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Sea Level Monitoring in Africa

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Abstract

This paper provides a review of the African sea level data set which is limited not only in size, especially given the great length of the African coastline, but also in quality. The review is undertaken primarily from Permanent Service for Mean Sea Level (PSMSL) and Global Sea Level Observing System (GLOSS) perspectives but the conclusions on the need for major new investments in sea level infrastructure are undoubtedly the same as would be arrived at through any other approach. Stations to be installed as part of the Ocean Data and Information Network for Africa (ODINAfrica) programme are described and a survey of currently existing and planned sea level stations in Africa is presented, together with information on where data for existing stations may be found.

Keywords: Sea level networks; Sea level data applications; Sea level data telemetry

1. Introduction

Africa presents a major challenge for environmental monitoring. The historical data sets of many parameters are limited in size and quality. In addition, while funding can sometimes be obtained for the installation of new monitoring equipment, resources for ongoing maintenance can remain hard to find.

Sea level provides a good example of such a challenge. Sea level is an essential parameter in climate change research, it can be employed in a range of operational oceanography applications, and it has many practical uses such as in harbour operations and coastal engineering (IOC 2006a). However, although the benefits of sea level monitoring have been recognised for many years, the existing African data set is smaller than that of many other parts of world, and until recently there was little investment in new equipment that could form the basis of a new African sea level network. This paper discusses the size and quality of the historical African sea level data set, and gives an overview of current plans for new investment in the sea level network.

2. The African Sea Level Data Set

Figure 1 exemplifies the challenge faced in sea level recording. It shows the status of monthly and annual mean sea level (MSL) data received by the Permanent Service for Mean Sea Level (PSMSL, Woodworth and Player 2003) from locations in the core network of the Global Sea Level Observing System (GLOSS, Woodworth *et al.* 2003). Category 1 sites are those from which data recorded in 2002 or later are included in the PSMSL data bank. Approximately two-thirds of GLOSS sites worldwide are Category 1. However, it can be seen that, with the major exceptions of stations in South Africa and of ocean islands, there are few Category 1 sites in Africa. Of course, there are other ways of measuring the status of a network, but in this case any other method would result in a similar conclusion.

A catalogue of data holdings of the PSMSL for Africa can be inspected at http://www.pol.ac.uk/psmsl while Figure 2 provides a map of locations for which at least some PSMSL data exist. Figure 3(a) provides a histogram of the length of records demonstrating that few are longer than 20 years. This is in spite of the record lengths shown being based on the complete PSMSL data set (called the 'Metric' data set in PSMSL documents) and not the smaller 'Revised Local Reference' (RLR) set which includes only records with reliable datum continuity; we return to this issue below. If one bears in mind that approximately 50 years of data are required if a long-term trend is to be calculated with a standard error several times smaller than the 1-2 mm/year associated with global sea level change and vertical land movements (Woodworth 1990, Douglas 1991), and hence be useful in those studies, then it is obvious just how limited the African MSL data set is. Figure 3(a) also indicates that approximately half of the records with less than 20 years originate from the 'outer African islands' of the Atlantic and western Indian Ocean.

Figure 4 presents the annual MSL time series for the six stations in continental Africa having record lengths over 40 years, with dots shown only for those years sufficiently complete to allow the computation of an annual mean. The secular trends for the six stations vary between -0.83 (for Mossel Bay) and 3.05 (for Takoradi) mm/year and average 1.0 mm/year, at the lower end of the rate of change of 20th century sea level reported worldwide (Church *et al*. 2001). Three of the six historic records come from South Africa, and gaps reflect many problems with acoustic gauges in South Africa during the 1990s. A further 17 stations can be seen in Figure 3(a) as originating from continental Africa, and having record lengths of 20 or more but less than 40 years. Nine of these stations are also from South Africa or Namibia; 2 from Egypt; 3 from West Africa; and 3 are from East Africa as shown in Figure 5.

Figure 5 leads onto two other problems with the available African records. It can be seen that all three East African time series include dots for fewer than 20 annual MSL values, even though there is sea level information in the PSMSL data set for each station for at least 20 years. The years of data which have been dropped from the figure are those which are insufficiently complete to allow the computation of an annual MSL, and/or are those for which the datum of the sea level measurements is unknown relative to that of other years. Similar problems beset the records from Lagos, Nigeria and other locations.

The datum continuity implied by the PSMSL RLR data set is of crucial importance to the study of the rate of change of coastal sea level. Figure 3(b) presents a histogram of the number of years of data with datum continuity for African stations in the RLR data set. If tide gauge authorities provided documentation for every station-year of data concerning the datum to which measurements were made, then Figures 3(a) and (b) would be identical. In practice, one can see that, not only is Africa deficient in the quantity of available data, but the ability to make maximum use of the information is much reduced.

The records from the 'outer African islands' of the Atlantic and western Indian Oceans tend to be of better quality but are in most cases only a decade long and contain gaps which partly reflect difficulties of access for maintenance. Nevertheless, some of them have been included in recent discussions of sea level trends (e.g. Woodworth 2005) and of the factors responsible for interannual variability of sea level (e.g. Andrew *et al.* 2006).

3. Possible Uses of the Present and Future Sea Level Data Set

Even though the present-day African data set may be limited, it is essential that it is studied in as many ways as possible in order to gain maximum insight into the reasons for sea level change around the continent, and to provide examples of the potential benefits to society of investment in sea level monitoring. It is important to emphasise that the uses of sea level data for science and for practical purposes are inter-dependent. For example, knowledge of long term sea level rise needs to be input into the engineering design of coastal structures, many of which will have a lifetime of many decades or a century. In addition, insight into the rate of sea level rise may also help in the understanding of complex coastal processes, such as sedimentation and erosion.

Even without the best possible datum information required for the computation of sea level trends, users of the African data set can study many aspects of sea level variability. For example:

- As long as data are correctly time-tagged, then a near-complete description of diurnal and semi-diurnal tides can be extracted, enabling production of tide tables. Of course, 'tidal constants' are available from many African ports (sometimes based on brief 19th century measurements) but there is little information on how the 'constants' change from year to year and therefore on the uncertainties in tidal predictions.
- The higher-frequency (e.g. hourly through to weekly) components of non-tidal variability can be extracted from the 'tidal residuals'. With some oceanographic insight, the non-tidal time series can provide information on the statistics of storm surges for input to the design of flood protection measures, and on ocean processes such as coastal upwelling. The residuals can be employed to validate predictions of tide-surge numerical models, which can in turn be used in flood warning, of special importance to major population centres in developing countries (e.g. Flather 1994). In Africa, this applies in particular to cities such as Lagos or Alexandria.
- One can usually determine the characteristics of seasonal MSL variability. In parts of Africa the seasonal cycle of MSL can have a range of the order of 20 cm and needs to be factored into seasonal sea level forecasts. Figure 6 shows the amplitudes of the annual cycle of MSL and the month at which the cycle peaks

> using currently available data and based on the methods of Tsimplis and Woodworth (1994). Amplitudes are near zero along parts of the South African coast, as discussed by Brundritt (1984), while they can exceed 10 cm in the Red Sea. Contrasts in the time of year at which the cycle peaks can be seen between West and East Africa and between the Red Sea and the Mediterranean. One looks forward to seeing this exercise repeated with a more copious African data set.

Future sea level installations can not only provide 'delayed mode' information that can be employed as described above, but also 'real time' data which opens up many possibilities for their use in port operations and a wide range of operational oceanography (Flather 2000). In addition, access to real-time data tends to result eventually in higher quality delayed mode information, as faults can be identified and remedied immediately.

The PSMSL data set referred to above contains monthly and annual MSL. Anyone interested in assessing the utility of higher frequency data (either delayed mode or real time) to their applications should investigate the historical information in the GLOSS Delayed Mode data set at the British Oceanographic Data Centre (accessible via the PSMSL web page), and in the University of Hawaii Sea Level Center (UHSLC) Research Quality Data Set (http://www.soest.hawaii.edu/UHSLC/). Real time (or near real-time) data have many uses that may not be well-known. For example, tide gauge data are nowadays the main means of calibrating sea level information from satellite radar altimeters (e.g. Mitchum 2000, Aman and Testut 2003, Aman *et al.* 2006).

4. Recent Developments

It would be incorrect to imply that there has been no investment at all in African sea levels. Several countries (e.g. Tunisia, Morocco, Nigeria, Kenya) have allocated, or plan to allocate, significant funding for sea level equipment. However, where such investments have already been made, our experience is that data are not always shared with neighbouring countries or made available to the international community.

One recent, encouraging example of collaboration was provided by the installation of a pressure tide gauge by the National Institute of Oceanography (NIO), India at Takoradi in Ghana. Although the Takoradi station has since been enhanced by a new radar and pressure system (see below), the NIO gauge proved the value of recording at this site, by providing a new set of tidal and non-tidal residual information and by the clear identification of the 2004 Sumatra tsunami (Joseph *et al.* 2006).

However, on a wider international level, there has been concern for some time that major gaps exist in the sea level network in Africa (e.g. WSSD 2002) and that, even where tide gauge stations exist, the equipment is often old. The opportunity has been taken on several occasions to seek new international resources, without great success. However, in 2003, funding became available from the Government of Flanders (Belgium) and the Intergovernmental Oceanographic Commission (IOC) in a programme called Ocean Data and Information Network for Africa (ODINAfrica) for the establishment of about ten new and refurbished stations (ODINAfrica 2003; Aman *et al.* 2006).

In December 2004, the project became more urgent following the Sumatra Tsunami, with the tsunami having been observed clearly along East and West African coastlines (Merrifield *et al.* 2005, Joseph *et al.* 2006). Concerns were subsequently expressed of tsunamis originating closer to East Africa, for example in the Makran Subduction Zone in the NW Indian Ocean. It became clear that any new equipment installed in Africa had to be suitable for tsunami network applications ('tsunami enabled'). In addition, training programmes had to be provided so that local people could effectively maintain any equipment installed.

Several sites in Africa and in countries in the NW Indian Ocean have recently received new equipment funded through the GLOSS and ODINAfrica programmes. The tide gauge hardware was selected and installed with the assistance of the Proudman Oceanographic Laboratory (POL) in collaboration with colleagues at IOC and the French and South African Hydrographic Offices. Each site received a consultant visit prior to delivery of equipment so that any local difficulties could be resolved, and most visits resulted in detailed reports available from www.gloss-sealevel.org. The first two new sites installed were at Pemba and Inhambane (Mozambique) in 2005, followed by Takoradi (Ghana), Nouakchott (Mauritania) and Karachi (Pakistan) in 2006. Three existing sites in South Africa were upgraded in early 2007, in addition to new installations in Djibouti and Pointe Noire (Congo). At the time of writing equipment is being delivered to Aden (Yemen), and will soon be delivered to Port Sonara (Cameroon), and consultant visits have been carried out to Alexandria (Egypt) and to possible sites in Morocco.

The equipment employed at most sites consists of a radar tide gauge, which measures sea level from the time-of-flight of the radar pulses reflected back from the sea surface. This sensor is believed to provide data with little instrumental drift, and, therefore, to result in sea level information suitable for tidal studies and research into sea level changes due to climate change. Nevertheless, regular checks on possible drifts in the radar sensor data are made with the use of either spot measurements in nearby stilling wells or observations with tide poles. In addition, the station is equipped with a sub-surface pressure sensor. This functions as a backup to the radar gauge, it can record any water level which exceeds the height of the radar sensor, and it can sample at a higher rate. Consequently, it can be regarded as the main 'tsunami sensor'. The final important component is the satellite transmission equipment which sends real-time data back to centres in Ostende (Belgium) and Hawaii (USA) and to any other centre which can access the Global Telecommunications System (GTS). For examples of ODINAfrica real time data, see http://www.vliz.be/vmdcdata/iode/ and also the UHSLC web site given above. It is planned that a subset of stations initially will also be equipped with Global Positioning System (GPS) receivers for the measurement of land movements: upcoming installations are planned at Pemba and Inhambane in Mozambique and at Takoradi in Ghana in a collaboration between IOC and the University of Beira Interior, Portugal. These GPS receivers and those at other tide gauge sites (http://www.sonel.org/stations/cgps/surv_update.html provides a survey of such stations worldwide) will provide an important contribution to the development of an African Geodetic Reference Frame (AFREF, http://geoinfo.uneca.org/afref/).

As an example of the good progress being made, at the time of writing, and as an indication of remaining problems, Figure 7 shows the entire PSMSL monthly MSL values held for Takoradi. The data up to 1965 are the same as those which are shown as annual means in Figure 4. After that date, there were a number of problems reported with the gauge and it is clear that the data values returned were not realistic. However, if the original tide gauge charts survive and if ancillary tide pole information is available, then it would in principle be possible to reanalyse the time series. This emphasises the importance to present-day studies of what is called 'data rescue' or 'data archaeology'. The dot shown in Figure 7 shows a preliminary estimate of MSL at Takoradi for the first 3 months of 2007, using data from the new ODINAfrica radar gauge. The dot is consistent with information from the earlier, less-precise NIO pressure gauge, and can be seen to be roughly consistent with the trend indicated in the earlier part of the record, and suggestive of an overall rate of rise of sea level of several mm/year. This is a higher rate of rise than one might expect and may arise from local geological conditions such as settling of reclaimed land. Such a finding is interesting but clearly a longer record from the new gauge is required for further study, in addition to GPS information to determine the magnitude of vertical land movements. Meanwhile, the new data have already been used to determine tidal constants for the port and study the character of non-tidal variability.

The North African coast has fewer sea level stations and a smaller historical data set than almost any other coastline in the world. Any new sea level information (whether tidal, surge, MSL or tsunami-related) collected from this area will be great interest to scientists and coastal engineers. Tsunami risk to northern African and European coasts is of considerable current concern with both European Union and IOC projects in progress (EC 2005, IOC 2006b). Tsunamis of various sizes have occurred in the recent past in southern Europe and North Africa. Examples in the historical record include the Lisbon event of 1755 (e.g. Baptista *et al.* 1998), a number of damaging tsunamis at Alexandria, such as due to the cataclysmic Santorini tsunami of 1638 BC and to lesser but still significant ones in 365 and 1303 AD (Hamouda 2006), and the Algerian earthquake and tsunami of 2003 (Alasset *et al.* 2006).

At present, African real time tide gauge satellite telemetry is based on the meteorological satellite (e.g. Meteosat or GOES) Data Collection Platform (DCP) system which is used in the Pacific Tsunami Warning System. However, tsunami travel times are much shorter in the Indian and Atlantic Oceans and Mediterranean Sea and the latency in DCP transmissions is less acceptable. As a result, IOC and POL have been working with INMARSAT to make use of its Broadband Global Area Network (BGAN) technology which provides ‘always on’ connectivity from almost anywhere on the Earth’s surface (Holgate *et al.* 2007).

5. Summary

Tables 1 and 2 and Figure 8 provide an overview of existing sea level stations in Africa, some of which will inevitably be in better condition than others. Also included are stations for which we believe there exist realistic plans for installations and upgrades in the near future. Even with the new installations, the network will remain sparse compared to those in many other parts of the world, but it is indeed gratifying that there have been significant recent improvements. One hopes that the progress in installations will continue and that a greater amount of international data sharing will take place.

However, the ODINAfrica (or any other) network will not be a success without consideration of factors other than initial investment in hardware. Such factors include the development of a local skill base to maintain the equipment, the national commitment to ongoing funding for the maintenance, and the collective ability to make maximum use of products generated from the data. This implies local technical training, including a recognition of the importance of benchmark infrastructure and regular calibrations which are sometimes overlooked in gauge operations, and yet are essential to the long-term datum control of a sea level time series. GLOSS/ODINAfrica training courses and materials and local training at the time of installations can help in this regard. Appreciation of the importance of the monitoring at government and national academic level is essential. Sea level networks have been installed previously at great expense in other parts of the world, but have subsequently failed due to a lack of resources for maintenance after the first few years, and also to a lack of local appreciation of the importance of a coherent network. It is essential that previous mistakes are not repeated in Africa.

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Figure Captions

1. Map of GLOSS Core Network stations in Africa. Those marked by stars are Category 1 (relatively recent data having been received by the PSMSL). Categories 2 and 3 indicate that historic but no recent data exist, while Category 4 stations have no historic or recent data at all. Categories are defined as of October 2006, see www.gloss-sealevel.org for details.

2. Map indicating locations in Africa for which some sea level data can be found in the PSMSL data set (see www.pol.ac.uk/psmsl for more details).

3 (a) Histogram of record lengths of stations from continental Africa and 'outer islands' in the PSMSL Metric data set. Black shading indicates holdings from continental Africa alone. (b) The corresponding histogram for stations with data in the PSMSL Revised Local Reference data set.

4. Annual MSL time series for the six stations in continental Africa with 40 or more years of data (Alexandria, Egypt; Ceuta, Spanish North Africa; Takoradi, Ghana; Port Nolloth, Simons Bay and Mossel Bay, South Africa). The Takoradi record in this figure has been truncated at 1965 when major problems with the gauge were reported. Five of the six are from the PSMSL RLR data set; the Alexandria record shown is from the Metric set but there is good reason to believe that the data were measured to the same datum. Each time series contains an arbitrary offset.

5. Annual MSL time series for 3 medium-length records in East Africa (Maputo, Mozambique; Zanzibar, Tanzania; Mombasa, Kenya). Each time series contains an arbitrary offset.

6 (a) Amplitude of the annual cycle of MSL at stations with at least 3 years of data in the PSMSL Metric data set. (b) Time of year at which the annual cycle peaks.

7. Monthly mean sea levels reported from Takoradi, Ghana expressed relative to the PSMSL RLR datum for the station. The dot represents MSL for the first 3 months of 2007 from a newly installed ODINAfrica tide gauge.

8. Map of the existing and planned sea level stations in Africa as described in Tables 1 and 2 (with the exception of Marion Is. which is off the map to the south).

Table 1: Existing and Planned Sea Level Stations in Continental Africa (as of May 2007)

Country	Station	Symbol on Figure	Current Type of Gauge	Delayed Mode Data Currently Sent to International Centres ? [1]	Real Time Data Available to International Community? [2]	Remarks
Egypt	Alexandria	•	Float and pressure	No	No	A new gauge is planned under ODINAfrica. See also [3]
	Marsa Matrouh	•	Pressure	No	No	
	Suez Canal	O		No	No	The Suez Canal Authority is known to operate several gauges along the Canal
Tunisia		O	Float at five sites and pressure	No	No	The Centre Hydrographique et Océanographique de la Marine Nationale has gauges at Bizerte, La Goulette, Kélibia, Sousse, Sfax and Zarzis
Algeria		O	Float	No	No	The Algerian Hydrographic Office has gauges at Annaba, Algiers and Oran but data are not shared internationally and has plans for 2 real-time systems
Spanish N. Africa	Ceuta	•	Float	Yes	No	
Morocco		O	Mostly radar, some float	No	No	Morocco has approximately 12 working tide gauges, none of which deliver data to the international community. An ODINAfrica gauge at Casablanca has been suggested. See [3]

Mauritania	Nouakchott	•	Radar and pressure	Yes	OB	An ODINAfrica radar and pressure system was installed in 2006
Senegal	Dakar	•	Acoustic	No	No	Gauge will be upgraded in 2007 when the tide hut has been refurbished
Côte d'Ivoire	Abidjan	•	Float	No	No	Côte d'Ivoire possesses several sea level stations but none deliver scientific quality data. The float gauge at Abidjan is believed to be operational but a new installation is also under consideration
	San Pedro	•	Float	No	No	A gauge exists but historical data are only in paper chart form
Ghana	Takoradi	•	Pressure and radar	Yes	OB	A pressure gauge exists provided by the National Institute of Oceanography, India. An ODINAfrica radar and pressure system was installed in 2006
	Tema	•		No	No	A pressure gauge provided by the National Institute of Oceanography, India will be installed in 2007
Nigeria	Lagos	•	Radar	No	No	A radar gauge is currently being brought into service
		O		No	No	A number of gauges are known to be operated in Nigeria by the oil industry
São Tomé	São Tomé	•	Pressure	Yes	ST	The present gauge was installed in 1988 but reinstalled at a slightly different position in 2004.
Cameroon	Port Sonara	•	Radar and presssure			An ODINAfrica system is planned for installation
Congo	Pointe Noire	•	Radar and pressure			An ODINAfrica system was installed in 2007 but as yet not fully operating
Angola	Luanda	•				A radar gauge with satellite telemetry is

						under consideration by the Benguela Current Large Marine Ecosystem project
	Namibe	•				A radar gauge with satellite telemetry is under consideration by the Benguela Current Large Marine Ecosystem project
Namibia	Walvis Bay	•	Float ?			A radar gauge with satellite telemetry is under consideration by the Benguela Current Large Marine Ecosystem project
	Luderitz	•	Float ?			A radar gauge with satellite telemetry is under consideration by the Benguela Current Large Marine Ecosystem project
South Africa [4]	Port Nolloth	•	Radar	Yes	No	
	Lamberts Bay	•				A radar gauge with satellite telemetry is under consideration by the Benguela Current Large Marine Ecosystem project
	Saldanha Bay	•	Acoustic	Yes	No	
	Cape Town	•	Acoustic	Yes	No	
	Simons Bay	•	Acoustic and radar	Yes	OB	Upgraded to Meteosat real time transmission in 2007
	Mossel Bay	•	Acoustic	Yes	No	
	Knysna	•	Radar	Yes	No	
	Port Elisabeth	•	Radar	Yes	OB	Upgraded to Meteosat real time transmission in 2007
	East London	•	Radar	Yes	No	
	Durban	•	Radar	Yes	OB	Upgraded to Meteosat real time transmission in 2007
	Richards Bay	•	Radar	Yes	No	

Mozambique	Maputo	•	Radar	No	No	
	Inhambane	•	Radar and pressure	Yes	OB	An ODINAfrica-like installation. Orbcomm data transmission recently upgraded to Meteosat
	Pemba	•	Radar and pressure	Yes	OB	Ditto
Madagascar	Nosy Be	•				There are national plans for major survey work to include permanent tide gauges. See also [3]
Tanzania	Zanzibar	•	Float	Yes	GR	
	Dar es Salaam	•	Float	No	No	
Kenya	Mombasa	•	Float	Yes	GR	
	Lamu	•	Float	Yes	GR	New gauge planned by Kenya Meteorological Department (KMD)
		O				KMD in understood to have plans for a new network of 3 stations at Lamu, Shimoni and Malindi
Djibouti	Djibouti	•	Radar and pressure	Yes	OB	At the time of writing a new gauge installed under ODINAfrica is beginning to deliver data
Red Sea		O				We understand that a Red Sea network is under consideration by the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA)

[1] International delayed mode data centres are those described in Section 3. A list of national centres with delayed mode data can be found at www.pol.ac.uk/psmsl/programmes/.

[2] In most cases, real time data are displayed at the ODINAfrica facility in Ostende, Belgium (denoted OB), while others are displayed at the GLOSS Real Time Centre at UHSLC (denoted UH). Some station data are displayed at both sites. São Tomé real time data can be found at the Réseau d'Observation Subantarctique et Antarctique du niveau de la MEr (ROSAME) web site www.legos.obs-mip.fr/fr/observations/rosame/ (denoted ST). A list of national real time data displays can be found at www.pol.ac.uk/psmsl/programmes/.

[3] See more details in GLOSS Technical Mission Reports, www.gloss-sealevel.org/publications/tech_mission_reports.html

[4] All South African acoustic gauges will be progressively replaced by radar sensors in 2007/8

Table 2: Existing and Planned Sea Level Stations in the 'Outer African Islands' (as of May 2007)

Islands	Station	Symbol on Figure	Current Type of Gauge	Delayed Mode Data Currently Sent to International Centres ? [1]	Real Time Data Available to International Community? [2]	Remarks
Canary Islands (Spain)		O	Acoustic, pressure and radar	Yes	GR	Puertos del Estado operate a network of 8 stations in the Canary Islands with a mixture of acoustic, pressure and radar gauges
Madeira (Portugal)	Funchal	•	Float	Yes	No	The Funchal station is presently being replaced by the station at Caniçal with an acoustic gauge
Cape Verde	Palmeira	•	Acoustic	Yes	GR	Moved from original site in Palmeira to Sal Island in 2000
Ascension (UK)	English Bay	•	Radar and pressure	Yes	GR	
St. Helena (UK)	Jamestown	•	Pressure	Yes	No	A radar gauge and improvements to real time data will be added in 2007
Tristan da Cunha (UK)		•				A pressure gauge will be installed in 2007
Marion Is. (South Africa)						A gauge will be installed in 2007 by the South African space agency in collaboration with GeoForschungsZentrum, Germany
Reunion (France)		•	Float	No	No	A radar gauge upgrade is planned in 2007
Mayotte	Dzaoudzi	•		No	No	A float gauge is no longer operational. A radar

						gauge upgrade is planned in 2007-8
Mauritius	Port Louis	•	Float	No	No	Station was upgraded in 2005 and had real time transmission capability but presently not working. It will be repaired and with new real time transmission equipment in 2007
	Rodrigues	•	Float	Yes	GR	An upgrade is planned in 2007
Seychelles	Pointe La Rue	•	Float	Yes	Yes	

[1] see comment 1 for Table 1
[2] see comment 2 for Table 1

GLOSS status within the PSMSL dataset

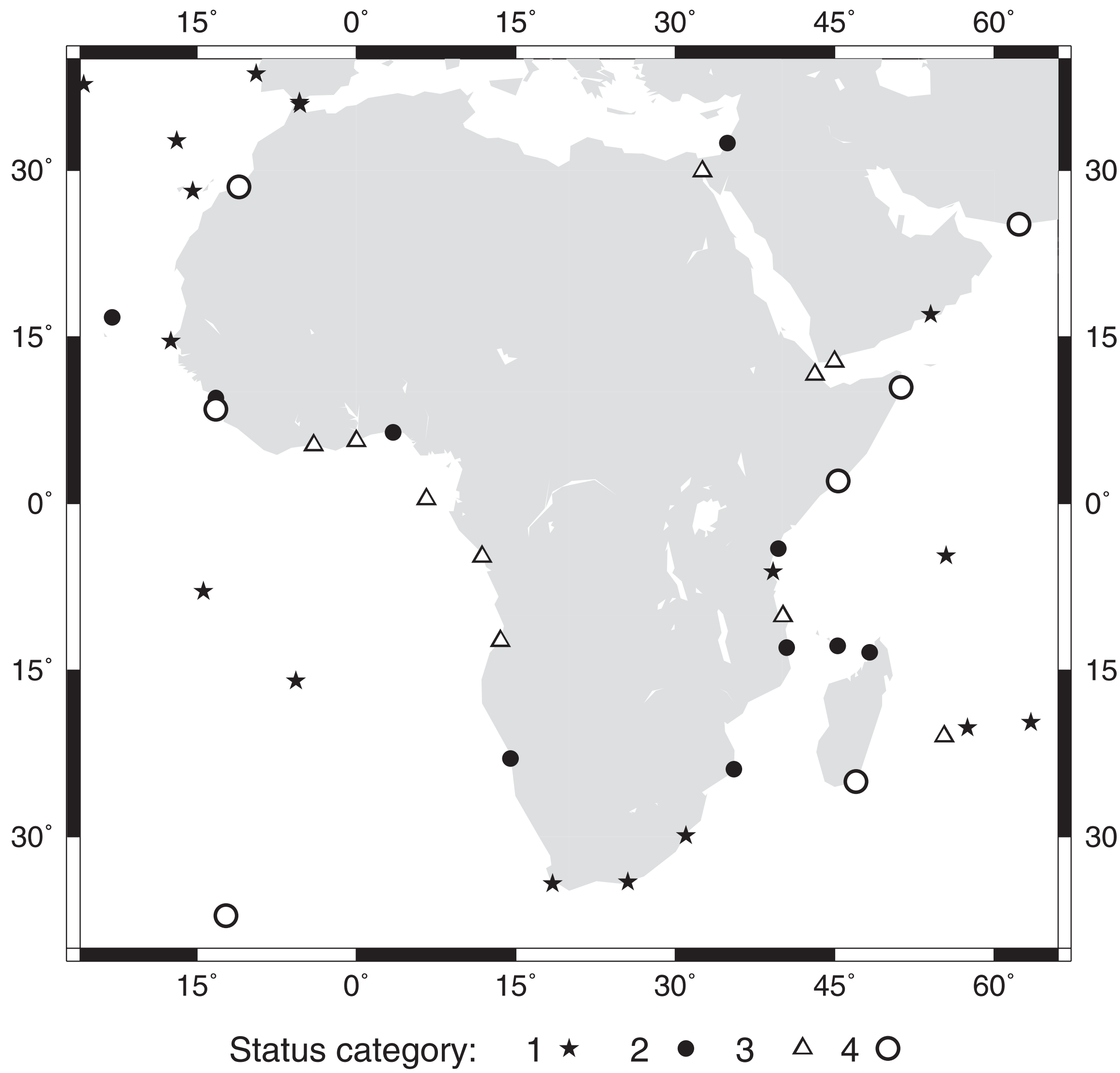


Figure 1

Distribution of PSMSL Stations

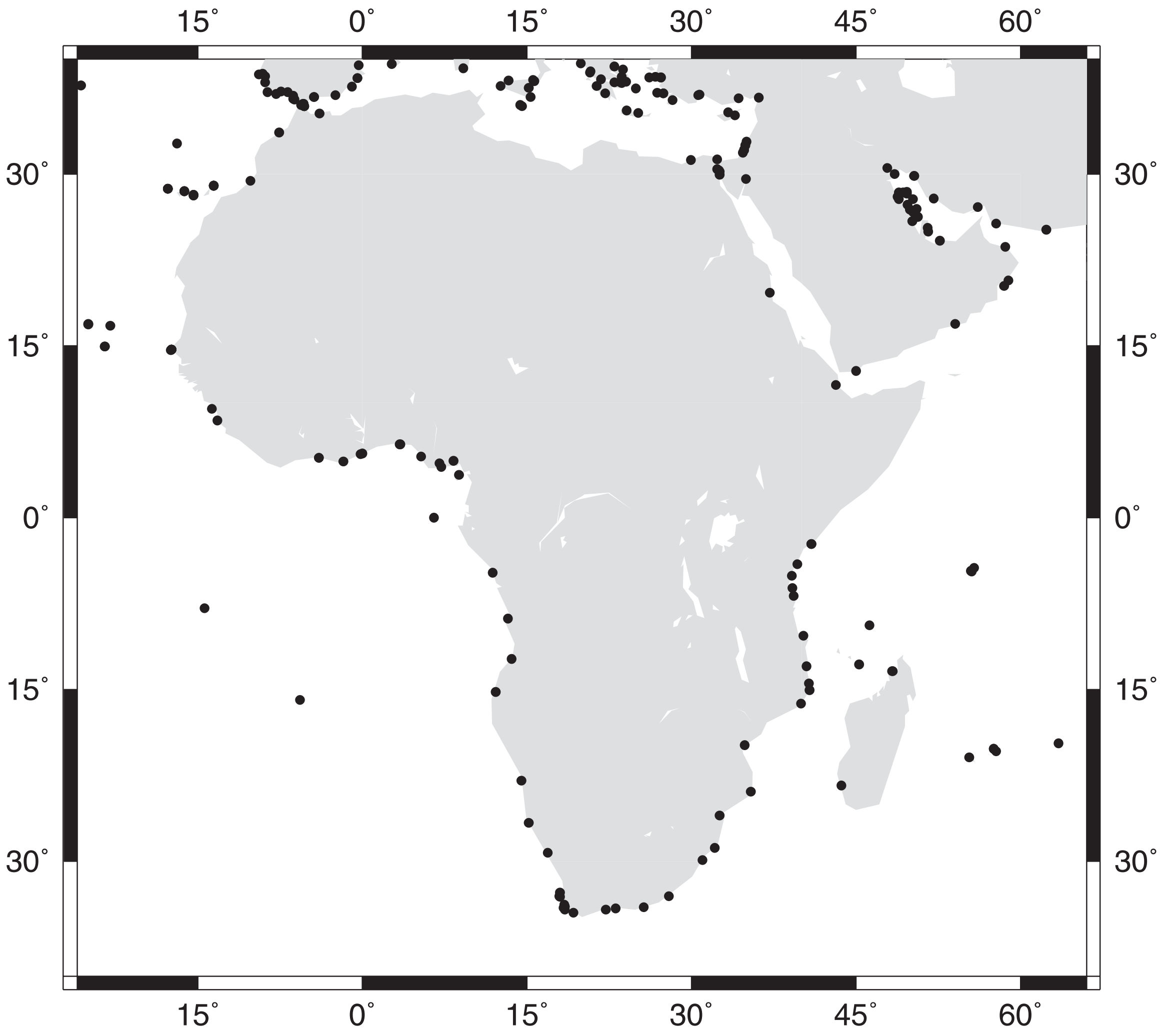


Figure 2

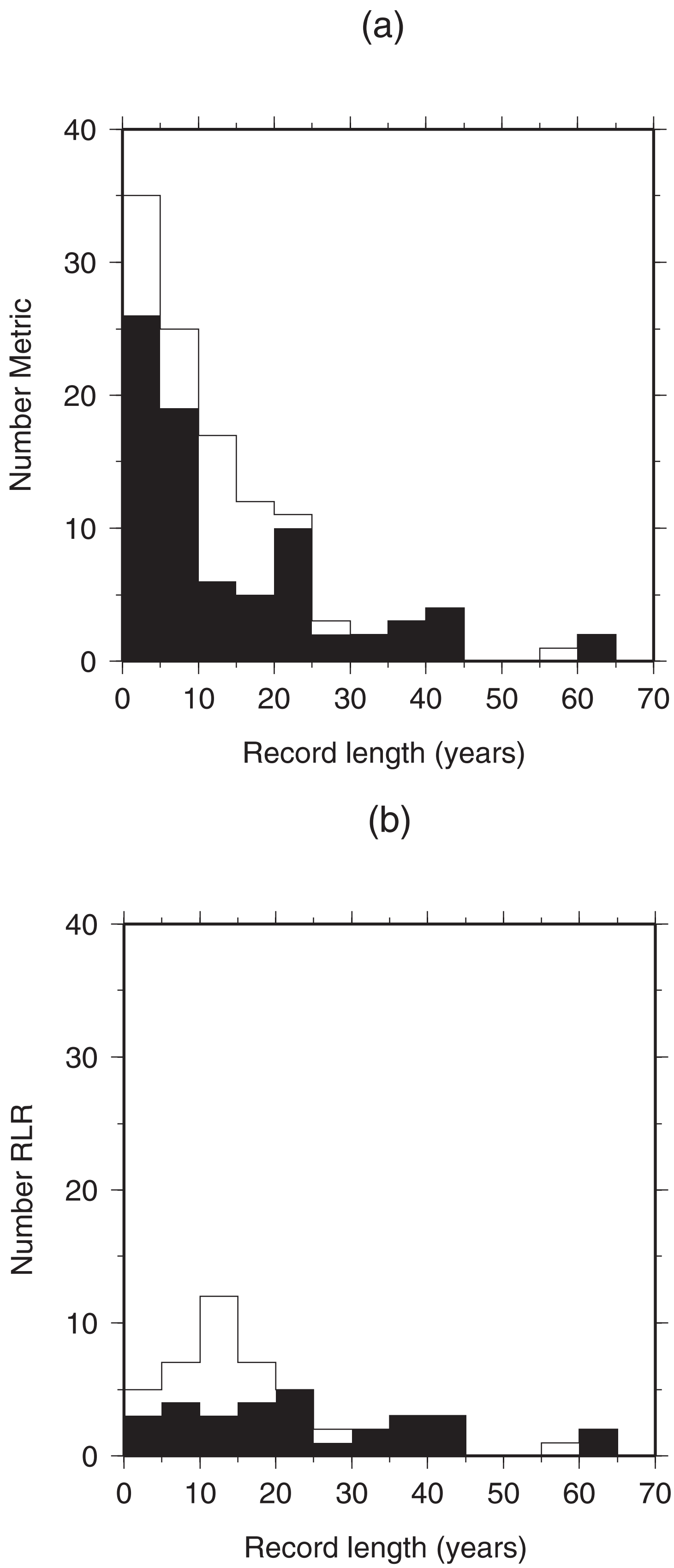
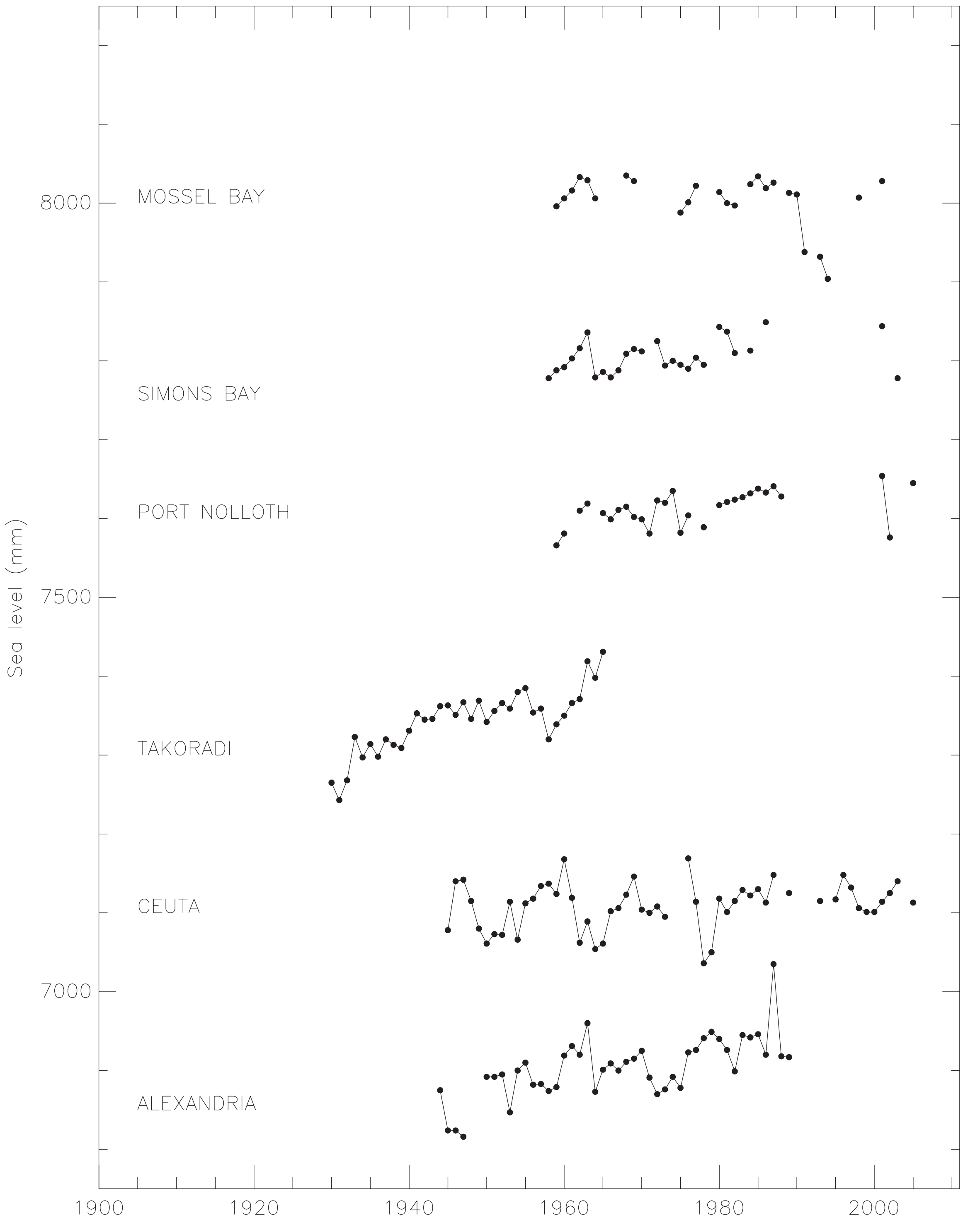

(a)
Number Metric
0
10
20
30
40
0
10
20
30
40
50
60
70
Record length (years)
(b)
Number RLR
0
10
20
30
40
0
10
20
30
40
50
60
70
Record length (years)

Figure 3



MOSSEL BAY
SIMONS BAY
PORT NOLLOTH
TAKORADI
CEUTA
ALEXANDRIA
Sea level (mm)
8000
7500
7000
1900
1920
1940
1960
1980
2000

Figure 4

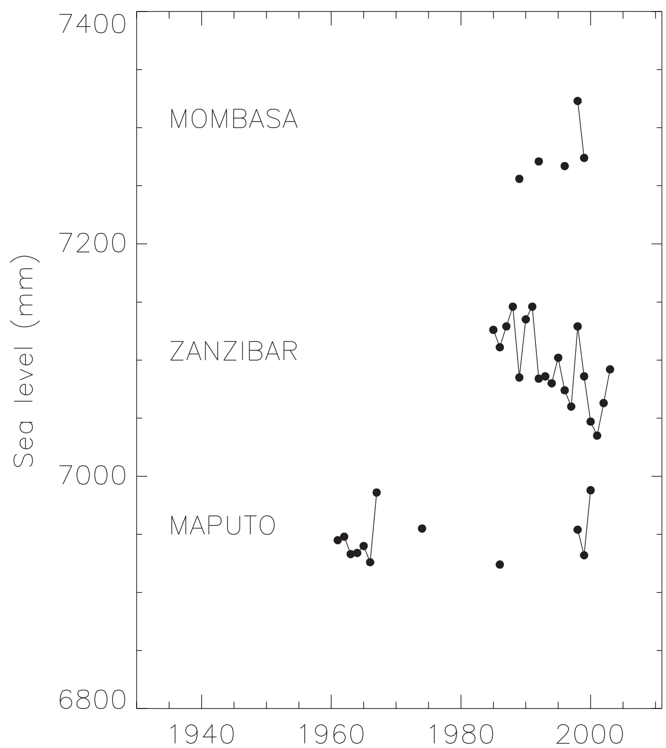

7400
7200
7000
6800
Sea level (mm)
MOMBASA
ZANZIBAR
MAPUTO
1940
1960
1980
2000

Figure 5

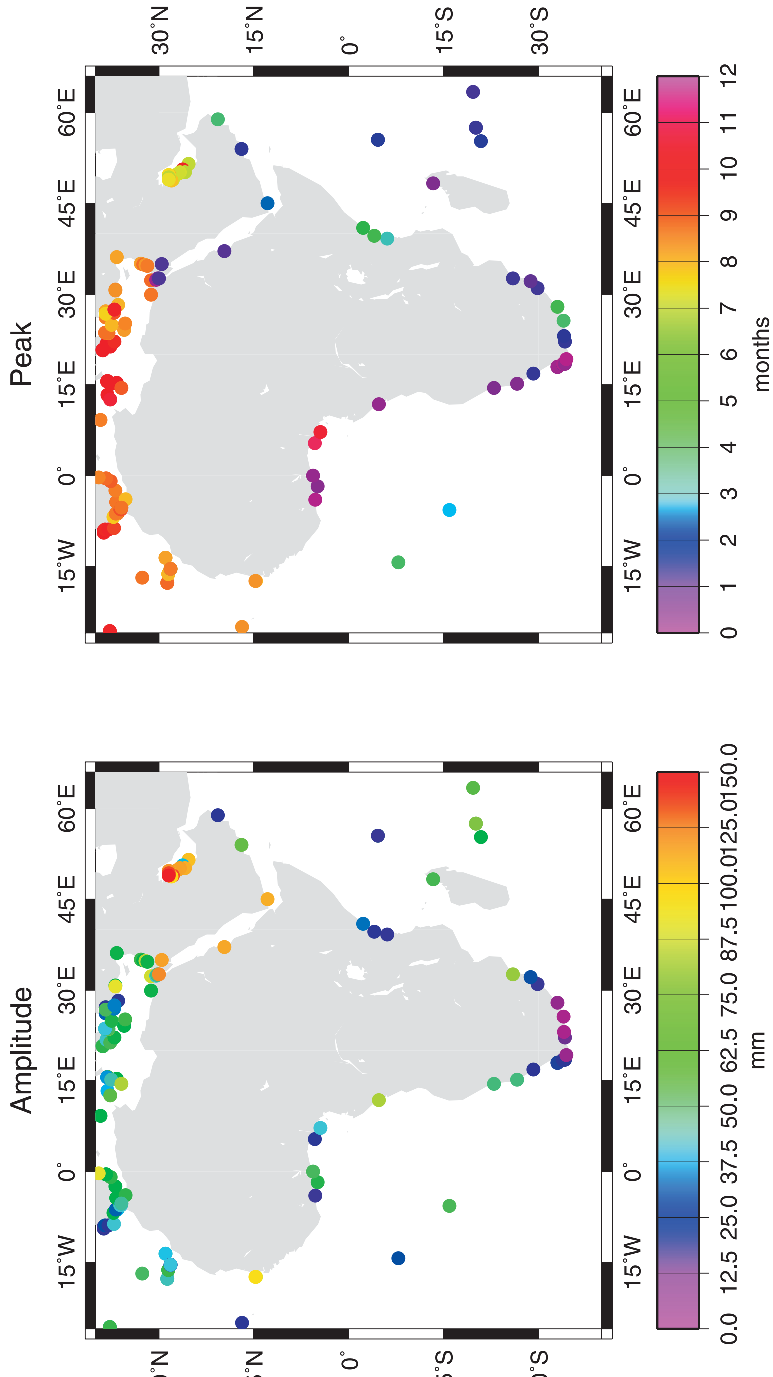

Amplitude
Peak
15˚W
0˚
15˚E
30˚E
45˚E
60˚E
30˚N
15˚N
0˚
15˚S
30˚S
0.0 12.5 25.0 37.5 50.0 62.5 75.0 87.5 100.0125.0150.0
mm
0 1 2 3 4 5 6 7 8 9 10 11 12
months

Figure 6

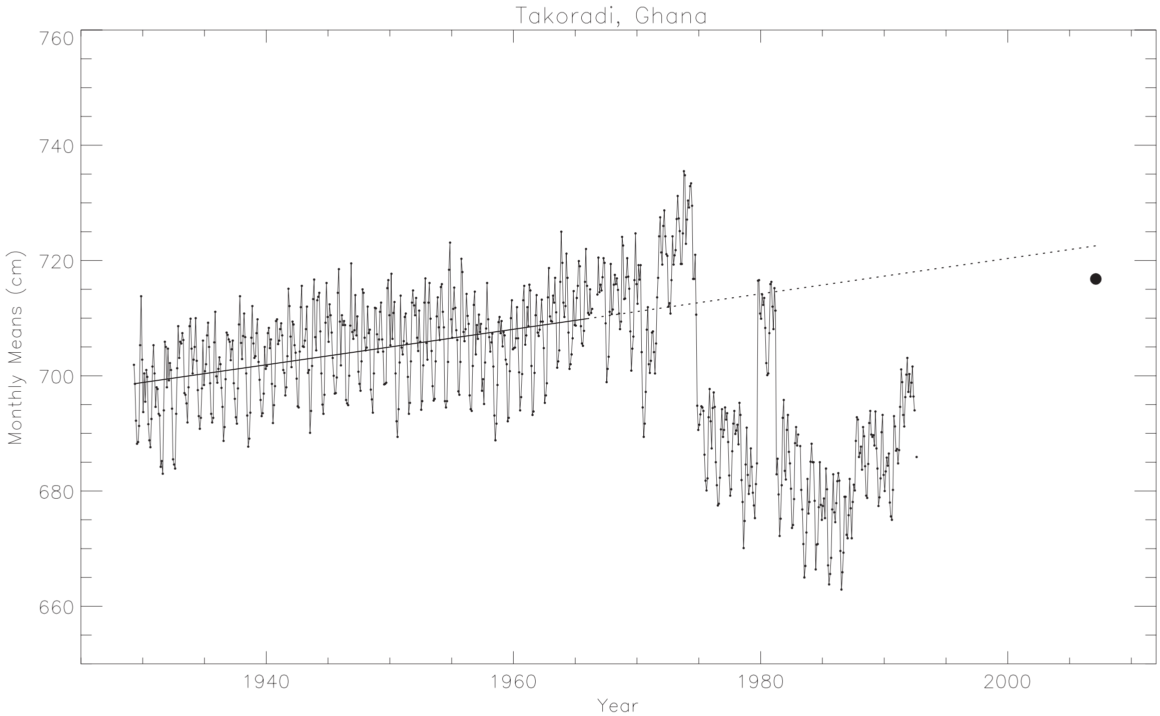

Takoradi, Ghana
Monthly Means (cm)
760
740
720
700
680
660
1940
1960
1980
2000
Year

Figure 7

Existing and Planned Sea Level Stations

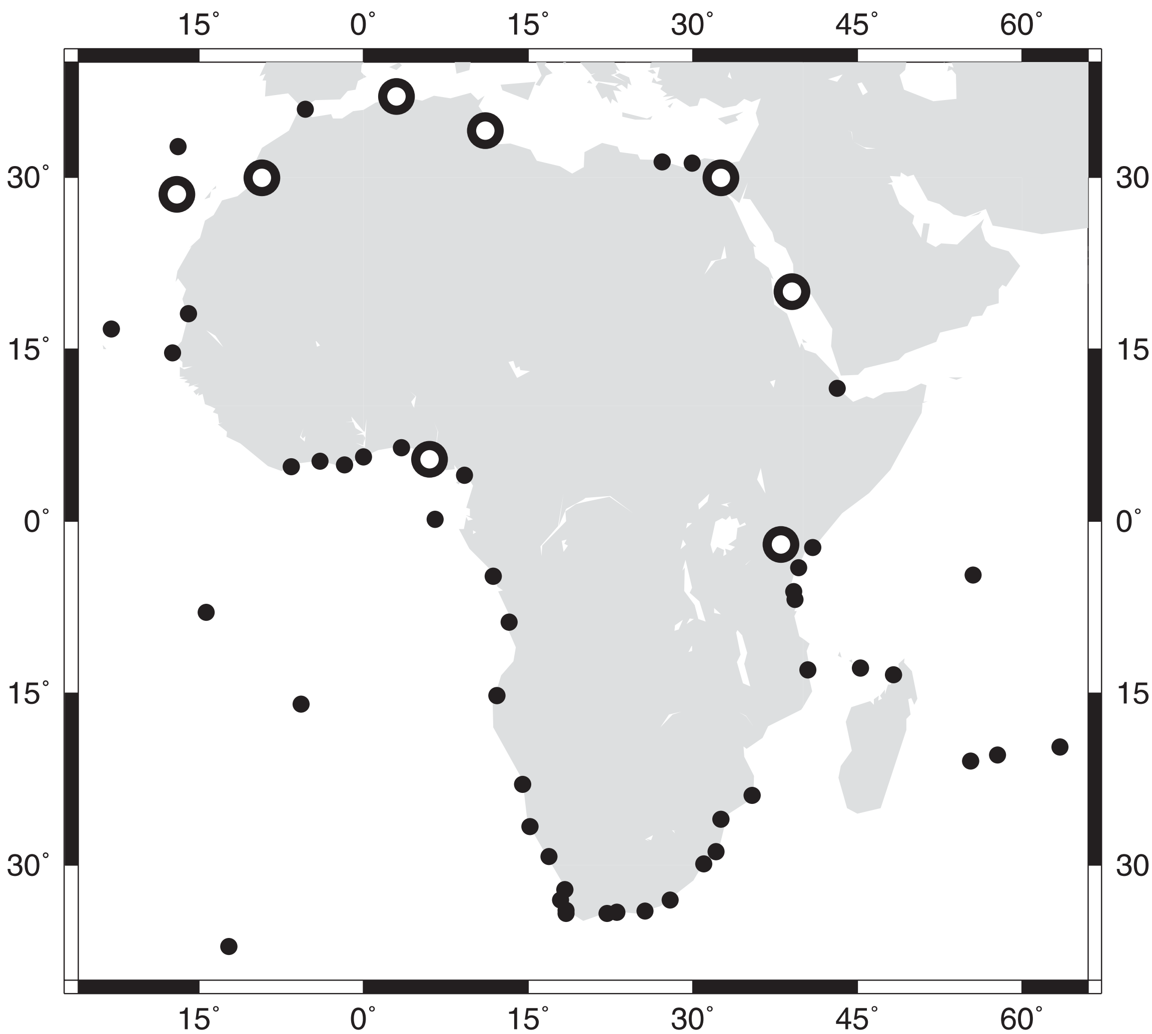


Figure 8