MISSIONE 4
ISTRUZIONE
RICERCA

ITINERIS

Implementazione delle variabili fisiche e biogeochimiche nel Nord e Sud Adriatico

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Deliverable number:	D5.29
Work package:	WP5 – Marine Domain
Intermediate Objective:	IO5.8
Deliverable type:	X Document, report
	☐ Websites, patent filings, videos, etc.
	☐ Other: please specify .....
Dissemination level:	X Public
	☐ Restricted
Estimated delivery (bimester):	B15
Actual delivery date:	31/05/2025
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Reviewed by:	ITINERIS Executive Board
Note:	

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System - CUP B53C22002150006 (D.D. n. 130/2022)
Funded by EU - Next Generation EU
Mission 4 “Education and Research” - Component 2: “From research to business” -
Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

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1. INTRODUCTION

Marine environmental monitoring is essential for assessing the health of marine ecosystems, understanding climate change, and supporting sustainable management policies. Through multidisciplinary observation networks, data are collected on physical, chemical, and biological parameters. These data make it possible to detect anthropogenic impacts, extreme events, and long-term trends. Monitoring is also fundamental for the implementation of European directives such as the **Marine Strategy Framework Directive**. An efficient observation system enables integrated management of marine resources.

The **Adriatic Sea** holds strategic importance for coastal and transitional water monitoring due to its unique geographical, hydrological, and ecological characteristics. It is a semi-enclosed basin with significant river inputs (especially from the Po River) and strong interactions between the coastal zone and the open sea, making it an ideal natural laboratory for studying complex dynamic and biogeochemical processes. The **Northern Adriatic**, shallow and highly productive, is particularly sensitive to climate change and anthropogenic pressures. Both the **Northern and Southern Adriatic** also play a key role in the formation of dense water masses, which influence deep circulation in the Mediterranean Sea.

Continuous monitoring of these areas helps to better understand transport mechanisms, responses to extreme events (such as **Medicanes** and **marine heatwaves**), and supports the sustainable management of marine and coastal ecosystems, contributing to both the **EU Biodiversity Strategy** and the **Marine Strategy Framework Directive**.

The objective of this deliverable is to highlight the planned implementations within the project and to provide an update on their current status. Within the **ITINERIS project**, the expansion and enhancement of the observational network in the **Northern and Southern Adriatic** has been foreseen through the integration of sensors measuring physical variables (temperature, salinity, currents) and biogeochemical variables (dissolved oxygen, chlorophyll, nutrients). This development involves various **ERICs** such as **Euro-Argo**, **Danubius**, and **EMSO**, as well as **RIs** such as **Ocean Gliders** and **JERICO**.

This expansion aims to:

- **Improve the spatial and temporal resolution** of coastal and transitional water observations, enabling a more accurate understanding of oceanographic dynamics and local ecosystem processes;
- **Support numerical modelling and operational forecasting**, by providing observed data for model calibration and validation;

- **Contribute to environmental monitoring** in line with European directives, such as the **Marine Strategy Framework Directive**, and with international initiatives;

- **Ensure data quality and operational continuity**, promoting the use of advanced technologies and the open sharing of data through interoperable platforms such as **IT-IOOS**.

2. STUDY AREA

Physical and Ecological Characteristics of the Northern and Southern Adriatic
The Northern and Southern Adriatic exhibit distinct yet complementary physical and ecological features, making the entire basin strategically important for marine monitoring.

The **Northern Adriatic** is shallow, with fresher, nutrient-rich waters due to substantial river inputs, particularly from the Po River. This area is characterized by strong temperature and salinity gradients, high primary productivity, and the presence of sensitive coastal and lagoon habitats, which are prone to eutrophication and algal blooms. During winter, intense atmospheric forcing leads to significant evaporation and heat loss, triggering **dense water formation** in coastal areas. This dense water flows along the Italian coast toward the Southern Adriatic.

The **Southern Adriatic**, deeper and saltier, serves as a key site for **open-sea dense water formation** and for water mass exchange with the Ionian Sea. It acts as a transition zone between coastal and deep marine environments, featuring complex ecological dynamics and important thermohaline ventilation and circulation processes.

Both regions are essential for understanding **climate change** and **anthropogenic impacts** on the Adriatic marine ecosystem.

Areas of Particular Interest: Dense Water Formation, River Inputs, Coastal Exchange Currents
Within the Adriatic context, several key zones are of particular relevance for environmental monitoring. The **Southern Adriatic** is well known as a critical area for **dense water formation**, a process that influences the Mediterranean's thermohaline circulation and contributes to deep oxygen transport. The **Northern Adriatic**, which also contributes to dense water formation, is heavily influenced by river discharges—especially from the Po River—which affect **salinity, turbidity, nutrient loading**, and **primary productivity**.

Throughout the basin, important **exchange currents** develop, such as the **Eastern Adriatic Coastal Current (EACC)** and the **Western Adriatic Countercurrent (WACC)**. These currents regulate the transport of water masses, suspended materials, and biogeochemical substances, with significant effects on environmental quality and marine ecosystems.

These areas are therefore **strategic for understanding oceanographic processes** and for promoting the **sustainable management of the marine environment**.

3. RESEARCH INFRASTRUCTURES INVOLVED AND SENSORS IMPLEMENTED

3.1 Coastal Monitoring Stations and Multiparametric Buoys in the Northern Adriatic

The coastal monitoring stations and multiparametric buoys in the Northern Adriatic are organized into two distinct yet complementary networks: the **Gulf of Trieste Platform (GoT)** and the **Operational Environmental Monitoring Network (MALO)** of the Grado-Marano Lagoon.

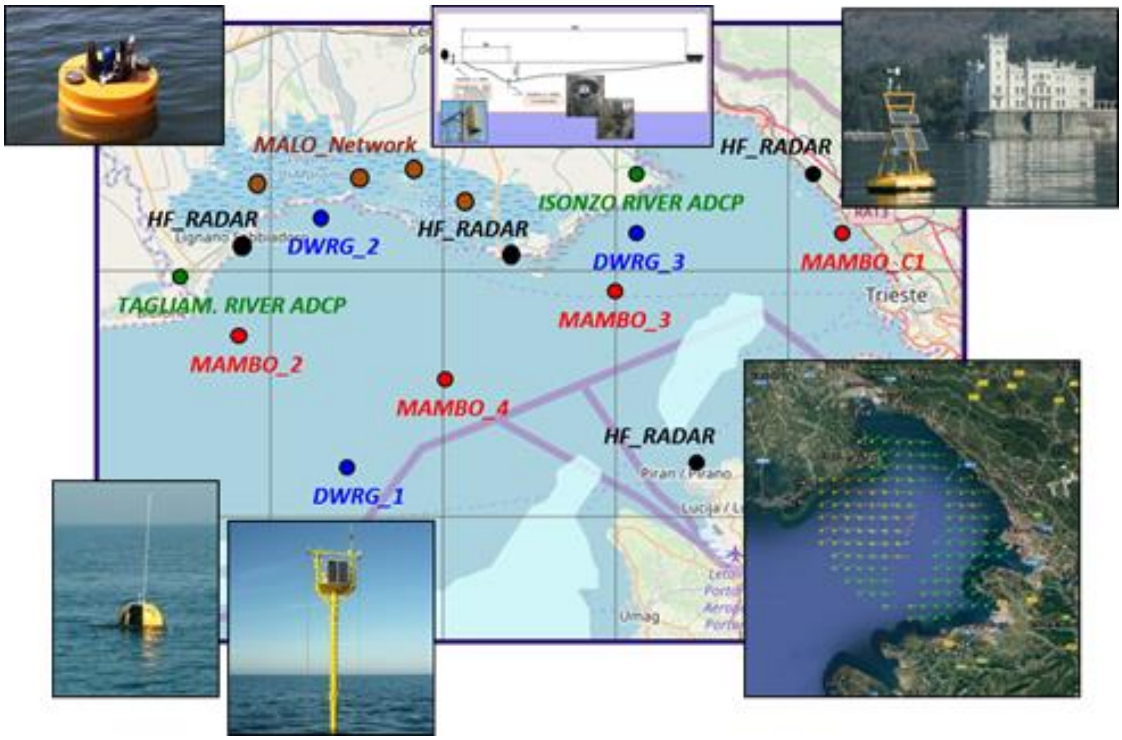


Figure 1:

3.1.3 Gulf of Trieste Platform (GoT)

MAMBO1 Miramare buoy, three new MAMBO2, MAMBO3, and MAMBO4 meteo-oceanographic beacons (replacing the previous three buoys), three directional wave rider buoys (DWRG1, DWRG2, DWRG3), one river current meter station on **the Isonzo River (CORRISO)**, one **piezometric station (PIEZTAG)** on the Tagliamento River, and a buoy in the Northern Adriatic (**NAOS**).

Most of the equipment installed in the GoT is part of the **JERICO-RI infrastructure**, while only part of the **MAMBO1 buoy** is associated with the **ICOS** and **DANUBIUS** research infrastructures.

Here, the **data flow** refers to the real-time data stream transmitted to the **ERDDAP server** hosted at the **OGS NODC**, which acts as the **endpoint** for GoT within the **ITINERIS** project.

Currently, construction is underway for the installation of the three new meteo-oceanographic beacons. Once deployed, all instrumentation previously installed on the older buoys will be transferred to the new platforms. The data flow will remain unchanged.

All instruments and structures planned in the project have been procured. If not yet fully installed, they are currently in the testing phase, aimed at completing their integration into the control system that manages each platform.

The delays encountered are due to a combination of factors, including: the complexity and duration of public procurement procedures, delivery delays, the time required to obtain the necessary permits, and unexpected technical issues encountered during the development and implementation phases of the instrumentation.

Here is the current status:

Piattaforma:	Boa Oceanografica Costiera MAMBO1 Miramare				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Stazione Meteo	JERICO-RI	Aria	Direzione e Intensità del vento, Temperatura Pressione e Umidità	Operativo	Operativo
Misurtore di pCO2	ICOS	-2m	pCO2 in acqua	Operativo	Operativo
Sonda Multiparametrica	ICOS	-2m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto	Operativo	Operativo
Misuratore di pH	ICOS	-2m	pH	Operativo	Operativo
Fluorimetro	ICOS	-2m	Clorofilla - A	In fase di installazione	In fase di realizzazione
Torbidimetro	ICOS	-2m	Torbidità	In fase di installazione	In fase di realizzazione
Sonda Multiparametrica	JERICO-RI	-10m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto, pH, PAR, Clorofilla-A e Torbidità	Operativo	Operativo
Analizzatore automatico di nutrienti	JERICO-RI	-10m	Nitrati	In fase di installazione	In fase di realizzazione
Sonda Multiparametrica	Danubius	-17m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto, pH, Clorofilla-A.	In fase di installazione	In fase di realizzazione
Misurtore di pCO2	ICOS	-17m	pCO2 in acqua	In fase di installazione	In fase di realizzazione
Correntometro ADCP	JERICO-RI	-17m	Profilo di corrente su tutta la colonna d'acqua e moto ondoso direzionale	In fase di installazione	In fase di realizzazione

Piattaforme:	Meda Oceanografica Cstiera MAMBO2				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Stazione Meteo	JERICO-RI	Aria	Direzione e Intensità del vento, Temperatura Pressione e Umidità	Operativo	Realizzato
Sonda Multiparametrica	JERICO-RI	-1m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto, Clorofilla - A, Torbidità e pH	Operativo	Realizzato
Correntometro ADCP	JERICO-RI	-17m	Profilo di corrente su tutta la colonna d'acqua	Operativo	Realizzato

Piattaforme:	Meda Oceanografica Cstiera MAMBO3				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Stazione Meteo	JERICO-RI	Aria	Direzione e Intensità del vento, Temperatura Pressione e Umidità	Operativo	Realizzato
Sonda Multiparametrica	JERICO-RI	-1m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto, Clorofilla - A, Torbidità e pH	Operativo	Realizzato
Correntometro ADCP	JERICO-RI	-17m	Profilo di corrente su tutta la colonna d'acqua	Operativo	Realizzato

Piattaforma:	Meda Oceanografica Cstiera MAMBO4				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Stazione Meteo	JERICO-RI	Aria	Direzione e Intensità del vento, Temperatura Pressione e Umidità	Operativo	Realizzato
Correntometro ADCP	JERICO-RI	-17m	Profilo di corrente su tutta la colonna d'acqua	Operativo	Realizzato

Piattaforma:	Boa Ondametrica DWRG1				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Boa ondametrica	JERICO-RI	Superficie	Moto ondoso direzionale: Altezza significativa d'onda, direzione e periodo.	Operativo	Realizzato

Piattaforma:	Boa Ondametrica DWRG2				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Boa ondametrica	JERICO-RI	Superficie	Moto ondoso direzionale: Altezza significativa d'onda, direzione e periodo.	Operativo	Realizzato

Piattaforma:	Boa Ondametrica DWRG3				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Boa ondametrica	JERICO-RI	Superficie	Moto ondoso direzionale: Altezza significativa d'onda, direzione e periodo.	Operativo	Realizzato

Piattaforma:	Stazione correntometrica su fiume CORRISO				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Correntometro ADCP	JERICO-RI	-17m	Profilo di corrente su tutta la colonna d'acqua	Operativo	Realizzato

Piattaforma:	Stazione piezometrica su fiume PIEZTAG				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Piezometro	JERICO-RI	-17m	Livello fiume	Operativo	Realizzato

Piattaforme:	Boa Oceanografica NAOS				
Strumento	Infrastrutura di appartenenza	Posizione	Parametri	Implementazione	Flusso dati
Stazione Meteo	JERICO-RI	Aria	Direzione e Intensità del vento, Temperatura Pressione e Umidità	In fase di installazione	In fase di realizzazione
Sonda Multiparametrica	JERICO-RI	-10m	Temperatura, Conducibilità, Pressione, Ossigeno Dsciolto, Clorofilla - A, Torbidità, PAR	In fase di installazione	In fase di realizzazione

3.1.4 *The Operational Environmental Lagoon Monitoring network (MALO)*

The Operational Environmental Lagoon Monitoring network (MALO) in the Grado-Marano Lagoon, once fully operational, will consist of:

4 buoys equipped with multiparametric probes (MALO1, MALO2, MALO3, and MALO4) for the measurement of the following parameters: temperature, conductivity, pressure, dissolved oxygen, chlorophyll-a, and turbidity;

4 current meter stations located at the lagoon inlets (MALO5, MALO6, MALO7, and MALO8) for measuring current profiles and sea level;

1 nutrient monitoring station (MALO9) equipped with a multiparametric probe for temperature, conductivity, pressure, dissolved oxygen, turbidity, and a nitrate analyzer.

This network is part of the DANUBIUS-RI infrastructure.

All instruments and structures foreseen in the project have been purchased. If not yet fully installed, they are currently undergoing testing to complete their integration with the control system that manages each platform.

The delays encountered are due to a combination of factors, including: the complexity and extended duration of procurement procedures, delivery delays, the time required to obtain permits, and unforeseen technical issues during the development and implementation phases of the instrumentation.

Regarding real-time data flow, as planned, data will be transmitted to the OGS NODC, which serves as the endpoint for MALO within the ITINERIS project. To this end, metadata and data assimilation procedures in ERDDAP are currently being defined, using test-mode data.

3.2 HF radar in the North Adriatic

The **HF-Radar network**, once fully operational, will consist of three stations. One is located at the **OGS headquarters in Aurisina (HFR-Nadr-AURI)**, which is currently installed and operational. The other two stations will be positioned along the **Friuli Venezia Giulia (FVG) coastline (HFR-Nadr-BIBIO and HFR-Nadr-GRADO)**.

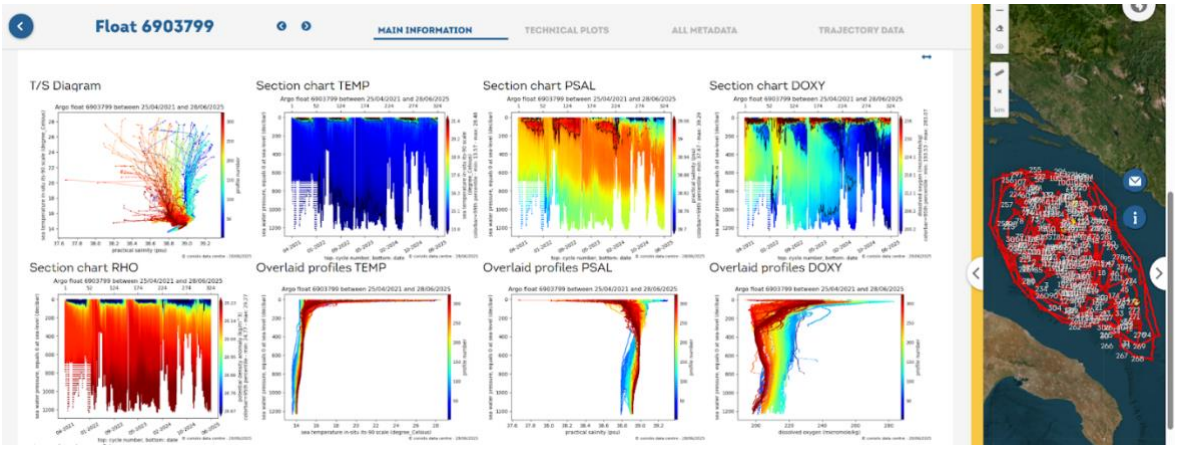
Regarding these latter two stations, all the instruments and infrastructure planned in the project have been purchased. If not yet permanently installed, they have been deployed at a temporary site to test their proper functioning.

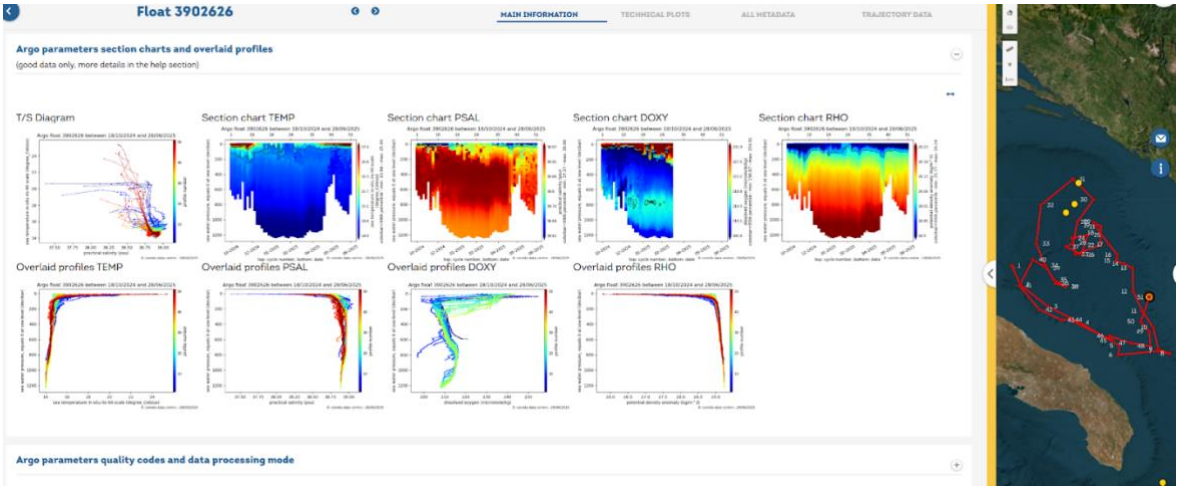
The delay in the final installation is due to the very lengthy time required to obtain permits from the competent authorities.

3.3 Float Argo (standard e BGC)

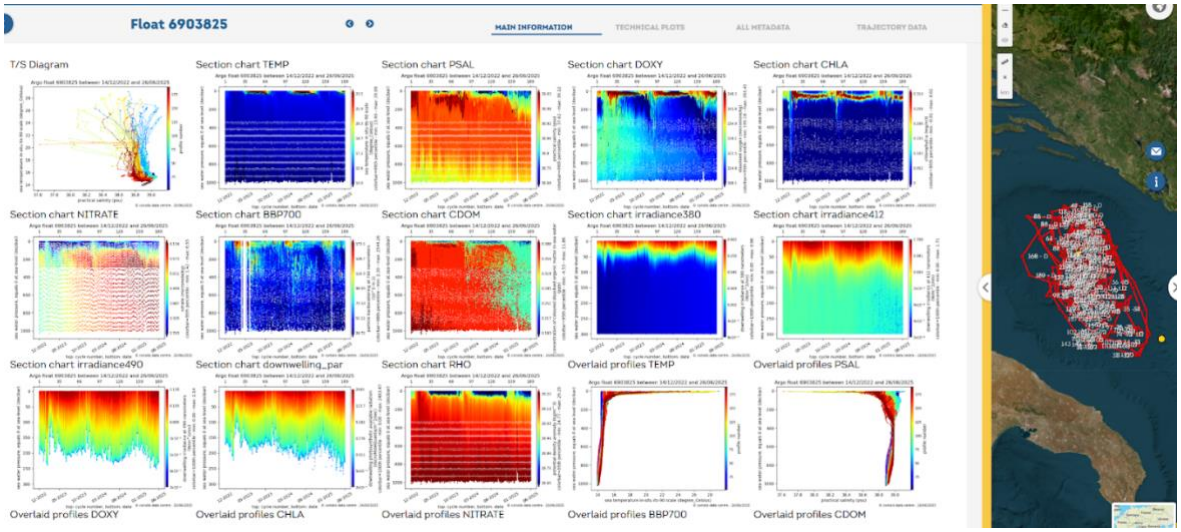
In the Southern Adriatic, there are currently four Argo floats:

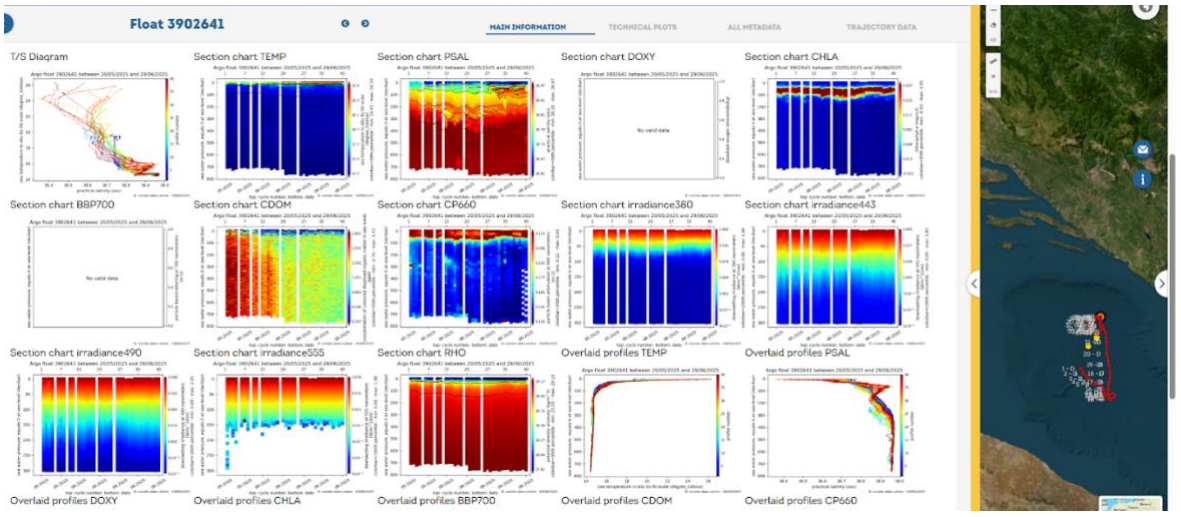
two Argo core floats equipped with oxygen sensors (Arvor-I-DO model), identified respectively as WMO 6903799, which is entering its fifth year of operation, and WMO 3902626, which has been active for only two years.





e due BGC il primo WMO 6903825 con con i seguenti sensori oltre temperatura e salinità presenta Ossigeno disciolto, fluorimetro per la concentrazione della Clorofilla, della concentrazione della sostanza organica disciolta CDOM, il back-scattering a 700 nm, la concentrazione di nitrato e la radiometria a 380, 412, 490 nm. Il secondo float WMO 3902641 mounts also bean attenuation for particles at 660nm but lacks in oxygen concentration and back-scattering sensors.


Float 6903825
MAIN INFORMATION
TECHNICAL PLOTS
ALL METADATA
TRAJECTORY DATA
T/S Diagram
Section chart TEMP
Section chart PSAL
Section chart DOXY
Section chart CHLA
Section chart NITRATE
Section chart BBP700
Section chart CDOM
Section chart irradiance380
Section chart irradiance412
Section chart irradiance490
Section chart downwelling_par
Section chart RHO
Overlaid profiles TEMP
Overlaid profiles PSAL
Overlaid profiles DOXY
Overlaid profiles CHLA
Overlaid profiles NITRATE
Overlaid profiles BBP700
Overlaid profiles CDOM


Float 3902641
MAIN INFORMATION
TECHNICAL PLOTS
ALL METADATA
TRAJECTORY DATA
T/S Diagram
Section chart TEMP
Section chart PSAL
Section chart DOXY
Section chart CHLA
Section chart BBP700
Section chart CDOM
Section chart CP660
Section chart irradiance380
Section chart irradiance443
Section chart irradiance490
Section chart irradiance555
Section chart RHO
Overlaid profiles TEMP
Overlaid profiles PSAL
Overlaid profiles DOXY
Overlaid profiles CHLA
Overlaid profiles BBP700
Overlaid profiles CDOM
Overlaid profiles CP660

3.4 Ocean Glider

The **OGS Ocean Gliders** are autonomous vehicles used in the Adriatic Sea for continuous monitoring of the water column. Equipped with multiparameter sensors (temperature, salinity, oxygen, chlorophyll, turbidity, dissolved organic matter), they collect high-resolution spatial and temporal data along programmed paths, operating for weeks even in adverse weather conditions. Missions focus on both the Northern and Southern Adriatic, contributing to the study of circulation, dense water formation, and anthropogenic impacts. New gliders will be used in the Otranto region to cover a broader area and measure currents on the vertical with new ADCPs. The data support oceanographic modeling and are integrated into European research infrastructures such as JERICO. Their data are present in IT-IOOS.

3.5 EMSO -SA E2M3A in the South Adriatic

The **EMSO-E2M3A South Adriatic Regional Facility** delivers **high-resolution, hourly measurements of temperature and salinity** throughout the water column, extending from the surface to the seafloor. These continuous time series enable the analysis of physical oceanographic processes across multiple temporal scales—**diurnal, seasonal, intra-annual, and inter-annual**—providing insights into both their **recurrence characteristics** (whether periodic or episodic) and **long-term climatic trends**.

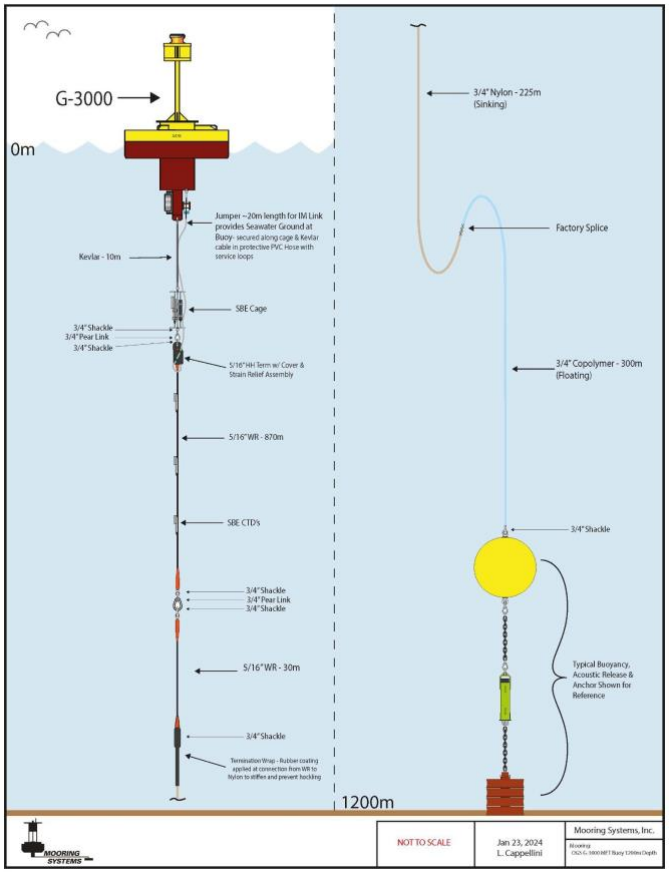
The observatory's configuration is optimized to investigate key dynamic processes in the South Adriatic, including **deep convection** and **vertical mixing** driven by **air–sea interactions**, as well as **intermittent advection of high-salinity waters from the Ionian Sea**, which contributes to **double-diffusive phenomena** such as **salt fingering**. The dataset obtained from E2M3A supports the monitoring of **short-term variability** associated with **convection and submesoscale dynamics**, as well as **intermediate-scale fluctuations** related to **basin-wide circulation patterns**. At **longer time scales**, the observatory captures signals of **regional climate variability**, making it a valuable asset for both process studies and long-term environmental monitoring.

Crucially, these processes interact in a **nonlinear** and often coupled manner, reinforcing the importance of **high-frequency, continuous observations**. Such data are essential not only for resolving transient events but also for accurately characterizing and interpreting slowly evolving background conditions and trends.

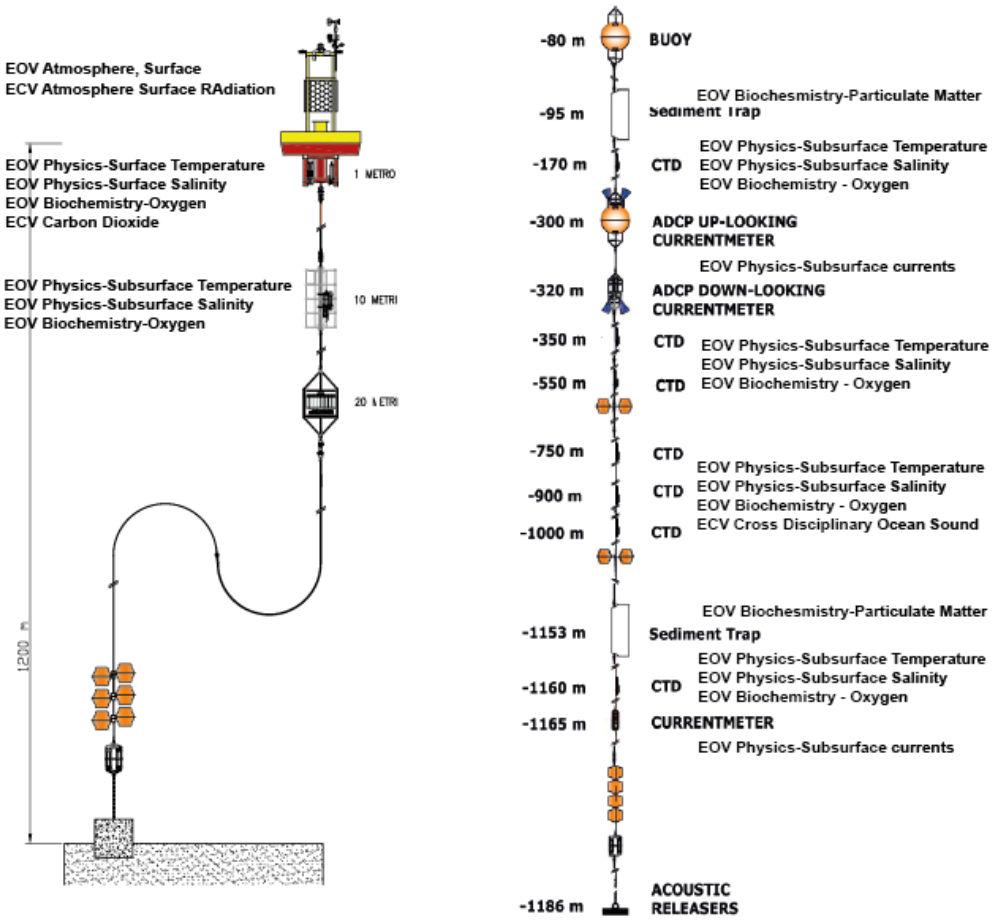
As part of the **ITINERIS project**, efforts are underway to **enhance the observational capabilities** of the Southern Adriatic site through the **implementation and improvement of a more stable and continuous real-time data transmission system**. This involves the use of **acoustic telemetry links** integrated with physical and biogeochemical sensors.

Unfortunately, this activity has experienced delays due to damage inflicted on the buoy by an unidentified vessel in the previous year. As a result, a **completely new buoy** must be constructed, including a full reconstruction of the **electronic systems and sensor interfaces**.

The **deployment of the new buoy**, equipped with updated instrumentation, is planned for **summer 2025**. In the meantime, **significant progress** has been made in the development and testing of the **acoustic communication technologies** required to support the planned data transmission capabilities. The deployment of new sensors at the southern Adriatic Regional site, permitted also to integrate the observational capacity of **biogeochemical and biological** parameters as partial CO2, ocean sound and Photosynthetically Active Radiation - PAR at the ecosystem level and fill the gaps in EOV measurements, especially at the bottom and surface level.



New mooring buoy scheme designed to improve the real-time capability



4. VARIABILI FISICHE IMPLEMENTATE

- Temperatura
- Salinità
- Correnti (superficiali e di profondità)

5. VARIABILI BIOGEOCHIMICHE IMPLEMENTATE

- Ossigeno disciolto
- pH
- Nitrati
- Clorofilla-a

- Torbidità
- Carbonio inorganico disciolto (DIC)
-

6. INTEGRAZIONE CON SISTEMI ESISTENTI E INTEROPERABILITÀ

- Contributo a reti europee (Euro-Argo, JERICO-RI, Copernicus)
- Connessione con portali dati (IT-IOOS, SeaDataNet, EMODnet)
