# New developments to progress Smart Buoy Idea

***Motyzhev S.*, Horton E.**, Lunev E.*,Kirichenko A.*,Tolstosheev A.*,Yachmenev V.***

*****Marine Hydrophysical Institute NASU/Marlin-Yug Ltd, Kapitanskaya,2, Sebastopol, Ukraine, 99011

** Naval Oceanographic Office, 1002 Balch Boulevard, Stennis Space Center, MS 39522-5001,USA

The cycle of investigations completed in 2006 has been connected with actions and recommendations of DBCP Data Users and Technology Workshop, which took place in Reading, United Kingdom, 27-28 March 2006. There were two directions of the job:

1. Evaluation of Smart buoy prototype on basis of SVP-B mini drifter
   - Design of SVP-B mini (34-cm hull, 61-cm drogue) as a whole to have a variety of mini drifters, e.g. subsurface temperature at the 12-m depth (SVP-BT mini drifter)
   - 30-month theoretical lifetime when continuous operation
   - Reliability of AP measurements
   - Indication of drogue attachment
   - Capability of surface waves estimation
   - Higher space-time resolution of measurements
   - Some smart parameters (e.g. real-time clock, self-determination of area and season, etc.)

2. Evaluation of SVP-BTC drifter with 80-m temperature chain
   - Development of the drifter
   - Reliability of AP measurements
   - Influence of drogue on vertical stabilization of chain
   - Determination of the chain profile
   - Indication of drogue attachment
   - Capability of surface waves estimation

According to the goals above two batches of drifters were built. First batch was 4 SVP-BT mini drifters with 34-cm hull and 61-cm drogue and second – temperature profiling drifters with 60-m and 80-m chains. The structure of drifters built is presented in the Table 1.

**Table 1. Variety of the experimental drifters deployed in the Black Sea in 2006**

| Model | SVP-B mini | | SVP-BTC | |
|---|---|---|---|---|
| Description | 34-cm hull; 3.6 cm OD single conductor logging cable as a tether line; 61-cm OD 5-segment holey sock: Drag Area Ratio (DAR)=40; 18-month lifetime. Equipped with modified barometric port. | | 41-cm hull; 5.6 cm OD single conductor logging cable as a tether line; 92-cm OD 6-segment holey sock; 12-month lifetime. Equipped with modified barometric port. | |
| Modification | SVP-BT mini drifter, equipped with subsurface temperature sensor at 12 m depth and new 1.4 W Marlin PTT with decreased power consumption | SVP-BT-GPS mini drifter, equipped with subsurface temperature sensor at 12 m depth and new Marlin PTT (0.5W emitted power and GPS module) | SVP-BTC60 drifter, equipped with 60-m temperature chain with 12 subsurface temperature sensors (10m, 12.5m, 15m, 20m, 25m, 30m, 35m, 40m, 45m, 50m, 55m, 60m) and depth sensor (60m) | SVP-BTC80 drifter, equipped with 80-m temperature chain with 16 subsurface temperature sensors (10m, 12.5m, 15m, 20m, 25m, 30m, 35m, 40m, 45m, 50m, 55m, 60m, 65m, 70m, 75m, 80m and 4 depth sensors (15m, 35m, 60m, 80m) |
| Argos IDs | 40414; 40418 | 40445; 47621 | 56090; 56091 | 56092; 56093 |
| Length of message | 88 bits; | 152 bits; | 216 bits; | 248 bits; |
| Technical file | SVP-BT mini Rank=5 | SVP-BT-GPS mini Rank=0 | SVP-BTC60 Rank=5 | SVP-BTC80 Rank=5 |

| | | | |
|---|---|---|---|
| Goal of deployments | Joint deployments in pairs of different mini barometric drifters to study the ways of long-live Smart Buoy creation with higher space-time resolution of sea currents measurements and high quality of AP measurements<br>Drifter to have easy deployment in the Ocean | Investigation of thermocline variability; influence of the drogue role on stabilization of upper point of tether location when surface waves take place | To increase the depth and accuracy of subsurface temperature measurements by means of increasing of chain length, number of temperature sensors and to check the mathematical model to have real depths of temperature sensors independently of the chain profile |

To increase a buoy lifetime the PTT MT105A has been updated to have smaller power consumption, when emitted power keeps its value as before. This PTT has gotten the MT105AM title. Also, the PTT equipped with GPS receiver has been developed to increase spatial-time resolution of drifter measurements. This PTT has gotten the MT305A title. In the Table 2 is shown a theoretical lifetime of SVP-BT mini drifter in months after 1 year of storage, when different PTTs are used.

**Table 2. Theoretical lifetime of SVP-BT drifter in months after 1 year of storage**

| MT105A | MT105AM | MT305A (with GPS) |
|---|---|---|
| 4*8=32 D-cell Alkaline Batteries | | |
| 17 | 20 | 13 |
| 5*8=40 D-cell Alkaline Batteries | | |
| 22 | 25 | 16 |

All the buoys were deployed in Black Sea by two batches. Each batch had same nomenclature of the drifters and included 2 SVP-BT drifters of two modifications and two temperature profiling drifters with 60-m and 80-m chains. The deployments were made July 3, 2006 in the points (32°31′44″; 43°53′42″) and (31°22′44″; 43°08′02″). The drifters with 60-m chains were equipped with modified chains, but unfortunately, this technology appeared as one with insufficient reliability. Both drifters with 60-m chain got fast failure of chains after deployments and data from them was taken in to account as the data from SVP-B drifters.

What are the main results of 2006 drifter experiment in the Black Sea? Modified PTT MT105AM with small power consumption provided good quality of communications and locations. The track of one SVP-BT mini drifter is shown in Figure1. Very interesting physical result demonstrated by this drifter is full turn around the Black Sea was during 3 months approximately. In contrast, the previous results demonstrated 4-5 months duration of circulation.

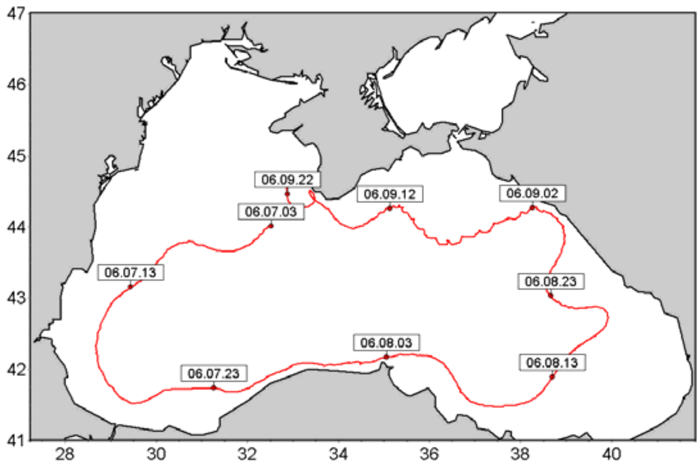



**Figure 1. Movement of SVP-BT mini drifter ID40414 in the Black Sea (July-September, 2006)**

The results of SST and subsurface temperature (12m depth) with this drifter are shown in Figure2. This picture demonstrates an ability of this kind of drifter to fix the heat processes at 12m depth of upper layer.

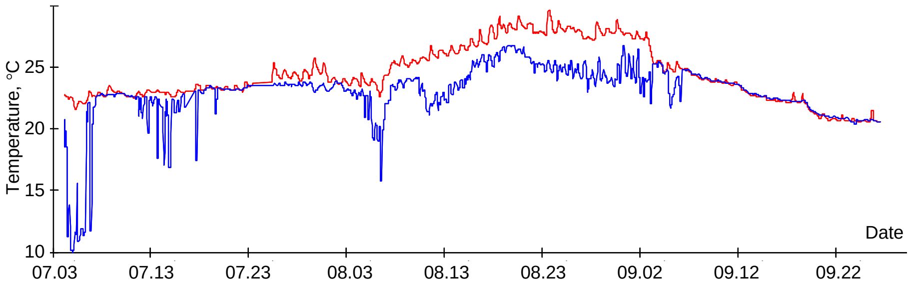



**Figure 2. SST and subsurface temperature measurement with SVP-BT mini drifter ID40414 in the Black Sea (July-September, 2006)**

One of the problems that restrained from application of mini barometric drifters was wrong air pressure measurements when wind more than 10m/s speed approximately took place. This phenomenon was fixed during last year experiment in the Black Sea with same kind of drifter. The wrong data had a view of negative spikes with amplitude near 10 hPa. Some study was done in 2005-2006 season to eliminate the problem and drifters deployed in this year have had a modified barometric port. The results of BP measurements by drifters in 2005 as well as in 2006 are shown in Figure 3. It is obviously that the drifter of 2006 generation did not have wrong BP data in contrast with last year drifters when same wind took place.

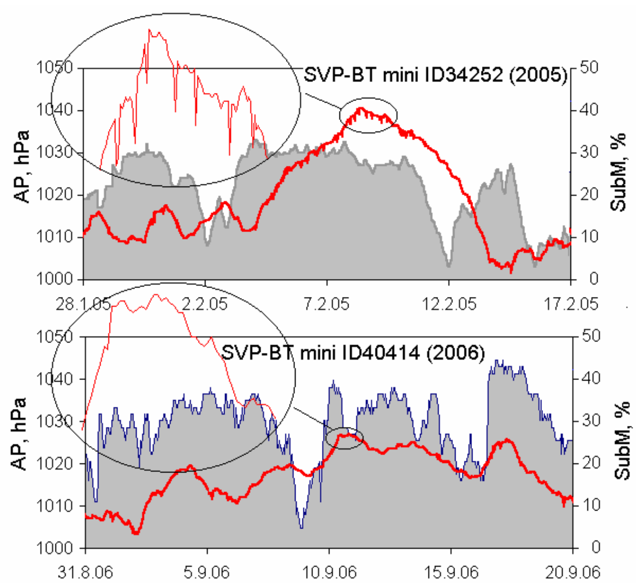



**Figure 3. AP measurements by SVP-BT mini drifters with old (ID34252) and modified (ID40414) barometric ports**

Very important task is a determination of drogue attachment during movement of drifter. If buoy has its drogue lost, this drifter cannot be determined as a Lagrangian buoy. Therefore, the system to indicate that drifter lost its drogue has to have fast reaction, when this even is happened. We guess that submergence sensor could be a reliable indicator of drogue attachment. The advantage of this method is that submergence sensor is cheap enough and its data are used also to prevent a transmitting when buoy is submerged. The last allows to have better communication and more locations. Disadvantage of submergence sensor as an indicator of drogue attachment is a vagueness with drogue when calm water keeps this status during long time. The time when drifter got its drogue lost is shown in Figure 4.

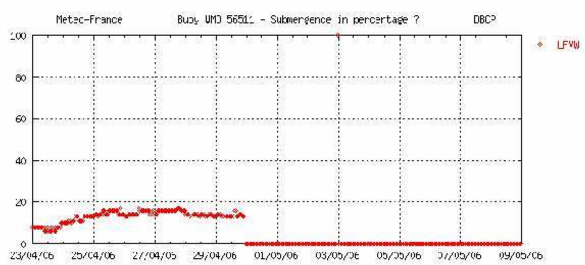


**Figure 4. Loss of drogue by SVP-B drifter in Indian Ocean.**

More, we guess that submergence sensor could be used to derive the ocean surface state as it was made in the Black Sea area. Of course, it is impossible to talk about measurement, but some understanding about surface activity could be. Picture 5 shows the correlation between level of submergence and model wind for one of the Black Sea buoys. The correlation value is 0.8 approximately, that allows to determine good link between those processes. In addition, it needs to take in to account level of biofouling and other things to have this technology as a task tool.

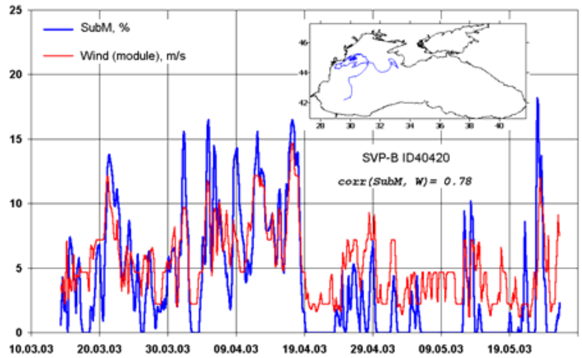



**Figure 5. The correlation between level of submergence and model wind for one of the Black Sea buoys.**

New step, at any rate for the Black Sea area, was done, when two SVP-BT mini drifters were equipped with GPS receivers and deployed in the sea. Figure 6 shows the tracks for one of buoys. The movement of buoy in general is demonstrated at the Black Sea map. The picture has two tracks provided by both ways: via Argos locations as well as GPS ones. In spite the fact that Argos PTT had 0.5W emitting power, the mean number of location per day was near 9. Two points are emphasized to demonstrate quality of GPS locations in contrast with Argos ones. It is obviously, the inertial oscillations in the sea can be described with larger spatial-time resolution exactly via GPS locations.

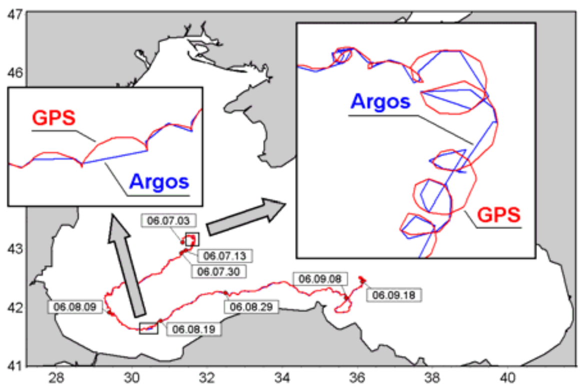



**Figure 6. Tracks of the buoy in the Black Sea by means of Argos and GPS locations.**

SVP-BTC drifter with 80-m chain, the structure of which is shown in Picture 7, has gotten new design in contrast with temperature profiling drifter with 60-m chain, used for a couple of last years. It has following distinctions in contrast with past generation of drifter:

- Depth of drogue connection with tether is 10 m instead 12.5 m
- 7 additional temperature sensors at 10, 12.5, 15, 65, 70, 75, 80m
- 3 additional depth sensors at 15, 35, 60m
- Modified barometric port

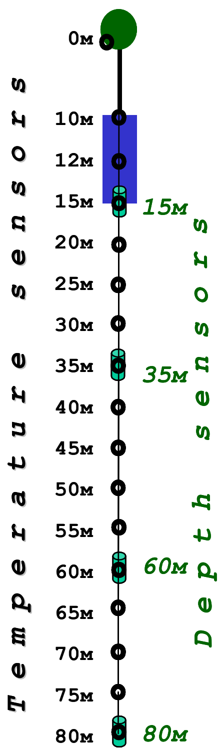



**Figure 7. Structure of temperature profiling drifter with 80-m temperature chain**

Two drifters were deployed from commercial ship "Sevastopol-1" along the trace "Sevastopol-Istanbul". One point of deployment was at north-west part of the sea and second point was at the center of west part. Figure 8 shows the tracks of both buoys. The buoy dropped at north part was involved with main the Black sea current and made a circulation around the sea to east, where it was caught with Batumi circulation. Another buoy kept its location on the center of west part for three months approximately. This fact allows to study thermodynamic processes, when wide variety water speeds took place.

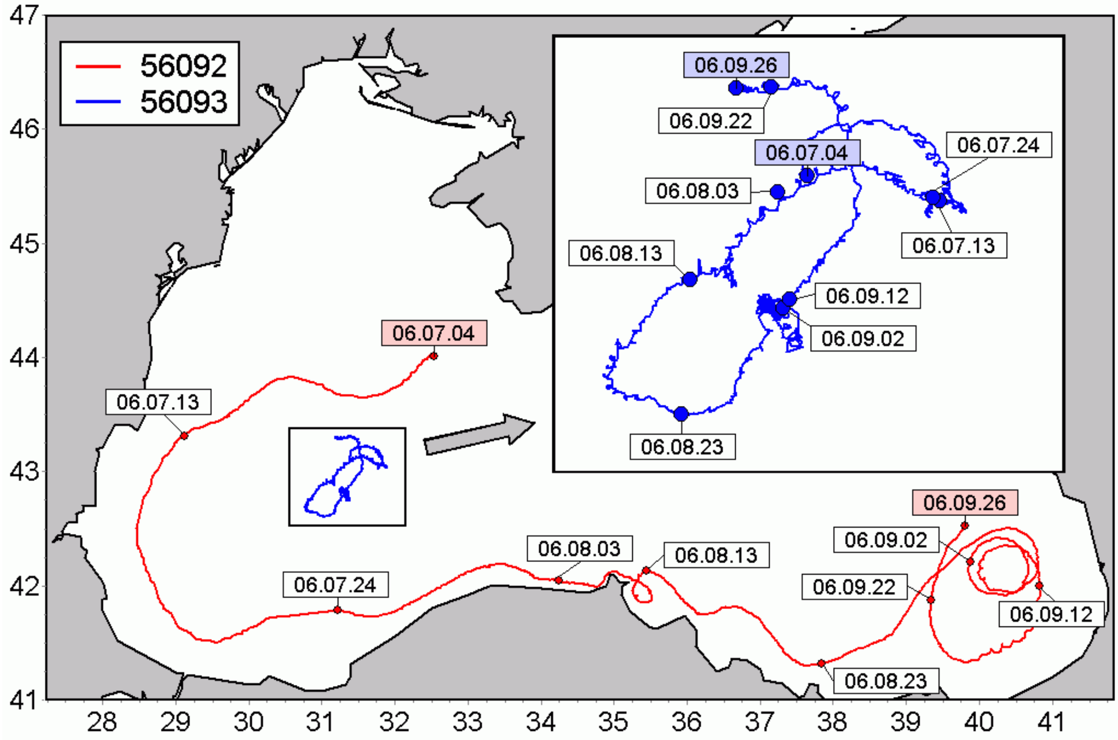



**Figure 8. Trajectories of two 80-m SVP-BTC drifters deployed in the Black Sea (July - September 2006)**

SVP-BTC drifter has more time submerged because of temperature chain, which makes it heavier in comparison with SVP-B drifter. The result of this fact was that AP measurements had some increased data because of inertia of barometric port membrane. Modified barometric port has metallic membrane instead plastic one and due to this fact it has smaller inertia. For example, Figure 9 shows the results of barometric pressure measurements by means of two drifters at same place approximately equipped with plastic (red) and metallic (blue) membranes. It is obviously that barometric port with metallic membrane provides more smoothed BP data.

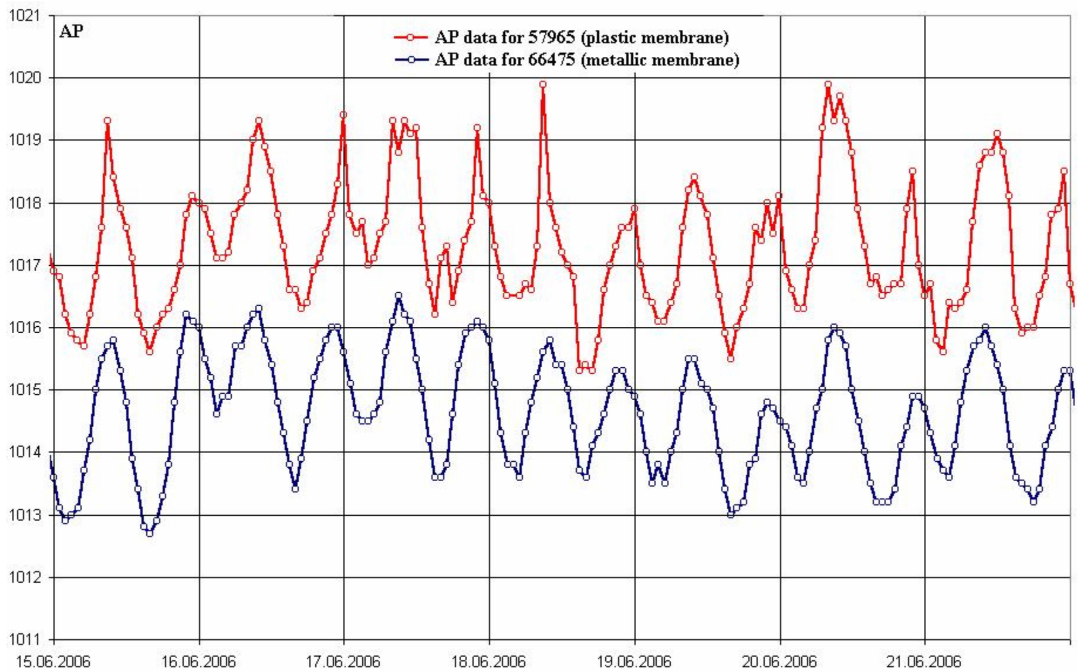



**Figure 9. BP data for 2 temperature profiling drifters deployed in 2006 by Meteo-France in Gulf of Guinea, equipped with plastic (red) and metallic (blue) membranes**

Figure 10 shows results of temperature measurements with the drifter in middle of west part of the Black Sea. This picture demonstrates the data "as is", without any preprocessing, e.g. connecting of temperature to the real depth.

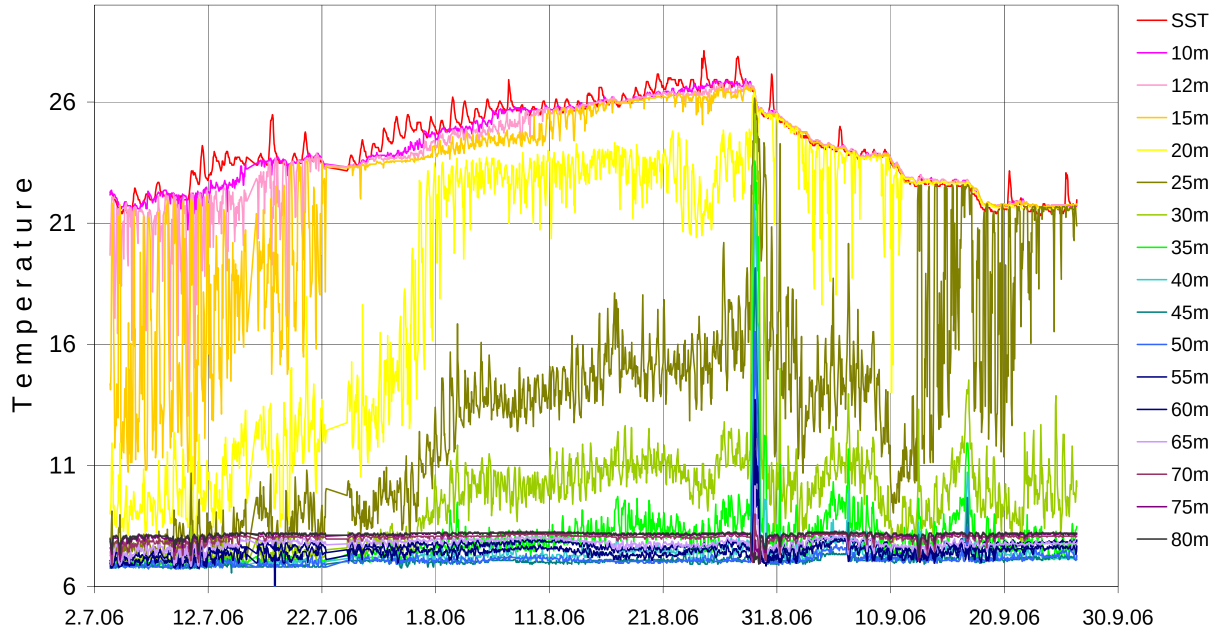



**Figure 10. The data from temperature sensors measured during drift of the SVP-BTC buoy ID56093 at the middle of the Black Sea west part (July - September 2006)**

Figure 11 shows the depths of isotherms 20, 18, 14, 12, 11, 10°C, processed by means of analysis of temperature data measured by another SVP-BTC drifter ID56092 along the trajectory (Fig.8) of its movement (July - September 2006).

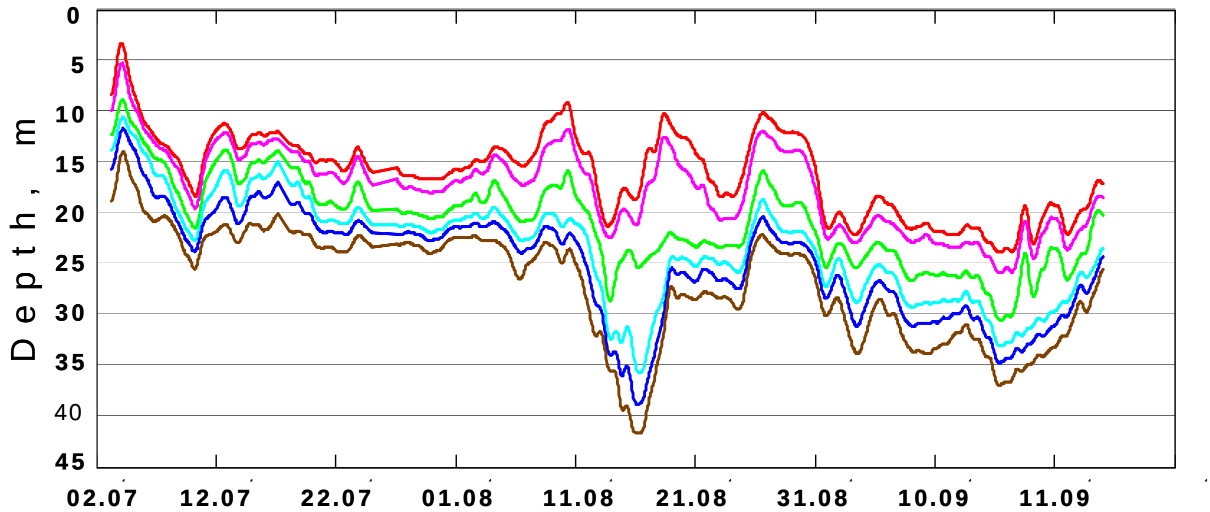



**Figure 11. Depths of isotherms 20, 18, 14, 12, 11, 10°C, measured by SVP-BTC drifter ID56092 around the Black Sea (July - September 2006)**

Temperature measurements by means of thermoprofiling drifting buoy are the result of measurement with high time resolution, e.g. one hour. This fact allows to watch carefully the dynamics of active layer from surface to maximum depth of a chain. For example, the Figure 12 shows the "freeze frames" of temperature profile as a whole (8 July 2006, 22:35), the profiles of mixed layer (30 July 2006, 14:35) and cold intermediate layer (9 August 2006, 10:35).

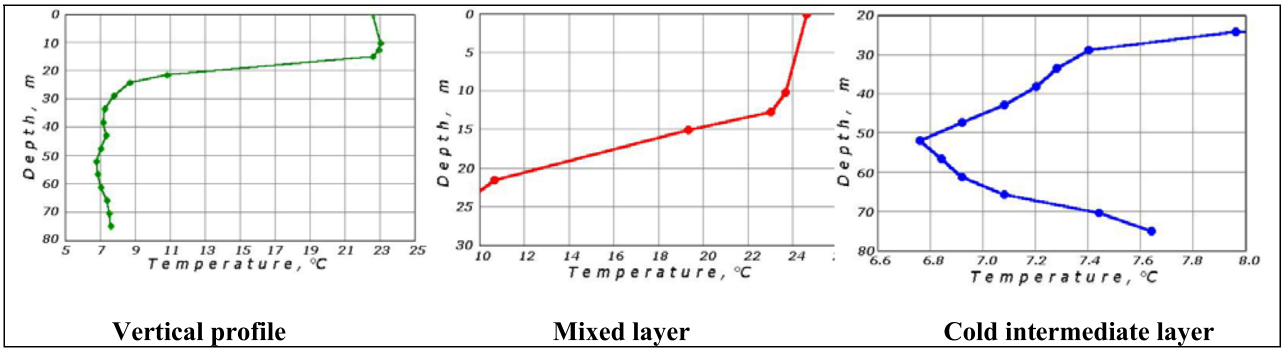



**Figure 12. Temperature variability of vertical profile as a whole and mixed layer as well as cold intermediate layer in particular**

Experimental job was done to determine the stabilizing role of buoy’s drogue on location of chain upper point. The chain has a connection with holey sock through bottom ring of drogue, which has large inertia in water due to developed extrinsic area and drag resistance. To look for the real positions of sensors along the chain, the one was equipped with 3 additional depth sensors as it is shown in Figure 7. The data from these sensors are shown in Figure 13.

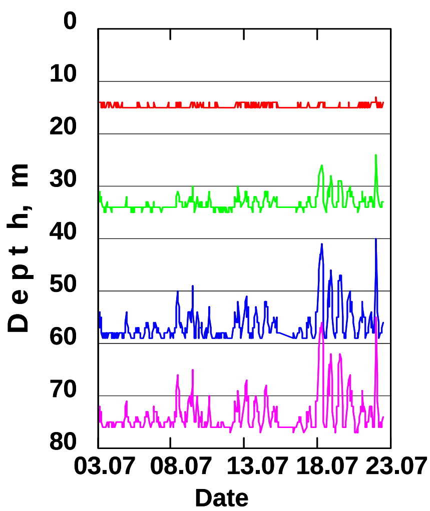
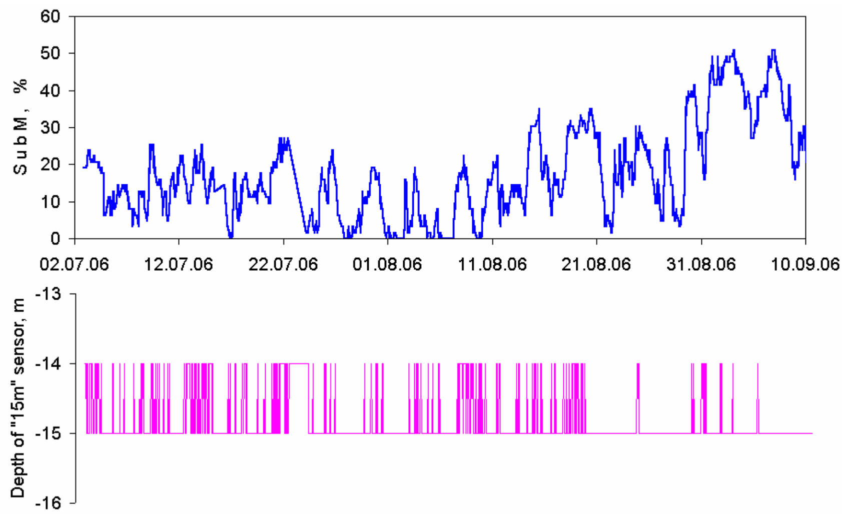
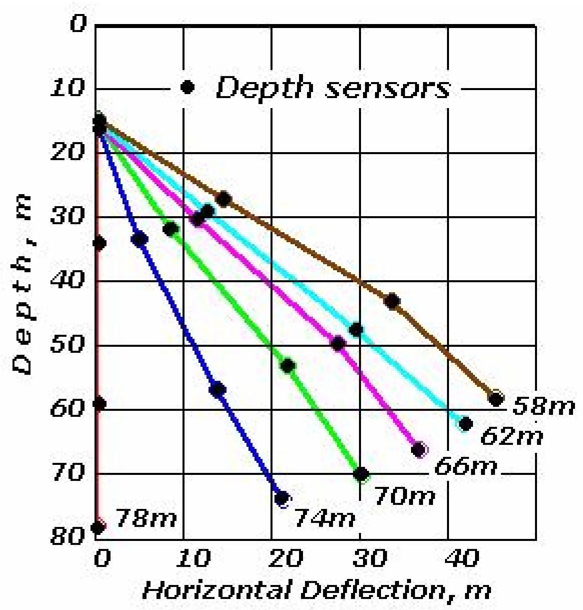



**Figure 13. Data from 4 depth sensors distributed along temperature chain: red – “15m”; green – “35m”; blue – “60m”; violet – “80m”**

Experiment with additional depth sensors along 80-m chain had to make more understandable the reaction of chain under different subsurface currents. The variations of data from upper depth sensor are always in the range +/-0.5m in different surface waves conditions. It means that surface waves had small influence on location of a chain upper point. Figure 14 shows this more thoroughly.

**Figure 14. Data from submergence sensor and depth sensor at 15 m depth on same time scale**






It is clear that there is not visible dependence between level of a chain upper point deflection and level of sea waves defined by means of submergence sensor. Different chain's profiles are shown in Figure 15. These profiles were accepted under different environmental conditions.

**Figure 15. The chain's vertical profiles under different environmental conditions.**

The location of each temperature sensor should be processed with taking into account the data from depth sensors. Same job was done some time ago for previous drifter with 60-m chain when we used numerical model together with data from one depth sensor at the bottom of chain. Using of additional depth sensors for buoys of this year provides verifying this model and makes the information about temperature profile more accurate. The result of this year job shown that accepted numerical model is reliable and it is possible to use it in future one sensor only at the end chain to get the accuracy within +/-1m range. Thus, the cost of such chain should be smaller in contrast with chain with additional intermediate depth sensors. To support the customers, some user's scripts and original software were developed for quick and easy recovering of temperature sensors locations.

## Conclusion

Results of SVP-B mini evaluation

- Design of the drifter ensures reliable operation for long time. Theoretical lifetime of the buoy is up to 31 months (after 1 year of storage), when PTT MT105AM is used, and 25 months when PTT MT305A (with GPS receiver) is used;
- BP channel provides reliable measurements under different environmental conditions;
- Sensor of submergence allows to determine the drogue attachment when rough sea surface. There is a problem for this sensor to determine a drogue status, when calm water takes place for long time;
- Submergence data could be used to derive sea state and waves.

Results of 80-m SVP-BTC evaluation

- Lifetime up to 3 months in-situ;
- BP channel ensures reliable measurements;
- Drogue provides good stabilization of chain's upper point;
- Depth sensor at the bottom of chain allows to have location of each temperature sensor within the range +/-1m;
- Sensor of submergence allows to determine the drogue attachment;
- Submergence data could be used to derive sea state and waves.

The results above will be used for 2007 generation of Marlin drifters.