# AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

Project ID: 10252001

# 3.1.2 Installations of relevant observing system components

## PP10 – UNIBO-CIRSA

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# 1. Aims and content of the document

UNIBO-CIRSA is responsible for the deliverable 3.1.2: 'Installation of relevant observing system components', which is part of the activity 3.1 'Design and implementation of the observing systems' within the Work Package 3 'Climate change monitoring (observing and modelling) systems'.
Deliverable 3.1.2. makes a contribution to the WP3 specific objective to develop and integrate the existing hydro-meteo-ocean observing systems and infrastructures at regional and sub-regional level, in order to achieve high-resolution climate information at a better geographical coverage at sea basin, sub-basin, and pilot areas scale in the Adriatic Sea.

To develop the existing observing infrastructure, the new observing components installed under the AdriaClim project, and their integration into the existing regional and sub-regional observing infrastructure and networks are described according to the designated pilot areas (Figure 1) :

- Adriatic regional infrastructure: Global Navigation Satellite System (GNSS) stations in Trieste, Ortona, Bari and Otranto,
- P1: atmospheric and marine sensors and digital tide gauge in the Gulf of Trieste.
- P2: two meteo-climatic stations in the coastal area of Veneto, three new tide gauges inside Po Delta lagoons.
- P3: Wave Buoy and GNSS Station, microbial probe, UV-VIS spectrophotometer in Emilia-Romagna coastal area.
- P4: multispectral radiometer in Apulia coastal area.
- P5: automatic meteo-oceanographic station, autonomous sensors in the Dubrovnik-Neretva Estuary area.
- P6: upgrading laboratory equipment (CCD camera, cytometer red laser, grain size analyzer) in the Split-Dalmatia coastal area.
- P7: oceanographic buoy installed in the north-eastern Adriatic Sea.
- P8: tide gauge station installed in Molise coastal area.


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|---|---|
| **PS1** | Grado and Marano Lagoon and Gulf of Trieste |
| **PS2** | Venice lagoon and Veneto coastal area |
| **PS3** | Emilia-Romagna coastal area |
| **PS4** | Apulia costal area |
| **PS5** | Dubrovnik Neretva-estuary area |
| **PS6** | Split-Dalmatia coastal area |
| **PS7** | North-Eastern Adriatic Sea |
| **PS8** | Molise coastal area |
| **PS9** | Marche coastal area |

*Figure 1. The AdriaClim pilot areas in the Adriatic basin.*

## 2. Observing regional and subregional infrastructure

ISPRA: Saverio Devoti, Stefano Calcaterra, Benedetto Porfidia, Luca Parlagreco, Gabriele Nardone

### 2.1 Description of the pilot area

This report presents the status of the new GNSS (Global Navigation Satellite System) stations co-located with the Italian tide gauge network and installed during the period July 2022 and October 2022. The sites selected are Trieste, Ortona, Bari e Otranto of Italian tide gauge network providing an update of those stations with geocentric sea level data and vertical land movement information. As tide gauges provide only mean sea level information relative to land (to a nearby tide gauge benchmark), co-location of a tide gauge with a permanent GNSS station is essential for referring coastal sea level data to the ellipsoid (global and geocentric reference) and to distinguish changes in absolute mean sea level from the land movements at each site.

## 2.2 Installation of observing system components

The Italian tide gauge network consists of 36 stations with only 6 co-located GNSS stations that provide continuous data for geodetic information; in the Adriaclim project other 4 stations are installed (**Table 1**).

The new installations are designed and fixed on the tide gauge building or, where the tide gauge stations are not eligible, the GNSS antenna are fixed on top of a steel mast bolted to concrete quay wall or to concrete quayside close to the tide gauge station.

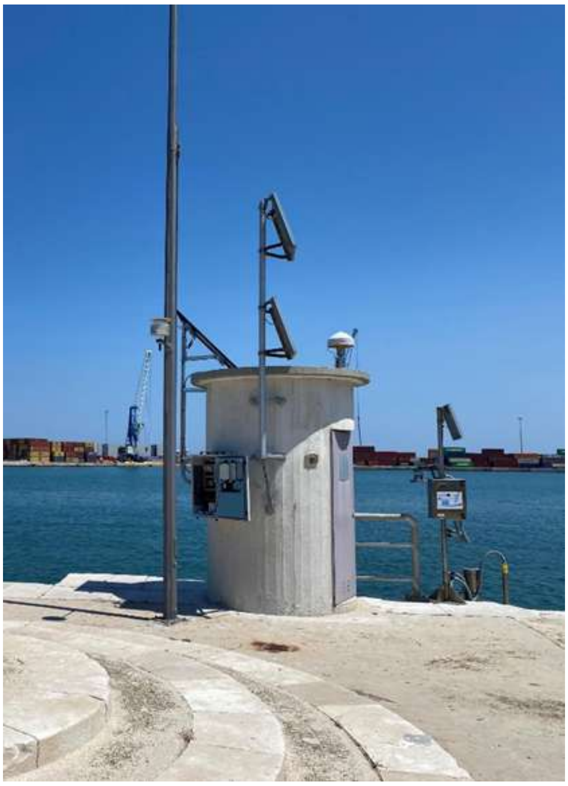
All the reference points of the GNSS antenna have been leveled to the tide gauge benchmark and can therefore be used for geodetic information like the definition of the ellipsoidal height and vertical velocity of the tide gauge linked to sea level data.

Table 1. AdriaClim Stations components.

| GNSS Station | Coordinates | Sensors |
|---|---|---|
| Trieste | Lat: 45°38’58.61’’<br>Lon: 13°45’31.65’’ | LEICA GR30 with Choke-Ring antenna LEICA AR20 |
| Ortona | Lat: 42°21’21.74’’<br>Lon: 14°24’53.44’’ | LEICA GR30 with Choke-Ring antenna LEICA AR20 |
| Bari | Lat: 41°08’ 24.46’’<br>Lon: 16°51’57.72’’ | LEICA GR30 with Choke-Ring antenna LEICA AR20 |
| Otranto | Lat: 40°08’50.01’’<br>Lon: 18°29’49.08’’ | LEICA GR30 with Choke-Ring antenna LEICA AR20 |

| | |
|---|---|
|  |  |
| Trieste GNSS station [ID:TRSE domes number: 14680M001] | |

| | |
|---|---|
|  |  |
| Ortona GNSS station [ID: OTNA domes number: 14678M001] | |

| | |
|---|---|
|  |  |

Bari GNSS station [ID: BARM domes number: 14677M001]

| | |
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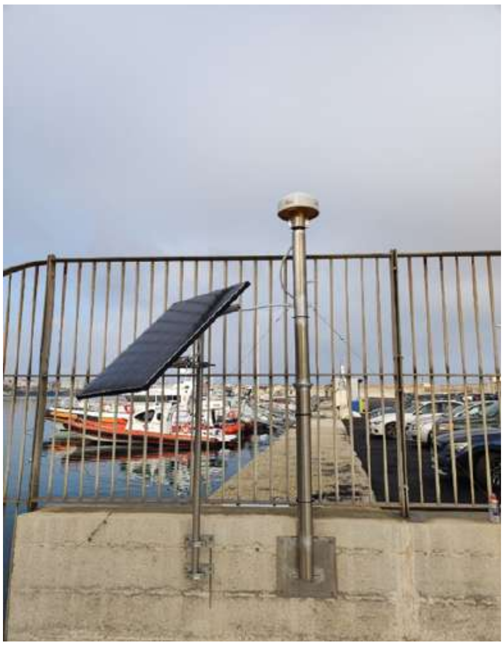
|  |  |
| Otranto GNSS station [ID: OTRN domes number: 14679M001] | |

## 2.3 Integration with the observing system components

The improvement of the new observing systems provides a GNSS data information for 7 out of 10 tide gauge stations of the network facing on the Adriatic Sea. The GNSS data are collected and after quality check stored on ISPRA data server in RINEX standard format file following the International GNSS Service (IGS) standards and will published via ftp protocols in the upcoming months.


*Figure 2. Map of Adriaclim GNSS stations co-located with RMN tide gauge network*

# 3. Grado and Marano Lagoon, Gulf of Trieste

ARPA-FVG: Dario Giaiotti, Claudia Orlandi, Denis Guiatti, Alessandro Acquavita and Nicola Bettoso

CNR-ISMAR: Christian Ferrarin and Fabio Raicich

## 3.1 Description of the pilot area

The pilot area is characterized by an open sea area, namely the Gulf of Trieste, and a lagoon, the Marano and Grado lagoon, which exchanges mass with the gulf through six mouths. The eastern coast of the pilot area is rocky and the input of fresh water from rivers is very low with respect the contribution of the two main rivers, the Isonzo and Tagliamento that are located in the central and the western section of the area, where the sandy beaches are the constant feature of the coast line.

In the Gulf of Trieste, CNR-ISMAR is managing:

- the Meteorological-marine station at Molo F. Bandiera (since 1986). Observed variables: 10 m air temperature and wind, sea temperature at 0.4, 2 and 6 m depths;
- the tide-gauge station al Molo Sartorio (since 1859). Observed variables: sea-level height, atmospheric pressure at 2.5 m;
- PALOMA mast (45°37.097’N, 13°33.913’E), 12 km offshore, bottom depth 25 m. Data: sea temperatures (0.4, 2, 15, 25 m below s.l.), wind speed and direction, air temperature, relative humidity, precipitation, solar radiation, air pressure. Data acquisition and elaboration every 5 minutes. Data transmission in real time (every 3 hours).

## 3.2 Installation of observing system components

Within the framework of the AdriaClim project, CNR-ISMAR installed (Figure 3):

- New atmospheric and marine sensors and new data transmission for the meteorological-marine station at Molo F. Bandiera);
- New digital tide gauge with built-in data transmission for the tide-gauge station al Molo Sartorio.

*Figure 3. Left: Meteorological-marine station at Molo F. Bandiera; Right: tide-gauge station al Molo Sartorio.*

CNR-ISMAR data acquired in the Gulf of Trieste are collected in the private ISMAR Meteomarine unified network (http://rmm.dati.ismar.cnr.it/). Real time sea level data are available without authentication throught the data portal of the I-STORMS project (https://iws.seastorms.eu/).

http://interreg.c3hpc.exact-lab.it/AdriaClim/MEASURES_available/MEASURES_available.php

Chemical data can be found on the regional Open Data portal at the web page https://www.dati.friuliveneziagiulia.it/en/Ambiente/Acqua-Acque-di-classificazione-Superficiali-marino/qcsf-bwk5

## 3.3 Integration with the existing observing systems

CNR-ISMAR manage several fixed monitoring stations in the Adriatic Sea:

- Trieste
- Meda Paloma
- Acqua Alta platform
- Meda Abate
- Meda S1
- E1 buoy
- Meda Senigallia
- Meda Gargano

measuring continuously several variables, e.g. sea temperature, salinity, sea level, currents, waves, meteorological parameters (Figure 4). These monitoring stations serve several European research infrastructuters such as LTER, DANUBIUS and JERICO (Figure 4).

The installation of the new components at Molo F. Bandiera and Molo Sartorio ensure the continuous monitoring of essential ocean variables (sea level, sea temperature, salinity air temperature, wind speed and directions). In this context, it is of crucial importance to guarantee long-term timeseries of the mentioned variables for detecting changes in the climate in the Adriatic Sea.


*Figure 4. CNR-ISMAR observational network in the Adriatic Sea.*

# 4. Venice lagoon, City of Venice and Veneto coastal area

ARPA Veneto: Francesco Rech, Umberto Fucigna, Fabio Zecchini

ISPRA: Sara Morucci, Franco Crosato, Andrea Bonometto

## 4.1 Description of the pilot area

The Veneto coastal area, regarding at the provinces of Venice, Padua and Rovigo, has an extension of about 6400 km2 and with about 2 million inhabitants is densely populated with a progressively ageing population. It is home to over 175000 active Enterprises and also the large chemical-industrial complex of Marghera is located in this area. There are 53000 farms and they operate on a usable agricultural area of around 3700 km2, mainly growing wheat, maize and soya, but with the wine-growing sector expanding. Tourism also plays an important role in the regional economy and is concentrated in the cities of Venice and Padua and on the sandy beaches of Bibione, Caorle, Duna Verde, Eraclea, Jesolo-Cavallino, Sottomarina and Rosolina. A more naturalistic tourism mainly concerns the Po Delta Park area.

In this territory are located :

- the terminal stretches and mouths of rivers draining the Alps and the Po Valley. In the first place we remember the Po River, but we also have, from north to south, the mouths of the Tagliamento, Lemene-Nicesolo, Livenza, Piave, Sile, Brenta-Bacchiglione, Adige and Fissero Tartaro Canal Bianco.
- Important road, motorway and railway routes provide the east-west connection of the Po Valley and the north-south connection of Italy.
- A complex hydrographic network with several watercourses that also run on hanging canals, as there is approximately 1320 km2 of territory below sea level and another 1580 km2 below 3 m above sea level.

We are therefore in the presence of a highly populated, highly anthropized, highly industrialised territory, with an important flow of tourists, significant vehicle and goods traffic, and intensive agriculture. Even if the Province of Rovigo presents significant differences compared to Padua and Venice, the whole territory is characterised by a complex mixture of urban, industrial and agricultural areas that often coexist.

Arpa Veneto operates in this context by monitoring hydro-meteorological variables, managing data both in real time and validating and archiving them for subsequent use; it also carries out weather forecasts and supports civil protection in the event of weather warnings.

## 4.2 Installation of observing meteo-climatic system components (ARPAV)

The two new meteo-climatic monitoring stations and the new sensors installed during the AdriaClim Project at 6 other pre-existing sites integrate and enhance a Veneto monitoring system managed by

ARPAV and operational since the early 1990s. This intervention guarantees an improvement in the meteorological-climatic monitoring of the coastal sector, which is characterised by the presence of breezes and particular thermal gradients compared to the Po Valley behind it.

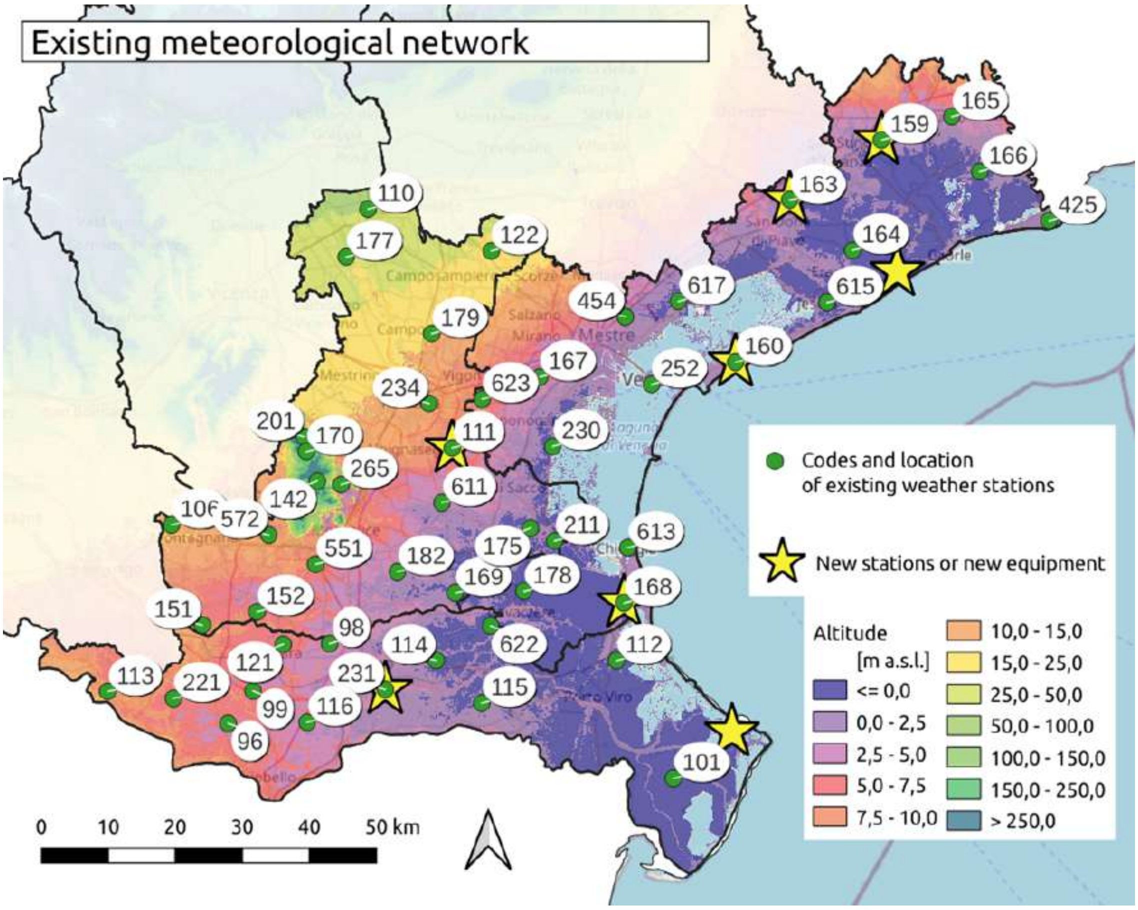



*Figure 5. Location of the existing network of meteorological stations and indication of the locations of new installations.*

The two new stations are installed in the municipality of Eraclea (VE) at Torre di Fine and in the municipality of Porto Tolle (RO) at Porto Peschereccio di Pila. The two new stations are complete with: rain gauge (heated in Porto Tolle); thermometer; hygrometer; barometer; heated sonic anemometer. In addition to the sensors, the support poles, datalogger, photovoltaic panel and transmission system via radio and LTE (via mobile telephony) are supplied and installed. The installation of these two stations is motivated by the need to thicken the existing observation network near the coast, a place that is affected by a local climate, different from that of the immediate hinterland.

The stations of Legnaro (PD), Portogruaro Lison (VE), Cavallino Treporti (VE) and Rovigo Sant'Apollinare (RO), already present in the network, are equipped with new instrumentation, which has never been implemented on other stations in the network. This consists of: nefoipsometer; present time sensor; 4-component net radiometer. In addition, the data logger and the LTE transmission system are replaced. This new instrumentation will be able to support forecasting activities and collect a historical series of variables never before recorded in this area.

Finally, for the stations of Chioggia Sant'Anna (VE) and Noventa di Piave (VE), new heated sonic anemometers will be installed, which will replace the current cup anemometers. Sonic anemometers require less maintenance, can detect lower wind speeds than cup anemometers, which have an initial inertia in their movement. They are less subject to wear and tear and maintain data quality for longer (Figure 5).

**Detail of installed sensors :**

| Stations | | | | Sensors | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Code | Longitude | Latitude | Unheated rain gauge | Heated rain gauge | Thermometer | Hygrometer | Barometer | Heated sonic anemometer | Web Cam | Nefoipsometer | Present time sensor | 4-component net radiometer |
| Eraclea - Torre di Fine | New | 12.79143 | 45.57564 | YES | | YES | YES | YES | YES | | | | |
| Porto Tolle - Porto Peschereccio di Pila | New | 12.47959 | 44.97805 | | YES | YES | YES | YES | YES | YES | | | |
| Legnaro | 111 | 11.95217 | 45.34735 | | | | | | | | YES | YES | YES |
| Portogruaro - Lison | 159 | 12.76129 | 45.74549 | | | | | | | | YES | YES | YES |
| Cavallino-Treporti | 160 | 12.48626 | 45.45872 | | | | | | | | | YES | |
| Rovigo - Sant'Apollinare | 231 | 11.82597 | 45.03340 | | | | | | | | YES | YES | |
| Chioggia - Sant'Anna | 168 | 12.27597 | 45.14632 | | | | | | YES | | | | |
| Noventa di Piave - Grassaga | 163 | 12.58851 | 45.66841 | | | | | | YES | | | | |

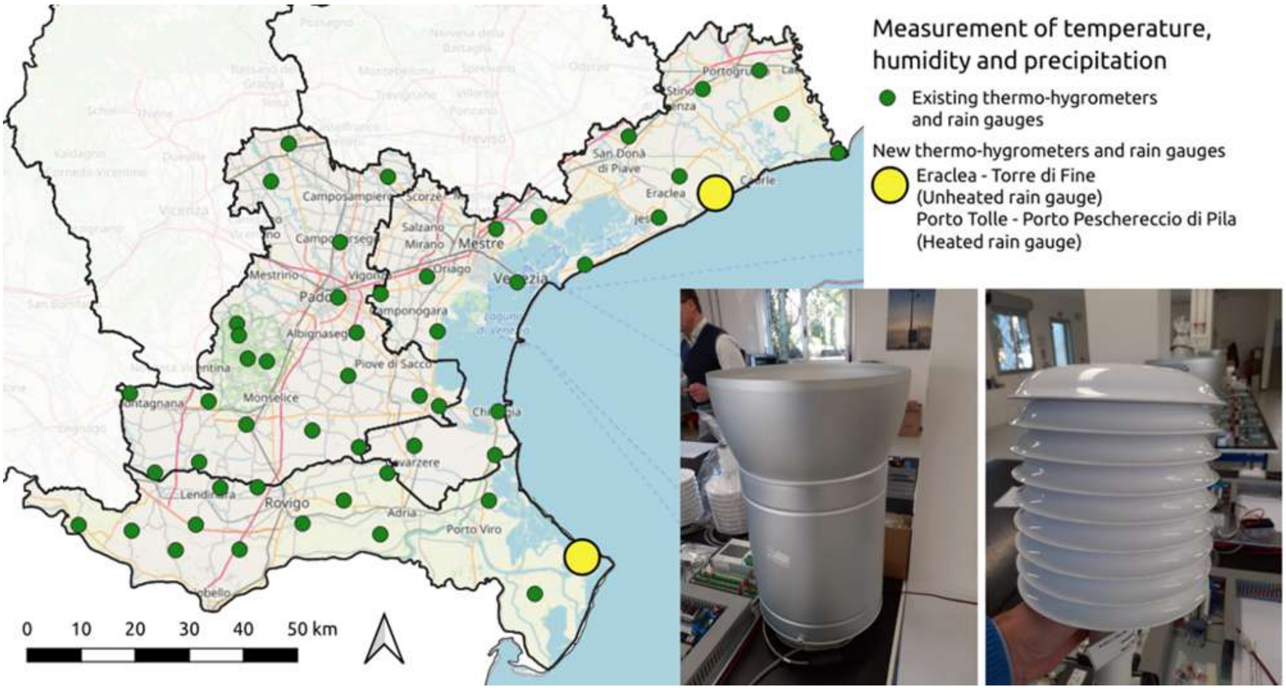



*Figure 6. Location of the existing weather stations (green) and the two new sites (yellow).*

The precipitation measurement is taken every 5 minutes. The daily precipitation is the sum of the 288 cumulative measurements between 00:05 on day n and 00:00 on day n + 1. The rain gauge has a calibrated mouth positioned 2 m above the ground, with a surface area of 1000 cm2. The measuring system consists of a double oscillating tank which, through a system of funnels, receives rain from the mouth of the instrument, oscillates when the weight of the collected water reaches 20 g (thus functioning like a balance) and then discharges the measured rain to the ground. The resolution (quantization error) is 0.2 mm of precipitation. The measurement error, which can be deduced from the calibration curves, is related to the intensity of the precipitation, with an increase in the underestimation of the rain falling as the intensity increases. On the instrument installed at Eraclea, there is a system of electrical resistances that ensures that the collection funnel is heated when temperatures fall below 0°C. This allows the water equivalent of any snowfall to be measured.

The air temperature is measured at 2 m above the ground by taking one (instantaneous) measurement every 15 minutes. The daily average temperature is the average of the 96 measurements taken between 00:15 on day n and 00:00 on day n + 1. The maximum and minimum temperature on day n are the maximum and minimum values between the 96 daily measurements. The platinum thermoresistance Pt100 sensor is housed in a white PVC radiation shield with fins for natural ventilation. The resolution (quantisation error) is 0.1°C, the measurement uncertainty is ± 0.5°C.

The relative humidity of the air is measured at 2 m above the ground by taking one (instantaneous) measurement every 15 minutes. Data are expressed as a percentage value (%). The capacitive sensor is installed inside a white PVC radiation shield with fins for natural ventilation.

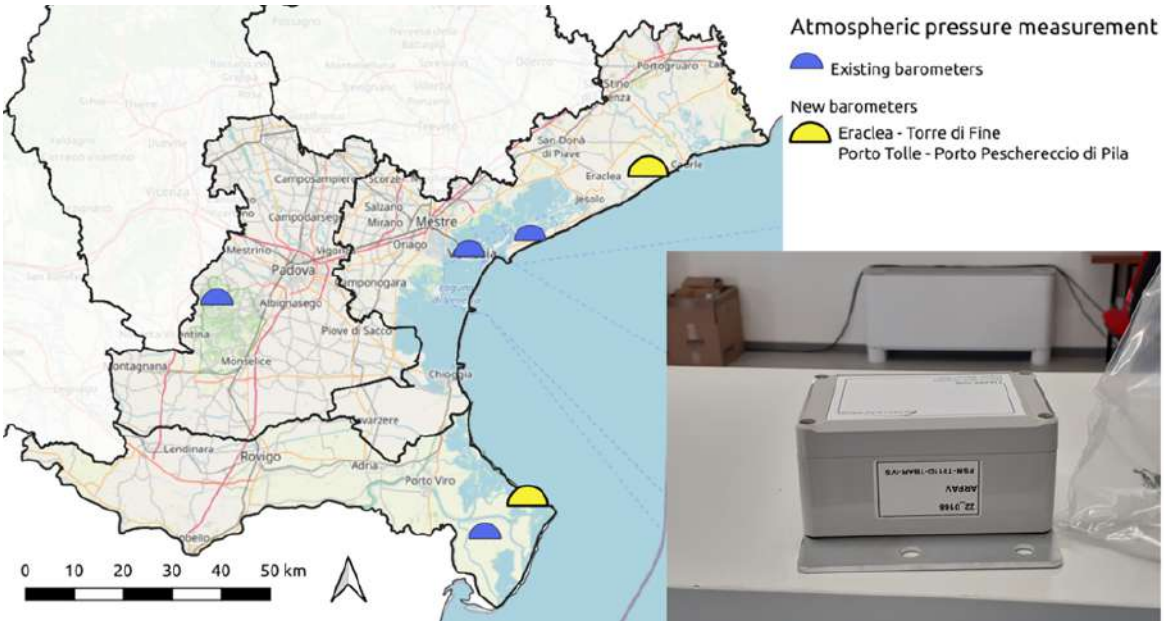



*Figure 7. Location of the existing barometers (blue) and the two new sites (yellow).*

Atmospheric pressure is acquired every 30 minutes (average of samples taken every 30 seconds). The data are expressed in hPa with a decimal value. The measurements in the SIRAV database refer to both the station altitude and the reduced altitude at sea level. The measuring instrument is a piezoresistive pressure sensor installed approximately 1.5 m above the ground.

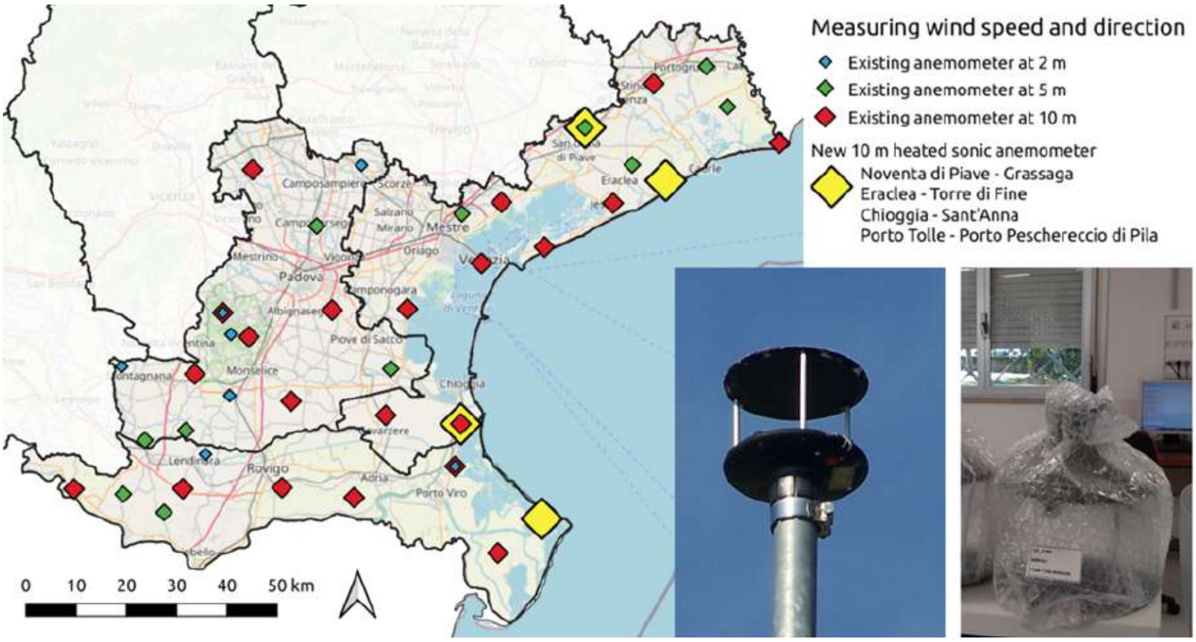



*Figure 8. Location and height of existing anemometers (in blue if at 2m, in green at 5m and in red at 10m) and installation sites for new sonic anemometers (yellow).*

Wind speed and direction are measured by taking a measurement (average of samples taken every 2 seconds) every 10 minutes. The wind speed data is a 10-minute scaled average of the speed measurements taken every 2 seconds. The data are expressed in $ms^{-1}$. The quantisation error is 0.1 $ms^{-1}$. Wind direction data are the direction measurements taken every 2 seconds. The data are expressed in sexagesimal degrees (°) referenced to the North and indicate the wind direction. The quantization error is 3°.

Wind measurements must be taken 10 m above ground level in an obstacle-free location (some ARPAV stations take wind measurements 5 m above ground for easy of installation or 2 m above ground for agro-meteorological measurements). These measurements are affected by the friction produced by the ground and the effect of obstacles.


*Figure 9. Nefoipsometer (a), present time sensor (b) and data acquisition and transmission system (c) before installation (left) and installed in Legnaro station PD (right).*

The nephoipsometer (Eliasson CBME80B) measures cloud base height and vertical visibility. It is based on the LIDAR principle. The light-emitting component is a low-power diode laser. The instrument, by means of special reading devices, is able to receive and possibly mark precise information on the amount of light returned by gaseous obstacles such as clouds, fog, mist. Based on the return time of the reflected laser light, the device calculates the height of the cloud base, returning a result that can consider up to three cloud levels.

The present weather sensor (Biral SWS-250) is a sensor for automatic and semi-automatic weather stations. It operates both as a versatile present weather sensor and as an accurate weather meter. Based on innovative technology, the sensor reliably identifies the type and intensity of precipitation. It can detect light rain and drizzle ; it calculates precipitation accumulation, the water equivalent of frozen precipitation and snow accumulation. It also measures the meteorological flow rate with great accuracy. The sensor is a multi-variable sensor, performing tasks that usually require a human observer and multiple instruments.

The data acquisition and transmission system via radio and via LTE (mobile phone) is also supplied and installed.

*Figure 10. 4-component radiometer before installation (left) and installed in Legnaro PD (right).*

The 4-component net radiometer is mainly used in scientific applications for studying energy balances and surface fluxes. It allows 4 separate measurements of solar (2 pyranometers) and long-wave radiation (2 pyrgeometers), oriented both upwards and downwards.

The data collected by the stations are transmitted to the acquisition centre. Currently, a selection of stations are interrogated every hour to get a real-time picture of the Veneto weather situation, while the remaining stations transmit their complete daily archive after midnight.

The data, both at the acquisition scan and as hourly and daily derived values, are stored in an ARPAV database called SIRAV (Veneto Regional Environmental Information System), which is a relational database in an ORACLE environment.

A specific application called VALIDAZIO allows a group of technicians to carry out daily checks on the consistency and quality of the data, activating, if necessary, the intervention of maintenance teams.

This application, thanks to automatic procedures and easy graphical representations, helps operators to detect missing data, format errors, exceeding instrumental rage values, exceeding values such as the 10 and 90 percentile, excessive persistence of data with the same value and excessive data variations within a limited period of time. In addition, the VALIDAZIO programme allows technicians to make comparisons between trends of different sensors on the same station and between trends of the same sensor on neighbouring stations. Comparisons between weather radar images and point values measured by rain gauges are also possible.

SIRAV is primarily a data archiving tool, equipped with back-up technology that guarantees the security of archived data. SIRAV also allows data consultation and is equipped with a detailed menu that allows data extraction in the form of files, tables, graphs, maps and processed data. SIRAV is a tool for the internal use of ARPAV that seeks to meet the main needs of the operators of the regional meteorological and hydrographic service.

Some SIRAV products are specifically designed to support decision-making processes for the management of hydrological and hydraulic emergencies by the Decentralised Civil Protection Functional Centre CFD. Using graphs, tables and maps, an attempt is made to create a real-time information picture that summarises the current situation of the territory and allows the main problems to be focused on. In addition, ad hoc data packets are automatically sent from SIRAV (currently also every 30 minutes) to feed the hydrological models and guarantee at national level (to the Central Civil Protection Department) the visibility of the monitored data in real time. Further data transmissions to institutional bodies take place in deferred time on a daily or monthly basis to monitor, for example, the availability of water resources at catchment area level or to update climatological products.

Sharing the data externally must wait until the installation phase of the new sensors and the interpretation of the incoming data are completed, particularly for those sensors first installed in the network. When fully operational, after appropriate verification, the data can be made available on the Agency's institutional website as historical data:

https://www.arpa.veneto.it/dati-ambientali/dati-storici
and as real-time data:
https://www.arpa.veneto.it/dati-ambientali/dati-in-diretta/meteo-idro-nivo/variabili_meteo

## 4.3 Installation of observing meteo marine stations (ISPRA)


*Figure 11. 5 ISPRA new tide gauges locations*

Three new tide gauges (Figure 11) have been installed inside Po Delta lagoons (North Adriatic Sea), in order to acquire sea level information for downscaling analysis and potential CC indicators (e.g numerical model calibration and validation).
Two out three new tide gauges have been placed in the inner area of Scardovari and Caleri lagoons, in order to measure the contribution of the wind induced set up to the total sea level during storm

surge events. The location of these stations was settled also considering the tide gauges already available in the Po Delta area (managed by ISPRA and ARPA Veneto, Fig. 5).
The third station has been placed in the Canarin lagoon, for supporting the analysis of water circulation and salinity variability.
The three stations are equipped with meteorological and marine instrumentation: wave buoy, wind and atmospheric pressure sensors, humidity sensor, rain gauge, air thermometer.
All of them are guaranteed for a life cycle of more than 20 years and are compliant with WMO recommendations. Instruments are actually under maintenance to check the right functionality.
Meteo-marine physical parameters are collected every 5 minutes.
Data have been collected starting from August 2022, and will be shared since the portal implementation will be concluded (https://www.venezia.isprambiente.it) and disseminated in one of the PPs ERDDAP nodes.

*Figure 14. Sacca del Canarin, platform details and Sacca degli Scardovari*

### 4.3.1 Marine Parameters

***Wave sensor***

The installed hydrometers are fully integrable and technologically homogeneous with the ones already belonging to the RMLV and they are able to guarantee the highest standards of quality and reliability of data.
Moreover these new instruments have been provided in their last and optimized version reaching an acquisition time of about 4 Hz, and allowing a remote control of specific sensors.
The hydrometers provide wave measures as well as sea level one, and data are provided as the average value every 5 min.
Data collection and real time transmission to the acquisition centre via GPRS is also supplied.

| Hydrometer | Technical details |
|---|---|
| Measure range | until 30 m |
| Measure spread | ≤ 2 mm |
| Angle of radiation | 4° |
| Output | Serial with protocol Modbus |
| Measure cycle time | ≤ 250 ms |
| Acquisition time | ≥ 4 Hz |
| Local memory | Eeprom |
| Operating temperature | -40...+80 °C |
| Bluetooth connection range | 25 m |
| Protection angle | IP68 |
| MTBF | More than 20 years |

**Meteorological instrumentation**

**Wind sensor**

Wind speed and direction are acquired by means of an ultrasonic anemometer 2D, composed by 4 transducers with both the acquisition and the transmission tool.
This anemometer is fully made of polycarbonate facing corrosion risk due to the exposure to marine environment and conditions.
Wind direction is expressed in sexagesimal degrees (°) referenced to the North and indicating the incoming wind direction.
Wind measurements are taken about 6 m above mean sea level reference level in an obstacle-free location.

**Thermo-hygrometer**
The sensor is composed of two instruments, a thermometer and an hygrometer in order to measure at the same time, both the referred physical parameters (temperature and humidity).

**Barometer**
Data are expressed in hPa. The measuring pressure sensor is installed approximately 3 m above the mean sea level reference level.

**Rain gauge**
The sensor provides rain measures with a mean acquisition error on the whole measure range (0 a 600 mm/h) less than 2%.

### 4.4 Integration with the existing observing systems

ISPRA new stations have been installed in three different lagoons in the North Adriatic sea, especially taking into account the meteo-marine stations already available in the Po Delta area and managed by ISPRA and ARPA Veneto (Figure 12).
The stations and sensors installed by ARPAV within the AdriaClim project are part of a network that has already been in operation since the early 1990s, adding important information for the meteorological-climatic characterisation of the coastal strip.

The table shows the active meteorological stations in the AdriaClim Project area (Table 2). Two new sites have been added to these, one for the province of Venice, on the northern coast, and one on the Po River delta, in the province of Rovigo. In addition, some existing stations were integrated with new instrumentation to measure variables and atmospheric phenomena never previously monitored by existing instrumentation. The measurements of cloud cover, visibility and present weather are important information for understanding the interactions of weather with tourist-recreational activities, transport and air quality.

The two atmospheric pressure sensors were added to the monitoring system due to the importance of these observations for the study and understanding of tidal phenomena. The increase in anemometric measurements is also important for the study of storm surges and coastal erosion.

The increase in rainfall measurement points is important because it is precisely in the coastal sector that the greatest precipitation intensities have been observed for extreme events lasting between 6 and 12 consecutive hours; these include

- 301.4 mm fallen in 6 hours and the 322.2 mm fallen in 12 hours in Campagna Lupia (VE) on 26 September 2007 ;
- 246.8 mm fallen in Mestre (VE) in 6 hours during the same event.

The strengthening of the measuring points for temperature and relative air humidity at 2 m above the ground is also important because it is precisely in the coastal sector that important thermo-udometric gradients are determined between the sea and the more inland sectors. In fact, these variables have markedly different daily trends compared to the Po Valley behind them, and furthermore, these dynamics are different in the various seasons of the year. Monitoring carried out in greater detail will improve the representation of these variables on the coastal strip.

Table 2. List of ARPAV automatic weather stations already in operation in the Provinces of Padua, Rovigo and Venice. The date of installation of the various sensors is shown on the right.

| Code | Name | Altitude [m a.s.l.] | Municipality | Lon | Lat | Barometer | Pyranometer | | Thermo. | Hygro. | Anemometer | | | Pluvio. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | up | down | | | 10m | 5m | 2m | |
| Province of Padua | | | | | | | | | | | | | | |
| 169 | Agna | 1 | AGNA | 11.95776 | 45.15926 | | 1992-02 | | 1992-02 | 1992-02 | | | | 1992-02 |
| 152 | Balduina (Sant'Urbano) | 7 | SANT'URBANO | 11.58416 | 45.13473 | | 1994-05 | | 1994-05 | 1994-05 | | 1994-05 | | 1994-05 |
| 611 | Bovolenta | 8 | BOVOLENTA | 11.93263 | 45.27657 | | | | 2020-12 | | | | | 2020-12 |
| 179 | Campodarsego | 16 | CAMPODARSEGO | 11.91336 | 45.49552 | | 1992-02 | 2022-06 | 1993-01 | 1992-02 | | 2017-05 | | 1993-01 |
| 110 | Cittadella | 50 | CITTADELLA | 11.79355 | 45.65647 | | 1991-09 | | 1991-09 | 1991-09 | | | | 1991-09 |
| 175 | Codevigo | 0 | CODEVIGO | 12.09971 | 45.24367 | | 1992-02 | | 1992-02 | 1992-02 | | 2017-10 | | 1992-02 |
| 211 | Codevigo - Ca' di Mezzo | 1 | CODEVIGO | 12.14506 | 45.22690 | | 1996-06 | | 1996-06 | 1996-06 | | | | 1996-06 |
| 142 | Faedo (Cinto Euganeo) | 250 | CINTO EUGANEO | 11.69772 | 45.30472 | | | | 1994-09 | 1994-10 | | | 1994-09 | 1994-09 |
| 265 | Galzignano - Ca' Demia | 3 | GALZIGNANO | 11.74269 | 45.30014 | | 2004-10 | | 2004-10 | 2004-10 | 2004-12 | | | 2004-10 |
| 177 | Grantorto | 32 | GRANTORTO | 11.75218 | 45.59472 | | 1992-02 | | 1991-12 | 1991-12 | 2005-03 | | | 1991-12 |
| 111 | Legnaro | 7 | LEGNARO | 11.95217 | 45.34735 | | 1991-07 | | 1991-07 | 1991-07 | 2001-09 | | | 1991-07 |
| 151 | Masi | 9 | MASI | 11.48088 | 45.11740 | | 1994-05 | | 1994-05 | 1994-05 | | 2021-04 | | 1994-05 |
| 106 | Montagnana | 12 | MONTAGNANA | 11.42279 | 45.24777 | | 1992-01 | | 1990-11 | 1990-11 | | | 1992-01 | 1990-11 |
| 201 | Monte Grande (Teolo) | 465 | TEOLO | 11.67282 | 45.36192 | | | | 1995-01 | | | | | |
| 572 | Ospedaletto Euganeo | 9 | OSPEDALETTO EUGANEO | 11.60649 | 45.23456 | | 2016-01 | | 2016-01 | 2016-01 | 2016-01 | | | 2016-01 |
| 234 | Padova | 12 | PADOVA | 11.90848 | 45.40496 | | | | 2000-05 | 2000-05 | | | | 2000-05 |
| 551 | Sant'Elena | 8 | SANT'ELENA | 11.69454 | 45.19660 | | 2013-07 | | 2013-07 | 2013-07 | | | 2013-07 | 2013-07 |
| 170 | Teolo | 155 | TEOLO | 11.67713 | 45.34273 | 1992-02 | 1992-02 | 1994-07 | 1992-02 | 1992-02 | 1992-02 | | 1992-02 | 1992-02 |
| 122 | Trebaseleghe | 23 | TREBASELEGHE | 12.02574 | 45.60240 | | 2013-07 | | 1995-07 | 1995-07 | | | 1995-07 | 1995-08 |
| 182 | Tribano | 3 | TRIBANO | 11.84880 | 45.18669 | | 1996-01 | | 1996-01 | 1996-01 | 1998-04 | | | 1996-01 |
| Province of Rovigo | | | | | | | | | | | | | | |
| 115 | Adria - Bellombra | -1 | ADRIA | 12.00768 | 45.01568 | | 1992-02 | | 1992-02 | 1992-02 | 2003-08 | | | 1992-02 |
| 96 | Bagnolo di Po - Pellizzare | 6 | BAGNOLO DI PO | 11.52951 | 44.98945 | | 1989-01 | | 1989-01 | 1989-01 | | 1998-08 | | 1989-01 |
| 113 | Castelnovo Bariano | 10 | CASTELNOVO BARIANO | 11.30253 | 45.03102 | | 1992-03 | | 1992-03 | 1992-03 | 2004-10 | | | 1992-03 |
| 98 | Concadirame (Rovigo) | 6 | ROVIGO | 11.72082 | 45.09314 | | | | 1989-01 | 1989-01 | | | | 1989-01 |
| 116 | Frassinelle Polesine | 4 | FRASSINELLE POLESINE | 11.67864 | 44.99058 | | 1992-03 | | 1992-03 | 1992-03 | | | | 1992-03 |
| 121 | Lusia | 6 | LUSIA | 11.63364 | 45.09242 | | | | 1995-07 | 1995-07 | | | 1995-07 | 1995-08 |
| 622 | Pettorazza Grimani loc. Botti Barbarighe | 2 | PETTORAZZA | 12.02445 | 45.11638 | | | | 2020-12 | | | | | 2020-12 |
| 101 | Porto Tolle - Pradon | -3 | PORTO TOLLE | 12.36910 | 44.91734 | 1989-11 | 1989-06 | | 1989-04 | 1989-04 | 1989-04 | | | 1989-04 |
| 112 | Rosolina - Po di Tramontana | -2 | ROSOLINA | 12.26178 | 45.07114 | | 1992-02 | 1992-02 | 1992-02 | 1992-02 | 1992-06 | | 1992-02 | 1992-02 |
| 99 | San Bellino | 6 | SAN BELLINO | 11.57663 | 45.03150 | | 1989-02 | | 1989-01 | 1989-01 | 2003-11 | | | 1989-01 |
| 231 | Sant'Apollinare (Rovigo) | 2 | ROVIGO | 11.82597 | 45.03340 | | 1998-01 | | 1998-01 | 1998-01 | 2003-08 | | | 1998-01 |
| 221 | Trecenta | 9 | TRECENTA | 11.42663 | 45.02167 | | 1993-05 | | 1993-05 | 1993-05 | | 2006-04 | | 1993-05 |
| 114 | Villadose | 0 | VILLADOSE | 11.92221 | 45.07145 | | 1992-03 | | 1992-03 | 1992-03 | | | | 1992-03 |
| Province of Venice | | | | | | | | | | | | | | |
| 425 | Bibione | 0 | SAN MICHELE AL TAGLIAMENTO | 13.07747 | 45.64137 | | 2008-02 | | 2008-02 | 2008-02 | 2008-02 | | | 2008-02 |
| 230 | Campagna Lupia - Valle Averto | 0 | CAMPAGNA LUPIA | 12.14156 | 45.34942 | | 1997-10 | | 1997-10 | 1997-10 | 1997-10 | | | 1997-10 |
| 160 | Cavallino Treporti | 1 | CAVALLINO TREPORTI | 12.48626 | 45.45872 | 1992-02 | 1992-02 | 1992-02 | 1992-02 | 1992-02 | 1992-02 | | | 1992-02 |
| 178 | Cavarzere | -2 | CAVARZERE | 12.08720 | 45.16150 | | 1996-01 | | 1996-01 | 1996-01 | 1998-04 | | | 1996-01 |
| 168 | Chioggia - Sant'Anna | 0 | CHIOGGIA | 12.27597 | 45.14632 | | 1992-02 | | 1992-02 | 1992-02 | 2021-05 | | | 1992-02 |
| 613 | Chioggia (centro) | 2 | CHIOGGIA | 12.28305 | 45.21813 | | | | 2020-12 | | | | | 2020-12 |
| 164 | Eraclea | -1 | ERACLEA | 12.70706 | 45.60317 | | 1992-04 | | 1992-02 | 1992-02 | | 2000-06 | | 1992-02 |
| 454 | Favaro Veneto | 2 | VENEZIA | 12.27848 | 45.51731 | | 2017-09 | | 2009-05 | 2009-05 | | 2009-05 | | 2009-05 |
| 165 | Fossalta di Portogruaro | 3 | FOSSALTA DI PORTOGRUARO | 12.89394 | 45.77567 | | 1992-02 | | 1992-02 | 1992-02 | | 2017-04 | | 1992-02 |
| 615 | Jesolo - Cortellazzo | 2 | IESOLO | 12.65882 | 45.53585 | | | | 2021-02 | 2021-02 | 2021-02 | | | 2021-02 |
| 166 | Lugugnana (Portogruaro) | 0 | PORTOGRUARO | 12.94669 | 45.70491 | | 1992-02 | | 1992-02 | 1992-02 | | 2017-04 | | 1992-02 |
| 617 | Marcon loc. Zuccarello | 1 | MARCON | 12.37831 | 45.53739 | | | | 2021-07 | 2021-07 | 2021-07 | | | 2021-07 |
| 167 | Mira | 3 | MIRA | 12.11692 | 45.43935 | | 1992-02 | | 1992-05 | 1992-02 | | | | 1992-02 |
| 163 | Noventa di Piave - Grassaga | 1 | NOVENTA DI PIAVE | 12.58851 | 45.66841 | | 1992-02 | | 1992-02 | 1992-02 | | 2021-04 | | 1992-02 |
| 159 | Portogruaro - Lison | 2 | PORTOGRUARO | 12.76129 | 45.74549 | | 1992-02 | 1992-02 | 1992-02 | 1992-02 | 1992-02 | | | 1992-02 |
| 623 | Stra | 9 | STRA | 12.00851 | 45.41067 | | | | 2020-12 | | | | | 2020-12 |
| 252 | Venezia - Istituto Cavanis | 18 | VENEZIA | 12.32810 | 45.42997 | 2004-08 | 2000-03 | | 2000-03 | 2000-04 | 2000-03 | | | 2000-03 |

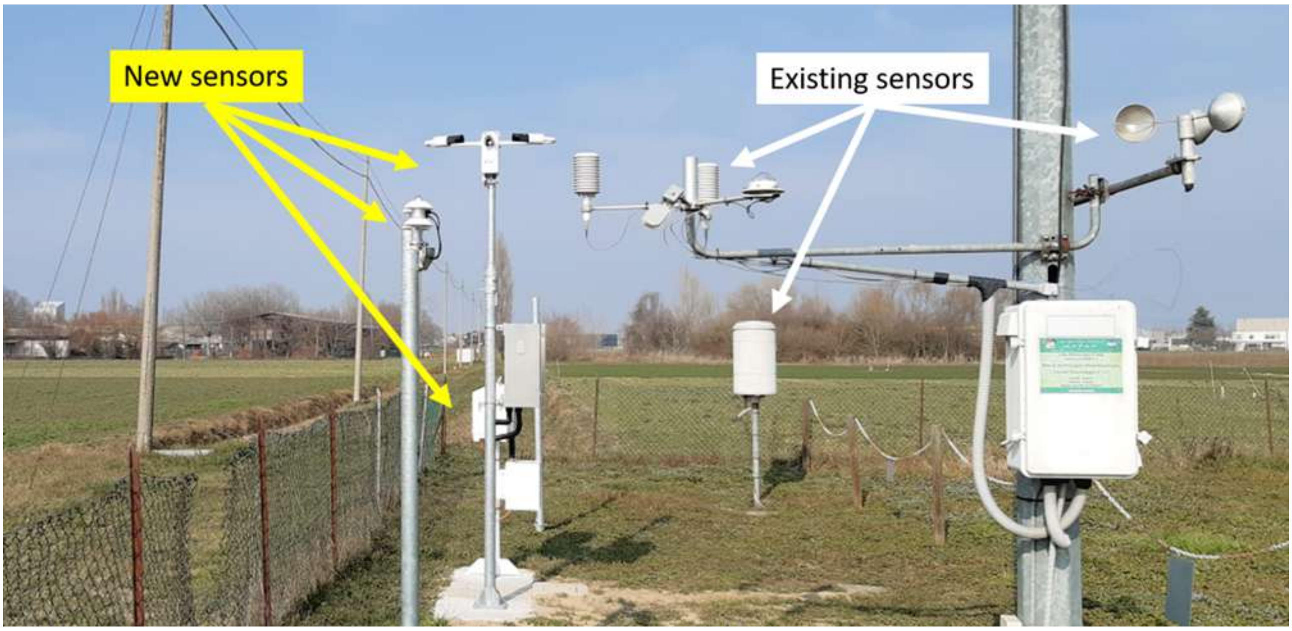



*Figure 12. Integration of the Legnaro station with the new sensor for measuring the present time, with the sensor for measuring the 4-component radiation and with the nefoipsometer.*

# 5. Emilia-Romagna coastal area

ARPAE: Silvia Unguendoli, Luis Germano Biolchi, Victor Outeiro Almeida, Andrea Valentini
ISPRA: Tommaso Petochi, Matteo Ciani, Antonello Bruschi, Ali Pourzangbar, Maria Paola Campolunghi, Giovanna Marino
IZSLER: Silva Rubini
UNIBO-CIRSA : Roberta Guerra, Nadia Pinardi

## 5.1 Description of the pilot area

The coast of Emilia-Romagna is located between the mouth of Po di Goro, on the northern border with the Veneto Region, and the mouth of Torrente Tavollo, between Cattolica and Gabicce, on the southern border with the Marche Region. This shoreline is characterized by a low and almost continuous sandy coast, with wide beaches from a few meters to over 200m, or in some cases without a beach, such as inside Sacca di Goro or in some stretches subject to strong erosion. Behind the coastal system there are wide reclaimed territories with altitudes below sea level, in particular in the northern sector of Ravenna and Ferrara, which are partly occupied by wet areas of high naturalistic importance. A greater anthropization sets apart the southern part of the Cesena and Rimini areas, with widespread urbanization and infrastructure. The coastal strip is a highly vulnerable territory marked by high risk for the natural systems, settlements and human activities. Amid the "natural vulnerabilities" shared along the whole regional coastal area, it is important to mention the low submerged beach slope and low emerged coast altitude, the local subsidence, the limited Adriatic circulation, the influence of the Po river discharge and the quantity and quality of local smaller river inputs. Added to the previous, anthropogenic pressures linked to intense urbanization, infrastructure, and the tourism industry/use of the territory are mostly observed in the southern sector. The Emilia-Romagna coast is shown in Figure 13 with the Northern and Southern boundaries delimited by the gray, solid line.

With the aforementioned vulnerabilities and the high-value of the established coastal infrastructure, the installation, upgrade and maintenance of observing and modelling systems assume fundamental importance on coast related decision making processes. Hence, in the following subchapters, some of the issues and the observing systems implemented are shown.

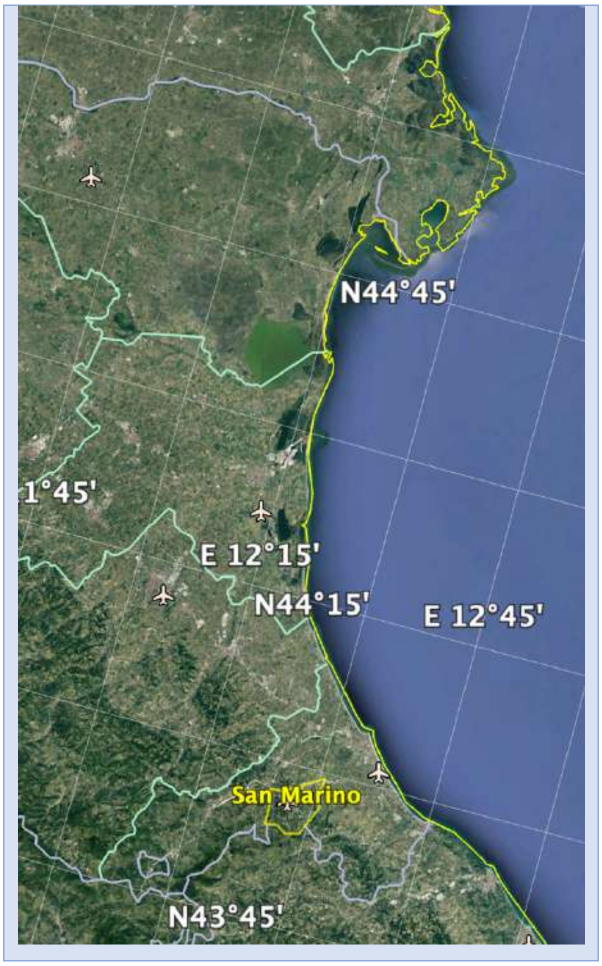



*Figure 13. The Emilia-Romagna coastal area within the gray solid lines, and its four coastal towns (delimited by the light green solid lines) Ferrara, Ravenna, Forlì and Rimini starting from the north*

## 5.2 Installation of observing system components (wave buoy, GNSS Station and Software)

### 5.2.1 Wave buoy, GNSS Station and Software

Among the equipment providing valuable oceanographic information, wave buoys and integrated sensors are of utmost importance. Starting in 2007, Arpae-SIMC installed a buoy (*Nausicaa*) just offshore the town of Cesenatico at about 10 m depth. The buoy was equipped with a directional waverider, sending the data collected every half an hour through radar (HF channel) and/or satellite (GSM) devices with its receiving stations being part of the Daphne oceanographic structure.

*Nausicaa* was decommissioned in 2022 and as its replacement, a new wave buoy, named *Nausicaa 2*, was purchased with funding from the AdriaClim project and installed in November, 2022.

The equipment purchased is a Datawell Directional WaveRider 4 (DWR4) 0.7m that measures the wave climate comprehending also wave direction, current intensity and direction, water temperature and GPS positioning. GSM-GPRS and radio transmission systems make it possible to have the measured data in (near)real-time allowing for its availability to different end-users. If the transmission systems are damaged, the DWR4 also stores the data in its internal memory card that can be recovered and processed whenever the buoy is taken off water for maintenance. Among the technical specifications of the wave buoy, it is important to mention that it has a solar power system that supplies energy to the wave buoy and also stores its surplus in Boostcap capacitors to be used when there is no incoming sunlight. This enhances the AdriaClim environmental rhetoric by using renewable energies and less environmentally damaging batteries. The specific details of the wave buoy are shown in Table 3.

Table 3. Technical details regarding the buoy Nausicaa 2 recently installed offshore the town of Cesenatico

| | | |
|---|---|---|
| **Current Meter** | General | Method: Doppler<br>Cell size: 0.4 m - 1.1 m from surface<br>Update rate: every 10 minutes<br>Sensors: three 2 MHz acoustic transducers |
| | Speed | Range: 0 - 3 m/s, resolution: 1 mm/s<br>Accuracy: 1% of measured value +/- 2 cm/s<br>Std. (1σ): 1 - 3 cm/s (depending on wave height) |
| | Direction | Range: 0° - 360°, resolution 0.1°<br>Accuracy: 0.4° - 2° (depending on latitude) typical 0.5°<br>Reference: magnetic north |
| **Wave sensor** | Type and processing | Type: Datawell stabilized platform sensor<br>Sampling: 8-channel, 14bit @ 5.12 Hz |

| | | |
|---|---|---|
| | | Data output rate: 2.56 Hz<br><br>Processing: 32bits microprocessor system |
| | Heave | Range: –20 m - +20 m, resolution: variable, 1 mm smallest step<br><br>Accuracy: < 0.5% of measured value after calibration<br>< 1.0% of measured value after 3 year<br><br>Period: 1.0 s - 30 s |
| | Direction | Range: 0° - 360°, resolution: 0.1°<br><br>Heading error: 0.4° - 2° (depending on latitude) typical 0.5°<br><br>Period: 1.0 s - 30 s (free floating),<br>1.0 s – 20 s (moored)<br><br>Reference: magnetic north |
| **Other** | Water temperature | Range: –10 °C - +50 °C, resolution: 0.01 °C<br><br>Sensor accuracy: 0.1 °C<br><br>Measurement accuracy: 0.2 °C |
| | Integrated data logger | Compact flash module 1024Mb - 2048Mb |
| | LED Flashlight | Antenna with integrated LED flasher, colour yellow (590 nm), pattern 5 flashes every 20 s. |
| | GPS position | 50 channel, update every 10 min, precision < 5 m |
| | Datawell HF link | Frequency range 25.5 - 35.5 MHz (35.5 - 45.0 MHz on request)<br><br>Transmission range 50 Km over sea, user replaceable.<br><br>For use with HVA compatible Datawell RX-C4 receiver. |
| **General** | Power consumption | 522mW |
| | Batteries | 0.7m diam. Operational life 10.5 months |

| | | |
|---|---|---|
| | | 0.9 m diam. operational life 21 months<br>Type RC24B (240 Wh black) |
| | Material | Stainless steel AISI316 or Cunifer10 |
| | Weight | Approx. 109 Kg 0.7m AISI316, 113 Kg 0.7m Cunifer10<br>Approx. 192 Kg 0.9m AISI316, 201 Kg 0.9m Cunifer10 |
| | Power switch | Data files are closed and secured |
| **Options** | Solar power system | Solar panel combined with Boostcaps capacitors (0.9m version only)<br>Peak power:5 W Capacity: 2WH |
| | Transmission | Iridium-SBD, Iridium-internet, GSM-internet and Argos |
| | Hull diameter | 0.7m (excluding fender) 0.9m (excluding fender) |
| | Hull painting | Brantho Korrux “3 in 1”paint system (no anti-fouling) |

On the 13th of November, 2022, following a two-day course (Figure 14) to understand the buoy system, how it operates, the software used for processing its data, the buoy was deployed offshore the town of Cesenatico. As the data was not being appropriately transmitted, the buoy was taken off the water and re-deployed on the 24th of November and it has been operational since then at longitude 12.47585°E and latitude 44.214583°N.

*Figure 14. Pictures taken during the two-day course in which the attendees were lectured about specific buoy details, involving material, sensors and processing of its data*

*Figure 15. Buoy deployed offshore the town of Cesenatico*

*Nausicaa 2* is already providing constant monitoring not only of waves, but also of temperature and currents adding value to the regional and Adriatic monitoring systems. Its data is open and freely available at Arpae's websites (https://simc.arpae.it/dext3r/) and it can be also visualized in (near)real-time (https://www.arpae.it/it/temi-ambientali/ mare/dati-e-indicatori/rete-di-monitoraggio-meteo-marina) (Figure 16).

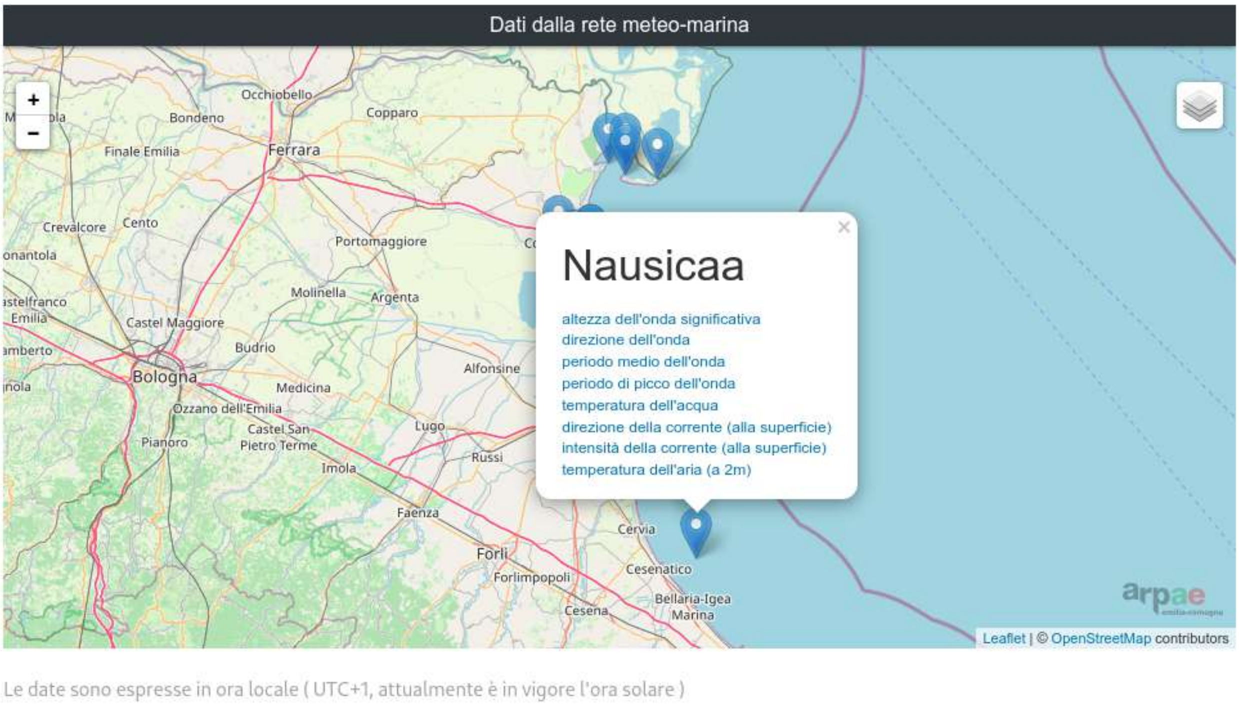



*Figure 16. How the new buoy data is shown in Arpae's official website (www.arpae.it). In this website, the old name has been kept as the data available dates back to the period when the old buoy was still operational.*

In addition to the oceanographic buoy, AdriaClim funding allowed for the acquisition and installation of a permanent GNSS Station (*Leica GM30*) and control software (*Leica GNSS Spider"*). The GNSS Station was installed in Tagliata, RA (Latitude 44.2247°N, Longitude 12.3769°E), and it provides ground level measurements in order to evaluate the subsidence rate over time as well as to provide a ground control point to be used during bathymetric or topographic surveys that rely on such a system. This station consists of GNSS multi frequency and multi constellation (GPS, GALILEO, GLONASS, BEIDOU) receivers that allow for a permanent GNSS station with geodetic accuracy. Furthermore, the station has:

- a 220V power supply module, with a 75 Ah backup battery;
- 2G/3G/4G communication module, complete with antenna for data transmission to the Arpae station;
- containment box for the acquisition, transmission and power supply components;
- support pole suitable for housing the containment box, the antenna of the 2G/3G/4G system.

This new system allows for (near-)real time high-resolution measurements that highly improve the already existing regional geodetic network. The data is transmitted and stored inside Arpae's databases and the general management and operation of the network is done through the control software previously mentioned.

### 5.2.2 Aquaculture: new observing system to evaluate the microbial pollution in shellfish waters

The Emilia-Romagna represents a major national and Adriatic production pole of bivalve shellfish (farms and natural banks). Production areas are located in both transitional and marine waters, from the shoreline to offshore. These areas are vulnerable to anthropogenic pressure and climate changes, with implications on shellfish ecosystem services, public health and seafood quality. An automatic probe to measure faecal bacteria in shellfish production areas was installed with the aim to implement model to assess the potential diffusion of the microbial pollution from point sources. The probe is under test in Sacca di Goro, a major production area of Emilia Romagna, characterized by 115 leisures for shellfish farming (12.86 sq km) mainly for japanese littleneck clam and a minor production of mussel and oyster, together with shellfish nursery areas. The probe was positioned in the porto turistico of Sacca di Goro, identified as a suitable test area together with IZSLER and ARPAE (Figure 17). The site is influenced by effluents and weather events but it is safety and easily accessible by operators. The probe will be move to other target shellfish areas in marine-coastal waters of Emilia-Romagna.

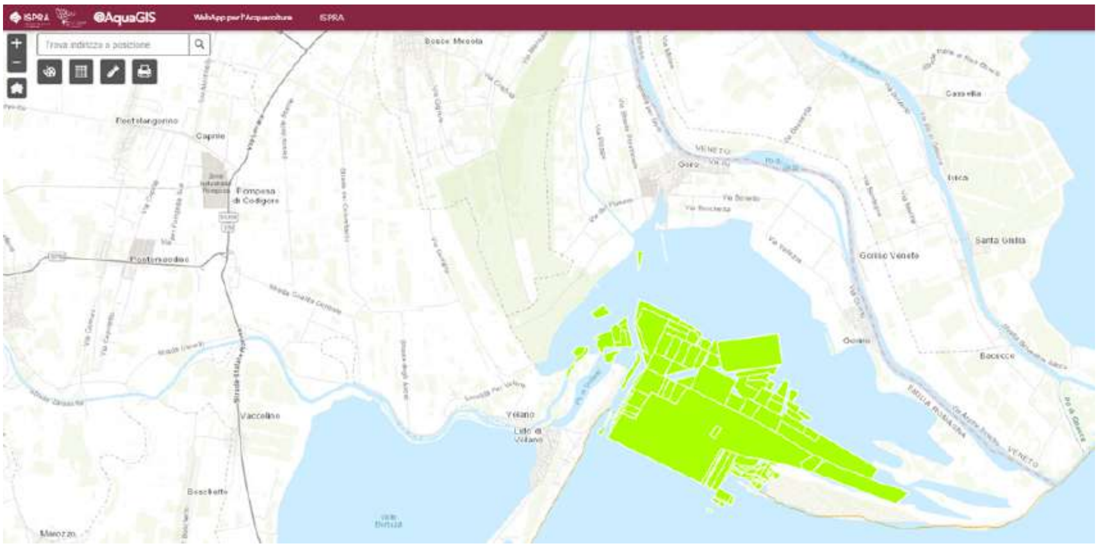



*Figure 17. Sacca di Goro area. Classified shellfish areas (source: webapp @ AquaGIS ISPRA) and microbial probe location (red dot).*

An *ad hoc* probe, the Fluidion Alert System V2, was purchased to measure microbial pollution in shellfish waters and to implement the microbial diffusion model. The probe is capable of automatic contamination-free sampling *in-situ*, reagent mixing and incubation, optical detection (absorbance and fluorescence), bacterial quantification (*E. coli*, total coliforms) and wireless data transmission. It can float like a buoy or can be installed on a rail at field locations or in a facility and can operate without an external power supply. The instrument can be remotely controlled from a mobile phone or web interface, and supplies data to the operator wirelessly via a cloud-based data analytics and visualization interface. The probe has a load capacity of 7 cartridges at a time and throughout a multispectral optical analysis, it can quantify response in terms of bacteria/100 mL present in the sampled water. Sampling in the disposable measurement cartridges is controlled by an internal vacuum module and the instrument implements a multispectral optical detection technology, which ensures consistent, uncontaminated sampling and measurements.

<u>Functional and validation test</u>: in December 2022 the microbial probe was firstly tested in ISPRA technical lab to check the proper functionality and operativity assisted remotely by Fluidion's technicians.

<u>Field test</u>: in January 2023 the probe was installed along 8 days of test in the Sacca di Goro area. During the field test, additional water samples were collected at the same point and time as those set for the probe and analysed by IZSLER for E. *coli* and total fecal bacteria through routine laboratory methods for further comparisons. The probe is actually under maintenance to check functionality of the optical reading system.


*Figure 18. Microbial probe and cartridges installation.*

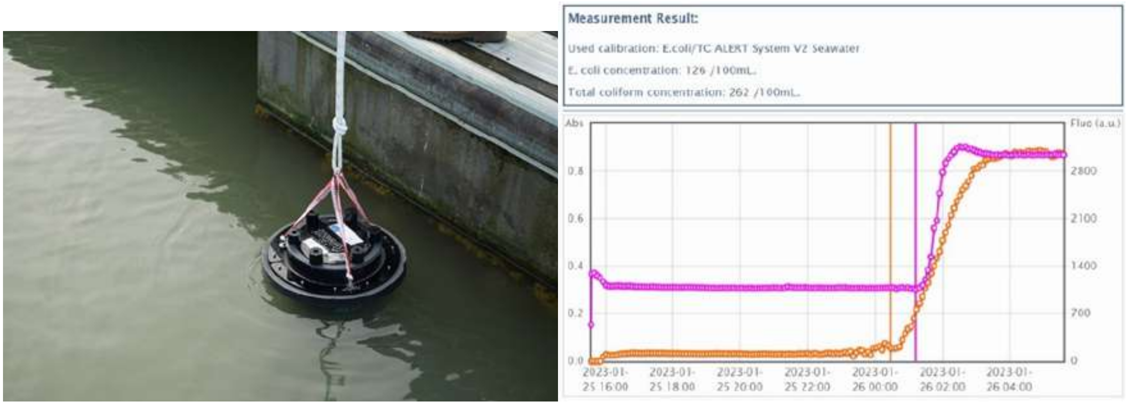



*Figure 19. In situ floating probe installation (left); Probe web interface with measurements result, absorbance and fluorescence curves (right).*

## 5.3 Integration with the existing observing systems

### 5.3.1 Wave Buoy and GNSS Station

By integrating buoy data with existing observation systems, end users can gain a more comprehensive understanding of how environmental factors interact and affect ecosystems. This can improve the accuracy of models used to predict changes in the environment and help identify potential areas of concern before they become major issues. Furthermore, the integration of buoy data with existing observation systems can enhance our ability to monitor and respond to events such as sea storms, storm surges and flooding. *Nausicaa 2* can provide valuable information on the strength and direction of currents, which can help predict the path and intensity of these events. This can be particularly helpful in coastal areas where early warning systems can save lives and reduce property damage.

With the new buoy, Arpae's already implemented observing system network not only maintains its wave related measurements but also increases the number of variables available to end users. By measuring the currents together with the waves, more information is provided relative to the local dynamics which can be of extreme importance on calibrating and validating hydrodynamics models. Furthermore, by adding a permanent GNSS station in the region's coastline, it will be possible to conduct topo-bathymetric surveys with higher accuracy in what refers to horizontal and vertical positioning. The new GNSS station also allows for long-term evaluations of natural or manmade vertical ground motions (e.g. subsidence) which are of utmost value when evaluating sea-level variations isolating isostatic and eustatic components.

### 5.3.2 New observing system to evaluate the microbial pollution in shellfish waters

The potential integration with the existing observing systems will be evaluated along the monitoring activity.

### 5.3.3 New observing system of sediment components

Existing water quality monitoring in the Emilia-Romagna coastal area is based on monthly and bi-monthy field cruises. The observing system of ERM pilot area is now complemented by new UV-VIS a double beam spectrophotometer with Xenon lamp and with up to to 8-cell carousel to speeding up laboratory analyses (Figure 20). Grain size, organic carbon, nitrogen, and phosphorus determined in the sediments will improve our understanding of seasonal changes in the pilot area, and will be used for model calibration.

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*Figure 20. UV-VIS Genesys TM 180 Spectrophotometer (Thermo Fisher Scientific) (UNIBO-CIRSA).*

# 6. Apulia coastal area

CMCC: Viviana Piermattei, Giorgia Verri

## 6.1 Description of the pilot area

The Apulia pilot site is characterized by the presence of the Torre Guaceto Marine Protected Area (MPA), delimited by a very varied coastline and characterized by the existence of Posidonia oceanica meadows. The MPA offshore boundaries are marked by a series of signal buoys, useful as protection measures necessary for the conservation of the area. The pilot area of Torre Guaceto MPA, falling within the municipalities of Brindisi and Carovigno, is about 8 km long. The coastline is characterized by a series of small coves with pocket beaches along the western sector ; while along the eastern area the coast is mainly sandy, with reduced rocky formations. The marine bottoms are characterized by the presence of two submarine cliffs, running parallel to the coast line, and by the presence of important habitats such as *Posidonia oceanica* meadows. Both the use of maritime national properties and adjacent areas and uncontrolled potential discharges of organic and inorganic pollutants may impact natural benthic community as well as the abiotic characteristics. For all these reasons, within the Adriaclim projectm CMCC is carrying out a series of activities for the characterization of Torre Guaceto Marine Protected Area (MPA) through innovative and low-cost instrumentation. In particular CMCC is equipping one of the delimitation buoys of the MPA with oceanographic sensors managed by a low-cost electronic system.


*Figure 21. Apulia Pilot Site and Buoy location inside the Torre Guaceto MPA*

## 6.2 Installation of observing system components

A low-cost measurement system was integrated onboard one of the delimitation buoys moored in the Torre Guaceto Marine Protected Area (MPA). The station is located in the GPS point Lat 40.7227778 E, Long 17.7779861 N (coordinates WGS84) and is based on low-cost and open access technologies (Figure 22). The technology behind the system was developed to manage different kind of signals and consequently of sensors, and also different kind of communication protocols. Once in operation, the fixed station will allow a continuous monitoring of the main physical and biogeochemical parameters of marine water and will be able to be installed in different kind of buoys or fixed infrastructures in order to extend the marine observing capacities. The system was laboratory and in situ tested with different kind of sensors, both developed in-house and commercial ones. The system is based on low-cost electronics and will allow managing analog and digital sensors and will acquire data with a frequency of 10 minutes. The data are transmitted to a server in .csv format. A series of in situ tests of low-cost sensors were carried out in a lab-coastal fixed site in order to verify the functioning and stability of electronic boards for sensors management and data transmission.

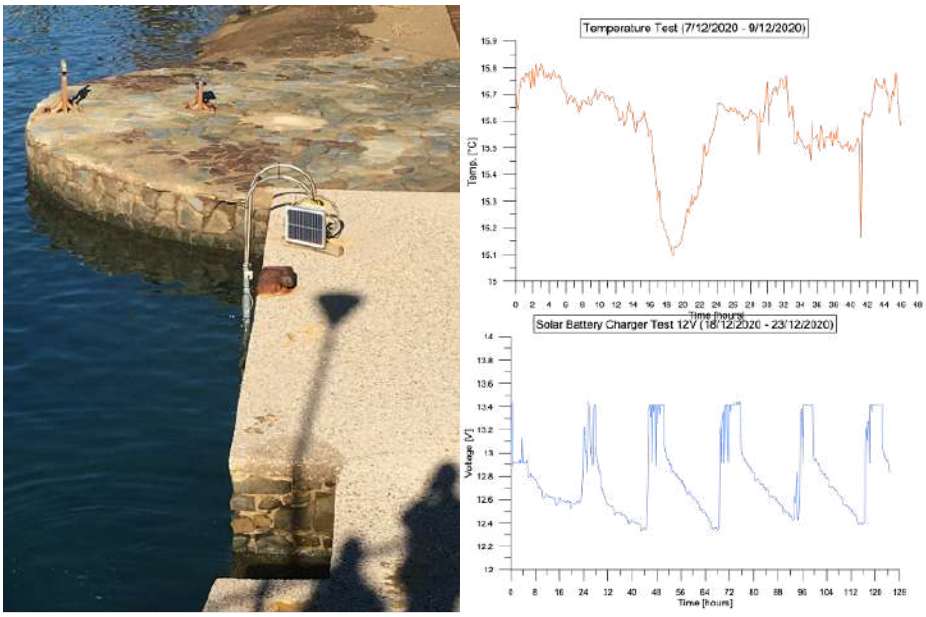



*Figure 22. Lab-coastal fixed site and first tests of the system*

Simultaneously, a first prototype of a new low-cost multispectral radiometer (18 channels) was designed and developed in order to be integrated in the future instrumentation onboard the buoy (Figure 23).

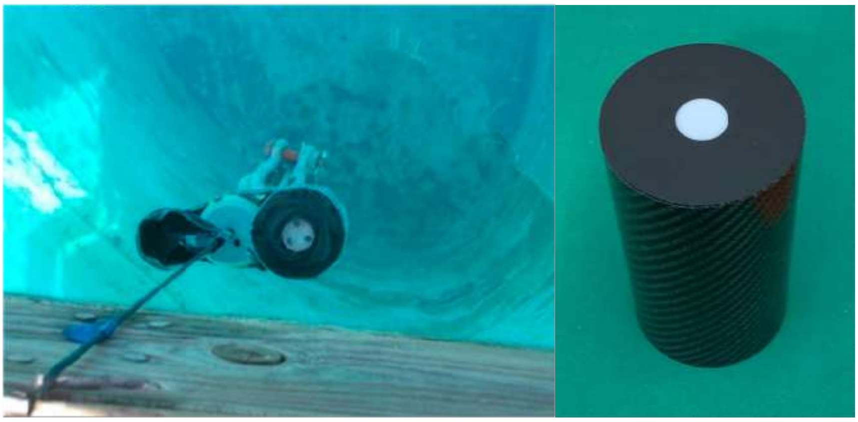


*Figure 23. Prototype of a new low-cost multispectral radiometer*

The monitoring system is composed by different components:

- Submerged part that includes electronics boards for sensors managing and conditioning, sensors;
- External box that includes electronics for transmission/reception, batteries, solar panel

The two parts are connected with a specific cable. The system samples the parameters with a frequency of 10 minutes; the acquired data are sampled for 30 seconds, preprocessed and transmitted to the electronics in the external box, that transmits to a server the data every 10 minutes.

CMCC applies standard procedures for temperature and conductivity in situ data quality control referring to SeaDataNet, 2010. Data Quality Control Procedures. Version 2.0 May 2010. Available at https://www.seadatanet.org. and Reverdin, G., Thierry, V., Utiz, J., d'Ortenzio, F., Bradshaw, E., & Pfeil, B. (2016). QC Report. AtlantOS project.

### 6.3 Integration with the existing observing systems

No existing observing systems in the pilot area.

# 7. Dubrovnik Neretva - estuary area

IOF: Gordana Beg Paklar, Hrvoje Mihanović, Stipe Muslim

## 7.1 Description of the pilot area

The Neretva River is the largest river in the eastern part of the Adriatic Sea. It springs near mountain Zelengora in Bosnia and Herzegovina, at an altitude of 1095 m above sea level. The course of the river has a total length of 218 km, of which only around 20 km are in Croatia. Neretva forms a delta with a total surface area of about 20 000 ha, of which the area of about 12 000 ha is a part of the Croatian territory. The delta is surrounded by hilly karst rich in groundwater that supplies numerous springs, streams and lakes. The Neretva River estuary is important from the economical and ecological point of view. The area is densely populated, about 35 600 people live there and the population mostly uses land for agricultural purposes. Unfortunately, the vicinity of the Adriatic Sea poses a threat to local agriculture due to salt water intrusions. This problem is expected to become even more severe in the future under projected climate change and due to potential rise of sea level and reduction of freshwater inflow during the summer. In addition, the estuary of the Neretva River is one of the most valuable wetlands on the eastern Adriatic coast. The most important functions of wetland habitats are flood control, groundwater restoration, shoreline hardening and protection from weather hazards in the coastal area, the retention of nutrients and sediments, climate change mitigation and water purification. The estuary is a part of the Natura 2000 protected area network as it represents habitat of great biological and genetic diversity.

**7.2 Installation of observing system components**

Within the AdriaClim project an automatic meteo-oceanographic station is installed in Metković harbor (43°03’19’’N, 17°39’06’’E) (Figure 24). The station is equipped with sensors for continuous measurements of wind speed and direction, air temperature, relative humidity, air pressure, water temperature, conductivity, hydrostatic pressure and with radar tide gauge. Meteorological parameters are measured with Lufft WS500, oceanographic with SeaBird HydroCAT SMP, while water level data are collected with OTT RLS tide gauge. Measurement interval for meteorological parameters and water level is one minute and for water temperature, conductivity and hydrographic pressure 10 minutes. Data transfer interval is 10 minutes. Visual presentation of collected data is available online at IOF web site: http://faust.izor.hr/autodatapub/postaje?jezik=eng.

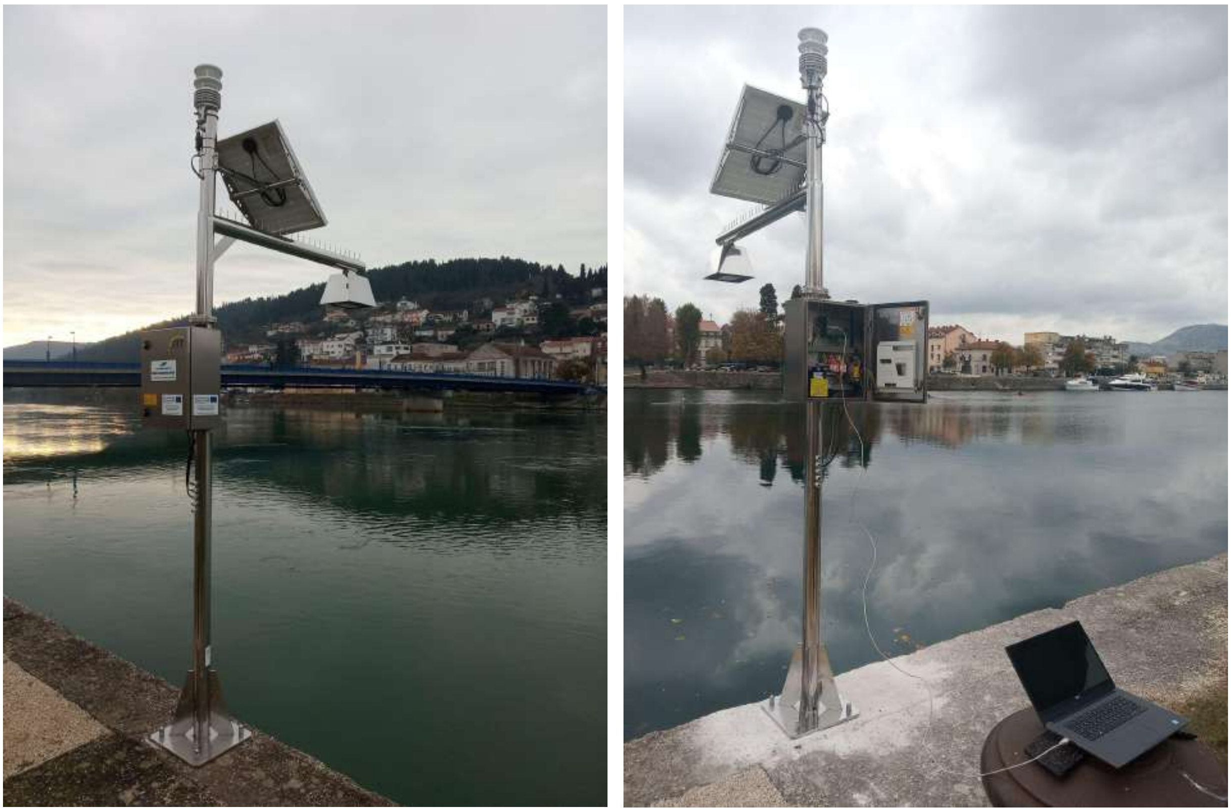


Figure 24. Meteo-oceanographic station in Metković harbour (Neretva River estuary).

Preparation for installation of autonomous sensors for continuous measurements in the Neretva River estuary is underway (Figure 25). Six CTD sensors (CTD-diver, Royal Eijkelkamp) and three sensors for dissolved oxygen content (mini DOT Logger, PME) will be installed at four selected locations in the Neretva River estuary (Metković, Opuzen, Komin, Rogotin). Sediment samples will be collected at the same four locations and grain size, organic carbon, nitrogen, organic phosphorus and carbon content will be determined in the laboratory.


*Figure 25. Autonomous sensors for continuous measurements in the Neretva River estuary: CTD sensors (upper left) and dissolved oxygen sensors with wipers (upper right). Testing of sensors using CTD probe: installation of sensors on the probe in the laboratory (lower left) and measurements in front of the IOF building (lower right).*

## 7.3 Integration with the existing observing systems

Existing monitoring in the Neretva River estuary is based on monthly field cruises and has only one station in the Croatian part of the Neretva River course. New continuous measurements of temperature, salinity and dissolved oxygen content at four locations along the river course, together with nearby meteo-oceanographic station, will greatly improve the existing observing system and will give valuable information on the dynamics of salt water wedge. Moreover, the Neretva River observing system is complemented with water level data from radar tide gauge. Grain size, organic carbon, nitrogen, organic phosphorus and carbon content determined in the samples will improve our understanding of environmental changes in the pilot area and will be used for model calibration as well.

# 8. Split-Dalmatia coastal area

IOF: Gordana Beg Paklar, Danijela Bogner, Branka Grbec, Živana Ninčević, Stefanija Šestanović, David Udovičić

## 8.1 Description of the pilot area

Split-Dalmatia County, geographically located in the central part of the Adriatic coast, is the largest Croatian county with a total area of 14106.40 km$^2$. Of this total area, a surface area of 4523.64 km$^2$ (8% of the Republic of Croatia) is covered by land, and the sea covers a surface area of 9576.40 km$^2$ (30.8% of the sea surface of the Republic of Croatia). Most of the land area consists of the hinterland (59.88%), while the islands make up a lower proportion of the land surface area (19%). The hinterland, in the continental part of the county, is crisscrossed by mountains that run parallel to the coastline. The area is sparsely populated and economically poor. The coastal area makes a narrow strip along the coast between the mountain ranges and the sea. This area is highly urbanized and economically developed compared to the hinterland. The island area of the county is made up of 74 islands and 57 islets and reefs, and the largest island in Split-Dalmatia County is Brač with a surface area of 395.57 km$^2$.

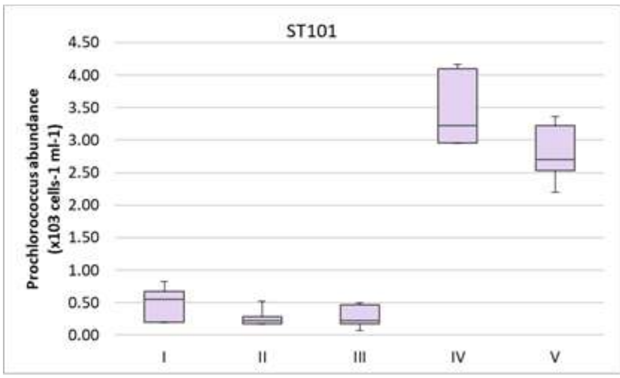
The IOF monitoring program in the Split-Dalmatia County is focused on the Kaštela Bay (Figure 26). Kaštela Bay is a semi-enclosed coastal bay, covering an area of 57 km$^2$ and having an average depth of 23 m. The length of the coast is 23 km and almost the entire coastal area is urbanized. The most important freshwater source is the Jadro River, a relatively small river with an average annual discharge of 8 m$^3$/s, which discharges into the eastern part of the Bay. Geologically, the area forms part of a large Cretaceous-Tertiary sedimentary complex, which belongs to the structural unit of the Adriatic cretaceous carbonate sediments. Based on the primary production, the Kaštela Bay may be considered a moderately productive basin. The coastal zone of the City of Kaštela has been exposed to long-term adverse anthropogenic activity and it is influenced by the proximity of two strong tourist destinations, Trogir and Split, and by the proximity of the airport. Due to its natural characteristics (closed bay) and intensive industrialization in the past, as well as increased urbanization, Kaštela Bay is one of the areas where the ecological balance has been disturbed, consequently increased eutrophication has been recorded. The area is suffering a number of issues related to climate change such as sea level and air temperature rise, increased frequency of various extreme events like heat waves, storms, flooding events and more frequent appearance of long-lasting dry periods.


*Figure 26. Kaštela Bay with monitoring stations. Temperature and salinity measurements, sediment, microbiological and phytoplankton samplings have been conducted at the central Kaštela Bay station ST101 (red circle). Additional sediment samplings have been conducted on ST103, Pantan 1 and Pantan 2 stations (yellow circles).*

## 8.2 Installation of observing system components

CTD measurements and samplings for analysis of microbiological and phytoplankton parameters were conducted from January 2020 to December 2022 at two stations with different trophic status: one is located in the center of the Kaštela Bay (central part of Kaštela Bay, 43°51′N; 16°38′E, depth 38 m) (Figure 26) and the other one is Stončica station near the island of Vis (central Adriatic Sea, 43°N; 16°33′E, depth 103 m). Data and samples were collected within 25 field cruises.

The structural and functional features of microbial food web was studied using the following parameters: abundance and production of heterotrophic bacteria (with different DNA content, i.e. High- DNA bacteria and Low- DNA bacteria), abundances of two cyanobacteria groups, i.e. *Prochlorococcus* and *Synechococcus*, abundances of pico-eukaryotic algae and abundances of protistan grazers (heterotrophic nanoflagellates). The microbiological investigations are improved within the AdriaClim project by upgrading laboratory equipment. A new CCD camera mounted on epifluorescent microscope improved research capacities by enabling a better view of fluorescence microscopy images, higher resolution and finer sensitivity. The laboratory flow cytometer is upgraded with an automatic plate loader that helps to optimize sample processing by time reduction (Figure 27). The cytometer red laser is activated.



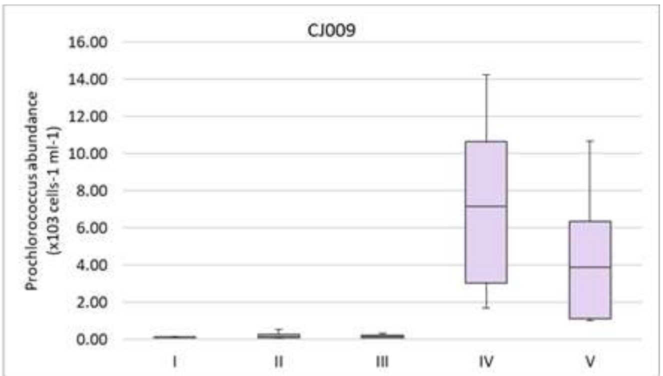



*Figure 27. Laboratory CytoFLEX cytometer and plate loader (up) and boxplot of Prochlorococcus abundances at investigated sites. Central line indicates median value, boxes indicate the lower and upper quartiles, and vertical lines indicate minimum and maximum (down).*

A new molecular method based on DNA microarray technology with the aim to improve detection and determination of harmful algae is introduced as the existing monitoring program based on light microscopy did not allow the identification of all harmful species down to the species level. Method is based on the labeling of the target nucleic acids, which then are hybridized to the probes on the microarray (Figure 28). The laser in a microarray scanner scans the slides and recognizes the hybridization pattern according to fluorescent excitation and identifies present species.

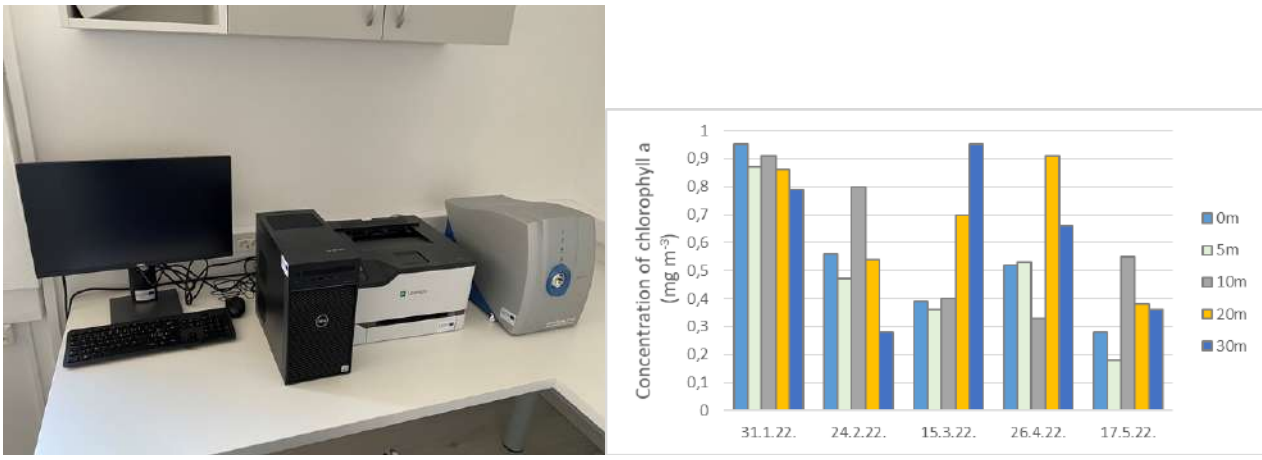



*Figure 28. Microarray scanner (left) and seasonal and vertical distribution of chlorophyll-a concentration in Kaštela Bay in the period January – May 2022 (right).*

Besides at the central station, sediment samples were collected at three additional stations in the Kaštela Bay (Figure 26) and at the Stončica station near the island of Vis. In order to improve sediment sample analysis, laser diffraction particle size analyzer (Figure 29), for particles in the range 1 – 1000 µm is purchased within the AdriaClim project. Until now sediment fraction <0.063 mm have been determined using the hydrometer method according to Cassagrande. Although the method mentioned was reliable, a new method using the laser particle size analyser gave more accurate values. In addition, the grain size analysis is significantly accelerated. Organic carbon, nitrogen, organic phosphorus and carbon content will be determined in the samples as well.

Data obtained within the AdriaClim project by the IOF team will be available on the AdriaClim Geoportal.

*Figure 29. Laboratory work with laser grain size analyser (MASTERSIZER).*

## 8.3 Integration with the existing observing systems

CTD measurements and samplings for analysis of microbiological and phytoplankton parameters were carried out at the same stations as within existing monitoring but laboratory analysis of the collected samples were significantly improved and accelerated by introduction of new equipment purchased within the AdriaClim project. The current monitoring program based on light microscopy did not allow the identification of all harmful phytoplankton species and therefore a new molecular method based on DNA microarray technology was introduced. The microbiological investigations were also improved by upgrading laboratory equipment. A new CCD camera mounted on existing epifluorescent microscope improved research capacities by enabling a better view of fluorescence microscopy images, higher resolution and finer sensitivity. The existing flow cytometer is upgraded with an automatic plate loader that helps to optimize sample processing by time reduction. Red laser at the cytometer is activated.

In addition, the existing observing system is upgraded by collecting sediment samples at additional stations in the Kaštela Bay and at the open sea station near the island of Vis. Moreover, laboratory analysis of the samples is improved and significantly accelerated by installation of a new laser grain size analyser purchased within the AdriaClim project. Organic carbon, nitrogen, organic phosphorus and carbon content will be determined in the samples to improve our understanding of environmental changes in the pilot area and for model calibration as well.

# 9. North-eastern Adriatic Sea

IBR: Ana Baricevic, Martin Pfannkuchen

## 9.1 Description of the pilot area

The northern Adriatic Sea is a highly productive, shallow, marine ecosystem that is characterized by steep spatio-temporal ecological gradients. The Po river, as the largest freshwater input into the Adriatic, represents the major driver for the northern Adriatic Sea ecosystem dynamics. River plumes across the entire northern Adriatic are regularly created and the area is supplied with nutrients enriched waters. The West Adriatic Current (WAC) transfers nutrients from north to south Adriatic along the western coast of the Adriatic Sea. There are also situations when the freshwater inflow is limited, and such events have a significant impact on the ecosystem functioning of the area. In addition to river dilution, there are periodic inflows of high salinity waters transferred by the Eastern Adriatic Current (EAC) from the southern to the northern part of the Adriatic Sea. Consequently, steep and diverse spatio-temporal ecological gradients are formed in the north - eastern Adriatic pilot area. The pilot area is an ideal basin to study the influence of freshwater inflows and fast oceanographic changes on marine ecosystem. Measured differences in oceanographic parameters (sea temperature, salinity, oxygen saturation, sea currents, etc.) represent strong and dynamic ecological gradients and allow deep insights into the driving forces of the ecosystem.

### 9.2 Installation of observing system components

New oceanographic buoy (Figure 30) is installed in the north-eastern Adriatic Sea on the position 5nm from the coast of Croatia (Lat: 45° 4' 31.7712'' N, Lon: 13° 35' 56.3208'' E). In the automatic identification system (AIS) of marine safety and traffic, installed buoy was named CIM ODAS II. The buoy is 3 m in diameter and has a platform large enough for two people to work on the buoy. The platform allows access to all installed maintenance and measurement instruments. Buoy provides fixed structure for attaching underwater sensors and placing other sensors, electrical and communication equipment at sea. The buoy is adapted to power systems of solar and wind charging and includes charge regulators and batteries. Oceanographic buoy is equipped with meteorological sensors (wind direction and speed, air temperature, relative humidity, atmospheric pressure, solar irradiation, precipitation, air visibility sensor), compass, 360 ° camera, GPS and GSM system and LED marine lantern for visibility at night (intensity of 5 NM). Measurements of physical and chemical sea parameters on the buoy include: Acoustic Doppler Current Profiler (ADCP), wave sensor, surface current measurement sensor, $PCO_2$ sensor, sea temperature, conductivity (salinity), dissolved oxygen, light transmission meter sensor, pH sensor, soluble organic fluorescence (FDOM), phytoplankton pigment sensors (phycocyanin, phycoerythrin, Chlorophyll A and backscatter Red sensor, backscatter blue sensor).

Data collection is near-real-time and will be shared for AdriaClim project activities and provided free of charge on the Center for Marine Research (RBI) specific web page. Oceanographic buoy measurements provide an integrated dataset across all platforms and datatypes.

## 9.3 Integration with the existing observing systems

Center for Marine Research, Ruder Boskovic Institute had an old oceanographic buoy installed at the similar position as the new buoy installed in the AdriaClim project and it was integrated in the long term monitoring of the eastern Adriatic in the period from year 2003 to 2020. New oceanography buoy enabled significant improvements of the measuring parameters and data collection and will also be integrated in the monitoring system of the eastern Adriatic.

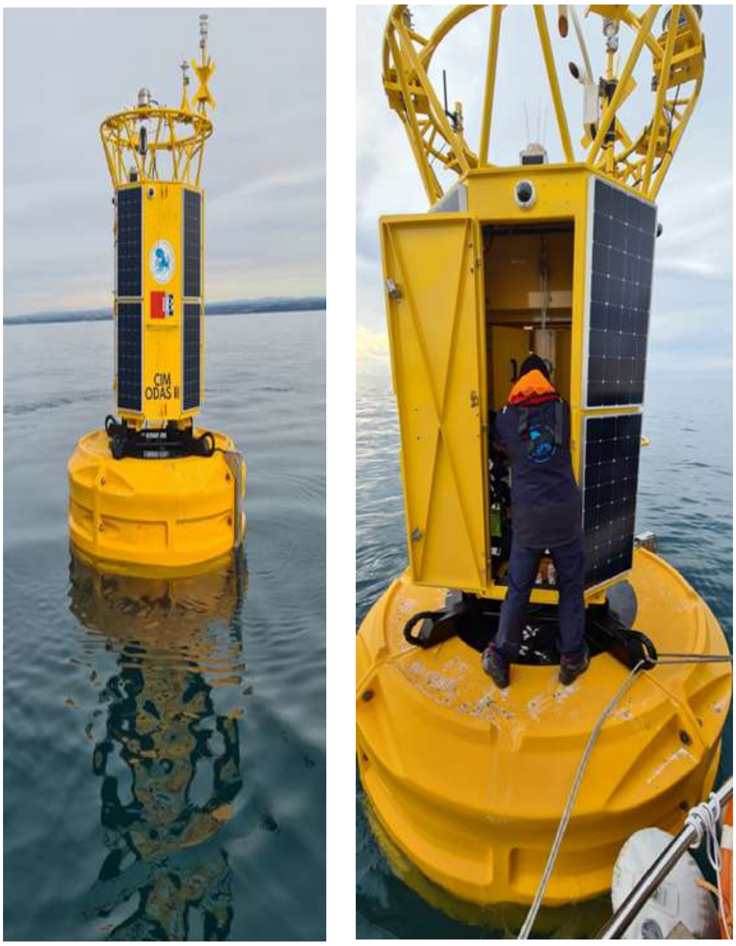



*Figure 30. Oceanographic buoy installed in the North-Eastern Adriatic Sea pilot area*

# 10. Molise coastal area

Molise Region – Civil Protection – CFD Molise: Antonio Cardillo

## 10.1 Description of the pilot area

The pilot area of the Molise Region is the entire stretch of regional coast bordering the Adriatic Sea, just 40 km long, but the sensor installation site is the Port of Termoli (Figure 31).

The identification of the monitored site was not easy in consideration of the fragmented properties and the constraints present in order to install the sensors. Having identified the most suitable site for most of the sensors, a great result was achieved, according to the Molise Region, since at the same time, another territorial cooperation project, REGPLORTS, needed to install sensors, for whom the final result was that to have a single measurement site but with many sensors available for both projects and the scientific community on three domains, meteorological, mareographic and water quality, all in real time and continuously, as the stations are integrated into the monitoring network regional civil protection managed by the Regional Functional Center of Civil Protection of the Molise Region.


*Figure 31. a) Coastal area of the Molise Region; b) Port of Termoli: sensor installation site.*

## 10.2 Installation of observing system components

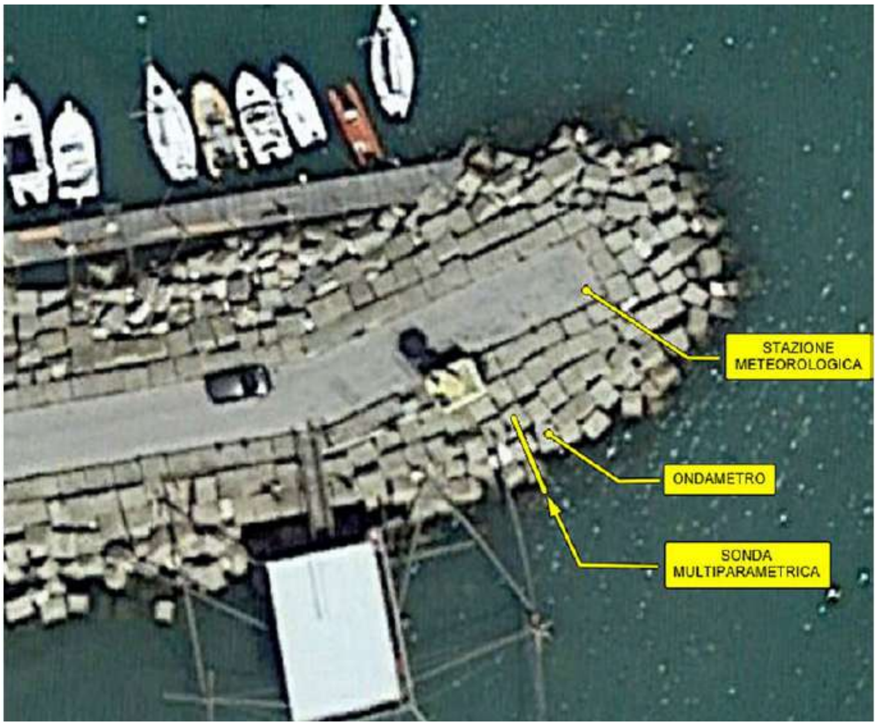
| Characteristic | Description |
|---|---|
| transmission system | UHF Frequency, GPRS |
| Power | Solar panel |
| Installation site properties | Termoli Municipality |

**Location**

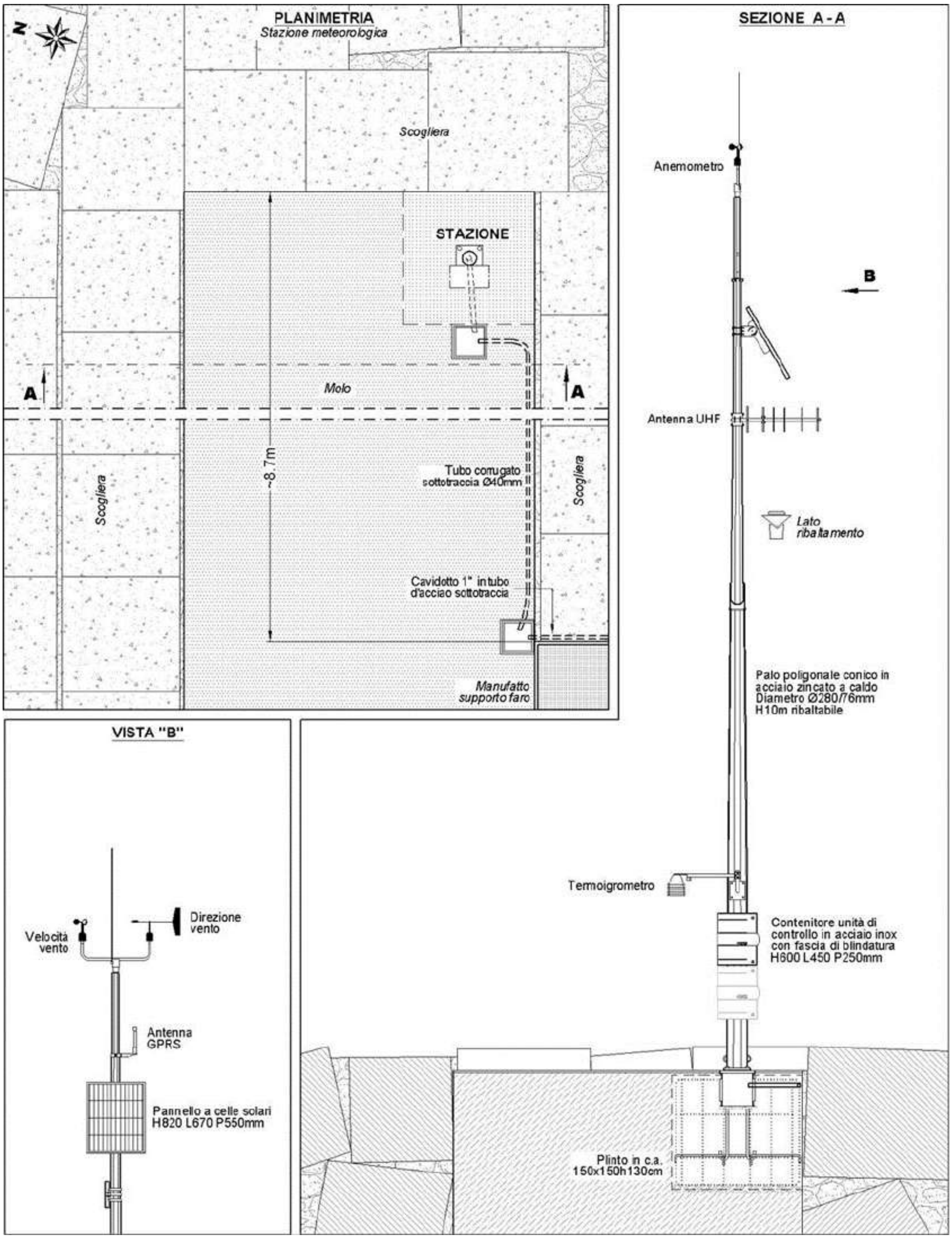

| **Coordinate System::**<br>**UTM/WGS84**<br>**EPSG:32632** | | **Coordinate System::**<br>**Monte Mario /Gauss – Boaga**<br>**EPSG:3004** | |
|---|---|---|---|
| *Zona:* | 33 T | *Zona:* | 2 |
| *Nord:*<br>*Est:* | 4650145.97 m 500254.79 m | *Nord:*<br>*Est:* | 4650151.814 m<br>2520263.321 m |

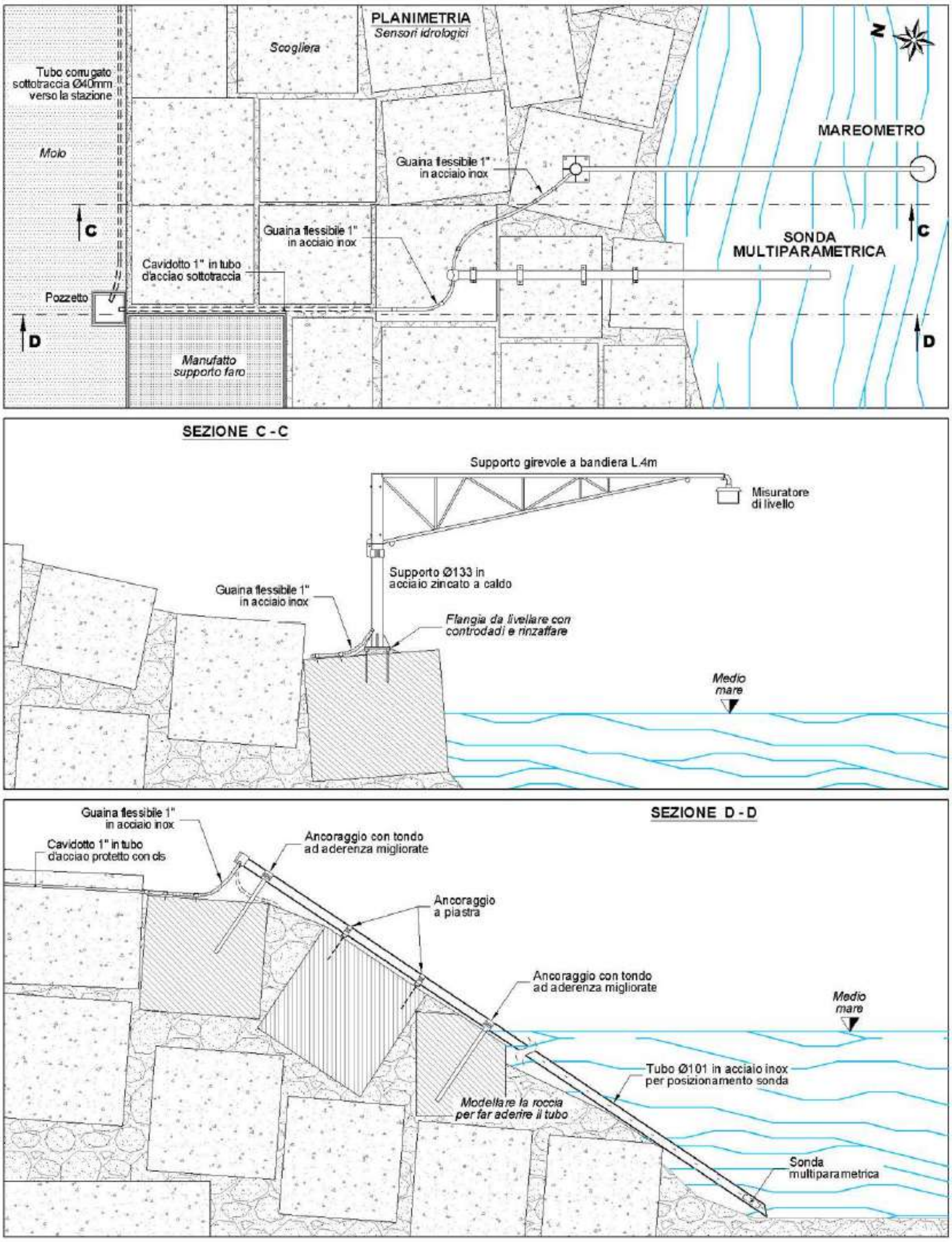
**Orthophotos of the site with equipment arrangement**

The tide gauge station is installed at the tourist port, south pier, of Termoli


STAZIONE
METEOROLOGICA
ONDAMETRO
SONDA
MULTIPARAMETRICA

**Project layout extracts**

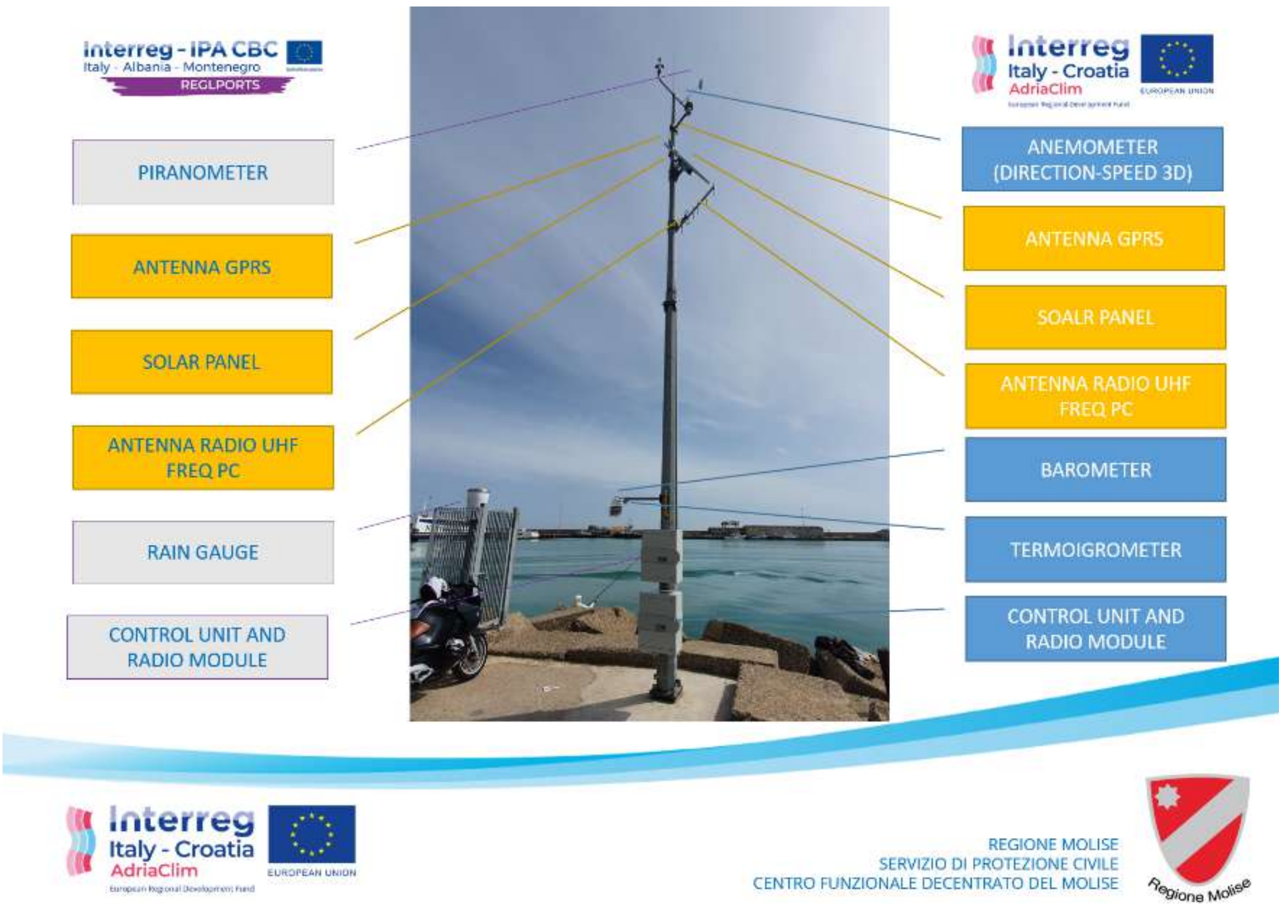



PLANIMETRIA
Sensori idrologici
Scogliera
Tubo corrugato sottotraccia Ø40mm verso la stazione
Molo
MAREOMETRO
Guaina flessibile 1" in acciaio inox
C
Guaina flessibile 1" in acciaio inox
SONDA MULTIPARAMETRICA
Cavidotto 1" in tubo d'acciaio sottotraccia
Pozzetto
D
Manufatto supporto faro
SEZIONE C - C
Supporto girevole a bandiera L.4m
Misuratore di livello
Supporto Ø133 in acciaio zincato a caldo
Guaina flessibile 1" in acciaio inox
Flangia da livellare con controdadi e rinzaffare
Medio mare
Guaina flessibile 1" in acciaio inox
SEZIONE D - D
Cavidotto 1" in tubo d'acciaio protetto con cls
Ancoraggio con tondo ad aderenza migliorate
Ancoraggio a piastra
Ancoraggio con tondo ad aderenza migliorate
Medio mare
Tubo Ø101 in acciaio inox per posizionamento sonda
Modellare la roccia per far aderire il tubo
Sonda multiparametrica

**Installation details**

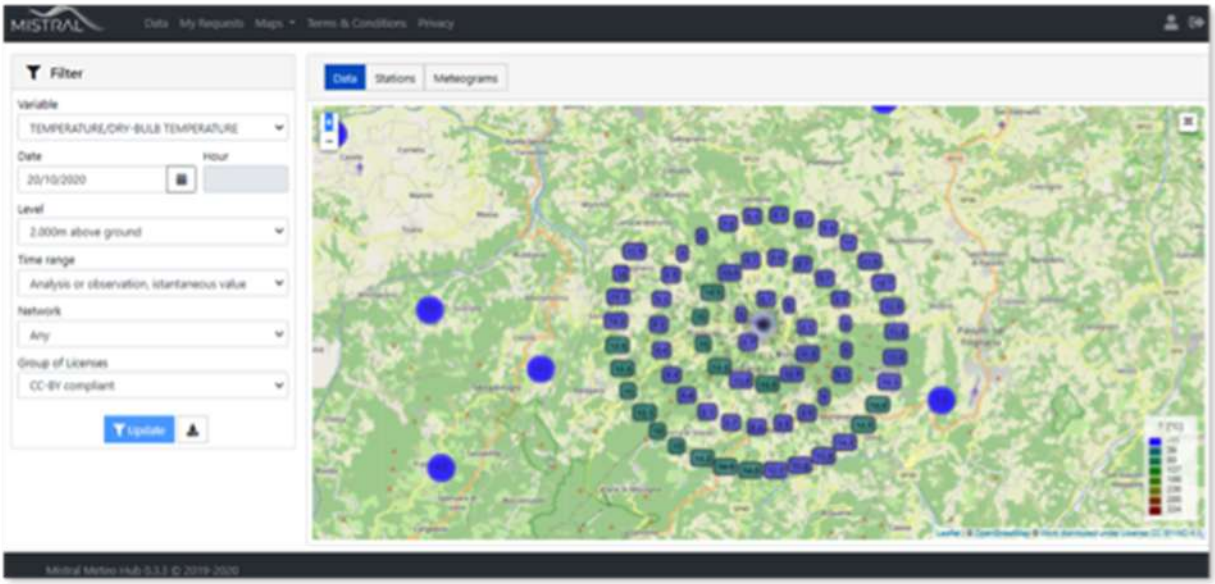
## 10.3 Integration with the existing observing systems

The marine weather and water quality station of Termoli port built with the ADRIACLIM project has been included in the regional and national network of Functional Centres. It is currently viewable with all the history of the Database of data recorded on the DEWETRA platform, available to all Regions and to the Civil Protection Department (reserved access). The data recorded with an eight-day history are free for access on the Meto HUB platform created with the MISTRAL project.




Interreg Italy - Croatia AdriaClim
European Regional Development Fund
EUROPEAN UNION
WAVEMETER
(COMPLETE WITH ALL WAVE PARAMETERS)
MULTIPARAMETRIC PROBE WATER QUALITY:
Water temperature
Conductivity (Sv/cm)
pH
Level (m)
Dissolved oxygen (mg/l)
REDOX potential (mV)
Turbidity (NTU)
Interreg Italy - Croatia AdriaClim
European Regional Development Fund
EUROPEAN UNION
REGIONE MOLISE
SERVIZIO DI PROTEZIONE CIVILE
CENTRO FUNZIONALE DECENTRATO DEL MOLISE
Regione Molise


Termoli Porto PRC
PRECIPITAZIONE
LIVELLO IDROMETRICO
TEMPERATURA ARIA
UMIDITÀ ARIA
DIREZIONE DEL VENTO
PRESSIONE ATM
RADIAZIONE


MISTRAL
Filter
Variable
TEMPERATURE/DRY-BULB TEMPERATURE
Date
Hour
Level
Time range
Network
Group of Licenses
CC-BY compliant
Data
Stations
Meteograms

## List of Tables



## List of Figures

## Web sites and data portals

- CNR-ISMAR Meteomarine unified network: http://rmm.dati.ismar.cnr.it/
- CNR-ISMAR real time sea level data: data portal of the I-STORMS project (https://iws.seastorms.eu/)
- ARPA VENETO institutional website as historical data and real-time data:
  https://www.arpa.veneto.it/dati-ambientali/dati-storici
  https://www.arpa.veneto.it/dati-ambientali/dati-in-diretta/meteo-idro-nivo/variabili_meteo
- ISPRA Meteo-marine physical parameters: https://www.venezia.isprambiente.it
- ARPAE regional and Adriatic monitoring systems: open data at https://simc.arpae.it/dext3r/, (near)real-time https://www.arpae.it/it/temi-ambientali/mare/dati-e-indicatori/rete-di-monitoraggio-meteo-marina, and www.arpae.it
- IOF: measuring stations are available online at http://faust.izor.hr/autodatapub/postaje?jezik=eng

- Molise Region and Civil Protection – CFD Molise: database of data recorded on the DEWETRA platform, available to all Regions and to the Civil Protection Department (reserved access), and 8-day data are free to access on the Meto HUB platform created with the MISTRAL project www.mydewetra.org