PROJECT FINAL REPORT

Grant Agreement number: 282915

Project acronym: GEOWOW

Project title: GEOSS Interoperability for Weather, Ocean and Water

Funding Scheme: Collaborative project

Period covered: from 1 September 2011 to 31 August 2014

Name, title and organisation of the scientific representative of the project's coordinator:

J.G. (Joost) van Bemmelen

Tel: +39 06 94180583

Fax: +39 06 94180688

E-mail: joost.van.bemmelen@esa.int

Project website address: www.geowow.eu

DEL-FR

Final Report

Abstract:

This document is the final report, providing an overview of main results and achievements and their potential impacts, of the EC-FP7 co-funded project *GEOWOW*, short for *GEOSS Interoperability for Weather, Ocean and Water*, that started on 1st September 2011 and ended on 31st August 2014. The GEOWOW main challenge was to evolve the Global Earth Observation System of Systems (GEOSS) in general and the GEOSS Common Infrastructure (GCI) in particular in terms of interoperability, standardisation and functionality, to the final purpose of providing users with improved discovery, access and usability of Earth Observation data and services. GEOWOW was implemented by a consortium coordinated by the European Space Agency with partners from all over Europe, and also from Japan and Brazil, in response to call ENV.2011.4.1.3-1 “Interoperable integration of Shared Earth Observations in the Global Context”. This Final Report also provides information about the use and dissemination of project foreground and a report on the societal implications.

Document Log

DATE	AUTHOR(S)	CHANGES	VERSION	STATUS
31 October 2014	Consortium	Final version	1.0	Delivered

TABLE OF CONTENTS

1. Introduction

1.1 Purpose and Scope

This document is the final report of the EC-FP7 co-funded project GEOWOW, short for GEOSS Interoperability for Weather, Ocean and Water that started on 1st September 2011 and ended on 31st August 2014, a project implemented by a consortium coordinated by the European Space Agency with partners from all over Europe, and from Japan and Brazil, in response to call ENV.2011.4.1.3-1 “Interoperable integration of Shared Earth Observations in the Global Context”.

This final report includes a publishable summary of project results and achievements and their potential impacts. It also provides information about the use and dissemination of project foreground and a report on the societal implications.

1.2 Document Organisation

This document is organised as follows:

- Section 1 provides an introduction to the document
- Section 2 provides the publishable summary of the project context and objective, the main results achieved by the project and their potential impacts.
- Section 3 provides information about the use and dissemination of the foreground.
- Section 4 reports on the project societal implications.

1.3 Reference Documents

[1] D2.3 - Application Requirements Analysis and System Requirements Specification v2

[2] D3.1 - Multidisciplinary Interoperability Requirements specification

[3] D7.2 - Contribution of GEOWOW to GEOSS Data-CORE and GCI v3

[4] GEOSS Data Sharing Action Plan (http://earthobservations.org/documents/geo_vii/07_GEOSS%20Data%20Sharing%20Action%20Plan%20Rev2.pdf)

[5] Report of the Data Sharing Task Force and Status of Data-CORE (http://earthobservations.org/documents/geo-viii/08(Rev1)_Report%20of%20the%20Data%20Sharing%20Task%20Force%20and%20Status%20of%20Data-CORE.pdf)

[6] D6.1 - Report on Key Ocean Information Products

All GEOWOW deliverables are available for download on the project website (http://www.geowow.eu).

1.4 Acronyms and Abbreviations

API	Application Programming Interface
CNR	Consiglio Nazionale delle Ricerche
CORE	Collection of Open Resources for Everyone
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science, Inc.
CXML	Cyclone XML
DAB	Discovery and Access Broker
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
eEOV	ecosystem Essential Ocean Variable
ESA	European Space Agency
ESGF	Earth System Grid Federation
FP7	Seventh Framework Programme
GCI	GEOSS Common Infrastructure
GEF	Global Environmental Facility
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GEOWOW	GEOSS Interoperability of Weather Ocean and Water
GOOS	Global Ocean Observing System
GTN-R	Global Terrestrial Network for River Discharge
IIB	Infrastructure Implementation Board
IOC-UNESCO	Intergovernmental Oceanographic Commission – United Nations Educational, Scientific and Cultural Organization
JRC	Joint Research Centre
KiWIS	KISTERS Web Interoperability Solution
LAM	Limited Area Model
MERIS	MEdium Resolution Imaging Spectrometer
NCEP	National Centers for Environmental Prediction
OGC	Open Geospatial Consortium
SAR	Synthetic aperture radar
SARvatore	SAR Versatile Altimetric Toolkit for Ocean & Land Research and Exploitation
SBA	Societal Benefit Area
SCIAMACHY	SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY
SOS	Sensor Observation Service
SWFDP	Severe Weather Forecast Demonstration Project
THORPEX	The Observing system Research and Predictability EXperiment

TIGGE	THORPEX Interactive Grand Global Ensemble
TWAP	Transboundary Water Assessment Programme
UNEP	United Nations Environment Programme
WIS	WMO Information System
WMO	World Meteorological Organization

2. Final publishable summary report

2.1 Executive Summary

GEOWOW, short for GEOSS Interoperability for Weather Ocean and Water, is a project co-funded under the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement no. 282915 in response to call ENV.2011.4.1.3-1 “Interoperable integration of Shared Earth Observations in the Global Context”.

The main challenge of **GEOWOW** was to evolve the GEO Global Earth Observation System of Systems (GEOSS) in general and the GEOSS Common Infrastructure (GCI) in particular in terms of interoperability, standardisation and functionality, to the final purpose of providing users with **improved discovery**, **access** and **usability** of Earth Observation data and services.

GEOWOW coordinates with GEO 2012-2015 Work Plan Tasks with special focus on the Infrastructure and Societal Benefits Implementation Boards.

The main achievements can be divided into two main categories: **technological solutions** produced either **to evolve** the existing GEOSS Common Infrastructure **or to extend** the current **GEOSS capabilities**, and the **exploitation of these solutions for addressing the needs** of an increased number of user typologies, **specifically supporting the GEOSS Societal Benefit Areas**.

GEOWOW has enhanced GEOSS by acting on two levels: on the one hand, by **developing the infrastructure functionalities** needed to improve data discovery, access and exploitation; on the other hand, by **promoting the GEOSS Data Collection of Open Resources for Everyone (GEOSS Data-CORE)**, a distributed pool of documented datasets with full, open and unrestricted access at no more than the cost of reproduction and distribution.

More in detail, GEOWOW has evolved the **GEO Data Access Broker** with **ranking** of search results, **semantic searching capabilities** and **improved access to data, services, and models** and has provided **data exploitation capabilities**, such as the Developer Cloud Sandbox, which enables GEOSS users to **access and process data** on the Cloud from their facilities. The sandbox provides virtualized work environments and the necessary interfaces to leverage the computing resources of Cloud providers. Key features are the support to development and validation of Earth Science models, the facilitated access to large Earth Science data repositories, as well as the publication and reuse of scientific datasets, algorithms and processing chains to reproduce experiments or adapt them to new contexts.

This has offered important opportunities for GEOSS to move beyond data discovery improvements, and has brought the GEOSS users to computational science for data intensive analysis.

Moreover, GEOWOW has **specifically supported** three Societal Benefit Areas (SBAs): **Weather**, **Ocean Ecosystems** and **Water**.

Thanks to the evolution that GEOWOW has brought to GEOSS, the **weather scientists’** community can **benefit from enhanced discoverability, accessibility and exploitability** of weather forecasts and other weather-related data. GEOWOW has provided **ocean scientists** with **means for assessing the ocean state**, including the state of ecosystems and the threats to their sustainability and has enhanced GEOSS to ensure that the different hydrological applications and data are accessible in the same way. This offers a **solution to the heterogeneity of Water data sources** allowing scientists to focus on the actual science rather than dealing with data access issues.

2.2 Project context and objectives

This section describes the project context and objectives by identifying the different typologies of users that GEOSS should serve, describing the functionalities they require and depicting the project response to such requirements in terms of identified "components", i.e. technological developments that enhance and complement the capabilities of the GEOSS "before GEOWOW".

2.2.1. The user characteristics

Different typologies of users and several communities from the Societal Benefit Areas (SBAs) could benefit from accessing resources through harmonised conditions facilitated by GEOSS.

The GEOSS Common Infrastructure (GCI) was initially designed to support a limited number of user typologies. In the perspective of an enhanced GEOSS, different categories of stakeholders need to be considered, from data scientists to decision makers, to citizens.

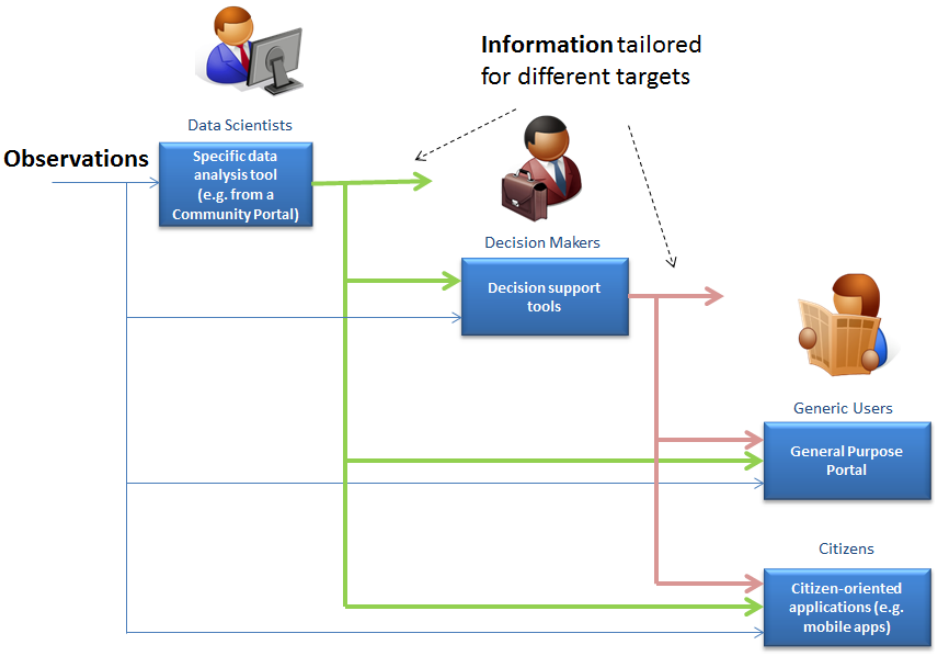

Figure 1 – Typologies of GEOSS users

In Figure 1, the **main user categories** are represented alongside their most representative work environments and tools "at hand".

The GEOWOW vision is that GEOSS should support discovery, access and exploitation of data at different levels:

- **"data scientists"** are mainly interested in observations and raw data (i.e. data still to be processed to be turned into meaningful information) and usually have their own community-specific clients or applications to analyse and further elaborate them and turn them into information that is meaningful for different profiles of users;
- **Decision-makers** can also be interested in observations, but often **need to access data products and information extracted from lower level data**. This means that they need to access information produced by e.g. the data scientists;
- **Decision-makers** in turn **may act as information "providers"** for citizens (e.g. they may inform the citizens about the outcome of their analysis regarding citizen-related

issues) and other generic users who may be interested in different information products according to their needs.

It is worth remarking that the diagram provides a schematic view of a reality where the different typologies of users are not overlapping. For instance, the emerging “citizen science” will further soften the boundaries between the mentioned roles in the future.

2.2.2. The user required functionalities

GEOWOW has elicited multidisciplinary requirements as well as requirements from the SBAs represented in the project, i.e. Weather, Ocean Ecosystems and Water, and has analysed them from a wider perspective, taking into account needs and feedback from other GEOSS stakeholders.

The analysis of the requirements elicited has led to the identification of the underlying needs for a set of functionalities: GEOWOW has produced software components implementing these functionalities.

In particular, GEOWOW has focused on efficient **data discovery** including results ranking; streamlined **data access**, including harmonisation of the result presentation; GEOSS resources **exploitability from external clients**, *to allow community-specific portals and applications to benefit from the GEOSS resources via high performance geo-processing services.* Users have in fact explicitly expressed the need for *modular infrastructure components* allowing for data manipulation and combination, application of algorithms for the calculation of indicators and repeatable environments that allow easy updating.

The main **functionalities** mentioned above contribute to achieve another specific objective of the project, which is to **support the GEOSS SBAs**, specifically the ones directly represented in GEOWOW, to the final goal of **improving the availability and accessibility of their data and resources in the GEOSS context.**

Therefore, GEOWOW supports the evolution of the SBA infrastructures via the development of **SBA-specific capabilities** that can benefit from and make use of the above described main functionalities.

2.2.3. The project response: component categories

Each group of functionality identified above is implemented by a specific category of components. More specifically, the “GEOSS resources discovery and access” capabilities are carried out via the **Discovery and Access Enablers**, i.e. multidisciplinary components, not depending on community specificities. This category includes the *GEO Discovery and Access Broker (GEO DAB)* and its evolution.

The “Data Exploitation” functionalities are carried out via the **Data Exploitation Enablers**, i.e. generic components that, once customised according to community-specific needs, enable the community clients with data processing capabilities and provide them with the necessary interfaces to access the (GEOSS) data resources and as computing resources. This category includes the *Data Casting Service*, the *Developer Cloud Sandbox* and the *Cloud Controller*.

The “SBA-specific capabilities” represent a broad category of functions carried out by components that are specific of the SBA infrastructures, i.e. **Community-Specific Components,** part of the community infrastructure, which may benefit from the above components and have been or are being evolved by the SBAs to improve the accessibility of their resources for interested users in general and for GEOSS users in particular. This category includes the *River Discharge Time Series Visualisation Tool*, the *Open Geospatial*

Consortium Sensor Observation Service (OGC SOS) Server, the *THORPEX Interactive Grand Global Ensemble (TIGGE) Archive evolutions* and the *TIGGE time-series Archive*.

For more details on these components and related components categories, please refer to [1].

To demonstrate examples of usage of these components, several GEOWOW showcases have been designed:

- *A new concept of operation for elaborating environmental indicators*;
- *Easy discovery and use of GEOSS resources for addressing multidisciplinary challenges related to drought scenarios;*
- *River discharge modelling and validation;*
- *Exploring TIGGE LAM (Limited Area Model) meteorological data*;
- *The SAR Versatile Altimetric Toolkit for Ocean & Land Research and Exploitation* (*SARvatore) experiment with CryoSat data;*
- *Vegetation analysis with MEdium Resolution Imaging Spectrometer (MERIS) data;*
- *Mesospheric sodium densities from SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) data.*

In the following paragraphs a brief description is provided for each of these showcases.

2.2.3.1. A new concept of operation for elaborating environmental indicators

This showcase has the purpose of demonstrating the innovative concept, proposed by GEOWOW, for elaborating environmental indicators. It shows how to investigate the impact of ocean acidification on pteropod habitats. Pteropods are microscopic living species at the bottom of the food web, known to be sensible to ocean pH, and as such considered an indicator species for ocean acidification.

In this scenario, the pteropod experts need an ensemble mean of the three-dimensional ocean temperature. For this purpose, they use the Developer Cloud Sandbox which improves the efficiency of the process by supporting the development of the processing algorithm (designed by experts in climate models) for producing high-level products as maps or graphics and by allowing usage of cloud computing resources.

2.2.3.2. Easy discovery and use of GEOSS resources for addressing multidisciplinary challenges related to drought scenarios

The purpose of this showcase is to demonstrate how the GEOSS resources as evolved in the context of GEOWOW (in particular the GEO DAB) can be used to address multidisciplinary challenges related to drought scenarios.

In this showcase, scientists are provided with the capability to discover and access drought information on a global or regional level, including socio-economic data, and visualise them to assess the validity of drought indicators.

2.2.3.3. River discharge modelling and validation

This showcase demonstrates a modelling scenario where river discharge is calculated using global weather forecast information. The weather data is stored in the TIGGE archive which holds the database of the World Weather Research Programme. Based on these data, river discharge is calculated. Then, to validate the results of the modelling, observed discharge data from the archive of the Global Runoff Data Centre (GRDC) is used. It is demonstrated

how the improved data exchange and interoperability standards as well as visualisation functionalities developed by GEOWOW allow for direct access to, and exchange of, hydrological data for various modelling purposes.

The modelling is conducted by the European Centre for Medium-Range Weather Forecasts (ECMWF). In doing so they apply their operationally used scheme for surface exchange over land (HTESSEL) coupled with the TRIP2 rover routing model.

2.2.3.4. Exploring TIGGE LAM meteorological data

This showcase depicts the situation where a scientist needs to find and visualise temperature forecasts from one of the models' outputs stored in the TIGGE LAM archive, by making use of the Developer Cloud Sandbox.

2.2.3.5. Other showcases: exploitation of ESA data

This section briefly describes other examples of usage of GEOWOW developed components (in particular the Developer Cloud Sandbox).

These showcases, defined and implemented during the GEOWOW project, have demonstrated the added value of using the GEOWOW components in ESA research activities.

2.2.3.5.1. The SARvatore experiment with CryoSat data

This experiment demonstrates the implementation of a scalable processing workflow over the data delivered by the CryoSat satellite, an ESA mission that is monitoring the changes in the thickness of marine ice.

The processing workflow is based on the *Synthetic aperture radar (SAR) Versatile Altimetric Toolkit for Ocean & Land Research and* Exploitation (SARvatore), designed and developed by the Altimetry Team at ESA-ESRIN. It was evolved by the GEOWOW team and integrated in the Developer Cloud Sandbox service.

The objectives of the SARvatore experiment, in which CryoSat data have been exploited using the Developer Cloud Sandbox, have been:

- to experiment in house research themes that will be further exploited in the ESA-funded R&D projects;
- to provide expert users with consolidated SAR geo-products to get acquainted with the novelties and specificities of SAR Altimetry.

2.2.3.5.2. Vegetation analysis with MERIS data

The Developer Cloud Sandbox has allowed exploring large Earth Observation temporal series for Land Change events detection, by making use of Cloud resources when needed.

2.2.3.5.3. Mesospheric Sodium densities from SCIAMACHY data

By taking advantage of the Developer Cloud Sandbox capabilities, scientists could extend the results obtained from a preliminary analysis in the temporal frame 2002-2007 to the full archive of SCIAMACHY data (2002-2012).

This gives the possibility to identify trends and may allow the possibility of defining a new inversion model for more accurate vertical profiles.

2.3 Main results/foreground

The GEOWOW project partners have prepared a long-term vision for the evolution of the GEOSS architecture in general and of the GCI in particular, in agreement with the GEO Infrastructure Implementation Board (IIB). This vision is available on line at http://www.geowow.eu/downloads/GEOWOW_vision_2.0.pdf. This living document has been updated by specific showcases developed in support to the GEO Societal Benefit Areas (SBA) and multidisciplinary areas.

The different technological and scientific **GEOWOW partners** have worked together in defining and analysing the requirements and identifying the functionalities currently missing in the GCI and the wider GEOSS infrastructure.

The partners in the **Weather SBA** have carried out a survey of forecasters participating in the Severe Weather Forecasting Demonstration Project (SWFDP) to assess requirements on forecast products for severe weather. They have started technical developments of the TIGGE-LAM archive. Regarding the set-up of a multi-model EPS time-series archive based on the TIGGE/TIGGE-LAM models, the final review of available technical solutions has been completed. Software has been developed to retrieve, read and plot the Tropical Cyclone CXML (Cyclone XML) ensemble tracks for named storms from different TIGGE data providers. Track forecast products using multi-model combinations of the European Centre for Medium-Range Weather Forecasts (ECMWF), National Centers for Environmental Prediction (NCEP) and Met Office models are now produced routinely. These products have now been made available to the SWFDP regional projects, starting with the South Africa and South Pacific regions – the two most mature SWFDP projects. Work is currently in hand to include the new products on the South Pacific SWFDP project website.

The partners in the **Water SBA** have gathered and analysed user requirements based on the available literature and by consulting relevant communities such as the GEO Integrated Global Water Cycle Observations Community of Practice (IGWCO CoP). This analysis has been an on-going process within GEOWOW and additional communities were consulted, as required. A user requirement workshop has been organised. The results were analysed to make sure that they are reflected in the standardisation activities, based on these findings a hydrology profile for the OGC SOS 2.0 specification was developed. The resulting profile was brought into the discussion process at the OGC Hydrology Domain Working Group and the OGC community to gather feedback for further improvement and has been accepted as an OGC Best Practice.

To provide as much data as possible to the GEOSS Data-CORE, the Global Runoff Data Centre (GRDC) repository continues even beyond the duration of GEOWOW to acquire more and more time series data from National Hydrological Services all over the world. Furthermore, in order to ensure that the provision of datasets to the GEOSS Data-CORE will also be possible after the completion of the GEOWOW project, an adaptation of GRDC's data infrastructure was performed. Testing and validation of interoperability issues were also performed using the Freshwater Fluxes data product of the GRDC. To allow for an always up-to-date data product, a new semi-automated methodology was developed. The results are provided to the GEOSS Data-CORE using WaterML 2.0 and SOS 2.0.

Interoperability and exchange of data across scientific domains is essential. Hence, a user scenario for multi-disciplinary cooperation on river discharge was prepared in collaboration between the **Water and Weather SBAs**. The discharge modelling based on the TIGGE forecast data has been addressed. The development of necessary tools and a modelling framework was performed. In parallel to the modelling, the technical aspects of the possibilities for providing the discharge forecasts (together with the observations) into the GCI were investigated, including issues of the visualisation, data standards and data transfer protocols.

The Ocean **Ecosystem SBA** partner has been working towards defining a set of “global coverage ecosystem” Essential Ocean Variables (EOVs), which will be important in a methodology developing indicators of a marine assessment for policymakers. Preliminary Ecosystem Ocean Variables (EOVs) that were defined in the TWAP (Transboundary Water Assessment Programme) methodology and for coastal observations were further refined during several meetings with the key stakeholders. The technological partners - through GCI component improvements - have provided input to support the development of indicators for a marine assessment. Contact was made with both the data provisioning partners and the working group of the TWAP, to ensure the availability and documenting of key datasets for the assessment. Data for developing these marine indicators has already been exposed to the GCI through the OneSharedOcean data portal (http://onesharedocean.org/). A GEOWOW 'showcase', assessing through indicators the vulnerability of ocean ecosystems to global temperature and ocean acidification changes, has helped to focus the development of GEOWOW. It also provides a clear example of the societal benefit potential of combining data available through GEO/GEOSS. Technological partners developed new components or evolved existing ones for addressing the identified requirements.

The current GEOSS Common Infrastructure (GCI) Brokering framework was enhanced to accommodate new operational capacities contributing to GEOSS and support new protocols for data discovery and access. Developments and tests were performed on the Discovery Broker component to connect to major information systems including the World Meteorological Organization (WMO) Information system (WIS), OneGeology infrastructure, United Nations Environment Programme (UNEP) Live data/service systems, and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) HYDRO Server. The Discovery Broker was enhanced adding the following capabilities: a Ranking scheme was implemented to present the resources discovered according to the following priorities: metadata completeness and quality and GEOSS Data-Core tagging. The Broker-client was enhanced to allow users to submit queries including legal constraints and showing the legal metadata. As for the Semantic Discovery Broker component, this is now able to use the several aligned controlled vocabularies.

Cloud Services were configured on the infrastructure of one of the project partners (Terradue) to enable user registration and provisioning of Developer Cloud Sandboxes to GEOWOW partners. The Developer Cloud Sandboxes service provides an environment for scientists to prepare data and processors (including development and testing of new algorithms), designed to automate the deployment of the resulting environment to a cloud computing facility.

New components were also developed as “enablers” for Cloud Computing operations, and support specific communities to select easily through community portals the data inputs required for a given compute-intensive processing task. They are aimed at developers for prototyping applications quickly (e.g. producing indicators for an assessment) accessing Cloud Computing resources for the computational tasks, and registering the results in GEOSS to make them discoverable and accessible by other users.

These enablers are integrated for an application developer in the Developer Cloud Sandbox PaaS (Platform as a Service) environment. The enablers produced during GEOWOW are: (i) a Data Casting server acting as a gateway to the Earth System Grid Federation (ESGF) servers, offering an “OpenSearch Geo & Time” front-end interface, and also managing the OpenID user credentials required for authentication by the ESGF servers, (ii) a browsable rendering of ESGF contents used to deliver task oriented search applications and (iii) an OpenSearch client (command line interface) to the ESGF Gateway, for integration within Developer Cloud Sandboxes environment. Their usage and capabilities were demonstrated in the showcase “A new concept of operation for elaborating environmental indicators”.

A considerable effort was devoted to the GEOWOW dissemination, focused during the initial phases on gathering feedback and new user requirements and during the second phase on promoting the work done and on sharing the GEOWOW vision for the evolution of the GCI and GEOSS.

Furthermore, the project included a number of assessments to analyse the project outcomes from the perspectives of multidisciplinary users, to identify the contribution of the project to the development of the GEOSS Data-CORE, to measure the added value of the GCI and the GEOSS Data-CORE to the scientific community and to evaluate the contribution of GEOSS to the innovation of SMEs active in the field of Earth Observation and Geographic Information.

2.3.1. GEOSS Common Infrastructure evolution: the GEO discovery and access broker

Requirements for a multi-disciplinary interoperability framework were collected and analysed during GEOWOW ([2]). For readers' convenience, we report here the high-level requirements that were identified:

- Multidisciplinary Resources Discoverability and Evaluation
  - Discovery results, provider metadata and resources quality assessment;
  - Classification and ranking of discovered resources;
  - Data harmonisation;
- Multidisciplinary Resources Accessibility and Use
  - Access to heterogeneous and distributed resources (Service Oriented, Resource Oriented, Event Based and Linked Data architectures);
  - Data harmonisation;
  - Possibility to compose processes and scientific models;
  - Integration of public participation;
- Non-functional requirements:
  - Scalability and flexibility;
  - Security and user registration/authentication.

As suggested in [2], GEOWOW built on existing components and collaborated with other on-going projects. Outcomes of past projects were the starting point for further developments, and enhancements of existing GCI components were developed when needed.

During the project, the existing brokering framework of the GCI – the GEO Discovery and Access Broker (DAB) – was enhanced to improve existing functionalities and add new ones addressing multidisciplinary requirements identified by the project. The GEO DAB framework is comprised of different brokers, each one dealing with a specific high-level functionality of the multi-disciplinary framework. Main existing brokers are: (i) Discovery Broker, (ii) Semantic (discovery) Broker, (iii) Access Broker, and (iv) Business Process Broker.

Detailed lists of single improvements are available in GEOWOW deliverables and in Periodic Project reports. Below we summarise main enhancements for each broker:

- Discovery Broker:
  - New brokered systems;

  - Flexible results ranking;
  - Support of the GeoViQua (www.geoviqua.org) extended metadata model for quality information;
  - Integration with user feedback catalogue to associate metadata entries with users' feedbacks;
  - New queryable elements – i.e. possibility to execute more refined queries;
  - Exploitable with GEO DAB JavaScript APIs;
- Semantic Discovery Broker:
  - Integration with GEOSS Web Portal;
  - New Vocabularies available;
  - Exploitable with GEO DAB JavaScript APIs;
- Access Broker:
  - New service protocols and data formats supported;
  - Tile generation for fast preview service;
  - Integration with GEOSS Web Portal (since the next GEO Plenary);
  - Exploitable with GEO DAB JavaScript APIs;
- Business Process Broker:
  - Developments of new interoperability solutions between GEOWOW and the MEDINA project (www.medinaproject.eu/), pilot in the GEOSS AIP-6.

A user authentication prototypal functionality (based on the OpenID and Single Sign On approaches) was developed. This functionality is designed to allow users to use their existing credentials on third-party social networks (e.g. Twitter, Google, etc.) or register/sign in with GEO DAB credentials. This functionality will be completed for the GEO Plenary 2014.

In the table below, we summarise the status of the fulfillment of the high-level requirements (identified in [2]) achieved by GEOWOW. Table 1 reports the main requirements and matches them against the broker providing the desired features. As outlined in [2], some of the identified requirements were already under investigation in other parallel projects, in such cases we report the projects GEOWOW coordinated with.

Requirement	Broker	Project
Access to heterogeneous and distributed Service Oriented, Resource Oriented, Event Based and Linked Data architectures	Discovery, Semantic Discovery, Access	
Classification and ranking of discovered resources	Discovery	
Possibility to compose processes and scientific models	BP Broker	UncertWeb, MEDINA
Data harmonization	Discovery, Access	
Integration of public participation	-	-
Discovery results, provider metadata and resources quality assessment	Discovery	GeoViQua

Table 1 - Multi-disciplinary requirements addressed in the GEOWOW framework

As to the non-functional requirements, the brokering framework operating in the GCI is deployed on cloud platform to assure the needed scalability. Each module (i.e. broker) was deployed on a machine cluster, taking advantage of the provided cloud tools for load balancing, auto-scaling, monitoring, and routing.

As far as flexibility, this is one of the basic principles of the brokering approach. All brokers are designed and implemented according to those principles. In particular, the adaptation and mediation design patterns assure the needed extensibility and flexibility.

2.3.2. GEOSS Data-CORE evolution

The first practical step toward the creation of the GEOSS Data-CORE was taken in 2010 when, at the GEO Ministerial Summit in Beijing, all GEO Members and Participating Organisations adopted the Beijing Declaration signifying their commitment to effectively create the GEOSS Data-CORE [4] and backed up their commitment by pledging a number of resources to it [5].

To bootstrap the implementation of the GEOSS Data-CORE and demonstrate its value, the GEOSS Architecture and Data Committee established a small Task force in March 2011 to Showcase Access to High Priority Earth Observation Data Sets (also known as the Sprint to Plenary initiative). The main activities of this initiative were i) to facilitate, through the GCI, the discovery of information from multi-disciplinary communities adopting different standards and protocols, and ii) to tag the datasets in the Global Change Master Directory with the GEOSS Data-CORE tag.

The results were presented at the GEO VIII Plenary. A search for GEOSS Data-CORE resources returned more than 8000 entries, thus demonstrating the existence and initial development steps of the Data-CORE.

After November 2011 however, not much progress took place in increasing the range and diversity of the GEOSS Data-CORE. This was identified as a key issue at the first meeting of the GEOSS Infrastructure Implementation Board held in Geneva on 2-3 May 2012. The basic problem identified was that the organisations that have made a pledge to the GEOSS Data-CORE were unclear about what they were supposed to do to have these resources registered, and classified as GEOSS Data-CORE. For this reason, GEOWOW and IEEE were asked by the Data Sharing Working Group to develop a short guideline document on what data providers should do, which could be used by the Data Sharing Working Group (DSWG) and the GEO Secretariat to contact the data providers again and move the process forward.

By October 2012, more than 40 organisations, initiatives, and projects had been contacted by the DSWG to either flag as “GEOSS Data-CORE” the already committed resources or to contribute with new ones to the GEOSS Data-CORE. Since this first call received only a moderate rate of responses, in the wake of the GEO Plenary (December 2012), the DSWG sent reminders to those who had not responded and contacted some other potential GEOSS Data-CORE contributors. This activity, coordinated by a member of the European Commission working on behalf of the GCI/Data-CORE Sub Group of the DSWG, has produced an increase in the number of GEOSS Data-CORE resources registered in the GCI that, in April 2013, resulted to be more than 1 million. This enormous increase was to a large extent due to the direct contacts established with each data provider to guide them step by step through the process of registering their resources committed to the Data-CORE.

In the framework of GEOWOW, project partners made a number of contributions to the Data-CORE. The complete list of resources which contributed to the Data-CORE can be found in [3].

Between July 2013 and in May 2014, two online surveys were circulated with the GEO Secretariat to the GEOSS Community (Task leaders and GEOSS mailing lists). Surveys were designed to assess the added value of the GEOSS Common Infrastructure (GCI) and GEOSS Data-Core to the GEOSS Community. Participants of the surveys were invited to answer about the actual discoverability and accessibility of resources providing information about perceived benefits, limitations and barriers. Participants have also been requested to provide their opinions on how to improve it in terms of visibility, quality and quantity of resources. The main objective was the production of evidences that will encourage GEOSS stakeholders to contribute further to, and make use of, the GEOSS Data-CORE and the GCI.

One of the main results of this activity is that a large part of GEO Members that participated in the surveys is still not aware of the concept of GEOSS Data-CORE and only very few of them either use its resources or contribute to it.

More alarming is the low rate of users and contributors among the ones that are aware of it, especially considering that most of the respondents belong to organisations that both use Open Data and make their own data available as such. Furthermore, at first glance, the low rate of involvement seems to be in contradiction with the fact that both users and contributors clearly indicate that there are a number of tangible and unequivocal benefits deriving from being actively involved in the GCI and the GEOSS Data-CORE and with the fact that the limitations of the GEOSS Data-CORE are not perceived as barriers preventing its use.

However, this can be explained by the fact that the main barriers, both for not using and contributing to the GEOSS Data-CORE, have been identified as either the lack of knowledge from GEOSS stakeholders on where to access its resources or how to make their data available as GEOSS Data-CORE.

Thus, based on our analysis of the responses and on comments provided by the surveys, it is extremely important to narrow the wide gap in GEOSS between infrastructure and data providers, and the scientific community of users. This can be done working more closely with the user community and providing practical demonstrations of what is already available in the GCI and in the GEOSS Data-CORE. Recent initiatives like AIP-7 move in this direction but much more still needs to be done to exploit GEOSS to the full. The European Commission is fully aware of this need and a new specific action to valorise and demonstrate the value of the GEOSS Data-CORE is planned for 2015.

The GRDC provides hydrological time series data from several countries and stations as contribution to the GEOSS Data-CORE. Based on an initial selection of about 400 stations that are part of the Global Terrestrial Network for River Discharge (GTN-R), negotiations with all the data providers have been made to get permission to distribute their data according to the GEOSS Data Sharing Principles. These principles include “full and open exchange of data, metadata and products shared within GEOSS”. This is opposed to the data policy of the GRDC based on WMO Resolution 25 (Cg-XIII-1999), which assures the National Hydrological Services that their data are only used for research, science and teaching and not for commercial purposes. Therefore, due to the changed circumstances, renegotiations have become necessary and are still ongoing. At this final stage of the project a total of 246 stations from 21 countries are available.

Furthermore, using long observed and regular measured river discharge at gauging stations of the GTN-R network, long-term freshwater inflow to the world’s oceans are calculated at regular intervals. The discharge time series data are used to calibrate the Global Freshwater Model WaterGAP[1] whose results are in turn used as input for a GIS workflow to calculate the data product "Freshwater Fluxes into the World Oceans". In the context of the GEOWOW project the GIS workflow has been adopted to recent developments of data processing. In order to be able to provide the data products more frequently based on the latest modelling data, the workflow has been implemented to be run automatically by a GIS system with a minimum of human interaction. The resulting GIS layers and the fluxes values, respectively, are also provided to the GEOSS Data-CORE by a Web Feature Service registered at the GEOSS CSR.

2.3.3. GEOSS Common Infrastructure Extensions: GEOWOW Components development

Another successful contribution of the technological partners to the project resides in the development of set of technological components that represent the proposed contribution of GEOWOW to the enhancement of GEOSS.

They have been successfully showcased in multidisciplinary contexts.

For instance, they have been deployed for IOC-UNESCO and integrated with their capacities for ocean ecosystems scientists to retrieve Climate projections Model data, thus carrying out

[1] "**Water G**lobal **A**ssessment and **P**rognosis" originally developed at the University of Kassel, Germany

a GEOWOW demonstrator where a scientist discovers and processes data to produce indicators that help assess the impact of acidification on the ocean ecosystems.

Moreover, they have been deployed for ECMWF and integrated with their capacities for Weather scientist to retrieve TIGGE-LAM weather Model data, process it on Cloud computing resources and visualise the resulting products.

The GEOWOW components have also been used in specific scenarios showcasing the exploitation of ESA data (in particular Envisat MERIS and SCIAMACHY, and CryoSat sensors data).

These software components belong to the Data Exploitation Enablers class (according to the components categorisation defined by GEOWOW, see D2.3 – “Application Requirements Analysis and System Requirements Specification, v2.0”). They are the Developer Cloud Sandboxes service, the Cloud Controller service, and a set of Data Casting Services (ESGF Gateway and ESGF Client) implementing the OGC® OpenSearch Geo & Time interface.

These enablers are customisable according to the characteristics of the specific community and as such can serve different contexts.

The Developer Cloud Sandboxes service provides a framework for preparing data and processors, designed to automate the deployment of the resulting environment to a Cloud Computing facility that can be provisioned on-demand. Scientists can develop and test new algorithms (elaboration, fine-tuning, configuration tasks, i.e. the preparation of the processors that are needed as part of a processing experiment). In some cases, this will be only a data preparation task as the solution supports reused scenarios, where scientists can reuse an already elaborated processor/algorithm to process a new input dataset (it can be a different source, a different set of acquisition parameters, a different time span and location, etc.). A Developer Cloud Sandbox offers a Virtual Machine pre-configured to support testing and validation of distributed, highly scalable Data processing workflows. Developers simply declare their application workflows in a template provided with the Sandbox, deploy the workflow execution codes on dedicated file system repositories, then simulate their application runs, check the application logs to eventually debug their processing chain, and finally deploy at scale the validated application on a Cloud Computing cluster. Data Staging tools are available from within a user Cloud Sandbox and support the developers in connecting their workflows to Data Access services. The Developer Cloud Sandbox and the related Cloud geo-processing components (i.e., Data Staging from distributed data archives) are available through the GEOWOW infrastructure hosted by Terradue (Cloud Controller component, see below), to deliver a flexible environment for accessing and processing Earth Science data.

The Cloud Controller system deploys the finalised Sandbox user environment to a selected Cloud resources cluster, leveraging standard Cloud APIs (EC2, JClouds, …).

The Data Casting Service supports community portals with the provision of a simple User Interface to search and filter dataset resources, and assemble a pool of references to these dataset resources. It searches from a configurable list of Data Providers endpoints (the definition of this list can be GCI-supported) and presents back a consolidated, harmonised set of online resources relevant for the search criteria. The Data Casting Service is designed so that new functionalities can be integrated, such as persistence of a user search context and user interests/preferences for results ranking. Moreover, it supports the registration of the results to GEOSS via the GEO DAB. The Data Casting Service can be easily exploited from a Developer Cloud Sandbox.

2.3.4. Thematic areas application development and GEOWOW proposed components integration

The contribution to the success of GEOWOW by the weather partners has centred on the improvement and utilisation of the TIGGE forecast archive. The THORPEX Interactive Grand Global Ensemble (TIGGE) is a major component of the WWRP-THORPEX research program, whose aim is to accelerate improvements in forecasting high-impact weather. TIGGE provides a database of ensemble predictions from leading operational NWP centers for scientific research on various topics, and has been instrumental in supporting cooperation between the academic and operational meteorological communities. The work in GEOWOW has focused on the following areas:

- Integrating the TIGGE archive into the GEO Common Infrastructure (GCI)
- Improving accessibility of key TIGGE data for a wide user community
- Improving methodologies to correct forecast biases and combine data from different forecast models
- Developing and demonstrating forecast products for high-impact weather events in collaboration with the WMO Severe Weather Forecast Demonstration Project (SWFDP)
- Demonstrating multidisciplinary use across different GEO Societal Benefit Areas (SBA)

The detailed description of developments carried out in the weather work package is listed in the following:

TIGGE-LAM archive

During GEOWOW the pre-existing global TIGGE archive (the first global ensemble forecasts were archived in TIGGE at the end of 2006) has been extended with the limited area (LAM) version, the TIGGE-LAM archive. The new database is updated regularly in the production mode with eight datasets from European LAM-EPS contributors (ALADIN-LAEF, COSMO-DE-EPS, COSMO-LEPS, DMI-HIRLAM, HUNEPS, MOGREPS, GLAMEPS and PEARP). These forecasts are produced on grids between 10 and 2 km resolution and provide detailed information for the short range, up to a few days ahead. This complements the larger-scale information provided by the global data in the established TIGGE archive. The TIGGE-LAM archive was officially launched at the TIGGE-GIFS conference at WMO headquarters on 19 March 2014.

TIGGE/TIGGE-LAM time-series archive

In order to improve the accessibility of the TIGGE and TIGGE-LAM databases a prototype of time-series archive has been developed. It provides an efficient way of accessing long time series (over several years) of forecast data at specific geographical locations. The test version of the time-series archive was available publicly for users by the end of the project. The successful demonstration of the prototype provides a strong basis for further development. The work on the time-series archive, including the uploading of available TIGGE data, will continue after the project.

TIGGE /TIGGE-LAM experiments on the cloud

During the work on the TIGGE archive an exciting new possibility was also explored. An opportunity, born out of the multidisciplinary aspect of GEOWOW, has been taken to cooperate with Terradue's team. They provided the access to a dedicated Developer Cloud Sandbox environment, including full support with the first steps for new users. Some of ECMWF's in-house software packages were installed on Terradue's infrastructure, configured for parallel processing with Hadoop, and used remotely to access, process and display TIGGE-LAM ensemble data. This exercise provided new ways of improving users' access to the data and tools to explore it. It demonstrated that such an approach can directly lead to even better TIGGE/TIGGE-LAM data accessibility and usability, especially with TIGGE's improved discoverability via the GEOSS GCI for a wide user community.

TIGGE/TIGGE-LAM severe weather warning products

A survey of forecasters participating in the SWFDP confirmed that there is considerable interest in the use of ensemble-based products to support forecasting of tropical cyclones, heavy precipitation and strong wind. The development and demonstration of ensemble forecast products in GEOWOW were therefore focussed on these areas.

An important feature of the archive is the 2-day delay before TIGGE data can be accessed. This comes from the status of TIGGE as a non-operational, non-commercial use research platform. The SWFDP forecasters therefore are unable to use products calculated from the TIGGE data archive in real time. To meet the needs of the SWFDP, a set of real-time products has been developed which will supply forecasters with plots showing the risks of strong winds and heavy rain up to 5 days ahead. The system is based on one originally developed by Mio Matsueda (of Tsukuba University and Oxford University). The products use ensemble predictions from four TIGGE partners: Met Office, ECMWF, NCEP (USA) and JMA (Japan). Agreement has been reached with JMA for JMA to supply predictions in real time for this project, starting in later July 2014. This enables the products to be supplied to SWFDP regional projects, starting with the South Pacific Islands and Southern Africa.

Evaluation of both sets of products has been carried out using the regular SWFDP evaluation protocols.

TIGGE/TIGGE-LAM tropical cyclone products

Additional products were also developed showing tropical cyclone track forecasts and strike probabilities combining predictions from multiple TIGGE ensembles. These have also been made available to the SWFDP forecasters. As part of this work the Met Office in-house tropical cyclone tracking has been updated to a new algorithm and prototyped for the global model. This new tracking algorithm can, in principle, be used for any NWP model resolution and for other forecast centre's NWP global models. Using this tracking system, an objective assessment has been made of the track, strike probability and intensity forecasts of tropical cyclones. The three ensemble systems considered are Met Office, NCEP and ECMWF. It was shown that there is significant benefit from combining results from more than one ensemble. The multi-model approach also has the benefit of reducing the risk for each storm of the observed track being outside the ensemble spread.

TIGGE/TIGGE-LAM exploratory study to demonstrate use in high impact weather forecasting

Within GEOWOW an exploratory study was carried out to demonstrate how TIGGE data can be used to aid forecasting of high impact weather events from a multi-model perspective. The goal was to assess how much information is present in the low resolution ensembles that could be used to identify convective events, and to provide suggestions on how TIGGE data could be used for downscaling purposes. An EOF- and fuzzy cluster analysis was used to identify distinct scenarios that are contained in the ensemble data.

In particular, case studies of three separate high precipitation events in association with the passage of African easterly waves over West Africa (events identified by the THORPEX African Regional Committee) were used to show how the inherent variability within the ensembles can be utilised to gain information on the possible ranges of intensity or evolution that can be supported by the large scale environmental conditions. The method has also been applied to a case study on tropical cyclone Haruna (South Indian Ocean, impacting Madagascar), as well as several cases affecting the region of the RSMC South Africa, demonstrating that this approach can be used for a range of different weather types.

TIGGE/TIGGE-LAM reforecast based developments

A new reforecast dataset, covering autumn and winter periods of the last 32 years, has recently been developed at MF-CNRM to document the model climate of the currently operational global ensemble forecast system (called PEARP from TIGGE). This reforecast dataset is used to calibrate PEARP forecasts. Using several post-processing methods, previous results have shown that the reliability and resolution of calibrated ensemble forecasts of the 24h precipitation amount are significantly improved. The reforecasts are used to compute forecast indexes such as the Extreme Forecast Index (EFI) and the Shift Of Tails index (all developed at ECMWF to measure the abnormality of a weather forecast). Preliminary results have shown that, using this reforecast data, we were able to detect well the recent storms that have hit the Brittany coast in France during the 2013/2014 winter. This approach has been more recently applied to the 50 most intense windstorms that hit France during the 30 last years. It appears that the ensemble system together with its climatology presents a satisfactory predictive skill even for extremes. It is now planned to compare similarly calibrated PEARP forecasts with a multi ensemble based on TIGGE models. This work related to the reforecast data was presented at the World Weather Open Science Conference (WWOSC) in August 2014.

TIGGE/TIGGE-LAM new ensemble calibration scheme

A peer-reviewed scientific paper has been published in the scientific journal *Tellus* that describes a new ensemble calibration scheme. The scheme directly targets the local statistical reliability of the ensemble predictions to minimise any systematic errors in the probabilities of forecast outcomes. This reliability calibration scheme was applied to recent, higher resolution TIGGE ensemble predictions for Europe to a range of parameters (precipitation, surface air temperature and dewpoint, surface wind speed and mean sea-level pressure) for a two-year period. The results demonstrate that the calibration improved the skill of the forecasts, as measured by probabilistic skill scores, including the Brier Skill Score. The results also confirmed that the combining predictions from three skilful ensembles to form a multi-model grand ensemble gave superior results to the best single ensemble.

TIGGE/TIGGE-LAM discharge modelling in the weather/water multi-disciplinary showcase

WP4 has contributed to the development of one of the showcases in GEOWOW to demonstrate multi-disciplinary use across different SBAs. The showcase in the weather/water cross-domain is the “Modelling of discharge forecasts based on TIGGE ensemble inputs and validation with observations from GRDC” (Global Runoff Data Centre). WP4 (weather) has worked on the hydrological modelling while WP5 (water) on the interoperable use of data standards and the observations and also other project partners contributed in the technical parts of the execution of the scenario.

The discharge modelling work was based on the HTESSEL land-surface model used operationally at ECMWF. The offline version of HTESSEL was extended to accommodate ensemble forecast runs from models in the TIGGE archive also using ECMWF climate and initial conditions. The hydrological model output runoff was finally coupled to the CaMa-Flood river routing scheme to provide river discharge for about 400 global catchments.

The production of the TIGGE based hydrological discharge forecasts covered the period 2009-2011. The analysis of this discharge data set was done using GRDC observations and the skill properties of the different TIGGE model’s hydrological predictions were highlighted in comparison with the multi-model combinations. The multi-model combinations appear to provide a clear advantage over the single ensemble systems.

To support the data provision in the multi-disciplinary scenario a dedicated data server with PostgreSQL database support and a SOS server (from 52°North) to service the data was installed at ECMWF. After the experimental period the discharge forecasts for four TIGGE models (ECMWF, Met Office, NCEP (USA) and CMA (China)) were uploaded onto the data server for a set of GRDC stations covering mainly the GEOSS Data-CORE stations. In close collaboration with other project partners the discharge data server was connected to the GEOSS through the GEOSS DAB and the visualisation of the modelled data (in parallel to the GRDC observations) was performed by the 52°North SOS client application.

The first functionalities of the system together with the GRDC observations were demonstrated at the January 2014 GEO-X Plenary and Ministerial Summit in Geneva, while the further improved scenario with the extended data coverage period and improved display options in the 52°North client (capabilities of displaying an ensemble forecast with all ensemble members in an easy way) is ready to be demonstrated (after GEOWOW’s official completion) at the GEO-XI meeting in Geneva or at other relevant events.

The starting point for the GEOWOW Water activities was the very heterogeneous landscape of data sources, interfaces and data formats within the hydrology domain. This lack of interoperability complicated the integration of new hydrological data sources into application systems and often caused a considerable effort for solving data access issues instead of the actual water-related/scientific question. To address this challenge, the main objective of WP 5 was to improve the GEOSS interoperability for the exchange of water-related data through the development of enhanced standards (data formats, interfaces) and new hydrological data services for the GCI taking into account user needs and requirements of the water domain.

The main results of the project include:

- The provision of an **interoperability model** for the water domain based on a newly developed Hydrology Profile for the OGC Sensor Observation Service (SOS 2.0) interface standard

- The Development of **Software Components** implementing the developed SOS 2.0 Hydrology Profile and their provision to the Global Runoff Data Centre (GRDC) and other data providers (i.e. ECMWF)
- The **enhancement of the GCI** by adding the ability to the GEO Discovery and Access Broker to connect to Hydrology SOS 2.0 servers offering WaterML 2.0 encoded data and to river discharge time series visualisation tools
- The demonstration of the improved interoperability and its benefits for the water domain by implementing a **"GRDC" showcase**, in which the GRDC established a SOS 2.0-based architecture that allows an eased and long-term provision of data sets
- The demonstration of the improved interoperability and its benefits for an interdisciplinary data exchange by implementing a **cross-domain showcase** on "River Discharge" including the international organisations ECMWF and GRDC
- The **enhancement of the GEOSS Data-CORE** through the contribution of river discharge data of the Global Runoff Data Center and its provision via SOS 2.0 service end points and through the contribution of the Global Freshwater Fluxes Data Product

Overall, through these developments GEOWOW has strongly contributed to an eased discovery of and access to hydrological data sets through the GCI.

Hydrological Standardisation Activities

To improve the interoperable exchange of hydrological data GEOWOW partners developed a Hydrology Profile for the specification of the OGC Sensor Observation Service (SOS) 2.0 Interface Standard in close collaboration with the Hydrology Domain Working Group of the OGC and the WMO. The OGC SOS 2.0 is a core standard of the OGC Sensor Web Enablement (SWE) framework and specifies a web interface for accessing sensor observation data and metadata in an interoperable manner. The Hydrology Profile for the OGC SOS 2.0 provides an optimized interface to access hydrological time series data encoded with the OGC WaterML 2.0 data model/format. Based on a continuous exchange with the OGC/WMO Hydrology Domain Working Group, the SOS 2.0 Hydrology Profile has been improved to a fully interoperable profile and advanced to an OGC Discussion Paper (available at https://portal.opengeospatial.org/files/?artifact_id=57327) resp. to an OGC Best Practice Paper. This voting was successfully completed in September 2014 after GEOWOW ended and the SOS 2.0 Hydrology Profile has been accepted as an OGC Best Practice.

During the standardisation process great emphasis was put on a continuous gathering and analysis of user requirements and showcases of hydrological data exchange to ensure that they are sufficiently reflected in the developed standards and the enhancement of the GCI.

Advanced Sensor Web Components

Several software components for the server and the client side implementing the SOS 2.0 standard and its Hydrology Profile have been developed:

Server components:

- 52°North SOS 2.0 Server (52°North SOS 4.x)
- KISTERS KiWIS SOS 2.0

Client components:

- 52°North Sensor Web Client
- 52°North JavaScript SOS-Client
- 52°North Sensor Web Client REST-API
- KISTERS WISKI Client With The DataServiceConsumer
- KISTERS Timeseries Widget

By enabling the GEO Discovery and Access Broker to connect to Hydrology SOS 2.0 servers offering WaterML 2.0 encoded data the discovery and access of hydrological data through the GCI has been eased significantly. Additionally, the GEO DAB has been connected to the visualisation clients that allow for the visualisation and interactive visual analysis of WaterML 2.0 encoded river discharge time series data (Figure 1). Through this the GCI has been supplemented by an interactive platform for the visualisation of time series data (e.g. river discharge data).

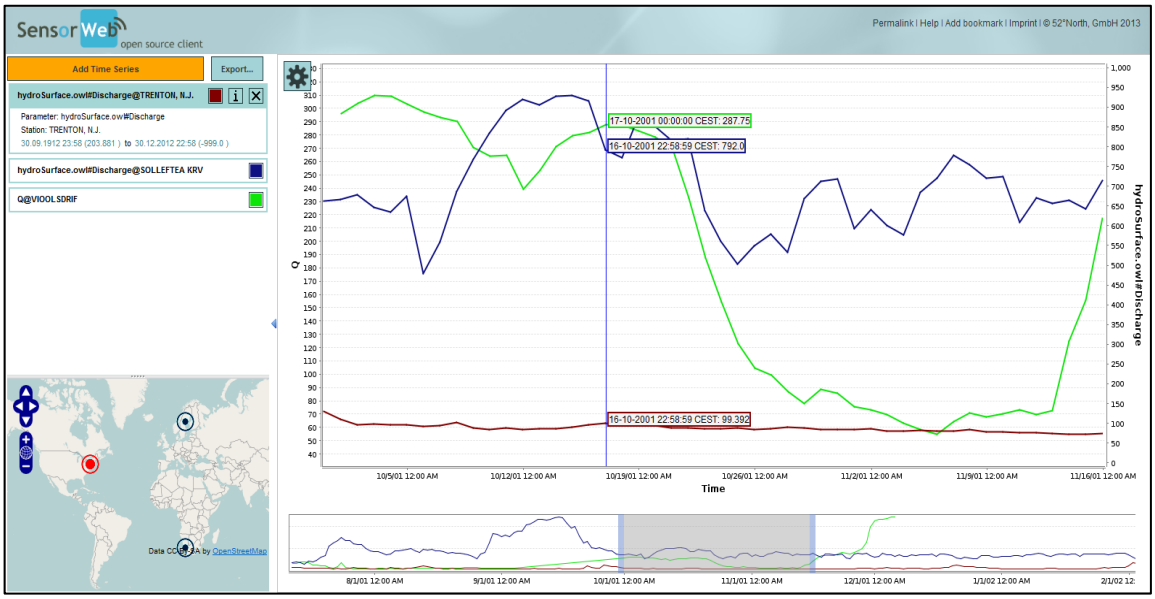

Figure 1 – 52° North Sensor Web Client showing data served by the two SOS implementations developed by 52° North and KISTERS

"GRDC" showcase

The developed software components of 52°North and KISTERS implementing the SOS 2.0 standard and its Hydrology Profile have been deployed and tested at the GRDC. The software architecture (Figure 2 shows the different architecture approaches from KISTERS and 52°North) has been adopted to the specific needs of the GRDC to ensure a sustainable provision of the river discharge data to the GEOSS infrastructure.

The software of KISTERS comprises GUI and various server components that are highly integrated and, thus, provide a complete system to handle the workflow from data input to data management to the provision of the data via a service based infrastructure.

In contrast, the components of 52°North are more loosely coupled and, therefore, provide more flexible configuration options. The 52°North Sensor Observation Service is directly coupled to the original GRDC database. Because the data policy of the GRDC required the

deployment of an access control system, the 52°North Web Security Service (WSS) combined with an additional component for a convenient administration of the WSS was installed to supplement the setup.

Both solutions have been deployed and tested in two ways. In a first step, test instances of the software have been set up at the technical partners with a limited volume of data sets. The respective service endpoints have then been registered at the GEOSS Component and Service Registry. While this allowed for a provision and connection of the data to the GEOSS infrastructure already at an early stage of the project, it was possible in the meantime to integrate the newly developed software components of both partners into the GRDC infrastructure and adapt it where it was necessary.

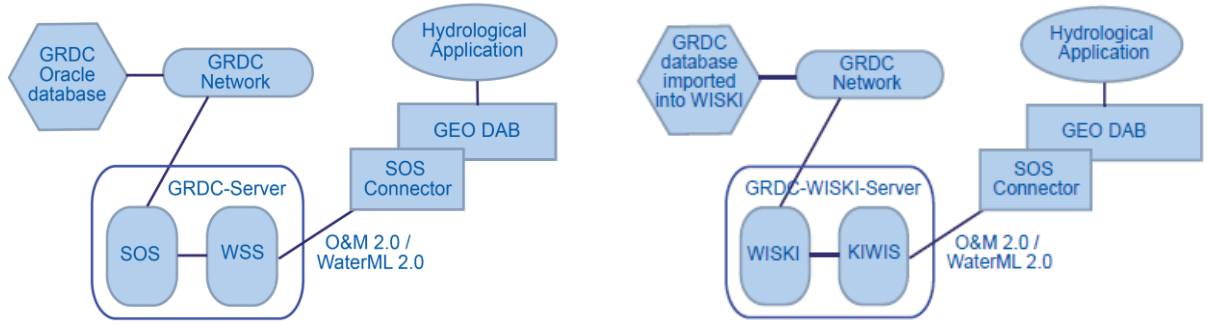

Figure 2 - Implementation architecture diagrams describing the integration of the 52°North SOS 2.0 interface (left) and the KISTERS SOS 2.0 interface (right) into the GRDC architecture. WSS = 52°North Web Security Service. WISKI = Water Information System Kisters. KiWIS = KISTERS Web Interoperability Solution.

Cross-Domain showcase

To demonstrate the enhanced interoperability on an interdisciplinary level, a showcase on “River discharge” was implemented between the Water and Weather Domain including the two international organisations: European Centre for Medium-Range Weather Forecasts (ECMWF) and the GRDC. Within the showcase the ECMWF calculates river discharge ensemble predictions using global weather forecast information from the THORPEX Interactive Grand Global Ensemble (TIGGE) archive. For the calibration and validation of the modelling procedure, observed discharge data from the GRDC database are needed and accessed via the enhanced GCI which is now connected to the Hydrology SOS 2.0 server of the GRDC. The final model results (river discharge ensemble data) of the ECMWF are then likewise provided via a SOS 2.0 server, which is connected to the GCI. Finally, this enables an end user of the GEOSS Portal to access both observed and predicted river discharge time series data. The developed river discharge visualisation tools allow the direct visualisation and visual comparison of both data types and a quick assessment of e.g. the accuracy of model results. This includes river discharge means as well as predicted river discharge ensemble data representing the possible range of model results caused by different initial conditions and the multi-model approach of the underlying weather predictions (Figure 3).

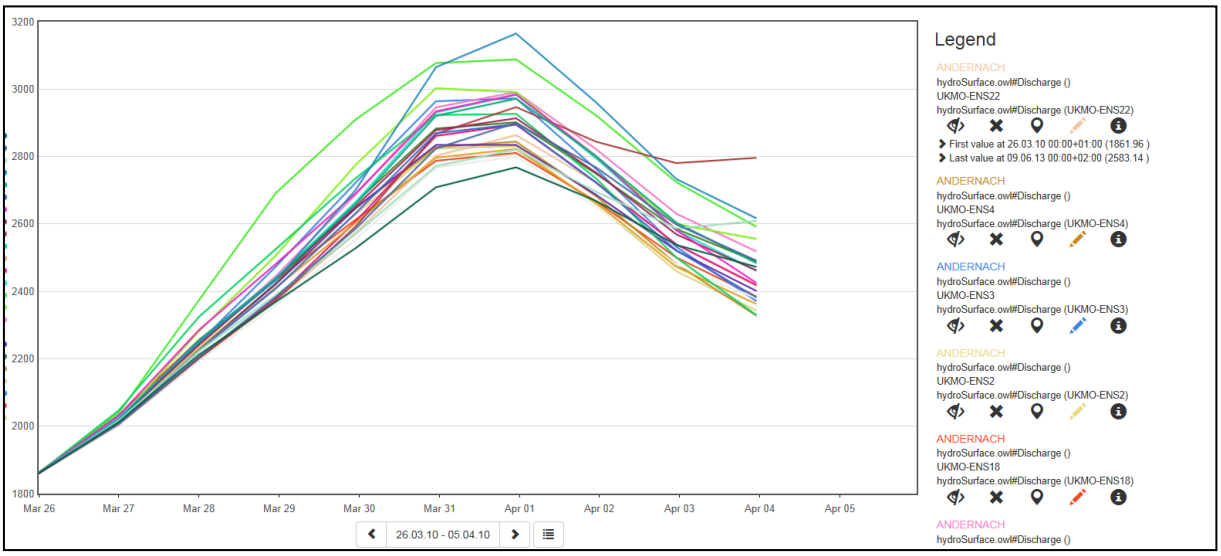

Figure 3 - 52°North JavaScript SOS-Client visualising ensemble data from ECMWF.

Marine ecosystems across the world are under threat directly and indirectly from human activities as well as natural fluctuations caused predominantly by an accelerated changing climate. Understanding the nature and rate of these changes requires access to marine data and in particular the 'ecosystem Essential Ocean Variables' (eEOVs), associated 'products' and indicators, which can show the present and projected state of health of marine ecosystems.

IOC-UNESCO mission is to promote international cooperation and to coordinate programmes in research, services, and capacity building, to learn more about the nature and resources of the ocean and coastal areas, and to apply this knowledge to improved management, sustainable development and protection of the marine environment and the decision-making processes of Member States. It is the host agency for the UN's Global Ocean Observing System (GOOS) which coordinates ocean observing networks for global and regional missions. GOOS is a contributing organization of the Group on Earth Observations (GEO) and one of the 'systems' within the Group's 'System of Systems' (GEOSS). It also leads a component in the GEO's new *Blue Planet* Task and the two marine components (Open Ocean and Large Marine Ecosystems) of the Global Environment Facility (GEF) funded *Transboundary Water Assessment Programme (TWAP).* TWAP is the world's first assessment of transboundary waters and the results will guide strategy for environmental and developmental investment and management. The TWAP marine components are formally co-financing partners with GEOWOW WP6.

GEOWOW Ocean Ecosystem partner, with added support from technological partners, progressed the development and integration of the GOOS, by way of eEOV data and marine indicators and products, into the GCI. This has been achieved by several activities, including working towards defining a global coverage of eEOVs, which were also important in the methodology to develop indicators for the TWAP marine assessment. Preliminary eEOVs that were defined in the TWAP methodology and for coastal and ocean observations via an initiative of the GOOS, were further refined.

Building on this, GEOWOW gathered and processed existing and new data (eEOV and other) to produce tangible maps and indicators that show the status of several prioritised themes and issues threatening the health of marine ecosystems. All the marine data and indicators collected and created by the various initiatives (e.g. via the GEOWOW and TWAP projects and partners, GOOS Biology and Biogeochemistry Panels) have been fed into a

decision-support system created under WP6 – the 'OneSharedOcean' web-portal (http://onesharedocean.org). This web-portal has facilitated the easy access of these 'essential' marine, climate and socio-economic data needed by scientists and policy-makers in their modelling and decisions for marine ecosystem management.

The GEOWOW technological partners also provided input to support the development of indicators for a global marine assessment through GCI component improvements, including helping to expose the eEOVs and marine products on the'OneSharedOcean' web-portal to the GCI. The code developed by IOC-UNESCO is available at https://github.com/IOC-CODE/esgf_ensemble_mean/releases/tag/r1.0 and also discoverable as a DOI from the CERN 'Zenodo' platform for scientific data sharing. The DOI is dx.doi.org/10.5281/zenodo.12601 (the codes are available under GNU public license). Moreover, a specific showcase assessing the vulnerability of ocean ecosystems to global temperature and ocean acidification changes, through indicators, helped to focus the development of GEOWOW through providing a clear example of the societal benefit potential of combining data available through GEO/GEOSS and the use of cloud computing tools for more efficient and repeatable data processing.

2.4 Potential impact

The GEOWOW main objective was to evolve the GEO Global Earth Observation System of Systems (GEOSS) in general and the GEOSS Common Infrastructure (GCI) in particular in terms of interoperability, standardisation and functionality, to the final purpose of providing users with improved discovery, access and usability of Earth Observation data and services.

An assessment of the technological and scientific developments achieved by GEOWOW was made to identify their value/ added value.

The assessment was planned in three different dimensions:

- Discovery of data, services and products in the GEOSS Common Infrastructure (GCI)
- Access to the data, services and products
- Reusability of developed components

At the beginning of the project (M0), a real multidisciplinary interoperability between thematic areas was very limited. Therefore, the assessment activity has been organised in two temporal phases: the first one comprising the period M0 - M24, and the second one comprising the period from M24 until the end of the project (M36).

The assessment includes also project partner observations and, where possible, feedbacks and opinions from potential users of the developments produced within the project. Potential users have been asked to assess the developments that the project has generated in the thematic and cross-thematic areas in terms of increased interoperability of technology, data, services and models.

Project partners agreed that GEOWOW has been a positive experience to learn how to efficiently collaborate with other domains, deal with different models, and how to involve specific communities. The multidisciplinary scenarios highlighted the importance of intercomparison studies to assess different models and to compare the use of different variables, stimulating the idea that there is the need to have different models and to compare the results.

The GEOWOW challenge to improve Earth Observation data discovery, accessibility and exploitability, and the evolution of GEOSS for the benefit of all Societal Benefit Areas (SBAs) with particular focus on Weather, Ocean Ecosystems and Water has been met. GEOWOW developments not only achieved the project's objectives but represent also a set of scientific and technological solutions that can be offered to other projects for the sustainability of their developments and their data.

However, many partners pointed out that it has been very hard to convince people to contribute to GEOSS and to the GEOSS Data-CORE, not only for organisational reasons as for example data policy issues, but also because a contribution means that everybody can judge the quality of contributed data. Despite the constant attempts to disseminate the concepts related to the GEOSS Data-CORE, it still seems to be unfamiliar to the large majority of the scientific community and thus there was reticence to commit data. The same is true for the concept of the GEOSS Common infrastructure. This results from a common lack of knowledge regarding the distinction between the GCI and the GEOSS.

These issues indicate that there is a clear need to improve communication with the potential stakeholders. Furthermore, considering that in the different SBAs there are experts on their domain, it is recommended to establish communities of practise for cross-domains programmes. In addition, there is a clear need to increase the interaction between SBAs and the data and technology providers, as a way to promote and support the interest of the scientific community in GEOSS.

GEOWOW is proposing a flexible architecture with a modular approach that will enable new categories of users from different SBAs to more easily access and exploit GEOSS, for their benefits. This simplified access and use of GEOSS will conversely enable new users to contribute to GEOSS resources. At the same time it emerges that actions for involving the private sector in the GEOSS implementation should be taken now that we are moving in a second 10-year implementation plan so that the business sector in Europe can maximise the opportunities created by this initiative.

The potential of the technological components developed by GEOWOW in terms of socio-economic impact derives from their ability to make otherwise complex scientific tasks easier, by improving significantly data accessibility and exploitability. This, along with the applicability of the selected approach to multidisciplinary contexts, demonstrated during the project, determine a great potential for a broad uptake of the GEOWOW solutions by different user communities even beyond the GEOWOW project lifetime.

Specific showcases designed in the framework of the GEOWOW project have demonstrated the ability of the project's components to respond to multidisciplinary needs and to tackle societal challenges.

In particular, ESA, Terradue and IOC-UNESCO have collaborated on setting up a solution for elaborating environmental indicators for investigating the impact of ocean acidification on pteropod habitats. This showcase has involved the exploitation of the components referred to above, i.e. the Developer Cloud Sandbox, the Data Casting Service and the Cloud Controller.

JRC and CNR have collaborated on the achievement of easy discovery and use of GEOSS resources for addressing multidisciplinary challenges related to drought scenarios (by exploiting the GEO DAB).

The University of Bonn, ECMWF, GRDC, KISTERS, 52°North and CNR have collaborated on a Water/Weather scenario regarding the modelling of river discharge using weather predictions and model validation based on river discharge observations. This has involved the GEO DAB and the OGC SOS 2.0 Hydrology Profile, as well as other community-specific components and has addressed multidisciplinary requirements identified during the project.

ECMWF, Terradue and ESA have collaborated on the realization of a scenario showing how to find meteorological data archived in the THORPEX TIGGE LAM archive and explore them using tools integrated in the Developer Cloud Sandbox.

The easy uptake of the GEOWOW components in such diverse contexts highlights the key advantages they provide.

In particular, the Developer Cloud Sandbox inherits a list of advantages typical of the cloud infrastructure. Cloud computing refers to the use of computing resources (hardware and/or software) that reside on remote and virtualized machine and are delivered to the end user "as a service" over a network, usually Internet. The cloud provides several advantages to the end users, since they are relieved from the technical activities of infrastructure management and support, or from the technical activities of application deployment.

Additional advantages of using a cloud solution are provided by the scalability of the infrastructure, which is very important when new resources are needed for a specific process. Cloud computing also leverages distributed architectures which offer easier multi-tenant operations (bringing several organisations in deploying a solution) and excellent availability and speed of computations. An increased need of storage can be easily accommodated with the cloud provider without worries about running processes out of the storage space or need to upgrade in-house hardware. This reduces capital expenses

(CAPEX) costs of an organisation for IT infrastructure and stand-alone software or servers. Furthermore, cloud computing offers backup and recovery services.

The Cloud Controller has demonstrated full flexibility in on-boarding several GEOWOW users and applications, thus explaining its easy uptake.

The “Data Casting Service” provides the great advantage of streamlining access to complex online resources from a Developer Cloud Sandbox by allowing a user to simply connect to the service via a Web Browser and intuitively navigate the metadata, thus rapidly understanding the scope and content of the served data resources, before moving forward with decisions for data exploitation (within the Sandbox for development and testing, or towards a Cloud cluster for massive data processing).

In order to spread awareness of the above and many other advantages of adopting the GEOWOW solutions, the project has taken an active part to several dissemination events, such as the 7th GEO European Projects Workshop, the GEOSS Future Products Workshop (where the GEOWOW Vision and the GEOSS Reference Architecture have been presented) and a GEOWOW side event (“GEOWOW meets the GEO stakeholders”) in occasion of the GEO-X Plenary and Ministerial Summit in Geneva.

The TIGGE-LAM archive, the extension of the global TIGGE database, is a new tool to improve regional ensemble forecasts of high-impact weather and so strengthen early warning and disaster prevention. TIGGE-LAM therefore complements the larger-scale information provided by the global data in the established TIGGE archive.

The TIGGE-LAM archive is part of the weather contribution to the GEO System-of-Systems (GEOSS) and is now discoverable through the GEO Common Infrastructure (GCI) which makes it visible for a wide user community.

In the questionnaire to identify the requirements for multidisciplinary interoperability coming from three thematic areas addressed in the GEOWOW Project ARPA Emilia Romagna describes the project: “Limited Area Model (LAM) EPS Comparison and Combination” as the main project carrying on research on integration and the best usage of global and limited area ensemble systems. The implementation of TIGGE-LAM archive as a complement to the already existing TIGGE archive is a very basic prerequisite which is needed in such research. The necessity of creation of the TIGGE-LAM archive to stimulate research on the use of global and high resolution LAM-EPS was also stressed by the TIGGE-LAM expert panel in the framework of the WMO/WWRP GIFS TIGGE.

The idea of such a limited area ensemble archive was originally proposed already in 2007, but without sufficient funding the TIGGE-LAM project could only recently materialise thanks to GEOWOW. It was launched at a conference at WMO headquarters on 19 March and this official launch was announced subsequently at several websites and since then the database was promoted at different conferences. Events such as the European Geosciences Union General Assembly in Vienna (27 April – 02 May 2014) which is the largest and most prominent European geosciences event covering a wide range of topics in different science fields and the “Using ECMWF's forecasts” meeting held at ECMWF 4 - 6 June 2014 which is a forum for exchanging ideas and experiences on the use of ECMWF data and products.

A distinct advantage of using the TIGGE/TIGGE-LAM archive is the standardised nature of the forecasts, i.e. the users do not need to worry about format and naming issues for different models and parameters, all these potential complications are harmonised by the archival system.

TIGGE-LAM will also have a strong positive impact on the Numerical Weather Prediction (NWP) science as it will enable users to compare models and improve the methodologies for

the generation and application of regional ensemble forecasts at short timescales. For the first time, we can easily access all of these ensembles and study their performance to improve our understanding. Moreover, it will also provide valuable feedback to global ensemble developments (simply by allowing comparisons with their global counterparts on the regional scale) as the resolution of these global systems is planned to increase significantly in the coming years.

The multidisciplinary aspect of GEOWOW was very important during the project and it proved to be useful to follow the work done in other work packages by various project partners. An opportunity has been taken to cooperate with Terradue's team in demonstrating new ways of accessing and processing TIGGE/TIGGE-LAM data on a Cloud Computing environment. Up-to-now this has been validated for a simple deployment of ECMWF's software tools, and some basic data processing. A more challenging task would be to host also the full data archive itself on the cloud. Due to its size (order of Petabytes in TIGGE) it is very important to explore similar ways allowing to get the data closer to users and processing applications. In the future follow up activities could experiment with much larger data samples directly on the cloud and investigate all related technical issues with user needs always in mind. This area of the GEOWOW work could potentially open up a whole new world of opportunities in working with weather or in general geo data.

Similarly if the concept and functionality of the TIGGE/TIGGE-LAM time-series prototype, to provide quick access to data for geographical points, prove to be successful, it will be used as a basis for other similar datasets which have been already produced or are planned to be produced soon at ECMWF such as ERA (ECMWF global atmospheric reanalysis), UERRA (Uncertainties in Ensembles of Regional Re-analysis) or S2S (Sub-seasonal to seasonal prediction Project).

The GEOWOW project, through the TIGGE and the new TIGGE-LAM archives, has facilitated the development and demonstration of probabilistic products for forecasting tropical cyclones and other severe weather events such as heavy precipitation and strong wind using both single-model and multi-model grand ensembles from TIGGE. It was shown that the construction of multi-model ensembles by combining several single-models can improve the skills of probabilistic forecasts of severe events. These new multi-model grand ensemble products provide forecasters with additional information on the forecast uncertainty and increase the level of confidence in the forecasts. This delivers a clear advantage for the users by providing earlier available and also more skilful warnings for potentially hazardous events.

Similarly the TIGGE databases will provide support in the future for further improvements in ensemble based high impact weather forecasting, to develop new methodologies and products for the benefit of the GEOSS community.

A specific contribution by GEOWOW to the weather community was the work that provided a get around the 2-day delay in the TIGGE data accessibility. As a result a large set of TIGGE -based single-model and multi-model early warning products for severe weather events were developed and supplied on a daily basis to SWFDP regional projects. These products can be used in real-time by the forecasters helping them to improve warnings of hazardous weather, and so avoid some of the associated impacts, especially in developing countries where NWP is unfamiliar to the public and more extensive damage is likely. Evaluation of all the GEOWOW products supplied to the SWFDPs is carried out using the regular SWFDP evaluation protocols.

The GEOWOW project has provided valuable funding to support this research and development work, and the related capacity-building activities. While GEOWOW has provided a very valuable impetus to this work, the work will not cease. We anticipate that the products will continue to be delivered to support SWFDP and similar initiatives into the future.

A wide dissemination of the results of the exploratory study carried out in GEOWOW to demonstrate the potential use of TIGGE in high impact weather forecasting was achieved by presenting the work at major scientific conferences attended by both research and operational weather forecasters. Besides this, a visiting scientist from the South African weather service (SAWS) was hosted by the KIT in May 2014 to gain experience with the method and the TIGGE dataset by applying it to case studies of actual high impact weather events that had proven challenging for forecasters at the time the events occurred. Another outcome of the visiting scientist opportunity was the development of a plan for how to transfer the results for operational use by forecasters at SAWS. A draft has been prepared for both the workflow and the web-page layout for the RSMC products for which the TIGGE data can be used. The feedback from the forecasters at SAWS has been very positive and it is expected that at least some of these products will become operationally available later this autumn/winter.

The activities related to the Ocean Ecosystem SBA have identified various priority marine themes, eEOVs and potential ocean monitoring projects that require urgent attention to inform pressing societal questions relating to the impacts of pollution, dead zones, increased carbon, ocean acidification, primary productivity and eutrophication (to name a few) and the resultant effects to marine ecosystem services and human health. Through this work, baseline knowledge has been established for those ecosystem variables 'essential' for providing the relevant data to inform and support marine management decisions for a healthy marine ecosystem with sustainable use of marine ecosystem services.

With this solid list of priority eEOVs, and potential monitoring projects, the efforts in GEOWOW are a significant first stage of an evolving process that will continue beyond its life. Recommendations set out by the IOC-UNESCO experts have already instigated further activities being progressed in particular by a new GOOS Biology and Ecosystems Panel, the GOOS Biogeochemistry Panel, GEOBON and SCOR Working Groups. In addition, the overall GEO impetus to progress the Blue Planet Task and definition of Essential Variables will support this process.

Data from eEOVs forms the backbone of the information needed to support research and development of many marine indicators and more broad marine assessments underway worldwide including the TWAP (described in [6]) and the UN directed World Ocean Assessment (WOA). Through a consortium of partners (marine scientists and modelers), GEOWOW has provided new eEOV data, created marine indicators and maps, and freely agreed for their work to be connected to the GCI The culmination of this is in the 'OneSharedOcean' web-portal built by GEOWOW (http://onesharedocean.org). This web-portal will become the initial point of reference for people wishing to access marine data and assessment information that can be used for decision-making in marine management and sustainable development, or other scientific work.

More specifically, the maps and indicators generated from the combined activities in GEOWOW will be used to inform the Global Environment Facility (GEF), and the World Ocean Assessment about the state of the global marine ecosystem, threats and projected changes from human-induced and natural impacts. GEF intends to use the maps to help guide their strategy to direct funding for appropriate interventions and/or management of the marine environment. The TWAP assessment is due for completion in April 2015. Until then, more marine data (especially eEOVs), indicators and maps will continue to be uploaded on the 'OneSharedOcean' web-portal and as well, exposed to the GCI.

The exposure to the GCI means that beyond the life of the GEOWOW and TWAP activities, new data (e.g. through the work of GOOS) can be easily updated and for public access. This means that critical or 'essential' ocean data and variables can be accessed and used, in

particular by scientists wishing to discover and use for their own models and/or to create new indicators. With the use of cloud computing, the time and storage needed to carry out this processing can be reduced with the availability of methods and codes too (tested in GEOWOW by the Ocean Ecosystem partners with the support of the technological partners). Significantly, with the marine data transformed into 'products' and/or 'indicators', policy makers (generally more interested in trends rather than scientific detail) can easily access the products to aid their decision making process for best practice and sustainable management of marine ecosystems. This feature of accessibility will become a valuable tool in the future.

Through the activities and achievements of GEOWOW, including identification and discoverability to eEOVs, plus the availability of maps and marine indicators via the 'OneSharedOcean' web-portal (and the GCI), there is now improved access to the necessary ocean data for informing policy and management issues for best practice management of marine ecosystems. As such, this is an important contribution to the process of sustainably managing the ocean environment and marine ecosystems now and into the future. This has been possible via GEOWOW's efforts to improve data discovery, interoperability, computation, and information display infrastructures, in partnership with the IOC-UNESCO, GOOS and the TWAP. These results leave a legacy for future research work and use in global and regional assessments related to ocean ecosystems and their interaction with human systems. As well, it has established a solid ground for further expansion of the capabilities of GOOS and GEO, linked together with the GEOSS and in particular via the GEO Task *Blue Planet.*

The progress being made with the development of the Hydrology profile for OGC SOS 2.0 in the area of standardisation significantly enhances the interoperability within the Hydrology Domain. If users accept the SOS interface standard it provides a simple and clear workflow for accessing hydrographic and hydrological data and requires less development efforts when they connect to new data from different sources and domains. This allows scientists and decision makers to focus on the actual scientific question or decision making process instead of spending time on solving data access issues.

Likewise, for National Hydrological Services (NHSs) or global data repositories such as the GRDC, standardised interfaces reduce the time spent on the provision of their data sets as it allows a more automatic data set delivery without the necessity to handle each individual data request.

The Hydrology profile for OGC SOS 2.0 provides a basis for agreements between national hydrological services to unify their data infrastructure and to allow a harmonised and INSPIRE compliant access to hydrological data sets on a national and international level. If NHSs agree to standards (i.e. OGC SOS 2.0 (Hydrology Profile), ISO/OGC O&M, OGC WaterML 2.0) the conduction of important regular global analyses of water cycle variables combining different data sources is much easier and faster than in case of heterogeneous data sources and interfaces. Global assessments of water cycle variables are important to capture and address the impact of environmental change on a global scale.

With the Sensor Web Clients for visualisation and its integration into the GEO Discovery and Access Broker, an interactive platform for the investigation of river discharge data has been created, which allows users to easily discover, load and quickly visualise time series data that are provided by different sources (i.e. made available by different providers) and from different domains (e.g. meteorology as a complementary domain to hydrology) in the GEOSS portal. The clients allow to visually assess the characteristics of a specific time-series before retrieving it and to compare various time series. This includes the comparison of modelled (based on weather predictions) and observed river discharge data sets which is crucial for a

multidisciplinary investigation of river discharge and the evaluation of the accuracy of different prediction systems and of potential flooding and drought predictions.

At the moment there is a motion to generalise WaterML 2.0 - Part 1 (Timeseries) and to remove the 'water' references. This is due to the quick success of WaterML 2.0 and the desire of other communities to use it as a general time series encoding standard. Even for a generalised standard the profile generated within GEOWOW could still be used and therefore multiple disciplines may benefit from it in the future. The SOS and client developments will not only be relevant for GEOSS but are expected to become relevant in the INSPIRE context, as well. For example, 52°North is currently working together with the JRC on a proposal how the INSPIRE Technical Guidelines for Download Services can be extended to better support observation data through the SOS interface.

As an outcome of the GEOWOW project, the GRDC is now able to provide the Freshwater Fluxes Data Product on a regular interval. The registration of a Web Feature Service at the GEOSS CSR enables a user to find the service endpoints and request the data directly.

Several hydrological data providers are currently testing and implementing the Hydrology Profile for the SOS 2.0 interface standard:

- In the framework of GEOWOW, the GRDC deployed and tested the developed software components for the server and the client side implementing the SOS 2.0 standard and its Hydrology Profile. A suitable software suite will be selected and integrated into the GRDC architecture to ensure a long-term provision of data sets.
- The German Federal Institute of Hydrology (BfG) is using a SOS 2.0 Server and the 52°North Sensor Web Client to provide national river discharge data sets to users.
- USGS has implemented WaterML 2.0 on their public pages according to the hydrology profile but is not using a SOS 2.0 yet.
- Natural Resources Canada also provides WaterML 2.0 via a preliminary SOS 2.0 setup and will implement the profile at some point in the future.
- Several German regional water authorities (e.g. Wupperverband in Germany) are currently testing or even running operational setups with KISTERS and 52° North profile compliant components to provide and consume hydrological time series data.
- Research centres such as "Forschungszentrum Jülich" use the SOS technology for sharing environmental data as part of research data infrastructures. In this context, the SOS and the 52°North Sensor Web Client were chosen by the Forschungszentrum Jülich for the German TERENO project.
- The agency for nature and environment of North-Rhine Westphalia (Landesamt für Natur, Umwelt und Verbraucherschutz NRW, LANUV) recently added a KISTERS KiWIS SOS2 server to provide their data within the internal network of regional agencies. The setup is currently being tested by other agencies and may be made public at some point in the future.

In addition, the achievements from GEOWOW offer a commercial exploitation perspective. The software components developed within GEOWOW, the generated experience with the standardisation for the exchange of hydrological data, as well as the improved standards offer new opportunities for the involved partners.

- The enhancement of software components (clients and servers) with support of WaterML 2.0 and the SOS 2.0 Hydrology Profile increases the value of the software products of 52°North and KISTERS for their customers in the hydrology domain.
- The experience with the standardisation process (i.e. the development of the SOS 2.0 Hydrology Profile) is highly valuable as it offers the opportunity to provide customers with consulting services on the interoperable exchange of hydrological data.
- The general 52°North client developments as well as the SOS 4.0 development line can be transferred to other domains beyond hydrology. This comprises for example air quality measurements or meteorology.
- The success of the Hydrology Profile and the good collaboration with the Hydrology Domain Working Group will open future options to acquire projects and possibly extend standardisation work that again leads to new or improved software.

2.5 Public project web site and relevant contact details

Project relevant communication is performed via the project website published at http://www.geowow.eu.

The GEOWOW website has been designed and developed to hold all the project relevant information, to provide a public access to the project deliverables and to the dissemination material, to inform about the project results and achievements and success stories.

The graphical layout has been designed to be appealing and it has been frequently updated. Many characteristics of the graphical layout of the website have been chosen to refer the GEO/GEOSS web site.

The key messages transmitted by the web site are:

- What the project is: a description of the project origins and the links with the FP7 calls
- Who is involved in the project: the consortium partners
- The project objectives: what we wanted to do
- How we achieved our objectives: The GEOWOW approach
- Main results:
    - The new capabilities / developments technologies that GEOWOW brings to GEO stakeholders with a special focus (but not only) on SBAs.
    - The GEOWOW approach to evolve the GEOSS infrastructure and GCIs in response to SBA needs
- Contact point for collaborations with the project

3. Use and dissemination of the Project Results

3.1 Section A

A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication ?
1	Calibrating ensemble reliability whilst preserving spatial structure	Jonathan Flowerdew (Met Office)	*Tellus, Series A: Dynamic Meteorology and Oceanography*	Citation: Tellus A 2014, 66, 22662	Blackwell Munksgaard		2014		http://dx.doi.org/10.3402/tellusa.v66.22662	Yes
3	The GEOSS solution for enabling data interoperability and integrative research	Nativi, S., Mazzetti, P., Craglia, M., and Pirrone, N.	*Environmental Science and Pollution Research*	Vol 21, issue 6	Ecomed Publishers		2014	4177-4192	ISSN: 1614-7499	No

[2] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[3] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[2] (if available)	Is/Will open access[3] provided to this publication ?
4	Earth science infrastructures interoperability: the brokering approach	Nativi, S., Craglia M., and J.Pearlman	*IEEE Journal of selected Topics in Applied Earth Observations and Remote Sensing*	Vol. 6, issue 3	Institute of Electrical and Electronics Engineers Inc.		2013	1118-1129		No

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
1	Conference (Networking)	ESA	VIII GEO PLENARY	14-18 Nov 11	Istanbul, Turkey	GEO community and stakeholders, scientific, technical and public audience	400	Global
2	Conference (Presentation)	ESA	OGC TC meeting, Hydrology domain Working Group	29 Nov 2011	Brussels, Belgium	Standardisation Community including representatives from academia, public administration and commercial companies	30	Global
3	Workshop	ESA	Workshop on User Requirements	1-2 Feb 2012	Frascati, Italy	GMES and GEO stakeholders	40	Global

[4] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[5] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
4	Workshop	ESA	GEO Oceans Community of Practice	17-27 Feb 2012	Salt Lake City (Utah), USA	Scientific community (higher education, Research)	30	Global
5	Conference (Presentation)	ESA	GEO IGWCO CoP annual meeting and WA-01 Task Team meeting	22-24 Feb 2012	Kona (Hawaii), USA	IGWCO CoP members	30	Global
6	Conference (Networking)	ESA	2012 GEO Work Plan Symposium	30 Apr-2 May 2012	Geneva, Switzerland	GEO members	250	Global
7	Workshop	ESA	GEOSS AIP-5 kick-off workshop	3-4 May 2012	Geneva, Switzerland	GEO stakeholders, AIP Team members	40	Global
8	Workshop	IOC-UNESCO	GEF TWAP project preparatory phase kickoff meeting	4-5 May 2012	Paris, France	Scientific community (higher education, Research)	50	Global
9	Workshop	IOC-UNESCO	Workshop on ecosystem Essential Ocean Variables (within ICES-PICES-IOC 2nd Symposium 'Effects of Climate Change in the World's Oceans'	16 May – 1 June 2012	Yeosu, Republic of Korea	Scientific community (higher education, Research)	100	Global
10	Workshop (Presentation)	ESA	Sixth 'GEO European Projects Workshop'	7-8 May 2012	Rome, Italy	Geo stakeholders	100	Europe, Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
11	Workshop	ESA	GEOWOW Water Work Package User Requirements Workshop	10-11 May 2012	Koblenz, Germany	Members of the WMO RA VI Working Group on Climate and Hydrology (WG-CH)	28	Global
12	Conference (Presentation)	ESA	Rio +20 EU GEOSS side event	18 June 2012	Rio de Janeiro, Brazil	GEO stakeholders	30	Europe, Global
13	Meeting	IOC-UNESCO	1st GOOS Steering Committee	20-22 June 2012	Paris, France	GOOS	30	Global
14	Meeting	ESA	OGC HDWG Meeting	25-28 June 2012	Reading, UK	Members of the HDWG	35	Global
15	Workshop	IOC-UNESCO	Global Alliance of Continuous Plankton Recorder Surveys (GACS) Working Group Meeting	18 Sept 2012	Paris, France	EOV specialists	20	Global
16	Meeting	IOC-UNESCO	Transboundary Waters Assessment Program Steering Committee Meeting	24-26 Sept 2012	Bangkok, Thailand	Marine assessment specialists	30	Global
17	Conference	IOC-UNESCO	Blue Planet Symposium	18-26 Nov 2012	Ilhabela, Brazil	EOV specialists	60	Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
18	Conference (Networking)	ESA	GEO-IX Plenary	19-21 Nov 2012	Foz do Iguaçu, Brazil	GEO community and stakeholders, scientific, technical and public audience	400	Global
19	Meeting	IOC-UNESCO	Helix Nebula Meeting	16 January, 2013	Frascati, Italy	Cloud computing specialists	100	Europe
20	Meeting	ESA	POGO-14 (Partnership for Observation of the Oceans) Meeting	22-24 January 2013	Capetown, South Africa	EOV specialists	40	Global
21	Conference (Presentation)	ESA	Conference “DWA-Tagung GIS und GDI in der Wasserwirtschaft” (German conference bringing together important national players from the hydrology business).	23 Jan 2013	Kassel, Germany	Representatives from hydrological organisations and public administration	100	Germany
22	Workshop (Presentation)	ESA	AfWCCI Workshop	4-5 Feb 2013	El Jadida, Morocco	GEO stakeholders, water resource managers	40	Africa, Global
23	Meeting	IOC-UNESCO	UNESCO’s IODE (International Oceanographic Data and Information Exchange)	5 February 2013	Oostende, Belgium	Scientific community (higher education, Research)		Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
24	Workshop	IOC-UNESCO	CLIVAR Working Group on Ocean Model Development: Workshop on Sea Level Rise	18-20 February 2013	Hobart, Australia	Scientific community (higher education, Research)		Global
25	Meeting	ESA	FP7 GENESI DEC Review	4 March 2013	Frascati, Italy	Scientific community (higher education, Research)		Global
26	Meeting	IOC-UNESCO	TWA Programme Marine Working Group Inception Meeting	20-22 March 2013	Paris, France	Scientific community (higher education, Research)		Global
27	Meeting	IOC-UNESCO	2nd GOOS Steering Committee Meeting	24-27 March 2013	Qingdao, China	Scientific community (higher education, Research)		Global
28	Meeting	IOC-UNESCO	TWA Programme Inception Meeting	3-5 April 2013	Copenhagen, Denmark	Scientific community (higher education, Research)		Global
29	Workshop (Presentation)	ESA	7th 'GEO European Projects Workshop'	15-16 Apr 2013	Barcelona, Spain	GEO stakeholders	200	Europe, Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
30	Conference (Presentation)	ESA	9th IGWCO Community of Practice Meeting	17-19 Apr 2013	Barcelona, Spain	IGWCO CoP members	20	Global
31	Meeting	IOC-UNESCO	GEOHAB Open Science Meeting	22-26 April 2013	Paris, France	Scientific community (higher education, Research)		
32	Conference (Presentation)	ESA	Runder Tisch GIS Conference	10-12 May 2013	Munich, Germany	Representatives from academia, public administration and commercial companies	30	Germany
33	Meeting	IOC-UNESCO	GEO Blue Planet Leaders Meeting	13-14 May 2013	Exeter, UK	Scientific community (higher education, Research)		Global
34	Meeting	IOC-UNESCO	Various Meetings with EC DG Portfolios, by WP6	16 May 2013	Brussels, Belgium	Scientific community (higher education, Research)		Global
35	Conference (Networking)	ESA	GEO Work Plan Symposium	3-6 June 2013	Geneva, Switzerland	GEO members	100	Global
36	Workshop (Presentation)	ESA	Workshop of OGC Hydrology Domain Working Group	17-21 June 2013	Quebec City, Canada	Members of the HDWG	35	Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
37	Meeting	IOC-UNESCO	UNESCO IOC Assembly and Side Events	26 June to 12 July	Paris, France	Scientific community (higher education, Research)		Global
38	Meeting	IOC-UNESCO	UNESCO IOC Seminar Series	13 Sept 2013	Paris, France	Scientific community (higher education, Research)		Global
39	Conference (Presentation)	ESA	FOSS4G 2013 Conference	19-21 Sep 2013	Nottingham, UK	Software developers and representatives from public administration	50	Global
40	Meeting (Presentation)	ESA	GEO Water Strategy Meeting at the DLR (German Aeronautics and Space Research Centre)	11 Oct 2013	Bonn, Germany	Representatives from the German Space Center, the Center for Remote Sensing of Land Surfaces and the GEO Water Task Lead	10	Germany , Canada
41	Meeting	IOC-UNESCO	UNESCO IOC Seminar Series	25 Oct 2013	Paris, France	Scientific community (higher education, Research)	20	Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
42	Conference	IOC-UNESCO	International Waters Conference (Side Events)	26 – 30 Oct 2013	Barbados	Scientific community (higher education, Research)	40	Global
43	Meeting	IOC-UNESCO	TWA Programme 2nd Steering Committee Meeting	31 Oct to Nov 2, 2013	Barbados	Scientific community (higher education, Research)	30	Global
44	Webinar	ESA	GEO Overview - Webinar	14 Nov 2013	Webinar (worldwide)	Scientific community (higher education, Research)		Global
45	Workshop	IOC-UNESCO	1st Technical Workshop on the Definition of Ecosystem Essential Ocean Variables (eEOVs)	12-17 Nov 2013	Townsville, Australia	Scientific community (higher education, Research)	50	Global
46	Meeting	IOC-UNESCO	Meeting of High-End Scenarios of Regional Sea Level Changes and Their Uncertainties	20-22 Nov 2013	Hamburg, Germany	Scientific community (higher education, Research)		Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
47	Meeting	IOC-UNESCO	TWA Programme - Meeting of Experts on phytoplankton and climate projections	25-26 Nov 2013	Plymouth, UK	Scientific community (higher education, Research)		Global
48	Meeting	IOC-UNESCO	UN World Ocean Assessment, Regular Process Meeting	3-5 Dec 2013	New York, USA	Scientific community (higher education, Research)		Global
49	Meeting	IOC-UNESCO	UNESCO IOC Seminar Series	12 Dec 2013	Paris, France	Scientific community (higher education, Research)		Global
50	Webinar	ESA	GEOWOW Water Webinar: “Sharing hydrological data across borders” (Part of the GEO-X Summit Showcase Campaign: “A modern explorer’s journey”)	20 Dec 2013	Virtual on the web	Representatives from academia, public administration and commercial companies	n/a	Global
51	Conference (Presentations)	ESA	Various Side events at GEO-X Plenary and Ministerial Summit	14-17 Jan 2014	Geneva, Switzerland	GEO stakeholders, scientific and technical audience	50	Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
52	Workshop	IOC-UNESCO	GESAMP (Group of Experts for Marine Environmental Protection) Task Team Pollution Workshop	25-28 Feb 2014	Monaco	Scientific community (higher education, Research)		Global
53	Workshop	ESA	Sensor Web Workshop at FOSSGIS 2014 Conference (German Conference on Open Source in Geoinformatics)	19-21 Mar 2014	Berlin, Germany	Software developers and representatives from public administration	10	Germany
54	Meeting	IOC-UNESCO	WP6 Meetings with various EC DG Portfolios	24 March 2014	Brussels, Belgium	Scientific community (higher education, Research)		Global
55	Meeting	IOC-UNESCO	TWA Programme 2nd Marine Working Group Meeting	April 7-11 2014	Paris, France	Scientific community (higher education, Research)		Global
56	Poster	ESA	Session “Service and Brokering Architecture challenges for multi-disciplinary interoperability and Future Internet”, European Geosciences Union	27 April - 2 May 2014	Vienna, Austria	Scientific and technical audience	20	Europe, Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
57	Conference	ESA	GEO Workplan Symposium	28-30 April, 2014	Geneva, Switzerland	Scientific community (higher education, Research)		Global
58	Workshop	IOC-UNESCO	46th Liege Colloquium on Ocean Dynamics	4-11 May 2014	Liege, Belgium	Scientific community (higher education, Research)	50	Global
59	Workshop	IOC-UNESCO	Workshop on indicators of floating plastics	17-19 May 2014	Woods Hole (Massachusetts), USA	Scientific community (higher education, Research)	20	Global
60	Conference (Presentation)	ESA	GEO IGWCO CoP annual meeting	29-30 May 2014	Tokyo, Japan	IGWCO CoP members, stakeholders of the water sector	40	Global
61	Workshop	IOC-UNESCO	8th GEO European Projects Workshop	12-13 June 2014	Athens, Greece	Scientific community (higher education, Research)		Global
62	Meeting (Presentation)	ESA	German GEO (D-GEO) Meeting	26-27 June 2014	Karlsruhe, Germany	German GEO stakeholders	25	Germany

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
63	Meeting	IOC-UNESCO	UNESCO IOC Executive Council	1-4 July 2014	Paris, France	Scientific community (higher education, Research)		Global
64	Meeting	IOC-UNESCO	Ocean Observations Panel for Climate (OOPC) Working Group Meeting	21-23 July 2014	Barcelona, Spain	Scientific community (higher education, Research)	20	Global
65	Meeting	IOC-UNESCO	3rd GOOS Steering Committee	24-26 July 2014	Barcelona, Spain	Scientific community (higher education, Research)	30	Global
66	Conference (Presentation)	ESA	11th International Conference on Hydroinformatics	17 – 21 Aug 2014	New York, USA	Scientific and technical audience	250	Global
67	Conference (Poster)	JRC-CNR	GEOWOW: a drought scenario for multidisciplinary data access and use	07-12 April 2013	Vienna, Austria	European Geosciences Union General Assembly 2013	n/a	Global
68	Conference (Poster)	CNR-JRC	Improve the ranking algorithm of the GEO Discovery and Access Broker through resource accessibility assessment	09-13 December 2013	San Francisco, USA	AGU Fall meeting 2013	n/a	Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
69	Conference (Poster)	JRC	Data-CORE, awareness, Involvmente and Challenges	12-17 January 2014	Geneva, Switzerland	Geo Plenary 2014	n/a	Global
70	Conference (Presentation)	JRC	The GEOSS Data-CORE and GEOSS Common Infrastructure (GCI): awareness, involvement and challenges	12-13 June 2014	Athens, Greece	GEO European Projects Workshop (GEPW-8)	n/a	Global
71	Brochure	ECMWF	TIGGE-LAM activities	April-August 2014	European Geosciences Union General Assembly (Vienna) and Use of ECMWF products meeting (Reading)	Scientific community (higher education, Research)		Global
72	Poster	ECMWF	Benefits of TIGGE weather forecast data for the GEOSS community	January 2014	GEO-X (Geneva, Switzerland)	Scientific community (higher education, Research)		Global
73	Conference (presentation)	Karlsruhe Institute of Technology (KIT)	Analysis of tropical high impact weather events using TIGGE data	Apr 2014	31st Conference on Hurricanes and Tropical Meteorology (San Diego, USA)	Scientific community (higher education, Research)		Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
74	Conference (presentation)	ECMWF	TIGGE applications	June 2014	Use of ECMWF products (UEF) meeting (Reading, UK)	Scientific community (higher education, Research)		Global
75	Press release	ECMWF	Official launch of TIGGE-LAM	March 2014	WMO or ECMWF websites	Scientific community (higher education, Research)		Global
76	Articles published in the popular press	JCR	GEOWOW: A framework for multi-disciplinary interoperability of ocean data and systems - by Craglia M and Nativi S.	2014	In Djavidnia S., Cheung V., Ott M. And Seeyave S. (Eds.) 2014.*Oceans and Society: Blue Planet*, 182-190.	Scientific community (higher education, Research)		Global
77	Articles published in the popular press	IOC-UNESCO	Report of the First Workshop of Technical Experts for the Global Ocean Observing System (GOOS) Biology and Ecosystems Panel: Identifying Ecosystem Essential Ocean Variables (EOVs) – by Grimes, S.	2014	GOOS Report No. 207 - http://ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=13586	Scientific community (higher education, Research)		Global

A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[4]	Main leader	Title	Date/Period	Place	Type of audience[5]	Size of audience	Countries addressed
78	Articles published in the popular press	IOC-UNESCO	First Technical Experts Workshop of the GOOS Biogeochemistry Panel: Defining Essential Ocean Variables for Biogeochemistry – by Telszewski, M & Tanhue, T.	2014	GOOS Report No. 206 - http://ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=13585	Scientific community (higher education, Research)		Global
79	Articles published in the popular press	BfG	Interoperability between GRDC's data holding and the GEOSS infrastructure	2014	Proceedings of 11th International Conference on Hydroinformatics	Scientific community (higher education, Research)		Global

3.2 Section B

3.2.1. Part B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.

Not applicable

3.2.2. Part B2

Type of Exploitable Foreground [7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of results through (social) innovation	52°north sensor web client: Comprehensive web client application for visualising observation data	No		Software	Public administration, environmental monitoring, hydrology	2013	Publication under an osi-approved open source license	52°North
Exploitation of results through (social) innovation	52°north sensor web client rest-api: Rest-api exposing the server-side business logic of the 52°north sensor web client. This can be used for developing new, lightweight client applications.	No		Software	Public administration, environmental monitoring, hydrology	2014	Publication under an osi-approved open source license	52°North

[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[8] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

Type of Exploitable Foreground [7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of results through (social) innovation	52°north java script sos-client: Lightweight javascript client (e.g. Also suited for mobile phones) to explore and visualise observation data. This client makes use of the 52°north sensor web client rest-api.	No		Software	Public administration, environmental monitoring, hydrology	2014	Publication under an osi-approved open source license	52°North
Exploitation of results through (social) innovation	52°north sos server 4.0: Server for publishing observation data in an interoperable, standardised manner.	No		Software	Public administration, environmental monitoring, hydrology	2014	Publication under an osi-approved open source license	52°North
Commercial exploitation of R&D results	Kisters kiwis sos2 server: Server for publishing observation data in an interoperable, standardised manner.	No		Software	Public administration, environmental monitoring, hydrology	2014	Commercial license	KISTERS AG
Commercial exploitation of R&D results	Kisters timeseries widget: Javascript based client for viewing, downloading and transforming timeseries data	No		Software	Public administration, environmental monitoring, hydrology	2014	Commercial license	KISTERS AG

Type of Exploitable Foreground [7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of results through (social) innovation	Public github repository of esgf data processing code: Codes for computing data ensemble means (ipcc compliant) at https://github.com/ioc-code/esgf_ensemble_mean and the DOI for this code is at: http://zenodo.org/record/12601#.VFzMRskcNec	No	N/a	Software	Scientific audience, climate and ocean model forecast under climate change	N/a	Gpl 2 HTTPS://GITHUB.COM/IOC-CODE/ESGF_ENSEMBLE_MEAN/BLOB/MASTER/LICENSE	IOC
Exploitation of results through (social) innovation	Web platform: Public repository and descriptions of the eov data, marine indicators, products and maps collected and developed in partnership by GEOWOW WP6, IOC-UNESCO, GEF TWAP and GOOS at : http://onesharedocean.org/ As well, the TWAP open ocean assessment report will be available here (when complete)	Yes	01/may/2015	Data and descriptions (of eovs, marine indicators, products and maps)	Scientific audience, public administration, climate and ocean model forecast under climate change	N/a	Data available under GEOSS Data-CORE, unless specified in their metadata	IOC

Type of Exploitable Foreground [7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Exploitation of results through (social) innovation	The TWAP open ocean technical report: this will describe the full open ocean assessment carried out by twap and in partnership with geowow wp6.	Yes	01/may/2015	Data and descriptions (of eovs, marine indicators, products and maps)	Scientific audience and public administration for, , climate and ocean model forecast under climate change	N/a	Unknown	IOC / UNEP / GEF
General advancement of knowledge	The TWAP open ocean summary for policy makers: this will summarise for policy makers the key messages from the open ocean assessment (carried out by twap and in partnership with geowow wp6).	Yes	01/may/2015	Descriptions of the key messages from the twap marine assessment	Public administration /policy makers/donors interested in, climate and ocean model forecasts under climate change and improved global marine ecosystem management	N/a	Unknown	IOC / UNEP / GEF

Type of Exploitable Foreground [7]	Description of exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application [8]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
General advancement of knowledge	The TWAP large marine ecosystem technical report : this will describe the full large marine ecosystem assessment carried out by twap and in partnership with geowow wp6)	Yes	01/may/2015	Data and descriptions (of eovs, marine indicators, products and maps)	Scientific audience and public administration for, climate and ocean model forecast under climate change	N/a	Unknown	IOC / UNEP / GEF
General advancement of knowledge	The TWAP large marine ecosystem summary for policy makers: this will summarise for policy makers the key messages from the large marine ecosystem assessment (carried out by twap and in partnership with geowow wp6).	Yes	01/may/2015	Descriptions of the key messages from the twap marine assessment	Public administration /policy makers/donors interested in, climate and ocean model forecasts under climate change and improved large marine ecosystem management	N/a	Unknown	IOC / UNEP / GEF

3.2.3. Exploitable foreground

The software generated by 52°North will be published under an OSI-approved Open Source license (GPL v2/Apache License Version 2). Based on this software, 52°North will be able to offer custom solution development services and consulting. To advance the developed components to cover further requirements (e.g. different types of data such as forecast data, data from other domains, and additional functionality such as alerting), additional research will be performed in the future. However, still the results of the project are considered an asset which can be commercially exploited.

All software produced by KISTERS will be available under a commercial license. Since both server and client components are extensions within already existing products, the terms of the licenses will depend on the individual contract. Additionally, KISTERS will continue to offer workshops and consulting for hydrological standardization as well as for the products themselves. Future research and projects may expand the results of the GEOWOW project and provide additional assets.

The achievements from GEOWOW offer a commercial exploitation perspective. The software components developed within GEOWOW, the generated experience with the standardisation for the exchange of hydrological data, as well as the improved standards offer new opportunities for the involved partners.

- The enhancement of software components (clients and servers) with support of WaterML 2.0 and the SOS 2.0 Hydrology Profile increases the value of the software products of 52°North and KISTERS for their customers in the hydrology domain.
- The experience with the standardisation process (i.e. the development of the SOS 2.0 Hydrology Profile) is highly valuable as it offers the opportunity to provide customers with consulting services on the interoperable exchange of hydrological data.
- The general 52°North client developments as well as the SOS 4.0 development line can be transferred to other domains beyond hydrology. This comprises for example air quality measurements or meteorology.
- The success of the Hydrology Profile and the good collaboration with the Hydrology Domain Working Group will open future options to acquire projects and possibly extend standardisation work that again leads to new or improved software.

4. Report on societal implications

A General Information *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	282915
Title of Project:	GEOWOW - GEOSS interoperability for Weather, Ocean and Water
Name and Title of Coordinator:	Joost van Bemmelen, Project Coordinator

B Ethics	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***No***
2. Please indicate whether your project involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	

• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes X No
• Research having the potential for terrorist abuse	No

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	3	5
Experienced researchers (i.e. PhD holders)	4	20
PhD Students		
Other		

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project?

● Yes
○ No

6. Which of the following actions did you carry out and how effective were they?

		Not at all effective				Very effective
☒	Design and implement an equal opportunity policy	○	○	○	●	○
☒	Set targets to achieve a gender balance in the workforce	○	○	○	●	○
❑	Organise conferences and workshops on gender	○	○	○	○	○
☒	Actions to improve work-life balance	○	○	●	○	○
○	Other:					

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

● No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

● No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

● No

F Interdisciplinarity

10. Which disciplines (see list below) are involved in your project?

●	Main discipline[9]:		
○	Associated discipline[9]:	○	Associated discipline[9]:

G Engaging with Civil society and policy makers

11a	**Did your project engage with societal actors beyond the research community?** *(if 'No', go to Question 14)*	○ ●	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

- ○ No
- ○ Yes- in determining what research should be performed
- ○ Yes - in implementing the research
- ○ Yes, in communicating /disseminating / using the results of the project

11c	**In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?**	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

- ○ No
- ○ Yes- in framing the research agenda
- ○ Yes - in implementing the research agenda
- ○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

- ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)
- ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)
- ○ No

13b If Yes, in which fields?

[9] Insert number from list below (Frascati Manual).

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level?

- ○ Local / regional levels
- ○ National level
- ● European level
- ● International level

H Use and dissemination

14. How many Articles were published/accepted for publication in peer-reviewed journals?	**3**
To how many of these is open access[10] provided?	**1**
How many of these are published in open access journals?	**0**
How many of these are published in open repositories?	**0**
To how many of these is open access not provided?	**2**
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[11]: ……	

15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*		**0**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark	**0**
	Registered design	**0**
	Other	**0**
17. How many spin-off companies were created / are planned as a direct result of the project?		**0**
Indicate the approximate number of additional jobs in these companies:		

[10] Open Access is defined as free of charge access for anyone via Internet.

[11] For instance: classification for security project.

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
❑	Safeguard employment, or	☒	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
☒	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
	Difficult to estimate / not possible to quantify

I Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ● No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ● No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	☒	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
☒	Brochures /posters / flyers	☒	Website for the general public / internet
☒	DVD /Film /Multimedia	☒	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	☒	English
❑	Other language(s)		

***Question F-10*:** Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)

2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]

2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. MEDICAL SCIENCES

3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)

3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)

3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. AGRICULTURAL SCIENCES

4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)

4.2 Veterinary medicine

5. SOCIAL SCIENCES

5.1 Psychology

5.2 Economics

5.3 Educational sciences (education and training and other allied subjects)

5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. HUMANITIES

6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)

6.2 Languages and literature (ancient and modern)

6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]