MODEL OF WATER FLOWS AND DISTRIBUTION OF SOLID WASTE IN THE BULGARIAN BLACK SEA COAST AREA

(FINAL REPORT)

This report is prepared in implementation of contract P-04-2 / 21.01.2020, concluded between the Foundation "VIA PONTIKA" and Nikola Vaptsarov Naval Academy for position 2 ***"Model of water flows and distribution of solid waste in the target area"*** *of the public procurement "Selection of a contractor for identification of hot spots and modeling of the distribution of solid marine waste in the target area (Bulgarian Black Sea coast)".*

Disclaimer

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Introduction

The present study was conducted in the interest of the detection of surface water flows in the marine environment and their impact on movement, respectively on the distribution of floating solid waste in the target area.

Figure 1 illustrates surface floating waste under the influence of sea surface flow.

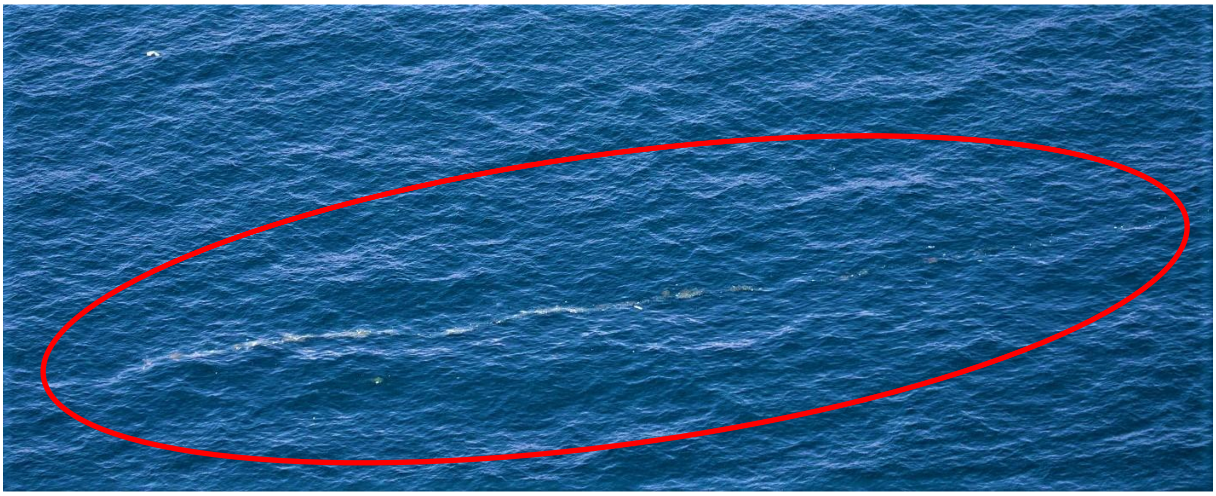


FIG. 1 Solid waste floating in the water column under the influence of surface water flows

It can be assumed that most of the floating solid waste is located in the water column at shallow depths or just at the boundary below the water surface. In this case, their movement is mostly caused by the sea surface flows, formed under the influence of sea surface currents.

It is also taken into account that depending on the material, size, shape, mass, volume and especially the degree of immersion of floating waste in the marine environment, to its movement on the sea surface, in addition to water flows, the so-called ground wind may have some influence. Examples of such floating debris are shown in Figure 2.

FIG. 2 Slightly submerged floating debris on the sea surface

For the purposes of modeling the processes in the surface layer of the marine environment, data sources with the required spatial coverage, resolution and time range, suitable for solving the studied problem have been analyzed.

1. General information on the implementation of the activities and tasks:

1.1. The requirements of the following guidelines and documents are compiled in order to fulfill the contract activities:

- **DIRECTIVE 2008/56 / EC** of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy (Marine Strategy Framework Directive)

  https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A32008L0056

- **Regulation (EU) №1255 / 2011** of the European Parliament and of the Council of 30.11.2011 establishing a program to support the further development of the Integrated Maritime Policy

  https://www.bsbd.org/UserFiles//File /Reglament%201255%20ot%202011_EC.pdf

- **Commission Decision (EU) 2017/848 of 17 May 2017** laying down criteria and methodological standards for the good environmental status of marine waters, as well as specifications and standardized methods for monitoring and evaluation, and repealing Decision 2010/477 / EU, available at the following internet address

  https://eur-lex.europa.eu/legal-content/BG/TXT/PDF/?uri=CELEX:32017D0848&from=EN

- **CONVENTION FOR THE PROTECTION OF THE BLACK SEA AGAINST POLLUTION**

  https://www.bsbd.org/UserFiles/File/Convention_for_Protection_of_the_BS_Against_Pollution.pdf

- **MARITIME STRATEGY OF THE REPUBLIC OF BULGARIA 2016-2021**

  https://www.bsbd.org/bg/m_env_and_action.html?URI=

- **ORDINANCE for protection of the environment in the sea waters,** adopted by Decree №273 of 23.11.2010, in force from 30.11.2010

  https://www.bsbd.org/UserFiles/File/Naredba%20za%20morskite_vodi.pdf

Data from the EuropeanEarth Observation Program**Copernicus**, where applicable - https://www.copernicus.eu/en

1.2. The following data has been used:

- European Copernicus Observation Program, https://www.copernicus.eu/
- data collected so far under the project "Innovative techniques and methods for reducing marine litter in the coastal areas of the Black Sea" - RedMarLitter, which are published in the database of the project (https://map.redmarlitter.eu/bg/database);
- data from other observations and analysis, including own observations and analyzes;
- Institutional monitoring of marine litter according to descriptor D10C1, indicator 1;
- Institutional monitoring of marine litter according to descriptor D10C1, indicator 2;
- Results obtained from position 1 "Identification of hot spots of solid marine litter pollution in the target area" of public procurement "Selection of a contractor for identification of hot spots and modeling of the distribution of solid marine litter in the target area (Bulgarian Black Sea coast)"

1.3. Target area: Bulgarian Black Sea coast, the waters of the Republic of Bulgaria in the Black Sea.

2. Analysis of the available data sources for the direction and speed of the sea currents in the surface layer (depth up to 5 meters).

In order to clarify the scale and dimensions of the problems of waste pollution of the Black Sea, it is necessary to apply a holistic approach, in which the Black Sea Basin is considered as part of the World Ocean. Figure 2.1 shows a diagram of the five largest offshore areas in the world ocean in which floating waste accumulates (mostly plastics).

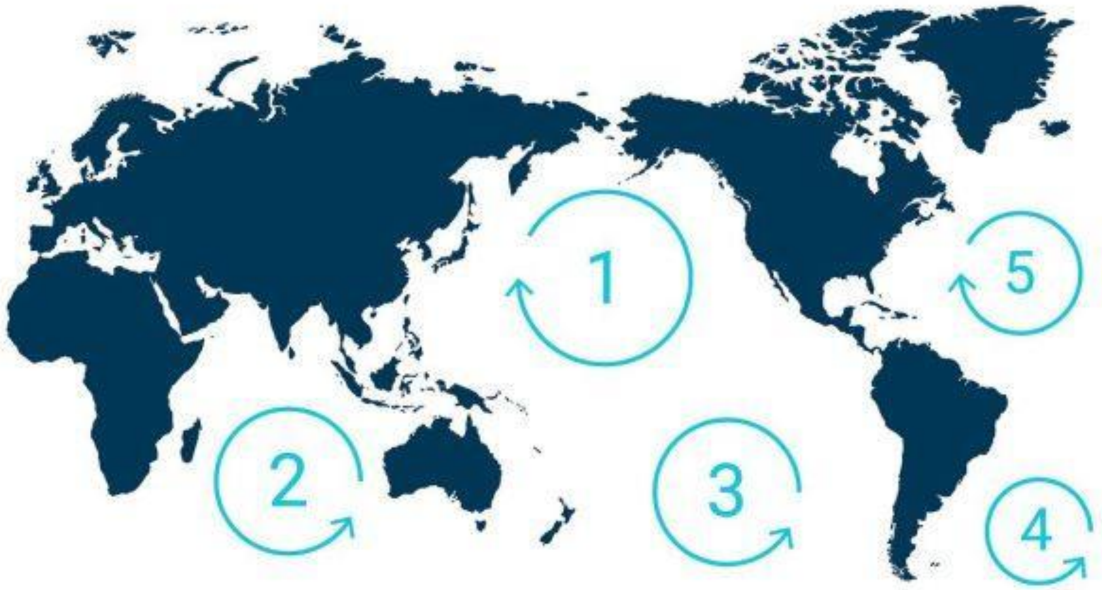
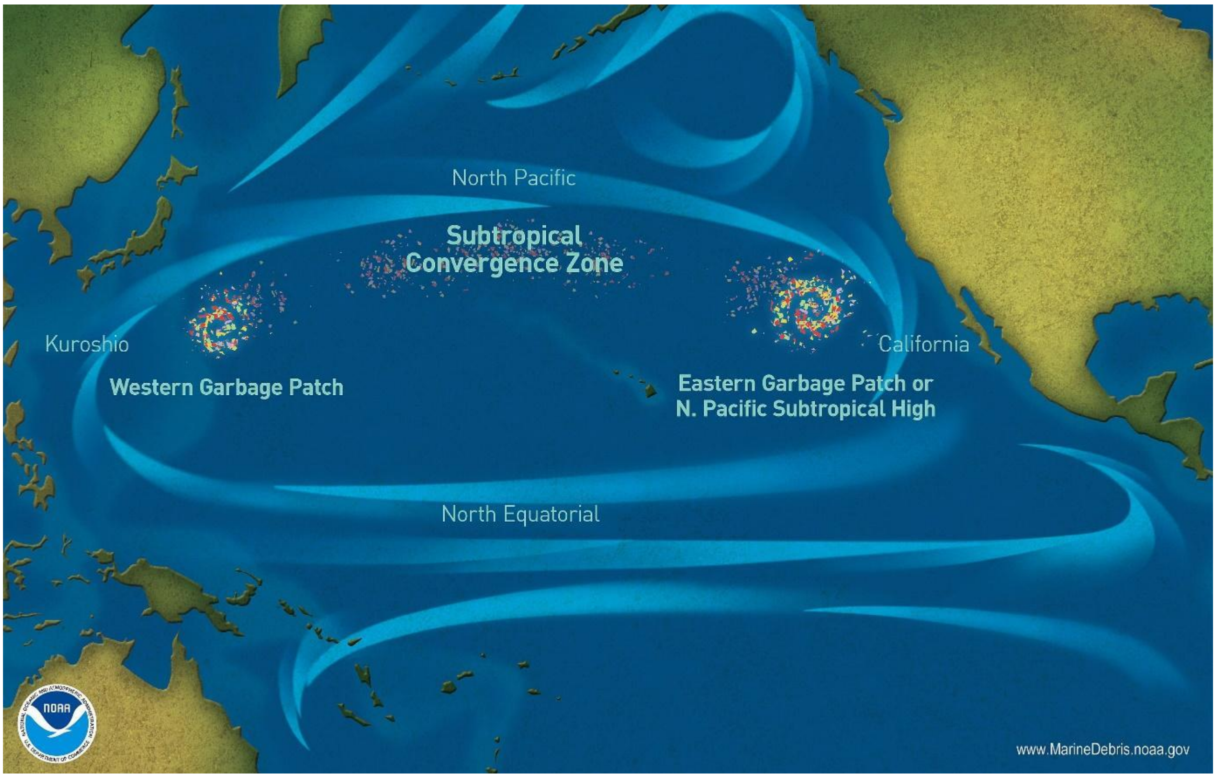


FIG. 2.1 Visualization of the circulation of the five largest offshore areas in the world's oceans with registered floating debris
(source: https://theoceancleanup.com)

The busiest, with approximately 1.15 to 2.41 million tonnes of plastic waste per year, is considered to be the NorthPacific zone (zone 1), with the highest concentrations of waste accumulation being registered in the western and eastern parts of the zone (Fig. 2.2)



2.2 Geographical distribution of floating waste accumulation zones in Zone 1

(source: https://marinedebris.noaa.gov/)

In this regard, for a global leader in data collection and processing, mathematical modeling and forecasting incentive models of the movement of water masses and the objects carried with them are the United States of America (USA).

2.1. National Centers for Environmental Information

One of the most reliable sources with freely available databases on the direction and speed of sea currents is maintained by an organization called the National Centers for Environmental Information (NCEI) - https://www.ncei.noaa.gov/) of the United States of America, established in 2015, uniting the centers:

- National Climatic Data Center (NCDC)
- National Geophysical Data Center (NGDC)
- National Oceanographic Data Center (NODC), which includes the National Coastal Data Development Center (NCDDC)

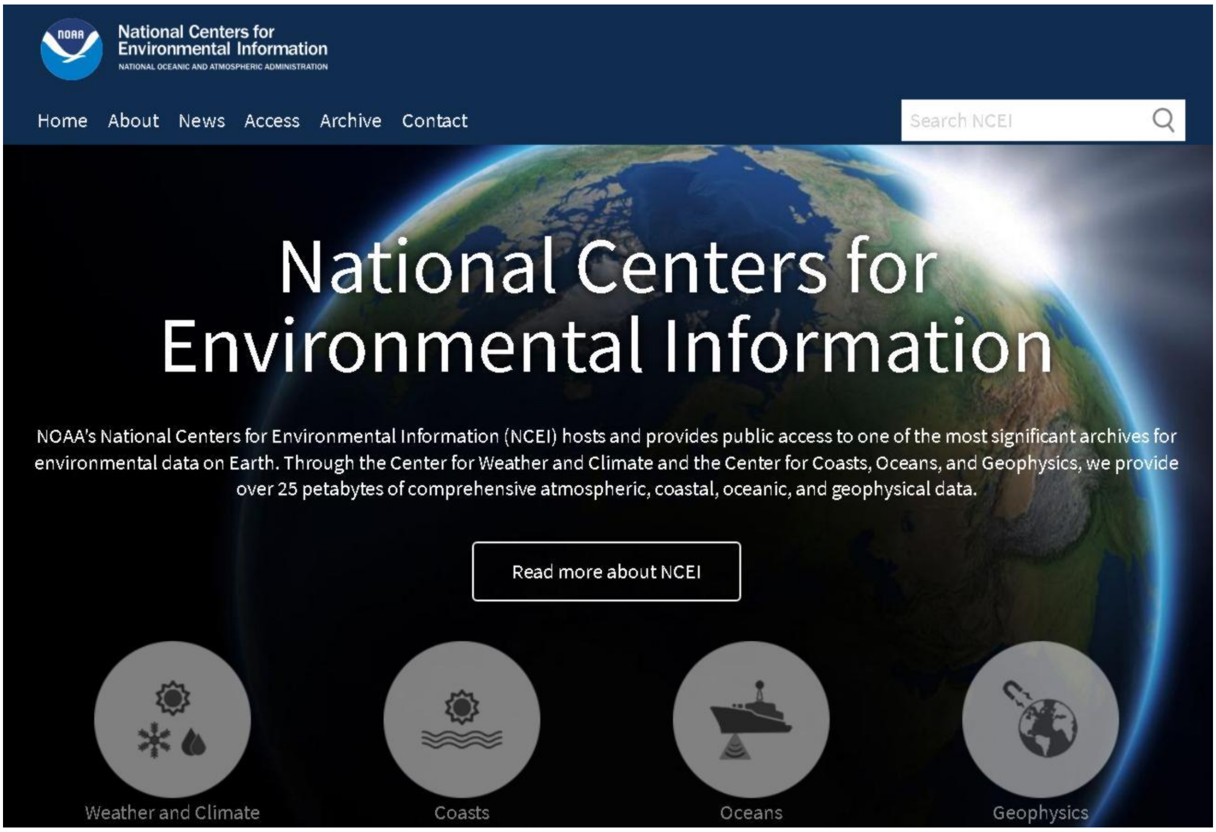


Fig. 2.3 National Center for Environmental Information (NCEI)

(source: https://www.ncei.noaa.gov/)

As a result of the creation of the center, the databases were merged and users were provided with access to the following categories (Access Data by Category):

Bathymetry & Global Relief

These data and products describe the height and elevation of the earth's surface above and below sea level.

- Bathymetric Data Viewer
- Digital Elevation Models
- ETOPO Global Relief Models
- International Hydrographic Organization Data Center for Digital Bathymetry
- Multibeam and Trackline Data
- National Ocean Service (NOS) Hydrographic Surveys

Climate Monitoring & Extremes

These data and products describe the state and change of weather and climate in the USA and globally, while providing a detailed picture of extreme natural phenomena such as droughts, tornadoes, hurricanes, etc.

- Climate at a Glance
- Climate Information
- Extreme Climate Events
- Global Ocean Heat and Salt Content
- Monthly, Seasonal, and Annual Climate Reports

Coastal & Regional

These data and products provide information related to the marine environment, seas and economy on specific coastal areas and regions around the world.

- Coastal Relief Models
- Coastal Water Temperature Guide
- Gulf of Mexico Data Atlas
- National Coastal Data Development Center
- Regional Climatology Atlases

Geomagnetism

These data and products describe terrestrial magnetism with models of the earth's magnetic field. These products are used as supports for activities such as global navigation and mineral exploration.

- Declination
- Field Calculators
- Models and Software

Interactive Maps

These products provide access to a variety of environmental data through online map applications that allow users to select and view data based on geographic parameters.

- Climate Data Online
- Coastal Habitats and Ecosystems
- Coastal Water Temperature Guide
- Geospatial Data and Services
- Gulf of Mexico Data Atlas
- Ocean Acidification Data Portal
- Ocean Exploration Digital Atlas

Land-Based Stations

These data and products provide access to ground-based observations, such as precise geographical location, temperature, precipitation and atmospheric pressure obtained from measuring instruments at stations around the world.

- Climate Data Publications
- Continuously Operating Reference Stations for GPS / GNSS Data
- Find a Weather and Climate Station
- Land-Based Station Datasets and Products
- Station Metadata

Marine Geophysics

These data and products provide a geophysical description of the sea and ocean floor as well as the seabed. lakes, providing data on gravity, magnetics, seismic impact, sonar data on the water column, etc.

- Marine Geology
- Trackline Geophysics
- Water Column Sonar Data
- Passive Acoustic Data

Marine Surface

These data and products provide information about the surface water layer of the world's oceans such as temperature, winds and waves.

-
- Marine and Ocean Surface Data Marine Environmental Buoy

Models - Models

These online systems and products provide access to environmental data from weather, geomagnetic and ocean systems modeling and forecasting.

- Climate Model Data
- Geomagnetism
- Ocean NOAA Operational Model Archive and Distribution System

- Vibrio vulnificus

Natural Hazards

These data and products provide information on natural environmental hazards, including tsunamis, earthquakes, volcanic eruptions, droughts, tornadoes and hurricanes.

- Earthquakes
- Extreme Climate Events
- Geophysical Data, Images, and Education
- Storm Data
- Tsunamis

Ocean Climatologies

These data and products provide long-term information, analysis and average data from observations of the world's oceans, including temperature and salinity.

- Marine and Ocean Surface Data
- Pathfinder Sea Surface Temperature Climate Data Record
- Regional Climatology Atlases
- World Ocean Atlas 2013

Ocean Data

These products provide access to a variety of observed Ocean parameters, including temperature, salinity, acidity, and information. associated with tsunami waves.

- Global Ocean Currents Database
- Global Ocean Heat and Salt Content
- Marine and Ocean Surface Data
- Ocean Acidification Scientific Data Stewardship
- Ocean Data Access
- Tsunami and Water Level Data
- World Ocean Database

Paleoclimatology

Obtained from observations on natural sources such as tree rings and ice cores, this data and product expand the archive of weather and climate information for hundreds to millions of years.

- Paleo Perspectives
- Paleoclimatology Data Search
- Paleoclimatology Datasets
- Paleoclimatology Products

Radar
These data and products provide information on the precipitation and thunderstorms recorded by radar networks. They can be used as tools for data visualization and study.

- Interactive Radar Map Tool
- Next Generation Weather Radar
- Terminal Doppler Weather Radar

Satellite
The following data and products provide access to continuous global environmental monitoring from the NOAA satellite fleet

- Climate Data Records
- Climate Satellite Data
- Earth Observation Group
- Geophysical Satellite Data Services
- Satellite Oceanography

Space Weather
These data, products and models have a range including the ionosphere, magnetosphere and solar measurements.

- Aeronomy and Geomagnetism
- Ionospheric Data
- Satellite Data Services
- Solar Data
- Space Weather Data

The study is of interest in the Global Ocean Currents Database (GOCD) category, whose data are divided into the following subcategories:

- Moored Current Meters
- Moored ADCPs
- Shipboard ADCPs
- Drifting Platforms
- HF Radar Systems
- Ocean Gliders

At this stage, data on the direction and speed of sea currents, mainly for the US waters, can be accessed from the system. This data has been used in creating simulations and models, however, the applicability of the models is limited to the marine areas for which they are designed.

There are also several main circulation zones in the Black Sea. According to various literature sources, they are Western and Eastern (see Fig. 2.4) or Western, Central, and Eastern (see Fig. 2.5).

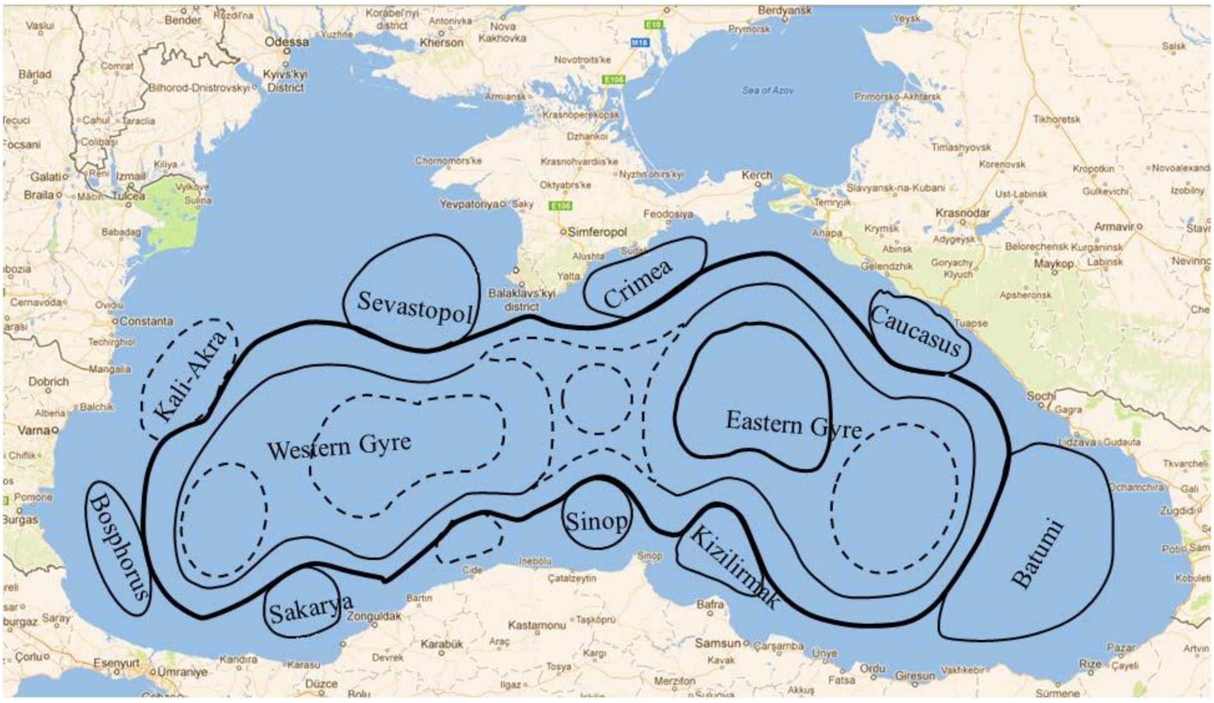
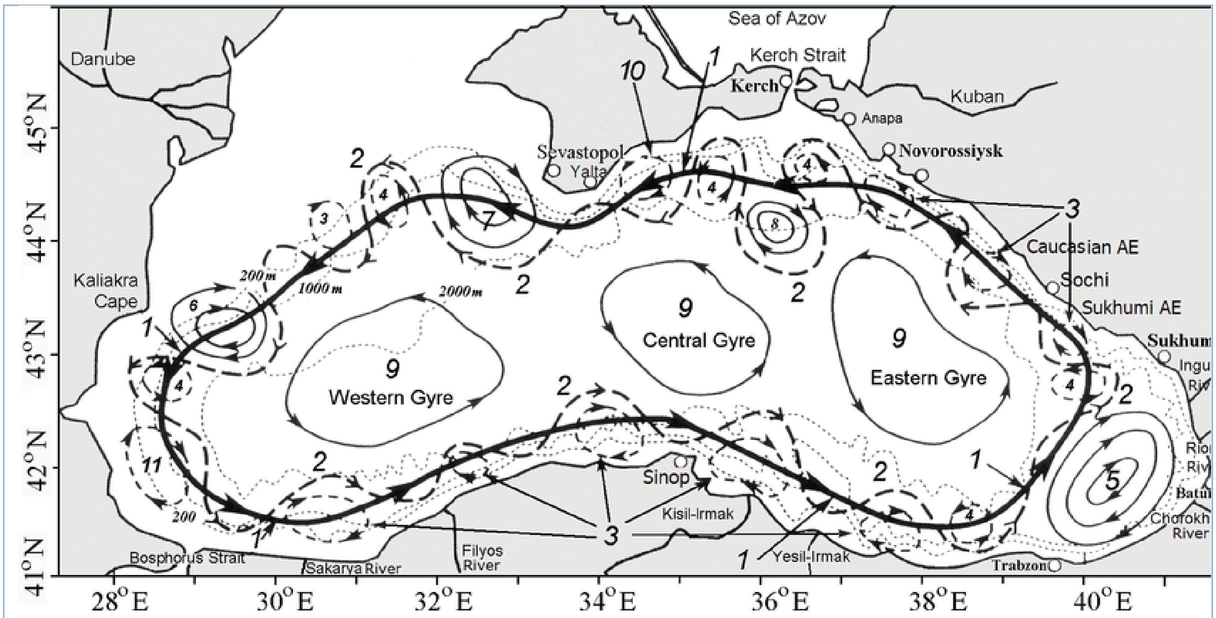


FIG. 2.4 Eastern and Western main circulation zones in the Black Sea

(source: http://dx.doi.org/10.4236/ijg.2013.47094)



1-mean position of the Rim Current jet;

2-meanders;

3-near-shore anticyclonic eddies (NAEs);

4-cyclonic eddies (CEs);

5-Batumi anticyclonic eddy;

6-Kaliakra anticyclonic eddy;

7-Sevastopol anticyclonic eddy;

8-Kerch anticyclonic eddy;

9-quasi-stationary cyclonic gyres;

10-Crimea anticyclonic eddy;

11-Bosphorus anticyclonic eddy

FIG. 2.5 Eastern, Central, and Western main circulation areas in the Black Sea

(source: DOI: 10.7717 / peerj.5448, https://peerj.com/articles/5448/)

The map in Figure 2.5 illustrates the main quasi-stationary circulation areas (9), as well as: the main surface flow (1); coastal anticyclonic (3) and cyclonic (4) vortices, as well as specific anticyclonic vortices in the waters of: Cape Kaliakra (6), Bosphorus Strait (11) and others.

Visualizing the borders of the Exclusive Economic Zone (EEZ) of the Republic of Bulgaria in the Black Sea (see Fig. 2.6), including the target territory of the present study, it is observed that in the waters of the Republic of Bulgaria, there are the main surface current (1), sequentially act anticyclonic (6), cyclonic (4) and anticyclonic (11) vortices, as well as the currents of the western quasi-stationary zone, which together form the flows of pollutants in the target area.

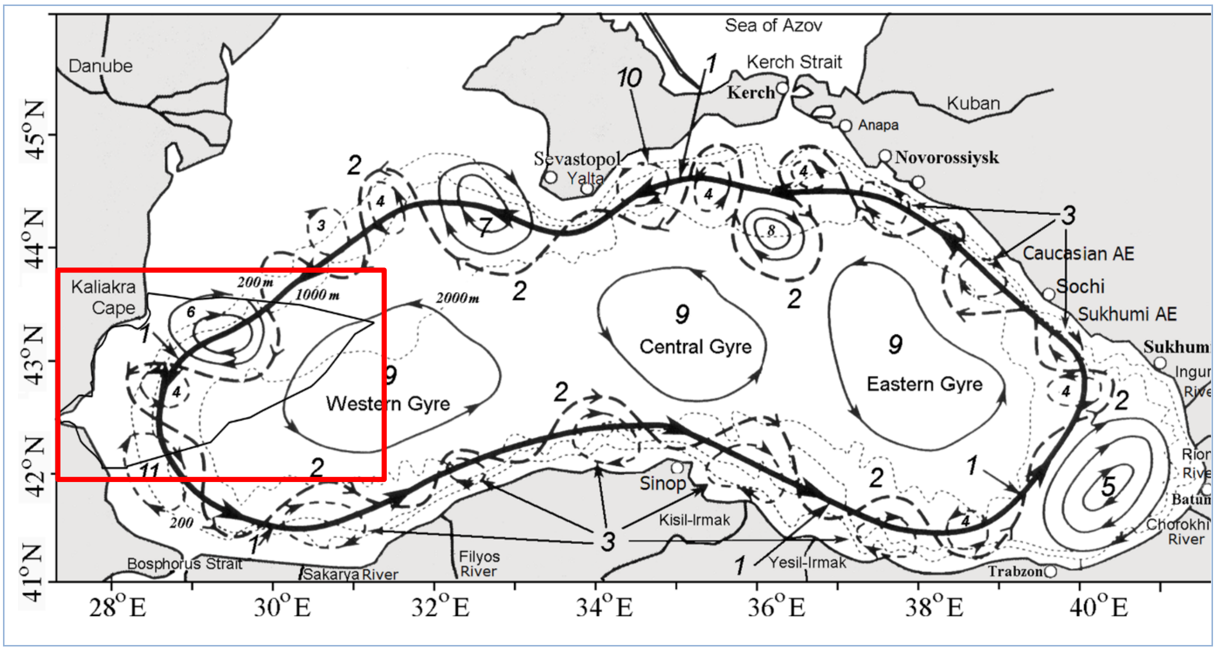


FIG. 2.6 Border of the EEZ of the Republic of Bulgaria in the Black Sea

(source: DOI: 10.7717 / peerj.5448, https://peerj.com/articles/5448/)

In order to develop an interactive computer model - a map of the movement of pollutant flows in the target area (Bulgarian waters of the Black Sea) under the influence of water and air currents, analogous to the above data is needed, but for the Black Sea. The data should be accompanied by metadata, to form a dense time series and be representative (including through a data quality control procedure without contradicting the INSPIRE directive) for the study area, and may be derived from actual observations or through use of remote sensing methods, or as a result of modeling using data from actual and remote observations.

2.2. Global system of free-floating buoys

Such a reliable and representative source of data on the direction and speed of sea currents is the **global system of free-floating buoys Argo** (http://www.argo.ucsd.edu/). It is at the heart of the information provision of the Marine Copernicus Monitoring Service of the European Commission, as well as the US National Environmental Information Centers.

Deployment of the Argo system began in 2000 and by November 2007, the millionth profile had been collected.

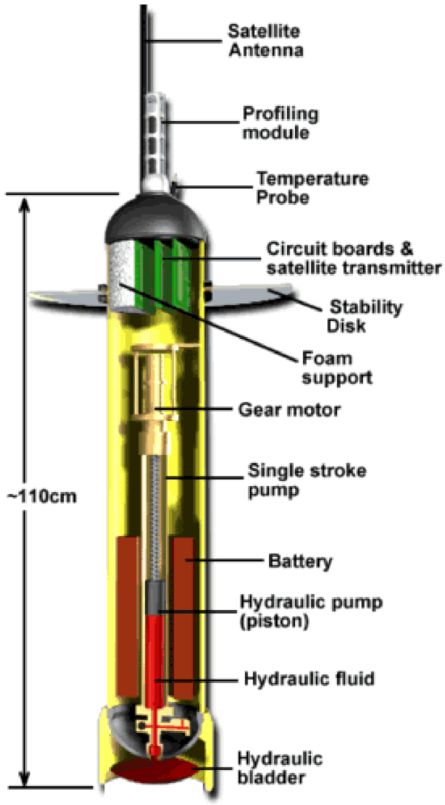


FIG. 2.4 Image of an Argo buoy
(source: http://www.argo.ucsd.edu/)

To date, more than 4,000 units of these technical devices have sailed in the world's oceans to measure the temperature and salinity of the upper 2,000 m (just over a nautical mile) of the ocean, and by tracking their movement the profile of the water currents is obtained with sufficient accuracy.

This allows, for the first time, continuous monitoring of the temperature, salinity and speed of the "upper ocean", with all data transmitted and made public within hours of collection. However, today there are still some areas of the ocean that are overcrowded, while others have gaps that need to be saturated with additional Argo buoys.

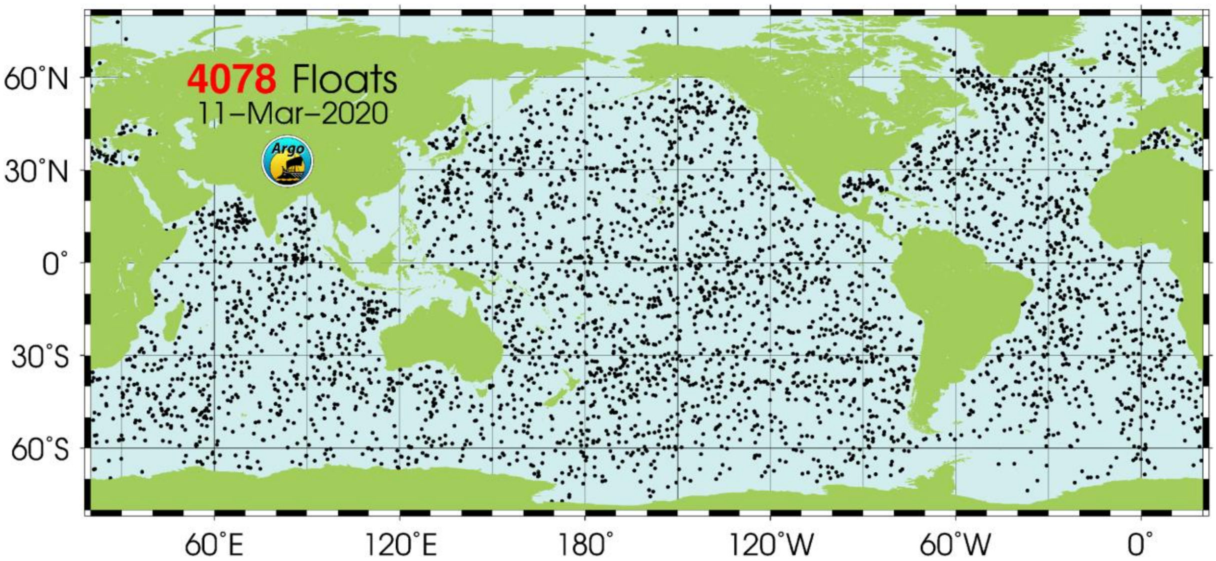


Fig. 2.3 Location of buoys globally, according to data from February 2020 (source: https://directory.eoportal.org/web/eoportal/satellite-missions/a/argo)

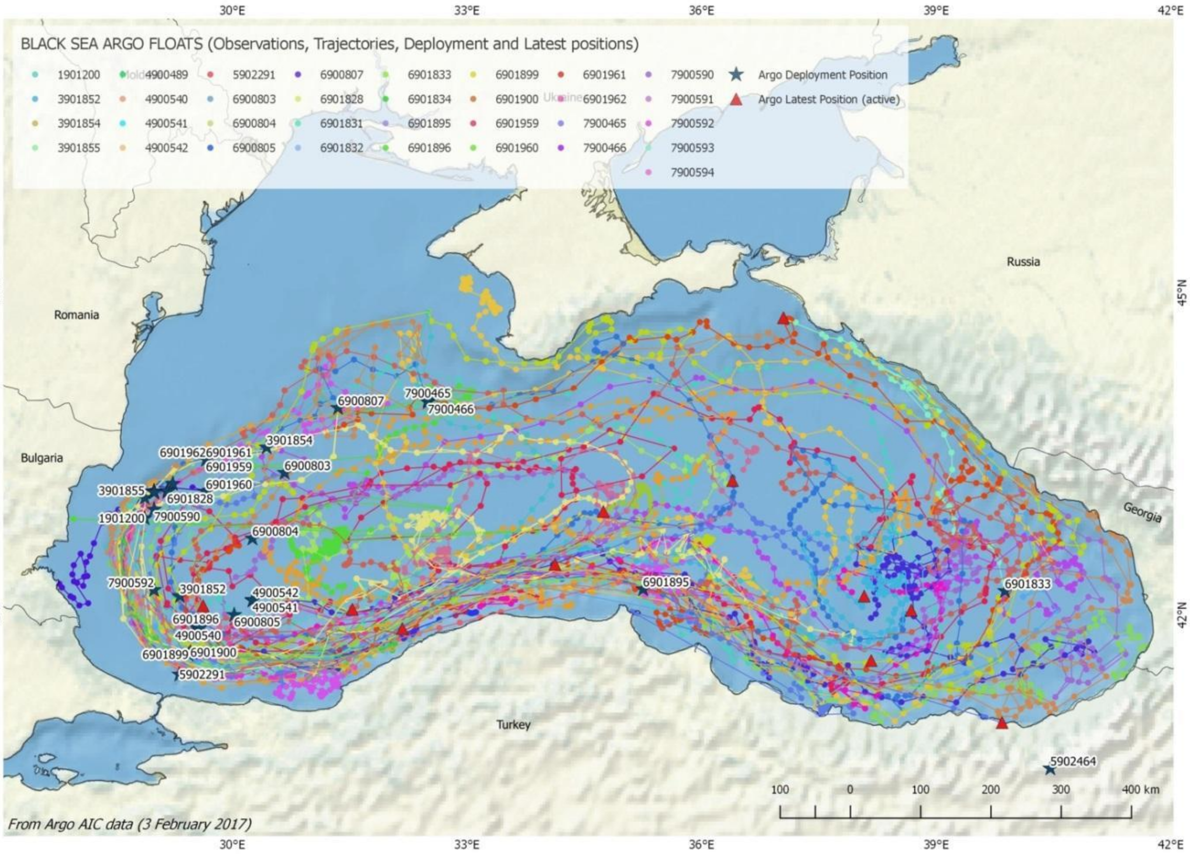


Fig. 2.6. Argo buoys and their trajectories in the Black Sea, 2002-2016r.

(source: https://www.euro-argo.eu/News-Meetings/News/News-archives/2017/Argo-activities-in-the-Black-Sea)

Of interest for the study are the Argo buoys located in the Black Sea.

In figure 2.6, according to „Argo activities in the Black Sea“ with authors: S. Balan (GeoEcoMar, Romania), B. Fach (Middle East Technical University (METU), Turkey), S. Grayek and E. Stanev (Helmholtz-Zentrum Geesthacht, Germany), PM Poulain (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale - OGS, Italy), A. Storto (Euro-Mediterranean Centre for Climate Change - CMCC, Italy) the locations of the buoys are shown, respectively, the points of measurement of the parameters of sea water from 2002 to 2016.

According to the same article, in December 2016 in the southwestern part of the Black Sea an Argo buoy for biochemical measurements was launched at a point with coordinates shown in Figure 2.7.

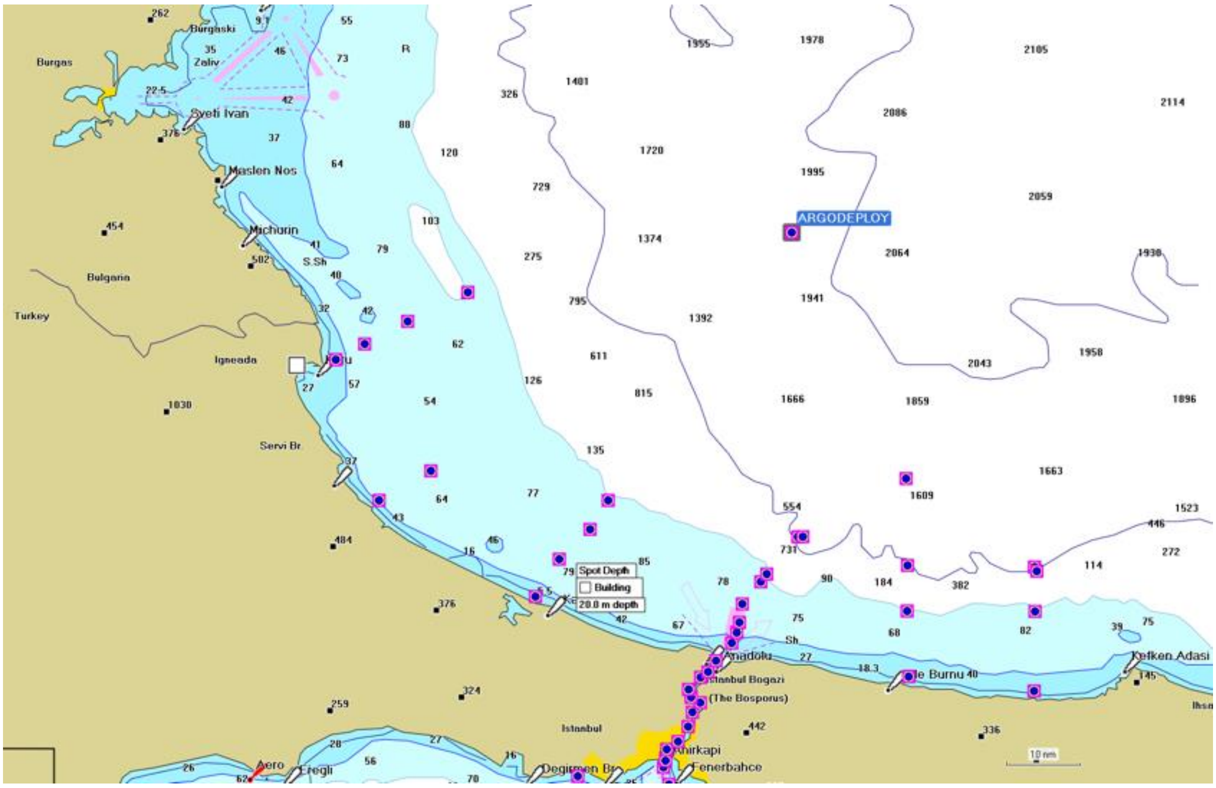


Fig. 2.7 Argo buoy for measuring of biochemical parameters in the Black Sea, 2016 г.

(source: https://www.euro-argo.eu/News-Meetings/News/News-archives/2017/Argo-activities-in-the-Black-Sea)

The next few Figures illustrate: the location, type, on-board sensors and operating time of the Argo buoys located in the Black Sea according to data from March 11, 2020.

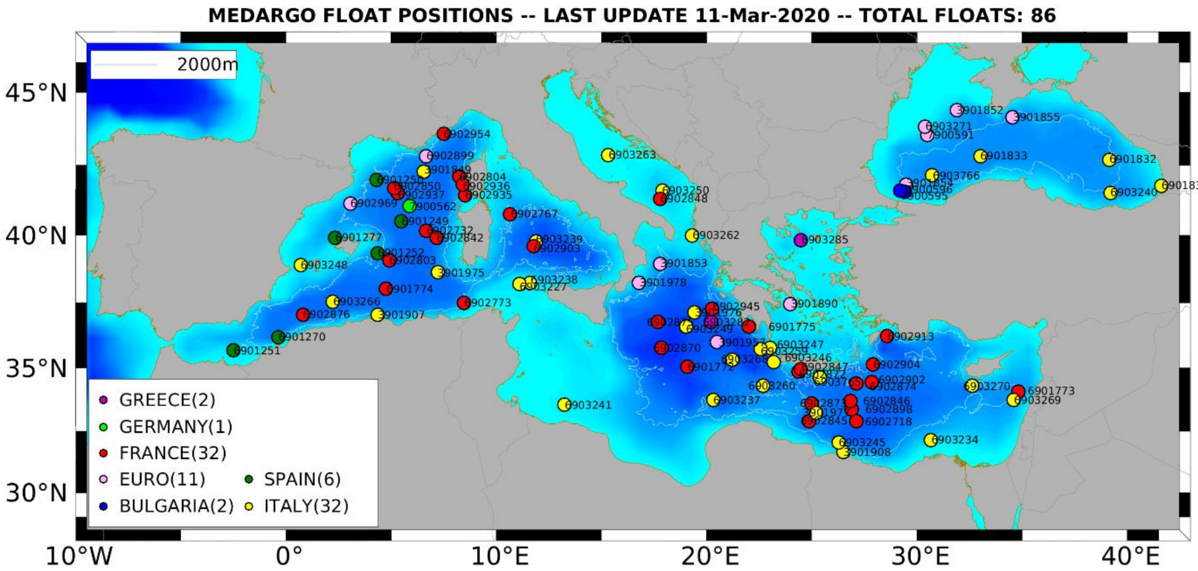


Fig. 2.8 Location of the buoys according to data from March 11, 2020

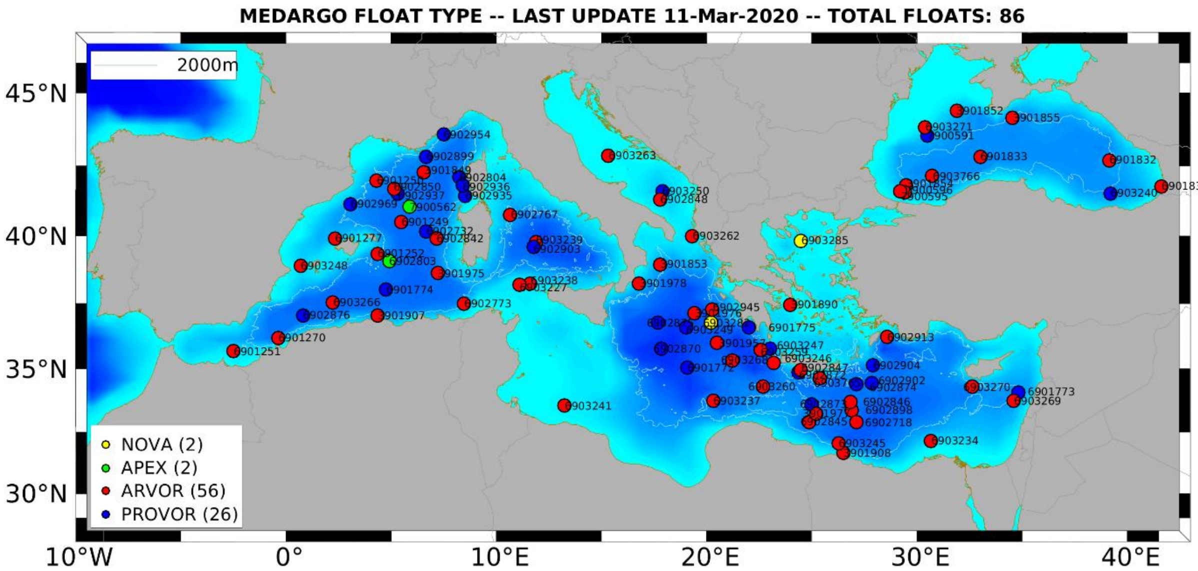


Fig. 2.9 Type of the buoys according to data from March 11, 2020

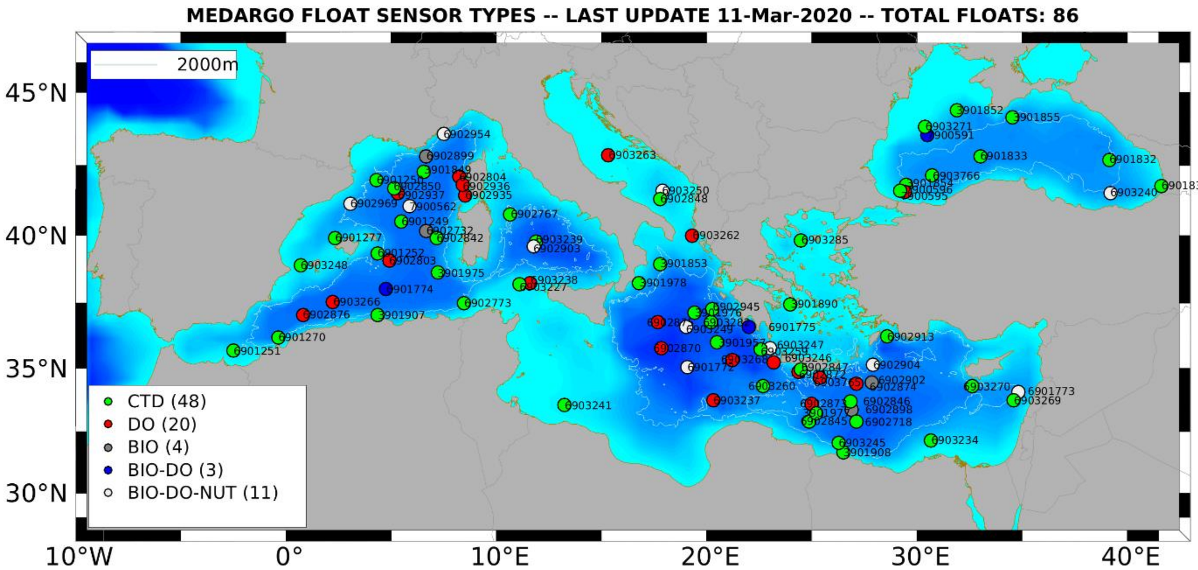


Fig. 2.10 Sensor types of the buoys according to data from March 11, 2020

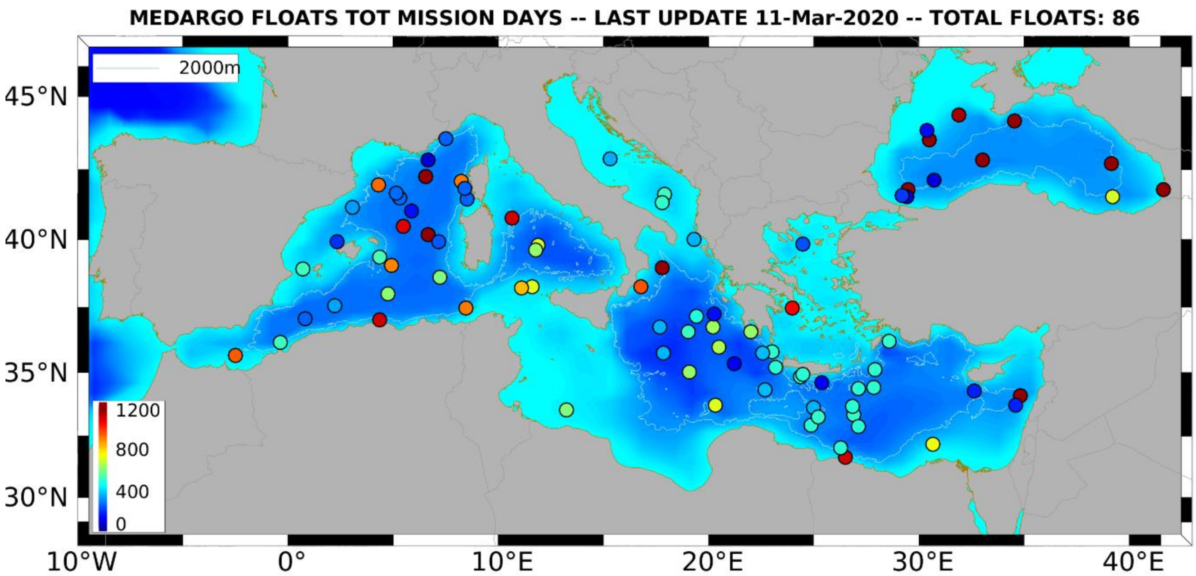


Fig. 2.11 Working days of the buoys according to data from March 11, 2020

The data for the profiles of the marine environment measured by the buoys can be downloaded by the identification number.

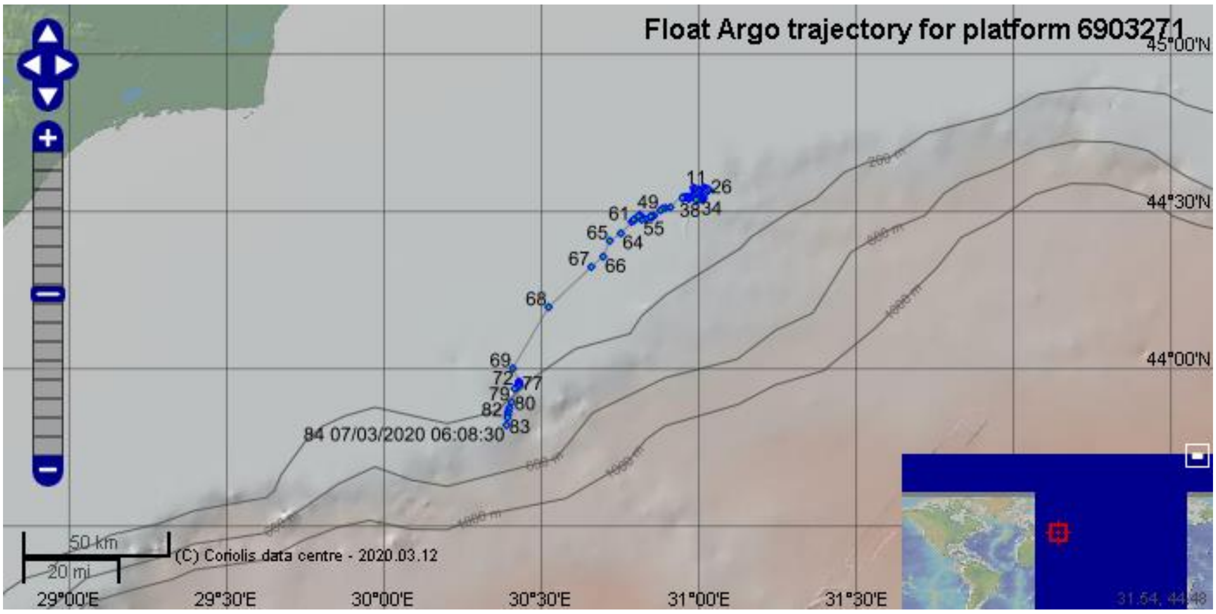


FIG. 2.12 Trajectory of an Argo buoy with number 6903271 in the Black Sea

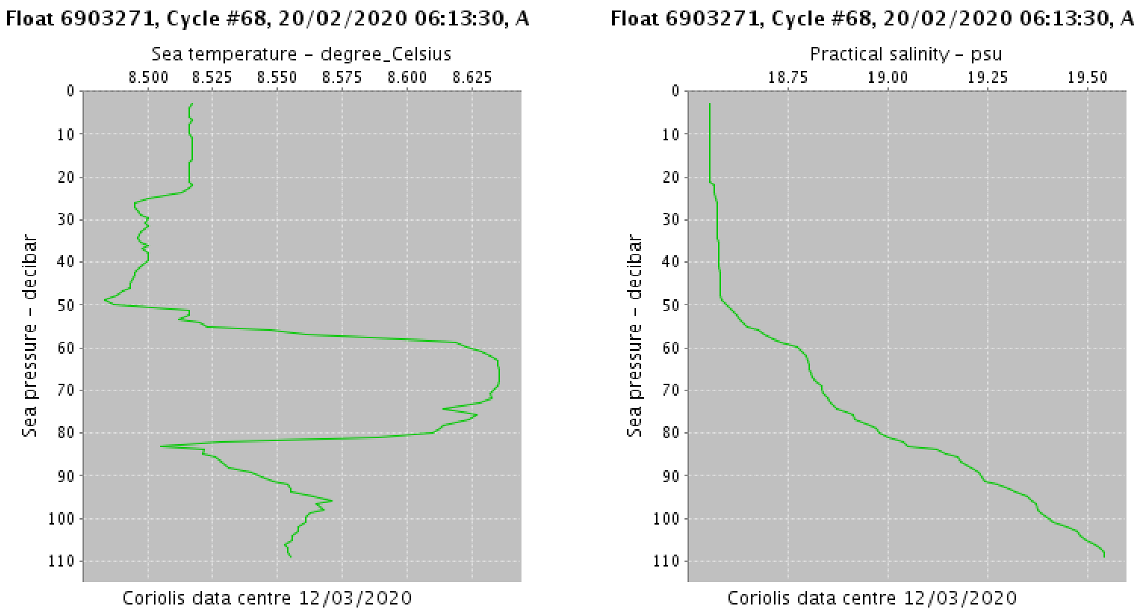


Fig. 2.13 Temperature and salinity profiles measured by buoy number 9603271 for cycle 68 from 20.02.2020 (data downloaded on 12.03.2020)

The Argo buoy network is a basic monitoring system capable of detecting changes in temperature and salinity at depth. Several Argo units in the Black Sea provide measurements at extremely high vertical resolutions (up to several thousand records in the first 100 m).

Fig. 2.14 Current situation (March 12, 2020)

The analysis of the information presented above, visualized in Figures 2.8 to 2.14, shows that twelve buoys from the Argo network operate in the Black Sea and the system continues to develop, with expectations to reach optimal numbers and density of observations in the next decade.

Although the main task of the buoy network is to measure the physicochemical parameters of the marine environment, by applying algorithms to smooth their trajectories during their free movement in the aquatic environment, they are successfully used to analyze marine currents.

2.3. Copernicus Marine Environmental Monitoring Service

The Copernicus Marine Environmental Monitoring Service performs daily analyzes and forecasts of and for the Black Sea. In this context, Argo buoy measurements are routinely adopted in the real-time data assimilation system, which applies a variation scheme to estimate the optimal initial conditions for forecasts made at a horizontal resolution of approximately 3 km.

The Copernicus Marine Monitoring Service is one of the six services of the European Copernicus Earth Observation Program (http://www.copernicus.eu) (see Figure 2.15).

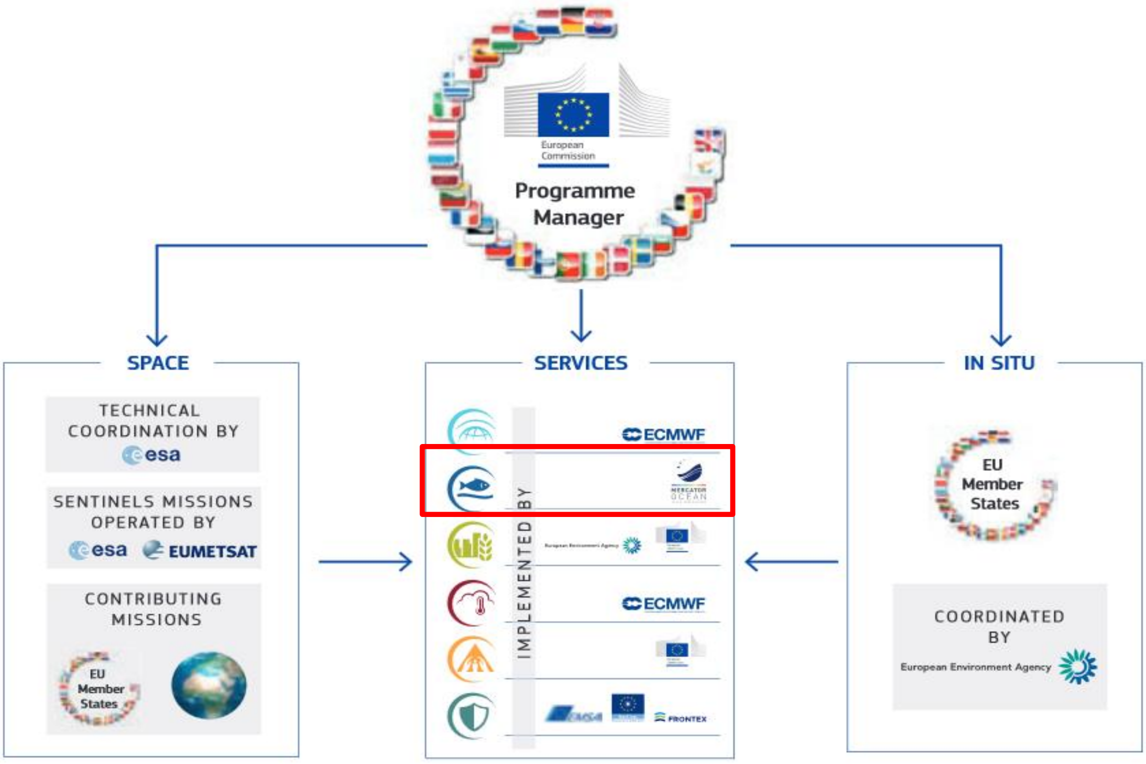


FIG. 2.15 Copernicus Program (data sources and services offered)

The Marine Monitoring Service was established by Mercator Ocean in early 2014 on the basis of an agreement with the European Commission. The Office's operational services were built in stages, as part of a series of European projects, starting with MERSEA (2004-

2008), followed by MyOcean (2009-2012) under FP7 and MyOcean2 (and beyond) from 2012 to 2015

To date, the catalog of the Copernicus Marine Environmental Monitoring Service lists more than 150 products from more than 40 suppliers divided into three main groups, shown in Table 2.2.

Regarding the geographical scope of the data, they are divided into 7 groups (see Fig. 2.16), and in terms of time range they are of three types: reanalyses, real-time data and forecast data.

Table 2.2

PARAMETER	MODEL			SATELLITE		INSITU	
	20 years in the past (surface to bottom of the ocean)	Today (surface to bottom of the ocean)	10-day forecast (surface to bottom of the ocean)	20 years in the past (surface of the ocean only)	Today (surface of the ocean only)	20 years in the past (Surface to 2000 meters depth)	Today (Surface to 2000 meters depth)
Sea Surface Height	□	□	□	□	□	□	□
Temperature	□	□	□	□	□	□	□
Salinity	□	□	□			□	□
Waves	□	□	□				
Currents/Velocity	□	□	□			□	□
Mixed Layer Depth	□	□	□			□	□
Sea ice	□	□	□	□	□		
Turbidity/Transparency				□	□		
Reflectance				□	□		
Nutrients	□	□	□			□	
Primary Production	□	□	□			□	
Oxygen	□	□	□			□	
Plankton	□	□	□			□	
Wind				□	□		

Programme co-funded by the EUROPEAN UNION

RedMarLitter

Black Sea CROSS BORDER COOPERATION

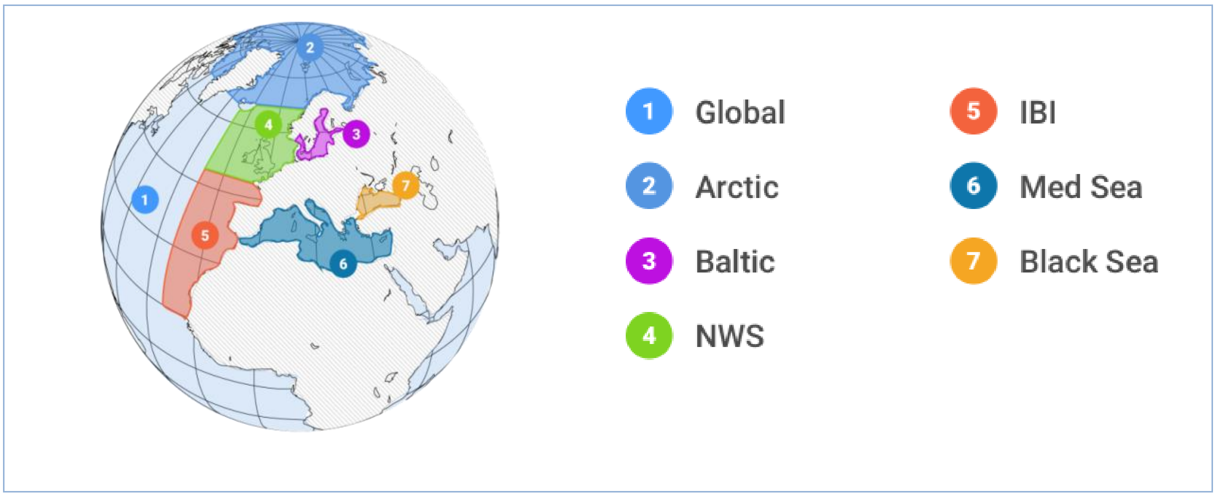


Fig. 2.16 Geographical scope thematic grouping of data

The analyzed data are both global and regional. Their purpose is to provide reference data for the last decades, using optimal resolution and coverage of observations, as well as using an analysis system corresponding to that which produces real-time analyzes and forecasts. Regional realizations usually offer either better physical data due to the configuration of the model, which is specially tuned for the given region (eg Black Sea), and/or higher resolution.

In order to generate the targeted data types (Table 2.1), daily, the so-called "supercomputers" start the algorithms of the global and regional oceanographic models for calculating the circulation of water masses in the given water basin, sampled in time for each point of the reference network, located in the three-dimensional space.

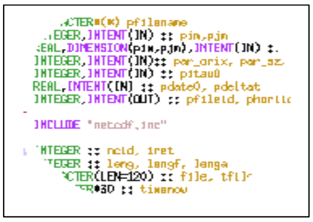
Equations mechanics of fluids

$$\frac{\partial T}{\partial t} = -u \cdot \nabla T + D_T + F_T$$

$$\frac{\partial S}{\partial t} = -u \cdot \nabla S + D_S + F_S$$

$$\frac{\partial u}{\partial t} = -u \cdot \nabla u + fv - \frac{1}{\rho_0}\frac{\partial P}{\partial x} + D_u + F_u$$

Algorithms



Supercomputers

The Ocean Models transform the ocean through numerical modeling into a "discrete ocean" by solving millions of equations in a strict time sequence for each point in the grid of the 3D spatial network of the ocean.

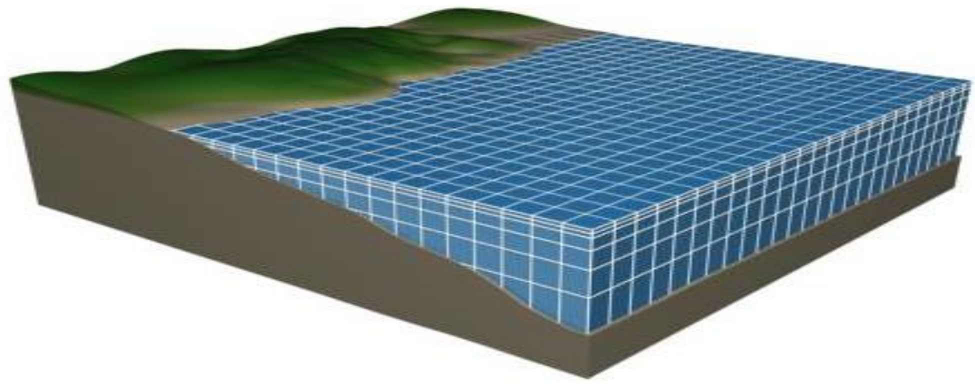


FIG. 2.17 Numerical modeling of the movement of water masses in time and space

For the needs of the research, the data on the surface sea currents for the Black Sea are of interest. Figure 2.16 shows the scheme of operation of the model, as well as its input data and catalog of generated products.

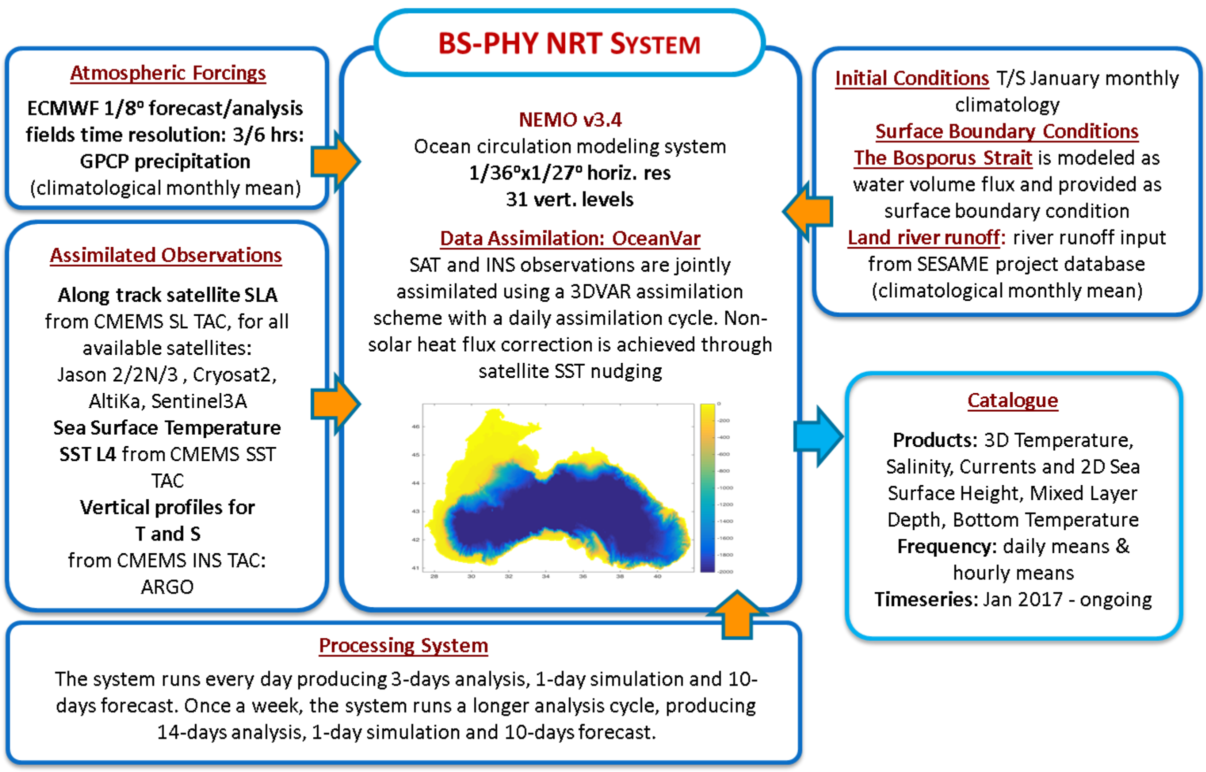


FIG. 2.18 Scheme of operation of the Black Sea model

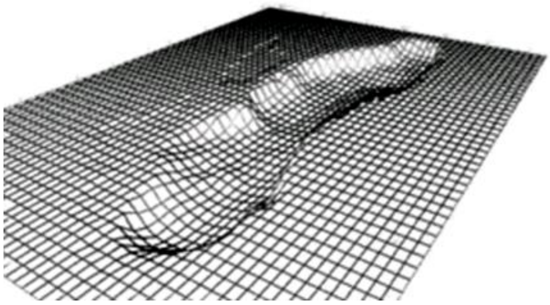


Fig. 2.19 Digital bathymetric model of the Black Sea
(source: http://www.blacksea-commission.org/)

The model used to analyze and predict water circulation is called NEMO, and its current version is 3.4. As shown in FIG. 2.18, in order for the model to work, it is powered by data from other models (air mass circulation model and bathymetric model of the seabed / trough), satellite data (from all satellites that have flown and collected data for the Black Sea: Jason 2 / 2N / 3, Cryosat2, AltiKa, Sentinel3A) and the so-called. In-Situ data (data measured on site) supplied mainly by the Argo buoy system in the form of vertical seawater temperature and salinity profiles (see Fig. 2.14) and additionally by other monitoring systems drifting or anchored buoys, ships, platforms, etc.).

This version of the NEMO model provides an opportunity to take into account the impact of river flows and circulation through the Bosphorus Strait on the overall circulation of water masses in the Black Sea, which are set as boundary conditions at the start of the model.

The targeted system is started daily as a result of which are generated: 3-day analyzes, 1-day simulations and 10-day forecasts.

Once a week, the system is run in a longer analysis cycle mode to generate a 14-day analysis, a 1-day simulation, and a 10-day forecast.

Georeferenced maps materials of the surface currents speed and directions data sets (depth up to 5 meters) are attached in Annex 1 to this report.

2.4. Reliable sources of data on the direction and speed of sea currents in the surface layer in the target area.

In order for the data related to the direction and speed of sea currents to be used as input data for creating an interactive computer model - a map of the movement of pollutant flows (solid marine floating waste) in the Bulgarian Black Sea area, it must meet the following basic requirements:

- data accuracy (data based on real research)

- provision with metadata

representativeness of the data (geospatial coverage, resolution, etc.)

- density of time series

Such data for the target area can be obtained only in the presence of systematic observations - monitoring of the marine environment in terms of parameters of interest (direction and speed of surface water currents to a depth of 5 m).

<u>The following reliable data sources for the direction and velocity of sea currents in the surface layer in the target area have been identified:</u>

- Global system of free-floating buoys Argo - in the part "Black Sea"
- Copernicus Marine Monitoring Service - in the Black Sea section
- NEMO model for analysis and forecasting of water circulation (for the Black Sea)

For the purpose of creating an interactive computer model - a map of the movement of pollutant flows under the influence of water and air currents, the input data should be those of the Marine Environment Monitoring Service of the Copernicus program for the Black Sea.

The data available through the Copernicus program integrates the data obtained from the global system of free-floating buoys Argo, which are input data for the NEMO model. Given the level of integrity of the data and information accumulated in the Copernicus program on marine currents, it should be used to develop an interactive model map of the flow of pollutants in the section "under the influence of water currents".

This data was used as input data in combination with data on the direction and speed of the winds over the specified water area and data from own observations (conducting an experiment - simulations implemented within the RedMarLitter project).

The data for the sea currents for the surface water layer (corresponding to a horizon of 2.5 meters from the product BLKSEA_REANALYSIS_PHYS_007_004) for the target territory for the period 2015-2018. are processed, visualized and presented in Annex 1. They are presented in XLSX format compatible with the open database of the RedMarLitter project https://map.redmarlitter.eu/en/database - Annex 8 (on CD).

3. Analysis of the available data sources for the direction and speed of air currents (height up to 10 m.)

3.1. World Meteorological Organization - WMO

The main source of data for the troposphere, including information on the direction and speed of wind currents, is the World Meteorological Organization (WMO). Each meteorological station registered in the database of the World Meteorological Organization has a unique identification number, and under this number is stored an archive of the tropospheric parameters measured by the meteorological station for a data reporting interval of maximum three hours.

Figure 3.1 shows a map of the locations of the meteorological stations of the World Meteorological Organization in the Black Sea region.

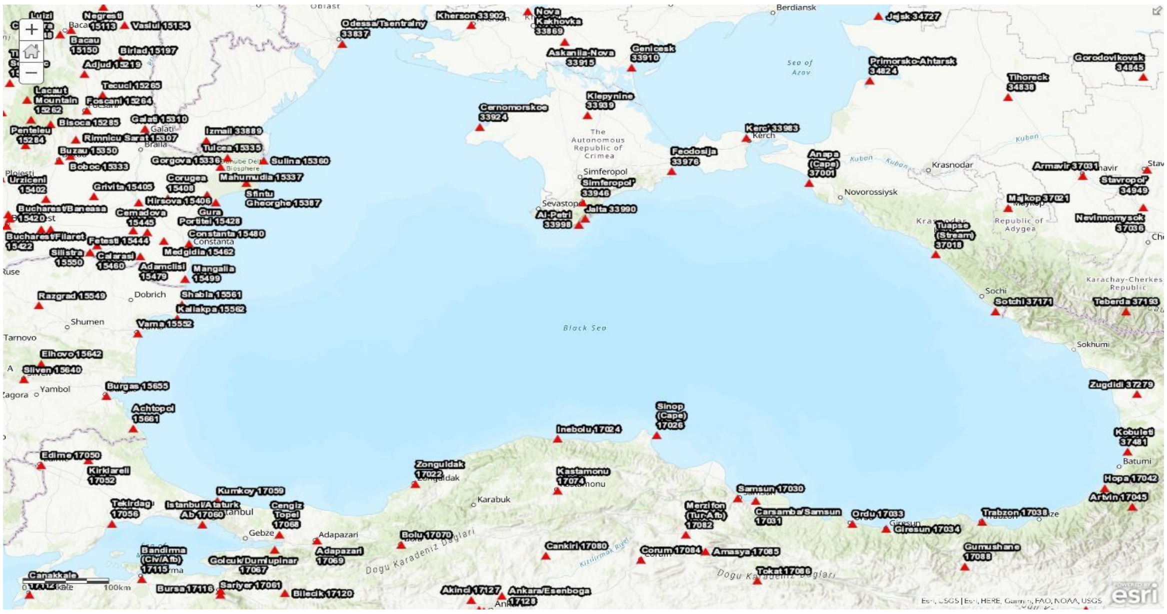


FIG. 3.1 Meteorological stations of the World Meteorological Organization in the Black Sea region

(http://www.arcgis.com/home/webmap/viewer.html?url=https%3A%2F%2Fgeo.fas.usda.gov%2Farcgis2%2Frest%2Fservices%2FG_Overlay%2FWMO_Station_Overlay%2FMapServer&source=sd)

The data is freely accessible through internet servers and/or pages. When submitting a request - station number (and observation period) the data can be downloaded and used. (Example of access to a five-day archive of data from the Varna meteorological station:

Weather reports from Varna WMO (15552))

Another way is to use "raw" weather data. The raw weather data is transmitted in text format using a special code known as SYNOP.

The raw meteorological data are available through some Internet servers up to 10 minutes after the meteorological observations are made by the meteorological stations. The SYNOP code also allows the transmission of meteorological data from ships equipped with meteorological stations (and the message must indicate the geographical coordinates of the ship when performing meteorological observations), meteorological balloons, etc.

The meteorological stations located near the Black Sea coast and the data from ship meteorological stations are of interest for the specific study. By using the SYNOP code, the process of receiving and processing meteorological data via a personal computer can be automated and the state of the troposphere, and in particular the direction and speed of air currents, can be successfully modeled.

As a disadvantage of the system it can be noted that it does not have the necessary geospatial coverage (especially in the interior of the sea basin) and the resolution of the data needed for the needs of the present study.

3.2. Space-based Earth observation systems

Another source of data on the direction and speed of air currents up to 10 meters above sea level are the raw radar data of various space-based Earth observation systems.

Nowadays, remote sensing methods are widely applied globally to the world's oceans and the marine environment in general, which allows the extraction and collection of data on the movement of air masses over land and sea surface.

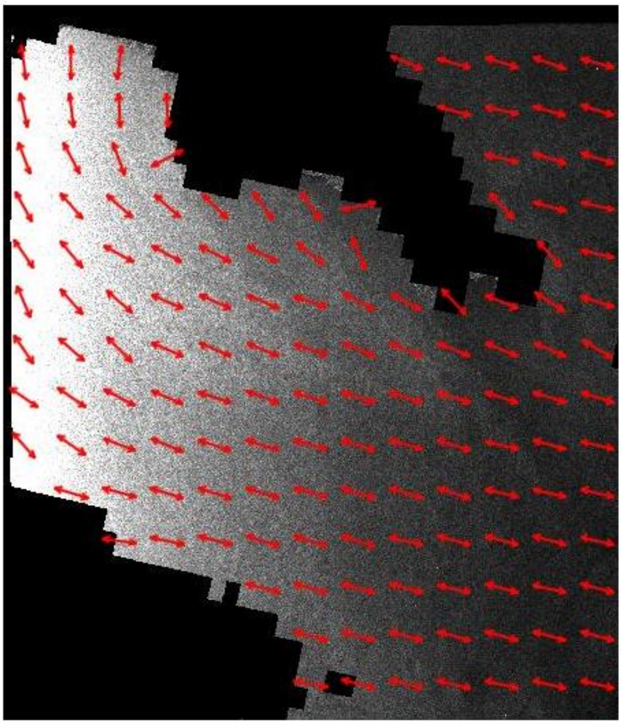


FIG. 3.2. Example of the application of the method

(source: European Space Agency)

Figure 3.2 shows an example of the use of this method. It can be used in applications to determine the parameters of air currents for a past period of time and for the so-called near-real-time when satellite data is used immediately after the satellite flies over the area of interest. **As a disadvantage of the method, it can be noted that it does not allow the necessary time density of the time series of data required for the needs of the present study.**

3.3. Copernicus Marine Environment Monitoring Service

Another source of data on the direction and speed of air currents is the Copernicus Marine Environment Monitoring Service.

From what is shown in Table 2.2 and Figure 2.18, it can be seen that data from space-based power supply systems of the ECMWF 1/8 ° model are used to perform analysis and forecasts for the state of air masses on a global scale.

Figure 3.3 shows a visualization of **averaged 6-hour wind direction and wind speed data of product WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006** for random selected date and height 10 meters.

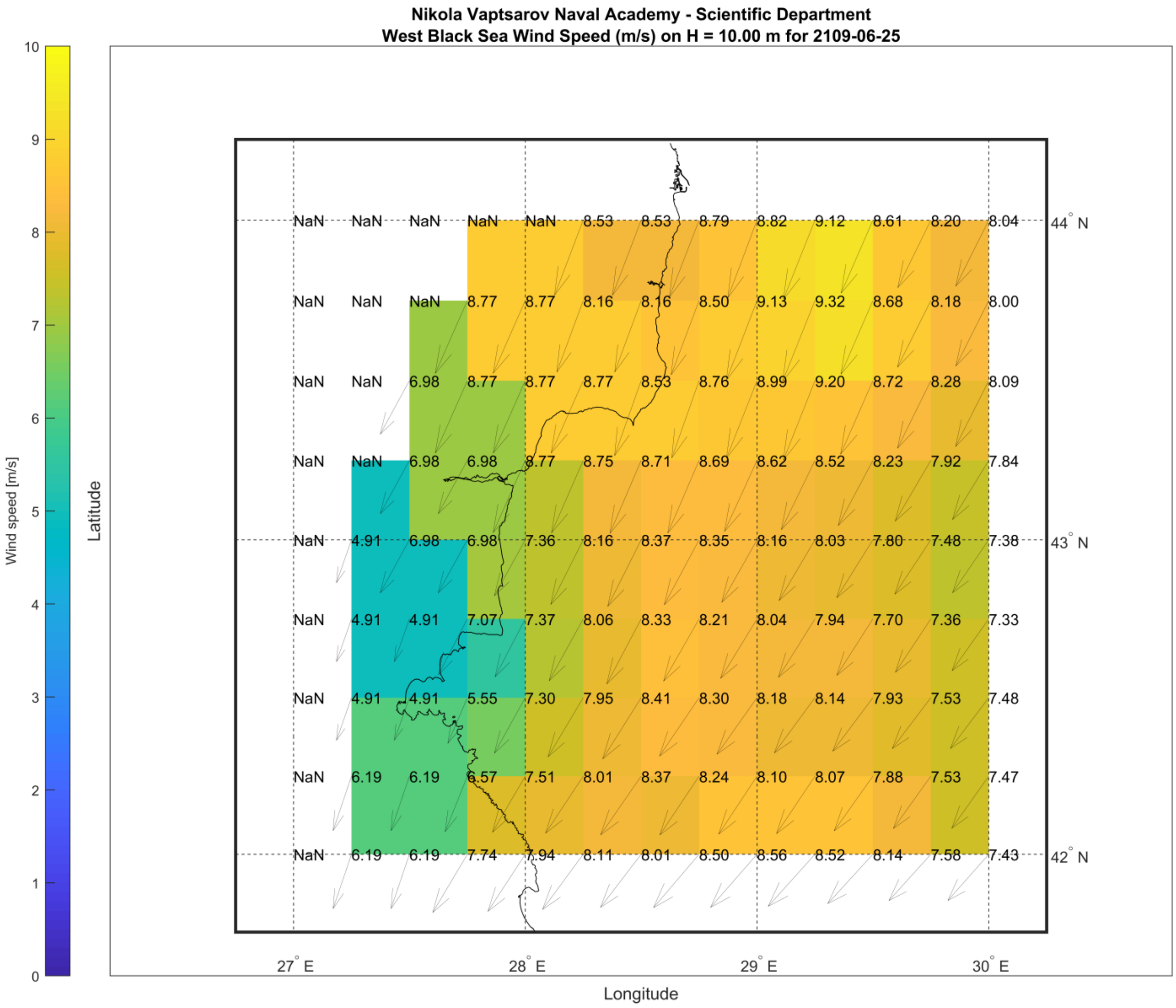


FIG. 3.3 Averaged 6-hour wind direction and speed data (m/s)

The data is calculated and a product is generated **WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006** for a network consisting of one layer 10 meters above sea level and a horizontal resolution of 0.125 or 0.25.

Although data on wind characteristics over the target area obtained from research projects are available, they are relatively short in duration and not suitable for 'entering' a model with forecasting capabilities.

3.4. Identified reliable data sources for the direction and speed of air currents at a height of up to 10 m in the target area.

In order for the data related to the direction and speed of air currents to be used as input data for creating an interactive computer model - a map of the movement of pollutant flows (solid marine floating waste) in the Bulgarian Black Sea area, it is necessary to meet the following general requirements:

- data accuracy (data based on real measurements)
- metadata provision
- data representativeness (geospatial coverage, resolution, etc.)
- time series density

The following **reliable data sources for direction and speed of air currents (up to 10 m altitude) above the target water area have been identified:**

- World Meteorological Organization (WMO)
- Copernicus Marine Environment Monitoring Service - in the Black Sea part
- Space-based Earth observation systems

For the purpose of creating an interactive computer model - a map of the flow of pollutants under the influence of water and air currents, the input data should be those from the Marine Copernicus Monitoring Service of the Black Sea Program.

This conclusion is necessary because, although the data of space-based Earth observation systems are reliable and accurate, they are instantaneous data and do not provide the necessary time density. On the other hand, WMO data are successfully applied in modeling the transport of atmospheric pollutants mainly over land, but their applicability as input data for determining the direction and speed of movement of drifting objects is limited.

The data obtained from the Marine Environment Monitoring Service of the Copernicus program on wind direction and speed up to 10 m altitude are highly similar to those on the direction and speed of sea currents, which is a prerequisite for obtaining high quality simulations with different nature input data.

For the purposes of developing an interactive computer model map for the movement of pollutant flows in the target area, averaging of the data for wind direction and speed from the Copernicus program for 24 hours was performed.

Thus processed and visualized data for the period 2015-2018. were used as inputs in combination with data on the direction and speed of sea currents in the surface water layer in the development of the computer model map.

They are presented in a format compatible with the open database https://map.redmarlitter.eu/en/database of the RedMarLitter project - **Appendix 8** (on CD).

4. Analysis of the available sources of information on the loading of solid marine litter in the target area, including the one collected through a study for such under this project.

In the course of realization of the project RedMarLitter and filling with data and information in the open database of the project https://map.redmarlitter.eu/en/database including those obtained from VVMU's own research (deliberately processed and visualized data), the project database can be considered as a separate information resource regarding the load of the target area with solid floating waste (Fig. 4.1).

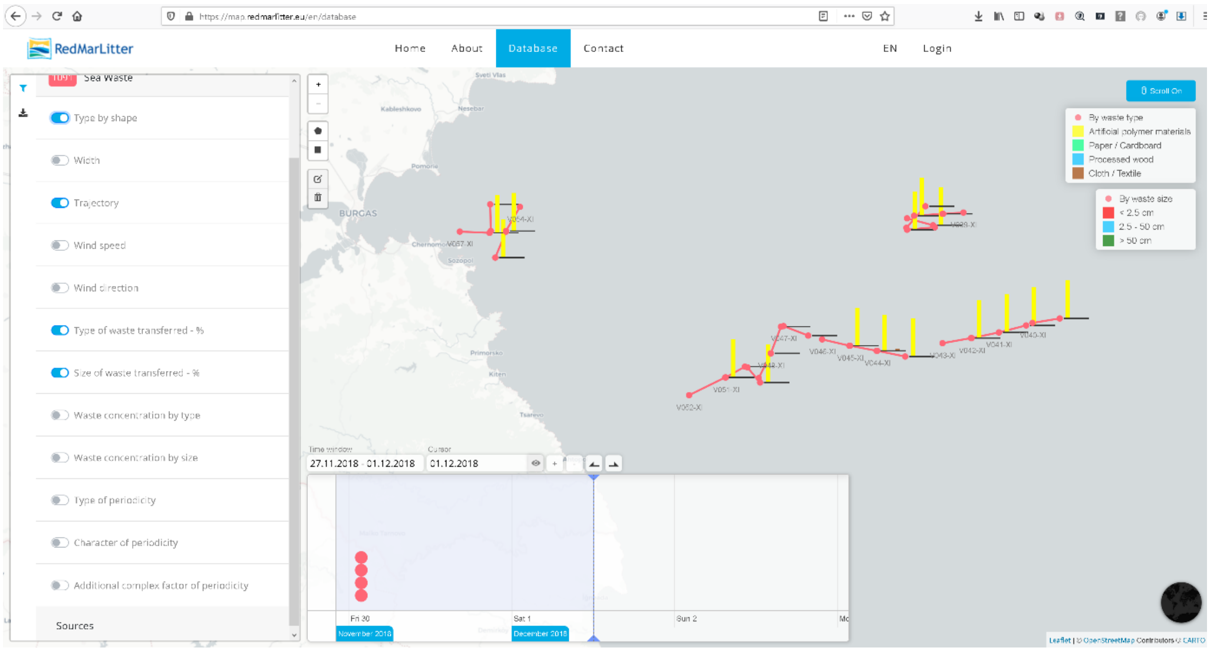


FIG. 4.1 Open database of the RedMarLitter project

(source: https://map.redmarlitter.eu/en/database)

The marine litter load in the target area is assessed at national level, through regular monitoring, in accordance with the Marine Strategy Framework Directive (RDMS) by descriptor D10. The evaluation is performed according to primary and secondary criteria.

The primary criteria are as follows:

- Criterion D10C1 - Primary: The composition, quantity and spatial distribution of waste along the coastline, in the surface layer of the water column and on the seabed are at levels that do not harm the coastal and marine environment.
  - Pressure indicator:
  - Indicator 1: Amount of beach / coastal waste> 2.5 cm, by category, expressed in number and weight (kg) per 100 m section.
  - indicator 2: Amount of waste> 2.5 cm floating on the sea surface, in number / km2.
  - indicator 3: Amount of waste (> 2.5 cm) deposited on the seabed, in number / km2.
- Criterion D10C2 - Primary: The composition, quantity and spatial distribution of micro-waste along the coastline, in the surface layer of the water column and the sediments of the seabed are at levels that do not harm the coastal and marine environment.
  - Pressure indicator:
  - indicator 1: Amount of beach / coastal waste < 5 mm by category, expressed in number and weight (g) per kilogram (kg) dry weight of sand / soil layer;
  - indicator 2: waste <5 mm floating on the sea surface by category, expressed in number and weight (g) per 100 m 2;
  - Indicator 3: Amount of waste <5 mm deposited in the surface sediment of the seabed, by category, expressed in number and weight (g) per kilogram (kg) dry weight of sediment.

Result of the evaluation according to criterion D10C1: - spatial distribution (GIS layer and maps) of the composition and quantity (number and weight) of the separate categories and the respective subcategories of waste> 2.5 cm by the separate zones (beaches, sea surface and bottom) and subdivisions for evaluation (eg each of the 10 beaches / coastlines). - integrated presentation of evaluation results (number of macro-waste exceeding threshold values and percentage).

Result of the evaluation according to criterion D10C2: - spatial distribution (GIS layer and maps) of the composition and quantity (number and weight) of the separate categories and the respective subcategories of waste < 5 mm by the separate zones (beaches, sea surface and bottom) and the evaluation units (eg each of the 10 beaches / coastlines) - integrated presentation of evaluation results (number of micro-waste exceeding threshold values and% ratio).

The secondary criteria D10C3 “Amount of waste and micro waste ingested by marine organisms” and D10C4 “Number of adversely affected individuals” are not the subject of this analysis.

The data from the national monitoring of marine litter are characterized by reliability and representativeness, which is why they are the basis of the present analysis. They are deliberately processed by VVMU and are available on the RedMarLitter project website through the open database.

Monitoring data for criterion D10C1, indicator 2 (waste> 2.5 cm floating on the sea surface). The program covers the coastal, territorial shelf and open sea waters of Bulgaria. In each of the assessment zones, depending on the type of pressure and impact and, respectively, on the origin of the waste, research sites have been identified, which are eight in the coastal zone, four in the shelf zone and two in the high seas.

In connection with the focus of the subsequent tasks, the analysis is focused mainly on marine litter floating on the water surface in the target area.

The implementation of monitoring of floating marine litter in Bulgaria begins with the implementation of the project **"Tools for assessment of waste, eutrophication and noise in marine waters (MARLEN)"** under Program BG02 "Integrated Management of Marine and Inland Waters" in 2015. The pilot monitoring was carried out in July 2016.

The scope of the pilot monitoring is presented in Figures 4.2 and 4.3

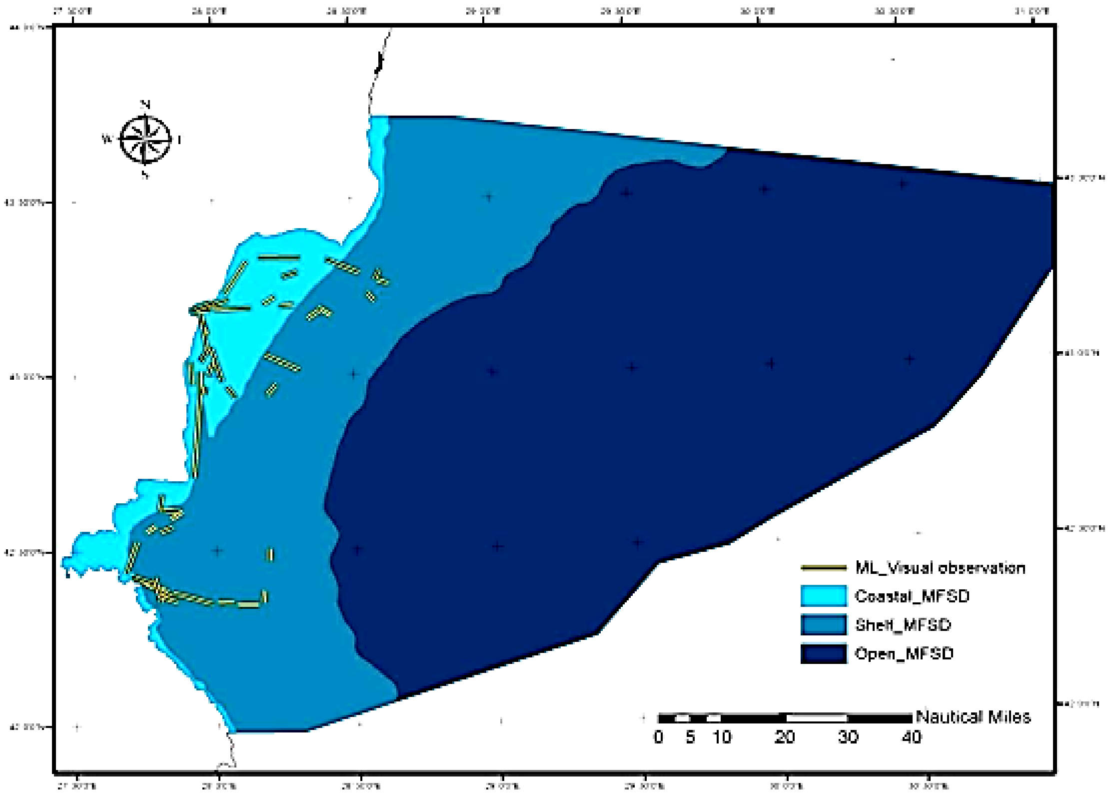


Fig. 4.2 Pilot monitoring of marine litter
floating on the sea surface, 2016
(source: Report on the project “Waste Assessment Tools” , eutrophication and noise in sea waters ”(MARLEN))

In the following years, 2017 and 2018, the monitoring was performed by the Institute of Oceanology at BAS, on behalf of the Ministry of Environment and Water through the Black Sea Basin Directorate. The data from the monitoring are stored and administered by the BSBD, which includes the exchange of information with the European Environment Agency.

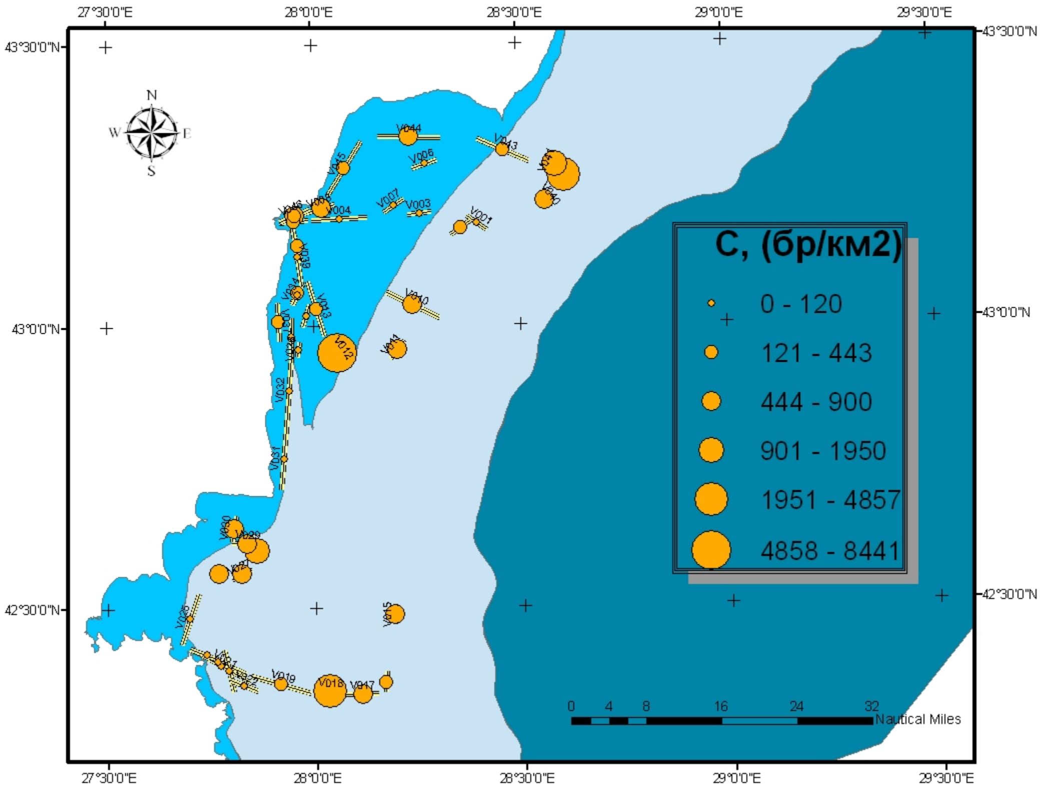


Fig. 4.3 Concentration of marine litter on sea surface, 2016

(source: Report on the project "Tools for waste assessment, eutrophication and noise in marine waters" (MARLEN))

Table 4.1 shows the dates on which the observations were carried out for marine litter floating on the sea surface.

Table 4.1

Year	Month	Dates
2016	7	2, 3, 4, 7, 8, 9, 11, 15
2017	10	9, 10, 11, 12, 13, 14, 15, 16
2017	11	22, 23, 24, 25, 26 , 27, 28, 29, 30
2018	7	21, 26, 27, 28, 30, 31
2018	8	7, 8, 13, 14, 15, 16, 26, 27
2018	9	10
2018	10	8, 18, 19, 20 , 31

Figures 4.4 and 4.5 show the summarized data on the load of solid marine litter in the target area for 2017 and 2018 according to data from the implementation of:

- **Monitoring of marine litter floating on the water surface (size> 2, 5 cm) for the year 2017 -** Agreement № D-33-28 / 31.07.2017. between the Ministry of Environment and Water and the IO-BAS for fulfillment of the obligations of the IO, arising under Art. 171, para 2, item 3 of the Water Act for fulfillment of the monitoring requirements of the Water Framework Directive and the Marine Strategy Framework Directive.
- **Monitoring of marine litter floating on the water surface (size> 2.5 cm) for 2018 -** Agreement № 409 / 03.07.2018 Annex № 1 / 30.10.2018 between the Black Sea Region Basin Directorate and Institute of Oceanology-BAS on the basis of Order № RD-410 / 03.07.2018 of the Minister of Environment and Water for implementation of the Marine Water Monitoring Program in 2018 in connection with the Marine Strategy Framework Directive (RDMS).

As of the date of the study, no officially published data on the results of the institutional monitoring under descriptor D10C1, indicator 2 for 2019, were found.

In search of more opportunities to obtain data on marine litter floating on the water surface, the possibilities were analyzed by non-commercial space-based Earth monitoring systems. At this stage, the resolution of their surveillance devices does not allow the detection of small (less than 10-15 meters) single floating marine litter. However, the so-called "Plastic islands" should be monitored by this type of system. Data for such islands in the Black Sea appeared on the Internet in September 2019, as a result of a study to count the cetaceans from the air in the northeastern part of the Black Sea under the EMBLAS-Plus project.

As of the date of the study, no officially published data on the coordinates of the targeted "plastic islands" were found, both in the target area and for their presence in other parts of the Black Sea.

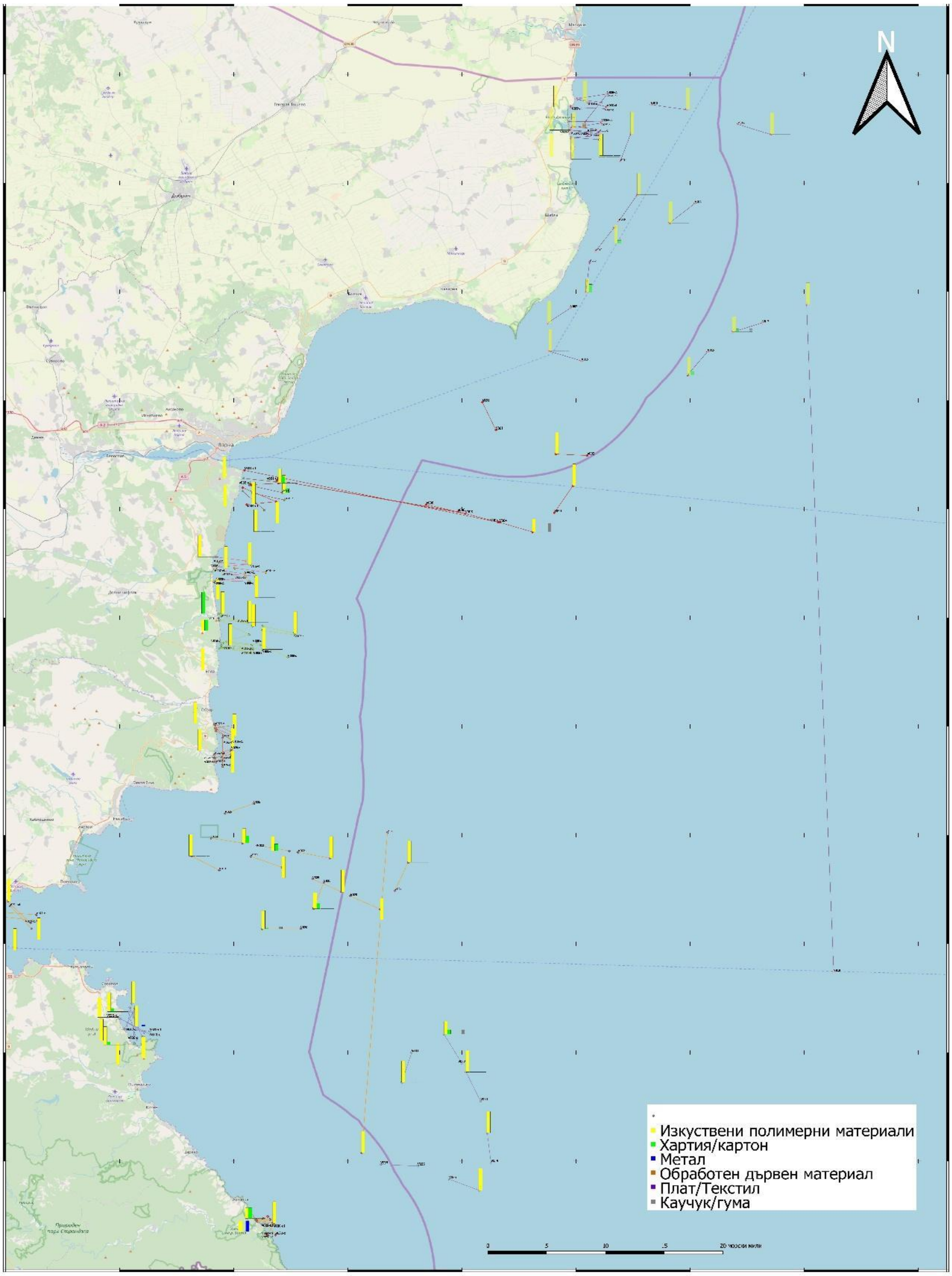


FIG. 4.4 Summary data on the load of solid marine waste in the target area for 2018 (data source: MOEW)

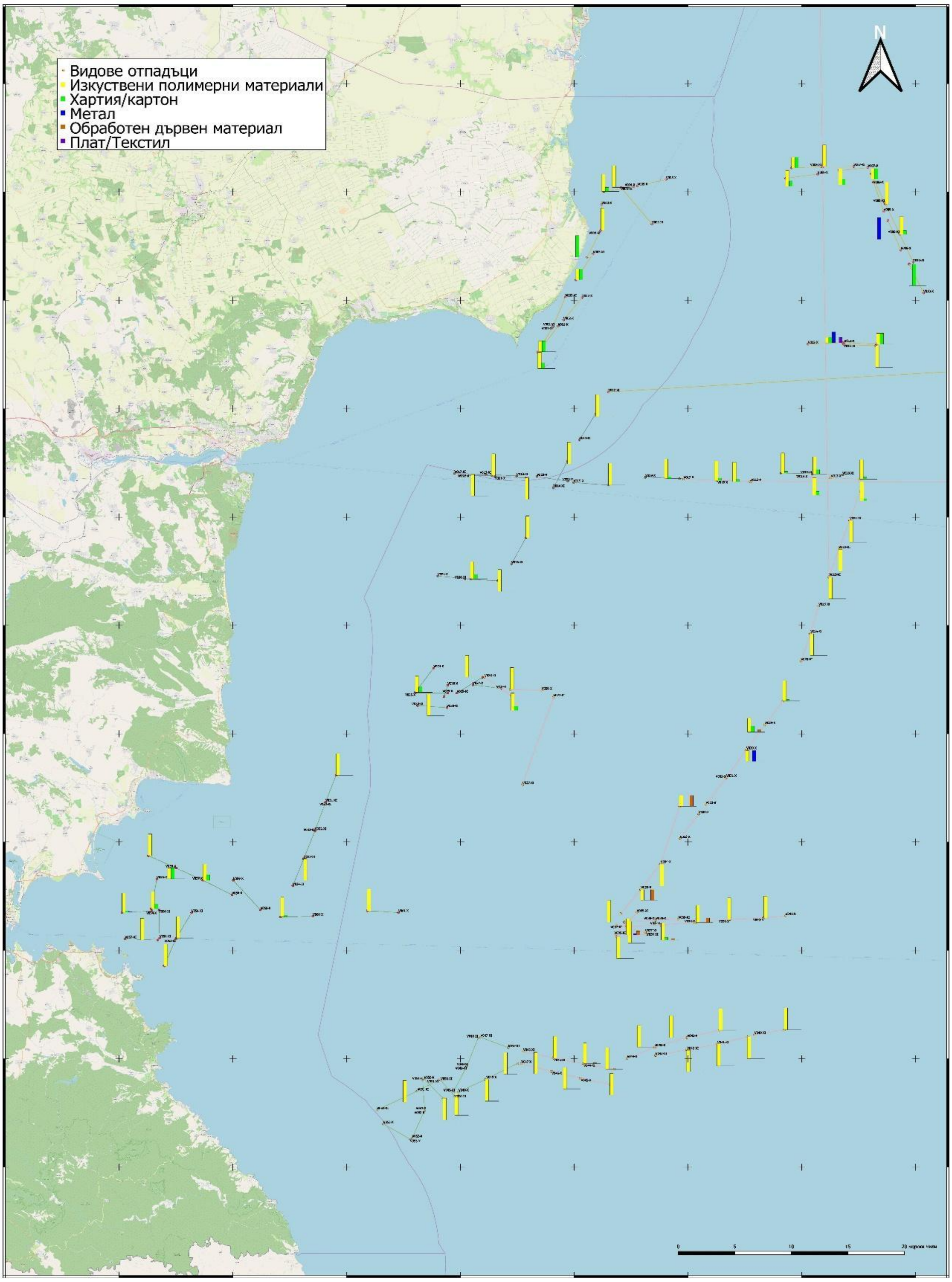


Fig. 4.5 Summary data on the load of solid marine waste in the target area for 2017 (data source: MOEW)

The analysis of the collected data on floating solid waste with sizes larger than 2.5 cm in the target area shows that The monitoring campaigns were conducted in the months of July - November, and the data for October for 2017 and 2018 can be considered as periodic in the time domain, but they were conducted in different waters of the target area, namely 2018. the year in the coastal zone, for 2017 partly in the coastal zone and mainly in the shelf zone.

Figures 4.6 to 4.18 show the data for the target time periods (October 2017 and 2018) and the spatial scope of the observations based on data from the Ministry of Environment and Water (BDHR) integrated in the open database of the RedMarLitter project.

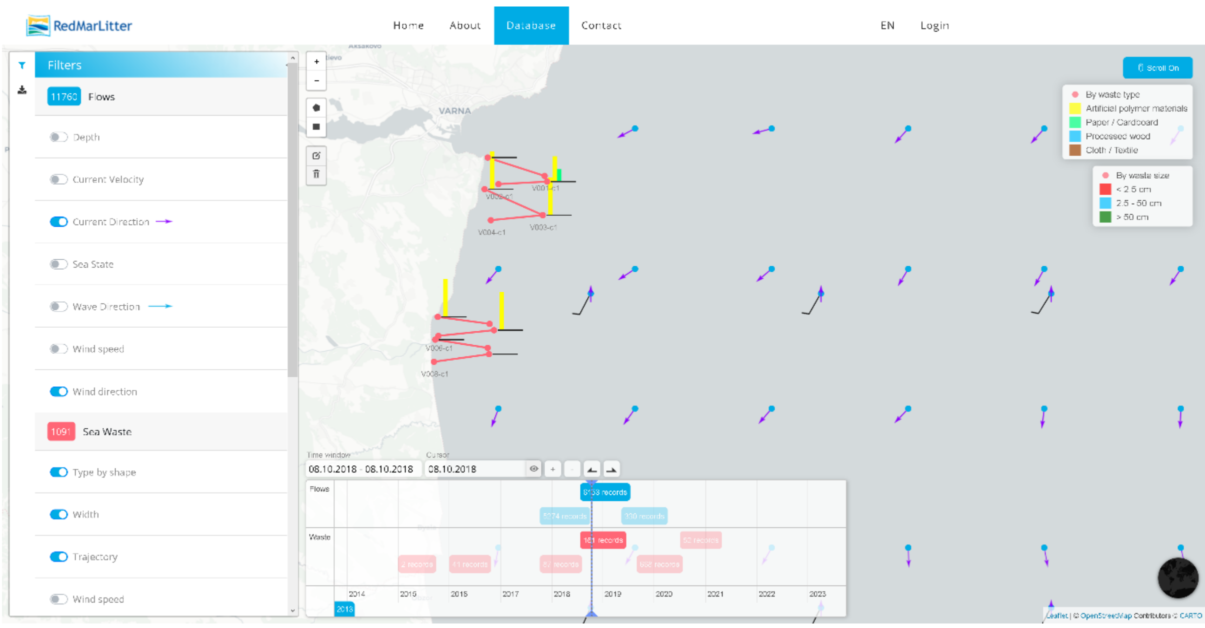


FIG. 4.6 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 08.10.2018 (coastal zone)

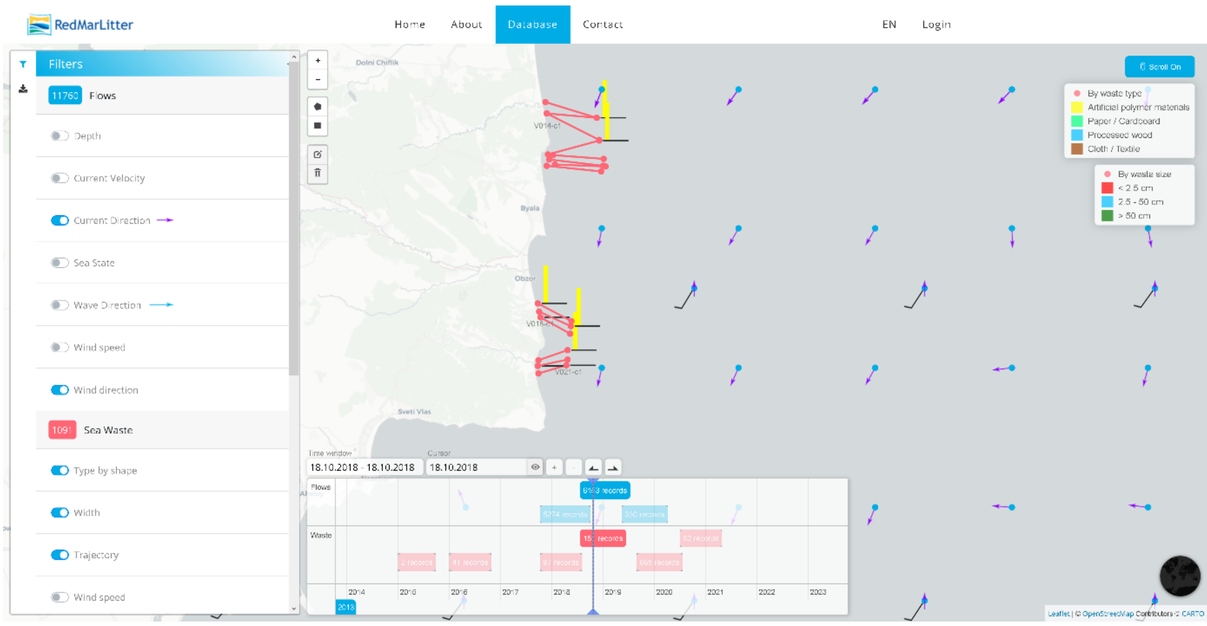


Fig. 4.7 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 18.10.2018 (coastal zone)

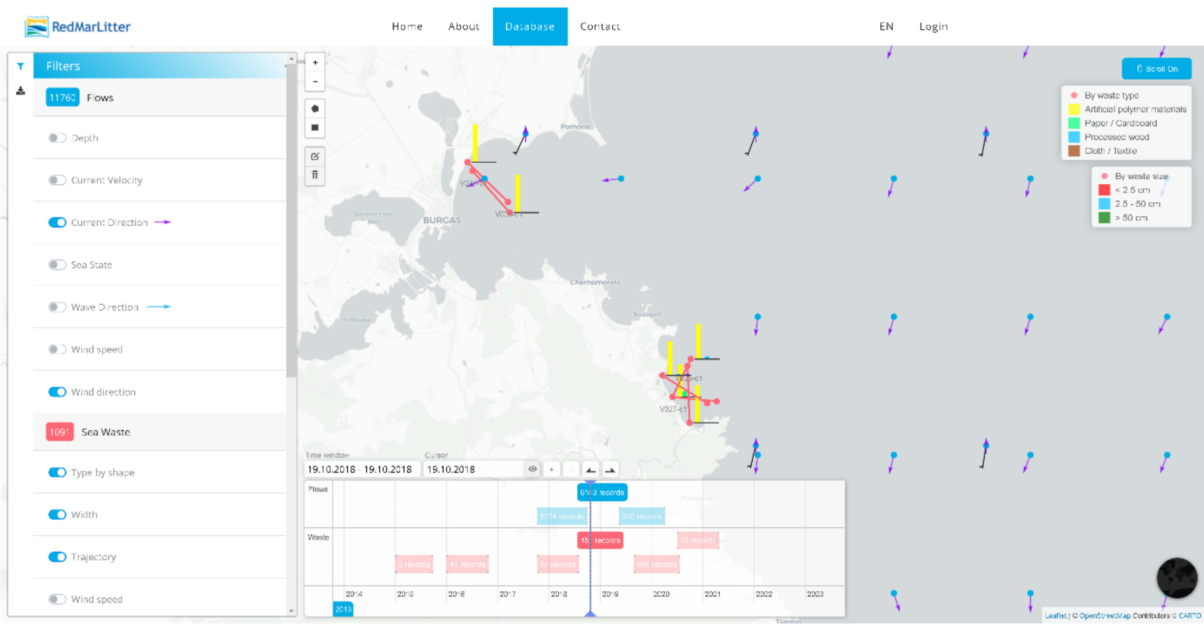


Fig. 4.8 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 19.10.2018 (coastal zone)

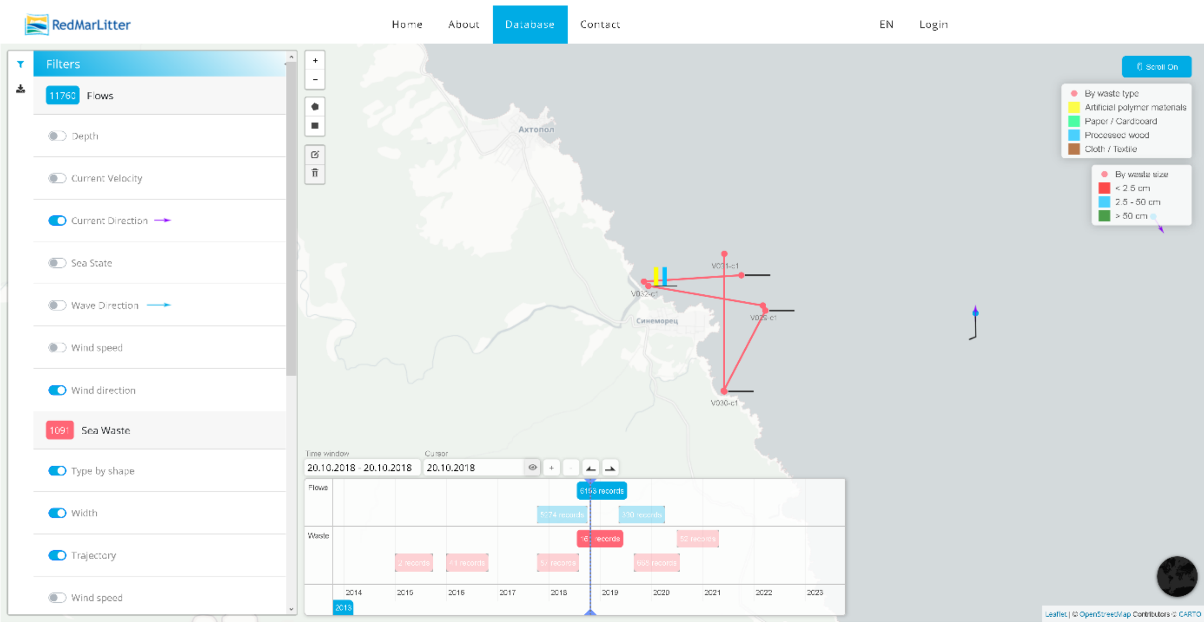


Fig. 4.9 Visualization of the data from the performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 20.10.2018 (coastal zone)

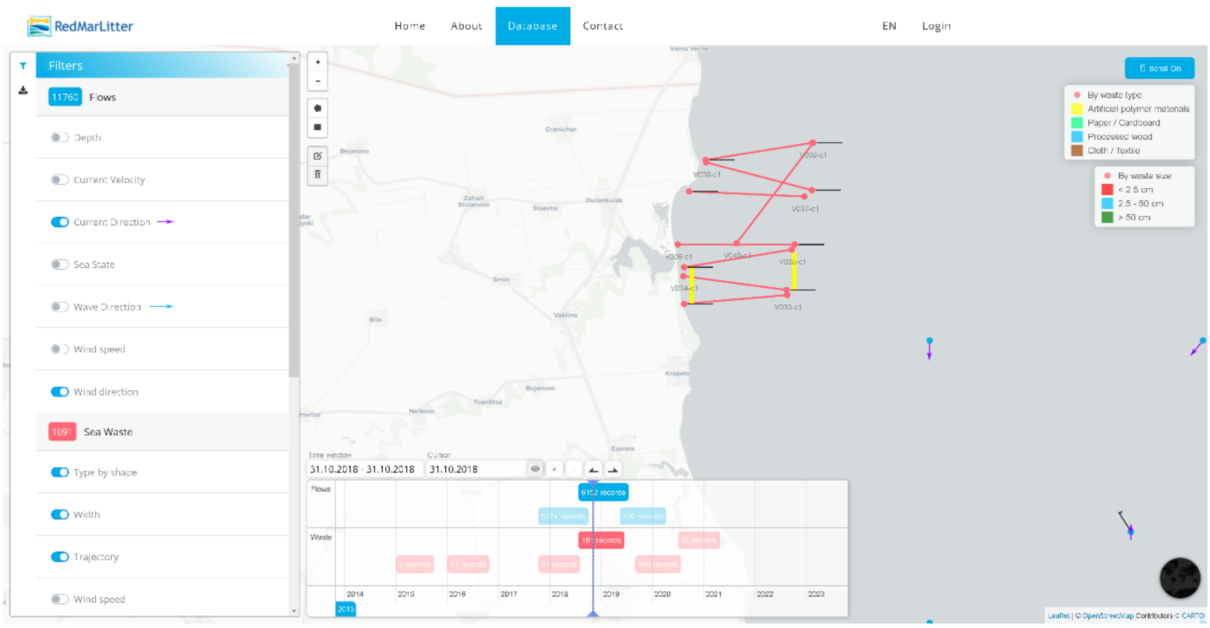


Fig. 4.10 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 31.10.2018 (coastal zone)

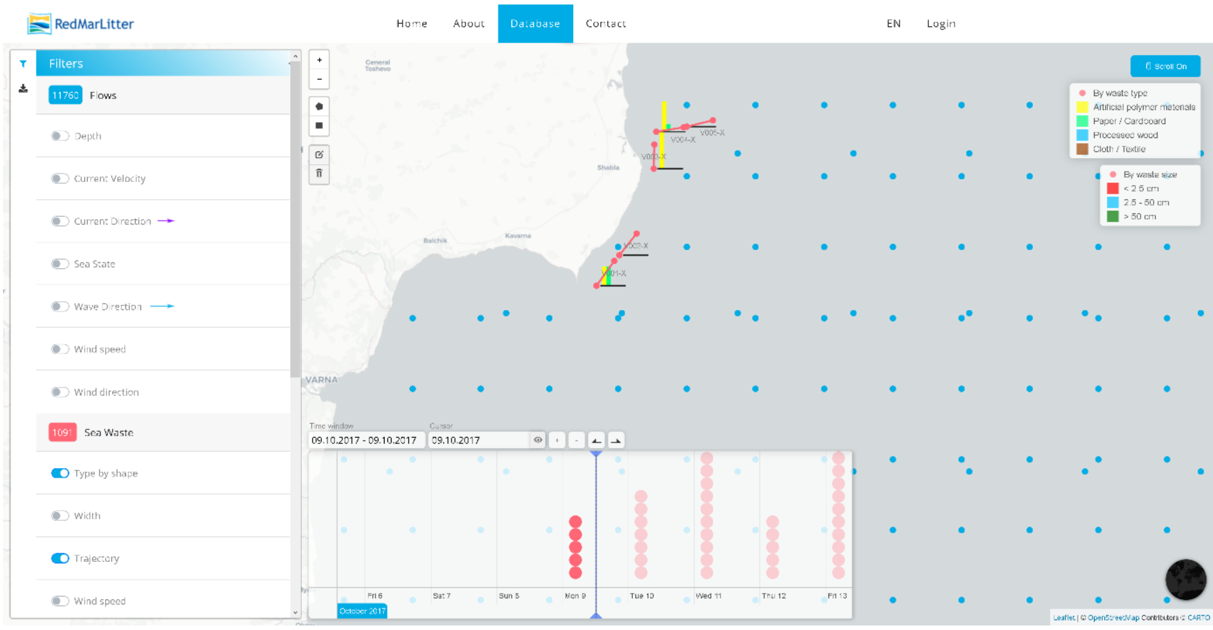


FIG. 4.11 Visualization of the data from performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 09.10.2017 (coastal zone)

Fig. 4.12 Visualization of the data from the performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 10.10.2017 (coastal and shelf zones)

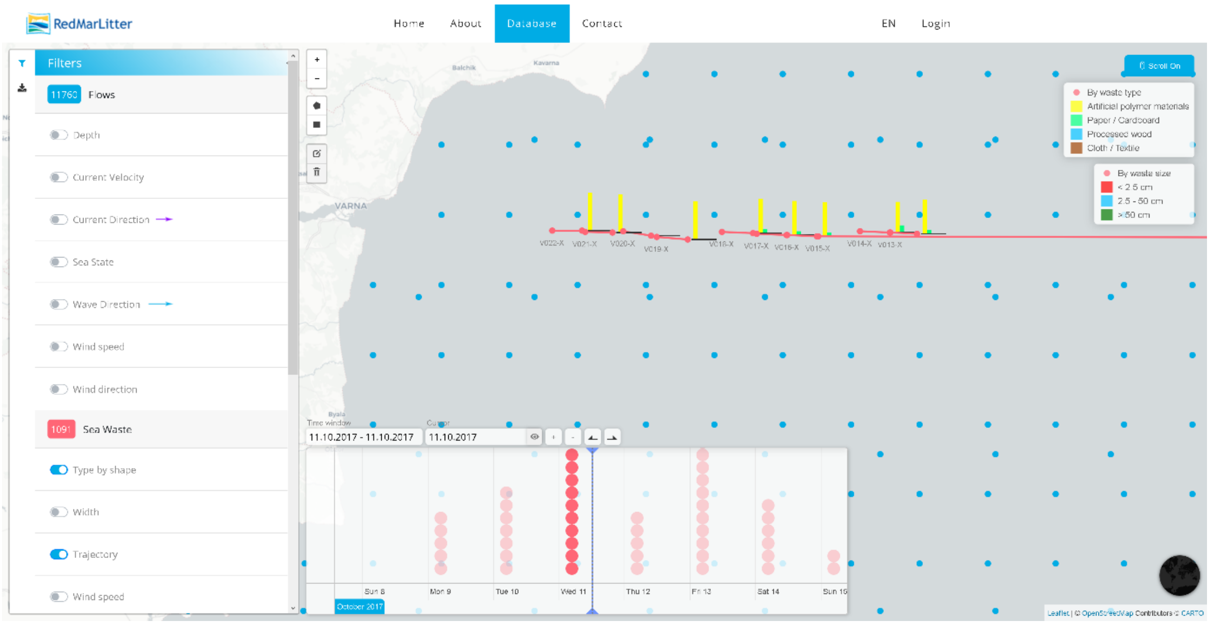


Fig. 4.13 Visualization of the data from the performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 11.10.2017 (shelf zone)

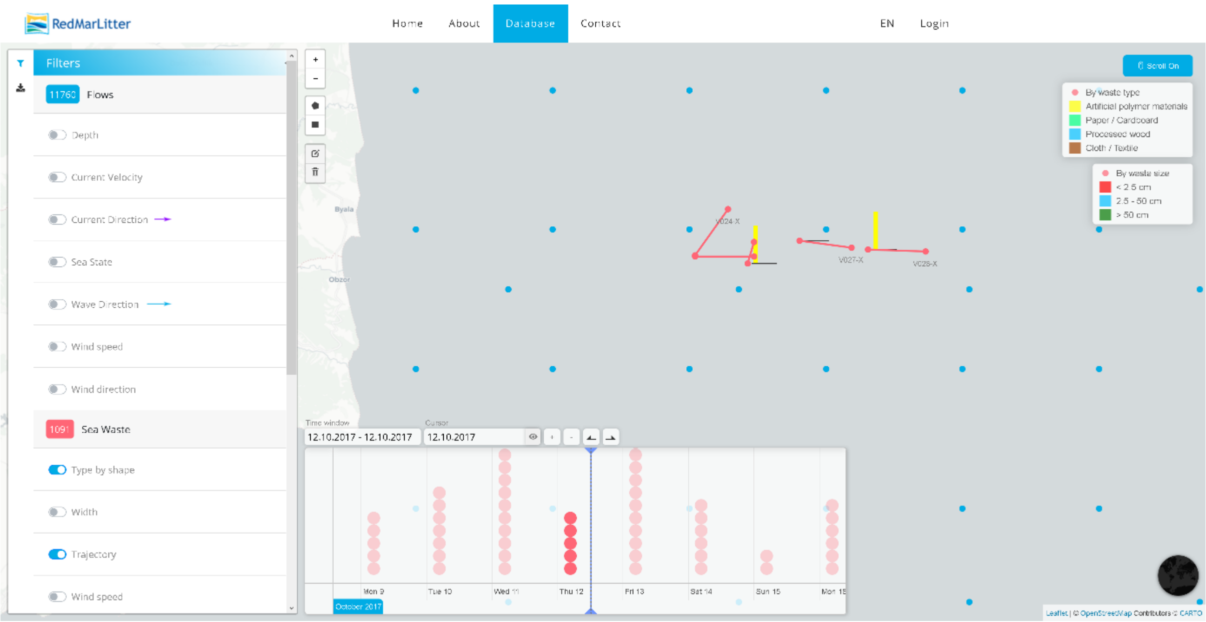


Fig. 4.14 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 12.10.2017 (shelf zone)

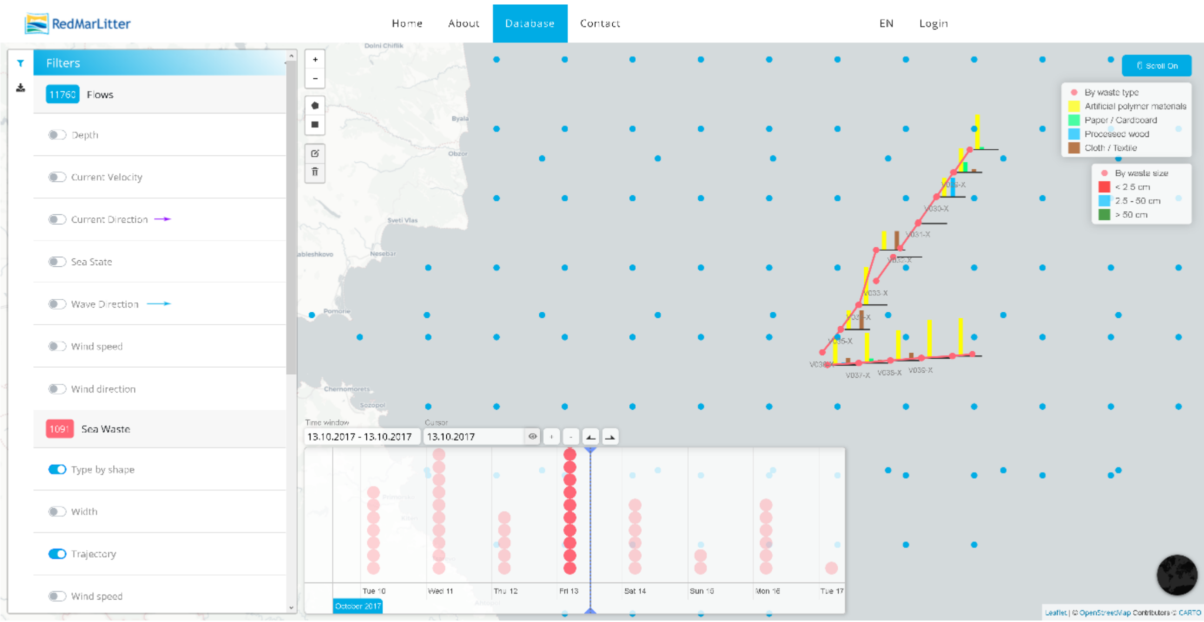


Fig. 4.15 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 13.10.2017 (shelf zone)

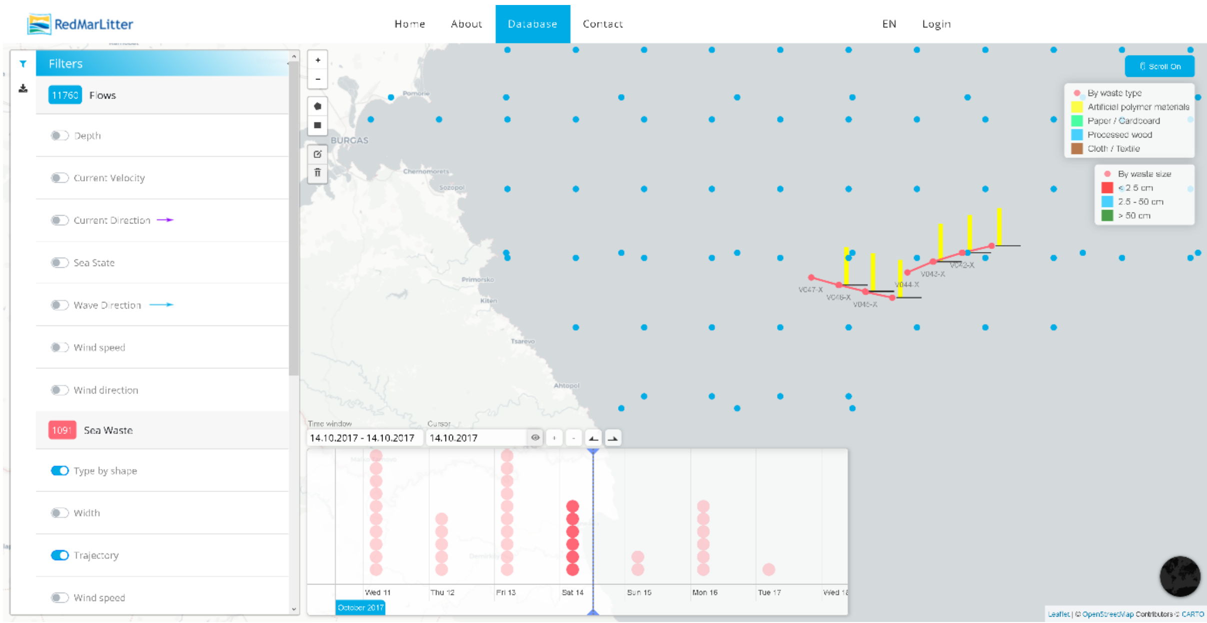


Fig. 4.16 Visualization of the data from the performed monitoring for floating on the sea surface solid waste with size> 2.5 cm for date 14.10.2017 (shelf zone)

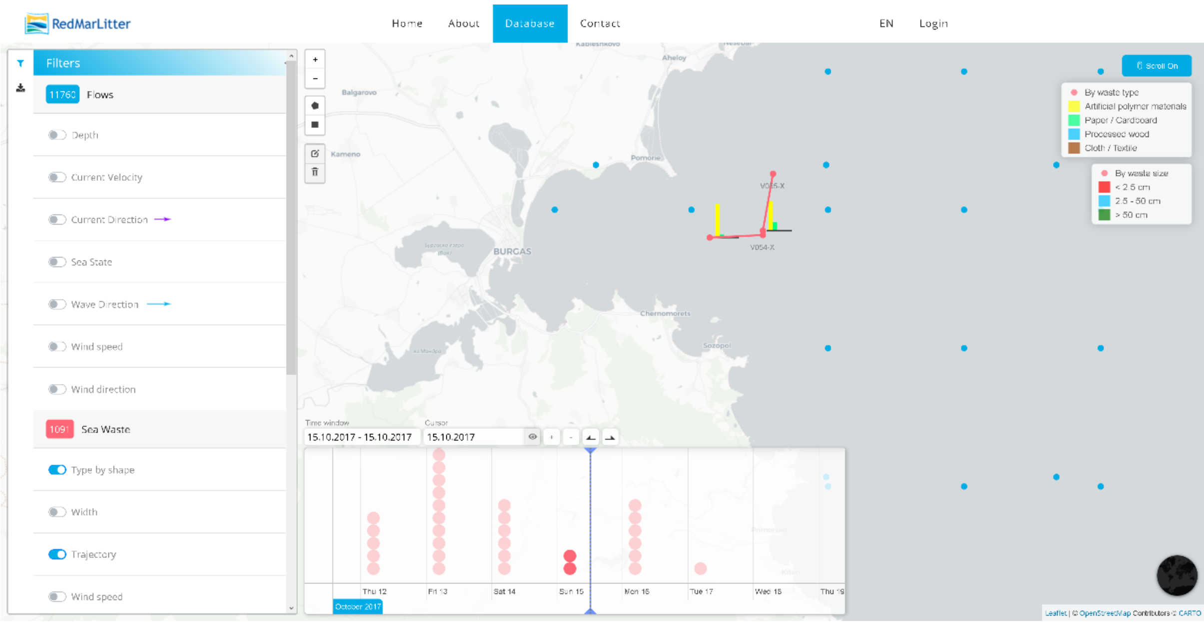


Fig. 4.17 Visualization of the data from performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 15.10.2017 (shelf zone)

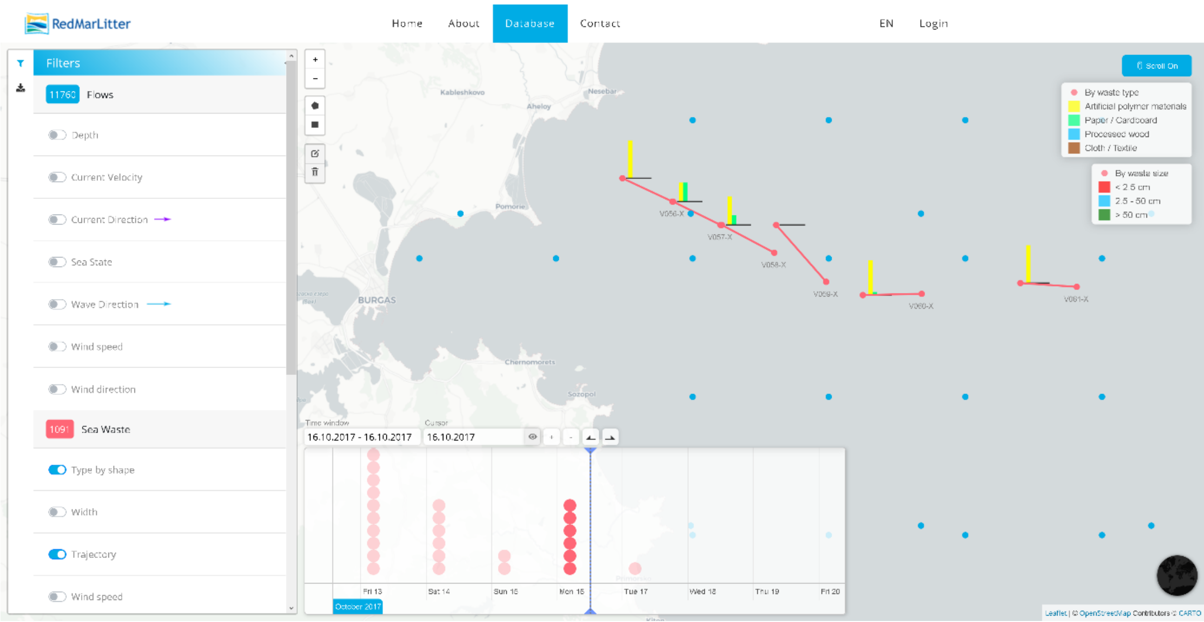


Fig. 4.18 Visualization of the data from the performed monitoring for solid waste floating on the sea surface with size> 2.5 cm for date 16.10.2017 (shelf zone)

It should be noted that the so-called Trajectory shows the trajectory of the vessel from which the observations were made, not the trajectories of the floating solid waste on the sea surface! At this stage, the trajectories of the floating solid waste on the sea surface are not described by the observers and they remain unknown. In FIG. 4.19 shows schematically the method used in the visual observations.

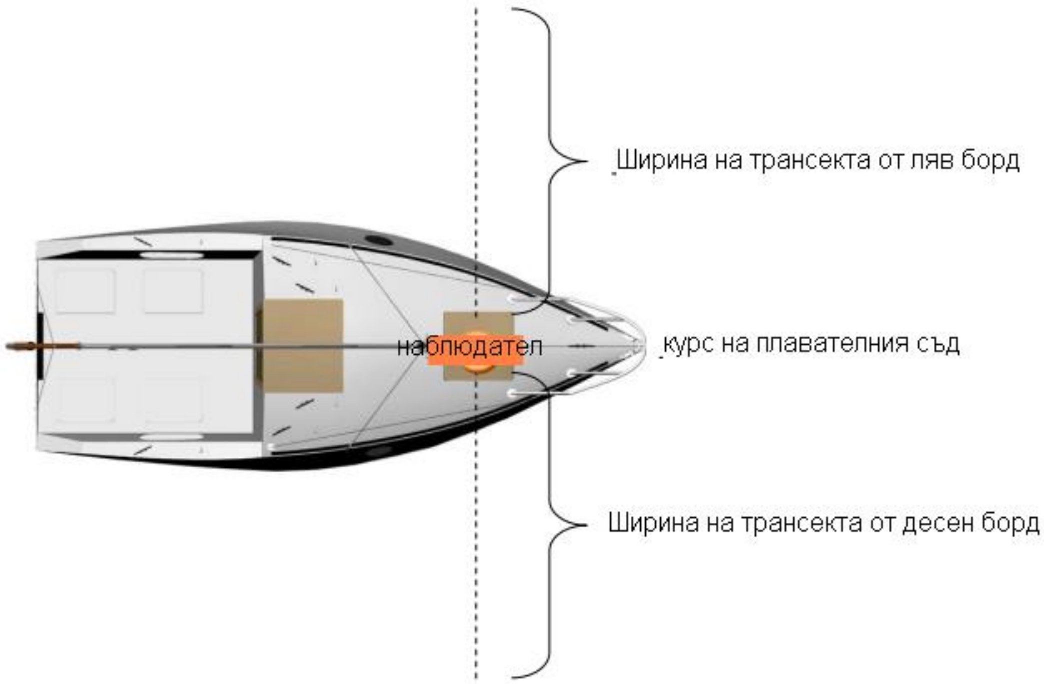


FIG. 4.19 Schematic representation of the method used in visual observations of solid waste on the sea surface with dimensions> 2.5 cm

(source: Report on the project "Tools for assessment of waste, eutrophication and noise in marine waters" (MARLEN))

As a result of the analysis of the collected data, it can be concluded that the data on floating solid waste on the sea surface with dimensions larger than 2.5 cm do not meet the requirements for the needs of modeling water flows and solid waste distribution **periodicity**, as both temporally and spatially. In practice, they can be considered only as "snapshots" of separate (different) waters of the target area (Bulgarian Black Sea coast).

Taking into account the above facts, for the purposes of modeling water flows and the distribution of solid waste in the target area, an approach based on mathematical modeling by simulations of floating solid waste on the sea surface should be used.

5. Development of algorithms and software code for import and processing of the collected data (according to tasks 1, 2, 3) and derivation of models of water flows in the surface layer and models of motion distribution and waste distribution.

Based on the analyzes made in sections 2 and 3 of this report, and taking into account that only the Marine Environment Monitoring Service of the Copernicus Program systematically develops, maintains and provides data on the Black Sea area, and in particular on the direction and speed of sea and air currents, algorithms and software code were developed for import and processing of the data collected by it in the environment of the software product MatLab.

Figure 5.1 shows data on sea currents in the surface layer of the Black Sea (horizon 2.5 m.) For 29.10.2018

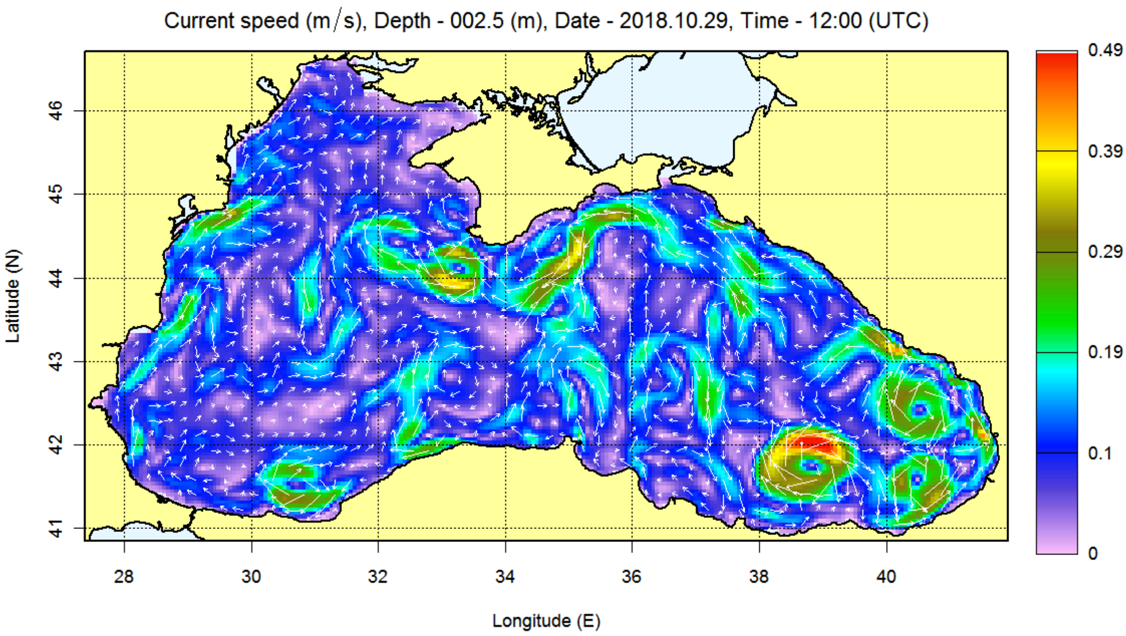


FIG. 5.1 Sea currents in the surface layer of the Black Sea (horizon 2.5 m.) For 29.10.2018 (source: http://bsmfc.net/Year_analysis.php)

For the derivation of the models of water flows in the surface layer were used the data for average monthly values of the surface marine currents of the Marine Environment Monitoring Service of the Copernicus Program for the period from 2015 to 2018, inclusive.

The average monthly data for the sea currents in the surface layer of the Black Sea (horizon 2.5 m) of the product **BLKSEA_REANALYSIS_PHYS_007_004**, which is characterized by the highest accuracy among the products of this class, are referred to.

Solid floating waste in the surface layer can be conditionally divided into two groups, as announced in the introduction of this report: solid waste floating in the water column at shallow depths (see Fig. 5.2) and solid waste floating on the water surface (see Fig. 5.3).

The conditional division is made in order to take into account mostly the influence of the so-called ground wind, if any, on the movement and distribution of solid waste on the sea surface.

Section 4 of this report analyzes and visualizes summary data from the conducted campaigns for monitoring of solid marine litter in the waters of the Republic of Bulgaria in the Black Sea.

As far as the data referred to in Section 4 for **floating** solid marine litter are episodic, the application of a simulation model based on marine current data from the Copernicus Marine Environmental Monitoring Service described in section 2 and airflow data described in section 3 of this report, **which are characterized by the required spatial coverage, resolution and time range**, is considered to detect their movement and distribution.

FIG. 5.2 Solid waste floating in the water column at shallow depths

Fig. 5.3 Solid waste floating on the sea surface

For the detection of the movement and distribution of solid marine waste from the **first conditional group** it is assumed that the surface wind does not have a direct impact on their movement because they are in the water column, but the influence of air masses / forces was taken into account in the generation of data on the direction and speed of surface marine currents from the model of the Marine Environment Monitoring Service of the Copernicus Program (see Figure 2.16).

Using this innovative approach and taking into account the derived data on water flows by mathematical modeling in MatLab environment, again by mathematical modeling in the same environment are generated simulations of the movement and distribution of floating solid waste (conditionally called drifters) at shallow depths (up to 5 meters) in the water column for all months from 2015 to 2018 inclusive, under the following conditions: virtual solid waste (drifters) are located on the parallel line with latitude 43.75 ° N, as they are evenly distributed along its length every 30 seconds (approximately 1 km) in the range from 28 ° 35'00''E to 30 ° 00'00''E, a total of 171 pieces.

In FIG. 5.3 in red shows the location of the starting line of the virtual drifters in the target area.

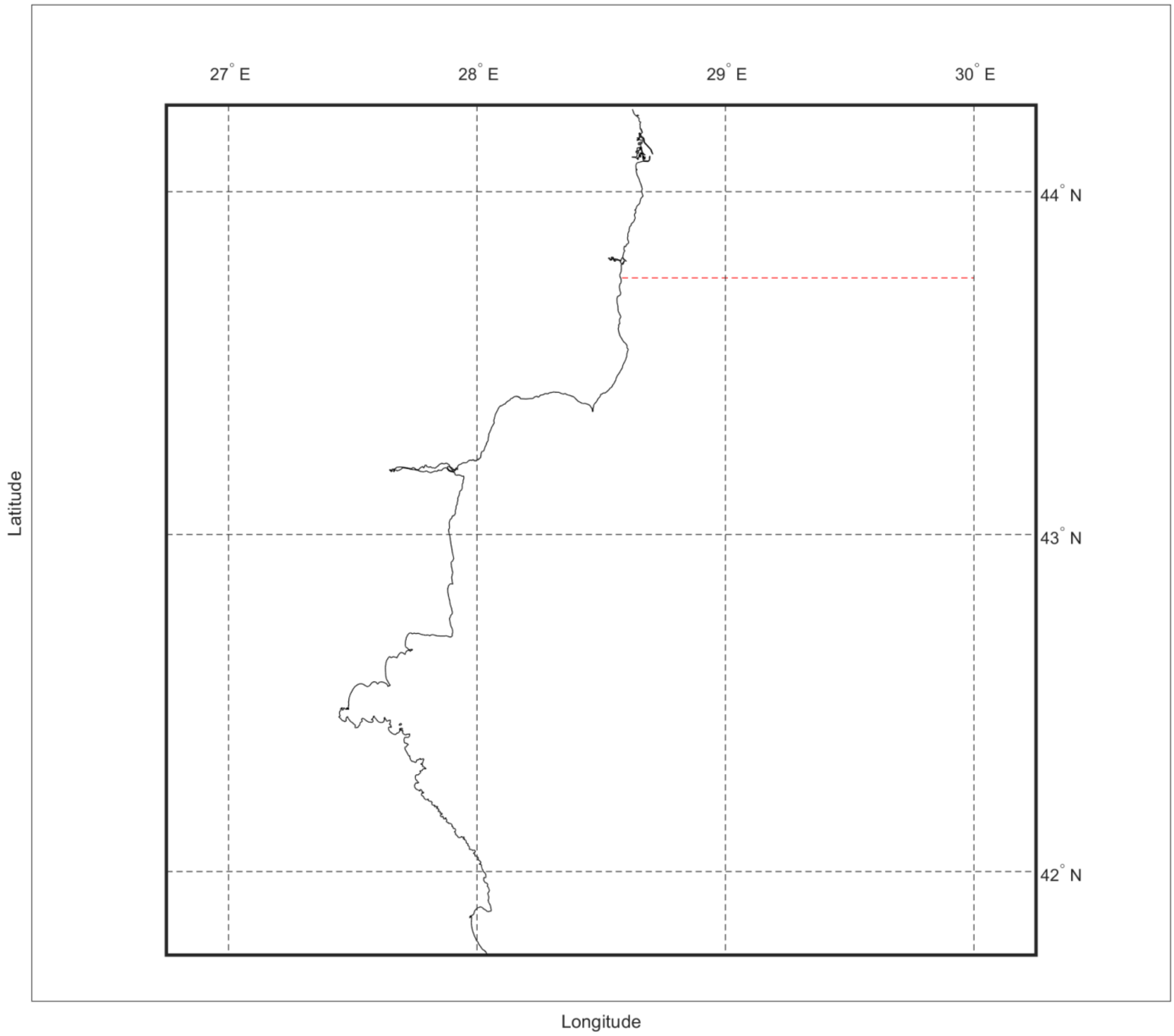


FIG. 5.3

Numerical modeling for the derivation of water flows is performed according to the algorithm shown in Figure 5.4.

The georeferenced map material, for each of the targeted months, visualizing the water flows is attached in Annex 2 to this report.

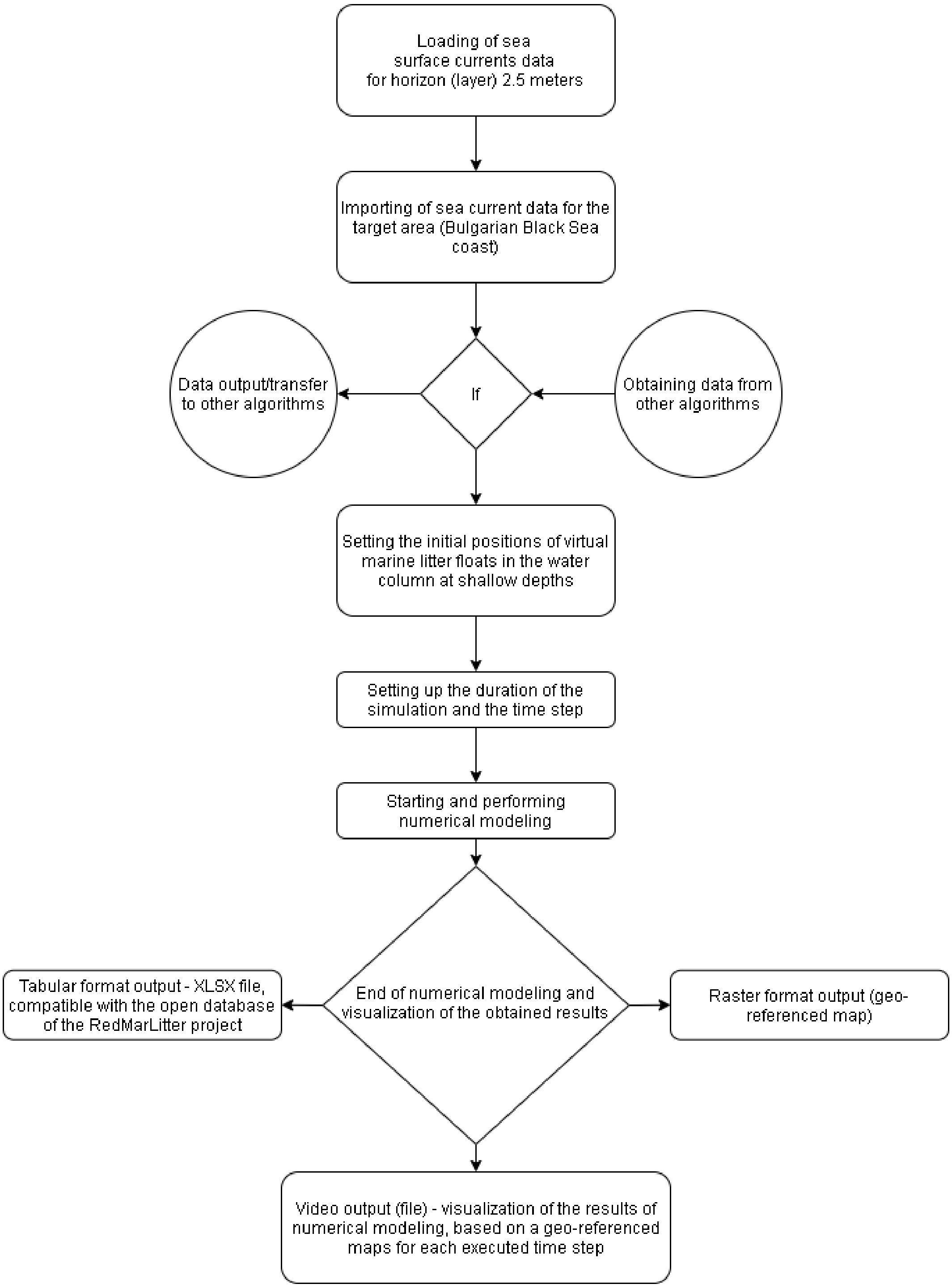


FIG. 5.4 Algorithm of mathematical modeling for derivation of water flows in the surface layer in the target area (Bulgarian Black Sea coast), based on product data of product **BLKSEA_REANALYSIS_PHYS_007_004**

As a result of mathematical modeling for the needs of project RedMarLitter8 generators from for the period 2015-2018 (for which the respective results are presented in the form of video materials, georeferenced data in raster format and in tabular format XLSX files compatible with the open database of the RedMarLitter project), showing the movement and distribution in time of the floaters at shallow depths in the water column solid waste.

The full volume of the video materials from the mathematical modeling, including the georeferenced map material for the movement and distribution of the solid floating waste are attached on optical media Annex 3 to this report and published with free access on the project page https://projects.nvna.eu/redmarlitter on the website of NVNA (see Fig. 5.5). A sample of georeferenced map materials of the distribution of solid floating waste in the surface layer of the Bulgarian Black Sea for every tenth day of the month for the period from 2015 to 2018 as a result of simulations through mathematical modeling are attached in Annex 4 of this report.

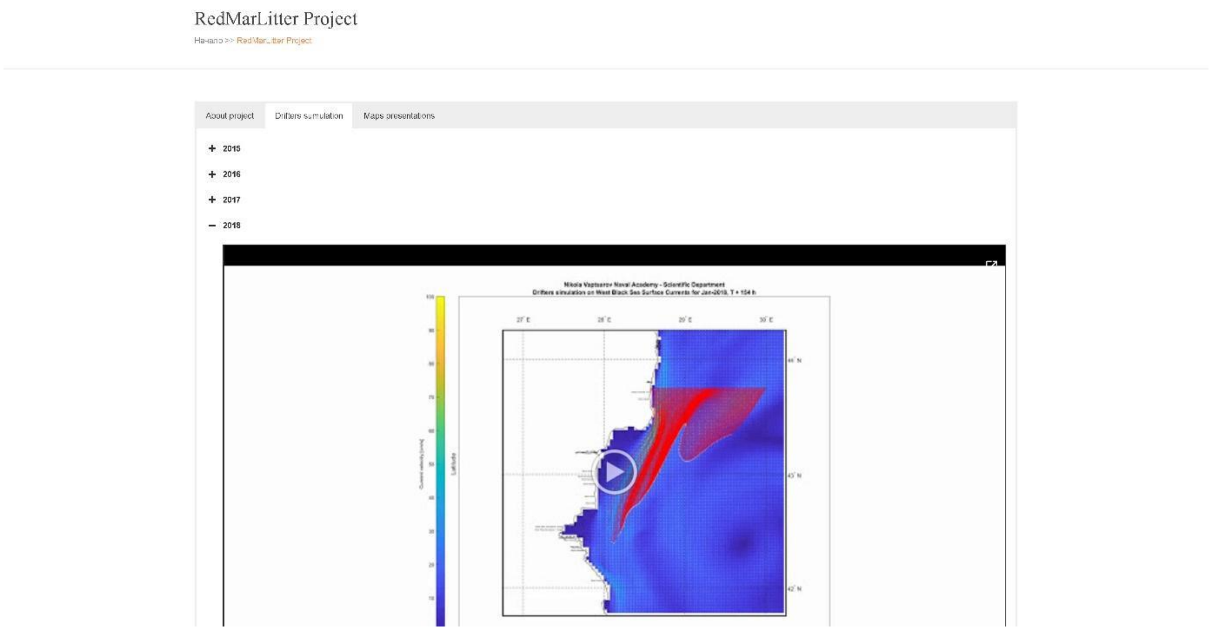


FIG. 5.5 Visualization of the video materials published on (https://projects.nvna.eu/redmarlitter)

For the detection of the movement and distribution of the solid marine waste from the **second conditional group,** data on the direction and speed of the air currents from the Marine Environmental Monitoring Service of the Copernicus Program (product

WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006) described in section 3 of this report, **which are also characterized by the required spatial coverage, resolution and time range, are also used.**

During the study, no information was found in the scientific literature on research in the field of determining the degree of impact of air currents on floating surface solid waste of mixed type, as shown in Figures 2 and 5.3.

One option for assessing the impact of the direction and speed of air currents on floating solid waste is the use of established methods for predicting the movement and spread of oil spills on the sea surface. They assume that the impact of air currents is within a **maximum of 3.0% to 3.5%** of the resultant force (resultant vector), formed by the sum of the forces (vectors) of sea and air currents.

The algorithm used to derive the direction and velocity data from product **WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006** of the Copernicus Marine Environment Monitoring Service is shown in Figure 5.6. It should be noted that the product concerned contains a single layer with data at a height of 10 meters above sea level.

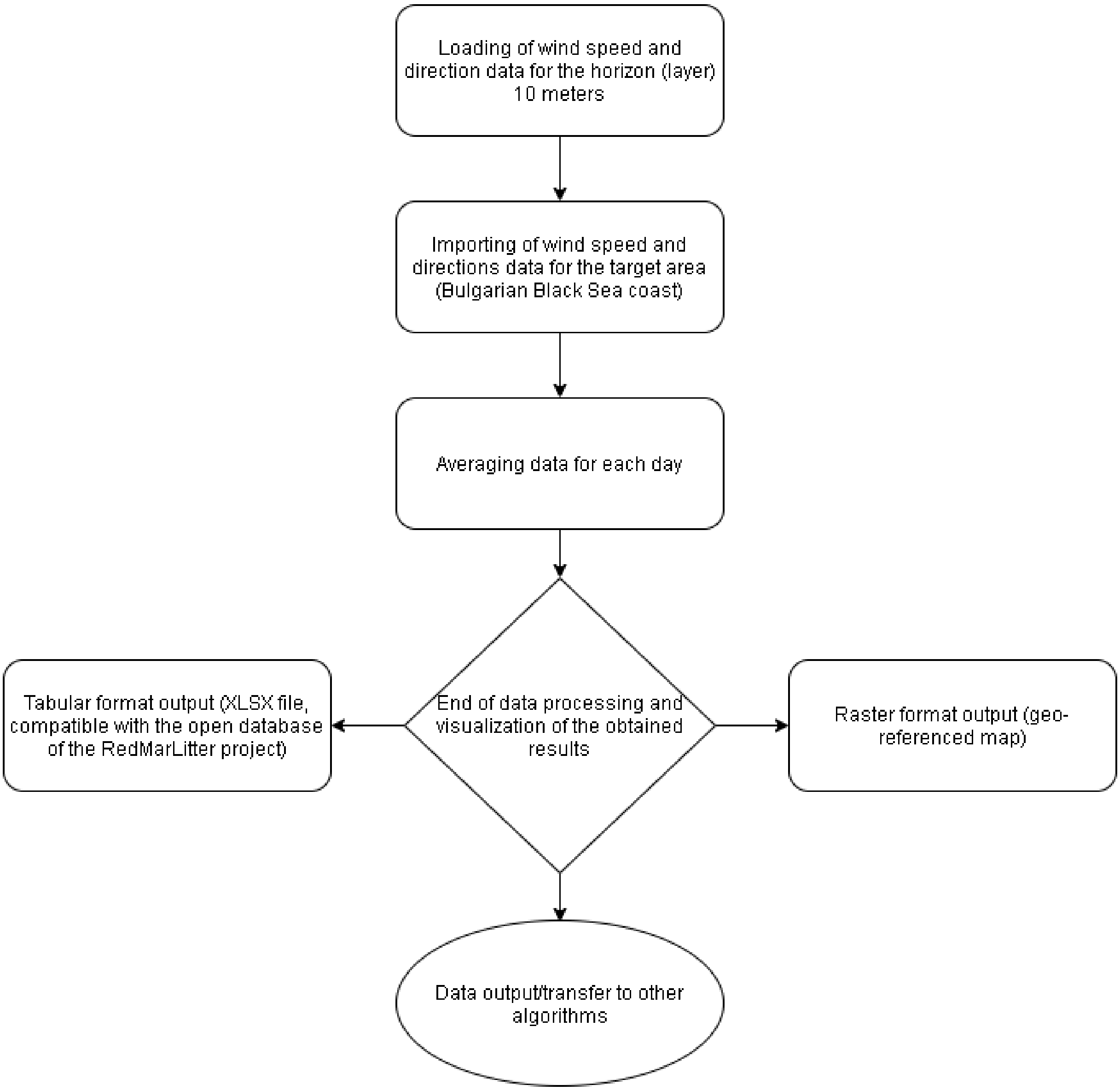


FIG. 5.6 Algorithm for deriving data on the direction and velocity of air currents from product **WIND_GLO_WIND_L4_REP_OBSERVATIONS_012_006** of the Marine Environment Monitoring Service of the Copernicus Program

As a result of the analyzes, the lack of specific data from studies on the degree of impact of air currents on the multivariance of the second conditional group, mathematical modeling and simulations for floating solid waste in the target area, it can be assumed that the direct impact of wind flows on of the second conditional group does not have a significant influence in determining the most endangered coastal areas.

For the needs of the mathematical modeling for definition of the water flows (carriers of floating solid waste on the sea surface) in the target territory additional algorithms and software code in MatLab environment have been developed, by which the ***density of the distribution of the floating solid waste on the sea surface, with dimensions larger than 2.5 cm, in the target area (Bulgarian Black Sea coast), is calculated.***

In FIG. Figure 5.7 shows a georeferenced map of water flows in the target area for 2015, based on mathematical modeling of floating solid waste on the sea surface and the obtained water flows according to the density of distribution of floating solid waste on the sea surface.

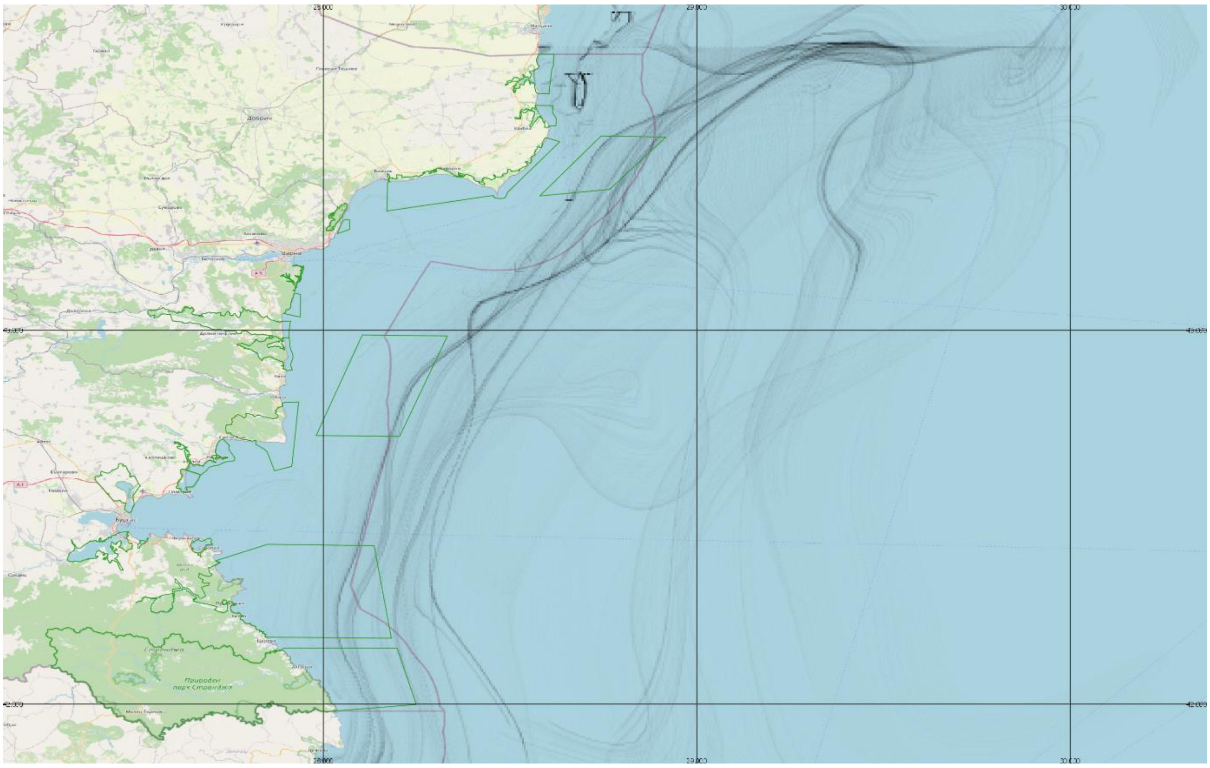


FIG. 5.7 Model of water flows in the surface layer of the target area for 2015.

The figure shows clear water flows, which mainly fall externally (east) from or on the border of the 12-mile zone. Some of the less pronounced water flows in the northern waters of the target area are located near the inner part of the border of the 12-mile zone, and at a later stage they are combined into a common stream, which re-enters the 12-mile zone. in the southern water area of the target area.

As noted earlier, the first (pilot) campaign for the Republic of Bulgaria to monitor waste floating on the sea surface was implemented within the MARLEN project in July 2016 within an 8-day expedition carried out in the period 01-20.07.2016. The monitoring covers the coastal (0-30 m) and shelf (30-200 m) areas of the area between Kaliakra and Sozopol. Visual observations of waste on the sea surface were made in a total of 46 transects, which were distributed equally for the coastal and shelf areas.

In FIG. 5.8 shows a georeferenced map of water flows in the target area for 2016, based on mathematical modeling of floating solid waste on the sea surface and the resulting water flows according to the density of distribution of floating solid waste on the sea surface. The places where the visual observations were carried out during the implementation of the pilot monitoring are plotted (with points), the results of which are shown in Figures 4.2 and 4.3.

The figure shows clear water flows that fall within the 12-mile zone and end in close proximity to the shoreline of the target area. The most pronounced are two water streams, ending near Varvara and Ahtopol and a third, branching in the direction of the coastline of Shkorpilovtsi. Less pronounced water flows are observed in the waters of Varna and Burgas bays, Kavarna, Nessebar, Ravda and Golden Sands.

The data from the observations performed within the MARLEN project show that there is a strong correlation between the formed water flows in the surface layer and the movement and distribution of floating solid waste on the sea surface with dimensions larger than 2.5 cm in the target area.

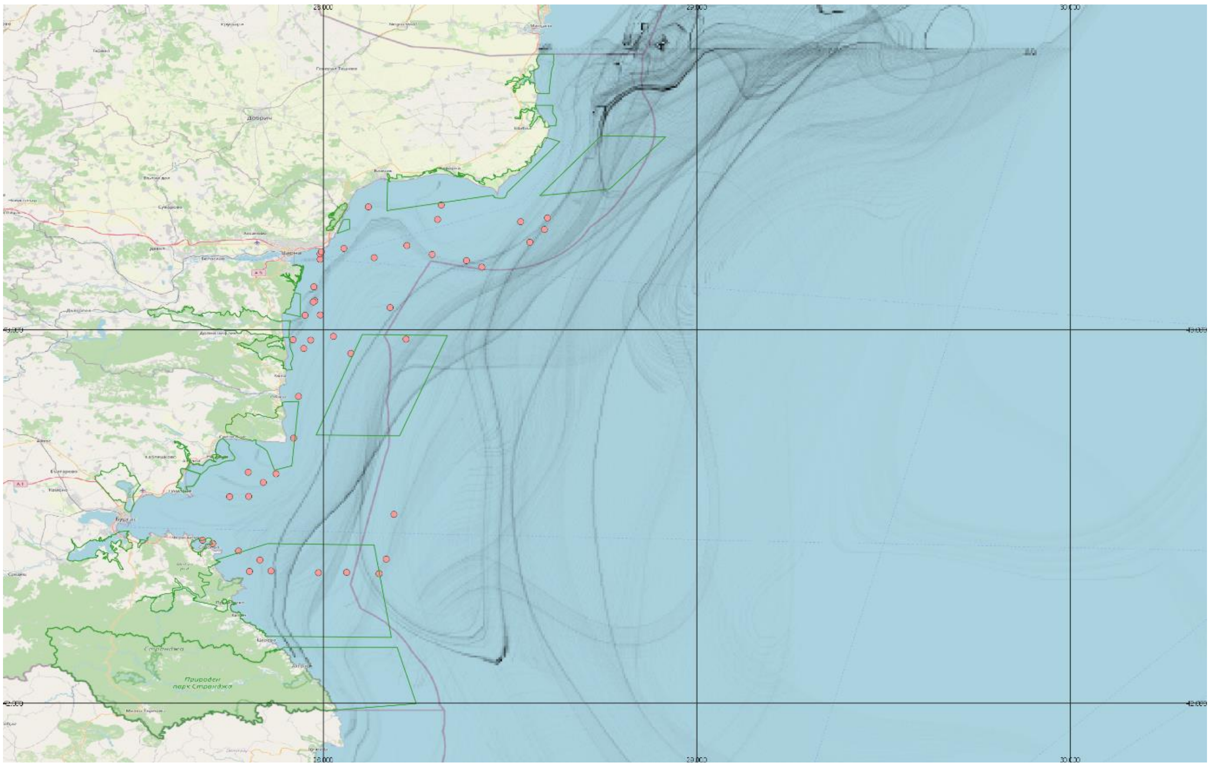


FIG. 5.8 Model of water flows in the surface layer of the target area for 2016.

In FIG. Figure 5.9 shows a georeferenced map of water flows in the target area for 2017, based on mathematical modeling of floating solid waste on the sea surface and the resulting water flows according to the density of distribution of floating solid waste on the sea surface.

In FIG. 5.10 shows a georeferenced map of water flows in the target area for 2017 and the places where the visual observations were conducted during the implementation of the national monitoring in the same year (see Table 4.1), the results of which are shown in Figures 4.5. and accessible through the open database of the RedMarLitter project https://map.redmarlitter.eu/en/database .

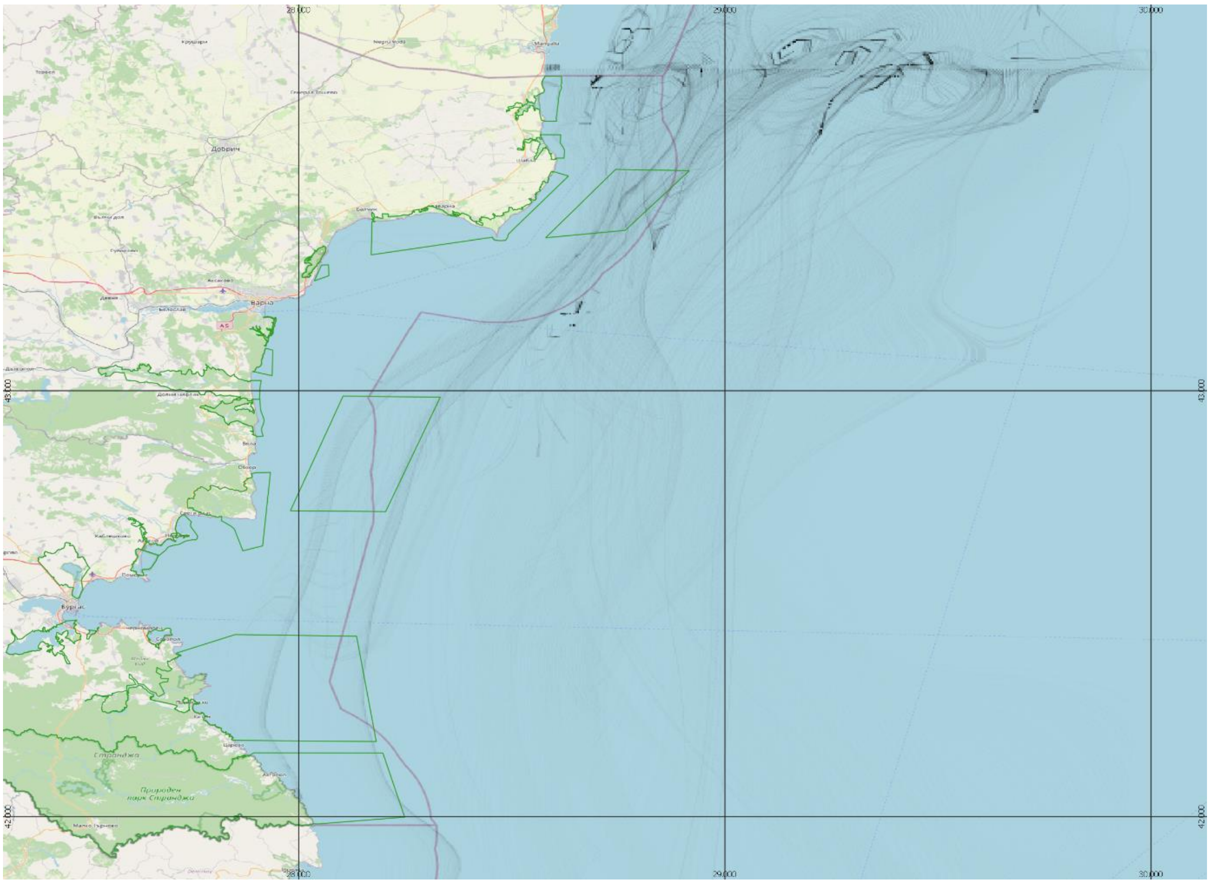


FIG. 5.9 Model of water flows in the surface layer of the target area for 2017.

The figure shows clear water flows, parts of which, like the previous two years analyzed, fall within the 12-mile zone. The most pronounced are two watercourses, one of which ends near the shoreline of the target area in the water area and south of the mouth of the Veleka River. The second continues its movement outside the target area. Less pronounced water flows are observed in the southern part of the target area, which end near the shoreline of the target area in the waters of Tsarevo, Varvara and Ahtopol, as well as weaker water flows in the shelf zone of the target area.

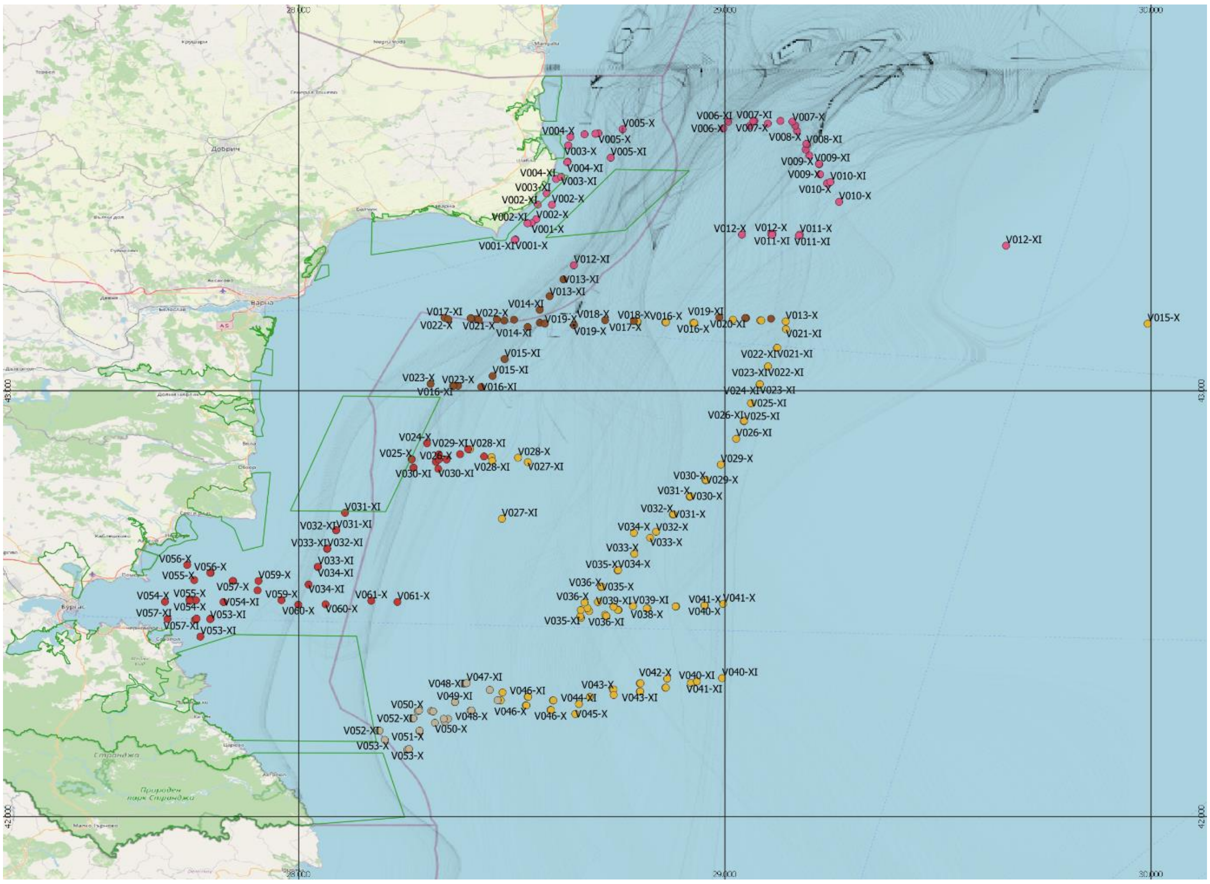


FIG. 5.10 Areas of visual observations during monitoring for floating solid waste with a size of> 2.5 cm in 2017

Figure 5.10 shows that most of the conducted visual observations fall within the identified for the calendar year water flows, and the analysis of the campaign data (see Fig. 4.5) shows that the floating solid waste with a size of> 2.5 cm is mainly made of artificial polymeric materials, which once again shows the strong correlation between the formed water flows in the surface layer and the movement and the distribution of floating solid waste on the sea surface.

Similar to the presented analysis of the data for 2017, Figures 5.11 and 5.12 present: georeferenced map of water flows in the target area for 2018, based on mathematical modeling of floating solid waste on the sea surface and the obtained water flows according to the density of distribution of floating solid waste on the sea surface; and a georeferenced map of water flows in the target area for 2018 and the places where the visual observations were carried out during the implementation of the national monitoring in the same year (see Table 4.1), the results of which are shown in Figures 4.4 and available through the open database of the RedMarLitter project https://map.redmarlitter.eu/en/database .

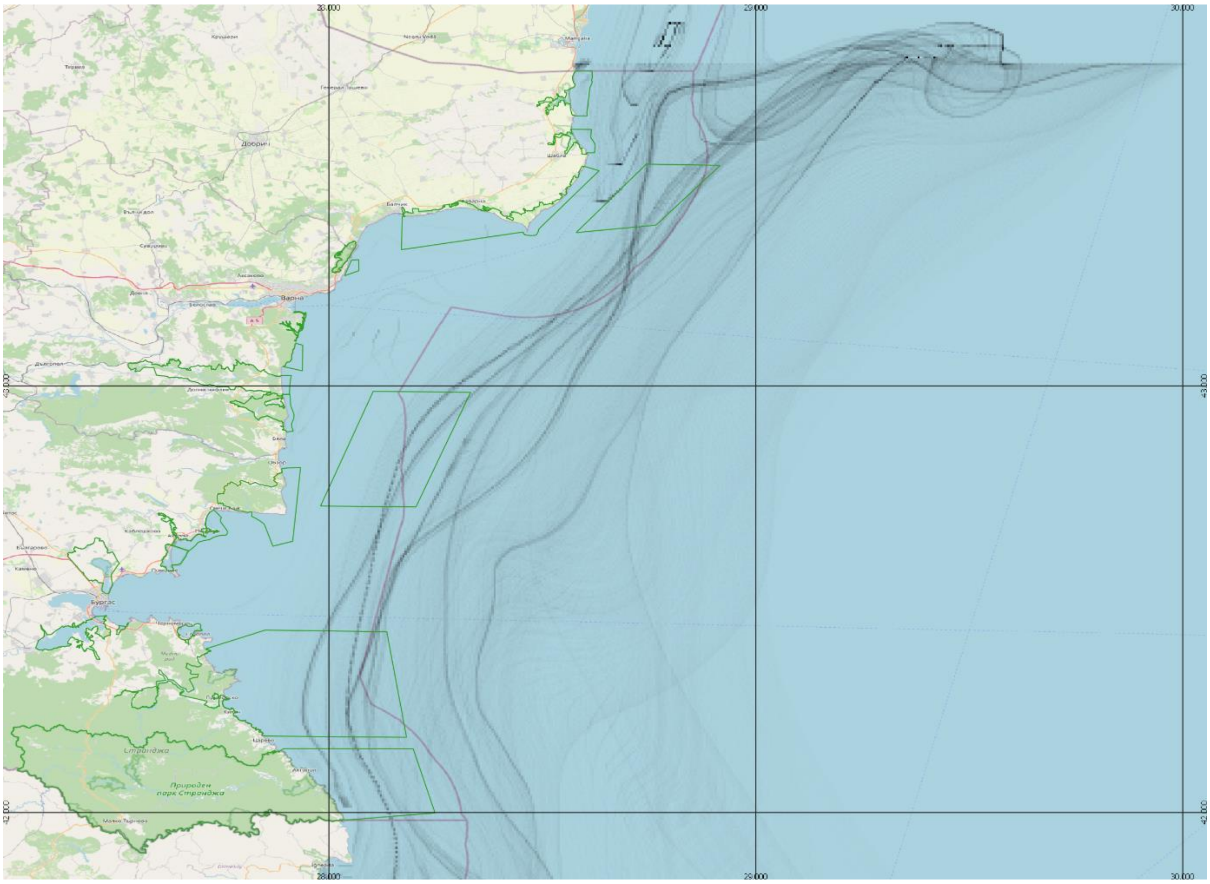


FIG. 5.11 Model of water flows in the surface layer of the target area for 2018.

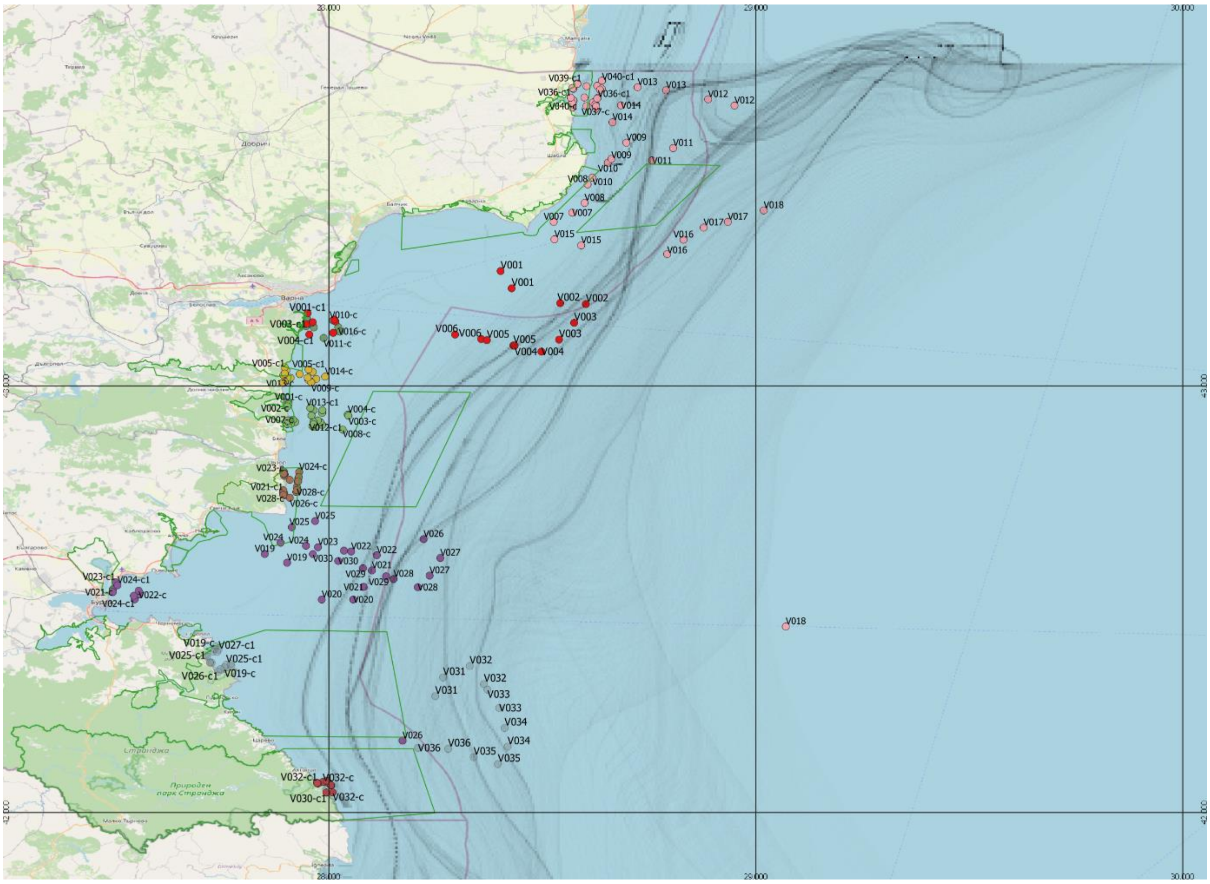


FIG. 5.12 Areas of visual observations during monitoring for floating solid waste with a size of> 2.5 cm in 2018

Figure 5.11 again shows clear water flows in the target area, part of which ends in close proximity to its coastline. There are five pronounced water flows, of which only one ends near the shoreline in the water area and south of the mouth of the Veleka River. The other four pronounced watercourses continue their movement outside the boundaries of the target area. Less pronounced water flows are observed in the northern coastal water area of the target area (section Durankulak - Kamen Bryag), in the central coastal water area of the target area (section Shkorpilovtsi - Byala), as well as in the water area of Tsarevo.

Figure 5.12 shows that a large part of the conducted visual observations fall within the water flows identified for the calendar year and especially those of the northern and southern coastal waters of the target area.

The analysis of the campaign data (see Fig. 4.4) shows that the floating solid waste with a size of> 2.5 cm is mainly made of artificial polymeric materials, which once again shows the strong correlation between the formed water flows in the surface layer and the movement and the distribution of floating solid waste on the sea surface.

All the figures visualizing the derived models of water flows in the northern part of the target area show the strong influence of the anticyclonic vortex called Kaliakra (see Fig. 2.4, 2.5 and 2.6 - Kaliakra anticyclonic eddy), as well as the interacting coastal cyclonic vortices (near-shore anticyclonic eddies) clearly distinguishable in Figures 5.7, 5.9 and 5.11 in the waters of the sections Durankulak-Krapets, Shabla-Tyulenovo, Kamen Bryag.

Using the algorithms referred to above, approximately 6 million positions (points) of floating solid waste on the sea surface were obtained, resulting from the mathematical modeling of all 8208 scenarios for the target area.

The final result is a georeferenced map (see Fig. 7.1) of the water flows in the target area (according to the summarized data for 2015-2018) according to the density distribution of floating solid waste on the sea surface (density map).

The patterns of movement, distribution and distribution of floating solid waste on the sea surface for the target area follow the models of the derived water flows in the surface layer.

6. Development of algorithms and software code for creating an interactive computer model-map for the movement of pollutant flows under the influence of water and air currents.

The interactive computer model-map for the movement of pollutant flows under the influence of water and air currents was developed in MatLab's environment, as a standalone application, based on the algorithms for importing these types of data from the Copernicus Marine Environmental Monitoring Service. and algorithms for modeling water flows in the surface layer and algorithms for modeling the distribution and distribution of floating solid waste.

Additionally, in this task, algorithms and software code have been developed for the creation of a graphical user interface for the operation of the application in the environment of MS Windows.

The graphical user interface of the application consists of seven interactive panels for data input and output, and control of its operation. Additionally, an uneditable information panel is placed at the top of the interface.

1 - Panel “Currents (monthly mean data)”

2 - Panel “Winds (daily mean data)”

3 - Panel “Flows”

4 - Panel “RedMarLitter Database File (* .XLSX)”

5 - Panel “Flows forecast (based on)”

6 - “Progress Information”

panel 7 - “Controls”panel

The graphical user interface (GUI) of the interactive map for the modeling of movement of waste flows under the influence of water and air currents is shown in fig. 6.1.

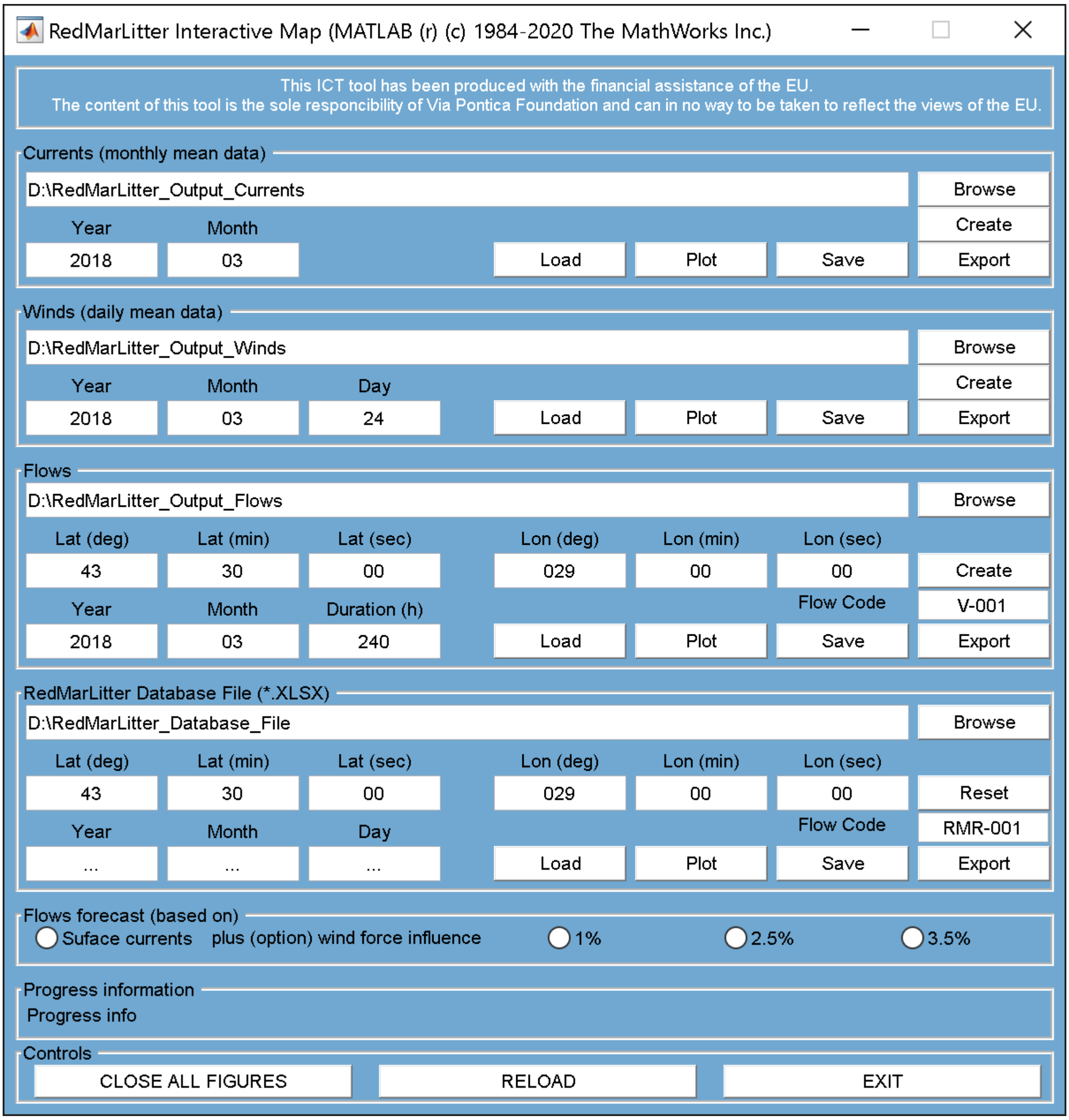


FIG. 6.1 Graphical user interface of the interactive computer model-map for the movement of pollutant flows under the influence of water and air currents

Panel "Currents (monthly mean data)"

The application integrates the data for the average monthly values of surface sea currents (per product BLKSEA_REANALYSIS_700) for all months for the period 2015-2018 inclusive, collected within the project for the target territory. The panel is shown in Figure 6.2.

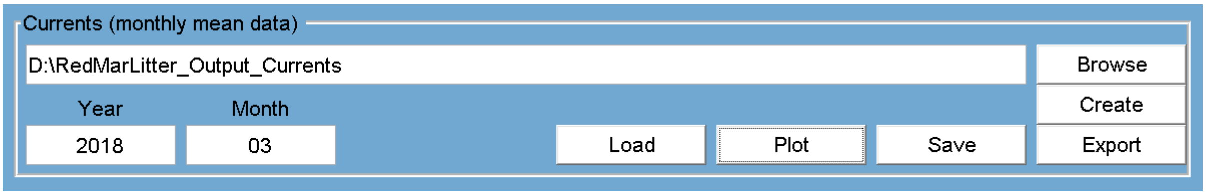


FIG. 6.2 Visualization of the "Currents (monthly mean data)"

Panel The "Currents (monthly mean data)" is designed for the purposes of managing this data. It consists of:

- "Browse" button with the help of which a directory / folder is selected in which to save the output files generated by the application according to parameters set by the user;
- Button "Create" with which to create a directory / folder with address (path) entered in the field in front of the button "Browse" in which to save the output files generated by the application by user-defined parameters;
- Fields "Year" and "Month" in which the user enters the desired month and year for visualization and display of data on average monthly values of surface sea currents;
- "Load" button with which the user after setting the time period loads the data into the computer's memory;
- "Plot" button with the help of which the user generates a georeferenced map in raster format visualizing the direction and speed of the surface sea currents (see Fig. 6.3);

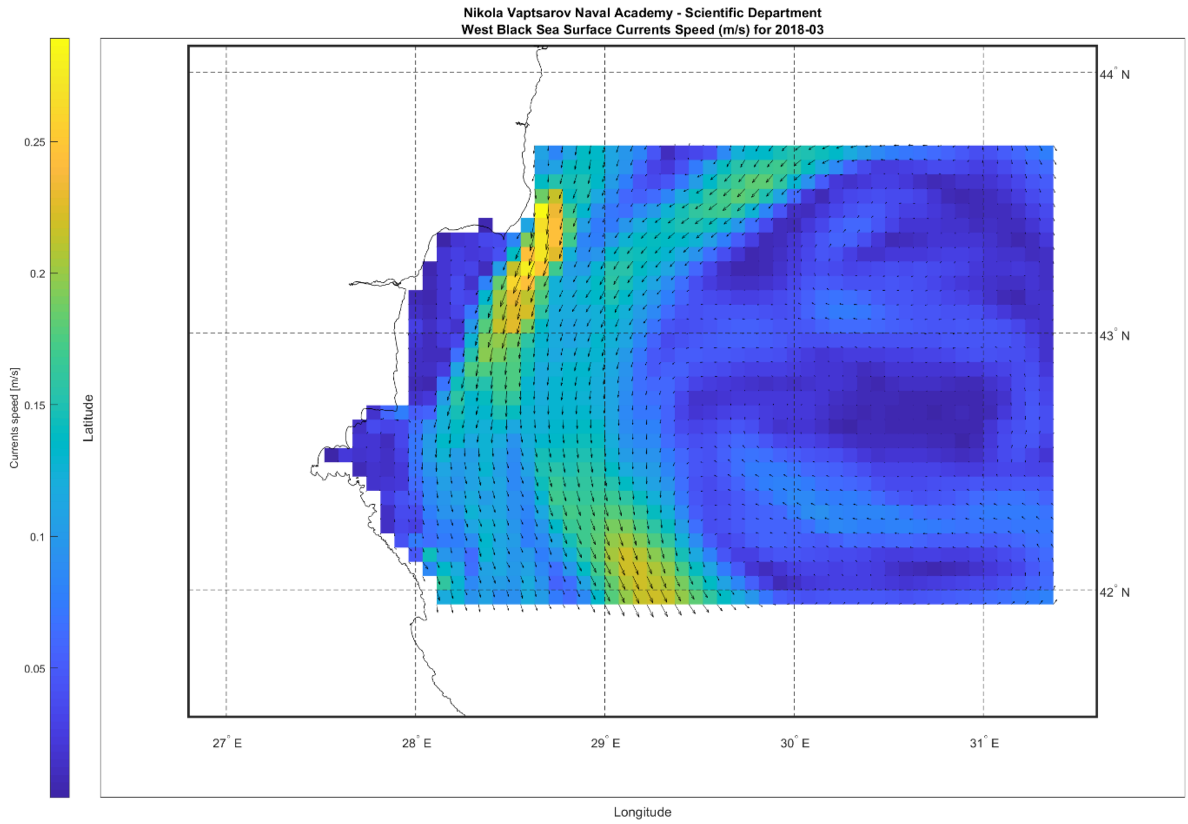
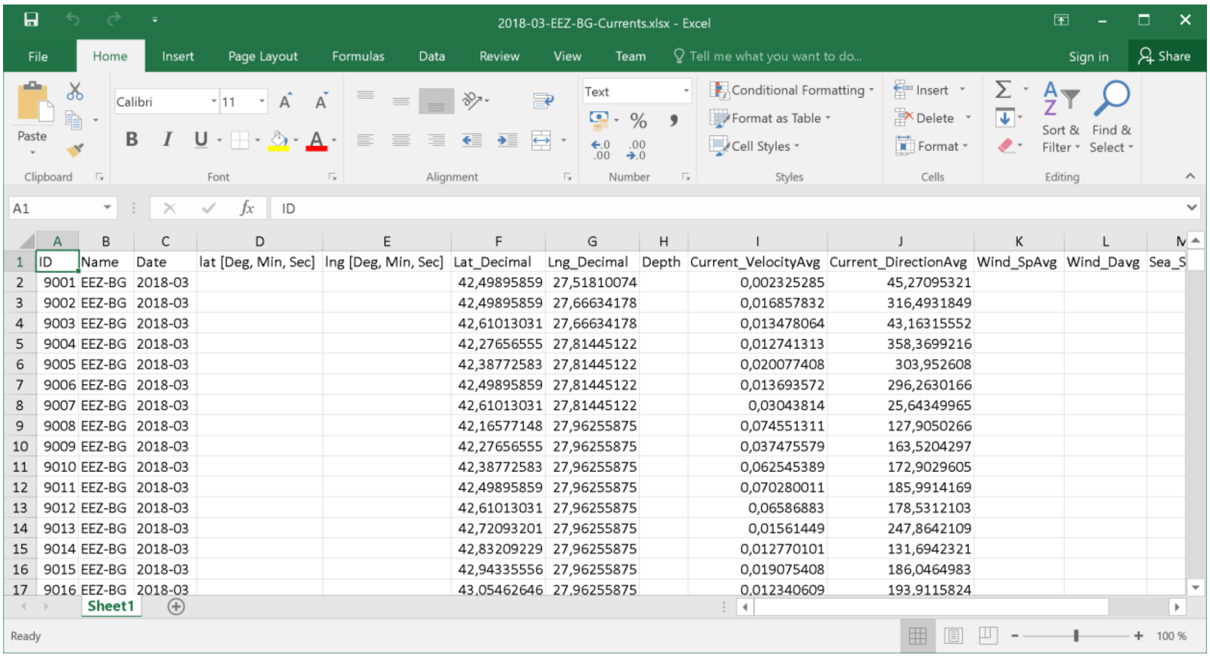


FIG. 6.3 Visualization of the direction and speed of surface sea currents in the form of a georeferenced map in raster format

- “Save” button with the help of which the user saves the map generated by the application in the predefined directory / folder;
- "Export" button with which the user stores the data on the direction and speed of surface sea currents in tabular form in XLSX format, compatible with the open database of the RedMarLitter project. This functionality is based on a specially developed additional algorithm for transforming the data on the direction and speed of marine currents by the Marine Environment Monitoring Service of the Copernicus Program in a format suitable for the open project database (see Fig. 6.4). Files of this type are entered into the open project

database https://map.redmarlitter.eu/en/database using the "Import XLSX" functionality (see Figures 6.5 and 6.6);



ID	Name	Date	lat [Deg, Min, Sec]	lng [Deg, Min, Sec]	Lat_Decimal	Lng_Decimal	Depth	Current_VelocityAvg	Current_DirectionAvg	Wind_SpAvg	Wind_Davg	Sea_S
9001	EEZ-BG	2018-03			42,49895859	27,51810074		0,002325285	45,27095321			
9002	EEZ-BG	2018-03			42,49895859	27,66634178		0,016857832	316,4931849			
9003	EEZ-BG	2018-03			42,61013031	27,66634178		0,013478064	43,16315552			
9004	EEZ-BG	2018-03			42,27656555	27,81445122		0,012741313	358,3699216			
9005	EEZ-BG	2018-03			42,38772583	27,81445122		0,020077408	303,952608			
9006	EEZ-BG	2018-03			42,49895859	27,81445122		0,013693572	296,2630166			
9007	EEZ-BG	2018-03			42,61013031	27,81445122		0,03043814	25,64349965			
9008	EEZ-BG	2018-03			42,16577148	27,96255875		0,074551311	127,9050266			
9009	EEZ-BG	2018-03			42,27656555	27,96255875		0,037475579	163,5204297			
9010	EEZ-BG	2018-03			42,38772583	27,96255875		0,062545389	172,9029605			
9011	EEZ-BG	2018-03			42,49895859	27,96255875		0,070280011	185,9914169			
9012	EEZ-BG	2018-03			42,61013031	27,96255875		0,06586883	178,5312103			
9013	EEZ-BG	2018-03			42,72093201	27,96255875		0,01561449	247,8642109			
9014	EEZ-BG	2018-03			42,83209229	27,96255875		0,012770101	131,6942321			
9015	EEZ-BG	2018-03			42,94335556	27,96255875		0,019075408	186,0464983			
9016	EEZ-BG	2018-03			43,05462646	27,96255875		0,012340609	193,9115824			

FIG. 6.4 Export file with data on the direction and speed of surface sea currents in tabular form (XLSX format), compatible with the open database of the RedMarLitter project

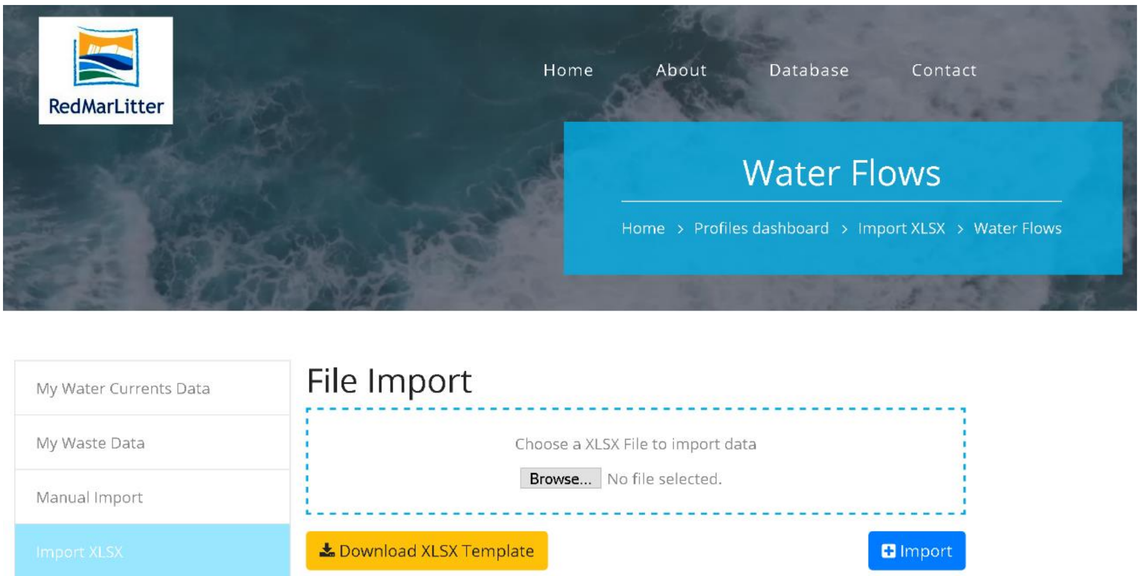


Fig. 6.5 "Import XLSX" functionality of the open project database https://map.redmarlitter.eu/en/database

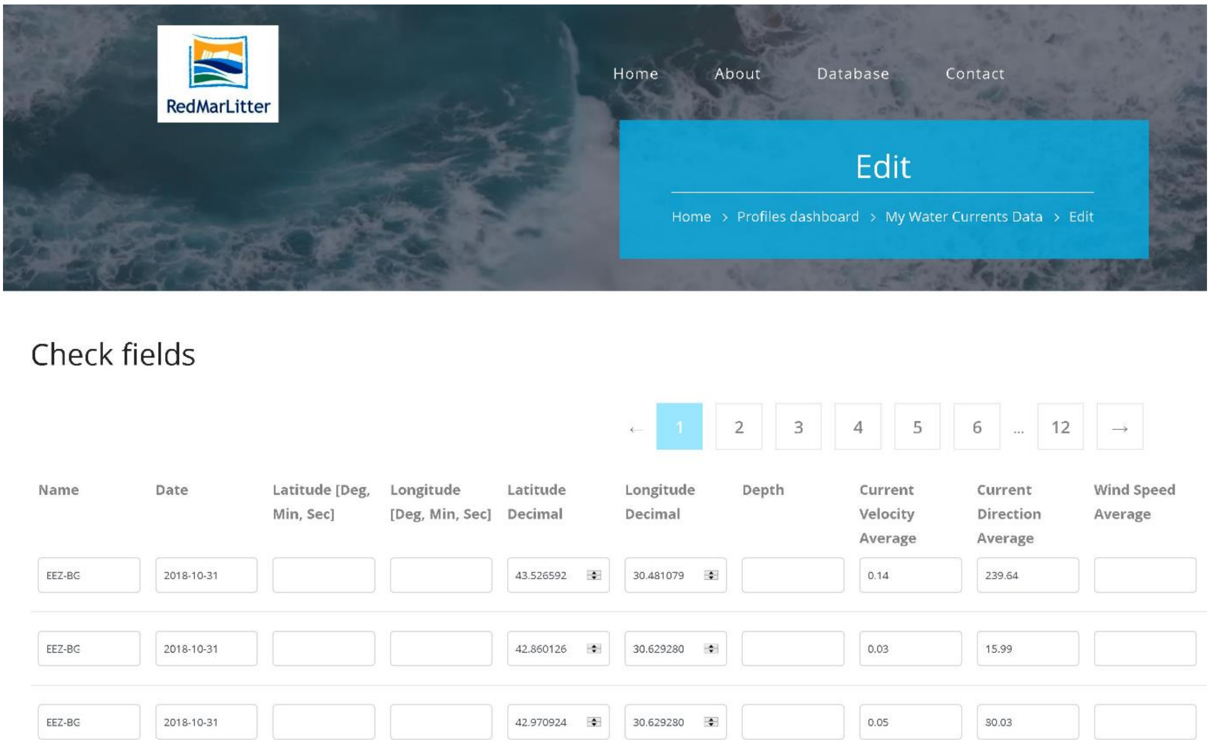


Fig. 6.6 Visualization of the functionality for viewing and editing the imported data in the open database of the RedMarLitter project

After importing the data in https://map.redmarlitter.eu/en/database they can be visualized and accessed using the interactive filters, buttons and tools on the website (see Fig. 6.7).

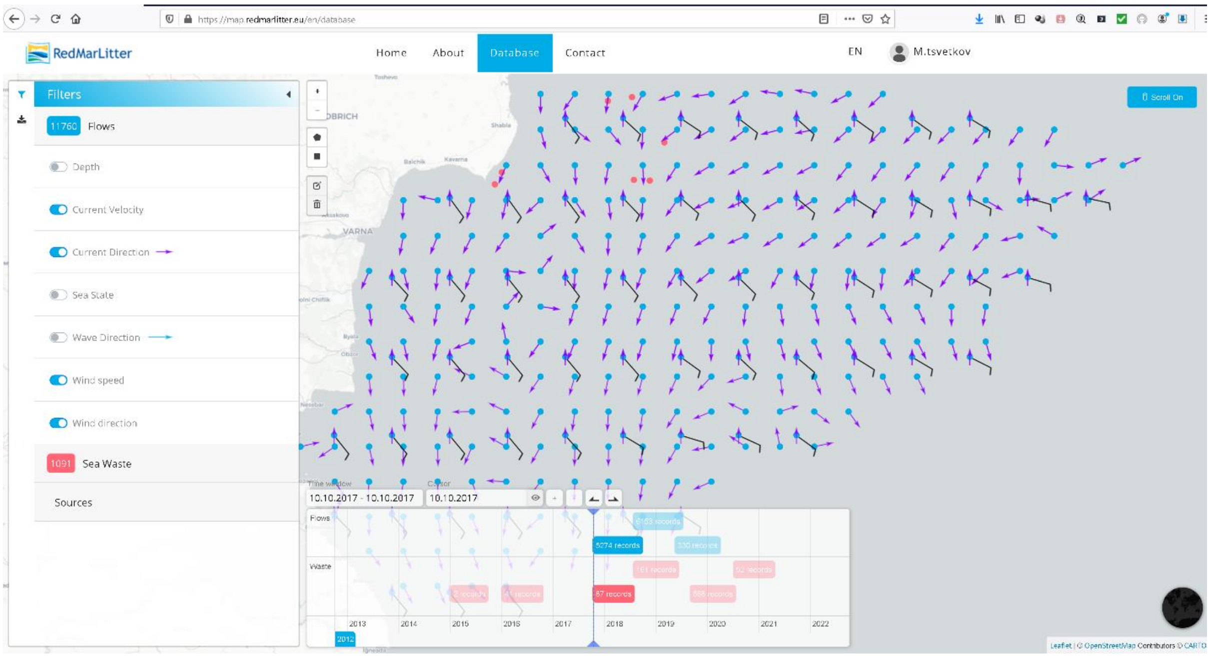


FIG. 6.7 Visualization of data on sea currents in the open database of the RedMarLitter project

Panel "Winds (daily mean data)"

The application integrates the data on the average daily values for the direction and wind speed at a height of 10 meters above sea level (on product WIND_GLO_WIND_L4_REP) for all days for the period 2015-2018 inclusive, collected within the project for the target territory. The panel is shown in Figure 6.8.

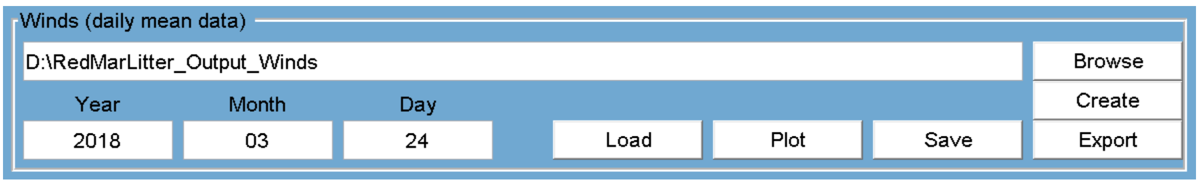


FIG. 6.8 Visualization of the "Winds (daily mean data)" panel

The “Winds (daily mean data)” panel is designed for the needs of the management of the wind direction and speed data integrated in the application. It is analogous to the already described Panel "Currents (monthly mean data)" and consists of the same fields, buttons and functionalities with an added field "Day" providing the ability to enter a day (date) by the user.

Preview of the direction and speed of the air currents in the form of a georeferenced map in raster format, generated by the application according to parameters set by the user is shown in fig. 6.9. Figure 6.10 shows an application-generated export file in XLSX format compatible with the open RedMarLitter project database.

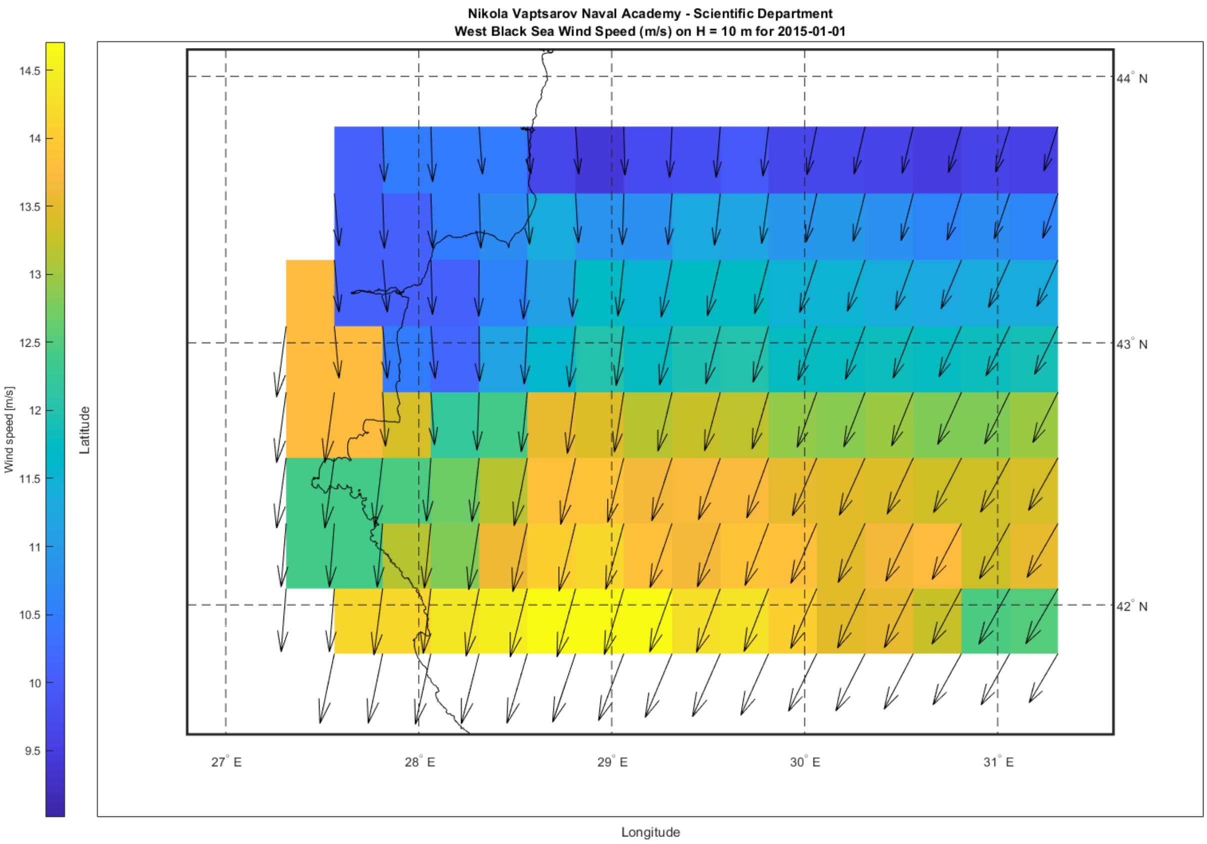
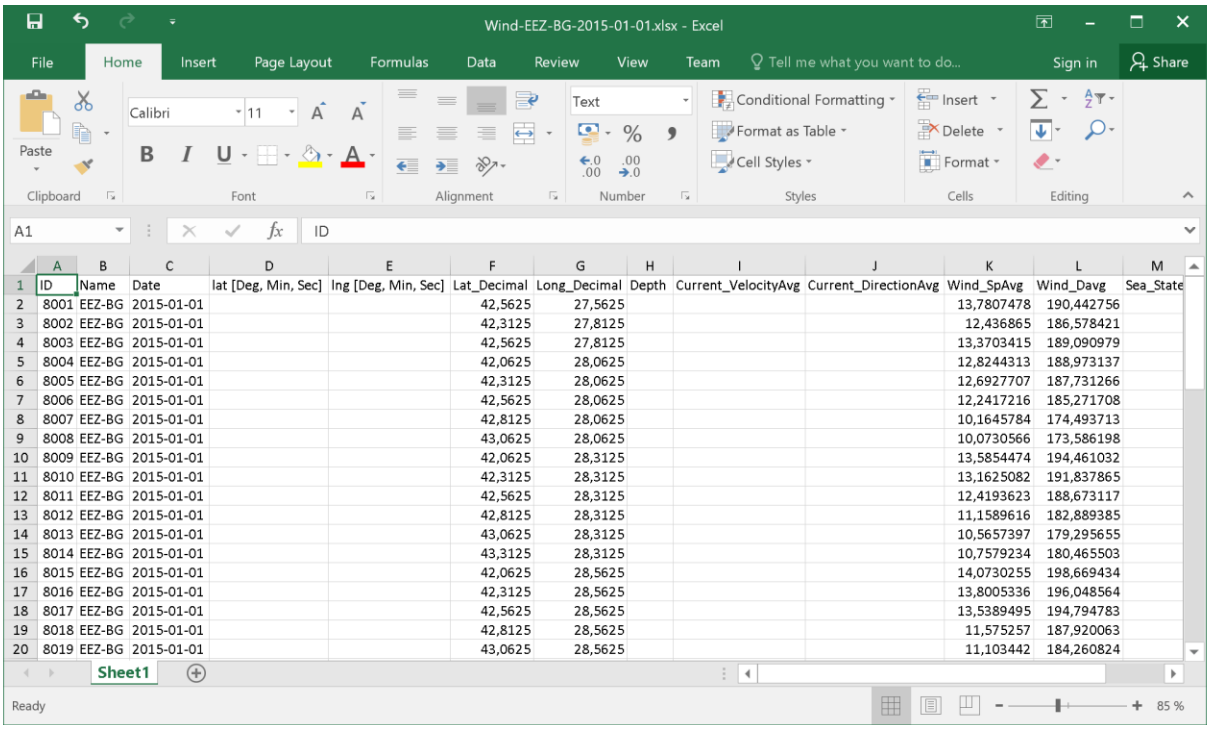


FIG. 6.9 Visualization of the direction and speed of the air currents in the form of a georeferenced map in raster format



ID	Name	Date	lat [Deg, Min, Sec]	lng [Deg, Min, Sec]	Lat_Decimal	Long_Decimal	Depth	Current_VelocityAvg	Current_DirectionAvg	Wind_SpAvg	Wind_Davg	Sea_State
8001	EEZ-BG	2015-01-01			42,5625	27,5625				13,7807478	190,442756	
8002	EEZ-BG	2015-01-01			42,3125	27,8125				12,436865	186,578421	
8003	EEZ-BG	2015-01-01			42,5625	27,8125				13,3703415	189,090979	
8004	EEZ-BG	2015-01-01			42,0625	28,0625				12,8244313	188,973137	
8005	EEZ-BG	2015-01-01			42,3125	28,0625				12,6927707	187,731266	
8006	EEZ-BG	2015-01-01			42,5625	28,0625				12,2417216	185,271708	
8007	EEZ-BG	2015-01-01			42,8125	28,0625				10,1645784	174,493713	
8008	EEZ-BG	2015-01-01			43,0625	28,0625				10,0730566	173,586198	
8009	EEZ-BG	2015-01-01			42,0625	28,3125				13,5854474	194,461032	
8010	EEZ-BG	2015-01-01			42,3125	28,3125				13,1625082	191,837865	
8011	EEZ-BG	2015-01-01			42,5625	28,3125				12,4193623	188,673117	
8012	EEZ-BG	2015-01-01			42,8125	28,3125				11,1589616	182,889385	
8013	EEZ-BG	2015-01-01			43,0625	28,3125				10,5657397	179,295655	
8014	EEZ-BG	2015-01-01			43,3125	28,3125				10,7579234	180,465503	
8015	EEZ-BG	2015-01-01			42,0625	28,5625				14,0730255	198,669434	
8016	EEZ-BG	2015-01-01			42,3125	28,5625				13,8005336	196,048564	
8017	EEZ-BG	2015-01-01			42,5625	28,5625				13,5389495	194,794783	
8018	EEZ-BG	2015-01-01			42,8125	28,5625				11,575257	187,920063	
8019	EEZ-BG	2015-01-01			43,0625	28,5625				11,103442	184,260824	

Fig. 6.10 Export file with airflow direction and velocity data in tabular form (XLSX format), compatible with the open database of the RedMarLitter project

Similarly, by using the functionalities and tools of the open database of the RedMarLitter project, the imported data can be viewed , edited and visualized (see Fig. 6.7).

Flows panel

This panel is designed for calculation by mathematical modeling and visualization of water flow input based on userdata and by using the integrated in the application data on the direction and speed of surface sea currents and the direction and speed of air currents.

The panel is shown in fig. 6.11.

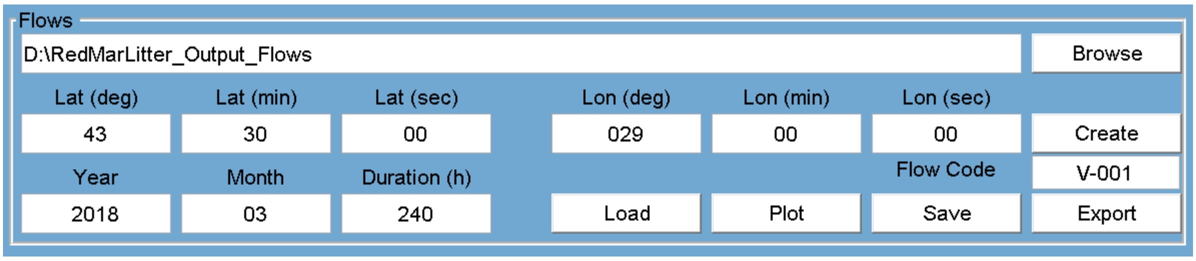


FIG. 6.11 Visualization of the “Flows” Panel

The panel consists of:

- “Browse” button with the help of which a directory / folder is selected in which to save the output files generated by the application according to parameters set by the user;
- Button "Create" with which to create a directory / folder with address (path) entered in the field in front of the button "Browse" in which to save the output files generated by the application by user-defined parameters;
- Fields “Year” and “Month” in which the user enters the desired month and year for use of the data for the average monthly values of the surface sea currents;
- "Duration" field with which the user sets the duration of the mathematical modeling in the form of the number of hours counted from the beginning of the calendar month. For example: a value of 240 means ten full days;
- The fields “Lat (deg, min, sec)” and “Lon (deg, min, sec)” are used by the user to enter the geographical coordinates of the starting position of the floating object for which the mathematical modeling will be performed and will be calculated. the trajectory of movement under the influence of surface sea currents forming a water flow;
- Field "Flow code" with which the user sets his own identification code of the flow. The identification code is integrated in the name of the source files generated by the application;
- "Load" button with which the user after setting all the input parameters loads the data into the computer's memory;
- The “Plot”, “Save” and “Export” buttons have the same purpose and functionality as their analogues described in the previous panels;

Flows forecast panel

The panel and its supporting algorithms are designed to enable the user to generate water flow forecasts. The panel works with input data from the “Flows” Panel or with input data from the “RedMarLitter Database File (* .XLSX)” panel. The panel is shown in fig. 6.12.

For the needs of mathematical modeling in the first case, the user can choose one of the four options:

- Forecast based only on the average monthly data on surface sea currents for the four years (2015-2018);
- Forecast based on the average monthly data for surface sea currents for the four years (2015-2018) plus wind impact reporting within 1%;
- Forecast based on the average monthly data for surface sea currents for the four years (2015-2018) plus wind impact reporting within 2.5%;
- Forecast based on average monthly data for surface sea currents for the four years (2015-2018) plus wind impact reporting within 3.5%;

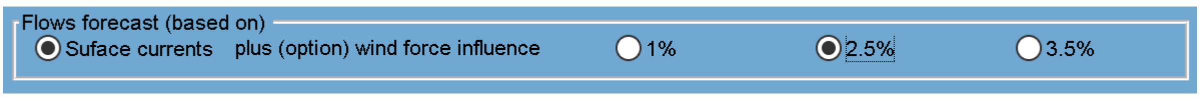


FIG. 6.12 Preview of the “Flow forecast” panel

The panel consists of four “radio” buttons with the help of which the desired combination (option) is selected by the user. The remaining input parameters are entered by using the “Flows” Panel as described above or by using the “RedMarLitter Database File (* .XLSX)” Panel. The results are displayed using the “Plot”, “Save” and “Export” buttons on the respective “Flows” panel or respectively on the “RedMarLitter Database File (* .XLSX)”.

The next four figures (6.13 to 6.16) show the results generated by the application for the four options with the same other input parameters.

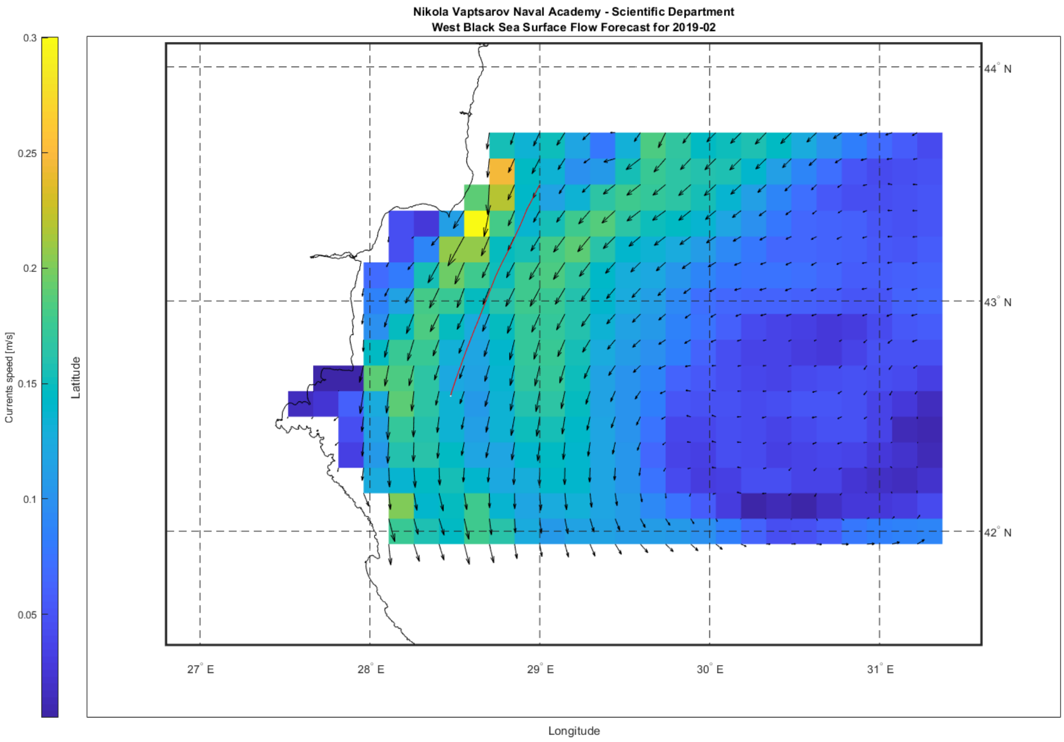


FIG. 6.13 Forecast based only on the average monthly data for the surface sea currents, without taking into account the influence of the wind

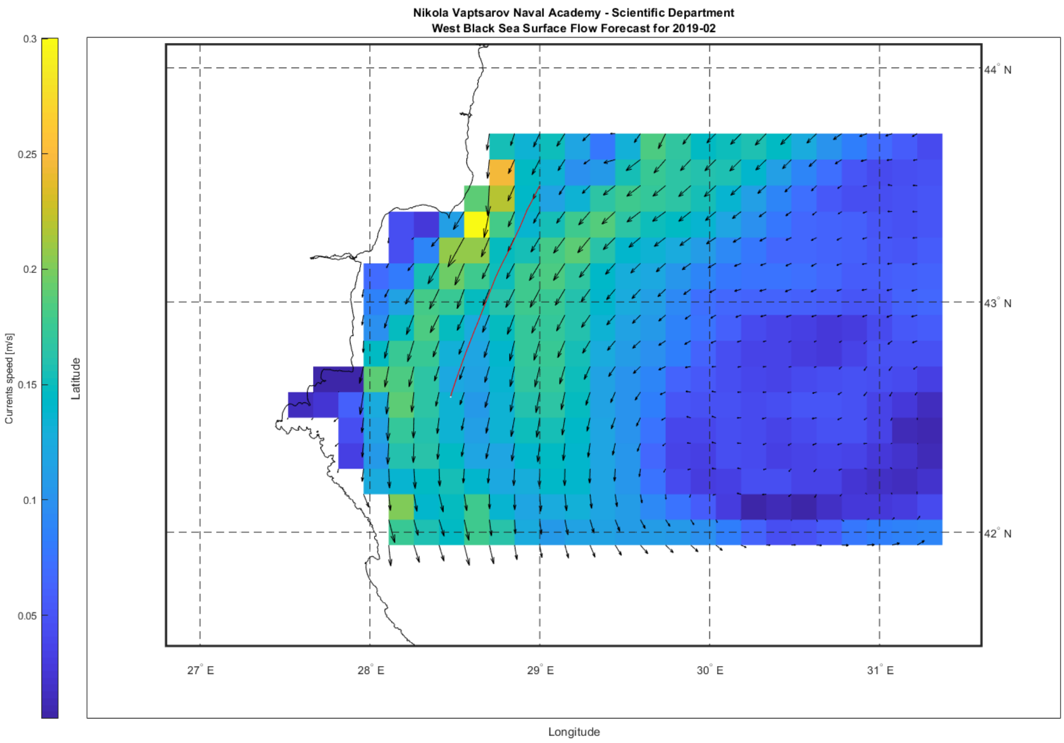


Fig. 6.14 Forecast based on the average monthly data for the surface sea currents taking into account the influence of the wind within 1%

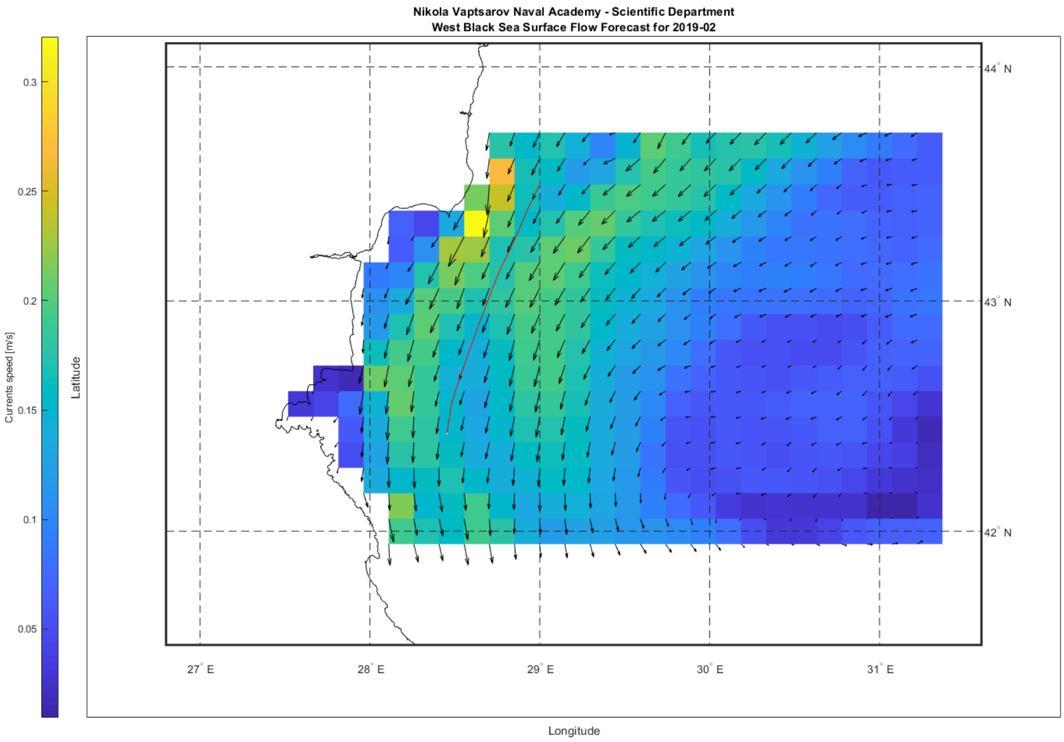


Fig. 6.15 Forecast based on the average monthly data for the surface sea currents taking into account the influence of the wind within 2.5%

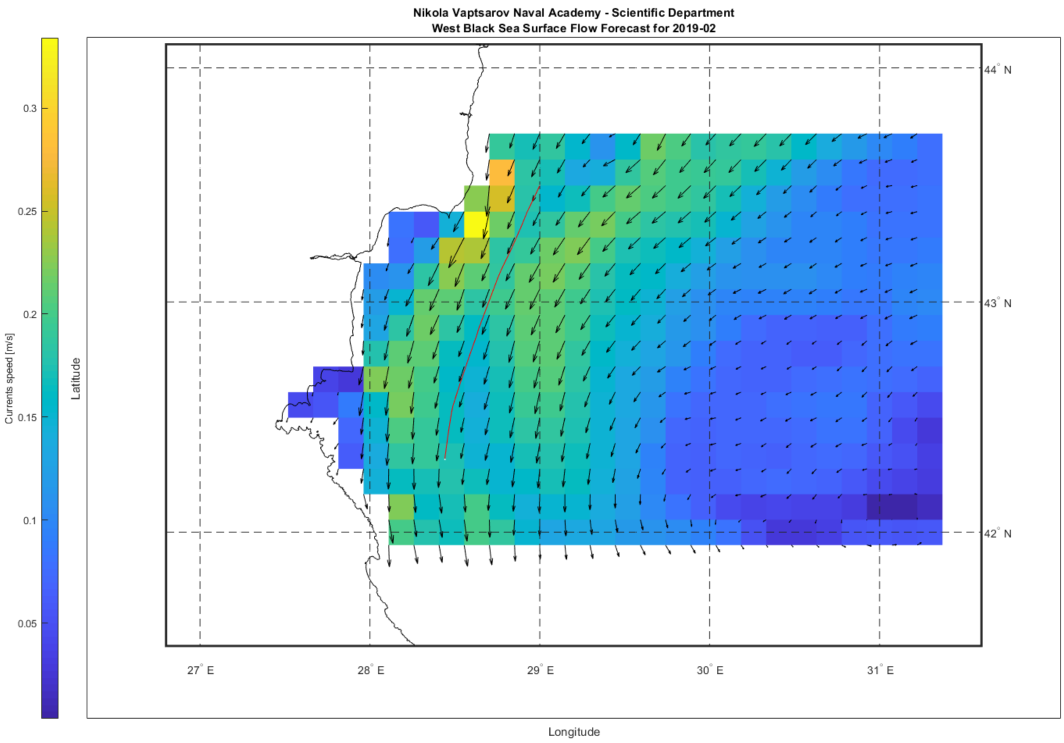


Fig. 6.16 Forecast based on average monthly data for surface sea currents taking into account the influence of wind within 3.5%

Panel “RedMarLitter Database File (* .XLSX)”

As far as the interactive computer model-map for the movement of flows from pollutants under the influence of water and air currents mainly generate data with the ability to integrate and visualize in the open database of the RedMarLitter project, then this panel is designed to enable the user to use downloaded from https://map.redmarlitter.eu/en / database data on the direction and speed of surface sea currents and wind, on the basis of which to perform mathematical modeling. The panel is shown in fig. 6.17.

Assuming that sea and air currents with the required spatial coverage, resolution and time range can be downloaded from the open project database for a future period of time (up to several days), this panel can be successfully used to forecast the movement of floating solid waste on the sea surface for the target area.

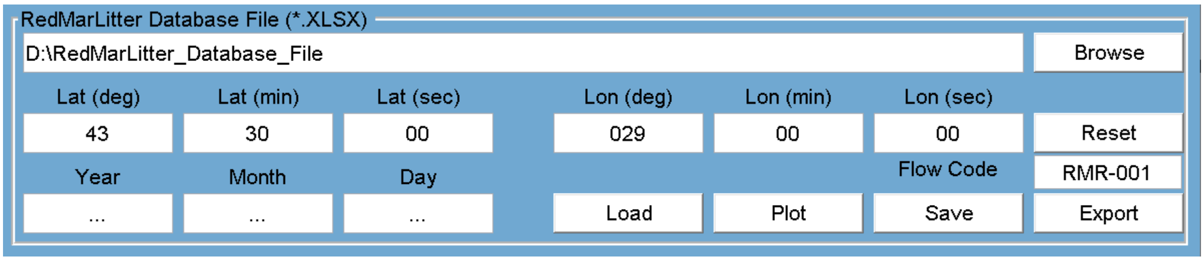


FIG. 6.17 Preview of the “RedMarLitter Database File (* .XLSX)”Panel

The panel is built similarly to the “Flows” Panel, except that using the “Browse” button it is selected downloaded from https://map.redmarlitter.eu/en / database and a file with the extension XLSX stored in the personal computer, and containing data on the direction and speed of the water currents or data on the direction and speed of the water and air currents.

The second difference is in the use of the fields "Year", "Month" and "Day", which in this case visualize the date to which the data in the downloaded file refer. The data is displayed after pressing the "Load" button.

The third difference is in the replacement of the "Create" button with the "Reset" button, which is used to reset the input parameters.

For clarity, the RedMarLitter Database File (* .XLSX) panel algorithm is described textually and illustrated visually in the following figures.

In the open database https://map.redmarlitter.eu/en/database in the menu "Flows" the data on the direction and speed of the sea and air currents are activated (see Fig. 6.18).

By using the “Time window” and “Cursor” tools, the user selects the time range for which he wishes to download data (see Fig. 6.18). The figure shows an example dated October 10, 2017.

Using the “Draw a rectangle” tool, the area for which the user wishes to download data is selected (see Fig. 6.19).

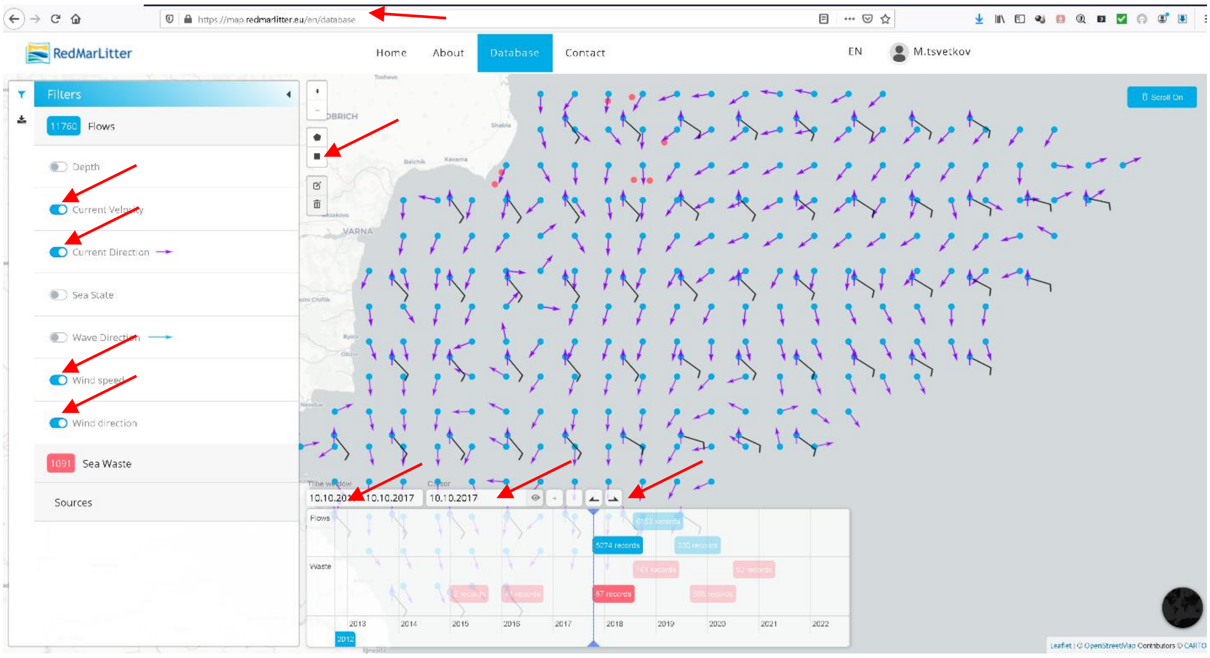


FIG. 6.18

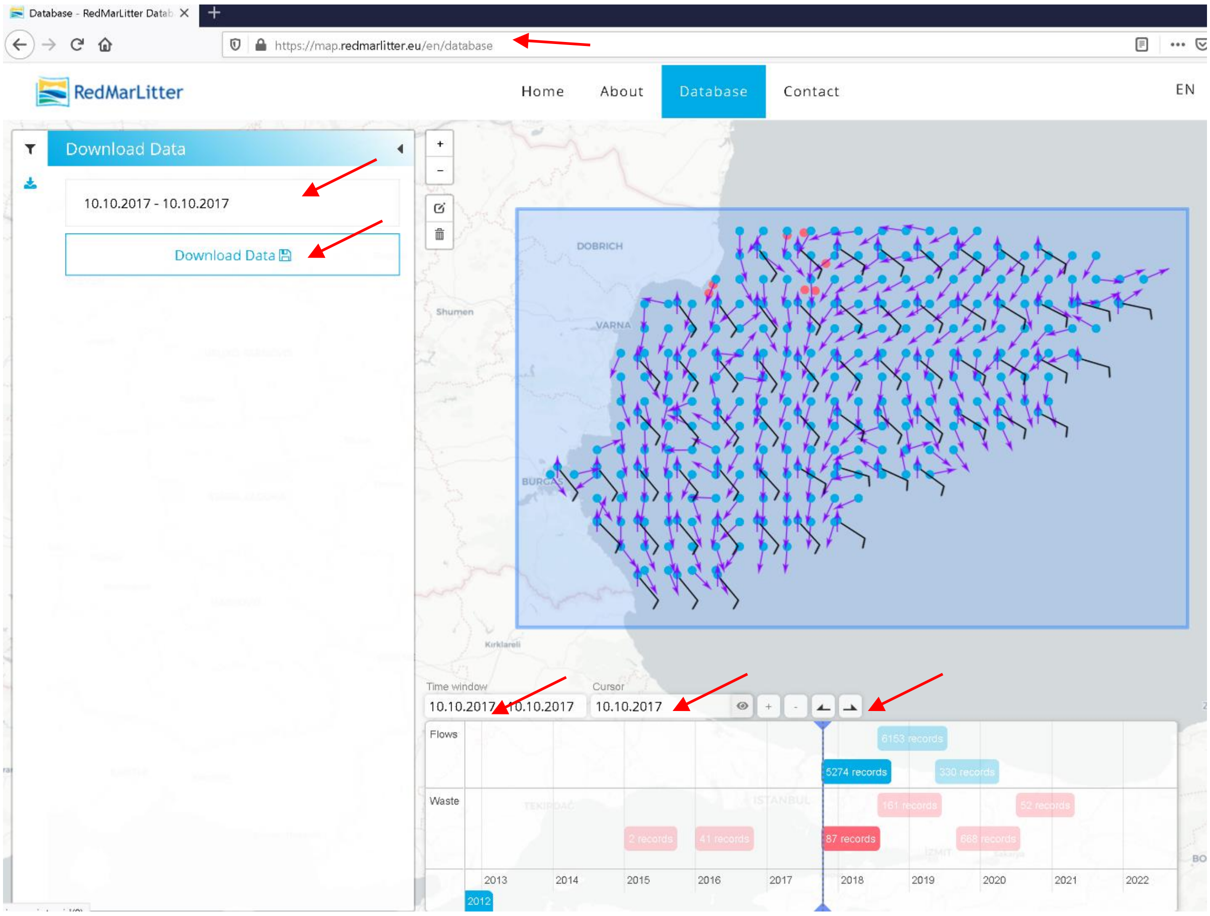


FIG. 6.19

Once the user has defined a geographical area and time range, he is able to download the data activated by him by using the "Download data" button from the open database of the RedMarLitter project (see Fig. 6.19).

The data is then downloaded as an XLSX file to the user's personal computer.

By using the "Browse" button on the panel "RedMarLitter Database File (* .XLSX)" the user selects the data file (see Fig. 6.20). The file name is displayed in the Progress information panel (see Fig. 6.21).

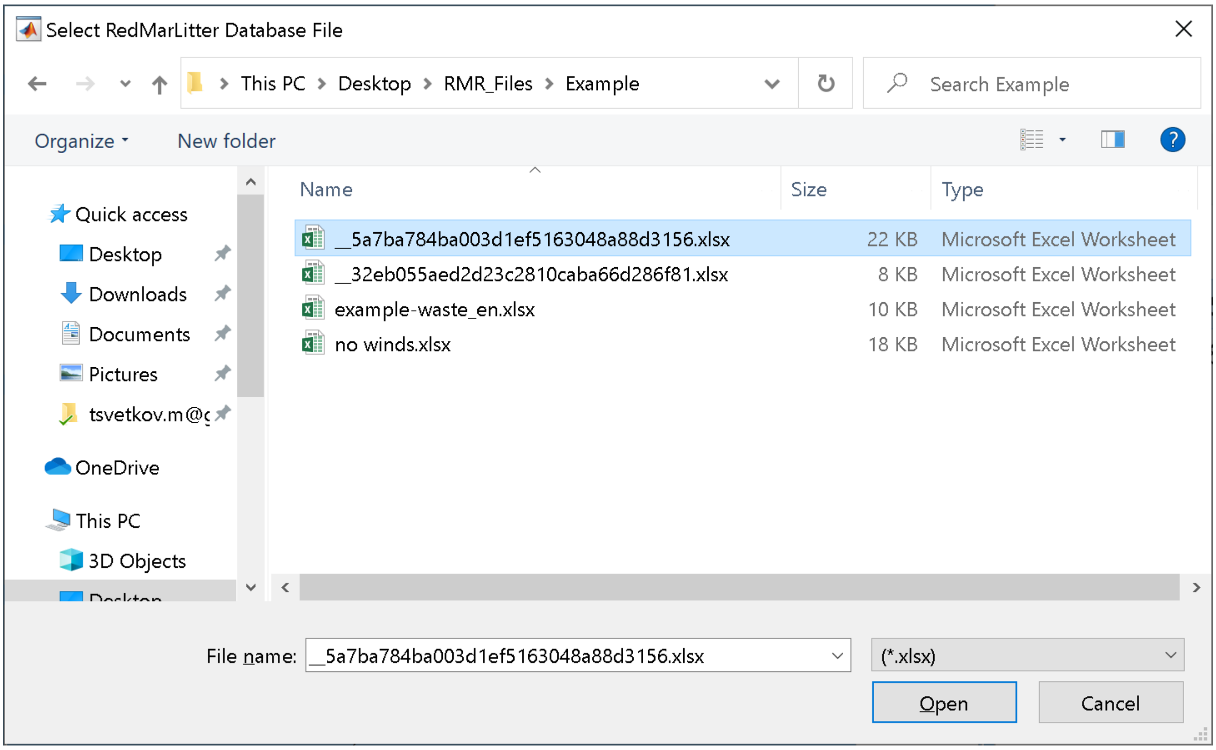


FIG. 6.20

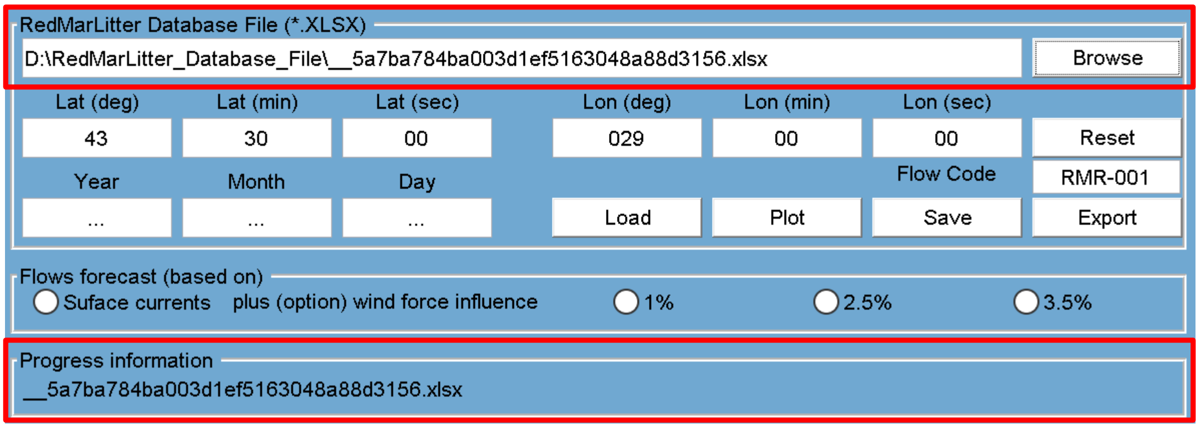


FIG. 6.21 The user sets the geographical coordinates of the starting position of the floating object for which the mathematical modeling will be performed and will calculate the trajectory under the influence of surface sea currents forming a water flow from the data downloaded from https: //map.redmarlitter. eu / en / database .

Using the "Load" button from the selected panel, the user loads the data from the downloaded file into the **RedMarLitter Interactive Map application**.

In the fields “Year”, “Month” and “Day” the data for the date to which the data for the direction and speed of the sea and air currents are visualized (see Fig. 6.22).

An information message also appears in the Progress information panel (see Fig. 6.22).

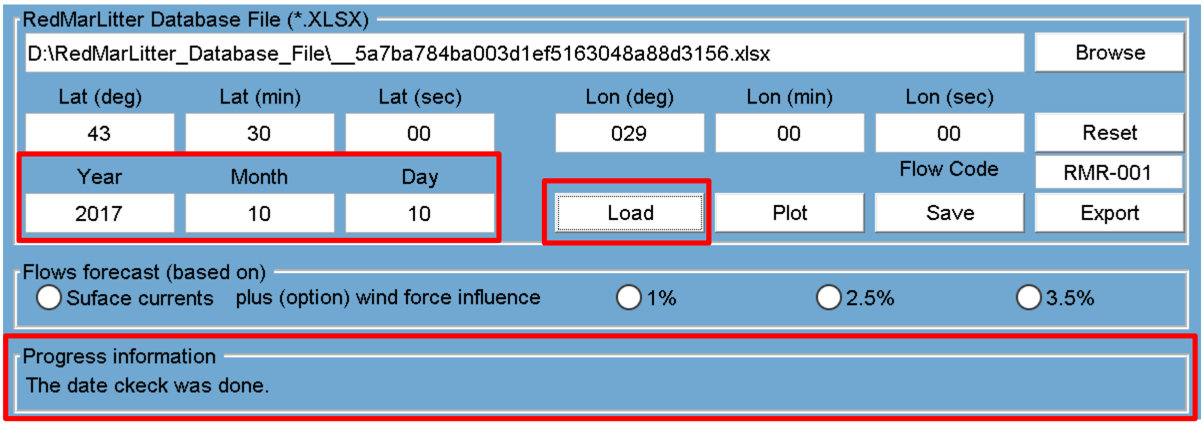
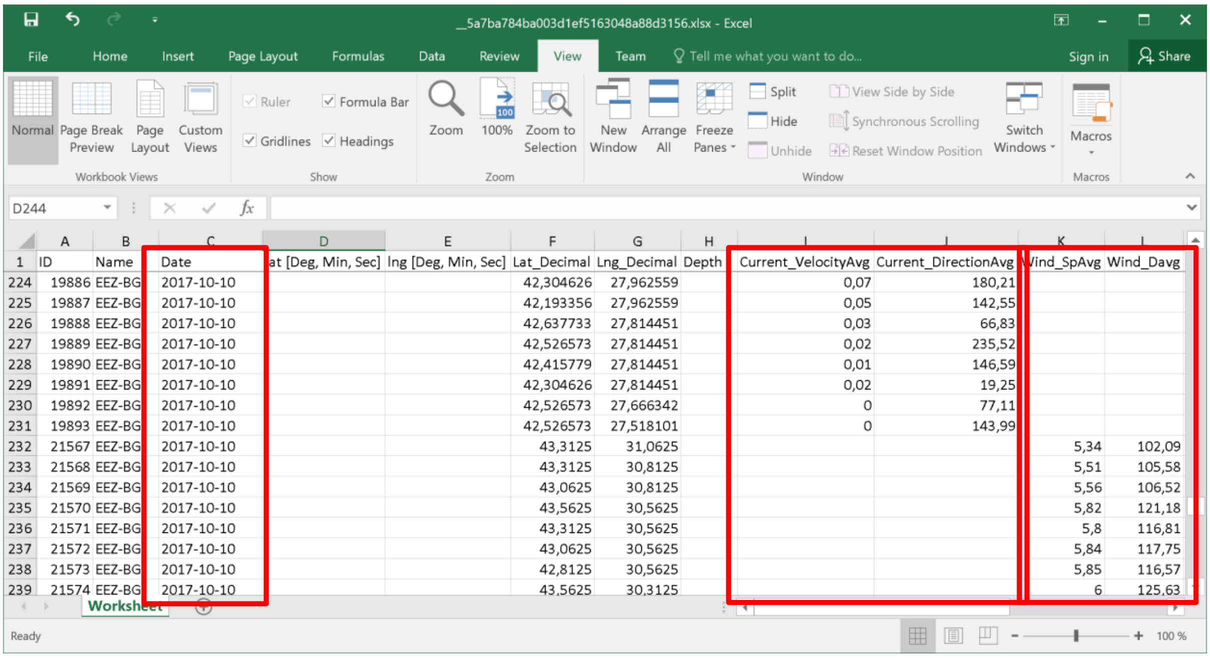


FIG. 6.22

Using the “Plot”, “Save” and “Export” buttons, the user starts the mathematical modeling, saves in raster format a georeferenced map depicting the results of the modeling and generates an export XLSX file, compatible with the open database of the RedMarLitter project and ready for import into https://map.redmarlitter.eu/en/database .

The data is stored in the same directory / folder as thedownloaded from https://map.redmarlitter.eu/en/database file with data on the direction and speed of the sea / air currents.

As noted earlier in the presentation, this panel can work in conjunction with the Flows forecast panel. The full functionality of this combination is achieved when the downloaded from https://map.redmarlitter.eu/en/database files contain direction and speed data for both sea currents and air currents (see Fig. 6.23). To be used as input for mathematical modeling, water and air flow data must have the required resolution and geospatial coverage (range).



	ID	Name	Date	at [Deg, Min, Sec]	lng [Deg, Min, Sec]	Lat_Decimal	Lng_Decimal	Depth	Current_VelocityAvg	Current_DirectionAvg	Wind_SpAvg	Wind_Davg
224	19886	EEZ-BG	2017-10-10			42,304626	27,962559		0,07	180,21		
225	19887	EEZ-BG	2017-10-10			42,193356	27,962559		0,05	142,55		
226	19888	EEZ-BG	2017-10-10			42,637733	27,814451		0,03	66,83		
227	19889	EEZ-BG	2017-10-10			42,526573	27,814451		0,02	235,52		
228	19890	EEZ-BG	2017-10-10			42,415779	27,814451		0,01	146,59		
229	19891	EEZ-BG	2017-10-10			42,304626	27,814451		0,02	19,25		
230	19892	EEZ-BG	2017-10-10			42,526573	27,666342		0	77,11		
231	19893	EEZ-BG	2017-10-10			42,526573	27,518101		0	143,99		
232	21567	EEZ-BG	2017-10-10			43,3125	31,0625				5,34	102,09
233	21568	EEZ-BG	2017-10-10			43,3125	30,8125				5,51	105,58
234	21569	EEZ-BG	2017-10-10			43,0625	30,8125				5,56	106,52
235	21570	EEZ-BG	2017-10-10			43,5625	30,5625				5,82	121,18
236	21571	EEZ-BG	2017-10-10			43,3125	30,5625				5,8	116,81
237	21572	EEZ-BG	2017-10-10			43,0625	30,5625				5,84	117,75
238	21573	EEZ-BG	2017-10-10			42,8125	30,5625				5,85	116,57
239	21574	EEZ-BG	2017-10-10			43,5625	30,3125				6	125,63

FIG. 6.23

In this case, the options from the "Flows forecast" panel can be selected (see Fig. 6.12) for the degree of influence of the air currents on the floating object.

Visualization of the results for 24 hour forecast (georeferenced map) with selected option: mathematical modeling based on sea currents plus 3.5% influence of air currents and geographical coordinates of the starting position of the surface floating object Latitude: 43deg. 30 min. 00 sec. North and Longitude: 029deg. 00min. 00sec. East is shown in fig. 6.24.

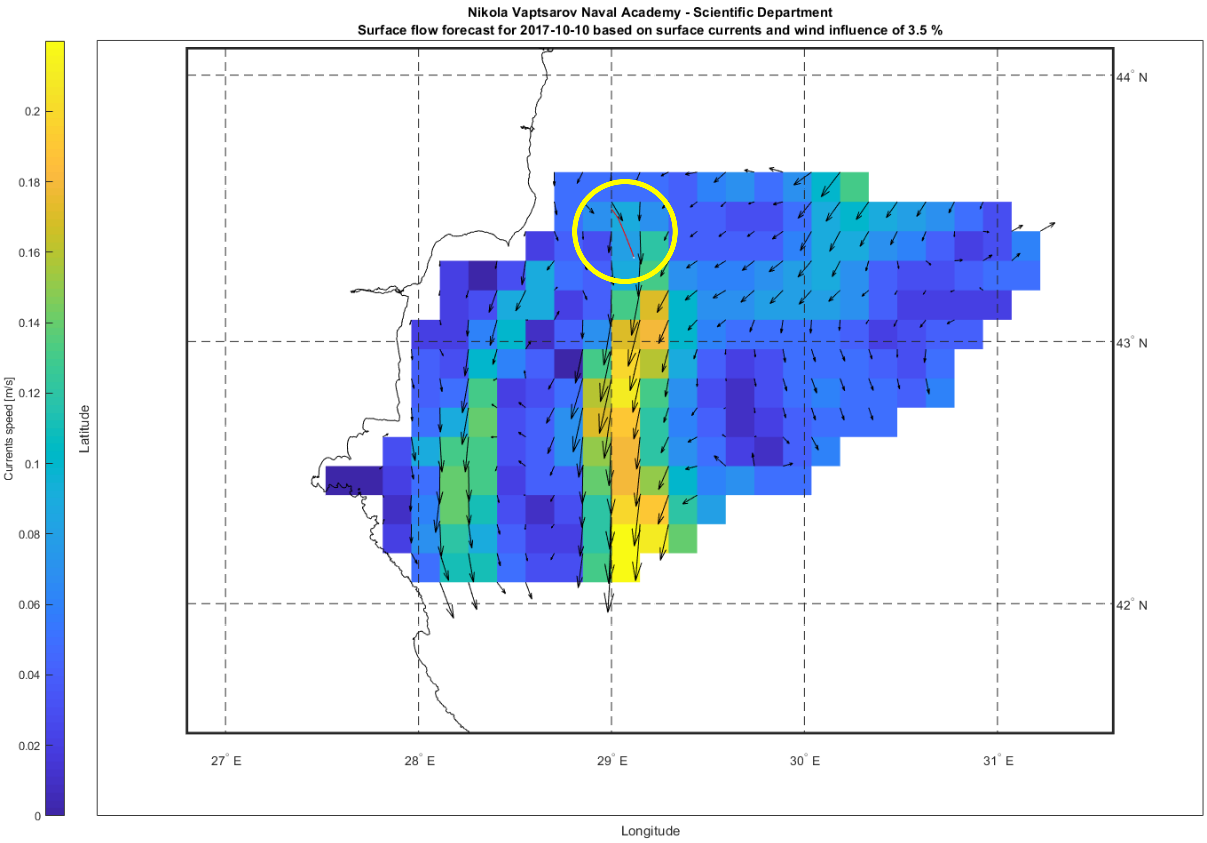


FIG. 6.24

Using the other panels: Progress Information Panel and Controls Panel, the user operates the standalone application.

An interactive computer model-map for the movement of pollutant flows under the influence of water and air currents is attached on an optical medium (Appendix 5) to this report.

7. **Conducting a study to identify and classify the most endangered coastal areas.**

The object of this analysis is the load of marine macro waste in the target area for the period 2015-2019 inclusive, and the impact of water and air flows on the movement and distribution of solid marine waste in the target area.

Data on 13 beaches were analyzed: 10 beaches, subject to national monitoring of marine litter deposited along the coast and 3 beaches monitored within the RedMarLitter project.

The surface sea currents in one with the air currents (height up to 10 m.) In the Bulgarian waters of the Black Sea, contributing to the spread of marine litter, are also analyzed.

In order to identify the most endangered coastal areas, the results obtained under item 1 "Identification of hotspots of solid marine litter pollution in the target area" shall be used: general analysis of the marine litter load in the target area; the developed scale for estimating the load of marine litter; the results of the extended analysis of the marine litter load in the target area (until 2019); identified hotspots of solid marine litter pollution in the target area; the digital virtual network developed within the framework of separate number 1 for reporting by an innovative method of the loading of the marine environment with solid waste.

The results of the mentioned studies have been submitted to the Assignor in previous reports for stage implementation under separate position 1. The

identification of the most endangered coastal areas cannot be performed only on the basis of the above results. It is also necessary to take into account: the analysis of the available sources of data on the direction and speed of sea currents in the surface layer (depth up to 5 meters); the analysis of the available data sources for the direction and speed of the air currents (height up to 10 m); the analysis of the available sources of information on the loading of solid marine litter in the target area, including the one collected through a study for such under this project; the developed algorithms and software code for import and processing of the collected data for derivation of models of water flows in the surface layer and models of motion distribution and waste distribution; developed algorithms and software code for creating an interactive computer model-map for the movement of pollutant flows under the influence of water and air currents, developed in the framework of OP-2 of this study project RedMarLitter.

In order to identify and categorize the most endangered coastal areas in terms of the load of marine litter in the target area, an assessment is performed according to **two criteria**:

1. **Influence of surface sea and air currents on the trajectories of floating marine litter;**
2. **Loading of marine macro waste on the coastal areas**;

The two criteria are considered to have equal relative weight in identifying and classifying coastal areas at risk of pollution.

The Rule applies **one out - all out**. Thus, the assessment is performed according to the criterion that shows the most unfavorable significance.

Regarding the reporting of the influence of surface sea and air currents on the disposal of marine litter and taking into account the obtained data on the density of distribution of simulated floating solid waste in the target area, a three-level scale is proposed to determine the degree of threat to coastal areas (low, medium and high risk).

Table 7.1

Assessment	**Scale levels**		
Qualitative assessment	Poorly endangered	Medium endangered	Highly endangered
Quantitative assessment -density distribution(average-annual)	from 1 to 5	from 5 to 12	over 12
Quantitative assessment / value by criterion 1	1	2	3

Regarding the reporting of the existing load of marine macro-waste of the coastal areas on their endangerment (criterion 2) a scale for classification of the endangered coastal areas in the target area is developed, developed on the basis of the index of the density of the marine waste - MLDI. The scale is 3-level and includes the following qualitatively and quantitatively defined levels: low risk (MLDI = 5 ÷ 8), medium risk (MLDI = 8 ÷ 11) and high risk (MLDI = 11 ÷ 20).

The scale for assessment and categorization of endangered coastal areas in the target area, based on the value of the load with marine macro-waste is presented in Table 7.2.

Table 7.2. Scale for assessment and categorization of endangered coastal areas (Bulgaria) by criterion 2

Assessment	Degrees of the scale		
Qualitative assessment	**Low endangered**	**Medium endangered ***	**Highly endangered ***
Quantitative assessment / value of MLDI	**MLDI = 5 ÷ 8**	**MLDI = 8 ÷ 11**	**MLDI = 11 (20**
Quantitative assessment / value by criterion 2	**1**	**2**	**3**

**** when not classified as hotspots***

For the target area, with a marine litter density index MLDI above 20 we assume (critical load) that the area is a hot spot of solid marine litter pollution.

For the target area with anvalue MLDI in the range of 10 ÷ 20, achieved by at least 2 observations on an annual basis in different seasons, it can be concluded that the area is a hot spot of pollution.

The target territory in value MLDI in the range 10 ÷ 20 achieved only at an observation (especially if this is the first observation of a given territory), it not can make definite conclusion that the area is a hotspot of contamination. This is due to the uncertainty regarding the period of waste accumulation and the rate of increase of the quantities. Such areas will require further monitoring and further analysis.

Medium and heavily congested areas are threatened to varying degrees by becoming hotspots for marine litter pollution.

The scale for classification of endangered coastal areas under Criterion 2 should be applied together with the scale for load assessment and after identification of hotspots of marine waste pollution in the target area. The full correlation between MLDI values, categorization of endangered coastal areas and values under criterion 2 is presented in Table 7.3.

Table 7.3. Evaluation criterion 2

Evaluation		Degrees of scale			
Qualitative assessment	Least	Poor endangered	average threatened *	Highly endangered *	Hot spot
Quantification / value MLDI	MLDI <5	MLDI = 5 ÷ 8	MLDI = 8 ÷ 11	MLDI = 11 ÷ 20	MLDI = 20 ÷
Quantitative assessment / value by criterion 2	0	1	2	3	4

**** when not classified as hotspots***

7.1. Analysis and assessment of the impact of surface sea and air currents on the trajectories of floating marine litter

The study to identify and classify the most endangered coastal areas was conducted with the developed interactive computer model-map for the movement of pollutant flows under the influence of water or air currents, simulations of different scenarios based on variation of the input parameters and out of phase (to take into account the seasonal features of marine, respectively air currents in the target area) and space (to take into account the influence of geographical distribution we of waste).

The scenarios cover the performance of simulations in the target area for each month for the period 2015-2018, taking into account the month-specific data on the direction and speed of sea and air currents, thus taking into account their seasonality.

On the summarized data is applied mathematical processing to determine the density of the distribution of simulated floating solid waste in the target area, using the developed in OP-1 digital virtual network for reporting by an innovative method of loading the marine environment with solid waste.

The obtained density data are plotted on a georeferenced map shown in Figure 7.1 and attached (Appendix 6) to this report.

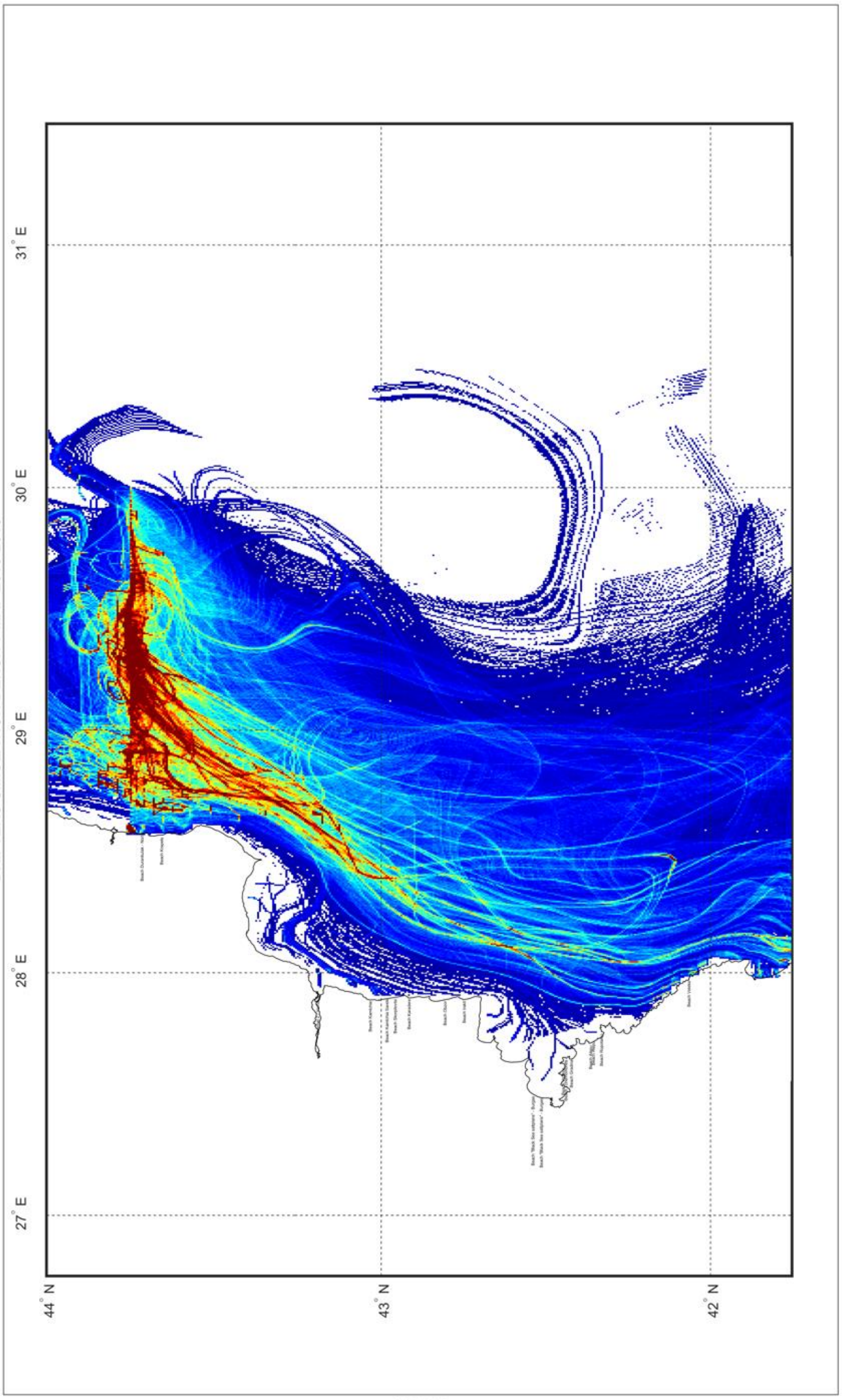


FIG. 7.1 Density map of the distribution of simulated floating solid waste in the target area

Based on the obtained data, an assessment of the degree of threat to the coastal areas is performed, based on criteria 1. The assessment according to criteria 1 is shown in Table 7.4

Table 7.4 Classification of endangered coastal areas by criteria 1

№	Beach	Degree on the scale by criteria 1
1.	Durankulak beach north	3
2.	Krapets beach	2
3.	new channel Varna lake - Black Sea	0
4.	Shkorpilovtsi beach north	1
5.	Byala beach - Karadere	1
6.	Obzor beach - children's camp	0
7.	Irakli beach	0
8.	beach near the Black Sea salt pans	0
9.	Aleppo beach	0
10.	beach at the mouth of the Veleka river	2
11.	beach north of the Black Sea salt pans - Burgas	0
12 .	beach at Gulf Vromos	0
13.	Alepu beach - between Holiday Village Dunes et al. Dunes South	0

7.2. Analysis and assessment of the marine macro waste in coastal areas (based on MLDI).

The *Marine Waste Density Index* - *Marine Litter Density Index (MLDI)* *(Toneva & Simeonova) is applied***,** which is calculated by the ***formula:***

$$MLDI = D_{av} K$$

Where:

D_{av} *- average density of waste from the main groups of materials* "Artificial polymeric materials", "Paper / Cardboard", "Treated wood" and "Metal" *for one monitoring campaign for the area of interest, [pcs./m²].*

K *- coefficient,* with accepted value **20** (for the needs of statistics)

The relation between the range of D_{av} and ***MLDI*** and assessment of the load area of marine litter**is** presented below (Table 7.5).

Table 7.5. Correlation between waste density, Marine waste density index and marine waste load assessment (*Toneva & Simeonova)*

D_{av} [pcs / m²]	*MLDI*	Estimate
D_{av} = 0 ÷ 0,1	***MLDI*** = 0 ÷ 2	**unloaded zone**/ zone with negligible load
D_{av} = 0.1 ÷ 0.25	***MLDI*** = 2 ÷ 5	**low load zone /** low load zone
D_{av} = 0,25 ÷ 0,5	***MLDI*** = 5 ÷ 10	**medium load zone /** medium load zone
D_{av} = 0,5 ÷ 1	***MLDI*** = 10 ÷ 20	**heavy load zone /** zone with heavy load
D_{av} ≥ *1*	***MLDI*** = 20 +	**critically loaded area /** area with critical load

The Marine Waste Density Index (MLDI) is calculated for the following 13 beaches on the Bulgarian Black Sea coast for the period 2015-2019:

- Beaches included in the national institutional monitoring of marine litter deposited along the coast: *Durankulak Northbeach, Krapets beach, new Varna Lake-Black Sea canal, Shkorpilovtsi north beach, Byala-Karadere beach, Obzor children's camp beach, Irakli beach, beach near the Black Sea salt pans, Aleppo beach , beach at the mouth of the Veleka River*
- Beaches, subject to monitoring of marine macro waste within the RedMarLitter project: *beach north of the Black Sea salt pans - Burgas, beach at Vromos Bay, Aleppo beach - between v.s. Dunes et al. Dunes South.*

The MLDI values by years for the indicated beaches are presented in Table 7.6

Table 7.6 MLDI by beaches and years,2015-2019.

№	Beach / Beach	MLDI by years / MLDI by year				
		2015	**2016**	**2017**	**2018**	**2019**
1.	**Durankulak north beach**	1.50	0.62	8.68	1.04	1.42
2.	**Krapets beach**	1.38	0.40	2.85	1 , 63	1.74
3.	**new canal Varna Lake - Black Sea**	7.47	7.01	64.44	40.73	23.96
4.	**Shkorpilovtsi beach north**	1.25	0.62	5.92	2.48	1.80
5 .	**Byala- Karadere beach**	na	na	5,94	2,26	2,43
6.	**beach Obzor- camp**	1.44	1.68	9.23	4.39	3.35
7.	**beach Irakli**	1.24	2.63	4 25	3.18	1.42
8.	**beach near the Black Sea salt pans**	2.20	1.97	3.37	3.51	2.51
9.	**Aleppo beach**	0.99	0.45	2.32	1.18	1.93
10.	**beach at the mouth of the river Veleka**	na	na	2.72	3.27	1.82
11.	**beach north of the Black Sea salt pans - Burgas**	na	na	na	na	8.19
12.	**beach at the bay Vromos**	na	na	na	na	11.35
13.	**Aleppo beach - between v.s. Dunes et al. Dunes South**	na	na	na	na	3.26

* na = not available

Of these beaches identified as **hot spots** (OP-1) are the following:

- **new channel Varna Lake - Black Sea**
- **beach at Vromos Bay**

Table 7.7 presents the estimates for criterion 2 for the analyzed beaches in the target area for the period 2015-2019.

Table 7.7. Evaluation by criterion 2 for beaches,2015-2019.

№	Beach	Score by criterion 2				
		2015	**2016**	**2017**	**2018**	**2019**
1.	**Durankulak beach north**	**0**	**0**	**2**	**0**	**0**
2.	**Krapets beach**	0	0	0	0	0
3.	**new channel Varna Lake - Black Sea**	**1**	**1**	**4**	**4**	**4**
4.	**Shkorpilovtsi beach north**	0	0	**1**	0	0
5.	**Byala- Karadere beach**	na *	na	**1**	0	0
6.	**Obzor beach - children's camp**	0	0	**2**	0	0
7.	**Irakli beach**	0	0	0	0	0
8.	**beach near the Black Sea salt pans**	0	0	0	0	0
9.	**Aleppo beach**	0	0	0	0	0
10.	**beach at the mouth of the Veleka river**	na	na	0	0	0
11.	**beach north of the Black Sea salt pans - Burgas**	na	na	na	na	**2**
12.	**beach at Vromos bay**	na	na	na	na	**4**
13.	**Aleppo beach - between v.s. Dunes et al. Duni South**	na	na	na	na	0

* na = not available

A complex analysis of the threat to the coastal areas in the target area has been performed based on the assessments under criteria 1 and 2 when applying the one out-all out rule. The results are presented in Table 7.8.

Table 7.8. Comprehensive assessment of the threat to the coastal areas in the target area

№	Beach	Score by criterion 1	Score by criterion 2					Score
			2015	2016	2017	2018	2019	
1.	**Durankulak North beach**	**3**	0	0	2	0	0	Highly endangered
2.	**Krapets beach**	**2**	0	0	0	0	0	Average endangered
3.	**new canal Varna Lake - Black Sea**	0	1	1	**4**	**4**	**4**	Hot spot
4.	**beach Shkorpilovtsi north**	**1**	0	0	**1**	0	0	Slightly endangered
5.	**beach Byala - Karadere**	**1**	na *	na	**1**	0	0	Slightly endangered
6.	**beach Overview - children's camp**	0	0	0	**2**	0	0	Moderately endangered
7.	**Irakli beach**	0	0	0	0	0	0	Not endangered
8.	**beach near the Black Sea salt pans**	0	0	0	0	0	0	Not endangered
9.	**Aleppo beach**	0	0	0	0	0	0	Not endangered
10.	**beach at the mouth of the Veleka River**	**2**	na	na	0	0	0	Moderately endangered
11.	**beach north of the Black Sea salt pans - Burgas**	0	na	na	na	na	**2**	Moderately endangered
12.	**beach at Vromos Bay**	0	na	na	na	na	**4**	Hot spot
13.	**Aleppo beach - between v.s. Dunes et al. Dunes South**	0	na	na	na	na	0	Not endangered

* na = not available

7.3. Conclusion

Based on conducted a comprehensive analysis by **highly threatened** in certain coastal areas in the target area:

- **beach Durankulak North (score 3 Criterion 1)**

As a **medium threatened** identify these coastal areas in the target area:

- **Krapets beach (score 2 by criterion 1)**
- **Obzor beach - children's camp (score 2 by criterion 2)**
- **beach at the mouth of the Veleka river (score 2 by criterion 1)**
- **beach north of the Black Sea salt pans - Burgas (score 2 by criterion 2)**

The following coastal areas in the target area are defined as **slightly endangered**:

- **Shkorpilovtsi North beach (score 1 by criteria 1 and 2)**
- **Byala - Karadere beach (score 1 by criteria 1 and 2)**

Georeferenced map of the most endangered coastal areas is presented in Figure 7.2 and attached on a large scale (Annex 7) to this report.

On the map, the so-called hotspots are marked with a red circle, the endangered coastal areas with a red square, the medium endangered coastal areas with a yellow square, the endangered coastal areas with a green square, and the coastal areas, which have been monitored, but the data obtained under criteria 1 and 2 show that they are not endangered, are marked with a white square.

Nikola Vaptsarov Naval Academy - Scientific Department
Georeferenced map of endangered coastal areas

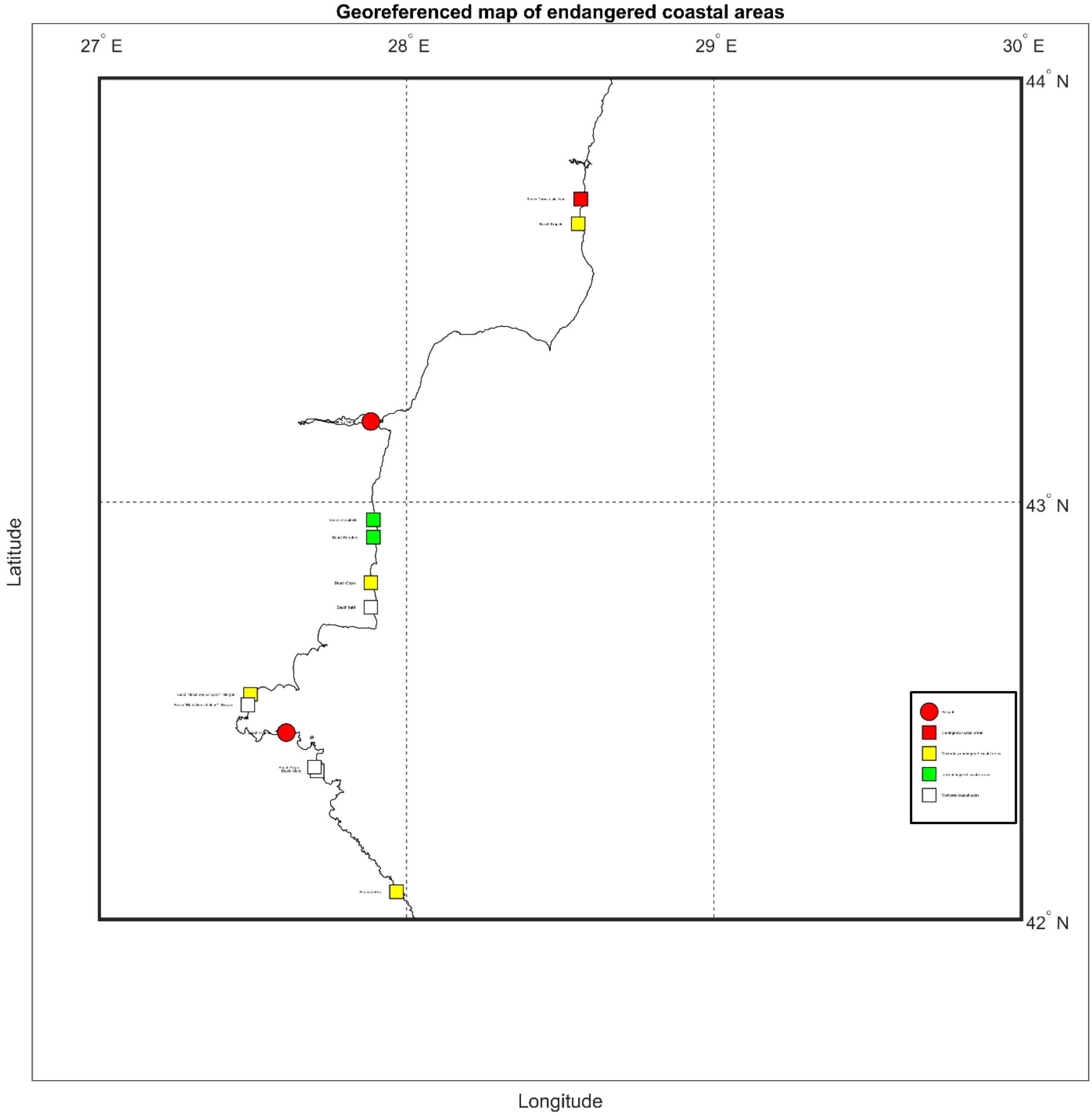


FIG. 7.2 Georeferenced map of the most endangered coastal areas

8. **Publication of the identified most endangered coastal areas in the open project database.**

Georeferenced maps reflecting the identified most endangered coastal areas are presented in electronic form so that they can be published on the project website.

The data for the identified most endangered coastal areas (geographical coordinates and scale assessment) are prepared in a form allowing integration into the open database of the project (https://map.redmarlitter.eu/bg/database/) in the specified format through the interface for manual entry of waste data in the project database at the Internet address (https://map.redmarlitter.eu/bg/profil-tablo/rchno-dobaviane/otpadtsi) shown in Figure 8.1

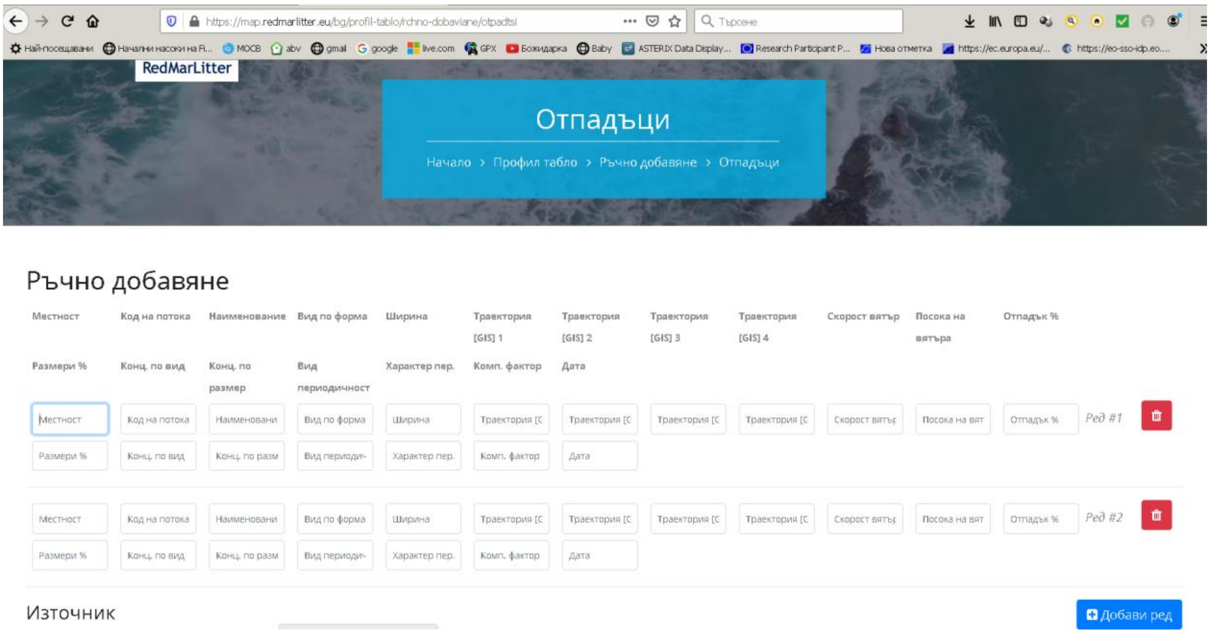


Fig. 8.1 Interface for manual data entry in the open database of the project

In addition, information products compatible with the information system (https://map.redmarlitter.eu/en/database/) in accordance with the formats under the manuals "RedMarLitter Database Working with the platform" and " Black Sea Waste Database Information " are presented as follows:

- Collected data on the direction and speed of sea and air currents - in the format of "Import XLSX - Currents". The format includes the following parameters (in Bulgarian or

English): *ID, Name, Date, Width [Degrees, Minutes, Seconds] Length [Degrees, Minutes, Seconds] Width_Decimal, Length_Decimal,Depth,Current_VelocityAverage, Current_DirectionAverage, Wind_VelocityAverage, Wind_Direction, Status_Water, Waves_Direction;*

- Derived models of water flows in the surface layer - in the format for "Import XLSX - Waste", field "Trajectory - GIS data - connection to metadata files", according to the above manuals;
- Derived models of traffic distribution and waste distribution - in the format for "Import XLSX - Waste", field "Trajectory - GIS data - connection with metadata files", according to the above-mentioned manuals;

This report was prepared by Nikola Vaptsarov Naval Academy in implementation *of the public procurement "Selection of a contractor for identification of hot spots and modeling of the distribution of solid marine waste in the target area (Bulgarian Black Sea coast)"***,** for **separate position 2 "Model of water flows and distribution of solid waste in the target area"** *with contracting authority "VIA PONTIKA" Foundation*