Satellite Observations of Mesoscale and Small-Scale Features in the North-eastern Black Sea

Mityagina M. and O. Lavrova

Space Research Institute of Russian Academy of Sciences
Moscow, Russia
The most isolated from the World Ocean, almost closed, non-tidal sea
One of the most deep interior seas. The water content of Black Sea is 6 times higher than that of the Caspian Sea and 16 times higher than that of the Baltic Sea, while the areas of all three seas are approximately equal.

- Huge catchment area: Territories of 17 countries
- 1/3 of continental Europe
- The ratio of the catchment area to the sea surface > 6

- Salinity from 17—18‰ near the surface up to 22.5‰ near the bottom
Main circulation feature - strong cyclonic basin-wide along-shore current which is referred to as the Rim Current

High hydrodynamical instability

High level of vortical activity
Our experience in satellite survey of the Black Sea includes three stages:

1. **1999 - 2005** (summer periods) - SAR ERS-2 and ASAR Envisat radar images of the Black Sea coastal zone in Novorossiysk – Gelendzhik area were obtained during periods of field experiments.

2. **2006-2008** - Satellite monitoring of water conditions and pollution level of the Russian part of the Black Sea. The work was performed under a contract with the Russian Federal Service for Hydrometeorology and Environmental Monitoring jointly with specialists from the Research Center «Planeta» and from P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences.

3. **2009-2012** - Satellite survey of the total aquatic area of the Black Sea (Space Research Institute of RAS)
Satellite sensors used

- Synthetic aperture radars Envisat ASAR, ERS-2 SAR: spatial resolution 25 - 150 m;
- IR radiometers NOAA AVHRR, spectral bands 10.3 - 11.3 µm, resolution 1 km;
- Imaging spectroradiometers Terra/Aqua MODIS, Envisat MERIS; spectral bands: 0.622-0.672 µm, 0.546-0.556 µm and 0.438-0.448 µm; resolution 250 m;
- Microwave scatterometers QuikSCAT, ASCAT;
Phenomena under consideration:

- Small-scale eddies (1-10 km) in coastal waters; seasonal variability of their manifestation
- Eddy dipoles; joint analysis of optical, IR and radar images
- Surface manifestations of non-tidal internal waves as viewed by SAR
Vorticity in northeastern Black Sea viewed by NOAA sensors

Movie is based on the SST field retrieved from NOAA IR data for three successive days
13.02.2007-15.02.2007
Courtesy of our colleagues from MHI NASU (Sevastopol, Ukraine)

"Workshop on (Sub–) Mesoscale Processes", Hamburg, UHH, 15 June 2012
The use of SAR data has allowed us to discover intense small-scale eddy activity in this region. These findings are significant in that, these eddies are smaller in sizes and more abundant than previously reported. They are so small that neither optical nor IR satellite sensors can detect them. These eddies can be visualized by SARs in several ways, but most commonly they become visible in radar images due to numerous bands of slicks of surfactant films which get entrained in the eddy motion. Eddies of kilometers to tens of kilometers scale can be seen in SAR images.

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Sea eddies / Atmospheric eddies

Envisat MERIS, 04.05.2008, 07:33 UTC
200 x 200 km.

Envisat ASAR, 04.05.2008, 07:34 UTC
200 x 200 km
Small-scale eddies in the northeastern Black Sea (spiral eddies)

Date | Time | ASAR Mode | Center coordinates | Size (km) | Type
--- | --- | --- | --- | --- | ---
2007.05.10 | 07:36:59 | WSM | 42.850 ° N; 39.979 °E | 22.50 | Cyclonic

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A schematic of small-scale vorticity in coastal waters of the northeastern Black Sea retrieved from Envisat ASAR imagery.

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Mostly small-scale (2-6 km in diameter) solitary eddies are observed. Predominantly cyclonic quasi two-dimensional structures, they are located in the immediate vicinity of the coastline and have short life-times.
Small-scale eddies (summer)

Envisat ASAR. 3 August 2006. 07:37 GMT. 25 x 25 km
Cyclonic eddy of 3.5 km in diameter

We could not detect these eddies in corresponding IR and visual data
Eddies have greater individual sizes of 4 to 25 km and tend to accumulate in clusters. These clusters are located about 30 km off the coastline, at the bounds of the Rim Current.
Both cyclonic and anti-cyclonic eddies are observed which have longer life-times and perform horizontal as well as vertical mixing of water.
Small-scale eddies (spring & fall)

Eddy clusters can be seen in optical data as well.
Short summary on seasonal variability of small scale spiral eddies in the north-eastern Black Sea

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

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Our observations show that the use of radar imagery allows us to:

- observe eddy dipoles of significantly smaller size (typically, several kilometres);
- observe early stages of emergence and development of eddy dipoles (before they are visible in IR and optical imagery);
- observe the fine structure of surface currents induced by a dipole
- observe the very first stages of eddy dipole formation

We didn’t detect any seasonal variability of eddy dipoles. Usually, their sizes range from tens to hundreds of kilometers.
2 ASAR Envisat images revealing the development of an eddy dipole. These images were acquired on two successive passes of the satellite within eleven hours from each other.

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A packet of internal waves observed at the edge of the anticyclonic part of the eddy dipole

The packet consists of 6 waves of average length of 175 meters.

IW propagate seaward at an angle to the shore and their fronts are parallel to the dipole jet.

Most probably, IW occur as a result of oscillations of the dipole jet.
Surface manifestations of non-tidal internal waves in the northeastern Black Sea retrieved from Envisat ASAR data (1)

- **a)** SST field derived from NOAA AVHRR data;
- **b)** Fragment of an Envisat ASAR image;
- **c)** An enlarged fragment of the Envisat ASAR image showing surface manifestations of internal waves in the sea.

**Table:**

<table>
<thead>
<tr>
<th>Leading wave crest length</th>
<th>Max wave length</th>
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<td>7200m</td>
<td>285 m</td>
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Surface manifestations of non-tidal internal waves in the northeastern Black Sea retrieved from Envisat ASAR data (2)

Leading wave crest length
12500 m

Max wave length
500m

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Surface manifestations of non-tidal internal waves in the northeastern Black Sea retrieved from Envisat ASAR data (2006-2009)

3 regions containing surface manifestation of IW:

I. The area near Kerch Strait between isobaths 50 and 100 m

II. The area near Tsemes Bay between isobaths 40 and 50 m

III. 25-28 miles to southwest from the coastline near...

In region (I) — internal waves can be generated by fronts of wind-driven up- and downwelling.
In region (II) — internal waves generation can be attributed to either internal seiches, relaxation of upwelling, or near-coastal eddies.

There is a particular interest in IW packets revealed in the deep water region (III). Combined analysis of radar and IR data obtained within a small time interval shows that all IWSMs registered in this region are located near the edge of a mesoscale eddy or an eddy dipole.


http://earth.esrin.esa.it/workshops/seasar2008/programme.html


THANK YOU!