Remote sensing applications in monitoring of certain marine and coastal ecosystems’ descriptors afferent to the Romanian shore of the Black Sea

IUBMB Symposium on Modern Biotechnologies in Sustainable Development of the Danube Delta
May 31 - June 2, 2016, Murighiol, Tulcea, Romania
Introduction – Regional General Data

BLACK SEA BASIN
Total area: 4.2 x 105 km²
Total water volume: 547,015 km³
Maximum depth: 2,212 m
Drainage basin: > 2 million km²
Shoreline length: > 4,100 km
Population: > 160 million people
Riparian countries: 6 (Bulgaria, Georgia, Romania, Russian Federation, Turkey, Ukraine)
NW Black Sea Basin

Romanian Shelf Waters (<200m)
- Highly dynamic system
- Most productive area of the Black Sea
  - strongly influenced by the Danube’s discharges
  - climatic processes
- High temporal variability of optimal blooming conditions

Open Waters
- Less productive system
- Less temporal variability of favorable blooming conditions
- Production mainly influenced by climatic processes which govern stratification, upwelling and water masses circulation
ROMANIAN COASTAL ZONE
Danube Delta Area

- Over 244 km length (between Musura Branch si Vama Veche). Represent 6% of total length of Black Sea shore
- Geographically is formed by:
  - Natural shore (beach and cliffs – circa 84%)
  - Artificial shore (ports, coastal structures for protection - circa 16%)
- The characteristic zones of the shore are divided in two geomorphological units:
  - Northern unit (the Danube Delta and the Razim-Sinoe lagoon complex), stretching on 170 km, from Ucraina border to Midia and consist on shore with delats, lagoons and levees, been formed of marine-river accretions, recent shells sands, desposed under shapes of beach and litoral belts with relativelow cota, often less than 2m;
  - Southern unit (Cap Midia - Vama Veche, at Bulgarian border), with a approximately length of 74 km, it is a relative high shore, with cliffs, mostly active, of maximum high is ircca 35 m., and small beaches at basis
Romanian Coast - cont
Hydrology/Hydrodynamics

Waves regime

Currents regime
(http://www.rmri.ro/RMRI/Forecasts/ForecastsRO.php)

Sea-level variability
(Eurogoos-IOC site)

Danube river discharge
Operational monitoring and forecast system

Main operational capacity of the national oceanographic network is to maintain public the oceanographic forecast provided by MyOcean (sea water temperature, salinity, sea level, sea currents)

http://www.myocean.eu

OCEAN MONITORING and FORECASTING
Providing Products and Services for all marine applications
**Forecast System on the Black Sea**

MyOcean BLACKSEA_ANALYSIS_FORECAST product temporal coverage:

- 4 days of analyses before current date 00:00 UTC

<table>
<thead>
<tr>
<th>Product</th>
<th>BLACKSEA_ANALYSIS_FORECAST_PHYS_007_001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographical coverage</td>
<td>27.4E - 41.9E, 40.9N - 46.7N</td>
</tr>
</tbody>
</table>
| Variables | Temperature, Salinity, Sea Surface Height  
Horizontal velocity (meridional and zonal component) |
| Analysis | Yes |
| Forecast | Yes |
| Available time series | From 1 January, 2012–ongoing |
| Temporal resolution | 3-hourly instantaneous fields and daily mean fields consistent with basic meteorological terms |
| Target delivery time | Forecast: daily 15:00 UTC  
Analysis: daily 15:00 UTC |
| Delivery mechanism | MyOcean Information System |
| Horizontal resolution | ~5 km (11/180 deg lon, 2/45 deg lat) |
| Number of vertical levels | 38 irregular levels |
| Format | NETCDF CF1.4 |
Dissemination of the Forecast results

- On the public NIMRD web-site (http://www.rmri.ro/Home/Products.Forecasts.html)
- and The National Oceanographic Data Center (www.nodc.ro)
Example of results validation

In-situ data gathered during oceanographic surveys shows that the distribution of the sea surface temperature and salinity are consistent with the results of the regional model for the Romanian Black Sea shelf.

The errors between the results of the forecasted sea parameters and in-situ data from the research cruises made in May 2010, are negligible, and consist only in the over-evaluation of the salinity by the model with approximately 1.00 PSU and under-evaluation of the sea surface temperature with 4 °C. The influence of the land is well described by the model with a good forecast of the sea parameters at the Danube Mouth and the near-shore area.
Distribution of sea surface temperature, salinity and oxygen at Mamaia beach during May – September 2010

In-situ data (CTD) on NW shelf of the Black Sea, cruise in May 20th 2010

Results of Regional Model for the upwelling phenomena (May 2010)
Project's synergy with European projects

Regional Atmospheric Model (ALADIN Family)

Remote Sensing Subsystem

Sea Surface Elevation $Ro \approx 1 \text{ km}$

170 $x$ 270
Use of RS data in NIMRD’s Oceanography Department

- important tool of monitoring marine waters in the Romanian National Monitoring Program: planning, developing and extension of all marine monitoring activities
- in several on-going national projects (annual reports)
  - The influence of Danube’s discharges on the trophic status of Romanian transitional and coastal waters in order to implement WFD and MSFD
  - Characterization of benthic and planktonic communities of the Romanian continental shelf
  - Evaluation of macrophyte communities from the Romanian coast (MACROEVAL)
  - Complex system for the application of remote sensing technics for environmental quality monitoring and Romanian ICZM implementation support (IMAGIS/ECOMAGIS projects)/coastal WQ studies
RS projects implementation

- operating an autonomous above-water radiometer on Gloria Oil platform in front of the Romanian coast/Danube Delta Biosphere Reserve
  - producing data for the continuous assessment of the atmospheric correction process of current satellite ocean colors sensors
  - part of the international AERONET-OC network.
- long-term operation: NIMRD with the support of the JRC > ensuring real-time data, available from the AERONET-OC data base and also from the ESA MERMAID server.

The project also had benefits from the NIMRD data archive of transparency and sea color produced during different oceanographic cruises from 1971 to 2015.
Site: Gloria
Location: Black Sea
Water type: Case-2 (sed. dom.)
Water depth: 50 m (height: 30 m)
Distance: ~20 nm
Period: 2010-present
Data access for the SeaPrism Radiometer
Specific objectives (flow)

Creation of an in situ data set of optical properties (inherent and apparent) and concentration of seawater optically significant constituents

Development of biooptical algorithms for the determination of optically significant seawater constituents

Generation of satellite ocean color products of the Black Sea freely accessible through web interface
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Symbol</th>
<th>Wavelengths range or center-wav.</th>
<th>Instrument/Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote sensing reflectance</td>
<td>$R_{rs}$</td>
<td>412,443,490,510,555,670,683 nm</td>
<td>JRC and NATO Satlantic micro-profiler</td>
</tr>
<tr>
<td>Diffuse attenuation coefficient</td>
<td>$K_d$</td>
<td>412,443,490,510,555,670,683 nm</td>
<td>JRC and NATO Satlantic micro-profiler</td>
</tr>
<tr>
<td>Total absorption coefficient</td>
<td>$a$</td>
<td>412,443,490,510,555, 630, 650, 676,715 nm</td>
<td>JRC WetLab AC-9</td>
</tr>
<tr>
<td>Absorption coefficient of pigmented particles</td>
<td>$a_p$</td>
<td>400-750 nm (with 1 nm resolution)</td>
<td>Spectrometry (JRC Perkin-Elmer Lambda 900)</td>
</tr>
<tr>
<td>Absorption coefficient of non-pigmented particles</td>
<td>$a_{dt}$</td>
<td>400-750 nm (with 1 nm resolution)</td>
<td>Spectrometry (JRC Perkin-Elmer Lambda 900)</td>
</tr>
<tr>
<td>Absorption coefficient of colored diss. organic matter</td>
<td>$a_y$</td>
<td>350-750 nm (with 1 nm resolution)</td>
<td>Spectrometry (JRC Perkin-Elmer Lambda 12)</td>
</tr>
<tr>
<td>Scattering coefficient</td>
<td>$b$</td>
<td>412,443,490,510,555, 630, 650, 676,715 nm</td>
<td>JRC WetLab AC-9</td>
</tr>
<tr>
<td>Backscattering coefficient</td>
<td>$b_b$</td>
<td>443,490,510,555,620, 670 nm</td>
<td>JRC HobiLabs Hydroscat-6</td>
</tr>
<tr>
<td>Volume scattering function</td>
<td>$\beta$</td>
<td>443,490,510, 532, 555,590, 620 nm</td>
<td>MHI VSF_Meter</td>
</tr>
<tr>
<td>Pigments concentration</td>
<td>Chl</td>
<td>Includes total chlorophyll-a</td>
<td>HPLC</td>
</tr>
<tr>
<td>Total suspended matter</td>
<td>TSM</td>
<td></td>
<td>Filtration and weighting</td>
</tr>
<tr>
<td>Salinity and temperature</td>
<td>S &amp; T</td>
<td>Typically down to 25-35 m</td>
<td>JRC and Mare Nigrum CTDs</td>
</tr>
<tr>
<td>Aerosol optical thickness</td>
<td>$\tau_a$</td>
<td>440, 490, 550, 670, 870 nm</td>
<td>JRC and NATO Sun-photometers</td>
</tr>
<tr>
<td>Fluorescence</td>
<td>Fl</td>
<td>Includes chlorophyll a and colored dissolved organic matter fluorescence</td>
<td>SIO Fluorimeter</td>
</tr>
</tbody>
</table>
Measurements

Water samples
- $a_{PH}(\lambda)$, $a_{PD}(\lambda)$, $a_{YS}(\lambda)$
- HPLC Pigments
- TSM

$R_{rs}(\lambda, 0^-)$

$a(\lambda), b_{bp}(\lambda)$

$a_{PH}(\lambda), a_{YS}(\lambda)$

[Chla] [CDOM] [TSM]

The same instrumentation and methodologies for ALL campaigns
Measurements - cont
Multi Layer Perceptron (MLP) neural networks algorithm
This section summarizes the specific application of Multi Layer Perceptron (MLP) neural networks developed to derive Chlorophyll-a concentration $C_{chl-a}$, absorption of the yellow substance at 412 nm $a_{ys}(412)$ and concentration of the total suspended matter TSM from remote sensing reflectance $R_{RS}$ spectral values for the Western Black Sea (D’Alimonte et al. 2011)
The applicability of *regional* bio-optical algorithms has been verified with the Medium Resolution Imaging Spectrometer (MERIS) remote sensing reflectance $R_{RS}$ (see Kajiyama et al. 2012)
Romanian National Monitoring Program (part of BSIMAP)

- Romanian Monitoring grid - 44 stations
  - 21 in coastal waters
  - 12 in transitional waters
  - 11 in marine waters

- inner shelf waters – covered quite well spatially and temporally in the National Monitoring Program

- outer shelf and open waters - occasionally covered within the framework of various projects
SUPPORT of the MARINE INTEGRATED MONITORING (SUB)SYSTEMS:

1. Marine pollution monitoring ;
2. Shellfish water monitoring;
3. Monitoring and control of dangerous substances in dredged sediments from ports and maritime shipping channels;
4. Monitoring of ballast waters;
5. Monitoring of coastal erosion;
6. Monitoring of the biological diversity, including marine mammals populations and marine habitats in the protected areas;
7. Monitoring of dolphins’ accidental catches and stranding;
8. Monitoring of the bathing waters and beaches quality (collaboration with Sanitary Directorate);
9. Monitoring of extreme marine phenomena (extreme surges, tsunamis);
10. Monitoring of accidental oil pollution (when needed).
Parameters monitored in parallel, *in situ* and remote sensing

- **Chlorophyll a**
  - commonly used parameter for the estimation of phytoplankton biomass and primary production
  - included in the list of indicators of eutrophication within WFD
  - proposed indicator related to “Direct effects of nutrient enrichment” criteria (Descriptor 5) in the MSFD

- **Transparency**
  - strongly related to the amount, size, composition of suspended material (sediments and organic material)
  - Transparency related to increase in suspended algae is proposed as MSFD’s indicator (Descriptor 5)
Validations of the RS data

- MSFD recommends appropriate methodologies for chlorophyll $a$ observation offshore using tools as satellite observation

- In open waters remote sensing methods are the most promise tool for eutrophication assessment, on synoptic scales through the detection of chlorophyll $a$ and water transparency

- Integration of in-situ and remote sensing data improves understanding of ecosystem processes and dynamics

- Identification of chlorophyll $a$ temporal trends
  - the use of remote sensing products for wider marine areas can provide a much finer resolution in time and space

- Identification and understanding the link between algal blooms and nutrients input

- Serious issues
  - provide reliable data at very low costs
BASISIMS platform (developed by Nelen & Schurmans) – GEO-Portal based on LIZARD water quality system. (active on NIMRDS website)
Results on BASISIMS server

Danube influence
(Chl_a )
Details on Danube Delta areas
(Total suspended matter – TSM)
It were processed

- 5 years MERIS data: 1366 images,
- 2 years MODIS data: 1766 images.

Total: 3132. (depending on cloud cover!)

Future developments:

- Sentinel 3 data
MODIS data processing in automatic mode, quasi real time (24 hours!)
Possible daily selections
Parameter value - click on location
Season distribution of WQ Parameters

Inorganic Matter in suspension
Seasonal distribution of WQ Parameters

Transparency
Results
Seasonal Distributions of WQ descriptors

Clorofila: Chl_a
Studies of marine water mass dynamics

Influence of regional circulation on shelf salinity distribution (Mihailov et al., 2013a)
New installations/2014

Automatic station at Mamaia touristic resort 2Km north of NIMRD
(near-real time/wireless data transmission)

miniADP/hydrometeorological station
CDT multiparameter/PAR/UV sensors included
Oceanographic radiometer (multispectral/UV)
Hydrodynamic model – Approach

- Level 1 - Black Sea
- Level 2 – Romanian Coast
- Level 3 - Constanta
Hydrodynamic model – Level 1

- Level 1 - Black Sea
- Grid
  - Horizontal Resolution 5.0 km
  - 42 Vertical Layers (Cartesian)
- Hydrodynamics Forcing
  - Wind
  - Discharges
- Initial Conditions
  - Temperature & Salinity (Copernicus)
- Boundary Conditions
  - Wind (GFS)
  - Heat Fluxes (GFS)
  - Discharges
    - Danube (3x)
    - Dnieper
    - Strait of Kerch (Don and Kuban)
    - Bosphorus (Surface and Bottom)
Hydrodynamic model – Level 2

- Level 2 - Romanian Coast
- Grid
  - Horizontal Resolution 1.25 km
  - 39 Vertical Layers (Cartesian)
- Hydrodynamics Forcing
  - Wind
  - Discharges
- Initial Conditions
  - From Black Sea Model (Level 1)
- Boundary Conditions
  - Wind (GFS)
  - Heat Fluxes (GFS)
  - Discharges
    - Danube (3x)
  - Black Sea Model (Open Boundary)
Hydrodynamic model – Level 3

- **Level 3 - Constanta Coast**
- **Grid**
  - Horizontal Resolution 0.3 km
  - 18 Vertical Layers (Cartesian)
- **Hydrodynamics Forcing**
  - Wind
  - Discharges
- **Initial Conditions**
  - From Romania Coast Model (Level 2)
- **Boundary Conditions**
  - Wind (GFS)
  - Heat Fluxes (GFS)
  - Romanian Coast Model (Open Boundary)
Hydrodynamic model - Configuration

- Model Configuration Inside MOHID Studio
  - Workspace “Black Sea”
- Each Domain as 2 Simulation Templates
  - Sim #1 (cold start)
  - Sim #2 (hot start)
- Scheduling
  - Model Run every Night at 0h10
  - Cold Start
    - 5 days Spinup
    - 3 days Forecast
  - Hot Start
    - 3 days Forecast
- Results
  - All Results are stored as HDF Files
  - Index in Database for further processing
Boundary Conditions - GFS

- **GFS**
  - air temperature
  - Solar radiation
  - Cloud cover
  - Relative humidity
  - Wind velocity

- **Scheduling**
  - Every Day at 20h00
  - Forecast of 5 days

- **Results**
  - All Results are stored as HDF Files
  - Index in Database for further processing
Initial Conditions - Copernicus

- **Copernicus**
  - salinity
  - temperature

- **Scheduling**
  - Before any Cold Start

- **Results**
  - Converted to MOHID Specific Input Files
Results – Currents and Salinity
Results – Vertical Profiles

Vertical Profile Location

Salinity (10 - 25)

Temperature (7° to 11°)

ACTION Beach Operational Model - Black Sea
Salinity and Temperature Profile - Spin Up

00:00:00
28-03-2016
Results – Nesting
Future developments

1. **Expand current AOP Analysis including Data from the previews Project**;
2. **Investigate AOP Features at Sub-Basin Level**;
3. **Investigate Commonalities in Bio-Optical Features between Black Sea and other EU Seas**;
4. **Forecast center for Romanian shelf / bathing areas**;
CONCLUSIONS

Northwestern BS Basin RS data should be more accurate data (if possible) in the inner shelf waters and fill data gaps in the coastal area.

- Contribution to improvement of data validation is important/crucial:
  - extended coverage area for in-situ measurements through common cruises
  - collect discrete samples (spatial and temporal) – continous

- Improvement the use of RS products it is required:
  - better dissemination (more papers based on data/RS techniques)
  - use data in more national and international projects
  - use data in other research areas (i.e. fisheries, marine ecology)
  - Training/assimilation of RS technology of processing and delivery
Thanks for your attention!