

**INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)**

**SEA LEVEL MEASUREMENT AND ANALYSIS IN THE
WESTERN INDIAN OCEAN**

NATIONAL REPORTS

MAURITIUS

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1. INTRODUCTION

History of sea-level measurement

In Mauritius, sea-level recording is available but in discontinuous mode. Information obtained from the Ministry of Housing, Lands, Town and Country Planning, indicates comprehensive levelling surveys were conducted all over island in 1881 by the H.M.S Navy and in 1902/03 by Mr. W.H. Harrison of the Colonial Office. Most of the mountains, hills and important places in Mauritius were measured to the nearest foot above the MSL. However, no details on the bench mark used for reference purposes could be found.

On the other hand, from the Bench Marks surveying book of the Public Works Department (now the Ministry of Works), it was found that four bench marks were established in March 1915 in Port Louis. One of the bench marks which is relevant to this study was a brass plate fixed at + 6.096 m (20 feet) AMSL against a wall situated inside the yard of the Treasury building, Port Louis.

The first hint about the existence of a tide-gauge was obtained from the Mauritius Marine Authority. Apparently the zero of this side staff was selected in 1929. It corresponded to the level of the mean low at spring tides which was obtained by taking the average of the low water spring tide levels over a 48 month period. However, no information on any bench marks which could be used for the present study is available for that period.

Further research revealed that the only continuous records of sea-level available at the Permanent Service for Mean Sea Level (PMSL) in Bidston, U.K. for Port Louis are obtained from a Munro floating type gauge which was located in a stone building on the south, corner of Quay D. On the request of the Ministry of Housing, Lands, Town and country Planning, a MSL was calculated for that period by the PSML using those measurements. Levelling to fixed marks was carried out in april 1964 by the "H.M.S. Owen" using that Mean Sea Level as reference datum. The National Primary levelling network is now tied to the 1964 Mean Sea Level. No other sea-level data is known to exist from 1964 to 1986.

In August 1986 the Mauritius Meteorological Service established a tide-gauge station of international standard with the help of the University of Hawaii, at Trou-Fanfaron Fishing Port in Port Louis. The sea-level gauge - a Stevens floating A type was a donation from the University of Hawaii and was installed within the framework of the Tropical Ocean and Global Atmosphere (TOGA) Programme and is one of the stations of the Global Sea Level Observing System (GLOSS) in the Indian Ocean, a programme which has been established by the Intergovernmental Oceanographic Commission (IOC) in 1985 to monitor sea-level changes over the globe.

Three bench marks emplaced in the vicinity of the gauge were tied to the National Primary Levelling Network in February 1987 - one is fixed on the base o the tide gauge, another one on the cover of the instrument and the third one is the three meters mark on the tide gauge staff. A survey on check levelling carried out by the Ministry of Housing, Lands, Town and Country Planning in July 1987, May 1988, February 1992 and May 1993 confirmed that the tide gauge was stable.

An almost continuous record of sea-level since September 1986 is now available at the Meteorological Service. Much precaution is taken in order to obtain a data set of high reliability. The sea-level station is maintained by the Marine Division of the Mauritius Meteorological Service. Time marks and staff readings are made regularly on a daily basis including Sundays, at the beginning of every month the recording chart is removed for quality control, analysis and computation under the supervision of the Head of the Division. Hourly sea-level data is forwarded on a monthly basis on diskette to the TOGA Sea-Level Centre in Hawaii where further quality control is performed.

2. MAURITIUS TIDE GAUGE NETWORK

2.1

Station Name	Port Louis
Gloss Station	No.18
Operational	Since August 1986
Latitude	20°9'S
Longitude	57°30'E
Local Time	GMT + 4 Hrs
Type	Steven's Floating A/Stilling Well
New gauge	Upgraded for real time satellite transmission to Hawaii
Authority Responsible	Meteorological Services

	Vacoas Mauritius
Email Address	Meteo @ Intnet.mu
Fax No.	686 1033
<p>Benchmarks:</p> <p>(a) 3 m mark on tide staff tied to the National Primary Leveling Network and Fundamental Benchmarks TTP30. The 3m mark is 1.6788 m above Admiralty Chart datum. The bolt on the gauge is 3.0488 above ACD.</p> <p>(b) One brass bolt at edge of wharf of tide gauge.</p> <p>(c) A bolt on the gauge</p>	
Latest Stability Check: 1993	1993 (performed by Ministry of Housing, Town and Country Planning)
Tide Predictions	performed by Hawai
Data sent to	PSMSL, Hawai (Toga), WOCE
Data format	Continuous analogue charts, diskettes
Data Communication at station	Charts
Nearest Meteorological Station	Meteorological Services, Vacoas, Mauritius
Other data available in vicinity	Sea level pressure, rainfall, winds

Annex I shows the location of the Tide gauge

The other station is located at Rodrigues Island, East of Mauritius

Station Name	Port Mathurin, Rodrigues (Indian Ocean)
Gloss Station Number	19 (Operational since 1987)
Latitude	19°41'S
Longitude	63°25'E
Local Time	GMT + 4 hours
Type	Leupold and Steven;s float/Stilling well
New Gauge	Real Time Satellite transmission
Authority Responsible	Meteorological Services, Vacoas, Mauritius

Benchmarks	A bolt at the edge of the wharf of the tide gauge. Zero of tide staff tied to benchmark which is a point on beam adjacent to tide gauge station.
Auxiliary Benchmarks:	(a) Brass tube fixed on a wall in the marine services area about 200m from tide gauge. (b) One benchmark located near entrance of the Port
Tide predictions	Performed by Hawaii
Data sent to	PSMSL, Hawaii, WOCE
Other data available in vicinity	Sea Level Pressure, rainfall, winds

Annex II shows the location of the tide gauge

2.2 Installed but not operational

Station Name	Agalega Island (Mauritius, Indian Ocean)
Gloss Station	No.16 - Not operational
Latitude	10°23'S
Longitude	56°36'E
Type	Pneumatic bubbler - washed away in 1988 by tropical storm.
Benchmark	Doppler datum point established on North Island in 1981. Will tie gauge benchmark to this point when station operational again.

2.3 Agalega Planned Station

Agalega is a strategic site for the installation of a sea level station to monitor changes in sea-level with reversal in wind direction. It usually experiences

trade winds during the winter months and North-westerly to westerly during the summer months.

A bubble-type gauge installed in March 1988 was washed away as a consequence of heavy swells. This bad weather conditions is a common occurrence. A sea-level station will provide information on storm surge and accompanied sea-level rise, which is a necessary prerequisite for coastal development. Sea-level data can also be used to monitor changes in ocean currents in the region.

The cost of the station is estimated at about \$ 5000.

The sea-level stations at Rodrigues and Mauritius have also to be upgraded. They have been established more than 13 years ago and spareparts are not easily available in case of complete breakdown. Request have already been made to the Government of Mauritius to replace them with Next Generation Sea-Level Station or SEAFRAME type which measure also meteorological parameters.

A Global Position System (GPS) station is being planned for the Rodrigues Stations to monitor change upto 1 mm of the platform.

3. AVAILABILITY OF DATA

Sea-level data is available on hard copy as well as on diskette according to international format.

Almost continuous hourly data except for a few breaks when the gauge was out of order is available as from September 1986 for Port Louis and November 1986 for Port Mathurin.

4. CAPACITY AVAILABLE

4.1 Installation and maintenance of gauges

The following officers are available for installation and maintenance of the station. They are all attached to the Mauritius Meteorological Services.

- | | |
|--------------------|---------------------------------------|
| (a) G. Soopramania | Class III Meteorological Personnel |
| (b) A. Ramburn | Class III Meteorological Personnel |
| (c) D. Mahumedally | Class III Meteorological Personnel |
| (d) G. Carpenen | City & Guilds (Electronic Technician) |

Processing and interpretation

- | Name | Designation |
|-------------------------------------|--------------------------|
| (a) S. Ragoonaden (Head of Section) | Divisional Meteorologist |
| (b) B.H Dunputh | Meteorologist |

(c) G. Soopramania	Principal Meteorological Technician
(d) A. Ramburn	Senior Meteorological Technician
(e) D. Mahumedally	Senior Meteorological Technician

4.3 Sea-Level courses

The following officers have followed the sea level courses

Name	Institutions	Remarks
(a) S. Ragoonaden	Bidston, UK, 1983	Still involved
(b) G. Soopramania	Bidston, UK, 1993	Still involved
(c) B.H. Dunpath	Cape Town, S. Africa	Still involved

5. SEA LEVEL PRODUCTS

Annual tide predictions are produced based on the previous year observations and compared with the prediction obtained from the University of Hawaii. The tidal prediction on a daily basis is included in public weather forecast broadcast on Radio and TV for the Media.

The high and low tides recorded is compared with the predicted high and low tides to identify any large difference in height and time of occurrence. Such difference at times occur as a consequence of abnormal weather conditions.

Sea-level anomalies are compiled mainly during cyclone and storm surge events. It has been noted that the highest anomalies occur whenever a tropical system passes to the South-East of Mauritius when the wind direction changes to North-Westerly. Abnormal rise also occur when tropical cyclones pass in other parts off Mauritius. During the passage of tropical cyclone Krissy to the South-East of Mauritius in March 1987, the sea level rose to 1 m above the predicted tide level.

Sea-level Products which would be useful are:

- **Return probability of storm surges**

This would have to be based on observations on how far inland does the water level penetrate at other sites during cyclone events besides the records on the tide gauge.

- **Sea Level residuals**

The software from Hawaii does provide this output but attempts to obtain it on a regular basis has not been successful. Residual from stations in the network does at time depict movement of ocean processes on a regional scale.

- **Monthly sea-level contour and anomaly charts of the Indian Ocean**

Such charts are published regularly for the Pacific Ocean. Monthly anomaly events which can contribute to the understanding of several weather and climate phenomena and other ocean processes occurring in this basin.

- **Coastal map contours at intervals of 0.5 m**

6. BIBIOGRAPHY OF SEA LEVEL LITERATURE

The following literature have been published.

- Tidal range and monthly means of sea-level at Port Louis by S. Ragoonaden, 1989.
- Activities of Mauritius in the monitoring and analysis of sea-level, published in proceedings of IOC-UNEP-WMO-SAREC Planning.
- Workshop on an Integrated Approach to coastal erosion, sea-level changes and impacts IOC Workshop, IOC Report No. 96 - Supplement 2, 1994
- Sea level variations in Indian Ocean by B.H. Dunpath, paper presented at the Cape Town Workshop, 1998.
- Island states at risk by S. Ragoonaden, Journal of coastal Research, Special issue, No. 24, 1997

7. RECOMMENDATIONS

It is essential that the sea-level stations at Port-Louis and Rodrigues be replaced by more sophisticated instruments in order to obtain a continuous long-term series of sea-level data to identify trends in sea-level changes together with meteorological data for data reduction.

Trend in sea-level changes has been compiled from the 13 year record (see section II).

Section II

8. OCEANOGRAPHIC AND METEOROLOGICAL DATA

8.1 Oceanographic data

No oceanographic parameters are measured in the region of the sea level station.

8.2 Meteorological data

A meteorological station (Fort William) manned by the personnel of the Mauritius Ports Authority is located on the coast at about 1 km to the South of the sea-level station.

8.2.1 Atmospheric pressure

Annex III shows the monthly mean atmospheric pressure. It is noted that the lowest atmospheric pressure occurs during the month of February which is one of the most active months of the cyclone season. Highest atmospheric pressure occurs in August when strong anticyclones influence weather over the region.

8.2.2 Winds

The winds are mainly South-East which is stronger during the winter months (June-August). During the summer months, the trades are weak and sea-breezes from the North-West is a common occurrence. However, the months also coincide with the cyclone season almost every year, a cyclone usually passes at least 100 km from Mauritius.

Annex II shows highest gusts recorded at Fort-William.

8.2.3 Rainfall

The sea-level station is situated on the rainfall shadow of the island. Port-Louis is mainly dry and torrential rain occurs only whenever a cyclone or very active cloud bands are in the vicinity.

Annex V - a&b shows the mean monthly rainfall near the station.

No major rivers are situated in the region of Port-Louis. Run off can become significant only in cyclone episodes and heavy rain events. Appendix VI - a shows the highest daily rainfall over 24 hours recorded during the occurrence of a cyclone.

Annexes V-b and VI-b show the monthly rainfall in millimetres and highest daily rainfall for Port Mathurin Rodrigues.

8.2.4 Sea-surface temperature

Sea surface temperature varies from 27°C (February) to 23°C (August). However, sea surface temperature at times rises up to 29°C in the summer months and can fall below 22°C during the winter months.

Annex VII shows the monthly mean temperature in the region of Mauritius.

9. SEA LEVEL PRODUCTS

The hourly sea-level values are analysed regularly and in depth investigation on any abnormal records are carried out.

9.1 Analysis of the monthly and annual values

The tidal range during spring tide is on the average about 75 cm around Mauritius. However, the absolute highest sea-level recorded during the period under review is 102 cm above the Admiralty Chart Datum (ACD) and absolute lowest 29 cm below the ACD.

It is noted that the monthly mean sea-level changes quite significantly with a maximum occurring in February/March and a minimum in July/August which corresponds with the maximum and minimum sea surface temperature observed in our region (Fig. 4). The annual range could be as much as 34.7 cm (1992) and the changes for corresponding months, from year to year are quite important - a difference of 21.7 cm between the month of March 1987 and that of 1992. The annual mean also differs from year to year and the difference between the values of 1987 and 1992 was as much as 12.3 cm.

9.2 Relative changes in mean sea-level since 1915.

In April 1967 a survey was conducted by the Ministry of Housing, Lands, Town and Country Planning to check the stability of the brass plate bench mark established in March 1915 in the yard of the Treasury Building. The value obtained was found to be +6.076 m AMSL indicating a change of about +2 cm from 1915 to 1967. However, it is admitted that caution should be exercised in the interpretation of this apparent rise. In 1915, the equipment available for levelling operation was not as accurate as that used in 1967 (Ramasawmy, personal communication).

From values obtained on primary bench marks established in 1964, the mean sea-level above the actual tide staff zero has been calculated for that period. The height obtained is +1.687 m above the tide staff zero.

It can be seen that a relative change of (+1.7) cm in the mean sea level has occurred between 1964 and the average over the preceding years. The rate of change or the apparent rate of increase in mean sea-level is, therefore, in the mean 0.7 mm/year in the region of Mauritius. This is comparable to the widely accepted value 1 mm/year as regards the global sea-level rise.

9.3 Abnormal Seiches in records

On the 2 June 1994 an earth-quake was recorded in the Indian Ocean on the sea-floor South of East Java with strength of 5.7 on the Richter scale at 18:17:36.6 Hours (GMT) at latitude 10° 20'S and longitude 113° 20'E at a depth of about 1500 m. (Fig.4). This seismic disturbance generated a tsunami which caused widespread damage in the region. The effect of the tsunami waves destroyed the south coast of East Java. Six villages were destroyed and 206 persons lost their life. 20 persons missing and 399 with serious or minor injuries were also deplored. 1226 houses and 426 boats were damaged and 15 livestock were killed. This region is vulnerable to earth tremours and has experienced several earthquakes in 1938, 1961, 1982 and 1987.

Tide gauge records of 3 June 1994 in Mauritius and Rodrigues

Usually seiches on the tide gauge record at Port-Louis are very pronounced as the tide gauge site is located within a bay with only one restricted opening towards the open sea. Seiches of range of about 8 cm usually occur during neap tides. During spring tides, seiches of range of about 6 cm and periodic time of 20 min occur during the "ebb" flow whereas during "flood", the range decreases to 3 cm and the periodic time to 10 min. At Rodrigues, the range of seiches is between 5-6 cm with periodic time between 20-22 min.

The earthquake on 2 June 1994 off Java generated potential energy which travelled the whole length of the South Indian Ocean to reach Rodrigues and Mauritius.

In the early morning of 3 June 1994, the pattern of seiches underwent a complete change at both Rodrigues and Mauritius as a consequence of the superposition of the Tsunami wave signals on the normal water-level fluctuations at both sea-level stations Annex X and XI. The tide record at Rodrigues showed a greater than normal rise of the seiches at about 0137 GMT on 3 June 1994 followed by an abnormal drop. Such abnormal seiches were observed until mid-night on 4 June. The range of these seiches was of the order of 18-20 cm and the periodic time 12-15 min at the outset when the signal was more pronounced. The range and period decreased gradually to reach 9 cm and 15 min towards the end of Tsunami signal.

9.4 Sea-Level Changes during Cyclone Events

During the passage of tropical cyclones in the vicinity of Mauritius, the characteristics of seiches also changed in the Port area. Abnormal seiches were recorded on 8 December 1996 when Tropical cyclone Daniella was at its closest distance to Mauritius. It is noted that the tide gauge record looks almost similar to the record at Port-Louis on 3 June 1994 (Annex XII). Table 1 shows the height of the water-level at its peak, together with data recorded during the passage of tropical cyclones Colina, Hollanda and Daniella.

TABLE 1

DATE	SYSTEM	RISE OF MEAN WATER LEVEL ABOVE PREDICTION	HIGHEST WATER MARK ABOVE MEAN SEA LEVEL	MEAN RANGE OF SEICHES	PERIOD OF SEICHES
3 Jun.1994	Tsunami wave signal	17.5 cm	33 cm	24 cm	2 min
18-19 Jan 1993	Tropical Cyclone Colina	36.0 cm	74.7 cm	27 cm	7 min
8 Feb.1994	Tropical Cyclone Hollanda	41.0 cm	-	15 cm	6 min
8 Dec.1996	Tropical Cyclone Daniella	22.9 cm	66.3 cm	34 cm	7 min

From the above table, it is noted that the rise in the mean water level was not to pronounced compared to the situation during cyclone events. This can be attributed to the fact that in the case of passage of cyclones in the vicinity of Mauritius, the combined effects of two factors - wind forcing and pressure difference - are mainly responsible for storm surges leading to abnormal rise of sea-level.