Climate Related Sea Level Change – An Inconvenient Fact or an Irritating Fiction?

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SUMMARY

Climate change has been a focus of scientific study for over 25 years. It has resulted in numerous scientific papers as well as five comprehensive assessment reports published by the Intergovernmental Panel on Climate Change (IPCC). Despite this plethora of data, there remain some, such as Lord Christopher Monckton and Professor Nils-Axel Mörner, prominent sceptics, who maintain that anthropogenic climate change is not happening and that rising sea levels do not constitute the risk claimed by the IPCC. Such sceptics typically see future changes as being small and the product of natural processes that are largely uninfluenced by human activity. This is a crucial issue for a number of FIG member bodies, particularly those associated with small, low-lying islands [sometimes known as Small Island Developing States (SIDS)]. This paper reviews the available science data (at least as it relates to sea levels) and compares it against the claims made by climate change sceptics such as Lord Monckton. Such claims are soundly refuted. The paper concludes by providing balanced guidance on likely sea level change to those who seek to prepare for the future.

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1. INTRODUCTION

In 2012 the United Nations Environment Programme issued its report on the most important emerging issues related to the global environment (UNEP, 2012). The top ranked issue in that report related to the alignment of land governance to the challenges of global sustainability. Global sustainability, however, has itself been firmly linked by the UN both to the challenges of mitigating the effects of climate change, and adapting to its impacts (UN, 2013). If climate change is a fiction, as suggested by sceptics such as Lord Christopher Monckton (see www.lordmoncktonfoundation.com/articles), then the challenge of global sustainability becomes considerably less severe, giving the human race more time to deal with some of its deep environmental issues.

One of the impacts of climate change of particular concern to surveyors is the issue of sea level rise. The height systems used for topographic mapping and for building coastal engineering infrastructure (e.g., storm water systems, bridges, roads, etc.) are typically referenced to Mean Sea Level (MSL). Coastal cadastral boundaries are also defined with respect to sea level datums such as Mean High Water (MWH) or Mean High Water Springs (MHWS). If there is no steady rise in sea level then apart from storm damage and the normal coastal erosion processes that have prevailed over the last two millennia, there should be no concern with possible long-term inundation.

While Lord Monckton makes many assertions regarding climate change, this paper will focus specifically on his arguments with respect to sea level change – arguments that are drawn almost exclusively from the work of ProfessorNils-Axel Mörner. Lord Monckton asserts that Professor Mörner is an expert on sea level change,"*who has written 520 papers on sea-level rise in his 35-year career*" (p.23, Monckton, 2009) – an amazing productivity of, on average, 15 papers/year. Professor Mörner is of the view that sea level rose from 1850 to 1930 at a rate of 1.1 mm/yr but then subsided again. In his words, and with respect to the current day, "*There's no trend, absolutely no trend*" (Mörner, 2007[a]). This paper, then, will examine Professor Mörner's claims in detail. Having refuted them, it will then suggest a reasonable sea level rise scenario that can be used for future planning purposes.

2. LORD MONCKTON'S ASSERTIONS

It is unfortunate that in some regards Professor Mörner's credibility is compromised by overly grandiose descriptions of his academic credentials. For example, Professor Mörner's seemingly amazing productivity of averaging 15 papers per year on sea-level rise does not stand up to closer scrutiny. A search using Google Scholar revealed at best 100 papers authored or co-authored by Professor Mörner that have been published in reputable journals

and that bear some relevance to sea level rise issues. Even allowing for the possibility of a substantial number of papers not appearing in a Goggle Scholar search, the difference between 100 and 520 is vast.

Aperusal of a wide sample of those papers indicatesthat Professor Mörner is a very capable paleogeophysicist with advanced knowledge of the Earth's lithosphere and plasticity. He has clearly undertaken a greatdeal of research intohistorical vertical crustal movements in Scandanavia over geological time scales (i.e., the last 100,000 BP). This material has been published widely. The knowledge developed from these studies, together with more recent field trips to places such as the Maldive Islands and Bangladesh forms the basis from which Professor Mörner makes his assessments of future sea level rise. Google Scholar showed no publications related to the comprehensive analysis of a global set of modern day tide gauge data. In this regard he has no recent refereed publications that compare with the types of analyses undertaken by Douglas, (1997); Peltier, (2001); Woodworth et al, (2008);Church and White, (2011); or Jevrejeva et al, (2013).Thus while his statement with regard to international sea level specialists that, *"There's no one who has beaten me"* (Mörner, 2007[a]),may have some validity with regard to paleogeophsicists, in the broader scheme of sea level researchers, it is an unfortunate misrepresentation of reality.

However, any judgment of an author must ultimately rest on the quality of his/her own work rather than on verbal assertions either of himself or of some third party. With this in mind, we now focus on some of the claims made in Professor Mörner's recent written work.

3. PROFESSOR MÖRNER'S ASSERTIONS

It is perhaps useful to begin this section by noting that Professor Mörner claims to base his assessments on observational data rather than purely on mathematical models (Mörner, 2007[a]; andhttps://www.youtube.com/watch?v=Ycq5CJiMer8). In his words, the observational data needs to fit reality. With this in mind, we now examine his primary assertions in the light of the observed data.

3.1 Assertion 1: There is no Rising Trend in Global Sea Levels

Mörner (2007[a]) is explicit is this assertion. He speaks of a maximum rising trend in global sea levels of 1.1 mm/yr from 1850-1930 followed by a fall. The net result is, in his words, "*absolutely no trend"*. He notes that tide gauging is very complicated, giving different answers wherever one might be in the world, thus necessitating the use of geological information for a correct interpretation of the results. There is no dispute with this comment. Not only are different regions of the world subject to different levels of glacio-isostatic adjustment (GIA) following earlier ice ages but local tide gauges can be subject to local subsidence due to ground water withdrawal or sediment compaction, and also to differing levels of tectonic deformation. These effects are well known and are fully described in Hannah, (2010). Indeed, there are many other errors that can subtley influence a tide gauge record (e.g., unrecorded datum offsets), that Professor Mörner does not mention and that can befar more important to a correct interpretation of a tide gauge record.Indeed, Professor

Mörner seems to be completely unaware of the techniques surveyors use to monitor the stability of a tide gauge datum.

When all these effects are appropriately considered, the observational data from a global set of reliable tide gauges will provide an unambiguous answer to the issue of global sea level trends over the 20th Century. Douglas (1997), using 24 long tide-gauge records and Tushingham and Peltier's (1991) GIA model estimated global sea levels to be rising at a rate of 1.8 ± 0.1 mm/yr. Peltier (2001), using essentially the same tide gauge set plus a more recent GIA model estimated the rise to be 1.84 – 1.91 mm/yr. Importantly, these are the very systematic effects that Mörner himself advocates as necessary for correcting tide gauge data.

Church and White (2011), using a "reconstruction" method on a sea level data set that extended from 1880-2009, determined a global sea level trend of 1.6 mm/yr when the data was weighted by its uncertainty estimates (a statistically correct procedure). Jevrejeva et al (2013), using a global set of 1227 tide gauge records, taken in 14 ocean basins/regional blocks, calculate a linear sea level trend of 1.9 ± 0.3 mm/yr for the 20th century. They note, however, that the choice of GIA correction is crucial to the result, having the ability to alter the global trend by 0.3-0.6 mm/yr. In New Zealand's case the observational data are unambiguous in revealing a non GIA corrected estimate of sea level rise since 1900 of 1.7 ± 0.1 mm/yr and a GIA corrected estimate of 2.1 mm/yr (Hannah, 2004; Hannah and Bell, 2012). In arriving at these figures, all factors have been considered, including any possibility of tide gauge subsidence.

Irrespective of the analysis method used, the data set, and the researcher, the outcome is the same, namely, that contrary to Professor Mörner's assertions, global sea levels have been rising consistently throughout the 20th Century at an average linear rate in the order of 1.8 mm/yr – a rate that Mörner (2010) opines (incorrectly), is largely due to tide gauge subsidence.

3.2 Assertion 2: The Results from Satellite Altimetry Data have been Fudged

While satellite altimeters have been in use since the 1980s, high precision altimetry began with the launch of Topex/Poseidon in 1992 and its successors Jason-1 (2001) and Jason-2(2008). It is the data from these last three missions that is used in the analysis of sea level change.

While it is difficult to fully understand the nature of the problem being identified inMörner (2007[a]), it becomes clearer both in Mörner (2003) and in the subsequent discussions found in Nerem et al, (2007) , and Mörner (2007[b]). In essence, Mörner starts from the premise that his view of global sea level rise, as outlined in Sec 3.1 is correct and that any contradictory evidence is incorrect. He thus dismisses the work of Douglas (1991, 1995, and 1997) as being "*widely debated and far from generally accepted*" (Mörner, 2007[b]). Unfortunately he is incorrect on both issues in that Douglas'work has been shown to be both robust, and has also been widely accepted, even by other paleogeophysicists (e.g., Peltier, 2001). Thus when sea level data from a global tide gauge network is used to calibrate the satellite altimeter data (as

is the case), Mörner dismisses the subsequent altimeter results as having been fudged.

In reality, Mörner 's concerns are refuted in Nerem et al (2007). In addition, the process of calibrating a satellite alimeter is described at *www.psmsl.org/train_and_info/training/gloss/gb/gb1/alt_cal.html*), whilst the creation of a single uniform altimeter data set from the various satellite altimeter missions is described in Leuliette et al, (2004) and Beckley et al, (2010). Both processes are open and transparent. Furthermore, Meyssignac and Cazenave (2012), show the full altimetry based mean sea level data set superimposed upon the 20th century mean sea level data set. Crucially, both data sets show an almost linear rise in sea level over the entire altimetry time period (1993-2010) with the altimetry data revealing a 3.2 ± 0.5 mm/yr rise over those years.

3.3 Assertion 3: Sea Levels in the Maldives Fell 20-30 cm in the 30 years Prior to 2004

This claim can be found in Mörner et al (2004) and is used as evidence to support his contention that global sea levels are not rising. Fortunately this claim, which is based upon an interpretation of morphological and sedimentological data, is made in a peer reviewed paper and thus is open to much wider scientific scrutiny than publications such as Mörner (2007[a]) or Mörner (2010). Mörner himself notes that a rate of change of 10 mm/yr in sea level is *"most surprising"*, attributing this fall to *"a regional eustatic change* ***confined***[my emphasis]*, to the central Indian ocean"*. This fall is attributed to the effect of increased evaporation. The objections to Mörner et al's comments are multiple.

Firstly, if the sea level fall were actually real, Mörner has already conceded that it can only be a localised regional effect. In that case, it cannot be used as the basis for any statement regarding global sea level change.

Secondly, Woodworth (2005), after examining a number of met-ocean data sets and regional climate indicies, at least one of which would have been expected to reflect a large sea level fall, could find no supporting evidence for such a fall. He not only concluded that such a fall was, *"implausible"* but that the suggestion that it could have been caused by an increase in evaporation was demonstrably incorrect.

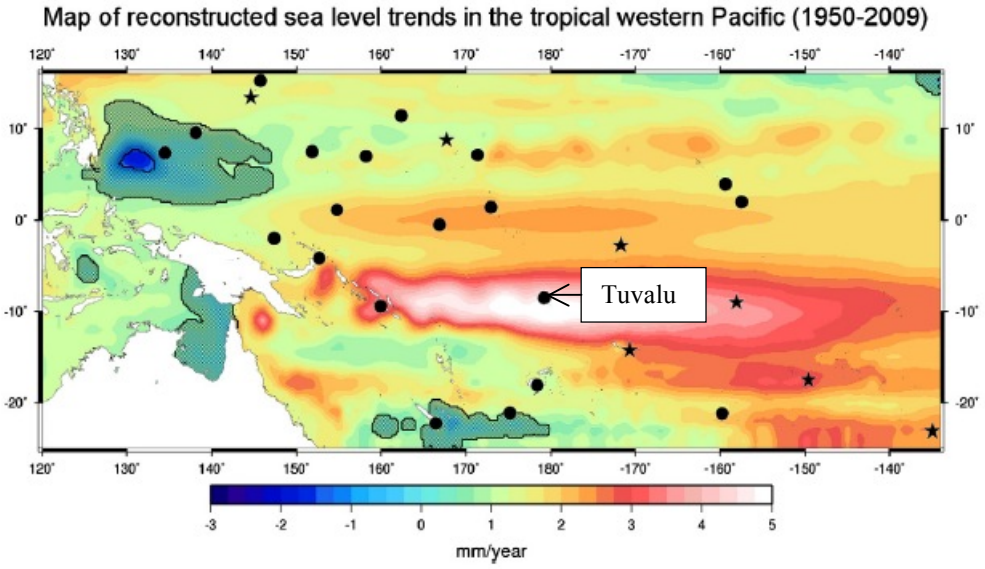
Thirdly, Kench et al (2004), challenge the correctness both of Mörner et al's interpretations and the conclusions drawn from their morphological evidence. Mörner and Tooley (2005) seek to reply to these challenges but are unable to do so in any detail, substantially falling back on the argument that all will be revealed in future presentations of their observational material. Such material, together with peer review assessments as to its accuracy, have yet to appear.

3.4 Assertion 4: There is no Rise in Sea Level at the Tuvalu Islands

As with the Maldives, this claim is made as supporting evidence that global sea levels are not rising. In Mörner's words,*"There is absolutely no signal that the sea level is rising"*.

The first response to this assertion is, ”so what?” As Professor Mörner should well know, the Tavalu Islands are located close to anactive and complex plate tectonic zone where vertical crustal deformation is likely. Until there is a history of tide gauge data coupled with continuous GPS data at the same site, any eustatic rise or fall in sea level here will be uncertain. These tectonic issues are the very factors that he himself promotes as being crucial to the interpretation of the sea level record.

However, putting this issue aside, Becker et al (2012) have examined in detail sea level variations in the tropical Pacific islands since 1950. By reconstructing the sea level record from 1950-2009 through the use of good quality tide gauge records and gridded heights an Ocean General Circulaton Model, they find that sea level has risen at Tavalu at a rate of approximately 5.1 ± 0.7 mm/yr over the period 1950-2009. Unlike Professor Mörner’s analysis, this result takes full cogniscance of the known periodic effects such as the 2-4 year ENSO effect and the 20-30yr Interdecadal Pacific Osillation (IPO). The reconstructed sea level trends for the trpoical western Pacific taken from Becker et al (2012), are shown below.



3.5 The Broader Picture

It is important to note that Professor Mörner typically chooses to make his assertions in non-peer reviewed publications, clearly being unwilling to allow his words to be subject to critical srcutiny from those in science community who have a technical understandingof the issues he raises. This is nowhere more apparent than in Mörner (2010) – a document that is more explicit in its critisms than Mörner (2007[a]). In this more recent document, he not only substantially fails to address the criticisms of his work raised in Secs 3.1 – 3.4, but he introduces new inaccuracies. He states for example, that local sedimentary ground changes cannot be recorded – ignoring the fact that many world tide gauge sites have been precisely monitored for well over 100 years using leveling techniques, and by GPS measurement techniques for at least a decade (e.g.,Wöppelmann et al, 2009,Santamaría-Gómez et al, 2012).

Furthermore, he introduces his owninterpretation of the Cuxhaven tide gauge record – an interpretation that is significantly affected by an oldeustatic sea level change model of his own making published in Mörner (1973).

Professor Mörner's writings indicate that he is an advocate of the theory that there is a global conspiracy amongst many of the world's scientists aimed towards confusing and deluding the unsuspecting public. Their supposed motivation – a desire to obtain and/or retain their research grants (Mörner, 2007[a]). In Mörner (2010), he further accuses scientists as being driven by a hidden 23 year old Intergovernmental Panel on Climate Change (IPCC) agenda that specifies what tide gauges in a global network should be selected for analysis. Having been associated with the first three IPCC assessment reports, the author of this paper can testify personally that this is a delusion of the highest order. Furthermore, the author has no research grants that hinge upon climate change and no vested interests in any particular outcome of this discussion, beyond seeing truth prevail.

It would thus seem that Lord Monckton's inaccurate claims of Professor Mörner's capability and status are matched by the failings in Professor Mörner's own writings. It is unfortunate that together they have become the source of mis-information to many.

4. FUTURE SEA LEVEL CHANGE

If there is a point at which the author and Professor Mörner are likely to agree, it is in the difficulty of assessing a most likely sea level rise scenario for the future. Clearly, some predictions have been alarmist in nature and not based upon strong science. However, as the science has improved so has the understanding of likely future sea level rise. It is now understood, for example, that while a global sea level rise scenario can be determined, it is likely that there will continue to be significant regional variations for periods of a decade or more, most likely due to changes in trade winds and other forcing factors (IPCC, 2013). Equally, vertical land motion due to local subsidence, GIA, or other tectonic factors will also have a marked influence. Fortunately, GPS techniques now allow such land motion to be measured in a global reference frame with a high degree of confidence.

While these factors must be recognised as being of potential influencein any local or regional future sea level rise scenario, a realistic estimate for a global sea level change scenario is still of importance.

Any future assessment of sea level change rests heavily upon the extent to which climate changes – change that is estimated through the use of climate models. These models produce a wide range of possible outcomes depending upon the various forcing factors used – factors that in turn depend upon assumptions relating to industrial growth, greenhouse gas emissions, deforestation, the impact of clouds, and human response (amongst other things).

IPCC (2013) provides a number of climate change model scenarios derived from the concentration-driven CMIP5 model simulations. The different model simulations produce temperature change scenarios that are then combined with process based models and a

literature assessment of glacier and ice sheet contributions to produce associated sea level change scenarios. These results are shown in Table 1. While higher projections for sea level rise than are shown inthe table have been mooted, the IPCC considers that there is insufficient evidence to evaluate the probability of specifc levels above the ranges shown. There remains a lack of consensus and low confidence in the semi-empirical model projections.

Table 1. Projected change in global mean surface air temperature and global mean sea level rise for the mid- and late 21st century relative to the reference period of 1986–2005, taken from IPCC(2013)

		2046-2065		2081-2100	
	Scenario	**Mean**	***Likely* range**	**Mean**	***Likely* range**
Global Mean Surface Temperature Change (ºC)	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range**	**Mean**	***Likely* range**
Global Mean Sea Level Rise (m)	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Given a mean reference period date of 1995, and an assumed rise in sea level of about 3 mm/yr since then (i.e., 0.05 m to the present day), a reasonable planning range for sea level rise to 2090 from the present day is between 0.21 m and 0.77 m (i.e., 0.26–0.05 m and 0.82-0.05 m).

In deriving a sea level change scenario for a particular region, one needs to take the global figures given above and correct them for any ground motion derived from local precise leveling and GPS tide gauge monitoring data. In New Zealand, for example, where most of the country has exhibited a general tectonic stability over the last 100 years (the Wellington region excluded), and where the local rates of sea level rise almost exactly match the global average, these numbers can be used directly.

5. CONCLUSIONS

The assertionsof the two vocal climate change sceptics Lord Monckton and Professor Mörner, at least with regard to sea level rise, have been fully refuted. Unlike the ocean basins, their arguments do not hold water and should thus be discarded.

Global oceans have been rising at a linear rate of approximately 1.8 mm/yr throughout the 20th century with satellite altimetry data indicating an increase in rate to 3.2 ± 0.5 mm/yr from 1993-2009. While there remains some debate as to whether or not this increase is permanent or whether that it reflects some periodic oceanic signal,or whether there has been an acceleration in the rate of sea level rise over the last few decades, best future sea level rise scenarios indicate a likely rise in global sea levels of between 0.26 m and 0.82 m, relative to

1986-2005 by 2081-2100.

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BIOGRAPHICAL NOTES

John Hannah completed his BSc (Surveying) in 1970, a Post Graduate Diploma of Science in 1971, and became a Registered Surveyor in New Zealand in 1974. He subsequently completed an MSc and PhD at The Ohio State University. From 1982 -1988 he was employed by the Dept. of Lands & Survey, New Zealand, as a Geodetic Scientist and then as Chief Geodesist/Chief Research Officer. After an appointment to the Chair in Mapping, Charting and Geodesy at the US Naval Postgraduate School, California in 1989-1990, he returned to New Zealand as Director of Geodesy and then Director of Photogrammetry for the Dept. of Survey and Land Information. In 1993 he joined the School of Surveying at the University of Otago as Professor and Head of Department. He became the School's Dean in 2001, relinquishing this role at the end of 2004. From 2005-2007 he was President of the NZ Institute of Surveyors. Upon his retirement from the University of Otago in 2012 he was appointed an Emeritus Professor. He is currently the Managing Director of his own consultancy, Vision NZ Ltd. He is Chair of the FIG Task Force on Climate Change and is on the Council of Standards New Zealand.

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