Research Data Management

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Outline

- Datascape
- the importance of data management
- Marine Data Value Chain
- Blue Data Infrastructures
- Data Life Cycle and Dataflow
- Data and Products' Quality
- FAIR principles and FAIRness assessment
- Data Publication
- workflow and Virtual Research Environment

Introduction

UN Decade of Ocean Science for Sustainable Development 2021-2030

Expected Outcomes

1. **A clean ocean** where sources of pollution are identified, reduced or removed
2. **A healthy and resilient ocean** where marine ecosystems are understood, protected, restored and managed
3. **A productive ocean** supporting sustainable food supply and a sustainable ocean economy
4. **A predicted ocean** where society understands and can respond to changing ocean conditions
5. **A safe ocean** where life and livelihoods are protected from ocean-related hazards
6. **An accessible ocean** with open and equitable access to data, information and technology
7. **An inspiring and engaging ocean** where society understands and values the ocean in relation to human wellbeing and sustainable development

→ **Data and information are key enablers of the Ocean Decade outcomes**

from Implementation Plan (https://www.oceandecade.org/)

ITINERIS

Ocean Monitoring

An healthy, resilient and productive ocean can be restored and preserved through constant and **systematic monitoring of the marine environment** which allows to:

- assess past and present ocean state
- understand its complex dynamics and evolution
- understand/mitigate the impact of human activity in a changing environment and climate
- exploit its natural recourses sustainably

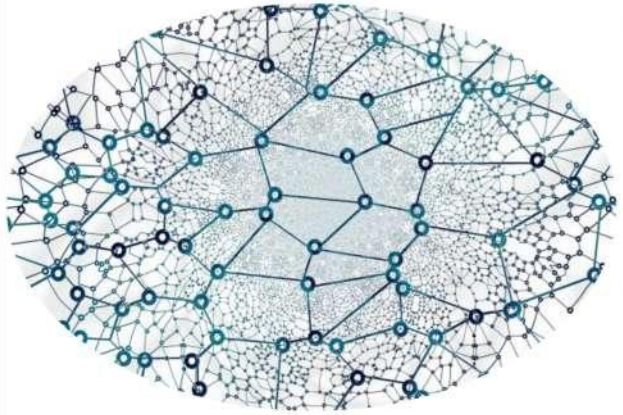
→ the management of the deriving marine data represents a societal priority

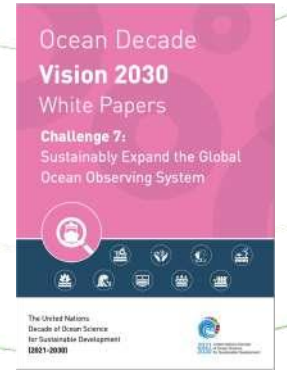
→ data sharing approach and open data policies maximize users' uptake, promoting knowledge and innovation, reducing costs, avoiding duplication of efforts

→ adoption of common vocabulary, formats and standards enable a rapid and efficient access to the data

→ FAIR principles (Findable Accessible Interoperable and Reusable - *Wilkinson et al., 2016*) and linked data approach are the foundation of this revolution to reduce uncertainties but preserving transparency and traceability

Ocean Decade: digital ecosystem





Data Strategy Implementation Group

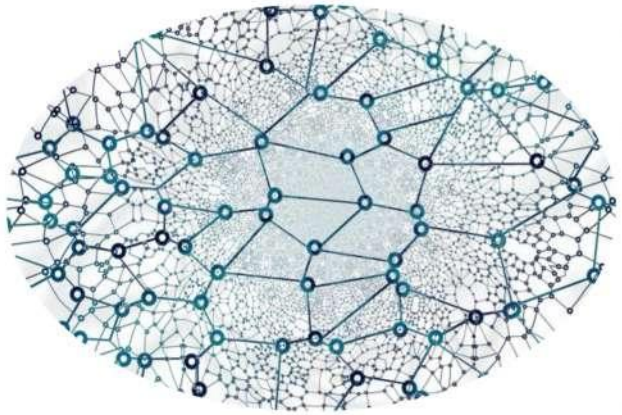
→**Data & Information Strategy** describes how data systems can co-create a distributed, robust and collaborative digital **ecosystem** to be actively used for decision making and to support sustainable ocean management

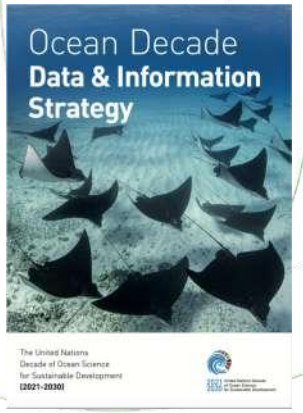
3 main components:

1. observation and data collection
2. data management and sharing
3. data processing (analytics, modeling and prediction)

UNESCO-IOC (2023). Ocean Decade Data & Information Strategy. Paris, UNESCO. (The Ocean Decade Series, 45)

Ocean Decade: digital ecosystem





Vision

A trusted, inclusive, and interconnected ocean data and information ecosystem that is actively used for decision making to support sustainable ocean management.

Mission

To catalyse a solution-oriented, global digital transformation for the digital ecosystem we need to overcome the Decade Challenges.

Strategic Objectives

1. **Develop an ocean digital ecosystem** that encourages the sharing and equitable access of multidisciplinary data, information and knowledge by all.
2. **Improve data and information discovery and usability** across the ocean digital ecosystem.
3. **Build trust in data and information** shared across the ocean digital ecosystem.
4. **Prioritise digital solutions that support decisions** for sustainable ocean management.
5. **Expand, empower, and mobilise global communities** to advance and maintain the ocean digital ecosystem.

Enablers

Technological Innovation // Partnerships // Durable Resourcing // Policy & Regulatory Frameworks

UNESCO-IOC (2023). Ocean Decade Data & Information Strategy. Paris, UNESCO. (The Ocean Decade Series, 45)

Digital Ecosystem Drivers

- **Open science** and **FAIR** (Findable, Accessible, Interoperable and Reusable) principles drive the development of a digital ocean ecosystem capable of supporting the preservation and sharing of a wide array of data, knowledge and information products
- **Ocean Best Practices** and a **FAIR digital asset** facilitate technological advances and community approaches for all methods to better understand and sustain our oceans
- **Virtual Research Environments** will provide to the new generation of scientists an easy access to big amount of data, analytics and HPC resources to create innovative applications and tackle the emerging societal challenges (DTO - Digital Twin of the Ocean)

Need of a Community Effort

Societal benefit of science can be enhanced through a community effort to collect, manage, and share the data acquired with specific purposes and to enable multiple stakeholders to reuse them many times and for different purposes

Ocean knowledge and information rely on an **integrated multidisciplinary and multiscale ocean observing and monitoring system**

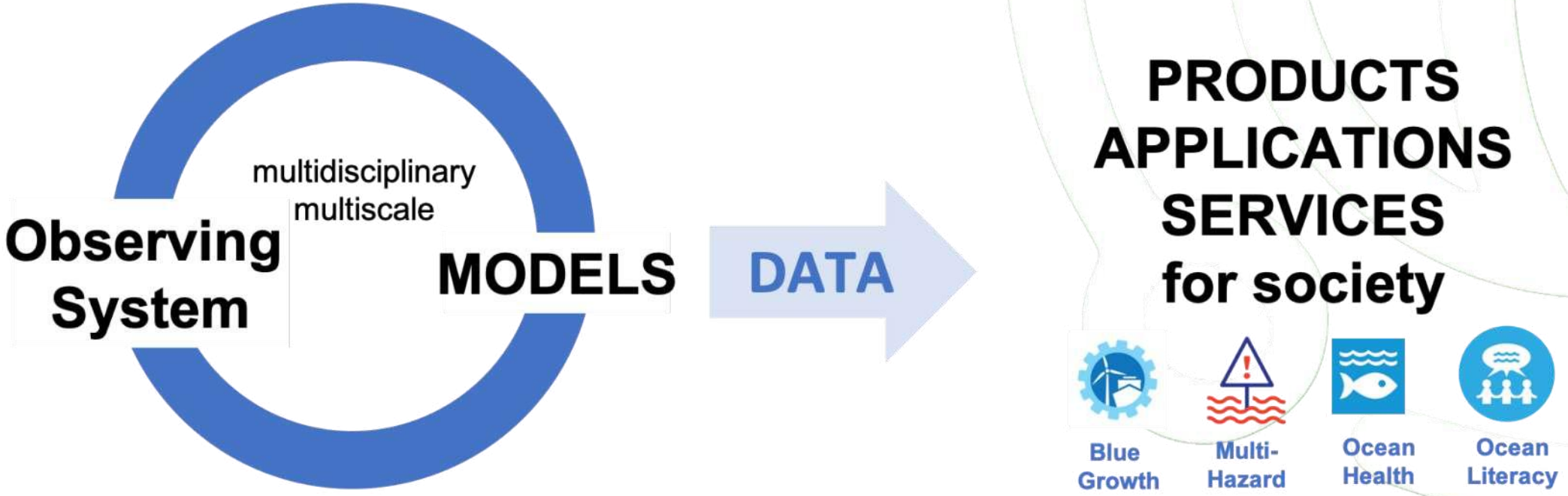
This implies the **engagement of multiple stakeholders along with the data value chain**

→ to continuously tailor data products **requirements** to the emerging societal needs

→ to identify **gaps**

→ to optimize the data flow

Integrated Observing and Monitoring System

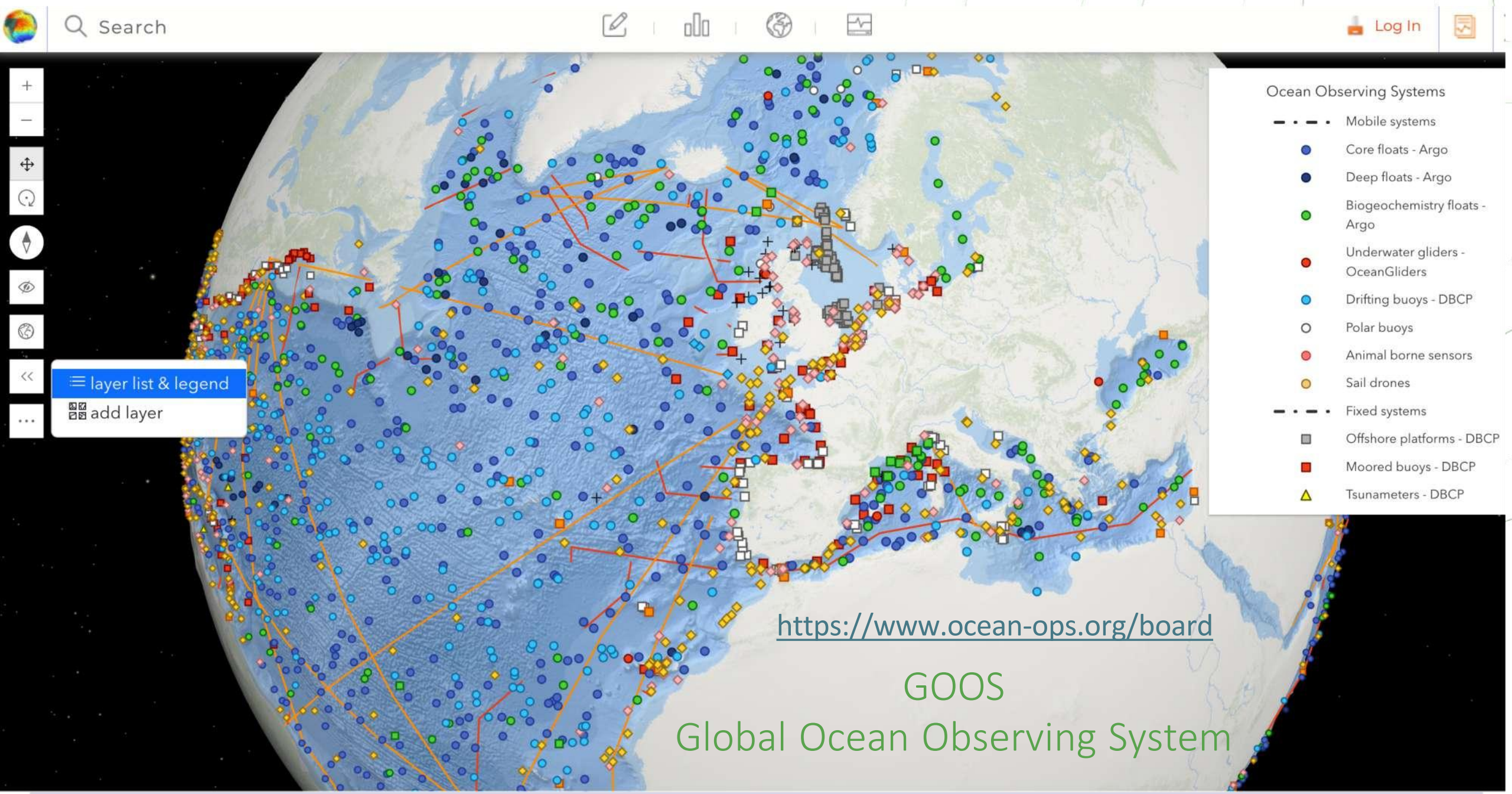


Simoncelli et al. 2022 https://doi.org/10.1016/B978-0-12-823427-3.00001-3

Global Ocean Observing System (GOOS)

https://goosocean.org

- led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and co-sponsored by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC) to support a community of international, regional and national ocean observing programmes, governments, UN agencies, research organizations and individual scientists
- goal: **implementation of an integrated and sustained ocean observing system to deliver maximum impact for our user base and society**
- with **systems approach** designed to be flexible and adapt to evolving scientific, technological and societal demands
- fit-for-purpose observing system: data flow on Essential Ocean Variables (EOVs), information services and applications that benefit the end users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Offshore platforms - DBCP
Moored buoys - DBCP
Tsunameters - DBCP
https://www.ocean-ops.org/board
GOOS
Global Ocean Observing System

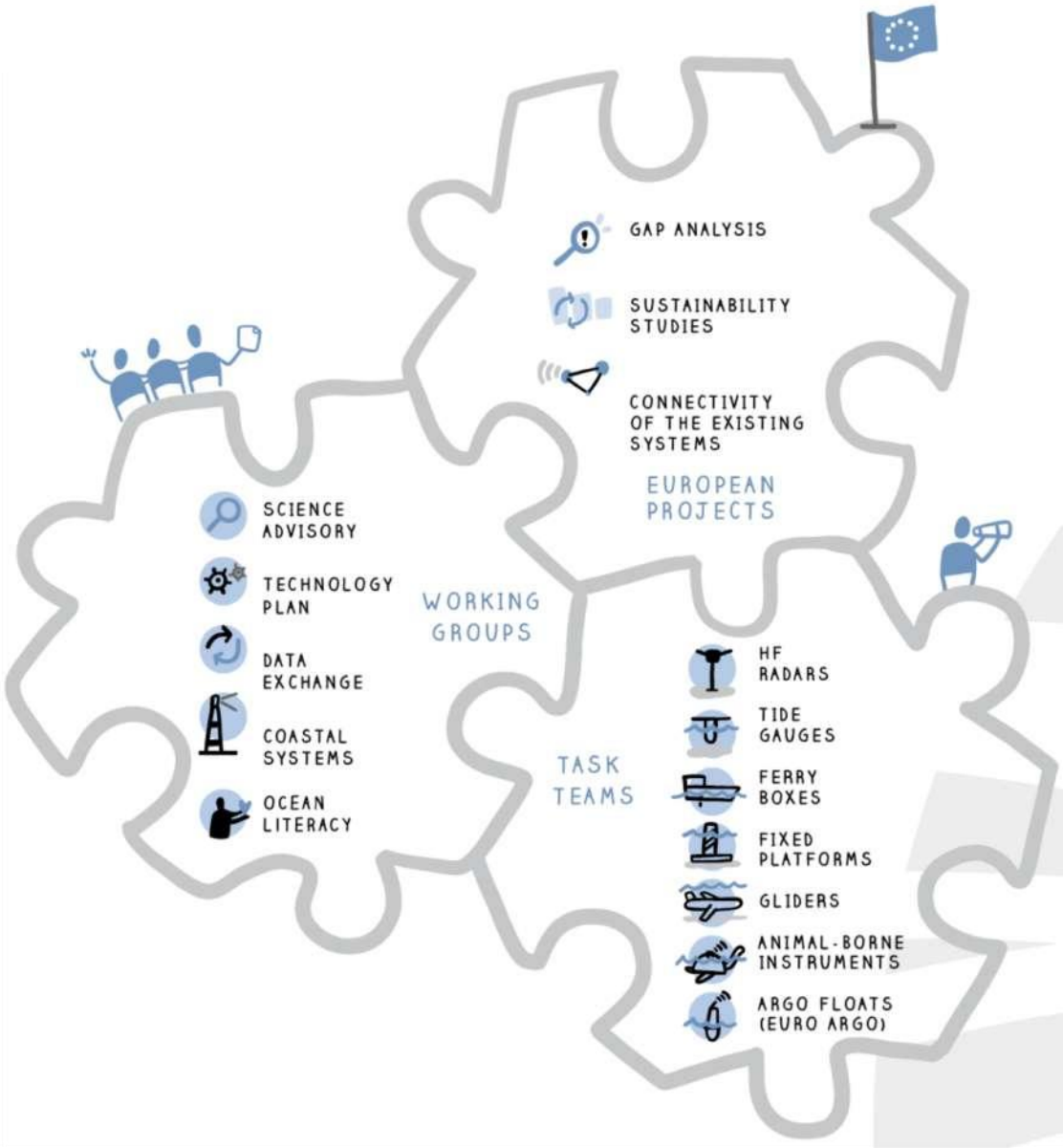
GOOS

- There are currently ~ 8000 in situ ocean observing platforms monitored by the GOOS operational centre OceanOPS
- systems of buoys, moorings, profiling floats, ships (merchant, academic, fishing), gliders and other uncrewed systems (e.g., sail drones), drones, planes, land-based stations (e.g., global sea level), satellites, HF radars, deep sea cables, and animal borne sensors measuring mostly physical data and some biogeochemical data
- 14 global ocean observing networks that vary in stage of implementation
- GOOS is organised in thirteen GOOS Regional Alliances (GRAs)

https://doi.org/10.25607/brxb-kr45

EuroGOOS https://eurogoos.eu/ https://www.eoos-ocean.eu/

- European component of the GOOS
- 48 members
- 5 Regional Systems
- Working Groups → Data Management WG
- networks of observing platforms (Task Teams)
- cooperation to unlock quality marine data and deliver common strategies, priorities and standards towards an integrated, sustained and fit-for-purpose European Ocean Observing System (EOOS)
- EOOS framework is driven by the European community to better coordinate Europe's ocean observing capacity



Marine Data Value Chain

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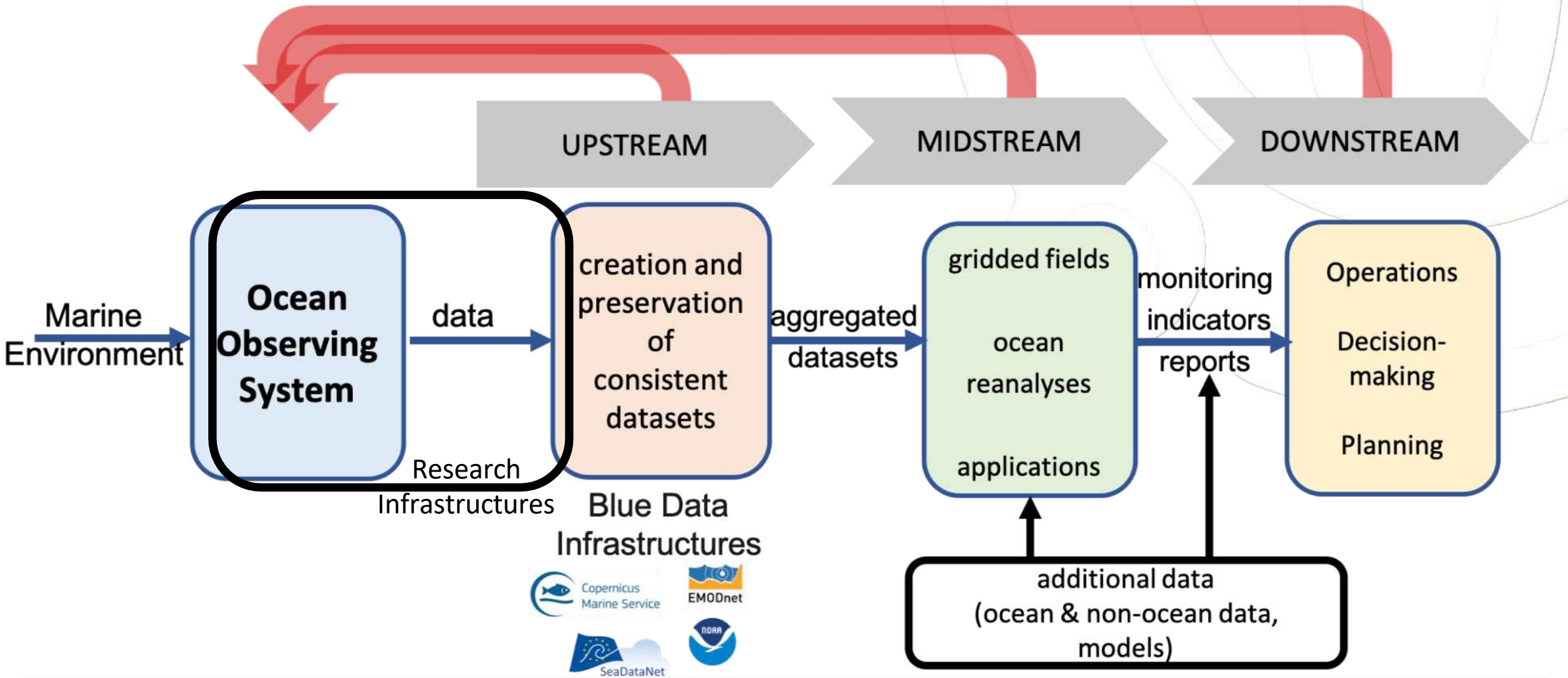
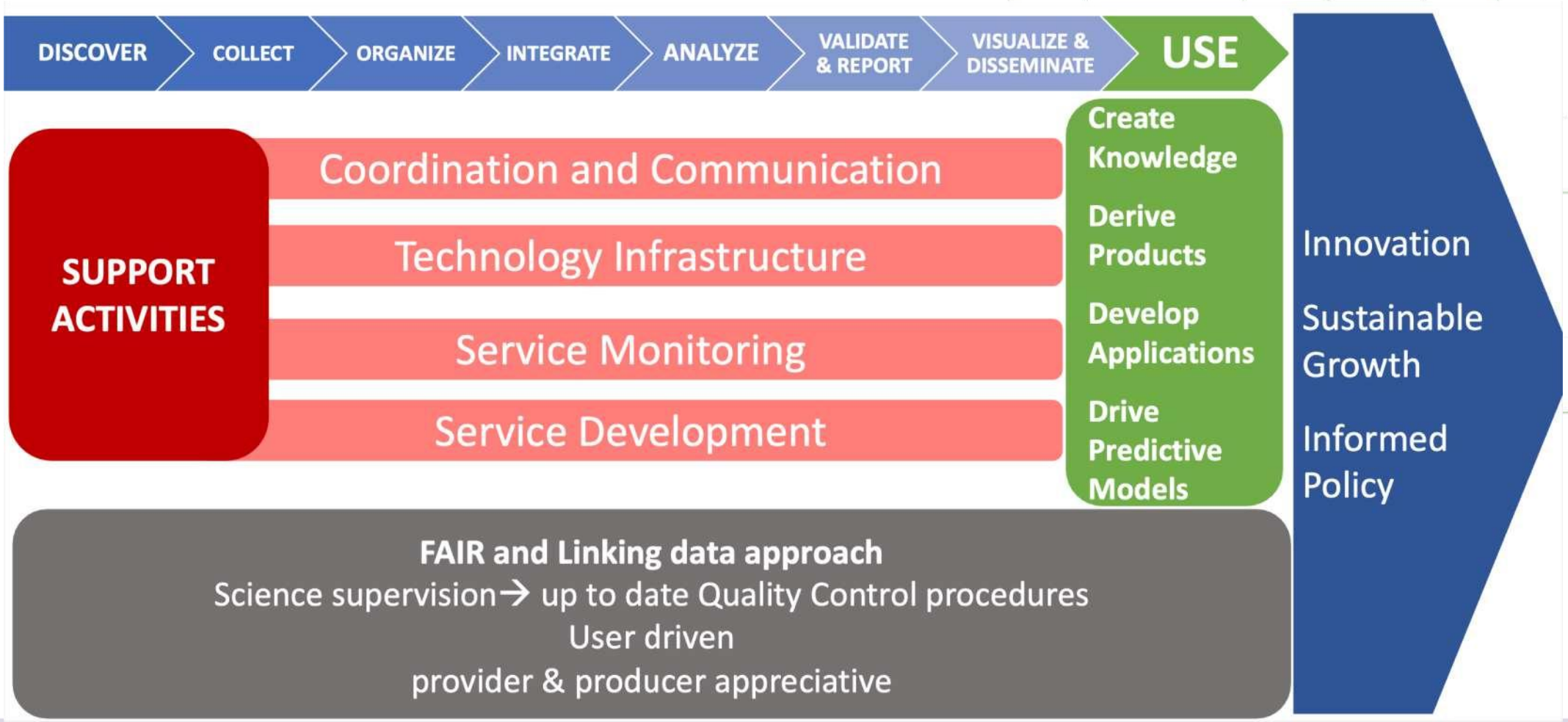


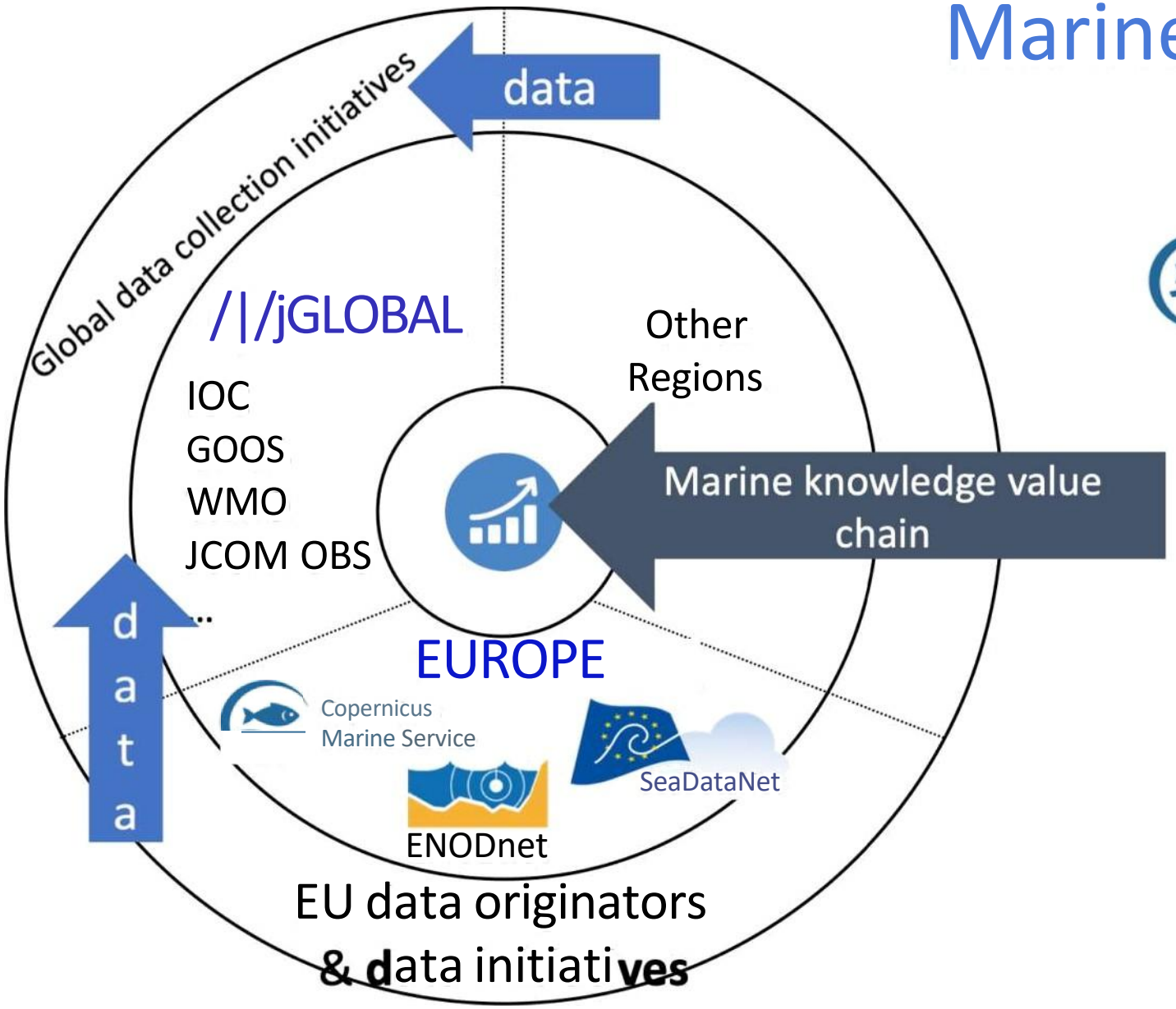
Blue Data Infrastructures

Marine data value chain: the necessary supporting activities to fulfill it and the underlying principles

Simoncelli et al. (2022) https://doi.org/10.1016/B978-0-12-823427-3.00001-3



Marine Data and Data Products Initiatives



adapted from *Martin Miguez et al.(2019)*

Copernicus Marine Service

DG-GROW

provides NRT&DM observations and predictions on the status and dynamics of the ocean and the ecosystem

SeaDataNet

DG-RTD

distributed Marine Data Infrastructure for the management of DM in situ data sets; it develops standards and vocabulary; it provides services/tools and data products

EMODnet

DG-MARE

organizes marine data in a unique infrastructure, deriving information from data, creating products targeted to multiple user communities

EMODnet: *in situ* marine data service

EMODnet serves users in policy, research, industry, and society, the EU Digital Twin Ocean and global ocean data initiatives

Chemistry
Physics
Biology
Seabed habitats
Human activities
Bathymetry
Geology

EMODnet
European Marine Observation and Data Network

EC marine data service developing pan-European data products* and aggregated datasets

Copernicus Marine Service
in situ Thematic Assembly Centre (INSTAC)

Marine *in situ* data pipeline to EMODnet: National Oceanographic Data Centres, regional and European data infrastructures and services

EurOBIS
European Ocean Biodiversity Information System

SeaDataNet

ICES CIEM

in situ ocean observations (collected in water/air/seafloor) are the foundation of the EMODnet marine data pipeline

- Operational oceanography (NRT) (ROOS, EuroGOOS)
- Research Infrastructures
- Research and Academia
- Hydrographic Offices
- Marine monitoring (national authorities, regulatory monitoring)
- Private sector & Blue Economy
- Other providers (citizen science, NGOs, etc)

*All EMODnet data products are published under an open data licence

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) 2021/1139 of the European Parliament and of the Council of 7 July 2021 establishing the European Maritime, Fisheries and Aquaculture Fund.

One central map viewer

to visualise all EMODnet data

1 OCEAN 1 EMODnet

One single portal

One central metadata catalogue

to enhance data search and discovery

120 partners

+100 use cases

Discover, visualise and download marine data and products across 7 thematics and hundreds of parameters

BATHYMETRY

HUMAN ACTIVITIES

PHYSICS

GEOLOGY

SEABED HABITATS

CHEMISTRY

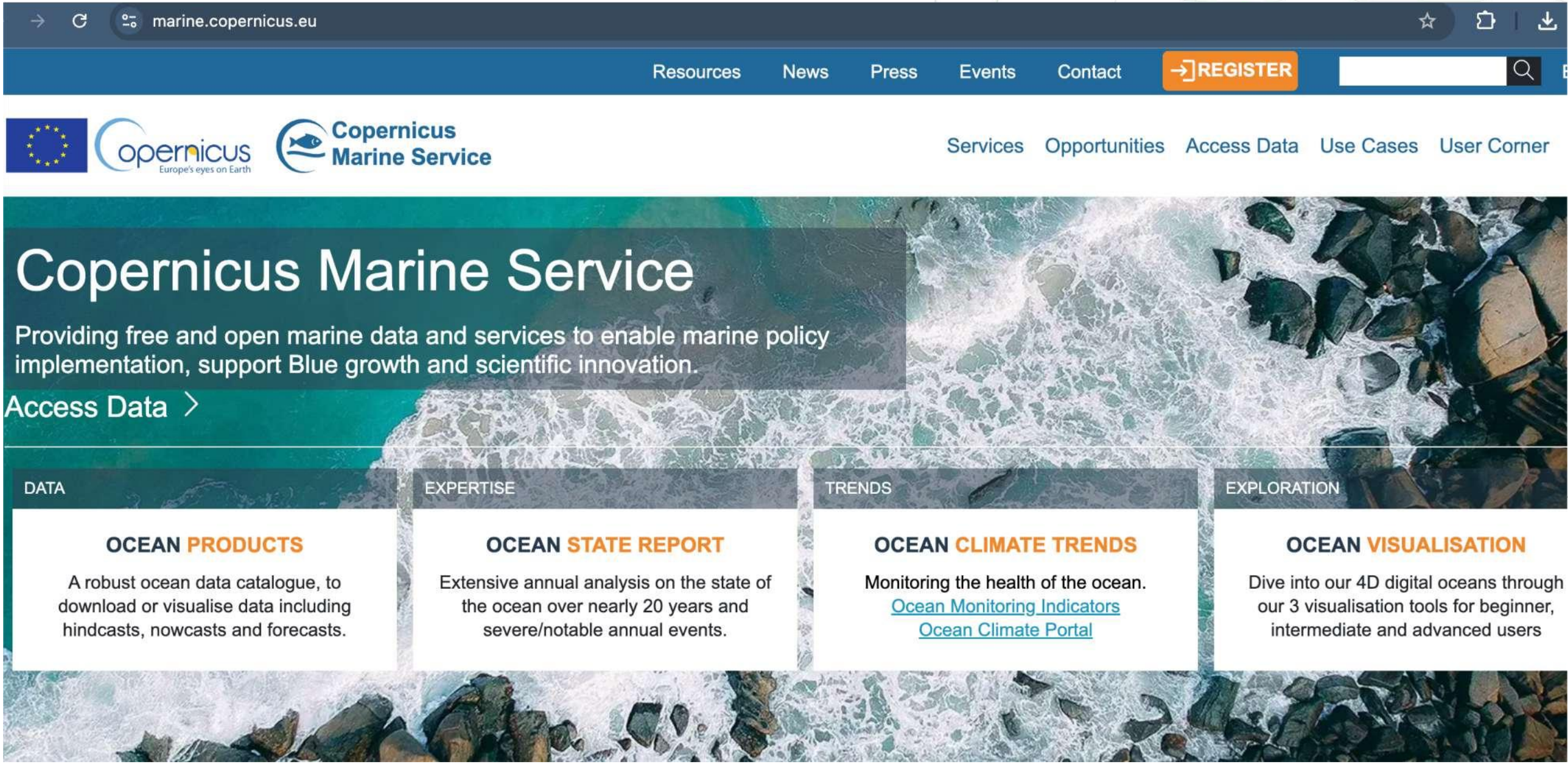
BIOLOGY

EMODNET.EC.EUROPA.EU

The European Marine Observation and Data Network (EMODnet) is financed by the European Union under Regulation (EU) 2021/1139 of the European Parliament and of the Council of 7 July 2021 establishing the European Maritime, Fisheries and Aquaculture Fund.

YOUR GATEWAY TO *IN SITU* MARINE DATA IN EUROPE AND BEYOND

EMODnet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Providing free and open marine data and services to enable marine policy implementation, support Blue growth and scientific innovation.
Access Data
DATA
OCEAN PRODUCTS
A robust ocean data catalogue, to download or visualise data including hindcasts, nowcasts and forecasts.
EXPERTISE
OCEAN STATE REPORT
Extensive annual analysis on the state of the ocean over nearly 20 years and severe/notable annual events.
TRENDS
OCEAN CLIMATE TRENDS
Monitoring the health of the ocean.
Ocean Monitoring Indicators
Ocean Climate Portal
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OCEAN VISUALISATION
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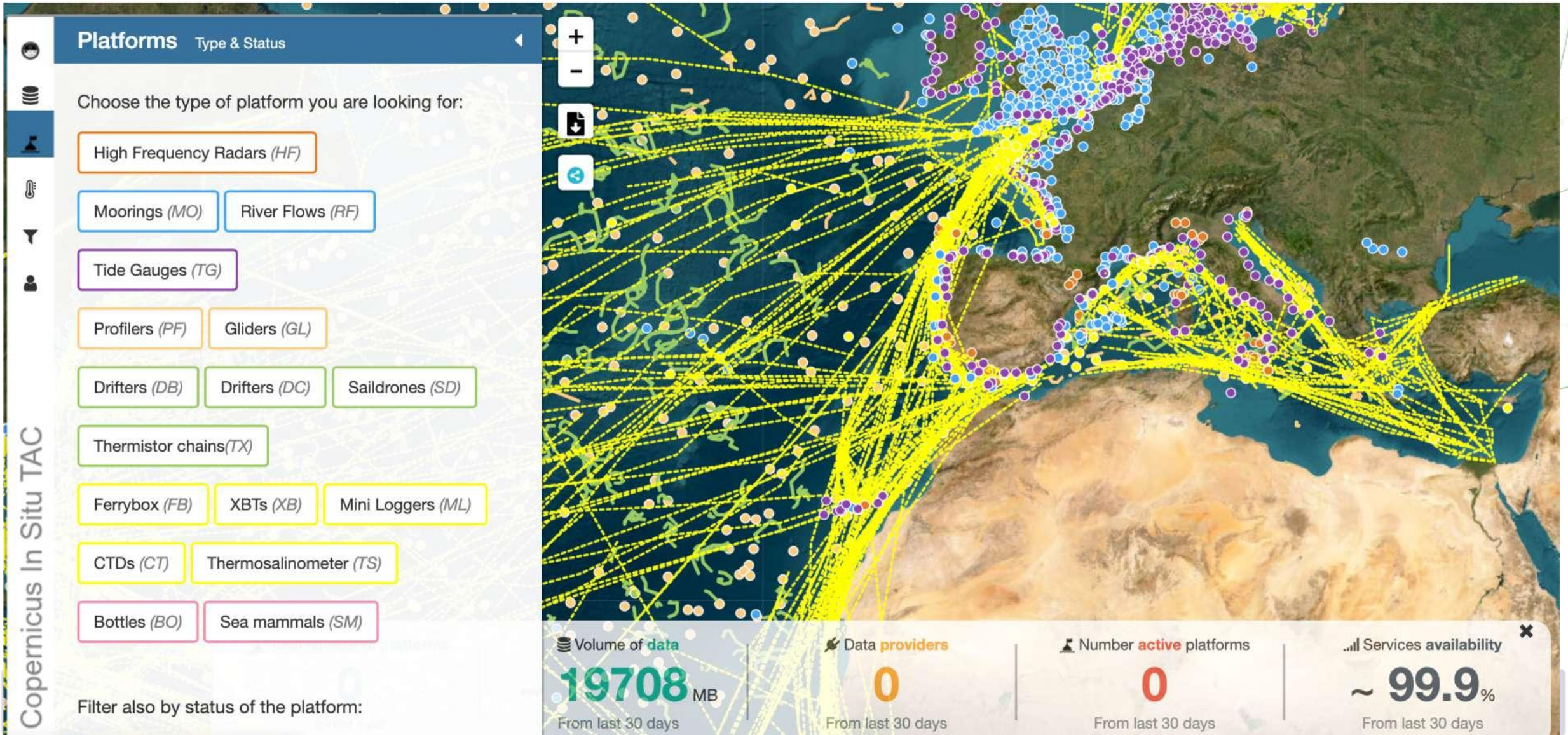
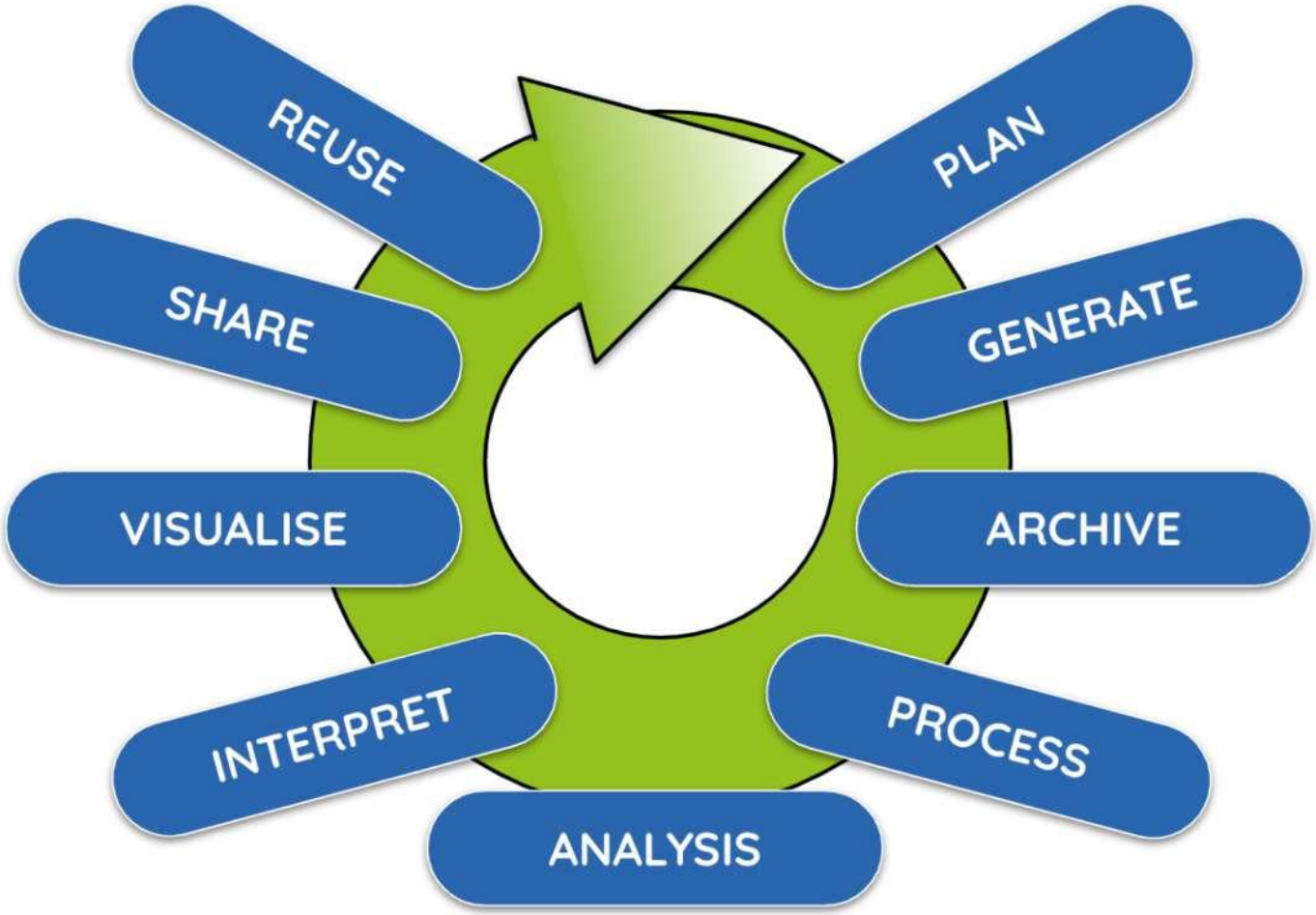


Research Data Life Cycle

adapted from Locati & Cacciola (2024) Research Data Management
https://istituto.ingv.it/ufficio-gestione-dati



Data Provider (PI)→ data generation and responsible for QA/QC

Data Curators → data curation (annotation, publication, presentation and preservation)

Data Stewards → making data **I**nteroperable

Data Managers → Governance and Data Management Plan

Data Management

from Locati & Cacciola (2024) Research Data Management https://istituto.ingv.it/ufficio-gestione-dati

Research Data Management (RDM)

Organization, storage, preservation, and sharing of data in a research environment throughout the **entire data life cycle and beyond**.
RDM ensures the efficiency, transparency, and reproducibility of research and include **practices and policies that aim to improve the quality and value of research data**.

Data Management Plan (DMP)

A formal document that outlines **how data is handled during and after a research project**.
Details how data is collected, analysed, preserved, and shared, including details about data formats, metadata standards, data storage, and data sharing policies.
It is **often a required component of grant proposals**, emphasizing the importance of responsible data management for funders and institutions.

Data collection: Quality Assurance and Best Practices

- Traditional view of data (collecting, processing, analyzing, and publishing of results) substituted by a life cycle approach that highlights the importance of finding, storing, and sharing data

- **Prior planning** has become mandatory to document data creation, content, context, but also to fulfill data quality requirements

- Data quality requires predefined Quality Assurance (QA) strategies based on the selection of internationally validated methodologies for sampling and analysis, the mandatory use of reference materials

The data providers (PI)

- are responsible of the adequacy of the sampling strategy to the scope
- must follow specific QA procedures and protocols applied before and during the dataset creation
- have responsibilities in terms of documentation, calibration/intercalibration exercise, sampling strategy, admissible ranges of data, algorithms used, corrections, and flags

QA/QC protocols and Standard Operating Procedures

Best practices have been developed from expert groups to have agreed and broadly adopted methods across ocean research, operations and applications

Best Practice:

- is a methodology that has repeatedly produced superior results relative to other methodologies with the same objective
- is method that has been adopted and employed by multiple organizations

https://www.oceanbestpractices.org/

Metadata

- Records of monitored parameters must include a minimum set of information mapped through metadata
- overview of the sensors and the methodologies (platform, instrument type, sensor's accuracy, calibration info)
- measurement position, date and time
- units
- quality information (quality flags)

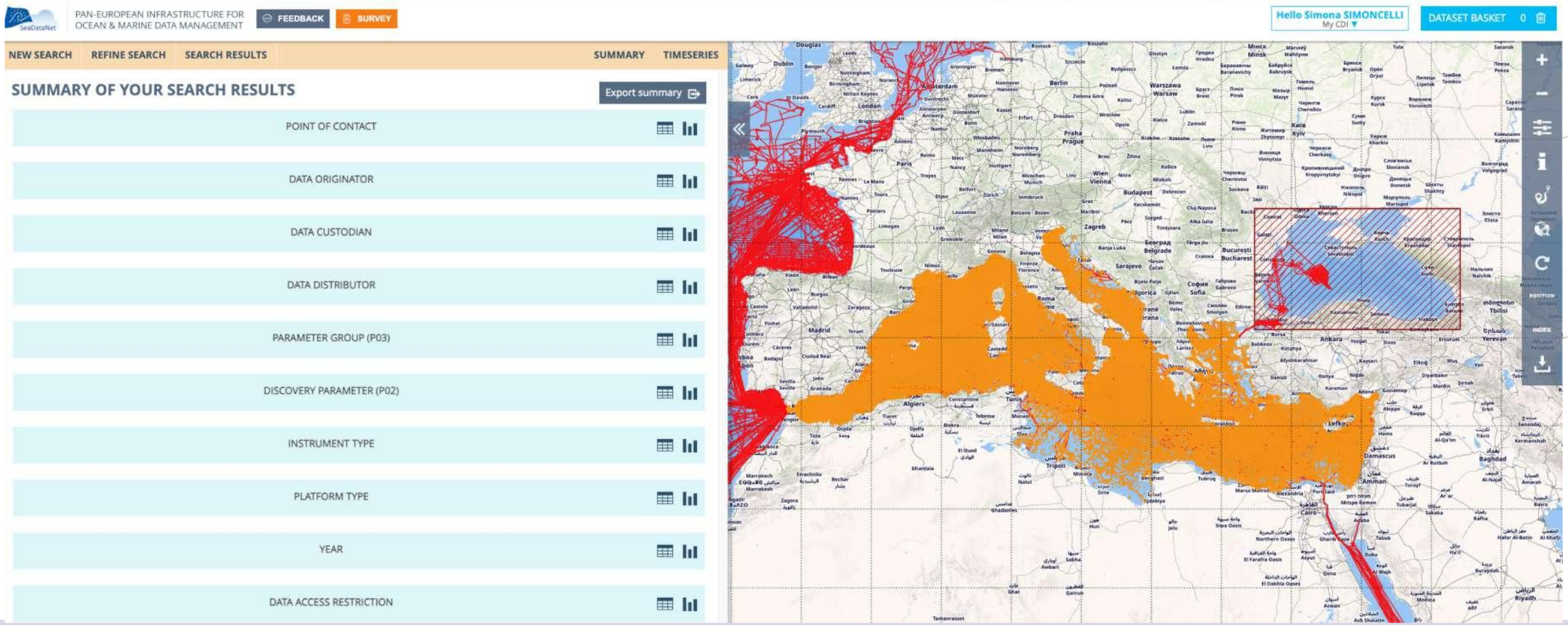
Standard and Formats

- controlled vocabularies
- ISO 19115 metadata standards
- Data Transport Formats
- common QC protocols and flag scales

The Power of Metadata

https://cdi.seadatanet.org/search

Metadata analysis can be used to monitor the **data sharing monitoring landscape:**
data originator/distributor, instrument type, platform type, y**and** ear, data access restrictions



The Power of Metadata

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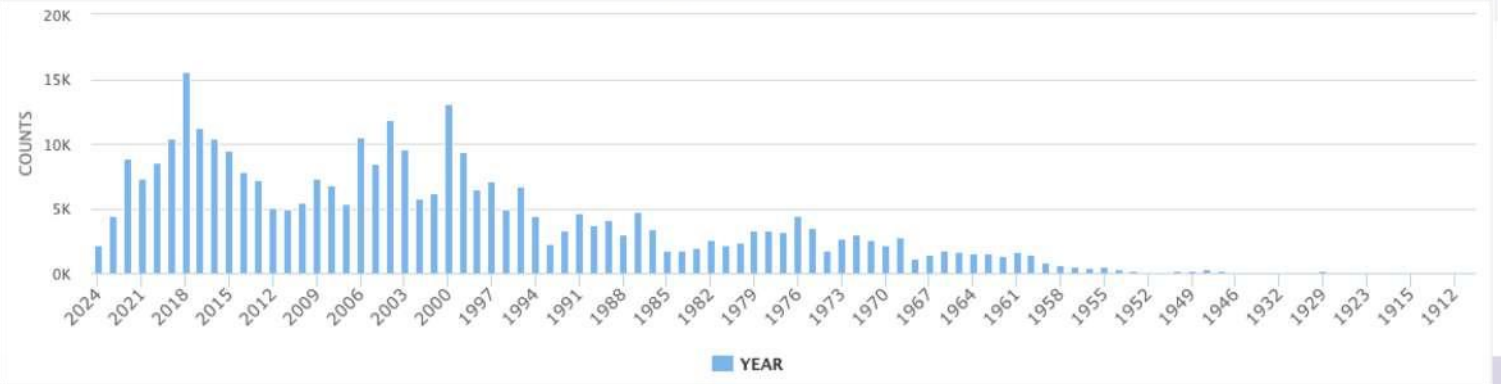
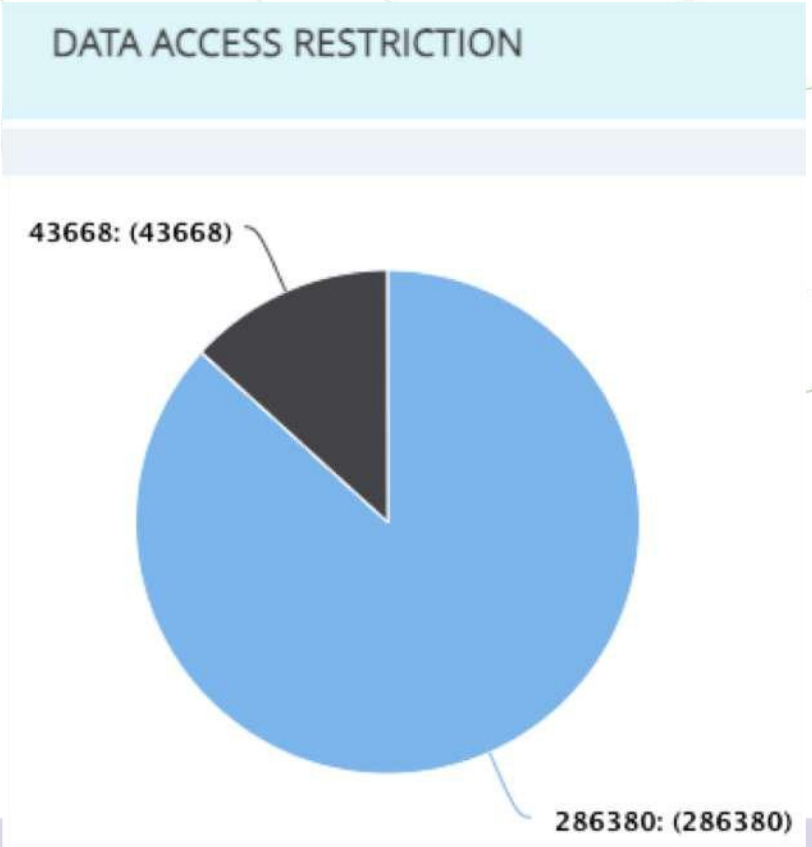


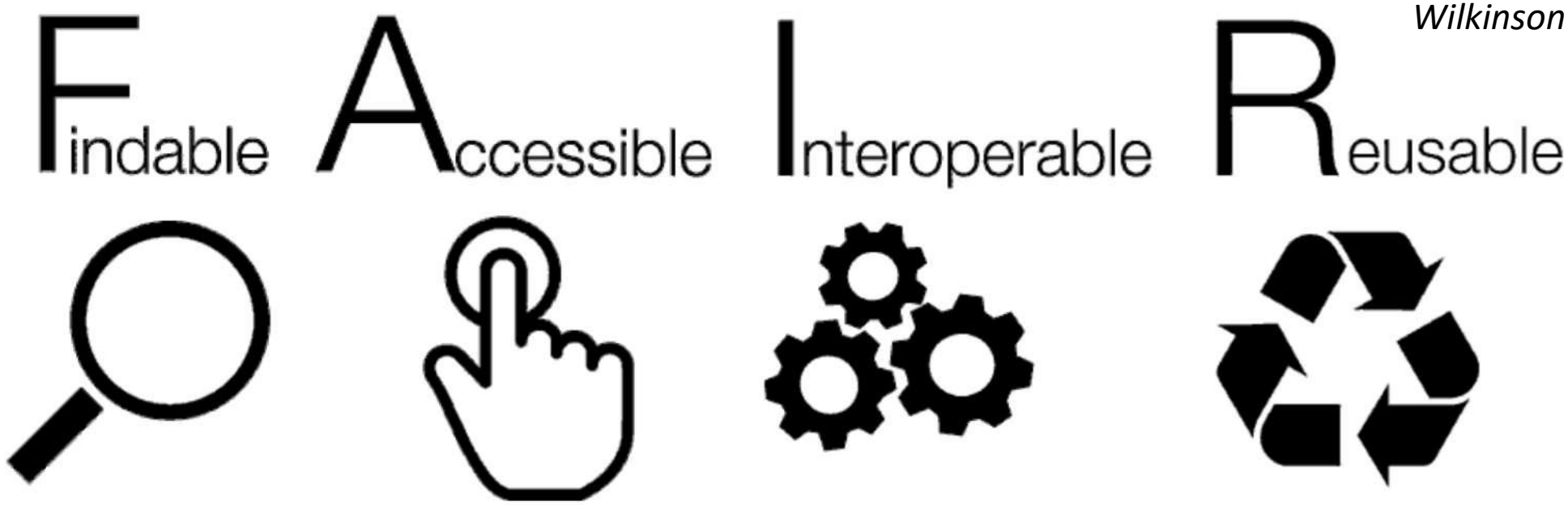
Metadata analysis from SeaDataNet data access portal on the specific data query results (i.e selected space-time domain, parameter)



FAIR data principles

from Locati & Cacciola (2024) Research Data Management https://istituto.ingv.it/ufficio-gestione-dati

Wilkinson et al. (2016)



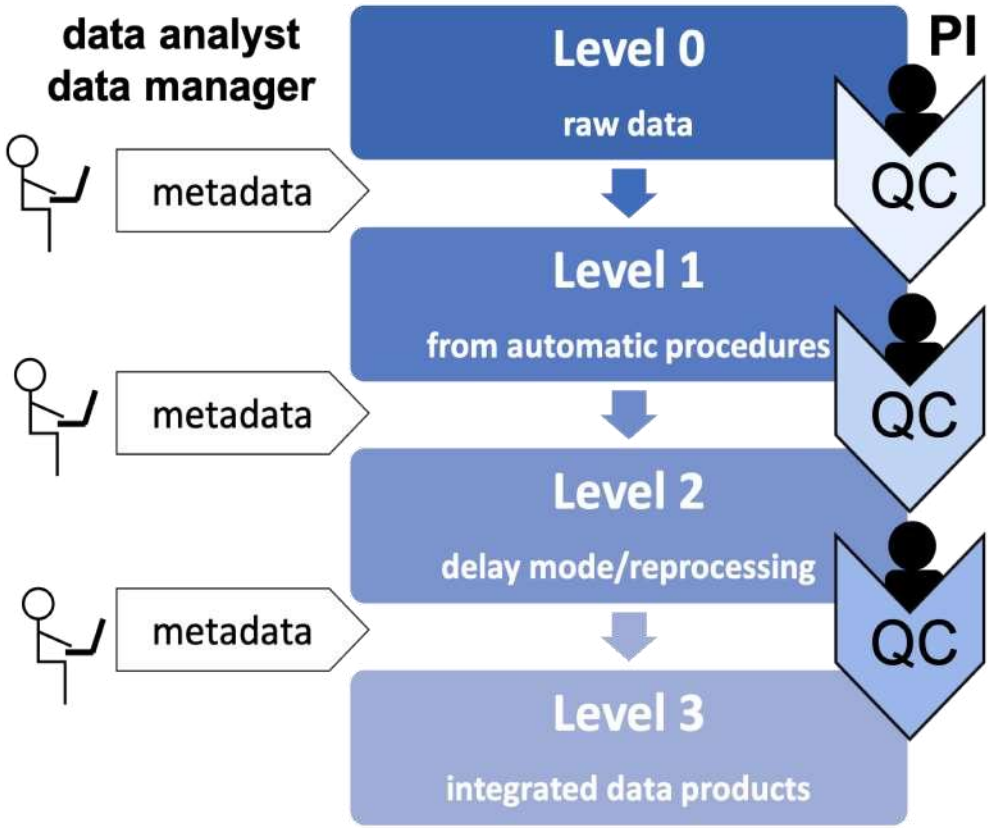
Findable: easy to find by humans and computers thanks to metadata and unique persistent identifiers

Accessible: stored for easy access and downloading

Interoperable: ready to be combined with other datasets by humans and computer systems

Re-usable: ready for reuse thanks to detailed, accurate documentation and clear usage license

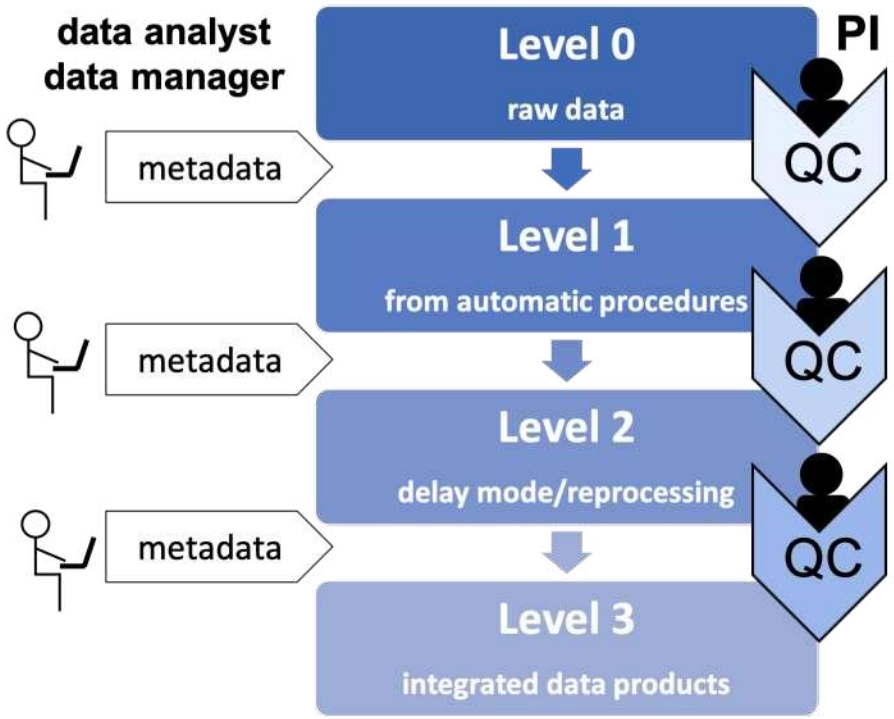
Data Processing Levels (DPL)



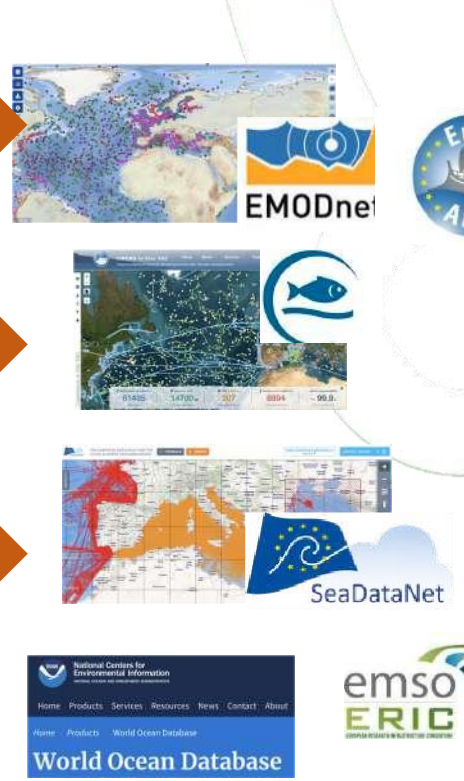
Data Latency	Purpose
Real Time	• ocean prediction • early warning
Near Real Time	
Delay Mode	• ocean state assessment • climate studies

This could generate issues related to different data versions and duplicates within data infrastructures

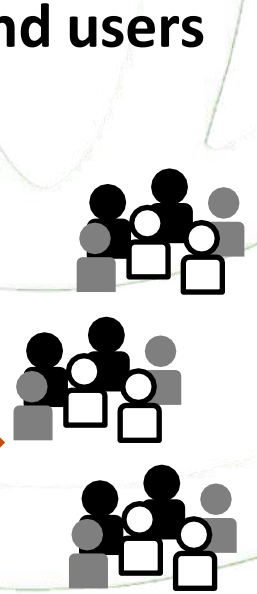
Dataflow

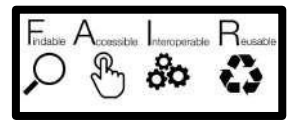


DOI
dataset paper +
scientific paper



data integration &
metadata harmonization





Quality Control

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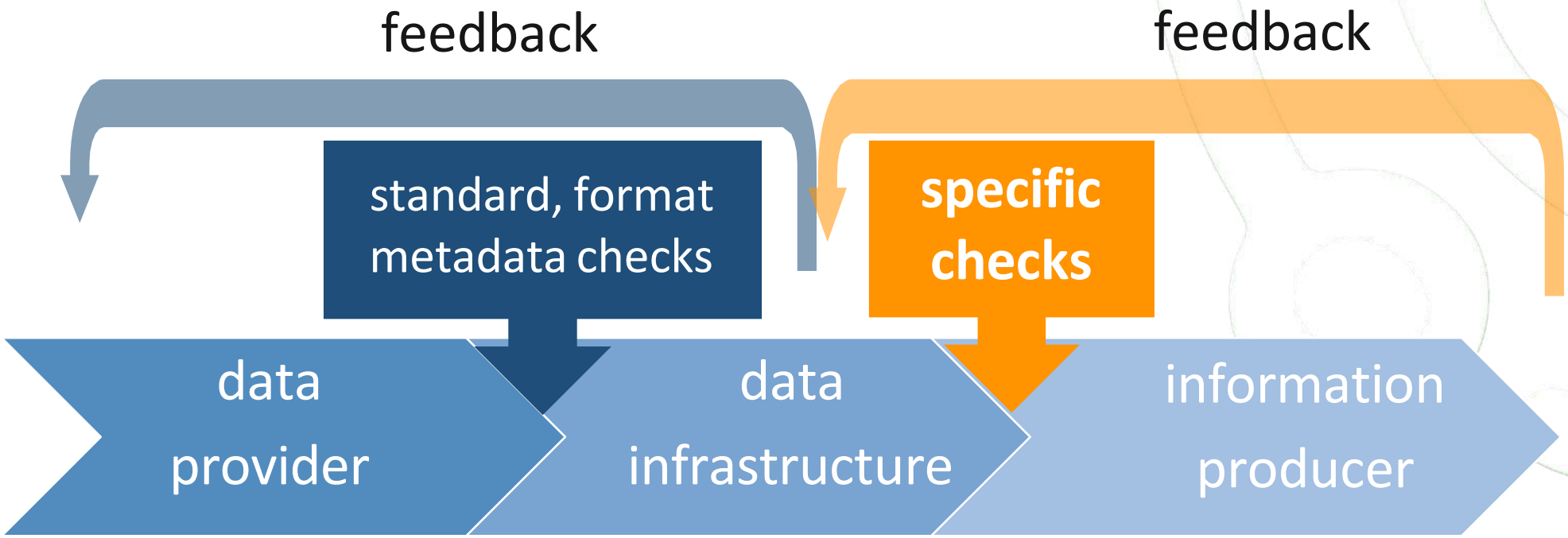


- **FAIRness**
- **integrity**
- **consistency**
- **completeness**

→ several actors apply QA/QC procedures along with the data value chain

→ **provenance** and **lineage information** are key elements to preserve

about Quality

Quality Assurance	QA is about adoptinge good measuring practices (sampling strategies, data collection methodologies, sample pretreatment, transport and storage)	Monitoring activity
Quality Control	QC process of anomalous data detection that apply after data gathering	data product L0-L4
Quality Assessment	It consists of evaluating if data meet the necessary quality requirements or are adequate for an intended use. It influences the selection of a data product among others	downstream product

Data accuracy and uncertainty are key quality elements of data reliability

Data **uncertainty determination and its propagation along with the data value chain** is still a present challenge

It is very important to annotate data uncertainty in the metadata

Quality Control

- QC is vital for data reuse, and without it data from different sources cannot be combined to gain value
- Scientific, analytical and statistical evaluations must determine if data present adequate quality to support the intended data usage, resulting in labeling each numerical value with a Quality Flag (QF) and avoid modifying the original data record following a harmonized scheme of QFs
- QFs ensure that the quality of the data is apparent to the user, who holds suffcient information to decide the suitability for a specific task applying the proper data filtering

QC practices include:

- data integrity checks (e.g., format)
- data value checks (range checks, spikes and outliers checks, neighbor checks, climatology checks)
- QC highly depend on the data thematic, sensor type and the available amount of time for the analysis (RT vs DM)

Automatic QC (RT procedures) → algorithms

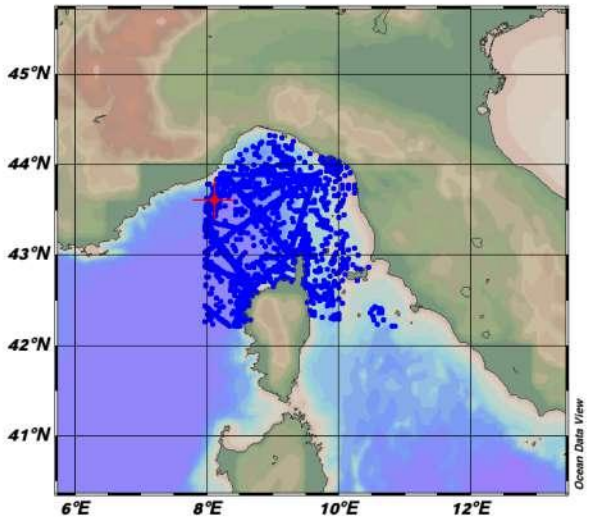
Visual QC (DM procedures) → visual tools (i.e. OceanDataView) and graphical interfaces

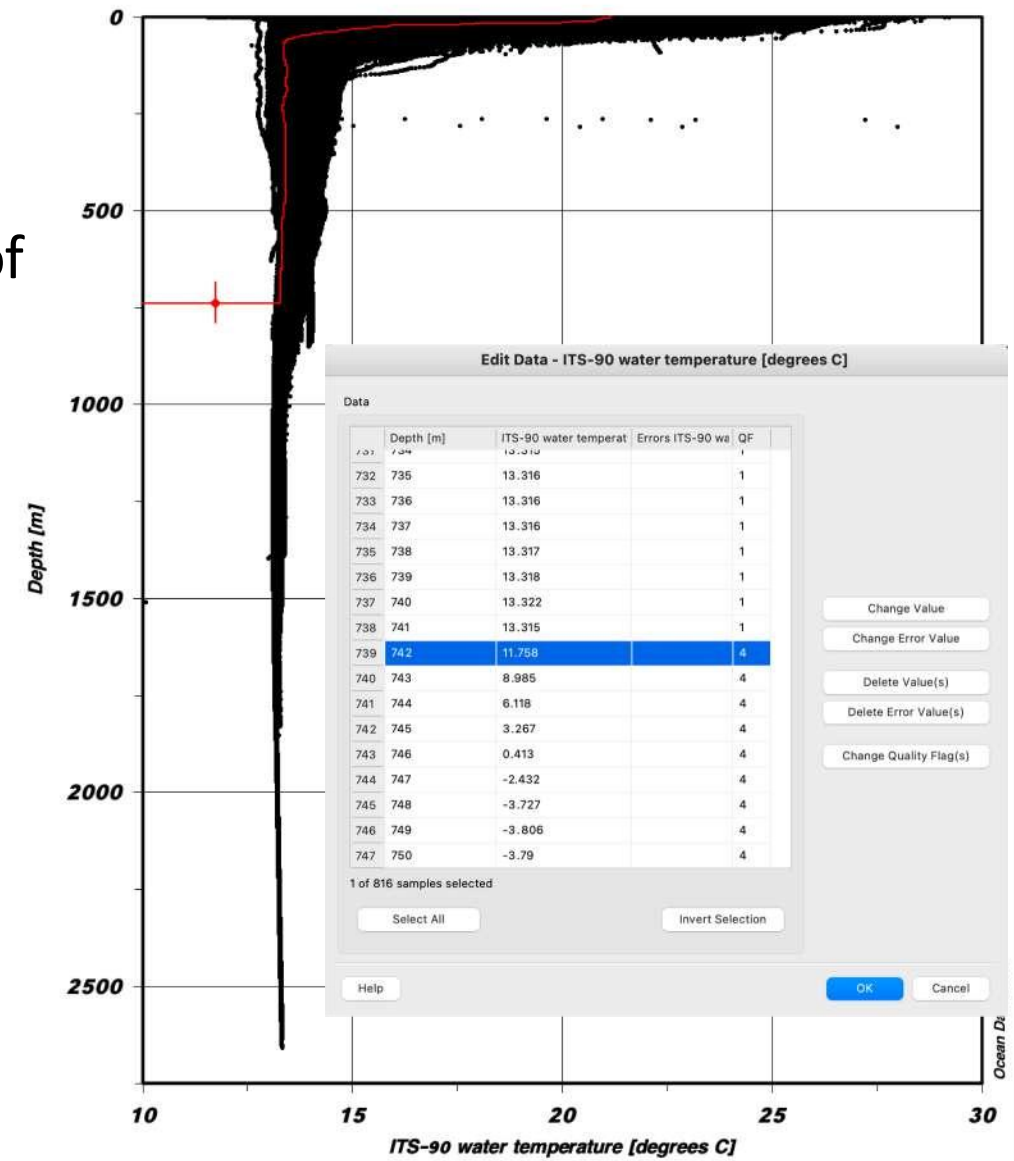
Quality Flags

- lables associated to each measurement that the user can use to filter data according to the needs
- SeaDataNet harmonised scheme of QC Flags to be used to label individual data values
- QC Flag scale is available in the SeaDataNet Common Vocabularies as list L20

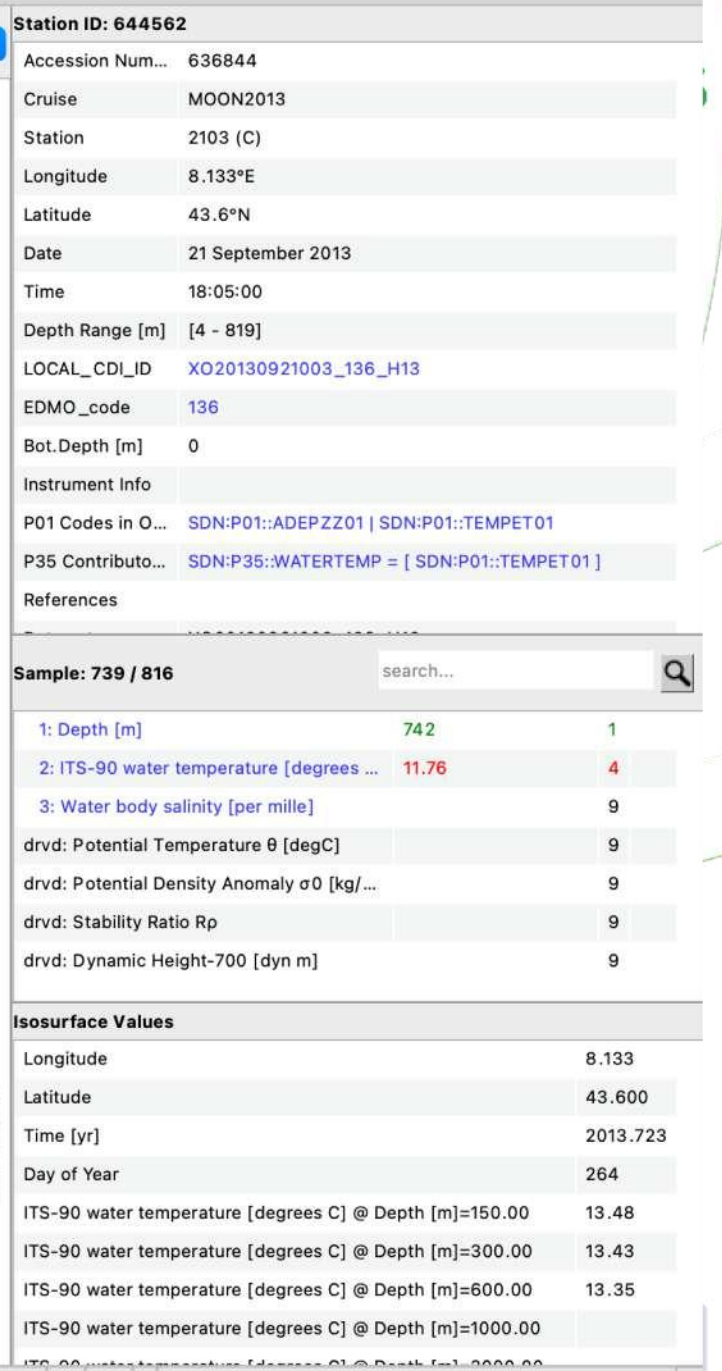
Key	Entry Term	Abbreviated term	Term definition
0	no quality control	none	No quality control procedures have been applied to the data value. This is the initial status for all data values entering the working archive.
1	good value	good	Good quality data value that is not part of any identified malfunction and has been verified as consistent with real phenomena during the quality control process.
2	probably good value	probably_good	Data value that is probably consistent with real phenomena but this is unconfirmed or data value forming part of a malfunction that is considered too small to affect the overall quality of the data object of which it is a part.
3	probably bad value	probably_bad	Data value recognised as unusual during quality control that forms part of a feature that is probably inconsistent with real phenomena.
4	bad value	bad	An obviously erroneous data value.
5	changed value	changed	Data value adjusted during quality control. Best practice strongly recommends that the value before the change be preserved in the data or its accompanying metadata.
6	value below detection	BD	The level of the measured phenomenon was too small to be quantified by the technique employed to measure it. The accompanying value is the detection limit for the technique or zero if that value is unknown.
7	value in excess	excess	The level of the measured phenomenon was too large to be quantified by the technique employed to measure it. The accompanying value is the measurement limit for the technique.
8	interpolated value	interpolated	This value has been derived by interpolation from other values in the data object.
9	missing value	missing	The data value is missing. Any accompanying value will be a magic number representing absent data.
A	value phenomenon uncertain	ID_uncertain	There is uncertainty in the description of the measured phenomenon associated with the value such as chemical species or biological entity.

Ocean Data View (ODV) software package for the interactive exploration, analysis and visualization of oceanographic and other geo-referenced profile, time-series, trajectory or sequence data





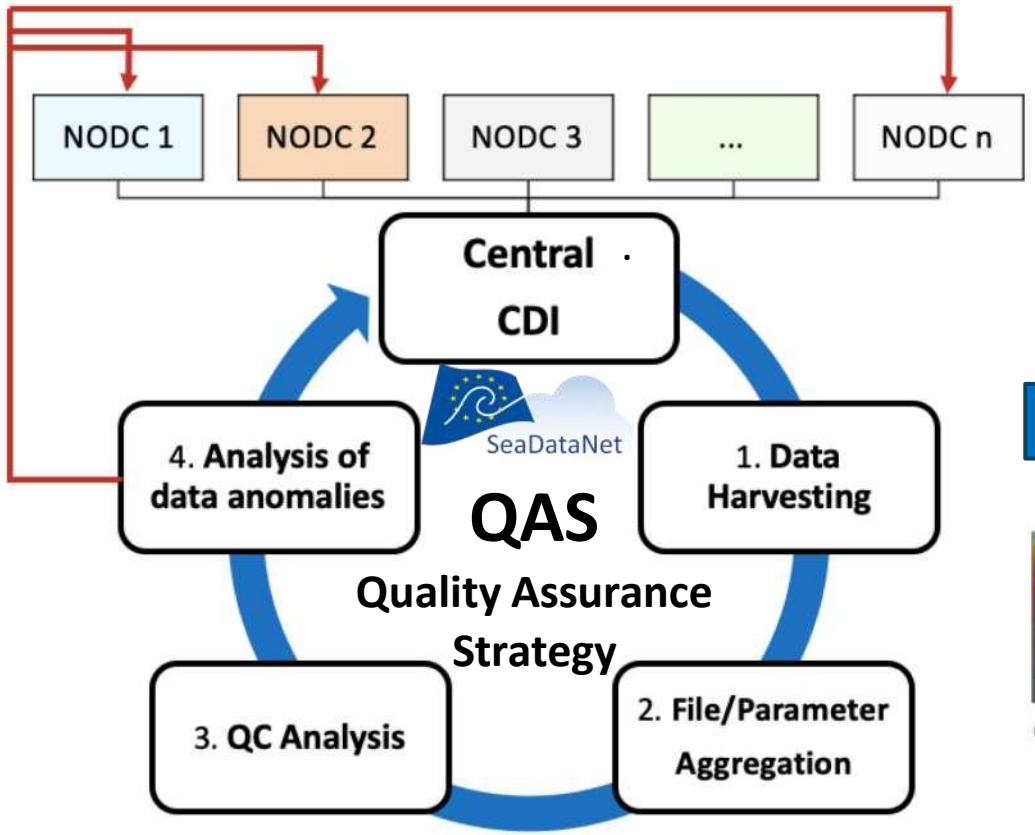
https://odv.awi.de/



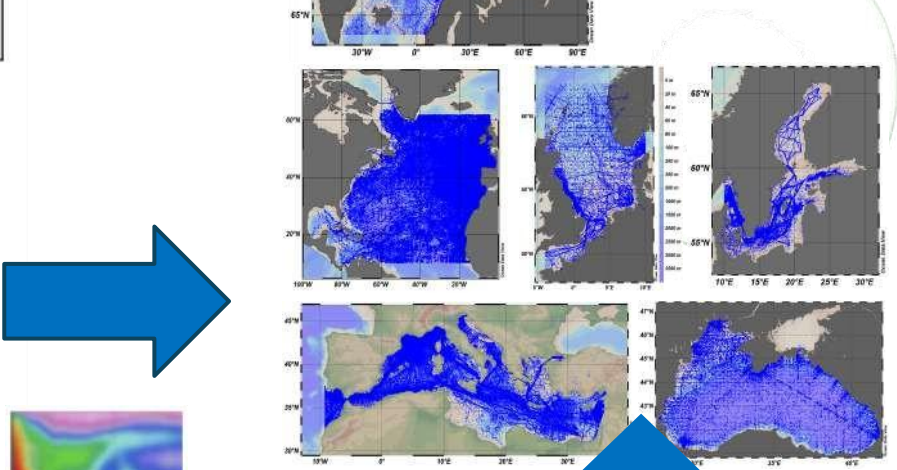
Data Products (example)

SeaDataCloud

network of SeaDataNet data centers



T&S aggregated dataset



Ocean Data View

SDN catalog
DOI
Product
Information
Document (PIDoc)

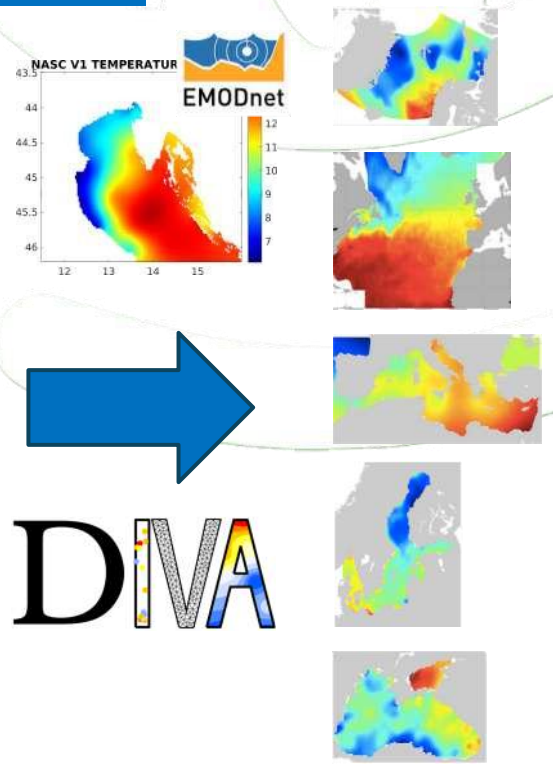
Copernicus Marine Service

NOAA

merging data from other BDIs

NEW

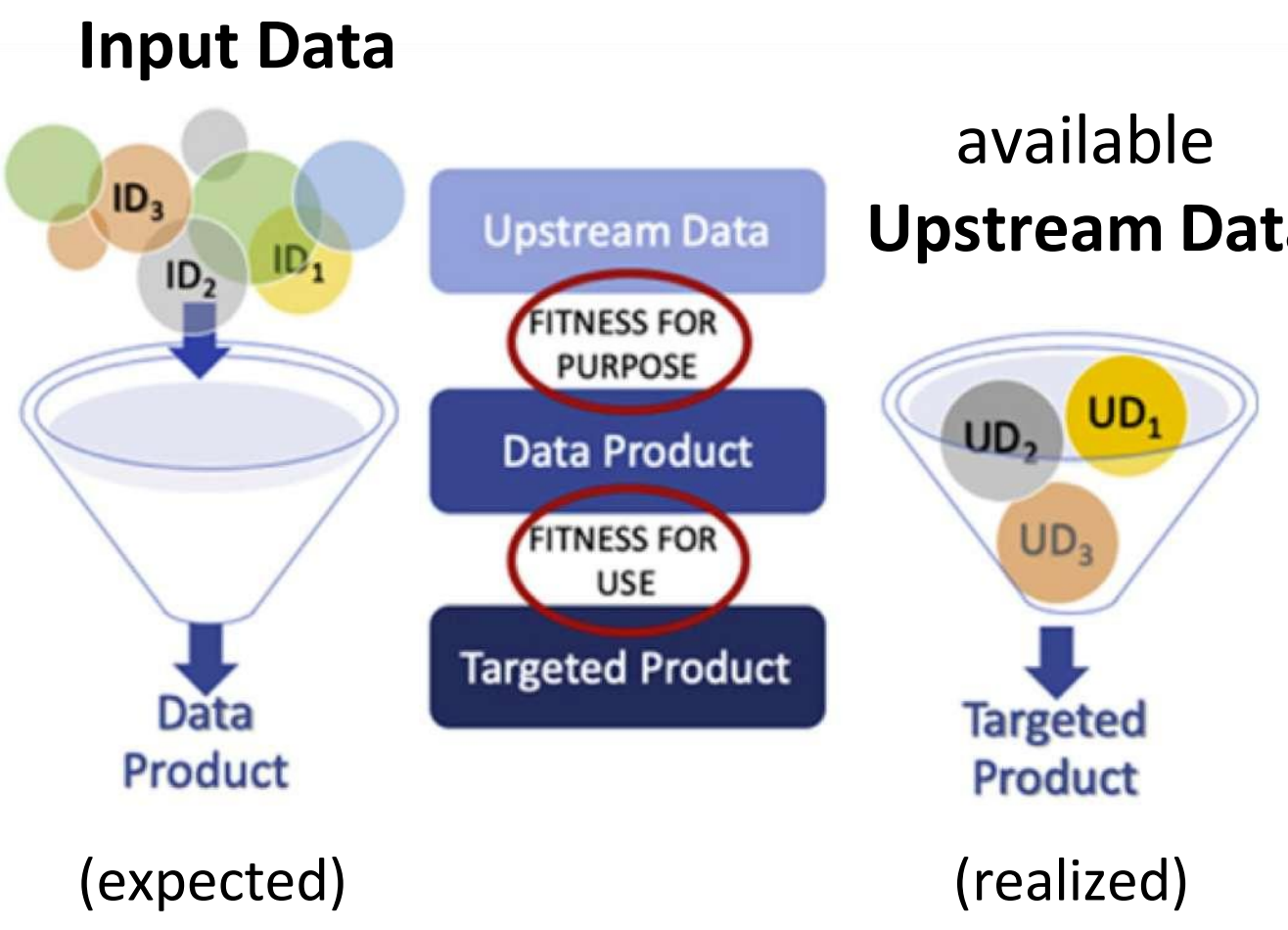
T&S gridded climatologies



DIVA

+ OHC, MLD, density, stratification products

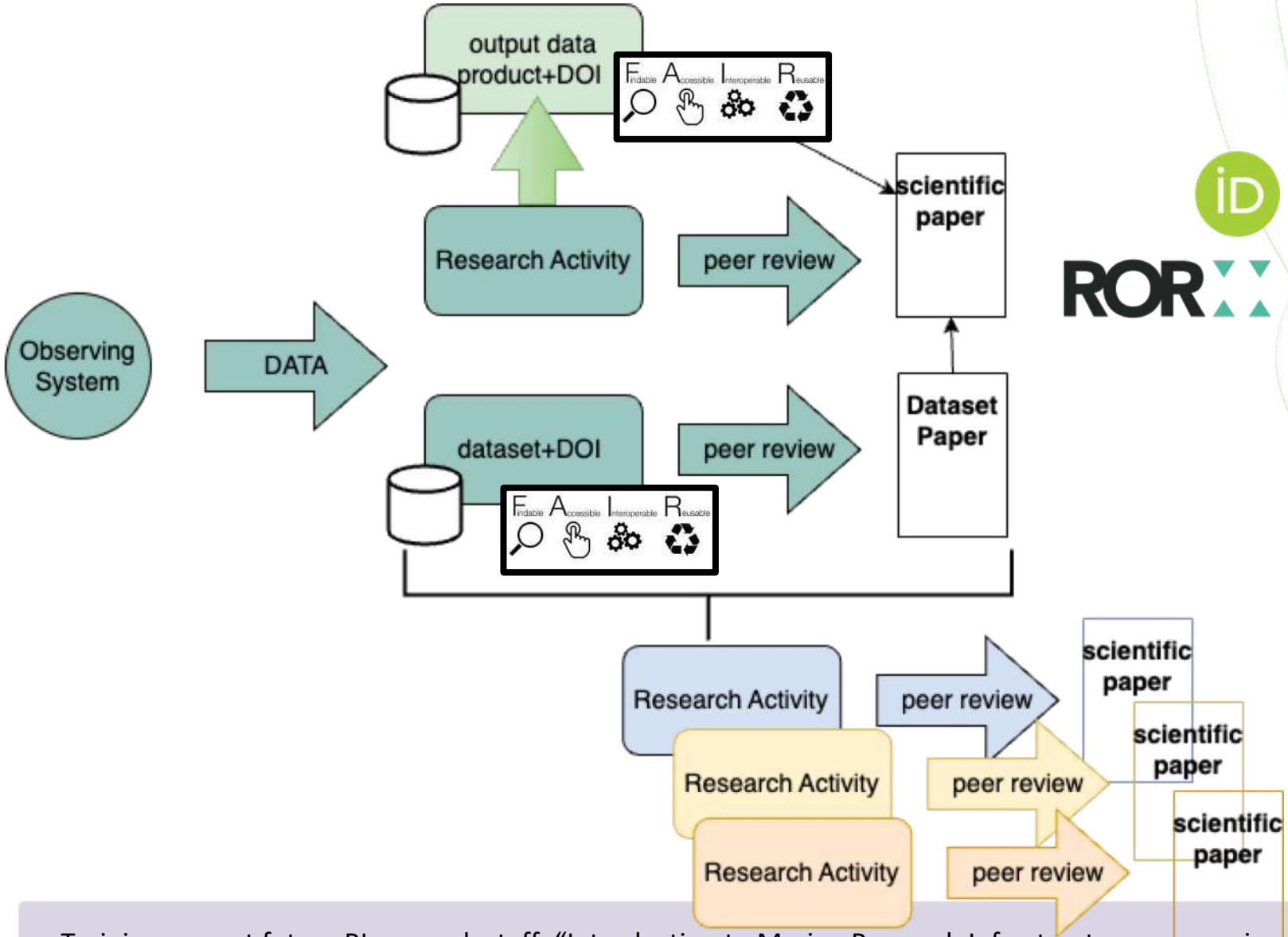
Quality Assessment



- User requirements define the **Data Product Specification** and the necessary **Input Data** to generate it
- the realized **Targeted Product Description** compared to the preliminary specification provide a measure of fit-for-use
- **Upstream Data** are fit-for-purpose if adequate for the targeted product realization
- Quality assessment process might provide a feedback on the **adequacy of observing system** for specific products/applications

Simoncelli et al. (2022) https://doi.org/10.1016/B978-0-12-823427-3.00001-3

Data Publishing Strategy



- a correct data management maximizes research impact for the scientist (ORCID) and the Research Institute (ROR)
- it promotes and enhances knowledge generation and innovation
- it guarantees transparency, traceability and reproducibility of scientific outcomes

Digital Object Identifier (DOI)

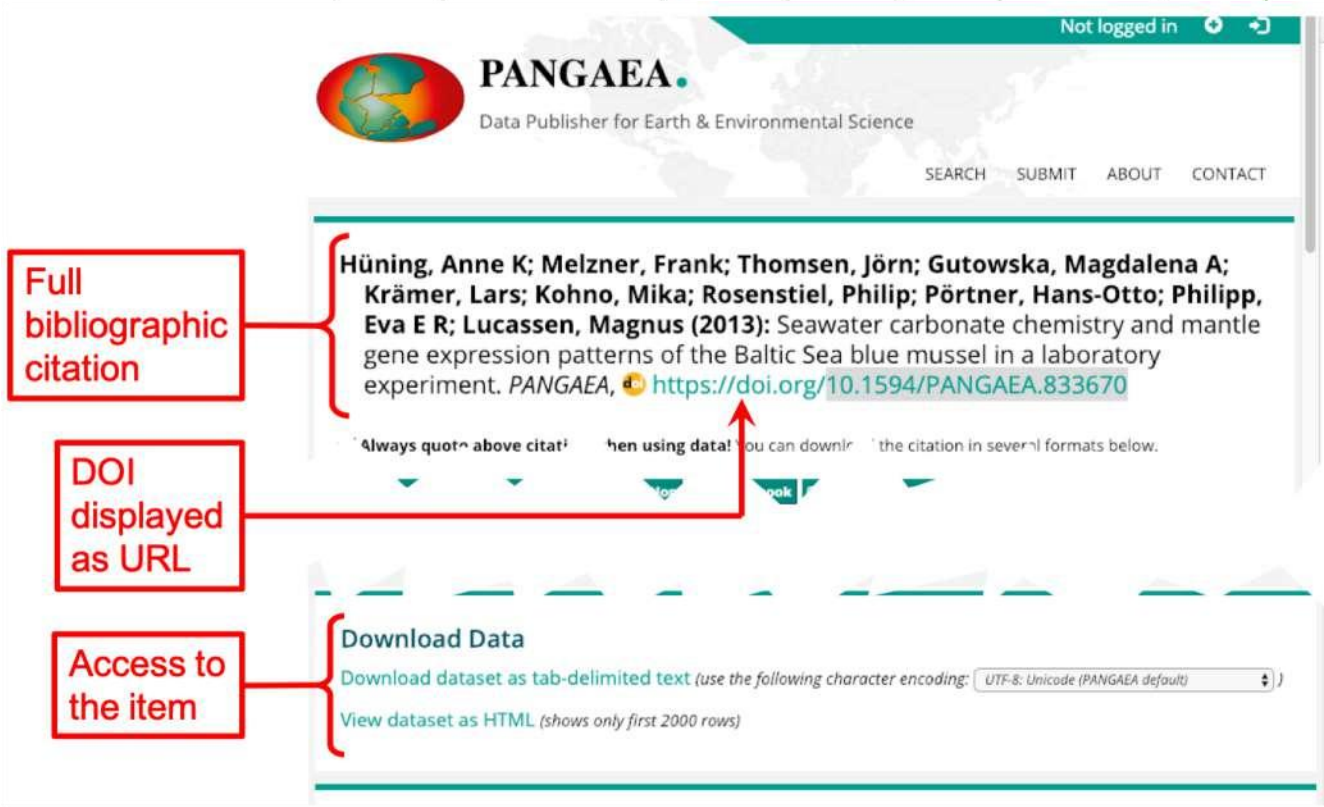
- DOI metadata schema

https://schema.datacite.org/meta/kernel-4.5/metadata.xsd

https://datacite-metadata-schema.readthedocs.io/en/4.5/

- Citation made by: creators, title, issue data → no changes are advisable
- landing page should contain How To Cite instruction and Data license
- landing page best practices at

https://support.datacite.org/docs/landing-pages



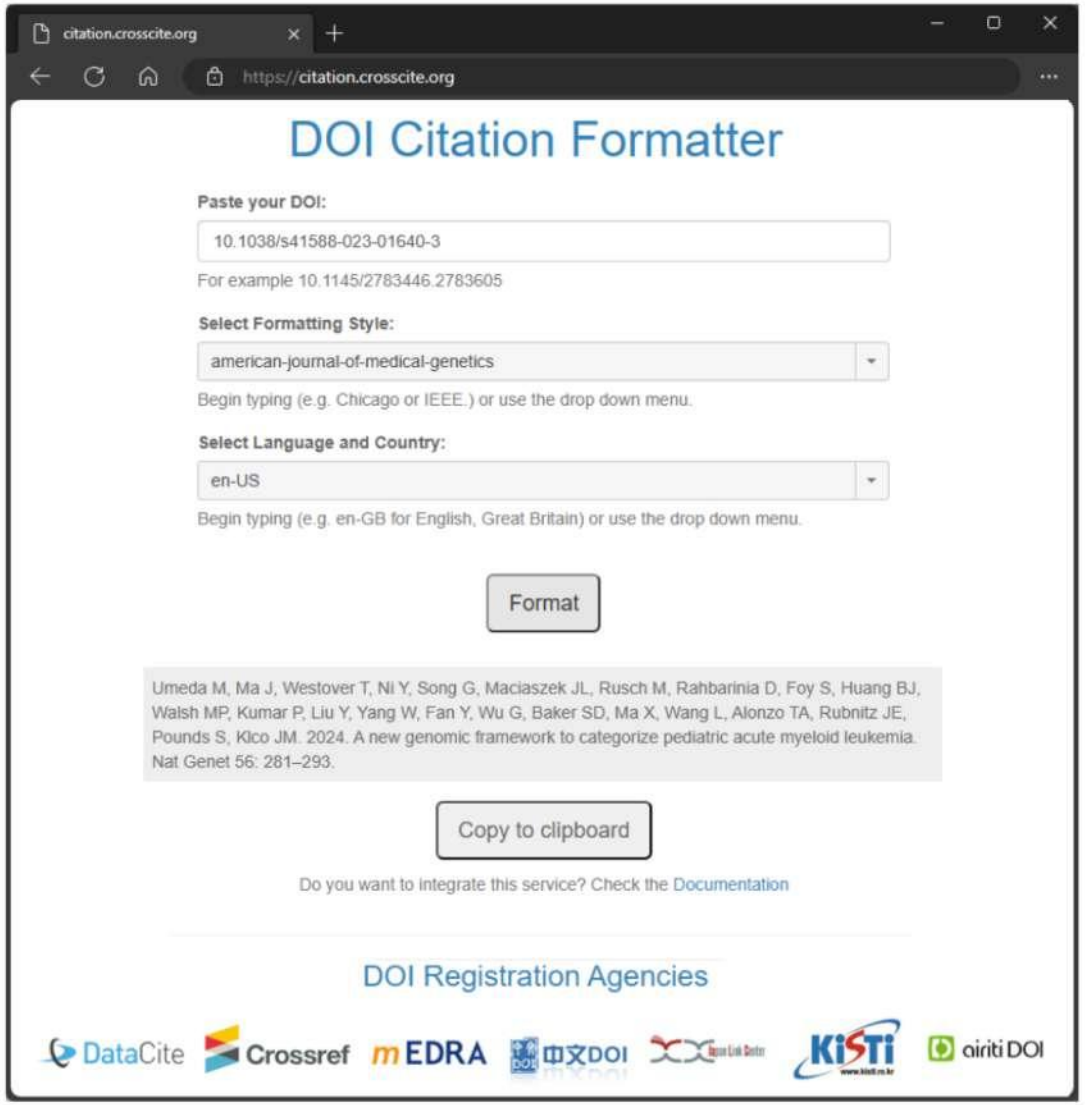
Data Citation

Citing source data is a compulsory requirement by most data licenses
(the “BY” component in a Creative Commons license)

A bibliographic citation of any digital object associated to a DOI can be obtained entering the code at

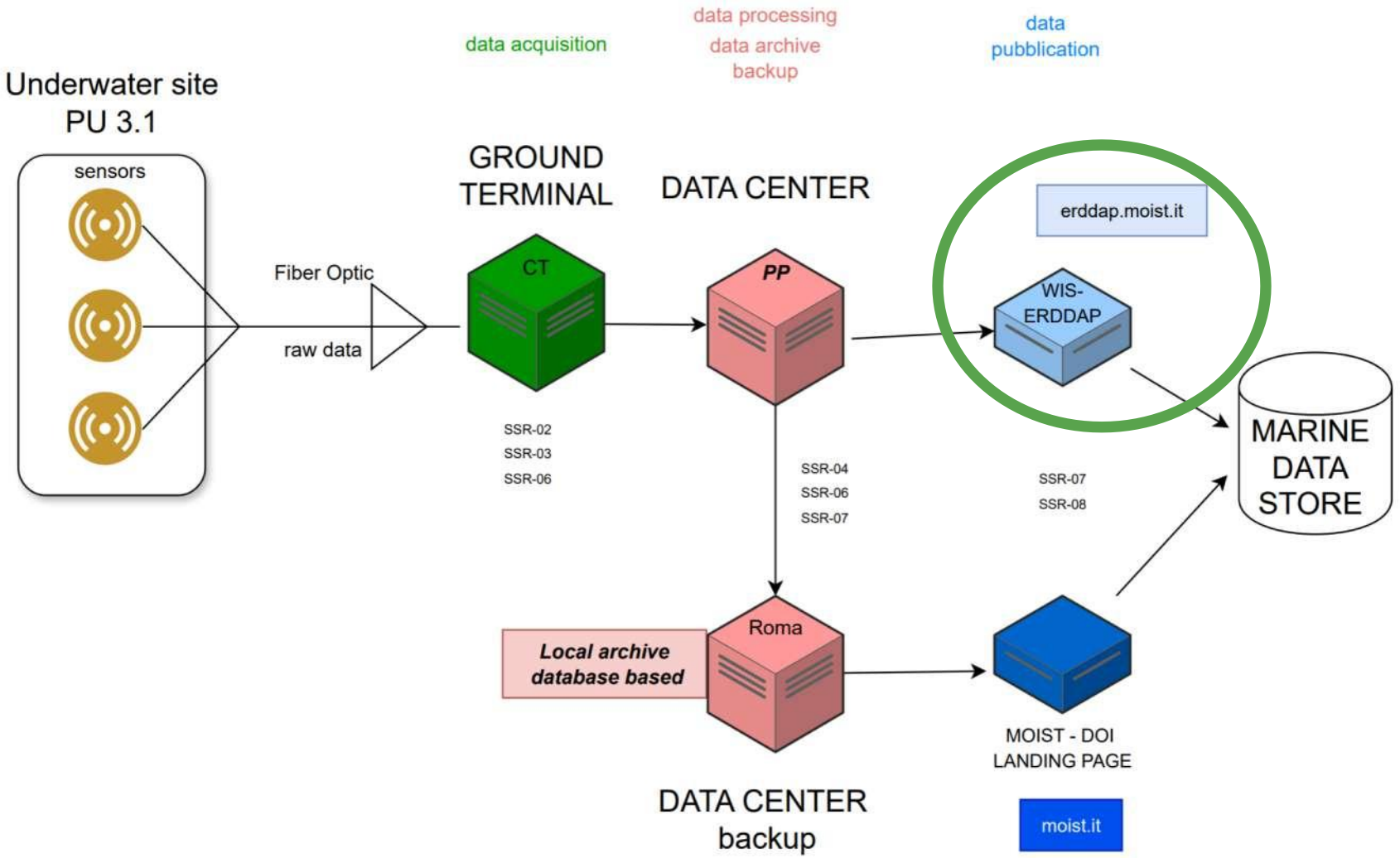
https://citation.crosscite.org/

from Locati & Cacciola (2024) Research Data Management
https://istituto.ingv.it/ufficio-gestione-dati



ITINERIS
WIS dataflow and ERDDAP data access service

ERDDAP → FAIR-compliant data access service in line with the GOOS Observations Coordination Group strategy



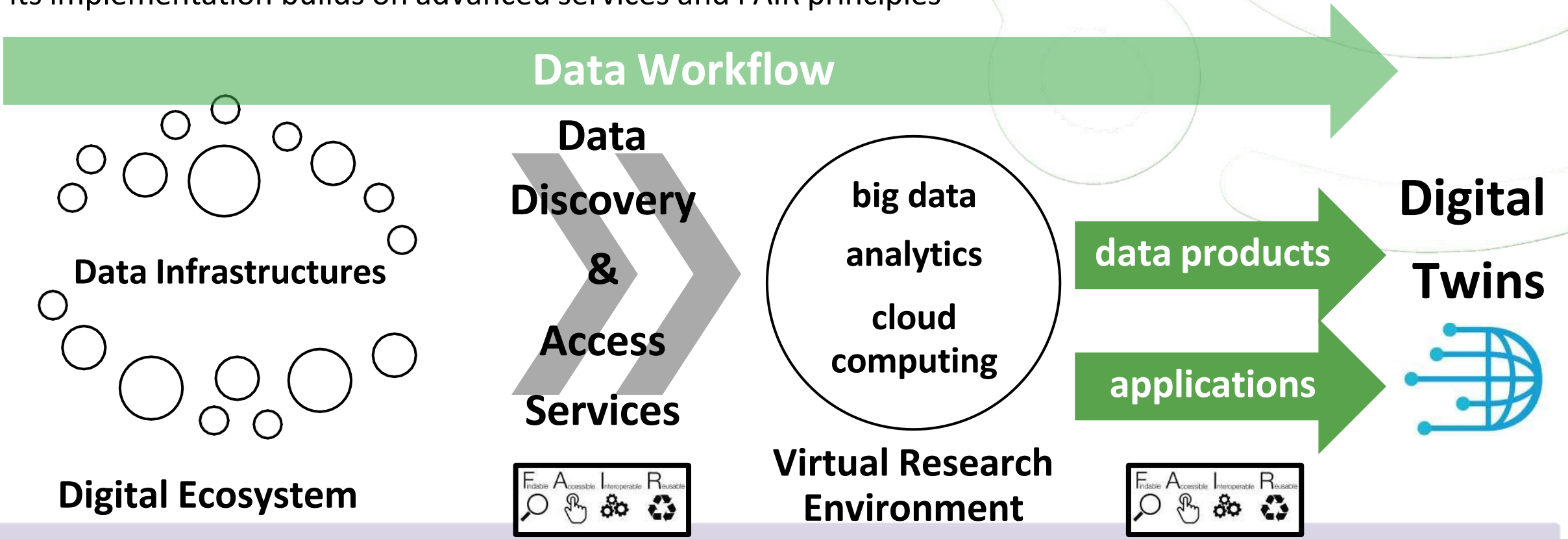
- supports dozens of popular formats
- provides standards-based metadata and formats
- supports federated access of distributed ERDDAP data services;
- supports both human and machine interactions
- supports sub-setting of large datasets
- provides improved discovery of datasets through commercial search engines
- provides support for archival of datasets

Workflows

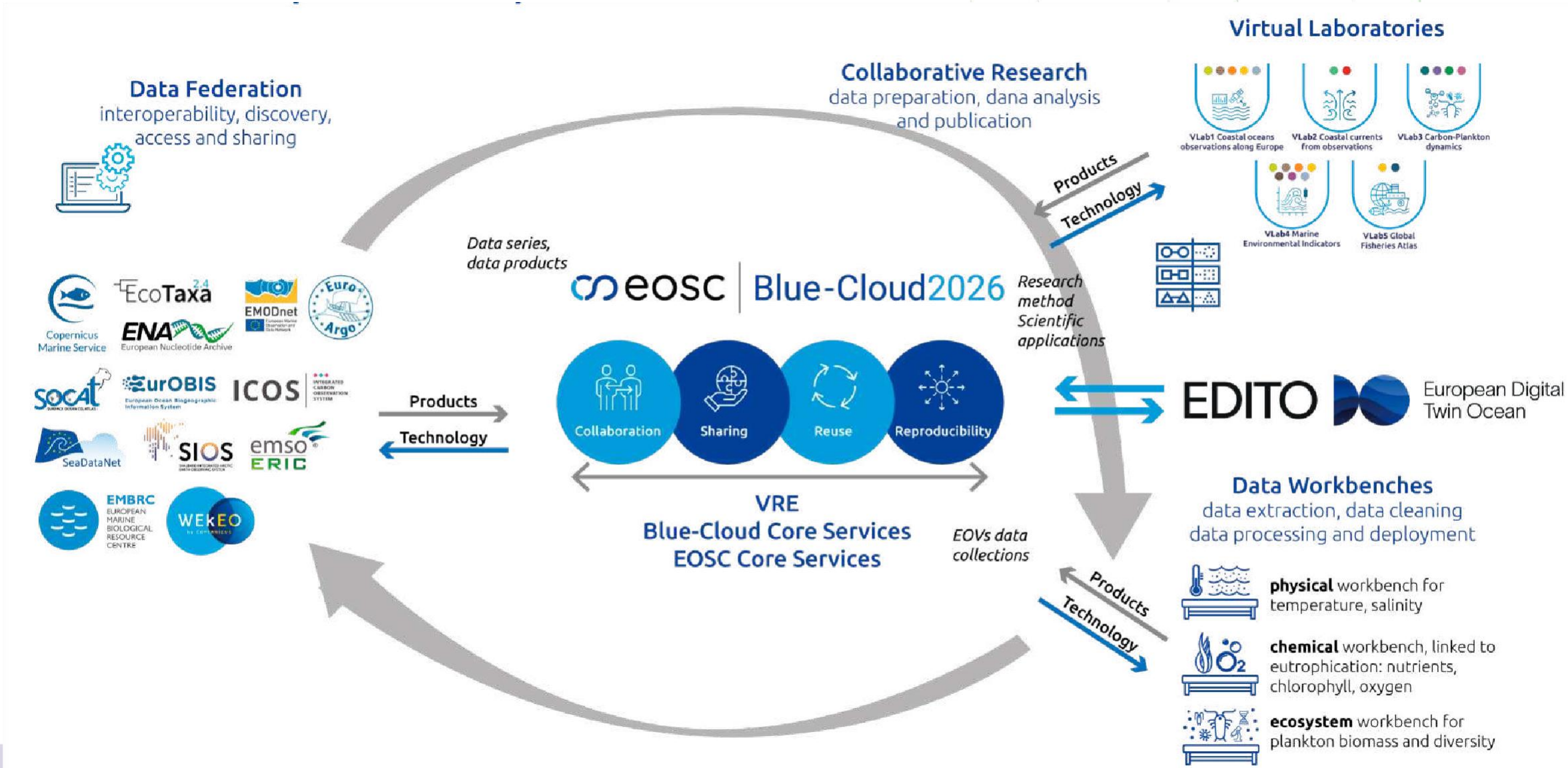
Workflow → a series of activities/processes that are necessary to complete a task

→ its **automation and managment process** increase efficiency, optimize the results, allows its replicability and monitoring

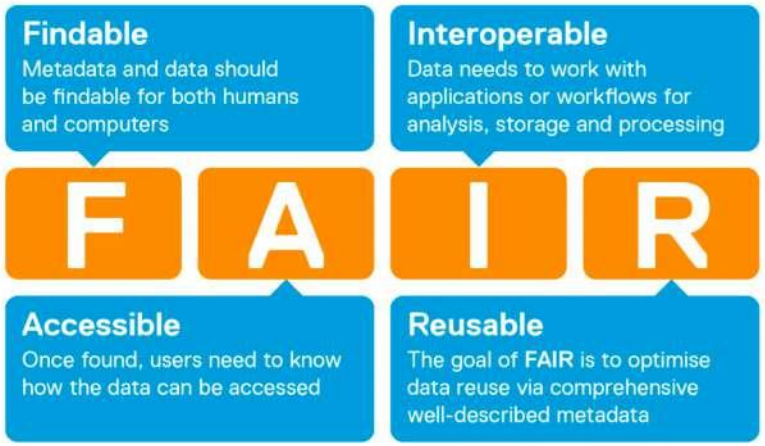
→ its implementation builds on advanced services and FAIR principles



Blue Cloud in a nutshell



FAIRness Assessment



FAIR proposed by the community https://force11.org/info/the-fair-data-principles/

Findable	
F1	(meta)data are assigned a globally unique and eternally persistent identifier.
F2	data are described with rich metadata.
F3	(meta)data are registered or indexed in a searchable resource.
F4	metadata specify the data identifier.
Accessible	
A1	(meta)data are retrievable by their identifier using a standardized communications protocol.
A1.1	the protocol is open, free, and universally implementable.
A1.2	the protocol allows for an authentication and authorization procedure, where necessary.
A2	metadata are accessible, even when the data are no longer available.

Interoperable	
I1	(meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
I2	(meta)data use vocabularies that follow FAIR principles.
I3	(meta)data include qualified references to other (meta)data.
Re-usable	
R1	(meta)data have a plurality of accurate and relevant attributes.
R1.1	(meta)data are released with a clear and accessible data usage license.
R1.2	(meta)data are associated with their provenance.
R1.3	(meta)data meet domain-relevant community standards.

FAIRness Assessment

Data FAIRness is useful for data providers to learn and adopt FAIR principles during data generation or to implement data FAIRification:

1. Data Maturity Model (FDMM) https://doi.org/10.15497/rda00050
2. F-UJI tool (automatic evaluation through DOI or URL) developed within FAIRsFair project https://www.f-uji.net/

FAIR principles and assessment is expanding to all «digital research objects» (data, software, semantic artifacts, VRE, ...)

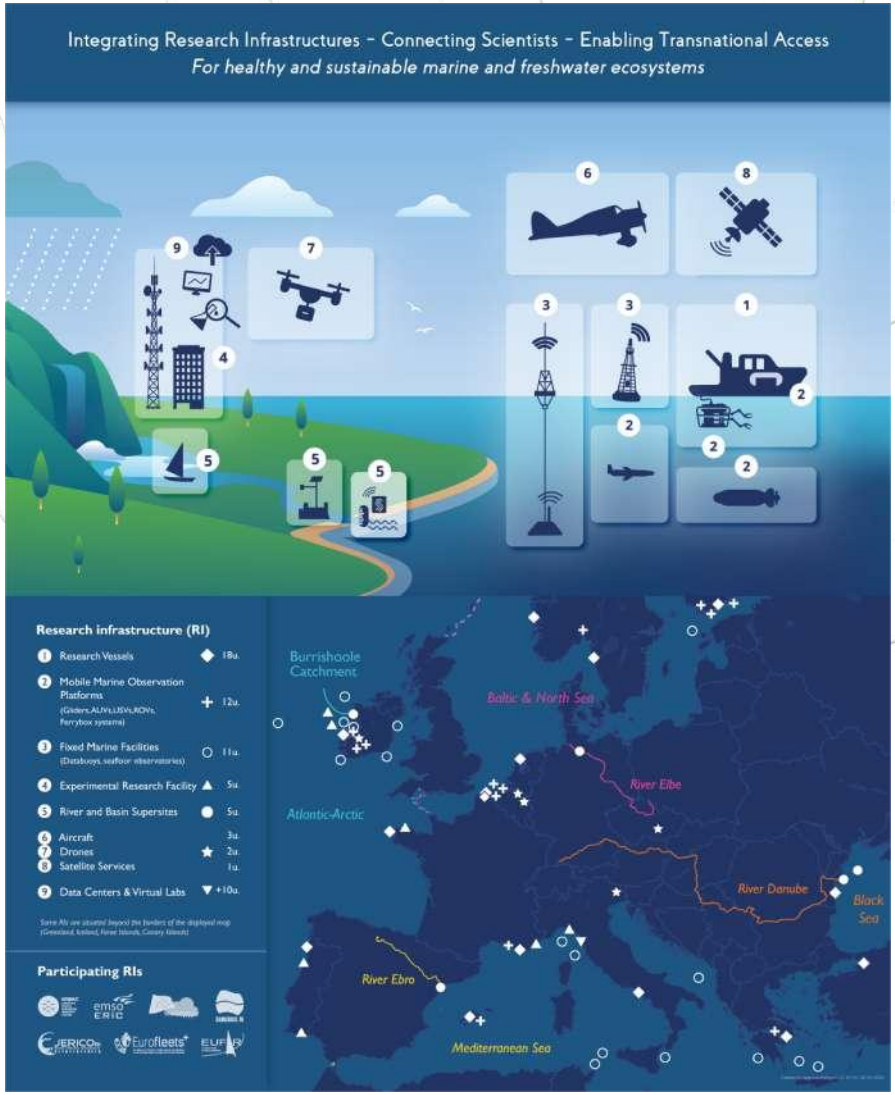
Software FAIRness

RDA FAIR4RS working group's principles → indicators under development https://doi.org/10.15497/RDA00068

AQUARIUS Project

- It **provides access to a comprehensive and diverse suite of integrated RIs** to address challenges and explore opportunities for the long-term sustainability of our marine and freshwater ecosystems
- through **Transnational Access (TA) funding calls** targets and supports research and innovation activities that contribute to the objectives, regional scope and implementation of the *EU Mission 'Restore our Ocean and Waters by 2030'*
- **4 lighthouse regions**: Baltic and the North Sea Basins, Black Sea, Atlantic/Arctic, Mediterranean Sea along with their associated major rivers
- brings together an **online catalogue of RIs** and support research and innovation projects via TA calls
- **Open data policy**, implemented via a dedicated **Data Management Plan**, to ensure that all gathered and generated metadata and data are managed in line with the FAIR principles

https://aquarius-ri.eu/



AQUARIUS Data Management Plan and data flow

data gathering

57 Ris

- research vessels
- marine mobile obs platforms
- fixed marine facilities
- aircrafts
- drones
- …

DMP template
Data Summary Log

expert data centers

feeding

EMODnet INGESTION

SEANOE

INS TAC
Copernicus Marine Service

SeaDataNet

EurOBIS
European Ocean Biodiversity Information System

elixir Core Data Resource

ICOS INTEGRATED CARBON OBSERVATION SYSTEM

feeding

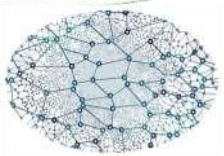
Copernicus Marine Service

EMODnet

eosc
Blue-Cloud2026

GEOSS
Global Earth Observation System of Systems

EDITOInfra
European Digital Twin Ocean



Ocean Decade Ecosystem

EMODnet INGESTION https://www.emodnet-ingestion.eu/

SEANOE https://www.seanoe.org/

All metadata/data become part of the archives managed and operated by leading EU data infrastructures for QA/QC, long term stewardship, wide access and use

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THANKS!

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