ENVIRONMENTAL IMPACT OF MARITIME LOGISTICS USING SATELLITE DATA

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1. **ABSTRACT:** Shipping continues to have a negative impact on the marine environment, contributing among others to eutrophication through NOx emissions. Today, ship detection is considered a key aspect of maritime surveillance, as it enables the monitoring of various maritime activities, such as maritime traffic, search and rescue, cargo transportation, maritime defense, illegal fishing, and also includes environmental aspects, such as environmental assessment of adverse effects, and oil spill detection and monitoring. In this context, paper presents a methodology that aims to collect, process, and analyse data on a large temporal and spatial scale for the assessment of environmental impacts due to maritime traffic, using satellite data. Data of ship detection and nutrients related to the phenomenon of eutrophication are used for the assessment. Both datasets are collected, stored and visualized through a developed geoportal, accessible by multiple users, providing download and visualization services. Geospatial portal is expected to provide access to high-resolution and easily understandable spatial data to a large group of people, scientists, decision makers and other interested parties.

2. INTRODUCTION

The phenomenon of marine eutrophication is the most common environmental problem that contributes to the degradation of the quality of coastal ecosystems and the marine environment by excessively increasing phytoplankton and phytobenthos [1,2,3]. When nutrient enrichment of waters does not come from human activities, eutrophication is a natural process. This process is influenced by various factors such as coastal upwelling, sediment resuspension and atmospheric deposition of nutrients through precipitation [4]. However, it seems that shipping contributes to the eutrophication through the NO_x emissions [5].

Vessel detection, as a part of maritime surveillance, is considered very important and plays a critical role in port management as well as environmental protection, in relation to maritime traffic, search and rescue, cargo transportation, maritime defense, illegal fishing, and oil spill detection and monitoring [6.7]. Today, maritime surveillance can be implemented using a variety of methodologies and tools, using either cooperative systems (in which vessels report their identity and position, together with information derived from other onboard systems), such as the Automatic Identification System (AIS), Long Range Identification and Tracking (LRIT) and Vessel Monitoring System (VMS), or non-cooperative systems, which do not demand any action from the ships. The latter typically use cameras or radars installed on platforms (e.g. satellites, etc.). It is also notable that, while AIS is widely used, the other two cooperative system options are not particularly widespread and consistently available at global level.

Ship detection using Sentinel 1 Synthetic Aperture Radar (SAR) data is included in non-cooperative systems and allows the tracking of ships that may not require AIS or similar systems (e.g. small-scale fishing vessels), or vessels involved in illegal activities (piracy, illegal and unregulated fishing, etc.) [8]. In addition, SAR images have the advantage of being independent of weather, thus enabling detection on a regular basis. SAR data is also used to detect vessels in extreme weather conditions and storms for search and rescue purposes [6, 8].

This paper proposes a methodology that aims to collect, process, and analyse data on a large temporal and spatial scale for the assessment of environmental impacts due to maritime traffic, using satellite data. The rapid development of remote sensing as well as the free availability of satellite data and other related products to the scientific community contribute to this objective. Section 3 describes the overall methodology. Section 4 presents the geospatial portal in which the datasets of ship detection and nutrients related to the phenomenon of eutrophication are collected stored and visualized, taking advantage of the possibilities provided by the satellite data use and data of the World Wide Web. Conclusions, findings and future research steps are summarized in section 5.

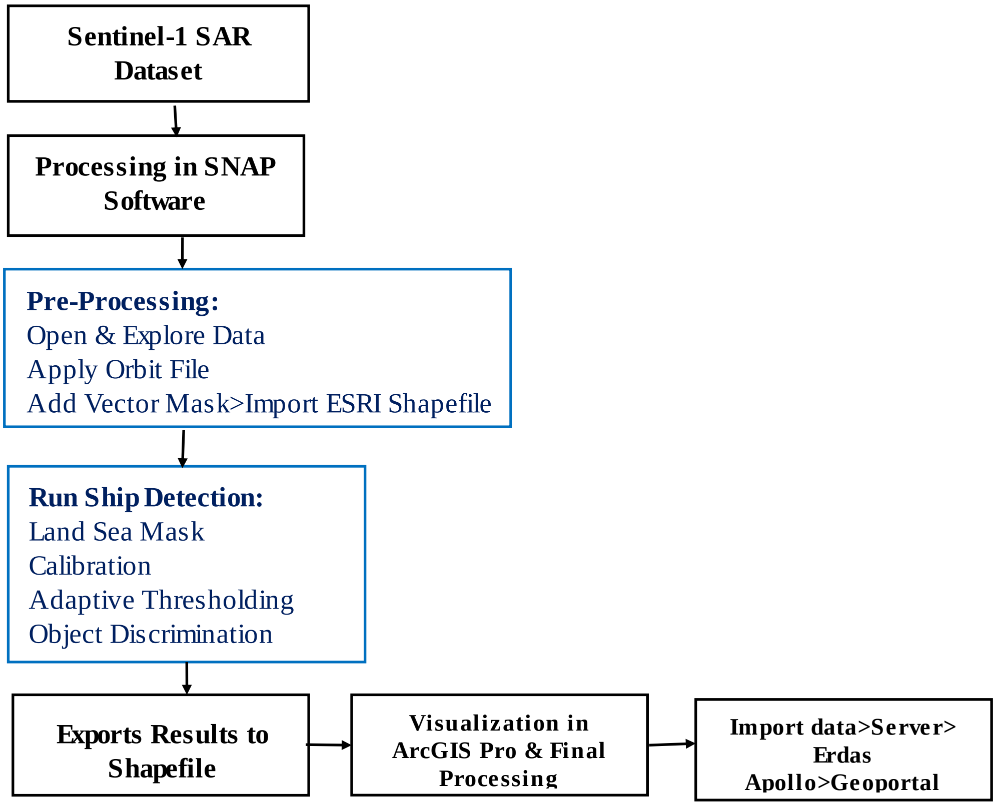
3. METHODOLOGICAL FRAMEWORK FOR ENVIRONMENTAL ASSESSMENT USING SATELLITE DATA

The methodology followed includes the processing of satellite data both for the detection of ships and the spatial distribution of nutrients in the marine environment. The processing steps are detailed below.

3.1 Tools and data for ship detection

This subsection describes in detail the proposed methodology for ship detection using Sentinel-1 SAR data. The whole process from obtaining the required data to visualizing the results is shown in Figure 1.

Sentinel-1 C Band SAR images for the area of interest (AoI) were obtained from Alaska Satellite Facility (ASF) [9], with the following characteristics: beam mode: IW[3], polarization: VV+VH[4] and flight direction: descending. Thirty images were downloaded, fifteen of each frame, all level 1-Ground Range Detected (GRD), from July 01 to December 31, 2021 (Figure 2). The software used is SNAP 9.0.0. Both satellite images and SNAP software are freely available to any user from ASF and the European Space Agency (ESA) through Science Toolbox Exploitation Platform (STEP) [10] respectively. The following paragraphs describe the overall methodology in the SNAP software and further manual processing.



[3] IW: Interferometric Wide
[4] VV: vertical transmit, vertical receive; VH: vertical transmit, horizontal receive.

Figure 1. Methodology Flowchart

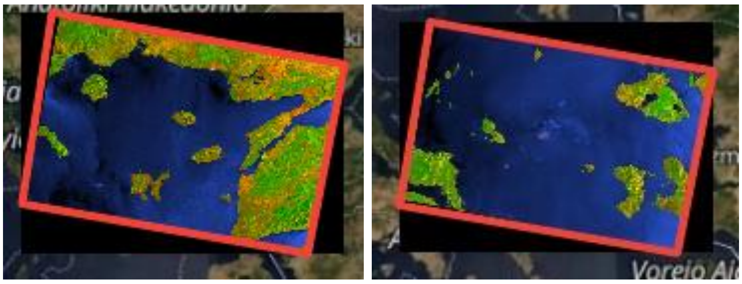


Figure 2. Area of Interest (AoI): A&B Frame. North Aegean Region (Greece).
Source: Alaska Satellite Facility [9].

Pre-Processing: Pre-processing is considered necessary for Sentinel-1 IW Ground-Range Detected High Resolution (GRDH) products, as they usually have some issues with their orbit information in the metadata. Orbit information included in the metadata of SAR images is usually not precise and can be improved with accurate orbit information available several days after the creation of the product. To address this issue, these products need to be updated with recently available orbit files that provide precise information about the satellite’s position and speed. This process is called “Apply orbit file”. As part of the pre-processing is also the creation of a vector mask. This mask is used as a layer to the area of interest and covers the land area, in order to avoid detecting false targets (vessels) on land. Although, the software provides a default “Shuttle Radar Topographic Mission (SRTM) 3sec Digital Elevation Model” option to mask out areas with positive elevation, it is not preferable, as it sometimes detects false targets, particularly in complex coastlines such as AoI. The main process for ship detection consists of the following sub-stages:

- Land-Sea-Mask: In this step, the already loaded vector mask is used (as discussed above).
- Calibration: Radiometric calibration is applied. Although, uncalibrated SAR images are considered adequate for qualitative purposes, calibrated SAR images are necessary to quantitative use of SAR data [8].
- Adaptive Thresholding: This method is considered very common for ship detection in SAR images. Software applies a Constant False Alarm Rate (CFAR) approach, as a specific type of this method. The general idea is that targets are displayed brighter compared to the surrounding darker area.
- Object Discrimination: In this final stage, the minimum and maximum size limits are set to avoid false target detections. 20m and 600m (default value) were respectively set for minimum and maximum size limit, which means that targets with dimensions larger or smaller than these thresholds are rejected [8].

In order the results from SNAP software to be more manageable and can be further processed and visualized in a Geographic Information System (GIS) software, such as ArcGisPro, they are exported to an ESRI shapefile. In ArcGisPro environment, all files are unified into six individual files, one for each month (i.e.: from July to December) (Figure 3).

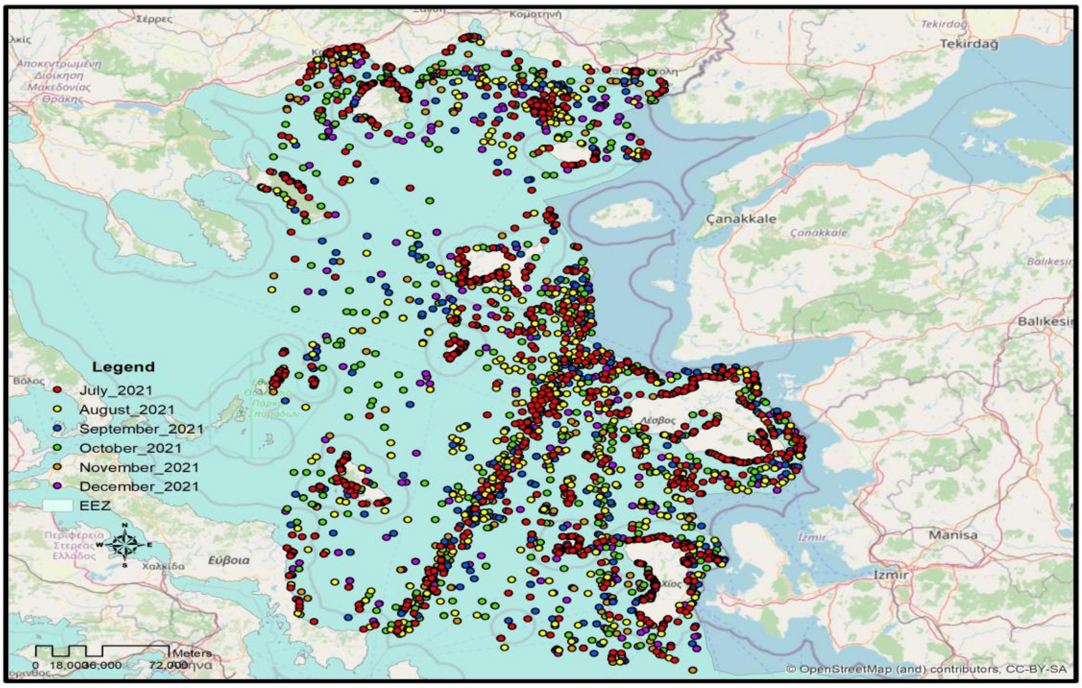


Figure 3. Visualization of final results for AoI in ArcGisPro environment.

3.2. *Data for eutrophication level assessment*

The data used were derived from the Marine Copernicus database for the years 2012-2021 and are L4 processing level data, namely: satellite measurements of surface chlorophyll *a*, as well as numerical model products of variables related to marine eutrophication. Data pre-processing is necessary to enable the calculation of monthly and seasonal eutrophication values. This includes a) the conversion of the data structure from Network Common Data Form (NetCDF) to ArcGIS Raster, b) the conversion of the data into a common coordinate system (EGSA'87[5]) and finally, c) the conversion of the spatial analysis of the data. Then a geodatabase was developed in a GIS environment for the period 2012-2022 consisting of average monthly concentrations of chlorophyll *a* (chl *a*, μg/L), nitrates (N-NO_3, μmol N/L), ammonium (N-NH_4, μmol N/L) and phosphate (P-PO_4, μmol N/L).

[5] EGSA'87: Greek Geodetic Reference System

4. DEVELOPMENT OF THE GEOSPATIAL PORTAL

The renewed web client of Erdas Apollo by Hexagon, the Catalog Explorer is used to catalog and deliver the geodatabase. Erdas Apollo provides a geospatial portal that stores, distributes, edits and downloads large volume of geospatial information. The spatial data infrastructure can be regularly updated and deliver into any client, on any device (Figure 4).

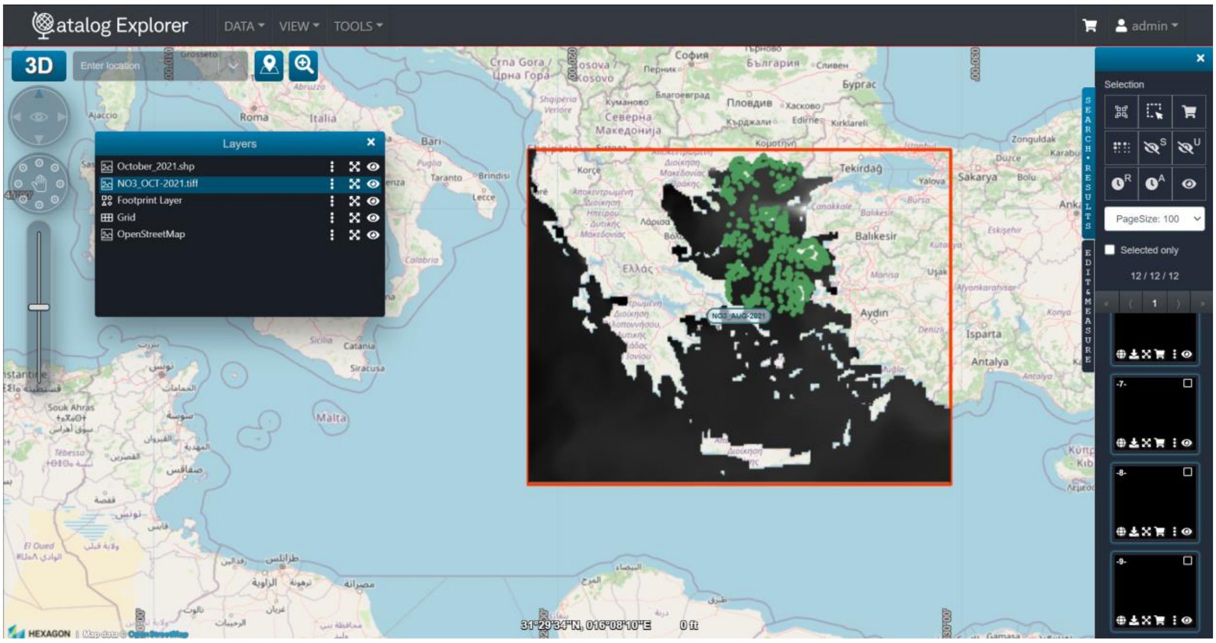


Figure 4. Geospatial portal interface where are selected to visualized the (a) concentration of nitrates and (b) the shipping detection for the October 2021.

5. DISCUSSION

The methodological framework presented in the article can serve as a tool for maritime/environmental policy in the long term. In particular:

- TSS (Traffic Separation Scheme) can be redefined to avoid problems of marine collisions in environmental sensitive areas, which are the main cause of accidents;
- Support the management of environmental risks in sensitive areas with increased shipping traffic;
- By processing data from the method it is possible to issues specific guidelines on ship operation (e.g. non discharge of liquid waste) to avoid polluting the areas;

- The maritime pollution response network (emergency stations) can be revised using data from maritime traffic and provide real time awareness of any environmental accident.

6. CONCLUSIONS

The assessment of seawater quality is of major importance and a prerequisite for decision-making and management of marine areas and the coastal zone. In this context, satellite images that visualize the spatial distribution of nutrients prove to be particularly useful as they contribute to the assessment of the phenomenon of eutrophication, which is one of the most important causes of marine water pollution.

Shipping continues to have a negative impact on the marine environment, contributing among others to eutrophication through NOx emissions. In this framework, satellite images and freely available softwares such as SNAP software can provide precise location of ships, regardless of weather conditions and coverage limits, to assess these adverse impacts.

Ship detection and nutrients datasets related to the phenomenon of eutrophication are collected, stored and visualized through a developed geoportal. The entire data infrastructure can be regularly updated and delivered to any client, on any device. As a result, decision-makers have an online tool with which they can combine visualized data on ship position and marine eutrophication levels. This tool can assist in adoption of strategies and more generally policies related to the maritime traffic and conservation and restoration of the environmental quality of the sea.

Future research includes the integration of a geoprocessing tool to assess eutrophication levels and visualize the spatial distributions of eutrophication levels, as well as the integration of a T-AIS dataset in order to compare/correlate AIS data with that obtained after processing from satellite SAR data. This comparison aims to double check and identify vessels that may not transmit AIS due to illegal activities. Finally, a Web Map Service (WMS) will be provided by the geospatial portal providing information on shipping density and covering a period from 2017 to 2021. Through geospatial portal, it is expected that a large group of people, scientists, local authorities, decision-makers and management as well as other involved groups will have access to high-resolution and easy-to-understand spatial data.

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