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Why observe the sea?

The state of the art of the Global Ocean Observing System
and the experience in the Adriatic Sea

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CNR IRBIM Ancona

Seminar Teaching Week 2024, FishMed-PhD program
Fano Marine Center

Pierluigi Penna, brief bio

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Degree

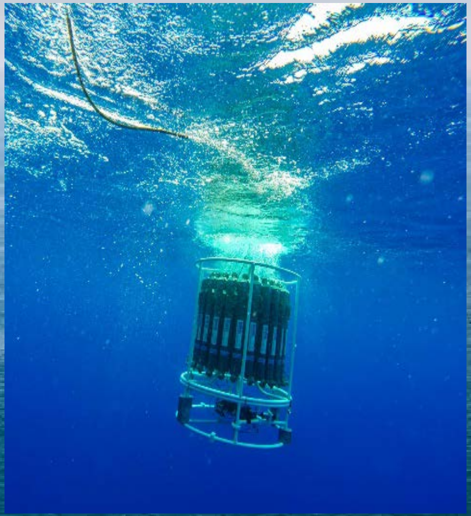
- ✓ Ms Computer Science 2010, UniV. Camerino
- ✓ PhD Information Sciences and Complex Systems Curricula (XXVI Cycle) 2014, International School of Advanced Studies – UniV. Camerino (MC)

Current activity

- ✓ Researcher at the Institute for Marine Biological Resources and Biotechnology of the National Research Council (CNR-IRBIM)

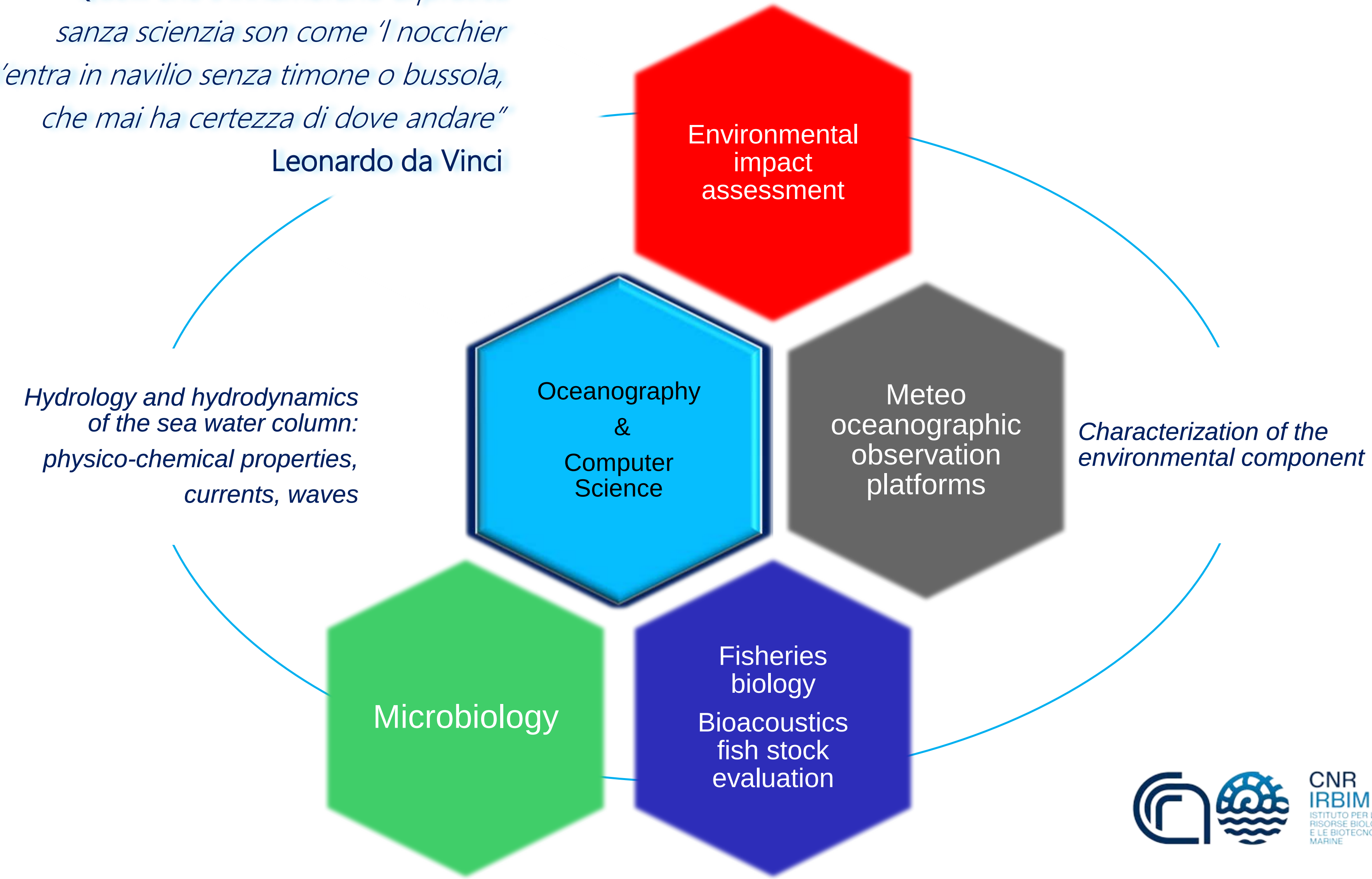
Research activity

- ➢ Experimental studies of physical and chemical oceanography
- ➢ Hydrology and hydrodynamics of the water column:
  - physicochemical properties
  - currents, waves, weather



Research activity: multidisciplinary approach

*"Quelli che s'innamorano di pratica
sanza scienzia son come 'l nocchier
ch'entra in navilio senza timone o bussola,
che mai ha certezza di dove andare"*
Leonardo da Vinci



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Topics We Will Cover:

- Introduction
- DAS:Data Acquisition Systems
- Sensors
- Sensor drift and calibration
- Making Measurements in Ocean
- Architecture of an Ocean Monitoring and Forecasting System
- Satellite and models
- Why observe the sea?
- Open discussion and conclusion

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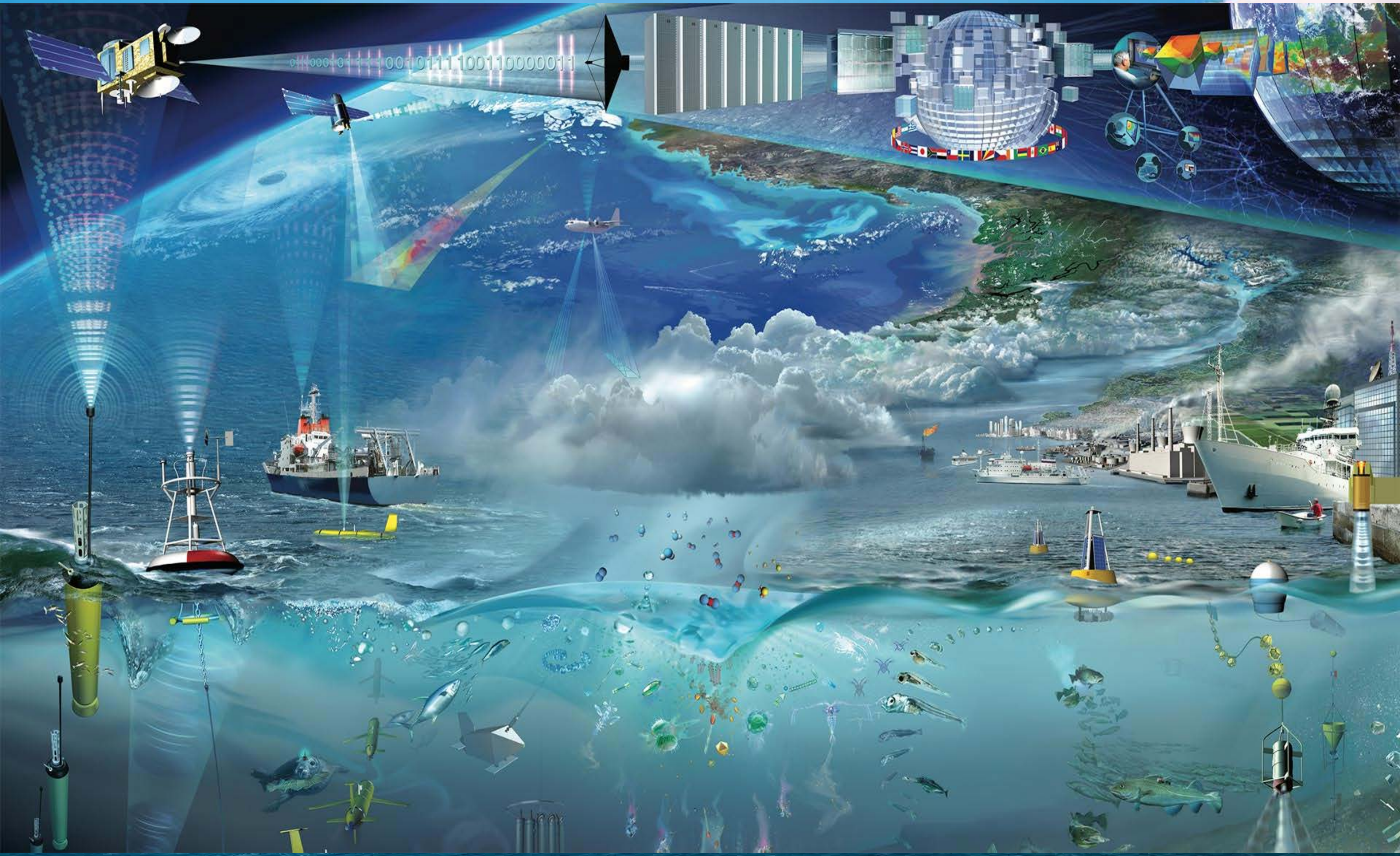
The Global Ocean Observing System

EuroGOOS
European Global Ocean Observing System



***Data acquisition** is the sampling, of the real world, to generate data that can be manipulated by a computer*

Sometimes abbreviated DAQ or DAS, data acquisition typically involves acquisition of signals and waveforms and *processing the signals to obtain desired information*

The components of data acquisition systems include appropriate **sensors** that convert any measurement parameter to an electrical signal, then **conditioning the electrical signal** which can then be acquired by **data acquisition hardware**

Acquired data are **displayed, analyzed, and stored on a computer,** either using vendor supplied software, or custom displays and control can be developed using various general purpose programming language

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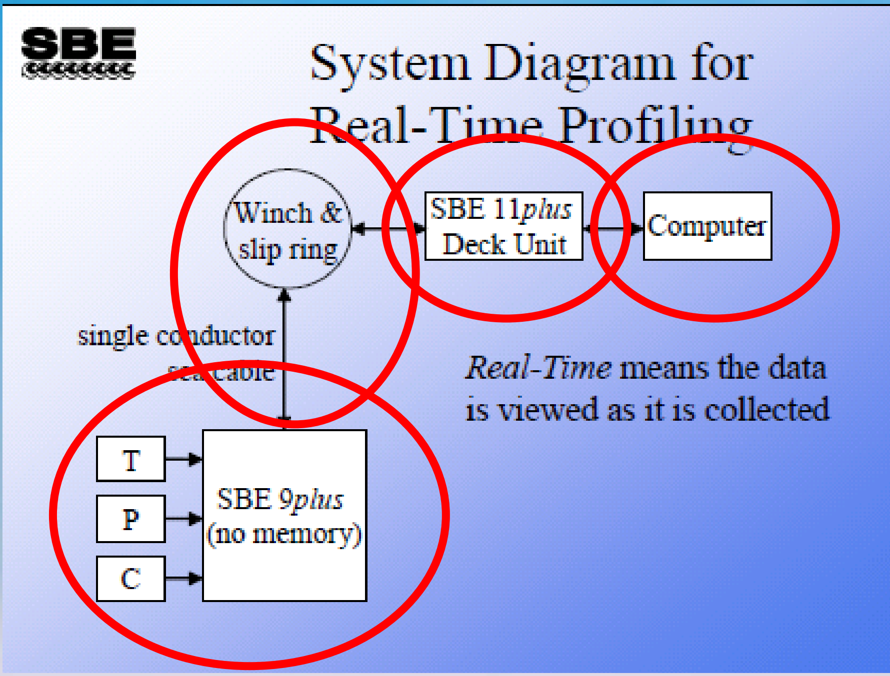
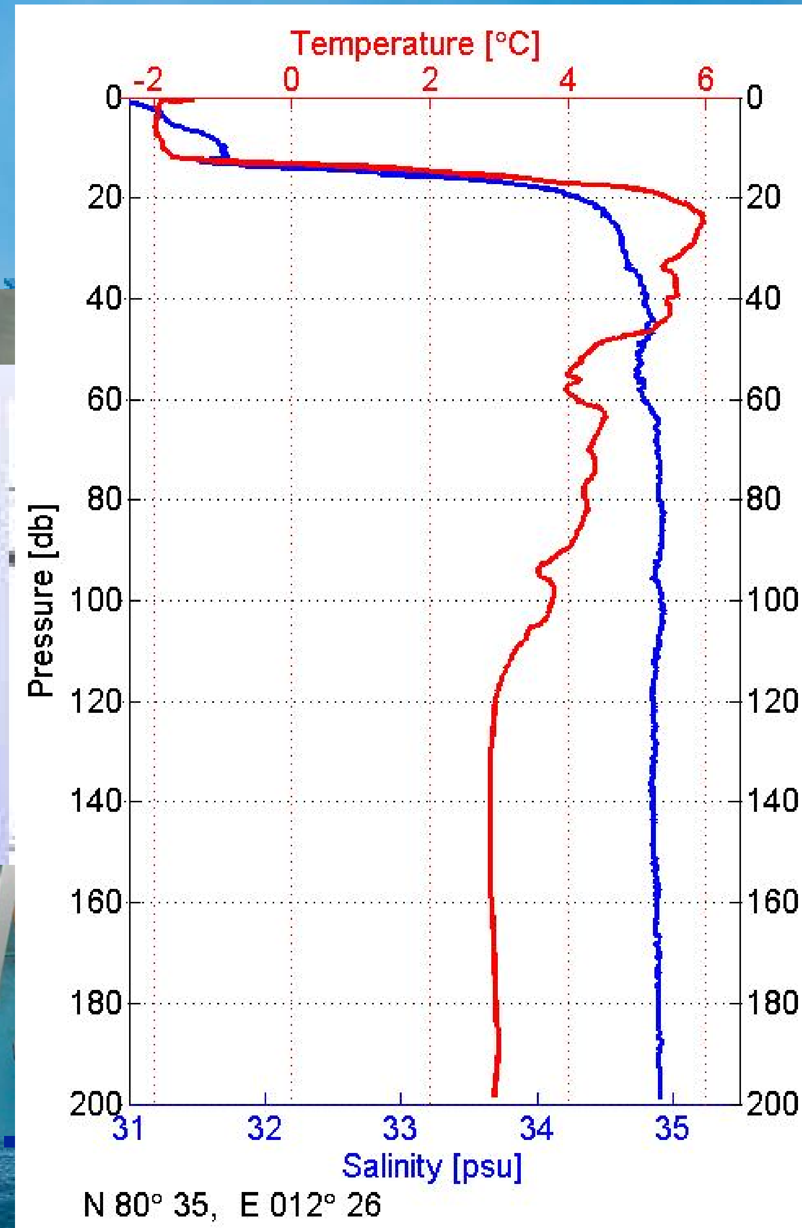
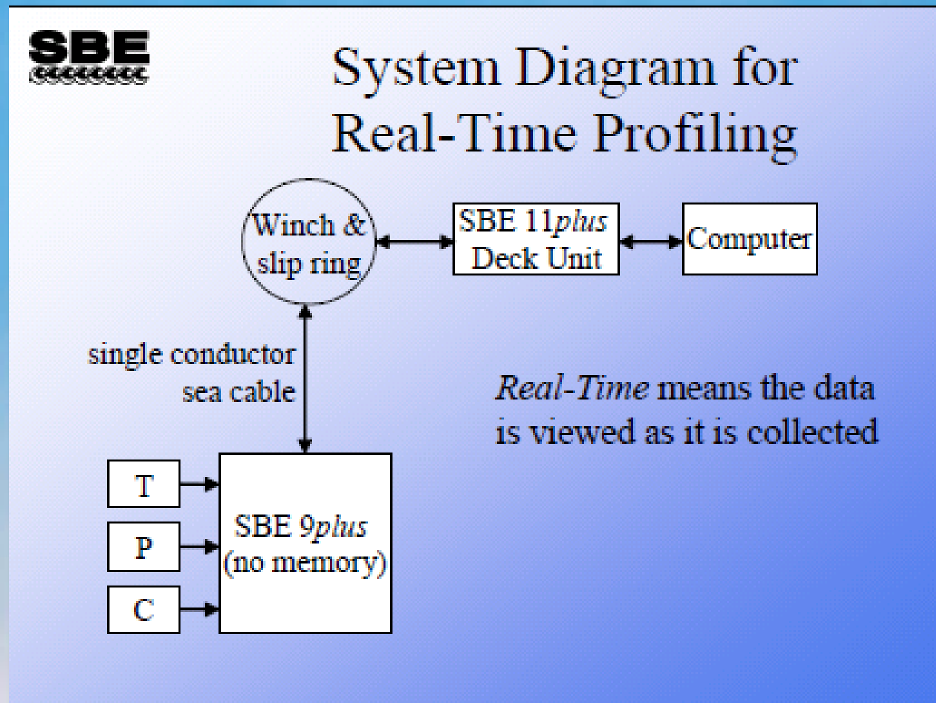
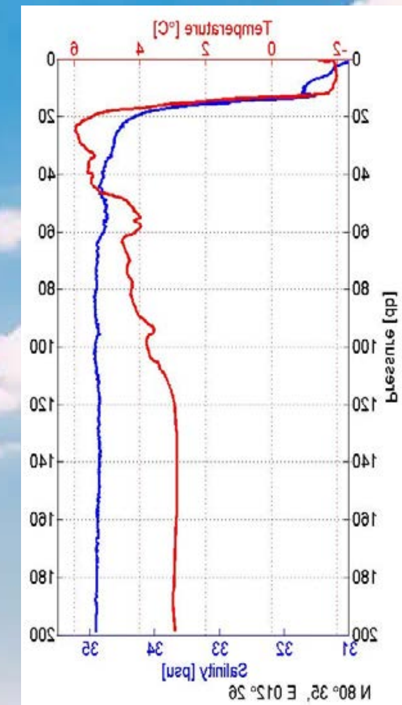

SBE
System Diagram for Real-Time Profiling
Winch & slip ring
SBE 11*plus* Deck Unit
Computer
single conductor
Real-Time means the data is viewed as it is collected
T
P
C
SBE 9*plus* (no memory)


Temperature [°C]
-2
0
2
4
6
Pressure [db]
0
20
40
60
80
100
120
140
160
180
200
31
32
33
34
35
Salinity [psu]
N 80° 35, E 012° 26

An example of oceanographic DAS





Signals may be *digital* (also called **logic signals** sometimes) or *analog* depending on

digitized using ADCs (Analog to Digital Convertes)

Various other examples of signal conditioning might be bridge completion, providing current or voltage excitation to the sensor, isolation, linearization, etc.

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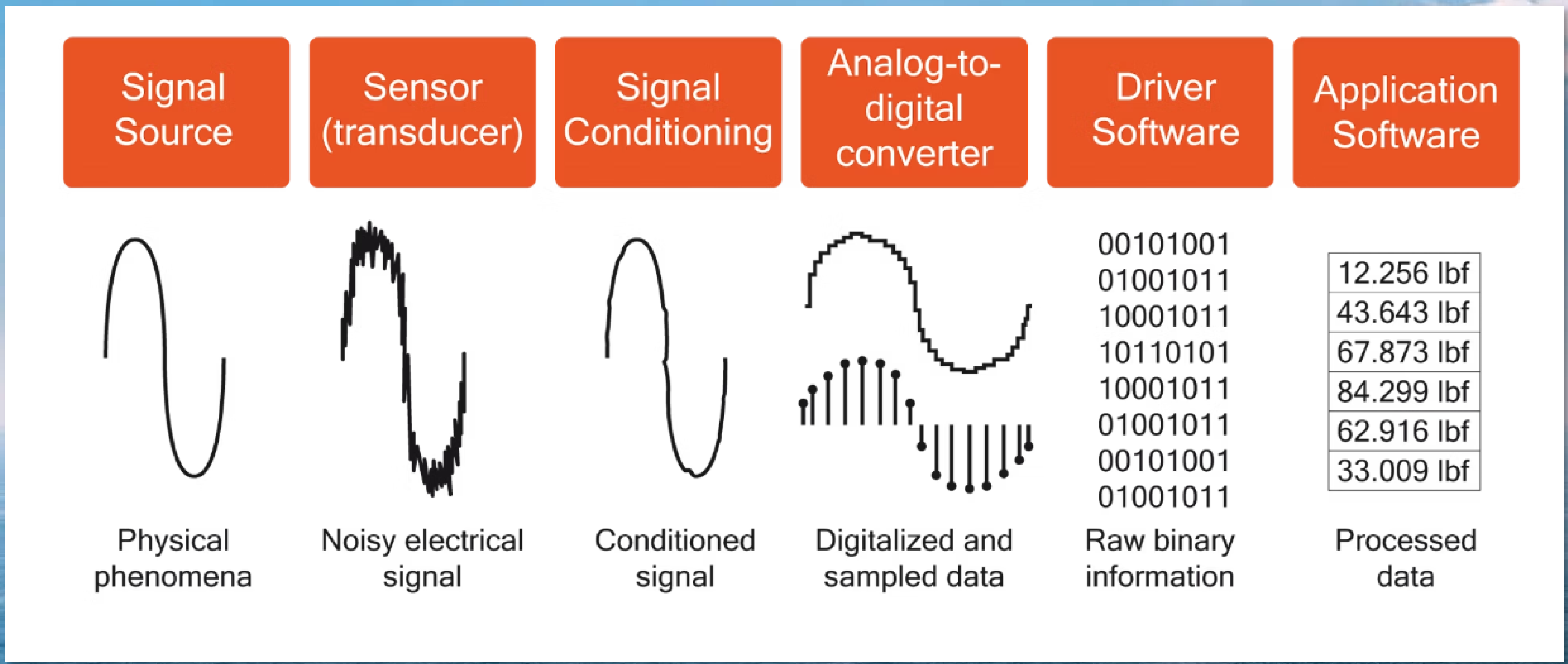
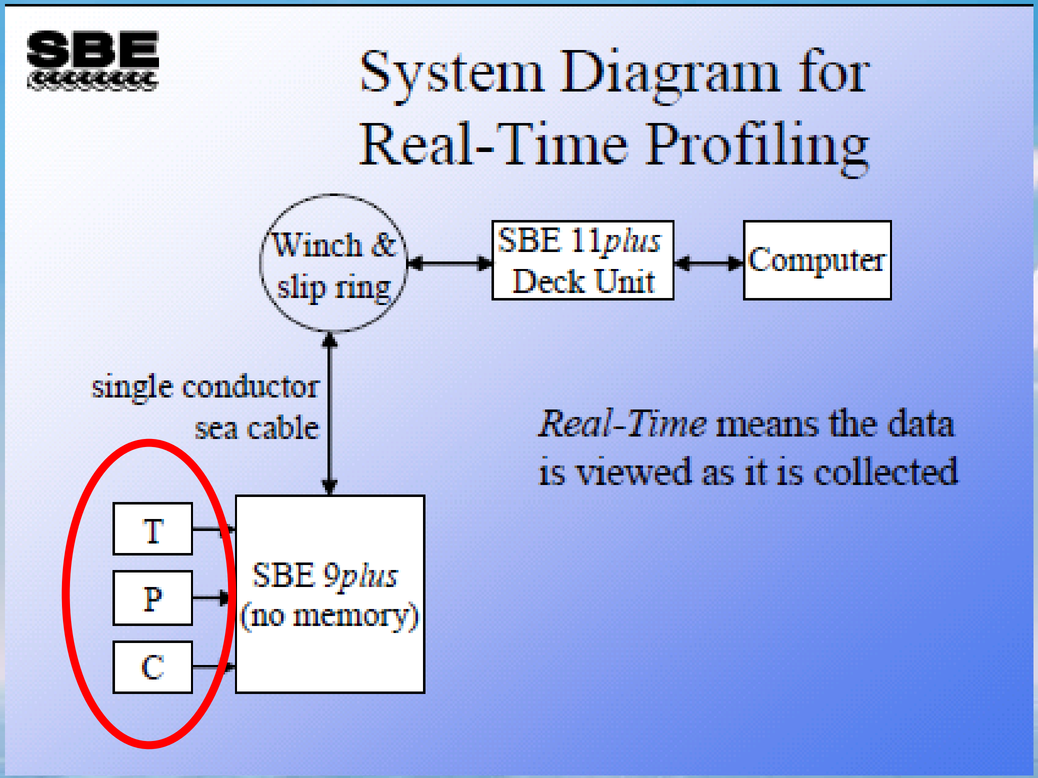
From an analog source to digital data, ready to be processed by a computer and software



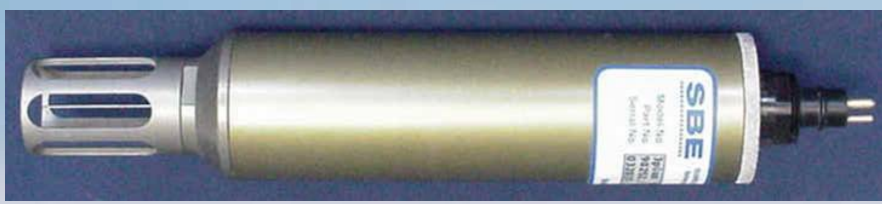


Focus on sensors

A **sensor** is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument

For example, a mercury thermometer converts the measured temperature into expansion and contraction of a liquid which can be read on a calibrated glass tube

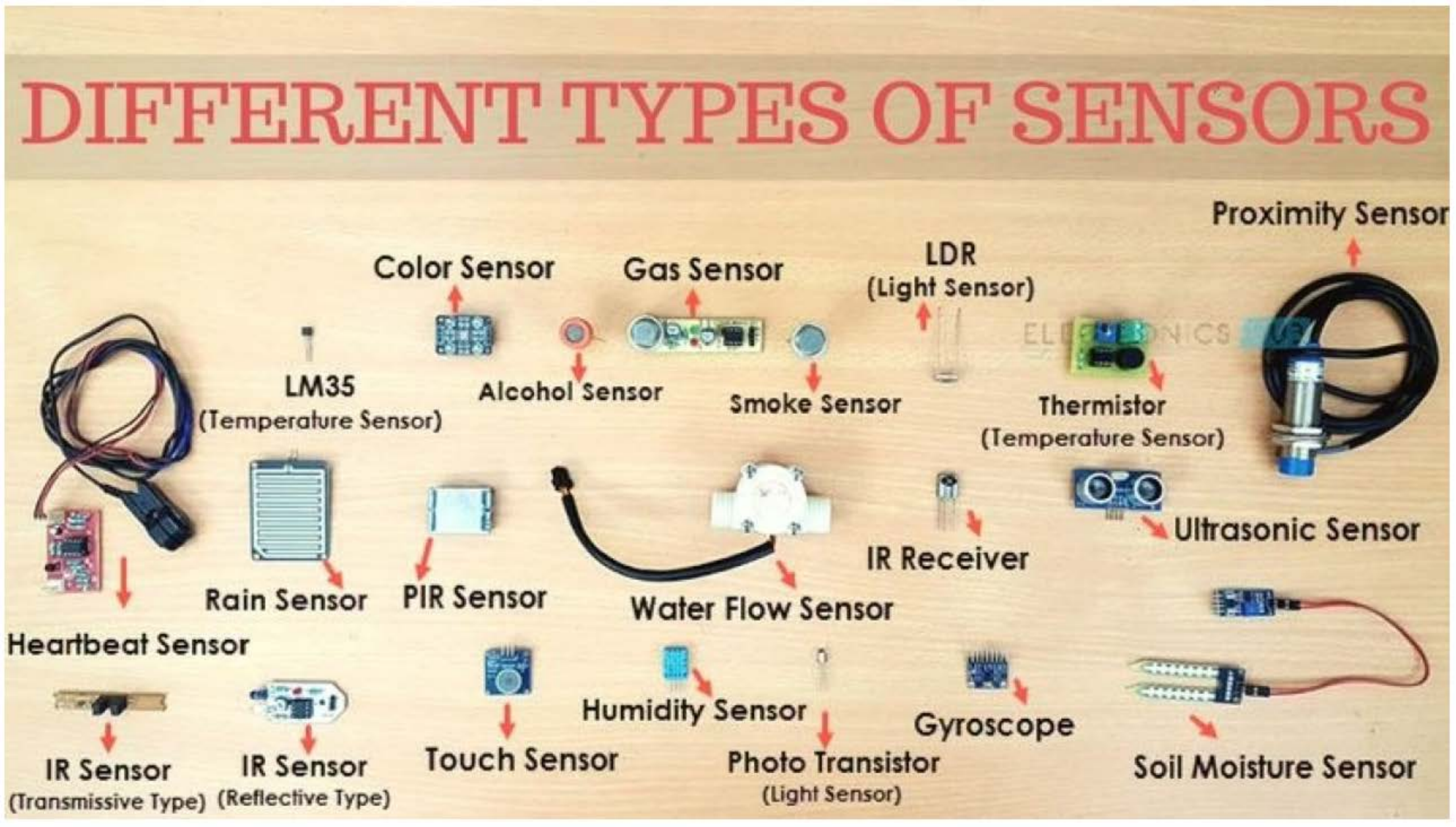
A thermocouple converts temperature to an output voltage which can be read by a voltmeter



Temperature

Magnetic

Light


DIFFERENT TYPES OF SENSORS
Proximity Sensor
Color Sensor
Gas Sensor
LDR
(Light Sensor)
LM35
(Temperature Sensor)
Alcohol Sensor
Smoke Sensor
Thermistor
(Temperature Sensor)
Ultrasonic Sensor
IR Receiver
Rain Sensor
PIR Sensor
Water Flow Sensor
Heartbeat Sensor
Humidity Sensor
Gyroscope
IR Sensor
(Transmissive Type)
IR Sensor
(Reflective Type)
Touch Sensor
Photo Transistor
(Light Sensor)
Soil Moisture Sensor

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A sensor's **sensitivity** indicates how much the sensor's output changes when the measured quantity changes. For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C

Sensors that measure very small changes must have very high sensitivities

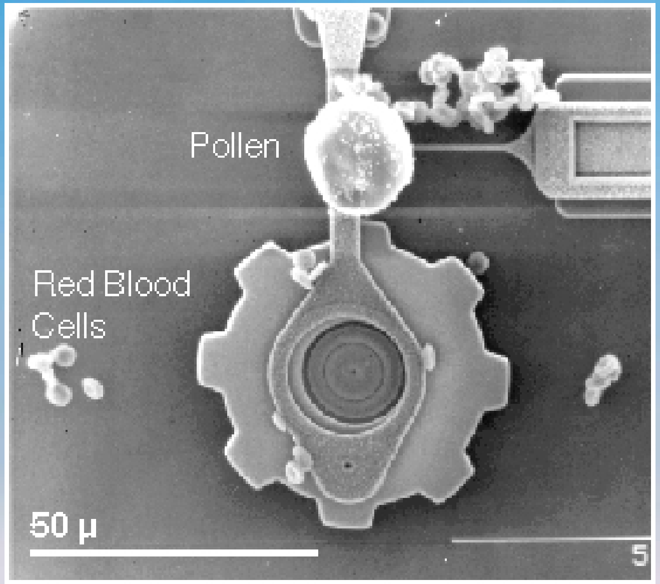
The **resolution** of a sensor is the smallest change it can detect in the quantity that it is measuring.The resolution is related to the precision with which the measurement is made

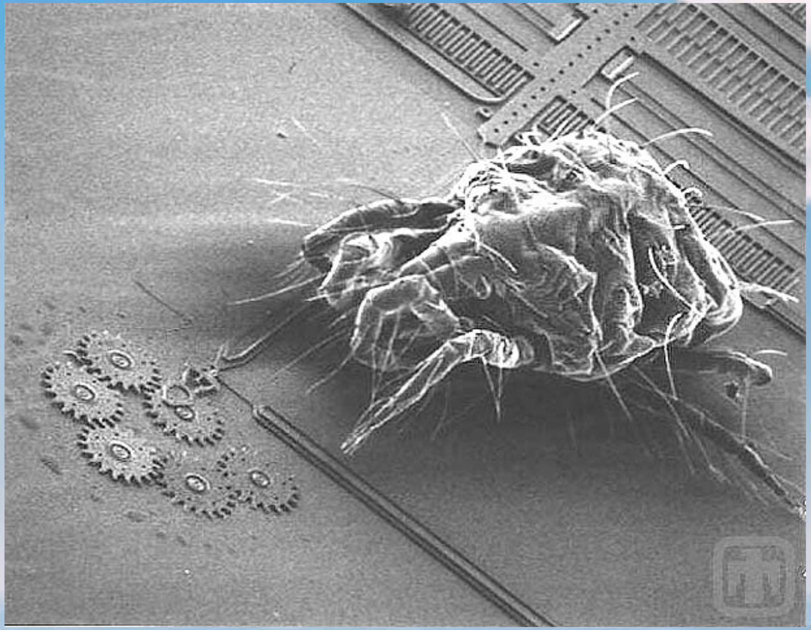
Sensors also have an impact on what they measure; for instance, a room temperature thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer

Technological progress allows more and more sensors to be manufactured on a microscopic scale as microsensors using MEMS technology.

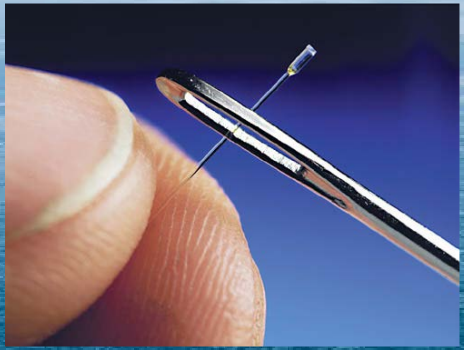
In most cases, a microsensor reaches a significantly higher speed and sensitivity compared with macroscopic approaches.

Micro Electro Mechanical Systems technology (aka MEMS)

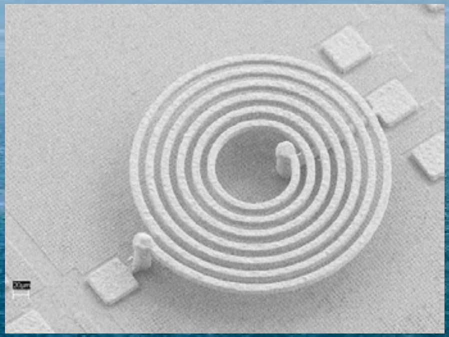




Vibration

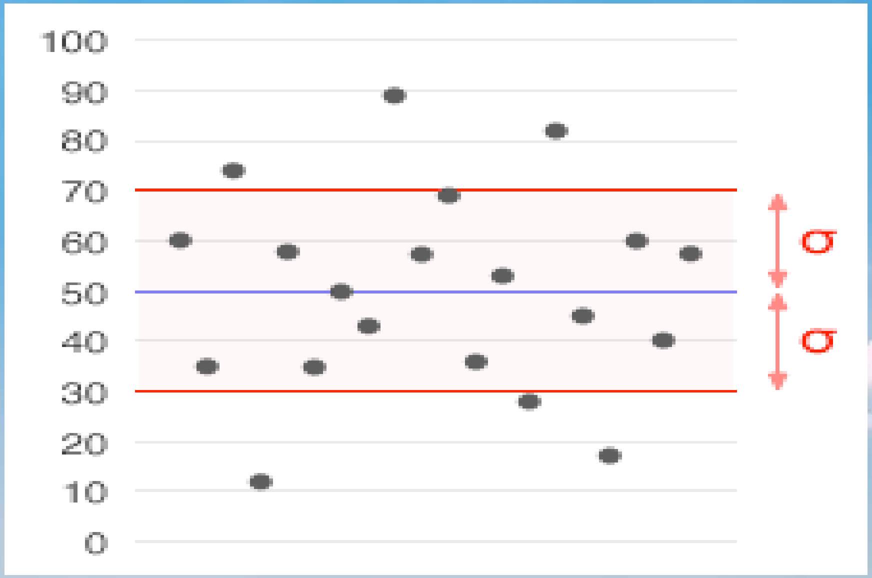


Blood pressure



RF MEMS

Some statistic : *Standard Deviation*

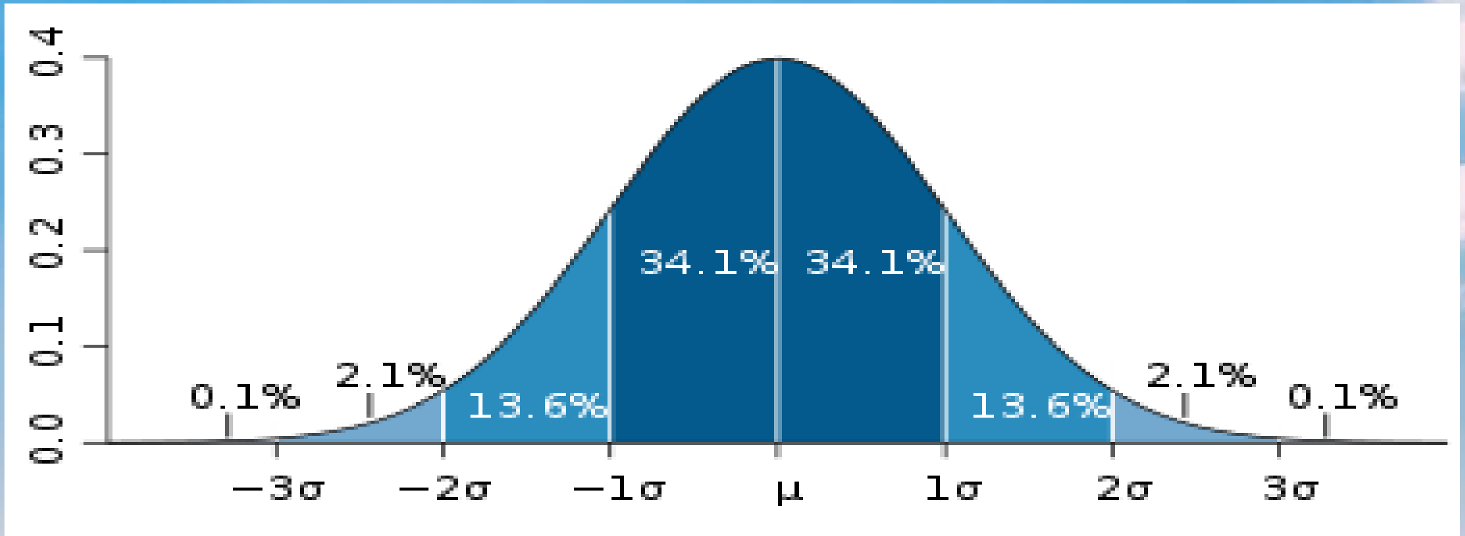


A data set with mean=50 and standard deviation=20

In probability theory and statistics, **standard deviation** is a measure of the variability or dispersion of a population, a data set, or a **probability distribution**

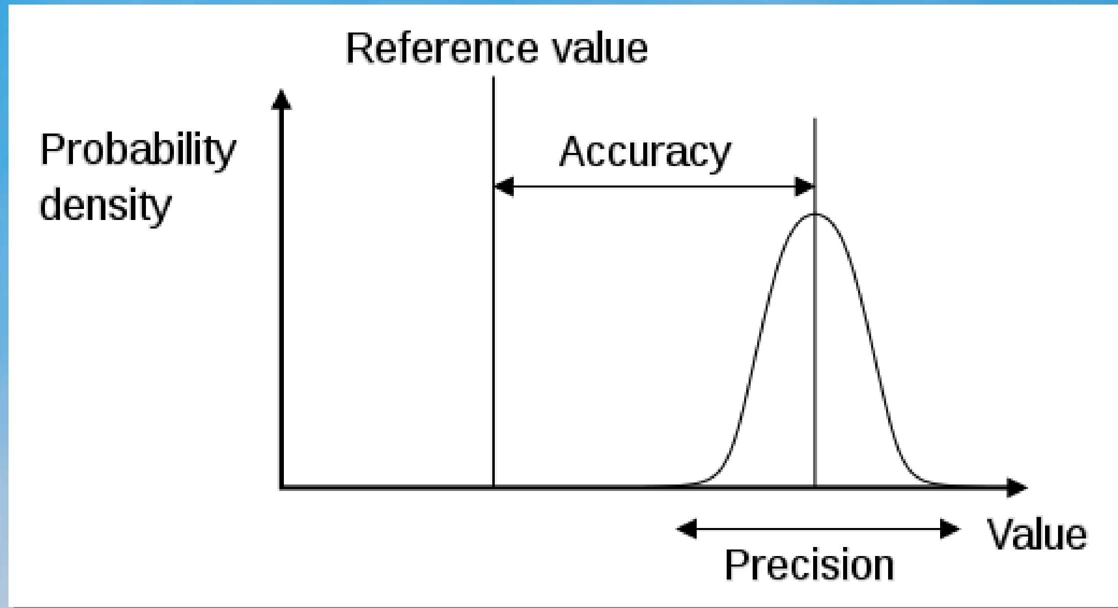
A low standard deviation indicates that the data points tend to be very close to the same value (the mean), while high standard deviation indicates that the data are "spread out" over a large range of values.

Normally distributed data: normal distribution (or Bell curve)



Dark blue is less than one standard deviation from the mean. For the normal distribution, this accounts for 68.27% of the set, while two standard deviations from the mean (medium and dark blue) account for 95.45%, three standard deviations (light, medium, and dark blue) account for 99.73%, and four standard deviations account for 99.994%.

The **central limit theorem** says that the distribution of a sum of many independent, identically distributed random variables tends towards the **normal distribution**. If a data distribution is approximately normal then about 68% of the values are within 1 standard deviation of the mean (mathematically, μ ± σ, where μ is the arithmetic mean), about 95% of the values are within two standard deviations (μ ± 2σ), and about 99.7% lie within 3 standard deviations (μ ± 3σ). This is known as the 68-95-99.7 rule, or the <u>empirical rule</u>



In the fields of science, engineering, industry and statistics, **accuracy** is the degree of closeness of a measured or calculated quantity to its actual (true) value.

The results of calculations or a measurement can be accurate but not precise, precise but not accurate, neither, or both. A measurement system or computational method is called **valid** if it is both accurate and precise.

Accuracy is closely related to **precision**, also called reproducibility or repeatability, the degree to which further measurements or calculations show the same or similar results

The related terms are **bias** (non-random or directed effects caused by a factor or factors unrelated by the independent variable) and **error** (random variability), respectively

High **accuracy**, but low **precision**

High **precision**, but low **accuracy**

Accuracy is the degree of veracity while precision is the degree of reproducibility

The analogy used here to explain the difference between accuracy and precision is the target comparison. In this analogy, repeated measurements are compared to arrows that are shot at a target.
Accuracy describes the closeness of arrows to the bullseye at the target center.
Arrows that strike closer to the bullseye are considered more accurate.

The closer a system's measurements to the accepted value, the more accurate the system is considered to be

High **accuracy**, but low **precision**

High **precision**, but low **accuracy**

To continue the analogy, if a large number of arrows are shot, precision would be the size of the arrow cluster.

When all arrows are grouped tightly together, the cluster is considered precise since they all struck close to the same spot, if not necessarily near the bullseye

The measurements are precise, though not necessarily accurate

High **accuracy**, but low **precision**

High **precision**, but low **accuracy**

However, <u>it is not possible to reliably achieve accuracy in individual measurements without precision</u> — if the arrows are not grouped close to one another, they cannot all be close to the bullseye

Their average position might be an accurate estimation of the bullseye, but the individual arrows are inaccurate

- Ideally a measurement device is both accurate and precise, with measurements all close to and tightly clustered around the known value.
- The accuracy and precision of a measurement process is usually established by repeatedly measuring some traceable **reference standard**
- Such standards are defined in the International System of Units and maintained by national standards organizations such as the National Institute of Standards and Technology or ISO
- In some literature, precision is defined as the reciprocal of variance, while many others still confuse precision with the confidence interval
- The interval defined by the standard deviation is the 68.03% ("one sigma") **confidence interval** of the measurements
- If enough measurements have been made to accurately estimate the standard deviation of the process, and if the measurement process produces normally distributed errors, then it is likely that **68.03%** of the time, the true value of the measured property will lie within one standard deviation, **95.4%** of the time it will lie within two standard deviations, and **99.7%** of the time it will lie within three standard deviations of the measured value.

- This also applies when measurements are repeated and averaged.

In that case, the term standard error is properly applied: the precision of the average is equal to the known standard deviation of the process divided by the square root of the number of measurements averaged.

- Further, the central limit theorem shows that the probability distribution of the averaged measurements will be closer to a normal distribution than that of individual measurements.

With regard to accuracy we can distinguish:

- the difference between the mean of the measurements and the reference value, the **bias**. Establishing and correcting for bias is necessary for **calibration**.
- the combined effect of that and precision

Sensor Response Times

- Sensors do not respond infinitely quickly to changes in their environment
- Sensor response to a step change in their environment is termed their

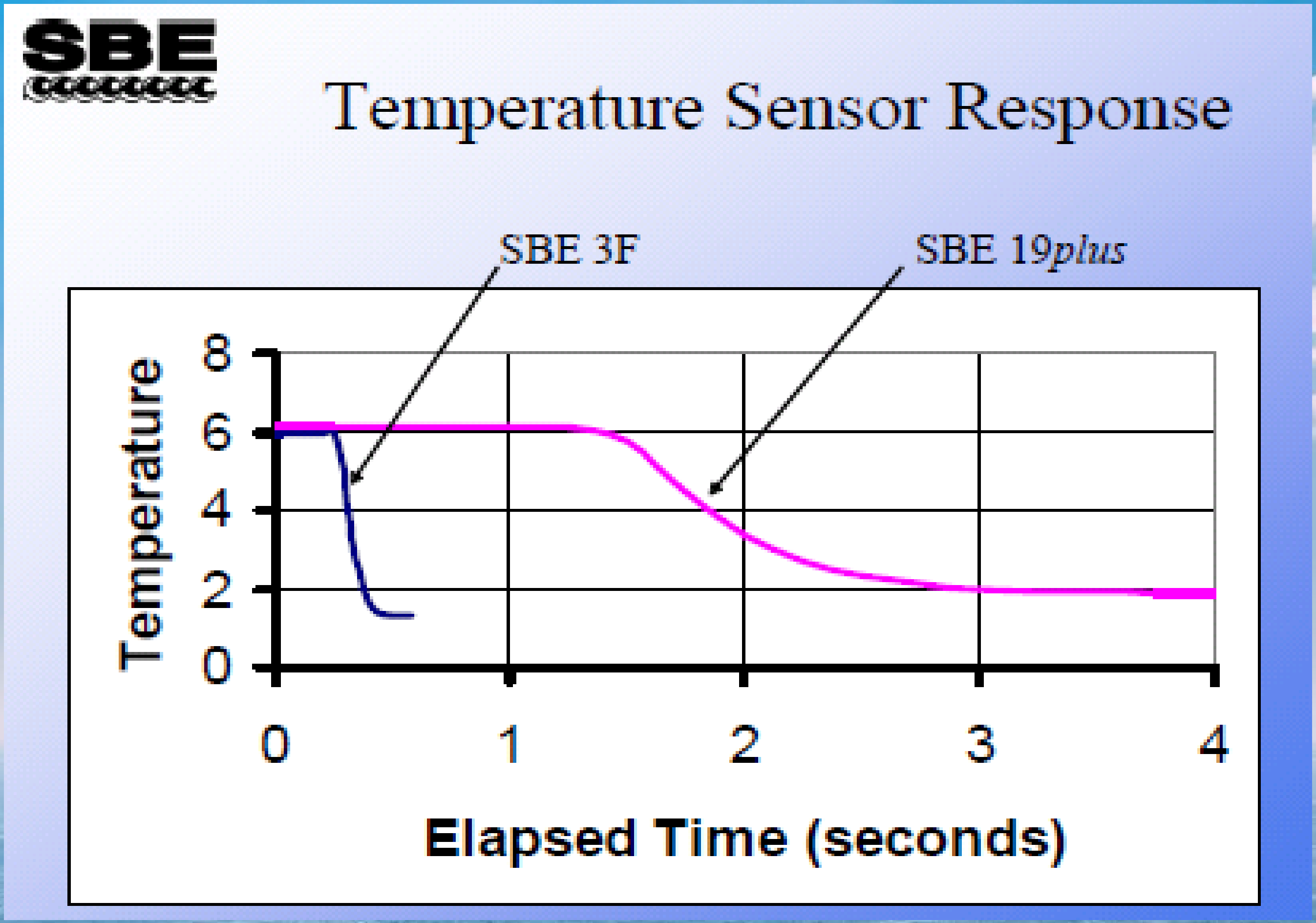
  time constant
- Time constant is typically stated as time to come to 63% of final value, given a ***stepchange in environment***

Sensors do not react infinitely quickly to a new environmental condition. *The reason for a slower response time for sensors is often found in the packaging of the active element of the sensor.*

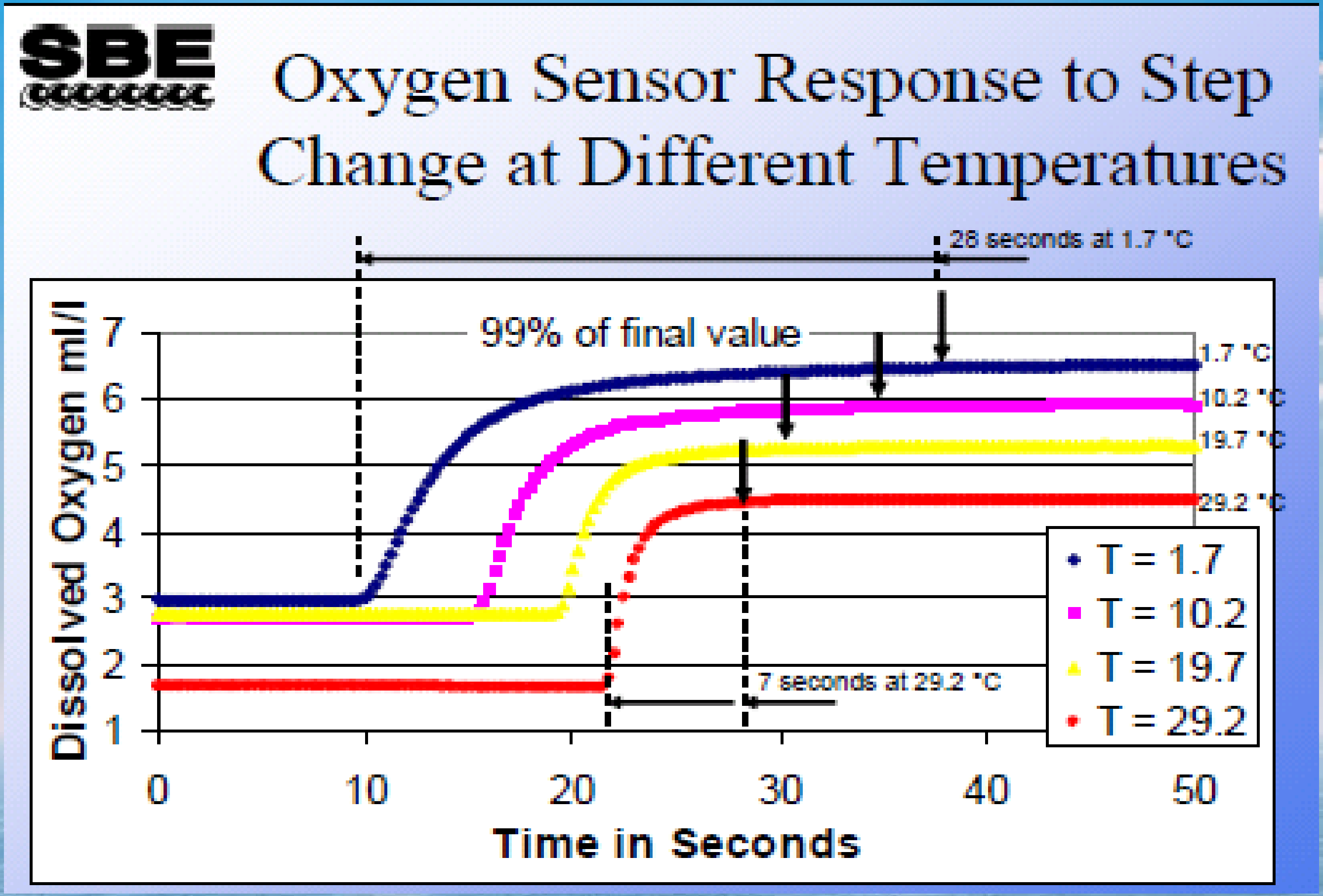
For example, a thermistor is housed in a thin metal sheath; the delay in response to a sharp change in temperature from warm to cold is due to the time required for the heat in the thermistor to diffuse into the environment.

For a conductivity cell, there is flushing time of the cell.

For a dissolved oxygen sensor, there is the time required for the concentration of O2 near the electrode to equilibrate with the environment. *The time constant, or* τ (tau), *of the sensor is expressed as the time for the sensor to come to 63% of its final value given a step input.*



This plot compares the time response of the SBE 3F with the SBE 19*plus*. The SBE 3F has a smaller thermistor and a smaller needle, giving it a faster response time



The plot above illustrates the effect that temperature has on a dissolved oxygen sensor.
The colder the water that the sensor is working in, the longer it requires to come to a final value

Contemplating a Sensor

- *Perfection*:
  – Reacts to only one physical characteristic of environment
  – Has a response to physical characteristic that is easily modeled mathematically

- *Reality*:
  – May react to more than one physical characteristic of environment
  – Response of sensor may be non-linear or may be parametric, with terms that reflect its reaction to physical characteristics other than one of interest

Sensor deviations

- The **sensitivity** may in practice differ from the value specified. This is called a sensitivity error, but the sensor is still linear
- If the sensitivity is not constant over the range of the sensor, this is called **nonlinearity**. Usually this is defined by the amount the output differs from ideal behavior over the full range of the sensor, often noted as a percentage of the full range
- Since the range of the output signal is always limited, the output signal will eventually reach a minimum or maximum when the measured property exceeds the limits. The **full scale range** defines the maximum and minimum values of the measured property
- If the output signal is not zero when the measured property is zero, the sensor has an **offset** or **bias**. This is defined as the output of the sensor at zero input
- If the deviation is caused by a rapid change of the measured property over time, there is a **dynamic error**. Often, this behaviour is described with a bode plot showing sensitivity error and phase shift as function of the frequency of a periodic input signal
- If the output signal slowly changes independent of the measured property, this is defined as **drift**

Sensor deviations

- **Long term drift** usually indicates a slow degradation of sensor properties over a long period of time
- **Noise** is a random deviation of the signal that varies in time. It can be reduced by signal processing, such as filtering, usually at the expense of the dynamic behaviour of the sensor
- **Hystereris** is an error caused by when the measured property reverses direction, but there is some finite lag in time for the sensor to respond, creating a different offset error in one direction than in the other

- If the sensor has a digital output, the output is essentially an approximation of the measured property. The approximation error is also called **digitization** error

Sensor deviations

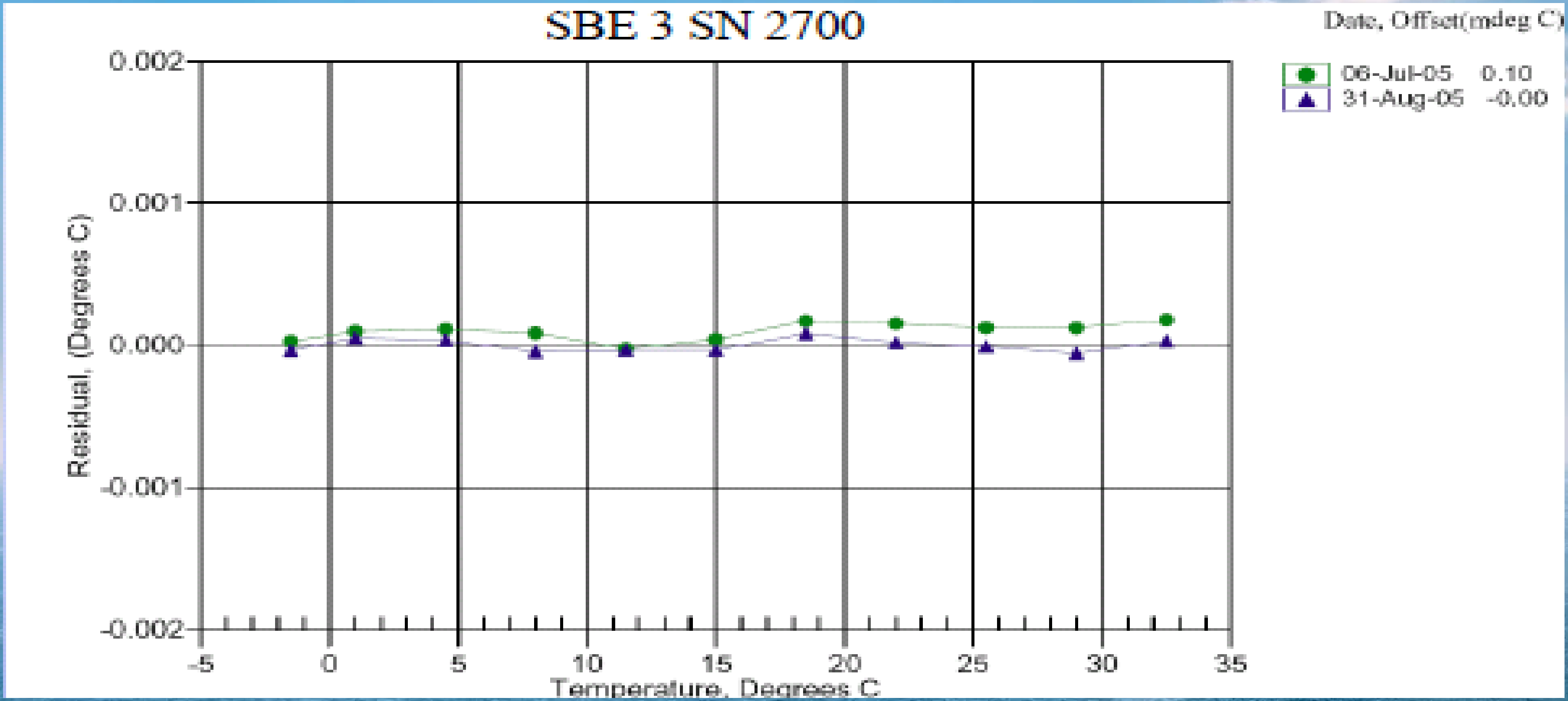
- If the signal is monitored digitally, limitation of the **sampling frequency** also can cause a dynamic error

- The sensor may to some extent be sensitive to properties other than the property being measured. For example, most sensors are influenced by the temperature of their environment

- All these deviations can be classified as **systematic errors** or **random errors**

Sensor drift and calibration

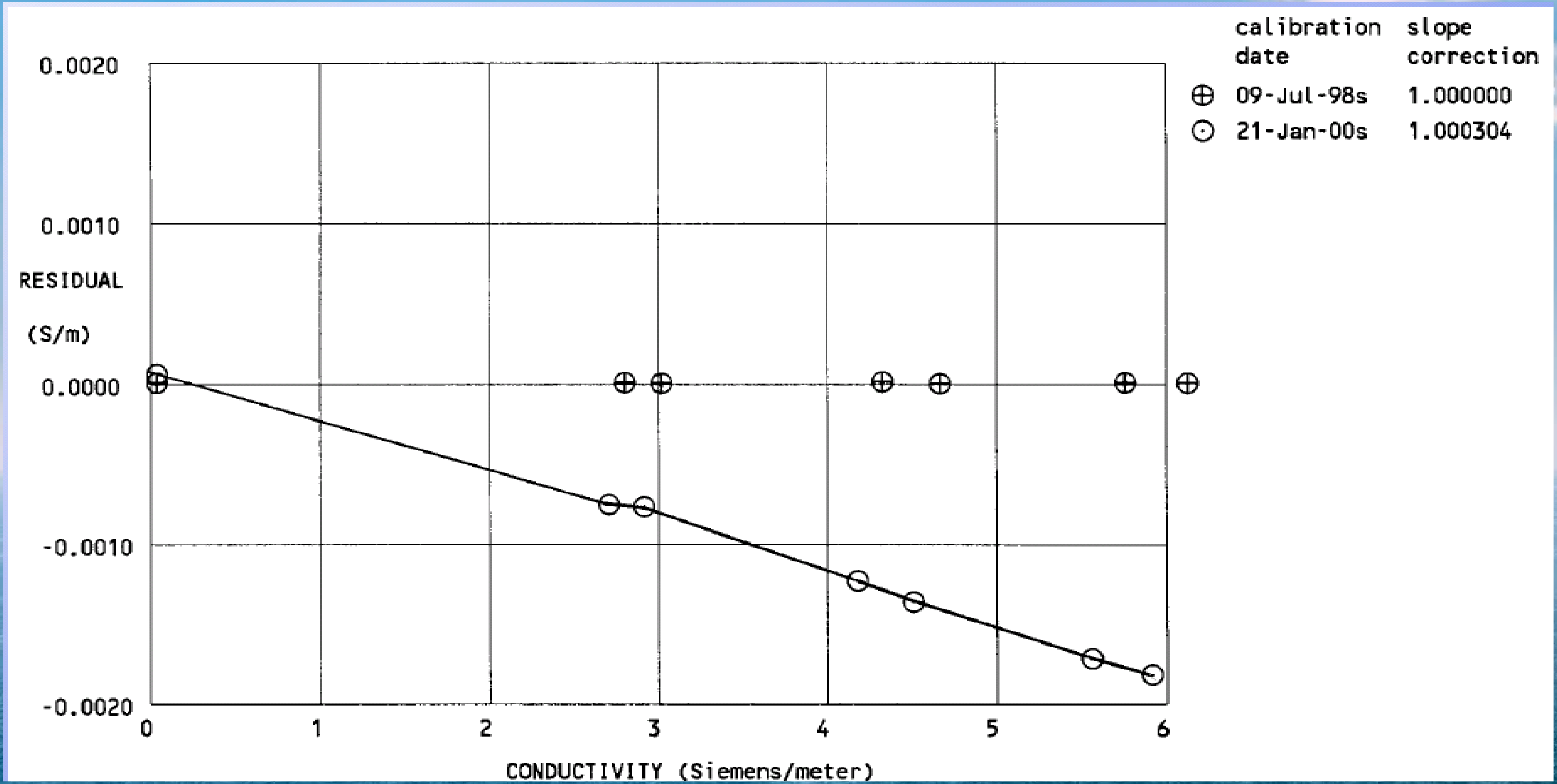
Temperature Sensor Drift Over Time



Typical drift rate for SBE 3F is 0.0002 °C/month

Sensor drift and calibration

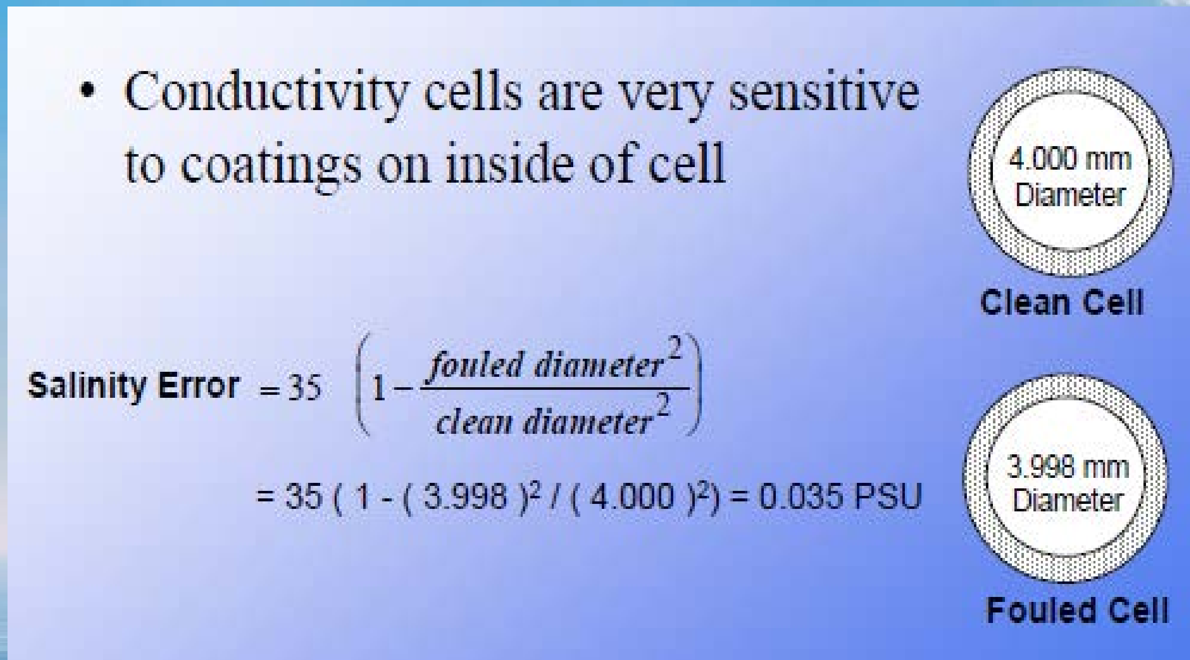
Conductivity Sensor Drift Characteristics



Conductivity sensors typically drift in slope. Drift rate is 0.0003 Siemens/meter/month

Sensor drift and calibration

Conductivity Sensor Drift Characteristics



Conductivity sensors have parts that interact with the seawater. There are 3 electrodes that are subject to fouling, and a cell that must maintain constant dimensions. A 0.001 mm coating will diminish the cell diameter by 0.002 mm, resulting in a salinity error of 0.035 PSU. A film thickness of 0.001 is not uncommon for oils on the sea surface. Another source of fouling is bacterial colonization.

Sensor drift and calibration

Pressure Sensor Drift Over Time

Pressure sensors tend to drift in offset

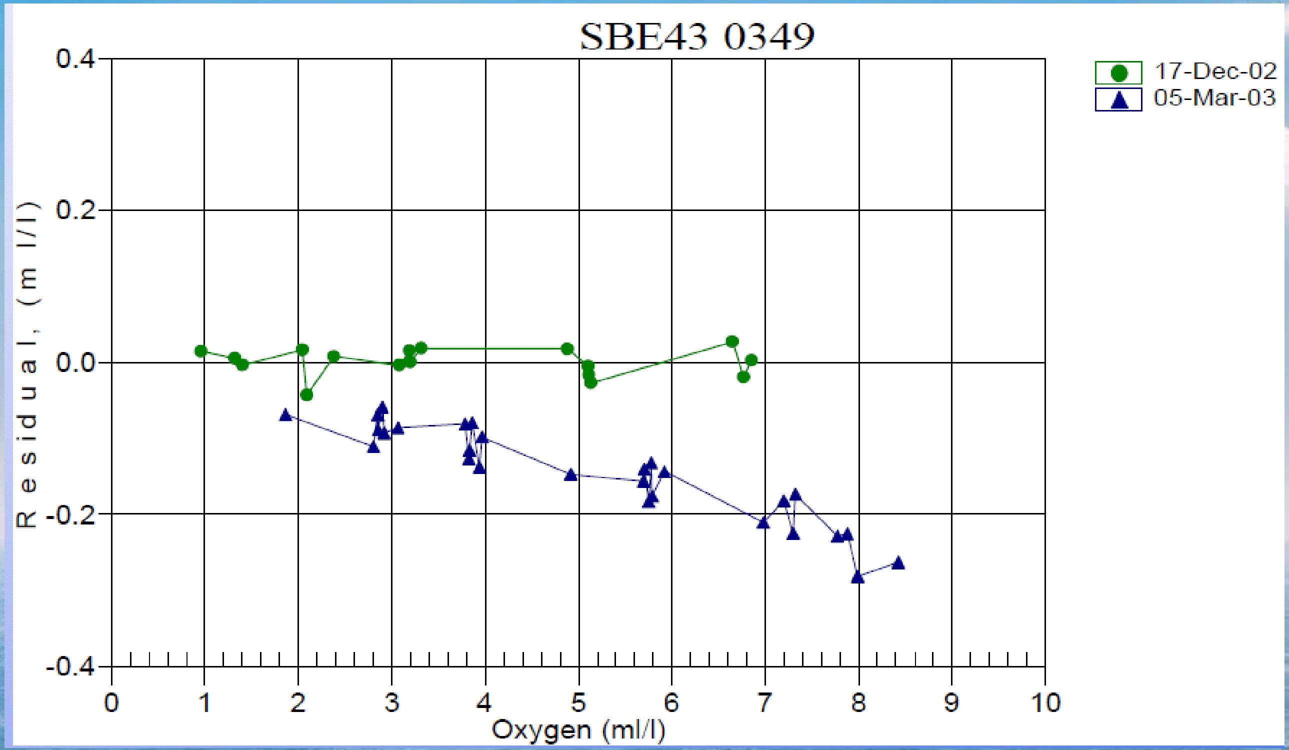
Typical drift rates are 0.018% - 0.05% of full scale / year. This is easily observed on deck before a cast

Occasionally, pressure sensors will exhibit hysteresis (different deck reading at start of cast than end of cast)

<u>Pressure sensors are usually trouble-free. Drifts are generally in offset</u>

Sensor drift and calibration

Dissolved O_2 Sensor Drift Over Time



Drift is expressed as % of full scale/month

Calibration

Systematic errors can be compensated for by means of some kind of **calibration** strategy

Calibration is simply the comparison of Instrument, Measuring and Test Equipment (M&TE), Unit Under Test (UUT), Unit Under Calibration (UUC), a Device Under Test (DUT), or simply a Test Instrument (TI) of unverified accuracy to an instrument or standards with a known (higher) accuracy to detect or eliminate unacceptable variations. It may or may not involve adjustment or repair

Calibration

In daily operations, Calibration Means:

- Accuracy Check: Calibration is like a health checkup for measuring tools. It’s the process of making sure that instruments like thermometers or scales are giving you accurate and reliable measurements
- Reference Comparison: Imagine you have a ruler, but you’re not sure if it’s exactly 12 inches long. Calibration is like comparing it to a known, precise ruler to confirm its accuracy
- Adjustment: Sometimes, instruments may drift and give slightly incorrect readings over time. Calibration involves fine-tuning or adjusting them to ensure they’re spot-on
- Standardization: It’s like setting the rules for a game. Calibration involves using standardized methods and reference points to ensure that measurements are consistent and can be trusted
- Trust Assurance: Calibration is about building trust in measurements. When something is calibrated, it means you can rely on it to give you trustworthy data, which is crucial in fields like science, engineering, and manufacturing

Calibration

Temperature Primary Standards

Over oceanographic temperature range, triple point of water and melting point of gallium are used as primary standards

- Triple point of water is 0.010000 °C
- Melting point of gallium is 29.764600 °C

Calibration

Pressure Standards

For instruments that have a strain gauge pressure sensor (Druck, Paine, Ametek,etc.), a complete pressure calibration is performed at factory, using Digiquartz pressure sensor as a secondary standard.

For instruments (SBE 9*plus*, 26*plus*, 53, etc.) that have a Digiquartz pressure sensor, a true calibration of the sensor is performed by the pressure sensor manufacturer. The quality of the Digiquartz is such that an adequate calibration requires a local gravity survey and dead certified weight tester.

Calibration

Conductivity Primary Standards

Unlike temperature, a primary standard for the conductivity of seawater is more difficult to come by.

In recognition of this, IAPSO commissions the Ocean Scientific International Corporation to provide *standard seawater*. Ocean Scientific sends small ships out into the North Atlantic with large tanks to collect seawater. The seawater is filtered and adjusted in salinity to be 35.000.
It is then sealed in vials or bottles and shipped to laboratories worldwide to be used in standardizing laboratory salinometers. Because everyone uses the same water to standardize their salinometers, we are all synchronized with Ocean Scientific.

The standard seawater service has been going on for decades under the auspices of various committees of scientists. It was first produced by a laboratory in Copenhagen and was initially dubbed *Copenhagen water*.

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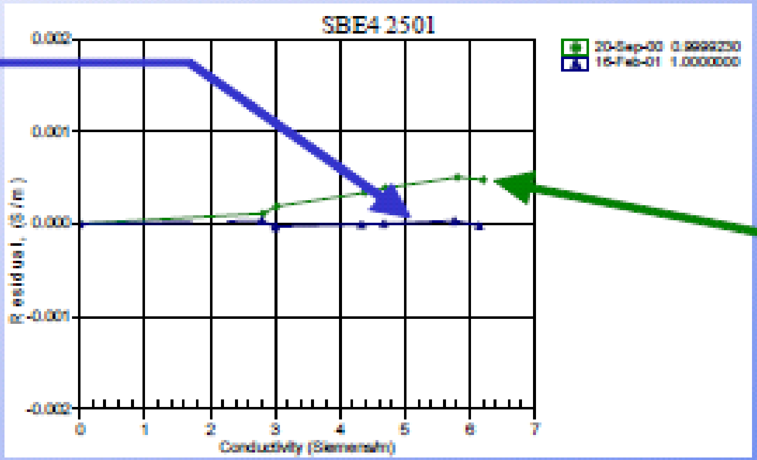
Calibration

Extract from Calibration certificate

16 February 2001

BATH T	BATH C	INST FREQ	INST C	RESIDUAL
0.0000	0.00000	2.59209	0.00000	0.00000
-1.4418	2.79561	4.97998	2.79564	0.00003
1.0179	3.00801	5.11588	3.00798	-0.00003
15.1720	4.33156	5.89228	4.33155	-0.00001
18.6482	4.67950	6.07982	4.67950	-0.00000
29.0558	5.76438	6.63029	5.76441	0.00003
32.6136	6.14700	6.81369	6.14698	-0.00002



The 16 Feb 2001 data produces the coefficients below

g = -1.03792385e+001
h = 1.54567700e+000
i = -7.48606670e-004
j = 1.54113205e-004

These coefficients are used with the 20 Sept 2000 data to produce the residuals on the right

20 September 2000

BATH T	BATH C	INST FREQ	INST C	RESIDUAL
0.0000	0.00000	2.59204	0.00000	0.00000
-0.9990	2.82081	4.99636	2.82092	0.00011
1.4948	3.03624	5.13381	3.03642	0.00018
15.9426	4.38866	5.92366	4.38901	0.00035
19.1702	4.71177	6.09713	4.71217	0.00040
29.7417	5.81272	6.65398	5.81323	0.00051
33.4512	6.21050	6.84389	6.21098	0.00048

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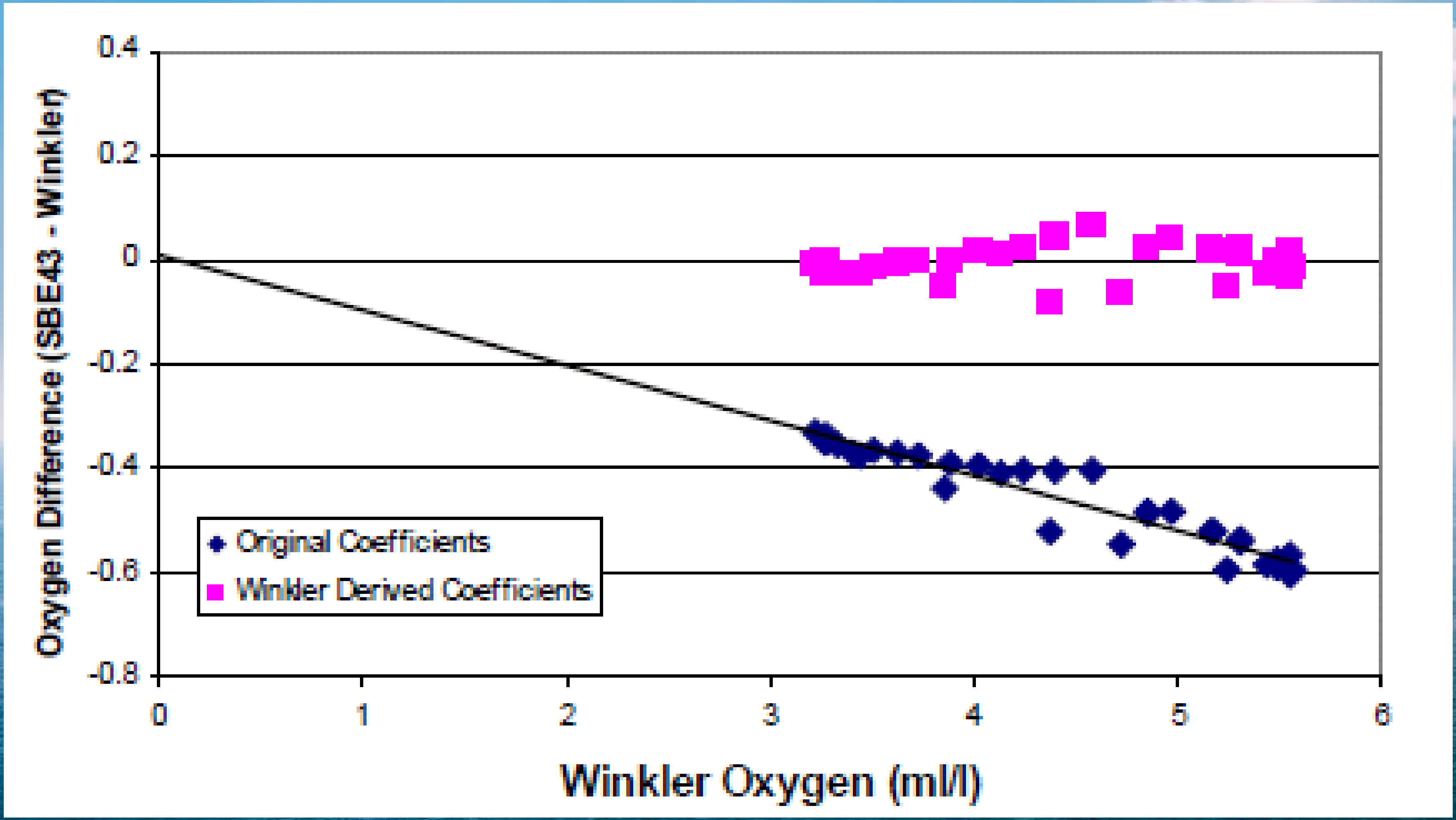
Calibration

Calibration result



Calibration

Converting Sensor Output to Scientific Units

As we have discussed, a sensor has an active element that interacts with the environment, and a conditioning circuit that converts the reaction into a signal that is measurable with normal techniques (e.g., Analog/Digital conversion or counting of a frequency).

Having acquired a digital representation of temperature or conductivity, we need to convert this into units useful to scientists and engineers.

The simplest sensor might have a linear response to the environmental parameter of interest. For example, a transmissometer has a simple relationship between voltage Output and percent transmittance of the water within its path:

$$\%T = (gain * voltage\ output) + offset$$

Calibration

Converting Sensor Output to Scientific Units

....but it's not always that simple!

Sensor output is converted to scientific units via polynomial

For example, a **conductivity sensor** has frequency output f:

$$C = (g + hf^2 + if^3 + jf^4) / (10 (1 + \delta t + \varepsilon p))$$

– Coefficients (g, h, i, j) ***are obtained by calibration***

– δ and ε are nominal values, characteristics of glass

Keep in mind

- Calibration is about building trust in measurements. When something is calibrated, it means you can rely on it to give you trustworthy data, which is crucial in fields like science, engineering, and manufacturing
- based on your budget, choose the most accurate, precise and fast response time sensor
- We measure physical quantities with instruments so…we always make a measurement error
- a small error in the original measurement can result in a large error in data analysis
- if you use a datasets, always ask for the degree of accuracy of the data (and therefore you will know in what order of magnitude your error is)
- always implement QA/QC procedures
- share your data openly and FAIR...someone might reuse it for other purposes

Are you tired?

CNR
IRBIM

break

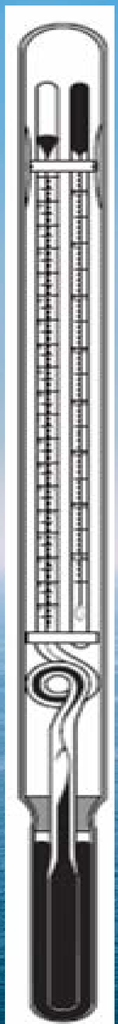
Measurements in Ocean : **Temperature**

Temperature in the ocean is measured 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

Mercury Thermometer

This is the most widely used, non-electronic thermometer.
It was widely used in buckets dropped over the side of a ship to measure the temperature of surface waters, on Nansen bottles to measure sub-sea temperatures, and in the laboratory to calibrate other thermometers.
Accuracy of the best thermometers is about ±0.001◦C with very careful calibration.

Measurements in Ocean : **Temperature**



Mercury Thermometer

One very important mercury thermometer is the **reversing thermometer** carried on Nansen bottles

It is a thermometer that has a constriction in the mercury capillary that causes the thread of mercury to break at a precisely determined point when the thermometer is turned upside down

Pairs of reversing thermometers carried on Nansen bottles were the primary source of sub-sea measurements of temperature as a function of pressure from around 1900 to 1970

Measurements in Ocean : **Temperature**

Platinum Resistance Thermometer

This is the standard for temperature. It is used by national standards laboratories to interpolate between defined points on the practical temperature scale. It is used primarily to calibrate other temperature sensors.

Thermistor

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

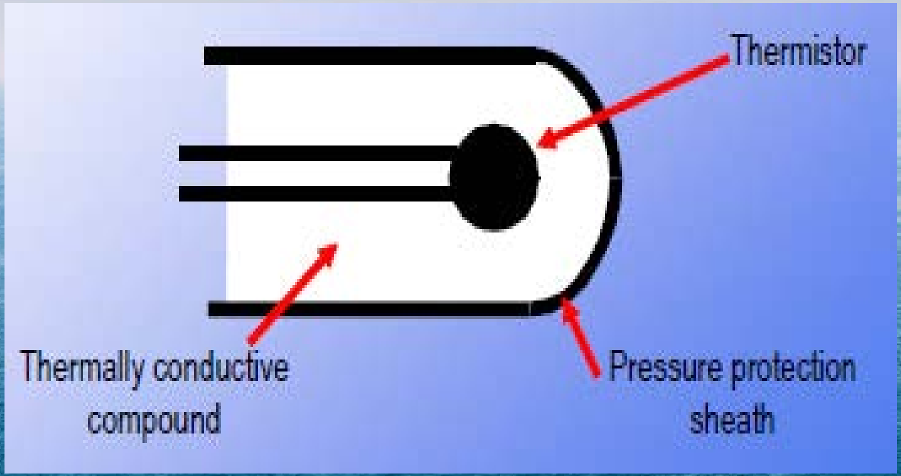
Measurements in Ocean : **Temperature**

SBE 3 Thermistor-Based Temperature Sensor

• Active element is a thermistor, a semiconductor that changes resistance when its temperature changes

• Conditioning circuit is an oscillator that changes frequency depending on resistance of thermistor

• Signal is a frequency that is measured with a frequency counter



Time constant for an SBE 3F or 3*plus* is 70 milliseconds (!)

Measurements in Ocean : **Conductivity or Salinity**

Conductivity is measured by placing platinum electrodes in seawater and measuring the current that flows when there is a known voltage between the electrodes.

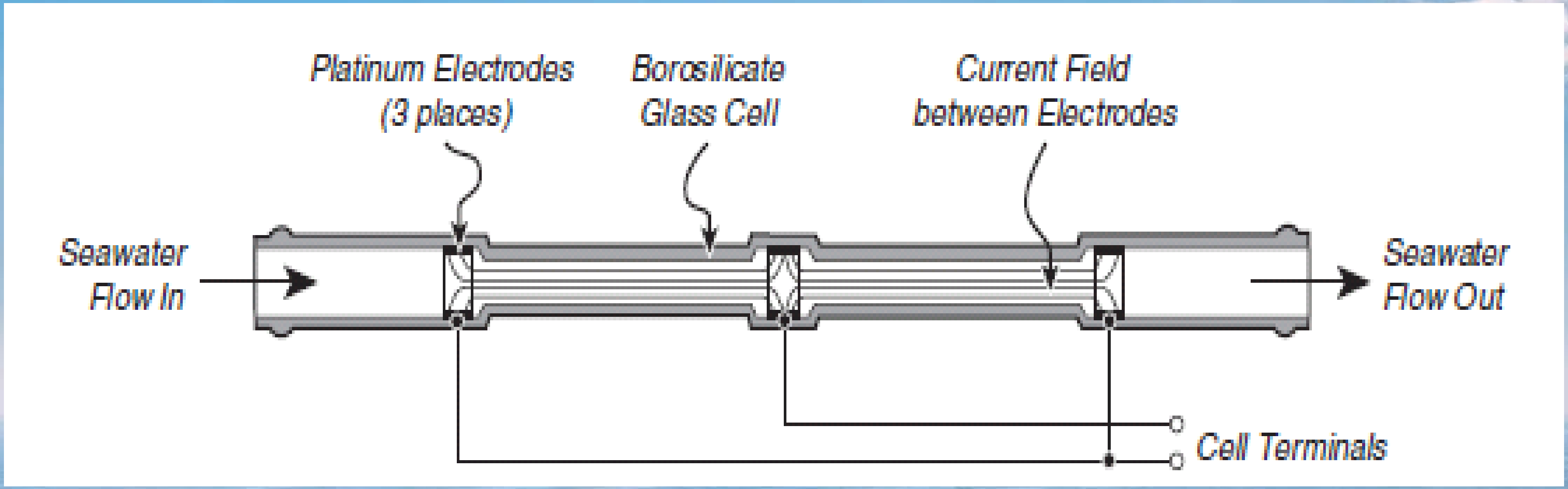
The current depends on conductivity, voltage, and volume of sea water in the path between electrodes. If the electrodes are in a tube of nonconducting glass, the volume of water is accurately known, and the current is independent of other objects near the conductivity cell.

The best measurements of salinity from conductivity give salinity with an accuracy of ±0.005

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

Measurements in Ocean : **Conductivity or Salinity**

SBE 4 Conductivity sensor



Conductivity sensor response is influenced by several factors

– Flow of sample through the cell

– Temperature and heat capacity of the cell

– Electrode condition

- A good estimate of SBE 4 time constant is 30 milliseconds. This is typical for all Sea-Bird conductivity cells

Measurements in Ocean : **Pressure or Depth**

Pressure is routinely measured by many different types of instruments.

The SI unit of pressure is the pascal (Pa), but oceanographers normally report pressure in decibars (dbar), where:

$$1 \text{ dbar} = 10^4 \text{ Pa}$$

because the pressure in decibars is almost exactly equal to the depth in meters.

Thus 1000 dbar is the pressure at a depth of about 1000 m

Measurements in Ocean : **Pressure or Depth**

Strain Gage

This is the simplest and cheapest instrument, and it is widely used.
Accuracy is about ±1%.

Vibratron

Much more accurate measurements of pressure can be made bymeasuring the natural frequency of a vibrating tungsten wire stretched in a magnetic field between diaphragms closing the ends of a cylinder. Pressure distorts the diaphragm, which changes the tension on the wire and its frequency.
The frequency can be measured from the changing voltage induced as the wire vibrates in the magnetic field. Accuracy is about 0.1%, or better when temperature controlled. Precision is 100–1000 times better than accuracy

Measurements in Ocean : **Pressure or Depth**

Quartz crystal

Very accurate measurements of pressure can also be made by measuring the natural frequency of a quartz crystal cut for minimum temperature dependence. The best accuracy is obtained when the temperature of the crystal is held constant

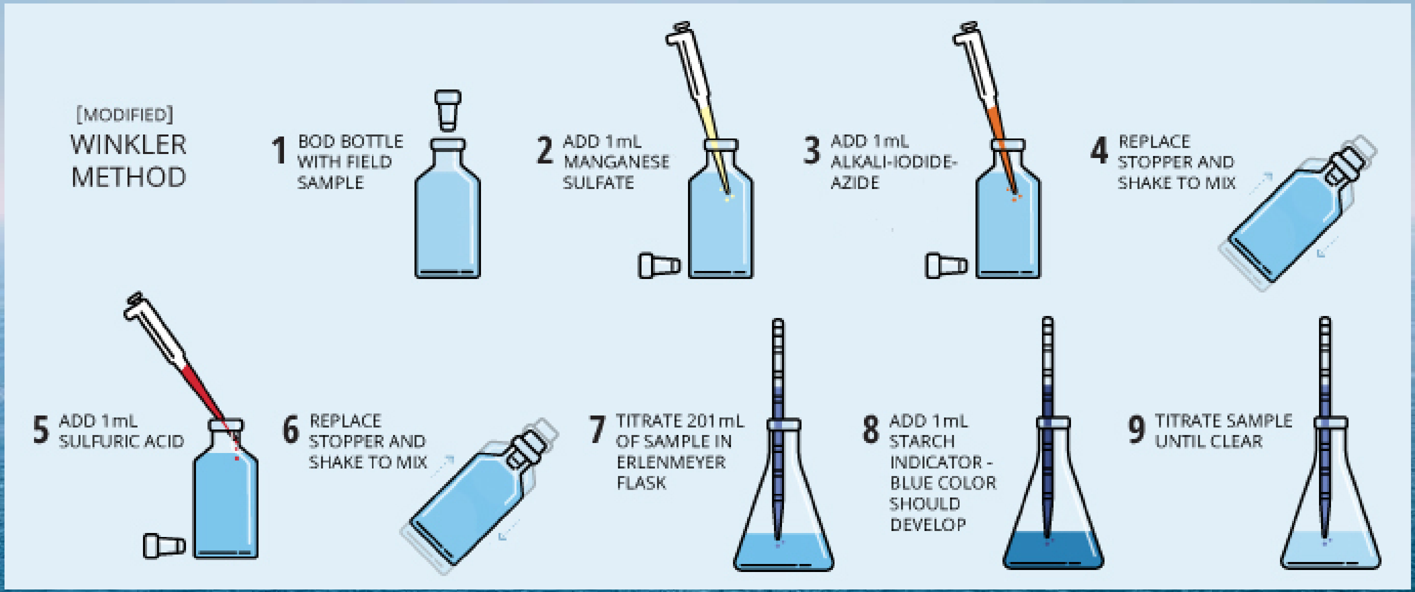
The accuracy is ±0.015%, and precision is ±0.001% of full-scale values. (used by Sea-bird CTD 9plus)

Measurements in Ocean : **Dissolved Oxygen**

Winkler Methods

Samples are collected, fixed and titrated, either in the field or in a lab

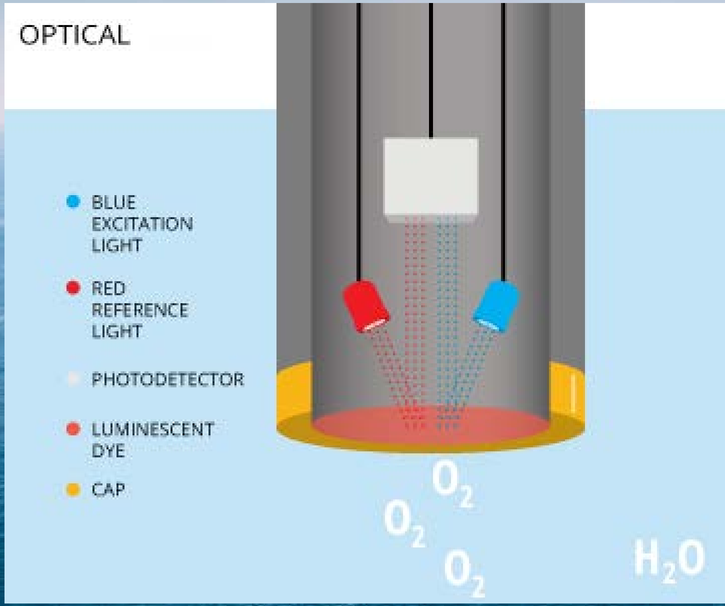
the amount of titrant needed to complete the reaction is proportional to the dissolved oxygen concentration of the sample



Measurements in Ocean : **Dissolved Oxygen**

Optical Dissolved Oxygen Sensors

Optical dissolved oxygen sensors measure the interaction between oxygen and certain luminescent dyes. When exposed to blue light, these dyes become excited (electrons gaining energy) and emit light as the electrons return to to their normal energy state. When dissolved oxygen is present, the returned wavelengths are limited or altered due to oxygen molecules interacting with the dye. The measured effect is inversely proportional to the partial pressure of oxygen

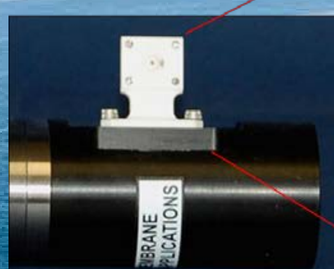


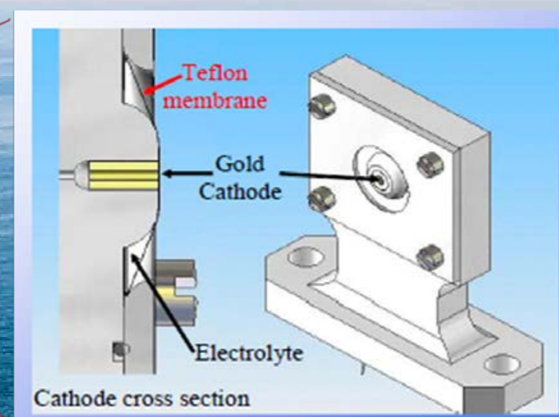
Measurements in Ocean : **Dissolved Oxygen**

polarographic membrane oxygen sensor

polarographic DO sensors use two polarized electrodes, an anode and a cathode, in an electrolyte solution. The electrodes and electrolyte solution are isolated from the sample by a thin, semi-permeable membrane

When taking measurements, dissolved oxygen diffuses across the membrane at a rate proportional to the pressure of oxygen in the water. The dissolved oxygen is then reduced and consumed at the cathode. <u>This reaction produces an electrical current that is directly related to the oxygen concentration</u>

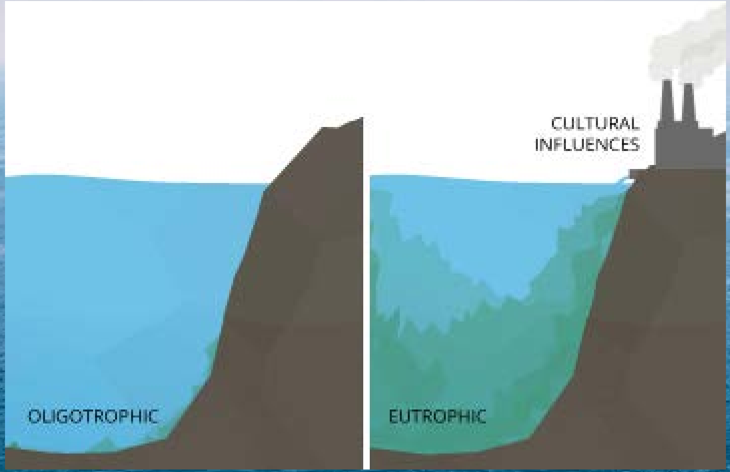




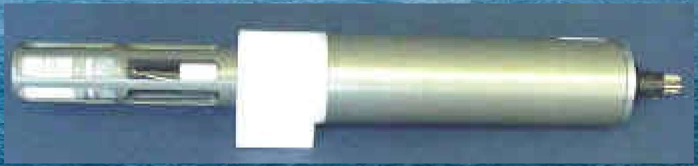
Measurements in Ocean : **pH, redox**

pH and ORP probes are both used for measuring the acidic intensity of liquid solutions. A pH probe measures acidity on a scale from 0 to 14, with 0 being the most acidic and 14 being the most basic.

Similarly, an Oxidation-Reduction Potential (ORP) probe returns a voltage proportional to the tendency of the solution to gain or lose electrons from other substances (which is linked directly to the pH of a substance)



A minor increase in pH levels can cause a oligotrophic (rich in dissolved oxygen) lake to become eutrophic (lacking dissolved oxygen).

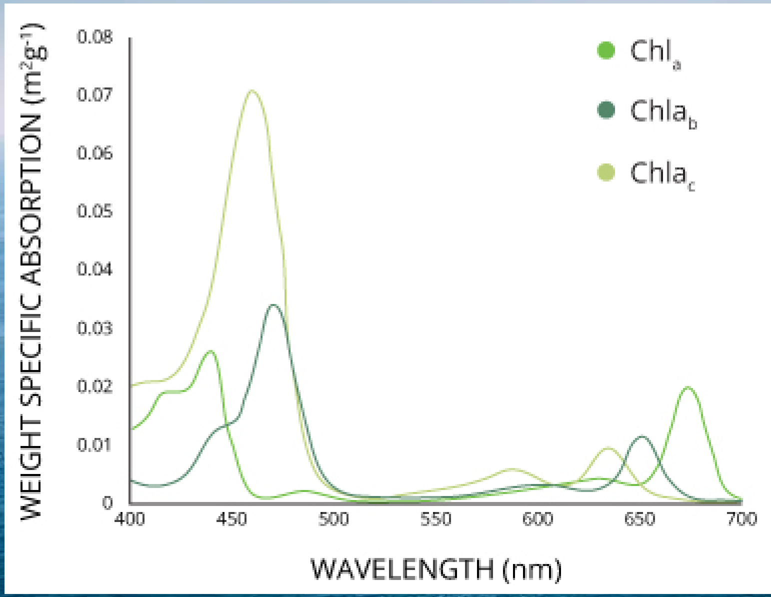


Measurements in Ocean : **Chlorophyll, Turbidity,CDOM**

Chlorophyll is a color pigment found in plants, algae and phytoplankton. This molecule is used in photosynthesis, as a photoreceptor.

Photoreceptors absorb light energy, and chlorophyll specifically absorbs energy from sunlight.

Chlorophyll makes plants and algae appear green because it reflects the green wavelengths found in sunlight, while absorbing all other colors



there are 6 different chlorophylls that have been identified

The different forms (A, B, C, D, E and F) each reflect slightly different ranges of green wavelengths.

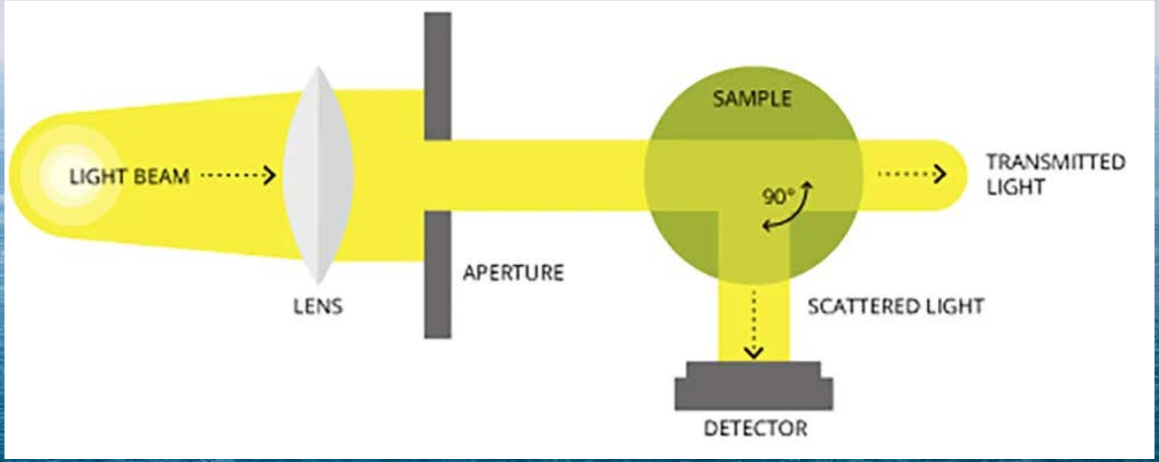
Chlorophyll A is the primary molecule responsible for photosynthesis

Measurements in Ocean : **Chlorophyll, Turbidity,CDOM**

Turbidity measurements are often used as an indicator of water quality based on clarity and estimated total suspended solids in water

The turbidity of water is based on the amount of light scattered by particles in the water column. The more particles that are present, the more light that will be scattered

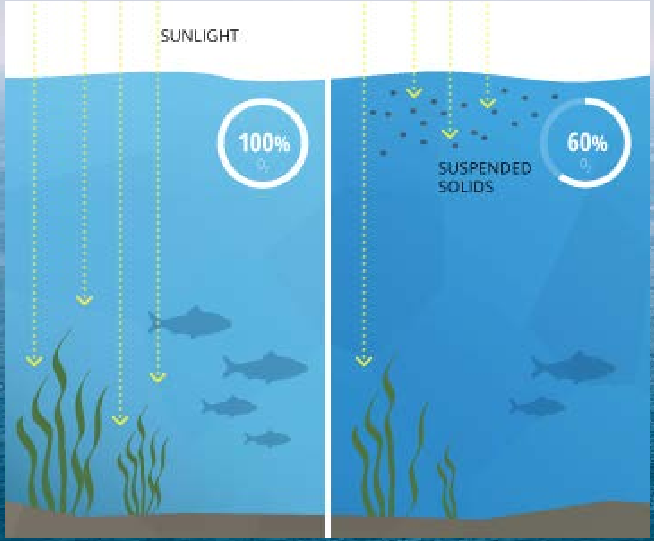
Photo Credit: NASA Visible Earth, via USGS



Measurements in Ocean : **Chlorophyll, Turbidity,CDOM**

Chromophoric (or Colored) Dissolved Organic Matter is the parameter that can be measured in aquatic environments as a product of decaying material. CDOM is largely a subset of DOM, or dissolved organic matter

The decay releases organic substances that stain waters and can have effects on light absorption and other aspects of water quality. Because it has effects on the conditions that aquatic life adapt to for survival, such as salinity, turbidity and light penetration, CDOM plays a large role in the health of aquatic system



Turbidity, or the cloudiness of water due to suspended solids and other substances, is closely linked with CDOM. But more chromophoric dissolved organic matter does not always mean that turbidity will go upscattered

Measurements in Ocean : **CO_2, CH_4**

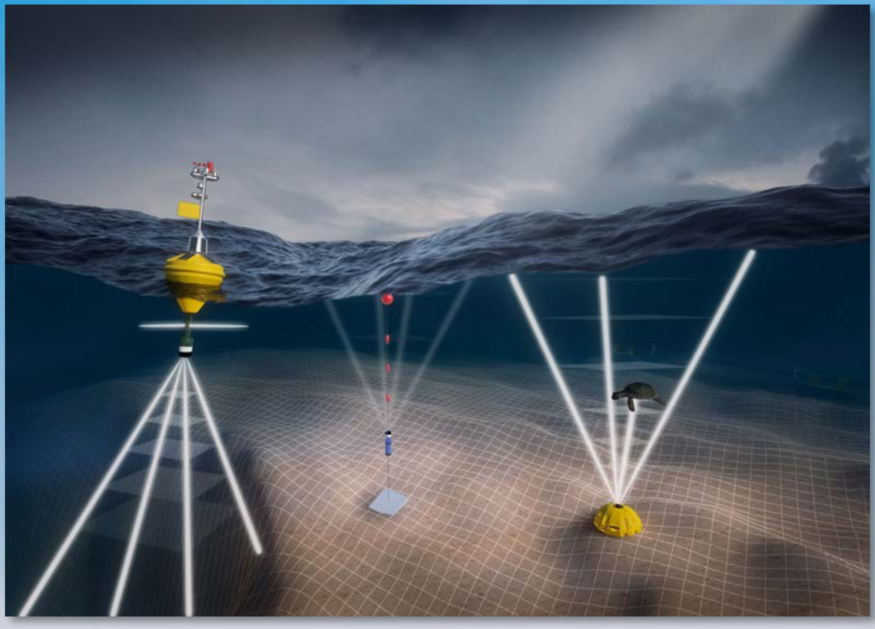
The Mini CO2 instrument uses infrared detection to measure the partial pressure of CO2 gas dissolved in liquids

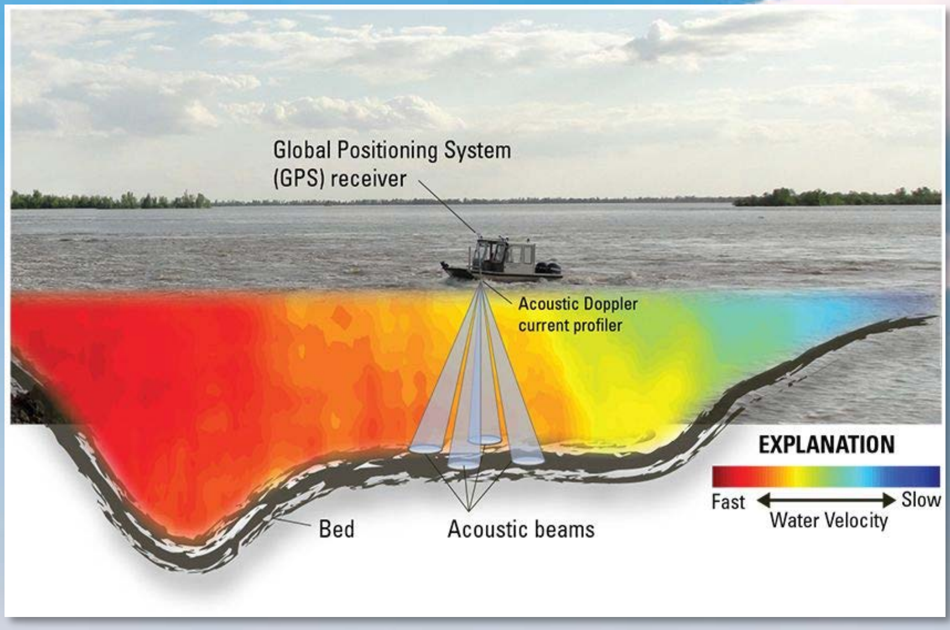
Sensor Performance	
CO_2 Measurement Ranges	0-2000 µatm CO_2 0-5000 µatm 0-1% (10,000 µatm) 0-100% *other ranges available
Total Dissolved Gas Pressure	0-2000 mbar
Accuracy: pCO_2	± 3% of max range
TDGP	± 1%
Equilibration rate (t63)	3 minutes
Resolution	0.1% of max range

The Mini CH4 instrument uses infrared detection to measure the partial pressure of CH4 gas dissolved in liquids. Conversion to dissolved methane concentration is simple with known temperature and salinity values

Sensor Performance	
pCH_4 Measurement Ranges	0-1% CH4 ; by volume (~0-300 µg/L; by mass) 0-10%v/v (~0-3 mg/L) 0-100%v/v (~0-30 mg/L)
Total Dissolved Gas Pressure	0-2 bar
Accuracy: pCH_4	± 3% of max range
TDGP	± 1%
Equilibration rate (t63)	~8 minutes (with water-pumped head)
Resolution	0.1% of max range

Measurements in Ocean : **water current**

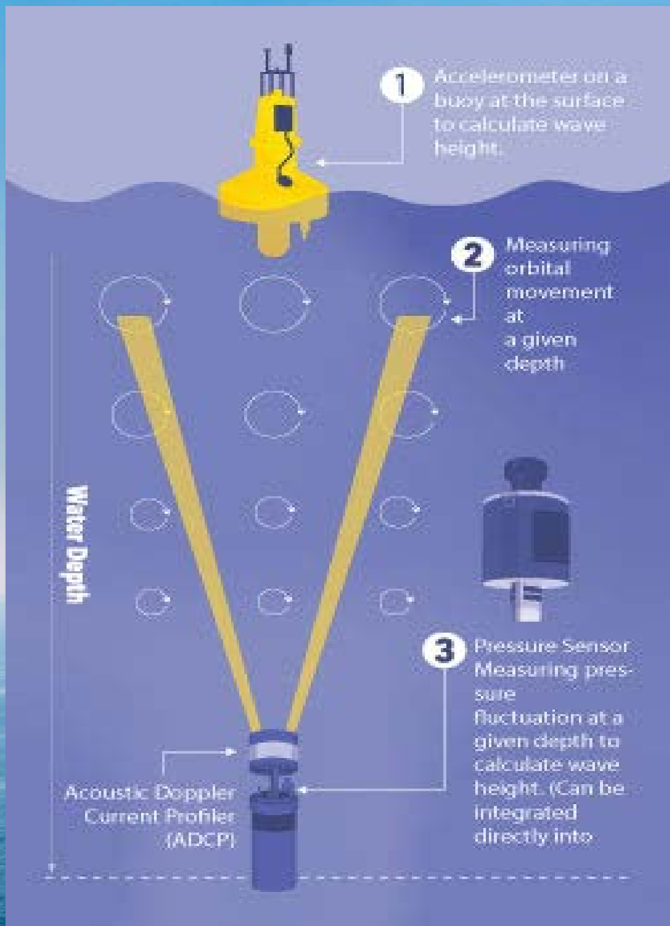


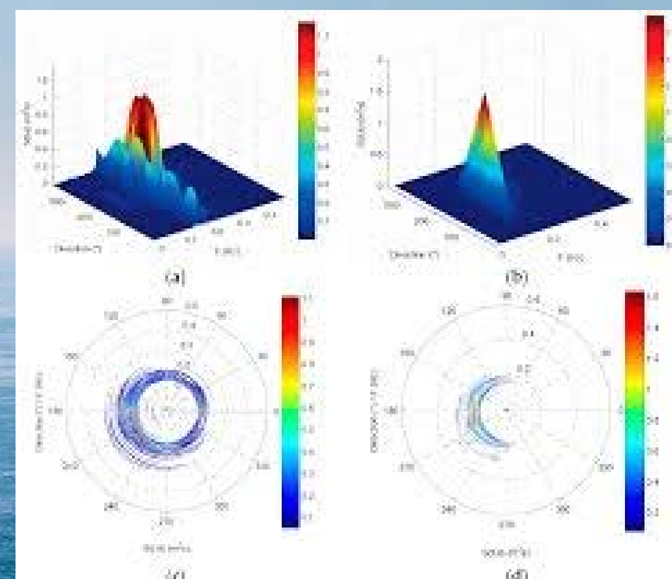


Using the acoustic Doppler technique, ADCPs measure water movement by interpreting sound waves transmitted by and reflected back to the instrument from particles in the water, marine life, etc

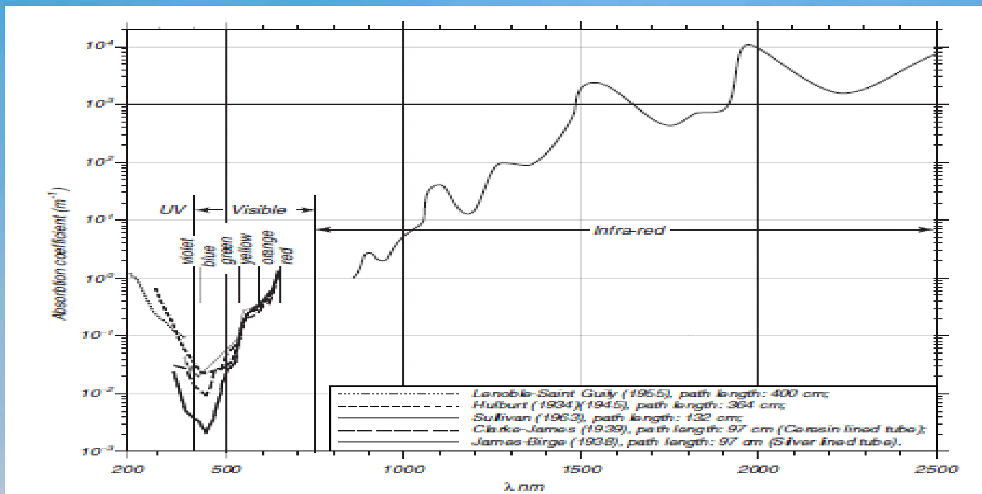
A vessel-mounted ADCP can produce a profile of the currents between the vessel and the seabed while the vessel is moving

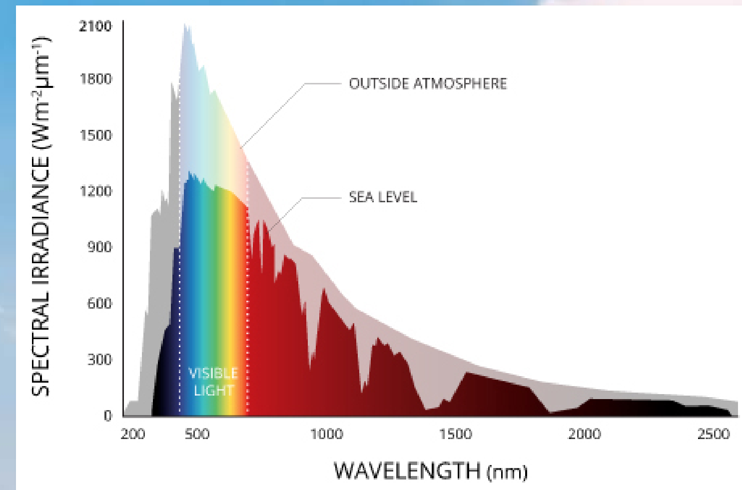
Measurements in Ocean : **waves**





Measurements in Ocean : light

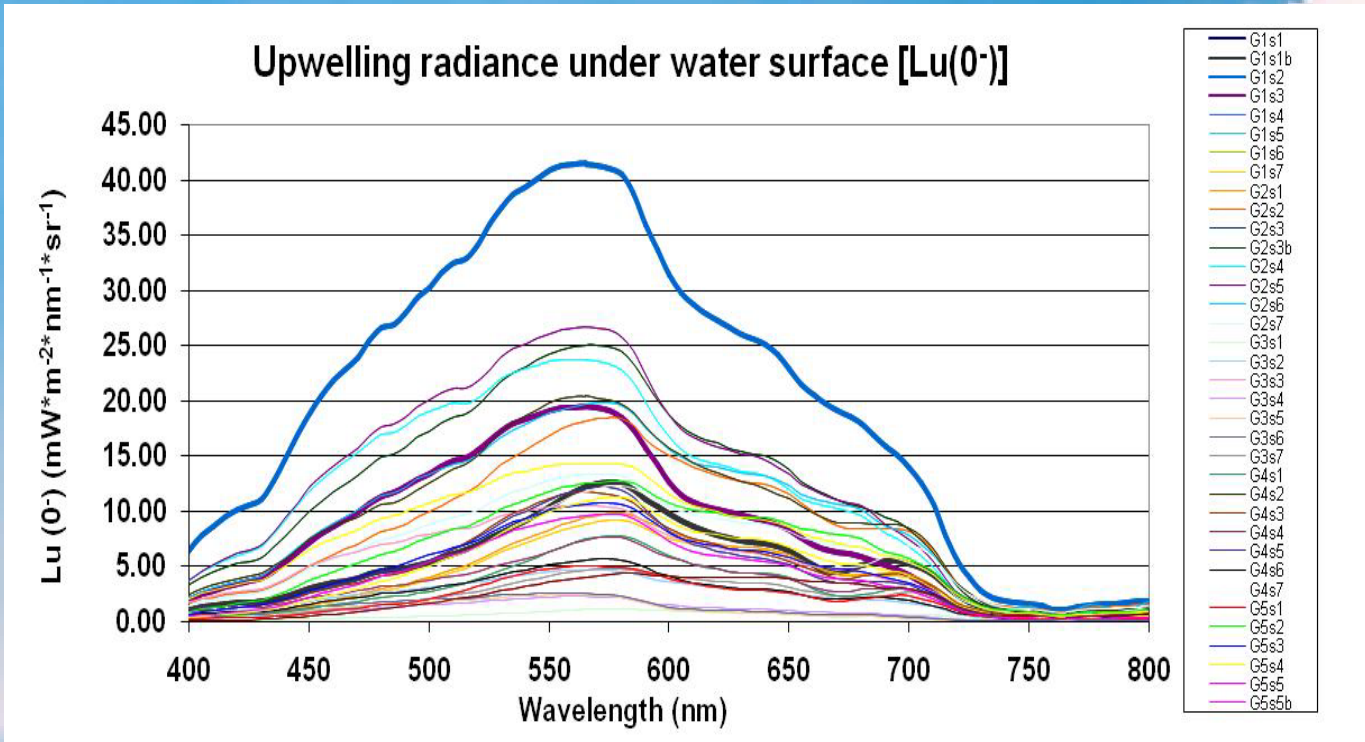




Sunlight in the ocean is important for many reasons: It heats sea water, warming the surface layers; it provides energy required by phytoplankton; it is used for navigation by animals near the surface;

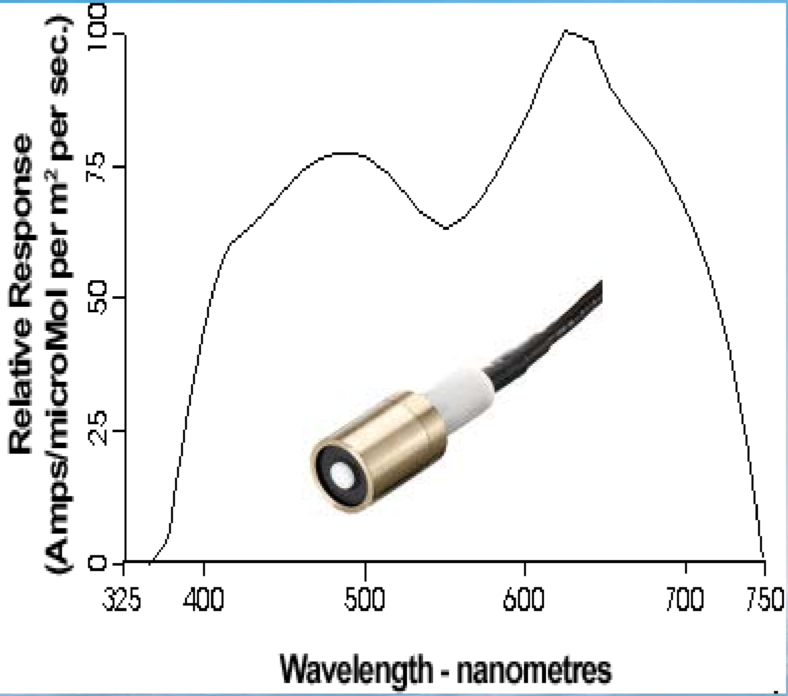
reflected subsurface light is used for mapping chlorophyll concentration from space

Measurements in Ocean : light



The **Spectroradiometer** Ramses is composed by 2 sensors (ACC and ARC) which measure the downwelling irradiance [Eu(z,λ)] and upwelling radiance [Lu(z,λ)] in the wavelengths 320-950 nm in 190 spectral channels with a resolution of 0.3 nm. Owing to the greater number of bandwidths, it will be possible to obtain a greater amount of information on the water column optical properties **(Chla, CDOM, TSM)**

Measurements in Ocean : light



Photosynthetic Active Radiation (PAR) irradiance includes *in vivo* absorption bandwidths of:

- chlorophyll *a, b, and c*
- the pigments contained within the cytoplasm of blue-green algae (cyanobacteria)
- the chloroplasts of plants (including phytoplankton) that capture light energy for photosynthesis.


SBE


exo


RBRconcerto3

The SBE 32 Carousel water sampling package consists of:

- water sample bottles with their lanyards
- trigger mechanism
- upper and lower pylons that hold the bottle on the frame
- upper and lower frame that protects the package from collision with the side of the ship

The Carousel trigger mechanism is an electro-mechanical device. It operates by energizing a solenoid magnet that pulls a mechanical trigger, releasing the nylon lanyards that hold the top and bottom caps of the water sampler open.

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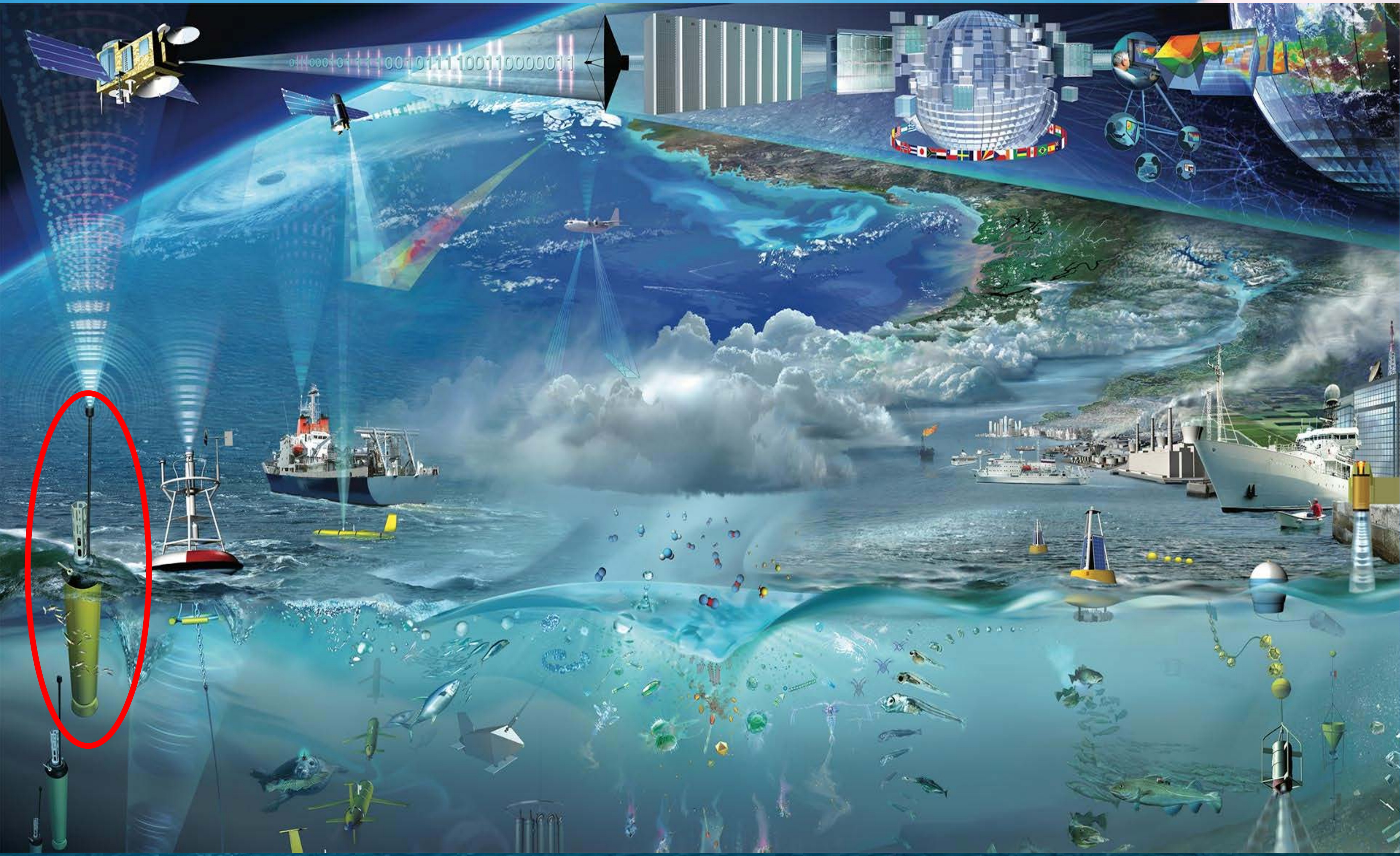
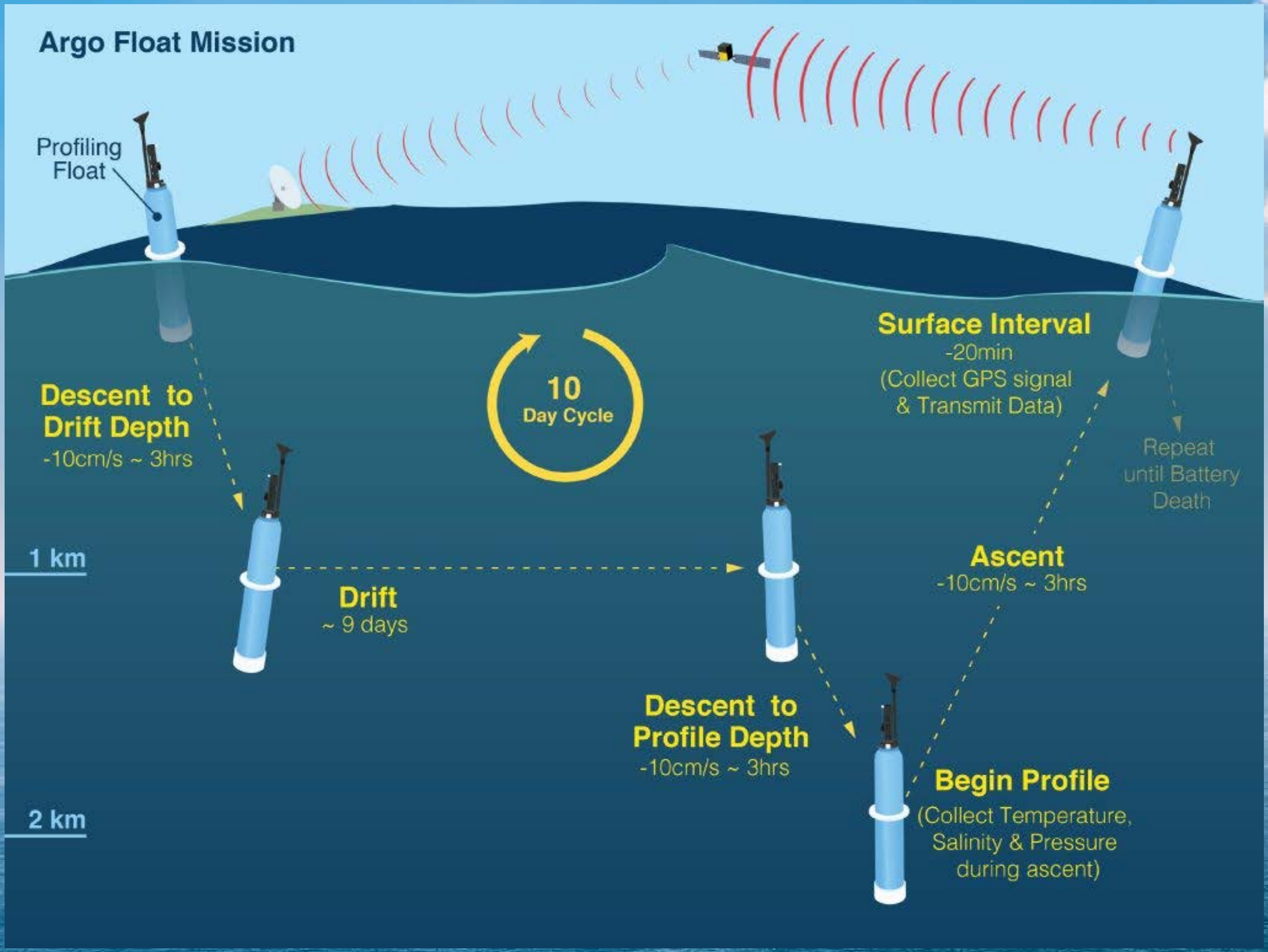
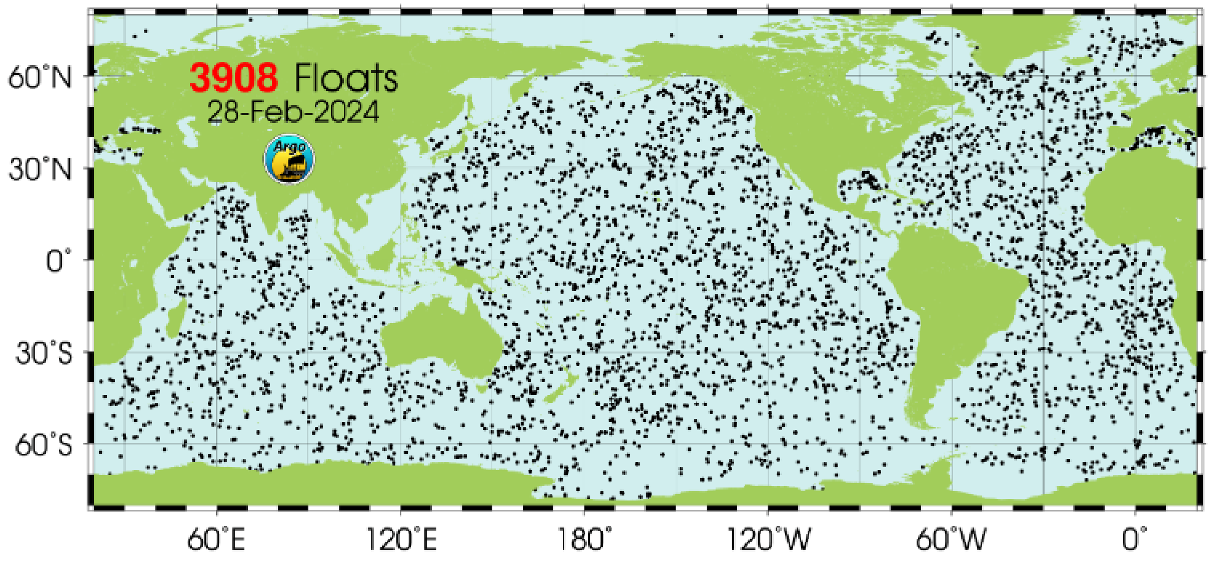


ARGO float



Argo Float Mission
Profiling Float
Surface Interval
-20min
(Collect GPS signal
& Transmit Data)
10
Day Cycle
Descent to
Drift Depth
-10cm/s ~ 3hrs
Repeat
until Battery
Death
1 km
Drift
~ 9 days
Ascent
-10cm/s ~ 3hrs
Descent to
Profile Depth
-10cm/s ~ 3hrs
Begin Profile
(Collect Temperature,
Salinity & Pressure
during ascent)
2 km

ARGO float



Maps displaying statistics about the Argo array, including its extensions into high latitudes and marginal seas, biogeochemical sensors, communication systems, float type, etc., can be found in the map section on the Argo Information Centre website.

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ARGO float

https://dataselection.euro-argo.eu/

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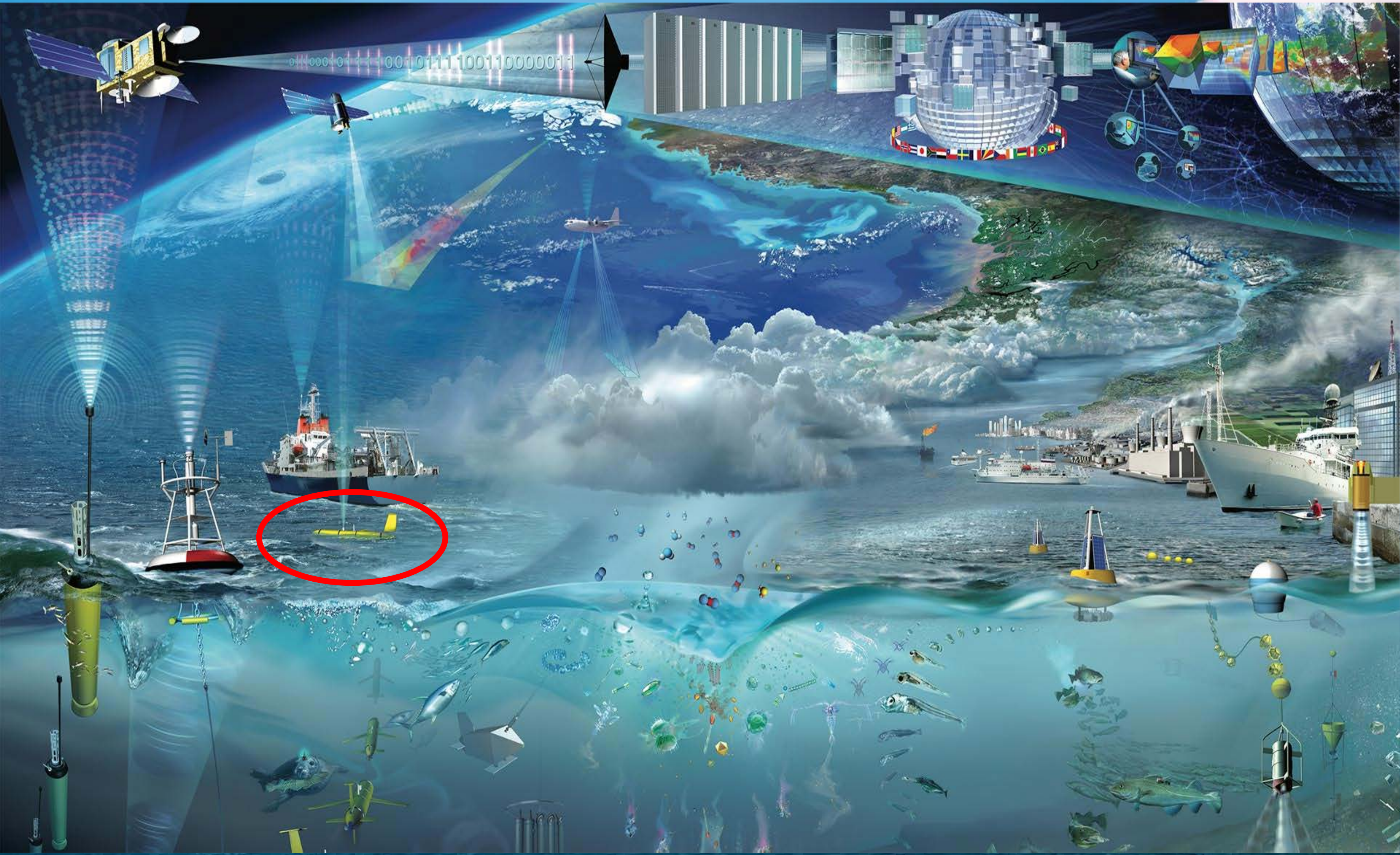
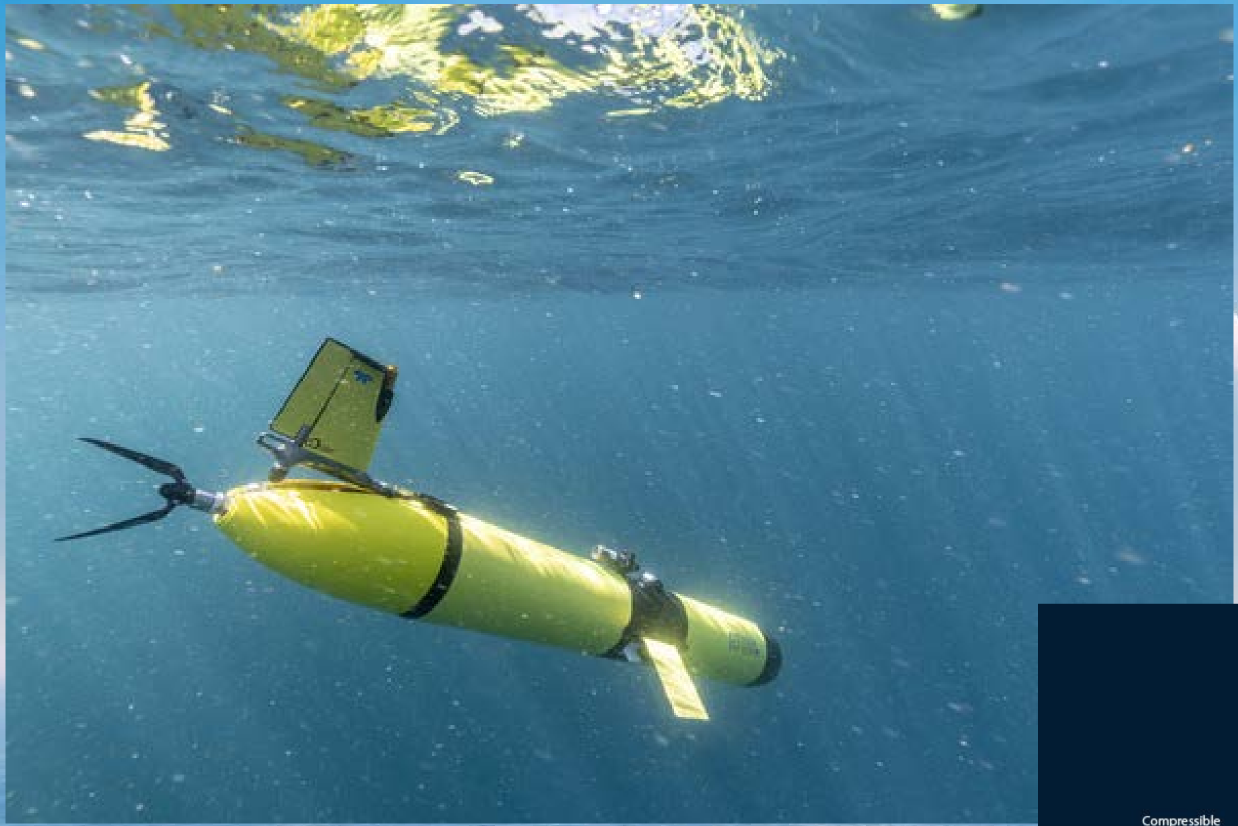
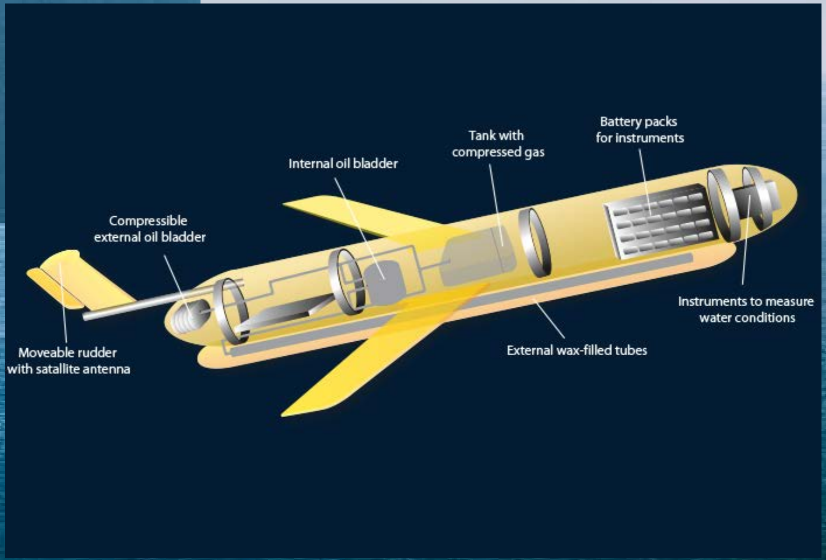
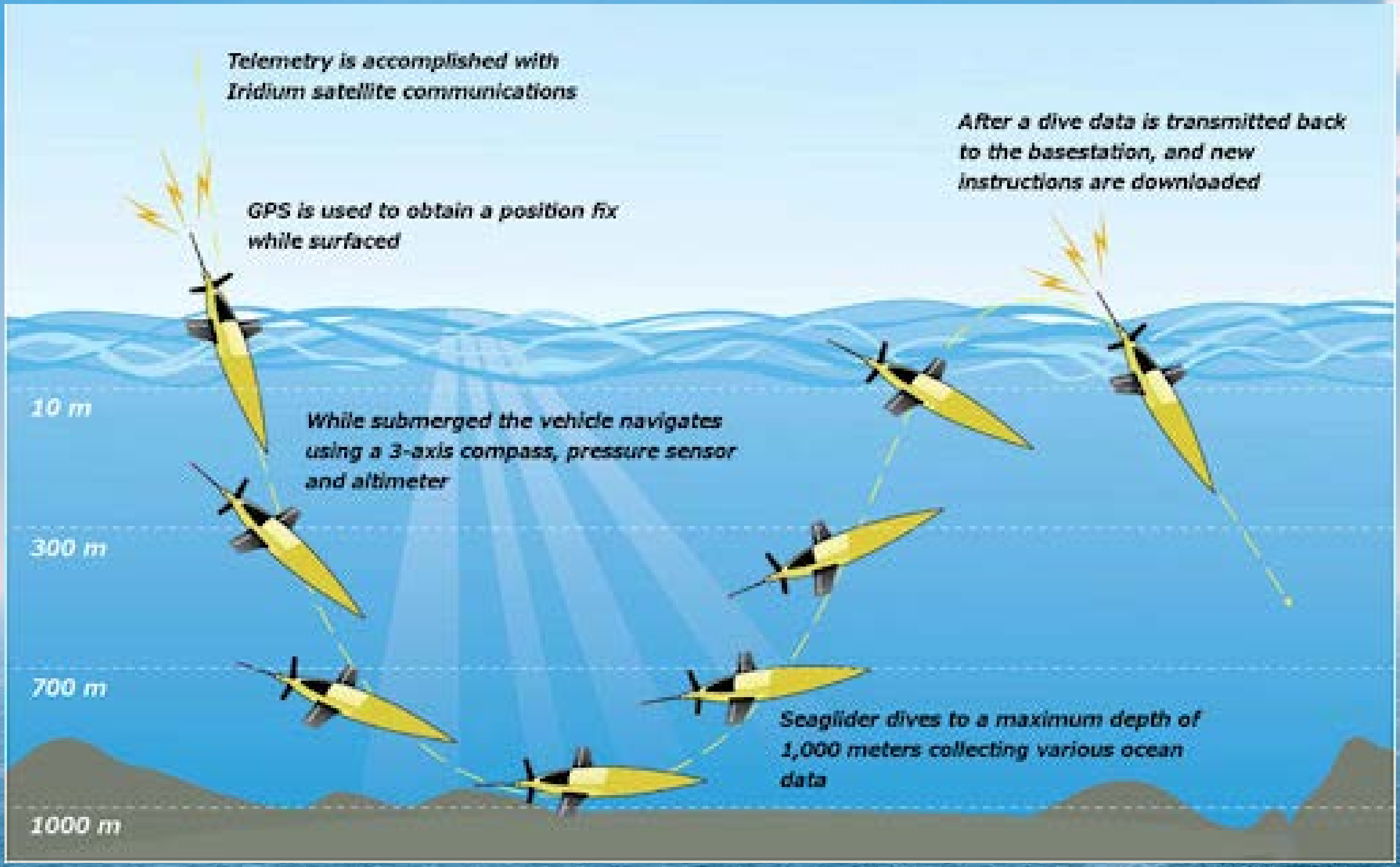


seaGlider



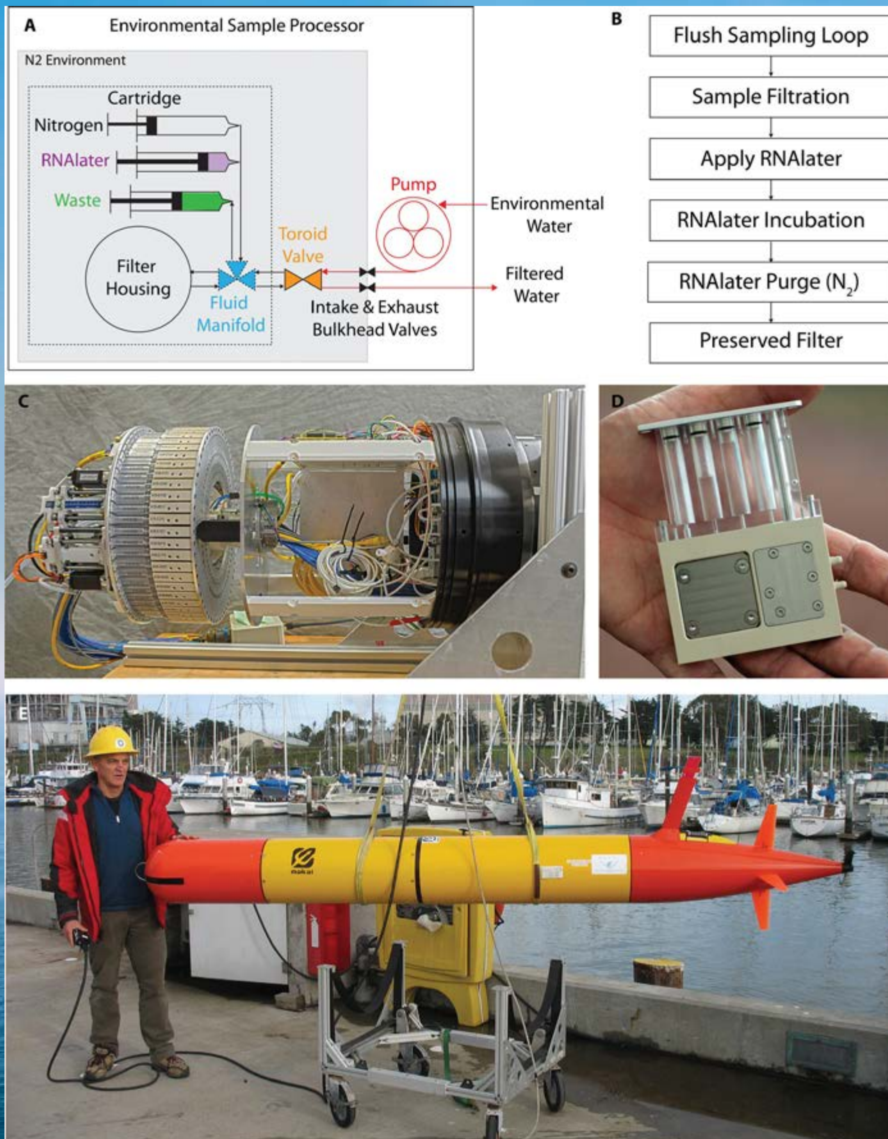

Battery packs
for instruments
Tank with
compressed gas
Internal oil bladder
Compressible
external oil bladder
Instruments to measure
water conditions
Moveable rudder
with satallite antenna
External wax-filled tubes

seaGlider



Telemetry is accomplished with Iridium satellite communications
After a dive data is transmitted back to the basestation, and new instructions are downloaded
GPS is used to obtain a position fix while surfaced
10 m
While submerged the vehicle navigates using a 3-axis compass, pressure sensor and altimeter
300 m
700 m
Seaglider dives to a maximum depth of 1,000 meters collecting various ocean data
1000 m

seaGlider



ORIGINAL RESEARCH article

Front. Mar. Sci., 16 July 2019
Sec. Marine Molecular Biology and Ecology
Volume 6 - 2019 | https://doi.org/10.3389/fmars.2019.00373

In situ Autonomous Acquisition and Preservation of Marine Environmental DNA Using an Autonomous Underwater Vehicle

waveGlider

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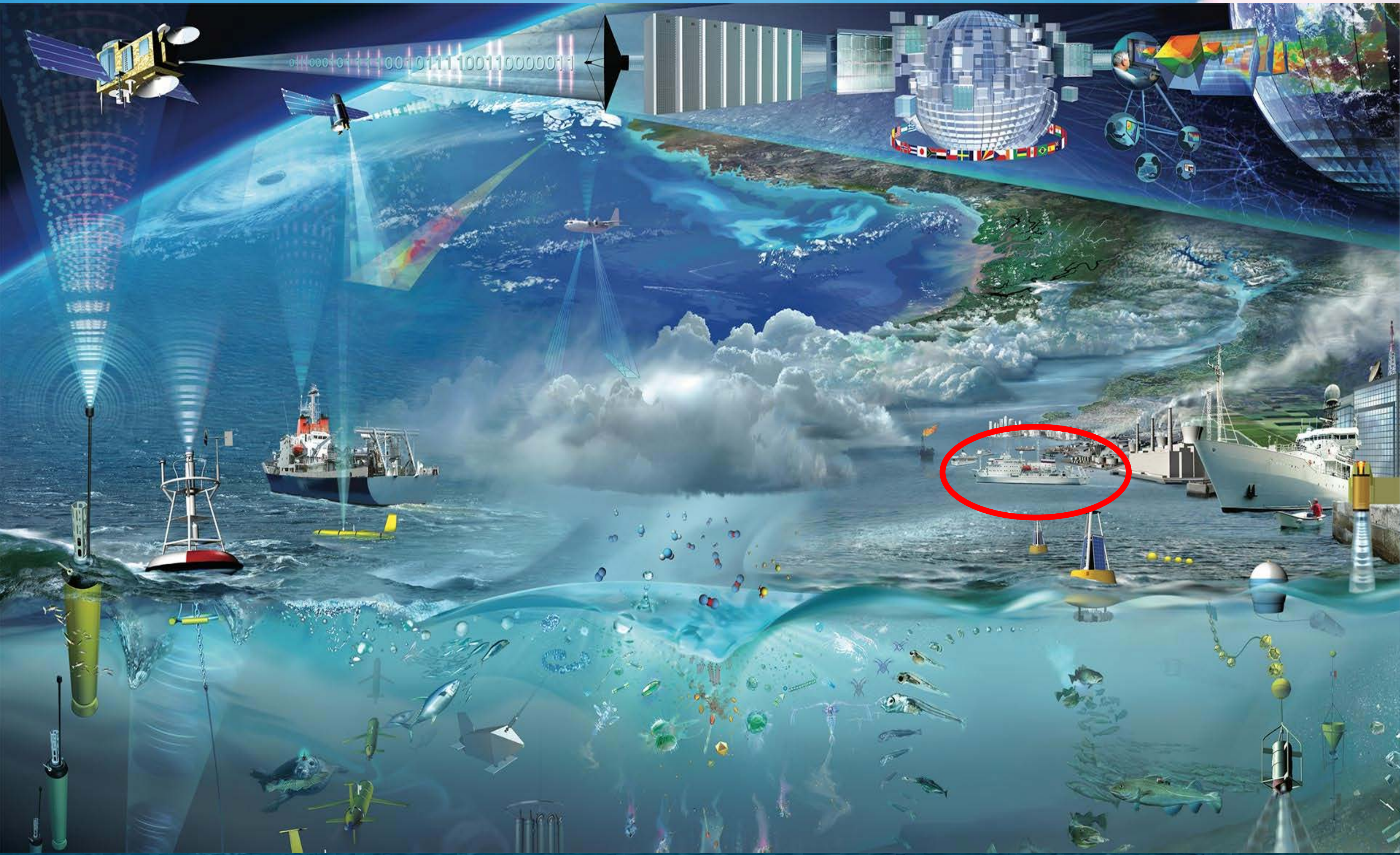
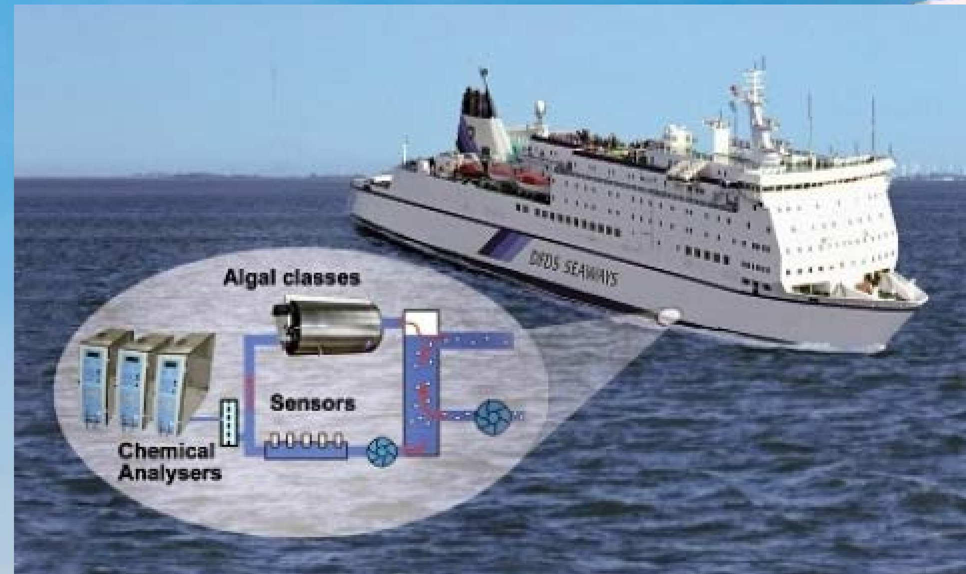


Voluntary Observing Ship (VOS)



JOURNAL ARTICLE

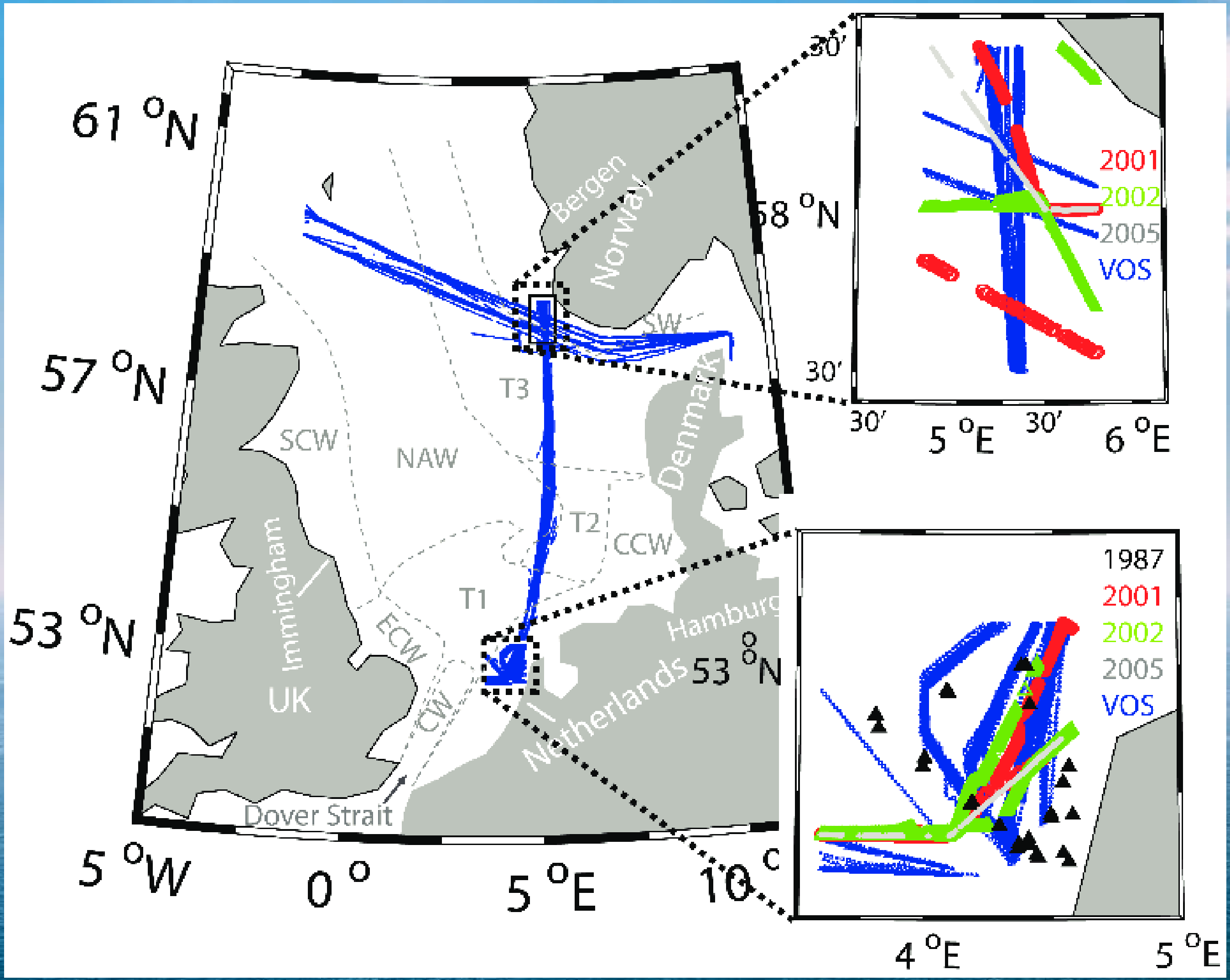
A framework for multidisciplinary science observations from commercial ships

Alison M Macdonald, Luna Hiron, Leah McRaven, Laura Stolp, Kerry Strom, Rebecca Hudak, Shawn R Smith, Julia Hummon, Magdalena Andres

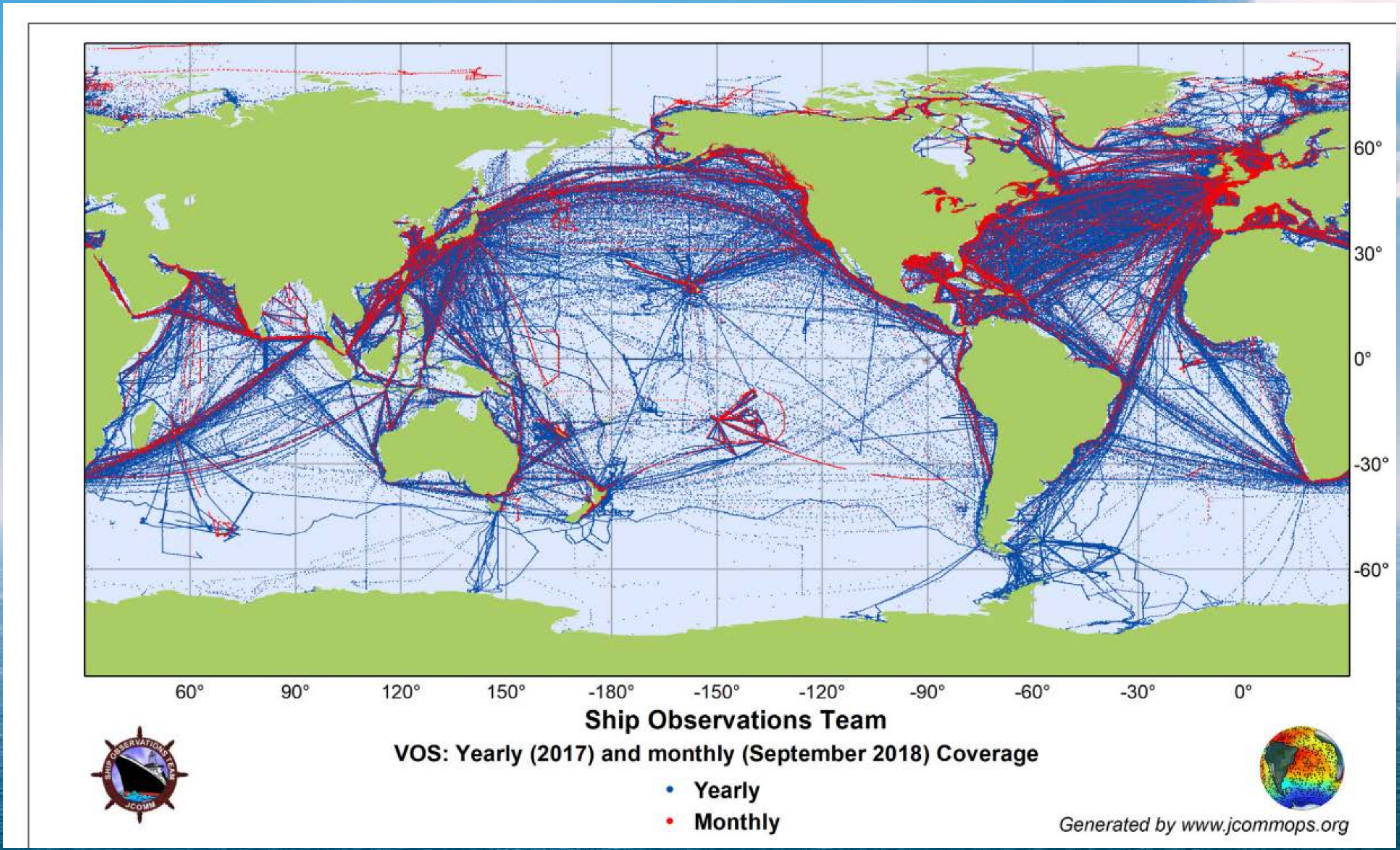
ICES Journal of Marine Science, fsae011, https://doi.org/10.1093/icesjms/fsae011

Published: 19 February 2024 **Article history** ▾

Voluntary Observing Ship (VOS)



Voluntary Observing Ship (VOS)



Ship-Based Contributions to Global Ocean, Weather, and Climate Observing Systems
Front. Mar. Sci., 02 August 2019 Sec. Ocean Observation Volume 6 - 2019 | https://doi.org/10.3389/fmars.2019.00434

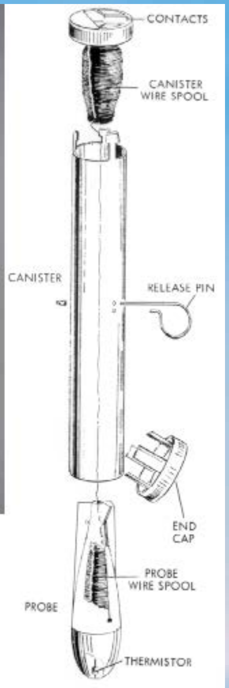
eXpendable BathyThermograph (XBT)

An EXpendable BathyThermograph (XBT) with it's probe inside a canister (top). On the right is an exploded view of the XBT.

An XBT is a probe that is dropped from a ship and measures the <u>temperature</u> as it falls through the water

A resistance in the head of the probe and a very thin twin-wire, connecting the probe to the equipment on the ship, compose the electronic circuit for measuring the water temperature

eXpendable BathyThermograph (XBT)



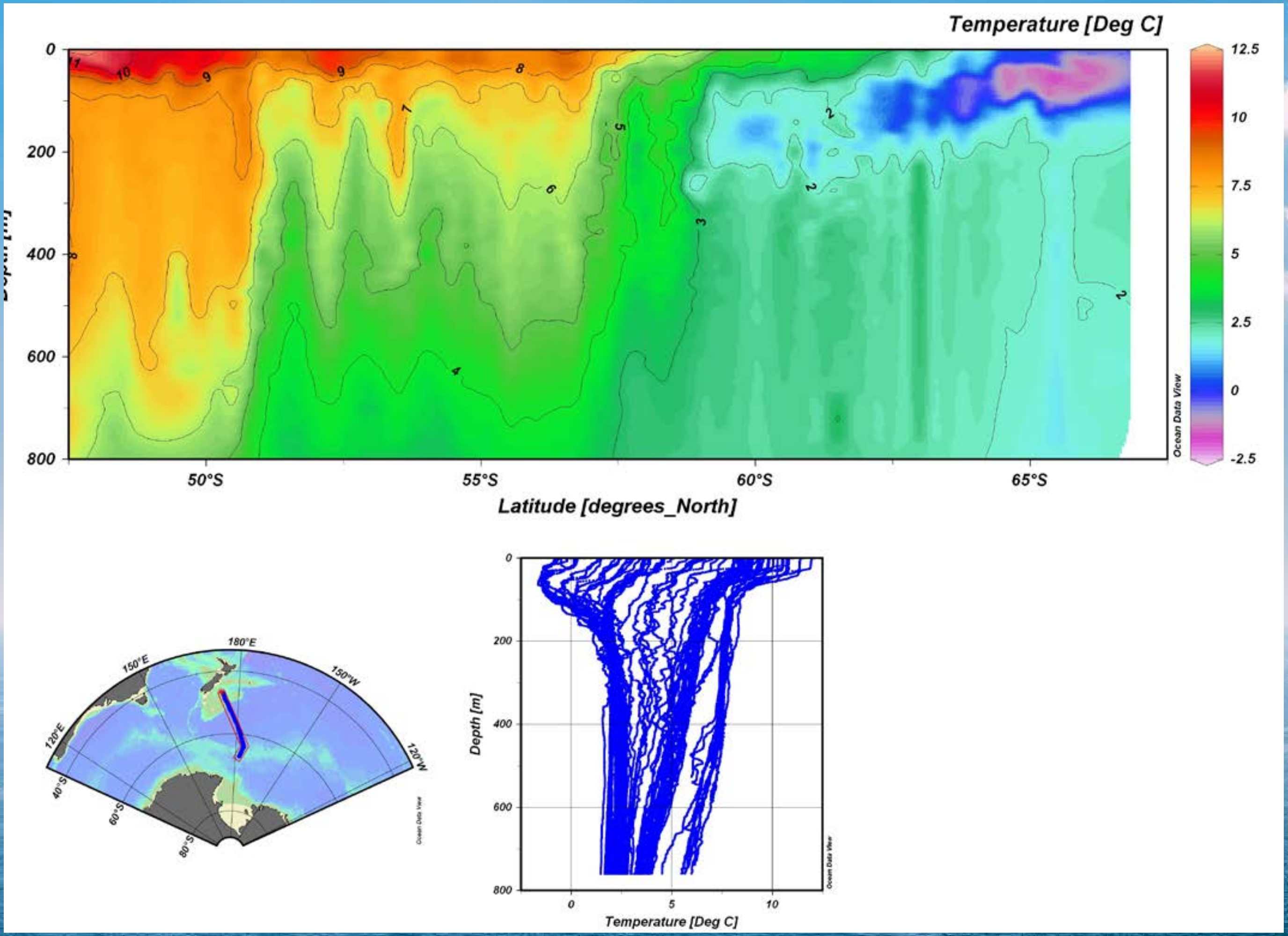
An EXpendable BathyThermograph (XBT) with it's probe inside a canister (top). On the right is an exploded view of the XBT.

A fall-rate equations are used to derive the depth of the XBT as a function of time after the XBT is deployed into the ocean:

$$z(t) = a\,t^2 + b\,t,$$

where z(t) is the depth of the XBT in meters, and a, b are constants determined using theoretical and empirical methods.

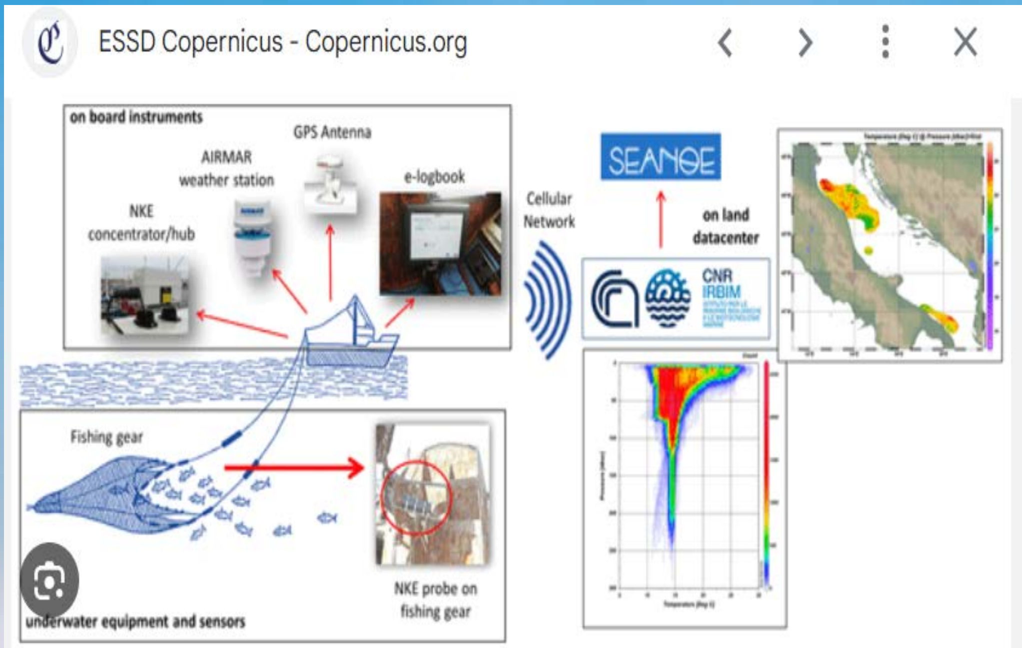
eXpendable BathyThermograph (XBT)



XXIX Italian national expedition to Antarctica, 2013-2014

AdriFOOS

Adriatic Sea (Fishery and Oceanography Observing System)



Dataset of depth and temperature profiles obtained from 2012 to 2020 using commercial fishing vessels of the AdriFOOS fleet in the Adriatic Sea

Pierluigi Penna, Filippo Domenichetti, Andrea Belardinelli, and Michela Martinelli

Earth System Science Data https://doi.org/10.5194/essd-15-3513-2023

NAUTILOS H2020 2020-2024

SEANOE Sea scientific open data edition

AdriFOOS Depth/Temperature profiles dataset 2012-2020

Date	2020-04-20
Temporal extent	2012-11-26 -2020-02-26
Author(s)	Penna Pierluigi[1], Belardinelli Andrea[1], Croci Camilla Sofia[1], Domenichetti Filippo[1], Martinelli Michela[1]

frontiers

REVIEW article

Front. Mar. Sci., 01 August 2023
Sec. Ocean Observation
Volume 10 - 2023 | https://doi.org/10.3389/fmars.2023.1176814

This article is part of the Research Topic
Recent Developments in Hydrodynamic Measurement, Simulation and Forecast in the Coastal Ocean
View all 5 Articles

Towards a global Fishing Vessel Ocean Observing Network (FVON): state of the art and future directions

Cooper Van Vranken[1*], Julie Jakoboski[2], John W. Carroll[1], Christopher Cusack[3], Patrick Gorringe[4], Naoki Hirose[5], James Manning[6], Michela Martinelli[7], Pierluigi Penna[7], Mathew Pickering[3], A. Miguel Piecho-Santos[8,9], Moninya Roughan[10], João de..., Hassan Moustahfid[11]

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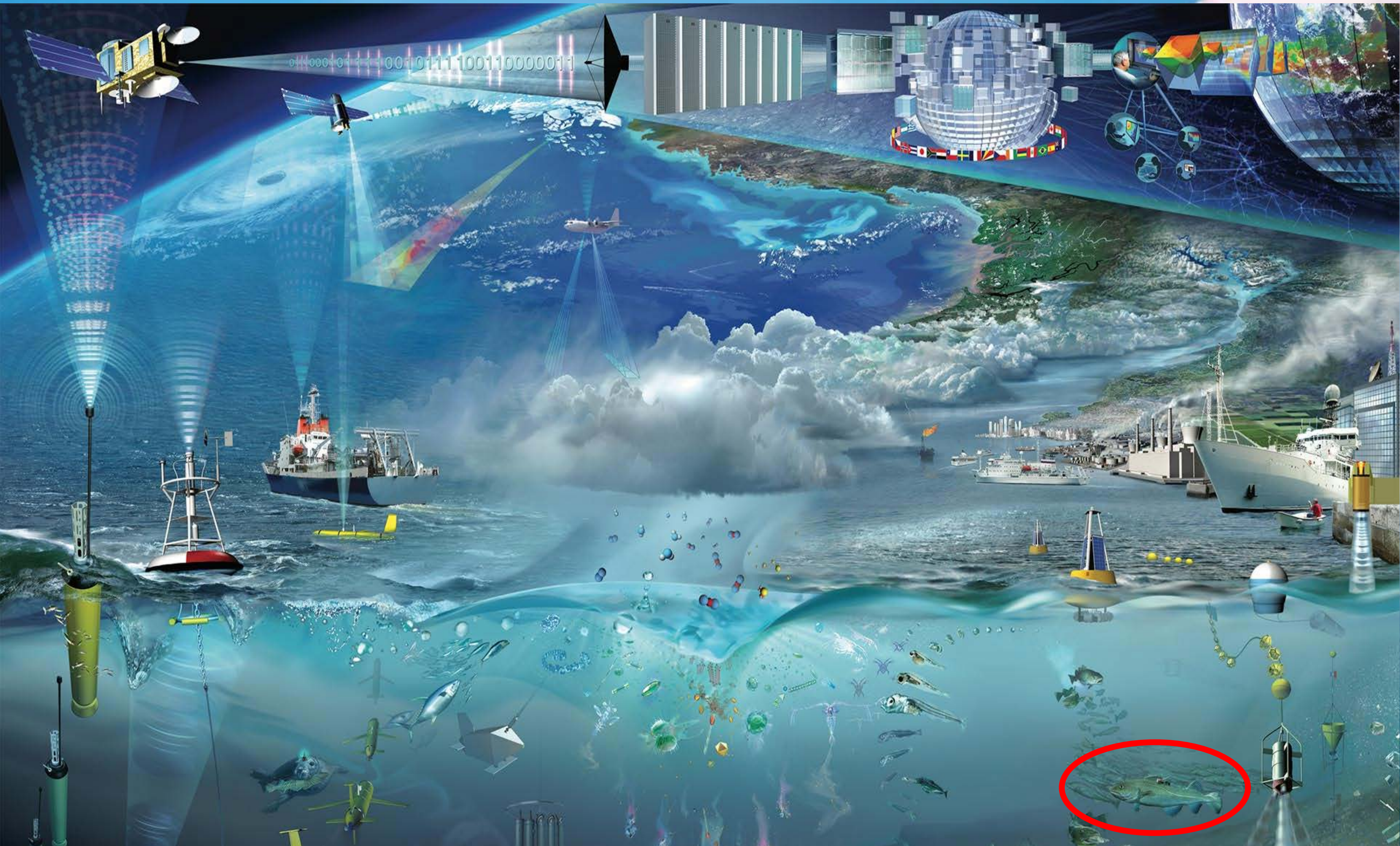

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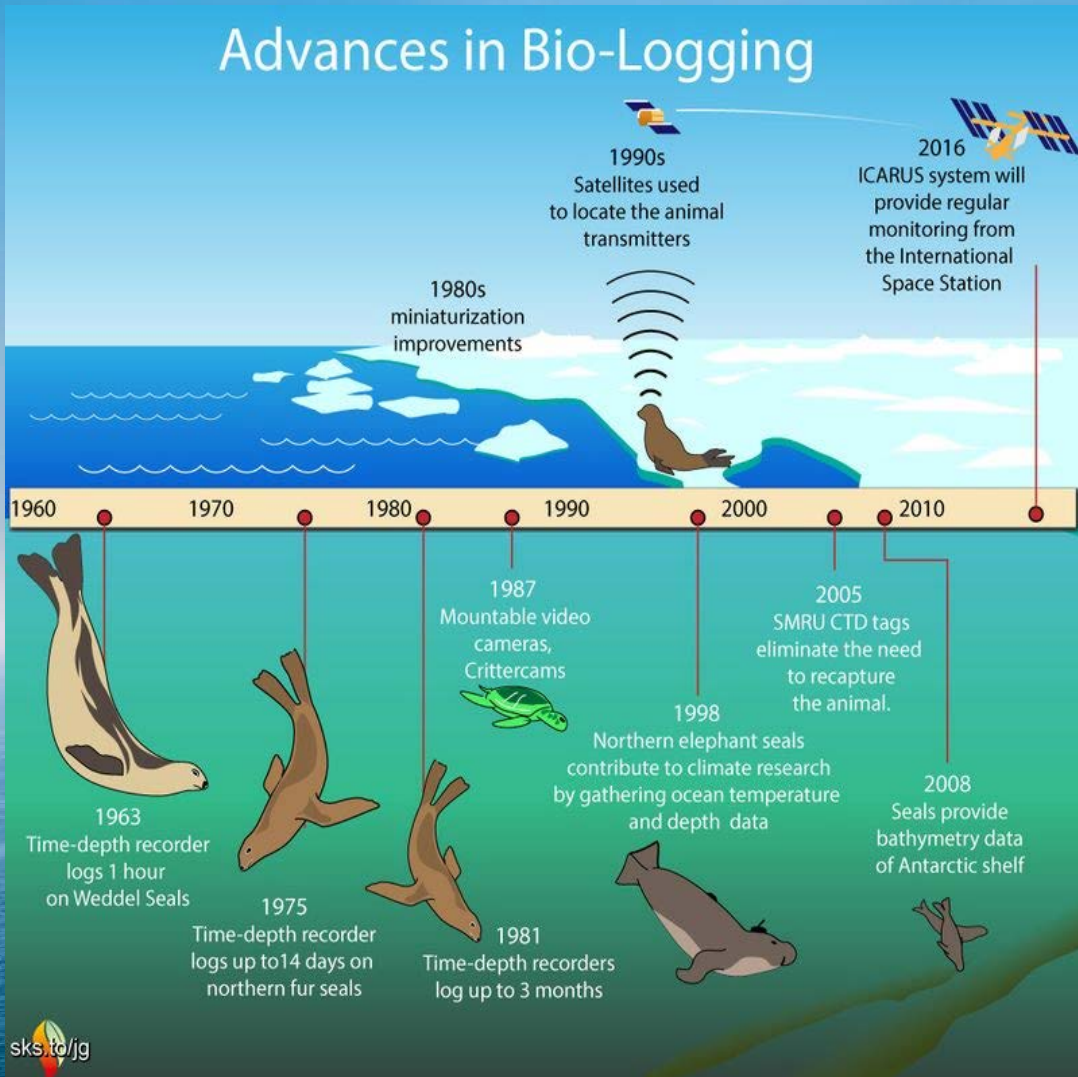
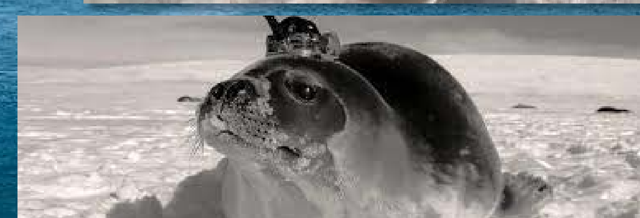
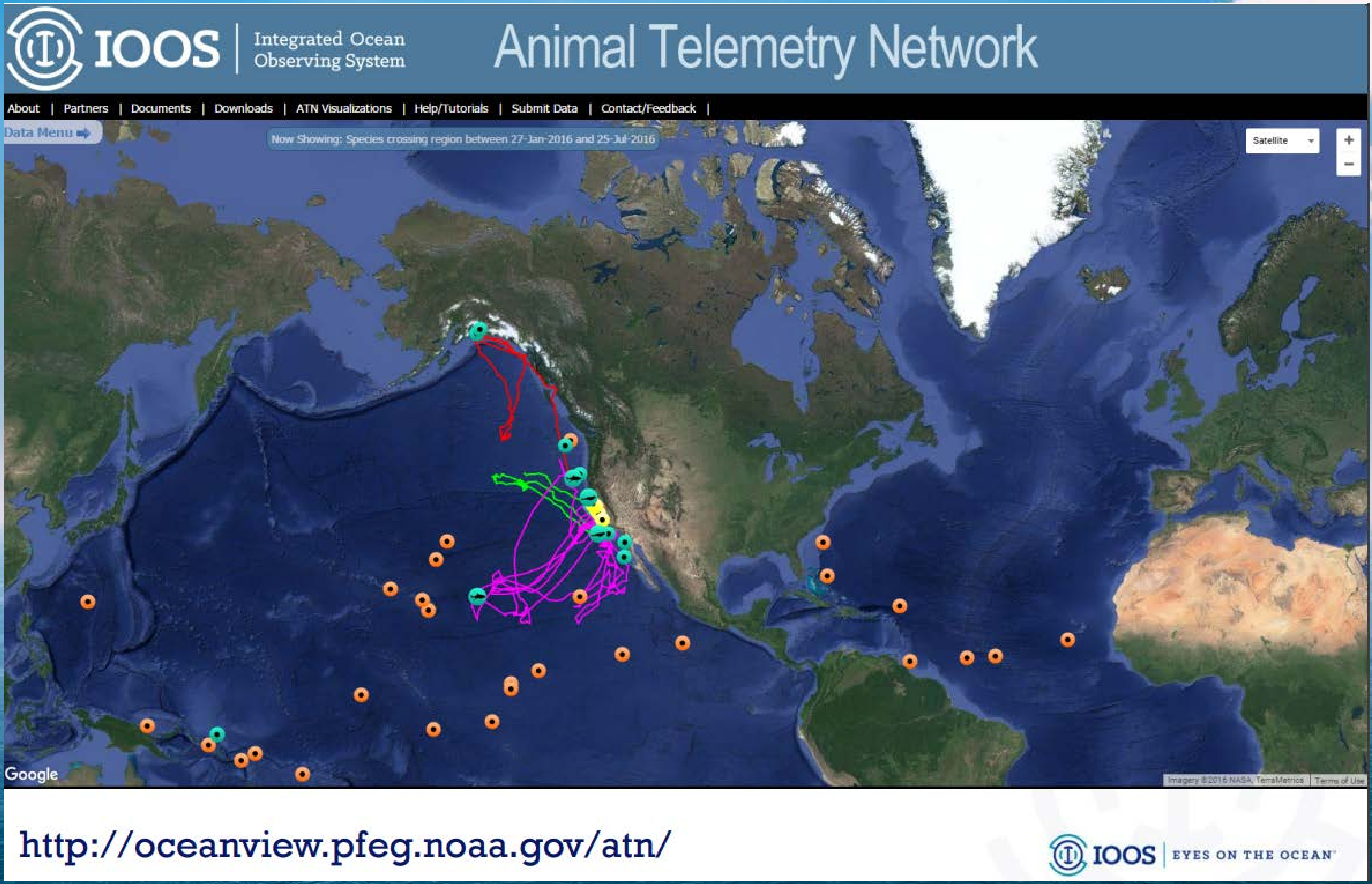
Animal tagging



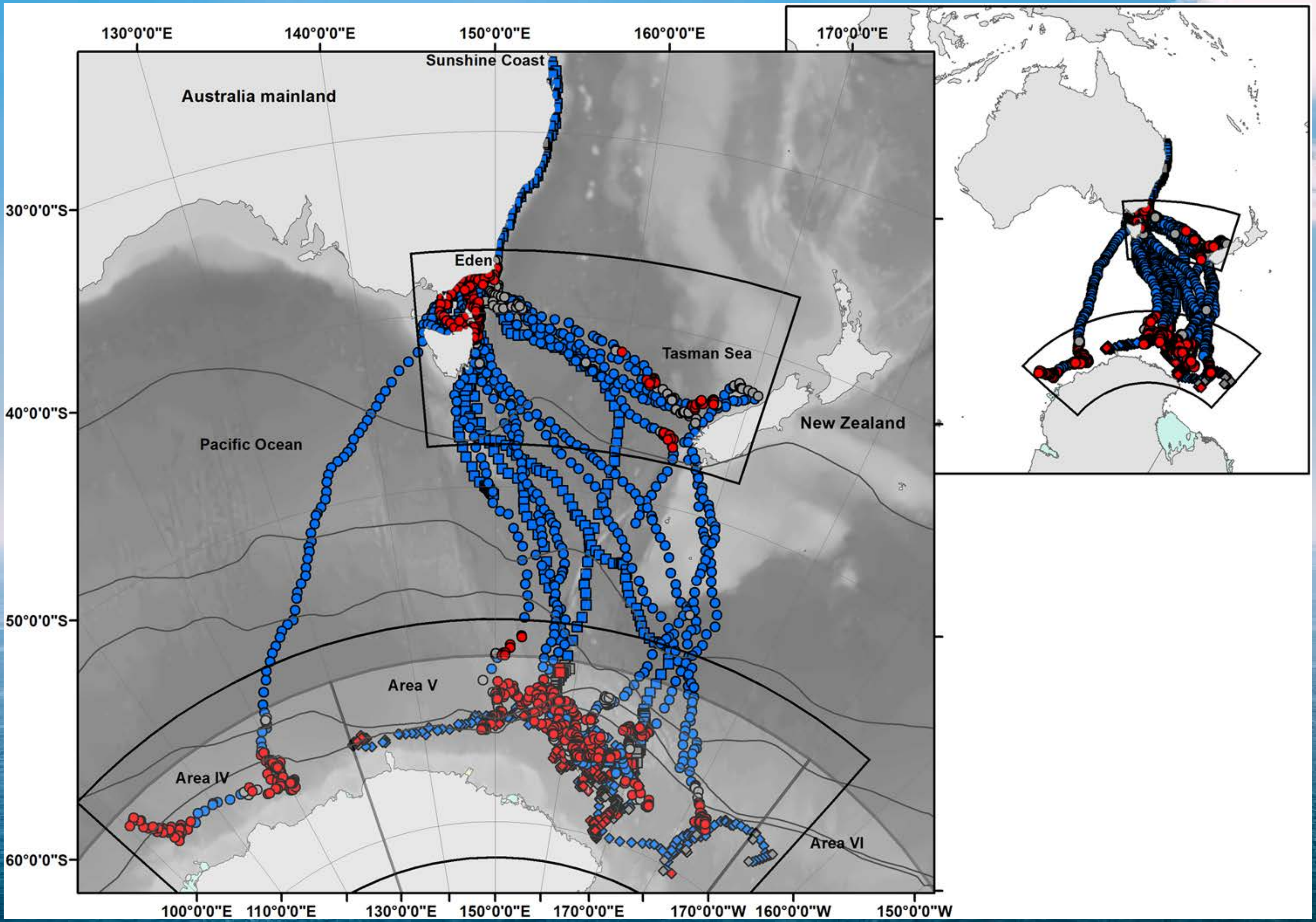


Animal tagging



CNR IRBIM
ISTITUTO PER LE RISORSE BIOLOGICHE E LE BIOTECNOLOGIE MARINE

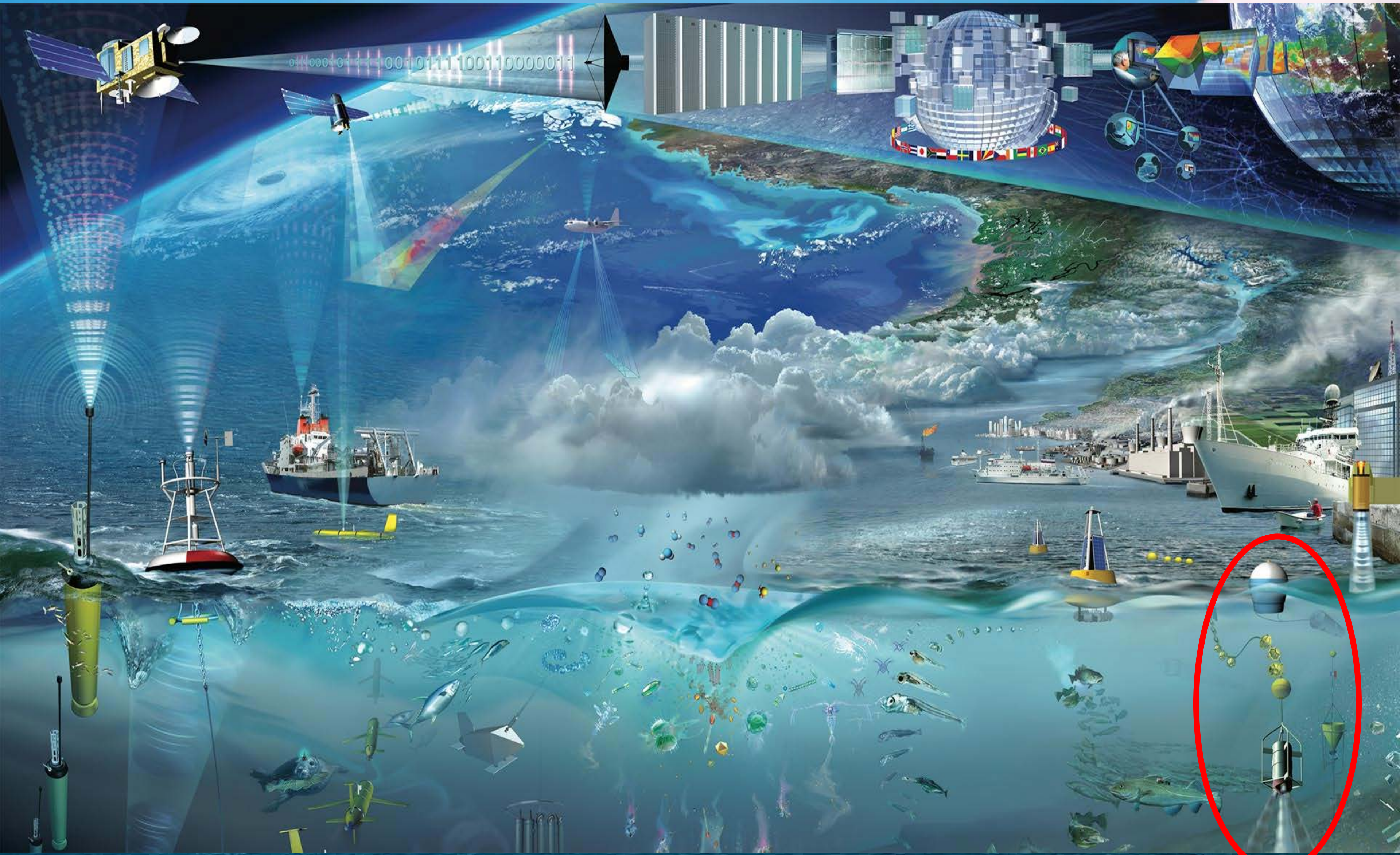
Animal tagging



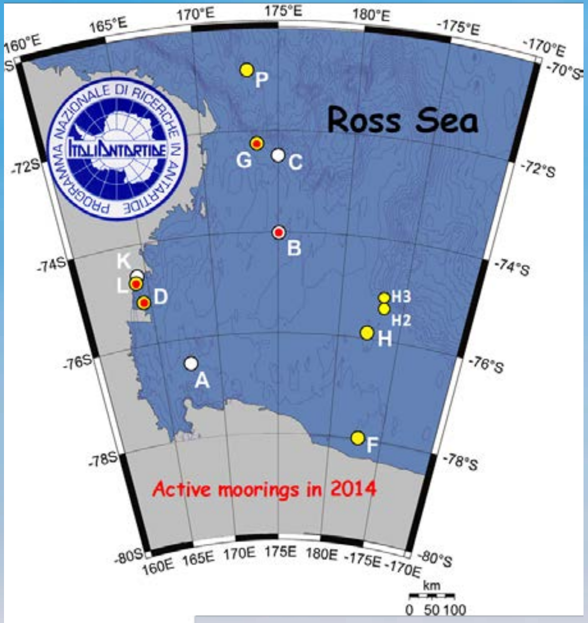
CNR IRBIM

The Global Ocean Observing System

EuroGOOS
European Global Ocean Observing System



Mooring



XXI Italian national expedition to Antarctica, 2005-2006

Anta XXXVII (2021-2022) Mooring B

Prof. (m)	Tipo componente	Lung. Parz (m)	Grafico	Pesi (kg)	Spinte (kg)
146.3	Omega 14 + Echosounder WBAT + omega 14	1.8		23.2	77.5
148.1	maillon rapide + cavo dynema + maillon rapide	25.0			
173.1	Omega 14 +Boe arancioni Mclane glass buoy (3+3+3)X10 kg	1.5			90.0
174.6	maillon rapide+ cavo bianco + SBE37 SN 4118 (183 m)+ maillon rapide	185.0		2.0	.
359.6	Boe gialle Mclane glass buoy (3+3+3)X10 kg	1.0			90.0
360.6	maillon rapide + cavo rosso + maillon rapide	45.0		0.5	
405.6	Omega 14 +2X3 boe MCLANE gialle 10kg + Omega 14	1.0			60.0
445.6	maillon rapide + cavo blu + maillon rapide	40.0		0.5	
446.6	cavo bianco + omega 14	4.0		0.2	
450.6	cavo bianco + omega 14	1.0			
451.6	Trappola Mcline 13cup + SBE16-04 SN 1437 + seapoint 1533	1.5		40.0	
453.1	omega 14 + cavo bianco + maillon rapide	1.0			
454.1	cavo kevlar rosso + maillon rapide	100.0		0.3	
554.1	2 boe Nautilus 25 kg con blocchetti neri + maillon rapide	2.0			50.0
556.1	omega 14 +Corrent. Aanderaa Seaguard SN 444+omega 14	0.7		15.0	
556.8	maillon rapide + cavo rosso + maillon rapide	5.0			
561.8	3 boe Nautilus 25 X 3	3.0			75.0
564.8	ovale+ maillon rapide + Cavo Marlowe bianco + omega 14	5.0		0.5	
569.8	Acoustic Releaser sn 2745 Type OCEANO AR861B2S, IXBLUE Battery Type: Tadiran TL 5930/s lithium, 18x3,65V-19Ah	0.5		50.0	
570.3	Acoustic Releaser sn 2746 Type OCEANO AR861B2S, IXBLUE Battery Type: Tadiran TL 5930/s lithium, 18x3,65V-19Ah				
570.3	Ovale + catena con 2 maniglioni Aanderaa 16	0.2		2.0	
570.5	Cavo grigio + manigl 20	5.0		0.0	
575.5	catena + manigl 20 + girella18+ Manig da 20	5.0		30.0	
580.5	Zavorra 3 ruote neozelandese (3*260)	0.5		780.0	
581.0	Fondo				
	TOTALI:	434.7		944.2	442.5
			peso strumenti	134.2	
Spinta netta al recupero (kg):					308.3

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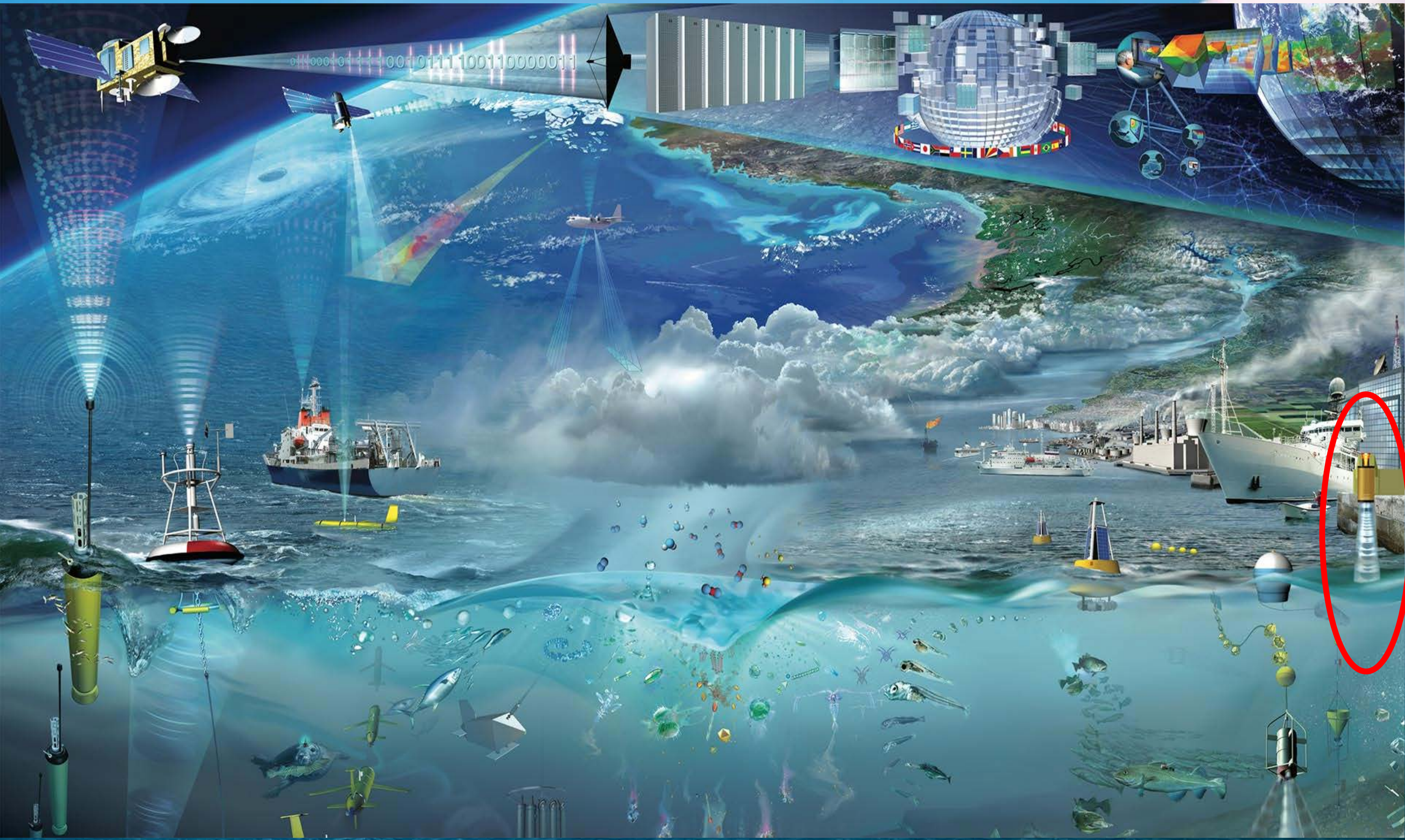
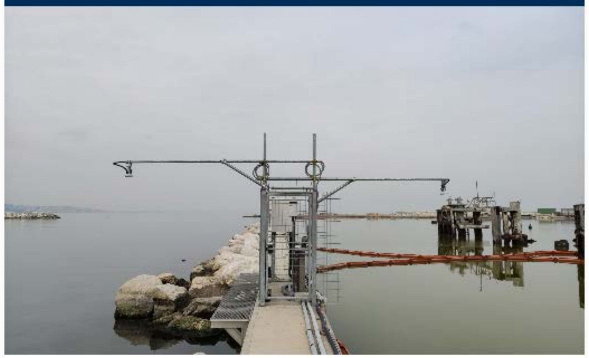


CNR IRBIM

Fixed meteo oceanographic observing site

ANCONA



Marine weather station located in the Port of Ancona.

LESINA

Station installed at the Lesina Lagoon

ANCONA

Weather station located on the roof of the IRBIM headquarters in Ancona

PORTO RECANATI

Marine weather station 200 meters from the coast near the mouth of the Potenza river

LESINA

Weather station located on the roof of the IRBIM headquarters in Lesina

SENIGALLIA

Marine weather station 1.5 miles off the coast of Senigallia (Ancona)

https://www.irbim.cnr.it/en/mare-in-tempo-reale/

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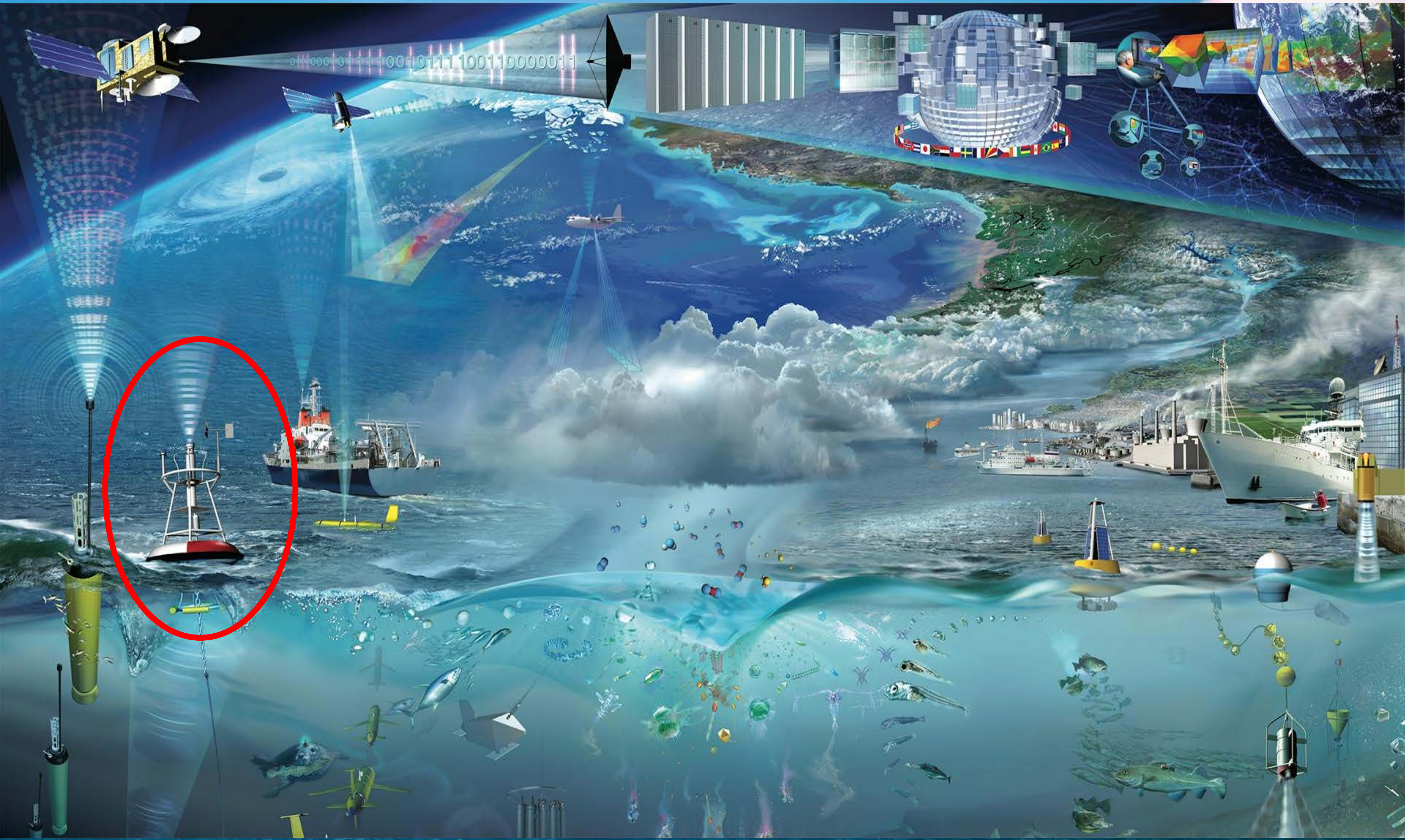
GOOS
The Global Ocean Observing System

EuroGOOS
European Global Ocean Observing System



meteo oceanographic buoy

FANO

Weather-marine station installed on buoy off the coast of Fano

PORTO RECANATI

Marine weather station installed on a buoy near the artificial barrier of Porto Recanati

https://www.irbim.cnr.it/en/mare-in-tempo-reale/

CNR IRBIM

GOOS
The Global Ocean Observing System

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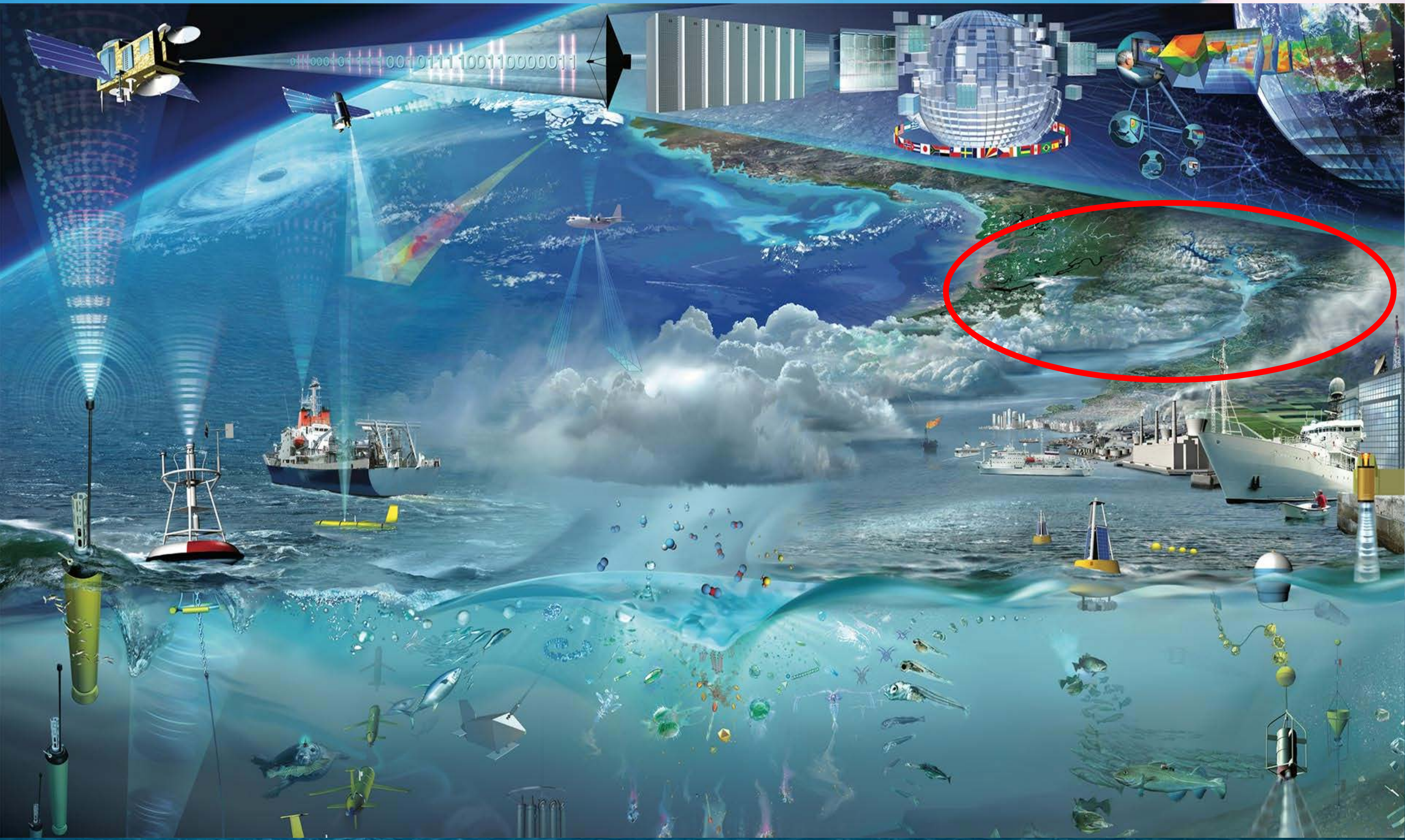
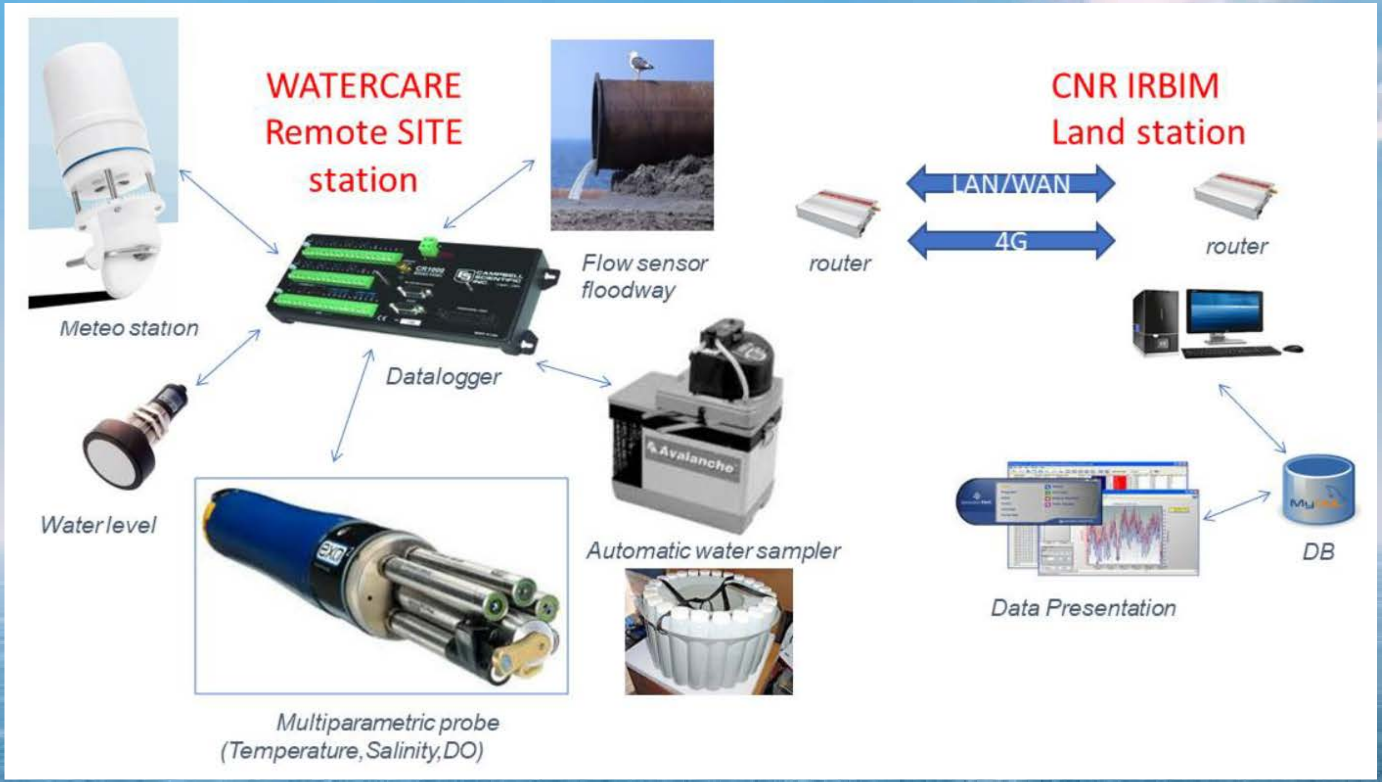


Water Quality Integrated System (WQIS)

FANO Arzilla river



https://www.irbim.cnr.it/en/mare-in-tempo-reale/

prototypes

sensors

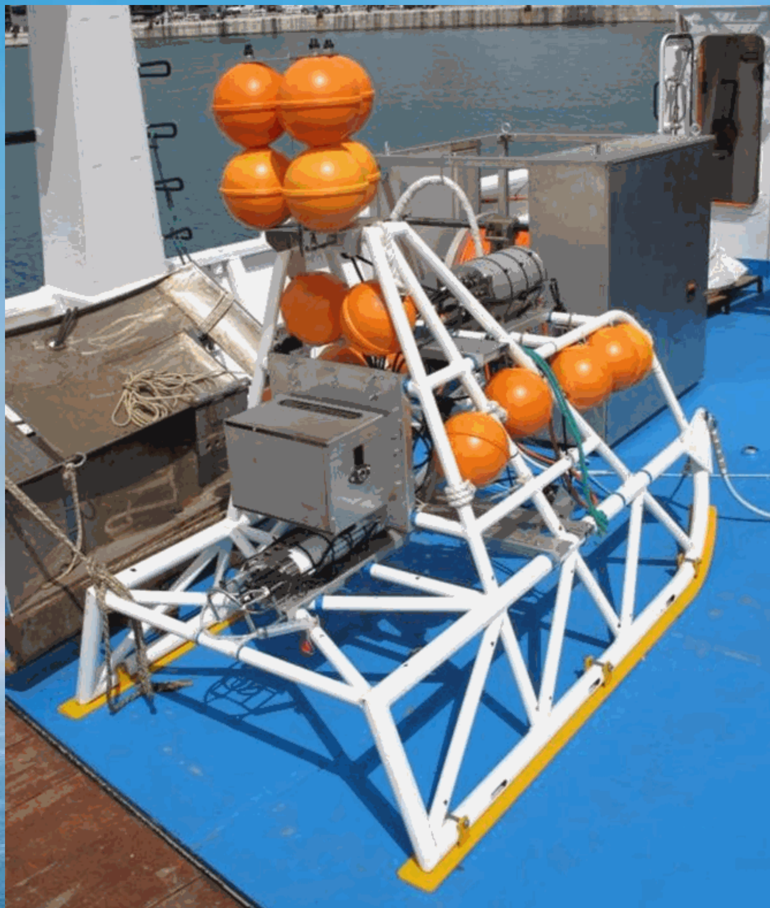
MDPI

Article

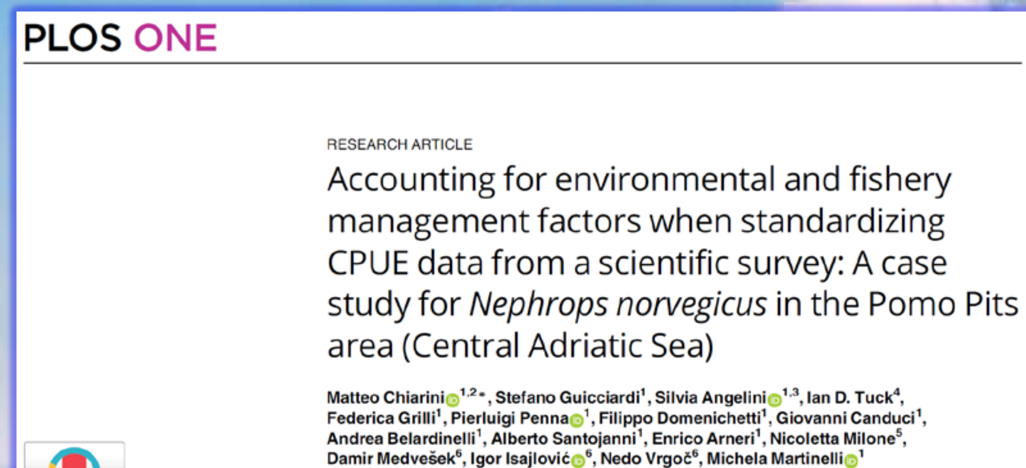
The AMERIGO Lander and the Automatic Benthic Chamber (CBA): Two New Instruments to Measure Benthic Fluxes of Dissolved Chemical Species †

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

prototypes



UWTV Under Water TV



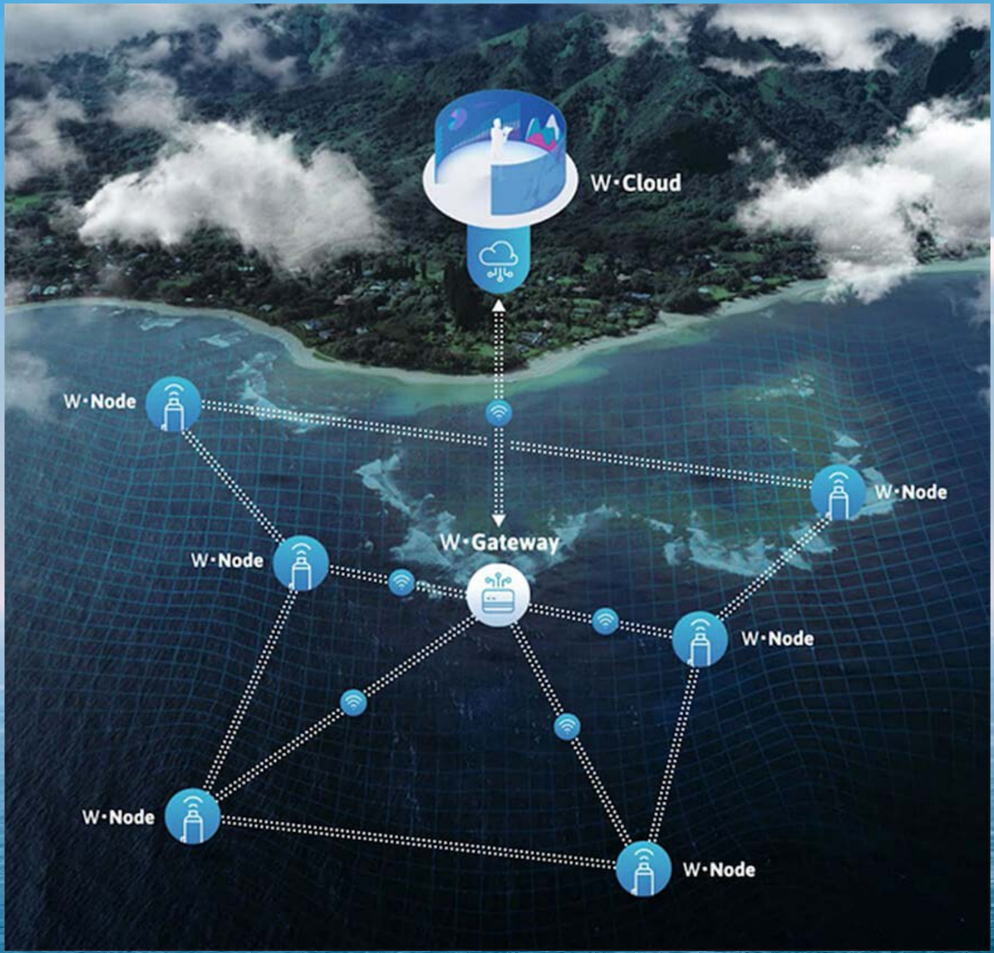
PLOS ONE

RESEARCH ARTICLE

Accounting for environmental and fishery management factors when standardizing CPUE data from a scientific survey: A case study for *Nephrops norvegicus* in the Pomo Pits area (Central Adriatic Sea)

Matteo Chiarini[1,2*], Stefano Guicciardi[1], Silvia Angelini[1,3], Ian D. Tuck[4], Federica Grilli[1], Pierluigi Penna[1], Filippo Domenichetti[1], Giovanni Canduci[1], Andrea Belardinelli[1], Alberto Santojanni[1], Enrico Arneri[1], Nicoletta Milone[5], Damir Medvešek[6], Igor Isajlović[6], Nedo Vrgoč[6], Michela Martinelli[1]

Internet of Underwater Things (IoUT)



Are you tired?

break

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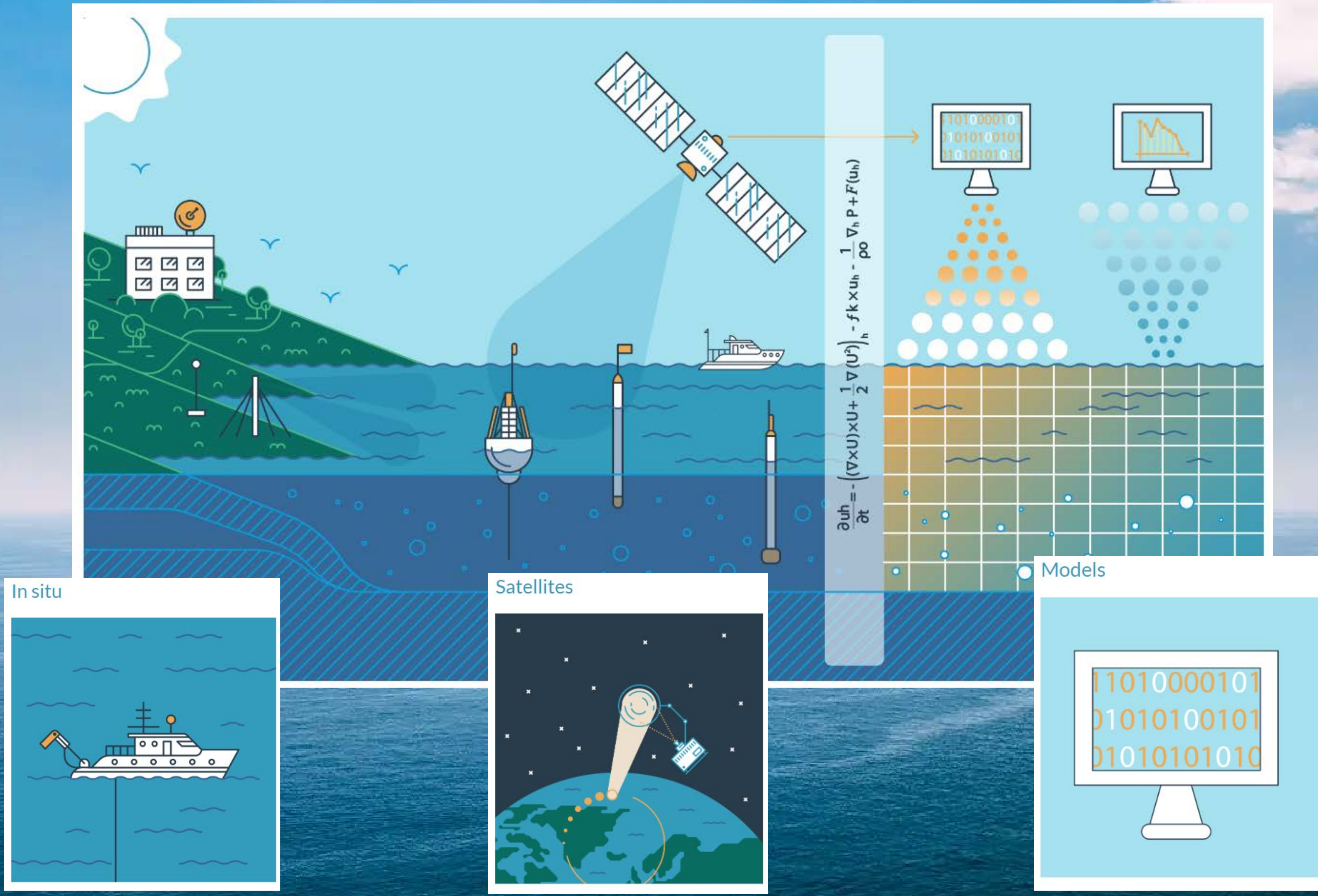
Architecture of an Ocean Monitoring and Forecasting System



Satellite and models

https://marine.copernicus.eu/explainers/operational-oceanography/monitoring-forecasting/satellites

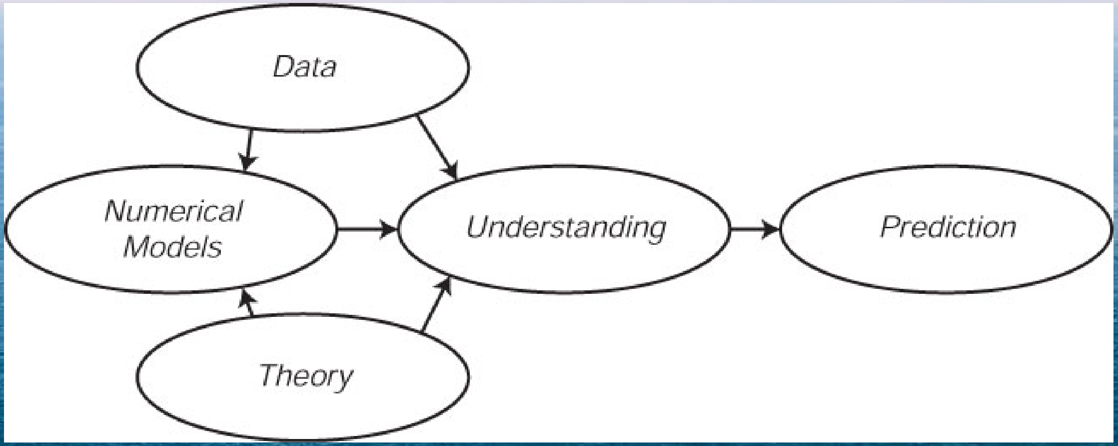
https://marine.copernicus.eu/explainers/operational-oceanography/monitoring-forecasting/models

Architecture of an Ocean Monitoring and Forecasting System

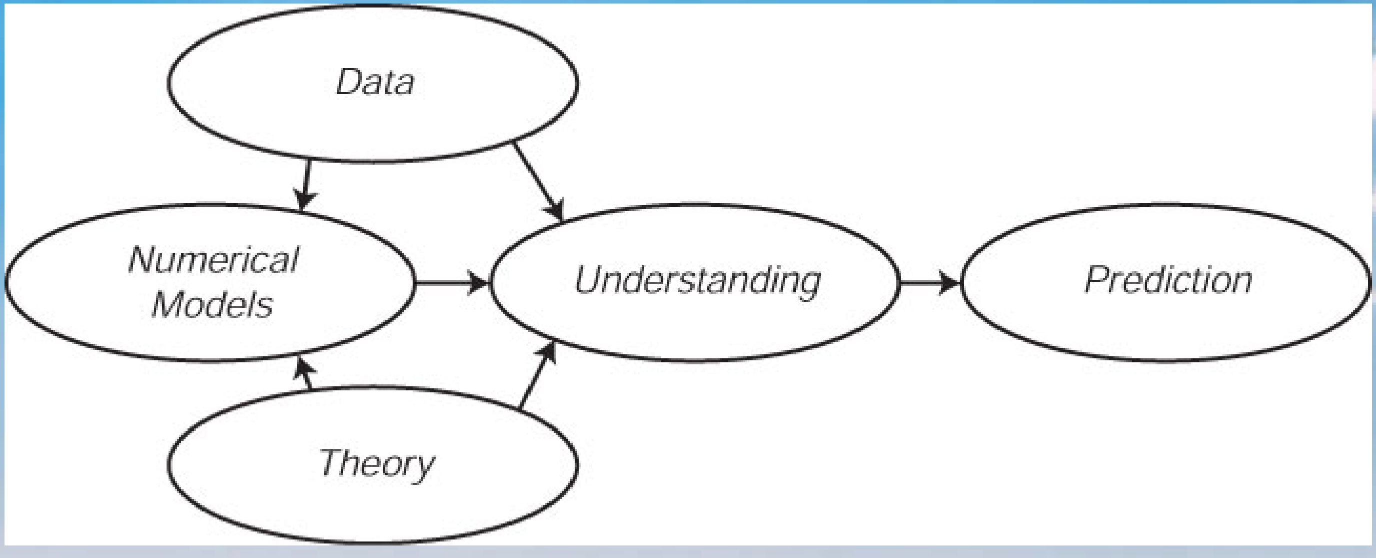
- Ocean models, in situ and satellite observations are the main components of an ocean monitoring and forecasting system.

- Observational data (satellite and/or in situ) can be integrated into the numerical models to ensure they are as close to reality as possible. This process is called ‘data assimilation’.

- While the observations only represent a portion of the global ocean, models complete the missing information with realistic ocean dynamics to provide an overall picture



Architecture of an Ocean Monitoring and Forecasting System

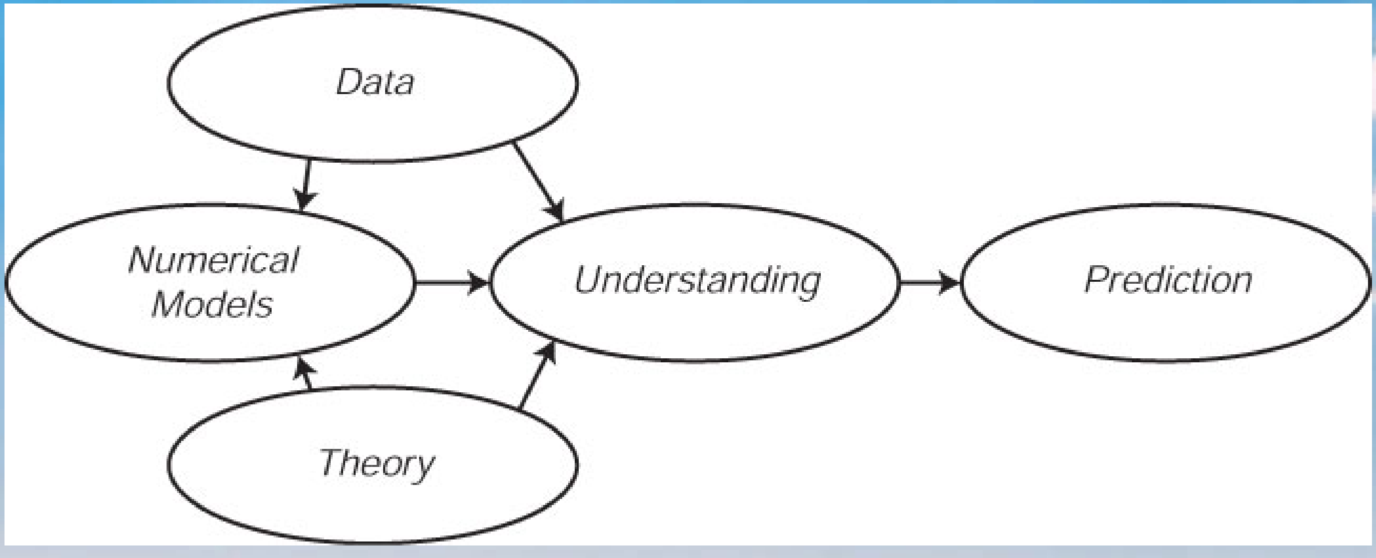


we use

1. Theory
2. Observations
3. Numerical models to describe ocean dynamics.

<u>None is sufficient by itself!</u>

Architecture of an Ocean Monitoring and Forecasting System



- By combining theory and observations in numerical models we avoid some of the difficulties associated with each approach used separately

- Continued refinements of the ***combined approach***
- are leading to ever-more-precise descriptions of the ocean, sea and coastal area

Architecture of an Ocean Monitoring and Forecasting System

The ultimate goal is to know the ocean well enough to predict the future changes in the environment, including climate change or the response of fisheries to over fishing

Data, numerical models, and theory are all necessary to understand the sea

Eventually, an understanding of the ocean-atmosphere-land system will lead to predictions of future states of the system

The combination of theory, observations, and computer models is relatively new (operational oceanography 1995)

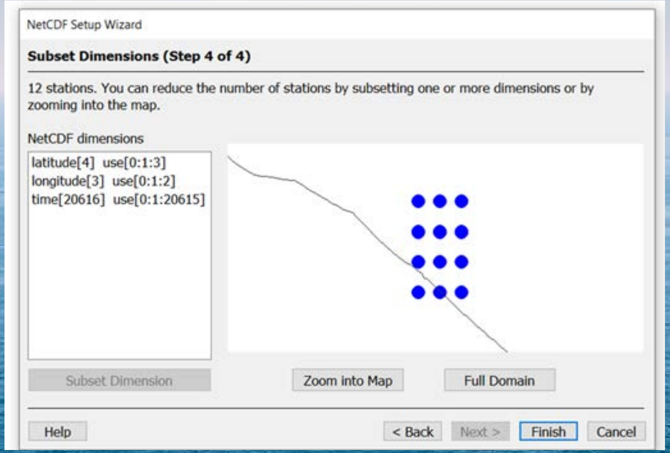
Exponential growth in computing power has made available powerrful computers capable of simulating important physical processes and oceanic dynamics
Link https://earth.nullschool.net/

AI will make an important contribution to improving the implementation of numerical models, lowering the uncertainty of predictions

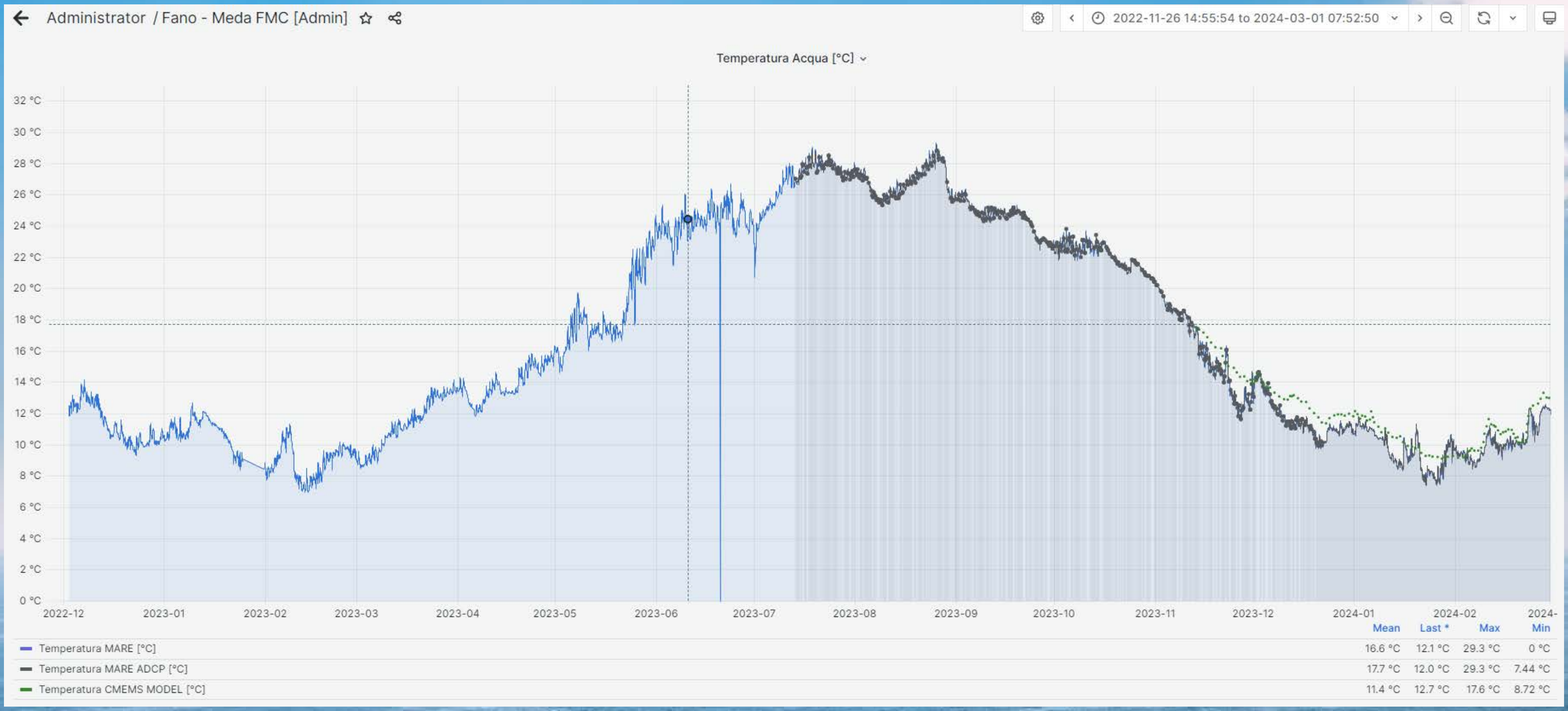
Lab activity

Fano marine center Buoy: data series and real time data

Comparison with Copernicus model data



Why observe the sea?



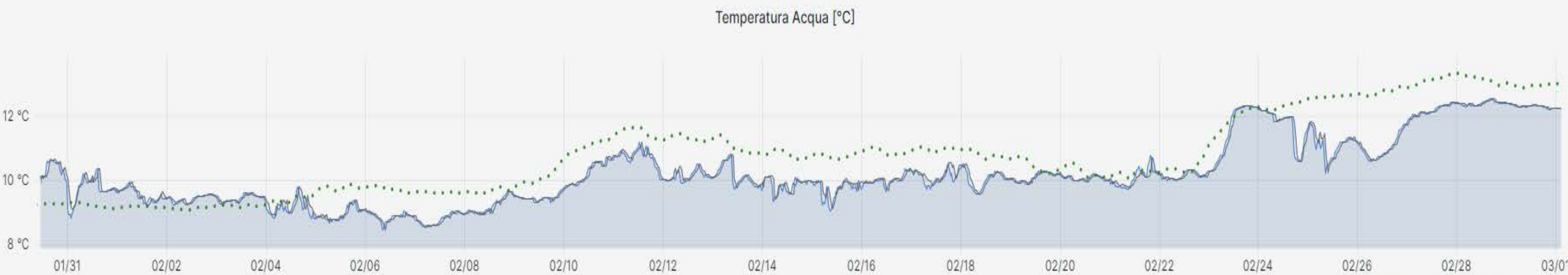
We construct long time series

Why observe the sea?

We observe phenomenon at microscale

Why observe the sea?

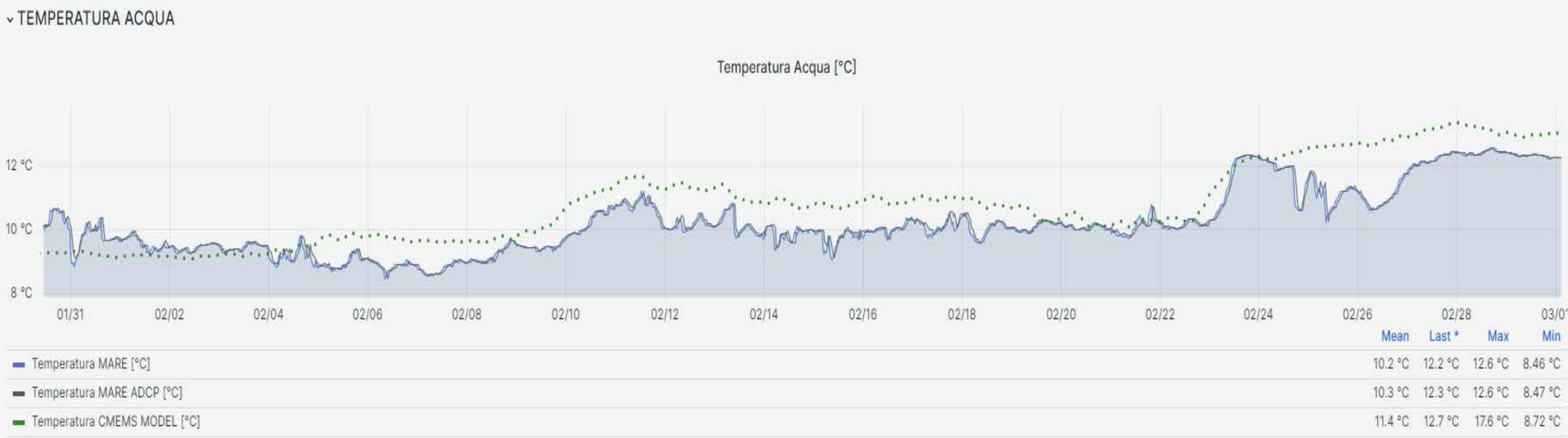
˅ TEMPERATURA ACQUA



	Mean	Last *	Max	Min
Temperatura MARE [°C]	10.2 °C	12.2 °C	12.6 °C	8.46 °C
Temperatura MARE ADCP [°C]	10.3 °C	12.3 °C	12.6 °C	8.47 °C
Temperatura CMEMS MODEL [°C]	11.4 °C	12.7 °C	17.6 °C	8.72 °C

We calibrate/validate ocean models

Why observe the sea?



https://goosocean.org/why-observe-the-ocean/

Why observe the sea?
Some effects of the climate change in Adriatic sea

Transetto Senigallia
Meteotsunami
Inondazione Pesaro simulate
Moria mosciolo
Blue crab
Attenti a quei 4
biodiversità

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Open discussion

Where does a fish live??


Thank you for attention !!
Se mi guardo attorno,
Penso che son fortunato,
Non so chi ha creato il mondo,
ma so che era innamorato
Vecchioni/Alfa