The Fourteenth MEDCOAST Congress on Coastal and Marine Sciences, Engineering, Management and Conservation

MEDCOAST 19
22 - 26 October 2019
Grand Yazici Club Turban Hotel,
Marmaris, Turkey

Organized by:

Mediterranean Coastal Foundation
# TABLE OF CONTENTS

**VOLUME I**

**Integrated Coastal Management, Ocean and Coastal Governance**

- Legal Aspects of Greek ICM & MSP: Review & Analysis
  - Z. I. Konstantinou and D. Latinopoulos .................................................. 1
- Satoumi and ICM
  - T. Yanagi ........................................................................................................ 13
- A Study of Multi-level Management System for Coastal Areas by Network Governance
  - T. Hidaka ........................................................................................................ 23
- Implementing the 1st MSFD Cycle in the Mediterranean: Lessons Learnt
  - T. Paramana, O. Chalkiadaki, G. Katsouras and M. Dassenakis ..................... 33
- Construction of Regional Environmental Governance in Seas of East Asia
  - X. Gao and K. Furukawa ................................................................................ 45

**Coastal Management Tools & Instruments**

- OPENCoastS: on Demand Forecast Tool for Management
  - M. Rodrigues, J. Rogeiro, S. Bernardo, A. Oliveira, A. B. Fortunato, J. Teixeira,
    P. Lopes, A. Azevedo, J. Gomes, M. David and J. Pina .................................... 57
- High Resolution Information Services at Sea
  - G. El Serafy, A. Spinosa, A. Mangin, A. Silva, S. van Dam, D. Pape, R. C. Peris
    and E. Geropanagiotis .................................................................................... 69
- Conceptual Modelling of Heterogeneous Data for Geoinformation Systems
  - L. Lomakina, A. Sarkova, D. Zheverchuk, S. Skorynin, I. Chernobaev,
    A. Subbotin, D. Gordeev, S. Romanov and M. Sementsov ................................ 77
- ODYSSEA: Operating Integrated Observatory Systems
  - G. El Serafy, L. Meszaros, S. Wanke and G. Sylviaos ....................................... 89
- Identification of Result Processing Systems for Ecosystem Monitoring
  - L. S. Lomakina, D. V. Zheverchuk, A. S. Sarkova, A. S. Zakharov, O. S.
Use of Remote Sensing for Coastal Management

Analysis of Coastal Zone by Using UAV Data
E. Boyko, A. Pogorelov and T. Volkova .......................................................... 113

The Current State of the Azov Sea Coastal Zone based on Landsat Data
O. E. Arkhipova ................................................................. 121

Monitoring and Analyses of Black Sea Coastline Relief by ALS and UAV
E. Boyko and A. Pogorelov ........................................................................... 131

Use of Satellite Data in Marine Early Warning System
M. Dimitrova, V. Galabov, A. Kortcheva and J. Marinski ......................... 139

Various Coastal Management Issues

Building with Nature, a Promising Strategy in Coastal Management
F. van der Meulen, Ç. Coskun Hapcan, H. Alphan and R. van Zetten .......... 151

Environmental Indicator Approach for Dredging
J. Lednova, G. Gogoberidze, V. Zhigulsky, M. Shilin and A. Chusov .......................... 161

A New Paradigm for UK Water Safety
A. T. Williams and C. Nelson ................................................................. 173

HES Indicator of the Coastal Zone of the Sea of Azov
O. Arkhipova and E. Chernogubova ......................................................... 183

Coastal Resources Management

Management of the Nile Delta Ground Water Aquifer
M. Moawad and M. Abd-El-Mooty ............................................................. 191

Bycatch in Pelagic Trawling off the Western Coasts of the Black Sea
E. Petrova, V. Mihneva, F. Tserkova, S. Valchev and A. Hyusein .............. 203

Sea Ports in the Sustainable Development of the Azov-Black Sea Coast
A. Turluchev, A. Filobok, T. Volkova and A. Ponomarenko ...................... 215

Marine Aggregates Deposits of Kissamos Bay, Crete, Greece
M. Anastasatou, A. Karditsa, S. Petrakis, A. Tsoutsia, V. Kapsimalis, P. Fourakis,
T. Hashiotis, G. Rousakis, A. Evangelopoulos, S. Poulos and M. Stamatakis ...... 221
Use of Satellite Data in Marine Early Warning System

Marieta Dimitrova\textsuperscript{(1)}, Vasko Galabov\textsuperscript{(1,2)}, Anna Kortcheva\textsuperscript{(1,3)} and Jordan Marinski\textsuperscript{(1,4)}

\textsuperscript{(1)} National Institute of Meteorology and Hydrology, 1784 Sofia, Bulgaria
\textit{E-mail: marieta.dimitrova@meteo.bg}
\textsuperscript{(2)} \textit{E-mail: vasko.galabov@meteo.bg}
\textsuperscript{(3)} \textit{E-mail: anna.kortcheva@meteo.bg}
\textsuperscript{(4)} \textit{E-mail: jordan.marinski@meteo.bg}
\textit{Tel: +359-886-314-724 Fax:+359-2-988-4494}

Abstract

Accurate and timely prediction of extreme weather events is crucial for sea safety and for successful decision-making and planning of operations to combat potential pollution of coastal areas and to protect the environment. This paper shows the results of improving the performance of NIMH early warning marine forecasting system via use of remote sensing technology for verification of numerical wind and wave forecast in the Black Sea. Satellite altimeter wind and wave data from Jason-2, Jason-3, and SARAL AltiKa and scatterometer wind data from MetOP ASCAT-B are used for the statistical evaluation of the marine forecasts and calibration of the operational wave models. This approach minimizes errors in the wave data from deep waters, allowing better boundary wave conditions for high-resolution grids in coastal regions. Analysis of the statistical data shows that the SWAN model provides an effective framework for prediction of the wave conditions in the Black Sea area and the coastal environment. Further the advanced GIS and WEB-based technologies are highly effective in all phases of disaster management cycle. Capabilities of a WEB GIS are demonstrated by the visualization of the sea state forecast provided by the SWAN. The SWAN wave model produces its output (significant wave height) in a NetCDF format that allows import, further processing and dynamical visualization in GIS. The results of numerical simulation technologies used in marine forecasting will be applied during integrated training activities within the ECOPORTIL project.
**Introduction**

The western part of the Black Sea area is subject to high navigation conditions and there is an increased risk of marine accidents that could lead to a strong environmental impact (Rata et al, 2017). The environmental impact of oil accidents is enormous both on aquatic ecosystems (offshore and coastal waters) and on the coastal environment. Strong winds, high waves and currents contribute to the creation of accidents and the spread of spills over wide areas. In addition, strong storms in the western part of the Black Sea pose a real danger to shipping as well as many other human activities in the coastal zones.

Accurate and reliable forecasting of sea conditions and timely early warning on severe weather, are an efficient tool for use in search and rescue, improving the safety and efficiency of offshore operations or pollutant spill operations at sea. Numerical modelling is a powerful tool for analysis and forecasting of extreme weather and marine events in the coastal zone of the Black Sea (Akpinar et al, 2016, Galabov et al, 2015, Kortcheva et al, 2018) that can be used for disaster risk reduction namely in terms of vulnerability and risk management for people, sea ports equipment, coastal infrastructure and environment. The operational marine forecasting system of the National Institute of Meteorology and Hydrology (NIMH) for the Black Sea is based on state of the art numerical models: numerical weather prediction model (NWP) ALADIN, wave models SWAN and WAVEWATCH III and the Meteo-France storm-surge model (Mungov and Daniel, 2000). From this system warning information on extreme weather events (strong winds, high waves and storm-surges) along the Bulgarian Black Sea coast is delivered to end-users and incorporated into a publically available European early warning alert system Meteoalarm on the website of NIMH freely accessible by the public. Using the Marine Forecasting System, NIMH is able to provide forecast of wind, waves, storms and distribution of pollutants in the Black Sea area.

Accurate prediction of the sea-state is absolutely necessary to minimise risk at sea. It needs to be noted that the number of marine surface observations along the Bulgarian Black Sea coast is sparse and the assessment of wave model performance is often not possible due to the lack of wave observations. Remote-sensed data is becoming important in the verification of wave models in the Black Sea area (Kortcheva et al, 2000, Akpinar et al, 2016, Dimitrova et al, 2013, Myslenkov et al, 2016, Rusu et al., 2014) and improvement of the accuracy of the operational numerical wind and wave forecasts and hindcast applications (Abdalla, 2015, 2017, Arkhipkin et al., 2014, Galabov et al, 2015). Scatterometers and altimeters provide important sources of near real-time marine wind and wave data. In this paper, gridded wind fields at 10 m above sea surface from ASCAT Metop-B and winds and significant wave height (SWH) data sets provided by three altimeter missions Jason2, Jason-3 and SARAL AltiKa satellites are used for the validation of atmospheric and wave models for the Black Sea basin.

This paper is organised as follows: satellite data and numerical models are briefly presented in Section 2, results of verification experiments are summarized in Section 3, and Section 4 summarizes key points of discussion and links the purpose of the paper to European and national legislation on the protection of marine environment and sustainable development of coastal zones.
Fig. 1: SWH from Jason-2, Jason-3 and SARAL AltiKa satellites tracks on 29.11.2018 over the Black Sea (up); SWAN SWH and mean wave direction at 02 hr UTC and Jason-3 along-track SWH on 29.11.2018 at 01 h 48 min hr UTC.

Data and Methods

Altimeter wind and wave data

The altimeter wind and wave data from Jason-2, Jason-3 and SARAL AltiKa satellites is received at NIMH in near real time (NRT) through the World Meteorological Organization (WMO, 1998) network GTS (Global Telecommunication System). The
European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) distributes the wind speed (WS) at 10m above the mean sea level and the significant wave height (SWH) as the operational geophysical data records (OGDR)-in BUFR format. European Centre for Medium Range Weather Forecast (ECMWF) encoding and decoding tools were used to convert the OGDR-BUFR data to ASCII format. The wind and wave data provided by the three altimeter missions mentioned above is passed through a quality control process according to the products handbooks (i.e., Jason-3, 2016) and the best quality data is selected for the study after applying the editing criteria for Jason-2, Jason-3 and SARAL AltiKa altimetry. Fig. 1 shows the daily coverage of satellite altimeter ground tracks over the Black Sea on 29 November 2018 (left) and Jason-3 along the track SWH on 29.11.2018 at 01 h 48min hr UTC (right).

**Scatterometer wind data**

Scatterometers provide estimates of wind by emitting microwaves and measuring radar cross section. In addition to the altimeter along track measurements, they provide estimates of 10 m wind speed and direction over a larger geographical region. Advanced Scatterometers ASCAT on board of polar orbiting Meteorological Operational satellite MetOP-B launched by the EUMETSAT, are the principal source of surface wind speed and direction data over the global ocean (ASCAT, 2015). We used the Royal Netherlands Meteorological Institute (KNMI), Global Wind Level-3 ASCAT 12 km coastal wind product downloaded from the CMEMS website (CMEMS, 2019). The ASCAT observations over the Black Sea are taken two times daily due to ascending swaths (between 17.00 and 20.00) and descending swaths between 06.00 and 09.00 UTC, (Fig. 2). The near real time daily and reprocessing L3 wind products contains gridded L2 scatterometer wind vector observations and allows for direct use without preliminary manipulation (ASCAT, 2015).

Scatterometer observations are widely used in the Numerical Weather Prediction NWP (Abdalla et al, 2017) for wind monitoring over the oceans, validation, assimilation and re-calibration of the NWP models. The ASCAT wind product represents an equivalent neutral wind speed at 10 m, in contrast within ALADIN, which are stability-dependent wind speeds, or actual wind. The scatterometer measurements should be interpreted as equivalent neutral winds. The neutral stability correction is most significant near the shore and the effect is of around 0.1m/s for the final statistics (Sikiric et al, 2015). We compare the scatterometer wind fields directly with the ALADIN model results and assume the neutral atmospheric stability. The scatterometer data were chosen with a minimal time difference (less than one hour) between the ALADIN model and ASCAT winds. In the second step the atmospheric model wind components were interpolated to the scatterometer observation locations using the bilinear interpolation method. Fig. 3 shows the ALADIN wind field over the Black Sea on 29.11.2018 and comparison between the ALADIN and scatterometer data. Comparison of the gridded wind data measured by the ASCAT satellite scatterometer and wind forecast of the numerical weather prediction model ALADIN over the Black Sea region is a current NIMH activity to prepare the scatterometer data for assimilation into the ALADIN model.
Fig. 2: Surface wind fields from Metop-B/ASCAT-descending swath measurements over the Black Sea on 29.11.2018 at 07.00 (left) and at 19.00 UTC ascending swath (right).

Fig. 3: ALADIN wind fields over the Black Sea on 29.11.2018 at 07 UTC. (up) and differences between ALADIN and wind speeds from ASCAT Metop-B (down).
Wave and atmospheric models

The operational system of NIMH for wind wave forecast in the Black Sea area is based on the SWAN (Simulating Waves NearShore) numerical spectral model (Booij et al. 1999). SWAN resolves the action balance equation with a full discrete two-dimensional wave spectrum. The model accounts for wave propagation in time and space, shoaling, refraction due to current and depth, frequency shifting due to currents and non-stationary depth and represents the processes of wave generation by wind, dissipation due to white-capping, bottom friction and depth induced wave breaking and non-linear wave-wave interactions (both quadruplets and triads) explicitly with state-of-the-art formulations (SWAN, 2019). SWAN is running operationally for the Black Sea (Galabov et al, 2012) twice a day at 06 and 18h UTC and produces main wave parameters 72 hours ahead with a grid spacing of 1/30°. The SWAN wave model is forced by the 3-hourly winds from the ALADIN model.

The numerical weather prediction model ALADIN (Bogatchev, 2008) is a hydrostatic limited area numerical weather prediction model. The 0.125x0.125 degree ALADIN spatial latitude/longitude grid covers the whole Black sea domain from 27 to 42 degrees east in longitude and 40 to 47 degrees north in latitude. The lateral boundary conditions are obtained from the global numerical weather prediction model ARPEGE of Meteo-France. The model is running every 12 hours at 06 and 18 h UTC and provides 3-hourly atmospheric forcing for the Marine operational system of NIMH for 72 h ahead over the Black sea area. The available data for marine forecasts are: wind speed and direction at 10 m above the sea surface and atmospheric pressure at the sea level.

Various validation tests were performed on the SWAN and ALADIN models, taking into account all available wind and wave data from the satellites. The most critical factors for increasing the reliability of the wave predictions are related to the calibration of the physical parameters of the SWAN model and to the accuracy of the wind fields used for the forced wave model. The SWAN wave model produces an output of wave parameters in NetCDF format that allows import, further processing and dynamical visualization in WEB-based GIS and supports the development of an innovative Black Sea monitoring system (MISBS, 2016, Kortcheva et al, 2017) and the implementation of the European Directive INSPIRE for establishing an Infrastructure for Spatial Information in the European Community (Directive 2007/2/EC,2007).

Results and Discussion

In the last years various studies (Van Vledder et al, 2015, Galabov et al, 2015, Rusu, 2014) have been performed to analyse the accuracy of the SWAN wave model performance in the Black Sea area using satellite-derived altimeter data. These studies used reprocessed and fully controlled AVISO (Archiving, Validation and Interpretation of Satellite Oceanographic) data .We used OGDR NRT products that do not contain all the environmental/geophysical corrections. To quantify the SWAN model performance, the wave model results were evaluated against the altimeter measurements from the above mentioned missions over the entire area of the Black Sea for the period of one year, from 1 January to 31 December 2018. The collocation data were used to compute the statistics. To match the model and altimeter data, hourly model SWH within 60 min of the altimeter
collection time were spatially interpolated from the SWAN grid points to the locations of the altimeter measurements along the satellite tracks, and in time to fit the time of the satellite passage. The statistical parameters used below are the bias, the RMS error, and the scatter index. The results are presented in Table 1. The model is generally with negative bias, reaching the highest values for stormy conditions. The scatter index is with acceptable values for such conditions. Obviously it is desirable to use the altimeter data to recalibrate the model specifically for such conditions.

The ability of altimeters to provide wind speed estimates is very useful in wave model verification. It allows us to distinguish between errors in the wind input fields from those caused by the wave model itself. We consider the wind at 10m from the ALADIN model and compare it with the results of the altimeter measurements of the wind speed over the Black Sea. A one-year period from January to December 2018 is considered in the comparison. The results are presented in Table 2. The general conclusion is that, overall, the atmospheric model ALADIN, when compared to the altimeter data, gives sufficient statistical results, with a scatter index below 0.25. More specifically, the ALADIN underestimates the wind speeds in stormy conditions V>15m/s, but still the relative bias is below 10%.

It can be seen in Table 2, Fig. 4 and Fig. 5 that a negative bias in the current ALADIN operational wind forecasts for the Black Sea contributes to a negative bias in the resulting wave forecasts when verified against satellite altimeter data from Jason-2, Jason-3 and SARAL AltiKa.

We tested the following parameterization formulations in SWAN: JANS (exponential wind growth following (Janssen, 1991) combined with the pulse-based whitecapping model (Hasselmann, 1974), WESTH (saturation based whitecapping parameterization combined by the wind input of Yan, following Van der Westhuysen (Westhuysen et al, 2007) and the recently implemented in SWAN ST6 formulation of the physical parameterizations (Zieger et al, 2015) that in our case is a combination of the observation based whitecapping parameterization combined with WAM cycle IV wind growth (Janssen, 1991) or the option ECMWF in the model name list.

**Table 1:** Comparison of SWH between the operational implementation of the SWAN model results and altimeter data for the Black Sea, January-December 2018.

<table>
<thead>
<tr>
<th>n</th>
<th>mean SWH SWAN</th>
<th>mean SWH altimeters</th>
<th>Bias</th>
<th>RMS error</th>
<th>Scatter index</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>36265</td>
<td>0.95</td>
<td>122</td>
<td>-0.27</td>
<td>0.43</td>
</tr>
<tr>
<td>0.5-1 m</td>
<td>17479</td>
<td>0.55</td>
<td>0.74</td>
<td>-0.19</td>
<td>0.29</td>
</tr>
<tr>
<td>1-2 m</td>
<td>14924</td>
<td>1.09</td>
<td>1.37</td>
<td>-0.28</td>
<td>0.43</td>
</tr>
<tr>
<td>2-3 m</td>
<td>2777</td>
<td>1.91</td>
<td>2.39</td>
<td>-0.48</td>
<td>0.64</td>
</tr>
<tr>
<td>&gt;3 m</td>
<td>1085</td>
<td>3.08</td>
<td>3.92</td>
<td>-0.84</td>
<td>1.05</td>
</tr>
</tbody>
</table>

**Table 2:** Comparison of WS (m/s) between ALADIN model results and altimeter data for
the Black Sea, for the period January-December 2018

<table>
<thead>
<tr>
<th>N</th>
<th>Mean WS ALADIN</th>
<th>Mean WS Altimeters</th>
<th>Bias</th>
<th>RMS error</th>
<th>Scatter index</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>48570</td>
<td>8.08</td>
<td>7.91</td>
<td>0.17</td>
<td>1.80</td>
</tr>
<tr>
<td>5-10m/s</td>
<td>40936</td>
<td>7.35</td>
<td>7.10</td>
<td>0.25</td>
<td>1.80</td>
</tr>
<tr>
<td>10-15m/s</td>
<td>7034</td>
<td>11.74</td>
<td>11.88</td>
<td>-0.14</td>
<td>1.72</td>
</tr>
<tr>
<td>15-20m/s</td>
<td>640</td>
<td>14.48</td>
<td>16.12</td>
<td>-1.64</td>
<td>2.44</td>
</tr>
</tbody>
</table>

It was found that the most effective formulation is ST6, but the one used back in 2018 for the operational system (WESTH in our case) also provides sufficient accuracy. In 2019 following the presented results and other tests we switched in the operational system to ST6. The values of the SWH statistical parameters corresponding to SWAN against the Jason-3 data are presented in Table 3 and the scatter diagrams are shown in Fig. 6.

The bias is negative for all parameterizations and it is the smallest for the ST6 parameterization scheme. The RMS error and the scatter index are also the lowest with ST6 formulation. Overly ST6 physics leads to a significant improvement when applied to the SWAN model in the Black Sea. Analysis of the statistical data shows that the SWAN model provides an effective framework for prediction of the wave conditions in the Black Sea area and the coastal environment. The accuracy of atmospheric forcing is considered the main factor to predict reliably the sea state. Additional efforts need to be done to improve the model results and reduce forecast errors by accompanying developments of model physics and parameterizations, and by adopting an appropriate assimilation technique using the available satellite data for the Black Sea area.

Table 3: Comparison of SWH between SWAN model results and altimeter data for the storm event in the Black Sea 28-30.11.2018.

<table>
<thead>
<tr>
<th>N</th>
<th>Mean SWH SWAN (m)</th>
<th>Mean SWH satellite (m)</th>
<th>Bias (m)</th>
<th>RMS error (m)</th>
<th>Scatter index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janssen All</td>
<td>392</td>
<td>2.61</td>
<td>2.94</td>
<td>-0.33</td>
<td>0.46</td>
</tr>
<tr>
<td>&gt; 3 m</td>
<td>160</td>
<td>3.42</td>
<td>3.92</td>
<td>-0.50</td>
<td>0.58</td>
</tr>
<tr>
<td>Westhuysen All</td>
<td>392</td>
<td>2.54</td>
<td>2.94</td>
<td>-0.39</td>
<td>0.54</td>
</tr>
<tr>
<td>&gt; 3 m</td>
<td>160</td>
<td>3.29</td>
<td>3.92</td>
<td>-0.63</td>
<td>0.72</td>
</tr>
<tr>
<td>ST6 All</td>
<td>392</td>
<td>2.78</td>
<td>2.94</td>
<td>-0.16</td>
<td>0.38</td>
</tr>
<tr>
<td>&gt; 3 m</td>
<td>160</td>
<td>3.53</td>
<td>3.92</td>
<td>-0.39</td>
<td>0.50</td>
</tr>
</tbody>
</table>
**Fig. 4:** Comparison of ALADIN with Jason-3 WSs along the track on 29.11 at 01.48hr (left), ALADIN & SARAL AltiKa wind on 30.11.2018 at 03.03 hr UTC(right).

**Fig. 5:** Comparison of SWAN (WESTH, JANS, ST6) with Jason-3 SWH along the track on 29.11.2018 at 01.48 hr (l); SARAL AltiKa SWH, on 30/11/2018 at 03.03 hr. (r).

**Fig. 6:** Scatter diagrams of the model SWH (different parametrizations) against the Jason-3 altimeter data for the storm situation in the Black sea 28-30.11.2018.
Conclusions

Coastal areas are complex zones, with environmental and economic challenges and problems. A key aspect of disaster risk reduction measures is the community preparedness of which early warning system (EWS) has been playing an important role (Haigh et al, 2018). EWS of coastal storms needs to provide timely, accurate and clear information on the potential severe weather conditions, so that the responsible authorities can take action to avoid or minimize disaster risk for coastal and sea ports infrastructure. When executed successfully, the early warnings provided by these systems can lead to a significant reduction in the impact on the environment of various extreme hydro-meteorological events.

It needs to be noted that assessment of wave model performance is often not possible due to the lack of wave observations. Remote-sensed data are becoming very important source of information in the verification of wave models and improvement the accuracy of the operational numerical wind-wave forecasts and hindcast in the Black Sea area. Available satellite-derived altimeter and scatterometer data help improve model results and reduce forecast errors by accompanying model verification and calibration in general and more specifically for stormy conditions. The implementation of Early Warning forecast systems will benefit the sustainable management of coastal regions. The ability to predict the evolution of extreme events constitutes an indispensable tool for risk assessment, sea safety and contingency planning as part of the decision support framework to implement European Union polices related to the protection of the marine environment and sustainable development of the coastal zones.

It is very important to provide end-users with simple and clear information on hazards, vulnerabilities, risks, and how to reduce disaster impacts. Information technologies capable of disseminating user-oriented information that is based upon the early warning system, numerical modelling, web-GIS technologies and remote sensed data will be applied within the project ECOPORTIL to increase the risk knowledge and awareness about natural disasters. This will increase the educational capabilities of the stakeholders regarding ports and their integrated environmental management and protection, according to national and international environmental legislations.

Acknowledgements

The presented work is a contribution for the project ECOPORTIL BMP1/2.3/2622/2017 (Environmental Protection of Areas Surrounding Ports using Innovative Learning Tools for Legislation), which was funded by INTERREG Balkan-Mediterranean - European Regional Development Fund.

References


SWAN Team,(2019), ” SWAN Scientific and Technical Documentation,SWAN Cycle III version 41.31”, Delft University of Technology.


Keywords
Early warning, winds, waves, coastal zone, Black Sea, SWAN, remote sensing, ECOPORTIL.