A.Crise, OGS

OCEAN MONITORING SESSION: OBSERVING SYSTEMS

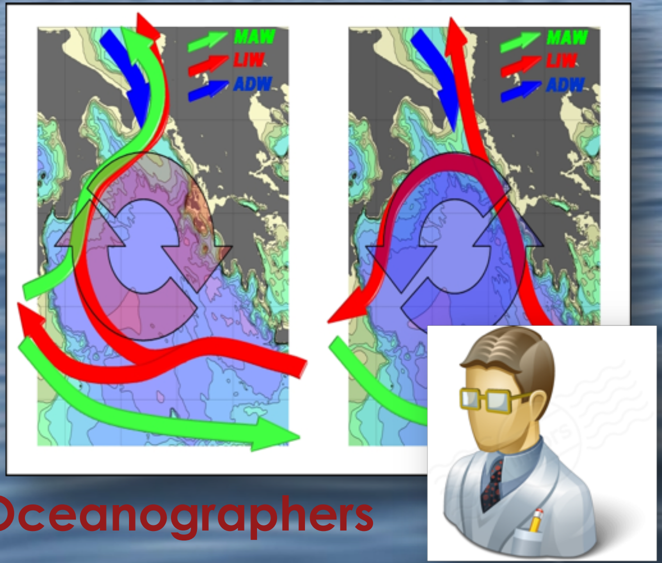
ICTP, Trieste, Italy
29 January 2019

ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE

Workshop on Rapid Prototyping of Internet of Things Solutions for Science

Maritime Risks Managers

Climatologists



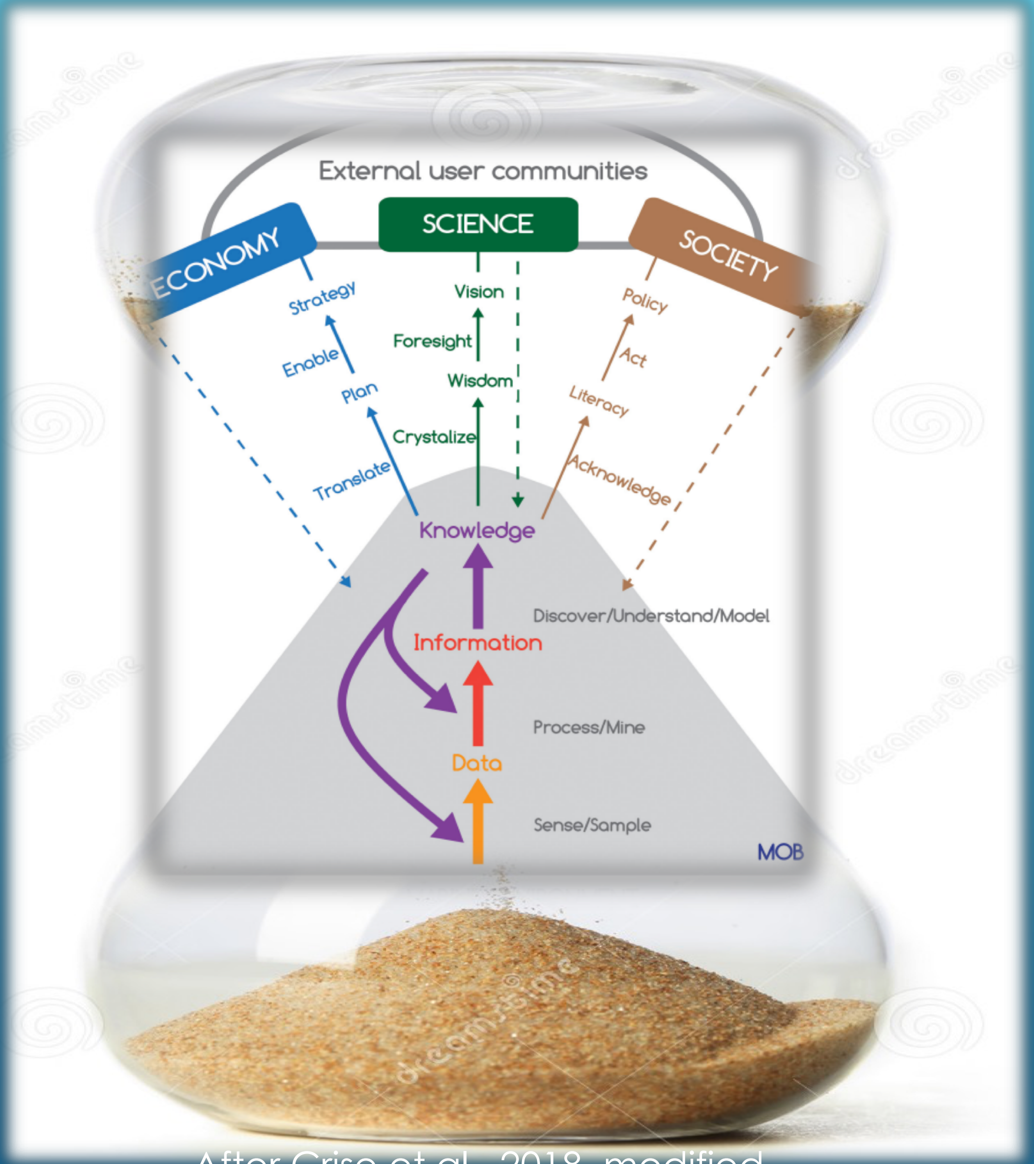
Oceanographers

Local authorities

Fishermen

WHAT DO THEY HAVE IN COMMON?

THE NEED FOR A **TIMELY ACCESS TO QUALIFIED MARINE DATA, INFORMATION AND KNOWLEDGE**



After Crise et al., 2018, modified

THE 'KNOWLEDGE HOURGLASS'

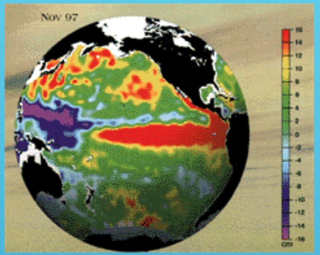
To be useful marine observations must be:

- ❖Timely
- ❖Sustained
- ❖Qualified
- ❖Fit-for –Purpose
- ❖Multiple use

MARINE OBSERVATIONS:
BEYOND PURE SCIENCE, TOWARD BLUE ECONOMY

Applications of marine data and knowledge

- **Shipping**
- **Offshore operations (constructions, drilling, ..)**
- **Fisheries & aquaculture**
- **Tourism & coastal economy**
- **Ocean renewable energy**
- **Health of marine environment (pollution, biodiversity)**
- **Protection from natural hazards (tsunami, HABs)**
- **Mitigation of climate change effects (e.g. sea level rise)**



HOW TO OBSERVE THE OCEAN?

To investigate the physical conditions of the deep sea in the great ocean basins ....in regard to depth, temperature, circulation

To determine the chemical composition of seawater at various depths from the surface to the bottom, the organic matter in solution and the particles in suspension.

To ascertain the physical and chemical character of deep-sea deposits and the sources of these deposits.

To investigate the distribution of organic life at different depths and on the deep seafloor

At each of the 360 stations the **crew** measured the bottom depth, temperature at different depths, observed weather and surface ocean conditions, and collected seafloor, water, and biota samples.

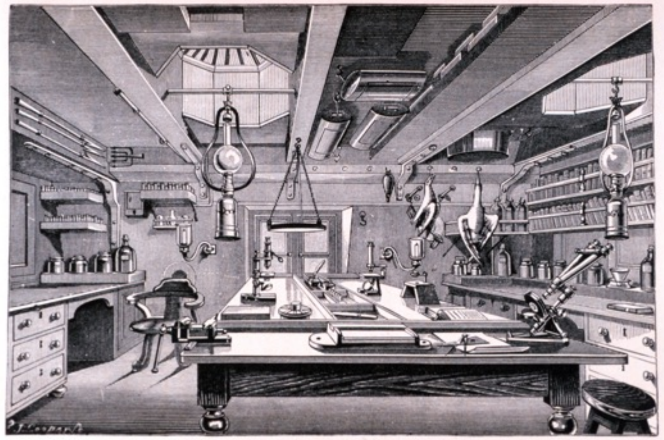
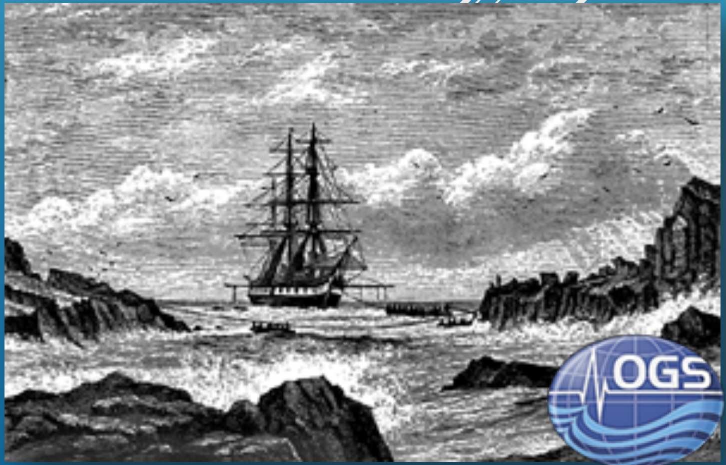
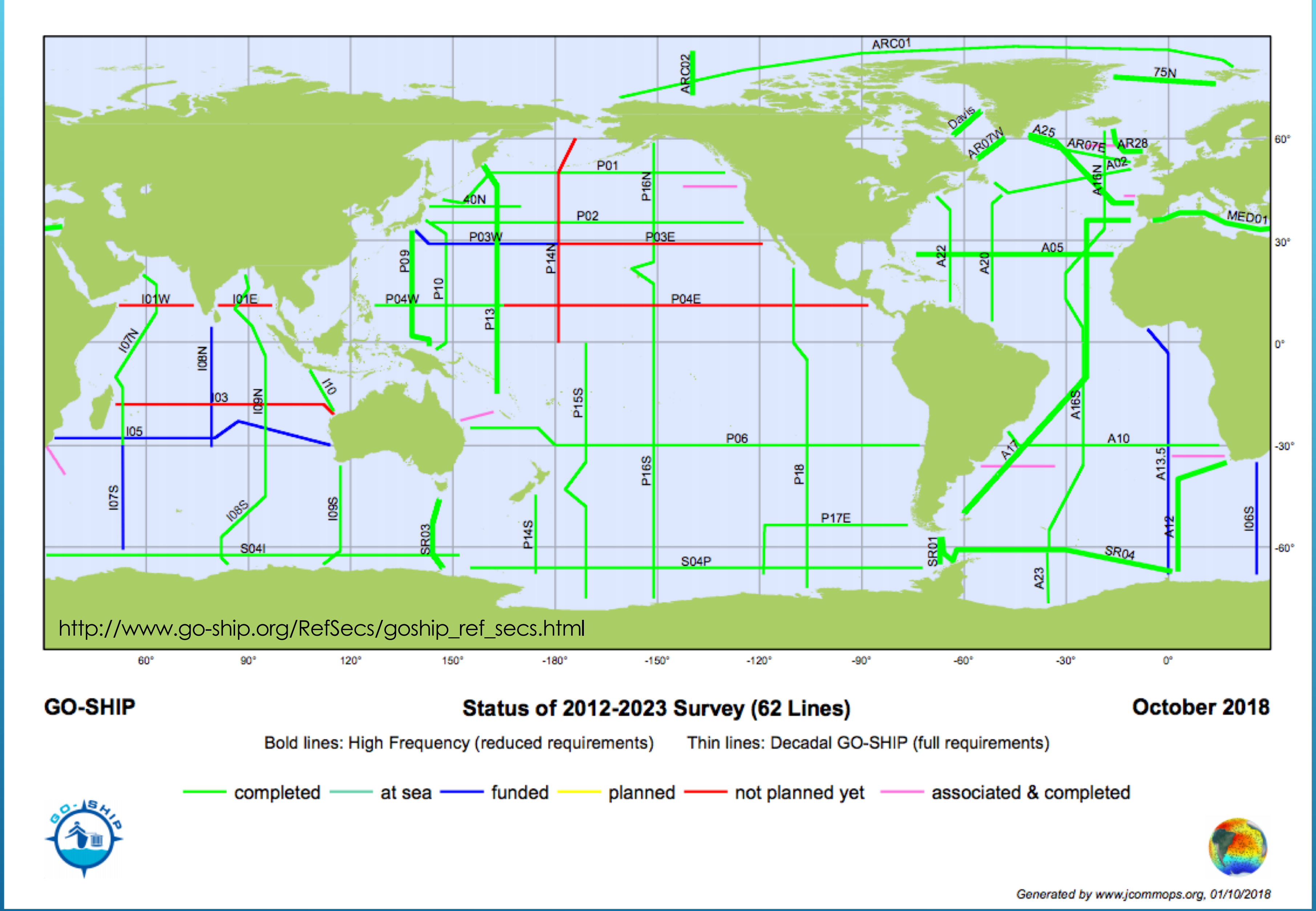


FIG. 1.—The Natural History Work-room.

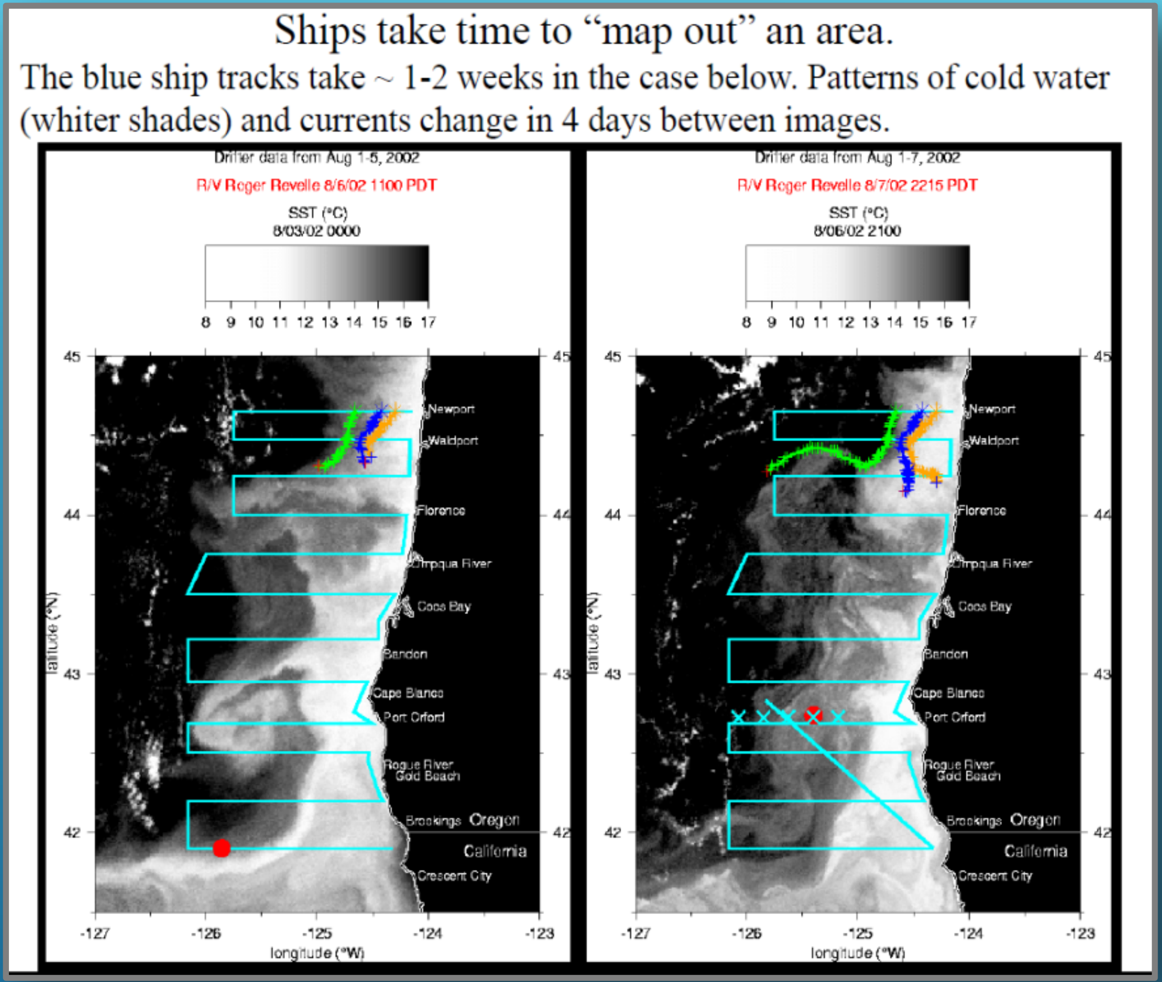
THE *CHALLENGER* EXPEDITION OF 1872–76



GO-SHIP Repeat hydrographic sections at decadal scale



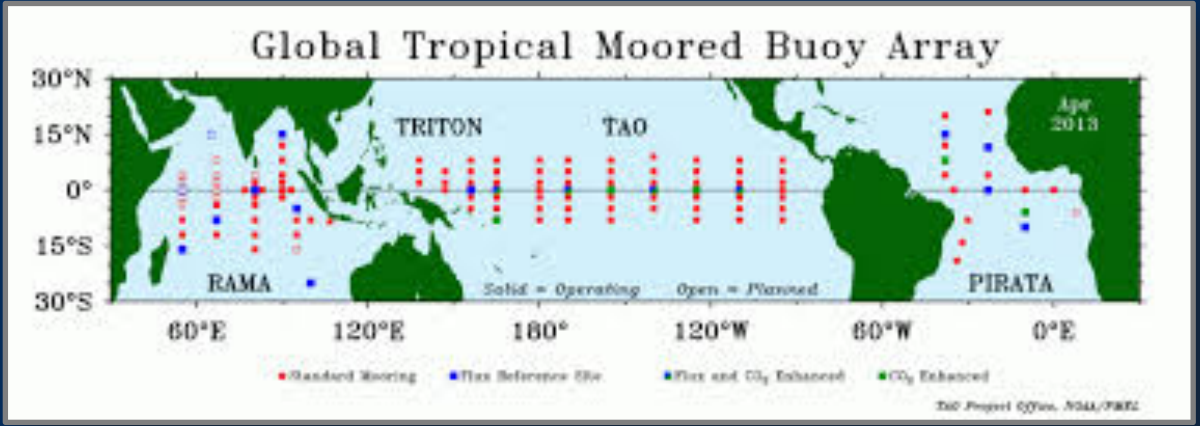
MORE THAN A CENTURY LATER….

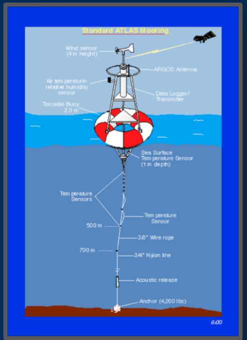


Ship observations limits

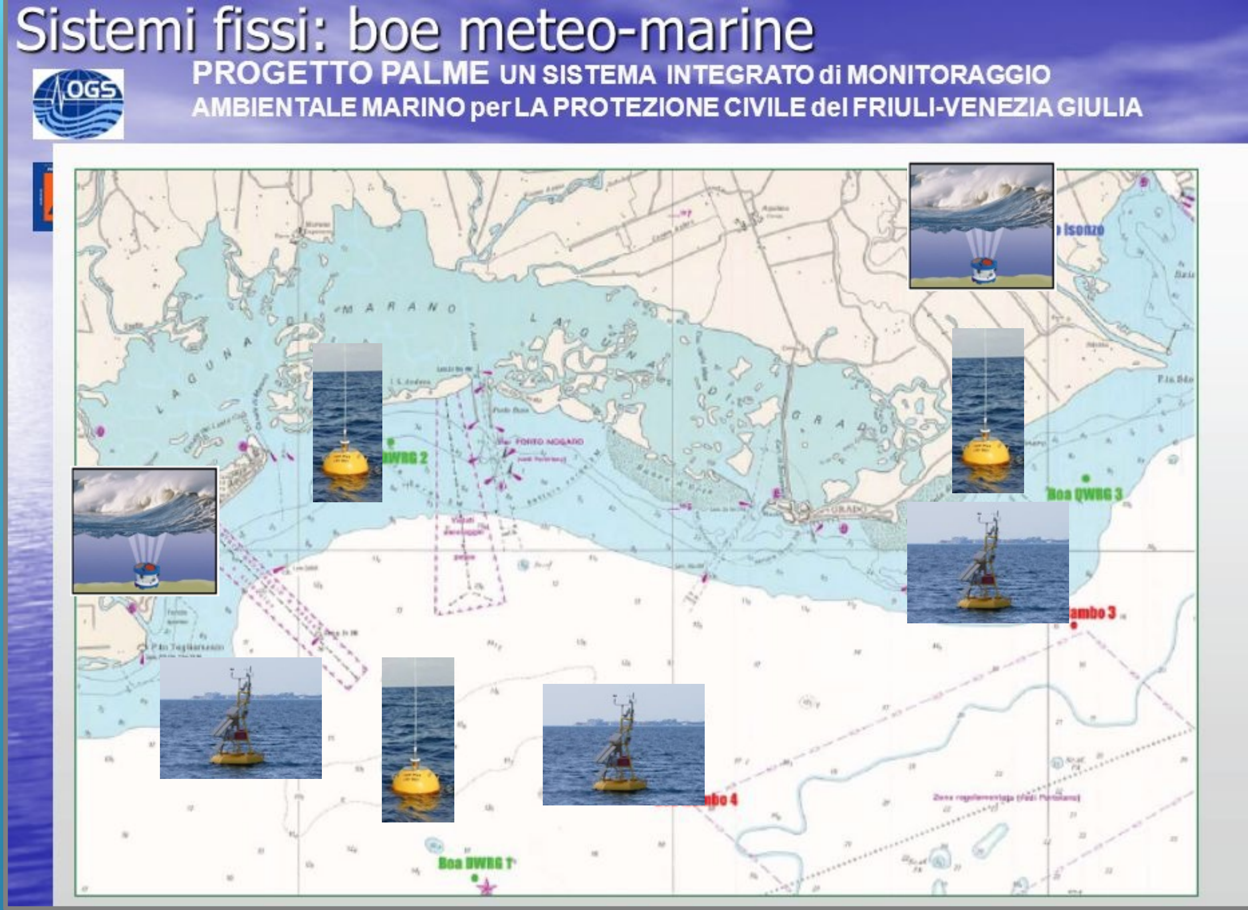
- **High cost** in operations
- Sampling only with
- **good sea state conditions**
- Coarse spatial resolution Too **slow** to capture a 'snapshot' of the sea state
- Tricky data release
- /dissemination *(some times it will never happen)*

SHIP CRUISES PROS AND CONS





Global scale mooring system



Regional tide gauge networks

FIXED MOORINGS SYSTEMS/ PERMANENT COASTAL STATIONS

WHY MOORING/PERMANENT COASTAL STATIONS?

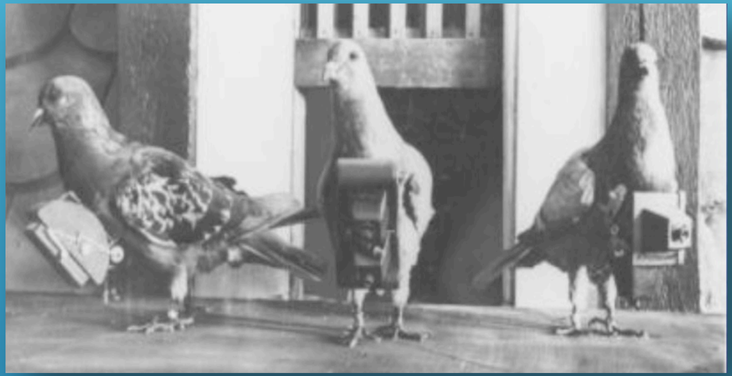
- Long-term time series at high temporal resolution in pre-defined sites (e.g. sea level rise)
- Early warning systems for large scale events (e.g. tsunami, storm surge)

BUT

OCEAN IS A HARSH ENVIRONMENT

- Sensors and platforms are subjected to permanent intensive evironmental attack (sun, erosion, aging…) and the maintenance is costly.
- Lack of assessment of the (spatial) relevance of the observation
- Limited vertical resolution
- Consolidated Murphy's Law (*Anything that can go wrong, will*)

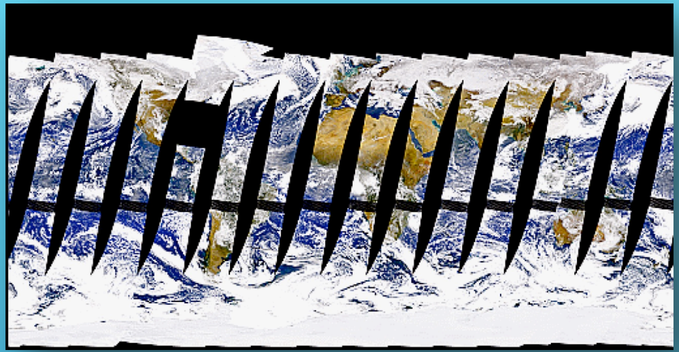
MOORINGS PROS AND CONS

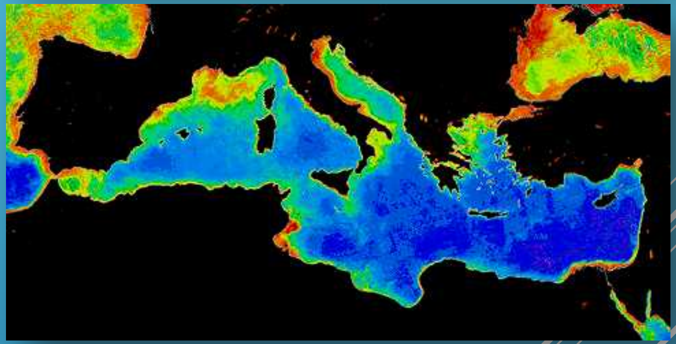


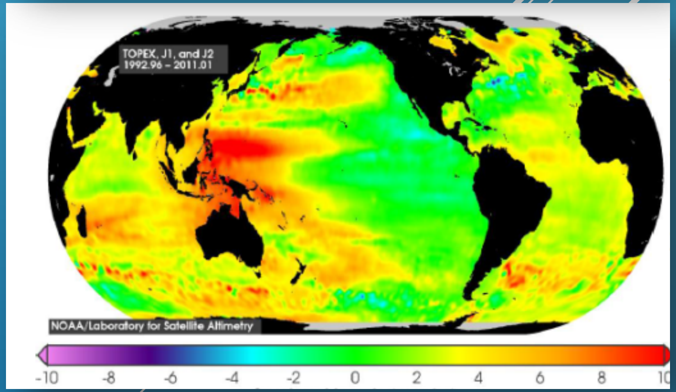
Spy pigeons

Seasat, the first civilian oceanographic satellite, lauched by NASA on June 28th, 1978. The mission lasted 48h.

Recent data and products

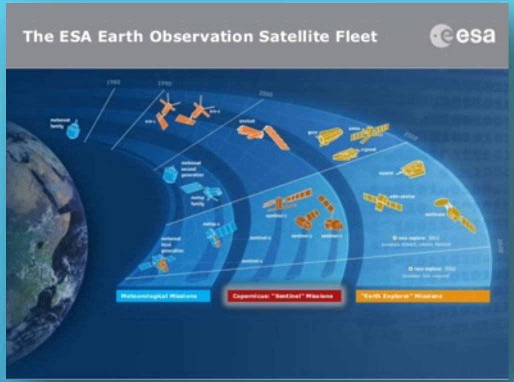






REMOTE OBSERVATIONS ERA

REMOTE SENSING PROS AND CONS



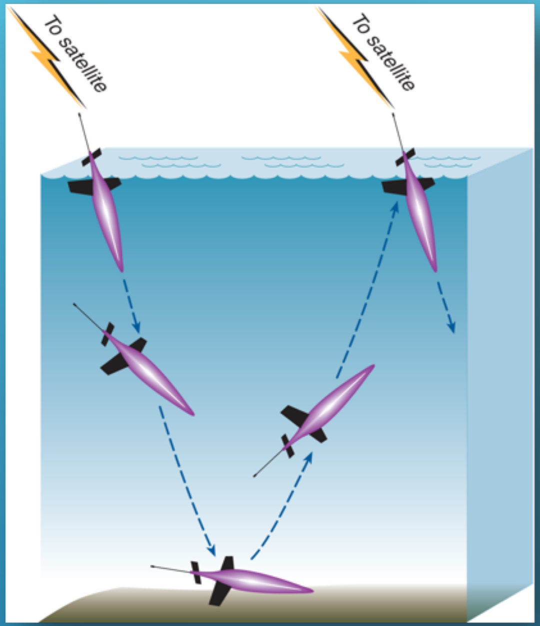
WHY SATELLITES?

- Provision of uniform sampling, hourly-to-monthly fields
- Relatively unexpensive , once the satellite is in orbit
- (Often) 'democratic' data access

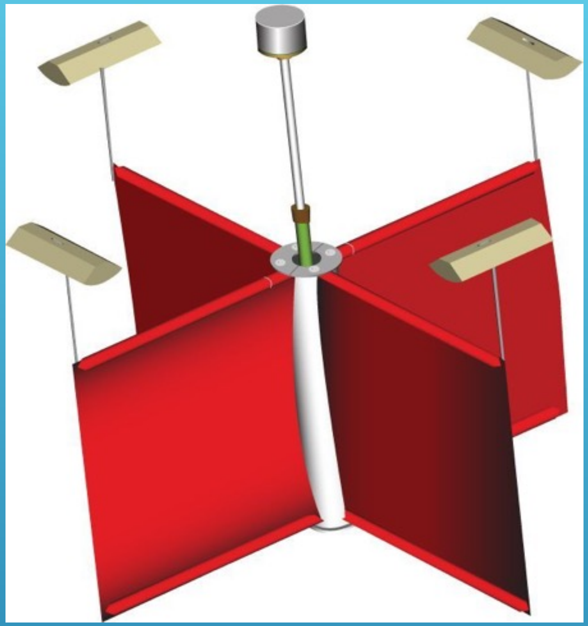
BUT

SPACE IS A HARSH ENVIRONMENT TOO

- Satellite malfunctions are difficult to fix
- Low signals to noise ratio
- No sub-surface measurements
- Indirect observations of a limited number of variables



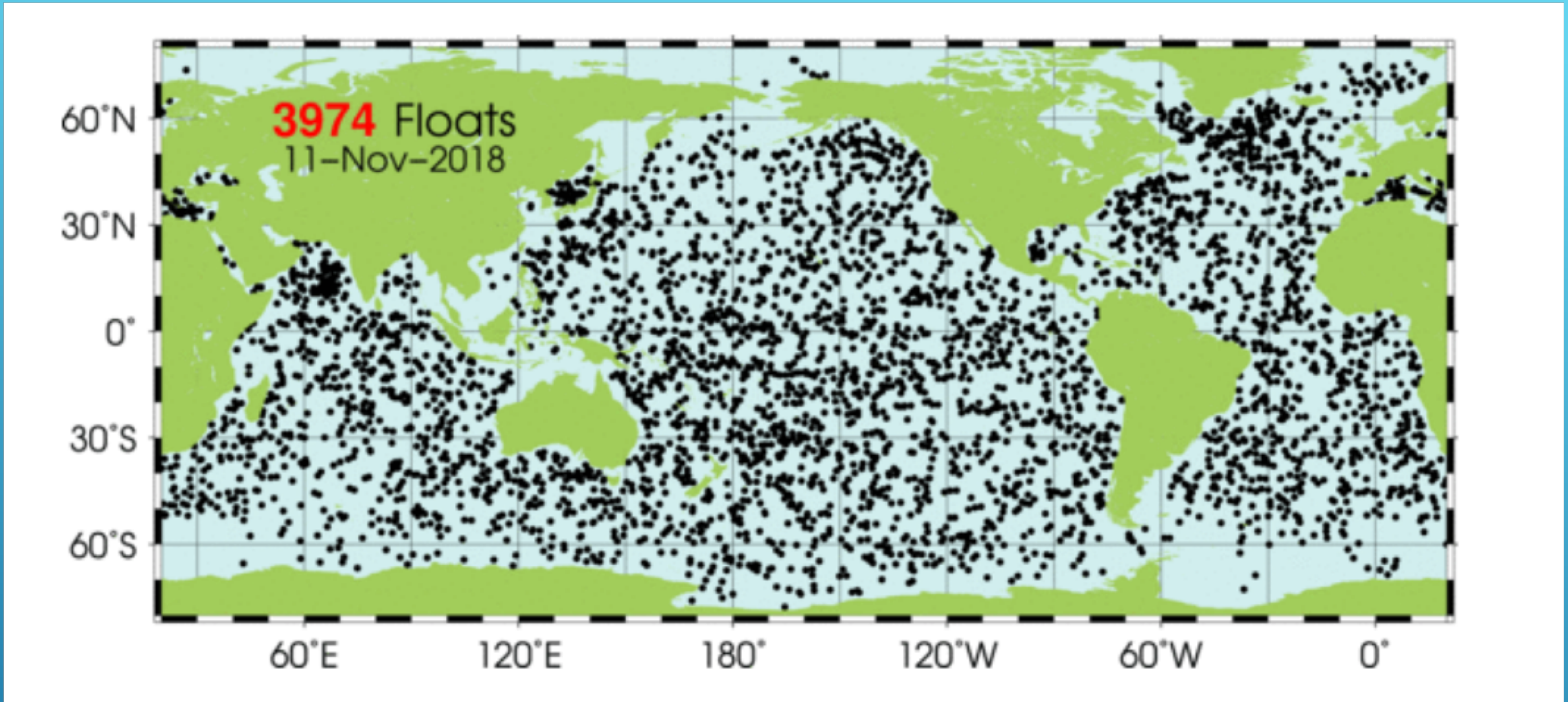
Glider



Drifter

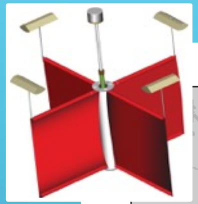
Float

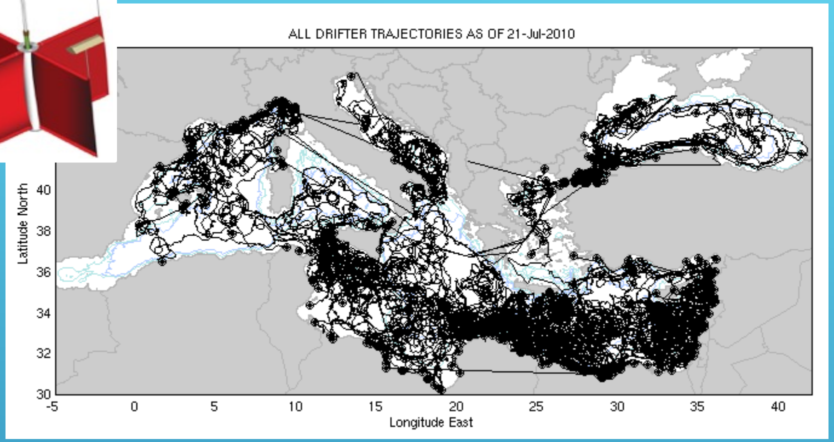
FOLLOWING THE STREAM….. (LAGRANGIAN PLATFORMS)

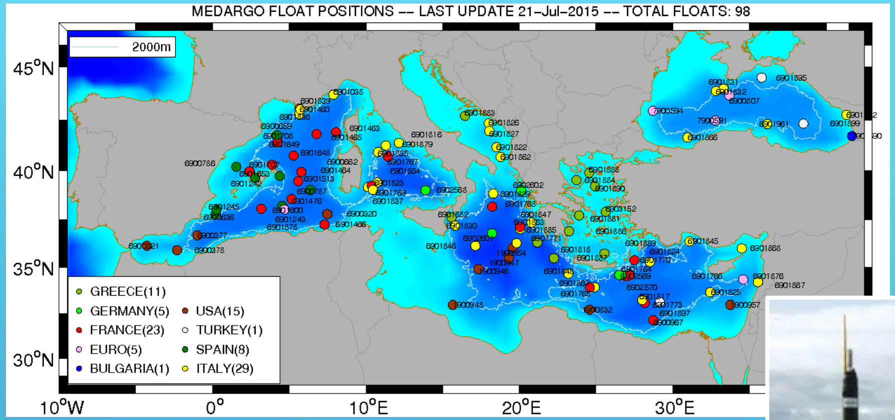


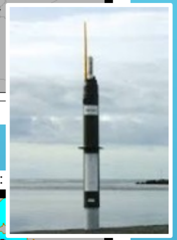
ARGO PROGRAM

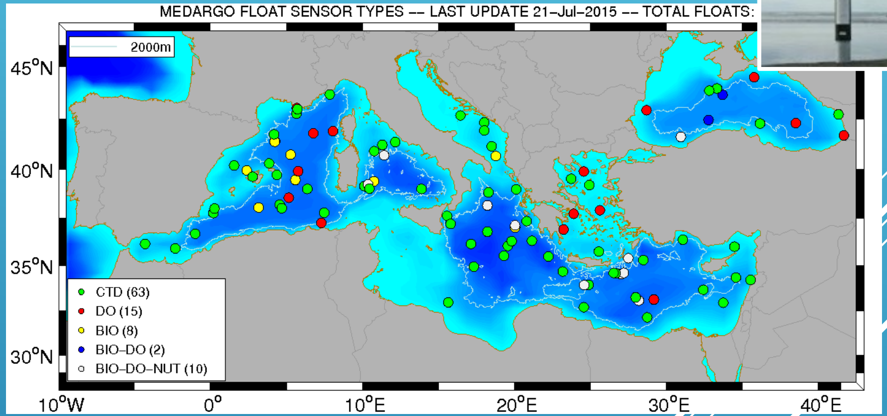
The broad-scale global array of temperature/salinity profiling floats, known as Argo, has already grown to be a major component of the ocean observing system

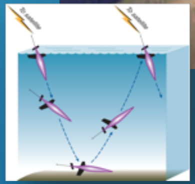












MEDARGO, MEDSVP, GROOM PROJECTS

Lagrangian measurements

- Large-scale open-ocean continuous coverage of main variables in the ocean interiors
- Adaptive sampling strategy

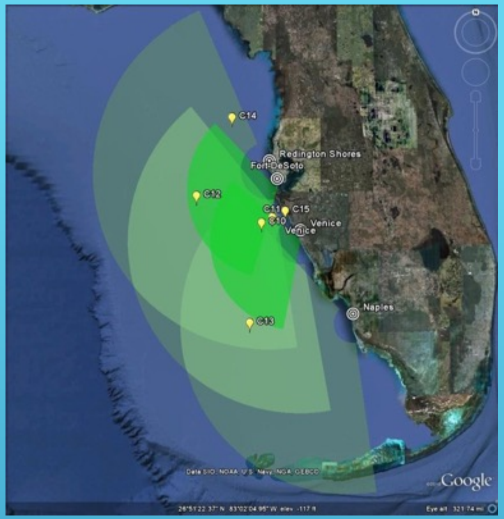
BUT

- Information needs to be statistically treated
- Difficulties to explore the deepest parts of the oceans
- Platforms cannot be precisely stirred
- Coastal areas are difficult to be investigated
- Large part of the equipment is expandible
- Limited number of variables are operationally available

LAGRANGIAN OBSERVATION PROS AND CON

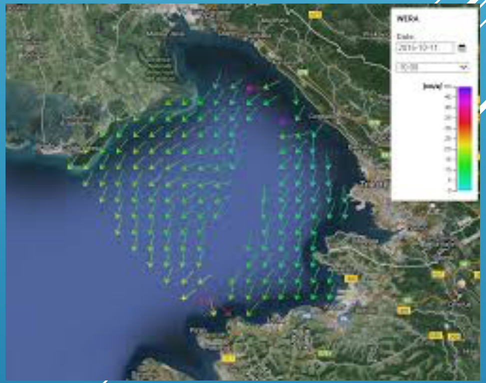
Hf coastal radars potential

- Estimate the surface velocity by evaluation of the Doppler shift (change of the frequency of the backscattered signal due to the velocity of the current)
- Long range (up to 100km, depending on the frequency and the waves regime)
- In some cases possibility to estimate also the waves



BUT

- At least two HF radars covering the same areq are required
- Difficulties in obtaining permits for the use of the HF band
- Spurous disturbances can hamper the the quality of the observations
- In case of weak wave motion, poor signal-to-noise ratio
- Observations limited only to the sea surface



HF COASTAL RADARS PROS AND CONS

NEW PLATFORMS/SENSORS

Swarms of micro-robots ....

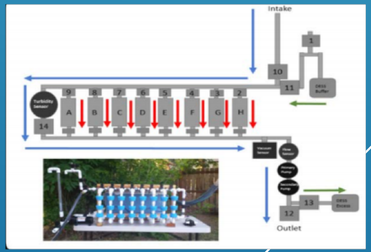
Unmanned Surface Vehicles ....

Autonomous Underwater Vehicles ....

Automated Flow Cytometry Buoys ....

Ecogenomic sensor (ESP) ....

Autonomous collection of environmental DNA ....



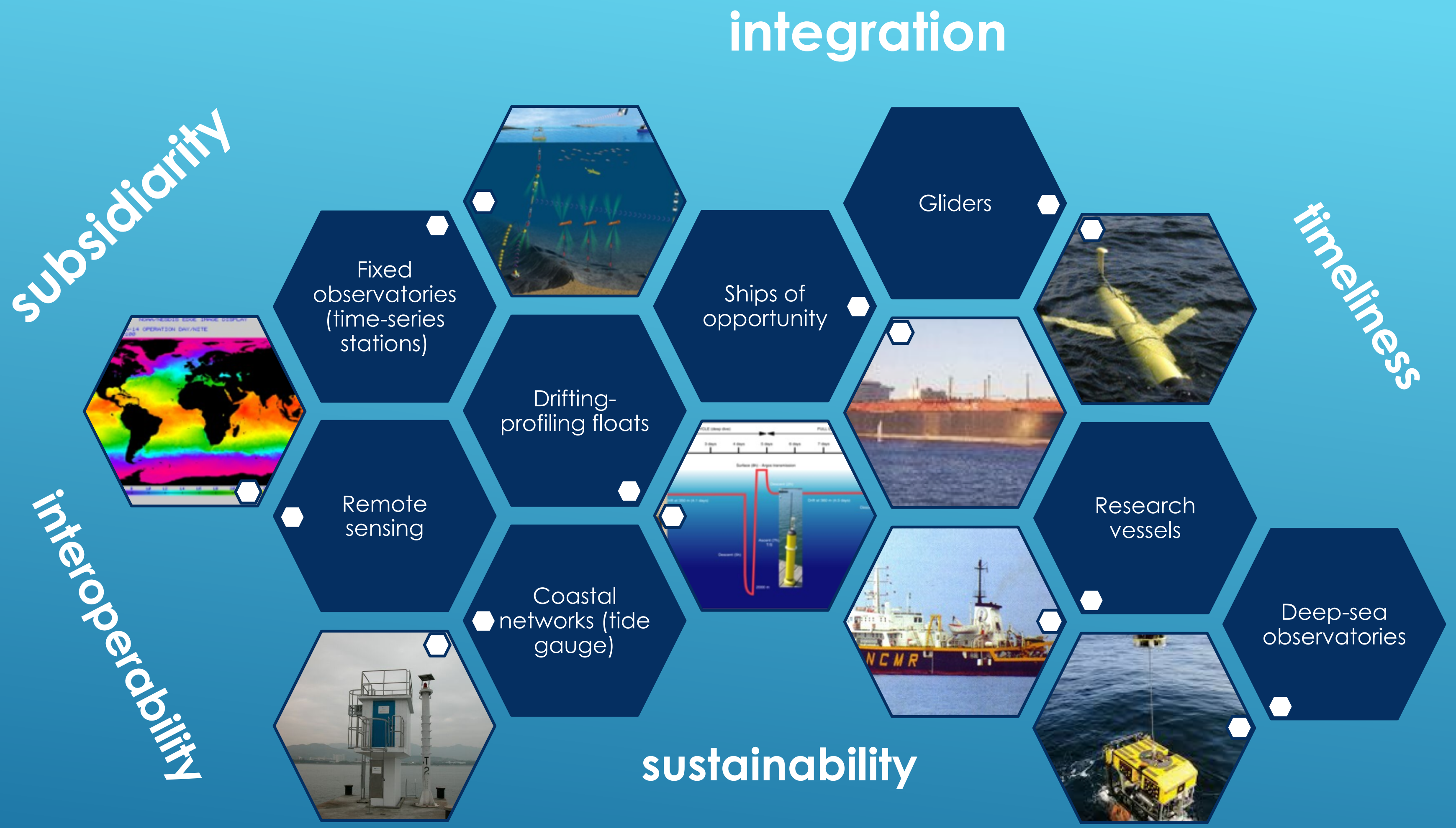
EU project SUNRISE (http://fp7-sunrise.eu/)

COOPERATIVE DIVING DRONES (AUV) IN ACTION

SWARMS OF COORDINATED ROBOTS

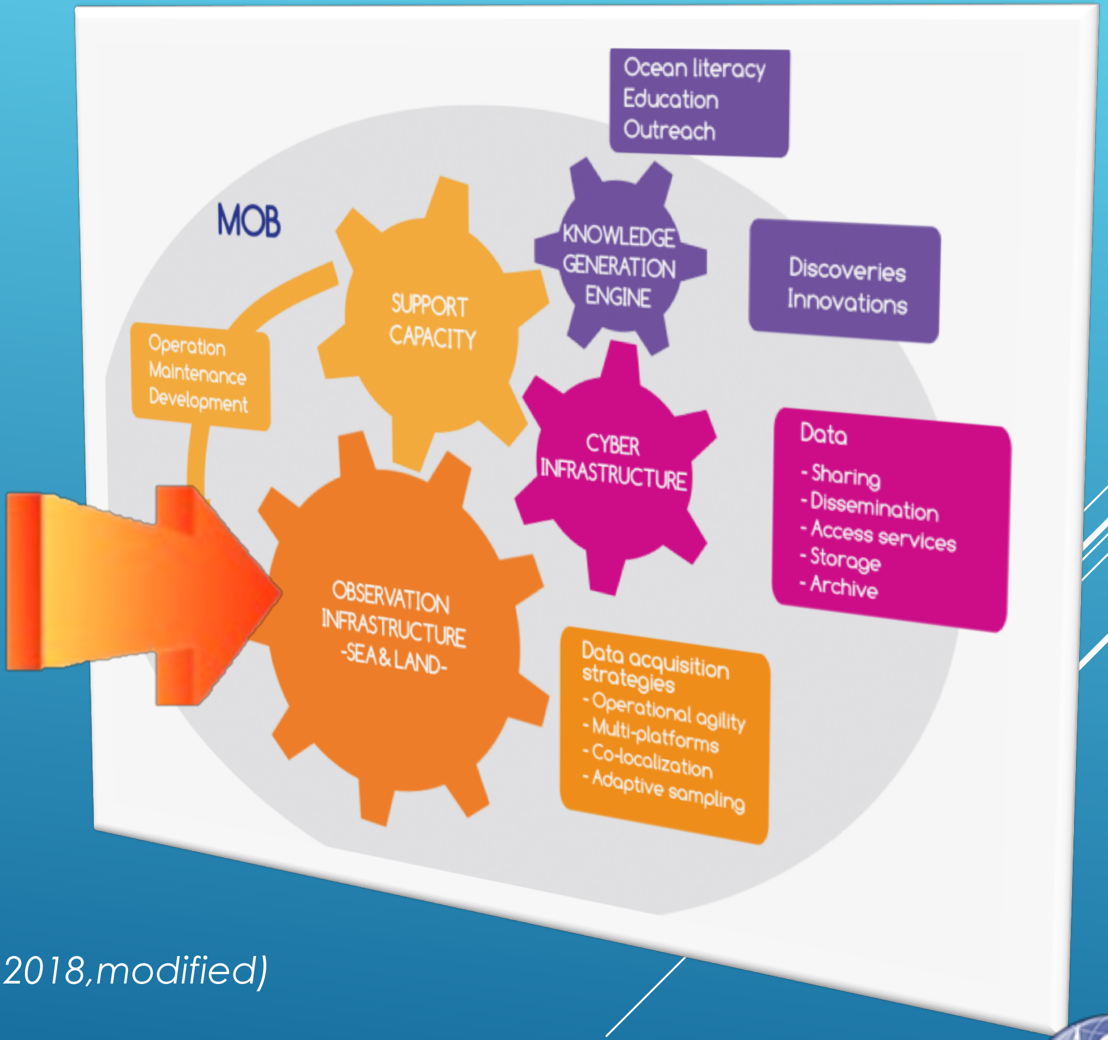
HOW CAN WE OBSERVE THE OCEAN?

With an Integrated Ocean Oberving System



INTEGRATED OCEAN OBSERVING SYSTEM: A MULTIPLATFORM OBSERVING NETWORK

Marine Observatory Framework



(After Crise et al. 2018,modified)

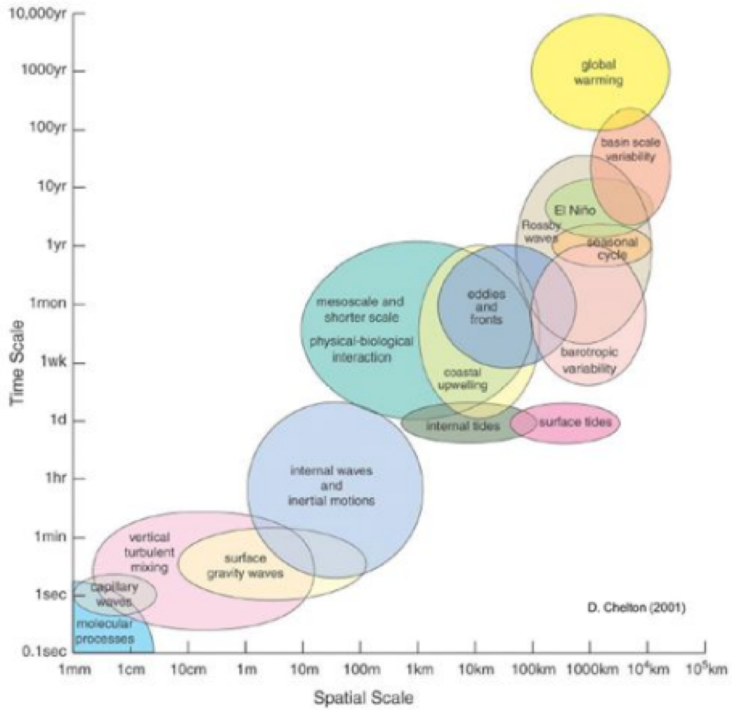
GOOS Essential Ocean Variables (EOVs)

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

EOVs are identified responding to the following criteria:

- **Relevance:** The variable is effective in addressing the overall GOOS Themes – Climate, Operational Ocean Services, and Ocean Health.
- **Feasibility:** Observing or deriving the variable on a global scale is technically feasible
- **Cost effectiveness:** Generating and archiving data on the variable is affordable, taking advantage where possible of historical datasets.

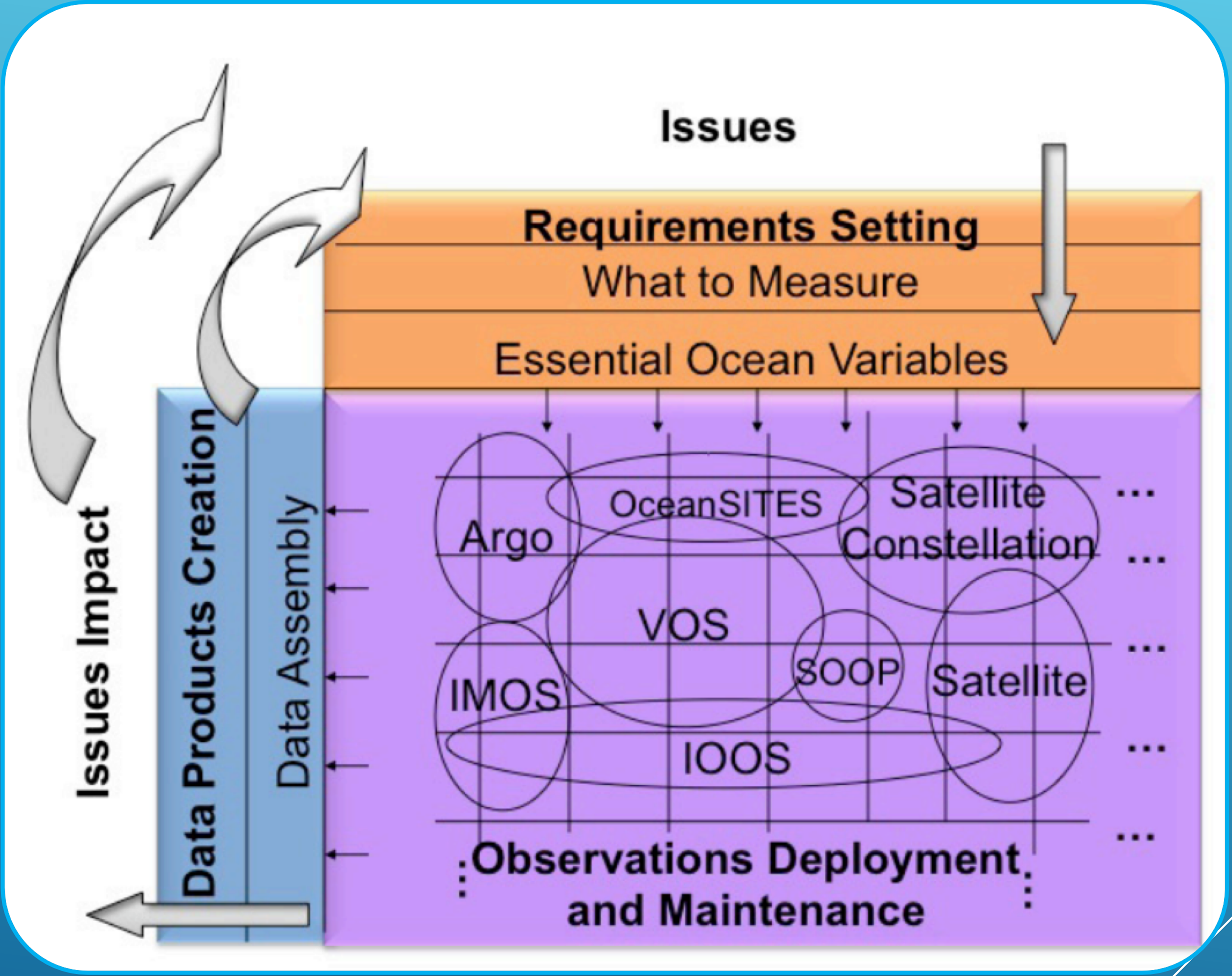
Ocean spatiotemporal scales governing surface variability

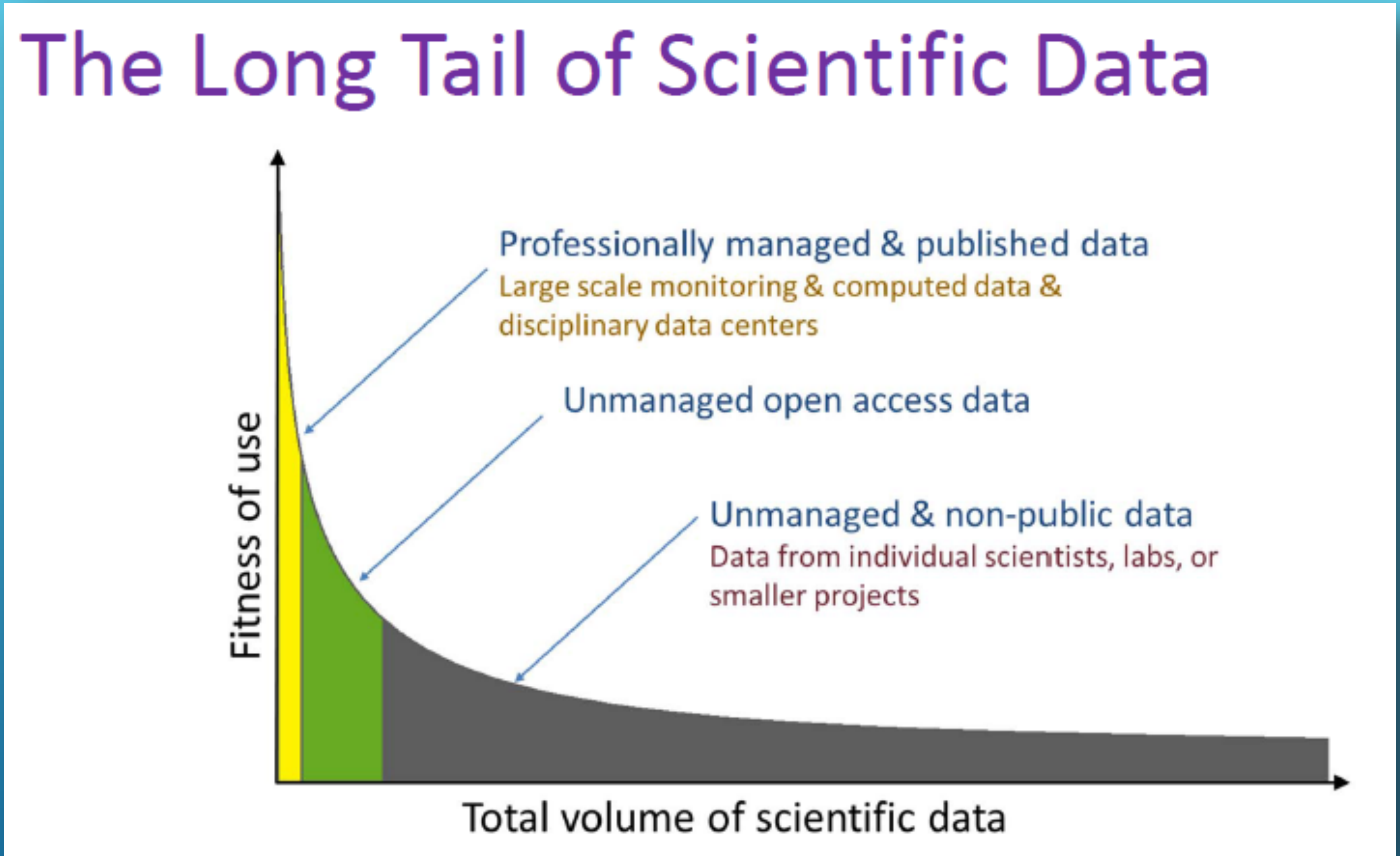


Chelton et al. (2001). *Satellite altimetry and earth sciences*, Chap. on Satellite altimetry, 57–64. Academic Press, NY

SCALES OF THE OCEAN VARIABILITY

FRAMEWORK FOR OCEAN OBSERVING





OBSERVATION IMPACT DEPENDS ON DATA MANAGEMENT

OpenMODs project

OPEN Access Marine Observation Devices (OpenMODs) for developing countries

- Partners:
  - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale – OGS, Italy
  - Alfred Wegener Institute, Germany
- Associates:
  - -4H-Jena-engineering G.m.b.H.
  - UNESCO/International Centre for Theoretical Physics
- High qualified researchers from institutions from 12 countries involved (6 African countries)
- Duration: 1/5/18-30/4/19

OPENMODS CONCEPTS

- Humanitarian environmental project;
- Comply with the Open Science approach;
- Easy-to-use, sustainable (automated) equipment;
- Low-cost technologies for the components, modular approach.

OpenMODs Objectives

- to prepare an international implementation framework through two workshops.

- to conceive/identify an easy-to-use, flexible and affordable core set of ocean sensors and platforms;
- to co-design the functionalities and the operational mode of a coastal observing network, closely working with the potential users to meet their requirements.

MINDELO MEETING OBJECTIVES

- To engage scientific institutes, universities from developing countries interested in implementing OpenMODs infrastructure;
- to produce a blueprint of the architecture of a modular platform hosting the basic sensor;
- to revise the requirements/advancements in the preparation of pilot studies implementing OpenMODs philosophy in terms of education, science and services
- Pave the way for the future initiatives.

Overarching Needs

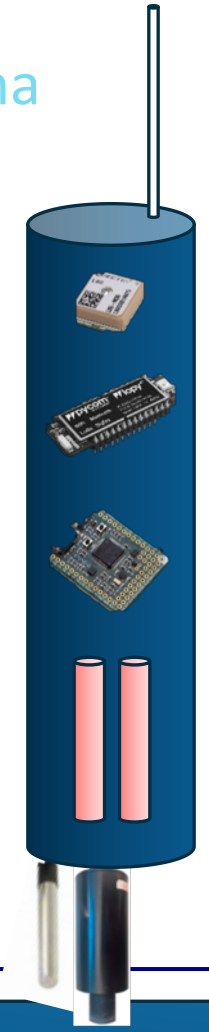
- Need for simple expendable instrumentation
- Need for additional platforms of opportunity (Involving Stakeholders)
- Need for shared infrastructure (e.g. reference infrastructure and reference stations)
- Need for discussion hub and networking of science West Africa
- Need for pilot studies
- Need for neutral umbrella (POGO)
- Need for plan for the way forward

ARCHITECTURE OF THE MULTIPURPOSE PLATFORM

One instrument

Antenna

No antenna
(Submersible)



GPS

Telemetry

LoRa, Sigfox,
WiFi, Bluetooth

Electronics

MicroPython or
Arduino Design

Battery pack

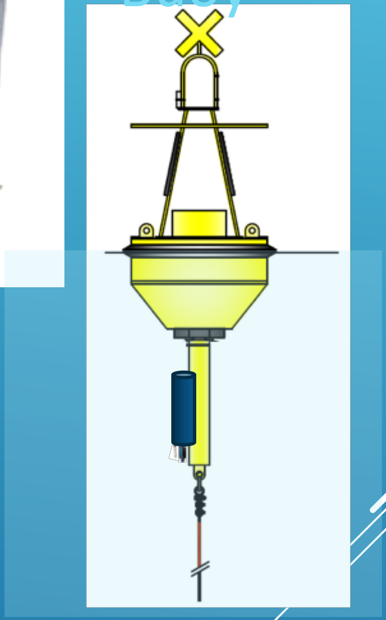
Rechargeble

Sensors

C,**T,D, Turbidity**
Chlorophyll/
Fluorescence
Dissolved Oxygen

Multiple platform

Drifting Buoy



Mooring Buoy

Fishermen Boat

- Low-cost
- Modular
- Easy-to-assemble (IKEA-like)
- Multi-system communications
- Components easily available
- Useful for educational purposes

OPENMODS PLATFORM CHARACTERISTICS

EXAMPLE: LOW-COST SVP DRIFTER DESIGN REQUIREMENTS

- To apply the Internet of Things (IoT) technology to the marine environment implementing a pervasive network of cost-effective equipment
- To adopt robust, cost-effective and versatile technologies that can be easily built, managed and maintained using an open design.
- To use low-cost communication systems based on LoRaWAN protocol (cheap hardware, no communication fees, free band),
- Data transmission range tested up to 10km (much longer with a better configuration of gateways)
- To design hardware, software and documentation in order to facilitate the co-design of pilot applications with local partners

MECHANICAL DESIGN

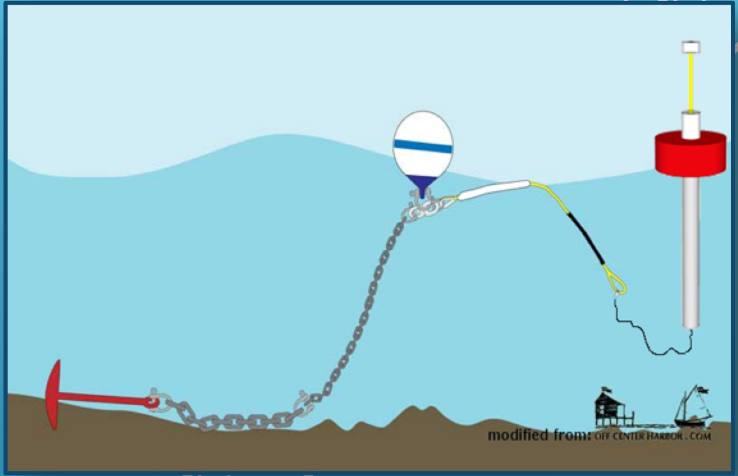
Versatile platform:

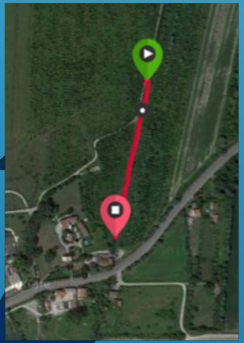
- It can host a limited number of sensors (the quality and the quantity may affect the cost and the duration of the platform batteries).
- Position, wave motion and temperature are among the sensor easiest to be installed. Air pressure and wind velocity can be also considered
- It can operate as **free-drifting buoy** (in fig.) or as a shallow –water buoy
- Standard CODE drifter performances

ADDITIONAL APPLICATIONS

Versatile platform:

- The platforms slightly modified is linked to a small mooring trough an umbilical to form a shallow-water buoy
- With a simple ballast can be used to estimate the rivers and canals flow

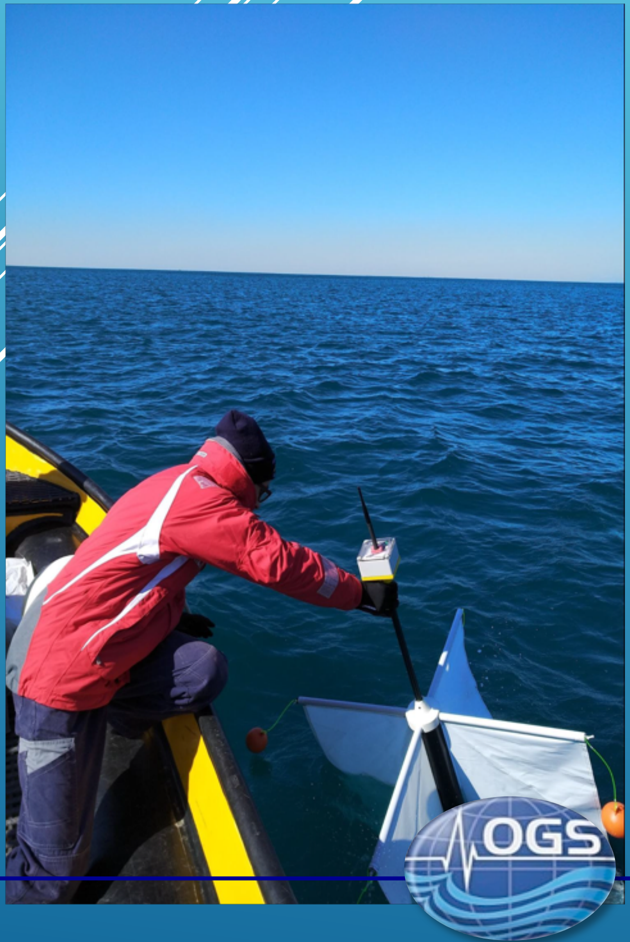




ELECTRONIC DESIGN

The electronic part is based on a **LoPy board** from Pycom together with a PyTrack module powered by a standard battery pack. It has been designed to perform the following tasks:

- Measure the position via GPS
- Store the data locally in a microSD card on the electronic board
- Send the data using LoRaWAN to one ore more gateways which forward it to the Internet



PERFORMANCIES

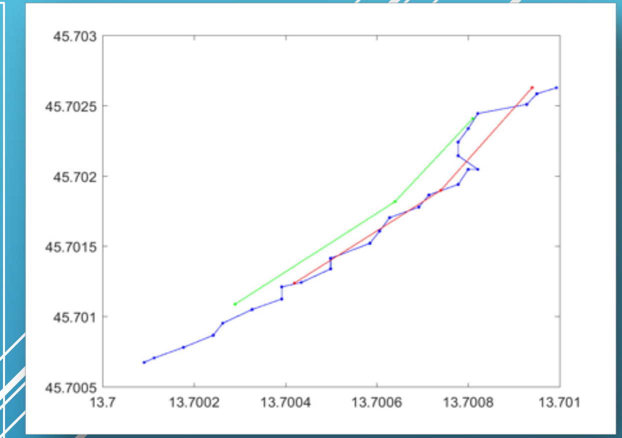
A test case has been performed in the Gulf of Trieste (North Adriatic, Mediterranean Sea).

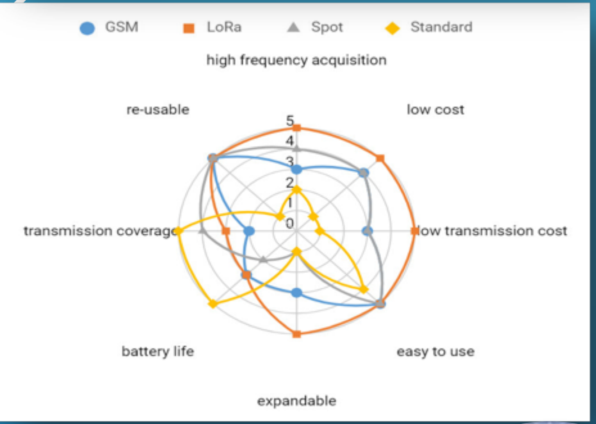
Comparison with a commercial CODE drifter (cost 1500$) and the low-cost prototype (equipped with position and accelerometer only the cost is about 500-600$). The Low-cost (LC) drifter has both LoRa and Spot communication systems installed for check)

The trajectories are similar (higher space-time resolution with LoRa)

The LC outperforms CODE in coastal area

Drifter trajectories
Blue: Drifter LC - LoRa data;
Red: Drifter LC - Spot data;
Green: CODE Drifter - Spot data





IoT Buoy System to monitor coral reefs in French Polinesia

The IoT buoy systems aim to measure the physico-chemical parameters of the water in the Opunohu lagoon in Moorea and monitor its pollution.

Connected buoys developed now make it possible to monitor the environment of coral reefs using data collected in real time.

Monitored parameters include temperature, salinity, turbidity and even certain pollutants.

A box PC acts as both a LoRaWAN-compatible IoT gateway and a network server. It converts the status information sent by these sensors into MQTT streams and enables continuous secure retrieval and remote analysis of this data.

IoT REGIONAL COASTAL NETWORK

The Ocean of Things: autonomous sensors and platforms cooperative operation and data fusion in the maritime domain

"DARPA envisions ocean-based "internet of things" made of small, low-cost floating sensors"

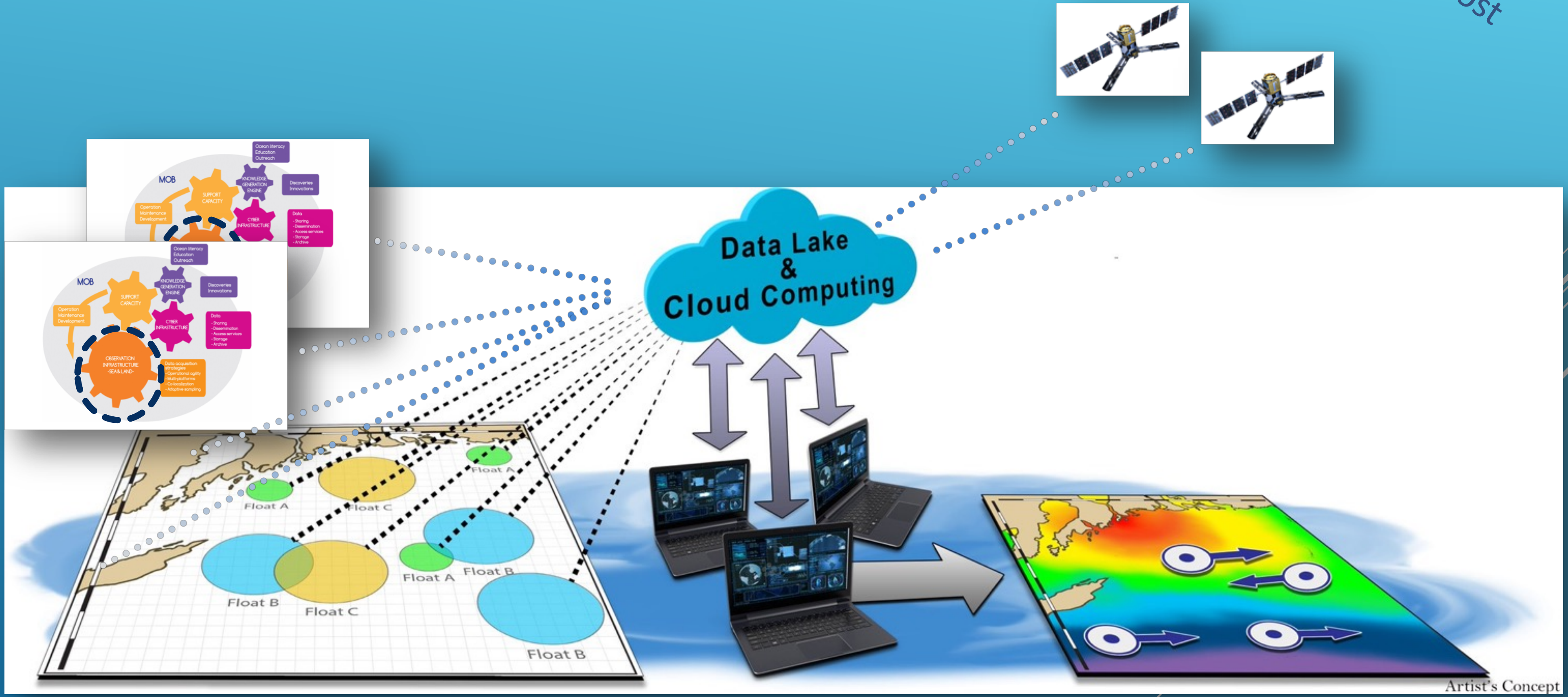
MOBs

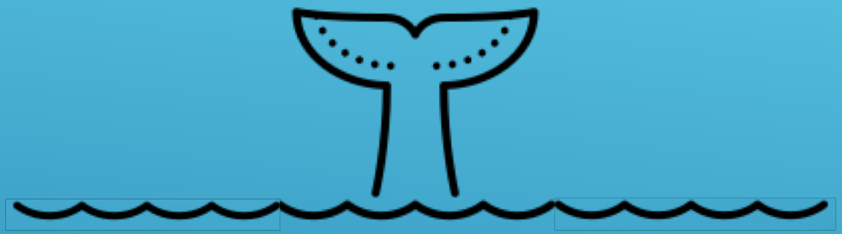
\-

Spatial coverage

\+

Pervasive Platforms





THANKS FOR YOUR ATTENTION!