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Is the sea level accelerating in the Marshall Islands? Pacific atolls are subject to subsidy

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ABSTRACT

It is shown that the sea level rate of rise is different in the two islands of Kwajalein and Majuro, located in the two atolls of Kwajalein and Majuro, in the Republic of the Marshall Islands. Kwajalein has a rate of rise of about 2 mm/year, up from a prior 1.4 mm/year, while Majuro has a rate of rise exceeding 3.6 mm/year about constant. The difference in the rates of rises and their recent changes are more likely explained by differential subsidy in space time at a higher rate especially in Kwajalein from the 2000s than by global warming thermal expansion of the oceans.

KEYWORDS

Sea level rise;
Sea level acceleration;
Land motion.

INTRODUCTION

The Marshall Islands are very close to sea level and the Marshall Islands Government is very concerned with the issue of global warming[1]. The Marshall Islands are often referred to as one of the front line state with regard to global warming. The Marshall Islands comprise approximately 1225 islets in 29 atolls, scattered over 2 million square kilometres, of average height above sea level 2 meters. Fragile coral reefs fringe the atolls serving as the only line of defence against the ocean surge. The clearance over the reef in the sections that are covered by water is usually no more than 60 centimetres and in other places the reef is only barely submerged.

Recently, the sea level graph from Kwajalein has been recently circulated to show an alarming acceleration of a proposed general sea level rise. The graph of Figure 1 (from[2]) shows oscillations about a long term trend rate of rise The mean sea level trend is 1.43 mm/year with a 95% confidence interval of +/- 0.81 mm/year based on monthly mean sea level data from 1946 to 2006. It is claimed that there is a clear departure from the linear trend from about the 2006.

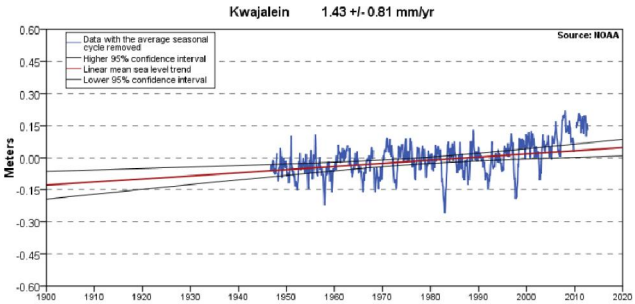

Figure 1 : Mean sea level measured in Kwajalein (from[2])

As commented in[3], the nearby Majuro has a composite record of 2 tide gauges suggesting a regularly oscillating sea level without too much of acceleration. The mean sea level trend of 3.60 mm/year with a 95%

confidence interval of +/- 1.22 mm/year based on monthly mean sea level data from 1968 to 2011. The graph of Majuro (from[4]) is presented in Figure 2.

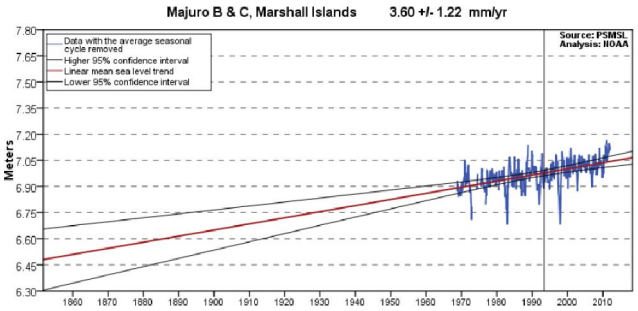

Figure 2 : Mean sea level measured in Majuro (from[4])

It is suggested in[3] that Kwajalein may be affected by a local subsidence or some sea level "correction" in order to have the rate of rise going up. The debate is still open, with two sides equally strongly supporting a claim the sea level is locally accelerating or it is not accelerating at all. The present contribution tries to give a conclusive statement about the rate of rise of sea level in the Marshall Islands introducing further data.

MORE DATA ARE NEEDED TO UNDERSTAND THE SEA LEVEL BEHAVIOUR

The uncertainty in determining the presence or the absence of a sea level acceleration in Majuro and Kwajalein is the result of the focus on a single information, the sea level measured by the tide gauges, without considering all the others information that may be available to further clarify. The selective focus on just a small frame of the big picture is unfortunately a common practice these days where very strong statements are made without really trying to understand the ocean behaviour.

The Permanent Service on Mean Sea Level presents the monthly (and yearly) average mean sea levels for Majuro and Kwajalein, but also additional information that may prove to be essential for better understanding[5-7].

For Kwajalein[5], the nearby GPS data[8] clearly shows a stable trend 1996 to 2000, and then a sharp decrease especially about 2002, as it is shown in Figure 3. It is possibly that this subsidy is responsible of the higher rate of rise of sea level of Figure 1 n the recent years.

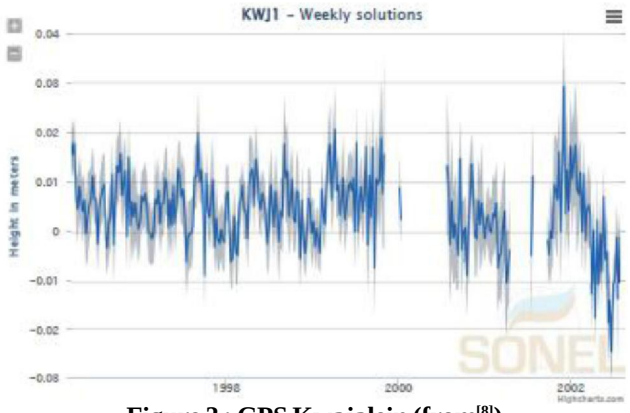

Figure 3 : GPS Kwajalein (from[8])

For Majuro[6,7], the nearby GPS data[9] in figure 4 does not show any sharp departure in the measured GPS with the height that is however slightly reducing over the years 2007 – 2011.

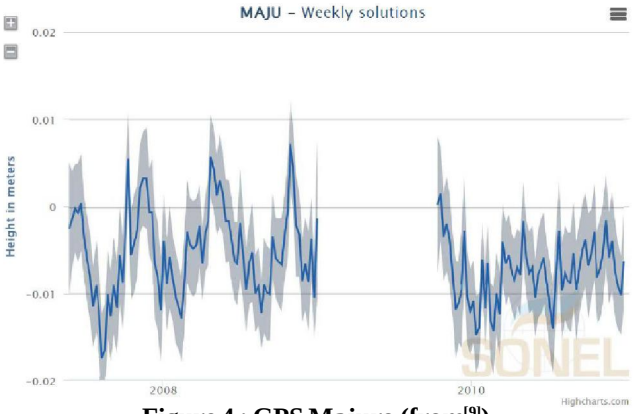

Figure 4 : GPS Majuro (from[9]).

The data of Figures 1 to 4 are everything but conclusive, because sea level trends cannot be inferred from consideration of less than 60-70 years of high quality data. Phenomena like subsidence or change of the instrument or change of the location of the tide gauge or damage of the instruments by storms or hurricanes are factors affecting the quality of the measurements that are often neglected.

The GPS data are unfortunately very scattered. The tide gauge data are short, especially in Majuro C, but with two different tide gauges Majuro B and C it is possible to produce a reasonably long composite tide gauge. Information on biasing factors is minimal. However, collecting trends from the tide gauge and the GPS data "as they are", as it is shown in Figures 5 to 8 it seems that the differential subsidy in space and time of Kwajalein and Majuro is the responsible of the apparent acceleration in the Kwajalein tide gauge.

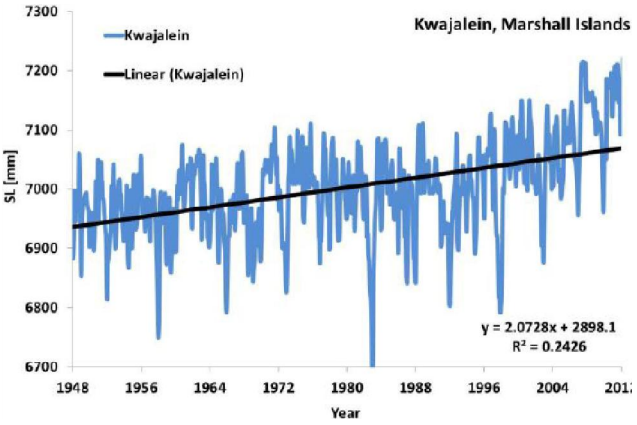

Figure 5 : MSL trend kwajalein

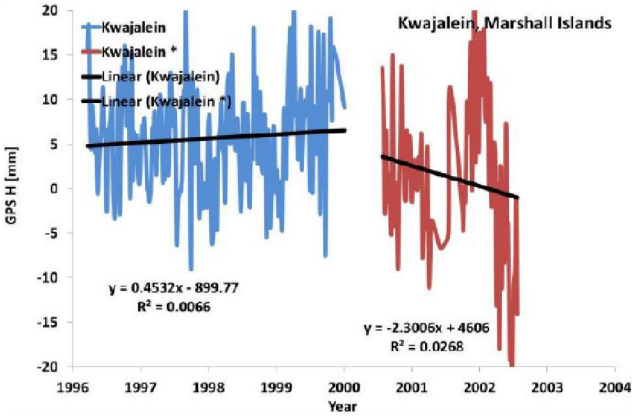

Figure 6 : GPS trend Kwajalein

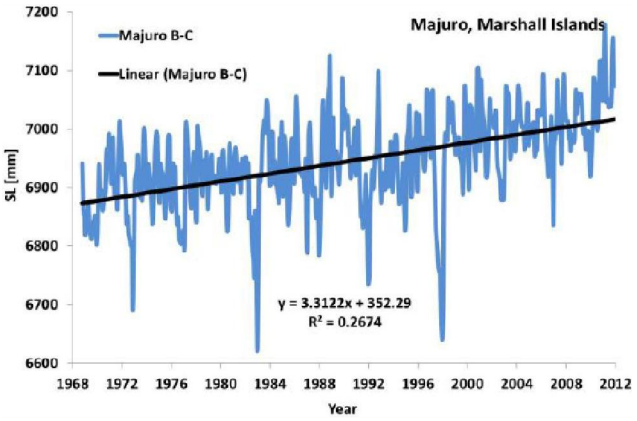

Figure 7 : MSL trend majuro

From 1996 to 2000, the average GPS H in Kwajalein was 5.64 mm while it was 1.26 mm during the period 2001 to 2002. This indicates a huge subsidy in Kwajalein. This is possibly due to huge constructions on the coral atoll starting about the year 2000. The time variation of the rate of subsidy is biasing the tide gauge result towards a positive acceleration. Before the year 2000, the subsidy seems minimal, and this is the reason of the low rate of rise of sea level.

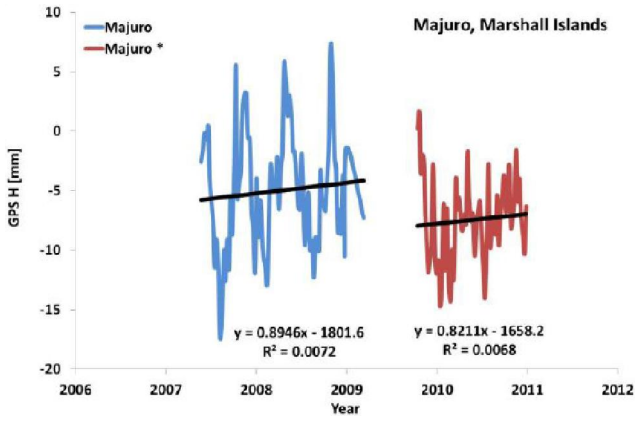

Figure 8 : GPS trend majuro

In Majuro, during the period 2007 to 2009 the average GPS H was -5.08 mm, while in 2010 it is -7.47 mm. The lack of further data only permits to guess a more constant subsidy in Majuro.

A better determination of the subsidy in Majuro and Kwajalein is difficult from these pictures because the data are certainly not enough and not exactly collected in the same locations of the tide gauges.

DISCUSSION

Majuro is an atoll, as an atoll is Kwajalein. Well before the onset of the global warming debate, Charles Darwin[10] explained the creation of coral atolls in the Pacific Ocean based upon observations made during a five-year voyage aboard the HMS Beagle as a sequence of gradual subsidence of what started as an oceanic volcano through barrier reef island to atoll. Therefore, it is not a novelty that atolls are subject to subsidy, even if many forgot. This subsidy is the main reason why some atolls of the Pacific have rates of rise of sea levels as measured by tide gauges higher than in other islands or along the continental coast of North America or Australia[11-14].

Majuro is a large coral atoll of 64 islands. The tide gauges B and C as well as the GPS are located in a narrow land mass accommodating the most part of the population of the Republic of the Marshall Islands and it has a port, a shopping district, hotels, and an international airport. As it seems from Figures 7 and 8, the subsidy is about constant in the limit of the few years of data available and possibly accounting up to about one third of the 3.3 mm/year of sea level rise measured by the subsiding tide gauge.

Kwajalein is another atoll, with the island of Kwajalein the southernmost and largest island in the atoll. While Kwajalein island is occupied by a large and heavily fortified US military base, the most part of the population of the atoll lives on Ebeye Island. As it seems from Figures 5 and 6, also in the limits of the few years of GPS data available, the subsidy of Kwajalein was much less than the subsidy in Majuro in the past, and possibly because of heavy constructions, the subsidy significantly increased in the 2000s.

The subsidy of the Pacific atoll tide gauges is very well known[15]. The South Pacific Sea Level and Climate Monitoring Project recognize that precise levelling of the tide gauge is needed to clear the rate of rise of sea level from the vertical motion of the land. A substantial subsidence is acknowledged for the Majuro tide gauge[15]. Considering the South Pacific Sea Level and Climate Monitoring Project openly overestimate the rate of rise of sea levels (the project was started early 1990s about a valley of the multi decadal oscillations but estimations of the rate of rise of sea levels were made even before 10 years of data were recorded without any mention of the unreliability of the short term estimate), the actual subsidence of the Majuro tide gauge is very likely much larger than what is reported in[15].

CONCLUSIONS

Since 1842 it is accepted that atolls may have subsidy, and this subsidy may certainly increase with heavy constructions.

It is unlikely that the sea level is accelerating in Kwajalein and it is not accelerating in Majuro because of global warming.

The tide gauges of Majuro and Kwajalein are more likely affected by subsidence of increasing magnitude over the 200s especially in Kwajalein.

Monitoring projects should not be sponsored by governments to prove that global warming has huge effects but to provide the accurate measurements of climate parameters needed to better assess the presence or the absence of present accelerations of sea levels.

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