All Ocean Obs

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Contents

Summary:

This deliverable is a report on the work carried out within the Work Package 2 of the project '*Study for Reporting Obligations for Ocean Observation*'. It identifies standards, best practices and guidelines followed to sample and measure/analyse physical, biogeochemical, biological, cross-disciplinary and bathymetric/geological parameters in the EU ocean observing community and internationally. The analyses are carried out by assessing the Essential Ocean Variables (EOVs), their variables and sub-variables.

This report clearly presents key information about these standards and best practices, such as the endorsement entity (if any), scope, availability online, usefulness at regional, EU and international level, and their linkages to societal needs and emerging environmental issues.

At the end of this document, some recommendations are suggested to help close the identified gaps in each type of observation.

1. Background

To optimise the EU ocean observing system, a coherent approach of reporting, sampling, measurement, data harmonisation and processing should be adopted across all EU Member States. A set of Essential Ocean Variables (EOVs) have been described by the Global Ocean Observing System (GOOS) for physical, chemical, and biological parameters. EOVs are to be delivered to climate operational services in order to harmonise ocean observing requirements and ensure the flow of good quality data and accurate forecasts. These EOVs are well adopted by EU Member States who are among the countries reporting these parameters to EU and international entities through their National Data Centers (*read more about this process in D3 of WP1*).

In the EU, an approximate budget of €1.5 billion is spent yearly to support the ocean observing system and its various activities by the EU Member States (europa.eu). However, there are still many EOVs that are not monitored (sampled and/or analysed) uniformly, since not all EOVs have standards to follow yet or an endorsed best practice adopted by the EU ocean observing community (Pearlman *et al*., 2019; OBPS - Ocean Best Practices System). As a result, multiple EOVs are hard to compare between the various EU Member States, and are thus reported differently. This is one of the main obstacles that are inhibiting the progress of the EU ocean observing system towards fulfilling the FAIR (Findable, Accessible, Interoperable, and Reusable) data principles (Tanhua *et al*., 2019) that are crucial to guarantee an efficient interoperability of data and can boost EU observing productivity.

2. Scope

This report focuses on identifying the ocean observations' standards adopted in the ocean observation reporting process through analysing systematically the current standards and best practices used to measure and report the EOVs recommended by GOOS. This report tackles standards, best practices, guidelines and manuals widely used by the ocean observing community to sample and/or to measure physical, biogeochemical, biological, and cross-disciplinary EOVs *in situ* or in the laboratory. In addition, other types of observations that are very useful in the current ocean observing activities were also assessed in this report, such as geological and bathymetrical ones.

The benefits of an improved harmonisation in sampling and analysing EOVs will increase the productivity, efficiency, comparability and innovation of the EU ocean observing system. This report also highlights the usefulness of ocean observation standards and best practices in tackling societal needs and their scope of use (regional, European and/or global).

3. Methodology

This report focuses on the EOVs of GOOS, as they are the ones adopted and recommended for reporting to national, EU and international authorities and bodies.

The current standards, best practices and guidelines used to measure and report the EOVs were identified. In addition to these EOVs, the assessment covers bathymetrical and geological parameters.

To appropriately identify standards and best practices, the following definitions have been relied upon (Pearlman *et al*., 2019):

- **Standards** have the same objectives as best practices, but the difference is that they may serve as benchmarks for evaluation in addition to being processes. Also, they are generally top-down and may become mandatory legislated standards, such as the European INSPIRE legislation. The International Standards Organization (ISO) defines standards as "documents of requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose." The time for the formation of a standard by a Standards Development Organization (SDO) is 3–5 years or more using formal working groups to write the standard.

- A **best practice** is a methodology that has repeatedly produced superior results relative to other methodologies with the same objective; to be fully elevated to a best practice, a promising method will have been adopted and employed by multiple organisations (Simpson *et al.*, 2018). This definition is similar to definitions used in other fields for best practices (Bretschneider *et al.*, 2005). Best practices can come in many forms such as "standard operating procedures," manuals or guides. However, they all have a common goal of improving the quality and consistency of processes, measurements, data and applications through agreed practices.

In our assessment, we considered all standards and best practices published before 2013 (more than 10 years ago) as "outdated", since despite the fact that there are well-known standards followed by EU observers, there is continuous emergence of new best practices (BPs) in the last decade. These BPs are also followed by these observers for various reasons (simplicity, convenient processes, new needs not well tackled in the already-existing ones, etc.). Although these standards are good and might deliver high quality results, they always have to be updated (every 5 years/the standards requirements) to give them again the necessary visibility within the observing community and to update their components in a way that satisfies the new needs of the users.

Several standards used by the EU ocean observing community are international, therefore to cover all available standards adopted by this community, we used the search engines of the International Organization for Standardization (ISO; iso.org), the European Committee for Standardization (CEN; cencenelec.eu) and the European and International Standards Online Store (en-standard.eu). For best practices, guidelines and manuals, the Ocean Best Practices System repository was utilised to identify widely-accepted and used documents within the EU ocean observation community (Ocean Best Practices). As our consortium is composed of experts who are already part of the EU ocean observing community, we were able to investigate all types of ocean observations thanks to the available expertises (Table 1).

Table 1. The type of observations, EOVs and the main partner who reported on them in WP2.

Type of observations	EOVs	Responsible
Physical	**Sea state (Significant wave height, wave period, wave direction, maximum wave height, swell, directional spectrum, whitecap fraction, Wavelength, whitecap fraction, rogue waves, Stokes drift, and ocean albedo, Visual surface roughness, surface currents, winds)**	GEOMAR
	Ocean surface stress (Equivalent neutral winds, stress equivalent neutral winds, scalar stress, Ocean upwelling indices, sea state, upper ocean mixing, Ekman transport and Ekman pumping, air-sea fluxes of heat, water and gases, height-adjustment of near surface oceanic and atmospheric variables, Near surface humidity and air temperature, sea surface temperature, vector wind, surface current, sea state, air pressure)	GEOMAR
	Sea ice	SHOM
	Sea surface height	SMHI
	Sea surface temperature	SHOM
	Subsurface temperature	SHOM

	Surface currents	SHOM
	Subsurface currents	SHOM
	Sea surface salinity	SMHI
	Subsurface salinity	SMHI
	Ocean surface heat flux	SMHI
Biogeochemical	**Oxygen**	GEOMAR
	Nutrients (bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate, etc.)	GEOMAR
	Inorganic carbon [Dissolved Inorganic Carbon (DIC), Total Alkalinity (TA), Partial pressure of carbon dioxide (pCO2) and pH]	GEOMAR
	Transient tracers [Chlorofluorocarbon and Sulfur Hexafluoride, Tritium, Helium]	GEOMAR
	Particulate matter [Particulate Organic Matter (POM), Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Particulate Organic Phosphorus (POP), Particulate Inorganic Carbon (PIC), Total Suspended Matter (TSM), POC flux, Calcium Carbonate (CaCO3) flux, Biogenic Silica (BSi) flux, and Particulate amino-acids, Particulate Carbohydrates]	GEOMAR
	Nitrous oxide (N2O) + methane	GEOMAR
	Stable carbon isotopes ((δ13C, 13C/12C)	GEOMAR
	Dissolved organic carbon	GEOMAR
Biological	**Phytoplankton biomass and diversity**	GEOMAR & ICES
	Zooplankton biomass and diversity	GEOMAR & ICES
	Fish abundance and distribution	GEOMAR & ICES
	Marine turtles	SMHI
	Marine Birds	ICES
	Mammals abundance and distribution	ICES
	Hard coral cover and composition	GEOMAR & SMHI
	Seagrass cover and composition	GEOMAR & SMHI
	Macroalgal canopy cover and composition	GEOMAR & SMHI
	Microbe biomass and diversity (*emerging)	GEOMAR & SMHI
	Invertebrate abundance and distribution (*emerging)	GEOMAR & SMHI
Cross-disciplinary	**Ocean colour**	SSBE
	Marine debris (*emerging)	SSBE
	Ocean sound	SSBE
Bathymetrical/geological (Not yet EOVs)	**Bathymetry**	SHOM
	Marine Soil investigation (In situ and geophysical)	SHOM

The analysis was conducted in a systematic way, consisting of extracting information from each identified standard and best practice, replying to pre-determined questions fixed by the WP2 consortium to holistically evaluate the usefulness of each document and better assess the gaps. Few EOVs had separate standards for sampling and for laboratory analysis/measurement, thus the template took it into consideration to optimise the number of standards/best practices compiled while having a clear distinction. Our analysis also investigated the scope of application of the identified documents and their specific usefulness related to societal needs in order to highlight the importance of adopting ocean observation standards/best practices, locally, regionally and globally. A template of the table containing the questions tackled for each identified document is illustrated in Table 2. Our assessment was conducted separately for each type of observation: physical, biogeochemical, biological, cross-disciplinary, geological and bathymetric observations.

Table 2. A template of the table containing the questions tackled for each identified document (standard/best practice).

Type of observations	**Physical, Biogeochemical, Biological, Cross-disciplinary, bathymetrical/geological**	
EOVs/Parameters	**X EOV**	
	Sampling	**Lab. analysis/measurement**
Standard		
What is/are the existing standard(s) for this parameter?		
Is this standard endorsed? (drop down list)		
Best practice		
What is/are the existing best practice(s) for this parameter?		
Is this best practice endorsed? (drop down list)		
Legitimacy/Source		
Who endorsed the Standard?		
Who endorsed the Best practice?		
What is the scope of the standard? (drop down list)		
What is the scope of the best practice?		
Is this best practice EU-developed?		
Who wrote/tailored the standard?		
Who wrote/tailored the best practice?		
What is the specific use of this standard/best practice?		
When was the standard developed?		
When was the best practice developed?		
Where is the standard available? (Please add the link/URL/citation)		
Where is the best practice available? (Please add the link/URL/citation)		
Usefulness		
Is this standard/best practice applied/useful at regional level?		
Is this standard/best practice applied/useful at EU level?		
Is this standard/best practice applied/useful at global level?		
What societal need is this standard/best practice covering? (Options: Climate, Food Security, Maritime Safety, Ocean Health, Operational needs, Vulnerable communities)		
Other		
Comments		
Links to other guides/background documents		

4. Results

As the main entities endorsing all investigated standards are international, all standards developed for all types of EOVs can be applied internationally and at the EU scale.

Hereafter, the main results of the assessment are presented.

4.1. Physical EOVs

EOVs standards:
In this type of observation, 11 EOVs were assessed. The results show that five of these do not yet have a standard that can be used by the ocean observing community in the EU or abroad, neither for sampling nor for measurement. These EOVs are namely:

- ➢ Ocean surface stress: Equivalent neutral winds, stress equivalent neutral winds, scalar stress, ocean upwelling indices, sea state, upper ocean mixing, Ekman transport and Ekman pumping, air-sea fluxes of heat, water and gases, height-adjustment of near surface oceanic and atmospheric variables, Near surface humidity and air temperature, sea surface temperature, vector wind, surface current, sea state, air pressure,
- ➢ Sea surface height,
- ➢ Sea surface salinity,
- ➢ Subsurface salinity,
- ➢ Ocean surface heat flux.

It is noteworthy to mention that although we have identified two standards for Sea state that are used in open ocean observations, one was originally tailored for coastal areas while the other is initially informing the marine energy sector. Thus, more specialised standards are needed.

The main entities endorsing the physical standards:
Where there is a standard, it is usually developed by technical committees of the International Organization for Standardization (ISO) (e.g., oil and gas industries including lower carbon energy, water quality, hydrometry, ships and marine technology), circulated to the member bodies and endorsed by ISO, then by the European Committee for Standardization (CEN), followed by national standardisation entities in Europe such as The British Standards Institution (BSI). One standard is developed by international bodies such as WMO and the International Electrotechnical Commission (IEC).

EOVs best practices:
All physical EOVs, including those that do not have standards, have a minimum of one best practice that can help the ocean observing community to sample and measure one or more variables and sub-variables of the assessed physical EOVs.

The main entities endorsing the best practices:
Best practices identified for physical EOVs are generally endorsed by regional (HELCOM) or international (e.g., ICES, WMO, IOC-UNESCO, JCOMM, SCOR, IAPSO) entities but some are endorsed by recognised national institutes located outside of the EU (e.g., NOAA and National Snow and Ice Data Center in the US).

The main scope of the best practices:
More than 60% of the best practices are developed to be applied at international scale, while the rest have EU, regional and local scopes as they are tailored by regional networks or by national entities.

Date of publication of standards and best practices:
33% of the available standards were developed before 2013 (more than 10 years ago). However, almost 60% of the best practices were published before 2013.

Availability of standards and best practices:
All standards and best practices identified for physical EOVs were easily findable via the search engines of the respective standardisation and ocean best practices websites. While best practices are freely available, all standards need to be paid for. Links to these documents are provided in the attached spreadsheet.

Societal usefulness of these standards/best practices:
All standards for physical EOVs are useful at international level but are also used regionally. Also, all best practices identified for this type of observations are used at regional, EU and global levels. In terms of societal needs, standards and best practices developed for physical EOVs cover mostly **operational needs** and **maritime safety**, then **ocean health**, and to a lesser extent **climate** and **vulnerable communities** (particularly for sea surface height).

4.2. Biogeochemical EOVs

EOVs standards:
In this type of observation, 8 EOVs and 19 sub-variables were assessed. The results show that ~ 42% of the sub-variables do not yet have a standard that can be used by the ocean observing community in the EU or abroad neither for sampling, nor for laboratory measurement, namely for the following EOVs and their sub-variables:

- ➢ Inorganic carbon: total dissolved inorganic carbon (DIC, CT), fugacity of carbon dioxide (fCO_2)/Partial pressure of carbon dioxide (pCO_2),
- ➢ Transient tracers: Chlorofluorocarbon (CFCs) and Sulphur Hexafluoride (SF_6), Helium (He),
- ➢ Particulate matter: Particulate Organic Carbon (POC), Particulate Inorganic Carbon (PIC), Particulate amino-acids, Particulate Carbohydrates, Particulate Organic Matter (POM), Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Particulate Organic Phosphorus (POP), Particulate Inorganic Carbon (PIC), Total Suspended Matter (TSM), POC flux, Calcium Carbonate ($CaCO_3$) flux, Biogenic Silica (BSi) flux,
- ➢ Nitrous oxide (N_2O)/Methane (CH_4).

The main entities endorsing the biogeochemical standards:
When there is a standard, it is usually developed by the technical committee ISO/TC 147, Water quality, circulated to the member bodies and endorsed by the International Organization for Standardization (ISO), then by the European Committee for Standardization (CEN), followed by national standardisation entities in Europe such as Asociación Española de Normalización/Spain (UNE), Deutsches Institut für Normung (DIN), the British Standards Institution (BSI) or abroad the American Society for Testing and Materials (ASTM).

EOVs best practices:
Best practices have been identified for ~ 95% of biogeochemical sub-variables. All biogeochemical EOVs that do not have standards to follow, do have best practices that can help the ocean observing community to sample and measure these EOVs.

The main entities endorsing the best practices:
Among the 28 best practices identified for biogeochemical EOVs, less than half were EU-developed. The main entities endorsing these best practices in Europe vary from local to regional such as GEOMAR, NANSEN, HELCOM, or at the EU level such as JERICO, European

Commission, while the international entities are ICES, IOCCP, PICES, IAEA, GO-SHIP, SCOR and NOAA.

The main scope of the best practices:
The majority of best practices are developed to be applied at international scale (~ 60%), while the rest have EU, regional and local scope as they are tailored by regional networks.

Date of publication of standards and best practices:
Biogeochemical standards are the most outdated among all standards developed for the various types of EOVs, as almost half (47%) of the available standards were developed at least 10 years ago (more than 20 years ago for oxygen and nitrogen).

A good percentage of best practices are also relatively old (~ 42% were published before 2013), for example best practices for Particulate matter were published in the 1990s, namely for Particulate Inorganic Carbon (PIC), Particulate amino-acids, Particulate Carbohydrates, Particulate Organic Matter (POM), Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Particulate Organic Phosphorus (POP), Particulate Inorganic Carbon (PIC), Total Suspended Matter (TSM), POC flux, Calcium Carbonate ($CaCO_3$) flux, Biogenic Silica (BSi) flux).

Availability of standards and best practices:
All standards and best practices identified for biogeochemical EOVs were easily findable on the internet. While best practices are freely available, all standards need to be paid for. Links are provided in the attached spreadsheet.

Societal usefulness of these standards/best practices:
All standards for biogeochemical EOVs are useful at international level but are also used regionally. Also, all best practices identified for this type of observations are used at regional, EU and global levels.

In terms of societal needs, biogeochemical EOVs are mostly related to **ocean health** , but are also useful to tackle **climate**, **food security** and **vulnerable communities**.

4.3. Biological EOVs

EOVs standards:
In this type of observation, 11 EOVs were investigated. Our assessment shows that nearly 90% of biological EOVs have standards to follow by the ocean observing community in the EU, and aboard. For Marine Turtles, there is only one document combining standards and guidelines for long-term monitoring, developed by a Regional Activity Centre for Specially Protected Areas (RAC/SPA) affiliated to the United Nations Environment Programme.

The following EOVs do not have a standard yet:

- ➢ Fish abundance and distribution: there are standards for sampling but not for lab. Analysis.
- ➢ Mammals abundance and distribution,

Although the available standards tackle the following EOVs in a general way under various vague terms [e.g., hard-substrate communities, seabed area, interstitial biota and soft-bottom macrofauna], there are no specific ones dedicated for their sampling and analysis in a specific way:

- ➢ Hard coral cover and composition,
- ➢ Seagrass cover and distribution,
- ➢ Macroalgal canopy cover and composition,

- ➢ Microbe biomass and diversity,
- ➢ Invertebrate abundance and distribution.

It is also noteworthy to mention that the available standards dedicated for Seagrass and Macroalgal cover and composition are tailored for EU littoral zones only.

The main entities endorsing the biological standards:
Most of the standards dedicated for biological EOVs are developed by ISO and CEN, and sometimes ASTM, then endorsed by DIN and UNE. There are a couple of standards that mostly satisfy the guidelines' requirements (Pearlmann et al., 2019). These are developed by RAC/SPA of the UNEP and HELCOM.

EOVs best practices:
Around 91% of biological EOVs have best practices. Biological EOVs that do not have standards to follow, do have best practices that can help the ocean observing community to sample and measure these EOVs, although there is a need for a better agreement on the use of certain best practices.

The main entities endorsing the best practices:
Among the 29 best practices identified for biological EOVs, most of them were developed at a regional level (HELCOM, OSPAR, UNEP/MAP). The other ones are either developed nationally (JNCC, MEDIN, NOAA) or at European or international level (ESAS, ICES, ICCAT, IWC, SEAGRASSNET).

Date of publication of standards and best practices:
Nearly 80% of standards for biological EOVs are relatively new, published after 2013. Best practices are quite updated, as only 21% were published before 2013 while the majority was developed during the least 8 years. Also, all biological EOVs are covered by at least one updated best practice.

Availability of standards and best practices:
All standards were easily findable on the internet but most of them were not free of charge (except for the ones that weren't developed via the usual international standardisation entities). However, best practices identified for biological EOVs were easily findable on the internet, and are freely available. Links are provided in the attached spreadsheet.

Societal usefulness of these standards/best practices:
Most of the standards were developed for international use and are fit to be used at EU and regional levels. The majority of best practices are developed to be applied at regional scale, and with less extent for local, European or international scales. Most of the standards and best practices identified for biological EOVs cover **ocean health** societal needs, but also **climate**, **food security** and **vulnerable communities** needs.

4.4. Cross-disciplinary EOVs

EOVs standards:
Three EOVs were checked for cross-disciplinary observations. The results show that these variables are covered by 16 standards (e.g., at least one for Ocean colour and up to 8 for Ocean sound).

The main entities endorsing the cross-disciplinary standards:
The standards are usually developed by the Technical Committees ISO/TC 147, Water quality, ISO/TC 8, Ships and marine technology, and ISO/TC 43, Acoustics, and was circulated to the

member bodies and endorsed by the International Organization for Standardization (ISO), then by the European Committee for Standardization (CEN), followed by national standardisation entities in Europe such as [UNE (Asociación Española de Normalización/Spain), Deutsches Institut für Normung (DIN), The British Standards Institution (BSI)] or abroad (American Society for Testing and Materials (ASTM)). Two standards are developed by the International Electrotechnical Commission (IEC) and by the American National Standards Institute (ANSI).

EOVs best practices:
All cross-disciplinary EOVs have best practices (34 identified) that can help the ocean observing community to sample and measure these EOVs.

The main entities endorsing the best practices:
Among the 34 best practices identified for cross-disciplinary EOVs, several of them were developed by HELCOM, JRC and ICES at International and regional levels. All the others were developed at various levels, from local to international (Universities, National agencies, Regional European or International initiatives).

Date of publication of standards and best practices:
Most of the available standards (>80%) were developed during the last 7 years (from 2016 to 2022). However, the only standard available for Ocean colour was developed in 1992.

Best practices are also generally recent,with almost 80% of them developed in the last 9 years. The only best practice available for Ocean colour was developed in 1992.

Availability of Standards and best practices:
All standards and best practices identified for cross-disciplinary EOVs were easily findable on the Internet. Most of these documents were free of charge. Links are provided in the attached spreadsheet.

Societal usefulness of these standards/best practices:
Standards have national, regional, international scopes. While best practices are developed to be applied mainly at regional and international scales. Most of the standards and best practices identified for cross-disciplinary EOVs cover **ocean health** societal needs. Some of them are also related to **Climate**, **Food security, Maritime safety** and **Operational** needs.

4.5. Bathymetrical and geological observations

It is crucial to note first that bathymetric and geological observations are not currently included in any existing EOVs (goosocean.org).

Parameters' standards:
Two parameters were checked for bathymetrical/geological observations: bathymetry (for bathymetrical observation) and marine soil investigation (for geological observations). The results show that both parameters have clear standards (i.e., focused on the safety of navigation for bathymetry). These standards can be followed by ocean observers.

The main entities endorsing the bathymetric and geological standards:
The bathymetrical standard was developed by the dedicated International Hydrographic Organization (IHO) working group, and was circulated to the IHO Member States and endorsed by the IHO.

For geological observations, standards for marine soil investigation were developed on one hand by the Technical Committee ISO/TC 67 and endorsed by the International Organization for Standardization (ISO), and on the other hand by the Technical Committee TC 250 and endorsed by the European Committee for Standardization (CEN), followed by national standardisation entities in Europe.

Parameters' best practices:
The bathymetric and geological parameters are well covered by several best practices (n = 10) that are followed by the EU ocean observing community.

The main entities endorsing the best practices:
For bathymetry, best practices are generally produced and endorsed by the national hydrographic offices or by the national entities in charge of the hydrographic surveys. However, two of them are endorsed by international entities (IHO and ICES). Regarding marine soil investigation (geology), best practices are endorsed by international entities (ISSMGE, IHO and SUT).

Date of publication of Standards and best practices:
For bathymetry, the last version of the IHO standard was endorsed in 2020. The available national best practices were developed at least 10 years ago, but most of them are updated in 2019 or after. International best practices are less updated, and only 14% of bathymetrical best practices are developed before 2013.
For marine soil investigation, the standards are older (2010 and 2014). The best practices were endorsed between 2005 and 2020.

Availability of Standards and best practices:
All standards and best practices identified were easily findable via the search engines of the respective standardisation and ocean best practices websites. While best practices and IHO standards are freely available, all ISO and CEN standards need to be paid for. Links are provided in the attached spreadsheet.

Societal usefulness of these standards/best practices:
Most of the best practices for bathymetry are developed to be applied at national level (the other two at international level). For marine soil investigation, they can be applied at international level. All standards and best practices cover mostly **maritime safety**, and **operational needs** and to a less extent the **vulnerable communities**' societal needs.

4.6 Summary tables

The results presented above are summarised in Table 3 for standards and Table 4 for best practices.

Table 3. Summary of the main findings for the standards used by the EU ocean observing community.

Type of observations	Standards	Physical	Biogeochemical	Biological	Cross-disciplinary	Bathymetrical/ geological
Number of EOVs		11	8	11	3	
Tackled sub-variables			19			2
Standards (n)		9	17	14	16	3
EOVs/variables with standards		55%	58%	91%	100%	100%
Endorsing entities		ISO, CEN, WMO, IEC, BS	ISO, CEN, DIN, UNE, BSI, ASTM	CEN, ISO, ASTM, DIN, UNE, HELCOM , RAC/SPA, UNEP/MAP	ISO, IEC, ANSI, ASA	IHO, ISO, CEN, DIN
EOVs without standards		5	4	1.5	0	0
Scope of standards	International	✔	✔	✔	✔	✔
	Regional	X	X	✔	✔	✔
	National	X	X	X	✔	✔
Availability of Standards	Available online but with fees	✔	✔	✔	✔	✔
	Available online for free	X	X	✔	✔	✔
	Not available online	X	X	X	X	X
Year of publication of standards	Before 2013 (> 10y)	33%	47%	21%	19%	33%
Societal needs covered by the existing standards	Climate	★	★★		★	
	Food security		★★	★★★	★	
	Maritime safety	★★★			★★	★★★
	Ocean health	★★	★★	★★★	★★★	
	Operational needs	★★★			★★	★★★
	Vulnerable communities		★★	★★★		★★

***3 Stars: Very likely related to this societal need, 2 stars: Likely related to this societal need, 1 star: Somehow related to this societal need, No-star: Not directly related to this societal need.**

Table 4. Summary of the main findings for the best practices used by the EU ocean observing community.

Type of observations	**Best practices**	**Physical**	**Biogeochemical**	**Biological**	**Cross-disciplinary**	**Bathymetrical /geological**
Number of EOVs		11	8	11	3	
Tackled sub-variables			19			2
Best practices (n)		17	26	29	34	10
EOVs/variables with best practices		100%	95%	91%	100%	100%
Endorsing entities		WMO, IOC-UNESCO, JCOMM, SCOR, ICES, IAPSO, NSIDC, HELCOM, NOAA	HELCOM, GO-SHIP, SCOR, IOCCP, PICES, IAEA, EU commission, ICES, JERICO, NOAA, GEOMAR, NANSEN, GOOS	HELCOM, OSPAR, ICES, ICCAT, RAC/SPA, UNEP/MAP, ESAS, IWC, MEDIN, RLS, CRCP, NOAA	ICES, JRC, GESAMP, MSFD, HELCOM, IOC, AMAP, VUA, JPI-Oceans SST, MIO-ECSDE, DeFishGear, NOAA, OSPAR, ICES, JOMOPANS, NPL, IQOE	UKHO, BGS, NZ, Ca, SHOM, IHO, NHS
EOVs without best practices		0	1	1	0	0
Scope of best practices	International	✔	✔	✔	✔	✔
	Regional	✔	✔	✔	✔	X
	National	✔	✔	X	X	X
Availability of best practices	Available online but with fees	X	X	X	X	X
	Available online for free	✔	✔	✔	✔	✔
	Not available online	X	X	X	X	X
Year of publication of best practices	Before 2013 (> 10y)	59%	42%	21%	18%	30%
Societal needs covered by the existing best practices	Climate	★	★★	★★	★	
	Food security		★★	★★	★	
	Maritime safety	★★★			★★	★★★
	Ocean health	★★	★★★	★★	★★★	
	Operational needs	★★★			★★	★★★
	Vulnerable communities	★	★★	★		★★

***3 Stars: Very likely related to this societal need, 2 stars: Likely related to this societal need, 1 star: Somehow related to this societal need, No-star: Not directly related to this societal need.**

5. Conclusions and recommendations

Our efforts show that some critical ocean parameters/Essential Ocean Variables do not yet have standards to follow or even updated best practices widely accepted by the EU ocean observing community. This makes the monitoring and reporting of several EOVs very heterogeneous and hard to compare between the various EU Member States. Our results also show that a couple of EOVs have multiple inconsistent best practices which lead to no better results.

In order to improve the efficiency and productivity of the EU ocean observing system, clear and simplified standards should be tailored for the EOVs that do not yet have them. This will certainly help harmonise the sampling and analysis procedures of critical ocean parameters and will ultimately help in unifying the reporting process of these EOVs across all Member States.

Our WP2 work clearly reflects the usefulness of standards and best practices at local, regional, EU and international scales. Updating these documents and drafting standards that can be followed to measure all EOVs, will help the EU ocean observing community to report these EOVs in a uniform manner and will help closing the gaps in covering all EOVs by all Member States.

Moreover, the bathymetrical parameter should be identified as an EOV and then endorsed by GOOS, since the knowledge of bathymetry is crucial for ocean modelling as it addresses ocean forecasts and operational ocean services. Therefore, the bathymetrical parameter is key for the safety of all maritime operations and to address multiple scientific questions. On the other hand, we concluded that geological parameters could include even more variables and this aspect of ocean observations should be investigated more thoroughly in the future. In addition, since the geological parameter is closely related to the bathymetry of the area and is a complementary variable, we recommend having both variables (bathymetry and geology) as principal components of a new EOV than can be endorsed during the UN Ocean Decade and can be very helpful for the EU ocean observing community.

Based on our assessment, we are providing hereafter the main recommendations that could help improve the efficiency and productivity of the EU ocean observing system through standards and best practices, per type of observations:

Physical EOVs:

- ➢ To develop standards for the following variables/sub-variables:
    - ➢ Ocean surface stress: Equivalent neutral winds, stress equivalent neutral winds, scalar stress, Ocean upwelling indices, sea state, upper ocean mixing, Ekman transport and Ekman pumping, air-sea fluxes of heat, water and gases, height-adjustment of near surface oceanic and atmospheric variables, Near surface humidity and air temperature, sea surface temperature, vector wind, surface current, sea state, air pressure,
    - ➢ Sea surface height,
    - ➢ Sea surface salinity,
    - ➢ Subsurface salinity,
    - ➢ Ocean surface heat flux.
- ➢ More specialised standards for Sea state are needed as the current ones are originally developed for coastal areas and the marine energy sector.
- ➢ To update the best practices related to the Ocean Surface Stress, Surface currents, Subsurface currents, and Ocean Surface Heat Flux, taking into consideration the community's feedback and lessons learned from the existing old ones.

Biogeochemical EOVs:

- To develop standards for the following parameters:
  - Inorganic Carbon: total dissolved inorganic carbon (DIC, CT), fugacity of carbon dioxide (fCO2)/Partial pressure of carbon dioxide (pCO2),
  - Transient tracers: Chlorofluorocarbon (CFCs) and Sulphur Hexafluoride (SF6), Helium (He),
  - Particulate matter: Particulate Organic Carbon (POC), Particulate Inorganic Carbon (PIC), Particulate amino-acids, Particulate Carbohydrates, Particulate Organic Matter (POM), Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Particulate Organic Phosphorus (POP), Particulate Inorganic Carbon (PIC), Total Suspended Matter (TSM), POC flux, Calcium Carbonate (CaCO3) flux, Biogenic Silica (BSi) flux,
  - Nitrous oxide (N2O)/Methane (CH4).
- To update the standards dedicated to sample and measure the dissolved oxygen and nitrogen (developed more than 20 years ago).
- To update the best practices for Particulate matter (the most recent ones were published in the 1990s): namely for Particulate Inorganic Carbon (PIC), Particulate amino-acids, Particulate Carbohydrates, Particulate Organic Matter (POM), Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Particulate Organic Phosphorus (POP), Particulate Inorganic Carbon (PIC), Total Suspended Matter (TSM), POC flux, Calcium Carbonate (CaCO3) flux, Biogenic Silica (BSi) flux).

Biological EOVs:

- Biological EOVs do have mostly clear and updated standards. However, it is needed to develop standards for the following parameters:
  - Lab. analysis/measurement of fish abundance and distribution,
  - Mammals abundance and distribution,

We also recommend developing specialised standards for the following EOVs as the current ones are targeting specific habitats:

- Hard coral cover and composition,
- Seagrass cover and distribution,
- Macroalgal canopy cover and composition,
- Microbe biomass and diversity,
- Invertebrate abundance and distribution.

- Moreover, we recommend the development of standards dedicated for sampling and analysis of Seagrass and Macroalgal cover and composition beyond the EU littoral zones.

- Even best practices need to be harmonised and somehow unified within the biological EOVs observing community.

Cross-disciplinary EOVs:

- To update or develop standards and best practices for Ocean colour.
- The two other EOVs appear to be sufficiently covered by the existing standards and best practices.

Bathymetrical and geological parameters:

- ➢ This type of observation needs deeper investigation to determine/identify variables and sub-variables that might be used to create a detailed and solid EOV, which can be then endorsed by GOOS and followed by the EU ocean observing community.
- ➢ The standards identified for the marine soil investigation can be updated, as they are dated to 2010 and 2014.
- ➢ The best practices related to the marine soil investigation should be better developed and the ones identified in this study need to be updated, as the most recent one (endorsed by IHO) is not fully dedicated to this parameter.

6. Acknowledgements

NA.

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Global Ocean Observing System - EOVs (goosocean.org)
Online Browsing Platform (OBP) (iso.org)
European and International standards online store - European Standards (en-standard.eu)
CEN - CENELEC - Search standards (cencenelec.eu)
Ocean Best Practices

Annexe 1.

List of Acronyms:

AMAP: Arctic Monitoring and Assessment Programme
ANSI: American National Standards Institute
ASTM: American Society for Testing and Materials
BGS: British Geological Survey
BSI: British Standards Institution
Ca: Canada
CEN: European Committee for Standardization
CRCP: Coral Reef Conservation Program
DeFishGear: The Project Derelict Fishing Gear in the Adriatic Sea
DIN: Deutsches Institut für Normung (DIN)
EOVs: Essential Ocean Variables
ESAS: European Seabirds At Sea
FAIR data: Findable, Accessible, Interoperable, and Reusable data
GEOMAR: GEOMAR Helmholtz Centre for Ocean Research Kiel
GESAMP: The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GOOS: Global Ocean Observing System
GO-SHIP: The Global Ocean Ship-based Hydrographic Investigations Program
HELCOM: The Baltic Marine Environment Protection Commission
IAEA: The International Atomic Energy Agency
IAPSO: The International Association for the Physical Sciences of the **Oceans**
ICCAT: The International Commission for the Conservation of Atlantic Tunas
ICES: International Council for the Exploration of the Sea
IEC: International Electrotechnical Commission
IHO: International Hydrographic Organization
IQOE: International Quiet Ocean Experiment
IOC-UNESCO (IOC): The Intergovernmental Oceanographic Commission of UNESCO
IOCCP: The International Ocean Carbon Coordination Project
ISO: International Standards Organization
ISSMGE: International Society for Soil Mechanics and Geotechnical Engineering
IWC: International Whaling Commission
JCOMM: The Joint Technical Commission for Oceanography and Marine Meteorology
JERICO: Joint European Research Infrastructure of Coastal Observatories
JNCC: Joint Nature Conservation Committee
JOMOPANS: Joint Monitoring Programme for Ambient Noise North Sea
JRC: Joint Research Centre
MEDIN: Marine Environmental Data and Information Network
MIO-ECSDE: Mediterranean Information Office for the Environment, Culture and Sustainable Development
MSFD: Marine Strategy Framework Directive
NANSEN: Nansen Environmental and Remote Sensing Center in Norway
NHS: Norwegian Mapping Authority Hydrographic Service
NPL: The National Physical Laboratory
NOAA: National Oceanic and Atmospheric Administration in the USA
NSIDC: National Snow and Ice Data Center in the USA
NZ: New Zealand

OSPAR: Oslo Convention. Named because of the original Oslo and Paris Conventions ("OS" for Oslo and "PAR" for Paris).
PICES: North Pacific Marine Science Organization
RAC/SPA: Regional Activity Centre for Specially Protected Areas
RLS: Regional Leaders Summit
SCOR: Scientific Committee on Oceanic Research
SDO: Standards Development Organization
SEAGRASSNET: An expanding, worldwide ecological monitoring program that investigates and documents the status of seagrass resources and the threats to this important and imperilled marine ecosystem. About | SeagrassNet
SHOM: Naval Hydrographic and Oceanographic Service
SUT: Society for Underwater Technology
TC: Technical Committee ISO/TC
UKHO: UK Hydrographic Office
UNEP/MAP: UN Environment Programme/Mediterranean Action Plan (MAP)
UNE: Asociación Española de Normalización, Spain
UNEP: United Nations Environment Programme
VUA: Vrije Universiteit Amsterdam
WMO: World Meteorological Organization

Annexe 2.

This Annexe refers to the spreadsheet attached to this report where all standards, best practices and guidelines identified for each type of observation and each EOV were identified. In each type of observation, all the extracted information are well presented based on the template table presented in this report (Table 2).

This spreadsheet contains several sheets:
1- Summary of the WP2
2- Task distribution
3- The question template agreed on
4- Physical EOVs
5- Biogeochemical EOVs
6- Biological EOVs
7- Cross-disciplinary EOVs
8- Bathymetrical/geological parameters
9- Summary tables