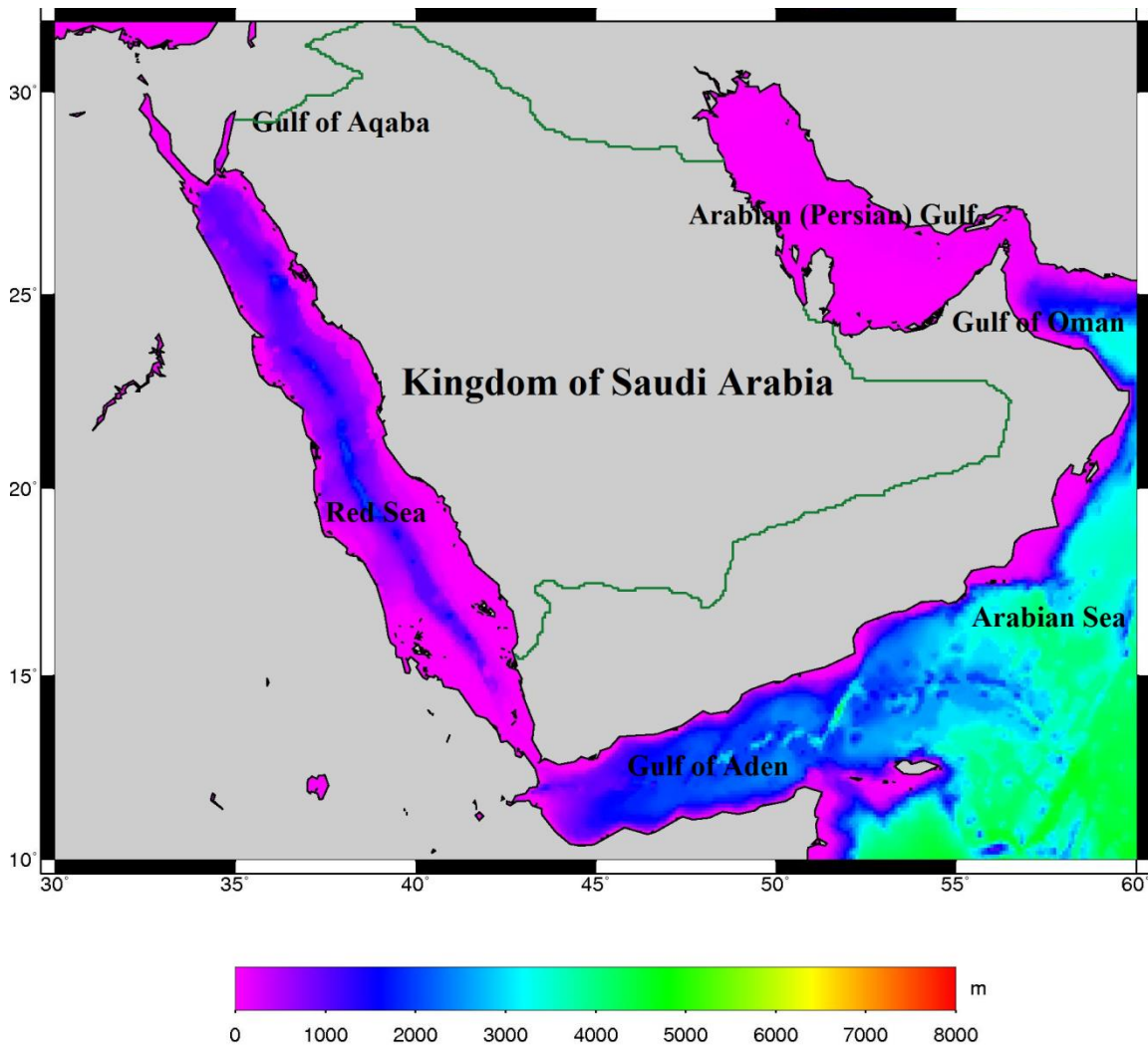


Sea Level Activities in the Kingdom of Saudi Arabia

A Report Submitted to Thirteenth Session of the Intergovernmental Oceanographic Commission (IOC) Group of Experts of the Global Sea Level Observing System (GLOSS)

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By

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I. Overview:

This report gives a brief overview of the sea level activities in the Kingdom of Saudi Arabia in the past two years. Saudi ARAMCO Oil Company has its own network along the Red Sea and the Arabian (Persian) Gulf with limited information. General Commission for Survey (GCS) has established tide gauges network to monitor the sea level in the Red Sea, Gulf of Aqaba and the Arabian (Persian) Gulf. Efforts from two Saudi Universities are still continuing to study the sea level variation.

The previous report, which was submitted in 2011, gave a history about the tide gauge deployments in the Kingdom. The report gave a general outline on the local and regional development efforts to measure water levels. The report has also mentioned the regional organizations works on focusing over the conservation and management of the coastal and marine resources of the Arabian (Persian) Gulf and the Red Sea, with little or no interest for monitoring sea level.

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II. Introduction:

Saudi Arabia has a long coastline along its western and eastern borders. The stretch of the coast is about 2640 km out of which nearly 70% is along the Red Sea and the remaining 30% is along the Arabian Gulf (Library of Congress, 2006) (Figure 1). Over the last few decades the Kingdom of Saudi Arabia has made parallel progress in programs for socio-economic development, more than 50% of the population of Saudi Arabia lives within 100 km of the Saudi coastline.

Modern studies of climate change have identified the mean sea level as an important indicator of change and of the associated processes. Different studies require and recommend a well distributed global sea level network and proper international collaboration in defining observational standards, data collection and processing.

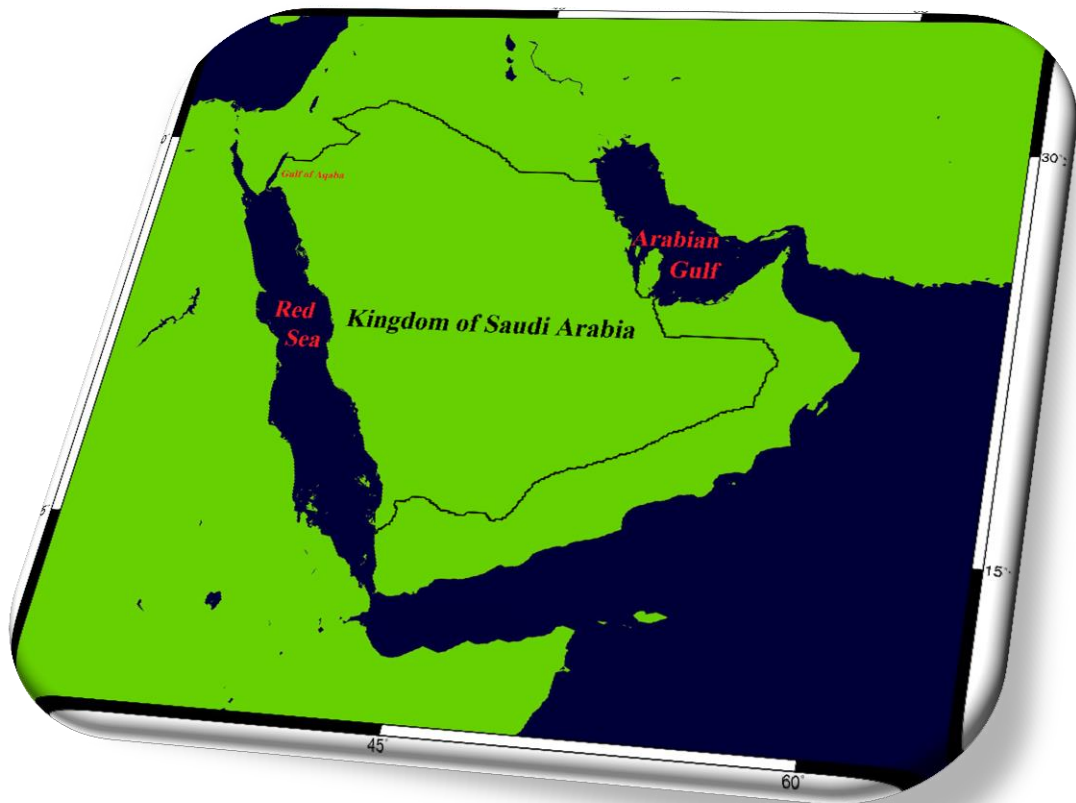


Fig. 1: A map showing the Red Sea, Arabian (Persian) Gulf and Gulf of Aqaba surrounding the Kingdom of Saudi Arabia.

III. Tide Gauges Networks along the Coast of Saudi Arabia:

The Pacific Aero Survey Company (PASCO) installed the first tide gauges in the Kingdom nearly half a century ago. Saudi ARAMCO Oil Company has the major effort for monitoring the sea level in the Kingdom and the data output is presented in periodical tide tables. General Commission of Survey (GCS) has established tide gauges network to monitor the sea level in the Red Sea, Gulf of Aqaba and the Arabian (Persian) Gulf. King Abdulaziz University (KAU) has installed three tide gauges with meteorological sensors in Jeddah area. The Red Sea Research Center (RSRC), King Abdullah University of Science and technology (KAUST), deployed an array of three bottom pressure/temperature/conductivity (PTC) instruments along the Saudi Arabian coast of the eastern Red Sea to measure the regional tidal variability of the bottom pressure field.

1) Saudi ARAMCO Oil Company:

ARAMCO Oil Company has a continuous monitoring monthly means of sea level in the Kingdom and provided to the permanent commission for mean sea level (PSMSL). The company has been operating 12 tide gauges in the Arabian Gulf at Quarriyah, Ras Tanura, Juaymah, Abu Safah, Abu Ali, Arabiyah Island, Tanajib, Lawnah, Marjan, Safaniya Pier, Zuluf, Safaniyah (Table 1) (ARAMCO, 2008a, 2008b and 2012). Five of these twelve have been operational since 1980, while the rest of the stations were operated since mid-eighties (Figure 2). After 1993, the float type tide gauges were replaced with acoustic tide gauges in GLOSS standard (Sammari, 2004).

In the 1998, ARAMCO operated 5 primary tide gauges along the Red Sea at Duba, Yanbo, Rabigh, Jeddah and Jazan (Jizan). These tide gauges are British brand tide gauges (Sonar Research Ltd), data at Red Sea stations are transmitted in real-time to Ras Tannura office, where they are archived and processed (Sammari, 2004).

In the 1986, ARAMCO tide table are referenced to Lowest Astronomical Tide (LAT). The LAT datum is defined as “the lowest water level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions at any specific location”. Before 1986, the tables were referenced to Indian Spring Low Water (ISLW) which resulted in several negative predicted tides during the year.

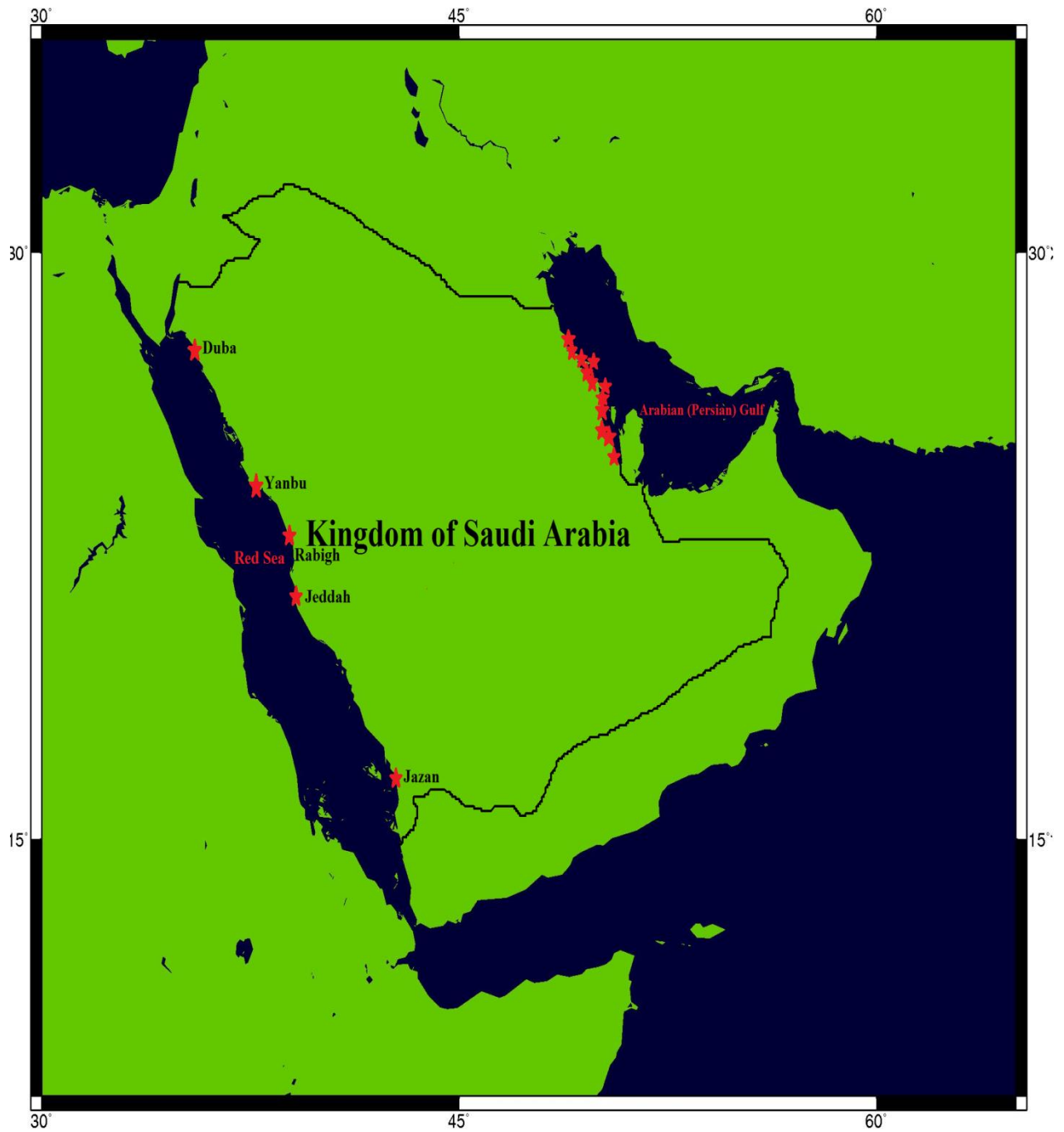


Fig. 2: ARAMCO Oil Company tide gauges network in the Kingdom of Saudi Arabia; 5 tide gauges along the Red Sea and 12 tide gauges along the Arabian (Persian) Gulf.

ARABIAN (PERSIAN) GULF

Locations	Lat.	Long.
QURAYYAH PIER	25° 53'	50° 07'
RAS TANURA (N. PIER)	26° 39'	50° 10'
JUAYMAH PIER	26° 52'	49° 54'
ABU SAFAH	26° 57'	50° 30'
ABU ALI PIER	27° 18'	49° 39'
ARABIYAH ISLAND	27° 47'	50° 11'
TANAJIB PIER	27° 47'	48° 53'
LAWHAH (1997)	28° 15'	49° 37'
MARJAN	28° 27'	49° 38'
SAFANIYA PIER	28° 00'	48° 46'
ZULUF	28° 24'	49° 16'
SAFANIYAH	28° 24'	48° 54'

Red Sea

DUBA	27° 19'	35° 43'
YANBU	23° 06'	38° 13'
RABIGH	22° 44'	38° 59'
JEDDAH	21° 25'	39° 09'
JAZAN (JIZAN)	16° 52'	42° 33'

Table 1: ARAMCO Oil Company tide gauges network; Arabian (Persian) Gulf and Red Sea tide stations with site names and approximate locations.

2) General Commission of Survey (GCS):

In the 2012, General Commission of Survey (GCS) has established a tide gauges network to monitor the sea level in the Red Sea and the Arabian (Persian) Gulf and is follow the major requirements for GLOSS-quality tide gauge station; IOC, 1997. Total of twelve stations are installed; six stations along the Red Sea, one station in the Gulf of Aqaba and five locations are selected in the east coast of the Kingdom along the Arabian (Persian) Gulf. Each tide station is equipped with GPS and four meteorological sensors; wind (speed and directions), air temperature, relative humidity and air pressure (Figure 3) and (Table 2).

The tide and meteorological data transmitted to the GCS headquarter in Riyadh for archiving and processing. The GCS has a plan to build a marine data center to provide reliable data records to most governmental authorities working within or for the marine environment.

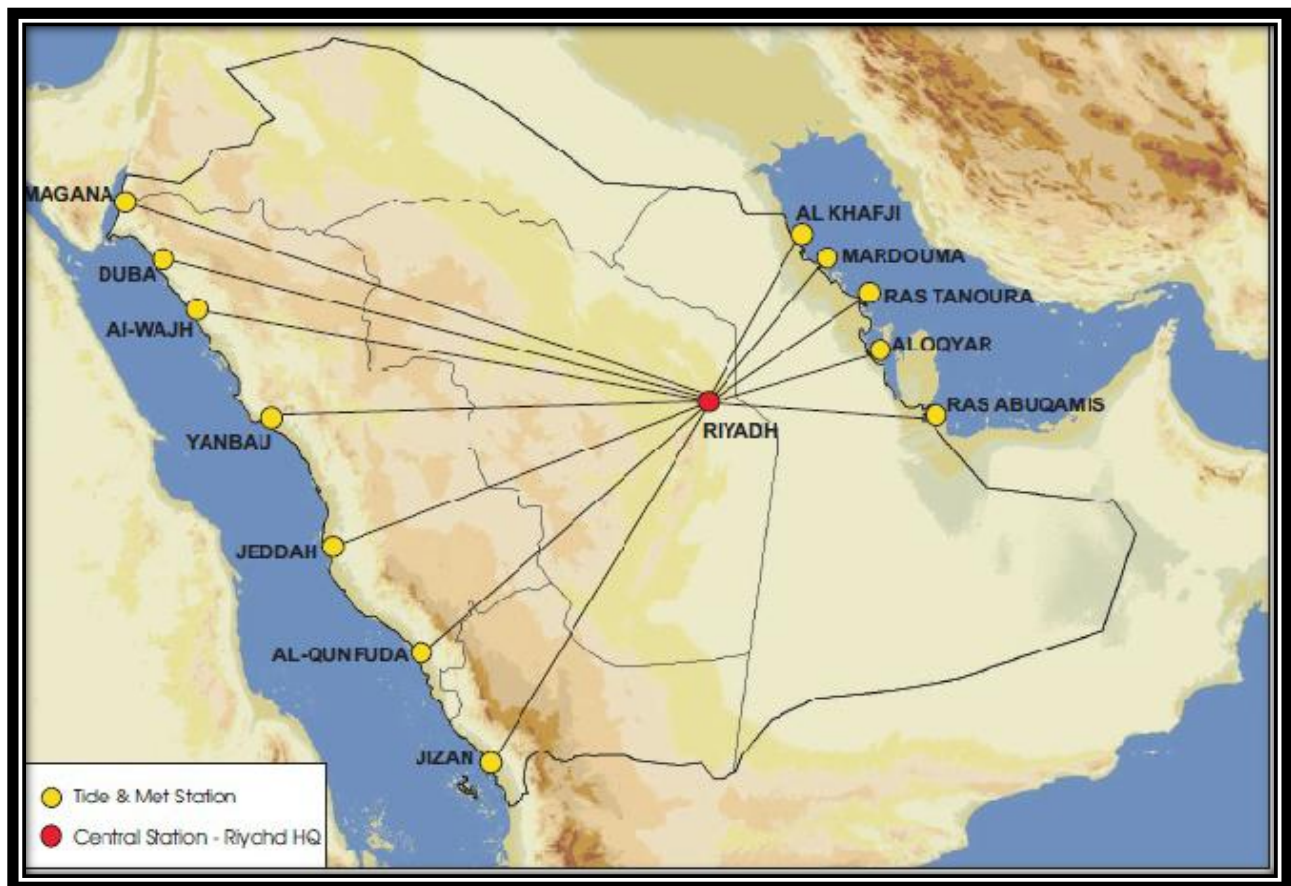


Fig. 3: GCS tide gauges network along the Arabian (Persian) Gulf, Gulf of Aqaba and Red Sea. The data collected and transmitted to the GCS headquarter in Riyadh.

ARABIAN (PERSIAN) GULF

Locations	Lat.	Long.
AI KHAFJI	28° 25'	48° 31'
MARDOUMA	27° 07'	49° 30'
RAS TANURA	26° 39'	50° 07'
ALOQYAR	25° 38'	50° 13'
RAS ABUQAMIS	24° 33'	51° 28'

Gulf of Aqaba

MAGANA	28° 24'	34° 44'
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Red Sea

DUBA	27° 33'	35° 32'
AL WAJH	26° 15'	36° 26'
YANBU	24° 08'	37° 56'
JEDDAH	21° 29'	39° 09'
AL QUNFUDA	19° 07'	39° 09'
JAZAN (JIZAN)	16° 53'	42° 32'

Table 2: GCS tide gauges network; Arabian (Persian) Gulf, Gulf of Aqaba and Red Sea tide stations with site names and approximate locations.

3) King Abdulaziz University (KAU):

The Faculty of Marine Science at King Abdulaziz University (KAU) in Jeddah has formed an intensive co-operation with the Research and Technology Centre of the University of

Kiel (FTZ Büsum, CAU); one of the subprojects is the development and application of a Coastal Monitoring System (CMS) for Jeddah coastal areas. By April 2011, three separately ultrasonic acoustic tide gauges with meteorological sensors were installed at the Coast Guard Stations of Obhur (northern side of Jeddah), Gahaz (Jeddah) and Saroom (southern side of Jeddah) for monitoring of water levels and winds were completed (Figure 4). Data from the three stations is currently being transferred and is available in real time both in Jeddah and Kiel. A future plan to deploy two more tide gauges at Jazan and Duba are currently under discussion (Mayerle and Al-Subhi, 2011).

Currently, the three tide gauges are still running and the data is available at the Marine Physics Department/KAU, unfortunately the array of the gauges has not been expanded as was planned (Personal communications with KAU).

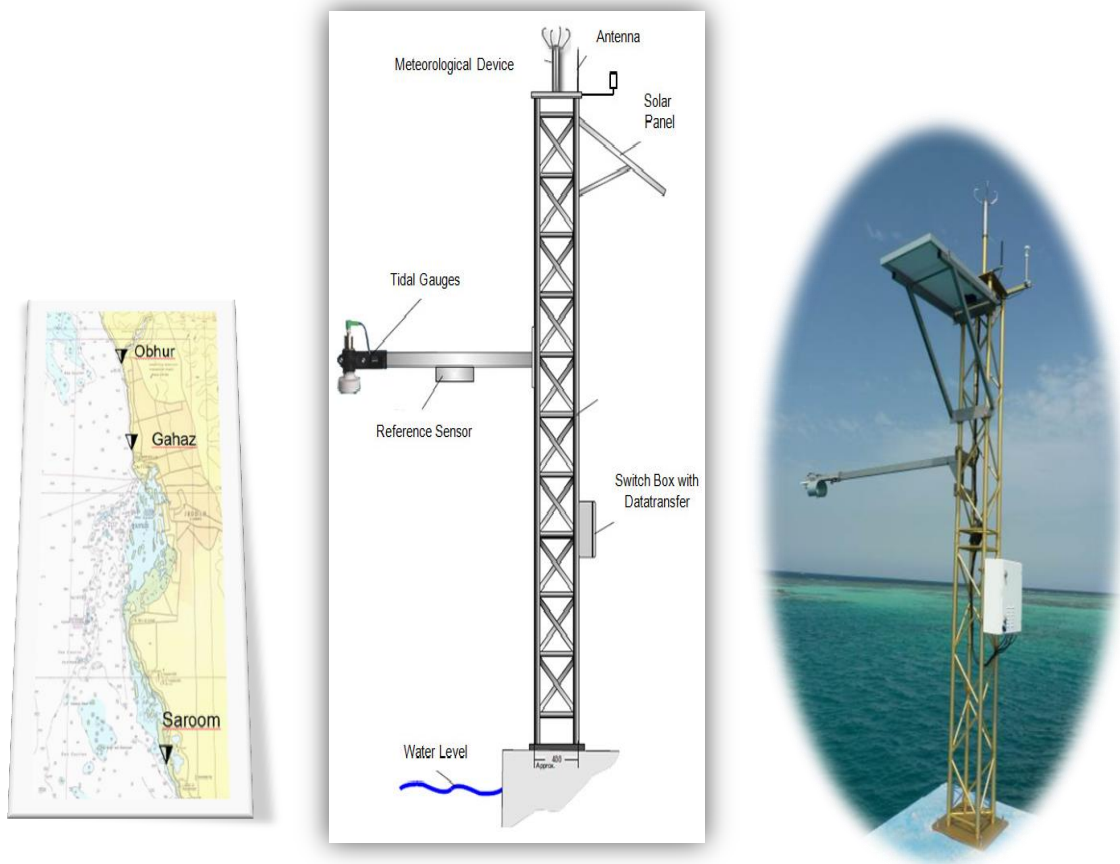


Fig. 4: Location of the tide gauge stations; Obhur (northern side of Jeddah), Gahaz (Jeddah) and Saroom (southern side of Jeddah) (left), technical details (centre) and tidal gauge at the Saroom Coast Guard (right) (After Mayerle and Al-Subhi, 2011).

4) King Abdullah University of Science and Technology (KAUST):

King Abdullah University of Science and Technology (KAUST) in Thuwal, which established on September 2009 and is located ~100km north of Jeddah, had an initial plan to observe the sea level in the Red Sea. However, since there are several activities by other local groups, this plan was changed and a communications were launched with these groups to exchange the benefits.

The Red Sea Research Center (RSRC) deployed an array of three bottom pressure/temperature/conductivity (PTC) instruments at Jeddah (now is located at Al-Lieth, 100km south of Jeddah), Qudaimah (now is located at KAUST water territories), and Rabigh (now is located at Al-Raiys, 80km south of Yanbu) along the Saudi Arabian coast of the eastern Red Sea (Figure 5). This PTC array accurately measured the regional tidal variability of the bottom pressure field and characterized the low frequency along-shore pressure, temperature and salinity gradients and their variability. Surface sea level/height was calculated from the bottom pressure measurements using the hydrostatic equation. Future measurements using similar instrument alongside with tide gauges at the west side of the Red Sea will augment the tidal variability study.

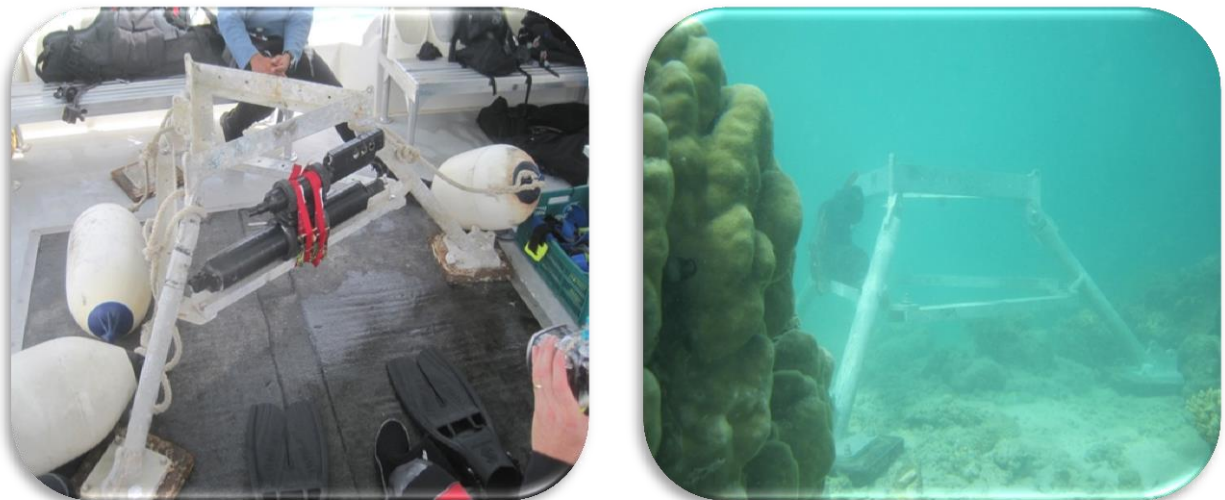


Fig. 5: The Red Sea Research Center (RSRC)/KAUST studying the tidal variability by deploying three bottom pressure/temperature/conductivity (PTC) instruments at three different locations along the Saudi Arabian coast of the eastern Red Sea.

IV. Data Quality:

Data quality depends on the leveling process and calibration; these procedures are used in ARAMCO stations beside the quality control. Periodicals prints made by ARAMCO, which including tidal tables are prepared based on these data and they are accessible upon request. However Tide Gauge Bench Marks (TGBMs) are not connected to a geodetic datum, calibration and leveling operations are carried out regularly and the time series from the stations are analyzed (Harmonic analysis and tide forecasts); data outputs are exclusively used for safe navigation (Moammar and Chaudhry, 2010).

General Commission of Survey (GCS) is following the major requirements for GLOSS-quality tide gauge station; IOC, 1997. Data collections are in accordance to the standards set by International Council for the Exploration of the Sea (ICES).

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