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Discussion of timescales for detecting a significant acceleration in sea level rise by parabolic fittings of naturally oscillating time series

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ABSTRACT

The authors of[20] are only the last of a long series[21-26] to apply parabolic fitting with different time windows to the time series of relative sea levels from tide gauges to assess the presence of positive or negative accelerations. This method is wrong because this approach produces positive or negative accelerations even dealing with simple sinusoidal oscillations about a linear trend where the acceleration is clearly zero, as it is the case of purely oscillating tide gauges signals. This contribution proposes clear and strong concerns about the validity of any claim made on the basis of parabolic fittings and propose a better analysis methods clearing the trends of the multi-decadal variability.

PARABOLIC FITTINGS AND NATURAL OSCILLATIONS

The authors[20] consider the measured relative sea levels for 10 tide gauges of the Permanent Service on Mean Seal Levels (PSMSL) data base[1], namely Sydney, Fremantle, Trieste, Den Helder, Newlyn, Brest, New York, Key West, San Diego and Honolulu, plus a '*coastal mean sea level*' (CMSL)) obtained by simply averaging the 10 tide gauge records, and the '*sophisticated reconstruction*' of the '*global mean sea level*' (GMSL) from Church and White[2]. The gaps in the individual tide gauge records are not filled and every tide gauge has a different starting point. The CMSL is obtained by stacking of the individual tide gauges and therefore has a population demography changing with time. The time series are fitted with 2nd order polynomials, and the average acceleration over the record length is computed as twice the second order coefficient. All the time series are updated up to 2009. In addition to the accelerations over their respective record lengths, the accelerations for the 12 records are also computed for five time periods, 1880–2009 with only 3 time series considered, 1900–2009 with 4 time series considered, and finally 1915–2009, 1930–2009, 1960–2009 with all the 12 time series. The accelerations over the record lengths (their TABLE1) are positive for 4 of the 10 tide gauges, and negative for the remaining 6. The CMSL and the GMSL have both positive accelerations over the record lengths. The acceleration over the 5 time windows are mixed for the 10 tide gauges, 4 negative and 6 positive over the short time window 1960-2009, 5 negative and 5 positive over the time window 1930-2009, 4 negative and 6 positive over the short time window 1915–2009. The CMSL has acceleration negative 1915–2009 and positive 1930–2009 and 1960–2009. The GMSL always has positive accelerations with maximum value over the shorter window 1960-2009.

The authors of [20] correctly conclude that the most important approach to earliest possible detection of a significant sea level acceleration lies in improved understanding (and subsequent removal) of inter-annual to multi-decadal variability in sea level records. This conclusion of the authors is perfectly correct but their technique is incorrect, because their method may produce positive or negative accelerations even when the relative sea levels from tide gauges are simply oscillating about a contant linear rise or fall.

This is immediately evident if the authors of [20] apply their parabolic fitting to a pure sinusoidal function

$$y = \sin\left(\pi\cdot\frac{x-x_c}{w}\right)$$

Where x is the independent variable, y the dependent variable, x_c is the phase and w is half the periodicity. Randomly (or carefully) selected time windowsin the parabolic fitting of the data over the time window may return positive or negative accelerations even if the time series has no acceleration at all.

Tide gauge results for the relative sea level do not follow a simple sinusoidal law, but the approximation of the measured values with a linear and mutiple sinusoidal fucntions is not that far from an accurate representation of the longer term trend and the oscillations about this trend.

Considering the relative sea levels are oscillating with many periodicities, with the longest detected so far a quasi-60 years[3,12], the sometimes positive and sometimes negative accelerations in the different tide gauges represent nothing else but the effect of the oscillations of different phase, amplitude and period about the longer term trend differing from one location to the other over the time window.

Suppose that the absolute sea levels are not rising faster because of the carbon dioxide emission producing global warming with the subsequent thermal expansion and mass addition contributions to the absolute rate of rise. In this case, what we would expect to detect with a tide gauge is an oscillatory movement about a longer term trend for the relative sea level, with a constant rate of rise or fall of the relative sea level closely following the isostatic subsidenceoruplift of the land.

If y_i are the monthly average relative mean sea level observations at the time x_i, the distribution $\{x_i,y_i\}$ i=1, …, N may be fitted with a line and multiple sinusoids[6,9]:

$$y^* = (y_0 + a\cdot x) + \sum_{i=1}^{n}\left[A_i\cdot\sin\left(\pi\cdot\frac{x-x_{c,i}}{w_i}\right)\right] + \varepsilon \quad \textbf{(1)}$$

Where y^* is the relative sea level, x the time, n the number of sinus functions and y_0, a, A_i, $x_{c,i}$, w_i are the fitting coefficients. a is the relative sea level velocity, and A_i, $x_{c,i}$, w_i are the amplitudes, phases and periods of the oscillations. In equation (1), ε is the error that includes noise, fitting inaccuracies, periodic oscillations not exactly sinusoidal, periodic oscillations that are not included or the influence of global warming (when detectable) producing a departure from the linear trand.

The technique proposed by the authors applied to a tide gauge of perfectly sinusoidal oscillations about a constant linear trend as per equation (1) with ε=0 or random noise may produce positive or negative values only because the time window is not a multiple of all the relevant periodicities of the oscillations while the longer term trend is perfectly linear.

Application of equation (1) is shown here after for the two tide gauges of Australia, Sydney and Fremantle, two of the tide gauges in their list of 10.

For a proper understanding of the multidecadal oscillations first of all it is necessary to complete the time series when there are gaps. The presence of significant gaps reduces any way the reliability of the analysis.

Sydney has two tide gauge records in Fort Denison. SYDNEY, FORT DENISON (PSMSL ID 65) has time span of data 1886 – 1993, and completeness (%) 100. SYDNEY, FORT DENISON 2 (PSMSL ID 196) has time span of data 1914 – 2012, and completeness (%) 98. The two tide gauges have almost 80 years of successful overlapping and the integration of the two records in a composite record spanning 1886 to 2012 without any gaps does not pose any quality issue.

Fremantle has only one tide gauge, FREMANTLE (PSMSL ID 111) of time span of data 1897 – 2012 and completeness (%) 92. This tide gauge has significant gaps, and the way the gaps are filled interpolating neighbouring years may change the result of a Fourier analysis of the time series.

By applying the Fourier analysis, the periodograms of Sydney and Fremantle show different periodicities of the multi-decadal oscillations[6,9]. As shown in[6,9], the relative sea levels of Sydney and Fremantle follow very well equation (1), with different phases, amplitudes and periodicities from one location to the other.

The relative sea levels measured by the tide gauges are not the absolute values. The PSMSL data base[1] has links to the nearby Système d'Observation du Niveau des Eaux Littorales (SONEL) stations [13] providing a quick estimate of the vertical motion of the tide gauge datum based on satellite global positioning system (GPS) monitoring. The land is subject to isostaticuplift or subsidence, and the land velocity is comparable to the relative sea level velocity.

For Sydney and Fremantle, whitin the limits of the GPS technique and the unassessed vertical motion of the tide gauge datum vs. the nearby GPS dome, the vertical velocity of the land near the tide gauge is of subsidence and larger than the sea level rate of rise[9].

The sea level rate of rise in Sydney is apparently constant at about 0.65 mm/year[9]. The nearby GPS indicates a land motion of -0.89 mm/year[9]. The sea level rate of rise in Fremantle is apparently constant at about 1.65 mm/year[9]**.** The PERTH GPS indicates a land motion of -2.99 mm/year[9].

It is, therefore, very likely that not only are the sea level records from individual tide gauges of Sydney and Fremantle not accelerating, but the absolute sea level directions are very likely negative in Sydney and Fremantle.

To assess the presence or the absence of a departure from the naturally oscillating behaviour about a linear trend what is needed is not a parabolic regression analysis of the monthly average mean sea levels $\{x_i,y_i\}$ i=1, …,N, but a study of the distribution of the residuals $\{x_i,\varepsilon_i\}$ i=1, …,N, where $\varepsilon_i=y_i - y^*(x_i)$ with y^* computed by fitting with a line and multiple sinusoids (or other) periodical functions.

For Sydney and Fremantle, Figure 1, the fitting with a line and multiple sinusoidal functions having the coefficients presented in TABLE 1 produces relatively good

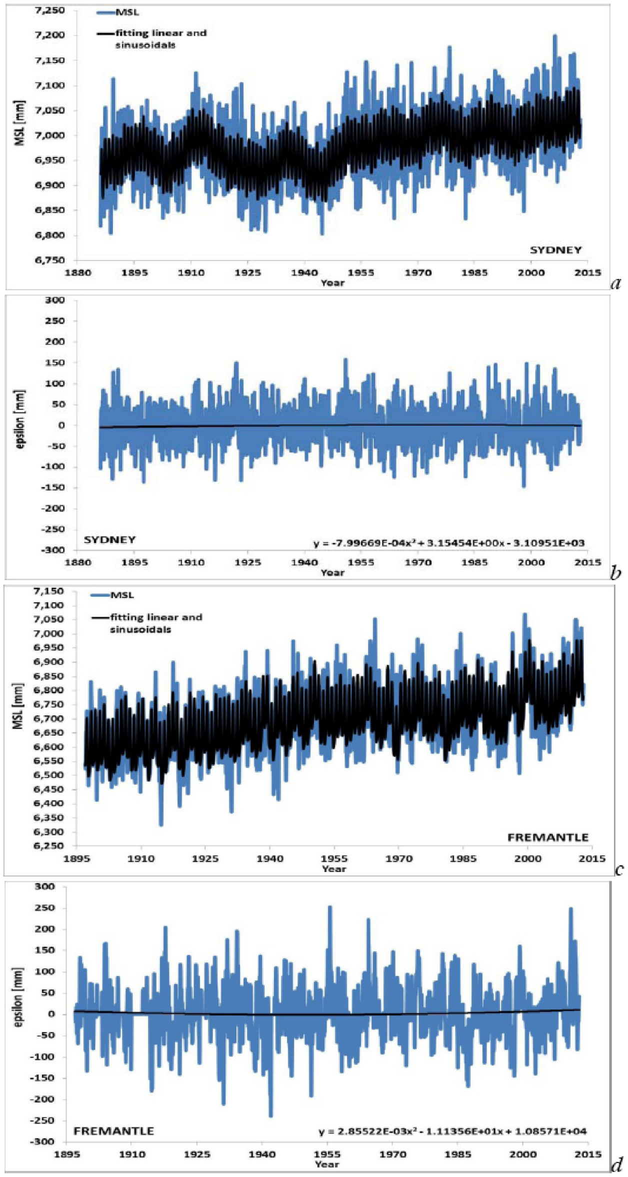

Figure 1 : a,b relative mean sea levels measured in Sydney and their fitting with a linear and multiple sinsoidal functions and fitting errors; c,d relative mean sea levels measured in Fremantle and their fitting with a linear and multiple sinsoidal functions and fitting errors. The two tide gauges show minimal departures vs. the oscillatory pattern about a contant linear trend with small negative accelerations for Sydney and small positive accelerations for Fremantle

TABLE 1 : Fitting coefficients for sydney and fremantle

Sydney		x_{ci}	**-0.996**	**0.12**	**257**	**145**	**-34.2**	**-545**	**0.737**	**18.1**	**-21.8**	**0.686**
a	0.634	w_i	0.5	0.25	47.5	9.85	6.47	27.1	0.25	2.1	11.3	0.824
y_0	5739.127	A_i	39.4	24.1	16.8	-12.6	10.5	14.2	7.84	7.25	-10.2	6.93
Fremantle		x_{ci}	**0.642**	**0.312**	**-24.3**	**4.25**	**16.7**	**-282**	**0.664**	**3.43**	**-37.6**	**-49.1**
a	1.55	w_i	0.5	0.25	2.8	2.07	1.8	33.6	6.44	1.45	5.91	1.19
y_0	3657.698	A_i	101	-30.6	19.5	-22.9	21.2	21.5	20	15.6	15.4	8.3

accuracy. The parabolic fitting of the residuals reveals very small accelerations of the order of $10^{-3} – 10^{-4}$ mm/year^2, of positive sign for Fremantle (having a shorter record and more gaps to fill), and negative sign for Sydney (witha longer record and almost no gaps). We may consider these accelerations negligeable.

Figure2 presents the parabolic fittings of the purely linear and sinusoidal approximation of the Fremantle tide gauge results over four different time windows 1897, 1915, 1930 and 1960 to 2009. Not a surprise, this parabolic fittings return negative, negative, positive and positive accelerations as in table 1 and table 2 of the authors of the commented paper, respectively -0.0136 vs. “0.0090, -0.0184 vs. “0.0140, 0.0062 vs. 0.0067 and 0.117 vs. 0.1414 mm/year^2 even if the fitted curve is clearly acceleration free. The minimal differences are mostly due to the fact that the authors use an incomplete time series of 92% completeness. The method of using parabolic fittings of different time windows to assess the presence or the absence of an acceleration is a non-sense.

Similar results are expected for the other tide gauges, where by using alternative approaches those discussed in have already been shown to be practically acceleration free.

Apart from the issue with the incorrectmethod to compute the sea level acceleration,[20] has a few other weaknesses, includingthe use of linear fittings over different time windows to compute higher or lower than legitimate rates of rise that include significant oscillatory components, the use of a CMSL obtained by simply stacking the 10 individual tide gauge results that has not too much significance, the consideration of the GMSL computational result as an observational result, and finally the use of the climate model simulation results 2010 to 2100 despite these models have already failed validationup to the present time without mentioning the open case of the missing heat.

As far as the CMSL is concerned, we note how this time series is not particularly meaningful, being the product of the simple stacking of tide gauge time series differing in the record length and the relative sea level velocity, producing stepwise positive or negative accelerations even when all the components are acceleration free.

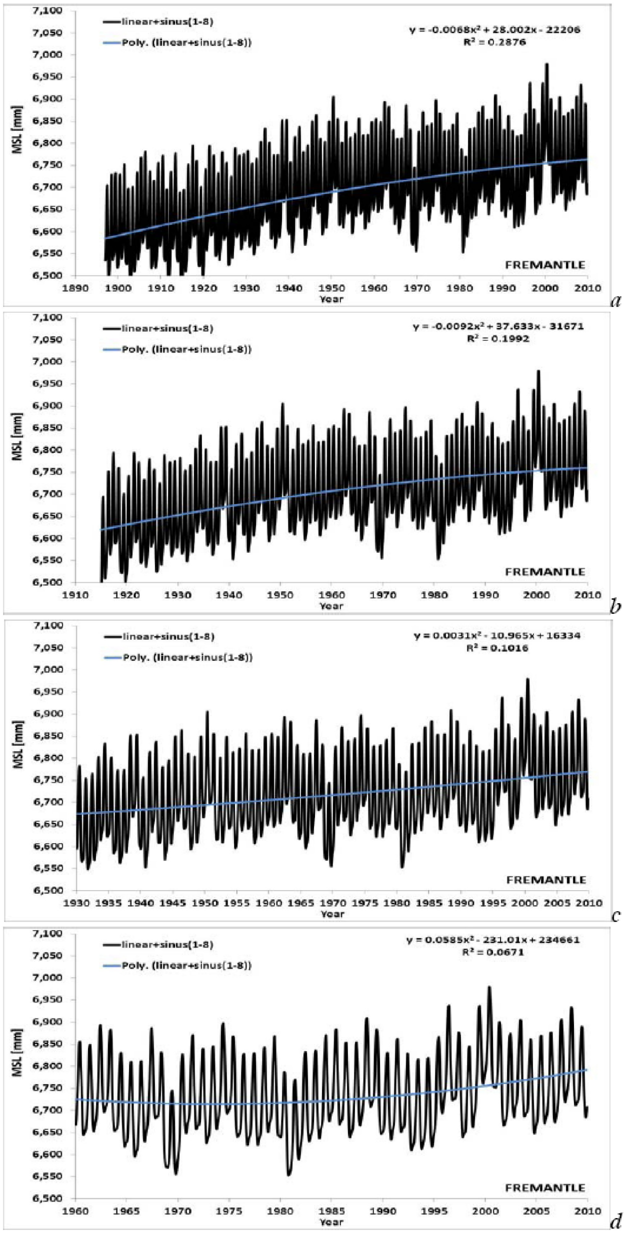

Figure 2 : a,b,c,d: Parabolic fitting of the purely linear and sinusoidal approximation of the Fremantle tide gauge results over four different time windows 1897, 1915, 1930 and 1960 to 2009. Not a surprise, this parabolic fittings return negative, negative, positive and positive accelerations as in table 1 and table 2 of the authors of the commented paper, respectively -0.0136 vs. “0.0090, -0.0184 vs. “0.0140, 0.0062 vs. 0.0067 and 0.117 vs. 0.1414 mm/year^2. The minimal differences are mostly due to the fact that the authors use an incomplete time series of 92% completeness. The method of using parabolic fittings of different time windows to assess the presence or the absence of an acceleration is a non-sense

As far as the GMSL is concerned[2], as already noted[10,12], this reconstruction is always accelerating following the carbon dioxide emission even if the individual tide gauges supposedly used to support the computational result are acceleration free. The authors have shown properly that this GMSL has an accelerating pattern different from the measured relative sea level from their selection of tide gauges. This GMSL is strongly accelerating especially this century, which has so far seen no warming of land and sea surface temperatures[14], practically no warming of the oceans 0-2000 m[15], and no loss of sea ice globally [16]. This GMSL result as it is merely a set of computations like many other climate models, and is not a true measurement. It could have certainly be disregarded when discussing the measurements of sea levels.

As for what the forecast pattern for the period 2010 to 2100, climate models have failed validation against. what has been measured to date, and there is a clear "*case of the missing heat*"[17,19] that the authors should acknowledge. The models have overrated the warming and also completely missed the natural oscillations. The authors do not even comment on the different pattern obtained with their method analysing the measured data prior of 2010 and the computational results 2010 to 2100. Simulations that overrate the warming and cannot produce the natural oscillations are probablyincorrect [7,8,18,19] and this should have been noted.

CONCLUSIONS

Tide gauge results of good quality, completeness and length may be analysed by using equation (1) to compute the long term relative rate of rise, the periodicities, phases and amplitudes of the natural oscillations, the presence or absence of a departure from the trend because of the thermal expansion and ice melting produced by global warming.

The use of linear and parabolic fittings over different time windows return misleading results, with accelerations positive or negative even if the time series are perfectly oscillating. Stacking of individual tide gauges of variable length, longer term trend and oscillatory parameters does not make any sense. More sophisticated techniques to compute global mean sea levels are similarly unreliable.

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