



Digital Twin for Innovation in Oceanic Visualization and Exploration (DIVE)

TECHNICAL NOTE OF USE CASE SCENARIOS AND USER REQUIREMENTS

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1. Introduction

1.1 Purpose

Digital Twin for Innovation in Oceanic Visualization and Exploration (DIVE) project introduces a novel **AI4Ocean** paradigm designed to advance the development and use of **Digital Twins of the Ocean (DTOs)** across three European sea basins: the Black Sea, the Norwegian Sea (LoVe region), and the Atlantic–Mediterranean offshore basins. The project responds to EU priorities related to **climate change mitigation and adaptation**, as well as the **sustainable use and protection of marine resources**.

DIVE aims to overcome current limitations in ocean data exploitation, where the complexity and heterogeneity of multimodal observations—satellite EO, in-situ sensors, simulation models, biogeochemical measurements, and generative/physical model outputs—challenge efficient information and knowledge extraction. To address this, the project proposes a new paradigm centered on **physics-aware, multimodal, generative, and causal AI models**.

The project develops **three complementary DTO components**:

- a **What-if Explorer**, enabling scenario simulation, parameter variation, and hypothesis testing using predictive, generative, and physics-based models;
- a **Causal Explorer**, enabling discovery, evaluation, and interpretation of cause–effect relations in complex environmental processes;
- an **Ocean Visualizer**, an interactive exploration and visualization tool for raw, simulated, and AI-generated ocean data.

Together, these components support advanced analysis, modelling, and decision-making across the project’s **three use cases**, addressing challenges such as coastal hydrodynamics in the Black Sea, biophysical ecosystem forecasting in the LoVe region, and rain-radar-enhanced predictive modelling for offshore wind operations.

DIVE’s architecture is designed to be **modular, scalable, and interoperable**, enabling integration with future Digital Twin components, expanded data sources, and additional sea basins. Through a **quadruple helix Living Lab**, the project ensures strong stakeholder engagement, co-creation, and long-term societal and scientific impact.

1.2 Scope

The Technical Note on Use Case Scenarios and User Requirements (TN-UCS-UR) covers:

- the detailed description of the **three DIVE use cases**:
 - **Use Case 1: Western Black Sea Coastal Areas**,
 - **Use Case 2: LoVe Blue Economy Digital Twin**,
 - **Use Case 3: Rain Radar Applications for Offshore Wind**, which will be used for the verification, validation, and demonstration of the DIVE Digital Twin components. These use cases reflect diverse environmental, ecological, and operational challenges across three European sea basins and serve as the primary drivers for data integration, AI model development, and scenario exploration within the project;
- the specific **user requirements** that guide the design, implementation, and evaluation of the DIVE system, ensuring that the What-if Explorer, Causal Explorer, Ocean Visualizer, and underlying data management workflows meet the needs of domain experts, stakeholders, and end users involved in marine monitoring, forecasting, and decision-support activities.

1.3 Document Overview

This document completely follows:

[Chapter 1](#) outlines of the purpose of this document

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[Chapter 2](#) lists the applicable and reference documents.

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2. User interaction

2.1 General information about the users

We will consider 2 main categories of users:

1. Primary actors

These partners are directly involved in the definition of requirements, system design, AI model development, validation, and demonstration of the DIVE DTO components:

- **National University for Science and Technology Politehnica Bucharest (UPB)** - *Coordinator; leads ARD generation, what-if modeling, causal integration, management, dissemination.*
- **German Aerospace Center (DLR)** - *Leads AI4Ocean components (causal explorer, visual analytics, data cube structure).*
- **Akvaplan.niva (APN)** - *Lead for LoVe use case; stakeholder engagement; ecosystem modelling.*
- **France Energies Marines (FEM)** - *Lead for offshore wind/rain radar use case; DTO component integration.*
- **National Institute for Marine Research and Development “Grigore Antipa” (NIMRD)** - *Lead for Black Sea use case; coastal monitoring and hydrodynamic modelling.*
- **IFREMER (Institut Français de Recherche pour l’Exploitation de la Mer)** - *Supports rain-radar and offshore operations modelling.*

These partners act as **primary system users**, defining functional and technical requirements and interacting with all DIVE components during their development and integration.

2. Secondary actors – external users engaged through the Living Lab and stakeholder networks

DIVE applies a **Quadruple Helix (QH)** model, engaging a wide range of societal, industry, academic, and governmental actors through the **3-basin Living Lab** (Black Sea, LoVe, Atlantic–Mediterranean). Stakeholders contribute to scenario co-creation, validation of the Digital Twin, requirements refinement, and long-term sustainability planning.

Secondary users include the following groups explicitly identified in the proposal:

- **Industry and economic actors** (*mentioned throughout Use Cases 2 & 3 and the Living Lab description*)
 - Offshore wind industry (e.g., EDF, Total Energies, Ørsted, RWE, Ocean Winds) – stakeholders in the rain-radar use case.
 - Fisheries and aquaculture clusters in Norway – e.g., Ocean Cluster Helgeland, Cod Cluster, NCE Aquaculture, Norwegian Seaweed Association.
 - Tourism sector representatives in the LoVe region – e.g., Arctic365, Visit Lofoten, Visit Vesterålen.
- **Governmental, public-sector, and regulatory actors** (*as required in marine governance, MSP, EU Taxonomy, and environmental policy context*)
 - Marine management authorities, coastal zone regulators.
 - Port authorities, coast guards, ecosystem management agencies.
 - Policy stakeholders aligned with EU directives (Marine Strategy Framework Directive, Common Fisheries Policy, Marine Spatial Planning).
- **Academic and research institutions** (*as part of QH model and foresight analysis*)
 - Universities and research centres collaborating in stakeholder workshops, foresight studies, and scenario development.
 - International ocean sustainability networks linked to APN, NIMRD, DLR, UPB, FEM, IFREMER.
- **Civil society and NGOs** (*referenced as part of the quadruple helix engagement*)
 - Environmental NGOs active in marine conservation and blue economy sustainability.
 - Community groups and local stakeholders in the Black Sea and LoVe regions.

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2.2 Methodology for user requirements gathering

User requirements in DIVE are collected through a structured, iterative process involving both the **consortium partners** and the **stakeholders engaged through the 3-basin Living Lab**. The methodology aligns with **WP1 – DTO component requirements** and **WP3 – Quadruple Helix stakeholder interaction**.

The approach integrates:

- **Thematic meetings among project partners**, including scientific, technical, and domain-expert teams involved in ARD generation, AI4Ocean component development (what-if, causal, visualizer), and use case implementation;
- **Living Lab activities**, which include foresight analysis, co-design workshops, and continuous feedback from stakeholders across academia, industry, public authorities, and civil society;
- **Targeted consultations with use-case providers**, to capture specific operational needs for the Black Sea, LoVe, and offshore wind scenarios.
- **Two-step iterative process**

The collection and refinement of user requirements follow two complementary stages:

1. **Initial requirement gathering (WP1 & early WP3)**
 - Bilateral discussions and technical meetings with use-case leads (NIMRD, APN, FEM).
 - Identification of required data types, system functionalities, modelling needs, visualization expectations, and interconnections among the DIVE components.
 - Assessment of environmental, operational, and policy-driven needs relevant to each basin.
 2. **Consolidation and cross-case harmonization (Living Lab workshops)**
 - Workshops organized within the 3-basin Living Lab to review and refine the requirements.
 - Identification of shared needs across basins, including interoperability, scalability, user interface expectations, and data access workflows.
 - Integration of stakeholder feedback into the design of the what-if explorer, causal explorer, and ocean visualizer.
- **Involvement of secondary actors**

Secondary users—industry representatives, public authorities, NGOs, and academic partners engaged via the Living Lab—contribute primarily through:

- **co-design sessions** (year 2) to shape the Digital Twin functionalities and explore scenario needs;
- **review workshops** (year 3) to validate the prototype, assess usability, and recommend improvements;
- **foresight analysis**, where stakeholders help define desirable future scenarios for the three sea basins and align DIVE outputs with real-world decision-making contexts.

This methodology ensures that system requirements reflect both **technical feasibility** (via consortium input) and **societal and operational relevance** (via stakeholder engagement).

2.3 Interaction with the primary actors

2.3.1 Questionnaires

1. Main objective of your RDI project (max. 500 characters)
2. Main applications related to your RDI project (max. 2000 characters)

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3. Use case scenario for DT components (max. 500 characters)
Specify the DT component and how you will exploit it to support your application

4. Analysed basin within the use case scenario (max. 500 characters)
Mention the areas of interest, ranked by the priority within your RDI project

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)
Mention the data's source, category (raw/collected) data's volume, temporal coverage, test site, GSD, URL, plus other relevant information

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)
Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)
Also specify the access modality

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

List of Acronyms:

RDI – Research, Development and Innovation
DT – Digital Twin
GSD – Ground Sampling Distance
URL – Uniform Resource Locator

2.3.2 Synergies between partners and specific projects

Consortium partners’ interaction across the specific projects is presented in the table below.

Specific Project	DTEclimat	ESA SAR & AI Projects	FEM Offshore Wind / DIONYSOS	LoVe Ecosystem Projects	DLR Visual Analytics Programmes
Partner					
UNSTPB					
DLR					
APN					
FEM					
NIMRD					
IFREMER					

Legend

Coordinator

Key partner

Contributor

2.4 Applications scenarios

The application scenarios will identify and illustrate the concrete capabilities of the **DIVE Digital Twin framework**, focusing on physics-informed AI, multimodal data integration, generative and causal exploration, and advanced ocean data visualization.

The DIVE concept and its core DTO components—the **What-if Explorer**, **Causal Explorer**, and **Ocean Visualizer**—will be evaluated and demonstrated through **three application scenarios**, corresponding to the project’s use cases. These scenarios reflect distinct environmental, operational, and socio-economic challenges across the three European basins addressed by the project.

The detailed descriptions of these scenarios are provided in the following sections.

2.4.1 Partner Ocean Visualizer

1. Main objective of your RDI project (max. 500 characters)

Implement an interactive visualisation tool that enables exploration and analysis of raw and simulated ocean data, supporting decision-making and scientific discovery.

2. Main applications related to your RDI project (max. 2000 characters)

Provide domain experts and decision makers with a flexible, interactive environment where they can load, colour-map, and filter multi-variate ocean datasets. Features such as colour-palettes, parallel-coordinates for scalar selection, and lens-based zoom/overview enhance both detail-on-demand and contextual understanding.

3. Use case scenario for DT components (max. 500 characters)

Specify the DT component and how you will exploit it to support your application

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Use the Digital Twin to load “what-if” output data and causal scenario simulations, feeding the results into the visualiser so that users can immediately compare simulated versus observed data and iterate on hypotheses.

4. Analysed basin within the use case scenario (max. 500 characters)

Mention the areas of interest, ranked by the priority within your RDI project

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)

Mention the data’s source, category (raw/collected) data’s volume, temporal coverage, test site, GSD, URL, plus other relevant information

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)

Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)

Also specify the access modality

What-if Scenarios

- What if simulations are pre computed on an HPC cluster; only the AI model distilled output (e.g., predicted temperature or salinity fields) is sent to the visualiser.
- No real time execution of full physics models (cost prohibitive).
- Access: read only REST/GraphQL endpoints, authenticated with an API key.

Causal Explorer engine

- Integrated directly inside the ocean visualiser.
- Uses a lightweight surrogate model, so its runtime cost is marginal.
- Users can “play” with parameters (wind stress, freshwater flux, etc.) and instantly see the effect.
- Access: embedded in the web UI; all interactions happen locally in the browser session.

Data ingestion pipeline

- Connects institutional data repositories (raw observations, simulation outputs, AI model results) to the visualiser.
- Pulls data via secure FTP/HTTP(S) or cloud object store (e.g., S3) (this latter only if not overkill).
- Normalises metadata and streams the data to the DT component.
- Access: secure API endpoints with role-based access; data cached in a fast in memory store (Redis) for quick retrieval.

Deployment artefact

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- The complete pre operational demonstrator is packaged as a single container image (Docker/OCI).
- Orchestrated by a lightweight runtime or run on prem VM, ensuring reproducibility and easy rollback.
- No separate “software engineering framework” layer is needed; the containerised bundle itself fulfils all deployment and compliance requirements.
- Access: pulled from a private Docker registry during deployment.

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

Users will interact through a web-based dashboard that allows:

1. Interactive choice from available datasets.
2. Real-time adjustment of colour maps and scalar ranges.
3. Selection of parallel-coordinates axes to filter multivariate data.
4. Applying Focus+Context and Overview+Detail techniques, i.e. lens tools, to focus on regions of interest while retaining a global context.
5. Exporting visualisations and data slices for downstream analysis or reporting.

2.4.2 Partner INCMD

1. Main objective of your RDI project (max. 500 characters)

To develop a Digital Twin prototype for the Western Black Sea coastal zone, through integration of AI/ML-enhanced in-sit and EO monitoring and modelling, encompassing a pattern visualization of coastal currents, wave propagations, and sediments transport to support a integrate/strategic coastal environmental management, and sustainable coastal development in compliance with European frameworks of MSP and MSFD.

2. Main applications related to your RDI project (max. 2000 characters)

The project aims to strengthen the capacity to monitor and forecast the impact of climate change and extreme events, on the hydrodynamic and sedimentary regime of the Western Black Sea, with a specific consideration of the new conditions of the coastal protection works extension on the southern Romanian littoral. Through the Digital Twin, multi-source data (EO, in-situ, modelled) will be combined and visualized to improve understanding of sub-mesoscale processes, sediment redistribution, and their implications for water quality, fisheries, aquaculture, and tourism at local and regional scales. The platform will provide an AI/ML-based early warning system capable of assessing deviations from baseline environmental conditions, triggering rapid alerts when abnormal shoreline variations, and hydrodynamic or turbidity

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patterns are detected. End-users (scientists, beaches administrator, port and environmental authorities, aquaculture farmers or touristic operators) will access interactive dashboards to explore high-resolution data and scenarios, contributing to informed decision-making and adaptive coastal management. The system will serve as a regional demonstrator aligned with the EU Digital Twin Ocean (DTO) initiative, contributing to the long-term integration of Black Sea data and (downstream) services into CMEMS and related Copernicus frameworks.

3. Use case scenario for DT components (max. 500 characters)

Specify the DT component and how you will exploit it to support your application

The DT integrates multi-sensor EO, in-situ monitoring, and hydrodynamic models into an AI/ML-supported “what-if” simulator. Users can visualize predicted effects of storms, protection works, or sea-level changes on local currents and sediment transport, comparing simulated and observed conditions in real time.

4. Analysed basin within the use case scenario (max. 500 characters)

Mention the areas of interest, ranked by the priority within your RDI project

Western Black Sea, with focus on the northern/natural/Danube Delta's shore, from Sulina to Corbu, and the build/southern Romanian coastal sector, from Constanta to Vama Veche. Priority areas: newly arranged and protected coastal stretches affected by coastal engineering works, encompassing the hard structures/coastal constructions extensions and beach nourishments.

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)

Mention the data's source, category (raw/collected) data's volume, temporal coverage, test site, GSD, URL, plus other relevant information

In-situ data (INCDM monitoring network):

- ADCP and wave riders' time-series: currents, waves, sea surface temperature (30 to 60 minutes resolution, since 2017).
- Sea-level recorders, turbidity sensors, and coastal webcams for real-time visualization.

Data volume: ~100 GB/year, formats: ASCII, CSV, NetCDF, jpg, avi/mp3.

Modelled data (CMEMS & local downscaling) 2D/3D hydrodynamic and wave model outputs (SWAN, MOHID, ROMS), with Spatial resolution: 500–100 m (nearshore), used for model validation and assimilation into the DT module.

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)

Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

- Hydrodynamics: surface/bottom currents, significant wave height, wave direction, and wave period.
- Sediment transport and turbidity: near-bottom concentration and optical water quality indicators.
- Coastal morphology: bathymetry/submerged bars' dynamics, shoreline changes, and protection structures.
- Meteorological forcing: wind stress, sea-level variations, atmospheric pressure, and precipitation fields. Sources: CMEMS, EMODnet Bathymetry, Copernicus EO products (Sentinel-2/3), and INCDM in-situ data. Temporal coverage: 2017–present; resolution: daily to hourly.

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)

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Also specify the access modality

- INCDM Coastal Observation Network: in-situ sensors (currents, waves, turbidity, webcams). Access: secure FTP/API with near-real-time upload.
- Numerical Modelling Cluster (MOHID–SWAN–ROMS): provides hydrodynamic and sediment simulations for “what-if” coastal scenarios. Access: CMEMS services with API, scheduled data export to the DT component.
- EO Data Gateway: Copernicus Hub and CMEMS services, integrated via API for automatic data ingestion. Access: read-only API, token-based authentication.

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

- Model grided results: maps distributions and time-series of currents, waves, sediment transport, and turbidity anomalies.
- Early warning indicators for coastal erosion, water quality changes, or ecosystem risk.
- Statistical summaries (mean, anomaly, trend) of hydrodynamic and optical parameters of the marine/coastal water bodies.
- Scenario comparison layers (e.g., pre- and post-protection works). Output formats: NetCDF, GeoTIFF, PNG, CSV for download and reporting.

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

Near-real-time (hourly updates for in-situ stations). Daily and weekly synoptic fields for EO and hourly to daily hydrodynamic model data. Monthly aggregated reports and event-based alerts during extreme events or anomalies.

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

Users will interact via a graphical interface or web-based dashboard featuring connected to DATA Cube DT:

- Layer selection and interactive map visualization (coastal currents, sediment, turbidity, bathymetry variation in relations with hydro-meteorological parameters).
- “What-if” scenario explorer for assessing impacts of storms or coastal works.
- AI-driven anomaly detection with alert notifications.
- Parallel coordinate plots for multi-parameter filtering.
- Focus and Context visualization with temporal/time horizon and spatial zoom.
- Export options (maps/spatial 2D distributions, time-series, reports) for use in environmental assessments/environment management or coastal/marine or policy documentation.

The graphical interfaces will ensure compatibility with institutional data repositories and CMEMS APIs, promoting interoperability and reuse of the developed modules within the broader Digital Twin Ocean framework.

2.4.3 Partner DLR

1. Main objective of your RDI project (max. 500 characters)

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Design, implement, and deploy a multidimensional Data Cube structure that stores and manages Analysis Ready Data (ARD) from multiple ocean-related use cases within DIVE.

The goal is to create a harmonized and query-efficient data repository supporting the core components: Ocean Visualizer, What-if Explorer, and Causal Explorer components, while ensuring standardized access for WP2 (AI4Ocean).

2. Main applications related to your RDI project (max. 2000 characters)

The Data Cube and ARD generation component of DIVE provides the foundation for storing, processing, and serving curated, harmonized datasets derived from all use case providers.

The data from the Use Case will be transformed into standardized Analysis Ready Datasets (ARD)—ensuring spatial, temporal, and thematic consistency.

These ARD cubes will feed the analytical modules of WP2 (AI4Ocean), where machine learning and data-driven models will be applied for ocean state estimation, prediction, and causal analysis.

The data cube will integrate diverse data sources (satellite, model, and in-situ), supporting spatiotemporal queries, visualization, and data analytics workflows through APIs and OGC-compliant services.

Additionally, the Data Cube will serve as the main data repository for storing outputs generated by T2.1 and T2.2, ensuring long-term accessibility, interoperability, and reproducibility.

3. Use case scenario for DT components (max. 500 characters)

Specify the DT component and how you will exploit it to support your application

The Data Cube acts as the core DT component for data management and integration. It supports the Ocean Visualizer for spatiotemporal data exploration, the What-if Explorer for scenario analysis, and the Causal Explorer for inference and knowledge extraction, enabling seamless data exchange within DIVE's Digital Twin architecture.

4. Analysed basin within the use case scenario (max. 500 characters)

Mention the areas of interest, ranked by the priority within your RDI project

Given by the use case providers.

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)

Mention the data's source, category (raw/collected) data's volume, temporal coverage, test site, GSD, URL, plus other relevant information

Given by the use case providers

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)

Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

Given by the use case providers

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)

Also specify the access modality

A relational database that has the ARD coming from the different use cases.

Possible technologies that can be used:

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- Open Data Cube (ODC) instance (TBD)
 - *Access modality*: REST API and Python client (datacube)
- xcube Server (TBD)
 - *Access modality*: OGC-compliant endpoints (WMS/WCS/WMTS) and xcube Viewer
- DIVE platform core services (TBD)
 - *Access modality*: Internal API calls for data extraction, scenario queries, and visualization within the Ocean Visualizer, What-if Explorer, and Causal Explorer.

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

Given by the use case providers

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

Given by the use case providers

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

Users will interact with the Data Cube DT component through both graphical and programmatic interfaces:

- Graphical interfaces: DIVE's Ocean Visualizer for map-based exploration, What-if Explorer for interactive simulations, and Causal Explorer for variable relationship analysis.

Programmatic interfaces: RESTful APIs and Python bindings (via datacube and xarray) enabling data scientists to query subsets, compute statistics, and run models.

2.4.4 Partner APN

1. Main objective of your RDI project (max. 500 characters)

The overarching goal of this task is to digitize the biophysical oceanographic data from the Lofoten-Vesterålen (LoVe) marine ecosystem to enable ecological forecasting with a special focus on how environmental changes affect human activities and socioeconomic conditions.

2. Main applications related to your RDI project (max. 2000 characters)

The digital twin will be used to explore and infer biophysical relationships in the data (e.g., how extreme freshwater discharge events may drive changes in coastal phytoplankton bloom phenology) and forecast its shorter-, intermediate- and longer-term environmental and ecological responses (in relation to marine the food web) and socioeconomic consequences mainly for fisheries, tourism and aquaculture sectors.

3. Use case scenario for DT components (max. 500 characters)

Specify the DT component and how you will exploit it to support your application

"LoVe Blue Economy Digital Twin" will be used (i) to explore causal relationships, forecast ecological states and explore future what-if scenarios. For the stakeholders provide (i) insights into present-day ocean dynamics, ecological interactions, and their socio-economic ties and (ii) application demonstrations

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that showcase the utility of the LoVe digital twin to render outcomes of different pre-defined future scenarios and invite them to be co-creators in this process (Living Labs).

4. Analysed basin within the use case scenario (max. 500 characters)

Mention the areas of interest, ranked by the priority within your RDI project

North Atlantic and Arctic basins (focus on LoVe region of Norway)

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)

Mention the data's source, category (raw/collected) data's volume, temporal coverage, test site, GSD, URL, plus other relevant information

Data Source	Platform type	Category (Raw/Collected)	Data Volume	Temporal Coverage	Test Site	GSD	URL	Other relevant info
Sailbuoy EK80	USV	ARD	10s MB	Continuous over 3-4 months campaign each time	LoVe and other parts of Norwegian coast	Gridded	tdb	Along track, Gridded abundance of zooplankton within the ocean's upper 100 m The data is agglomerated into the same cells as Pascal at the same temporal resolution.
Sailbuoy CTD	USV	ARD	10s MB	Continuous over 3-4 months campaign each time	LoVe and some other parts of Norwegian coast	NA	tdb	Along track measurements of salinity and temperature measure at 0.5 m depth

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Seaglider M1 CTD	AUV	ARD		Continuous over 1 month	LoVe and some other parts of Norwegian coast	NA	tbd	Along track measurements of salinity, temperature over depth profiles (maximum depth of 1000 m)
Seaglider M1 EK80	AUV	ARD		Continuous over 1 month	LoVe and some other parts of Norwegian coast	NA	tbd	Along track abundance of zooplankton from echos under for each glider profile
Seaglider M1 UVP6	AUV	ARD		Continuous over 1 month	LoVe and some other parts of Norwegian coast	NA	tbd	Along track imaging of large particulate matter (100–2000 µm) and plankton
Seaglider M1 OTS	AUV	ARD		Continuous over 1 month	LoVe and some other parts of Norwegian coast	NA	tbd	Along track measurements of Chl-a, f-CDOM, turbidity
Seaglider M1 Intrinsic	AUV	ARD?		Continuous over 1-2 months	LoVe and some other parts of Norwegian coast	NA	tbd	Depth average current measurements GPS data at surfacing of glider
Model PASCAL	NA	ARD	100s GB	Continuous	LoVe and some other parts of	Gridded	tbd	6 hourly Biomass Distribution of Calanus finmarchicus

					Norwegian coast			in the whole ocean basin.
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6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)

Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

Data Source	Platform type	Category (Raw/C collected)	Data Volume	Temporal Coverage/ Temporal Frequency	Test Site	GSD	URL	Other relevant info
Sentinel 2	Satellite	ARD		5-6 days	Norwegian Coast	Various (10, 20, 60 m)	https://dataspace.copernicus.eu/	L2A Bottom of Atmosphere reflectances
Sentinel 3 OLCI	Satellite	ARD		Sub-daily to 2 days	Global	300 m	https://dataspace.copernicus.eu/	Ocean Color data and products (L2)
CMEMS Biophysical Parameters (Chl-a etc)	Multiple Satellites	ARD		Daily	Global	0.25 deg	https://marine.copernicus.eu/access-data/	Ocean Color and Chlorophyll Concentration, other products could be relevant as layers too
Model MET Norway Norkyst800	NA	ARD		Hourly + forecast	Norwegian Coast		https://thredds.met.no/thredds/fou-hi/norkystv3.html	13 years + Forecast Structured Grid x,y,z,t, and forecasts

<i>Model CMEMS Global Model</i>	<i>NA</i>	<i>ARD</i>		<i>Hourly (2 year hindcast + forecast), daily (~15 year hindcast)</i>	<i>Globa l</i>		<i>https://marine.copernicus.eu/access-data/</i>	<i>Structu red grid x,y,z,t</i>
<i>Model CMEMS arctic model</i>	<i>NA</i>	<i>ARD</i>		<i>Continuou s (2 year hindcast + forecast), daily (~15 year hindcast)</i>	<i>Globa l</i>		<i>https://marine.copernicus.eu/access-data/</i>	<i>Structu red grid x,y,z,t</i>
<i>Model ERA5</i>	<i>NA</i>	<i>ARD</i>		<i>Continuou s 3 Hourly hindcast (>40 years)</i>	<i>Globa l</i>		<i>https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview</i>	<i>Structu red grid, atmosph ere so surface layer only x,y,t</i>
<i>Model CMEMS arctic wave forecas t</i>	<i>NA</i>	<i>ARD</i>		<i>Continuou s (2 year hindcast + forecast))</i>	<i>Globa l</i>		<i>https://marine.copernicus.eu/access-data/</i>	<i>Structu red grid x,y,t, wave so surface only</i>

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<i>Model</i>				<i>Hourly hindcast, 2 years for Nordland grid, shorter for subgrids</i>	<i>Nordl and area (Lofoten + vesteralen), also various fjords have higher resolution subgrids run for short periods</i>	<i>tbd</i>	<i>Unstructured in horizontal (x,y scattered points on triangular grid), terrain following in vertical (vertical coordinate locations vary with bathymetric depth but number of layers is fixed)</i>
<i>FVCOM unstructured grid</i>							

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)
Also specify the access modality

EMODnet (Esp. High res. Bathymetry and other data - <https://emodnet.ec.europa.eu/geoviewer/>),
EURO-ARGO (BGC-Argo data - <https://dataselection.euro-argo.eu/>),
Sea DataNet (Various - <https://cdi.seadatanet.org/search>)
The Copernicus Marine in Situ Dashboard (note it combines both Copernicus Marine & EMODnet data – various <https://marineinsitu.eu/dashboard/>)
CMEMS (<https://marine.copernicus.eu/>)
CDSE (<https://dataspace.copernicus.eu/>)
Climate data store - (<https://cds.climate.copernicus.eu/datasets>)
*Ideally, EDITO would be best to integrate if a single infrastructure is needed, but it is in beta testing phase for relevant applications for use cases.
**Mostly available by REST API
[Integration at least at Basin Use Case Level]

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

Visualization of data (in-situ, satellite, model, other platforms) Near Real Time Satellite Maps and Products
Time series of historical data/forecasts

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

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Near-Real-Time for satellite data and in-situ data
6 hourly/12 hourly/daily for model-based products and forecasts

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

Choice of layers
Zoom in zoom out functionality
Selection of Region of Interest for analysis
Overlaying layers
Historical to Forecast trends
Setting Time period range
Setting depth range (and interpolation across coarse depth layers)
3D visualization of data (spatiotemporal)
Satellite data/footprint
Simple tools correlation plots
Visualizing histograms, etc.
Cursor (value of data point with lat-lon)
Options of different colormaps
Option to manually set limits
Dynamical downscaling using ML approach?

2.4.5 Partner DLR Causal Explorer

1. Main objective of your RDI project (max. 500 characters)

To develop the Causal Explorer component of the DIVE software stack. The Causal Explorer will interface with the ARD/data cube component in order to access harmonized input data. Its main function is to detect and analyze causal structures in Earth observation and model datasets using methods from causal inference and time-series analysis. The component will provide tools for formulating and testing causality-related questions, such as the effect of one variable on another or the presence of feedback loops.

Use case holders will be able to query the Causal Explorer to examine specific hypotheses and evaluate counterfactual scenarios. Results will be made accessible through a set of analysis functions and visualizations, allowing the inspection of inferred causal graphs, dependencies, and robustness measures.

2. Main applications related to your RDI project (max. 2000 characters)

The main application of the Causal Explorer component within the DIVE software stack is to support systematic investigation of causal relationships in ocean and climate data. Whereas correlations between variables are straightforward to detect, they do not provide information on directionality, drivers, or feedback mechanisms. The Causal Explorer addresses this by applying methods from causal inference and time-series analysis to harmonized input from the ARD/data cube. Researchers and other users can employ it to identify dependencies between environmental variables. Beyond detection, the component enables the formulation and testing of counterfactual questions, allowing users to explore how system behavior might change under different conditions or assumptions. In this way, the Causal Explorer provides a dedicated environment for moving beyond descriptive analysis toward causal reasoning,

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offering a means to generate scientifically grounded hypotheses, evaluate robustness of inferred relationships, and better understand complex ocean-climate interactions.

3. Use case scenario for DT components (max. 500 characters)
Specify the DT component and how you will exploit it to support your application
 We will rely on the ARD component primarily for data input. Also, on use cases to provide specific usability and feature requests.

4. Analysed basin within the use case scenario (max. 500 characters)
Mention the areas of interest, ranked by the priority within your RDI project

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)
Mention the data’s source, category (raw/collected) data’s volume, temporal coverage, test site, GSD, URL, plus other relevant information

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)
Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)
Also specify the access modality
 There are no infrastructure needs associated with it since it should be able to run on a single machine on demand. It will rely on any software development associated resources we choose (e.g. GitHub).

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)
 The Causal Explorer will present information as causal graphs and visual summaries that show how variables influence each other. Users will see relationships, effect strengths, and possible outcomes of “what-if” scenarios in an accessible graphical form, supported by key numerical results where needed.

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

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The component comes in a form of a Python library to be used in other DT components. Interaction will be done through the visualization component.

2.4.6 Partner FEM

1. Main objective of your RDI project (max. 500 characters)

Develop a demonstrator integrating rain radar, synthetic aperture radar (SAR) Satellites, and Numerical Weather Predictions (NWP) outputs with machine learning correction models to deliver forecasts of wind for offshore wind farm maintenance planning.

2. Main applications related to your RDI project (max. 2000 characters)

The application focuses on improving weather prediction for offshore wind farm Operation & Maintenance (O&M). Current NWP models (e.g., ECMWF, AROME) have difficulty in forecasting realistic rain patterns and corresponding wind behaviour, leading to uncertainty in weather windows. Our procedure will fuse multi-source observations with NWP outputs using machine-learning models.

The system will:

- Build a colocated database combining AROME forecasts, rain radar information, and synthetic aperture radar (SAR) imagery.
- Train ML models to correct wind and precipitation fields, focusing on timing, location, and intensity.

3. Use case scenario for DT components (max. 500 characters)

Specify the DT component and how you will exploit it to support your application

A weather Digital Twin integrates radar and satellite observations with NWP outputs, applying ML-algorithms to generate forecasts for offshore wind farms, supporting maintenance scheduling and risk assessment.

4. Analysed basin within the use case scenario (max. 500 characters)

Mention the areas of interest, ranked by the priority within your RDI project

1. Western English Channel
2. Iroise Sea
3. French Mediterranean: Gulf of Lion

5. Description of the data within your institution, relevant for the use case scenario (max. 1000 characters per data source)

Mention the data's source, category (raw/collected) data's volume, temporal coverage, test site, GSD, URL, plus other relevant information

AROME forecasts: External, 1–2 km resolution, hourly, multi-year archive

Rain radar (Météo-France): External, 5-min steps, regional coverage

SAR imagery (IFREMER), Partner

6. Description of the information layers relevant for the use case scenario (max. 1000 characters per data source)

Mention the source, category (available within your institution / external), volume, temporal coverage, test site, GSD, URL, plus other relevant information

7. Description of the infrastructures to be connected within the DT component in support of the use case scenario (max. 1000 characters per infrastructure)
Also specify the access modality

HPC cluster, GPU nodes for ML training (SSH access)
Institutional repository: SFTP for common database

8. Type of information expected to be extracted from the DT component (max. 1000 characters)
If available, include samples of similar data as example

High-resolution (≤ 1 km) corrected forecasts for wind

9. Mention the temporal intervals at which you would like to receive information (max. 500 characters)

Updates every 15 min for nowcasting; hourly for short-term

10. Describe how would you like to interact with the DT component and with the information generated by it (max. 2000 characters)

Web dashboard with time series visualization. REST API for automated data retrieval and integration.

3. Initial Proposal for DTO Component

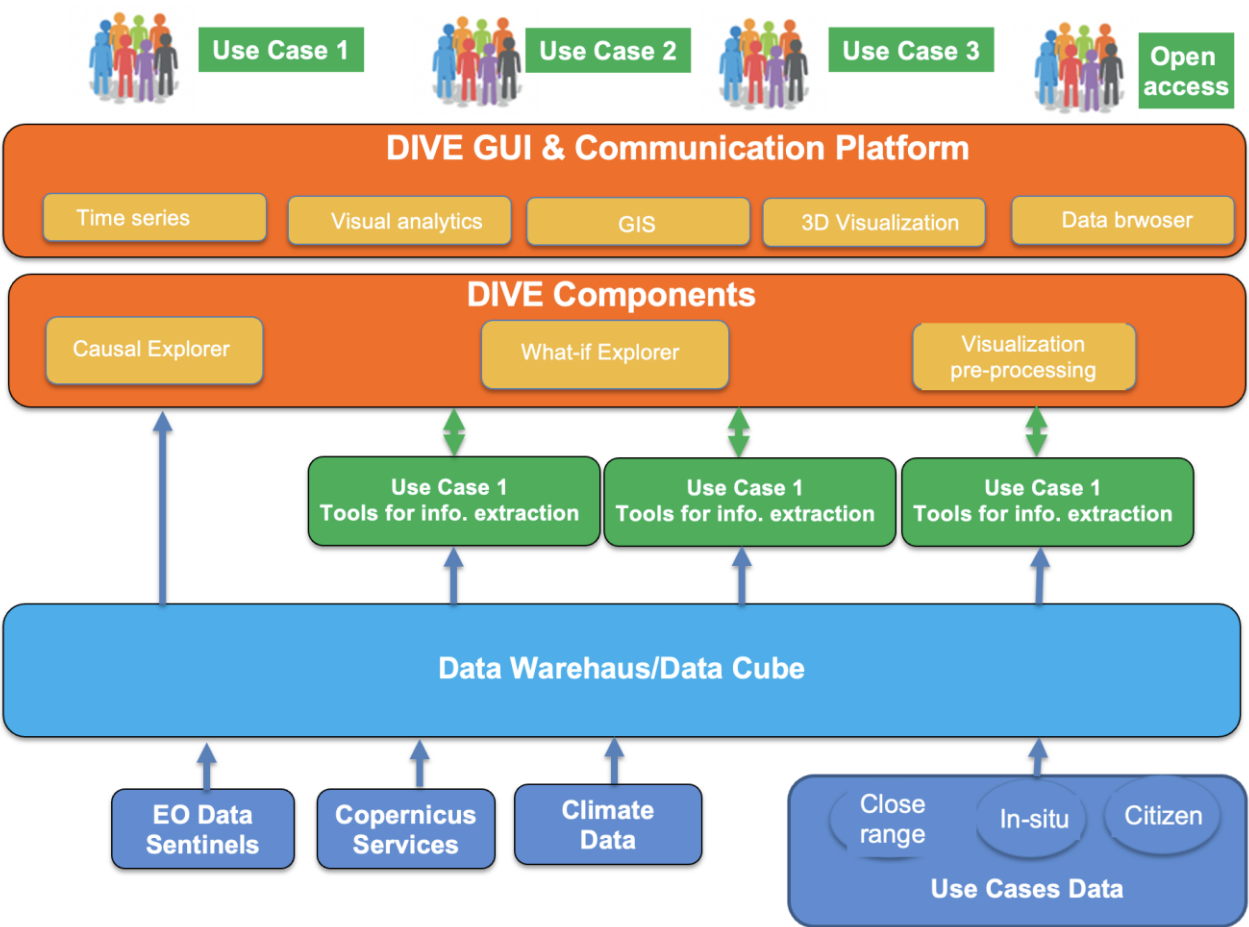


Figure 1. Schema architecture for DIVE platform.

The above schema presents the overall architecture of the DIVE platform, structured as a vertically integrated pipeline linking heterogeneous environmental data sources to advanced analytic and visualization capabilities. Multisource inputs—ranging from EO Sentinel data and Copernicus services to climate records and use-case-specific in-situ or citizen measurements—are consolidated within a unified Data Warehouse/Data Cube. Dedicated information-extraction modules then transform these datasets into higher-level indicators tailored to each use case. These feed the core DIVE components, which include causal analysis, scenario exploration, and visualization pre-processing. The resulting outputs are exposed to end-users through the DIVE GUI and Communication Platform, which provides interfaces for time-series analysis, visual analytics, GIS exploration, and 3D visualization. This architecture ensures consistent data integration, efficient processing, and user-oriented analytical access across all use cases. Below, we illustrate 4 use cases where the above schema is applied.

3.1. Initial Proposal Architecture for Use Cases

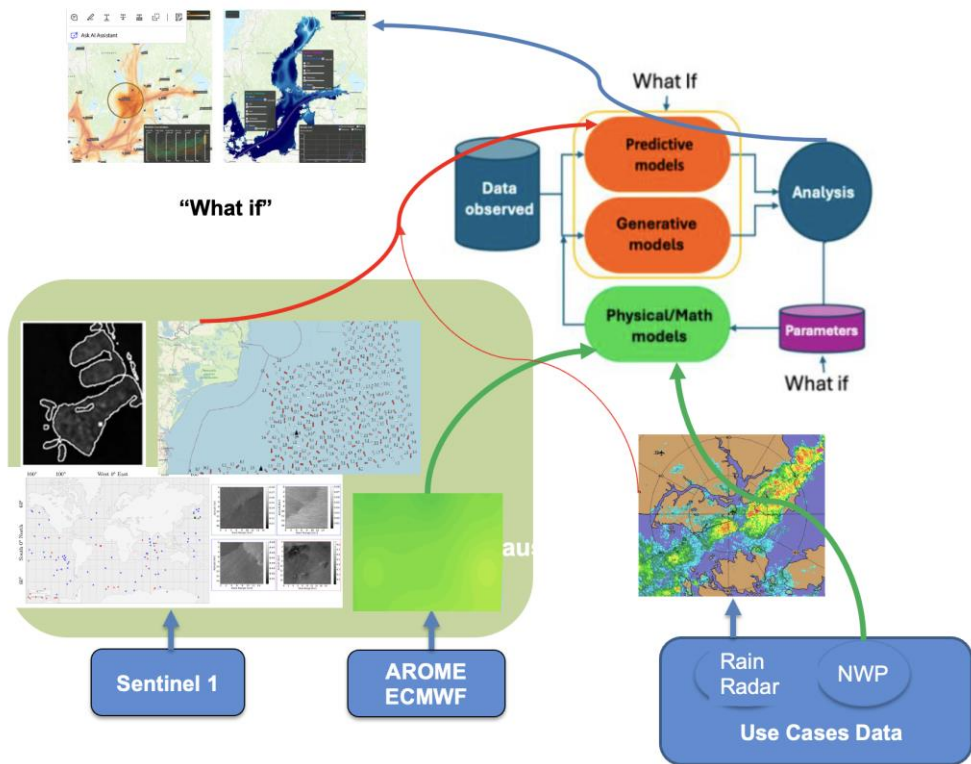


Figure 2. Specific use case for DIVE schema

In Figure 2, the schema illustrates an integrated workflow for “what-if” analysis combining multi-source environmental observations with predictive, generative, and physical modelling. Input data from Sentinel-1, numerical weather prediction systems (AROME/ECMWF), and use-case-specific sources (e.g., rain radar) feed into a processing layer that extracts spatial and temporal features relevant to the studied phenomena. These observations serve as inputs to a modelling framework composed of predictive models, generative models, and physical/mathematical models, which simulate alternative scenarios under modified parameters. The outputs of these models are then analysed and visualized in an interactive “what-if” interface, enabling users to explore the effects of hypothetical conditions and assess system behaviour across different environmental scenarios.

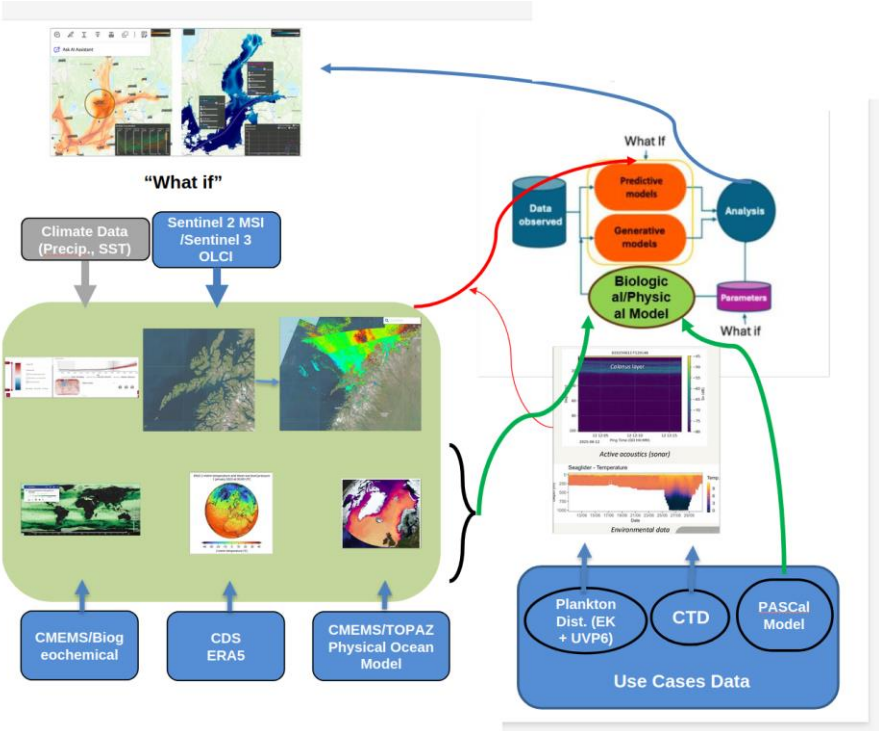


Figure 3. Specific use case for DIVE schema

In Figure 3, the presented schema outlines a specific use case within the broader DIVE analytical framework, illustrating how multi-source environmental data are integrated, processed, and transformed into domain-specific insights. It depicts the flow from raw observational inputs—such as Earth Observation products, numerical weather prediction outputs, and in-situ or use-case data—through dedicated extraction and modelling components that derive relevant indicators or scenario-dependent outputs. These processed data streams interface with the DIVE analytical modules, enabling causal reasoning, scenario evaluation, and visualization. The schema thus demonstrates how DIVE operationalizes a complete data-to-knowledge pipeline tailored to a particular application context, bridging heterogeneous environmental inputs with advanced exploratory and decision-support tools.

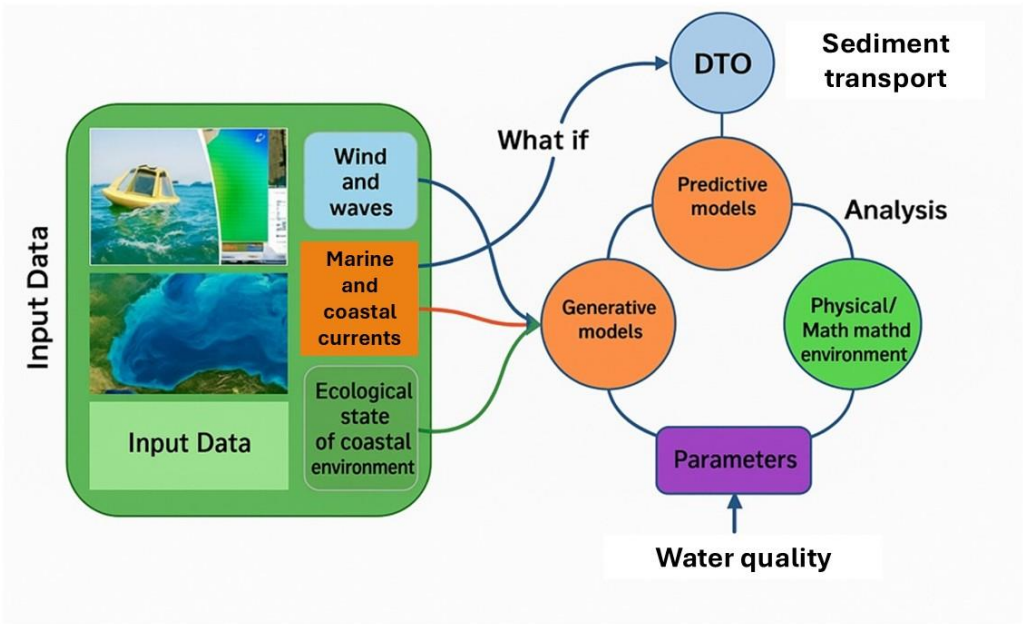


Figure 4. Specific use case for DIVE schema

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In Figure 4, we illustrate another use case for DIVE platform. It begins with input data such as wind and waves, marine technology data, and the ecological state of the coastal environment. These inputs feed into generative and predictive models, which simulate “what-if” scenarios. The models operate within a physical/mathematical environment, producing parameters related to ocean conditions, including water quality. The DTO then supports analysis tasks like sediment transportation and environmental assessment.