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The Fiji Tide-Gauge Stations

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Abstract

We analyse the location, stability and continuity of the two tide-gauge stations in Fiji. Both stations are awkwardly placed on heavy harbour constructions resting on soft sediments susceptible to serious compaction problems. The nearby GPS stations resting on a bedrock hill offer no solution to the stability problems. The Suva tide-gauge has been moved three times, and must accordingly be analysed in segments. Even the last location covering years 1989 to 2917 provides a mixed picture of 16 years of stability, 10 years of rapid rise, and 4 years of rapid fall in relative sea level. This suggests the interaction of subsidence and cyclic changes in sea level. Any application of mean trends would produce meaningless values rather misguiding than assisting in the handling of estimation of on-going absolute sea level changes. We find this vital for the discussions of local sea level changes to be held at the UN conference on "Our Oceans, Our Future" in June in New York and at the main COP23 conference in November in Bonn.

Keywords

Fiji Islands, Relative and Absolute Sea Level Changes, Tide-Gauges, Sediment Compaction, Coastal Stability, GPS-Stations, COP23

1. Introduction

The nation of Fiji will play an important international role in 2017. The governments of Sweden and Fiji are co-hosts for the UN conference on "Our Oceans, Our Future" in New York, June 5-9 [1]. The government of Fiji is the main organizer of the UNFCCC COP23 conference in Bonn, November 6-17 [2]. At both conferences, the oceans and the changes in sea level are bound to play a central role.

There are several papers addressing past sea level changes in the Fiji Islands; e.g. [3] [4] [5]. There is, however, a dearth of papers addressing the present situation in a scientific observationally-based manner. In order to overcome this shortcoming, a new international project termed "*The Fiji New Sea Level Project*" was started and had its first expedition in March 2017 [6].

The official documents on the present day situation in Fiji are quite meager [7] [8], and primarily refer to general statements driven by the IPCC-project [9]. The only real data on present day relative sea level changes on the Fiji Islands comes from the two tide-gauge stations on the main island of Viti Levu. Therefore, it seems urgent to undertake a careful examination of the stability and continuity of these stations.

2. Fiji Tide-Gauge Stations

The nation of Fiji consists of some 330 separate islands. There are two tide-gauges in the Islands of Fiji, both located at the main island on Viti Levi (**Figure 1**);one is located in Lautoka in the NW and one in Suva in the SE (numbers 1805 and 1327, respectively, in the PSMSL database [10]).

The Lautoka station provides a continual record from 1992 up to today.

The Suva station has a more complex history (PSMSL, no. 1327).The first gauge at Kings Wharf was destroyed in 1983 and then moved to Walu Bay Naval Faculty. It has a 3-month overlap to the present tide gauge at Suva harbour (first run by NOAA, now by the Australian National Tidal Faculty).The combined records cover the period 1972-2016.

Figure 2 gives the two tide-gauge records synchronized on a mutual scale for comparisons.

3. Laukota

The Lautoka station has a very unfortunate location on a heavy harbour construction resting on marine sediments (**Figure 3**). This implies unstable condi-

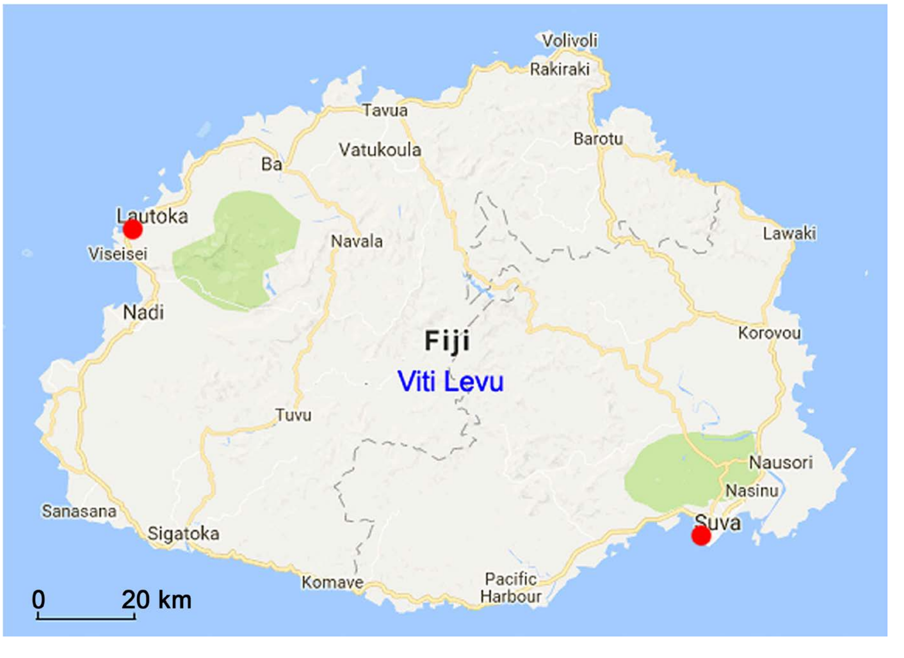

Figure 1. Location of the Fiji tide-gauge stations at Laukota and Suva (red dots).

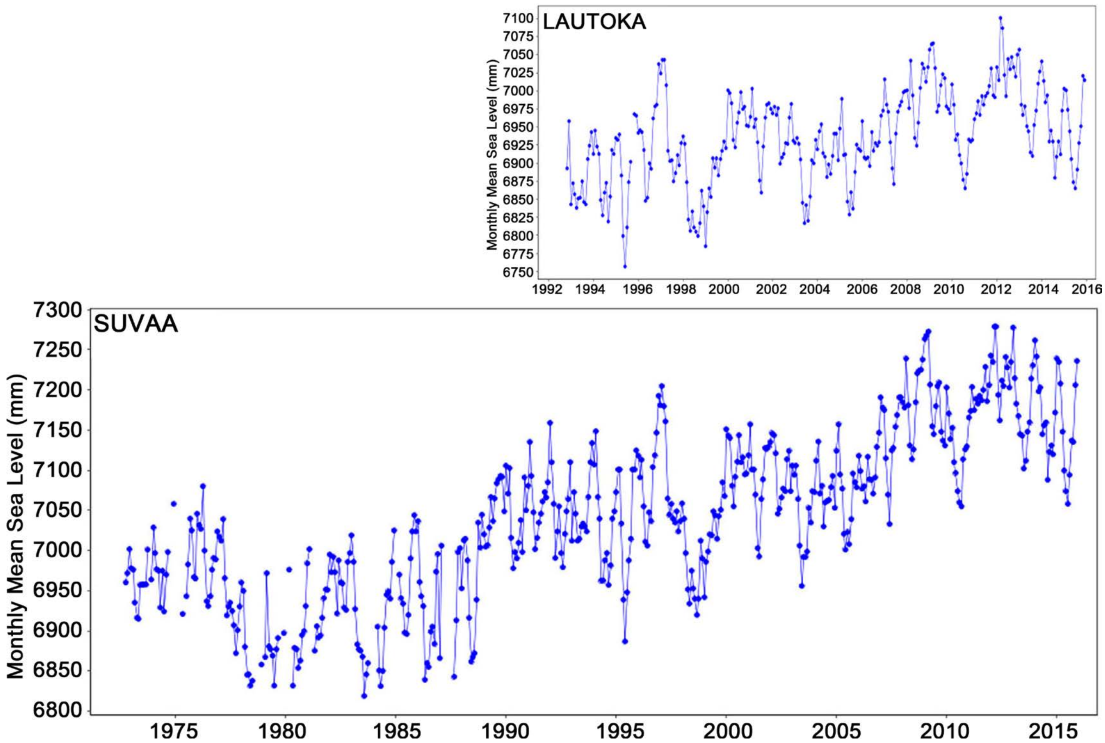

Figure 2. Location of the Fiji tide-gauge stations at Lautoka (above) and Suva (below).

Figure 3. Location of the Lautoka tide-gauge station (green dot) in the harbour of Lautoka. The station is attached to heavy harbour constructions, resting on marine soft sediments, susceptible to compaction. This probably implies a site-specific component of subsidence.

tions, where sediment compaction may play a significant role. We inspected the site (March 13, 2017), and were able to conclude that the site is very poorly chosen in regards to substrate stability (**Figure 4**).

There is a GPS station at Lautoka. It is located on a hill at an elevation of +89 m (Figure 5), without any relation what-so-ever to the tide-gauge station. The GPS-station is said to record a subsidence of −1.15 ± 0.26 mm/yr. The record is cut in four segments by earthquakes in 2016 and 2009, and technical problems in 2012. The record shows stability 2002-2006, a subsidence of −1.0 mm/yr 2006-2009, a subsidence of −0.5 mm/yr 2009-2012, and a rise of 0.5 mm/yr 2012-2014. This is far more complicated than a mean subsidence of 1.15 ± 0.26 mm/yr.

In conclusion, we have a tide-gauge station in unstable conditions due to a heavy harbour construction resting on soft sediments. The GPS station is located on a bedrock hill 1.0 km away. Despite the mixed character, the station might record a component of regional crustal subsidence.

4. Suva

The Suva station has an unfortunate location on heave wharf constructions resting on marine sediments (Figure 6). This implies unstable conditions where sediment compaction may play a significant role. We inspected the site (March 14, 2017), and were able to conclude that the site is very badly chosen in regards to stability (Figure 7).

Figure 4. The tide-gauge station is located at the main wharf of Lautoka consisting of heavy construction resting on soft marine sediments. The load is bound to generate site-specific subsidence, seriously affecting the tide-gauge record.

Figure 5. Location of the Lautoka GPS station on a bedrock-hill at an elevation of +89 m. It seems to record a weak crustal subsidence. The tide-gauge station in the harbour rests on soft marine sediments, and is therefore likely to record an additional site-specific loading subsidence due to compaction of the underlying deposits.

Figure 6. The present tide-gauge station at Suva (green dot) in the harbour of Suva. The station is attached to heavy harbour constructions, resting on marine soft sediments, susceptible to compaction.

Figure 7. The tide-gauge station is located at the main wharf of Suva consisting of heavy construction resting on soft marine sediments. The load is bound to generate site-specific subsidence, seriously affecting the tide-gauge record.

There is a GPS station at Suva. It is located at a hill at an elevation of +74 m (Figure 8), without any relation what-so-ever to the tide-gauge station. The station is built on gently dipping sedimentary bedrock. This implies a questionable stability. The GPS-station is classified as "non robust", and it was deactivated in 2002. This may be construed as shedding additional doubts on the stability of the tide-gauge station located on huge and heavy harbour constructions resting on soft sediments.

Furthermore, the Suva area was subjected to earthquakes; e.g. the 1953 event

Figure 8. Location of the Suva GPS-station on a hill at an elevation of +73 m. The bedrock consists of gently dipping sedimentary rocks of questionable stability. The station has been classified as "non robust" and was deactivated in 2002.

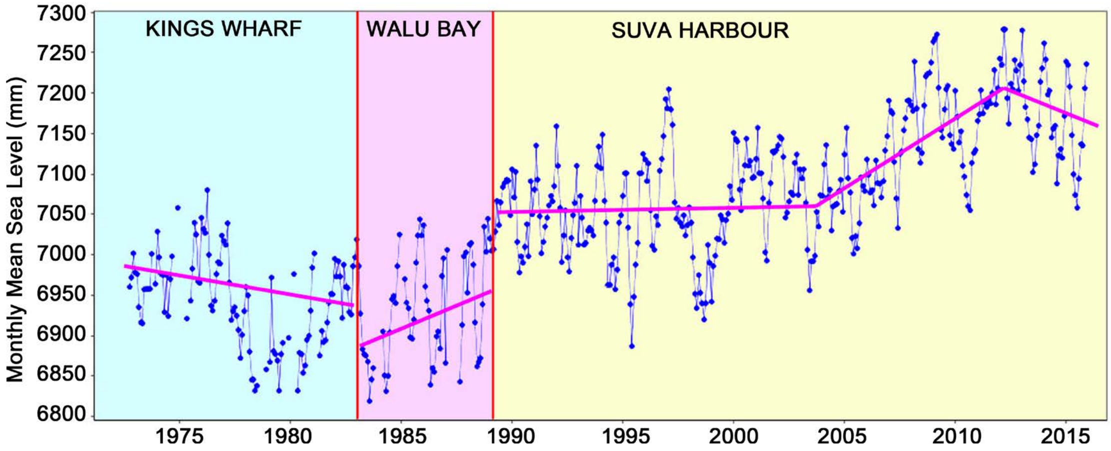

Figure 9. The complex tide-gauge record at Suva [10] cut up in three segments representing the location of the station at Kings Wharf, Walu Bay and Suva Harbour. Each segment must be analyzed by itself.

of magnitude 6.8, and the 2009 event of magnitude 7.1 [11].

5. Discussion

The Suva tide-gauge record as appearing in the PSMSL database [10] shows a misleading trend as, in fact, this record represents the combined measurements at three different locations. This is illustrated in **Figure 9**: the 1972-1983 record at Kings Wharf gives a fall in relative sea level, the 1983-1989 record at Walu Bay gives a sea level rise, and the 1989-2016 record at Suva harbour gives a 3-part sequence of 16 years of stability, 10 years of sea level rise and 4 years of sea level fall. This implies that the picture of sea level changes is very mixed, and complicated.

The 3 site locations at Suva (**Figure 9**) seem to represent different modes of site-specific stability and effects of compaction. The location at Kings Wharf records no compaction. The location at Walu Bay seems to record significant site-specific compaction problems. The present location at Suva Harbour provides a mixed record in need of further analysis (**Figure 10**).

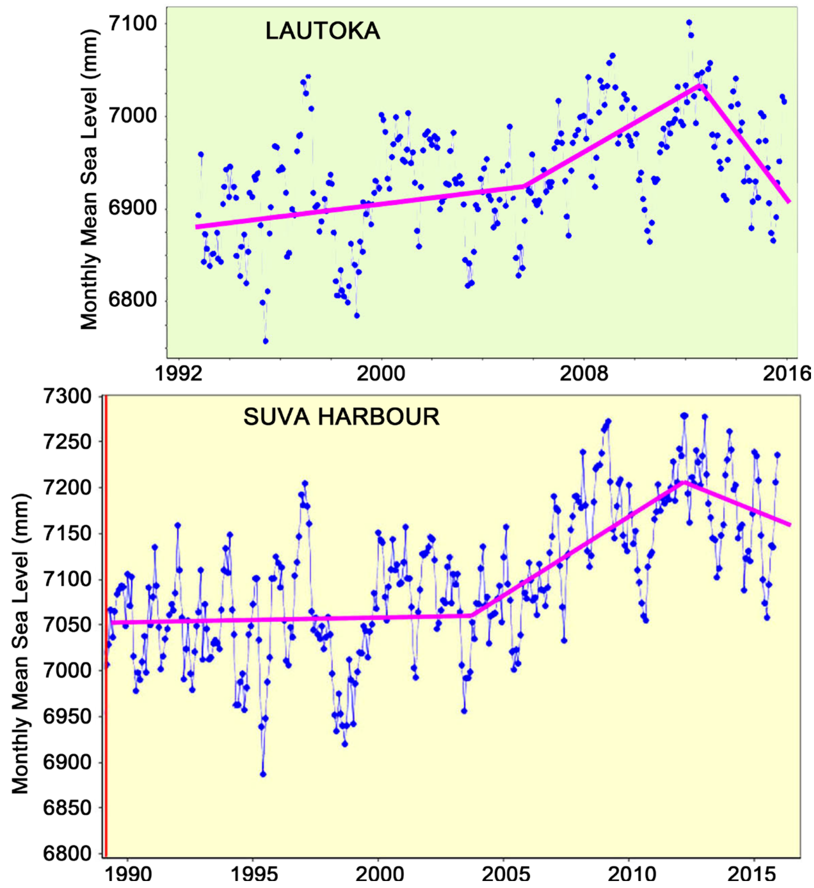

Figure 10. Comparison between the tide-gauge record at Lautoka and Suva. Both records show a 3-parted sequence of somewhat different time and amplitude. The largest signals refer to ENSO events (1997/98, 2009/10). The 3-parted sequences seem dominated by cyclic sea level changes in combination with crustal subsidence and local site-specific compaction.

The highest rates of sea level changes refer to the ENSO events in the years 1997-98 and 2009-10. They represent the redistribution of water masses [12] with little or no thermal effects from expansion/contraction of the upper column of the ocean [13].

Both stations record a general 3-part sequence. Though differing somewhat in time and amplitude, the main shape is so similar that it must be caused by a common factor. We suggest that this is cyclic changes in sea level. We have to consider the 18.6, around 30 and around 60 year cycles, two of which have a planetary background [14]. These cyclic events represent the redistribution of water masses of "Super-ENSO" type [12]. Besides this, there seems to be an influence from crustal subsidence and site-specific effect of compaction.

Both records have a mean rate of relative sea level rise of 5.4 mm/yr over the periods of recording. This has no real dynamic implication, however. The 3-parted segmentation is the dominant factor, and it calls for an origin in cyclic sea level changes in combination with regional subsidence and local compaction effects.

Very detailed morphological and stratigraphical analyses of possible sea level change in the Yasawa Islands [15] indicate a general absence of any on-going sea level rise. This is in harmony with other records from the Indian Ocean [16] [17].

6. Conclusions

Fiji has two tide-gauge stations; one at Lautoka and one at Suva. Both records are very unfortunately placed on quite extensive and heavy wharf constructions, resting on soft marine sediments. The load is likely to induce site-specific compaction. In addition, there may be a weak regional crustal subsidence factor, as suggested by the GPS-station at Lautoka.

Both tide-gauge stations record a general 3-part sequence, which must refer to cyclic changes in sea level [14]. Such changes represent the redistribution of water masses over the globe [12] [16], however.

Any application of mean trends would produce meaningless values, more detrimental than helpful estimation on-going absolute sea level changes. NOAA [18] is unfortunately making just this mistake by applying a long-term mean trend over the combined record at Suva (**Figure 9**). The value obtained (6.30 ± 1.51 mm/yr) has no physical significance, creates confusion and must be challenged from a scientific as well as geoethical point of view.

Besides the 3-part sequence dominating both records, there must also be an interaction from site-specific subsidence due to compaction, and probably also a general crustal subsidence.

As to the determination of regional eustatic sea level changes, neither of the two sites provides any conclusive message. In this case, we have to rely on more extensive records elsewhere [16] [17], and evidence from the nearby Yasawa Islands [15].

Acknowledgements

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