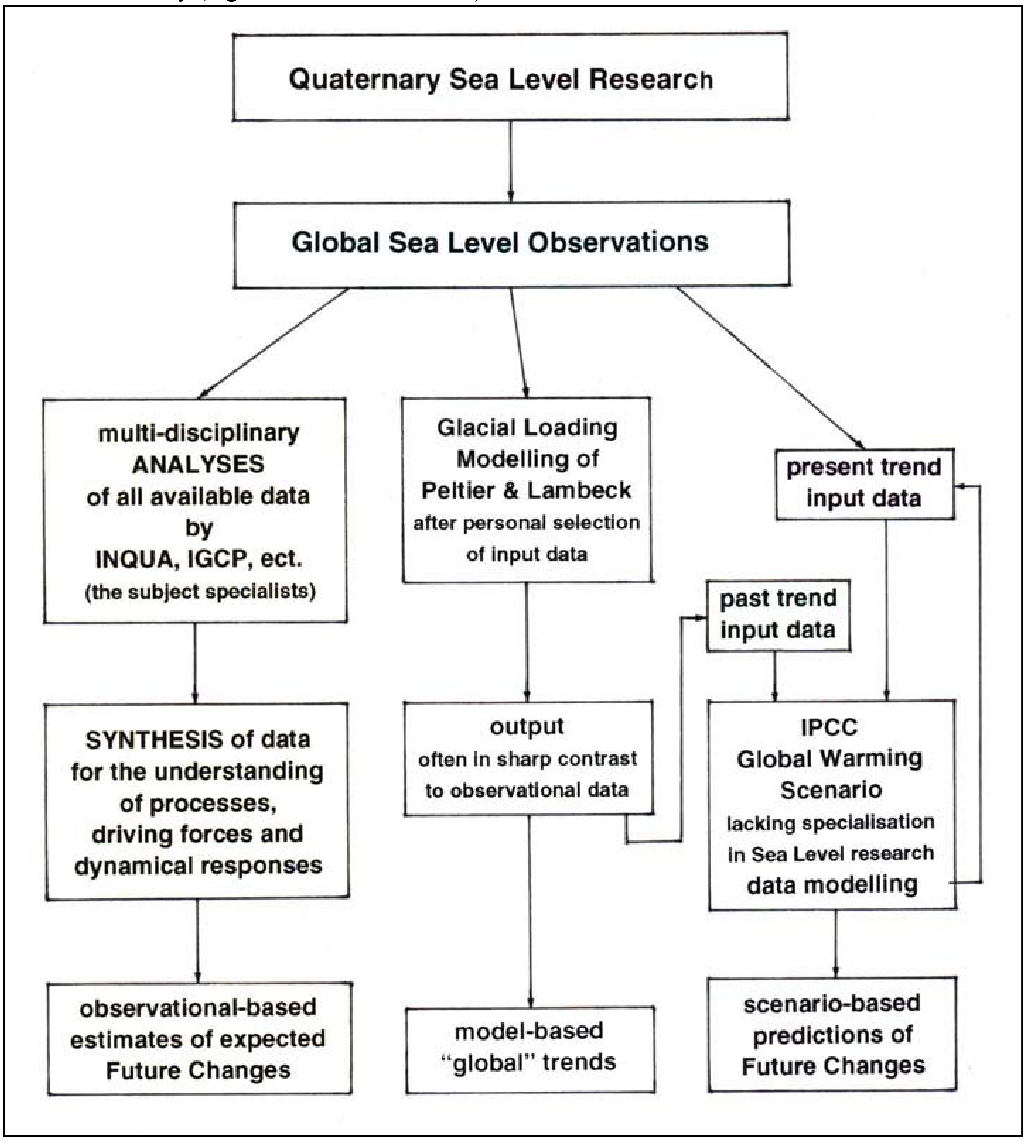

Figure 4. The three different way of handling sea level data; (1) that of INQUA and IGCP leading to observational-based predictions, (2) that of the glacial loading models leading to model-based predictions, and (3) that of IPCC leading to scenario-based predictions. The predictions values for year 2100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

In the Maldives Project of the INQUA Commission on Sea Level Changes and Coastal Evolution, we have tested the flooding scenario in the field and found solid observational data contradicting an on-going sea level rise in this area (Mörner et al., 2003).

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 1–3), our best estimate of possible future sea level changes is +10 $\pm$10 cm in a century or, maybe, even better: +5 $\pm$15 cm.Therefore, we have to discard the model out-put of IPCC (2001) as untenable, not to say impossible (Mörner, 1995; 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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