INTERNATIONAL JOURNAL OF MARITIME TECHNOLOGY
IJMT Vol.16/ Summer 2021 (107-110)
Available online at: www. ijmt.ir

Satellite Image Dataset of Internal Waves in the Persian Gulf

Hossein Farjami[1*], Sajad Andi [2]

[1]Iranian National Institute for Oceanography and Atmospheric Science (INIOAS), Address: No.3, Etemad Zadeh St., Fatemi Ave., Tehran, IR. Iran; hfarjami@gmail.com
[2]Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Noor, Iran; sajad.andi9655@gmail.com

ARTICLE INFO

Article History:
Received: 24 Apr. 2022
Accepted: 05 Sep. 2022

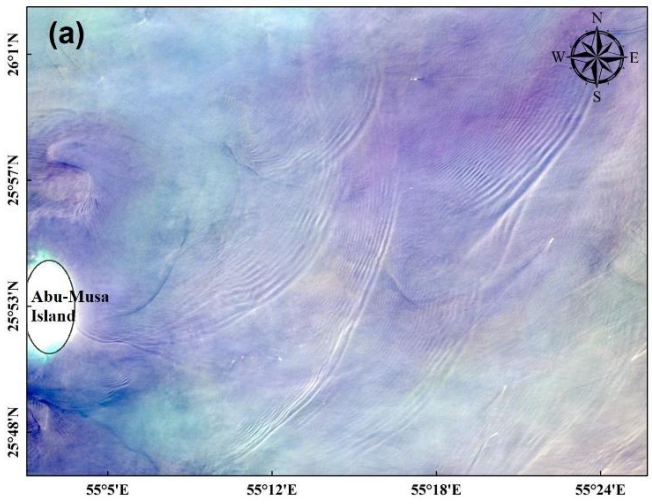
Keywords:
Dataset
Internal Waves
Persian Gulf
Satellite Imagery

ABSTRACT

In the present article we report for the first-time satellite image dataset on the internal waves of the Persian Gulf. These data include more than 3000 satellite images from Landsat 7, Landsat 8, Santinel-1, Santinel-2 and ASTER across the Persian Gulf, in which more than 400 images were detected internal waves during 2000 - 2015. The Prewitt and Canny's edge detection algorithm have been used to show internal waves in the satellite images. Also, some characteristics of internal waves, such as propagation direction, crest length, wavelength, width of solitons, length and area of packets and the distance of two consecutive packets inferred from imagery. This dataset of satellite images provides the main information for the analysis of internal waves in the Persian Gulf, which have been recorded in all seasons and in suitable weather conditions.

1. Introduction

The dataset in this article describes the formation mechanism of internal waves, development and propagation of these waves in the Persian Gulf basin using satellite imagery. The field measurements also were used to validate. In this regard, satellite raw images such as Landsat 7, Landsat 8 and Sentinel-1 in TIFF format ASTER in HDF format and Sentinel-2 in JP2 format were collected to better spatio-temporal coverage. These images have a resolution between 10 and 30 meters, which allow to consider internal waves in the presented basin. In this dataset collected about 3000 satellite Images from 2000 to 2015 then all images were analyzed and filtered based on sharpness quality. From these images selected about 400 images which observed internal waves packet(s) in the Persian Gulf. Figure 3 shows some of detected internal waves in satellite imagery on the Persian Gulf bathymetry. Moreover, Figure 1a is an example of internal waves in Landsat 8 image through the collected dataset. The characteristics of the internal waves which can be obtained from dataset are described in Figure 1b. These characteristics include: 1) The length of the internal wave packet (L) which is between 1 and 10 km, 2) the long wave speed (C_0) which is usually between 0.5 and 1.0 m per second, 3) the distance between two consecutive packets (C_0T) which the range of this distance can between 10 and 90 km, 4) the wavelength of the internal waves (λ_0) which can be from 100 to 1000 meters [1], 5) the crest length (Cr) which is about 0 to 30 km and 6) the saliton width that is between 0 and 100 m. Also, propagation of internal waves packet can determine by the shape of the packet, hence the propagation direction is from the small length crest to bigger length crest [2]. Figure 2a and 2b show example of detecting internal waves from satellite images dataset using edge-finding algorithms.



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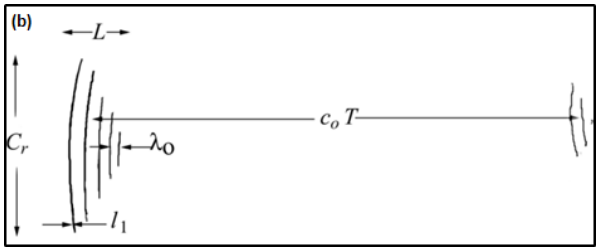


Figure 1. An example of internal waves by Landsat 8 on March 31, 2014 in the Persian Gulf (a); Schematic formation of internal waves on the fracture zone of the continental shelf (b) [2]**.**

Internal waves database in various areas of the World Ocean and inland basins was published based on remote sensing and in-situ measurements[3]. Also, internal waves detected in UK shelf seas using the ENVISAT ASAR Sensor [4]. Satellite-field measurements and lab experiment are used to build internal waves datasets in the Andaman sea [5].

2. Value of the Data

- This database, which was prepared using satellite and radar images as well as statistical data, has been made available to those interested in oceanography, marine biology, climatology, meteorology, coastal engineering, etc. Also, can mention the fast and free delivery of the product and their availability, which has made it easier and more valuable to process and analyse this data.
- This set of data can be used to detect and analyse internal waves and to examine the effect of these waves on the surface processes of the oceans.
- The dataset will be beneficial for modelling purposes, relating to internal waves.
- Analysis performed on satellite images to detect internal waves can be used by other researchers for comparison.

Other researchers can employ the Prewitt and Canny's edge detection algorithm provides indices to detect internal waves in other sea and ocean basins with certainty.

Table 1. Specifications Dataset of Internal Waves in the Persian Gulf

Subject	Marine Sciences, physical oceanography
Specific subject area	Ocean dynamics, satellite oceanography
Type of data	Table, Image, Chart and Figure
How data were acquired	Satellite image data was collected from the Landsat 7, Landsat 8, and ASTER provided by the USGS Earth Explorer, and the European Space Agency Copernicus Sentinel 1 and 2 database.
Data format	Raw and analysed and filtered dataset
Parameters for data collection	Internal wave parameters (The distance between two consecutive packets, packet length, wavelength, crest length, soliton width and propagation direction). The monthly and yearly time-series data of internal waves parameters. The spatial distribution, regions of regular occurrence.
Description of data collection	We used field measurement data and satellite images to collect database. The Prewitt and Canny's edge detection algorithm used for appearance of internal waves on the database mentioned above.
Data source location	The Persian Gulf is located between Iran and the Arabian Peninsula in the middle east. Latitude: between 24 °N to 30 °N, Longitude: Between 48 °E to 56 °E
Data accessibility	Data is available from the Iranian National Center for Ocean Data (INCOD) upon registration and reasonable request. Direct URL to data: http://incod.inio.ac.ir/Data-Access/InternalWaves_PG Also, data is available from the corresponding author upon reasonable request.
Related research article	Andi, S., Rashidi Ebrahim Hesari, A., & Farjami, H. (2020). Detection of internal waves in the Persian Gulf. Remote Sensing Letters, 1-9 [6].

3. Experimental Design, Materials and Methods

Thus far, there has not been any dataset to investigate internal waves over the entire basin of the Persian Gulf. Because of field measurement difficulties such as expensive and spatial-temporal limitation, the satellites provide a suitable opportunity to investigate oceanic processes in particular internal waves. Detection of these waves can be used in submarine navigation and in the tidal models to calculate converting of kinetic energy.

Due to the effect of the internal waves on the sea surface, they are recognizable on satellite visible images through modulation of the sea surface roughness [7, 8].Therefore edge-finding algorithms and color combinations were used to identify internal waves. Figure 3a is Landsat 7 satellite image which

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recorded on 19.05.2000 around the Island of Abu-Musa. In this figure the internal waves have shown changing color combination of the image. Then applying Prewitt and Canny's algorithms on satellite images, the internal waves were detected by MATLAB. Figure 2a is the result of processing on the satellite image of Figure 2b. This algorithm used to decrease unnecessary information and remote noises from the images while structural features are maintaining [9, 10].

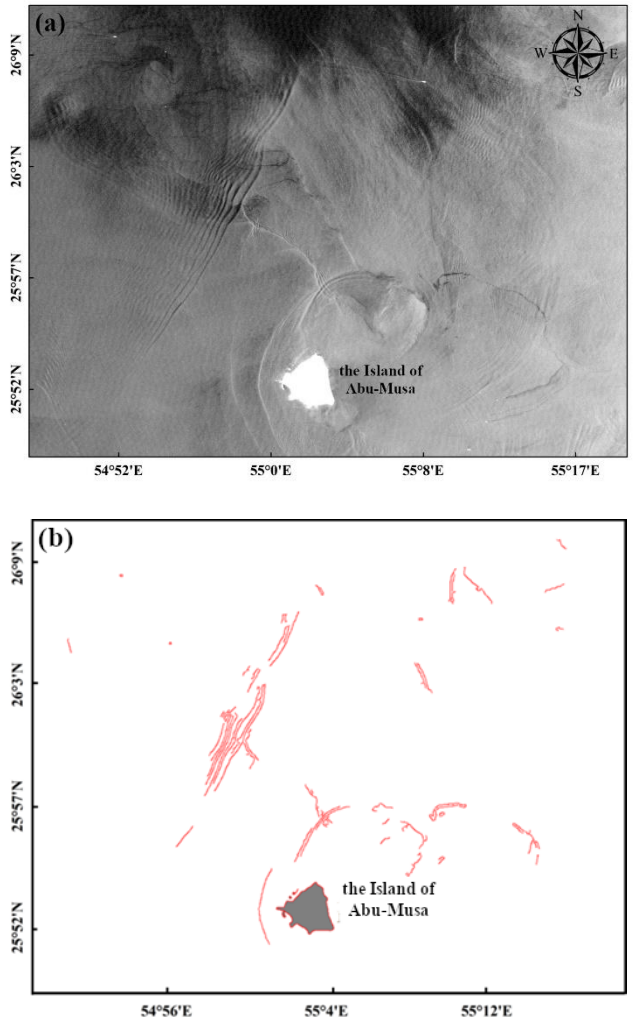


Figure 2. Internal waves on Landsat 7 on May 19, 2000 around the Island of Abu-Musa in the Persian Gulf (a), Result of edge detection algorithm on the related image (b).

In this article after collecting in-situ measurements data, Landsat 7, Landsat 8, ASTER, Sentinel-1 and Sentinel-2 images in the Persian Gulf we processed these data by SNAP, ArcMap and ENVI software.

Edge detection is a process of classifying and perceiving sharp cutouts in an image to extract internal waves feature line. One of the suitable Edge detection is the Prewitt and Canny's algorithm. In this research we applied the Prewitt and Canny's algorithm to manifest internal waves in the Persian Gulf.

The analysis of satellite images data reveals that the internal waves appear usually from April till July in the Persian Gulf during the warm seasons. Also, these waves are mostly formed in the south, southwest and west of Larak Island; southwest and west of Hengam Island; north and northeast of the Halul Island; north and northeast of Al-Dahirah; around Abu-Musa and Siri Islands; the south and southwest of Bibi-Khatun and Nakhiloo, as well as in the vicinity of Farur, Lavan, Kish, Hendorabi, Sir Abu Nu'Ayr, Dalma, Das, Kran, Farsi, Harghus, Khark, Greater Tunb and Lesser Tunb Islands (Figure 3).

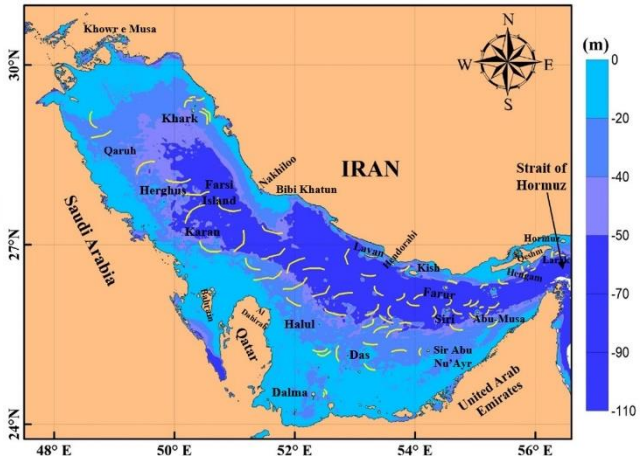


Figure 3. Location and bathymetry of the Persian Gulf. The yellow curves are some of detected internal waves.

After detecting internal waves in satellite imagery, some characteristics of the internal waves can be inferred from imagery, such as the length of the internal waves packets, the propagation direction, the distance between two consecutive packets, width of internal solitary waves and area of internal waves packets with the help of mentioned softwares. Therefore, researchers can use the results of the present article and analysed data with suitable accuracy in the Persian Gulf basin.

Acknowledgments

We would like to thank INIOAS to provide access measurement data in the Persian Gulf. The authors are also thankful to USGS website (https://earthexplorer.usgs.gov/) and the European Space Agency (https://earth.esa.int/eogateway/) for providing satellite images.

List of Symbols

L	The length of the internal wave packet
C_0	the long wave speed
C_0T	the distance between two consecutive packets
λ_0	the wavelength of the internal waves
C_r	the crest length

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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