

D8.9 - Report on the available information on downstream environmental and climate change effects, including identification of knowledge gaps.



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Author(s) (Partner-OU):	Nydia Catalina Reyes Suarez (OGS-OCE), Alessandra Giorgetti (OGS-OCE), Alexia Cociancich (OGS-OCE), Alessandro Altenburger (OGS-OCE), Rachele Franceschini (OGS-GEO), Giuliana Rossi (OGS-GEO)
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Terminology

Terminology /Acronym	Description
BGC	Biogeochemical
D4Science	Data Infrastructure hosting +175 Virtual Research Environments to serve the biological, ecological, environmental, social mining, culture heritage, and statistical communities world-wide.
EMSO	European Multidisciplinary Seafloor and water column Observatory
GOT	Gulf of Trieste
ICOS	Integrated Carbon Observation System
ICOScp	ICOS Carbon Portal python library
ITINERIS	Italian Integrated Environmental Research Infrastructures System
MAMBO	Monitoraggio AMBientale Operativo, Operational environmental monitoring
NRT	Near real time
ODV	Ocean Data View software package
RI	Research Infrastructure
S	Salinity
T	Temperature
UC	Use Case
VRE	Virtual Research Environment

SUMMARY

This deliverable will focus on the available information on downstream environmental and climate change effects and the identification of knowledge gaps. Downstream effects of climate and environmental change involve all domains and necessarily require a systemic approach. The Virtual Research Environment (VRE) [1] on downstream effects of environmental change (DOWNSTREAM VRE) is dedicated to the use of Research Infrastructures (RI) data on the nexus of climate and environmental change effects, carbon, and Earth System response to provide tools for the visualisation, analysis, and sharing of data provided by the different RI, focusing on the impact of environmental change in the marine and terrestrial domain. For this purpose, two toolboxes will be developed and deployed in the VRE, one for the marine domain and one for the terrestrial domain.

1. DATA INFRASTRUCTURE

D4Science [2] is a Hybrid Data Infrastructure combining over 500 software components and integrating data from more than 50 different data providers into a coherent and managed system of hardware, software, and data resources. The D4Science infrastructure drastically reduces the cost of ownership, maintenance, and operation thanks to the exploitation of gCube. As an infrastructure, D4Science offers a rich array of services to its end users directly or to Infrastructure Managers and Service Providers [3]. D4Science is connecting +18.000 scientists in +50 countries, integrating +50 heterogeneous data providers, executing +50,000 models & algorithms per month, and providing access to over a billion quality records in repositories worldwide. D4Science also hosts +175 Virtual Research Environments to serve the biological, ecological, environmental, social mining, culture heritage, and statistical communities world-wide.

The downstream VRE from the ITINERIS project is one of the 7VREs/Vlabs hosted by the D4Science infrastructure [2], [4]. The following link points to the ITINERIS gateway in D4Science: <https://itineris.d4science.org/group/itineris-gateway>.

1.1 Workspace

The workspace service is a key component of every D4Science-based VRE and VLab. It resembles a typical file system with items organised in folders. Internally, it supports an open-ended set of items that (i) contain rich and extensible metadata and (ii) rely on an array of storage solutions. The Workspace is fully integrated with the rest of the services of a VRE/VLab (Figure 3) to facilitate access to and store new content [2], [5]. The graphical user interface of the ITINERIS Workspace is shown in Figure 1.

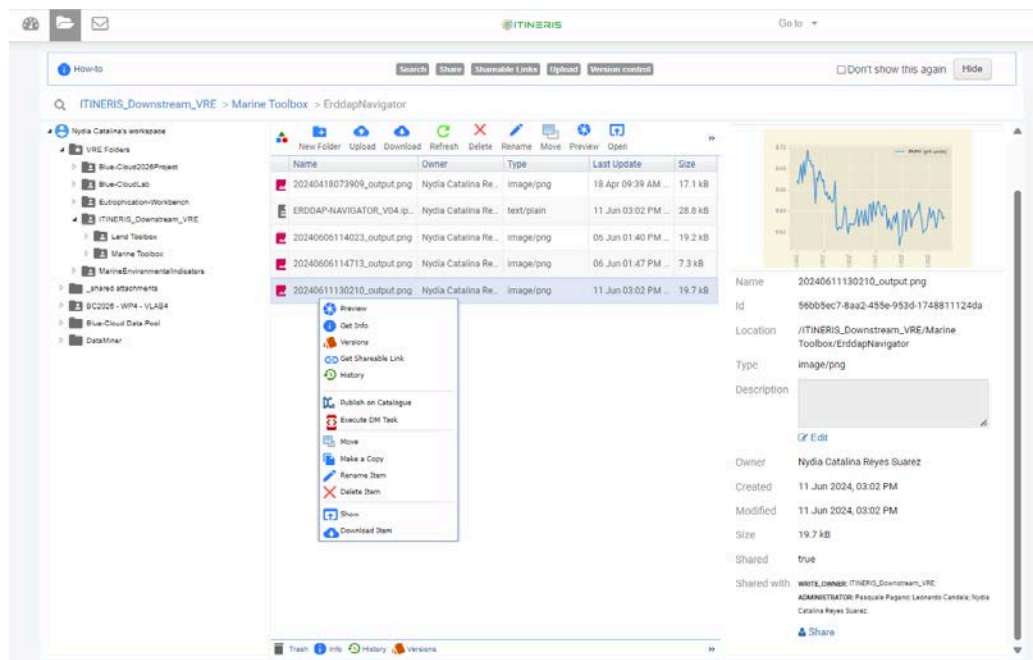


Figure 1. ITINERIS Workspace graphical user interface hosted at D4Science data infrastructure accessed through the ITINERIS gateway.

The workspace content is organised in folders. Two types of a folder are supported:

- VRE folder: paired with a VLab and available to all VLab members;
- plain folder created by a user and either accessible only to her/him or shared with other users.

For every workspace element, either a folder or an item, it is possible to see some metadata (e.g., a name, a description, creation, and update dates) and possibly a preview of its content. Moreover, it is possible to create links (as URI's) pointing to it. For folders, it is possible to create links as well enabling those who receive it to access the folder in “guest mode”, and no login will be requested [5].

1.2 JupyterHub

JupyterHub is a web-based interactive development environment for Jupyter notebooks, code, and data. It allows users to configure and arrange the user interface to support a wide range of workflows in data science, scientific computing, and machine learning.

The ITINERIS VRE makes the JupyterHub accessible on the D4Science infrastructure ensuring its operation and orchestration in a cluster, which is made by multiple hosts assigned exclusively to a user for an entire online session. JupyterHub uses ephemeral storage. The content locally stored is removed at the end of each session. All the data, scripts, and other resources that the user needs to persist must be stored in the

Workspace that is accessible through JupyterHub [5]. Currently, for the DOWNSTREAM VRE the following server options are offered (Figure 2):

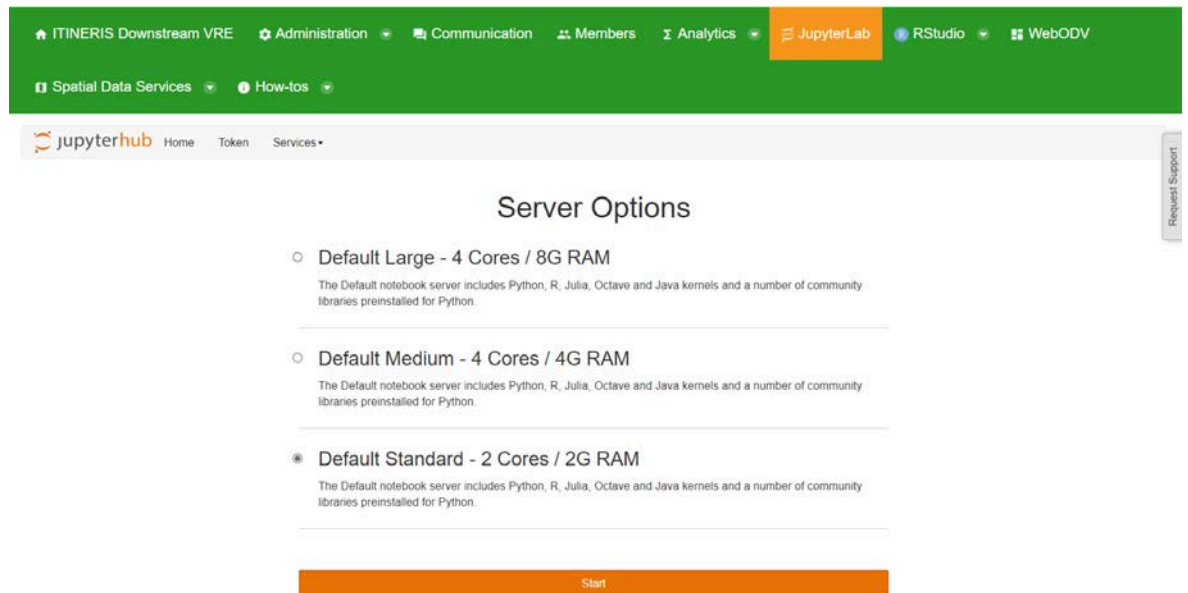


Figure 2. JupyterHub server options and workspace.

2. DOWNSTREAM VRE

The DOWNSTREAM VRE is dedicated to the use of OGS and RI data on climate, carbon, and environment response nexus to provide services for the visualisation, analysis, and sharing of data provided by the different RIs, if available. Particular emphasis will be given to the integration of data streams originated by OGS participation in marine infrastructures in a data set accessible through a common access point for experimental observations referring to the Adriatic Sea and for products derived from their integration/elaboration. There will be a focus on the available information useful to derive a budget of the carbon cycle and acidification, or some of its components. As a test, the activity will point to a specific area, in this case the North Adriatic sea for the marine domain. When enough information is available, a first-order quantitative assessment of the carbon cycle and acidification will be provided, highlighting critical gaps.

There will be a focus on the possible effects of climate change on the pilot test sites. Based on an inventory of landslides and available data, considering different models for the expected climate changes in the region (and the consequent modification of the identified proxies), scenarios will be carried out to estimate their downstream impact on landslide susceptibility, taking into account uncertainties.

The toolboxes within the VRE are subdivided in two domains: Marine domain toolbox and Land domain toolbox as follows.

2.1 MARINE DOMAIN

The marine domain toolbox will take advantage of the data available in the following RI's: ICOS, EMSO-ERIC and EURO-ARGO in order to generate an integrated dataset for PH, pCO₂ and fCO₂. Once the data is harvested a subsequent data validation and merging will be performed, where the integrated dataset will be used to calculate climate change indicators such as ocean acidification and ocean carbon cycle budget for the north adriatic sea with focus on OGS data for the last 10 years as use case. Figure 3 depicts the general workflow of the marine toolbox.

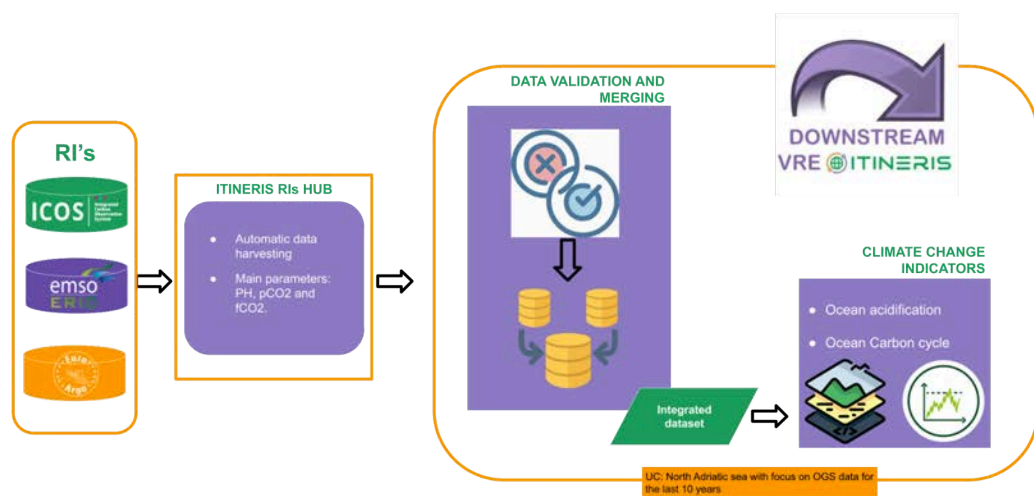


Figure 3. Marine domain toolbox workflow.

2.1.3 Background

A decrease in surface ocean pH (i.e., ocean acidification) is primarily a consequence of an increase in ocean uptake of atmospheric carbon dioxide (CO₂) concentrations that have been augmented by anthropogenic emissions [6]. Ocean acidification is thus an ongoing source of concern due to its strong influence on marine ecosystems ([7], [8]). Tracking changes in yearly mean values of surface ocean pH at the global scale has become an important indicator of both ocean acidification and global change ([9], [10]). In line with a sustained establishment of ocean measuring stations and thus a rapid increase in observations of ocean pH and other carbonate variables (e.g. dissolved inorganic carbon, total alkalinity, and CO₂ fugacity) since the last decades, recent studies ([11], [12], [13]) have put attention on analysing secular trends of pH and their drivers from time-series stations to ocean basins.

2.1.4 Data availability for the Use Case

Reviewing data availability for PH, pCO₂, fCO₂, within the different RIs in their respective data portals for the North Adriatic Sea produced the following results (Table 1):

RI	Data portal/server	Result
EMSO ERIC	- ERDDAP - Home Page (emso.eu) and - EMSO - Data Portal	No data available
Euro-Argo ERIC	- Argo Data access - Euro-Argo ERIC - Argo Fleet Monitoring - Euro-Argo	No data available
ICOS	ICOS data search (icos-cp.eu)	2 stations: - MIRAMARE (IT-FOS-MIRAMARE) and, - PALOMA (IT-FOS-PALOMA)

Table 1. Data availability in the different data portals.

Only the ICOS portal produced results for the north Adriatic and only one of the 2 stations has data from OGS (Figure 4).

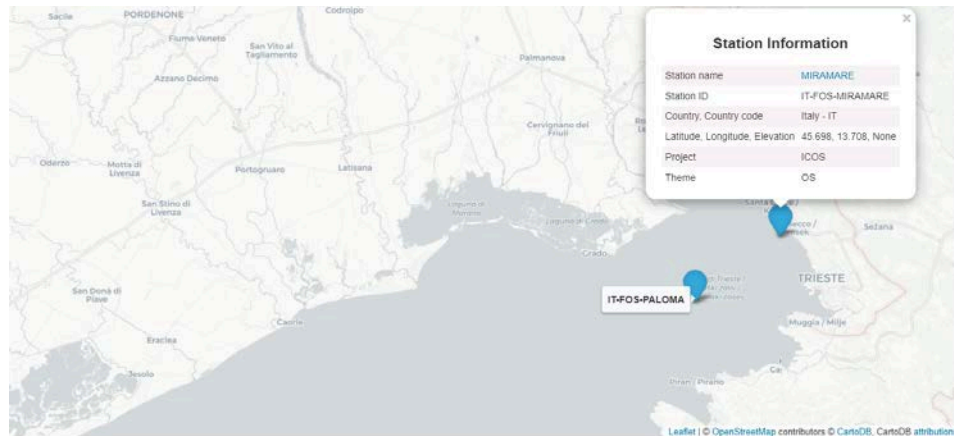


Figure 4. ICOS available stations for the North Adriatic Sea. The plot has been generated using the ICOScp python library in the downstream VRE.

The ICOS Carbon Portal Python library (ICOScp python library [14], [15]) for direct access to ICOS time series has been implemented in the VRE. It showed that only fCO₂ and pCO₂ data from the selected station (IT-FOS-MIRAMARE) was available, thus for pH another broker or data provider was needed. OGS NODC's ERDDAP provides access to the latest oceanographic data collected by OGS at fixed stations. Accordingly, the ERDDAPY [16] library and the ERDDAP-navigator were implemented, and it was found that the data from the MAMBO1-MIRAMARE station (nodc.ogs.it/erddap), decoded in ICOS as IT-FOS-MIRAMARE, contain records of pH, as well as pCO₂ and fCO₂ (Figure 5). Other stations such as MAMBO2, MAMBO3 and MAMBO4 also produced results for pH, but are not part of the ICOS network (Figure 5).

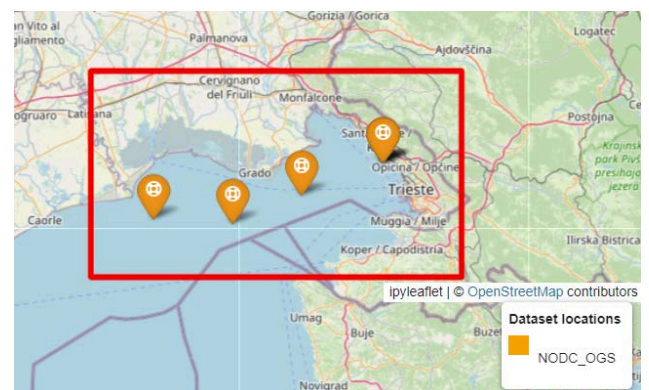
```
[6]: min_time = "2013-01-01T00:00:00Z"
max_time = "2024-05-31T23:00:00Z"
min_lon, max_lon = 13, 13.9
min_lat, max_lat = 45, 46
standard_name = "sea_water_ph_reported_on_total_scale"

constraints = {
    "standard_name": standard_name,
    "min_lon": min_lon,
    "max_lon": max_lon,
    "min_lat": min_lat,
    "max_lat": max_lat,
    "min_time": min_time,
    "max_time": max_time,
    "cde_data_type": "timeseries",
}

[7]: e.response = "csv"
search_df = pd.read_csv(e.get_search_url(response="csv", **constraints))
search_df = search_df[['Institution', 'Dataset ID', 'tabledap']]
search_df

[7]:
```

	Institution	Dataset ID	tabledap
0	National Institute of Oceanography and Applied...	MAMBO1_SBE16PLS01	https://nodc.ogs.it/erddap/tabledap/MAMBO1_SBE...
1	National Institute of Oceanography and Applied...	MAMBO1_SEAFET	https://nodc.ogs.it/erddap/tabledap/MAMBO1_SEAFET
2	National Institute of Oceanography and Applied...	MAMBO1_2021_2023_TS	https://nodc.ogs.it/erddap/tabledap/MAMBO1_202...
3	National Institute of Oceanography and Applied...	MAMBO1_TS	https://nodc.ogs.it/erddap/tabledap/MAMBO1_TS
4	National Institute of Oceanography and Applied...	MAMBO2_TS	https://nodc.ogs.it/erddap/tabledap/MAMBO2_TS
5	National Institute of Oceanography and Applied...	MAMBO3_TS	https://nodc.ogs.it/erddap/tabledap/MAMBO3_TS
6	National Institute of Oceanography and Applied...	MAMBO4_TS	https://nodc.ogs.it/erddap/tabledap/MAMBO4_TS



2.1.5 MAMBO1-MIRAMARE BUOY

The MAMBO1 buoy is part of the Coastal marine observatory site Gulf of Trieste (GOT) which is designed for long term monitoring of ecological and Oceanographic processes in the northernmost part of the Adriatic Sea [17]. The Gulf of Trieste (Figure 6), is under the influence of the Isonzo river and the inflow of southern waters from the Ionian basin. Another important feature of this area is the physical pump during winter dense water formation [18]. The operational history of this station dates back to 1999 till present [17].

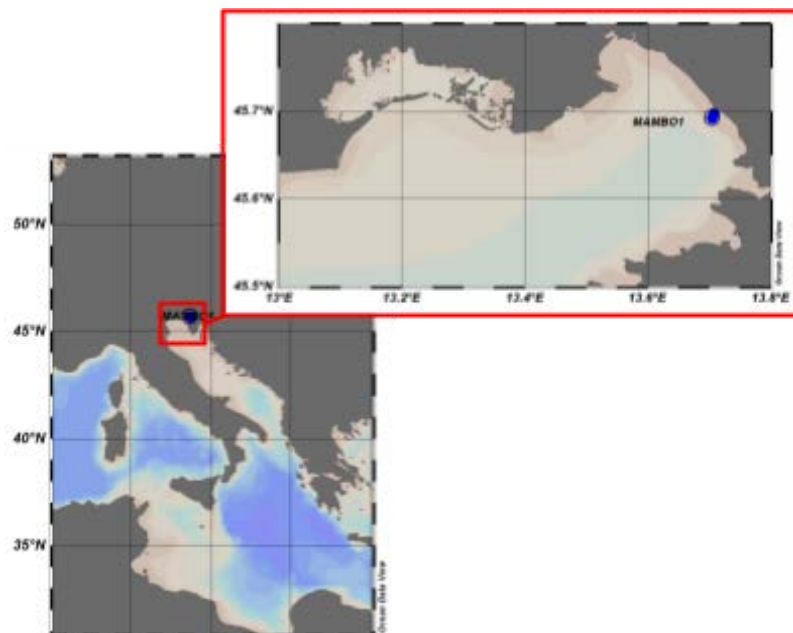


Figure 6. UC area and position of MAMBO1-MIRAMARE buoy. The plot has been created using ODV [19]

The MAMBO Miramare buoy site offers a multidisciplinary pilot platform suitable for the testing and experimentation of sensors and instrumentation. The buoy is easily accessible from the land and moored in a Marine Protected Area, it has its own power supply by means of solar panels and batteries. It is equipped with the following instrumentation (Figure 7) providing data in near real time (NRT):

- weather station R.M Young Company (wind speed and direction, temperature, pressure and humidity).

- system for the study of the carbon cycle, placed at a depth of 1.5m and consisting of pCO₂ Pro-Oceanus sensor, pH SeaFET sensor, CT SBE37-ODO with optical oxygen sensor.
- SBE16 multi-parameter probe, located at a depth of 10 m, consisting of CTD, dissolved oxygen sensor, pH, fluorescence, turbidity and irradiance.
- SBE16 multiparameter probe at a depth of 15 m consisting of CTD, dissolved oxygen sensor, and pH.

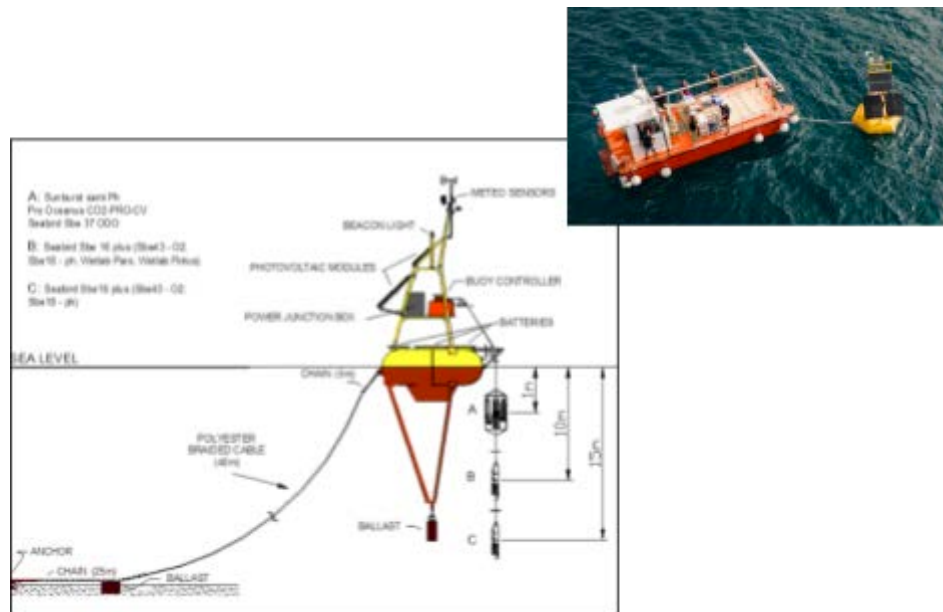


Figure 7. MAMBO1-MIRAMARE buoy sea view and instrumentation setup courtesy of ICOS project [17], [20].

2.1.5.1 ICOScp and ERDDAPY library for GOT data availability

ICOS data available from the ICOS data portal were plotted using the ICOScp Python library in the downstream VRE. This library provides full metadata and partial data access to the data hosted at the ICOS Carbon Portal (<https://data.icos-cp.eu/>). A Jupyter Notebook was written to test the library and explore the data from MIRAMARE (IT-FOS-MIRAMARE) in the VRE. Figure 8 shows the data available for MIRAMARE station using the `dobj.variables` function, which provides access to all available variables, including the unit, a short description (type) and the 'landing page' for the format used.

[9]:		name	unit		type	format
0		TIMESTAMP	None		time instant, UTC	http://meta.icos-cp.eu/ontologies/cpmeta/iso86...
1		Temp [degC]	°C		water temperature	http://meta.icos-cp.eu/ontologies/cpmeta/float32
2		Temp [degC] QC Flag	None		quality flag (int)	http://meta.icos-cp.eu/ontologies/cpmeta/bmpChar
3		P_sal [psu]	psu		practical salinity	http://meta.icos-cp.eu/ontologies/cpmeta/float32
4		P_sal [psu] QC Flag	None		quality flag (int)	http://meta.icos-cp.eu/ontologies/cpmeta/bmpChar
5		pCO2 [uatm]	uatm	CO2 partial pressure (water), SST		http://meta.icos-cp.eu/ontologies/cpmeta/float32
6		pCO2 [uatm] QC Flag	None		quality flag (int)	http://meta.icos-cp.eu/ontologies/cpmeta/bmpChar
7		fCO2 [uatm]	uatm	CO2 fugacity (water), SST		http://meta.icos-cp.eu/ontologies/cpmeta/float32
8		fCO2 [uatm] QC Flag	None		quality flag (int)	http://meta.icos-cp.eu/ontologies/cpmeta/bmpChar

Figure 8. Dobj.variables output for the ICOS station IT-FOS-MIRAMARE

Extracting the station metadata we obtain the following output:

```
[20]: myStation = station.get('IT-FOS-MIRAMARE')
      myStation.info()

[20]: {'stationId': 'IT-FOS-MIRAMARE',
      'name': 'MIRAMARE',
      'theme': 'OS',
      'icosclass': '2',
      'siteType': 'Fixed Station',
      'lat': 45.698,
      'lon': 13.708,
      'eas': None,
      'firstName': 'Michele',
      'lastName': 'Giani',
      'email': 'mgiani@inogs.it',
      'country': 'IT',
      'project': ['ICOS'],
      'uri': ['http://meta.icos-cp.eu/resources/stations/OS_48MB']}

[21]: myStation.products()

[21]: 0
      0 Post-processed ocean observations archive
      1 ICOS OTC FOS NRT Product

[24]: myStation.data(level=1)

[24]:
```

	spec	datalevel	specLabel	station	dobj	timeStart	timeEnd	bytes	samplingheight
1	http://meta.icos-cp.eu/resources/cpmeta/icosOTC...	1	ICOS OTC FOS NRT Product	http://meta.icos-cp.eu/resources/stations/OS_48MB	https://meta.icos-cp.eu/objects/kvYm4zWqLf9L...	2023-10-17T00:00:24.448Z	2024-05-23T20:00:23.418Z	411146	

Figure 9. Metadata available for the ICOS station IT-FOS-MIRAMARE. The output was obtained using the ICOScp python library.

As shown in Figure 9, only one product is available, the ICOS OTC FOS NRT product and data availability spans from 2023-10-17T00:00:24.448Z til 2024-05-23T20:00:23.418Z. Parameters available for the NRT product are shown in Figure 10.

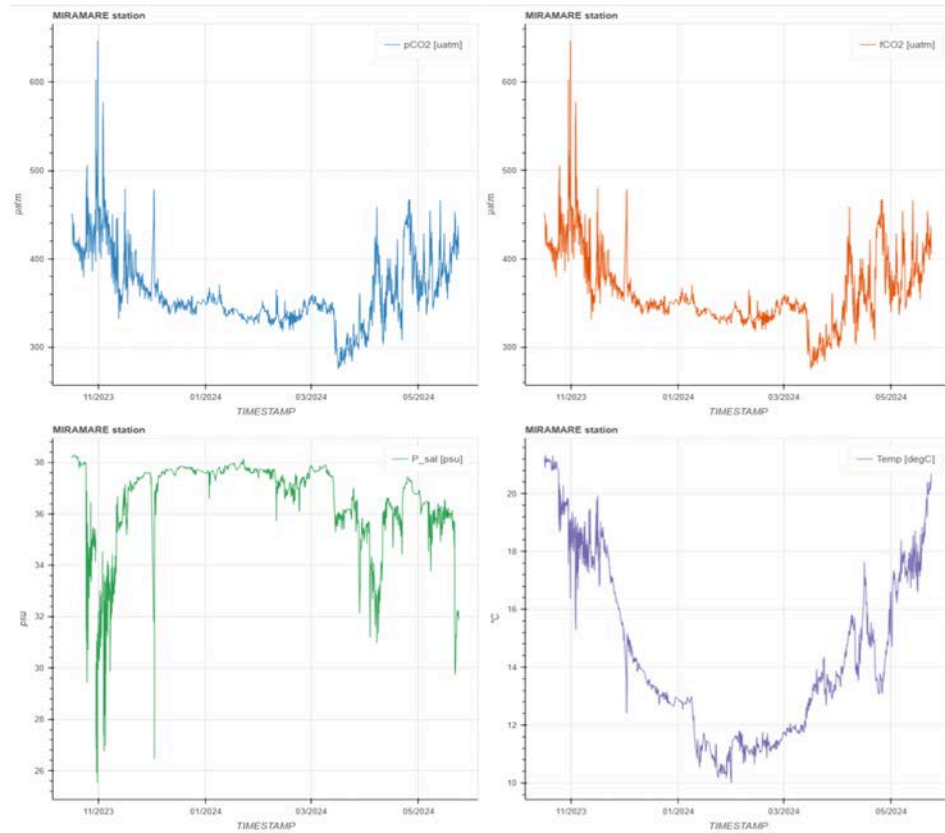


Figure 10. Parameters and data availability for the ICOS station IT-FOS-MIRAMARE.

2.1.5.2 ERDDAP navigator

ERDDAP_navigator is a python toolbox developed at the NODC that uses ERDDAPY and other python libraries to harvest data from different ERDDAP servers. We looked for pH, pCO2 and fCO2 within the ERDDAP list, where nodc.ogs.it/erddap/ give access to the datasets from MAMBO1. The time coverage spans 2021-01-01 to present, but the dataset is scattered in different sub-datasets as shown in Figure 5.

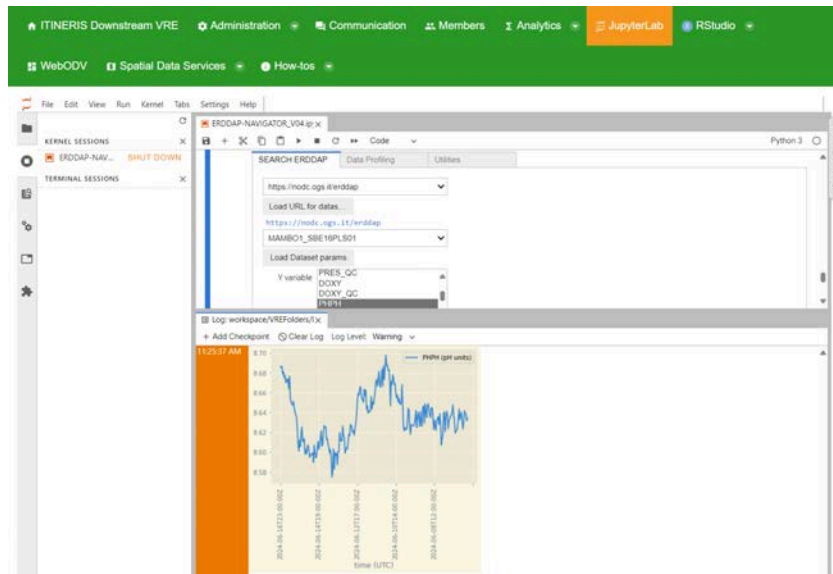


Figure 11. ERDDAP navigator running in the Downstream VRE

2.1.5.3 SeaDataNet

pH datasets were downloaded from SeaDataNet ([CDI - Marine data access \(seadatanet.org\)](http://CDI - Marine data access (seadatanet.org)), [21]) portal and treated with ODV desktop version 5.7.0. SeaDataNet is a pan-European infrastructure to ease the access to marine data measured by the countries bordering the European seas. Ocean Data View (ODV) is a software package for the interactive exploration, analysis and visualisation of oceanographic and other geo-referenced profile, time-series, trajectory or sequence data. Figure 12 shows the pH data distribution available since 2012 with removed outliers at different depths (instrument depths as in the MAMBO1 configuration, Figure 7).

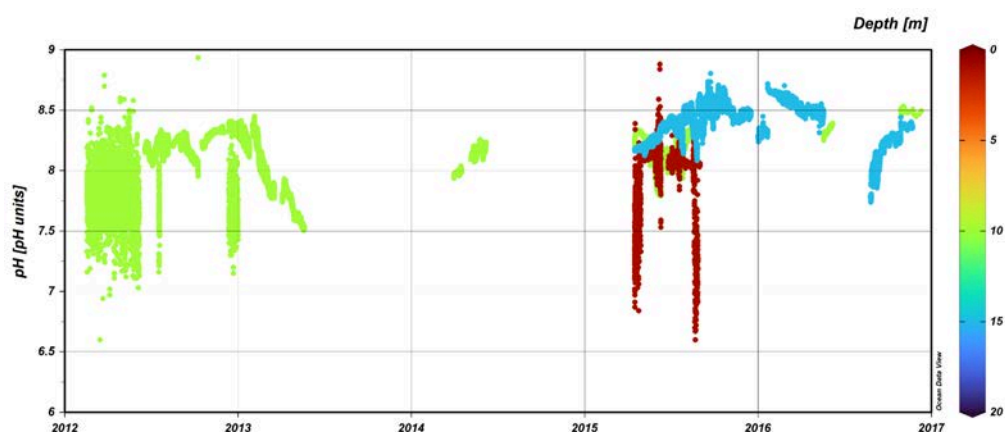


Figure 12. pH data distribution since 2012 in the SeaDataNet portal. The plot has been created using ODV v5.7.0 [19]. The colorbar represents the data at different depths.

As a further development, the VRE at the moment hosts an instance of the webODV application where some Argo (biogeochemistry, BGC and temperature, T and salinity, S), as well as SeaDataNet (TS) datasets are available. The idea would be to create the ODV collection of pH, fCO₂ and pCO₂ to be ready to use in the VRE for the user to do further analysis.

2.1.5.4 Carbon cycle budget and acidification, PYCOS2SYS toolbox

Coastal ecosystems are subject to multiple processes that drive pH change over time. Therefore, efforts to understand the variability in the coastal carbonate system are crucial to assess the marine ecosystem vulnerability to acidification [22]. By 2100, under the IPCC scenario of business as usual and without the effect of biological processes, pH is expected to decrease by ~0.3, yet not reach undersaturation values. Even though the northern Adriatic is characterised by high alkalinity buffering, pH seasonal variability will likely be more pronounced, due to the strong decoupling of production and respiration processes driven by stratification of the water column [22].

As a next development, once the dataset is quality controlled, gap filled and validated, we will implement the PyCO₂SYS which is a Python toolbox for solving the marine carbonate system [23].

2.2 LAND DOMAIN

The land domain aims to analyse areas subject to hydrogeological hazards, purely landslide phenomena. A web-gis will be implemented in this context. The web-gis that will enable an analysis of the spatial and temporal distribution of the instability is being realised. The data will be in raster and shape format for map visualisation and location of the event, and there will also be tabular data to obtain graphs useful for description (time series of the displacement).

The available monitoring systems (GNSS, inclinometers, GB-InSar or EGMS by Copernicus, extensometers, webcams, etc) will collect data in tabular form, which will be useful for reconstructing graphs and time series of displacements.

The synergy provided by the spatial and temporal data will provide the overall picture and evolution of the event in real-time (Figure 13).

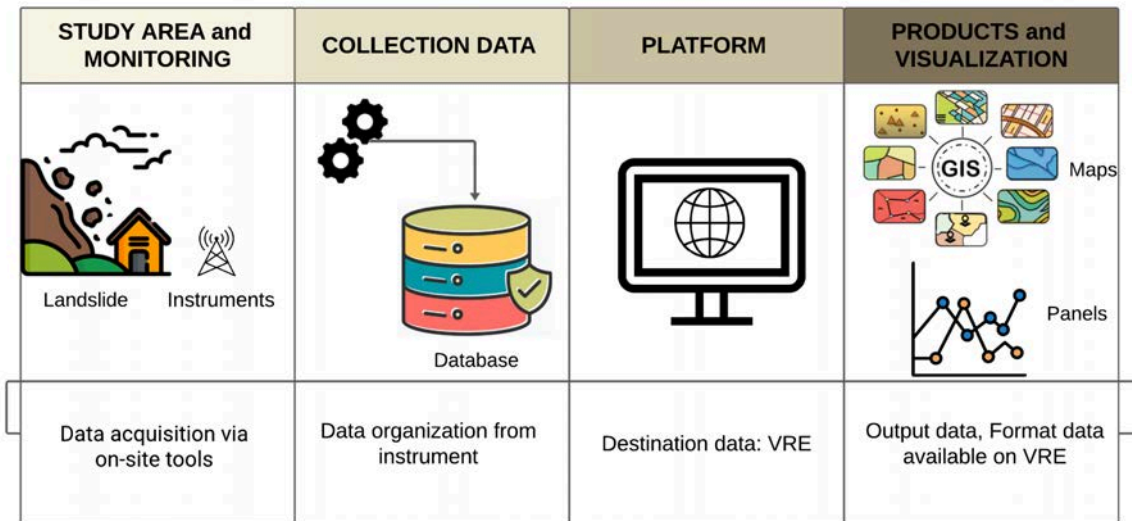


Figure 13. Land domain toolbox workflow.

2.2.3 Web-gis

A prototype web-gis was created within Downstream VRE (Figure 14). The Python language within Jupyter was used to build the prototype web-gis. The libraries implemented to load and process the data are as follows: pandas, geopandas, folium, matplotlib, io, and base64. Currently, three products have been tested and imported: shapefile, .csv, and .txt. The viewable formats are polygonal and point type. The possibilities of using the web-gis will be many, in addition to uploading files of various formats, it will be possible to obtain information of the uploaded data by querying or metadata the map.

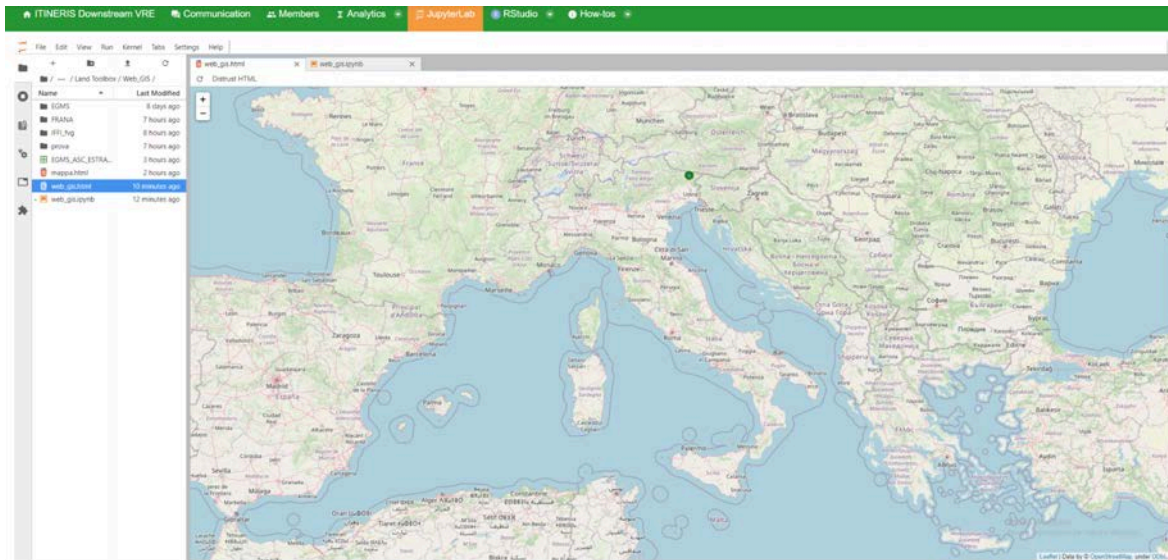


Figure 14. web-gis prototype.

A detail is shown in Figure 15, in which point and polygon-type products are represented. Currently, polygons and points are queryable within the prototype web-gis. Examples of landslide phenomena and interferometric data (EGMS) are currently uploaded within the prototype web-gis. Landslide phenomena come from the Inventory of Italian Landslide (IFFI - <https://idrogeo.isprambiente.it/app/page/open-data>) and consist of multiple metadata describing the gravity process. A detail can be seen in Figure 7. In this context and as an example, EGMS interferometric data from Copernicus (<https://egms.land.copernicus.eu/>) were loaded and classified according to the average annual strain rate (expressed in mm/year). The uploaded EGMS data are afferent to the Sentinel-1 constellation with an acquisition in ascending geometry for a time period from 2018 to 2022.

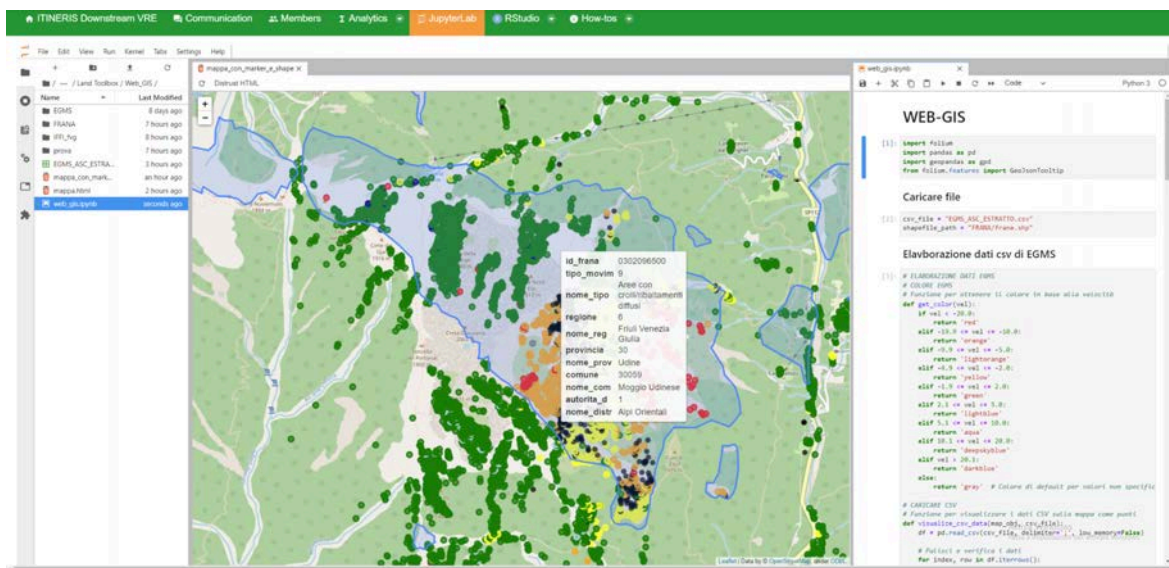


Figure 15. A detail within the web-gis prototype.

In addition to EGMS data in .csv format, an additional format was used for spatial and graphical reading and representation within the web-gis. In this sense, the time series of a GNSS installed in Codroipo was downloaded from the FReDNet network. The .txt format file consists of multiple metadata: location, deformation measurements, and time data.

The SMINO national infrastructure (Sistema di Montoraggio terrestre dell'Italia Nord-Orientale -Northeast Italy monitoring system) of the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale -OGS has the task of surveillance and research on seismic activity in North-eastern Italy, also for Civil Protection purposes. It consists of a seismic network, a strong motion network and the Friuli Regional Deformation network (FReDNet). The latter, formed by continuously operating Global Navigation Satellite System (GNSS) receivers monitors the crustal deformation along the northeast boundary of the Adriatic microplate, of the order of 5 mm/yr north-south convergence. The principal goals of the FReDNet program are to determine the distribution of deformation in this region, to estimate interseismic strain accumulation on its active faults to better assess seismic hazards, to monitor hazardous faults for emergency response management, and to provide infrastructure for geodetic data management and processing.

Figure 16 shows the GNSS point at the town Codroipo in Friuli Venezia Giulia. The GNSS point can be interrogated obtaining the recorded time series. This example demonstrates the potential of the web-gis portal which will allow, in the updated version, the possibility of having a graphical visualisation (plot).

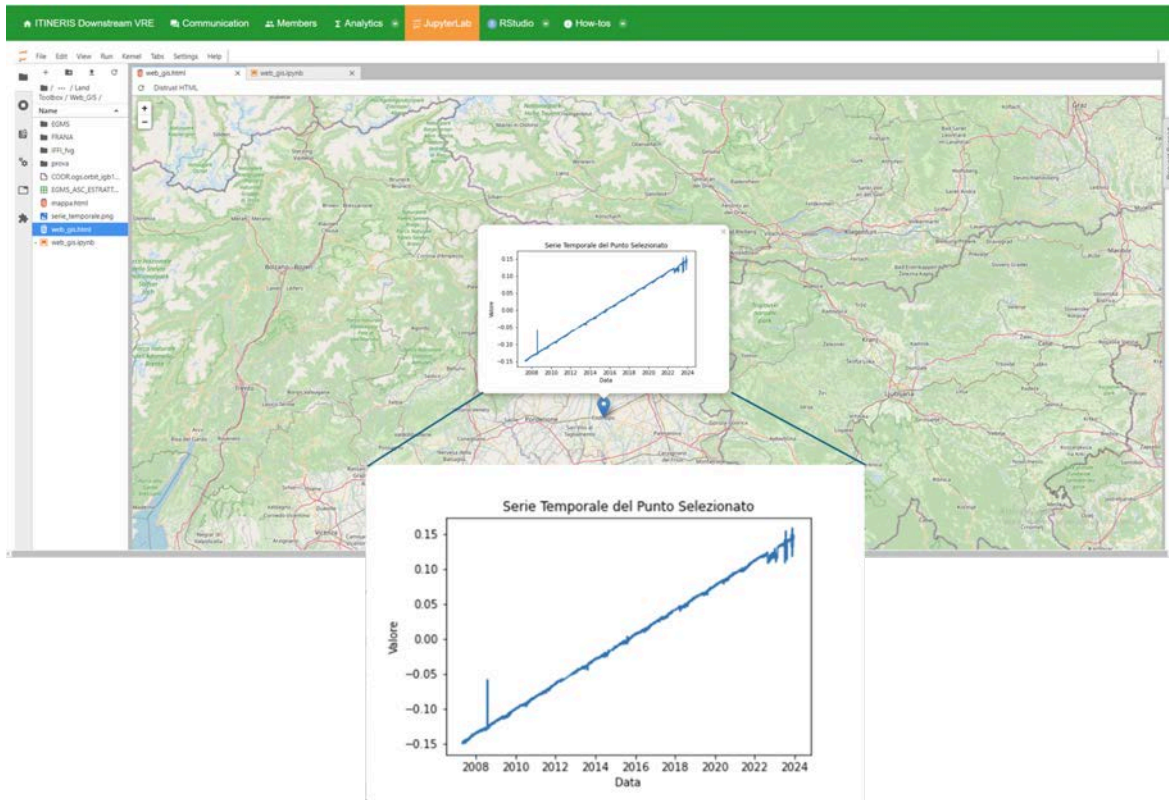


Figure 16. A detail within web-gis prototype with time series from GNSS.

The web-gis is currently a prototype for the data visualisation and queries and includes considerable limitations and gaps that need to be resolved in the near future. The portal currently works in the Python language. A knowledge of coding is required to upload and visualise. This feature results in a significant limitation in use, making the web-gis not user-friendly.

Moreover, at the moment, the uploaded data are afferent only to .csv, .txt, and shapefile formats with point and polygonal type representation. No additional formats, such as e.g. raster, have been implemented at the moment.

Presently, we considered plotting only time series, and no other type of statistical distribution. This aspect results in an additional limitation of analysis.

To resolve the limitations and gaps currently present, a geoserver within Downstream VRE must be implemented. In addition, the main objective is to make the use of web-gis easier and more intuitive for more stakeholders.

3. CONCLUSIONS

One of the biggest gaps in the marine domain concerns data access and the lack of the Marine Data Store for easy and centralised data harvesting. At the moment, there is no link between the ITINERIS data hub and the VRE and thus no direct data access for the UC. On the other hand, the data harvested from the existing data portals and brokers need to be quality controlled, integrated and validated, to overcome harvesting and data inhomogeneities. Further collaboration with ICOS RI would improve the data validation step for the data collections implemented using QuinCe [24]. Once all datasets have been harmonised and validated, they will be integrated within the webODV service, already available in the Downstream VRE. This will provide further data extraction, analysis, exploration and visualisation.

For the land domain, currently a prototype web-gis was created within Downstream VRE. Shapefile, .csv and .txt have been tested and imported within web-gis. Examples of landslide phenomena and interferometric data (EGMS) are currently uploaded within the prototype web-gis as polygons and points respectively. In addition, through interaction with a pop-up, it is possible to view the time series of displacement of a GNSS. The web-gis is currently a prototype for the data visualisation and queries and includes considerable limitations and gaps, such as python language, no additional format have been implemented, that need to be resolved in the near future.

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