THEMO: the Texas A&M - University of Haifa - Eastern Mediterranean Observatory

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Abstract—We introduce the new Texas A&M - University of Haifa - Eastern Mediterranean Marine Observatory (THEMO). Including two sensory arrays for shallow and deep water with realtime data transmission to shore, THEMO is currently the most advanced marine observatory in the Eastern Mediterranean regime. THEMO is aimed to serve as an offshore platform that supplies oceanography, chemical, biological, meteorological, and acoustic data. The data is freely shared over the THEMO website themo.haifa.ac.il. In this paper, we introduce the operation of THEMO, discuss its technical details, and present its quality assurance algorithms.

Index Terms—Marine Observatories; THEMO; Sensor calibration; Mooring; profiler; acoustic recording; communication to buoy

I. INTRODUCTION

Understanding the ever-changing oceans, biota and atmosphere is one of the great global challenges of the next several decades. The future of measuring and forecasting long-term trends and variability in coastal and deep water ecosystems and climate, lies in sustained long-term measurements of key ocean indicators from ocean observing systems. A new era in ocean observing has begun, one of an integrated, organized approach to gathering and sharing information. The Texas A&M University and the University of Haifa have joined forces and developed THEMO: Texas A&M – University of Haifa – Eastern Mediterranean Observatory. THEMO is located in the Levant Basin of the Mediterranean Sea. The observatory is stationed off the coast of Northern Israel in two locations: a shallow mooring at water depth of 125 m, and a deep mooring at water depth of 1500 m.

Fig. 1 shows a picture of the deployed shallow mooring. Each of the two moorings includes a sensor array attached to a surface buoy of various sensor types: inductive temperature and pressure sensors, Fluorometer, ADCP current meter, CTD, meteorological sensors, and underwater acoustic sensors. Meteorological measurements include redundant wind speed and direction, barometric pressure, air temperature and humidity, longwave irradiance using an Eppley Labs Precision Infrared Radiometer (PIR) as well as short wave irradiance using a Standard Precision Pyranometer (SPP). The data from those sensors that are deployed on the mooring’s cable is transmitted to the surface buoy using inductive communication, and is then processed internally. The location of the University of Haifa on top of Mt. Carmel some 600 m above sea level allows the transmission of the data from the surface buoy to a surface station via real-time RF communication. The data is received at a shore station and is openly shared for view and download on the university’s server. A two-way communication link allows the offshore servicing of the moorings. THEMO is similar to the observation systems that the Geochemical and Environmental Research Group (GERG) operates for the state of Texas (Texas Automated Buoy System, TABS) consisting of 10 operational buoys along the Texas Shelf and the Flower Garden Marine Sanctuary. Yet, its communication capabilities to shore and its extended number of sensors makes it the most advanced. More information on THEMO can be found in [1].

Fig. 2 shows the locations of the two moorings. As shown in Fig. 3, the shallow mooring is deployed at the edge of a deep underwater canyon that goes from 130 m rapidly to 700 m. This creates a diverse environment with strong water current rising from the canyon walls and exposing the otherwise berried rock formation up to the shallow platue. The deployment area is surrounded by small rocky hills that host a deep reef of sponge corals, soft corals, and a vibrant environment of both reef and pelagic fish. The area was declared as Israel’s first deep water nature marine reserve. The location of the deep water was chosen to be outside...
the main shipping routes to the Haifa’s harbour but within a 70 km radius from the University of Haifa to be within a radio communication range.

II. SPECIFICATIONS OF THEMO

The shallow mooring (Fig. 4) and deep mooring (Fig. 5) consist of a 2.25m diameter discus buoy equipped with solar panels and satellite as well as HF radio communications for real time data telemetry. Each mooring includes an acoustic release system roughly 30 m above the sea bottom, and a 2.5 ton steel weight connected to the mooring via a steel chain. The bottom and upper sides of the mooring’s cable are kept steady with the help of a swivel, and to avoid the cable to twist and turn due to the motions of the surface buoy, the cable is connected to the buoy with the help of a hard pipe. While the mooring at the shallow site forms a straight line from bottom to surface, the deep one is an inverse catenary mooring with a straight sensory line from surface to roughly 600 m, then, to soften the tension along the cable, the mooring is being floated up to a depth of 100 m, where it inverse and drops to the bottom at roughly 1500 m. In 2019, the deep mooring would
support two additional moorings, once servicing a sediment trap, and one including a McLane moored profiler (MMP) to measure conductivity and temperature with fine resolution. The collected data from the later will be sent to the main deep mooring via underwater acoustic communications.

The buoy controller is a GERG custom system consisting of a PC104 based computer running an AEL version of embedded LINUX with a GERG designed web interface. Each sensor is treated as a completely independent separate module. The buoy supports 16 analog channels, 13 serial ports, 2 USB and 8 Ethernet ports as well as 15, 12 V switchable power ports and two 24V POE lines. An additional UDOO x86 processor board and Ethernet extender are also built into the system to handle real time acoustic data from acoustic experiments mounted on the mooring. The system measures wave parameters using a 6 axis accelerometer, near surface currents using a single point Doppler current sensor, current profiles using a 250 kHz acoustic Doppler current profiler, near surface temperature, conductivity, turbidity, Chlorophyll and CDOM. The system also measures water temperature and pressure at ten discrete locations within the water column to a depth of 93 m. Passive acoustics are measured using a Jasco Applied Sciences Inc. Amar G-3 passive acoustic recorder at 95m depth.

III. Electrical Design

The block diagram of THEMO is shown in Fig. 6. THEMO’s platform integrates the computation system that supports the operation of the sensors, a power supply system, and a communication system. The three systems are located in a dry well that stationed on the surface platform. Two airways with snorkel valves ventilate the dry well to release air pressure and accumulated gas that may be produced by the batteries. Temperature and humidity sensors inside the well of the surface buoy monitor the level of air pressure in the well.

A. Power Supply

The power supply for the mooring is based on high capacity batteries that are recharged by three solar panels. As illustrated in Fig. 7, each solar panel charges a group of three 12V/100 AH batteries, which are connected in parallel. This configuration forms a total power supply of 12V/900AH. Through a diode bridge that connects the set of batteries, the design ensures that each solar panel works independently. A control circuit measures the voltage and current’s consumption from each battery, and has the ability to cut the power consumption in case of overload. This design is essential for the survival of the mooring in case of malfunction.

B. Computation System

THEMO’s computation system is based upon a single PC104 computer that includes a power supply, a 24 port analog-to-digimal board, 8 port UART, and a PXA270 controller. The PX270 board controls a power switching board that powers on and off each sensor. The triggering is based on a simple daily scheduling table that can be altered from the shore station. Data from the sensors is processed on the PC104 and saved in a hard disk.

C. Radio Communication System

The radio communication system is based on a MikroTik NetMETAL 5 system. The system includes an omni-directional antenna at 5.8 GHz with a source power of 24 V. On top of the mooring, the modem is connected directly to the PC104 board and draws 0.8 Amp. We note that, to save on operating power, at the mooring side we also tried to use a BATS 5.8 GHz communication system that operates a digital steering of the transmission beam according to the bearing to the receiver on the shore station, which is estimated via power measurements. However, we have found that, at sea, the motion of the surface buoy in the three axises is often too strong or too fast for the system to track, and thus communication availability was poor, and the communication system was replaced by an omni-directional MikroTik antenna. At the shore side, the reception is performed using an 80cm dish for the shallow mooring that sits roughly 30 km from the receiver, and a 120cm dish for the deep mooring that sits roughly 60 km from the receiver. The data from the mooring flows directly to a university server, and a secured connection to the mooring that permits an ssh session and ftp file exchange.
IV. DATA MANAGEMENT

THEMO sensors produce more than 3000 samples per day. On top of that, hundreds of logs recording the sensor’s activities and status are being sent. Upon reception, this data is replicated to the mainland server where it is processed, validated, stored and become available for viewing or download per demand. The process involves overcoming the challenge of having data of different types. This includes parsing data files of different formats, handling various units set by the different sensor’s manufacturers, and deciding on final visualization formats for all the sensors.

To handle the data flow, the THEMO shore station includes a dedicated server with virtual capacity that can grow upon demand. The server repeatedly checks for new arriving data, and categorize it to different clusters of data samples, operation logs, and sensor’s status indicators. The samples data are parsed and reformat to a JSON string [2]. It is then placed in a designated database. The whose process takes less than a second, so that, since the radio communication allows realtime data transfer, the data becomes available almost immediately after it was created.

The THEMO database is a document-oriented database system (Mongo) [3]. We chose the Mongo framework since it allows flexibility when integrating sensors of different structure and types. The stored data becomes publicly available through the THEMO website, themo.haifa.ac.il. The website allows the following functionality:

1) **Data download**: user can chose one or more sensors on one or more mooring to download data from. The download can be of all the data or for specific dates. Data samples identified as unreliable (see Section V) are marked with an ‘x’ sign. The downloaded data format is CSV.

2) **Data viewing**: user can chose recordings from specific dates of one or more sensor types for viewing. The data is viewed as a time-domain plot.

3) **Sensor information**: the sensors’ type, make, deployment date, and calibration date are available for viewing.

4) **User notification**: the system allows registered users to set thresholds for real-time notifications of events. These thresholds include upper bounds, lower bounds, and trends like monotonous increasing slop. The user gets an email notification upon event triggering.

V. QUALITY ASSURANCE

Upon receiving the periodic transmission from the moorings, the data is processed for quality assurance (QA) with the aim of presenting only what seems to be accurate measurements. Our QA protocol includes two layers. The first, is a rough filtering operation that complies with the NOAA QARTOD guidelines that are described in [4]. These guidelines allow a sanity check that mostly makes sure that the data should lie within some broad upper and lower thresholds. The first QA scheme also makes sure the data is not completely fixed on a certain level, which often point on a sensor’s malfunction.

The second QA layer, performs a fine tune analysis to check for non-characteristic trends in the data. These can be a monotonic rise or decline in the data; a sudden increase or decrease in the data’s spread (e.g., variance); a different distribution characteristics; or sharp transients. Towards the aim of identifying these trends, we combine three change-detect algorithms:

1) **Clustering**: We expect that the data flow produced by a functional and calibrated sensor would follow the statistics of a single distribution. This can be for example a Gaussian distribution of some mean and variance, or a Laplace distribution with a constant mode. In that context, if the data can be justifiably clustered into two or more distribution classes, then the data is non-consistent and should be validated. To cluster the data, we use the Expectation-Maximization algorithm for a mixture of General Gaussian distributions [5], [6].

2) **Detection of Transients**: The existence of signal transients reflects on the cleanliness of the sensor’s data. Sharp, very rapid in time, transients points on a non-calibrated sensor or a malfunction. To detect such transients, we make use of the wavelet de-noising technique...
In this paper, we introduced the THEMO system — the most advanced offshore marine observatory in the Eastern Mediterranean. THEMO includes a deep and shallow moorings, each with more than 40 sensors, whose data is transmitted to shore in real-time every 30 min, and is freely shared globally for research purposes. We presented the technical details of THEMO including its functionality, the hardware used, the data processing schemes, and the protocols for data quality assurance before releasing to public. We also presented examples from real data accumulated via the THEMO mooring, as well as conclusions from our deployment attempts. With THEMO up and running, research in the Mediterranean now have eyes and ears in the water.

VI. DEPLOYMENT AND RECOVERY

In this section, we would like to share from our experience in the deployment of THEMO. The THEMO shallow mooring is a simple wire and chain catenary mooring (see illustration in Fig. 4) with inductive sensors distributed throughout the top 93 m and an Amar passive acoustic sensor at 95 m depth. The mooring was completely assembled on deck prior to the start of operations with the inductively coupled sensors mounted to the inductive cable flaked on deck. Following confirmation that all sensors were working correctly, the mooring was deployed using a conventional buoy-first-anchor-last method. The buoy was streamed slowly behind the ship and the inductive cable and sensors deployed by hand as they were pulled off the stern of the ship. Following the inductive sensors and passive acoustics, the acoustic release was slipped into the water and the mooring tied off on the chain below the acoustic release. The ship towed the array onto location at which point the chain was released and allowed to freefall as the ship continued forward. The anchor was then allowed to slide off a stern ramp when the ship reached location.

Because the mooring is deployed in a marine sanctuary, the anchor cannot be left on the seafloor and must be recovered. To that aim, below the sensors is an acoustic release with a recall canister designed to allow recovery of the chain and train wheel anchor weights in 125 m of water. Recovery of the mooring is accomplished by triggering the acoustic release located between the passive acoustic system and the chain. Glass buoyancy on the mooring brings the release to the surface as the recall system pays out 200m of half inch Dyneema rope. Once the recall package has surfaced, the 2.25 m buoy is recovered first along with the inductive sensors and passive acoustic system. When the acoustic release is recovered, the ship’s winch is connected to the recall line at an in line link below the acoustic release and the acoustic release is taken out of line leaving a direct connection between the winch and the anchor. The remaining mooring along with the train wheel anchor is then winched aboard.

VII. CONCLUSION

In this paper, we introduced the THEMO system — the most advanced offshore marine observatory in the Eastern

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