

THE EFFECT OF MONSOON ON THE IRANIAN COASTS IN THE GULF OF OMAN

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ABSTRACT

Monsoon is a very important meteorological phenomenon that affects a large part of the Indian Ocean every year. These effects sometimes extend to the seas and bays connected to this ocean, especially the Gulf of Oman, and have destructive effects on the economic activities of this area. Although the effects of monsoon on the coasts of Iran are much less than the coasts of the Arabian Sea, but local reports indicate that the monsoon usually affects two bays belonging to Iran, Chabahar Bay and sometimes Pazm Bay in the northeast of the Gulf of Oman. In this research, the monsoon phenomenon in the northwest of the Indian Ocean has been analyzed in order to investigate its effects on the waters of the Gulf of Oman. One of the important results of this study is the extraction of Monsoon Line. In this study, the monsoon line is defined as the boundary line of the monsoon. This line, if we call it the Monsoon line, indirectly connects Ras Al-Had to the west of Chabahar Bay and sometimes also includes Pazm Bay.

1. Introduction

Indian Ocean monsoon is a well-known phenomenon that strong monsoon winds periodically affect most of the western parts of the Indian Ocean. This phenomenon starts in late spring and continues until almost the end of summer.

Monsoon refers to a special weather system that occurs especially in tropical and subtropical regions. This phenomenon is related to seasonal changes in rainfall and wind patterns and is particularly well known in India and its surrounding countries. These are some of the key features and aspects of Monsoon:

❖ Definition and characteristics:

- Rainy season: Monsoon generally refers to a period of the year that brings heavy and continuous rainfall, usually in the summer season.
- Wind changes: During this period, changes in atmospheric pressure cause winds to move from oceanic areas to land, which leads to heavy rainfall [1] [2].

❖ Affected areas:

- India: Monsoon coming from southwest to India brings heavy rains to large parts of the country.

- Neighboring countries: Pakistan, Bangladesh, Nepal and some South East Asian countries are also affected by the monsoon [3] [4].
- ❖ Seasonal causes
 - Temperature difference: The temperature difference between the land and the oceans creates different atmospheric pressures that lead to the movement of winds and precipitation.
 - Earth movement: seasonal changes in the position of the sun and the movement of the earth also play an important role in creating monsoons [5] [6].
- ❖ Economic and social impacts
 - Agriculture: Monsoon is very important for agriculture because its rains can provide water for the fields.
 - Natural hazards: heavy monsoon rains can lead to floods, landslides and other natural hazards [7].
- ❖ Monsoon data analysis
 - To analyze the effects of monsoon, one can examine atmospheric data, such as temperature, humidity, and

precipitation. These data are usually accessible from databases such as ECMWF or NOAA [8].

Although the effects of monsoon on the coasts of Iran are much less than the coasts of the Arabian Sea, but local reports indicate that the monsoon usually affects two bays belonging to Iran (namely, Chabahar Bay and sometimes Pazm Bay), which are located in the northeast of the Gulf of Oman. But its effects are rarely reported in the west of Pazm Bay. It has even sometimes been observed that monsoon storms have entered to the inner regions of the Gulf of Oman [9].

The Gulf of Oman, including Pazm Bay, is influenced by the southwest monsoon winds of India during the summer. This monsoon brings changes to the marine environment, impacting factors such as fisheries, plankton biodiversity, and larval fish assemblages in bays along the Gulf of Oman. The onset of the summer monsoon contributes to enhanced fisheries in coastal bays like Pazm Bay. It's important to note that studies have been conducted on the effects of monsoons on various aspects of marine life in different bays within the Gulf of Oman, highlighting the significant impact of these seasonal winds on the ecosystem [10] [11].

For example, in June 2007, Hurricane Gonu swept across large parts of the Gulf of Oman and even affected parts of the Iranian coast(10,16,17). The Gulf of Oman is a deep waterway that connects the Persian Gulf to the Indian Ocean. Due to the importance of this water basin, many studies have been done, especially in the field of oceanography and ocean engineering in this region(1,2,5-9,11-15,18). This study was conducted to determine the extent to which the effects of the Indian monsoon typically enter the Gulf of Oman, and what parts of the coast of Iran are affected.

2. Material and Methods

In this research, the studied area is the Northwest Indian Ocean and the Gulf of Oman. The northwest region of the Indian Ocean experiences the monsoon phenomenon every year. In this study, atmospheric data related to the study area in the months of monsoon occurrence were extracted and analyzed. In order to investigate the effects of monsoon winds and the resulting waves, wind field, wave statistics and swell have been analyzed. The ocean-atmosphere database is used to achieve this goal. This database is a reliable source that has been used as a reference for many studies(3,4,19).

To analyze the impact of the Indian monsoon on the waves in the Oman Sea, we can follow the steps below. In the following, the necessary materials and methods for our analysis are described in detail and a block diagram of the work steps is presented [12] [13].

2.1. Materials

The main materials used in this research can be categorized as follows [14] [15]:

a) Dataset:

For atmospheric and oceanic data analysis, there are several databases that can help you get accurate and comprehensive information. In the following, some valid databases are introduced:

- ECMWF (European Medium-Term Weather Forecast Center):
 - Weather data provider including forecasts and observations of pressure, temperature, humidity, precipitation, etc.
 - Wave and ocean data are also available in this database [16].
- NOAA (US National Oceanic and Atmospheric Administration):
 - Includes atmospheric and oceanic data, such as temperature, precipitation, ocean currents and hurricane statistics.
 - GHCN (Global Historical Climatology Network) database for historical climate data [17].
- NASA (United States National Aeronautics and Space Administration):
 - Providing climate and ocean data through projects such as MODIS (Moderate Resolution Imaging Spectroradiometer) and other space missions [18].
- Copernicus Climate Change Service (C3S):
 - This database contains a set of climatic and atmospheric data that includes forecasts and observations [19].
- World Ocean Database (WOD):
 - A global database of ocean observations, including temperature, salinity, oxygen and other parameters [10] [20].
- Global Historical Climatology Network (GHCN):
 - A collection of historical climate data including temperature and

precipitation from different stations around the world [21].

▪ **Argo Project:**

- A global project that includes ocean depth observations through automatic floats [22].

These databases are useful sources for analyzing atmospheric and oceanic data [23]. Depending on the type of analysis we want to do, we can take advantage of these resources. In this research, due to some factors such as the amount of access to the data of the target area and accessibility, etc [24]., from the ECMWF dataset was used. access to the ECMWF database, in particular:

- wave data (significant wave height, wave period, wave direction)
- Atmospheric pressure data.

b) Software tools:

There are many tools and software for analyzing and displaying atmospheric-oceanic data, for example, these can be mentioned:

- Python or R for data analysis
- Libraries: NumPy, Pandas, Matplotlib for Python; dplyr, ggplot2 for R.
- GIS tools (such as QGIS) if spatial analysis is needed
- Statistical software (such as R or SciPy in Python) for regression analysis
- Ocean Data viewer packages such as ODV, Ferret, etc., in order to analyze and display atmospheric and oceanic data in terrestrial coordinates [25].

c) Hardware requirements:

A computer with enough processing power and memory to manage big data.

2.2. Methods

In order to analyze the corresponding atmospheric and oceanic data in the monsoon months, as well as to investigate its effects in the Gulf of Oman [26], the following steps and methods were followed:

a) data extraction:

- Extraction the relevant datasets from ECMWF for the study period that includes the Indian monsoon season (June to September).
- Ensuring that the data includes wave and atmospheric parameters [7].

b) Data preparation:

- Dataset cleaning by managing missing values and outliers.

- Converting data into a usable format (such as time series) [27].

c) Data analysis:

- Correlation analysis between monsoon low pressures and wave characteristics in Oman Sea.
- Using statistical methods such as regression analysis to determine the effect of monsoons on wave height and direction.
- Visualize data trends using graphs and charts [28].

d) Interpretation of the results:

- Interpreting statistical results to understand the relationship between Indian monsoon and wave activities in the Oman Sea.
- Discuss the findings in relation to the existing literature on ocean wave behavior and monsoon effects [29].

e) Documentation:

- Preparation of a report that explains the methods, results and interpretations in detail.
- Inclusion of visual representations of data analysis (graphs, charts) [30].

3. Results

In this study, atmospheric data related to the study area in the months of monsoon occurrence were extracted and analyzed. In order to investigate the effects of monsoon winds and the resulting waves, wind field, wave statistics and swell have been analyzed. To detect anomalies, we used various statistical and machine techniques. By applying these techniques, we can effectively detect anomalies in our datasets or systems.

Figure (1) shows the wind field in the northeastern Indian Ocean during the Monsoon period.

Figure (2) shows the wave field in the northeastern Indian Ocean during the Monsoon period. As this figure shows, a definite boundary has been formed between the Monsoon area and the Gulf of Oman. This line, if we call it the Monsoon line, indirectly connects Ras Al-Had to the west of Chabahar Bay and sometimes also includes Pazm Bay (figure 3).

Figures (4) and (5) show the local wave field and Swell field in Chabahar Bay during the Monsoon period, respectively. The average height of the local wave in this area is about 0.5 meters, while the height of the swell is about 2 meters. This significant difference shows that during the Monsoon period, Chabahar Bay was strongly influenced by the swell caused by the Monsoon.

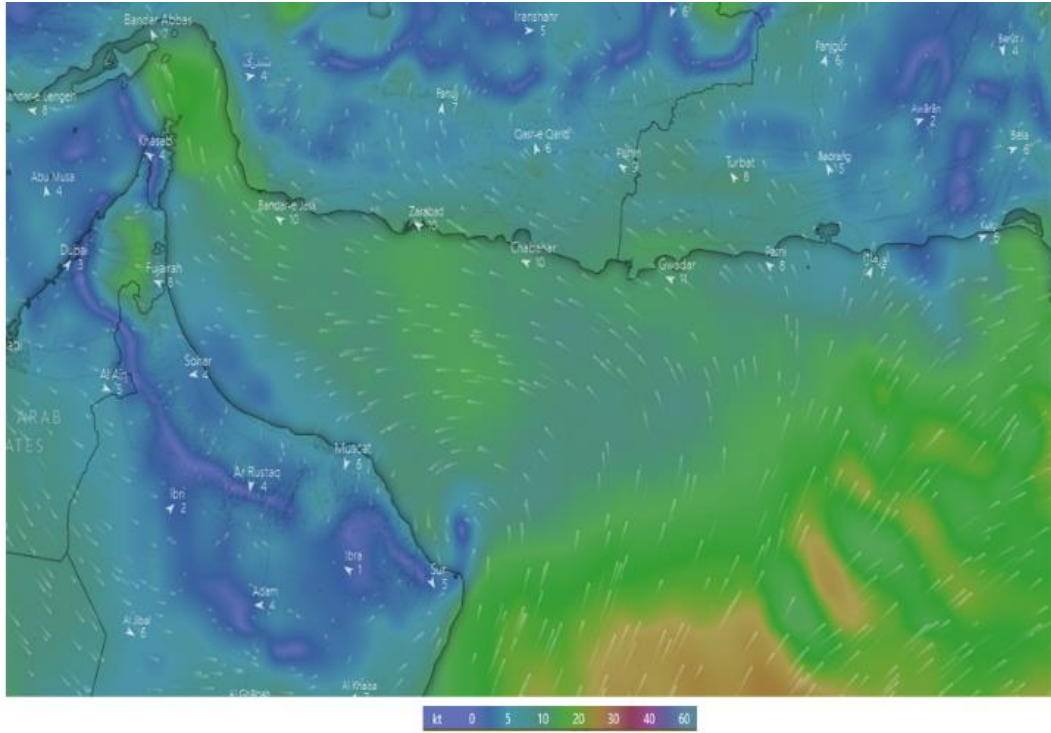


Figure 1. Wind field in the northeastern Indian Ocean during the Monsoon period.

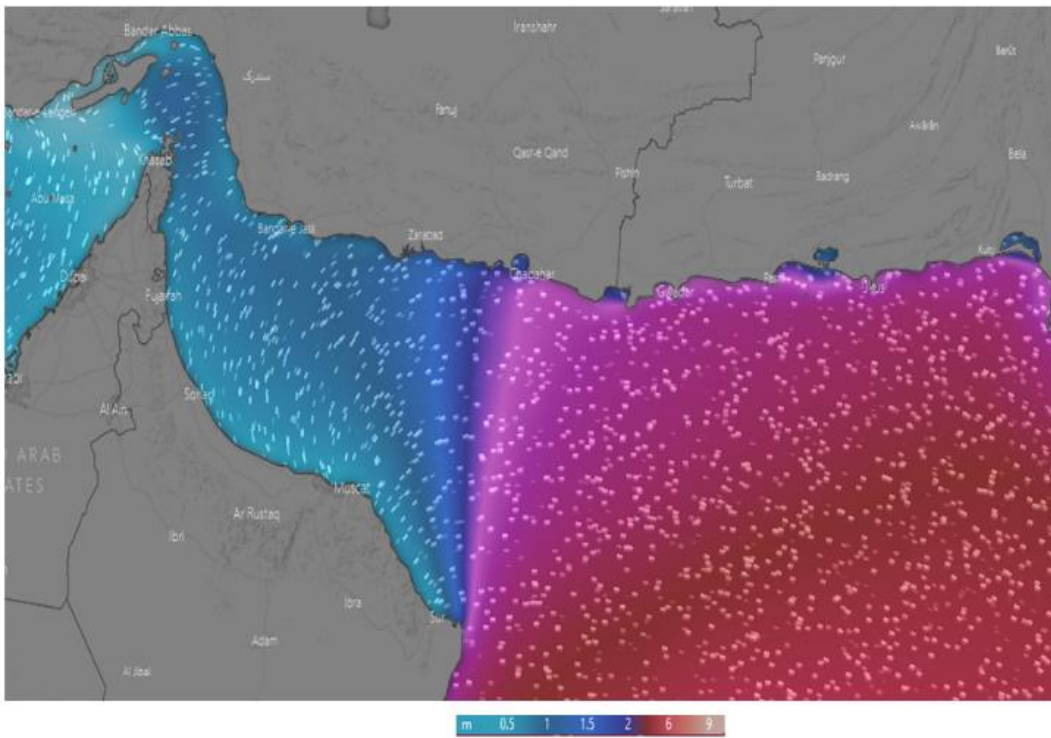


Figure 2. Wave field in the northeastern Indian Ocean during the Monsoon

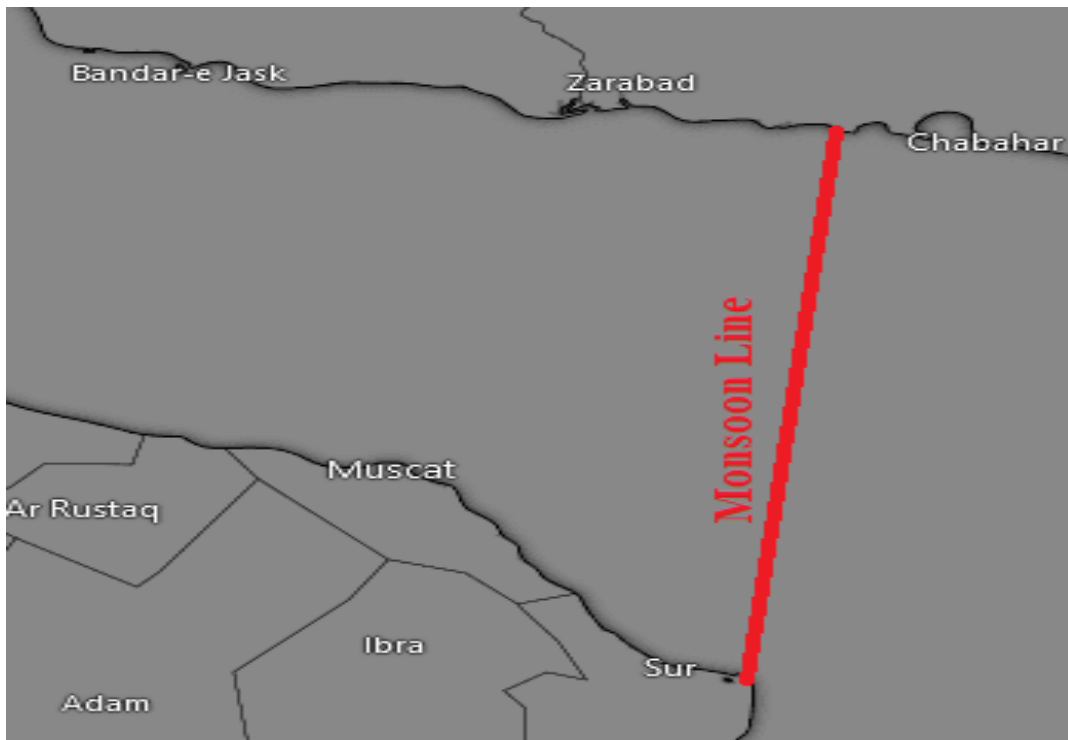


Figure 3. Monsoon Line

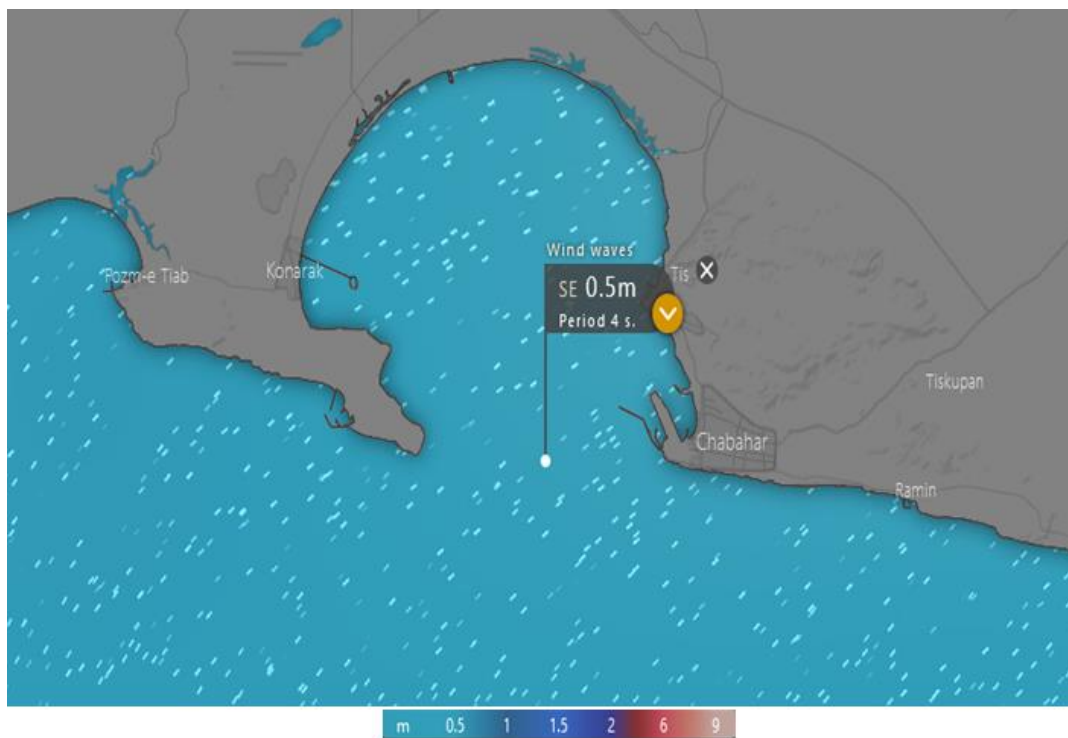


Figure 4. Local wave field in Chabahar Bay during the Monsoon period.

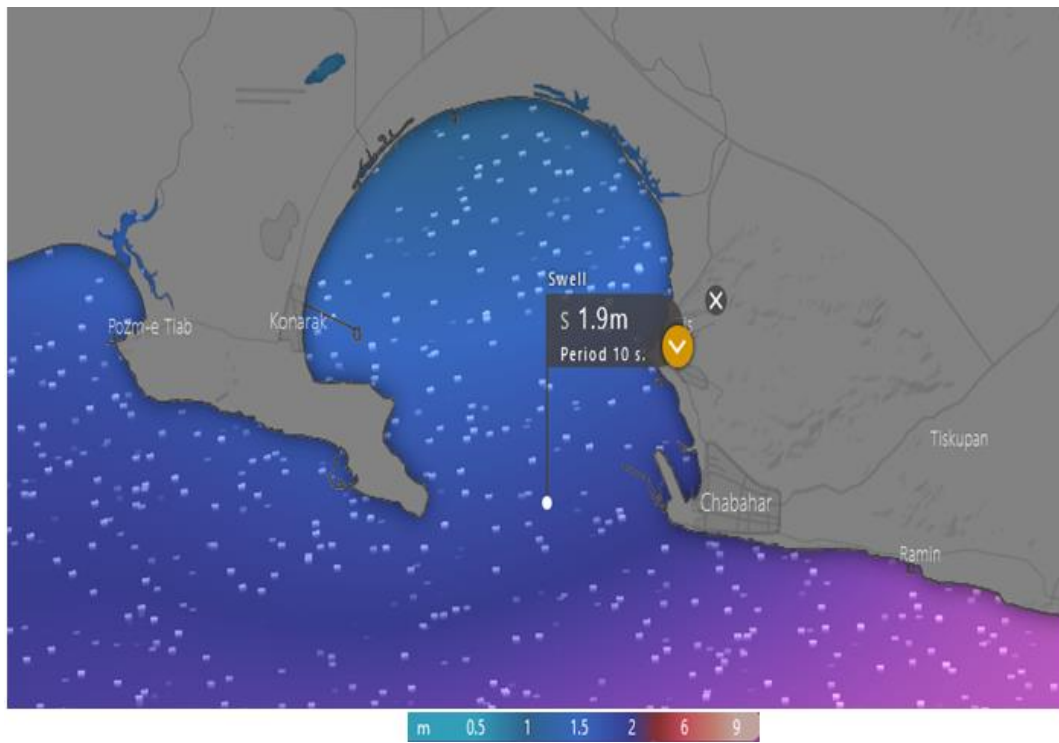


Figure 5. Swell in Chabahar Bay during the Monsoon period.

4. Conclusions

Strong monsoon winds usually affect the western part of the Indian Ocean during the monsoon months. It is rare for monsoon storms, such as Gonu cyclone, to enter the Gulf of Oman. But the study of wind and wave fields in this area shows that the waves that are formed due to monsoon winds and storms in the northwest of the Indian Ocean, enter the eastern part of the Gulf of Oman in the form of swell and affect parts of the coast of Iran. A definite boundary has been formed between the Monsoon area and the Gulf of Oman. This line, if we call it the Monsoon line, indirectly connects Ras Al-Had to the west of Chabahar Bay and sometimes also includes Pazm Bay.

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