Oceanographic signals at the Benthic Boundary Layer in the Mediterranean Sea

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ABSTRACT:

The Benthic Boundary Layer (BBL) is considered a quite homogeneous environment where a wide variety of processes (chemical, physical, geological and biological) occur producing often front structures or inducing turbulence phenomena. The typical stratification of these zones can be interrupted by episodic events which effects can diffuse to the ocean interior exploiting by local current and mixing processes.

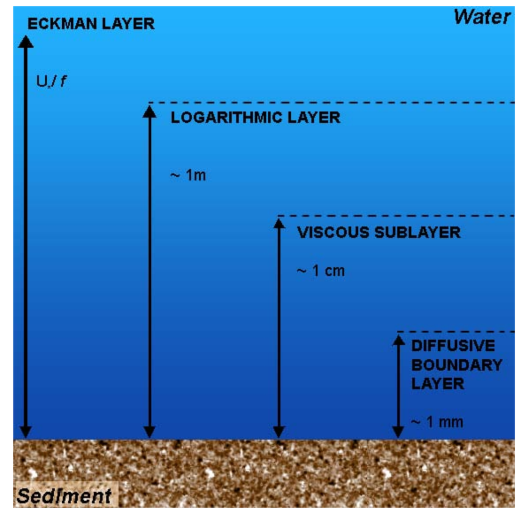
According to hydrodynamic definition, the BBL thickness may vary from few millimetres up to 100 metres depending on the friction intensity with the sea bed and the stability of water column above it. Generally, in deep-sea condition, the BBL thickness is defined by the ratio between the friction velocity and the Coriolis parameter according to the Ekman scale.

In the latest years several experiments have been carried out in the deep water of Mediterranean Sea, focusing on the survey and study of benthic processes following a multidisciplinary approach. Benthic observatories, such as SN-1 and GEOSTAR, allow to record long time-series of geochemical, seismological, geomagnetic, geodetic and oceanographic data and allow to understand the dynamics and evolution of the processes through comparison and interpolation of different types of signals. From a oceanographic point of view, the technology of these benthic observatories brings the possibility to observe and measure directly the hydrological properties at seafloor, collecting data for long-time series and with high sampling rate.

The observatories deployed in Mediterranean Sea, have provided good information about variations and oscillations of hydrological parameters in deep water where the monitoring is almost lacking. In some cases it has been possible to link these deep-sea datasets with upper data collected by ship-handled system during the same period or during different cruises. This allows to have a more complete idea of the linkage between surface, intermediate and bottom sea.

Hence, the multidisciplinary approach represents a very important aspect for this kind of study, because it allows not only a cross check of functionality among all the instruments but also an important tool to recognise and better understand possible non-physical oceanographic phenomena.

THEORETICAL BACKGROUND:



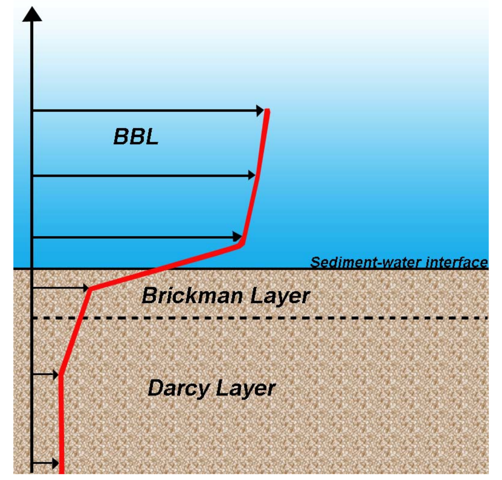
The BBL thickness depends on the height of frictional influence whit the bottom:

In the **ECKMAN LAYER** the flow is affected by earth rotation (f) and bottom friction (U_*).

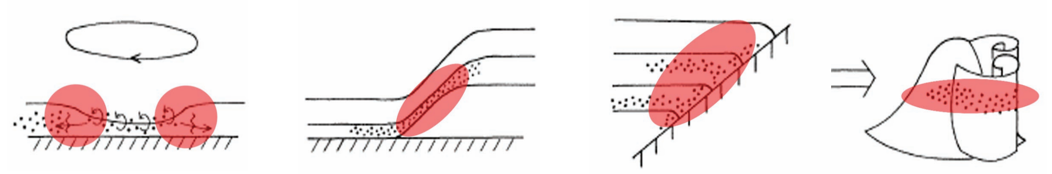
The **LOGARITHMIC LAYER** involves flows in which the velocity profile is rapresented by a logarithmic funcion.

Over the sediment surface, due to the internal water friction, the **VISCOUS SUBLAYER** is controlled by molecular viscosity processes.

The **DIFFUSIVE BOUNDARY LAYER (DBL)** is characterised by eddy diffusion at the water-sediment interface. It involves generally millimetrical thickness, but it can spread toward other layers.



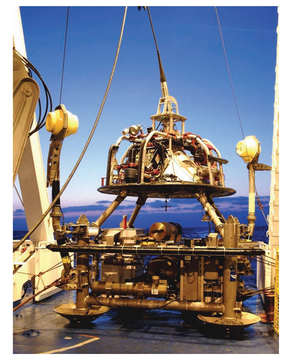
This figure illustrates flow regimes at BBL and at the interface water-sediment.
The **BRICKMAN LAYER** represents the sediment zone affected by diffusion processes. It depends on the sediments porosity and permeability.
The **DARCY ZONE** depicts every pressure-driven flow whitin the sediment. The Darcy's law relates the flow rate and the fluid viscosity to a pressure gradient applied to the porous medium.



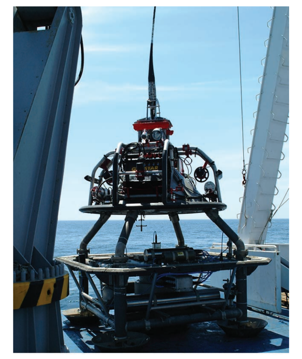
EDDIE MIXING | FRONT STRUCTURE | INTERSECTION WITH ISOPYCNAL SURFACES | INTERSECTION WITH TOPOGRAPHY

At the bottom interface (water-sediment), some turbulence processes can occur, inducing mixing phenomena and remarkable structures

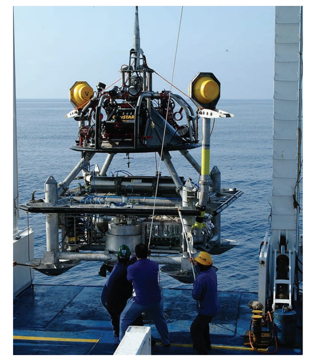
MULTIDISCIPLINARY BENTHIC OBSERVATORIES:



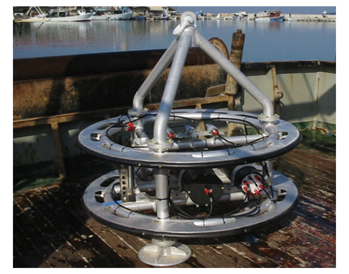
GEOSTAR (1996-2001), 3500 m w.d. in the South Thyrrenian Sea (25 km N-E of Ustica Island)



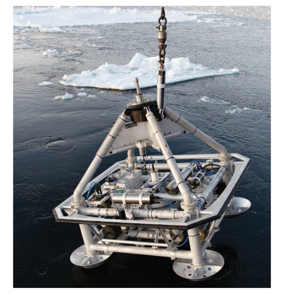
SN-1 (2002-2003), 2105 m w.d.in the Ionian Sea (12 nautical miles in the Catania offshore).Becaming a permanent submarine station from January 2005



ORION (2003-2005), 3400 m w.d. in the Thyrrenian Sea nearby Marsili Volcano.



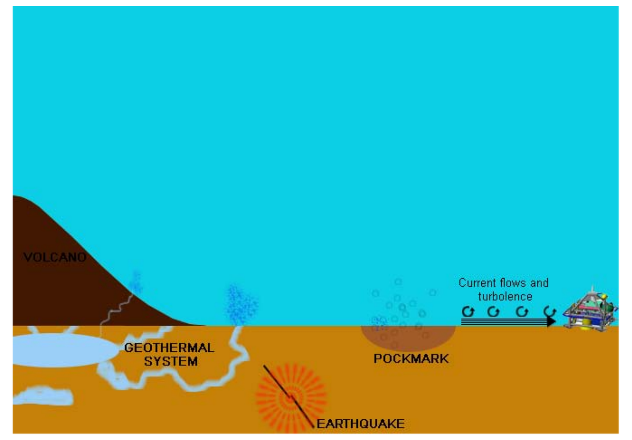
GMM e NODO 4 (2004 -2005), 42 m w.d in the Patras Gulf (Greece)



MABEL (2005-still on site),1870 m w.d. Weddell Sea (Antarctica)

The benthic observatories offer a good opportunity to investigate different kind of environmental processes.They are stable and opened platforms that can mount any type of instruments giving several advantages on power autonomy and high sampling rate.

Each instrument samples with a unique and accurate time reference allowing, subsequently, an easy comparison between all recorded data and a prompt analysis of possible events.



The versatility of these multidisciplinary stations permits to study at the same time different natural fields through the long time series collected.

The multidisciplinary approach is one of the main aspect to consider in order to observe and understand the benthic environment and all the possible events related to them.

SOME DATA EXAMPLES :

Oceanographic data acquired throughout 4 months by the SN-1 benthic observatory in the Ionian Sea at 2100 m depth.

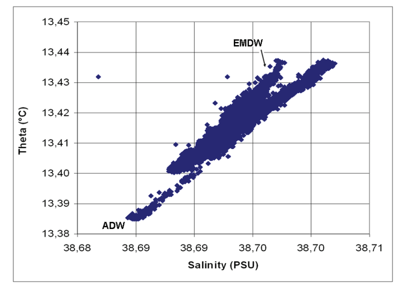


Fig.1: Potential temperature (°C) versus salinity diagram identifies the major water masses involved in this area (ADW: Adriatic Deep Water; EMDW: Eastern Mediterranean Deep Water).

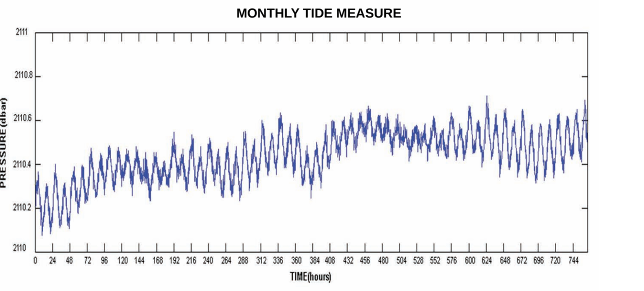


Fig.2: Detail of monthly tidal fluctuation measured at the deep sea by accurate pressure sensor

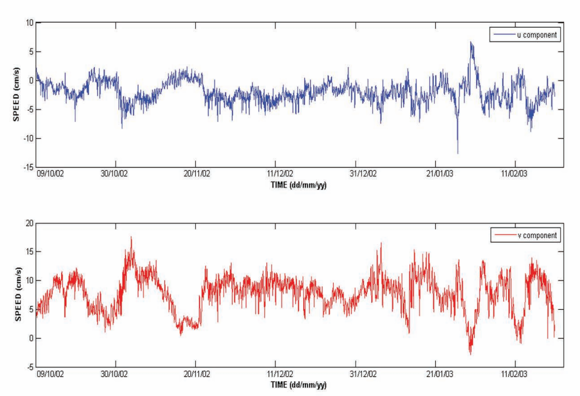


Fig.4: Time series of *u (East- West)* and *v (North-South)* components amplitude measured by single point 3D ACM. The *v* component shows major velocity in conformity with the general dynamic of the Sicilian Strait that have North-South main flows. It presents random fluctuations of amplitude especially during the first and last period of measurement according to the T and S fluctuations.

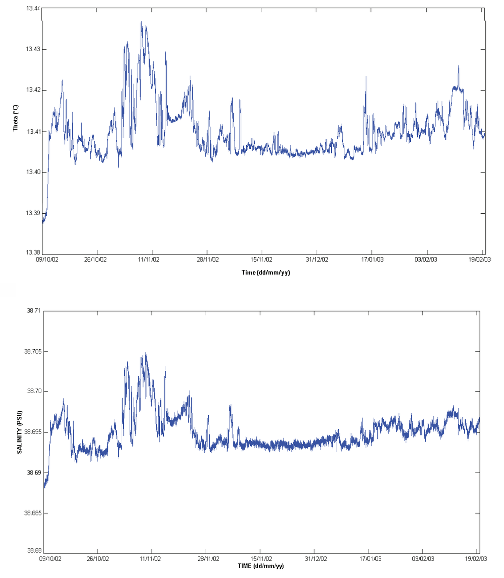


Fig 3: Potential Temperature (°C) and Salinity (PSU) measured at the sea bottom by CTD probe. Strong and rapid oscillations of T and S are showed in different time.The conformity of both parameters reflects the oscillation of water mass in the above layers.

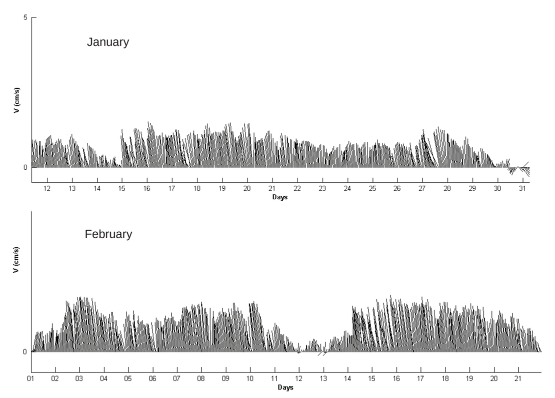


Fig. 5: Stick Plot of (hourly) *u* component of January and February period of measure. It shows a behaviour gererally not turbolent with velocity that, some time, reaches zero value.

Geochemical and Oceanographic data acquired during 6 months of measure by GEOSTAR 2

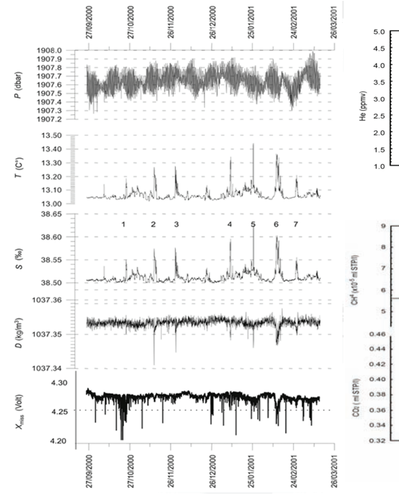


Fig.1: CTD data of pressure (P); temperature (T); salinity (S); Density (D); light transmission (Xmiss). In the temperature and salinity 7 events are recognisable. They are in almost regular occurrence (roughly every 2-3 weeks). These T-S peaks, in accord with the reported reference for this area, suggest a rapid (hours/days) lowering of the interface separating the warm and saline water of eastern origin, from the underlying water of western origin.
The pressure sensor confirmed to be able to sense sea level variation of a few mm at the deep sea.

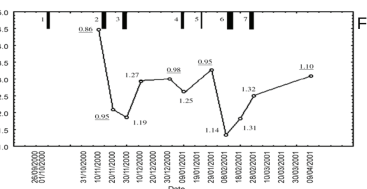


Fig.3: Helium variation. $^3He/^4He$ (x 10^{-6})is reported for each data point

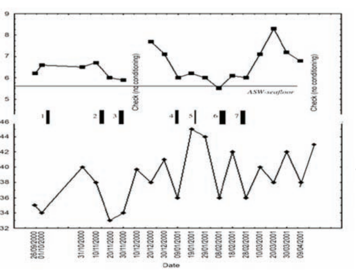


Fig.2: CO_2 and CH_4 variations. Vertical bars are the 7 main T-S peaks marked in Fig.1. ASW is the Air Satured Water (equilibrium with the atmosphere calculated at the seafloor conditions).

Long-term monitoring of a pockmark by GMM

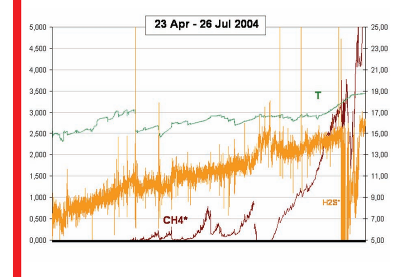


Fig.1:Time series collected by GMM (Gas Monitoring Module).
Long-term measurement of methane (CH_4) and hydrogen sulphide (SO_4) concentrations integrated with oceanographic data, has been recorded for a period of 6.5 months in a pockmark in the Gulf of Patras (Greece), at ca. 40 m water depth.
This continous recorded data show a random association between gas and T peaks. More of 60 events has been counted during all period of measure.

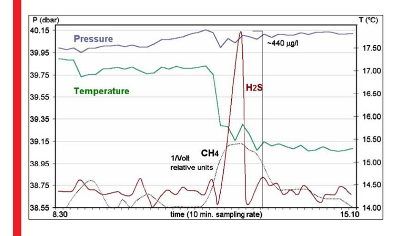


Fig.2 : Detail of one event showing association between geochemical and oceanographic data. Temperature and pressure drop are associated with gas peaks. This example shows a very rapid temperature drop (ca. 1°C in 7 minutes).

Multidisciplinary data acquired in the Thyrrenian Sea at 3300 m depth by ORION Observatory

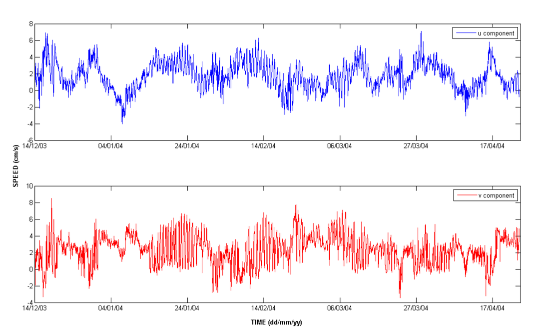


Fig.1: Time series of velocity components *u* and *v*, measured by single point 3D ACM at 3300 m water deep. Both of them show quite similar velocity range and complementary peaks meaning that an absolute and predominat flow direction is missing.

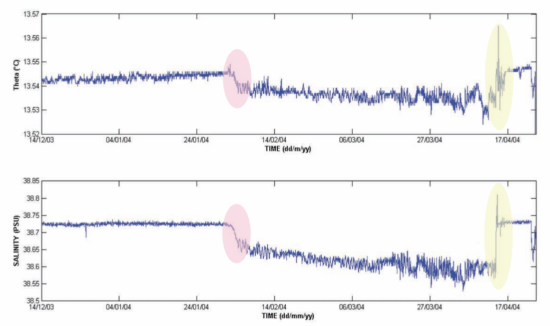


Fig.4: Potential temperature (theta) and salinity behaviour during the first part of monitoring (5 months). They present the same variation and in particular they show two strong and rapid changing (less than 24 hours for the variation marked in red and only 4 hours for the yellow one)

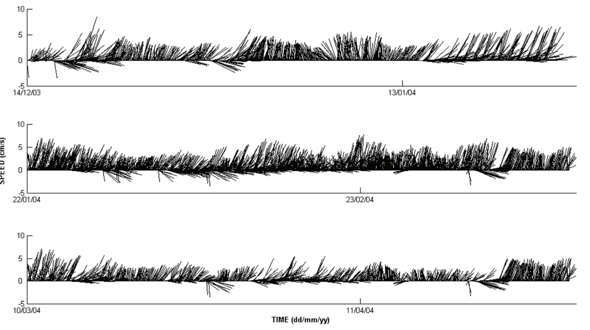


Fig.2: Stick plot calculated for the *Vx* (*u* component) shows a tipical dynamic at the bottom layer. The rotation effect of the vectors reflects the presence of inertial eddie systems.

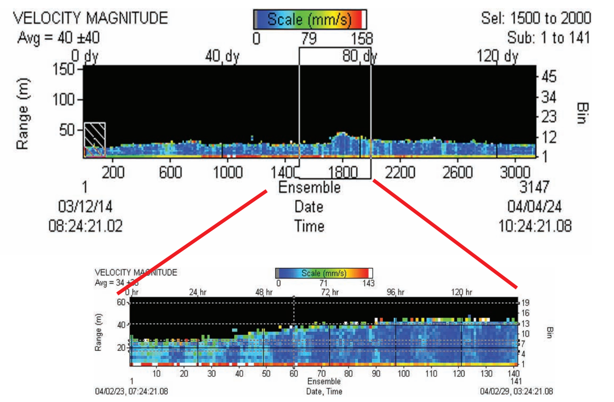


Fig.3: Long-term measurement of current recorded by 300 KHz ADCP (Acoustic Doppler Current Profiler). It adds important information about the dynamic flow of layer immediatly above the observatory.
In spite of typical range of the instrument (150 m), it measures a less thickness of water, probably because of the water trasparency at this water depth.In the zoomed sketch an increasing thickness is showed. This change in capacity is probably due to the entry of a different water mass (see also Fig.4).

Fig.5: Comparison between chemical and ocenographic data. Instrumental and analitical data provide the same information about the main peaks of variation recorded during all period of measure. The plots show a surprising correlation between pH and sulfate measures and temperature data.

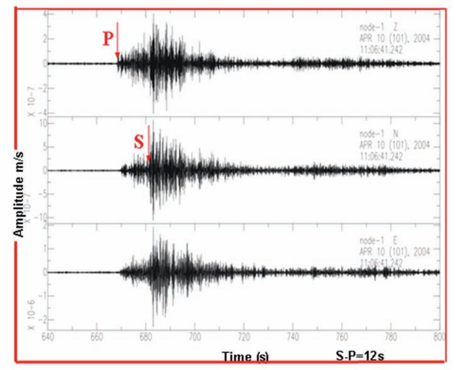


Fig.6: The main variations recorded during the ORION mission has been compared also with the seimological registrations. These data provide in fact a very helpful contribution in order to identify and set possible origin of processes that occur at the bottom layer.

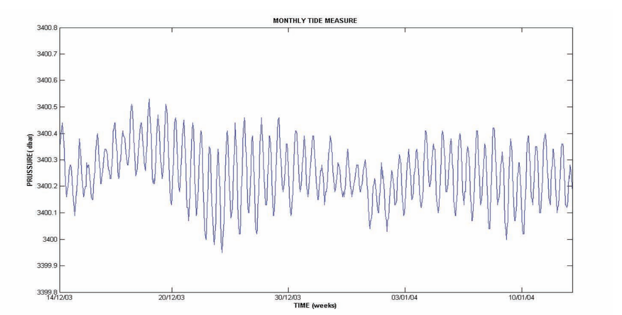


Fig.7: Tide fluctuations measured by sensitive and accurate pressure sensor at the deep sea. The new technologies allow to appreciate very small oscillations having a sensitivity of 1x 10^{-3} dbar for deep sea measurements.

CONCLUSIONS:

Up to now, the most part of BBL processes have been explained only by indirect models.
Especially in the deep sea, the long-term multidisciplinary monitoring is still not well developed because of the logistical difficulties and because of the technological limitation that are not still totally solved.

The multidisciplinary approach should be the main purpose of BBL investigation. Various, continous and simoultaneous dataset collected by different kind of instrument are indispensable in order to study the BBL and understand the complicate ecosystems at the bottom ocean.
All the processes are in fact often linked by sophisticated feedback cycles. Then understanding one of them means improving the knowledge of the entire sea floor system.

Although the BBL is classicaly defined as a very stable layer, the long term series of data, collected at the deep sea, have showed that rapid variations can involve this enviroment. Thus, in order to appreciate significant changes the study of the benthic layer should be considered in the Global Change monitoring, while it is generally focused only on the observation of oceanographic chemical-physical variations at the surface and intermediate layers.

REFERENCES:

Boundreau B.P. & Jørgensen B.B. (2001) - The Benthic Boundary Layer, transport processes and biogeochemictry- OXFORD PRESS

Richards K.J. (1990) - Physical processes in the benthic boundary layer - Phil. Trnas. R. Soc. Lond A 331, 3-13

EtiopeG. et al. (2006) - The Benthic Boundary Layer: geochemical and ocenagraphic data from the GEOSTAR-2 Observatory - Annals of Geophysics, Vol. 49, N 2/3

Marinaro G., et al. (2006) - Monitoring of a methane-seeping pockmark by cabled benthic observatory (Patras Gulf , Greece)- Geo-Mar Lett D01

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