Framework Service Contract EEA/IDM/15/026/LOTs 1 for Services supporting the European Environment Agency's (EEA) implementation of cross-cutting activities for coordination of the in situ component of the Copernicus Programme Services

Lot 1 In situ - Observations
State of Play Report

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EXECUTIVE SUMMARY

Society demands many products and services from the Copernicus Services, but may not connect their needs to the in situ observations required to deliver these products. These societal needs are translated into requirements for observations, data management and flow, as well as synthesis and analysis finally ending up in useful fit-for–purpose products and services for the user. The value chain ranging from observations to products and services delivered to the end user is long and complex and far from transparent to the user, whose involvement is often restricted to a dialogue with the service provider with direct focus on the required products and services. In the justification process for a suitable in situ observing system to meet a downstream user requirement, there is an important task to visualise to the users the entire production chain required to produce the needed information to the required resolution and quality. Thereby this better understanding of the value chain opens up more sophisticated dialogue between user and service provider on design of product and services.

In situ data is the basis for our understanding the physical, biogeochemical and biological processes on Earth and they are a vital input to the Copernicus Services for product generation, calibration and validation. It is therefore vital to map the requirement (resolution in space and time, quality, timeliness) for in situ data and compare it to the existing observation system to find gaps. At the same time, a tightening fiscal environment requires that the design of a future observation system shall be optimised – efficient, cost-effective. This optimisation is made more difficult by the fact that the observing system cannot be designed from scratch, but has to be integrated from a collection of disparate observing programs, each with different goals, methods, and governance. As a result, much of the work in designing an integrated observing system addressing Copernicus' needs involves ensuring that these existing programs can be integrated coherently into a holistic system that is fit-for-purpose. That is, there needs to be a clear set of standards for components of the observing system, as well as careful consideration of the societal benefits that need to be addressed.

In the preparation of the present "State of Play" report all Copernicus Services have been interviewed to map:

- Present use of in situ data;
- Requirements (resolution, quality, timeliness, formats);
- Identified gaps;
- Data availability.

Analysis of this information has subsequently led to the following overall conclusions:

- The six services operate at differing levels of maturity, some established over many years and well linked to utilisation of relevant observational in situ data and with a good understanding of their own requirements, data gaps and issues. Others may have little awareness of what observational data could be available to them and how they could go about accessing and incorporating this into their products and services;
- There is a general need for a detailed requirement mapping process across the Copernicus Services in order to perform a comprehensive gap analysis and subsequent optimal observation system design. The results shall be entered into the Copernicus In Situ Information System (CIS[2]) under development at the EEA;

- Large parts of the existing in situ observation network are funded by time limited research funds and parts of the remaining system are under pressure due to financial restrictions, instrument degradation etc. It is therefore recommended that an analysis of the sustainability of the existing observation system is carried out;
- As entrusted entity, the EEA should work with member states (at political level) to consolidate and sustain their contribution to the in situ component of Copernicus;
- As soon as possible the evolution of the in situ observing system that is critical and necessary for Copernicus services should be implemented, both at member state and EU levels;
- The basis for an effective use of in situ data is through a real open and free data exchange, which is far from a reality today. There is therefore a need for addressing data policies and data exchange agreements to optimise the use of in situ data in Copernicus;
- Dialogue and cooperation between the individual Services could be improved or enhanced. It is therefore regarded essential to build closer relations between all the Copernicus services including the In Situ Coordination Team to develop awareness and cooperation among the services on in situ data;
- It would be beneficial for the Copernicus Services to liaise with existing H2020 Research project and Research Infrastructures to capitalise on their work and findings regarding in situ observations; but also, to ensure that Copernicus requirements are articulated and taken into account in planning and design on in situ observation systems utilised within the individual projects and infrastructures. For example, CMEMS partners already interact with ATLANTOS, INTAROS, ODYSSEA, JERICO-Next.

These conclusions will form the basis for the planning of activities within the In Situ Coordination Team over the second contract period.

SECTION ONE

1. INTRODUCTION

1.1 Purpose and audience

In situ data is an important input for Copernicus services' products generation, in particular through model initialisation and assimilation, calibration and validation. It is required to develop and improve processing algorithms, to align satellite-derived measurements with measurements of known accuracy, to provide corrections, and to confirm that the final products meet the service requirements and user needs. A lack of in situ data in each of these processes can cause products to be poorly characterised and inconsistent, causing accuracy to vary greatly between areas where extensive in situ data exists and where it is limited. This variation in uncertainty can be difficult to convey to the users of the products

The present report represents the first attempt to provide a coherent overview of the status of the Copernicus In-situ component and future perspectives and challenges. Results of analysis of the main in situ data sources required for the delivery of the Copernicus Services is presented. The report will describe the current situation on a service by service basis, present the main cross-cutting issues (gaps, risk and challenges) and outline the expected evolution of the Copernicus services' requirements.

The primary audiences of the report are Copernicus stakeholders in the Member States (for example, via the Copernicus Committee and the Copernicus User Forum) and the European Commission.

1.2 The coordinating role of the EEA

The European Environment Agency (EEA) has been entrusted with the coordination of the Copernicus In Situ Component, under a Delegation Agreement signed in December 2014 with the European Commission. The EEA's mandate includes monitoring the state of play of Copernicus in situ data, the operational provision of cross-cutting in situ data, managing partnerships with data providers, and supporting the European Commission, Copernicus Service Providers and the Entrusted Entities in overcoming challenges associated with accessing in situ data.

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1.3 Methodology applied

The methodology for analysing in situ data requirements of the Copernicus Services (CS) is based on a 5-step approach:

- **Step 1: Building the baseline:** the baseline of in situ data currently used or required by the Copernicus services is developed based on preliminary desk research and taking advantage of existing knowledge and experience.
- **Step 2: Validating the baseline:** the baseline is validated (and, if necessary, adjusted) through a direct interaction with the Entrusted Entities of the Copernicus Services.
- **Step 3: Assessing the gaps:** the validated baseline will be used to identify in situ data requirements gaps, characterise them and place them in order of priority.
- **Step 4: Proposing actionable recommendations:** understanding and analysis of identified gaps and cross cutting in situ data requirements will allow the definition of actionable recommendations to improve in situ data access/quality on the most relevant items.

- **Step 5: Monitoring in situ data evolution:** the availability of in situ datasets will be monitored, with a view to updating the gap analysis and the requirements database based on the latest releases of relevant datasets and progress in arrangements with data providers and other stakeholders.

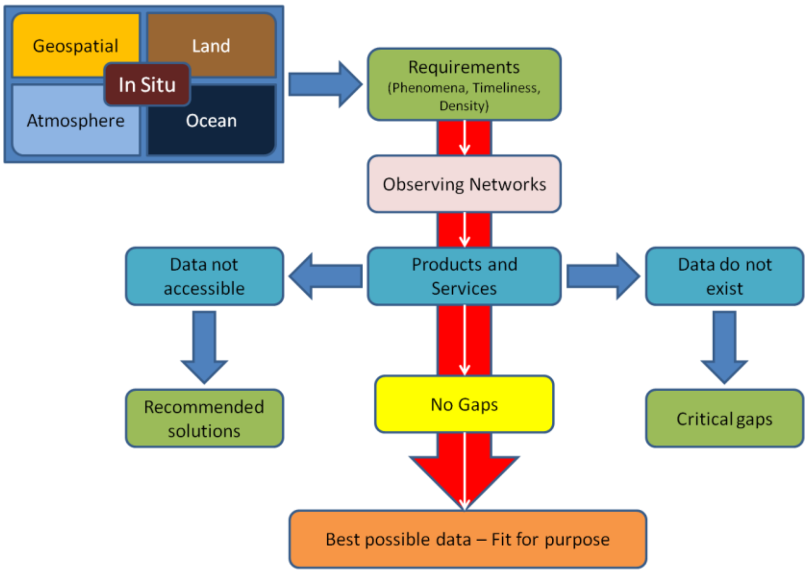

Figure 1: Overarching gap analysis methodology

Extensive research supplemented with interviews with the Copernicus Services and the outcomes of workshops has been analysed and assessed within the first step of the approach. The Fact Sheets produced within this contract provide an overview of the main in situ data sources used within each service component for the delivery of the Copernicus Services, constituting an extract and summary of the information comprising the baseline for this study.

A series of interviews has been carried out with the Entrusted Entities of the Copernicus Services. The interviews served both to validate the baseline information and to finalise the Fact Sheets. Additional information relevant to the main cross-cutting issues, gaps and challenges has also been collected with the support of the Services.

2. Cross Cutting Issues - Atmosphere, Land and Ocean Observations

Meteorological, hydrological and oceanographic in situ observations have relevance across the Copernicus Services, whilst those of atmospheric composition hold key relevance to CAMS and C3S. Collectively these provide historic baselines, essential data for model assimilation, current situational awareness and a baseline for the prediction of air quality. Access to the best and most relevant in situ observations data is essential to support the operational provision of many products provided by the Copernicus Services.

Air quality observations data are arranged well through EIONET, but the network density differs strongly per country. Other key observational data sources are the research infrastructures and WMO GAW, which have a strong focus on very high quality regional data, although traditionally with a long delay between measurements and data publication. Data from research infrastructures is usually available for free with open access, but requires attribution of the data use in derived products by proper citation.

Much in situ land and some atmospheric observational data is owned by national meteorological and hydrological services, which are generally well organised with robust operational data networks, however this data in total is not always shared outside of an owning nation. Other important land observational data sources include scientific or research organisations and industry including energy, water management and agriculture, whose data may be treated as nationally or commercially sensitive information which may not always be shared openly.

Several Copernicus Services - CMEMS, C3S, CSS - have a need for ocean in situ data. It is, therefore an important task for the EEA, in close cooperation with the mentioned services, to map their requirements for ocean data in more detail. After defining the requirements for sustained ocean observations, a set of relevant phenomena and Essential Variables, considering the regional context, will emerge. The phenomena assist in determining time and space scales over which the observing is to be executed. The phenomena also narrow down the Essential Variables that belong to the observing objective. From the combination of phenomena and Essential Variables the set of “Fit-for Purpose” observing platforms and sensors emerge.

The individual Copernicus Services may have different requirements for ocean observations; but the general approach in design of ocean observations systems is to establish cross-cutting multipurpose observations to obtain maximum benefit from investments. It is therefore crucial to find a common agreement on these requirements. Some guidelines on requirements of operational services and climate can be found in the WMO OSCAR Requirements database and in the GCOS 2016 Implementation Plan. In addition, CMEMS regularly updates the service requirements for the in-situ system, driven by evolving user needs. Several ongoing H2020 projects – AtlantOS, INTAROS, Odyssea, JERICO-NEXT etc – will contribute to a clarification of required resolution in time and space and an important tool in this context is Observing System Simulation Experiments (OSSE).

When this analysis has been accomplished a detailed gap analysis can be carried out. Observations are fundamental to advancing scientific understanding and delivering the vetted, timely, and purposeful information needed to support decision making in many sectors. Observations and monitoring are key elements of the emerging global framework for environmental services and more generally support research, the assessment of changes, and the development of policy responses. For these purposes, observational datasets in general need to be traceable to quality standards, be readily interpretable and freely available, and cover sufficiently long periods.

An Essential Variable (EV) is a physical, chemical, or biological variable or a group of linked variables that critically contributes to the characterization of earth's environment. EV datasets provide the empirical evidence needed to understand and predict the evolution of environment, to guide mitigation and adaptation measures, to assess risks and enable attribution of events to underlying causes, and to underpin environmental services. The EVs must not be understood as a selected group of stand-alone variables; they are part of a wider concept – EVs are identified based on the following criteria:

- Relevance: The variable is critical for characterizing the system and its changes.
- Feasibility: Observing or deriving the variable on a global scale is technically feasible using proven, scientifically understood methods.
- Cost effectiveness: Generating and archiving data on the variable is affordable, mainly relying on coordinated observing systems using proven technology, taking advantage where possible of historical datasets.

To make practical use of the EVs, guidance and best practices are needed to enable and support the generation of high-quality, traceable EV data records. The EV concept accommodates mixed or changing observing system technologies and is therefore conducive to meeting user needs for information over the long term. The EV concept in general, related definitions, and methodological framework is highly relevant for Copernicus and will be used across the Copernicus Services in connection with the analysis, description and categorisation of their in situ data requirements and gaps.

The relevant thematic EVs' that will be applied in his context and the overlap between them are illustrated in Figure 2.

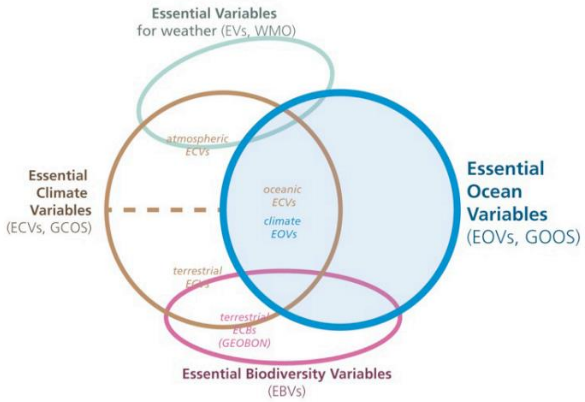

Figure 2: Link between Essential Variables defined by the WMO for weather forecasting, Essential Climate Variables defined by GCOS, Essential Biodiversity Variables defined by GEOBON and Essential Ocean Variables defined by GOOS.

An overarching analysis of prioritised cross cutting issues that constrict access to necessary meteorological, hydrological, air quality and oceanographic observations across the Copernicus Services is set out in *Table 1*. The table categorises identified in situ data issues for each of the Copernicus Services relating to thematic data types (atmosphere, meteorology and hydrology, ocean) which are relevant or needed in their service production, with the most important factors to individual services indicated by red crosses. The categories relate to the following questions put forward to the Copernicus Services:

- Data gaps – are missing data in space and time compromising the quality of produced services?
- Quality – are poor data quality a detriment to the Services?
- Space and time coverage – are time and space resolution not meeting the needs for service production?
- Timeliness – are there requirements for data availability that are not met (real time or delayed mode)?
- Accessibility – are there requirements for access to data that exists but is currently unavailable?
- Sustainability – are there concerns about the long term availability of data or maintenance of data sources (sensors or networks)?
- Future requirements - are future data requirements identified including new data types?

CROSS CUTTING ISSUES ANALYSIS		Data Gaps (missing data)	Quality of data	Space/Time coverage	Timeliness	Data policy and accessibility	Sustainability	Future requirements/ needs
ATMOSPHERE - Observations								
CAMS		**X**	x	**X**	x	x	**X**	x
CMEMS								
CLMS	Local & pan European							
	Global							
C3S		**X**	x	**X**	x	x	**X**	**X**
CEMS	MAPPING							
	EARLY WARNING							x
CSS	SEA (SatCen)							
	Border Surveillance (FRONTEX)							
	Marine Surveillance (EMSA)							
METEOROLOGY AND HYDROLOGY - Observations								
CAMS		x		x	x		x	
CMEMS					x	**X**	x	
CLMS	Local & pan European							x
	Global							x
C3S		**X**	x	**X**	x	**X**	x	**X**
CEMS	MAPPING							
	EARLY WARNING	**X**	x	**X**	**X**	**X**		x
CSS	SEA (SatCen)							x
	Border Surveillance (FRONTEX)			x		x		x
	Marine Surveillance (EMSA)							
OCEAN - Observations								
CAMS								
CMEMS		**X**	**X**	**X**	**X**	**X**	**X**	**X**
CLMS	Local & pan European							x
	Global							
C3S		**X**	x	**X**	x	**X**	**X**	x
CEMS	MAPPING							
	EARLY WARNING							x
CSS	SEA (SatCen)	x		x		x		x
	Border Surveillance (FRONTEX)	x		x		x		x
	Marine Surveillance (EMSA)	**X**	x	**X**	x	**X**	**X**	x

Table 1: Top level analysis of cross cutting issues – In Situ Observations
(Red X's represent the highest priority to each service).

The following paragraphs 2.1 to 2.6 aim to give an overview of the present status regarding the use of observational in situ data by the Copernicus Services with focus on cross-cutting issues between the services. This analysis reflecting the categories defined in table 1:

- Data gaps
- Quality of data
- Space/time coverage
- Timeliness
- Data policy and accessibility
- Sustainability

Future requirements are addressed in Chapter 3

2.1 Data Gaps (missing data)

A detailed gap analysis has to be carried out relative to requirements defined by the individual Copernicus services. Independent of the Service, the gap can be identified in the observing network itself or in the use of the data for product generation. Only when based on the requirements and the work flow leading up to an observing product, can it be possible to determine where a gap is and how to close it.

Gaps can be divided into four categories:

1. **Gaps in the observing Networks**
   - Spatial coverage by in situ observing is insufficient when considering the phenomena
   - Gaps in baseline data
   - There are gaps in observing infrastructure to allow for (near) real-time data transmission
   - Lack of standardization and best practise for certain observing networks or certain variables
2. **Gaps in data availability (free and open exchange)**
   - Some data originators have strict data policies and are unable to share
   - Data collected by Naval/Military is often not made publicly available
   - Data collected in the context of research & development is held back in order to publish results before sharing
   - In some institutes data are sold and hence they are not willing to freely share data as that would compromise a part of their income stream
   - Data collected in the context of research & development is held back because of concerns about "incorrect" interpretation of [environmental] data.
3. **Sustainability gaps**
   - There is a lack of sustained funding for observations in general
   - Observing networks lack sustained funding for coordination or management of the network (staff, travel)
   - In-situ observations are based on infrastructures, mainly supported by national agencies and the number of observation sites or platforms may decrease due to:
     - Ageing of instruments/networks
     - Changes in scientific goals and priorities
     - Funding opportunities decreasing
     - Environmental effects (climate change, harsh environment)
4. **Gaps in technology**
   - New technology and sensors are required

- Technological development is required to close gaps in (near) real-time data transmission (for example surface buoy, automatic system from vessels).

These gap categories were explored during the analysis and interview process with the individual services that has informed this report. It is anticipated that attention to these categories and sub-sets will help to refine the broad areas where cross-cutting issues have been identified, to identify specific targeted courses of action based on the recommendations presented in chapter 3.

With respect to the atmosphere, missing data or specific data types that are not available for certain areas is a cross cutting issue affecting the CAMS and C3S services. This particularly concerns air quality, aerosol speciation and ozone measurements.

ICOS and ACTRIS are expanding their networks to more and more countries, also outside the EU28, IAGOS is expanding the number or airlines and equipped planes for improved spatial coverage but all these processes require political and logistical support.

The feedback from the CAMS service pointed at the following essential improvements:

- For air pollution there are only very few observations available in some EU28 countries and in most countries the density of the observations could be improved.
- The TCCON network forms a unique bridge between satellite remote sensing and the in situ network observations for both reactive gases and greenhouse gases. These valuable observations currently lack sustainable funding where even expansion would be desirable. TCCON is not yet (part of) an operational research infrastructure.
- For air pollution, especially chemical speciation and vertical profiles of aerosol are lacking in all countries. Data on $PM_{2.5}$ is still relatively scarce and it spatial coverage should be improved.

With respect to the ocean in-situ observing system, data access and data processing/dissemination issues are today well handled through CMEMS in-situ TAC and cooperation with EMODnet and SeaDataNet. Main issue/concern is the upstream in situ infrastructure, since there is a lack of sustained funding for ocean observations in general. Sustaining the Argo global array, consolidating its regional components (in particular in European Seas) and implementing its major extensions (BioGeoChemical Argo and Deep Argo) are strong priorities to CMEMS. Improving ROOSes (Regional Ocean Observing Systems) and key observing systems such as FerryBoxes, gliders, tide gauges and HF Radars are also strong priorities for regional CMEMS products.

Meteorological and hydrological data gaps are a cross cutting issue primarily affecting the CAMS, C3S and CEMS services. Where there is commonality of these, key issues relate to data not being collected or coordinated at a national level, this being a common issue with hydrological data where sub-national organisations often hold key data sets, in addition not all good data is archived, as is the case with potentially valuable automatic weather station data, which is not archived by WMO. If these issues are not addressed then large, sometimes national or regional data gaps will persist. This will significantly degrade the capacity of the Copernicus services to understand, model and react to real time events such as flooding or air pollution events in these areas. Gaps in the data also influence the background information (a priori) in the models which can have a big impact on the quality of model outputs.

The Copernicus services' capability to detect and understand the longer timescale impacts and effects of an evolving climate will similarly be constricted, with implications for well informed and robust policy decisions.

2.2 Quality of data

The variability of appropriate metadata to contextualise in situ data has been identified as a cross cutting issue, in that this varies in formats and definitions across different data types, nations and regions. A number of the Copernicus Services have indicated that international standardisation or harmonisation is required to ensure that data is appropriately understood and contextualised across the Services. This is an issue that restricts the effective use of some data and leads to products and services having a reduced level of confidence and assurance.

Within the European Union the directive, Infrastructure for Spatial Information in the European Community (INSPIRE) is currently being implemented. This addresses spatial data themes for environmental applications and includes legislation regarding the harmonisation of metadata describing environmental observational data. Adoption of this is not complete, with adherence to this being inconsistent across the member nations at present, however over time this should lead to improvement in commonality of metadata standards and practices across the EU.

In the case of atmospheric composition and meteorological observations the metadata issue is handled on the global scale by WMO GAW and the WIGOS system. For meteorological observations this system is well developed and followed by the data providers, but for atmospheric composition the system is still under development and adherence to the system needs to be improved.

Within the framework of WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), IODE has been cooperating with WMO on the agreement on standards (OceanDataStandards project). The scope of this project was expanded by IODE in 2013 when it established the "Ocean Data Standards and Best Practices" project which also disseminate and promote "best practices" in addition to "standards". The CMEMS In-Situ Thematic Assembly Center (INS TAC) makes a considerable effort implementing these practices.

2.3 Space/Time coverage

Whilst many of the Services have indicated that greater density of observations would be generally beneficial, variance in spatial or time coverage of in situ land and atmospheric observations is an issue that collectively cuts across the CAMS, C3S, CEMS and CSS services. The key factor being that data coverage often jumps at national land borders, which can relate to a step change in the actual density or reporting frequency of observations, or alternatively be due to data accessibility and data policy issues. These issues can result in inconsistency within products that span nations and potentially introduce errors where the step changes are not understood by users. For example, resolution and confidence in a product may be assumed to be consistent across borders, where this may not be actually the case, resulting in poor decisions being made because based upon false assumptions.

There are few clear recommendations or internationally agreed requirements for time and space resolution of observations, but it is an important component of the process of defining requirements for observations. The starting point in this process (as described above) is to define the important phenomena to observe which will lead to a process of investigating which essential variables (for example ECV's and EOV's) to observe and the appropriate resolution in time and space in order to resolve and describe this phenomenon properly. An important component of this process is also to identify possible "Hot Spot" – areas that needs particularly high spatial or temporal resolution of observations. The individual Copernicus Services may have different requirements for time and space resolution of observations from different domains, for example the climate service will generally require data at coarser resolution than the operational services, where high local accuracy can be required to inform operations such as search and rescue.

2.4 Timeliness

In many instances, it is necessary to receive observational data within a specified timeframe for this to be utilised to provide value to Copernicus products and services. A shortfall of timely data has been raised as a cross cutting issue, although the criteria for this can vary significantly across the services. Timeliness ranges from real-time to delayed mode of up to several months depending on the use of data. The delayed mode data normally has undergone a detailed quality control procedure while real-time data is often raw data with basic automatic quality control. For example, CAMS require air pollution data within hours and greenhouse gas data within days, whilst C3S requires access to some data where a year's delay can be acceptable. By contrast, CEMS and CMEMS require access to 'real time' meteorological, hydrological and ocean observations in order to support early warning and the efficient application of emergency management processes.

A lack of timely data can result in loss of current situational awareness which in the case of emergency management can lead to poor information resulting in inefficient use of resources and ultimately introduce the potential for unnecessary risks to safety and health. With respect to longer timescales, a lack of timely data will weaken the confidence and resilience of judgements made, especially those based on model predictions where these are lacking the necessary rigour brought to bear through incorporation of appropriate data and validation.

2.5 Data policy and accessibility

Limited access to data due to the lack of proper licensing between the Copernicus services and the data owner or provider has been raised by a number of the services. This is the greatest cross cutting issue that degrades access to meteorological, hydrological and oceanographic observations, affecting observations from national organisations, from industry and from the scientific research community. This affects access to real time or near real time relevant observations alongside access to historic data time series and can result in data steps and therefore introduce inconsistency and potential errors when crossing national boundaries.

Data exchange in the marine community is guided by a very general data policy approved by the members of the Intergovernmental Oceanographic Commission (IOC) under UNESCO (see Appendix C). Within the five EuroGOOS Regional Operational Oceanography Systems (ROOSes) two of them have established a "Data Exchange Agreement" which is more specific than the IOC Data Policy. Both are however outdated and need a review and update. Several of the ocean observing research projects, e.g. FixO$_3$, JERICO NEXT, AtlantOS and INTAROS have established their own specific Data Policy; but it only applies to the project partners and for the limited period of the project duration.

The CMEMS INS TAC assembles data from the Regional Systems (ROOSes) of EuroGOOS. In some cases, this data sharing is guided through Data Exchange Agreements while in other cases agreements are not in place. Data are also exchanged with EMODnet , and SeaDataNet (delayed mode, high quality data), strengthening the cross-cutting use of the ocean data within Copernicus.

For observations of atmospheric composition, this issue is of much lower prominence as access to research infrastructure data is usually readily available. There are however issues with the contribution of sufficient data to EIONET from some European states, whilst the use of data from the WMO GAW networks outside of European research infrastructures requires permissions from each individual Principal Investigator.

Without proper access to the necessary data to produce robust and consistent products informed by the best possible resolution of data, the quality and reliability of products will be degraded and sub-optimal products and advice will be produced leading to poor decisions being made .

2.6 Sustainability

There are sustainability issues across many networks within Europe and globally, even those that are operated by national institutions or networks such as EIONET or the EUMETNET Observation Programmes, as these can be affected by the political will of any host nation. However, the greatest sustainability issues affect those observations provided through research infrastructures and international networks or collaboration, without dedicated funding streams or with time limited funding.

In the case of marine observations, in situ data is available to any Copernicus Service through a combination of national data sets (climate, environment, operational, research), international networks e.g. Argo, SOT, DBCP, GO-SHIP, GOSUD and through research infrastructures.

Most national marine institutes and data providers are typically funded on a year-to-year basis having to make an explicit case for in situ data collection annually. Strong commitments exist at national level in most cases to continue this data collection subject to the caveat above. The most severe risks to the marine in-situ observing system are related to sustainability:

- There is a lack of sustained funding for ocean observations in general, about 70% of data in the GOOS is funded by time-limited research projects.
- Observing networks suffer sustained funding for coordination/management of the network (staff, travel).
- In-situ ocean observations are based on infrastructures, mainly supported by national agencies and the number of observation sites/platforms decrease due to:
  - Ageing of instruments/networks
  - Changes in scientific goals and priorities
  - Funding opportunities decreasing
  - Environmental effects (climate change, harsh environment)

A recent example of sustainability of the tide gauge networks in Europe (a fundamental parameter for CMEMS, C3S and CSS), is presented in the figure below (credit: EuroGOOS Tide Gauge Task Team 2017). The tide gauge stations are colour coded based on the extent to which the stations are sustainably funded (see legend).

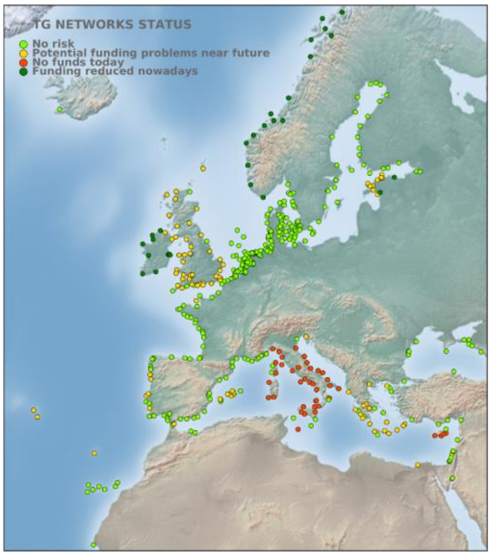

Figure 3: Status of European tide gauge network. Colours indicate whether platforms are at risk of decreased funding in the near future (see map legend)

Research Infrastructures often have a long term horizon of 20 years or more, however the actual commitment period and funding security of these is usually limited to 5 years or less. Networks are usually supported at the national level and vulnerable over time to decisions made in host nations as to which research infrastructures they support or not, potentially leading to large areas with spatial or temporal gaps in observations.

Networks that aren't maintained and sustained through assured commitment and investment, will eventually deliver poor quality data or decline to leave data gaps in networks. This leads to the degradation of the quality and reliability of a product which may be gradual over time and undetected by users. Ultimately a poor decision could lead to a significant incident occurring, where the decisions are based on products that are informed by low quality or insufficient observational data.

3. FUTURE REQUIREMENTS/NEEDS - THE WAY FORWARD AND RECOMMENDATIONS

Some of the Copernicus Services currently use little or no in situ observational data. This may be appropriate in some cases, where these data may deliver no or negligible additional value to their portfolio of services. It is however, clear from interviews that some of the Copernicus Service components have limited knowledge of what in situ data is effectively available or could be utilised to add value to their portfolios of services, this is more the case especially for those Services whose outputs are less directly linked to atmospheric, hydrological or oceanographic conditions.

Most of the progress on weather and air quality predictions in recent years is, next to increased model resolution, due to the improved availability of observations. Further improvements are possible and needed but at the expense of more and better observations. Research Infrastructures, EEA and Copernicus Services should jointly promote awareness of the indispensability of observations for the products. This is possibly best carried out with initial workshops with the Service Operators and also DG GROW to foster a mutual understanding of the availability and potential benefits of in situ data to all of the Copernicus Services. This idea has also arisen during interviews with the Copernicus Service Operators, for instance at an interview with the SEA component of the Security Service.

It is clear that we need to build stronger relationships with the individual Service Operators and also with DG GROW. Therefore, following on from the above workshop, it is recommended that further work be undertaken to liaise closely and iteratively with the Copernicus Service Operators to develop awareness of in situ data relevant to their specific services, where a need for this is identified. This could potentially be carried out through provision of expert face to face advice, to assist identification of appropriate data and clarify the ways and means to access and incorporate this into services to realise greatest value. To deliver this aspect and also to support the Service Operators going forward, there needs to be clearly identified Points of Contact on both sides. This will ensure that the Service Operators can be supported properly as far as their needs and requirements for in situ data.

3.1 General requirements/needs

Atmosphere

The in situ observations of atmospheric composition required for Copernicus Services cannot be seen separate from the global perspective. The World Meteorological Organisation's program Global Atmosphere Watch (WMO GAW) coordinates worldwide the observations of air composition, be it that the focus of the in situ observations is largely at background and regional representative locations. Air pollution in densely populated regions and thus strong signals from fossil fuel burning and other human activities are to this day missing from the network. WMO GAW recently upgraded its Implementation Plan for the period 2016-2023, and is now also targeted to support services in urban and populated areas.

The new WMO GAW Implementation Plan (IP) builds upon the growing importance of atmospheric composition observations and predictions and focuses on research related to atmospheric composition. New GAW-lead thematic application areas will help reduce societal risks from climate change, high-impact weather and events and urban air pollution and will support conventions and treaties focused on sustainable development.

Particular contributions of GAW include the improvement of forecasting capability for air quality in support of disaster risk reduction as well as sustained long-term global observations of the major climate change drivers. A new addition is the development of the Integrated Global Greenhouse Gas Information System (IG^3IS) that will be useful for greenhouse gas emission negotiations in support of the UNFCCC and the Global Framework for Climate Services (GFCS), GCOS, and the Montreal protocol. GAW coordinated observations also contribute to the implementation of the WMO Integrated Global Observing System (WIGOS) and CLRTAP.

More attention will be given to providing near real time data in support of forecasting services. GAW also supports the enhancement of aviation meteorological services through research of atmospheric aerosol dispersion. It also promotes research related to Polar and high-altitude mountain regions through analysis of the impact of atmospheric composition on air quality and snow albedo in relevant areas.

In Europe the research infrastructures ICOS, ACTRIS and IAGOS contribute to the GAW observations and these partners play important roles in the IG^3IS system. WMO GAW provides the calibration centres for all important measurements and also provides the measurement best practice guidelines and global data portals that curate the data. The communities involved in the mentioned research infrastructures play important roles in these GAW tasks.

It is therefore of utmost importance that these roles are sustained as this will ensure the proper connection between the observations used in Copernicus and the developing global network, including the links to the remote sensing through GCOS. Important in this respect is also GEO, the Global Earth Observation program that collects metadata of all types of earth observations in the GEOSS (GEO system of systems).

In the case of local air pollution data, the situation is arranged under EIONET. The current action plan 2017 includes support to greenhouse gases; clearly this would require close coordination with the Greenhouse Gas Research infrastructures and WMO.

Meteorology and Hydrology

It is anticipated that a new data policy and access agreement between EUMETNET and the EEA (currently being defined) will largely satisfy the stated future in situ meteorological and hydrological observational requirements of the Copernicus services. It is recommended that the future requirements captured through interview with each service are set out within the Annex of this agreement to ensure that these can be made available and accessed when required. Any needs for further data that fall outside of this agreement should then be addressed individually.

The WMO are currently engaged in a process of establishing global data processing and forecasting systems for hydrology which, when operational, may play a significant role in enabling access to global hydrological data to enhance current products and inform the development of future products provided by the Copernicus services. It is recommended that engagement with this process is initiated in order to articulate cross cutting requirements and leverage maximum benefit for the Copernicus Services.

Ocean

The Copernicus Marine Service (CMEMS) has well established links to data providers via the In Situ Thematic Assembly Centre (INSTAC). The ocean data made available via the CMEMS data portal can support the requirements for ocean data from other Copernicus services primarily C3S and CSS and possibly also the atmospheric service. Examples of Ocean data available in CMEMS In situ portal is given in section 4.2.

There may be some merit in establishing a forum that brings funders, operators and users of in situ data together at a European level. This has been suggested through the European Ocean Observing System (EOOS) initiative promoted by EuroGOOS and European Marine Board and could be explored further as a contribution to all Copernicus services relying on marine data.

Additionally, new objectives for the future observing system requires new sampling strategies (time/space/sensor) and continuous development of new more sophisticated instruments. This is especially true for biogeochemical and biological observation technology that needs substantial support for technological development to occur – several H2020 funded projects do however have focus on developing and maturing required new technology.

General

It is recommended that continued liaison between the Copernicus Services and nominated thematic expert points of contact should be maintained from here on; in most cases this should be one of those who conducted the interview which each service. If this is not possible, then a point of contact should be agreed and contact be initiated between them and the service they support. Through this continuity of liaison activity, new or evolving needs from each of the Copernicus Services should be anticipated and where possible, built into policy and data agreements thereby ensuring that the most appropriate data is readily available to support new products or services. The point of contact should also be active in making their nominated service aware of data types and sources relevant and potentially useful to their service.

3.2 Data Gaps (missing data), Space/Time coverage and Timeliness

Although this is not an absolute requirement, in general the density of all observations should be improved - even in Europe - but especially in the regions surrounding Europe, as this would improve the accuracy and uncertainty of the products. The data assimilation techniques deployed at CAMS and CMEMS may be used to demonstrate where the observational network reduces uncertainties most and where more observations would improve the prediction skill. Some exploratory studies could be performed to indicate where expansion of which networks would provide greatest value. The outcome should be, together with the other factors that influence the network and Research Infrastructure developments, important guides for development of the networks and research infrastructures.

Atmosphere

Using the existing network of air pollution networks and research infrastructures the Copernicus Services have already implemented useful services and can develop more. Although the operation of the networks and modifications or extensions clearly fall beyond the scope of Copernicus, future product developments or improvement might have a big impact on requirements and thus would impact on the desired network density, coverage, quality of the measurements and/or require additional parameters. We therefore recommend that network design studies are performed to evaluate the benefits of increased network density, overall or in specific under-sampled regions or areas important for background conditions, and new parameters for model development and reduction of uncertainties of model predictions.

Timeliness of data has improved a lot in recent years but for data from the research infrastructures ICOS and ACTRIS improvements of the operational delivery of NRT data is required. A process to enable this has already been started, through which access to the data will also be improved.

Meteorology and Hydrology

The cross cutting issues set out associated with access to relevant global and European data at relevant resolution and frequency in a timely manner could potentially be addressed to some extent through the WMO playing a facilitating role for the Copernicus Services.

It is recommended that engagement take place with EUMETNET and the WMO (with EUMETNET potentially acting as a broker), in order to raise awareness of the issues and data gaps that the Copernicus Services face. A good means to capture and articulate requirements and gaps for meteorological and hydrological observational data would be through the WMO OSCAR Surface database and it may be feasible and advantageous to create a Copernicus specific area within this.

Direct engagement (for example at meetings or assemblies) could further raise the profile of these issues and it may be possible through coordination and sponsorship of particular targeted WMO programmes such as the Global Atmospheric Watch (GAW), to shape the development of observation data and networks to specifically satisfy the needs of the Copernicus Services vis à vis data type, spatial resolution, frequency of reporting and timeliness of data collation and dissemination.

Ocean

In-situ ocean observations are mandatory for CMEMS but also critical for C3S and CSS. Main source of concern at the moment is the lack of an adequate network of biogeochemical and deep (> 2000 m) measurements.

Internationally, sustained ocean observation is coordinated through the UNESCO-IOC Global Ocean Observing System (GOOS) as well as the Global Climate Observing System (GCOS). The current ocean observing system remains fragmented especially for in situ observations. In addition, several of the networks and individual contributions are not well resourced and lack long term funding perspectives. There is therefore a strong rationale to advance the current system components towards a more sustainable, better-coordinated and more comprehensive ocean observing system to jointly deliver integrated ocean information to assess current trends and predict future scenarios.

The importance of ocean observations has recently attracted great attention especially after the G7 Minister’s statements of June 2016. In Europe, several programs and projects focus on design and implementation of effective ocean observing capacities, improving their efficiency and their timely and high-quality information delivery for climate, health of the ocean, operational services, security and science. It is recommended that Copernicus actively engage in a dialog with the individual projects consortia to secure that requirements from the Copernicus Services are taken into account in the planning and design of observations systems.

Up to 2030, Europe is building an end-to-end, integrated and sustained European Ocean Observing System (EOOS)[1] under the leadership of EuroGOOS and European Marine Board, which *is a coordinating framework designed to:*

- ***align*** *and* ***integrate*** *Europe's ocean observing capacity;*
- ***promote*** *a systematic and collaborative approach to collecting information on the state and variability of our seas;*
- ***underpin sustainable management*** *of the marine environment and its resources*

EOOS will need to perform an extensive network assessment and optimization. It is foreseen that the main stream of such studies will have to use "simulated observations". Therefore, it is important to develop an efficient "EOOS Simulator" which can easily conduct various kinds of OSSEs. The future EOOS assessment and optimal design framework can be built up by using the "EOOS Simulator". Considering that OSSEs are more or less model dependent, a multi-model approach will be needed.

3.3 Quality of data

Across the EU INSPIRE will increasingly be fundamental to the harmonisation of metadata associated with all environmental in situ data, whilst WMO GAW plays a key role in the global standardisation of metadata associated with atmospheric composition observations from research infrastructures. Out of these there is potential for a common approach to be extended to the national networks of air pollution in EIONET, where improvement of measurement metadata on data quality is required.

Alongside this, the WMO could potentially assist more widely with the harmonisation and standardisation of metadata associated with meteorological, hydrological and atmospheric observations. This could benefit CAMS, C3S, CLMS and other services where there is a remit beyond the boundaries of Europe or where incorporation of accurate observational data beyond the European domain would help improve the quality of products for Europe. It is recommended that this be investigated, together with the potential benefit of utilising EUMETNET to help broker this. This could help define benchmarks which could be applied more broadly and championed for adoption by operators of research infrastructure and private industry observations leveraged and supported by the Copernicus Services and EEA.

Considerable work on data quality has been conducted by the marine community. The EuroGOOS working group on Data Management and Quality (DATA-MEQ) has coordinated work on data quality across CMEMS INSTAC, EMODnet and SeaDataNet (http://eurogoos.eu/data-management-exchange-quality-working-group-data-meq/). As part of the ongoing AtlantOS project, partners have produced a deliverable entitled "Recommendations for an automatic RT or NRT QC for selected EOVs (T&S, Current, Oxygen, Chl-a, Nitrate, Carbon, Sea level)" (https://www.atlantos-h2020.eu/download/7.2-QC-Report.pdf)

It is recommended that Copernicus play an active role in the definition of quality requirements for ocean data to meet the needs of the Copernicus Services.

[1] http://www.eoos-ocean.eu/download/promotional_materials/EOOS_ConsultationDocument_02.12.2016.pdf

3.4 Data policy and accessibility

Atmosphere

The relevant research infrastructures (ACTRIS, IAGOS, ICOS, Euro-Argo, EMSO etc) follow a free and open access data policy that allows the Copernicus Services to use their data under the conditions of proper attribution. All these infrastructures already have or are working together with the Copernicus Services on the operational data stream. In the case of ICOS for example, the data licence is CC4BY (Creative Commons Open Data License with attribution) which even allows data redistribution. However, ICOS remains the owner of the data and in all products in which the data was used, the licence information should be transferred and attribution should be made to ICOS. This mechanism is not implemented in Copernicus yet and will be required before ICOS data can be used. It must however be stressed that this mechanism will be almost impossible to implement in practice. It is therefore recommended to work on finding a better solution that clearly emphasises the role of the in-situ data without blocking its use because it is impossible to fulfil the data licence requirement.

For the TCCON an operational data-stream is yet to be established, because this network is not part of an operational research infrastructure. As this information is essential for calibration and validation of satellite products of atmospheric composition we recommend that steps are taken to integrate TCCON into relevant research infrastructures and develop its operational data streams.

For air pollution measurements, data access is guaranteed through EIONET. For information on observations from areas that fall outside this EIONET agreement and the European RIs the Copernicus Services will have to rely on WMO GAW observations. Use of these observations requires the permission of individual station investigators which can be a difficult process. A default more open license from WMO GAW would help to resolve this.

Meteorology and Hydrology

The six services and their sub-components currently access a range of observational in situ data from various sources and in some cases, utilise different means to access the same data.

It is recommended that common access agreements enabling assured access to in situ observational data are established across the Copernicus service elements and that actions are taken to ensure that all of the Copernicus Services understand how to apply these in order to realise benefits.

In recognition of the fact that in situ observations are a critical building block for the production of the Copernicus Services, the meteorological community in Europe, through their two European organisations, EUMETNET and ECOMET have agreed that all of the meteorological and hydrological products required for the production of the Copernicus Services that are owned by their members can be made freely available to the Copernicus Service Operators, with some restrictions on further redistribution and proper acknowledgement of ownership.

A data policy and access agreement is being negotiated between EUMETNET and the EEA, which should enable free access for the Copernicus Services to all member observations specified within this. The agreement, when finalised, will likely take the form of an overarching agreement regarding the principle of free sharing of observations, with a supplementary Annex reflecting the specifics and framework under which data will be made available. It is envisaged that this agreement will work significantly to mitigate the cross cutting issue described in 2.4, relating to meteorological and hydrological observations in regions where data owners are EUMETNET members and the desired data exists.

With respect to observations owned by industry or other non-government groups it is recommended that further specific research be conducted to investigate the potential to make these available to Copernicus, through approaches to key groups. For example, AGRHYMET, based in Niger and representing 13 west African nations, who own in situ networks who's precipitation data would be valuable to C3S in particular or energy companies both within and outside of Europe, who's data is not routinely shared, but could be of value to many of the Copernicus Services. An alternative approach however could be for the EEA to raise the importance of access to these observations with the EU Commission DG GROW in an effort to leverage policy directive. This could potentially take the form of enabling access to observations through clauses built into EU funded programmes such as the Global Climate Change Alliance or the Food Security Thematic Programme. In the case of the EU energy sector this could be through obligations to share specific observational data with the Copernicus Services. In return, the Copernicus Services could offer to provide access to enhanced products that would assist the energy companies (for example flood risk assessment tailored for transformer sites).

Ocean

The lack of a widely-approved policy for open and free exchange of ocean data means that national and/or institutional policies govern the data exchange in the marine community. The development over the past two decades has been towards a more open and free exchange of data; there are however still huge amounts of data that are not available to the Copernicus Services. It is therefore important to continue to trace data and negotiate with data owners to release their data for the benefit of society.

It is recommended to implement some strengthening of data exchange agreements within the ocean community to the benefit of all Copernicus Services needing ocean data. It could be a task of EuroGOOS to address this problem.

General

It is recommended that a mechanism be developed for the sharing of information on what environmental in situ data types and sources are available and utilised and in what context by all of the Copernicus Services. The proposed development of such an information system could provide a solution to this, provided an outcome would be a simple way of sharing this information (for example through a top level directory of data types, sources and products or services).

3.5 Sustainability

Data sources that lack a guaranteed long-term future due to resilience or funding uncertainty are a key cross cutting issue for the Copernicus Services.

CAMS already do some work to reference support and assist data providers on quality control and timely data delivery, and we recommend that this work be expanded, coordinated and collectively delivered across the Services. The EEA may be a suitable coordinator for this action so as to provide collective referenced support spanning the requirements of all of the Copernicus Services and help leverage funding based on the key cross cutting needs of the Copernicus Services or alternatively any high priority needs of a single Service. This mechanism could deliver good effect, particularly where seeking to develop robust cases to leverage financial support from the EU commission for cross cutting in situ observational provision.

The different networks for climate and operational monitoring in the Joint Commission for Oceanography and Marine Meteorology (JCOMM) operate independently; most of them are trying to monitor commitments by national funding agencies and programs towards their own networks. Some networks e.g. Argo, have a specific tally of anticipated deployments. Consequently, there are a range of confidences about these assessments with most commitments for the current year. There are no IOC or WMO resolutions to commit countries to maintaining networks at present.

The JCOMM Ocean Observing Report Card project has recently been initiated. This is targeting high level IOC and WMO members, conveying the role of ocean observations to address societal needs and the status of these networks. The status will likely be presented in terms of:

1) Implementation against a metric and trend over the past year;
2) International support (e.g. number of countries sponsoring) and trend over the past year.

It is important that Copernicus Services are linked closely up to these international initiatives.

CMEMS data portal has a well-developed link with the Euro-Argo ERIC, as the Argo programme constitutes a critical component of the in situ data requirement for Copernicus Services relying on ocean data (CMEMS, C3S). In principle, other Research Infrastructures e.g. EMSO could contribute to Copernicus as an in situ data provider. These links are not well developed at present.

The three major marine databases in Europe – CMEMS INSTAC, EMODnet and SeaDataNet – are all part of EU-funded programmes with a time limited time horizon (2020); which constitutes a potential sustainability risk after 2020.

3.6 Copernicus In Situ Component Information System

The EEA is in the process of developing an information system/database to capture, review and maintain currency of the in situ data requirements, gaps and issues across the Copernicus Services. It is envisaged that this system will capture requirements across all environmental observational domains alongside geospatial requirements and it is here that the outcomes from our recent studies and interviews will transposed into current, reviewable, sustainable and traceable elements. This should deliver an effective, accessible and living platform, through which effective interrogation, of captured current requirements and issues will be enabled.

There are a variety of ways in which products and requirements could be linked within such a system and when discussed at interviews, the atmospheric monitoring service expressed an opinion that in situ requirements should ideally be linked individually (product by product), rather than by grouping product types and requirements more generically. It is however recognised that initially a good understanding of specifically what questions the system will be required to answer, who will be its users and who will assist in defining a suitable solution.

It is recognised that to be effective going forward, the system must be reviewed and kept current. This would reflect evolving data requirements and availability together with the development and maturing of product portfolios across the Copernicus Services. An approach advocated in interview with CAMS would for example see a continuous dialogue between providers of meteorological, hydrological and atmospheric data and the Copernicus Services that would feed requirements back into the ongoing WMO OSCAR Rolling Review of Requirements.

3.7 Copernicus services and in situ development

There is risk in attempting to address all six of the Copernicus services along with their sub-components 'as one' with respect to in situ data. There is large variation in the maturity across the six services and of their utilisation of observational in situ data, with significant differences in the ways in which the six services operate:

- Some utilise in situ observational data routinely, whereas others do not;
- Some ingest and manage in situ observational data themselves, whereas others do not;
- Some have agreements in place with third party providers, for provision of necessary model data, others do not;
- Some utilise 'open source' web-services for weather and oceanographic information, which carries the risk that this information source may not be resilient and also that the information may not be of an understood level of quality and assurance;
- Some employ third party organisations or contractors for the production of their services, whereas others do not.

In some cases, there are linkages between the Copernicus Services, for example between CLMS and CMEMS over the new coastal service, this should facilitate a mutually beneficial exchange of expertise. Other services that cover similar domains appear to operate more autonomously.

The six services operate at differing levels of maturity, some established over many years and well linked to utilisation of relevant observational in situ data and with a good understanding of their own requirements, data gaps and issues. Others may have little awareness of what observational data could be available to them and how they could go about accessing and incorporating this into their products and services.

Through the process of establishing interviews with the various services and their components, we have experienced a variety of levels of enthusiasm and engagement with the analytic work tasked through the EEA. Some of the more mature services may have felt that they have been asked the same questions before (for example by the GISC project team), whereas for those more recently established, this has been a new process.

It is important that we are able to engage all of the services proactively in this process, to demonstrate relevance and express that this work, alongside any needs analysis they may have done themselves will both refresh and re-invigorate progress. The process of expert thematic engagement going forward should therefore be reflective of the differing needs across the various services.

3.8 Summary of recommendations

Regarding observational data, it is recommended the following activities be considered in the frame of the Copernicus In Situ component and in close cooperation with the Copernicus Services:

- Work directly with the Copernicus Services whose outputs are less directly linked to environmental conditions to ensure that they are updated on the availability of in situ data relevant for their service;
- Carry out a detailed gap analysis when the requirements from the individual services have been mapped;
- Analyse the need for a common data policy framework across meteorological, atmospheric composition and marine data delivered to Copernicus Services;

- Support that common access agreements enabling assured access to in situ observational data are established across the Copernicus Service elements and that actions are taken to ensure that all of the Copernicus services understand how to apply these;
- Work on finding practical solutions to data licensing and attribution that clearly emphasises the role of the in-situ data without blocking its use because it is impossible to fulfil the data licence requirement.
- Investigate how to harmonise and standardise metadata associated with meteorological, hydrological and atmospheric observation in cooperation with WMO:
- Play an active role in definition of data quality requirements for ocean data to meet the need of Copernicus services;
- Analyse the sustainability of existing European observation networks;
- In cooperation with EuroGOOS and EOOS establish a forum that brings funders, operators and users of marine in situ data together;
- As entrusted entity, EEA should work with member states (at political level) to consolidate and sustain their contribution to the in-situ component of Copernicus;
- Analyse the results of OSE and OSSE experiments carried out in research projects to identify where additional observations can improve prediction skills and reduce uncertainties of Copernicus forecast models. Part of the task should address knowledge transfer on assimilation techniques between the meteorological and oceanographic communities;
- Secure good linkage between the Copernicus Requirement web portal and the WMO Rolling Requirement Review system OSCAR;
- Actively engage in a dialogue with individual H2020 research projects that focus on design of observations systems, the G7 process etc. to ensure that Copernicus requirements are properly taken into account in the planning a design of observations systems;
- Start as soon as possible the implementation both at member state and EU levels, the main evolutions of the in-situ observing system that are mandatory for Copernicus services (e.g. BGC and Deep Argo);
- Together with research Infrastructures, EEA and Copernicus Services jointly promote awareness of the indispensability of observations for the products. This is possibly best carried out with initial workshops with the Service Operators and also DG GROW to foster a mutual understanding of the availability and potential benefits of in situ data to all of the Copernicus Services. This idea has also arisen during interviews with the Copernicus Service Operators, for instance at an interview with the SEA component of the Security Service;
- Build stronger relationships with the individual Service Operators and also with DG GROW. Therefore, it is recommended that further work be undertaken to liaise closely and iteratively with the Copernicus Service Operators to develop awareness of in situ data relevant to their specific services, where a need for this is identified. This could potentially be carried out through provision of expert face to face advice, to assist identification of appropriate data and clarify the ways and means to access and incorporate this into services to realise greatest value. To deliver this aspect and also to support the Service Operators going forward, there needs to be clearly identified Points of Contact on both sides. This will ensure that the Service Operators can be supported properly as far as their needs and requirements for in situ data.

Section Two

4. Service specific reports, gaps and issues

During spring 2017 a series of interviews with the individual Copernicus Services was carried out. The services were asked to reply to number of predefined questions. The outcome of these interviews is presented in this chapter.

4.1 Copernicus Atmosphere Monitoring Service (CAMS)

4.1.1 Products and services

The Copernicus Atmosphere Monitoring Service (CAMS) monitors and forecasts the composition of the atmosphere as related to air quality, ozone layer concentrations, solar radiation and emissions. Some of the biggest environmental challenges for society relate to the atmospheric composition. Data about the atmosphere has practical applications for energy, health and transport sectors to name just a few.

The service can answer questions such as 'What kind of air will the inhabitants of Europe breathe tomorrow? Will the smoke from forest fires in Canada affect the air quality in Europe? What is the optimal location for my solar panel farm?'
CAMS provides both consistent multi-annual global datasets as well as real-time analyses and forecasts.

4.1.2 What in situ data is required for this component?

In-situ observations of atmospheric composition species are required from European and global networks. Networks used are based on existing partnerships (e.g., EEA/EIONET), European Research Infrastructures (ICOS, ACTRIS, IAGOS), and international collaborations (e.g., NDACC, TCCON, AERONET). Also, ground-based data measuring solar radiation (UV and visible) are required for optimal performance of the CAMS services (e.g., BSRN, enerMENA, EUVDB, NEUBrew).

4.1.3 Why do we need access to in situ data?

Accurate, stable and well-calibrated observations are needed to constrain the air quality models at the near-surface level of exposure, as well as to validate the global and regional forecasts and reanalyses. While satellite observations provide a global view of the atmosphere, their vertical and temporal coverage is limited. In situ observations ensure that there is the important quality control on the combined information from models and satellite observations.
Only the combination of all the data sources including in situ data will provide users with reliable and up-to-date information related to environmental and security issues.

4.1.4 Detailed in situ data requirements on atmospheric composition

The following data requirements shall be highlighted:

- Concentrations of major air pollutants (NO_x, PM_{10}, $PM_{2.5}$, CO, SO_2, HCHO, Pb, TSP, C_6H_6, among others)
- Improved observation of size resolved chemical composition of aerosol
- Improved global observations of greenhouse gas concentrations and related species (CO_2, CH_4, N_2O, 14C, …)
- Vertically resolved concentration data of pollutant gases and aerosol
- Solar radiation and UV

4.1.5 Challenges and opportunities

Challenges (with priority ranking):

- 1: More sustainable funding for in situ observations
- 2: More information on aerosol size distribution is needed and is lacking from standard observation networks.
- 2: More vertical profile information on all components would help to improve the model evaluation and assimilation
- 2: As a good indication for the quality of the predictions, model analyses and forecasts are compared to in situ observations as close to real-time as feasible. For data assimilation purposes data should be available within 5 hours and for validation purposes within a week.
- 3: More comprehensive metadata and metadata harmonisation and standardisation
- 4: More global data and international collaboration with networks outside Europe

Opportunities:

- In situ data are now available from locations that are representative for the air quality at the exposure level and that can be represented well in the global and the regional air pollution models. This data is essential for model evaluation and improvement of prognoses through data assimilation
- CAMS analysis and forecasts also feedback to observation networks and science discussions, e.g. help for interpretation of measurements.
- In situ observations of air quality and greenhouse gases can potentially be used to improve current prescribed emission inventories in accuracy, also in terms of time profile and spatial distribution of sources. This will have potential for improving air quality forecasts.
- New applications like prediction of solar power plants energy production through predictions of (desert) dust would benefit from validation with in-situ observations of deposition.

4.1.6 Data gaps, data policy and accessibility

At interview CAMS stated that, whilst more data and a higher density of stations is always better, they are pragmatic in their approach and will work with any data of the required quality that is available.

However, one important gap in atmospheric composition data - where more and dense data availability is of highest priority to CAMS -is with vertically resolved aerosol information, for example from AERONET and TCCON. In addition, better information on aerosol speciation is also needed. They believe that improved collaborations with international networks would be advantageous, though difficulties might arise here because of different funding schemes and priorities. They also expected a clear coordinating role from WMO.

Concerning required air quality data coverage, there is specifically low density or missing data from some western European countries and for most of central and eastern Europe. Useful Research infrastructure (RI) data sources for model validation are the so called supersites (tall towers) where different RIs perform measurement at regionally representative locations.

CAMS would be very interested in gaining access to global surface air quality measurements from regions of interest that are currently data sparse, such as China.

4.1.7 Quality of data

Overall the data is fairly consistent and as much of the in situ data is used for validation purposes, this allows more time to resolve any problems than would be the case for operational products. The main direct impact on operational CAMS products comes from the EIONET air quality data, where there have been problems and discussion with the EEA to improve the situation is on-going.

4.1.8 Timeliness of data

In general, the data CAMS rely on for validation needs to be available within several days or at least within one week. Currently NRT data used for air quality validation has a time lag between 1 day and 1 year, which should be substantially improved. CAMS do have a budget to facilitate these specific requirements and this funding is currently being put in place to improve the situation with various networks.

4.1.9 Sustainability of data

Many data sets required for CAMS have an uncertainty regarding long-term funding. This applies to European Research Infrastructures but even more so to international networks without dedicated funding. TCCON is a data source valuable to both CAMS and C3S which lacks sustainability and may be forced to close all together due to lack of funding. It is therefore important to understand and set out its criticality. It is important to reinforce the importance of this data for CAMS, C3S, ESA and the CSC, with WMO GAW holding a key role here.

4.1.10 Future requirements or needs

The development of the service over the next five years is currently under discussion but expectations are that any changes will not have a significant influence on the requirements for in situ observational data.

4.1.11 Meta-data issues

It is important that data formats are properly documented and that appropriate metadata is available. CAMS state that more international standardisation and harmonisation is required and that this should be done in coordination with WMO.

4.1.12 Research infrastructure reliance

CAMS rely heavily on in situ data from both existing research networks and developing research infrastructures. As far as possible additional support is provided by CAMS to support development of the specific requirements of the service, such as improved quality control, availability of (near-) real-time data and better and/or faster access to data. CAMS is also willing to reference its support for more sustainable funding streams for the RIs, for example in strategic forums like European Strategy Forum on Research Infrastructures (ESFRI) and the EU Commission.

4.1.13 Additional points from interview

Previous studies and workshops have indicated that key in-situ data gaps and issues for CAMS relate to:

- Insufficient geographic density of observations,
- Lack of representative data sites,

- Lack of access to historical archive data,
- Lack of vertical atmospheric profiles,
- Accessibility (data policy), consistency and sustainability of data given the numerous reliant systems and networks, some time-limited and set in a research regime.

At the interview, CAMS reported that in general the situation has improved and it is foreseen that this will further improve with the new research infrastructures and improvements in EIONET.

4.2 Copernicus Marine Environment Monitoring Service (CMEMS)

4.2.1 Products and services

CMEMS produces a variety of products at global and regional level for both physical and biogeochemical parameters. The CMEMS delivers a core information service to any user related to 4 areas of benefits:

- Maritime Safety,
- Coastal and Marine Environment,
- Marine Resources, and Weather,
- Seasonal Forecasting and Climate activities

4.2.2 What in situ data is required for this service

Available physical variables from models include temperature, salinity, ocean currents, geopotential height, sea surface height, sea ice and mixed-layer depth, sea state (significant wave height, wave spectra). Available biological variables from models include chlorophyll, dissolved oxygen, nutrients and micro-nutrients e.g. iron, primary production and in regional cases zooplankton, radiative flux, pH and methane. Satellites provide sea level anomaly, optical properties, chlorophyll, sea surface temperature, sea ice concentration, wind and waves data at global level. Regional satellite products include all of the above variables and sea ice drift.

Upstream satellite and in-situ data are used for assimilation in ocean models, for validation and verification of ocean models results and also for limited validation of remote sensing data for ocean colour, sea level and sea surface temperature.

To illustrate the availability and thereby the potential for cross-cutting use an overview of data in the CMEMS data portal is given in the following.

The number of in situ platforms providing data during the last year for the global ocean distributed by type of platform is shown in Table 2. There is a total of 8745 observing platforms delivering observations to the global CMEMS INSTAC during this one-year period. They include all types of autonomous platforms, research vessels and river flow observations.

Table 2: Number and type of observing platforms available in the global INSTAC during last year.

Number of Platforms by type [1]													
BA	**CT**	**DB**	**DC**	**FB**	**GL**	**ML**	**MO**	**PF**	**RF**	**TE**	**TS**	**XB**	**Total**
70	106	2858	23	38	21	39	1202	4809	96	429	53	1	**9745**

[1]BA: Bathythermograph; CT: CTD profiles; DB: drifting buoys; DC: Drifting Buoy Reporting current; FB: Ferry Box; GL: Gliders; ML: Mini Logger; MO: Moorings; PF: Profiling Floats; RF: River Flow; TE: Tesac; TS: Thermosalinograph; XB: XBT or XCTD.

The most numerous observing platforms in the global CMEMS INSTAC are the profiling floats (4809). This number represent the number of different profiling floats that have been active in the past year, some of them died, other were deployed, in order to maintain an array of about 4000 profiling floats at any time in the year.

Figure 4 shows the geographical distribution of all the *in-situ* platforms in the Global INSTAC.

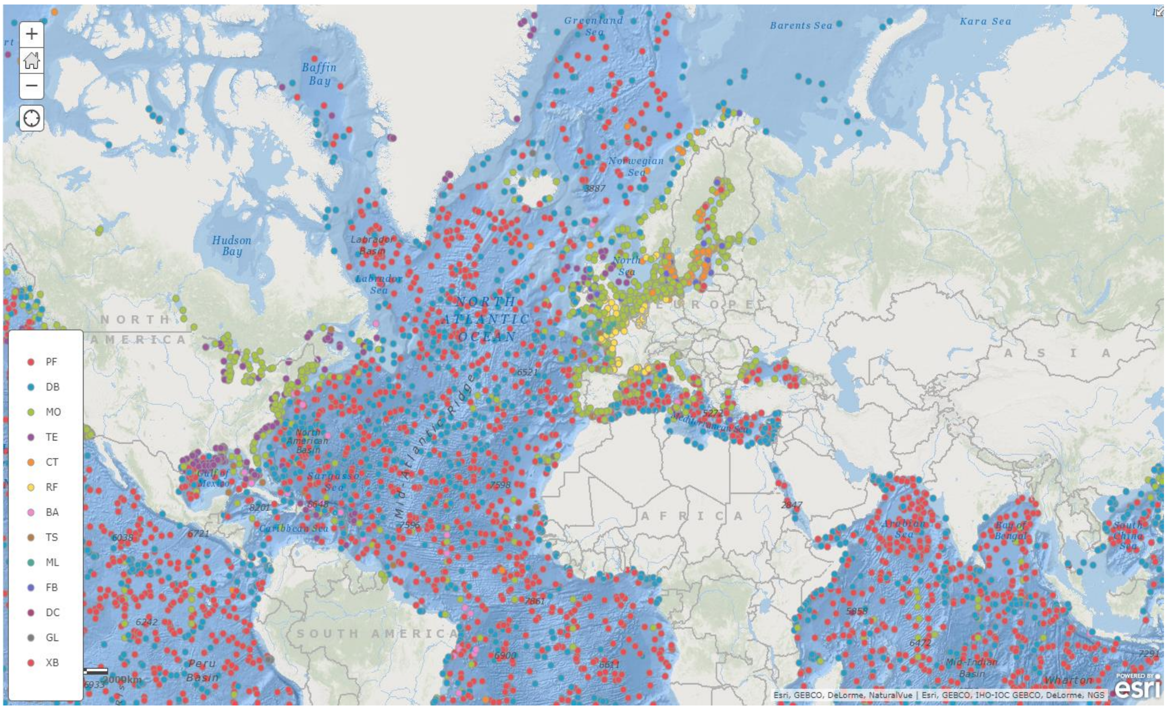

Figure 4: In-situ observing platforms in global CMEMS INSTAC coloured by type of platform.

Each of the Regional INSTAC service uses in-situ data for assimilation, validation and verification of the regional ocean model. In the table 3 below, there is the number of in-situ platforms available in each of the CMEMS regional services. Note that the In-Situ TAC areas overlap in some cases (See Figure 5 for the geographical definition of regionals INSTACs) and, therefore, some of the platforms can be used in more than one regional service.

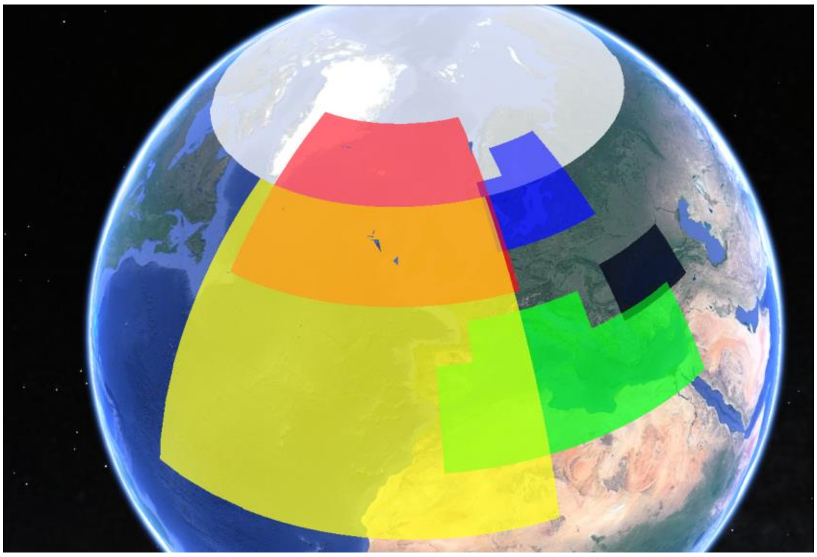

Figure 5: CMEMS In Situ TAC areas: Blue – Baltic Sea; Orange – North West Shelf; Yellow - Iberia Biscay Ireland; Green – Mediterranean; Black – Black Sea; White: Arctic Sea

Table 3: Number and type of observing platforms available in each regional CMEMS In Situ TAC area during last year.

Regional INSTAC	Number of Platforms by type[1]													
	BA	CT	DB	DC	FB	GL	ML	MO	PF	RF	TE	TS	XB	Total
Baltic Sea		79			21	1		222	12	3				**338**
North West Shelf	1	8	123		13	4	27	360	168	54	25	6		**789**
IBI – Iberia Biscay Ireland	2	8	255	3	13	5	37	482	306	94	19	19	1	**1244**
Mediterranean	3	2	90	3	1	8		119	111	19		6	1	**363**
Black Sea		1			2			22	14					**39**
Arctic	1	22	228		6	6	1	76	138		58			**536**

[1]BA: Bathytermograph; CT: CTD profiles; DB: drifting buoys; DC: Drifting Buoy Reporting current; FB: Ferry Box; GL: Gliders; ML: Mini Logger; MO: Moorings; PF: Profiling Floats; TE: Tesac; TS: Thermosalinograph; XB: XBT or XCTD

There are, however, great differences in how dense the observations point are for the various EOV's as illustrated in the following for temperature and chlorophyll.

Temperature

There was a total of 1592 in situ observing platforms available in CMEMS measuring temperature during the last year period in the European Seas, with a distribution by type of platform shown in the following Table 4.

Table 4: Number of in-situ platforms in the European Seas measuring temperature by type of platform.

Number of Platforms by type [1]													
BA	CT	DB	DC	FB	GL	ML	MO	PF	RF	TE	TS	XB	Total
6	101	507	3	27	15	38	256	541		77	20	1	**1592**

[1]BA: Bathytermograph; CT: CTD profiles; DB: drifting buoys; DC: Drifting Buoy Reporting current; FB: Ferry Box; GL: Gliders; ML: Mini Logger; MO: Moorings; PF: Profiling Floats; TE: Tesac; TS: Thermosalinograph; XB: XBT or XCTD

Figure 6 shows the distribution of in-situ platforms measuring Temperature (both profiles and/or time series) which are available in CMEMS INSTAC for the last year.

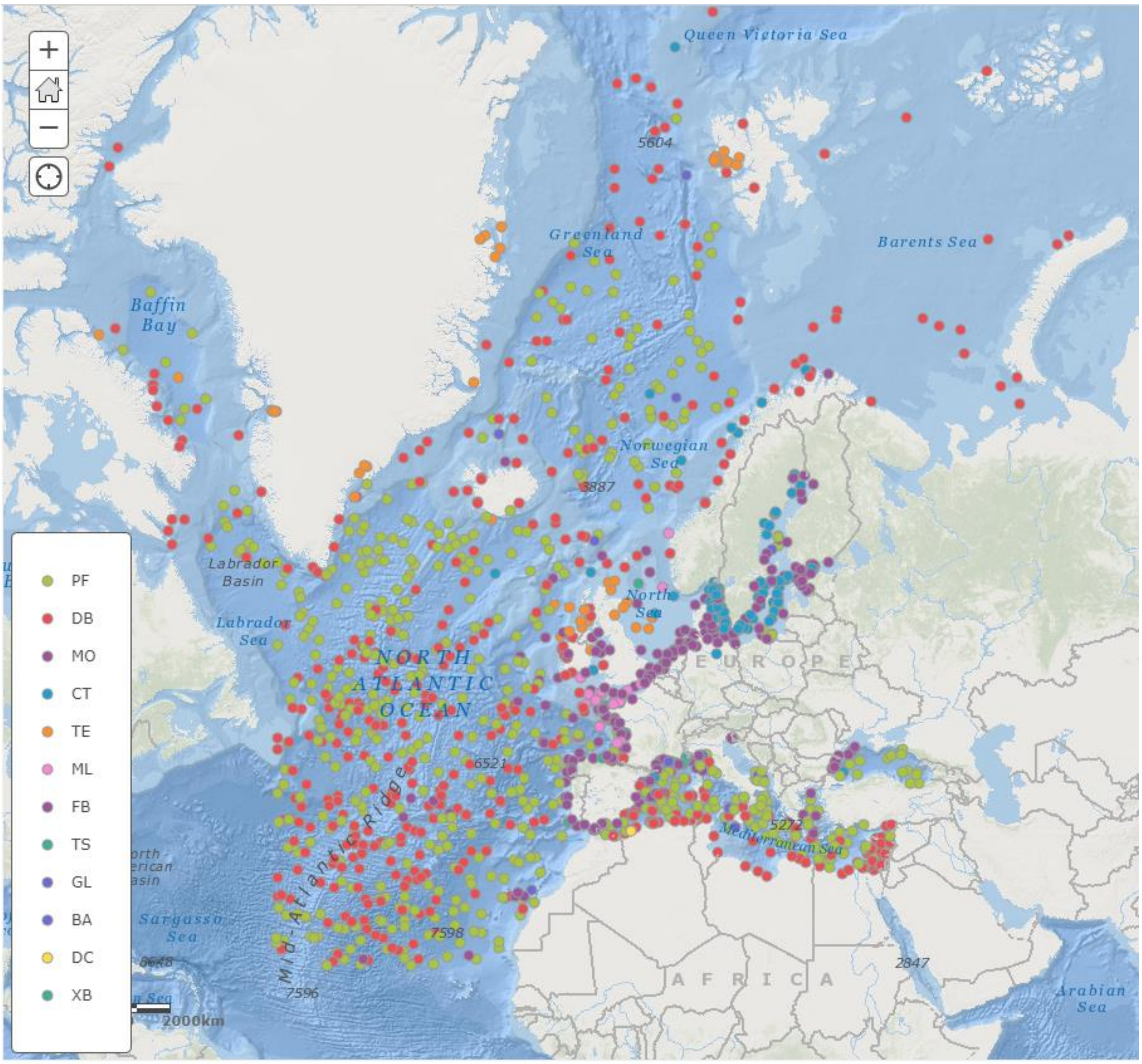

Figure 6: Distribution of in-situ observing platforms measuring Temperature during an one year period available in CMEMS INSTAC. The colours represent the type of platform: BA: Bathythermograph; CT: CTD profiles; DB: drifting buoys; DC: Drifting Buoy Reporting current; FB: Ferry Box; GL: Gliders; ML: Mini Logger; MO: Moorings; PF: Profiling Floats; TE: Tesac; TS: Thermosalinograph; XB: XBT or XCTD.

Chlorophyll

There were 68 platforms available in CMEMS measuring in-situ Chlorophyll during the last year in the European Seas, with a distribution by type of platform shown in Table 5. Note there were 50 Profiling Floats measuring in-situ Chlorophyll. See in Figure 7 the geographical distribution of platforms among the different basins.

Table 5: Number and type of in-situ platforms available in CMEMS measuring Chlorophyll during the last year.

Number of Platforms by type [1]													
BA	**CT**	**DB**	**DC**	**FB**	**GL**	**ML**	**MO**	**PF**	**RF**	**TE**	**TS**	**XB**	**Total**
	1			2	8		3	50		1	3		**68**

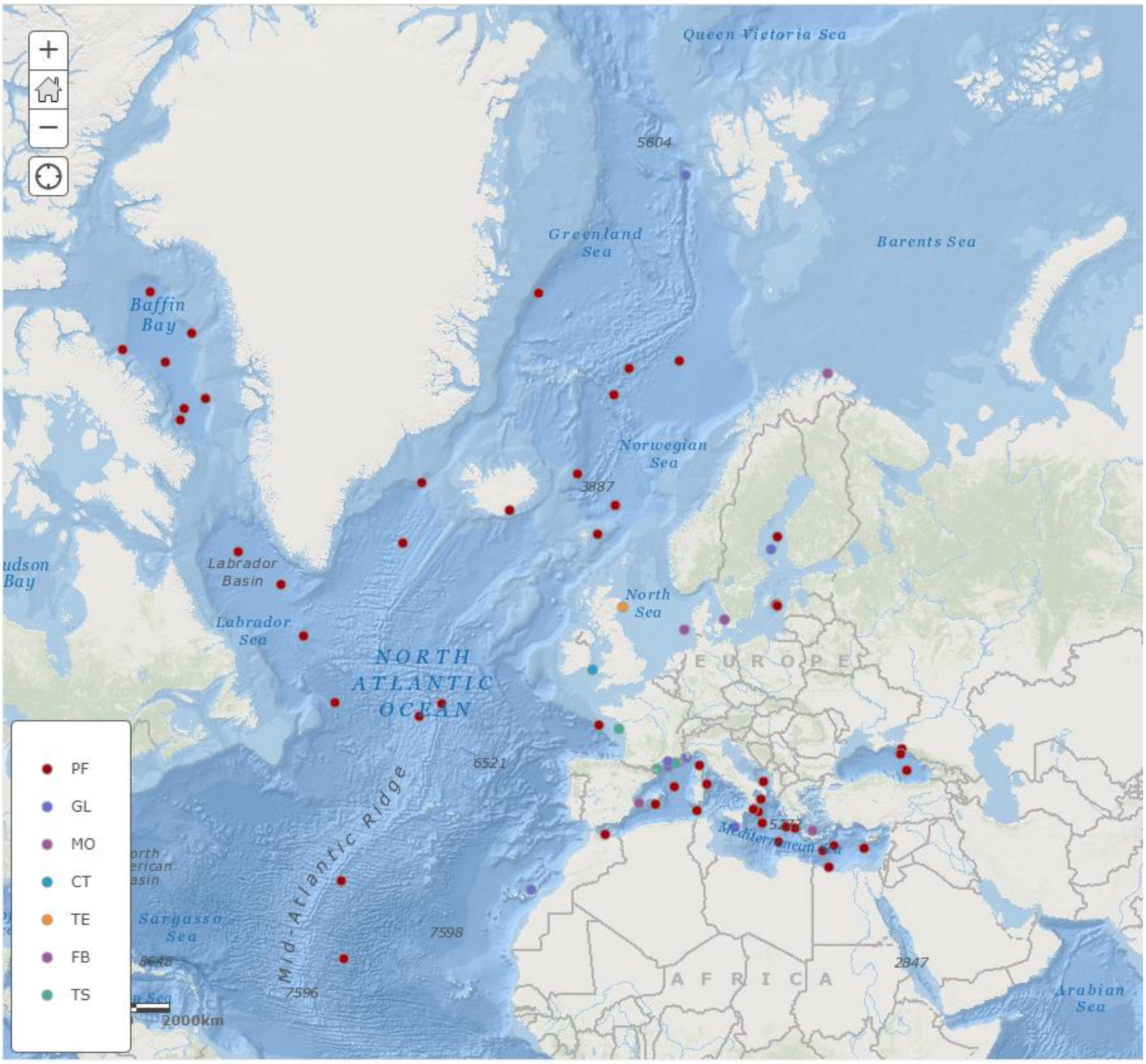

Figure 7: Distribution of in-situ observing platforms measuring Chlorophyll during a one year period available in CMEMS INSTAC. The colours represent the type of platform: PF: Profiling Floats; MO: Moorings; TE: Tesac; TS: Thermosalinograph; GL: Gliders; CT: CTD profiles; FB: Ferry Box.

4.2.3 Why do we need in situ data

Data are used for initialisation and assimilation in ocean models, for validation and verification of ocean models results and also for limited validation of remote sensing data for ocean colour, sea level and sea surface temperature.

4.2.4 Detailed in situ requirements

CMEMS would like to focus on key variables such as chlorophyll, dissolved oxygen, pH and pCO_2 in the short to medium term as they have a potentially high positive impact on product quality within CMEMS.

In situ requirements for multi-year and near real-time model and observation products include:

- In situ data to validate all variables produced by the models e.g. for assimilation into ocean forecasts and for use in multi-year gridded products (often maps).
- Maintenance of Argo core mission (physical variables) at the present level and increased proportion of biologically equipped Argo profiling floats (Bio-Argo).
- Implementation of the Deep Ocean Observing System, in particular deep Argo floats for all relevant variables with near real-time data delivery where feasible.
- Provision of wave data and atmospheric analysis based on in situ met observations to improve wave and coastal models for both circulation and biogeochemical variables.
- Provision of tidal data, more accurate bathymetric maps, river outflow data (volume, nutrients and sediments).
- Enhanced data access to member state coastal in situ observations.
- Extension of relevant in situ time series data to periods exceeding 20 years.

CMEMS are interested in all delayed mode data that can make a difference to model skill. These data could be up to 1 month old. They are also pushing to have delayed mode data available as close to real-time as possible. Discussions are ongoing to have reanalysis of satellite position data by the space agency's (ESA and EUMETSAT) within 1 month of data collection.

CMEMS have identified critical in situ measurements required to validate and enhance products in the current product catalogue for both model products and observation products, see Table 5 a,b.

4.2.5 Challenges and opportunities

Challenges

- Collection of requirements for resolution in time and space
- More sustainable funding for ocean observations
- Open and free exchange of data
- Coordination and governance of ocean observations
- In the future there is a strong need to focus on biogeochemical, biological and ecosystem variables

Opportunities

- Several H2020 projects focus on design of ocean observation system in European regional sea's
- G7 Ministers resolution on ocean observations
- Establishment of EOOS as a coordination and governance body for ocean observations.

Table 6a   Critical in situ measurements required for CMEMS model products

Model products: Critical In-situ measurements required	Platform		Argo T/S	Argo BGC	Mooring T/S Wind Waves	Mooring BGC	Mooring Current meter	Ship-based T/S	Ship-based BGC	Ship Based ADCP	ITP (planned)	Drifter Currents, T	Tide gauge SL., T	CPR (planned)	Gliders BGC, T/S	HF Radars (Planned)
	Scale															
Multi year model products	Global	Physics	■◆		■◆		■◆	■◆		◆	■◆	■◆	■◆		■◆	■◆
		BGC		■◆		■◆			■◆					■◆		
NRT model products		Physics	■◆		■◆		■◆	■◆		■◆	■◆	■◆	■◆		■◆	■◆
		BGC							◆					■◆		
Multi year model products	Regional	Physics	■◆		■◆		■◆	◆		◆	■◆	■◆	■◆		■◆	■◆
		BGC							■◆					■◆		
NRT model products		Physics	■◆		■◆		■◆	■◆		■◆	■◆	■◆	■◆		■◆	
		BGC		■◆	■◆	■◆		■◆	■◆					■◆	■◆	

■	Assimilated in forecast models
◆	Used for model validation
⊙	Used for satellite validation

Table 6b Critical in-situ measurements required for CMEMS observation products

Platform		Argo T/S	Argo BGC	Mooring T/S Wind, Waves	Mooring BGC	Mooring Current meter	Ship-based T/S	Ship-based BGC	Ship Based ADCP	ITP (Planned)	Drifter	Tide gauge	CPR (Planned)	Gliders BGC, T/S	HF Radars (Planned)
Variable															
Ocean Color	Physics														
	BGC		⊙		⊙			⊙							
Sea Level	Physics	⊙									⊙	⊙			
	BGC														
Sea Surface Temperature	Physics	⊙		⊙			⊙			⊙	⊙				
	BGC														
Sea Ice	Physics									⊙	⊙				
	BGC														
Wind & waves	Physics			⊙											⊙
	BGC														

■	Assimilated in forecast models
◆	Used for model validation
⊙	Used for satellite validation

4.2.6 Gaps, data policy and accessibility

There are critical sustainability gaps and major gaps for biogeochemical observations (e.g. carbon, oxygen, nutrients, chl-a) at global and regional scales. Sustaining the Argo global array, consolidating its regional components (in particular in European Seas) and implementing its major extensions (BioGeoChemical Argo and Deep Argo) are strong priorities to CMEMS.

Improving ROOSes (Regional Ocean Observing Systems) and key observing systems such as FerryBoxes, gliders, tide gauges and HF Radars are also strong priorities for regional CMEMS products.

Some of the gaps identified in the biogeochemical observation system include:

- Gaps in collocated physical, biogeochemical and biological measurements
- Gaps in the geographical coverage of the in-situ ocean observing network
- Gaps relative to societal benefit product data requirements

Gaps in data availability

- Provision of wave and tidal data, more accurate bathymetric maps, river outflow data (volume, nutrients and sediments).
- Improve the data access to member state coastal in situ observations.

Sustainability gaps

- Gaps in centralized data management
- Gaps in quality control and inter-comparability
- Gaps in usage of Certified Reference Materials (CRMs)

Gaps in technology include insufficient accuracy and portability of biogeochemical sensors deployed on autonomous platforms and restricted usage of instruments and sensors due to their high cost, specifically impacting measurements coverage in regions and periods not (readily) accessible by manned platforms.

4.2.7 Quality of data

The CMEMS In-Situ Thematic Assembly Center (INS TAC) includes a strong component of quality assurance and control (QA/QC) based on internationally agreed "Ocean standards and best practices" formulated within the framework of IOC-IODE, WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) and the EuroGOOS working group on Data Management and Quality (DATA-MEQ).

4.2-8 Timeliness of data

CMEMS is primarily an operational service which means that real-time or near-real-time delivery of in situ data is a mandatory request. However, for the reanalysis component of CMEMS delayed mode and high-quality data are requested.

4.2.9 Sustainability

The most severe risks to the marine in-situ observing system are related to sustainability:

- There is a lack of sustained funding for ocean observations in general, about 70% of data in the GOOS is funded by time-limited research projects
- Observing networks suffer sustained funding for coordination/management of the network (staff, travel)

- In-situ ocean observations are based on infrastructures, mainly supported by national agencies and the number of observation sites/platforms decrease due to:
    - Ageing of instruments/networks
    - Changes in scientific goals and priorities
    - Funding opportunities decreasing
    - Environmental effects (climate change, harsh environment)

As entrusted entity, EEA should work with member states (at political level) to consolidate and sustain their contribution to the in-situ component of Copernicus.
Additionally, new objectives for the future observing system requires new sampling strategies (time/space/sensor) and continuous development of new more sophisticated instruments. Especially biogeochemical and biological observation technology needs substantial support for technological development.

To this end it is of paramount importance to start as soon as possible the implementation both at member states and EU levels of the main evolutions of the in-situ observing system that are mandatory for Copernicus services (e.g. BGC and Deep Argo).

4.2.10 Future requirements

It is included in the CMEMS implementation plan to regularly update the service requirements for in situ data driven by evolving user needs and an analysis of what is feasible. Monitoring of new technology development is therefore an important component of this work, see also 4.2.6 for details

4.2.11 Meta data issue

It is mandatory that all in situ data are accompanied by adequate metadata based on community standards. Inadequate metadata mean that data will be of limited value. CMEMS INSTAC are actively involved in international and European harmonisation efforts.

4.2.12 Research Infrastructures

Out of six marine infrastructures CMEMS has established formal links to two (EuroARGO, SeaDataNet), while an open dialog is ongoing with one (JericoNEXT). The three remaining RI's (EMBRC, EMSO, Eurofleet) are not currently linked to CMEMS or any other Copernicus Service.

4.3 Copernicus Land Monitoring Service (CLMS)

Pan-European components (coordinated by the EEA)

4.3.1 Current requirement for in situ observations

Little or no observational in situ data is currently utilised by the service providers for the Pan-European and Local components of this service. As service coordinators, rather than a production centre, the EEA don't have always have full current oversight of what, if any in situ observational data is utilised.

4.3.2 Future requirements or needs

A coastal service is currently being developed in partnership with CMEMS, which is intended to bridge the current gap between land and ocean services. Access to appropriate in situ observational data for both CLMS and CMEMS domains should inform this, with anticipated key data type requirements being;

- Hydrological, including freshwater river flow and discharge data,
- Rainfall,
- Soil moisture,
- Ground water level,
- Temperature.

Global component (coordinated by the JRC)

4.3.3 Current requirement for in situ observations

At present there is no systematic collection of in situ observational data for the production or validation process of Land products within CLMS (Global). The current portfolio of products is available through the CLMS Global web-site (http://land.copernicus.eu/global/products/), which also indicates the current status of these (in development or production).

4.3.4 Future requirements or needs

In situ data will be used for calibration and validation of products in the future, with this work carried out by external contractors (ACRI). This service will be provided through the Ground-Based Observation for Validation of Copernicus Global Land Products (GBOV) project and will contribute to the validation of 7 of products:

- 3 energy products: Top of Canopy Reflectance, Surface Albedo and Land Surface Temperature;
- 4 vegetation products: Leaf Area Ondex, Fraction of photo synthetically active radiation absorbed by the vegetation (FAPAR), Fraction of green vegetation cover and (Fcover) and Soil Water Index.

The collected raw data will be processed and up-scaled to produce appropriate reference measurements to be applied to land product validation.

The GBOV framework contract, managed by JRC, has duration of 4 years and also foresees the implementation of a web-based interface for in-situ observational data storage and data access for Users, including the Copernicus Global Land lots in charge of product generation and validation. A risk to the success of this work is the non-availability of the necessary ground measurements, this may be due to restricted access to data, unknown but potentially useful data sources, data gaps or data location not being representative of a region. It was stated at interview that a catalogue of potentially available data would be useful to help map the landscape of potentially useful data. To this end, the CIS[2] may be useful by providing information on available data sources and networks that are utilised by the other Copernicus Services and their components.

To help mitigate issues of insufficient data CLMS will have a budget to procure additional instrumentation where necessary and possible. To supplement this, there may be a role for the EEA and Lot 1 to assist with leverage of access to necessary data and to develop understanding of how or where to support reliant networks (including NEON and FluxNet). For example, there may be value in collaboration with WMO over access to data in Africa through linkage with GFCS/GCOS. It may also be useful to do some work to understand where requirement synergies and sustainability issues intersect across multiple Services and therefore where there is a cross-cutting need to support critical instrumentation or networks for mutual benefit. Whilst the Copernicus In Situ component doesn't have a budget to support networks, we can document and evidence the importance and relevance of measurements within the holistic in situ observing system.

4.4 Copernicus Climate Change Service (C3S)

4.4.1 Products and services

The Copernicus Climate Change Service (C3S) combines observations of the climate system with the latest science to develop information about past, current and future states of the climate in Europe and worldwide. This service covers a wide range of components of the Earth-system and timescales spanning seasons to centuries. Products include: consistent estimates of Essential Climate Variables; global and regional reanalyses covering atmosphere, ocean, land, carbon; data sets of past and present observations; a near-real-time climate monitoring facility; multi-model seasonal forecasts and climate projections at global and regional scales. C3S will inform policy development to protect citizens from climate related hazards, improve planning of mitigation and adaptation practices, and promote the development of new services for the benefit of society.

4.4.2 What in situ data is required for this component?

The service requires high-quality observational records of variables that critically contribute to the characterisation of Earth's climate: the so-called Essential Climate Variables (ECVs). Long, consistent data series are needed to detect climatic trends of, for example, the frequency of extreme climatic events that may have a severe impact on society.

4.4.3 Why do we need access to in situ data?

For the Climate Change Service historical in situ climate observations complement satellite observations because of their long historical record and as the ground-truth of satellite data, and the ability to generate deep ocean information, while they lack the spatial coverage of satellite instruments. There are three main applications of in situ data in the climate service:

1) Climate reanalysis In situ observations provide essential information about the past climate, its variability and change. They are fundamental to all datasets used to assess climate change, including those derived from observations alone as well as the widely used model-based reanalyses.

2) Calibration and validation of satellite observations to enable production of multi-decadal Climate Data Records (CDRs) with global coverage, providing information about many different ECVs.

3) Evaluation and improvement of climate models by comparing model output with observations of the current and past climate, using historical forcings.

In addition, C3S users require in-situ data for a wide range of downstream applications, for instance in hydrology, agriculture (crop yield), health, insurance, etc.

4.4.4 Detailed in situ data requirements

The Global Climate Observing System (GCOS) established a list of the Essential Climate Variables (ECVs) needed to systematically monitor the Earths' climate (updated as of December 2016). As the service is in development, there will be a gradual increase of ECVs as the Climate Change Service develops from a pilot phase towards the a fully *operational* service.
In situ data requirements with respect to operational services are as follows:

Atmospheric (over land, sea and ice)

- **Surface:** Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation (daily and sub-daily), Surface radiation budget;

- **Upper-Air:** profiles of Temperature, Wind speed and direction, Water vapour; Cloud properties, Earth radiation budget (incl. solar irradiance);
- **Composition:** Carbon dioxide, Methane, and other long-lived greenhouse gases, Ozone and Aerosol (incl. visibility), supported by their precursors.

Oceanic

- **Surface:** Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton;
- **Sub-Surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.

Terrestrial:

- **Hydrology:** River discharge, Water use, Groundwater, Lakes, Snow cover (depth and extend) , Glaciers and ice caps, Ice sheets (thickness and extend), (profiles of) Soil moisture;
- **Other:** Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, (profiles of) Soil temperature

4.4.5 Challenges and opportunities

For climate research, reanalysis, and impact assessments, data need to be inter-comparable over the entire record. Inconsistencies can arise over a long-period record through changes in measurement environment and observing practices, including instrumentation. Homogenisation and harmonised QA/QC and gridding procedures applied to historical time series of observations are needed to avoid spurious trends and incorrect statistics of extremes. Historical in situ observations are not always documented according to modern standards which makes quality assessment difficult.

4.4.6 Data gaps and space/time coverage

Data rescue is important to get data from data-sparse regions, e.g. Southern Hemisphere or Africa. Homogeneous time series of 30-year length or more are needed for seasonal forecasts, and much longer for decadal predictions, particularly from the pre-satellite period. Time series starting in the 1960s or even 1950s are particularly valuable.

4.4.7 Timeliness

For the daily updates of reanalysis, observation data should be available within 18 hours.

CO_2 and CH_4. Total Carbon Column Observing Network (TCCON) validation network: data is made available after 1 year, whereas it would be ideal to make this available sooner. Flask measurements should also be made available sooner after the time of observation.

4.4.8 Data policy and accessibility

Some relevant in situ networks are not operated by national meteorological and hydrological services and their data not shared by the meteorological community (e.g. AGRHYMET). Of particular relevance to C3S are precipitation data.

Wind observations at 60-150 m by the energy sector are not currently available for commercial reasons. Also SODAR and LIDAR wind profiles exist but are not available.

Solar radiation observations made by the energy sector are similarly not available for commercial reasons. This is less critical because of the availability of representative satellite data, however in cloudy regions in situ is more important, as cloud reduces the accuracy of the satellite products compared to regions with clear skies. Separation of direct and diffuse radiation is desired by C3S because of their different PV efficiencies, whilst aerosol measurements are sometimes needed for attenuation estimates.

The hydropower sector takes in situ measurements of snow stock and other reservoir data, enough of which are not currently available to C3S to be of value. Similarly, data on water levels in general, for example, from the water management communities is often not made available.

Atmospheric radio sounding data are often only available for standard pressure levels, whereas full data access at their original vertical resolution would be beneficial to C3S.

Some river water temperature data, for example near nuclear power plants are classified and therefore not made available.

Data density across borders often displays jumps, not only due to differences in measurement density but also to differences in data availability.

Glacier data or pictures are not readily available, particularly airborne and satellite observations, particularly from South America and Central Asia.

Automatic Weather Station data from stations that meet WMO standards are not archived by WMO and therefore, often have poor availability.

Observational in situ data that result from nationally funded scientific agency research and journal papers are often not made available.

ECV	Qualification of coverage	Priority for expansion
Air temperature	Excellent to insufficient	medium
Wind speed	Excellent to non-existent	high
Wind direction	Excellent to non-existent	high
Water vapour	Excellent to non-existent	high
Pressure	Excellent to poor	low
Precipitation	Excellent to insufficient	medium
Snow depth	Excellent to non-existent	low
Cloud Cover	Excellent to non-existent	low
Sunshine duration	Excellent to non-existent	high
Surface radiation	Non-existent	high

Table 7: Current distribution of in-situ observations of ECVs in the European Climate Assessment and Dataset, to be expended for the C3S gridded observations products.

For the preparation of gridded Essential Climate Variables (ECV's) based on in situ data, the availability and priority of these are given in table 6. Most of these data are provided by national meteorological services. To prepare the Copernicus gridded products and make them available for all types of users (including commercial users), Copernicus should obtain a uniform license from all station data owners. Provenance and traceability would be best served when the station data would also be freely available to the users of the derived (gridded) data.

Data should be centrally available via international archives. Scattered availability should be avoided. This also applies to data rescue results.

Sometimes meteorological and hydrological data are difficult to collect because they are scattered over many institutes (e.g. in Italy).

Feedback from users to the database providers should be organised, with the subsequent actions to improve database content made transparent.

As the European Water Archive is not sustained, the Global Precipitation Climatology Project (GPCP, Koblenz) is even more relevant.

Updates sometimes rely too much on goodwill and voluntary actions; a more organized and regular approach is needed.

ECVs are generally validated within a year after observation time. However, not all observations are made available within this timescale.

NOAA's National Climatic Data Centre (NCDC) lacks modern functionality and would benefit from investment to improve this.

The visibility of data providers should generally be improved.

4.4.9 Sustainability

TAO TRITON array (a network of buoys spread across the equatorial Pacific to monitor the subsurface ocean and surface meteorology of the ocean): maintenance is not assured.

ARGO float (Oceanographic observing buoys): funding is vulnerable, and the density of floats in the southern hemisphere should be improved.

4.4.10 Future requirements / Needs

In-situ observations that are currently missing or with insufficient coverage are:

Thermohaline circulation transport is measured by the RAPID array at 26 N; an additional array to the north is desired.

Precipitation measurements at higher levels in mountainous areas (present observations are mostly in valleys).

Data on rivers that have a completely dry season.

CO_2 and CH_4 measurements.

The Total Carbon Column Observing Network (TCCON) validation network: preferred additional measurements at complex (e.g. Sahara near large albedo gradients) and remote (e.g. Amazonia) regions. More flask measurements and AIRCORE profile measurements are desired.

Measurements of temperature and precipitation in built-up urban environments.

4.5 Copernicus Emergency Management Service (CEMS)

Early Warning Component

The Early Warning component utilises meteorological and hydrological in situ observations in real/near real time, which are essential to effective delivery of its services, as well as historic data for calibration and validation. In addition they collect meteorological and hydrological data through a third party contractor for use within their Service component. This data is not currently shared with other Copernicus Services due to data license restrictions. The main gaps and issues raised during interview, relating to in-situ observation data requirements for the delivery of the European Flood Awareness System (EFAS) and European Forest Fire Information System (EFFIS) are summarised as follows:

4.5.1 Data Gaps - Existing in situ observations – Data density or access

At the interview, CEMS early warning stated that meteorological and hydrological data generally are often not collected at a national level in many countries but at regional or river basin level for example . Where there is a lack of access to these data, this is most likely to be due to a lack of licensing agreement and sometimes also to a lack of technical capacities.

4.5.2 Quality of Data

The range of data formats, with different standards, varying projection systems or not consistent time stamps has been highlighted as a quality issue, particularly with respect to hydrological data, but also for certain meteorological variables.

CEMS highlighted harmonisation of hydrological data and in particular data definitions as an area that needs to be addressed. For example run-off data is defined in different ways in various nations and organisations. Sometimes this can be instantaneous run-off, sometimes over a defined period and there is great variability in the way in which the data itself is collected.

CEMS have been invited to WMO region 6 meetings on hydrology, but don't have official status within this. Therefore, there could be some value in establishing a formal status for Copernicus within the WMO hydrological community.

4.5.3 Timeliness and Space/Time coverage of data

The considerable variation in density of meteorological and hydrological observations across nations and regions was raised as an issue at the interview, which is likely a symptom of both a lack of data access agreements and also step changes in all available data across borders between nations.

Timeliness of receipt of 'real-time' data is an issue, with delays sometimes negating the effectiveness and value that could be gained through timely receipt of in situ observations.

4.5.4 Access condition and Data policies

There are a multitude of data owners with different data licences, some of which are not prepared to share their meteorological and/or hydrological data and a lack of a common overarching access licence for the provision of all required data (meteorological and hydrological).

There is a lack of transparency of data policy in the purchasing or licensing of data from the various sources, which complicates negotiating and understanding access to in situ observational data.

4.5.5 Future requirements or needs

Requirements for access and use of marine in situ observations may change in the future following the introduction of a storm surge model, which is currently in development. This would likely have requirements for in situ data and specifically tide-gauge data that would cut across those of CMEMS. Given that this development is at an early stage then these requirements aren't yet certain however and the model output still has to be accepted/assured as suitable to feed a future product for CEMS Early Warning.

There was some discussion about the Climate Data Store and the potential utility of this as a data hub. It was thought that this could potentially act as a Copernicus hub for historical data sets, but that real-time/near real-time data would need to be/should continue to be hosted under the current contractual agreement for CEMS.

EFFIS are developing their dispersion/plume modelling capability with a view to producing 48 hour predictions. There may here be an emerging new requirement for air quality data to verify this. There have been experiments utilising a rapidly deployable suite of sensors for this, alongside existing CAMS outputs. This could develop into a new future requirement, which could also be useful for CAMS.

The process to set up a consortium to deliver forest fire early warnings services is currently ongoing – expected to conclude in the next few months. Sharing of the same meteorological data between the currently existing (EFAS/EFFIS) and future (droughts) components of EMS is already ongoing.

The WMO WHOS programme could be a useful interface to develop data access and leverage Copernicus requirements to the global hydrological community. However, in its current form it has only limited functionalities and it depends therefore on its future development whether this could be a useful interface to develop data access and leverage Copernicus requirements. That said there was recognition that formal observer or similar status with WMO could be beneficial.

4.6 Copernicus Security Service (CSS)

To date, only FRONTEX have attempted to utilise in situ observational data to inform its products. These being maritime observations data from the southeastern Mediterranean, which were found not to have adequate density of coverage to provide value and they have subsequently moved to reliance on model data only for this region.

Border Surveillance (delivered by FRONTEX)

4.6.1 Future requirements or needs

FRONTEX don't currently utilise any observational in situ data, although they do have a contractual agreement with MeteoGroup who provide meteorological and ocean forecast products through custom API and OGC a user interface and toolkit, which satisfies current requirements. At interview however, they highlighted some observational in situ data types that they believe could provide additional value, particularly with respect to services supporting operational maritime search and rescue on migrant routes.

These being:

- Maritime and coastal observations in key areas of interest, if density and access to observations were improved,
- Radar rainfall coverage for areas of interest,
- Lightning detection (ATDnet or similar).

Figure 8: Copernicus Security Service – Border Surveillance – Area of Responsibility (Credit: FRONTEX)

In addition, to assist in future analysis, assessment and planning, it was stated that climatological data-sets or re-analysis data-sets for the following data types over areas of interest could prove valuable;

- Temperature,
- Precipitation,
- Wind,
- Wave height and swell.

Their area of responsibility and therefore the area over which observations would be required covers the Mediterranean Sea, Black Sea, North Sea and a large part of the North Atlantic Ocean (see map below), with key current areas of interest largely governed by geo-political and crisis situations.

Support to EU External Action (SEA, delivered by EU SatCen)

4.6.2 Future requirements or needs

The SEA component doesn't currently utilise any observational in situ data, although they do access some web based meteorological forecasts through WeatherCast.

When interviewed some examples of products were discussed that could in future benefit from inclusion of observational data. These being road network status, assessment of trafficability, camp analysis and crisis situation pictures. Key elements that hold potential here are;

- Rainfall
- Flooding

- Solar radiation
- Temperature
- Wind

Maritime Surveillance Component (delivered by EMSA)

4.6.3 Future requirements or needs

The Maritime Surveillance component doesn't currently utilise any observational in situ data and whilst they haven't conducted a requirements analysis for observational in situ data there was recognition that integration of in situ observations could add value to their real-time support for live operations, for example search and rescue or for management of oil spills. For this to be effective they would require European wide data, received in near real-time and of sufficiently high resolution.

Of secondary value would be access to observational data to support planning and post event analysis.

Elements they have an interest in are;

- Sea surface temperature
- Sea surface currents
- Wind
- Sea wave height
- Sea state
- Sea ice

ANNEX A – INTERVIEWEES

Copernicus Atmosphere Monitoring Service (CAMS)

Richard Engelen - Deputy Head CAMS (richard.engelen@ecmwf.int)

Copernicus Marine Environment Monitoring Service (CMEMS)

Antonio Reppucci – Mercator Ocean
Pierre-Yves Le Traon - Scientific Director Mercator Ocean

Copernicus Land Monitoring Service (CLMS)

Pan-European and Local components
Tobias Langanke (Tobias.Langanke@eea.europa.eu)
Matteo Mattiuzzi (Matteo.Mattiuzzi@eea.europa.eu)
Global component
Marco Clerici (Marco.CLERICI@ec.europa.eu)

Copernicus Climate Change Service (C3S)

Anca Brookshaw (ECMWF) & Paco Doblas Reyes (Institut Català de Ciències del Climas) – Seasonal forecast
Hans Hersbach & Gionata Biavati (ECMWF) – Reanalyses
Christel Prudhomme & Gwyn Rees (Centre for Ecology and Hydrology) – Hydrology
Else Swinnen (VITO) & Roselyne Lacaze (HYGEOS) & Christoph Paulik (TU Wien) – Land surface
Per Undén (SMHI) – Regional reanalyses
Michael Buchwitz (IUP Bremen) – CO_2 and CH_4
Robert Vautard (IPSL) & Laurent Dubus (EDF) – Energy
Jean-Noël Thépaut & Dick Dee (C3S) & Adrian Simmons (ECMWF) – In-situ observations in general
Michael Zemp (WGMS) – Glaciers

Copernicus Emergency Management Service (CEMS)

Emergency management - European Flood Awareness System (EFAS)
Peter Salamon (peter.salamon@ec.europa.eu)

Emergency management - European Forest Fire Information System (EFFIS)
Jesus San-Miguel (jesus.san-miguel@ec.europa.eu)

Copernicus Security Service (CSS)

European Border and Coast Guard Agency (FRONTEX)
Daniel Hernandez Sanz (Daniel.Hernandez@frontex.europa.eu)

Support to EU External Action (SEA/EU SatCen)
Denis Bruckert (Denis.Bruckert@satcen.europa.eu)

Maritime Surveillance Component (EMSA)
Pedro Lourenco (Pedro.LOURENCO@emsa.europa.eu)

ANNEX B – ADDITIONAL INFORMATION

Copernicus Security Service (CSS)

European Border and Coast Guard Agency (FRONTEX) Total Area of Interest

Copernicus Security Service – Border Surveillance – Area of Responsibility (Credit: FRONTEX)

Area of Interest coordinates

-43°34'4.12''W	17°7'33.26''N
-43°34'4.12''W	64°48'11.62''N
42°45'56.47''E	73°35'12.52''N
42°45'56.47''E	17°29'58.22''N

ANNEX C IOC OCEANOGRAPHIC DATA EXCHANGE POLICY

IOC Oceanographic Data Exchange Policy

During its twenty-second session (24 June - 4 July 2003) the IOC Assembly adopted Resolution IOC-XXII-6 entitled 'IOC Oceanographic Data Exchange Policy.

IOC OCEANOGRAPHIC DATA EXCHANGE POLICY

The Intergovernmental Oceanographic Commission,

Recalling Resolution XX-11 on Oceanographic Data Exchange Policy (1999),

Noting:

(i) WMO Resolution 40 (Cg-XII) which defined a policy and practice for the international exchange of meteorological and related data and is intended to promote the free and unrestricted exchange of basic data,

(ii) The "Statement on Data Management Policy for Global Ocean Programmes" as submitted by the IOC Committee on IODE (Recommendation IODE-XIV.6, December 1992) and adopted by the IOC Assembly at its 17th Session (Paris, 25 February–11 March 1993) (para. 220 of the Summary Report of the Session),

Considering the reports of deliberations of:

(i) The Ad hoc Working Group on Oceanographic Data Exchange Policy (Paris, 15–17 May 2000),

(ii) The First Session of the Intergovernmental Working Group on IOC Oceanographic Data Exchange Policy (Brussels, 29–31 May 2001),

(iii) The Second Session of the Intergovernmental Working Group on IOC Oceanographic Data Exchange Policy (Paris, 17–18 June 2002),

Adopts the IOC Oceanographic Data Exchange Policy as detailed in the Annex to this Resolution.

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Financial implications: none

Annex to Resolution XXII-6

IOC Oceanographic Data Exchange Policy

Preamble

The timely, free and unrestricted international exchange of oceanographic data is essential for the efficient acquisition, integration and use of ocean observations gathered by the countries of the world for a wide variety of purposes including the prediction of weather and climate, the operational forecasting of the marine environment, the preservation of life, the mitigation of human-induced changes in the marine and coastal environment, as well as for the advancement of scientific understanding that makes this possible.

Recognising the vital importance of these purposes to all humankind and the role of IOC and its programmes in this regard, the Member States of the Intergovernmental Oceanographic Commission agree that the following clauses shall frame the IOC policy for the international exchange of oceanographic data and its associated metadata.

Clause 1

Member States shall provide timely, free and unrestricted access to all data, associated metadata and products generated under the auspices of IOC programmes.

Clause 2
Member States are encouraged to provide timely, free and unrestricted access to relevant data and associated metadata from non-IOC programmes that are essential for application to the preservation of life, beneficial public use and protection of the ocean environment, the forecasting of weather, the operational forecasting of the marine environment, the monitoring and modelling of climate and sustainable development in the marine environment.

Clause 3
Member States are encouraged to provide timely, free and unrestricted access to oceanographic data and associated metadata, as referred to in Clauses 1 and 2 above, for non-commercial use by the research and education communities, provided that any products or results of such use shall be published in the open literature without delay or restriction.

Clause 4
With the objective of encouraging the participation of governmental and non-governmental marine data gathering bodies in international oceanographic data exchange and maximizing the contribution of oceanographic data from all sources, this Policy acknowledges the right of Member States and data originators to determine the terms of such exchange, in a manner consistent with international conventions, where applicable.

Clause 5
Member States shall, to the best practicable degree, use data centres linked to IODE's NODC and WDC network as long-term repositories for oceanographic data and associated metadata. IOC programmes will co-operate with data contributors to ensure that data can be accepted into the appropriate systems and can meet quality requirements.

Clause 6
Member States shall enhance the capacity in developing countries to obtain and manage oceanographic data and information and assist them to benefit fully from the exchange of oceanographic data, associated metadata and products. This shall be achieved through the non-discriminatory transfer of technology and knowledge using appropriate means, including IOC's Training Education and Mutual Assistance (TEMA) programme and through other relevant IOC programmes.

Definitions
'Free and unrestricted' means non-discriminatory and without charge. "Without charge", in the context of this resolution means at no more than the cost of reproduction and delivery, without charge for the data and products themselves.
'Data' consists of oceanographic observation data, derived data and gridded fields.
'Metadata' is 'data about data' describing the content, quality, condition, and other characteristics of data.
'Non-commercial' means not conducted for profit, cost-recovery or re-sale.
'Timely' in this context means the distribution of data and/or products, sufficiently rapidly to be of value for a given application
'Product' means a value-added enhancement of data applied to a particular application.
To find out more about the process that led to the adoption of this Policy click here

Annex D - Index of Acronyms

A

ACTRIS	European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases.
ADCP	Acoustic Doppler Current Profiler - Used to measure water current velocities over a depth range.
AERONET	AErosol RObotic NETwork – A federation of ground-based remote sensing aerosol networks.
AGRHYMET	Regional agro-meteorological and hydrological monitoring organisation - A specialized agency of the Permanent Inter-State Committee against Drought in the Sahel (CILSS).
AirCore	Balloon hosted atmospheric profiler delivering vertical atmospheric profiles of CO_2, CH_4 and CO.
API	Application Programming Interface
Argo	International program that uses floats to observe temperature, salinity, currents, and bio-optical properties in the oceans.
Argo float	Ocean going float that measures ocean temperature, salinity, currents, and bio-optical properties.
AtlantOS	Research and innovation project aiming to optimise ansd enhance the integrated Atlantic Ocean Observing System

B

BGC	BioGeoChemical.
Bio-Argo	Programme for developing, testing and utilising ocean floats that measure BioGeoChemical parameters.
BOOS	Baltic Operational Oceanographic System.
BSRN	Baseline Surface Radiation Network – Aimed at detecting changes in the Earth's radiation field at the Earth's surface which may be related to climate changes.

C

C_6H_6	Benzene.
C3S	Copernicus Climate Change Service.
CAMS	Copernicus Atmosphere Monitoring Service.
CC4BY	ICOS data licence (Creative Commons Open Data License with attribution).
CEMS	Copernicus Emergency Management Service.
CH_4	Methane.
Chl-a	Chlorophyll-a - A specific form of chlorophyll used in oxygenic photosynthesis.
CLMS	Copernicus Land Monitoring Service.
CLRTAP	Convention on Long-range Transboundary Air Pollution - A broad framework for co-operative action on air pollution under the United Nations Economic Commission for Europe (UNECE).
CMEMS	Copernicus Marine Environment Monitoring Service.
CO	Carbon monoxide
CO_2	Carbon dioxide
COSYNA	Coastal Observing SYstem for Northern and Arctic seas - Programme to develop an integrated observing and modelling system to describe the environmental status of the North Sea and Arctic coastal waters.
CPR	Continuous Plankton Recorder.
CRM	Certified Reference Material.
CSS	Copernicus Security Service.
CTD profiles	Ocean Conductivity, Temperature and Depth profiles – Delivering seawater salinity, temperature and pressure measurements.

D

DATA-MEQ	Data Management, Exchange and Quality Working Group - EuroGOOS working group to help improve harmonization and integration of European marine data.
DBCP	Data Buoy Cooperation Panel - Programme coordinating the use of autonomous data buoys to observe atmospheric and oceanographic conditions, over ocean areas where few other measurements are taken.
DG GROW	Eurpean Commission - The Directorate-General (DG) for Internal Market, Industry, Entrepreneurship and SMEs.

E

E-AIMS	Euro-Argo Improvements for the GMES Marine Service - To improve the European contribution to the international Argo observing system and to prepare the next scientific and operational challenges for in-situ monitoring of the world ocean.
ECMWF	European Centre for Medium-Range Weather Forecasts.
ECOMET	Economic interest grouping of the National Meteorological Services of the European Economic Area.
ECOOP	European Conference on Object-Oriented Programming - European forum for researchers, practitioners, and students in topics related to programming languages, software development, object-oriented technologies, systems and applications.
ECV	Essential Climate Variable.
EDF	Électricité de France S.A.
EEA	European Environment Agency.
EFAS	European Flood Awareness System.
EFFIS	European Forest Fire Information System
EIONET	European Environment Information and Observation Network
EMODnet	European Marine Observation and Data Network
EMSA	European Maritime Safety Agency
EMSO	European Multidisciplinary Seafloor and water-column Observatory
enerMENA	Energy for the Middle East and North Africa – Programme for the sustainable realization of Concentrating Solar Power (CSP) power plants in the MENA region.
EOOS	European Ocean Observing System.
EOV	Essential Ocean Variable.
ESFRI	European Strategy Forum on Research and Innovation - To support a coherent approach to policy-making on Research Infrastructures (Ris) in Europe and to facilitate multilateral initiatives leading to the better use and development of RIs.
EUMETNET	Grouping of 31 European National Meteorological Services that provides a framework to organise co-operative programmes between its Members in the various fields of basic meteorological activities.
Euro-Argo	European contribution to Argo program - The European infrastructure for Argo program that aims at sustaining 1/4 of the global network and enhance coverage in European seas.
EuroGOOS	European Global Ocean Observing System - Identifies priorities, enhances cooperation and promotes the benefits of operational oceanography to ensure sustained observations are made in Europe's seas underpinning a suite of fit-for-purpose products and services for marine and maritime end-users
EU SatCen	European Union Satellite Centre.
EUVDB	European Ultra Violet Data Base - A repository and quality analyzer for solar spectral UV irradiance.
EV	Essential Variable.

F

FAPAR	The Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) project.
Ferry Box	Automated instrument packages on ships of opportunities, providing various oceanographic data.
FixO3	Fixed point Open Ocean Observatory network – Aims to integrate European open ocean fixed point observatories and to improve access to these for the broader community.
FRONTEX	The European Border and Coast Guard Agency (EBCG).

G

GCOS	Global Climate Observing System.
GEO	Global Earth Observation programme.
GEOSS	Global Earth Observation programme System of Systems.
GFCS	Global Framework for Climate Services.
Gliders	An autonomous underwater vehicle used to collect ocean data.
GOOS	Global Ocean Observing System.
GO-SHIP	The Global Ocean Ship-based Hydrographic Investigations Programme.
GOSUD	The Global Ocean Surface Underway Data project - Intergovernmental Oceanographic Commission (IOC) programme designed as an end to end system for data collected by ships as they traverse their ocean tracks.

GPCP	Global Precipitation Analysis.
GROOM	Gliders for Research, Ocean Observation and Management.

H

H2020	Horizon 2020 – EU programme.
HCHO	Formaldehyde.
HF Radar	High Frequency Radar.
HYGEOS	A small company specialized in Earth observation through satellite remote sensing and planetary radiative transfer.

I

I4C	Carbon 14.
IAGOS	In-service Aircraft for a Global Observing System - Aims to establish a sustainable distributed research infrastructure for the global observation of atmospheric composition.
IBI-ROOS	Ireland-Biscay-Iberia Regional Operational Oceanographic System
ICOS	European Integrated Carbon Observation System
IG^3IS	Integrated Global Greenhouse Gas Information System.
INSPIRE	Infrastructure for Spatial Information in the European Community
INSTAC	In-situ Thematic Assembly Centre.
INTAROS	Integrated Arctic Observation System, multidisciplinary system for the integration of atmosphere, ocean, cyyosphere and terrestrial sciences.
IOC	International Oceanographic Commission.
IODE	International Oceanographic Data and Information Exchange.
IP	Implementation Plan.
IPSL	institut pierre Simon Laplace.
ITP	Ice Tethered Profiler - An autonomous instrument for sustained observation of the Arctic Ocean.
IUP Bremen	Institute of Environmental Physics, Bremen.

J

JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology.
JERICO-NEXT	Joint European Research Infrastructure for Coastal Observations. NEXT aims to strengthen and enlarge the European network to support delivery of high quality data and information for European coastal seas.

L

LAI	Leaf Area Index.
LIDAR	Light Detection And Ranging - A surveying method that measures distance to a target by illuminating that target with a pulsed laser light, and measuring the reflected pulses with a sensor.

M

Mini Logger	Temperature data logger for marine and freshwater environments.
MONGOOS	Mediterranean Operational Network for the Global Ocean Observing System.

N

N_2O	Nitrous oxide.
NCDC	National Climatic Data Center – Now known as LCEI National Centres for Environmental Information.
NDACC	Network for the Detection of Atmospheric Composition Change.
NEUBrew	NOAA-EPA Brewer Spectrophotometer Ultraviolet and Ozone Network.
NO_X	Nitrogen oxides.
NOAA	National Oceanic and Atmospheric Administration.
NODC	National Oceanographic Data Centre.
NOOS	National Data Buoy Center (NDBC) Ocean Observing System.
NRT data	Near Real-Time Data.

O

ODON	Optimal Design of Observational Networks - EU research project.
Odyssea	Association devoted to marine biology and any other matter related to the oceans.
OGC	Open Geospatial Consortium
OPEC	Operational Ecology project - Developing and evaluating ecosystem forecast tools to help assess and manage the risks posed by human activities on the marine environment and improve our ability to predict the "health" of marine ecosystems.
OSE	Observing System Experiment.
OSSE	Observing System Simulation Experiment.

P

Pb	Lead air pollution.
PM2.5	Particle pollution - Produced from all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.
PM_{10}	Particle pollution - Produced from sources including crushing or grinding operations and dust stirred up by vehicles on roads.
Profiling Float	Oceanographic instrument platform that changes its buoyancy in order to move vertically in the ocean, repeatedly collecting data that spans a range of depths.
PV	Photovoltaic.

Q

QA/QC	Quality Assurance/Quality Control.

R

RI	Research Infrastructures.
ROOS	Regional Ocean Observing System.
RT	Real-Time

S

SANGOMA	Stochastic Assimilation for the Next Generation Ocean Model Applications
SeaDataCloud	SeaDataCloud project (2016-2020), aims to considerably advancing SeaDataNet Services and increase their usage, adopting cloud and high performance computing technology for better performance.
SeaDataNet	Pan-European infrastructure for ocean & marine data management.
SEA	Copernicus Security Service component 'Support to EU External Action'.
SMHI	Swedish Meteorological and Hydrological Institute.
SO2	Sulphur dioxide.
SODAR	Meteorological wind profiler - Measures the scattering of sound waves by atmospheric turbulence to derive wind speed at various heights above the ground and the thermodynamic structure of the lower layer of the atmosphere.
SOT	Ship Observations Team - In situ network of the global module of GOOS, coordinated by JCOMM.

T

T/S or T&S	Temperature and Salinity
TACs	Thematic Assembly Centres.
TAO TRITON	Tropical Atmosphere Ocean Triangle Trans-Ocean Buoy Network project - in-situ data collection of oceanographic and surface meteorological data from the Pacific Ocean for monitoring, forecasting, and understanding of climate swings associated with El Niño and La Nina.
TCCON	Total Carbon Column Observing Network.
TEMA	Training Education and Mutual Assistance.
Tesac	Data format, which is in a Traditional Alphanumeric Code unsed for oceanographic observations.

TSP	Total Suspended Particulate - Solid matter or liquid droplets from smoke, dust, fuel ash, or condensing vapours that are suspended in the air.
TU Vien	Technische Universitat, Vienna, Austria.

U

UNESCO	United Nations Educational, Scientific and Cultural Organization.
UNESCO-IOC	United Nations Educational, Scientific and Cultural Organization - Intergovernmental Oceanographic Commission.
UNFCCC	United Nations Framework Convention on Climate Change.
UV	Ultraviolet.

V

VITO	An independent European research and technology organisation working in the areas of cleantech and sustainable development, with expertise in climate change.

W

WDC	World Data Centre.
WGMS	World Glacier Monitoring Service.
WIGOS	World Meteorological Organisation Integrated Global Observing System.
WMO	World Meteorological Organisation.
WMO-IOC JCOMM	World Meteorological Organisation-Intergovernmental Oceanographic Commission - Joint Technical Commission for Oceanography and Marine Meteorology.
WMO GAW	World Meteorological Organisation - Global Atmospheric Watch.
WMO OSCAR	World Meteorological Organisation - Observing Systems Capability Analysis and Review.

X

XBT	EXpendable BathyThermographs - Used to collect temperature observations of the upper 1km of the ocean.
XCTD	EXpendable Conductivity-Temperature-Depth profiler – Observe vertical temperature and salinity profiles in polynyas and other openings surrounded by sea-ice.