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Present-to-future sea level changes: The Australian case

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ABSTRACT

We revisit available tide gauge data along the coasts of Australia, and we are able to demonstrate that the rate may vary between 0.1 and 1.5 mm/year, and that there is an absence of acceleration over the last decades. With a database of 16 stations covering only the last 17 years, the National Tidal Centre claims that sea level is rising at a rate of 5.4 mm/year. We here analyse partly longer-term records from the same 16 sites as those used by the Australian Baseline Sea Level Monitoring Project (ABSLMP) and partly 70 other sites; i.e. a database of 86 stations covering a much longer time period. This database gives a mean trend in the order of 1.5 mm/year. Therefore, we challenge both the rate of sea level rise presented by the National Tidal Centre in Australia and the general claim of acceleration over the last decades.

KEYWORDS

Sea level rise;
Australian tide gauges;
Present trends;
Future predictions;
No disastrous flooding.

INTRODUCTION

In their report published in 2007, the Intergovernmental Panel on Climate Change[1] concluded that sea level (SL) is likely to rise between 18 and 59 cm or 38.5 ±20.5 cm by year 2100. Though this is a significant lowering from previous estimates by IPCC, viz. 62.5 ±47.5 cm in 1990, 53.5 ±40.5 cm in 1995, 48.5 ±39.5 cm in 2001 and 38.5 cm ±20.5 cm in 2007, it has still been widely cited as a major threat to human habitation on low-lying coasts and islands.

The Australian Federal Government's Climate Commission[3] recently claimed that global warming could cause global sea level to rise even up to more than 1 metre by 2100. Furthermore, they stated that the primary cause of global warming almost surely was due to anthropogenic activity. In their sea level prediction, the commission[3] also included predictions by Rahmstorf[34] and proposed reconstructions of global mean sea level by Church and White[11]. They conclude the sea level has changed by about 3.25 cm over the period 1970-1990 and by about 5.4 mm/year over the period 1990–2010, indicating a significantly accelerating in the rate of sea level rise over the last two decades.

In this paper, we will try to demonstrate that neither the mean rates given nor the proposed sea level acceleration can be substantiated by observational facts. We also want to stress that a proper evaluation of available data on present sea level change is vital as the outcome forms the basis for a number of important socio-economic decisions.

THE USE OF TIDE GAUGE RECORDS

Tide gauges are far from ideal to monitor sea level changes. They may be affected by regional uplift as well as by subsidence, and, not least, by site-specific instability[23,25]. Very often, however, tide gauges are our only means of assessing the sea level changes of an area. So, for example, do available tide gauges at Tuvalu, Kiribati and the Marshal Island in the West Pacific provide sea level records that lack any rising trend[19,25,29].

Morphological and stratigraphical data may often provide more conclusive additional information on the actual sea level stability. This is, for example, the case with the Maldives[24,28], Bangladesh[26] and Goa in India[29,31]. Old watermarks may give useful long-term benches; e.g. the bench on Isle of the Dead, Tasmania from 1841[15] and the sea level measure at Saint-Paul Island from 1874[37].

A tide gauge record must be analysed with care and skill. Linear trends are usually quite misleading, and ignore actual dynamics. A tide gauge record includes cyclic variations, occasional spikes and signals, and individual decadal fragments. The 18.6 tidal cycle is fundamental[5] and should always be considered. There is a very good documentation of this cycle from Surinam and French Guiana[18], exhibiting cyclic ups and downs around a stable zero level[25]. The 60-year cycle, evident in solar forcing and a number of marine records[35], like in the Pacific Decadal Oscillation (PDO), is another cycle that has to be considered[10]. The ENSO signal sets up quite drastic ups and downs in many Pacific tidal records. They should be considered as spikes, and removed from longer-term trend analyses[25].

An educational tidal record comes from Mumbai/Bombay[26,31] and show a sequence composed of 4 parts; a 32 year stability 1878-1910, a 48 year rise 1910-1958, a 4 year fall 1958-1962 and a 50 year stability from 1962 up to today. The four periods must, of course, be treated separately, and a mean trend through them is directly misleading[38].

In recent years it has become popular to ignore the dynamics of a tide gauge record and only look for trends by fitting linear or polynomial lines to the record. This specifically applies in the searching for regional or global trends. In those cases, a new basic factor becomes the selection of records considered[27], often after personal classification in uplifting, subsiding and stable stations. The Permanent Service of Mean Sea Level[32] has a database of more than 2000 stations. The National Oceanic and Atmospheric Administration[33] in Colorado has a database of 159 selected tide gauges. The rates of those 159 records give a spectrum with a sinusoidal distribution from uplifted to subsided stations and with a transitional sequence of 68 stations of semi-stable conditions ranging between ±0.0 and +2.0 mm/year[27,31]; i.e. well below the estimate of IPCC[1] but close to the value of INQUA[22,23]. Out of this highly variable spectrum, Douglas[16] selected 25 records and arrived at a mean sea level rise of 1.8 mm/year, Church et al.[11] selected 6 records and arrived at a value of 1.4 mm/year, and Holgate[20] selected 9 records and arrived at 1.45 mm/year. This way of personal selection is very subjective. The stations selected are few and the method of fitting linear regression lines has been addressed above. Despite fairly similar results, the methodological means of assessing global sea level changes must be strongly questioned[27]. Today, the NOAA database is increased to 204 stations with a mean value of 0.75 mm/year sea level rise[31].

There are many different values proposed ranging from the very high values of 5.4 mm/year[2] and 3.25 mm/year[11], via values around 1.5 mm/year[8,11,16,20,40,46], to ±0.0 to max 0.7 mm/year of Mörner[27,31]. In many cases the authors do not live up the requirement of minimum of 50 years of recording[17].

As to the acceleration proposed for the last decades, the evaluations differ significantly from very strongly increased rates[12] to an absence of acceleration[6,27,39].

The least we can say is that the situation is far from conclusive and straightforward.

Method

We fit linear and 2nd order polynomial lines to the sea level data recorded along the coasts of Australia in order to assess the accelerating trends and to compare with the reconstruction of Church and White[12]. If Y is the mean sea level (MSL) and X is the year, then clearly the sea level rise is SLR=dY/dX and the sea level acceleration is SLA=d^2Y/dX^2. The linear fitting gives the average SLR over the observation period. The 2nd order polynomial fitting gives the average SLA over the observation period. Finally, we compare our Australian records with global sea level records.

The analyses are made under the assumption that the data proposed by the Permanent Service for Mean Sea Level[32], the Australian Government Bureau of Meteorology Tide Predictions, Metadata and Monthly Sea Level Statistics[4], the Australian Baseline Sea Level Monitoring Project[2] and the CU Sea Level Research Group of University of Colorado[14] are all reliable measurements. We are aware of the fact that this assumption is questionable, and we know that there are errors in the databases and that the satellite data have high potential computational-correctional error[27,31]. Still, this seems to be an appropriate way of tackling the main questions, viz. the average sea level changes around Australia and the presence or absence of a recent acceleration.

The Australian tide gauge records

The sea level changes along the Australian coastline have been measured at many locations starting in the late 1800s. In the early 1990s, the Australian Baseline Sea Level Monitoring Project[2] was designed in order to monitor the sea level changes around Australia and to identify decadal trends with respect to the enhanced greenhouse effect. A sequence of SEAFRAME[36] stations (SEA-Level Fine Resolution Acoustic Measuring Equipment) was installed on 16 South Pacific islands to measure the sea level and to record meteorological parameters (both at stations previously covered by standard tide gauge equipment and stations previously not covered by tide gauges). The vertical stability of the gauges is surveyed by State organizations using GPS.

Besides the16 SEAFRAME stations managed by the ABSLMP, there are 70 additional stations included in the National Tidal Centre (NTC) database[4] making a total of 86 stations. Previously, the National Tide Centre analyzed all tide gauge data from stations having more than 25 years of recording. This survey ended in year 2003, and was replaced by the ABSLMP[2] data set containing the measurements restricted to the 16 ABSLMP stations. Nowadays, NTC neglects all the data previously measured at these stations as well as at other sites, many of which exceed 25, and sometimes 50, years of recording.

The ABSLMP[2] and AFGCC[3] statement of sharply rising sea levels with an average sea level rise of 5.4 mm/year for the period 1990–2010 is, of course, based on far too short period of recording. The short SEAFRAME data are strongly affected by the recovery from the ENSO sea level low in 1998, which was significant at many stations. Besides, this high rate of sea level rise is strongly contradicted by other available records.

In 2009, there were 39 sites on the Australian mainland (Figure 1), where relative sea levels had been measured for at least 25 years and with the average length being 42 years[4]. We have computed the mean sea level rise of all the individual stations by a linear fit to the observational data. The average trend of all the 39 stations is 0.9 ±1.9 mm/year.

The geographical pattern of relative sea level trends around the Australian coastline is fairly uniform (Figure 1). Parts of the Australian coastline are strongly affected by the ENSO events. The longest sea level records show quasi bi-decadal sea-level oscillations.

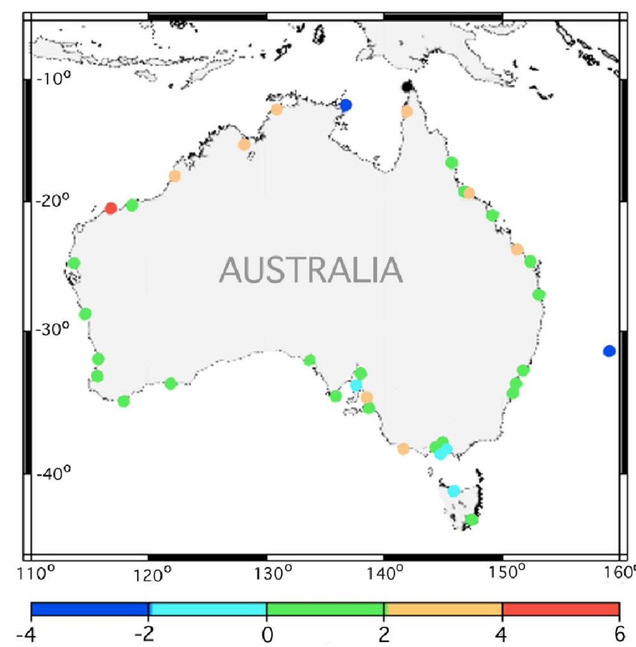

Figure 1 : Distribution of tide gauge station in Australia. Location and average rates of the 39 tide gauge stations in mainland Australia having a period of recording of at least 25 years. The mean rate of all 39 stations is 0.9 mm/year.

Next, we consider all the data available on the NTC database; i.e. the 16 ABSLMP stations and 70 other, non-ABSLMP, stations, making a total of 86 tide gauge stations. Linear and polynomial fittings were applied to the data recorded in all the 86 locations. Separate fittings are applied to the data recorded over the years 1990–2000 and 2000–2010 as well as to the full data set 1990–2010; not to derive a sea level trend but to understand quality and biasing issues of the ABSLMP records. The only conclusion that can be drawn from this analysis is that despite fluctuations, there is no evidence any significant changes in the rate of sea-level change. No fitting produces a sea level rise in excess of 1.5 mm/year. The average sea level rise over the period 1990–2010 is a negligible 0.1 mm/year for the 70 non–ABSLMS stations. Balancing the higher average sea level rise during the same period in the ABSLMP stations, this gives a general average of 1.5 mm/year for all the 86 stations. Therefore, the official statement of the NTC (AFGCC) that Australia is experiencing strong sea level acceleration with a present sea level rise of 5.4 mm/year cannot be validated by observational facts; the 39 mainland stations of Figure 1 giving 0.9 mm/year, the 70 non–ABSLMS stations giving 0.1 mm/year, and all the 86 stations giving 1.5 mm/year (see further below).

The long tide gauge record of Sydney[7] shows negligible sea level acceleration for the 1890–2010 period, and a negative trend (i.e., sea level fall) for the last 20 years.

The tide gauge record from Fremantle (15 km SW of Perth) provides a very informative record (Figure 2). It shows fluctuating over a 113 year time span. This indicates that one cannot obtain meaningful trend values from shorter segments like tha last 10 to 20 years. We provide two different alternative analyses; viz. (1) a long-term mean trend analysis (Figure 2a) and (2) a dynamic analysis (Figure 2b).

The first step was to apply a mean trend over the whole 113 years time series (Figure 2a). The mean trend is 1.5 mm/year; i.e. a value well below the SEAFRAME (2011) database. The 1913-1993 changes may also be looked upon as an 80-year cycle, justifying a mean trend analysis of the relative sea level rise. The shift from 1993 to 1998 is somewhat unclear as it coincides with the major change in instrument operation (above) and includes the big ENSO event in 1998.

A more dynamic approach is to fit mean rates to segments of the total record (Figure 2b). This gives 5 segments; a stability 1897-1913, a rising trend 1913-1956 (by 2.5 mm/year), a slightly downward trend 1956-1993, a rapid rise 1993-1998, and virtually stability 1998-2011. The rise from 1913 to 1956 was the order of 2.5 mm/year. Because there was a general global eustatic rise during this period of about 1.1 mm/year[23,27,31], the Fremantle tide gauge is likely to include a local subsidence factor in the order of 1.4 mm/year (purpel line). Considering this subsidence, there is not much sea level rise left; virtually stable conditions over the last 60 years and full stability over the last 14 years implying no traces of any present-day acceleration.

According to our analyses, Fremantle data set shows a relative sea level rise of 1.5 mm/year (Figure 2a), which corresponds to a mean absolute sea level rise of ±0 mm/year over tha last 14 years (Figure 2b). This is in agreement with a number of high-priority observational facts from others sites scattered over most of the Indian Ocean[27,31].

Confining the rate analysis to the last 10-20 years, as the Australian governmental offices have done[2-4], would have given meaningless rates in the order of 6.0-6.5 mm/year (Figure 2a) in line with the 20-years SEAFRAME mean record of 5.4 mm/year (*op.cit.*). Such values cannot be used for longer-term predictions[30,31]. What they unfortunately do, however, is to feed unfounded fear and misuse of economical and intellectual resources[27].

Comparison with worldwide tide gauge records

There are different ways of making comparisons. The best way is, of course, to prefer quality to quantity. Quality implies careful analyses of the record, the stability of the instrument and the long-term site stability. Quantity implies the utilization of a large number of sites without evaluation of affecting oceanographic and crustal variables, and relying only on a mean value. We are aware of the fact that the search for average rates in large databases may provide values that might be meaningless and even misleading. In this case, however, we investigate two well-known databases of global tide gauge; PSMSL[32] and NOAA[33].

The PSMSL[32] database includes records from 2059 sites scattered all over the globe. There is a strong bias to northern hemisphere records. Still, the large number of worldwide sites might provide an acceptable value of the mean sea level rise. We fit 2nd order polynomial to the PSMSL data for 1890–2010, and linear and 2nd order polynomial to the data for 1990–2010. The cures arrived at are very close and suggest a global mean sea level rise of about 30 mm over the last 20 years; i.e. a rate of 1.5 mm/year. The similarity between the rates for the period 1890-2010 and 1990-2010 seems to provide firm indication of an absence of any recent acceleration in sea level rise.

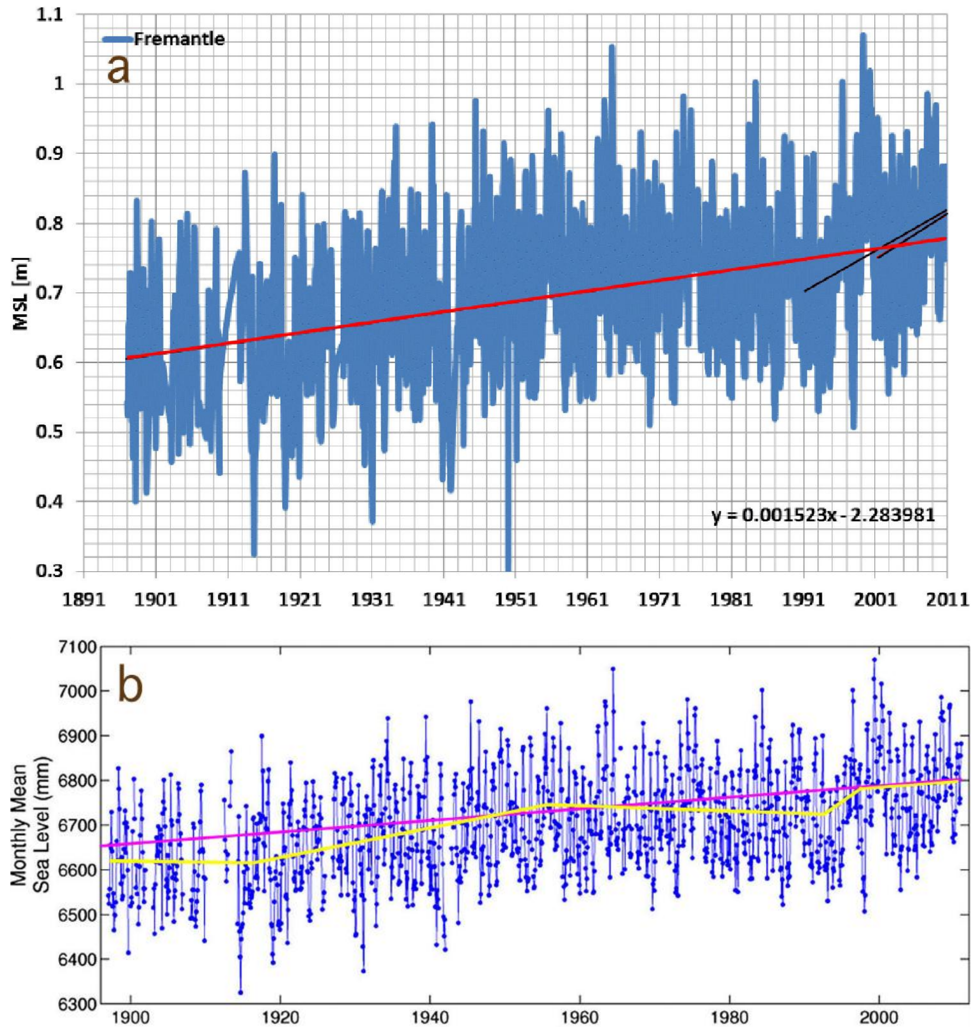

Figure 2 : Sea level record from Fremantle (SW of Perth) with two different analyses. *Above*: Mean sea level changes at Fremantle from 1897 to 2011 (AGBM, 2011) with a long-term avarage rate of sea level rise of 1.5 mm/year (red line) and arbitrary mean lines for the last 10 and 20 years (black lines) in the order of 6.0-6.5 mm/yearn (not good for longer-term rate estimates). *Below:* A more dynamic approach fitting a mean rate to segments (yellow line) of the total record (PSMSL, 2011). This gives 5 segments; a stable trend to 1913, a rising by 2.5 mm/year about 1913 to 1956, a vaguely falling trend 1956 to 1993, a rapid rise 1993 to 1998, and virtually stability thereafter. The rise from 1913 to 1956 was the order of 2.5 mm/year. Because there was a global eustatic rise during this period, which seems to have been about 1.1 mm/year (Mörner, 2004, 2011c, 2013), the Fremantle tide gauge is likely to include a local subsidence factor in the order of 1.4 mm/year (purpel line). Considering this subsidence, there is not much sea level rise left; virtually stable conditions over the last 60 years and full stability over the last 14 years (i.e. no traces of any present-day acceleration). The rise 1993-1998 is somewhat strange, but may have something to do with the change in instrumental operation and the big ENSO event in 1998. The 1913–1993 changes may also be looked upon as an 80-year cycle.

NOAA[33] has a global network of 159 tide gauges. The mean of those records is a sea level rise of 0.5 mm/ year according to Burton[9]. The distribution of rates gives a nice sinusoidal curve ranging from uplifted sites to subsided sites with an intermediate platform of 68 sites representing quasi-stable conditions with a range in rate of 1.0 ±1.0 mmyear[30]. Today, the number of NOAA stations has increased to 204 with a mean of

0.75 mm/year[31].

Comparison with satellite altimetry records

Since 1993, the Topex and Jason satellites have provided measurements of sea level changes via radar altimeters. Whilst tide gauges are limited to the shore, satellite altimetry provides measure of the entire oceans covered by the satellites[14]. This means that we get records both of the vertical changes and the horizontal redistribution of water masses. There seems to be serious problems in calibration, however, as given by the changes in mean trends[23,30,31]; viz. ±0 mm/year for 1993–2000, +2.3 mm/year for 1993–2003 and 3.1 mm/year for 1993–2010. In the present paper we use the record of 2011. The mean rate 1993–2011 is given as 3.1 ±0.4 mm/year. We note that the rate decreased to about 2.0 mm/year for the period 2006–2010, and in the last two years has become zero. Indeed, there is no sign of a recent acceleration.

DISCUSSION

In Figure 3, we compare the different data sets and confront the Australian governmental offices claim of a present mean rise in sea level of 5.4 mm/year obtained from the 16 SEAFARE stations (1) with the our analyses of the 39 mainland stations of 0.9 ±1.9 mm/year (2a), the 70 non-ABSLMP stations of 0.1 mm/year (2b) and all the 86 stations of 1.5 mm/year (2c), the mean of all 2059 PSMSL[32] stations of 1.5 mm/year (3a) and the mean of NOAA's[33] 159 stations of 0.5 mm/year (3b), the curve of Church and White[12] with an extreme acceleration 2007–2010 (4), and the satellite altimetry record[14] of 3.1 ±0.4 mm/year mean rate of sea level rise with a decelerating trend over the last six years (5).

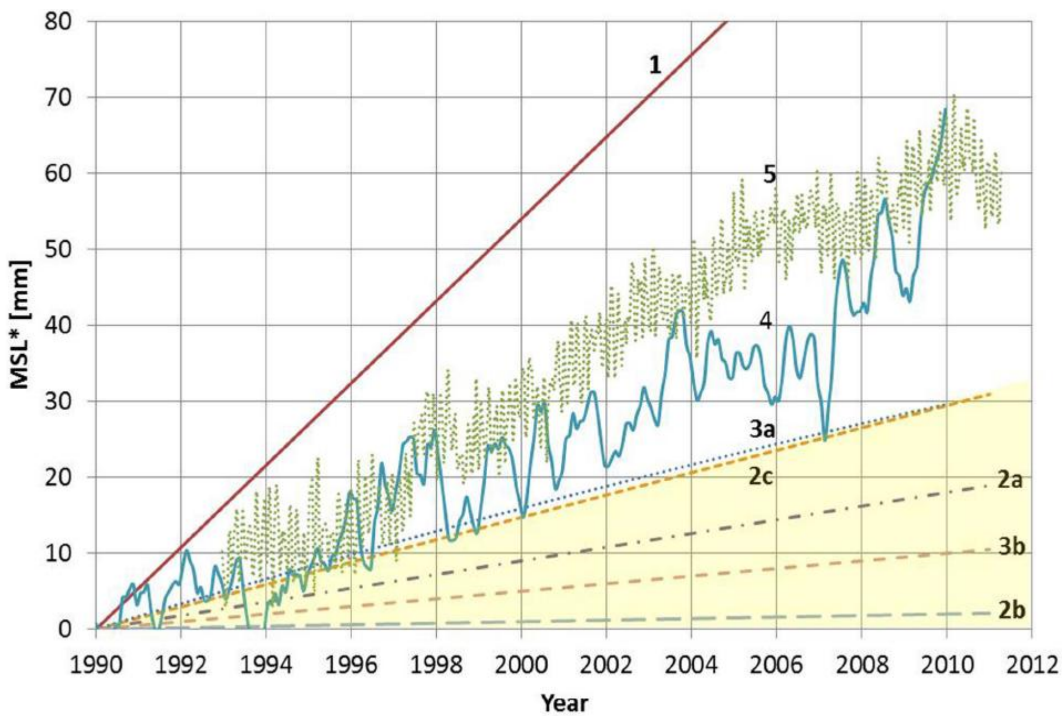

Figure 3 : Comparison among different sea level data sets; (1) the Official Australian claim (AFGCC, 2011; ABSLMP, 2011), (2a) the Australian 39 station record, (2b) the Australian 70 station record, (2c) the Australian 86 station record, (3a) the 2059 station PSMSL (2011) average, (3b) the 159 station NOAA (2011) average, (4) the reconstruction of sea level changes by Church and White (2011), and (5) the Topex/Jason satellite altimetry record (CU, 2011). All the data are shifted for a zero MSL in January 1990. The differences are far too large not to include serious errors in some of the records. The official Australian trend (1) lies far above all the other curves, indicating a strong exaggeration. The Australian (2a-c) as well as global (3a-b) curves vary between 0.1 and 1.5 mm/year. The satellite altimetry records (5) include "calibrations" previously questioned (Mörner, 2004, 2011c, 2013). The record (4) of Church and White (2011) lies between the satellite altimetry curve (5) and all the graphs representing global (3a-b) and Australian (2a-c) tide gauge records. The acceleration in curve 4 is strongly contradicted by all the other records. The same absence of acceleration is found in many other records (further discussed in the text) indicating that the concept of acceleration ought to be revised.

From this comparison it seems obvious to us that the Australian governmental value of 5.4 mm/year must be significantly exaggerated. The Australian data analysed by us provide a range from 0.1 to 1.5 mm/year. The same over-estimation seems to apply for individual sites when comparing our values from Darwin (their 8.6 versus our 2.2 mm/year) and from Stony Point (their 2.6 versus our –2.1 mm/year).

Our records from the 39 (0.9 mm/year), 70 (0.1 mm/year) and all 86 stations (1.5 mm/year) are in reasonable agreement with the average rates of global tide gauge networks, viz. PSMSL (1.5 mm/year) and NOAA (0.5 mm/year). This may be taken to suggest that the mean sea level rise according to global as well as Australian tide gauge data is to be found within the sector ranging from 0.1 to 1.5 mm/year (yellow wedge in Figure 3), which is well below the record of Church and White[12] and satellite altimetry[14], and strongly below the official Australian value[2,3].

The satellite record[14] and the sea level curve of Church and White[12] differ considerably. Besides, they both (4, 5) lay well above the average global tide gauge values[9,33].

All the data presented by us contradict an acceleration is sea level rise over the last years or decade. Acceleration is only seen in the record (4) proposed by Church and White[12]. The satellite graph (5) even gives a decrease after 2005. Besides, an absence of acceleration is reported by several authors for sites scattered all over the globe[19,21,24,39,40,41].

CONCLUSIONS

Trend lines are not the correct way of decoding the true dynamics of sea-level changes. It may be used for comparative purposes, however. In view of the data presented, we believe that we are justified to draw the following conclusions:

(1) The official Australian claim[2,3] of a present sea level rise in the order of 5.4 mm/year is significantly exaggerated (Figure 3).

(2) The mean sea level rise from Australian tide gauges as well as global tide gauge networks is to be found within the sector of rates ranging from 0.1 to 1.5 mm/year (yellow wedge in Figure 3).

(3) The claim of a recent acceleration in the rate of sea level rise[2,3,12] cannot be validated by tide gauge records, either in Australia or globally (Figure 3). Rather, it seems strongly contradicted[19,21,24,39-41].

The practical implication of our conclusions it that there, in fact, is no reason either to fear or to prepare for any disastrous sea level flooding in the near future. This does, of course, not mean that we should ignore the problem; just that we should study it carefully and with open eyes. The decisive facts must be found in nature itself; ideas and computer models are simply not good enough.

ACKNOWLEDGEMENTS

In recent years, sea level research has become an issue of controversy. Instead of being the reason of different interpretations of available data, it has become the reason of the author's personal relation to the concept of global warming. In this paper, we try to avoid personal views and build up the story on straightforward analyses of different databases of tide gauge records both nationally for Australia and globally from available international networks. It is the exaggerations we find urgent to decode because it has the potential to set up unnessary fear and socio-economical missinvestments.

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