



Mediterranean Forecasting System:
Toward Environmental Predictions



Deliverable WP2D18

***E2M3A equipment fully integrated and tested
ready for the 6-month TOP***

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ready for the 6-month TOP*

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1. Introduction

The configuration of the E2-M3A system follows the same principles applied as the M3A buoy in the Cretan Sea. However, choice of instruments, measurement depths and parameters to be monitored will be adapted to the mentioned specific oceanographic and bio-geo-chemical properties of the Adriatic Sea. The E2-M3A surface buoy is based on an existing 6 m diameter discus shaped hull, partially instrumented (available scientific payload includes a meteorological station, a sea surface C/T sensor, and one WS NO₃ sensor) in the framework of a nationally funded research project. Therefore, air-sea interface and nutrient data will be made available to the project at no cost. More specifically, in addition to air-sea interface measurements, the scientific payload includes: four CTD measurement depths (50, 75, 100 and 200 m); fluorescence and dissolved oxygen at 50, 75, 100 m depths; PAR measurements at 50 and 100 m depths. Nutrient measurements are to be carried out at depths of 25, 50, 75 and 200 m via pumping system.

The buoy configuration also includes: mooring line, data acquisition and control electronics, power management systems, battery packs, photovoltaic panels, buoy status monitoring sensors (such as GPS, battery voltage and current, internal temperatures, tilt, heading etc.), signaling devices as required by the national regulations.

The overall integration and tests were carried out in two phases; the first phase was completed in August 2004, while the second one in September before the system deployment. In August after having assembled the system according to the above scheme, it was left in mission mode during the night: only CTD chain data collection was active while nutrient sensor data collection is still disabled. The nutrient sensor syringe did not complete up and down movements, it was thus dismantled and tested using an external power supply and a PC directly connected to it. The problem is identified in the syringe moving mechanism. Because of unforeseen problems found on the multi-level sampling system and the unavailability of spare parts, the integration activities were not properly completed. Therefore, it has been decided to dismantle both the sampling system and the nutrient sensor, and to transfer them to Tecnomare laboratory for the necessary corrective actions and maintenance work.

A set of tests and modifications to the buoy control system were carried out in Tecnomare workshop in order to solve problems observed during August integration tests. In particular:

- the damaged valve of the pumping system was substituted with a new one;

- the multi-level sampling system was integrated in a temporary test setup allowing water pumping, flushing and discharge;
- the software bug which caused disabled quotes to be sampled was corrected;
- it was decided to allow nutrient sensor refresh (Macro R) also when the system is in idle mode; this was to satisfy a CNR-ISMAR request to avoid corruption of cadmium column inside the sensor during the navigation to the mission site; minor modifications were made to make the system more flexible in order to facilitate data recovery.

E2-M3A consists of the following major subsystems:

- hull and superstructure
- mooring system
- data acquisition and control system
- telemetry system
- power system
- payload (sensors)
- auxiliary equipment
- man-machine interface

2. Hull and superstructure

E2-M3A hull is of welded steel construction and has a discus shape (6 m diameter, 1.4 m height). It provides three main compartments, provision for installation of sensors, ballast compartments and provision for the attachment of the superstructure.

The three compartments are reserved for:

- Data acquisition and control system (see figure 2.1)
- Battery packs (see figure 2.2)
- A special payload consisting of an automatic water sampling system (see figure 2.3) that makes available to sensors onboard water pumped from up to 5 different depths

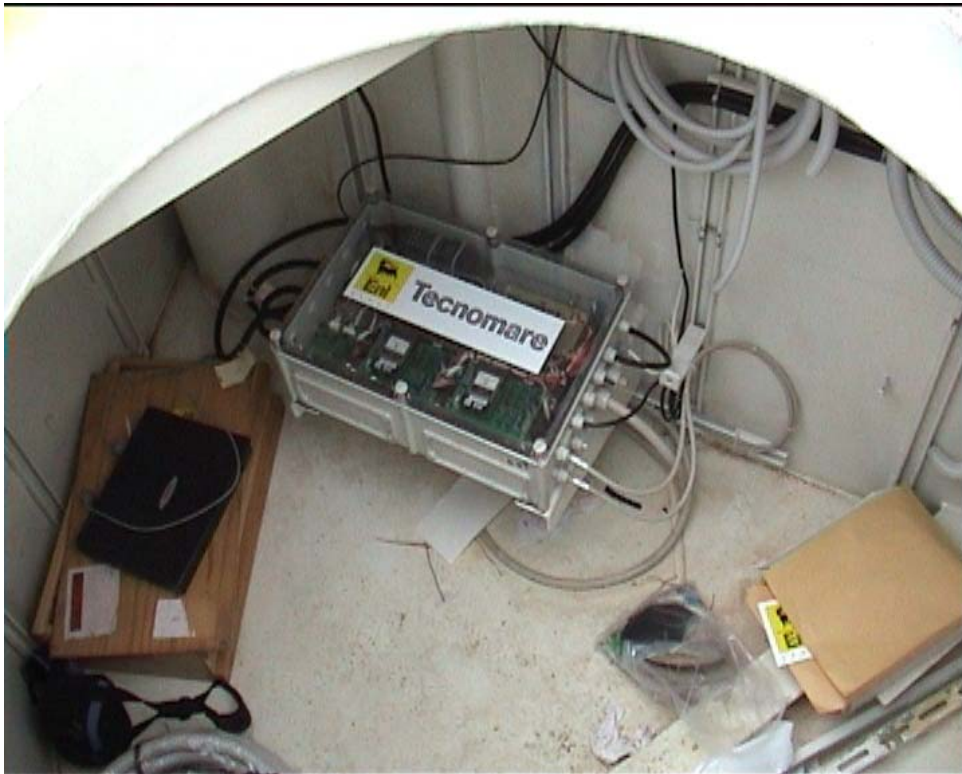


Fig 2.1 –The buoy electronics compartment



Fig 2.2 –The battery compartment



Fig 2.3 –The automatic water pumping and analysis compartment

Access is provided from the deck level to the three equipment compartments by 1-meter diameter openings having watertight covers and a latch to secure the cover when in the open position. There are twenty 14 mm nuts and bolts that secure each cover. The peripheral compartments are sealed to ensure buoyancy of the buoy if all the equipment compartments are flooded. Four of the peripheral compartments have access from the deck and are used as ballast compartments. The ballast compartments have the capacity for 1135 kg (total) of water, which may be used to trim and/or ballast the buoy to the desired displacement as defined by the following information:

Displacement 13.600 kg

Hull weight 9080 kg

Mast weight 320 kg

Payload 2700 kg max

Reserve (trim, ballast, payload) 1500 kg

Two wells, 12 inches in diameter, penetrate the hull and are accessible from the deck. One standpipe in the electronics compartment provides for the installation of sensors in water. The standpipe extends above the water line, with openings sealed to prevent water entry. The

superstructure is a steel tripod structure supporting an aluminum cage with GPS and cellular antennas, radar reflector and light. This cage permits ready access to the equipment mounted at the 6.5 m level. The superstructure is coupled to a mast supporting the wind sensor at the 10 m level and the meteorological sensors. The mast supporting wind and meteorological sensors can be lowered to permit servicing of the sensors from the cage. The sensor wires, antenna cables and battery vent tubes are routed through the tripod elements from the sensor cage to the hull equipment compartments.

3. Payload

E2-M3A payload includes the instruments/systems described in the following paragraphs:

a) Scientific Payload

The sensors dedicated to the acquisition of scientific measures are listed below

- meteorological station
 - wind speed and direction (RM Young model 05106-MA)
 - pressure sensor (RM Young model 61201 + 61002)
 - temperature and humidity (Rotronic MP-102A-T4-W4W)
 - solar radiation (mfr. and model to be defined)
 - heading (RM Young model 32000)
- CT + pump (hull mounted) (SeaBird SBE-37SI + SBE-5T)
- Chain of CT connected via inductive modem
 - 50 m: CT + pump (SeaBird SBE-16plus + SBE-5T), pressure sensor, fluorometer (SCUFA II);
 - 75 m: CT + pump (SeaBird SBE-16plus + SBE-5T), fluorometer (SCUFA II);
 - 100 m: CT + pump (SeaBird SBE-16plus + SBE-5T), PAR (Biospherical QSP-2200);
 - 200 m: CT + pump (SeaBird SBE-16plus + SBE-5T), pressure sensor, dissolved oxygen (SBE-43)
- Nutrient Sensor for nitrate measurements (WS NAS-2E) at 50 m
- Automatic water sampling system that makes available onboard the buoy water from 5 different depths (25, 50, 75, 100 and 200 m), according to a sampling schedule programmable by the operator. Connected to this system are (in BOMA configuration):
 - multiparametric probe equipped with T, C, dissolved oxygen, turbidity, chlorophyll sensors (Idromar IM-51)
 - Nutrient Analyser (nitrate) (NOTE: if not mounted fixed at 50 m)

E2- M3A CONFIGURATION																
<i>Param/ depth</i>	DR YT	WS PD	WD IR	AT MS	REL H	CN DC	TE MP	PRE S	OS AT	TU R6	FLU 2	LG H1	SVE L	NT RA	PSA L	
meteo	●	●	●	●	●											
1m						●	●						●			
50m						●	●	●		☐	☐			●	☐	
75m						●	●			☐	☐				☐	
100m						●	●			☐	☐	●			☐	
150m										☐	☐				☐	
200m						●	●	●	●	☐	☐				☐	

● BUOY MEASUREMENTS

☐ boma measurements

● BUOY MEASUREMENTS

● MOORING INSTRUMENTS

Status Sensors

The data acquisition and control electronics manages also the following status sensors:

- ❑ GPS receiver (Latitude, Longitude, GMT);
- ❑ Heading, Pitch, Roll;
- ❑ Z acceleration;
- ❑ Electronic box internal temperature;
- ❑ Battery Voltage;
- ❑ Battery Current;
- ❑ Load Current;
- ❑ Current supplied by the photovoltaic panels;
- ❑ Photovoltaic panel monitoring box internal temperature;
- ❑ Three Water Detectors (one for each buoy compartment).

The GPS receiver is necessary to keep the clock of the data acquisition and control electronics correctly synchronised with the Greenwich Meridian Time and to get the correct

position of the Buoy: detection of a position out of a pre-defined “Watch Circle” will generate an alarm condition. The Water Detectors (one for each buoy compartment) will generate an alarm condition in case of detection of water at a certain level from the buoy floor.

4. Data acquisition and control system

E2-M3A is equipped with a Data Acquisition and Control Electronics (hereafter referred as to DACS), based on three microprocessor boards custom designed and developed by Tecnomare.. The *UCM-C* (Mission Control Unit – Communication board) has in charge the following tasks:

- to manage the Communication Systems;
- to synchronise the data acquisition activities during the autonomous acquisition mission;
- to monitor the status sensors (GPS, Compass, Z-accelerometer, Water detectors and the status board attached to the photovoltaic panels regulator);
- to save acquired data in its Mass Memory (Flash card EEPROM);
- to execute the watch-dog task to reset partially or totally the DACS in case of internal re-boots.

The *UCM-D* board has in charge:

- the acquisition of data from all the scientific packages (meteorological, oceanographic) and from the UPQ (see below);
- the pre processing of acquired data to generate hourly and daily reduced data to transfer to UCM-C
- the storage of all acquired scientific data in hourly data files (e.g. all meteorological data acquired at 2 Hz are saved in hourly files);

The *UPQ* is specifically dedicated to manage the automatic water sampling system (operation of pumps and valves) and the acquisition from the sensors connected to it; in BOMA configuration the sensors are a multiparametric probe and a Nutrient Analyser. Basically the UPQ can be considered like a complex instrument able to manage the hydraulic system and a set of sensors: in this unit a

dedicated software command layer was developed to manage independently and directly each valve, each pump and each sensor.

5. Telemetry system

In the present buoy configuration, the telemetry system is composed of a Phone Interface INT-5000 connected with an E-TACS phone and with a standard Modem: the modem supplies asynchronous RS232 serial interface at 1200 baud (N,8,1) for the UCM-C unit. The E-TACS phone has been chosen after a dedicated test carried out on the installation site that evidenced the absence of coverage from the Italian GSM phone network in the area.

The Modem is configured as auto-responding after the reception of one RING signal from a remote unit in order to activate automatically a transparent link after the modems negotiation procedure. The software implemented in UCM-C relative to the management of this communication channel allows:

- to receive commands and data requests from a remote unit (MMI);
- to send the relative reply;
- to execute on command a call-back to a predefined phone number (to generate traffic using the pre-paid card);
- to send 3 RING signals in case of detections of alarm conditions (buoy out of Watch Circle or Water detected in a compartment).

a) Optional System

The introduction of an optional E-TACS system will be evaluated: in this system the second E-TACS phone will be connected via interface INT-5000 with a modem equipped with an IP module. The IP module will be programmed with the network parameters of an ISP (Internet Service Provider) account. It will be evaluated the feasibility (and the possible development) of an additional communication software layer allowing the UCM-C to send e-mail to some pre-programmed users to signal alarm conditions or to transfer attached files containing the daily reduced data generated by the DACS.

6. Power system

The buoy power system consists of:

- a) a rechargeable battery pack (12 V nominal, 1050 Ah)
- b) 6 Photovoltaic panels I-110 Isofoton (100 mW/cm^2 , 25°C) with the following main characteristics:
 - Max Power: 110 W;
 - Short circuit current: 6.76 A;
 - Open circuit voltage: 21.6 V
 - Max current @ (max Power): 6.32 A
 - Voltage @ (max Power): 17.4 V

a) Configuration File

The *Configuration File* is a data structure saved in the mass memory of DACS that contains the following main parameters:

- site position (latitude, longitude and water depth)
- mass memory available in the DACS
- battery capacity
- status sensor alarm thresholds:
 - max currents (panels, battery, load)
 - min and max voltages (load and battery)
 - min and max temperatures (DACS and power regulation box)
 - max tilt
 - watch circle
- scientific packages enabled/disabled in MISSION mode
- period between two consecutive UPQ measurements (3, 6, 12 hours)
- sampling quotes enabled for measurement in UPQ

This file can be edited with a dedicated panel of the MMI and can be transferred to the DACS via telemetry link.

b) Test and Mission Management Interface

It is part of the MMI composed of the following set of control panels:

- a raw data panel to check all scientific packages:
 - CT mounted on the hull
 - CT chain
 - Nutrient Analyser
 - Meteorological sensors
 - UPQ (Multiparametric Probe and Nutrient Analyser)
- a mission management panel
 - to start/stop the mission
 - to manage the mass memory
 - to download a new Parameter File
 - to monitor the status sensors
 - Compass
 - GPS
 - Power monitoring system
 - Water detectors
 - to recovery daily data files (*.SUM)
- general purpose commands to check the status of the electronic boards constituting the DACS

All commands described above will be also available in a text menu through a direct connection via terminal application.

c) Data Conversion

A dedicated panel allows converting the binary files YYMMDD.SUM, YYMMDDHH.SEA and YYMMDDHH.MET produced by the DACS in the corresponding text files YYMMDD_SUM.DAT, YYMMDDHH_SEA.DAT and YYMMDDHH_MET.DAT where data series are written in tab-separated columns. These files can be easily loaded with standard tools like EXCEL to be displayed and plotted.

7. *Software Architecture*

Operating modes

The software implemented in the DACS allows to operate the buoy in two different modes:

- IDLE mode
- MISSION mode

a) **Idle mode**

In IDLE MODE the following tasks are executed by UCM-C

- hourly acquisition of GPS and Water Detectors: in case of detection of alarm conditions (buoy out of the watch circle or water detected in a compartment) an alarm is sent through the telemetry system;
- reception and execution of commands / data request received via communication system.

In this operating mode the only functions executed by UCM-D are the commands/data requests received from the communication system via UCM-C. All scientific instruments and UPQ with relative sensors are powered off and they can be switched on only on remote request.

b) **Mission mode**

In MISSION MODE the buoy manages automatically the acquisition of scientific data: the tasks executed by UCM-D in this operating mode are the following:

- the acquisition of the scientific sensors enabled, according to the *Configuration File*
- the storage of all acquired scientific data in hourly files in its mass memory (flash card);
- the calculation of hourly reduced data to be transferred to UCM-C;

whereas the functions executed by UCM-C in this operating mode are:

- management of communications;
- management of status sensors events/alarms;
- request to UCM-D of hourly reduced data;
- the storage of all reduced data (status data and scientific data);

Detailed description of how data are acquired and how they are processed to generate reduced data is supplied in the next paragraph (acquisition strategy).

c) Acquisition Strategy

In MISSION MODE the scientific packages are managed and acquired by the UCM-D as reported in the following list:

□ *CT sensor*

- the instrument is continuously powered on (when enabled);
- a sample per hour is acquired (exactly at hh:30:00)
- the sample contains the following data:
Temperature; tt.tttt [degC] -5..35 degC
Conductivity; cc.ccccc [S/m] 0..7 S/m
Salinity; sss.ssss [psu]
Sound Velocity; vvvv.vvv [m/s]

□ *CTs Chain*

- the CTs in the chain are powered with the proper internal battery and are interfaced with DACS by mean of an inductive modem;
- all instruments at the different quotes will be acquired a time per hour (at hh:30) at the same time (time spaced of few seconds);
- ranges and resolutions of the acquired parameters will be defined after the reception of documentation from the instrument supplier.

□ *UPQ*

- data supplied by multiparametric probe and by the nutrient analyser can be collected from the 5 quotes every 3 hours, 6 hours or 12 hours;

Multiparametric Probe

- it is continuously powered on (when enabled);
- parameters relative to a single quote are the following:
Temperature; tt.tt [°C]
Conductivity; cc.ccc [mS/cm]
Dissolved Oxygen; oo.o [%sat]
Turbidity; yyy.y [FTU]
Fluorometer; ff.ff [mg/m³]

Nutrient Analyser

- it is continuously powered on (when enabled);
- the macro <R> will be executed every hour;
- the macro <T> will be executed a time a time per day (at 00:00);
- the measurement macro <S> will be executed at each quote every 12 hours;
- voltage values in mV [0000..4095] supplied by colorimeter will be acquired. The nutrient concentration will be calculates in phase of post processing.

□ ***Meteorological Sensors***

- all meteorological sensors are continuously powered on (when enabled);
- data are continuously acquired at 2 Hz
- a single meteo sample is composed of
 - Wind Speed; ss.sss [m/s]
 - True Wind dir; ddd.d [deg]
 - Temperature; tt.tt [°C]
 - Humidity; hh.h [%]
 - Pressure; pppp.p [mbar]
 - Compass; ccc.c [deg]
 - Solar Radiation; (tbd)
- every hour 10 minutes of complete (raw) data (hh:00..hh:10) are saved in a dedicated file;
- mean values are calculated from the 10 minutes of saved data;
- gust and sustained speed/direction for wind are calculated from all the acquired data in an hour (after calculation the data acquired in the period hh:10..hh:59:59.5 are discarded)

□ ***GPS***

- it is continuously powered (like in IDLE MODE)
- data are acquired and saved a time per hour in the reduced data daily file
- data supplied by GPS are:
 - time
 - latitude (SWG84)
 - longitude (SWG84)

- it is verified that the buoy position is inside the “Watch Circle”: centre and radius of the circle are in the *Configuration File*;
- ***Compass and Z-accelerometer***
 - Compass and Z-accelerometer are continuously powered (like in IDLE MODE)
 - Every 3 hours the compass and the Z-accelerometer are acquired for 20 minutes (from hh:00 to hh:20) at 2 Hz and saved in a dedicated file
 - Each sample contains the following data:
 - Heading; hhh.h [deg]
 - Pitch; pp.pp [deg]
 - Roll; rr.rr [deg]
 - Z-acceleration g.ggg [g]
- ***Water Detectors***
 - the three water detectors are acquired a time per hour and saved in the daily reduced data file.
- ***Power System Monitoring Unit***
 - The electronic unit dedicated to the acquisition of the status of the power system is switched on and acquired a time per hour: data are saved in the daily reduced data file;
 - acquired data are the following:
 - battery voltage
 - battery current
 - load current
 - current of one of the two panels of the first pair
 - current of one of the two panels of the second pair
 - current of one of the two panels of the third pair
 - temperature of the battery-panels regulator

The acquisition strategy described above and more details of the acquisition/processing tasks for each parameter are summarised in the following table:

<i>Sensor</i>	<i>Sampling rate</i>	<i>Calculated parameters</i>	<i>Rate</i>	<i>Processing</i>	<i>Saved in</i>
Wind speed	2 s/s	Mean speed	Hourly	Average calculated on 10' of data sampled at 2 Hz	10 mins of data are saved in YYMMDDHH.MET Mean speed is saved in YYMMDD.SUM
		Sustained wind speed	Hourly	Maximum among 60 scalar averages calculated over 1 minute for the entire hour	YYMMDD.SUM
		Gust speed	Hourly	Maximum among 1200 scalar averages calculated over 3 seconds for the entire hour	YYMMDD.SUM
Wind direction	2 s/s	Mean direction	Hourly	Vectorial average calculated on 10' of data sampled at 2 Hz	10 mins of data are saved in YYMMDDHH.MET Mean direction is saved in YYMMDD.SUM
		Direction associated to	Hourly	Vectorial average evaluated over 1 minute	YYMMDD.SUM

		sustained speed		period relative to the sustained speed	
		Direction associated to gust	Hourly	Vectorial average evaluated over the 3 seconds period relative to the gust speed	YYMMDD.SUM
Air temperature	2 s/s		Hourly	Average calculated on 10' of data sampled at 2 Hz	10 mins of data are saved in YYYYMMDDHH.MET Mean temperature is saved in YYMMDD.SUM
Air humidity	2 s/s		Hourly	Average calculated on 10' of data sampled at 2 Hz	10 mins of data are saved in YYYYMMDDHH.MET Mean humidity is saved in YYMMDD.SUM
Barometric pressure	2 s/s		Hourly	Average calculated on 10' of data sampled at 2 Hz	10 mins of data are saved in YYYYMMDDHH.MET Mean pressure is saved in YYMMDD.SUM
Compass	2 s/s		Hourly		YYMMDD.SUM
Solar radiation	2 s/s		hourly	Average calculated on 10'	YYMMDD.SUM

				of data sampled at 2 Hz	
CT at surface	1 s/hour	Temperature	Hourly		YYMMDD.SUM
	1 s/hour	Conductivity	Hourly		YYMMDD.SUM
	1 s/hour	Salinity	Hourly	Calculated	YYMMDD.SUM
	1 s/hour	Sound velocity	Hourly	Calculated	YYMMDD.SUM
CT at 50 m	1 s/hour	Temperature	Hourly		YYMMDD.SUM
	1 s/hour	Conductivity	Hourly		YYMMDD.SUM
	1 s/hour	Pressure	Hourly		YYMMDD.SUM
	1 s/hour	Chlorophyll	Hourly		YYMMDD.SUM
CT at 75 m	1 s/hour	Temperature	Hourly		YYMMDD.SUM
	1 s/hour	Conductivity	Hourly		YYMMDD.SUM
	1 s/hour	Chlorophyll	Hourly		YYMMDD.SUM
CT at 100 m	1 s/hour	Temperature	Hourly		YYMMDD.SUM
	1 s/hour	Conductivity	Hourly		YYMMDD.SUM
	1 s/hour	PAR	Hourly		YYMMDD.SUM
CT at 200 m	1 s/hour	Temperature	Hourly		YYMMDD.SUM
	1 s/hour	Conductivity	Hourly		YYMMDD.SUM
	1 s/hour	Pressure	Hourly		YYMMDD.SUM
	1 s/hour	Dissolved oxygen	Hourly		YYMMDD.SUM

Nutrient analyser	1s/3h or 1s/6h or 1s/12h	Nitrate	Selectable (every 3, 6 or 12 hours)		YYMMDD.SUM
Pumping system at 5 quotes	1s/3h or 1s/6h or 1s/12h		Selectable (every 3, 6 or 12 hours)	A set of measures (temperature, conductivity, dissolved oxygen, turbidity, florescence) for each of the 5 sampling quotes. In addition a set of measures is taken on the washing solution (one before the cycle and one after)	YYMMDD.SUM
GPS	1 s/hour 1 s/hour 1 s/hour 1 s/hour	Latitude Longitude Time Number of satellites	Hourly Hourly Hourly Hourly		YYMMDD.SUM YYMMDD.SUM YYMMDD.SUM YYMMDD.SUM

Power monitoring system	1 s/hour	Current produced by photovoltaic panels (side 1)	Hourly		YYMMDD.SUM
	1 s/hour	Current produced by photovoltaic panels (side 2)	Hourly		YYMMDD.SUM
	1 s/hour	Current produced by photovoltaic panels (side 3)	Hourly		YYMMDD.SUM
	1 s/hour	Load current	Hourly		YYMMDD.SUM
	1 s/hour	Battery current	Hourly		YYMMDD.SUM
	1 s/hour	Load voltage	Hourly		YYMMDD.SUM
	1 s/hour	Battery voltage	Hourly		YYMMDD.SUM
	1 s/hour	Internal temperature	Hourly		YYMMDD.SUM
Buoy attitude	2 s/s	Pitch	Hourly + 3-hourly		20 mins of data are saved in YYYYMMDDHH.SEA

					Hourly standard deviation is saved in YYMMDD.SUM
	2 s/s	Roll	Hourly + 3-hourly		20 mins of data are saved in YYMMDDHH.SEA Hourly standard deviation is saved in YYMMDD.SUM
	2 s/s	Heading	Hourly + 3-hourly		20 mins of data are saved in YYMMDDHH.SEA Hourly standard deviation is saved in YYMMDD.SUM
	2 s/s	Internal temperature	Hourly + 3-hourly		Hourly mean value is saved in YYMMDD.SUM
	2 s/s	Z acceleration	Hourly + 3-hourly		20 mins of data are saved in YYMMDDHH.SEA Hourly standard deviation is saved in YYMMDD.SUM

d) Data Storage

Data produced are stored in the following files:

File	Produced	Content
YYMMDD.SUM	Daily (updated hourly)	Reduced data from all sensors; status parameters
YYMMDDHH.MET	Hourly	10' of wind speed, true wind direction, temperature, pressure and humidity data, sampled at 2 Hz
YYMMDDHH.SEA	Three hourly	20' of data from pitch, roll, heading and Z-accelerometer sensors, sampled at 2 Hz

These files code the data in binary format. To convert them in text format it is necessary to use the MMI application. Data file *.SUM and *.SEA saved in UCM-C can be recovered via telemetry link, whereas the files *.MET containing all meteorological data can be recovered only directly from the flash card of the UCM-D.