

## SEA LEVEL VARIATION ALONG THE WESTERN COAST OF THE ARABIAN GULF

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### Abstract

Observed hourly tidal heights from six stations during the period 1980-1987 were used in the analyses. Daily readings of the pressure at mean sea level from three meteorological stations were also used. The variations of the observed daily mean sea level were studied at the six stations, giving low values in the winter season, and high ones in summer and spring seasons. The monthly mean sea level showed higher values during July and August and lower ones in the winter season. As the Arabian Gulf is generally considered a shallow sea, the meteorological conditions are the main cause of the sea level variation. This was shown by the variation of the daily mean sea level residual at the six stations. From the analyses of the coherence of several parameters, the pressure difference over the Gulf area did not give a noticeable effect with either the daily observed sea level or the daily sea level residual. Generally speaking, the important factor affecting the sea level variation in the Arabian Gulf is the pressure system covering the area either during the summer or the winter seasons.

### INTRODUCTION

The Arabian Gulf is very shallow with an average depth of 25 m where the semidiurnal and the diurnal tides can give rise to resonance oscillations. According to the dimensions of the Gulf, 850 km long, 250 km wide and a mean depth of 50 m, A. DEFANT (1961) estimated that the free oscillation period of the basin was in between 21.7 h and 22.6 h.

E. LISITZIN and J. PATTULLO (1961) discussed the principal causes of sea level fluctuations which are «steric» (thermal and haline) and atmospheric pressure effects. As the Arabian Gulf is generally considered a shallow sea, the meteorological conditions are the main cause in the sea level variation.

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The tides in the Arabian Gulf are complex, consisting of a variety of tidal types. The most common type of tidal pattern in the Arabian Gulf is a semi-diurnal one.

In the Arabian Gulf, the energy enters through the Strait of Hormuz and propagates for each constituent, sloping up towards the Iranian coast and down the Saudi side, with the range increasing from the middle of the Gulf in a Kelvin style wave (W.J. LEHR, 1983, C. LE PROVOST, 1983).

According to the pressure system affecting the Arabian Gulf, the winter season is characterized by the predominant north westerly wind with high pressure over most of the Gulf area. The summer season brings a contrast between the persistent hot north westerly winds over the northern part of the Arabian Gulf and the cooler winds of the south westerly monsoon, east of the Gulf of Oman.

The main object of the analyses is to study the sea level variation along the Saudi coast of the Arabian Gulf and to correlate that to the effect of the pressure difference. The data used in these analyses are those of the hourly readings of sea level obtained from the tidal records at six stations of ARAMCO during the period 1980-1987. These stations are from north to south, Safaniya Pier, Manifa Pier, Abu Ali Pier, Juaymah Small Boat Pier, Ra's Tannurah North Pier and Qurayyah (Fig. 1). The meteorological data used in this analysis are taken from Qaisumah, Dhahran and Doha International Airport stations.

## DATA ANALYSES

The data used in these analyses are the hourly values of the observed and predicted tidal height values at the six ARAMCO stations during the period 1980-1987. From the observed hourly tidal heights, the daily mean sea level at each station was computed using an IBM-3081 computer at the Automated Data Processing (ADP) facility of the Naval Base at Jubail.

From the residual hourly height, the daily residual was computed for each station. From the daily mean sea level, daily residual of mean sea level, pressure gradient between Qaisumah and Dhahran, pressure gradient between Dhahran and Doha International Airport, the coherence between each two parameters was examined using the Statistical Analyses System (SAS).

## DAILY AND MONTHLY VARIATION OF SEA LEVEL

The variation of the daily mean sea level at the six stations showed generally low values during the winter season and high ones during the spring and summer seasons (S.H. SHARAF EL DIN, 1988).

The variation of the daily mean sea level residual at the six stations also indicates low values during the winter season and high ones during the summer and spring seasons. This coincides with the same pattern given by the variation

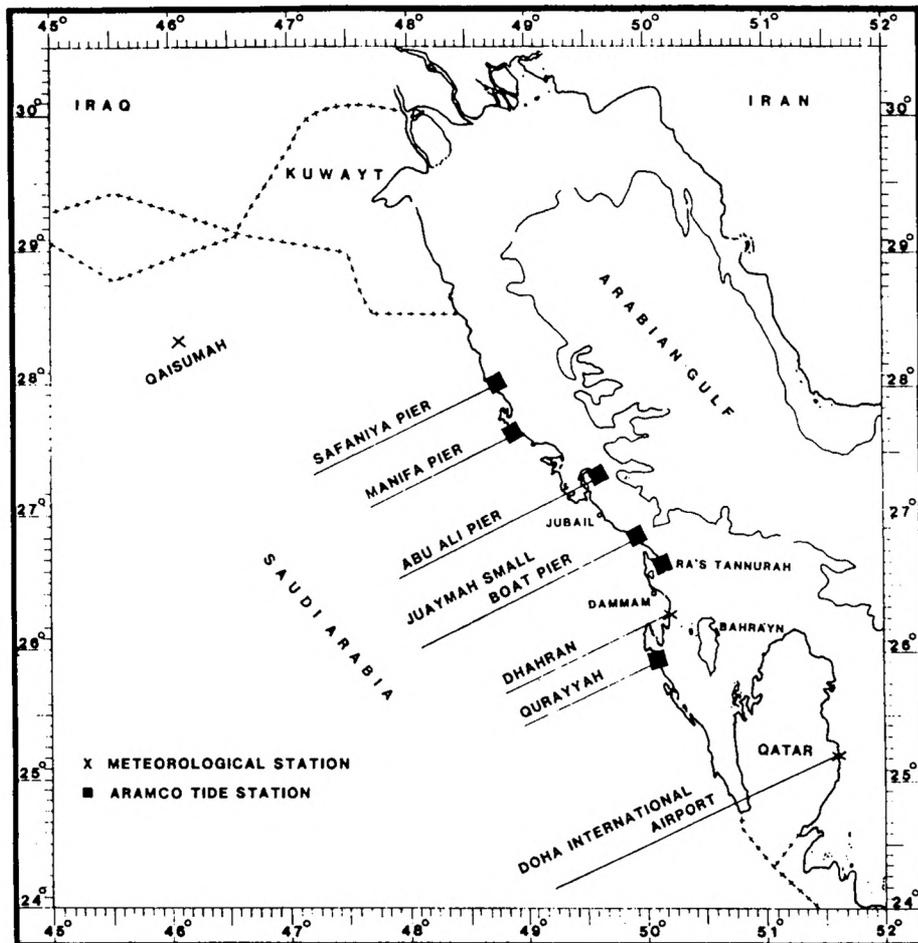


FIG. 1. — Map showing the location of ARAMCO tide gauges and the meteorological stations.

of the daily mean sea level. The variation of the monthly mean sea level at the six stations taken during the period 1980-1987 is shown in Figure 2. At Manifa Pier, the zero base of the tide gauge was changed to that of Tanajip station due to equipment failure during the period 1985-1987. This graph indicates that the highest values of the monthly mean sea level occurred during the months of July and August of 1983 at most of the stations. The lowest values of the monthly mean sea level oscillated between January and March of 1983 and 1985 at most of the stations.

The low values of the monthly mean sea level during the winter season can be attributed to the fact that the Arabian Gulf area is covered by high pressure during that period which varies from about 1016 mb to 1018 mb. During the summer and spring seasons, the intensive heating of the Arabian continent leads to the formation of a low pressure area extending over the Arabian Gulf. This is a major factor in raising the level of sea surface in the Gulf during the summer and spring seasons.

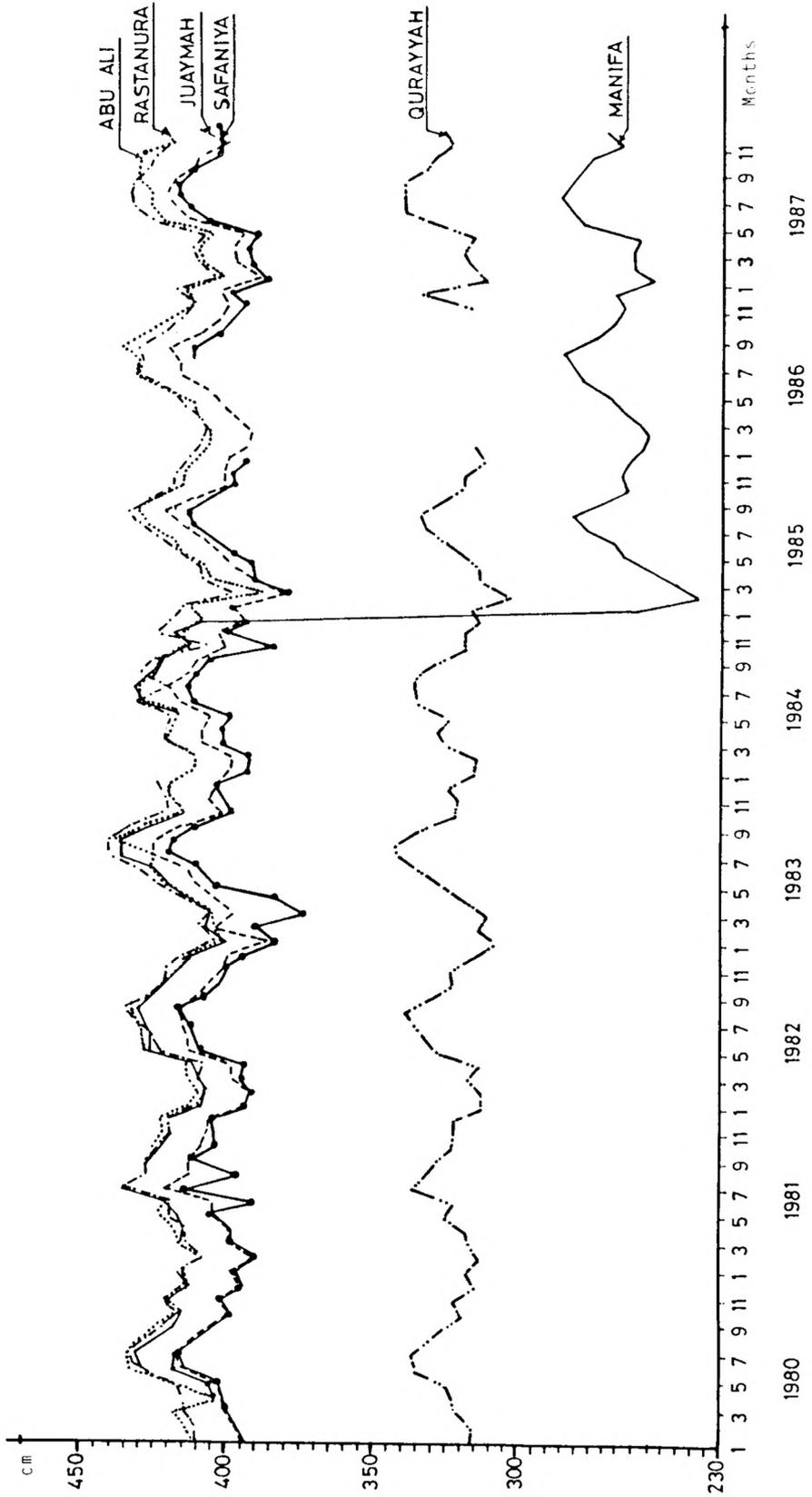


FIG. 2.— Monthly mean sea level at the six stations along the Saudi Coast of the Arabian Gulf.

### THE MAIN TIDAL CONSTITUENTS IN THE ARABIAN GULF

The tides in the Arabian Gulf region present semi-diurnal and diurnal amphidromes which must lead to various kinds of tidal cycles. The main four harmonic constituents of the tidal regime in the Arabian Gulf are M2, S2, O1 and K1. The M2 and S2 constituents have two amphidromic points, one in the northwestern part of the Gulf and the other in the southern part (W.J. LEHR, 1983). The K1 and O1 have a single amphidromic point.

The main harmonic constituents at the eight stations in the Arabian Gulf region are given in Table 1.

The amplitudes of the main constituents at the eight stations, (Table 1), showed clearly the type of tide at each station.

The semi-diurnal and the diurnal tide along the Saudi coast of the Arabian Gulf, Bahrain, Iraq and Iran coasts agreed to a certain extent with the result obtained from the model of Evans-Roberts (1979).

**Table 1**

Maximum of amplitudes (cm) for the main constituents at 8 stations in the Arabian Gulf region.

| Semi-diurnal          |          |          |          |          |         |
|-----------------------|----------|----------|----------|----------|---------|
|                       | M2       | S2       | N2       | K2       | L2      |
| Fao (Iraq)            | 82.4/337 | 25.3/39  | 16.7/303 | 10.7/27  | 6.9/351 |
| Safaniya Pier         | 25.0/13  | 6.9/76   | 5.3/336  | 2.6/57   | 1.7/64  |
| Manifa                | 22.7/98  | 8.5/166  | 4.1/65   | 3.3/151  | 2.0/114 |
| Abu Ali               | 45.5/132 | 15.5/192 | 9.3/102  | 5.4/178  | 3.0/152 |
| Ra's Tannurah         | 60.9/130 | 20.7/188 | 12.7/100 | 7.5/176  | 3.8/160 |
| Mina Salman (Bahrain) | 66.1/152 | 21.8/213 | 14.7/121 | 6.9/195  | 4.6/177 |
| Qurayyah              | 8.2/251  | 1.8/308  | 1.4/222  | 0.7/281  | 0.9/296 |
| Bandar Abbas (Iran)   | 100/298  | 36/334   | 21.9/280 | 10.4/332 |         |

| Diurnal               |          |          |          |         |
|-----------------------|----------|----------|----------|---------|
|                       | K1       | O1       | P1       | Q1      |
| Fao (Iraq)            | 43.8/315 | 25.4/268 | 10.6/312 | 3.1/264 |
| Safaniya Pier         | 39.5/311 | 26.5/261 | 12.3/301 | 4.4/251 |
| Manifa                | 31.8/316 | 21.7/268 | 9.4/307  | 3.2/250 |
| Abu Ali               | 17.7/323 | 13.7/272 | 5.3/311  | 2.2/247 |
| Ra's Tannurah         | 14.3/340 | 12.3/280 | 4.6/324  | 2.1/263 |
| Mina Salman (Bahrain) | —        | —        | —        | —       |
| Qurayyah              | 2.1/108  | 1.7/30   | 0.9/80   | 0.3/358 |
| Bandar Abbas (Iran)   | 33.8/64  | 20.7/52  | 11/62    | —       |

The tides in the Northern area (Fao, Safaniya and Manifa), showed a combination of diurnal and semi-diurnal type.

From Abu Ali to Qurayyah including Bahrain, the tide is mainly of the semi-diurnal type. At Bandar Abbas (Iran), the tides showed a combination of diurnal and semi-diurnal frequency with predominantly semi-diurnal type.

### COHERENCE BETWEEN SEA LEVEL AND ATMOSPHERIC PRESSURE DIFFERENCE

Changes in atmospheric pressure influence the sea level which, at least theoretically, reacts like a reverse barometer (E. LISITZIN, 1974). Over the Gulf area, the pressure is high in winter and gets its maximum value during December and January and sometimes February and November (S.H. SHARAF EL DIN, 1988). During the summer season, the pressure over the Arabian Gulf is low, with its lower values in July and sometimes in August.

Using the Statistical Analysis System (SAS), the coherence between the daily mean sea level, the daily mean sea level residual and the pressure difference between Qaisumah, Dhahran and Doha International Airport (Fig. 1) was calculated.

The correlation coefficient between the daily mean sea level at six stations during the period 1980-1987 and the pressure difference between (Qaisumah and Dhahran gave a very weak coherence.

Also, there is no coherence between the daily observed sea level and the pressure difference between Dhahran and Doha International Airport stations.

The daily sea level residual at the six stations did not give any coherence between either the pressure difference between Qaisumah and Dhahran or the pressure difference between Dhahran and Doha International Airport. From these analyses, the pressure difference over the Gulf area does not play any appreciable role on the sea level variation. The important factor which considerably affects the sea level variation is the pressure system affecting the Gulf area either in the summer or in the winter season.

### CONCLUSION AND DISCUSSION

The Arabian Gulf area is covered by a high pressure system during the winter season and low one during the summer. This is a major factor in the variation of the daily mean sea level, giving low values in the winter season, and high ones in summer and spring seasons. The monthly mean sea level showed higher values during July and August and lower ones in the winter season.

It is known that the principal causes of sea level fluctuations are the steric and atmospheric pressure effects. As the Arabian Gulf is generally considered a shallow sea, the meteorological conditions are the main cause in the sea level residual at the six stations which gave a low value during the winter season and high ones during summer and spring.

The stages of the tide in the Arabian Gulf do not occur simultaneously along the Saudi coast; the tidal stages lag from north to south. Based on many years of observation away from coastal stations, the MSL figures indicate that the high tides are experienced progressively later from Marjan in the extreme north of ARAMCO's operating areas to Qurayyah in the south (R. WILLIAMS, 1979). This was clearly indicated in the variation of the harmonic constituents from 11 stations along the Saudi coast of the Arabian Gulf (S.H. SHARAF EL DIN, 1988).

The coherence between the daily mean sea level, daily sea level residual, pressure difference between Qaisumah and Dhahran and Dhahran and Doha International Airport was studied in detail (S.H. SHARAF EL DIN, 1988).

From the analyses, the pressure difference over the Gulf area did not give a noticeable change with either the daily sea level or the daily sea level residual. Generally speaking, the important factor affecting the sea level variation is the pressure system covering the Gulf area either in summer or in the winter season.

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