Application of Radar Data for Oceanography and Hydrodynamics of Seas

Olga Shishkina

Institute of Applied Physics RAS, 46 Ul'janov str., 603950, Nizhny Novgorod, Russia
(Dated: 17 July 2014)

Olga Shishkina

1 Introduction

Nonlinear internal waves generated as the result of interaction of the stratified water with the bottom topography are observed in many parts of the world ocean. The ability of oceanic nonlinear internal waves to exist within the pycnocline for a long time after their generation plays the key role in transformation of the energy of large-scale tidal motion to smaller-scale waves and turbulence. A study of those processes is very important for understanding of the oceanic hydrological phenomena in application to environmental prediction and modeling.

2 Main Matter

An interaction of internal waves with the shelf edge in the time periods related to the presence of a pronounced seasonal pycnocline for the Alboran Sea and the southern Caspian Sea is analyzed via satellite photos and SAR images. A comparison of the fluid motion studied by satellite observations showed a qualitative difference in hydrodynamics of these regions. In the waters of the Caspian Sea with low tidal activity the generation of internal solitary waves is possible here in the case of simultaneous action of atmospheric driving force at the background of the pycnocline's sharpening in the presence of any bottom unevenness. Tidally generated internal waves in the western Mediterranean Sea are more predictable being determined in timing, location and geometry of the Strait of Gibraltar. Both types of hydrological driving forces are analyzed by remote sensing methods. Examples of temporal and spatial transform of linear and non-linear internal waves while their propagation from the place of generation versus horizontal and vertical seasonal water density gradients are analyzed.

3 Tidal sea: the Alboran Sea

But there is still no systematic analysis of the correlation between the hydrological field of the Alboran Sea and different corresponding trajectories of propagation of tidally induced internal waves while their passage after the Gates of Hercules. A preliminary study for this area was made in Shishkina, Sveen and Grue (2013) by means of a comparison of the satellite views of the area with the map of the mixed layer depth restored for the date of the certain observation. In the present study the transform of internal wave field was analyzed from viewpoint of seasonal variations of the mixed layer depth.

The hydrological field of this region is characterized by an absence of the seasonal pycnocline from December till March and a pronounced vertical density gradient during spring to autumn period. A pronounced seasonal pycnocline is formed here by the end of April. And its presence is reflected at the satellite views. In Figure 1 (left panel) the alongshore flow observed in winter time is still presented together with the solitary wave structure appeared in April. The latter obviously follows the mixed-layer depth towards its deepening, i.e. following the negative horizontal density gradient (right panel).

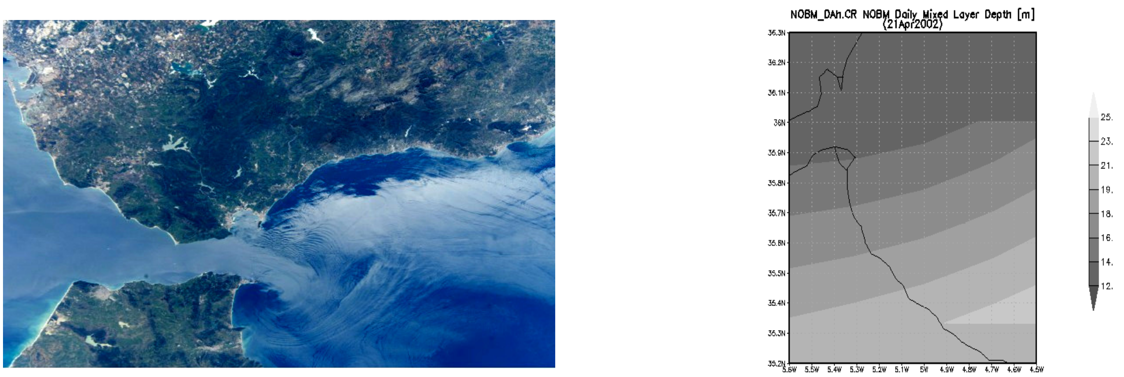


Figure 1: NASA photo ISS004-E10224 and corresponding field of the day-averaged mixed layer depth on 21 April 2002.

It is known that local variations of the stratification profile lead to changes in the phase speed of solitary internal wave (Small, 2001). And the following Figures 2 display propagation of the nonlinear solitary waves in the vertically and horizontally inhomogeneous fluid in June 2004. It could be seen that initially semi-circular internal waves start to curve and then form three plain sectors with different horizontal orientation (marked with the dashed lines in the left panel). The physical reason of such wave transformation follows from the right upper panel where the mixed layer depth for the corresponding time period is shown.

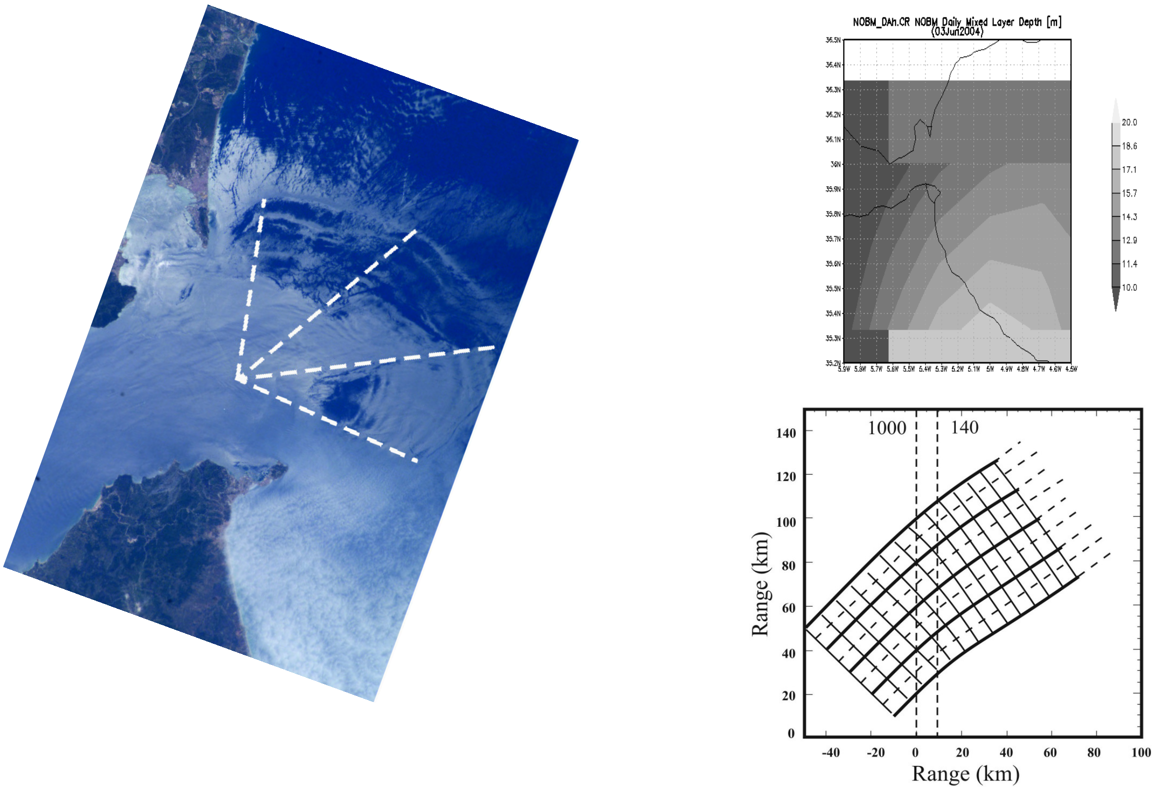


Figure 2: NASA photo ISS009-E-09952, day-averaged mixed layer depth (right upper panel) on June 2004 and numerical model of refraction of nonlinear internal waves while their shoaling above the shelf edge (right lower panel from Small, 2001).

4 Non-tidal sea: the Caspian Sea

The Caspian Sea relays to the closed continental estuaries without any hydrological links to the outer World Ocean waters. This feature leads to the specific conditions of dynamics of the upper water layers forming the seasonal pycnocline. As the tidal activity is negligible in such seas the main governing hydrodynamic forces are the air pressure and the wind force at the free water surface. The first of these two conditions leads to intense internal wave generation in the upper water layers due to interaction between moving stratified flow and the bottom topography. And the latter causes the event of upwelling along the shelf slope.

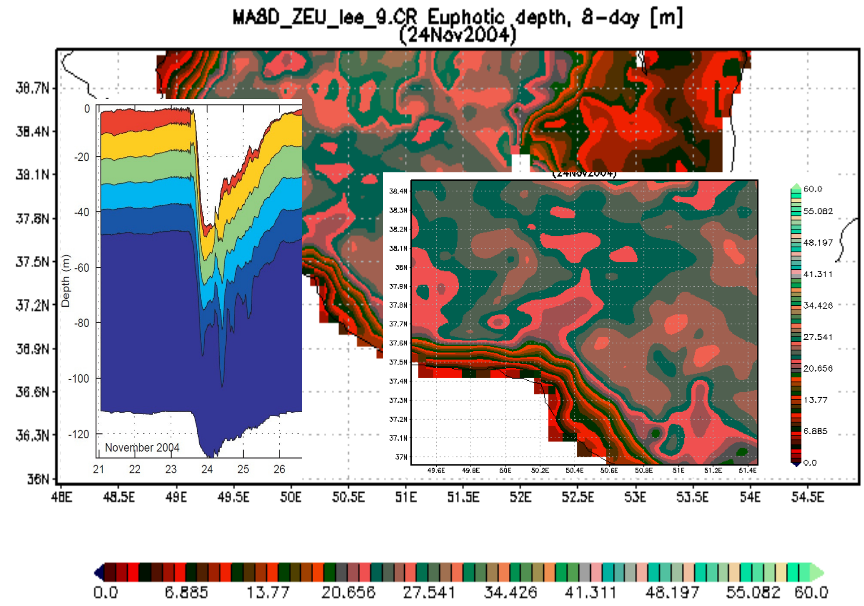
The results of the field measurements of temporal variations of the temperature parameter of stratification in the south-western part of the Caspian Sea have been obtained by Weber and Ghaffari (2014). The hydrological data and the satellite radar views of the euphotic depth field related to in situ measurements on 24 November 2004 and 2 December 2004 could be seen in the Figures 3,*a* and 3,*b* respectively. The optical features of natural waters follow the parameters of the density field both in horizontal and vertical directions. So the euphotic depth reflects the seasonal pycocline dynamics here. A local hydrology in this place is governed by the river fresh-water discharge and the cross-shelf bathymetric step-down.

From the comparative analysis of the data depicted at the left inner panels in Figures 3,*a,b* (I and II - temperature variations related to the 1-st and the 2-nd internal wave modes respectively) it is obvious that in November the stratification profile in the upper layers is more sharp so providing almost two-layer stratification (field data taken from Fig. 3 in Weber and Ghaffari, 2014). These natural conditions make possible the generation of strong non-linear internal waves of soliton type. Such a wave measured here on 24 November 2004 has an asymmetric profile of the main soliton with the almost vertical forward front and the amplitude of about 45 meters followed by a number of smaller solitons at its rear part.

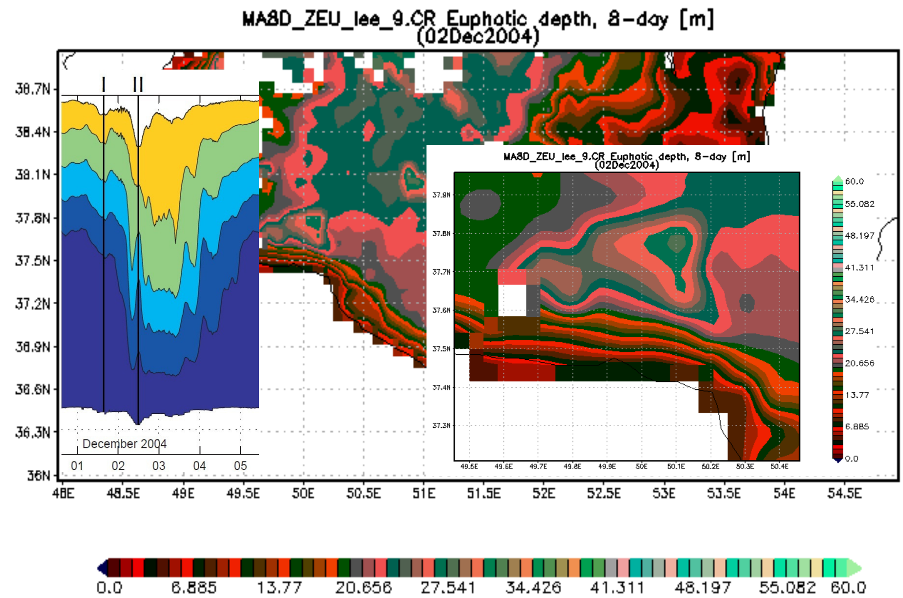
The vertical mode structure of this wave is formed by the 1-st internal mode when all of the water layers have the same direction of their vertical displacement from the equilibrium level similarly to the free water surface. The local structure of such wave has quasi-plain form with almost strait crest oriented normally to the shoreline (see right panel in Figure 3,a).

Contrary to late November the hydrological field in early December (Figure 3,b) represents a typical behaviour of linear internal waves where the 1-st and the 2-nd internal modes propagate independently in accordance with their dispersion characteristics, i.e. having individual phase velocity C_1 and C_2, where $C_1 > C_2$. This typical feature of the dispersion dependence of linear internal wave modes leads to their relative shift in time series and satellite data on 2 December 2004.

Prediction of intense internal wave motion is applicable in forecasting of pollution dynamics, for secure free surface and underwater operations, for fishery, for shore protection and navigation support.



a



b

Figure 3: Horizontal field of the euphotic depth of MODIS color radar radiometry restored with GIOVANNI data processing system (zoom of the studied area is presented at the right panel) with corresponding temporal variations of the seasonal pycnocline: a – data on 24 November 2004, b - data on 2 December 2004.

Acknowledgement

The source of the satellite photos is the Image Science & Analysis Laboratory, NASA Johnson Space Center, "The Gateway to Astronaut Photography of Earth". Analyses and visualizations used in this paper were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

This work was partially supported via grant RFBR 13-05-91175-SFNS_a.

References

Small J. A nonlinear model of the shoaling and refraction of interfacial solitary waves in the ocean. Part II Oblique refraction across a continental slope and propagation over a seamount // J. Phys. Oceanogr. - 2001. - 31: No. 11. - pp. 3184 - 3199.

Shishkina O.D. and Sveen, J.K. and Grue, J Transformation of internal solitary waves at the "deep" and "shallow" shelf: satellite observations and laboratory experiment // Nonlin. Proc. Geophys. - 2013. - 20: No. 5. - pp. 743 - 757. DOI: 10.5194/npg-20-743-2013

Weber J.E.H. and Ghaffari, P. Mass transport in internal coastal Kelvin waves // Eur. J. Mech. - B/Fluid. April 2014. DOI: 10.1016/j.euromechflu.2014.02.006 http://dx.doi.org/10.1016/j.euromechflu.2014.02.006