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direzione emittente		codici documento

MFSTEP

E2-M3A BUOY
TEST REPORT

distribuzione: TECNOMARE, OGS, CNR-ISMAR, INGV-BO

informazioni supplementari: Project deliverable WP2 D17

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8							
7							
6							
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TABLE OF CONTENTS

1 SCOPE

Scope of this document is to report about the test activities carried out on E2-M3A buoy (project subtask 2430). Objective of this subtask was to test the overall functioning of the developed system and evaluate its performance.

According to the project Description of Work (annexed to the contract /1/), activities included:

- overall mechanic and electronic (hardware/software) integration of the E2-M3A elements (sensors, power supply, data acquisition and control electronics);
- integration of the communication modules into the E2-M3A fixed station;
- execution of laboratory tests, with mission simulations;
- (where applicable) execution of sea tests.

2 APPLICABLE DOCUMENTS

/1/ MFSTEP project contract

/2/ E2-M3A Buoy design; Tecnomare document A1356-REL-W100-002.0

/3/ Report on the buoy upgrade work; Tecnomare document A1356-REL-W300-008.0

/4/ Report on integration and test activities (Bari, August 2004), Tecnomare document A1356-RAP-W300-001.0

3 TEST ORGANISATION

Test program of E2-M3A buoy included three main tasks, some of which carried out in parallel.

a) basic functional tests
b) buoy upgrade functional tests
   a. new status sensors
   b. telemetry
c) new scientific payload tests
   a. CTD chain
   b. Nutrient analyser

3.1 Basic functional tests

Basic functional tests are described in Section 4. These tests were aimed at verifying in real conditions the correct and reliable operation of the main subsystems of the buoy, namely

- data acquisition and control electronics (hardware and software), custom developed by Tecnomare
- power supply, based on battery pack recharged by photovoltaic panels
- status monitoring equipment, including GPS receiver, heading, tilt, power monitoring
- CT sensor (mounted on buoy hull)
- Meteo station
- Main telemetry (based on mobile phone link, with buoy operating as slave and shore station as master)

These tests were carried out in two phases:

- May-October 2003 (buoy installed in Trieste harbour)
- February-June 2004 (buoy installed in MFSTEP TOP site, southern Adriatic Sea)

Marine operations were managed by OGS, while Tecnomare managed the data collection.

3.2 Buoy upgrade functional tests

This phase of test (see Section 5) was aimed at verifying the correctness of the new hardware and software implemented on the buoy, to manage the additional functionalities imposed by the E2-M3A configuration, namely

- management of CTD chain
- management of Nutrient analyser
- second telemetry, allowing automatic daily transmission of data to OGS ftp server
- additional status monitoring sensors

Being the buoy physically not available (as under operation at sea), these tests were carried out connecting the new subsystems to a second data acquisition and control unit, specifically developed by Tecnomare for this purpose. In this way the buoy operation could be simulated and the new functionalities verified.

These tests were carried out in Tecnomare workshop, in the period January-August 2004, in parallel with the Basic Functional tests.

3.3 MFSTEP scientific payload tests

The third phase of test (described in Section 6) was focused on the new scientific payload to be added on the buoy basic configuration, and in particular on the Nutrient analyser requiring a dedicated activity to define its correct set-up, validate its operation and ensure optimal interface with the water sampling system implemented on E2-M3A.

For this reason activities on the Nutrient Analyser included both laboratory test (managed and carried out at CNR-ISMAR chemical laboratory) and functional test (carried out in Tecnomare workshop).

This activity started on April 2004, with some delay with respect to the project schedule, due to the necessity to send the instrument to the manufacturer for some upgrade and servicing work.

Test on CTD chain were quite simpler, being the sensors “off-the-shelf” and not requiring any specific set-up.

4 BASIC FUNCTIONAL TESTS

The buoy basic functionalities were tested over more than 7000 hours of continuous operation in real conditions, subdivided into two periods: test in Trieste harbour (see 4.1) and test in TOP site (Southern Adriatic Sea, see 4.2).

Test were successful and all the buoy functionalities were verified, while allowing at the same time collection of significant scientific data. During all this period Tecnomare managed the daily connection with the buoy, technical checks of the buoy operation and data dissemination, while OGS validated and archived scientific data collected.

4.1 Test in Trieste harbour

After integration and preliminary test in Trieste shipyard, on May 20 2003 the buoy (in its preliminary configuration, i.e. without some of the sensors and functionalities pertaining to the MFSTEP configuration, under parallel development) was put in water in Trieste harbour and the first mission started. This mission was concluded on October 16, after more than 4000 hour of continuous operation.

Significant examples of data collected by the buoy in this period are shown in the following figures 2 to 10). Data refer to meteorological, oceanographic and internal status parameters, collected daily and processed on a monthly basis (hours starting from 00 h of the first day of the month are indicated in ascissa).

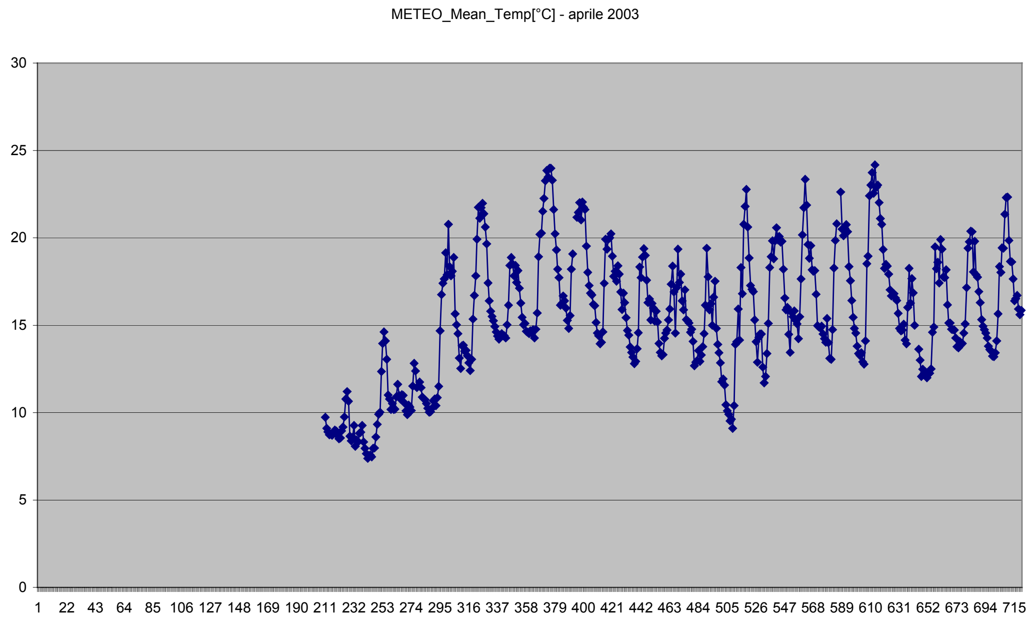


Figura 2 – Air temperature during April 2003

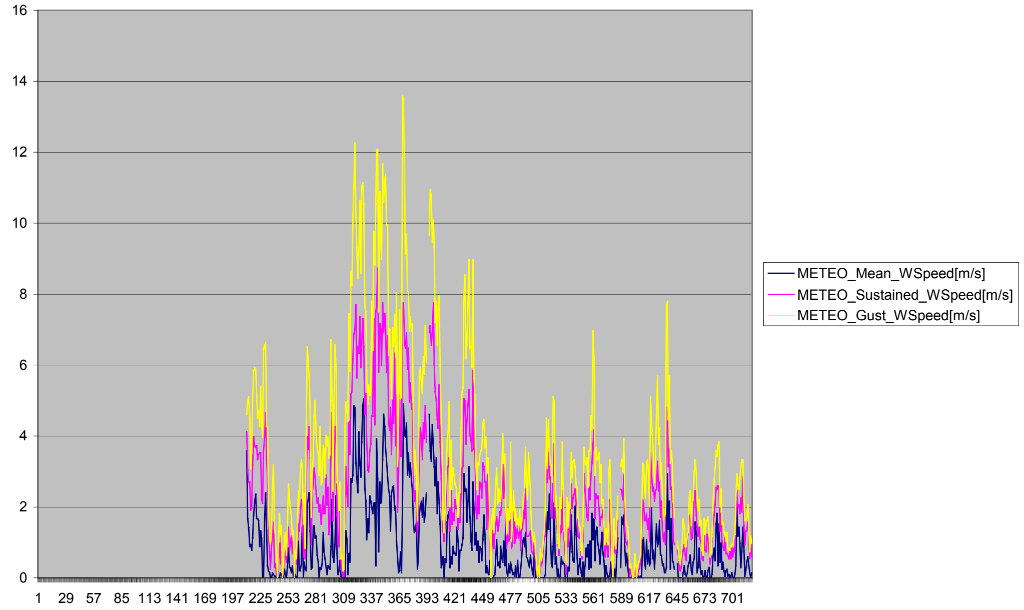


Figura 3 – Wind speed during April 2003

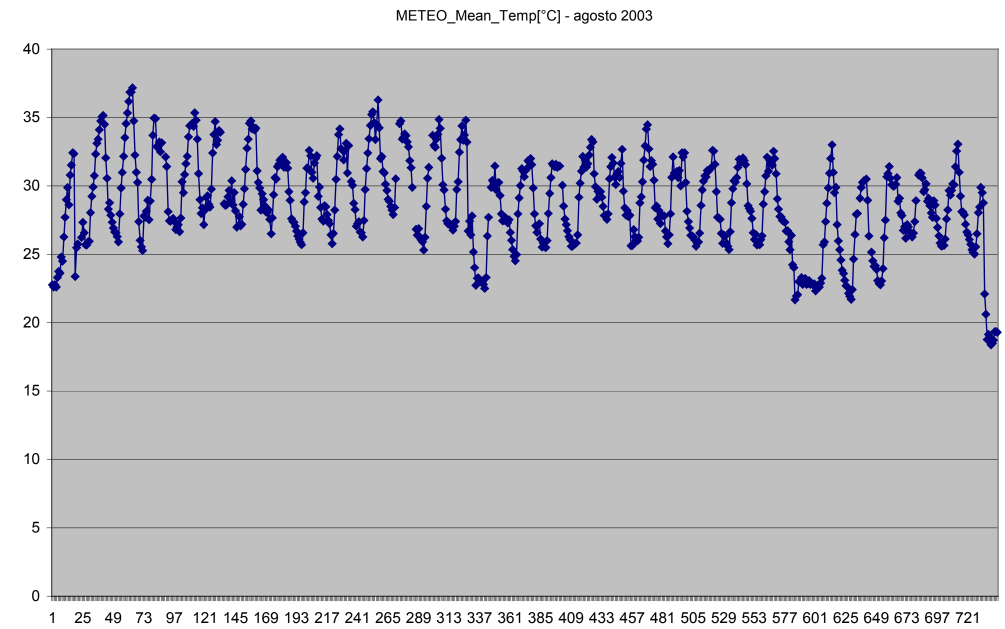


Figura 3 – Air temperature during August 2003

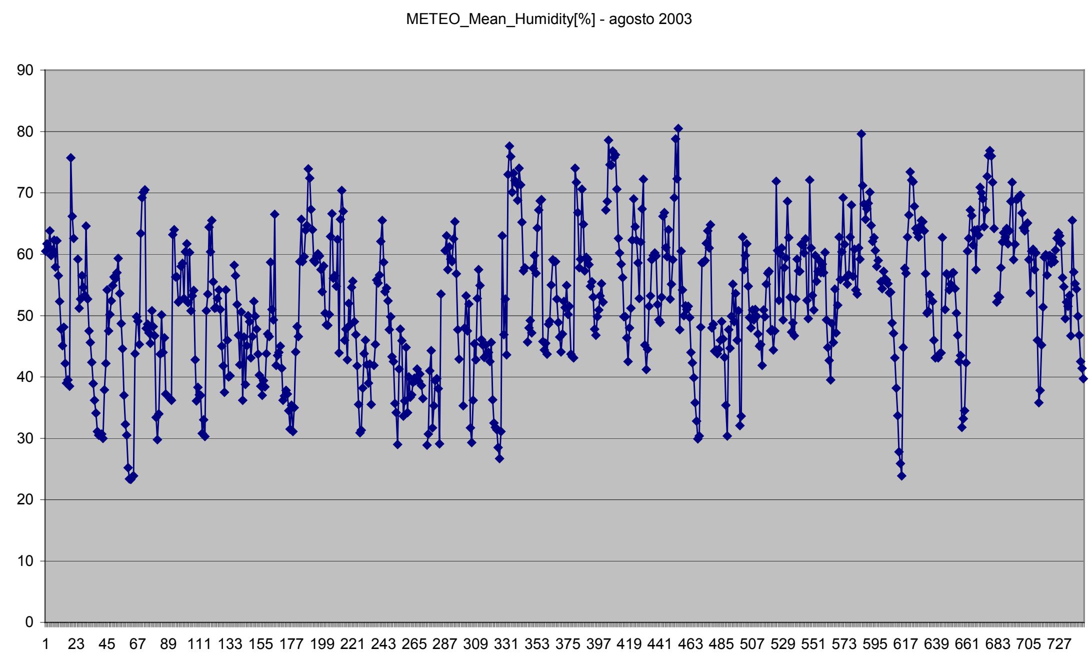


Figura 4 – Air humidity during August 2003

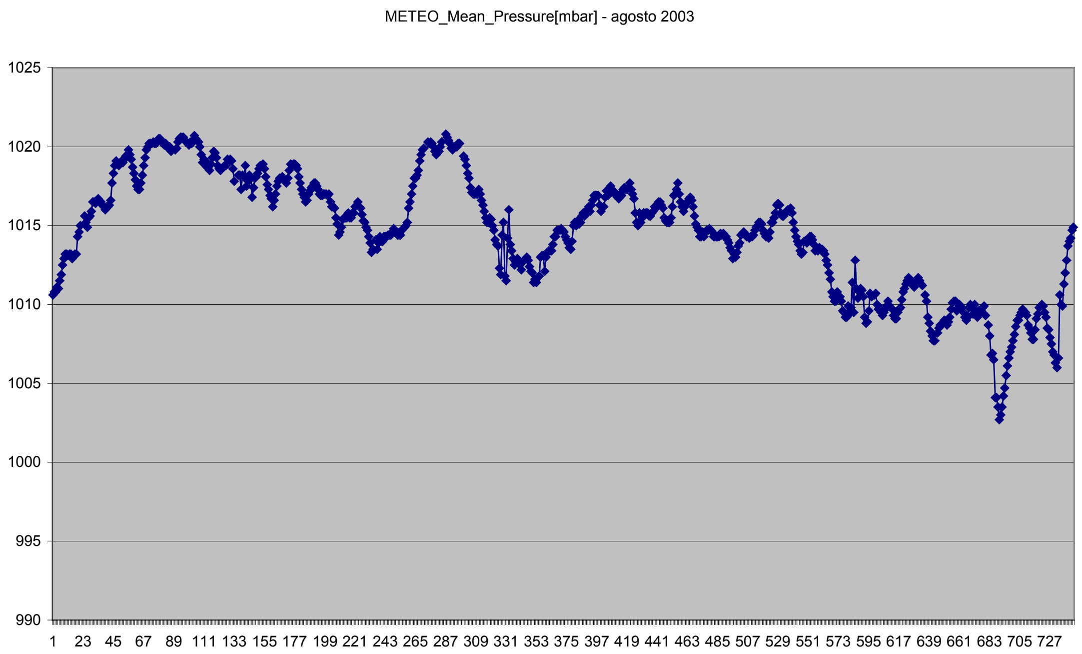


Figura 5 – Atmospheric pressare during August 2003

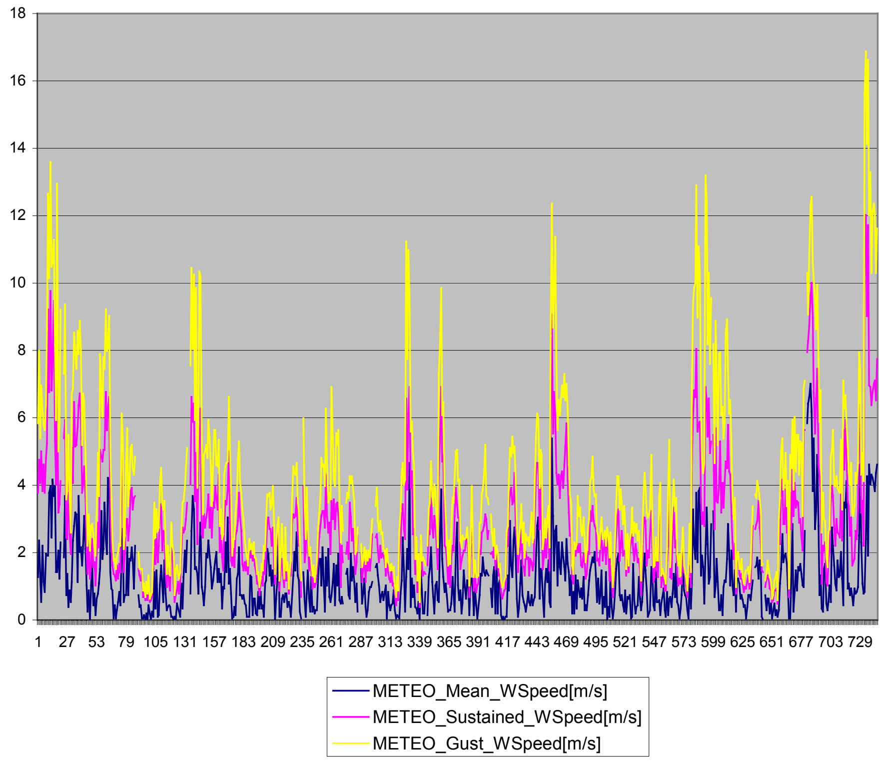


Figura 6 – Wind speed during August 2003

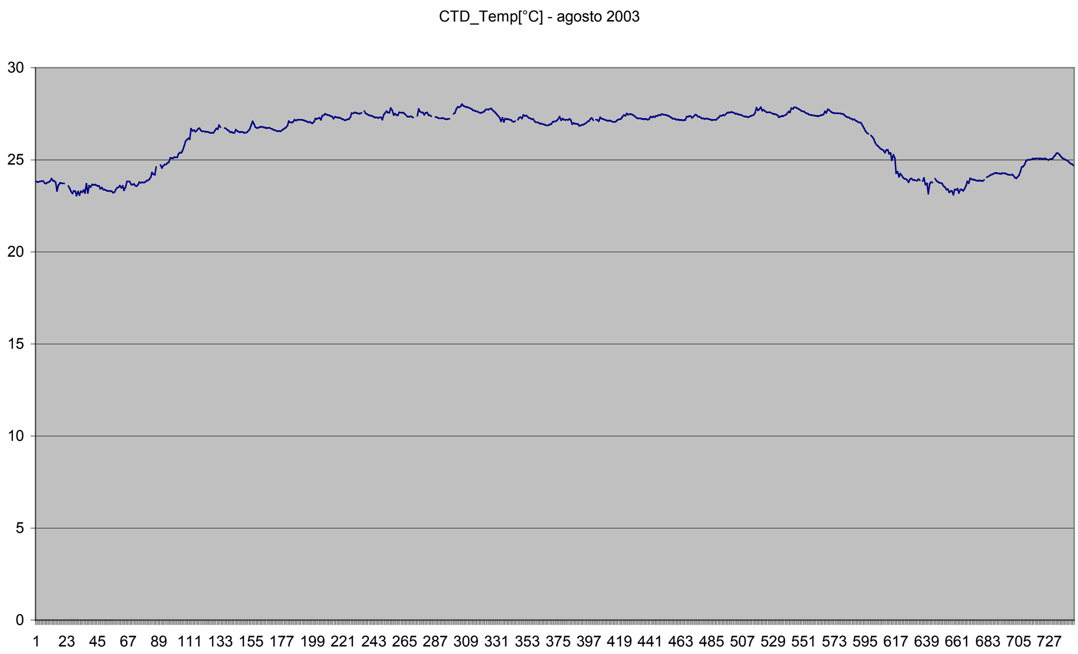


Figura 7 – Water temperature during August 2003

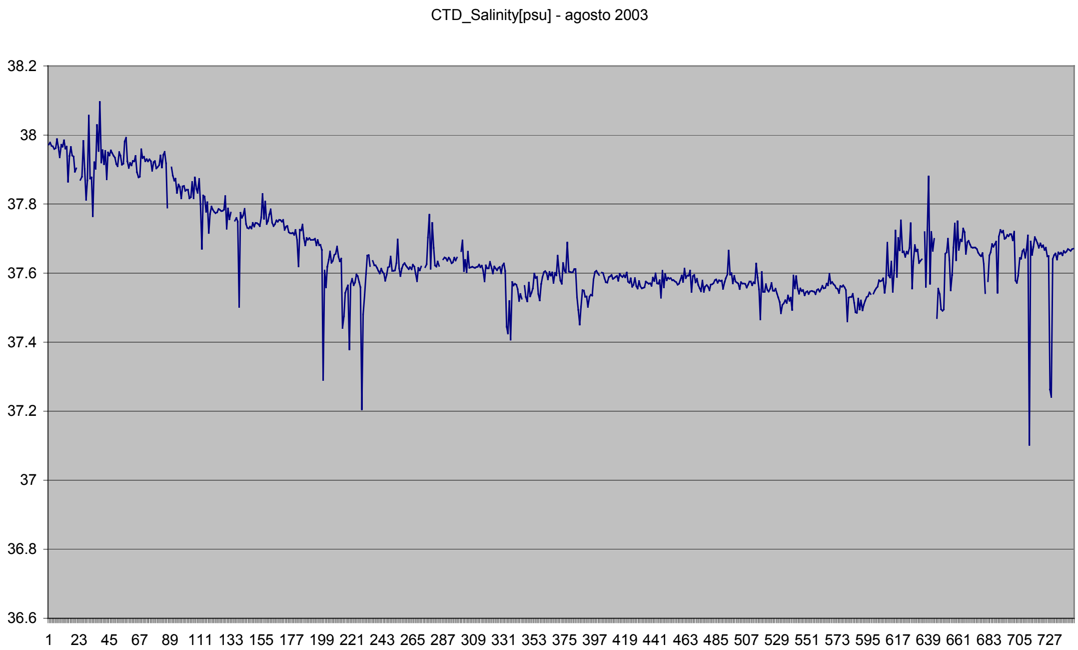


Figura 8 – Water salinity during August 2003

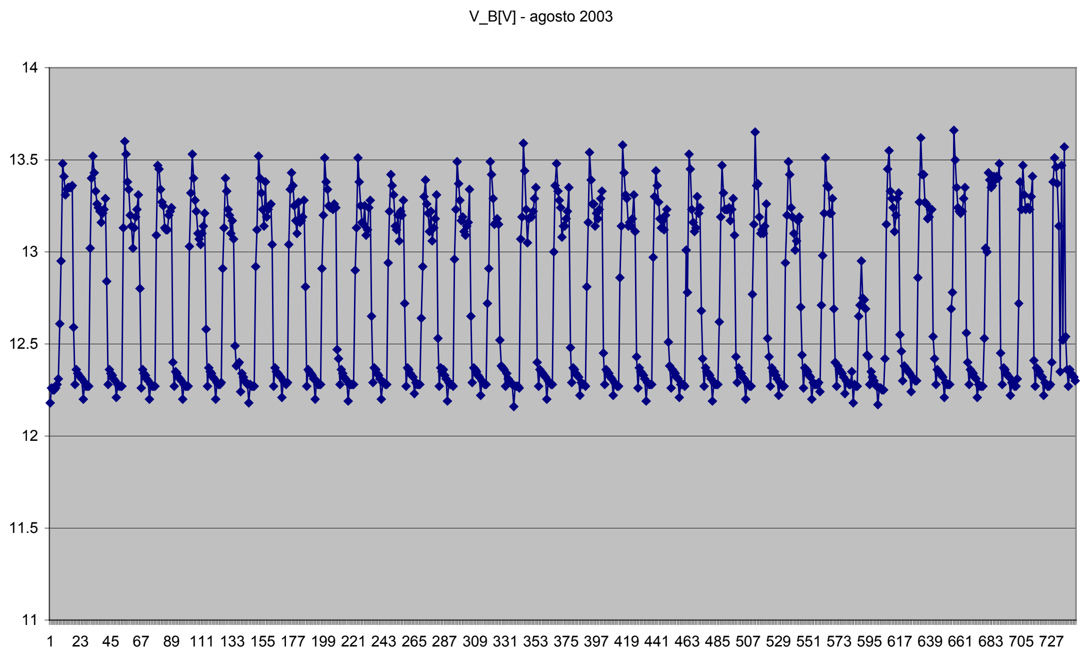


Figura 9 – Battery voltage during August 2003

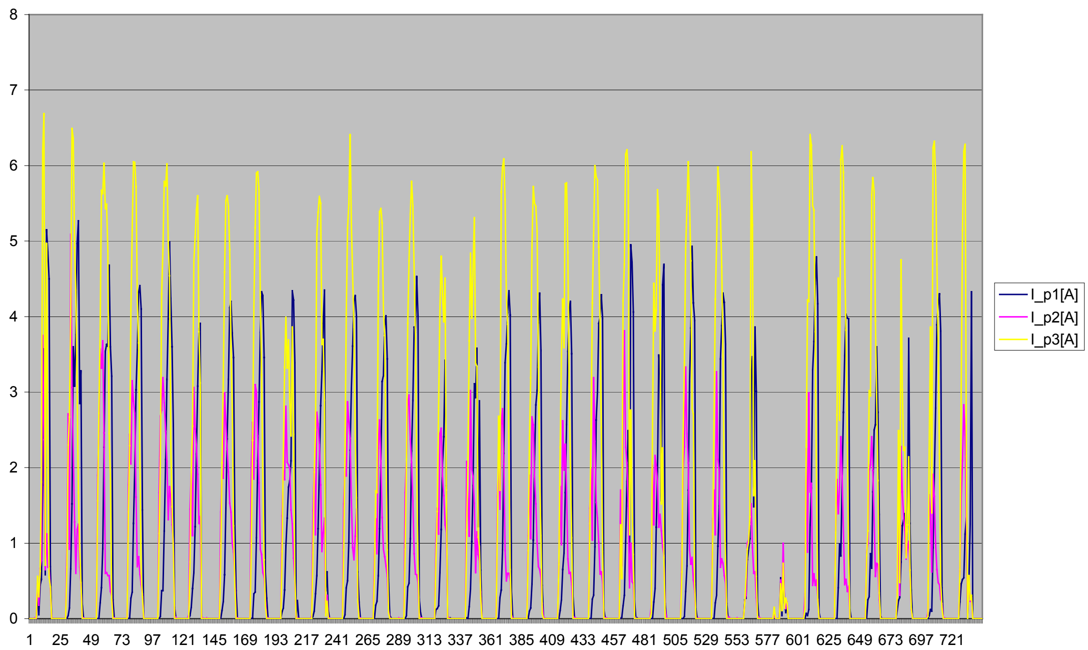


Figura 10 – Current produced by photovoltaic panels during August 2003

4.2 Test at TOP site

After arrival of the mooring line, on January 2004 the buoy was transferred to Bari harbour. On February 16 2004 the buoy has been installed in the site selected for the TOP (Southern Adriatic Sea, offshore Brindisi, 1050 mwd) and mission started.

Significant examples of data collected in this period are shown in following figures 11 to 19).

All scientific data downloaded from the buoy via daily interrogation (carried out by Tecnomare) were made public by OGS on a weekly basis in the site http://doga.ogs.trieste.it/boma_mfstep/.

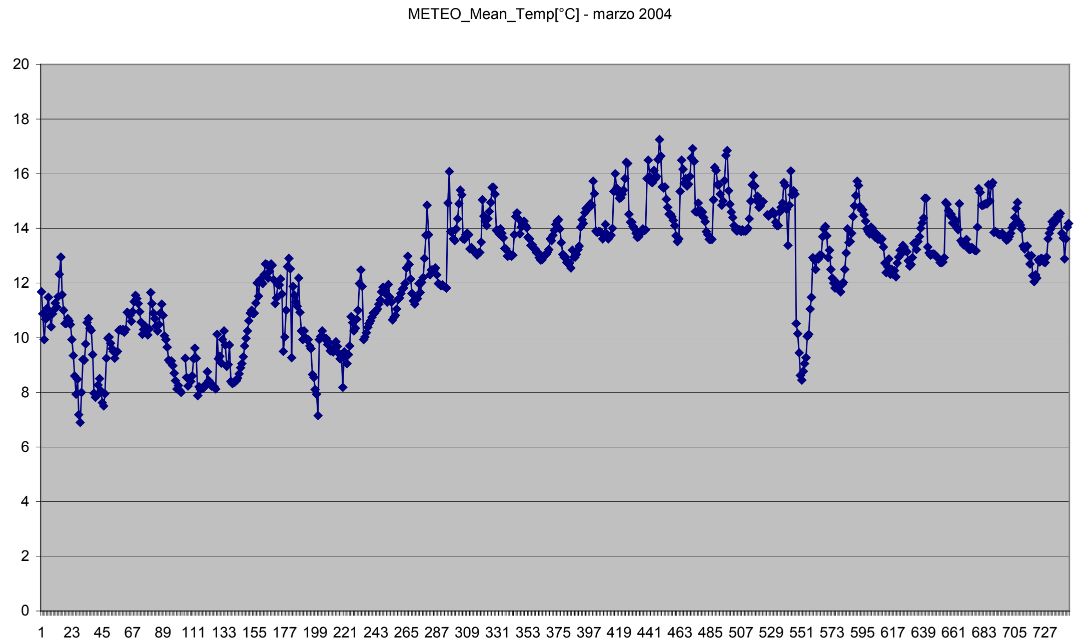


Figura 11 – Air temperature during March 2004

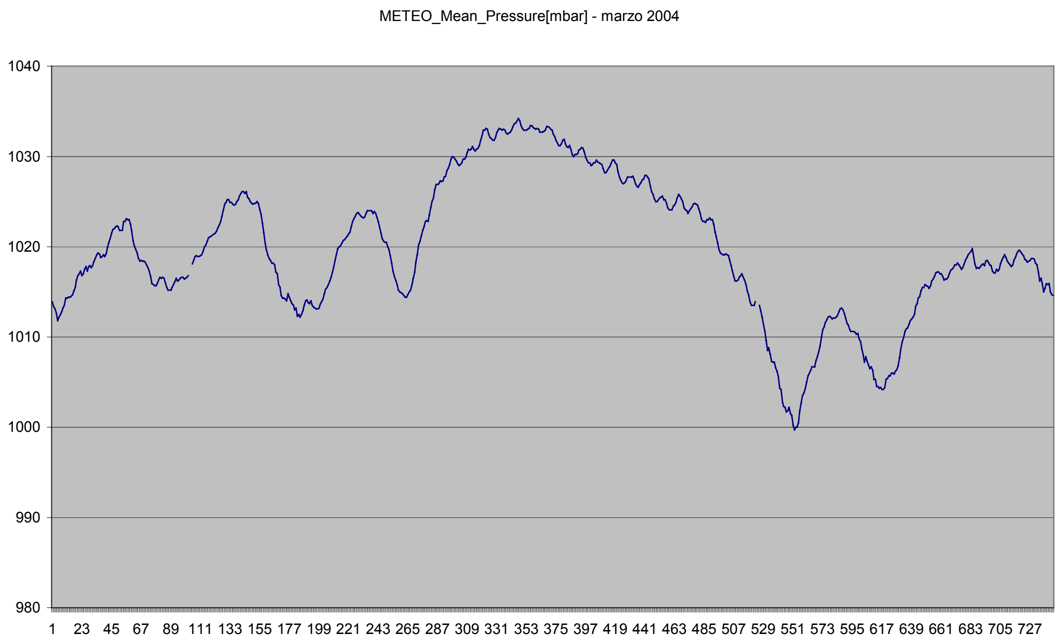


Figura 12 – Atmospheric pressure during March 2004

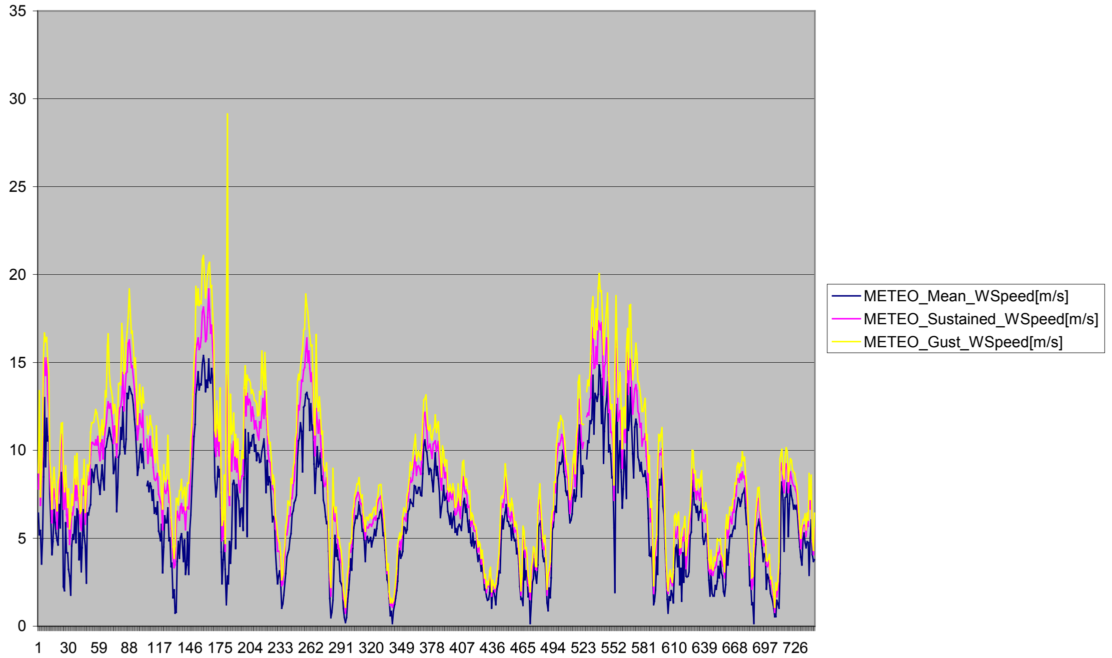


Figura 13 – Wind speed during March 2004

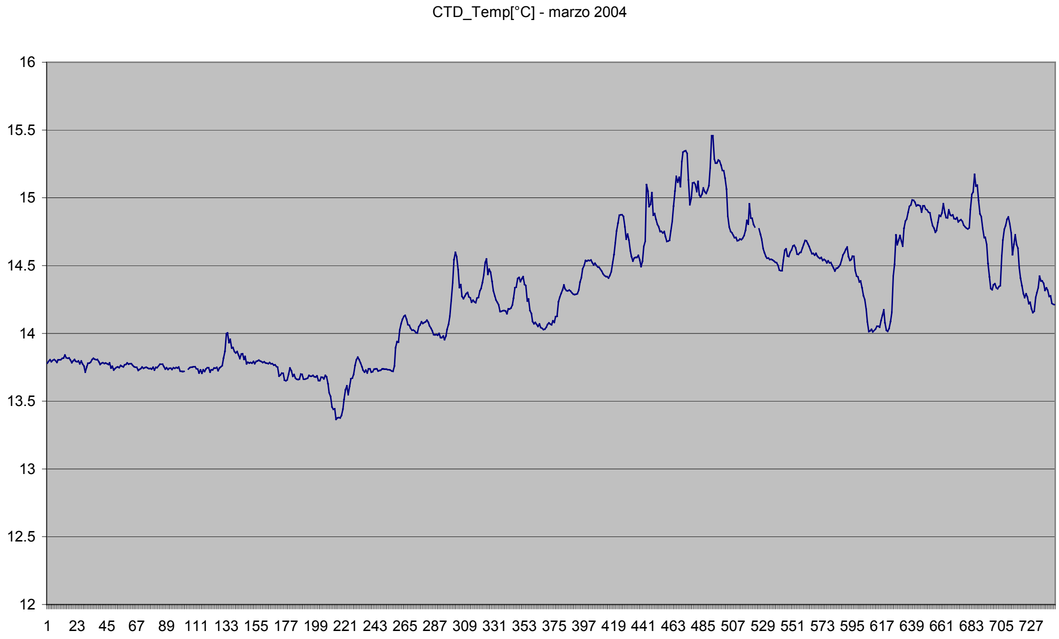


Figura 14 – Water temperature (surface) during March 2004

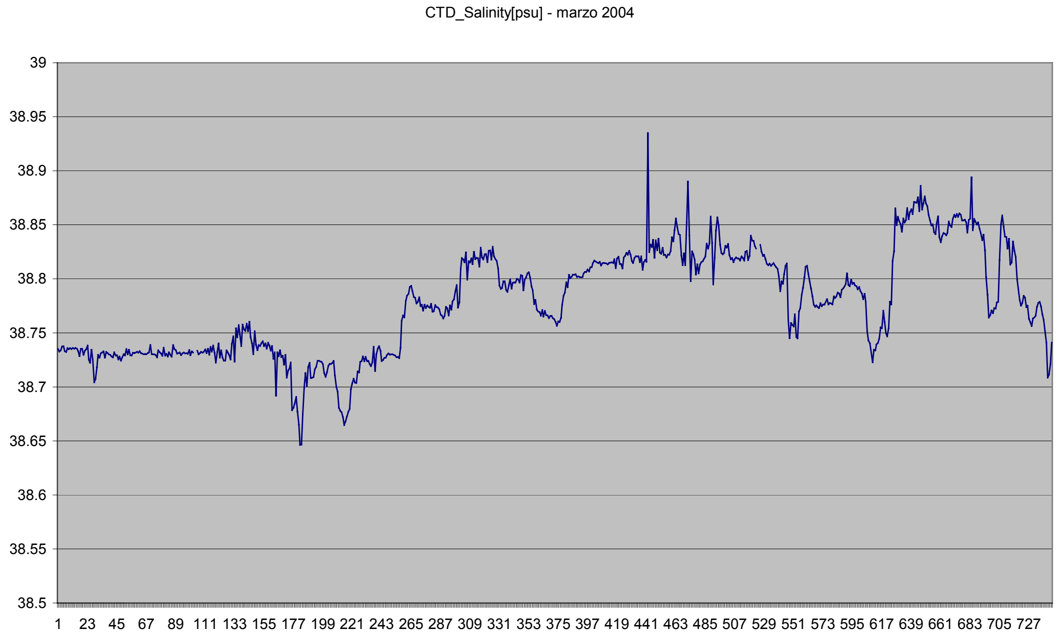


Figura 15 – Water salinity (surface) during March 2004

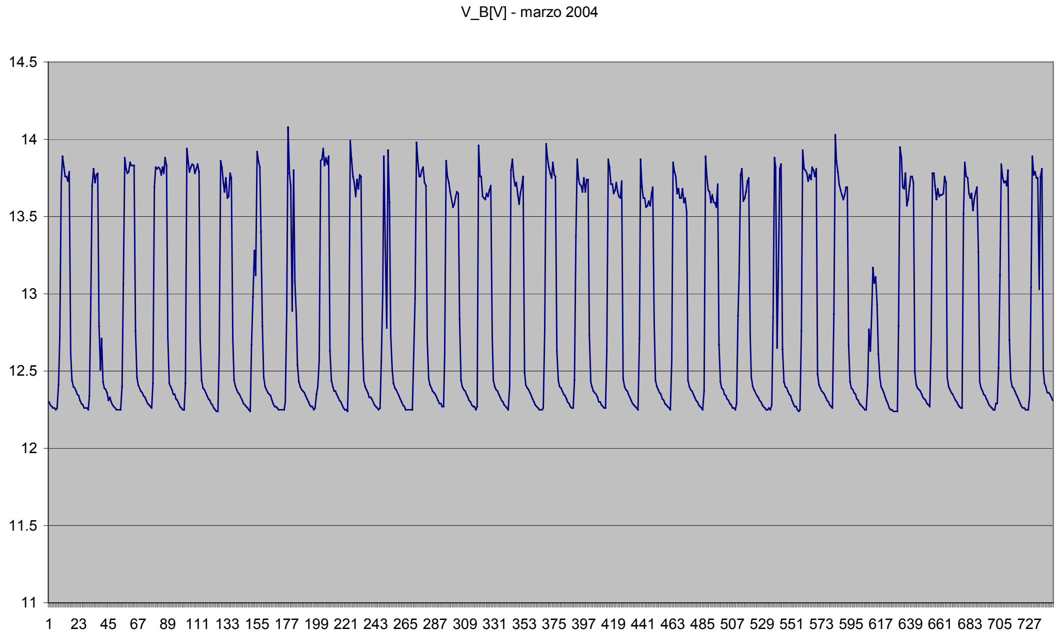


Figura 16 – Battery voltage during March 2004

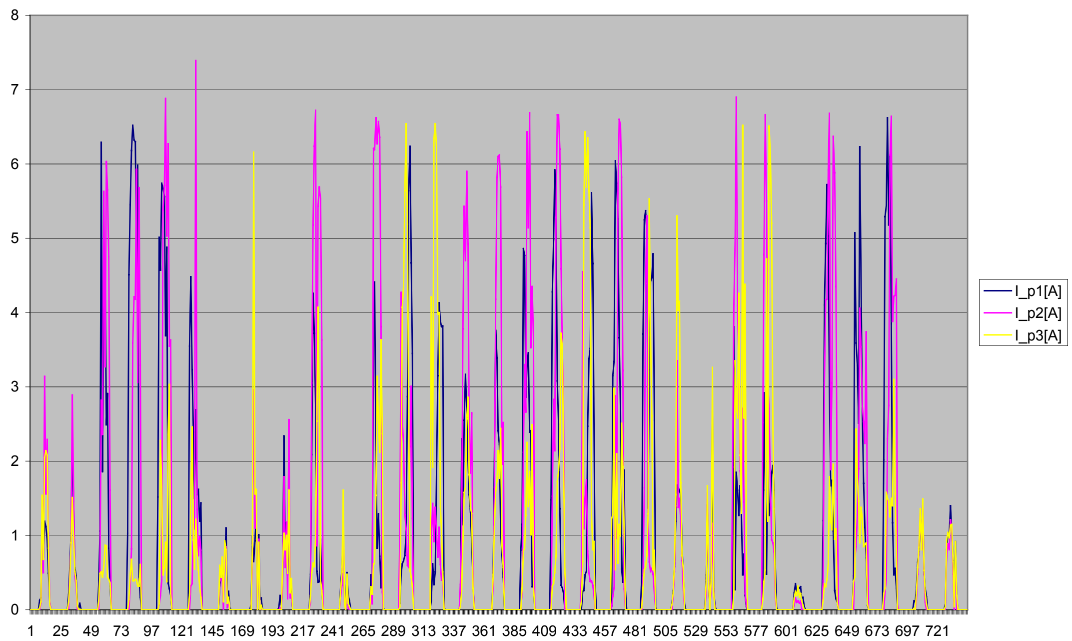


Figura 17 – Current produced by photovoltaic panels during 2004

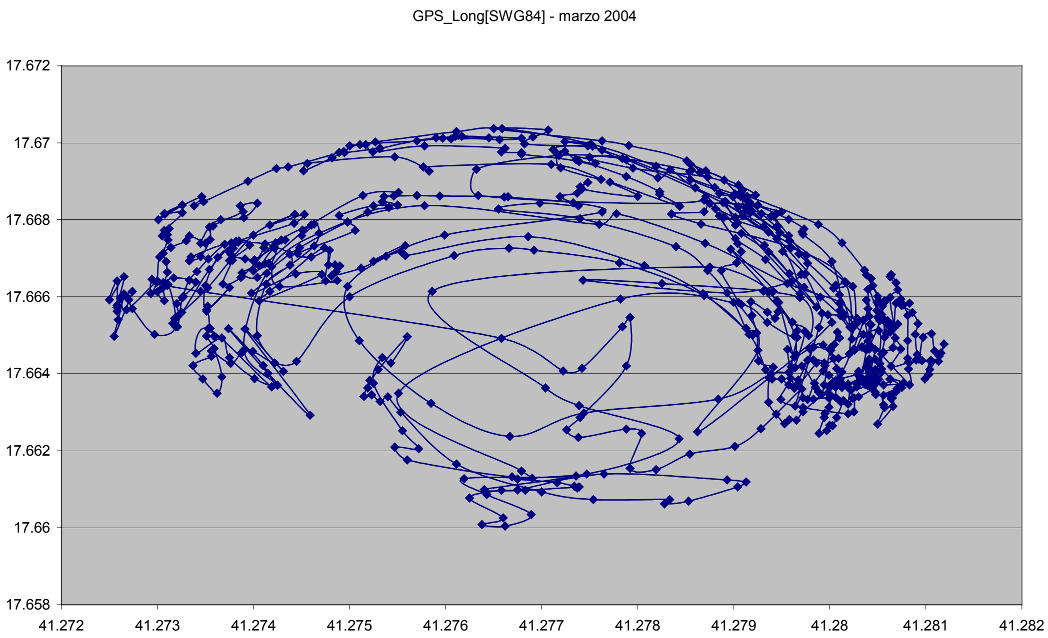


Figura 18 – Buoy position during March 2004

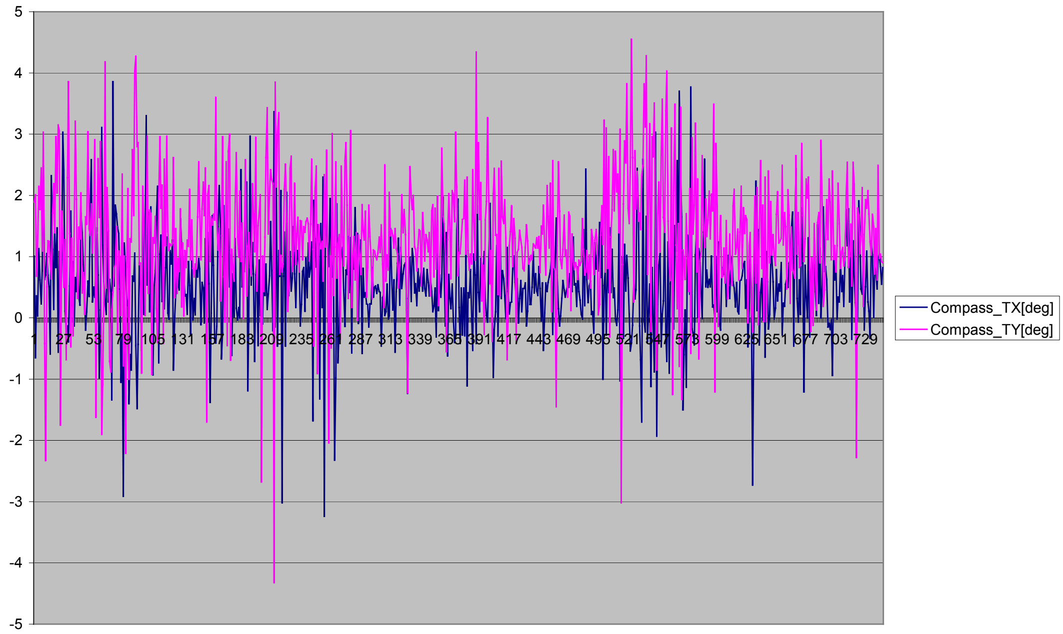


Figura 19 – Buoy tilt during March 2004

This mission was stopped on June 8 2004, to allow the upgrade of the buoy to the E2-M3A configuration, according to MFSTEP project requirements.

5 BUOY UPGRADE FUNCTIONAL TESTS

These tests included

a) management of the CTD chain
b) management of the Nutrient Alalyser
c) operation of the second telemetry
d) additional status monitoring sensors

As regards the CTD chain, tests were carried out connecting the four CTDs to their inductive cable and verifying the correct acquisition of CTD data by the buoy data acquisition system (to which the inductive modem was integrated). These tests, carried out in air (Tecnomare workshop, gave successful result, demonstrating the correctness of the hardware and software developed.

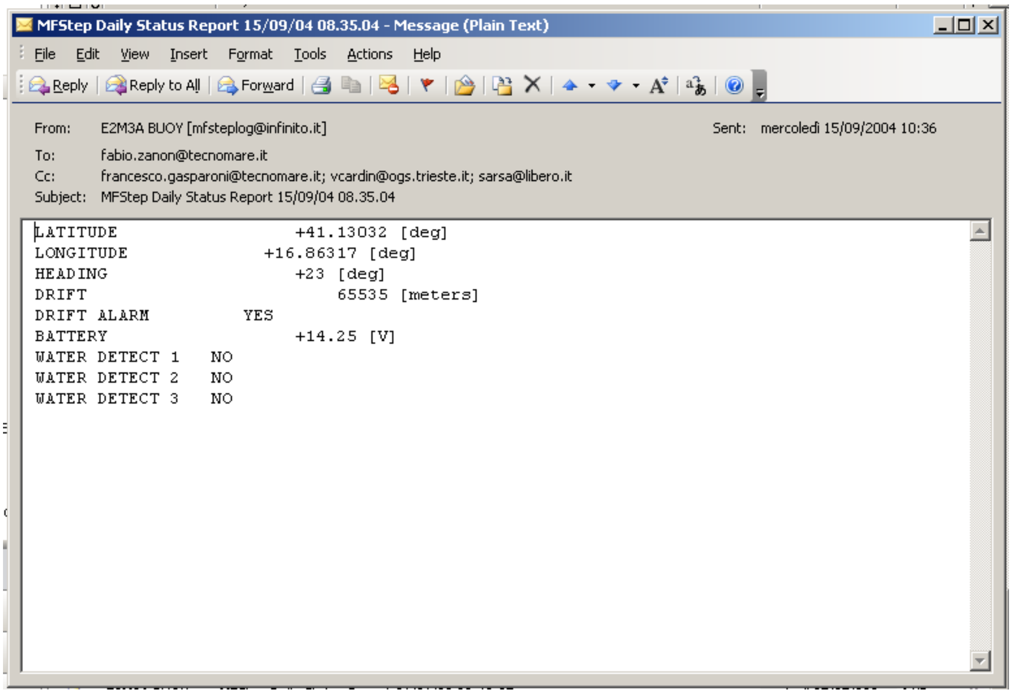
Functional tests of the Nutrient Analyser were carried out in a similar way: connection of the instrument to the buoy data acquisition electronics and verification of the correctness of data/commands exchange between the two units. After successful completion of these tests, a complete subsystem composed of Nutrient Analyser and dedicated acquisition and management board was transferred to CNR-ISMAR, making possible to carry out a dedicated phase of scientific tests (see 6.2).

Functional tests of the second telemetry unit were aimed at verifying the correctness of the new features added to the buoy, namely:

a) automatic daily transmission of a data file from the buoy to the OGS ftp server;
b) daily automatic notification via e-mail of the buoy technical status to pre-defined e-mail addresses;
c) automatic notification via e-mail of alarm conditions.

These tests were carried out from Tecnomare workshop, carrying out simulated missions with a second data acquisition and control electronics (an exact replica of the one installed on the buoy, undergoing tests at sea, see section 4) and verifying arrival of the messages as programmed. Result was positive; figure 20 shows an example of daily e-mail notification of buoy status.

Note: the second telemetry unit, based on cellular phone modem, was designed and provided by Tecnomare, replacing the originally foreseen satellite communication system (never provided by the greek partner NCMR).


MFStep Daily Status Report 15/09/04 08.35.04 - Message (Plain Text)

File Edit View Insert Format Tools Actions Help

Reply | Reply to All | Forward

From: E2M3A BUOY [mfsteplog@infinito.it]   Sent: mercoledì 15/09/2004 10:36
To: fabio.zanon@tecnomare.it
Cc: francesco.gasparoni@tecnomare.it; vcardin@ogs.trieste.it; sarsa@libero.it
Subject: MFStep Daily Status Report 15/09/04 08.35.04

```
LATITUDE                 +41.13032 [deg]
LONGITUDE              +16.86317 [deg]
HEADING                  +23 [deg]
DRIFT                        65535 [meters]
DRIFT ALARM         YES
BATTERY                  +14.25 [V]
WATER DETECT 1   NO
WATER DETECT 2   NO
WATER DETECT 3   NO
```

Figura 20 – E2-M3A daily status report automatically transmitted by e-mail

Finally, the Water Detect and Acceleration Monitoring Unit was tested connecting to the data acquisition electronics and verifying the correctness of data/commands exchanged. Water alarm occurrence was simulated and correctly detected.

6 MFSTEP SCIENTIFIC PAYLOAD TESTS

6.1 CTD chain

Being these sensors supplied with test and calibration certificates from the manufacturer (SeaBird), no dedicated "scientific" test was carried out. Functional tests (carried out in air) were described in section 5.

6.2 Nutrient Analyser

6.2.1 General

6.2.1.1 Instrument characteristics

The determination of nitrate in seawater is based on the method of Morris and Riley (1963) and modified by Strickland and Parsons (1968). Nitrate is reduced to nitrite using a cadmium-copper column. The nitrite produced reacts with sulfanilamide in an acid solution. The resulting diazonium compound is coupled with N-(1-Naphthyl)-ethylenediamine dihydrochloride to form a colored azo dye, the extinction of which can be measured spectrophotometrically.

The NAS-2E Nitrate Analyzer (WS EnviroTech) is configured to measure nitrate plus nitrite with a linear response in the 0-30 μM range. The NAS-2E relies on conventional wet chemistry to determine the nutrient via a colorimetric reaction which compares the sample response to that of on board standard of a known concentration (*W.S Ocean Systems,* 1999).

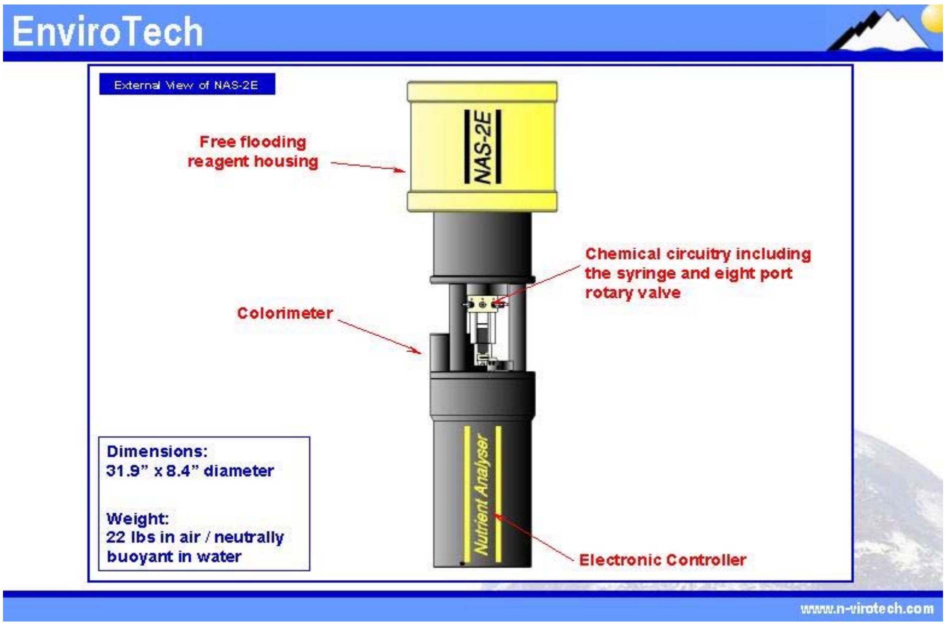


Figure 21 – NAS-2E external layout

The NAS-2E has five major components (figg.21 and 22): eight-way rotary valve, motor driven syringe, colorimeter, reagent housing and the electronic controller.

The rotary valve and syringe are both driven by stepper motors controlled by the NAS-2E electronics. Reagents are stored in plastic “transfusion” bags, in the reagent housing (refrigerated in our modified configuration).

The colorimeter consists of a narrow capillary with a LED light (wavelength 560 nm) positioned at one end and a photodiode detector at the other.

6.2.1.2 Sampling process

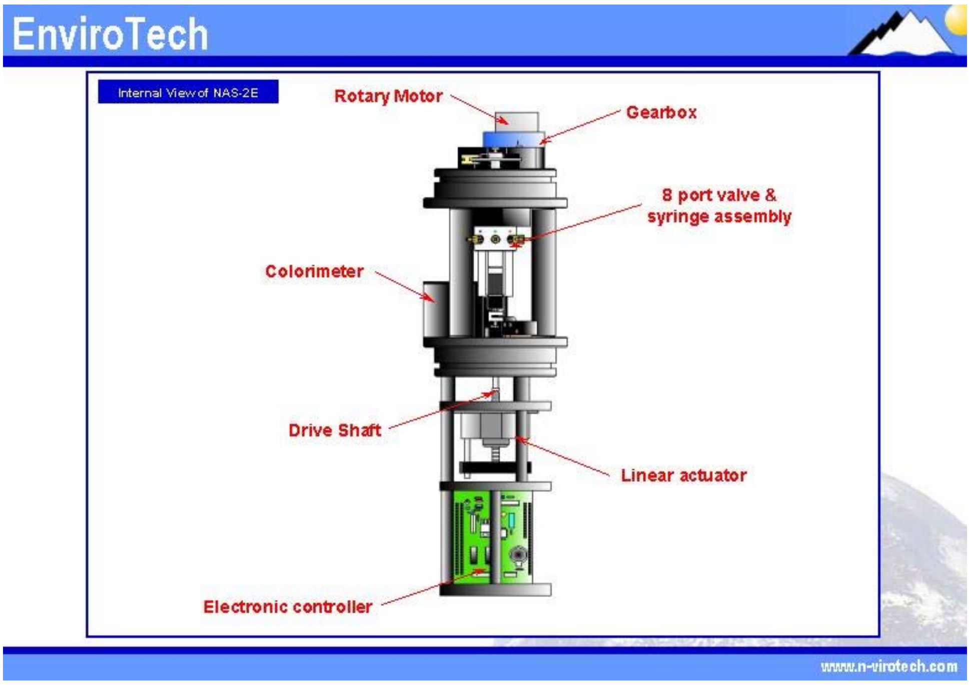


Figure 22 – NAS-2E internal configuration

To perform the analysis the valve is positioned at the inlet and the sample is drawn into the syringe chamber. The valve is then turned to the cadmium column port and the sample is forced over the copperised cadmium. The sample is removed from the column by again extracting the syringe plunger. By a similar method, reagents are added to the sample, mixing occurs in the syringe chamber where the colour initially develops and finally the reacted sample is inserted into the colorimeter capillary for measurement.

6.2.1.3 Measuring principle

The actual sample cycle is somewhat more complex. First, a blank measurement is carried out for each sample before the the reagents addition. Then, the analytical reaction takes place.

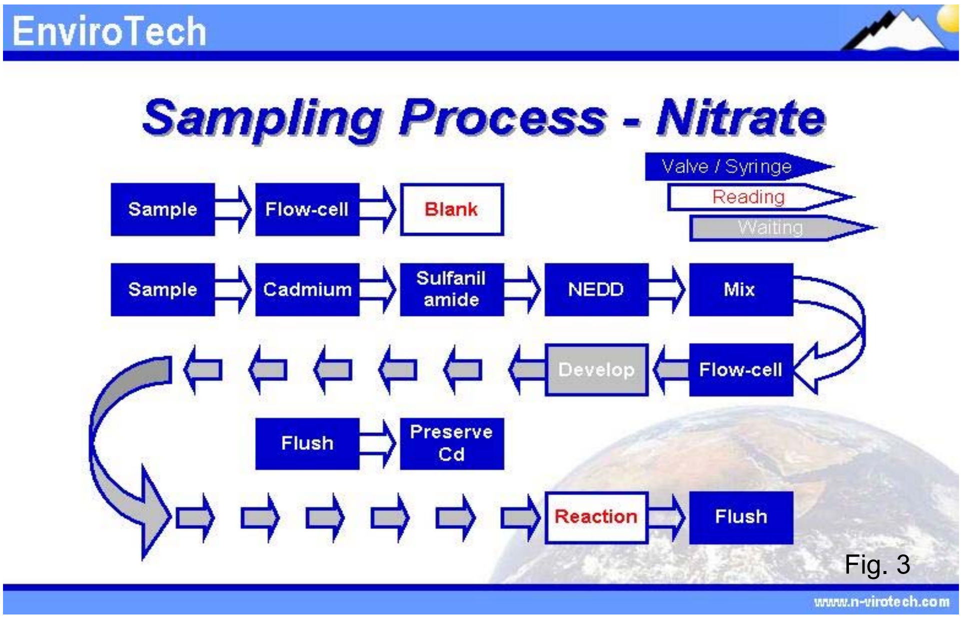


Figure 23 – Sampling process

The transmission of light through a solution with a given concentration is described by Beer-Lambert's law. This law is applied to the data during post processing, in order to obtain the nutrient concentration values. Then, the Beer-Lambert law states:

$\log_{10} I_0 / I = kcl = D$ (1)

where:

I_0 = intensity of incident light

I = intensity of transmitted light

l = length of the optical path

c = concentration of the coloured substance in solution

k = constant

D is known as the optical density for the particular radiation used.

If I_0 is assumed to be the blank reading and *I* is the sample reading for a given solution, *D* can be evaluated for each sample nitrate concentration after a calibration curve of D against concentration *c* is calculated. The reduction efficiency of the cadmium column is monitored by means of the on-board standard (OBS), and the sample concentration will be corrected according to equation (2):

$c = [D_{sample} / DOBS] \cdot c_{OBS}$ (2)

6.2.1.4 Data acquisition

The NAS-2E controls the analysis through its internal software that provides analysis routines via a macro language. The system supplies four types of macro that are nominally Q, R, S and T. Conventionally S is designated as sample macro, T as on-board standard macro, R as housekeeping routine (or refresh) macro, and Q as operative sequence of R, S and T macros. It is possible to re-designate (from keyboard) the default R, S and T routines to optimize the analytical procedure.
All raw data are recorded as voltages representing the light transmitted through the sample along the colorimeter pathway. The raw data are downloaded to PC and converted to absorbance units and nutrient concentration.

6.2.2 Laboratory tests

Laboratory tests have been carried out in order to:

- verify manufacturer's specification and functioning: sensitivity, precision, accuracy, cadmium column efficiency;
- integrate the working routines to the buoy automatic water sampling system (five depths in the range of 0-200 m depth);
- optimise the NAS performance in oligotrophic environment (max nitrate concentration 5µM) in an open ocean area;
- simulate a mission for short/medium period.

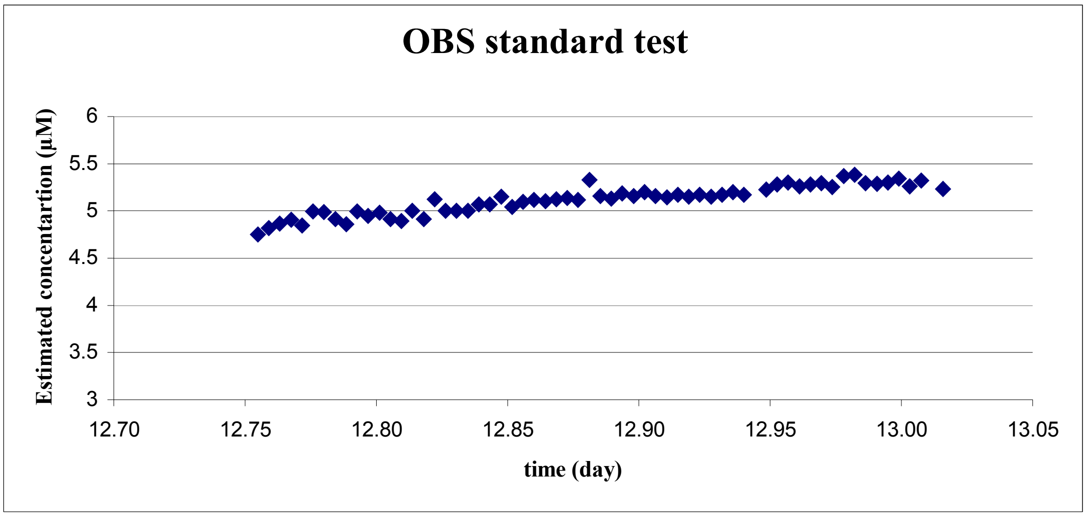
Main results obtained are summarised in the following paragraphs.

6.2.2.1 Sensitivity

Sensitivity has been tested: the minimum measurable interval is 2% of full scale interval, as indicated in the manufacturer's specifications.

6.2.2.2 Precision and accuracy

Many tests have been performed to define the precision and the accuracy of the instrument. On Fig.24 the precision test (72 replicates) for the OBS (On Board Standard) is reported.



Precision		Accuracy	
average	5.11 µM	True value	5.00 µM
Standard deviation	0.15	Standard deviation	0.15
Variability coefficient (%)	3.00	Variability coefficient (%)	3.07

Figure 24

Precision and accuracy vary with the concentration of the standard; higher the sample concentration, better the precision and accuracy. Within the considered concentration range (0-6µM), the variability coefficient varied between 2% and 6%.

Other tests have been performed to evaluate the reproducibility of samples in a longer time interval, including short period of inactivity of the column (that even will occur during the normal functioning of the NAS). A 5µM standard has been analysed, with intervals of hours, for three days, simulating a working mission. On Fig. 25 the results for six groups of standard replicates (total of 60 analyses) are shown.

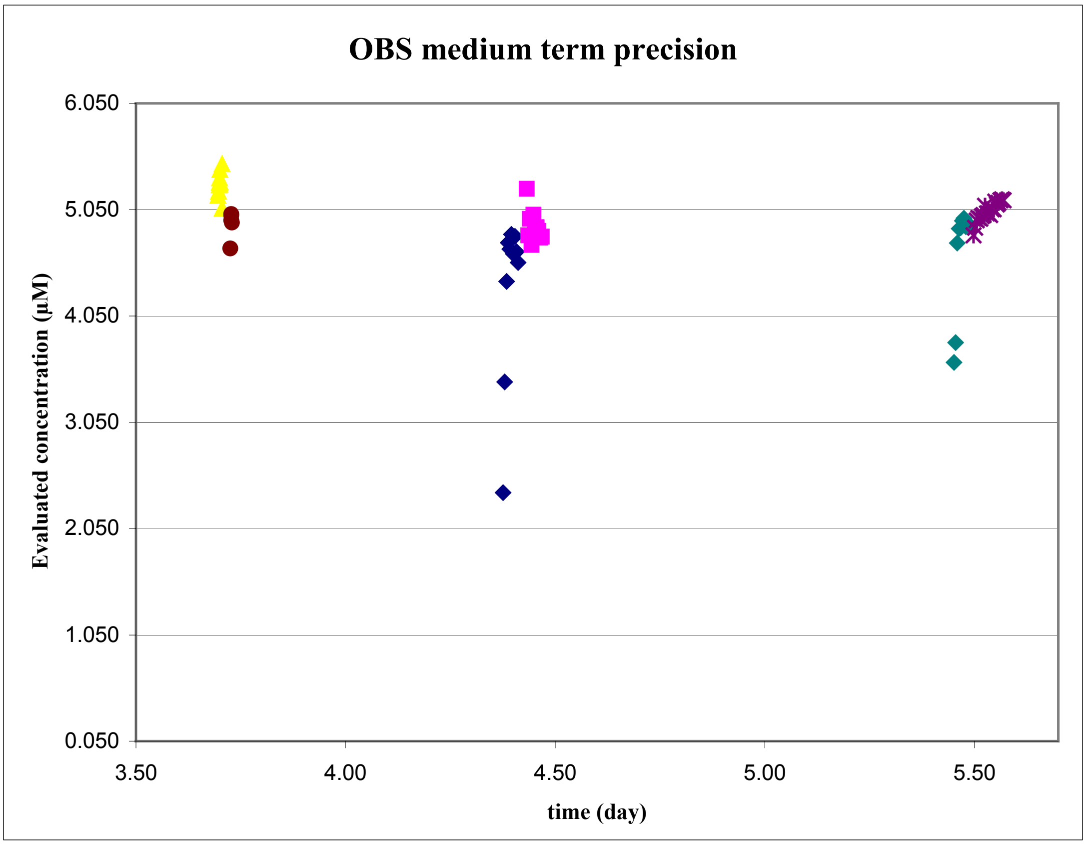


Figure 25

Precision		*Accuracy*	
average	5.01 µM	true value	5.00 µM
Standard deviation	0.18	Standard deviation	0.18
Variability coefficient (%)	3.67	Variability coefficient (%)	3.68

The first values of each group resulted quite wandered from the average. This depends from the dormancy of the cadmium column, as described in the section 6.2.2.3. To solve this problem, besides a good maintenance of the cadmium column with frequent refreshing routines, it is necessary to increase the number of replicates to get a stable signal. This aspect is considered in the sequence of routines performed by the NAS (three sample replicates).

6.2.2.3 Cadmium column

As described above, the nitrate reduction to nitrite is a fundamental step in the analysis of nitrate. Then, the reduction efficiency of the cadmium column is crucial for the analytical performance. The system provides the introduction of nitrate spiked seawater into the column at frequent intervals, followed by fillings of the column with ammonium chloride solution, in order to mantain the optimal condition for the cadmium reductor.

The deterioration of the cadmium column is generally caused by a combination of four factors:

- low nitrate concentrations;
- dormancy;
- surface deposition;
- poisoning.

The two most important factors, with regard to the cadmium column efficiency during long term off-shore deployments, are the periods of inactivity between samples and the low nitrate levels of the samples analysed. In order to reduce the inactivity periods, the frequence of the refreshing routine (R) has been properly set.

6.2.2.4 Integration of the working routines

Considering that:

- replicated analyses are useful to get robust data;
- the inactivity period for the cadmium column must be properly minimize;
- frequent refreshing are needed due to the low nitrate levels to be analysed;

then, the sequence planned for each sample analysis is:

RRR**S**RRR**S**RRR**S**RRR**T**

Where R is the refreshing routine, **S** is the sample rourine, **T** is the OBS routine.

Every day, two analytical cycles take place at 10 am and 10 pm (UTC), including five samples pumped from 25, 50, 75, 100, and 200 m depth. Every analytical cycles takes 4h 30m. Between one cycle and the other, R is carried out every 30 minutes.

The investigated area is an oligotrophic zone; then, the best nitrate concentration range has been set at 0-5µM; the electronic signal has been properly optimize.

6.2.3 References

- W.S. Ocean Systems Ltd., NAS-2E Operating Manual, issue G1, W.S Ocean Systems Ltd., Omni Business Center, Omega park, Alton, Hants., GU34 2QD UK, 1999.
- Morris and Riley. (1963). Analytica Chimica Acta, 29, 272–279.
- Strickland, J.D.H., and Parsons, T.R. (1968). Determination of reactive nitrate. In: A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada, Bulletin 167, 71–75.
- Grasshoff, K, M. Ehrhardt, M. and K. Kremling (1983). Determination of nutrients. In: Methods of Seawater Analysis. p. 143

7 CONCLUSIONS

Test activities were successfully concluded around mid September 2004, with the buoy in Bari harbour. After completion of integration work, on September 18 the buoy was transferred on site and installed.

TOP period started on September 19, 2004.