KM3NeT –INFRADEV – H2020 –739560

Report on the rules of access for external users

KM3NeT –INFRADEV GA DELIVERABLE: D8.1

Document identifier	KM3NeT-INFRADEV-WP8-D8.1
Date:	20/11/2019
Work package:	WP8
Lead partner:	INFN
Document status:	Final
Dissemination level:	Public
Document link:	

Abstract

The KM3NeT Research Infrastructure will offer to the Earth and Sea Science community a wide opportunity of using data or accessing the infrastructure to perform deep-sea experiments.
This document presents a survey of these options as well as a first list of interests and requests expressed by scientist of the oceanography, marine geology, acoustics and marine biology communities.

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DELIVERY SLIP

	Name	Partner/WP	Date
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Reviewed by	P. Mijakowski	KM3NeT/Institute Board	27/05/2019
Approved by	PMB		20/11/2019

DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	25/10/2018	Draft	INFN
2	15/12/2018	Includes parts by F. Simeone and S. Viola	INFN
3	30/01/2019	Some corrections and text polishing. Ready to be distributed to PMB.	F. Simeone, S. Viola / INFN
4	28/05/2019	recommendations by reviewer	R. van der Meer/NWO-I
5	07/10/2019	Implemented comments by reviewer	

APPLICATON AREA

This document is a formal deliverable for the GA of the project, applicable to all members of the KM3NeT– INFRADEV project, beneficiaries and third parties, as well as its collaborating projects.

TERMINOLOGY

ANTARES	Astronomy with a Neutrino Telescope and Abyss environmental RESearch (first deep-sea neutrino telescope)
CTD	Conductivity-Temperature-Depth probe
DAQ	Data Acquisition System

DOM	Digital Optical Module
DOMO	Deep Ocean Mooring Observatory
DU	Detection Unit
ESFRI	European Strategy Forum on Research Infrastructures
ESS	Earth and Sea Sciences
EOV	Essential Ocean Variables
GDACS	Global Data Assembly Centres
GOOS	Global Ocean Observing System
IB	Institutional Board (KM3NeT governing body)
IU	Instrumentation Unit
NEMO	Neutrino Mediterranean Observatory (neutrino telescope pilot project)
NESTOR	Neutrino Extended Submarine Telescope with Oceanographic Research Project (neutrino telescope pilot project)
OHC	Ocean Heat Content
PMB	Project Management Board
PMT	Photomultiplier Tube
RI	Research Infrastructure
TNA	Trans-National Access

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PROJECT SUMMARY

KM3NeT is a large Research Infrastructure that will consist of a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for Earth and Sea sciences. Following the appearance of KM3NeT 2.0 on the ESFRI roadmap 2016 and in line with the recommendations of the Assessment Expert Group in 2013, the KM3NeT-INFRADEV project addresses the Coordination and Support Actions (CSA) to prepare a legal entity and appropriate services for KM3NeT, thereby providing a sustainable solution for the operation of the research infrastructure during ten (or more) years. The KM3NeT-INFRADEV is funded by the European Commission's Horizon 2020 framework and its objectives comprise, amongst others, the preparation of services to provide access of users external to the astroparticle physics community to the RI (work package 8).

EXECUTIVE SUMMARY

The KM3NeT RI will be a distributed infrastructure with deep-sea instrumentation east of the Sicilian Coast (Italy), south of Toulon (France) and off the South-West coast of Peloponnese (Greece). It will not only host the latest generation of deep-sea neutrino detectors in the Mediterranean Sea but will also be a platform for research in Earth and Sea Sciences.

The present document describes the way of accessing KM3NeT resources of interest for the Earth and Sea Science community. In particular we focus on the access to environmental data that are recorded by the neutrino telescope mostly for calibration purposes and to the access to user ports, both on-shore and off-shore.

The content of this report is mostly based on the outcome of a first workshop that brought together representative of the KM3NeT RI and of the Earth and Sea Science (ESS) community. Aspects related to oceanography, geophysics, marine acoustics and marine biology were explored.

For what concerns the neutrino telescope data, it was concluded that an appropriate selection of these calibration data, in particular those from the acoustic sensors, and of the optical data recorded by the KM3NeT photomultipliers is of relevant interest for the ESS community.

These data will be made publicly available. The policy and modalities of this data distribution, such as the time frame over which the average rates are computed or the frequency of the average rates provided, will be defined according to specific requests of external users. These modalities will be the subject of further studies by work package 8 in synergy with work package 4.

Deep ocean monitoring is a challenge for the scientific community, given the multi-scale processes and their multi-disciplinary nature. Data time series are important for understanding and predicting ocean variability as well as geological, geodetic, and seismological processes. Such time series can be measured from moored multi-disciplinary observatories at very high frequency, i.e. seconds. The Mediterranean Sea is a logistically convenient site for such a monitoring, given the vicinity of the open, deep ocean to the coasts. In particular, the KM3NeT infrastructure offers the opportunity to develop a deep-ocean monitoring site, providing long multi-disciplinary data time series with a high

data sampling frequency, thus allowing to adequately resolve the temporal behaviour of all those crucial variables that allow the understanding of oceanographic, climate and geological processes.

The use of the KM3NeT infrastructure for underwater acoustic research is also of high interest. It can be anticipated that the KM3NeT infrastructure will provide valuable data for a number of acoustic research activities, including, among others, bioacoustics, acoustic noise monitoring and detection of acoustic anomalies. Many of these studies can also be used for outreach and educational purposes. These possibilities will be explored in synergy with work package 3.

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1. Introduction

KM3NeT, the large Research Infrastructure (RI) that will host the latest generation of deep-sea neutrino detectors in the Mediterranean Sea, will open a new window on our Universe, but also advance the research on the properties of neutrinos. KM3NeT will be a distributed infrastructure with deep-sea instrumentation east of the Sicilian Coast (Italy), south of Toulon (France) and off the South-West coast of Peloponnese (Greece). The main science objectives, a description of the technology and a summary of the costs are presented in the KM3NeT 2.0 Letter of Intent [1].

The present document describes the way of accessing KM3NeT resources. For simplicity these are divided in three main branches:

- Access to recorded data
- Access to User Ports (on-shore and off-shore)
- Symbiotic access to infrastructure and sea operations vessels

For all the three, modalities of access will be defined in the framework of the KM3NeT legal entity. The KM3NeT collaboration foresees:

- Open access to a sample of calibrated and certified data
- Access with restrictions to real-time or pre-analysed data (MoU)
- Access with restrictions to underwater and on-shore User Ports (MoU)
- Access with restrictions for symbioitic use of infrastructure and sea operation vessels (MoU)
- Full Access for the Collaboration Members

[1] *Letter of Intent for KM3NeT 2.0.* **Adrián-Martínez, S., et al.** 2016, Journal of Physics G: Nuclear and Particle Physics, Vol. 43 (8), p. 084001. arXiv:1601.07459 [astro-ph.IM]. DOI: 10.1088/0954-3899/43/8/084001

2. Methodology

As a first step, it was recognized as crucial to hold a survey of possible options to provide public data as well as to identify the interests and requirements from the Earth and Sea Science (ESS) community.

It was agreed that the most suitable option was the organization of a dedicated workshop with the aim at bringing together KM3NeT and representatives of the ESS community. This workshop, denoted as "Earth and Sea Science with KM3NeT" was held in Athens on 4-6 December 2017 (https://indico.cern.ch/event/676718/). For a proper organization of this workshop, a committee of experts from KM3NeT was set up. This committee was consisted of: V. Bertin (CNRS), A. Margiotta (INFN), C. Markou (NCSR-D), G. Riccobene (INFN). This committee identified three major areas of interest shared between KM3NeT and the ESS community:

- Marine acoustics
- Oceanography and geophysics
- Marine biology and marine litter

Three experts, external from KM3NeT, have been invited to join the committee, help preparing the workshop and help identifying the research topics that could be pursued at the KM3NeT RI. They are: W. Zimmer (CMRE-NATO, La Spezia) for marine acoustics; F. Falcini (INGV, Roma) for oceanography and geophysics; N. Bellou (HCMR, Athens) for marine biology and marine litter.

It should be noted that, although being a successful event with more than 50 participants and a large number of presentations, the workshop did not provide clear indications on the preferred options on how to provide potential users with data or services. In particular, it has to be noted that the definition of the modalities of access to the underwater infrastructure to install additional instrumentation strongly depends on the choices that will be made on the structure and rules of the KM3NeT ERIC consortium, which are being elaborated within WP2 of the KM3NeT-INFRADEV project.

However, a significant number of informal expression of interest has been put forward. Further workshops of the same kind are therefore needed and will be organized.

3. Survey of option of access to recorded data

The KM3NeT detector offers a plethora of data recorded by the sensors of the telescope, for the sake of neutrino astronomy studies and for the ESS community.

Among them, of particular interest are considered:

- Data from photon sensors (photomultiplier tubes);
- Data from acoustic sensors (hydrophones and piezo sensors);
- Data from compasses;
- Data from oceanographic sensors;

- Data from acoustic sensors.

In the following of this section a brief description of these items is given.

Data from photon sensors

The basic detection unit of the KM3NeT neutrino telescope is the Digital Optical Module (DOM). Each DOM comprises 31x 3'' photomultiplier tubes (PMTs) enclosed inside a pressure resistant 17-inch glass sphere. The PMTs are being read separately by a front-end electronics capable to send to shore time and amplitude information on detected light signals (400-700 nm). The components of the DOM are shown in Fig. 1.

The so-called optical data stream contains mainly information on photon background produced by radioactive elements decay (^{40}K) and bioluminescence. Previous experience with the ANTARES neutrino telescope in France and with the NEMO pilot experiment in Italy has shown that this data can be of valuable interest for biologist as they can provide information of bioluminescent activity. Some results on the use of neutrino telescope data for bioluminescence studies are available in literature [2,3].

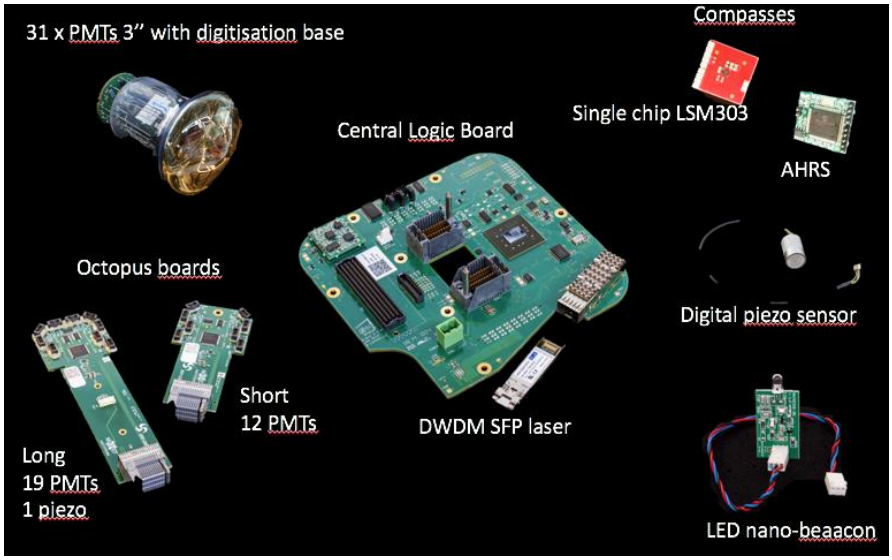

Figure 1: Exploded view of DOM components: sensors and front-end electronics.

[2] C. Tamburini et al., Deep-Sea bioluminescence blooms after dense water formation at the ocean surface, PLOS ONE 8 (2013) e67523

[3] J. Aguzzi et al., Inertial bioluminescence rhytms at the Capo Passero (KM3NeT-Italia) site, Central Mediterranean Sea, Scientific Reports 7 (2017) 44938

The Data Acquisition System (DAQ) system, installed on-shore, records:

- Events, which are approximately 100 µs long dump of data from all PMTs, when a default coincidence trigger, i.e. a coincidence of 2 Photons in 1 DOM in a 25 ns time window, is present;
- The instantaneous PMT photon hit rate, as an average over 100 ms.

Data are saved in the collaboration database.

Instantaneous rates from each PMT can be averaged at different time resolutions, depending on specific requirements by users. A daily average can also be provided.

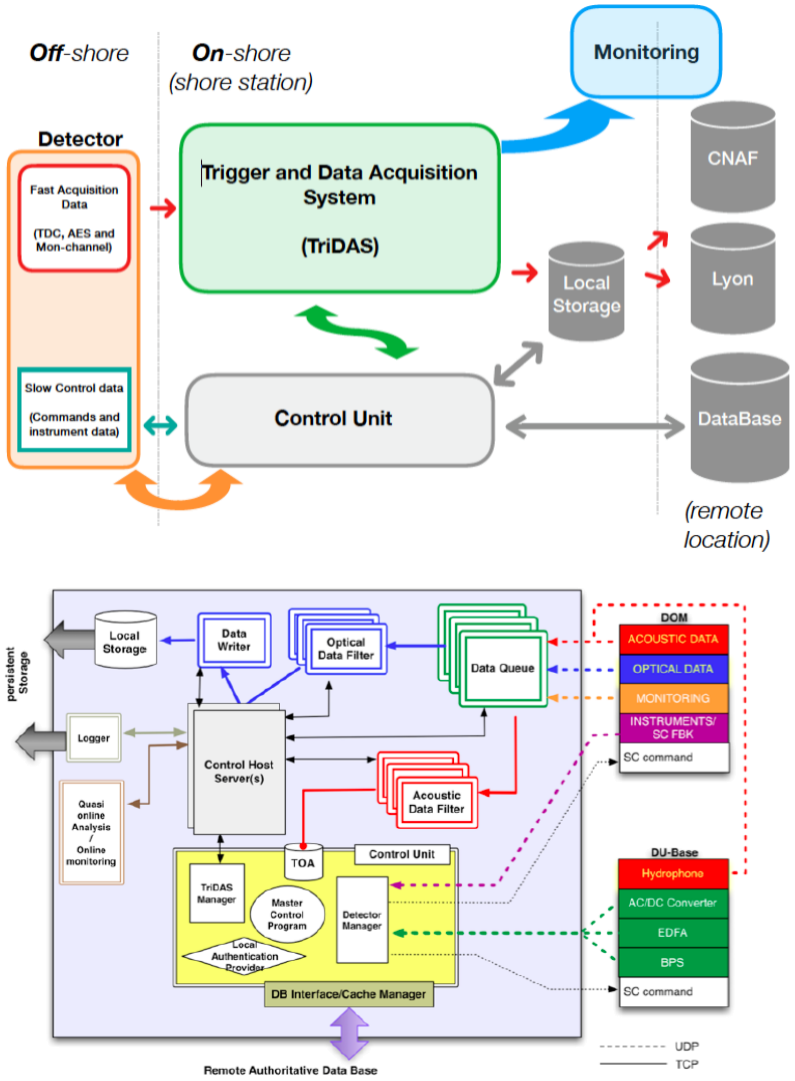

Figure 2 : The DAQ configuration of the KM3NeT Detector.

Event data, which contain information relevant for the neutrino detection, can be made available according to the policies defined within WP4 of the KM3NeT-INFRADEV project.

Average optical rates, can be publicly distributed according to the request of the ESS community. Modalities of this data distribution, such as the time frame over which the average rate is computed or the frequency of average rates provided, can be adjusted according to specific requests of external users. These modalities will be the subject of further studies by work package 8.

Compass data

A compass is installed in each DOM as part of the positioning and orientation system of the detector. Raw data from compasses (3 axial accelerometers and magnetometers) are continuously recorded in the KM3NeT collaboration database at a rate of 0.1 Hz.

Software tools developed by the collaboration permit the calibration and fast analysis of the data, retrieving for each DOM, yaw, pitch and roll. These data are instrumental to provide the precise positioning and orientation of each KM3NeT DOM and are therefore crucial for the correct reconstruction of particle tracks.

These data can be provided as a tool to infer the intensity and direction of deep-sea currents.

Oceanographic data

KM3NeT will soon incorporate special mooring lines dedicated to monitoring of oceanographic parameters of the water column. The so-called instrumentation unit (IU) hosts standard oceanographic probes such as CTDs, Sound Velocimeters and current metres.

Collected data will be averaged underwater and sent to shore every 20 min approximately, following the standard recording strategy of oceanographic mooring lines.

Oceanographic data will be recorded in the collaboration database.

Acoustic data

The telescope is also equipped with acoustic sensors: 1 piezo-electric ceramic sensor is installed in each DOM, 1 hydrophone on each DU base and on the junction boxes of the seafloor network. Main purpose of these sensors is to provide real time positioning of each DOM with cm accuracy.

The sensors are piloted by the detector master clock forming a synchronous antenna. Data are sampled in situ at 24 bits, 195 kHz and the full stream is transmitted to shore.

The hydrophone sensitivity (ominidirectional) is about -173 dB re 1V/uPa over the frequency band between few tens Hz and 70 kHz, that makes this sensor also suitable for interdisciplinary studies. The sensitivity of the each piezo cannot be easily derived since it strongly depends on the coupling with glass under pressure. An average value of -170 dB re 1V/uPa at 30 kHz can be fairly assumed in the band 20-40 kHz.

The default KM3NeT DAQ has been designed to identify only the (known) acoustic signals emitted by a long baseline of acoustic sensors among the full data stream (Figure 2).

A further implementation of the DAQ is foreseen in KM3NeT 2.0, permitting on-line analysis, display and recording of the underwater noise spectrum through a dedicated channel.

Spectra will be averaged at selectable time resolution through a custom application.

A daily average can be provided as open access data.

4. Oceanography

Deep ocean monitoring is a challenge for the scientific community, given the multi-scale processes and their multi-disciplinary nature. Interdisciplinary time series are important for understanding and predicting ocean variability as well as geological, geodetic, and seismological processes. Such time series can be measured from moored multi-disciplinary observatories at very high frequency, i.e. seconds.

The Mediterranean Sea is a logistically convenient site for such a monitoring, given the vicinity of the open, deep ocean to the coasts. In particular, the KM3NeT infrastructure offers the opportunity to develop a long, multi-disciplinary time series deep-ocean monitoring site, where the data acquisition frequency is very high, thus allowing to adequately resolve the temporal frequency of all those crucial variables that allow the understanding of oceanographic, climate and geological processes.

From an oceanographic perspective, the Ionian Sea and, in general, deep sites, are indeed critical locations for ocean monitoring because deep waters formed in the shallower seas, arrive here and mix with other water masses, activating the main meridional overturning circulation of the Mediterranean.

For marine geology, deep basins in the Mediterranean represent areas where very complex and not yet fully understood geodynamic processes take place. Geophysical monitoring at depth is therefore crucial for the understanding of seismicity and margin evolution, as well as for improving hazard assessment for the coasts, in both near- and far-field, and detection capability in an early warning perspective.

Investigations in Physical Oceanography

The heat contained in the ocean (OHC = ocean heat content) represents a fundamental parameter for understanding climate changes. However, paucity of observational data hampers our knowledge on OHC variability, particularly in abyssal areas. Investigations in this field should analyse water characteristics in the abyssal layers of the Mediterranean Sea. In particular, in the Ionian Sea OHC accumulation stems from progressive warming and salinification of the Eastern Mediterranean, producing warmer near-bottom waters. Deep ocean observations, in such a context, are therefore crucial for the understanding of those processes that involve convectively-generated waters reaching the abyss as well as the triggering of a diapycnal mixing due to rough bathymetry, which brings to a warming and thickening of the bottom layer, also influencing water-column potential vorticity.

Non-steady behaviours of the deep Mediterranean thermohaline circulation revealed, indeed, convective and mixing dynamics that need to be properly observed and understood. The meridional overturning circulation of the Eastern Mediterranean might be characterized by multiple equilibria states that are controlled by atmospheric forcing. The Ionian abyssal layer (from 3000 to 4000 m depth) is indeed undergoing a warming and salinification phase, likely associated with an active Mediterranean overturning circulation state. An interplay between advection and mixing processes may be therefore at the base of the anomalous heat storage. Moreover, the ecosystem structure is similar to the one of the Atlantic subtropical gyre with phosphorous limitation and small phytoplankton primary producers, including iron fertilization by Saharan dust events.

Investigations in Marine Geology

The KM3NeT monitoring system represents a unique opportunity for geophysical research: KM3NeT-IT is close to the southern termination of the Hyblean-Malta escarpment and to the shallower part of the Calabrian Arc and subduction zone; KM3NeT-GR is in correspondence with one of the sectors of the largest active subduction zone in the Mediterranean, the western Hellenic arc. Large-magnitude earthquakes were generated in the past in both regions, some of which were tsunamigenic. They caused severe death toll and damage along the nearby eastern Sicily coasts. Sources of geophysical hazard are indeed earthquakes, submarine landslides/turbidity currents, and tsunamis. In particular, Eastern Sicily is affected by earthquakes and tsunamis of local and remote origin. Recent studies have put emphasis on the role of submarine landslides as the direct cause of the main local tsunamis, envisaging that earthquakes did produce a tsunami, but also that they triggered mass failures that were able to generate an even larger tsunami. Moreover, the faults that generated such earthquakes are not yet known as it is unknown whether the associated tsunamis were generated directly by earthquakes or indirectly by seismically-triggered undersea slides. The lack of an adequate network of seismic stations at the bottom of the Ionian Sea and of a continuous acquisition of geophysical and geochemical parameters on the medium and long terms prevents the full understanding of the tectonic, seismological, and geomorphological phenomena of the western Ionian Sea.

Future prospects for monitoring activities

Physical Oceanography

Ocean is a complex system and, therefore, there is a need to avoid duplication of efforts, across observing platforms and networks, and to adopt common standards for data collection and dissemination to maximize the utility of data. To address these concerns, ocean observations are focusing on Essential Ocean Variables (EOV), ensuring assessments that cut across platforms and recommend the best, most cost effective plan to provide an optimal global view for each EOV.

Essential Ocean Variables are identified by the GOOS Expert Panels (http://goosocean.org/index.php?option=com_content&view=article&id=14&Itemid=114) by means of a series of recommendations, including what measurements are to be made, various observing options, and data management practices.

Table 1: List of the GOOS EOVs (from http://goosocean.org)

PHYSICS	BIOGEOCHEMISTRY	BIOLOGY AND ECOSYSTEMS
Sea state	Oxygen	Phytoplankton biomass and diversity
Ocean surface stress	Nutrients	Zooplankton biomass and diversity
Sea ice	Inorganic carbon	Fish abundance and distribution
Sea surface height	Transient tracers	Marine turtles, birds, mammals abundance and distribution
Sea surface temperature	Particulate matter	Hard coral cover and composition
Subsurface temperature	Nitrous oxide	Seagrass cover
Surface currents	Stable carbon isotopes	Macroalgal canopy cover
Subsurface currents	Dissolved organic carbon	Mangrove cover
Sea surface salinity	Ocean colour *(Spec Sheet under development)*	Ocean Sound
Subsurface salinity		Microbe biomass and diversity (*emerging)
Ocean surface heat flux		Benthic invertebrate abundance and distribution (*emerging)

An innovative Deep Ocean Mooring Observatory (DOMO) should be equipped with:

1. air-sea interaction measurements such as surface radiation, air temperature, winds, air humidity, waves, dust recording, CO2 fluxes.
2. water column CTD, nutrients, POC, DOM, chlorophyll and radiation sensors;
3. Sediment traps;
4. Acoustic sensors for animal tracking;
5. Imaging cameras;
6. Deep sea bottom sensors for temperature, salinity, biochemistry and pressure.

All these sensors should acquire data at the same time and at very high temporal resolution, i.e. few tens of seconds. DOMO will increase our understanding of:

a) the coupling between atmosphere and ocean and the flux of chemicals through the air-sea interface;
b) the coupled ocean and biogeochemical dynamics at the finest time and vertical space scales;
c) the bottom pressure
d) the sediment flux composition and the sedimentation rates.

KM3NeT Deep Ocean Monitoring Observatory should:

1) provide sustained in-situ observations at a fixed open-ocean geographic location (typical record length of at least 5 years)
2) sample frequently enough to resolve tidal and diurnal frequency variability;
3) transmit in real time with telemetry to Copernicus marine Environment Monitoring System and GDACS (Global Data Assembly Centers)

Marine Geology

Particular focus for deep-site monitoring activity is on seismicity and slope stability/margin dynamics. This can be accomplished with the aid of:

1. three-component seismometers
2. seafloor geodesy instruments (acoustic transponders)
3. inclinometers/extensometers.

In addition to the instrumentation pertaining to pure oceanography, KM3NeT Deep Ocean Monitoring Observatory (DOMO) should have a network of sea bottom pressure sensors to track currents and sediment transport patterns, and to detect possible "exceptional" events, such as tsunamis and turbidity currents. In particular, one or more pressure sensors installed on the seafloor around the KM3NeT-IT installation would detect the tsunami arrivals, close to the source in a very short time (less than 4 minutes), likely not enough to alert the coasts in the near-field (eastern Sicily), but early enough to alert the western Greek coasts, where the waves would be detected by the KM3NeT-GR sensors 45-50 minutes after the tsunami onset. On the other hand, One or more pressure sensors installed on the seafloor around the KM3NeT-GR installation would detect the coseismic displacement and the subsequent tsunami evolution in time in the source area. This would represent a first piece of information to issue an alert also for distant coasts, such as eastern Sicily, where the tsunami waves would arrive after being detected by the KM3NeT-IT instruments

Moreover, the acquisition of seismic reflective multi-channel data and gravity cores taken from the seabed together with the contribution of a new permanent monitoring station allowed at least the definition of a new tectonic framework of the Ionian Sea. Faults that may have generated one or more destructive earthquakes and tsunamis have been recently identified and mapped. KM3NeT should, in such a context, provide some help in:

1. monitoring these faults and determine whether they are seismically-active;
2. monitoring possible precursory events, such as degassing processes and/or fluid venting from structures such as mud volcanoes;
3. establishing whether gravitational movements (e.g. landslides) along the Sicilian-Calabrian margins can be triggered by earthquake events of low magnitudes.

Finally, applications on natural hazard, for real time monitoring in difficult environment (such as far offshore, deep borehole, sea mountains/volcanoes), optical interferometry for measuring displacement as well as optical lines equipped with seismometers, borehole tiltmeter, long base hydrostatic tiltmeter would be useful.

5. Acoustics

Previous work

The interdisciplinary usage of acoustic sensors of different deep-sea neutrino telescopes has a long history. For example, in an 2009 article in Nature, Nicola Nosengo reports on a partnership between marine biologists and particle physicists [4], where an underwater effort to detect neutrinos has ended up detecting Sperm whales instead.

An overview on the use of a deep-sea neutrino telescope as abyssal cabled observatory was presented some time ago[5]. This presentation covers important interdisciplinary aspects, from geophysics with special focus on geo-hazards, physical oceanography, marine biology, and astroparticle physics. An important aspect is the capability for unique long-term, real-time, high-sampling rate multi-parametric monitoring in the Mediterranean Sea, thus representing an important step for future Mediterranean protection, development and conservation.

Another more specific example evidence has more recently been presented [6] on how the KM3NeT infrastructure may be used for passive acoustic monitoring of cetaceans and therefore may contribute to the protection of whales and dolphins.

Underwater acoustics is closely related to underwater noise, a subject that is of general public concern. Consequently, the use of KM3NeT infrastructure for long-term monitoring underwater noise is an important activity and is covered by an interdisciplinary project (https://www.researchgate.net/project/Monitoring-underwater-noise-for-the-implementation-of-the-EU-Marine-Strategy).

Opportunities for KM3NeT

During the ESS-KM3NeT workshop in Athens, 2017, the following more recent acoustic research papers were presented and discussed:

- Michel André, et al., 2017, Sperm whale long-range echolocation sounds revealed by ANTARES, a deep-sea neutrino telescope, Sci. Rep. 7, 45517; doi: 10.1038/srep45517.
- Francesco Caruso, et al., 2015, Size Distribution of Sperm Whales Acoustically Identified during Long Term Deep-Sea Monitoring in the Ionian Sea, PLOS ONE | DOI:10.1371

[4] Gianni Pavan and Giorgio Riccobene

[5] Paolo Favali, et al.,2013, NEMO-SN1 Abyssal Cabled Observatory in the Western Ionian Sea, IEEE Journal of Oceanic Engineering, DOI: 10.1109/JOE.2012.2224536.

[6] Gianni Pavan, et al. 2014. MONITORAGGIO DEL RUMORE SUBACQUEO PER LA PROTEZIONE DEI CETACEI. Associazione Italiana di Acustica,41° Convegno Nazionale, Pisa, 17-19 giugno 2014

- Virginia Sciacca, et al., 2015, Annual Acoustic Presence of Fin Whale (Balaenoptera physalus) Offshore Eastern, Sicily, Central Mediterranean Sea, PLoS ONE 10(11): e0141838
- Francesco Caruso, et al., 2017, Long-Term Monitoring of Dolphin Biosonar Activity in Deep Pelagic Waters of the Mediterranean Sea, Science Report 7: 4321
- Virginia Sciacca, et al., 2017, Shipping noise and seismic airgun surveys in the Ionian Sea: Potential impact on Mediterranean Fin whale, Proceedings of Meetings on Acoustics, Vol. 27, 040010
- S. Viola, et al., 2017, Continuous monitoring of noise levels in the Gulf of Catania (Ionian Sea). Study of correlation with ship traffic, Marine Pollution Bulletin, http://dx.doi.org/10.1016/j.marpolbul.2017.05.040

These research work was based on data that were recorded by both deep-sea neutrino telescopes (ANTARES and NEMO) using mainly the state-of-the-art hydrophones that are characterized by 192 kHz sampling rate, 24 bits data word and sigma delta ADC technology. These hydrophones are very much suitable for underwater acoustic research.

The presentations cover mostly bio-acoustic research, detecting and tracking cetaceans that were found at the two deep sea locations. Therefore, the KM3NeT acoustic data have been proven suitable for bio-diversity research and conservation.

The so-far presented research work is only a taste of what is possible with the KM3NeT acoustic data, especially if combined with other in-situ obtained data (e.g. optical) or in connection to other information (e.g. surface ship AIS data).

While most research, especially early academic work, may rely on archived acoustic data, ongoing monitoring a conservation activities desire real-time access of raw KM3NeT data. While this requirement is technically not demanding, it requires specific management actions protecting the KM3NeT intellectual property.

The use of the KM3NeT infrastructure for underwater acoustic research is of high interest and it can be anticipated that the KM3NeT infrastructure provides valuable data for the following acoustic research activities:

Bio acoustic application

- Cetacean presence and behavioral monitoring
    - Sperm whales
    - Fin whale
    - Beaked whales
    - Dolphins
- Habitat characterization
    - Active (prey field mapping)
    - Passive (soundscape assessment)

Other acoustic application

- Noise monitoring
  - MSFD support (noise register)
  - Correlation noise ship traffic (AIS)
  - Sonar
  - Air guns (seismic exploration)
  - Hazard assessment for environmental risk mitigation
- Acoustic anomaly detection
  - Explosions
  - Earthquakes

Interdisciplinary use: acoustic for ocean science

- Environmental inversion (using sound propagation)
  - Water column characterization
    - Physical
    - Chemical
  - Atmospheric driven sound
    - Wind
    - Rain
    - Lightning and thunder

Other use

- Scientific education
- Public outreach

6. Marine biology and marine litter

The Scope of the "Marine Biology and Marine Litter" session held at the first KM3NeT-ESS workshop was to present the current knowledge on Marine Biology and Marine Litter related to KM3NeT study site and the deep-sea environment, with scope to define gaps in information needed by KM3NeT Scientists in the research areas of "Marine Environmental Science", as well as to define areas of scientific investigation that KM3NeT could support.

Key scientists were invited to present their results (Table 1) and participated in the workshop either with physical presence or via multimedia). The Abstracts of the presentations are presented in the following.

The topics related to deep sea studies performed in the Mediterranean Sea included macro faunal (fishes), Benthic Fauna (diversity), Larvae (diversity), Microbes (Bacteria & Archaea) (biolumiscence and biofilms), Sedimentation (Organic Carbon, Nitrogen, Carbonates, bio-Si, Lithogenic Matter, Zooplankton (e.g. fecal pellets), etc.) and Litter (Macro and Micro-litter). The geographical

implementation of these studies in the Mediterranean Sea is presented in Figure 3, where a clear imbalance between West, Central and East Mediterranean was observed. The methodologies to investigate these topics included video observations, field experiments, monitoring and data collection of already published articles.

The following key questions should be answered before and during future meetings:

- Which other experts will be involved?
- What are the cross-sections with other disciplines?
- Which questions would we like to answer?
- What is the timeframe for the next steps?
- What data would be needed?
- How can we integrate all different disciplines to achieve a standardized sampling, monitor etc. procedure?

The key areas of investigations that were defined were:

- The use of ROV footage for monitoring the abundance and/or impact of macro litter and characterization of macro and megafauna
- Experimental field studies for larvae, biofilms and biofouling (characterization via various methods)
- Sediment traps estimating organic carbon and ballast minerals fluxes. Calculations of the exported production out of the euphotic zone to the mesopelagic and bathypelagic zones.

It was underlined that an open call to Earth and Sea Science researchers to use the KM3NeT structure should ensure and include funding from KM3NeT to implement the research. By this means KM3NeT could play an important role in bringing together key scientists from the West, Central and Eastern Mediterranean. Trans-National Access (TNA) projects scheme from Jerico-NEXT and EMSO-ERIC could be of inspiration, while the open KM3NeT calls should include funding, both in terms of travels as well contribution towards sample analyses.

Table 2: Agenda of the marine biology and marine litter session

Topic / Title	Presenter	Institute
Welcome & Adoption of Agenda by Chair	Nikoleta BELLOU	HCMR
Bathyal and Abyssal demersal scavenging fauna around KM3NeT sites in the Eastern	Monty PRIEDE	ABDN
Seasonal and interannual variability of sinking particulate matter in the deep Ionian	Aleka GOGOU	HCMR
Bioluminescence rhythms at the Central Mediterranean KM3NeT deep-sea neutrino	Jacopo AGUZZI	ICM CSIC
Looking out for deep-sea connectivity in open ocean observatories	Luciana GENIO	UA
The potential influence of fouling on deep sea structures	Nikoleta BELLOU	HCMR
Discussion		

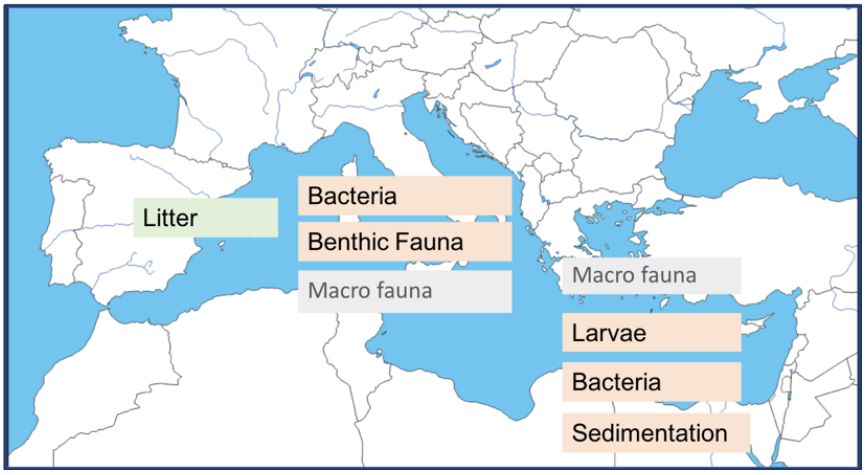

Figure 3 : Geographical implementation of research related to KM3NeT in the Mediterranean Sea.

Abstracts of presentations given at the KM3NeT-ESS workshop

Bathyal and Abyssal demersal scavenging fauna around KM3NeT sites

in the Eastern Mediterranean Sea.

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Abstract

Baited cameras deployed over a depth range of 532-5111 m in the vicinity of the KM3NeT sites in the Ionian Sea attracted a combined total of 10 different species of deep-sea fishes, *Polyprion americanus* and *Dipturus oxyrinchus* (532 m depth), *Helicolenus dactylopterus dactylopterus* (532-737 m), *Centrophorus granulosus* (532-943 m), *Conger conger* (737 m), *Hexanchus griseus* and *Helicolenus dactylopterus* (1346 m), *Lepidion lepidion* (1346-1841 m), *Etmopterus spinax* (1841 m) and *Coryphaenoides mediterraneus* (3400-5111 m). The record of C. *mediterraneus* at 5111 m depth at the Calypso deep off Pylos is a new maximum depth for this species and establishes that fish inhabit the deepest point in the Mediterranean Sea. Three species of crustacea were observed: the shrimps, *Aristeus antennatus* (532-737 m) and *Acanthephyra eximia* (1346-5111 m) and the crab *Chaceon mediterraneus* (1841 m). Arrival time (tarr; min) of the first fish increased exponentially with depth; Y = 0.784 + X * 0.000254, where Y is the Log10 transformed tarr and X is the depth (m), indicating a decrease in bait attending fish density of ~70% of per 1000 m of depth down to 12 fish.km 2 at depths over 5000 m. Bait attending deep-sea fish abundance was estimated as ~9% of the global ocean average at equivalent depth. It is concluded that life at great depths in the Ionian Sea is sparse but nevertheless not absent with specialist active species present at all depths. The KM3NeT infrastructures will be valuable for long term monitoring of these species.

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Seasonal and interannual variability of sinking particulate matter in the deep Ionian Sea: ecological and biogeochemical perspectives

Alexandra Gogou[1] , S. Stavrakakis[1], V. Lykousis[1], E. Krasakopoulou[1], A. P. Karageorgis[1], M. Triantaphyllou[2], K.S. Parinos[1], M. Dimiza[2], F. Paraschos[1], E. Skampa[2], H. Kontoyiannis[1], G. Rousakis[1], D. Velaoras[1], G. Kambouri[1], I. Stavrakaki[1]

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Abstract

Sinking particulate matter is the major vehicle for exporting carbon from the sea surface to the ocean's interior. During its transit towards the seafloor, most particulate organic carbon (POC) is returned to inorganic form and redistributed in the water column. This redistribution determines the surface concentration of dissolved CO2, and hence the rate at which the ocean can absorb CO2 from the atmosphere. The ability to predict quantitatively the depth profile of remineralization is therefore critical to deciphering the response of the global carbon cycle to natural and human-induced environmental changes.
Biotic and abiotic processes that form, alter, transport, and remineralize particulate organic carbon, silicon, calcium carbonate, and other minor and trace chemical species in the water column are central to the ocean's ecological and biogeochemical functioning and are of fundamental importance to the ocean carbon cycle. Our overall goal in this study is to develop a comprehensive description of carbon fluxes and associated mineral ballast fluxes throughout the water column in the deep Ionian Sea, northeastern Mediterranean.
A mooring line of five sediment traps was deployed from 2006 to 2012 at 5 successive water column depths (700, 1200, 2000, 3200 and 4300 m) in the SE Ionian Sea, where the deepest part of the Mediterranean Sea is located ('NESTOR' site). Aiming to investigate the significant ecological and biogeochemical features and provide new insights on the sources and cycles of sinking particulate matter in the open Ionian Sea, we have examined long-term records of downward fluxes for Corg, Ntot, δ13Corg and δ15Ntot, along with the associated ballast minerals (opal, lithogenics and CaCO3), selected lipid biomarkers and coccolithophores. Our ultimate goal is to identify the mechanisms governing particle transport in the study area, and to explain (i) the seasonal, and (ii) the interannual variation of mass and main constituent fluxes, in relation to oceanographic conditions, regional and large scale circulation patterns and climate variability.

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Bioluminescence rhythms at the Central Mediterranean KM3NeT deep-sea neutrino telescope

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Abstract

In the deep sea, cyclic water flow changes modulate the behavior and physiology of deep-sea organisms replacing day-night fluctuations as the main control of biological rhythms. The deep KM3NeT-Italy Neutrino Telescope (off Capo Passero, Sicily) instrumented with light detecting Photo-Multipliers Tubes (PMT) represents an appropriate site to describe the synchronization of bioluminescent activity of poorly known abyssopelagic organisms with hydrodynamic cycles above and close to the seabed. We used PMT readings of a prototype tower detector composed of 8 floors (at 3349, 3309, 3269, 3229, 3189, 3149, 3109, and 3069 m depth), to characterize the occurrence of any rhythmic bioluminescence pattern in June 2013. We also aimed to describe deep-sea mesoscale flow fields via these bioluminescence rhythms in response to depth-oriented water mass movements (using the orientation and rate of displacement of the detector arms as a proxy for current flow). We detected a significant 20.5 h periodicity in the bioluminescence signal, corresponding to inertial fluctuations. Waveform analysis, PMT and water flow data showed a phase overlap between rhythms and cycles suggesting a mechanical stimulation of bioluminescence (with defensive emission of light) as organisms carried by currents collide with the telescope infrastructure. A bathymetric shift in PMT phases indicated that drifted organisms travelled in discontinuous deep-sea undular vortices consisting of chains of inertially pulsating mesoscale cyclones/anticyclones. Considering such promising results, future analyses will focus on shading light on bioluminescence phenomena, specifically: 1) the matching of bioluminescence signals with faunal data extracted from ROV filming (at tower maintenance) and nearby CREEP-2 cameras outputs, seeking for putative emitting species; 2) the comparison of bioluminescence tracking performance between the old and the new PMT line, by

assessing time series analysis parameters in obtained time-series; and finally, 3) the assessment of benthopelagic coupling processes on deep-sea productivity via seasonal variations in bioluminescence rate according to oxygen, temperature and primary productivity (by remote sensing).

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Other info: https://www.nature.com/articles/srep44938

Looking out for deep-sea connectivity in open ocean observatories

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Abstract

Sustainable management of deep-sea resource exploitation requests improved knowledge on population connectivity to advance the understanding of source-sink dynamics in deep pelagic and benthic ecosystems. With the LO3CAted project, we aimed to investigate spatial and temporal patterns of larval assemblages and settlement across geographic and bathymetric gradients in the Atlantic ocean and Mediterranean Sea.
A new modular device that consists of a colonization frame hosting biogenic substrates attached to passive larval tube traps was deployed at bathyal and abyssal water depths using fixed-point open observatories (PAP, ESTOC, CVOO and PYLOS). Samples were retrieved in spring and fall of 2017 resulting in deployment periods between 6 and 12 months.
An initial examination of samples revealed little degradation of organic substrates and metazoan colonizers were not visually detected. Further laboratory analyses with light and scanning electron microscopy, as well as molecular tools are being used to taxonomically identify trapped larvae and characterize microbial biofilms.
Current marine policy that mandates integrated ecosystem assessments demands temporally intensive and spatially extensive predictions of key populations and ecosystem processes and services, particularly those related to habitat use and distribution. The KM3NeT infrastructure could offer an opportunity to complement long-term water column observations of larval dispersal and setllement processes with seafloor installations, expanding the geographic coverage in the Mediterranean sea.
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The potential influence of fouling on deep sea structures

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Abstract

The colonization of surfaces and biofilm formation of microbial communities has been widely investigated in coastal marine systems while in the deep open sea only one in situ study has reported the presence of biofilm on artificial substrate and characterized the bacterial composition applying a fingerprinting method. Due to the increasing number of deployments of oceanographic instrument in the deep sea, there is increasing interest into biofilm formation in deep-sea environments and on the microbial community composition in these biofilm.

To characterize the bacterial communities in deep-sea biofilms developing on oceanographic instruments, which were deployed at the deepest point of the Mediterranean Sea, the Hellenic Trench, at 4500m depth for 155 d (October 2007 May to 2008) pyrosequencing was use. Samples were taken from the surface of OCEANO deep-sea acoustic releaser (Aluminum Alloy -Hard Anodized/+Epoxy Paint, Aluminum – 50µm hard eloxadize), the basic biofilm sampling platform, the connection rod of the platform (stainless steel) and from the Neutrino telescope glass.

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