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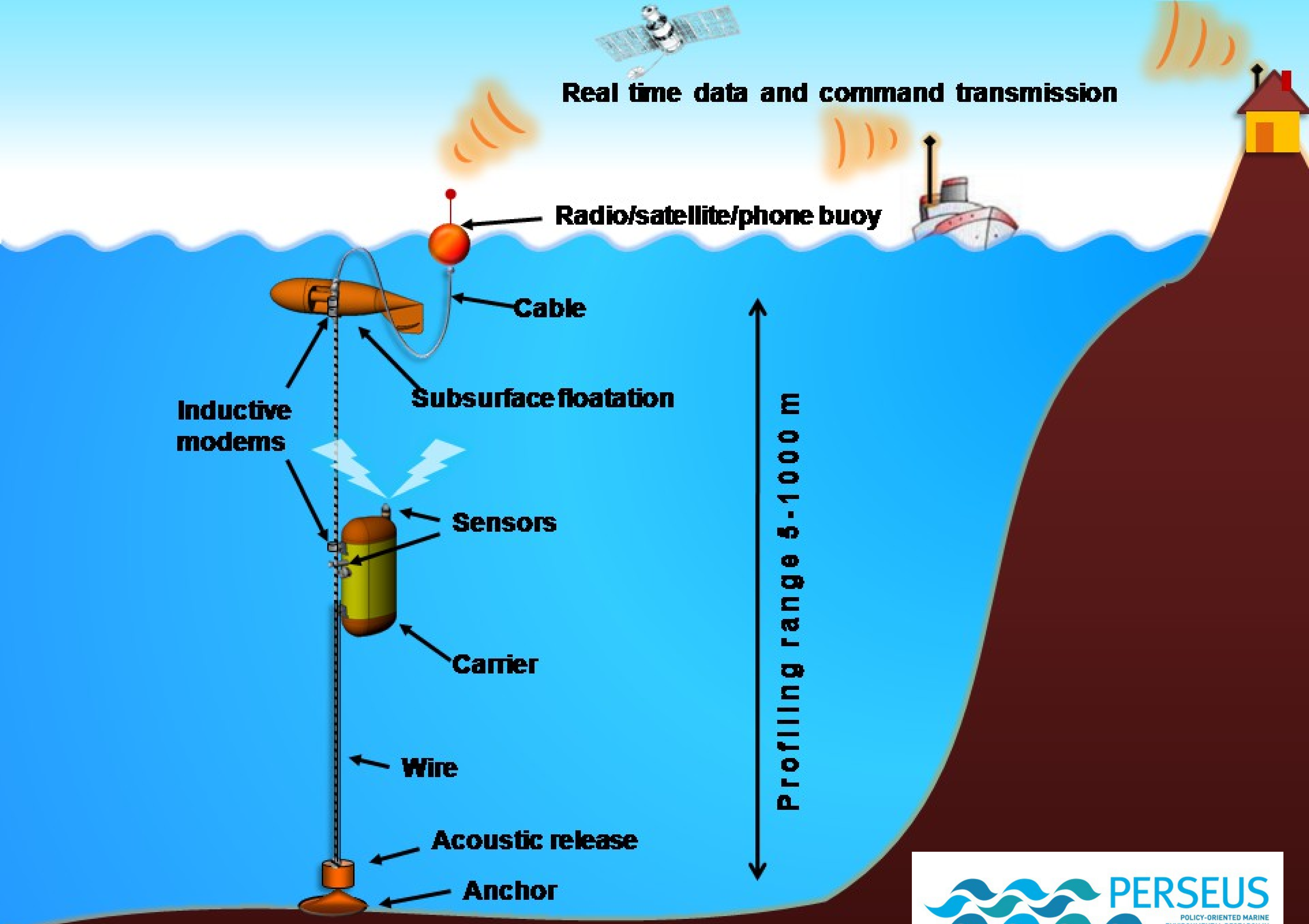
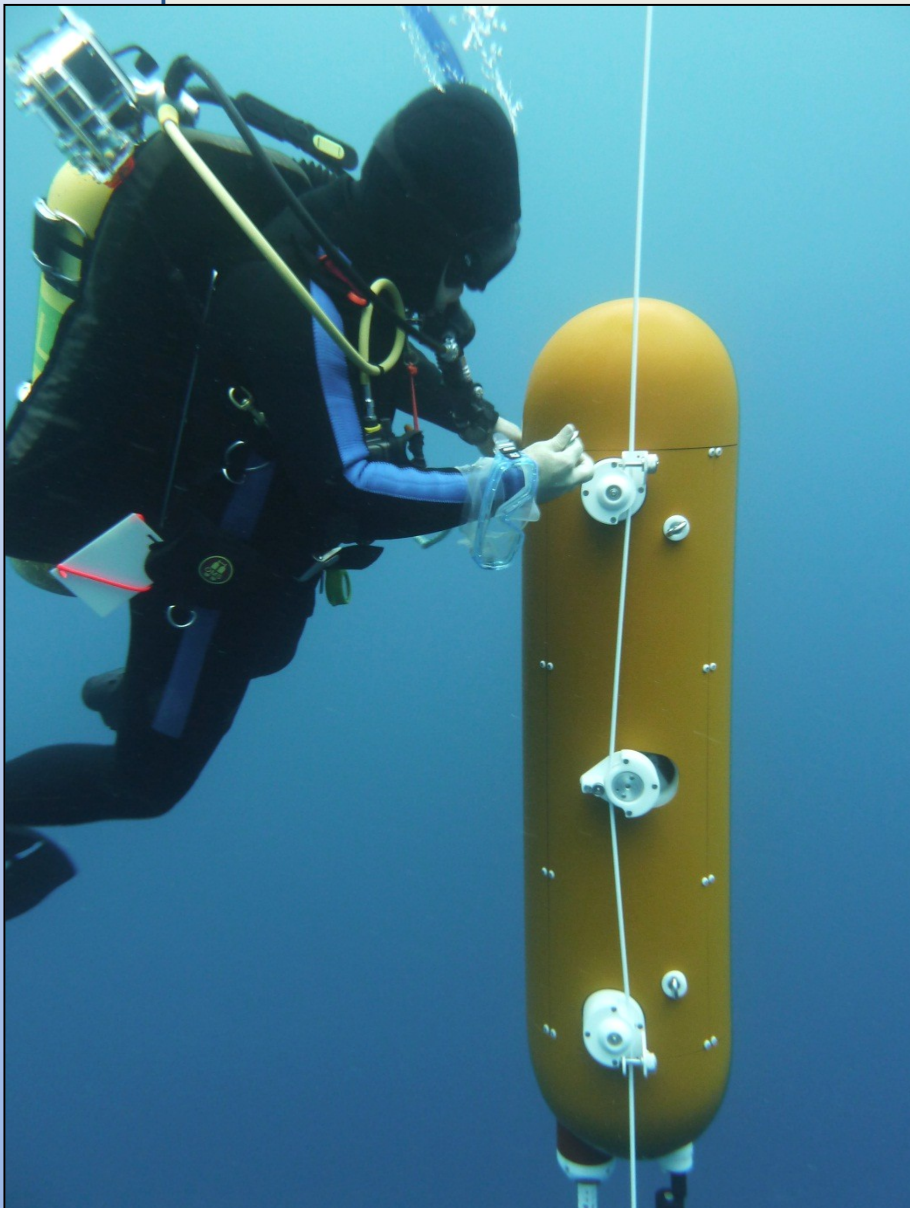
The PERSEUS WP3 profiler Aqualog in the Black Sea: Studies of the coastal zone ecosystem

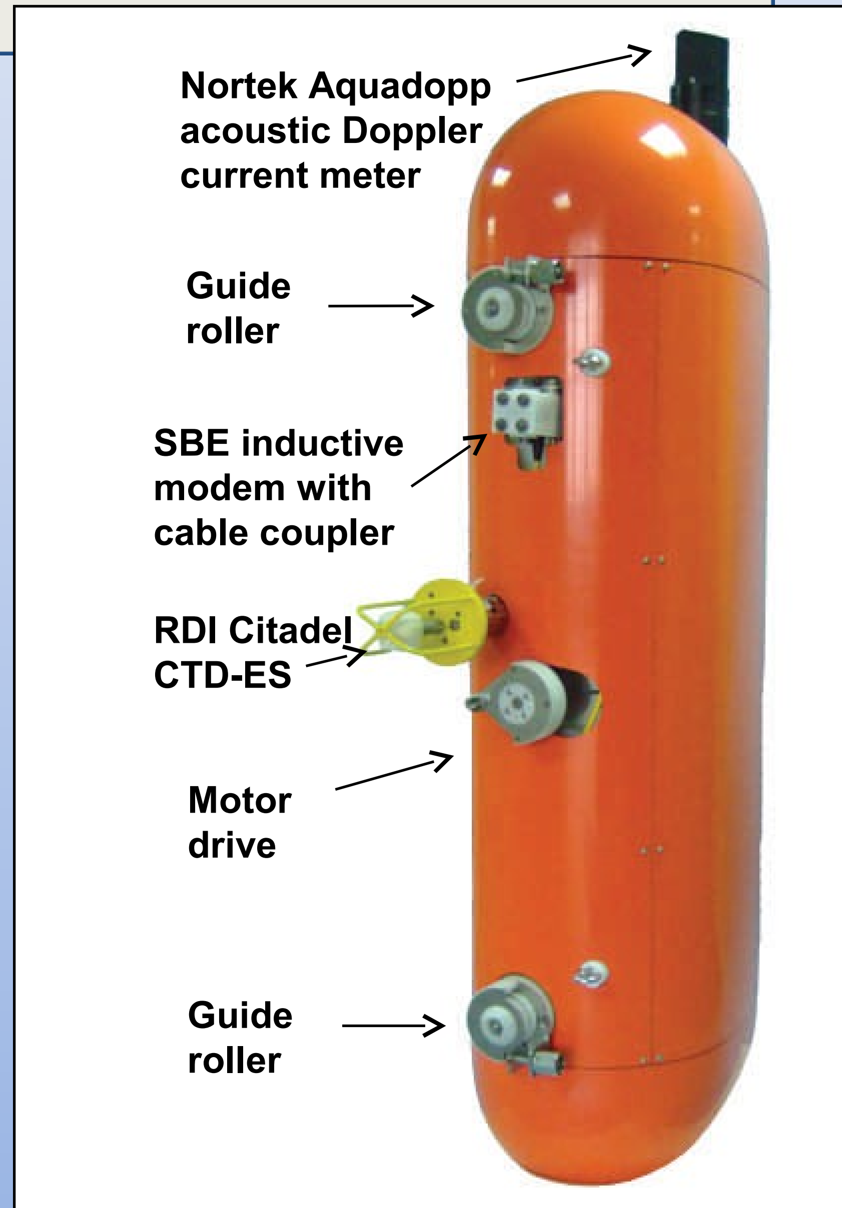
P.P. Shirshov Institute of Oceanology, Moscow, Russia – 14.06.2013



The moored profiler AQUALOG

Moored profiler Aqualog, 2010~

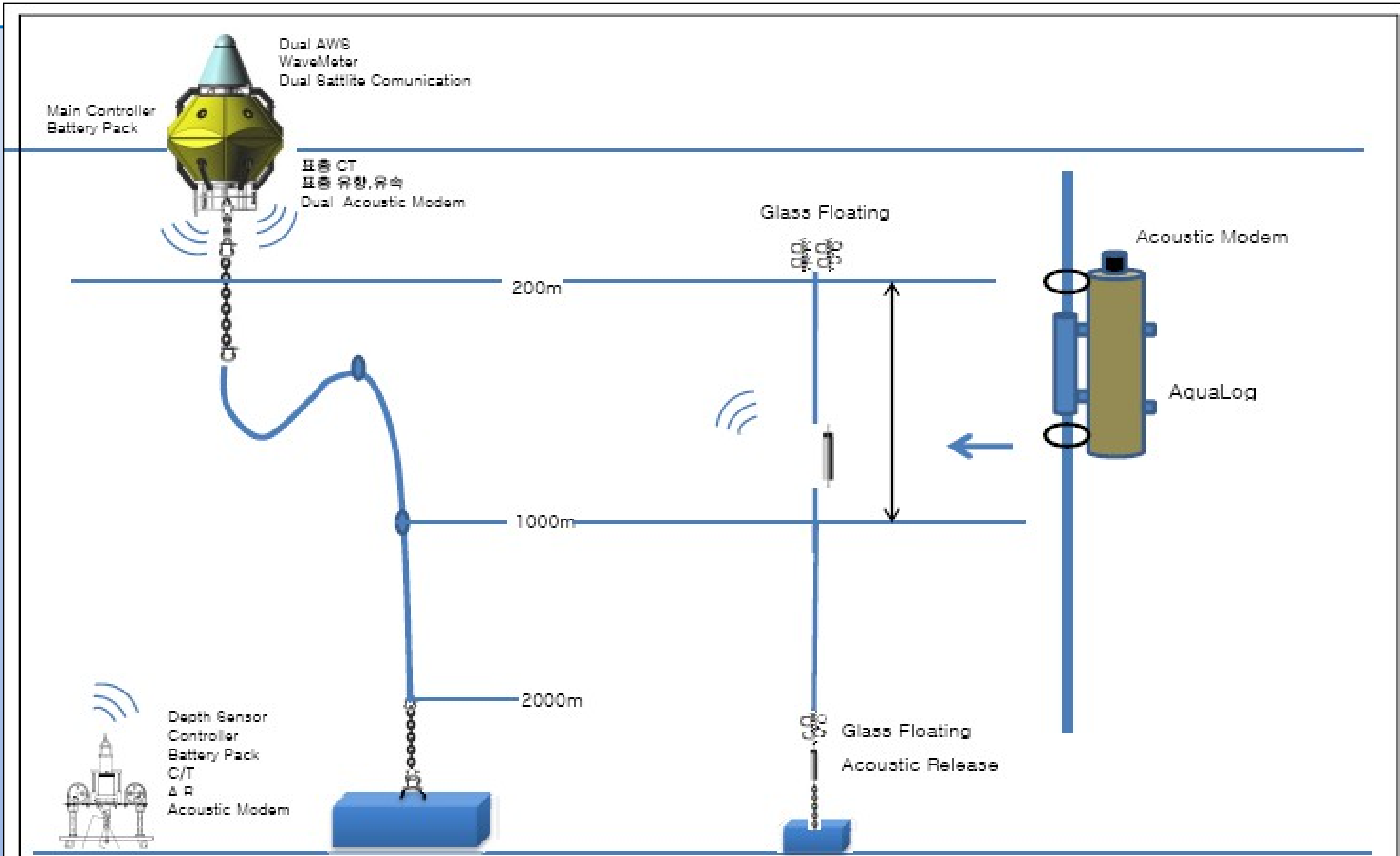




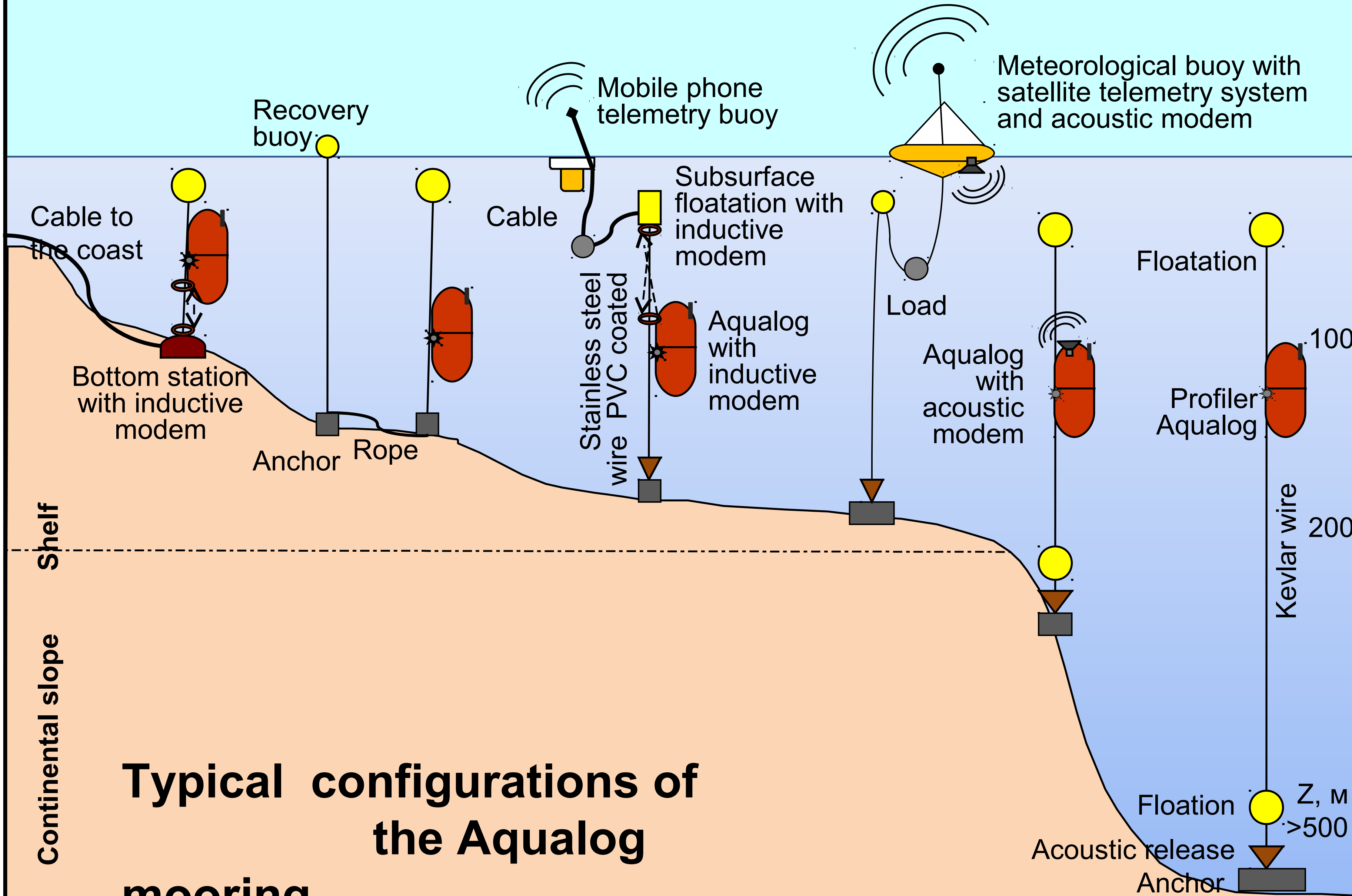
Aqualog provides a researcher with homogeneous and regular time series of the vertical profiles of ocean quantities

Minimizing the risk of loss of equipment	• Anchored ocean station simplifies technical maintenance of the power source, cleaning of sensors from biofouling and etc.
Operational capability	• Real-time data and telemetry transmission, e.g., via radio channel 430-470 Hz (no license is required).
Optimizing the cost of monitoring	• Continuous measurements of vertical profiles by single probe requires a single set of sensors unlike the conventional mooring where the equipment is placed on fixed depths.
Adaptive sampling approach	• Aqualog is a sea lift that carries a payload of various self-contained sensors like Nortek Aquadopp current meter or RDI Citadel CTD-ES, a set of the sensors is configured by the user.

A new approach to the ocean mooring system



Typical configurations of the Aqualog mooring

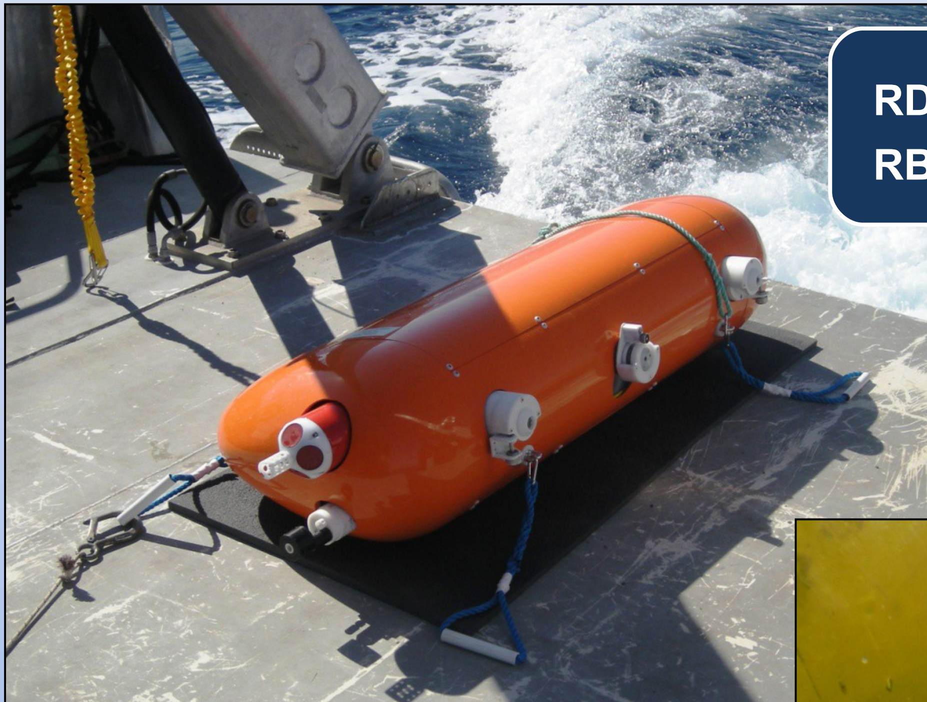


Moored profiler Aqualog deployments in the European Seas since 2010

Ocean sensors integrated at the Aqualog profiler

pH, ORP, Dissolved Oxygen, Nitrates, Fluorescence, Turbidity sensors

Ocean sensors integrated at the Aqualog profiler (continued)



RDI DVS current meter
RBR XR620 CTD

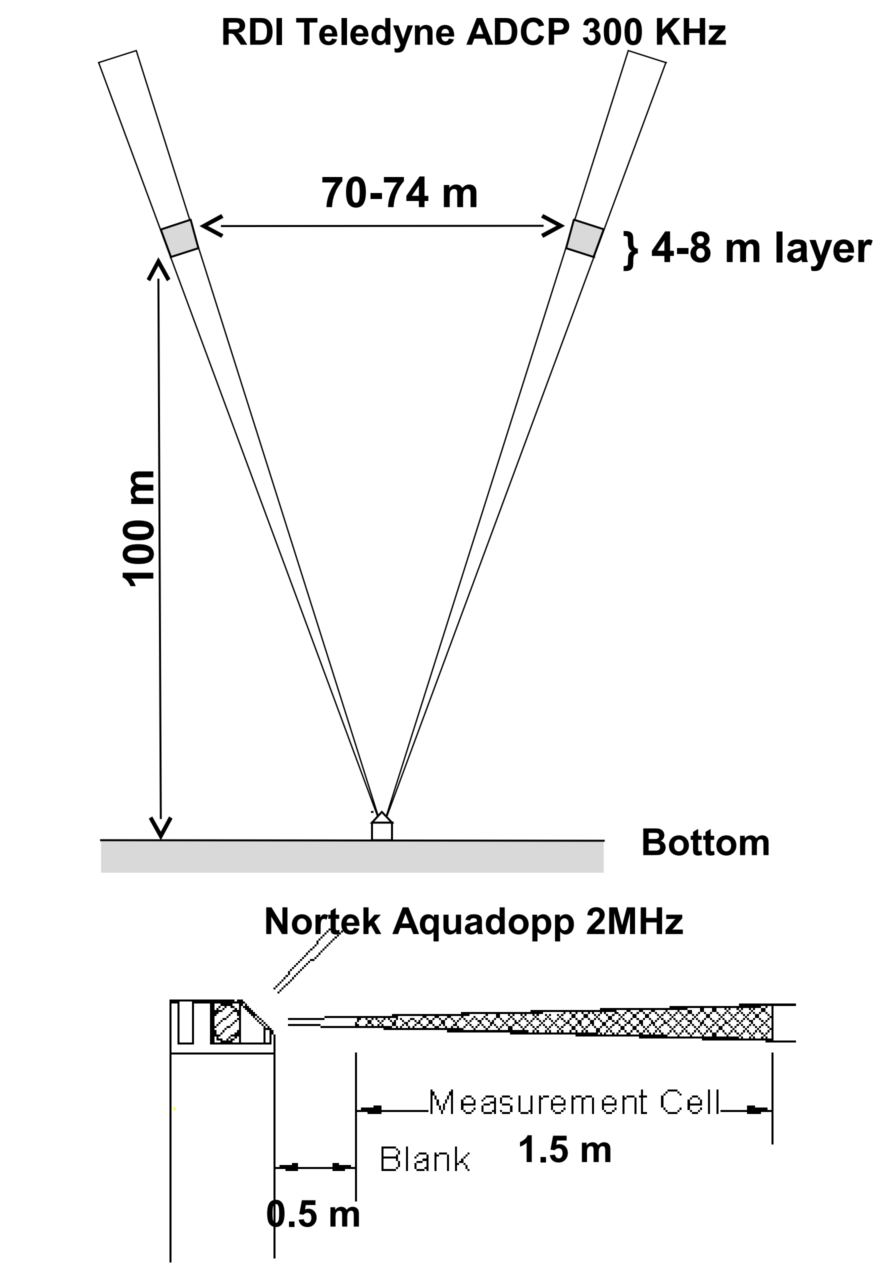
Nortek Aquadopp current meter

Idronaut 316 CTD with pH, DO, Redox sensors

TRDI Citadel CTD

SBE CTD 49

Aqualog profiler with Aquadopp or RDI DVS vs ADCP



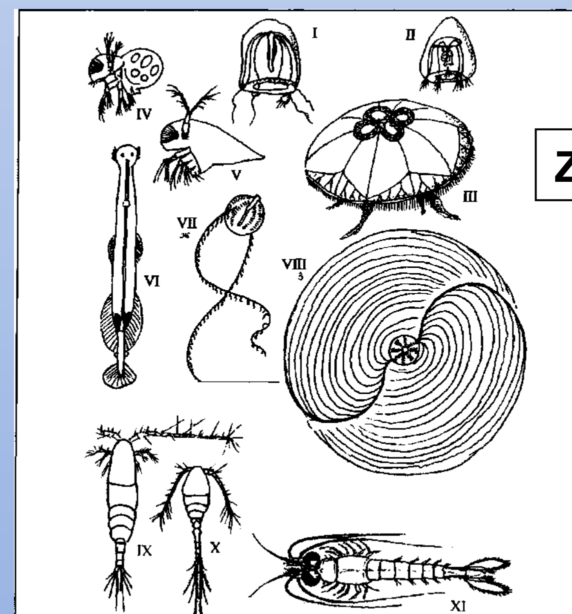
ADCP	Aqualog with Nortek Aquadopp
Longer the working range - poorer the vertical resolution, e.g., 100 m range requires at least 4 m binned layers	Constant resolution 0.2 m does not depend on the profiling range
The longest range ever is 644 m (75 kHz ADCP)	Profiling depth is limited to 3000 m
The horizontal span of the acoustic beams widens proportionally to the range	Measurement area is fixed at 0.5-2 m from the profiler.
Acoustic backscatter at low frequency of 75-470 KHz is more sensitive to larger scatters, e.g., swimming nekton species	Acoustic backscatter at high frequency of 1-2 MHz is most sensitive to the particles of the size less than 0.5 mm
Synchronous sampling of entire water column	For 100 m water column the profiling takes approximately 8 min
Finer time resolution	Less frequent sampling of profiles
The current profiles only	Simultaneous profiles of current velocity, temperature. salinity, oxygen, and etc.

Doppler current meter Nortek Aquadopp 2 MHz

Different acoustic frequencies have different particle size sensitivities. Sensitivity is defined as the volume scattering strength for a given concentration. The peak sensitivity occurs at a values of k*a=1, when the circumference of the particle is equal to the acoustic wavelength, where "k" is the acoustic wave number (2*π/λ or 2*π*f/c) and "a" is the particle radius. In general, the Aqaudopp can detect, with reasonably good sensitivity, particles sizes where k*a>0.05 as long as there is no significant concentration of particles with k*a ≈ 1.

Frequency (MHz)	Particle diameter for k*a = 1
10	50 μm
3.0	160 μm
1.5	320 μm
0.50	960 μm

Zooplankton scatterers:
- swim-bladdered fish,
- Pteropods,
- Capepods.



Zaitsev, 1998

Underwater communication link

SBE Inductive modem with cable coupler

1. Data is transferred real-time to the subsurface flotation by using inductive modems.
2. Then the tether transmits the information from the subsurface flotation to the surface buoy.

The wire rope, in contact with seawater at each end, conducts electrical signals in a loop, where seawater is the electrical return path. IM devices couple to this loop inductively along the insulated (jacketed wire) part of this loop without direct electrical connection. The coupling is achieved using a toroid transformer in which the mooring wire and seawater return form a single winding. Since there is only one current path, only one device can transmit at a time (half-duplex).

The AQUAscat ® 1000s Acoustic Backscatter System

Application of the AQUAscat 1000s on the profiler (jointly with University of Leicester, UK)

Sediments	Typically 20 µm to 2000 µm radius Typically 0.01 g/l to 20 g/l over 1 m
Measurement cells	256 x 40 mm ≈ 10 m
Measurement burst interval	Internally generated once every minute

The AQUA*scat* transmits pulses of high frequency sound on 4 transducers, each of which may operate at a different frequency in the range from 500 kHz to 5 MHz. It measures the sound scattered by sediment or other suspended materials at discrete spatial intervals programmable from around 2½ millimetres to several centimetres.

Underwater communication link – Acoustic modem

Teledyne Benthos Acoustic telemetry modem 903 transducer

1. Data is transferred real-time to the subsurface flotation by using inductive modems.
2. Then the tether transmits the information from the subsurface flotation to the surface buoy.

Baud Rate	140-15,360 bps
Data Storage	6144 Kbyte Data logger standard
Distances/Range	2-6 km common, greater distances possible, 20+ km available using repeater functionality

Underwater communication link – Acoustic modem (continued)

Evologics S2CR 7/17 modem

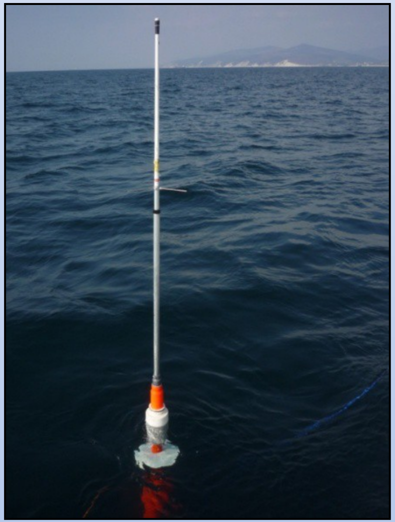
The Black Sea trials in September - October 2014.

Reliable operation below the seasonal thermocline at the distances up to 4 km.

Air communication link

GPRS (mobile telemetry) buoy

Radio buoy	
Type	Frude-type
Max. dimensions	4480 × 480 mm
Transportation length	1300 mm
Height above the sea surface	1500-2000 mm
Storm loadings	5 grade
Weight in air	40 kg
Modem	Integra TR
Antenna	Anlia 100-MU
Transmission speed	19200 Kb
Transmission distance	10-12 km
Frequency	430-470 MHz

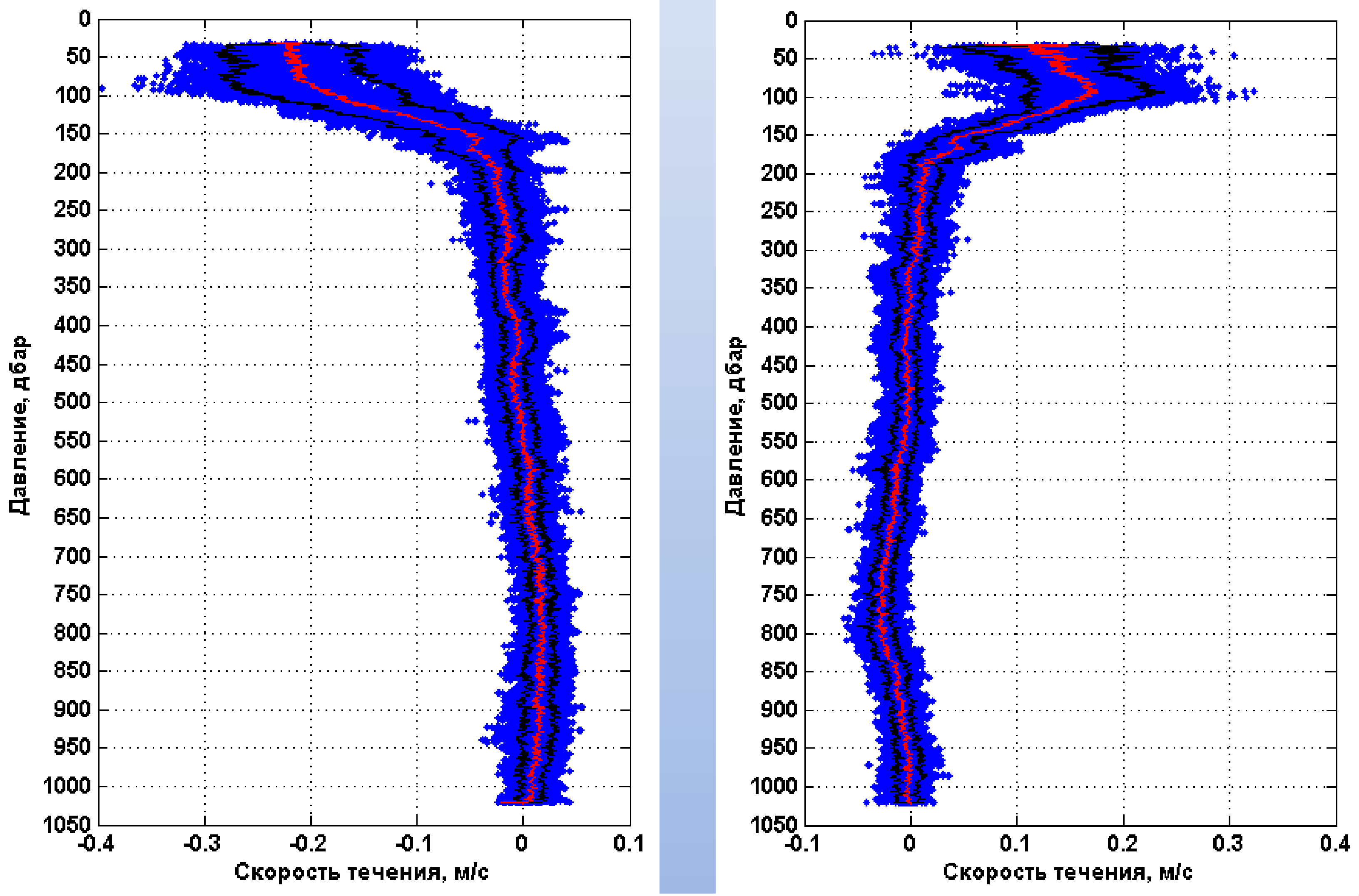


3. The GPRS buoy serves for the data and command exchange between the mooring and a user via Internet.

4. The radio buoy transmits the observational data and telemetry information from the mooring to the coastal station. In return, it receives commands from the coastal station.

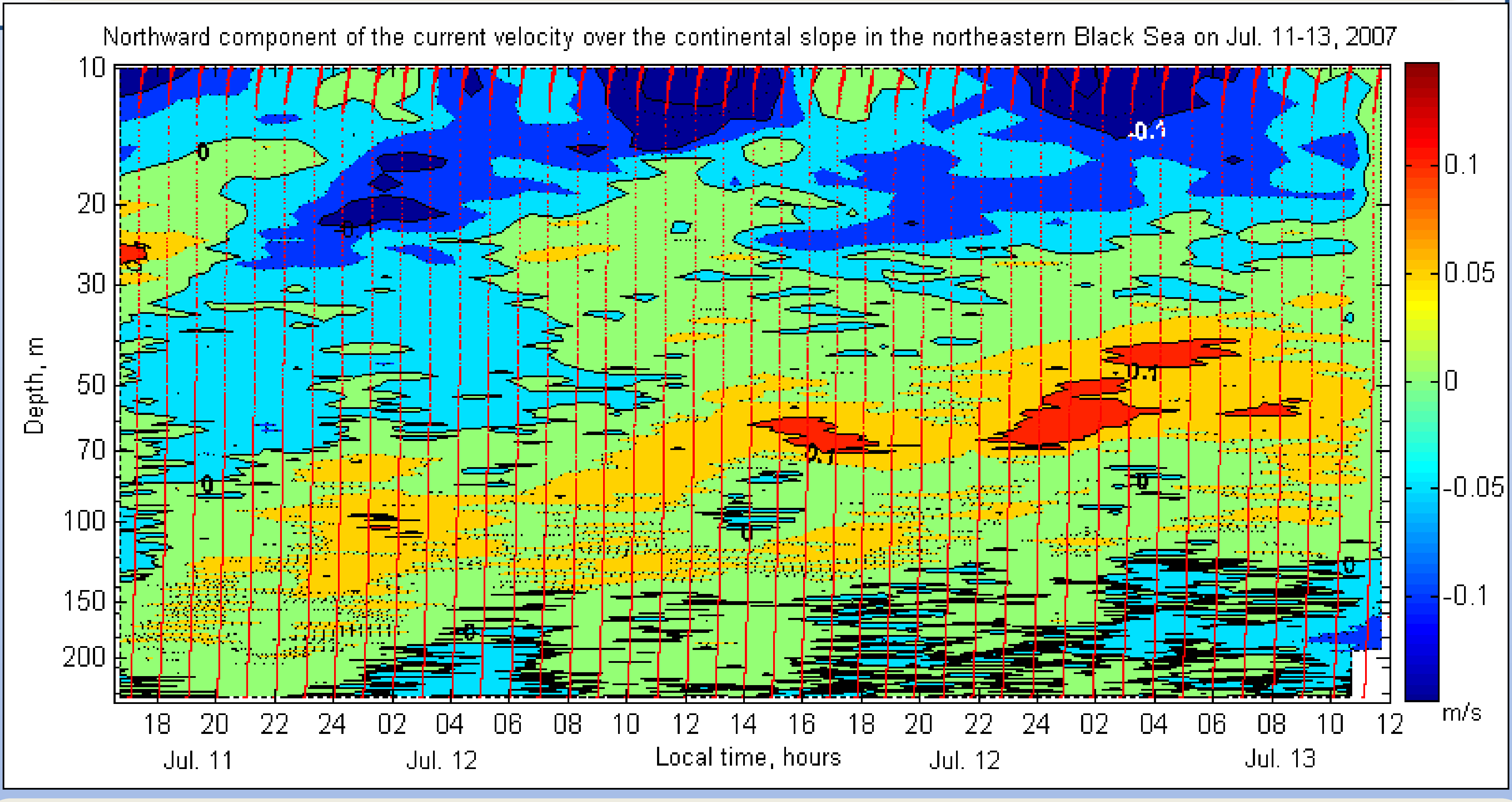
The short term variability of hydrophysical and biological processes over the northeastern Black Sea continental slope

Deep profiles of the ocean current fine structure (the NE Black Sea, June 2011)



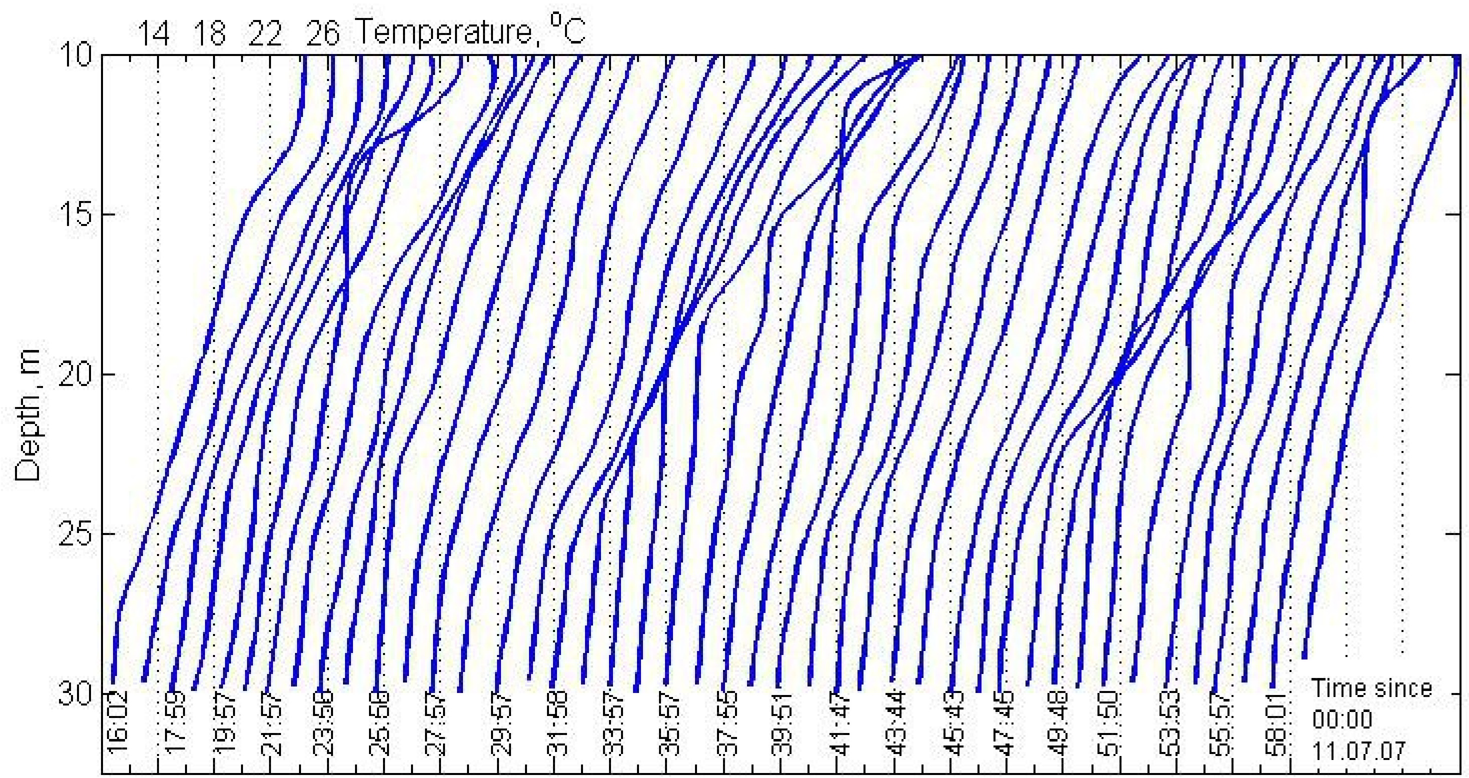
Zonal current velocity **Meridional current velocity**

Internal waves and near-inertial motions interacting with the mesoscale eddies and the Rim Current



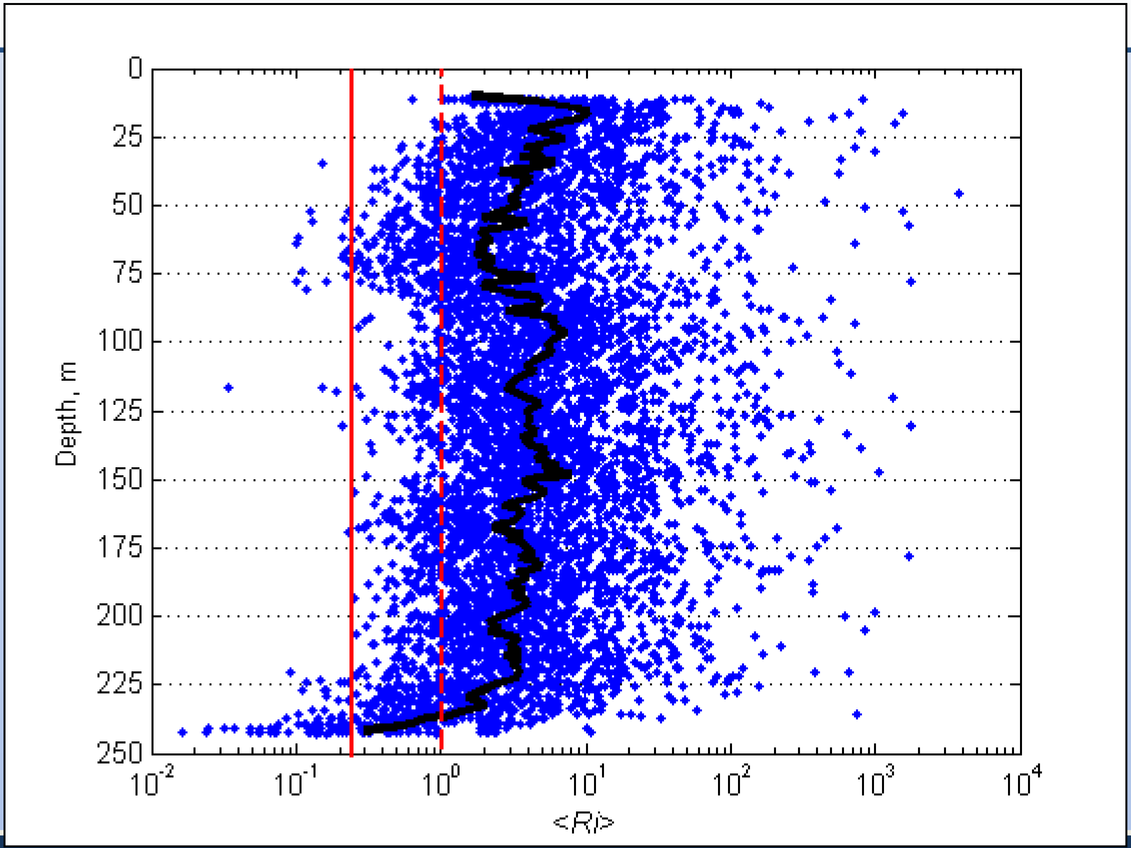
Example: Northward component of the current velocity over the continental slope in the northeastern Black Sea in July 2007. Thin red lines indicate location of the profiler during the survey.

Near-inertial oscillations in seasonal thermocline off the Gelendzhik Bay in the Black Sea on July 2007



Sequential vertical profiles of the temperature are shifted by 2°C along X axis. Lower part from 30 m to 250 m is not shown.

Estimates of vertical momentum and heat exchange



The mean gradient Richardon number $\langle Ri \rangle = \langle N^2 \rangle / \langle U_z^2 \rangle$ as estimated from the profiler data on July 11-13, 2007. The thick black line is the vertical profile of the median values $\langle Ri \rangle$. Red line indicates $\langle Ri \rangle = 0.25$. Red dotted line indicates $\langle Ri \rangle = 1$.

The coefficients of vertical eddy viscosity and eddy diffusivity

$$\nu = A_0/(1+aRi)^2 + A_1, \qquad \kappa = \nu/(1 + aRi) + A_2$$

(Pacanowski and Philander 1981)

Adding perspective from space

Distribution chlorophyll-a over the north-east Black Sea as observed by MERIS of Envisat around 08:14 of October 3, 2009 and the sites of the moored profilers (Aqualog-1 – shelf, Aqualog-2 - continental slope)

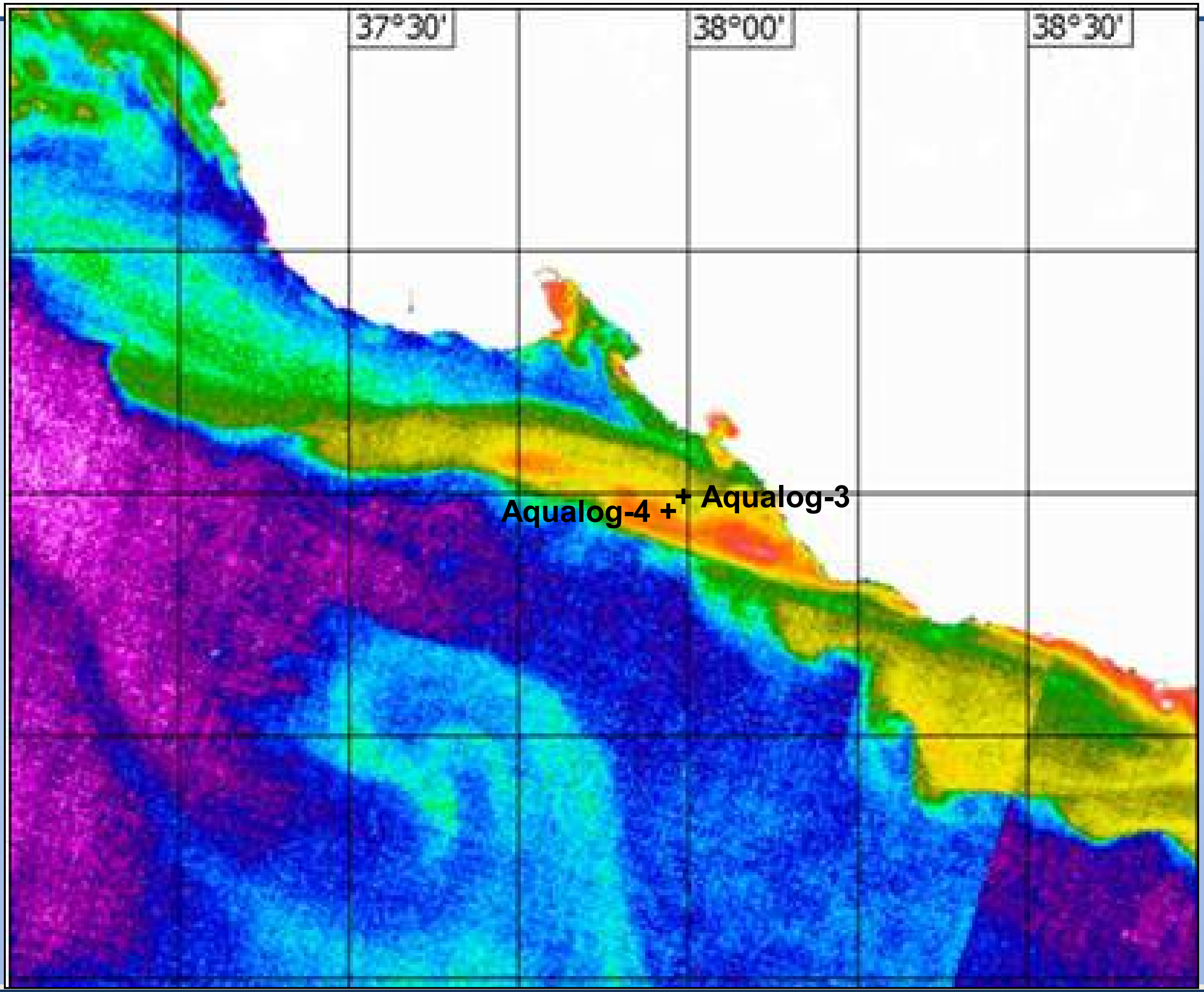
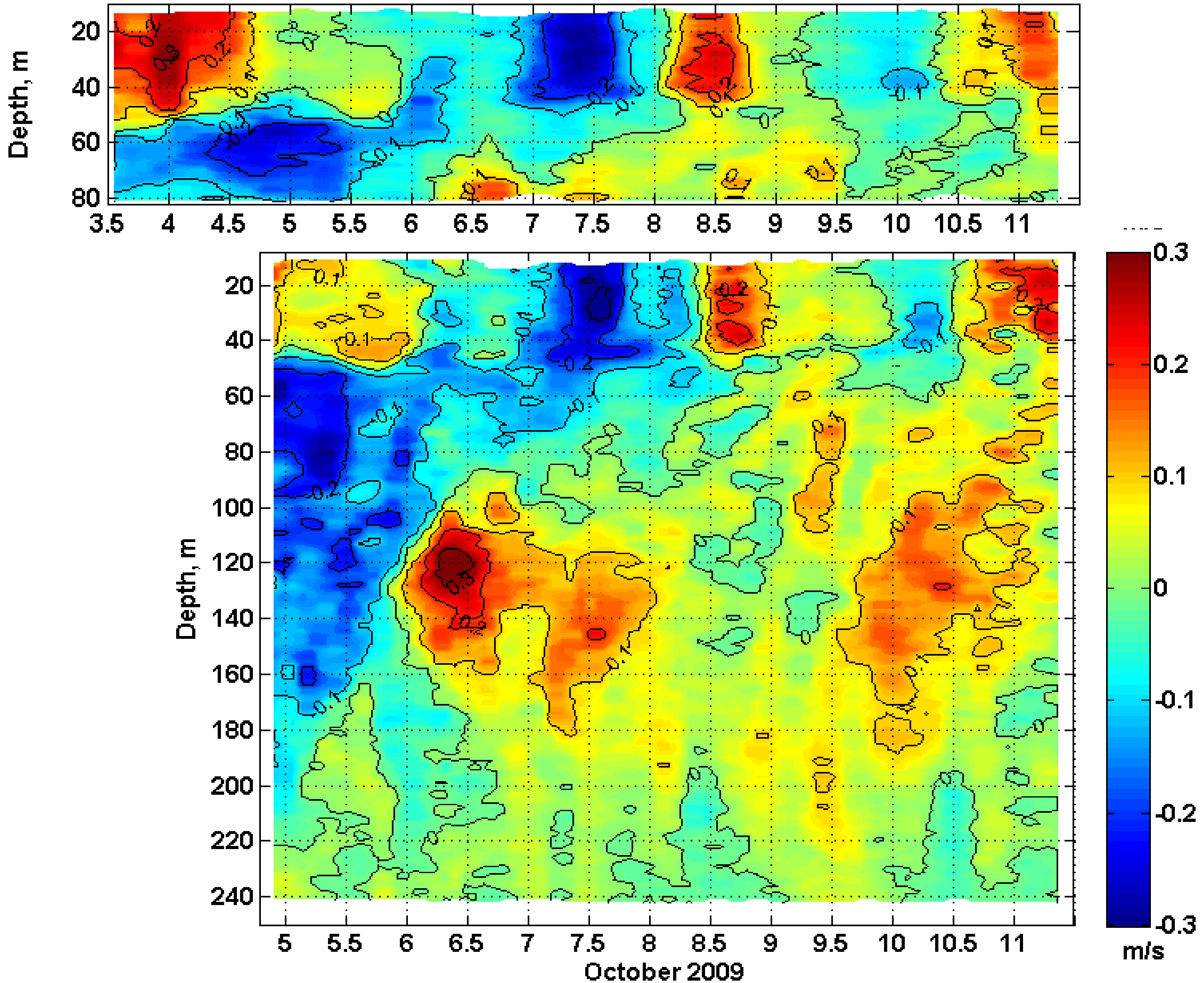
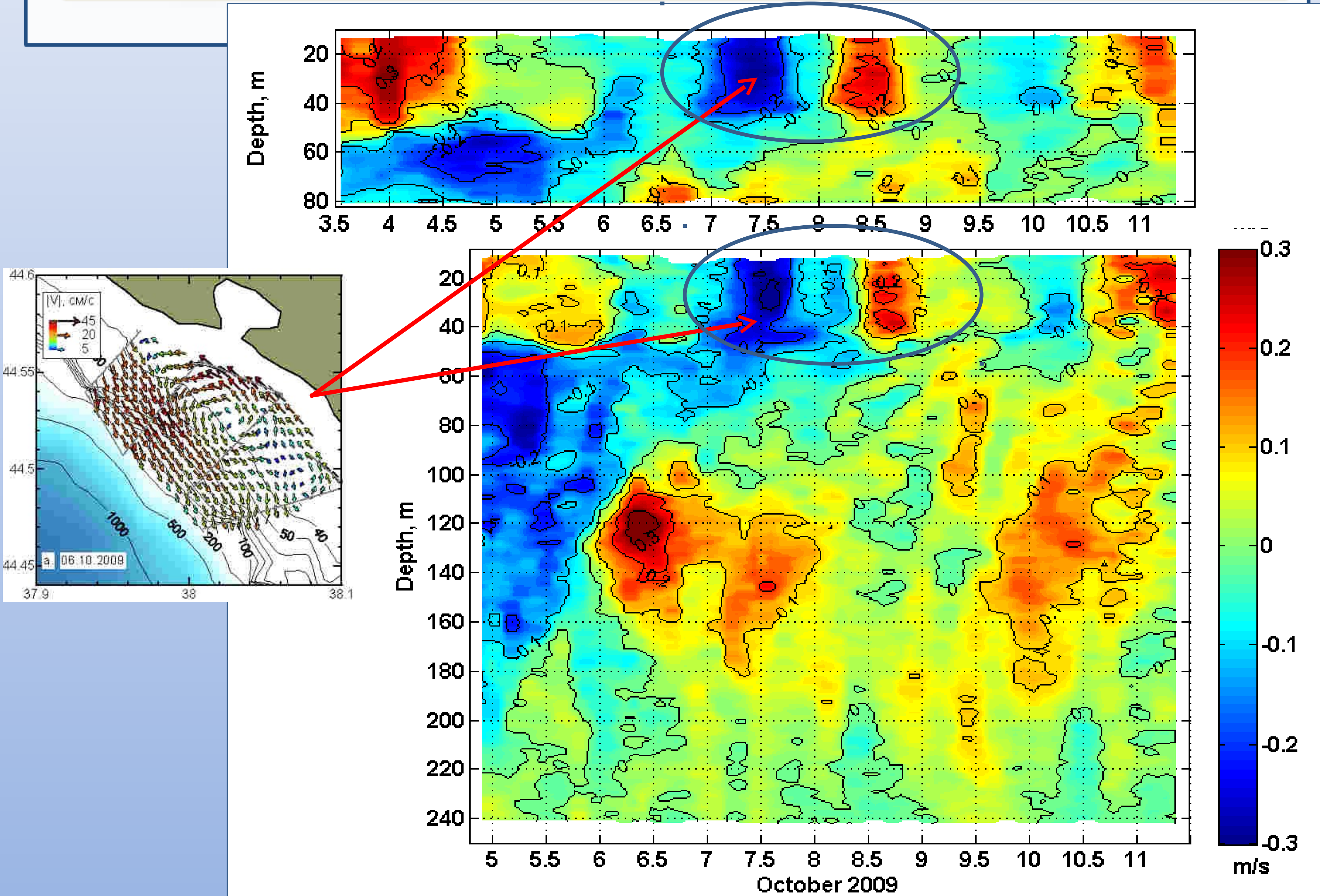


Image courtesy of Dr. Soloviev, MHI, Ukraine.

Along-coast components of the current velocity at two moored sites

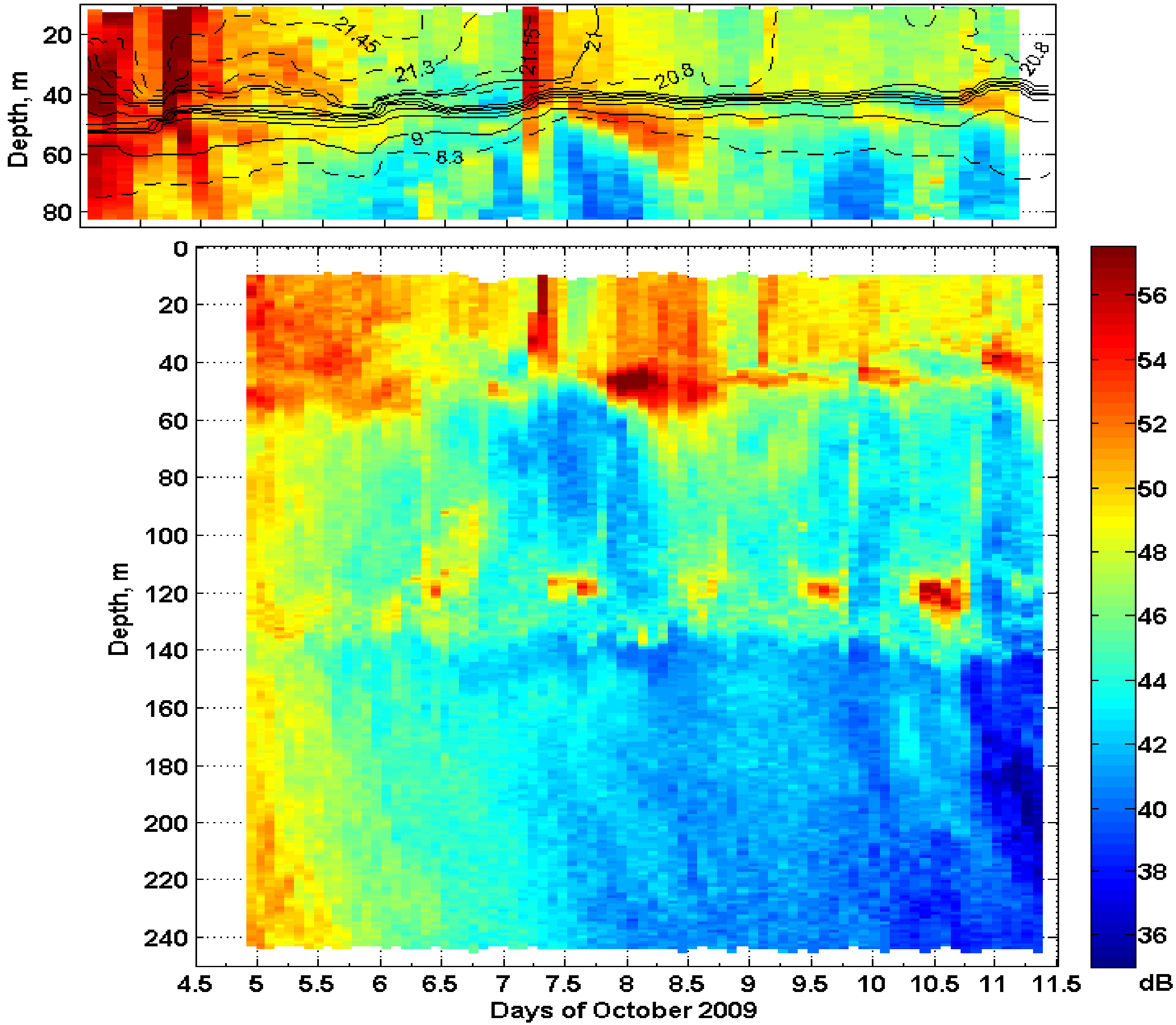


Along-coast components of the current velocity at two moored sites

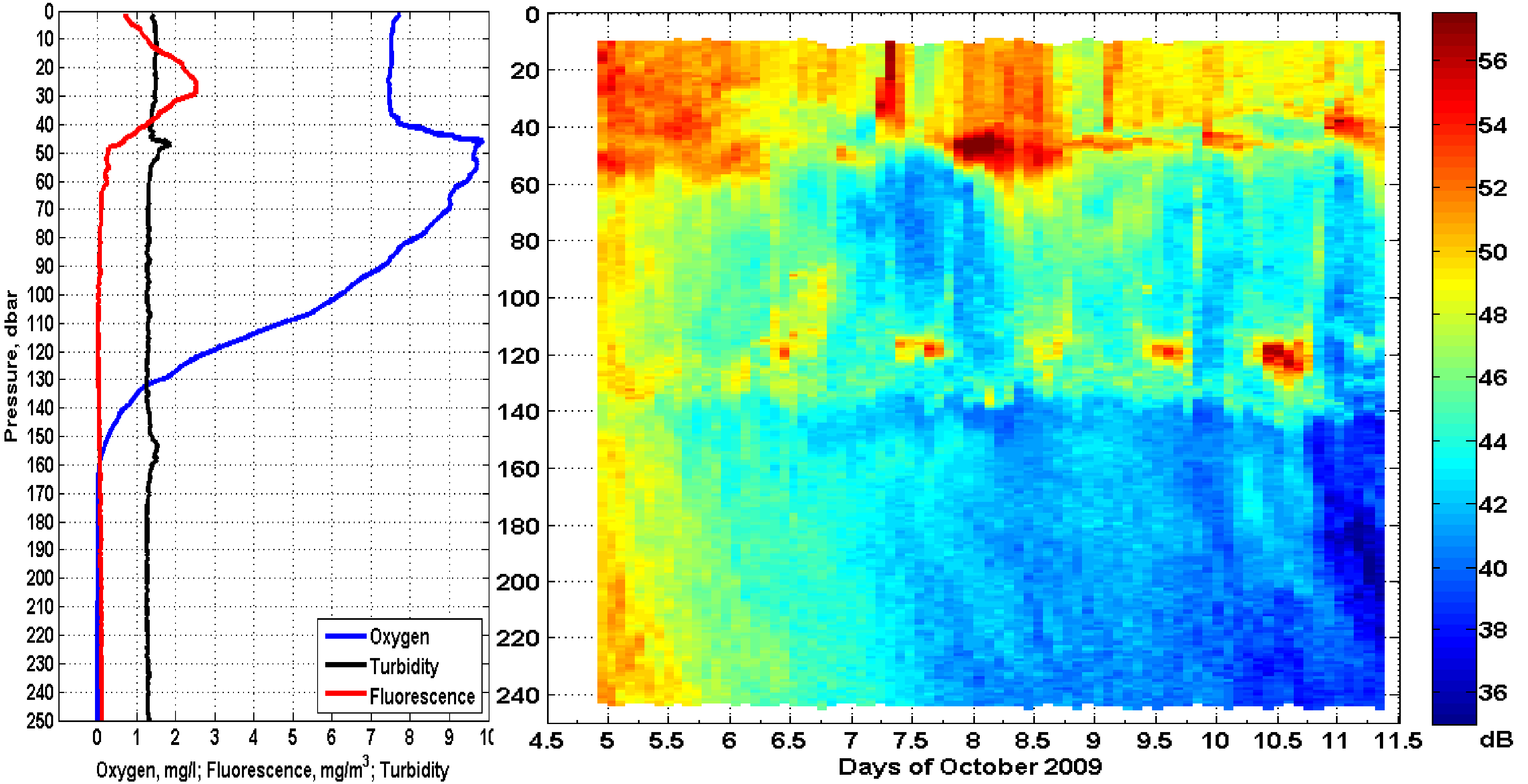


Listening the sound backscatter layers

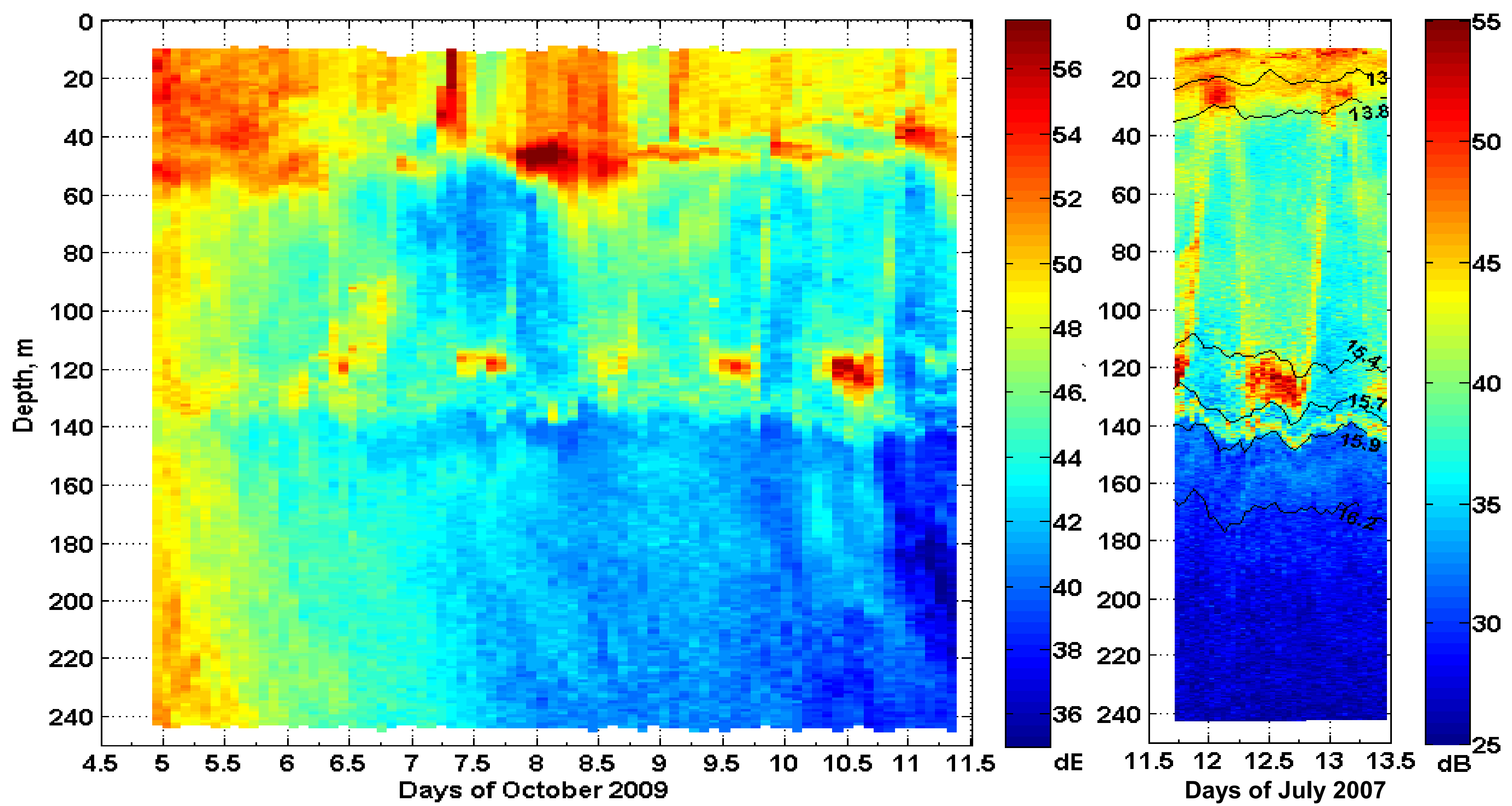
Variability of the acoustic backscatter at 2MHz at two moored sites



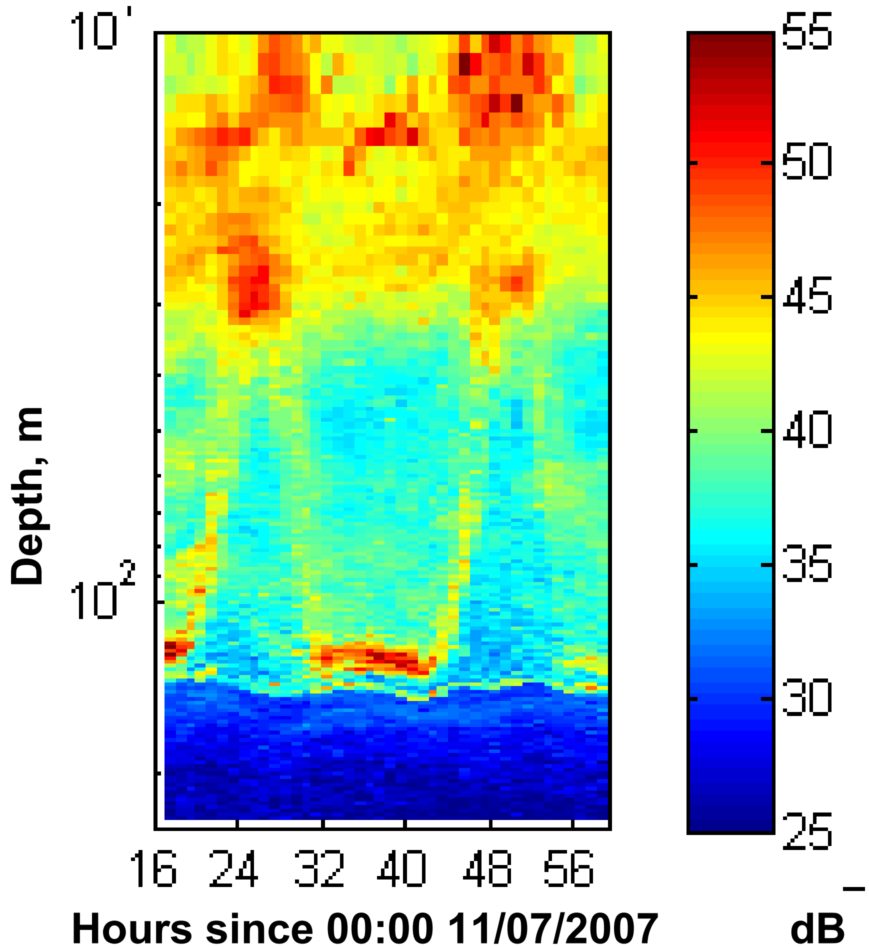
Variability of the acoustic backscatter at 2MHz at the coastal shelf break moored site during the survey and the vertical profiles of dissolved oxygen, fluorescence and turbidity as of October 4, 2009



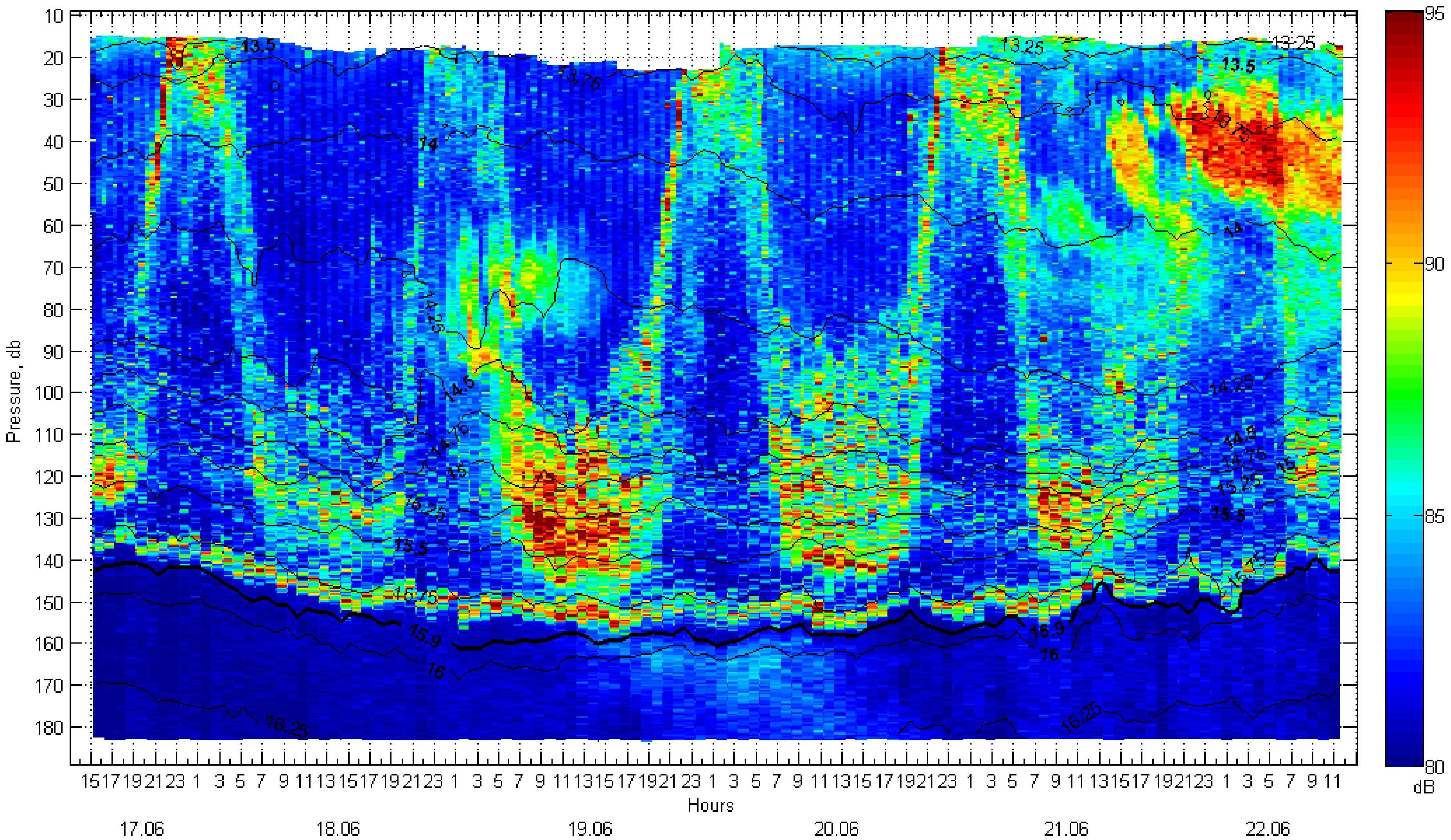
Comparison of variability of the 2MHz acoustic backscatter at the coastal shelf break moored site in October 2009 and inJuly 2007



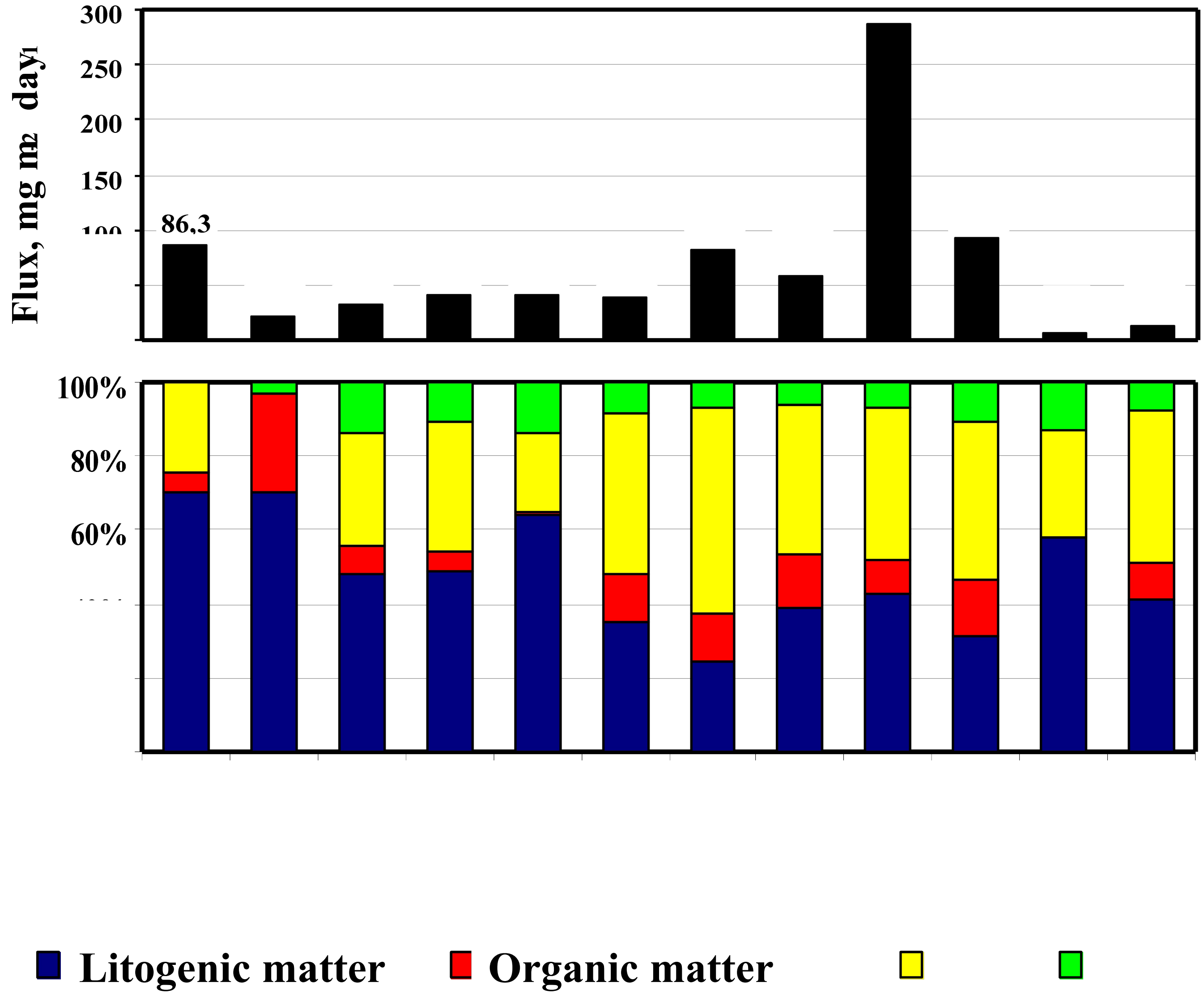
Diel migrations of zooplankton



Diel migrations of zooplankton and patches of the suspended sediments over the upper part of the continental slope in the northeastern Black Sea in June 2011

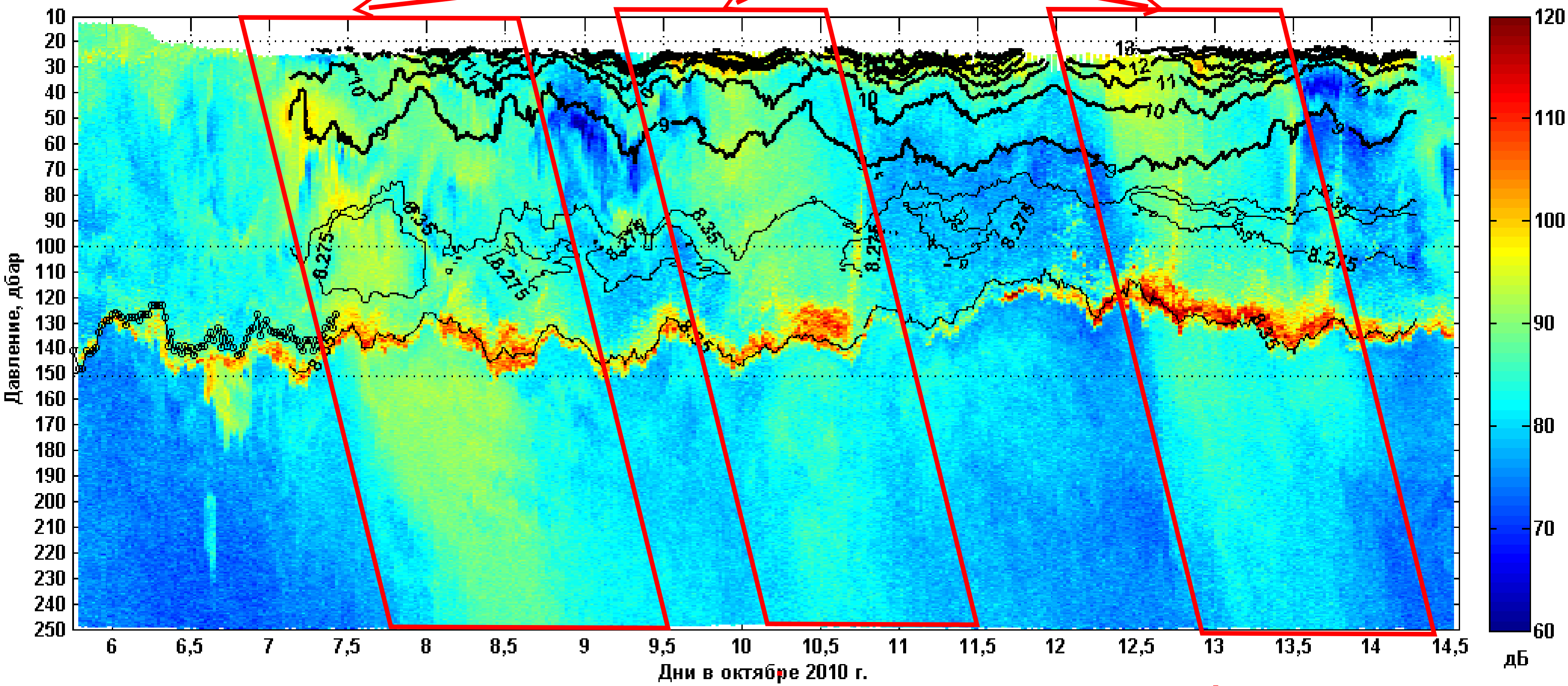


Comparison with the sediment trap data collected nearby at the distance of 500 m



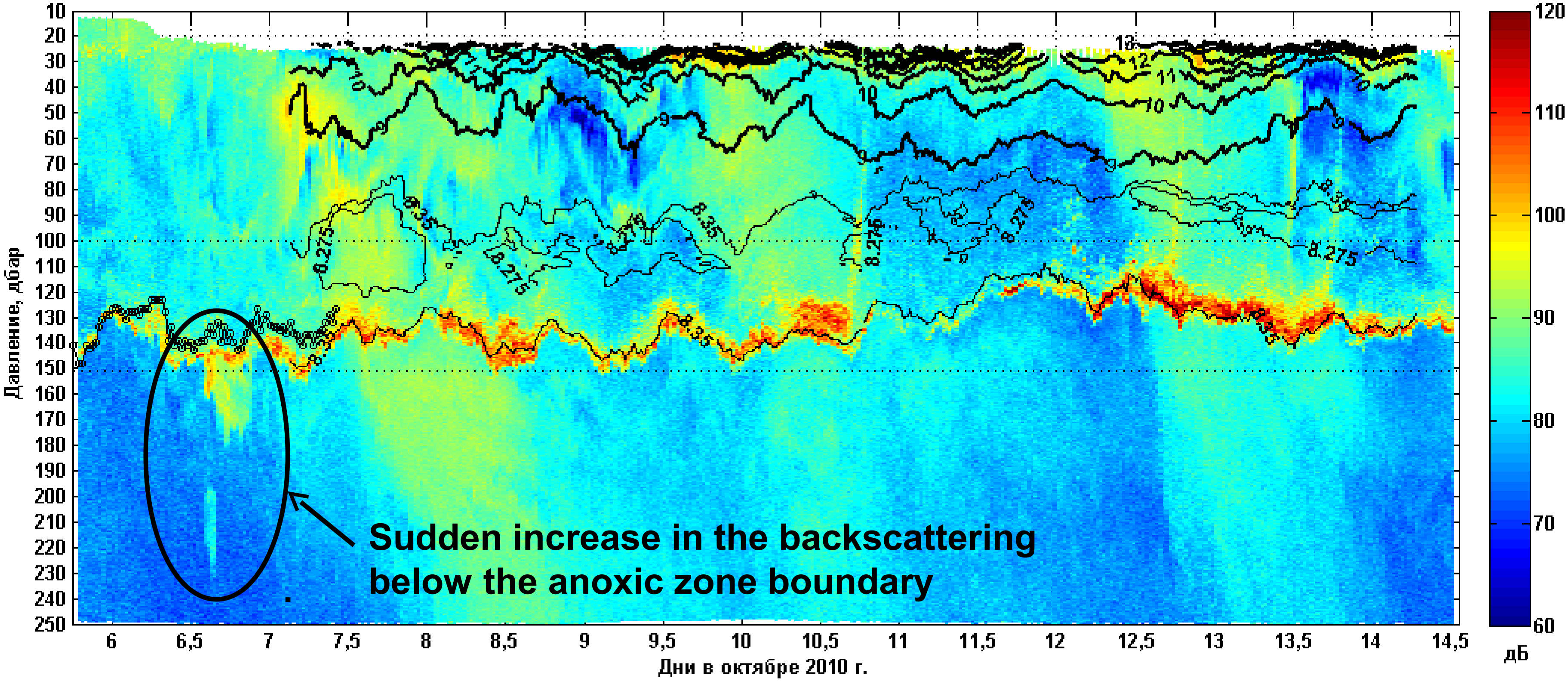
Suspended sediments and the boundary of anoxic layer in 2010

Patches of particles sinking with speed 2.5-3.5 mm/s



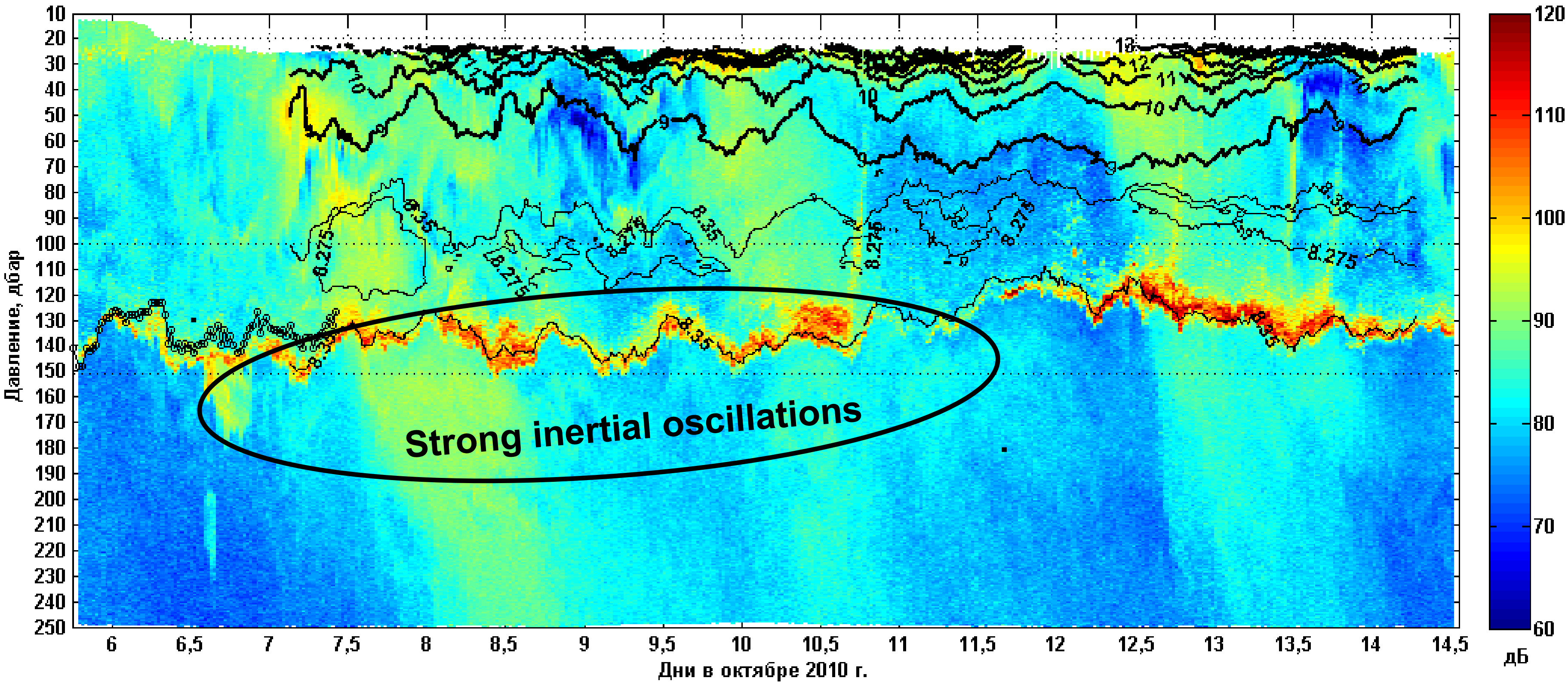
Acoustic backscatter at 2 MHz observed by means of the profiler mooring over the upper part of the continental slope off shore the Gelendzhik bay in October 2010.

Suspended sediments and the boundary of anoxic layer in 2010



Acoustic backscatter at 2 MHz observed by means of the profiler mooring over the upper part of the continental slope off shore the Gelendzhik bay in October 2010.

Suspended sediments and the boundary of anoxic layer in 2010



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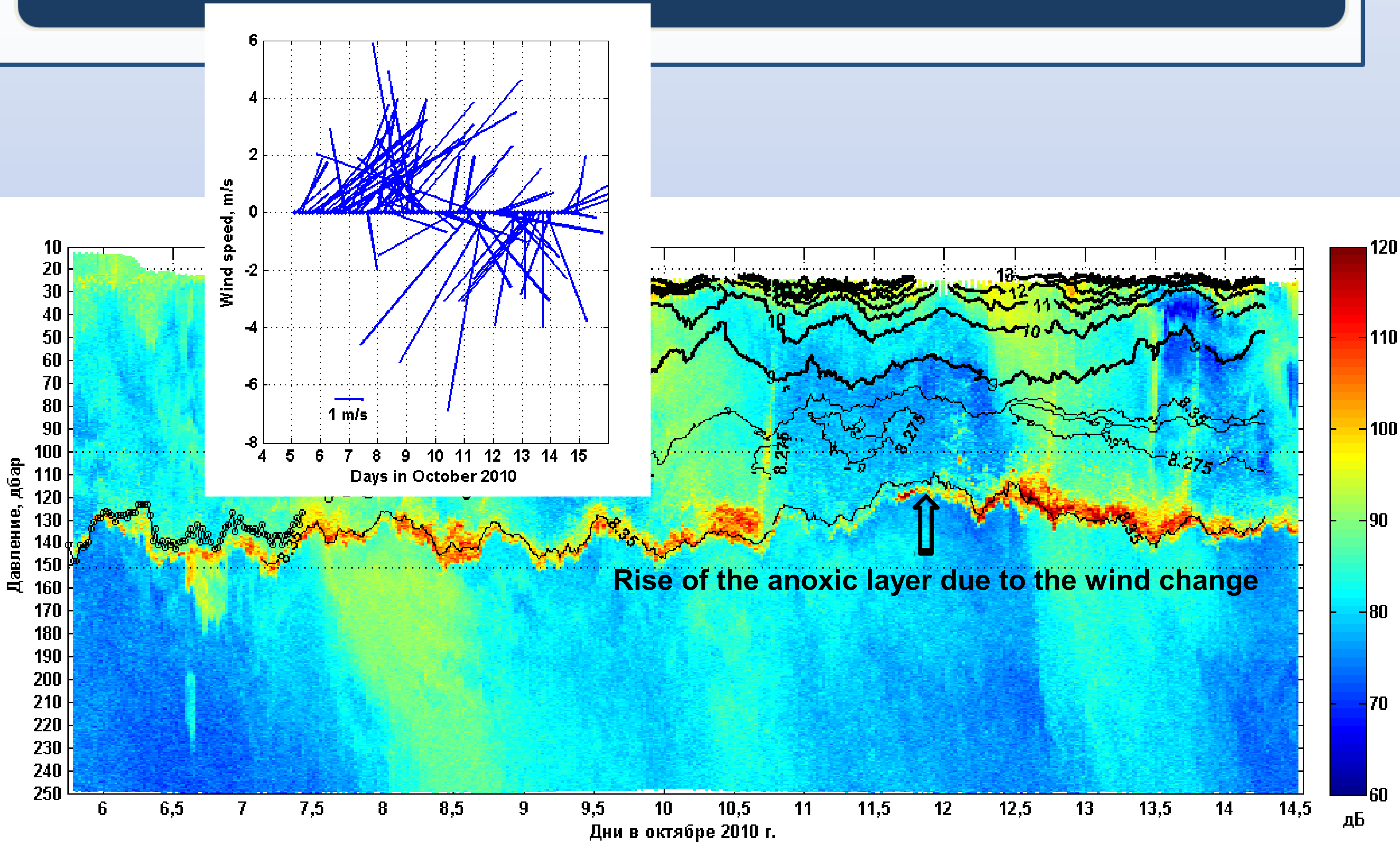
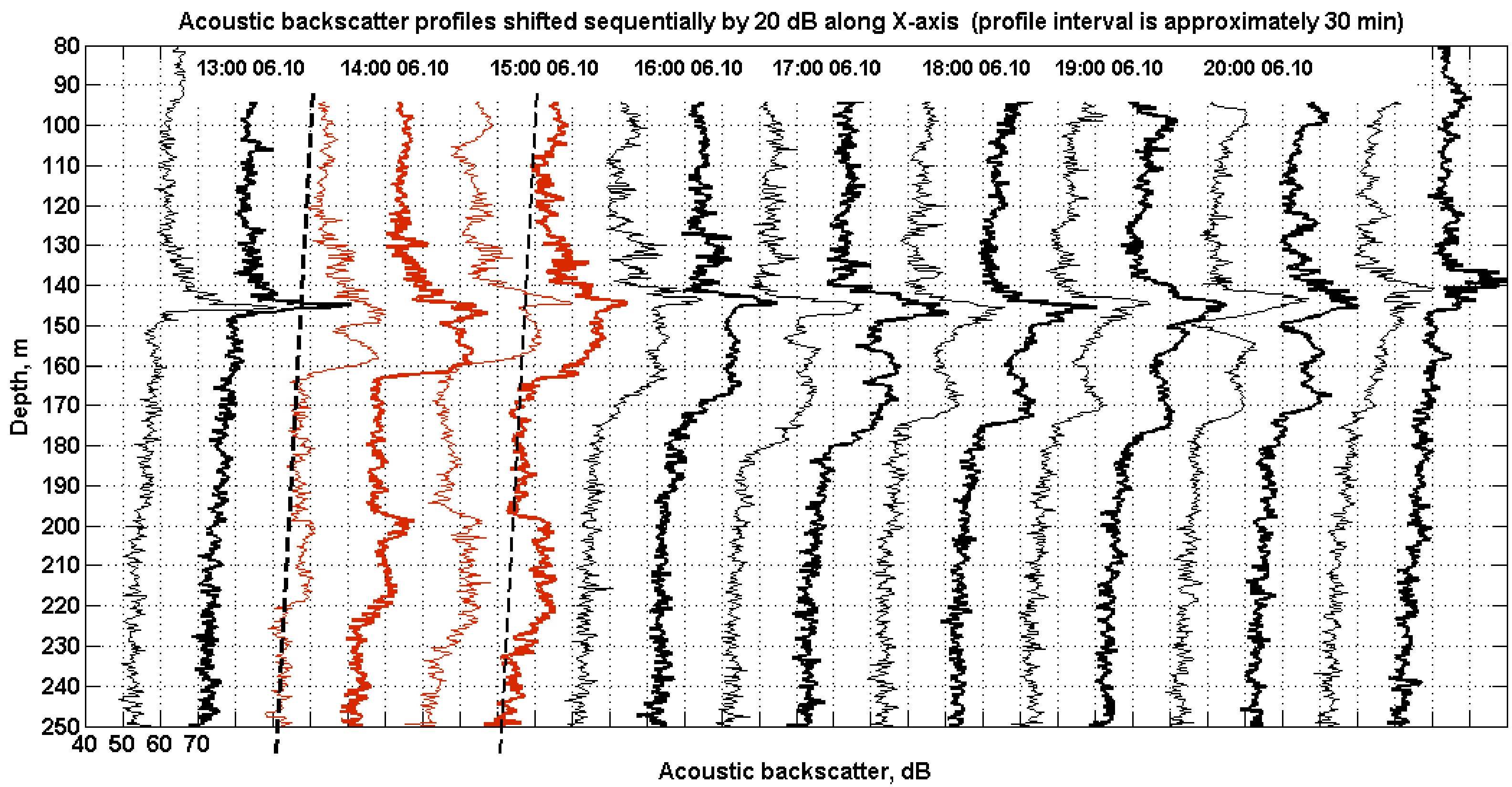
Suspended sediments and the boundary of anoxic layer in 2010



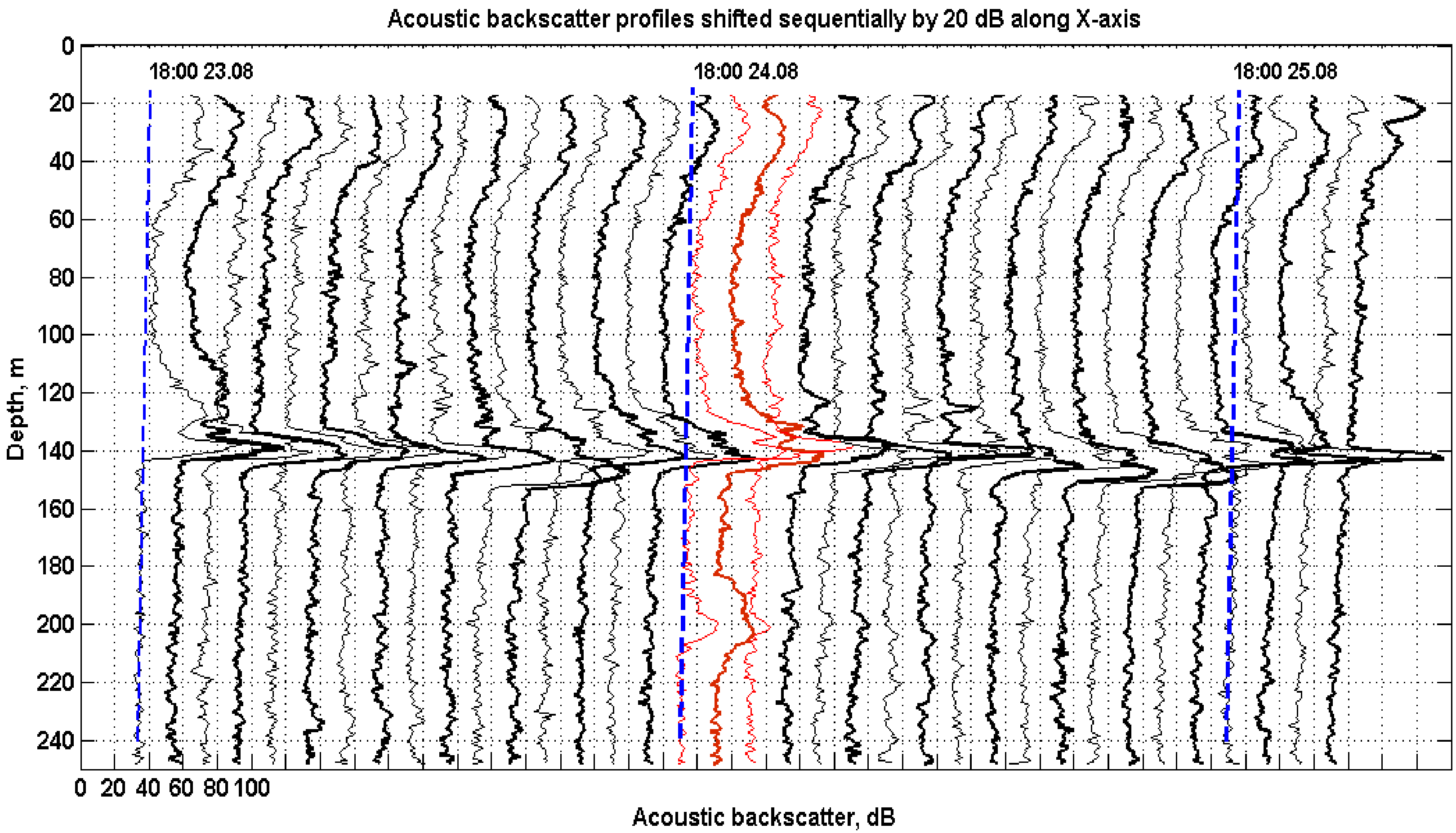
Acoustic backscatter at 2 MHz observed by means of the profiler mooring over the upper part of the continental slope off shore the Gelendzhik bay in October 2010.

Suspended sediments and the boundary of anoxic layer in 2010

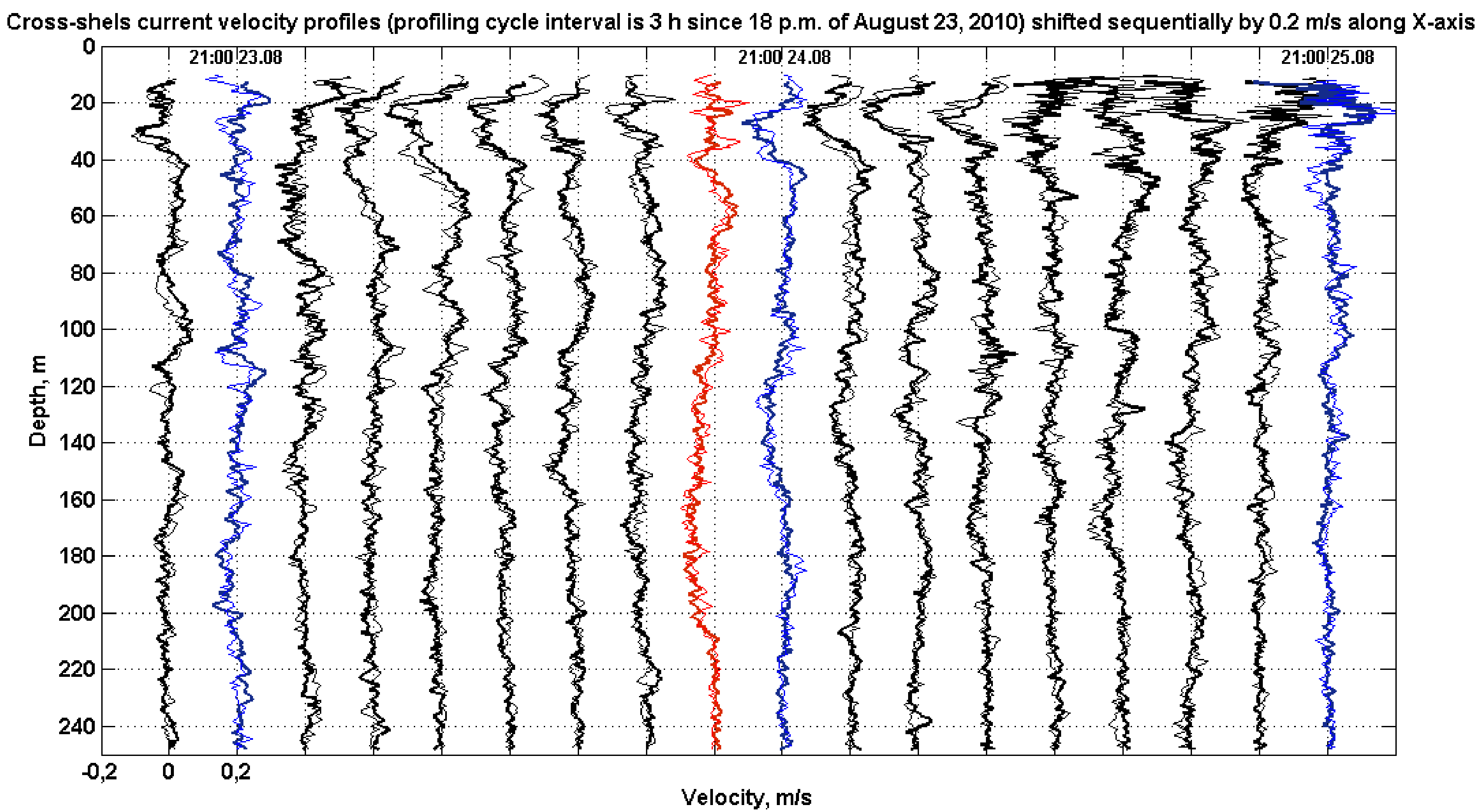


Acoustic backscatter at 2 MHz observed by means of the profiler mooring over the upper part of the continental slope off shore the Gelendzhik bay in October 2010.

Suspended sediments and the boundary of anoxic layer in 2010

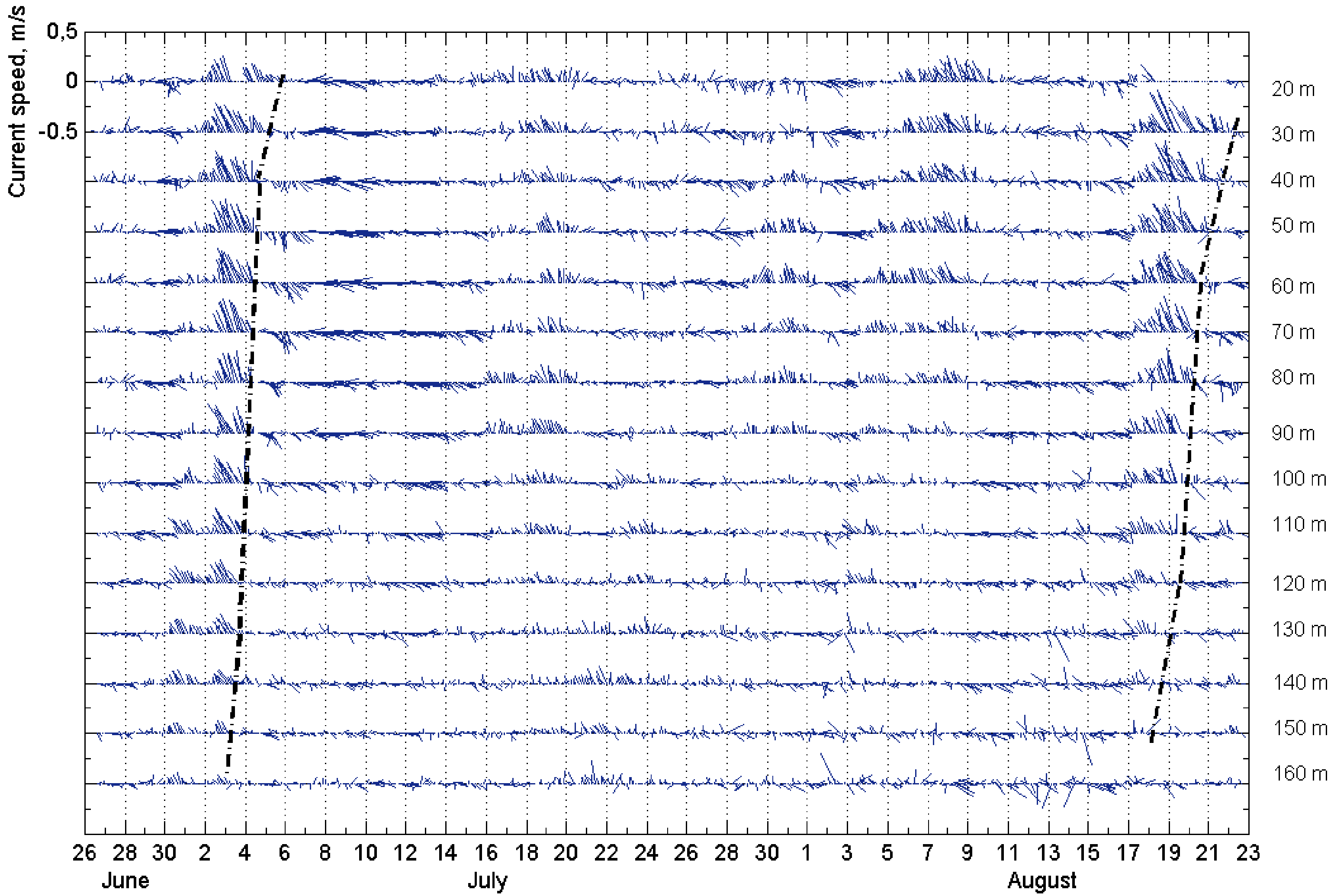


Acoustic backscatter at 2 MHz observed by means of the profiler mooring over the upper part of the continental slope off shore the Gelendzhik bay in August 2010.



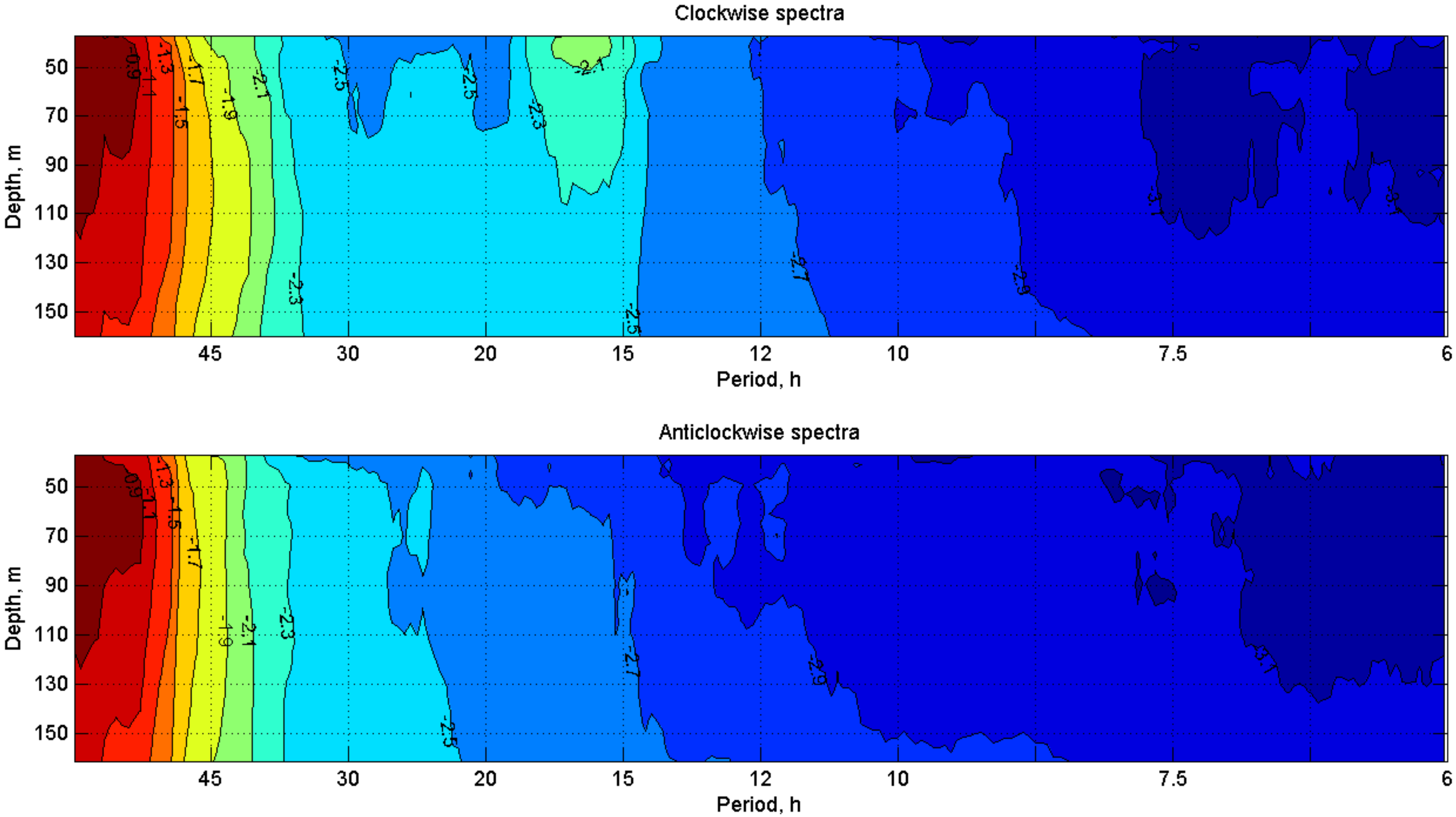
Cross-shelf north-eastward component of the current velocity observed by means of the profiler mooring over the upper part of the continental slope off the Gelendzhik bay in August 2010.

The stick vectors of the current velocity in June-August 2011



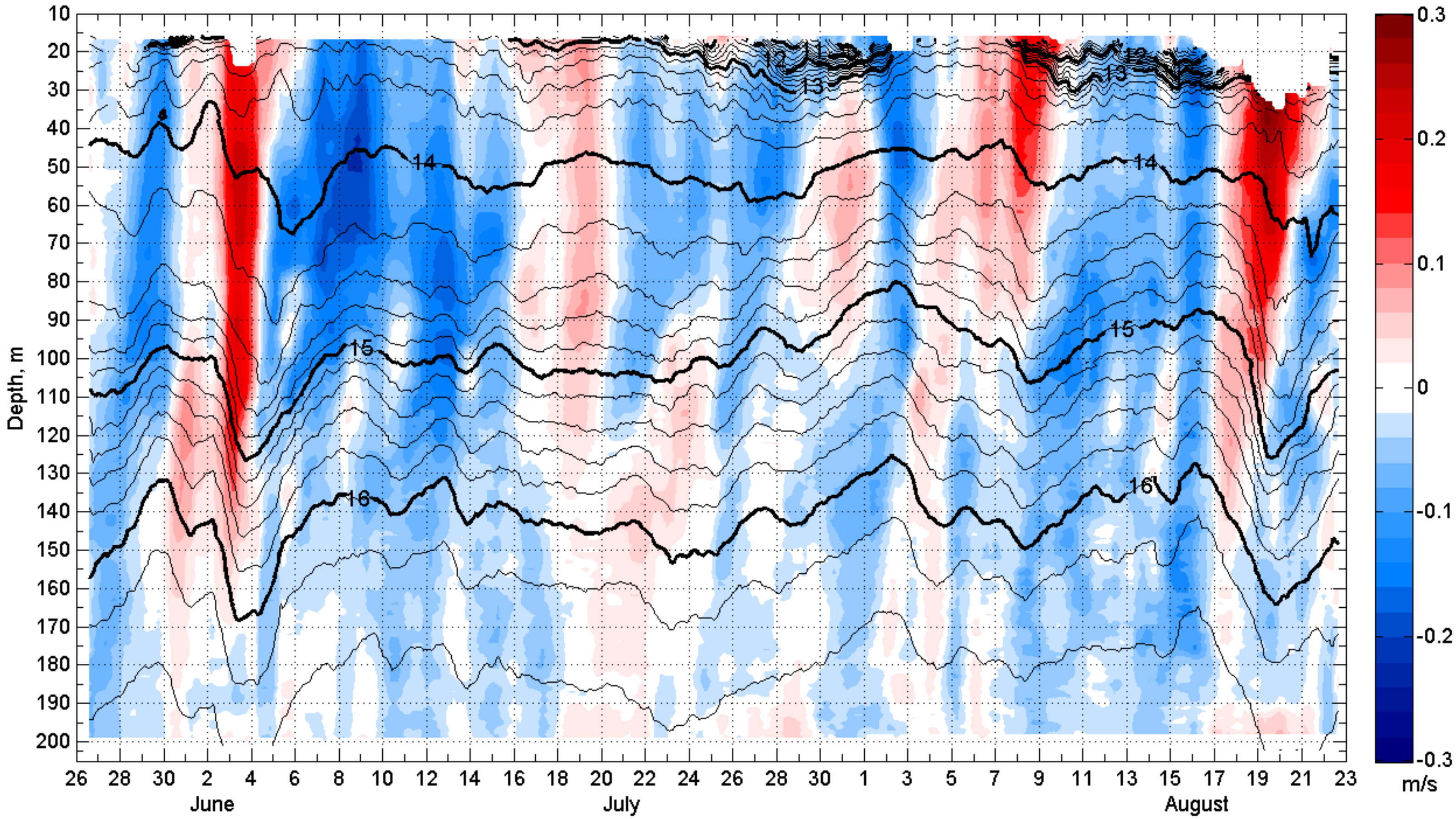
Mesoscale and submesoscale eddies prevailed in the dynamics.

The Multitaper rotary spectra of the current velocity in June-August 2011



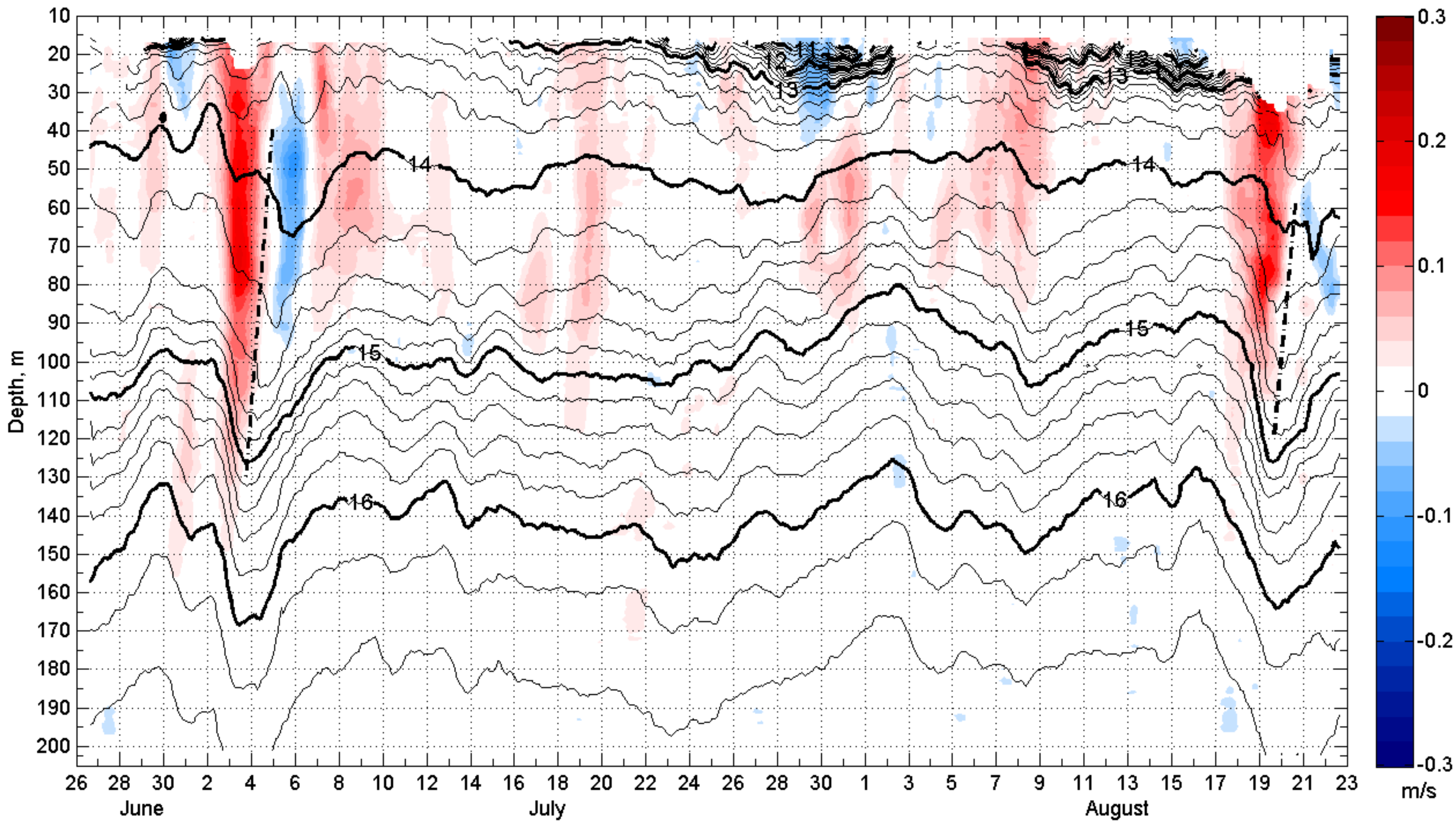
The normalized spectral density is shown in logarithmic log10 scale.

Alongshore north-westward current in June-August 2011 (the high-frequency variability was filtered out)



The potential density isopycnals (black lines) are superimposed on the time-depth diagram of the current variations .

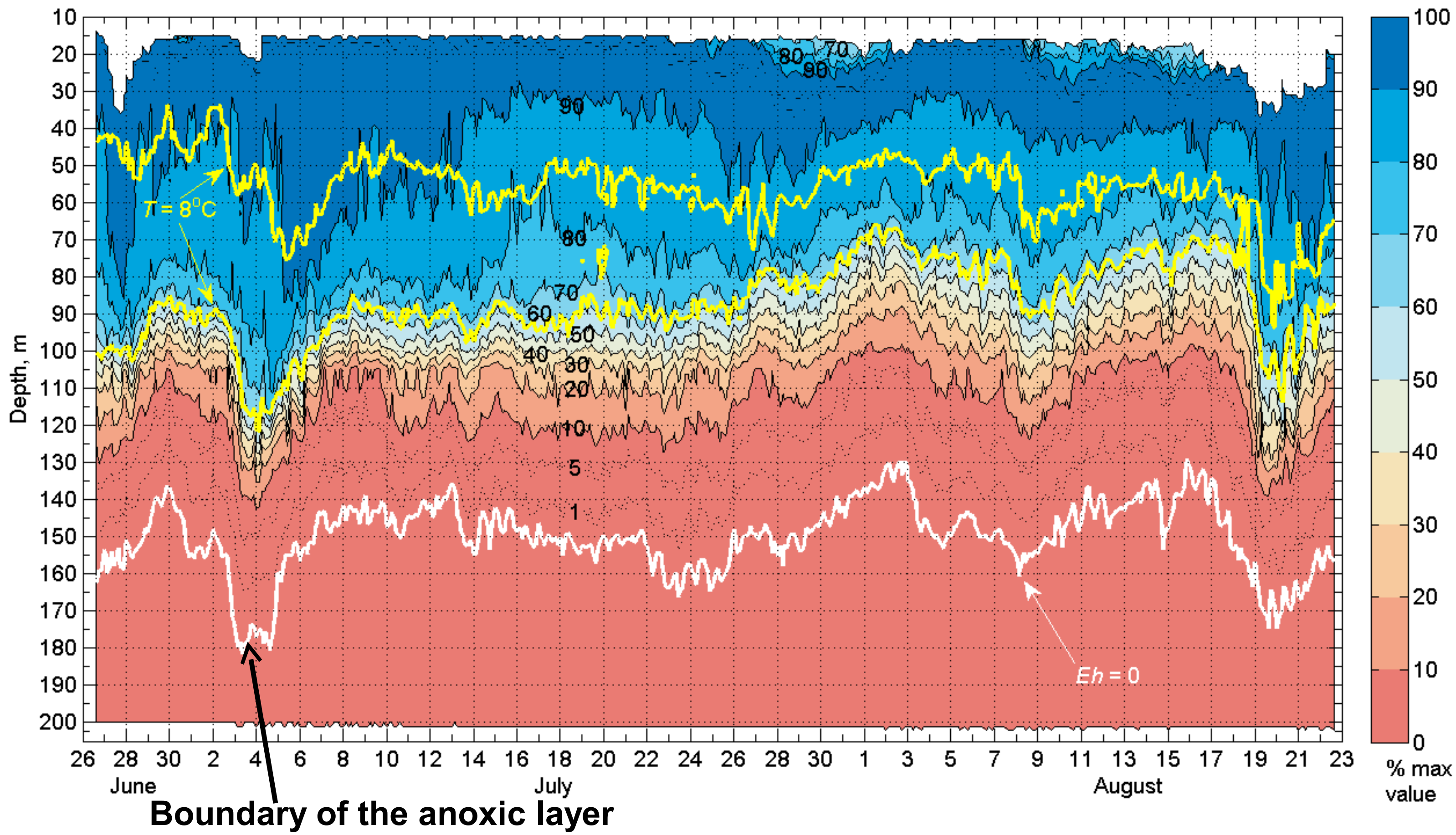
Cross-shore north-eastward current in June-August 2011 (the high-frequency variability was filtered out)



The potential density isopycnals (black lines) are superimposed on the time-depth diagram of the current variations .

Observations of the upper boundary of the anoxic zone

Fluctuations of the Black Sea anoxic zone boundary in June-August 2011



Acoustic backscatter at 2 MHz observed by means of the profiler mooring at the upper part of the continental slope off shore the Gelendzhik bay in 07-09. 2011.

Conclusions

Autonomous profiling multiparametric observatories of the moored type have great potential for being the key tools for marine environmental monitoring at the boundary zone between the deep ocean and the coastal waters.

The vertical profiling in contrast to the fixed depth measurements is capable of resolving the ocean fine structure, thermohaline lenses and intrusions, plankton accumulations, and acoustic scattering layers with resolution better than 1 m.

For the epipelagic zone the measurements of vertical profiles of physical, chemical, and biological parameters can be carried out most frequently (~1 h) helping to avoid aliasing of periodic processes associated with daily cycles, tides and inertial oscillations.

The vertical profiling technology for multidisciplinary measurements is a useful tool for research on coupling of biological and physical processes in the sea on time scales from a few hours to several months.

Thank you for your attention.

For more information, please, visit http://aqualog.ocean.ru