Multi-Sensor Observations of Mesoscale and Small-Scale Features in the Northeastern Black Sea Coastal Waters

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DATA USED

- Radar data from ERS-2 SAR and Envisat ASAR
- Optical and IR data from Terra/Aqua MODIS and NOAA AVHRR

The ERS and ENVISAT satellite data were provided by the European Space Agency.

✓ AO3.224 “Investigation of perturbing action of atmospheric and internal oceanic processes on the waved sea surface using ocean remote sensing data”
✓ C1P.1027 “Lee waves and vortex streets behind natural obstacles in ocean and atmosphere”
✓ AO Bear 2775 “Detection and characterisation of organic pollution in the coastal environment (DeCOP)”

PROJECTS

I. INTAS 03-51-4987 «Slicks as indicators of marine processes (SIMP)»
II. INTAS 06-1000025-9091 «Monitoring of Oil Pollution using Earth Observation Data: a multi-sensor, multi-platform approach (MOPED)»
III. Black Sea Scientific Network (Contract # 022868)
The most isolated from the World Ocean, almost closed, non-tidal sea

Black Sea
Black Sea catchment area

- Territories of 17 countries
- 1/3 of continental Europe
- The ratio of the catchment area to the sea surface > 6
Main structural element: strong cyclonic basin-wide near-shore current

Hydrodynamically highly unstable. May be considered as a system of moving mesoscale rings and anti-cyclonic eddies
Vorticity in northeastern Black Sea viewed by NOAA sensors

Sea Surface Temperature according to NOAA data 13.02.2007-15.02.2007

Courtesy of our colleagues from MHI NASU (Sevastopol, Ukraine)
Small-scale eddies in the northeastern Black Sea (spiral eddies)

- Spiral eddies of kilometers to tens of kilometers scale can be seen in SAR images.
- In SAR images, these small eddies are visualized due to numerous bands of slicks.
Almost closed area
Large amount of surface films
Slow water replacement process
Eddies entering the Bay under south-eastern winds play an important role in water replacement and self-cleaning
Initial eddy diameter is 2-3 km
Eddies lifetime is 1-10 days
Small-scale eddies in the northeastern Black Sea (spiral eddies)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>ASAR Mode</th>
<th>Center coordinates</th>
<th>Size (km)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007.05.10</td>
<td>07:36:59</td>
<td>WSM</td>
<td>42.850 ° N; 39.979 °E</td>
<td>22.50</td>
<td>Cyclonic</td>
</tr>
</tbody>
</table>
A schematic of small-scale vorticity in coastal waters of the northeastern Black Sea retrieved from Envisat ASAR imagery.
Small scale eddies (summer)

A – 3.75 km  
B – 3 km  
C – 4.5 km  
D – 2.5 km  
E – 4.25 km
Small-scale eddies (summer)

Envisat ASAR. 3 August 2006. 07:37 GMT. 25 x 25 km
Cyclonic eddy of 3.5 km in diameter
Small-scale eddies (spring & fall)

1) Greater individual sizes
2) Tend to accumulate in clusters
3) Located at the bounds of the Rim current
4) Both cyclonic and anticyclonic eddies are observed

A – 22.5 km
B – 25 km
Small-scale eddies (spring & fall)

Eddy clusters can be seen in optical data
Seasonal variability

COMMON FEATURES

Spiral-shaped structures
Manifestation mechanism: concentration of surface films in current convergence zones

SUMMER

• Solitary eddies
• Small sizes: 2-6 km
• Location close to the shore
• Mostly cyclonic eddies
• Quasi two-dimensional structures
• Short lifetimes
• Impact of wind on eddy formation (direct and indirect)

SPRING & FALL

• Aggregations of eddies – eddy clusters
• Sizes of 4-30 km
• Location at the bounds of the Rim Current
• Cyclonic and anti-cyclonic eddies
• Cause both horizontal and vertical mixing
• Longer lifetimes
• Current meandering and breaking of large-scale eddies

Seasonal variability

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Eddy dipoles (mushroom flows)

1) No seasonal or spatial variability

2) Well developed eddy dipoles may be distinctly visible in optical & IR data

The image was acquired under low wind and weak surface waves

$L = 87.5$ km

$B = 65$ km

Eddy dipole manifested through bands of surfactant slicks
Eddy dipoles

1) An eddy dipole visualized by slicks. Envisat ASAR June 19, 2006
   a) 07:52 UTC
   b) 19:10 UTC

2) The dipole hardly can be detected in the IR and optical images obtained the same day.

3) This eddy dipole appeared in MODIS Aqua images acquired the next day, June 20, 2006.

Temperature contrasts are more diffuse and less expressed.

Maximal chlorophyll-a concentrations approximately correspond to convergence zones of eddy dipoles.
Eddy dipoles (mushroom flows)

Dynamical structures of this kind:

- are regularly observed in the northeastern Black Sea;
- induce not only horizontal but also vertical mixing of water;
- contribute to hydrodynamical instability of the nearshore current;
- intensify the transport of coastal water to the open sea
THANK YOU!