Best practices related to mooring set-up

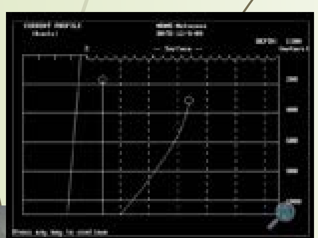
Manuel Bensi, mbensi@ogs.trieste.it
Giuseppe Siena, gsiena@ogs.trieste.it

OGS, Trieste, ITALY

Workshop on training for less experienced users of hardware
15th September 2015, Trieste, Italy

FixO3 FIXED-POINT OPEN OCEAN OBSERVATORIES

WHY BEST PRACTICES?



Handbook

1

BEST PRACTICES approaching an oceanographic mooring

Principles of "Best Practices" in all phases of the system (pre-deployment test, maintenance, calibration etc.) should be followed.

They cover the entire infrastructural chain of data acquisition from sensor (performance, robustness, accuracy, etc.) to supporting system (cabling, electric and electronic components, etc.). The user needs to take into account:

- Scientific aim (geographic location, physical and biogeochemical properties in the region, etc.)
- Mooring Design
- Chose of hardware
- Technical and scientific staff
- Logistics
- Costs
- Risks

2

Mooring design

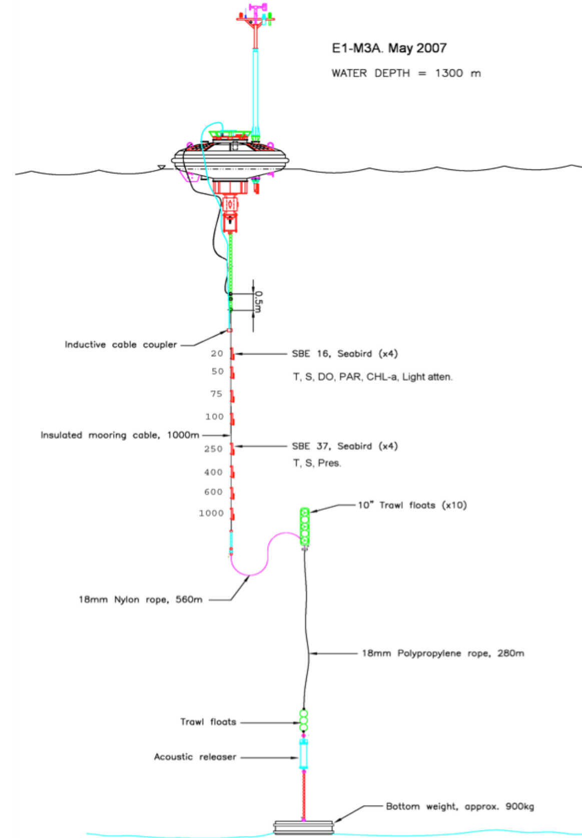
First considerations to be done

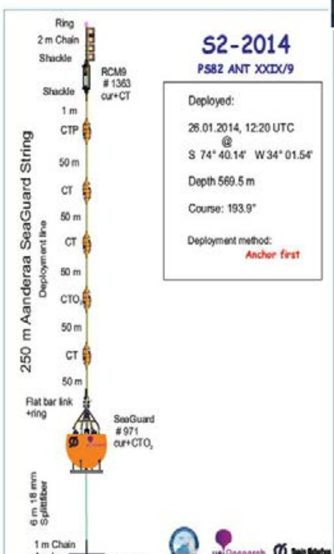
1. **Scientific aim**
2. Location (logistics and more)
3. Water depth
4. Environmental conditions
5. Current speed / Wind speed
6. Bottom currents
7. Bottom conditions (Sandy/rocky)
8. Life expectancy of the experiment
9. Proximity to shipping ports, sea-lanes, or fishing
10. Access and general costs for maintenance

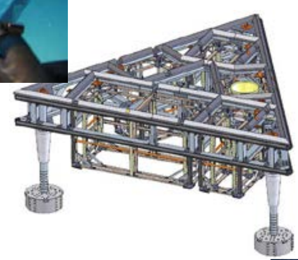
1. Parameters?
    1. Temperature
    2. Salinity
    3. Oxygen
    4. Etc…

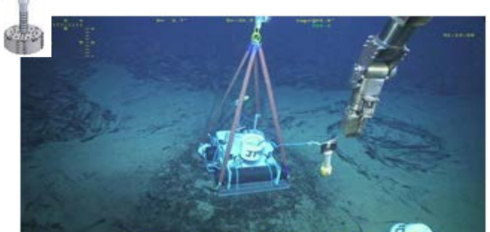
Examples of mooring types

1. Surface mooring
2. Sub-surface mooring
3. Seabed platform









Basic components

1. **Anchor** (Concrete/iron blocks, railroad car wheels, others??). *Their material can affect measurements close to the intruments!!*


2. **Flotation (Buoys):** *must provide the necessary buoyancy in all Meteo conditions.*



3. **Mooring line system:** Rope/chain (Nylon, Polyester, Polypropylene, Polyethylene)»» *Elongation must be taken into account (2-4 %).*



4. **Hardware:** Shackles, swivels, thimbles (*Which material?: Stainless steel, carbon steel, aluminium, etc…).*

5. **Mooring finder**: a device that enables positioning of a mooring.

6. **Sensors:** Physical – Chemical - Biological
   Which parameters Do we want to measure?
   *Note that **pressure** is important to visualize mooring drag/elongation and calculate derived variables.*



7. **Releasers:** *better a double system than a single one!*

Double Release system

Planning a mooring design? Which software…

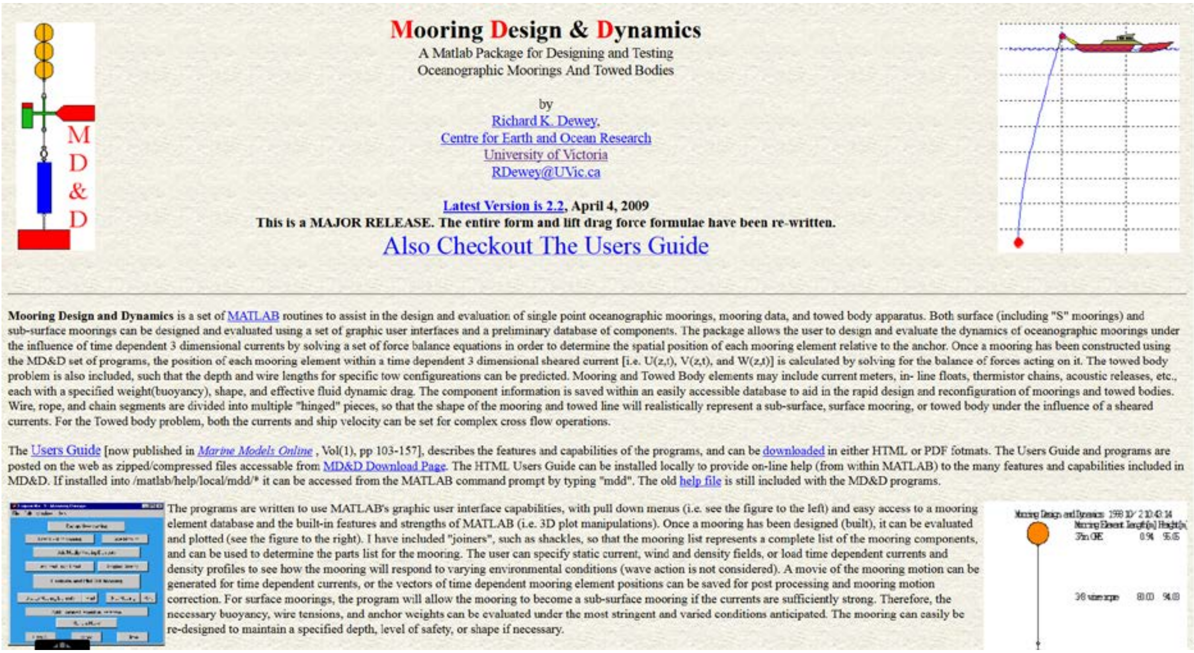
CABLE (WHOI)* } coded in FORTRAN

MDD** (Univ. of Victoria)
KIEL package*** } coded in MATLAB

The packages output the tensions throughout the mooring line, the required anchor weight and the knockdown for any given current profile

* **WHOI Cable v2.0 : time domain numerical simulation of moored and towed oceanographic systems**
** **Mooring Design and Dynamics**
***

Planning a mooring design?



Mooring Design & Dynamics

A Matlab Package for Designing and Testing Oceanographic Moorings And Towed Bodies

by
Richard K. Dewey,
Centre for Earth and Ocean Research
University of Victoria
RDewey@UVic.ca

Latest Version is 2.2, April 4, 2009
This is a MAJOR RELEASE. The entire form and lift drag force formulae have been re-written.

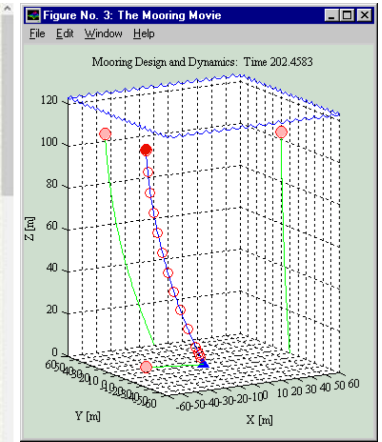
Also Checkout The Users Guide

Mooring Design and Dynamics is a set of MATLAB routines to assist in the design and evaluation of single point oceanographic moorings, mooring data, and towed body apparatus. Both surface (including "S" moorings) and sub-surface moorings can be designed and evaluated using a set of graphic user interfaces and a preliminary database of components. The package allows the user to design and evaluate the dynamics of oceanographic moorings under the influence of time dependent 3 dimensional currents by solving a set of force balance equations in order to determine the spatial position of each mooring element relative to the anchor. Once a mooring has been constructed using the MD&D set of programs, the position of each mooring element within a time dependent 3 dimensional sheared current [i.e. U(z,t), V(z,t), and W(z,t)] is calculated by solving for the balance of forces acting on it. The towed body problem is also included, such that the depth and wire lengths for specific tow configureations can be predicted. Mooring and Towed Body elements may include current meters, in- line floats, thermistor chains, acoustic releases, etc., each with a specified weight(buoyancy), shape, and effective fluid dynamic drag. The component information is saved within an easily accessible database to aid in the rapid design and reconfiguration of moorings and towed bodies. Wire, rope, and chain segments are divided into multiple "hinged" pieces, so that the shape of the mooring and towed line will realistically represent a sub-surface, surface mooring, or towed body under the influence of a sheared currents. For the Towed body problem, both the currents and ship velocity can be set for complex cross flow operations.

The Users Guide [now published in *Marine Models Online* , Vol(1), pp 103-157], describes the features and capabilities of the programs, and can be downloaded in either HTML or PDF fotmats. The Users Guide and programs are posted on the web as zipped/compressed files accessable from MD&D Download Page. The HTML Users Guide can be installed locally to provide on-line help (from within MATLAB) to the many features and capabilities included in MD&D. If installed into /matlab/help/local/mdd/* it can be accessed from the MATLAB command prompt by typing "mdd". The old help file is still included with the MD&D programs.

The programs are written to use MATLAB's graphic user interface capabilities, with pull down menus (i.e. see the figure to the left) and easy access to a mooring element database and the built-in features and strengths of MATLAB (i.e. 3D plot manipulations). Once a mooring has been designed (built), it can be evaluated and plotted (see the figure to the right). I have included "joiners", such as shackles, so that the mooring list represents a complete list of the mooring components, and can be used to determine the parts list for the mooring. The user can specify static current, wind and density fields, or load time dependent currents and density profiles to see how the mooring will respond to varying environmental conditions (wave action is not considered). A movie of the mooring motion can be generated for time dependent currents, or the vectors of time dependent mooring element positions can be saved for post processing and mooring motion correction. For surface moorings, the program will allow the mooring to become a sub-surface mooring if the currents are sufficiently strong. Therefore, the necessary buoyancy, wire tensions, and anchor weights can be evaluated under the most stringent and varied conditions anticipated. The mooring can easily be re-designed to maintain a specified depth, level of safety, or shape if necessary.

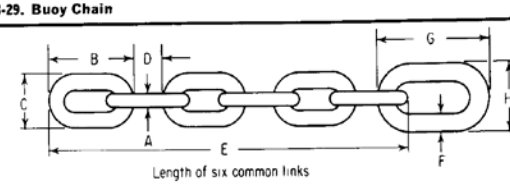
Richard K. Dewey: **Mooring Design & Dynamics—a Matlab® package for designing and analyzing oceanographic moorings,** Marine Models, Volume 1, Issues 1–4, December 1999, Pages 103–157.



An example mooring simulated in Mooring Design and Dynamics. This is my southern thermistor chain mooring from Juan de Fuca Strait in 1997. The simulated and

1. Can help you to predict the different tensions along the mooring system
2. Can plot the predicted trajectory based on given environmental factors
3. Does not consider inertia, vibration, or snap loading
4. **Use with caution**

TABLE 4-29. Buoy Chain

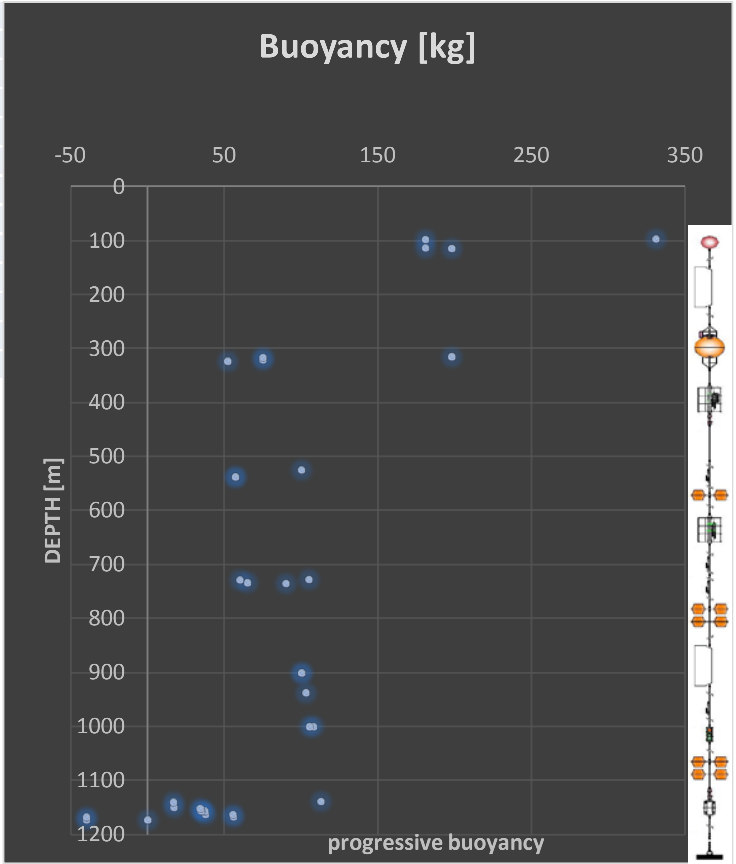


Common links					End links			Link tolerance, length and width	Proof load, lb	Break load, lb	Wt. per 15 fathoms, lb
Wire diam *A*	Length *B*	Width *C*	Space between ends of links, *D*	Length of six links, *E*	Wire diam *F*	Length *G*	Width *H*				
½	3	1⅞	1	13	¾	4½	2⅝	1/32	7,500	15,000	210
⅝	3¾	2¼	1¼	16¼	¾	4½	2⅝	1/32	11,500	23,000	323
¾	4½	2⅝	1½	19½	⅞	5¼	3⅛	1/16	16,000	32,000	442
⅞	5¼	3⅛	1¾	22¾	1⅛	6¾	3⅞	1/16	22,000	44,000	608
1	6	3½	2	26	1¼	7½	4⅜	3/32	29,000	58,000	780
1⅛	6¾	3⅞	2¼	29¼	1¼	7½	4⅜	3/32	38,500	77,000	990
1¼	7½	4⅜	2½	32½	1½	9	5¼	⅛	45,500	91,000	1,245
1½	9	5¼	3	39	1⅝	11¼	6½	5/32	65,500	131,000	1,762
1⅝	9¾	5 11/16	3¼	42¼	1⅞	11¼	6½	5/32	76,500	153,000	2.040
1¾	10½	6 1/16	3½	45½	2⅛	12	7 3/16	3/16	86,500	173,000	2,370
1⅞	11¼	6½	3¾	48¾	2⅛	12	7 3/16	3/16	100,000	200,000	2,640

TABLE 4-30. High-test Chain

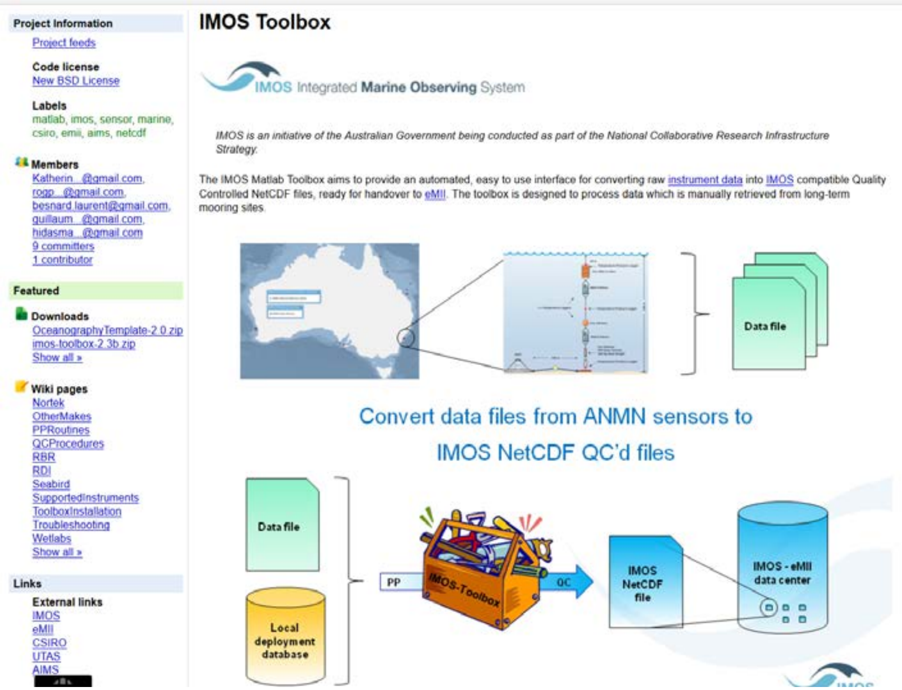
Buoyancy calculation

Mooring E2M3A	instruments weigth	Buoyancy	instruments+ Buoyancy	progressive Buoyancy	length	elevation from sea bottom	DEPTH [m]	Bottom [m]
South Adriatic observatory	(kg)	(kg)	(kg)	(kg)	(m)	(m)	(m)	(m)
BALLAST			750					
Iron chain	-25				5	5.0	1178	1183
Kevlar rope d=12mm , two splices			0	0	5	10.0	1173	1183
Acoustic Releasers AR 661 CS sn 433 & sn 398	-40		-40	-40	1	11.0	1172	1183
Kevlar rope d=12mm , two splices			0	-40	5	16.0	1167	1183
N. 4 Vitrovex clampati		96	96	56	0	16.0	1167	1183
Kevlar rope d=12mm , two splices			-0.5	55.5	5	21.0	1162	1183
Seaguard with frame	-18		-18	37.5	0.7	21.7	1161	1183
Kevlar rope d=12mm , two splices			-0.5					
SBE 37 ODO sn 10598	-2.3		-2.3					
Kevlar rope d=12mm , two splices			-0.5					
PPS Sediment Trap	-17		-17					
Kevlar rope d=12mm , two splices			-0.5					
N. 4 Vitrovex		96	96					
Kevlar rope d=12mm , two splices			-5					
SBE 37 ODO sn 10599	-2.3		-2.3					
Kevlar rope d=12mm , two splices	-2.5		-2.5					
Kevlar rope d=12mm , two splices	-2.5		-2.5					
SBE 37 4514	-3		-3					
Kevlar rope d=12mm , two splices			-10					
SBE 16 6274 with cage (-8.6 kg CTD + cage)	-25		-25					



Note that the releaser must remain in a vertical position during deployment

Process data and deployment information?

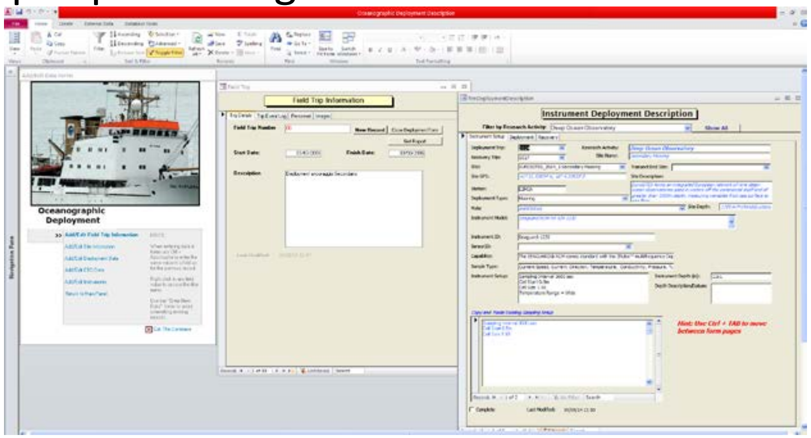


https://code.google.com/p/imos-toolbox/

An easy to use interface for converting raw instrument data into IMOS compatible.

It helps to:

1. Collect info before deployment
2. Collect info after deployment
3. Imports data set into Toolbox and performs some pre-processing tasks.

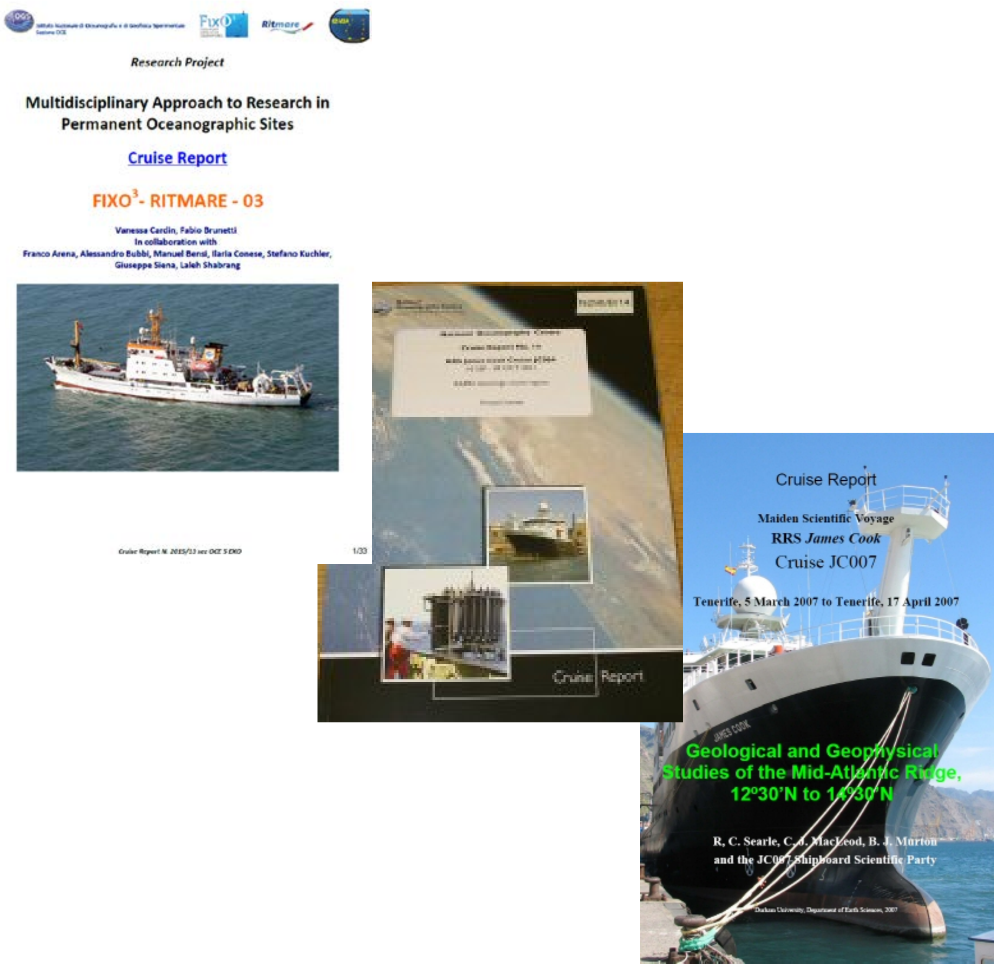


1. **Easy and standard way to collect historical metadata (Microsoft Access)**
2. **MATLAB package to read data (it uses metadata info)**

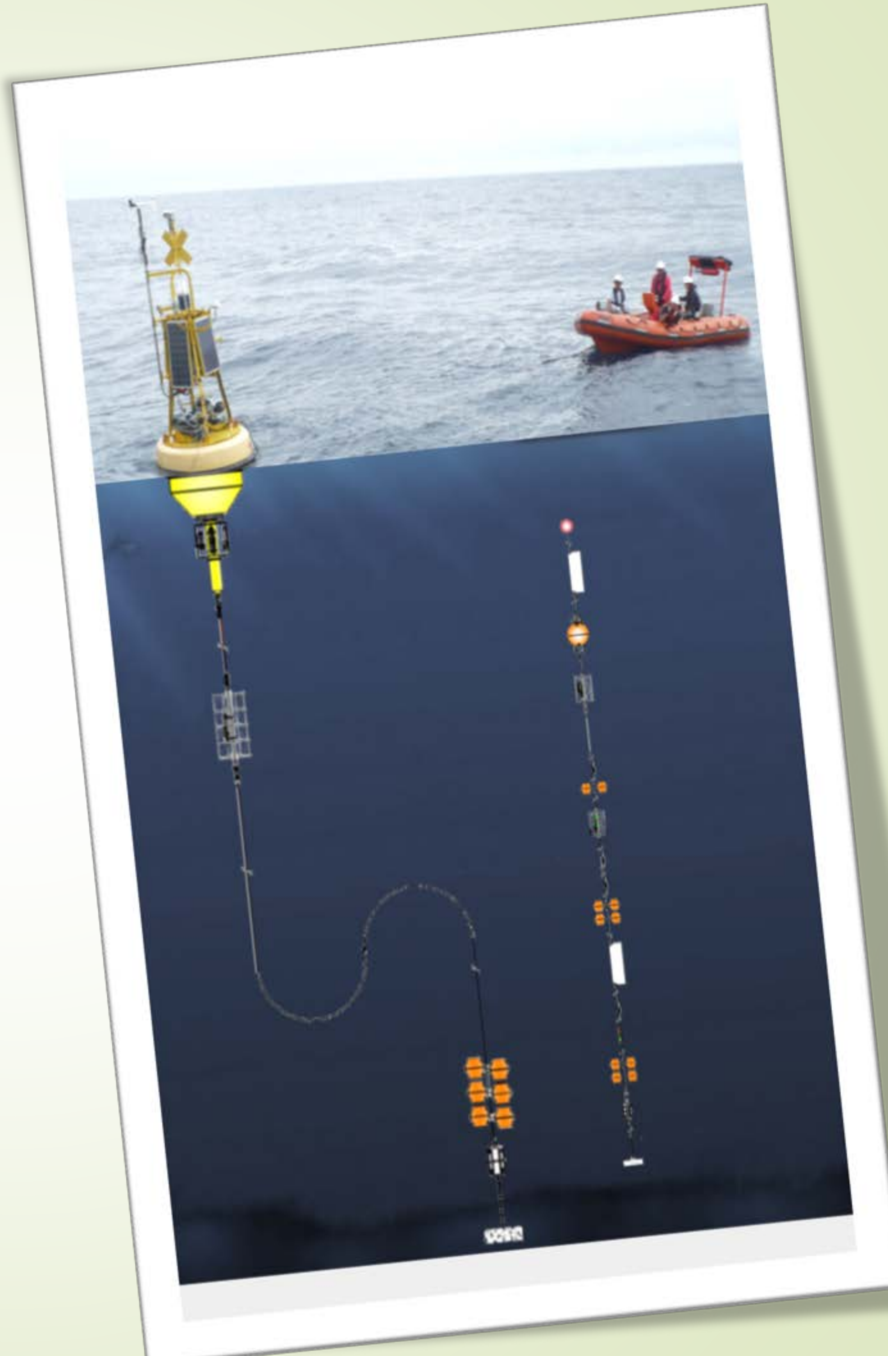
3. **The MATLAB package has a not updated library of sensors. The updates need a knowledge of MATLAB language**

Report after cruise

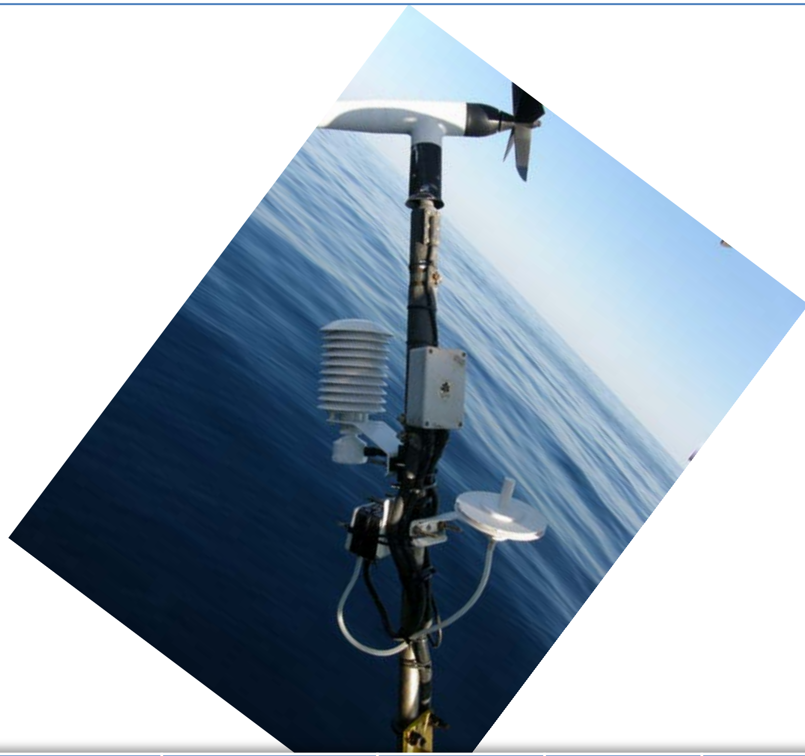
A detailed cruise report should be prepared after each oc. Cruise, in order to collect and made Publicly available all the info collected during the cruise, the sequence of activities and even the problems faced at sea.



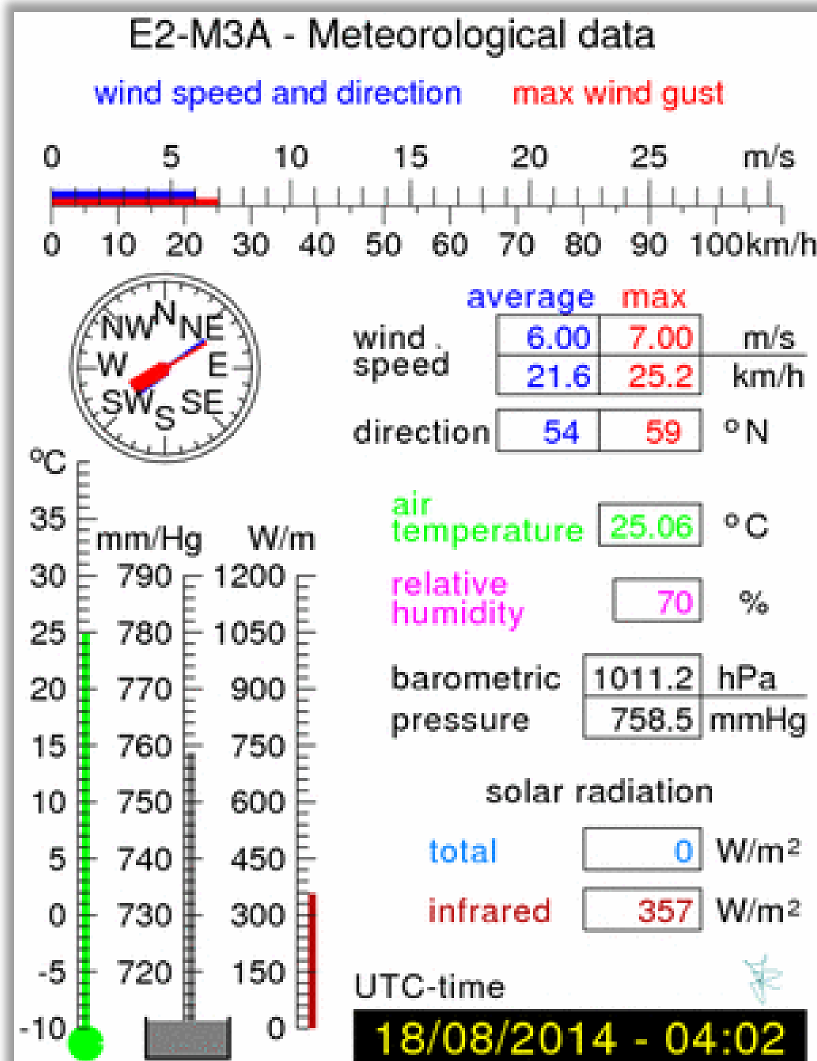
Sailor E2-M3A



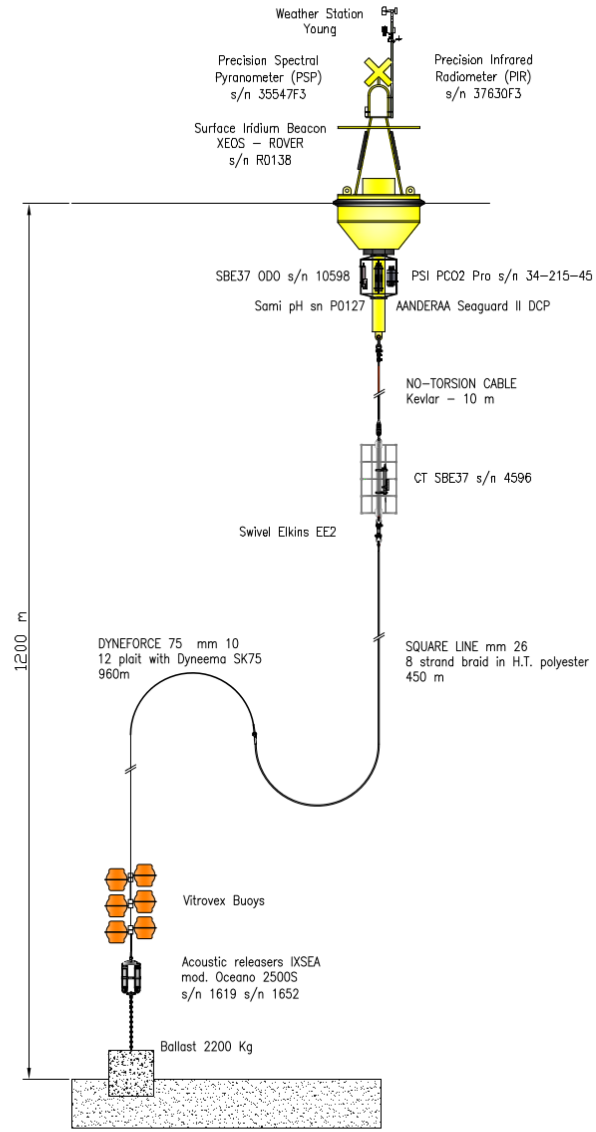
E2-M3A meteorological station



Parameter	Manufacturer	Model	Range	Unit
Wind speed	Young	05106	0-100	m/s
Wind direction	Young	05106	0 - 360	deg
Relative Humidity	Young	41382VC	0-100	%RH
Air temperature	Young	41382VC	-50 to +50	°C
Air pressure	Young	61202V	500-1100	hPa
Infrared radiation	Eppley	PIR	300 to 450	Wm^{-2}
Solar radiation	Eppley	PSP	Spectral 295-2800	nm

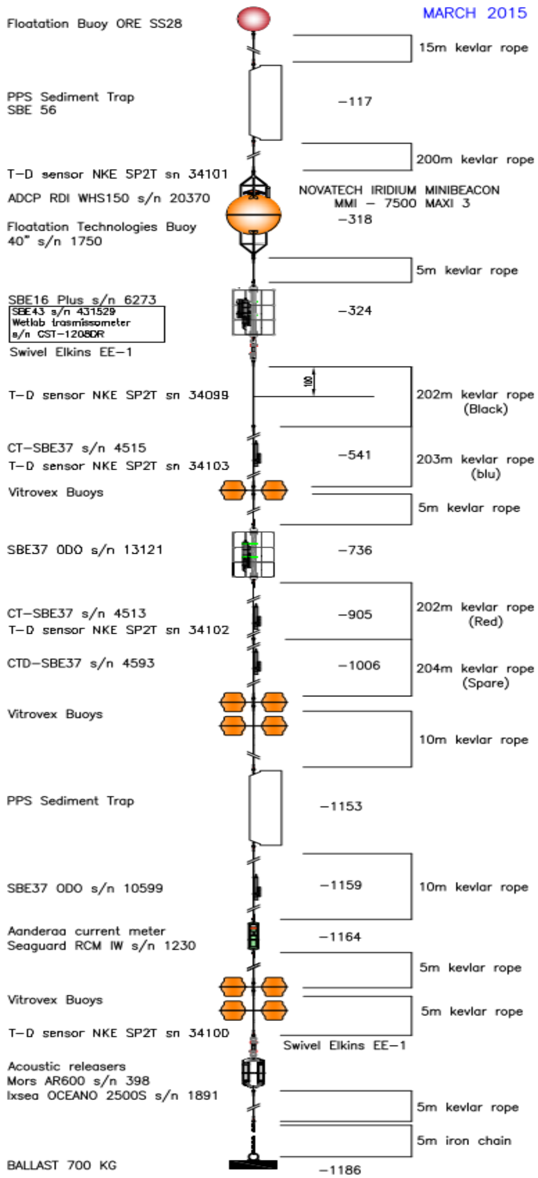


E2-M3A surface buoy



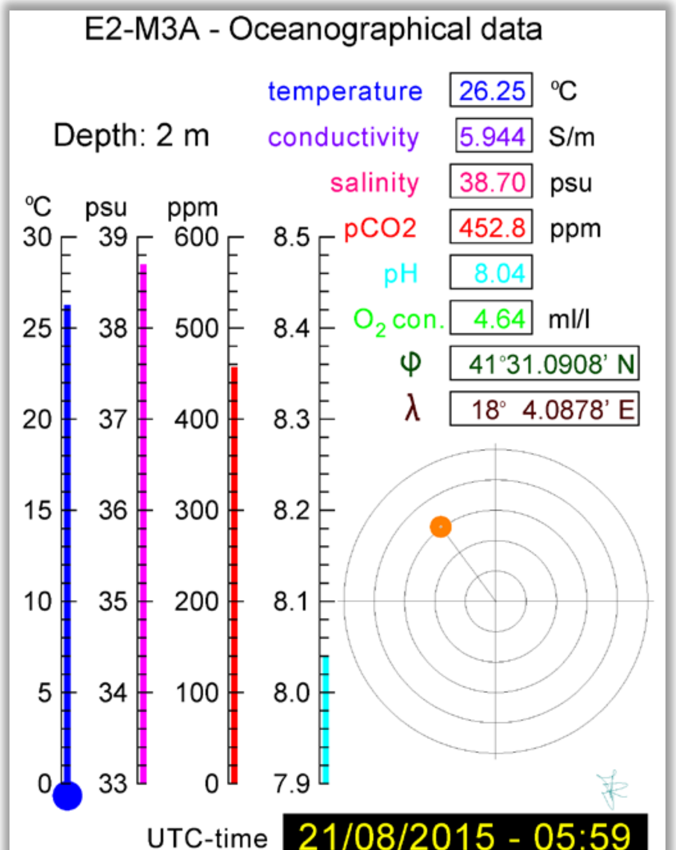
Parameter	Manufacturer	Model	Range	Unit
Conductivity	SBE	SBE37	0 to 7	S/m
Temperature	SBE	SBE37	-5 to – 45	°C
Dissolved Oxygen	SBE	SBE63 /SBE43	0 to 450	µmol/kg
pH	Sunburst	Sami	7 to 9	pH units
pCO2	PRO-OCEANUS	CO2-Pro	0 to 600	ppm

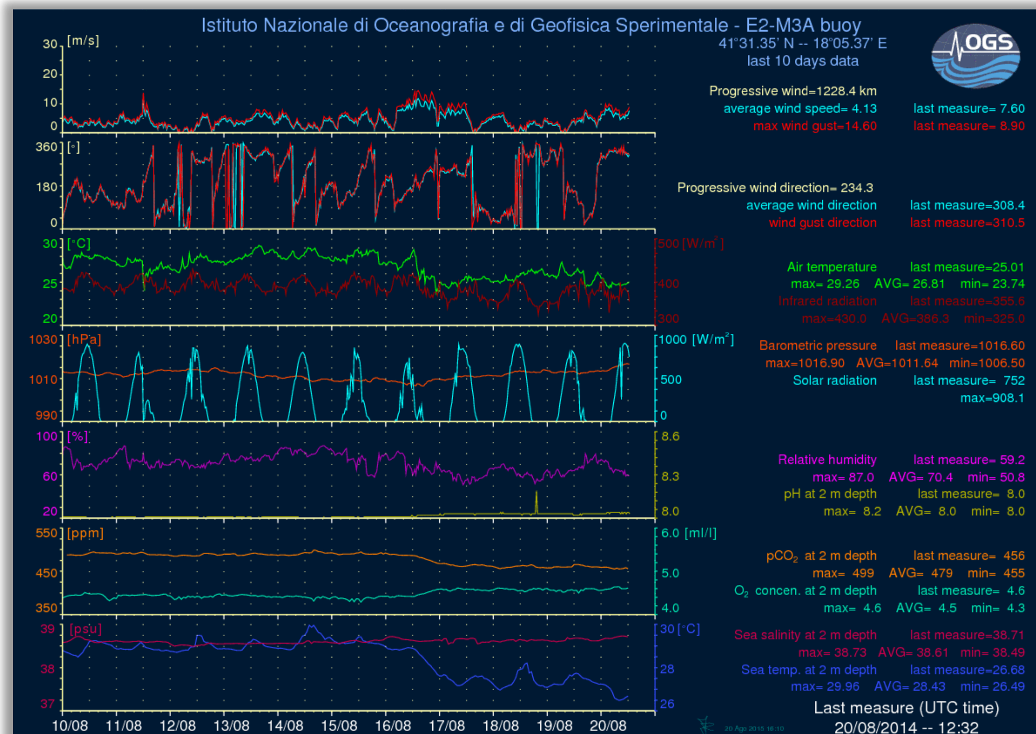
E2-M3A Subsurface Mooring



NRT data

http://nettuno.ogs.trieste.it/e2-m3a/





Core Parameters

Instrument Specification Definitions

Range – Maximum and minimum value over which a sensor works well

Accuracy – How good the data is when compared with a recognized standard

The degree to which a measurement represents the true value of the attribute that is being measured

Resolution – Ability of a sensor to see small differences in readings

Precision - Describes how well a measurement system will return the same measure (**Repeatability**)

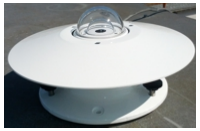
Drift – Low frequency change in a sensor with time (aging of components – bio fouling)

Meteorological

- **Surface air pressure** measurements help to investigate atmospheric circulation patterns in the climate system. Long-term air pressure time series can be used to assess changes, fluctuations and extremes in climatic circulation regimes.

- **Surface air temperature** is considered to be the principal variable for determining the state of the climate system.
- Measures of **surface humidity** over the ocean help to determine the latent heat flux, a major term in the energy exchange between the atmosphere and ocean.
- The **surface wind field** is the primary driver of the ocean circulation, which transports important amounts of heat, freshwater and carbon globally. It is a sensitive measure of the state of the global coupled climate system.

- **The surface radiation budget** (SRB) is a fundamental component of the surface energy budget that is crucial to nearly all aspects of climate and needs to be monitored systematically.



Ocean Parameters

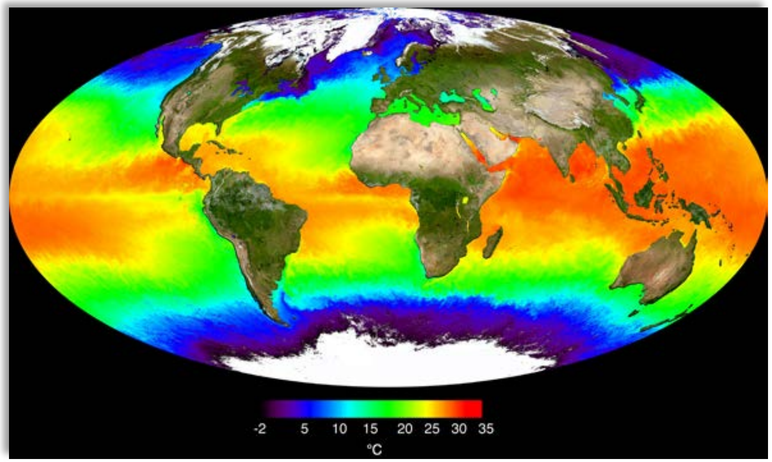
Temperature and salinity play an important role in determining the stability of the water column

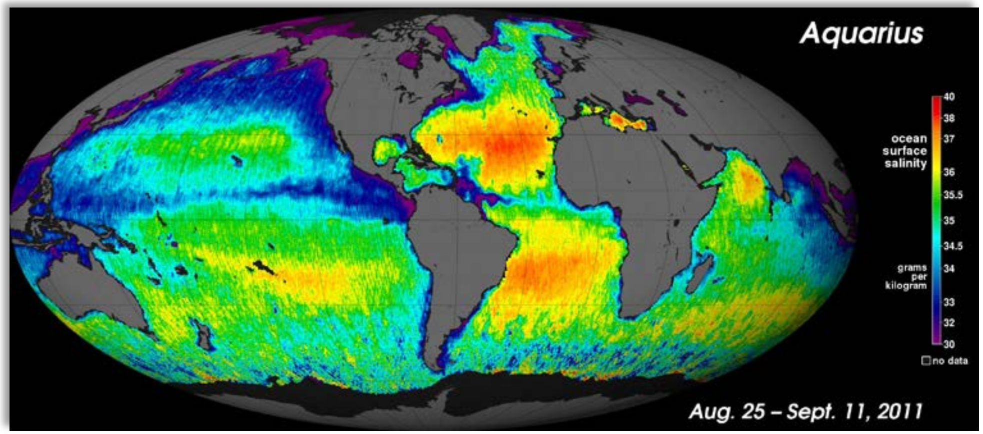
Heat fluxes, evaporation, rain, river inflow, freezing and melting of sea ice all influence the distribution of temperature and salinity at the ocean's surface

Temperature, salinity, and pressure are used to calculate density. The distribution of density inside the ocean is directly related to the distribution of horizontal pressure gradients and ocean currents

Water sinking from surface into the deeper ocean retains a distinctive relationship between temperature and salinity which helps to track the movement of deep water

For all these reasons, we need to know the distribution of temperature, salinity, and density in the ocean.





Measurement of Temperature

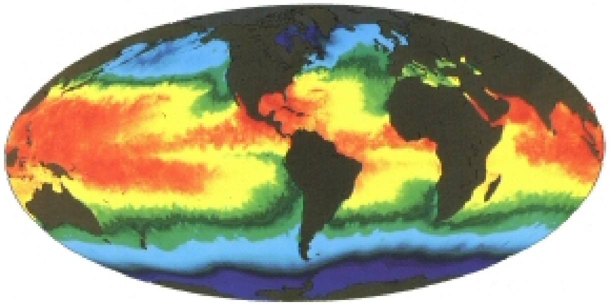
Temperature in the ocean has been measured in many ways:

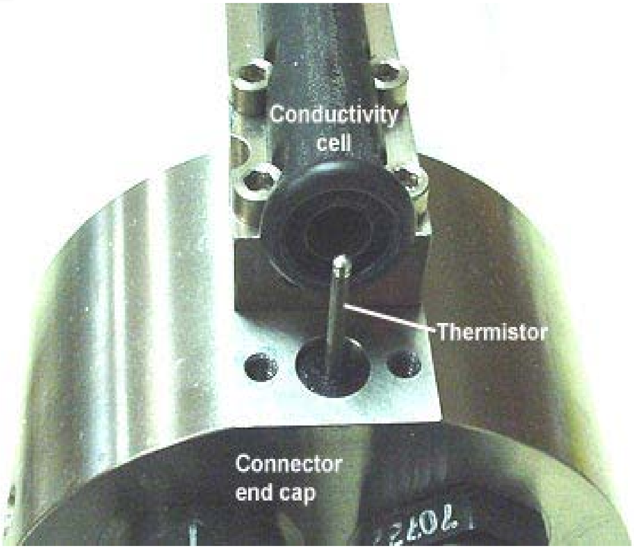
Thermistors and **mercury thermometers** are commonly used on ships and buoys. These are calibrated in the laboratory before being used (and after use if possible), using mercury or platinum thermometers with accuracy traceable to national standards laboratories.

The most recent scale is the International Temperature Scale of 1990 (ITS-90)

Thermistors

- A thermistor is a **semiconductor** having resistance that varies rapidly and predictably with temperature. It has been widely used on moored instruments and on instruments deployed from ships since about 1970
- It has high **resolution** and an **accuracy** of about **± 0.001°C** when carefully calibrated





Infrared **radiometers** on satellites measure the ocean's surface temperature.

Measurement of Salinity

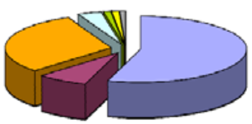
Ocean salinity is generally defined as the salt concentration (e.g., Sodium and Chloride) in sea water

The UNESCO Joint Panel recommended in 1978 that salinity be defined using only **conductivity**

The Practical Salinity Scale of 1978 is now the official definition

Ocean Salinity ≡ ionic salt concentration in sea water

Unity = PSU (Practical Salinity Unit)
1 PSU≈ 1 g/kg.



Chloride (Cl-):	19 g
Sodium (Na+):	11 g
Sulphate (SO4--):	3 g
Magnesium (Mg++):	1.5 g
Calcium (Ca++):	0,35 g
Potassium (K+):	0,35 g
Others :	0,00.. g

Total ≈ 35 g/kg

(Mean chemical composition)

Salinity is measured in unit of PSU (Practical Salinity Unit), based on the sea water conductivity. It is equivalent to **per thousand** or (o/00) or to **g/kg**

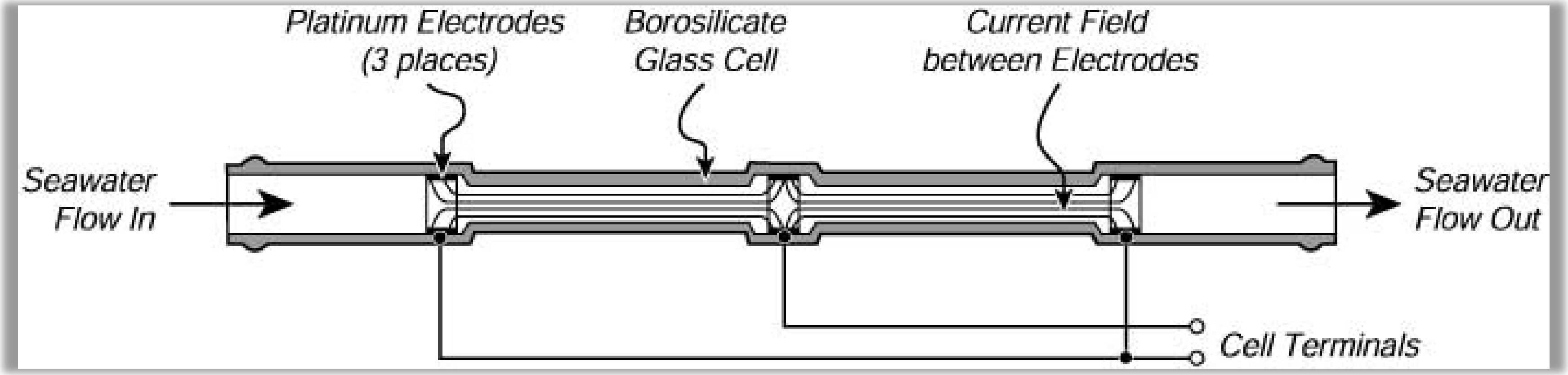
The averaged salinity in the global ocean is **35.5 PSU**, varying from less than 15 PSU at the mouth of the rivers to more than 40 PSU in the Dead Sea

All laboratories use the same calibrated standard water as reference in salinity determinations:
the **IAPSO Standard Seawater** is intended for single-point calibration of bench salinometers

Measurement of Salinity

Before conductivity measurements were widely used, salinity was measured using **chemical titration** of the water sample with silver salts

The best measurements of salinity from titration give salinity with an accuracy of ±0.02



Conductivity is measured by placing platinum electrodes in seawater and measuring the current that flows when there is a known voltage between the electrodes. The current depends on **conductivity**, **voltage**, and **volume** of sea water in the path between electrodes

The best measurement of salinity from conductivity gives salinity with an accuracy of ±0.005

Ocean Parameters

Pressure is often used instead of depth to express the vertical coordinate in the ocean
Pressure is a function of depth, density, and gravitational acceleration

Pressure in the ocean is usually expressed in units of **decibars**, abbreviated dbar
The SI unit for pressure is kPa (kilopascals) = 10^3 Pa. 1 dbar = 10 kPa

The pressure in dbar and the depth in meters are **approximately equal**

Although the total pressure at a point in the ocean would be due both to the weight of the seawater above it and the atmospheric pressure, unless otherwise specified, the **pressure at a point in the ocean is taken to be just that due to the seawater**

Sea pressure at the surface is 0 dbar

Measurement of Pressure

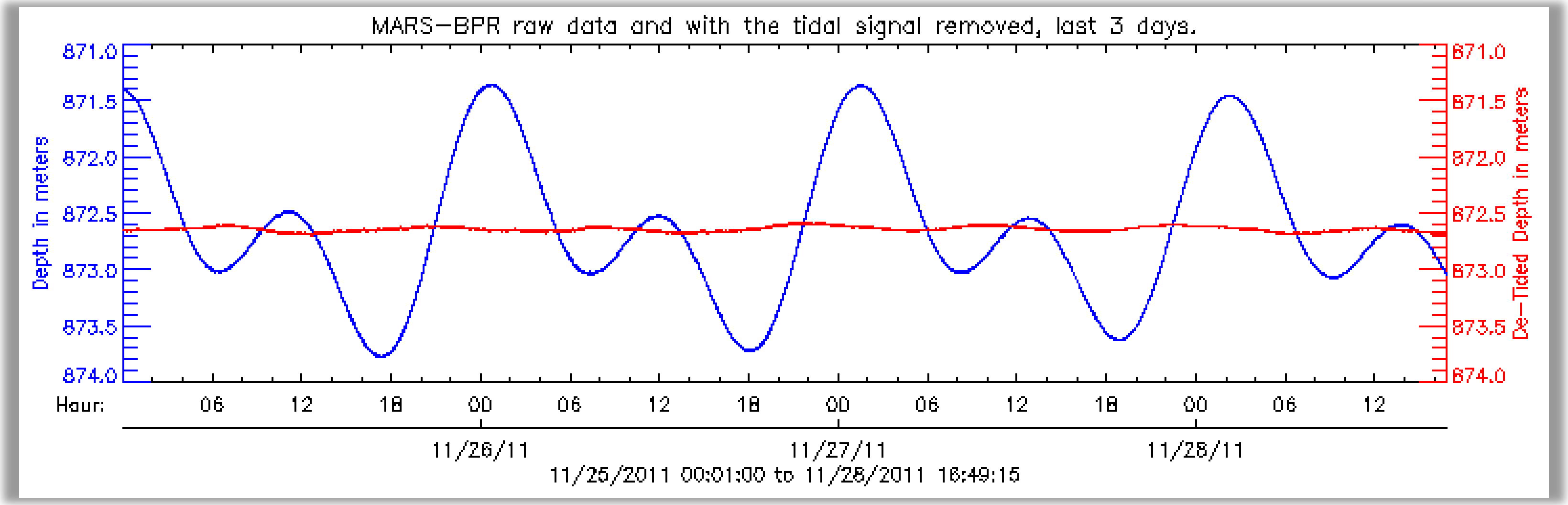
Pressure is related to depth through the hydrostatic relation: $p = \rho g z$

Pressure can be precisely converted to depth using the local value of gravity and the vertical density profile

Pressure is now measured directly on most instruments. Very accurate pressure measurements can be made using a **quartz crystal**, whose frequency of oscillation depends on pressure. This technology is used in modern CTDs.

Accuracy is ±0.015% of full scale range and precision is 0.001% of full-scale values

e.g. A Bottom Pressure Recorder (BPR) precisely measures the pressure of the overlying ocean. The raw BPR data (**blue**) closely follows predicted ocean tides. Subtracting the tides from the BPR data, the difference (**red**) can show any vertical movements of the seafloor



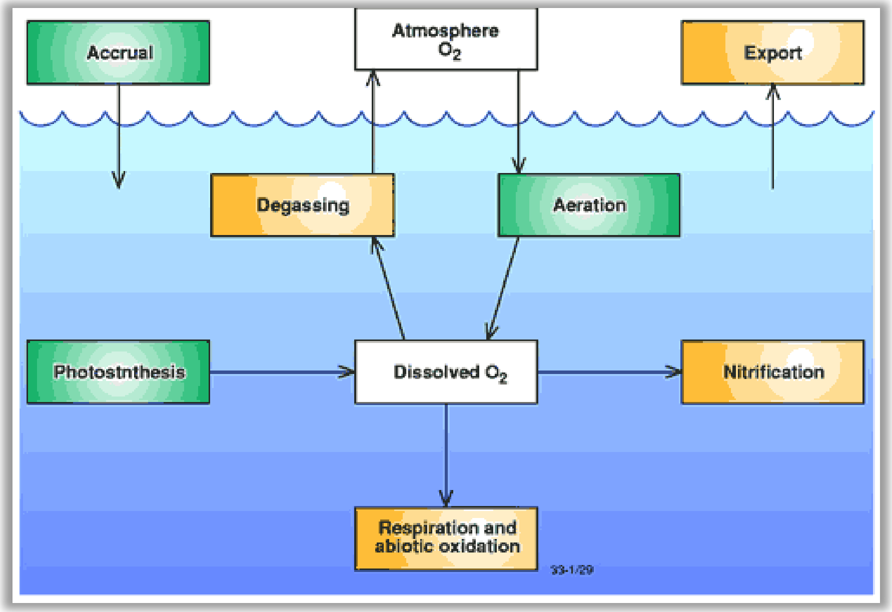
Ocean Parameters

Dissolved oxygen (DO) refer to the amount of oxygen gas dissolved in a body of water and may be used to trace water masses, to assess mixing processes, and to understand the biogeochemical conditions of their formation regions

Measures of dissolved oxygen provides a sensitive early warning system for the climate change trends

DO in sea water mainly comes from the atmosphere. The movement of **waves and currents** allows oxygen from the atmosphere to dissolve in sea water.

Photosynthesis by phytoplankton, seaweeds and sea grasses also results in increases in dissolved oxygen in sea water



Among oxygen-consuming processes are: **aerobic respiration, nitrification, chemical oxidation**

Oxygen has limited solubility in water, usually ranging from 5 to 14 mg L^{-1} and is inversely correlated with temperature and salinity

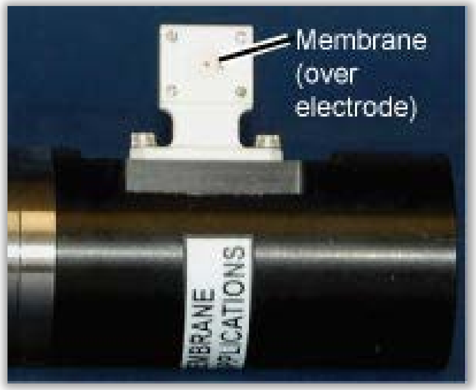
Measurement of Dissolved Oxygen

The two standard methods for measuring dissolved oxygen concentrations are **membrane electrodes** and the **Winkler** (iodometric) method. An alternative **optical method** has been developed

Membrane electrodes are the most practical for in situ determinations and for continuous monitoring protocols

Membrane electrodes

The transfer of oxygen across the membrane is proportional to the partial pressure of oxygen in the fluid



The electrochemical sensor drifts with time and must be calibrated against lab measurements

Iodometric titration

One mole of O2 reacts with four moles of thiosulphate and, by calculation of amount of thiosulphate, it's possible calculate how many dissolved oxygen is in samples

Dissolved oxygen measurements are often expressed as **percentage saturation** values as this parameter is independent of temperature and salinity

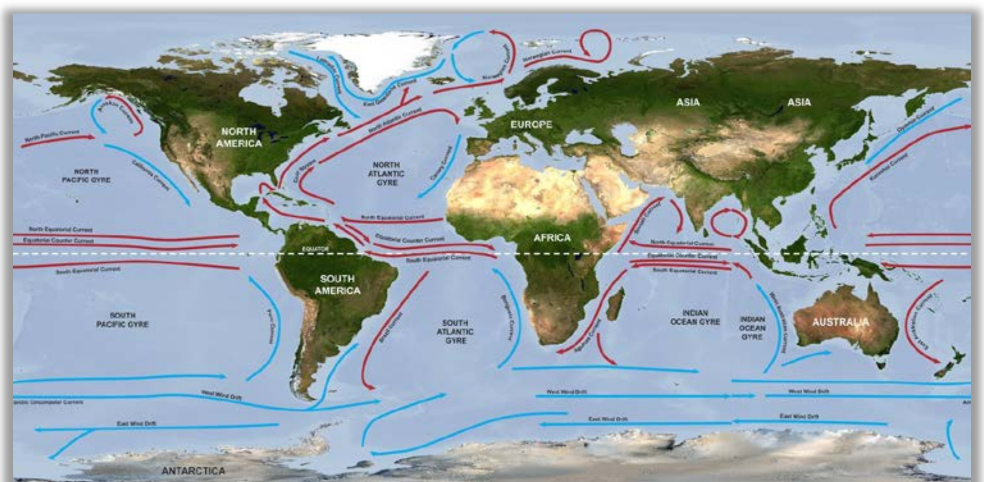
Ocean Parameters

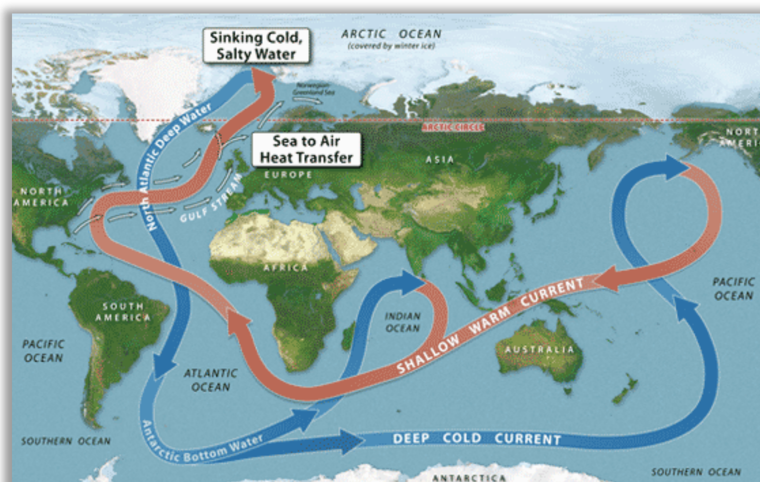
Currents are generated from the forces acting upon the water such as :
planet rotation – wind - temperature and salinity differences - gravitation of the moon

Depth contours, shoreline and other currents influence **direction** and **strength** of a current

There are two types of currents in the ocean, surface and deep:

- the **surface** current interests the top 400 meters of the sea, and is largely influenced by wind and gravity
- the **deep** current, driven by sinking of cold dense water at high latitudes, also generates currents through the whole depth of the ocean (Global Conveyor Belt), giving important contribution towards heat and energy exchange between the poles



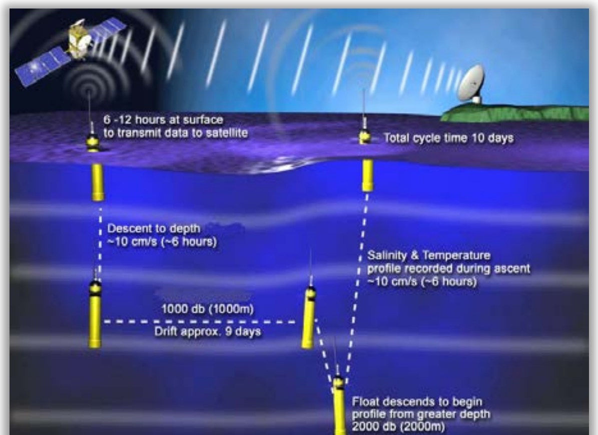


Measurement of Currents

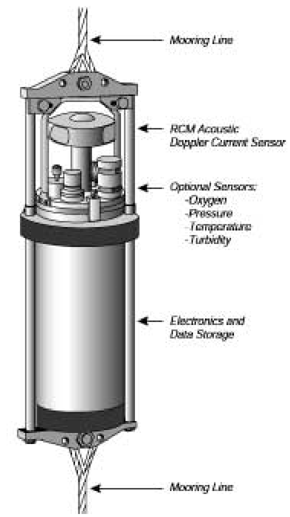
There are two basic ways to describe fluid flow:

- **Eulerian** method, in which the velocity is given or observed at every point in the fluid
- **Lagrangian** method, in which the path followed by each fluid particle is given or observed as a function of time

The simplest Lagrangian current indicator is an object **floating** in the water, carried by the ocean current with a minimum of surface exposed to the wind, or below the surface of the water



Current meters are deployed at a **fixed** location and record the current speed and direction over time



Modern technology adopted the **Doppler effect**, by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water

There are still problems associated with the moorings movement in strong currents, but an autonomous, moored string of current meters is an efficient way to resolve and monitor ocean current behavior over a period of time

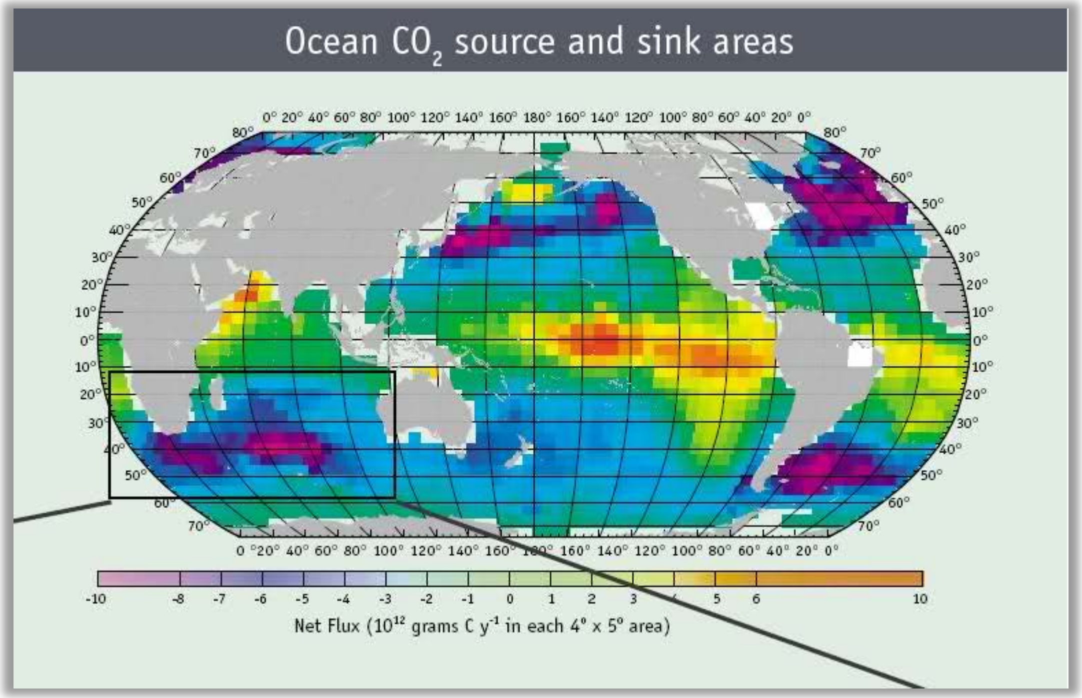
Ocean Parameters

Partial pressure of carbon dioxide (CO_2)

The world's oceans exchange CO_2 with the atmosphere

The CO_2 dissolves in water to an extent determined by its partial pressure and the chemical reactions with other solutes

pCO_2 is a critical parameter of the oceanic **inorganic carbon system** because it determines the magnitude and direction of the exchange of CO_2 between the ocean and atmosphere

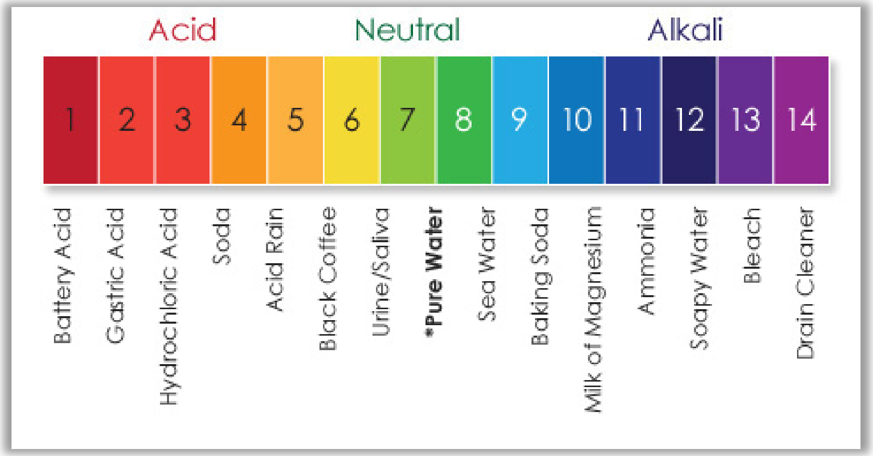


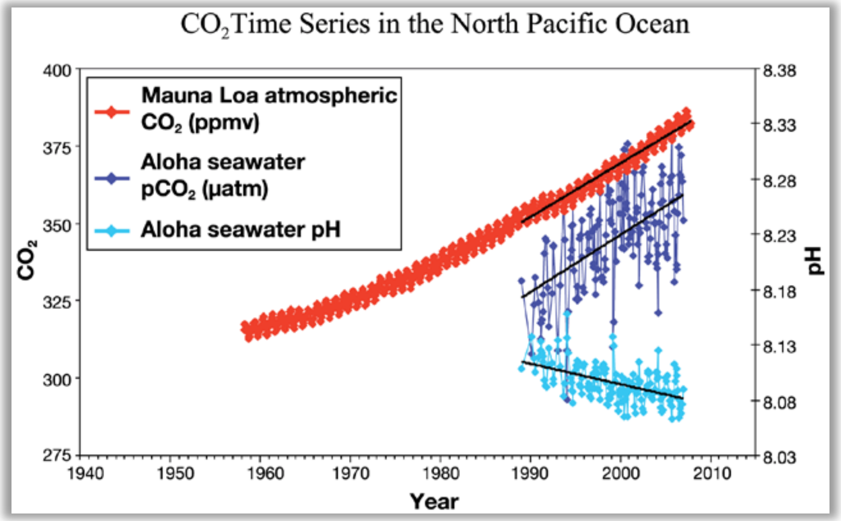
The direct method for measuring pCO_2 involves equilibrating air (or another carrier gas) with water and then measuring the pCO_2 of the equilibrated air by either **gas chromatography** or **infra-red spectroscopy**

Ocean Parameters

The **pH** measures the concentration of hydrogen ions (H+) in the water

pH is used to measure the ocean acidification due to the uptake of carbon dioxide from the atmosphere. Ocean water is generally always at a pH of 7.5 to 8.5

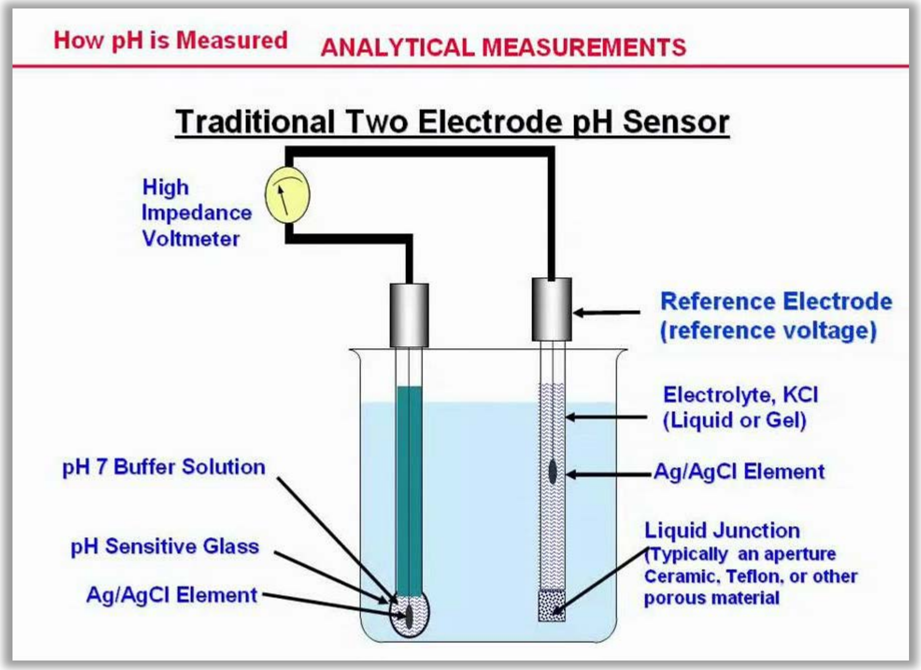




Ocean acidification causes a relatively slow, long-term increase in the acidity of the ocean, corresponding to a decrease in pH

Measurement of pH

pH of water is best measured in situ using a meter equipped with a pH probe

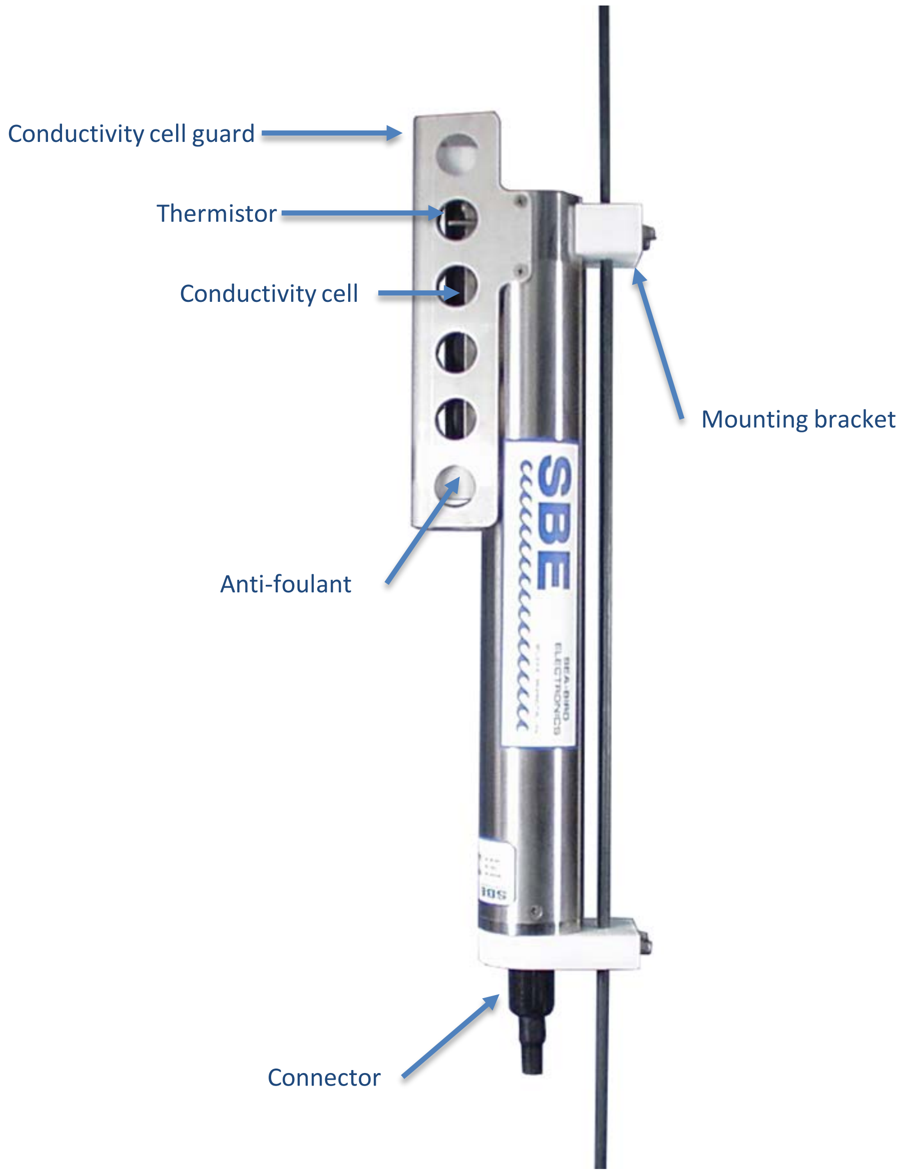


1. The pH probe is placed in the water sample and connected to the pH meter
2. At the tip of the probe there is a thin glass bulb
3. Inside the bulb are two electrodes that measure voltage
4. One electrode is contained in a liquid with a fixed pH
5. The other electrode responds to the pH of the water sample
6. The difference in voltage between the two probes is used to determine the pH

Types of Instruments

SBE 37-SMP

- The SBE 37-SMP pumped MicroCAT is a high-accuracy conductivity, temperature and pressure recorder with serial interface (RS-232 or RS-485), internal batteries, memory, and integral pump
- The MicroCAT is designed for moorings or other long-duration, fixed-site deployments
- Data are recorded in memory and can be output in real-time
- Measured data and derived variables (salinity, sound velocity) are output in engineering units
- Memory capacity exceeds 530,000 samples
- Battery endurance varies, depending on sampling scheme. Sampling every 2-1/2 minutes, the MicroCAT can be deployed for 2 years



SBE 37-SMP

Measurement Range

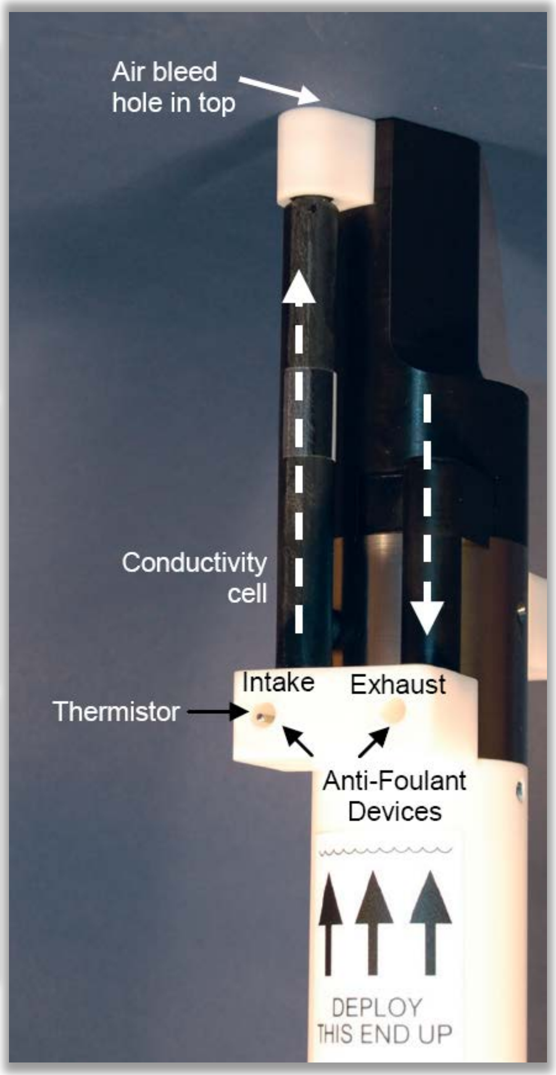
Conductivity	0 to 7 S/m (0 to 70 mS/cm)
Temperature	-5 to 45 °C
Optional Pressure	20 / 100 / 350 / 600 / 1000 / 2000 / 3500 / 7000 (meters of deployment depth capability)

Initial Accuracy

Conductivity	± 0.0003 S/m (0.003 mS/cm)
Temperature	± 0.002 °C (-5 to to 35 °C); ± 0.01 °C (35 °C to 45 °C)
Optional Pressure	± 0.1% of full scale range

Resolution

Conductivity	0.00001 S/m (0.0001 mS/cm)
Temperature	0.0001 °C
Optional Pressure	0.002% of full scale range



SBE 16plus V2

- The SBE 16plus V2 SeaCAT is a high-accuracy conductivity, temperature and pressure recorder designed for moorings or other long-duration, fixed-site deployments
- It supports numerous auxiliary sensors (dissolved oxygen, turbidity, fluorescence, PAR, etc.) with six A/D channels and one RS-232 data channel
- The 16plus V2 communicates via an RS-232 serial interface, and has internal batteries and memory
- It is well suited to networked sensor arrays where its operation can be triggered by satellite, radio, or hardwire telemetry equipment
- Data is recorded in memory and can also be output in real-time in engineering units or raw HEX
- Battery endurance varies, depending on the sampling scheme; nine alkaline D-cells provide power for 355,000 samples of C and T

SBE 16plus V2

Measurement Range

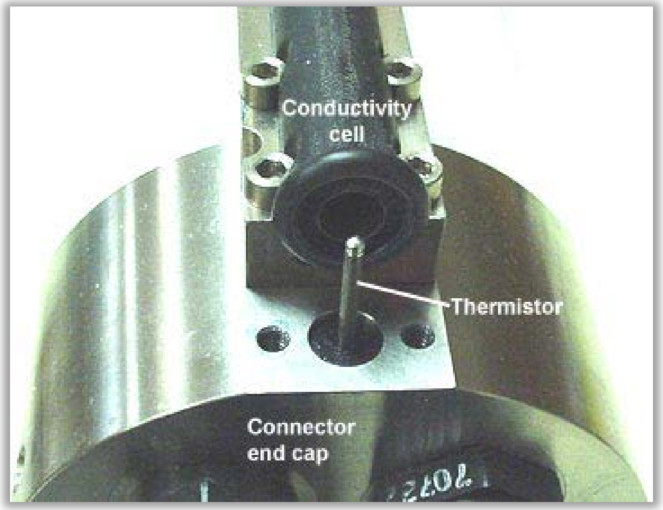
Conductivity	0 to 9 S/m
Temperature	-5 to +35 °C
Optional Pressure	Strain-gauge 0 to 20/100/350/600/1000/2000/3500/7000 m; Quartz 20/60/130/200/270/680/1400/2000/4200/7000/10,500 m

Initial Accuracy

Conductivity	± 0.0005 S/m
Temperature	± 0.005 °C
Optional Pressure	Strain-gauge ± 0.1% of full scale range; Quartz ± 0.02% of full scale range

Resolution

Conductivity	0.00005 S/m typical
Temperature	0.0001 °C
Optional Pressure	Strain-gauge 0.002% of full scale range; Quartz 0.0006% of full scale range for 1-sec integration



Pressure

The NKE SP2T measures and records temperature and pressure

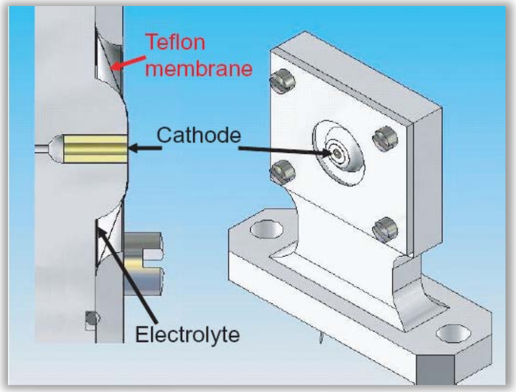
- Fast wireless configuration and data transfer (Inductive) connected to the USB port of a PC
- Easy maintenance
- Optimal protection of the sensors
- Lithium batteries for long-term

It has been designed to be used down to 4000m

DESIGNATION		SP2T10	SP2T30	SP2T150	SP2T300	SP2T600	SP2T1200
Order code	SI version	60-07-145	60-07-212	60-07-146	60-07-147	60-07-148	60-07-155
	PR version				60-07-237	60-07-197	
Depth (D)	Depth	10 m	30 m	150 m	300 m	600 m	1200 m
	Accuracy	<2 cm	<6 cm	<30 cm	<60 cm	<1.2 m	<2.4 m
	Resolution	0.3 cm	0.9 cm	5 cm	9 cm	18 cm	36 cm
	Max depth	75 m	75 m	750 m	750 m	3000 m	3000 m
Temperature (T)	Range	-5°C to +35°C					
	Resolution	11m°C at 0°C, 13m°C at 10°C, 20m°C at 20°C					
	Accuracy	0.05°C from 0 to 20°C / 0.1°C otherwise					
	Response time (63%)	SI : <1s PR : <0.5s					

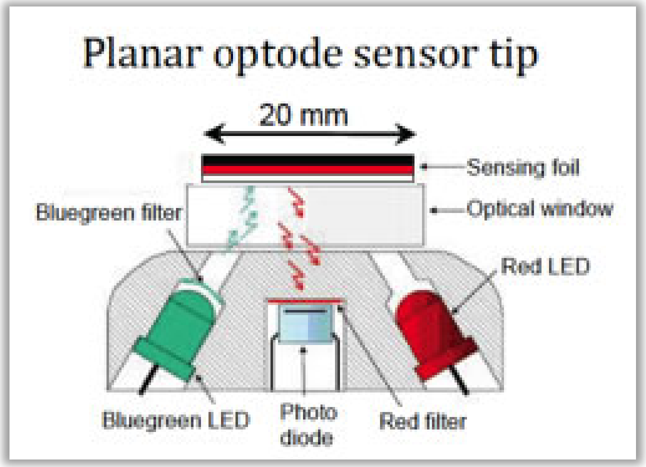
SBE 43

- The SBE 43 determines dissolved oxygen concentration by counting the number of oxygen molecules per second (flux) that diffuse through the membrane from the ocean environment to the working electrode
- At the working electrode (cathode), oxygen gas molecules are converted to hydroxyl ions (OH-) in a series of reaction steps where the electrode supplies four electrons per molecule to complete the reaction
- The sensor counts oxygen molecules by measuring the electrons per second (amperes) delivered to the reaction
- The chemistry of the sensor electrolyte changes continuously as oxygen is measured, resulting in a slow but continuous loss of sensitivity that produces a continual, predictable drift in the sensor calibration with time
- Membrane fouling also contributes to drift by altering the oxygen diffusion rate through the membrane, thus reducing sensitivity
- Biological fouling can be troublesome, because the living organisms either consume or create oxygen



Aanderaa Optode

- The oxygen optode provides a more suitable method than electrochemical sensors for direct measurement of dissolved oxygen
- Optode technology has been known for years but it is relatively new to the aquatic research
- The fundamental principle is based on the ability of selected substances to act as dynamic fluorescence quenchers
- In the case of oxygen, if a ruthenium complex is illuminated with a blue light it will be excited and emits a red luminescence with an intensity and lifetime that depends on the ambient oxygen concentration
- The “Oxygen Optode” from Aanderaa Instruments is based on oxygen luminescence quenching of a platinum porphyries complex
- The lifetime and hence the oxygen measurement is made by a so-called phase shift detection of the returning, oxygen quenched red luminescence



Comparison

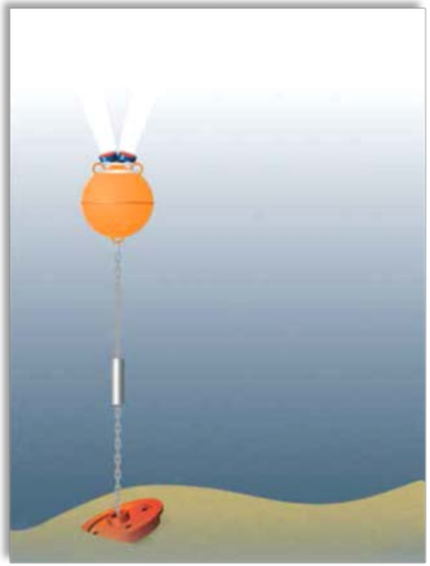
OXYGEN	O_2-Concentration	Air Saturation
Measurement Range:	0 - 500 µM[1)]	0 - 150%
Resolution:	< 1 µM	0.4 %
Accuracy:	<8 µM or 5%[2)] whichever is greater	<5 %[3)]
Response Time (63%):	4330F (with fast response foil) <8 sec 4330 (with standard foil) <25 sec	

TEMPERATURE:	
Range:	-5 to +40°C (23 - 104°F)
Resolution:	0.01°C (0.018°F)
Accuracy:	±0.03°C (0.18°F)[4)]
Response Time (63%):	<2 sec

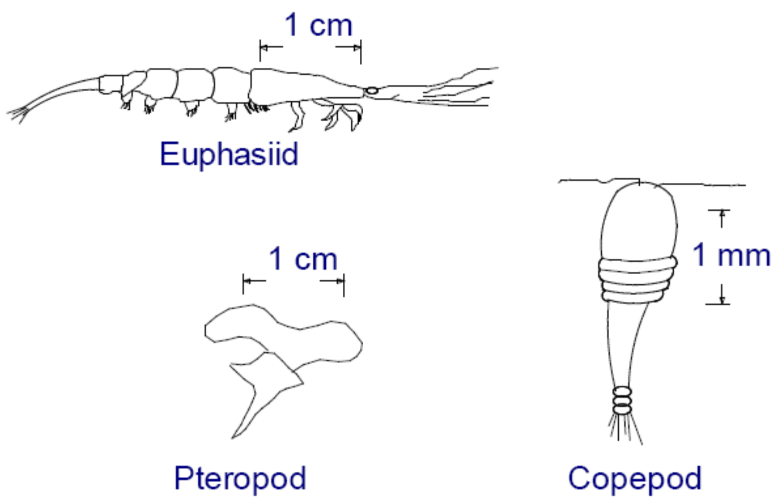
Performance

Measurement Range	120% of surface saturation in all natural waters (fresh and salt)
Initial Accuracy	± 2% of saturation
Typical Stability	0.5% per 1000 hours (clean membrane)
Response Time Tau*	2 to 5 sec for 0.5-mil membrane, 8 to 20 sec for 1.0-mil membrane **Time to reach 63% of final value for a step change in oxygen; dependent on ambient water temperature and flow rate (see Application Note 64 for discussion)*

ADCP



ADCPs use the **Doppler effect** by transmitting sound at a fixed frequency and listening to echoes returning from sound scatterers in the water. These sound scatterers are small particles or plankton that reflect the sound back to the ADCP

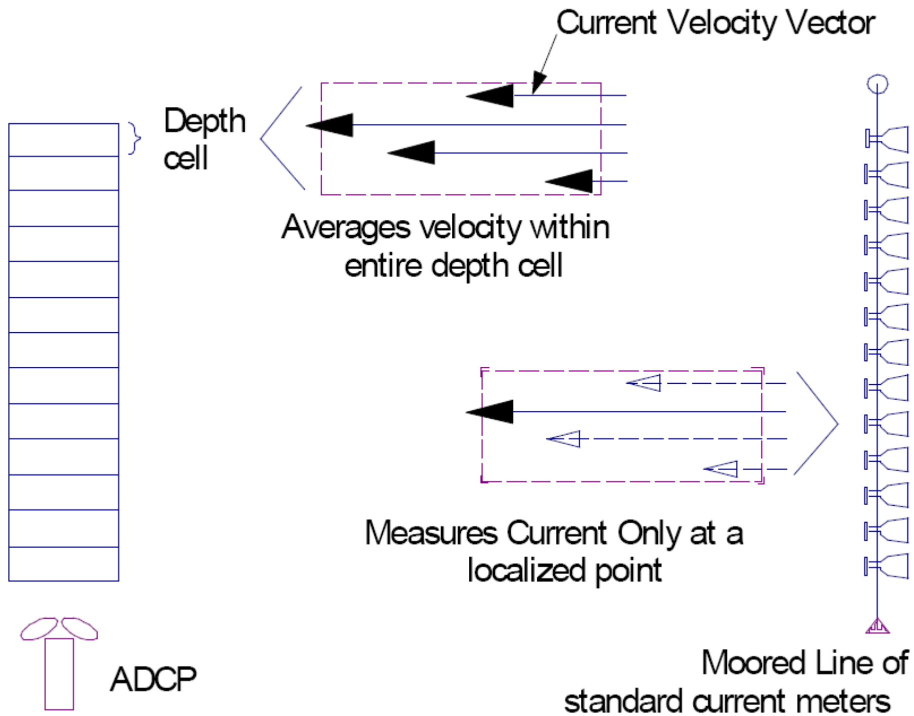


Scatterers are everywhere in the ocean. They float in the water and on average they move at the same horizontal velocity as the water

Based on the Acoustic Doppler technology is possible to measure the currents in a single point or a layer of the water column

ADCP

The most important feature of ADCPs is their ability to measure current profiles. ADCPs divide the velocity profile into uniform segments called depth cells



Each depth cell is comparable to a single current meter, therefore an ADCP velocity profile is like a string of current meters uniformly spaced on a mooring

PRODUCT FEATURES

- **Versatility:** The highly versatile QuarterMaster offers ranges of up to 300m, as well as self-contained and direct read configurations.
- **Precision data:** Teledyne RDI's Broadband signal processing produces high-resolution, precise measurements without compromising battery life.
- **Reliability:** Set it and forget it; the highly reliable and energy-efficient Quartermaster can be deployed for three, six, or even twelve months of worry-free operation.
- **4-beam solution:** Teledyne RDI's 4-beam design provides a redundant data source in case of a blocked or damaged beam, as well as an independent measure known as error velocity to ensure the quality of the data.

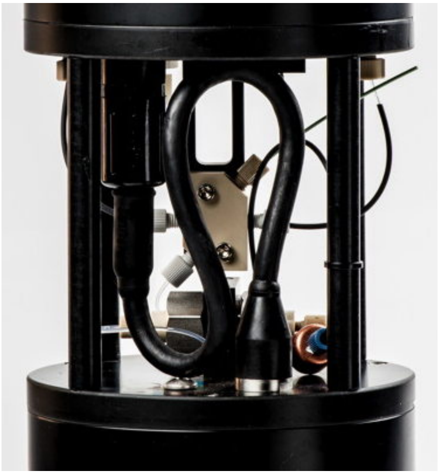
pCO_2

The main principle of pCO_2 measurement is based on the equilibration of a carrier gas phase with a seawater sample and subsequent determination of the CO_2 in the carrier gas by an infrared analyzer featuring automatic zero point calibration, that removes all CO_2 from the detector prior to a zero reference measurement

- High sampling rate
- Pumped interface
- Low cost
- Long term stability

pH

- Measures pHT (total hydrogen scale) in the marine pH range of 7-9
- Uses a highly accurate colorimetric reagent method
- System does not suffer from the drift that plagues most electrode based pH probes
- Designed to provide researchers with valuable in-situ time series data at depths up to 600 meters
- 234-day deployment capability (hourly measurements)
- Extra battery package allows to run for more than a year
- Can support up to 3 external instruments (e.g., PAR, dissolved oxygen, chlorophyll fluorometer, CTD)
- Supports Seabird underwater inductive modems or external loggers via RS-232



Seaguard RCM

The SeaGuard RCM utilizes the well known Doppler Shift principle as basis for its measurements

The Zpulse Doppler Current Sensor (DCS) is the standard sensor on the SeaGuard RCM. The sensor outputs Absolute Current Speed and Direction

Seaguard RCM

Four transducers transmit short pulses (pings) of acoustic energy along narrow beams. The same transducers receive backscattered signal from scatterers that are present in the beams, which are used for calculation of the current speed and direction

ZPulse Doppler Current Sensor (DCS) Specifications	
Current Speed:	(Vector averaged)
Range:	0-300 cm/s, higher range on request
Resolution:	0.1 mm/s
Mean Accuracy:	± 0.15 cm/s
Relative:	± 1% of reading
Statistic variance (std):	0.3 cm/s (ZPulse mode), 0.45 cm/s [1]
Current Direction:	
Range:	0 - 360° magnetic
Resolution:	0.01°
Accuracy:	±2°
Tilt Circuitry:	
Range:	0-90°
Resolution:	0.01°
Accuracy:	±1.5° [2]
Acoustics:	
Frequency:	1.9 to 2.0 MHz
Power:	25 Watts in 1ms pulses
Beam angle (main lobe):	2°
Installation distance:	
From surface:	0.75m
From bottom:	0.5m

Data quality control

A good practice 1: Instrument test before deployment

Instrument test with sensors attached to the CTD rosette at 180m depth

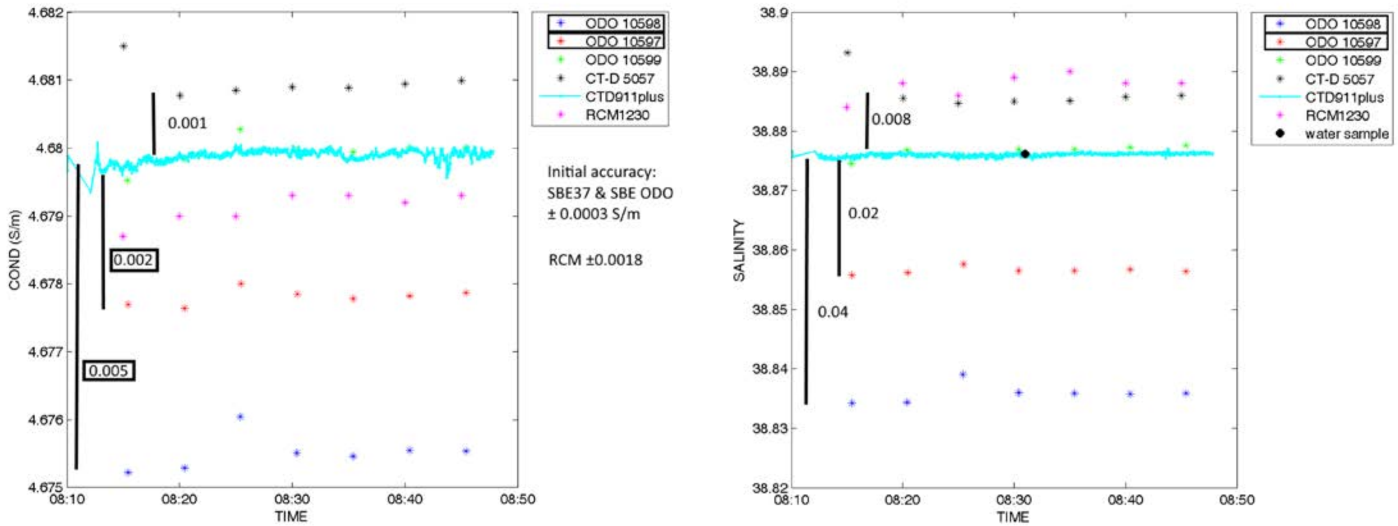


photo 1

photo 2

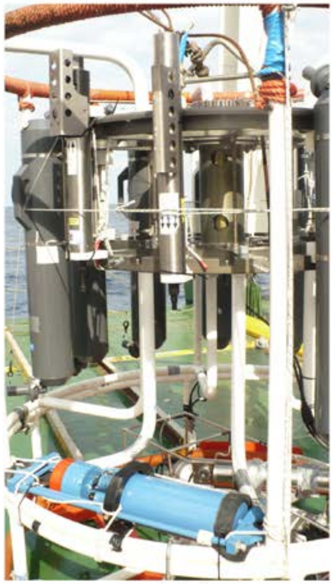
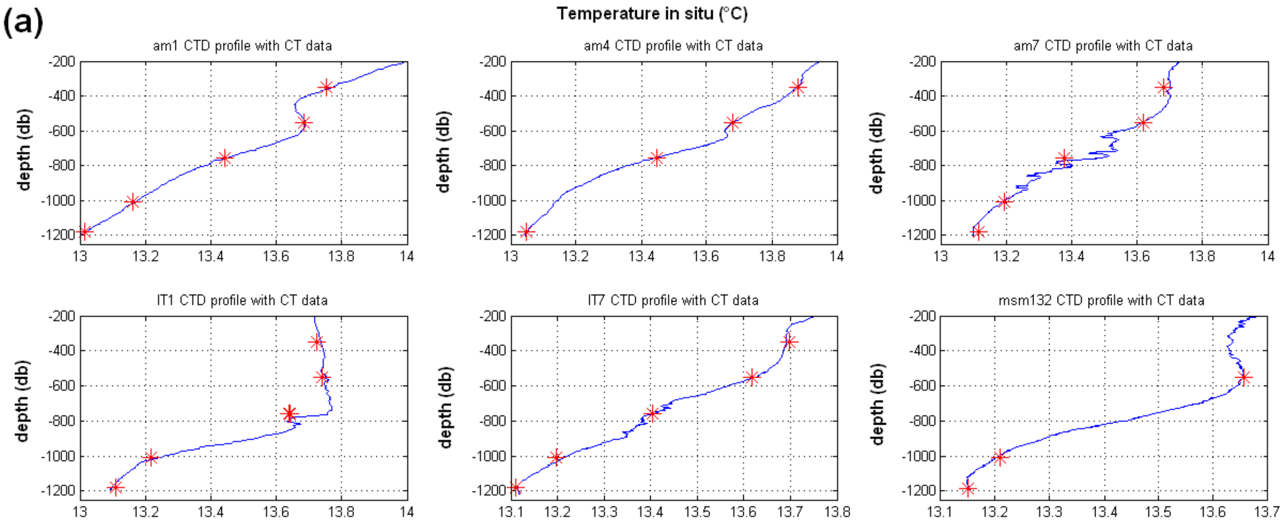
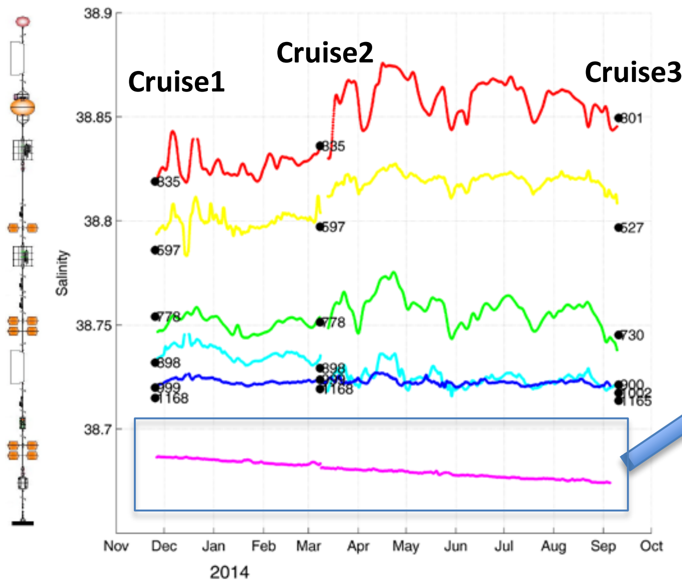


photo 3

A good practice 2: CTD cast before recovery and after deployment





Instrument problems (E2-M3A team experience)

Fouling

Acoutic modems

Failed communication
(distance/technology)
Battery consumpion

SBE 16plus V2 SeaCAT C-T (P) Recorder

AT FIRST DEPLOYMENT

1. Anomalous battery consumption
2. Anomalous corrosion that affected measurements
3. Diss.Ox. To be evaluated

New RCM Seaguard I

Conductivity sensor failed
(close to the bottom)
Diss. Ox. To be evaluated

New SBE 37 ODO

Conductivity sensor failed
(close to the bottom)
Diss. Ox. To be evaluated

Pro Oceanus PCO2

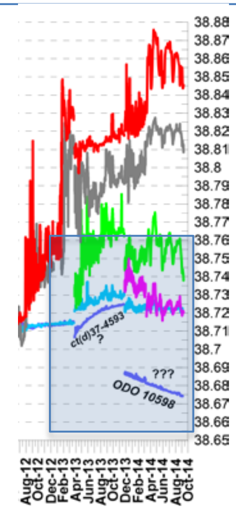
Problems with temperature compensation (solved)
Firmware problems (solved)
Flooding

SAMI - pH

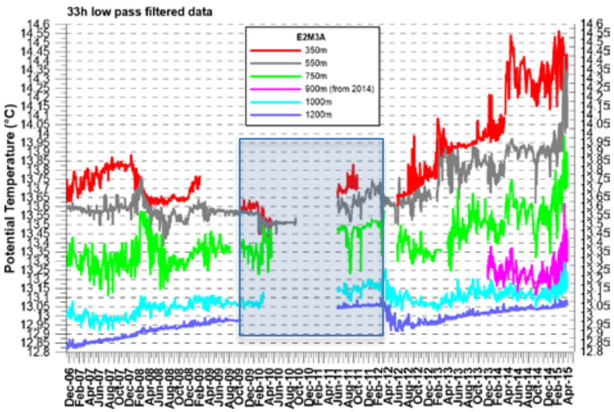
Pressure problems
(it works at the surface but not at 15m depth)

DATA acquisition problems (E2-M3A team experience)

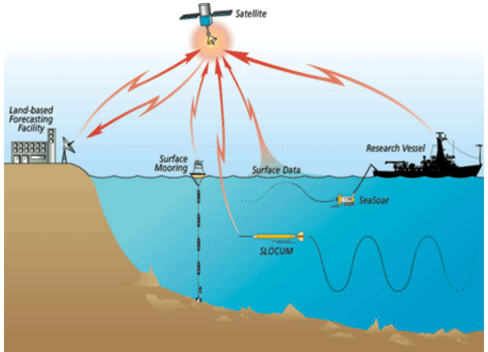
1. **Data discontinuity**
   a) instrument changes
   b) technical problems



2. **Data gaps**
   a) instruments failure
   b) anomalous battery consumption

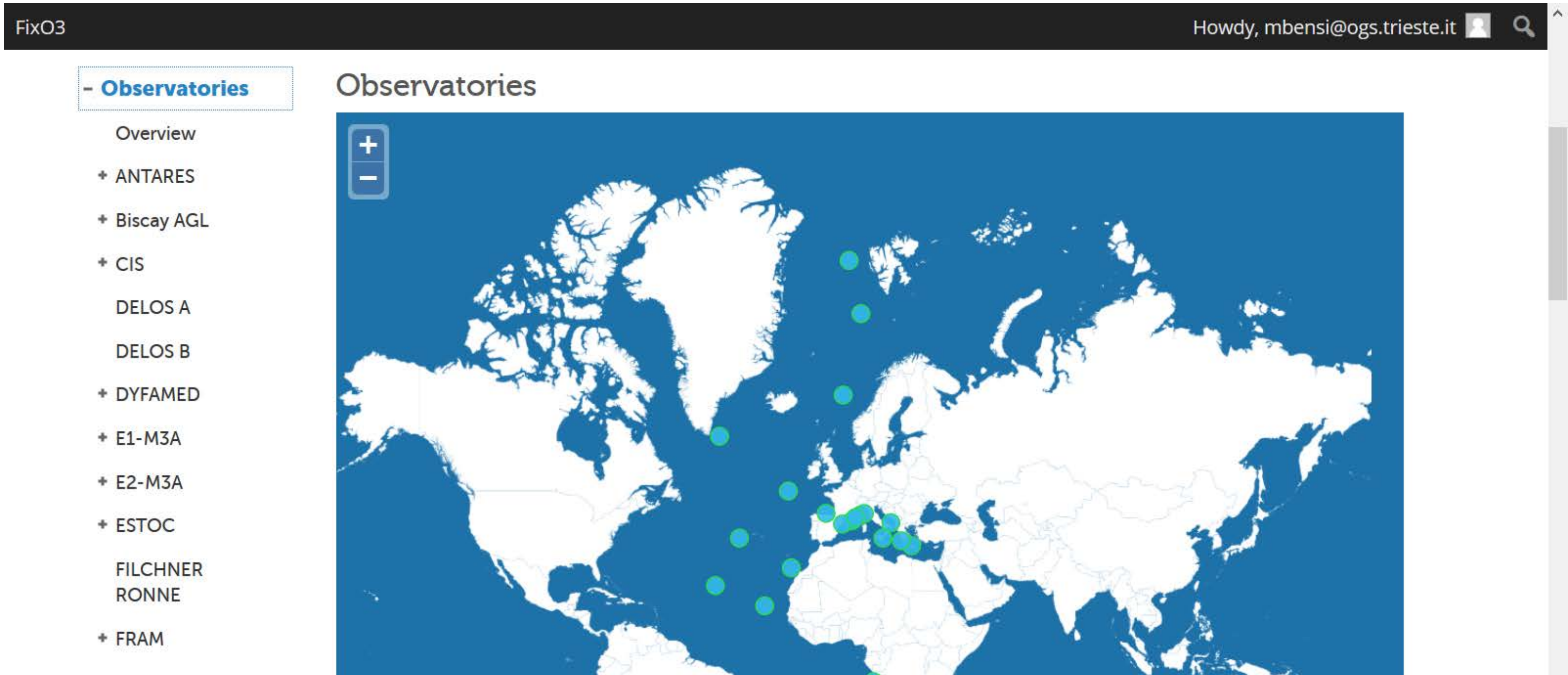


3. **Real time data communication**
   a) high cost
   b) technical problems



Common problems raised in the first year within the FIXO^3 network

1. **Biofouling** of the deployed instruments
2. Anomalous **battery consumption** for some instruments
3. **Deployment of hardware** such as deep-sea benthic landers and sediment trap moorings, which require a large ship for recovery
4. **Damage** due to **vandalism or meteorological events**
5. Converge towards common procedure for **data Inter-comparison**
6. How to share experiences within the network? **WEB-TOOL must often be updated (link to yellow pages required)**



4

Tool for Interoperability and Standardization

Tool for Interoperability and Standardization

http://www.esonetyellowpages.com/

How to provide **feedbacks** for the Hardware/Software used?

Summary: best practices approaching a mooring set-up

1. Geographic location and scientific aim

2. Type of surface buoys-moorings (according to location, meteo conditions, power consumption, intruments hosted, etc…)

3. Mooring design (basic components and tools for design)

4. Core parameters

5. Intrument frame technologies and types (temporal scales, accuracies, endurance, etc…)

1. Good practises at sea to assure valid data collection

2. Intrument and data problems

3. Tool for interoperability (yellow pages within FIXO3)

1 **Sequence of mooring maintenance**

Afternoon session

Operating Scheme/Schematic (with time intervals)

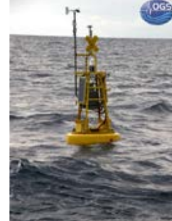
- **Pre-deployment:** preparation of spare equipment (from 1 week to 2-3 months if specific tests are required).
- **Deployment:** recovery, cleaning, download data, quality check, re-deployment (3-5 days).
- **On the field:** position monitoring via Iridium beacon, real-data transfer, data post-processing (2-3 months)

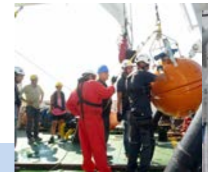
Pre-deployment (procedures in short)

- Mooring Design and buoyancy calculation
- Maintenance/service issues planning (periodic/after failure)
- **Calibration issues:** Instrument calibration at OGS or at factory when required
- Preparations of all equipment and spare components
- Organization of stuff shipping, personnel travel, cruise plan

FixO3 FIXED-POINT OPEN OCEAN OBSERVATORIES

E2-M3A OGS





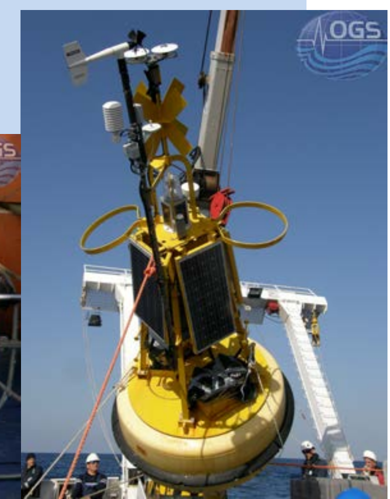
Deployment (procedures in short)

- **Ship/vessel used:** R/V (if available), fishing ship, glider survey
- **Maintenance on board:**
  - **CTD cast before mooring recovery (water samples collection for specific analyses required)**
  - VISUAL INSPECTION OF THE SURFACE BUOY AT SEA
  - VISUAL INSPECTION OF THE METEOROLOGICAL SENSORS
  - **RECOVERY** AND INTRUMENTS CHECK OF THE SURFACE BUOY (REQUIRE ADEQUATE SHIP)
  - **RECOVERY** OF THE SUB-SURFACE MOORING
  - INTRUMENTS CLEANING
  - DOWNLOAD DATA, BATTERY REPLACEMENTS, DATA QUALITY CHECK
  - RE-DEPLOYEMENT
  - **CTD cast after mooring deployment**
- **Specific tests** can be operated on board if time and meteo conditions permit.
- **Check and/or replacement** of damaged Kevlar rope parts and swivels before re-deployment.

On the field (procedures in short)

- **Data transfer:** Real time data transfer through the Globalstar Satellite Modem
- **Surveys:** CTD casts and or visual checks are performed by means of opportunity ships when available
- **Emergencies:** The position of the buoy is controlled with GPS and monitored by Iridium beacon (Short burst message) that transmits the position if the anchor line is accidentally severed
- **Data post processing:** quality-control, filtering, averaging, statistics, plots (MATLAB, instruments software).
- **Data management:** data archived at the NODC-OGS

[http://nodc.ogs.trieste.it/nodc/homepage]

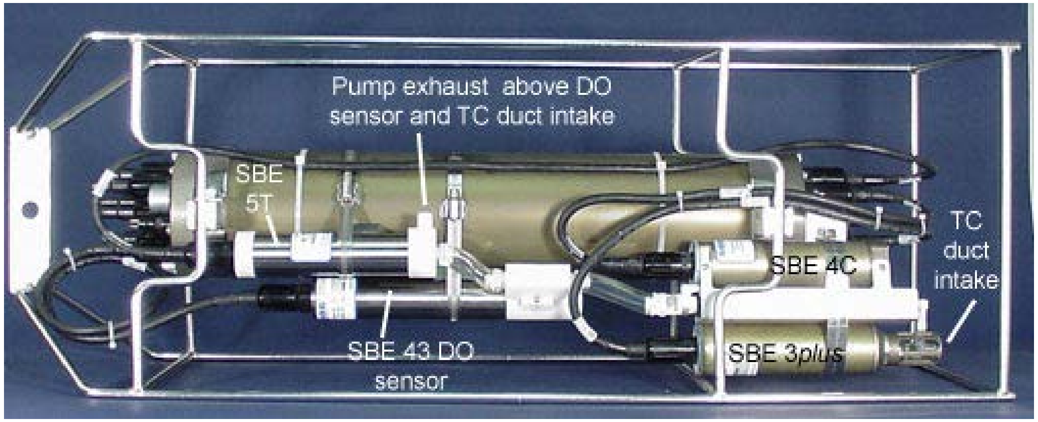


CTD SBE 911 plus

SBE 911plus CTD

The SBE 911plus CTD is the primary oceanographic research tool used by the world's leading institutions, providing 24 Hz sampling with an SBE 9plus CTD Unit and SBE 11plus V2 Deck Unit

The 911plus system provides real-time data collection over 10,000 meters of cable, integrated with an SBE 32 Water Sampler



The 911plus' pump-controlled, T-C ducted flow minimizes salinity spiking and allows for slow descent rates, improving dynamic accuracy and resolving small scale structure in the water column

The 911plus supports numerous auxiliary sensors with eight A/D channels

SBE 911plus CTD

Measurement Range

Conductivity	0 to 7 S/m
Temperature	-5 to 35 °C
Pressure	0 to 1400 / 2000 / 4200/ 6800 / 10,500 m (2000 / 3000 / 6000 / 10,000 / 15,000 psia)

Initial Accuracy

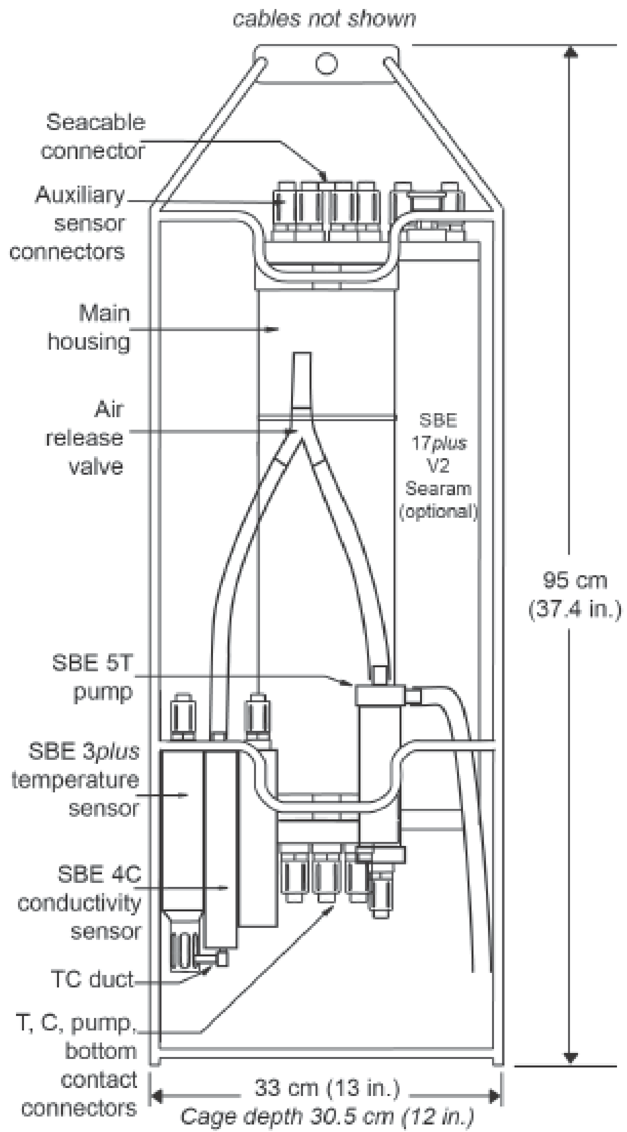
Conductivity	± 0.0003 S/m
Temperature	± 0.001 °C
Pressure	± 0.015% of full scale range

Typical Stability

Conductivity	0.0003 S/m per month
Temperature	0.0002 °C per month
Pressure	± 0.02% of full scale range per year

Resolution (at 24 Hz)

Conductivity	0.00004 S/m
Temperature	0.0002 °C
Pressure	0.001% of full scale range



SBE 32 Water Sampler