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Discussion of sea-level forcing by synchronization of 56- and 74-year oscillations with the moon's nodal tide on the northwest European Shelf (Eastern North Sea to Central Baltic Sea)

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ABSTRACT

There has been a debate about the computation of amplitudes and periodicities of multi-decadal sea level oscillations aimed to prevent claims the relative sea level rates of rise higher than the recent past in some areas may be the result of natural oscillations. We show here that while the relative sea level rates of rise are actually not only higher, but also lower than the recent past, it all depends on the phasing of the oscillations that also changes from one area to the other, the sinusoidal approximation of the oscillations is an imperfect model with nonlinearities applied to describe a much more complex pattern. Therefore, the determination of amplitude, phase and period of the sinusoidal oscillations approximating a more complex pattern may certainly slightly vary from one approach to the other. However, this does not change too much the conclusion that the sea levels generally oscillates with multi-decadal periodicities of about 20 years and about 60 years in many locations worldwide, and these oscillations should not be sold as proof of the existence of global warming where convenient.

SEA LEVELS ALONG THE EASTERN NORTH SEA TO CENTRAL BALTIC SEA NORTHWEST EUROPEAN SHELF

Hansen, Aagaard, and Kuijpers[1], HAK thereafter, have proposed a mechanism of sea level forcing by synchronization of 56- and 74-years oscillations with the Moon's Nodal Tide on the Northwest European Shelf (Eastern North Sea to Central Baltic Sea) by analyzing the relative sea level data from the long term tide gauges of the area. Their statistical analysis reveal a strong correlation between sea-level changes and the sum of identified harmonic oscillations, corresponding to the lunar nodal period and four multiples of it. Their iterative method for least residual sine regression identifies the harmonic sea-level oscillations, and the authors suggest correlation with the gravitational sea-level effects of the lunar nodal oscillation. The 3 relatively large harmonic in the sea-level oscillations with period lengths of 18.6, 60.5 and 76.1 years correspond very well to factors 1, 3, and 4 of the 18.6-year lunar nodal period. The sum of these oscillations leaves small residuals resolved into 2 further, statistically less significant oscillations with apparent period lengths of 28.1 and 111.1 years, corresponding to factors 1½ and 6 of the lunar nodal period. Strong quasi-oscillations occur. According to the authors, the present sea level oscillations about the longer term trend for the area is characterized by a large quasi-oscillation commenced in 1971 that should culminate in 2011, with the temporary relative sea level rates of rise higher than the longer term trend expected to reduce by then below this longer term trend.

Schmith, Thejll and Nielsen[2], STN hereafter, disagree with HAK criticizing important aspects of their analysis and thereby casting doubt on their conclusions. STN claim that opposite to HAK the 18.6-year variations in sea level are not supported by tidal theory and the existence of such variations must be explicitly shown. The alternative statistical method used by STN to calculated the amplitude spectrum of the annual sea level by harmonic analysis found no signifcant peaks at the periods claimed by HAK finding that the variability near 18.6 years is actually present in the residuals, questioning that the decomposition by HAK does not describe the 18.6 years variability. A seven times lower amplitude for the 18.6-year periodicity is claimed by STN than claimed by HAK. STN conclude that the HAK's mode selection criteria is invalid and none of the modes identified by HAK are statistically significant.

In their reply, Hansen, Aagaard and Kuijpers[3] confirm the validity of their findings no matter of the findings by STN could be different. Their fve individual oscillations including a significant 18.6 year oscillation caused by the lunar nodal oscillation (LNO), of amplitude 70 mm, whereas STN, found other spectra and a consequently much smaller amplitude of the LNO of 10 mm. These differences are neither strange nor inexplicable but are caused by the two fundamentally different methods proposed by HAK and STN. As a proof of the superior methodology they propose, HAK evidence how the sum of the five sea-level oscillations constitutes a theoretical sea level curve of the eastern North Sea to the central Baltic Sea which correlates very well with the observed sea-level changes from 26 long tide gauges of the 160-year period 1849–2009.

HAK stress the point not acknowledged by STN that such identiûcation of inter-annual and multi-decadal oscillators and general trends over 160 years is of great importance for distinguishing long term, natural developments from possible, more recent anthropogenic sea level changes. STN play the card of

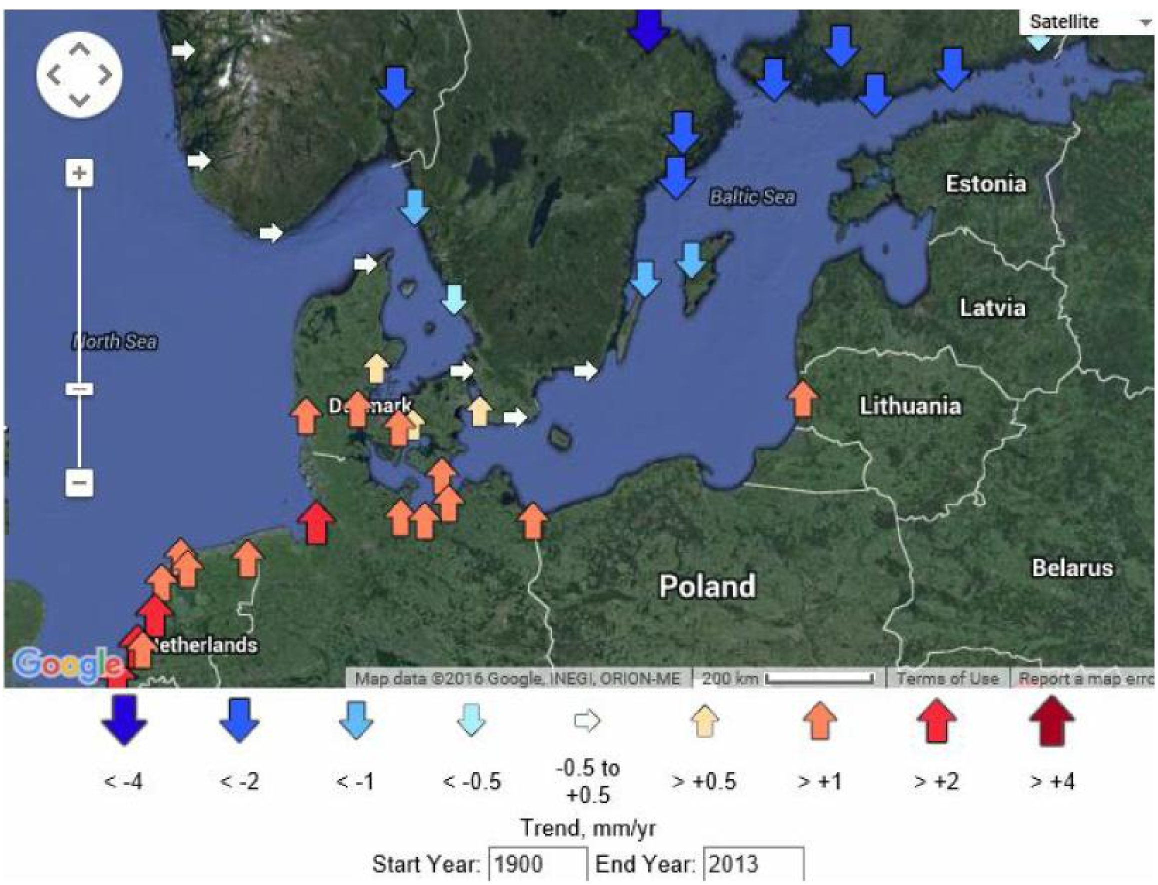

Figure 1 : Relative sea level rise of long term tide gauges about Denmark (image from PSMSL). As more tide gauges are located in areas subject to subsidence rather than uplift, the naïve averaging may suggest a small positive relative rate of rise for the Eastern North Sea to Central Baltic Sea that however a better geographical averaging may reduce to negligible

the possible unaccuracies in the assessment of the periodicities and amplitudes of the oscillations to negate the existence of the multi-decadal oscillations on the assessment of sea level rise. More than the method, what is under discussion is if the larger local relative sea level rise after 1970 is only part of natural oscillations – HAK view – or it is a sign of anthropogenic global warming – the STN view.

As we wrote many times, Parker, Saad Saleem and Lawson[4], Parker and Watson[5], Parker[6-12, 13-17, 27], Parker and Ollier[18-22], a proper understanding of the present sea level pattern requires a proper understanding of the subsidence of the tide gauge instrument and the availability of many years of recorded data without major perturbations to clear a trend of the multi-decadal oscillations, that are very well-known to exist in the climate since several thousands of years. Therefore, the discussion may be at the most about the specific periodicities of the oscillations that depends on their modelling assumption and the algorithm used to compute, and not certainly on the existence of these oscillations, but however it is common practice in the climate debate to focus on the irrelevant details to avoid discussing the big picture.

It is unfortunately a common occurrence that short term records in selected areas are used to suggest

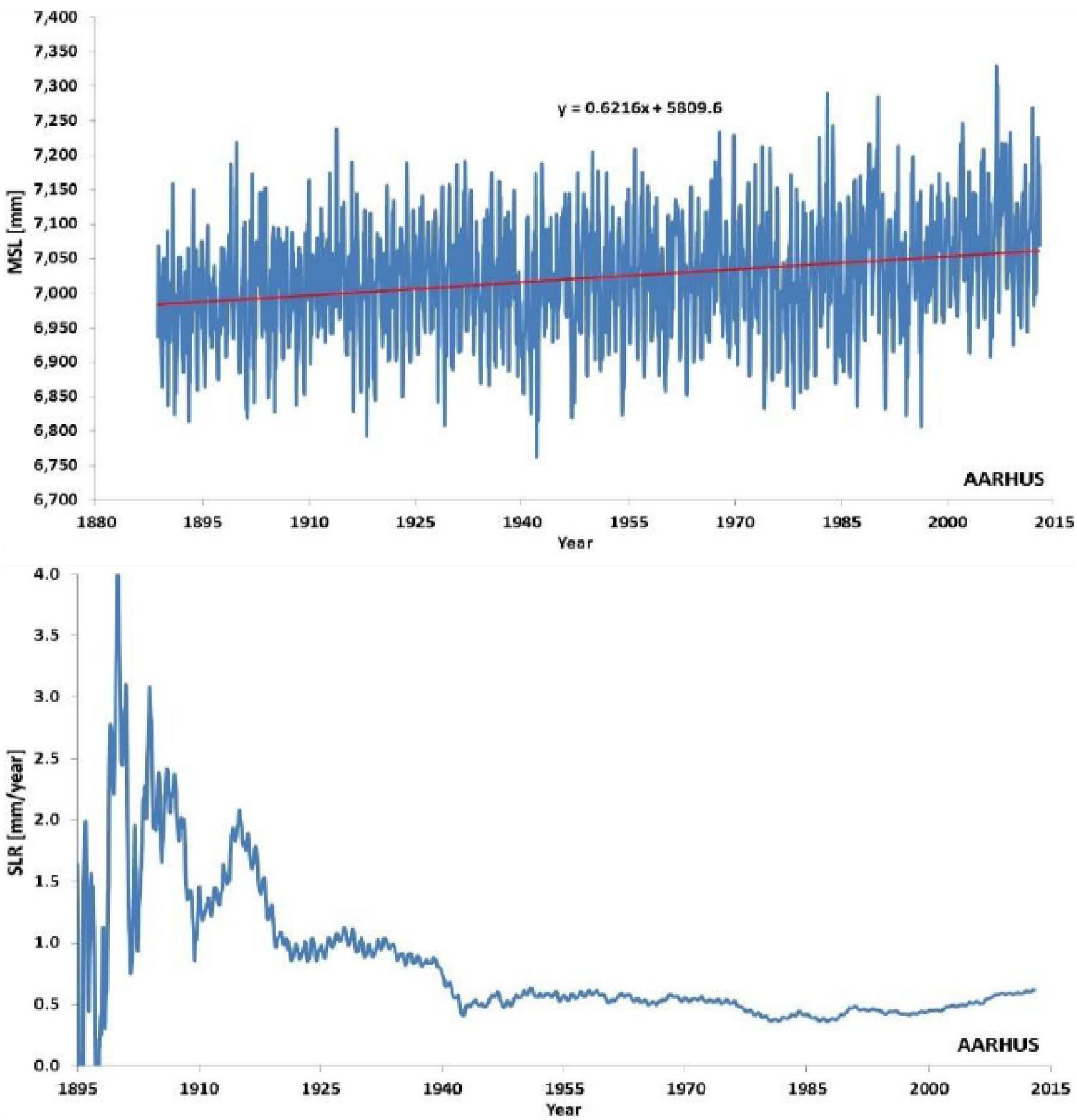

Figure 2 : Sea level rate of rise for Aarhus

relative rates of rise much larger than the recent past calling these areas hot spots of sea level rise (see for example the East Coast of the United States, with sea level data analyzed with a 20 or 30 years' time window). It is not similarly common to use short term records in complementary areas where the relative rates of rise on the short window may suggest much smaller than the recent past sea level rises and therefore be called cold spots of sea level rise (see for example the West Coast of the United States, Canada and Alaska with sea level data analyzed with a 20 or 30 years' time window). Similarly, it is very common to propose tide gauge records from areas subjected to subsidence, as for example the East Coast of the United States or the Gulf of Mexico mostly due to ground water extraction, and not discuss at all tide gauge records from areas subjected to uplift as Alaska.

What is measured by a tide gauge is the level of the sea relative to the tide gauge instrument. The coastal tide gauge instrument may be subjected to subsidence vs. the main land that may be subjected to subsidence or uplift. Subsidence may strongly vary from one tide gauge instrument to another for processes as glacial isostatic adjustment, land compaction, ground water extraction, mining and others factors. For the specific of the area of concern for HAK and STN, Figure 1, the long term tide gauges show relative sea level rises from positive in the Netherlands, Denmark and Germany, to negative in Finland, Norway and Sweden. This is not the result of differential global warming, but only of the differential subsidence or uplift of the tide gauge instrument.

Rather that coupling together different tide gauge records to make an individual tide gauge by stacking non-homogeneous time series of different length, different quality, different completeness and different subsidence of the instrument, it only makes sense to analyze individual tide gauges, and then produce naïve or geographically weighted averages of the results. The analysis of the tide gauge time series typically includes a linear fitting to compute the relative rate of rise of sea levels, multiple linear fittings to compute the time series of the relative rate of rise of sea levels, and therefore the sea level acceleration as its time rate of change, plus eventually the periodogram from a Fourier analysis or also the fitting with multiple sinusoidal functions, returning period, amplitude and phase of the oscillations. Worth of mention, the oscillations are not perfectly sinusoidal not only because the tide gauge signal may be disturbed, and the computation of the parameters of a non-linear fitting may also depend on the numerical method and the initial guess.

We may certainly analyze the time series of Aarhus (data from PSMSL) of time span of data 1888 – 2012 and completeness 97%. We may compute a relative rate of rise (SLR) at any time as the slope of the linear fitting of all the data available up to that time, and we may then compute the relative sea level acceleration by

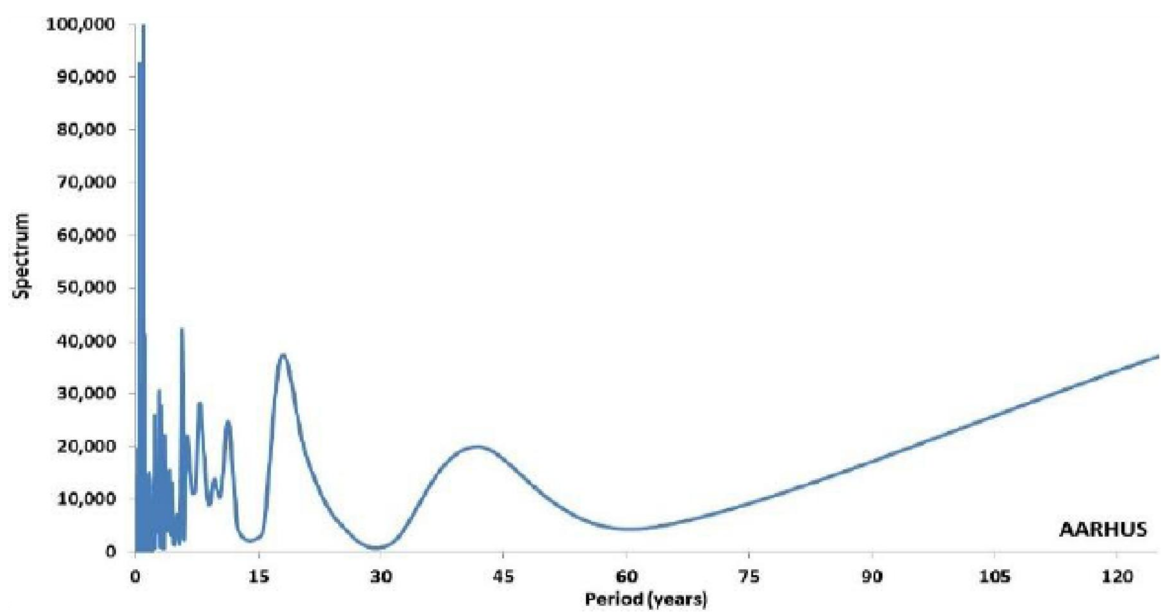

Figure 3 : Periodogram of the MSL oscillations for Aarhus from Wessa.net

the time rate of change of this parameter, Figure 2. Apart from the first 60 years of recording where the computed SLR may differ considerably from the longer term trend as a result of the inter-annual and multi-decadal oscillations (the spikes from below 0 to above 4 mm/year in a location with a long term trend of 0.5-0.6 mm/year are an indication of how relevant are the oscillations not acknowledged by STN), the SLR has been reducing approx. 1950 to about 1980-1990, and it is increasing since then. If we do apply a fitting not just with a line, but with a line plus multiple sines, then we may sort out how much of this acceleration is "natural" and how much is "man-made". About 20 and about 60 years oscillations are almost everywhere in the world, it would not be a surprise also Aarhus could be affected by such oscillations.

We start here from monthly average mean sea levels. We perform first the linear fitting, then all the sinusoidal fittings, by minimizing the residuals. The linear fitting $y=a\cdot x+b$ returns a=0.6216 [mm/year] b=5809.6 [mm]. The first sinusoidal fitting $y=y_0+A\cdot\sin((x-x_c)/w)$ returns y_0=-0.10914 [mm], x_c=5.02587 [years], w=0.50013 [years] and A=76.19627 [mm]. w is half the periodicity. The second sinusoidal fitting returns y_0=0.01487, x_c=-1.63399, w=0.24991 and A=-15.79709. As expected, the short term oscillations during the year are by far the

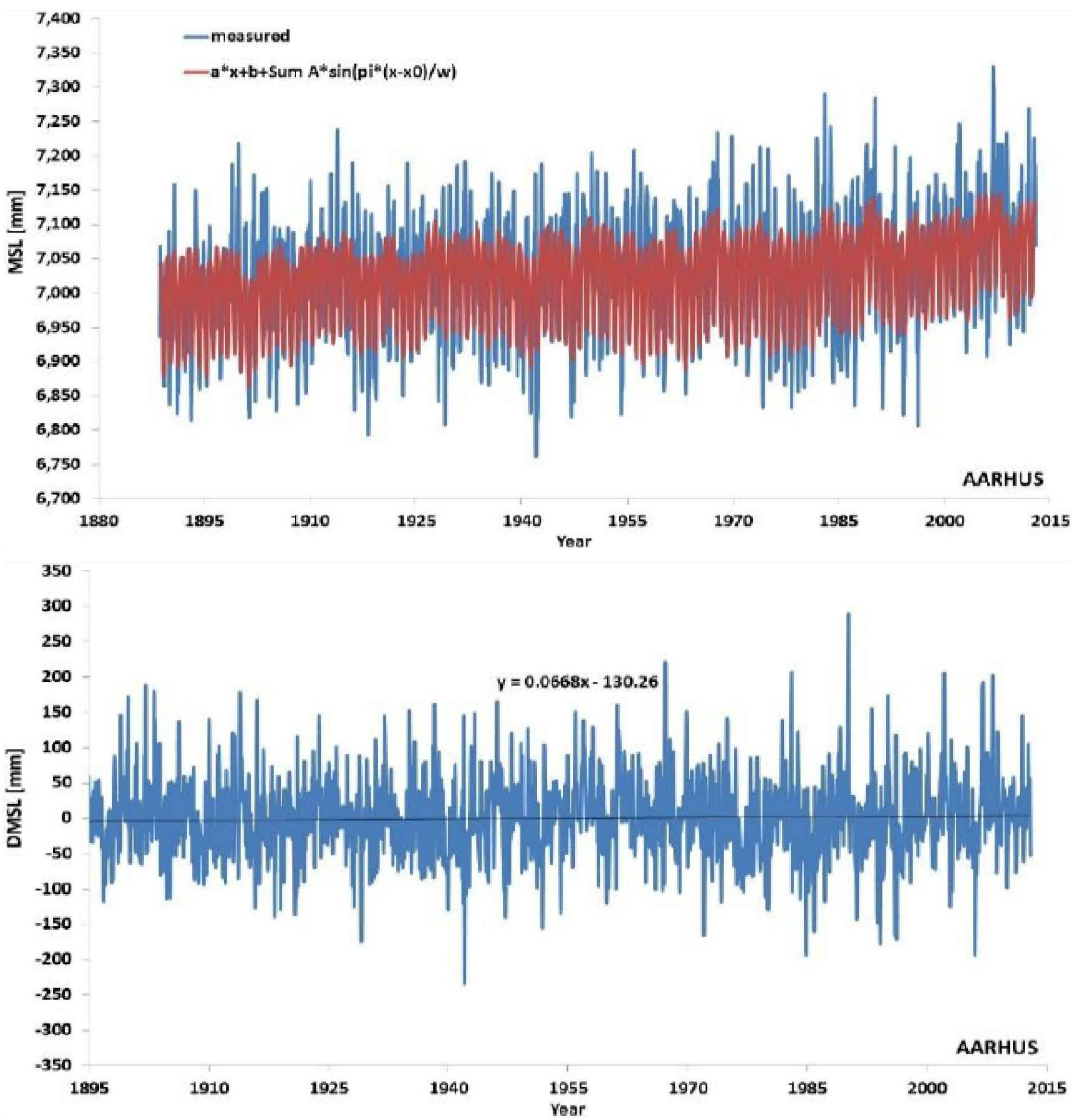

Figure 4 : Measured and computed MSL and residuals for Aarhus

strongest, and the yearly pattern is not exactly sinusoidal. The following sinusoidal terms are y_0=0.03406 mm, x_c=-16.37244 years, w=2.84745 years, A=11.00549 mm; then y_0=-0.85026, x_c=379.83071, w=48.91136, A=-12.3201; then y_0=0.03738, x_c=4.26814, w=1.54788, A=9.87555; then y_0=-0.03634, x_c=8.58698, w=3.86678 A=9.68653; then y_0=-0.47654, x_c=-132.33205, w=9.44269, A=10.86366 and finally y_0=-0.00176, x_c=-1.00831, w=0.5058, A=8.80001.

It does not make too much sense to continue with further sinusoidal fittings. By using a sinus or a cosinus fitting, a squared sinus or a squared cosinus, but also a different guess of the fitting parameters, it is possible to compute somehow different parameters, and the above amplitudes may certainly differ from the amplitudes of a periodogram as the one of wessa.net of Figure 3. There is for sure an important oscillations of about 20 years, and there is certainly another important oscillation above the 20 years that the limited data do not permit to fully evidence with accuracy, plus higher frequency oscillations.

Without being picky on the accuracy of the estimation of the periodicity or the amplitude, what has to be considered is how close is the fitting with a line and multiple sines to the measured data, and if the residuals are trended or not. Figure 4 proposes a comparison of the measured and fitted monthly average mean sea levels for Aarhus, plus the residuals. Figure 5 finally proposes a comparison of the computed and measured SLR for Aarhus.

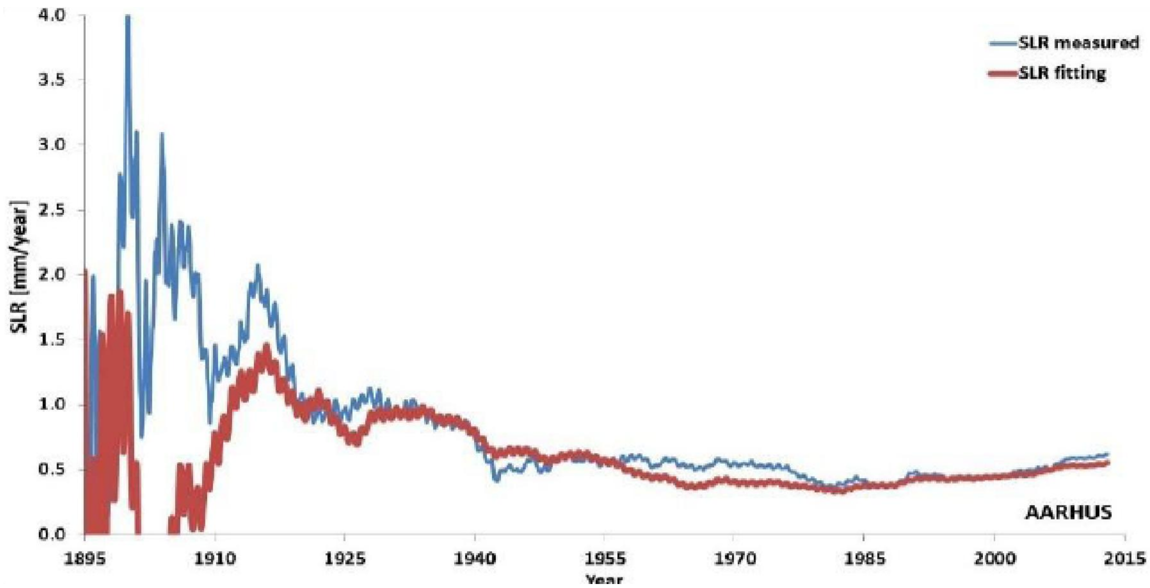

Figure 5 : Measured and computed SLR for Aarhus

CONCLUSIONS

The simple oscillatory model explains the increasing sea level rise since the mid-1980s, as it explains the reducing sea level rise 1950 to mid-1980s. Considering the many uncertainties in collecting the data, Figures 2 to 5 definitively prove HAK is correct and STN is wrong, and the first sign of accelerating sea levels is still missed for this area as everywhere else in the world.

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