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Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates?

A.S. Unnikrishnan *, D. Shankar

National Institute of Oceanography, Dona Paula, Goa, 403004, India

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Abstract

Mean-sea-level data from coastal tide gauges in the north Indian Ocean were used to show that low-frequency variability is consistent among the stations in the basin. Statistically significant trends obtained from records longer than 40 years yielded sea-level-rise estimates between 1.06–1.75 mm yr^{-1}, with a regional average of 1.29 mm yr^{-1}, when corrected for global isostatic adjustment (GIA) using model data. These estimates are consistent with the 1–2 mm yr^{-1} global sea-level-rise estimates reported by the Intergovernmental Panel on Climate Change.

Keywords: regional sea-level rise; mean-sea-level; tide gauge; north Indian Ocean

1. Introduction

Apart from changes in the atmospheric variables, global sea-level rise is one of the good indicators of climate change. Increase in global atmospheric temperature has a direct effect on the ocean by causing a rise in ocean temperature and melting of glaciers. Both these processes lead to a rise in global sea level. There have been numerous studies of 20th century sea-level rise based on analysis of past tide-gauge data. This was made possible by the availability of monthly-mean sea-level data through the Permanent Service for Mean Sea Level (PSMSL; Woodworth and Player, 2003). The Intergovernmental Panel on Climate Change (IPCC) reported (Church et al., 2001) values between 1–2 mm yr^{-1} for the 20th century sea-level rise based on tide-gauge data.

Though global sea-level rise has been studied extensively during the last two decades based on tide-gauge data, the same is not true of trends in regional sea level. The variability seen in regional sea level is less well understood owing to two causes. First, the distribution of tide gauges is not uniform over the globe, and not many records from the tropics are long enough for a reliable estimate of sea-level trends. Second, vertical land movements make problematic the determination of changes at the coast, where the tide gauges are located. Global Positioning System (GPS) measurements to determine vertical land movements are often not available.

Satellite altimetric data, available since 1993, not only overcome this shortcoming, but also have the advantage of spatial coverage: global patterns of sea-level rise using altimetric data, particularly TOPEX/Poseidon, have been

* Corresponding author. Tel.: +91 0 8322450311; fax: +91 0 8322450602.
E-mail address: unni@nio.org (A.S. Unnikrishnan).

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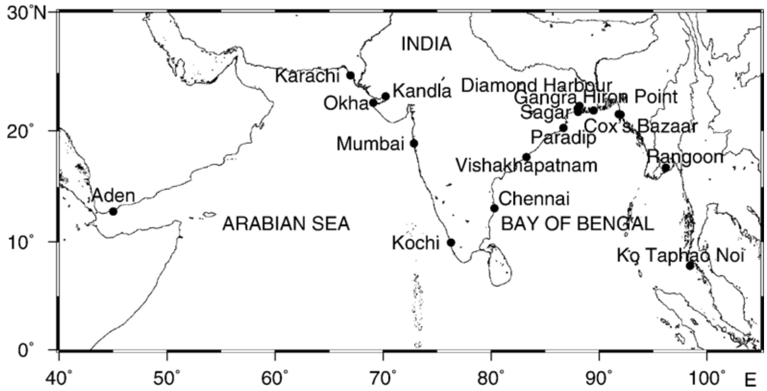

Fig. 1. Location of tide gauges with records longer than 20 years in the north Indian Ocean.

widely documented (Nerem and Mitchum, 2001; see Cazenave and Nerem (2004) for a review). The length of the satellite-based sea-level record is too small, however, for estimating long-term sea-level rise.

Studies on sea-level rise in the north Indian Ocean have been few, and are mostly based on tide-gauge data from India. Emery and Aubrey (1989) used monthly-mean sea-level data till 1982 at several tide-gauge stations along the Indian coast to estimate long-term trends in sea level. The trends showed considerable variability because even short records were included in the analysis. This inconsistency was also noted by Douglas (1991), leading him to conclude that the stations in the Indian subcontinent are not suitable for estimating global-mean sea-level rise. Using tide-gauge data all over the globe, Church et al. (2004) used reconstruction methods to determine the spatial pattern of sea-level variability during 1950–2000. These results were used to describe regional sea-level changes and suggest values close to 2.0 mm yr^{-1} in the north Indian Ocean, except the northeastern part of the Bay of Bengal, where values of more than 4 mm yr^{-1} are found.

In this paper, we make two points. First, we show that the data from several tide gauges along the coasts of the north Indian Ocean are consistent with one another and can be used for estimating regional sea-level rise. In doing this, we extend the work of Unnikrishnan et al. (2006), who used monthly-mean tide-gauge data till 1996 from India to estimate the trends for four selected stations; Mumbai, Kochi, and Vishakhaptanam showed an increase of about 1 mm yr^{-1} and Chennai showed a slight decrease. Studies on interannual and interdecadal sea-level variability also show a coherence along the coast of the north Indian Ocean (Clarke and Liu, 1994;

Table 1
Linear correlation coefficient for the annual-mean relative sea-level for tide gauge records at stations in the Arabian Sea (Bay of Bengal) with that of Mumbai (Vishakhapatnam)

Station (duration of the record)	Number of years of data availability	Reference station for correlation	Linear correlation coefficient	Confidence limit (%)
Aden (1880–1969)	58	Mumbai (1878–1993)	0.68	99.9
Karachi (1916–1992)	44	Mumbai	0.31	95
Kandla (1950–1996)	43	Mumbai	−0.04	<90
Okha (1975–2004)	22	Mumbai	0.67	99.9
Kochi (1939–2003)	54	Mumbai	−0.04	<90
Kochi (1939–2003)	54	Vishakhaptanam	0.43	99.0
Chennai (1916–2003)	39	Vishakhapatnam (1937–2003)	0.62	99.9
Paradip (1967–2003)	20	Vishakhapatnam	0.91	99.9
Sagar (1937–1987)	48	Vishakhapatnam	0.22	<90
Gangra (1974–2002)	25	Vishakhapatnam	0.88	99.9
Diamond Harbour (1948–2004)	55	Vishakhapatnam	0.46	99.9
Hiron Point (1983–2003)	21	Vishakhapatnam	0.75	99.9
Cox's Bazaar (1979–2000)	20	Vishakhapatnam	0.43	90.0
Rangoon (1916–1962)	25	Vishakhaptnam	0.34	90.0
Ko Taphao Noi (1940–2002)	58	Vishakhapatnam	0.29	95