Con il patrocinio di:

Dipartimento di Scienze della Terra Sapienza Università di Roma

SCUOLA ESTIVA DI GEOMORFOLOGIA, ECOLOGIA E BIOLOGIA IN AMBIENTE MARINO E INSULARE

TERZA EDIZIONE

PONZA 20-23.09.2022

Sala Comunale

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La misura dei flussi all'interfaccia acqua-sedimento con camere bentiche e non

Misura dei flussi all'interfaccia acqua-sedimento con camere bentiche

Federico Spagnoli

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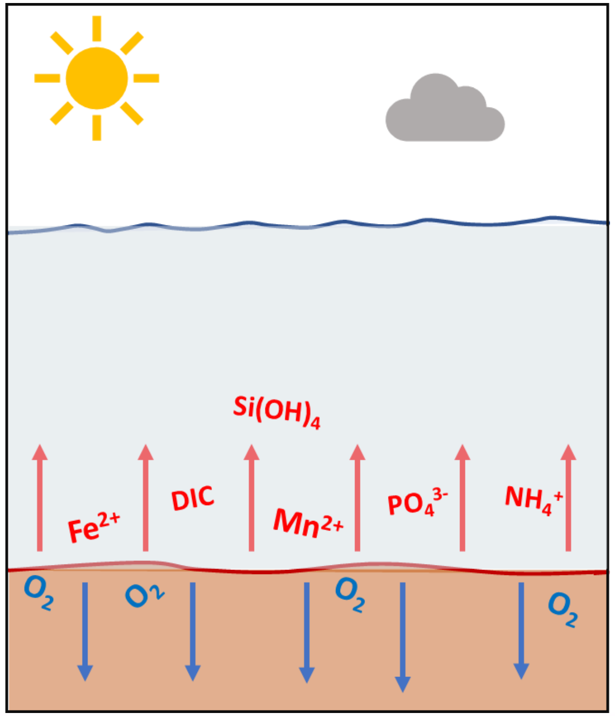
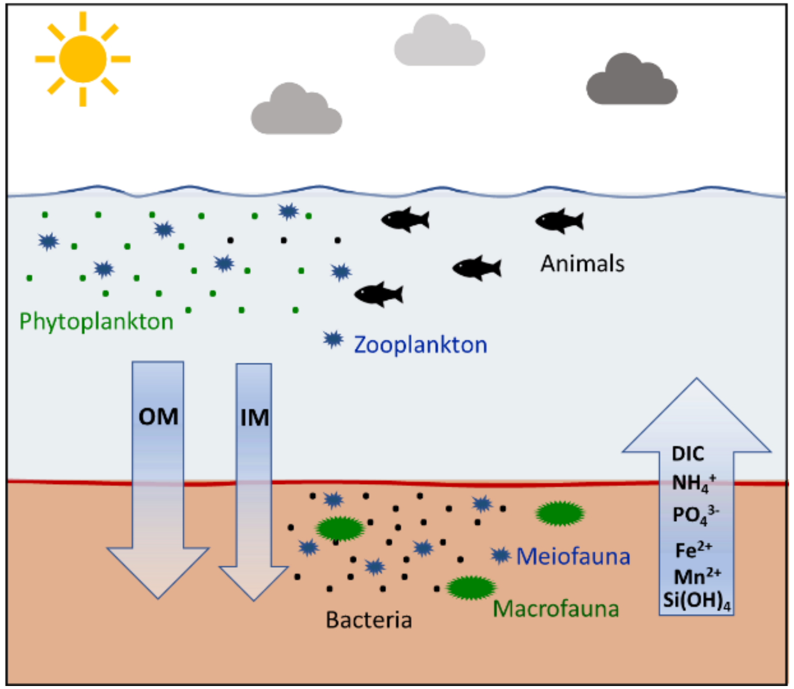
What the dissolved benthic fluxes are?

- Fluxes of dissolved chemicals at the sediment-water interface
- Fluxes can be positive of negative that is released or adsorbed by the seabed sediments
- They are generated by
  - early diagenesis processes
  - fluids from high sub-bottom depths
  - by volcanic or hydrothermal processes



Early diagenesis engine

- **The biogeochemical reactions and processes occurring in the upper cm of the sediment**
  - due to fall and accumulation of organic (OM) and inorganic (IM) matter on seafloor
    - Following organic matter deposition and degradation;
    - Mineral dissolution
    - Mineral precipitation



OM consits of:

Marine POC (mPOC), terrestrial POC (tPOC), aggregates or flocs of DOC

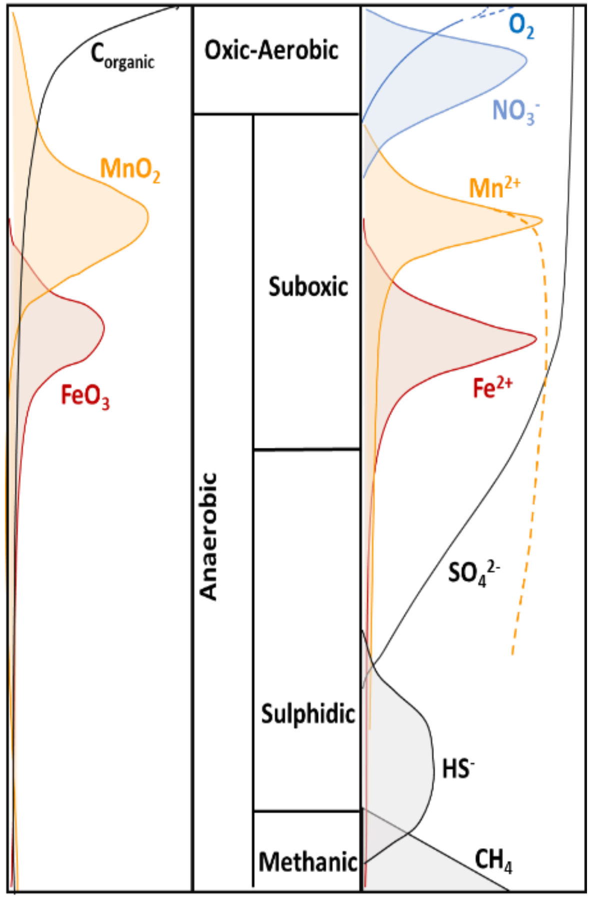
IM consists of:

IC, SiOx, trace elements, pollutants, others

Early diagenesis processes

Blue: final electron acceptors

Red: Organic matter degradation products



Aerobic biodegradation

$(CH_2O)106(NH_3)16(H_3PO_4)+138O_2 <=> 106CO_2+16HNO_3+H3PO_4+122H_2O$

Anaerobic biodegradation

Denitrification (Nitrate reduction)

$5(CH_2O)106(NH_3)16(H_3PO_4)+472HNO_3 <=> 236N_2+520CO_2+5H_3PO_4+886H_2O$

Oxi-hydroxi-Mn-reduction

$5(CH_2O)106(NH_3)16(H_3PO_4)+236MnO_2+472H+<=>236Mn^{2+}106CO_2+8N_2+H_3PO_4^{3-}+336H_2O$

Oxi-hydroxi-Fe reduction

$(CH_2O)106(NH_3)16(H_3PO_4)+212Fe_2O_3+848H+<=>424Fe^{2+}106CO_2+8NH_3^-+H_3PO_4^{3-}+530H_2O$

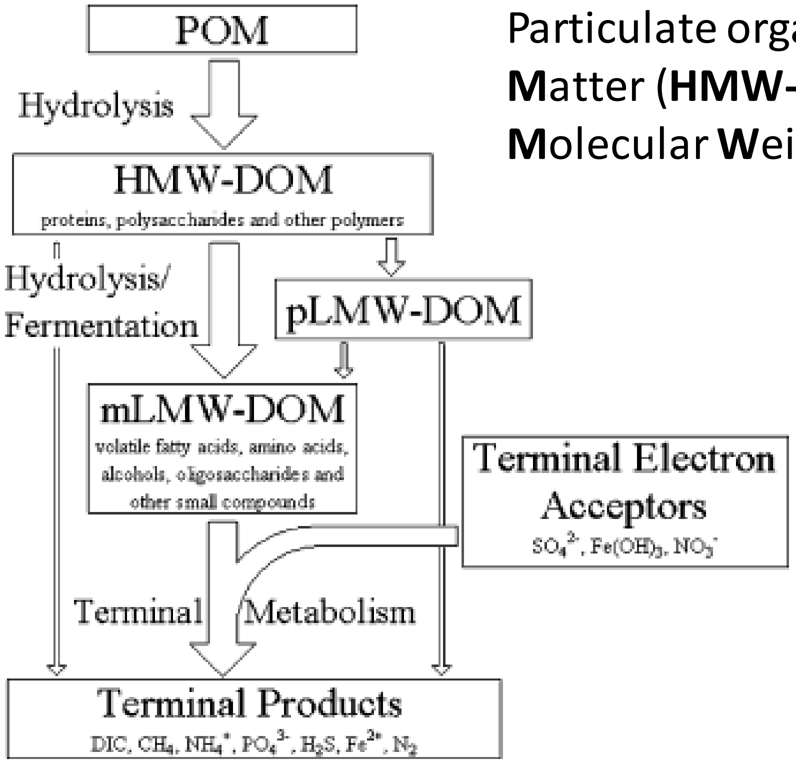
Sulfate reduction

$(CH_2O)106(NH_3)16(H_3PO_4)+55SO_4^{2-}<=>106CO_2+16NH_3^-+55S^{2-}+H_3PO_4^{3-}+106H_2O$

Methanogenesis

$(CH_2O)106(NH_3)16(H_3PO_4) <=> 53CH_4+53CO_2+16NH_3^-+H_3PO_4$

Schematic way of organic matter breakdown in anaerobic sediments



Particulate organic matter (POM) is initially hydrolyzed to **H**igh **M**olecular **W**eight **D**issolved **O**rganic **M**atter (**HMW-DOM**), which is then further hydrolyzed and fermented to **m**onomeric **L**ow **M**olecular **W**eight **D**issolved **O**rganic **M**atter (**mLMWDOM**).

The terminal oxidation of **mLMW-DOM** is coupled to the reduction of terminal electron acceptors [largely sulfate (**$SO4_2$**) in marine systems, but also iron and manganese oxyhydroxides (such as $Mn(OH)_2$, $Fe(OH)_3$) and nitrate (**NO_3**), producing dissolved inorganic carbon (**DIC**), methane (**CH_4**), ammonium (**NH_4^+**) and phosphate (**PO_43^-**) as terminal end products of organic matter mineralization, as well as hydrogen sulfide (**H_2S**), reduced iron (**Fe^{2+}**) and Mn (**Mn^{2+}**) and dinitrogen gas (**N_2**) as the reduced forms of the electron acceptors.

Some fraction of **HMW-DOM** is degraded into **p**olymeric **L**ow **M**olecular largely refractory and unavailable to the sedime**W**eight **D**issolved **O**rganic **M**atter (**pLMW-DOM**) which is nt microbial community.

Modified from Weston et al. (2006)

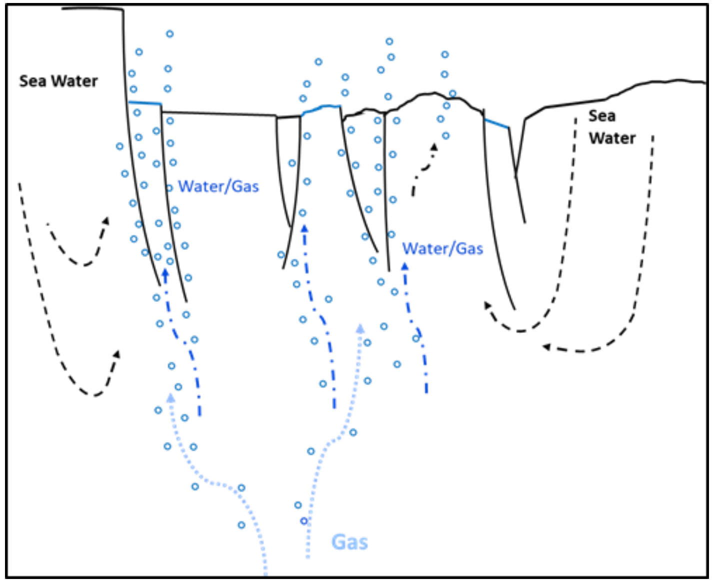
Early diagenesis processes generate dissolved fluxes at the sediment-water interface

- **Outward the sediment**
- **Inward the sediment**

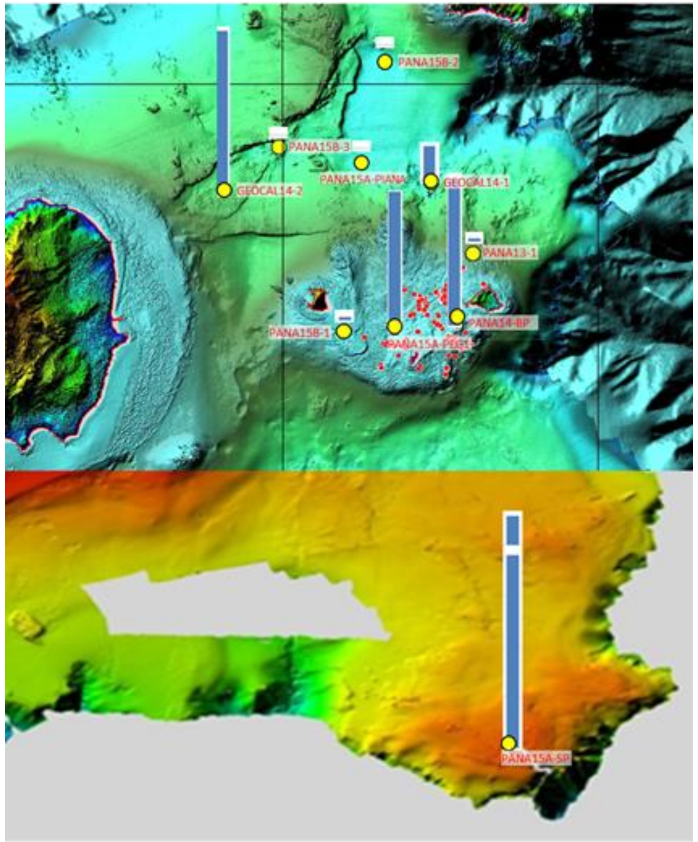
Factors affecting Early Diagenesis Processes

- High fresh organic matter contents
  - High productivity
- Presence of Fe an Mn Oxi-Hydroxides
- High sedimentation rates
- Fine grain-size
- Limited resuspension processes

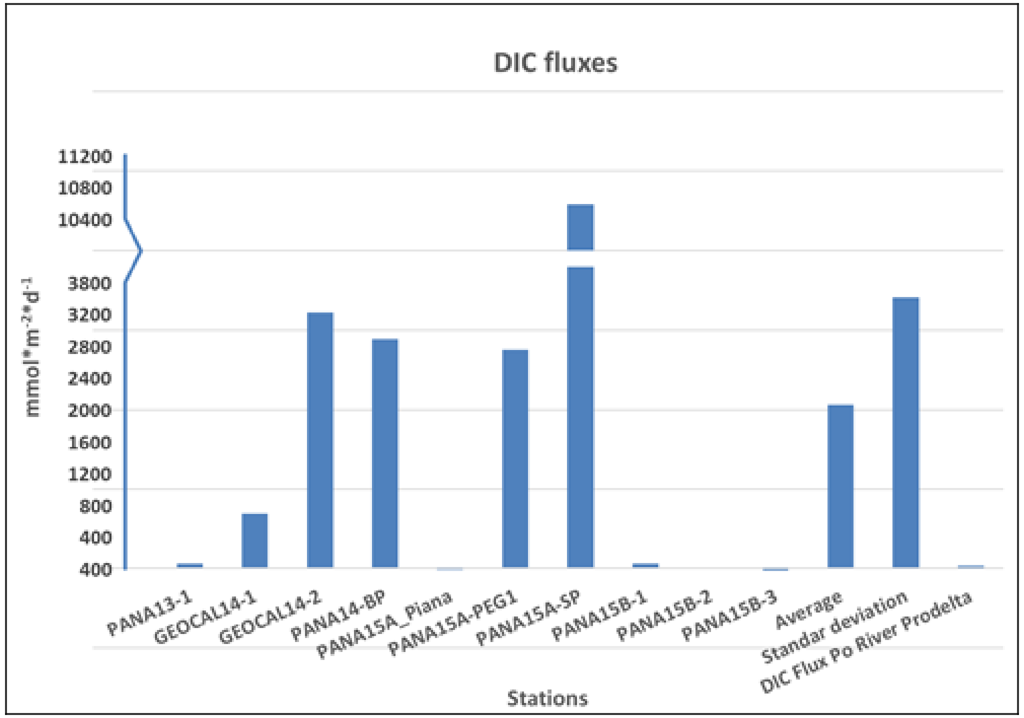
Dissolved fluxes at seafloor in volcanic environment Panarea Volcanic Comples (PVC)



Fluids and gases ascent and seep in volcanic environment



Location and graphical view of the DIC fluxes in the Smoking Land Valley and the *Secca dei Pesci.*



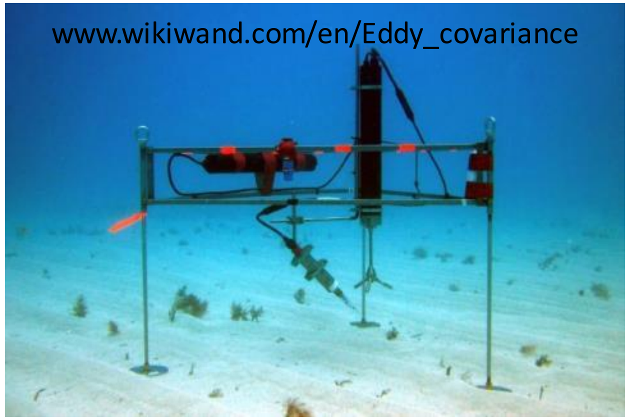
Graph of the DIC fluxes measured at seafloor interface around the PVC.

(Spagnoli et al., submitted)

The dissolved fluxes at the sediment-water interface can be measured or calculated by different methods

- **Measured**
  - ***In situ***
    - Benthic chamber deployments
    - Eddy covariance
  - ***In lab***
    - Core incubations on deck
- **Calculated**
  - Pore water profile modeling

In situ benthic chamber

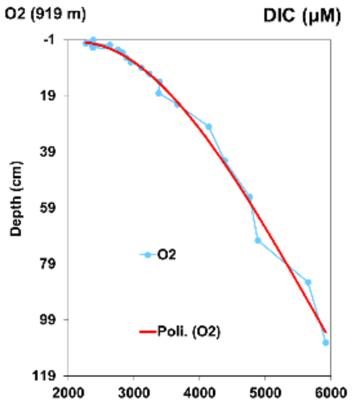


Eddy covariance

Core incubations on deck

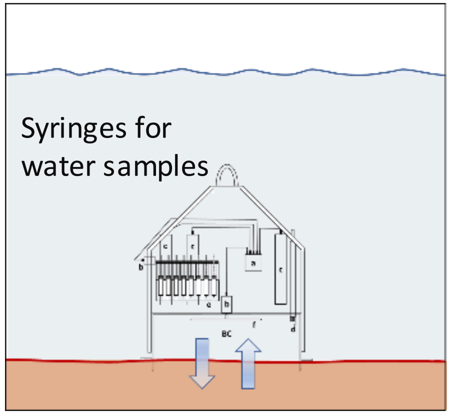
$$J_i = -\phi D_i \left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$

Pore water profile modeling



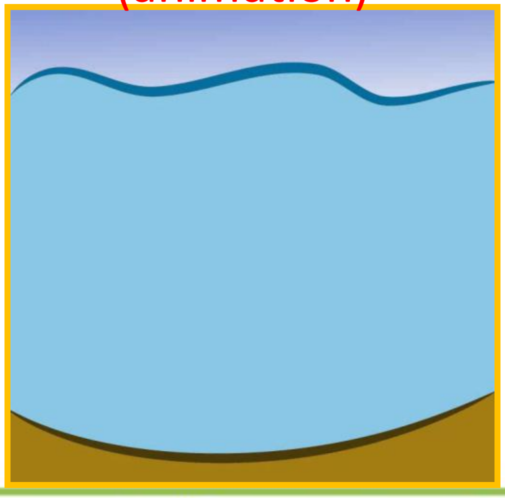
What a benthic chamber is

The benthic chamber measures the fluxes of dissolved substances at the sediment-water interface

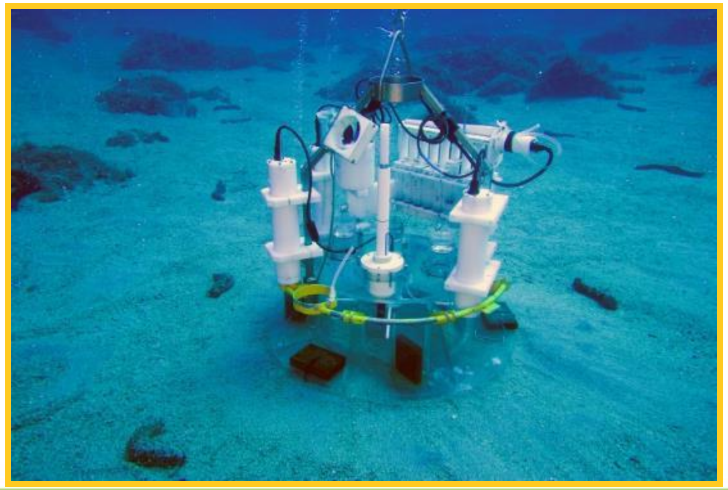


- A benthic chamber is a box placed over the bottom sea with a sealed top and an open bottom;
- Types of benthic chambers range from very simple to very complex for shallow and deep environments.

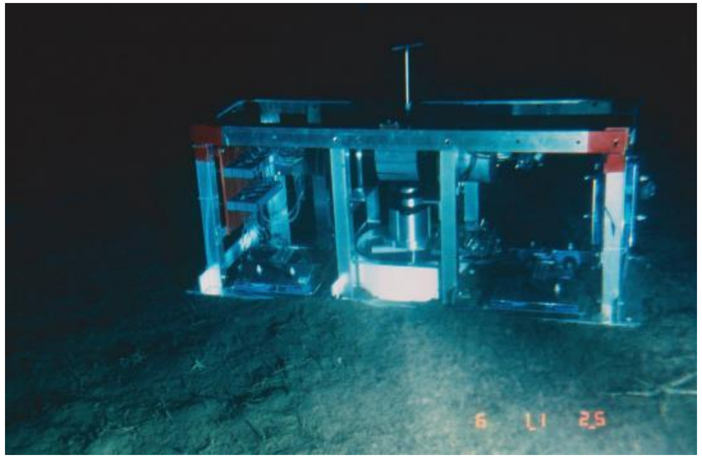
Schematic functioning (animation)



On the bottom



The evolution of **CNR benthic chambers**



Doug Hammond, 1984, USC, USA


sensors

MDPI

Article

The AMERIGO Lander and the Automatic Benthic Chamber (CBA): Two New Instruments to Measure Benthic Fluxes of Dissolved Chemical Species †

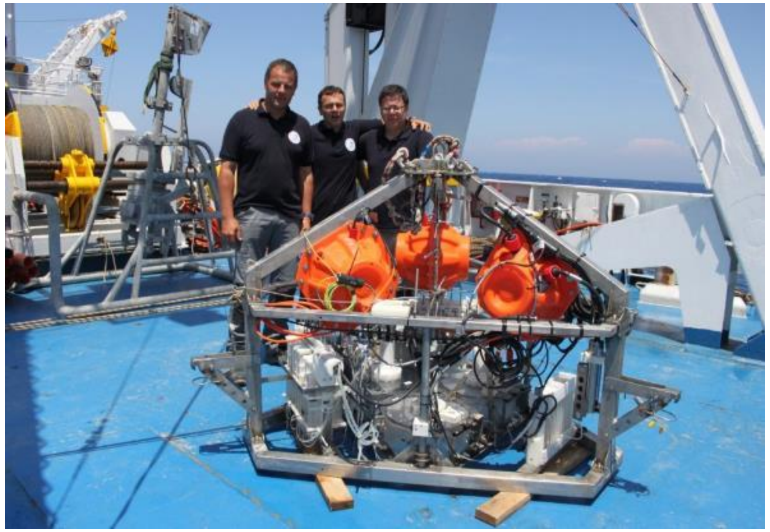
Federico Spagnoli 1,*, Pierluigi Penna 1, Giordano Giuliani 1, Luca Masini 2 and Valter Martinotti 3

Abstract: Marine environments are currently subject to strong ecological pressure due to local and global anthropic stressors, such as pollutants and atmospheric inputs, which also cause ocean acidification and warming. These strains can result in biogeochemical cycle variations, environmental pollution, and changes in benthic-pelagic coupling processes. Two new devices, the Amerigo Lander and the Automatic Benthic Chamber (CBA), have been developed to measure the fluxes of dissolved chemical species between sediment and the water column, to assess the biogeochemical cycle and benthic-pelagic coupling alterations due to human activities. The Amerigo Lander can operate in shallow as well as deep water (up to 5000 m), whereas the CBA has been developed for the continental shelf (up to 200 m). The lander can also be used to deploy a range of instruments on the seafloor, to study the benthic ecosystems. The two devices have successfully been tested in a variety of research tasks and environmental impact assessments in shallow and deep waters. Their measured flux data show good agreement and are also consistent with previous data.

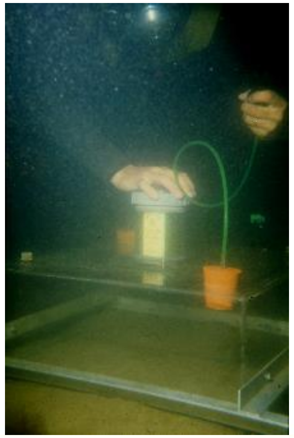
Keywords: lander; benthic chambers; benthic fluxes of dissolved chemical species; marine technology; marine instrumentation

Spagnoli et al., 2010

Spagnoli et al., 2014

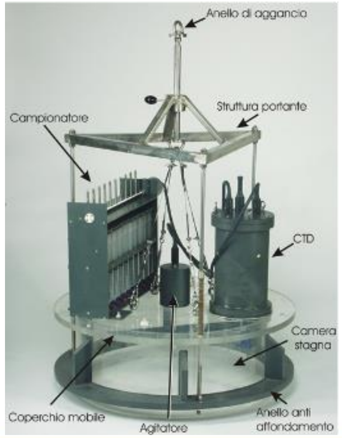


Hammond, Giordani, Frascari, 1984



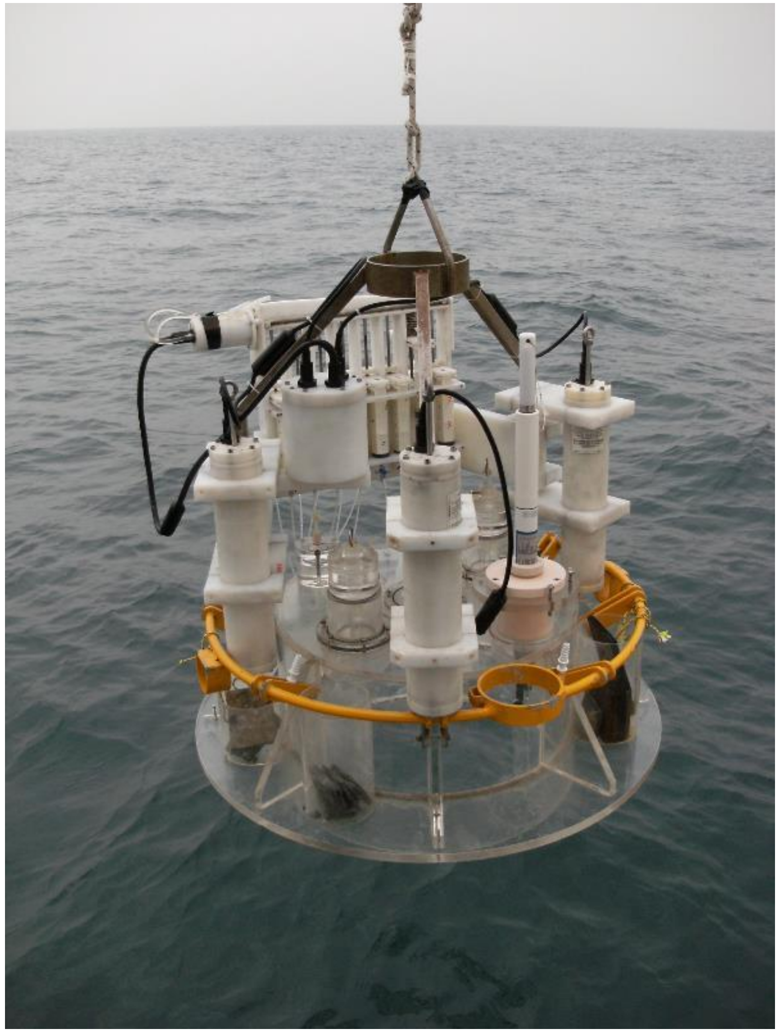
Spagnoli & Frascari, 1984

Spagnoli & Masini, 1996



The present CNR benthic chamber an Lander

AdaN



Amerigo

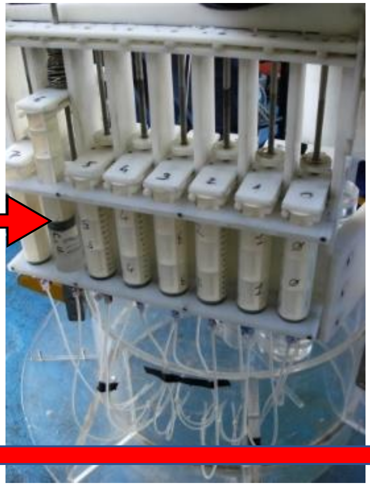
Spagnoli et al., 2019

AdaN (Ada Natali, Massa Fermana (FM), 5 marzo 1898 – 27 aprile 1990. First woman major after WWII)

The automatic benthic chamber AdaN is made by a polymethylmethacrylate cylinder (80 cm ID, 33 cm h) closed on the top and open on the bottom

AdaN is equipped with:

- A device for collecting water samples inside or outside the chamber or to inject a tracer inside the chamber (the VAMPIRE);
- A multiparametric probe (Hydrolab MS5) to measure oxygen, pH, Eh, temperature, conductivity (i.e. salinity) inside the chamber;
- Simple and commercial available electronic (Idec MicroSmart FC6A PLC);
- Batteries.

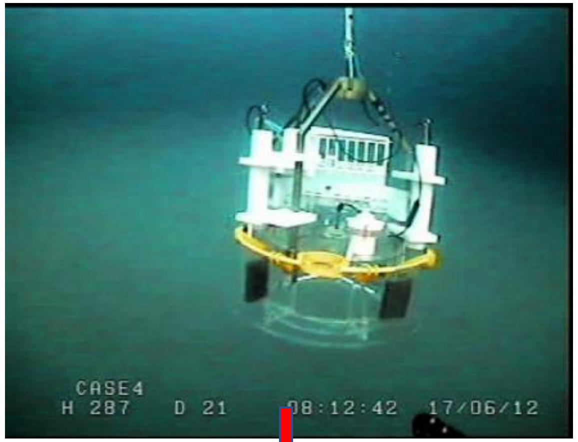


Spagnoli et al., 2019

AdaN deployment

AdaN can operate on the continental shelf (up to 200 m depth)

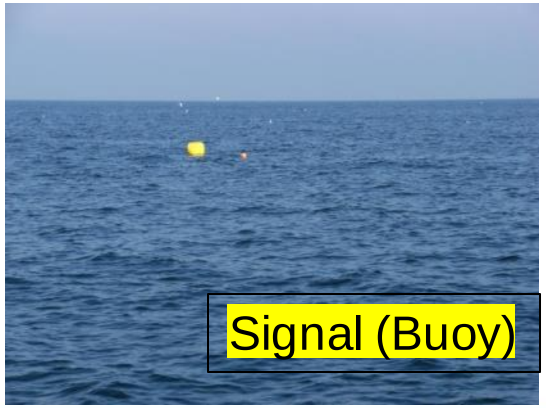
Deployment on the sea bottom (by rope)



Landing

Bottom activity

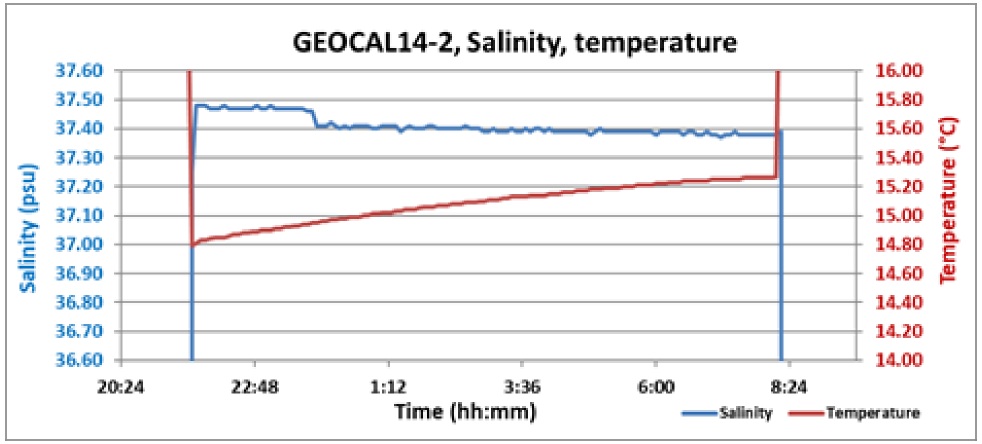
Recovery



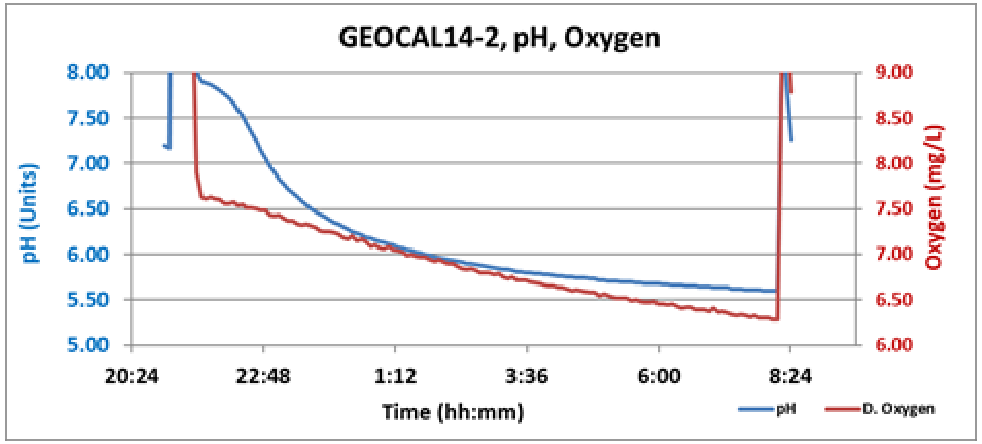
Signal (Buoy)

AdaN, Multiparametric probe data

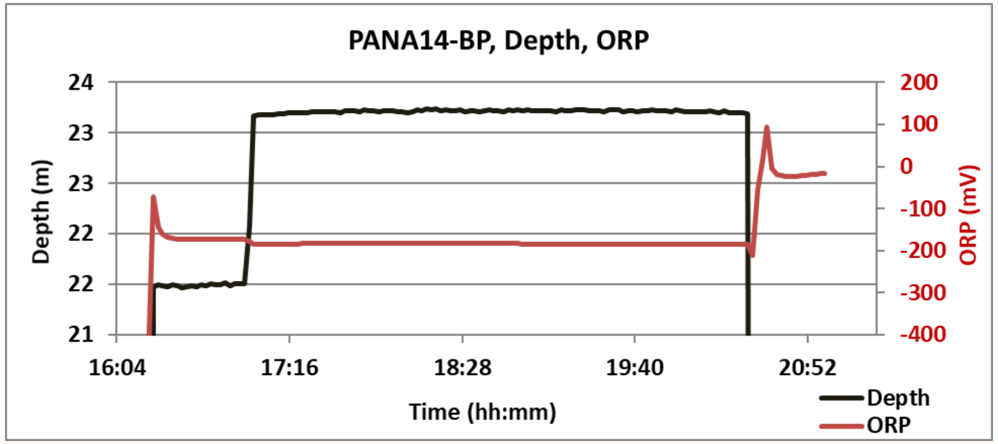
Salinity and Temperature



Oxygen and pH



- **Salinity step**
- **Increasing temperature**
- **Decreasing pH**
- **Decreasing O2**
- **Changing depth**



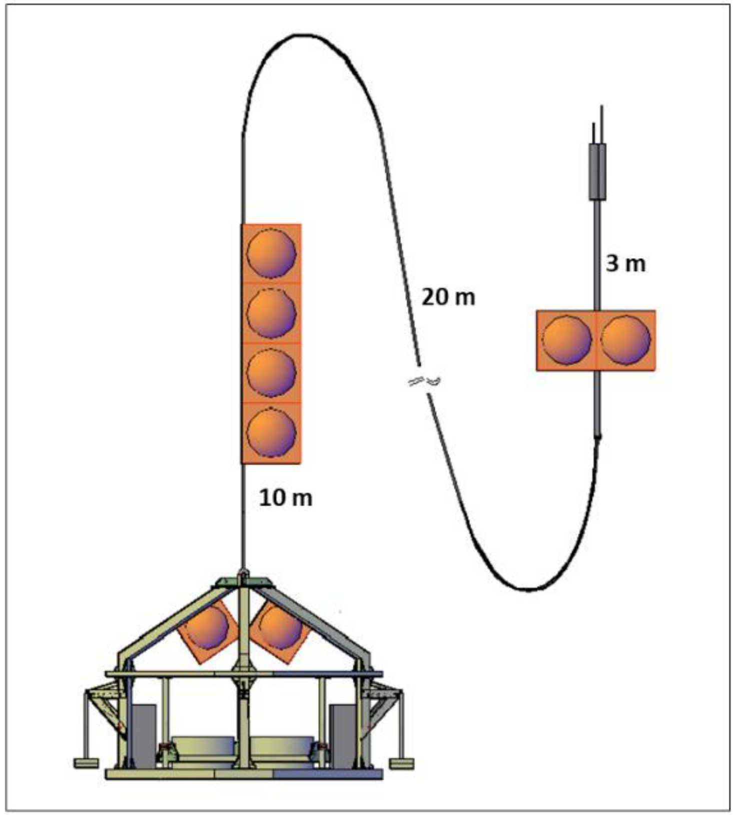
Depth and ORP

Video CB Landing

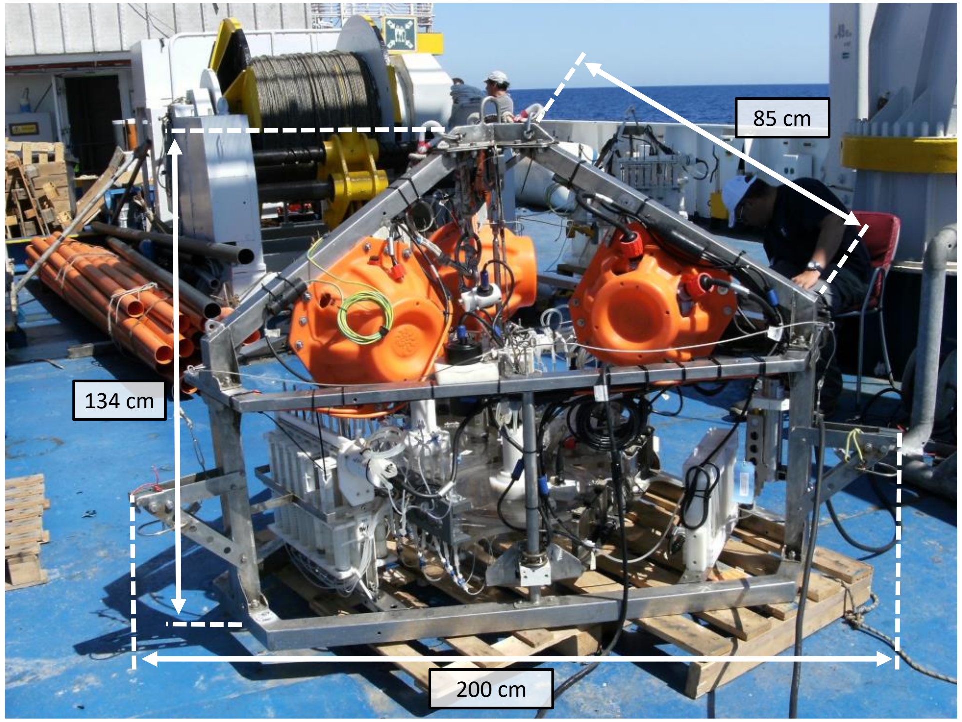
Da tagliare

The lander **Amerigo**

Landing set up

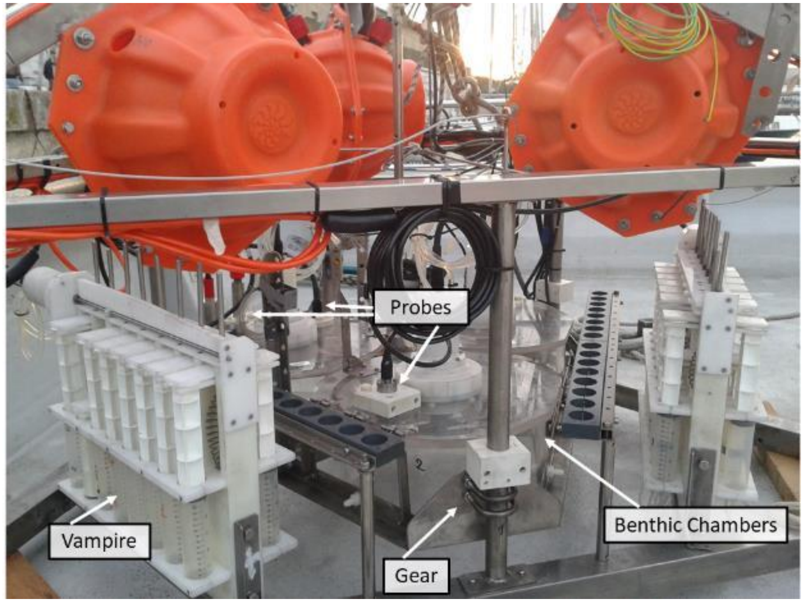


On board

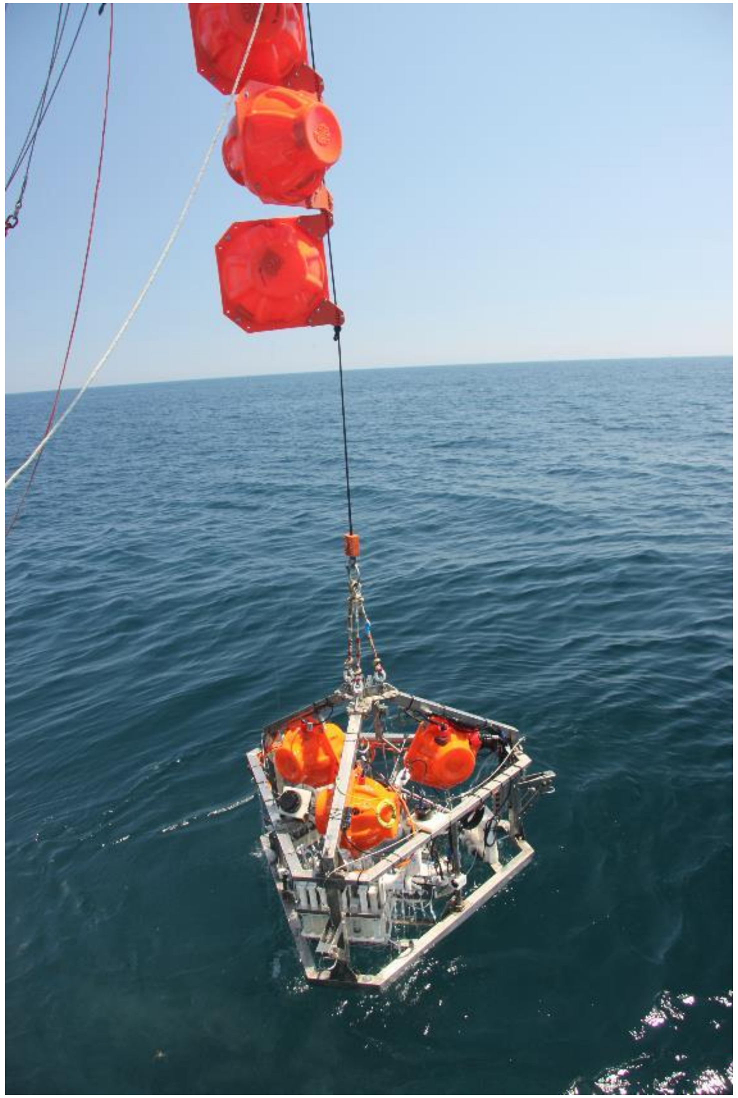


A lander is a device that reach the sea bottom by controlled falling due to the gravity

Main components



The Lander Amerigo



Main characteristics

- Amerigo is a lander (able to reach (by controlled gravity falling) and operate on the sea bottom and return (by controlled buoyancy) to the surface autonomously;

-At present is configured for the measurement of dissolved fluxes at the sediment-water interface, including dissolved gases, nutrients, metals and pollutants;

- it is prepared to host other instruments for different monitoring and measurement studies:

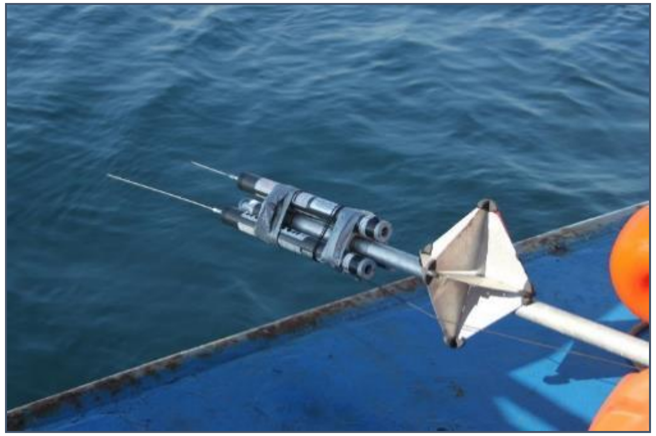
- sensors for water column (oxygen, pH, methane, PAHs, pCO_2, H_2S, turbidity, fluorimeter);
- Instruments: microprofiler, (sediment-water interface properties), penetrometer (mechanical properties of the surface sediments), gravimeter, wave and current meter, corer.

Amerigo can operate from continental shelf to abyssal plain (up to 6000 m depth).

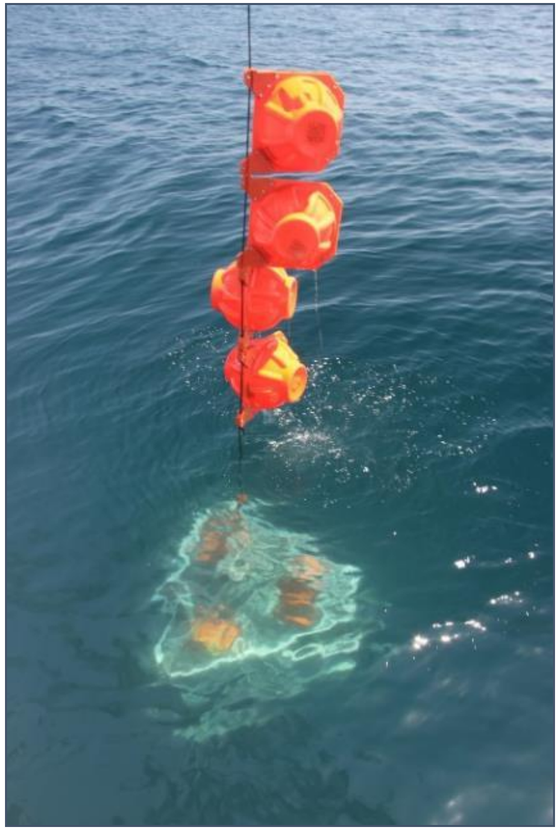
Amerigo Equipment: Devices for the dropping, landing and rising

Ballasts for Controlled gravity falling

Radio, flash and GPS for the recovery

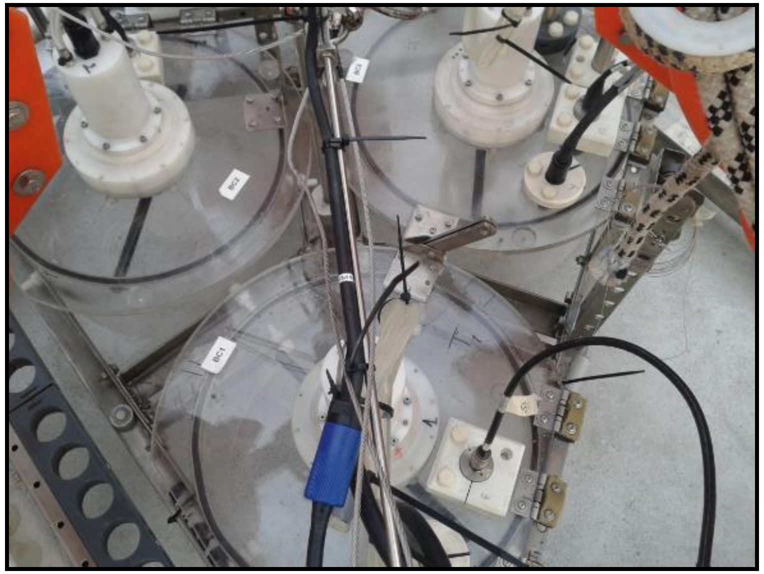


The buoy array for the rising



Amerigo

3 benthic chambers (for dissolved flux measurements at the sediment-water interface)

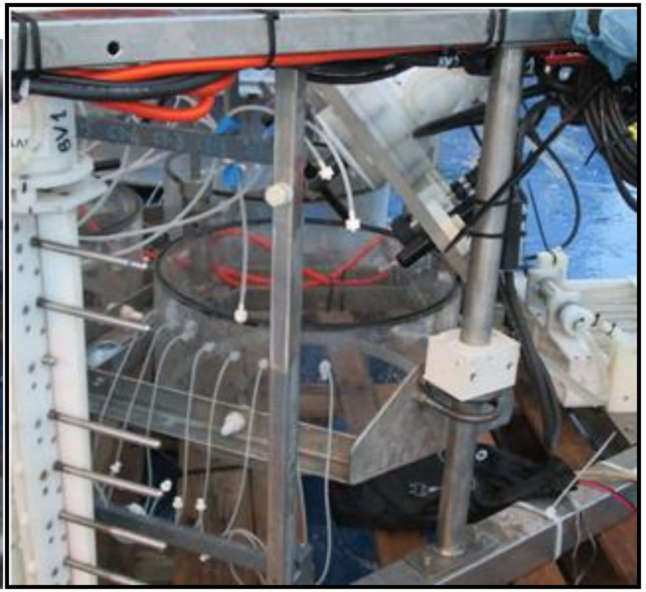


Benthic chambers

- polymethylmethacrylate cylinder, 37.5 cm ID, 15 cm h;
- Open lid;
- Rotating paddle;
- Collecting syringes;
- Sensors;
- Oxistat;
- Landing carousel.

Benthic chamber (top view)

Benthic chambers (lateral view)



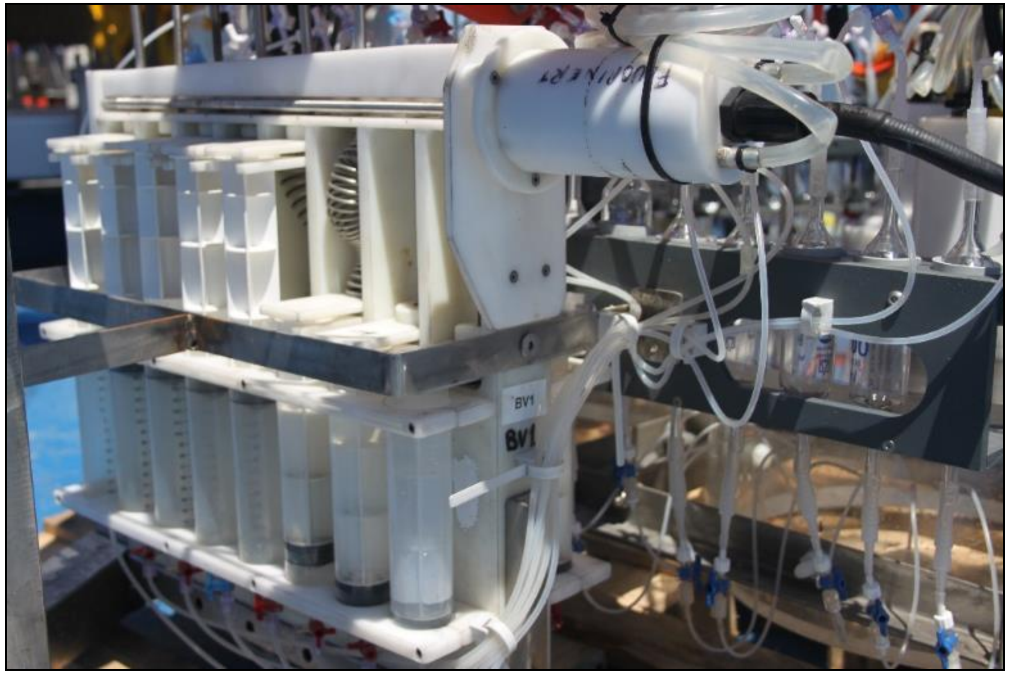
Sensors:

- Oxygen;
- pH;
- Methane;
- Turbidity.

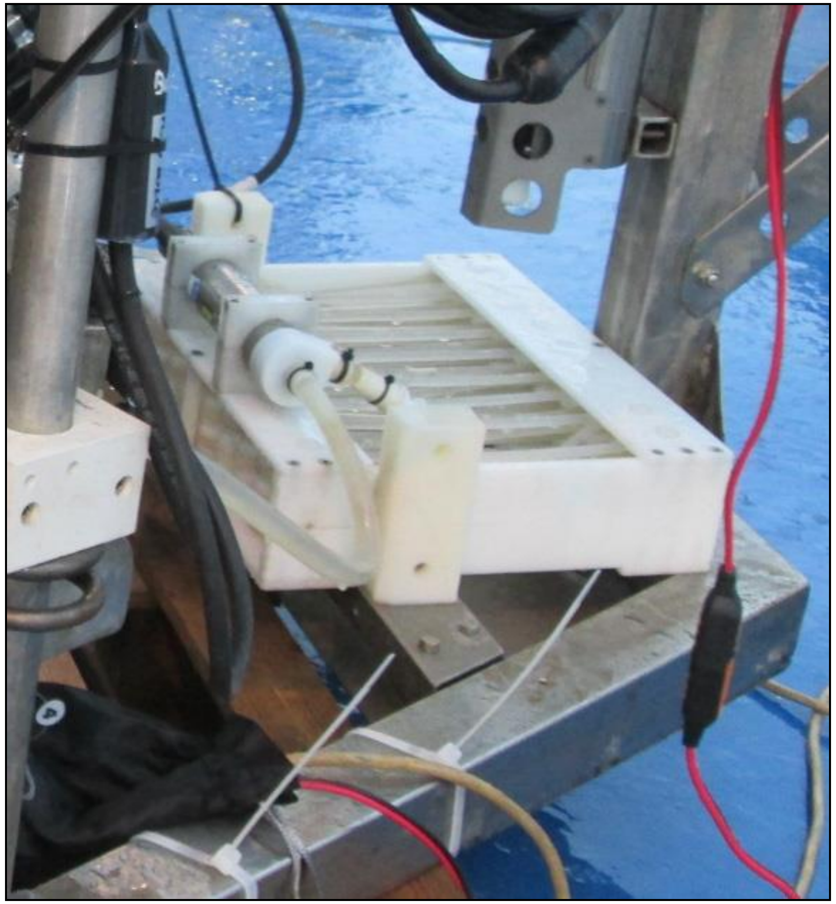
Possible: pCO_2, H_2S, others?

Amerigo equipment: devices for collecting water samples and oxygen replacement

VAMPIRE. Device for collecting water samples inside and outside the chamber and to inject tracers



OXYSTAT. Device for replacing oxygen inside the chambers



Glass ampoules for collecting gas samples

The Vampire

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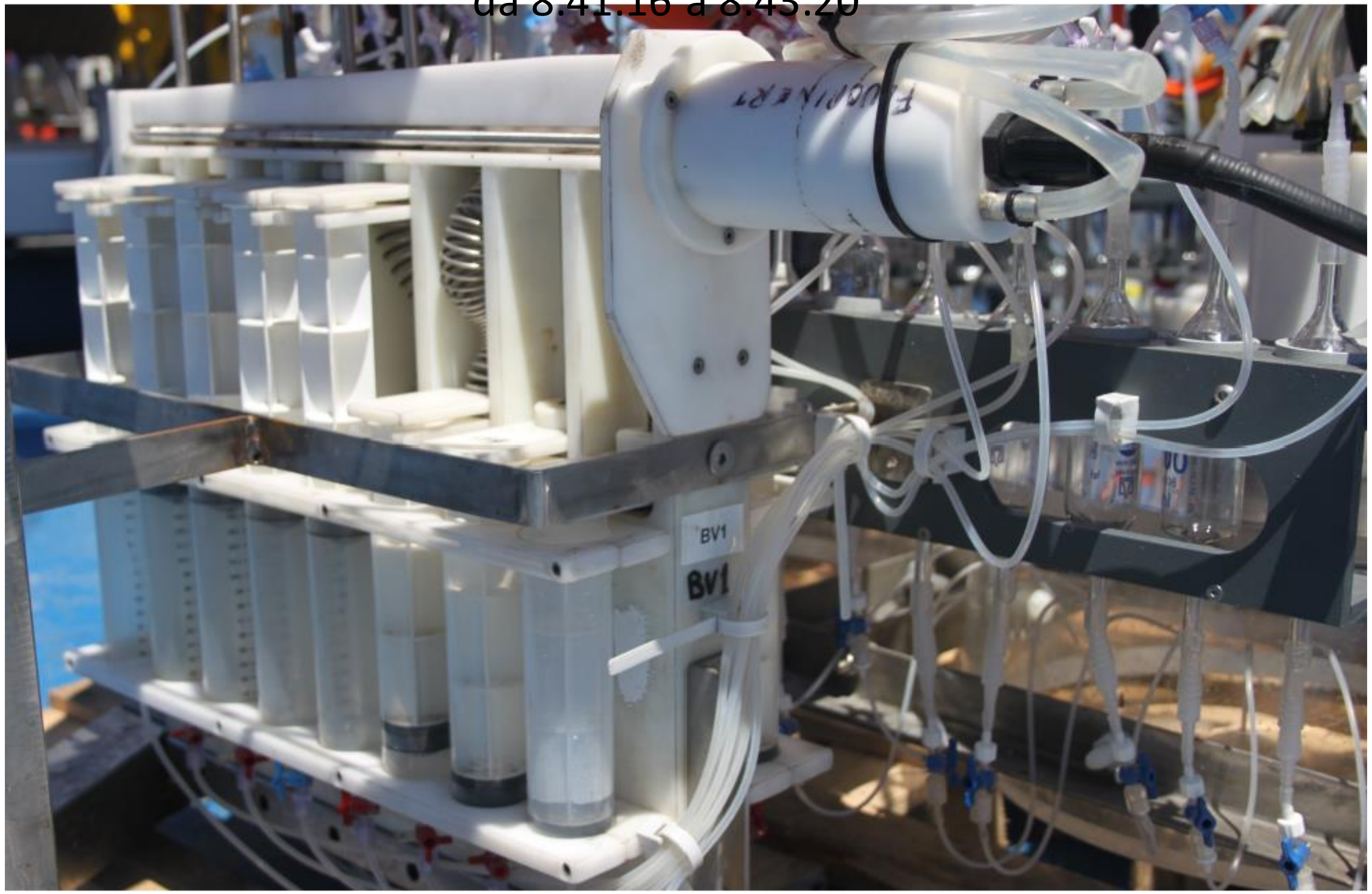
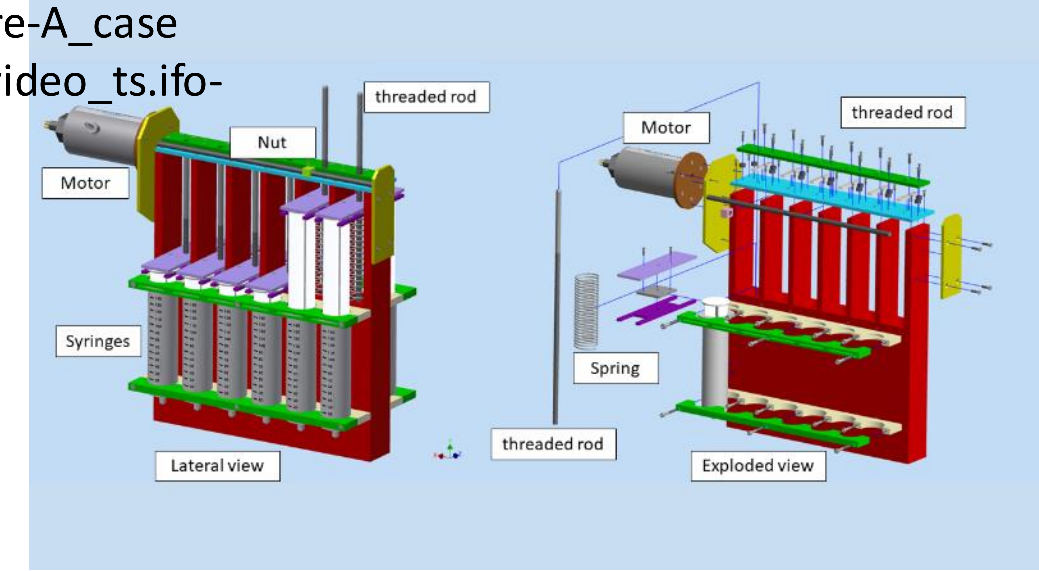
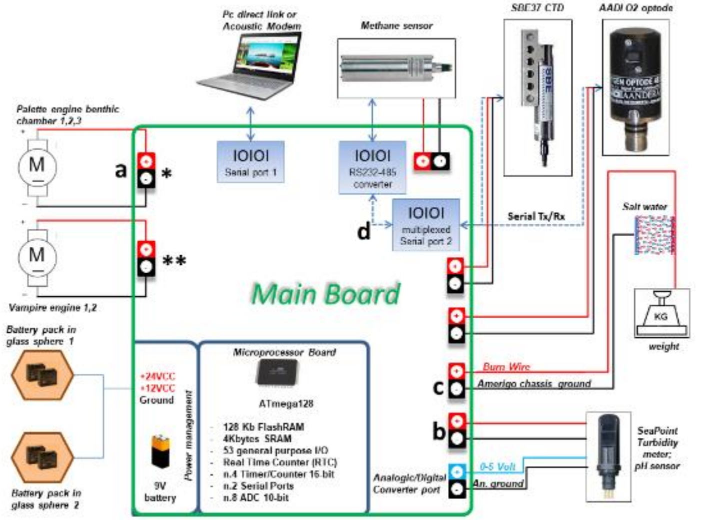




Amerigo equipment: The electronic

The in house made electronic

- microprocessor Atmega128, 2 RS232 ports, 1 RS485 port; 3 analogic ports, 19 on/off ports, in a glass sphere;
- 12V rechargeable Pb batteries in two glass spheres.



The glass sphere housing of the electronic and batteries (up to 700 bars)

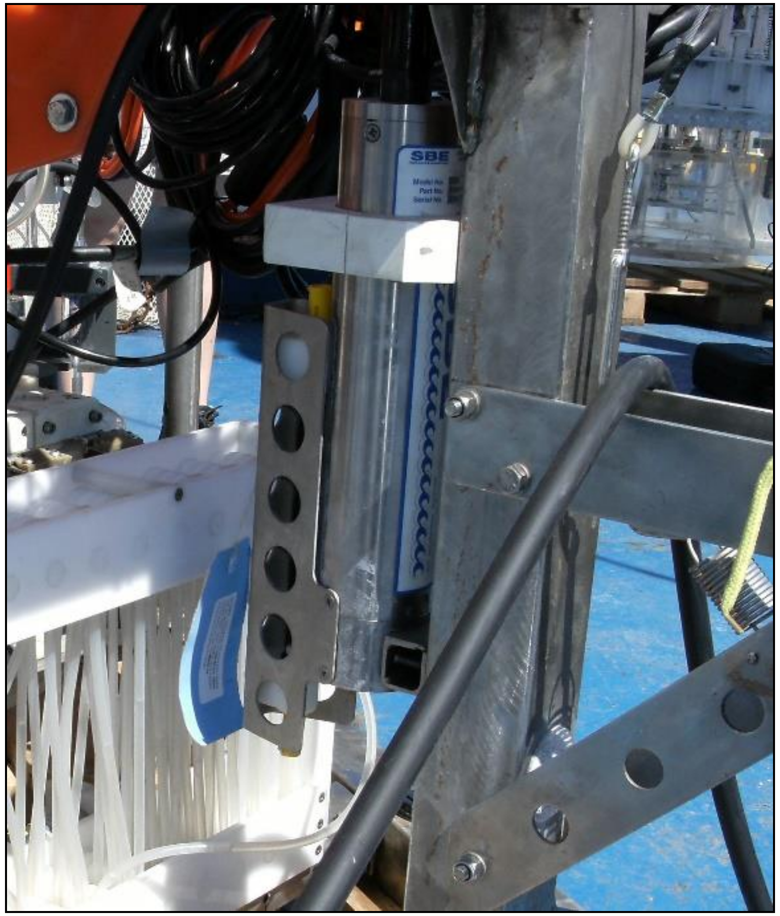
The Amerigo Lander: Other devices (to monitor the activity)

The video camera

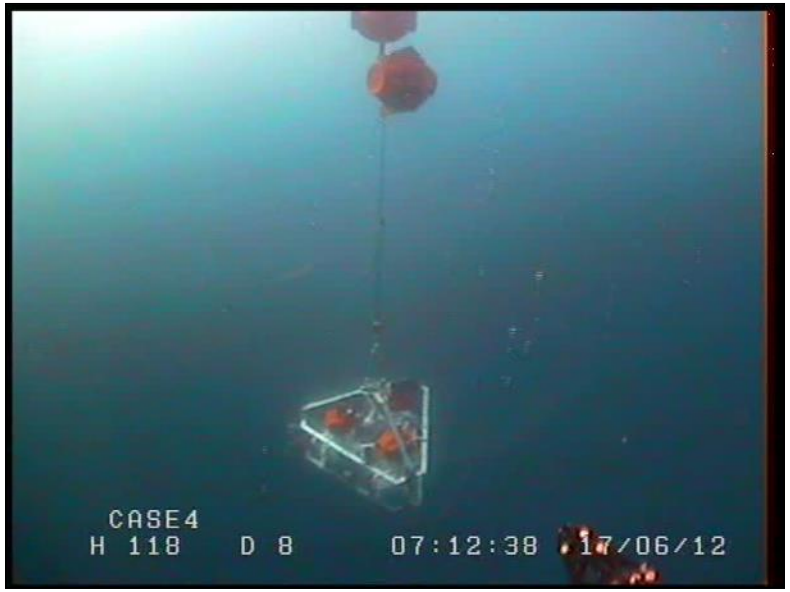
(Telesub Lanterna)

The CTD

(SBE 37-SI MicroCAT)

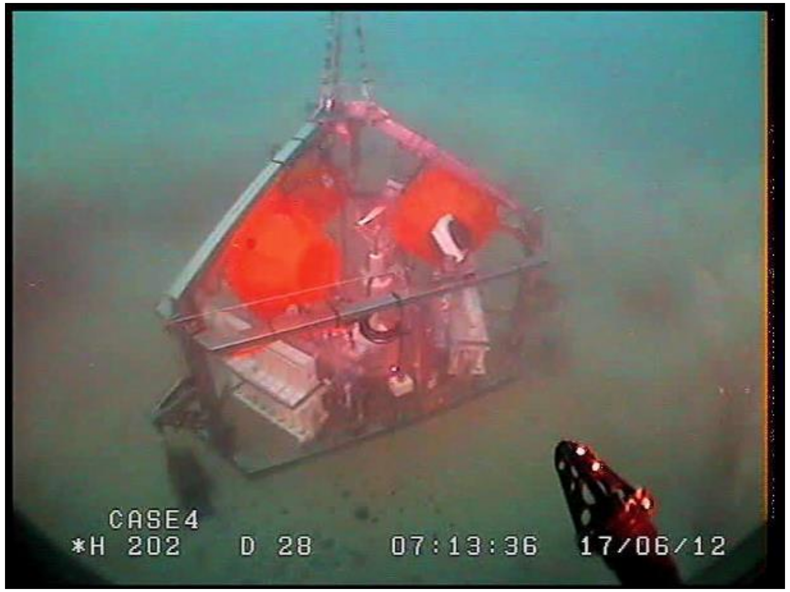


AMERIGO at work



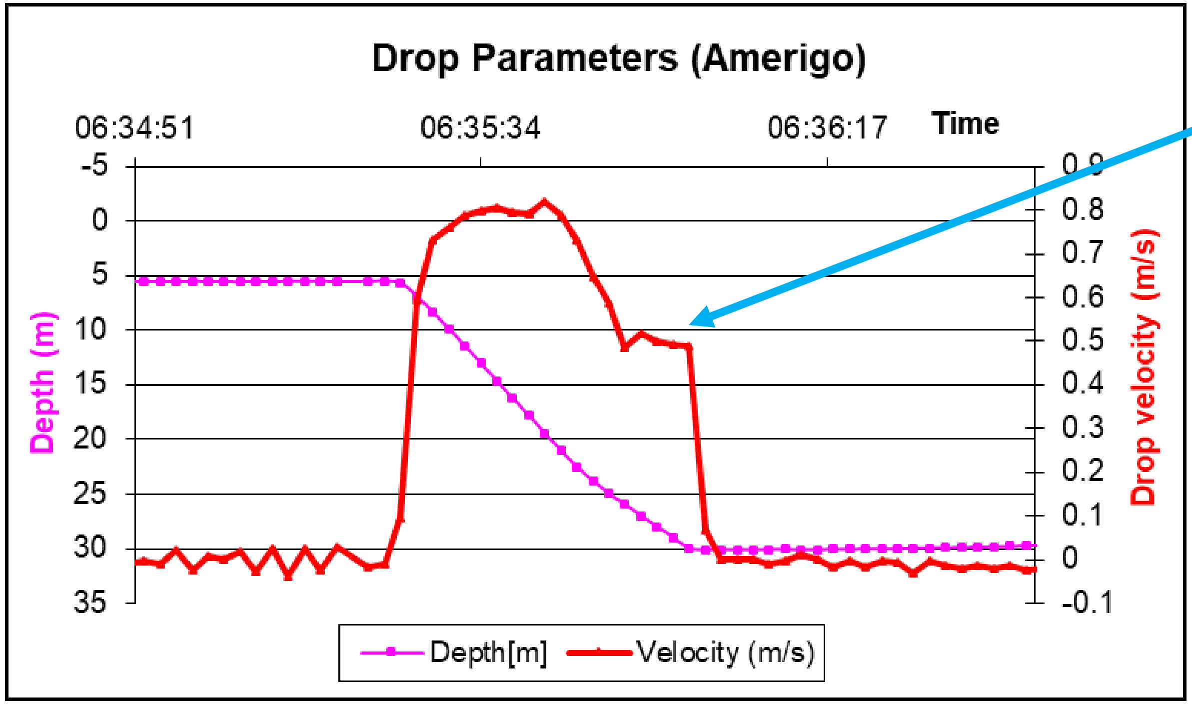
Controlled gravity Fall

On the bottom sea

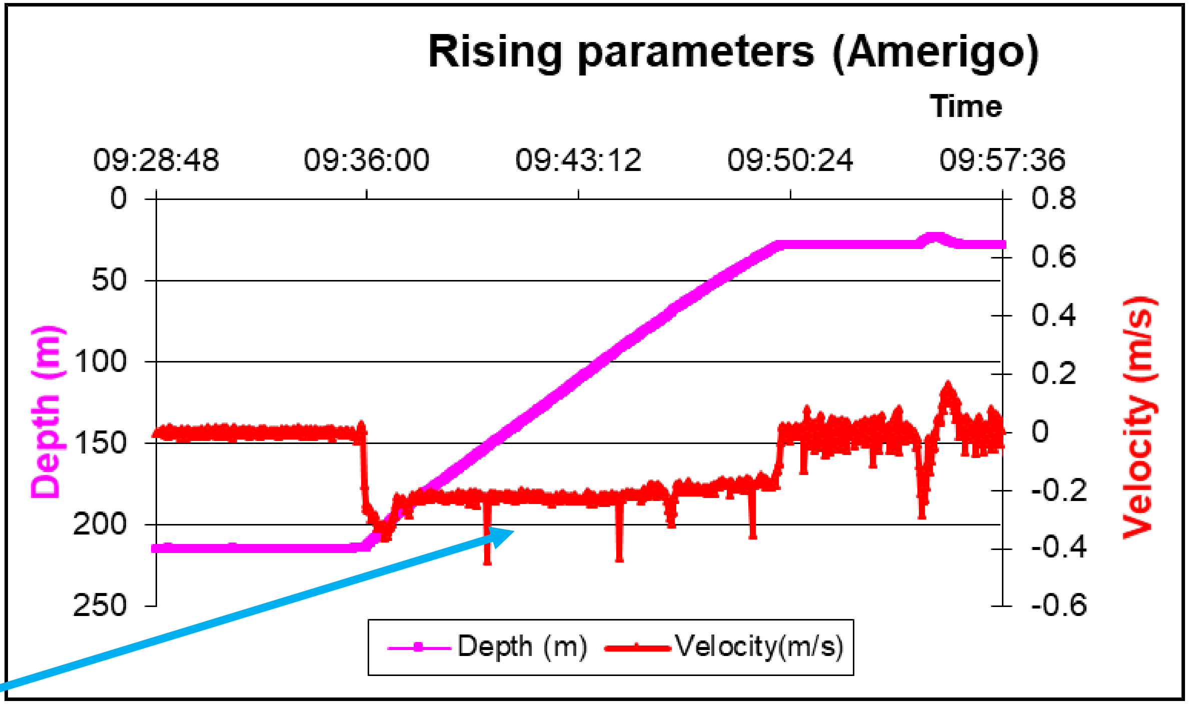


Survey activity

AMERIGO: technical data



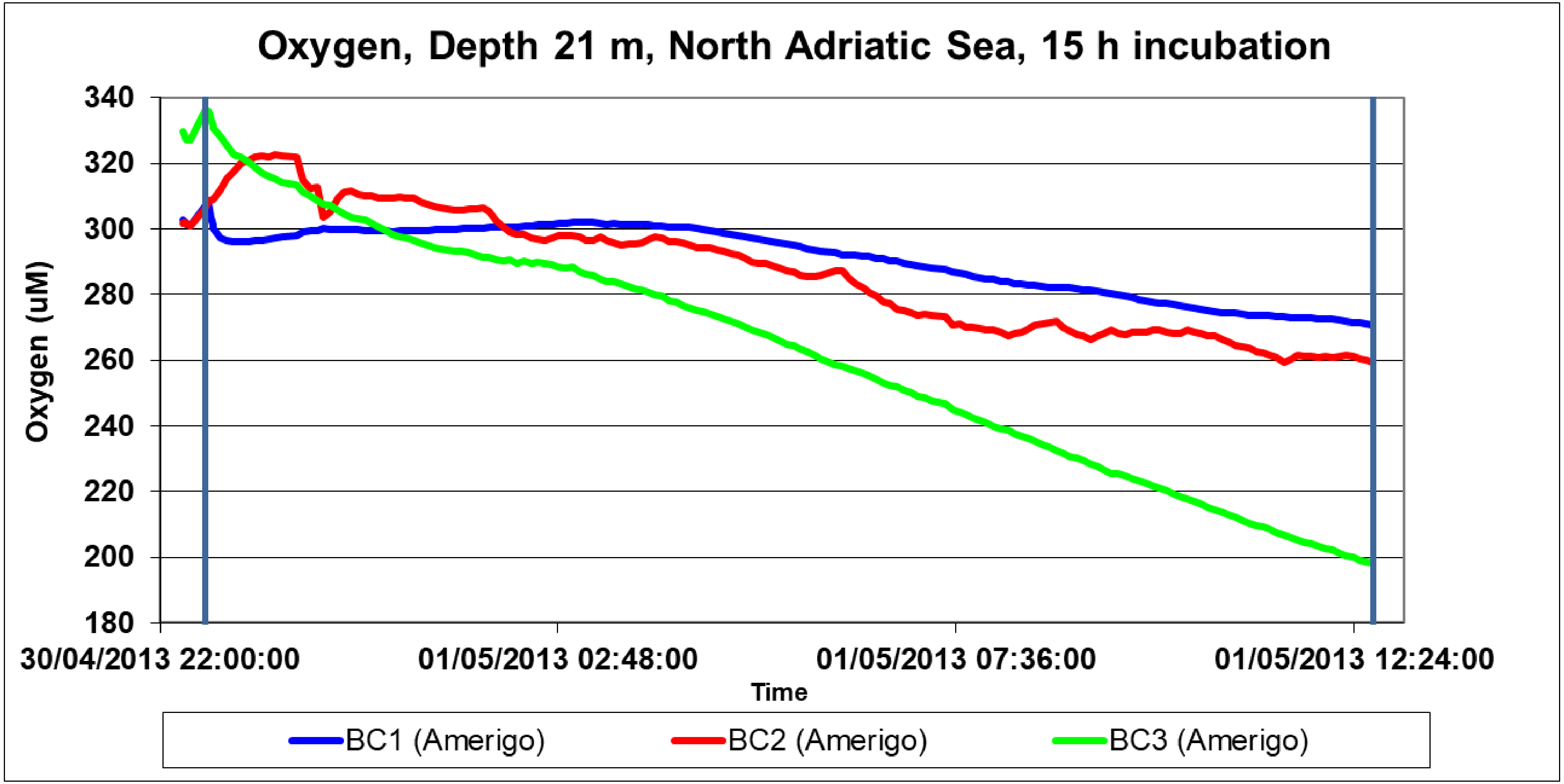
Fall rate: 0.5 m/s



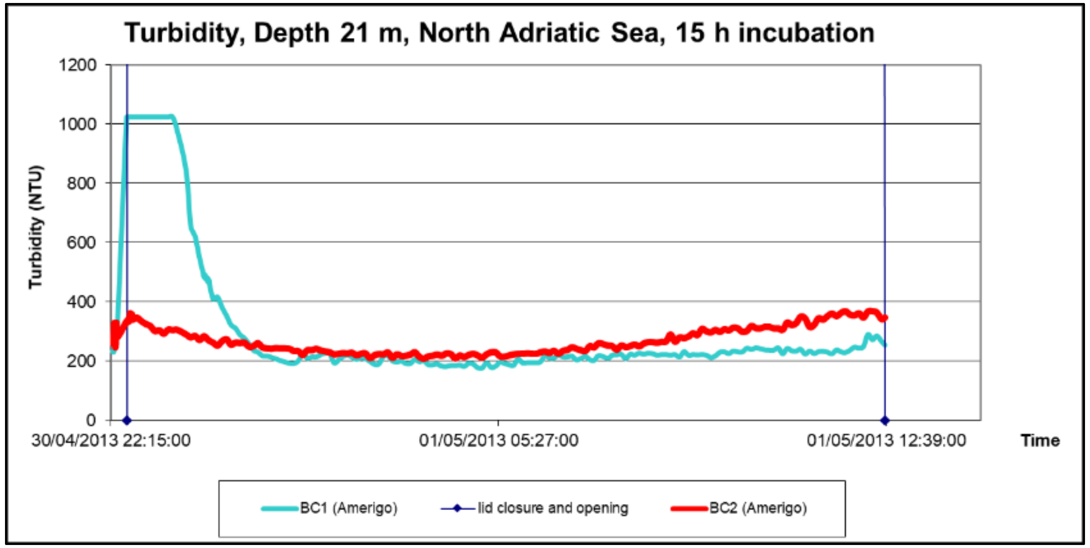
Rising rate: 0.2 m/s

AMERIGO: Sensor data

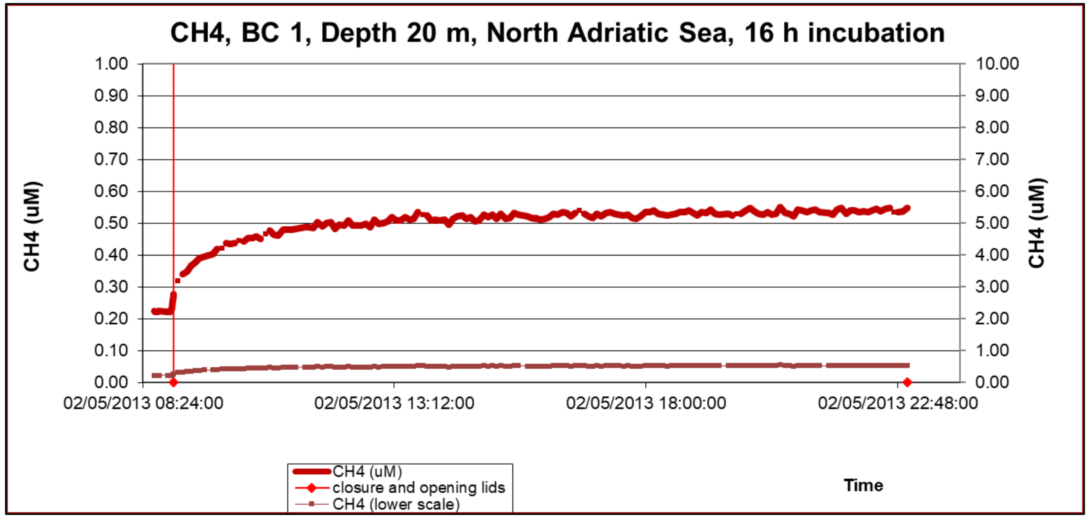
Oxygen in Benthic Chambers 1, 2 and 3



AMERIGO, Sensor data



Turbidity in Benthic Chamber 1 and 2

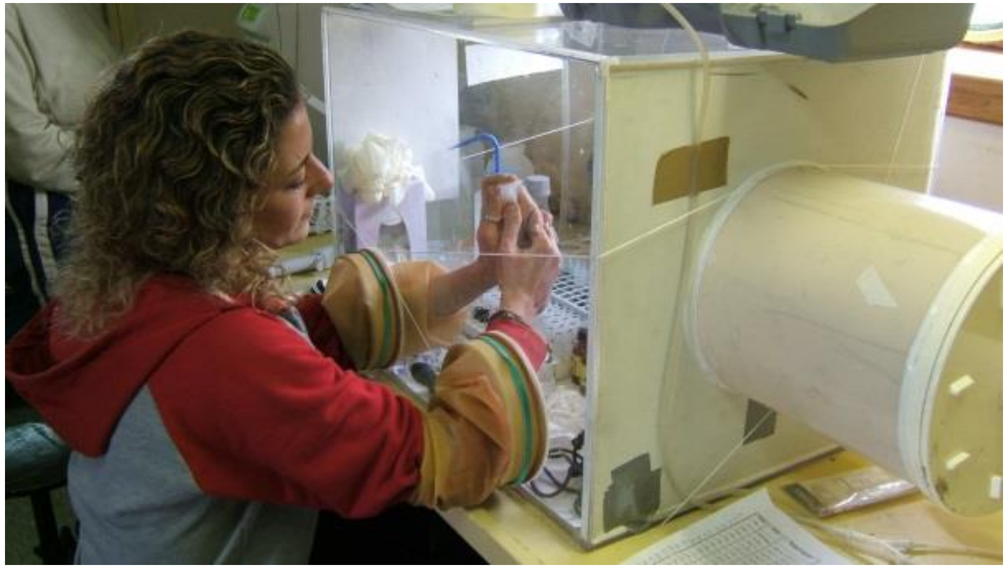


Methane in Benthic Chamber 1

Video Lander
Amerigo

Amerigo and AdaN: Water sample treatment and analyses

On board

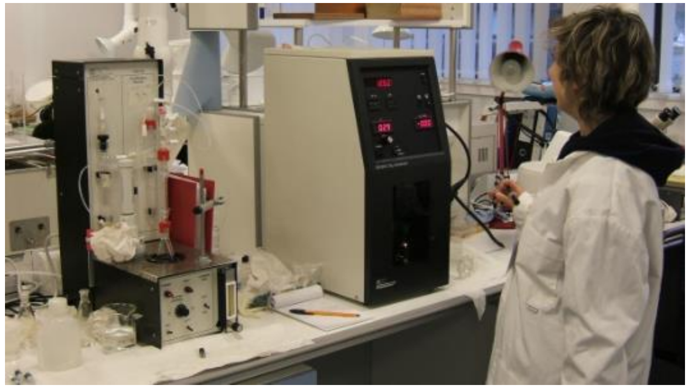


Water sample separation and conservation treatments in inert atmosphere for the following chemical analyses

Chemical analyses:

- Nutrients (NH_3, NO_3, NO_2, PO_4, $Si(OH)_4$);
- Metals (Fe, Mn, Ca, Mg);
- DIC, Alkalinity;
- others (organic and inorganic pollutants, other metals, etc.).

Laboratory analyses

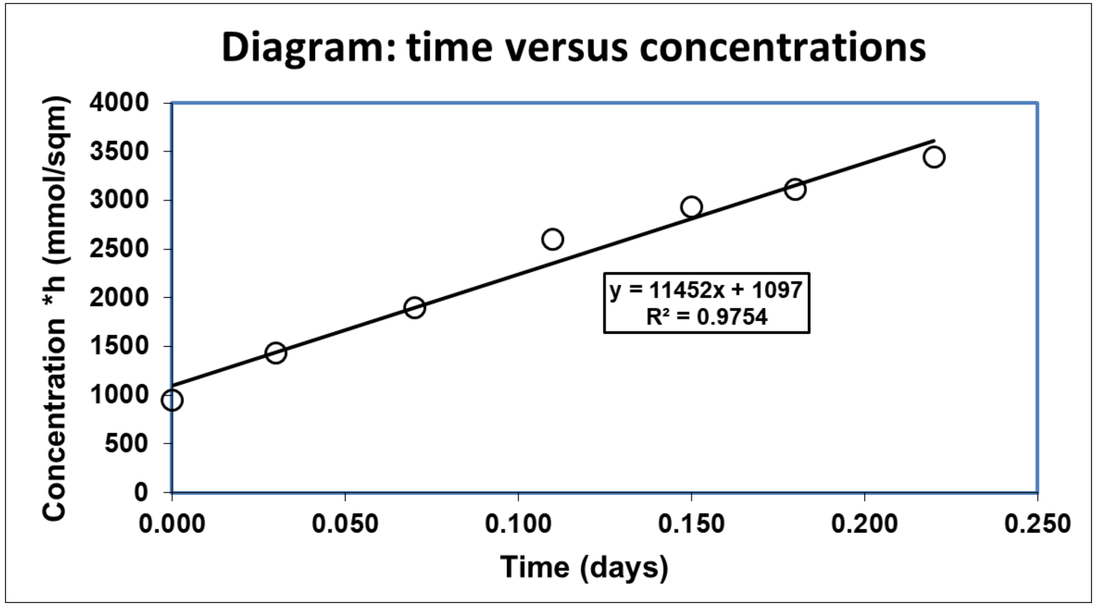


On board analyses

Dissolved flux calculations

Dissolved fluxes at the sediment-water interface are calculated by:

- Dividing the concentration of each chemical species (measured in the water samples collected or measured by probes, inside the chamber) by the time of collection/measurement
- Multiplied by the volume of the chamber
- Divided by the bottom area of the chamber



$$J = \frac{\partial C_i}{\partial t}\,(V/A)$$

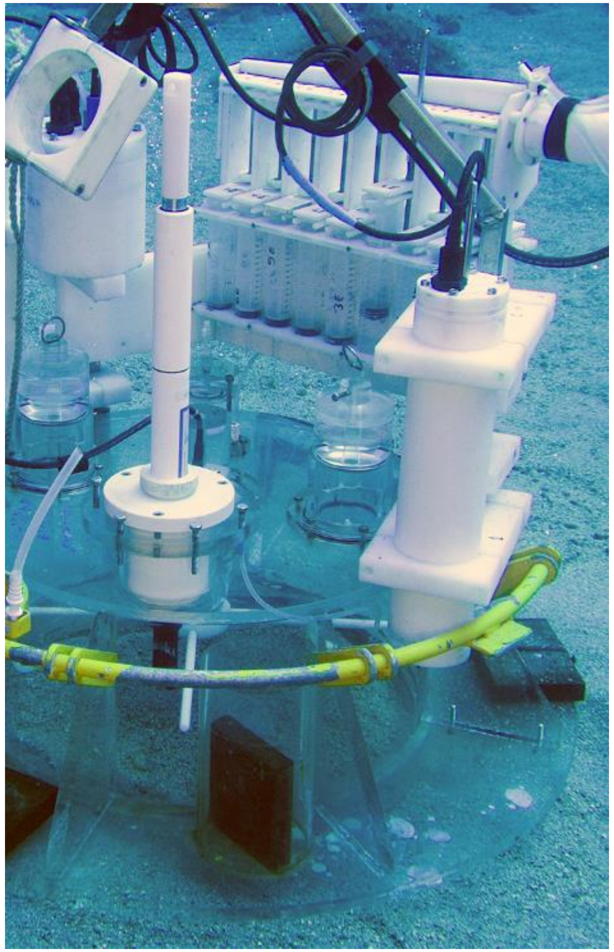
J = Flux at sediment-water interface
C_i= Concentration of i^{th} chemical compound
t = time of measurement
V = actual volume of the chamber
A = bottom area of the chamber

$$J = m * h$$

m = angular coefficient (slope) of the C_i/A – t
h = height of the benthic chamber

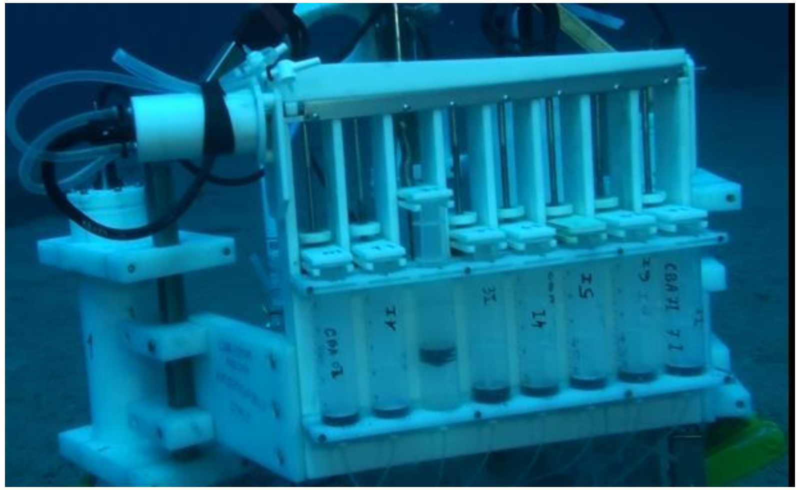
Determination of real internal volume of the chamber

The real volume of the chamber during the deployment is determined by injecting a tracer (CsCl or deionized water) in the chamber



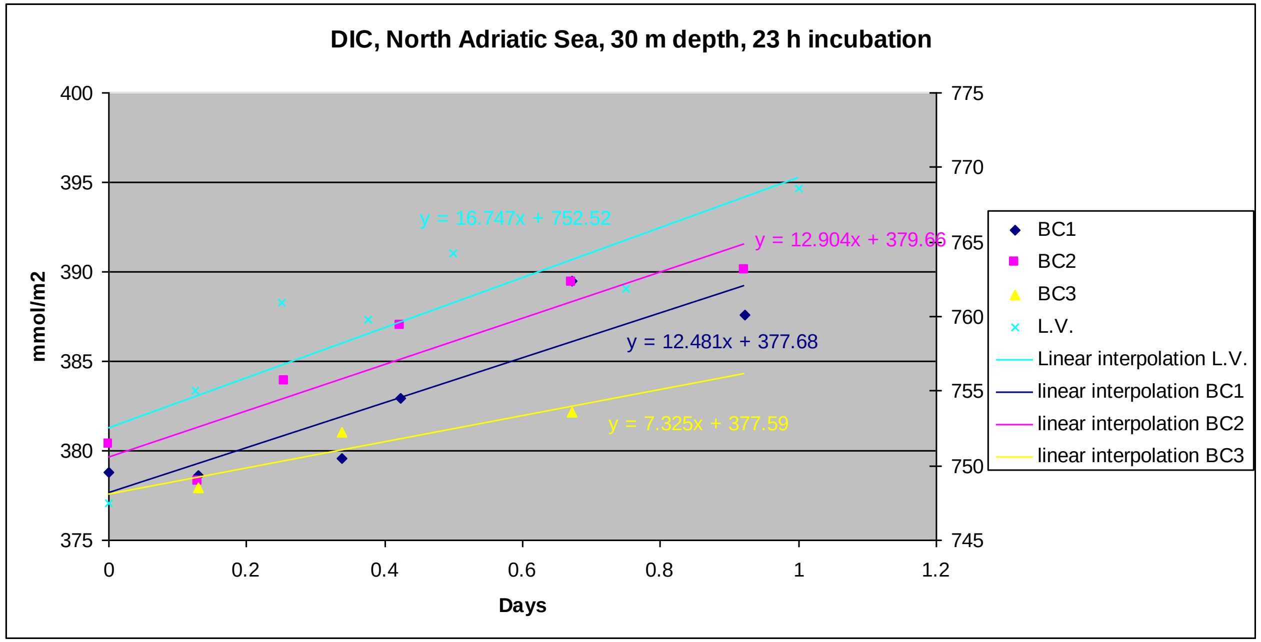
$$V_2 = \frac{\partial V_1}{C_1}\ C_2$$

C_1= Concentration of tracer laboratory solution
V_1 = volume of the tracer injected
C_2= concentration of the tracer inside the chamber
$V2_2$ = actual volume of the chamber

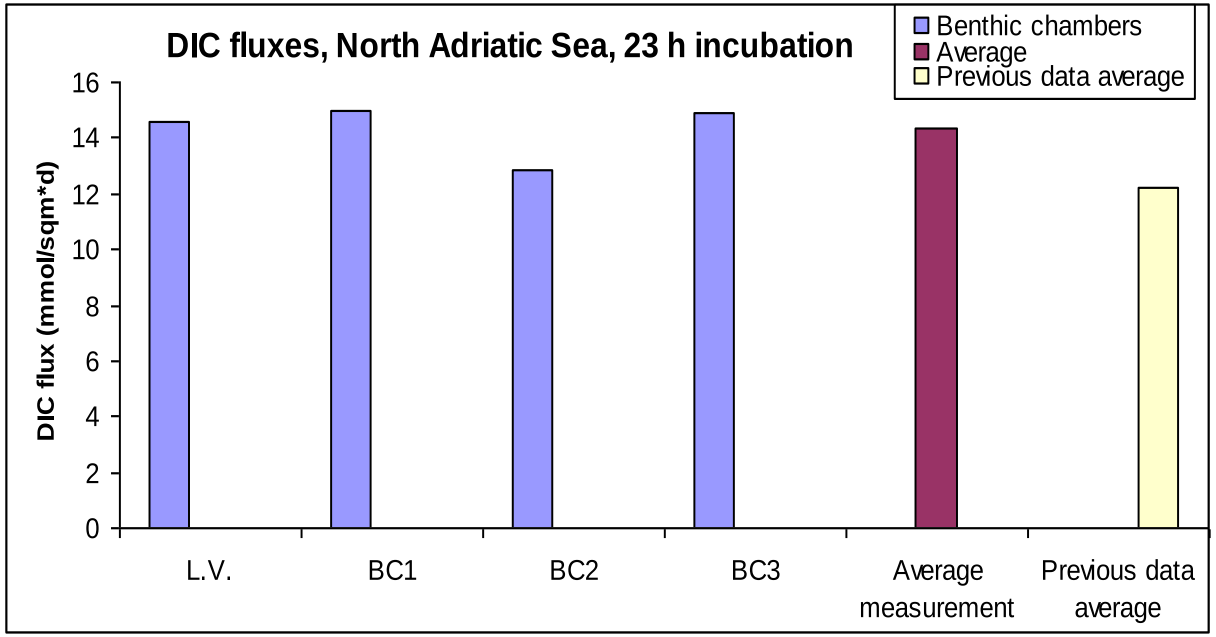


AMERIGO and AdaN data comparison

DIC surface concentration in Benthic Chamber 1, 2, 3 and AdaN (L.V.)



DIC benthic fluxes in chamber 1, 2, 3 and AdaN (L.V.) and previous data



Calculated benthic fluxes

$$J_i = -\emptyset D_i \left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$

$\emptyset$= porosity

$D_i = diffusion\ coefficent$

The diffusive exchange of solutes through the Sediment-water interface can be calculated from concentration gradients along the sediment water boundary by applying Fick's first law of diffusion

(Berner, 1980)

$$\left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$

concentration gradients at the Sediment-water interface

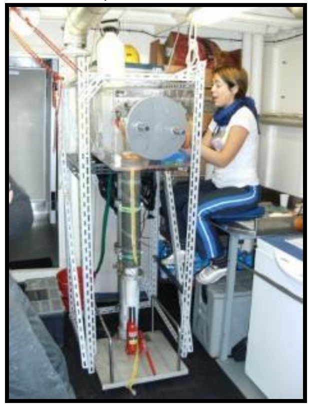
Early diagenesis studies

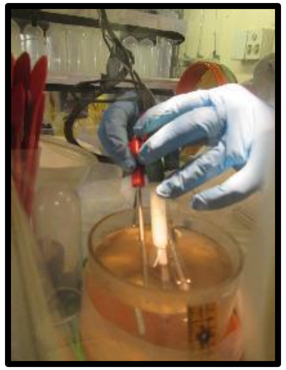
Early diagenetic processes are investigated by sediment cores collected by SW104 corer.

CORE SAMPLING

Sediment collected by SW104 corer

PORE WATER EXTRACION

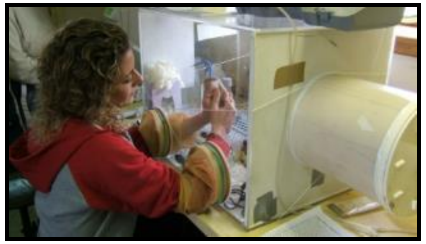




Sediment core slicing in inert atmosphere

Sediment slices centrifugation in inert atmosphere

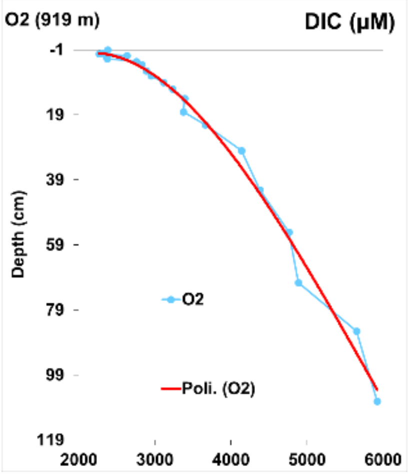
PORE WATER ANALYSES



Pore water filtration, separation and conservation treatment in inert atmosphere

analyses

PORE WATER MODELING



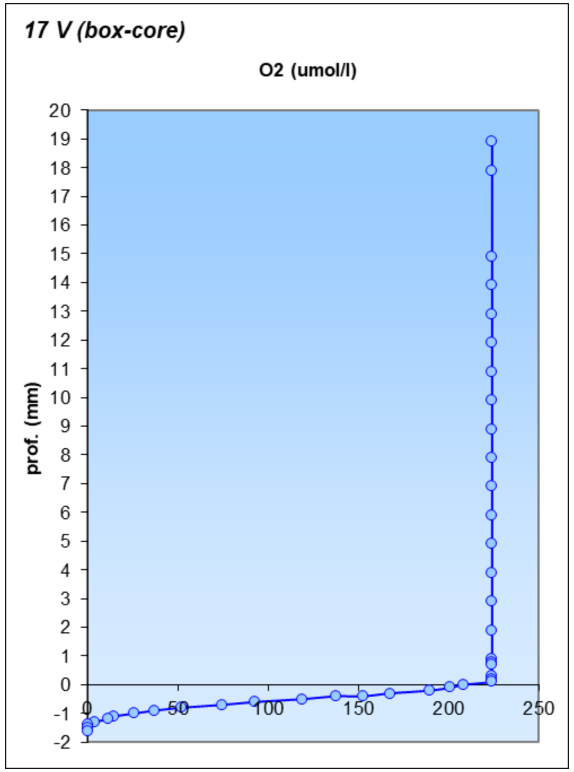
$$\frac{\delta C}{\delta t} = Ds\left(\frac{\delta^2 C}{\delta z^2}\right) - w(1+K)\left(\frac{\delta C}{\delta z}\right) + R_z + I_z = 0$$

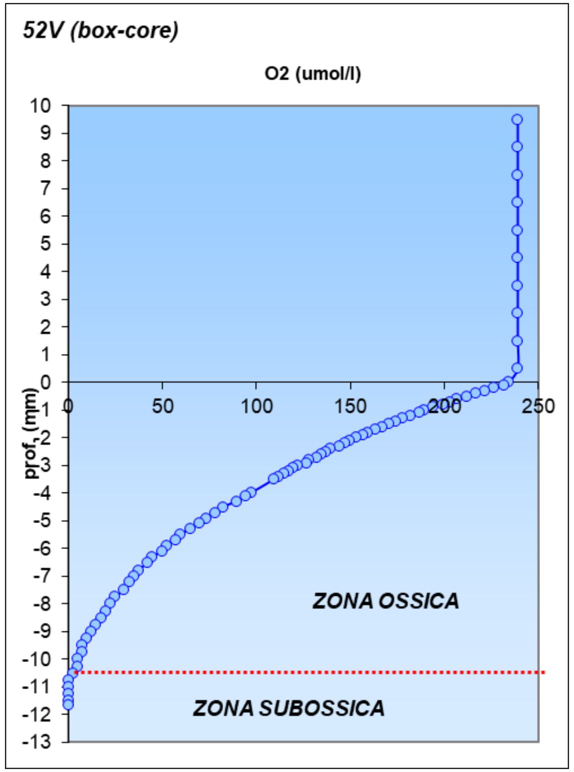
Early diagenesis studies

In-situ profiling with a microprofiler (MPI Bremen/AWI)

On-board profiling with a microprofiler (CNR)

Pore water microprofiling at the sediment-water interface





Calculated benthic fluxes

$F_{total} = F_{diff} + F_{irr} + F_{adv}$

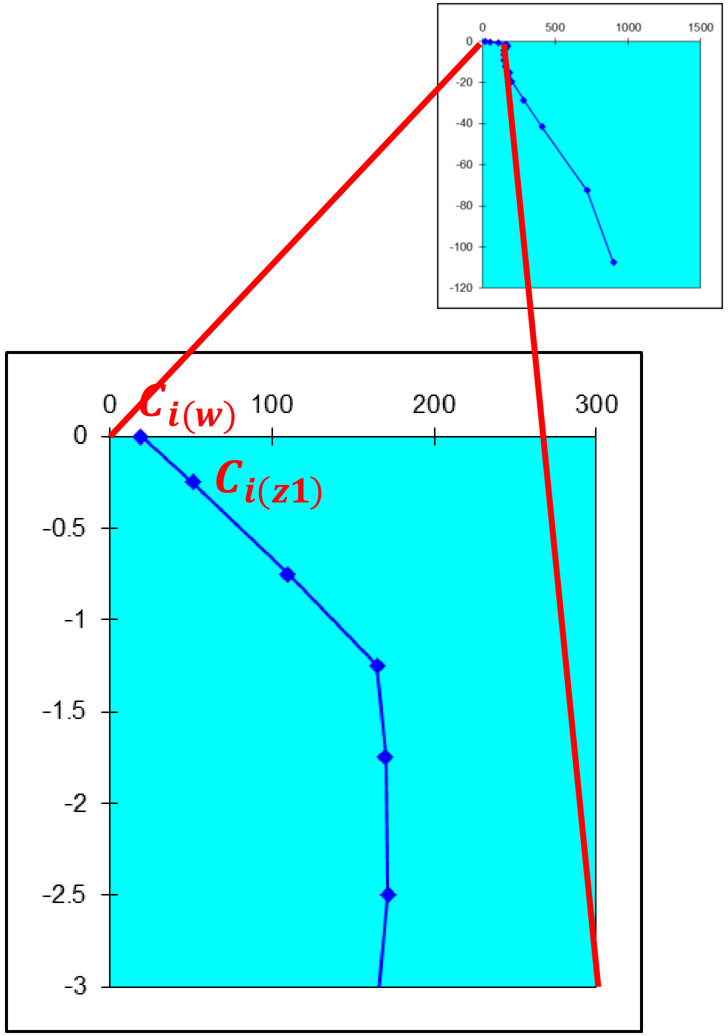
where

F_{total} is the total benthic fux

F_{diff} molecular diffusion

F_{irr} irrigation

F_{adv} advection



Calculated (diffusive) fluxes (mmol/m²*day)

$$\left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$ **Gradient at z=0**

First approach: $\frac{C_{i(w)}}{C_{i(z_1)}}$

$C_{i(w)}$ = Concentration of i^{th} chemical compoundin near sea bottom water

$C_{i(z1)}$ = Concentration of i^{th} chemical compoundin in the first near surface core sediment sample

Calculated benthic fluxes

$F_{total} = F_{diff} + F_{irr} + F_{adv}$

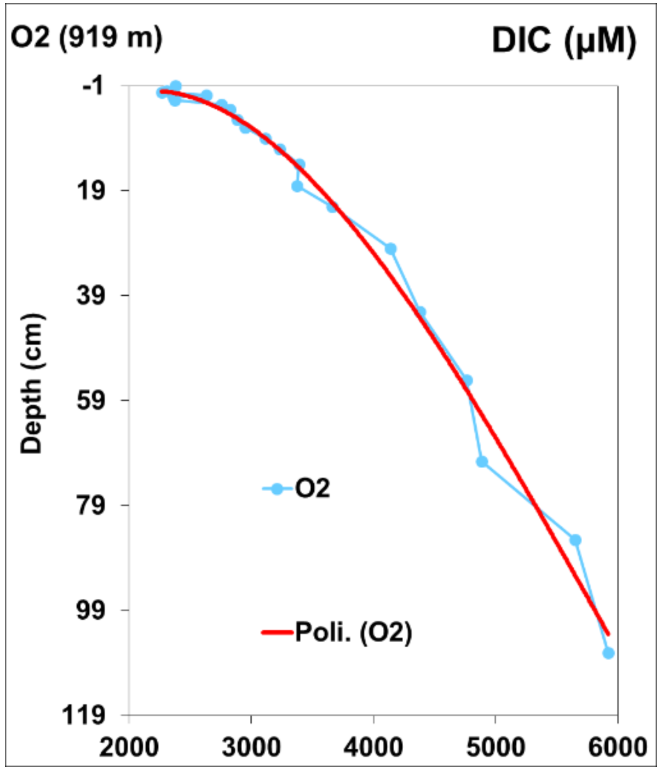
where

F_{total} is the total benthic fux

F_{diff} molecular diffusion

F_{irr} irrigation

F_{adv} advection



$$\frac{\delta C}{\delta t} = Ds\left(\frac{\delta^2 C}{\delta z^2}\right) - w(1+K)\left(\frac{\delta C}{\delta z}\right) + R_z + I_z = 0$$

General diagenetic equation

(Berner, 1980)

Ds = diffusion coefficient

z = depth

w = accumulation rate

R_z = adsorpion-desorption

I_z = irrigation

R_z = constant $C = C_0 + a_1 z$

R_z = quadratic $C = C_0 + a_1 z + a_2 z^2$

R_z = exponential $C = C_\infty\left(1 - e^{bz}\right) + C_0 e^{-bz}$

$$\left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$

Measured and calculated bethic fluxes

Measured fluxes from the benthic chamber

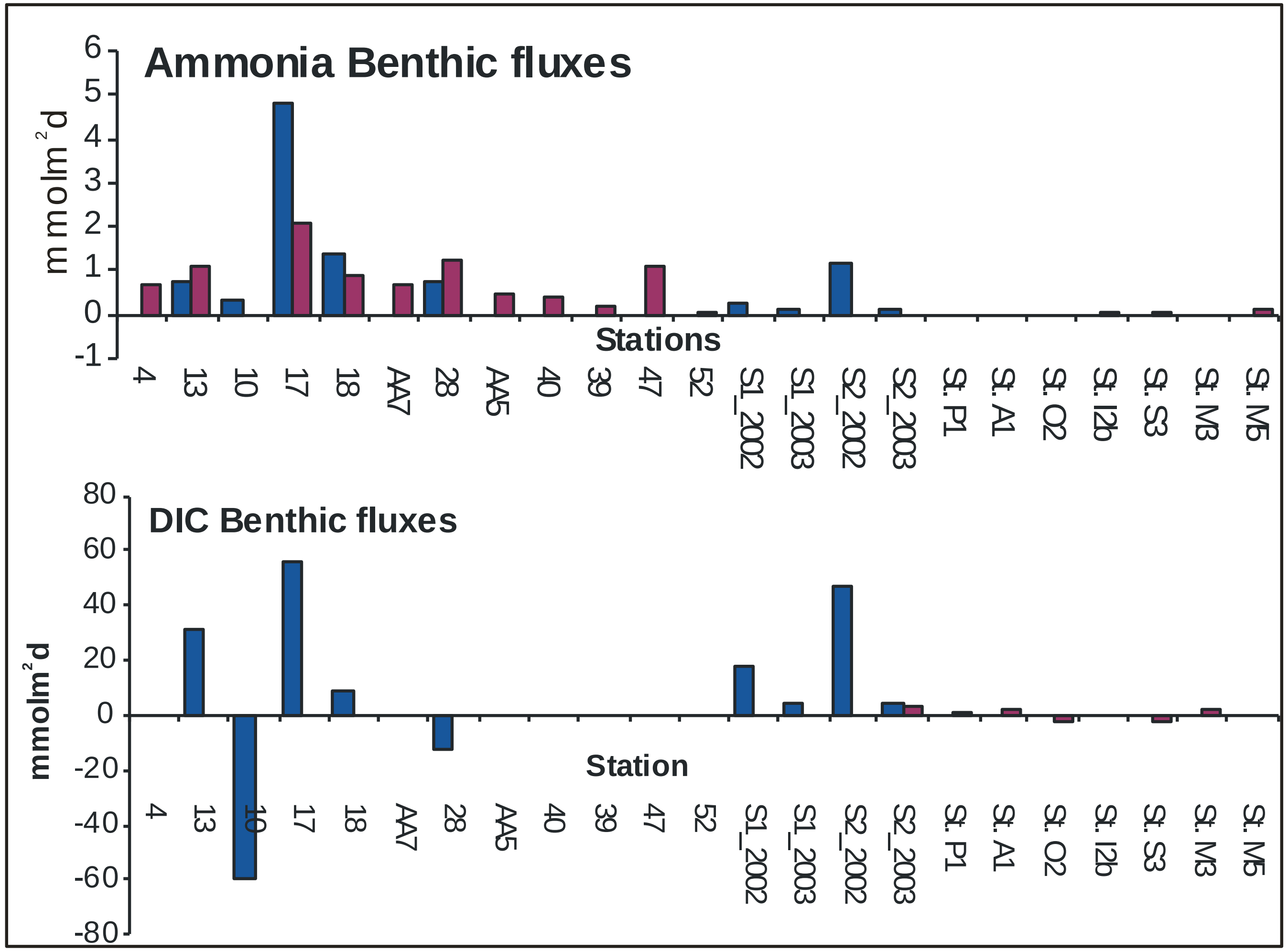
$$J = \frac{\partial C_i}{\partial t} V/A$$

Calculated fluxes from pore waters

$$J_i = -\emptyset D_i \left(\frac{\partial C_i}{\partial z}\right)_{z=0}$$

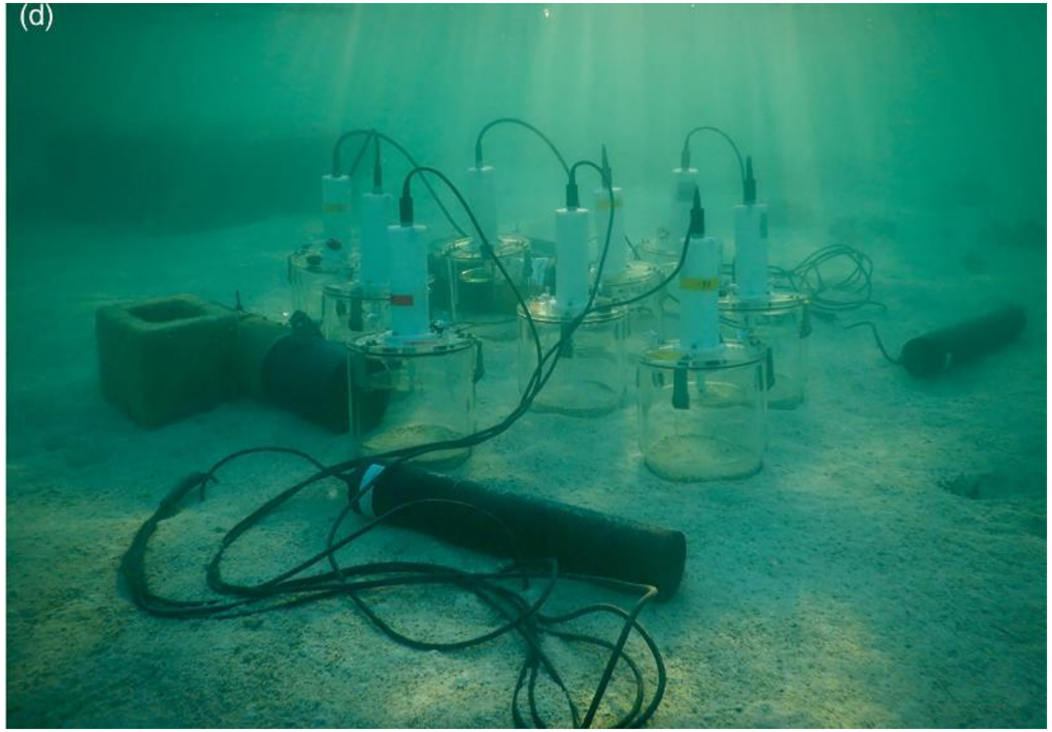
- **Irrigation**
- **Bad definition of sediment water interface gradient**

Measured and calculated benthic fluxes

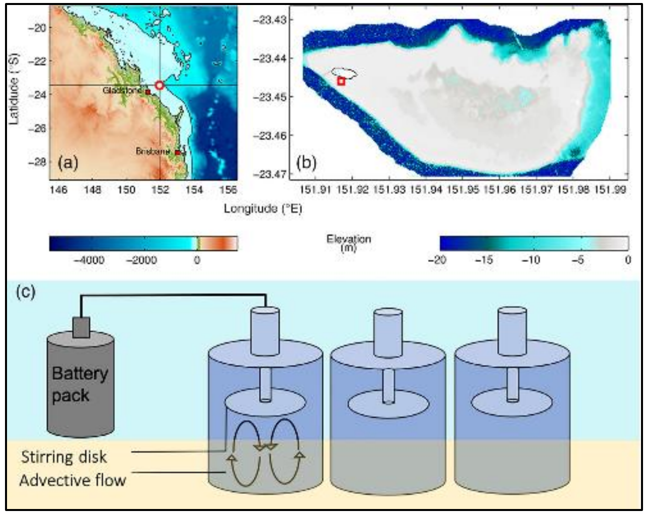


- Benthic fluxes generally decrease from Po River mouths (increasing distances from main sediment and nutrient sources, continuous reworking, lower primary production, less reactive organic matter)

- Negative DIC fluxes in central Adriatic and Ionian slopes (DIC sediment trap?)



Tests and simulations



LIMNOLOGY and OCEANOGRAPHY

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Seasonal variability of calcium carbonate precipitation and dissolution in shallow coral reef sediments

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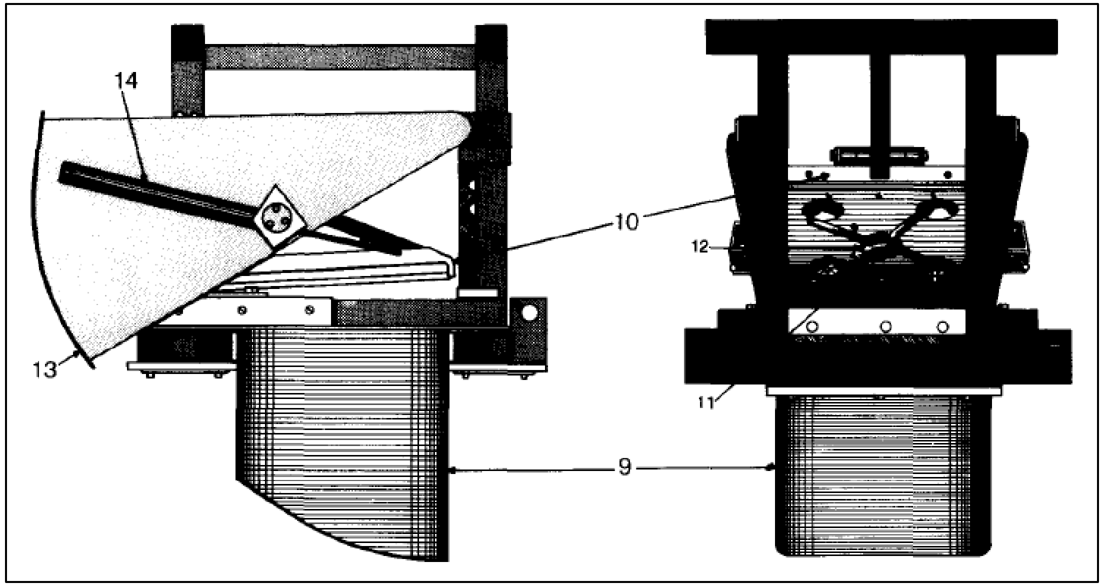
[2]Halmos College of Natural Science and Oceanography, Nova Southeastern University, Dania Beach, Florida

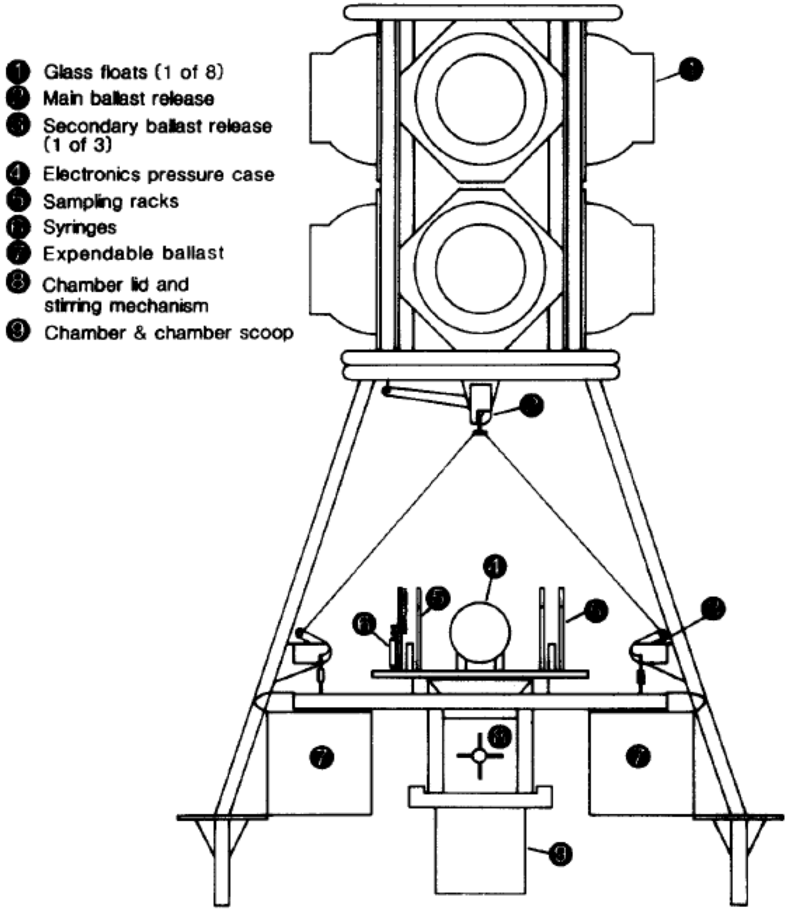
Abstract

Shallow, permeable calcium carbonate ($CaCO_3$) sediments make up a large proportion of the benthic cover on coral reefs and account for a large fraction of the standing stock of $CaCO_3$. There have been a number of laboratory, mesocosm, and in situ studies examining shallow sediment metabolism and dissolution, but none of these have considered seasonal variability. Advective benthic chambers were used to measure in situ net community calcification (NCC) rates of $CaCO_3$ sediments on Heron Island, Australia (Great Barrier Reef) over an annual cycle. Sediments were, on average, net precipitating during the day and net dissolving at night throughout the year. Night dissolution rates ($-NCC_{NIGHT}$) were highest in the austral autumn and lowest in the austral winter driven by changes in respiration (*R*) and to a lesser extent temperature and Ω_{arag}/pH. Similarly, precipitation during the day ($+NCC_{DAY}$) was highest in March and lowest in winter, driven primarily by benthic net primary production (NPP) and temperature. On average, sediments were net precipitating over a diel cycle (NCC_{24h}) but shifted to net dissolving in July and December. This shift was largely caused by the differential effects of seasonal cycles in organic metabolism and carbonate chemistry on NCC_{DAY} and NCC_{NIGHT}. The results from this study highlight the large variability in sediment $CaCO_3$ dynamics and the need to include repeated measurements over different months and seasons, particularly in shallow reef systems that can experience large swings in light, temperature, and carbonate chemistry.

Benthic chambers and landers

Side and front views of the chamber assembly.

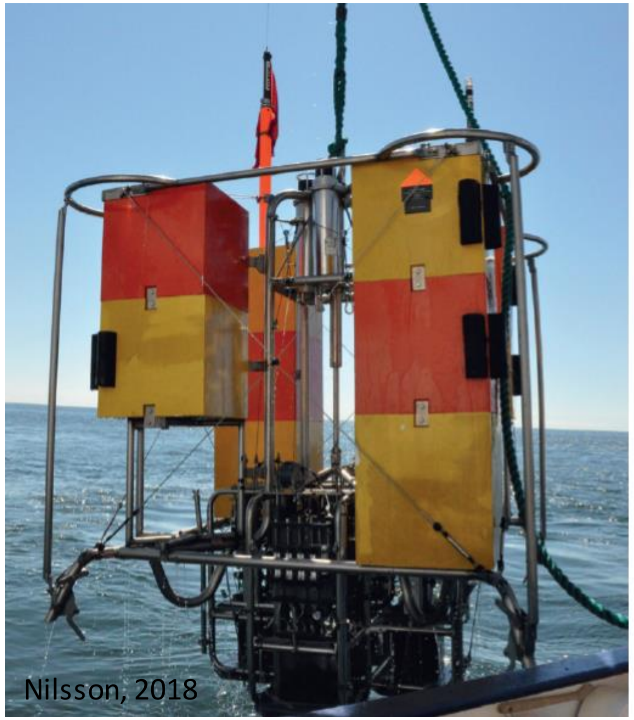




Titanium chamber (9)
chamber lid (10),
gasket in the upper edge of the chamber against which the lid seals (11)
chamber water stirring mechanism (12)
scoop for recovering the sediments within the chamber at the end of the experiment (13)
hydraulic cylinder (1 of 2) which closes the scoop (14)

Jahnke and Christiansent, 1989

Other benthic chambers



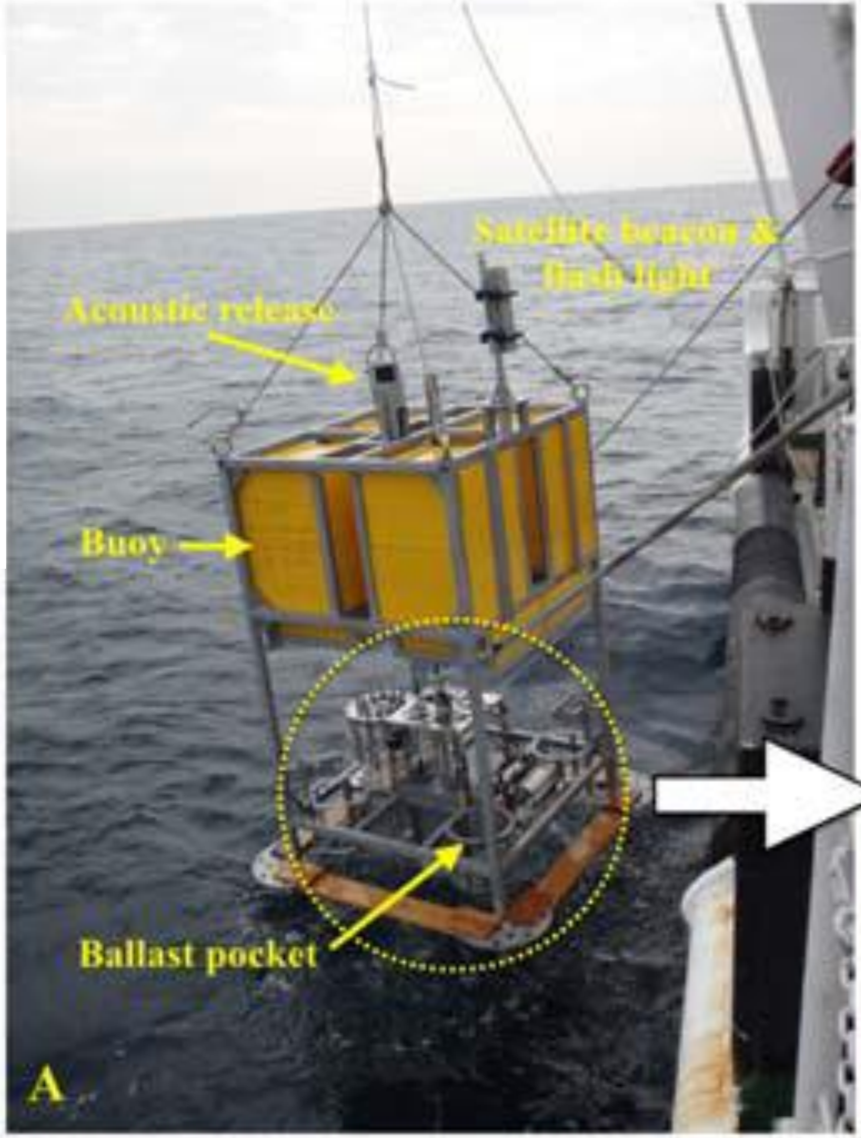
Gotheborg benthic lander recovery

Benthic chamber with syringes samplers

The KIOST benthic lander

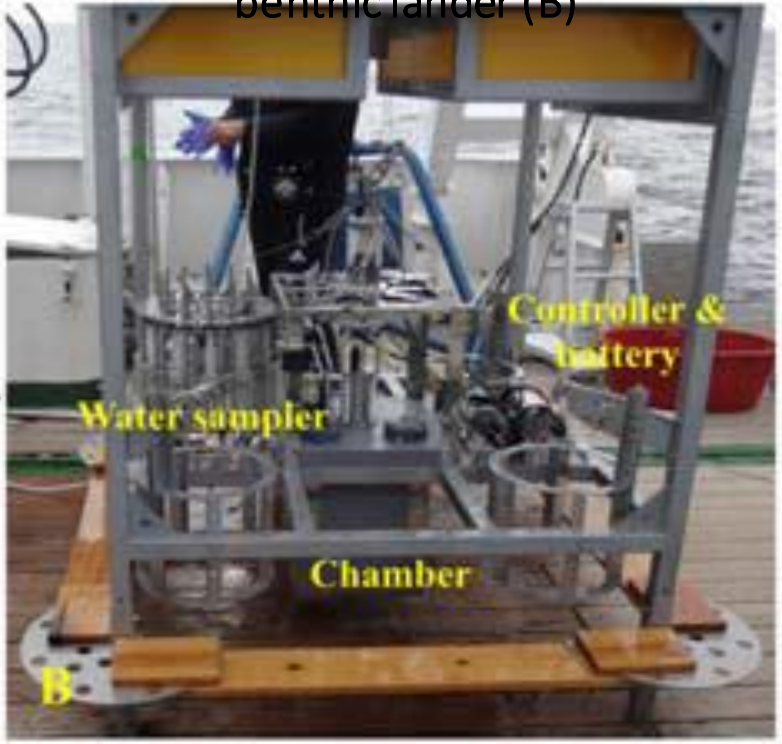
Lee et al., 2015

	Specification
Frame materials	SUS312
Chamber materials	PVC
Water sampler materials	SUS316
Height (cm)/Weight (kg)	250/550
Positive buoyance (kg)	~ 62
Chamber area (cm^2)	841
Stirring speed (rpm)	30–35
Acoustic release	Teledyne Benthos, 865-A
DC power (V)	17 V
DO sensor	Aanderra Oxygen Optode 4330DW



Recovery of the benthic lander (A)

BelcII: Chamber, water sampler, and controller with power supply) is installed in the lower part of the benthic lander (B)



Ultra-landers (11000 m depth)

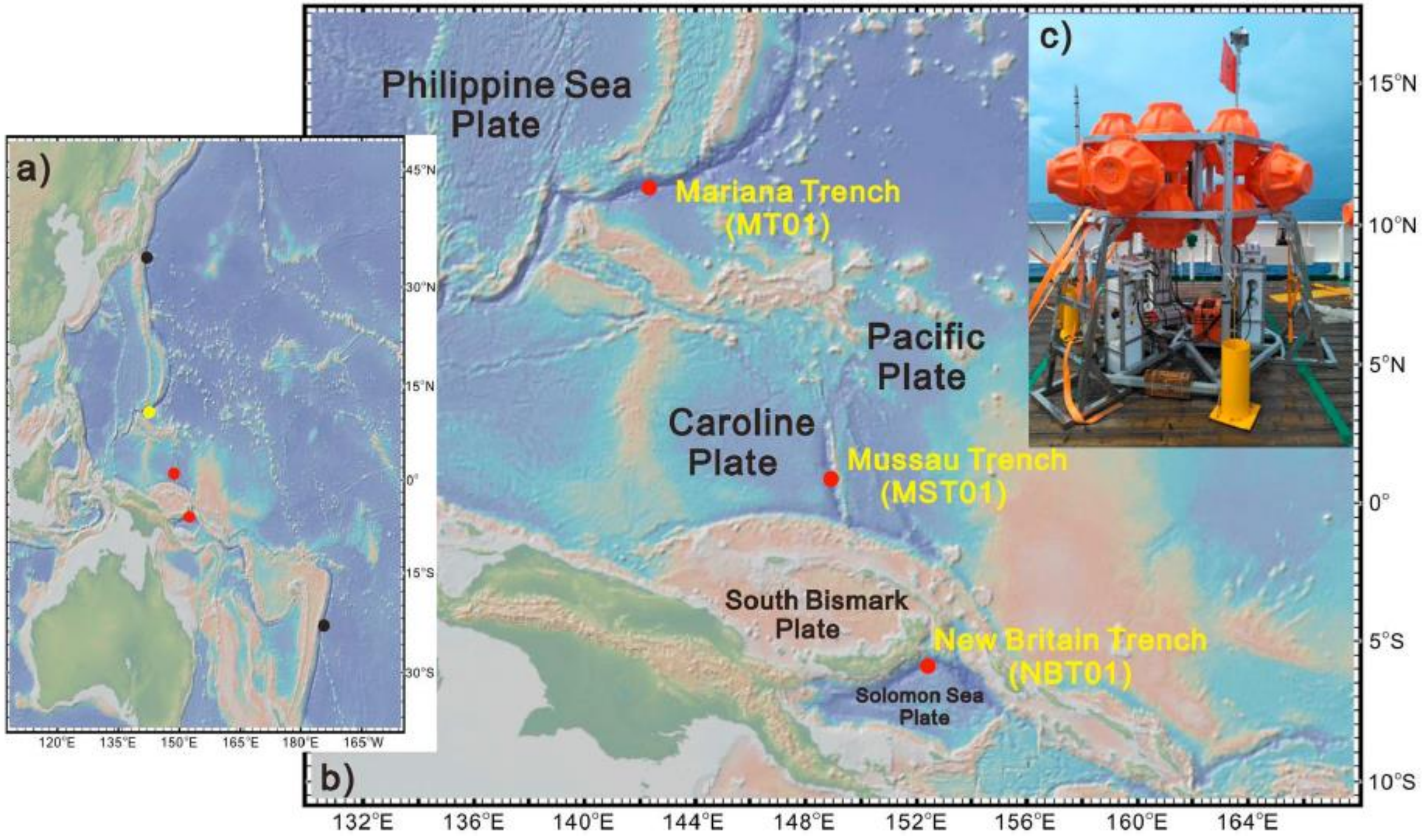


Figure 1. (a) Locations of available in situ benthic O_2 flux data from hadal settings. The black dots represent the sites reported in Wenzhöfer et al. (2016). T
are the lander deployment sites of this study. The yellow dot represents the overlapped site of this study and Glud et al. (2013). (b) Overview of the stuc
locations of lander deployment sites reported in this study (red dots). (c) Picture of the lander (Lander-II) prior to deployment.

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1002/2017GL076232

Key Points:
- Total oxygen uptakes were measured for the first time in hadal trenches using in situ benthic chamber incubations
- Data compilation from hadal trenches suggests that rates of benthic carbon mineralization reflect the surface ocean productivity
- However, factors governing the diagenetic activity in hadal trenches apparently include supply of terrestrial organic material

Supporting Information:
- Supporting Information S1

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Citation:
Luo, M., Glud, R. N., Pan, B., Wenzhöfer, F., Xu, Y., Lin, G., & Chen, D. (2018). Benthic carbon mineralization in hadal trenches: Insights from in situ determination of benthic oxygen consumption

Benthic Carbon Mineralization in Hadal Trenches: Insights From In Situ Determination of Benthic Oxygen Consumption

Min Luo[1,2,3], Ronnie N. Glud[4,5], Binbin Pan[1], Frank Wenzhöfer[6,7], Yunping Xu[1], Gang Lin[1], and Duofu Chen[1,2]

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Abstract Hadal trenches have been proposed as depocenters of organic material and hot spots for organic matter mineralization. In this study, we for the first time quantified the total benthic O_2 uptake in hadal trenches using in situ chamber incubations. Three trenches in the tropical Pacific were targeted and exhibited relatively high diagenetic activity given the great water depths, that is, the Mariana Trench (2.0×10^2 µmol O_2 m^{-2} d^{-1}, 10,853 m), the Mussau Trench ($2.7 \pm 0.1 \times 10^2$ µmol O_2 m^{-2} d^{-1}, 7,011 m), and the New Britain Trench ($6.0 \pm 0.1 \times 10^2$ µmol O_2 m^{-2} d^{-1}, 8,225 m). Combined with the analyses of total organic carbon and $\delta^{13}C$ of total organic carbon in the sediments and previously published in situ O_2 microprofiles from hadal settings, we suggest that hadal benthic carbon mineralization partly is governed by the surface production and also is linked to the distance from land. Therefore, we highlight that terrestrial organic matter can be of importance in sustaining benthic communities in some hadal settings.

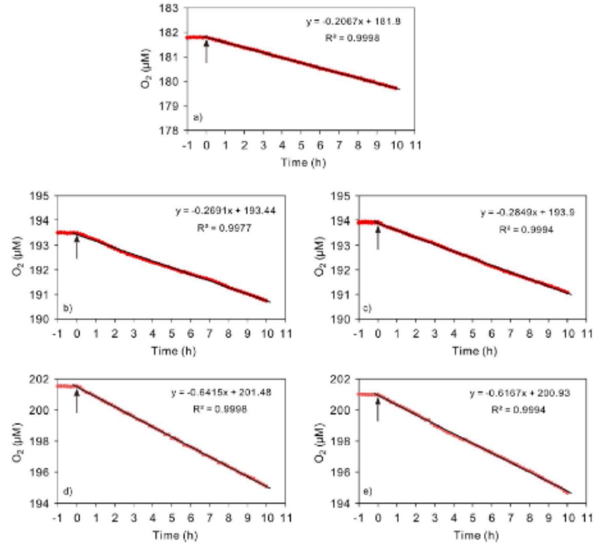


Figure 2. O_2 concentrations measured during chamber deployments at the trench axes of the (a) Mariana Trench, (b and c) the Mussau Trench, and the (d and e) New Britain Trench. The arrows indicate the time when the lids were closed and incubations started. Straight lines represent the linear regression fits to the measured O_2 concentrations. Due to malfunctioning of the newly customized optodes, we only successfully obtained one set of O_2 data from the Mariana Trench and two sets of O_2 data from the Mussau Trench and the New Britain Trench, respectively. Data were provided by one oxygen optode in each chamber.

(A) Autonomous Underwater Vehicle (AUV ABYSS);

(B) Ocean Floor Observing System (OFOS);

(C) Remotely-Operated Vehicle (ROV Kiel 6000);

(D) teleoperated crawler of ONC (Ocean Networks Canada: http://www.oceannetworks.ca);

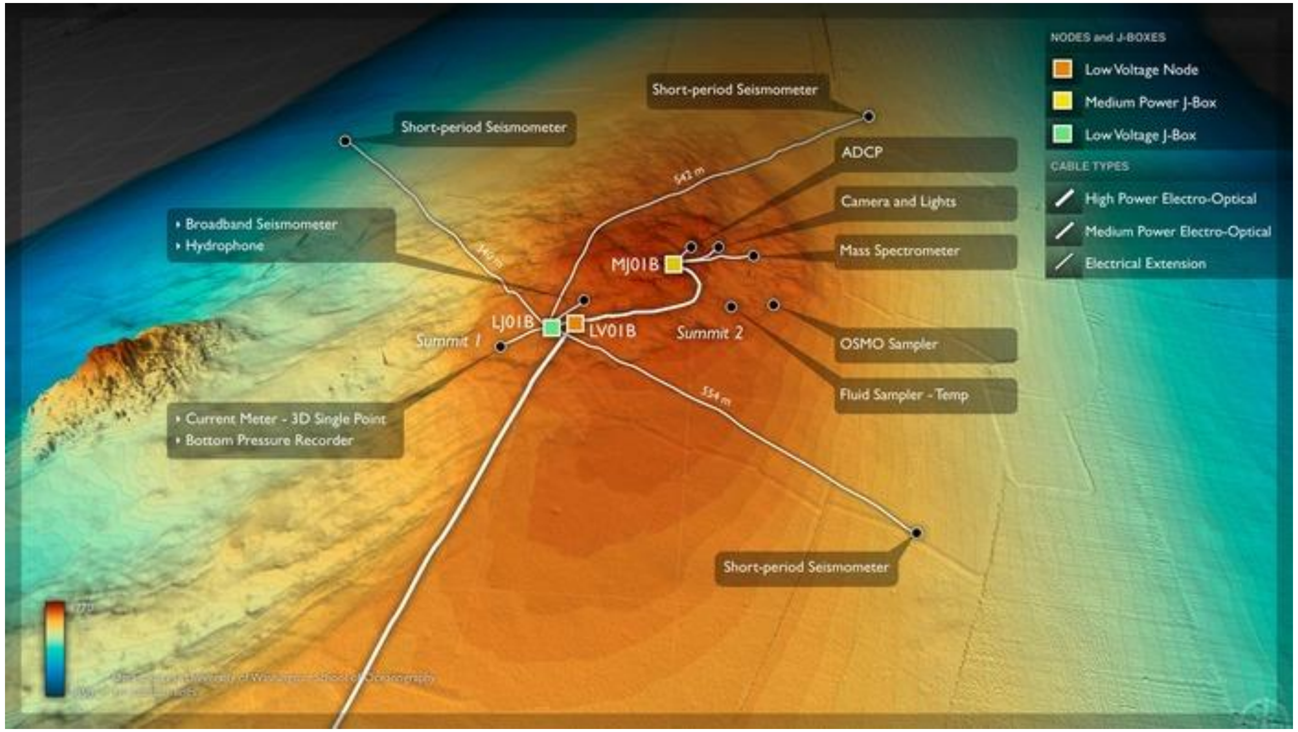
(E) stationary lander system (these can also be equipped with baited traps, as shown in the image).

Brandt et al., 2016

Cutting the Umbilical: New Technological Perspectives in Benthic Deep-Sea Research

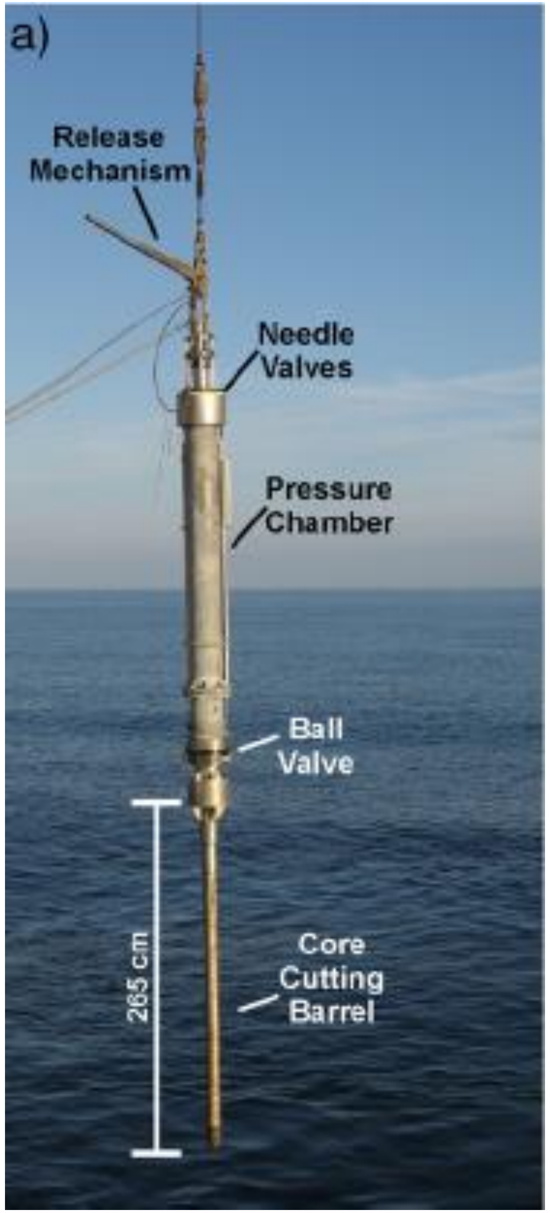
Autonomous seafloor vehicle:
combination of central lander and mobile robot for operations of up to 6 km
the crawler returns to the central station to transfer the data and recharge it batteries (http://www.robex-allianz.de/en/).
Source: Geomar; design: Meyer.

Hydrate Ridge



Regional Scale Nodes study sites (Hydrate Ridge)

The real-time interactive capabilities of the cabled observatory are critical to studying gas-hydrate systems because many of the key processes may occur over short time scales and will require adaptive response and sampling capabilities that include fluid sampling, increases in data accumulation rates and imagery from cameras, and in situ manipulation of chemical sensors (OOI Website).



Dynamic Autoclave Piston Corer (DAPC). Pape et al. 2010

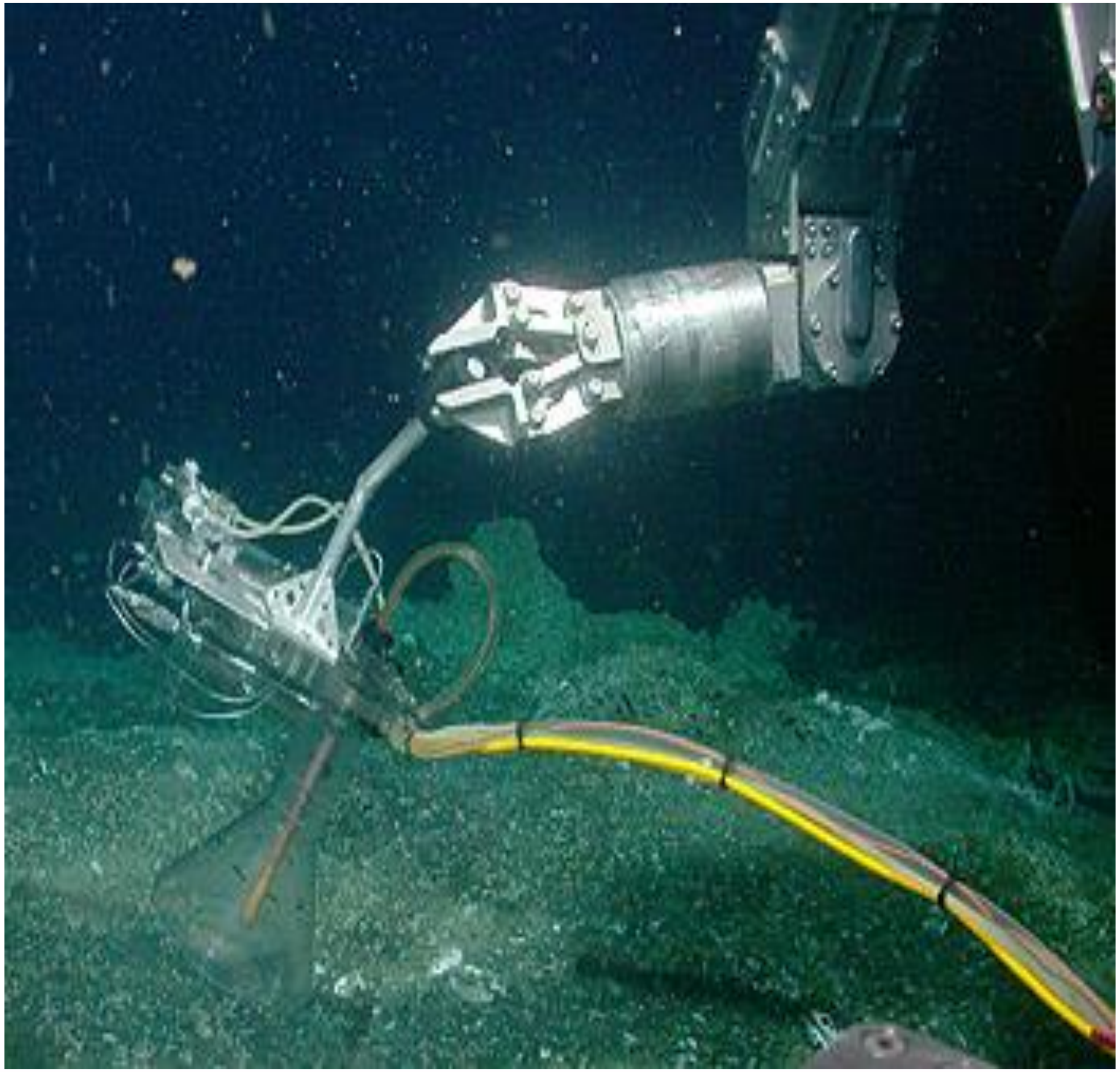
Technology development

Pressured-core-sampling systems (Abegg et al., 2010; DAPC, Pape et al., 2010);

Example of Pressure Core Sampler

MeBo-Pressure Core Sampler (MDP, left and middle) for use with MeBo and MDP for use in free-fall mode (right). BMWi Project SUGAR II

Special funnel to collect samples of natural gas bubbling up from the seafloor. Image: © 2003 MBARI



Intensive Porewater Sampling for Detailed Hydrate Distribution

The absolute quantity of natural gas within the core, whether dissolved in pore fluid, frozen in hydrate, or even present as free gas, can be measured in the laboratory through controlled depressurisation experiments. (GEOTEK Ltd)






Grazie

Thank you