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Environmental parameters and water characteristics from deep-sea surveys at the NEMO sites.

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Since 1998 the NEMO Collaboration started a long term activity dedicated to improve deep-sea technologies and to characterize an optimal site for the installation of a km^3 neutrino Telescope. More than 25 sea campaigns were performed to deploy and recover instrumented lines of multi-functional detectors, dedicated to survey the environmental characteristics and water optical properties at the Capo Passero site (36 deg 19′ N, 16 deg 05′ E), which is 80 km from the southern coast of Sicily, in Italy, and 3500 m below the Sea level. The data collected over almost 7 years, together with recent measurements indicate the very good quality of the site and the feasibility of the project. We also present results of environmental measurements at the NEMO Test-Site, 20 km away from Catania at a depth of 2000 m.

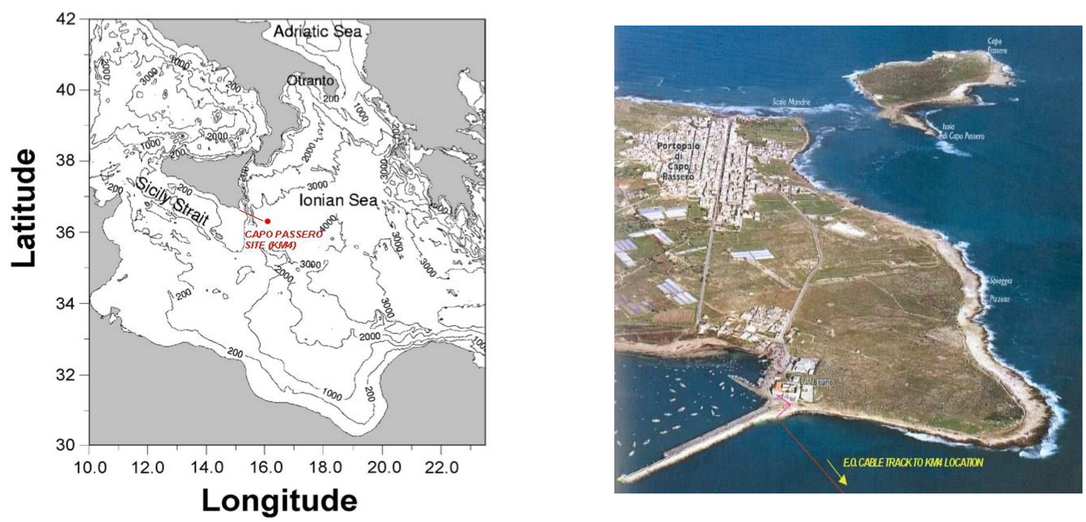

Figure 1. Left: The KM4 site. Right: the Capo Passero site with the Shore Control Center and the electro-optic cable starting point.

1. Introduction

The realization of a Cerenkov Telescope on a km^3 scale is one of the most challenging experimental tasks of modern neutrino (ν) Astrophysics. The NEMO Collaboration was formed with the aim to preform accurate R&D studies to extend the present technological features for under-water ν-Telescopes, to reach the 1 km^2 detector effective area [1]. The interactions of ν with matter are rare, and the sensitivity of the detector must be maximized as much as possible. Thus the choice of the best suitable site is extremely important. The attenuation of the Cerenkov signal and the effective optical background strongly depend on the optical quality of the water and on the general environmental conditions.

2. KM4 Site characterization

The Mediterranean Sea offers optimal conditions, on a worldwide scale, to locate the Telescope. The seabed along the Italian coast can be deep beyond 3300 m, even at distances less than hundred of kilometers from the shore. These characteristics are very important, since deep water helps to filter out the bulk of the low energy component of down going atmospheric muons, and the closeness to the coast allows the data transfer between the shore and the detector by means of standard commercial electro-optical cables, without expensive special hardware adds-on. After 25 sea campaings since July 1998, the site named KM4 outcame as the best candidate, far from shelf breaks or submarine canyons. It is located in close to Capo Passero, in the South-East part of Sicily in the Ionian Sea (36 deg 19′ N, 16 deg 05′ E), as shown in Figure. 1. It consists of a wide plateau at a depth of about 3500 m, at less than 80 km from the shore. Capo Passero offers excellent naval facilities, with well equipped harbours (Catania, Siracusa and Augusta) and infrastructures (Laboratori Nazionali del Sud, INFN) for providing thecnical supports during the construction and deployment of the future detector.

2.1 Water optical properties of KM4 site

In order to describe the transparency of natural waters as a function of photon wavelength, it is necessary to measure *in situ* the so called Inherent Optical Properties of the water, such as the absorption $L_a(\lambda)$, scattering $L_b(\lambda)$ and attenuation $L_c(\lambda) = \left(\frac{1}{L_a} + \frac{1}{L_b}\right)^{-1}$ lengths [2]. Deep Sea optical properties are functions of

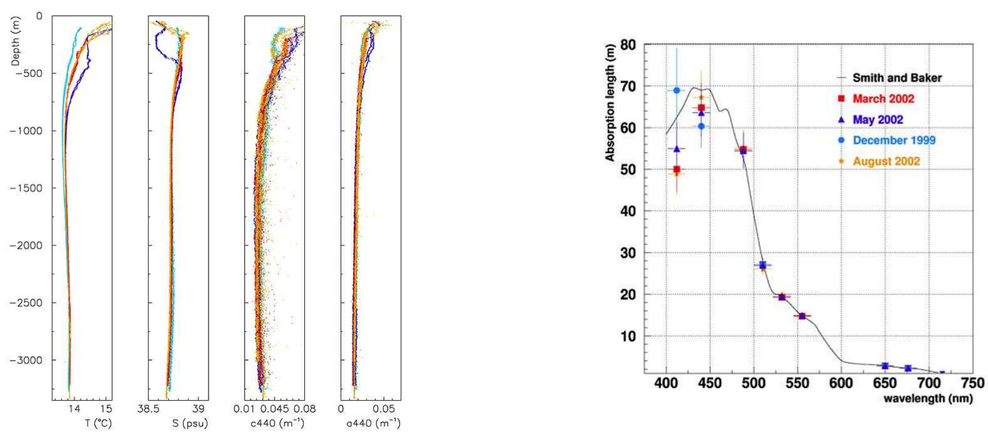

Figure 2. Left: Profiles of temperature (T), salinity (S), attenuation c(440 nm) and absorption a(440 nm) coefficients as a function of depth. Right: absorbtion length from different sea campaigns in different wavelengths. The colour-legenda of the right plot refers to measurements performed in different seasons and applys to both figures.

environmtal parameters such as the water temperature, salinity, depth and particulate. Figure. 2, left, shows, for different periods of the year, the temperature and salinity of sea water at KM4 at different depths, together with the light absorption ($a(\lambda) = \frac{1}{L_a}$) and attenuation ($c(\lambda) = \frac{1}{L_c}$) coefficients. The $a(\lambda)$ and $c(\lambda)$ coefficients were measured indipendentely with the AC9 transmissometer [3], which used two different light paths and spanned the light spectrum over nine different wavelengths, from 412 nm to 715 nm; the coefficients accurancy was of about 1.5×10^{-3} m^{-1}. Significant variations of these parameters were observed in shallow water layers only (less than ∼1000 m). Figure. 2, right, shows, for depths greater than 2500 m, the values of $L_a(\lambda)$ in the wavelength interval of the AC9 (coloured dots). It was measured in several campaigns performed in different seasons. It is evident that KM4 site water is compatibile with pure water (black line [4]). We do not observe significant seasonal variations. The averaged values for L_a and L_c in the blue region (440 nm) resulted to be 66 m and 35 m, respectively.

2.2 Measure of the optical background at KM4 site

The Optical Modules counting rate in an undersea ν detector is strongly affected by two kind of natural causes: the decay of radioactive elements diluited in water and the luminescence produced by biological entities. Main background form natural radioactivity comes form ^{40}K decays. Both its two decaying channels ($^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ca} + e^- + \nu$; $^{40}\mathrm{K} \rightarrow {}^{40}\mathrm{Ar} + \nu + \gamma$) contribute to the production of optical noise. Deep in the KM4 site, such noise was measured repeatedly along the years. In Figure. 3, left, we present the data taken during the last sea campaign in 2004, by using a dedicated "Optical Background"instrumented with a set up of two 8$''$ PMT (the "low noise" EMI 9356KA) plus a current meter. It is perfectly compatible with similar measurements performed in the past and previously reported [5]. Bioluminescence is mainly produced by bacteria emitting

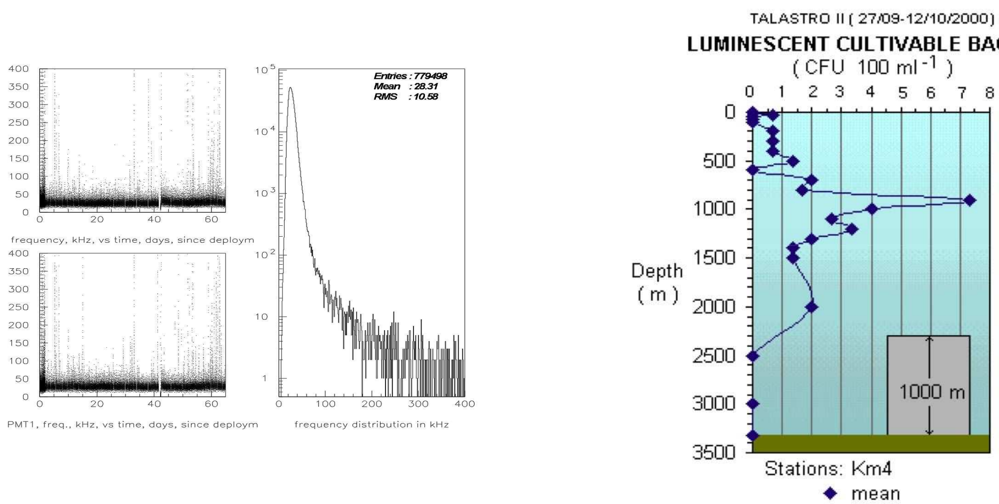

Figure 3. Left: the optical noise rate measured with the PMTs in the "Optical background" mooring. The averaged optical background rate amounts to 28 kHz. Right: Measured content of luminous bacteria (expressed in Colony Forming Units per ml^{-1}) in Capo Passero site as a function of depth. Below 2500 m the content of luminous bacteria is negligible.

light at the level of single photon intensity. Allthough a high level of bacteria concentration can give rise to an optical noise several orders of magnitude more intense than the one due to ^{40}K, beyond a depth of about 2500 m, the biological source of optical noise dramatically disappears, as shown in Figure. 3, right. Thus the biological signal limits itself to rare high rate spikes due to bioluminescence. The measured baseline of optical noise rate for a 8$''$ PMT with a threshold of 0.3 p.e. amounts to of $\sim$ 28 kHz at a depth of 3000 m.

2.3 Other KM4 site characterizations

Current meter chains were moored in the region of Capo Passero since July 1998, to measure the water current intensity and direction in a range of ∼500 m above the seabed. Over more than 7 years of data taking the currents at a depth of about 3000 m appear to be low and regular (2-3 cm/s average; 12 cm/s maximum).
On the same mooring chain, a sediment trap was installed at about 110 m above the seabed and programmed to collect sediment samples over periods of 15 days. The Total Mass Flux (TMF) measured shows a rather constant low particle flux (average 20 mg m^{-2} d^{-1}) in the August to February period, with an enhancement during the March-June period (average 156 mg m^{-2} d^{-1}). They are essentially constituted by faecal pellets and remains of planktonic organisms.
Measurements of biofouling were performed on an independent mooring chain, with an array of photodiodes placed inside a Benthos glass sphere and enlighted by pulsed blue LEDs. A short term measurement (40 days in the period January-February 2000) has been performed. Data measured with photodiodes placed at different zenith angles show no effects of bio fouling on optical surfaces on this time scale. Longer lasting data taking results, from the last campaign in 2004, are currently under analysis.

3. Characterization of the NEMO Test-Site

The NEMO Phase-1 project consits of the construction of a demonstrator experiment for testing all the critical elements of the proposed km^3 detector. It is under realization at the Underwater Test-Site of the Laboratori Nazionali del Sud, 20 km away from the Catania harbour (Sicily), at a depth of 2000 m. The characterization of the Test-Site started in 2002. The absorption $L_a(\lambda)$ and attenuation $L_c(\lambda)$ lenghts were determined by means of the same AC9 transmissometer used in the KM4 site. The measured values for L_a and L_c at 440 nm are 50 m and 36 m, respectively. L_a is lower than the one measured in KM4 site due to the lower Sea depth. Currently, measurements for determining the optical background in the Test-Site are under completion: a new instrumented chain with two 8$''$ PMTs and current meter will be deployed during a further sea campaign in August 2005.

4. Conclusions

Results of Site survey activities performed since 1998 by the NEMO Collaboration suggest that a large region located at ∼ 80 km SE of Capo Passero (Sicily) is excellent for the installation of the km^3 underwater neutrino Telescope. The optical properties of Test-Site for the NEMO Phase-1 project were measured and resulted such to allow the prototyping activity. New measurements for determining the optical background in the Test-Site are under completion.

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