Article

Insight into Long Term Sea Level Change based on New Tide Gauge Installations at Takoradi, Aden and Karachi

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Abstract

Three sea level stations with extensive historical information have recently been equipped with new technology tide gauges, following large gaps in recording at the stations. The new and historical data in combination provide information on the rates of sea level rise along parts of the global coastline not well-represented in scientific studies to date. In these cases, the rates were found to be similar to those observed at many other locations around the world. However, it is suggested that other stations, where historical data exist and where gaps in recording have occurred, could be similarly equipped with new gauges, thereby expanding the spatial coverage of our knowledge of sea level rise.

Résumé

Trois stations de mesure du niveau de la mer possédant de très nombreuses informations historiques ont récemment été équipées de marégraphes d'une nouvelle technologie, à la suite d'importants manques observés dans les enregistrements faits à ces stations. La combinaison des données nouvelles et des données historiques fournit des informations sur la vitesse de l'élévation du niveau de la mer le long de certaines parties de la ligne de côte globale qui n'est pas bien représentée dans les études scientifiques à ce jour réalisées. Dans ces cas, les vitesses enregistrées ont été similaires à celles observées dans de nombreux autres endroits du monde. Néanmoins, il est suggéré que d'autres stations qui possèdent des données historiques, et pour lesquelles des manques ont été observés dans les enregistrements, pourraient être équipées de la même manière avec de nouveaux marégraphes, ce qui permettrait d'élargir la couverture spatiale de nos connaissances relatives à l'élévation du niveau de la mer.

Resumen

Tres estaciones de medición del nivel del mar con extensa información histórica han sido recientemente equipadas con mareógrafos de nueva tecnología, tras grandes vacíos en el registro de las estaciones. La combinación de los datos históricos y los nuevos proporciona información sobre los índices de elevación del nivel del mar a lo largo de partes de la línea de costa global, que no ha sido bien representada en los estudios científicos hasta esta fecha. En estos casos, se ha descubierto que los índices eran similares a aquellos observados en muchos otros lugares del mundo. Sin embargo, se sugiere que otras estaciones, en las que existen datos históricos y donde han tenido lugar vacíos en el registro, podrían ser equipadas de un modo similar con nuevos indicadores, expandiendo de este modo la cobertura espacial de nuestro conocimiento del aumento del nivel del mar.

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The evidence for sea level rise is derived primarily from long tide gauge records which are far from being geographically well-distributed (Bindoff et al. 2007). Additional information on rates of sea level change has been obtained from the recommencement of measurements at sites where previous recording was discontinued but where the original tide gauge benchmarks have survived. For example, Hunter et al. (2003) demonstrated that useful information on the rate of long term sea level rise could be obtained from only 1-2 years of historical measurements, and from a similar amount of modern data acquired over 160 years later.

In this paper, we report on three examples of sites where the available historical sea level data sets are much larger than that used by Hunter et al., and indeed are long enough to have provided good estimates of trends in the first part of the 20th century. However, for various reasons, the monitoring of sea level was discontinued, or was not undertaken to acceptable standards for studies of long term sea level change in recent years. In each case, new radar gauges, complemented by pressure and stilling well measurements, have been in operation for over a year after gaps in recording of several decades.

The three sites are Takoradi (Ghana), Aden (Yemen) and Karachi (Pakistan) for which historical monthly and annual means of sea level are archived at the Permanent Service for Mean Sea Level (PSMSL, Woodworth and Player, 2003) (Figure 1). Funding for the new equipment was provided through the Ocean Data and Information Network for Africa (ODINAfrica) and Indian Ocean Tsunami Warning System (IOTWS) programmes of the Intergovernmental Oceanographic Commission (IOC) in collaboration with the Survey of Ghana and the port authorities of Aden and Karachi. Recording methods at each site are as described by Woodworth et al. (2007).

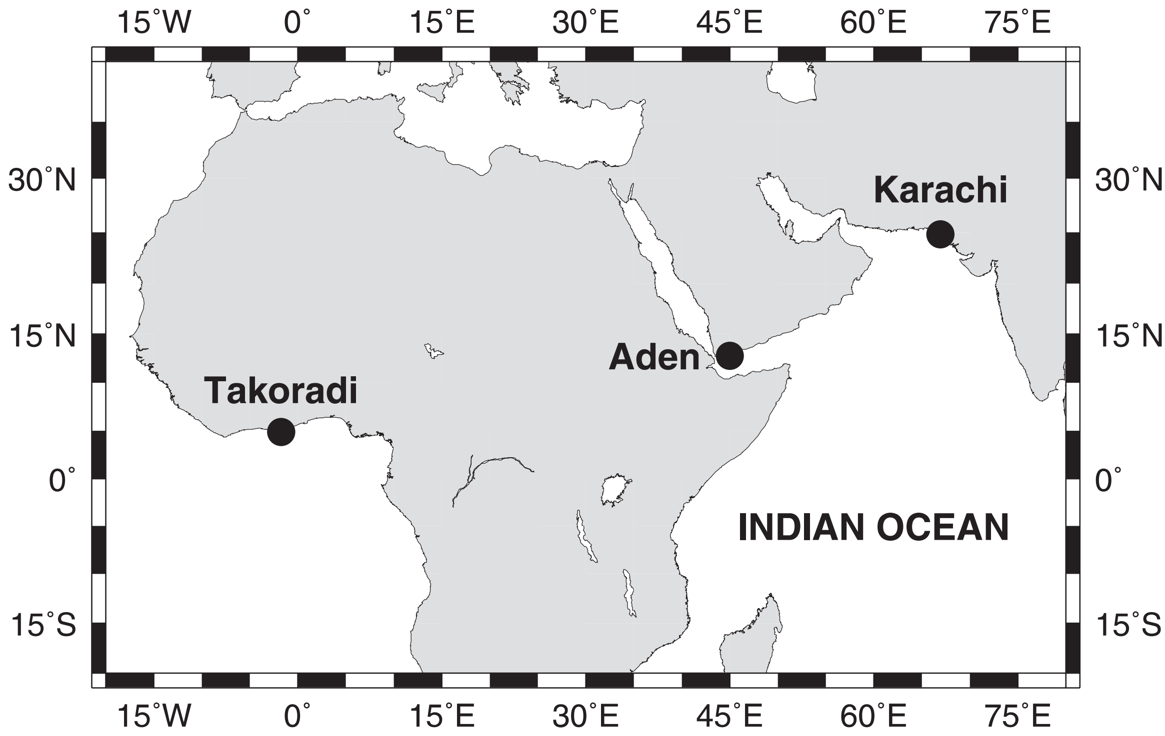

Figure 1: Locations of Takoradi, Aden and Karachi.

Figure 2 presents the historical monthly mean sea level values for each site together with seasonal (three-monthly) values derived from the recent measurements. Seasonal values were preferred for the new data as their time series acquired so far contain many short gaps. These have arisen partly from station start-up teething problems and partly from drop-outs in the telemetry between the stations and the data centre at Ostende, Belgium. The present telemetry, based on Meteosat Data Collection Platforms, will be duplicated shortly at some sites by INMARSAT Broadband Global Area Network (BGAN) equipment (Holgate et al. 2007).

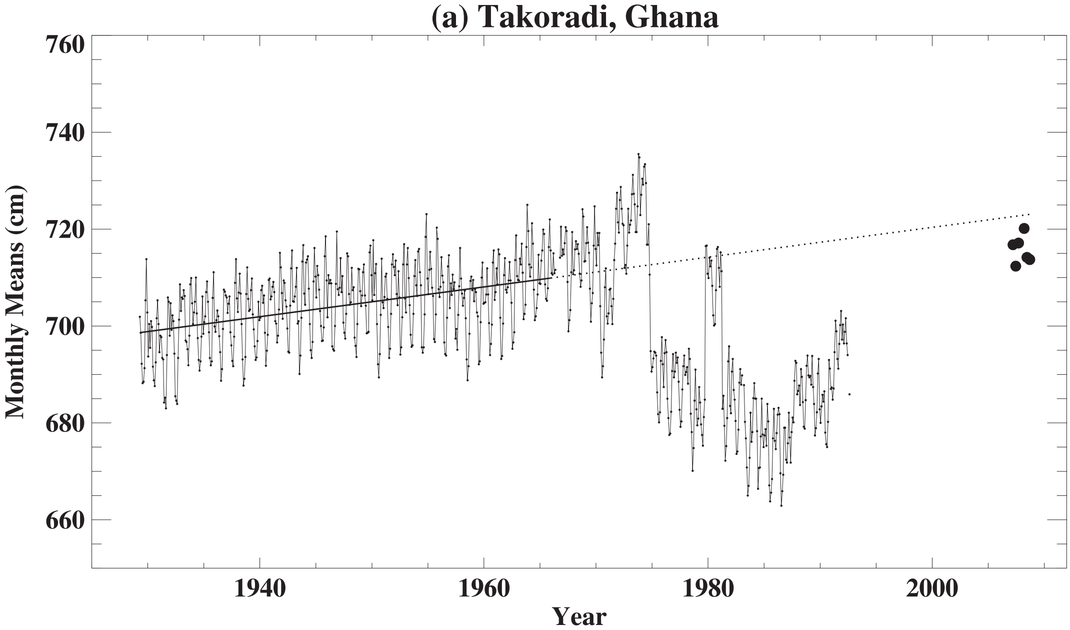

Figure 2 (a) : Historical monthly mean sea levels from Takoradi, Ghana together with recent seasonal mean values (large dots). The solid line is a linear fit to the historical data with an extrapolation to the present shown by the dotted line (data after 1965 are clearly suspect and are flagged accordingly in the PSMSL data set and have not been used in the linear fit).

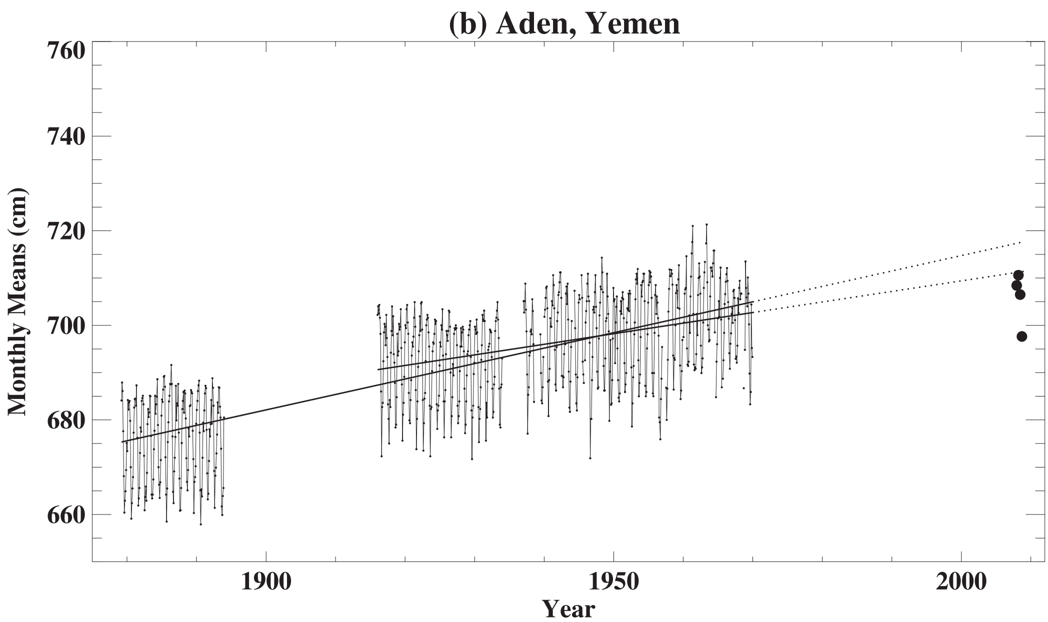

Figure 2 (b): Historical and recent data for Aden, Yemen. Linear fits are shown for 19th and 20th century dat combine and for 20th century data only.

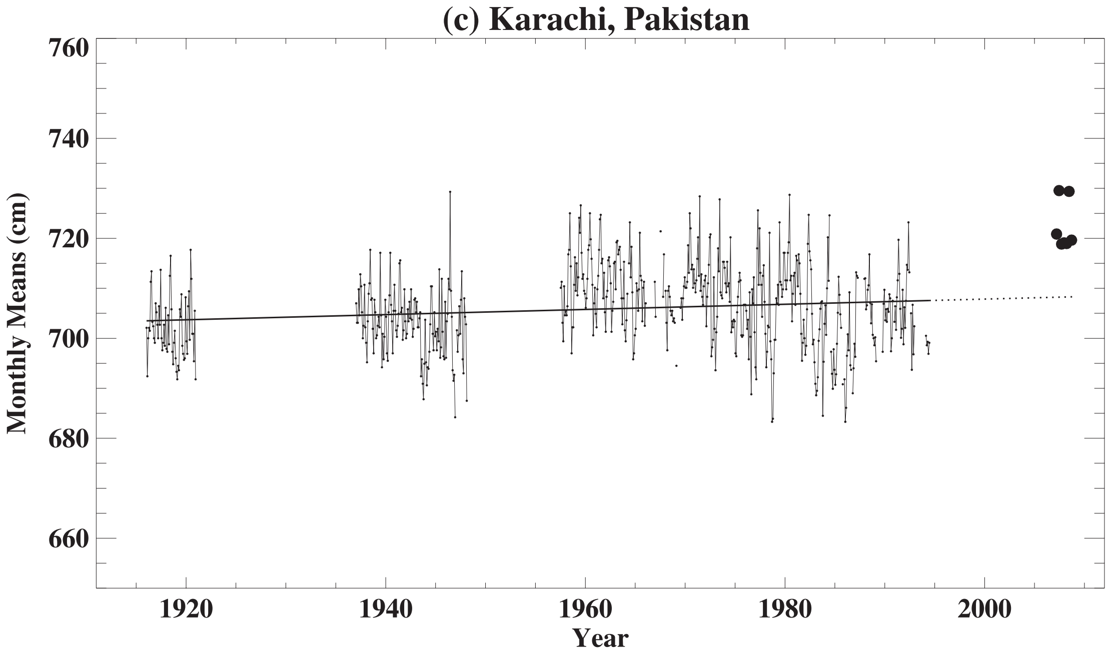

Figure 2 (c) : Historical and recent data for Karachi, Pakistan. All levels are shown with respect to local Chart Datum.

Even though the recent data sets are short, they demonstrate that the trends observed in the historical data, which will have been the result of vertical land movements in addition to any ocean changes in ocean volume, have largely persisted to the present day. This confirms to some extent the quality of the historical data. The recent data for Takoradi and Aden lie slightly below extrapolations from the historical measurements (in the case of Takoradi our extrapolation is based on data up to 1965 only as measurements thereafter were clearly of lower quality), while those for Karachi lie slightly above the extrapolation. These findings are consistent with observations at other sites which suggest little overall acceleration or deceleration in rates of sea level change during the twentieth century as a whole (Woodworth et al. 2008). We note that the linear trends of the extrapolations of the historical data at Takoradi, Aden and Karachi have gradients of 3.1, 3.3 and 0.5 mm/year respectively (2.2 mm/year at Aden if only 20th century data are considered). Part of these trends will be due to vertical land movements of which Glacial Isostatic Adjustment (GIA) forms one component, and is the only component which it is possible to estimate at present. On the basis of the ICE-5G VM4 GIA model of Peltier (2004), available from the PSMSL web site (http://www.pol.ac.uk/psmsl/peltier/), one sees that GIA rates are at only the -0.1 mm/year level for Takoradi and Aden, but could be -0.45 mm/year (i.e. emergence) at Karachi. This factor can explain partly the lower trend obtained at that site, as could the fact that the last few years of historical data were lower than earlier information. The Takoradi value (and that for Aden if 19th century data are included) is larger than the typically 1.7 mm/year one might have expected from other studies of 20th century sea level change (e.g. Bindoff et al. 2007) and may arise from local geological conditions such as settling of reclaimed land, in addition to large-scale processes such as GIA. Such findings are interesting but clearly longer records from the new gauges are required for further study, in addition to Global Positioning System (GPS) information to measure the actual magnitude of local vertical land movements (IOC 2006).

These findings provide limited but useful confirmation that 20th -21st century changes at parts of the global coastline not represented in previous studies have been similar to those observed elsewhere. However, more importantly, they demonstrate that investment in new equipment at such sites, where benchmarks survive, can produce results on recent sea level trends of interest to the scientific community within a short period (1-2 years), in contrast to the several decades that would be required for a completely new installation owing to the magnitude of interannual and decadal sea level variability (e.g. Shennan and Woodworth 1992). Of course, while such a temporary installation can produce interesting results, it would be of much greater interest to maintain the installation in the long term. The tide gauge system will also provide thereby information relevant to a wide range of users in operational oceanography. These users include specialists in storm surge and tsunami monitoring, in addition to agencies responsible for local tidal predictions and other practical applications. An example of such an application in our new data sets is the quantification of the large surge (≥ 1 metre) at Karachi that accompanied Tropical Cyclone 03B (Yemyin) which caused major loss of life and damage along the Pakistan coast in June 2007.

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Biographies of the authors

Philip Woodworth is a former Chair of the Global Sea Level Observing System (GLOSS) of the Intergovernmental Oceanographic Commission (IOC). Together with Peter Foden, Jeff Pugh and Andrew Mathews at the Proudman Oceanographic Laboratory in Liverpool, he has in the last few years been collaborating with IOC and with local agencies in order to establish reliable GLOSS regional networks in Africa and the Indian Ocean. These are required so as to provide sea level data for scientific research, tsunami monitoring and local applications. It is with regard to the development of tsunami-related technology that Woodworth, Foden and Pugh were awarded Denny Medals of IMAREST in 2009. Thorkild Aarup is Technical Secretary for the GLOSS programme at IOC in Paris and also has responsibilities for aspects of the tsunami networks in the Indian Ocean and other regions. Angora Aman was a leader for the ODINAfrica programme of IOC, which has seen the installation of approximately a dozen new stations in Africa and refurbishment of others. Emmanuel Nkebi and Joseph Odametey at the Survey of Ghana were responsible for one of the first such stations at Takoradi. Similar recent installations have been made at Indian Ocean locations such as Aden, Yemen and Karachi, Pakistan for which Roy Facey and Mustafa Yousef Abdulgafor Esmail and Muhammad Ashraf respectively took the main responsibility.

Back to Contents