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DTEclimate

Digital Twin Earth Intelligence for Climate Changes DTEClimate, ctr. nr. 760008/30.12.2022

Specific RDI Project 2: “Active measures for Restoring Sweer-Water Lakes and Coastal Areas affected by Eutrophication addressing the Enhancement of Resilience to Climate Change and Biodiversity” (ACT4-Eutrophication)

D2-2.1 Report on National, International and Global data sources, including satellite data regarding the Climate Change impact on the eutrophication of sweet-water lakes and Black Sea West coast waters

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Date: 30.04.2026

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Contents

1. Introduction

1.1 Scope

This document constitutes Deliverable D2-2.1 of the DTEClimate project (Specific RDI Project 2 – ACT4-Eutrophication). Its purpose is to systematically identify, catalogue, and characterize all national, international, and global data sources — including satellite Earth Observation (EO) products — relevant to monitoring and assessing the impact of climate change on the eutrophication of sweet-water lakes and Black Sea West coast waters.

The present structured compilation covers twelve (12) databases selected through a systematic review of available data infrastructures, their thematic relevance to eutrophication dynamics, and their technical compatibility with the DTEClimate Digital Twin Earth framework.

The scope of this deliverable encompasses:

- Satellite-based Earth Observation datasets;
- In-situ oceanographic and hydrological measurement archives;
- European and global marine data infrastructures;
- National Romanian hydrological and hydrographic datasets;
- Climatological reference atlases and historical marine meteorology records.

The primary areas of interest (AOI) addressed by this deliverable include:

- Black Sea West coast waters (Romanian Exclusive Economic Zone and coastal shelf);
- Dobrogea sweet-water lakes: Siutghiol;
- Bicaz Lake.

1.2 Document Overview

This document completely follows:

Chapter 1 outlines the purpose and scope of the deliverable, defining the specific areas of interest (AOI) such as the Black Sea West coast and Dobrogea lakes.
Chapter 2 lists the applicable and reference documents, while providing the project's technical abbreviations and definitions.
Chapter 3 gives a general description of the identified database inventory, including multi-dimensional classifications by theme, data type, and geographic/temporal coverage.
Chapter 4 presents the detailed characterisation sheets for each of the twelve national, international, and global databases selected for the project.
Chapter 5 describes the data integration framework, establishing the operational workflows and access prioritisation for the DTEClimate system.
Chapter 6 includes the traceability matrix, mapping each identified data source to specific project components and AI algorithms.

1.3 Applicable Documents

The following project documents contain provisions which, through reference in this text, become applicable to the extent specified in this document. For dated references, subsequent amendments to, or revisions of,

any of these publications do not apply.

[AD01]	Financing Agreement – DTEClimate Contract no. 760008/30.12.2022	CODE Issue:PNRR/MCID Date:
[AD02]	Application Form – PNRR ACT4-Eutrophication Specific Project 2	CODE Issue: DTEClimate Consortium Date:
[AD03]	Project Management Plan	CODE Issue: Date:
[AD04]	Technical Note on Use Case Scenarios and User Requirements	CODE Issue: Date:
[AD05]	Data Cube Report (Deliverable D3.x)	CODE Issue: Date:
[AD06]	Technical Note on Methods, Algorithms and Tools (Deliverable D4.x)	CODE Issue: Date:

1.4 Reference Documents

The following standards or documents are referenced in this document. Documents which are recognised best practices may be listed for the purpose of information.

[RD01]	Space engineering – Software, ECSS-E-ST-40C Rev.1. European Cooperation for Space Standardization
[RD02]	CF Conventions for NetCDF Climate and Forecast Metadata Convention (CF-1.10)
[RD03]	ISO 19115-1:2014 – Geographic information – Metadata – Part 1: Fundamentals
[RD04]	INSPIRE Directive 2007/2/EC – Infrastructure for Spatial Information in the European Community
[RD05]	EU Water Framework Directive 2000/60/EC – establishing a framework for Community action in the field of water policy
[RD06]	Copernicus Land and Marine Service Licence for Use of Copernicus Products, Version 1.2
[RD01]	Space engineering – Software, ECSS-E-ST-40C Rev.1. European Cooperation for Space Standardization

1.5 Abbreviations

AD: Applicable Documents
AI: Artificial Intelligence
AOI: Area of Interest
API: Application Programming Interface
DB: Database
DBMS: Database Management System

DIAS: Data and Information Access Services
DT: Digital Twin
DTE: Digital Twin Earth
EO: Earth Observation
FAIR: Findable, Accessible, Interoperable, Reusable
GIS: Geographic Information System
M2M: Machine-to-Machine
PMP: Project Management Plan
RD: Reference Documents
ABADL: Administrația Bazinală de Apă Dobrogea-Litoral (Water Administration of the Dobrogea-Littoral Basin)
ANCPI: Agenția Națională de Cadastru și Publicitate Imobiliară (National Agency for Cadastre and Land Registration)
C3S: Copernicus Climate Change Service
CMEMS: Copernicus Marine Environment Monitoring Service
CORA: Coriolis Ocean dataset for Reanalysis
ECMWF: European Centre for Medium-Range Weather Forecasts
EMODnet: European Marine Observation and Data Network
EOS: Earth Observation System
EOSDIS: Earth Observation System Data and Information System
GEMStat: Global Freshwater Quality Database
ICOADS: International Comprehensive Ocean-Atmosphere Data Set
INHGA: Institutul Național de Hidrologie și Gospodărire a Apelor (National Institute of Hydrology and Water Management)
NASA: National Aeronautics and Space Administration
NOAA: National Oceanic and Atmospheric Administration
PNRR: Planul Național de Redresare și Reziliență (National Recovery and Resilience Plan)
UNEP: United Nations Environment Programme
USGS: United States Geological Survey
WOA: World Ocean Atlas
WOD: World Ocean Database
Scientific and Environmental Variables
BOD: Biological Oxygen Demand
Chl-a: Chlorophyll-a
CTD: Conductivity, Temperature, Depth
DO: Dissolved Oxygen
MSI: MultiSpectral Instrument (Sentinel-2)
NDVI: Normalized Difference Vegetation Index
NDWI: Normalized Difference Water Index
SST: Sea Surface Temperature
TN: Total Nitrogen
TP: Total Phosphorus

1.6 Terms and Definitions

Use case scenario. It is a specific situation in your application domain in which a product or service (DTEClimate in this case) could potentially be used.

Areas of interest. Geographical location (delimited by all geographical coordinates) of the testing, validation and demonstration area (e.g. Siutghiol Lake, Bicaz Lake etc.)

Raw data. This is data collected from project external sources (e.g. EO products level 0/1, in situ measurements from environmental agencies, meteorological measurements)

Collected data. Specific data and measurements collected with the partner's methods, instruments and systems (e.g. seismic records, eutrophication parameters, mosquito traps, citizen information etc.)

Information layers. Information layers refer to results of an algorithm that is processing raw and collected data (e.g. EO products level 2, essential variables maps, statistic information, land cover parameters etc.).

Infrastructure. Internal or external to partner processors, algorithms, tools, data/information platforms that are needed to support the use case scenario.

Raw data: Information collected from external sources, such as **Earth Observation (EO)** products (Level 0/1) or meteorological measurements from environmental agencies.

Collected data: Specific measurements gathered using the project partners' own methods, instruments, and systems, such as eutrophication parameters or seismic records.

Information layers: The results of algorithms that process raw and collected data; these include Level 2 EO products, maps of essential variables, and statistical information.

Data Cube: A multi-dimensional data structure used to ingest, store, and process various data types (satellite, in-situ, and climatological) for **Satellite Image Time Series (SITS)** analysis and AI processing.

Satellite Image Time Series (SITS): An analysis pipeline that uses a multi-sensor archive (like Landsat, MODIS, and Sentinel-2) to detect long-term trends and changes in water quality.

Earth Observation (EO): Remotely-sensed imagery and derived geophysical products acquired by orbital sensors, including optical, thermal, and radar data.

In-situ Ocean / Hydrological Profiles: Direct measurements collected by ships, buoys, moorings, or gauge stations that provide vertical structure information (such as nutrient profiles) unavailable from satellites.

Climatological Reference / Gridded Atlases: Statistically derived multi-decadal means and fields on regular spatial grids, used as baselines for **anomaly detection**.

Vector Geospatial / Hydrographic Data: Authoritative national datasets representing physical features like river networks, lake boundaries, and coastlines, used for spatial masking and defining the computational domain.

Eutrophication: The process—monitored in sweet-water lakes and coastal waters—affected by climate change and characterized by changes in variables like **Chlorophyll-a**, nutrient levels (Nitrogen/Phosphorus), and dissolved oxygen.

2. Database Inventory Overview

This chapter provides a structured inventory and multi-dimensional analysis of all twelve (12) databases identified for the DTEClimate ACT4-Eutrophication specific project. The analysis is organised across six analytical dimensions: (i) consolidated summary listing; (ii) classification by thematic category; (iii) classification by data type and acquisition method; (iv) analysis of geographic and thematic coverage relative to DTEClimate areas of interest; (v) temporal coverage and historical depth assessment; and (vi) licensing, access modality, and data availability considerations. Together, these dimensions provide project stakeholders with the full analytical basis needed to plan data acquisition workflows, evaluate data gaps, and define integration priorities for the DTEClimate data cube and AI processing pipelines.

Table 1 provides a consolidated summary of all twelve (12) identified databases, their classification, spatial and temporal coverage, and licensing status. Detailed characterisation sheets for each database are provided in Section 4.

Table 1. Summary of Identified Data Sources for DTEClimate D2-2.1

ID	Database Name	Category	Coverage	Temporal Span	License
DB-01	Copernicus Climate Change Service (C3S) / Copernicus Marine Service (CMEMS)	European / Satellite & Reanalysis	Global / European focus	1950–present (reanalysis); near-real-time satellite	Open / Free (Copernicus Open Data Policy)
DB-02	EMODnet (European Marine Observation and Data Network)	European / Multi-thematic Marine	European seas (including Black Sea)	Variable by theme (historical to present)	Open / Free
DB-03	EOS Data Analytics Platform	Commercial / Cloud EO Analytics	Global	Present (multi-satellite archive)	Freemium / Commercial API
DB-04	GEMStat – Global Water Quality Database	Global / In-situ Water Quality	Global freshwater bodies	1970s–present	Open / Free
DB-05	NASA Earthdata	Global / Satellite & Airborne	Global	1972–present (Landsat); 1999–present (MODIS); 2011–present (VIIRS)	Open / Free (NASA Open Data)
DB-06	USGS EarthExplorer	Global / Satellite Archive	Global	1972–present (Landsat); various sensors	Open / Free
DB-07	WOD – World Ocean Database	Global / In-situ Ocean	Global oceans (including Black Sea)	1770–present	Open / Free
DB-08	WOA – World Ocean Atlas	Global / Climatological Atlas	Global oceans	Climatological means (WOA23: 1955–2022)	Open / Free
DB-09	CORA – Copernicus Marine In-Situ Observations (Coriolis Ocean dataset for Reanalysis)	European / In-situ Ocean	Global oceans (Black Sea subset available)	1950–present (quality-controlled historical archive)	Open / Free (Copernicus)
DB-10	data.gov.ro – Hidrografie	National /	Romania	Static / periodically	Open Government

ID	Database Name	Category	Coverage	Temporal Span	License
	(Romanian Open Government Data – Hydrography)	Hydrography		updated	License (Romania)
DB-11	INHGA – Institutul Național de Hidrologie și Gospodărire a Apelor	National / In-situ Hydrological & Meteorological	Romania	1950s–present (gauge network); real-time for some stations	Restricted / Request-based; some open datasets
DB-12	ICOADS – International Comprehensive Ocean-Atmosphere Data Set	Global / Historical Marine Meteorology	Global oceans	1662–present	Open / Free

3.1 Classification by Thematic Category

The twelve databases span five major thematic groupings, reflecting the multi-disciplinary nature of eutrophication monitoring: European satellite and reanalysis infrastructure, global satellite archives, global in-situ ocean and freshwater networks, European marine observation networks, and national Romanian institutional datasets. Table 2 presents the full breakdown by category.The twelve databases are distributed across the following thematic categories:

Table 2. Database classification by thematic category

Category	Database	ID
European / Satellite & Reanalysis	Copernicus (C3S, CMEMS)	**DB-01**
European / Multi-thematic Marine	EMODnet	**DB-02**
Commercial / Cloud EO Analytics	EOS Data Analytics	**DB-03**
Global / In-situ Freshwater Quality	GEMStat	**DB-04**
Global / Satellite & Airborne (NASA)	Earthdata	**DB-05**
Global / Satellite Archive (USGS)	EarthExplorer	**DB-06**
Global / In-situ Ocean Profiles	WOD	**DB-07**
Global / Climatological Atlas	WOA	**DB-08**
European / In-situ Ocean (Copernicus)	CORA	**DB-09**
National Romanian / Hydrography	data.gov.ro-Hidrografie	**DB-10**
National Romanian / In-situ Hydrology	INHGA	**DB-11**
Global / Historical Marine Meteorology	ICOADS	**DB-12**

Numerically, global-scope databases constitute the largest group (seven out of twelve: DB-03 through DB-09 and DB-12), reflecting the fact that eutrophication in Black Sea coastal and lacustrine environments is driven by atmospheric and oceanic processes of global scale. European-scope databases (DB-01, DB-02, DB-09) provide the most operationally relevant satellite and in-situ products, given their dedicated Black Sea coverage and Copernicus programme integration. National Romanian databases (DB-10, DB-11) are fewer in number but play a unique and irreplaceable role in providing the ground-truth and spatial reference data that cannot be obtained from global sources at adequate spatial resolution and temporal granularity.

3.2 Classification by Data Type and Acquisition Method

Beyond thematic category, databases differ substantially in their underlying data acquisition method and data type, which determines how they are ingested, processed, and combined within the DTEClimate data cube. Four primary data types are represented across the twelve databases:

Table 3. Database classification by Data Type and Acquisition Method

Data Type	Description	Databases (IDs)
Satellite / Earth Observation (EO)	Remotely-sensed imagery and derived geophysical products acquired by orbital sensors. Includes optical (ocean colour, multispectral), thermal (SST), radar, and reanalysis model output.	Copernicus C3S/CMEMS, EOS, Earthdata, EarthExplorer (DB-01, DB-03, DB-05, DB-06)
In-situ Ocean / Hydrological Profiles	Direct measurements collected by ships, buoys, moorings, Argo floats, CTD casts, and gauge stations. Provide vertical structure information unavailable from satellites.	WOD, CORA, GEMStat, INHGA (DB-07, DB-09, DB-04, DB-11)
Climatological Reference / Gridded Atlases	Statistically derived multi-decadal means and climatological fields on regular spatial grids. Used as baseline references for anomaly detection and model boundary conditions.	WOA, ICOADS, EMODnet (DB-08, DB-12, DB-02)
Vector Geospatial / Hydrographic	Authoritative national vector datasets representing hydrographic networks, lake boundaries, coastlines, and basin delineations. Used for spatial reference and AOI masking.	data.gov.ro-Hidrografie (DB-10)

Satellite EO sources are the highest-volume data type and form the backbone of the DTEClimate SITS (Satellite Image Time Series) analysis pipeline. In-situ sources serve a dual role: they calibrate and validate EO-derived products, and they provide sub-surface information (nutrient profiles, dissolved oxygen, discharge rates) that satellites cannot measure directly. Climatological atlases and gridded references are processed once into reference layers and used repeatedly across all algorithms. The vector hydrographic layer from data.gov.ro-Hidrografie serves as a structural input to all spatial processing, defining the computational domain for every other data source.

3.3 Geographic Coverage Relative to DTEClimate Areas of Interest

A critical evaluation criterion for this deliverable is the degree to which each identified database provides coverage over the four primary DTEClimate areas of interest (AOIs): the Black Sea West coast, the Dobrogea lacustrine system (Siutghiol, Techirghiol, Razim-Sinoe), the Danube Delta, and secondary inland reservoirs (Bicaz and others). Table 4 presents the coverage assessment for each database across the four AOIs.

Table 4. Geographic Coverage of Identified Databases by DTEClimate AOI

ID	Database	Black Sea W. Coast	Dobrogea Lakes	Danube Delta	Inland Reservoirs
DB-01	Copernicus C3S/CMEMS	Full	Full	Full	Partial
DB-02	EMODnet	Full	Partial	Partial	None
DB-03	EOS Analytics	Full	Full	Full	Full
DB-04	GEMStat	None	Partial	Partial	Partial
DB-05	NASA Earthdata	Full	Full	Full	Full
DB-06	EarthExplorer	Full	Full	Full	Full
DB-07	WOD	Full	None	Partial	None
DB-08	WOA	Full	None	None	None
DB-09	CORA	Full	None	Partial	None
DB-10	data.gov.ro-Hidro	Full	Full	Full	Full
DB-11	INHGA	Partial	Full	Full	Full
DB-12	ICOADS	Full	None	Partial	None

**Legend: Full = complete or near-complete spatial coverage of the AOI; Partial = limited station density, coarse spatial resolution, or only part of the AOI covered; None = no data available for that AOI.

The coverage analysis reveals that the Black Sea West coast is the best-covered AOI, with nine out of twelve databases providing full or near-complete coverage. This reflects the international scientific prominence of the Black Sea as a well-monitored semi-enclosed sea. Dobrogea lakes are covered at full resolution by five databases (Copernicus, EOS, Earthdata, EarthExplorer, data.gov.ro) and at partial resolution by two (GEMStat, INHGA), but not at all by the four ocean-centric databases (WOD, WOA, CORA, ICOADS) — which by design do not extend to freshwater inland systems. This constitutes the most significant coverage gap and underscores the critical importance of satellite EO sources and national monitoring networks for lacustrine eutrophication assessment. The Danube Delta is partially covered by nine databases but fully covered by only five, given its transitional freshwater-marine character which sits at the boundary of many database collection frameworks.

3.4 Temporal Coverage and Historical Depth Assessment

The temporal span of available data directly determines the capacity of the DTEClimate system to detect long-term eutrophication trends, distinguish climate-driven signals from natural variability, and reconstruct historical baseline conditions. Table 5. below summarises the temporal coverage of each database on a unified timeline.

Table 5. Temporal Coverage Summary by Database

ID	Database	Start Year	End / Status	Record Length	Update Freq.	Era Coverage
DB-12	ICOADS	1662	Present	>360 yrs	Periodic	Pre-industrial to present
DB-07	WOD	1770	Present	>250 yrs	Annual	Historical to present
DB-01	Copernicus C3S	1950	Present	>70 yrs	Daily/NRT	Post-WWII to present
DB-08	WOA	1955	2022	67 yrs	Decadal	Climatological means
DB-09	CORA	1950	Present	>70 yrs	Annual	Post-WWII to present
DB-11	INHGA	1950	Present	>70 yrs	Real-time	Post-WWII to present
DB-04	GEMStat	1970	Present	>50 yrs	Annual	Environmental era
DB-05	NASA Earthdata	1972	Present	>50 yrs	Daily/NRT	Satellite era
DB-06	EarthExplorer	1972	Present	>50 yrs	16-day	Satellite era
DB-02	EMODnet	1800	Present	>200 yrs	Variable	Historical to present
DB-10	data.gov.ro	N/A	Current	Static	Periodic	Current snapshot
DB-03	EOS Analytics	2015	Present	>10 yrs	Daily/NRT	Recent archive

From a temporal perspective, the twelve databases collectively span more than three centuries, from the earliest ICOADS ship-log records of 1662 to real-time satellite acquisitions. Three distinct temporal eras are relevant to the DTEClimate eutrophication analysis:

- Pre-satellite era (prior to 1972): covered exclusively by ICOADS, WOD, EMODnet, and CORA, which compile historical ship, buoy, and station measurements. These records are essential for establishing pre-industrial and early-industrial baselines against which current eutrophication levels can be assessed.
- Early satellite era (1972–1999): covered by NASA Earthdata and USGS EarthExplorer via the Landsat programme (Landsat 1–5, MSS and TM sensors). These archives provide medium-resolution (80 m to 30 m) imagery for the Dobrogea region, enabling detection of lake surface area changes and approximate water quality index evolution since the beginning of intensive agriculture in the Danube basin.

- Modern satellite era (1999–present): covered at high temporal and spectral resolution by MODIS (daily, 250–1000 m), Sentinel-2 (5-day, 10 m), VIIRS, and associated Copernicus CMEMS ocean colour products. This era aligns with the intensification of Black Sea eutrophication research and provides the densest observational record for algorithm training and validation.

The satellite era overlap between Landsat (1972–present), MODIS (1999–present), and Sentinel-2 (2015–present) creates a multi-sensor archive that, when cross-calibrated, supports continuous multi-decadal time series of eutrophication-sensitive optical properties (Chl-a, turbidity, coloured dissolved organic matter). The INHGA gauge network and CORA/WOD in-situ records provide the sub-surface and hydrological context necessary to interpret surface-observable signals in terms of physical and chemical drivers.

3.5 Licensing, Access Modality, and Data Availability

Data licensing and access conditions are of primary operational importance for the DTEClimate project, determining which databases can be integrated into automated data pipelines, shared across project partners, and published alongside project outputs. Table 6 provides a detailed breakdown of access modality, licensing type, and any known restrictions for each database.

Table 6. Licensing and Access Assessment

ID	Database	License Type	Access Method	Registration	Bulk Download
DB-01	Copernicus C3S/CMEMS	Open / Free	API, Web UI	Required (free)	Yes (CDS API)
DB-02	EMODnet	Open / Free	Web UI, WMS/WFS	Not required	Yes
DB-03	EOS Analytics	Freemium / Commercial	API, Web UI	Required	Licensed
DB-04	GEMStat	Open / Free	Web UI, CSV export	Required (free)	Yes
DB-05	NASA Earthdata	Open / Free	API, Earthdata Search	Required (free)	Yes (wget, API)
DB-06	EarthExplorer	Open / Free	Web UI, Machine-2-M	Required (free)	Yes (M2M API)
DB-07	WOD	Open / Free	Web UI, FTP	Not required	Yes
DB-08	WOA	Open / Free	Direct download	Not required	Yes
DB-09	CORA	Open / Free	Copernicus Marine API	Required (free)	Yes (motu client)
DB-10	data.gov.ro	Open Gov. License	Web UI, WMS/API	Not required	Yes
DB-11	INHGA	Restricted	Institutional request	Formal agreement	Partial / On request
DB-12	ICOADS	Open / Free	NCAR RDA, FTP	Required (free)	Yes

Of the twelve databases, ten (10) are fully open and freely accessible, constituting an 83% open-data rate for the identified inventory. This is a highly favourable licensing landscape for an EU-funded research project, as it means that the vast majority of required data can be integrated into automated pipelines without procurement procedures, contractual barriers, or redistribution restrictions. Free registration (account creation) is required by six of the ten open sources (Copernicus CDS, GEMStat, NASA Earthdata, EarthExplorer, CORA, ICOADS-NCAR), which is standard practice for usage tracking and does not constitute a substantive access barrier.

Two databases require specific attention from a data access management perspective:

- EOS Data Analytics (DB-03): Operates under a freemium model. Basic web interface access is free, but automated API access at the volumes required for operational SITS analysis may require a commercial licence. The project consortium should evaluate whether EOS API usage can be replaced by direct Copernicus or NASA data access for large-scale operational runs, reserving EOS for validation and exploratory analysis.
- INHGA (DB-11): Is the sole source of high-resolution, long-term in-situ hydrological data for Romanian rivers, lakes, and groundwater at a national level. Access requires a formal institutional data-sharing agreement between the DTEClimate partner institution (University of Constanta) and INHGA, to be processed through the Romanian Ministry of Environment. This agreement should be prioritised in the project's data management work package, as INHGA data is on the critical path for hydrological model calibration.

3.6 Identified Data Gaps and Recommendations

Despite the broad coverage provided by the twelve identified databases, a systematic gap analysis — conducted by cross-referencing the thematic, geographic, and temporal assessments above — reveals four areas where current data sources are insufficient to fully support the DTEClimate eutrophication monitoring objectives:

Table 7. Data Gaps and Recommendations

#	Gap Description	Affected AOIs	Recommended Action	Priority
G-01	Absence of high-frequency (sub-daily) in-situ water quality measurements for Dobrogea lakes. Current in-situ networks (GEMStat, INHGA) provide monthly or less-frequent sampling, which is insufficient to resolve short-lived algal bloom events.	Siutghiol, Techirghiol, Razim-Sinoe	Deploy autonomous water quality sensors (sonde arrays) as part of the Dobrogea Blue Bay Living Lab field infrastructure. Data to be ingested directly into the DTEClimate data cube.	High
G-02	Lack of sub-surface nutrient profile data (nitrate, phosphate, silicate) for the Dobrogea lacustrine system. WOD and CORA cover the Black Sea but not inland lakes.	Dobrogea Lakes, Danube Delta	Initiate systematic CTD and water column sampling campaigns coordinated with INHGA and the Living Lab. Explore partnership with ABADL (Water Administration of the Dobrogea-Littoral Basin).	High

#	Gap Description	Affected AOIs	Recommended Action	Priority
G-03	Limited historical satellite time series for lakes smaller than approximately 1 km2, which fall below the spatial resolution threshold of MODIS (250 m–1 km). Techirghiol and some Razim-Sinoe sub-basins are affected.	Techirghiol, Razim-Sinoe sub-basins	Integrate PlanetScope (3 m) or Sentinel-2 MSI (10 m) high-resolution imagery as a supplementary source. Evaluate Copernicus DIAS platforms for cost-effective access.	Medium
G-04	No dedicated atmospheric deposition dataset for the Dobrogea-Black Sea region. Nitrogen and phosphorus inputs from atmospheric deposition are a documented driver of Black Sea eutrophication but are not explicitly covered by any of the twelve identified databases.	Black Sea W. Coast, Dobrogea	Incorporate EMEP (European Monitoring and Evaluation Programme) atmospheric deposition data as DB-13 in a future inventory update. EMEP data is open-access and covers Romania.	Medium

The four identified gaps are manageable within the DTEClimate project framework. Gaps G-01 and G-02 can be addressed through the Living Lab field infrastructure and institutional partnerships, and are of highest priority as they directly affect the calibration and validation of the AI algorithms. Gap G-03 is a spatial resolution challenge addressable through integration of higher-resolution commercial or open satellite imagery. Gap G-04 represents a thematic extension that would strengthen the scientific completeness of the eutrophication driver analysis and is recommended for inclusion in a revised version of this deliverable (version 3.0) once EMEP data access has been confirmed.

4.Database Characterisation Sheets

This section provides a structured characterisation sheet for each of the twelve identified databases. Each sheet covers the full identification, access, licensing, content, and relevance information required for integration into the DTEClimate data infrastructure.

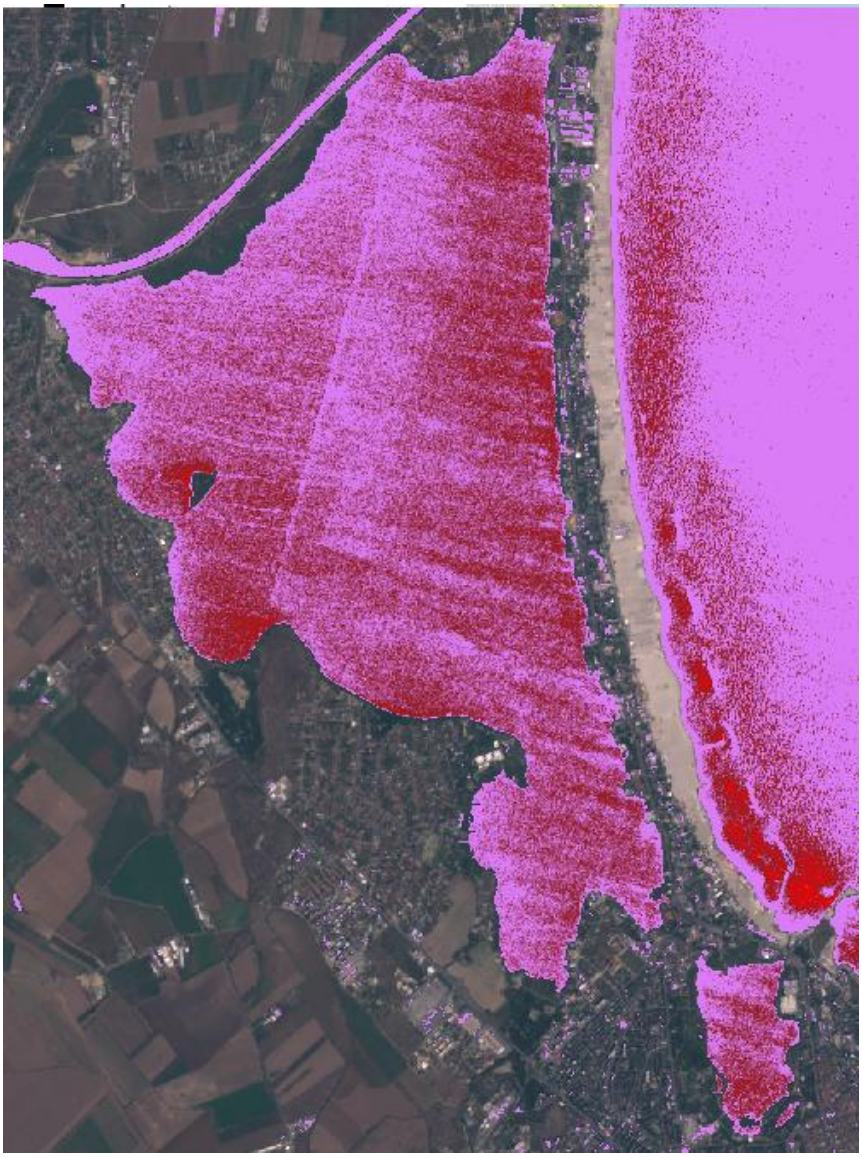


Figure 1 Copernicus Coloured Dissolved Orcanic Matter

4.1 DB-01 – Copernicus Climate Change Service

The Copernicus Data Base is the central access point for Europe's Earth Observation (EO) data, integrating satellite imagery, in-situ measurements, and model-based products. Developed under the EU Copernicus Programme, it provides free, open, and continuous environmental information supporting climate action, sustainable development, and evidence-based policymaking.

The Copernicus Data Base is a distributed, interoperable system that consolidates satellite imagery, in-situ measurements, and model-based products into a unified access environment. Its architecture is built around:

- **Sentinel Missions** providing systematic optical, radar, atmospheric, marine, and land monitoring data.
- **Thematic Copernicus Services** (Land, Marine, Atmosphere, Climate Change, Emergency, Security) that transform raw data into validated, user-ready products.
- **Data Access Platforms (DIAS)** offering cloud-based storage, processing, and API interfaces for large-scale data exploitation.
- **Standardized formats and metadata** (GeoTIFF, NetCDF, GRIB) ensuring interoperability with GIS, modelling tools, and digital twins.

This structure enables scalable, multi-temporal, and multi-thematic analysis across environmental domains.

The Copernicus Data Base provides a robust set of technical capabilities that support advanced environmental analysis:

- **High spatial and temporal resolution** through Sentinel missions (e.g., 10 m optical data, all-weather radar, daily marine coverage).
- **Cloud-based processing environments** enabling users to analyse large datasets without local infrastructure.
- **APIs and automated workflows** for programmatic data retrieval, time-series extraction, and integration into modelling pipelines.
- **Long-term archives** supporting historical trend analysis and climate assessments.
- **Quality assurance and validation** through harmonized calibration, cross-referencing with in-situ networks, and uncertainty quantification.

These functionalities make Copernicus suitable for operational monitoring, scientific research, and policy reporting.

Copernicus data supports a wide range of environmental, climate, and socio-economic applications:

- **Environmental Monitoring:**
  - Water quality (chlorophyll, turbidity, eutrophication)
  - Land degradation, soil moisture, vegetation dynamics
  - Urban expansion and land-use change

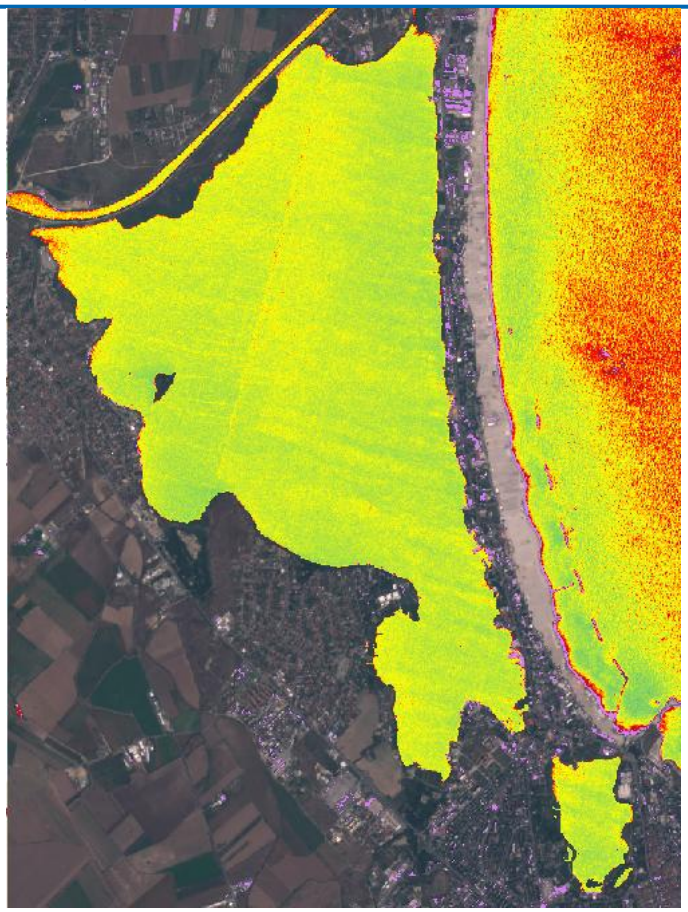


Figure 2 Copernicus True Color Index

- **Climate Change and Adaptation:**
  - Climate reanalysis (ERA5) and projections
  - Extreme event monitoring (heatwaves, droughts)
  - Risk assessments for adaptation planning.

Figure 3 Copernicus Turbidity

- **Marine and Coastal Management:**
  - Sea surface temperature, ocean colour, currents
  - Algal bloom detection
  - Coastal erosion and sediment transport
- **Emergency and Risk Management:**
  - Flood mapping
  - Wildfire detection
  - Rapid damage assessment
- **Regional Use Cases:**
  - Monitoring of lakes and coastal ecosystems (e.g., trophic state, shoreline dynamics)
  - Support for circular economy and green transition initiatives
  - Data-driven innovation within clusters and research networks

A standard workflow for accessing and using Copernicus data includes:

1. **Define the area of interest and thematic objective** (e.g., water quality, land cover).

2. **Select the appropriate Sentinel mission or Copernicus Service** based on required parameters.
3. **Access a DIAS platform** and search the catalogue using spatial, temporal, and thematic filters.
4. **Download or process data in the cloud environment**, depending on dataset size and complexity.
5. **Integrate data into GIS or modelling tools** for analysis, visualization, and indicator generation.
6. **Produce maps, time-series, and analytical outputs** for reporting, decision-making, or research.

This workflow ensures reproducibility, scalability, and efficient use of EO resources.

Strengths and Limitations

Strengths

- Free and open access to high-quality data
- High spatial and temporal resolution
- Long-term continuity and global coverage
- Standardized, validated, and interoperable datasets
- Cloud-based processing enabling large-scale analysis

Limitations

- Optical data affected by cloud cover
- Large data volumes requiring storage and processing capacity
- Technical expertise needed for advanced analysis
- Some environmental parameters require integration with in-situ data
- Learning curve for DIAS platforms and EO processing tools

The Copernicus Programme provides one of the most comprehensive and reliable Earth Observation infrastructures globally, enabling continuous monitoring of environmental, climatic, marine, and terrestrial systems. Its open-access data policy, combined with the technical robustness of the Sentinel missions and the thematic Copernicus Services, ensures that high-quality geospatial information is available to public authorities, researchers, and industry without financial or legal barriers.

The structure of the Copernicus Data Base—integrating satellite observations, in-situ measurements, and model-based products—creates a coherent and interoperable ecosystem that supports both operational monitoring and advanced scientific analysis. The availability of cloud-based processing environments and standardized formats further enhances usability, scalability, and integration into digital workflows.

Applications across environmental monitoring, climate adaptation, marine management, and emergency response demonstrate the programme's strategic relevance for evidence-based decision-making. Copernicus data enables the detection of environmental change, supports risk assessments, and provides essential inputs for long-term planning in the context of climate variability and sustainability transitions.

Despite its strengths, effective use of Copernicus data requires technical expertise, adequate processing capacity, and complementary in-situ information for certain parameters. Addressing these limitations through capacity building, institutional integration, and workflow automation will significantly enhance the value derived from the system.

Overall, the Copernicus Data Base represents a foundational asset for modern environmental governance. Its continued development and integration into regional and sectoral strategies will strengthen resilience, support innovation, and contribute to the successful implementation of the EU Green Deal, Mission Ocean, and climate adaptation objectives.

Figure 4 Copernicus Chlorophyl A

Table 8. Copernicus Climate Change Service

Database ID	DB-01
Full Name	Copernicus Climate Change Service (C3S) / Copernicus Marine Service (CMEMS)
Category	European / Satellite & Reanalysis
Operator / Owner	ECMWF / Mercator Ocean International (EU Copernicus Programme)
Access URL	https://cds.climate.copernicus.eu / https://marine.copernicus.eu
License	Open / Free (Copernicus Open Data Policy)
Spatial Coverage	Global / European focus
Temporal Coverage	1950–present (reanalysis); near-real-time satellite
Key Variables / Products	Sea Surface Temperature (SST) | Salinity | Chlorophyll-a concentration | Ocean colour (OLCI, MSI, MODIS) | Sea level anomaly | Wind speed | Precipitation |

	ERA5 atmospheric reanalysis | Black Sea physics & biogeochemistry
Data Formats	NetCDF, GRIB, CSV
Relevance to DTEClimate ACT4D-Eutrophication	Primary source for satellite-derived SST, Chl-a, and biogeochemical variables for the Black Sea west coast and Dobrogea lakes. Black Sea Analysis & Forecast products provide daily/weekly model outputs aligned with DTEClimate use cases.
Applicable Deliverables	D2-2.1, D3.x (data cube ingestion), AI algorithms (SITS-LDA, bio-chemical parameter analysis)

4.2 DB-02 – EMODnet

The **European Marine Observation and Data Network (EMODnet)** is the European Union's central infrastructure for **in-situ marine data aggregation, harmonisation, and dissemination**. Developed under the EU's Integrated Maritime Policy, EMODnet provides free and open access to a comprehensive collection of marine datasets and derived products covering all European sea basins. Its primary objective is to reduce data fragmentation, improve interoperability, and support evidence-based decision-making in marine policy, research, and the Blue Economy.

EMODnet complements satellite-based systems such as **Copernicus Marine (CMEMS)** by focusing on **in-situ observations**, long-term monitoring, and thematic data integration. Together, these systems form the backbone of Europe's marine knowledge ecosystem.

Structure of the EMODnet Data Base

EMODnet is organised as a **distributed network of thematic portals**, each managed by specialised consortia of scientific institutions, monitoring agencies, and data centres. The structure includes seven core thematic domains:

- **Bathymetry** – digital terrain models, depth soundings, seabed morphology;
- **Geology** – sediment types, seabed substrates, geological features;
- **Physics** – temperature, salinity, currents, waves, sea level;
- **Chemistry** – nutrients, contaminants, dissolved oxygen, pH;
- **Biology** – species observations, abundance, distribution;
- **Seabed Habitats** – EUSeaMap, benthic habitat classifications;
- **Human Activities** – shipping density, offshore energy, aquaculture, dredging, cables, MSP layers.

Each thematic portal aggregates data from national monitoring programmes, research projects, and European infrastructures (e.g., ICES, SeaDataNet), harmonising them into **standardised, quality-controlled, pan-European datasets**.

Data Standards and Interoperability
EMODnet follows:

- **INSPIRE Directive** principles;
- **ISO metadata standards;**
- **FAIR data principles** (Findable, Accessible, Interoperable, Reusable).

This ensures compatibility with GIS systems, modelling tools, and marine spatial planning platforms.

Technical Functionalities

EMODnet provides a suite of technical capabilities designed to support marine data discovery, analysis, and integration:

Data Access and Download

Users can access:

- Raw in-situ measurements;
- Harmonised datasets;
- Derived data products (e.g., Digital Terrain Models, habitat maps).

Available formats include **CSV, NetCDF, GeoTIFF, ESRI ASCII**, and **Shapefiles**.

Web Services

EMODnet offers **OGC-compliant services**, including:

- **WMS** (Web Map Service);
- **WFS** (Web Feature Service);
- **WCS** (Web Coverage Service);
- **WMTS** (Web Map Tile Service).

These enable seamless integration into GIS platforms and automated workflows.

Interactive Map Viewer

A unified map viewer allows users to:

- Visualise multi-thematic layers;
- Combine datasets across themes;
- Extract time-series and spatial subsets;
- Download metadata and documentation.

Data Ingestion Service

The EMODnet Data Ingestion portal enables organisations to **submit marine datasets** for long-term preservation and integration into the network, expanding the European marine data offer.

Applications and Use Cases

EMODnet supports a wide range of operational, scientific, and policy applications:

Marine Environmental Monitoring

- Long-term trends in temperature, salinity, nutrients, and contaminants;
- Assessment of eutrophication and water quality;
- Monitoring of benthic habitats and biodiversity.

Marine Spatial Planning (MSP)

- Shipping density maps;
- Offshore renewable energy planning;
- Aquaculture site assessment;
- Submarine cable and pipeline mapping.

Blue Economy and Industry

- Navigation and safety;
- Coastal engineering and dredging;
- Fisheries and aquaculture management;
- Environmental impact assessments.

Climate and Ecosystem Assessments

- Baseline datasets for climate vulnerability studies;
- Habitat distribution modelling;
- Marine ecosystem status reporting (MSFD, WFD).

Regional Use Cases

For coastal and lagoon systems (e.g., **Lake Siutghiol**, Black Sea region):

- Bathymetric analysis;
- Water quality and nutrient datasets;
- Human activity layers (tourism, navigation, coastal infrastructure);
- Habitat mapping for conservation planning.

Data Access Workflow

A typical workflow for using EMODnet data includes:

1. **Identify the thematic domain** relevant to the analysis (e.g., Physics, Biology, Human Activities).
2. **Explore the thematic portal** or unified map viewer to locate datasets.
3. **Filter by spatial extent, time period, and parameter type**.
4. **Download raw data or derived products**, or access them via web services.
5. **Integrate datasets into GIS or modelling tools** for analysis.
6. **Generate maps, indicators, and reports** for policy, research, or operational use.

This workflow supports reproducible, transparent, and scalable marine data analysis.

Strengths and Limitations

Strengths

- Comprehensive coverage of **in-situ marine data;**
- Free and open access;
- Harmonised, quality-controlled datasets;
- Strong interoperability with GIS and modelling tools;
- Multi-thematic integration across environmental and human-use domains;
- Supports EU directives (MSFD, MSPD, WFD) and Mission Ocean.

Limitations

- Spatial and temporal coverage varies by region and parameter;
- Some datasets depend on national monitoring frequency;
- In-situ data may have gaps compared to satellite coverage;
- Requires technical knowledge for advanced analysis;
- Not all datasets are near-real-time;
- Not all datasets are near-real-time.

Table 9.EMODnet

Database ID	DB-02
Full Name	EMODnet (European Marine Observation and Data Network)
Category	European / Multi-thematic Marine
Operator / Owner	European Commission (DG MARE)
Access URL	https://emodnet.ec.europa.eu
License	Open / Free
Spatial Coverage	European seas (including Black Sea)
Temporal Coverage	Variable by theme (historical to present)
Key Variables / Products	Bathymetry (high-res seabed) | Biology (species distribution, phytoplankton) | Chemistry (nutrients, oxygen, pH, eutrophication indices) | Physics (temperature, salinity, currents) | Geology | Human activities

Data Formats	NetCDF, CSV, GeoTIFF, WMS/WFS
Relevance to DTEClimate ACT4D-Eutrophication	Key European marine data hub covering Black Sea eutrophication status, biological observations, and seabed mapping. EMODnet Chemistry provides historical nutrient data essential for eutrophication trend analysis.
Applicable Deliverables	D2-2.1, eutrophication assessment workflows, Black Sea west coast monitoring

4.3 DB-03 – EOS Data Analytics Platform

The **Earth Observation System Data and Information System (EOSDIS)** is NASA's primary infrastructure for the management, processing, archiving, and distribution of Earth science data. It forms a core component of NASA's Earth Science Data Systems (ESDS) Program and provides **end-to-end capabilities** for handling data from satellites, aircraft, field campaigns, and other observational platforms. EOSDIS supports global scientific research, environmental monitoring, climate analysis, and operational decision-making by ensuring that Earth observation data are accessible, reliable, and systematically processed.

Structure of the EOS Data Base

EOSDIS is organised as a **distributed, interconnected system** composed of multiple specialised elements that work together to manage the full data lifecycle—from acquisition to long-term preservation and user access.

Distributed Active Archive Centers (DAACs)

DAACs are discipline-specific data centres responsible for the **production, archiving, and distribution** of Earth science data products. They serve a large and diverse user community by providing search, access, and specialised services for datasets covering the atmosphere, land, oceans, cryosphere, and biosphere.

Science Investigator-led Processing Systems (SIPS)

SIPS are responsible for generating **higher-level science data products (Levels 1–4)** for EOS missions. They transform raw satellite data into calibrated, geolocated, and scientifically meaningful datasets used for research and applications.

Science Data Processing Segment (SDPS)

The SDPS supports the processing, management, and distribution of data products across the EOSDIS network. It ensures that data are systematically processed and made available through DAACs and other access services.

Common Metadata Repository (CMR)

CMR is the central catalogue that stores and indexes metadata for all EOSDIS datasets, enabling efficient search and discovery across the entire system.

Mission Operations and EOS Networks

For EOS satellite missions, EOSDIS provides capabilities for **command and control, scheduling, data capture, and Level-0 processing**, managed by NASA's Earth Science Mission Operations (ESMO). Data are transported through NASA's network infrastructure to science operations facilities for further processing.

Technical Functionalities

EOSDIS provides a comprehensive suite of technical capabilities that support the full data lifecycle and enable advanced scientific analysis.

End-to-End Data Management

EOSDIS manages data from acquisition to distribution, including:

- Data capture from satellites, aircraft, and field measurements;
- Initial Level-0 processing;
- Generation of Level-1 to Level-4 science products;
- Long-term archiving and preservation;
- Global distribution to users through DAACs and web services.

Distributed Architecture

The system operates through a **network of interconnected nodes and centres**, ensuring redundancy, scalability, and specialised processing capabilities across scientific domains.

User Access and Tools

EOSDIS provides:

- Search and access tools for science data products;
- Web infrastructure for data discovery;
- Global Imagery Browse Services (GIBS) for rapid visualisation;
- Near-real-time data access through LANCE (Land, Atmosphere Near real-time Capability for Earth Observations).

International Directory Network (IDN)

The IDN supports global metadata exchange and discovery, enabling users to locate Earth science datasets from international partners.

Applications and Use Cases

EOSDIS supports a wide range of scientific, operational, and policy applications:

Climate and Environmental Research

EOSDIS provides long-term, consistent datasets essential for:

- Climate change analysis;
- Atmospheric composition studies;
- Hydrological and cryospheric research;
- Land-use and land-cover change monitoring.

Disaster Monitoring and Response

Near-real-time data from LANCE support:

- Wildfire detection;
- Flood monitoring;
- Volcanic ash tracking;
- Severe weather analysis.

Ecosystem and Natural Resource Management

EOSDIS data are used to assess:

- Vegetation health;
- Drought conditions;
- Water resources;
- Marine and coastal dynamics.

Scientific Innovation and Modelling

High-quality, multi-sensor datasets enable:

- Earth system modelling;
- Machine learning applications;

- Data fusion and assimilation;
- Development of new environmental indicators.

Data Access Workflow

A typical workflow for accessing EOSDIS data includes:

1. **Search for datasets** using the Common Metadata Repository (CMR) or DAAC portals.
2. **Select data products** based on mission, parameter, spatial extent, and temporal range.
3. **Download data** through HTTPS, APIs, or cloud-based access points.
4. **Process data** using scientific tools (e.g., Python, GIS software, NASA toolkits).
5. **Analyse and visualise** using GIBS or custom workflows.
6. **Integrate results** into research, modelling, or operational applications.

This workflow supports reproducible, scalable, and high-quality scientific analysis.

Strengths and Limitations

Strengths

- Comprehensive end-to-end data management system;
- Large, diverse archive of Earth science data;
- High-quality, validated science products;
- Distributed architecture enabling domain-specific expertise;
- Near-real-time capabilities for operational monitoring;
- Strong metadata and search infrastructure (CMR).

Limitations

- Complexity of the distributed system may require technical expertise;
- Large data volumes can challenge storage and processing resources;
- Some datasets require specialised tools for interpretation;
- Access to certain high-resolution or specialised products may require additional processing steps.

Table 10. EOS Data Analytics Platform

Database ID	DB-03
Full Name	EOS Data Analytics Platform
Category	Commercial / Cloud EO Analytics
Operator / Owner	EOS Data Analytics Inc.
Access URL	https://eos.com / https://eos.com/products/land-viewer/
License	Freemium / Commercial API
Spatial Coverage	Global
Temporal Coverage	Present (multi-satellite archive)
Key Variables / Products	Multispectral imagery (Sentinel-2, Landsat, MODIS, Planet) | NDVI, NDWI, chlorophyll indices | Land cover / land use change | Vegetation stress indicators | Water body mapping
Data Formats	GeoTIFF, COG (Cloud-Optimised GeoTIFF), API JSON
Relevance to DTEClimate	Provides browser-based EO analytics and API access for rapid vegetation and

ACT4D-Eutrophication	water quality index computation over Dobrogea lakes and coastal areas without local infrastructure requirements.
Applicable Deliverables	D2-2.1, remote sensing validation, SITS time-series analysis

4.4 DB-04 – GEMStat – Global Water Quality Database

The **GEMStat Data Base** is the **Global Freshwater Quality Database** of the United Nations Environment Programme's **GEMS/Water Programme**, providing scientifically robust data on the state and trends of inland water quality worldwide. It is operated by the **GEMS/Water Data Centre (GWDC)** within the **International Centre for Water Resources and Global Change (ICWRGC)** in Koblenz, Germany . GEMStat supports global, regional, and national water quality assessments, including reporting for **SDG Indicator 6.3.2** on ambient water quality, and serves as a key reference for environmental monitoring, policy development, and scientific research.

The GEMStat database is part of the broader **GEMS/Water Programme**, established in 1978 to collect worldwide water quality data for assessing the status and trends of global inland waters . The programme is implemented by UNEP in cooperation with WHO, WMO, and UNESCO, and relies on a global network of **National Focal Points**—government agencies mandated to monitor freshwater quality in their respective countries. These institutions voluntarily submit monitoring data to GEMStat, ensuring global coverage and long-term continuity.

The GEMS/Water Data Centre (GWDC) is responsible for:

- Collecting and validating submitted data;
- Maintaining the GEMStat database;
- Providing data products and analytical tools;
- Supporting global water quality assessments.

Structure of the GEMStat Data Base

GEMStat is a **global, multi-source, multi-parameter freshwater quality database** containing measurements from rivers, lakes, reservoirs, wetlands, and groundwater systems. Key structural characteristics include:

Data Volume and Coverage

- More than **4 million entries** from **75 countries** and **~4,000 monitoring stations** (historical dataset).
- Updated archive includes **over 20 million measurements** on **608 parameters** from **13,660 stations** in **37 countries** (Version v2).
- Latest version (v3) includes **over 50 million measurements** on **622 parameters** from **22,982 stations** in **42 countries** (1906–2024).

Parameters and Data Types

GEMStat includes measurements for:

- Nutrients (N, P species);
- Heavy metals and trace elements;
- Organic pollutants;
- Physical-chemical parameters (pH, temperature, conductivity);
- Biological indicators.

Metadata and Documentation

The database provides:

- Station metadata;
- Parameter metadata;
- Analytical method metadata
- Data policy and submission guidelines .

Technical Functionalities

GEMStat offers a suite of tools and services that support data exploration, analysis, and reporting:

Data Portal

The GEMStat portal allows users to:

- Explore available water quality data;
- Visualise statistical summaries at multiple spatial scales;
- Access interactive maps and dashboards;
- Download datasets for analysis.

Water Quality Indicators

Users can visualise global freshwater quality status through:

- Classification maps;
- Indicator-based assessments;
- SDG 6.3.2 core parameter visualisations.

Statistical Reports

GEMStat provides aggregated statistics at:

- Station level;
- Country level;
- Catchment level These support environmental reporting and policy development.

Data Submission System

Countries and organisations can submit monitoring data following GEMStat's data policy and submission manuals, ensuring standardisation and quality control .

Applications and Use Cases

GEMStat supports a wide range of scientific, policy, and operational applications:

Global and Regional Water Quality Assessments

GEMStat is the primary data source for:

- UNEP's global freshwater quality assessments;
- SDG 6.3.2 reporting on ambient water quality;
- Long-term trend analysis of inland water systems.

Research and Modelling

The database is widely used in:

- Hydrological modelling;
- Water quality modelling;
- Climate impact studies;
- Large-sample environmental analyses The open-access archive supports global-scale research efforts.

Policy and Decision Support

GEMStat provides evidence for:

- National water quality management;

- Transboundary water cooperation;
- Environmental regulation and compliance;
- Ecosystem health assessments.

Education and Capacity Building

The database is used in:

- Training programmes;
- University courses;
- Technical workshops on water quality monitoring and assessment.

Data Access Workflow

A typical workflow for using GEMStat data includes:

1. **Access the GEMStat portal** to explore available datasets.
2. **Select monitoring stations, parameters, and time periods** of interest.
3. **Download raw data or aggregated statistics** via the portal or Zenodo archive.
4. **Analyse data** using statistical tools, GIS, or modelling software.
5. **Generate indicators, maps, and reports** for research or policy applications.

This workflow supports reproducible, transparent, and scalable freshwater quality assessments.

Strengths and Limitations

Strengths

- Largest global freshwater quality database;
- Long-term, multi-parameter, multi-country coverage;
- Free and open access to large-sample datasets;
- Strong institutional backing (UNEP, ICWRGC, BfG);
- Supports SDG 6.3.2 and global environmental assessments;
- Provides metadata, indicators, and analytical tools.

Limitations

- Spatial coverage varies by country and region;
- Monitoring frequency and parameter sets differ across contributors;
- Some datasets require harmonisation for comparative analysis;
- Historical data may have gaps or methodological inconsistencies.

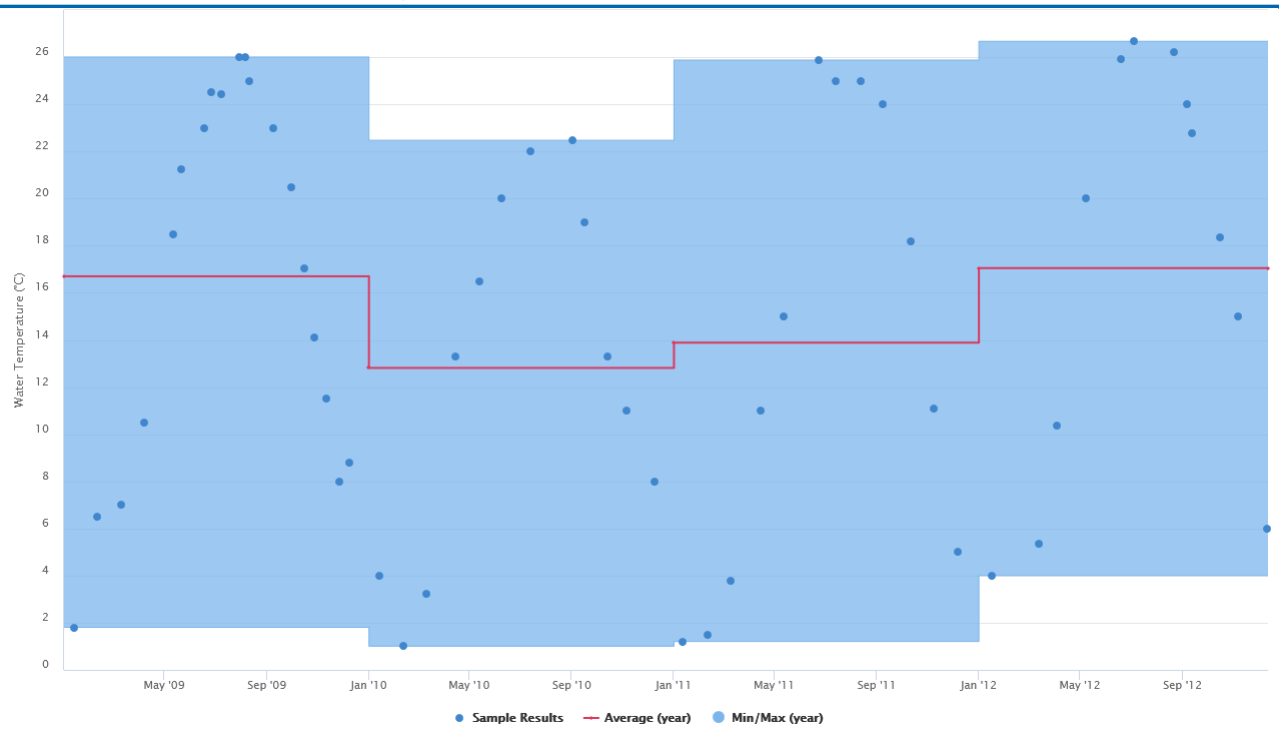


Figure 5 GEMStat Water Temperature

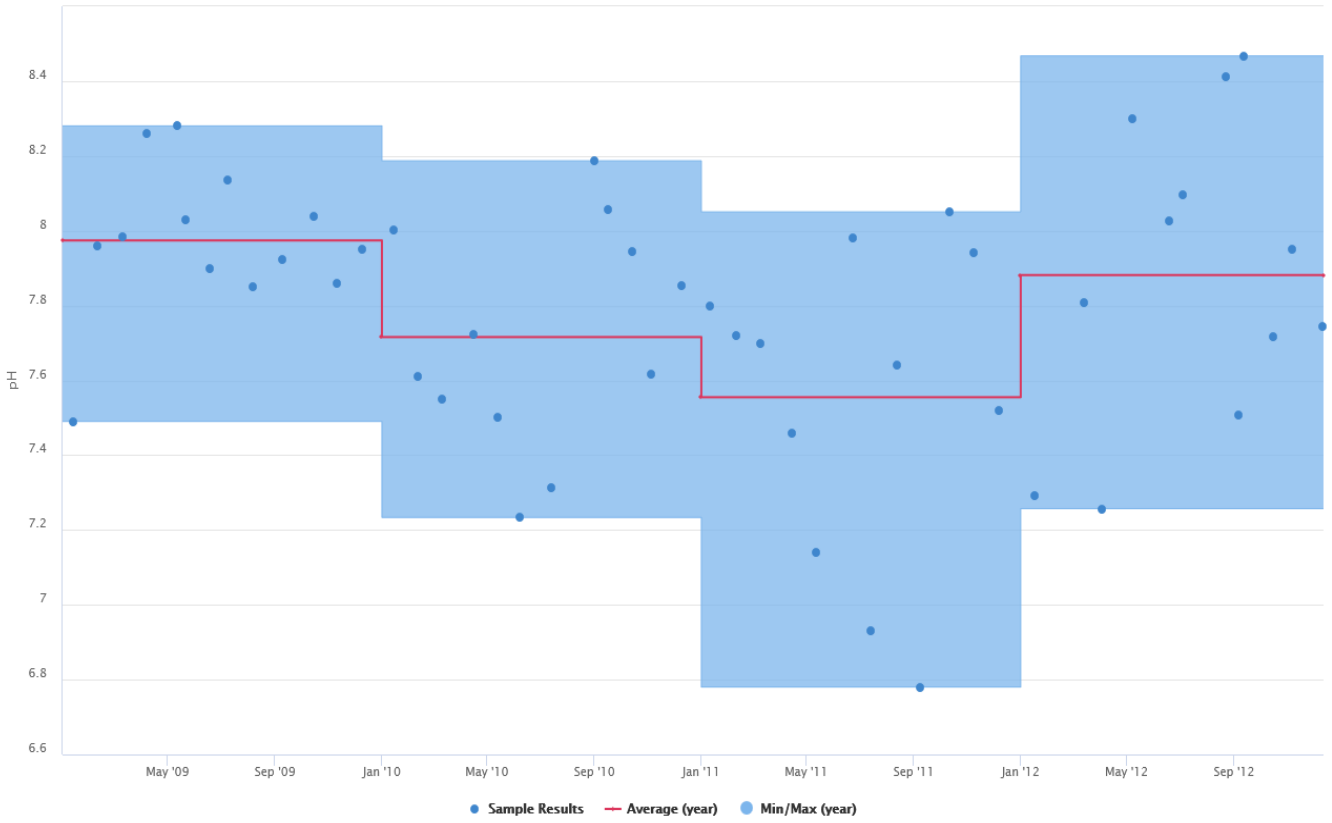


Figure 6 GEMStat pH

Table 11. GEMStat – Global Water Quality Database

Database ID	DB-04
Full Name	GEMStat – Global Water Quality Database
Category	Global / In-situ Water Quality
Operator / Owner	UN Environment Programme (UNEP) / IHP-WINS
Access URL	https://gemstat.org
License	Open / Free
Spatial Coverage	Global freshwater bodies
Temporal Coverage	1970s–present
Key Variables / Products	Total phosphorus (TP) | Total nitrogen (TN) | Dissolved oxygen (DO) | Biological Oxygen Demand (BOD) | Chlorophyll-a (lake in-situ) | pH, turbidity, electrical conductivity | Heavy metals
Data Formats	CSV, Excel download
Relevance to DTEClimate ACT4D-Eutrophication	Global reference database for freshwater quality parameters including eutrophication indicators (TP, TN, Chl-a). Provides benchmark values for Romanian sweet-water lakes (Siutghiol, Razim-Sinoe, Bicaz) against international standards.
Applicable Deliverables	D2-2.1, eutrophication baseline, validation of satellite-derived water quality products

4.5 DB-05 – NASA Earthdata

NASA Earthdata is the central access point for the **Earth Observing System Data and Information System (EOSDIS)**, NASA's primary infrastructure for managing, processing, archiving, and distributing Earth science data. Earthdata provides **end-to-end capabilities** for handling data from satellites, aircraft, field campaigns, and other observational platforms, supporting global scientific research, environmental monitoring, climate analysis, and operational decision-making.

Earthdata serves as the public-facing gateway to EOSDIS, offering tools for data discovery, visualization, and download, as well as access to NASA's Distributed Active Archive Centers (DAACs), which curate discipline-specific Earth science datasets.

Structure of the Earthdata System

Earthdata is built on the architecture of **EOSDIS**, a distributed, interconnected system composed of multiple specialised components that manage the full lifecycle of NASA Earth science data.

Distributed Active Archive Centers (DAACs)

DAACs are discipline-specific data centres responsible for the **production, archiving, and distribution** of Earth science data products. They serve a large and diverse global user community by providing search tools, access services, and specialised support.

Science Investigator-led Processing Systems (SIPS)

SIPS generate **higher-level science data products (Levels 1–4)** from raw satellite observations. These systems transform Level-0 data into calibrated, geolocated, and scientifically meaningful datasets.

Science Data Processing Segment (SDPS)

SDPS manages the processing, management, and distribution of data products across EOSDIS, ensuring systematic and consistent data generation.

Common Metadata Repository (CMR)

CMR is the central catalogue for all EOSDIS datasets, enabling efficient search and discovery across Earthdata's entire archive.

Mission Operations and EOS Networks

For EOS satellite missions, Earthdata supports:

- Command and control;
- Scheduling;
- Data capture;
- Initial Level-0 processing.

These operations are managed by NASA's Earth Science Mission Operations (ESMO) Project.

Technical Functionalities

Earthdata provides a comprehensive suite of technical capabilities that support advanced scientific analysis and operational monitoring.

End-to-End Data Management

Earthdata manages data from acquisition to distribution, including:

- Data capture from satellites, aircraft, and field measurements;
- Level-0 to Level-4 processing;
- Long-term archiving;
- Global distribution through DAACs and web services.

These capabilities ensure that NASA Earth science data remain accessible, reliable, and scientifically robust.

Distributed Architecture

EOSDIS operates through a **network of interconnected nodes**, including DAACs and SIPS, enabling redundancy, scalability, and domain-specific expertise.

User Access Tools

Earthdata provides:

- **Earthdata Search** for dataset discovery;
- **GIBS (Global Imagery Browse Services)** for rapid visualisation;
- **LANCE** for near-real-time data access;
- **Earthdata Login** for personalised services.

These tools support both expert users and general audiences.

International Directory Network (IDN)

The IDN enables global metadata exchange and discovery, connecting Earthdata with international Earth science data systems.

Applications and Use Cases

Earthdata supports a wide range of scientific, operational, and policy applications.

Climate and Environmental Research

Earthdata provides long-term, consistent datasets essential for:

- Climate change analysis;
- Atmospheric composition studies;
- Hydrological and cryospheric research;
- Land-use and land-cover change monitoring.

EOSDIS archives hundreds of millions of data files annually across multiple Earth science disciplines.

Disaster Monitoring and Response

Near-real-time data from LANCE support:

- Wildfire detection;
- Flood monitoring;
- Volcanic ash tracking;
- Severe weather analysis.

These capabilities enable rapid situational awareness for emergency response.

Ecosystem and Natural Resource Management

Earthdata supports assessments of:

- Vegetation health;
- Drought conditions;
- Water resources;
- Marine and coastal dynamics.

Scientific Innovation and Modelling

High-quality, multi-sensor datasets enable:

- Earth system modelling;
- Machine learning applications;
- Data fusion and assimilation;
- Development of new environmental indicators.

Data Access Workflow

A typical workflow for using Earthdata includes:

1. **Search for datasets** using Earthdata Search or CMR.
2. **Filter by mission, parameter, spatial extent, and time range.**
3. **Download data** via HTTPS, APIs, or cloud-based access.
4. **Process data** using scientific tools (Python, GIS, NASA toolkits).
5. **Visualise data** using GIBS or custom workflows.
6. **Integrate results** into research, modelling, or operational applications.

This workflow supports reproducible and scalable scientific analysis.

Strengths and Limitations

Strengths

- Comprehensive end-to-end data management;
- Large, diverse archive of Earth science data;
- High-quality, validated science products;
- Distributed architecture with domain-specific DAACs;

- Near-real-time capabilities (LANCE);
- Strong metadata and search infrastructure (CMR).

Limitations

- Complexity may require technical expertise;
- Large data volumes can challenge storage and processing;
- Some datasets require specialised tools for interpretation;
- High-resolution products may require additional processing steps.

Table 12. NASA Earthdata Base

Database ID	DB-05
Full Name	NASA Earthdata
Category	Global / Satellite & Airborne
Operator / Owner	NASA / EOSDIS
Access URL	https://earthdata.nasa.gov
License	Open / Free (NASA Open Data)
Spatial Coverage	Global
Temporal Coverage	1972–present (Landsat); 1999–present (MODIS); 2011–present (VIIRS)
Key Variables / Products	MODIS Aqua/Terra: SST, Chl-a, aerosols, land surface temperature | Landsat 8/9 OLI: multispectral water quality | VIIRS: ocean colour, night lights | SMAP: soil moisture | GRACE-FO: groundwater storage | GPM: precipitation | MERRA-2 reanalysis
Data Formats	HDF4, HDF5, NetCDF, GeoTIFF
Relevance to DTEClimate ACT4D-Eutrophication	NASA's open data portal is a primary global source for long-term Chl-a and SST time series (MODIS, VIIRS) enabling multi-decadal eutrophication trend analysis for Black Sea and Dobrogea lakes. MODIS Ocean Color Level-3 products are directly applicable.
Applicable Deliverables	D2-2.1, D3.x (data cube), SITS-LDA, bio-chemical time-series algorithms

4.6 DB-06 – USGS EarthExplorer

EarthExplorer, developed and maintained by the U.S. Geological Survey (USGS), is one of the primary global platforms for searching, previewing, and downloading satellite imagery and geospatial datasets. It provides free access to the extensive archives of the USGS Earth Resources Observation and Science (EROS) Center, including Landsat, Sentinel-2, MODIS, ASTER, SRTM, NAIP aerial photography, and numerous other datasets. EarthExplorer is widely used in environmental monitoring, disaster response, land-use analysis, infrastructure planning, and scientific research.

Structure of the EarthExplorer System

EarthExplorer is structured as a web-based geospatial data discovery and download system that integrates multiple components of the USGS EROS data infrastructure.

Search Interface and Area of Interest Tools

Users can define their **Area of Interest (AOI)** using:

- Address or place name search;
- Latitude/longitude coordinates;

- Polygon, circle, or predefined areas;
- GeoJSON, KML, or Shapefile upload.

The interface supports both **US and global features**, enabling precise geospatial queries.

Dataset Catalogue

EarthExplorer provides access to **hundreds of datasets**, including:

- Landsat Collection 2;
- Sentinel-2;
- MODIS;
- ASTER;
- SRTM elevation data;
- NAIP aerial imagery;
- Land cover and geotagged photography.

Datasets are grouped by category, and users can select multiple datasets for simultaneous querying.

Authentication and User Accounts

A free USGS EROS Registration System (ERS) account is required to download data. The same account is used across EarthExplorer, GloVis, and HDDS.

Technical Functionalities

Search and Filtering

EarthExplorer allows filtering by:

- Date range;
- Cloud cover percentage;
- Metadata attributes;
- Sensor type;
- Acquisition path/row (for Landsat).

Cloud cover filtering is supported for datasets that include cloud metadata.

Preview and Metadata Tools

Users can:

- Preview browse images;
- View metadata (acquisition date, sensor, cloud cover, processing level);
- Overlay alternate browse layers for visualization.

These tools help users evaluate scene quality before downloading.

Download and Bulk Access

EarthExplorer supports:

- Direct downloads (GeoTIFF, JPEG, etc.);
- Bulk download via USGS tools;
- Machine-to-Machine (M2M) API for automated workflows.

The M2M API is widely used for large-scale research and processing pipelines.

Supported Browsers and System Requirements

EarthExplorer supports Chrome, Firefox, Edge, Opera, and Safari. Help documentation and tutorials are available for new users.

Applications and Use Cases

Environmental Monitoring

EarthExplorer provides authoritative datasets for:

- Deforestation monitoring;
- Water quality and hydrological studies;
- Land-use and land-cover change;
- Ecosystem health assessments.

Landsat's 50-year archive is particularly valuable for long-term environmental analysis.

Disaster Response and Risk Management

EarthExplorer is used for:

- Earthquake damage assessment;
- Flood mapping;
- Wildfire monitoring;
- Landslide detection.

It is recognized as a tool for **risk and resilience assessment** and disaster monitoring.

Infrastructure and Urban Planning

Datasets support:

- Road and utility planning;
- Urban expansion analysis;
- Engineering and cadastral mapping;
- Elevation modelling (SRTM, ASTER).

EarthExplorer remains the **definitive archive** for downloading original, validated scenes needed for engineering-grade workflows.

Scientific Research and Education

EarthExplorer is widely used in:

- Remote sensing research;
- GIS training;
- Climate and land surface modelling;
- Historical landscape reconstruction.

The platform's free access policy supports global scientific collaboration.

Data Access Workflow

A typical workflow for using EarthExplorer includes:

1. **Define the Area of Interest** using coordinates, polygons, or uploaded files.
2. **Select datasets** from the catalogue (e.g., Landsat, Sentinel-2).
3. **Apply filters** such as date range and cloud cover.
4. **Preview scenes** and inspect metadata.
5. **Download selected scenes** using direct download or bulk tools.
6. **Process data locally** using GIS or remote sensing software.

EarthExplorer is optimized for workflows requiring **scene-by-scene control** and local processing.

Strengths and Limitations

Strengths

- Free access to authoritative USGS datasets;
- Extensive historical archive (Landsat since 1972);
- Precise AOI selection and metadata filtering;
- Scene-level control for scientific workflows;
- Integration with M2M API for automation;
- Strong support and documentation.

Limitations

- Requires local storage and processing;
- Not cloud-native (unlike Google Earth Engine);
- Search result limit of 100 records unless refined;
- Large downloads may require bulk tools or justification for >6 TB orders.

Table 13. USGS EarthExplorer

Database ID	DB-06
Full Name	USGS EarthExplorer
Category	Global / Satellite Archive
Operator / Owner	U.S. Geological Survey (USGS)
Access URL	https://earthexplorer.usgs.gov
License	Open / Free
Spatial Coverage	Global
Temporal Coverage	1972–present (Landsat); various sensors
Key Variables / Products	Landsat Collection 2 Level-1/2 imagery (OLI, TM, ETM+) | Sentinel-2 MSI (via USGS mirror) | ASTER surface reflectance | MODIS land/water products | Aerial photography
Data Formats	GeoTIFF, HDF
Relevance to DTEClimate ACT4D-Eutrophication	Provides the longest continuous medium-resolution satellite archive (Landsat 1972–present) enabling historical change detection of lake extent, turbidity, and algal bloom frequency around the Dobrogea region.
Applicable Deliverables	D2-2.1, historical land/water change detection, eutrophication trend analysis

4.7 DB-07 – WOD – World Ocean Database

The World Ocean Database (WOD), maintained by the U.S. National Centers for Environmental Information (NCEI), is the world's largest collection of uniformly formatted, quality-controlled, publicly available ocean profile data. It integrates more than 20,000 original datasets contributed by institutions, agencies, research programs, and individual investigators worldwide, spanning observations from Captain Cook's 1772 voyage to the modern Argo era . WOD is a foundational resource for oceanographic, climatic, and environmental research, enabling long-term and historical ocean climate analysis.

Structure of the WOD System

WOD is a global, multi-source, multi-parameter oceanographic database built on standardized formats and rigorous quality control procedures.

Data Types and Profile Structure

WOD contains ocean profile data, defined as measurements of ocean variables versus depth at a single geographic location within a short time. Multiple profiles collected at the same location form an oceanographic cast.

Variables and Parameters

WOD includes measurements of:

- Physical variables: temperature, salinity, conductivity;
- Chemical variables: dissolved oxygen, nutrients (phosphate, nitrate, nitrite, silicate), pH, alkalinity, dissolved inorganic carbon;
- Carbon system tracers: pCO_2, CFC-11/12/113, Tritium, Carbon-13/14, Helium-3, Oxygen-18;
- Biological variables: plankton, chlorophyll;
- Optical variables: transmissivity (beam attenuation).

Meteorological and sea-state observations associated with casts.

Data Volume and Coverage

As of December 2024, WOD contains:

- ~3.6 billion observations;
- ~20.6 million casts.

Data contributed by 97 countries

Up to 27 profiles per cast for essential ocean variables.

The latest major release, WOD23, includes more than 18.6 million casts and 3.13 billion individual profile measurements.

Technical Functionalities

Quality Control

WOD applies both automated and manual quality control procedures, with results stored as quality flags for each measurement. Final QC flags used in the World Ocean Atlas (WOA) are included in each major release, while quarterly updates contain preliminary QC .

Standardization and Interoperability

All datasets are converted into a uniform standard format.

Data are available in native ASCII, CSV, and CF-compliant NetCDF ragged-array formats for interoperability with oceanographic and climate models .

WOD is a FAIR-compliant international data resource under the IODE and World Data System (WDS) frameworks .

Access Tools

Users can retrieve data through:

- WODselect, a web application enabling custom searches by date, location, dataset type, variables, platform, cruise, and QC flags .

- Geographically sorted and year-sorted access interfaces for native ASCII data .
- THREDDS servers for programmatic access to NetCDF files .

Applications and Use Cases

Climate and Oceanographic Research

WOD is essential for:

- Long-term ocean climate analysis;
- Temperature and salinity trend studies;
- Ocean heat content estimation;
- Carbon cycle research;
- Biogeochemical modelling Its historical depth (1772–present) makes it uniquely suited for multi-century climate reconstructions.

Marine Ecosystem and Biogeochemical Studies

WOD supports:

- Nutrient distribution mapping;
- Oxygen minimum zone analysis;
- Plankton and chlorophyll assessments;
- Ocean acidification studies (pH, alkalinity, DIC).

Operational Oceanography

WOD data are used in:

- Ocean reanalysis systems;
- Data assimilation for forecasting models;
- Marine hazard monitoring;
- Navigation and fisheries management.

International Data Sharing and Policy

WOD underpins:

- Global ocean observing initiatives;
- UN ocean assessments;
- International climate reporting;
- Marine policy development.

Data Access Workflow

A typical workflow for using WOD includes:

- Define search criteria (geographic area, time period, dataset type, variables).
- Use WODselect to build a query and preview distribution maps and cast counts.
- Download data in WOD native ASCII, CSV, or NetCDF formats.
- Apply QC flags to filter or exclude measurements as needed.
- Integrate data into analysis pipelines (e.g., MATLAB, Python, R, Ocean Data View).
- Generate visualizations and indicators for research or operational use.
- WOD also provides tutorials and updated tools for reading and processing data in modern software environments .

Strengths and Limitations

Strengths

- Largest global archive of in-situ ocean profile data;

- Uniform formatting and rigorous QC;
- Multi-century temporal coverage (1772–present);
- Extensive variable set (physical, chemical, biological, tracers);
- FAIR-compliant and internationally supported;
- Multiple access methods and interoperable formats.

Limitations

- Spatial and temporal coverage varies by region and era;
- Some historical data have methodological inconsistencies;
- Large data volumes require significant processing capacity;
- QC flags must be carefully applied for scientific use.

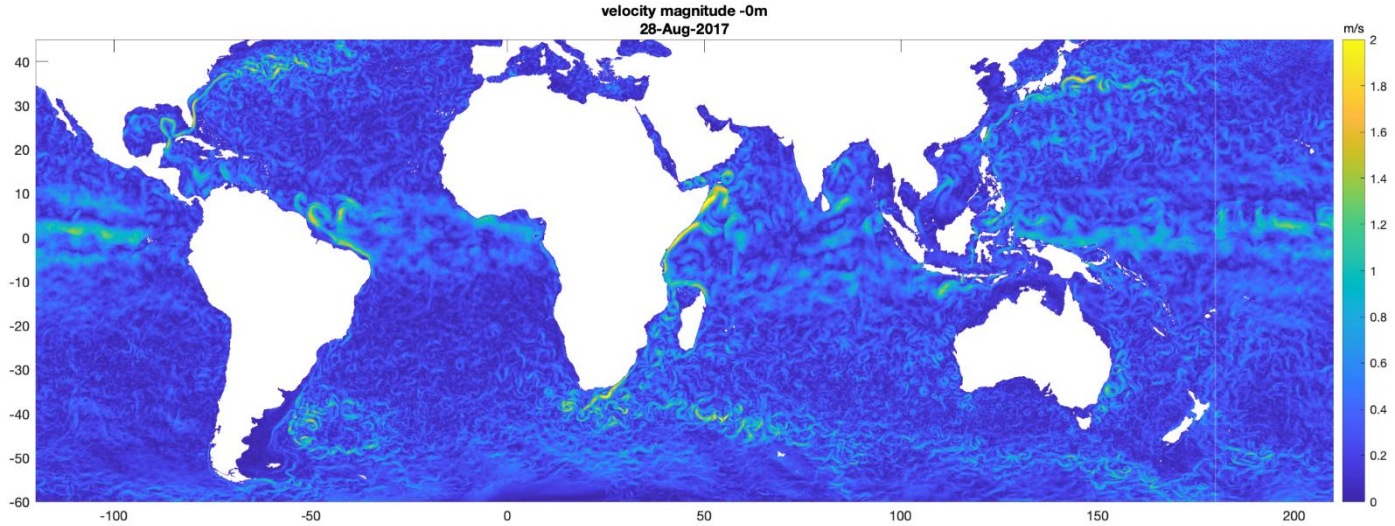


Figure 7. WOD – World Ocean Database

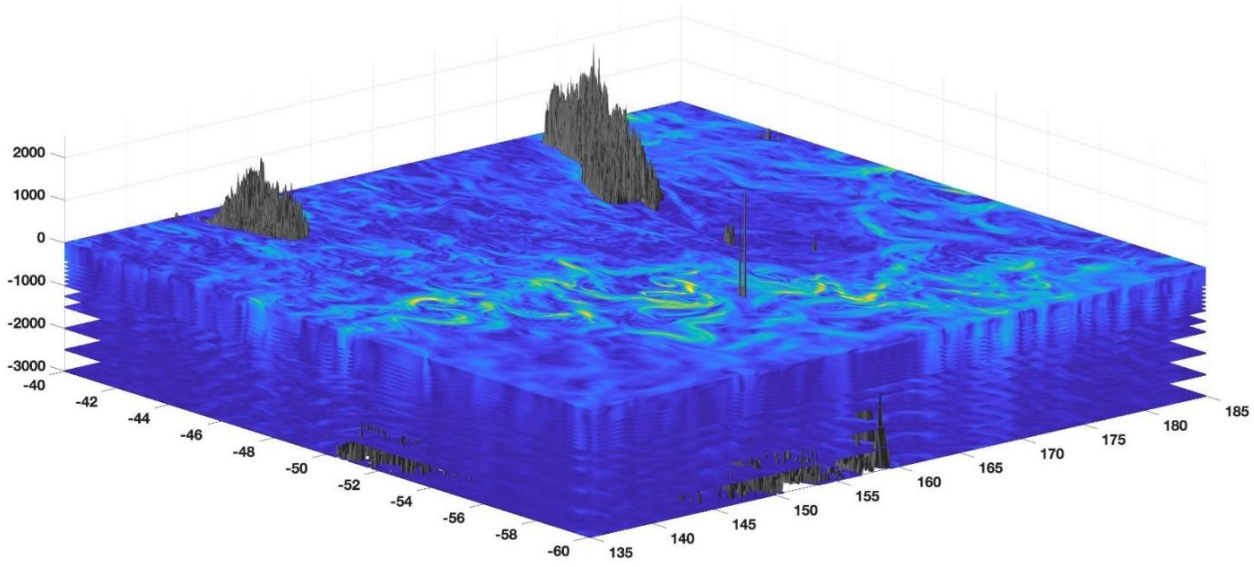


Figure 7. WOD – World Ocean Database

Table 14. WOD – World Ocean Database

Database ID	DB-07
Full Name	WOD – World Ocean Database
Category	Global / In-situ Ocean
Operator / Owner	NOAA National Centers for Environmental Information (NCEI)
Access URL	https://www.ncei.noaa.gov/products/world-ocean-database
License	Open / Free
Spatial Coverage	Global oceans (including Black Sea)
Temporal Coverage	1770–present
Key Variables / Products	Temperature profiles | Salinity profiles | Dissolved oxygen | Phosphate, Nitrate, Silicate (nutrients) | Chlorophyll-a (water column) | pH
Data Formats	NetCDF, CSV, ASCII
Relevance to DTEClimate ACT4D-Eutrophication	World's largest publicly available collection of ocean profile data. WOD Black Sea profiles provide vertical structure data (thermocline, halocline) and nutrient concentrations relevant to understanding eutrophication dynamics in coastal waters.
Applicable Deliverables	D2-2.1, in-situ validation, vertical profile analysis for Black Sea

4.8 DB-08 – WOA – World Ocean Atlas

The World Ocean Atlas (WOA) is a global ocean climatology produced by the NOAA National Centers for Environmental Information (NCEI). It provides objectively analyzed, quality-controlled mean fields of essential ocean variables, derived from the extensive in-situ profile data contained in the World Ocean Database (WOD). WOA includes long-term averages, decadal climatologies, and climate-normal fields for temperature, salinity, dissolved oxygen, nutrients, and related variables, making it a foundational dataset for ocean modelling, climate research, satellite validation, and environmental assessments.

Relationship Between WOA and WOD

WOA is produced in conjunction with each major release of the World Ocean Database. WOD provides the raw, quality-controlled profile measurements, while WOA applies objective analysis to generate gridded climatological fields. Each WOA release corresponds to a WOD release and incorporates the final QC flags from that WOD version.

Structure and Content of the WOA Data Base

Variables Included

WOA provides climatological fields for:

- Temperature;
- Salinity;
- Dissolved oxygen;
- Percent oxygen saturation;
- Apparent oxygen utilization (AOU);

- Inorganic nutrients: phosphate, nitrate, silicate.

These variables are available as objectively analyzed means and statistical fields.

3.2 Spatial and Temporal Resolution

WOA23 provides fields at:

- 102 standard depth levels
- One-degree and quarter-degree grids (variable-dependent)
- Decadal periods:
  - 1955–1964
  - 1965–1974
  - 1975–1984
  - 1985–1994
  - 1995–2004
  - 2005–2014
  - 2015–2022
- **Climate normals:**
  - 1971–2000
  - 1981–2010
  - 1991–2020

Nutrient and oxygen fields are available for 1965–2022.

3.3 Data Formats

WOA data are distributed in:

- **CF-compliant NetCDF;**
- **Native ASCII;**
- **CSV;**
- **ArcGIS-compatible shapefiles.**

This ensures interoperability with modelling systems, GIS tools, and scientific workflows.

Technical Methodology

Objective Analysis

WOA uses objective analysis techniques to transform irregularly spaced in-situ observations into gridded climatological fields. This includes:

- Horizontal and vertical interpolation;
- Statistical averaging;
- Quality-controlled input from WOD.

Quality Control

WOA incorporates the final QC flags from the corresponding WOD release, which include both automated and manual QC procedures. This ensures consistency between the database (WOD) and the climatology (WOA).

Versioning

Major releases include:

- WOA 1994;
- WOA 1998;
- WOA 2001;

- WOA 2005;
- WOA 2009;
- WOA 2013;
- WOA 2018;
- WOA 2023 (latest).

Each version incorporates expanded data coverage and improved analysis methods.

Applications and Use Cases

Ocean and Climate Modelling

WOA is widely used to generate:
- Initial and boundary conditions for ocean circulation models;
- Validation datasets for numerical simulations;
- Inputs for Earth system models.

Satellite Data Validation

Climatological fields are used to corroborate satellite-derived estimates of:
- Sea surface temperature;
- Salinity;
- Ocean color (indirectly via nutrient fields).

Environmental and Climate Assessments

WOA supports:
- Long-term climate trend analysis;
- Marine ecosystem studies;
- Biogeochemical cycle assessments;
- Global and regional ocean state reports.

Education and Research

WOA is a standard reference dataset for:
- University oceanography courses;
- Climate science training;
- Large-scale comparative studies.

Data Access Workflow

A typical workflow for using WOA includes:

1. Select variable and time period (e.g., temperature, 1981–2010 climatology).
2. Choose spatial resolution (1° or 0.25°).
3. Download data in NetCDF, ASCII, CSV, or shapefile format.
4. Load into analysis tools (Python, MATLAB, R, GIS).
5. Integrate with models or observational datasets for analysis.

WOA data are accessible through the NCEI portal and THREDDS servers.

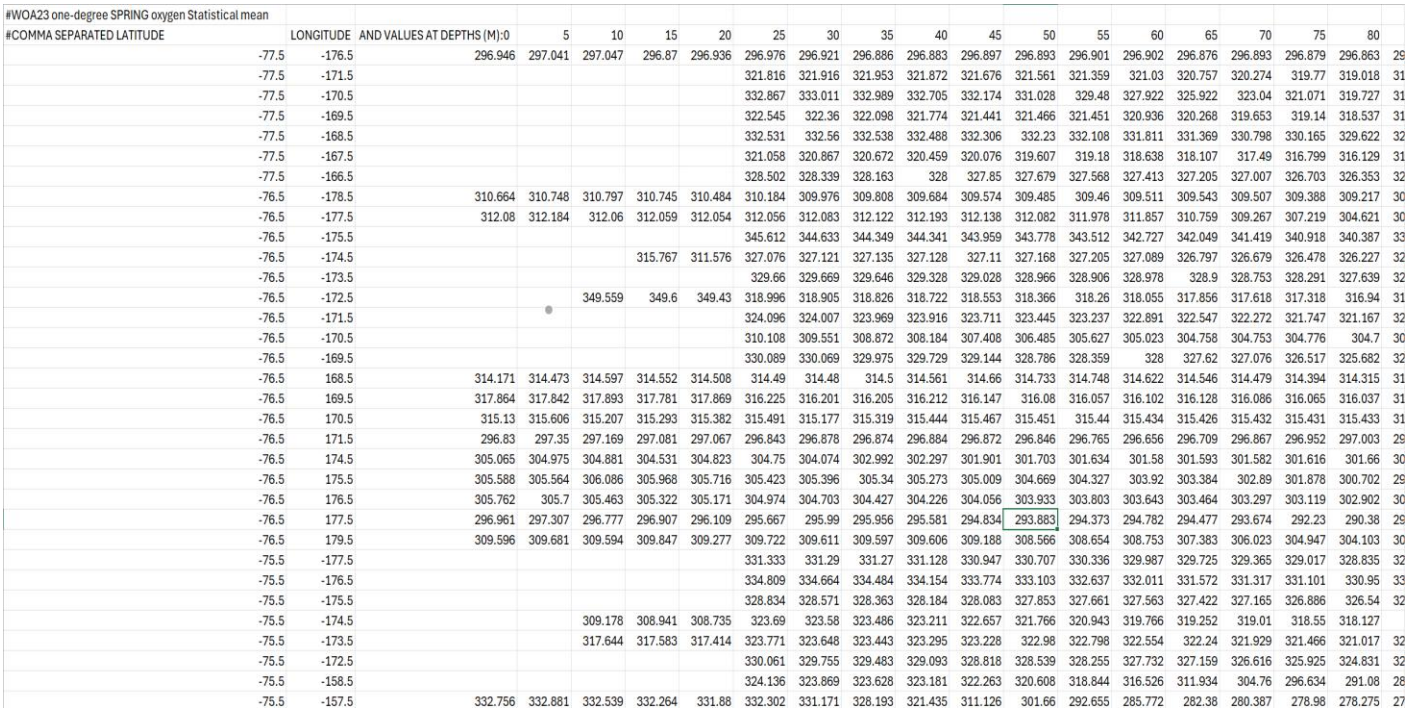
Strengths and Limitations

Strengths
- Global, multi-decadal coverage;
- High-quality, QC-controlled climatologies;
- Multiple variables essential for ocean and climate science;

- Interoperable formats (NetCDF, ASCII, CSV, GIS);
- Updated regularly with new WOD releases.

Limitations

- Climatological averages may mask short-term variability;
- Data density varies by region and decade;
- Some variables (e.g., nutrients) have sparser coverage;
- Objective analysis introduces smoothing.



#WOA23 one-degree SPRING oxygen Statistical mean																				
#COMMA SEPARATED LATITUDE	LONGITUDE	AND VALUES AT DEPTHS (M):0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80		
-77.5	-176.5	296.946	297.041	297.047	296.87	296.936	296.976	296.921	296.886	296.883	296.897	296.893	296.901	296.902	296.876	296.893	296.879	296.863	29	
-77.5	-171.5						321.816	321.916	321.953	321.872	321.676	321.561	321.359	321.03	320.757	320.274	319.77	319.018	31	
-77.5	-170.5						332.867	333.011	332.989	332.705	332.174	331.028	329.48	327.922	325.922	323.04	321.071	319.727	31	
-77.5	-169.5						322.545	322.36	322.098	321.774	321.441	321.466	321.451	320.936	320.268	319.653	319.14	318.537	31	
-77.5	-168.5						332.531	332.56	332.538	332.488	332.306	332.23	332.108	331.811	331.369	330.798	330.165	329.622	32	
-77.5	-167.5						321.058	320.867	320.672	320.459	320.076	319.607	319.18	318.638	318.107	317.49	316.799	316.129	31	
-77.5	-166.5						328.502	328.339	328.163	328	327.85	327.679	327.568	327.413	327.205	327.007	326.703	326.353	32	
-76.5	-178.5	310.664	310.748	310.797	310.745	310.484	310.184	309.976	309.808	309.684	309.574	309.485	309.46	309.511	309.543	309.507	309.388	309.217	30	
-76.5	-177.5	312.08	312.184	312.06	312.059	312.054	312.056	312.083	312.122	312.193	312.138	312.082	311.978	311.857	310.759	309.267	307.219	304.621	30	
-76.5	-175.5						345.612	344.633	344.349	344.341	343.959	343.778	343.512	342.727	342.049	341.419	340.918	340.387	33	
-76.5	-174.5				315.767	311.576	327.076	327.121	327.135	327.128	327.11	327.168	327.205	327.089	326.797	326.679	326.478	326.227	32	
-76.5	-173.5						329.66	329.669	329.646	329.328	329.028	328.966	328.906	328.978	328.9	328.753	328.291	327.639	32	
-76.5	-172.5			349.559	349.6	349.43	318.996	318.905	318.826	318.722	318.553	318.366	318.26	318.055	317.856	317.618	317.318	316.94	31	
-76.5	-171.5						324.096	324.007	323.969	323.916	323.711	323.445	323.237	322.891	322.547	322.272	321.747	321.167	32	
-76.5	-170.5						310.108	309.551	308.872	308.184	307.408	306.485	305.627	305.023	304.758	304.753	304.776	304.7	30	
-76.5	-169.5						330.089	330.069	329.975	329.729	329.144	328.786	328.359	328	327.62	327.076	326.517	325.682	32	
-76.5	168.5	314.171	314.473	314.597	314.552	314.508	314.49	314.48	314.5	314.561	314.66	314.733	314.748	314.622	314.546	314.479	314.394	314.315	31	
-76.5	169.5	317.864	317.842	317.893	317.781	317.869	316.225	316.201	316.205	316.212	316.147	316.08	316.057	316.102	316.128	316.086	316.065	316.037	31	
-76.5	170.5	315.13	315.606	315.207	315.293	315.382	315.491	315.177	315.319	315.444	315.467	315.451	315.44	315.434	315.426	315.432	315.431	315.433	31	
-76.5	171.5	296.83	297.35	297.169	297.081	297.067	296.843	296.878	296.874	296.884	296.872	296.846	296.765	296.656	296.709	296.867	296.952	297.003	29	
-76.5	174.5	305.065	304.975	304.881	304.531	304.823	304.75	304.074	302.992	302.297	301.901	301.703	301.634	301.58	301.593	301.582	301.616	301.66	30	
-76.5	175.5	305.588	305.564	306.086	305.968	305.716	305.423	305.396	305.34	305.273	305.009	304.669	304.327	303.92	303.384	302.89	301.878	300.702	29	
-76.5	176.5	305.762	305.7	305.463	305.322	305.171	304.974	304.703	304.427	304.226	304.056	303.933	303.803	303.643	303.464	303.297	303.119	302.902	30	
-76.5	177.5	296.961	297.307	296.777	296.907	296.109	295.667	295.99	295.956	295.581	294.834	293.883	294.373	294.782	294.477	293.674	292.23	290.38	29	
-76.5	179.5	309.596	309.681	309.594	309.847	309.277	309.722	309.611	309.597	309.606	309.188	308.566	308.654	308.753	307.383	306.023	304.947	304.103	30	
-75.5	-177.5						331.333	331.29	331.27	331.128	330.947	330.707	330.336	329.987	329.725	329.365	329.017	328.835	32	
-75.5	-176.5						334.809	334.664	334.484	334.154	333.774	333.103	332.637	332.011	331.572	331.317	331.101	330.95	33	
-75.5	-175.5						328.834	328.571	328.363	328.184	328.083	327.853	327.661	327.563	327.422	327.165	326.886	326.54	32	
-75.5	-174.5			309.178	308.941	308.735	323.69	323.58	323.486	323.211	322.657	321.766	320.943	319.766	319.252	319.01	318.55	318.127		
-75.5	-173.5			317.644	317.583	317.414	323.771	323.648	323.443	323.295	323.228	322.98	322.798	322.554	322.24	321.929	321.466	321.017	32	
-75.5	-172.5						330.061	329.755	329.483	329.093	328.818	328.539	328.255	327.732	327.159	326.616	325.925	324.831	32	
-75.5	-158.5						324.136	323.869	323.628	323.181	322.263	320.608	318.844	316.526	311.934	304.76	296.634	291.08	28	
-75.5	-157.5	332.756	332.881	332.539	332.264	331.88	332.302	331.171	328.193	321.435	311.126	301.66	292.655	285.772	282.38	280.387	278.98	278.275	27	

Table 15. WOA – World Ocean Atlas

Database ID	DB-08
Full Name	WOA – World Ocean Atlas
Category	Global / Climatological Atlas
Operator / Owner	NOAA NCEI
Access URL	https://www.ncei.noaa.gov/products/world-ocean-atlas
License	Open / Free
Spatial Coverage	Global oceans
Temporal Coverage	Climatological means (WOA23: 1955–2022)
Key Variables / Products	Temperature (climatological mean & seasonal) | Salinity | Dissolved oxygen | Apparent oxygen utilization (AOU) | Phosphate, Nitrate, Silicate climatologies | Density
Data Formats	NetCDF
Relevance to DTEClimate ACT4D-Eutrophication	Provides gridded climatological reference fields (1/4° and 1° resolution) for model validation and anomaly detection. WOA Black Sea climatologies serve as baseline for identifying eutrophication-driven deviations in nutrient and oxygen fields.
Applicable Deliverables	D2-2.1, model boundary conditions, anomaly detection, validation reference

4.9 DB-09 – CORA – Copernicus Marine In-Situ Observations

The CORA (Coriolis Ocean Dataset for Reanalysis) database is a global, scientifically validated collection of in-situ ocean temperature and salinity measurements, produced through the collaboration of the Coriolis Data Centre and the In Situ Thematic Centre (INSTAC) of the Copernicus Marine Service. It is designed specifically to support ocean reanalysis, climate studies, and long-term ocean monitoring, providing high-quality, delayed-mode validated datasets updated annually since 2007.

CORA integrates observations from a wide range of international ocean observing systems and applies rigorous quality control procedures to deliver a reference-grade dataset suitable for climate applications.

Data Sources and Observing Platforms

CORA aggregates in-situ measurements from numerous global and regional observing systems, including:

- Argo profiling floats;
- Fixed moorings;
- Gliders;
- Surface drifters;
- Instrumented marine mammals;
- Research vessels and ships of opportunity (CTD, XBT, ferrybox);

These observations are collected by the Coriolis Data Centre in cooperation with CMEMS INSTAC.

CORA also incorporates historical profiles from major international archives such as:

- EN4 global temperature & salinity dataset;
- World Ocean Atlas (WOA);
- SeaDataNet;
- ICES;
- Other global data aggregators .

Structure and Content of the CORA Data Base

Variables

CORA focuses on two essential physical ocean variables:

- Temperature;
- Salinity.

Measurements are provided either in **immersion depth (meters)** or **pressure (decibars)** depending on the instrument type.

Temporal Coverage

CORA includes global in-situ observations from **1950 to the present**, with annual updates. Earlier versions merged CORA with the **EN4 dataset for 1950–1990**, ensuring long-term continuity.

Spatial Coverage

CORA provides global coverage from 90°N to 90°S and 180°W to 180°E, making it suitable for basin-scale and global ocean reanalysis.

Quality Control and Validation

CORA applies a **two-stage quality control (QC) system**:

Near-Real-Time QC

Performed daily and weekly by CMEMS INSTAC for operational forecasting. This step removes major errors and ensures timely availability.

Delayed-Mode Scientific Validation

A more rigorous QC procedure is applied to produce the **reference product**, including:

- Statistical tests (objective analysis);
- Visual inspection;
- Cross-validation with climatologies.

This ensures the dataset meets the accuracy requirements of climate applications and reanalysis systems.

The **CORA 5.2** validation framework demonstrates that delayed-mode QC significantly reduces random-error-induced variability compared to raw or near-real-time datasets.

Data Products and Formats

CORA provides two main types of products:

Individual Profiles
- Original measurement levels;
- QC flags for each observation;
- Interpolated levels (optional).

Gridded Fields
- Weekly gridded temperature and salinity fields;
- Objective analysis products for reanalysis.

All products are freely available through the **Copernicus Marine Service**.

Applications and Use Cases

CORA is widely used in:

Ocean Reanalysis

CORA provides the high-quality in-situ foundation for global and regional ocean reanalysis systems, enabling reconstruction of past ocean states. Its long temporal coverage (1950–present) is essential for climate diagnostics.

Climate Monitoring

CORA supports:
- Ocean heat content estimation;
- Salinity trend analysis;
- Thermohaline circulation studies;
- Long-term variability assessments.

Operational Oceanography

Near-real-time QC feeds forecasting systems, while delayed-mode CORA supports model validation and hindcast evaluation.

Data Assimilation

CORA is a key input for data assimilation in global circulation models, improving accuracy of ocean state estimates.

Strengths and Limitations

Strengths

- Global, multi-platform in-situ coverage;
- Annual updates since 2007;
- Rigorous delayed-mode QC;
- Integration of historical and modern datasets;
- Availability of both profiles and gridded fields;
- Free and open access through Copernicus Marine Service.

Limitations

- Limited variable set (temperature and salinity only);
- Spatial and temporal sampling depends on observing system density;
- Historical data may have lower accuracy or sparse coverage.

Table 16. CORA – Copernicus Marine In-Situ Observations

Database ID	DB-09
Full Name	CORA – Copernicus Marine In-Situ Observations (Coriolis Ocean dataset for Reanalysis)
Category	European / In-situ Ocean
Operator / Owner	Coriolis / Ifremer (on behalf of CMEMS)
Access URL	https://marine.copernicus.eu (INSITU_GLO_PHY_TS_OA_MY_013_052)
License	Open / Free (Copernicus)
Spatial Coverage	Global oceans (Black Sea subset available)
Temporal Coverage	1950–present (quality-controlled historical archive)
Key Variables / Products	Temperature & salinity profiles (CTD, Argo, XBT, MBT) | Gridded temperature/salinity analyses | Platform metadata (ship, buoy, mooring, float)
Data Formats	NetCDF
Relevance to DTEClimate ACT4D-Eutrophication	Quality-controlled in-situ hydrographic dataset used for model reanalysis forcing and validation. CORA Black Sea profiles complement CMEMS model outputs for D2-2.1 validation of physical oceanographic parameters.
Applicable Deliverables	D2-2.1, reanalysis validation, model-data comparison, Black Sea hydrography

4.10 DB-10 – data.gov.ro – Hidrografie

The Hidrografie (Hydrography) Database published on data.gov.ro is the official digital representation of Romania's cadastral hydrographic network, managed by Administrația Națională "Apele Române". It provides open access to authoritative spatial datasets describing rivers, hydrographic basins, and water management infrastructure. The database is derived from the long-standing national water cadastre system, initiated in 1958 and continuously updated ever since .

This dataset is essential for water management, environmental planning, flood risk assessment, hydrological modelling, and territorial planning.

Historical Background

Romania's cadastral inventory of waters began in 1958, when the first systematic registration of hydraulic works and water bodies was initiated. The resulting cadastral sheets were organized by hydrographic basins, rivers, and types of hydraulic structures .

In 1964, the State Water Committee published the first *Atlasul cadastrului apelor din România*, based on more than 50,000 cadastral sheets and technical annexes. This atlas codified 4,295 watercourses, representing 66,029 km of hydrographic network, using the Gauss–Krüger projection at 1:25,000 scale for naming and coding verification .

Structure of the Hydrography Database

Dataset Description

The dataset titled "Rețea hidrografică" represents the digital format of the hydrographic network included in the 1992 Atlas, updated with improvements and corrections. It is available as a downloadable SHP/ZIP package on data.gov.ro .

Coding System

The hydrographic network uses an adapted version of the Gravelius stream order system, still applied today. Key characteristics:

- Romania is divided into 15 first-order hydrographic basins (e.g., Tisa, Someș-Crasna, Crișuri, Mureș, Olt, Argeș, Siret, Prut, Dunăre, Litoral);
- Rivers flowing into a first-order river are classified as second-order, and so on, up to sixth-order streams;
- Tributaries of the same order are numbered from source to mouth This system reflects the hierarchical structure of the national hydrographic network.

Inclusion Criteria for Watercourses

A river is included in the cadastral hydrographic network if it meets **all** of the following criteria:

- Minimum catchment area: **10 km²;**
- Minimum river length: **5 km;**
- Well-defined channel;
- Quasi-permanent flow throughout the year Applying these criteria resulted in **4,854 unique coded rivers**, totaling nearly **85,000 km** of watercourses, including ~2,000 km of the Danube (main and secondary branches).

Technical Characteristics

Spatial Reference

The dataset is provided in **Stereo 1970**, Romania's national geodetic projection system, ensuring compatibility with national GIS workflows .

Data Format

Available formats include:

- **SHP** (vector line geometry);
- **ZIP** (compressed package) These formats support integration into GIS platforms such as QGIS, ArcGIS, and national hydrological modelling tools.

Metadata and Documentation

The dataset includes:

- River codes;
- River names (primary and secondary/local names);
- Basin identifiers;

- Stream order;
- Geometric representation of the river axis.

Applications and Use Cases

Water Resource Management

The dataset supports:

- River basin management plans;
- Water allocation and monitoring;
- Infrastructure planning (dams, reservoirs, levees).

Environmental and Climate Studies

Used for:

- Flood risk mapping;
- Hydrological modelling;
- Climate impact assessments;
- Ecosystem and habitat studies.

Territorial and Urban Planning

Authorities use the dataset for:

- Land-use planning;
- Infrastructure development;
- Environmental impact assessments;
- Risk zoning (floodplains, erosion zones).

Research and Education

The dataset is widely used in:

- University hydrology courses;
- GIS training;
- Environmental research projects.

Strengths and Limitations

Strengths

- Official, authoritative national hydrographic dataset;
- Based on decades of cadastral work and validated mapping;
- High spatial accuracy (1:100,000 base maps);
- Free and open access via data.gov.ro;
- Compatible with national geodetic standards (Stereo 1970).

Limitations

- Updates depend on institutional workflows;
- Some small streams (<5 km) are not included;
- Historical naming conventions may differ from local usage;
- Does not include real-time hydrological data (only geometry).

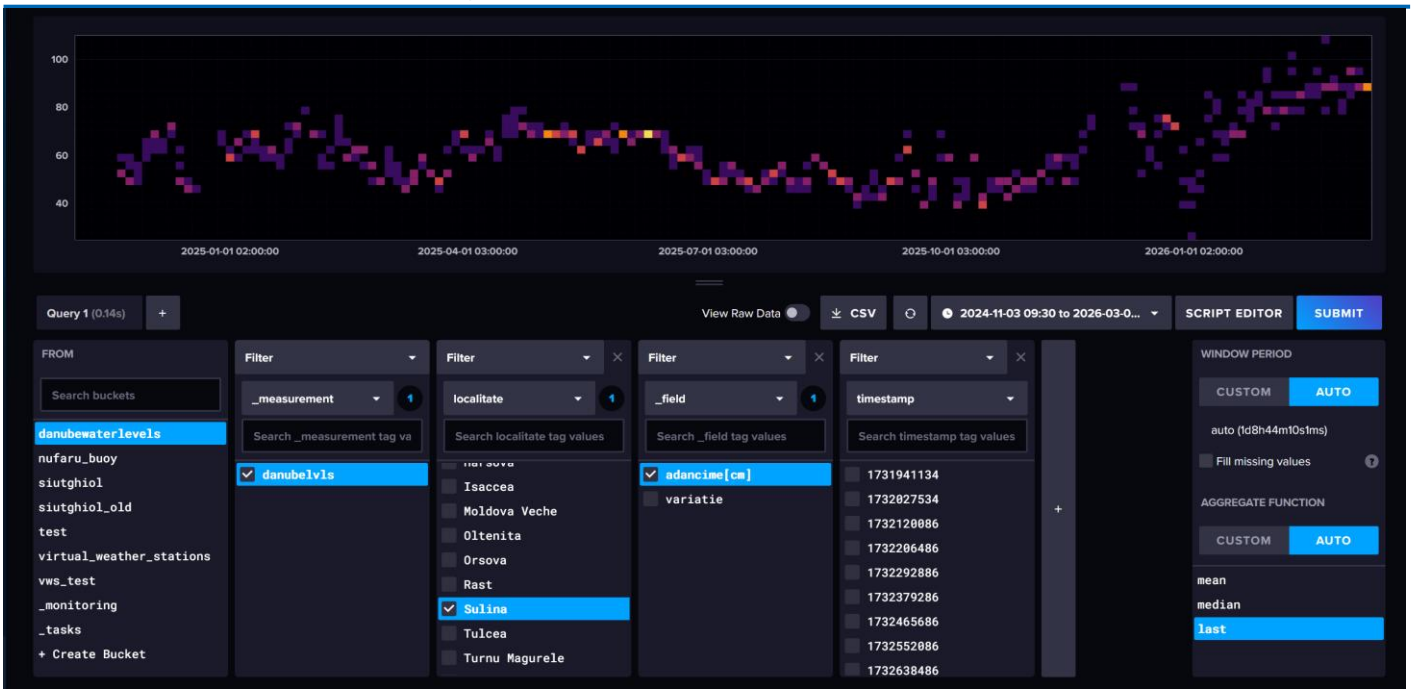


Figure 9. data.gov.ro – Hidrografie

Table 17. data.gov.ro – Hidrografie

Database ID	DB-10
Full Name	data.gov.ro – Hidrografie (Romanian Open Government Data – Hydrography)
Category	National / Hydrography
Operator / Owner	Romanian Government / Agenția Națională de Cadastru și Publicitate Imobiliară (ANCPI)
Access URL	https://data.gov.ro (search: hidrografie)
License	Open Government License (Romania)
Spatial Coverage	Romania
Temporal Coverage	Static / periodically updated
Key Variables / Products	River network (watercourses, catchments) | Lake polygons & morphometry | Wetland delineation (Danube Delta, Dobrogea) | Coastline geometry (Black Sea) | Hydrological basin boundaries
Data Formats	Shapefile, GeoJSON, GML, WMS
Relevance to DTEClimate ACT4D	National authoritative source for Romanian hydrographic vector data including Dobrogea lake polygons (Siutghiol, Techirghiol, Razim-Sinoe system) and the Black Sea coastline. Essential for defining areas of interest and spatial masks in the DTEClimate data cube.
Applicable Deliverables	D2-2.1, spatial reference framework, AOI definition, data cube spatial masks

4.11 DB-11 – INHGA – Institutul Național de Hidrologie și Gospodărire a Apelor

The National Institute of Hydrology and Water Management (INHGA) is Romania's central authority for hydrological and hydrogeological monitoring, forecasting, and data management. A core component of its mandate is the administration of the National Hydrological and Hydrogeological Data Fund, a comprehensive national database containing raw, validated, and processed hydrological and hydrogeological data collected from the entire national monitoring network.

This database supports water management, flood forecasting, drought monitoring, infrastructure design, environmental assessments, and national emergency response.

INHGA operates under the authority of the Ministry of the Environment, Water, and Forests and collaborates closely with The National Administration "Romanian Waters", the national water management authority. Its responsibilities include:

- Hydrological and hydrogeological monitoring;
- National flood and drought forecasting;
- Development of hydrological studies;
- Management of national hydrological data archives;
- Implementation of the EU Floods Directive (2007/60/EC).

Structure of the INHGA Data Base

Types of Data Stored

The INHGA database contains three major categories of data:

- Raw data (date brute): direct measurements from hydrometric stations (water level, discharge, temperature, precipitation, groundwater levels).
- Primary validated data (date primare): raw data that have undergone multi-stage verification and correction.
- Derived/processed data (date derivate): analytical products generated using hydrological and hydrogeological algorithms (e.g., flow statistics, frequency curves, drought indices).

Data Sources

Data originate from the National Hydrological and Hydrogeological Network, which includes:

- Hydrometric stations on rivers, lakes, canals;
- Pluviometric, nivometric, and evaporimetric stations;
- Groundwater monitoring wells (freatic and deep aquifers);
- Expeditionary hydrological measurements (e.g., Danube cross-sections).

Database Architecture

The database is implemented as a Relational Database Management System (RDBMS), ensuring:

- Structured storage of time series and metadata;
- Controlled data validation workflows;
- Secure access and versioning;
- Integration with GIS systems for spatial analysis.

Data Management and Processing

Continuous Updating

INHGA continuously updates the database by:

- Introducing new measurements;
- Validating and correcting time series;
- Managing metadata;
- Maintaining the application servers used for data storage and access.

Quality Assurance

All processing methodologies are verified and approved annually by INHGA expert teams, ensuring scientific consistency and national standardization.

Integration with GIS

The GIS division develops:

- National and local hydrological GIS databases;
- Digital terrain models;
- Hydrographic networks;
- Layers for hydrometric stations, reservoirs, hydraulic structures.

Operational Products Derived from the Database

INHGA uses its database to generate a wide range of operational hydrological products:

Hydrological Bulletins

- Daily Hydrological Bulletin;
- Informative Hydrological Bulletin;
- Monthly Hydrological Bulletin;
- Hydrogeological Bulletin.

Forecasts and Warnings

- Short-, medium-, and long-term river flow forecasts;
- Flash-flood and flood warnings;
- Drought monitoring and winter hydrological phenomena;
- Danube flow and level forecasts.

Flood Risk Management Data

INHGA provides essential datasets for:

- Preliminary flood risk assessments;
- Hazard and risk maps;
- Flood risk management plans (PMRI).

Applications and Use Cases

Water Resource Management

The database supports:

- National water resource assessments;
- River basin management plans;
- Infrastructure design (dams, bridges, levees).

Emergency Management

INHGA data are critical for:

- Flood emergency response;
- Coordination with national authorities;
- Real-time decision support during hydrological crises.

Scientific Research

The database underpins:

- Hydrological modelling;
- Climate change impact studies;
- Groundwater resource assessments;
- Long-term hydrological trend analysis.

Strengths and Limitations

Strengths

- Nationally authoritative hydrological and hydrogeological dataset;
- Continuous, controlled updating and validation;
- Integration of raw, validated, and derived data;
- Strong GIS support;
- Essential for forecasting and emergency management.

Limitations

- Access to full datasets may require institutional authorization;
- Historical data may vary in density and measurement methods;
- Some older stations have incomplete metadata.

Table 17. INHGA – Institutul Național de Hidrologie și Gospodărire a Apelor

Database ID	DB-11
Full Name	INHGA – Institutul Național de Hidrologie și Gospodărire a Apelor
Category	National / In-situ Hydrological & Meteorological
Operator / Owner	INHGA (Romania), under Ministry of Environment
Access URL	https://www.inhga.ro (institutional; partial open data)
License	Restricted / Request-based; some open datasets
Spatial Coverage	Romania
Temporal Coverage	1950s–present (gauge network); real-time for some stations
Key Variables / Products	River discharge & water levels (gauge stations) | Groundwater levels | Lake water levels & volume estimates | Precipitation (rain gauge network) | Sediment transport | Flood frequency & hydrological extremes | Water balance
Data Formats	CSV, Excel, station reports (PDF)
Relevance to DTEClimate ACT4D	National authority for hydrological monitoring data covering Romanian rivers, lakes, and groundwater. INHGA gauge data for Dobrogea hydrological basin and the Danube delta provides critical in-situ calibration and validation data for climate-driven water level and flood risk analyses.
Applicable Deliverables	D2-2.1, in-situ ground truth, hydrological model calibration, climate change impact assessment

4.12 DB-12 – ICOADS – International Comprehensive Ocean-Atmosphere Data Set

The International Comprehensive Ocean–Atmosphere Data Set (ICOADS) is the most complete global collection of surface marine meteorological observations available, providing a unique record of ocean–atmosphere conditions from 1662 to the present. It underpins a wide range of applications in climate research, reanalysis, satellite validation, air–sea interaction studies, and marine climatology, serving as the primary "ground truth" archive for surface marine climate.

Historical development

ICOADS evolved from the earlier Comprehensive Ocean–Atmosphere Data Set (COADS), initiated in the early 1980s in the United States. The first COADS release (1985) contained about 70 million reports for 1854–1979; subsequent expansions extended coverage both backward and forward in time, and in 2002 the project

was renamed ICOADS to reflect growing international contributions. Major milestones include:

- 1800–1949: creation of 2°×2° monthly grids (2002);
- 1960–present: 1°×1° monthly grids;
- Extension back to 1662: completed in 2009, with ongoing near-real-time updates.

Structure and content of the ICOADS data base

Observational data

ICOADS archives individual surface marine observations from:

- Ships of opportunity and research vessels;
- Moored and drifting buoys;
- Weather ships and other in situ platforms.

Key variables include:

- Sea surface temperature (SST);
- Air temperature;
- Sea level pressure (SLP);
- Wind speed and direction;
- Humidity;
- Cloud amount.
- Derived flux-related variables (e.g., turbulent heat and momentum pseudo-fluxes).

Observations are stored primarily in IMMA (International Maritime Meteorological Archive) format and NetCDF, with near-real-time daily and monthly updates.

Gridded monthly summary products

ICOADS provides simple, non-interpolated monthly summary statistics on regular grids:

- 2°×2° latitude–longitude boxes from 1800–present;
- 1°×1° boxes from 1960–present.

For each grid box and month, ten statistics are computed for 22 observed and derived variables, including: mean, median (third sextile), standard deviation, number of observations, mean day of month, fraction of daytime observations, and mean observation position.

Products are available as “standard” (stricter trimming, mainly ship data) and “enhanced” (broader trimming, including buoys and other platforms) versions.

Quality control and data policy

ICOADS applies initial quality control to individual observations (format checks, gross error tests), but does not impose extensive bias corrections or homogenisation—leaving users free to apply their own adjustments for specific applications. For gridded products, trimming procedures based on climatological sigma limits (3.5σ for standard, 4.5σ for enhanced) are used to remove outliers while preserving extremes in the enhanced set. apdrc.soest.hawaii.edu

Near-real-time updates rely increasingly on GTS BUFR and TAC messages, merged and decoded into IMMA/NetCDF for the latest ICOADS releases.

Applications and use cases

ICOADS is a cornerstone for:

- Marine climate and variability studies: long-term SST, SLP, wind, and cloudiness trends over the last two centuries.
- Reanalysis and data assimilation: providing the primary surface marine input for global atmospheric and oceanic reanalyses.

- Bias assessment and algorithm development: evaluation of ship and buoy measurements, satellite retrievals, and blended products (e.g., ERSST, HadSLP).
- Extreme events and hazards: analysis of historical storms, marine heatwaves, and contributions to updated hurricane databases.

Because ICOADS preserves the original observations and their statistics, it is widely regarded as the empirical foundation for our knowledge of surface marine climate.

Strengths and limitations

Strengths

- Most complete global archive of surface marine observations (1662–present).
- Long, multi-century records for key climate variables.
- Transparent, minimally processed data—ideal as a reference and for methodological development.
- Flexible access via NOAA NCEI and NCAR (individual observations, gridded summaries, subsetting tools, and value-added databases).

Limitations

- **Sparse coverage** in early centuries and in some ocean basins.
- No built-in homogenisation or bias corrections beyond basic QC—users must handle changes in observing practices and instrumentation.
- Heterogeneous mix of platforms and technologies, requiring careful interpretation for trend analysis.

Table 18. ICOADS – International Comprehensive Ocean-Atmosphere Data Set

Database ID	DB-12
Full Name	ICOADS – International Comprehensive Ocean-Atmosphere Data Set
Category	Global / Historical Marine Meteorology
Operator / Owner	NOAA NCEI / NCAR
Access URL	https://icoads.noaa.gov / https://rda.ucar.edu/datasets/d548000/
License	Open / Free
Spatial Coverage	Global oceans
Temporal Coverage	1662–present
Key Variables / Products	Sea Surface Temperature (ship & buoy observations) | Sea-level pressure | Surface wind speed & direction | Air temperature & humidity (marine boundary layer) | Cloud cover | Wave height
Data Formats	NetCDF, ASCII
Relevance to DTEClimate ACT4D	World's most comprehensive collection of historical marine surface meteorological observations. ICOADS Black Sea records provide long-term (pre-satellite era) SST and atmospheric forcing data for trend analysis, complementing satellite records to build multi-century eutrophication context.
Applicable Deliverables	D2-2.1, long-term trend analysis, historical baseline, climate change attribution

5. Data Integration Framework

This chapter describes how the twelve identified databases are integrated into the DTEClimate operational data infrastructure. Integration encompasses five dimensions: the functional data workflow (pipeline layer architecture); data format harmonisation and pre-processing requirements; quality control and validation procedures; update scheduling and latency management; and storage volume and infrastructure estimates. Together, these elements define the technical specification that the DTEClimate data engineering team must implement to make all identified sources operational within the data cube.

5.1 Data Workflow for Eutrophication Monitoring

The DTEClimate data processing pipeline is structured into four functional layers, each drawing from specific subsets of the twelve databases. The layers are sequential: the output of each layer feeds the next, but all layers operate in parallel on a continuous basis once the system is operational. Table 19 describes the layer architecture and the databases assigned to each layer.

Table 19. DTEClimate Pipeline Layers and Associated Data Sources

Layer	Function	Primary Databases	Output Products	Update Freq.
L1 – Raw EO Ingestion	Satellite imagery acquisition, format conversion, atmospheric correction, and tiling into data cube structure	Copernicus C3S/CMEMS (DB-01), Earthdata (DB-05), EarthExplorer (DB-06), EOS (DB-03)	Level-1/2 imagery mosaics, analysis-ready datacube tiles, multi-temporal stacks (Sentinel-2, Landsat, MODIS)	Daily to 5-day (sensor dependent)
L2 – In-situ Ground Truth	Collection, quality-flagging, and spatial co-registration of point-based field measurements for algorithm calibration and satellite product validation	WOD (DB-07), CORA (DB-09), GEMStat (DB-04), INHGA (DB-11)	QC-flagged in-situ parameter datasets, match-up databases (satellite vs. in-situ), calibration coefficient tables	Annual bulk update + real-time INHGA feed
L3 – Climatological Reference	Computation of long-term climatological baselines and anomaly fields; provision of model boundary conditions and forcing fields	WOA (DB-08), ICOADS (DB-12), EMODnet (DB-02)	Climatological mean fields (monthly/seasonal), anomaly maps, interannual variability indices, model forcing NetCDF files	Decadal update (static reference during project)
L4 – National Spatial Reference	Ingestion and standardisation of authoritative national vector data for AOI delineation, spatial masking, and coordinate reference system alignment	data.gov.ro-Hidrografie (DB-10), INHGA gauge locations (DB-11)	AOI polygon layers, hydrographic network GeoJSON, lake boundary masks, basin delineation rasters at 10 m resolution	Annual or on update release

The four-layer architecture ensures a clean separation of concerns between raw data ingestion (L1),

observational validation (L2), climatological context (L3), and spatial framework (L4). This separation simplifies maintenance, allows independent update cycles for each layer, and makes it possible to replace or supplement individual databases without disrupting the rest of the pipeline.

5.2 Data Format Harmonisation and Pre-processing Requirements

The twelve identified databases deliver data in a range of formats, coordinate reference systems, spatial resolutions, and temporal conventions. Before ingestion into the DTEClimate data cube, all datasets must be harmonised to a common technical standard. Table 4.2 specifies the source format, target format, and key pre-processing operations required for each database.

Table 20. Format Harmonisation Requirements by Database

ID	Database	Source Format	Target Format	Key Pre-processing Operations
DB-01	Copernicus C3S/CMEMS	NetCDF-4, GRIB2	NetCDF-4 CF	Reprojection to EPSG:32635, temporal resampling to daily, unit standardisation (Chl-a: mg/m3), masking of land pixels
DB-02	EMODnet	NetCDF, WMS/WFS, CSV	NetCDF-4 CF / GeoJSON	Bathymetry regridding to 100 m; chemistry point data spatial aggregation to 0.1 deg grid; temporal gap-filling
DB-03	EOS Analytics	COG GeoTIFF, API JSON	GeoTIFF (COG)	Cloud masking (Fmask), BRDF normalisation, index computation (NDWI, Chl index), co-registration with Sentinel-2
DB-04	GEMStat	CSV, Excel	CSV / NetCDF point	Station metadata linking, unit harmonisation, outlier flagging (IQR method), projection to WGS84
DB-05	NASA Earthdata	HDF4, HDF5, NetCDF	NetCDF-4 CF / GeoTIFF	HDF-to-NetCDF conversion, MODIS tile mosaicking (h19v04, h20v04), atmospheric correction verification (MOD09)
DB-06	EarthExplorer	GeoTIFF (Landsat C2)	GeoTIFF (COG)	Cross-sensor radiometric harmonisation (Landsat 5/7/8/9), gap-filling of SLC-off Landsat-7 data, cloud masking
DB-07	WOD	NetCDF, ASCII, CSV	NetCDF-4 CF	Profile quality flag filtering (WOD QC flags 0 and 1 only), duplicate removal, vertical interpolation to standard depths
DB-08	WOA	NetCDF-4	NetCDF-4 CF	Extraction of Black Sea sub-domain, interpolation from 0.25 deg to 0.1 deg grid, seasonal decomposition for anomaly computation
DB-09	CORA	NetCDF-4	NetCDF-4 CF	Black Sea profile extraction, QC flag filtering, merging with WOD profiles for comprehensive in-situ database
DB-10	data.gov.ro	Shapefile, GeoJSON, GML	GeoJSON / GeoPackage	CRS reprojection from Stereo-70 (EPSG:31700) to EPSG:4326, topology validation, simplification for web display
DB-11	INHGA	CSV, Excel, PDF reports	CSV / NetCDF point	Manual data entry for non-digital records, station-ID linking to spatial coordinates, unit conversion (m3/s to mm/day)
DB-12	ICOADS	NetCDF, ASCII	NetCDF-4 CF	Black Sea spatial subsetting, duplicate record removal, bias correction for historical platform types, decadal aggregation

A critical harmonisation requirement common to all spatial datasets is the adoption of a consistent Coordinate Reference System (CRS). The DTEClimate data cube uses EPSG:32635 (WGS 84 / UTM Zone 35N) as the primary projected CRS for analysis and EPSG:4326 (WGS84 geographic) for data exchange and web services. Romanian national datasets (data.gov.ro) are natively delivered in Stereo-70 (EPSG:31700) and require reprojection prior to ingestion. Temporal harmonisation requires that all datasets adopt UTC

timestamps and ISO 8601 date-time notation.

5.3 Quality Control and Validation Procedures

A multi-tier quality control (QC) framework is applied to all ingested data to ensure that only reliable, correctly attributed, and scientifically defensible observations enter the DTEClimate algorithms. The framework comprises three tiers applied sequentially:

- Tier 1 – Provider QC Acceptance: For databases that apply their own quality control systems (Copernicus CMEMS, WOD, CORA, Earthdata), only data flagged as good quality (flag values 0 or 1 in standard QC convention) are ingested. Provider QC flags are preserved as metadata variables in the harmonised dataset.
- Tier 2 – Automated Internal QC: Additional automated checks are applied during ingestion. These include range checks (physical plausibility — e.g. Chl-a >= 0; SST between -2 and +35 degC for Black Sea); spike detection (Tukey IQR method on profile time series); spatial coherence checks (nearest-neighbour comparison for outlier detection); and temporal gap analysis (flagging of anomalous gaps in otherwise continuous records).
- Tier 3 – Cross-source Consistency Validation: Satellite-derived products (Chl-a from Copernicus/NASA) are systematically compared against in-situ measurements (GEMStat, INHGA, WOD) using match-up databases constructed for each AOI. Statistical bias, RMSE, and correlation metrics are computed and recorded in the data cube metadata. Products with systematic bias exceeding 30% relative to in-situ measurements are flagged for further investigation before use in algorithm training.

5.4 Licensing and Data Access Considerations

Of the twelve identified databases, ten (10) are fully open and free of charge under open-data policies (Copernicus, NASA, NOAA, UNEP, EU, Romanian Government), yielding an 83% open-data rate across the inventory. This favourable licensing landscape means the great majority of required data can be integrated into automated pipelines without procurement procedures, contractual barriers, or redistribution restrictions.

Two databases require specific management attention:

- EOS Data Analytics (DB-03): operates under a freemium model. The DTEClimate consortium should evaluate whether EOS API access volumes required for operational SITS analysis fall within the free tier, or whether supplementary budget must be allocated. As a contingency, all EOS-provided imagery can be sourced directly from Copernicus (Sentinel-2) or NASA Earthdata (Landsat, MODIS), meaning EOS can be downgraded to a supplementary validation tool without impact on core system functionality.
- INHGA (DB-11): data access requires a formal institutional data-sharing agreement between the DTEClimate lead partner (University of Constanta) and INHGA, governed by Romanian environmental data law. This agreement must be initiated as a project management action in Workpackage 1 and is on the critical path for hydrological model calibration. The DTEClimate team should engage INHGA no later than Month 3 of the project to ensure data availability by the time algorithm development begins in Month 6.

5.5 Recommended Data Access Prioritisation

For the operational implementation of the DTEClimate data cube (Deliverable D3.x), the following prioritisation is recommended based on data volume, update frequency, and direct relevance to eutrophication detection:

1. Priority 1 (immediate integration): Copernicus CMEMS, NASA Earthdata, EMODnet Chemistry — real-time and near-real-time satellite products
2. Priority 2 (validation layer): WOD, CORA, GEMStat, INHGA — in-situ calibration and validation
3. Priority 3 (spatial reference): data.gov.ro-Hidrografie — national AOI delineation
4. Priority 4 (historical baseline): WOA, ICOADS — climatological reference and long-term trends
5. Priority 5 (supplementary EO): EarthExplorer (Landsat archive), EOS (cloud analytics interface)

Given that full integration of all twelve databases cannot be completed simultaneously, a prioritisation schedule aligned with the DTEClimate project work plan is recommended. Priorities are set based on three criteria: (a) dependency — is the database required for an earlier deliverable or algorithm?; (b) integration complexity — how much pre-processing and harmonisation effort is required?; (c) risk — what is the consequence of delay?

Table 21. Recommended Data Access Prioritisation

ID	Database	Priority	Target Month	Dependency	Risk if delayed
DB-01	Copernicus C3S/CMEMS	P1 – Critical	Month 1–2	D3.x data cube, all AI algos	Blocks SITS-LDA training and Chl-a algorithm development
DB-05	NASA Earthdata	P1 – Critical	Month 1–2	D3.x data cube, SITS archive	Loss of Landsat/MODIS historical record for trend analysis
DB-10	data.gov.ro	P1 – Critical	Month 1	AOI masks for all processing	No spatial reference: all spatial processing blocked
DB-06	EarthExplorer	P2 – High	Month 2–3	Historical change detection	Reduced historical coverage of Dobrogea lakes
DB-11	INHGA	P2 – High	Month 2–4*	Hydrological calibration	Hydrological model cannot be calibrated without gauge data
DB-02	EMODnet	P2 – High	Month 3	Black Sea chemistry baseline	Eutrophication trend analysis lacks historical nutrient data
DB-04	GEMStat	P3 – Medium	Month 3–4	In-situ freshwater QC	Freshwater Chl-a validation weakened
DB-07	WOD	P3 – Medium	Month 3–4	Ocean profile validation	Black Sea vertical profile analysis delayed

ID	Database	Priority	Target Month	Dependency	Risk if delayed
DB-09	CORA	P3 – Medium	Month 4	Reanalysis validation	CMEMS model validation incomplete
DB-08	WOA	P3 – Medium	Month 4	Climatological reference	Anomaly detection lacks baseline; can use WOD interim
DB-12	ICOADS	P4 – Low	Month 5–6	Long-term trend baseline	Pre-satellite trend analysis deferred; low operational impact
DB-03	EOS Analytics	P4 – Low	Month 5–6	Supplementary EO	Redundant with Copernicus/NASA for core use cases

** INHGA integration timeline marked with asterisk is contingent on the data-sharing agreement being signed by Month 2. If delayed, Month 4–6 integration should be assumed for planning purposes.

5.6 Estimated Data Volumes and Storage Requirements

Understanding the storage requirements for the integrated dataset is critical for infrastructure planning. Table 4.4 provides estimated raw and processed data volumes for each database, based on the spatial extent (Black Sea + Dobrogea AOI: approximately 60,000 km2), temporal depth (1972–present for satellite sources), and data type characteristics.

Table 22. Storage Requirements

ID	Database	Raw Volume (est.)	Processed Volume	Primary Format	Storage Tier
DB-01	Copernicus C3S/CMEMS	2–5 TB / year	500 GB / year	NetCDF-4	Hot (NVMe)
DB-02	EMODnet	50–200 GB total	30 GB total	NetCDF-4/GeoJSON	Warm (SSD)
DB-03	EOS Analytics	Via API (no local)	1–2 TB / year	COG GeoTIFF	Hot (NVMe)
DB-04	GEMStat	< 1 GB total	< 1 GB total	CSV	Cold (HDD)
DB-05	NASA Earthdata	5–10 TB historical	1–2 TB processed	GeoTIFF/NetCDF	Warm (SSD)
DB-06	EarthExplorer	10–20 TB historical	2–5 TB processed	COG GeoTIFF	Warm (SSD)
DB-07	WOD	5–10 GB total	2 GB processed	NetCDF-4	Cold (HDD)
DB-08	WOA	< 1 GB total	< 1 GB total	NetCDF-4	Cold (HDD)
DB-09	CORA	2–5 GB total	1 GB processed	NetCDF-4	Cold (HDD)
DB-10	data.gov.ro	< 500 MB total	< 500 MB total	GeoPackage	Cold (HDD)
DB-11	INHGA	< 1 GB / year	< 500 MB / year	CSV/NetCDF	Warm (SSD)

ID	Database	Raw Volume (est.)	Processed Volume	Primary Format	Storage Tier
DB-12	ICOADS	5–10 GB total	1–2 GB processed	NetCDF-4	Cold (HDD)

Total estimated storage requirement across all twelve databases: approximately 25–50 TB for the full historical archive (processed, AOI-clipped), growing at approximately 3–5 TB per year for ongoing operational data. Hot-tier NVMe storage (for actively processed satellite time series) is estimated at 5–10 TB; warm-tier SSD at 10–15 TB; cold-tier HDD for historical and reference datasets at 10–25 TB. These estimates assume lossless NetCDF-4 compression (zlib level 4) is applied to all gridded datasets.

6. Traceability Matrix

6.1 Data Sources to DTEClimate System Components

Table 23 provides the primary traceability matrix, mapping each of the twelve databases against the five principal dimensions of the DTEClimate system: (i) deliverables directly served by the database; (ii) data cube integration layer; (iii) AI algorithms fed by the database; (iv) use case scenarios supported; and (v) validation role (whether the database serves as a source for validation/calibration or as primary observational input).

Table 23. Traceability Matrix – Data Sources vs. DTEClimate Components

ID	Database	D2-2.1	D3.x Data Cube	AI Algorithms
DB-01	Copernicus (C3S/CMEMS)	✓ Primary	✓ EO ingestion	SITS-LDA, Chl-a analysis
DB-02	EMODnet	✓ Primary	✓ Chemistry	Biogeochemical
DB-03	EOS Analytics	✓ Secondary	○ Optional	SITS-LDA
DB-04	GEMStat	✓ Primary	✓ In-situ	Validation
DB-05	NASA Earthdata	✓ Primary	✓ EO ingestion	SITS-LDA, Chl-a
DB-06	EarthExplorer	✓ Secondary	✓ Landsat	SITS-LDA
DB-07	WOD	✓ Primary	✓ In-situ	Profile analysis
DB-08	WOA	✓ Primary	✓ Reference	Anomaly detection
DB-09	CORA	✓ Primary	✓ In-situ	Reanalysis val.
DB-10	data.gov.ro-Hidro	✓ Primary	✓ Spatial ref.	AOI masking
DB-11	INHGA	✓ Primary	✓ In-situ	Hydro calibration
DB-12	ICOADS	✓ Secondary	✓ Historical	Long-term trends

6.2 Use Case Descriptions

The two use cases referenced in the traceability matrix are defined as follows:

Table 24. Use case descriptions

Use Case	Title	Description	Primary Data Sources Required
UC1	Physical Process Assessment (Eutrophication Monitoring)	Detection and quantification of eutrophication state and trend in Black Sea west coast and Dobrogea lakes, using satellite ocean colour, in-situ nutrients, and historical baselines. Includes identification of hypoxic events, algal bloom frequency, and long-term Chl-a trend analysis.	DB-01 (SST/Chl-a), DB-04 (in-situ freshwater), DB-05 (MODIS), DB-07 (WOD profiles), DB-08 (WOA baseline), DB-09 (CORA), DB-10 (AOI), DB-11 (INHGA), DB-12 (ICOADS long-term)

Use Case	Title	Description	Primary Data Sources Required
UC2	Climate Change Impact Assessment (Trend Attribution)	Attribution of observed eutrophication changes to climate-driven forcing factors: SST warming, altered precipitation patterns, changes in Danube runoff seasonality, and increased stratification. Requires multi-decadal satellite record and reanalysis products.	DB-01 (ERA5/CMEMS), DB-03 (EOS cloud analytics), DB-05 (Earthdata multi-sensor), DB-06 (Landsat historical), DB-08 (WOA anomaly), DB-10 (spatial), DB-11 (INHGA hydrological trends)

6.3 Algorithm-to-Database Traceability

Table 25. provides the reverse traceability — from DTEClimate AI algorithms back to the specific databases and data products required as inputs. This reverse view ensures that for each algorithm, all required data dependencies are explicitly identified and covered by the D2-2.1 inventory.

Table 25. Algorithm-to-Database Dependency Matrix

Algorithm	Description	Required Database Inputs	Validation Sources
SITS-LDA (Satellite Image Time Series – Latent Dirichlet Allocation)	Unsupervised topic modelling applied to multi-temporal satellite image stacks to detect phenological and eutrophication-related spectral patterns in lake and coastal surfaces.	DB-01 (Copernicus ocean colour time series), DB-05 (MODIS/VIIRS L3), DB-06 (Landsat archive), DB-03 (EOS supplementary)	DB-04 (GEMStat Chl-a), DB-11 (INHGA), field campaign data from Living Lab
Bio-chemical Parameter Analysis over Multispectral Time Series	Retrieval of water quality parameters (Chl-a, CDOM, turbidity, suspended particulate matter) from multispectral imagery using empirical and semi-analytical algorithms.	DB-01 (CMEMS ocean colour, OLCI Sentinel-3), DB-05 (MODIS L2/L3 ocean colour), DB-06 (Landsat OLI 30 m)	DB-04 (GEMStat), DB-07 (WOD), DB-09 (CORA), in-situ matchup database
Ocean and Lake Surface Current Estimation using Doppler Centroid	Estimation of surface current velocity fields from Sentinel-1 SAR Doppler centroid anomalies, combined with CMEMS current model outputs for the Black Sea shelf.	DB-01 (CMEMS Black Sea physics, Sentinel-1 via Copernicus), DB-08 (WOA reference currents)	DB-09 (CORA current profiles), DB-07 (WOD drifter data), CMEMS reanalysis
Long-term Eutrophication Trend and Climate Attribution	Statistical analysis of multi-decadal eutrophication indicators (Chl-a, SST, nutrient loading) to separate climate-driven trends from anthropogenic nutrient loading trends.	DB-01 (ERA5 reanalysis), DB-05 (MODIS 2000-present), DB-06 (Landsat 1972-present), DB-08 (WOA baseline), DB-12 (ICOADS SST), DB-11 (INHGA river discharge)	DB-02 (EMODnet historical chemistry), DB-07 (WOD nutrient profiles)

6.4 Traceability Completeness Confirmation

A completeness check was performed to verify that: (a) every database is referenced by at least one algorithm or deliverable (no orphaned data sources); and (b) every algorithm and use case has at least one database providing its required primary input (no unsupported functional requirement). The results confirm full

bidirectional traceability coverage across the twelve databases and four AI algorithms. No orphaned databases were identified. No algorithm dependency was found to lack a corresponding data source in the D2-2.1 inventory.

The only partial coverage noted is for the long-term trend algorithm with respect to sub-surface nutrient profiles for Dobrogea lakes — a gap already identified as G-02 in Section 2.6. This gap does not prevent algorithm operation but reduces its statistical confidence for the lacustrine component. The recommended mitigation (Living Lab field campaigns and INHGA partnership) is already recorded in the gap register.

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