SOUTH PACIFIC SEA LEVEL: A REASSESSMENT

Vincent R Gray
Climate Consultant

75 Silverstream Road, Crofton Downs, Wellington 6035, New Zealand
Email vinmary.gray@paradise.net.nz

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ABSTRACT

The individual sea level records obtained from the SEAFRAME study on 12 Pacific Islands have all been assessed by the anonymous authors of the official reports as indicating positive trends in sea level over all 12 Pacific Islands involved since the study began in 1993. This assessment studies individual records and finds that all of them show no change of sea level in almost all of the records following the 1998 cyclones.It is considered that cyclones and tsunamis not only induce false readings which should be ignored when calculating a trend, but they also disrupt the leveling of the equipment so that previous years' figures should also not form part of a trend.

1. INTRODUCTION

The following **Introduction** appears in each individual Report (1)

The South Pacific Sea Level and Climate Monitoring Project (SPSLCMP) was developed in 1991 as an Australian Government response to concerns raised by member countries of the South Pacific Forum over the potential impacts of human-induced global warming on climate and sea levels in the Pacific region.

The Project has been running for over 14 years and is now in its fourth phase, which commenced on 1 January 2006 and is due to end on 31 December 2010.

The first three phases of the project established a network of 12 high resolution SEAFRAME (Sea Level Fine Resolution Acoustic Measuring Equipment) sea level and climate monitoring stations throughout the Pacific. These stations are sited at locations in participating countries (Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu) and provide a wide coverage across the Southwest Pacific basin. All of the stations, with the exception of the one located at Pohnpei (FSM), which was established in December 2001, have been operational since October 1994.

A major new initiative in this Phase was the installation of a Continuous Global Positioning System (CGPS) network linked to the SEAFRAME sites and managed by Geoscience Australia. The CGPS network is designed to monitor vertical movement of the gauges and help determine absolute sea level. Ten of the 12 CGPS stations planned were installed. During this Phase the NTFA became a part of the Australian Bureau of Meteorology and was renamed the National Tidal Centre (NTC), with its offices collocated with the Bureau's South Australian Regional Office in Adelaide.

The SEAFRAME equipment is shown in Figure 1.

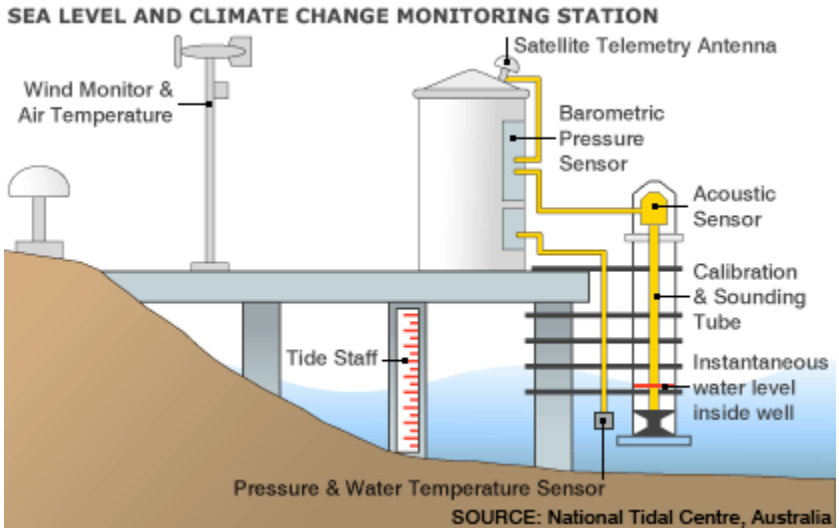

Figure 1. SEAFRAME equipment

Further details are on their website (2) and a summary paper was prepared by Hall (3) There are 14 annual reports, for 2007 for each Pacific Island site (1)

This paper is based on the information supplied by Hall's paper and by each of the 14 2007 reports.

1.1 GENERAL

This project is undoubtedly the most modern and sophisticated attempt to monitor sea level and other climate variables and the reports give impressive details on the equipment and procedures. The actual data on sea level measurement are not described fully. They must evidently have been averaged over each entire month in some way, for the original data are presented in each island report in the form of charts showing the maximum, minimum and mean monthly averages since the beginning of the SEAFRAME installations.

All of the reports have a Disclaimer which states that the views expressed are those of the authors and are not necessarily those of the Australian Agency for International Development (AusAID). The names of the authors are, however, not disclosed.

The reports also provide charts of previous sea level measurements over many pf the Pacific islands, but this report will assess only the most recent and accurate figures from the SEAFRAME charts.

It is immediately evident that these charts do not have a very prominent place in the reports. None are shown in Hall's summary report (3) and in each island report (1) they only appear towards the end. The earlier part of each report gives information from the processing of the actual records, with emphasis on determining the trends, and the anomalies. Graphs showing the anomalies and relative trends from all the islands are present in every report whereas only the actual data from that island are given in each island report.

1.2 ACCURACY

Sea level measurements are notoriously inaccurate. I have repeatedly complained to the IPCC that thei figures quoted in the earlier IPCC Reports include only one standard error, a confidence interval of only two in three, instead of the usual 95% interval of two standard errors. In these reports all figures are quoted without any confidence intervals, so we are not told how accurate they are. I quote here one section from every report which deals with the matter as follows:

Sea level in the Pacific Forum region undergoes large inter-annual and decadal variations due to dynamic oceanographic and climatic effects such as El Niño. Such variability or 'noise' affects estimates of the underlying long-term trend. In general, more precise sea level trend estimates are obtained from longer sea level records as is shown in Figure 6. Sea level records of less than 25 years are thought to be too short for obtaining reliable sea level trend estimates. A confidence interval or precision of 1 mm/year should be obtainable at most stations with 50-60 years of data on average, providing there is no acceleration in sea level change, vertical motion of the tide gauge, or abrupt shifts in trend due to tectonic events.

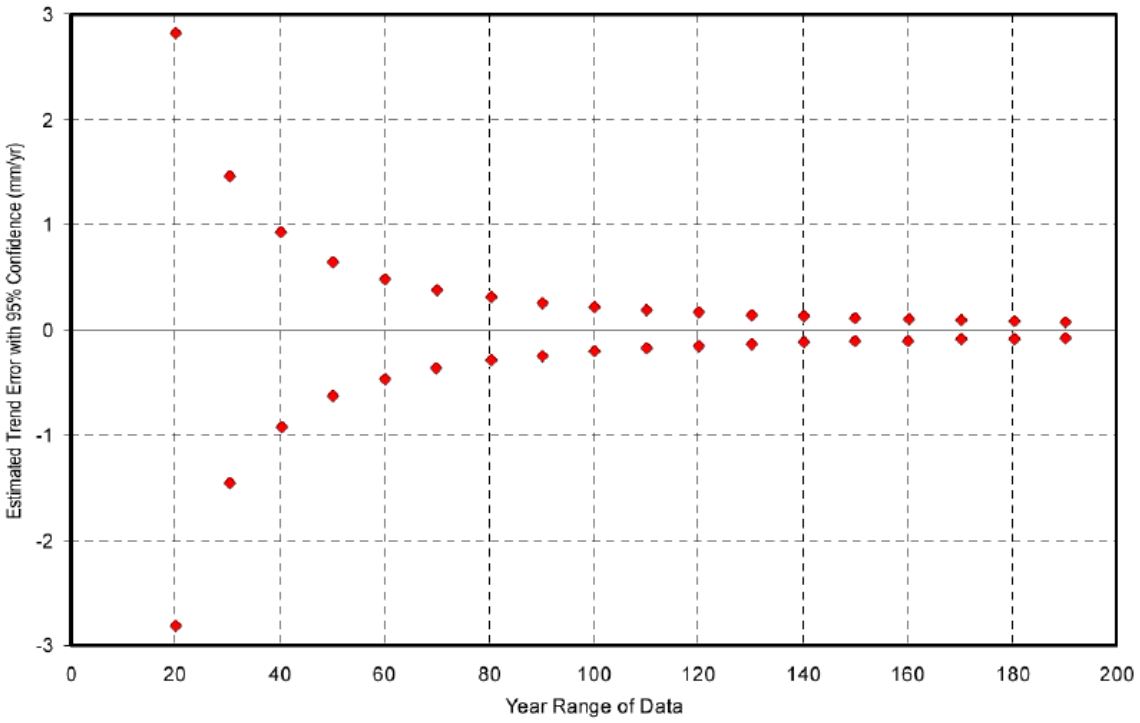

Figure 2. 95% Confidence Intervals for linear mean sea level trends (mm/year) plotted as a function of the year range of data. Based on NOAA tide gauges with at least 25 years of record, from (1) and Zervas, (4).

Figure 2 (4) tells us that any sea level sequence of less than 20 years has a 95% confidence interval for any calculated trend of more than ±3mm/yr. This means that most of the figures quoted in these reports are extremely unreliable and the stated trends have very large confidence intervals, which in many cases exceed the mean figure. For this reason I have not attempted to obtain original figures from any of the diagrams to determine an accurate linear regression trend, but have assessed them purely by eye, a

procedure that is justified from the above analysis. My assessments are also subject to considerable, unknown, inaccuracy.

There is also the question of whether a linear trend of any duration could ever have meaning when derived from irregular climate data.

This study is an assessment of the original data by comparison with the deductions and conclusions that are drawn from them in the early part of each report.

The reports will be examined in the order in which they appear on the website.

2. THE ISLANDS

2.1 THE COOK ISLANDS.

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Rarotonga, Cook Islands, in February 1993. The site is at Avatiu on the North Coast.*

●*The sea level trend to date is +4.8 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +4.9 mm/year. Nearby gauges, with longer records but less precision and datum control, show trends of +4.34 and +1.69 mm/year.*
● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *In October-November 1997 Tropical Cyclone Martin devastated the northern Cook Islands. In December 1997 Tropical Cyclone Pam passed Rarotonga as a category 2 cyclone and caused high sea levels and flooding.*

● *The SEAFRAME at Rarotonga, Cook Islands has recorded 12 separate tsunami events since its installation. The largest tsunami signal was recorded after an earthquake of magnitude Mw8.3 that occurred near the Kuril Islands on 15 November 2006. The trough-to-peak tsunami height was 40cm for the 1-minute sea level data, or 17cm for 6-minute sea*

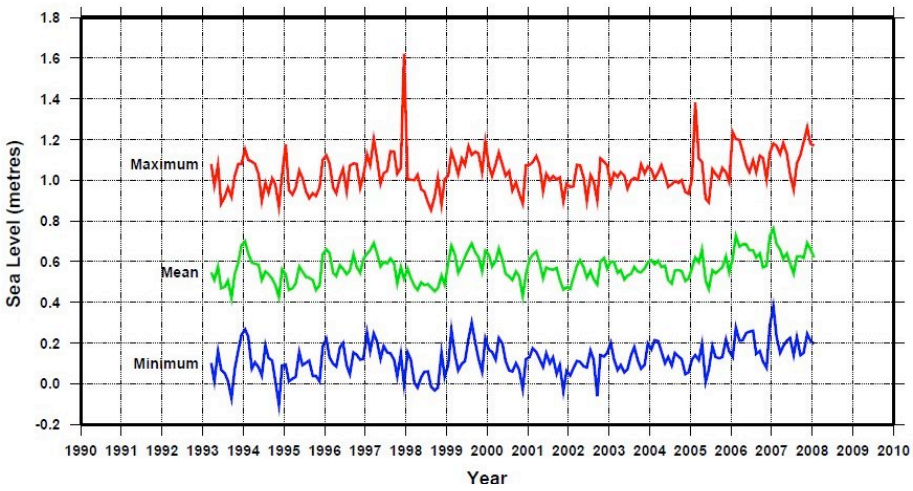

Figure 3 Monthly sea level figures from SEAFRAME at Avatiu .

2.1.1 COMMENTS

There is no overall trend since 1994 despite the depression caused by the 1998 cyclone, an unexplained depression in 2001 and the 20007 peak resulting from the tsunami in November 2006.

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2.2 FEDERATED STATES OF MICRONESIA

The **Executive Summary** states:

A SEAFRAME gauge was installed in Pohnpei, FSM, in December 2001.

Pohnpei "upon (*pohn*) a stone altar (*pei*)" (formerly known as **Ponape**) is the name of one of the four states in the Federated States of Micronesia (FSM), and among the Senyavin Islands (part of the larger Caroline Islands group). Palikir, the FSM's capital, is located on Pohnpei. Pohnpei International Airport (IATA code PNI) is located near Kolonia, on a small island named Deketik off the northern coast of the main island. The gauge itself is at Kolonia

● *It is too early to calculate a meaningful sea level trend from the Pohnpei SEAFRAME. Nearby gauges, with longer records but less precision and datum control, show trends of +1.78, –0.42, +1.46, +1.79 and +0.75 mm/year (as compared to a global average of 1-2 mm/year).*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *Since installation, no tropical cyclone has passed near enough to the Pohnpei gauge to have caused extreme low barometric pressure.*

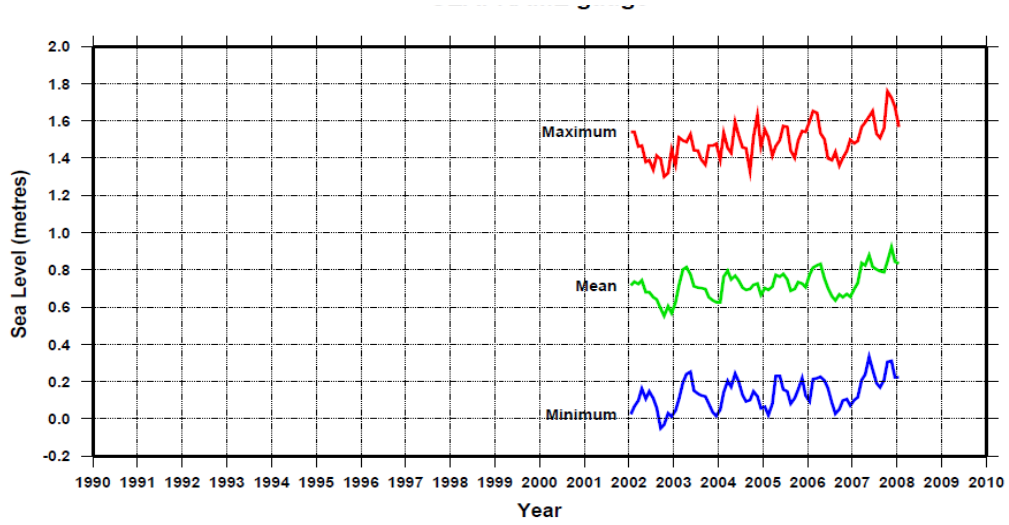

Figure 4. Monthly sea level record from SEAFRAME at Pohnpei, Federated States of Micronesia

2.2.1 COMMENTS

Between 2003 and 2007 there was no change. A slightly lower figure for 1992 and a slightly higher figure for 2008 cannot be regarded as establishing a trend. Despite this, Table 7 in the Report gives a preliminary figure for the trend in sea level at Pohnpei as 23.7mm/yr, corrected to 23.8mm/yr

2.3 FIJI

The **Executive Summary** states:

- *A SEAFRAME gauge was installed in Lautoka, Fiji, in October 1992.*

Lautoka is the second largest city of Fiji. It is in the west of the island of Viti Levu

● *The sea level trend to date is +3.5 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +2.9 mm/year. A nearby gauge, with longer records but less precision and datum control, shows a trend of +4. 7 mm/year.*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *In 1993, 1997 and 2003 tropical cyclones caused widespread devastation in Fiji, including the main islands Viti Levu and Vanua Levu. The 1993 and 1997 cyclones were recorded as extreme low pressures on the SEAFRAME.*

● *The SEAFRAME at Lautoka, Fiji has recorded 14 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 22 cm was recorded after an earthquake of magnitude Mw7.5 that occurred near Vanuatu on 26th November 1999.*

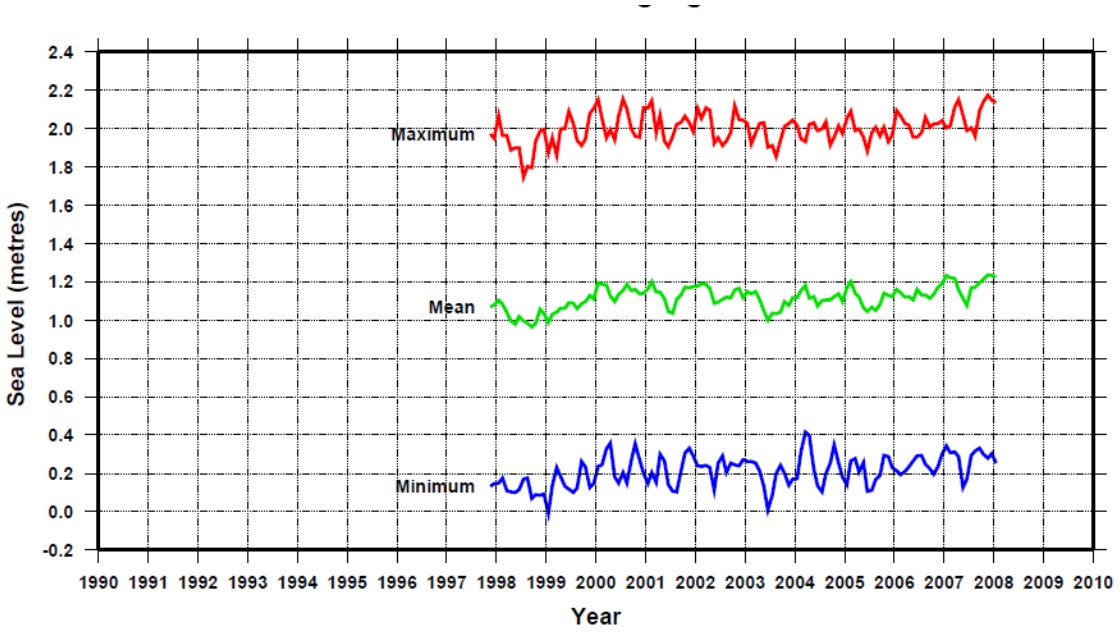

Figure 5. Monthly sea level record from SEAFRAME at Lautoka, Fiji

2.3.1 COMMENTS

Figure 4 gives the SEAFRAME record. There is no change between 2000 and halfway through 2007. A "long-term trend" of 3.5mm/yr has made use of slightly lower figures for the two early years, 1998 and 1999, which were influenced by El Niño and should not be used to conceal the stability of the next 7½ years.

2.4. KIRIBATI

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Betio, Tarawa, Kiribati, in December 1992.*

● *The sea level trend to date is +5.1 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +4.7 mm/year. Nearby gauges, with longer records but less precision and datum control, show trends of –3.78, 0.8, 3.15 and –0.43 mm/year.*

● *Variations in monthly mean sea level include a very small seasonal cycle and were affected by the 1997/1998 El Niño.*

● *The equatorial location of Tarawa means that it is not subject to tropical cyclones.*

● *The SEAFRAME at Kiribati has recorded 10 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 9 cm was recorded after an earthquake of magnitude Mw8.2 that occurred near Irian Jaya on 17th February 1996*

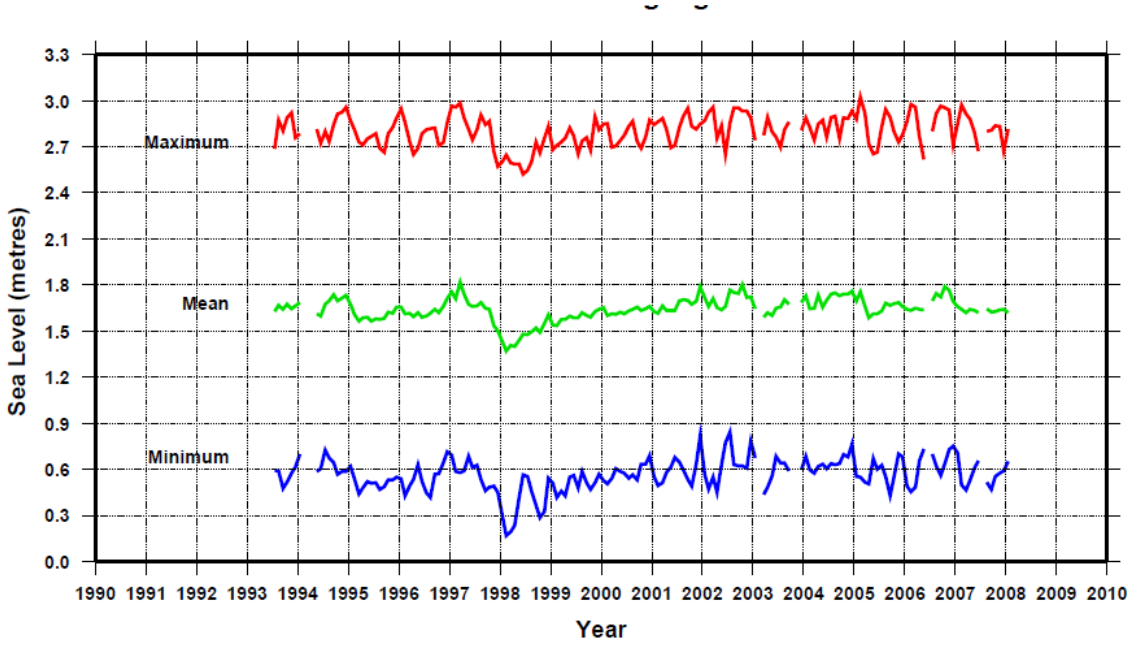

Figure 6. Monthly sea level record from SEAFRAME at Betio, Kiribati

2.4.1 COMMENTS

There was a depression in 1998 which was obviously caused by the El Niño event of that year. Otherwise there was no sea level change whatever between 1993 and 2008. 15 years. The claim that there was a "trend" of +5.1mm/yr is completely unjustified.

2.5. MARSHALL ISLANDS

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Majuro, Marshall Islands, in May 1993.*

Majuro, is the capital and largest city of the Republic of the Marshall Islands, built on the Majuro atoll

● *The sea level trend to date is +4.4 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +3.6 mm/year. Nearby gauges, with longer records but less precision and datum control, show trends of +2.3, +1.3, and +1.3 mm/year.*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *Typhoon Paka passed the Marshall Islands on 10th December 1997 and caused around US$80 million (1997) in damage.*

● *The SEAFRAME at Majuro, Marshall Islands has recorded 12 separate tsunami events since its installation. The largest tsunami signal with trough-to-peak height of 11 cm was recorded after an earthquake of magnitude Mw8.3 that occurred near Kuril Islands on 4th October 1994.*

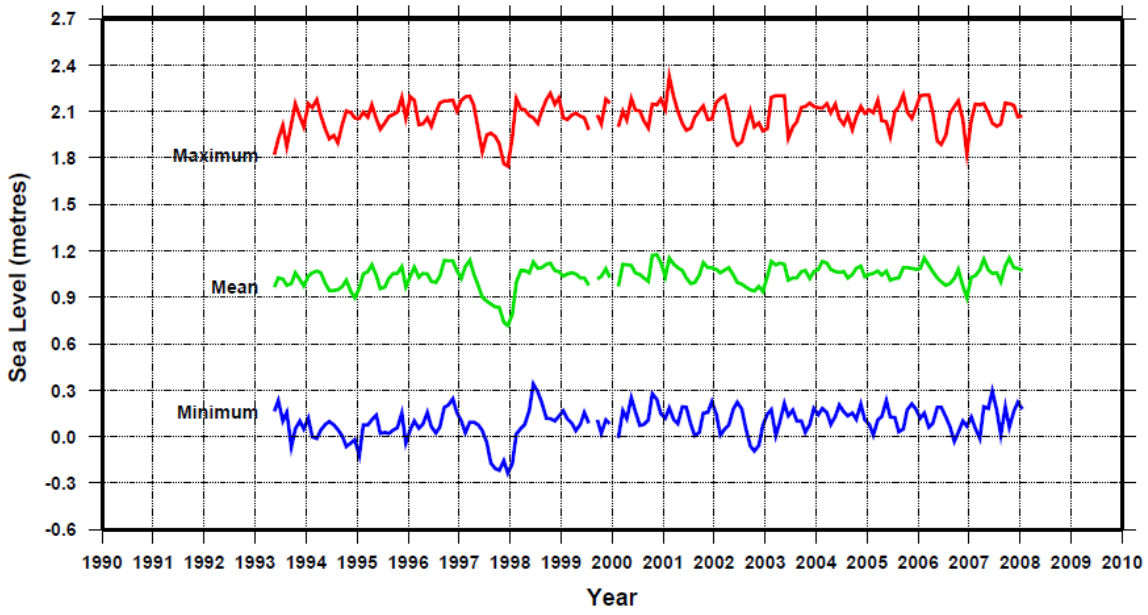

Figure 7. Monthly sea level record from SEAFRAME at Majuro, Marshall Islands

2.5.1 COMMENTS

If the 1998 depression, caused by the El Niño of that year, is ignored, the sea level at Majuro was unchanged from 1994 to 2008. 14 years. The slightly lower figure right at the beginning, 1993, does not justify a claim that there has been an upwards trend of 4.4mm/yr

2.6. NAURU

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Nauru, in July 1993.*

● *The sea level trend to date is +6.0 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +5.6 mm/year. A nearby gauge, with longer records but less precision and datum control, shows a trend of –0.42 mm/year.*

● *Variations in monthly mean sea level include a very small seasonal cycle and were affected by the 1997/1998 El Niño.*

● *The equatorial location of Nauru means that it is not subject to tropical cyclones.*

● *The SEAFRAME at Nauru has recorded 6 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 16 cm was recorded after an earthquake of magnitude Mw8.2 that occurred near Irian Jaya on 17th February 1996.*

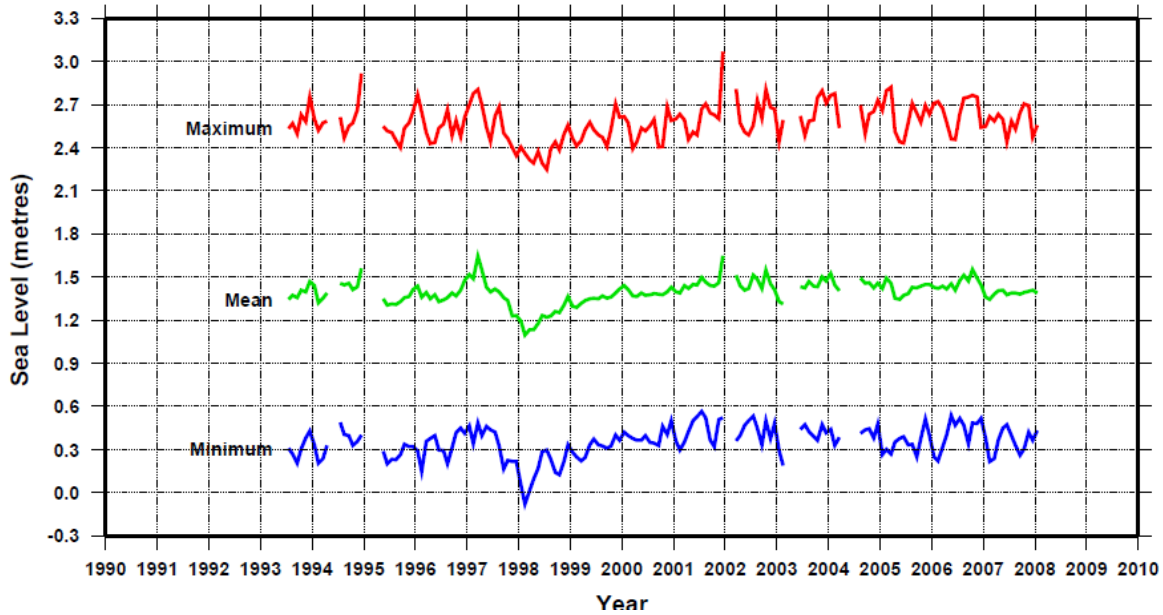

Figure 8. Monthly sea level record from SEAFRAME at Nauru

2.6.1. COMMENTS

Again, there was a depression in 1998 caused by El Niño of that year. A peak in 1997 is, however, unexplained. There was, however, no overall trend between 1993 and 2008, 15 years , and it is quite unjustified to claim an upwards trend of 6mm/yr over that period.

2.7., 2.8 NIUE, PALAU

These reports are ignored as they have no SEAFRAME installation, although Palau has something similar, but only just installed.

2.9.PAPUA NEW GUINEA

The **Executive Summary** states:

** A SEAFRAME sea level and climate monitoring unit was installed on Manus island,Papua New Guinea in September 1994. Manus Island is the largest island of the Admiralty islands. The site is Lombrum Point where there is an Australian war memorial.*

● *The sea level trend to date is +7.0 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the net trend is +5.3 mm/year.*

● *Variations in monthly mean sea level are dominated by seasonal cycles and were affected by the 1997/1998 El Niño. The seasonal cycle shows a peak early in the year*

● *Manus Island is protected from tropical cyclones by virtue of its proximity to the equator.*

● *The SEAFRAME at Manus, PNG has recorded 6 separate tsunami events since its installation. The tsunami that followed a magnitude Mw7.1 earthquake and underwater landslide on 17 July 1998 caused numerous deaths and widespread devastation near Aitape on the northern mainland*.

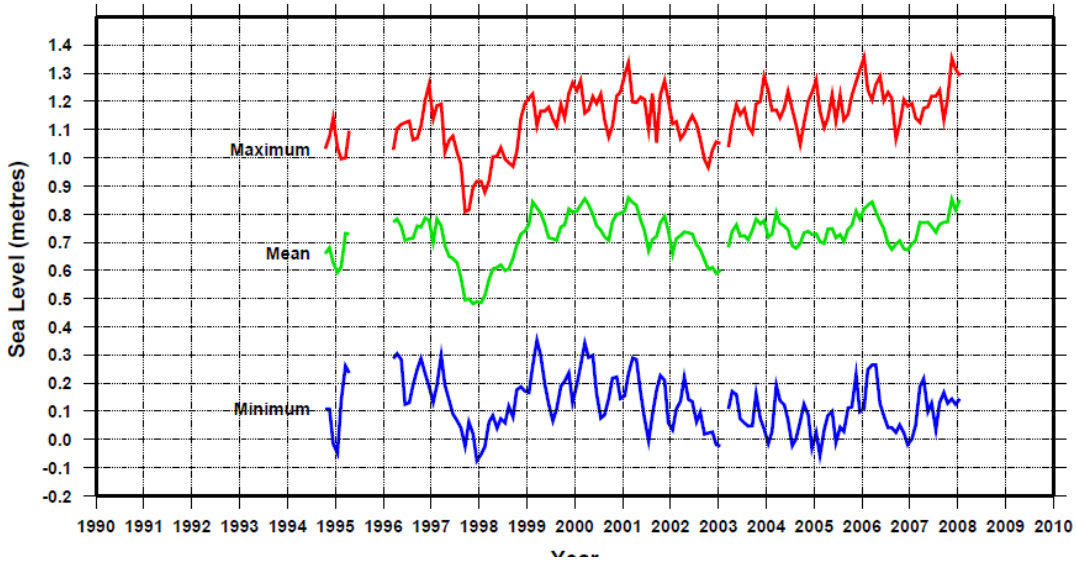

Figure 9. Monthly sea level record from SEAFRAME at Lombrum. Papua New Guinea

2.9.1.COMMENTS

Again there was a depression caused by the 1998 El Niño, but apart from that, there was no sea level change from 1995 to 2008, 13 years. A blip on the record in 1993 indicates teething troubles with the equipment which may explain similar early anomalies with several of the other records. A claim that this record shows an upwards trend of 7.0 mm/yr has no justification

2.10.SAMOA

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Apia, Samoa, in February 1993.*

● *The sea level trend to date is +6.3 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +4.9 mm/year. A nearby gauge, with longer records but less precision and datum control, shows a trend of +1.88 mm/year.*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *A number of Tropical Cyclones have passed near the Samoan Islands since the SEAFRAME was installed. Tropical Cyclone Heta caused widespread damage to Samoa in January 2004.*
● *The SEAFRAME at Apia, Samoa has recorded 18 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 57 cm was recorded after an earthquake of magnitude Mw8.3 that occurred near Kuril Islands on 15th November 2006.*

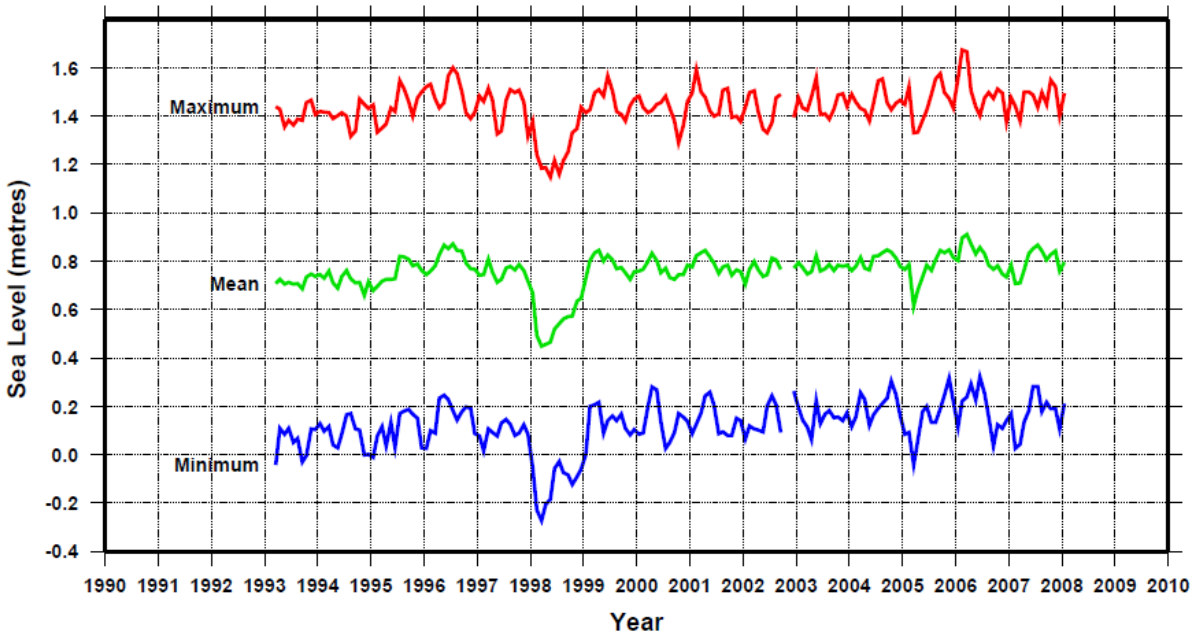

Figure 10. Monthly sea level record from SEAFRAME at Apia, Samoa

2.10.1.COMMENTS

The 1998 depression due to El Niño still features. There is no sea level change from1996 to 2008, 12 years. The period between 1993 and 1996, which was lower, but probably caused by displacement of the equipment by the cyclone, does not justify a claim that the whole period showed a “trend” of +6.3 mm/yr.

2.11. SOLOMON ISLANDS

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Honiara, Solomon Islands, in July 1994.*

● *The sea level trend to date is +6.1 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted*

barometric pressure effect, the trend is +5.9 mm/year. A nearby gauge, with longer records but less precision and datum control, shows a trend of –5.65 mm/year.

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *Since installation, no tropical cyclone has passed near enough to the Honiara gauge to have caused extreme low barometric pressure. In December 2002 an intense tropical cyclone struck the southern islands of Anuta and Tikopia.*

● *The SEAFRAME at Honiara, Solomon Islands has recorded 12 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 39 cm was recorded after an earthquake of magnitude Mw8.1 some 350 km ESE from Honiara on 1st April 2007.*

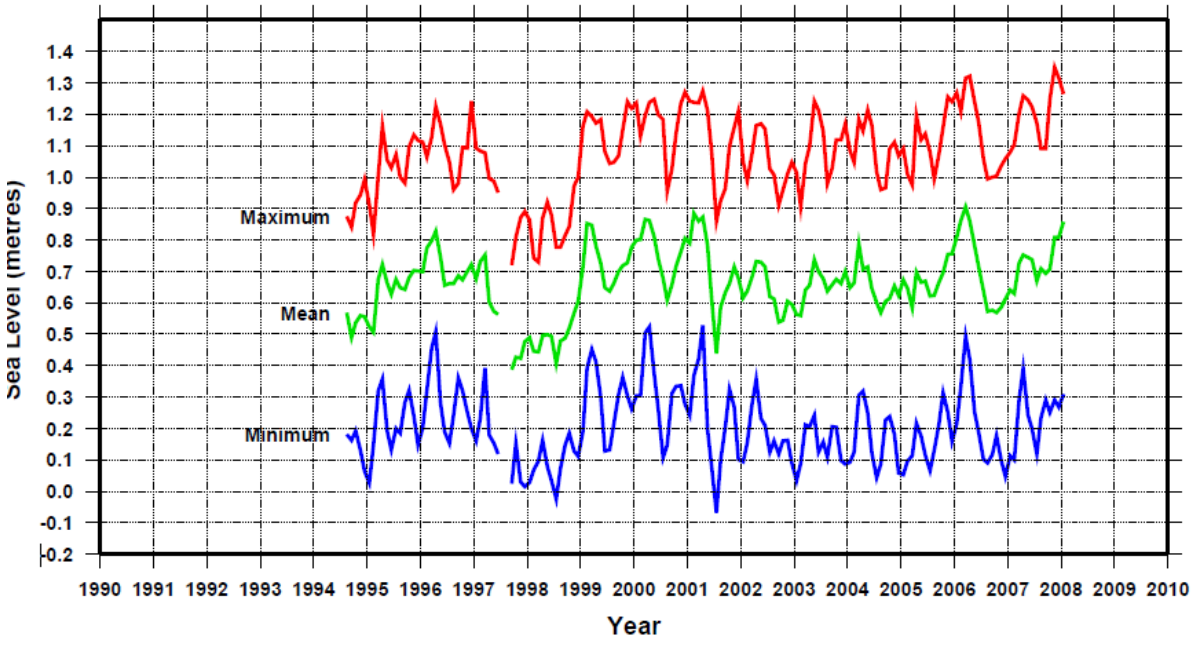

Figure 11. Monthly sea level record from SEAFRAME for Honiara, Solomon Islands

2.11.1. COMMENTS

The seasonal variability seems greater than with the other records. The 1998 El Niño appears once more, and this time it seems to have disrupted the measurements, suggesting one reason why they make a slight upwards jump. Despite the variability that might have been related to the several tsunamis is no overall change between 1999 and 2008, giving no indication that there is the claimed steady upwards trend of 6.1mm/yr during this period.

2.12.TONGA

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Nuku'alofa, Tonga, in January 1993.*

● *The sea level trend to date is +8.7 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +7.2 mm/year. A nearby gauge, with longer records but less precision and datum control, shows a trend of +6.3 mm/year.*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *In 1997 and 1998 tropical cyclones caused widespread devastation in Tonga, including the main island Tongatapu. Wind gusts recorded by the SEAFRAME at Tonga reached 90 knots and 68 knots respectively.*

● *The SEAFRAME at Nuku'alofa, Tonga has recorded 17 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 40 cm was recorded after an earthquake of magnitude Mw8.0 that occurred near Tonga around 160km NE of Nuku'alofa on 3rd May 2006*

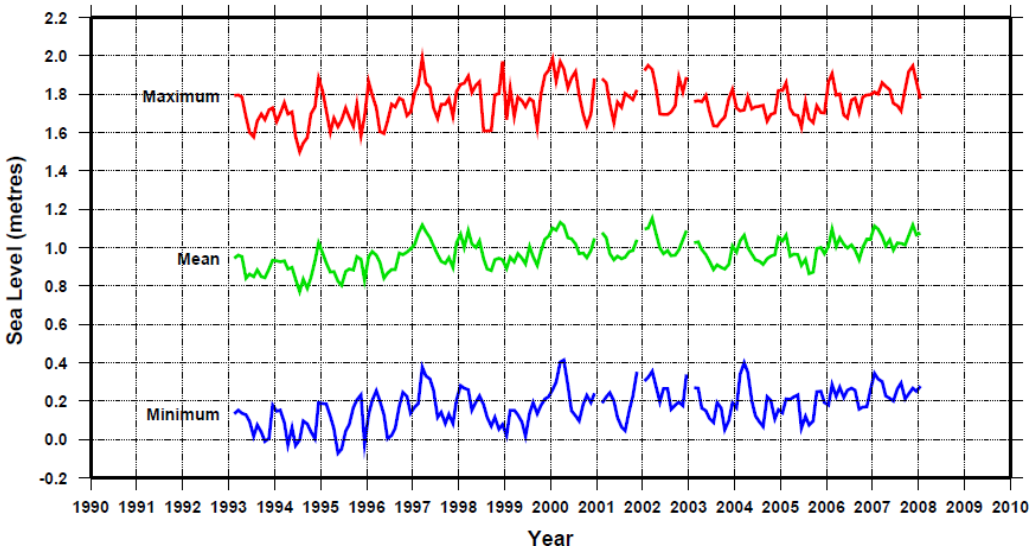

Figure 12 Monthly sea level record from SEAFRAME at Nuku'alofa, Tonga

2.12.1. COMMENTS

There has been no change in sea level from 1997 to 2008, 11 years. The previous period 1993-1997 was slightly lower, and has been used to provide an upwards trend of 8.7mm/yr which does not apply to the past 11 years. This behaviour is similar to several other records and suggests that the cyclone of 1998 might have altered the adjustment of the equipment.

2.13.TUVALU

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Funafuti, Tuvalu, in March 1993.*

● *The sea level trend to date is +6.0 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +5.3 mm/year. A nearby gauge, with a longer record but less precision and datum control, shows a trend of +0.9 mm/year.*

● *Variations in monthly mean sea level, air and water temperatures are dominated by seasonal cycles and were affected by the 1997/1998 El Niño.*

● *The seasonal sea level cycle shows a peak early in the year, a time when Funafuti frequently experiences flooding.*

● *Since installation, at least two cyclones have passed through Tuvalu, but only one, Tropical Cyclone Gavin, was registered as extreme low pressure on the SEAFRAME at Funafuti.*

● *The SEAFRAME at Funafuti, Tuvalu has recorded 14 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 8 cm was recorded after an earthquake of magnitude Mw8.3 that occurred near Kuril Islands on 15th November 200*

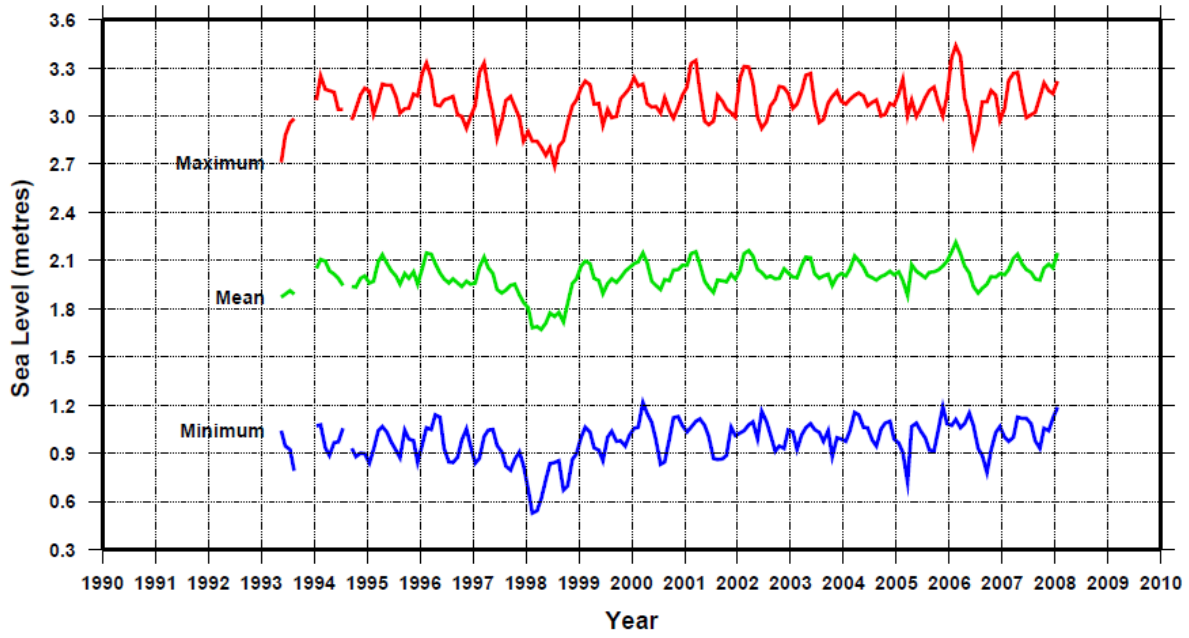

Figure 13 Monthly sea level record from SEAFRAME for Funafuti, Tuvalu

2.13.1. COMMENTS

If the depression of the 1998 cyclone is ignored there was no change is sea level at Tuvalu between 1994 and 2008; 14 years, despite 14 separate tsunami events The claim of a trend of + 6.0mm/yr is without any justification.

2.14 VANUATU

The **Executive Summary** states:

● *A SEAFRAME gauge was installed in Port Vila, Vanuatu, in January 1993*

● *The sea level trend to date is +3.6 mm/year but the magnitude of the trend continues to vary widely from month to month as the data set grows. Accounting for the precise levelling results and inverted barometric pressure effect, the trend is +2.5 mm/year. An older gauge at Port Vila operated from 1977-1982.*

● *Variations in monthly mean sea level include a moderate seasonal cycle and were affected by the 1997/1998 El Niño.*

● *A number of destructive Tropical Cyclones (TC) have passed near Vanuatu since the SEAFRAME was installed. In particular TC Prema caused damage to the SEAFRAME in March 1993.*

● *The SEAFRAME at Port Vila, Vanuatu has recorded 29 separate tsunami events since its installation. The largest tsunami signal of trough-to-peak height 77 cm was recorded after an earthquake of magnitude Mw7.5 that occurred near Vanuatu on 26th November 1999. Vanuatu is prone to tsunamis and two in particular have caused loss of life and damage to property in the period since installation.*

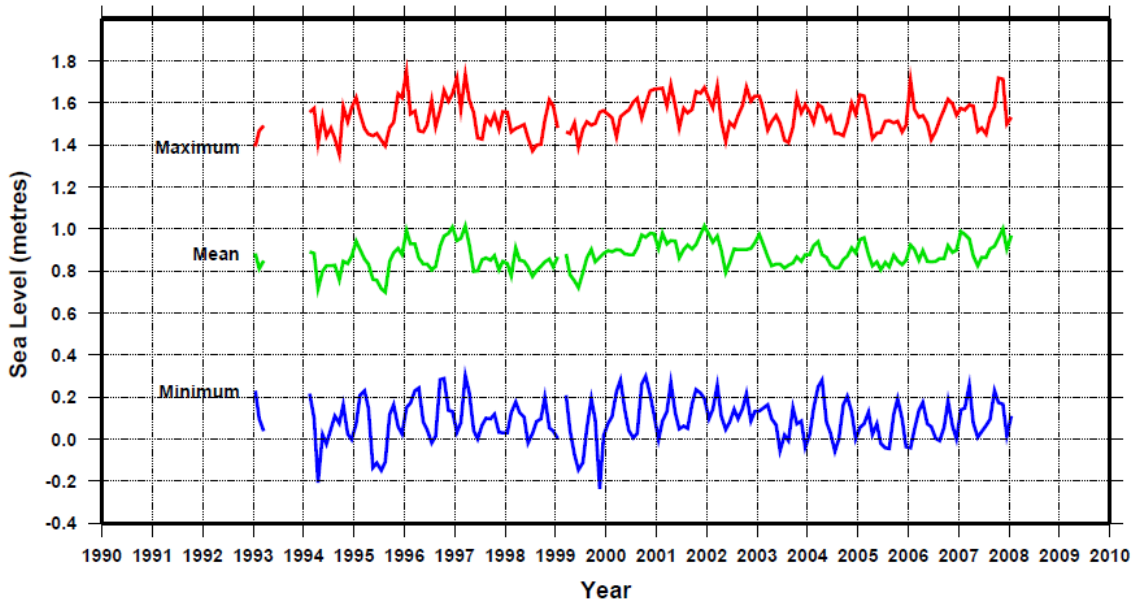

Figure 14. Monthly sea level record from SEAFRAME at Port Vila, Vanuatu

2.14.1.COMMENTS

There has been no change in sea level at Vanuatu from 1995 to 2008. A claimed trend of +3.6mm/yr is unjustified

3. CONCLUSION

The following Table summarizes this assessment.

ISLAND STATE	Claimed sea level trend	Years with zero trend	
Cook Islands	+4.3mm/yr	1994-2006	
Federated States of Micronesia		2003-2007	
Fiji	+3.5mm/yr	2000-2007	
Kiribati	+5.1mm/yr	1993-2008	
Marshall Islands	+4.4mm/yr	1994-2008	
Nauru	+6.0mm/yr	1993-2008	
Papau New Guinea	+7.0mm/yr	1995-2008	
Samoa	+6.3mm/yr	1996-2008	
Solomon Islands	+6.1mm/yr	1999-2008	
Tonga	+8.7mm/yr	1997-2008	
Tuvalu	+6mm/yr	1994-2008	
Vanuatu	+3.6mm/yr	1995-2008	

Instead of examining climate records for evidence of the factors that influence them, there seems to be an emphasis instead on trying to discern ”trends”. There is little realization that any trend depends heavily on

the starting point and finishing point. These reports have all chosen as starting points the beginnings of the installation of the SEAFRAME gauges, which were often at different times, and as a finishing point the latest year of measurement. This is supposed to help to determine “long-term” trends. It is, however, clear from the measurements so far that such a concept is disturbed by natural events such as cyclones and tsunamis. Most of the records shown here show signs that they have being disrupted by the widespread cyclones in the Pacific in 1998. Not only was the record for that year disrupted, but there is a suspicion that the leveling for the previous measurements, sometimes since 1993, may have been changed. For these reasons the best starting point for the determination of any trend should be 1999. instead of the beginning of the measurements. The “long-term” zero trends which are listed above are therefore the most reliable indication of what is happening to the sea level in Pacific Islands. There is no evidence from this work that the sea level in the 12 Pacific islands is increasing. It isto be hoped that the GSPS installation from 2007 will help to correct any future disruption by extreme events.

4. REFERENCES

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Vincent R. Gray , M.A.,Ph.D., F.N.Z.I.C.

Climate Consultant

75 Silverstream Road, Crofton Downs Wellington 6035, New Zealand

Phone (FAX) (064) (04) 47959 39

Email vinmary.gray@paradise.net.nz