Sustainable Marine Environmental Information Services to Meet Collective European Needs

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1 Conduct of the Study

The combined SEPRISE kick-off and GMES Workshop on Services for Marine Operational Forecasting held in November 2004 generated a list of currently and soon to be available information products and those which are required and thought to be feasible in the longer term. The Workshop also agreed the essential components of 'best practice' in marine service provision and a number of relevant recommendations.

At an early stage and subsequently, the SEPRISE Workshops have approved the strategy of building a sustainable, integrated operational system based on the GMES Marine Core Service (MCS), with integrated, coordinated upstream *in situ* and EO data provision and downstream services dedicated to meeting individual needs for services. The political momentum of GMES, the selection of the marine domain as one of the GMES Fast Tracks, the strong support of ESA and their Member States for the transition to operational missions, the conviction of the oceanographic community that the architecture of an MCS is correct, based as it is on the highly successful architecture for operational meteorology, and the strong European focus on environmental protection and climate change, helped to sustain this decision. Additionally, the GMES initiative came at a time when oceanographic science had received substantial support from Member States and the Commission, through the Framework Programmes 5 and 6 and in the wider international community through programmes such as WOCE and GODAE.

The EuroGOOS Chair, and author of this plan, was appointed as chairman of the Marine Core Service Implementation Group (MCS_IG) following acceptance of the Service as one of the three GMES 'Fast Tracks', based on the successful kick-off meeting during 27–28 October 2005. Most of 2006 was taken up by preparation of a draft Strategic Implementation Plan and consultation on its findings and recommendations. The MCS Strategic Implementation Plan forms the basis of this plan. The strategy is elaborated in chapter 4 of this report.

To ensure that the MCS is user driven, the IG is composed of representatives of the EEA, OSPAR, EMSA, the Maritime Policy Task Force, the ESF, EUMETNET and EuroGOOS (through the chair). HELCOM and UNEP/MAP receive working papers and reports and are able to comment as appropriate. ESA and EUMETSAT are observers and have attended most of the meetings. The IG has formed working groups composed of members of the IG and participants in the MERSEA IP to carry out particular studies to guide its work. The IG met in plenary on 5 May, 26 June, 9 October and 23 November 2006 to agree the issues to be addressed, allocation of responsibilities for the preparation of working papers, the line to take on the identified issues and to review draft documents. The Chairman took on the responsibility of:

- Drafting a number of the working papers and the Final Report
- Presenting the emerging results to four meetings of the GMES Advisory Council (GAC), composed of EU Member State representatives
- Consulting EuroGOOS members at the Annual meeting held in Exeter during 15–16 November 2005, the SEPRISE meeting held in Brussels during 12–13 January 2006, the SEPRISE Workshops held in Stockholm during 28 February – 1 March 2006 and in Limassol on 4 October 2006, and the NOOS Annual meeting held in Lowestoft on 5 September 2006.
- In recognition of the importance of the Marine Environmental Strategy as a driver for operational oceanography, presentation of the emerging results of the work at a preliminary meeting of European Marine Monitoring & Assessment (EMMA) WG held in Copenhagen during 3–4 April 2006 and presentation of the then draft MCS Strategic Implementation Plan during a further EMMA meeting in Copenhagen during 23–24 October 2006.

The Chairman has also been active as an advisor to the Commission on the conduct of the MERSEA IP and as a member of the Strategy Group of the MarCoast GSE for the Project Board and ESA. These roles have been useful in keeping abreast of these projects and their potential contribution to this deliverable.

The MCS Strategic Implementation Plan was presented to and was well received by the GAC at a meeting held in Brussels on 14 February 2007. It is now providing guidelines for the preparation of responses to the FP7-SPACE-2007-1 call – see www.gmes.info/183.0.html for more information.

2 Introduction

2.1 The MCS Strategic Implementation Plan (SIP)[1]

The SIP provides guidelines and prioritisation for implementation ratified by the GMES Advisory Council. This includes a strategy for the provision and access of coordinated upstream EO and *in situ* data required by the MCS and some major downstream services. In the short term it is envisaged that the SIP will guide current R&D and demonstration activities being pursued with EC and ESA funding, in particular those that will be funded within the Space Theme of FP7. It is hoped that the SIP will also provide a roadmap for a long-term, sustainable Marine Core Service able to support a wide range of downstream services, some of which can be seen today but many of which will only emerge when the MCS is in place. With this in mind, an effort has been made to describe the rationale for the guidelines and priorities, not simply the proposals themselves. It is hoped that the MCS Strategic Implementation Plan will give confidence to the EC and Member States that their expectations of GMES in the marine domain have a good chance of being fulfilled and that their continued support is warranted.

To fulfil its mandate and build upon the conclusions of the initial Workshop, the IG has addressed a number of specific issues:

- **The purpose, scope and functionality** of the Marine Core Service, especially of its global and regional components
- **Links and interfaces between the Marine Core Service and downstream services**, including the requirements of downstream services for MCS products, their dependencies in terms of product delivery (timeliness, quality control, …) and the associated contractual issues
- **The space infrastructure required by the Marine Core Service**, including the requirement for and continuity of current European capacities (space and ground segments) operated by EUMETSAT, ESA and national agencies, and the possibilities for international cooperation (complementary or shared capacities)
- ***In situ* infrastructure for the Marine Core Service**, especially the requirement for and sustainability of European capacities and their contribution to international systems as well as the European coordination to manage these capacities
- **Structure and governance of the Marine Core Service**, including, for example, the sharing of activities and operational responsibilities between the service provision partners and the associated service level agreement process, defined between the GMES Management Authority, representing the MCS user communities, and, for example, a MCS Provider Consortium, including the impacts of this service level agreement on the consortium partner status and on service information policy.

The first two of these issues are fundamental to the design of the overall system and are reviewed at some length in chapter 3 before the implementation roadmap is developed and described; the proposed resolution of the other identified issues is described at the appropriate point in the roadmap.

2.2 Simulations – how to respond to ‘What if?’ questions

Much policy-making raises questions of the kind ‘What if we were to do x or y?’ as a precursor to formulating a response to the unwelcome impact of a pressure. This requirement was identified at the October 2005 workshop and the overall system needs to respond to it.

The requirement can be met in a number of ways, but in essence, the capability is needed to run experiments in which all of the important processes affecting the outcome are mimicked and the consequences of the hypothesised action are tested. Scaled physical models can be used for this purpose to test the consequences of changing the morphology of an estuary for example, but on the scale of the oceans and seas, recourse has to be made to numerical earth system[2] models of sufficient scope to internalise all the important processes and feedbacks between them. The models developed to assimilate data and model

1. GAC/2007/7

oceanographic processes for the MCS are certainly capable of mimicking internal processes sufficiently well and therefore test the consequences of possible changes to inputs, e.g. of the consequences of large-scale changes to nutrients from land-based sources, but they are not designed for this purpose.

2. In general such models need to embrace the important, relevant processes on/in the land, sea, cryosphere and atmosphere, and interactions between them.

Fortunately suitable world class earth system models have been developed and do exist within Europe – to assess the consequences for climate of increased greenhouse gas emissions and deforestation for example. The obvious strategy is not to attempt to replicate such (major) capabilities but for the intermediate and downstream users to contract out for them when required. That approach is advocated.

3 The Purpose, Scope and Functionality of the MCS

3.1 Purpose

The purpose of the MCS is to make available and deliver a set of basic, generic services based upon common-denominator ocean state variables that are required to help meet the needs for information of those responsible for environmental and civil security policy making, assessment and implementation.

The ***Policy drivers*** have been identified as:

- Regional Conventions between Member States and the EC – OSPAR/HELCOM/Barcelona
- 6th Environmental Action Plan; in particular its Climate Change and Marine Environmental Strategy[3] components
- The Sustainable Development imperative which is written into the Rome Treaty and is now being developed through the Green Paper on Maritime Policy[4]
- Relevant existing EU Directives, such as the Water Framework Directive in its application to coastal waters
- Concerns over civil security which manifest themselves in two broad ways. Firstly over the safety of life and property in the marine environment, and through the recognition that whilst there are risks to be managed through well designed warning systems, defences and other preventive measures, major natural hazards and man-made accidents will occur that also need to be managed. The Prestige accident in 2003 and flooding in Holland and England in 1953 and in New Orleans in 2005 are examples. Secondly, the concept of civil security, in the sense of protection against illegal activities, clearly exists as a driver for GMES and hence for the MCS and appropriate downstream services. However that concept has not yet been developed beyond the realisation that any such protection requires maritime surveillance and means of vessel identification and tracking, as well as the actual and forecast state variables to be provided by the MCS.

All of these require long-running data sets to define the mean state[5] of the marine environment, fluctuations about that, past trends and future predictions of change (particularly in an era of uncertainty about climate) to establish baselines for environmental management and design criteria for structures operating in the environment. In addition, short range predictions (out to several days ahead in general and with a few hours lead time with greater accuracy) are required particularly of hazardous conditions, but also for the efficient conduct of every day operations.

The MCS must be designed and implemented to meet these needs in a reliable, easy-to-use, operational[6] manner, with information of useful precision and stability.

The Lisbon agenda is also an important policy initiative for GMES as a whole, noting that the programme is included in the Quick Start Programme and expected to foster the creation of new, innovative information-based services and knowledge.

3.2 The nature of the MCS

The information services required to fulfil this purpose need to have global and pan-European scope. The variables about which information is provided will be domain-specific; i.e. likely to vary between the regional seas and global oceans and between high and mid latitudes.

3. See section 4.6.1
4. The **Maritime Policy Green Paper** has emphasised that commercial sectors such as shipping, fishing, oil exploration, offshore construction, aquaculture, and tourism, and public sectors such as coastal protection, defence, search and rescue, R&D and government policy-making all need data on past, present and future meteorological, oceanographic, hydrographic and ecological state of the seas and the oceans. Global-scale monitoring is required to meet this need and the EU is being encouraged to set up a European Marine Observation & Data Network to provide sustainable, improving access to information. EuroGOOS has responded to the Green Paper by suggesting that the MCS and its upstream and downstream components provide an excellent basis for that.
5. Here we mean the physical, biological and chemical state of the environment, in general. The need for the biological component is likely to be expressed in terms of the state of ecosystems, and habitats; the chemical component in terms of pollutants and nutrients.
6. Here we mean having guaranteed availability to meet user needs.

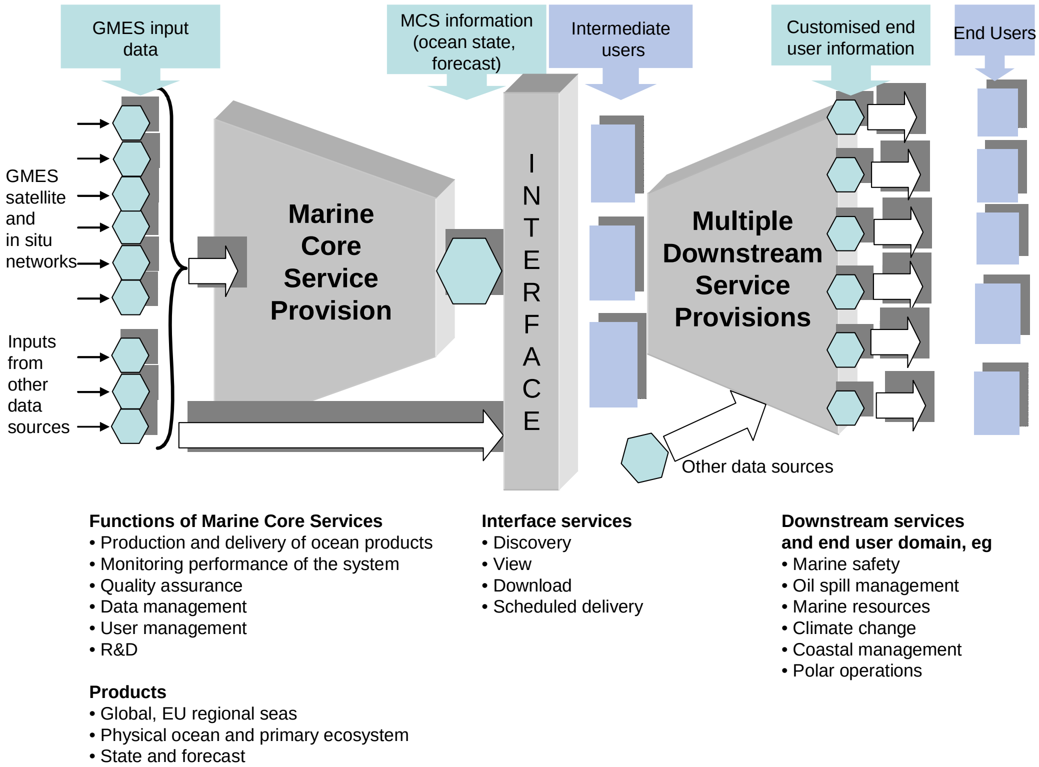

Figure 1 *the position of the MCS in the overall chain of service delivery from GMES input data to the provision of multiple information services to end users.*

The MCS is conceived as one part of a processing chain which operates on observational and other forms of data to help create tailored information services to meet a wide range of end user needs. Almost all such end user services relating to the marine environment require access to information about the state and dynamics of the oceans and seas. The MCS provides that information to intermediate users who combine this with other forms of information and data to provide customised downstream services for end users. The concept is illustrated in Figure 1 and further elaborated in section 3.2.

The implementation of the overall chain needs to have some flexibility. As components of downstream services are developed to serve multiple uses, it may be more efficient for them to be provided as part of the MCS.

The envisaged MCS variables and products are described in the Appendix. The applications / areas of benefit that these are capable of serving are indicated in Table 1.

3.3 The scope of the MCS and its rationale

At the present time it is entirely feasible, with useful accuracy, to describe the physical state of the oceans and seas, including the relevant dynamics, from the surface to the sea floor, provided that representative data are available to:

a) resolve the main dynamical and physical characteristics sufficiently often to span the period of useful predictability of current numerical models (a few weeks)

b) describe the forcing from the atmosphere.

It is valuable, and for some purposes and locations essential, to know the extent and nature of ice cover and the flux of fresh water from the major rivers. The nature of the bottom topography is clearly important but that is sufficiently well known, on the broad scale at least.

Some *in situ* measurements are available from research vessels to characterise the biological and chemical state of the seas but these are often sparse in time and space and tend to be concentrated in coastal waters. They are rarely available in near real-time[7]. They do allow identification of long period trends at (hopefully) representative locations. Some limited properties can be inferred more frequently and extensively from EO data, e.g.

7. Some moorings and the FerryBox technology are capable of near real-time biogeochemical reporting. New technologies such as gliders and ARGO floats can also collect biogeochemical data and are very promising for the provision of near real-time data.

primary productivity and sediment levels from ocean colour measurements. The presence of some pollutants, in particular oil spills and excessive nutrients, leading to extensive algal blooms at the ocean surface, can be inferred from EO data too. But there is no doubt that additional *in situ* data are needed to define the biological and chemical state more comprehensively.

Time-dependent models of the oceans and seas are crucial for maximising the value of intermittent sparse data to deliver the best possible descriptions of their past, current and future state. Physical models are well developed and available with increasing resolution for the global oceans and regional seas. Methods for nesting limited area, higher resolution models within global and regional models are available too. Models of biological and chemical processes in the seas that are capable of providing useful analyses and predictions of at least the lower trophic levels of ecosystems remain in the research domain. Substantial powerful computing facilities, housed and operated to achieve 24-hour/7-day-a-week availability are essential to deliver truly operational services and such facilities are required to conduct development of ecosystem models for future operational use. These exist in the National Meteorological Services, National Oceanographic Agencies or major research facilities that have a mandate to provide operational services, but are few in number.

Table 1 *A generic summary of areas of benefit, product lines, intermediate and final users*

Area of benefit	Products	To intermediate users[a]	Final user
Climate research	Comprehensive and inferred observational data sets reanalysed in state of the art models	Climate research centres	Ocean and climate research; validation of scenarios. Policy-making on climate change
Marine Environmental Protection	State and impact data and associated indicators	EEA, OSPAR, HELCOM, Barcelona, National environmental agencies	DG ENV, Policy makers, general public
Seasonal forecasting and extended weather forecasts	Initial ocean conditions; reanalysis	ECMWF, National Meteorological Services (NMS)	Agriculture, insurance, energy, transport; public safety preparedness; research
Marine safety	High resolution ice/sea state and ocean current forecasts	NMSs, National Oceanographic Agencies, National Marine safety agencies, maritime transport industry	Search and rescue, drifting object management; extreme wave forecast preparation; marine transportation
Fisheries, ecosystems	Physical conditions; re-analysis of past conditions	National marine and fisheries institutes	ICES, DG FISH, National fisheries; research
Shipping and offshore industries	High resolution ice/sea-state and current forecasts for operations: reanalyses for design	Value adding service companies	Operation support, ship routing, structure design criteria, risk assessment; EMSA
Oil Spill management	Temperature, wind, wave and current data	Responsible National marine agencies and European Marine Safety Agency (EMSA)	Affected coastal public authorities and businesses
Civil Security	Temperature, wind, wave and current data	Customs and Excise, Coast Guards	DG TREN, Immigration and drug control agencies, police forces
Marine Environment, Ecosystems	Boundary and initial conditions, data products	National Coastal monitoring and forecasting system	National environmental or marine agencies; National WFD reporting; Coastal management.

a. In practice, the actual intermediate users may be contractors appointed by the listed agencies or institutes

With these caveats, and the hope that continuity of EO data can be maintained and *in situ* monitoring improved, it is clear that an MCS that can fulfil its purpose, given the availability of the necessary computing, data collection and processing facilities and skilled staff to operate them.

The descriptions above provide necessary but insufficient criteria to define the scope of a practical, deliverable MCS. It is also necessary to place some limits on the areal extent and resolution of common services to be provided as part of the MCS and those which will be more properly and efficiently provided as downstream services – see below. There are strong arguments (see section 4.3.1) for recognising the particular characteristics and needs for MCS products on a global scale, for the oceans which border Europe and their shelf and regional seas. But the needs for descriptions of the physical, biological and chemical state of every estuary or coastal zone cannot be met by the MCS. This would require high resolution models of every EEZ to be maintained and operated when needed, for example to predict the evolution of major accidental releases of pollutants as part of the MCS. There are important specialised, normally national, needs such as these which should be met by downstream services, coordinated where necessary at a regional or EU level. Such services will be supported by the MCS through the provision of broader scale state descriptions, in particular in the form of the boundary and initial conditions for high resolution models of coastal or otherwise defined domains of interest.

The rationale for this conclusion is both political and economic.

Firstly, the principle of subsidiarity notes that: "nothing should be done by a larger and more complex organisation which can be done as well by a smaller and simpler organisation". The architecture that is proposed in section 4.3.1, a system of systems, from global to regional, follows that tenet. The coastal domain, where the greatest diversity of end users arises, is not considered part of the MCS, since it can be served most effectively at a national and local level by downstream services. If the MCS was to maintain the capability to provide diverse, high-resolution services everywhere, for all possible purposes requiring information about the common denominator state variables, it would need to be a very large and complex organisation. Furthermore, it would still be necessary for the MCS to interface with intermediate users to combine the state variables with all other local information necessary to resolve real social, economic and environmental issues, so there would be few savings and the potential for complex, unmanageable interfaces. This is not to deny that some of the 'front end' functions of the MCS (see section 4.5.1) could and should not be carried out at regional centres, particularly where they can make use of existing capabilities.

Secondly, the substantial investment that will be needed to provide MCS services requires the number of computer-intensive modelling/data assimilation centres at least to be kept to a minimum, consistent with the recognised large-scale variation in the global and regional European oceans and seas and a desire for some technical competition at the margin. The envisaged consolidation and integration to relatively well-equipped centres brings the potential for improved value for money and scientific quality, as well as robustness to the system. In the spirit of the European Research Area, the integration of the MCS can play a significant role in drawing the intellectual resources and tapping the expertise of a wide community. **The Workshop which led to the decision for Fast Track MCS implementation, and much prior discussion, recognised this and concluded that the number of such centres should be of order 10. Provided that information from the MCS is freely and readily available for further elaboration in downstream services and there is a sharing of tools, that conclusion was upheld by the IG and is an integral part of this plan.** This will release public and private downstream service providers from the need to duplicate the services provided by the MCS and enable them to focus on the many localised, tailored services that are required by end users.

The intention to provide significant EU funding through the FP7 Space Programme to support the further development and demonstration of the MCS, whilst investment in downstream service provision is likely to fall mainly to Member States and commercial organisations, provides a countervailing pressure to maximise the size and scope of the MCS. The IG believed this pressure to be unfortunate because it could deliver an unsustainable outcome in the long term unless managed carefully. It would be a huge mistake to support development and demonstration of a multiplicity of pre-operational systems (potentially with sub-optimal performance) through FP7 which could not be sustained. This again argues for an MCS which is as small as necessary to deliver its fundamental purpose at the European scale. This is not to deny

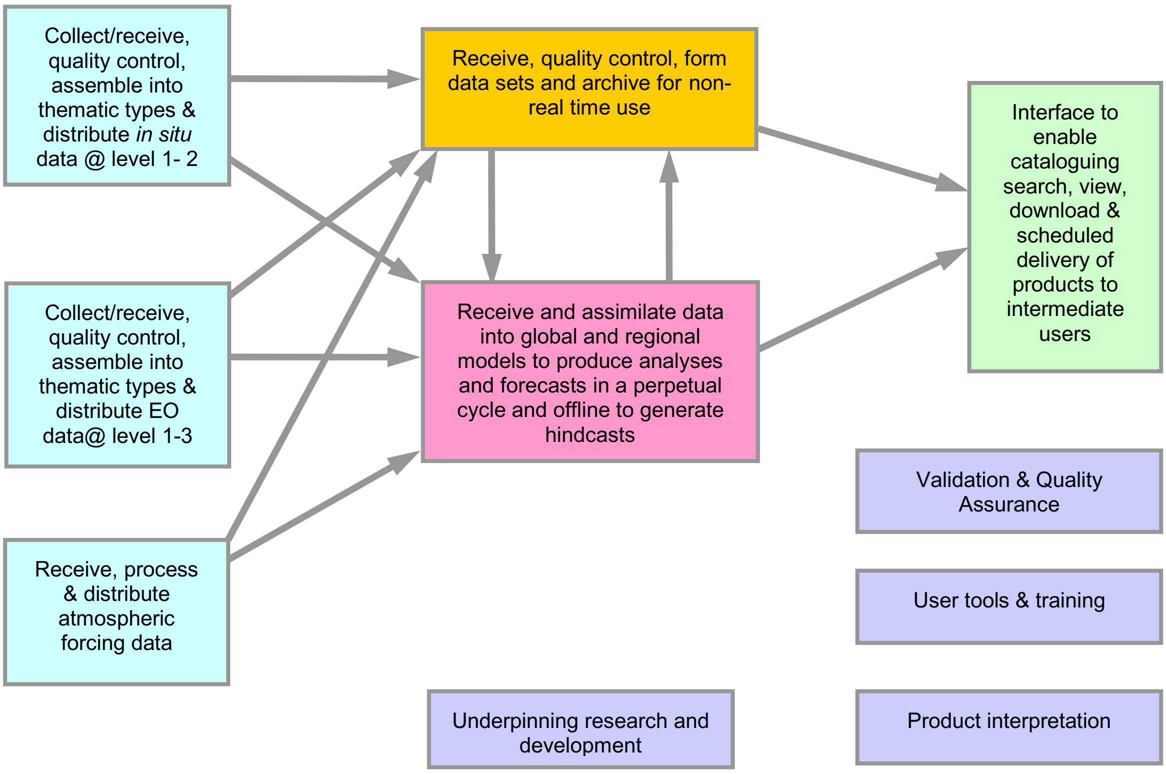

Figure 2 *The essential functions of an MCS*

the need to build up expertise in Member States to use the MCS information for their specific needs. The issue of funding is discussed further in section 4.5.5.

3.4 Marine Core Service Functionality

Recognising that the MCS must collect, quality-control and process data, using numerical models and standard analytical tools, to produce and deliver hindcasts, analyses and forecasts, the required operational functions of an MCS are as illustrated in Figure 2.

Briefly the functions are to:

- Acquire data from the ground segment of the space-based observing systems and *in situ* networks. Typically these will be at level 1 or 2[8]
- Acquire atmospheric forcing data (atmospheric winds, temperatures, fluxes) from NMSs and ECMWF
- Assemble these into QC thematic datasets (i.e. specific data types such as sea surface temperature, salinity profiles…) suitable for the generation of more extensive data sets for subsequent use, analytical products and assimilation by ocean models. Much of this has to be carried out in near real-time, but data of the highest quality can be assembled in slower time
- Run numerical ocean models in near real-time to assimilate the thematic data and generate analyses and forecasts from them to an agreed and generally perpetually repeating cycle, which uses information from earlier forecast cycles as well as the most recent thematic data. The centres also need to operate off-line to produce reanalyses / hindcasts from the high quality data

8. CEOS has defined a number of data/product levels for use in Earth Observation. It is helpful to use a common nomenclature in discussing data processing.
Level 0 Data: Raw data after restoration of the chronological data sequence for each instrument, i.e. after demultiplexing of the data by instrument, removal of any data overlap due to the data dump procedure and relevant quality checks. Raw instrument data information (telemetry packets) is maintained during this process.
Level 1a Data: Instrument data in full resolution with radiometric and geometric (i.e. Earth location) calibration computed and appended but not applied.
Level 1b Data: Calibrated, earth located and quality controlled data, expressed as radiance or brightness temperature, in the original pixel location, and packaged with needed ancillary, engineering and auxiliary data.
Level 1c Data: In case of the IASI spectra, level 1b data after application of the apodisation function.
Level 2 Product: Earth located pixel values converted to geophysical parameters, at the same spatial and temporal sampling as the level 1b data.
Level 3 Product: Gridded point geophysical products on a multi-pass basis.
Level 4 includes the use of other data sources, e.g. model results etc.

- Prepare products suitable for external service provision at the 'Interface' shown in Figure 1 and Figure 2. That interface must have discovery and viewing capabilities and the ability to download specific products in response to requests. It must also be able to deliver, probably quite large volumes of data, routinely to an agreed schedule to meet the needs of specific intermediate users.

The required support functions are elaborated further in section 4.5.3; they are essentially to monitor and validate the performance of the MCS to assure the quality of its products, provide customer support in the form of interpretive tools and training, and prioritise and oversee the research and development needed to sustain the MCS.

3.5 The concepts of upstream providers, intermediate users and end users

The division into upstream and downstream components of the service chain is based on the imperative "to produce information once but use it many times" for specific public or commercial end user applications. Not all environmental information services are suitable for delivery in this way, but wherever there is a need for information about the current or predicted future state of the environment, widely defined, it makes sense to try to meet this once rather than many times. This is particularly true when, as here, substantial resources (computers and skilled people) are needed to assemble basic state data, assimilate them and use high-resolution, complex models to predict future states. This lesson has been learned and applied extensively in operational meteorology and recent research has demonstrated that it is equally applicable to operational oceanography. Figure 1 exemplifies the chosen architecture of the chain.

Upstream providers collectively comprise the providers of relevant EO and *in situ* data and atmospheric forcing information required by the Marine Core Service and directly by the intermediate users – see below. In simple terms it is expected that these upstream providers will:

- Develop, construct and operate the space and ground based facilities necessary to deliver the required data; in fulfilling the delivery function, they will calibrate instrument measurements and convert them to geo-located estimates of geophysical, chemical or biological variables (i.e. generate level 2 data sets)
- In some areas produce coherent, quality controlled data sets, possibly from multiple sources (i.e. generate level 3 products).

The purpose of the MCS is set out in section 3.1 and the required functionality is described in section 3.4.

The **intermediate users** are recipients of the data and products generated by the MCS from the combined use of atmospheric forcing information and basic *in situ* and EO data, models and data assimilation. Typically they will generate information services that downscale the larger scale MCS products to the local scale and increase the number of analysed, predicted state variables at the local level to meet needs. Therefore, such services will generally require the capture of additional forms of data to deliver economic or societal benefit. Typically such additional data might be high-resolution meteorological forcing in delivering storm surge predictions, socio-economic in a policy development context, pressures (e.g. catch and fisheries effort data) to set alongside state variables from the MCS to understand observed environmental impacts, assets at risk in managing a hazardous event, vessel identification and tracking information for maritime surveillance, etc. The resulting information services are **downstream services**. It is recognised that downstream services today might become core services in future, as multiple uses are found for particular data sets and types of information. Therefore the definition of these two service streams has been couched in general terms to provide flexibility in future.

Ultimately the public will validate, or not, the benefit of these services. But, as characterised in Table 1, in general **end users** can be categorised as:

- Governmental departments/agencies, at EU or Member State level, that require marine products and information for developing and validating policies respectively (e.g. DG Environment, DG Fish, DG TREN, National Departments of Environment, …)
- "Public downstream services" that actually implement public policies, and are frequently part of the mandate of national agencies (e.g. flood risk managers, environmental protection agencies)
- Providers of maritime services of various kinds, (e.g. shipping, port operations, coast guards …)
- Commercial and industrial end users (e.g. offshore oil, gas and aggregate extraction companies, fishing companies, …).

4 The Strategic Implementation Plan

4.1 Principles and sources of guidance used

In developing proposals for an MCS supplied by upstream data providers and able to supply intermediate users with the common denominator products that they require, the IG adopted a number of principles:

a) GMES is a joint initiative of the EC, ESA and Member States so it is assumed that all have a vested interest in its success, judged by the value of the information services that it delivers, and will be willing to commit commensurate resources and adapt working practices to achieve that success.

b) To be judged successful in these terms, the MCS must be genuinely driven to support intermediate users on behalf of their end users, all of whom will appreciate the value of its services and be able to determine its output and influence its evolution.

c) Given the impossibility of operating an IG containing a large number of users, representatives from EEA, EMSA, EUMETNET, EuroGOOS and the Maritime Policy Task Force have federated intermediate and end user needs. They were able to draw on their own and colleagues' experience of existing services in Member States and from relevant ESA GSEs.

d) The MCS must be designed and implemented to meet identified needs in a reliable, easy-to-use, operational manner, with information of useful precision and stability.

e) There is considerable scope for integration and coordination of existing efforts.

The MCS must:

- make maximum use of past investment and existing facilities
- be sustainable on an operational basis, with appropriate governance and funding built into the system.

Guidance has been obtained as follows:

a) Advice on scientific/technical matters and priorities for R&D from the ESF

b) Current user needs and experience in meeting them from EuroGOOS members and their publications, the EEA and EMSA

c) Proffered national guidance and proposals

d) Published material on best practice from GOOS, GCOS, and Regional Conventions

e) Findings and capabilities developed from FP5/6 projects: the MERSEA IP in particular

f) The experience of the ESA GSEs: MarCoast and Polar View in particular

g) Experience from EUMETNET in generating efficiencies through collaborative efforts: in particular in coordinating *in situ* observing systems.

4.2 System[9] foundations

In keeping with the imperative to ensure that the needs of end users are understood and acted upon, and to make maximum use of past investment and existing facilities, these matters have been reviewed to establish sound foundations upon which to build the System.

The identified needs are summarised in section 3.1 and the Appendix.

The System foundations can be characterised as:

a) The existing infrastructure in the form of *in situ* observing systems, EO systems and data collection and modelling systems that are in place to provide environmental information services

b) Those information services themselves

c) Previous and current R&D projects that have or are delivering relevant understanding, tools and capabilities – including but not limited to the Operational Forecast Cluster of FP5/6.

The IG's task of gaining an appreciation of these foundations and that of SEPRISE has been greatly aided by the proceedings and papers of the four triennial EuroGOOS conferences, stretching back to 1996.

9. In this context the System comprises the upstream data provision, MCS and intermediate users providing downstream services.

4.2.1 Existing infrastructure

Existing infrastructure was identified in the form of:

- *In situ observing systems* funded by Member States to meet national needs, e.g. for defence, safety and environmental protection, to fulfil national obligations under Regional Conventions and Directives, sustain research programmes and participate in international programmes partially funded by non-EU states. Generally these have not been designed for multiple uses and the research programmes are rarely funded on other than a short term basis. They do tend to use the technologies listed in section 4.4.2, to a variable extent. Any coordination that takes place seems to be on an *ad hoc*, best endeavours basis, based on the premise that the sum of the parts will probably represent a satisfactory outcome. The SEPRISE project has established that monitoring sites are generally placed to serve very local needs, that the resulting networks are of highly variable density (see Figure 6) and there is little natural inclination to exchange data beyond near neighbours, although the project has demonstrated that wider regional exchange can be facilitated in practice.
- *Space-based Earth Observation systems* funded by Member States via their respective ESA and EUMETSAT membership, or through national programmes. The investments are used to sustain research programmes, meet operational needs, e.g. in defence and meteorology, develop and demonstrate technology, improve industrial capacity and build markets. Access is also gained on various terms to EO systems funded and operated by non-European Space Agencies. The resulting data are used for utilitarian purposes.

  For the marine domain, the technologies that are used and the data requirements and priorities are shaped by the requirement to monitor state, as described above, and what it is feasible to measure to useful accuracy from space-based instruments. Appendix 3 of GAC/2007/7 and section 4.4.1 of this report characterises current needs, on the basis of the demonstrated capabilities of the current infrastructure. The key issue is that, with the exception of the (EU and non-EU) meteorological (and inaccessible defence) systems, none of the current systems capable of meeting these needs are truly operational. As a result, continuity of data supply cannot be guaranteed. This apart, Europe has access to all the necessary capabilities and technologies to meet those needs, in particular through ESA and its Member States and their commitment to GMES.
- *Ocean Modelling* funded by Member States to meet national needs, e.g. for defence, safety and environmental protection and to sustain research programmes. There are large numbers of the latter, built firstly for research purposes, impossible to describe in a plan such as this, and arguably with an uneasy connection to the needs described in section 3.1, other than through the results of those research programmes. Those that are relevant to implementation of the plan, i.e. capable of being operated operationally, are identified with their attending data management infrastructure in section 4.5.2. It is important to recall again that models that have the necessary, demonstrated performance capabilities require major investment in very powerful computing facilities that are sufficiently robust (e.g. with appropriate attention being paid to backed-up power supplies and telecommunication links and to staffing). There are rather few of these and most are linked in some way to the meteorological services.
- *Operational information dissemination* of the real-time component and high-volume satellite and model output at least is always going to be an issue. Fortunately this is not a problem which is unique to the System and so the presumption has to be that it will be solved through the use of existing commercially or otherwise available solutions – not through bespoke methods. The EUMETCAST facility is an operational facility currently available for distribution of the SAF data referred to below. The internet provides a suitable vehicle for the exchange of small amounts of data in the form of ftp files and for the discovery/view functions – see section 4.5.3.

4.2.2 Relevant existing information services

Relevant existing information services include those provided:

- As public goods by Member State agencies for international Conventions such as HELCOM, OSPAR, Barcelona and ICES and for/via the EEA, for example as environmental or climate assessments
- As public goods by Member State agencies in the form of national environmental assessments and to help secure safety of life and property. Typically the core information services for the

latter are provided by the National Meteorological Services for elaboration in downstream services by national agencies according to their particular mandates (e.g. flood risk management, pollution control, etc.)

- as public and private goods provided by EuroGOOS (www.eurogoos.org/) agencies, some of whom provide prototype MCS-type and downstream services, e.g. as analyses (and jointly with others in the form of the data services provided by SeaDataNet) and model-based forecasts of sea level, temperature and currents for the regional seas, oil slick and algal bloom forecasts
- as thematic data services by European agencies for their Members, e.g. the EUMETSAT Ocean & Ice SAF (www.osi-saf.org/), ocean forcing information by ECMWF, marine observations by EUMETNET and the ESA rolling archive providing access to products obtained from the ERS and ENVISAT missions
- as service demonstration projects delivering relevant geo-information on an operational basis (e.g. ESA GSEs: Polar View (www.polarview.org/) for ice services and MarCoast (marcoast.info/) for oil spill and water quality services)
- as private goods by public and private organisations offered to their customers to confer commercial advantage, e.g. for enabling increased efficiency and/or effectiveness (offshore industries, transport).

All of these have some lessons to offer and provide points of departure for the System design. In particular:

- The high and known quality of the data required to meet the legal requirements of the Conventions
- The tested architecture of the Meteorological Services provision as a useful model for that of the MCS and its downstream services
- The value of the critical mass and the resulting world class performance that can be achieved by carrying out some functions at a European level
- The possibility of creating and satisfying markets by tailoring and fusing data within specialist services, particularly where these can be served, in part at least, by core information generated once and used many times.

There are difficulties too. As far as the Conventions are concerned, the time between “sampling events” and publication of assessed results is presently about three years. The involvement of an operational MCS, as described in section 4.6.1, may be able to reduce this delay.

4.2.3 Past and current R&D projects

Some of these were funded within the 5th and 6th Framework Programmes, others through ESA or by national investment. It is neither necessary nor possible in this plan to describe them all but the following examples have contributed substantially to the building blocks of an effective, efficient MCS and the associated upstream observing systems and downstream services.

From the Framework Programmes, in the form of:

- Observing systems foundations – EDIOS, ODON
- *In situ* observing systems – GYROSCOPE, ANIMATE, BRIMOM, FerryBox
- EO-based observing systems – SOFT, GAMBLE
- Capacity Building – MAMA, PAPA, ARENA, GRAND
- Sea-level monitoring – GAVDOS, ESEAS-RI
- Safety of Shipping – MaxWave, IRIS
- Ice Services – DAMOCLES
- Pre-operational pilots – TOPAZ, IOMASA, MFSTEP
- GMES preparations – MerSea Strand 1, OCEANIDES
- Integrated Projects – MERSEA, ECOOP

The MERSEA IP is currently developing and demonstrating the capabilities required of an MCS as discussed further in sections 4.5.1 – 4.5.3.

From ESA projects:

- Medspiration – developing a European service for near real-time precise sea surface temperature
- GlobColour – developing a European service for ocean colour.

The GODAE Sea Surface Temperature Pilot Project (GHRSST-PP) is a good example of an international project that has spun up a global service, with European contributions from the Medspiration project and EUMETSAT Ocean & Sea Ice SAF, and which now provides an excellent basis for a truly operational, comprehensive European SST service within the MCS, to mirror the US Global Data Analysis Center (GADC).

In addition there have been innumerable national R&D projects which have developed relevant specific capabilities, many of which are now contribute to operational services. These include:

- MERCATOR (France) – global and regional models
- FOAM (UK) – global and regional models
- Coriolis (France) – a data management system
- MONCOZE (Norway) – for coastal environment management
- SmartBuoy (UK) – *in situ* physical, biological and chemical monitoring
- Alg@line (Finland, Estonia) – automated ship-borne monitoring
- Seatrack Web (Sweden/Denmark) – an oil drift forecasting system
- POL (UK) – a coastal observatory
- POSEIDON (Greece) – an *in situ* monitoring and forecasting system
- ADRICOSM (Italy) – an *in situ* monitoring and forecasting system for the Adriatic Sea.

All of these have brought or are bringing some new insights and tools of relevance to operational oceanography and hence to the MCS and downstream services. Unsurprisingly the recent MERSEA IP is of particular importance in developing and demonstrating capabilities that are of fundamental importance to an operational MCS. Much of the ensuing design is based on the exploitation of those capabilities and lessons learned. There is more to do to develop observing systems, other data collection mechanisms and forms (e.g. surveys) and models to provide the information for soundly-based ecosystem management and the ECOOP IP is needed to help push these capabilities further towards the coast. It is very important that the MCS, as an operational system, has a closely coupled R&D programme – another important lesson learned in operational meteorology, and elsewhere.

4.3 The proposed strategy for the MCS and its application

The requirement is to be responsive to intermediate users and, through them, to end users, who will respectively deliver and use the information generated as outlined below to inform policy-making, validation and implementation in the areas outlined in section 4.2.1. The chosen strategy to accomplish this is to build on the foundations described above by making maximum use of existing systems and past investment in knowledge and tools. The existing systems are distributed so the design of the System must be distributed. In effect a system of largely existing systems and those under development will be the goal.

The strategy must then be to analyse the required functionality of the component systems to establish whether and if so where they exist or might easily be upgraded to perform as required. The reports of the WGs on the space-based and *in situ* infrastructures are used for this, together with other knowledge and insights obtained as discussed in section 4.1. Remaining gaps are identified, at least in functional terms and hopefully with some candidates to fill them. Where possible a road map for that process is suggested and priorities are established and recommendations made.

The suitability of the strategy is demonstrated in section 4.6 through a small number of end-to-end case studies of its envisaged application.

4.3.1 Architecture of the MCS

The key step is to recognise that modelling of the marine environment can and needs to be carried out at different scales in different domains and that biological and chemical processes take place within the context of the prevailing physical environment. This recognition leads to the adoption of two categories of nesting[10] of models; (i) physically from the global, to the regional, to the national, to the local and (ii) nesting of ecosystem process modelling within an appropriate physical model.

For (i), the actual choice of domains is determined by the combination of physical geography and user needs. Thus:

- The Mediterranean, Baltic and Black Seas have their own particular physical and ecosystem characteristics largely defined by their bathymetry, fluvial inputs and limited but important exchanges with their adjoining seas.
- The Arctic Ocean is predicted to be the location of the most rapid and dramatic climate changes during the 21st century, with the potential of major ramifications for mid-latitude climate. It

10. In principle a variable-scale model can achieve a similar economy of computing resource by concentrating high resolution where it is needed and relaxing to larger scales elsewhere. But the models that are readily available for actual and near-operational use are largely based on the use of a fine-scale model covering a small domain embedded within a model of larger scale and domain. Ideally there is two way exchange of properties at the boundaries, but one way exchange from the large to the small is also practised. Models of biological and chemical processes require specification of the physical domain in which they take place. These are imported from a physical model.

also plays a major role in the freshwater balance of the North Atlantic and is a very hostile environment.

- The North West shelf is one of the most complex in the world in terms of the intensity of marine exploitation, multiplicity of industries, services and social amenities, complexity and detail of regulation, adjoining population density and industrial development. It is also subject to input from large European rivers, agricultural run-off and sensitivity to climate change.
- The North Atlantic plays a major role in the global circulation and has significant effects on European weather and climate. It provides the boundary conditions directly for the North West shelf and interacts strongly with the Arctic Ocean.
- Seasonal and climate prediction are impossible without knowledge of the three-dimensional state and dynamics of the global ocean. Europe has global interests requiring access to global information.

It is envisaged that the MCS will comprise at least one operational modelling and data assimilation activity for each of these domains, with an exchange of boundary conditions as necessary, e.g. between the global and ocean basins and their shelf seas, and between the enclosed regional seas and their adjoining ocean or shelf sea. The resolution of the models is not prescribed but should aim to be state-of-the-art for provision of the common denominator data that are required from the MCS.

- Many examples of the adoption of this architecture can be cited; it is almost ubiquitous in its application in the research domain. Figure 3 and Figure 4 are taken from a presentation by J.I. Allen of the Plymouth Marine Laboratory at the MERSEA Annual Science meeting held in London during March 2006.

In Figure 3, in an operational context, the North Atlantic and Atlantic Margin Models might contribute to the MCS, whilst the higher resolution models would take boundary conditions and be employed in the provision of down-stream services that could justify the higher resolutions.

In addition, as outlined in section 3.4, the modelling centres need to be supported by data assembly centres and service delivery capabilities to carry out the operational and support functions described there. Before outlining how these might be implemented, it is noteworthy but not a coincidence that this architecture and rationale for segmentation into the global ocean and regional seas is reflected into the current organisation of operational oceanographic services by public bodies within intergovernmental programmes.

The Global Ocean Observing System (GOOS) www.ioc-goos.org/ has now organised its work into a global component, largely targeted upon understanding and describing the role of the oceans in

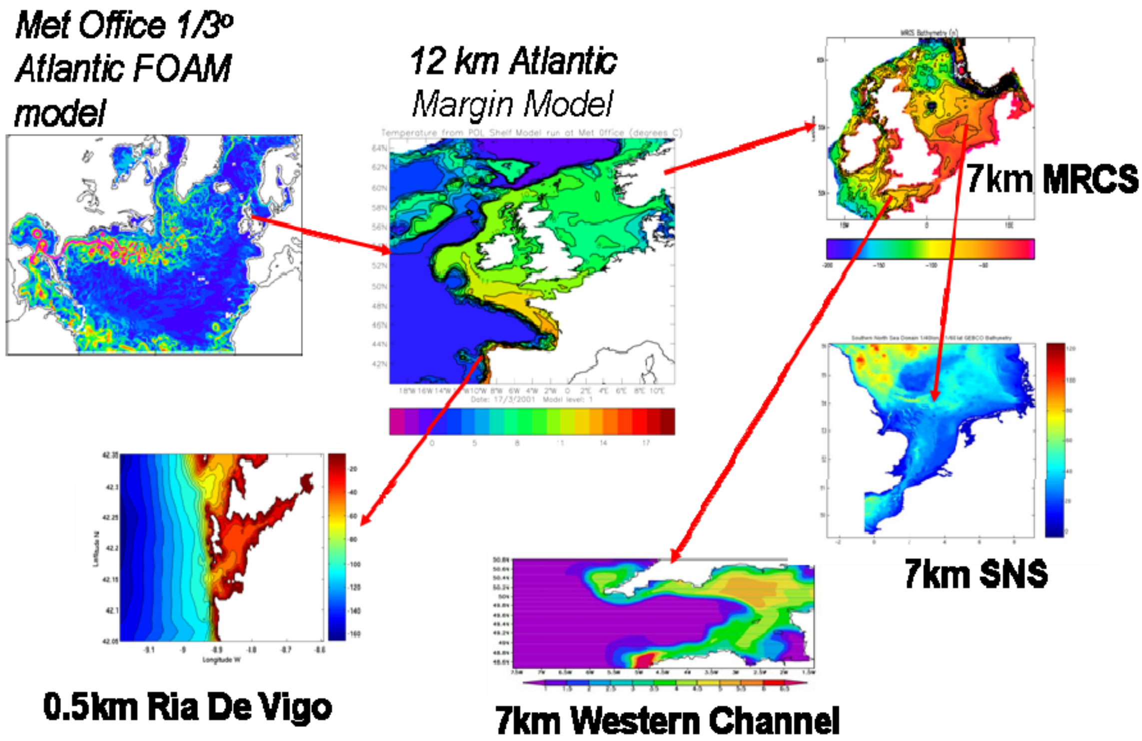

Figure 3 *An illustration of the use of physical nesting*

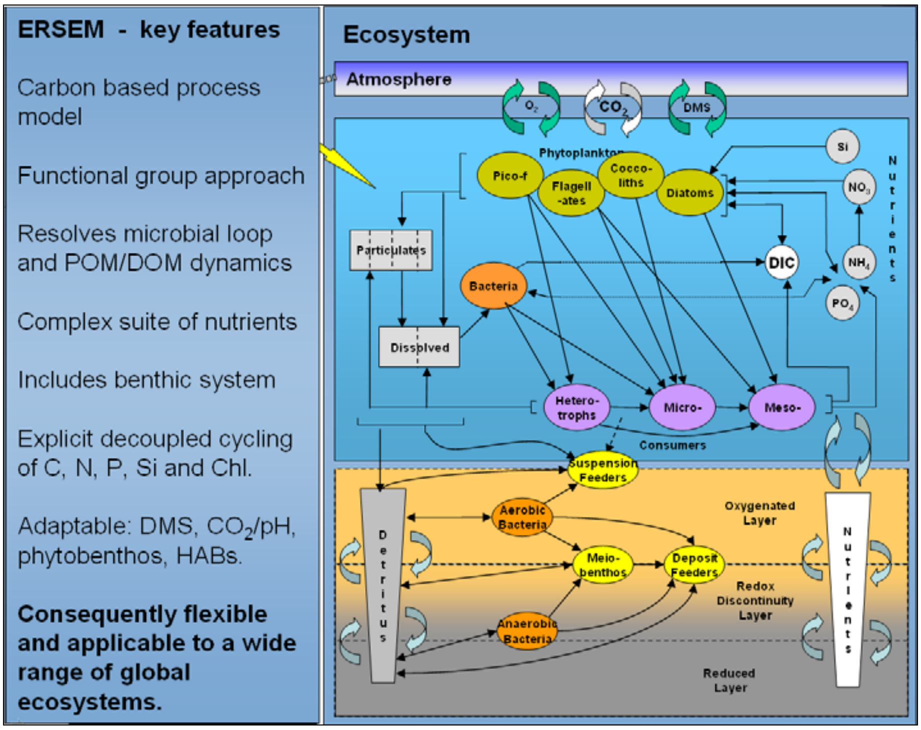

Figure 4 *The complex ERSEM model, which is nested in the physical POLCOMS in this example, aims to characterise benthic and water column processes.*

climate research and prediction, and regional observing systems developed by Regional Alliances. These regional observing systems aim to deliver information relevant to climate on these scales but also to the full range of policy issues described in section 3.1, for the European area.

EuroGOOS is the GOOS Regional Alliance for Europe. It liaises, at an institutional level, with MedGOOS in the Mediterranean to work with non-European States there and with Black Sea GOOS, to aid capacity building. Both are members of SEPRISE.

From this liaison and through its 33 member institutes, a number of Regional Task Teams have been set up based on the rationale above. Most of these have now made formal agreements to form Operational Oceanographic Systems/Networks (collectively known as ROOSes) to implement best practice and achieve effective day-to-day collaboration. At present these comprise:

- Arctic TT → AROOS, with a pending MoU designed to deliver operational oceanography in the Arctic
- Baltic TT → BOOS, with an MoU between 19 institutes to do likewise in the Baltic
- North West Shelf TT → NOOS, with an MoU between 19 institutes with an interest and relevant capabilities on the North West shelf, including the North Sea
- Biscay/Iberian TT → IBI-ROOS (MoU pending), with similar interest and capabilities in those shelf areas
- Mediterranean collaboration → MOON, secured by an MoU between 26 institutes in the riparian states
- Black Sea – to be created.

This is helpful because it provides a body of organisations, agencies and individuals that have learned to work together to provide operational oceanographic services and the associated infrastructure in the form of *in situ* observing systems, models, data assembly centres and communication/distribution systems to meet the needs of their end users.

The available evidence suggests that the implementation of standard technologies and the development and deployment of new *in situ* sensors are organised effectively at the regional level. A general knowledge of the physical, biological and chemical characteristics of the domain and appropriate logistic and technical expertise are generally available. Relatively rapid decisions can be taken and data exchange within a ROOS can be achieved. As indicated earlier, it is less clear that deployments are made other than to meet national priorities, i.e. regional coordination of network design is weak.

A global coordination is needed for homogenisation of sampling criteria at regional level, for exchange of experience and information, and for homogenisation of quality assurance/control. Global coordination is required to define common protocols and guidelines (quality assurance of field work, calibration – intercalibration of sensors, quality control procedures, standards, etc.). ESA, EUMETSAT, their Member States and national space agencies have been very effective in building up these capabilities for the exploitation of EO data.

4.3.2 Implementing the architecture

Figure 1 illustrates the functional architecture of the MCS in the context of data supply and downstream services. The functions which need to be carried out within an operational MCS are described briefly in section 3.4 and their connectivity is illustrated in Figure 2.

The MERSEA IP Consortium, which comprises 38 partners/contractors, has adopted a functional architecture for a demonstration of its perception of the MCS based on three Thematic Assembly Centres (TAC) and five Monitoring and Forecasting Centres (MFC), which it jointly describes as Thematic Portals (TEPs). The five MFC cover the main ocean domains: Global, Arctic, North West Shelves and NE Atlantic, Baltic, and Mediterranean (the Black sea remains to be integrated). Figure 5 provides a schematic of the interconnections between the TEPs, which generally has physical implementation but in practice consists of a collection of services distributed among providers' physical systems. Nevertheless, responsibility for the necessary services resides with the appropriate TEP. This is an attractive concept which, carried to a logical conclusion, should enable flexibility in service definition and provision with new players able to contribute, provided that they conform to 'the rules of the game'.

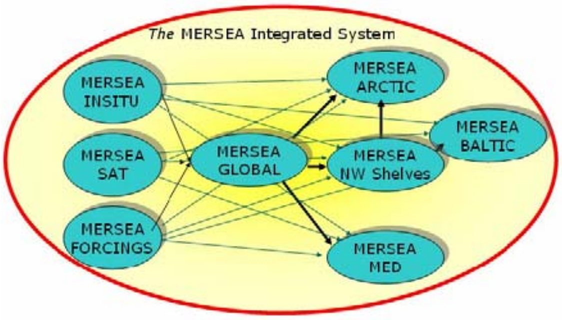

Figure 5 *Schematics of the System architecture, as it is being developed by the MERSEA Project, including Thematic Assembly Centres and Monitoring and Forecasting Centres.*

Figure 6 illustrates the connectivity of the TACs to the modelling/assimilation centres and delivery interface, which in a simplified way mirrors the required functionality, described in Figure 2, Figure 3 and Figure 4 and section 3.4. In this manifestation, the TACs are in charge of processing the required *in situ* and satellite data to meet the needs of the centres so that they can meet the needs of end users through the delivery interface. In addition, the forcing fields for the predictive models need to be secured from Numerical Weather prediction centres operated by the National Meteorological Services and ECMWF.

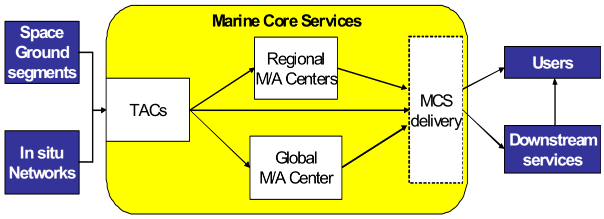

Figure 6 *Connectivity of the Thematic Assembly Centres, Modelling/Data Assimilation Centres and prototype MCS delivery interfaces being developed by MERSEA.*

The MERSEA consortium asserts that in their manifestation of the MCS:

"The components of this system of systems are linked by an information system that allows efficient transfer and exchange of data within the system, as well as easy access to the products by the users: timely delivery of high volume data and products; discovery, access, retrieval of products; monitoring of the MCS system efficiency, user desk; implementation of common procedures, formats, metadata as agreed by international standards (WMO, JCOMM).

The Information Management system will rely on a partnership of few partners that will dedicate real manpower to it. This partnership will perform coordination activities to ensure the link with international standardisation bodies, ensure the MCS catalogue maintenance, the user desk and the monitoring of the system as well as the maintenance and evolution of the MCS Information Management System.

The architecture conforms to the specifications of the WMO Information System (WIS), which is designed and implemented to serve the information exchange needs of NMS and other national centres, such as relevant non-NMHS agencies /users, national disaster management platforms, research, and international programmes. A major upgrade of the GTS, the WIS is being implemented from 2006; it is articulated around Data Collection and Production Centres (DCPC), whose mission is to fulfil an international responsibility for the generation and provision for international distribution of data, forecast products, processed or value-added information, and/or for providing archiving services; and to provide basic WIS functions such as metadata catalogues, internet portals and data access management."

Whilst care will be needed to ensure robustness and avoid single points of failure, implementation based on the MERSEA design, using the capabilities, tools, techniques, procedures and standards developed, adopted and being tested by the consortium, is an attractive way ahead and the IG has recommended their adoption for the MCS. A key feature of the design is its commitment to interoperability and distributed functionality. This should allow potential contributors to the MCS, who are not members of the IP, to augment its capabilities by contributing <u>needed</u> services, provided that they operate according to the rules which ensure interoperability and ease of use by intermediate users.

Before amplifying this proposal, by identifying the opportunities for such augmentation, the proposed implementation of the space based and *in situ* is developed.

4.4 The roadmap for the required upstream observational components

4.4.1 The required space infrastructure:

Space Segment

The MCS_IG set up a Working Group to provide:

- A description of the best case specification for those parameters required by the Marine Core Service that can be estimated from space.
- A description of possible degradations of these specifications and their likely impact upon the Marine Core Service.
- A description of the satellite systems and instrument specifications required to fulfil these various options.
- An analysis of the foreseeable satellite systems worldwide which would contribute to fulfil these various options.
- An analysis of the specifications to request to ESA and European national space agencies for their foreseeable projects to meet the requirements as well as possible for the lowest cost. In this analysis, the Sentinel 3, Jason series, MSG and METOP missions should be considered in particular.
- An analysis of the major gaps in terms of continuity, parameters, precision, space time coverage and their impact on the Marine Core Service.

Subsequently, the WG was asked to expand its deliberations to include the needs of intermediate users for EO data that would not be processed by the MCS but were nevertheless important for core services (i.e. required by multiple users) falling within the remit of GMES in the marine domain. This ensured that the case for operational SAR (e.g. Sentinel 1) was reviewed and confirmed, as appropriate. The work relied on existing ESA reports (Roadmap study, Sentinel MRDs) and background knowledge of the WG members.

Appendix 3 of GAC/2007/7 provides the recommendations of the Space Infrastructure WG that were endorsed by the MCS_IG. These are primarily addressed to ESA to secure the EO data required by the MCS and some major downstream services.

The main recommendations are:

- Continuity of observation is crucial. This is particularly critical around 2010 when data gaps could occur for several of the most critical observations. Decisions for developing the first of the GMES satellites must be taken most urgently.
- It is more critical to establish satellite series for sustainable service availability than to try optimising the specifications and designing for any one satellite and its instruments, if the latter leads to expensive, non-renewable satellites. Establishing satellite series should lead to significantly lower production costs.
- GMES should allow for research and technological developments. In particular, the possibility of embarking new instruments with the potential to meet GMES needs should be considered. Wide Swath altimetry and geostationary ocean colour are the two most important new technology developments that will benefit the GMES MCS in the long run.
- The Jason series (high accuracy altimeter system for climate applications and as a reference for other missions) is an essential and critical component of the GMES satellite

programme for MCS. Planning of Jason-3 must be a priority for GMES.

- The MCS requires a high-resolution altimeter system with at least three altimeters in addition to the Jason series. Sentinel-3 should include a constellation of two satellites, flying simultaneously, providing adequate coverage and operational robustness. Instrumentation costs for S3 should be reduced as much as possible to allow for a two-satellite system.
- Compared to the present design of S3 instrumentation, the priority for Sea Surface Temperature is for high accuracy dual view measurements. The large swath requirement has a much lower priority, in particular (but not only) if S3 is a two satellite system. As far as Ocean Colour is concerned, a sensor having a similar spectral resolution to MERIS is essential to meet the important shelf and coastal ocean water quality measurement requirements. The use of a SeaWiFS type of instrument (reduced number of channels) would serve only the minimum operational requirements for the open ocean.
- SAR data (Sentinel 1) are required, in particular, for downstream oil spill detection and sea ice monitoring. These are European core data in the sense that they have multiple uses and are required for downstream services in the marine domain. The requirement is for at least one and preferably two SAR missions in addition to the other non-European missions (e.g. RADARSAT)
- Access to other European and non-European (e.g. NPOESS, RADARSAT) satellite data in real-time is fundamental for the MCS.

The current offer from ESA and EUMETSAT is described in section 4.3.3 of GAC/2007/7, but in outline:

- The WG recommendations have been acted upon by ESA in the design of Sentinels 1 and 3.
- ESA has a mandate, as part of the GMES programme approved by the ESA Member States, to manage and coordinate the overall GMES space infrastructure including the access to all satellite data required by GMES, starting in 2008 and develop GMES-specific space infrastructure.
- At present, continuity of the Jason series of satellites is not secure but there are proposals under consideration by the EUMETSAT governing bodies.
- EUMETSAT has signalled its interest in acting as a data provider for the MCS through the provision of a consolidated real-time satellite data stream (including EUMETSAT, NOAA and other 3rd party data), with the exception of the SAR data.
- A consolidated ESA/EUMETSAT approach regarding the provision of EO data to the MCS is expected to be available during 2007.

The funding of the space component will come from both the ESA GMES programme and the FP7 Space Theme work programme, in agreement with the EC.

Part of the EC's FP7 funding (130 M€ total for 2007–2013) is planned to be made available to ESA in order to organise the coordinated and harmonised access to EO data for GMES services. In this framework, ESA is setting up agreements with EO mission data providers in Europe and worldwide.

Ground Segment

The Ground Segment of the Space Infrastructure required for the MCS and downstream services consists of two stages: (i) the basic processing that generates ocean data products from each individual sensor; and (ii) the additional processing that prepares data from multiple sources for operational tasks such as assimilation into ocean forecasting models. The first stage is a space agency task, following well-established EO practices. Previously responsibility for the second stage, if it takes place at all, has been shared in an *ad hoc* way between the space agencies, major data users and the EO science community. It is recommended that, for the MCS and intermediate service providers, this stage of additional processing should be performed by Thematic Assembly Centres (TACs) – see below – as an integral part of the MCS, tailored to the special requirements of operational users of particular data products. Implementation of these latter functions is described in section 4.5.1.

At the end of the SEPRISE project, detailed ground segment requirements and solutions remain to be addressed. But, for Sentinel 3 the main recommendation is likely to be that the GMES ground segment should develop robust interfaces with EUMETSAT Ocean & Sea Ice SAF and with the MCS satellite Thematic Assembly Centres. For Sentinel 1, the ESA rolling archive for ASAR has already demonstrated the capability to deliver near real-time SAR strips to support both routine Arctic sea ice monitoring and specific operational applications but in future clear guarantees will need to be provided for data delivery, as is the case for RADARSAT now.

4.4.2 The required *in situ* infrastructure

Appendix 4 of GAC/2007/7 contains the report of the *in situ* infrastructure WG. As in the case of the space infrastructure, it identifies the candidate technologies that are available for a composite operational *in situ* observing system capable of meeting the needs of an MCS serving the purposes identified in section 3.1; essentially they are those that are sufficiently tried and tested in such applications. Potentially useful technologies are identified for possible future use too.

Candidate observing systems comprise:

- Drifting Argo Floats for the measurement of temperature and salinity profiles to ~2000 m and, by tracking them, mean subsurface currents.
- Research vessels which deliver complete suites of multidisciplinary parameters from the surface to the ocean floor. The information collected is of high accuracy, quite necessary for various validation tasks, but very sparse, with intermittent spatial coverage, at very high cost of operations and with very limited real-time transmission. Such vessels should be encouraged to collect and report routine surface observations whenever they are underway.
- XBTs launched by research vessels and ships of opportunity underway for the measurement of temperature and salinity profiles to ~450–750 m depth.
- Surface Moorings capable of measuring subsurface temperature and salinity profiles, in particular those that measure continuously over long periods of time. Currents are often monitored and meteorological measurements are usually made too. Biofouling restricts the range of measurements that can be made from long deployments in the photic zone but surface salinity and biogeochemical measurements are attempted.
- FerryBox and other regional ship-of-opportunity measurement programmes for surface transects which may include temperature, salinity, turbidity, chlorophyll, nutrient, oxygen, pH and algal types.
- The Continuous Plankton Recorder (CPR) operated by the Sir Alister Hardy Foundation for Ocean Science which is towed from merchant ships on their normal sailings in order to monitor the near-surface plankton of the North Atlantic and North Sea on a monthly basis.
- The network of tide gauges which provides long term reference and validation sea level data.

Priorities for implementing these technologies in a coordinated manner to provide continuity and expand their utilisation, particularly to achieve near real-time data collection, are discussed further below.

There are several difficulties associated with the deployment of systems based on these technologies. Almost all are deployed for research purposes or as national contributions to ongoing environmental assessment programmes committed under the Regional Conventions. The latter tends to be concentrated in coastal waters and none deliver real-time data. Although some attempt has been made to coordinate deployments for individual research programmes, there is no mechanism at present to coordinate efforts to produce what might be described as a designed, composite network. The ODON project, listed in section 4.2.3, developed techniques for this but they are not known to have been used since the end of the project.

In order to make progress it does seem that two specific actions are needed. Firstly, **where the impact of the data is either global or pan-European it would be appropriate for an investment to be made by the EC on behalf of Member States or by the Member States acting together**. A case of this kind has been put for investment in the Argo technology within the European Roadmap for Research Infrastructures. It should be taken up. The impact of the CPR (measured by the maturity of the technology, the length and extent of the existing record and uniqueness and importance of the data which result) is a further candidate for such coordinated investment.

Secondly, there is a need and opportunity within the context of GMES, supported jointly by the Commission, ESA and Member States, **for integration and coordination of *in situ* monitoring efforts. On the regional scale, the EuroGOOS Regional Task Teams or Operational Oceanographic Systems/Networks (where they have been formed) would be ideally placed to take this on, perhaps coordinated overall by the EEA**[11]. In due course a EUMETNET-like arrangement might be put in place for this purpose. There is a need for a relatively small investment in efforts to identify where such actions would bear most fruit, and it is hoped that this can be found within the GMES Space Component of FP7. On the global scale the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) provides an appropriate mechanism at an intergovernmental level for planning and coordinating the acquisition, exchange and management of marine observations, although it would be helpful if a mechanism for developing a common EU position on this could be agreed, particularly if EU funding is provided for specific components of the global observing network, such as the Argo float technology.

At this stage the following priorities are suggested to guide these two actions:

- Sustain the Argo network: ~800 new floats to be deployed each year to replace the ones that fail. The European 'fair share' of this is about 250 units.
- Encourage the deployment of and collection of near real-time data from automated observing systems such as XBTs, Ferrybox and CPR on research vessels and ships-of-opportunity.
- Encourage Member States to continue to make marine observations that are useful for national purposes and, if shared in near real-time, would help sustain the MCS and downstream services. Specific examples include data from the tide gauge network and moorings.
- Investment is needed in carefully chosen well-equipped observatories at locations where data would provide valuable constraints on models.

4.5 Implementation of the MCS

4.5.1 Data collection, assembly and quality control within the MCS

Section 3.4 and Figure 2 outline the data collection and processing functions which are needed by the MCS. Figure 6 illustrates how the TACs are conceived within the MERSEA IP as the gateways through which observational data reach the rest of the MCS activities. Because of the diversity of different sources from which observational data are acquired, including different sensor types that sample the same ocean product in different ways, the TACs are needed to harmonise the data to facilitate their ingestion and assimilation into ocean forecasting models, and where appropriate to blend the data into analysis products for application by downstream users.

The TACs perform the following generic functions:

- Collection of level 1/2 data EO data from the ground segment of the space segment and relevant global and regional *in situ* networks.
- Real-time additional processing of level 2 data products received from European sensors, if necessary, to generate a common data format and product standard, facilitating an interoperable, harmonised data distribution system within the MCS.
- Near real-time level 3/4 processing activities, generating analysis products that correspond to the best estimate of an ocean property, blending data from various sources.
- Providing ready access to all data products using a spectrum of delivery methods to users, including real-time high volume data flow to the M/A centres and other operational users, solutions tailored to individual downstream services and web access for general public users.
- Delayed mode level 3/4 processing activities, including the updating of ancillary data as they become available within a few days of acquisition, as well as later reanalyses to produce higher quality products for climate monitoring.
- Quality control, validation and error characterisation, applying to the products and forecasts produced within the TAC. This activity needs to be underpinned by *in situ* observations. This does not remove the requirement for the space agencies to validate their basic level 2 products.
- Interfacing with international activities for the same type of data, and with TACs for other data types including *in situ* data for validation.
- Providing effective feedback on data products between users and the observing systems.

For processing EO data:

A number of collaborative multi-mission processing and dissemination facilities are already in place within Europe which perform the whole or part of the TAC functions for Altimetry, Sea Surface Temperature, Ocean Colour, Sea Ice and Winds, and which are already interfaced with different satellite ground segments. These represent a point of departure at least for the implementation of the MCS. They include:

11. According to its Mandate (especially Art 3, Council Regulation (EEC) No 1210/90 of 7 May 1990) EEA plays a key role in the European *in situ* monitoring community. In July 2004 EEA outlined its view of the objectives and role of *in situ* monitoring within GMES (GAC (2004)6), followed by a first progress report on the development of the GMES *in situ* monitoring component in November 2004 (GAC(2004)21.

- The CNES/CLS SSALTO/DUACS processing activity for sea surface topography.
- The ESA DUE project Medspiration and MERSEA, serving as the European component of the international GHRSST Project, delivers a set of harmonised SST products that are now being used operationally by a steadily growing user base. It has an upstream interface with EUMETSAT's Ocean & Sea Ice SAF and downstream interfaces with operational users.
- Ocean Colour data have been provided for MERSEA by a consortium led by EC/JRC. Merged products are also being developed by the ESA DUE GlobColour project. Some consolidation will be appropriate.
- CERSAT delivers Sea Surface Winds and fluxes (interfaces with Ocean & Sea Ice SAF).
- EUMETSAT's Ocean & Sea Ice SAF provides Sea Ice data from passive radiometry on an operational basis.

It is evident that each of these data types has its own distinct user requirements and its processing system has achieved a different level of maturity. Thus although the TACs will serve the same generic functions (see the left hand side of Figure 2), it is important to treat each ocean data product type individually. **Further consideration is needed to define the comprehensive requirements for fulfilling the TAC functions for each type of ocean data product. It also remains to be decided whether Regional TACs are required or whether regional data can be provided satisfactorily by a global TAC**.

In the future, it may be appropriate to consider developing a TAC for the processing of synthetic aperture radar (SAR) in which all SAR data over European waters are analysed to extract their information content concerning surface winds, wave spectra, oil pollution, ship detection, sea ice and other ocean phenomena. This could evolve from both geographically-limited sea ice analysis, and the service currently being developed by EMSA for routine monitoring of European SAR data to detect oil spills at sea. Oil spill detection and characterisation based on SAR data is being carried out by a combination of KSAT (Norway), Boost Technologies (France) and Telespazio (Italy) within the MarCoast project.

Regarding services tailored to the Arctic (see section 4.6.2) several new regular sea ice products need to be produced from wide swath SAR data such as:

1. Sea ice deformation including drift, convergence, divergence and shear zones
2. Presence of leads and polynyas
3. Identification of fast ice zones
4. Deformed versus undeformed ice and ice-ocean discrimination using polarisation ratio.

Algorithms to produce these products already exist, and are being further developed by ESA's GlobICE project. In due course, they should be implemented for operational use as part of the TAC function for sea ice.

Depending on the success of the ESA SMOS mission in measuring ocean salinity, there may be a need to develop a TAC for Sea Surface Salinity from 2010.

For processing *in situ* data:

- The Coriolis centre in France is providing the necessary functionality for global and some regional data within MERSEA.
- SeaDataNet, which aims to develop an efficient, distributed Pan-European Marine Data Management Infrastructure for managing the large and diverse marine data sets[12]. The objective is to network the existing professional data centres of 35 countries, active in data collection, and provide integrated databases of standardised quality, on-line.
- The TAC functions and assignments to meet regional requirements remain to be determined. The tasks are being carried out to some extent by the ROOSes (NOOS, BOOS, MOON) and exchange of the resulting data sets has been demonstrated very successfully in the SEPRISE project[13]. This has shown what is possible but also demonstrates the acute differences that still exist in the availability of data and products based upon them across Europe and the lack of integration of data sets across national boundaries.

For atmospheric forcing data:

ECMWF and several NMSs are capable of carrying out this function and do provide the required information routinely within MERSEA. Where coupled ocean-atmosphere models are being run operationally, two way coupling is possible.

12. www.seadatanet.org/
13. SEPRISE (2007): European Capacity in Operational Oceanography and the SEPRISE Demonstration, Deliverable D2 and D3

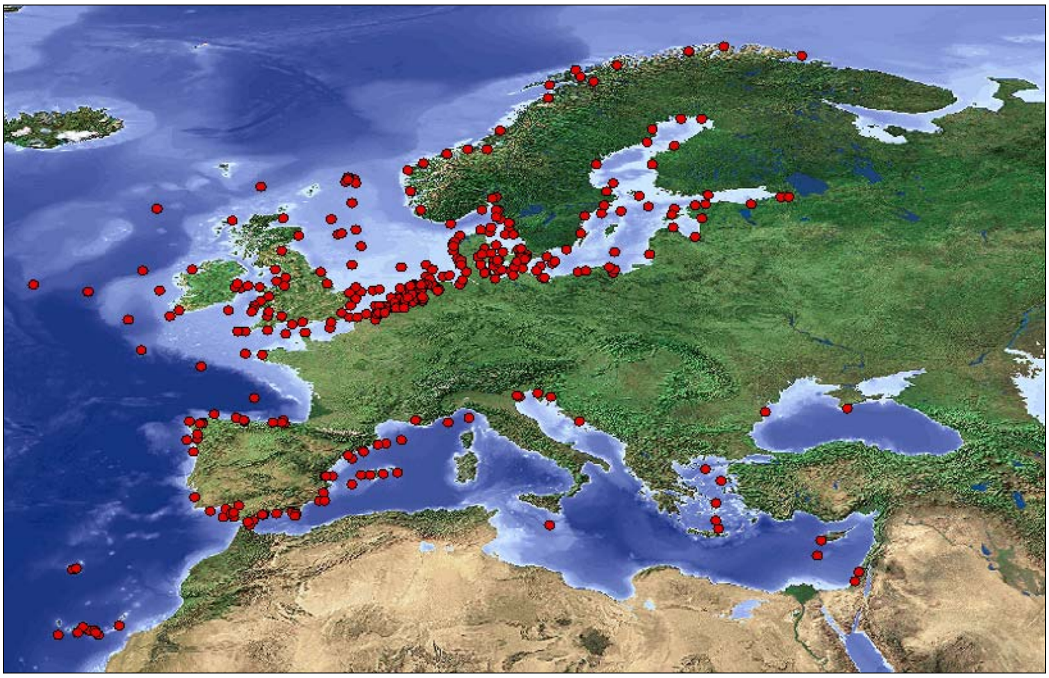

Figure 7 *Availability of data from fixed marine sites*

4.5.2 Ocean modelling and data assimilation

There are a relatively small number of global and regional ocean models capable of assimilating data and being run operationally in Europe and which could contribute to the MCS. The MERSEA IP Modelling TEPs are highlighted. Candidates known to be available are:

a) Global models, at various resolutions:
   - PSY3V1 operated by Mercator
   - FOAM operated by UK Met Office

b) For the Arctic / North Atlantic Oceans:
   - TOPAZ operated by NERSC/Met Norway

c) For the Baltic:
   - BALECO operated by FIMR
   - HIROMB operated by SMHI
   - BSHCmod operated by DMI +
     both of the latter require boundary conditions from the North West Shelf Area and therefore provide output in this domain too.

d) For the North West Shelf / North East Atlantic:
   - POLCOMS and FOAM respectively operated by the UK Met Office
   - PSY2V2 operated by Mercator

e) For the Mediterranean:
   - The Mediterranean Forecasting System operated by INGV

In addition, there are many examples of smaller domain models being operated for local, national purposes taking boundary conditions from the above and delivering specialised products, e.g. surges, ice, oil and S&R drift, eutrophication, etc.

There is substantial model development within MERSEA to:

- develop a new modelling framework – the NEMO code
- improve multivariate data assimilation methods
- increase model resolution
- incorporate ecosystem modules
- …

It is to be expected that this will deliver new, more capable global and regional ocean models.

Given the substantial investment needed in computing resources and skilled staff necessary to operate, maintain and develop them, and the agreement reached between the partners over the global and regional responsibilities of the individual centres, it will be wise to base the initial MCS, at least on the MERSEA assignments. However, if there is a possibility of providing a choice of model products to the downstream service providers that option should not be precluded, i.e. there should be no 'closed shop'. However, the services provided by the MCS consist of much more than model products. Any supplier will need to commit to the supporting services outlined in section 3.4 and described in more detail below.

4.5.3 Service generation, access, delivery and support

State-of-the-art capabilities are being developed by MERSEA for implementation in 2008. These aim to provide a portal for each domain, which comprises:

- A discovery service
- A viewing service
- A download service, which will need to include or be supported by the facility for sustained, scheduled delivery of high volume datasets for intermediate users, who are themselves running continuous operations that need such a service.

Product descriptions are to be standardised and available in a homogenous catalogue.

The MERSEA consortium is committed to a number of supporting activities that guarantee a level of quality in service provision and that follow standards to be spelled out in *Service Level Agreements*. They are all crucial to the success of the MCS and are broadly compatible with the desired functional analysis of section 3.4. Others who might aspire to contribute to the MCS should expect to provide equivalent services and commit to the same Service Level Agreements.

Five service lines are proposed:

a) SL1: production of marine core information and data

b) SL2: dissemination of marine core products

c) SL3: assessment and expertise on marine products

d) SL4: ocean analysis tools development and maintenance

e) SL5: training and research coordination.

a) SL1 Production

Operators will need to develop and produce quality controlled fields (analyses and forecasts) describing the global ocean and European seas, based on space and *in situ* observations data and their assimilation into appropriate ocean models. This activity includes different *product lines*:

- Observation and model products for the state variables listed in Table 2 for example
- In several modes: nowcasting, forecasting (several days), and re-analysis (up to some decades)

The latter requires both real-time operational lines and delayed mode data lines.

b) SL2 Dissemination

All operators must provide to users the advertised information on the ocean state, either through their own production (SL1) or by being a reference

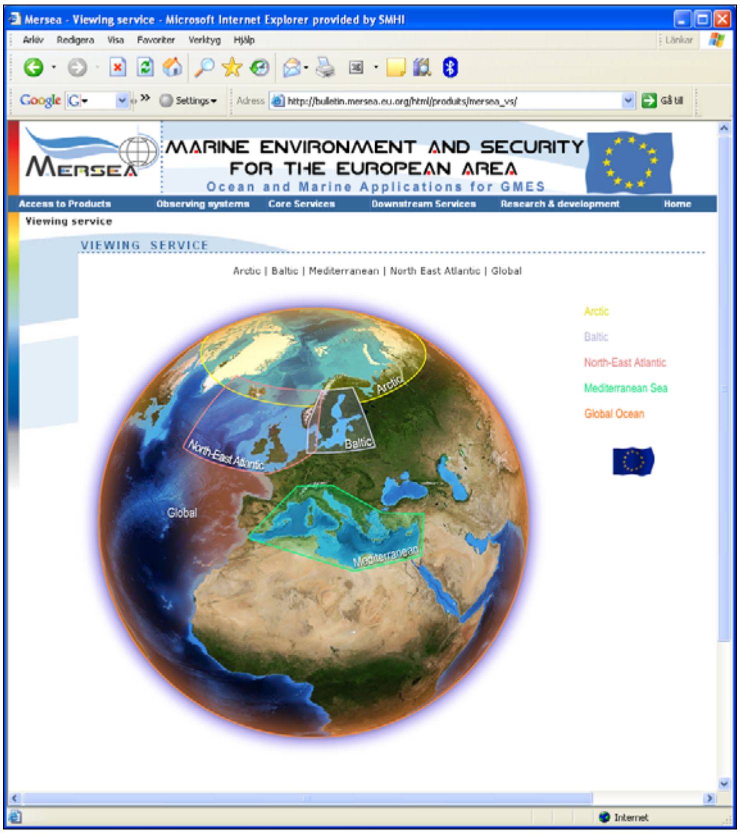

Figure 8 *The MERSEA Consortium*

access point to other production from centres that are not part of the MCSMO (MCS Management Organisation). This will include the appropriate tools for **search and discovery, viewing, and downloading of products**. The download service will need to include or be supported by the facility for sustained, scheduled delivery of high volume datasets for intermediate users, who are themselves running continuous operations that need such a service.

Catalogues and inventories of products must be homogenous, readily accessible, searchable, and updated regularly.

The dissemination will be subject to the data policy to be agreed upon, but hopefully as set out in section 4.5.5.

The proposed assignment of responsibility for the portals that will carry these tools is that chosen by the MERSEA consortium and illustrated in Figure 8.

Information products accessible through each portal should relate to the domain in question, meet the standards described in section 4.5.4 and other service qualities set out below, including guidance in their use. The aim will be to give the easiest possible access to information and, where it exists, choice to the user.

c) SL3 Assessment and expertise

All production of the MCS must be fully validated, with known accuracy and error estimates. MCS must provide expertise on the marine core products, to support efficient use of its output or bring directly information to interested users. Human expertise is added to the production and dissemination functions, to proceed **from data to information** for the benefit of users.

Access to information from forecasts produced by different Centres is a powerful tool for assessment of their reliability and accuracy; it is desirable that the MFC should enable such multi-model interpretation and presentation.

For instance, regular bulletins and assessment reports can be published **to explain** the main features of some of the products; expert analysis can give a **thematic interpretation** of the marine core products; specific post-processing, on demand, to extract subsets of products, or to elaborate summary indicators based on MCS data (selection and transformation).

The expertise service could include the elaboration of calculated fields derived from the state variables (e.g. mixed layer depth, upwelling indices, transports, heat content), anomalies, climatologies or statistics.

In cooperation with expert topic centres, the service should contribute to reference reports on the ocean state (Regional Conventions, EEA, ICES, etc.), or simple and systematic studies of observing networks (Argo, altimetry, etc.), or for operational user agencies.

d) SL4 Ocean analysis tools, development and maintenance

The MCS should develop and maintain, for the benefit of the European community of intermediate users and other operators, a suite of reference codes and frequently-needed tools required to use MCS products and to develop downstream activities and services. It is mandatory that the codes be maintained at the forefront of the state-of-the-art and be fully validated; with error estimates. This requires expertise in the transfer of research results into the operational suites.

The capabilities required to sustain and improve the MCS also need to be developed, validated, upgraded, maintained and disseminated at European level. These include tools such as the NEMO Ocean modelling code; data assimilation tools; toolboxes for nesting, downscaling, and interfacing models; validation algorithms (metrics, observations/model, …); data handling codes; visualisation; diagnostics routines.

e) SL5 Training, research, and outreach coordination

The MCS should actively develop and promote scientific and educational programmes for the benefit of operational oceanography as a contribution to the development of European capacity in the subject.

An active research community must be entrained in disciplines and fields of research of relevance to operational oceanography. MCS can play a leading role in research networking and connection with research teams in Europe, and beyond; it can promote coordination of research initiatives linked to operational oceanography, and it must contribute to capacity building and outreach.

Training can be provided through summer schools, conferences, or students courses on operational oceanography; traineeships, PhD and post-doc programmes can be associated with the MCS Centres.

These research programmes will be of two types:

- One must be closely coupled to the MCS to ensure that projects are driven, in part at least by the specific needs of the operators, and remain aware of emerging research results. There is no doubt that progress in ocean modelling, monitoring and prediction will be achieved only if such programmes are effectively pursued, coordinated and funded. **Experience from other successful providers of services of the kind to be offered by the MCS suggests that a fraction of the turnover of the endeavour (of the order of 5–10%) should be set aside for such closely coupled research; such examples include the major NMSs and ECMWF**.

- The other will be driven by the **need to resolve priority issues in the relevant sciences (as identified by the ESF Marine Board for example)** and to explore new technologies for monitoring the marine environment, using EO and *in situ* methods. These are likely to be funded within national research programmes, the Framework Programmes, or by ESA through their Explorer missions and industry.

GMES and GEOSS share a range of strategic and technical issues and offer opportunities for interactions (e.g. space and non-space observation platforms, data exchanges and network connections, tasking and integration of observations, *ad hoc* campaigns). At the European level, the two initiatives are closely related in that:

- As it develops itself, GMES will become, with the data it can generate, a main European contribution to the GEOSS
- GMES will benefit from the observations collected and exchanged in the frame of the international GEOSS activities.

European GEO consultation meetings are regularly organised and chaired by the Research DG to coordinate the position of all European GEO members supported by the Framework Programme in order to ensure a strong European voice and influence on decision-making at the GEO plenary meetings. This includes ensuring appropriate European representation in the GEO Executive committee and providing the European share of funding of the GEO secretariat out of the EU Framework Programme.

It will be important that the MCS plays its part in ensuring that this 'European voice' is well-informed by the benefits which the marine sector can gain from and contribute to the GEOSS.

4.5.4 Standards

One of the objectives of the MCS is to provide consistent quality and standard of service. This puts strong requirements in terms of robustness of the products and delivery channels; timeliness of production and delivery; fitness for purpose against specific requirements; stability and homogeneity of re-analyses; traceability and quality performance. Users of MCS serviced must not need bespoke interfaces to access and use its products. **GMES as a whole has to deliver interoperability between its components, so conformity to the expected INSPIRE Directive will be mandatory**.

In order to achieve this goal, the MCS delivery of data and data products should conform to International Open standards as will be promoted within the INSPIRE program. In particular the viewing services should conform to Open GIS standards, providing Web Feature Services (WFS) for *in situ* data and Web Map Services (WMS) to allow viewing of geospatial gridded data. These can be live services working directly upon the data repositories. These viewing services should be available (with appropriate security) at all MCS service centres to allow the overlaying within a web portal of MCS geospatial view products with each other and with third party GIS based products without the exchange of the data themselves. For data exchange the MCS should eventually conform to the Web Coverage Service (WCS) standards although interim methods such as secure ftp or OPeNDAP are envisaged.

The MCS should provide sufficient underpinning support for the development of appropriate viewing services to allow information to be viewed within any downstream GIS-based services conforming to the Open Standards. This could include commissioning of specific viewing services appropriate to the marine domain. As a Fast Track Service the MCS should be resourced to take the lead in this area which will

1. Greatly increase the visibility and availability of MCS products in a highly professional way
2. Provide easy-to-use calibration/validation services for use within the consortium, e.g. by overlaying MCS products with satellite images
3. Provide a lead for future European geospatial services.

The MCS should also seek to develop partnerships with other geospatial information services around Europe. A directory of all Geospatial information services in OGC format should be available with a portal to combine and overlay them. This would go a long way towards providing an integrated view of the European Environment as outlined in the INSPIRE initiative.

Standards to be applied will be specified or referenced in Service Level Agreements (SLA), and/or Service Charter for overall MCS consistency, which must cover the points above, as well as requirements to maintain the system at state of the art; to use all available information; to perform multi-model estimation and forecasts; to engage in research and development (see SL4 and SL5 above); specification of the areas of service provision; the rules for access to infrastructure; consideration of the operational status, security, system monitoring, etc.

4.5.5 Funding and Data Policy

At present there are no reliable estimates of the full costs of a reliable, efficient MCS or of the upstream and downstream capabilities that are required to deliver value from it. Such estimates are required during the next year or so as experience grows during the FP7 funded demonstration phase; not least to ensure that the case for long-term funding is robust.

In the interim, it is assumed that, because the services being delivered by the MCS are public goods they will be co-funded by the EU and Member States, not at the point of delivery by charges levied on intermediate users. This is the model adopted for the development and demonstration phase of the GMES Fast Track MCS funded through the FP7 Space Programme. Continued adoption of this model has to be verified, probably within the context of the proposed INSPIRE initiative. The scale of the expenditure required suggests that some form of cost sharing by Member States and the EU would be agreed to deliver the service defined ultimately in the SLA(s) between the GMES Management Authority and the MCSMO or operators. In effect this is the current funding model of the space infrastructure with ESA too. Presumably some Member State contributions would be in-kind, in the form of national support for the operators and data collection/provision (both EO and *in situ*).

On this basis, it is further assumed that upstream data and MCS data, products and services made available to intermediate users will be free of charge, except for the cost of delivery, if they are used exclusively for GMES purposes.

It is expected that intermediate users will be financed through user charges in effect for the value that they add to the information and services that they obtain from the MCS and other upstream service providers. Some ancillary data may fall within the scope of the INSPIRE Directive while others will be available on terms specified by their suppliers.

There is no doubt that some EU level support will be desirable for intermediate service providers during the MCS demonstration phase at least. It is understood that this is planned within FP7. At present such support is being provided by the ESA GSEs, in particular MarCoast and Polar View, and through the data purchase activities of EMSA. The ESA-managed, EC-funded data-buy planned within FP7 will be crucial in this regard too.

4.5.6 Governance and related issues

There are a number of issues to be resolved that transcend the strictly scientific and technical matters which guide the infrastructure design and implementation. Some considerations, particularly those of top-down governance of the implementation of the GMES, will be settled at a political level, presumably in the GMES Bureau and GMES Advisory Council. However it is reasonable to suppose that the structure and day-to-day governance of the MCS can and will be designed according to some general principles.

a) Accountability and Management structures

It is envisaged that the MCS will be distributed and comprise a number (of order 10 as discussed in section 3.3) of operators that will produce and offer products and services, as characterised in the Appendix and section 4.5.3, to intermediate users. Some such operators are likely to be consortia. Other operators will be responsible for the Thematic Assembly Centres described above. Other actors will exist in the form of external data providers, such as ESA and EUMETSAT for Earth Observations and agencies in Member States for *in situ* data, acting singly or as the consortia which comprise the Operational Ocean Systems/Networks of EuroGOOS. If the EEA assumes greater responsibility for oversight of *in situ* data collection for GMES generally, it may act *in loco parentis* for such agencies and consortia.

Two broad classes of solution can be envisaged to manage the interfaces between these providers and the expected GMES Management Authority described in GAC(2006)6.

i) The GMES Management Authority itself could manage all of the interfaces with all of the actors. Logically it would need to do so for all the Fast Tracks and their follow-ons, which would be a complex business requiring a detailed knowledge of very diverse technical operations.

ii) Alternatively and more realistically, in order to provide the necessary degree of integration and coordination of policies and decisions made in common by the MCS operators, an MCS Management Organisation (MCSMO) could be formed. This would need to have a legal personality. Looking inwards, it would be responsible for ensuring that the operators as outline above delivered their offered services according to agreed Service Level Agreements (SLAs). The external data providers (ESA, EUMETSAT, *in situ* consortia, EEA, etc.) would probably have SLAs with the GMES Management Authority, but the alternative of making them with the MCSMO is for consideration. Looking outwards, such an Authority would represent the MCS in its interaction with the GMES Management Authority with respect to the 'General Management' Function described in GAC(2006)6. An MCSMO would be better able to exercise the Technical Management function described in that document than would a GMES-wide Authority, simply because the user demand, technical solutions, actual performance, research needs and qualification processes are likely to be specific to the marine domain at least. Of course in this model the MCSMO would be accountable to the GMES Authority for all the functions for which it was responsible.

In the very short term, i.e. in responding to opportunities to demonstrate and develop the MCS within FP7, such a Management Organisation might be created and operated by a lead partner and comprise an executive composed of representatives of a consortium of operators. However, **in the longer term, there would be some merit in creating a separate entity with its own legal identity. The European Economic Interest Group (EEIG) has some characteristics which would make it an attractive company structure**.

The EEIG, i.e. **European Economic Interest Grouping** is a company structure which can be registered in all European Union Member States according to EC Law (Regulation (EEC) 2137/85). The EEIG offers the possibility of cross-border co-operation and collaboration within Europe especially to small and middle-sized enterprises of every legal category including associations and local authorities. A precondition is however that at least two of the enterprises or other bodies of the grouping are located in at least two different EU Member States; enterprises from Member States of the European Economic Area can also take part. To date approximately 1200 EEIG have been registered in the EU with altogether about ten thousand members.

As a result of the growing demands on companies within the field of cross-border transactions, the EEIG is an attractive alternative for co-operation in various economical fields; examples are the establishment of a purchasing and marketing association, joint research and development or co-operation in fields of personnel and training. In addition an EEIG may have significant tax advantages (an EEIG is not submitted to corporate taxation etc.).

These include the following:

- It is a legal framework which aims to develop and facilitate the collaboration between entrepreneurs and can represent a profit centre for its members of its own
- It is a very flexible and unbureaucratic legal instrument, whose rules can be decided by the members in observance of a few guidelines fixed in the European regulation
- A grouping can be founded with or without assets, investment or know-how transfer
- A grouping can be established by subjects with a different legal status: self-employed persons, private limited company, chambers of commerce, etc.
- The members of a grouping go on carrying out their own activities autonomously. They maintain the activities they ran before and besides obtain new business opportunities
- A grouping can guarantee a high-level liability: members have unlimited and several liability for its debts
- Profits and losses resulting from its activities are taxable only in the hands of the members; profits must be divided up among the members, if not reinvested
- A grouping pays neither company taxes nor taxes on earnings
- A grouping can run its own business and can have a trade mark
- The official address of a grouping can be easily transferred within the Community. Other legal

instruments require a previous winding up of the enterprise, which involves costs, activities and loss of corporate image

- Due to the European regulation no. 2137/85 constituting the legal basis of EEIG and, being drafted in each European official language, there is no discrimination because of the use of a foreign language.

b) Interactions with intermediate users

Day to day interactions between product and service providers and their users should be conducted directly. Proposals for cataloguing and searching for data, products and services are made in the Strategic Implementation Plan. However **there will be a need for intermediate users to interact with the operators and MCSMO (or GMES Management Authority as appropriate, depending on the adopted management model) to determine, at a more strategic level, the scope and characteristics of services to be offered, any changes to them and agree priorities and an associated R&D programme. Some form of MCS Commissioning Forum, meeting at least annually, could provide a suitable body for this**. It seems likely that there will be a wide range of intermediate users. Some means of brigading common interests will be helpful and probably necessary, perhaps through involvement of associations in the Forum, rather than individual organisations.

c) Criteria for selecting operators and modification of the partnership

The services will be provided by operators (i.e. institutes, agencies, companies, or consortia) that manage and operate functional centres. They should be selected on the basis of their ability to fulfil the requirements of a legally binding contract, their access to the required resources, their expertise (scientific and technical), their operational status, track record and previous performance, commitment to work with the interfaces, and cost-effectiveness. Regional knowledge and ownership will clearly be important, as well as sound repartition of the work between Member States.

The composition of the MCS should be reviewed periodically to allow for modifications of the partnership (inclusion of new members or severance). Several elements could be considered in such reviews, e.g. the (duly weighted) national resources committed to the system, the relative performance and strengths of potential operators, national policies, needs for new services, and their ability to provide fully operational and sustainable services.

A level of competition in some aspects of the process chain will be appropriate to create incentives to innovate and improve performance. For this purpose there will be a need to encourage a measure of functional duplication. However, this will need to be balanced against the imperative to create critical mass in a relatively few centres and the difficulty of duplicating major investments.

Although the major modelling centres that are likely to form the MCS and most of the currently capable thematic data assembly centres are public organisations – because it is they who have made the necessary investments – there is every reason to suppose that the capabilities required by them and the other up and downstream services will be supplied by the private sector. Some are likely to be provided and operated under contract by the private sector, particularly outside the modelling and specialist data processing centres.

Conflicts of interest

Potential MCS operators have their own downstream service activities and will wish to use the MCS data and products in the latter. This includes both public and private entities. This possibility raises issues of equity, particularly when they are in competition with other intermediate users/service providers who are not part of the MCS.

A priori it seems possible to address this question in the frame of the SLAs and the MCS and GMES governance. The SLAs will clearly identify the tasks to be carried out in the MCS and the resources available for this purpose. The MCS and GMES governances will need to clarify the decision making mechanisms for the MCS activities. It might be specified, for example, that teams involved in an MCS operational activity, or in MCS development activities be clearly identified, and perhaps separated from teams involved in downstream and other services. Of course this problem would also be solved if MCS data and products were freely available to all engaged in serving GMES purposes, and MCS operators were fully funded.

4.6 Implementation of downstream services

A significant effort is still required to elaborate and market downstream services. The data policy recommended in section 4.5.5 should

encourage this because the free access to basic data and MCS products will act as a considerable stimulus to the market. There is evidence for this in the subsidised provision of EO data and support for the ESA GSEs, which has encouraged and begun to satisfy downstream use. Furthermore, the well-developed strong private meteorological service sector in the US is sustained by the same data policy and centralised provision of core (meteorological) services. There is every reason to expect similar strong innovation and growth in Europe in the marine sector.

Even without that stimulus there are a number of clear requirements for end user services that can and will be met, in part at least, by the combination of upstream data services, the MCS and intermediate service providers offering down-stream services. These include:

4.6.1 Marine Environmental Strategy Directive and related Conventions

Context[14]

Europe's marine environment is faced with increasing and severe threats. They include

- Climate change
- Pollution (including contamination by dangerous substances, from land-based sources, litter, microbiological, oil spills as a result of accidents as well as pollution from shipping and offshore oil and gas exploration, pollution from ship dismantling, and noise pollution)
- The impacts of commercial fishing
- The introduction of non-native (exotic) species principally through discharge of ships' ballast water
- Nutrient enrichment (eutrophication) and associated algal blooms
- Illegal discharges of radionuclides.

Against this background a new **Marine Environmental Strategy and associated Directive** is proposed[15]. It aims to promote sustainable use of the seas and to conserve marine ecosystems, by giving priority to achieving good environmental status in the Community's marine environment, to continuing the protection and preservation of that environment, and to ensuring that subsequent deterioration is prevented. For this purpose Member States will be required to prepare Marine Strategies which, while being specific to their own waters, reflects the overall perspective of the appropriate Marine Region[16]. For this purpose they will be required initially to carry out assessments of the current state of their marine waters. Subsequently they will need to establish environmental targets and monitoring programmes for ongoing assessment, enabling the state of the waters concerned to be evaluated on a regular basis. Then programmes of measures, which are designed to achieve good environmental status, will need to be established and implemented.

14. COM(2005)504 final
15. COM(2005)505 final

Service requirements

Assessments will be required to include physical and chemical features, habitat types, biological elements – at several trophic levels – the hydromorphology and any particular problems such as nutrient inputs and chemical hotspots. Analyses of pressures and social and economic issues are also required.

Indicators will need to be developed and determined in order to establish where intervention is required and whether resulting measures are proving successful in delivering the aims of the Strategy and Directive. Many pressures are episodic and some arise from crises that create substantial pollution events. Services capable of informing policing and emergency responses will also be required.

A recent EEA-led EMMA Workshop[17] concluded that operational oceanography in general, and the MCS in particular, can contribute to marine monitoring and assessments[18] by:

- Providing input to indicator development (especially the State and Impact components of the DPSIR assessment framework)
- Identifying temporal variability
- Describing spatial variability and dynamics
- Contributing to crisis management and episodic events that affect the state of the marine environment.

Providing context for *in situ* sampling and interpretation of their data

As indicated in the Appendix, the primary contribution in the short term will be in the form of

16. The Marine Regions are specified as the Baltic, North East Atlantic and Mediterranean, coinciding with the three of the regions of the MCS.
17. Held at the EEA, Copenhagen, 23–24 October 2006
18. See for example the series of reports generated by a joint ICES/EuroGOOS Pilot Project, NORSEPP, which is focusing on the relationships between fish stocks and the physical state of the atmosphere and marine environment, e.g. www.ices.dk/marineworld/norsepp.asp

physical and a subset of the chemical and biological variables. Furthermore in the longer term it will be impossible to describe and understand biological and chemical characteristics unless the physical context is clear. In particular much effort could be wasted on measures if the major natural marine transport pathways and structures are not well described, and their role understood and accepted; allowing actions to be taken when and where they will be effective. Examples of this are to be found in the identification of regions where oxygen depletion is a natural consequence of a lack of mixing in shallow water (with associated productivity) rather than a signal of eutrophication. Similarly, phytoplankton growth is known to be concentrated along a thin boundary (the thermocline) at the base of warm summer waters in the northern North Sea where the favourable combination occurs of sunlight and a supply of nutrients from below. This has consequences for the development of Harmful Algal Blooms (HAB) and the formation of a reliable food source for organisms further up the food web. Dependencies of these kinds need to be understood and quantified if measures are to deliver what is expected of them.

Although direct monitoring is limited to the sea surface, EO data provide a valuable source of timely information about water quality. Inferences about the development and extent of algal blooms and sediment loads can be made from ocean colour observations. Additional *in situ* sampling is required to identify the potential for and existence of HAB, nutrient concentrations and the presence of other pollutants. Managers and communities need forecasting systems that address where a harmful algal bloom is today and where it will be in the near future. This places a particular emphasis on near real-time collection of such *in situ* data. The use of SAR data in oil spill detection is described in section 4.6.3.

Specific product requirements

- Reanalyses of EO and *in situ* observations over a number of years are required to establish mean physical and chemical states (including currents) in a GIS format, together with variations about the mean and for identification of trends
- Indicators and state data contributing to indicators
- Analyses of meteorological and oceanographic conditions, to provide context to measurement campaigns and during environmental crises, such as those manifest as eutrophication, oil spills and algal blooms
- Forecasts of the evolution of such crises to enable coordinated responses.

Observing system requirements

EO: Continuity of ocean measurements as described in section 4.2.1.

In situ: physical, chemical and phyto- and zooplankton variables to contribute to the above products using the technologies, also described in section 4.2.1.

Relevant current coordinating organisations

- EEA and its partners in the European Environment Information and Observation Network
- The Regional Conventions: HELCOM, OSPAR, Barcelona; UNEP-MAP
- ICES
- IOC-SCOR Scientific Steering Committee for GEOHAB (Global Ecology and Oceanography of Harmful Algal Blooms).

End-to-end services

EO data in the form of measurements of sea surface height and temperature and *in situ* measurements of salinity, temperature and current profiles are required for assimilation by MCS models. Ocean colour data provide context and indications of the annual cycle of primary production and abnormalities such as algal blooms at the sea surface, which may be harmful. *In situ* measurements of the biogeochemical and biophysical variables listed in Table 2 provide important contributions for the assessments and to validate the specific products listed above, which will be created by the MCS. The Regional Conventions, OSPAR and HELCOM, have made a joint statement on their prospective contributions to the implementation of the Marine Environmental Strategy[19]. This includes commitments to establish systems to minimise any overlaps in their individual monitoring programmes; to ensure that collecting and reporting information on the marine environment can be carried out by single processes; and that the resulting information is then shared between the relevant bodies. OSPAR has adopted a strategy for a Joint Monitoring and Assessment Programme, from which the relevant regional components of the MCS might hope to benefit, through access to data, and to which the MCS can contribute, through the provision of capable physical and biogeochemical models.

19. First Joint Ministerial Meeting of the HELSINKI and OSPAR COMMISSIONS (JMM) Bremen: 25–26 June 2003, Record of the Meeting – Annex 6.

The MCS will provide some indicators but intermediate users participating in the work of the Regional Conventions and within the EEA's Topic Centres are likely to use the MCS products to generate more. These products will also be used by intermediate users carrying out research to construct and validate the measures required to deliver good ecological status. Estimates of the transport across EEZ and territorial water boundaries will also be prepared to determine the extent to which pollutants are being exported and imported.

A number of EuroGOOS members and other national agencies provide water quality services, largely based on ship-borne surveys, augmented by routine monitoring from moorings and transects carried out using the FerryBox technology. Some also make regular use of Ocean colour data to provide context and indications of abnormalities, as indicated above. The MarCoast GSE currently has some 30 users, largely amongst national authorities responsible for monitoring and maintaining water quality, for services based on variables such as Chlorophyll-*a* and suspended matter that are inferred from MERIS and MODIS data. Invariably temperature and current data are provided too to assist in their interpretation. In future the latter are likely to be provided by the MCS.

4.6.2 Ice Services

Context[20]

The Arctic Climate Impact Assessment report, which has been developed under the Arctic Council, shows that the global warming in the Arctic is dramatic with many significant consequences. There are enormous oil and gas fields, minerals, fisheries and other resources in the Arctic regions that will be increasingly important for Europe. The exploration and exploitation of the resources in these regions are severely hampered by harsh climate and in particular by the presence of sea ice. Sea traffic in the Baltic Sea is growing (731 Mtons in 2003 is expected to grow into 1148 Mtons by 2020), especially oil transport from Russia via the new oil terminals in the Gulf of Finland (according to conservative estimates, 200–250 Mtons by 2015). Marine operations including transportation by ships in the Northern Sea Route between Russia and Western Europe is increasing with associated risk for accidents and damage to the environment.

20. Based on a paper provided by Mr. Kimmo Kanto of the Finnish Funding Agency for Technology and Innovation and material from references and the Polar View website.

Global climate change with many severe consequences is on the political agenda. The Arctic is of particular interest because the global warming is predicted to be the most pronounced in this region with many implications for sea transport, resource exploitation, construction, ecosystems, and the environment. The Arctic sea ice is predicted to be reduced by 80% during summer at the end of this century, while during winter the now seasonally ice-covered Barents Sea is expected to be ice-free. This will have a range of important potential biogeophysical consequences and associated socio-economic impacts. The Arctic environment is very vulnerable and small disturbances can have a very long-lasting impact. Environmental policies have defined a number of regulations with impact on all human activities in high latitudes.

National ice services have been providing sea ice information for almost a hundred years. Ice charts and ice forecasts are the most important outputs today. A list of national ice services and their products with examples can be found at WMO No 574: Sea Ice Services in the World (www.jcomm-services.org/modules/documents/documents/WMO_574.pdf).

A joint North American Ice Service (NAIS) has been created between the National Ice Service (USA), Canadian Ice Service (Canada) and International Ice Patrol (USA), which in a few years will combine operations, budgets and manpower under a single system. Compared to Europe this new service cluster will have a powerful influence in all Arctic ice services.

The ESA GSE **Polar View** offers integrated monitoring and forecasting services in the Polar Regions using satellite earth observation data to support improved decision-making, planning and adaptation to climate change. The intent is to deliver those services that address both the operational and scientific needs of stakeholder groups who are interested in issues related to sustainable economic development, marine safety, and the environment. The GSE includes over 30 different user groups.

Current products include:

- Global and regional daily maps at medium resolution (3–6 km) of ice extent and composition based on the US Advanced Microwave Scanning Radiometer (AMSR-E) and Advanced Synthetic Aperture Radar Global Mode mosaics (~1 km) from ENVISAT

- Ice drift estimates at low resolution (30–60 km) based on the sources above and scatterometer data
- An IPY portal designed and operated jointly by national ice services via the International Ice Charting Working Group (IICWG). The main purpose is to provide ice information in near real-time to all research vessels engaged in the IPY
- The Finnish Institute of Marine Research provides forecasts of ice motion, concentration, thickness, ridges and deformations for the Baltic Sea
- The Swedish Meteorological and Hydrological Institute provides operational ice forecasts based on HIROMB (High-Resolution Operational Model for the Baltic).

The **International Polar Year** (IPY) is scheduled from March 2007 to March 2009. It has a number of objectives (www.ipy.org/development/objectives.htm), including to:

- Utilise the vantage point of the polar regions to carry out an intensive and internationally coordinated burst of high quality, important research activities and observations that would not otherwise occur
- Lay the foundation for major scientific advances in knowledge and understanding of the nature and behaviour of the polar regions and their role in the functioning of the planet
- Leave a legacy of observing sites, facilities and systems to support ongoing polar research and monitoring.

In particular an **integrated Arctic Ocean Observing System** (iAOOS) has been proposed[21], which if implemented will provide a very substantial resource capable of observing the Arctic Ocean from space to the sea bed. It will use satellites, surface ships, manned ice camps, autonomous ice-tethered platforms (ITP) and IABP/ICEX buoys, floats, moorings, gliders and AUVs. The DAMOCLES IP is providing a network of floats and gliders. Measurements from observatories at key locations are also planned for the sub-Arctic seas. The aspiration to leave a post-IPY legacy – informed by findings from the major research programme – has obvious potential to aid information service provision well beyond the experimental phase.

21. B Dickson, 'The Integrated Ocean Observing System (iAOOS): an AOSB-CliC Observing plan for the International Polar Year', Oceanologia, 48(1), 2006, pp 5-21

The Antarctic is also an important region for European countries in terms of national importance, economic activity and global climate significance. Many European nations are signatories to the Antarctic Treaty, which has governed affairs on the continent since 1957, with European nations comprising approximately a third of the national signatories. This underlines the importance of the European regional presence in Antarctica and the responsibilities in leading international affairs in the region. The economic importance of the Southern Ocean has also grown rapidly in recent years. In addition to the significant increase in tourist numbers to the continent, the Southern Ocean also includes important fisheries and shipping routes. With the Antarctic playing such an important role in the global climate system, the contributions of the scientific research activities into the Antarctic have international significance.

Service requirements

There is a requirement for both better and more harmonised monitoring and forecasting of ice evolution and movement. In particular, services and products at higher spatial resolution are needed (approaching a ship's scale if possible) for marine transportation in ice and the offshore industry. In an era of climate change, long-running data sets are required to understand the changes that are taking place and to provide adequate guidance for the design of structures and operations in the Polar Regions.

Specific product requirements

High quality, reliable descriptions and forecasts of sea ice extent, type, thickness and movement on a daily basis for day to day operations plus long term datasets.

Observing system requirements

EO: Continuity of visual/infrared, passive and active microwave and SAR data, e.g. currently SSM/I, AMSR-E, SEAWINDS, RADARSAT and ENVISAT.

In situ – for characterisation of composition – field expeditions and buoys – but the IPY legacy may provide other options.

Relevant current coordinating organisations – Baltic Sea Ice Meeting, Expert Team on Sea Ice within JCOMM, EuroGOOS Arctic Task Team (AROOS), International Ice Charting Working Group.

End-to-end services

On the assumption that the basic EO data streams to support ice monitoring will be guaranteed and

Member States will provide access to relevant *in situ* data and atmospheric forcing data, the MCS will comprise in part a subset of existing national ice services and regional oceanographic organisations and be able to provide:

- Suitable TACs for the required EO data (e.g. by developing and expanding the remit of existing centres)
- Integrated state-of-the-art modelling using regional ocean models of the Arctic, Baltic and a global ocean model for the Antarctic, with ice physics and dynamics, taking atmospheric forcing from ECMWF and National Meteorological Service NWP
- The use of such models to create long period datasets for climate research and prediction
- Short period services in the form of analyses and forecasts of ice concentration, ice thickness, ridged ice density and height, ice motion (direction and velocity) and likely areas of ice compression, in standard formats
- The evaluation of *in situ* observing systems and the case for their development, in particular for retaining *in situ* observing systems used during the IPY
- Validation data on the quality of forecasts
- Advice/training on their use
- Boundary conditions for higher resolution, national modelling
- Coordinated R&D to develop the services.

Downstream services will be able to provide:

- The robust, operational, bespoke ship routing and other integrated, high-resolution data and advisory services required by marine transport and offshore industries in the Arctic and Baltic
- Iceberg monitoring services.

Benefits

The MCS services will enable intermediate users to offer specialised downstream services that will improve the safety, efficiency and effectiveness of marine transport and the offshore industry in polar waters, iceberg monitoring, datasets for climate change assessment, and decision support systems, etc.

4.6.3 Oil spill monitoring

Context

The Erika and Prestige disasters focused attention on the hazards associated with the transport of oil on which the successful functioning of the European economy depends. European oil imports a total of 27% of the world total trade in oil of which 90% is transported by sea. 70% of the EU oil imports are channelled along the Brittany coast while 30% of the global oil trade transits through the Mediterranean. This will increase as new terminals are brought on-stream for Caspian and Russian exports. As the economy expands, demand for oil increases, generating higher levels of tanker traffic. This in turn creates an increased risk of oil tanker collision or grounding and well-known consequences for the surrounding marine and coastal environment.

However, the impact of these accidents represents only a fraction of the oil released by shipping operators and this in turn represents only a small part of the total volume of oil discharged into the marine environment. For shipping operators, the main cause of pollution is operational discharges, either accidental or deliberate. As levels of maritime traffic increase, the impact of these discharges is expected to get worse. These discharges and accidents threaten fragile coastal ecosystems, impact on tourism and generate significant clean-up costs – as an indication, direct clean-up costs following the Prestige are estimated to be in the region of €2.5 billion.

In Europe, several regional agreements have been set up to prevent operational discharges in the North Sea, the Baltic Sea and the Mediterranean Sea. These are actively supported by cooperation agreements for aircraft surveillance of shipping lanes to detect vessels making illicit discharges and the exchange of evidence between states to improve the prosecution of offenders.

The European policy goal is a complete elimination of discharges into the marine environment by 2020. New legislation has been put in place including the creation of the European Maritime Safety Agency, the introduction of double-hulled tankers and the Ship Source Pollution Directive. This Directive makes any discharge in European waters or adjacent areas of the High Seas a criminal offence. These packages represent a significant expansion of the legal apparatus available to deter operational discharges in European seas. However, without effective surveillance and enforcement these objectives will not be met.

Even with such policies in place, accidents can still occur and effective response tools are critical to protect Europe’s sensitive coastal areas. Timely deployment of clean up and containment assets is critical and this requires effective monitoring and forecasting of the evolution and drift of large spills in order to identify areas at risk and the most appropriate responses.

Service requirements

Routine surveillance of sea lanes in Europe appears to be acting as a deterrent on illegal discharges but more needs to be done. Wide area SAR coverage of European waters on a regular (daily) basis can ensure oil slicks are detected within 20–30 minutes of the satellite overpass. Combining SAR images with AIS data streams can enable a match between an oil slick and a vessel track, supporting improved polluter identification.

Drift forecasting services are the first stage in cueing an emergency response to a major oil slick. These require high resolution models (approximately 1 km) capable of forecasting the evolution of a large oil slick in time steps of 6–12 hours out to a forecast time of 72–96 hours in advance. Their operation, typically by a specialist intermediate user, is a downstream service (as provided by the ESA GSE MarCoast and the Seatrack Web service in the Baltic for example). These local models must have access to boundary conditions provided by regional seas models (in future operated by the MCS) to ensure accurate representation of oceanic conditions and effective characterisation of their effects on the oil slick (e.g. weathering, evaporation, advection, beaching, etc.). Access to geographic information on sensitive ecosystems, beach types and local infrastructure is also essential.

Specific product requirements

For polluter identification:

- High quality rapid (within 30 minutes of satellite overpass) identification of oil spills with better than 90% probability of detection for large spills and a false alarm rate lower than 10% of all high confidence spills
- Co-registration of SAR detected oil spills with AIS data streams with a geometric accuracy no worse than a single pixel of the SAR data.

For drift and spill evolution forecasting:

- Current, salinity, temperature analysis and forecast profiles with spatial samplings for regional seas
- Wind and wave analysis and forecast profiles with performance levels equivalent to current European regional products.

Observing system requirements

To support these activities, SAR systems with a swath of 400 km, a spatial resolution of 100 m and a daily revisit over European waters are required. In addition, the ground segment must ensure that SAR imagery for all European waters are processed and analysed within 30 minutes of the satellite overpass.

Access to AIS data streams (and LRIS when available) is critical for polluter identification. This must be on timescales consistent with those of the SAR data processing.

Finally, to support the oil spill drift forecasting, ocean state observations are necessary. These are based on state-of-the-art regional seas models for all European waters which require both satellite and *in situ* measurements. Satellite measurements include sea surface temperature at 1 km spatial resolution and sea level anomaly data with a precision and sampling at least equivalent to that obtainable currently from the combination of Jason and Envisat radar altimeter data.

Relevant current coordinating organisations

- European level organisations: EMSA, MCMP
- Regional level agreements and networks – HELCOM, Bonn Agreement, REMPEC, Network of North Sea Prosecutors
- Expert groups – EGEMP.

End-to-end services

GMES (in partnership with EMSA) will guarantee the basic EO data streams to support oil spill detection and polluter identification. Under contract to EMSA, a data assembly centre will identify oil slicks and issue warnings as appropriate.

The MCS will support oil spill detection and drift forecasting through:

- The provision of basic oceanographic data to enable operators to improve the quality of their oil spill identification working practices
- The provision of state-of-the-art modelling using regional seas models for the Arctic, Baltic, North Sea, North West Atlantic, Mediterranean and Black Seas. These will include the integration of appropriate atmospheric forcing terms. This will ensure:
  - Integrated long range drift forecasting for tier 3 slicks (e.g. Prestige type events)
  - Accurate boundary, initial and forcing conditions on local models used for high resolution oil spill evolution forecasting
  - Validation data on all oceanographic products provided and advice and training on the use of these products.

Based on the above and ancillary data (shown in *italics*) downstream service providers will:

- Provide advice to operators (Coastguards) on actions to be taken based on the location, *type of oil*, *volume released*, forecast drift and evolution, *assets at risk*
- Assemble evidence necessary for prosecution
- …

Benefits

Sustained, regular access to SAR data and their expert interpretation (to achieve the required detection performance) coupled with the MCS services described above and access to local, high-resolution models operated by intermediate users/downstream service providers on a sub-regional scale, should allow a uniform service to be delivered everywhere it is required within European waters. The existence and widespread advertising of such a service will act as a strong deterrent to would-be offenders and contribute significantly to their detection and prosecution if they are not deterred.

Although a major accidental release is unlikely to be detected for the first time from SAR data, subsequent updates which characterise the extent and structure of the spill at the sea surface acts as validation (or otherwise) of drift and evolution predictions and provides a new source term for subsequent predictions. Forecasts of beaching and prospective contamination of other marine assets at risk enable prioritisation of efforts to collect oil at sea and the assembly of clean-up resources.

5 Conclusions

5.1 At an early stage and subsequently, the SEPRISE Workshops have approved the strategy of building a sustainable, integrated operational system based on the GMES Marine Core Service (MCS), with integrated, coordinated upstream *in situ* and EO data provision and downstream services dedicated to meeting individual needs for services.

5.2 The purpose of the MCS is to make available and deliver a set of basic, generic services based upon common-denominator ocean state variables that are required to help meet the needs for information of those responsible for environmental and civil security policy-making, assessment and implementation.

5.3 An MCS can fulfil its purpose, given the availability of the necessary computing, data collection and processing facilities and skilled staff to operate them, provided that continuity of EO data can be maintained and *in situ* monitoring is improved as indicated in the plan.

5.4 For EO data:

- Continuity of observation is crucial. This is particularly critical around 2010 when data gaps could occur for several of the most critical observations. Decisions for developing the first of the GMES satellites must be taken most urgently.
- It is more critical to establish satellite series for sustainable service availability than to try optimising the specifications and designing for any one satellite and its instruments, if the latter leads to expensive, non-renewable satellites. Establishing satellite series should lead to significantly lower production costs.
- GMES should allow for research and technological developments. In particular, the possibility of embarking new instruments with the potential to meet GMES needs should be considered. Wide Swath altimetry and geostationary ocean colour are the two most important new technology developments that will benefit the GMES MCS in the long run.
- The Jason series (high accuracy altimeter system for climate applications and as a reference for other missions) is an essential and critical component of the GMES satellite programme for MCS. Planning of Jason-3 must be a priority for GMES.
- The MCS requires a high-resolution altimeter system with at least three altimeters in addition to the Jason series. Sentinel-3 should include a constellation of two satellites, flying simultaneously, providing adequate coverage and operational robustness. Instrumentation costs for S3 should be reduced as much as possible to allow for a two-satellite system.
- Compared to the present design of S3 instrumentation, the priority for Sea Surface Temperature is for high accuracy dual view measurements. The large swath requirement has a much lower priority, in particular (but not only), if S3 is a two satellite system. As far as Ocean Colour is concerned, a sensor having a similar spectral resolution to MERIS is essential to meet the important shelf and coastal ocean water quality measurement requirements. The use of a SeaWiFS type of instrument (reduced number of channels) would serve only the minimum operational requirements for the open ocean.
- SAR data (Sentinel 1) are required, in particular, for downstream oil spill detection and sea ice monitoring. These are European core data in the sense that they have multiple uses and are required for downstream services in the marine domain. The requirement is for at least one and preferably two SAR missions in addition to the other non-European missions (e.g. RADARSAT).
- Access to other European and non-European (e.g. NPOESS, RADARSAT) satellite data in real-time is fundamental for the MCS.

5.5 In order to make necessary improvements to *in situ* observing systems, two specific actions are needed.

Firstly, where the impact of the data is either global or pan-European it will be appropriate for an investment to be made by the EC on behalf of Member States or by the Member States acting together.

Secondly, there is a need and opportunity within the context of GMES, supported jointly by the Commission, ESA and Member States, for integration and coordination of *in situ* monitoring efforts. On the regional scale, the EuroGOOS Regional Task Teams or Operational Oceanographic Systems/Networks (where they have been formed) are ideally placed to take on the work necessary to pursue this, perhaps coordinated overall by the EEA.

5.6 The Workshop which led to the decision to Fast Track MCS implementation, and much prior discussion, concluded that the number of computing data processing centres should be of order 10. Provided that information from the MCS is freely and readily available for further elaboration in downstream services and there is a sharing of tools, that conclusion was upheld by the IG and is an integral part of the plan.

5.7 It is envisaged that the MCS will comprise at least one operational modelling and data assimilation activity for each of the global and identified regional domains, with an exchange of boundary conditions as necessary: e.g. between the global and ocean basins and their shelf seas, and between the enclosed regional seas and their adjoining ocean or shelf sea. The resolution of the models is not prescribed but should aim to be state-of-the-art for provision of the common denominator data that are required from the MCS.

5.8 Whilst care will be needed to ensure robustness and avoid single points of failure, implementation based on the MERSEA design, using the capabilities, tools, techniques, procedures and standards developed, adopted and being tested by the consortium, is an attractive way ahead and their adoption for the MCS is recommended. A key feature of the design is its commitment to interoperability and distributed functionality. This should allow potential contributors to the MCS, who are not members of the Integrated Project, to augment its capabilities by contributing <u>needed</u> services, provided that they operate according to the rules which ensure interoperability and ease of use by intermediate users.

5.9 Further consideration is needed to define the comprehensive requirements for fulfilling the TAC functions for each type of ocean data product. It also remains to be decided whether regional TACs are required or whether regional data can be provided satisfactorily by a global TAC.

5.10 Given the substantial investment needed in computing resources and skilled staff necessary to operate, maintain and develop them, and the agreement reached between the partners over the global and regional responsibilities of the individual centres, it will be wise to at least base the initial MCS on the MERSEA assignments. However, if there is a possibility of providing choice of model products to the downstream service providers that option should not be precluded, i.e. there should be no ‘closed shop’.

5.11 The MERSEA consortium is committed to a number of supporting activities that guarantee a level of quality in service provision and that follow standards to be spelled out in **Service Level Agreements**. They are all crucial to the success of the MCS and are broadly compatible with the desired functional analysis of section 3.4. Others who might aspire to contribute to the MCS should expect to provide equivalent services and commit to the same Service Level Agreements.

5.12 Experience from other successful providers of services of the kind to be offered by the MCS suggests that a fraction of the turnover of the endeavour (of the order of 5–10%) should be set aside for closely-coupled research; such examples include the major NMSs and ECMWF.

5.13 It will be important that the MCS plays its part in ensuring that the ‘European voice’ is well informed by the benefits which the marine sector can gain from and contribute to the GEOSS.

5.14 GMES as a whole has to deliver interoperability between its components, so conformity to the expected INSPIRE Directive will be mandatory.

5.15 The MCS should provide sufficient underpinning support for the development of appropriate viewing services to allow information to be viewed within any downstream GIS-based services conforming to the Open Standards.

5.16 It is assumed that, because the services being delivered by the MCS are public goods they will be co-funded by the EU and Member States. On this basis, it is further assumed that upstream data and MCS data, products and services made available to intermediate users will be free of charge, except for the cost of delivery, if they are used exclusively for GMES purposes.

5.17 In order to provide the necessary degree of integration and coordination of policies and decisions made in common by the MCS operators, an MCS Management Organisation (MCSMO) could be formed. This would need to have a legal personality. In the longer term, there would be some merit in creating a separate entity with its own legal identity. The European Economic Interest Group (EEIG) has some characteristics which would make it an attractive company structure.

5.18 There will be a need for intermediate users to interact with the operators and MCSMO to determine, at a more strategic level, the scope and characteristics of services to be offered, any changes to them and agree priorities and an associated R&D programme. Some form of MCS Commissioning Forum, meeting at least annually, could provide a suitable body for this.

5.19 A significant effort is still required to elaborate and market downstream services. The recommended data policy (**5.16**) should encourage this because the free access to basic data and MCS products will act as a considerable stimulus to the market. Even without this, the existence of legal obligations, in the form of the Regional Conventions and environmental Directives such as the WFD, and the provision of subsidised EO data by ESA to their GSEs has led to the implementation of specific information services. These are essential for policy development and assessment, and day-to-day operations respectively. The role of the upstream data and MCS in these examples is elaborated in section 4.6.

6 Appendix

6.1 Characterisation of MCS variables and products

The most basic service of the MCS is the transformation of raw data into quality-controlled data sets and products. Marine core products include all real-time and archived observational data, and real-time and archived output from the numerical ocean prediction systems which have undergone automated quality control and/or automated processing, e.g. data synthesis and gridded fields. All information that results from the transformation or processing of data, or from mathematical models, in the form of pictures, charts, text or data files is also a product.

The marine core products can be derived directly from observations (satellite and *in situ*; global and regional) or from numerical prediction models (Global, Arctic, Baltic, Mediterranean, N-W Shelf, Black Sea).

A preliminary list of marine state variables to be monitored is contained in the recommendations of GOOS, the Coastal Ocean Observing Panel (COOP), including the *Essential Climate Variables* of GCOS extended by considerations of environmental variables of specific European interest (oil slicks). The related marine core products are listed in Table 2 together with their expected delivery status by 2008.

It must be recognised that ecosystem variables present a scientific challenge at present and that uncertainties with them are much larger than for the physical variables. Care must be taken not to release products prematurely, before full confidence can be stated. Winds and wave core products will need to be carefully coordinated with Meteorological Offices. The bio-chemical, bathymetry and shoreline state variables are monitored by existing coastal observational networks and they should be coordinated through EEA actions; several of those variables are more in the near-shore domain and therefore a result of national monitoring.

Generally, the MCS will deliver products in real time, in the form of short-term forecasts (10 days), and as archives of observational and optimal estimates of the relevant state variables and the 3-D state of the ocean. Regular re-analysis over extended periods (several years) will be produced, as more data are retrieved and quality controlled, and based on the latest modelling upgrades. Reports and bulletins for Institutional users will be produced on a periodic basis.

Services are distinguished by the delivery of products and, where necessary, guidance on their essential characteristics and optimum use. The availability of such guidance will be a hallmark of the MCS.

Table 2 *The first column is derived from the common state variables indicated by the COOP Implementation Plan (2005) and the essential climate variables of GCOS. The second and third column indicate the basic information source for the products and the third those that will be available by 2008 (most are already available).*

Geophysical State Variable	Marine core products derived from observa-tions	Marine core products derived from models	Products expected to be available by 2008
Sea level, sea surface height	YES	YES	YES
Temperature	YES	YES	YES
Salinity	YES	YES	YES
Currents	YES	YES	YES
Surface winds	YES	YES	YES
Surface waves	YES	YES	YES
Sea ice (extent, concentration, thickness, motion)	YES	YES	YES
Biophysical State Variable			
Attenuation of solar radiation[a]	YES		YES
Bio-geochemical State Variable			
Chlorophyll-*a*	YES	YES	YES
Dissolved inorganic nutrients	YES	YES	
Dissolved O_2	YES	YES	
pCO_2	YES		
Benthic biomass[b]	YES		
Sediment grain size and organic content	YES		
Faecal indicators[c]			
Oil slicks[d]			

a. For assimilation by models, it may be more fruitful to deliver the Intrinsic Optical Properties of the ocean surface inferred from the EO Ocean Colour measurement.
b. This requires extensive, labour intensive observation and analysis. There is no prospect of obtaining such data in near real-time.
c. This is not a common denominator variable, although it provides a useful indication of the presence of specific forms of pollution. It is also monitored close to shore rather than on a regional or global scale.
d. This is not a common denominator variable, but is certainly of regional importance. The envisaged role of the MCS is to provide the products that enable predictions of the evolution and movement of oil slicks in dedicated downstream services – see section 4.6.3.